Contribution ID: **209** Type: **Poster**

P1.39: Design and optimization of a MPGD-based HCAL for a future experiment at Muon Collider

Monday, 26 June 2023 15:29 (1 minute)

In the context of the European strategy for particle physics, a multi-Tev Muon Collider has been proposed as an interesting alternative to investigate the Standard Model with unprecedented precision after the full exploitation of the High-Luminosity LHC.
Some of the physics goals of the Muon Collider include precision measurements of the Higgs boson couplings (requiring excellent Z/H separation) and search for new physics at TeV scale. This demands accurate full event reconstruction, namely the identification and the four-momentum estimation of electrons, photons, muons, neutral and charged hadrons, as well as the clustering in jets. The most suited approach to accomplish this task is the Particle Flow (PF) algorithm, where the information of tracking, calorimeter and muon detectors are combined for particle identification and measurement of momenta/energies: the measurements of the charged particle momenta is performed in the tracking detectors, while the energy measurements for photons and neutral hadrons are obtained from the calorimeters. Therefore, the crucial step in PF, i.e. the correct assignment of the calorimeter hits to the reconstructed particles, requires a combination of an excellent tracking system with high granularity calorimeters.
At a Muon Collider, the PFA is complicated by the Beam Induced Background (BIB), that is due to the decays of the muons of the beam. It represents one of the major challenges for the experiment design and poses potential limitations on the detector performance and requirements on radiation hardness. The discrimination of signal showers from the BIB requires high granularity, superb energy resolution and precise timing. The calorimeter should thus provide 5D measurement (3D position, time and energy).
The hadron calorimeter (HCAL) that we propose in this contribution consists of a sampling of absorber and Micro Pattern Gas Detectors (MPGD) as active layer, for digital and semi-digital readout.
MPGDs represent the ideal technology, featuring high rate capability (up to 10 MHz/cmˆ2), flexible spatial and good time resolution (few ns), good response uniformity (30%); they use eco-friendly gas mixtures and have modest cost for large area instrumentation. Furthermore, gaseous detectors have the advantage of being radiation hard and allow for high granularity (1x1 cmˆ2 cell size).
Dedicated studies are needed to assess and optimize the performance, as well as the development of medium scale prototypes for performance measurements. In particular, the response of HCAL to the incoming particles is studied and presented in this contribution with Monte Carlo simulations performed using Geant4. The implementation of the HCAL geometry in Geant4 starts with a simplified model of Argon and Iron sampling with 1x1 mˆ2 transversal size with 1x1 cm2 segmentation, ˜10 nuclear radiation lengths (☒) of longitudinal size. The response to pion beams is studied over an energy range of 1-100 GeV, comparing the performance of a digital and semi-digital readout, taking the energy resolution as a figure of merit. Besides, the same geometry has been implemented in the Muon Collider software to study the impact on the jet reconstruction in the context of the full apparatus and in presence of the BIB. Besides, a small size calorimeter cell is currently under preparation. It will be instrumented with the most advanced resistive MPGD technologies, resistive μ-RWELL and resistive Micromegas detectors, which demonstrate excellent performance for spatial resolution, operational stability (discharge quenching) and detector uniformity. The prototype will have 6-8 layers (˜ 1 ☒) of alternating 2 cm of absorber and MPGD detectors and will be tested in test beam with pions of energy ranging between 1 to 10 GeV. A preliminary test on the detectors alone will be performed with MIPs at CERN SPS in order to measure the efficiency, cluster size, hit multiplicity, spatial and time resolution. Some preliminary results obtained from the performance measurements on the detectors will be shown.

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Session Classification: Poster (incl. coffee)