Recent results of NA48 on neutral kaon rare decays

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On Behalf of NA48 Collaboration [a]

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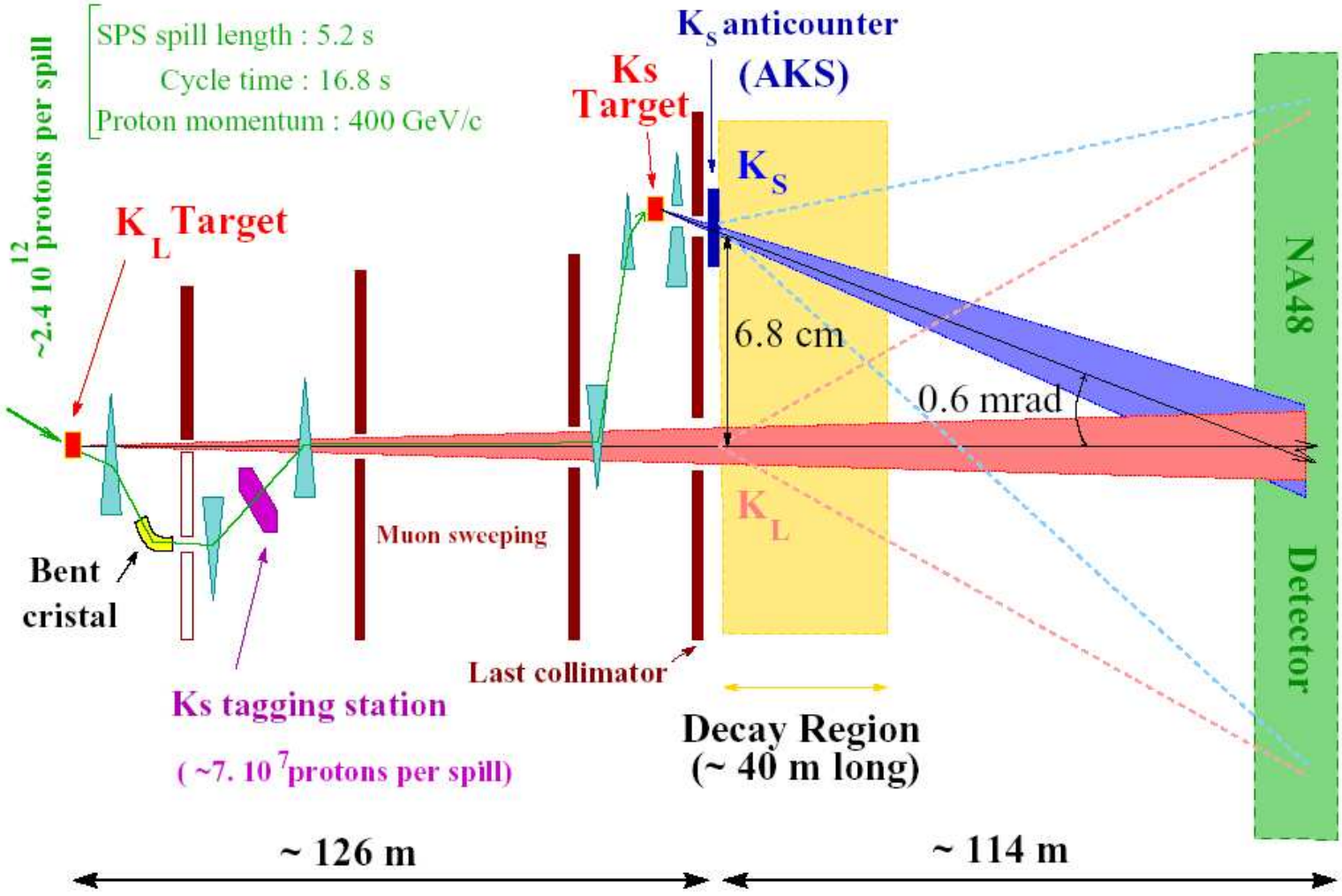
Outline

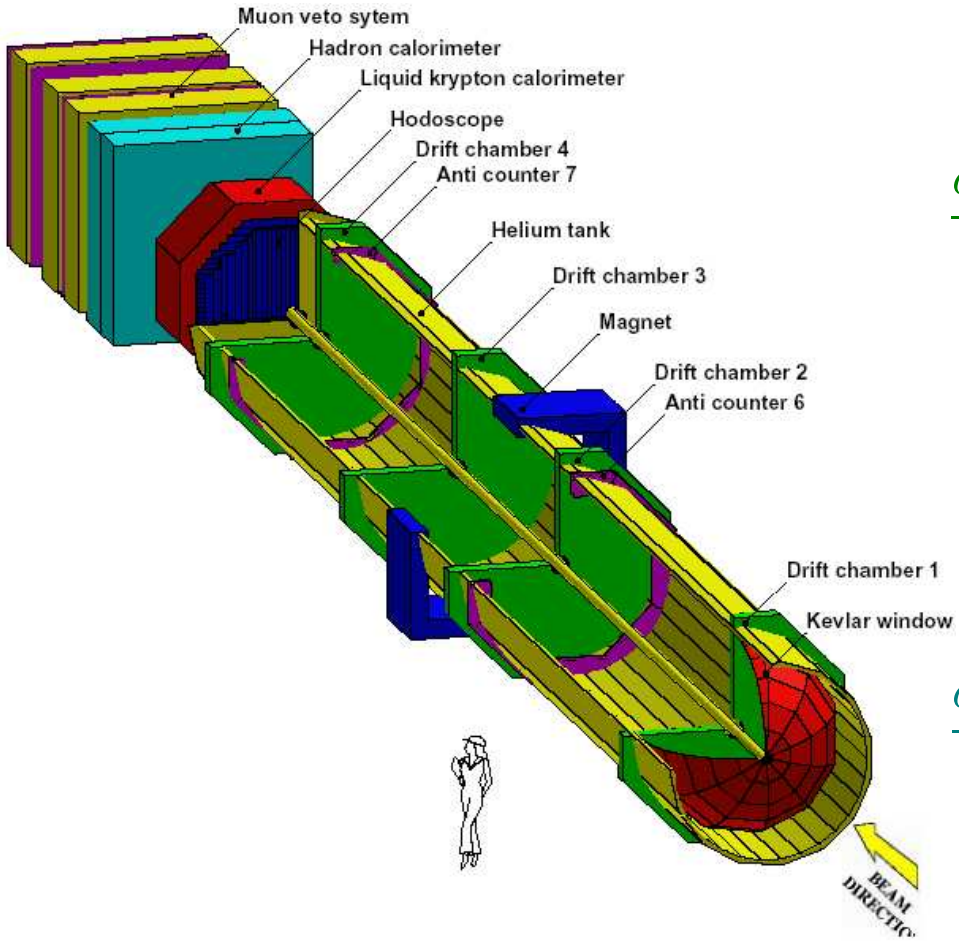
- NA48 Setup
- Data samples
- First observation of $K_S \to \pi^0\gamma\gamma$
- Detailed study of $K_{L,S} \to \pi^+\pi^-e^+e^-$
- Present and future
  - 2002
  - 2003

NA48

Experimental setup: *the beam lines*



Experimental setup: *the detector*



Magnetic Spectrometer

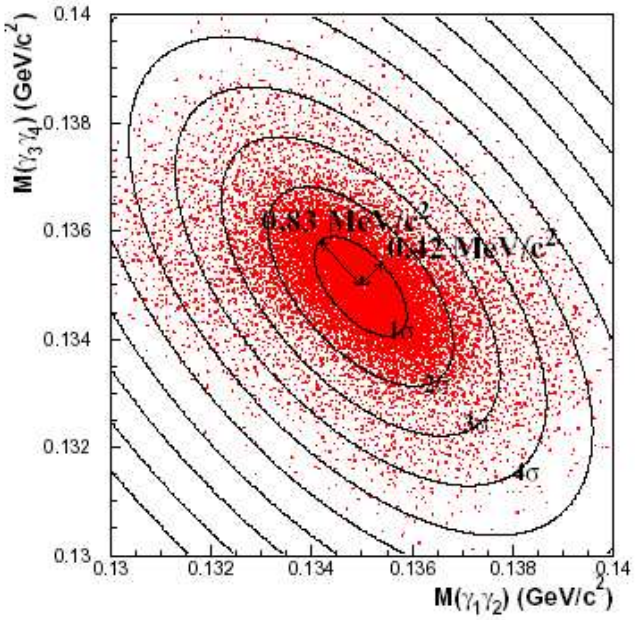
$$\frac{\sigma_p}{p}(\%) = 0.48 \oplus 0.009 \times p(\mathrm{GeV/c})$$

Liquid Kr e.m. spectrometer

$$\frac{\sigma_E}{E}(\%) = \frac{3.2}{\sqrt{E}} \oplus \frac{10.0}{E} \oplus 0.5(\mathrm{GeV})$$

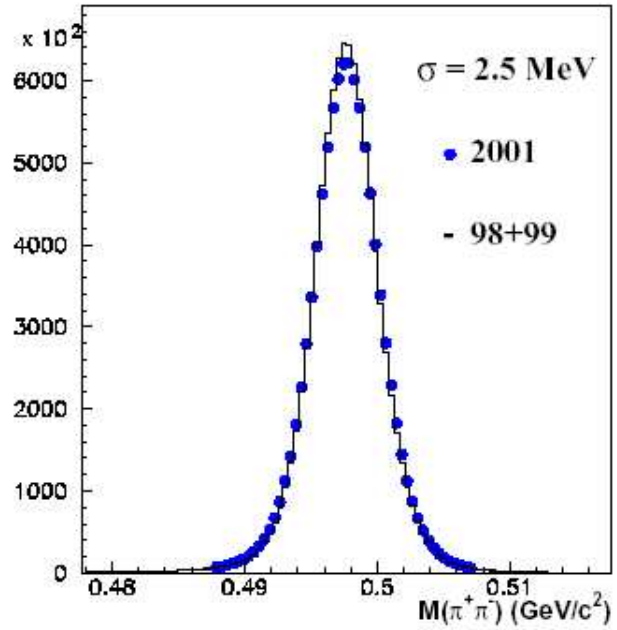
Experimental setup: *resolution*

LKr e.m. calorimeter



$\gamma\gamma$ invariant mass in
$K_S \to \pi^0\pi^0$ candidates

Spectrometer



Kaon invariant mass in
$K_S \to \pi^+\pi^-$ candidates

Data samples

1997	$\rightarrow$	ϵ'/ϵ run $(K_L + K_S)$
1998	$\rightarrow$	ϵ'/ϵ run $(K_L + K_S)$
1999	$\rightarrow$	ϵ'/ϵ run $(K_L + K_S)$ K_S high intensity
2000 (no spectr.)	$\rightarrow$	K_L only K_S high intensity
2001	$\rightarrow$	ϵ'/ϵ run $(K_L + K_S)$ K_S high intensity
2002	$\rightarrow$	K_S high intensity
2003	$\rightarrow$	$K_+ + K_-$

$$K_S \to \pi^0\gamma\gamma$$

$K_S \to \pi^0\gamma\gamma$: motivation

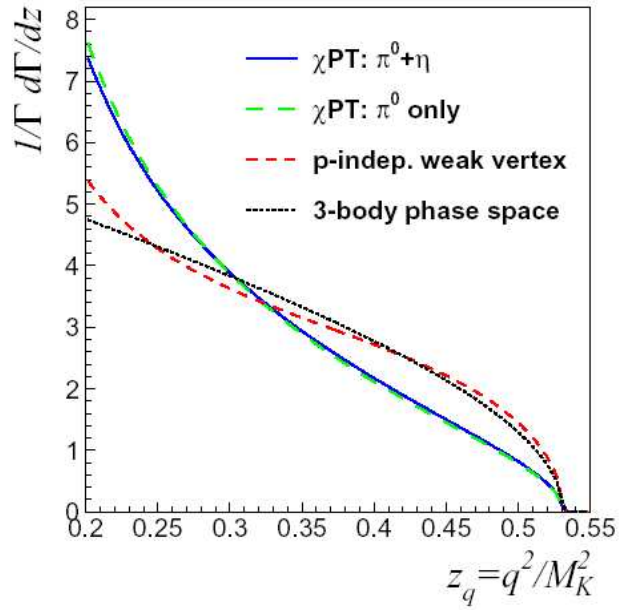
χPT prediction:

(Ecker, Pich, De Rafael – 1987)

- $\mathrm{BR}(K_S \to \pi^0\gamma\gamma)|_{z>0.2} = 3.8 \times 10^{-8}$
- $\mathrm{d}\Gamma/\mathrm{d}z$ distribution $\to$ structure of the week vertex

Experimental limit:

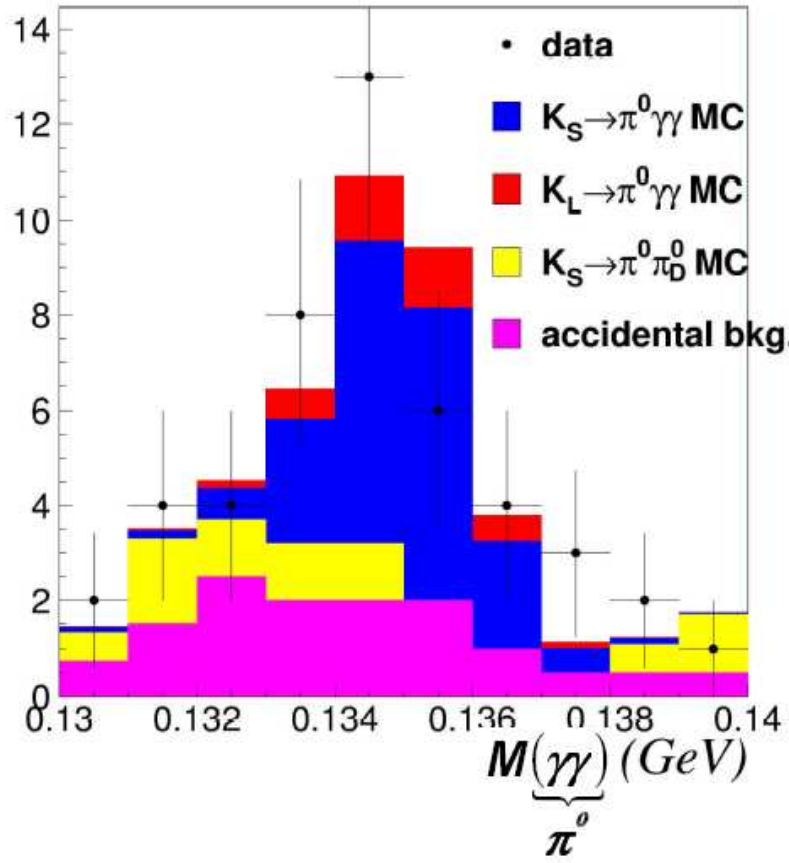
- NA48 recently (1999 test run data)
  $\mathrm{BR}(K_S \to \pi^0\gamma\gamma)|_{z>0.2} < 3.3 \times 10^{-7}$



$K_S \to \pi^0\gamma\gamma$: backgrounds

- beam activity
  - time cuts
  - anti-counters
- $K_S \to \pi^0\pi^0$, $K_S \to \pi^0\pi^0_D$
  - kinematical cuts
- $K_L \to \pi^0\gamma\gamma$
  - irreducible
- $\Xi^0 \to \Lambda\pi^0 \to n\pi^0\pi^0$
  - E_γ asymmetries cut
  - Esitmated using neutron shower profile distribution

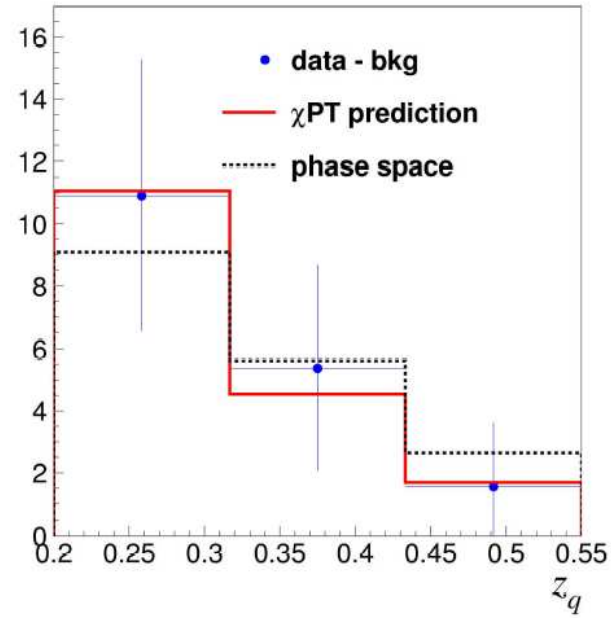
preliminary



$K_S \to \pi^0\gamma\gamma$: preliminary result

- 31 candidates in the signal region
- backgrounds & systematics (estimated events)

beam activity	7.4 ± 2.4
$K_S \to \pi^0\pi^0_D$	2.4 ± 1.2
$K_L \to \pi^0\gamma\gamma$	3.8 ± 0.0
acceptance	± 0.7
total	13.6 ± 2.8



Preliminary result:

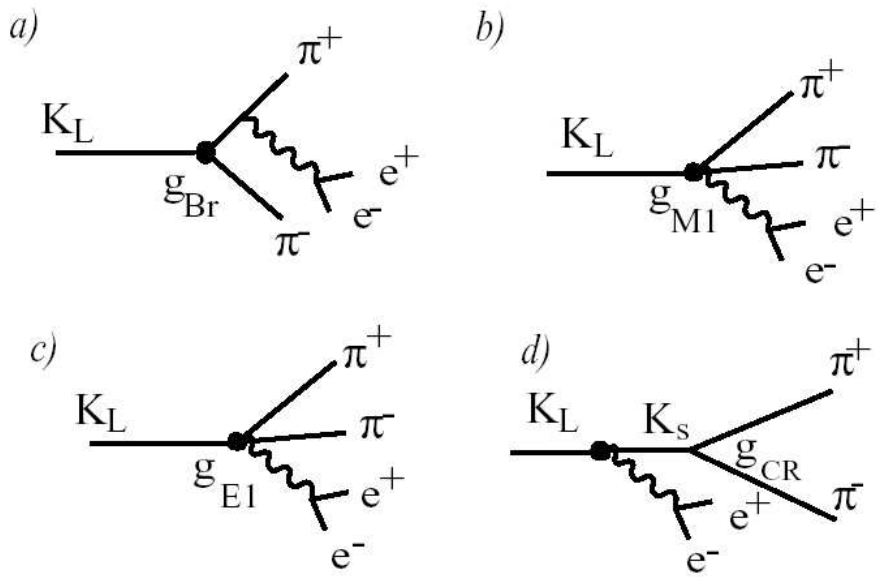
$$\mathrm{BR}(K_S \to \pi^0\gamma\gamma)|_{z>0.2} = (4.9 \pm 1.6_{\mathrm{stat}} \pm 0.8_{\mathrm{syst}}) \times 10^{-8}$$

Probability of background fluctuation: $< 9 \times 10^{-4}$

$$K_{L,S} \to \pi^+\pi^-e^+e^-$$

$K_{L,S} \to \pi^+\pi^-e^+e^-$: motivation

Matrix element of $K_L \to \pi^+\pi^-e^+e^-$ receives contributions (Helinger, Sehgal – 1993) from:

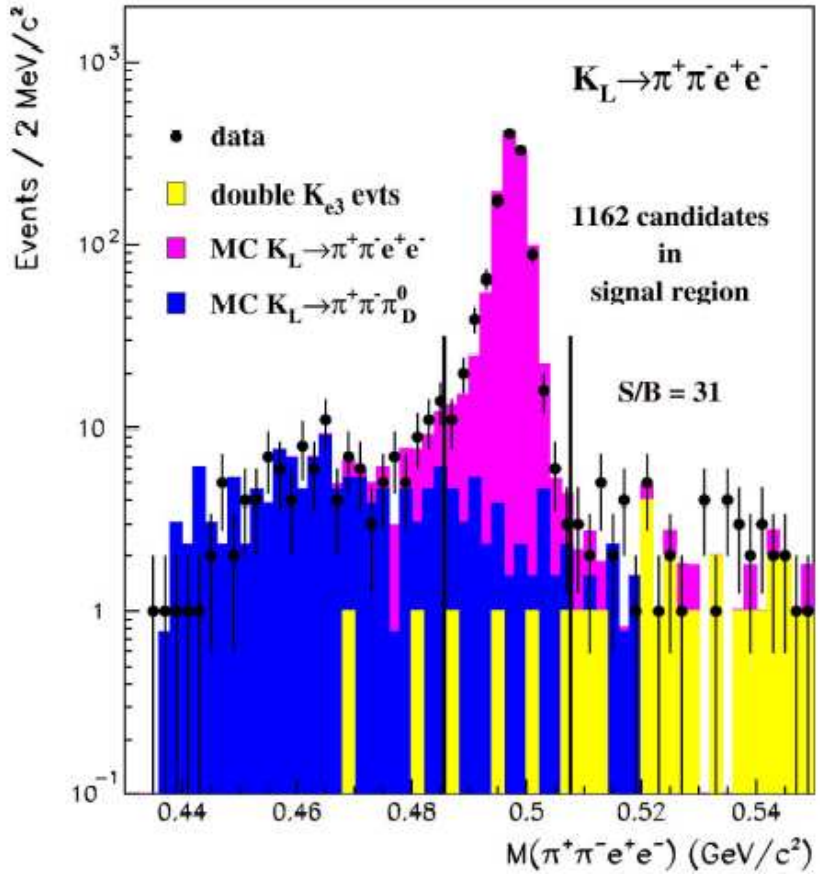


In the K_L case, interference between CP violating Inner Brem. and CP conserving Direct Emission processes, produces an asymmetry in the distribution of ϕ between $\pi^+\pi-$ and e^+e^- decay planes ($\sim 14\%$).

In the K_S case, the only contribution is IB.

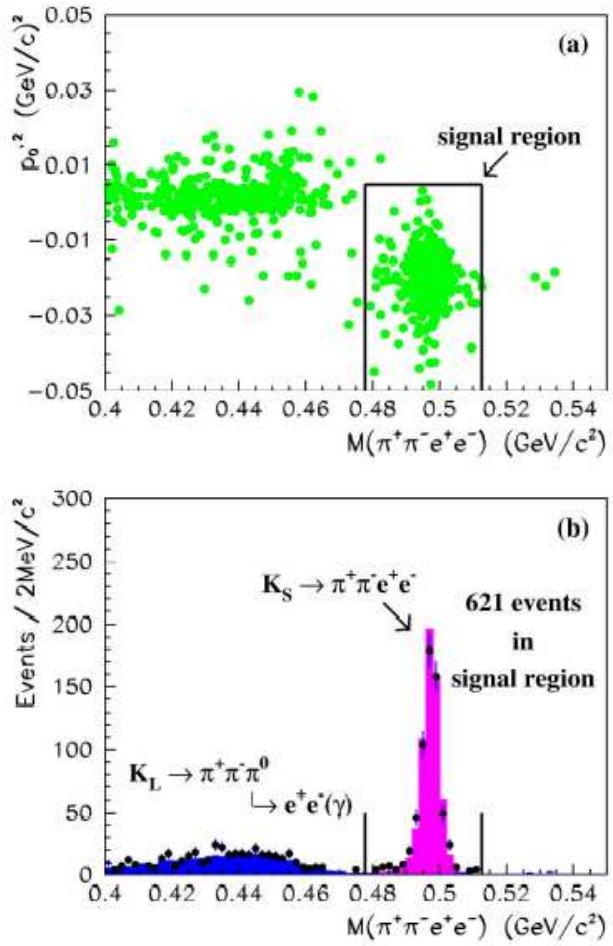
$K_L \to \pi^+\pi^-e^+e^-$: backgrounds

- $K_L \to \pi^+\pi^-\pi^0_D$ (γ lost)
  - kinematical cuts
- 2 overlapping $Ke3$
  - vertex quality cut
  - π^+e^- vs. π^-e^+ time cut
  - estimated using $\pi^\pm\pi^\pm e^\mp e^\mp$ accidental events
- $K_L \to \pi^+\pi^-\gamma + \text{conv.}$
  $K_L \to \pi^+\pi^- + \text{acc.}\gamma + \text{conv.}$
  - negligible



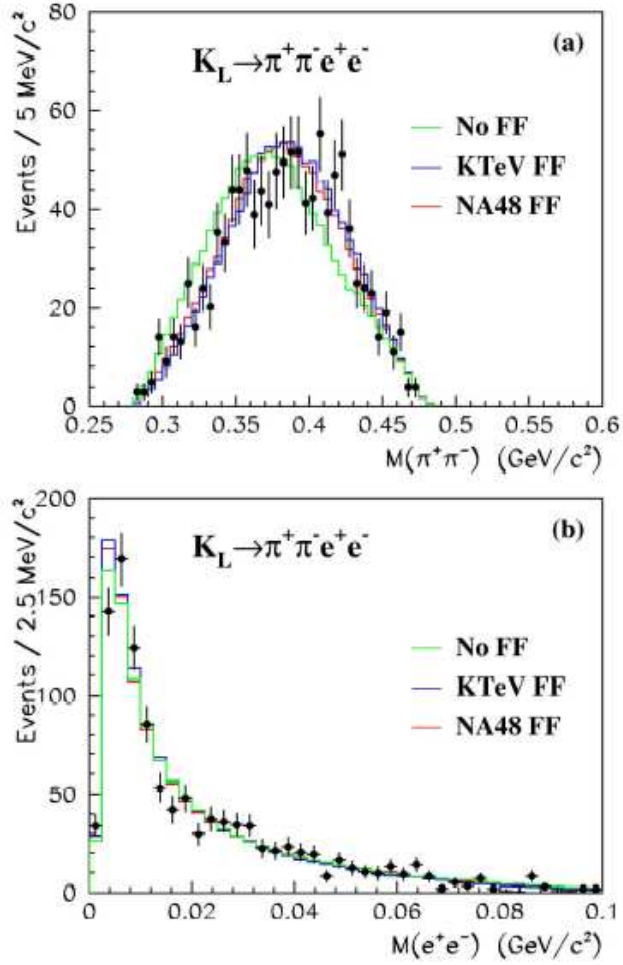
$K_S \to \pi^+\pi^-e^+e^-$: backgrounds

- $K_L \to \pi^+\pi^-\pi^0_D$
  (much smaller than in K_L)
  - looser kinematical cuts
- $K_L \to \pi^+\pi^-e^+e^-$ (irreducible)
  - constraint on Z of the decay vertex
- $\Xi^0 \to \Lambda\pi^0_D$
  - Λ mass rejection cut
- Interactions and γ conv. in the collimator
  - AKS anti-counter



$K_{L,S} \to \pi^+\pi^-e^+e^-$: couplings

- Couplings are extracted by max likelihood fitting of data to MC
  - $a_1/a_2 = \left(-0.81^{+0.07}_{-0.13\,\mathrm{stat}} \pm 0.02_{\mathrm{syst}}\right) \mathrm{GeV}^2$
  - $\tilde{g}_{M1} = 0.99^{+0.28}_{-0.27\,\mathrm{stat}} \pm 0.07_{\mathrm{syst}}$
  - $g_{CR} = 0.19 \pm 0.04_{\mathrm{stat}} \pm 0.02_{\mathrm{syst}}$
- In agreement with KTeV results
- K_S data is consistent with pure IB



$K_{L,S} \to \pi^+\pi^-e^+e^-$: BR results

- $K_L \to \pi^+\pi^-e^+e^-$

$$\mathrm{BR} = (3.08 \pm 0.09_{\mathrm{stat}} \pm 0.15_{\mathrm{syst}} \pm 0.10_{\mathrm{norm}}) \times 10^{-7}$$

- $K_S \to \pi^+\pi^-e^+e^-$

$$\mathrm{BR} = (4.69 \pm 0.30) \times 10^{-5} (\mathrm{adding\ 98\ data})$$

- the main systematic errors come from the model applied (K_L) and the variation of selection cuts (both K_L and K_S)

$\to$ the results agree with Helinger and Seghal predictions

$K_{L,S} \to \pi^+\pi^-e^+e^-$: results for A_ϕ

- $K_L \to \pi^+\pi^-e^+e^-$
  after acceptance correction:

$$A_\phi^L = (14.2 \pm 3.0_{\rm stat} \pm 1.9_{\rm syst})\,\%$$

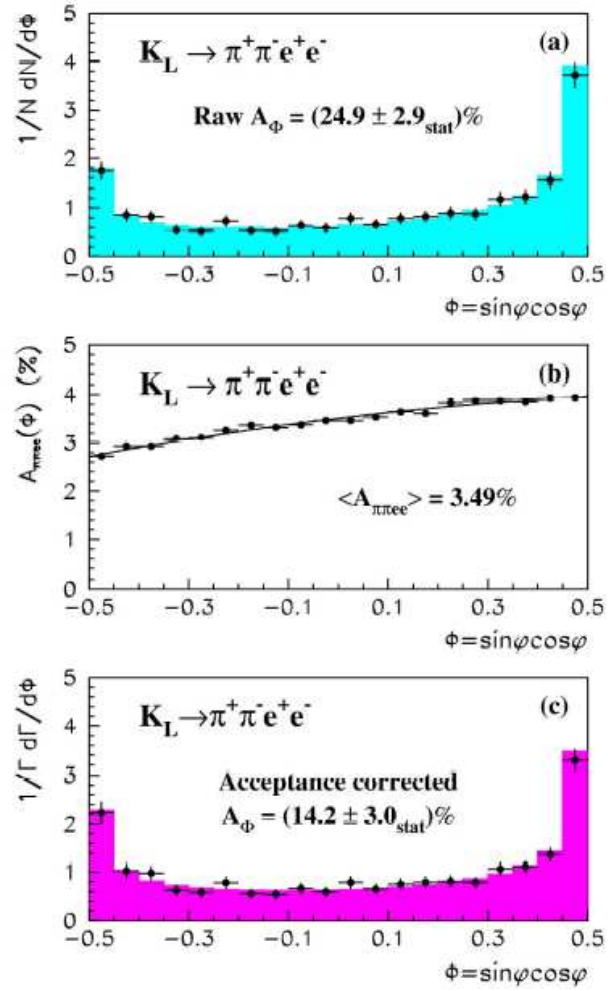
  - clear signature of indirect CP-violation
  - in agreement with KTev results and theoretical predictions

- $K_S \to \pi^+\pi^-e^+e^-$

$$A_\phi^S = (-1.1 \pm 4.1)\,\%(\text{adding } 98 \text{ data})$$

  - consistent with 0

- main systemantics sources as in BR



Conclusions

NA48: conclusions

- we observed for the first time the $K_S \to \pi^0\gamma\gamma$ decay

  $\mathrm{BR}(K_S \to \pi^0\gamma\gamma)|_{z>0.2} = (4.9 \pm 1.6_{\mathrm{stat}} \pm 0.8_{\mathrm{syst}}) \times 10^{-8}$

- we performed a full study of $K_{L,S} \to \pi^+\pi^-e^+e^-$ decay

Both the analysis are consistent with the predictions of the χPT

NA48: present (... and near future)

- 2002 data taking with a high intensity K_S beam
  - search for $K_S \to \pi^0 e^+ e^-$ ... *almost ready*
  - study of Ξ^0 semileptonic decays (BR and form factors)
- 2003 data taking with simultaneous K^+ and K^- beams (*now*)
  - direct CP-violation in the asymmetry of Dalitz plots for 3 charged pions decays
  - scattering length a_0^0 form $K^\pm e4$ decays
  - rare $K^\pm$ decays