FISRT OBSERVATION AND STUDY OF $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ DECAY AT THE NA48/2 EXPERIMENT

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A sample of almost 2000 $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ rare decays with a background contamination below 3% is observed for the first time by the NA48/2 experiment at CERN/SPS. The preliminary branching ratio in the full kinematic region is obtained to be $BR(K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}) = (4.06 \pm 0.17) \times 10^{-6}$ by analyzing the data set recorded in 3-month NA48/2 run during 2003. The measured value is in agreement with the theoretical prediction within one standard deviation.

1 Introduction

The $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ decay proceeds through virtual photon exchange which undergoes internal conversion into electron-positron pair, i.e. $K^{\pm} \to \pi^{\pm}\pi^{0}\gamma^{*} \to \pi^{+}\pi^{0}e^{+}e^{-}$. Two possible mechanisms can lead to this rare kaon decay mode: Inner Bremsstrahlung (IB), where the γ^{*} is emitted by one of the charged mesons and Direct Emission (DE), when γ^{*} is radiated off at the weak vertex of the intermediate state of the process. The $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ amplitude consists of two terms: the dominant long-distance IB contribution (pure electric part) and the DE component (electric and magnetic parts). As a result, the differential decay width is a sum of IB, DE and (electric and magnetic) interference terms.

Detailed study of the various contributions to the amplitude of the considered rare process has been performed in the Ref. [1] whereas Ref. [2] provides identification of each dynamical contribution by a Dalitz plot analysis using a specifc set of kinematical variables. The $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ differential decay width with respect the invarant masses of the dilepton and dipion systems has been also calculated in both the kaon rest of frame and in the $(e^{-}e^{+})$ center-of-mass [3].

The first observation of the $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ decay and a preliminary result of the first experimental measurement of its branching fraction, using $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ with $\pi^{0}_{D} \to e^{+}e^{-}\gamma$ as a

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normalisation channel, are reported in the present work.

2 NA48/2 beam and detector system

Two simultaneous $K^{\pm}$ beams were produced by 400 GeV/c protons from the CERN/SPS impinging on a beryllium target. Opposite charge particles with a central momentum of (60±3)GeV/c were selected by an achromatic system consisting of two dipole magnet pairs and a collimator between them. The small transverse size (~1cm) of the kaon beams was achieved by a system of quadropole magnets. The kaon beams passed through cleaning and defining collimators before entering the decay volume housed in a 114 m long evacuated tank closed by 0.3% radiation lengths thick Kevlar window. The momenta (p) and positions of the charged decay products were measured in a magnetic spectrometer composed of four drift chambers and a dipole magnet. It was followed by a scintillator hodoscope consisting of two planes segmented into horizontal and vertical strips achieving a very good ~150 ps time resolution. A liquid krypton calorimeter (LKr), 27 radiation length thick, was used to measure electromagnetic deposits (E) and to identify electrons through their E/p ratio. Additional detector elecments as the hadron calorimeter, the muon and the photon veto counters were not used the present analysis. A detailed description of the NA48/2 detector set-up is available in Ref. [4].

3 $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ selection and reconstruction

$K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ (denoted as $K_{\pi\pi ee}$ below) event candidates are reconstructed from exactly three charged tracks and two photons, forming a neutral pion, pointing to a common vertex in the fiducial decay volume. The charged track is identified as electron/positron if its E/p ratio is greater than 0.85, and as a charged pion if the E/p ratio is lower than 0.85. Two independent clusters without associated track in the LKr (γ-candidates), with energy more than 3 GeV and distance to the adjacent clusters greater than 10 cm are required to identify the two photons which reconstruct the nominal neutral pion mass within ± 10 MeV/c^2. The invariant mass of the charged pion, the electron, the positron and the reconstructed neutral pion is computed and is requested to be in the range (0.484 - 0.504) GeV/c^2 (± 10 MeV/c^2 from the nominal PDG $K^{\pm}$ mass [5]).

Two kaon decay modes are identified as background sources: $K^{\pm} \to \pi^{\pm}\pi^{0}_{\gamma\gamma}\pi^{0}_{D}$ ($K_{3\pi_D}$), where one of the neutral pions is subjected to a Dalitz decay $\pi^{0}_{D} \to e^{+}e^{-}\gamma$; $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ ($K_{2\pi_D}$) and its radiative decay – $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}\gamma$ ($K_{2\pi_D\gamma}$). The suppression of the $K_{3\pi_D}$ background events is achieved by requiring the squared invariant mass of the dipion system to be greater than 0.120 GeV^2/c^4. The invariant mass of the electron, the positron and one of the photons reconstructing the π^0 is demanded to be ± 7 MeV/c^2 away from the nominal mass of the neutral pion in order to reject $K_{2\pi_{D(\gamma)}}$ background contamination.

The data sample collected in a 3-month run in 2003 has been analysed. The number of the $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ candidates in the signal region is 1916 while the overall background is below 3% and composed of (26 ± 5.1) $K_{2\pi_{D(\gamma)}}$ and (30 ± 5.5) $K_{3\pi_D}$ events (Fig. 1). All background contributions are estimated with the help of Monte Carlo simulations generated for each kaon mode.

4 Branching ratio measurement

The $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ branching ratio (BR) is determined as:

$$BR(s) = \frac{N_s - N_b}{N_n} \cdot \frac{A_n \cdot \epsilon_n}{A_s \cdot \epsilon_s} \cdot BR(n),$$

where N_s is the number of the signal candidates (1916), N_b is the number of the estimated background events (55.8±7.4), A_s and ϵ_s are the geometrical acceptance and the trigger efficiency

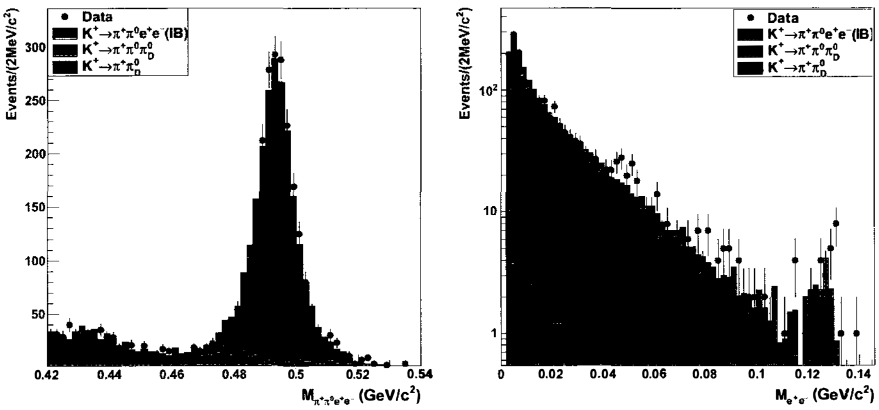

Figure 1 – Left: Invariant mass distribution of the $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ reconstructed candidates before the final mass selection ((494 ± 10) MeV/c^2). Right: Invariant mass of the $(e^{-}e^{+})$-pair. Simulated signal events are plotted in red while the simulated background $K_{3\pi_D}$ and $K_{2\pi_{D}(\gamma)}$ events are superimposed in green and blue, respectively. The data distribution (black dots with error bars) is compatible with the sum of the simulated signal and background events.

of the signal. The "N_n, A_n, ϵ_n" notations are the corresponding quantities for the normalisation channel $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ decay. The normalisation branching ratio $BR(n) = (2.425 \pm 0.076) \times 10^{-3}$ is the world average taken from [5]. The acceptances are obtained by MC simulations: $\sim 0.58\%$ for the signal mode and $\sim 3.6\%$ for the normalisation channel. The trigger efficiencies (ϵ_s and ϵ_n) are similar ($\sim 98\%$), determined from control data sample.

4.1 Normalisation channel

Both the signal and the normalisation kaon modes are selected concurrently by using the same trigger logic. A common event reconstruction is considered as much as possible aiming partial cancellation of systematic effects such as particle identification and trigger inefficiencies.
The event selection of the $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ mode follows the same set of requirements used for the signal except for the π^0-reconstruction and background suppression parts. In case of $K_{2\pi_D\gamma}$, the neutral pion is reconstructed by demanding only one γ-candidate cluster, well separated from the adjecent clusters and with energy greater than 3 GeV, to be in time within 5ns with the electron and positron. The only background source for the normalisation channel is the $K^{\pm} \to \pi^{0}_{D}\mu^{\pm}\nu_{\mu}$ ($K_{\mu 3_D}$). Almost 6.715 million $K_{2\pi_D}$ candidates are selected with $K_{\mu 3_D}$ background contamination smaller than 0.1%.

4.2 Signal mode acceptance

The acceptances of the signal, the normalisation and the background channels are computed by GEANT3-based [6] Monte Carlo (MC) simulations which included the full detector and material description, stray magnetic fields, beamline simulation and local detector imperfections.
The MC simulation for the different $K_{\pi\pi ee}$ contributions – the IB, the DE and the electric interference, have been generated on the basis of the theoretical description given in Ref. [2]. The magnetic interference is not taken into account in the present measurement. The total $K_{\pi\pi ee}$ geometrical acceptance is calculated by using the theoretical fractions of different contributions [2]

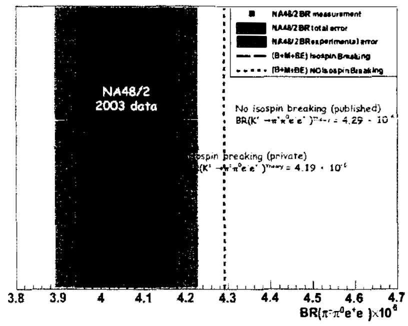

Figure 2 – The $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ branching ratio obtained by the NA48/2 2003 data sample is plotted with its experimental error (shaded blue band) and its total error (shaded green band). The total error included statistical, systematic and external errors. The small dashed line represents the theoretical prediction of the $BR(K_{\pi\pi ee})$ with no isospin breaking published in Ref. [2]. The big dashed line shows the expected branching ratio with isospin breaking (thanks to the authors of Ref. [2], private communication). The experimental value of the $BR(K_{\pi\pi ee})$ is in a very good agreement with the theoretical predictions (within one standard deviation).

as the present data sample is not large enough to measure them:

$$A_s = \frac{A^{IB} + A^{DE} \cdot Frac_{DE}^{theory} + A^{El.Int.} \cdot Frac_{El.Int.}^{theory}}{1 + Frac_{DE}^{theory} + Frac_{El.Int.}^{theory}}.$$

As radiative corrections to the $K_{\pi\pi ee}$ mode are not available, the signal MC simulation included the following effects: the classical Coulomb attraction/repulsion between charged particles and the real photon(s) emission as implemented in the PHOTOS package [7].

5 Results

A sample of 1860 genuine $K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}$ events has been collected by NA48/2 Collaboration analysing the 2003 data sample. The preliminary result of the $K_{\pi\pi ee}$ branching ratio is obtained:

$$BR(K^{\pm} \to \pi^{\pm}\pi^{0}e^{+}e^{-}) = (4.06 \pm 0.10_{stat.} \pm 0.06_{syst.} \pm 0.13_{ext.}) \times 10^{-6},$$

where systematic errors include uncertainties on acceptance, particle identification, trigger efficiencies and radiative corrections. External error originates from the normalization mode BR uncertainties and it is the dominant error in the present result (Fig.2).

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