The KLOE drift chamber

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Preprint submitted to Elsevier Preprint *26 May 2000*

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Abstract

The tracking detector of the KLOE experiment is 4 m diameter, 3.3 m length drift chamber, designed to contain a large fraction of the decays of low energy K_L produced at the Frascati DAΦNE ϕ–factory. The chamber is made by a thin carbon fiber structure and operated with a helium based gas mixture in order to minimise conversion of low energy photons and multiple scattering inside the sensitive volume. The tracking information is provided by 58 layers of stereo wires defing 12,582 cells, 2×2 cm^2 in size in the 12 innermost layers and 3×3 cm^2 in the outer ones. Details of the chamber design, calibration procedure and tracking performances are presented.

The main goal of the KLOE experiment [1] at the Frascati ϕ–factory DAΦNE is the measurement of the CP violation parameter $\Re(\varepsilon'/\varepsilon)$ in the decay of neutral kaons. This requires a large acceptance for K_L decays into charged and neutral particles, precise location of the decay vertices, good invariant mass resolution, γ–e–π identification and good self-calibrating capabilities of the detector. The two main KLOE sub-detectors are thus a lead-scintillating fiber e.m. calorimeter [2] and a large volume drift chamber, both surrounded by a superconducting coil providing a 0.6 Tesla magnetic field. In the December 1999 pilot run KLOE collected 2.42 pb^{-1}, corresponding to about 7.7 millions ϕ decays, which allowed precise calibration of the detector and first physics studies.

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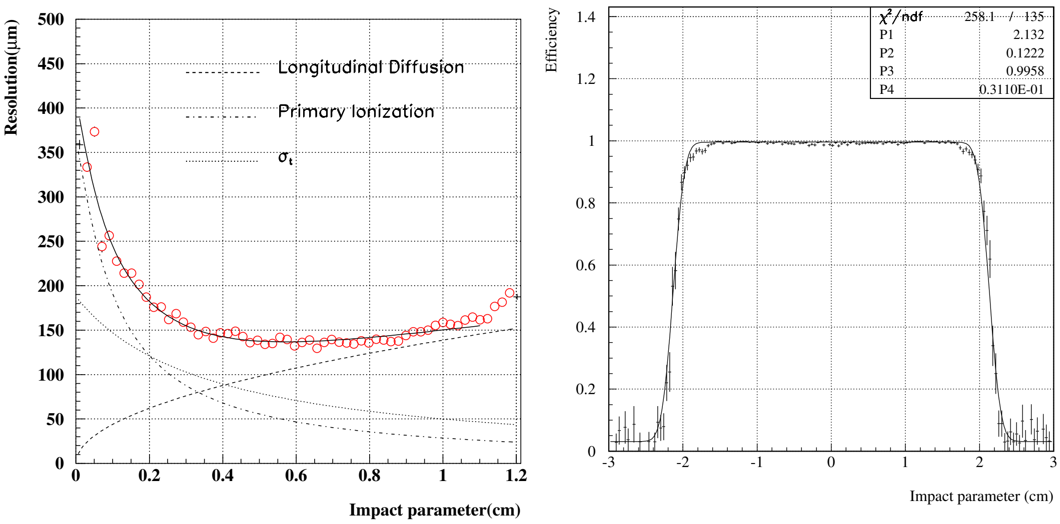

Fig. 1. Left: Spatial resolution (left) and cell efficiency (right) as a function of the impact parameter.

1 Requirements and specifications

The design of the tracking detector[3] is driven by the requirements of having a large, homogeneous active volume that should also be highly transparent to minimise K_L regeneration, photon conversion before the calorimeter and multiple scattering. It should provide tracking in three dimensions with a resolution in the bending plane of ~ 200 μm and a decay vertex resolution of ~ 1 mm over the whole sensitive volume. It also should be used to provide a fast trigger on charged particles to complement the calorimetric trigger[4]. The chamber is made by a 4 m diameter, 3.3 m long C-fiber cylinder, closed by 2 C-fiber 8 mm thick spherical end-plates, and is filled with a 90% He–10% iC_4H_{10} gas mixture. There are 12 582 approximately square cells, 12 2×2 cm^2 layers in the inner part, and 46 3×3 cm^2 outer layers; the geometry is "all-stereo" with alternating angles ($60\div150$ mrad) at costant drop (1.5 cm). The ratio between the silver plated 80 μm Al field wires and the gold plated 25 μm W wires is 3:1, for a grand total of 52 140 wires.

2 Performances

Since drift velocity is not saturated and the shape of the cells vary along the chamber axis according to the stereo geometry, track reconstruction is based on a set of 232 time-to-space relations depending on 6 cell-shape parametrisations and different incidence angles. Each relation is defined by a sixth order Chebychev polynomial computed by an iterative procedure applied to tracks produced by cosmic rays and/or Bhabha pairs. Space-to-time relations are

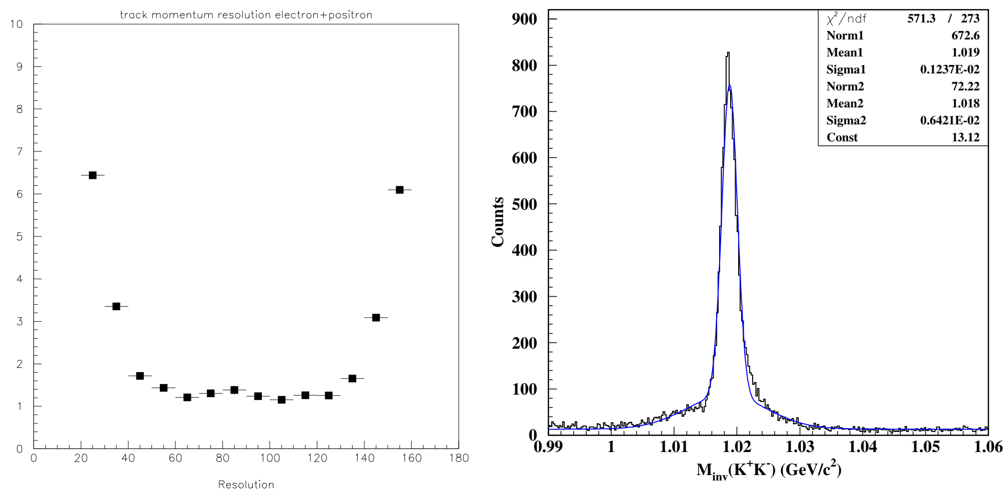

Fig. 2. Momentum resolution for Bhabha's (left) and reconstructed invariant mass of $\phi \to K^+K^-$ (right).

varied until track fit residuals are smaller than 50 μm (with the exclusion of the region near the wire). As a result a spatial resolution (Fig. 1) of about 140 μm over the largest part of the cell is achieved. Tracking efficiency is estimated by interpolating fitted tracks and looking for hits at the intersection of the expected trajectory with layers. As shown in Fig. 1 the efficiency is larger than 99% over the whole cell.

The absolute momentum scale is fixed using Bhabha, di-muon and $\pi^+\pi^-\pi^0$ events produced in e^+e^- collisions and from a series of decays such as $K_s \to \pi^+\pi^-$, $K_L \to \pi^+\pi^-\pi^0$ and $K_L \to \ell\nu_\ell\pi$ which span the full momentum range. Tracking takes into account the precise determination of wire positions and the measured map of the magnetic field. Deviations from nominal values are at the level of 0.1%, while momentum resolution is better than 0.3% for large angle Bhabha's ($45^\circ < \theta < 135^\circ$), as shown in Fig. 2. The energy loss in the drift medium (gas+wires) and in the chamber walls is also taken into account. This correction is particulary relevant for the low momentum kaons produced in $\phi \to K^+K^-$ decays. In Fig. 2 the reconstructed ϕ peak is reproduced at the nominal value with an accuracy of 1.2 MeV/c^2.

The advantage of a ϕ-factory is that K_s and K_L are automatically produced in pairs, thus providing simple and effective tags. The drift chamber is used to tag the presence of a K_L by identifying a $K_S \to \pi^+\pi^-$, complementing the $K_S \to \pi^0\pi^0$ tagging with the calorimeter. The beam pipe around the IP is spherical in shape with a radius of 10 cm ($\simeq 16\ \lambda_S$), so that all K_s's decay in vacuum. The K_s is tagged using the charged decays of the K_L (mostly semileptonic and $\pi^+\pi^-\pi^0$) by the presence of a two-tracks vertex well inside the chamber. Since about 70% of K_L's do not decay in the chamber, this tag is complemented by another identyfing those K_L ($\sim 15\%$) which interact in the calorimeter. Fig. 3 shows the two-pions invariant mass in the CP allowed $K_S \to \pi^+\pi^-$ and CP violating $K_L \to \pi^+\pi^-$ decays: the nominal value for

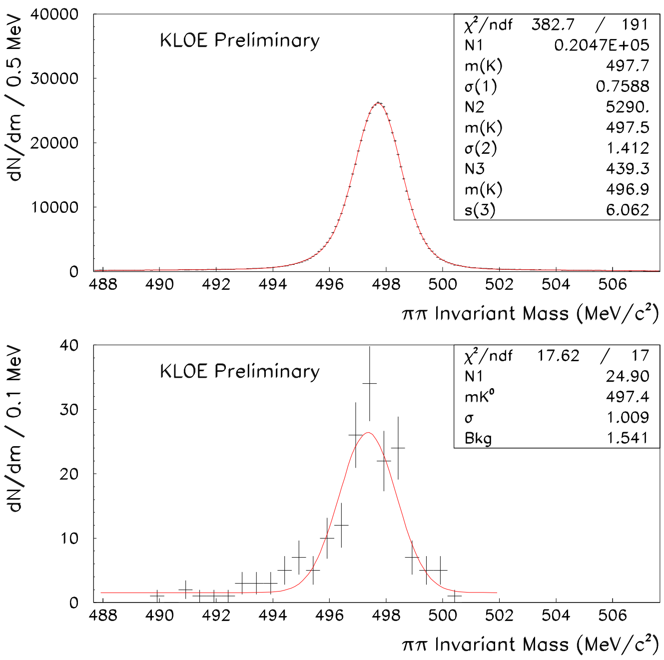

Fig. 3. Reconstructed invariant mass of $K_S \to \pi^+\pi^-$ and $K_L \to \pi^+\pi^-$.

the neutral kaon mass is found with a resolution of about 1 MeV$/c^2$. The CP violating sample was selected among the tagged K_L decays into two charged particles, by loose requirements on the missing mass and missing momentum of the two pions system.

In conclusion data collected during the 1999 DAFNE pilot run have been used to confirm the good performances of the drift chamber, which had already measured with cosmic rays since the chamber installation in March 1998. In addition e^+e^- data have allowed a precise calibration and an exaustive test of tracking capabilities, which fully satisfy design requirements thus allowing a clean observation of CP violating events and preliminary kaon decays studies.

References

[1] The KLOE collaboration, LNF-93/002 (1993).

[2] S. Miscetti for the KLOE collaboration, *First performances of the KLOE electromagnetic calorimeter at DAΦNE*, these proceedings, and references therein.

[3] The KLOE collaboration, LNF-94/028 (1994).

[4] B. Sciascia for the KLOE collaboration, *The KLOE trigger system*, these proceedings, and references therein.