

A Triple-GEM Detector with Pixel Readout for High-Rate Beam Tracking in COMPASS

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1. Introduction

COMPASS [1] is a two-stage magnetic spectrometer, built for the investigation of the gluon and quark structure of nucleons and the spectroscopy of hadrons using high-intensity muon and hadron beams from CERN’s SPS. After the muon beam program will be completed, experiments with a hadron beam of $2 \cdot 10^7$ particles/s are foreseen from 2008 onward to perform spectroscopy of mesons and baryons in the light quark sector. For these experiments the tracking of charged particles in the beam region requires fast detectors providing good resolution in space and time in order to disentangle pile-up and multi-track events. Further demands of the high hadron flux density to the detectors are radiation hardness and minimal mass in order to avoid secondary interactions. Based on the experience with large-area triple-GEM tracking detectors in COMPASS [2,3], a set of triple-GEM beam trackers with combined pixel readout in the central region and 2-D strip readout in the periphery has been proposed (“PixelGEM”). After a successful prototype test in high-intensity muon and hadron beams in 2006, a total of five detectors is being built and tested for 2008.

2. Design of the PixelGEM Detector

The electron signal emerging from the triple GEM amplification stack of the PixelGEM detector is read out by a $100 \mu\text{m}$ thin, Kapton-based flexible printed circuit foil with three conductive layers, carrying both the pixel and the strip structure, and the signal lines from the pixel region. Pixels of $1 \times 1 \text{ mm}^2$ size have been chosen since they are expected to yield cluster sizes larger than one, thus allowing to improve the spatial resolution by applying clustering algorithms. With a total of 32×32 pixels the beam region is fully covered while at the same time it is still technologically feasible to route the signals from the pixels on a single layer to the front-end electronics mounted 15 cm away from the active area. Surrounding the central square of pixels, a strip readout with $400 \mu\text{m}$ pitch has been realized on the same thin film printed circuit so that the complete active area of the detector amounts to $10 \times 10 \text{ cm}^2$. A total of 2048 channels are read out through 16 APV25 preamplifier/shaper ASICs with an analog pipeline with a capacity of 192 25 ns-spaced samples. Upon trigger, three samples are forwarded to digitization and further processing, so that pulse shape analysis allows to determine the time of a hit relative to the trigger with a precision of $\lesssim 10 \text{ ns}$.

For $r < 1.5 \text{ cm}$, i.e. in the center of the detector, the amount of detector material was reduced to a total thickness of 0.4% radiation length (X_0) and 0.09% interaction length (λ_I) respectively. Utilisation of GEM foils with Cu layer thickness of $1 \mu\text{m}$ instead of $5 \mu\text{m}$ is being investigated and may result in an even lower thickness of 0.2% X_0 and

0.08% λ_I respectively.

3. Prototype Test

Figure 1 shows a top view of the full-size detector prototype:

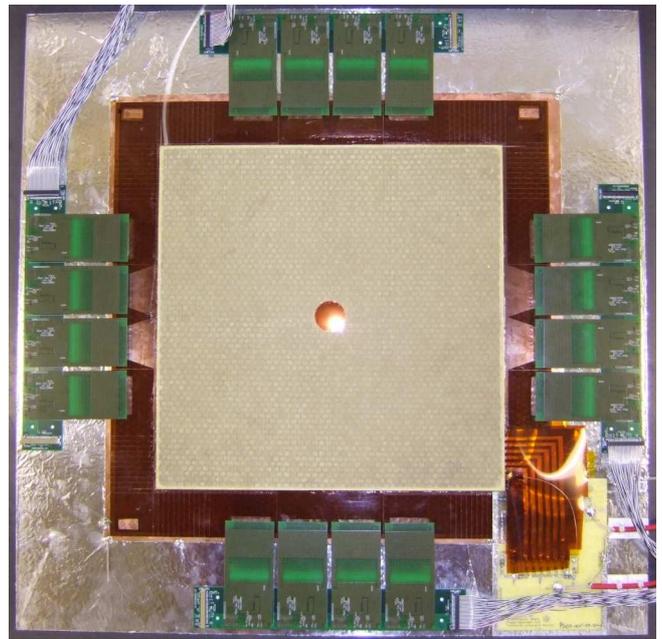


Fig. 1: Photograph of a PixelGEM detector prototype.

The detector is mounted on a light honeycomb sandwich structure serving as base panel and carrying the high voltage distribution, the front-end electronics, the readout foil, and the GEM stack.

It was characterized in the laboratory using various ionization sources, and then successfully tested in the 2006 COMPASS high-intensity muon beam at a flux density of about $5 \cdot 10^4 \mu/\text{mm}^2/\text{s}$. A different test utilizing a $190 \text{ GeV}/c$ pion beam focused at the position of the PixelGEM achieved a local intensity of the same order of magnitude. For the 2008 hadron beam a similar flux density is expected, although a greater area will be illuminated.

First analysis shows a spatial resolution of $\sim 100 \mu\text{m}$ and an average cluster size of ~ 3 in the pixel region. No electrical instabilities or discharges were observed during these tests, making this type of detector a promising candidate for a low-mass, radiation-hard beam tracker in high-rate hadron beams.

References

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- [2] C. Altunbas *et al.*, *Nucl. Instr. Meth. A* **490** (2002) 177–203
- [3] B. Ketzer *et al.* *Nucl. Instr. Meth. A* **535** (2004) 314–318