# Photon detection and localization with GEM

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*Abstract*-- **We describe the performance of a photon detector based on the Gas Electron Multiplier (GEM), with a CsI photocathode deposited on the first electrode of a cascade of three or four. The excellent position and multi-hit resolution achieved makes it suitable for RICH applications. A special readout board, providing three projections for each coordinate, permits to resolve ambiguities for multi-hit events.**

## I. Introduction

The Gas Electron Multiplier (GEM) is a thin, metal-clad polymer foil chemically pierced by a high density of holes [1]. On application of a voltage between the two conducting faces, each hole acts as an individual proportional counter: electrons released in the upper gas volume drift into the channels, multiply in avalanche and transfer into a lower drift region. Several foils can be cascaded, permitting to achieve higher gains. The multiplying electrodes are electrically separated from the readout plane; this effectively protects sensitive electronics from accidental discharges [2], and permits freedom in the choice of the readout pattern, pads or strips of arbitrary shapes [3].

The avalanche confinement in the holes results in efficient ion- and photon-mediated feedback suppression, and permits to attain very large gains [4]. Multi-GEM devices are capable to detect and localize single electrons emitted by an internal photo-cathode; particularly suitable are $CH_4$ and $CF_4$ gas fillings, in which quantum efficiencies close to vacuum have been obtained, [5-7].

An attractive option is to deposit a reflective photocathode on the upper GEM electrode, facing the window (Fig. 1) [8-10]. The high surface field permits to efficiently extract photoelectrons and to inject them into the cascade of multipliers; a reverse field in the drift region eliminates the contribution of ionization released by charged particles in the gap, an essential advantage for RICH counters. Photon feedback from the avalanches is absent altogether; as most of the ions are produced in the last stage, ion feedback is also strongly reduced [11, 12].

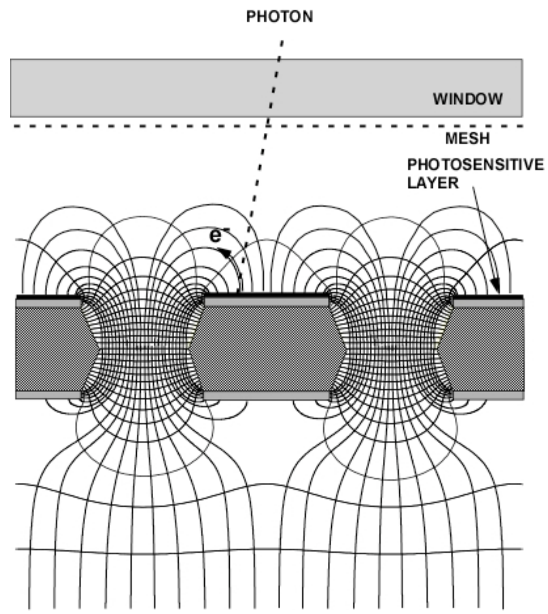


Fig. 1. Schematics and field lines of a GEM with reflective photocathode.

Results obtained in the detection of single photoelectrons with a triple-GEM detector with one-dimensional strip readout have been reported in a previous paper [13]. Single photon detection efficiency close to 100% and localization accuracy close to 100 µm rms were demonstrated. This report describes recent measurements made with a device providing three projective coordinates for each point, and aimed at resolving ambiguities arising in multi-photon events.

## ~~II.~~I. GEM Detector with Hexaboard Readout

Two-dimensional readout of coordinates can be achieved using a perpendicular set of strips [3]; for moderate multiplicities, the correlation between charges recorded on the two projections can be used to resolve ambiguities [14]. A 2-D projective strip readout is however not suitable for close multi-photon events, such as those encountered in RICH detectors. The ultimate multi-hit resolution can be achieved using as pick-up electrode a matrix of pads; this is however a very expensive proposition. An elegant alternative, offering performances between projective strips and pixel readout, has

Manuscript received October 15, 2004.

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Submitted to the IEEE-Nuclear Science Symposium (Rome, October 16-22, 2004)

been developed under the name “hexaboard”; it consists in a matrix of adjacent charge collecting hexagonal pads, interconnected on the backside in rows along three directions at 120º to each other [15]. For each event, three independent charge profiles are recorded, providing an ambiguity-free reconstruction up to large multiplicities; charge correlation adds to the resolution power. With a pad size of around 500 µm, charge is shared between adjacent strips in each projection, permitting accurate positioning.

To investigate its performance in the detection of photons, we have built a detector with a hexagonal-shaped hexaboard anode plane (Fig. 2). The device has 170 readout channels for each of the three projections, each channel providing the signal from a row of connected hexagonal pads at a pitch of 520 µm.

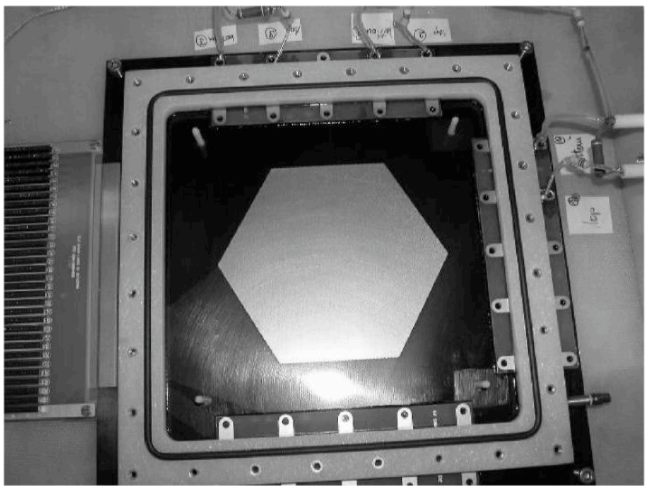

Fig. 2. The detector assembly, open to show the hexaboard readout circuit, ~ 8 cm in diameter. Several framed GEM multipliers, 10x10 $cm^2$ active, can be mounted on insulating pillars over the board.

A set of four framed GEM foils, with 10x10 $cm^2$ active area, are mounted over the padded anode on insulating pillars; the upper side of the first GEM, facing the UV-transparent quartz window, is coated with CsI. Only 48 strips (16 for each of the three projections) are equipped with a charge recording circuit, an integrated fast amplifier followed by the a highly integrated ADC system developed for the ALICE Time Projection Chamber (ALTRO [16]). With 10 bits conversion and 25 MHz sampling rate, the circuit records the charge in 3 to 4 subsequent registers. Typically, the charge is shared between two adjacent rows, therefore permitting charge interpolation in the calculation of the coordinates; the cluster width in all coordinates has ~ 250 µm rms (Fig. 3).

Using a mask with several holes, we have studied the resolution properties of the detector for multi-photon events; Fig. 4 shows as an example of the signals recorded along the three projections for a double photon event. In this case, the reconstruction is free from the ambiguities that would arise in case of overlap of signals in one projection. As for charged tracks, we observe a strong correlation between charges recorded on the three projections, that can be exploited in reconstruction. Fig. 5 gives as an example the pulse height correlation between one pair of coordinates; similar plots are obtained for the others. Due to the wide spread in amplitude for single photoelectron avalanches, charge correlation appears a very powerful tool for the resolution of ambiguities in high multiplicity events.

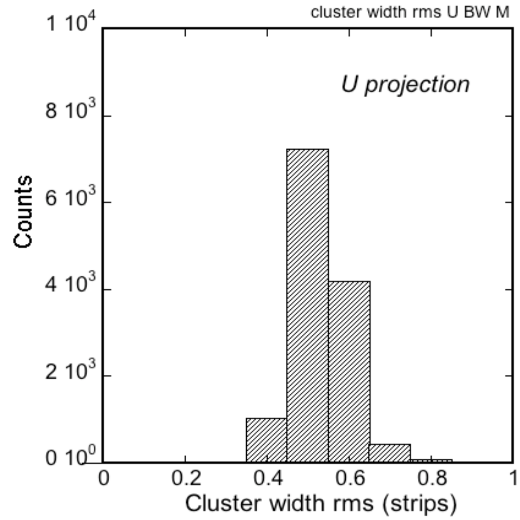


Fig. 3. RMS distribution of the cluster width for one projection.

With around 100 µm position accuracy and ambiguity-free multi-photon reconstruction, the GEM detector with hexaboard readout appears to be a powerful tool for the realization of fast RICH detectors.

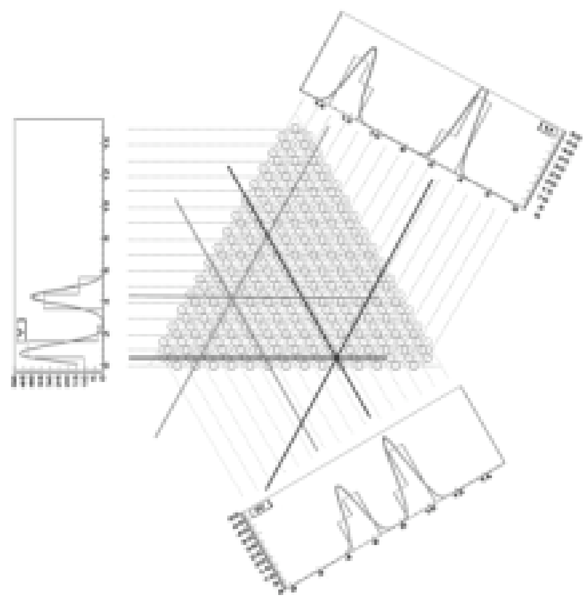

Fig. 4. Double photon event recorded with the hexaboard

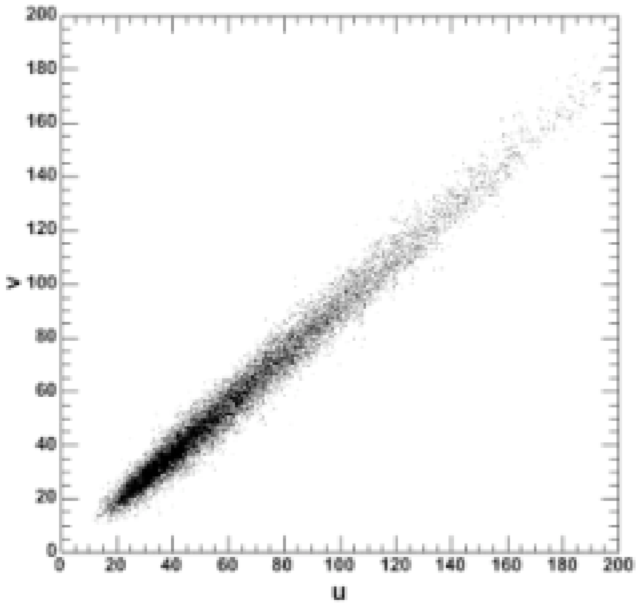


Fig. 5. Cluster charge correlation between two projections (arbitrary units).

## II. Conclusion and Future Prospects

The high gain and feedback suppression properties of multi-GEM detectors with a photosensitive layer deposited on the first electrode permit efficient detection and localization of single photoelectrons extracted by UV light. In view of applications as Cherenkov Ring Imaging, we have investigated the localization and multi-photon resolution properties of the hexaboard readout, providing three independent projections of each avalanche; the narrow pitch of the readout strips (520 $\mu$m) together with a good charge correlation between the three views of the same cluster suggest unprecedented ambiguity-resolving power. Further data analysis and possibly a beam exposure are needed to confirm this point.

## III. References


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