K_L^0 Detector for a Neutral Beam Test Facility

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October 6, 2003

Abstract

A relatively simple two-arm detector for detection of two prong K_L^0 decays in the neutral beam test facility is described. The estimated detection rate is ~ 10 $K_L^0 \to \mu^\pm\pi^\mp\nu$ decays per 10^{12} protons on target. With a bunched beam, the K_L^0 momentum could be measured to a precision of $\sim 5\%$.

At the proposed Neutral Beam Test Facility, we would like to measure the K_L^0 and neutron spectra and flux both relative and absolute. Following earlier work with a bunched neutral beam at the Princeton-Pennsylvannia Accelerator [1], I studied the capabilities of a simple two-arm detector for detecting two-prong K_L^0 decays.

Five million $K_L^0 \to \mu^\pm\pi^\mp\nu$ decays in the range $400 < Z(K_L^0) < 800$ cm for the standard 100×5 mrad^2 beam aspect ratio were generated with the FastMC where $Z(K_L^0)$ is the K_L^0 decay point. The K_L^0 were generated with the Kapinos 45° spectrum with no angular dependence. In this note, the units are cm, ns and MeV unless otherwise noted. The effect of pion decays is neglected in this study.

The detector is two telescopes; each telescope is a pair of scintillation counters on each side of the beam envelope as diagrammed in Figure 1. The scintillation counters were chosen to have the same dimensions 40×50 cm^2 as the charged veto counters now being investigated at PSI [2].

Figure 2 shows the $X(K_L^0)$ *vs* $Z(K_L^0)$ of all $K_L^0 \to \mu^\pm\pi^\mp\nu$ decays where each arm is traversed by a charged track. The accepted $P(\mu)$ *vs* $P(\pi)$ spectra are shown in Figure 3. The accepted rate of produced K_L^0 is 40.8×10^{-6}. This translates to 11 $K_L^0 \to \mu^\pm\pi^\mp\nu$ per spill assuming a K_L^0 production rate per proton of 10^{-6} and 10^{12} protons on target per spill. Assuming similiar acceptance for the other dominant two-prong decays, $K_L^0 \to e^\pm\pi^\mp\nu$ and $K_L^0 \to \pi^0\pi^+\pi^-$, gives ~ 30 events per spill.

Figure 4 shows the X of the K_L^0 decay *vs* the time difference between the hits in the innermost counter of each telescope. This shows that the time difference information could be used to determine $X(K_L^0)$ to 10 cm or better and that the $X(K_L^0)$ acceptance is a smooth function of $X(K_L^0)$.

Assuming that the resolution on $X(K_L^0)$ is 10 cm and that the hit position in Z in each counter has a resolution of 5 cm [2], the resolution of a single telescope on the reconstructed $Z(K_L^0)$ as a function of $X(K_L^0)$ is shown in Figure 5. Since $\sigma(P)/P \approx \sigma(Z)/Z$, we could measure the K_L^0 momentum to 5% or better. The acceptance is reasonably uniform in $P(K_L^0)$ as show in Figure 6.

The telescopes could be in other positions relative to the beam. Positioning the telescopes on either side of the beam permits a measurement of the angular dependence of the K_L^0 beam, reduces the rate from cosmics and eases installation. They would also be in the most intense part of the neutron halo and would thus provide a good test of the proposed charged veto counters.

To combat neutron background, the earlier experiment [1] added a thin steel sheet in front of the outermost counter in each telescope as well as a thick absorber and an additional counter in anti-coincidence. Some shielding upstream of the telescopes would probably be needed.

In combination with some sort of neutron detection, we could probably get a reasonably precise measurement of the relative K_L^0 to neutron rates. It is not clear to me that we could measure the absolute K_L^0 rate with this simple detector.

I thank Nicolo Cartaglia, Laur Littenberg and Mike Sivertz for helpful discussions.

References

[1] K.G. Vosburgh *et al.*, Phys. Rev. **D 6** (1972) 1834.

[2] `http://pubweb.bnl.gov/people/e926/meetings/phone/cpv_aug03.pdf`

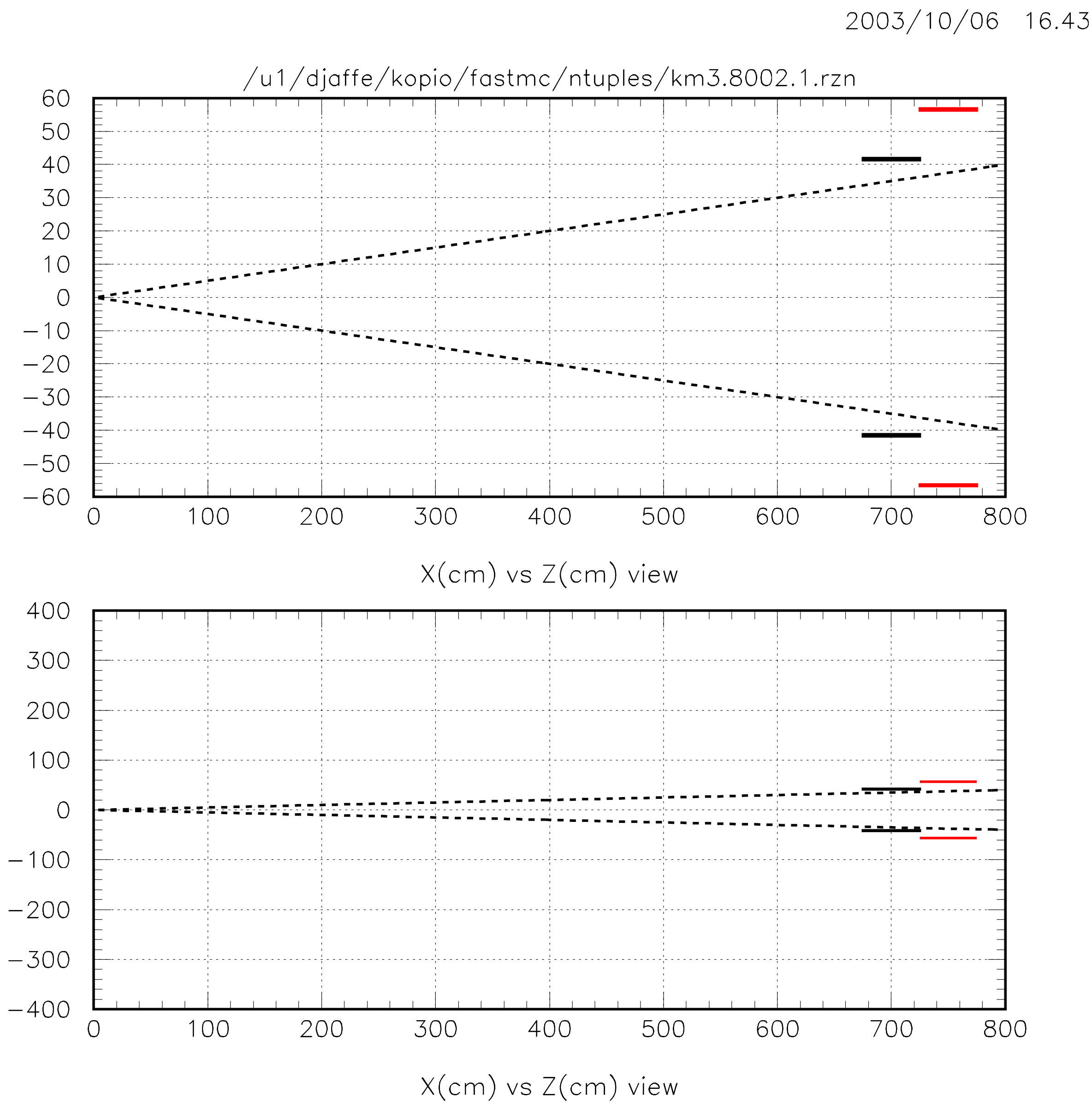

Figure 1: The X vs Z view of the two-arm detector. The horizontal and vertical scales are the same in the lower figure and the horizontal scale is expanded in the upper figure. The dashed line shows the beam envelope. The black and red rectangles represent the detectors.

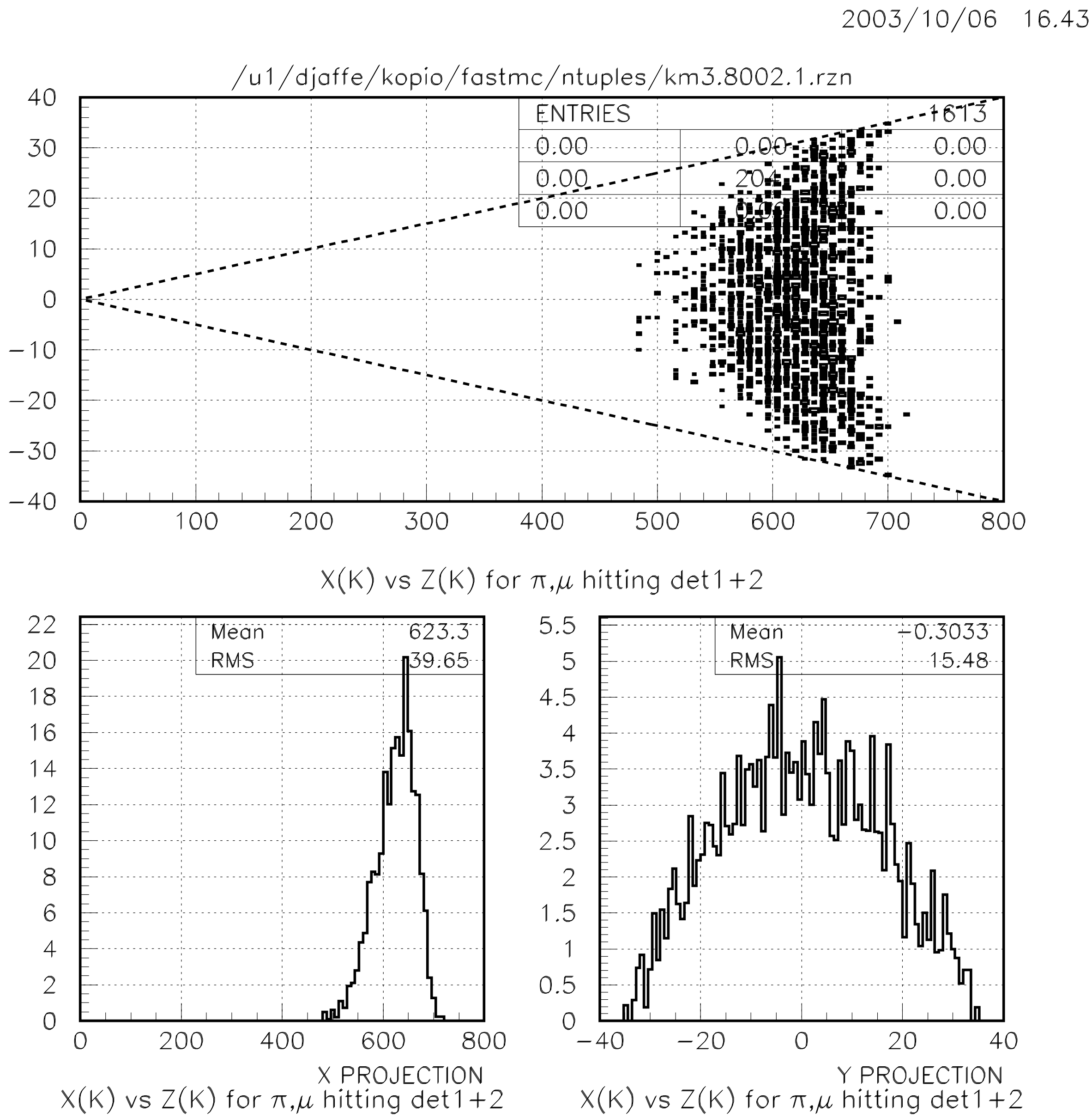

Figure 2: The X vs Z of the K_L^0 decay point accepted by the two-arm detector. The dashed line shows the beam envelope. The lower two plots show the projections on the horizontal and vertical axes.

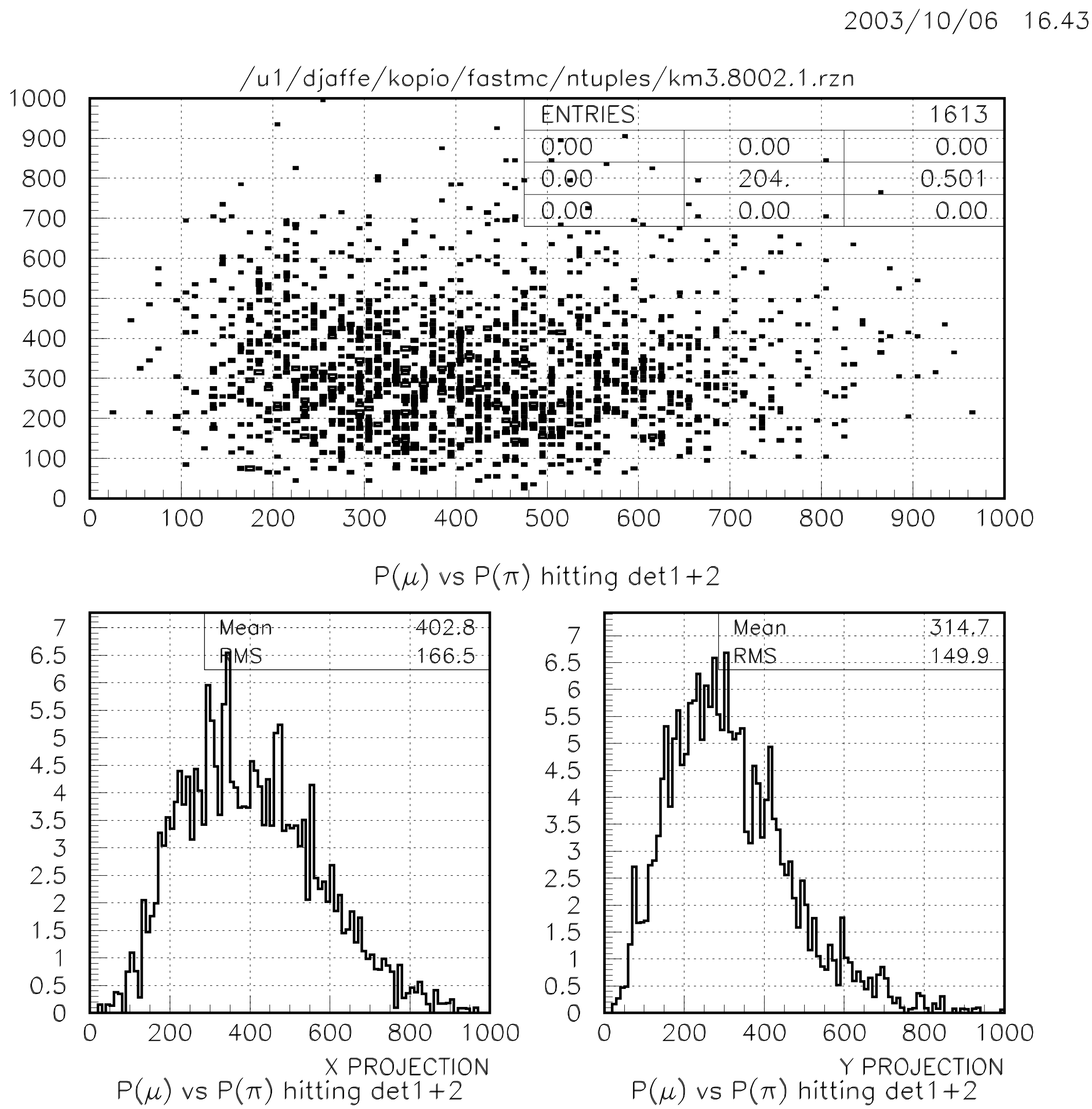

Figure 3: The accepted μ vs π momentum spectrum in MeV/c. The lower two plots show the projections on the horizontal ($P(\pi)$) and vertical ($P(\mu)$) axes.

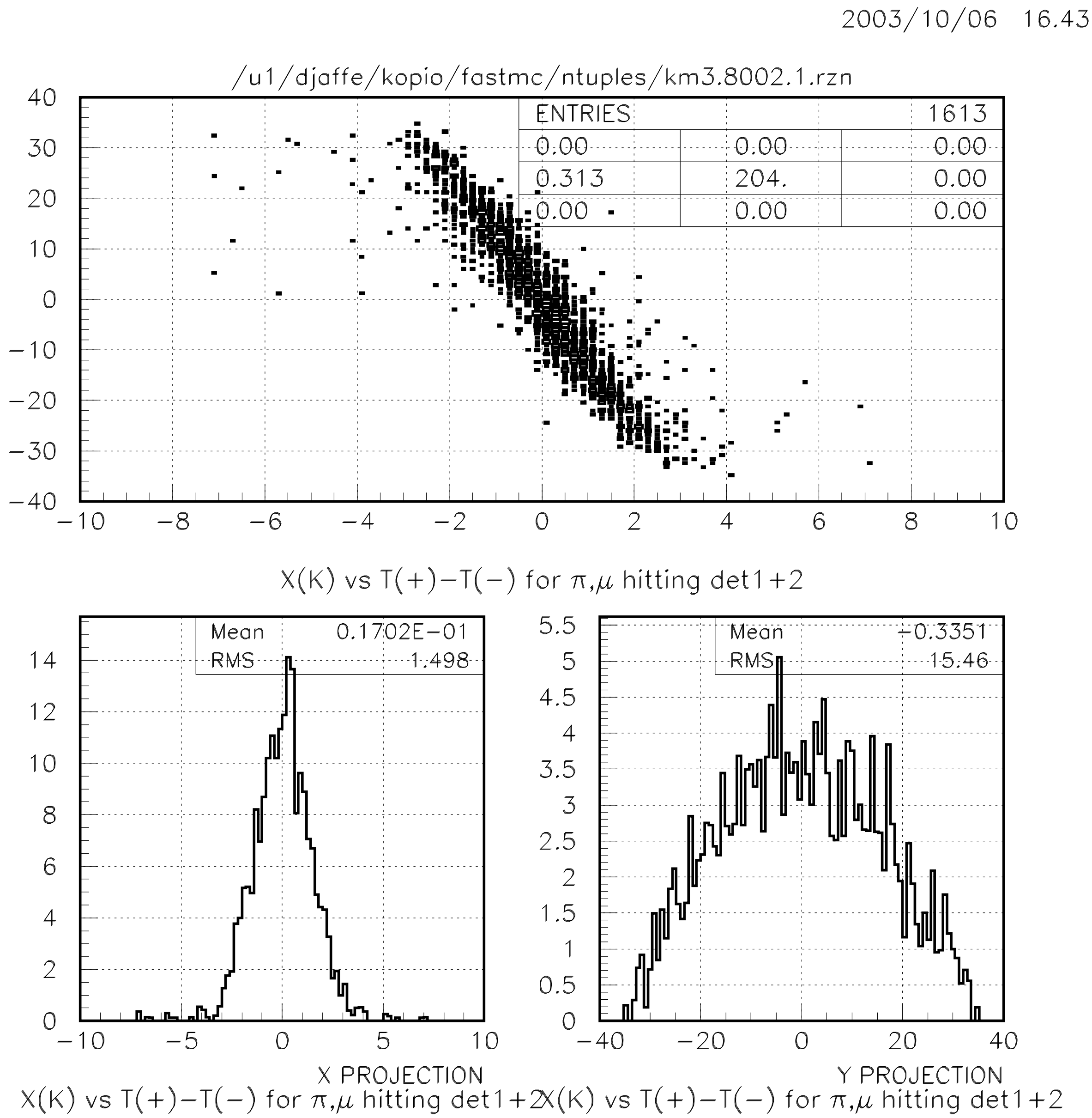

Figure 4: The accepted X of the K_L^0 decay *vs* the time difference between the hits in the innermost counter of each telescope. The lower two plots show the projections on the horizontal and vertical axes.

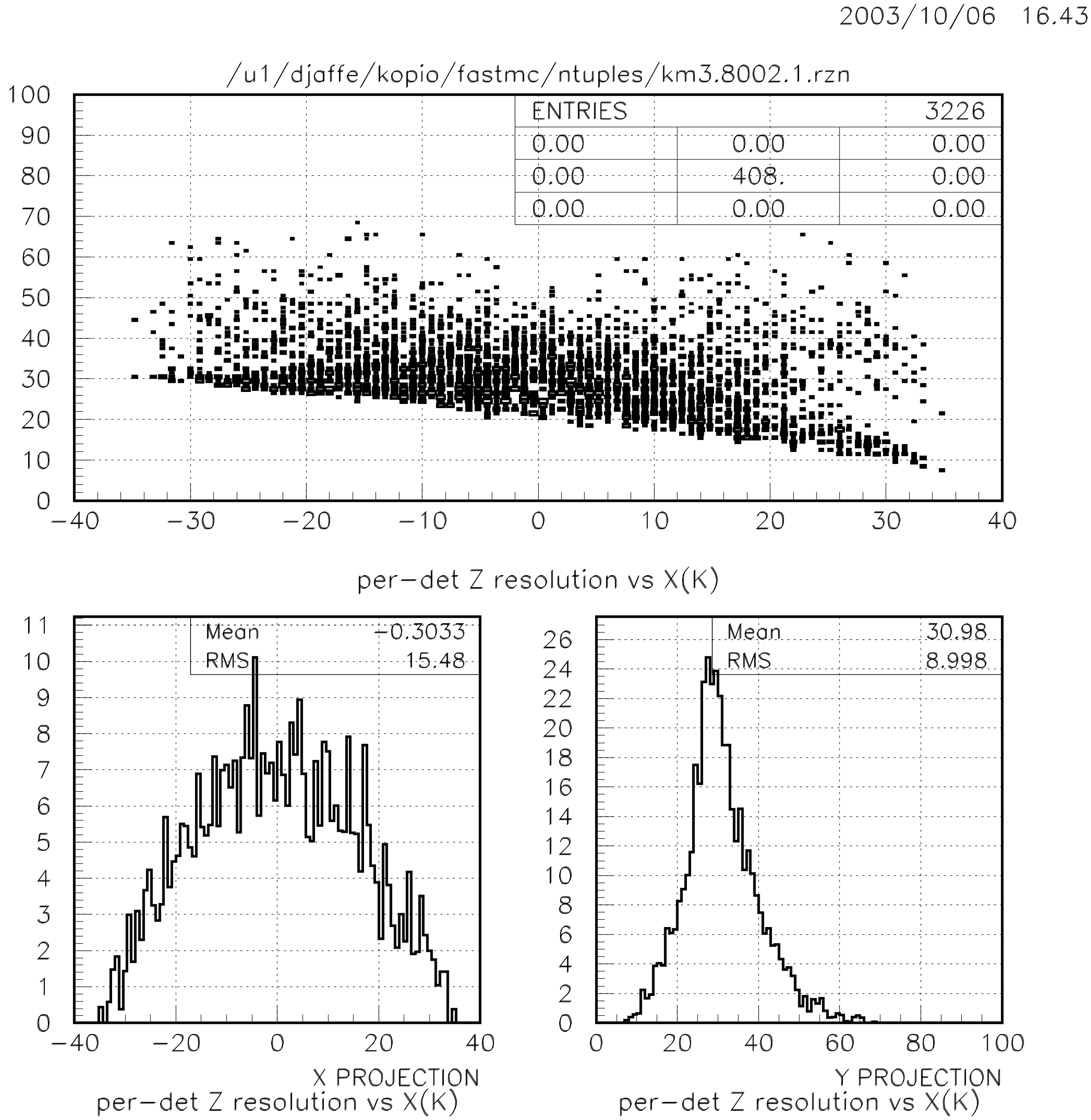

Figure 5: The calculated per-detector $Z(\mathrm{K_L^0})$ resolution as a function of $X(\mathrm{K_L^0})$ for the telescope on the +X side of the beam. The lower two plots show the projections on the horizontal and vertical axes.

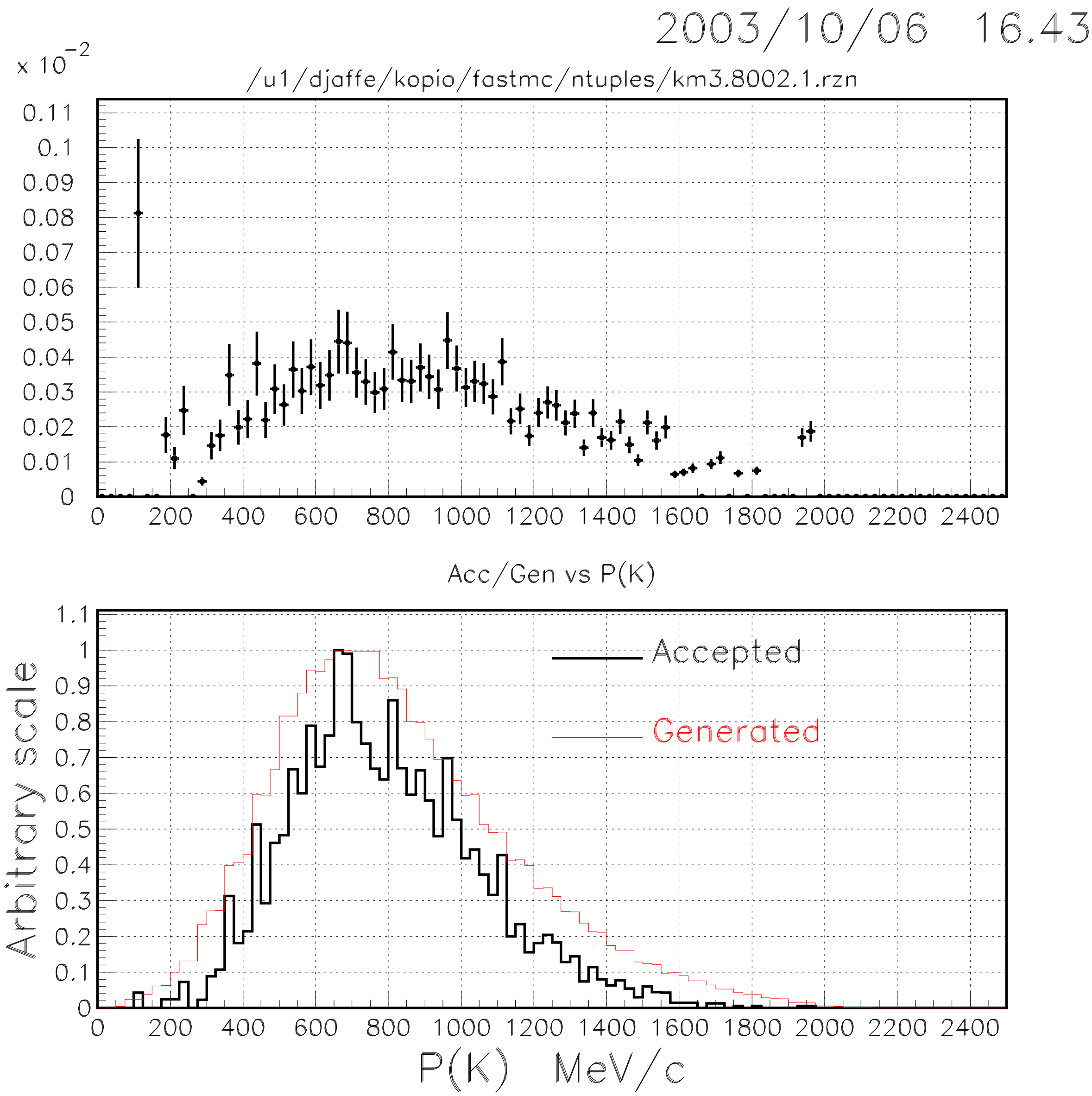

Figure 6: Upper: The acceptance as a function of $P(\mathrm{K_L^0})$. Lower: The generated (accepted) distribution of events with an arbitrary vertical scale as a function of $P(\mathrm{K_L^0})$ is shown as a thin red (thick black) line.