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1 A Cylindrical GEM Detector with Analog Readout for
2 the BESIII Experiment

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22 **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.

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

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24 experiment

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26 **1. Introduction**

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

38 **2. The CGEM Project**

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

44
45 Such a detector will match the requirements for momentum resolution ($\sigma_{pt}/p_t \sim$
46 0.5% at 1 GeV) and radial resolution ($\sigma_{xy} \sim 120\mu m$) of the existing drift cham-
47 ber and will improve significantly the spatial resolution along the beam direction
48 ($\sigma_z \sim 150\mu m$) with very small material budget (less than 1.5% of X_0).

49 A new Rohacell [5] based technique will be adopted to manufacture the anode
50 and cathode structures in order to minimize the material budget with respect to
51 the state of the art. Building supports for the sub-layers composed of Rohacell

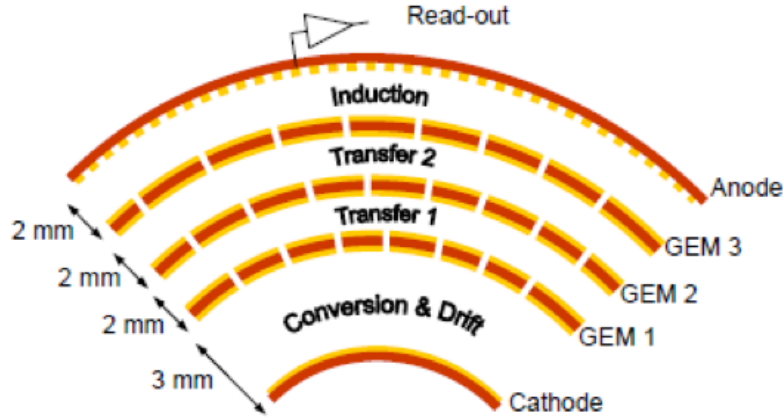


Figure 1: Cross-section of the triple GEM detector used for the BESIII CGEM-IT.

52 instead of the standard Honeycomb allows to significantly reduce the total radi-
 53 ation length of detector, down to almost 50% compared to equivalent structure
 54 composed of Honeycomb.

55 The readout anode circuit is manufactured by EST-DEM CERN Workshop
 56 starting from the $5\ \mu\text{m}$ copper clad, $50\ \mu\text{m}$ thick polyimide substrate, the same
 57 used for GEM foils. Two such a foils with copper segmented in strips will be
 58 used to have the two dimensional readout. The strip pitch will be $650\ \mu\text{m}$,
 59 $570\ \mu\text{m}$ wide X-strips are parallel to CGEM axis, providing the $r\varphi$ coordinates;
 60 while the V-strips, having a stereo angle with respect to the X-strips, are 130
 61 μm wide and, together with the other view, gives the z coordinate. The stereo
 62 angle depends on the layer geometry. A jagged-strip layout has been developed
 63 to minimize the capacitance couplings: the inter-strip capacitance reduction
 64 w.r.t. the standard strip configuration is about 30%. The anode design has
 65 been studied by means of Maxwell and Garfield simulations and will be tested
 66 on a small-scale planar prototype.

67

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

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

78 **3. Beam Test on a Planar Prototype**

79 A beam test has been performed at CERN in order to measure the perfor-
80 mance of a detector GEM prototype suitable for BESIII. The prototype was
81 instrumented by a XY anode plane, with 650 μm strips, readout by means of
82 APV25 analog hybrid cards [6]. Tracks were reconstructed with an external
83 telescope composed by four additional GEM chambers. Efficiency, cluster size
84 and spatial resolution have been measured with different gas mixtures. Fig. 2
85 reports the tracking efficiency as function of the gas gain with Ar/Isobutane
86 (90/10) gas mixture; the plateau starts at a gain of about 6000. The efficiency
87 in the plateau region is above 97%. Spatial resolution has been preliminarily
88 evaluated from the residual distribution of the test chamber clusters with re-
89 spect to the reconstructed track; in the plateau region the resolution does not
90 depend on the gain. Fig. 3 shows the σ of the residual distributions as function
91 of the gas gain: the average value is about 90 μm . Such preliminary results are
92 very encouraging, nevertheless a new beam test is required in order to study the
93 GEM behaviour inside a high magnetic field where the Lorentz force is expected
94 to distort the electron avalanche.

95 **4. Conclusions**

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

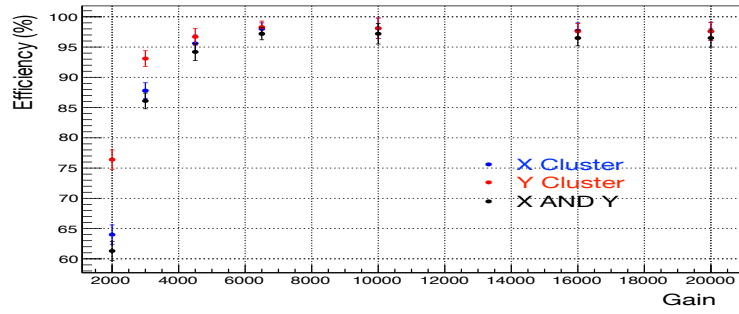


Figure 2: Efficiency of GEM planar prototype as function of the gas gain.

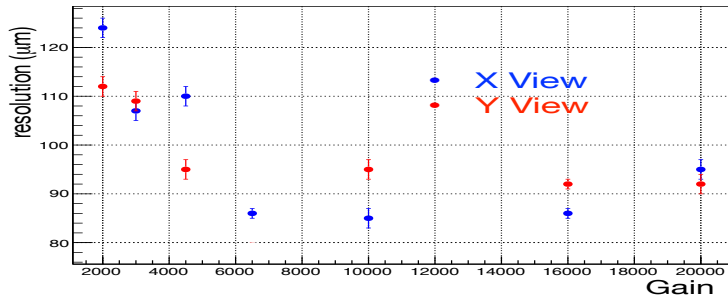


Figure 3: Spatial resolution of GEM planar prototype as function of the gas gain.

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