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Cluster counting algorithms for particle identification at future colliders

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The large statistical fluctuations in the ionization energy loss high energy physics process by charged particles in gaseous detectors implies that many measurements are needed along the particle track to get a precise mean, and this represent a limit to the particle separation capabilities that should be overcome in the design of future colliders. The cluster counting technique (dN/dx) represents a valid alternative which takes advantage of the Poisson nature of the primary ionization process and offers a more statistically robust method to infer mass information. Simulation studies by using Garfield++ and Geant4 prove that the cluster counting allows to reach a resolution two times better than traditional dE/dx method over a wide momentum range in the use-case of a helium-based drift chamber. It consists in singling out, in ever recorded detector signal, the electron peak structures related to the arrival of the electrons belonging to a single primary ionization act (cluster) on the anode wire. However, the search for hundreds of electron peaks and the cluster recognition in real data-driven waveform signals is extremely challenge because of their superimposition in the time scale. The state-of-the-art open-source algorithms fail in finding the expected number even in low-noise conditions. In this talk, we present cutting-edge algorithms to search for electrons peaks and identify ionization clusters in experimental data using the latest available computing tools and physics knowledge. To validate the algorithms and show the advantages of the cluster counting technique, two beam tests has been performed at CERN/H8 facility collecting data with different helium based gas mixtures at different gas gains and angles between the wire direction and the ionizing tracks using a muon beam ranging from 40 GeV/c to 180 GeV/c on a setup made of different size drift tubes, equipped with different diameter sense wires. We show the data analysis results concerning the ascertainment of the Poisson nature of the cluster counting technique, the establishment of the most efficient cluster counting and electrons clustering algorithms among the various ones proposed, and the definition of the limiting effects for a fully efficient cluster counting, like the cluster dimensions, the space charge density around the sense wire and the dependence of the counting efficiency versus the beam particle impact parameter.

Significance

The most recent test beam in July 2022 gave us the possibility to demonstrate that the number of counted clusters follows the Poisson statistics, as expected, indicating that a particle identification at the 2% level is at reach.

References

https://agenda.infn.it/event/28874/contributions/169554/
https://agenda.infn.it/event/22092/contributions/166630/

Experiment context, if any

The beam tests were performed on drift tubes which could be the elementary units of the IDEA drift chamber. The IDEA (Innovative Detector for an Electron-positron Accelerator) general-purpose detector concept has

been designed to study electron-positron collisions in a wide energy range provided by a very large circular leptonic collider.

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