EMUZAG STUDIO

User guide

Model setup, calculation
and results



EMUZAG 1.1.2 / Edition 1.69

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Modeling and input reference for Studio
with an external EMUZAG Solver.

About this guide

This guide is for engineers and researchers who create electromagnetic models in EMUZAG Studio and run them with EMUZAG Solver. It follows the left-hand project navigation, but also shows the order in which decisions should be made. You can read the first three chapters as a walkthrough, then use the remaining chapters as a task and input reference.

Studio is the graphical authoring, execution and inspection application. Solver is a separate executable: it performs meshing and numerical work and, for trial builds, enforces the license. This guide defines numerical terms beside their controls and links settings that depend on choices elsewhere in the project.

> **Edition and compatibility**
>
> This edition describes the EMUZAG 1.1.2 interface and covers Windows, macOS and Linux workstation, Linux HPC account and shared cluster trial workflows. Use the workflow matching the supplied Solver's reported capability. Exact Studio and Solver builds are recorded in `MANIFEST.json`. Solver capabilities determine which calculations are available; connecting a different Solver can change that availability. The included exercise is a workflow tutorial, not a measured reference benchmark.

How to read the pages

Sans-serif words name interface controls. `Monospaced text` names files or literal settings. Numbered lists are procedures; tables describe accepted values and dependencies. "Must" identifies a requirement; "recommended" identifies a suggested practice. The glossary links key terms to their detailed explanations.

Screenshots show controlled, synthetic examples. Their appearance may differ slightly from the current theme; the procedures name the corresponding controls.

Item	What it means
First use	Read Chapters 1–3.
CAD or imported geometry	Chapter 5; pay particular attention to units, material assignment and tessellation.
A disabled or rejected input	Read its reference table and the dependency map in Appendix A.
Run, restart or licensing problem	Chapters 2, 10 and 13.
Numerical terms and results	Start with Section 3.1; see Chapters 8–12 for method, integration, and analysis definitions.

Before reporting a result

Check dimensions, material data, source normalisation, and boundary conditions. Compare the reported quantity across mesh and observation-duration refinements; for CAD-to-STL, vary calculation STL tolerances separately. The walkthrough in Chapter 3 shows how to separate these checks.

Contents

About this guide i

1. Find your way around 1
- 1.1. Navigate a project . . . 1
- 1.2. Local graphics settings . . . 1
- 1.3. A reliable working order . . . 3
- 1.4. Selection, drafts and validation . . . 3
- 1.5. Files, saving and portable projects . . . 4
- 1.6. Importing a project is not importing geometry . . . 5

2. Connect Solver and activate a trial 7
- 2.1. Choose the supplied Linux edition . . . 7
- 2.2. Start with the Solver connection button . . . 7
- 2.3. If Solver came with your project or package . . . 8
- 2.4. If you need to select Solver yourself . . . 8
- 2.5. Activate a Windows workstation trial . . . 9
- 2.6. Activate and update a macOS workstation trial . . . 9
- 2.7. Complete runtime readiness and start work . . . 10
- 2.8. Recover from a Windows activation problem . . . 11
- 2.9. Activate a shared cluster trial . . . 11
- 2.10. Activate a Linux HPC account trial . . . 12

3. Your first complete workflow 15
- 3.1. What this calculation measures . . . 15
- 3.2. Create and inspect a small model . . . 15
- 3.3. Check the domain, boundaries and source together . . . 16
- 3.4. Build a mesh before the first solve . . . 16
- 3.5. Run and make a first interpretation . . . 16
- 3.6. Check sensitivity to numerical settings . . . 17

4. Case and units 18
- 4.1. Name the calculation and choose units first . . . 18
- 4.2. What a new project contains . . . 19
- 4.3. Read a field's state, not only its number . . . 19
- 4.4. Validation and a safe edit cycle . . . 20

5. Geometry: model, import, and prepare 21
- 5.1. Choose the right geometry route . . . 21
- 5.2. Choose calculation geometry per body . . . 22
- 5.3. Find and inspect the right object . . . 22
- 5.4. Build native primitives . . . 26
- 5.5. Create and constrain a Sketch . . . 27
- 5.6. Extrude and Revolve a reusable profile . . . 29
- 5.7. Combine and modify editable solids . . . 31
- 5.8. Position and repeat geometry . . . 32
- 5.9. Import STEP or BREP . . . 33
- 5.10. Import or replace STL . . . 34

5.11. Choose CAD display quality . . . 36
5.12. Model a zero-thickness screen . . . 37
5.13. Save safely and prepare for computation . . . 39
5.14. Troubleshoot Geometry by symptom . . . 41

6. Materials **43**
6.1. Choose the physical representation . . . 43
6.2. Define, save, and assign . . . 43
6.3. Ideal conductor and finite volume properties . . . 44
6.4. Explicit Lorentz dispersion . . . 45
6.5. Tabulated electric and magnetic response . . . 46
6.6. Thick and homogeneous-depth conducting walls . . . 47
6.7. Physical coatings and multilayer walls . . . 48
6.8. Zero-thickness screens . . . 49
6.9. Libraries, appearance, and verification . . . 49

7. Domain, boundaries, and mesh **51**
7.1. Domain extent and material background . . . 51
7.2. Boundary conditions on the six faces . . . 52
7.3. Choose Cartesian cell spacing . . . 53
7.4. Advanced meshing and geometry preparation . . . 54
7.5. PML absorber controls . . . 55
7.6. Section Assembly: order and repeat longitudinal sections . . . 56
7.7. Inspect Mesh View and Material Mesh . . . 57
7.8. A practical mesh-verification sequence . . . 59

8. Excitation source and Solver **60**
8.1. Switch calculation type . . . 60
8.2. Charged-bunch inputs . . . 60
8.3. Field method and automatic changes . . . 61
8.4. Time-step and duration policy . . . 62
8.5. Finite-beta compatibility . . . 63
8.6. Initial field and beam self-wake correction . . . 64
8.7. Advanced Solver controls . . . 65
8.8. Two-port multimode scattering . . . 66

9. Wake and outputs **69**
9.1. Wake length and transverse trajectories . . . 69
9.2. Direct and indirect wake integration . . . 69
9.3. Power-loss monitoring . . . 70
9.4. Field-slice preview requests . . . 71
9.5. Check the measurement before a long run . . . 72

10. Execution, Jobs, and restart **73**
10.1. Before starting a job . . . 73
10.2. Set MPI layout and worker count . . . 73
10.3. Follow a calculation and interpret its state . . . 74
10.4. Browse history and remove a job safely . . . 75
10.5. Understand automatic mesh reuse . . . 77
10.6. Configure checkpoint publication . . . 77
10.7. Restart and check compatibility . . . 78

11. Live and recorded fields **80**
11.1. Request the field information you need . . . 80
11.2. Choose the recording and move through time . . . 80
11.3. Separate colour, contrast, and geometric aspect . . . 81
11.4. Export the appropriate evidence . . . 82
11.5. If a field appears empty or incomplete . . . 82

12. Results and analysis **83**
12.1. Select the source before interpreting the plot . . . 83
12.2. Read wake-potential components . . . 84
12.3. Calculate and interpret impedance . . . 85
12.4. Fit and assess resonances . . . 86
12.5. Read scattering results . . . 88
12.6. Read power-loss curves and recorded preview frames . . . 88
12.7. Keep a result reproducible . . . 89
12.8. Opposite-charge pair results . . . 89
12.9. Wake gradient and quadrupole coefficient . . . 90

13. Troubleshooting and recovery **91**
13.1. Curved or hybrid meshing stops . . . 91
13.2. Geometry is missing or cannot become a solid . . . 91
13.3. A setting changes, disappears or blocks the job . . . 92
13.4. Build or Run cannot start, or stops early . . . 93
13.5. Fields or results look wrong . . . 93
13.6. Studio is blank or stops responding on Windows . . . 95
13.7. Prepare a useful support report . . . 95
13.8. Return logs from a cluster job . . . 95

A. Cross-setting dependency map **97**

B. Shortcuts, units and terminology **98**
B.1. Core Windows shortcuts . . . 98
B.2. Units at a glance . . . 98
B.3. Terminology . . . 99

C. Readiness and study record **101**

Index **102**

1. Find your way around

1.1. Navigate a project

Start from Home, create a new case or open an existing project YAML file. Create New Case and File > New Case from Template ask for the new project's name and location. After saving the initial project, Studio opens Geometry; Import Geometry can then preserve sources in that project without asking you to save an untitled case first. Cancelling the location dialog keeps the current workspace. Return to Case appears on Home only after you have entered a case workspace in this Studio session. Create or open a case, then click Home to see the button. It returns to that case without reopening it and preserves unsaved edits and the selected workspace. The Home toolbar/File action and Ctrl+Shift+H also return to an entered case; they do not open the internal default template on startup.

The EMUZAG Studio logo appears on Home; the light emblem identifies the application in the taskbar. Find the product version in Help > About > About EMUZAG Studio and library notices in Help > About > Third-Party Software.

The left-hand tree is the main navigation. Selecting an entry changes the central workspace and the relevant inspector; it does not create another independent model. Geometry, setup, fields and results are views of the same project or its recorded runs.

A *case* is one calculation setup. A *run* is an execution of a recorded setup. An *artifact* is a file produced by that run, such as a mesh, log, wake curve, or field recording. YAML is the text format used to store the case's named settings; you can use the guided editors without editing YAML directly.

Item	What it means
Model	Case & Units, Geometry, Materials: define the problem, its physical regions and their properties.
Domain & mesh	Domain & Boundaries, Mesh, Mesh Setup, Mesh View, Material Mesh; Section Assembly is relevant when composing repeated sections.
Calculation	Excitation Source, Solver, Wake & Outputs: choose how to excite the model, evolve fields and observe the response.
Run	Execution, Field, Results: configure processes, start work and interpret the recorded output.
Activity area	Jobs, progress and diagnostics explain what is running or why an operation cannot proceed. A diagnostic route may preserve the current central view.

1.2. Local graphics settings

Open Edit > Settings… on Windows or Linux. On macOS use EMUZAG Studio > Settings… (Command-comma). The Graphics tab controls geometry transparency, not the system graphics driver. Preferences are saved for this Studio user, outside the project: they do not change the YAML, mesh, Solver calculation or recorded results.

The selected mode applies to geometry whether or not domain boundaries are shown.

Choose Mode for next Studio startup:

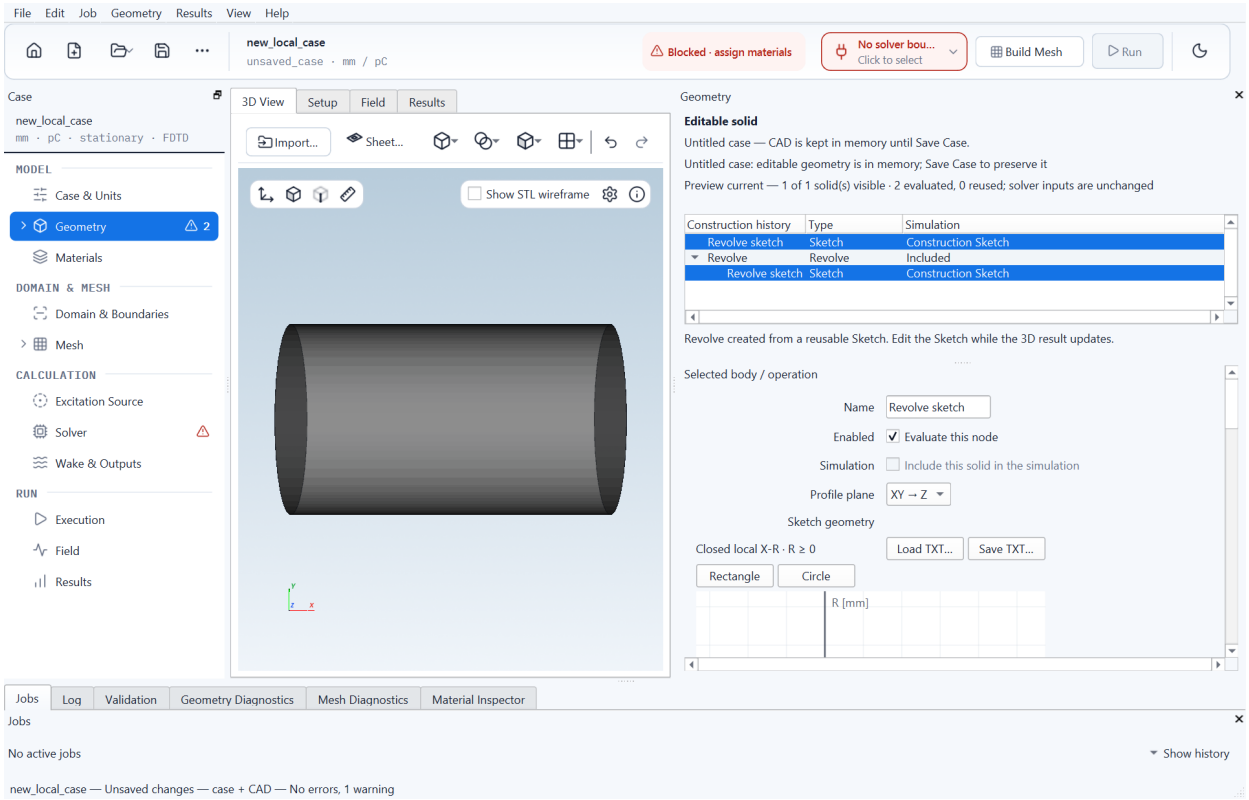


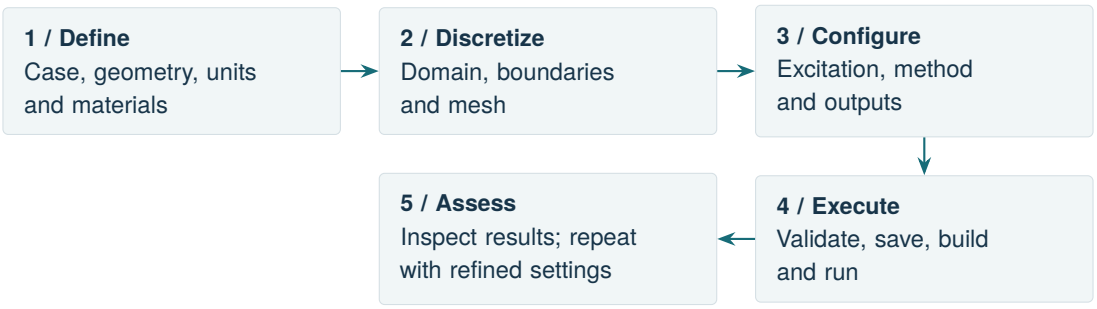
Figure 1.1.: The project tree at left, the geometry workspace in the center and a sketch inspector at right. This example has no assigned material or connected Solver, so readiness is blocked. The visible Revolve result already exists; the selected sketch is its construction profile.

Item	What it means
Automatic (recommended)	Uses standard depth peeling for Parallels/virgl graphics and VTK's default selection on other GPUs. This is the initial preference.
Standard depth peeling (compatibility)	Preserves transparency with the standard peeling technique verified on Parallels. Use it when the automatic choice causes missing surfaces.
Dual depth peeling	Requests dual peeling; an unsupported context uses standard peeling. This mode can produce missing surfaces on Parallels even when the driver reports successful use.
Basic transparency (no depth peeling)	Uses ordinary alpha blending. Surfaces remain transparent, but overlapping surfaces may appear in the wrong order. This is not software rendering on the CPU.

Click OK to save, then restart Studio when convenient. The dialog never restarts Studio or stops a calculation; the current session keeps its startup preference. Cancel discards the dialog selection. Restore Automatic selects Automatic in the dialog; click OK to save that choice.

The read-only diagnostics identify the current view's graphics vendor, renderer, OpenGL version, active session preference and last transparency pass. They also show the saved preference for the next startup. A view that has not rendered yet reports that explicitly. The reported pass is not proof of correct visible output. Use Copy Graphics Diagnostics when reporting missing geometry. If a manually selected mode loses surfaces, reopen Settings, restore Automatic and restart.

1.3. A reliable working order



You may visit pages in any order. The order above limits avoidable rework: changing units or geometry after choosing a mesh can invalidate assumptions in several other pages. A later edit is not prohibited, but its dependent settings need review.

1.4. Selection, drafts and validation

Select a geometry row or a visible solid to inspect it. Available modeling operations depend on what is selected: an operation requiring two bodies is not enabled by selecting only one. A construction sketch has its own inspector but is not itself a Solver volume.

Many numeric controls commit when you finish editing or leave the field. For case setup, Properties and case table fields and the checkpoint fields, Save Case, Save Case As…, Build Mesh, Run and the unsaved-changes prompt also commit the value you are typing, and Save Case becomes available with your first typed change. After Save Case, focus stays in a setup or Properties field; after `Tab` it is in the next field with its text selected. A table cell editor closes. If Studio rejects the input, the operation stops and the status bar names the reason. For Build Mesh and Run this happens once the background licence check finishes, and Log also records it. Text the case accepts but cannot validate, such as a word in a numeric field, stays visible and Save reports the validation error. CAD fields in the Geometry inspector, such as names, dimensions, transforms, tolerances and edge sizes, follow the same rule as one CAD edit (Section 5.13). Sketch point tables and arc radius still apply only on `Enter` or when you leave the field; a constraint value is used when you click Add constraint. MPI layout and field-preview settings stay drafts until Apply layout or Apply preview settings, or until Reset discards them. Other edits and navigation keep them, Save Case does not apply them, and Build Mesh and Run stop while one is pending. Materials also have explicit draft/apply behavior. Resolve an active draft before changing project or starting another operation. A displayed value is not evidence that a whole case is valid: read the validation message and repair the named field or its dependent setting.

If a saved value is absent from a fixed-choice editor's available options, the table cell and the open editor show Unavailable with that value, or Not set for an empty value. A true/false setting saved as another value also shows Unavailable instead of a check box. Opening or leaving that editor does not select a replacement. Choose a supported option explicitly to repair it, then check the validation message. An unavailable material reference needs a material that exists in the current case. In an automatic field, saved text that matches a choice name, such as Automatic, is not that choice: the table cell shows Unavailable, and the open editor keeps the text and says so in its tooltip. A recognized older spelling of a choice stays in the file and is shown as that choice.

Standard exposes the usual working controls. Expert adds advanced parameters with the same validation requirements. Preserved expert/YAML settings can affect a run even when they are not on the current page. Inspect the saved configuration when reproducing or reviewing a case.

Visibility, inclusion and readiness are different

A visible solid can be excluded from simulation. An included solid can lack a material. A valid project can still lack a usable Solver or sufficient runtime resources. Treat each of these as a separate check.

1.5. Files, saving and portable projects

Use Save Case to save the current case and CAD authoring state. Use Save Case As… to make a new working copy of the current state, including unsaved changes; save or cancel an open material definition first. Keep related project files together when transferring the project.

If Studio reports that the project *was saved* but it could not finish a later step, such as refreshing the window, the saved files are complete. Do not save again to retry; reopen the project from Open Recent before continuing. If Studio then still lists unsaved CAD changes, choose Discard: the reported save already holds them, unless you edited the model after that message.

Opening a case, including through Open Recent, makes that YAML file the active document. The title, header and project tree use its case name. If it still contains the template name `new_local_case`, Studio displays the filename instead (the containing folder for a generic `case.yaml`). This display fallback does not rename or modify the file. Hover over the header name to check the active case path.

If Studio asks about unsaved changes before New, Open, Open Recent or Import Project, choosing Discard approves replacing the current project. Cancelling the next dialog, or selecting a case that cannot be read, keeps the current project and any unapplied material definition. Choosing Save requires you to save or cancel that material definition first. If opening fails after Studio has begun replacing the current project, the error names the failed stage. Studio then closes the partially opened project without saving it and returns to Home with the startup template; the previously open project is not restored. Reopen the case once the cause is resolved.

Referenced geometry paths are resolved relative to the case file's folder, not Studio's installation or current working directory. Absolute references remain absolute. If a referenced solid or sheet file is missing, the Geometry view shows a Missing geometry files notice with the expected paths; hover for the complete list. The case remains open for repair. Restore the correct STL files at those paths, or use Import Geometry to add the matching geometry and update the missing object/sheet references. Check materials and units; importing another object does not repair an old reference automatically. For CAD, the selected STL or native geometry is prepared automatically before Build Mesh or Run; their absence alone does not show this warning. Missing original STEP/BREP sources do show the warning. After restoring files, choose Geometry > Reload Geometry. Studio does not search unrelated folders or silently substitute another file with the same name.

For New Case or a new save, Studio derives a project folder from the filename selected in the dialog: choosing `example.yaml` creates `example/example.yaml` under the selected parent folder. The guide uses `case.yaml` as the generic name for the Solver configuration; a saved project may use your chosen basename. New Case requires a new folder: choose another name or location if that folder already exists. A failed creation reports its error. If an incomplete folder is retained, its path is reported so you can inspect it; Studio does not remove unrelated files to retry creation.

Save Case As… writes the current working state into the new project, including unsaved case, CAD, imported-STL, material-source and display-colour changes, and Studio then continues there. The original project keeps its last saved files and runs. External CAD sources are copied to `Geometry/CAD Sources` in the new project; after unsaved CAD changes, only the sources the model still uses are copied. Files of objects removed since the last save are not copied, and Undo starts afresh

in the copy. Choose a new sibling project name: Studio rejects an existing destination, nesting inside the current project, and placing a second case file in the same project folder. A failed Save As creates no project and keeps the current one open with its unsaved changes. Save As copies the modeled inputs and authoring assets; it is not a backup of arbitrary files, previous runs or checkpoints. Preserve those separately when archiving a study.

Item	What it means
`case.yaml`	The authoritative Solver configuration: geometry references, material definitions, domain, mesh, excitation, method, monitors and execution settings. Opening only this file is insufficient if its referenced assets are missing.
`Geometry/cad-model.yaml`	Editable CAD authoring state. Retain it to change native construction and imported BRep geometry. It is not the mesh read by Solver.
`Geometry/`	Original and/or prepared geometry and related provenance. Native geometry documents transfer curved CAD boundaries to Solver. Keep the referenced files, not merely a screenshot of the model.
Material source files	Tabulated material data are part of the model's inputs. Retain the files referenced by the case and the normalization/provenance needed to interpret them.
`EMUZAG Studio Results/`	Visible run storage, snapshots and artifacts. See Chapter 10; a run uses a recorded input state, not whatever the editor shows later.
`EMUZAG Checkpoints/`	The new-case checkpoint directory setting, used only when the relevant checkpoint workflow is configured. It is not a substitute for saving the authored project.
`conversion-report.json`	Provenance and semantic decisions from project conversion. Keep it with an imported GdfidL case.

> **Do not repair a project by deleting its generated files**
>
> Save and allow Studio to prepare geometry through Build Mesh or Run. Manual replacement of a prepared geometry document can disconnect it from the editable CAD model or a recorded run. To keep a standalone imported surface, use the supported geometry import workflow and keep its provenance.

1.6. Importing a project is not importing geometry

Geometry imports supported shape files into the current model (Chapter 5). Import Project… converts a supported external setup into a new EMUZAG case. The implemented project converter is the restricted GdfidL STL-based adapter; do not assume that other simulation formats or arbitrary GdfidL programs are supported.

1. Choose Import Project… and the GdfidL setup. Supply its referenced closed STL material volumes and select a destination for the converted bundle.
2. Review reported unsupported statements. The converter does not run GdfidL, execute general scripts or recreate its geometry-construction commands.
3. Open the resulting case and read `conversion-report.json`. Check the axis mapping, dimensions, source charge, materials, boundary faces, mesh policy and mode before building a mesh.
4. Inspect the normalized geometry, then follow the normal validation and convergence process. A completed conversion is not numerical equivalence to the source simulation.

If the destination already contains a project, Replace Project asks for confirmation. Conversion keeps the existing contents until the new project is ready. A conversion failure or cancellation before replacement leaves those contents in place. Choosing Replace Project authorizes removal of the old contents; choose a new destination to keep both. Once final replacement starts, Cancel does not undo a completed import.

If the destination changes during conversion, Studio preserves it and asks you to review the destination and retry. If replacement fails, Studio attempts to restore the previous project. If restoration also fails, the error identifies the recovery folder containing the old project. A completed import can also report a cleanup warning if the old backup could not be removed. Keep any reported recovery folder until you have reviewed and resolved the warning or error.

Item	What it means
Coordinates	GdfidL longitudinal z becomes EMUZAG x; source x becomes y, and source y becomes z. Source geometry in metres is normalized to millimetres; charge in coulombs becomes pC.
Geometry and materials	Requires final closed oriented STL volumes and a supported all-space PEC background. Supported finite isotropic, passive Lorentz and conductive-wall subsets have explicit mappings; anisotropy and incomplete/active poles are rejected.
Excitation and ports	The supported source is one positive-charge, positive-z Gaussian line bunch with zero offset convention. The required longitudinal full-plane ports and any accepted transverse ports are mapped to EMUZAG faces. Partial or modal ports are outside this converter subset.
Mesh and method	The converter applies its own mesh and method policy; source spacing and time-safety values are not promises that the same discretization is retained. At this edition, $d_x = \sigma/5$ and $d_y = d_z = 1.05\sqrt{2}\,d_x$. The report records what was emitted.
Mode	Source requested wake extent greater than the converted structure's effective X span selects stationary mode; otherwise the converter selects a moving window. This span reflects clipping and grid alignment. Review the emitted choice and wake interval.
Rejected constructs	General loops/scripts, constructed primitives, conditional material overlays, non-supported material physics, multiple bunches and partial/duplicate or modal port arrangements are not silently approximated.

Conversion does not require an installed Solver and does not launch one. Resource estimates in its report list their exclusions. Check the actual run's memory summary when choosing resources for larger calculations.

2. Connect Solver and activate a trial

Studio needs a connected Solver for meshing and calculations. Geometry authoring does not require one. Trial activation applies to the Solver executable, not to Studio or the project YAML file.

2.1. Choose the supplied Linux edition

Use the named launcher supplied with the installation. The workstation developer edition uses a Solver without trial licensing. The workstation trial edition uses the same workstation Studio with a TPM-bound Solver. The cluster GUI edition uses the matching site Solver and its HPC workflow. Each Linux edition keeps its own saved Studio preferences; the launcher verifies the selected binaries before opening the application. Studio remains unlicensed in every edition.

A Linux workstation trial does not use a cluster profile or shared activation folder. In Trial Activation, the heading identifies the Linux workstation. Generate a request there, send the saved file to EMUZAG, then install the returned license using the same workstation, Linux account and local activation directory. The machine requires accessible TPM 2.0 hardware. The default directory is `EMUZAG/Licensing/Workstation` inside the account's home; installation instructions may select another private local directory. Moving project folders or updating normal libraries does not change the TPM device key.

The signed trial lasts 30 days from vendor issuance. Copying activation files to another computer does not transfer that key. If the TPM is unavailable or protected state is missing, retain the Solver diagnostic and contact support; do not clear the TPM or delete activation state. Workstation MPI supports ranks on one machine. Use the cluster edition for submitted multi-node jobs.

2.2. Start with the Solver connection button

Find the Solver connection button in the top bar, beside Build Mesh and Run. It shows the selected Solver and its current readiness. *Bound* means that Studio has selected an executable; it does not mean that a trial is activated.

Item	What it means
No solver bound	No executable is selected. Click the button and follow Section 2.4.
Trial activation required / Click to activate	A trial Solver is already selected but cannot yet perform protected work. Click this same top-bar button to open Trial Activation; do not select the EXE again.
Trial valid	The trial is active; no new request is needed. With MPI ready, clicking opens licence status. If the second line requests MPI setup, complete that separate step as described in Section 2.7.
License check failed	The status command did not complete. Finish any system access prompt, then click Click to retry. This keeps the selected Solver and does not generate a request or restart a calculation.
Non-trial	This Solver does not require trial activation. Continue with runtime and project readiness checks.

Before meshing or running, Studio rechecks the licence in the background. The last successful connection status stays visible while Run and Build Mesh wait for the reply. An initial check, or

a retry after a failed check, uses an informational indicator, not an error. If the check fails or reports an expired or unusable licence, the button shows the problem and work remains blocked. A previously valid status cannot authorize a new calculation.

2.3. If Solver came with your project or package

A project may be delivered with a Studio/Solver trial package. In the standard Windows package layout, Studio can find the accompanying `emuzag-solver.exe` beside its own executable automatically. Studio also restores a previously selected Solver when it is available.

1. Launch the supplied Studio with the package files kept in their delivered layout, then open the project. Wait for the Solver check to finish.
2. Look at the top-bar Solver connection button. If the detected trial has not been activated, it shows Trial activation required and Click to activate.
3. Click that button. Trial Activation opens; continue with Section 2.5.

> **An automatically detected trial does not open activation by itself**
>
> Startup discovery or restoration selects the Solver and checks its status, but leaves the activation dialog closed. Open it by clicking the Solver connection button. No request file has been generated yet.

Automatic discovery depends on the package layout or a saved/configured Solver location. It does not search arbitrary project folders for an EXE. A previous selection can take priority over the bundled Solver: check the selected path in the Solver button's tooltip, and use Job > Select Solver… if you need the executable supplied with this delivery. If the button still says No solver bound, use the manual procedure below.

2.4. If you need to select Solver yourself

1. Click No solver bound, or choose Job > Select Solver…. The menu also lets you replace an already bound Solver.
2. Select the supplied `emuzag-solver` on macOS or Linux, or `emuzag-solver.exe` on Windows, not a shortcut, MPI launcher, or installer. Studio checks compatibility and reads the executable's licence status; it does not identify trial capability from the filename.
3. If this is an unactivated trial, Trial Activation opens automatically after the checks succeed. Continue below. A valid trial needs no new activation; an ordinary non-trial Solver has no trial activation step.

Studio remembers the selection. On the next launch, the automatic-restoration behavior in Section 2.3 applies. If you close an activation dialog before finishing, reopen it from the top-bar Solver button or Job > Activate Trial…. Once valid, the menu action becomes Trial License Status….

2.5. Activate a Windows workstation trial

Generate the request, install the licence and run Solver on the same workstation and Windows account. An available TPM 2.0 (Trusted Platform Module) is required for hardware-backed key protection. Request generation needs no administrator rights.

There are two files, with different roles:

Item	What it means
`customer.request`	Created on your workstation. You send it to EMUZAG so a licence can be issued for that workstation/account.
`customer.license`	Returned by EMUZAG. You install it through Studio on the workstation/account that created the request.

1. Generate the workstation request

Click Generate Workstation License Request… and save `customer.request`. After the success message, use Reveal Request File to locate it. The file is created only on request, not when you connect Solver or open the dialog.

2. Send the request and receive the licence

Send `customer.request` to your EMUZAG contact; Studio does not send it for you. EMUZAG returns `customer.license`. The request contains a public device key and identifier, not a private key; treat it as customer data.

You may close Studio while waiting and reopen activation from the Solver button. If you already have the matching licence, skip request generation.

3. Install the returned licence

Click Install Trial License… and select `customer.license`, not the request. Solver installs it; no manual copy beside the EXE or into the project folder is needed. Keep the file for retry if installation is interrupted.

4. Confirm activation before running

Wait for the refreshed Trial license is valid status, check the expiry, then Close. If the licence remains blocked, use Section 2.8. With MPI ready, the top-bar button shows Trial valid and the expiry; otherwise complete runtime setup below.

Refresh Status rechecks the licence without renewing it. Change Solver… selects another EXE; it does not transfer the licence.

> **When the 30 days begin**
>
> The trial lasts 30 days (2,592,000 seconds) from vendor issuance in UTC, not from request creation, installation or first use. Delayed installation and reinstallation do not extend its signed expiry.

2.6. Activate and update a macOS workstation trial

The macOS 1.1.0 package targets Apple Silicon with Secure Enclave and macOS 26 or later. Keep the complete extracted package together; its external Solver is `bin/emuzag-solver`. Open Solver

status in Studio, generate a workstation request and send that request to EMUZAG. Install the returned licence through the same dialog on the Mac and login account that created the request. Studio remains free to use. The Solver trial lasts 30 days from issuance and permits MPI ranks on one physical Mac.

macOS may request access to the EMUZAG Solver offline license device key in the login Keychain. Enter the account password only in that system dialog. Choose Always Allow to retain access for this executable. Studio allows up to two minutes for a macOS status query while you respond. If the check fails, click Click to retry in the Solver button after completing the system prompt. A changed ad-hoc executable signature may require approval again after an update. The package README explains its ad-hoc signing and first-launch procedure.

Solver stores activation outside the program directory, under `~/Library/Application Support/EMUZAG/Licensing/Workstation/`. Do not edit or remove that protected state. Replacing the package on the same Mac and account preserves a valid licence from the same issuer and does not restart its expiry period. After updating, check that Studio reports Solver version 1.1.0; if it still selects an older copy, choose Job > Select Solver… and select `bin/emuzag-solver` in the new package. The supplied MPI runtime is bundled.

2.7. Complete runtime readiness and start work

MPI (Message Passing Interface) coordinates calculation processes, called ranks. Windows production runs require Microsoft MPI even with one rank. For MPI setup required / Click to install, click the Solver button, then Install MPI Runtime in the confirmation. Approve the administrator prompt if authorized; wait for setup and Studio's recheck. If no installer is offered, ask your administrator to install or repair the runtime.

Resolve project validation before Build Mesh or Run (Chapter 3); activation does not repair model inputs.

Job > Forget Local Solver clears Studio's selection without uninstalling Solver, deleting its licence, or resetting the trial.

2.8. Recover from a Windows activation problem

Item	What it means
No licence installed	Generate a request, or install the matching response you already received.
Expired	Contact the vendor. Reinstalling the same licence does not change its signed expiry.
Wrong device or user	Return to the workstation and Windows account that created the request. Contact support for a genuine workstation change.
State missing / interrupted installation	Try Install Trial License… again with the returned signed file. If validation still fails, retain the diagnostic and contact support.
Clock rollback / not yet valid	Check that Windows has the correct date and time. Refresh status after correcting it; contact support if the problem remains.
Invalid	Read the Solver diagnostic. Do not edit the licence or remove licensing state in an attempt to repair it.

Clock rollback detection tolerates five minutes of backwards time, not extra trial duration. Status refresh is read-only. Do not clear the TPM: that destroys the device key used by the licence.

Studio rechecks status before protected workflows. A failed licence check stops the job; status refresh never retries it. Correct the condition, then restart the workflow.

A Windows MPI trial supports multiple ranks on *one physical shared-memory host*. Multi-host execution is rejected even with a valid licence.

2.9. Activate a shared cluster trial

Use this workflow when Studio offers Generate Cluster License Request…. This temporary offline trial is bound to the supplied cluster build configuration and one shared licensing location. Different users may use that installation; one protected Solver command may run at a time, with all its MPI ranks sharing the calculation slot. A Slurm allocation account is still a scheduler setting, not the user identity licensed by this trial.

The installation owner chooses a directory on shared storage and grants access through an existing shared group, following the supplied installation instructions. Set `EMUZAG_LICENSE_DIRECTORY` to that same absolute directory before starting Studio and in submitted jobs. This trial has no per-user default location.

1. The installation owner selects the supplied Solver, chooses Generate Cluster License Request…, and sends the saved `customer.request` to EMUZAG. Request creation does not start the trial.
2. The installation owner selects `customer.license` through Install Trial License…. Other users use this shared installation without generating separate requests or copying private keys.
3. Refresh status and check the exact UTC expiry. The signed period is 30 days from vendor issuance. Jobs check authorization when Solver starts, including after waiting in the Slurm queue.

Cluster calculation slot is occupied means another command holds the slot, or its termination needs investigation. Wait for normal completion and refresh. After an interrupted job, the installation owner must confirm that every worker has stopped before following the supplied recovery procedure. Closing Studio, losing scheduler contact or a launcher process exiting does not prove this.

Studio never clears an occupied slot automatically. Do not delete or recreate shared trial state; reinstalling the licence does not clear the slot or renew it.

Solver enforces the limit for direct command-line and scheduler use too. Licensing runs at command startup and completion, outside numerical time steps. An admitted command may finish after expiry; a later command validates again. Slots are not reserved across gaps between a pipeline's separate commands.

This configuration-bound trial uses software protection, without TPM hardware attestation. It is not an online licence service. Site acceptance must separately verify distinct-user permissions, shared locking and scheduler cleanup.

2.10. Activate a Linux HPC account trial

This workflow applies only when the selected Solver reports an HPC account trial and Studio offers Generate HPC Account License Request…. An ordinary Linux build marked Non-trial has no protected trial backend. The package manifest and site acceptance record identify the supplied build and which cluster checks have been completed.

Use the same Unix account, including its account name and numeric user ID, on graphical and compute nodes. Its private licensing directory must be on shared storage, visible at the same absolute path on every participating node. The default is `~/EMUZAG/Licensing`. If your site needs another location, set `EMUZAG_LICENSE_DIRECTORY` to that absolute directory before starting Studio, and retain the same setting for submitted jobs. Ask the site administrator to confirm shared storage and account consistency; do not copy another account's key or licensing directory.

1. Select the supplied Linux Solver from the top-bar connection button and open Trial Activation if activation is required.
2. Choose Generate HPC Account License Request…, save `customer.request`, then send that file to your EMUZAG contact. Generating the request does not start the trial clock.
3. Choose Install Trial License… and select the returned `customer.license` under the same Unix account and shared-directory setting. Studio invokes Solver to install it; do not edit the file or its contents.
4. Wait for fresh Trial license is valid status and check the exact UTC expiry before submitting work. A queued job validates again when Solver starts on its compute nodes.

The signed period is exactly 30 days from vendor issuance. Reinstalling the same licence does not renew it. An authorized running command may finish after expiry, but every later protected command validates again. Multi-node MPI execution is permitted for the matching account and installation; it does not grant independent trials to other accounts.

The installation key is held in software with private Unix file permissions. This is not the Windows TPM-backed, non-exportable-key trial and is not a floating-licence server. Keep private key/state files in the shared licensing directory; send only the explicitly generated request to EMUZAG.

For a wrong-account or installation status, use the account and directory that created the request. For missing state after an interruption, reinstall the returned signed licence and refresh status. For clock rollback or a not-yet-valid licence, ask the administrator to check time synchronization on graphical and compute nodes. Retain any diagnostic if retry fails. Studio never retries failed work automatically after refreshing status.

Use the cluster's documented MPI installation and scheduler configuration. A local compatibility build or passing local MPI test does not establish multi-node interconnect, scheduler, shared-filesystem locking or graphical-node acceptance on your cluster.

Submit mesh and solve jobs through Slurm

Ask your administrator to configure the supplied Slurm launcher for your approved partition, allocation account, node count, time limit and memory. The separate `linux-slurm-setup.md` instructions explain this one-time setup and how to review a batch script without submitting it. Keep projects, runs, executables and licensing state on shared paths visible to compute nodes.

In the Linux HPC edition, choose Configure HPC… in the top bar or Job menu. It appears when the selected Solver identifies an HPC account or shared cluster trial, including before activation. It is hidden in ordinary Studio editions and for other Solver backends. The HPC edition requires its matching Solver for calculations and does not switch to local MPI when cluster setup is missing.

Choose Import site profile… for the profile supplied by your administrator. Then review the following settings:

Partition and allocation account Select the approved queue and project account. An empty account uses the site's default only where permitted.

Compute nodes Request the number of nodes. It cannot exceed the MPI rank count in this case.

Time limit per job Enter hours, minutes and seconds; a days prefix is also accepted. Mesh and solve each receive this limit as separate jobs.

Memory per node Enter MiB for each requested node; 1024 MiB is 1 GiB.

QoS Supply a quality-of-service name only when your site requires it; otherwise leave it empty.

The Case resources summary shows MPI ranks and threads per rank. Change them, and any explicit Cartesian layout, in the case Execution settings. There is one source of these values: the HPC dialog does not duplicate their editors, change the YAML, or substitute additional threads for requested ranks.

Show site setup contains the shared project root, MPI launcher and Slurm command paths. Imported MPI arguments and runtime paths come from the site profile. The displayed license folder is informational; the site launcher selects it before Studio starts. Configuration changes never move activation files or renew a trial. Projects and run folders must be under the selected shared root, with the same paths available to compute nodes.

Check configuration checks the profile and partition access without submitting a job. Studio remains responsive during this check. A pass does not establish account or QoS eligibility, remote mount visibility, MPI communication or shared-filesystem locking; those require the administrator's site validation.

Save keeps preferences for future jobs in this installation and selected site profile. Cancel discards dialog edits. Changing settings clears the previous check result; import the profile again to adopt changes to its file. Each run retains its own configuration snapshot, so later changes do not alter an active job. This version submits new Slurm jobs even when the graphical session inherits an interactive allocation; it does not reuse that allocation.

After setup, use Build Mesh and Run normally. Each mesh or solve stage submits a separate job with the case's MPI ranks and workers per rank. Studio stays open on the graphical node and reads shared logs and Field previews as the calculation produces them. Queue waiting does not renew the trial; compute ranks validate when their command starts.

Cancel requests cancellation from the scheduler. If the scheduler confirms that the job stopped, Studio shows cancelled. If contact is lost, cancellation is unconfirmed or the local launcher is killed, Studio shows interrupted and explains that the cluster outcome is unknown. The job may still be running. Before retrying or deleting that run, have the recorded job ID checked with the scheduler. The visible `Slurm Jobs` folder retains the submission, job receipt and logs. Closing Studio cannot

guarantee that cluster jobs stop, and Studio never automatically submits a replacement for an uncertain job.

3. Your first complete workflow

This exercise builds a simple vacuum region in a PEC background. Its purpose is to teach model creation, meshing, execution, and result selection. Use a compatible Solver for meshing and execution; you can perform authoring steps without it.

3.1. What this calculation measures

The bunch travels along X and excites electric and magnetic fields. X is *longitudinal*; Y and Z are *transverse*. An electric field **E**, measured in V/m, and a magnetic field **H**, measured in A/m, describe the local response at a position and time. A field image is therefore a view of one component on one recorded plane.

A *wake potential* describes the accumulated effect of these fields on a witness charge following a chosen trajectory. Studio reports it per unit drive-bunch charge, in V/pC. The primary result is now physical voltage in V; select the physical voltage curve is converted during analysis to V/pC. The longitudinal component describes an accelerating or decelerating voltage; transverse components describe kicks. A witness is a test trajectory, not another bunch added to the simulation.

A *wake function* conventionally describes excitation by a point charge; a finite-bunch wake potential includes the bunch's longitudinal distribution. *Impedance* describes the response versus frequency and is derived in Results from the wake, with bunch-spectrum compensation when enabled (Section 12.3). The three views—field, wake potential, and impedance—answer different questions.[1]

PEC means *perfect electric conductor*: an ideal metal that neglects finite conductivity and wall loss. In this example, a vacuum box cut from a PEC background defines a straight channel.

3.2. Create and inspect a small model

1. Create a new case from the template. In the save dialog, choose a parent folder and enter `first-studio-case.yaml`. Studio creates the matching project folder, `first-studio-case`, and saves the YAML file inside it.
2. In Case & Units, confirm millimetres and pC before entering dimensions. Do not assume a file's physical units can be inferred from its extension.
3. In Geometry, choose Create and Box. The initial box has $10 \times 10 \times 10$ model-unit dimensions, centered on the origin: each axis spans -5 to 5 mm. For this exercise retain the dimensions and position.
4. In Materials, confirm that the case contains vacuum and pec. Return to the box and set its Simulation material to vacuum. Confirm that Include this solid in the simulation is on in its inspector (Included in the geometry overview) and the background material remains pec.
5. Fit the view, inspect the box extents, and save. If its position does not enclose the intended transverse beam location, correct that before proceeding. Do not infer its physical location from the camera angle alone.

[1] For the physical distinction, see F. Reimann and U. van Rienen, *Wakefields—An Overview*, CERN Yellow Reports: School Proceedings, 2018. Product units and signs are specified in Chapter 12.

Which side is the metal?

The box is vacuum; the background is PEC. Assigning PEC to both removes the vacuum channel. Check the assignment, not just the display colour.

3.3. Check the domain, boundaries and source together

In Domain & Boundaries, use Full for the first exercise and inspect the fitted domain. Keep the new-case open longitudinal ends and PEC transverse faces. Confirm the beam lies inside the intended vacuum channel and any wake observation trajectories are inside the modeled domain.

Retain the new-case stationary, explicit FDTD setup: fields are advanced in time on a fixed grid (Section 8.3). In Excitation Source, inspect the Gaussian bunch, 1 pC charge, 0.5 mm RMS length and centered transverse location. RMS length is the standard deviation of the bunch's longitudinal charge distribution, not its full length. An omitted beam beta means $\beta = 1$; do not enter a lower beta without reviewing all dependencies in Chapter 8.

Do not apply symmetry by appearance

Half, Quarter and Rotate fit domain extents. They do not decide the correct electromagnetic symmetry boundary or guarantee that all trajectories remain inside the domain. Learn these controls with the full model first.

3.4. Build a mesh before the first solve

1. Inspect Mesh and the new-case 0.1 mm spacings. These values are an exercise starting point, not a general recommendation for production.
2. In Execution, choose a resource allocation appropriate for a small local test. One MPI rank and one thread per rank limit process count; a production MPI Solver still needs its MPI runtime even with one rank.
3. Click Build Mesh (F6). Studio validates the case and prepares included CAD as the selected STL or curved geometry automatically. Correct any missing-material, geometry or numerical error before continuing.
4. Inspect Mesh View and Material Mesh. Confirm the vacuum channel, PEC transverse boundary faces, expected extents and resolved features. The full fit need not leave a finite-thickness layer of PEC mesh cells. A geometric preview cannot replace this material-mesh inspection.

3.5. Run and make a first interpretation

Inspect Wake & Outputs: a wake monitor must exist to obtain wake curves; configure field preview before starting if you want live field inspection. Keep the initial automatic time-step and duration choices for this exercise and read the resulting plan. Click Run (F5), watch Jobs and diagnostics, and wait for normal completion. Use Stop (Shift+F5) if you need to cancel.

Open Results, select the completed run and the desired artifact/presentation. Check the source charge, units, component and trajectory before interpreting a curve. A uniform straight channel is not a good demonstration of a strong cavity resonance; small or nearly zero wakes are not automatically an output failure. Field preview and exported numeric results serve different purposes (Chapters 11 and 12).

3.6. Check sensitivity to numerical settings

Save a separate version before changing the model. Choose a quantity of interest and compare it across controlled refinements. Do not refine every parameter at once: you would lose the ability to identify which approximation changed the answer.

Item	What it means
Geometry check	Verify physical units, intended open/closed surfaces, material ownership, overlaps and minimum gaps. For STEP/BRep/native CAD, check the retained curved boundary and prepared geometry diagnostics.
Surface refinement	For CAD-to-STL, compare calculation STL tolerances separately from grid spacing. Curved surfaces retain the supported boundary directly. Display quality affects inspection only; a finer field mesh cannot restore a feature absent from an STL source.
Mesh refinement	Reduce relevant spacings while retaining a valid method/time-step combination. Inspect material boundaries and compare the same result definition across runs. Memory and runtime can grow rapidly.
Observation refinement	Extend duration/wake coverage when the quantity requires a longer tail. For impedance and resonance analysis, check usable bandwidth and observation length; padding is not additional physical data.
Reproducibility	Keep the case, geometry, material data, Solver version, run snapshot and analysis settings with the result. Record why the chosen settings are adequate for the intended engineering decision.

Record a small comparison table for the output you need: settings, result, and change from the previous run. For a nonzero result R, one useful measure is $100|R_{\text{fine}} - R_{\text{coarse}}|/|R_{\text{fine}}|$ percent. Near zero, use an absolute difference in the result's units instead. Choose an acceptance threshold before comparing runs; a single small change can be accidental, so check the trend over further refinement.

> **A useful second exercise**
>
> Replace the box with an imported STEP part representing the intended physical region. Confirm units and material, select STL calculation geometry, then compare two calculation STL tolerances at the same mesh spacing. This separates a CAD approximation issue from a Solver mesh issue and is often the quickest way to diagnose a suspicious curved boundary.

4. Case and units

A Studio project joins geometry, material definitions, a calculation setup, and the files needed to run that setup. The authoritative calculation document is the project's YAML file (for example, `first-studio-case.yaml`). The guided editors change that document; they are not a separate database. Geometry authoring and imported-source metadata accompany it in the project directory. See Chapter 5 for the distinction between a source object and a Solver-ready surface.

4.1. Name the calculation and choose units first

Setting	Values / units	Meaning and dependencies
Case name	Nonempty text	A descriptive calculation identifier. The new-project name is `new_local_case`. Use a name that distinguishes the model variant; the name alone does not record a material or mesh change.
Length unit	`m`, `cm`, or `mm`	New projects use millimetres. Coordinates, dimensions, mesh spacing, layer thickness, bunch RMS length, wake length, and scaled time quantities use this unit.
Charge unit	`C`, `nC`, or `pC`	New wakefield projects use picocoulombs. Required when a beam is present; not part of a scattering case.
Schema version	`4`	The case format accepted by this Studio version. Do not change this number to make an older input appear compatible: the structure and meanings of the fields must also match.

> **A unit selector is not a model-rescaling command**
>
> Choose units before creating the model. Changing Length unit edits the case unit; it does not constitute a coordinated conversion of every authored dimension and source file. A value of 10 interpreted as centimetres is not the same physical length as 10 millimetres. Likewise, changing the charge unit does not preserve the physical charge unless its number is converted too. For an existing model, work on a copy, convert the affected data deliberately, and verify known dimensions.

Some quantities always use SI units, independently of the length selector: conductivity is S/m, material and scattering frequencies are Hz, Lorentz damping is s^{-1}, the PML complex-frequency shift is m^{-1} (not Hz), backing impedance is ohms, and sheet resistance is ohms per square. Relative permittivity, relative permeability, and beta are dimensionless.

Time is often displayed as a length

Scaled time step means $c\,\Delta t$, not seconds. Scaled simulation time means $c\,T$. Both are expressed in the case length unit. For example, a scaled duration of 100 mm corresponds to approximately 0.334 ns; it is not a 100 ns run. The symbol c denotes the speed of light, while a beam at beta below one has speed $v = \beta c$. Do not replace c by v when interpreting these fields. The numerical constraints on time step appear in Section 8.4.

4.2. What a new project contains

The starting template is a convenient complete setup, not an engineering recommendation for an arbitrary structure. It contains no simulation geometry. Create or import geometry, assign its material, and verify the domain before meshing. Chapter 3 gives the complete first-run sequence.

Item	What it means
Geometry and medium	Empty geometry list; vacuum and PEC material definitions; PEC background. One unrepeated X section initially spans 0 to 10 mm.
Domain and mesh	Y and Z initially span -5 to 5 mm. All three mesh spacings are 0.1 mm. X boundaries are Open/Open; Y and Z are PEC/PEC.
Source	Gaussian point bunch, charge 1 pC, RMS length 0.5 mm, transverse position $(0, 0)$. Beta is omitted and therefore means exactly 1.
Field method	Stationary, FDTD, Explicit, Standard conformal treatment; automatic scaled time step and duration; waveguide initial field.
Monitoring	Wake length 10 mm; one additional trajectory at $(dy, dz) = (0.1, 0.1)$ mm; indirect integration enabled. Power-loss monitoring is off. No field-slice preview is requested by default.
Execution	Eight MPI ranks and one thread per rank; checkpoint publication off. Review the available machine resources in Chapter 10.

4.3. Read a field's state, not only its number

A *finite* number is neither infinity nor an undefined value such as NaN. Scientific notation uses powers of ten: `1e-6` means $10^{-6} = 0.000001$. *Dimensionless* means that no physical unit is attached; a ratio or a relative material property is dimensionless. A relative tolerance is a ratio, whereas an absolute tolerance has the units of the quantity being compared.

Compact numeric displays are for readability, not a statement of physical accuracy. Beta is shown at full authored precision because rounding a value below one to one would hide a method-compatibility distinction (Section 8.5).

Numeric parameter fields leave room for values such as `-1000.123` and expand for longer displayed values. In a narrow Domain & Boundaries panel, each minimum/maximum pair stacks vertically. Widen the panel to compare the pair side by side. Resizing does not apply an unfinished edit or change its precision.

Item	What it means
New-project value	A value actually written by the Studio template. Opening another project does not replace its values with these starting values.
Omitted-field default	A documented meaning when an optional field is absent. For example, omitted beta means 1; omitted bulk conductivity means zero. Required fields cannot be repaired simply by leaving them blank.
Automatic	A deliberate policy, rather than a missing value. A downstream setting such as mesh spacing can change the derived result.
Inactive but retained	Some method-specific settings remain in the document when another method is selected. Their controls may disappear; this does not mean their stored values were deleted.

Continued on next page

Item	What it means (continued)
Staged material draft	A material edit is not committed merely because it is visible. Use Save changes, or Cancel to discard the draft.

Normal and advanced parameter views change what is presented, not what the Solver is allowed to read. Moving-domain controls appear for Moving; implicit controls appear for Implicit. Other specialised settings have dedicated controls rather than a generic scalar row. The YAML view also preserves unknown extensions, but preservation is not a promise that the connected Solver accepts them.

4.4. Validation and a safe edit cycle

An *error* means the authored case fails a known requirement. Examples are a negative mesh spacing, incompatible finite-beta method, missing required material property, or duplicated monitor location. Such errors block ordinary save/run readiness. Fix the cited field or combination.

A *warning* identifies risk without necessarily making the case illegal. Examples include a duration shorter than the requested wake or an unknown YAML extension. `case.yaml` lists an object or sheet only once it has a material; while imported or modeled geometry still waits for one, its warning reads that geometry is present but has no simulation material yet. An *information* message can report a derived adjustment, such as nearest-grid sampling. It may change the interpretation of a result even though it does not block execution.

After an important edit, review Validation, save the project, and recheck the readiness state. A structurally valid file alone is insufficient: required surface and material-data files must exist, and the installed Solver must accept the case. Solver preparation can detect restrictions that a desktop form cannot establish, such as an invalid material fit or unsuitable resolved geometry. Use the preparation diagnostic to correct the setup, then repeat the affected stage.

> **Work in controlled variants**
>
> For a material, mesh, or boundary sensitivity study, save a clearly named project copy before the change. Change one modelling decision at a time and record the resulting mesh and run. This makes a numerical comparison interpretable instead of mixing several untracked edits.

5. Geometry: model, import, and prepare

The Geometry stage is where you create and inspect the shapes that define your simulation. Native Studio bodies, imported CAD solids, and imported triangle surfaces can appear together in the same view. They do not all have the same editing capabilities. Before building a mesh, establish three things: the geometry has the intended physical size, the intended objects are included, and each simulation object has a compatible material.

> **What Solver receives**
>
> Choose calculation geometry explicitly for CAD and STEP/BREP bodies: STL or Curved surfaces. STL remains the default for new projects. Curved surfaces retain their shape and trimming in prepared `.emgeom` documents. Both routes keep the editable source; display triangles are independent of calculation geometry. Direct STL inputs keep their original triangles. The selected Solver must support the chosen route; Studio reports incompatibility before calculation.

5.1. Choose the right geometry route

CAD means computer-aided design. A *BRep* (boundary representation) describes a solid by its faces, edges, vertices, and their connections. STEP is a CAD exchange format; STL represents only a triangulated surface. Neither the STL triangles nor the viewport's display grid are the Solver's volume mesh.

The Simulation geometry table calls this Geometry type: Editable solid, STL surface, or Zero-thickness screen. Its Triangles column counts display triangles, not simulation mesh cells. A prepared native document without a CAD authoring model is shown as Native geometry.

Item	What it means
Native Studio CAD	Use Create for primitives, or build a Sketch and then Revolve, Extrude, or Loft. Dimensions, feature inputs, and construction history remain editable.
STEP or BREP	Use Import Geometry… for `.step`, `.stp`, `.brep`, or `.brp`. Imported solids can participate in Studio's CAD operations. Import does not reconstruct the originating CAD system's feature history.
Direct STL	Use Import Geometry… for `.stl`. You can measure, move, rotate, rename, replace, and assign the surface, but cannot use it as an editable BRep for Boolean, Fillet, Chamfer, or Shell operations.
Zero-thickness screen	Import an STL with Add sheet…, or extract a CAD face with Create Screen. This is a distinct physical role; see Section 5.12.

STEP/BREP import and native construction require a CAD-enabled Studio build. A build without that capability can still work with STL geometry. The general geometry importer does not accept IGES, OBJ, DXF, or native files from arbitrary CAD products. Export a supported exchange format from the source application instead.

Keep the simplest useful representation

If a design is already available as STEP, retain that source for design changes and solid editing. If you have only STL, treat its triangles as the available geometric detail. A finer simulation mesh cannot reconstruct curvature or small features that were lost in an earlier STL export.

5.2. Choose calculation geometry per body

Open Calculation geometry in the CAD workbench. Choose the Project default as STL or Curved surfaces. For each body, Representation can inherit Project default or override it explicitly; Uses shows the effective choice. A hybrid scene contains both representations in the same calculation. Changing one body does not require changing the rest of the scene.

For CAD-to-STL, set STL linear deflection in the CAD document length unit and STL angular deflection in radians. Each body can inherit these tolerances with Use project, or use its own values. Smaller tolerances generally add triangles and preparation cost. They do not set the calculation-grid spacing. Directly imported STL retains its existing triangles and is not retessellated by these controls.

Item	What it means
Display quality	Controls the CAD preview only. A smoother image is not a finer calculation surface.
Calculation representation	Selects STL approximation or retained curved surfaces for each CAD body. Calculation STL tolerances apply only to the STL route.
Mesh spacing and Face areas	Control the Cartesian calculation mesh and how finite volume material areas are obtained. Both face-area policies work with STL, curved and hybrid geometry; see Chapter 7.

Save, then use Build Mesh or Run. Studio prepares the selected bodies automatically. Materials, priorities, source identities and previous job snapshots are preserved when changing representation. Existing projects retain their saved choice. Unsupported native geometry produces a diagnostic: select STL explicitly for the affected body, or correct its source, and rebuild. STL is an approximation whose tolerance must resolve the intended feature; it does not repair an invalid shape or a screen topology that the calculation mesh cannot represent.

5.3. Find and inspect the right object

Select Geometry in the project tree. Use the joined geometry list to identify a solid or screen and the right-hand inspector to see its representation and applicable controls. Selecting a native body opens its dimensional settings; selecting a construction Sketch opens the profile editor. A Sketch has no independent material volume and therefore does not need an entry in the simulation-solids list to exist.

Use the search field in Simulation geometry to find a name, material, geometry type or identifier. Matching ignores letter case, and the count beside it reports how many rows are shown. Search filters the list only: it does not hide objects in the 3D view, change their simulation inclusion or clear your selection. A selection hidden by search is explicitly counted; assignment, Fit selected and Isolate selected still act on the complete selection. Clear the search field to see all rows again. Point at an object's Geometry label for its identity details when names repeat.

In Geometry, selected objects retain their material colour and become opaque; other objects become translucent while keeping their colours. This makes an interior selection easier to identify. CAD

bodies also retain their selection outline. Dense STL triangle edges are suppressed during this focus so the material colour remains readable. Hidden objects stay hidden. A selected object hidden in the view is counted in the geometry list; a single direct STL object's Properties also reports its Visibility.

Click empty space in ordinary body-selection mode to clear the selection and restore the normal display. Face, edge, measurement and transform tools retain their own click behavior. Selecting an object preserves your viewing direction, zoom and active cut. Focus changes the display only; simulation inclusion, materials and calculation geometry are unchanged. Translucent context surfaces remain pickable; use the list or Cut view to select an enclosed object.

In the geometry list or project tree, use Ctrl-click (Command-click on macOS) to add or remove one row, or Shift-click to select a range. In the Geometry and CAD views, Ctrl-click (Command-click on macOS) or Shift-click on a CAD body toggles that body in the selection. Shift does not select a range in the 3D view. A direct STL pick, or any pick in Source STL or Assembly, selects that object alone even with a modifier; use the list to add those objects. Picking a body clears the list search and reveals its exact row, including when names repeat.

Choose Fit selected to frame the selected objects while retaining the viewing direction, projection, visibility and active cut. Fit uses the complete object extent, including the part hidden by a cut. Fit and isolation require geometry for every selected object to be available in the scene. Studio reports unavailable geometry without changing the current view.

Isolate selected temporarily shows only the selected objects. Its button becomes Exit isolation, which restores the preceding visibility, camera and active cut, discarding visibility changes made while isolated. Changing a material or reloading the same objects retains the session. If objects are added, removed or given new identifiers, Studio ends the session and reports that the preceding view can no longer be restored; use Show all if needed. Show all abandons isolation and makes all available bodies visible, including construction bodies and translucent intermediate operands. Disabled CAD operations stay hidden. The camera and cut are unchanged; Show all does not restore the preceding view. The eye checkbox changes only viewport visibility, without recalculating CAD or changing simulation inclusion. Use Included to exclude or restore a result body for simulation; an intermediate operand belongs to its result.

The command bar groups operations under Create, Boolean, Modify, and Arrange. When space is narrow, some commands use compact icons; their tooltips retain the command names. The active interaction mode changes what a click selects: body, face, edge, measurement reference, or transform handle. Check the selection/status text before applying an operation.

Item	What it means
Camera and fit	In the view, left-drag rotates, middle-drag (or Shift+left-drag) pans, and the wheel or right-drag zooms. Use Fit selected for the selection or Fit all (Fit at the top right of the view, or the Geometry menu) for all visible objects. Standard views restore a named orientation. In face/edge modes, dragging still allows camera navigation; a click and a drag serve different purposes.
Zoom to Region	Choose Zoom at the top right of the view, or Geometry > Zoom to Region, then drag a rectangle: the view zooms until the rectangle fills it, keeping the view direction. One rectangle ends the tool; a click without a drag, Esc or switching to another page cancels it. Nothing is selected or moved. Use Fit all to show everything again. In perspective, the rectangle is taken at the depth of the view's centre, so nearer or farther parts end up larger or smaller.

Continued on next page

Item	What it means (continued)
Smart distance	Click the ruler to activate Smart distance, then click two references to measure their distance in the case length unit. Blue points snap to geometry; orange points are free surface picks. Clear starts a new measurement; click the ruler again to turn it off. Dragging still navigates the camera. The ruler has no other measurement modes. Measurements describe the available geometry, not the Solver's eventual discrete mesh.
Transparent solids (X-ray)	Solids, sheets and CAD bodies are drawn opaque by default, which keeps crowded models fast. Turn on the Transparent solids (X-ray) checkbox at the top right of the Geometry and CAD view (labelled X-ray when the view is narrow), or Geometry > Transparent Solids (X-ray), to draw them translucent and see inner parts. Studio remembers the choice for the next start; it is never saved in the project. Selection focus, Domain & Boundaries and construction bodies keep their own transparency.
Opacity and isolation	Use X-ray, an imported STL's Opacity % or isolate/show controls to inspect nested parts. An Opacity % you enter applies with X-ray on or off. These are display operations; do not use them to exclude a body from a solve.
Show STL wireframe	Inspect the triangular surface representation. This is particularly useful for checking STL detail and the display tessellation of CAD faces. It is not a display of the simulation mesh.
Faces and edges	Use evaluated editable CAD for topology operations. A direct STL is a triangle surface even when it looks like a cylinder, plane, or sphere.

Display controls and screenshots

The application Geometry menu also exposes controls for the shared 3D view. They change presentation, not the saved shape, material, or mesh discretization.

Item	What it means
Zoom to Region / Fit all	Zoom to a dragged rectangle, or show every visible object again. Both keep the view direction.
Orthographic Projection	Removes perspective foreshortening from the view. The Standard View choices also select orthographic projection. Use measurement values, not apparent screen distances, for physical dimensions.
Bounding Boxes	Shows available bounds overlays. A bounding box encloses a shape; it is neither that shape's exact boundary nor proof of the simulation-domain settings.
Face Normals	Shows available surface-normal overlays for inspection. These are vectors perpendicular to the surface. They do not specify a screen's coating order.
Orientation Axes	Shows the compact X/Y/Z triad in the lower-left corner. This identifies orientation, not the physical origin of every selected body.
Beam Guide	Shows each source's beam axis as a thin line from a dot at the entrance, with small arrowheads along it and a larger arrowhead at the downstream end. A positive charge is drawn in coral red, a negative one in azure; the shades follow the light or dark theme. The guide is schematic, not an inspection probe or a simulation coordinate; read source coordinates under Excitation Source.

Continued on next page

Item	What it means (continued)
Save View Screenshot...	Saves the displayed 3D view as a PNG image. Choose a `.png` filename. This is not a geometry export or an image of every settings panel; save the project and relevant input/result metadata with a report.

Cut a geometry or mesh view for inspection

Geometry > Cut View hides one side of a plane so that you can look inside the model. While the Geometry route is active, choose View > Inspection Controls to open the plane and position controls. In Inspection Controls > View layers, the Cut view checkbox controls the same state. X is the longitudinal coordinate; Y and Z are transverse. Choose the plane by the coordinate it fixes:

Item	What it means
XY — fixed Z	The default. A longitudinal cut at one transverse Z position, exposing the interior along X.
XZ — fixed Y	The alternative longitudinal cut at one transverse Y position.
YZ — fixed X	A transverse cross-section at one longitudinal X position.

The position field is labelled with its axis and the case length unit, for example Z [mm], and shows the stored coordinate with all of its digits. Type an exact model coordinate and press Enter to apply it. The slider moves the cut across the extent of the currently visible cuttable geometry; the first cut on a plane starts in the middle of that extent. Each plane keeps its own position. Orbiting or zooming, hiding objects, assigning materials, and loading another object do not move the cut. They can change only the extent offered by the slider, so its handle may move while the coordinate stays the same. While nothing cuttable is visible and no position is stored for the plane, the position field is empty and unavailable, the slider is unavailable, and the status line says that there is no visible geometry to cut yet. Changing the case length unit re-centres the cut on the reinterpreted geometry, because the same number would otherwise name a different physical position.

By default, the cut keeps geometry at or below the coordinate. Flip side keeps the other side instead. The status line names the visible part, for example Showing Z $\leq$ -15 mm. Clearing Cut view restores the complete model and remembers the position for the next cut. Reset turns the cut off and restores the XY plane, a centred position, and the default side. Every replacement of the open project starts without a cut: New Case from Template (or the Home page equivalent), Open Case, Open Recent, Import Project, Revert to Saved Case, and continuing in the copy after Save Case As. Geometry reloads within the same project, such as after a material assignment, keep the cut.

The cut applies to direct STL surfaces, live CAD previews, assembled surfaces and mesh section views, including their outlines and bounds, face, edge and dependency selection highlights, and the highlight of the measurement reference under the pointer. Geometry on the discarded side cannot be picked or selected and does not offer measurement snap points. Annotations are not cut: placed measurement points and their labels, inspection probes, CAD diagnostic markers, section-boundary drafts, the beam guide and the domain overlay remain fully drawn. A visible domain overlay keeps pick priority for boundary selection, including where its faces lie in front of discarded geometry; hide the overlay to pick parts inside it. The move/rotate handles also remain available. Material Mesh slices are never cut, and their view does not show the cut controls. The cut draws no cap: a closed solid appears open at the cut, showing its inner surfaces, cavities and enclosed parts.

A cut does not remove material from the problem

A visually cut surface remains unchanged in the project and Solver inputs. A cut does not create a hole, export a cut solid, alter inclusion, or change domain bounds. Use CAD construction for a geometric cut and Domain & Boundaries for the computational domain.

Visibility, inclusion, and materials are different controls

The eye controls whether an object is drawn. The adjacent Included checkbox controls participation in meshing and simulation. Excluding an object automatically hides it and invalidates an existing mesh. You may deliberately turn its eye back on as a visible reference while leaving it excluded. Re-inclusion shows it again.

Creating or importing a solid does not silently assign vacuum, the background, or the first available material. Material required is a setup task, not a colour preference. An unassigned object can be visible while not yet having a complete Solver geometry entry. Assign a compatible material using the Geometry assignment controls; material definitions are edited in Materials (Chapter 6). Follow the current readiness message if an incomplete object still blocks preparation.

The background material is defined under Domain & Boundaries, not by hiding a body. Overlap priority is a separate expert property of volume solids; setting priority to zero does not exclude a solid. Screens do not have a volume overlap priority. A priority edited in the Geometry table applies to the shown objects without loading the geometry again.

5.4. Build native primitives

1. Choose Create and the required primitive. It appears in the Geometry view and is selected for editing.
2. Confirm the CAD Length unit before entering physical dimensions. Enter the body's dimensions in Selected body / operation.
3. Wait for the preview to finish and inspect the dimensions, position, and diagnostics.
4. Rename the body meaningfully, assign its simulation material, and confirm inclusion.
5. Save the project. You may continue authoring before a Solver is connected; meshing and simulation are separate steps.

Studio centers a Box about its local origin. Cylinder/tube and truncated-cone lengths extend along local X and are centered about that origin. The torus axis is local X. Use the body's transform to orient these local conventions within the project.

Local coordinates belong to the selected body; *global* coordinates belong to the project. A translation moves the local origin, and a rotation changes the orientation of the body's local axes. For a torus, the major radius is from its axis to the centre of the tube; tube radius describes the circular tube cross-section, not the overall outer radius.

Setting	Values / units	Meaning and dependencies
Box size X, Y, Z	Positive lengths	All three dimensions must be finite and greater than zero. A zero-thickness Box is not the screen representation.
Outer radius; Length	Positive lengths	Cylinder/tube dimensions. The inner radius must be smaller than the outer radius by more than the modeling tolerance.

Continued on next page

Setting	Values / units	Meaning and dependencies (continued)
Inner radius	Nonnegative length	Zero makes a solid cylinder or sphere. A positive value makes the hollow form. A value at tolerance scale can be treated as zero.
Radius at $-X$; Radius at $+X$	Positive lengths	The two ends of a truncated cone. Both radii must be positive; a zero-radius apex is not accepted by this primitive.
Major radius; Tube radius	Positive lengths	Torus dimensions. The major radius must exceed the tube radius by more than the modeling tolerance.
Spherical shell radii	Outer > 0; $0 \leq$ inner $<$ outer	A zero inner radius gives a solid sphere. A positive inner radius must leave a resolvable wall.
Translation X, Y, Z	Signed lengths	Position the selected CAD body's local origin. These are not domain bounds.
Rotation X, Y, Z	Degrees	Orient the CAD body. Inspect the final orientation, especially when combining rotation with local-axis operations.

An accepted number is not always a valid shape

A numeric editor can accept a value that makes the whole operation impossible: for example, a wall thicker than its enclosing body, coincident Loft sections, or a Fillet larger than the available space. Read the operation diagnostic. Changing tessellation quality is not a remedy for an invalid underlying solid.

5.5. Create and constrain a Sketch

A Sketch is one ordered contour of straight lines and circular arcs. With Closed contour enabled it has at least three points and joins the last point to the first. An open contour has at least two points and no closing segment. Solid features require a closed contour; screen extrusion and revolution accept both. The Sketch is reusable construction geometry, not an independent simulated sheet. It can be created as the first object in an empty project; an existing primitive is not required.

Choose Create > Sketch…. Select its Profile plane and edit the profile in the canvas or coordinate table. The supported plane choices are XY → Z, XZ → Y, and YZ → X; the arrow states the positive extrusion direction. The coordinate table changes with the profile context. For a Sketch driving a Revolve, think in local X and nonnegative radius R rather than ordinary positive/negative planar height.

Canvas and profile controls

Item	What it means
Select and drag	Select a vertex or segment in the canvas. Use `Shift`-click for additive profile selection. Drag a point to change its coordinates; existing constraints are considered during the edit.
Grid and Snap	Grid sets the visual spacing and optional point-snap increment in model units. Snap affects dragged or inserted points; it is not a permanent dimensional constraint.
Fit and navigation	Fit, or F in the profile editor, frames the whole profile. The wheel zooms and middle/right dragging pans. `Escape` cancels an active gesture.
Add, Remove, Up, Down	Change the ordered vertex list. Only a closed contour connects the last point back to the first. Point order changes the boundary, not just its presentation. Double-clicking an edge inserts a point.

Continued on next page

Item	What it means (continued)
Closed contour	Connect or disconnect the last and first points. This topology change clears constraints and is undoable. An edit that would invalidate a dependent solid is rejected.
Rectangle or Circle	Replace the current Sketch with a closed template. Circle uses four circular arcs. Replacement is undoable; it does not add an independent second loop.
Outgoing	Defines the segment from the selected point to the next point. Choose Line or Arc; arcs also use Arc radius, CCW/CW, and Major.
Fillet corner	Trims two adjacent line segments and inserts a tangent circular arc. The chosen radius must fit the available corner geometry. Open endpoints have no corner fillet or outgoing segment at the final point.

An arc's endpoints and radius must describe a possible circle. Changing the direction or Major choice changes which circular connection is used. A visually plausible point list can still self-intersect or enclose zero area, which prevents a solid feature. Avoid duplicate consecutive points and crossing segments. Use a Boolean operation between bodies when you need a hole or compound shape that is not represented by this single profile.

Constraints: what to select

Select the relevant geometry, choose a constraint, enter a value where applicable, and click Add constraint. The constraint list is separate from the coordinate table. The status reports remaining degrees of freedom and residual information. A *degree of freedom* is an independent movement or shape change still allowed by the constraints. *Under-constrained* means some remain; *fully constrained* means none remain locally. A *residual* measures how far a constraint is from being satisfied. Conflicting constraints cannot all be satisfied, such as assigning two different lengths to the same segment. An under-constrained Sketch can still be a valid closed profile.

Setting	Values / units	Meaning and dependencies
Horizontal / Vertical	One segment	Constrains its endpoint direction in the local profile coordinates.
Coincident	Two points	Constrains their coordinates to coincide. Do not collapse an edge unintentionally; the resulting closed profile must remain usable.
Tangent	Two consecutive segments	Their order follows the profile. The current constraint requires adjacent segments, not two arbitrary distant edges.
Equal length	Two segments	Constrains endpoint-to-endpoint lengths. For curved segments, do not interpret this as an arc-length constraint.
Distance	One segment; positive length	Sets the distance between that segment's endpoints. It is not a general two-body or arbitrary two-point dimension tool.
Angle	One segment; degrees	Constrains its orientation in the profile plane. It is not an angle-between-two-selected-segments command.
Radius	One circular-arc segment; positive length	Applies to an arc, not a line. The radius must also be compatible with the arc endpoints.

If adding a constraint fails, read the inline explanation, remove or revise the conflicting requirement, and try again. Select a constraint row and use its Remove button to remove that constraint. Ordinary coordinate edits are checked against existing constraints. Topology-changing edits—such as adding/removing/reordering points, changing a Line to an Arc, replacing the Sketch, or

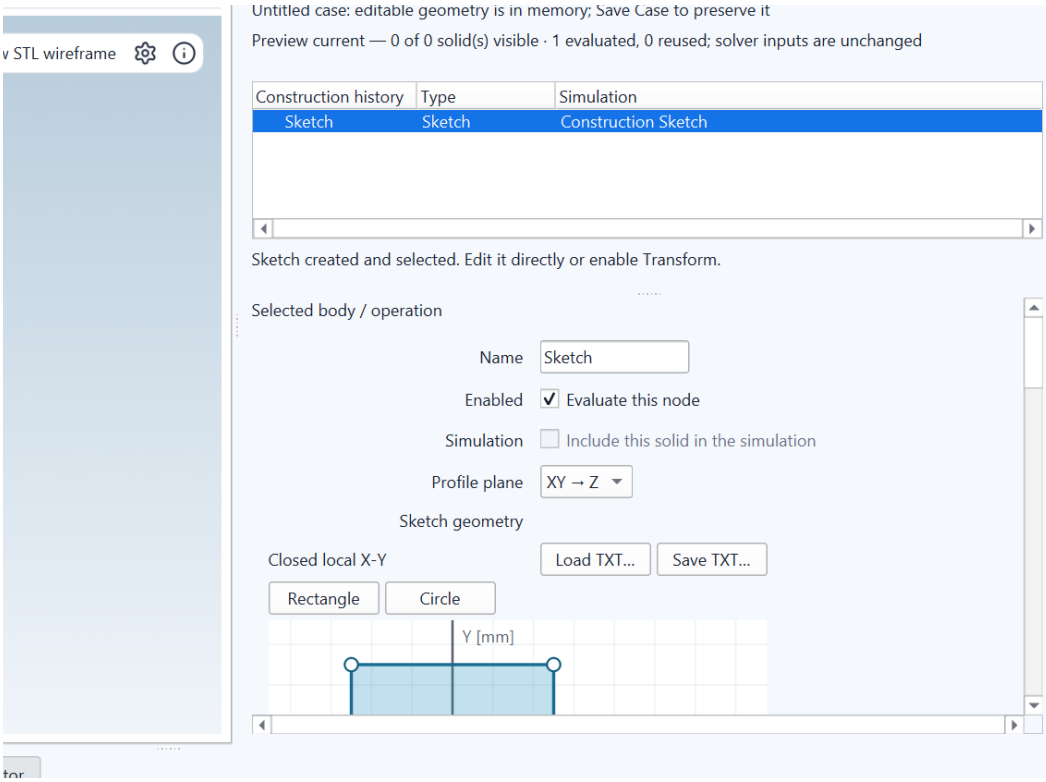


Figure 5.1.: A construction Sketch selected in the inspector. The simulation checkbox is inactive because the sketch is not itself a volume. Choose the profile plane and edit the canvas; scroll the inspector for the remaining profile controls. Cropped from an unmodified synthetic Studio capture.

loading a profile—can clear the constraint set. The editor reports this; use Undo to recover the previous state.

Profile TXT is a coordinate interchange, not a CAD backup

Load TXT… replaces the selected Sketch profile. Supply exactly two finite numbers per non-comment line, separated by whitespace. Blank lines and text after # are ignored. Use a decimal point. At least three points are required. For a Revolve profile the columns are X and Radius R, and R must not be negative.

> **Preserve the project when you need exact curves and constraints**
>
> Save TXT… exports point coordinates and linearizes curved segments. Loading the file creates straight segments and clears Sketch constraints. A units comment in a TXT file is descriptive: the importer does not read it to convert coordinates. Use the current CAD model unit consistently. Save the Studio project to preserve exact arcs, constraints, reusable-feature connections, and the construction model.

5.6. Extrude and Revolve a reusable profile

Both Create > Extrude profile… and Create > Revolve profile… use the selected Sketch when one is selected. Otherwise Studio creates a reusable Sketch for the new feature. With a newly created source, the Sketch may remain selected so you can edit the shape immediately. Select the resulting Extrude or Revolve in the construction tree when you want to change the feature's length, angle, or source.

Extrude: make a prism along the profile normal

1. Create or select a closed Sketch, and choose the intended Profile plane.
2. Choose Extrude profile….
3. Select the Extrude result. Set Extrude length to a positive value in model units.
4. Choose whether to Center the total length on the profile plane. On places half the total length on each side; off extends from the plane in its positive normal direction.
5. Inspect the result from a second view and assign its material.

Editing the source Sketch changes the dependent feature. Use Source sketch to identify the connection before modifying a reusable profile shared by several features. A profile does not become a valid extrusion merely because all its point coordinates are finite: it must form a usable closed face and the extrusion length must be positive.

Revolve: use a radius, not a signed transverse coordinate

Revolve turns a closed X–R profile about the body's local X axis. R is a distance from that axis and must satisfy $R \geq 0$. The Revolve angle editor offers $0.01°$ to $360°$; a full turn makes the complete body of revolution and a smaller positive angle makes a partial body. Rotate the resulting body if its axis must point elsewhere in the project.

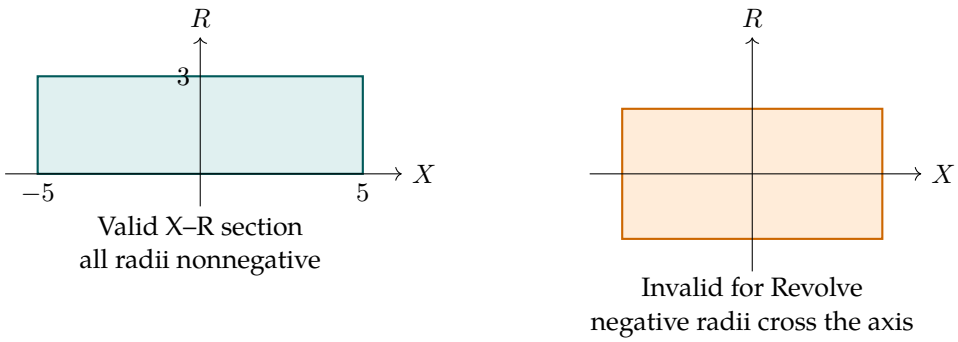


Figure 5.2.: A planar Sketch may be valid for Extrude but invalid as a Revolve section. The second coordinate has a different meaning. Diagrams are schematic.

Worked example: a 10 mm long, 3 mm radius body

Start with a CAD document in millimetres. Choose Create > Sketch…, then use the coordinate table or load the following two-column TXT profile:

```
-5 0
-5 3
 5 3
 5 0
```

The closing segment is implicit. Select this Sketch and choose Revolve profile…. Select the Revolve result and set Revolve angle to $360°$. The intended result extends from $X = -5$ mm to $X = 5$ mm and has outer radius 3 mm. Inspect its bounds and cross-section, assign a material, and save. It is still necessary to configure a domain, mesh, excitation, and outputs for a calculation; see Chapters 7, 8, and 9.

A newly created centered rectangular Sketch normally has points on both sides of its second-coordinate origin. Move or edit it into the nonnegative radial half-plane before revolving. If you

receive an $R \geq 0$ diagnostic, the failed creation leaves the Sketch unchanged and does not add a successful feature to the undo history. Edit the profile into the nonnegative radial half-plane, then create the Revolve again. Negative X values are valid; negative R values are not.

5.7. Combine and modify editable solids

Boolean operations combine volumes by union, subtraction, or intersection. A *Loft* joins a sequence of cross-sections; a *Shell* creates wall volume by offsetting selected source faces. A *Fillet* rounds an edge with a curved transition; a *Chamfer* replaces it with a bevel. Selection order matters for subtraction, Loft, and face mating.

Item	What it means
Union	Select two or more editable CAD result bodies, then right-click the selection in either geometry list and choose Union selected solids, or use Boolean > Union. The group is combined in one undoable edit; original bodies remain as construction history. Studio checks connectivity in the background and leaves the originals unchanged if it cannot form a valid connected solid. Assign a material to the new result. Separate parts can share a material without Union.
Subtract	Select the target first and the tool second. The result removes the tool from the target. Reversing the operands changes the construction.
Intersect	Select exactly two editable CAD bodies. The result is their common volume; disjoint or merely touching bodies may not yield a usable volume solid.
Loft selected sketches	Select at least two Sketches in section order. Their transforms position the sections. Consecutive sections must not be coincident within modeling tolerance.
Loft from faces	Enter face selection and select at least two planar section faces in Loft order. Straight uses ruled walls; Smooth is intended for an interpolated transition through multiple sections. Inspect for twisting or collapse.
Shell from opening faces	Select one or more opening faces on the source body, enter a positive Wall thickness, then choose direction and corner treatment. The result must remain a valid closed volume body.
Fillet / Chamfer	Enter edge selection and select one or more edges on one editable body. Set a positive Fillet radius or symmetric Chamfer distance in model units. Use the All/straight/circular edge filter when it helps identify the intended edges.

For Shell, Inside preserves the source outer size; Outside grows away from the source faces. Sharp intersects offset walls, while Rounded adds corner rounding. These controls define geometric wall volume. They do not assign a conductive wall material or a multilayer boundary model automatically.

Large Fillet radii, large Chamfer distances, closely spaced sections, and narrow walls can fail even when the field values are positive. Reduce the feature size, select fewer edges, or simplify the source shape and inspect the diagnostic. Do not repeatedly increase healing tolerance to force an arbitrary topology to succeed.

Feature operands remain part of construction history and may become intermediate geometry rather than independent simulation outputs. To modify an earlier shape, select its source in the construction tree. Removing a source used by an unselected dependent feature is guarded; re-

move or revise the dependency deliberately. Do not reintroduce intermediate operands into the simulation merely to make them visible.

The construction-tree context menu names these roles explicitly. Use as construction geometry keeps a selected CAD body for authoring rather than as an independent simulation output. Include in simulation restores eligible final solids to the simulation set; an intermediate operand consumed by another feature is not restored as a separate output by that command. Include the result solid instead. Neither command substitutes for assigning a compatible material. The geometry list's Included state and readiness diagnostics show the resulting simulation intent.

Undo (`Ctrl+Z`) and Redo (`Ctrl+Y`) act on the CAD construction history in Geometry and CAD. The first material assignment of an editable CAD body is one step of that history: Undo removes the body's simulation entry and its claim on the generated solver surface, even when the entry's material was changed later, and Redo restores both with the material first assigned. A material created for the assignment stays defined. Changing the material of a body that already has an entry is not a separate step. Redo is refused, with a log message and nothing changed, when the entry's ID is used again or its material was removed. Removing an editable CAD body is one step as well: Undo restores the body, its simulation entry at its former place with the fields it had, and its generated surface, also after Save moved that surface to `Geometry/Recovery`. Case edits made after the removal, such as mesh spacing, the domain or other bodies' materials, are kept. Undo is refused, with a log message and nothing changed, when another entry or an imported object now uses the body's ID; rename or remove that object first, because older CAD steps cannot be undone until then. When one removal also took imported STL objects, Undo restores the CAD bodies only. Edits to directly imported STL objects, including their material assignment, are not part of that history, so Undo after such an edit reverts the last CAD edit instead. `Escape` cancels an active drag and never undoes an edit. It does not revert text typed into a CAD parameter field; that value is applied when the field loses focus.

Undo/Redo is a working-session editing aid, not a project-version archive. Initial saving, relocation, or source localization can establish a new history baseline. The saved construction model retains its feature relationships, but do not depend on reopening a project to recover a previous session's undo stack. Keep deliberate project revisions when comparing alternative designs.

5.8. Position and repeat geometry

Transform operates on one selected CAD body or one selected direct-STL object. Drag an arrow to translate or a ring to rotate; dragging elsewhere continues camera navigation. Press `Escape` before releasing the button to cancel the drag: the object and handles return to where they were and nothing is applied. CAD offers Global and Local axes. Direct STL uses global XYZ; its normalized surface change is staged until Save, and its original imported bytes are retained.

Setting	Values / units	Meaning and dependencies
Move step	10^{-6} to 10^{6} in the displayed length scale	Snaps viewport translation. Also supplies the offset used by Duplicate. A gesture smaller than a snap increment may produce no committed movement.
Rotation step	0.01° to 180°	Snaps viewport rotation. Reduce it for a smaller intended rotation.
Reset position	CAD only	Returns the selected CAD body's translation to zero; it does not fit or move the computational domain.
Reset rotation	CAD only	Returns the selected CAD body's rotation to zero. Check the resulting local-axis orientation.

Use Arrange > Move, align, mirror, pattern… for deliberate placement and repetition of editable CAD. The dialog identifies selection and coordinate units.

Item	What it means
Move origin to global point	One selected body; specify global X, Y, Z. This moves its origin, not an arbitrary picked surface point.
Align local axes	Select the fixed target and moving body. Choose their local axes, optional opposite direction, and whether body origins should also match.
Mate selected planar faces	Select exactly two planar faces on different bodies. The first stays fixed; the second body moves so face centers coincide and normals oppose.
Mirror copy	Choose a global XY, XZ, or YZ plane and its offset. Inspect the new copy and its material/inclusion state.
Linear pattern	Choose global axis, finite nonzero signed spacing, and total occurrences from 2 to 1000. The total includes the original.
Circular pattern	Choose global axis, center, total occurrences from 2 to 1000, and a nonzero sweep between $-360°$ and $360°$. A full turn spaces the occurrences without duplicating the endpoint; a partial turn includes both ends.

Duplicate makes selected CAD copies and offsets them along X using the configured movement step. Do not confuse geometric CAD repetition with section/layout repetition used by the simulation assembly. They have different ownership and downstream effects; see Chapter 7 before representing the same repetition in both places.

5.9. Import STEP or BREP

1. Create or open a project, then choose Import Geometry… and select a supported STEP/BREP file. New Case has already saved the project location so source geometry can be preserved with it.
2. Follow the activity bar above the 3D view: Reading STEP/BREP geometry… is followed by Preparing CAD preview. The moving indicator shows work in progress, not a percentage or a remaining-time estimate. Large assemblies may take time. Cancel requests cancellation; the current CAD step may need to finish first. You can keep editing the case and the CAD model while the file is read; these edits do not cancel the import. The preview shows CAD edits made meanwhile once reading has finished or stopped. Cancel, opening, reopening or reverting the project, Save As under another path, another import or Union stops the import. Build Mesh and Run report Wait for the STEP/BREP import to finish or cancel it until reading has ended.
3. Inspect the imported solids and their arrangement. A file can create multiple separate solids; importing an assembly is not the same as reconstructing its feature history or simulation section layout.
4. Measure a known overall length and check the physical units before assigning a domain or meshing. In particular, verify exchange files exported using a different unit convention. Do not use the document unit selector as an unverified resize command.
5. To assign a material, select one or more solids in the case tree, right-click one of the selected solids and choose Assign Material…. This opens the same material dialog as the Simulation geometry table. Assign volume solids and zero-thickness screens separately. Choose inclusion, inspect the curved regions, and Save the project to localize its source files.

Studio preserves imported solid occurrences and their placements while suppressing duplicate occurrences of the same imported shape/location. It keeps the original exchange source for authoring; on Save the source is localized below `Geometry/CAD Sources`. Files that do not contain usable solid geometry can fail import. An arbitrary collection of curves or open faces is not automatically turned into a closed physical body.

You do not need to build the simulation mesh to view imported CAD. Studio prepares the selected STL or native geometry documents automatically before Build Mesh or Run. An absent generated document is not a missing source file. A missing original STEP/BREP source still needs to be restored.

> **Check size before fixing apparent accuracy problems**
>
> A unit error changes the physical geometry. Coarse CAD display tessellation changes the preview only. First compare a known imported dimension with the design. Refine the calculation grid independently of display quality. For direct STL, the source triangle approximation remains part of the calculation geometry.

5.10. Import or replace STL

STL coordinates do not provide a reliable unit choice for this workflow. Studio asks you to interpret them. The initial choice follows the case unit and is not a detected property of the selected file.

1. Choose Import Geometry… and select `.stl`.
2. Choose Volume solid or Zero-thickness screen as the simulation role.
3. Set Units in this file to mm, cm, or m, according to the numeric coordinates used by the exporter.
4. Review the displayed extents, triangle count, and any disconnected-shell count. For example, a coordinate extent of 100 interpreted as mm is 0.1 m, not 100 m.
5. Click Import Solid or Import Sheet. Then assign the compatible material in Geometry and inspect the surface in the shared view. Until it has a material, the object is shown but is not part of the calculation: the header reads Blocked · assign materials and Validation asks for its material. A replacement staged with Replace source… reads Blocked · save project until you save.
6. Save before depending on the imported geometry as a portable project input.

For an STL file of 1 MiB or more, Studio reads and checks the file, and after you confirm the review converts it to the case unit, in the background. A busy dialog names the step and the file, for example Reading and checking or Converting … to case units; the window keeps drawing, and Cancel ends the import at once without changing the project. The review opens when reading is complete. If another project is opened meanwhile, the file is not imported. Studio then writes the preserved source and the working surface into the project while the dialog shows Saving … into the project; Studio does not respond until both are written, which takes a few seconds for a million triangles. Replace source… still reads and converts its file before responding.

If Studio reports that the STL import *was saved* but it could not finish refreshing the window, the imported files are complete. Do not import the file again; Studio would refuse the repeated ID. Reopen the project before continuing.

While Studio loads the updated scene after an import, the objects already shown stay visible with their visibility, appearance, and cut. Until loading completes they are display only: wait before selecting, measuring, or hiding them. The new object appears, and selection resumes, when the complete scene is ready. If a surface cannot be read, the loaded scene reports that error instead of keeping the earlier objects in its place. A material assignment made while the scene is still loading

behaves the same way. When loading completes, Studio fits the view to every object, including the new one, as long as the view is still Studio's own: the view fitted when the scene loaded, or the isometric view Studio shows in Geometry. While loading, Studio may already turn the objects shown to that isometric view. Any other view, for example one you zoomed, rotated, or chose, or one changed by the mesh view, stays exactly as it is when the new object lies wholly inside it. If any part of the new object's bounding box lies outside the view, Studio keeps the viewing direction and refits the view to show the new object together with the objects that were in view; objects outside your view are not added. Choose Geometry > Fit all to show every object. Opening or switching projects never shows the previous project's objects: until the opened project's objects are ready, the view shows only its background and the message Loading geometry… in its centre.

The original imported source is preserved separately from the normalized working surface. Multiple disconnected shells in one STL are reported; they are not automatically offered as separate material assignments. If different enclosed parts need different materials or priorities, prepare separate STL objects in the source application and import them separately.

Imported STL topology is not editable CAD. Changing CAD display quality will not make it smoother, repair an opening, or add missing curvature. Return to the original CAD model and export a better STL, or import the CAD exchange source instead.

During inspection and Build Mesh, Solver already applies the safe STL repairs allowed by the case settings. To persist a repaired working STL for one directly imported volume, select it in Geometry and use Try automatic repair…. Studio uses the same case relative geometry tolerance to remove degenerate or duplicate triangles, correct orientation, and try closing isolated triangular holes. Review the reported changes before accepting. The original imported STL stays preserved; Save Project publishes only this object's repaired working surface. Then run Build Mesh. The repair refuses ambiguous openings, non-manifold edges and other defects it cannot resolve without changing the intended shape. Its message names the remaining defect and explains what to fix in an STL editor or source design before using Replace source….

Rename, replacement, and removal

Use the selected imported object's actions to rename, replace, or remove it. Renaming changes the object identity presented to the user without silently rewriting the triangle coordinates. Replacement asks for another STL and its source unit; review its extents as carefully as on first import. The workflow preserves source and working-surface recovery data rather than treating the replacement as an unrelated untracked file copy.

Geometry IDs are read-only in Setup's Case geometry records (expert), in Properties and in the parameter list; change the ID of an imported or file-based object with Rename…. The surface of an imported object is read-only there as well; use Replace source…. A CAD body's ID, surface and `geometry_id` come from the CAD model; the body name in its details is only a display name. A file-based entry can still point its surface at another file. An edit of a read-only field leaves `case.yaml` unchanged, and the Log names the action to use.

Removal changes the project's object collection; retained files and recovery handling protect against accidental loss. Do not manually delete arbitrary geometry files merely because an object was removed or renamed. Shared references and source provenance can still matter. CAD Undo does not bring back a removed imported object, also when it was removed together with editable CAD bodies. The intended project state is committed through Save. If another geometry entry, including an excluded one, still references the removed object's surface, Save keeps that file in place and the Log names the entries that use it. The file then belongs to that entry; a later Save does not move it to `Geometry/Recovery`. To try such changes as a variant, use Save Case As…

before saving: the new project receives the renamed, replaced, transformed or repaired objects and omits removed ones, while the original project is left unchanged.

An STL import needs these changes saved first. If imported STL objects have unsaved removals, renames, replacements, transforms or repairs, Import Geometry… asks to save the project: Save Project and Import saves and continues, Cancel changes nothing. That Save moves a removed object's files to `Geometry/Recovery`, so a later import can use its name again. A renamed object keeps its file names; an import that reuses the old name keeps the ID and stores its files under a numbered name, for example `Geometry/STL Sources/body-2.stl`. Original source in the object's Properties names its file. If a file at the name's own location belongs to no object, Studio suggests a different ID, such as `body_2`, rather than overwriting it. If Studio cannot check that location, for example because access to the folder is denied, the import stops with an error instead.

Unlike an import, renaming or removing an object, and the Save that applies a replacement or removal, still reload the whole display: the objects disappear until that loading completes.

Check volume surfaces before meshing

A volume STL needs a closed surface enclosing the intended region, consistent face orientation, and no self-intersections. A *disconnected shell* is a separate connected group of surface triangles; it may describe another body or a cavity boundary. Inspect the arrangement and Solver's meshing diagnostics. Use the screen role for an intentionally zero-thickness physical surface, not for a volume whose CAD export has missing faces.

5.11. Choose CAD display quality

Open CAD display quality in the Geometry view. The slider has five presets. It applies to imported STEP/BREP and Studio-created CAD bodies; it does not alter direct STL. Adjusting it changes the CAD surface tessellation used for preview only. The calculation representation and its STL tolerances are unchanged. Exact display settings are also available in the CAD document inspector.

Tessellation is the approximation of a curved CAD boundary by flat triangles. Linear deflection controls the allowed geometric deviation in the model length unit; angular deflection controls directional change in that approximation. Smaller values request finer curved-surface detail. A radian is an angle unit: π rad is $180°$, so the default 0.25 rad is about $14.32°$.

Setting	Values / units	Meaning and dependencies
Draft	Linear 0.10; angular 0.50 rad	Fast, coarse surface approximation.
Coarse	Linear 0.05; angular 0.35 rad	More detail than Draft.
Medium	Linear 0.01; angular 0.25 rad	Default display preset.
Fine	Linear 0.005; angular 0.15 rad	Smaller surface deflections; expect increased preview work and memory on curved geometry.
Very fine	Linear 0.001; angular 0.08 rad	Smallest preset deflections. Use when the lower levels do not resolve the relevant curved features.
Custom exact settings	Finite, positive values	Linear deflection uses the CAD document length unit; angular deflection is in radians. The UI identifies settings between presets as custom.

Linear deflection is absolute in the model's length unit, not a percentage of object size. Consequently, the same numerical setting has a different physical scale in mm and m. Angular deflection

is independent of that unit. Both influence curved-surface approximation; do not judge success solely by whether the total triangle count changes. Planar faces may retain the same triangulation.

For example, linear deflection 0.01 in a millimetre CAD document is 0.01 mm (10 micrometres); in a metre document it is 10 mm. If a rounded edge or gap is comparable to the display deflection, reduce that value to inspect it clearly. This display change does not alter the geometry used for meshing.

Check display and calculation accuracy separately

Confirm physical dimensions and the smallest important features. Start with Medium; use Fine or exact display settings when the preview does not show those features clearly. Then compare calculations under field-mesh refinement. Changing display quality alone must not change native geometry bytes or calculated coefficients. For directly imported STL, obtain a better source surface when its triangles do not resolve the intended shape.

CAD validity, display tessellation and simulation discretization answer different questions. Modeling and healing tolerances can affect the represented shape; display deflection controls its picture; grid spacing controls discretization.

Document settings and tolerances

Setting	Values / units	Meaning and dependencies
Length unit	m, cm, or mm; new CAD defaults to mm	Governs CAD coordinates and length-valued controls. Set it before authoring. Changing the unit reinterprets the existing numeric dimensions; it is not a rescaling operation that preserves size.
Modeling tolerance	Finite positive length; default 10^{-7}	Used in geometric construction and validation. Features at or below tolerance scale can collapse or be treated as coincident. It is not a simulation cell size.
Healing tolerance	Finite positive length; default 10^{-6}	Used when repairing imported/evaluated CAD topology. Increase only with a specific geometric reason and then recheck small features and dimensions.
Tessellation deflection	Finite positive length; default 0.01	Absolute surface display detail in the CAD unit; affects native and imported CAD previews, not direct STL.
Angular deflection	Finite positive radians; default 0.25	Additional curved-surface tessellation control. This field is in radians even though body rotations are in degrees.

CAD source units and case units are recorded separately. Native geometry stores its own unit scale; Solver converts it to metres once and Studio converts previews to the current display unit. Recheck physical bounds after changing either convention. Do not interpret rounded display values as a reason to edit authoritative geometry files by hand.

5.12. Model a zero-thickness screen

A zero-thickness screen represents a two-sided surface whose geometric thickness is negligible in the chosen model. It is not equivalent to a finite coating or a very thin closed body. Choose the representation from the physical problem first.

Item	What it means
Zero-thickness screen	An STL surface or one oriented CAD face, with PEC or scalar resistive-sheet material. There is no volume thickness or overlap priority. For a resistive sheet, the material uses sheet resistance in ohms per square.
Finite-depth conductive or layered wall	A volume boundary with a wall material, conductivity, and applicable depth/layer/backing settings. It is not a transmissive two-sided screen obtained by entering a small thickness.
Finite material volume	A closed solid whose actual thickness matters geometrically; use compatible volume material and a mesh appropriate to that representation.

Choose Add sheet…, select an STL, and confirm its coordinate unit. This dedicated command locks the role to a zero-thickness screen. The general STL import dialog also allows the role to be chosen explicitly. Assign PEC or a resistive-sheet material; the assignment workflow filters for role compatibility. A mixed solid/screen selection has fewer shared choices than either role separately.

To create a screen directly, choose Create > Screen extrusion… or Create > Screen revolution…. The command uses the selected Sketch or creates an open two-point Sketch. Edit the contour with lines and circular arcs. Extrusion exposes its length and symmetric placement; the Sketch plane selects the direction. Revolution exposes its angle, up to 360°, about local X with radius R nonnegative. A segment lying entirely on the axis is invalid. The result is only the swept surface: no thickness, end caps or auxiliary volume are created. A closed contour can produce, for example, an open-ended tube by extrusion or a toroidal screen by revolution. The Sketch remains editable; Undo/Redo and Save retain the operation and its parameters.

To extract a screen from existing CAD, select one evaluated face, choose Screen in the face-operation controls and click Create Screen. Its outer boundary and holes are retained. The whole source body becomes an intermediate operation: it remains editable in CAD history, but its other faces and volume are excluded from calculation publication. To retain that volume as a separate physical object, create an independent copy before extracting the face.

For either route, assign a compatible material and explicitly choose STL or Curved surfaces for the screen in Calculation geometry. The screen can inherit the project default or override it independently of every other body. STL is only the default for new projects. Curved publication sends the exact rational surface directly to the mesher, without an intermediate calculation STL. The same choices and editable sources are available to headless preparation.

Native screens can retain multiple surface patches, disjoint holes and periodic seams in one face. Supported resolved gaps, isolated tangencies and certified attachments to native or STL PEC supports preserve material priorities and intentional openings. Curved conducting volume walls are also supported; they remain a different physical role from two-sided screens.

A visible screen still needs a representable mesh

Multiple-face screens, sheet junctions, intersecting trim loops, nested islands, unresolved near contacts and unproved coincident rational surfaces are rejected. Subcell holes, disconnected cuts and partly covered grid-aligned entities may require a finer mesh or a physically justified geometric change. Switching to STL alone is not a guaranteed solution for these shared topology limits. Never close an intentional aperture or enlarge the domain merely to silence a diagnostic.

Inspect apertures and outer edges. A screen has a persistent outline and two-sided surface presentation. Select it and use Face screen when the surface is edge-on. Visibility, opacity, measurement,

transform, replacement, and removal remain available. A screen-only project can be a valid geometry configuration; missing screen source files are nevertheless blocking input errors.

In Setup, Duplicate under Case geometry records (expert) copies a CAD screen as a new CAD body, offset like other CAD copies; assign the copy its own material before preparing geometry. Imported or file-based screens cannot be duplicated, because the copy would be a second screen on the same surface file. Import the source again with a new screen ID instead.

Build the mesh and inspect the actual Solver artifacts in Material Mesh, as described in Chapter 7. The appearance of a screen in Geometry is not proof that its aperture or interaction with surrounding materials is resolved. Solver minus/plus side identities in a mesh artifact are not a user-authored front/back coating order. Results should be interpreted using the selected physical representation (Chapter 12).

5.13. Save safely and prepare for computation

The project keeps different kinds of information for different purposes:

Item	What it means
`case.yaml`	Solver-facing setup: materials, geometry references and assignments, domain, mesh, excitation, outputs, and execution settings.
`Geometry/cad-model.yaml`	Studio CAD authoring: construction, source references, transforms, Sketches, feature connections, and conversion settings.
Original geometry sources	Preserved inputs, including localized CAD sources and direct STL originals. Keep them with the project when they are referenced.
Prepared geometry	CAD-generated STL, native `.emgeom` boundaries or directly imported STL consumed by Solver. Studio may regenerate surfaces it explicitly owns as CAD outputs; direct/legacy inputs have a different ownership boundary.

Use normal project Save rather than hand-copying individual generated files. Build Mesh and Run save pending project/CAD changes through the project workflow and invoke automatic geometry preparation. If the case has no location, the workflow asks for one. Prepare Geometry (advanced) is available for an explicit earlier check; manual publication is not a prerequisite for the ordinary Build Mesh/Run path.

A value you are still typing or stepping in a CAD inspector field counts as well: Save Case becomes available, and Save Case, Build Mesh, Run and the unsaved-changes prompt first apply it as one ordinary CAD edit. This includes a fillet or chamfer size whose preview already shows the typed value. If CAD rejects the value, or the number is incomplete, the operation stops and nothing is saved or prepared; the status bar names the reason. After Save Case the value and focus stay in the field.

Included CAD outputs are regenerated at this boundary; a stale preview/freshness label is not used as permission to run with an older shape. Direct or legacy STL inputs are checked but not regenerated by CAD preparation. Explicit user-requested STL transforms or replacement are separate operations.

Preparation can block on invalid case data, missing material, invalid CAD, missing source or direct STL, conflicting output ownership, or files changed outside Studio. Read the first actionable diagnostic and correct it before trying again. Do not copy a random older STL over a generated output to bypass an error. That can separate the visible design from the geometry actually solved.

If Build Mesh or Run reports that the project or the prepared geometry *was saved* but Studio could not finish a later step, no calculation was started. The saved files are complete; reopen the project, then choose Build Mesh or Run again.

An unrelated Save or geometry import does not acknowledge external changes to another tracked geometry file. If a later replacement reports a conflict, inspect the named file and reconcile the intended project state. Reopening the case establishes a new loaded state; resolve pending edits and review the on-disk files before doing so. Existing jobs keep their recorded inputs.

> **A run is tied to its input snapshot**
>
> Execution captures immutable inputs for the run. Later Geometry edits describe a new project state, not a correction to an already completed run. When comparing results, identify the selected run and its inputs; see Chapters 10 and 12.

Reload is not Revert

Geometry > Reload Geometry refreshes the case's geometry scene. While the project keeps its folder and length unit, this and every other geometry reload compares each file's content with the file last shown and loads again only files whose content changed or that could not be shown, also when their name, size and modification time stay the same. Studio's first load, opening a project from another folder, Save As into another folder, and a changed length unit load every file again. If an existing mesh preview is being displayed, reload invalidates that preview and returns to the current case geometry/assembly presentation. Existing run artifacts are retained. A configured external geometry inspector may run again after the geometry is loaded. Reload is not a command to discard every pending project edit or to bypass an external file-change conflict.

File > Revert to Saved Case has a broader and potentially destructive meaning: after confirmation, it discards unsaved case, geometry, CAD, material-definition, provenance, and display-appearance changes and reloads the saved project. Read the confirmation carefully. Save a wanted alternative before reverting; use ordinary geometry visibility controls if you only need to recover a confusing view. If the saved case cannot be read, the current project and any unapplied material definition are retained. If reloading fails after replacement has begun, Studio returns to Home without saving (Section 1.5); reopen the saved project from there.

Headless preparation and mesh updates

The same CAD preparation is available without opening Studio's interface:

```
emuzag-studio --prepare-geometry case.yaml
```

For explicit project/body representation and STL-tolerance options, run:

```
emuzag-studio --prepare-geometry --help
```

Use the Studio executable from the complete installation. CAD conversion belongs to Studio. Solver consumes the prepared case and geometry without a CAD library or running Studio process.

When updating from 1.0.x to 1.1.0, rebuild calculation meshes, including direct STL. Corrected boundary handling changes the common mesh dependency; native, hybrid, sheet and conducting-wall preparation also has updated identities. The geometry and material settings remain authored inputs; do not copy an old mesh over a rejected cache or weaken its identity checks. Existing jobs retain their input snapshots and results. A checkpoint requiring the older mesh must not be resumed with a different newly prepared mesh.

Advanced diagnostic routes

Read Geometry Diagnostics by origin. VTK preview checks the original display STL, before Solver repair. With a current selected Solver, Solver inspector checks a volume or sheet using the case's repair settings. The same `geometry.repair.relative_tolerance` controls the relative geometry tolerance in the conformal mesher. The `inspection_scope` row identifies which check ran. A separately selected inspector may check only raw STL; select the case Solver for a case-aware check.

Studio runs one inspector check at a time, so results appear object by object; in CAD mode an arriving result does not move the camera. A reload, a geometry or repair-setting change, another inspector or Solver, or another project discards the checks still waiting and stops or ignores the running one. Such a check shows no result and is not an inspection failure. After a licensing rejection (exit code 3) Studio starts no further check of that batch; use Reload Geometry once the license is valid, or when a check does not finish.

An open edge in the preview is not necessarily an unresolved hole after repair. After a successful volume check, preview boundary edges are informational. Warnings about filled triangular holes or corrected orientations remain visible: review these changes and confirm that they match the intended geometry. For a zero-thickness sheet, open boundaries may be intentional and hole filling is disabled. Do not classify a broken volume as a sheet to bypass an error.

If the Solver inspector rejects a body, select it in Geometry and turn on Show STL wireframe. For a CAD-owned body, read the CAD diagnostics. When the calculation STL triangles fail to represent a valid curved detail, refine that body's STL tolerances in Calculation geometry and rebuild the mesh. For a preview-only defect, adjust CAD display quality. If the CAD shape itself has a gap or crossing, edit its source operation in the construction tree. For imported STEP/BREP, correct the original shape in its source CAD application and re-import it. Conversion quality alone cannot close an invalid CAD body. For direct STL, use Try automatic repair… on the selected volume and review the proposed changes. If it cannot complete, repair or re-export a closed, consistently oriented volume, use Replace source…, save and rebuild the mesh. For an intentional sheet, preserve its open boundary and repair its orientation instead. Review the single case relative tolerance if small triangles are removed unexpectedly; then run Build Mesh to confirm the complete mesh.

Surface inspection does not build or validate the complete calculation mesh. Build Mesh and Run perform their own checks; a successful run does not make an unrelated inspection error harmless. Correct genuine errors or confirm that the diagnostic used the same settings and geometry role as the case.

The Geometry menu contains two additional inspection routes. They are not required for the ordinary Create/Import, Build Mesh, Run workflow.

Item	What it means
Open Existing Mesh Preview…	Opens one or more backend-generated `model.msh` files. This inspects existing mesh data; it does not build a new mesh or establish that the files match the currently edited project. Read any message about displaying unique templates without layout assembly.
Select Solver Geometry Inspector…	Selects an installed Solver executable for external geometry diagnostics. Use a compatible Solver, not a CAD file or converter. Inspection can fail or be blocked by the Solver's license state; the diagnostic and log distinguish an inspection failure from a successful geometry check.

5.14. Troubleshoot Geometry by symptom

Item	What it means
Sketch exists but no solid appears	A Sketch is construction geometry. Select it to open the profile editor, then create Extrude, Revolve, or Loft. Check which item remains selected before looking for feature dimensions.
Revolve creation fails with $R \geq 0$	The profile uses negative radii, often from a centered planar rectangle. Correct the radial coordinate; do not remove valid negative X positions. See the worked example above.
Dragging appears to do nothing	Verify the interaction mode and selected target. In Transform, drag a handle, not the camera background. Check Move/Rotation step; a substep gesture can snap back. In Sketch, check constraints and Snap.
Body disappears after a Boolean or feature	Inspect the result and construction tree. Operands can become intermediate geometry. Confirm eye visibility and inclusion separately; do not automatically add every operand as a simulation volume.
Import is the wrong size	Check the export convention and a known dimension. For STL, review the chosen source unit. For STEP/BREP, verify the exchange result before using document units to make an apparent correction.
Curves look faceted after STEP import	Confirm the body is CAD-backed. Adjust CAD display quality and inspect wireframe. A direct STL cannot be retessellated from absent CAD.
Finer quality changes little	The inspected faces may be planar, or detail may already be adequate there. Compare curved regions. Display settings do not change the simulation grid.
Imported body is visible but mesh is blocked	Check material assignment, included state, case/domain validation, missing files, and Solver diagnostics. Visibility alone is not a readiness test.
Fillet, Shell, or Loft fails	Check selection type/order, available space, feature size, and section coincidence. Start with fewer edges or simpler sections; read the exact diagnostic before changing tolerances.
TXT reload loses arcs or constraints	TXT is a linearized coordinate interchange. Recover from Undo or the saved Studio CAD project, which preserves richer authoring data.
Saved geometry changed outside Studio	Inspect the named file, reconcile the intended on-disk state and pending edits, then reopen deliberately. Reload Geometry only refreshes the display; do not overwrite originals or generated files blindly to silence a conflict.

Continue with Domain & Boundaries and Mesh in Chapter 7.

6. Materials

Choose a material by the physical role it must represent, then supply the data needed by that role. A familiar substance name is not enough: the same metal can be represented as an ideal boundary, a surface-loss model, or a resolved conducting volume. Those choices have different inputs and different resolution requirements.

6.1. Choose the physical representation

Studio presents six representations built from four case-level model families. Vacuum, dielectric, and magnetic volume are configurations of the same linear-isotropic family, not additional model names.

Linear means that doubling the applied field doubles the material response. *Isotropic* means that the same property applies in every direction. *Passive* means that the material does not supply energy. A *dispersive* material has properties that vary with frequency. These terms describe the material model, not the shape of the object.

Item	What it means
Ideal metal (PEC)	Ideal conductor with no finite material parameters. Choose it when wall loss and penetration are intentionally neglected.
Volume material	A resolved three-dimensional isotropic medium: vacuum, dielectric, magnetic material, lossy bulk material, explicit Lorentz dispersion, or tabulated complex response.
Thick finite-conductivity wall	Compact surface response for a thick, homogeneous good conductor. Conductivity is the authored physical parameter; the external Solver prepares the frequency-dependent response.
Homogeneous depth-resolved wall	A one-dimensional normal-depth model with conductivity and a maximum depth-cell count. This is not a user-specified coating thickness.
Coating or multilayer wall	An ordered physical layer stack, with thickness and properties for each layer and a backing behind the last layer.
Zero-thickness resistive sheet	A two-sided, isotropic, memoryless screen with one sheet-resistance value. It is neither a volume material nor a layered wall coating.

PMC, Open, and PML are not material choices. PMC and Open belong to domain faces; PML is an absorbing-domain treatment. Physical conductivity and the PML conductivity scale are unrelated inputs despite the similar names.

6.2. Define, save, and assign

Physical model identifies the material response. Display color selects how that material appears in the 3D view; its colour is saved with the project's appearance settings, separately from the material's numerical parameters.

1. Open Materials. Use Define new material… or Add from library…. Choose the physical use; a finite-conductivity wall offers a secondary choice between thick-surface treatment and resolved depth.
2. Give the material a unique ID and fill the required fields. Generic creation forms leave required physical fields blank; enter values for the material you intend to model.

3. Inspect the draft diagnostics. Use Save changes when the definition is complete. Cancel leaves the existing case definition unchanged.
4. In Geometry, select the relevant solids or screens and use Assign material…. Volume-solid and screen assignments are handled separately because their allowed materials differ.
5. Choose the background in Domain & Boundaries, not by assigning a material to an arbitrary visible object. Recheck all material uses before meshing.

Studio keeps your camera, cut, selection, visibility and opacity when it can update the loaded object's material in place. A first CAD assignment or a change in geometry may require a preview refresh or reload. After an assignment, objects already shown stay visible while that refresh runs; they cannot be picked until it completes. A view you framed yourself and the cut are kept.

Resolve an open material definition with Save changes or Cancel before Build Mesh or Run. Studio returns to Materials and starts no job until the draft is resolved. This applies to both CAD and imported-STL projects. A draft opened during a license check also prevents the requested job from starting; resolve the draft, then request the operation again.

Item	What it means
Background	Any supported volume/background family except resistive sheet. A conductive wall is permitted as a background; it contributes a wall response where it meets an active finite-volume region.
Volume solid	PEC, linear-isotropic volume, or conductive wall. A resistive-sheet definition cannot be assigned as a volume material.
Zero-thickness screen	PEC or resistive sheet only. A screen has no physical volume thickness, overlap priority, depth-cell count, or backing stack.

The background fills the computational box before included volume objects modify it. In overlapping closed volumes, higher explicit priority wins; declaration order is not an ordering mechanism. For a cavity, a PEC background with an appropriately placed vacuum volume describes the space in which fields are to exist. Giving both the background and cavity volume PEC does not create vacuum merely because the viewport shows a hollow-looking surface.

Removing a material that is still used is rejected. Reassign its uses first. Changing a definition is also rejected if its new representation would invalidate an existing volume or screen assignment. A valid model change removes properties that do not belong to the new representation; do not expect an old bulk conductivity to be silently reinterpreted as wall conductivity.

6.3. Ideal conductor and finite volume properties

PEC has only its ID and model. Do not add permittivity, permeability, conductivity, Lorentz poles, a table, or wall parameters to it. For a finite volume, choose Volume material and use the following reference.

Relative permittivity $\varepsilon_r = \varepsilon/\varepsilon_0$ describes electric response relative to vacuum; relative permeability $\mu_r = \mu/\mu_0$ describes magnetic response. Conductivity σ relates conduction-current density to electric field, $\mathbf{J} = \sigma\mathbf{E}$. It dissipates energy in a passive conducting volume. The subscript zero denotes the corresponding vacuum constant.

Setting	Values / units	Meaning and dependencies
Relative permittivity	Finite $\varepsilon_r > 0$; dimensionless	Required for explicit-property volume materials. With electric Lorentz poles it is the high-frequency baseline, not the static sum. Vacuum uses 1.
Relative permeability	Finite $\mu_r > 0$; dimensionless	Required for explicit properties. With magnetic poles it is the high-frequency baseline. Vacuum and a nonmagnetic dielectric use 1 only when that is physically appropriate.
Conductivity	Finite $\sigma \geq 0$; S/m	Optional bulk loss; blank means omit, with zero conductivity when absent. May accompany explicit properties, Lorentz poles, or a tabulated response. It is not sheet resistance.
Electric poles	Absent, or 1–10 complete poles	Optional passive electric dispersion. Requires the explicit-property representation; incompatible with a tabulated-response definition.
Magnetic poles	Absent, or 1–10 complete poles	Independent of the electric family. Both families may be present with nonnegative bulk conductivity.

Loss tangent is not a broadband conductivity value

Loss tangent, $\tan\delta$, is the ratio of the dissipative to the reactive part of a material's response at a specified frequency. At a reference frequency f, the equivalent dielectric conductivity is $\sigma = 2\pi f \varepsilon_0 \varepsilon_r' \tan\delta$. The equivalence is at that frequency. A constant conductivity does not produce a constant loss tangent over an entire band. Use a dispersion model or measured response when that frequency dependence matters.

Skin depth is the distance over which field amplitude falls to $1/e$ of its surface value inside a thick conductor. When that depth is too small for the volume mesh, use an applicable wall model or refine the mesh through the penetration region. Increasing conductivity alone does not resolve it.

6.4. Explicit Lorentz dispersion

A Lorentz pole is one damped-resonance contribution to the material response, not a resonance of the complete cavity. Its strength sets the low-frequency contribution, its resonance frequency locates the response, and its damping controls its breadth and loss. Several poles can represent several material resonances.[1]

Electric and magnetic poles use the same three-field structure. All supplied numbers must be finite. Add, remove, and review poles in their respective families; an incomplete row is not a disabled pole.

Setting	Values / units	Meaning and dependencies
Static susceptibility	Positive; dimensionless	The pole strength $\Delta\varepsilon$ or $\Delta\mu$. The zero-frequency relative property is the high-frequency baseline plus the strengths in that family.
Resonance frequency	Positive; Hz	Ordinary cyclic frequency f, not angular frequency. Enter a value in Hz, including an explicit scientific exponent where appropriate.
Damping rate	Nonnegative; s^{-1}	The damping parameter itself. Do not multiply this input by 2π as though it were a cyclic frequency.

Continued on next page

[1] For the damped-oscillator interpretation, see the Meep materials reference. Its software units and supported models differ from Studio's; use the input units and limits in this table.

Setting	Values / units	Meaning and dependencies (continued)
Pole count	1–10 per present family	Electric and magnetic families have separate limits. Remove an unwanted family rather than leaving an empty or unfinished authored list.

Check the preview over the frequency band of your calculation. A magnetic baseline of 1.2 and pole strength 3 give a static relative permeability of 4.2, not 1.2. This distinction is important when transferring a value described as “static permeability” from a data sheet.

> **Keep dispersive volumes out of PML**
>
> Nonzero electric or magnetic Lorentz strength is not supported in PML cells. The restriction also applies to tabulated materials fitted to Lorentz response. Place the absorbing region so the dispersive body does not overlap it, and inspect the resolved mesh. The Solver does not replace such overlap with a harmless static approximation.

6.5. Tabulated electric and magnetic response

Use Import table… when the material is supplied as complex electric and magnetic response versus frequency. Save the project first: the source is copied into a project-owned CSV so the definition does not depend on a file in Downloads or another workstation’s directory.

Complex response uses a real part and a loss part to describe both amplitude and phase. Here $i^2 = -1$, $\omega = 2\pi f$, and the assumed harmonic time dependence is $e^{+i\omega t}$. Under this convention a passive loss is entered as minus the imaginary part. A data sheet using $e^{-i\omega t}$ has the opposite imaginary-part sign; convert the convention, not the nonnegative loss columns. The fit replaces the sampled table with a passive Lorentz model usable during time stepping; it is not point-by-point lookup.

The accepted CSV has exactly these five columns, in this order:

Item	What it means
`frequency_hz`	Positive, strictly increasing frequency in Hz. Duplicate or out-of-order frequencies are rejected.
`epsilon_real`	Positive real part of relative permittivity.
`epsilon_loss`	Nonnegative electric loss, defined as $-\operatorname{Im}(\varepsilon_r)$ for the $\exp(+i\omega t)$ convention.
`mu_real`	Positive real part of relative permeability.
`mu_loss`	Nonnegative magnetic loss, $-\operatorname{Im}(\mu_r)$ under the same convention.

The header is the comma-separated sequence of those names. The file must contain at least three data rows and must not exceed 16 MiB. Use finite numeric data, decimal points, and comma-separated columns. Blank lines and lines beginning with **#** are ignored. A spreadsheet’s semicolon-delimited export, extra index column, opposite loss sign, or frequency values in GHz under a Hz header is not the required format.

Setting	Values / units	Meaning and dependencies
Fit minimum frequency	Positive; Hz	Lower bound requested for the passive fit. Choose a band justified by both the source data and the calculation.
Fit maximum frequency	Greater than minimum; Hz	Upper fit bound. A broad displayed plot does not prove that the fitted band covers the useful excitation.
Maximum relative fit error	$0 < e < 1$	Optional case default is 0.01, meaning 1%, not 0.01%. A smaller target requests a more accurate fit; it may be unachievable with the selected model or pole limit.
Maximum poles per response	Integer 1–10	Optional case default is 10. The external Solver owns the fitted poles; this is a limit, not a request to force every response to contain exactly that many poles.

Review the fit, not just the input table

1. Prepare and independently sanity-check the source CSV, including units and loss sign. The data must describe the intended grade, temperature, and band.
2. Import it, choose the fit interval, and set tolerance and pole limit. Update fit settings updates the staged request. Use Save changes to commit the material definition.
3. With a compatible Solver connected, allow the Solver-owned fit preview to complete. Compare source and fitted real and loss curves for both ε and μ. Use Show table for the read-only numeric comparison.
4. Review the reported fit error and diagnostics. If preparation fails, correct the data or the justified fit request; do not represent the missing fit as a valid constant material.
5. Save, rebuild the affected mesh as required, and inspect material placement before using the case for production conclusions.

Tabulated response replaces explicit relative properties and authored pole lists; the two sources cannot compete. Optional bulk conductivity may remain. Switching back with Use explicit properties is a modelling change: review the newly shown baseline properties rather than assuming the original pre-import material was restored. Studio does not run its own passive fit; a preview requires the external Solver. Without that result, the data can be authored but the fit has not been verified.

6.6. Thick and homogeneous-depth conducting walls

Thick finite-conductivity wall

This model represents a thick homogeneous good conductor through a surface response. Enter positive finite conductivity in S/m. Permittivity, permeability, thickness, depth count, Lorentz lists, and backing properties are not authored parameters of this representation. The external Solver determines the frequency response and reports preparation diagnostics.

Use the read-only Solver plan to assess the prepared wall. A bunch-length change can change the relevant frequency band even if conductivity is unchanged. Do not choose this approximation merely because it uses fewer cells; confirm that a thick, homogeneous good-conductor assumption is justified for the actual wall and excitation.

Homogeneous depth-resolved wall

Depth-resolved means that field penetration is sampled along local lines normal to the wall surface. This adds a one-dimensional depth grid to the boundary treatment, not a three-dimensional coating mesh.

Setting	Values / units	Meaning and dependencies
Conductivity	Finite and positive; S/m	Homogeneous conducting depth medium. The public representation fixes relative permittivity and permeability to one.
Maximum depth cells	Integer 1–4096	Upper bound on the one-dimensional depth discretisation. The Solver may choose fewer cells. This is not the Cartesian mesh cell count or an authored physical coating thickness.
Backing	Fixed by this representation	The homogeneous model has a PEC back plane. For a physical thickness or selectable backing, use a coating or multilayer wall instead.

Neither conducting-wall representation is the two-sided transmission law of a resistive sheet. Their response acts on the interface between the active field volume and the wall. A material entry that is never reached by the resolved geometry does not become an active wall merely because it is listed in Materials.

6.7. Physical coatings and multilayer walls

Layers run from the field-facing surface into the wall. Their order is physical: reversing a stack generally defines a different model. Use Add layer, Duplicate, Remove, Move up, and Move down to organise the staged stack. Check the order again after any duplication or reordering.

The *backing* specifies what lies behind the last layer. *Semi-infinite* means that the backing conductor is treated as continuing without a rear reflecting face; it is an approximation to a sufficiently deep substrate, not an infinite CAD object to create.

Setting	Values / units	Meaning and dependencies
Layer thickness	Positive; case length unit	Required for every layer. For example, 10 micrometres is 0.01 in a millimetre case, not 10. Keep the physical layer thickness distinct from the Cartesian spacing. A library template records the unit of its thicknesses; adding it converts them exactly to the case unit.
Layer conductivity	Nonnegative; S/m	Required even for a lossless dielectric layer, where the value is zero. This permits dielectric, magnetic, conductive, or combined passive layers.
Layer relative permittivity	Positive; dimensionless	Optional case default is 1. An explicit value must remain positive and finite.
Layer relative permeability	Positive; dimensionless	Optional case default is 1. The physical-stack representation does not expose a Lorentz-pole list inside each layer.
Layer list	At least one complete layer	Properties belong inside the layers. Do not add competing top-level conductivity, relative properties, or a homogeneous maximum-depth-cell setting to a physical stack.

In the layer-thickness editor, a recognised explicit suffix is converted to the case unit: `m`, `cm`, `mm`, `um` (micrometres), or `nm`. For example, `10 um` becomes 0.01 in a millimetre case. This convenience is specific to that editor; do not assume every numeric field accepts a unit suffix.

The last layer terminates in one of three backing choices:

Setting	Values / units	Meaning and dependencies
Ideal metal behind the stack	No additional property	PEC backing; also the case default when the backing selector is omitted. Back impedance and back conductivity must both be absent.
Fixed resistive impedance	Positive impedance; Ω	A frequency-independent terminal resistance. Requires back impedance and forbids back conductivity.
Bulk conductor continues below	Positive conductivity; S/m	A semi-infinite conducting continuation. Requires back conductivity and forbids scalar back impedance.

A depth model is not a full three-dimensional coating mesh

The wall approximation resolves the normal direction locally. It does not resolve lateral currents or surface curvature inside that depth line. Review the Solver's depth and scale diagnostics, then assess curvature and tangential field variation for the actual geometry. A favourable automatic scale check does not replace those engineering checks.

For a coating over bulk metal, define the coating as a physical layer and select Bulk conductor continues below; do not give a homogeneous depth-cell model a coating thickness. For an ideal metal behind a dielectric film, define the film's positive thickness, zero conductivity if lossless, justified relative properties, and the ideal-metal backing.

The Solver owns depth planning. Very demanding thickness/property/band combinations may exceed its bounded preparation limits or fail accuracy checks; the correct result is a reported preparation failure, not silently reduced physical fidelity. Studio displays the returned diagnostics but does not construct an independent layered-response curve from them.

6.8. Zero-thickness screens

For a resistive screen, enter positive finite Sheet resistance in Ω/sq and assign the material to a geometry screen. PEC screens instead use the PEC material and have no sheet-resistance parameter. Resistance per square is not bulk resistivity and is not a length-unit conversion.

Sheet resistance relates tangential electric field to surface-current density. For a uniform resistive square contacted along opposite edges, its resistance is the sheet-resistance value regardless of the square's size; this explains the unit Ω/□. *Memoryless* means that the surface response depends on the field at the current time, without additional dispersive states.

The public resistive-screen model is isotropic and memoryless. It has no layer ordering, thickness, backing, depth grid, dispersive poles, or true multilayer two-sided response. If those properties are essential, the scalar screen model does not represent that physical problem. See Chapter 5 for importing a surface as a screen rather than a closed volume.

6.9. Libraries, appearance, and verification

A library entry is copied into the case; it is not a live external dependency. Review its reference and applicability, including metal grade, condition, temperature, and the chosen physical model. A user template requires explicit reference and applicability information. Project-local tabulated CSV materials cannot currently be saved as reusable library templates because the library does not package their source assets.

A layered template saved from a case records that case's length unit (m, cm, or mm) for its layer thicknesses; the save dialog shows it read-only. Add to case converts each thickness exactly to the destination case unit, and the inspector shows the template value beside the value to be added: 0.25 saved in a millimetre case is added as 0.00025 in a metre case. Layered templates saved by earlier Studio versions have no recorded unit. The inspector says so, and Add to case stays unavailable until Edit user template… or Duplicate user template… declares Layer thickness unit; choose the unit of the case the template came from. The same dialogs correct a mistaken declaration. Declaring or correcting a unit never changes the stored numbers, and an edit increments the template revision. Earlier Studio versions list templates with a declared unit as unsupported instead of copying their raw numbers.

Material display colours are Studio-only appearance data. Changing a colour does not change permittivity, losses, priority, or meshing. A material legend helps identify assignments; Material Distribution uses its own scientific coefficient colour scale. After meshing, inspect the actual inverse-permittivity, permeability, and conductivity distributions, especially in overlapping objects and small inserts. See Chapters 7 and 12.

The supported public media are isotropic and passive. Anisotropic tensors, nonlinear or gain media, negative active conductivity, and independent Debye, Drude, gyrotropic, or hysteretic models are not additional selectable material families. A field that can be typed into raw YAML does not extend this catalog.

7. Domain, boundaries, and mesh

The geometry surface describes where material regions lie. The computational domain describes where the calculation is performed. The mesh discretises that domain: it replaces continuous space with cells at which fields and material coefficients are represented. A solid must lie inside the domain and be resolved by those cells to affect the intended calculation.

7.1. Domain extent and material background

In an ordinary single-section project, Domain & Boundaries exposes the X, Y, and Z extents. X is longitudinal. In a repeated or multi-section model, Periodic Mesh Assembly owns the longitudinal layout and the domain controls retain the transverse Y/Z ranges. See Chapter 5 before enabling periodic assembly; repetition is not merely a display transform.

Setting	Values / units	Meaning and dependencies
X minimum / maximum	Finite; case length unit; minimum below maximum	Ordinary single-section longitudinal extent. Initially 0 and 10 mm. In periodic assembly, review the section intervals and repeated layout that determine the full X span.
Y minimum / maximum	Finite increasing interval; case length unit	Initial range $[-5, 5]$ mm. Together with Y spacing determines transverse grid placement.
Z minimum / maximum	Finite increasing interval; case length unit	Initial range $[-5, 5]$ mm. Also controls beam and monitor locations relative to the mesh.
Background material	Existing compatible material ID	Initially PEC. Fills the box before priority-resolved volumes replace it; not merely a viewport colour.

Full, Half, Quarter, and Rotate

Full fits current solids and expands to whole mesh cells. For an ordinary single section it fits all three axes; for periodic assembly it preserves the assembly-owned X layout and fits Y/Z. Half fits one transverse half around the authored beam position while retaining the full X extent. Quarter fits a transverse quadrant. Rotate changes the selected transverse half/quadrant orientation; it is a domain-fitting control, not a rotation of the CAD object or the camera. Each cut face lies on the mesh plane through the beam, or on the next plane outward when the beam lies between planes; its value keeps the digits needed to contain the beam. Rotate needs Half or Quarter chosen in the current project: opening, creating or reverting a project, or continuing in a Save Case As… copy, clears the choice.

Fitted extents are written without the floating-point residue of the stored solid bounds. STL files store vertices in single precision, so a face modelled at -0.7 mm is read as -0.69999999; the fit uses -0.7, the shortest decimal with the same stored value. An STL imported in another unit is converted before it is stored, so -0.39 cm becomes -3.8999999 mm; the fit uses -3.9, which the same conversion stores identically. Native CAD bounds lose only arithmetic noise in their last digits. A face within 10^{-5} mm of a mesh plane (10^{-6} cm, 10^{-8} m, and at most 1% of a cell) is then placed on that plane: a closed end at 10.00001 mm fits as 10 mm, and a face that Transform stored as 0.70000005 mm fits as 0.7 mm. A larger offset, such as 10.000015 mm, is geometry and still expands to the next whole cell. The X minimum anchors the X mesh, so it becomes the shortest decimal within that tolerance, 0 included: a part moved onto $X = 0$ with Transform starts at 0, and a solid whole cells long keeps its cell count. Beyond about 128 mm (16 cm, 0.125 m) from the origin one single-precision step exceeds the tolerance, so a face moved there with Transform can keep a

residue digit. Values are not forced to a fixed number of decimals: a fine mesh, a metre-unit case or a spacing such as $0.2/1.5$ keeps the digits its mesh planes need. This applies to Full, Half, Quarter, Rotate and the automatic fit of a new project; typed extents are never changed.

When a conducting volume is too close to a domain boundary or a gap has too few field samples, Solver treats only the unsupported wall patches as PEC and continues. The remaining supported patches retain finite conductivity. Jobs shows local PEC; the Log and the files matching `results/conductive_wall_pec_fallback*.csv` record affected objects, patch-centroid coordinate bounds, areas and represented surface fractions. Those PEC patches have no wall loss, and the approximation can also change wake results even when the loss monitor is off. To retain finite conductivity there, move the adjacent boundary outward or refine the gap, then rebuild the mesh. Solver and Studio do not automatically enlarge the domain or edit the geometry, openings or material assignments. Two-sided sheet support errors remain blocking.

> **Cropping is not automatic symmetry modelling**
>
> Half and Quarter do not choose new electromagnetic boundary conditions. Inspect the newly cut faces and assign the boundary conditions justified by the source and field symmetry. An off-axis source or asymmetric insert can invalidate the assumption even when the outer wall looks symmetric. Power-loss symmetry scaling is a separate setting in Chapter 9.

After fitting, inspect the transparent solid against the domain faces. Confirm that a small flange, an imported insert, and the beam path have not been excluded. If the model intentionally continues through an open port, distinguish that continuation from an accidental cropped feature.

A new project refits its domain when solids are added, resized or removed, also after Save Case, until you type an extent, edit the YAML source, or use Full, Half, Quarter, Rotate or Fit to Geometry. A project opened from disk, reverted or copied with Save Case As… keeps its saved extents, even when they match the solids. After changing its geometry, press Full to refit.

7.2. Boundary conditions on the six faces

Each axis has a lower and upper face, in that order. The supported authored boundary values are Open, PEC, and PMC. PML settings configure the absorber; `pml` is not an alternative value to type into a face selector.

Item	What it means
Open	An open computational termination using the applicable Solver boundary treatment. It is not a material. Leave adequate physical and numerical clearance and review PML and port settings.
PEC	Ideal electric-conductor boundary. It may represent an actual ideal wall or an electric symmetry plane. Tangential electric field is zero at the face.
PMC	Ideal magnetic boundary, commonly used for a justified complementary symmetry plane. Tangential magnetic field is zero at the face; this is not a bulk magnetic material.

The new-project choices are Open/Open on X and PEC/PEC on Y/Z. They suit a common waveguide starting pattern, not an arbitrary imported solid. Stationary FDTD has the same boundary/reference choices at beta below one as at one; transverse open boundaries retain their ordinary PML settings. Scattering requires Open/Open X and PEC/PEC Y/Z. Common reference restrictions are collected in Chapter 8 so a change here is not considered in isolation.

For a charged-bunch calculation, Solver checks each Open X end before preparing fields. If a source or wake observation meets PEC or inactive material there, it moves that end inward in whole X steps to the first section where all source and observation trajectories have active channel support. The calculation then uses a separate rebuilt mesh and a shorter domain. Review the warning's original and effective coordinates and total cell count. The saved case and original mesh remain unchanged; `open-boundaries.txt` in the calculation folder records the effective limits and mesh. If no suitable section remains, Solver stops with an explanation before field evolution. This applies to stationary and moving calculations, including FDTD; PEC ends and transverse boundaries are unchanged. Active trajectories alone do not establish that the shortened port is uniform.

7.3. Choose Cartesian cell spacing

Setting	Values / units	Meaning and dependencies
X spacing	Finite and positive; case length unit	New project: 0.1 mm. Sets longitudinal discretisation; for dispersion-free it also fixes $c\Delta t = dx$. Changing it can require a different time-step policy, port placement, and mesh.
Y spacing	Finite and positive; case length unit	New project: 0.1 mm. Resolves transverse geometry and source/monitor sampling; participates in explicit stability limits.
Z spacing	Finite and positive; case length unit	New project: 0.1 mm. Has the same roles on Z. Unequal spacings are permitted but must satisfy the selected method's stability and geometric-resolution requirements.
Recommended Steps from σ	Requires positive Gaussian RMS length	Sets $dx = \sigma/5$. For FDTD or implicit dispersion-free it sets $dy = dz = dx$; explicit dispersion-free uses exactly $dy = dz = 1.5\,dx$, for both stationary and moving meshes. Dispersion-free time step is set to Automatic.
Y/Z from X	Requires finite positive X spacing	Keeps the entered X spacing and sets $dy = dz = 1.5\,dx$ for explicit dispersion-free, or $dy = dz = dx$ for FDTD and implicit dispersion-free. It does not require a Gaussian RMS length.
X/Z from Y	Requires finite positive Y spacing	Keeps Y and sets $dz = dy$. For explicit dispersion-free it sets $dx = dy/1.5$; for FDTD and implicit dispersion-free it sets $dx = dy$. Dispersion-free time step is set to Automatic.

These buttons are in the Cell spacing group. To choose a longitudinal step yourself, enter X spacing and click Y/Z from X; for example, X = 0.1 mm gives Y = Z = 0.15 mm for explicit dispersion-free. To start from transverse resolution, enter Y spacing and click X/Z from Y; Y = 0.09 mm gives X = 0.06 mm and Z = 0.09 mm for explicit dispersion-free. One click applies the current edit; pressing Enter first is unnecessary. These are one-time actions: all three spacings remain independently editable, and later spacing or method changes do not apply a button automatically.

Tab, Enter or clicking another field applies a typed spacing. A spacing changes no geometry, so applying it does not prepare the CAD preview again or redraw the view. In a new project whose domain still follows the solids, the domain is realigned to the new cells in the same update (Section 7.1).

The recommendation resolves the source with five longitudinal cells per RMS length. A narrow gap, curved surface, dielectric wavelength, or required peak response may demand finer resolution. Increasing source RMS length and pressing the recommendation can coarsen the mesh, even though the smallest geometric feature did not change. Review geometry after using it.

Authored extents and effective grid extents

Solver places transverse grid lines at integer multiples of the Y and Z spacing from the fixed origin $(Y, Z) = (0, 0)$. It rounds both transverse bounds outward to cover the authored domain. Studio preserves those authored bounds in the run snapshot, reports the predicted effective coordinates, and displays the mesh returned by Solver. Moving the beam never translates the grid. Off-node beam and wake trajectories select the nearest node; review the effective coordinates and displacement. Authored transverse minima and maxima may be arbitrary finite coordinates, including for PMC. Every boundary type uses the same outward alignment, and its selected condition is applied at the effective mesh face. PMC specifies a magnetic boundary condition; it does not require the face to be a geometric symmetry plane. Review the reported effective domain when exact boundary placement matters.

Longitudinal alignment retains its existing policy: in an ordinary single-section workflow Studio expands a closed right boundary outward or clips an open right boundary inward to whole cells before execution. Changing transverse spacing can change the selected beam node; changing transverse extents does not shift the zero-origin lattice.

7.4. Advanced meshing and geometry preparation

Face areas selects how the material portion of each mesh face is calculated. *From surfaces* integrates the represented volume boundaries; *From edge lengths* retains the previous reconstruction. Opening an older case displays From edge lengths without modifying its saved input. Select From surfaces explicitly to compare the two methods on the same mesh. Changing this setting requires a new mesh and makes an old checkpoint incompatible. Thin screens retain their existing split-face construction. The selected Solver must support selectable face areas; Studio reports an incompatible older Solver before starting the job. Direct areas do not remove the need for a mesh-convergence study.

Oblique dielectric tensor. The Oblique dielectric tensor checkbox in Mesh Setup enables an additional electric-material correction for supported flat dielectric interfaces tilted to the grid. A tensor couples electric components when their directions do not follow the interface normal and tangent. The setting defaults to off; opening an older project displays an unchecked box without adding a YAML field. Its saved key is `mesh.conformal.dielectric_tensor`. Interfaces parallel to the grid axes retain their automatic diagonal preparation with either choice.

Enable it when a supported inclined dielectric interface matters to the calculation. It can increase calculation time and memory. Solver certifies the represented interface and reports admitted and excluded supports; the switch does not make every curved surface, corner or material junction a supported tensor interface. Compare results on finer meshes.

The supported methods are stationary FDTD and Explicit Dispersion-Free with a stationary or moving mesh. Implicit ATI does not support the tensor option; Studio reports an error while preserving the choice so it can be corrected. Actual tensor meshes require positive, lossless, nondispersive bulk materials and vacuum sources. Combinations with conductivity, electric or magnetic dispersion, conductive walls or thin screens are not qualified. Studio warns about these material combinations; Solver determines applicability from the actual mesh. Aligned-only material preparation retains its ordinary behaviour.

For FDTD, an actual tensor mesh requires an explicit time step with stability margin; the automatic vacuum endpoint is insufficient. Choose a smaller explicit step. Explicit Dispersion-Free retains its existing grid/time-step relation; Solver checks the prepared tensor at the selected step. Neither Studio nor Solver silently reduces an authored step to pass this check.

Changing the checkbox requires a new mesh and makes an old checkpoint incompatible. Previous jobs, their frozen input copies and their results remain available. The selected Solver must advertise support for the new setting, including an explicitly saved false value; Studio reports an incompatible older Solver before building a mesh. Omitted settings retain older-project compatibility.

The repair and triangle-search controls below apply to triangle input. Native CAD and STEP/BREP bodies selected as Curved surfaces preserve their surfaces and trims. Bodies selected as STL use their calculation STL tolerances. Neither route uses the display tessellation; representation can be selected per body. CAD display controls are described in Chapter 5. A coarsely tessellated STL source cannot recover its lost curvature simply by using a finer Cartesian mesh.

Welding merges vertices considered coincident within a tolerance. *Topology* describes how edges and faces connect, including whether a surface is closed. *AABB* means axis-aligned bounding box: the accelerated search groups triangles in boxes so irrelevant groups can be skipped. Leaf capacity controls the number of triangles in a terminal search group, not the number of field cells.

Setting	Values / units	Meaning and dependencies
Weld tolerance	Nonnegative; case length unit	New project: 0. A geometry-repair tolerance; increasing it may merge distinct nearby vertices. Inspect thin gaps before and after changing it.
Geometry relative tolerance	$0 < r \leq 1$; dimensionless	New project: 10^{-12}. The case's single relative geometry tolerance controls removal of degenerate triangles, surface validity and conformal-mesh intersections and fractions. It does not weld vertices; use Weld tolerance for that. Large admissible values are not generally sensible engineering choices.
Fill triangular holes	True or false	New project: false. Allows the specified repair action; it is not a general reconstruction of a missing CAD face or an arbitrarily open shell. Verify the intended topology.
Triangle search method	AABB acceleration or Exhaustive	New project: AABB. A search-strategy choice, not a different physical material model. Exhaustive search can be costly for a detailed triangle surface.
Leaf capacity	Positive integer	New project: 8. Advanced triangle-search parameter. Changing it does not increase the source surface's geometric accuracy.

7.5. PML absorber controls

PML (*perfectly matched layer*) is an artificial absorbing region used to let outgoing waves leave a finite computational domain with low reflection. It is not a physical wall. A finite, discretised PML can still reflect; check sensitivity to absorber depth and separation when reflected fields could affect your result.[1]

Keep its parameters separate from physical wall properties and resistive-sheet values. Required fields remain in the case even when a particular domain configuration does not visibly expose every absorber region.

[1] S. G. Johnson, *Notes on Perfectly Matched Layers*, 2021, introduces the absorber and its numerical limitations.

Setting	Values / units	Meaning and dependencies
Depth	Integer, at least 2 cells	New project: 10. Physical depth depends on mesh spacing. It also enters automatic scattering-port placement.
Conductivity scale	Positive scalar	New project: 0.8. Numerical absorber scale, not physical material conductivity in S/m.
Complex-frequency shift	Nonnegative; m^{-1}	New project: 20. Numerical PML frequency-response control in inverse metres whatever the case length unit. Despite its name it is not a frequency in Hz, the scattering center frequency or a material resonance.
Conductivity order	Nonnegative scalar	Optional field; new project writes 3. Controls how absorber conductivity varies with depth, not physical conductivity.
Shift order	Nonnegative scalar	Optional field; new project writes 1. Controls how the frequency-shift profile varies with depth. Check reflected-field sensitivity when changing absorber profiles.

7.6. Section Assembly: order and repeat longitudinal sections

Open Mesh → Section Assembly for the optional Repeated-structure assembly workflow. It is called *Periodic Mesh Assembly* in explanatory text. A normal case has one section used once and needs no additional assembly setup. The status becomes Activated when there is more than one section template, more than one layout entry, or an entry repeated more than once; this is derived from the case, not a separate enable checkbox.

Setting	Values / units	Meaning and dependencies
Template ID	Unique, nonempty identifier	Names a reusable longitudinal section. Layout entries refer to this ID; renaming or removing a referenced template also requires correcting those references.
X minimum / maximum	Finite increasing interval; case length unit	Source interval from which the section is taken. Review whole-cell alignment and the effective interval reported by the mesh. A zero or reversed interval is invalid.
Template actions	Add, Duplicate, Remove	Add supplies a new ID and a short starting interval; edit it to the intended source range. Creating a template does not automatically add its occurrence to the layout.
Layout Position	Read-only order, starting at 1	Use Move up and Move down to change order. Position is not an independently editable physical X coordinate.
Layout Section	Existing template ID	Select the section for this occurrence. An unknown reference is invalid.
Layout Repeat	Positive integer	Repeat 1 uses the section once; zero does not disable an entry. Remove an unwanted entry deliberately.
Layout actions	Add, Duplicate, Remove, Move up, Move down	Add initially selects the first template with Repeat 1. Both the template list and layout must remain nonempty. Recheck references and order after every structural edit.

The layout concatenates section lengths along X, including all repeats. The ordinary assembly preview starts at the first used section's source minimum; later occurrences are translated into their assembled positions. For example, one 10 mm cell with source interval $[0, 10]$ mm and Repeat 3 makes three physical occurrences spanning 30 mm. Inspect material continuity and the intended geometry at every join. Moving-field coordinates have their own documented frame (Chapter 11).

Mesh assembly is not CAD duplication or mesh-file import

Repeating a section reuses a longitudinal mesh section; it does not copy or edit native CAD bodies. CAD linear/circular arrangements create source geometry and are a different workflow. Importing an STL supplies triangles, not a ready-made Solver mesh or a repeated layout. Do not repeat both the CAD geometry and its section unless that compounded structure is actually intended.

With assembly active, the layout owns total X; Domain & Boundaries fitting preserves that layout and adjusts Y/Z. Fit to Geometry in the assembly inspector is limited to one section used once. When available, it insets open ends by one X mesh cell; it does not construct a multi-section layout for you. The terminal regions still need the intended straight, uniform continuation.

In Assembly preview, the Source geometry authoring probe can help choose source limits: read a source-surface coordinate, use Use cursor X as start and Use cursor X as end, then Create section template. Start must be less than end. This creates a template only; add it to the layout separately and review the typed coordinates. A cursor pick is not an automatic valid-interface detector. The retired per-section `slices` field is not a supported way to subdivide a section; internal meshing tiles are Solver-owned.

Automatic dielectric and magnetic interface preparation. The Solver automatically corrects supported single planar material interfaces parallel to the grid axes, including planes between grid lines. The correction covers positive isotropic permittivity and permeability; electric and magnetic components use their own staggered averaging regions. Supported volume conductivity and electric/magnetic Lorentz dispersion use the complete material response: arithmetic along the interface and passive series composition across it. The same complete single-interface certificate is required. Inspect the mesh log for corrected and excluded supports. The separate oblique tensor option above has its own narrower material/method scope. Curved interfaces, corners, contacts and unsupported materials retain their applicable treatment; this correction does not establish their accuracy.

No project setting is required. If a development case contains the retired `mesh.conformal.dielectric_interface` field, remove it. Rebuild meshes prepared before this correction before starting a new calculation. Existing saved jobs and results remain available; an old checkpoint cannot resume against changed material coefficients. Retain the old job when comparing results.

7.7. Inspect Mesh View and Material Mesh

After Build Mesh, expand Mesh in the project tree. Mesh Setup provides setup/diagnostics, Mesh View shows generated sections and their grid, and Material Mesh shows coefficient slices. These are different inspection representations, not simultaneously superimposed layers. A pre-mesh assembly preview does not prove that coefficient artifacts have been generated.

Item	What it means
Physical section	Select an occurrence from the list or use the previous/next arrows. Repeated physical sections can share one underlying template. Verify both the occurrence and its assembled location before inspecting a local feature.
Mesh section outlines	Mesh View overlay of generated section bounds in final assembled coordinates. Initially on when available.

Continued on next page

Item	What it means (continued)
Selected grid	Mesh View overlay of the selected section's sampled wire grid. Initially off. Sampling keeps the view manageable; counting displayed lines is not a reliable way to count every computational cell.
Cut view	Mesh View: hide one side of an XY, XZ or YZ plane at an exact coordinate in the case length unit, with a slider, Flip side and Reset. This cuts the display only; it does not change the computational domain or discard mesh cells.
XY / XZ / YZ	Mesh View: align the camera to an axis plane; repeating the same button reverses viewing direction. ISO gives an orthographic isometric view.
Fit	Mesh View: fits visible objects without changing view direction. It moves the camera, unlike Domain & Boundaries fitting, which authors the domain.
Zoom	Mesh View: drag a rectangle in the view to zoom to it, as Zoom to Region does in Geometry; Esc cancels and Fit shows everything again.

Read a material slice

In Material Mesh, choose the physical section, the Display quantity, the plane, and its index. The available index range is derived from the selected component's valid grid dimensions; the slider and numeric index select the same plane. Read the position shown in the inspector instead of treating the integer index as a physical distance.

Material Mesh automatically faces the selected plane when opened or when the plane orientation changes. Moving the index keeps the camera with the slice and preserves the current zoom and pan. This view has no separate View orientation or Cut view controls; a cut selected in a volume view does not cut the material slice or its contours. Use Face active slice to restore a fitted view after navigating the camera.

Setting	Values / units	Meaning and dependencies
Display	Inverse permittivity X/Y/Z; permeability X/Y/Z; volume conductivity X/Y/Z	Select a coefficient family and its directional component. Inverse permittivity is $1/\varepsilon$, not ε. This is not a material-ID colour plot.
Plane	YZ, XZ, or XY	The named axes span the displayed slice; the fixed coordinate is X, Y, or Z, respectively. Unlike live field preview, all three mesh slice orientations are available.
Index / slider	Zero-based valid plane index	The range follows the loaded component. Changing section or component can change that range.
Show mesh	On or off	Logical cell boundaries on the coefficient slice; independent of geometry-contour selection.
Contours	Assembled geometry, Input geometry, or Off	Initially Off. Compare final section-layout contours with original source contours deliberately: repeated positions need not coincide with source coordinates.
Face active slice	View action	Makes the camera face the current slice; does not choose a different component or plane.
Export slice CSV	Current slice	Writes indices, physical coordinates in metres, and coefficient values. It is not a full-mesh export. Retain the quantity and section identity with the file.
Slice screenshot	PNG view capture	Records the visual presentation, not substitute numeric data. Show Mesh folder opens the current mesh artifact folder.

Restored dimensionless inverse-permittivity and permeability views use a fixed 0–2 colour scale; conductivity uses its SI data range. Dense-file boundary factors are removed for this interpretation, but conformal weights still must not be read as discrete material IDs. Inspect the numeric probe and coefficient summary when a colour alone is ambiguous.

Click a coloured slice to pin an inspection probe and read its location/value; use Clear probe to release it. Changing the data can make a pinned probe stale: reselect a visible cell rather than treating old text as a measurement of the new slice. For screens, the topology legend uses cyan/magenta for independent minus/plus identities, amber for split-support cells, and red for passive surface patches. These are Solver topology identities, not STL front/back colouring or an invented finite screen thickness.

7.8. A practical mesh-verification sequence

1. Confirm a known geometric dimension and the case length unit. Check source tessellation if a curve or small feature is visibly faceted.
2. Inspect material IDs, priorities, background, and inclusion state. Verify that the intended field volume is actually present.
3. Fit or author the domain, then review all six boundaries independently. Recheck symmetry assumptions after any source-position change.
4. Select the field method before accepting a spacing recommendation. Read the time-step and effective-grid diagnostics.
5. Build the mesh and inspect Material Distribution. Look at cuts through thin features and overlaps, not only the external shaded surface.
6. Refine the mesh and compare the chosen output. Check domain clearance and absorber sensitivity separately if reflections could affect it.

For a missing object, check inclusion, material, priority, domain coverage, prepared geometry, and spacing. Mesh reuse is described in Section 10.5.

8. Excitation source and Solver

The source and field method must be chosen together with the domain. Studio supports a charged-bunch wakefield workflow and a two-port multimode scattering workflow. They share geometry and materials but do not use the same excitation and monitor sections.

8.1. Switch calculation type

The Excitation Source workbench provides the calculation-type workflow. Read the preview before creating a new calculation from the geometry. The conversion retains geometry, materials, mesh, and execution configuration, but replaces incompatible calculation sections; it is not a reversible toggle that stores two independent complete physics setups.

Item	What it means
Wakefield to scattering	Removes charge units, beam, initial-field, wake-monitor, and indirect-integration sections. Selects Stationary, Open/Open X, PEC/PEC Y/Z, creates two ports, and writes an explicit initial duration. Review the generated frequency and mode choices before running.
Scattering to wakefield	Removes scattering data, supplies charge units if needed, creates a centered Gaussian point bunch and waveguide initial field, enables indirect integration, adds a wake monitor, and restores automatic duration. Generated RMS and wake lengths depend on the current mesh/domain; they are not the remembered values of a previous wakefield calculation.

Save a separate variant if both analyses are needed. A scattering case must not retain beam, initial-field, wake, indirect-integration, or charge-unit sections in raw YAML. A wakefield solve requires its boundaries, beam, initial field, and monitors as a complete group.

8.2. Charged-bunch inputs

A *bunch* is the charge distribution that excites the fields as it travels along X. Its longitudinal Gaussian profile is bell-shaped. The RMS length σ is the standard deviation of charge position about the bunch centre; it is not a hard end-to-end length. For a Gaussian, the full width at half maximum (FWHM) is $2\sqrt{2\ln 2}\,\sigma \simeq 2.355\sigma$. Thus the default $\sigma = 0.5$ mm corresponds to a FWHM of about 1.177 mm. The dimensionless speed $\beta = v/c$ is beam speed divided by vacuum light speed.

Setting	Values / units	Meaning and dependencies
Beta (v/c)	Finite $0 < \beta \leq 1$	Omitted field means exactly 1. New projects show 1.0 without writing a beta key. Values below 1 impose the restrictions in Section 8.5.
Longitudinal profile	Gaussian	The currently supported authored bunch profile. The form does not accept arbitrary imported longitudinal time series as an alternative profile.
RMS length	Positive; case length unit	New project: 0.5 mm. This is an RMS length, not full bunch length or FWHM. It influences source resolution and material-planning frequency considerations.

Continued on next page

Setting	Values / units	Meaning and dependencies (continued)
Sources	Nonempty list of transverse points	Each row has a finite nonzero signed charge and absolute Y/Z coordinates. New project: one 1 pC source at $(0, 0)$. All sources share the same Gaussian profile, RMS length and beta.
Source Y / Z	Finite; case length unit	Inspect each source against active geometry, the domain, symmetry planes, and its effective nearest grid node.

A trajectory between grid nodes is sampled at the nearest node. Studio reports the effective position and preserves the authored coordinates. A small coordinate edit can therefore leave the sampled trajectory unchanged, while crossing a nearest-node threshold changes it. This applies independently to every source and observation. Two sources must not collapse onto the same node.

Add source adds an independent charged trajectory. Choose Create dipole pair along Y or Create dipole pair along Z to replace the source list with equal opposite charges about a chosen centre, separated only along that axis. Enter both centre coordinates, the separation along the selected axis, and the charge magnitude. Numeric fields use a decimal point, independently of system region settings. Separation defaults to twice the mesh spacing along the chosen axis and is the full displacement from the negative to the positive source, not a half displacement. The optional centre observation is added without moving existing observations. Removing a source leaves observations unchanged. The last source and last observation cannot be removed.

Physical charges are entered only in the Sources table. There is no separate normalization charge. All sources produce voltage in V; per-charge V/pC analysis is derived in memory, and an equal opposite pair produces a V/pC/m dipole companion. The retired `beam.reference_charge` is removed during in-memory migration; source charges and positions are preserved. Save to write the current syntax.

Valid older single-source projects are converted in memory on opening. Their implicit beam observation and relative offsets become explicit absolute rows in the same order. The original file is written only when you save the project.

> **Beta is intentionally shown at full authored precision**
>
> For example, `0.9999999999999999` is less than 1. Beta therefore keeps its full authored precision even where other numeric displays are compact. Visiting the default 1.0 field does not modify legacy input. A method change never silently resets an authored beta to make the combination valid.

8.3. Field method and automatic changes

The field solver advances electric and magnetic fields through a sequence of times. *FDTD* means finite-difference time-domain: spatial and temporal derivatives in Maxwell's equations are approximated on a grid. An *explicit* update obtains the next values from already known values; an *implicit* update also solves coupled equations for new values. Implicit is a different update method, not a higher-accuracy setting.

Numerical dispersion is an error in wave propagation caused by the discrete grid and time step. It is distinct from a material's physical frequency-dependent response. Studio's Dispersion-free choice targets longitudinal propagation error using the required $c\Delta t = dx$ step; the name does not mean that curved boundaries, transverse propagation, or material interfaces have zero discretisation error.

Stationary keeps the computational window fixed. *Moving* advances the window along the structure with the bunch; geometry does not move physically. *Conformal* treatment accounts for interfaces cutting Cartesian cells instead of representing every interface only as full, axis-aligned cells. Standard is the available treatment for explicit methods. Implicit stepping also offers Simplified. These choices do not change CAD tessellation quality.

Item	What it means
Stationary FDTD	Explicit stepping and Standard conformal treatment. Selecting FDTD also selects Stationary, Explicit and Standard.
Stationary dispersion-free	Explicit with Standard; Implicit with Simplified or Standard. Requires the dispersion-free time-step equality described below.
Moving dispersion-free	Explicit with Standard; Implicit with Simplified or Standard. Selecting Moving also selects dispersion-free and Automatic time step.
Unsupported method combination	Moving FDTD, or implicit FDTD. Finite beta adds further restrictions even where this general method table permits a choice.

Setting	Values / units	Meaning and dependencies
Domain motion / Behavior	Stationary or Moving	New project: Stationary. Changes which moving-specific controls are shown. Selecting Moving changes scheme and time-step policy; it is not camera motion.
Scheme	FDTD or Dispersion-free	New project: FDTD. Selecting dispersion-free sets time step to Automatic; selecting FDTD fixes Stationary, Explicit and Standard.
Time stepper	Explicit or Implicit	New project: Explicit. Implicit requires dispersion-free. A legal selection still needs compatible source and grid.
Conformal scheme	Standard; also Simplified for Implicit	New project: Standard. Explicit uses the complete Standard treatment; Implicit offers its stable specialization or the local Simplified treatment. This does not control STEP tessellation quality.
Scaled time step	Automatic or positive length	New project: Automatic. Interpret as $c\Delta t$ in the case length unit, with method-specific constraints.
Scaled simulation time	Automatic or positive length	New project: Automatic. Interpret as cT. Scattering requires an explicit value. Too short a wakefield duration can produce incomplete requested wake output.

Legacy explicit cases requesting Simplified (including historical YAML aliases) now use Standard. Studio displays an informational notice and the effective selection without rewriting the file on load. Switching to Explicit selects Standard. A checkpoint evolved with explicit Simplified is incompatible with Standard; start a fresh calculation. Implicit Simplified remains available.

The displayed names are Standard and Simplified. For compatibility, case files retain `enhanced` and `simple`, respectively. The historical YAML alias `standard` retains its earlier meaning as `simple`; it is not the serialized spelling of the new Standard display name.

Settings for an inactive Moving or Implicit method are retained in the document and hidden from the normal applicable form. Returning to that method can expose their previous values. Do not equate "not visible" with "reset to factory defaults."

8.4. Time-step and duration policy

The time step Δt is the interval between field updates; duration T is the total simulated time. Studio displays both multiplied by c, so they use the case length unit (Section 4.1). *Stability* means

that the numerical update does not develop uncontrolled growth from discretisation error. The CFL (Courant–Friedrichs–Lewy) restriction limits an explicit time step relative to cell size. It does not measure accuracy. A *convergence study* instead repeats a calculation with finer resolution and compares a chosen output, such as loss factor or resonance frequency.[1]

For stationary FDTD the desktop stability check uses the Cartesian limit

$$c\Delta t \leq \left(\frac{1}{dx^2} + \frac{1}{dy^2} + \frac{1}{dz^2}\right)^{-1/2}.$$

Automatic FDTD time step selects that limit. These are mesh spacings in one consistent length unit. A manual positive value above the limit is rejected.

Dispersion-free requires $c\Delta t = dx$; an arbitrary smaller manual time step is not an alternative stable policy for that scheme. Explicit dispersion-free also checks the guarded transverse condition

$$dx \leq \frac{1}{1.05}\left(\frac{1}{dy^2} + \frac{1}{dz^2}\right)^{-1/2}.$$

Consequently, switching a cubic FDTD grid to explicit dispersion-free can make the setup invalid even with Automatic selected. Follow the diagnostic: reduce the longitudinal spacing appropriately or choose a justified implicit dispersion-free calculation. Implicit does not remove the $c\Delta t = dx$ equality, geometric-resolution requirements, or the stationary-only finite-beta requirement.

Editing X spacing in a dispersion-free case resets the authored time-step policy to Automatic. The derived step then follows the new X spacing. Recheck the source and mesh together rather than manually restoring a stale previous step.

Automatic simulation duration is selected by Solver. With an explicit wakefield duration, a value shorter than requested wake length produces an incomplete-wake warning. A longer duration may be needed to capture late fields or resolve nearby spectral peaks. Check the returned wake extent before analysing its spectrum.

8.5. Finite-beta compatibility

For $0 < \beta < 1$, Studio supports three stationary method combinations. Beta is the dimensionless velocity ratio (v/c); it changes the bunch velocity, not the definition of the time-step control. Boundary and reference choices follow the same rules as at beta one:

Item	What it means
Solver	Stationary FDTD with Explicit stepping, or Stationary dispersion-free with Explicit or Implicit stepping. The implicit dispersion-free policy is ATI. Moving dispersion-free remains beta-one only; FDTD with Implicit stepping remains invalid.
Spatial policy	Explicit methods use the complete Standard treatment. Implicit methods offer Simplified and the stable specialization of Standard. This selection does not change CAD tessellation.

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[1] For the general grid/time-step relationship, see the Meep FDTD introduction. The equations below are Studio's own compatibility checks, not Meep defaults.

Item	What it means (continued)
Time step	Dispersion-free still requires $c\Delta t = dx$, not $\beta c\Delta t = dx$. Explicit dispersion-free retains its transverse stability check; implicit ATI does not remove geometric-resolution checks.
Initial field	An open entrance accepts Waveguide or compatible Open space. A PEC entrance uses a zero initial state and retains the authored model.
Longitudinal boundaries	Either X face may be Open or PEC. Two open ends or two TF/SF ports are not required solely because beta is below one.
Transverse boundaries	Open/PML, PEC and supported PMC symmetry follow the ordinary reference-model checks. Open space permits only Open/PMC faces, with at most one PMC symmetry plane per transverse axis.
Wake processing	Indirect integration is optional. Its physical pipe-tail reference requirements still apply when enabled.

For example, to author a beta-0.8 calculation, choose Stationary and then either FDTD/Explicit, dispersion-free/Explicit, or dispersion-free/Implicit. Select Standard, or Simplified if using Implicit, then choose the physically justified boundaries and initial-field model. Enter 0.8; enable indirect integration only when appropriate. Review the trajectory, source length, mesh, and wake request just as for beta one. Setting beta does not automatically change the method, mesh, bunch dimensions, geometry, or other tabs.

Changing beta alone may permit reuse of an unchanged mesh, but it changes checkpoint compatibility. The Solver decides whether a restart is compatible; a rejected restart remains a failed run, with no automatic fallback to a fresh calculation. Finite-beta checkpoint/restart uses the existing Execution workflow; see Chapter 10 for installed-build verification and platform prerequisites. Do not infer support merely from a connected executable's version label.

8.6. Initial field and beam self-wake correction

The *initial field* represents the bunch's incident electromagnetic field at the start of the calculation. Waveguide and Open space describe different source environments; they are not choices for the final structure's wake. The preparation includes a *linear solve*: finding unknown field values that satisfy a set of linear equations.

An iterative linear solver approaches the solution through repeated updates. Its *residual* measures how well the current values satisfy those equations; a relative tolerance sets the solver's normalised stopping criterion. For example, 10^{-6} requests a one-millionth relative criterion for that solve. It does *not* imply a one-part-per-million error in the final wake. The maximum iteration count caps this work; reaching the cap without convergence requires checking the reported stage and diagnostic.

Beam self-wake correction is an optional correction intended to reduce numerical wake error associated with the bunch. It changes the simulated fields as well as the resulting wake. It can introduce artificial excitation outside a shielded beam channel and is therefore disabled by default in new and imported projects. Existing enabled or disabled choices are preserved. Its applicability depends on the field method and initial-field model as listed below.

Setting	Values / units	Meaning and dependencies
Initial-field model	Waveguide or Open space	New project: Waveguide. Choose according to the actual source environment. Either model is available for finite-beta stationary FDTD and dispersion-free; common reference checks apply. Both models require linear-solver settings in the case.
Relative tolerance	$0 < r < 1$	New project: 10^{-12} for the initial-field solve. A smaller tolerance is a stricter solve request, not a replacement for resolving geometry or source correctly.
Maximum iterations	Positive integer	New project: 10000. A convergence failure should be investigated before merely increasing the cap.
Beam self-wake correction	Enabled or disabled	New and imported projects: disabled. The preference is active for stationary explicit FDTD with Waveguide or the zero state inferred at a PEC entrance. No open-left or two-port requirement applies. Read its displayed status.

For dispersion-free explicit and implicit ATI in a Release build, the self-wake control is disabled. An existing true or false value remains visible, is preserved unchanged in YAML, and is silently ignored at every beta; it does not block Run or create a validation warning. Returning to a stationary FDTD waveguide setup reactivates the control. Active open-space initial fields use their intrinsic incident treatment; the optional waveguide preference remains stored for a later applicable calculation. Turning the checkbox off in an applicable FDTD setup is therefore not a way to disable the intrinsic open-space treatment.

Open-space initialization and FDTD self correction share a free-space reference that does not support opposing PMC mirrors on one transverse axis. An all-PMC waveguide can run without self correction using Solver's reported neutralized reference. Retain that diagnostic; it is not a missing-PEC error or merely a potential-gauge change.

8.7. Advanced Solver controls

These fields control numerical preparation and boundary spacing. TFSF means *total-field/scattered-field*: an interface used to separate an imposed incident field from the scattered response. A terminal is a numerical end interface; PML is the absorber beyond it. Their separations are cell counts, so changing mesh spacing also changes the corresponding physical distances.

Conformal interfaces can leave only a small active part of a Cartesian cell. The active-fraction and virtual-cell controls govern numerical treatment of these small cut-cell regions. Keep their starting values unless a Solver diagnostic or a documented method study calls for a change.

Setting	Values / units	Meaning and dependencies
Moving initialisation passes	Nonnegative integer	New project writes 0. Applicable Moving control; retained when another method is selected.
Geometry to TFSF cells	Nonnegative integer	New project: 0. Grid-cell gap from geometry to the total-field/scattered-field interface. Physical distance changes with mesh spacing.
TFSF to terminal cells	Integer, at least 1	New project: 2. Source-interface to terminal separation in cells. Do not enter a length in millimetres.
Terminal to PML cells	Integer, at least 2	New project: 2. Terminal-to-absorber separation. Review together with open boundaries and absorber depth.

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Setting	Values / units	Meaning and dependencies (continued)
Implicit correction sweeps	Nonnegative integer	New project: 2. Applicable only to Implicit stepping. The value remains in YAML when another time stepper is selected and becomes active again when Implicit is restored. Opening an older Implicit project without the key inserts 2 and marks the project for Save.
Standard virtual-cell level	Automatic, or $0.5 \leq u < 1$	New project: Automatic. Advanced Standard stability control. Use only one authored public level field; competing old/new keys are invalid.
Minimum active fraction	$0 < f \leq 1$	New project: 0.01. Advanced stability threshold; changing it is not equivalent to refining a small geometric feature.

The case requires the stationary distance group for every Solver mode. Do not delete it from raw YAML just because the selected method is Moving. Required configuration, applicability in a particular phase, and guided visibility are different concepts.

8.8. Two-port multimode scattering

A *port* is a waveguide cross-section through which incident and outgoing waves are described. A *mode* is one allowed transverse field pattern in that guide. TE modes have no longitudinal electric-field component; TM modes have no longitudinal magnetic-field component. Below a mode's *cutoff* frequency it is evanescent: it decays along the guide instead of carrying ordinary propagating power. Inspect which channels are resolved across your band.

The *modal plane* is where fields are projected onto port modes. The *reference plane* is where the reported incident and outgoing amplitudes are defined. Translating that reference through a uniform guide is often called *de-embedding*; it removes or adds the propagation between the two planes. It changes the reported phase/reference, not the CAD geometry.

Scattering excites every declared port mode independently and produces the corresponding matrix data. There is no single "active incident mode" selector to author in the current case format. Old `scattering.excitation.port` or `scattering.excitation.mode` fields are rejected rather than silently treated as a matrix calculation.

Domain and port prerequisites

Use Stationary field-solver motion, Open/Open X, and PEC/PEC Y/Z. Exactly two ports are required. The lower-X port faces in the positive-X direction; the upper-X port faces in the negative-X direction. Their planes must be distinct. Each reference plane lies inward from its own modal plane, and the two reference planes remain ordered.

Setting	Values / units	Meaning and dependencies
Automatic port placement	Requires a complete, grid-aligned X domain	Uses X extent, X spacing, and PML depth. The domain must be long enough for both ports, their reference planes, absorber clearance, and ordinary interface cells.
Port aperture	Y/Z domain intervals	Automatically follows the transverse domain in the normal workflow. Changing Y/Z bounds updates both apertures; check the physical guide cross-section, not only the numeric extent.

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Setting	Values / units	Meaning and dependencies (continued)
Reference plane X	Finite; case length unit	Advanced control. Must remain inward from its modal plane, with lower reference below upper reference. Changing reference planes changes the reporting reference, not the geometry.
Port ID	Unique nonempty identifier	Identifies the port in the authored case and results. Port geometry and directions are handled by the dedicated workflow, not exposed as arbitrary normal scalar choices.
Mode ID	Unique within its port	Identifies a requested modal channel. Use distinct IDs when declaring several modes.
Mode family	TE or TM	Numerical PEC waveguide mode family. This is not a free-form analytic TE_{mn} formula selector.
Mode ordinal	Positive integer, starting at 1	Selects a member of the requested numerical family. Each port needs at least one mode. Inspect returned mode and matrix information rather than assuming every declared channel carries useful propagating power throughout the requested band.

Automatic placement places modal planes five cells beyond the PML depth from each X end and the initial reference planes one further cell inward. Consequently, increasing PML depth or coarsening X spacing can make an unchanged physical X domain too short. Expand a physically appropriate domain or revise the mesh; do not move reference planes past each other to suppress the error.

Excitation and requested frequency band

The Gaussian-modulated pulse is an oscillation at the centre frequency with a Gaussian envelope. Its RMS bandwidth describes the spread of its spectrum; the output band selects which frequencies to report. In the power-normalised port convention, squared propagating-wave amplitude has units of watts: an amplitude of $2\sqrt{\mathrm{W}}$ corresponds to 4 W in that convention, not to a uniform electric field of 2 V/m.

Setting	Values / units	Meaning and dependencies
Waveform type	Gaussian-modulated	Current supported scattering waveform. Not an imported arbitrary pulse or a continuous-wave boundary field.
Center frequency	Positive; Hz	Pulse center. Interpret every frequency field in Hz, including values typed from a GHz specification.
RMS bandwidth	Positive; Hz	RMS spectral bandwidth of the pulse. Distinguish it from full bandwidth or the requested output interval.
Amplitude	Positive; $\sqrt{\mathrm{W}}$	Excitation amplitude in the documented power-normalised convention. It is not bunch charge or an electric-field value in V/m.
Frequency minimum / maximum	Positive and strictly increasing; Hz	Requested scattering band must lie within center frequency plus/minus three RMS bandwidths.
Incident relative threshold	$0 < r < 1$	Optional default when omitted: 10^{-8}. A threshold for usable incident content; inspect result validity instead of treating a low-incident sample as an ordinary trustworthy value.
Scaled simulation time	Explicit positive length	Automatic duration is not accepted for scattering. Verify the duration against the intended transient and frequency resolution. Extend the duration to check sensitivity of the result.

Scattering setup sequence

Save a separate case variant. Review boundaries, ports, modes, frequency band, material response, and explicit duration. Re-run automatic port placement after X-domain, spacing, or PML changes. Build and inspect the mesh, then run. See Chapter 12 for channel interpretation.

9. Wake and outputs

Output settings decide what is measured and retained, not only how the eventual plot looks. Set them before running. A field slice that was not requested cannot be reconstructed from a screenshot; a wake trajectory outside the saved monitor set is not automatically available afterward.

9.1. Wake length and transverse trajectories

The drive bunch excites the fields. A *witness trajectory* is the path of a test charge used to evaluate their effect; an additional trajectory does not add another drive bunch. Wake coordinate s describes longitudinal separation within and behind the drive bunch, not the object's global X coordinate. Wake length controls the requested extent of that response. See Section 3.1 for the distinction between field and wake potential.

Setting	Values / units	Meaning and dependencies
Wake length	Positive; case length unit	New project: 10 mm. Requested wake extent, distinct from the geometric X length and from scaled simulation duration.
Observation Y / Z	Finite; case length unit	Absolute transverse coordinates, independent of every source. New project: $(0, 0)$ and $(0.1, 0.1)$ mm.
Observation list	Nonempty sequence	Every observation is explicit, including one coincident with a source. There is no implicit first trajectory.

For a source at $(1, 2)$ mm and an observation at $(1.2, 1.9)$ mm, moving the source leaves the observation at $(1.2, 1.9)$ mm. Each observation must lie inside the domain and is sampled at its nearest grid node. Two observations must select different nodes; an observation may coincide with a source. Refining the mesh can distinguish nearby points; extra decimal places alone cannot.

> **Requested wake length and run duration must agree**
>
> If an explicit scaled simulation duration is shorter than the requested wake length, Studio warns that the wake may be incomplete. Review the actual extent of the returned data. Do not fill a missing tail with zeros and treat it as a computed result. Increasing requested wake length should be accompanied by a review of duration and response convergence.

9.2. Direct and indirect wake integration

Wake integration converts the computed electromagnetic response into its accumulated effect along a witness trajectory. The two methods target the same physical wake quantity, but evaluate the integral differently. Solver performs this work during the wakefield calculation; enabling a field-preview monitor is not required.

Item	What it means
Direct integration	Accumulates the longitudinal electric field, or transverse electric-plus-magnetic force per unit charge, along the witness path at the appropriate times. Contributions can continue into the outgoing guide, so a short tracking path can leave the integral incomplete.
Indirect integration	Uses an alternative field/boundary formulation to account for the downstream contribution without following the entire direct path. Its auxiliary solve has the tolerance and iteration controls below. It is not interpolation, curve smoothing, or a different charge normalisation.

For the numerical principle, see Zagorodnov's *Indirect methods for wake potential integration*. That paper describes several formulations; the supported Studio combinations are the ones documented here, including the finite-beta requirements in Section 8.5.

Leave indirect integration enabled for the default wakefield workflow. Compare Direct and Indirect on the same run, component, and trajectory when checking the wake calculation. A disagreement calls for checking wake extent, resolution, boundaries, and solve diagnostics; do not average the two curves.

Setting	Values / units	Meaning and dependencies
Enabled	True or false	New project: true. Requires wakefield monitors. Indirect integration is optional for finite beta; it is not a scattering setting.
Relative tolerance	$0 < r < 1$	New project: 10^{-14} for the indirect solve, independent of the initial-field linear solver's tolerance. See Section 8.6 for what a relative stopping criterion means.
Maximum iterations	Positive integer	New project: 10000. A separate cap from the initial-field solve; check which stage produced a convergence message.

When the indirect-integration section is authored, its required solver settings must remain complete, even if its enabled preference is false. Direct and indirect X/Y/Z wake components are Solver-produced artifacts, not interchangeable labels for the same curve. See Chapter 12 for selecting components and comparing returned traces.

The current output locations are fixed by the public artifact contract. Do not add custom `monitors.wake.output` or `indirect_integration.output` fields. New projects use `beam.sources` and `monitors.wake.trajectories`. Legacy charge/point-profile and additional-offset syntax is accepted through read-time migration only; mixing the forms is invalid.

9.3. Power-loss monitoring

In Setup, select Wake & Outputs. The Power-loss monitor Enabled control is available even when an older project omits this monitor from its YAML. It then shows disabled without changing the project. Editing one of these controls creates the monitor settings; enabling it records losses on the next run. Disabling recording does not disable physical material losses.

Setting	Values / units	Meaning and dependencies
Enabled	True or false	New project: false. Enable when material-loss observations are part of the study; a material's nonzero conductivity is not itself a request to display a saved power-loss trace.
Sample interval steps	Positive integer	New project: 1. An interval in Solver steps, not physical seconds or wake-distance samples. Larger intervals retain less temporal detail.
Symmetry factor	Positive finite scalar	New project explicitly writes 1. A separate requested multiplier for interpreting a symmetry-reduced calculation. Do not assume Half/Quarter domain fitting sets it automatically.

Choose a symmetry factor only when the geometry, material placement, source, and boundary conditions justify the corresponding full structure. Applying a factor of two to an asymmetric half-domain model does not repair its missing physics. Keep the factor and domain choice in the calculation record when comparing different runs.

9.4. Field-slice preview requests

The Field preview controls in Wake & Outputs request a bounded field-slice stream for the wakefield calculation. Enable it only when needed. With no preview monitor, the Solver does not perform the corresponding preview sampling and Studio does not poll for that stream.

Setting	Values / units	Meaning and dependencies
Component	Electric X/Y/Z or Magnetic X/Y/Z	One native component, not a vector magnitude or arbitrary derived scalar. Returned electric values are V/m and magnetic values are A/m, not tesla.
Plane	XY at fixed Z, or XZ at fixed Y	Current supported plane choices. Choose the corresponding fixed-coordinate value in the case length unit.
Coordinate	Finite; case length unit	The physical location of the slice. Check it against the intended domain and structure. A plane outside the useful field region cannot show the desired feature.
Resolution	Two positive axes, each at most 4096	Maximum requested sampling resolution. It does not refine the simulation mesh or manufacture sub-cell detail.
Retention	Bounded history or Latest frame only	History enables replay of retained frames; latest-only minimises storage but does not preserve earlier frames for post-run replay.
Maximum frames	Integer 1–100000	Bound on retained history. The latest-only selection disables the editable history-frame control.
Apply preview settings	Explicit action	Commits the request. Changing a display control after a run cannot retroactively create unsampled field data.
Reset	Explicit action	Discards unapplied preview values and shows the case's request again.

Changed preview values, including an invalid coordinate, stay a draft until Apply preview settings or Reset. Other edits, searches, navigation and Save Case keep the draft; Save Case stores only the applied request. A change of the case length unit, of the first monitor or of the calculation type discards it, and Log records that. While a draft is pending, Build Mesh and Run stop with Apply or reset the live field preview settings and open Wake & Outputs. Enabled still applies at once.

If the first saved monitor has a value these controls cannot offer, such as an unknown component, a resolution axis above 4096, zero frames or a coordinate that is not a number, the controls including

Enabled are read-only. An unknown choice shows Unavailable with its saved text, a coordinate that is not a number is left blank, and a resolution or frame count the control cannot hold shows the control's limit. The summary names each problem and, for a number outside a control's range, the saved number. Apply preview settings cannot replace these values; repair the monitor in YAML Source. A coordinate edit that changes only the sign of zero, from 0 to −0 or back, is applied like any other change.

The normal preview workflow manages its monitor identity. For externally authored multiple field-slice monitors, IDs must be unique and contain only letters, digits, underscores, or hyphens. This reference does not imply that every valid raw monitor-list construction has a separate guided editor. When a case has several monitors, a note below Enabled lists their IDs. The controls edit the first monitor, and Apply preview settings leaves the others unchanged. Enabled is the switch for the whole case: clearing it lists every monitor and asks for confirmation before it removes all of them. Cancel keeps the case and any unapplied control values. Re-enabling creates one new default monitor; it does not restore the removed settings. See Chapter 11 for playback, native-component interpretation, coordinate frames, and storage-aware troubleshooting.

9.5. Check the measurement before a long run

1. Write down the quantity needed for the engineering decision: a wake component on a specific trajectory, a loss trace, a scattering channel, or a field component on a plane. These are different output requests.
2. Verify beam and monitor locations after the latest mesh/domain change. Resolve duplicate-node or outside-domain errors; review nearest-node information.
3. Choose a wake length and duration sufficient for the intended comparison. Review loss sample interval and any symmetry factor separately.
4. Enable only useful field previews, with justified retention bounds. A higher preview resolution is not a substitute for a convergence study.
5. Perform a short configuration check, inspect the produced artifacts and labels, and only then commit resources to the production-duration run. Retain the run inputs and full diagnostics for reproducibility.

If a run completes but a requested plot is absent, first check whether the monitor was enabled in that run's saved input, whether the selected artifact exists, and whether it contains valid samples. Do not assume the currently edited project describes a historical run. Run ownership and immutable input snapshots are explained in Chapter 10.

10. Execution, Jobs, and restart

Build Mesh prepares the computational representation; Run performs the calculation, building or reusing an eligible mesh as needed. Inspecting the mesh before a long run is useful: a smooth CAD preview and a correctly resolved computational mesh are different things.

10.1. Before starting a job

Complete the modelling and setup chapters first. Resolve unapplied material or geometry edits, inspect validation issues, and check Solver readiness. Build and Run can prepare supported CAD geometry and save current project changes. An untitled ready project asks for a project location when work starts. Do not rely on an older on-disk YAML file to describe the new job.

Each job receives an immutable input snapshot. Its results describe that snapshot, not whatever is currently visible in an editor after later changes. The job records its backend identity, commands, logs, and execution summaries. Only one local calculation pipeline can be active in a Studio instance.

> **A first execution check**
>
> For a small, newly authored example, start with one MPI rank and one thread per rank, build the mesh, and inspect it. Increase resources only after the case and runtime work at that baseline. Assess mesh convergence separately, using the comparison in Chapter 3.

10.2. Set MPI layout and worker count

Open Execution, then MPI execution. MPI ranks are separate processes; threads are workers inside each rank. The notation P4/T2, when used in run discussion, means four ranks and two threads per rank—not four threads total. The nominal worker product is $P \times T$, but it is not a performance forecast.

The *Cartesian rank grid* divides work along X, Y, and Z. Its dimensions PX, PY, and PZ count process partitions, not mesh cells. For example, PY=2 partitions the Y direction between ranks; it does not set Y resolution.

Setting	Values / units	Meaning and dependencies
MPI layout	Automatic or Explicit PX × PY × PZ	Choose exactly one policy. Automatic asks Solver to select the Cartesian factorization; explicit specifies the grid yourself.
MPI ranks	Positive integer in Automatic mode	Requests the MPI world size. Solver chooses the actual axis factorization.
PX, PY, PZ	Positive integers in Explicit mode	Their product is the MPI rank count. Complete all three, then use Apply layout; do not try to maintain a separate contradictory rank count.
Threads per MPI rank	Positive integer	Applies in both layout modes. Account for available CPU and memory resources, including other processes on the workstation.

Changed layout values stay a draft until Apply layout. Other edits, searches, navigation and Save Case keep the draft; Save Case stores only the applied layout. Reset beside Apply layout discards

the draft. Opening, reverting or importing a project also discards it, and so does a change to the case's MPI settings, for example in YAML Source, which Log records. While a draft is pending, Build Mesh and Run stop with Apply or reset the MPI layout and open Execution.

The editors accept values up to 1,000,000 for an individual count. That is an input bound, not a supported workstation size or a recommended allocation. The complete layout must still pass validation and Solver's decomposition requirements. More ranks can increase communication and memory overhead.

The controls cannot show a saved count above that bound, or saved settings that fail validation, such as `mpi_ranks: 0`, both `mpi_ranks` and `cartesian_rank_grid`, or a grid without three axes. They are then read-only and may show a default or the nearest value they can hold. The summary names each problem with the saved count or grid it refers to, and Studio leaves case.yaml unchanged; edit these settings in YAML Source. Build Mesh and Run neither shorten nor repair them: a valid case runs with the saved values, and validation refuses an invalid one.

For example, explicit $[1, 2, 2]$ requests four ranks. With two threads per rank, it requests eight nominal workers. Automatic with four ranks requests the same world size but leaves its factorization to Solver. Read the recorded execution summary to see the actual layout; do not infer it from the request alone.

10.3. Follow a calculation and interpret its state

Use Jobs for the durable job state and Log for the detailed process messages. A run may include preparation, mesh-key lookup, meshing, and solving; progress is tied to the current stage. Preparation can consume substantial time or memory without a field-evolution percentage advancing.

The active stage and Stage elapsed remain visible when history is hidden. Elapsed time is not time remaining or a Solver heartbeat. Progress not reported means no percentage has arrived for this stage; the compact moving bar is not an error indicator.

Building mesh prepares the calculation mesh. Computing initial field prepares the starting electromagnetic field. Preparing fields initializes field, material and boundary data before Time stepping begins. Percentages, when reported, are labelled of stage, including preparation progress where available. At 100%, wait for Succeeded: a completed stage is not a completed job. The active progress strip disappears when the job ends.

Find the messages that need attention. The Log, Validation, Geometry Diagnostics, Mesh Diagnostics, and Material Inspector panels have compact Information, Warnings, and Errors filters shown as symbols and counts; hover for their names. Information and zero-count filters are neutral. Warning and error symbols gain colour only when their count is nonzero, even if those rows are hidden. Click a filter to hide or show that severity; the underlying records remain available. Material coefficient statistics are information, not warnings merely because they differ from a bulk reference.

Log entries show the local date and time when Studio received the event. Diagnostic tables show a small snapshot refresh time at the right; hover for the full date and time. Jobs retains each run's recorded creation time. Clear in Log clears only the session display, not saved run logs or results. Select a finding and click Go to to open its known setting, geometry, mesh view, or material. Double-clicking a diagnostic row also navigates. The button is disabled when no source is known; log links from another case cannot redirect the current project. Process output without an explicit severity is informational, including ordinary messages written to the error stream.

Item	What it means
Preparing	Studio copies and hashes the job inputs into the new run folder in the background and stays responsive. Until the copy ends, Save Case and actions that save the project first, such as preparing geometry or importing an STL file with unsaved changes, are refused; repeat them afterwards. Stop takes effect after the current copying or hashing step, which for large inputs can take seconds, and removes the unfinished folder. The job appears in Jobs once its input snapshot is complete.
Mesh ready	A completed mesh is available for inspection. This does not necessarily mean field evolution completed successfully.
Succeeded	The requested pipeline completed. Inspect numerical outputs and warnings before accepting engineering conclusions.
Memory warning	Solver reported high or uneven memory usage. A successful calculation remains successful; inspect Log for the reported phase, peak, average, rank distribution, and node pressure.
Failed	Read the original diagnostic and identify the failing stage. Validation, launch, licensing, mesh compatibility, and numerical failures require different remedies.
Cancelled	Stop was requested. Completed artifacts may remain, but missing results are not silently promoted to complete results.

Use the square Stop button beside Run to cancel a running pipeline. They are separate controls: Stop never becomes Run. After one Stop request, the header shows Stopping…; both buttons remain disabled until the pipeline finishes stopping. Stop then stays disabled, and another calculation requires an explicit Run request once the case is ready. Closing Studio during a local calculation asks about cancelling the calculation and then about unsaved project changes. Declining cancellation, cancelling the unsaved-changes prompt, or a Save that cannot complete keeps Studio open and leaves the calculation running. Cancellation is requested only after all Close decisions are accepted. Cancellation is not a request to publish a checkpoint immediately. A last complete checkpoint may survive, but do not assume that every cancelled job is restartable. Likewise, a successful mesh can remain usable after a later solve failure.

If Studio cannot write a run log or its history record, it reports the failing path and stops the local backend through the normal termination procedure. The job is not reported as successfully recorded. Keep the visible diagnostic and the run directory, then restore access or free space before starting a new job. Logs after the storage failure may be incomplete. If the final history record could not be written, reopening shows the last state that was successfully recorded; the in-session diagnostic may not have been saved. If artifact indexing also fails, Studio retains the original failure and any mesh recovery location before reporting the indexing error. For an unconfirmed Slurm outcome, reconcile the scheduler job before retrying: stopping its local launcher does not establish that the cluster calculation stopped.

10.4. Browse history and remove a job safely

In Jobs, choose Show history to expand the recorded jobs table; Hide history hides the table without deleting it or hiding the active stage. Drag the divider above the bottom panel to choose its height. Switching between its tabs, returning from Home with Return to Case and restarting Studio keep that height. Show history and Hide history, starting a run, opening a case that has job history, Review validation, Mesh Setup and a failed run resize the panel explicitly; a run that fails while Home is shown does not. Double-click a job to select its recorded run and inspect its available mesh. A

successful full run also opens its preferred supported result. For a failed or cancelled run, inspect only the artifacts it actually completed.

Opening a project reads its saved job history without changing unfinished jobs to Interrupted. A saved Running or Cancelling row reports the last recorded state; it does not prove that the process is still alive. Studio does not reconnect to that process, and Stop controls only a job launched by the current window. Such a row adds not in this window to its state; it cannot be stopped or deleted there. Reopen the project to refresh another window's progress. While a job runs, its Studio holds the visible lock file `studio-run.lock` beside `studio-run.json` and removes it when the job ends.

If the Studio that started a job exited without finishing it, select the row and choose Mark Interrupted…. Studio first checks that no running Studio owns the job and that its last recorded local process has ended; otherwise the job is not changed. A job that meanwhile finished keeps its saved state. A job recorded by an older Studio without ownership information needs an explicit confirmation that ownership cannot be verified. This action does not stop solver processes or Slurm jobs. A lock written by Studio on another computer, for example on a shared project folder, cannot be checked; Studio then refuses to mark or delete that job.

A damaged, unsupported or locked job record (`studio-run.json`) no longer hides the other jobs and their results. It appears after them as an unreadable record row named after its folder; hover over the row for the manifest path and the reason. The row cannot be selected, opened or deleted, and Delete All Jobs… ignores it. The Jobs summary counts unreadable records and the Log reports each one as a warning. If the job history folder itself cannot be listed, a single Job history folder row reports that instead. Studio does not delete, repair or rewrite these folders: inspect the folder, restore it from a backup, or remove it yourself.

When automatic result opening is enabled, successful field evolution enters Results, loads the preferred supported artifact for that immutable run, and brings Result Analysis to the foreground. This replaces an active Field view as soon as the calculation finishes and selects Results in the left case tree. When the case enables the power-loss monitor and the completed run contains `results/power_loss.csv`, Studio selects that material-power-loss result ahead of wake artifacts. Other cases retain the preferred supported wake or recorded field-preview selection; a configured scattering calculation retains its scattering-matrix priority. Mesh-only completion remains a mesh-inspection step, and a run that finishes while the separate Home page is visible does not pull you away from Home. You can always choose another run and artifact manually in Results.

Jobs use short labels such as Run 10:54:31 or Mesh 10:54:31; the Created column shows local date and time. Hover over the label for its full identifier, case name and folder. Internal identifiers and saved folders remain stable. The Stage progress column shows the last reported percentage for active or successful jobs. Failed, cancelled and interrupted jobs show a dash; hover over that cell to inspect any retained stage percentage without mistaking it for successful completion. The State column remains authoritative.

Select multiple rows with Ctrl-click (Command-click on macOS), Shift-click, or Select All. Choose Delete Selected… below the table or in its context menu. Delete All Jobs… selects every finished job in the current project, regardless of the table selection. One confirmation lists the affected jobs. The complete run folders, including logs, input snapshots, signals and results, move to Trash. Jobs recorded as unfinished and the current window's active job are retained even in a mixed selection; both actions are unavailable while a result reader is using run files. Immediately before each move, Studio reads the manifest again and requires the same job identity and a finished state, and checks that no running Studio owns the job. A missing, unreadable or changed manifest, or an owner that is running or cannot be checked, prevents that move. Failed removals remain in history and are reported. These actions do not merely hide rows.

That final history check does not establish ownership of an external process. Before deleting an Interrupted job, confirm that its local or remote workers have stopped. In particular, an unconfirmed Slurm outcome is not proof that the cluster job has ended.

The shared Mesh Store entry and the persistent checkpoint root are retained. This action therefore does not promise to reclaim all storage associated with the study. Recovery of a mistakenly removed folder depends on the operating system's Trash/Recycle Bin and whether it has been emptied; there is no Studio modelling-Undo action for job removal. Preserve a separate archive for results that must not depend on Trash recovery.

10.5. Understand automatic mesh reuse

Studio asks Solver for a mesh-dependency key and checks the shared `EMUZAG Studio Results/Mesh Store`. An exact verified hit avoids a repeated mesh build; a miss builds a new entry. Store identity includes the exact backend build. A solver update can therefore require a new mesh even for unchanged geometry. Looking up, verifying and storing a mesh run in the background, so Studio stays responsive; a Stop or closing Studio meanwhile takes effect when that step ends, and a mesh stored by then remains in Mesh Store.

Do not predict reuse solely from which tab was edited. Solver owns the dependency definition and checks the staged mesh against current inputs. The job records whether it *produced* or *reused* its mesh. Changing a beam parameter may allow reuse while still changing the solve and invalidating a checkpoint.

Meshes are shared independently of individual jobs. Cancelling or removing a job does not delete its shared mesh; retained checkpoints also have a separate lifetime. Avoid deleting files directly from Mesh Store to free space while other jobs may reference them.

If storing a generated mesh fails after staging begins, Studio tries to restore the generated files to that job's `calculation/mesh` directory. If that location is occupied or restoration fails, it retains them in a visible `Publishing` directory inside Mesh Store. Keep the reported directory and the job log when investigating the failure. If no recovery location is shown, preserve the job's calculation directory and any matching `Publishing` directory while investigating; an unexpected exit or a later error can leave no detailed publication report. Retained files are not a verified reusable entry, especially if verification caused the failure. Starting another job may build its mesh again; Studio does not currently offer a command to resume publication of the retained files.

10.6. Configure checkpoint publication

Enable Checkpoint and restart to author checkpoint settings. A checkpoint is Solver-owned restart state, not a mesh, a screenshot, or an ordinary result export. Studio does not repair its internal contents.

Setting	Values / units	Meaning and dependencies
Publish periodic checkpoints	On / off	Controls new periodic publication. It can be off while an existing checkpoint is used for restart.
Visible project directory	Relative directory; for example `EMUZAG Checkpoints`	The persistent checkpoint root. It must remain inside the project and separate from run history and input files.
Interval	1–4,294,967,295 steps	Positive publication interval in Solver steps, not seconds. The value must be valid even when the mapping is retained for a restart.

Continued on next page

Setting	Values / units	Meaning and dependencies (continued)
Restart	Beginning / latest complete / specific	Start from the beginning does not consume an existing generation. Latest complete generation asks Solver to choose its latest complete state.
Selection	Generation ID or manifest path	Used by Specific generation or manifest; interpreted relative to the configured checkpoint directory.

The controls cannot show saved checkpoint settings that fail validation, such as an interval of 0 or one that is not a number, an empty restart selection, or a directory outside the project. They are then read-only, the summary names each problem and any saved text it refers to, and Studio leaves case.yaml unchanged until you repair the settings in YAML Source.

Typed directory, interval and restart text is committed when you leave the field and also by Save Case, Build Mesh, Run and the unsaved-changes prompt. A rejected path or an incomplete interval stops that operation. After Save Case the text stays in the field for correction; a later refresh of the case from another edit shows the saved settings again.

For example, `step-00000000000000000100` identifies a specific generation; its `manifest.bin` can also be selected through the supported relative path. Use an actual published generation, not a name invented from a desired step number.

Checkpoint directories cannot escape the project using an absolute path or `..`, use hidden dot-prefixed components, overlap `EMUZAG Studio Results`, or traverse an existing symbolic link in the project path. A file where a directory is expected also blocks launch. Publication may create the directory; restart requires it to exist already.

Studio exposes that persistent directory to each immutable calculation using a checked directory link. If Windows reports that a required privilege is not held, the launch cannot safely stage the checkpoint path. Ask the administrator or release provider for the supported link-capable setup; do not move checkpoint files into a random run directory or run all of Studio elevated as a routine workaround.

10.7. Restart and check compatibility

1. Retain the original project and complete published checkpoint root.
2. Choose the intended restart mode and directory in Execution.
3. Decide independently whether to publish additional checkpoints.
4. Review any input or MPI-layout changes, then start Run.
5. Check the log for acceptance of the restart and the final job state.

The current public interface permits finite-beta checkpoint/restart, including restart with publication disabled. This does not make arbitrary changes compatible: changing beta can preserve the mesh key while invalidating the checkpoint. Solver makes the final compatibility decision. A rejection remains a failed run; Studio does not change beta, choose another layout, or silently fall back to a fresh calculation. See Chapter 8.

Release 1.1.2 uses indexed conducting-wall and thin-screen meshes and an updated complete-mesh checkpoint identity for thin screens. When Solver reports an unsupported mesh index or format, rebuild the affected mesh for a new job. An older checkpoint may be incompatible with that mesh or preparation identity; retain the original job and results, and start a fresh calculation when restart is rejected. Do not edit binary records or rewrite an earlier job to bypass compatibility checks.

Finite-beta terminal checkpoints now require TP3 with accumulated source state. If Solver rejects an older finite-beta TP2 terminal checkpoint, regenerate it with the current Solver and the intended calculation. Do not change beta or discard terminal state to bypass the rejection. Beta-one TP2 is unchanged; Studio does not interpret the private binary checkpoint record.

Checkpoint write summaries report measured generation bytes, retained previous bytes, available capacity, maximum-rank bytes, and write duration. Leave space for publication and retained generations, not only the apparent size of a single result file. For scattering, the configured directory is the complete matrix checkpoint root; do not select an individual excitation column as a replacement root.

11. Live and recorded fields

Field displays one recorded field component on a two-dimensional plane. To record it, configure an optional field monitor before the run. The recording contains only the requested plane and component, not a complete 3D field history.

When a run with a field monitor starts, Studio opens Field and selects Field in the left case tree. A run without a field monitor does not make that automatic switch. Clicking the Field or Results tab also selects the matching tree entry; returning to 3D View restores the tree context for the displayed geometry or mesh. Home remains separate from these automatic workspace changes.

11.1. Request the field information you need

In Wake & Outputs, open Live field preview, enable it, choose the settings, and use Apply preview settings. Review the storage summary before running. The standard editor configures the primary monitor; multiple monitors can be authored in Expert YAML. Refer to Chapter 9 for their relationship to the calculation's other outputs.

Setting	Values / units	Meaning and dependencies
Component	Electric X/Y/Z or Magnetic X/Y/Z	One native component. Electric values are V/m; magnetic values are A/m.
Plane	XY — fixed Z or XZ — fixed Y	Selects the two plotted axes and the coordinate held fixed. A YZ plane is not a choice in this monitor editor.
Coordinate	Project length unit	Requested fixed Z for XY, or fixed Y for XZ. Choose a finite coordinate consistent with the modelled domain and inspect the selected native plane reported by Solver.
Resolution	Compact 128×64; Standard 256×128; Detailed 512×256; High 1024×512	These are U/V ceilings, not a replacement for mesh spacing. A higher display ceiling cannot create spatial information missing from the mesh.
Retention	Bounded history or Latest frame only	Bounded history supports replay. Latest-only replaces one frame and minimizes retained history, so it cannot replay earlier frames after the run.
Maximum frames	1–100,000; primary default 200	Bounded-history capacity. Disabled for latest-only. Review the displayed retained-byte ceiling rather than guessing from frame count alone.

The primary defaults are Electric X, XY, coordinate zero, Standard resolution, 200 frames, and bounded history when no existing monitor supplies values. Loaded projects can contain different settings and custom resolution values. The coordinate editor's broad numeric range is not evidence that a coordinate outside the calculation domain is meaningful.

Without a field monitor, there is no preview sampling or Studio polling. Turning preview on after a job finishes cannot recover its missing history. Output is sampled on a bounded schedule, not necessarily on every Solver step.

11.2. Choose the recording and move through time

Select the Field run and Field stream. A stream identifies one monitor, not an arbitrary slice of a volume recording. Read the lifecycle label and the frame information together: the currently displayed complete frame may be older than the active calculation step.

During a local run, Follow current run returns to the newest validated frame and continues following arrivals. Selecting an earlier frame or playing a recording lets you inspect history instead. Use the timeline and playback controls for retained frames; Fit field plane restores the camera framing. Playback can slow while the next frame loads rather than skipping data.

Recorded frames carry native sample coordinates and component time. Different electric and magnetic components can have staggered times and positions. Compare their metadata; do not assume that two screenshots with similar frame numbers show exactly the same physical time layer.

11.3. Separate colour, contrast, and geometric aspect

Setting	Values / units	Meaning and dependencies
Physical / Log detail	Linear / sign-preserving logarithmic colour	Log detail emphasizes weak nonzero structure without changing raw values or the sign of the field. It is the initial display mode. In Physical mode, automatic contrast uses one tenth of the reference limit to emphasize weaker fields; the legend and exports report this actual display limit. Manual limits are unchanged.
Sample aspect / Physical aspect	Equal screen size per retained interval / equal physical distances	Sample aspect is the initial readability view. Physical aspect preserves metre-for-metre proportions. This selector is independent of colour mode.
Automatic contrast	On / off	Uses producer recommendations when available. Older recordings use the compatible retained-range policy. Turning it off exposes manual diagnostics.
Fixed recording / Recorded contrast	One recording scale / per-frame recommendations	Available where the retained recording supports them. Fixed recording is suited to amplitude comparison across frames; recorded contrast follows each producer recommendation.
Neutral below	Non-negative finite value in the field unit	Display-only floor: magnitudes at or below it appear neutral. It is not a material property or a solver convergence tolerance. The default is 10^{-9} in the field component's physical unit.
Manual $\pm A$ and Set limit	Positive finite field magnitude	Sets a symmetric colour limit. Scientific notation is accepted. Values outside the range may clip in the display while the raw samples remain intact.

> **Two different meanings of physical**
>
> Physical changes the colour transfer to linear; Physical aspect changes the geometric proportions. For a metrically faithful plane with linear colour, select both. Do not measure distances from the default Sample aspect screenshot.

When available, Use observed scale chooses a provisional range from received finite values; later frames can exceed it. Expand to current peak is a display recovery action, not a recalculation. State the contrast mode and limits when using screenshots to compare amplitude.

Moving-window views keep their recorded global positions. The frame rectangle may stay fixed on screen while source-geometry contours pass behind it as the camera follows the window. That visual movement does not mean Studio has moved or edited your geometry. Moving contours are context only and do not mask out valid samples. Missing geometry cannot invalidate an otherwise readable frame.

11.4. Export the appropriate evidence

Item	What it means
Save field screenshot	A PNG of the displayed view. Useful for a report; not a substitute for numeric samples.
Export selected raw frame	The selected native binary frame. Keep the original stream and associated metadata/support files for a complete archive.
Export display metadata	Display settings and frame context, useful for explaining aspect and contrast choices alongside an image.
Export field frame sequence	A sequence of rendered images with a `field-sequence.json` manifest. This is an image sequence, not an encoded video or a complete numeric field history.

For numeric reuse, retain the original project/run identity and recording. Confirm that any requested output file was actually written before moving or sharing it.

11.5. If a field appears empty or incomplete

First confirm that the selected run had this monitor enabled and that the selected stream has a complete frame. Then inspect lifecycle, component, plane, native time, and reported range. Use Fit field plane, check aspect, and consider Log detail for a weak signal. A high manual limit or neutral floor can make a nonzero frame look blank.

Do not treat a display-support warning as proof that numeric values are absent. Studio can retain a valid numeric frame when optional masking metadata is missing or invalid. Conversely, a malformed or truncated numeric artifact is not silently repaired. Non-finite samples are shown as invalid samples rather than converted into plausible field values. Preserve the diagnostic and source files if the warning remains.

12. Results and analysis

Results reads public artifacts produced by a calculation and can derive impedance or resonance estimates from a recorded wake. These analyses do not launch another field evolution or modify the original run input.

12.1. Select the source before interpreting the plot

Choose a Source, then an artifact. Inspect its selected source path and the recorded execution summary. Project-folder artifacts and immutable run artifacts are different sources: a run is always interpreted with its own input snapshot, never with a newly edited bunch length, charge, or mesh.

The Latest suffix identifies the newest successful non-mesh-only run for the opened case. It does not mean the current edited inputs were calculated. Run labels show a readable local date and time. Hover over the source label or selector for its full ID and folder. Results stored with project means files stored directly with the project, not a recorded job. Studio has no record of the inputs that produced them. It interprets them with the saved case file, never with unsaved edits, and marks their wake and current results producing inputs unverified. If the case file was saved after a result file was written, the source summary and Displayed result warn that the charge, RMS length, spacing and observations may differ from the producing inputs; after any Save this can appear although nothing numerical changed. Rerun the case or restore the producing values before relying on curves that depend on them. Their wake curves are named Results stored with project in the legend and CSV export. This entry appears only when those files exist. Sources without result files are omitted; mesh-only files do not count. With one source, Studio shows its name without a dropdown. With none, it shows No results yet.

Selecting a supported artifact displays it immediately, with either the mouse or keyboard row navigation. Result Sources stays visible while browsing. Selecting a wake shows its recorded quantity; a dipole artifact selects Dipole coefficient. Browsing does not start an impedance or resonance fit. Open Result Analysis to choose those analyses. Bunch current displays `signals/current.txt` separately in amperes; with multiple sources its label is Source currents. In Result Analysis, Current on plot appears only with multiple sources and selects one source, the signed total, or all sources. With one source, its current is shown automatically. Source choices show the source number and signed charge; hover over a choice for its coordinates. The same selection controls the overlay on wake curves. For an equal opposite pair, the positive source is selected initially; otherwise the total is selected. Individual curves retain their charge signs and use amperes. A zero total is shown as a visible zero line with a cancellation explanation. The provenance file `results/excitation.json` is metadata, not a curve, and is available through Show run folder. File sizes include units; hover over a size to see the exact byte count.

Compare… is available when the selected source and another source have saved wake results. It is disabled while reading a result; wait for completion or use Cancel read. Hover over the disabled button for the reason.

Use Load / Analyze to load the chosen source or start the requested analysis. The Displayed result section describes what is actually on the chart. Hover over Analysis for help on the selected mode. After changing a source or fit parameter, do not export a previous display under a new label before its analysis completes.

Item	What it means
Open raw	Open the selected artifact using the operating system's associated application. This is not a request for Studio to repair it.
Show run folder / Show project folder	Open the selected run's folder, or the case folder when viewing results stored with the project.
Load / Analyze	Load or compute the selected presentation. New resonance fits are explicit actions, not silent effects of editing a parameter.
Cancel read	Cancel background reading or analysis. This is separate from Stop for a running Solver calculation.
Reset plot	Restore chart bounds after zoom or pan; it does not reload or recompute the data.
Export CSV… / Screenshot…	Export the displayed curves or a PNG of the current result view. Verify source, units, and analysis first.

On a result chart, left-drag to zoom to a rectangle, middle-drag to pan, or use the mouse wheel to zoom. Reset plot restores the bounds without changing the source or fit. These chart gestures are separate from the 3D geometry camera controls.

12.2. Read wake-potential components

Setting	Values / units	Meaning and dependencies
Analysis	Wake potential; Wake gradient (quadrupole); Dipole coefficient; Impedance; Resonances	Chooses presentation/analysis of the selected source, not a Solver method.
Integration	Indirect / Direct	Reads that recorded integration. Indirect is preferred initially; if it was not produced, Studio explicitly selects an available Direct artifact. Selecting a missing result does not compute it. The methods are defined in Section 9.2.
Component	X / Y / Z	X is longitudinal; Y and Z are transverse physical wake-potential components. These are not dipole or quadrupole normalization modes.
Trajectory	Authored observation in list order	Every observation is explicit. Solver's stored coordinates are the actual sampled nodes; moving a source does not move observations.

The main wake response contains physical voltage in V for the authored sources. For per-charge analyses, Studio divides the selected physical wake by the source charge in memory. For example, 6 V from 3 pC gives 2 V/pC. An equal opposite pair produces a separate dipole coefficient in V/pC/m. Studio uses the physical wake artifact and the selected analysis to determine the display units. The plotted values, metrics and CSV agree.

The X curve uses the *accelerating-wake convention*: positive voltage is accelerating in that convention. A passive structure's positive longitudinal *loss factor* is the negative Gaussian-weighted mean of the X wake, in V/pC. Individual parts of the X curve need not all have the same sign.

Bunch weighting averages along the wake using the Gaussian charge distribution, rather than giving every sample equal weight. Studio reports the charge-weighted loss voltage for X or kick voltage for Y/Z and the *RMS spread*, which measures variation about the weighted mean. These voltage metrics already include the source charges; do not multiply them by charge again. Specifically, X loss voltage is minus the charge-weighted mean X wake; Y/Z kick voltage uses the signed

charge-weighted mean directly. A transverse kick voltage is not itself a deflection angle, which also depends on particle momentum.

Direct calculations produce three component files; enabling indirect integration produces the corresponding three indirect files as well. Files belonging to one run must have consistent longitudinal sampling and ordered trajectory coordinates. Studio does not guess that an older tensor file or a renamed component file is equivalent.

To compare two wakes, use Compare…, choose Compare with, and check the same integration, component, and physical observation trajectory for both runs. Their case settings still matter: Observation 1 in two independently authored runs is not by itself proof of an equal position. Comparison is a wake presentation feature; the control is hidden for spectral and resonance views. It does not perform the removed paired-run dipole reconstruction.

12.3. Calculate and interpret impedance

Select Impedance, choose the component and trajectory, set the band, and use Load / Analyze. A *Fourier transform* resolves the sampled wake into frequency components. *Complex impedance* retains both magnitude and phase: its real and imaginary parts describe the in-phase and quadrature parts under the chosen transform convention. Magnitude is $\sqrt{(\mathrm{Re}\, Z)^2 + (\mathrm{Im}\, Z)^2}$; phase is their angle, not a propagation time by itself.

Both the longitudinal and physical transverse-component impedances are reported in ohms; do not relabel a transverse-component result as ohms per metre without a separately defined normalization.

Gaussian bunch deconvolution divides out the known drive-bunch spectrum to estimate the point-charge response. Where that spectrum is small, the division amplifies errors and noise; this is why a frequency limit is applied. With deconvolution off, the transformed response still contains the finite bunch's spectral weighting.

Windowing changes the weight of samples near the end of the record. An abrupt cutoff can spread a spectral feature into nearby frequencies (*spectral leakage*). The Hann-tail window softens that cutoff, but also changes the tail's contribution. Compare windows when a slowly decaying tail reaches the record end; tapering does not replace a longer calculation.

Setting	Values / units	Meaning and dependencies
Minimum frequency	Non-negative GHz; initially zero	Lower edge of the requested analysis band. It must leave a usable interval inside the reliable upper limit.
Maximum frequency	Positive GHz, or zero shown as Automatic (stable)	Automatic uses the bunch-supported band. An explicit maximum requests a band but cannot remove Nyquist and deconvolution limits.
Plot	Magnitude; real and imaginary; magnitude and phase; all components	Magnitude, real and imaginary values are in ohms; phase is in degrees. This is a presentation choice.
Gaussian bunch deconvolution	On by default	Compensates the Gaussian drive spectrum within the supported band. Disabling it changes the transform interpretation, not the recorded wake.
Window	Rectangular or Hann tail (last 10%)	Hann tail is the initial choice. It leaves the first 90% unchanged and tapers the final 10%; Rectangular leaves the samples unwindowed.

Let Δs be the saved longitudinal sample spacing in metres and N the sample count. The public analysis reports the sampling bounds

$$f_{\text{Nyquist}} = \frac{c}{2\Delta s}, \qquad \Delta f_{\text{physical}} = \frac{c}{N\Delta s}.$$

Here c is vacuum light speed. The public spatial transform uses e^{-iks} with $k = 2\pi f/c$, including for finite-beta output; do not substitute beam speed v into this analysis convention. The *Nyquist limit* is the highest frequency distinguishable from this sampling grid. Content above it can be confused with lower-frequency content (*aliasing*). The record-length scale $\Delta f_{\text{physical}}$ describes how closely spaced features the available wake can separate. Other errors, including field-mesh dispersion, can restrict usefulness below Nyquist.

Zero padding appends zeros for the transform and produces denser plotted frequency bins; it adds no measured wake and does not improve the record-length resolution. For example, a 1 m sampled wake has a frequency scale near 0.30 GHz; changing only the padding cannot turn that into 0.03 GHz physical resolution.

The Gaussian bunch spectrum falls with frequency. Automatic band selection uses a normalized bunch-spectrum threshold of 0.05. An explicit maximum uses the more permissive threshold 10^{-6}, but the returned impedance is still bounded by the requested maximum, the bunch-supported limit, and Nyquist. Near the upper band limit, inspect sensitivity to bunch length, mesh, window, and record length before interpreting a feature.

> **Plan the calculation for the question**
>
> To distinguish close spectral features, obtain a sufficiently long, valid wake; do not merely ask for more plotted bins. To study higher frequencies, review bunch length and spatial resolution together. See Chapters 7 and 8.

Impedance analysis requires finite, uniformly spaced samples, at least two samples, and valid positive mesh spacing and RMS bunch length from the source case. A rejected band or artifact is not repaired by changing plot scale.

12.4. Fit and assess resonances

Choose a Resonances presentation, start with automatic settings, and press Load / Analyze. The background progress identifies reading, spectrum, fit, and reconstruction work. A resonance estimate is a model fitted to the selected wake tail, not an independent eigenmode calculation.

A *resonance* is an oscillatory response that can persist after excitation. The *tail* is the later part of the wake chosen for fitting, after the prompt bunch response. Studio represents it as an offset plus a sum of damped sinusoids. Each term has amplitude, frequency, phase, and decay rate. A fitted *pole* summarises one such frequency/decay pair; it is not necessarily a unique physical cavity mode.

The *reconstructed wake* is the sum predicted by the fitted model. The *residual* is the difference between that reconstruction and the recorded wake. An independent *eigenmode calculation* would instead solve for natural field patterns and frequencies from the electromagnetic boundary-value problem; this Results tool does not perform that calculation.

Setting	Values / units	Meaning and dependencies
Mode selection	Automatic / Fixed	Automatic returns supported candidates up to the chosen limit. Fixed requests an exact count and can fail when that many decaying in-band modes are not resolved.
Mode count / limit	1–32; initially 20	Maximum in Automatic mode, exact count in Fixed mode. More modes do not automatically make the interpretation more reliable.
Automatic tail start (10 sigma)	On by default	Starts the selected tail at ten RMS bunch lengths and uses the available end. It does not silently move later just to obtain a better fit error.
Fit start, Fit end	Coordinates in the source case length unit	Enabled for a manual interval. Start must precede end and the selected interval must contain at least 32 valid samples. These are positions along the wake, not time in seconds or sample indices.
Minimum/Maximum frequency	GHz	Limits the mode search. Automatic maximum is bunch-supported; an explicit maximum overrides that automatic search cap but remains below Nyquist.

Item	What it means
Spectrum and poles	Original and reconstructed tail spectra, with bars at fitted pole frequencies. Look for missed or displaced peaks as well as a small time-domain error.
Fitted impedance	Original-tail and reconstructed-tail impedance magnitudes. Gaussian deconvolution and window controls apply here.
Reconstructed wake	Original tail and fitted reconstruction in common wake units. Inspect onset, decay, and residual structure over the whole interval.

The spectrum and reconstructed-wake views do not expose impedance-only window and deconvolution controls. Reusing an already calculated fit across these presentations does not repeat the expensive fit. Changing the source, search band, mode selection/count, or fit interval invalidates that reuse and requires a new explicit analysis. Export only after the intended result is displayed.

Read quality diagnostics together. Studio reports the full-tail reconstruction error and the mismatch at detected spectral peaks; the worse diagnostic governs the quality classification. A strong resonance should not hide a missed weak peak. Growing or unresolved candidates are rejected or marked, not silently promoted to plausible resonances.

What a fitted Q means

Quality factor Q measures persistence of an oscillation relative to its frequency: larger Q means slower decay. For a fitted term $Ae^{-\alpha(s-s_0)}\cos(k(s-s_0)+\phi)$, Studio reports $f = ck/(2\pi)$ and loaded $Q = k/(2\alpha)$. Here α is decay per unit distance, k is angular spatial frequency, s_0 is the tail origin, and ϕ is phase. The corresponding amplitude decay time is $Q/(\pi f)$.
Loaded means that all losses present in the recorded response contribute. A single wake trace does not separate intrinsic, external, wall, material, and radiation losses. A tail with too little measurable decay cannot establish a well-resolved Q merely because a fit returns a number. Compare fit windows and resolution, and retain the reported quality diagnostics with any engineering result.

If the recording ends before $s = 10\sigma$, the automatic start leaves no usable tail. Extend the calculation, or select an earlier manual interval only if it is already dominated by the decaying response

of interest. The interval must still contain at least 32 samples. Raising the mode count does not lengthen the record.

12.5. Read scattering results

A scattering calculation produces a different artifact: `results/scattering_parameters.csv`. Select that result to inspect the resolved coefficient magnitude and phase by excitation and output channel. Wake-analysis selectors do not convert scattering output into a wake.

An S-parameter $S_{ij} = b_i/a_j$ is the outgoing modal amplitude in channel i divided by the incident amplitude in excited channel j, with other incident channels unexcited. Each channel names a port and a mode. Reflection returns to the incident port; transmission leaves through the other port, possibly in a different mode. For resolved, propagating power-normalised channels, $|S_{ij}|^2$ is the corresponding power fraction, while $\arg S_{ij}$ is phase relative to the selected reference planes.

Each declared port mode is an independent excitation and an observed output. With N declared modes, the matrix requests N field evolutions and N^2 complex coefficient traces per resolved frequency. Workload therefore grows with the complete mode list, not just the channel of interest in a plot. The setup requirements and mode authoring are in Chapter 8.

Unresolved rows are not plotted as valid coefficients. A derived dissipated power fraction $1 - \sum |S_{\text{output}}|^2$ is shown only where all declared output channels are present exactly once. The remainder is not clamped to conceal a negative value. A missing balance curve can mean incomplete channel evidence, not zero dissipation; an unexpected balance requires checking the calculation rather than rescaling the graph.

12.6. Read power-loss curves and recorded preview frames

If material power-loss recording was requested, Studio selects and loads `results/power_loss_materials.csv` when available, otherwise the aggregate `results/power_loss.csv`, when the run finishes. When revisiting another run, select that artifact and use Load / Analyze. The time axis is in seconds. For one source, recognized material-power columns are shown in W/pC^2; cumulative-loss columns are in V/pC. The plot initially shows total power only. Use Quantity to select power or cumulative loss/energy on a single vertical axis, and Show loss mechanisms to display the contributing channels as well as the total. When the saved file contains material IDs and names, use Material to choose All materials or an individual material. The legend then includes its saved name and ID. Aggregate-only files disable individual selection and explain that a material breakdown was not recorded; Studio does not reconstruct one from the current project. The selected run appears in the result context, without repeating its name in every legend entry. CSV export retains all saved channels and both quantities and materials, independently of these display choices. Complete files include conductive walls/sheets, volume conductivity, electric dispersion and magnetic dispersion, and their four-channel total. Historical files label their limited total as wall plus conductivity; missing dispersion is unknown, not zero. Read the axis label: normalized power is not already watts for the authored bunch, and cumulative loss is not a second power curve.

Power is averaged over the recording interval ending at the plotted time; cumulative loss accumulates dissipated energy. PML absorption, radiation and reversible stored energy are excluded. To recover physical power from W/pC^2, multiply by the square of the single source charge in pC. To recover energy from V/pC, multiply by that same square and by 10^{-12} to obtain joules. For example, 2 W/pC^2 at 3 pC is 18 W, and 2 V/pC at 3 pC is 18×10^{-12} J. For multiple sources, power-loss files instead contain physical power in W and cumulative energy in J; no arbitrary charge or neutral sum is used as a divisor. Retain any authored symmetry factor in the comparison.

Other supported, indexed post-processing CSV artifacts can also be loaded. Their headers define their plotted coordinates and units. A CSV extension alone does not make an arbitrary file a supported result: the reader requires consistent columns and valid numeric data. An artifact without a supported reader remains accessible through Open raw.

Results groups recorded field-preview files by monitor directory. Select a group to expose Preview frame; choose an ordinal from 1 to the number of complete retained frames, then load it. The ordinal is a position in the recording, not the Solver step number. The latest complete frame is selected initially, and the displayed metrics identify its actual step and native time. With no complete frames, loading is disabled. Frame changes load the selected frame when the reader is idle.

Use the Field workspace in Chapter 11 for the timeline, replay, contrast controls, and frame-sequence export. The Results frame selector is an artifact-inspection route, not a request to sample a new plane or recreate unrecorded history. Curve CSV export is available when curves are displayed; field images use Screenshot or the Field workspace's dedicated export actions.

12.7. Keep a result reproducible

Before exporting, verify the run/source path, component and trajectory, integration, analysis type, units, and parameters in Displayed result. Export CSV for numeric curves and PNG for presentation. Keep the immutable input snapshot and original artifacts alongside the interpretation: a screenshot alone does not preserve bunch charge, fit interval, or Solver build. Results stored with the project have no snapshot; keep the case file that produced them alongside them.

If an artifact is missing, incomplete, from an unsupported format, or inconsistent with its source case, preserve the original files and diagnostic. Select the correct run or complete/repeat the intended calculation. Do not rename a binary artifact to another component, edit headers, or replace snapshot metadata to force acceptance.

12.8. Opposite-charge pair results

An equal opposite pair produces physical voltage curves and separate `results/*_dipole.bin` artifacts. In Result Analysis, choose Dipole coefficient, then the integration, component and observation. Studio selects the matching saved coefficient and multiplies it by the actual magnitude of one source charge, giving V/m. For a pair $+q, -q$ with $q > 0$ and full effective separation d, the displayed response is $D_V = qD_{\text{saved}} = V_{\text{pair}}/d$. Do not use the zero total charge or $2q$. The option is unavailable when that run, integration and component have no saved coefficient; its tooltip explains why. It does not generate missing results. Selecting a dipole artifact in Result Sources opens the same presentation. Solver uses the effective source-to-source separation after grid snapping; the signed moment and its direction are recorded in `results/excitation.json`. The finite pair approximates a directional source derivative and includes higher odd terms; convergence should be checked by reducing the separation on a resolving mesh. A pair in an asymmetric structure does not isolate a pure eigenmode.

The graph, signed mean and RMS spread, and CSV all use V/m. The metric table also shows the magnitude of one source charge. Spectral analysis requires a single-source per-charge curve and automatically derives it from a one-source voltage when needed. A multi-source voltage has no unique per-charge scaling for this analysis.

Current on plot initially shows the positive source of the pair. Choose the negative source, total or all sources to inspect the excitation. The total is zero for equal opposite charges sharing a profile; their individual currents remain nonzero. For each source $I_i(s) = q_i v \lambda(s)$, with $v = \beta c$. Studio scales the recorded profile using the selected run's source charges and velocity. It does not synthesize

a missing current file. Changing this selector never changes the wake curve, its mean or RMS spread.

The Physics Guide explains the source-derivative definition, full-separation normalization and convergence procedure. Do not divide the saved coefficient by the separation a second time.

12.9. Wake gradient and quadrupole coefficient

Choose Wake gradient (quadrupole) in Analysis, a component X, Y or Z, the target Trajectory, a Reference trajectory, and Derivative axis Y or Z. Both observations must differ only along the selected axis. The result is

$$\frac{V_\alpha(\text{target}) - V_\alpha(\text{reference})}{r_{\text{target}} - r_{\text{reference}}}.$$

Studio uses Solver's stored sampled positions, converts their signed difference to metres, and reports that separation beside the plot. Coincident sampled points and pairs differing in both Y and Z are rejected. Swapping target and reference preserves the derivative because both numerator and denominator change sign.

For transverse components near the reference orbit, this estimates the detuning or quadrupolar coefficient. The name does not turn a general finite difference into a pure quadrupole component. The component and derivative direction are independent: X gives the transverse variation of the longitudinal wake, while Y/Z give variations of transverse wakes. The recorded current profile remains visible on the right axis in amperes, as in Wake potential view; it is not differentiated or divided by observation separation. With multiple sources, use Current on plot to select an individual source, the total or all sources. With one source, no selector is needed. The dipole-coefficient view uses the same control.

For one or several sources the physical voltage difference gives V/m. The graph, mean, RMS spread and exported CSV use these units. No source-charge division is applied to the physical gradient. Spectral analysis does not apply to this view. The mean and centred RMS spread of either a gradient or dipole response $F(s)$ are

$$\mu_F = \int \lambda(s) F(s)\, ds, \qquad \sigma_F = \sqrt{\int \lambda(s)[F(s) - \mu_F]^2\, ds}.$$

Here λ is the common normalized Gaussian profile of the synchronous sources. The mean keeps the curve's sign for X, Y and Z; the spread is nonnegative. Both have units V/m. The second central moment itself has squared units; Studio displays its square root. The selected current is only an overlay. Subtracting the reference removes a constant transverse kick that simple division by distance would retain. This estimates dependence on observation position, not the source position. A detuning coefficient requires a small-offset convergence study about the intended orbit; refine the mesh and vary the resolved observation separation.

13. Troubleshooting and recovery

Start with the first relevant error in Validation, Geometry Diagnostics, Mesh Diagnostics or the job log. Later messages may be consequences of that first failure. Preserve the original case and failed-run log before making changes. Fix one cause at a time and repeat the operation.

13.1. Curved or hybrid meshing stops

If the log says contact could not be certified, preserve the failed job and read the named screen, support and cell. An unproved coincidence is a supported refusal, not a successful mesh with missing material. Re-export the affected geometry or select STL explicitly for that body in Calculation geometry, then rebuild. Keep the same units, materials, priorities and intentional openings. Changing display quality has no effect on the calculation contact. A shared screen-topology error may require mesh refinement even after changing representation.

If an update reports an obsolete mesh dependency, use Build Mesh for the current project. Keep old job folders and results; do not overwrite them with new inputs. The new mesh cannot be substituted into an old checkpoint with a different dependency identity. See Section 5.2.

13.2. Geometry is missing or cannot become a solid

Item	What it means
Sketch seems to create nothing	A sketch is construction geometry, not a volume. Select it to open the profile inspector; create a Revolve or Extrude result to obtain a solid. Sketch creation works in an empty project. See Chapter 5.
Revolve is rejected	Check the local X–R profile, nonnegative radius, closure, non-self-intersection and a nondegenerate region. Correct the profile; do not merely retry the same invalid input.
Extrude/Boolean/fillet fails	Check required selections, profile validity, positive dimensions, intersecting operands and feature size. A radius larger than the available local feature may not be geometrically possible. Reduce complexity to isolate the failing operation.
Imported file is invisible	Confirm supported format, source availability, explicit units, object extents and visibility. Fit the camera. Check whether the imported item is a raw triangulated surface or editable CAD; their available operations differ.
Imported object is visible but Build is blocked	Imported STL, STEP or BREP bodies become calculation geometry only when they have a material. Until then the header reads Blocked · assign materials, and Validation says that geometry is present but has no simulation material yet. Assign a material in Geometry; reopening the project does not change this state. Blocked · save project means a staged STL replacement waits for Save Project.
Inner parts are hidden	Solids are opaque by default. Turn on Transparent solids (X-ray) at the top right of the Geometry view, use Cut view, or isolate the part. See Chapter 5.

Continued on next page

Item	What it means (continued)
Only boundaries are prominent	In Domain & Boundaries, solids are intentionally transparent. Check geometry visibility, inclusion and the selected geometry/assembly representation. If solids disappear only on this page, try Automatic or Standard in Settings > Graphics, save with OK and restart. Copy Graphics Diagnostics for support; see Section 1.2.
A visible object is absent from the mesh	Check Included, material assignment, domain clipping and overlap priority. Showing an excluded object with its eye control does not restore its participation in simulation.
Curves look faceted or a small gap disappears	Inspect STL wireframe. For CAD/STEP/BRep, refine display quality to inspect the retained curved boundary; for directly imported STL, obtain a better source STL. Inspect calculation mesh spacing separately.
Import succeeds but meshing fails	Import display is not proof of a valid closed material volume. Read topology, self-intersection, duplicate/degenerate facet and material diagnostics. Use a deliberate repair tolerance; do not close a physically intentional opening without understanding its role.
Solver inspection rejects a body	Select it in Geometry and turn on Show STL wireframe. For an imported STL volume, use Try automatic repair…, review changes and save. If it reports a remaining defect, correct it in an STL editor or source design, export a closed STL, then use Replace source…. For invalid CAD, correct its source operation or STEP/BREP source. Preserve an intentional sheet's open edge.

13.3. A setting changes, disappears or blocks the job

Item	What it means
Changing units alters the model meaning	Unit selectors do not promise a global physical rescale of every value and external file. Choose units first and audit dimensions and dependent data after changes. See Chapter 4.
Time step returns to Automatic	The dispersion-free method ties $c\Delta t$ to d_x. Changing the longitudinal spacing can restore automatic policy. Repair the method/mesh combination rather than trying to force an independent time step.
Automatic time step is still rejected	Explicit dispersion-free fixes $c\Delta t = d_x$ and still needs compatible transverse spacings. Check the inequality in Section 8.4; reduce d_x or use an applicable implicit method.
Lower beta makes the case invalid	Preserve beta and use stationary explicit FDTD. Boundary/reference rules are the same as at beta one; check the specific diagnostic. Neither indirect integration nor two open ends is mandatory. Do not replace beta with one to bypass validation.
Self-wake correction is retained but inactive	It belongs to the supported explicit-FDTD waveguide path. A stored enabled value does not mean it applies to every method or open-space configuration.
Full/Half/Quarter/Rotate causes an error	Review the resulting domain, beam and every wake trajectory. A trajectory may now lie outside the domain. Correct its offsets, remove it deliberately or enlarge the domain; set symmetry faces separately.
Domain did not follow new geometry after reopening	A project read from disk, reverted or opened as a Save Case As… copy keeps its saved extents, even when they match the solids. Only a new project refits automatically, until you first edit the domain or the YAML source. Press Full in Domain & Boundaries to refit; reapply Half or Quarter if the project used one. See Section 7.1.

Continued on next page

Item	What it means (continued)
A material editor refuses a model change	The material is used by a geometry role or background that would become invalid. Resolve those assignments or choose a compatible representation. A sheet material is not a volume background.
Changing calculation type removes source controls	Wakefield and scattering workflows have different source/output structures. Review the conversion proposal and emitted case; this is not a cosmetic change of labels.

13.4. Build or Run cannot start, or stops early

Item	What it means
Run is unavailable	Check material drafts, validation, Solver connection, licensing, MPI readiness and another active job. There is no single "force run" remedy for these different conditions.
Solver was connected yesterday	Its path, runtime installation or trial status may have changed. Reselect the intended executable and refresh readiness. Selecting an unrelated binary with a familiar filename is not a compatibility fix.
A protected job stage was rejected by licensing	The job remains failed. Follow the refreshed licensing status and Chapter 2; Studio must not silently retry the calculation. Validation occurs at protected-command boundaries; do not assume continuous mid-stage expiry checks.
MPI launch fails even with one rank	A production MPI executable still needs the compatible MPI runtime. Read the launcher error and use the supported runtime installer/repair route. Do not copy isolated MPI DLLs from another machine.
Memory pressure or allocation failure	Reduce the actual workload or select appropriate resources. Check grid cells, active window, material states, monitors, rank/thread count and per-rank memory. Resource estimates have exclusions; more ranks on the same machine do not automatically create more memory.
Checkpoint restart fails before Solver starts	Check the persistent checkpoint directory, selected relative path, file conflicts and Windows directory-link permissions. Numerical restart compatibility is checked by Solver after launch. Do not move checkpoints into unrelated folders to bypass path safety checks.
Mesh reused but restart rejected	These are different compatibility decisions. A mesh can remain usable after changes that invalidate a numerical checkpoint. Start a new solve or restore exactly compatible inputs; do not rewrite checkpoint metadata.
Jobs shows local PEC	Some conducting volume patches lack field samples and were treated as PEC. The calculation continues with zero wall loss on those patches; wake can change. Read the Log and the conductive-wall PEC CSV reports for objects, centroid bounds and affected areas. If needed, move the adjacent domain boundary outward or refine the gap, then rebuild the mesh. Geometry, openings and authored materials are preserved. Two-sided sheet failures remain errors.
Cancel leaves files behind	Completed artifacts, logs and shared mesh data may remain intentionally. Inspect Jobs and the recorded run state; retained files do not mean a canceled run completed.

13.5. Fields or results look wrong

Item	What it means
Field view has no data	Configure a supported field monitor before Run, choose the correct run and wait for output. No preview monitor means no retrospectively recoverable field history.
Field animation has only one frame	Latest-only output replaces earlier frames; it is not an archive. Use the appropriate recording policy when a temporal history is required.
Field geometry looks stretched	Inspect the aspect policy. Sample aspect emphasizes grid samples; Physical aspect represents coordinate proportions. The display policy does not change the solved geometry.
Wake curve is missing	Confirm the selected run, artifact, component, direct/indirect method and trajectory. Indirect output requires its integration setting; scattering results are not wake results.
Noisy/high-frequency impedance	Check the bunch-spectrum acceptance threshold, sampling, record length and usable band. Do not infer trustworthy high-frequency impedance from division by a nearly zero excitation spectrum.
Zero-padding changes a plot but not the physics	Padding interpolates the sampled transform. Increase the physical observation interval to improve frequency discrimination; padding alone adds no measured information.
Resonance fit is unstable	Review the selected samples and wake-coordinate fit interval, number of modes and signal content. Fit start/end use the case length unit, not seconds. Increase observation duration or reduce model order when justified. A fitted loaded Q is not an intrinsic material Q.
Compare is not available	Compare is exposed for wake-potential presentation, not every spectral or resonance presentation. Use compatible quantities and units when comparing run outputs.
Numeric export differs from a screenshot	A plot/image is a presentation; raw or tabular export represents the selected numeric data with its own coordinates and units. Read the export definition, scale, component and active analysis settings.

13.6. Studio is blank or stops responding on Windows

The Windows package records local startup diagnostics automatically. Find the `Diagnostics` folder beside `Start EMUZAG.cmd`. Direct launches of `emuzag-studio.exe` are logged too. If the package is not writable, logs go to `%LOCALAPPDATA%/EMUZAG/Studio/Diagnostics` instead.

Reproduce the problem once, wait 30 seconds, then close Studio (use Task Manager only if it does not respond). Send the newest `studio-*.log` to support and state whether you used Remote Desktop. Filenames and entries have UTC timestamps. Keep a separate copy before further launches: only the latest three launch logs are retained, each limited to 4 MiB. Active sessions are never removed, so concurrent instances can temporarily retain more. Ignore temporary `.lock` files.

Logs contain startup stages, operating-system/library versions, graphics and memory information, and UI responsiveness counters. They do not automatically include project files, calculation results, licence contents or process dumps. Nothing is uploaded. Review a log before sharing it. Solver job logs remain separate in their run folders.

These diagnostics do not change graphics drivers or select a software renderer. An installed GPU alone does not establish which OpenGL renderer a remote session provides. The log can identify the renderer when a context initializes; a blank window alone does not establish that the GPU driver is the cause.

13.7. Prepare a useful support report

Provide enough information to reproduce the failure without exposing unrelated customer information. Review the contents before sending a bundle.

1. Record Studio and Solver versions, Windows version, and whether the Solver is ordinary or trial-enabled. Include the visible status and diagnostic text.
2. Describe the shortest reproducible sequence and the expected versus actual behavior. A screenshot of the whole relevant panel is more useful than a cropped number with no label or unit.
3. Include the affected project YAML file, necessary geometry/material assets and the failing run's logs, subject to your organization's sharing policy. Prefer an original synthetic reproducer if the model is confidential.
4. For numerical questions, record mesh spacings, geometry representation and calculation STL tolerances, source parameters, method, duration, trajectory/component and analysis options. Explain whether the discrepancy persists under controlled refinement.
5. For a trial problem, report status and use the vendor's approved transfer channel for request/license files. Never clear the TPM, delete protected license state or change the system clock as a troubleshooting experiment.

13.8. Return logs from a cluster job

For jobs submitted by Studio's HPC launcher, use Show run folder and find the affected stage below `Slurm Jobs`. Mesh and solve each have a separate job directory. It retains the command, requested resources, timestamped scheduler events and complete `stdout.log` and `stderr.log`. The compute receipt records executable and input fingerprints, the launcher host and its outcome. An unfinished receipt does not prove remote workers stopped.

The supplied `docs/linux-slurm-setup.md` describes exporting one stage through the launcher's `--export-job` option into a new support ZIP. This operation requires no activation and submits no job. The export contains selected logs and a manifest; for files above 8 MiB it keeps the last 8 MiB and records the truncation. Full original logs remain in the job directory. Review the archive before sending it: program messages can contain paths. Project inputs, results and licence files are not automatically attached.

The HPC package also supplies `diagnostics/vacuum-pec-cube` for a basic installation check. Follow its README to prepare a new shared scratch folder and run one small two-rank mesh/calculation sequence. It uses the ordinary Solver and needs a valid trial for calculations. It is not a scaling study or a substitute for checking the site's real multi-node configuration.

A. Cross-setting dependency map

Use this page when an edit made in one navigation section affects another. The individual chapter remains the detailed authority for that control.

When you change…	Recheck…	Reason / reference
Case or import units	Geometry extents, material lengths, mesh, beam, wake and duration	Unit choices change interpretation. Verify physical dimensions rather than assuming global conversion. Chapters 4, 5.
CAD or source geometry	Inclusion, materials, prepared surfaces/mesh	Re-prepare the selected STL/native route and inspect material ownership. Chapter 5.
Calculation STL tolerances	CAD-generated STL and mesh reuse	Change calculation STL, not display quality or grid spacing. Direct STL is unchanged. Chapter 5.
Eye visibility	Your visual interpretation only	Hidden is not excluded; showing an excluded object does not include it. Chapter 5.
Included or priority	Material mesh, background and mesh reuse	Inclusion controls participation; priority resolves overlaps, not source visibility. Chapters 5, 6.
Material representation	Volume, sheet and background uses; frequency data and runtime cost	Some representations are prohibited for certain geometry roles. Do not mix tabulated and explicit constitutive data. Chapter 6.
Domain fit or symmetry extent	Boundary faces, source and every trajectory	Fitting extents does not select symmetry physics. Chapter 7.
Mesh spacing	Domain snapping, source sampling, stability and resource plan	A finer grid can change the permitted time step and cell ownership. Chapters 7, 8.
Assembly layout	Longitudinal domain, interfaces and source placement	Repeated sections own their assembled X range. Mesh section reuse does not imply checkpoint reuse. Chapters 7, 10.
Stationary/moving or FDTD/dispersion-free	Time stepping, initial field, beta and correction applicability	Some selections deliberately change companion settings; others retain inactive values. Chapter 8.
Beta below one	Method, reference compatibility and restart	Requires stationary explicit FDTD; ordinary FDTD boundary/reference rules apply, indirect integration is optional, and near-one beta retains precision. Chapter 8.
Charge or bunch length	Wake normalization, bandwidth, recommended mesh and duration	Source normalization and spectral support affect result interpretation. Chapters 8, 12.
Wakefield/scattering type	Excitation and monitor groups, ports and duration	This converts calculation structure. Review before applying. Chapters 8, 9.
Wake offsets or indirect integration	Domain/symmetry containment, sampled path and available artifacts	Offsets are relative to the bunch trajectory. Distinct authored offsets may snap to one path. Chapter 9.
Field monitor policy	Recorded history, preview storage and later exports	Monitoring must be requested before execution. Latest-only cannot supply full replay. Chapter 11.
MPI grid or thread count	Resource availability and run provenance	Explicit Cartesian product determines ranks; thread count is per rank. Chapter 10.
Checkpoint source	Numerical compatibility and path/permission checks	Checkpoint restart is stricter than mesh reuse. Chapter 10.
Results analysis	Analysis, band and units	Recalculate explicitly; plot controls do not rerun Solver. Retain analysis settings with exports. Chapter 12.

B. Shortcuts, units and terminology

B.1. Core Windows shortcuts

These are the explicit application-level shortcuts for this edition. Modeling shortcuts are selection-sensitive; see Chapter 5. A text editor can own a key while it has focus.

Item	What it means
Ctrl+N	Choose a name and location, then create a saved case from the template.
Ctrl+O	Open case.
Ctrl+S	Save case and its changed CAD authoring state.
Ctrl+Shift+S	Save case as a new working copy.
Ctrl+Shift+H	Open Home; return only after entering a case in this session.
Ctrl+Z	In Geometry or CAD, undo the last CAD construction edit. Edits to directly imported STL objects are not part of this history.
Ctrl+Y	In Geometry or CAD, redo the last undone CAD construction edit.
Escape	Cancel an active viewport handle drag, Sketch point drag or Zoom to Region. Escape never undoes an edit; dialogs and table cells keep their usual Escape behavior.
F6	Build Mesh, subject to readiness and validation.
F5	Run, subject to readiness and validation.
Shift+F5	Stop the active job.

B.2. Units at a glance

Always read the unit beside the control or in the exported header. Case length and charge selectors do not replace the SI units used by material-frequency tables and derived analyses.

Item	What it means
Position, size, spacing and wake coordinate	Case length unit: m, cm or mm. Wake observations use absolute transverse y, z coordinates.
Scaled time $c\Delta t$, cT	A length in the case length unit. Divide the physical length in metres by c to obtain seconds.
Beam charge	Case charge unit: C, nC or pC. Inspect normalization before comparing exports.
Beta, relative permittivity/permeability	Dimensionless; $\beta = v/c$.
Conductivity	S/m. It is not loss tangent and not sheet resistance.
Sheet resistance	$\Omega/\square$; a zero-thickness surface model, not a thickness field.
Frequency	Material-table and excitation inputs use Hz; Results frequency controls use GHz. Read the control or exported header rather than transferring an unconverted number between them.
Electric and magnetic field	Electric field V/m; magnetic field H in A/m. Do not interpret H as magnetic flux density B.

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Item	What it means (continued)
Wake response	V for physical potential plots and metrics; V/m for gradient and dipole plots, means, RMS spreads and CSV. Saved normalized files are converted with the actual source charge.
Material power loss	CSV time is seconds; normalized power is W/pC^2 and cumulative loss is V/pC. The cumulative curve uses a secondary axis. For several sources the file instead contains W and J without charge normalization.
Longitudinal and physical transverse impedance	Ω. No displacement, dipole or quadrupole normalization is applied. Retain the component and displayed unit with the exported data.
Q	Dimensionless; resonance fitting reports loaded Q.

B.3. Terminology

Definitions below are reminders; the references lead to the control or workflow where the term is explained in context.

Item	What it means
Aliasing	Confusion of frequencies above the sampling limit with lower frequencies. Section 12.3.
Artifact	A generated file: for example a mesh, log, wake, or field recording. Chapter 1.
Assembly	Ordered occurrences of reusable longitudinal sections. Section 7.6.
Background material	Material filling domain regions not overridden by included volumes. Chapter 6.
Beta	Beam speed divided by vacuum light speed, $\beta = v/c$. Values below one impose joint method restrictions. Section 8.5.
BRep	Boundary representation: CAD faces, edges, vertices, and their connections. Chapter 5.
Checkpoint	Saved numerical state for a compatible restart, distinct from authored project inputs. Section 10.6.
Conformal treatment	Accounts for material interfaces cutting Cartesian cells. Section 8.3.
Construction geometry	A sketch or feature operand retained for authoring, not an independent simulation region. Chapter 5.
Convergence	Reduction of change in a chosen output under further numerical refinement. Distinct from an iterative solve reaching its stopping criterion. Chapter 3.
Deconvolution	Removal of the known bunch-spectrum weighting from the transformed wake, within the usable band. Section 12.3.
De-embedding	Translation of modal amplitudes between measurement and reporting planes through a uniform guide. Section 8.8.
Direct / indirect integration	Two evaluations of the accumulated wake effect along a witness path. Section 9.2.
Dispersion	Frequency-dependent propagation or response; material dispersion is physical, numerical dispersion is discretisation error. Section 8.3.
DPAPI	Windows Data Protection API; protects local trial state in its Windows account context. Chapter 2.
Explicit / implicit	Updates from known values / coupled solution involving new values. Section 8.3.

Continued on next page

Item	What it means (continued)
FDTD	Finite-difference time-domain approximation of Maxwell's equations on a space/time grid. Section 8.3.
Fourier transform	Resolves a sampled response into frequency components. Section 12.3.
Impedance	Complex frequency-domain response derived from the wake, with a stated transform and normalisation. Section 12.3.
Loaded Q	Measure of resonance persistence including the losses present in the recorded response. Section 12.4.
Lorentz pole	One damped material-resonance contribution, specified by strength, frequency, and damping. Chapter 6.
Loss factor	Negative Gaussian-weighted mean of the longitudinal accelerating wake, in V/pC. Section 12.2.
Mesh Store	Shared, verified mesh storage; reuse is independent of checkpoint compatibility. Section 10.5.
MPI rank / thread	Separate calculation process / worker within a process. Chapter 10.
Nyquist limit	Highest frequency distinguishable on the recorded sampling grid. Section 12.3.
PEC / PMC	Ideal faces with zero tangential electric / magnetic field, respectively. Chapter 7.
PML	Perfectly matched layer: an artificial absorbing region at a computational termination. Chapter 7.
Port / mode	Waveguide cross-section / allowed field pattern used to describe incident and outgoing waves. Section 8.8.
Residual / relative tolerance	Equation mismatch / normalised stopping threshold for an iterative solve. Section 8.6.
RMS bunch length	Standard deviation of longitudinal charge position; Gaussian FWHM is about 2.355σ. Chapter 8.
Run snapshot	Immutable inputs used by one job; later editor changes do not rewrite them. Chapter 10.
S-parameter	Complex outgoing-to-incident modal amplitude ratio for an excited channel. Chapter 12.
Skin depth	Distance over which field amplitude decays to $1/e$ inside a thick conductor. Chapter 6.
Stability / CFL limit	Bounded numerical evolution / a restriction relating explicit step size to cell size. Section 8.4.
STL / prepared STL	Triangle-surface format / a surface generated from CAD for Solver. Neither is a field-volume mesh. Chapter 5.
Tessellation / deflection	Surface triangulation / controls on its geometric deviation and direction change. Section 5.11.
TFSF	Total-field/scattered-field interface separating an imposed incident field from the scattered response. Chapter 8.
TPM	Trusted Platform Module: hardware-backed key protection used by the offline trial. Section 2.5.
Wake potential / wake function	Response for the finite drive bunch / the corresponding point-charge excitation convention. Section 3.1.
Windowing / zero padding	Weighting recorded samples / appending zeros for denser transform bins. Neither adds a computed wake tail. Section 12.3.
Witness trajectory	Test path used to evaluate wake effects, not an additional drive bunch. Chapter 9.

C. Readiness and study record

Use this checklist when handing a case or result to a colleague. Record the comparison runs and any remaining limitations alongside the reported value.

1. **Problem:** physical objective, calculation type and quantity of interest are stated; idealizations and symmetry assumptions are recorded.
2. **Geometry:** source files and units are known; dimensions, topology, inclusion, material assignments, overlaps and computational clipping are checked.
3. **Discretization:** Calculation representation, STL approximation and field mesh are assessed separately; the quantity of interest is stable under justified refinement.
4. **Excitation:** charge, bunch shape/length, position, beta or scattering port excitation match the intended problem and supported method.
5. **Numerics:** boundary, initial-field, mode, time-step and stability requirements are satisfied; duration covers the physical response being analyzed.
6. **Observations:** needed wakes, trajectories, losses and field history were requested before the run; observation and spectral limits are understood.
7. **Execution:** compatible installed versions, license/runtime readiness, resource plan and normal completion are recorded. Restart claims refer to an actually exercised compatible checkpoint, not just an enabled checkbox.
8. **Interpretation:** units, normalization, windowing, component and analysis settings accompany the result; fit diagnostics and reliable band are recorded.
9. **Transfer:** a reproducible project/run bundle is retained, and any shared model or support package has been checked for confidential information.

A compact result note

Record: Studio/Solver versions; case/run identifier; geometry source and units; representation and calculation STL tolerances; material-data source and applicable band; d_x, d_y, d_z; mode/method/time policy; excitation; boundaries; duration/wake length; monitor definition; process layout; analysis options; convergence comparison; known limitations.

Index

aliasing, 85
automatic settings
  time step, 62

background material, 51
backing conditions, 48
beam
  charge, 60
  position, 60
  RMS length, 60
beam self-wake correction, 64
beta, 63
  precision, 63
Boolean operations, 31
boundary conditions, 52

CAD
  display quality, 36
  primitives, 26
calculation type
  conversion, 60
Cartesian rank grid, 73
Case and units, 18
case.yaml, 18
CFL limit, 62
checkpoints, 77
clipping plane, 25
coatings, 48
conductive walls, 47
conductivity
  bulk, 44
  surface model, 47
conformal treatment, 61
contrast
  field, 81
convergence, 15
CSV
  material response, 46
cut view, 25
cutoff frequency, 66

de-embedding, 66
defaults
  new project, 19
  omitted values, 19
dependencies, 97
diagnostics
  startup, 95
dispersion-free, 61
domain
  effective extent, 54
  extent, 51
  fitting, 51
Domain and Boundaries, 51
duration, 62

eigenmode, 86
Excitation Source, 60
Execution, 73
explicit stepping, 61
export
  mesh slice CSV, 58
Extrude, 29

FDTD, 61
Field, 80
field
  definition, 15
field preview, 80
  request settings, 71
Fillet and Chamfer, 31
finite beta
  compatibility, 63
fit interval, 86
Fourier transform, 85
FWHM, 60

Gaussian bunch, 60
Gaussian bunch deconvolution, 85
GdfidL, 5
Geometry, 21
geometry
  automatic preparation, 39
  calculation representation, 22
  display controls, 24
  representations, 21
  transforms and patterns, 32
  visibility and inclusion, 26
glossary, 99

HPC
  job logs, 95

impedance, 85
implicit stepping, 61
import
  project, 5
  STEP and BREP, 33
  STL, 34
inactive settings, 19
initial field, 64
input snapshot, 77
isotropic material, 43
iterations, 64

Jobs, 73
history, 75

keyboard shortcuts, 98
Keychain, 9
kick voltage, 84

licensing, 9
shared storage, 12
linear material, 43
loaded Q, 86
Loft, 31
Lorentz poles, 45
loss factor, 84
loss tangent, 44
loss voltage, 84

material assignment
geometry, 26
Material Mesh, 57
Materials, 43
materials
assignment, 43
dispersion, 45
display colour, 49
drafts, 43
fit verification, 47
library, 49
tabulated response, 46
mesh, 51
coefficient slices, 58
grid alignment, 54
inspection, 57
nearest-node sampling, 69
recommended steps, 53
repair tolerances, 54
repetition, 56
reuse, 77
section templates, 56
spacing, 53
triangle search, 54
Mesh Store, 77
Mesh View, 57
mode
TE and TM, 66
moving window, 61
MPI
ranks and threads, 73
runtime installation, 7
multilayer walls, 48

navigation, 1
numerical dispersion, 61
Nyquist limit, 85

Parallels, 1
passive material, 43
PEC
boundary, 52
material, 44
permeability, 44
permittivity, 44
phase, 85
Physical aspect, 81
PMC
boundary, 52
PML
controls, 55
pole
resonance fit, 86
port, 66
power loss
monitoring, 70
results, 88
Preview frame, 88
probe
material mesh, 58
project
files, 4
opening, 1

quick start, 15

reference plane, 66
relative tolerance, 64
release readiness, 101
Reload Geometry, 40
residual
linear solve, 64
wake reconstruction, 86
resonances, 86
restart, 77
Results, 83
Revert to Saved Case, 40
Revolve, 29
RMS length, 60
RMS spread, 84

S-parameters, 88
Sample aspect, 81
Save Case As, 4
scaled time, 18
scattering
excitation, 67
frequency band, 67
ports and modes, 66
results, 88
setup, 66
screens
materials, 49
screenshots
Geometry view, 24
Section Assembly, 56
Settings
Graphics, 1

sheet resistance, 49
Shell, 31
Sketch, 27
    constraints, 28
    TXT interchange, 29
skin depth, 44
Solver
    advanced controls, 65
    automatic changes, 61
    bundled discovery, 8
    configuration, 60
    connection, 7
    connection button, 7
    manual selection, 8
spectral leakage, 85
stability, 62
study record, 101
support, 95
    cluster jobs, 95
symmetry
    domain fitting, 51
    power-loss factor, 70

tessellation, 36
TFSF, 65
time step
    stability, 62
TPM, 7, 9
transparency, 1
Trash, 75
trial
    activation, 9
    automatically detected, 8
    clock rollback, 11
    expiry, 11
    HPC account, 12
    Linux workstation, 7
    macOS, 9
    shared cluster, 11
troubleshooting, 91
    geometry, 41

units, 98
    changing, 18
    length and charge, 18
    STL interpretation, 34
    time, 18

validation, 91
    errors, warnings and information, 20

wake
    direct integration, 69
    indirect integration, 69
    length, 69
    observation derivative, 90
    offset trajectories, 69
Wake and Outputs, 69
wake function, 15
wake potential, 83
    definition, 15
windowing, 85

zero padding, 85
zero-thickness screens, 37