A GEM TPC End Panel Pre-Prototype

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A GEM TPC end panel pre-prototype was constructed for a large LC-TPC prototype to test its basic design philosophy and some of its engineering details. Its interim test results are presented.

1 Introduction

Three out of the four detector concepts for the ILC feature a Time Projection Chamber (TPC) as their main trackers. The LC-TPC is required to have more than 100 sampling points with a spatial resolution of 150 μm or better and a two-track separability down to 2 mm. Beam tests of a small prototype [2, 3] have shown that the required performance is achievable if we adopt a pad width of as narrow as $\sim$1 mm or a resistive anode to spread the signal charge on a pad plane. Basic properties of a TPC with a micro pattern gas detector (MPGD) readout plane are also understood through these small prototype tests. Our next target is to construct a large prototype having multi-MPGD-panels with small readout pads, and to demonstrate the required performance under more realistic experimental conditions with panel boundaries and distortions, thereby allowing a smooth extrapolation to the real LC-TPC. The LCTPC collaboration plans to have a beam test with a large prototype at DESY in the summer of 2008. For the beam test, we will prepare Gas Electron Multiplier (GEM) panels. Our basic design goals for the pre-prototype GEM end panel includes the following: to allow the required smallness and density of readout pads, to minimize dead spaces due to phi-boundaries of adjacent panels, and to allow easy replacement of GEM foils when necessary. Considering these requirements, we decided to use as large GEM foils currently available as possible, and to stretch the GEM foil in the radial directions so as to avoid thick mullions introducing dead regions for high momentum tracks. We also designed a GEM mounting system though which we can supply necessary high voltages to the GEM foils. Prior to the production of GEM panels for the beam test, we constructed a pre-protoype to test its basic design philosophy and some of its engineering details including fabrication methods for the GEM end panels.

2 Construction of the GEM TPC End Panel Pre-Prototype.

2.1 GEM

Our GEM foils are supplied by Scienergy Co. [4] and consist of 5 μm thick copper electrodes sandwiching a 100 μm thick liquid crystal polymer insulator. The thick GEM foils allow stable operation with higher gain than popular 50 μm thick GEM foils. A double GEM configuration is hence enough to give a gain of more than 10^4. The hole diameter and pitch are 70 μm and 140 μm, respectively. The hole shape is cylindrical due to dry etching unlike that of CERN GEMs, which is biconial. The active area is fan-shaped spanning 9.2° in the ϕ direction with inner and outer radii of 128 and 139 cm ($\sim 20 \times 11\,\mathrm{cm}^2$), which is about 2 times larger than the GEM foils we used for our small prototype. To keep the stored energy small enough, the GEM electrodes are divided into two in the radial direction with a boundary of 100 μm.

A set of G10 frames should be glued to each GEM foil in order to be mounted on a readout PC board. For the frame gluing we developed a GEM stretcher, which consists of two parts. One is an acrylic GEM stretcher frame and the other is a set of a middle frame and a GEM adjuster made of aluminum. The lower part of the acrylic stretcher frame has a groove with a depth of 2 mm and the upper part has screw holes aligned to it. The middle aluminum frame has the same size as the groove. By sandwiching a GEM foil with the lower and the upper parts of the acrylic stretcher frame together with the aluminum frame, and by screwing bolts into the holes of the upper piece and pressing down the aluminum frame into the groove, we could stretch the GEM foil. The GEM foil, the G10 frames, and the adjuster have through holes aligned to each other. We stacked them up together, put pins into the holes of the adjuster to align them, and glued the G10 frames with epoxy adhesive to the GEM foil. Notice that the frames covered only the inner and outer edges of the GEM foil to reduce the dead space pointing to the interaction point. This fabrication method has been established and allowed us to produce 3 panels per day.

2.2 Readout PC Board

The electrons multiplied by the GEM foils are read out by a PC board. The PC board is $2\,\mathrm{mm}^t$ thick and has a size enough to cover the GEM foils, spanning 9.2° in ϕ and having inner and outer radii of 127 and 140 cm, which are about 1 cm extended in both inner and outer directions to facilitate the GEM mounting. It carries 20 pad rows on its front side of which the inner 10 have 176 pads each and the outer 10 have 192 pads each, with every two rows staggered by half a pad width to minimize the so-called hodoscope effect. A typical pad size is about 1.1×5.5 mm which is small enough for the intrinsic charge spread of $\sim 350\,\mu$m. The pads are wired to readout connectors on the back side of the PC board through a five-layer FR4. The PC board, being of six layers, has no through-holes due to wiring, thereby assuring the gas-tightness required for the TPC operation.

We used connectors supplied by JAE [5]. Each connector has 40 channels, of which 32 are used for signal readout and the remaining 8 for ground. Its size is about $15 \times 5\,\mathrm{mm}^2$, which is one of the smallest connectors commercially available. Pre-amplifiers are connected to the PC board with flexible cables. For the large prototype, pre-amplifiers and flash ADCs will be mounted on small PC boards and are directly connected to the readout PC board. We will not use the connectors for the real ILC TPC, since pre-amplifiers and flash ADCs will be mounted on the surface of the PC board.

High voltage (HV) electrodes are also wired through the PC board. To apply the HVs to the GEM electrodes, we adopt a bolt-and-nut method. A brass nut is adhered to an electrode on the front side of the PC board. We tried two methods to fix the nut. One is soldering, the other is gluing with a conductive paste (dotite by Fujikura Kasei Co. [6]). It turned out that soldering is much stronger than the conductive paste, besides the dotite produces threads. We will hence use soldering for the large prototype construction. The lower and the upper GEM foils are stacked on the PC board, and bolted through their G10 frames to bite the GEM electrodes so as to supply required HVs through the bolts. The spacings between the GEM foils and the readout pad plane are determined by the thicknesses of the G10 frames, resulting in a transfer gap of 4 mm and an induction gap of 2 mm. An aluminum flange with a groove for an O-ring is glued to the back side of the PC board with epoxy adhesive to avoid mechanical distortion and to be mounted to a gas container. When we glued the aluminum flange, we aligned the flange and the PC board by hand since there are no alignment holes or posts in the PC board and the flange. The positions of the readout pads are determined by this flange, so some alignment posts should be prepared for the large prototype. The GEM end panel was mounted on a gas container with 16 M3 bolts.

3 Measurement of Gain Uniformity over the Panel.

The pre-prototype chamber is filled with a 90:10 mixture of Ar and iso-butane gases. We applied 410 V to each of the two GEM foils, and electric fields of 100, 2050, and 3075 V/cm to the 25 mm long drift, the 4 mm long transfer, and the 2 mm long induction regions, respectively. Under these conditions, the gas gain was about 2×10^4 and the signal spread was about 550 μm. We irradiated the pre-prototype panel with X-rays from ^{55}Fe through the windows of the test chamber to measure the gain uniformity over the panel.

First, we checked the charge distribution over the readout pads. Since the signals sometimes spread over 2 pad rows, we required the signal charge be shared by 2 pad rows and summed the signals over 5 contiguous pads on each of these two rows to avoid mis-collection. Figure 1 shows the charge sum distributions for 10 pads. Both a 5.9 keV main peak and a 2.9 keV escape peak can be clearly seen.

Second, we checked the charge spread. A center of gravity was calculated from the measured pad signal charges and their ϕ positions as well as the charge fraction on each pad. By plotting the charge fraction as a function of the charge center measured from the middle of the central pad, we could get an image of the charge distribution over the pad plane. Gaussian fit to the distribution resulted in a (1-σ) width of about 550 μm corresponding to half a pad width as expected (Fig. 2) from the diffusion.

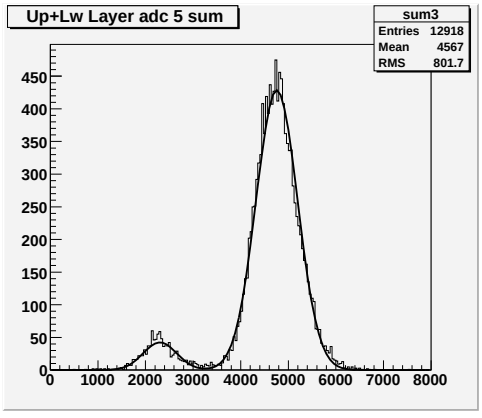


Figure 1: Charge sum distribution.

We then measured the charge sum distributions at 28 positions over the panel for the uniformity test, usually requiring the charge sharing. We found, however, that charge sharing never happened near the boundary

of the inner and the outer GEM electrodes. The exact reason is still unknown but it could be attributed to the charge-up of the insulator of the GEM boundary affecting the charge collection. The charge sharing was hence not required for the positions in the boundary region. After normalizing the charge sums to that of some reference position, we found that the normalized charge sums range from 0.49 to 1.08. The observed gain non-uniformity is 2.5 times larger than the expected 20% or less from the mechanical tolerance of the panel. We found a large field distortion near the panel edges, which partly explains the non-uniformity but not all of it. Further investigations for possible causes are needed including variations of operation conditions such as gas concentration, etc..

4 Summary

We have constructed and tested a pre-prototype of the GEM TPC end panels to verify basic design philosophy and some of engineering details including fabrication methods for the large prototype of the real ILC TPC. We have basically established a GEM framing scheme with some minor problems to be improved for the large prototype construction. We have also measured the gain uniformity over the pre-prototype panel and observed a 50% non-uniformity at maximum. The non-uniformity could partly be attributed to the field distortion due to the test chamber setup, but requires further studies to fully validate our basic design philosophy.

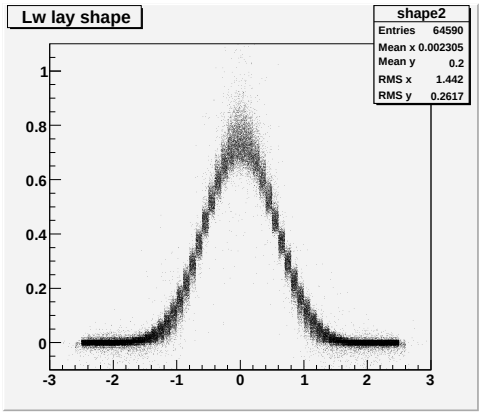


Figure 2: Signal spread.

Acknowledgements

This study is supported in part by the Creative Scientific Research Grant No. 18GS0202 of the Japan Society for Promotion of Science.

References

[1] Slides:
http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=317&sessionId=74&confId=1296

[2] D. C. Arogancia *et al.*, arXiv:0705.2210 [physics.ins-det].

[3] M. S. Dixit, J. Dubeau, J. P. Martin and K. Sachs, Nucl. Instrum. Meth. A **518**, 721 (2004).

[4] http://www.scienergy.co.jp/

[5] http://www.jae.co.jp/e-top/

[6] http://www.fkkasei.co.jp/english/index_e.html