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A Cylindrical GEM Detector with Analog Readout for the BESIII Experiment

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Abstract

A cylindrical GEM detector with analog readout is under development for the upgrade of the Inner Tracker of the BESIII experiment at IHEP (Beijing). The new detector will match the requirements for momentum resolution ($\sigma_{pt}/p_t \sim 0.5\%$ at 1 GeV) and radial resolution ($\sigma_{xy} \sim 120\mu m$) of the existing drift chamber and will improve significantly the spatial resolution along the beam direction ($\sigma_z \sim 150\mu m$) with very small material budget (less than 1.5% of X_0). With respect to the state of the art the following innovations will be deployed: a lighter mechanical structure based on Rohacell, a new XV anode readout plane with jagged strip layout to reduce the parasitic capacitance, and the use of the analogue readout inside a high intensity magnetic field to have good spatial resolution without increasing the number of channels.

Keywords: Tracking detectors, GEM, Micro-pattern Gas Detectors, BESIII

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experiment

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1. Introduction

The BESIII spectrometer and the BEPCII e^+e^-collider offer an unique experimental setup to investigate Particle Physics [1, 2]. The excellent performances of the spectrometer and the unprecedented luminosities of BEPCII have already allowed to collect in the last few years world record statistics at different center of mass energies in the Charmonium and Open Charm mass range, and more will come in the next years. BESIII is in fact expected to take data until at least 2022 and more likely until 2024. Due to the very high BEPCII luminosities, the current Inner Tracker of the BESIII spectrometer, a drift chamber, is starting to show aging effects that in few years could affect significantly the detector performance. A possible solution would be to build a new Inner Tracker (IT) composed of Cylindrical Gas Electron Multiplier (CGEM) detectors.

2. The CGEM Project

The new IT will be composed by three layers of triple cylindrical GEM [3, 4]; each layer will be assembled with five cylindrical structures: one cathode, three GEMs and the anode readout (see Fig. 1). To minimize the material, no support frames are used inside the active area and the GEM foils are mechanically stretched being glued to fiberglass rings at their ends.

Such a detector will match the requirements for momentum resolution ($\sigma_{pt}/p_t \sim$ 0.5% at 1 GeV) and radial resolution ($\sigma_{xy} \sim 120\mu m$) of the existing drift chamber and will improve significantly the spatial resolution along the beam direction ($\sigma_z \sim 150\mu m$) with very small material budget (less than 1.5% of X_0).
A new Rohacell [5] based technique will be adopted to manufacture the anode and cathode structures in order to minimize the material budget with respect to the state of the art. Building supports for the sub-layers composed of Rohacell

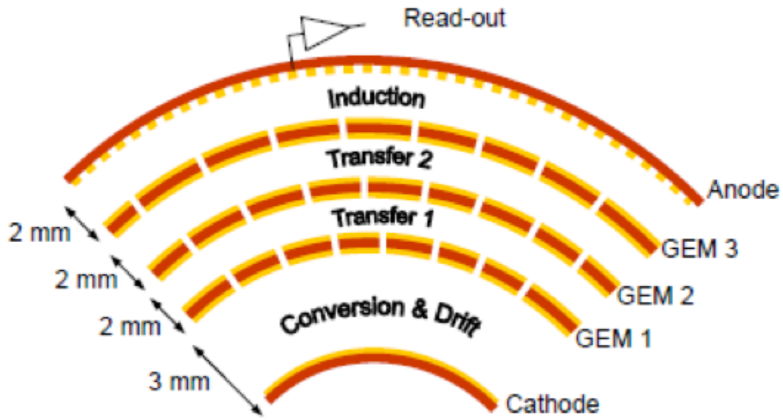

Figure 1: Cross-section of the triple GEM detector used for the BESIII CGEM-IT.

instead of the standard Honeycomb allows to significantly reduce the total radiation length of detector, down to almost 50% compared to equivalent structure composed of Honeycomb.

The readout anode circuit is manufactured by EST-DEM CERN Workshop starting from the 5 μm copper clad, 50 μm thick polyimide substrate, the same used for GEM foils. Two such a foils with copper segmented in strips will be used to have the two dimensional readout. The strip pitch will be 650 μm, 570 μm wide X-strips are parallel to CGEM axis, providing the rφ coordinates; while the V-strips, having a stereo angle with respect to the X-strips, are 130 μm wide and, together with the other view, gives the z coordinate. The stereo angle depends on the layer geometry. A jagged-strip layout has been developed to minimize the capacitance couplings: the inter-strip capacitance reduction w.r.t. the standard strip configuration is about 30%. The anode design has been studied by means of Maxwell and Garfield simulations and will be tested on a small-scale planar prototype.

Due to the relatively strong BESIII magnetic field (1 T), a digital readout electronic cannot be suitable to match the requirements of the BESIII CGEM-IT.

This would require a high segmentation and a prohibitive number of channels. Therefore, an innovative readout based on analogue information and data pushing architecture will be developed. Analogue readout allows identifying the charge centroid with a moderate strip pitch (650 μm). While data pushing architecture allows to move the overall apparatus readout synchronization to the off-line farms using the time-tag approach. The charge will be measured by a time-over-threshold technique and the new ASIC chip will be based on UMC-110nm technology.

3. Beam Test on a Planar Prototype

A beam test has been performed at CERN in order to measure the performance of a detector GEM prototype suitable for BESIII. The prototype was instrumented by a XY anode plane, with 650 μm strips, readout by means of APV25 analog hybrid cards [6]. Tracks were reconstructed with an external telescope composed by four additional GEM chambers. Efficiency, cluster size and spatial resolution have been measured with different gas mixtures. Fig. 2 reports the tracking efficiency as function of the gas gain with Ar/Isobutane (90/10) gas mixture; the plateau starts at a gain of about 6000. The efficiency in the plateau region is above 97%. Spatial resolution has been preliminarily evaluated from the residual distribution of the test chamber clusters with respect to the reconstructed track; in the plateau region the resolution does not depend on the gain. Fig. 3 shows the σ of the residual distributions as function of the gas gain: the average value is about 90 μm. Such preliminary results are very encouraging, nevertheless a new beam test is required in order to study the GEM behaviour inside a high magnetic field where the Lorentz force is expected to distort the electron avalanche.

4. Conclusions

We are developing a cylindrical GEM detector with analog readout to upgrade the BESIII IT. The project has been funded within the Executive Pro-

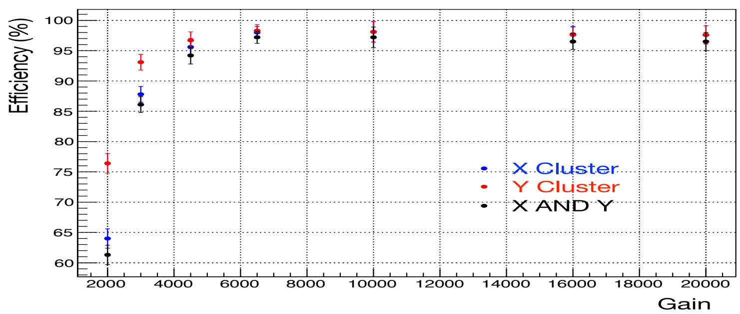

Figure 2: Efficiency of GEM planar prototype as function of the gas gain.

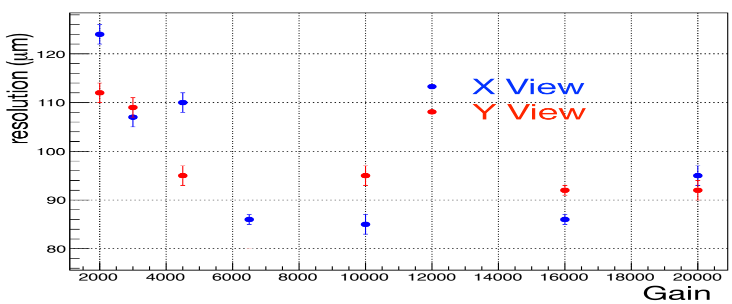

Figure 3: Spatial resolution of GEM planar prototype as function of the gas gain.

gramme for Scientific and Technological Cooperation between Italy and P.R.C. for the years 2013-2015, and and with the acronym BESIIICGEM has been selected as one of the project funded by the European Commission within the call H2020-MSCA-RISE-2014..

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