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Parallelized and Vectorized Tracking Using Kalman Filters with CMS Detector Geometry and Events

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The High-Luminosity Large Hadron Collider (HL-LHC) at CERN will be characterized by higher event rate, greater pileup of events, and higher occupancy. Event reconstruction will therefore become far more computationally demanding, and given recent technology trends, the extra processing capacity will need to come from expanding the parallel capabilities in the tracking software. Existing algorithms at the LHC are based on Kalman filter techniques, which have proven themselves to be robust and offer good physics performance. We have therefore developed Kalman-filter-based methods for track finding and fitting that are adapted for many-core SIMD processors, since this type of hardware is increasingly dominant in high-performance systems.

This effort has been underway for some time now, and our software has matured in several important ways. (1) The detector geometry now includes two endcaps as well as the barrel, and tracks can propagate through layers of both types, as well as the transition regions between them. (2) We are therefore able to reconstruct events in realistic detector geometries, including an accurate representation of the CMS-2017 tracker. (3) Hit data can be imported from CMSSW-generated events, including pileup, and is no longer restricted to artificial muon-only simulations. (4) The reconstructed tracks can be validated against either the CMSSW simulation that generated the hits, or the CMSSW reconstruction of the tracks. (5) Groups of track candidates can now be tracked and assessed all the way through the detector using a single, consistent set of vectorizable data structures. In general, the code's computational performance has continued to improve while the above capabilities were being added.

The presentation summarizes the latest features of this software, beginning with the data structures and code constructs that facilitate vectorization, as well as the multiple levels of parallel tracking tasks that have been multithreaded with TBB. We demonstrate that the present Kalman filter implementation is able to reconstruct events with comparable physics performance to CMSSW, while providing generally better computational performance. Further plans for advancing the software are discussed.

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