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

Stefano Gramigna\textsuperscript{a,b,*} on behalf of the CGEM-IT working group

\textsuperscript{a}Department of Physics and Earth Science, University of Ferrara, Via Giuseppe Saragat 1, Ferrara, Italy
\textsuperscript{b}National Institute for Nuclear Physics (INFN), Section of Ferrara, Via Giuseppe Saragat 1, Ferrara, Italy

E-mail: stefano.gramigna@edu.unife.it

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 \( \mu \)m in xy plane and better than 350 \( \mu \)m 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.
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 photolithographic 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$_4$H$_{10}$ (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
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.

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
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

We acknowledge the support of INFN and the European Commission in the MSCA-RISE-H2020-2014 (BESIIICGEM) and MSCA-RISE-H2020-2020 (FEST) frameworks.

References