Micro-Pattern Gas Detectors for Calorimetry

J. Yu (UTA), M. Hohlmann (Florida Inst. of Tech.), V. Polychronakos (BNL) and A. White

Physics Driver: All physics requiring precision energy measurements and triggering in future high-energy lepton colliders (ILC, CLIC, muon collider, etc).

Time Frame: Long

Physics Justification: Precise determination of the properties of the Higgs and any other newly discovered particles at the LHC require unprecedented jet energy resolution of 3%$\Delta E/\sqrt{E}$ so that the invariant masses of W and Z particle in their two jet final states can be distinguished. A good technique for meeting this requirement is the particle flow algorithm (PFA) which utilizes the momentum measured in the tracking system to replace the charged particle energy deposit in the calorimeter. The calorimeter measures the energy deposit from the neutral hadrons and any electromagnetic particles resulting from secondary interactions. PFA is already in use in the CMS experiment to improve the experiment's jet energy resolution.

Technical Requirements: An important technical requirement for a successful PFA is the ability to match and subtract the charged particle energy deposit and to minimize confusion. A PFA requires a fine-granularity calorimeter for tracking individual shower particles. The calorimeter cell size must be optimized to meet this requirement. Micro-pattern gas detectors (MPGDs) are a promising candidate technology for such a tracking and imaging calorimeter. Economic construction of large-area MPGD detectors, low-cost electronic readout, highest tolerance against radiation damage, high-rate capability of $\mathcal{O}(100\ \mathrm{MHz/cm^2})$ are some of the technical requirements. Suitable low-cost readout electronics are necessary to accommodate the large number of channels.

Current Technical Capabilities: A prototype RPC based calorimeter with one-bit digital readout electronics system was constructed and has demonstrated feasibility of an imaging calorimeter. Tracking detectors based on MPGD's such as Gas Electron Multipliers and Micromegas are operating with good stability in current experiments at particle rates up to 12 $\mathrm{MHz/cm^2}$ (TOTEM). Single-hit efficiencies of typically 98% or better have been seen in current experiments and various beam test experiments. Best track position resolution and timing resolution achieved are on the order of 50 μm (COMPASS) and 3-4 ns (LHCb). The flexibility of MPGD's allows various shapes of detectors. MPGD's can be made thin, typically 1 cm or less. Anode patterns take many forms from simple micro-strips to complex two-dimensional patterns. Advanced MPGDs are now reaching sizes of 1-2m length at the prototype level (ATLAS and CMS). On-board electronics for rapid pre-amplification are being developed.

Key R&D Directions:
- Optimal structures and sizes of the readout anode for precisely matching tracks to energy deposition
- Cost effective on-board readout electronics and number of readout digitization bits
- Innovative signal induction structures to reduce readout cost and to improve performance
- Structures with resistive layers (e.g. Thick-GEM or Glass GEM) for discharge control

- Integration of flex-circuit readout electronics directly into the MPGD structure
- Detector structures that minimize dead area
- Development of large-scale MPGD base material (GEM foils and Micromegas) construction techniques for (industrial) mass production
- Development of an industry base with MPGD mass production capabilities within the US