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Improved algorithms for determination of particle directions in space with Timepix3

Timepix3 pixel detectors [1] have shown potential to contribute to a variety of fields. In particle tracking, their improved time and energy resolution, (1.56 ns and 2 keV at 60 keV, respectively) permits precise vertex determination and particle identification via stopping power [2]. Following previous studies of their 3D reconstruction capabilities [3,4], the presented work provides a comprehensive comparison of regression methods for estimation of spatial directions from tracks, which are produced by clustering hits recorded in the detector. Developed methodology is evaluated on simulated data, where ground truth information is available (shown in Fig. 1), and later applied to real-world data acquired in test beam campaigns, in the LHC tunnel (shown in Fig. 2), and the Monopole and Exotics Detector at LHC (MoEDAL), CERN [5]. Assessment of the particle dE/dx and the impact angle allows the characterization of the complex radiation field on a track-by-track basis.

The selection of evaluated regressors comprises a broad range of commonly available methods with varying degree of sophistication and runtime complexity. This includes direct trigonometric calculations, methods that exploit per-pixel Time-of-Arrival as well as Time-over-Threshold information and expensive numerical fitters that rely on iterative convex optimization. Due to morphological selection of input clusters, it is possible to investigate advantages of data preprocessing with operators such as skeletonization. Finally, presented approaches are contrasted with cheap surrogate models (e.g. random forests [6]) that were previously trained in supervised scheme.

Evaluated regressors are compared by means of computing resources and accuracy, which is measured as FWHM in two spherical angles (azimuth φ and zenith θ). The best overall resolution in simulated data FWHM(φ) = 1.3° and FWHM(θ) = 1.2° was achieved with random forest regression.

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