Triple-GEM Detectors for the Forward Tracker in STAR

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***Abstract*— The study of flavor-separated polarized quark distributions in the proton is one of the cornerstone measurements of the RHIC-Spin program with polarized proton collisions at $\sqrt{s}$ = 500 GeV. This measurement requires the detection of W bosons through their electron (positron) decay mode. The identification of the charge of the outgoing lepton at forward rapidity is crucial for this measurement since this provides information on the flavor of the quarks in the initial hard collision. This requires an upgrade of the forward tracking system of the STAR detector. A design based on six large area triple-GEM disks using GEM foils produced by Tech-Etch Inc. has emerged as a cost-effective solution. We report first results from a beam test of three test detectors using Tech-Etch produced GEM foils and a laser etched two dimensional strip readout. Current results from optical quality tests of Tech-Etch foils will also be presented and the current status of the design of the STAR Forward GEM Tracker will be reviewed.**

I. Introduction

The upgrade of the forward tracker of the STAR experiment [1] at the Relativistic Heavy Ion Collider is a crucial part to achieve the goals of the RHIC Spin program. In order to identify the charge sign of electrons produced from the decay of W bosons at forward rapidity a multi-layer low mass tracker with $\sim$80 μm spatial resolution or better is needed. Triple-GEM tracking detectors satisfy the requirements for tracking in the forward region in STAR and provide a cost-effective solution. GEM detectors are based on electron avalanche multiplication in strong electric fields created in holes etched in thin metal clad insulator foils. This concept, introduced in 1996, is referred to as the Gas Electron Multiplier (GEM) [2]. Since the electron amplification occurs in the holes in 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 [3], with a material budget of significantly less than 1% X_0 per tracking layer (providing a 2D space point).

II. The STAR Forward GEM Tracker

The baseline design of the Forward GEM Tracker FGT consists of 6 triple GEM disks along the beam direction, covering the acceptance of the endcap electromagnetic calorimeter

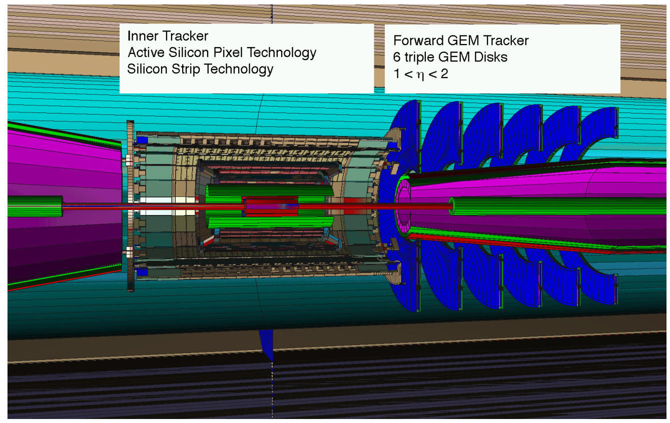

Fig. 1. Sketch of the STAR tracking upgrade. The Forward GEM Tracker with its 6 triple-GEM disks is shown as well as the planned inner silicon tracker, consisting of active silicon pixel sensors and silicon strip detectors.

[4] for $1 < \eta < 2$ over the full extend of the interaction diamond in the experiment. The GEM disks have an outer radius of 43 cm, and an inner radius between 12 cm and 25 cm, depending on the position of the detector. Figure 1 shows a sketch of the planned detector upgrades. The detector disks will be constructed from four quarter sections. This construction requires large area GEM foils. So far the most reliable source of GEM foils is CERN. For a project of that size it is also desirable to have a commercial source of GEM foils as the production capabilities of the photolithographic workshop at CERN are not sufficient. A collaboration with Tech-Etch, Inc., based on an approved SBIR[1] proposal, has been established to provide a commercial source for GEM foils and to study the production of large area foils. The mechanical construction of the triple GEM disks will be based on light-weight materials such as honeycomb or carbon fiber. A two dimensional projective strip readout will be used. The details of the readout geometry are still under investigation. The readout system is based on the APV25-S1 front-end chip [5], and will also be used for parts of the silicon tracker upgrade in STAR. Recently the FGT project was reviewed by the Brookhaven National Laboratory Detector Advisory Board and was recommended to be pursued on an aggressive schedule. The total project cost is estimated to be below $2 million will allow for an accelerated construction of the detector and an installation by fall 2009.

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[1]Small Business Innovative Research, US-DOE funded program to foster collaboration of small companies and academic institutions

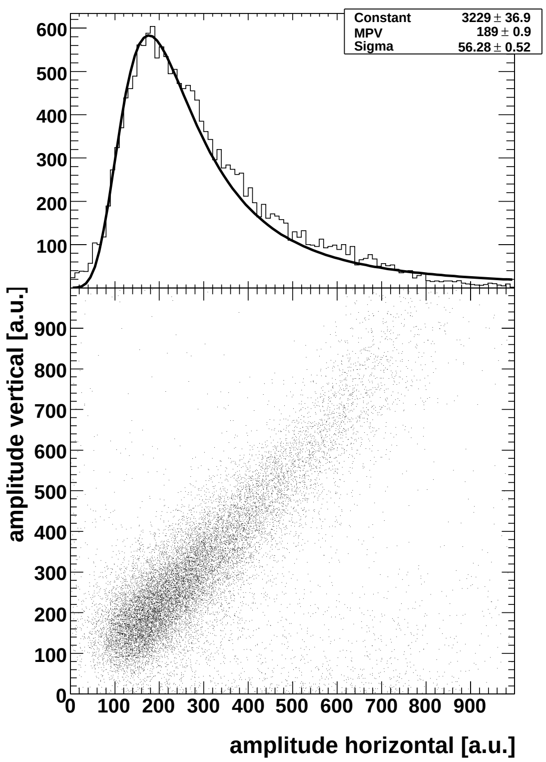

Fig. 2. Correlation of hit amplitudes between readout coordinates and amplitude distribution. The results are based on a very preliminary analysis of not pedestal subtracted data with primitive cluster finding. Good charge sharing between the readout planes is apparent.

III. Test Detectors and First Results

In order to evaluate the performance of GEM foils produced by Tech-Etch in an application environment, a test detector based on the geometry used in the COMPASS experiment [3] has been developed at MIT. The detector is a triple GEM design with a two dimensional projective strip readout. The foils are powered from a single high voltage source through a resistor chain with equal voltage sharing between the three foils. The drift gap of the detector between the cathode foil and the top GEM is 3 mm, the transfer gap between the other foils and between the bottom GEM and the readout board are 2 mm. The readout structure is a laser etched printed circuit board with a strip pitch of 635 μm. The width of the strips have been selected to obtain equal charge sharing between both coordinates. The test detectors are designed to allow for easy replacement of individual foils. A pre-mixed gas of Ar:CO_2 (70:30) is used for all measurements. Before installation in the detectors all GEM foils are tested for electrical stability and undergo an optical analysis to establish their geometric parametes, using an automated high resolution scanning setup [6].

Currently three triple GEM test detectors with Tech-Etch produced GEM foils are tested in the MTest test beam area at Fermi National Accelerator Laboratory. The detectors are installed as a tracking telescope with 125 mm spacing between them. The middle detector can be rotated around the vertical axis to study the effect of track inclination on spatial resolution and efficiency. First preliminary results indicate a stable operation of the detectors. A fast offline analysis with primitive cluster finding on not pedestal subtracted or noise corrected data was performed to evaluate the detector performance. Figure 2 shows the correlation of cluster amplitudes between readout coordinates of one detector together with the distribution of amplitudes. Good charge sharing between planes is apparent, as well as the expected Landau distribution of the cluster charge. Figure 3 shows the track residuals in the middle detector of the setup. This first analysis, without final alignment and data corrections, indicates a spatial resolution of better than 90 μm. Significant improvements are expected with more advanced analysis techniques.

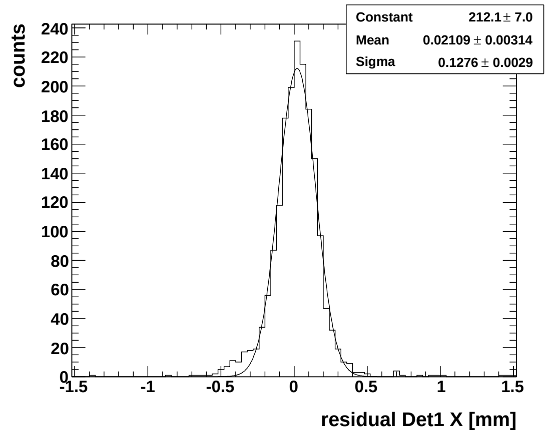

Fig. 3. Residuals of tracks in the middle detector of the test beam setup. The results are based on a very preliminary analysis of not pedestal subtracted data with primitive cluster finding. The observed width of the distribution corresponds to a spatial resolution of $\sim$90 μm.

IV. Conclusion

The STAR experiment is preparing an upgrade of its forward tracking system based on triple GEM detectors. Three test detectors using commercially produced GEM foils by Tech-Etch are currently undergoing a test beam program at Fermilab. This first test of Tech-Etch foil based triple GEM trackers indicate good performance and high resolution of these devices, demonstrating that devices using commercially produced GEM foils satisfy the requirements of forward tracking in the STAR experiment at RHIC.

References

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