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New physics and old errors: validating the building blocks of major Monte Carlo codes

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A large-scale project is in progress, which validates the basic constituents of the electromagnetic physics models implemented in major Monte Carlo codes (EGS, FLUKA, Geant4, ITS, MCNP, Penelope) against extensive collections of experimental data documented in the literature. These models are responsible for the physics observables and the signal generated in particle detectors, including those originating from the products of hadronic interactions.

Total and differential cross sections, angular distributions and other basic physics features are examined. In addition to currently implemented models, theoretical calculations, semi-empirical models and physics data libraries not yet exploited in Monte Carlo codes are evaluated and compared to those currently in use. The results of this analysis identify and quantify the state of the art achievable in Monte Carlo simulation based on the available body of knowledge.

This validation analysis highlights similarities and differences in the modeling choices adopted by major Monte Carlo codes, and quantitatively documents their accuracy based on rigorous statistical methods. Categorical data analysis techniques are applied to quantify objectively the significance of the differences in compatibility with experiment among the examined Monte Carlo codes.

Duplicated models are identified, not only across different Monte Carlo systems, but also between packages of the same system, and even within the same package. Guidelines for pruning duplicated functionality in Geant4 are discussed.

In parallel to the evaluation of physics accuracy, the computational performance of alternative physics models and calculation approaches is estimated. Quantitative results show that there is no univocal winner between analytical calculations and data library interpolation in terms of computational speed.

The interplay of this validation methodology with epistemic uncertainties embedded in Monte Carlo codes and its applicability also to hadronic physics models are discussed.

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