

# G4beamline and Enhanced G4beamline “GUI” (new DOE SBIR proposal)

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Software Mini-Workshop  
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# G4beamline & AllPlot

- G4beamline: open-source, easy-to-use, beamline-oriented wrapper around Geant4
  - incorporates precisely modeled EM fields & precise particle tracking, decays, passage through matter
  - has been downloaded by >1500 unique users over 22 years
- Written  $\approx$  2002 at IIT by Tom Roberts (now at Muons, Inc.)
  - T. J. Roberts and D. M. Kaplan, “G4beamline Simulation Program for Matter-dominated Beamlines,” Proc. PAC07, Albuquerque, NM, paper THPAN103 (2007)
- Now maintained by Muons, Inc.
- AllPlot also provided: simple, easy-to-use plotting program
- Demo(?)

# SBIR Topic Description

## a. Graphical User-Interfaces for Accelerator Modeling

The HEP program supports theoretical and experimental research in elementary particle physics and fundamental accelerator science and technology [1]. Particle accelerator and beamline modeling for both conventional and advanced accelerator concepts has undergone major advances with the advent of the world's first Exascale supercomputer in the US DOE (Frontier at OLCF), GPU-accelerated computing and novel algorithms [2]. Yet, advanced modeling tools could have a significantly wider impact in research and industry if they were accessible via modern, intuitive design-centric interfaces and were able to be coupled easily to control systems in experiments. Addressing these points, applications are sought after that can develop extensible, graphical user interfaces, which can leverage community standards in modeling for simulation control and data [1-3] and control asynchronous particle accelerator modeling workflows on remote computing hardware (edge computing close to experiments, on clusters, cloud, and/or HPC).

#### STATEMENT OF THE PROBLEM OR SITUATION THAT IS BEING ADDRESSED.

Graphical user interfaces (GUIs) are sought to support particle accelerator and beamline modeling for both conventional and advanced accelerator concepts. Downloaded over 1500 times in the last 22 years, G4beamline (available gratis from Muons, Inc.) has been used for diverse applications in science and industry, representing over 50M\$ of economic activity. Its strengths include ease of use compared to its underlying CERN Geant4 package, flexibility in modeling beamline elements (as well as other systems such as particle detectors), and use of the well tested Geant4 libraries to track particles in electromagnetic fields and in matter—of particular importance in simulating muon cooling and muon colliders. Its current GUI interface is however rather rudimentary. A more comprehensive and modern GUI would enhance the program's utility and user appeal, attracting a wider community of users in accelerator science and related fields. Furthermore, the ongoing maintenance of the package relies on the availability of the original developer, Muons, Inc. Sr. Scientist and Vice President Thomas Roberts; a path towards sustainable ongoing support is highly desirable. Finally, the many available accelerator simulation tools each employ their own geometry-descriptor and output protocols, making comparisons challenging.

#### GENERAL STATEMENT OF HOW THIS PROBLEM IS BEING ADDRESSED.

Envisioned enhancements include “drag-and-drop” graphical selection and placement of beamline elements from palettes (with additional provision for fine parameter adjustments). A particular feature needed for development of muon beam cooling and muon colliders is inclusion of the BLAST codes (Beam, Plasma & Accelerator Simulation Toolkit, <https://blast.lbl.gov/>, including WarpX) to model both muon-beam interactions in dense hydrogen-gas absorber and space-charge effects in “vacuum” muon-cooling channels. Another valuable feature would be “hooks” in the GUI interface for additional commonly used simulation programs such as MCNP and MAD-X, easing comparisons among alternative accelerator modeling tools by providing a common geometry description and output format. The envisioned Phase I and II awards will thus put G4beamline on a footing for continued and enhanced productivity in the 21<sup>st</sup> Century.

#### GENERAL STATEMENT OF HOW THIS PROBLEM IS BEING ADDRESSED.

By collaborating with a national laboratory on the proposed GUI enhancement, we can obtain (at Phase II) a commitment for ongoing maintenance of the package as its code base and the platforms on which it is deployed (and their operating systems) evolve in future. This collaboration will also ease inclusion within the enhanced package of WarpX and other commonly used codes maintained at national laboratories.

#### WHAT WILL BE DONE IN PHASE I.

In Phase I we will a) move the source code to a cloud server such as GitHub, b) implement a more capable GUI with beamline-element drag-and-drop, c) containerize distributions to alleviate user installation issues encountered with current and recent versions, and d) implement WarpX capability.

#### COMMERCIAL APPLICATIONS AND OTHER BENEFITS

In Phase II we will implement advanced features, including incorporation of alternative simulation codes, and thoroughly test the resulting enhanced package before making it available for distribution.

KEY WORDS: beam, accelerator, modeling, simulation, GUI, high-performance computing, HPC.

SUMMARY FOR MEMBERS OF CONGRESS:

# Outlook

- G4beamline available (for many years) for free download:

<https://www.muonsinc.com/Website1/G4beamline>

- Also Python-based plotting tool: AllPlot
- Muons, Inc. SBIR proposal submitted Oct. 8
- Partnership with Univ. S. Dakota, Kitware, LBNL
- If funded, anticipate updated, easier-to-use, more-powerful G4beamline (including WarpX collective effects) by Summer 2026