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Abstract

Three Gas-Electron-Multiplier tracking detectors with an active area of 10 cm × 10 cm and a two-dimensional, laser-etched orthogonal strip readout have been tested extensively in particle beams at the Meson Test Beam Facility at Fermilab. These detectors used GEM foils produced by Tech-Etch, Inc. They showed an efficiency in excess of 95% and spatial resolution better than 70 μm. The influence of the angle of incidence of particles on efficiency and spatial resolution was studied in detail.

Keywords: Tracking detectors, GEM, Micro-pattern Gas Detectors
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1. Introduction

Micro-pattern gas detectors have proven to be versatile devices for high resolution particle tracking. One of the most successful micro-pattern technologies is the Gas Electron Multiplier (GEM), introduced in 1996 at CERN [1]. The GEM is a thin metal-clad insulator foil that is chemically perforated with a large number of small holes. Voltage applied across the foil generates strong electric fields in the holes, which leads to avalanche multiplication of electrons. Since the electron amplification occurs in the holes of the GEM foil and is separated from charge collection structures, the choice of readout geometries for detectors based on the GEM is very flexible. For tracking applications several GEM foils are cascaded to reach higher gain and high operating stability. Spatial resolutions of better than 70 μm have been demonstrated with triple GEM detectors [2], with a material budget of significantly less than 1% of a radiation length (X_0) per tracking layer (providing a 2D space point).

To meet the increasing demand for GEM foils for research applications the establishment of commercial producers is desirable. A collaboration with Tech-Etch, Inc., based on an approved SBIR[1] proposal, has been formulated to provide a commercial source for GEM foils and to study the production of large area foils. GEMs produced by Tech-Etch, Inc. have been evaluated in detail both with optical methods and in test detectors to study geometrical uniformity as well as gain performance [3].

One application for the GEM foils produced by TechEtch, Inc. is the Forward GEM Tracker (FGT) [4] of the STAR Experiment [5] at the Relativistic Heavy Ion Collider (RHIC). This approved upgrade will provide high-precision tracking at forward rapidity, covering the acceptance of the STAR endcap electromagnetic calorimeter (EEMC) [6]. With this upgrade, the charge sign of high transverse momentum electrons and positrons from W decays can be identified, which is crucial for the study of flavor-separated polarized quark distributions in the proton. To achieve this, a multi-layer low mass tracker with ~80 μm spatial resolution or better is needed, making GEM detectors a good choice for this upgrade.

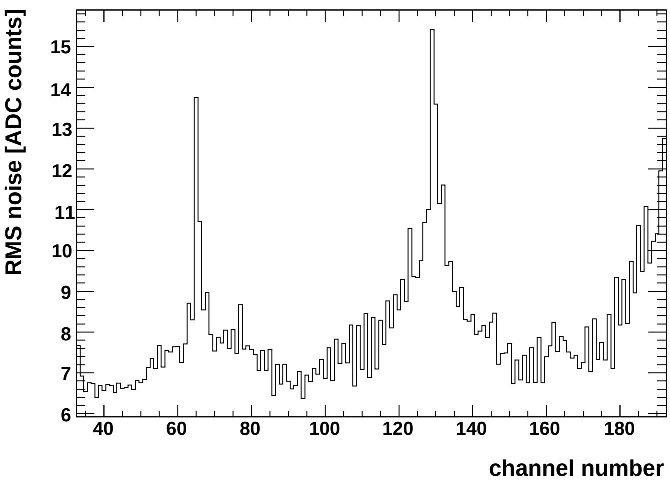

Figure 1: Channel by channel noise distribution for the horizontal coordinate of the first detector. The first 32 channels are not connected, and not shown in the histogram. As only every other input channel is connected, the borders between chips are located at channel numbers 64, 65, 128, 129 and 192. These regions show elevated noise levels.

2. Data Reconstruction and Analysis

The Fermilab main injector was delivering beam to the test beam area for a four second spill once per minute, with typically

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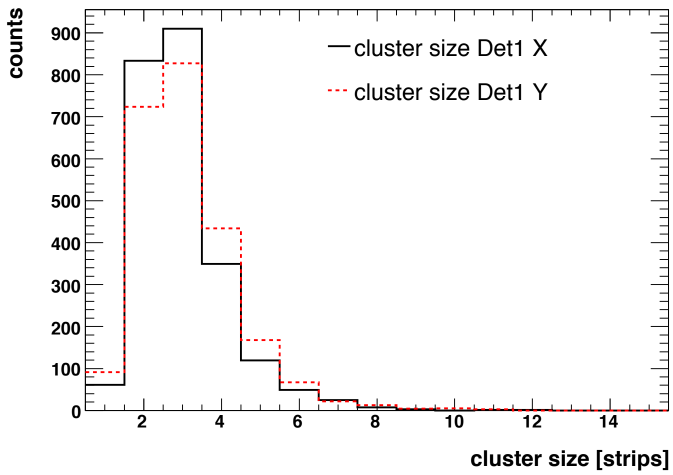

Figure 2: The size of reconstructed clusters in strips (635 μm strip pitch) for both readout coordinates of the central detector.

a few thousand particles per spill. For an intensity scan this was increased by about two orders of magnitude at the end of the test beam campaign, as discussed later. Data were taken in runs of around 10 000 to 20 000 events, at event rates of a few hundred to a thousand per spill. The data taking rate was limited by the readout time of the system.

Since the strip occupancy in the test beam was very low, on the order of 1% to 3%, the data events themselves were used to determine the channel pedestals on a run-by-run basis. The channel by channel pedestals and noise were determined from Gaussian fits to the distribution of the channel amplitudes after common mode noise subtraction. Figure 1 shows the distribution of the channel-by-channel noise for one detector projection. Typical noise levels were between 7 and 12 ADC counts, corresponding to an equivalent noise charge ranging from approximately 1 250 to 2 200 electrons. This relatively high noise level was due to the imperfect grounding and shielding of the electronics and readout system. In particular the regions at the chip borders show elevated noise levels.

Figure 2 shows the cluster size in the middle detector in the tracking setup for clusters on tracks defined by the other two detectors. The most likely cluster size is between 2 and 3 strips on both coordinates, with a few percent of all found clusters being only one strip wide. This shows that a smaller strip pitch is desirable to obtain an optimal efficiency and the best possible spatial resolution.

2.1. Higher Rate Running

At the end of the test beam period, the beam intensity was maximized to study the behavior of the GEM detectors when exposed to intense radiation. For this study the 120 GeV primary proton beam was used with the highest intensity permissible by the radiation safety limits in the test beam area. Data were taken with up to $\sim 1.6 \cdot 10^5$ protons within 4s spills corresponding to 40 kHz peak rate. With the size of the beam spot and the Gaussian profile discussed above, this corresponds to an intensity of a few kHz/mm^2 in the center of the beam spot. The time substructure of the spill was in bunches such that the peak intensities were probably considerably higher over very short periods, which is however not exactly known. The efficiency and the spatial resolution of the detectors measured at the highest intensities agree with the low intensity results within the measurement errors. The higher beam intensity thus led to no observable effects on the detector performance, and also did not induce any instabilities in the operation of the detectors.

3. Conclusion

Three test detectors using commercially produced GEM foils by Tech-Etch and a laser-etched two dimensional readout board produced by Compunetics have been tested extensively in a beam at Fermilab. The detectors showed stable performance during two weeks of beam operations. An efficiency in excess of 95% and a spatial resolution better than 70 μm was achieved, with a resolution of $\sim$ 50 μm for the majority of tracks. Two different versions of a laser-etched 2D orthogonal strip readout board were tested, giving important information on the charge sharing between readout coordinates depending on the board geometry. The detectors performed without problems at particle rates up to a few kHz/mm^2. Overall, the results of the beam test demonstrate that devices using commercially produced GEM foils from Tech-Etch and a laser-eched 2D readout achieve performance parameters comparable to those of triple-GEM detectors currently in operation in high energy physics experiments.

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