Performance Test of a Micro-Pattern Stereo Detector with Two Gas Electron Multipliers

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Abstract

We report on the performance of a large micro-pattern detector with two gas electron multiplier foils (GEM) and a two-layer readout structure at ground potential. The two readout layers each have a $406\ \mu$m pitch and cross at an effective angle of 6.7 degrees. This structure allows for two orthogonal coordinates to be determined. Using a muon beam at CERN together with a silicon tracking system, the position resolutions of the two coordinates are measured to be $50\,\mu$m and 1 mm respectively (1 stand.dev.). The muon detection efficiency for the two-dimensional space points reaches 96%. The detector was found to be well operational over a wide range in the settings of the different electrical fields.

1 Detector Module

The detector module is a closed system of four trapezoidal detector units with dimensions 100×95 mm each. They were produced on a common board forming a segment of a ring with the readout electronics and high voltage connections outside of the gas volume of the detector. Figure 1a shows a schematic view of the detector consisting of three gas gaps formed by frames supporting the readout structure, the GEM-foils (developed by F. Sauli [1]) and the drift cathode.

The two coordinate information is extracted from the signals of crossing strip electrodes produced in four trapezoidal segments on a 300 μm thick board. The artwork of the readout structure is based on etched capton technology and has been produced at CERN [1] using the same procedures as for the production of GEMs. The strips cross at an angle of 6.7 degrees. In order to minimize the crossing area and the capacitive coupling between the two layers the strips are not made as straigth

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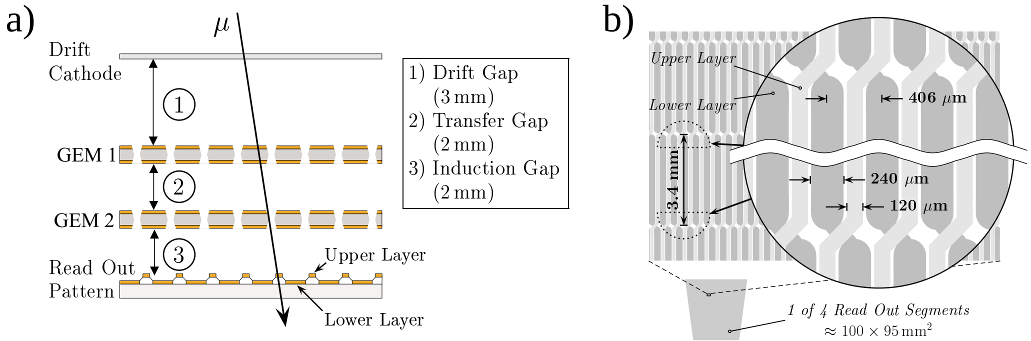

Fig. 1. A schematic view of the detector module, and of the stereo readout structure

lines but show a ’steplike’ shape producing up to 28 radially segmented readout pads (see Fig. 1b). The widths of the strips are chosen to approximately equalize the charge sharing between the two readout planes resulting in upper strips that are 120 μm wide and lower strips 240 μm wide. The thickness of the gold-plated copper strips is about 5 μm. Both strip planes have a pitch of 406 μm and 256 readout lines per detector unit.

The GEMs consist of a 50 μm thick Kapton foil, copper cladded on both sides. The pitch of the holes is 120 μm and the diameter is 80 μm in the copper and about 45 μm in the Kapton. Applying a voltage difference between both copper sides produces a dipol field high enough to provide gas amplification.

A set of 4 PreMux front end chips, each containing 128 channels of charge preamplifiers, shaper-amplifiers and double-correlated sampling circuitry as well as an analogue multiplexer, forms the readout hybrid. One hybrid serves each of the four individual detector units. Together with an additional output buffer board, a single Flash-ADC channel is sufficient to readout the entire detector module.

2 Detector Performance

The performance of the detector was evaluated in a low intensity, high energy muon beam in the X5 beam line of the CERN West area. Examples for signal distributions of the largest signal cluster in the event are shown in Fig. 2a. The distributions are found to approximately follow the Landau distribution. The corresponding fits are shown by the curves.

The charge correlation between the two readout layers is analysed in Fig. 2b,c: the box symbols represent the largest signal clusters found in the upper and lower readout layers. For charge collection within the pads, the signals of the upper readout layer are larger by a factor of 1.5 ± 0.1 compared to the lower readout layer as is shown in Fig. 2b by the symbols together with a linear fit to these values. In the

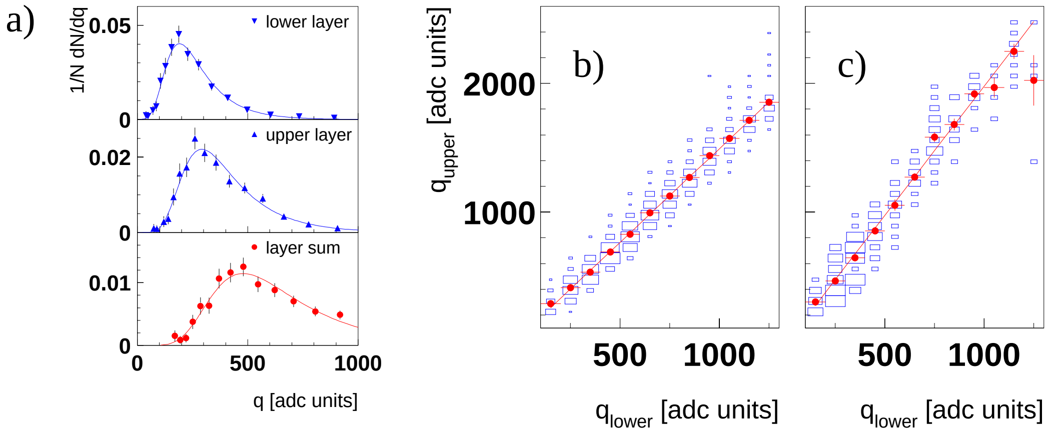

Fig. 2. a) Distributions of the cluster charge q for the lower layer, the upper layer, and the sum of both. Correlations of the cluster charges b) collected within the region of the pads, and c) in the crossing region of the two readout layers.

small regions where the two layers cross, the signal of the upper layer is found to be a factor of 2 above that of the lower layer (Fig. 2c). The strong correlation between the charges collected with the two readout layers provides a major advantage for the suppression of combinatorial background.

In order to determine the optimal field strengths and to derive the corresponding signal in comparison to the noise level, field scans have been performed. They show that the detector allows for stable operating conditions in large intervals of the different voltages where typical values are $E_{Drift} = 3$ kV/cm, $E_{Transfer} = 4.5$ kV/cm, $E_{Induction} = 5$ kV/cm, and $\Delta U_{GEM} = 430$ V. The signal over single strip noise ratio was found to be 80 for the upper readout layer and 50 for the lower layer respectively.

To test the tracking quality of the GEM detector, muon tracks were reconstructed in the silicon telescope [2] and extrapolated to the surface of the GEM detector. Two orthogonal coordinates were measured using the sum and the difference in the position measurements of the two layers.

The position resolution σ perpendicular to the pads has been determined from the residual distributions using Gaussian fits. In Fig. 3a the fit results are shown depending on the relative gain Q. Here Q denotes the most probable value of the Landau distribution fitted to the corresponding signal distributions. As expected, the position measurements are best for large cluster signals and reach $\sigma \approx 50\ \mu$m.

The quality of the measurement of the coordinate along the 3.4 mm long pads is shown in Fig. 3b. To give values comparable to the Gaussian widths shown in Fig. 3a, we present here the width of the residual distribution containing 67 % of the detected events. We observe a resolution in the direction along the pads of $\sigma \approx 1$ mm.

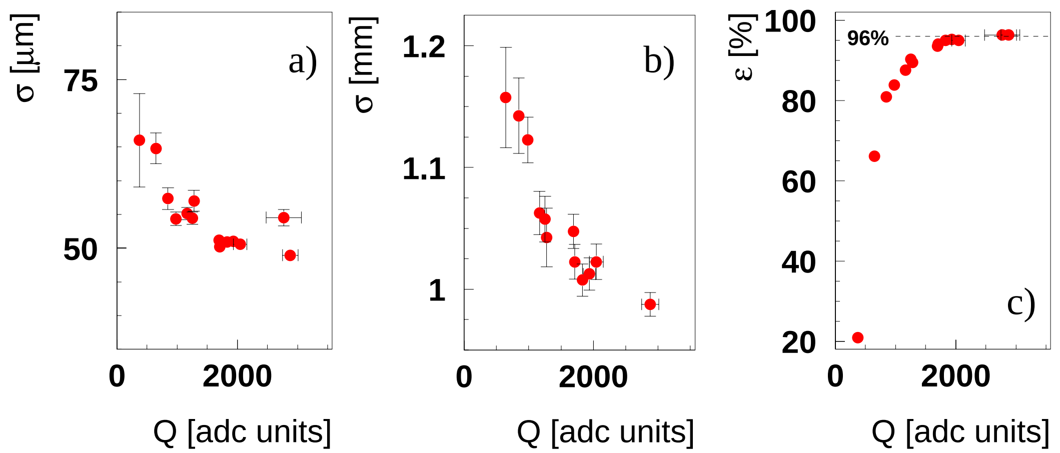

Fig. 3. The position resolution of the coordinate a) perpendicular to the pads, and b) along the pads is shown as a function of the relative gain Q. c) Efficiency for space points as a function of Q.

The efficiency of detecting a muon track in both layers is shown in Fig. 3c as a function of the relative gain. We define the efficiency as $\varepsilon = N\left(|x_{GEM} - x_\mu| < 5\sigma\right)/N_\mu$, where N_μ is the number of muon tracks, and the nominator denotes the number of clusters in the detector which are associated with the predicted muon track within 5 standard deviations of the measured position resolution. Measurements of 2-dimensional space points reach an efficiency of $96\,\%$.

References

[1] F. Sauli et al., NIM **A386** (1997) 531.

[2] L. Celano et al., NIM **A381** (1996) 49.