Design and optimization of a MPGD-based HCAL for a future experiment at Muon Collider

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In the context of the European strategy for particle physics, a multi-Tev Muon Collider [1] has been proposed as an interesting alternative 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 and search for new physics at TeV scale. This demands accurate full event reconstruction, for which one of the most suited approaches is the Particle Flow (PF) algorithm [2], where the information of tracking, calorimeter and muon detectors are combined. 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) [3], that is due to the decays of the muons of the beam ($\mu \rightarrow e\, \boldsymbol{\nu}_{\mu}\, \boldsymbol{\nu}_{e}$) and that represents one of the major challenges for the experiment design. In this context, the calorimeter should provide 5D measurements (3D position, time and energy), that translate in high granularity, superb energy resolution and precise timing to allow for the discrimination of signal showers from the BIB.
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/cm2), 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 are radiation hard and allow for high granularity (1x1 cm^2 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 with Monte Carlo simulations performed using Geant4 [4], where the calorimeter is described as a sampling of Argon and Iron, with 1x1 m^2 transversal size with 1x1 cm^2 segmentation, ~10 nuclear radiation lengths ($\boldsymbol{\lambda}$) 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. The same geometry has also been implemented in the Muon Collider software to study the impact on jet reconstruction in the context of the full apparatus and in presence of the BIB. Besides, a small calorimeter cell is currently under preparation. It will be instrumented with the most advanced resistive MPGD technologies, resistive μ-RWELL [5-6] and resistive Micromegas [7-8] detectors. The prototype will have 6-8 layers (~ 1 $\boldsymbol{\lambda}$) of alternating stain-less steel 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 to measure the efficiency, cluster size, hit multiplicity, spatial and time resolution.

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