ISBN: 978-3-95450-261-5 ISSN: 2673-7000 doi: 10.18429/JACoW-NAPAC2025-THP096

VISUALIZATION TOOLS FOR EGUN SIMULATIONS

K. Casey*, M. Shumail†
SLAC National Accelerator Laboratory, Menlo Park, CA, USA

Abstract

DC electron guns are essential sources of moderate-energy electron beams for both particle accelerators and klystrons. EGUN is one of the simulation software tools employed to design such DC guns. EGUN produces detailed data of electron ray trajectories for a given gun geometry, cathode temperature, bias-voltage, and beam current — whether space-charge limited or not. We use Mathematica and Python for advanced mathematical processing and visualization of the EGUN data. For example, we generate phase-space plots at various longitudinal cross-sections and show the evolution of phase-space parameters along the beam axis. The visualization we generate is much richer than the simple trajectory plots generated by EPLOT software that accompanies EGUN. In this work, we present an example of a practical klystron gun and the results of our post-processing software.

SLAC ELECTRON TRAJECTORY PROGRAM

The SLAC Electron Trajectory Program, also known as EGUN, was last updated in 1979 [1]. Although the software is old, it is reliable. For those reasons, instead of rewriting new software in a more modern language, we wrote code that will run EGUN without requiring the user to program in FORTRAN.

EGUN has a plotting tool, EPLOT, which mirrors the electron gun geometry along the z-axis, showing the electric field lines and the electron trajectories. All of this information is stored in one of six files, each containing unlabeled sections of data. To simplify data access, we create code that automatically extracts and organizes relevant information.

ELECTRON GUN

To validate the accuracy of our code, we used the geometry of a gun currently used for an experiment involving a small linear accelerator [2]. Without access to the original drawings of the Hermosa Electronics Gun (Fig. 1), we had it profiled using a precision metrology tool. With the dimensions, we could begin to use this gun geometry for simulations.

EGUN accepts only circles and straight lines for geometry calculations, so we converted the metrology data into a series of lines and arcs using Mathematica. This processed geometry was then used in the EGUN input.

* kncasey@usc.edu
† shumail@slac.stanford.edu

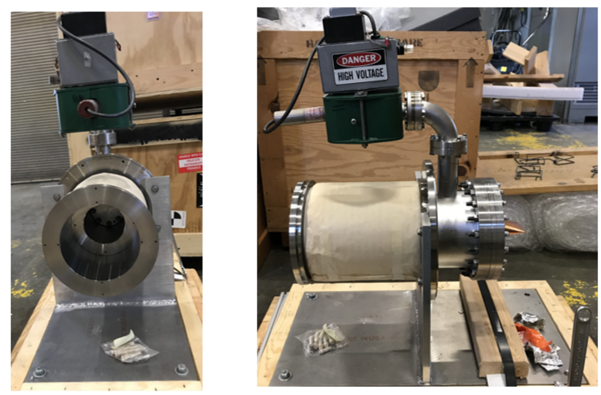

Figure 1: Hermosa Electronics Gun Big, version 7, 3 cm^2 planar cathode.

EGUN vs MATHEMATICA VISUALIZATION

EPLOT outputs the gun geometry, electric field lines, and electron trajectories, with minimal control over display parameters beyond zooming. In contrast, Mathematica allows for fine control of the plotted content, easy export of graphics and data, and automatic labeling of extracted quantities (Fig. 2).

We write functions to extract specific data, enabling quick determination of results such as current saturation without manually combing through files. EGUN also produces data for phase-space parameters at various longitudinal positions, beam size and divergence, and emittance values.

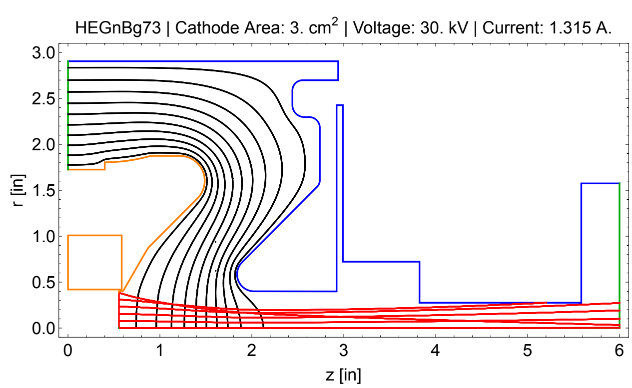

Figure 2: EGUN data of the Hermosa Electronics Gun plotted in Mathematica. The black lines are the electric field, the red lines are the electron trajectory.

ISBN: 978-3-95450-261-5 ISSN: 2673-7000 doi: 10.18429/JACoW-NAPAC2025-THP096

VISUALIZATION TOOLS LEADING TO A GREATER UNDERSTANDING

With modern visualization methods, beam properties such as size, emittance, and energy can be presented in a clear, interpretable form. Visualization tools condense complex data sets, allowing for the identification of issues or noise even without a deep technical background.

Figure 3 is a collection of four graphs. They are made to provide information about the quality of the beam at a given position. The top left is a Transverse Position Distribution graph. This graph tells us if the beam cross-section is uniform or not. It also shows if the beam is well collimated. The bottom left is a Longitudinal Phase Space graph. What we see in this graph is a narrow horizontal energy spread. All electrons have nearly identical energies - monoenergetic. The graphs on the left are of the horizontal and vertical phase spaces. Both indicate that the beam is defocusing.

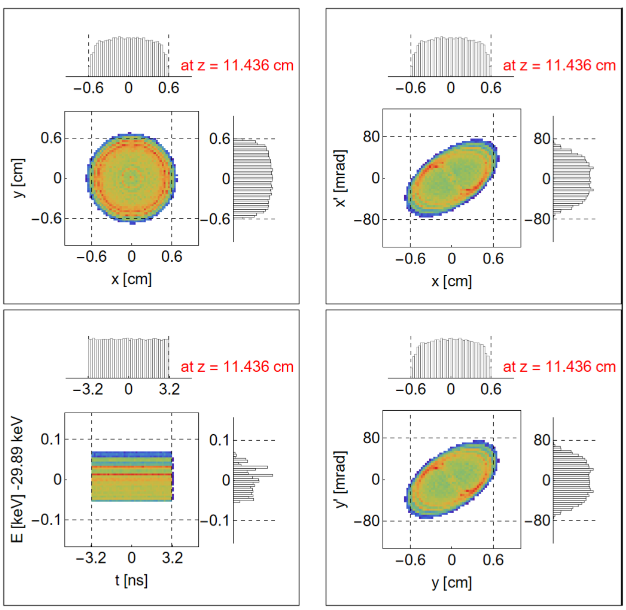

Figure 3: Example beam visualizations at the end of electron gun.

APPLICATION TO SIMULATIONS

An example of this tool being applied is seen in Figure 4. This layout is for a linac that is in the process of being built. Its end goal is waste water treatment. The end of the electron gun in Figure 4 is where the data for Figure 3 is taken from.

FUTURE

In the future, the plan is to write the code in Python and develop an interactive tool that visually displays key parameters—such as beam size, emittance, energy, and position-momentum correlation—directly on the trajectory line plot. This tool will also include tomographic visualizations of phase space at various longitudinal locations, providing deeper insight into the beam's behavior throughout its path.

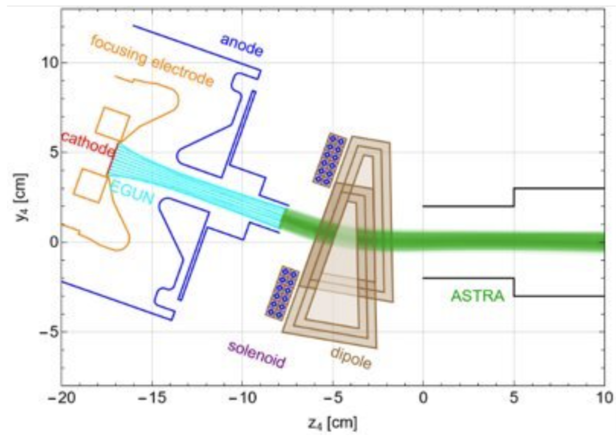

Figure 4: DC Gun simulation for environmental application.

ACKNOWLEDGEMENTS

Science Undergraduate Laboratory Internships (SULI) is supported by the U.S. Department of Energy, Office of Science.

This work is supported by the U.S. Department of Energy, Office of Science, through the Accelerator Stewardship program under FWP 100624.

REFERENCES

[1] W. Herrmannsfeldt, "EGUN-an electron optics and gun design program", SLAC National Accelerator Laboratory, Menlo Park, CA, Rep. SLAC-331, 1988. https://www.slac.stanford.edu/pubs/slacreports/reports10/slac-r-331.pdf

[2] R. Koontz, "CID thermionic gun system", SSLAC National Accelerator Laboratory, Menlo Park, CA, Rep. SLAC-PUB-2824, 1981. https://www.slac.stanford.edu/pubs/slacpubs/2750/slac-pub-2824.pdf