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MEASUREMENT OF DIRECT PHOTON EMISSION IN $K^+ \rightarrow \pi^+\pi^0\gamma$ DECAY USING STOPPED POSITIVE KAONS

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1 Motivation

Since the discovery of kaons, their decay properties have continued to provide testing grounds for interaction and structure physics. While various kaon decay channels have long histories as remarkable tools to test the weak and electromagnetic interactions, they also offer means to study strong interaction dynamics at low energy in terms of effective theories such as chiral perturbation theories (ChPT), which have been developing recently.

Since the $K^+ \rightarrow \pi^+\pi^0$ decay is hindered as it violates the ΔI=1/2 rule, the internal bremsstrahlung (IB) to the radiative $K^+ \rightarrow \pi^+\pi^0\gamma$ ($K_{\pi 2\gamma}$) decay is also suppressed. This feature, in turn, enhances the direct emission (DE) which is sensitive to the meson structure. It should be noted this is rather

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unusual, since most of the radiative decays of mesons are predominantly IB type. The current interest of the DE process is the sensitivity to the chiral anomaly which appears as the magnetic component of DE. In terms of ChPT, it enters the magnetic amplitude at $O(p^4)$ predominantly, while IB arises from $O(p^2)$ with suppression. Also, the electric amplitude of DE may arise from $O(p^4)$, which one can identify through the interference pattern (INT) with IB.

Four experiments [3, 4] have reported on the DE branching ratio in the region of $55 < T_{\pi^+} < 90$ MeV, where T_{π^+} is the π^+ kinetic energy. Although the DE component is significantly enhanced with decreasing π^+ energy, these experiments restrict the π^+ energy region to remove backgrounds from $K^+ \to \pi^+\pi^0\pi^0$ ($K_{\pi 3}$). Here, we present a measurement of DE in the $K_{\pi 2\gamma}$ decay. The experiment used a stopped K^+ beam in conjunction with a superconducting toroidal spectrometer. We collected the $K_{\pi 2\gamma}$ events by extending the T_{π^+} region below the $K_{\pi 3}$ end-point energy $T_{\pi^+}^{\max} = 55$ MeV.

2 Experiment

The experiment (KEK-PS E470 experiment) was performed at the KEK 12 GeV proton synchrotron. The $K_{\pi 2\gamma}$ data were collected with the experimental apparatus based on the E246 experiment searching for T-violation in $K^+ \to \pi^0\mu^+\nu$ decay [5]. Beside the T-violation search, spectroscopic studies for various decay channels have been carried out using the same detector system [6]. For the E470 experiment, a Pb-plastic sandwich detector with 2.6 radiation length was newly installed at the outer radius of the magnet pole to monitor photons escape from the photon detector holes.

A separated 660 MeV/c K^+ beam ($\pi^+/K^+ \sim 7$) was used. The kaons were slowed down by a degrader and stopped in the active target located at the center of the detector system. The $K_{\pi 2\gamma}$ events were identified by analyzing the π^+ momentum with the spectrometer and detecting three photons in the CsI(Tl) calorimeter. Charged particles from the target were tracked and momentum-analyzed using MWPCs. The π^+ were discriminated from e^+ and μ^+ by measuring time-of-flight between counters.

The most important point to reconstruct $K_{\pi 2\gamma}$ was to determine which photons were a pair from a π^0, because there are three combinations to form the π^0. The pair which satisfies the $K_{\pi 2\gamma}$ kinematics was adopted as the correct π^0 pair. However, because of the finite kinematical resolution, the correct pairing probability was 85% for IB and 79% for DE. Since $K_{\pi 3}$ and $K_{\pi 2}$ decays do not satisfy the $K_{\pi 2\gamma}$ kinematics, these backgrounds can be rejected by this analysis.

3 Results

The number of good $K_{\pi 2\gamma}$ events is 4434. The solid lines in Fig. 1 show the experimental $K_{\pi 2\gamma}$ spectra. In order to obtain the detector acceptance and response functions, a Monte Carlo simulation was performed using a GEANT-based Monte Carlo code. The background fraction of the $K_{\pi 3}$ decay was estimated to be 1.2% from the simulation.

The DE branching ratio was determined using the three observables, $\cos\theta_{\pi^+\gamma}$, $\cos\theta_{\pi^0\gamma}$, and E_γ which have characteristic spectra corresponding to the decay processes. The experimental distribution $\rho(\cos\theta_{\pi^+\gamma}, \cos\theta_{\pi^0\gamma}, E_\gamma)$ was fitted to the simulation spectrum of IB[1+α(DE/IB)+β(INT/IB)] with α and β being free parameters. The dotted and dashed lines in Fig. 1 show the fitted spectra and the sole DE components, respectively. The DE and INT components were obtained to be $\alpha = 0.92^{+0.44}_{-0.38}\%$ and $\beta = -0.58^{+0.91}_{-0.83}\%$, respectively [7]. The DE branching ratio in the region of 55$< T_{\pi^+} <$ 90 MeV was then derived as $Br(\mathrm{DE}) = [3.2 \pm 1.3(\mathrm{stat.}) \pm 1.0(\mathrm{syst.}] \times 10^{-6}$ [7], which is consistent with the previous stopped experiment [4]. On the other hand, any significant effects due to the INT term were not observed [7].

4 Conclusion

We have performed a measurement of the $K^+ \to \pi^+\pi^0\gamma$ decay by extending the T_{π^+} region lower bound down to 35 MeV. The detector response and acceptance functions were evaluated by a Monte Carlo simulation based on GEANT. The $K_{\pi 3}$ background contamination in the $K_{\pi 2\gamma}$ data sample was estimated to be negligible by the simulation. The observed DE branching ratio is consistent with the previous stopped experiment. We did not observe any significant effect due to the interference component for IB and DE, indicating the pure magnetic nature of the direction photon emission in the $K_{\pi 2\gamma}$ decay.

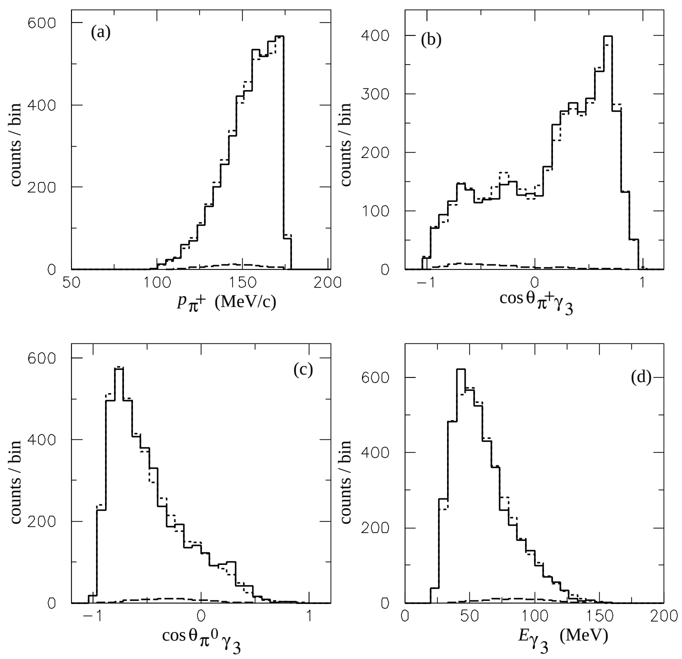

Figure 1: $K_{\pi 2\gamma}$ spectra: (a) π^+ momentum, (b) opening angle between π^+ and γ, (c) opening angle between π^0 and γ, (d) γ energy. The solid lines are the experimental data. The dotted and dashed lines show the fitted spectra and the sole DE components, respectively. The bump structure in (b) is due to the CsI(Tl) assembly structure with 12 holes.

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