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# Application of state quantization-based methods in HEP particle transport simulation

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Simulation of particle-matter interactions in complex geometries is one of the main tasks in high energy physics (HEP) research. Geant4 is the most commonly used tool to accomplish it.

An essential aspect of the task is an accurate and efficient handling of particle transport and crossing volume boundaries within a predefined (3D) geometry.

At the core of the Geant4 simulation toolkit, numerical integration solvers approximate the solution of the underlying differential equations that characterize the trajectories of particles in an electromagnetic field with a prescribed accuracy.

A common feature of Geant4 integration algorithms is their discrete-time nature, where the physics state calculations are essentially performed by slicing time into (possibly adaptive) steps.

In contrast, a different class of numerical methods replace time discretization by state variable quantization, resulting in algorithms of an asynchronous, discrete-event nature. The Quantized State Systems (QSS) family of methods is a canonical example of this category. One salient feature of QSS is a simpler, lightweight detection and handling of discontinuities based on explicit root-finding of polynomial functions.

In this work we present a performance comparison between a QSS-based standalone solver and combinations of standard fixed step 4th order Runge-Kutta (RK4) and adaptive step RK4/5 methods in the context of Geant4.

Our results show that QSS performance scales significantly better in situations with increasing number of volume crossings. Finally, we shall present the status of our work in progress related to embedding QSS within the Geant4 framework itself.

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