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Towards energy discretisation for muon scattering tomography in GEANT4 simulations: A discrete probabilistic approach

The emerging applications of cosmic ray muon tomography lead to a significant rise in the utilization of the cosmic particle generators, e.g. CRY, CORSIKA, or CMSCGEN, where the fundamental parameters such as the energy spectrum and the angular distribution about the generated muons are represented in the continuous forms routinely governed implicitly by the probability density functions over the corresponding vast intervals. Despite this perceptible increase in the diversity of the muon generators, the common difficulties in the hands-on applications that might be exemplified as burdensome effort in the code implementation, unnecessarily broad and unmodifiable parametric intervals, extensive execution times, and complications in the particle tracking partly remain steady. In this study, by attempting to eliminate the disadvantageous complexity of the existing particle generators, we present a discrete probabilistic scheme adapted for the discrete energy spectra in the GEANT4 simulations. In our discrete probabilistic approach, we initially compute the discrete probabilities for each discrete energy bin, the number of which is flexible depending on the computational goal, and we solely satisfy the imperative condition that requires the sum of the discrete probabilities to be the unity. Regarding the implementation in the GEANT4 code, we construct a one-dimensional probability grid that consists of sub-cells equaling the number of the energy bin, and each cell represents the discrete probability of each energy bin by fulfilling the unity condition. By uniformly generating random numbers between 0 and 1, we assign the discrete energy in accordance with the associated generated random number that corresponds to a specific cell in the probability grid. This probabilistic methodology does not only permits us to discretize the continuous energy spectra based on the Monte Carlo generators, but it also gives a unique access to utilize the experimental energy spectrum measured at the distinct particle flux values. Thus, we initially perform our simulations by discretizing the muon energy spectrum acquired via the CRY generator over the energy interval between 0.1 and 8 GeV along with the measurements from the BESS spectrometer and we determine the average scattering angle, the root-mean-square of the scattering angle, and the number of the muon absorption by using a series of slabs consisting of aluminum, copper, iron, lead, and uranium. Eventually, we exhibit a computational strategy in the GEANT4 simulations that grants us the ability to verify as well as to modify the energy spectrum depending on the nature of the information source in addition to the exceptional tracking speed.

Significance

The discretized non-linear energy spectra for muon tomography in the GEANT4 simulations have been employed in this submission for the first time.

References

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