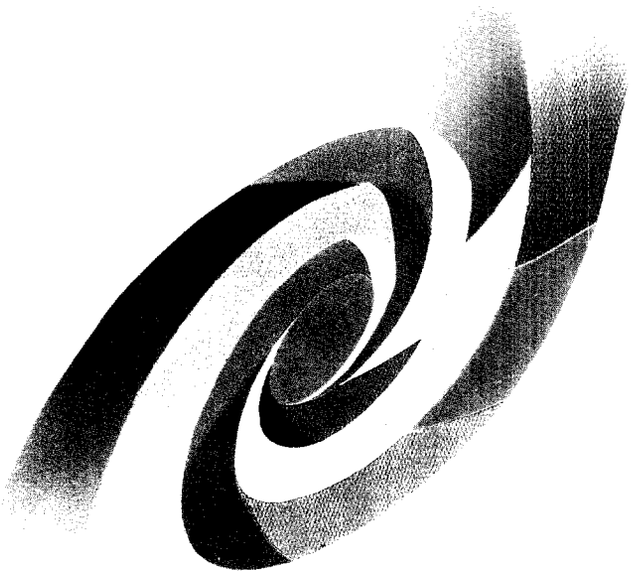
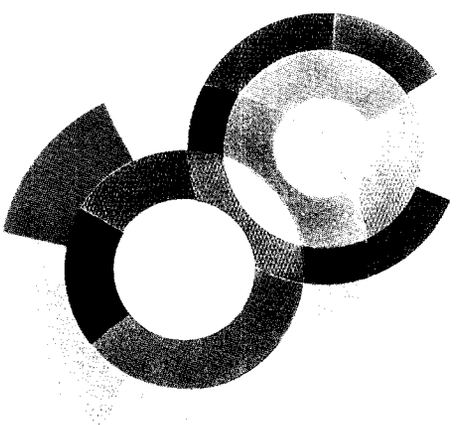
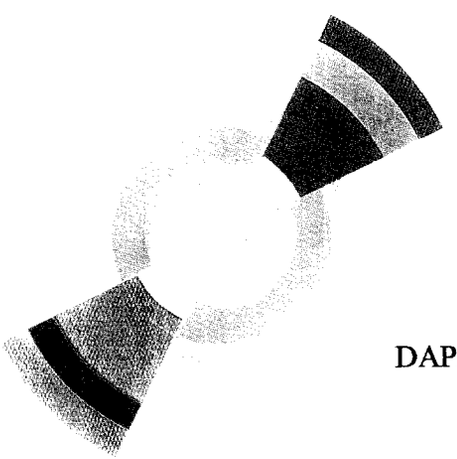
CEA/SACLAY
DSM

SERVICE DE PHYSIQUE DES PARTICULES







DAPNIA/SPP 99-07 March 1999

STUDY OF $K_L \to \pi^+\pi^-e^+e^-$ IN THE NA48 EXPERIMENT

Julien Cogan

DAPNIA

Talk given at the International Workshop on CP violation in K, Tanashi, Tokyo (Japan), December 18-19 1998

Département d'**A**strophysique, de Physique des **P**articules, de Physique **N**ucléaire et de l'**I**nstrumentation **A**ssociée
CEA/Saclay F-91191 Gif-sur-Yvette Cédex

Study of the $K_L \to \pi^+\pi^-e^+e^-$ decay mode in the NA48 experiment

Julien Cogan*
CEA/SACLAY-DAPNIA/SPP
91191 Gif sur Yvette Cedex, France

December 18^{th}, 1998

*On behalf of the NA48 Collaboration: Cagliari, Cambridge, CERN, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna and Warsaw.

Abstract

The study of $K_L \to \pi^+\pi^-e^+e^-$ decay mode in the NA48 experiment is presented. Using a fraction of the data collected during 1998, a preliminary measurement of the branching ratio based on 240 ± 16 events gives $(3.13 \pm 0.23) \times 10^{-7}$.

*electronic address: cogan@hep.saclay.cea.fr

The decay $K_L \to \pi^+\pi^-e^+e^-$ is dominated by the virtual process $K_L \to \pi^+\pi^-\gamma^* \to \pi^+\pi^-e^+e^-$. Experimental studies of $K_L \to \pi^+\pi^-\gamma$ have revealed the existence of two components in the decay rate [1] : a bremsstrahlung contribution associated with the CP-violating decay $K_L \to \pi^+\pi^-$ and a direct emission term which is CP conserving. The interference of these two terms produces a CP-violating circular polarization of the photon in $K_L \to \pi^+\pi^-\gamma$. For $K_L \to \pi^+\pi^-e^+e^-$ decays, it leads to a CP-violating asymmetry in the angular distribution of the e^+e^- plane with respect to the $\pi^+\pi^-$ plane [2]. Theoretical expectations are in good agreement with recent measurements: Fermilab KTEV (E799-II) experiment has determined the branching ratio to be $[3.32 \pm 0.14(\text{stat}) \pm 0.28(\text{sys})] \times 10^{-7}$ and has measured an asymmetry of $[14.6 \pm 2.3(\text{stat}) \pm 1.1(sys)]\%$ (see [3] and the presentation of B. Cox in this Workshop).

Preliminary results from the study of the $K_L \to \pi^+\pi^-e^+e^-$ mode in the NA48 experiment are reported here. The description of the apparatus is presented in a different contribution to this Workshop (see "NA48: direct CP violation in K^0 decays").

In 1998, a specific algorithm was implemented in the Level 2 charged trigger (L2C) to select events consistent with four charged particles, concurrently to the $\text{Re}(\varepsilon'/\varepsilon)$ charged trigger. The L2C performs a fast tracking of charged particles in the spectrometer. The 4-track trigger requires at least 2 compatible 2-track vertices within ± 3 m and at least 3 space-points in the most downstream chamber. The trigger inefficiency due to the algorithm itself is around 15%. In addition, about 20% of good 4-track events are lost because the processing time in the L2C exceeds the maximum latency allocated to the trigger.

Before being written to tape, data are reconstructed using on-line calibration of the detector. About 2/3 of the sample collected during the 1998 NA48 data taking period are used in this analysis. $K_L \to \pi^+\pi^-e^+e^-$ events selection requires four reconstructed tracks in the spectrometer, pointing well inside the acceptance of the e.m. calorimeter for particle identification. Two opposite charged tracks must be compatible with electrons while the two others have to be of opposite charge and consistent with pions. The 4-track vertex must be found inside the first 90 m of the decay region. Finally, to help removing events with missing particles, the transverse momentum of the reconstucted event has to to be smaller than 0.01 GeV/c.

$K_L \to \pi^+\pi^-\gamma$ decays where the γ was converted in the end of decay volume kevlar window, satisfy all the above requirements as well. To remove these background events, the invariant mass of the e^+e^- pair is required to be larger than 2.5 MeV if the e^+e^- pair vertex is located beyond the evacuated decay volume. $K_L \to \pi^+\pi^-\pi^0{}_D$ (where $\pi^0{}_D$ indicates the Dalitz decay $\pi^0{}_D \to e^+e^-\gamma$) can be misidentified if the photon is not detected. They are eliminated using the $P^2_{\pi^0}$ variable. $P^2_{\pi^0}$ characterize the longitudinal momentum of the π^0 in the frame where the kaon momentum is orthogonal to the momentum of the $\pi^+\pi^-$ pair. It is defined as : $P^2_{\pi^0} = \frac{(M^2_K - M^2_{\pi^0} - M^2_{\pi^+\pi^-})^2 - 4M^2_{\pi^0}M^2_{\pi^+\pi^-} - 4M^2_K P^2_{\perp(\pi^+\pi^-)}}{4(P^2_{\perp(\pi^+\pi^-)} + M^2_{\pi^+\pi^-})}$ where M_K and M_{π^0} are the K_L and the π^0 masses, $M_{\pi^+\pi^-}$ is the invariant mass of the $\pi^+\pi^-$ system and $P_\perp(\pi^+\pi^-)$ is the transverse momentum of the $\pi^+\pi^-$ with respect to the kaon

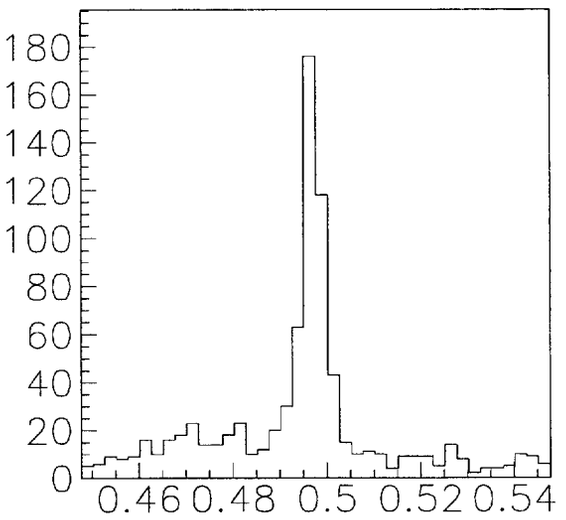


Figure 1: Invariant mass for $K_L \rightarrow \pi^+\pi^-e^+e^-$ candidates

line of flight. Requiring $P^2_{\pi^0}$ to be smaller than -0.01 $(GeV/c)^2$ reduces substantially the $K_L \rightarrow \pi^+\pi^-\pi^0$ background at the cost of about 11% loss of the signal. Two accidental K_{e3} decays close in time and space can in principle imitate a $K_L \rightarrow \pi^+\pi^-e^+e^-$ decay. In most of the cases, the invariant mass of the $(\pi^+\pi^-e^+e^-)$ system is larger than the kaon mass and such events contribute very little to the signal region. After all cuts, 455 events remain in a signal region of ± 8 MeV around the kaon mass (Fig 1).

Using about 60% of the sample presented above, a preliminary estimate of the branching ratio of $K_L \rightarrow \pi^+\pi^-e^+e^-$ decay is obtained using $K_L \rightarrow \pi^+\pi^-\pi^0{}_D$ events as the normalization mode. Since both decay channels have very similar topology and are selected through the same trigger, reconstruction and trigger inefficiencies tend to cancel in the branching ratio measurement. The $K_L \rightarrow \pi^+\pi^-\pi^0{}_D$ decays are fully reconstructed requiring an isolated cluster in the liquid krypton calorimeter. The acceptance for both modes are computed using a detailed Monte-Carlo simulation. For the $K_L \rightarrow \pi^+\pi^-e^+e^-$ decay, the matrix elements described in [2] are used. Based on 240 ± 16 good events, with a signal to background ratio of about 6, the branching ratio is measured to be : $(3.13 \pm 0.23) \times 10^{-7}$ where the error quoted is purely statistical.

The analysis of the full 1998 sample is in progress. About 500 events are expected in total. The systematic errors are being evaluated in detail and the asymmetry of the angle between the e^+e^- and $\pi^+\pi^-$ planes studied. The data taking will continue in future runs to improve the statistical accuracy.