KOPIO TN064

K_L^0 and neutron propagation in KOPIO GEANT MC

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Abstract

The status of K_L^0 and neutron propagation and interaction in the KOPIO GEANT MC v05_2 is described. Several problems have now been remedied.

1 The problem and the solution

We use the GEANT3 GCALOR package in the KOPIO Monte Carlo (MC). It has several known flaws [1] that are troublesome for KOPIO.

1. Neutron elastic scattering for kinetic energy above 20 MeV is not implemented. Accurate simulation of neutron elastic scattering is crucial for simulation of the neutron halo [1].

2. The K_L^0 interaction cross section for kinetic energy below 50 MeV is zero.

The MC has been modified to use GEANT3 FLUKA for neutron kinetic energy above 20 MeV. FLUKA has neutron elastic scattering enabled. For neutrons with energy below 20 MeV, the MICAP package, which has elastic neutron scattering, of GCALOR is still used.

For the K_L^0 the MC has been modified to use GEANT3 GHEISHA for kinetic energy below 50 MeV with the K_L^0 cross-section coming from code donated by the KLOE experiment. Above 50 Mev, GCALOR is used.

GCALOR is used for all other particles.

2 Results

Figure 1 shows the generated and accepted neutron momentum spectra for the KOPIO MC with a 5 cm thick lead spoiler in the neutral beam. The results are compared to the expectations based on the $n, {}^{208}$Pb total cross section [2, 3]. Figure 2 shows the same result but in terms of neutron kinetic energy. Figure 3 shows the results for kinetic energy less than 200 MeV. The expected and MC results are compared in a single figure as a function of momentum and kinetic energy in Figure 4. There is a small, but clear, discontinuity in the transmission rate at 20 MeV where the MC switches from MICAP to FLUKA. The agreement between the calculation and the MC is good with MICAP and adequate with FLUKA.

Similar transmission measurements as a function K_L^0 momentum and kinetic energy are shown in Figures 5 and 6. In order to compute the K_L^0 transmission, the K_L^0 was artificially given an infinite lifetime in the MC. The MC results are compared with expectations based on the measured K_L^0, Pb cross section for momenta between 168 to 343 MeV/c [4], above 2.1 GeV/c [5] and the calculated cross section from the eikonal approximation [6]. There is good agreement between KOPIO MC and the expectations from the measured cross section. In contrast to the neutron situation, there is no clear discontinuity in the K_L^0 transmission rate at the transition between the GHEISHA and GCALOR simulations. Prior to the inclusion of the KLOE modifications, the K_L^0 transmission rate below 50 MeV was zero with GHEISHA and 100% for GCALOR. The step like structure in the generated K_L^0 spectrum at low kinetic energy is due to the interpolation algorithm used in the KOPIO MC.

The transmission rate for neutrons and K_L^0 through the 5 cm lead spoiler averaged over the generated spectra is $53.35 \pm 0.16\%$ and $69.23 \pm 0.12\%$, respectively, for a relative n/K_L^0 rate of $77.06 \pm 0.27\%$. In TN-023 [1], the comparable neutron and K_L^0 transmission rates at 0.75 GeV/c are 51.8% (Table 1) and $\sim 65\%$ (Figure 3 "FLUKA no interaction"), respectively, for relative n/K_L^0 rate of $\sim 70\%$. For the current KOPIO MC at 0.75 GeV/c and 5 cm of lead, the neutron and K_L^0 transmission rates $63.3 \pm 0.9\%$ and $72.1 \pm 0.6\%$, respectively. Extrapolating these results to 7 cm of lead gives 52.7% and 63.3%, respectively, in good agreement with the results of TN-023.

3 Conclusion

The neutron and K_L^0 interactions as simulated in v05_2 in the KOPIO Monte Carlo are now in reasonably good agreement with measurements. Neutron elastic scattering is now implemented for all momenta.

4 Acknowledgements

Matthew Moulsen of the KLOE collaboration kindly provided the KLOE memo [6] and the relevant code from the KLOE Monte Carlo. I had informative discussions with Hiro Watanabe and GeiYoub Kim of KEK E391a concerning their use of GEANT3 FLUKA for the E391a collimator and beam line design. I relied on conversations with Andrei Poblaguev and Jaap Doornbos for information about simulations of neutron interactions. Mike Sivertz and Laur Littenberg gave useful comments and guidance.

References

[1] A.A. Poblaguev and M.E. Zeller ,*High Enegy Neutron Halo Simulation*, KOPIO TN-023, 16 July 2001.

[2] Seven representive points were taken from Figure 1 of R.L.Schutt *et al.*, Phys. Lett **B203** (1988) 22.

[3] Table III of W. Schimmerling *et al.*, Phys. Rev. **C7** (1973) 248.

[4] G.A. Sayer *et al.*, Phys. Rev. **169** (1968) 1045.

[5] V.M. Berezin *et al.*, Yad.Fiz. **43** (1986) 358.

[6] R. Baldini and A. Michetti, K_L *interactions and* K_S *regeneration in KLOE*, KLOE memo 30, July 1995.

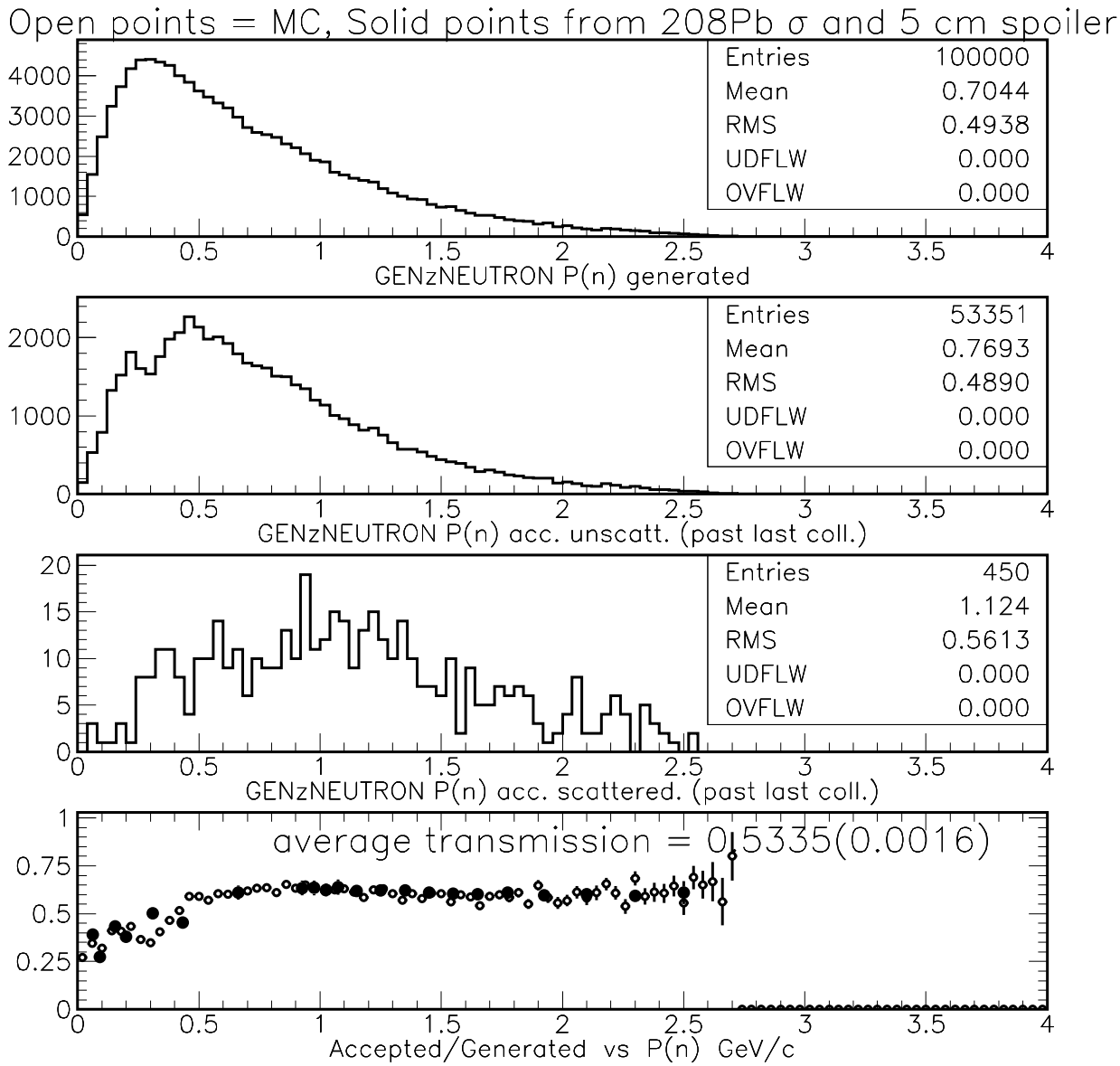

Figure 1: Top: Generated neutron momentum spectrum,
second from top: accepted, unscattered neutron spectum,
second from bottom: accepted, scattered neutron spectrum,
bottom, open points: ratio of the accepted, unscattered neutron spectrum to the generated spectrum,
bottom, closed points: calculated transmission for a 5 cm thick ^{208}Pb spoiler. "Accepted" means that the neutron was in the beam at a z position beyond the most downstream collimator.

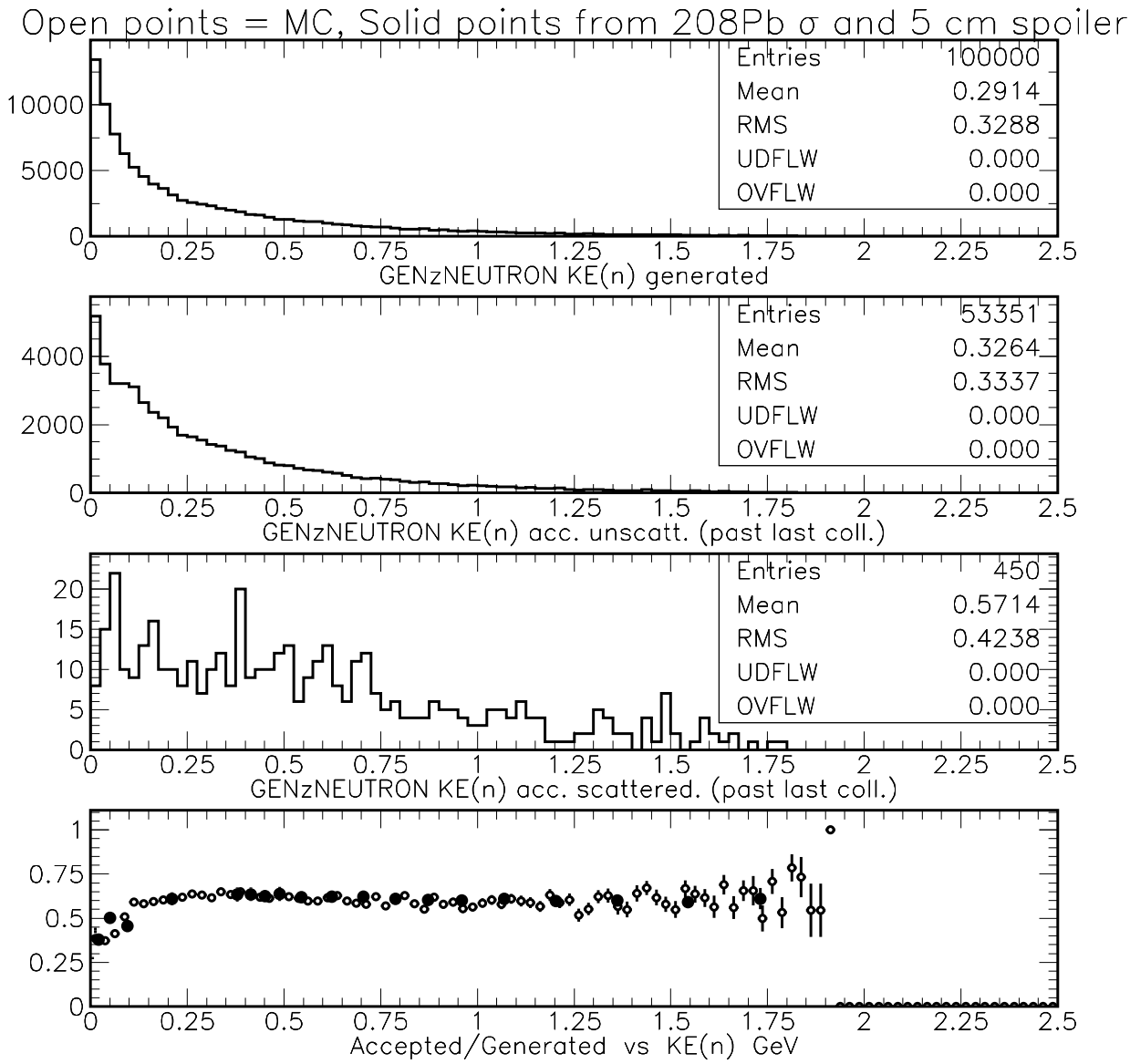

Figure 2: Top: Generated neutron kinetic energy spectrum,
second from top: accepted, unscattered neutron spectum,
second from bottom: accepted, scattered neutron spectrum,
bottom, open points: ratio of the accepted, unscattered neutron spectrum to the generated spectrum,
bottom, closed points: calculated transmission for a 5 cm thick ^{208}Pb spoiler. "Accepted" means that the neutron was in the beam at a z position beyond the most downstream collimator.

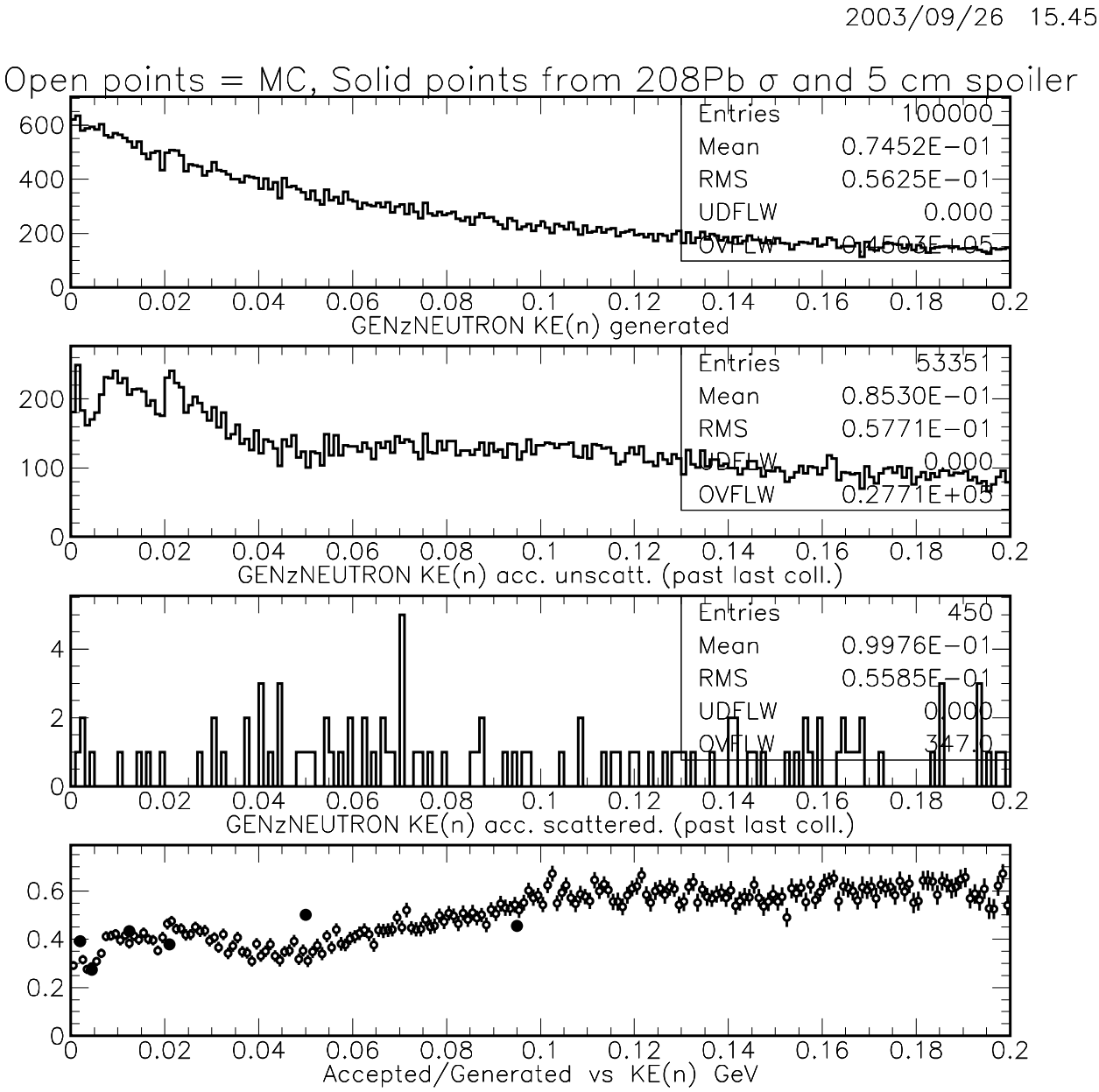

Figure 3: As for Figure 2 but for the low kinetic energy region only.

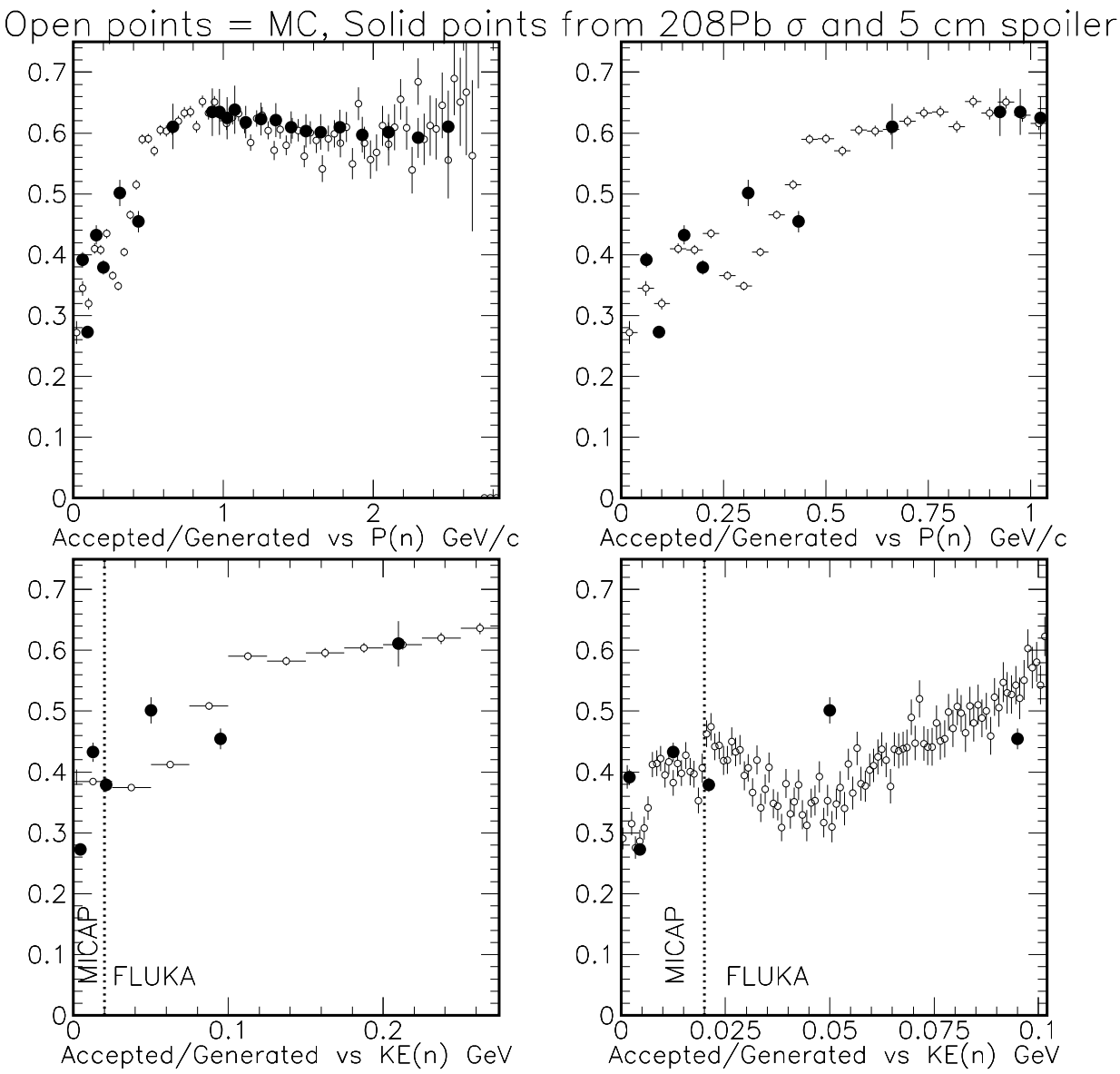

Figure 4: Comparison of MC results (open points) and expectation (solid points) as a function of momentum (top) and kinetic energy (bottom). The applicable regions in kinetic energy for the MICAP and FLUKA simulations are indicated.

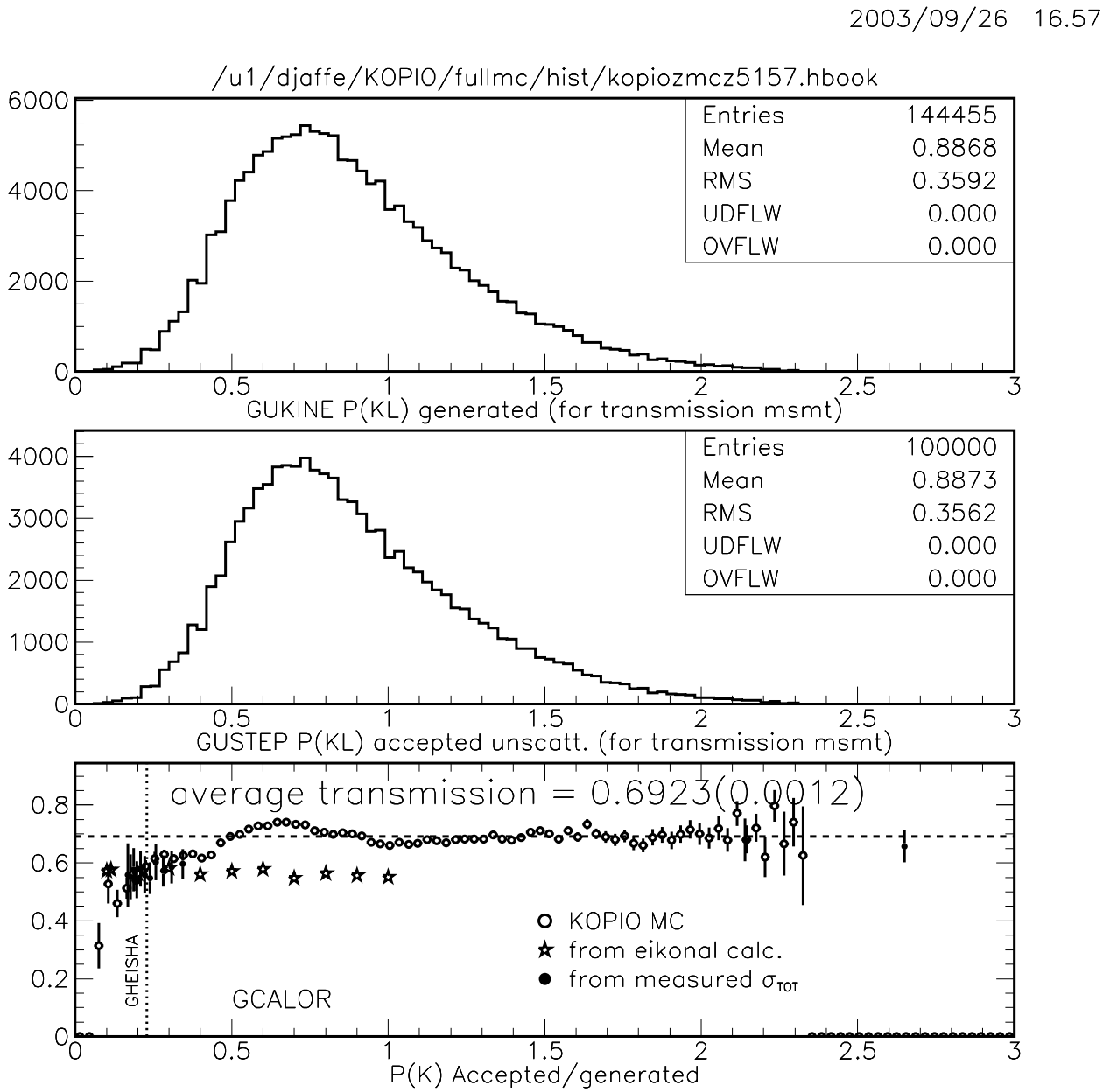

Figure 5: Top: Generated K_L^0 momentum spectrum in GeV/c,
middle: accepted, unscattered spectum,
bottom, open points: ratio of the accepted, unscattered spectrum to the generated spectrum,
bottom, closed points (stars): calculated transmission for a 5 cm thick ^{208}Pb spoiler based on the measured (calculated) K_L^0, Pb cross section. "Accepted" means that the K_L^0 was in the beam at a z position beyond the most downstream collimator. The applicable regions for the GHEISHA and GCALOR simulations are indicated.

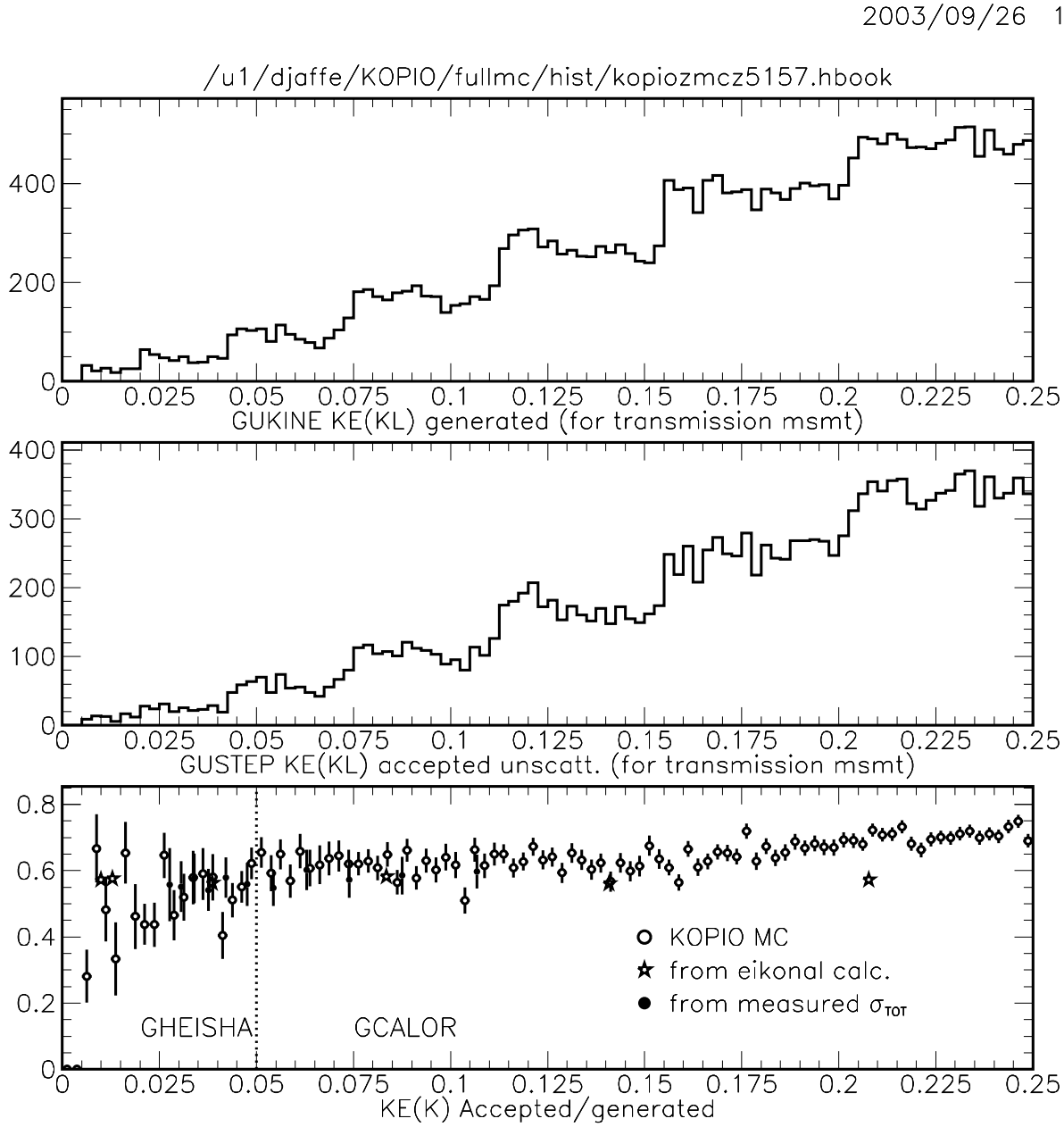

Figure 6: Top: Generated K_L^0 kinetic energy spectrum in GeV,
middle: accepted, unscattered spectum,
bottom, open points: ratio of the accepted, unscattered spectrum to the generated spectrum,
bottom, closed points (stars): calculated transmission for a 5 cm thick ^{208}Pb spoiler based on the measured (calculated) K_L^0, Pb cross section. "Accepted" means that the K_L^0 was in the beam at a z position beyond the most downstream collimator. The applicable regions for the GHEISHA and GCALOR simulations are indicated.