PROCEEDINGS OF SCIENCE

Observation of the radiative kaon decay $K^- \to \mu^- \nu \pi^0 \gamma$ and precise measurement of the K_{e3} decay rate *

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The ISTRA+ results on first observation of the radiative kaon decay $K^- \to \mu^- \nu \pi^0 \gamma$ are presented. Preliminary results on the new precise measurement of the K_{e3} decay rate are described.

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1. Radiative decay

The study of the radiative kaon decays can give valuable information on the kaon structure and allows for good tests of theories describing hadron interactions and decays, like Chiral Perturbation Theory (ChPT). Until now the studies of the radiative K_{l3} decays are restricted by the decay modes with electrons in the final state or by the studies of K_L decays. Only one paper [1], dated by 1973, published the upper limit on the branching ratio of the $K^+_{\mu 3\gamma}$ decay. The interest to the study of $K_{l3\gamma}$ decays is further enhanced by the theoretical proposals to search for effects of new physics using T-odd kinematical variable $\xi = \vec{p}_\gamma \cdot (\vec{p}_l \times \vec{p}_\pi / m_K^3$ [2, 3].

First observation of the radiative $K^-_{\mu 3}$ decay , made by the ISTRA+ Collaboration [4], is described in this Section. Only few essential points are given, more details can be found in [4].

350 million trigger events were collected using the ISTRA+ spectrometer in the negative unseparated secondary beam with beam momentum ≈ 25 GeV/c during physics run at the end of 2001. Events with one charged track and three electromagnetic showers in the calorimeter SP_1. were selected, effective mass of two showers should be near m_{π^0}. The muon identification was based on the MIP signal in the calorimeter SP_1 and on the information from the hadron calorimeter HCAL. Two variables have been used, the total HCAL response near charged track, and the fraction of energy released in three last planes of the calorimeter. Fig. 1 illustrates the behaviour of these variables for selected $K_{\pi 2}$ and $K_{\mu 2}$ samples. Clear separation between pion and muon hypotheses is observed.

Two estimators have been used to search for signal, the effective mass $M(\mu\nu\pi^0\gamma)$, calculated assuming that the missing momentum is taken away by the zero-mass particle and the missing mass squared $m^2(\mu\pi^0\gamma)$ to the $(\mu\pi^0\gamma)$ system. The effective mass and missing mass squared spectra for the region with the photon energy E^*_γ in the kaon rest frame below 30 MeV are shown in Fig. 2. Clear signal is observed in both spectra. Three main backgrounds survive at the final stage: $K_{\pi 3}$ contribution (red), $K_{\mu 3}$ with extra photon(blue) and non-π^0 background (the remaining cross-hatched area). The signal has been parameterized by the sum of two Gaussians with the width and the central position fixed using MC events. The number of signal events is equal to 383.7 ± 40.9 for the efective mass spectrum and is equal to 412.9 ± 36.2 for the missing mass squared spectrum.

The measured branching fraction for this region, normalized to the BR($K_{\mu 3}$), is equal to $R = (2.70 \pm 0.29(\text{stat}) \pm 0.26(\text{syst})) \times 10^{-3}$. This value agrees with theoretical prediction equal to 2.1×10^{-3}.

The asymmetries in the photon angular distribution and in the ξ distribution have been measured also, see Fig. 3. It has been found that the angular asymmetry is 2 standard deviations away from the theoretical prediction.

2. K_{e3} branching ratio

Our approach to the measurement of the branching ratio is based on the observation the K_{e3} decay is the dominant source of inclusive electrons in the one track sample, the backround processes do not exceed fraction of % of the Br(K_{e3}) and can be easily corrected for. The number of electrons has been determined from the fit of the E/p distribution (where E is equal to the SP_1 shower energy

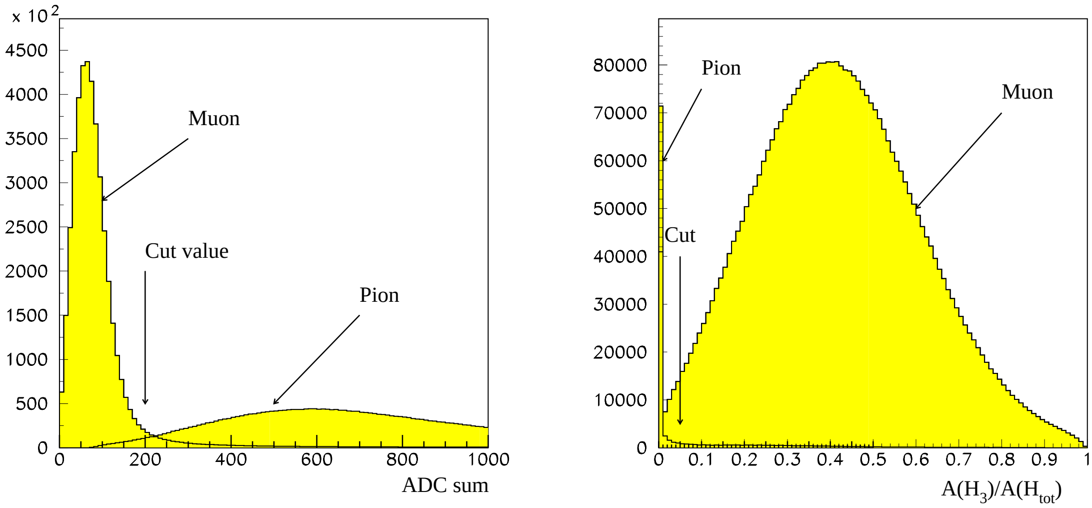

Figure 1: Muon identification variables, the HCAL response(left) and the fraction of energy in three last planes(right).

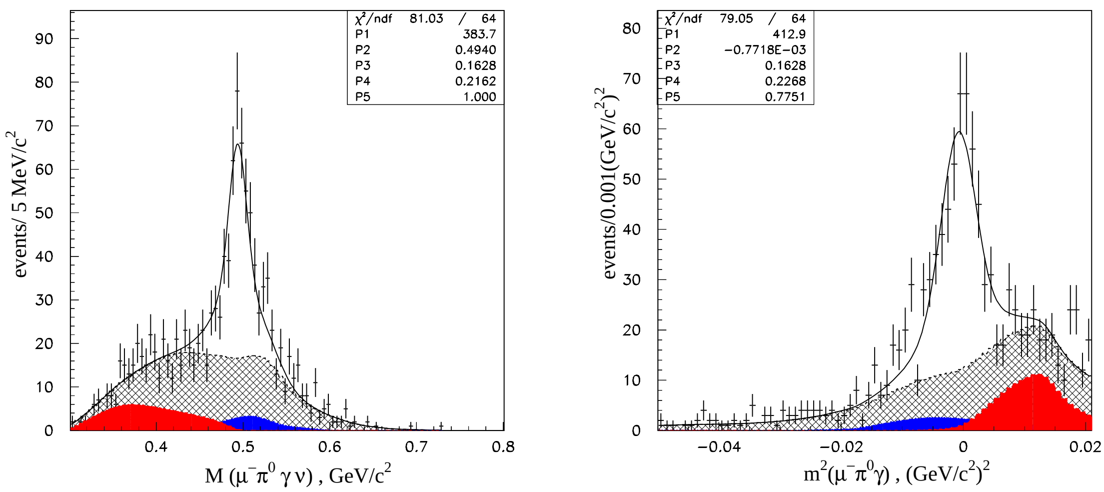

Figure 2: Effective mass(left) and missing mass squared(right) spectra for the region with photon rest energy below 30 MeV.

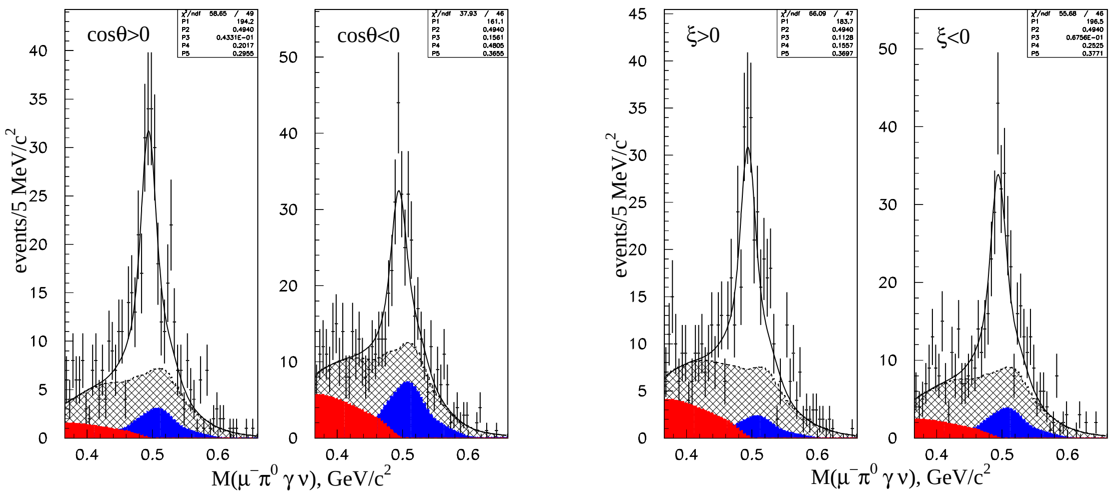

Figure 3: Effective mass spectra for two $\cos\theta$ intervals(left part) and two ξ intervals(right part).

and p is equal to the track momentum). The number of $K_{\pi 2}$ events, used for normalization, has been determinend from the fit of the peak in the p^*_π (charged pion momentum in the kaon rest frame) distribution. No π^0 reconstruction is needed in this method.

E/p and p^*_π spectra are shown in Figs 4 and 5 for MC data and for real events respectively. The spectra in Fig.5 have been parameterized by the sum of two Gaussians and smooth exponential background $A \times \exp(-p1 * x - p2 * x^2)$. The number of observed electrons is equal to $N_e = (2.1781 \pm 0.0024) \times 10^6$, the number of $K_{\pi 2}$ events is equal to $N(K_{\pi 2}) = (10.426 \pm 0.0056) \times 10^6$.

Our preliminary estimate of the branching ratio is equal to $(5.22 \pm 0.014(\text{stat}) \pm 0.035(\text{norm}) \pm 0.1(\text{syst}))\%$. This value is consistent with the measurement of the E865 Collaboration[5]. Our studies of systematics are still in progress.

References

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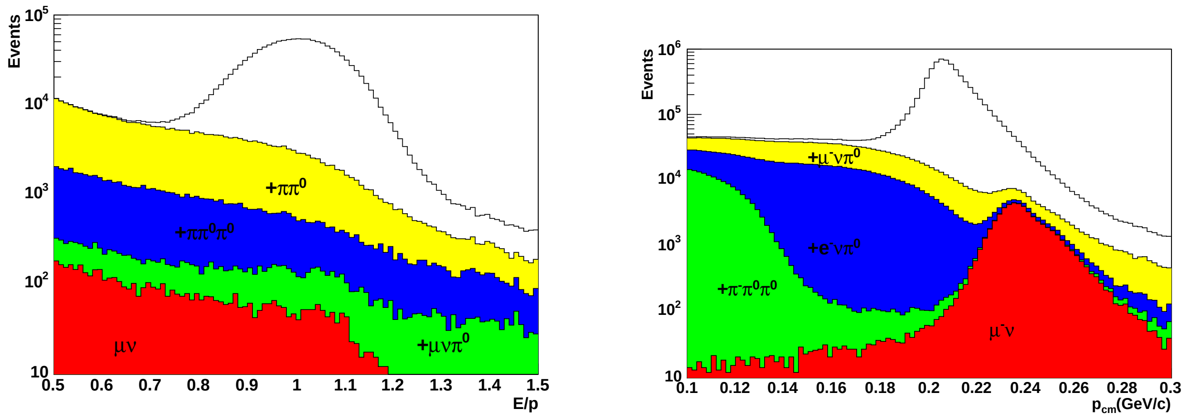

Figure 4: E/p and p^*_π spectra for MC data. Different colours show contributions of the dominant kaon decay modes.

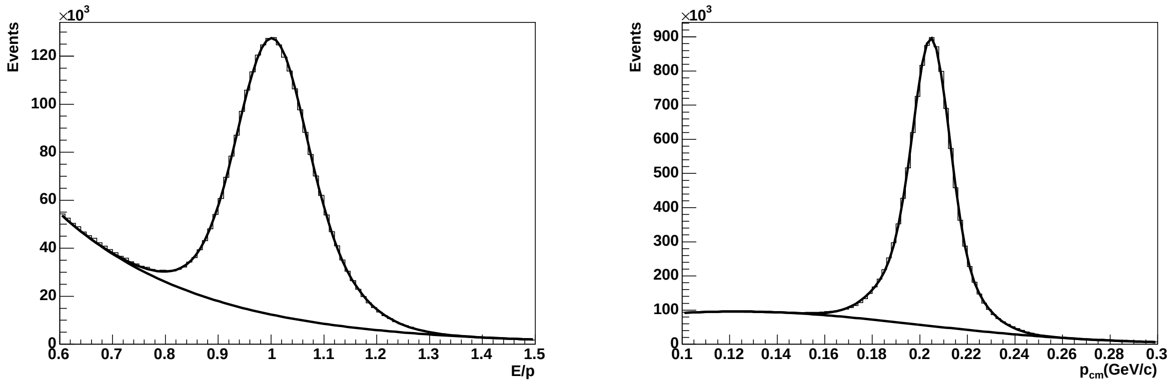

Figure 5: E/p and p^*_π spectra for real events.