New results from NA48 on rare neutral K decays

$$K_L \to \pi^0\gamma\gamma$$

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

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NA48 collaboration:

Cagliari, Cambridge, CERN, Dubna, Edimburgo, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna, Varsavia

XXXVth RENCONTRES DE MORIOND

Electroweak interactions and unified theories

Les Arcs, Savoie, France

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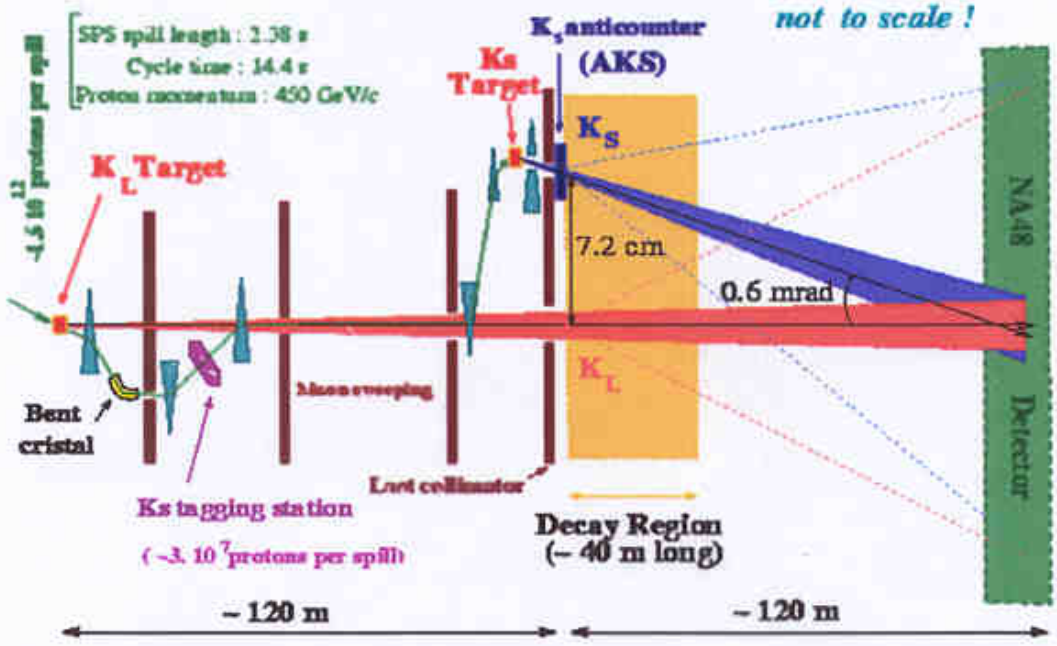
NA48 Experiment

Designed for

$$Re(\epsilon'/\epsilon) = \frac{1}{6}\left(1 - \frac{\Gamma(K_L \to \pi^0\pi^0)}{\Gamma(K_S \to \pi^0\pi^0)} \cdot \frac{\Gamma(K_S \to \pi^+\pi^-)}{\Gamma(K_L \to \pi^+\pi^-)}\right)$$

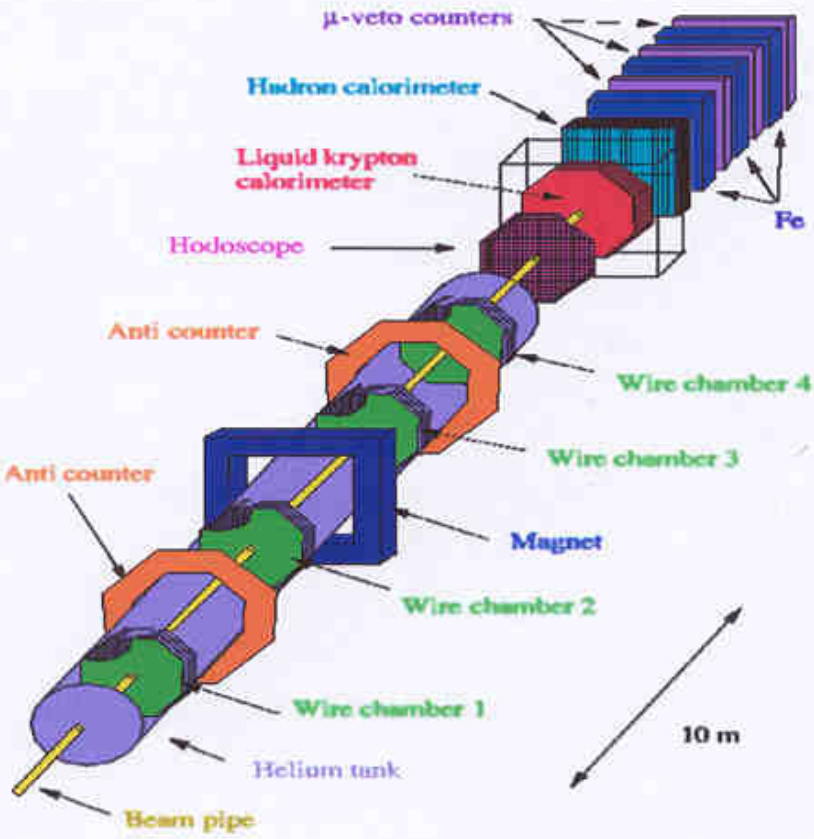
K_L and K_S simultaneous beams



K_S tagged by T.O.F.

of the proton upstream of K_S target

NA48 Detector



Spectrometer (DCH)

$$\sigma_{X,Y} = 100\ \mu m$$

$$\frac{\sigma_P}{P} = 0.48\% \oplus 0.009\% \cdot P$$

(P in $\frac{GeV}{c}$)

Liquid Kripton Calorimeter (LKR)

$$\sigma_{X,Y} = 1mm$$

$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{0.10}{E} \oplus 0.5\%$$

(E in GeV).

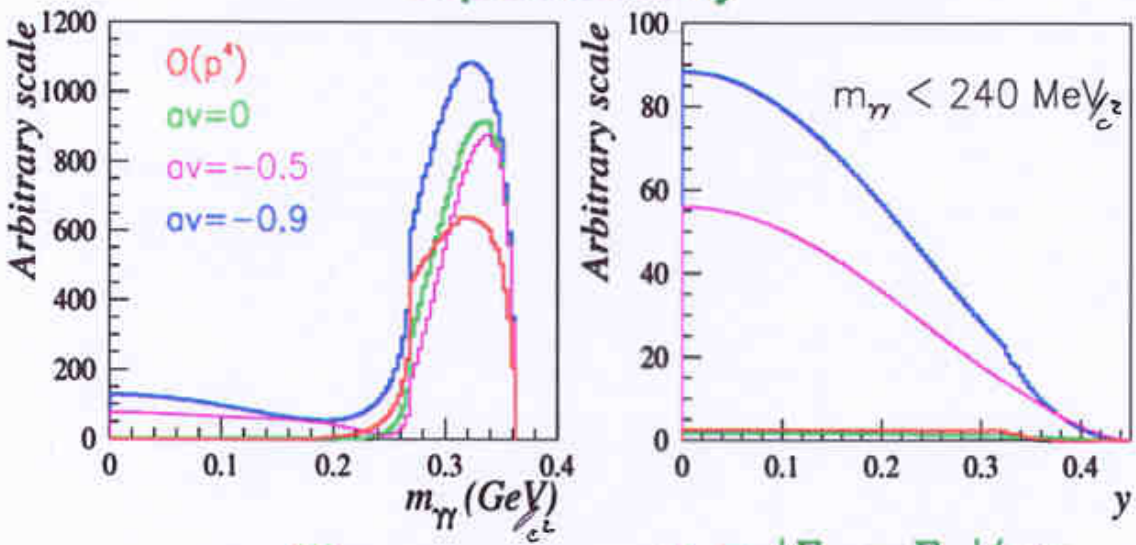
$$\sigma_T \sim 260\ ps$$

$K_L \to \pi^0\gamma\gamma$: physics motivations

- To verify the predictions of χPT

χPT doesn't explain BR togheter with kinematical variable spectra without considering an extra contribution from VMD mechanism (A_V parameter)

VMD relative strength has to be bounded experimentally



$m_{\gamma\gamma}$ $\qquad$ $y = |E_{\gamma_1} - E_{\gamma_2}|/m_K$

- To estimate the

$K_L \to \pi^0 e^+ e^-$ CP-conserving amplitude

via $K_L \to \pi^0\gamma^*\gamma^* \to \pi^0 e^+ e^-$

$K_L \to \pi^0\pi^0$ background

Due to γ conversions or mis-reconstructions

→ $\chi^2_{2\pi^0} > 100$

→ **No DCH hit in time**

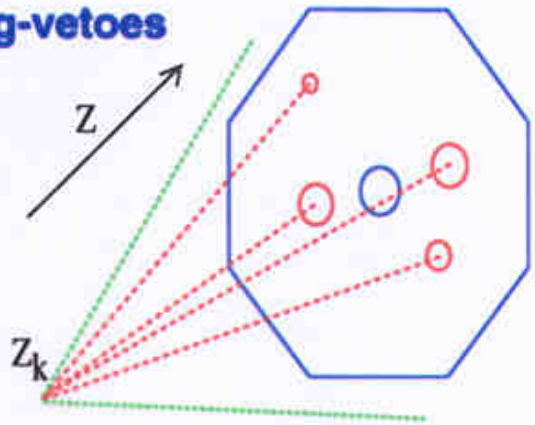
$K_L \to \pi^0\pi^0\pi^0$ background

Due to lost or overlapped γs

→ **No hit in time (2ns) in the ring-vetoes**

$$Z_K = Z_{CAL} - \frac{\left(\Sigma E_i E_j d_{ij}^2\right)^{1/2}}{m_K}$$

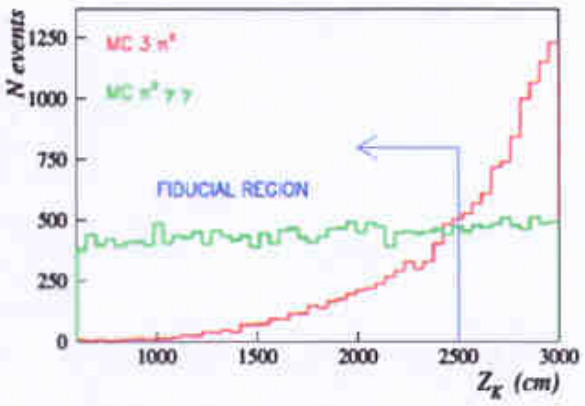
is overestimated by $\geq$ 600 cm



→ $Z_{coll} < Z_K < 2500$ **cm**

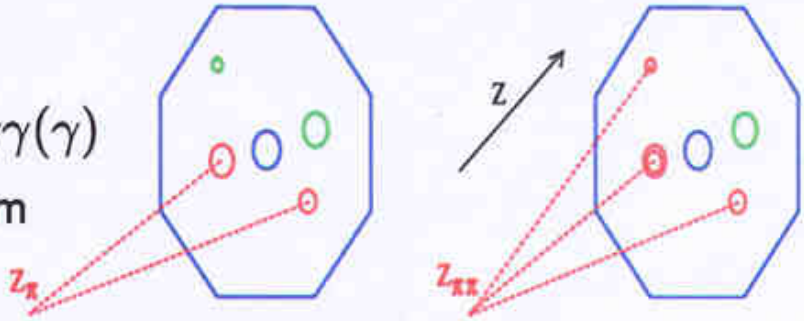
$Z_{K_S\ Target} = 0$ cm

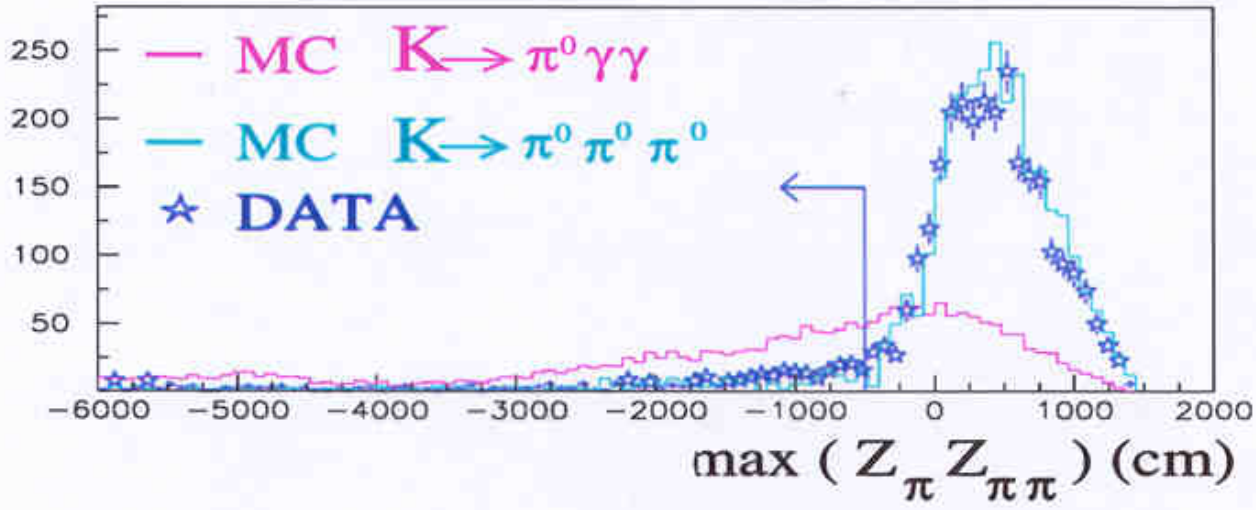
$Z_{Coll} = 600$ cm



$K_L \rightarrow \pi^0\pi^0\pi^0$ background

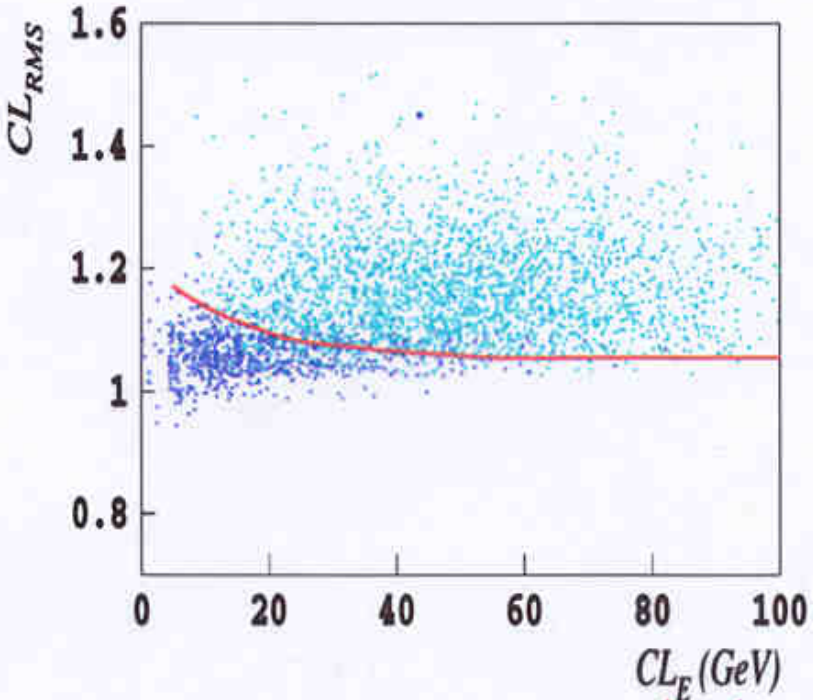
We use the π^0 mass
to reject events with $\gamma\gamma(\gamma)$
combinations upstream
of the K vertex





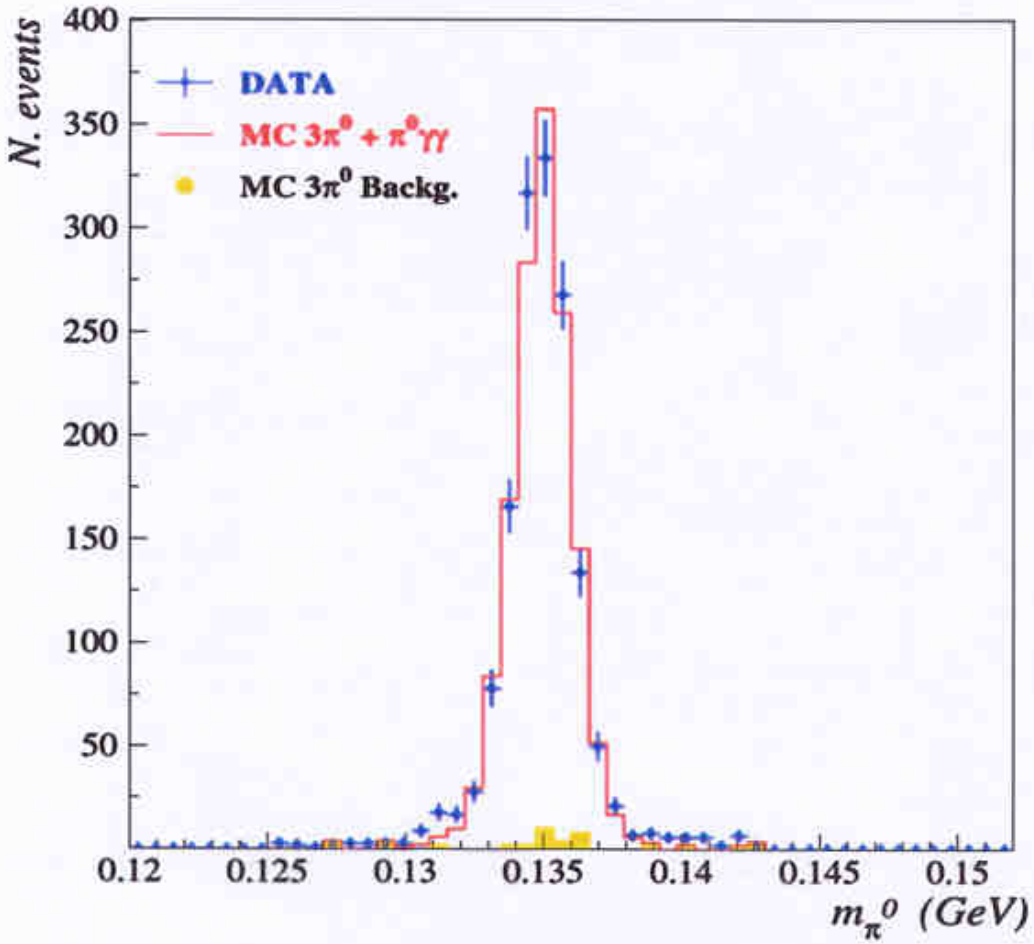
→ No π^0's decays
in the
collimator zone

→ Cluster RMS
vs energy cut



Results: BR($K_L \to \pi^0\gamma\gamma$)

Preliminary (99 + fraction of 98)



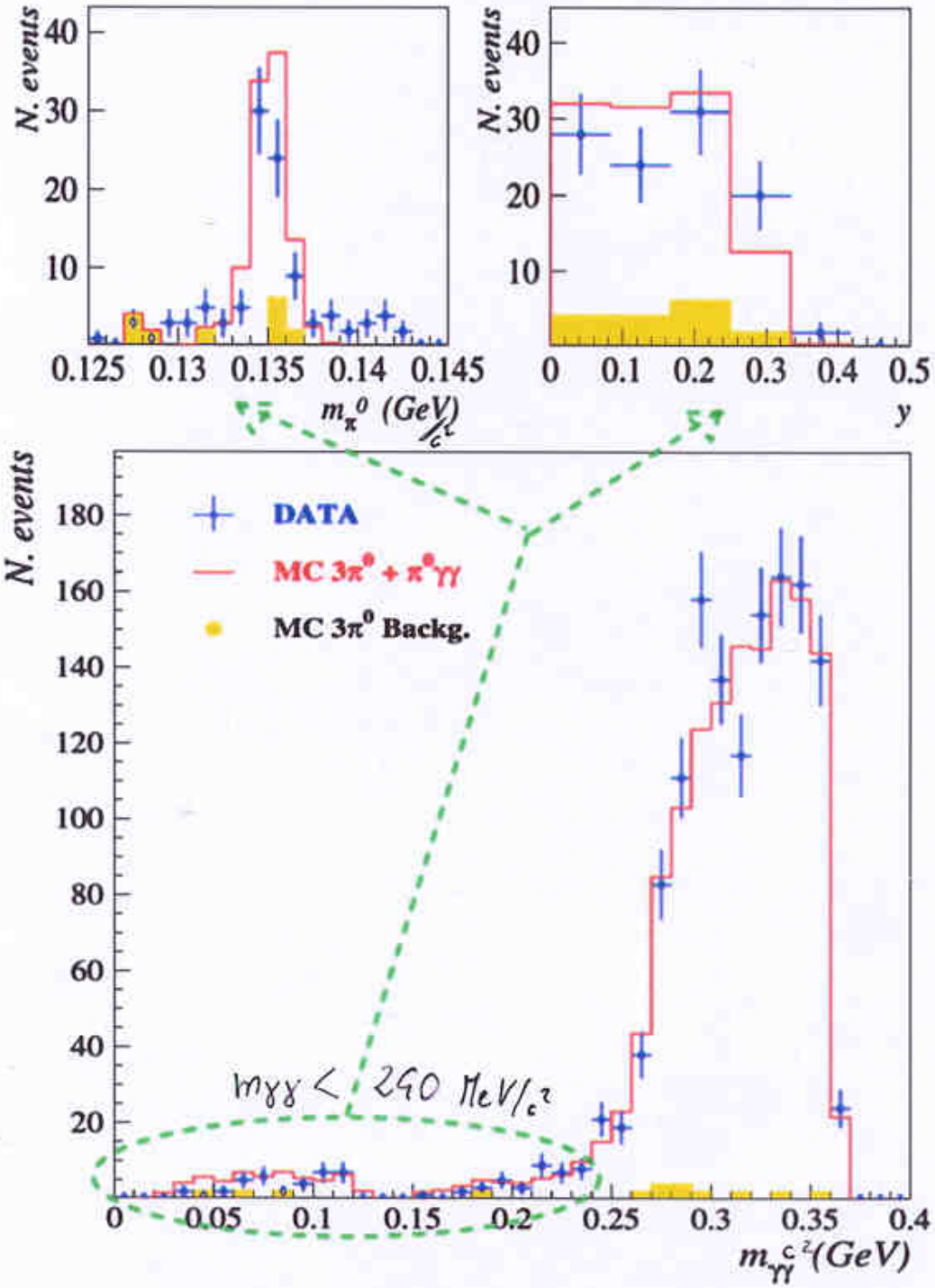
1397 candidates (∼ 30 backg.)

with $a_V = -0.45$ KTeV $a_V = -0.72$

$$BR = (1.51 \pm 0.05\,(stat) \pm 0.20\,(syst)) \cdot 10^{-6}$$

KTeV: $BR = (1.68 \pm 0.07 \pm 0.08) \times 10^{-6}$

Results : Low $m_{\gamma\gamma}$ tail

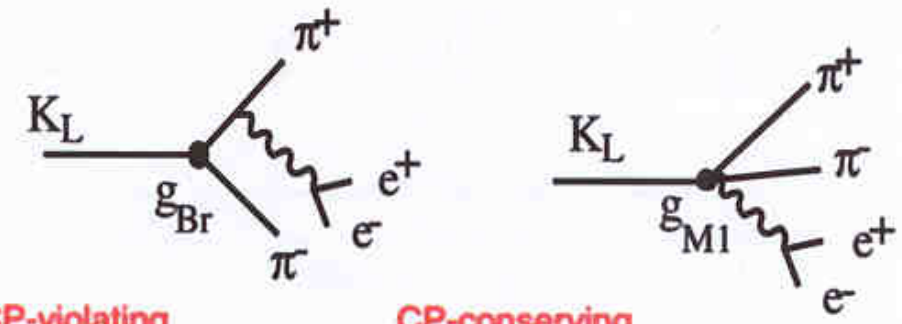


with $a_V = -0.45$

KTeV: low $m_{\gamma\gamma}$ events : 73 (+97 backgr.)

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

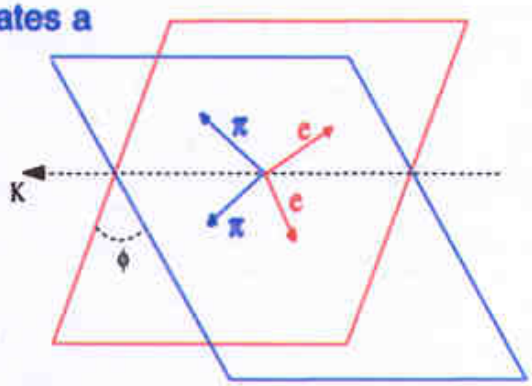
K_L :



CP-violating bremsstrahlung (IB)

CP-conserving M1 γ emission (DE)

The interference between the two terms originates a CP-violating circular polarization of the γ^* and a T-odd term in the decay rate

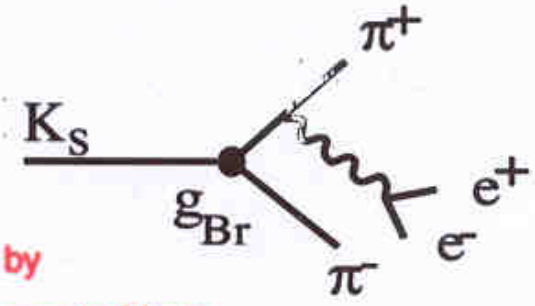


$$\frac{d\Gamma}{d\phi} = \Gamma_1 cos^2\phi + \Gamma_2 sin^2\phi + \Gamma_3 cos\phi sin\phi$$

The effect is visible as the asymmetry on the decay rate

$$\frac{N_{\cos\phi\sin\phi>0} - N_{\cos\phi\sin\phi<0}}{N_{\cos\phi\sin\phi>0} + N_{\cos\phi\sin\phi<0}}$$

K_S :

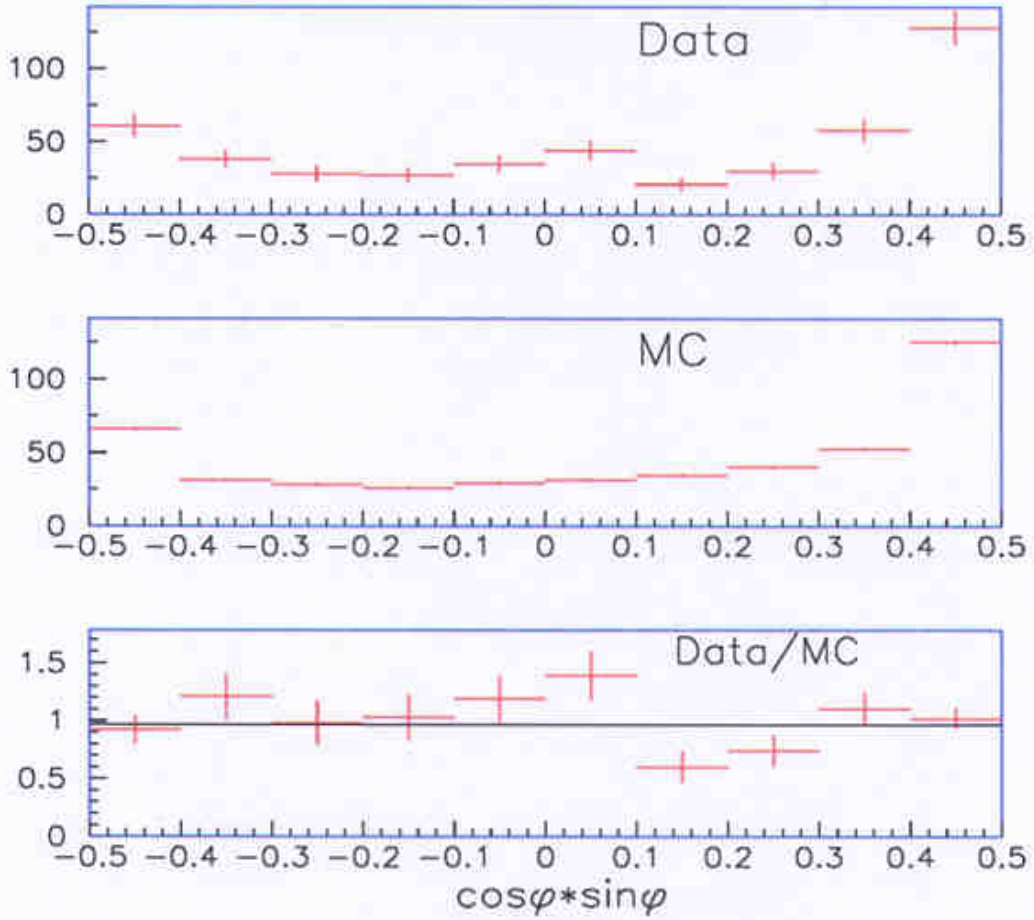


Dominated by CP-conserving bremsstrahlung

No CP-violating asymmetry expected

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

1998 $\sim$ 460 events



Asymmetry studies (preliminary):

Data Observed asymmetry$= (20 \pm 5)\%$

Monte Carlo **generated** 14% $\Rightarrow$ **Reconstructed** 22%

generated 0% $\Rightarrow$ **Reconstructed** 0%

KTeV: observed asymmetry = $23.3 \pm 2.3\%$

acceptance corrected: $13.6 \pm 2.5(stat) \pm 1.2(syst)\%$

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

FIRST EVIDENCE

2 different DATA samples:

→ **1998 Normal ϵ' run** (1 year)

$3 \cdot 10^7$ ppp

To reject the huge number of $K_L \to \pi^+\pi^-\pi^0_D$

both tagged proton and vertex position are used

→ **1999 High intensity K_S-only run** ($\sim$ 2 days)

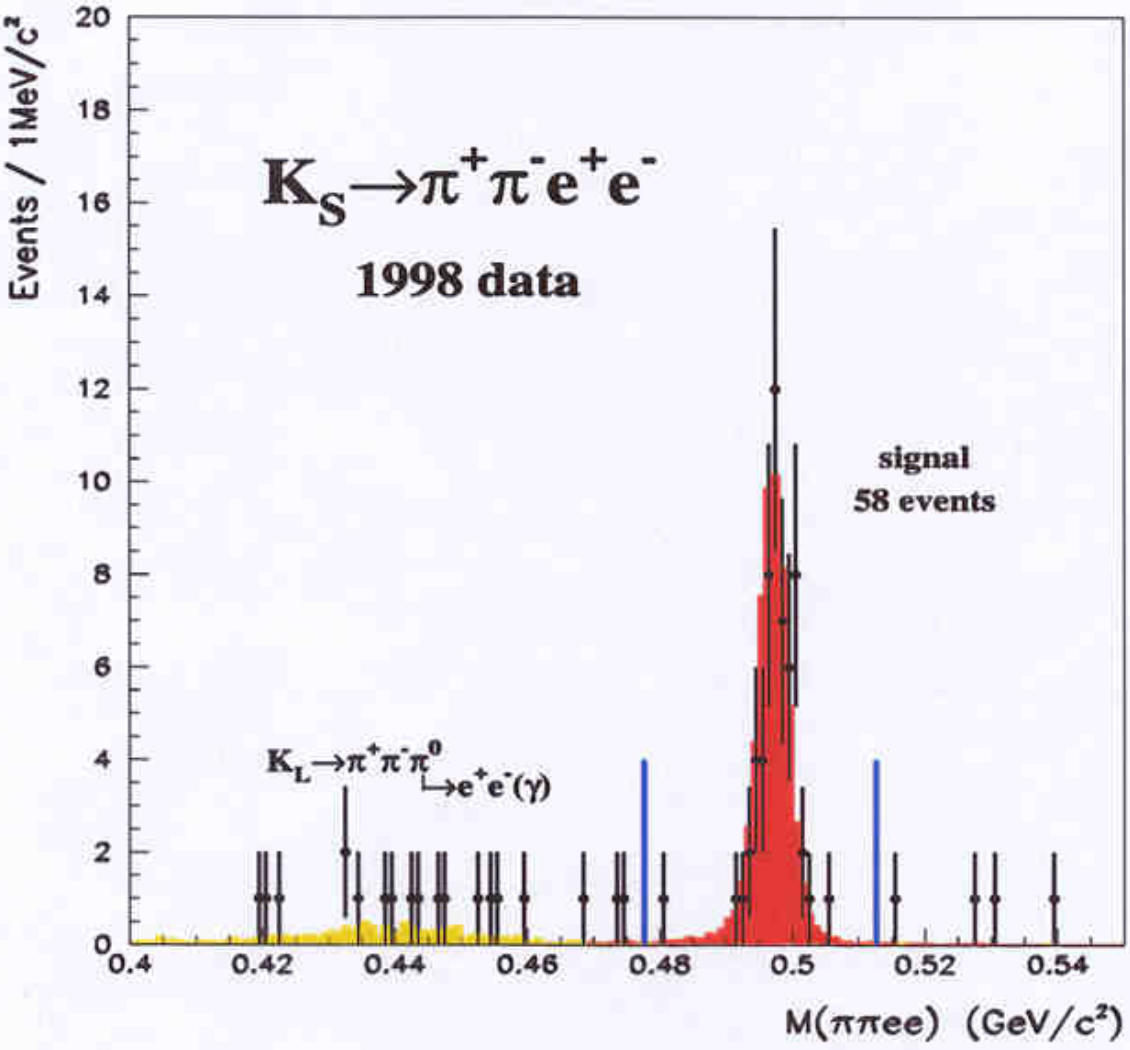
$4.5 - 8 \cdot 10^9$ ppp

$\sim$ $\times$ 200 nominal one

No K_L: much cleaner sample

1998: First observation of $K_S \to \pi^+\pi^-e^+e^-$

Preliminary



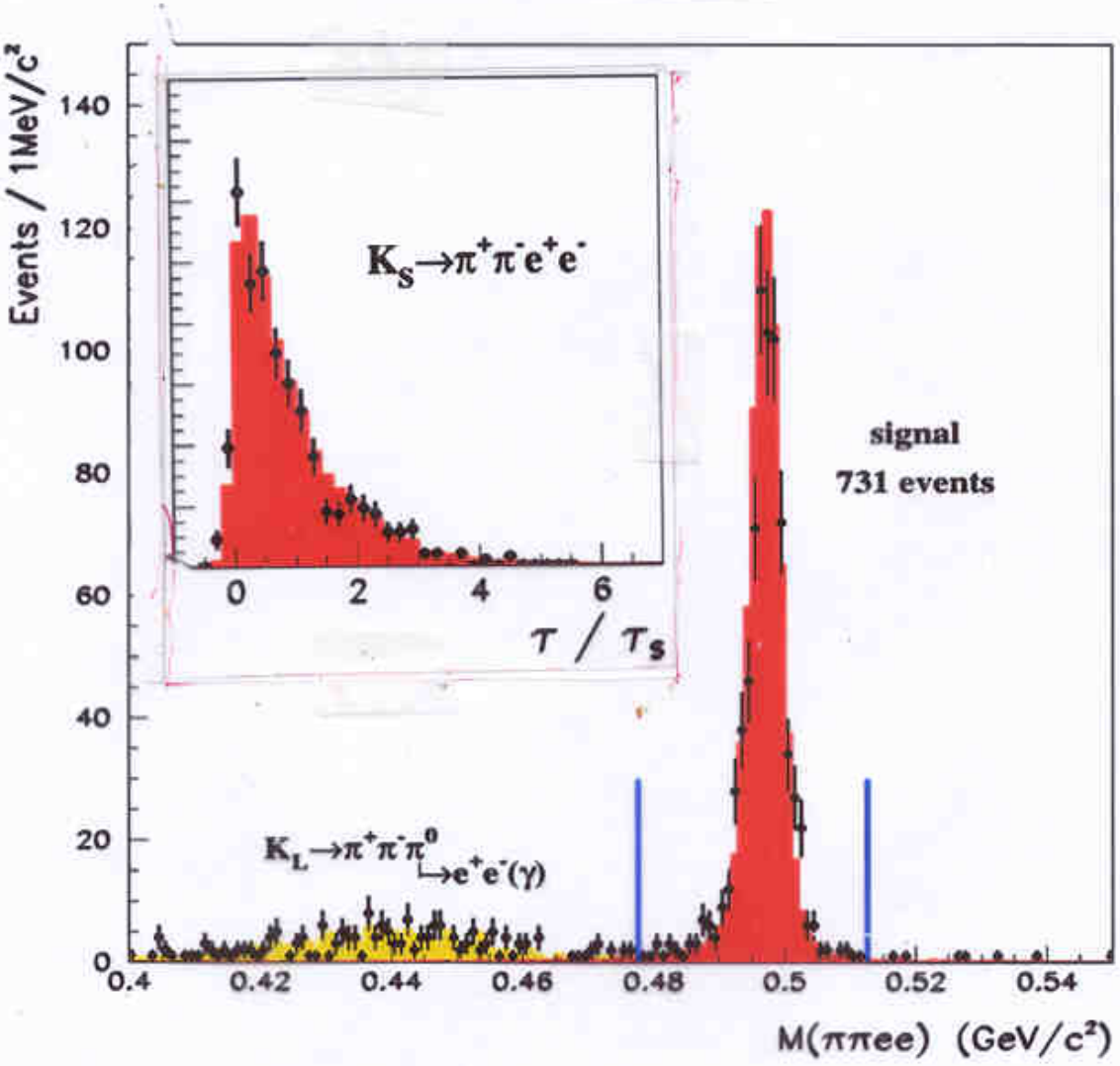
$K_L \to \pi^+\pi^-\pi^0_D$ from K_S target ($\sim$ 100 ev)

are used as normalisation

BR ($K_S \to \pi^+\pi^-e^+e^-$) $\sim 4 \cdot 10^{-5}$

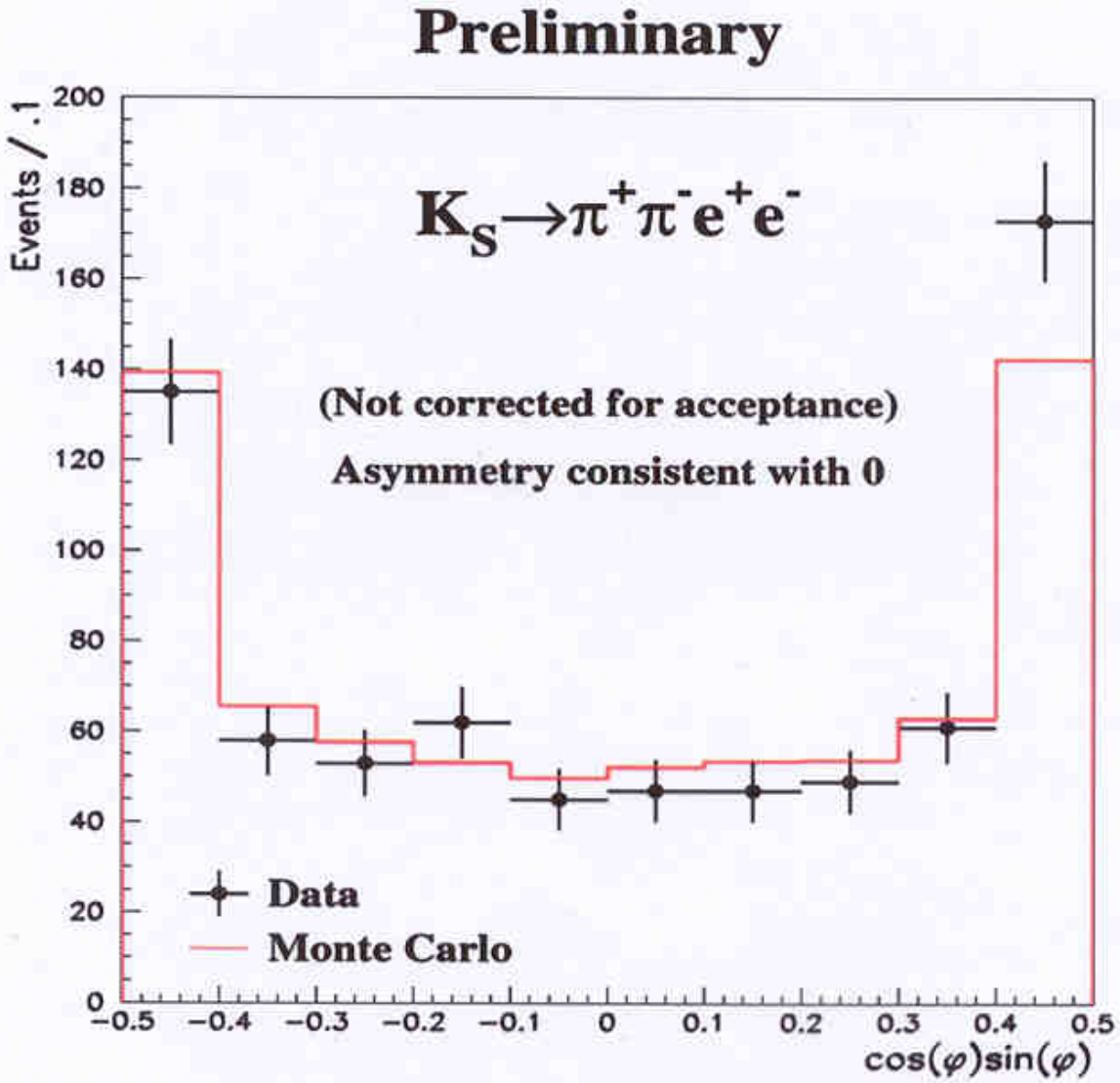
1999 $K_S \to \pi^+\pi^-e^+e^-$

High intensity
K_S beam



731 $K_S \to \pi^+\pi^-e^+e^-$ candidates

1999 $K_S \to \pi^+\pi^-e^+e^-$: Asymmetry



Results : Conclusions

→ NA48 reports a preliminary measurement of

$$BR(K_L \to \pi^0\gamma\gamma) = (1.51 \pm 0.05(stat) \pm 0.20(syst)) \cdot 10^{-6}$$

based on $\sim$ 1400 events

with only $\sim$ 30 background events

→ NA48 demonstrates the low $m_{\gamma\gamma}$ tail
with very low backgrounds

→ Measured asymmetry in $K_L \to \pi^+\pi^-e^+e^-$
consistent with theory

→ First observation of $K_S \to \pi^+\pi^-e^+e^-$

→ First measurement of

$$BR(K_S \to \pi^+\pi^-e^+e^-) \sim 4 \cdot 10^{-5}$$

based on 58 events collected during the 98 ϵ'/ϵ run

→ Measured asymmetry consistent with zero within few %