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BoGEMMS-HPC: development of Geant4 simulations in High-Performance Computing environments

Geant4 is a C++ toolkit library for the transport of particles through matter and it is commonly used for the simulation of high energy space missions, allowing for the evaluation of their performance and driving the instrument design. The increasing complexity of the new technology involved for the high-energy Universe observation requires the development of modern large-scale simulations and presents new challenges in managing increasingly large datasets, as well as higher demands in storage and computational resources. This evolving landscape drives the implementation of next-generation High-Performance Computing (HPC) techniques and efficient I/O transfers for the Geant4 simulations. We propose the development of an open-source multi-threading (MT) and multi-node Geant4-based simulation framework with ad-hoc I/O interfaces (e.g. run-time input configuration, databases) based on the Bologna Geant4 Multi-Mission Simulator (BoGEMMS), an astronomy-oriented Geant4-based application developed at INAF OAS. The BoGEMMS-HPC framework uses the Geant4 built-in MT library to evenly distribute the simulation events (i.e. primary particles) on different threads, which write the output to a common FITS file or SQLite database. The event-level multi-node parallelism is instead achieved using the (Open MPI) G4MPI library, where the tasks write to independent output files. The performance speed-up has been tested using the CINECA Leonardo resources. Exploiting the 112 cores of a single Leonardo node, we achieved a maximum speed-up (with respect to a serial execution) of about 70 using G4MPI and of about 12 using MT, whose main bottleneck derives from the simultaneous writing from the threads to the same file. We used as a test case the simulation of the Anti-Coincidence System of COSI, a NASA Small Explorer satellite mission with a planned launch in 2027. In this presentation, we show the results on the performance tests, the advantages/bottlenecks between different parallelization strategies and output data formats, and the development plans for the future.

Giorno preferito

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