PROCEEDINGS OF SCIENCE

Operation of the new CGEM Inner Tracker for the Upgrade of the BESIII Experiment

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A ten years extension of the data taking of BESIII experiment, recently approved, motivated an upgrade program both for the leptonic collider BEPCII and for some of the sub-detectors of the spectrometer. In particular, the current inner drift chamber is suffering from aging and the proposal is to replace it with a detector based on cylindrical GEM technology. The CGEM detector is made of three coaxial layers of triple GEM. The tracker is expected to restore the efficiency, to improve the z determination and the secondary vertex position reconstruction with respect to the current inner tracker, with a resolution of 130 μm in xy plane and better than 350 μm along the beam direction. A cosmic telescope instrumented with two out of three layers is in operation in Beijing since January 2020, remotely controlled by Italian groups due to the pandemic situation. In this presentation, the general status of the project will be presented with a particular focus on the preliminary results from the cosmic data taking and future plans.

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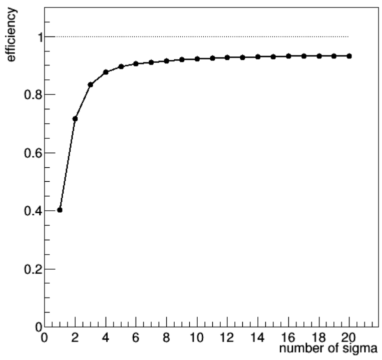
1. Context and Motivation

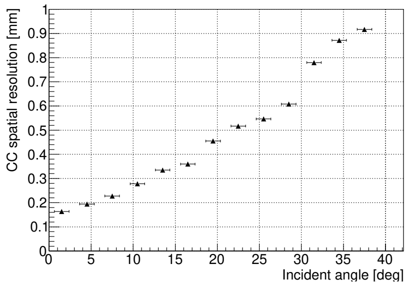
The development of a new Cylindrical GEM (Gas Electron Multiplier) Inner Tracker, the CGEM-IT, stems from the need for the replacement of the inner drift chamber of the BESIII (Beijing Spectrometer III) experiment, which has been suffering a loss in performance due to aging phenomena [1] [2]. BESIII is a high energy physics experiment located at the southern interaction point of the BEPCII (Beijing Electron Positron Collider II) storage ring, at the Institute of High Energy Physics (IHEP) in Beijing. BEPCII operates in the energy range between 2.00 and 4.95 GeV, also known as the τ-charm region, and it reached its design luminosity of 10^{33} $cm^{-2}s^{-1}$ at a center of mass energy of 3.78 GeV in 2016. The configuration of BESIII was optimized for flavor studies, with its five subsystems symmetrically enveloping the interaction point [3]. A superconducting solenoid generates a 1 T magnetic field, inside which are located: the tracker of the experiment, a Multilayer Drift Chamber (MDC); the time of flight system, whose barrel is an array of plastic scintillators read by phototubes and endcaps consist of multi-gap resistive plate chambers, and the electromagnetic calorimeter, a matrix of CsI(Tl) crystals read by photodiodes. Outside the magnet, inserted between the steel plates of the flux return yoke, layers of resistive plate chambers (RPCs) constitute the muon detector of the experiment. Thanks to this configuration and to the high luminosity of its interaction point, the BESIII experiment can investigate a broad physics program that ranges from the study of charmed hadron decays to the search for exotic states, from QCD studies to precision measurements of the standard model.

2. The CGEM-IT Project

The CGEM-IT is based on the adaptation of GEM technology to a cylindrical configuration. A GEM is a 50 µm polyimide foil, coated on both sides with 5 µm of copper and perforated, through photolitographic techniques, by a large number of 50 µm wide holes separated by a pitch of 140 µm [4]. Applying a voltage of 250-280 V to the two faces of the GEM foil, it is possible to achieve an electric field of the order of 50 kV/cm inside its holes. This strong electric field can be exploited to multiply the electrons that are produced by the passage of a charged particle in a gas. The CGEM-IT will consist of three tracking layers, each of which will be an independent CGEM detector with three multiplication stages, a cathode and a readout anode. The stacking of multiple GEM foils allows to operate at lower voltages, reducing the risk of a discharge and thus prolonging the life of the detector, and to reach higher gains, up to order 10^4 for a triple GEM detector. GEM technology is particularly well suited to high rate environments and it will allow the detector to operate up to rates of 10^6-10^7 Hz/cm^2 [5]. The larger surfaces of the electrodes are less prone to aging effects when compared to the thin wires used in drift chambers, but the additional material in the active area has to be compensated for by using advanced lightweight composites to realize the mechanical structure of the detector. Finally, the main improvement will regard the capability of reconstructing secondary vertexes, thanks to an improvement in the spatial resolution along the beam direction of almost a factor 3. The gas mixture adopted to operate the CGEM-IT is Ar/iC_4H_{10} (90/10), which was chosen to maximize the spatial resolution by favoring the diffusion of the avalanche and, therefore, increasing cluster multiplicity. Due to the GEMs sensitivity to dust, the whole construction process, up to the sealing of the layers, has to be performed inside a clean



(a)



(b)

Figure 1: First figures of merit for the CGEM-IT detector: (a) tracking efficiency within different numbers of standard deviation from the reconstructed position and (b) spatial resolution calculated using the charge centroid algorithm at different incident angles.

room of class 10000 or better. The layers 1 and 2, that is the innermost and the middle one, were realized within the clean room of INFN Frascati National Laboratories (LNF), while the third layer of the CGEM-IT, the largest one, is currently under construction. To achieve the spatial resolution, time resolution and rate requirements of the upgrade, a full readout chain has also been developed alongside the detector [6]. The on-detector electronics are developed by the INFN section of Turin and revolve around a new Application Specific Integrated Circuit (ASIC), specifically designed for the readout of GEM detectors, called TIGER (Torino Integrated GEM Electronics for Readout) [7]. This new chip is capable of performing simultaneous charge and time measurements on input signals up to 50 fC for input capacitances up to 100 pF. Thanks to its triggerless operation mode, the chip is capable of operating at rates of 60 kHz per channel and it can achieve a time resolution better than 5 ns for characteristic GEM signals. Two TIGER chips, each capable of reading up to 64 channels, are installed on each of the custom Front End Boards (FEBs) that will be connected to the anodes of the detector; the three layers of the CGEM-IT will be instrumented with a total of 80 FEBs for about 10000 channels overall. The off detector electronics are developed by INFN Ferrara and include the GEM Readout Cards (GEMROCs) together with a series of ancillary modules. The GEMROCs are based on a commercially available FPGA development kit and a custom interface card. Each module operates up to 4 FEBs and handles: the low voltage power distribution of both the digital and analog voltages, the configuration of the FEBs, the monitoring of their operating parameters and the flux of data towards the rest of the acquisition chain.

3. Operation of the CGEM Detectors

Layer 1 and Layer 2 are currently installed in a dedicated cosmic ray telescope setup at IHEP. The cosmic ray data taking has proven to be fundamental for continuing both the integration of the detector with its electronics and the development of the control and analysis software [8]. Since 2020, due to the recalling of the team of researchers working on-site, the detectors have been operated remotely. A series of remote control and monitoring tools has been deployed and a shift system has been established. For all those operations that require an on-site presence, like the

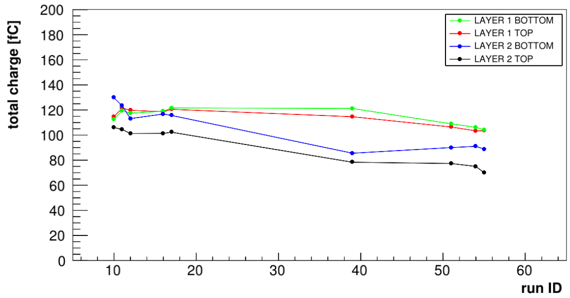


Figure 2: Average cluster charge for the top and bottom halves of both layers in different runs collected in almost a year of remote operation.

changing of the gas bottles or the maintenance of the chiller, we rely on the help our Chinese colleagues working at IHEP. The data collected thanks to this remotely operated cosmic ray data taking provided the first figures of merit for the CGEM-IT detector. The efficiency of the top half of layer 1, in fig. 1a, reaches values around 95%. The spatial resolution in fig. 1b refers to cluster positions determined using the charge centroid method, which provides optimal results for tracks perpendicular to the anodes. The contribution of the tracking system is evaluated through a toy montecarlo simulation and subtracted, allowing to reach a resolution of about 100 µm for tracks at small angles, which is compatible with analogous measurements performed on planar test chambers. Finally, despite the lack of our presence on-site and, therefore, with minimal maintenance, the results of our measurements remain relatively consistent, as shown in fig. 2.

Acknowledgments

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