International Journal of Modern Physics A

FIRST OBSERVATION OF $K_S \to \pi^0 e^+ e^-$ AND $K_S \to \pi^0 \mu^+ \mu^-$ AT NA48/1.

S. GOY LÓPEZ
Dipartamento di Fisica Sperimentale, Università e Sezione dell'INFN di Torino.
Torino, I-10125, Italy

FOR NA48/1 COLLABORATION

Received (Day Month Year)
Revised (Day Month Year)

Using data taken on 2002 at the CERN SPS accelerator, the NA48/1 collaboration has made the first observation of the rare decays $K_S{\to}\pi^0 e^+ e^-$ and $K_S{\to}\pi^0\mu^+\mu^-$. Seven events were found in the electron channel with an estimated background of $0.15^{+0.10}_{-0.04}$. For the muon channel 6 events were observed with a background of $0.22^{+0.18}_{-0.11}$. Using vector a matrix element with unity form factor the resulting branching ratios are: BR($K_S{\to}\pi^0 e^+ e^-$)= $(5.8^{+2.8}_{-2.3}(\text{stat}){\pm}0.8(\text{syst}))\times10^{-9}$ and BR($K_S{\to}\pi^0\mu^+\mu^-$)= $(2.8^{+1.5}_{-1.2}(\text{stat}){\pm}0.2(\text{syst}))\times10^{-9}$.

Keywords: NA48/1; rare decays.

1. NA48/1 beamline and detector

The experiment NA48/1 was performed at CERN SPS and used the NA48 beamline and detector[1], optimized for the search of K_S rare decays.

2. The decay $K_S{\to}\pi^0 e^+ e^-$

2.1. *Event selection*

Selected events were required to have two tracks with 0.95< E/p < 1.05, and four clusters within 3ns in the electromagnetic calorimeter.

Signal and control regions were kept masked while tuning the cuts, in order to avoid biasing the selection. The signal region was defined as a box delimited by $|M_k - m_{ee\gamma\gamma}| < 2.5 \times \sigma_{m_{ee\gamma\gamma}}$ and $|M_{\pi^0} - m_{\gamma\gamma}| < 2.5 \times \sigma_{m_{\gamma\gamma}}$. The control region covered from $3.0 \times \sigma_{m_{ee\gamma\gamma}}$ to $6.0 \times \sigma_{m_{ee\gamma\gamma}}$ and from $3.0 \times \sigma_{m_{\gamma\gamma}}$ to $6.0 \times \sigma_{m_{\gamma\gamma}}$. The values of $\sigma_{m_{ee\gamma\gamma}} = 4.6$ MeV/c^2 and $\sigma_{m_{\gamma\gamma}} = 1.0$ MeV/c^2, were evaluated with $K_S \longrightarrow \pi^0 e^+ e^-$ Monte Carlo validated with $K_S \longrightarrow \pi^0 \pi^0_D$ [a] data.

[a] Where π^0_D denotes the Dalitz decay $\pi^0 \longrightarrow e^+ e^- \gamma$

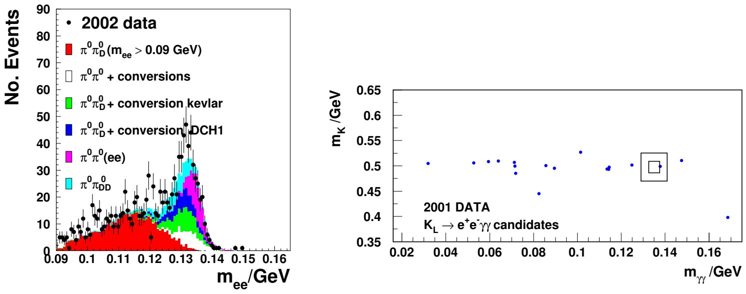

Fig. 1. (a) Distributions of m_{ee} after all cuts. Superimposed are the Monte Carlo predictions for background sources; (b) Scatter plot for events selected as $K_L \to e^+e^-\gamma\gamma$ in 2001 data.

2.2. *Background*

The following background sources were found to contribute:

- *K_S decays with Dalitz pion decays and photon conversions.* To avoid this background the event was rejected if $m_{e^+e^-}$ or both $m_{e\gamma}$ were less than 165 MeV$/c^2$. A limit of < 0.01 events in signal region was given by Monte Carlo. Fig. 1(a)
- *Greenlee:* $K_L \to e^+e^-\gamma\gamma$. It is suppressed by $m_{e^+e^-}$ cut and by $m_{\gamma\gamma} = m_{\pi^0}$ condition. NA48 data from 2001 was used to estimate a contribution of $0.08^{+0.03}_{-0.02}$ background events from this source. Fig. 1(b)
- *Accidental background.* It comes from partially reconstructed fragments of two kaon decays overlapping in time. Data in the time sidebands satisfying all other cuts was used to obtain an estimation of $0.07^{+0.07}_{-0.03}$ events.

2.3. *Result*

Seven events were found on the signal region with a background of $0.15^{+0.10}_{-0.04}$

Using the flux from $K_S \to \pi^0\pi^0_D$ and computing model independent acceptance the resulting branching ratio is:

$$BR(K_S \to \pi^0 e^+e^-)_{(mee>0.165\ \mathrm{GeV})} = (3.0^{+1.5}_{-1.2}(stat) \pm 0.2(syst))10^{-9}$$

Using unity form factor to extrapolate to all m_{ee} the result is:

$$BR(K_S \to \pi^0 e^+e^-) = (5.8^{+2.8}_{-2.3}(stat) \pm 0.8(syst))10^{-9}$$

3. The decay $K_S \to \pi^0\mu^+\mu^-$

3.1. *Event selection*

To be identified as muons, tracks should be associated to hits in the muon detector and have low energy deposition in the calorimeters. Signal and control regions analogous to $K_S \to \pi^0 e^+e^-$ were defined. The values of $\sigma_{m_{\mu\mu\gamma\gamma}} = 3$ MeV$/c^2$ and $\sigma_{m_{\gamma\gamma}} = 0.8$ MeV$/c^2$ were obtained from $K_L \to \pi^0\pi^+\pi^-$ data.

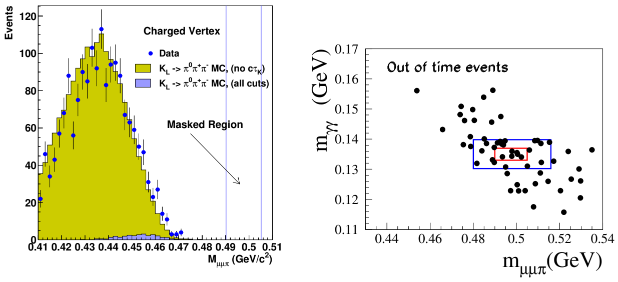

Fig. 2. (a) Distribution of $m_{\mu\mu\pi}$ with and without cut at three K_S lifetimes. Superimposed $K_L \to \pi^0\pi^+\pi^-$ Monte Carlo; (b) Scatter plot for events in the out-of-time window.

3.2. *Background*

- $K_L \to \pi^0\pi^+\pi^-$ *where both pions decayed in flight.* From Monte Carlo <0.018 events were expected in signal region. Fig. 2(a)
- *Greenlee:* $K_L \to \mu^+\mu^-\gamma\gamma$. From Monte Carlo the expectation was $0.04^{+0.04}_{-0.03}$.
- *Accidental background.* Six events were found on out-time signal region. Extrapolating to in-time signal region gave an expectation of $0.18^{+0.18}_{-0.11}$ events. Fig. 2(b)

3.3. *Result*

Six events were found in the signal region with a total background of $0.22^{+0.18}_{-0.11}$

Using the flux from $K_S \to \pi^+\pi^-$ the resulting branching ratio is:

$$BR(K_S \to \pi^0\mu^+\mu^-) = (2.8^{+1.5}_{-1.2}(stat) \pm 0.2(syst))\times 10^{-9}$$

4. Implications for K_L

The measured $BR(K_S \to \pi^0 l^+ l^-)$[b] allows to predict the CP-violating component of $BR(K_L \to \pi^0 l^+ l^-)$ as a function of Im(λt)[c] within a sign ambiguity. Taking the world average for Im(λt) we get:

$$BR(K_L \to \pi^0 e^+ e^-)_{CPV} \simeq (17.2_{IND} \pm 9.4_{INT} + 4.7_{DIR}) \times 10^{-12}$$
$$BR(\mathrm{K_L} \to \pi^0\mu^+\mu^-)_{CPV} \simeq (8.4_{IND} \pm 3.3_{INT} + 1.8_{DIR}) \times 10^{-12}$$

References

1. J. R. Batley *et al.*, *Physics Letters* B **544**, 97 (2002)
2. J. R. Batley *et al.*, *Physics Letters* B **576**, 43 (2003)
3. Preliminary result. Submitted to *Physics Letters*

[b] Here l refers to e, μ
[c] Where Im(λt)=Im($V^\star_{ts}V_{td}$) being V_{ij} the CKM matrix elements