An innovative tracker for precision measurements at KLOE-2

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Summary. — A new Inner Tracker is going to be realized for the KLOE-2 experiment at DAΦNE. The tracker is based on GEM technology in order to improve vertices resolution near the interaction point, thanks to the low material budget and consequently a low effect of multiple scattering. Here there follows a description of the detector and some measurements performed.

PACS 29.40.Cs – Gas-filled counters: ionization chambers, proportional and avalanche counters.
PACS 29.40.Gx – Tracking and position-sensitive detectors.

1. – The KLOE experiment

The KLOE experiment [1] collected an integrated luminosity $\int L dt \sim 2.5 \text{fb}^{-1}$ at the Frascati $\phi$-factory DAΦNE, an $e^+e^-$ collider, at a center-of-mass energy of 1020 MeV. The experiment achieved several precision results both in kaon and hadron physics: the measurements of all branching ratios of $K_S, K_L$ and $K^\pm$, the study of scalar and pseudoscalar mesons and $e^+e^- \rightarrow \pi^+\pi^-$ cross section, giving the low-energy hadronic contribution to the muon anomaly. A detailed description of the experiment can be found in [1].

2. – KLOE-2

At KLOE-2 the interest will be focused on physics coming from the IR: $K_S$ decays, $K_S-K_L$ interference, $\eta, \eta'$ and $K^\pm$ decays, multi-leptons events. Such a research requires an additional tracker detector (Inner Tracker) [2, 3] between the beam pipe and the inner wall of the central tracking chamber. It will: 1) reduce the track extrapolation length and improve the decay vertex reconstruction capability; 2) increase the geometrical acceptance for low momentum tracks; 3) improve track momentum resolution (fig. 1).

The Inner Tracker must satisfy the following requests: $\sigma_{r\phi} \sim 200 \mu\text{m}$ and $\sigma_Z \sim 500 \mu\text{m}$, $< 2\%X_0$ material budget, 5kHz/cm$^2$ rate capability.
Fig. 1. – Simulated resolution $\sigma_{p_T}/p_T$ on the transverse momentum measurement as a function of $p_T$ for $K_S \to \pi^+\pi^-$ (left) and $\eta \to \pi^+\pi^- e^+e^-$ (right) with DC only (circles) and with the addition of the IT information (triangles).

3. – The Inner Tracker

The proposed solution is based on GEM technology: four layers of cylindrical triple-GEM with radii between 13 cm and 23 cm, 70 cm active length, $XV$ strips readout with a stereo angle of 40° and a total radiation length of 1.5%$X_0$. A full-scale CGEM prototype was built, with 15 cm radius and 35 cm active length. The construction process is described in [2]. The anode was patterned with 650 $\mu$m pitch longitudinal strips. The chamber was tested with X-rays and, once equipped with 16-channels prototype GASTONE ASIC chip, tested at CERN with 10 GeV pion beam. The detector was flushed with Ar : CO$_2$ 70 : 30 gas mixture and operated with the fields $E = 1.5/2.5/2.5/4$ kV/cm and with the GEM voltages 390/380/370 V, corresponding to a gas gain of $2 \times 10^4$. The tracks reconstructed by two external tracker stations were compared to those reconstructed by the prototype [4]. The reconstruction efficiency is about 99.6% while the CGEM spatial resolution is $\sim 200 \mu$m, in good agreement with what expected from a digital readout of the strips. Since the IT will be equipped with $XV$ patterned strips and it will operate in magnetic field, a dedicated test to address these issues was performed at CERN with 150 GeV pion beam line. Five $10 \times 10 \text{cm}^2$ planar triple-GEM detectors were assembled with 650 $\mu$m pitch strips. Four of them were equipped with standard $XY$ readout [5], while the fifth with the $XV$ geometry. All the chambers were placed in magnetic field adjustable up to 1.5 T. The magnetic field affects the drift motion of electrons making a displacement between the track and the area where signals are induced and increasing the electron spread over the readout, as shown by GARFIELD simulations (fig. 2 (left)). The gas mixture was Ar : CO$_2$ 70 : 30, with the fields 1.5/3/3/5 kV/cm and the voltages 390/380/370 V applied on GEM foils. In order to measure the displacement $d_x$, the four $XY$ chambers were likewise oriented, while the $XV$ chamber was reversed. The distance between the reconstructed track and the point of the $XV$ chamber is twice the displacement of the electrons in a chamber. The $d_x$ was measured for different magnetic fields (fig. 2 (right)). The spatial resolution was measured as a function of the gain of the GEM and of the magnetic field (fig. 3 (right)). As shown in fig. 3 (left), the efficiency drops as the magnetic field increases. This effect can be reduced working at higher gain which consequently involves a worse spatial resolution.
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Fig. 2. – GARFIELD simulation (left) and measurements of electron displacement as a function of the magnetic field (right).

Fig. 3. – Efficiency as a function of voltage and magnetic field (left) and $x$ resolution as a function of the magnetic field (right).

4. – Conclusions

The beam tests performed on the KLOE-2 Inner Tracker prototype have demonstrated the feasibility of this detector. The readout geometry was validated and the test in magnetic field was successful in terms of achieved spatial resolution. The R&D phase is concluded and the construction of the Inner Tracker has started.

REFERENCES