Particle identification with the cluster counting technique for the IDEA drift chamber
(Innovative Detector for an Electron-positron Accelerator)

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The IDEA 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 [1,2].

Drift chamber

It is supposed to provide an efficient tracking, a high precision momentum measurement and an excellent particle identification (PID) by exploiting the application of the cluster counting (CC) technique [3]. The effectiveness of the CC algorithms' usage for PID has been demonstrated by theoretical results.

Cluster Counting and PID expected performance

Using the information about energy deposit by a track in a gaseous detector, PID can be performed. The large and intrinsic uncertainties in the total energy deposition represent a limit to the particle separation capabilities. Cluster counting (CC) technique can improve the particle separation capabilities. The method consists in singling out, in ever recorded detector signal, the isolated structures related to the arrival on the anode wire of the electrons belonging to a single primary ionization act (dN/dx).

1 Analytical calculations

Starting from detailed studies of Garfield++ simulations results about the ionization process in Helium-based gas mixtures, an algorithm which reproduces the cluster size and cluster distribution using the energy deposit information by Geant4 has been developed under the assumption of a 100% cluster counting efficiency [4]. dN/dx improves particle separation capabilities of a factor of 2.

2 Full simulation results

A simulation of the ionization process in 200 drift cells, 1 cm wide, in 90% He and 10% IC4H10 gas mixture has then been performed both in Garfield++ and in Garfield-modelled Geant4.

3 Conclusions

Garfield++ in consistent with analytical calculations, up to 5 GeV momentum, then falls much more rapidly at higher momenta.

Further advantages of Helium

Low primary ionization density implies a large time separation

- $\Delta t = 800 \mu$m in 90% He, or 30 ns
- low drift velocity means larger time separation ($\Delta t_{H} = 2.5$ cm/$\mu$s)
- low average cluster size $<N_{e}\text{cluster}/\text{cluster}> = 1.6$
- simple electron diffusion ($<110 \mu$m for 0.5 cm drift, or <4.5 ns)

Cluster counting algorithms applied to H8 CERN test beam data

A beam test has been performed during November 2021 at CERN on the H8 line in a parasitic mode to validate the simulations results by using a muon beam.

References

- Garfield++ is a simulation for track reconstruction, developed by CERN, European Organization for Nuclear Research.
- Geant4 is a Monte Carlo simulation software for a wide variety of applications, developed by CERN, European Organization for Nuclear Research.
- Particle Identification by Cluster Counting: A Simulation Study, H8 Test Beam, INFN, CNCS, European Organization for Nuclear Research.
- High Precision Momentum Measurement in a Large Circular Leptonic Collider, INFN, CNCS, European Organization for Nuclear Research.