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Celeritas: Bringing GPU capabilities to detector simulation R&D

The next generation of High Energy Physics experiments have set a new baseline of computational needs in all DOE frontiers. The energy frontier with the main experiments at the future High-Luminosity Large Hadron Collider, the intensity frontier with neutrino and dark matter experiments, and the cosmic frontier with unprecedented amounts of data from new observatories. The Snowmass community effort has defined that efficient use of accelerated hardware (GPUs) is paramount to enable the full potential of these experiments. It also acknowledges the challenges that come with it, as most codes require a full rewrite to be performant. This need was the main driver for the Celeritas Project, a new GPU-optimal particle transport code that has shown high performance gains on multiple High Performance Computing (HPC) systems. On Perlmutter, an example test problem simulating electromagnetic showers executed on an Nvidia A100 has the same performance as 166 AMD EPYC CPU cores, while using around 3 times less electricity. Celeritas is currently capable of simulating electromagnetic showers and is being expanded to incorporate electromagnetic and decay physics for muons, as well as optical photon physics. In order to be easily integrated with existing Geant4 workflows, Celeritas can be executed within a Geant4 application by offloading available particles and physics to GPU and returning hit information back to Geant4. The extensive R&D needed for a muon collider as proposed by the International Muon Collider Collaboration (IMCC) is a case where the use of current and future HPC systems is fundamental. In this scenario, Celeritas is the ideal avenue for leveraging HPC hardware for detector R&D. Therefore, we will present Celeritas' capabilities, performance results, and describe its usefulness in the context of the IMCC objectives.

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