

NSTGRO23 Proposal: Model-Agnostic Monte Carlo Radiation Transport

Duncan Wilkie

31 September 2022

1 Project Narrative

Current Monte Carlo radiation transport simulation technology is showing its age. The user asks: “I’ve got some radiation and some matter it’s going to hit. Can you tell me what will happen?” Existing software, mostly agglomerations of purpose-specific FORTRAN codes that have asymptotically approached generality over the past half-century, can answer this question reasonably well; well enough to design accelerators, reactors, and hardened silicon, and roughly predict risks associated with living things’ exposure to radiation. The user interfaces can be recalcitrant, with many programs recently restructured or wrapped to admit friendlier interaction than an input card format, now accessible from Python or a graphical window. Their physical models’ coverage of the radiation spectrum was often partial, their supported matter types limited, and admissible shapes of both target and source quite specific. These have been rectified as their market expanded, simulating ever-wider ranges of energies, elements, and geometries.

However, only the latter brought very general user control, with tetrahedral, general, and combinatorial geometry description. As underlying models of the radiation-matter interaction grew, each code system became increasingly tied to its chosen models, only modifiable through user-defined Fortran routines for specific edge cases where input cards were deemed insufficient. For most purposes, this is adequate, as they are the purposes for which the models were designed.

Space medical physics, by contrast, sees such large discrepancy between prediction and observation that model-level innovation is likely to be necessary. Current research uses Monte Carlo tools widely, to probe observed discrepancy between animal and human resilience to exposure, for automated design of optimal space-

craft shielding, and to create phantom models for beamline measurements. At the same time, current research attempts to improve mathematical modeling of the radiation interactions, e.g. for thick targets like spacecraft shielding. The former science would benefit from swift integration of the latter’s advancements, but as-is there are few possibilities to do so outside correspondence with the developers.

I propose the development of a model-agnostic transport program core, capable of interfacing with current model code and new model code as the user sees fit. The user will provide programmatic description of the desired geometry and radiation sources, and a selection of models to use under different conditions. The program will mediate between this representation and the representation expected by the underlying models, switching between them as instructed, and returning aggregate results to the user. It should provide a scheme for parallel and distributed computation as well, enabling the use of standard high-performance computing resources. The user ought to be able to use the program as a module in a common, general-purpose programming language in which extensive tooling for data analysis and further computation is available.

Setup and marshaling of user input is a minimal proportion of CPU and developer time in existing codes. As this software

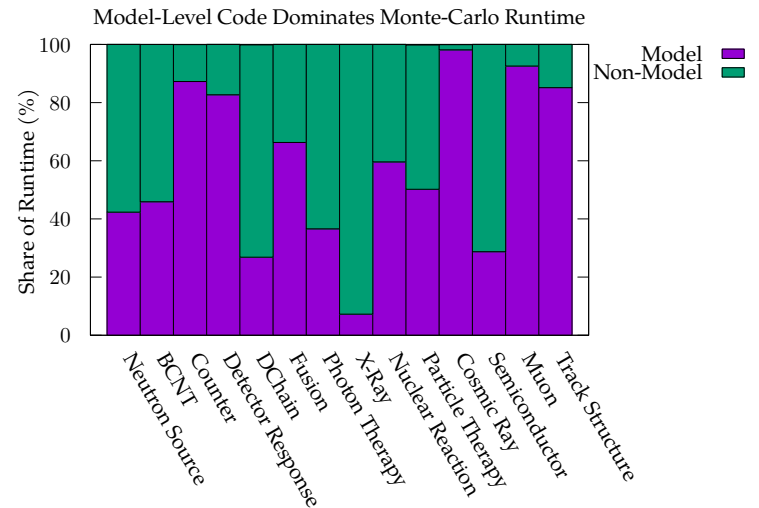


Figure 1: Self-sourced investigation; these are PHITS-provided examples that are all relatively short (<2min runtime). The slight correlation seen (the x -axis is ordered by total runtime) can be expected to shrink, as most non-model code is one-time.