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The KLOE-2 Inner Tracker: Detector commissioning and operation

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ABSTRACT

The KLOE-2 experiment started its data taking campaign in November 2014 with an upgraded tracking system including an Inner Tracker built with the cylindrical GEM technology, to operate together with the Drift Chamber improving the apparatus tracking performance. The Inner Tracker is composed of four cylindrical triple-GEM, each provided with an X–V strips-pads stereo readout and equipped with the GASTONE ASIC developed inside the KLOE-2 collaboration. Although GEM detectors are already used in high energy physics experiment, this device is considered a frontier detector due to its cylindrical geometry: KLOE-2 is the first experiment to use this novel solution. The results of the detector commissioning, detection efficiency evaluation, calibration studies and alignment, both with dedicated cosmic-ray muon and Bhabha scattering events, will be reported.

1. The KLOE-2 experiment

The KLOE apparatus is in operation at the DAϕNE e^+e^- collider, the Frascati ϕ-factory. With a large drift chamber ($\sigma_{p_\perp}/p_\perp = 0.4\%$, $\sigma_{r\varphi} = 150\ \mu\text{m}$ and $\sigma_z = 2$ mm) and an electromagnetic calorimeter ($\sigma_t = 54\ \text{ps}/\sqrt{E(\text{GeV})} \oplus 100$ ps, $\sigma_E/E = 5.7\%/\sqrt{E(\text{GeV})}$) operating in a 0.52T axial magnetic field, the KLOE experiment achieved several results in kaon and light hadronic physics [1]. Since the collider has been upgraded in order to increase a luminosity up to $2 \times 10^{32}\text{s}^{-1}\,\text{cm}^{-2}$, the KLOE collaboration planned the insertion of new subdetectors with the aim to improve the previous measurements. The data taking period started on November 17th, 2014 and successfully reached the target of 1fb^{-1} by July 2015 (Run-I). In November 2015 the Run-II started, planning to acquire 2.5fb^{-1} by July 2017. The KLOE-2 physics program covers kaon interferometry, K_S, η and η' rare decays and searches for exotic particles [2]. The apparatus has been upgraded with the insertion of new calorimeters and of an Inner Tracker [3–7] with the aim to improve the reconstruction performance for tracks near the Interaction Point. The Inner Tracker (IT) solution makes use of the GEM technology [8], already used in forward region of experiments at hadronic machines (COMPASS, LHCb, TOTEM). KLOE-2 is indeed the first experiment to use cylindrical GEM chambers, equipped with X–V strips-pads made of a flexible kapton/copper circuit, produced in the same workshop of the GEM foils.

2. The KLOE-2 Inner Tracker

The four cylindrical GEM detectors of the IT have been installed in the region between the beam pipe ($r = 10$ cm) and the inner wall of the Drift Chamber ($r = 25$ cm). The active length is 700 mm. These dimensions imply the use of very large GEM foils and this motivated the CERN TE-MPE-EM workshop, manufacturing the GEM foils, to develop a new production process called single-mask technique [9]. Setting up this process is a milestone in the field of Micro-Pattern Gaseous Detectors. However, the size of foils is still insufficient to cover the foreseen cylindrical surface with a single sheet. For this reason, each of the 12 cylindrical electrodes splices together three GEM foils [10]. All the four layers have been completed (Fig. 1 (top)) and equipped with the GASTONE FEE [11], an ASIC chip developed inside the KLOE-2 IT project, and then inserted one on top of the other (Fig. 1 (bottom)). A total of 180 boards, each hosting two GASTONE chips, were necessary to equip all the layers. The detector has been integrated around the DAϕNE interaction point.

3. Optimizing the IT operation point

The IT is flushed with Ar:iC_4H_{10} 90:10 gas mixture. A study on the axial strips occupancy shown some dips in the distribution in correspondence of the separation of the HV sectors on the GEM foils. The sectorization of the GEM foils results in a increase of the HV channels to be supplied up. This setup divides the foils in

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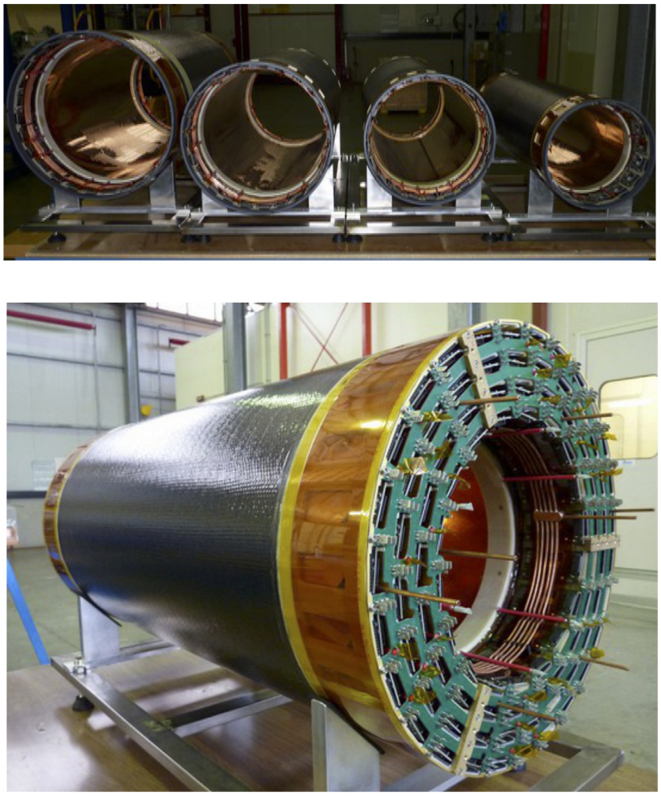

Fig. 1. The four layers composing the Inner Tracker before (top) and after (bottom) the final assembly.

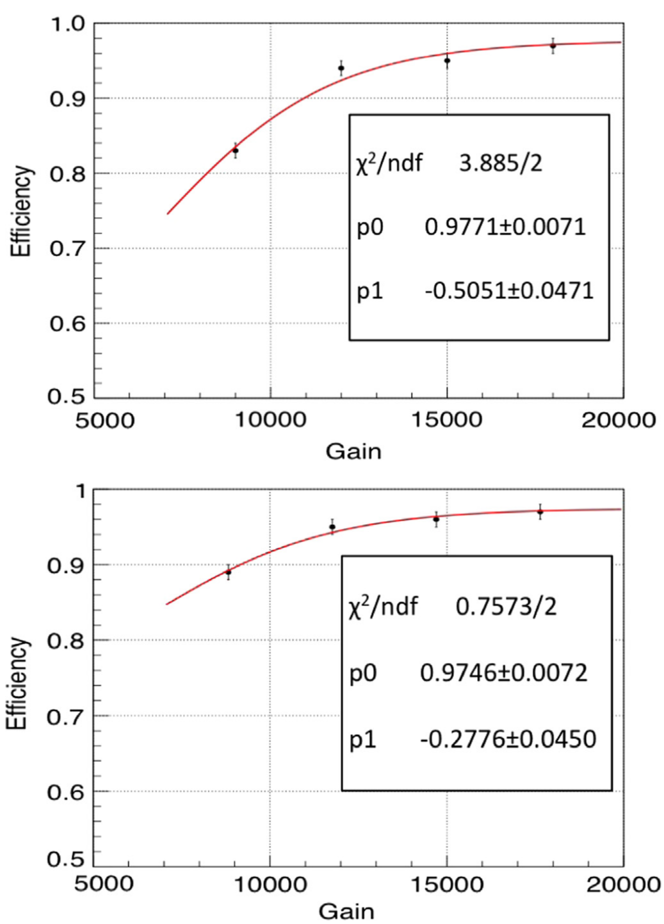

Fig. 2. Single-view efficiencies for layer 1 (top) and layer 2 (bottom). The points are fitted with a Fermi-Dirac function.

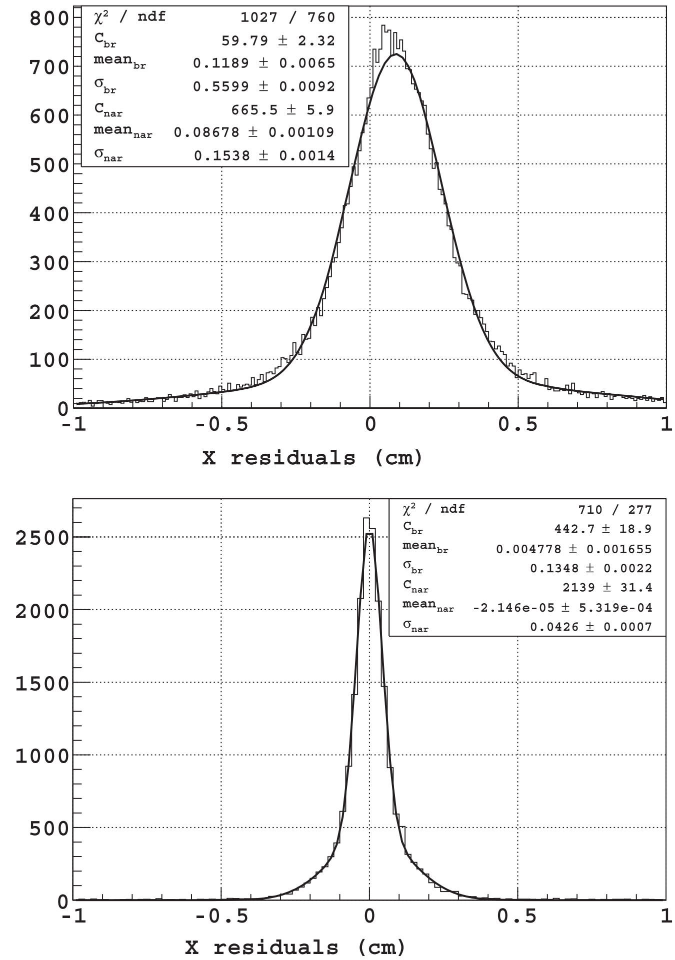

Fig. 3. X-residuals measured on Layer 4 before (top) and after (bottom) a first alignment and calibration of the detector response. The distributions are fitted with two gaussians.

smaller capacitors, so to reduce the energy dissipated in case of discharges between the two GEM surfaces. To deal with eventual discharge problems, the HV distribution system has been designed to supply an entire triple-GEM is supplied up with an active divider which quenches the discharge when it occurs [12]. A first optimization of the detector working point has been done increasing the induction field from 5 kV/cm up to 6 kV/cm. The efficiency has been then evaluated with cosmic-ray muons data, using the tracks reconstructed by the large KLOE Drift Chamber and extrapolating these tracks on each layer of the IT. A scan of the efficiency has been done for different detector gains, reaching a plateau of ~98% in single view (Fig. 2). On the base of the efficiency curves the detector is operated at an effective gain of 12,000.

4. Detector alignment and calibration

The alignment of a cylindrical detector working in a magnetic field is a very challenging task. The geometry of the detector and the Lorentz effect on the drifting charges provide some systematic effects that must be carefully evaluated for a good track reconstruction. For this reason different datasets have been acquired (cosmic-ray muons with and without magnetic field, Bhabha events). A first alignment and calibration (Fig. 3) with cosmic-ray muons in presence of the magnetic field has been then applied to a Bhabha data sample obtaining a X-residuals width of ~400 μm.

5. Conclusions

KLOE-2 is the first experiment using cylindrical-GEM detectors. These devices are used as Inner Tracker, to track charged particles in the volume between the DAϕNE interaction region and the inner wall of the Drift Chamber. The integration of the detector on the apparatus has been completed, the working point has been optimized and a very good detector stability has been reached due to the HV distribution system. The four layers have been aligned with cosmic-ray muons from which we also obtained the calibration of the detectors response. An upper limit to the single hit spatial resolution of $\sigma_{Xres} \sim 400\ \mu\text{m}$ has been obtained from the Bhabha events sample.

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