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A cylindrical tripleGEM detector for the BESIII experiment: Measurement of the performance in a magnetic field and project status

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Summary. — A new cylindrical GEM detector is under development to upgrade the tracking system of the BESIII experiment at the IHEP in Beijing. The new detector will replace the current inner drift chamber of the experiment in order to increase significantly the spatial resolution along the beam direction ($\sigma_z \sim 300$ μm) and to grant the performance of momentum resolution ($\sigma_{p_t}/p_t \sim 0.5\%$ at 1 GeV) and spatial resolution ($\sigma_{xy} \sim 130\,\mu$m). A cylindrical prototype with the final detector dimensions has been built and the assembly procedure has been successfully validated. Moreover the performance of a $10 \times 10\,\text{cm}^2$ planar GEM has been studied inside a magnetic field by means of a beam test at CERN. The data have been analyzed using two different readout mode: the charge centroid (CC) and the micro time projection chamber (μTPC) method.

1. – Introduction

BESIII is a particle physics experiment located at the BEPCII e^+e^- collider at IHEP in Beijing. The Italian collaboration is leading the effort for the development of a cylindrical Gas Electron Multiplier (CGEM) detector with analog and time readout to replace the current inner Multilayer Drift Chamber (MDC) that is suffering early ageing due to beam background and increasing luminosity [1]. A GEM [2] is a 50 μm kapton foil covered by 5 μm copper on both sides, pierced with 50 μm holes produced by chemical process with 140 μm of pitch. The full geometry of a triple-GEM is composed by 5 electrodes: 3 GEM planes, anode and cathode. These define 4 gaps: the conversion gap between the cathode and the first GEM, the transfer gap between the GEMs and the induction gap between the last GEM and the anode. When an electric field of $\sim 10^5$ V/cm is applied between the two sides of the GEM, it allows an electron multiplication of about 10^2 in a single GEM plane, while a triple-GEM structure permits to achieve a gain of 10^4 with a low discharge probability. Argon-based gas mixtures are mainly used to provide ionization primary pairs; the electrons drift toward the anode and each times a GEM plane is crossed the multiplication occurs [3]. Three independent cylindrical layers of triple-GEM will be used in the new BESIII inner tracker.

2. – Construction and assembly

The main mechanical challenge in the development of the BESIII CGEM inner tracker is to create a large area triple-GEM ($\sim 820 \times 770\,\text{mm}^2$) with cylindrical shape using minimum amount of material. The electrodes are produced by the CERN EST-DEM workshop and then shaped by means a mould with a tollerance of $\sim 100\,\mu$m on a radius of tens cm. The 3 GEM foils and the anode are glued directly around the mould while the cathode is glued to a structure that will provide the mechanical support of the cylindrical GEM detector. Similarly another structure is glued outside the anode for the external support. The support structure is made by a double sandwich of kapton and rohacell. The cylindrical shape is then maintained by permaglass rings glued at the edges of the foils once they are rolled onto the mould. This leads the CGEM to have a robust structure with a very low material budget: less than 1.5% of X_0 for the 3 cylindrical layers. A vertical insertion system is used to assembly the 5 cylindrical electrodes. Glue is applied between the permaglass rings to guarantee the gas tightness.

3. – Performance measurement of a planar prototype

The behavior of the triple-GEM inside a magnetic field has been studied by means of a beam test performed in the SPS H4 line at CERN in order to validate the analogue and μTPC readout for different gas mixtures and geometry configurations. The test setup is composed by 2 test chambers inside a magnetic dipole that can reach a magnetic field up to 1.5 Tesla and 4 tracking chambers outside the magnet. The chambers are filled with Argon-Isobutane (90/10) or Argon-CO_2 (70/30) gas mixture. Two different conversion gap have been tested (3 mm and 5 mm). The beam is composed by muons with momentum of $150\,\text{GeV}/c$. As the HV on the GEM increases, the detector increases its efficiency reaching a plate value of $\sim 97\%$ at ~ 4000 of gain. Contiguos fired strips are clusterized using the charge information collected at the anode to reconstruct the particle position. The cluster position is the weighted average of the strips position with their charge. The spatial resolution of orthogonal tracks without magnetic field is less than $100\,\mu$m. The effect of the magnetic field is to worsen the resolution almost linearly with the strength of the Lorentz force: at 1 tesla the resolution of the chamber is about $400\,\mu$m; this is due the deformation of the electron cloud due to the Lorentz force. It is possible to improve the resolution by optimizing the electric field in the conversion gap, who is dedicated to the collection of the primary electron. Magboltz simulations show the dependence of the Lorentz angle as function of the electric field at 1 tesla magnetic field: as the Lorentz angle decreases the resolution of the CC method improves. A scan of drift field has been performed and a resolution of $\sim 190\,\mu$m at the value of 2.5 kV/cm has been reached at 1 tesla with Ar-Isobutane (90/10) gas mixture as shown in fig. 1 on the left. Together with the electric charge, the readout electronics is capable to provide time information that can be used to improve the spatial resolution of the detector inside the magnetic field and for tracks not perpendicular to the chamber. The idea is to reconstruct, for each fired strip, the position of the primary ionization from the measured time and the drift velocity taken from simulation. This method transforms the

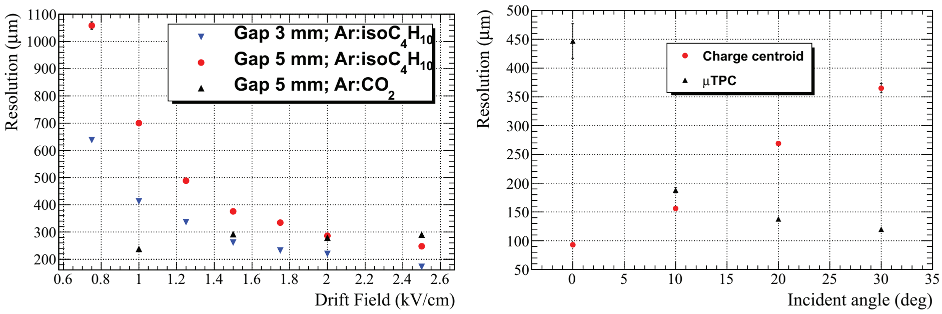

Fig. 1. – On the left the spatial resolution of a planar triple-GEM as function of the drift field for different gas mixtures and drift gap. Red and blue dots uses Argon-Isobutane (90/10), black ones Argon-CO_2; while red and black dots uses 5 mm drift gap while the blue ones 3 mm. On the right spatial resolution of a planar triple-GEM with 5 mm conversion gap and Argon-Isobutane (90/10) gas mixture as function of the angle between the beam and the normal to the chamber surface. Charge centroid method shows a linear behavior with the angle while the μTPC improves its performance as the angle increases.

triple-GEMs detector in a time projection chamber of few mm (μTPC) [4]. Contiguos fired strips provide the path of the incident particle and a linear fit can provide the direction of the track and its improved position, measured as the point along the line that correspond to the middle of the conversion gap. At first the μTPC approach has been tested on the easiest configuration, *i.e.* without magnetic field and with diagonal tracks. Results are reported in fig. 1 on the right: in the case of perpendicular tracks the number of fired strip is low (~ 3) then CC method provides the best result, but as the incident angle vary from the perpendicular value the number of the fired strips increases and the μTPC perform better and reaches a value of $\sim 130\,\mu$m.

4. – Conclusion

A planar prototype of triple-GEM has been tested with a muon beam and two reconstruction methods have been developed: the CC method and the μTPC with best optimization. The CC inside 1 tesla magnetic field reaches $190\,\mu$m of spatial resolution, while the μTPC approach showed the feasibility to reconstruct the angled tracks retaining good spatial resolution. Beside the study of the performance and the behavior of the planar triple-GEM, a validation of the construction technique of a cylindrical GEM has been achieved through its construction.

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