MENU 2007
11th International Conference
on Meson-Nucleon Physics and
the Structure of the Nucleon
September10-14, 2007
IKP, Forschungzentrum Jülich, Germany

HIGHLIGHTS ON RADIATIVE KAON AND HYPERON DECAYS FROM NA48/2

A. Bizzeti [1]
Università degli Studi di Modena e Reggio Emilia
I-41100 Modena, Italy
and INFN, Sezione di Firenze
I-50018 Sesto Fiorentino (FI), Italy

Abstract

Recent results on radiative charged Kaon decays from NA48/2 experiment and on Ξ^0 weak radiative decays from NA48/1 experiment are presented. A precise measurement of the Direct Emission contribution in $K^\pm \to \pi^\pm\pi^0\gamma$ has been performed, and interference with the dominating Inner Bremsstrahlung has been observed for the first time. The first observations of the very rare decay $K^\pm \to \pi^\pm e^+e^-\gamma$ and of the weak radiative decay $\Xi^0 \to \Lambda e^+e^-$ are also presented.

1 Beam line and detector

The NA48/2 experiment took data in 2003 and 2004 using two simultaneous beams of (60 ± 3) GeV/c oppositely charged kaons, produced by 400 GeV/c protons from CERN SPS impinging on a beryllium target.

The charged particle reconstruction is provided by a magnetic spectrometer, consisting of a dipole magnet and four drift chambers, with a spatial resolution of 100 μm and a momentum resolution $\Delta p/p = (1.0 \oplus 0.044 p[\mathrm{GeV/c}])\%$.

The energy and position of photons and electrons are precisely measured by a Liquid Kripton electromagnetic calorimeter, consisting of a $27X_0$ almost homogeneous ionization chamber with high-granularity tower read-out: its energy resolution is $\Delta E/E = 3.2\%/\sqrt{E[GeV]} \oplus 9\%/E[GeV] \oplus 0.42\%$ and its spatial resolution about 1.5 mm.

A scintillator hodoscope for fast triggering and precise time measurement, muon and photon veto counters and an iron-scintillator hadron calorimeter complete the experimental apparatus, a detailed description of which can be found in [1].

[1] representing the NA48/1 and NA48/2 collaborations

2 The radiative decay $K^\pm \to \pi^\pm\pi^0\gamma$

The $K^\pm \to \pi^\pm\pi^0\gamma$ decay amplitude is the sum of two terms: one arises from the inner bremsstrahlung (IB) associated to the decay $K^\pm \to \pi^\pm\pi^0$ in which the photon is emitted from the outgoing charged pion, the other is due to direct emission (DE) in which the photon is radiated in the intermediate states of the decay.

Although suppressed by the $\Delta I = 1/2$ rule, the IB term dominates the sum. The DE term contains a magnetic amplitude which can be evaluated using Chiral Perturbation Theory (ChPT) and an electric amplitude for which there is no definite theoretical prediction. The latter can be determined by measuring its interference (INT) with the purely electric IB.

In order to kinematically separate (on a statistical basis) IB, DE and INT components in the differential decay width we use the Lorentz invariant variable W, defined as $W^2 = (P^*_K \cdot P^*_\gamma)(P^*_\pi \cdot P^*_\gamma)/(m_K m_\pi)^2$, where P^*_x is the 4-momentum of the particle $x = K^\pm, \pi^\pm, \gamma$.

The differential decay width depends on both W and the charged pion energy T^*_π in the kaon rest frame. Integrating on T^*_π we obtain an expression that splits the different contributions into terms with different powers of W:

$$\frac{d\Gamma^\pm}{dW} \simeq \frac{d\Gamma^\pm_{\rm IB}}{dW}\left[1 + 2\frac{m_\pi^2}{m_K^2}W^2|E|\cos((\delta_1-\delta_0)\pm\phi) + \frac{m_\pi^4}{m_K^4}W^4\left(|E|^2+|M|^2\right)\right] \tag{1}$$

where $|E|$ and $|M|$ describe electric and magnetic DE transitions, $(\delta_1 - \delta_0)$ is the $\pi\pi$ phase shift difference, ϕ is an unknown phase responsible for CP violation and the three terms in the sum represent IB, INT and DE contributions respectively. A recent theoretical work by Cappiello and D'Ambrosio [2] suggest the presence of a form factor in the DE term, not yet included in the present analysis, that would modify Eq. (1).

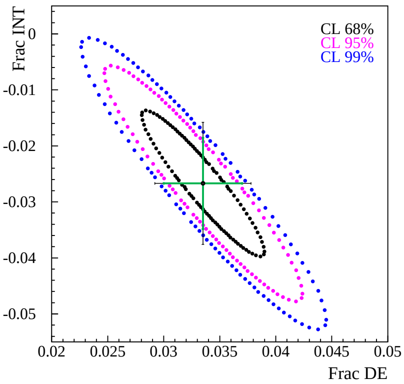
The IB component has been measured by Abrams *et al.* [3] and is in good agreement with QED predictions. Measurements of the DE component have been performed up to now [4–7] ignoring the INT term, in the kinematical region 55 MeV $< T^*_\pi <$ 90 MeV where the dangerous background from $K^\pm \to \pi^\pm\pi^0$ and $K^\pm \to \pi^\pm\pi^0\pi^0$ decays is strongly suppressed.

An almost background-free data sample of $1.24 \cdot 10^5$ $\pi^\pm\pi^0\gamma$ candidate events with $T^*_\pi <$ 80 MeV and $E_\gamma >$ 5 GeV has been selected from data taken in 2003. Its W distribution has been fitted to the sum of Monte Carlo simulated W spectra for IB, DE and INT, obtaining the following preliminary values for the fractions of DE and INT with respect to IB:

$$Frac(DE) \equiv \Gamma(DE)/\Gamma(IB) = (3.35 \pm 0.35_{stat} \pm 0.25_{syst})\% \tag{2}$$

$$Frac(INT) \equiv \Gamma(INT)/\Gamma(IB) = (-2.67 \pm 0.81_{stat} \pm 0.73_{syst})\% \tag{3}$$

This is the first measurement of a non vanishing interference term in the $K^\pm \to \pi^\pm \pi^0 \gamma$ decay. Fig. 1 shows the very high correlation of the DE and INT contributions ($\rho = -0.92$). A substantial reduction in both statistical and systematic errors is foreseen using the full 2003-2004 data set.



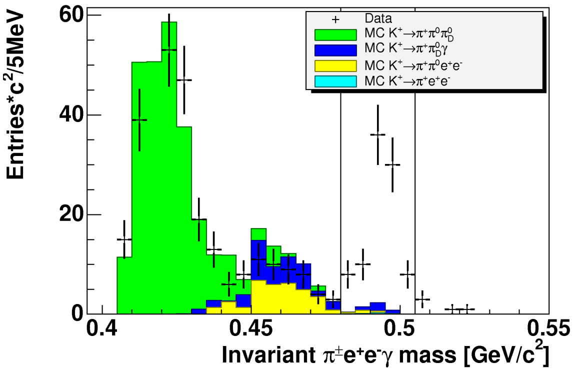


Figure 1 (left): $\Gamma(K^\pm \to \pi^\pm \pi^0 \gamma)$ DE and INT fractions (normalized to IB).
Figure 2 (right): Invariant mass distribution of $\pi^\pm e^+ e^- \gamma$ candidate events.

3 First observation of $K^\pm \to \pi^\pm e^+ e^- \gamma$

The $K^\pm \to \pi^\pm e^+ e^- \gamma$ decay kinematics is very similar to that of the $K^\pm \to \pi^\pm \gamma\gamma$ decay, with one of the photons internally converting into an e^+e^- pair. A naïf estimate of the branching fraction gives $\mathrm{BR}(K^\pm \to \pi^\pm e^+ e^- \gamma) \approx \mathrm{BR}(K^\pm \to \pi^\pm \gamma\gamma) \cdot 2\alpha = 1.6 \cdot 10^{-8}$. Model dependent theoretical estimates based on ChPT [8] predict a BR in the range $(0.9 - 1.6) \cdot 10^{-8}$.

Fig. 2 shows the reconstructed $\pi^\pm e^+ e^- \gamma$ invariant mass of the selected events: the signal region contains 92 events, with a 1 ± 1 accidental background and a 5.1 ± 1.7 misidentification background (mainly $K^\pm \to \pi^\pm \pi^0_D \gamma$ events with a lost photon). This is the first observation of the radiative decay $K^\pm \to \pi^\pm e^+ e^- \gamma$. Using $K^\pm \to \pi^\pm \pi^0$ as normalization channel we obtain the preliminary result $\mathrm{BR}(K^\pm \to \pi^\pm e^+ e^- \gamma) = (1.27 \pm 0.14_{stat} \pm 0.05_{syst}) \cdot 10^{-8}$.

4 Decay asymmetries in Ξ^0 radiative decays

Radiative decays of the Ξ^0 hyperon have been studied by the NA48/1 experiment. The same detecting apparatus as NA48/2 has been used, with a neutral beam originating from a target close to the beginning of the decay fiducial region.

A sample of 43814 $\Xi^0 \to \Lambda\gamma$ candidate events has been selected (the Λ being identified through its $p\pi^-$ decay), with a 0.8% background.

The asymmetry parameter $\alpha_{\Xi\Lambda\gamma}$ is extracted from the distribution in the angle $\theta_{\Xi p}$ between the directions of the incoming Ξ^0 and the outgoing proton in the Λ rest frame: $dN/d\cos(\theta_{\Xi p}) = (N/2)\,[1 - \alpha_{\Xi\Lambda\gamma}\alpha_- \cos(\theta_{\Xi p})]$ (where $\alpha_- = 0.642 \pm 0.013$ [9] is the asymmetry parameter for the decay $\Lambda \to p\pi^-$), obtaining $\alpha_{\Xi\Lambda\gamma} = -0.68 \pm 0.02_{stat} \pm 0.06_{syst}$. The same method has been used to measure the asymmetry parameter in the $\Xi^0 \to \Sigma^0\gamma$ decay. From a sample of 13068 events with a $\approx 3\%$ background we obtain $\alpha_{\Xi\Sigma\gamma} = -0.68 \pm 0.03_{stat} \pm 0.07_{syst}$, in excellent agreement with the measured $\alpha_{\Xi\Lambda\gamma}$.

5 First observation of the $\Xi^0 \to \Lambda e^+e^-$ decay

In 2002 NA48/1 run the $\Xi^0 \to \Lambda e^+e^-$ decay was observed for the first time. A data sample of 412 candidates has been selected, with an estimated background of 15 events. Using the $\Xi^0 \to \Lambda\pi^0$, $\pi^0 \to \gamma e^+e^-$ decay as normalization channel we obtain a branching fraction $\mathrm{BR}(\Xi^0 \to \Lambda e^+e^-) = (7.7 \pm 0.4_{stat} \pm 0.4_{syst}) \cdot 10^{-6}$. The measured e^+e^- invariant mass spectrum is consistent with an inner conversion-like e^+e^- production mechanism.

The decay asymmetry parameter $\alpha_{\Xi\Lambda ee}$ has been mesaured from the angular distribution $dN/d\cos(\theta_{\Xi p}) = (N/2)\,[1 - \alpha_{\Xi\Lambda ee}\alpha_- \cos(\theta_{\Xi p})]$. The obtained value $\alpha_{\Xi\Lambda ee} = -0.8 \pm 0.2$ is in good agreement with the measured $\alpha_{\Xi\Lambda\gamma}$. A detailed description of the data analysis can be found in [10].

References

[1] V. Fanti *et al.*[NA48 Collab.], *Nucl. Instr. Methods* **A574**, 433 (2007).

[2] L. Cappiello and G. D'Ambrosio, *Phys. Rev. D* **75**, 094014 (2007).

[3] R. J. Abrams *et al.*, *Phys. Rev. Lett.* **29**, 1118 (1972).

[4] S. C. Adler *et al.*[E787 Collab.], *Phys. Rev. Lett.* **85**, 4856 (2000)

[5] M. A. Aliev *et al.*[KEK-E470 Collab.], *Phys. Lett. B* **554**, 7 (2003)

[6] M. A. Aliev *et al.*[KEK-E470 Collab.], *Eur. Phys. J. C* **46**, 61 (2006)

[7] V. A. Uvarov *et al.*, *Phys. Atom. Nucl.* **69**, 26 (2006)

[8] F. Gabbiani, *Phys. Rev. D* **59**, 094014 (1999)

[9] W.-M. Yao *et al.*[PDG], *Journal of Physics G* 33, 1 (2006)

[10] J. Batley *et al.*[NA48/1 Collab.], *Phys. Lett. B* **650**, 1 (2007)