



Contribution ID: 534 Contribution code: THU 29

Type: Poster

Real-time monitoring of LHCb interaction region with a fast trackless methodology

Thursday 24 October 2024 16:00 (15 minutes)

The increasing computing power and bandwidth of FPGAs opens new possibilities in the field of real-time processing of HEP data. LHCb now uses a cluster-finder FPGA architecture to reconstruct hits in the VELO pixel detector on-the-fly during readout. In addition to its usefulness in accelerating HLT1 reconstruction by providing it with pre-reconstructed data, this system enables further opportunities. Thanks to the triggerless readout architecture of LHCb, these reconstructed hit positions are available for every collision, amounting to a flow of 10^{11} hits per second, that can be exploited further.

We have implemented a set of programmable counters, counting the hit rate at many locations in the detector volume simultaneously on the fly. We use this data to measure, and continuously track, both the motion of the interaction region and the relative position of the detector elements, with precisions of $O(\mu m)$ and time granularity $O(ms)$. To this purpose we use a linearized calculation, based on a principal component analysis (PCA) of these low-level counters, that can be executed online with minimal computational effort. This methodology, being based on just the raw hit positions, differs in a substantial way from methodologies commonly in use, that rely on reconstructing of particle trajectories and their origin vertex, and are therefore computationally much more complex and more prone to biases due to internal detector misalignments. We report results obtained with real data in the 2024 run of LHCb.

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Session Classification: Poster session

Track Classification: Track 2 - Online and real-time computing