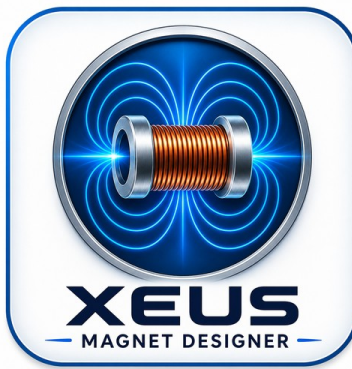




Xeus Magnet Designer User Manual

Version 1.0.15

Barker Magnet and Compensated Solenoid Design Software

Xeus Technologies Ltd.

Operating guide for simulation, parameter studies, optimization, comparison and report generation

About this manual

This manual explains how to use Xeus Magnet Designer v1.0.15 to define, simulate and compare Barker magnets and compensated solenoids. It follows the normal engineering workflow from a first single simulation through parameter sweeps, optimization, candidate comparison and export of a complete results package.

The software is an independently developed Python-based analytical magnetic-field simulation tool. It implements established electromagnetic equations, including the Biot-Savart law, using purpose-built calculation engines for the supported coil geometries. It is not a finite-element modelling package.

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Terminology

Term	Meaning
Bz	Axial component of the magnetic flux density.
Centre field	Calculated Bz at or nearest to $z = 0$.
Homogeneity	Relative peak-to-peak field variation over a selected central span.
ppm	Parts per million; lower magnitude indicates a more uniform field.
C-C	Centre-to-centre spacing between coil locations.
Wire pitch	Centre-to-centre spacing between adjacent turns, including insulation and winding allowance.

1 Installation and startup

1.1 Installing the Windows release

1. Close any earlier version of Xeus Magnet Designer.
2. Run the supplied Xeus Magnet Designer installer and accept the software licence.
3. Choose the installation location offered by the installer.
4. Launch Xeus Magnet Designer from the Start menu or desktop shortcut.

1.2 Starting from the source package

For an engineering or development installation, keep the main program, both GUI modules, both physics engines and the icons folder together. Install Python and the required packages, then run `Xeus_Magnet_Designer_v1_0_15.py`.

Required component	Purpose
Python 3	Runs the application.
PySide6	Qt graphical interface.
NumPy and SciPy	Numerical calculations and scientific constants.
Matplotlib	Plots and PDF graphics.
Pandas	Tabular result handling and export.

1.3 Startup behaviour

- A splash screen appears while the scientific modules and interface load.
- Only one application instance is permitted. A second launch restores the existing window.
- The last selected magnet architecture and appearance theme are restored when possible.

1.4 Default result location

By default, output is stored below `Documents/Xeus Magnet Designer/Results`. Barker and Compensated Solenoid results are separated automatically. Use `File > Choose Results Folder` to select a different root folder.

2 Interface overview

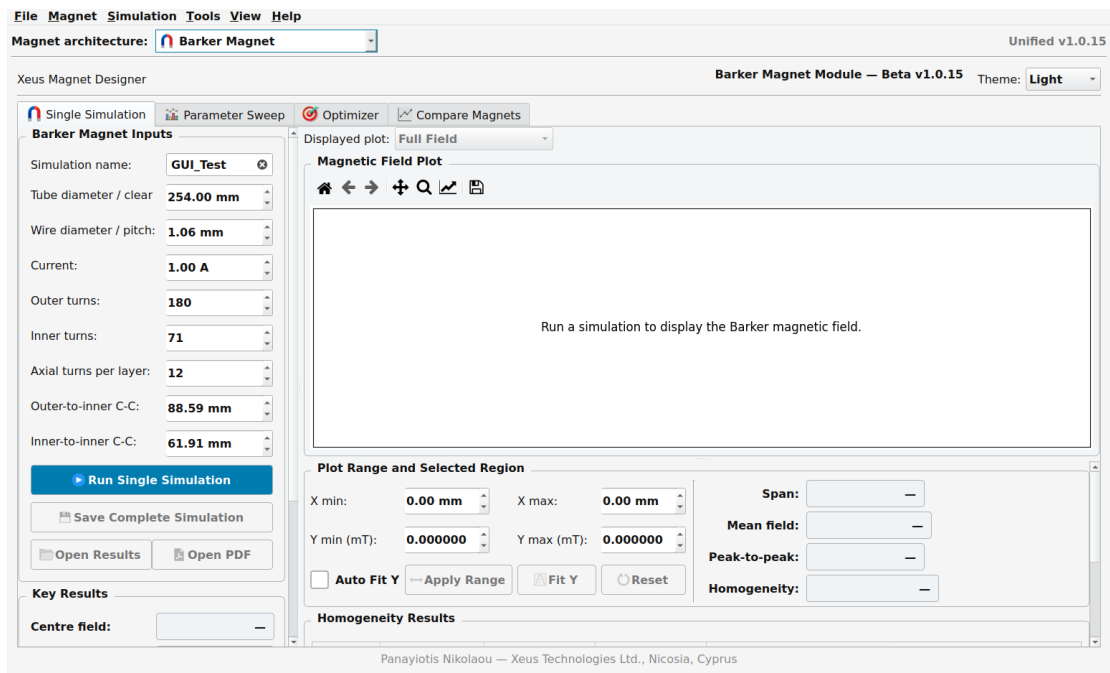


Figure 1. Barker Magnet Single Simulation workspace before calculation.

Area	Purpose
Menu bar	File, magnet selection, simulation workflow, tools, view and help commands.
Magnet architecture	Switches between Barker Magnet and Compensated Solenoid while retaining each module state.
Workflow tabs	Single Simulation, Parameter Sweep, Optimizer and Compare Magnets.
Input panel	Geometry, electrical values, simulation name and run controls.
Plot panel	Magnetic-field plots with pan, zoom, fit and save tools.
Results panels	Field, geometry and homogeneity values calculated by the active engine.
Status area	Reports readiness, progress, completion or validation errors.

2.1 Main menus

- File controls complete-package saving, result folders, PDF opening and exit.
- Magnet switches architecture without discarding the inactive module state.
- Simulation selects a workflow or runs the current calculation.
- View selects the light or dark appearance theme.

3 Quick start

Begin with a single simulation. Once a valid baseline exists, use a sweep to understand sensitivity, the optimizer to search a bounded design space, and Compare Magnets to review a short list of finalists.

5. Select Barker Magnet or Compensated Solenoid.
6. Open Single Simulation.
7. Enter a descriptive simulation name.
8. Enter the physical geometry and operating current.
9. Check wire pitch and winding dimensions against the intended conductor and former.
10. Select Run Single Simulation.
11. Inspect the field plot, centre field and homogeneity table.
12. Use Parameter Sweep or Optimizer only after the baseline design runs successfully.
13. Use Compare Magnets for final side-by-side evaluation.
14. Select Save Complete Simulation to preserve the numerical data, plots and PDF report.

Recommended study sequence

Stage	Question answered
Single Simulation	Does this exact geometry produce a sensible field and fit the intended envelope?
Parameter Sweep	How does one controlled design change affect field and homogeneity?
Optimizer	Which candidates best meet the selected objective and constraints?
Compare Magnets	Which finalist offers the best overall engineering compromise?
Save Complete Simulation	What evidence should be retained or shared?

4 Barker Magnet

The Barker model represents four coaxial circular coils: two inner coils and two outer coils. The calculation engine sums the on-axis contribution from every modelled loop. Layer radius increases with each radial layer, while axial winding length follows the turn count and wire pitch.

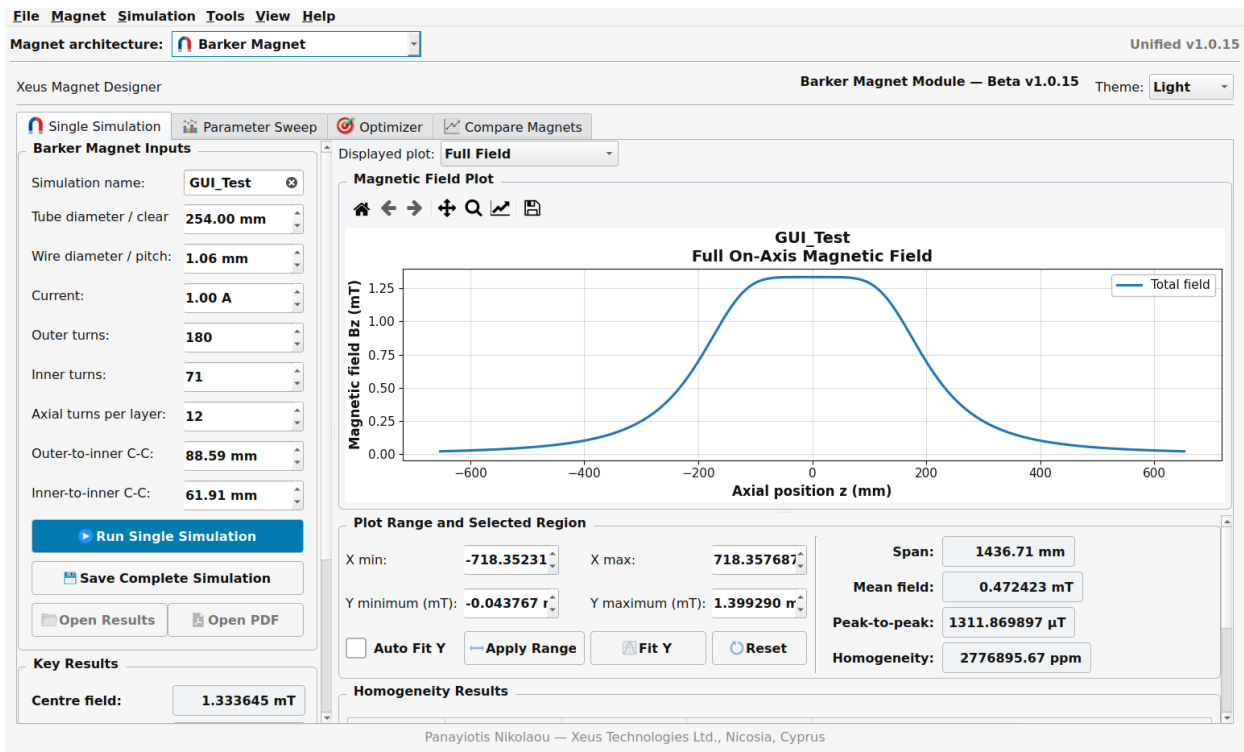


Figure 2. Completed Barker Magnet single simulation using the default demonstration values.

4.1 Primary inputs

Input	Description
Simulation name	Identifier used in plots and saved output.
Tube diameter / clear bore	Clear internal diameter available inside the winding.
Wire diameter / pitch	Axial and radial centre spacing assigned to adjacent turns.
Current	Applied conductor current in amperes.
Outer turns	Total turns assigned to each outer winding.
Inner turns	Total turns assigned to each inner winding.
Axial turns per layer	Turns placed along the axis before moving to the next radial layer.
Outer-to-inner C-C	Centre spacing from each outer coil to its adjacent inner coil.
Inner-to-inner C-C	Centre spacing between the two inner coils.

A numerically valid Barker design may still be difficult to manufacture. Confirm conductor size, insulation, inter-layer clearance, support structure, lead routing and the physical separation between adjacent coils.

5 Compensated Solenoid

The compensated-solenoid architecture combines a main solenoid with compensation windings. The compensation windings reshape the axial field profile and can improve uniformity over the selected central region.

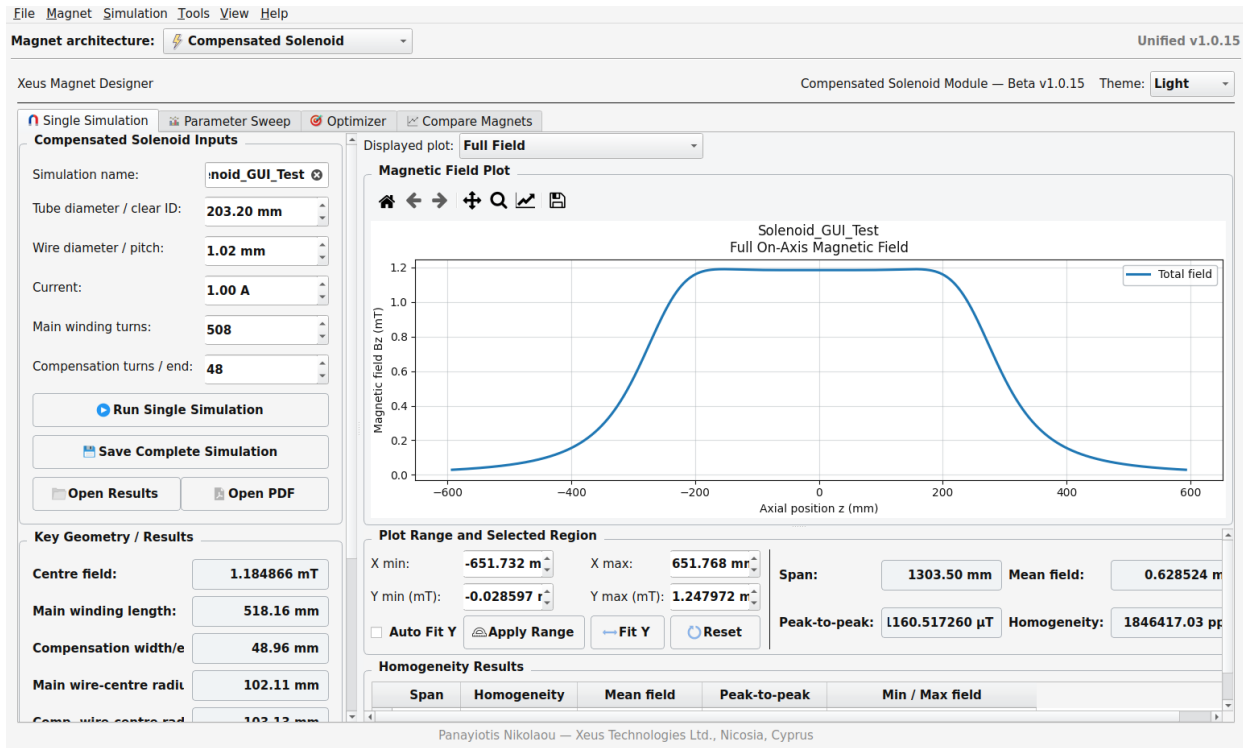


Figure 3. Completed Compensated Solenoid single simulation using the default demonstration values.

5.1 Primary inputs

Input	Description
Simulation name	Identifier used in plots and saved output.
Tube diameter / clear bore	Clear internal diameter inside the winding assembly.
Wire diameter / pitch	Turn-to-turn centre spacing used for geometry.
Current	Applied conductor current.
Main turns	Total turns in the central main winding.
Compensation turns per end	Turns in each compensation winding at the two ends.

5.2 Reported geometry

After calculation, the module reports the main winding length, compensation width, main and compensation wire-centre radii and total conductor turns. Use these values to check the mechanical envelope and winding plan.

6 Single Simulation

Single Simulation is the reference workflow for one defined magnet. It should be used to verify all inputs and establish a baseline before running a larger design study.

6.1 Running a calculation

15. Enter or review every geometry field.
16. Select Run Single Simulation. The button is disabled while the engine calculates.
17. Wait for the completion message in the status area.
18. Review the full-field plot and calculated numerical results.
19. Select another displayed plot when a central-span or winding-contribution view is required.
20. Adjust the exact X and Y plot range if a closer inspection is needed.

6.2 Plot controls

Control	Use
Home	Returns the Matplotlib view to its saved home extent.
Back and Forward	Moves through recent plot views.
Pan	Moves the plot while retaining the current zoom.
Zoom	Selects a region for magnification.
Configure	Adjusts subplot spacing where available.
Save	Exports the visible plot image.
Auto Fit Y	Fits the vertical range to the selected horizontal region.
Apply Range	Applies exact X and Y limits entered below the plot.
Reset	Restores the software-calculated plot limits.

6.3 Validation messages

If the geometry is invalid, the calculation is stopped and the status area identifies the issue. Correct the reported value before continuing. Do not treat the absence of an error as proof that the design is manufacturable.

7 Parameter Sweep

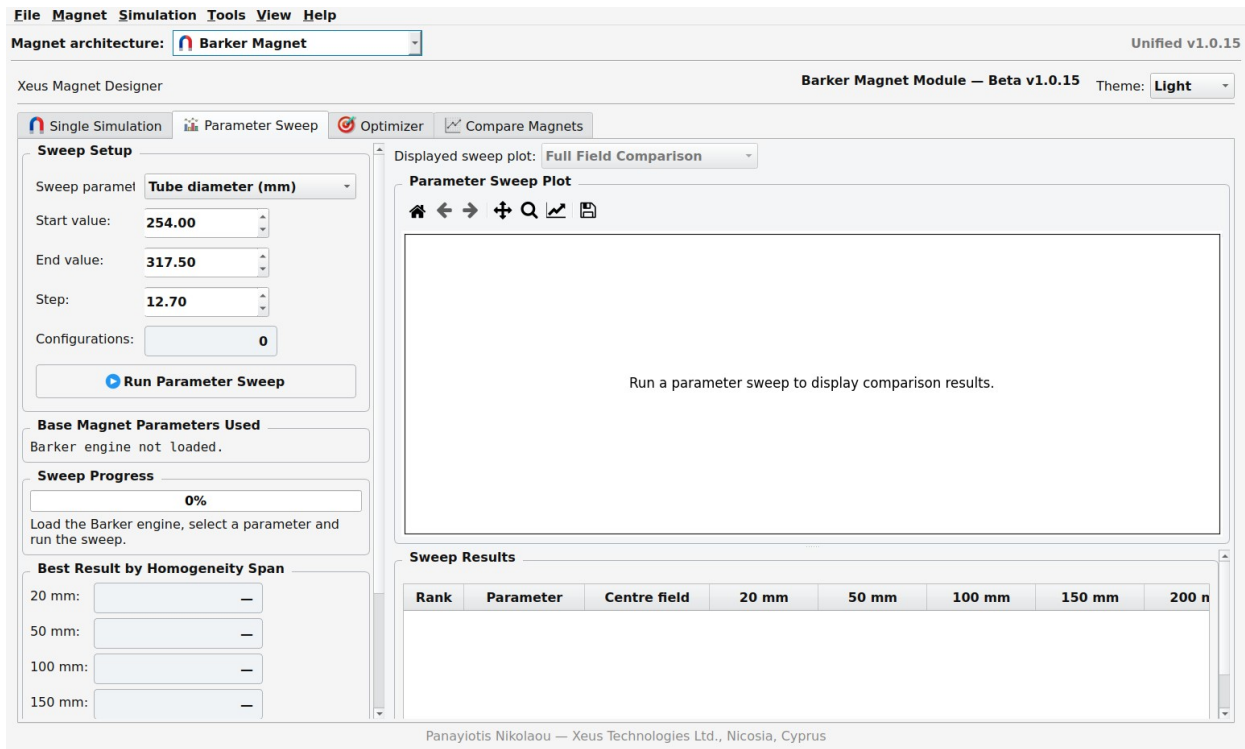


Figure 4. Barker Magnet Parameter Sweep workspace.

Parameter Sweep evaluates a series of related designs over user-defined ranges. It is most useful for identifying sensitivity and locating promising regions of the design space.

21. Select the parameter or parameters to vary.
22. Enter start, end and step values.
23. Review the displayed number of simulations before starting.
24. Run a coarse sweep first.
25. Inspect field, homogeneity and geometry trends.
26. Repeat with a narrower range and finer step around the promising region.

Managing calculation size

The number of combinations grows rapidly when several variables use fine increments. If a sweep becomes unnecessarily large, reduce the number of simultaneous variables, narrow the ranges or increase the step sizes.

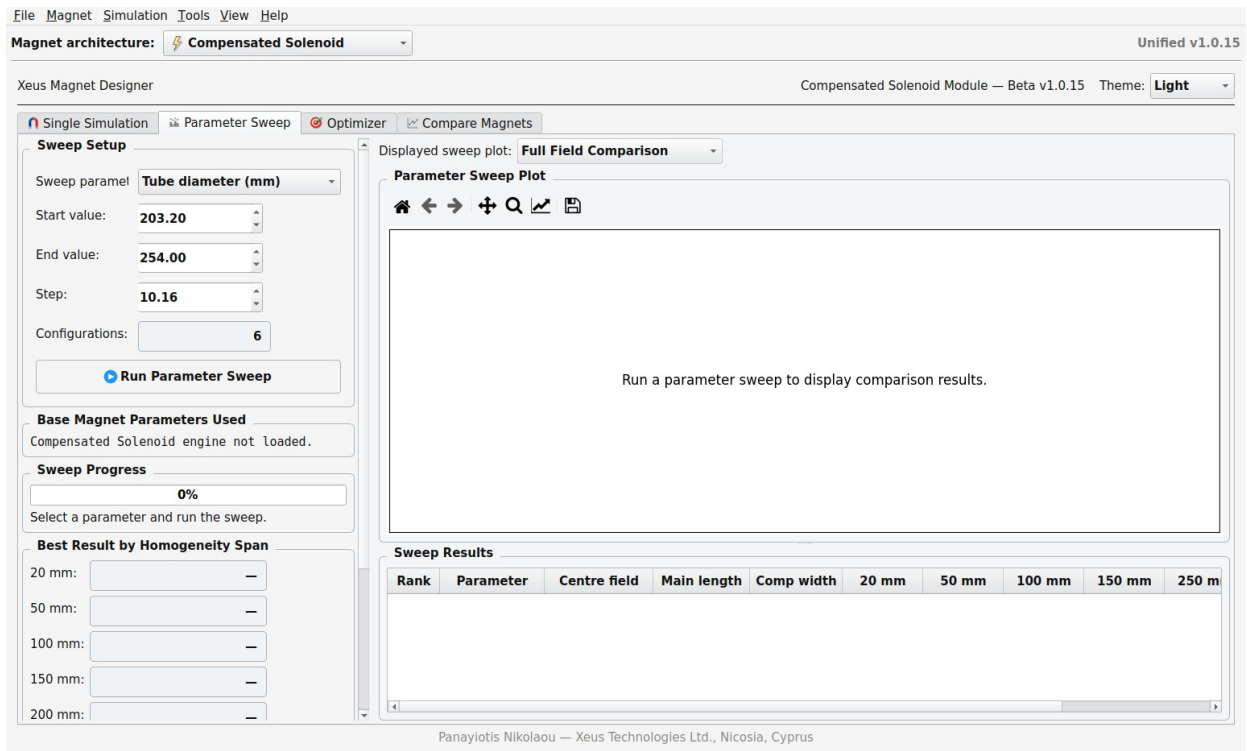


Figure 5. Compensated Solenoid Parameter Sweep workspace.

8 Optimizer

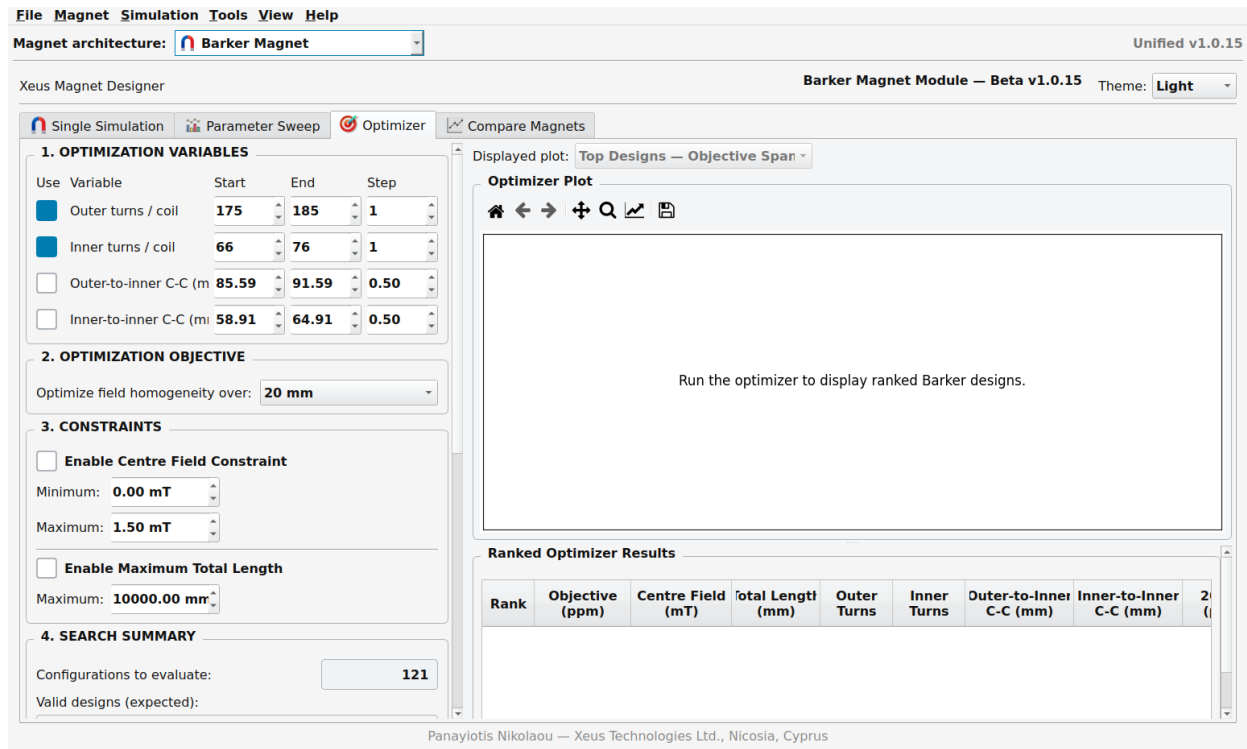


Figure 6. Barker Magnet Optimizer workspace.

The Optimizer searches a bounded design space and ranks candidate geometries. Define realistic ranges and select the field-homogeneity span that matches the actual experimental region of interest.

27. Choose the homogeneity span or objective.
28. Define permissible ranges for the design variables.
29. Apply field, length or geometry constraints where available.
30. Review the estimated candidate count.
31. Run the optimizer and wait for completion.
32. Inspect several leading candidates rather than selecting only the lowest ppm result.
33. Transfer promising candidates to Compare Magnets for final review.

Engineering selection criteria

- Required centre field and available power supply.
- Homogeneity over the required physical span.
- Total winding length and magnet envelope.
- Conductor packing and layer transitions.
- Current density, resistive heating and cooling requirements.
- Mechanical tolerances and alignment sensitivity.

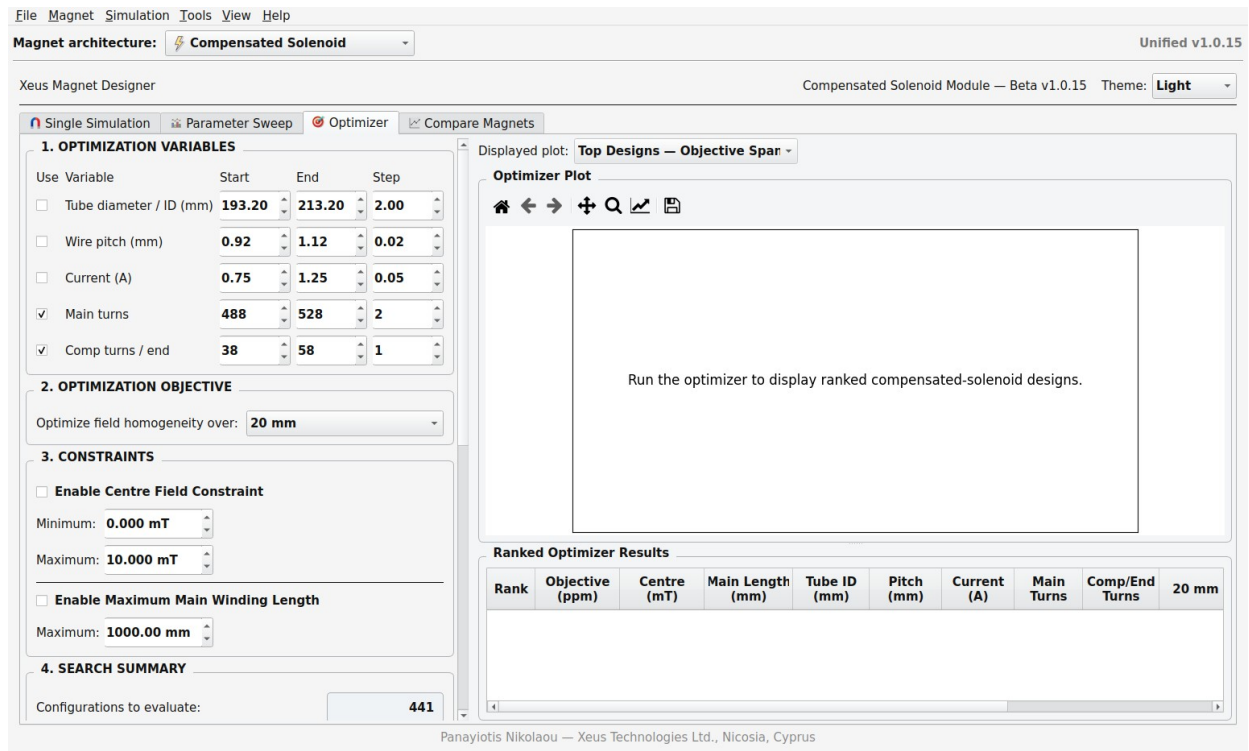


Figure 7. Compensated Solenoid Optimizer workspace.

9 Compare Magnets

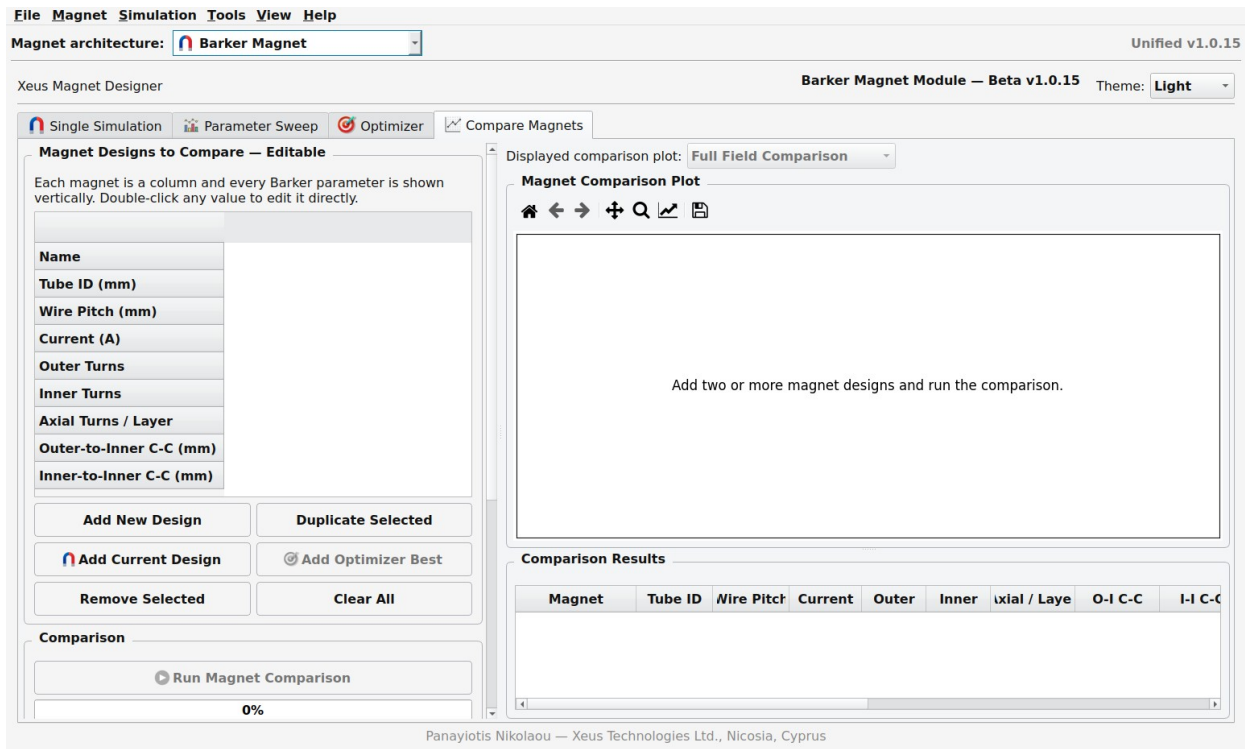


Figure 8. Barker Magnet comparison workspace.

Compare Magnets is intended for a small set of finalist designs. Candidate values can be reviewed side by side so that field strength, uniformity and physical geometry are considered together.

34. Add or load the candidate designs.
35. Confirm that all candidates use compatible units and evaluation spans.
36. Edit a candidate parameter only when the intended comparison requires it.
37. Run or refresh the comparison.
38. Review overlaid field profiles and the comparison table.
39. Select the candidate that offers the best overall engineering compromise.

Do not rank designs solely by the smallest ppm value. A slightly less uniform design may be preferable if it provides adequate field with a practical winding length, lower current or greater tolerance to manufacturing variation.

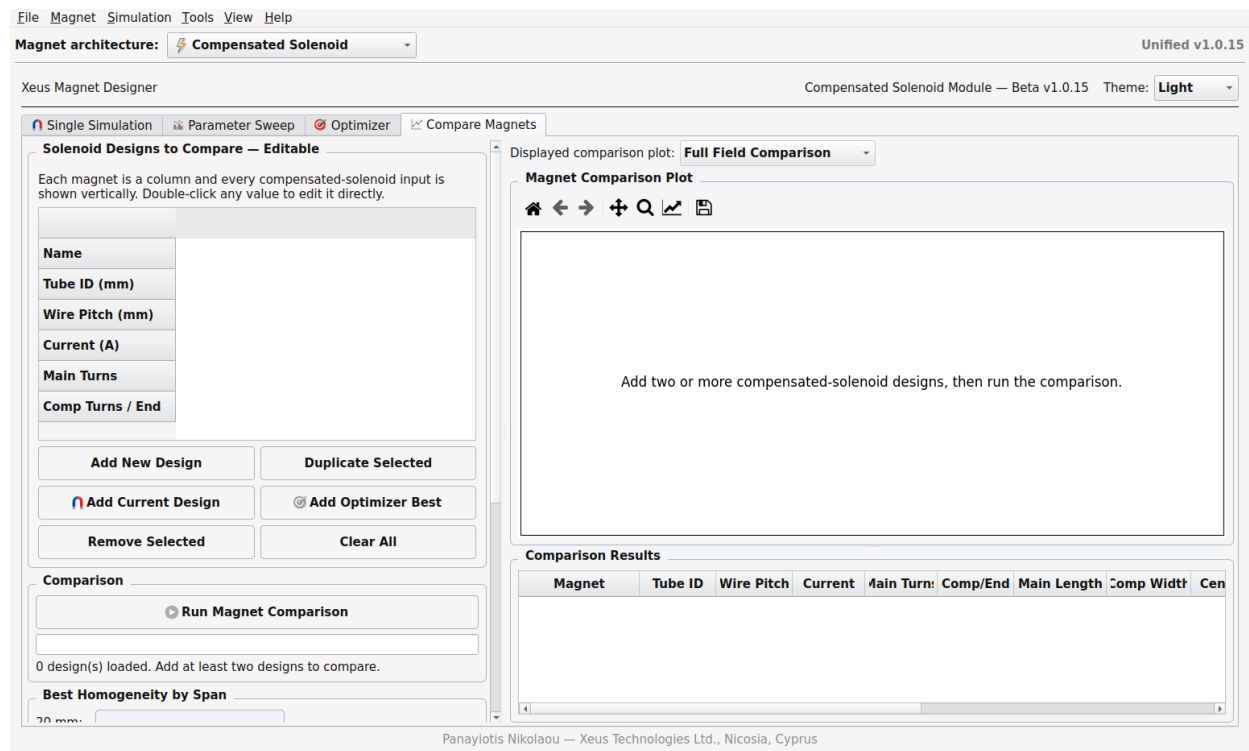


Figure 9. Compensated Solenoid comparison workspace.

10 Interpreting plots and homogeneity

10.1 Field profile

The horizontal axis is axial position z in millimetres. The vertical axis is axial magnetic flux density B_z , normally displayed in millitesla. The centre of the magnet is $z = 0$.

10.2 Homogeneity calculation

For a selected symmetric span, the software determines the minimum, maximum and mean field. Relative peak-to-peak variation is reported in parts per million:

$$\text{Homogeneity ppm} = (\mathbf{B_{max}} - \mathbf{B_{min}}) / |\mathbf{B_{mean}}| \times 1,000,000$$

A smaller absolute ppm value indicates a flatter field over that span. Homogeneity normally worsens as the evaluated span becomes larger, so comparisons must use the same span.

Reported value	Interpretation
Span	Total axial width of the evaluated central region.
Mean field	Average B_z across the selected region.
Peak-to-peak	Difference between maximum and minimum B_z .
Homogeneity ppm	Peak-to-peak variation relative to the mean field.
Minimum / maximum	Field extremes inside the selected region.

10.3 Individual winding contributions

Where available, select Individual Winding Contributions to view the field generated by each winding together with the total. This helps explain how compensation windings reshape the combined profile.

11 Saving results and PDF reports

11.1 Save Complete Simulation

40. Complete a successful simulation.
41. Select Save Complete Simulation from the left panel or File menu.
42. Wait for the modal saving window to finish. The operation runs separately so the interface remains responsive.
43. Use Open Results to inspect the output folder.
44. Use Open PDF to open the combined report when it is available.

11.2 Typical output package

Output	Use
CSV data	Numerical results for independent analysis or archiving.
TXT report	Human-readable summary of inputs and calculated values.
JPEG or PNG plot	Convenient image for presentations or documents.
Vector PDF plot	High-quality scalable field graph.
Combined PDF report	Shareable record combining design inputs, numerical results and plots.

11.3 Good recordkeeping

- Use a unique, descriptive simulation name.
- Retain the input values with every exported result.
- Record software version 1.0.15 in publications and controlled design records.
- Keep experimental field measurements with the matching simulated design.
- Do not overwrite a validated study with exploratory results.

11.4 Suggested publication description

Xeus Magnet Designer is an independently developed, Python-based analytical magnetic-field simulation tool. It implements established electromagnetic equations, including the Biot-Savart law, to calculate the on-axis magnetic-field distribution of supported coil geometries. Numerical calculations use NumPy and SciPy, and Matplotlib is used for graphical visualization. The software uses purpose-built analytical calculation engines rather than an external commercial or finite-element simulation engine.

12 Troubleshooting and limitations

Problem	Recommended action
Application does not start	Confirm that the full installation is present. For source operation, confirm Python, PySide6, NumPy, SciPy, Matplotlib and Pandas are installed.
Calculation reports invalid geometry	Review turn counts, pitch and coil spacing. Confirm that adjacent windings do not overlap.
A homogeneity span is unavailable	Increase the calculated axial range so the full symmetric span is present.
Sweep or optimizer takes too long	Narrow variable ranges, increase step sizes or vary fewer parameters simultaneously.
Saving appears slow	Keep the saving dialog open and allow plot and PDF generation to finish.
Design cannot be wound physically	Recheck conductor dimensions, insulation, pitch, layer count, winding length, spacing and support clearance.
Results differ from measurement	Check actual current, winding placement, mechanical alignment, nearby magnetic materials, thermal effects and probe calibration.

12.1 Model limitations

The software predicts idealized on-axis fields for the implemented coil geometries. It does not automatically model every real-world effect. Manufacturing tolerances, conductor cross-section, winding displacement, current stability, heating, magnetic shielding, nearby ferromagnetic materials and mechanical alignment can change measured performance.

12.2 Engineering disclaimer

Xeus Magnet Designer is a design and evaluation aid. Calculated results should be independently reviewed and experimentally validated before a magnet is used in a safety-critical, clinical, regulated or otherwise critical application.

12.3 Support information to retain

- Software version and magnet architecture.
- Simulation name and complete input values.
- Screenshot or PDF showing the issue.
- Saved CSV and text result files.
- Exact error message and the action that produced it.
- Windows version and installation method.

Appendix A Input review checklist

Check	Confirmed
Simulation name is unique and descriptive	☐
Architecture is correct	☐
Dimensions use millimetres	☐
Current uses amperes	☐
Wire pitch matches the insulated conductor	☐
Coils do not overlap	☐
Required homogeneity span is defined	☐
Power and thermal requirements were reviewed	☐
Mechanical envelope was checked	☐
Final design will be experimentally validated	☐

Appendix B Version identification

This manual applies to Xeus Magnet Designer v1.0.15, the unified Barker Magnet and Compensated Solenoid release. Interface labels or result formats may differ in later versions.