Recent Rare Decay results from NA48

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The NA48 Collaboration:

Cagliari, Cambridge, CERN, Dubna, Edinburgh,
Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa,
Saclay, Siegen, Torino, Vienna, Warsaw.

Results presented herein are preliminary unless otherwise stated

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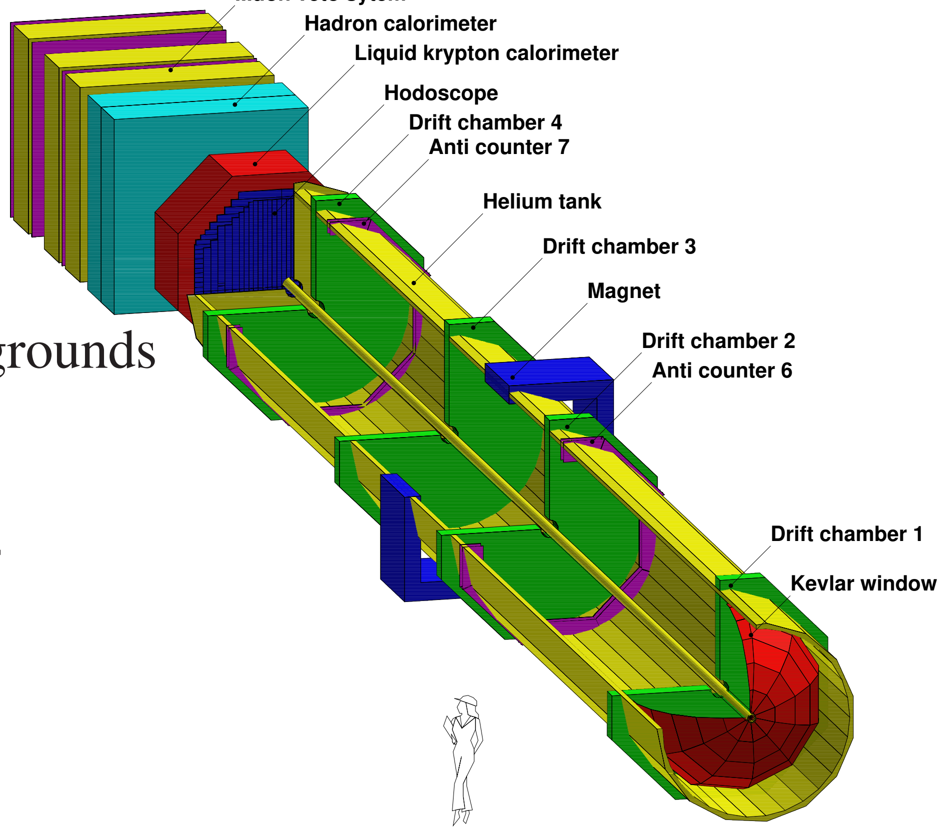
- Summary

The NA48 Experiment

- Designed to measure ϵ'/ϵ to $\sim 10^{-4}$
- High kaon fluence
  - $\longrightarrow$ Rare Decay studies
  - $\longrightarrow$ High quality data
  - $\longrightarrow$ Low accidental backgrounds



- Magnetic spectrometer:

$$\frac{\sigma_P}{P} \simeq 0.5\% \oplus 0.009.P$$

with P in GeV/c

- LKr Calorimeter:

$$\frac{\sigma(E)}{E} \simeq \frac{0.100}{E} \oplus \frac{0.032}{E} \oplus 0.005$$

with E in GeV

Search for $K_S \rightarrow \pi^0 e^+ e^-$

Motivation; The decay rate constrains the indirect CPV component of

$$K_L \rightarrow \pi^0 e^+ e^-.$$

Data; 2 day high intensity K_S run in 1999.

	decay products detected	acceptance (%)	events
Signal	$\pi^0 e^+ e^-$ $(M_{ee} > 165 MeV)$	7.68	0
Norm.	$\pi^0 \pi^0_D$	4.81	83960
Bgnd.	$\pi^0 \pi^0_D \rightarrow \pi^0 e^+ e^-$		0.3

Systematics include LKr cluster limitation (3%)

Radiative Corrections 4% – To Do!

Data/MC difference (3%)

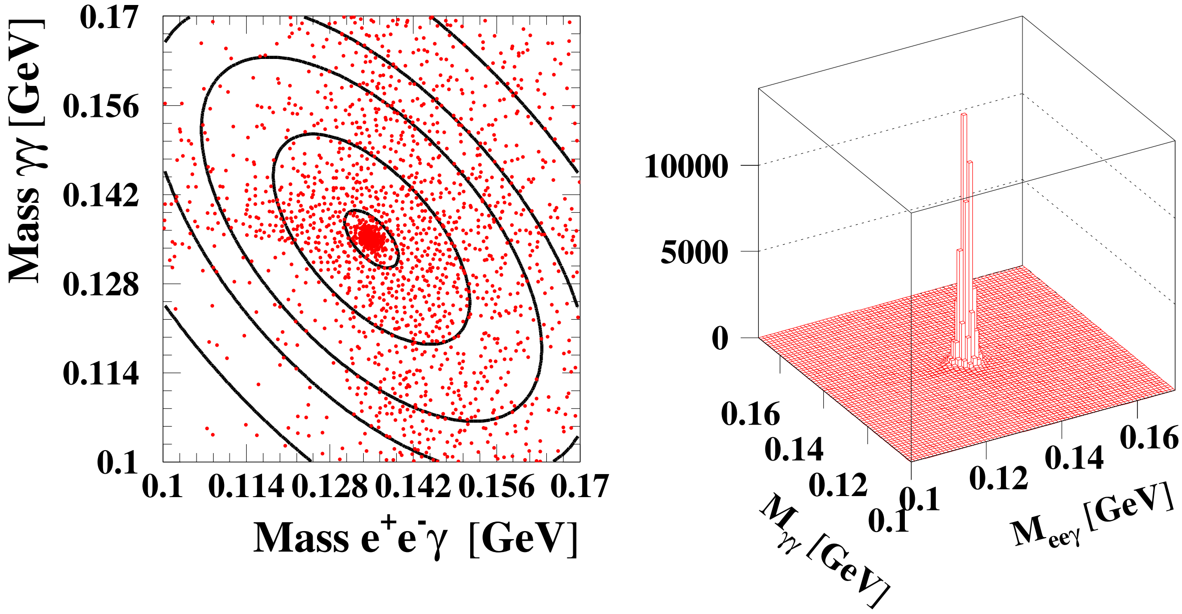
Model: G. D'Ambrosio, G. Echer, G. Isidori, and J. Portolés

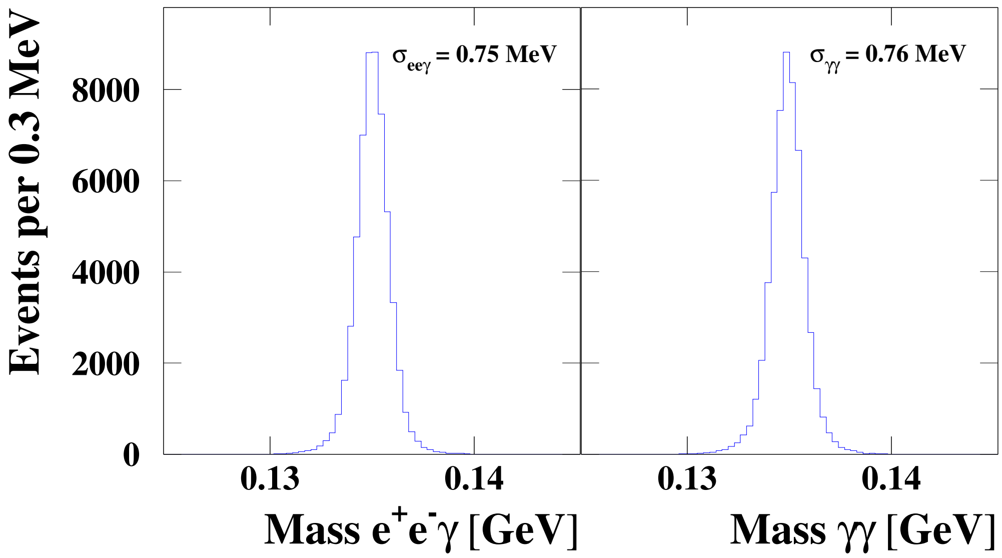
$(hep - ph/9808289)$

G. Echer, A. Pich and E. de Rafael (Nucl. Phys B **303**, p665, 1998)

$K_S \to \pi^0 e^+ e^-$;

Normalization events - $K_S^0 \to \pi^0 \pi_D^0$

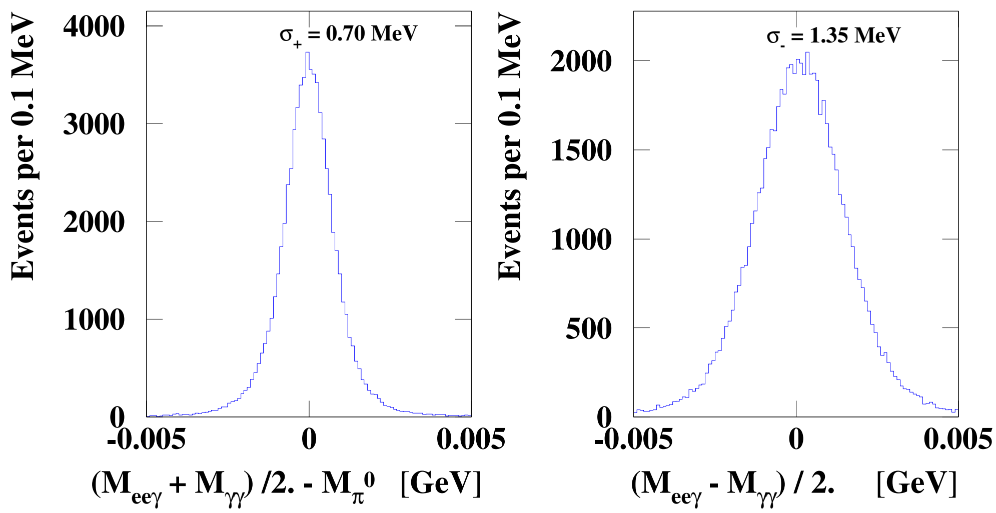


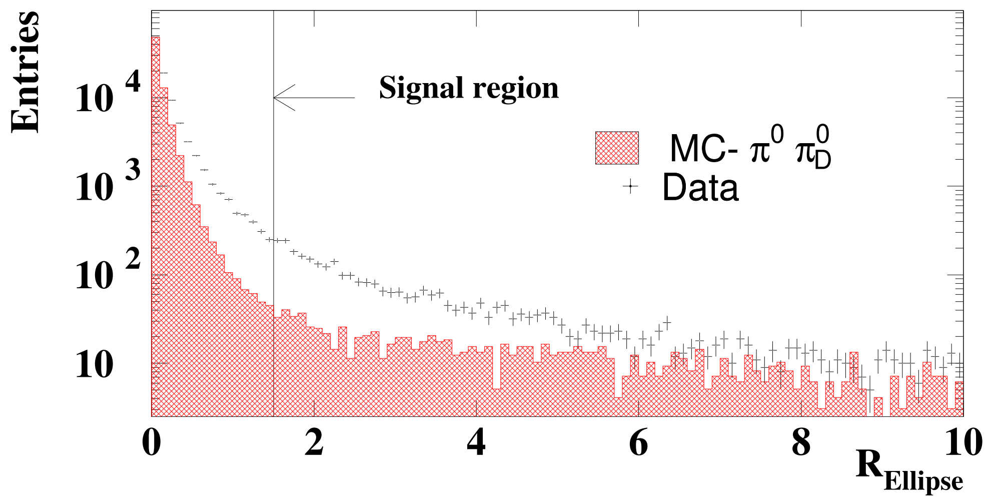


83960 reconstructed $K_S^0 \to \pi^0 \pi_D^0$ events

$K_S \to \pi^0 e^+ e^-$;

Normalization events - $K_S^0 \to \pi^0 \pi_D^0$

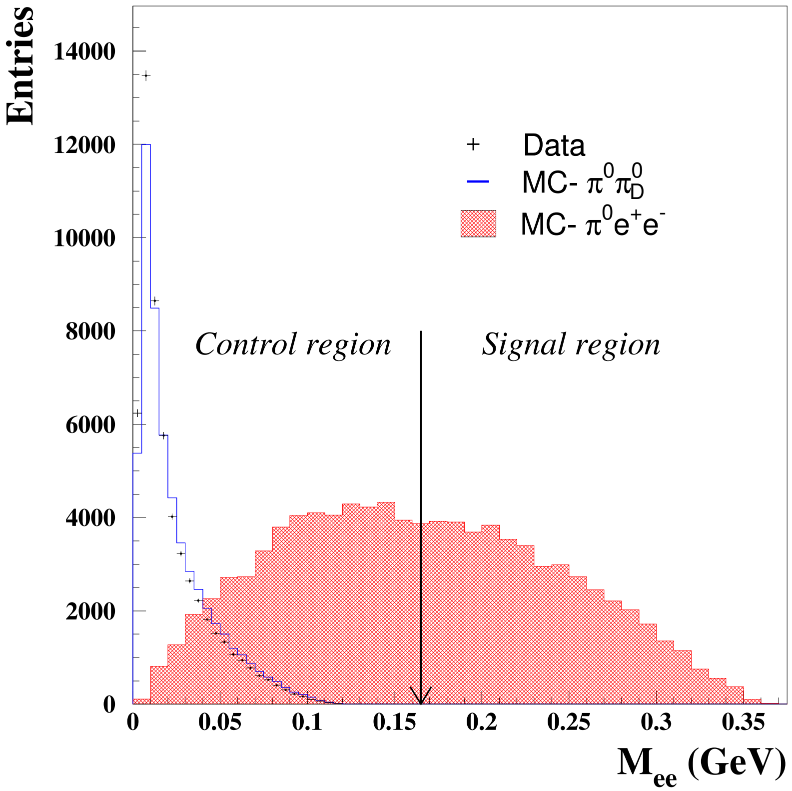




Reconstructed $K_S^0 \to \pi^0 \pi_D^0$ data:MC comparison

$K_S \rightarrow \pi^0 e^+ e^-$ Signal

$$\Gamma(K_S \rightarrow \pi^0 e^+ e^-; M_{ee} > 165\ MeV) < 8.3 \times 10^{-8}\ (90\% C.L.).$$
$$\Gamma(K_S \rightarrow \pi^0 e^+ e^-; M_{ee} > 165\ MeV)_{THEORY} < 1.6 \times 10^{-7}$$



0 events in signal region

Expect 0.3 background events

M_{ee} Spectra for data and Monte Carlo data.

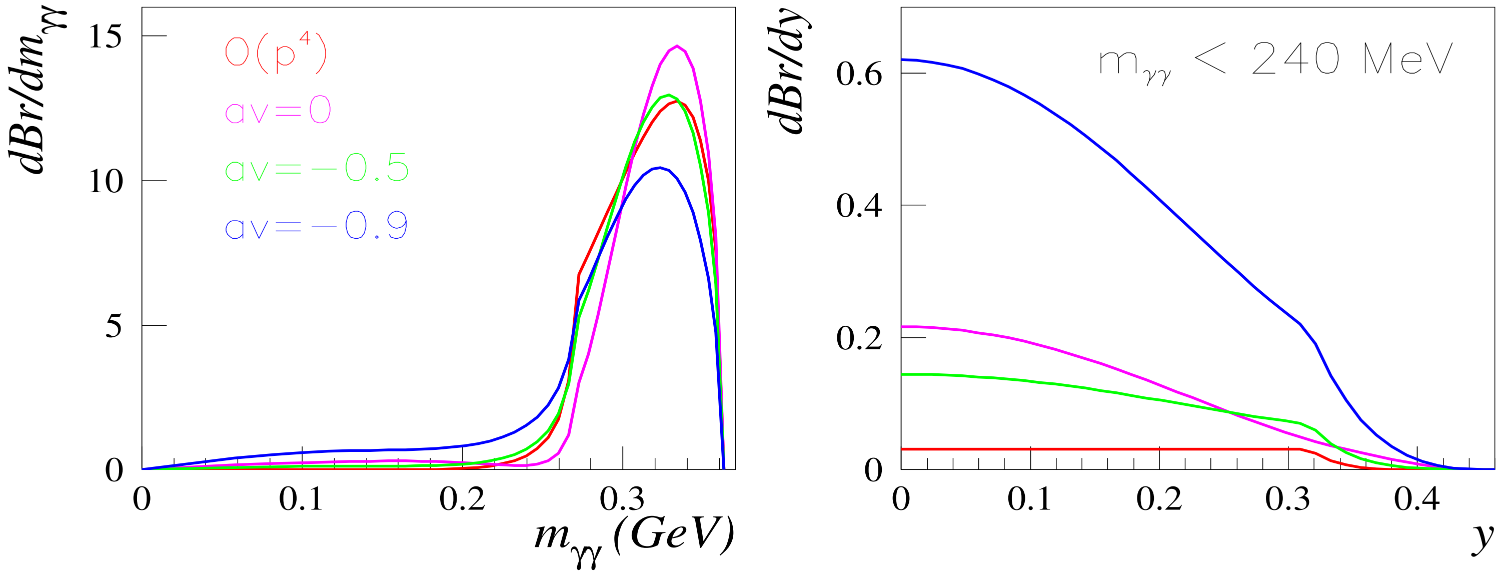
$K_L \rightarrow \pi^0\gamma\gamma$

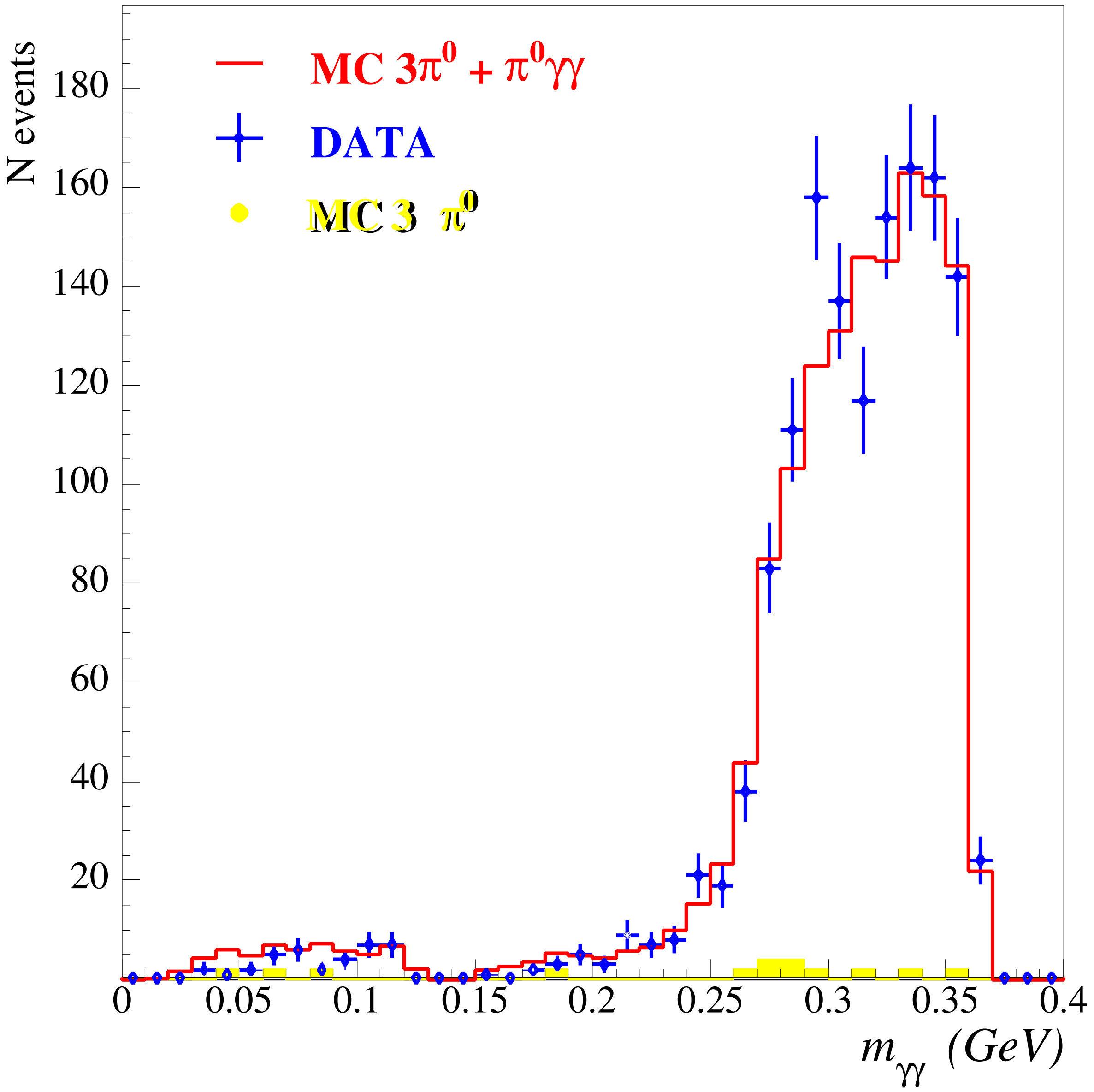
Motivation: Test of χPT to $O(p^6)$ test of VMD mechanism

estimate the CP-conserving amplitude of $K_L \rightarrow \pi^0 e^+ e^-$

- Data: part of the 1998 run and 1999 data
- MC assumes $a_v = -0.45$

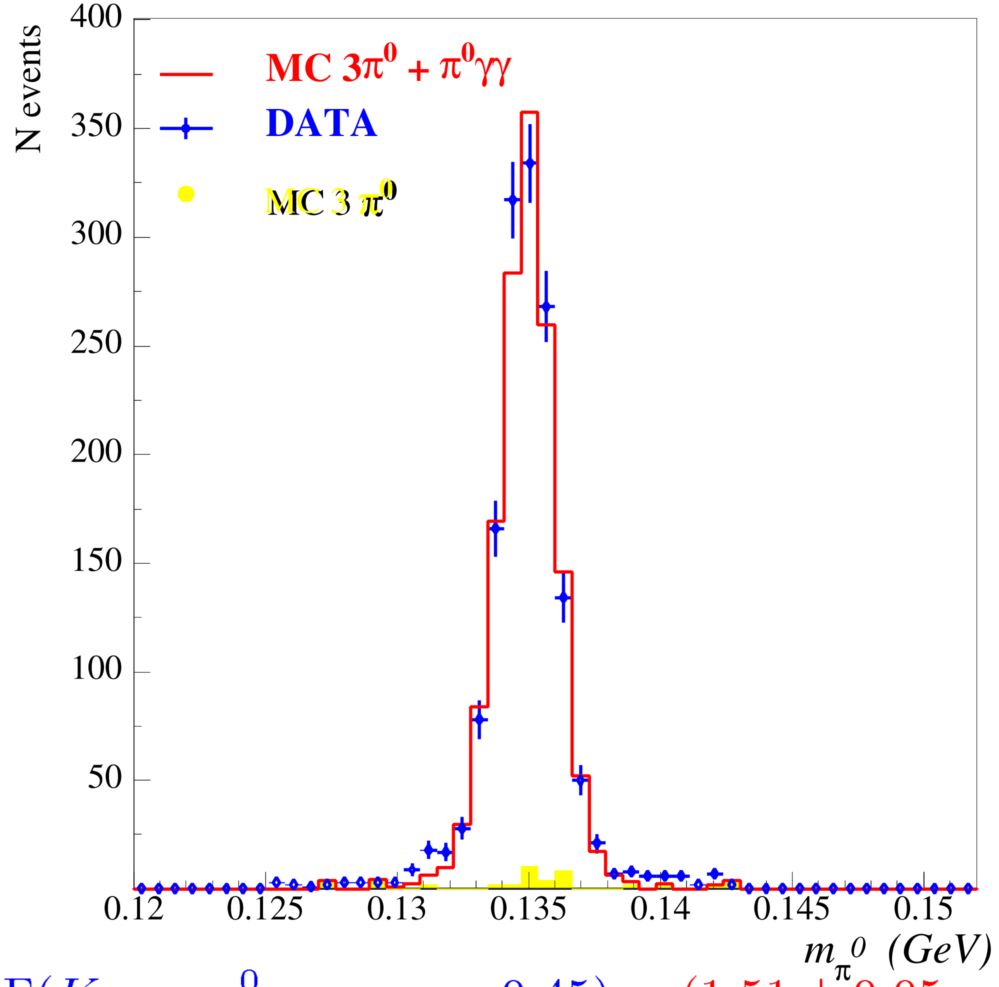
$y = |E_1^\star - E_2^\star|/M_K$





$M_{\gamma\gamma}$ spectrum for all 1397 $K_L \to \pi^0\gamma\gamma$ candidates (est. 30 bgnd.).

Events with $M_{\gamma\gamma} < 0.2\ GeV$ are a clear indication of p^6 contribution.

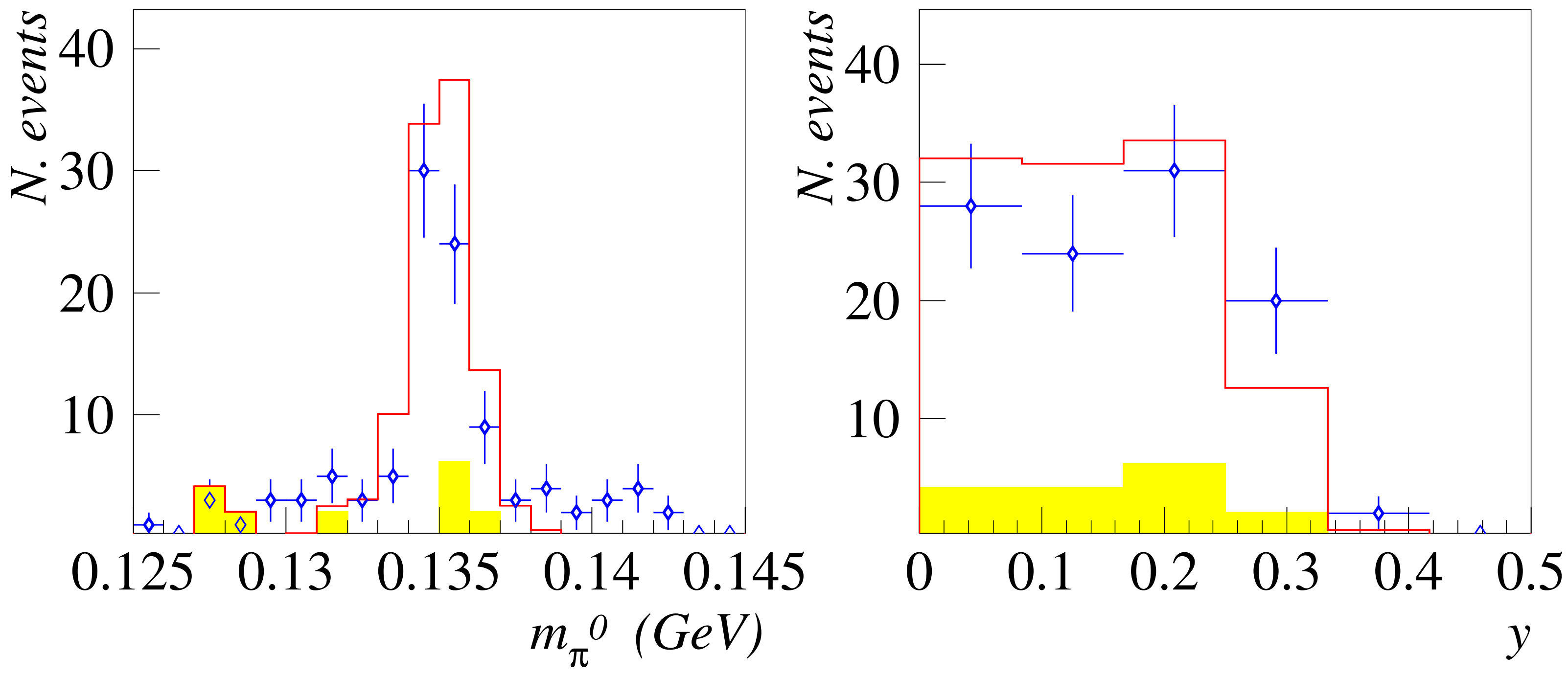


Reconstructed M_{π^0}

for all events

$$\Gamma(K_L \to \pi^0\gamma\gamma; a_v = -0.45) = (1.51 \pm 0.05_{STAT} \pm 0.20_{SYST}) \times 10^{-6}$$

Reconstructed M_{π^0} for events with $M_{\gamma\gamma} < 240\ MeV$.



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

Motivation: CP conserving decay with no T odd asymmetry in the angle between the $\pi^+\pi^-$ and e^+e^- plane.

Study of this checks the method used to measure the T odd asymmetry measured in the CPV decay $K_L \rightarrow \pi^+\pi^-e^+e^-$

and also quantifies the CP-conserving amplitude in that decay.

$$A = sin\phi cos\phi$$

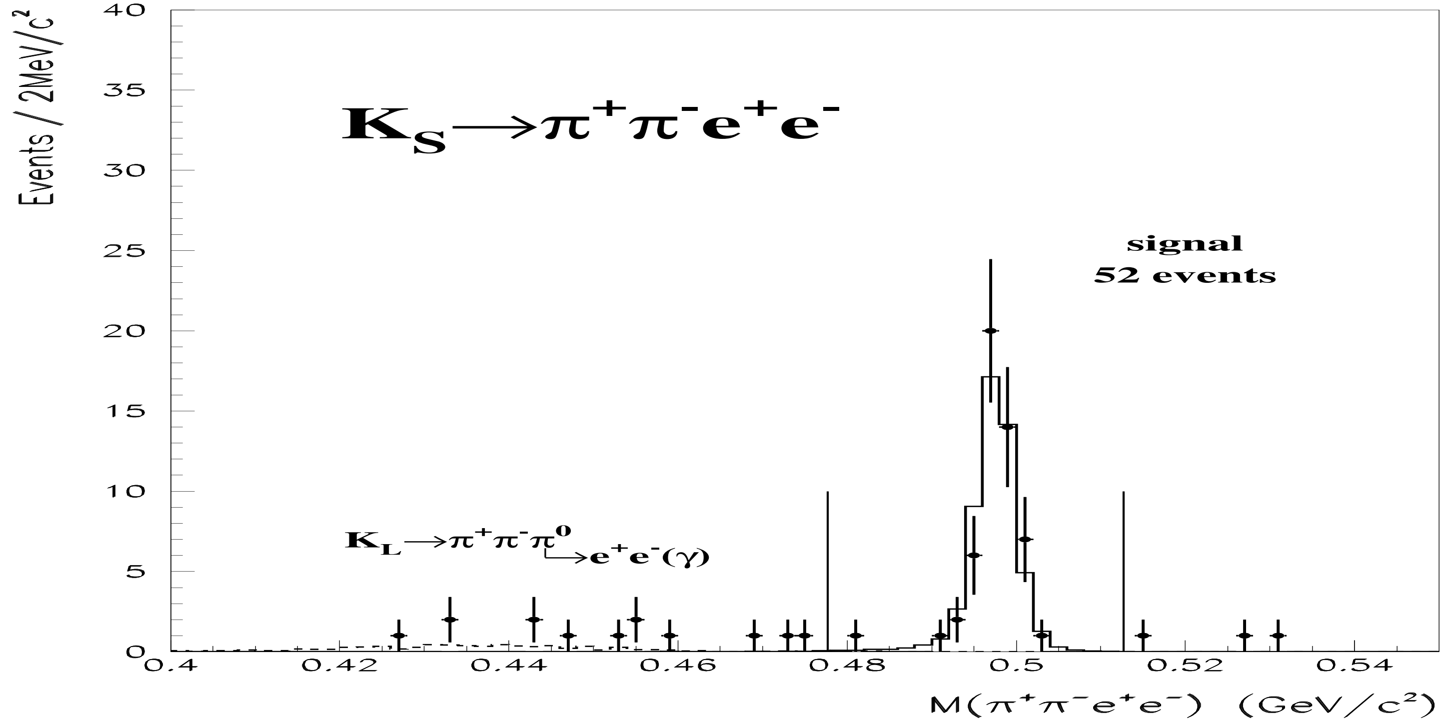
$$\phi = \overrightarrow{(\pi^+\pi^-\ plane)} \times \overrightarrow{(e^+e^-)\ plane}$$

see Heileger Sehgal - 1993 calculation of $K_L \rightarrow \pi^+\pi^-e^+e^-$.

Observed 52 $K_S \to \pi^+\pi^-e^+e^-$ candidates events in 1998 give

$$\Gamma(K_S \to \pi^+\pi^-e^+e^-) = (5.1 \pm 0.9_{STAT} \pm 0.3_{SYST}) \times 10^{-5}$$

where $K_L \to \pi^+\pi^-{\pi^0}_D$ is used for normalization. Background from $K_L \to \pi^+\pi^-{\pi^0}_D$ in signal region is < 1 event.



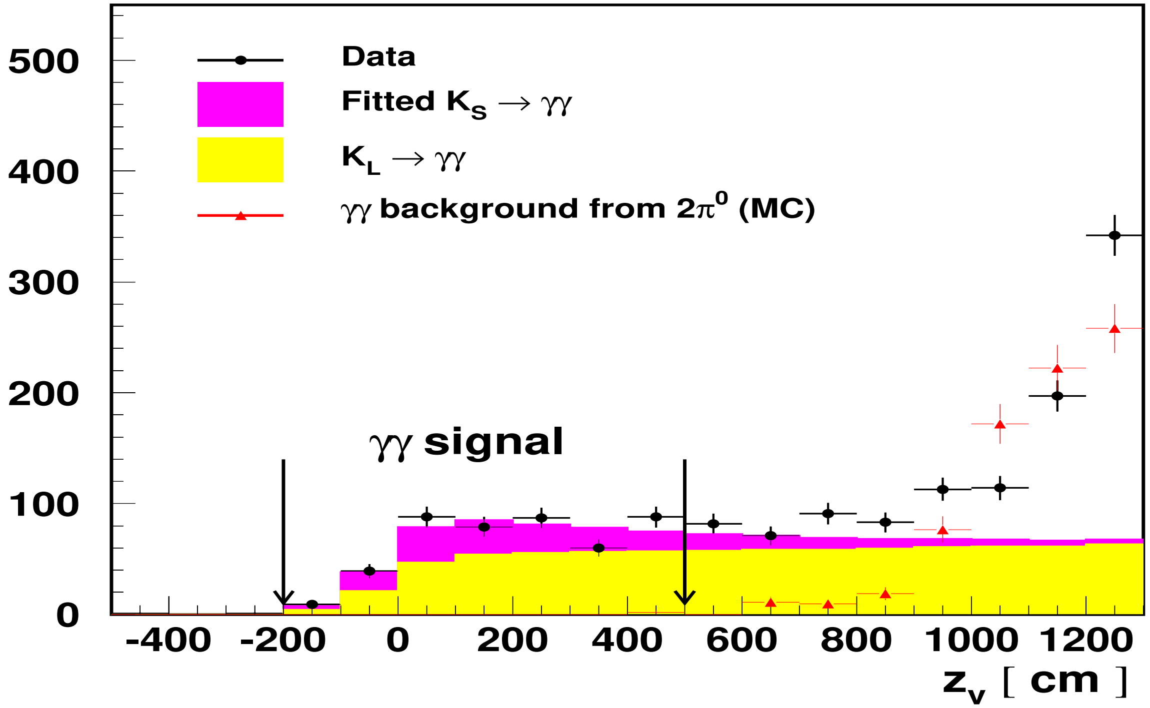
the data are consistent with no asymmetry.

$K_S \to \gamma\gamma$ (final result from 99 data)

Motivation: test of χPT; there is no short distance contribution and the rate is calculable to 10%; $\Gamma(K_S \to \gamma\gamma)_{THEORY} = 2.25 \times 10^{-6}$

Data: 2 day high intensity K_S run in 1999

Method; ML fit to Z_{VERTEX} spectrum of $K \to \gamma\gamma$ decays.



Signal:

$K_S \to \gamma\gamma$

Backgrounds:

$K_L \to \gamma\gamma$

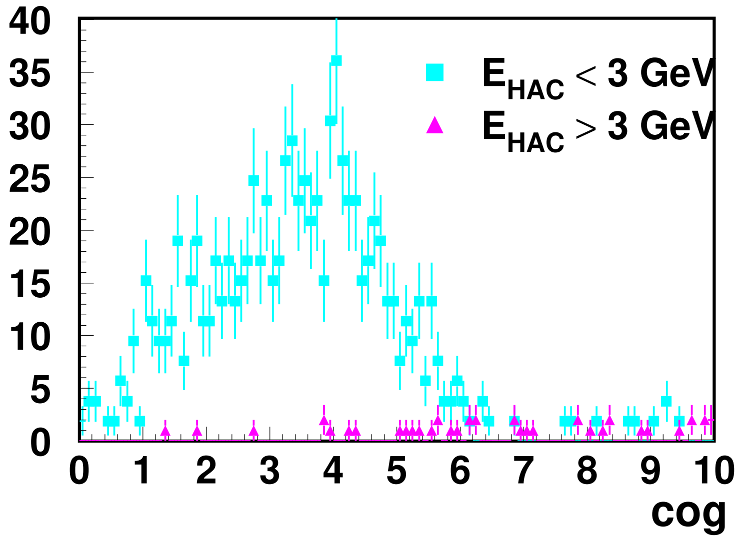
$K_L \to \pi^0\pi^0$

$K_S \to \gamma\gamma$ Event Selection

- $3 < E_{\gamma\ i,\ j} < 100\ GeV$
- $r_{\gamma\ ij} > 10.0\ cm$
- time window $\pm 5.0\ ns$
- no extra clusters with $E > 1.5\ GeV$
- $-200.0 < Z_{VERTEX} < 500.0\ cm$

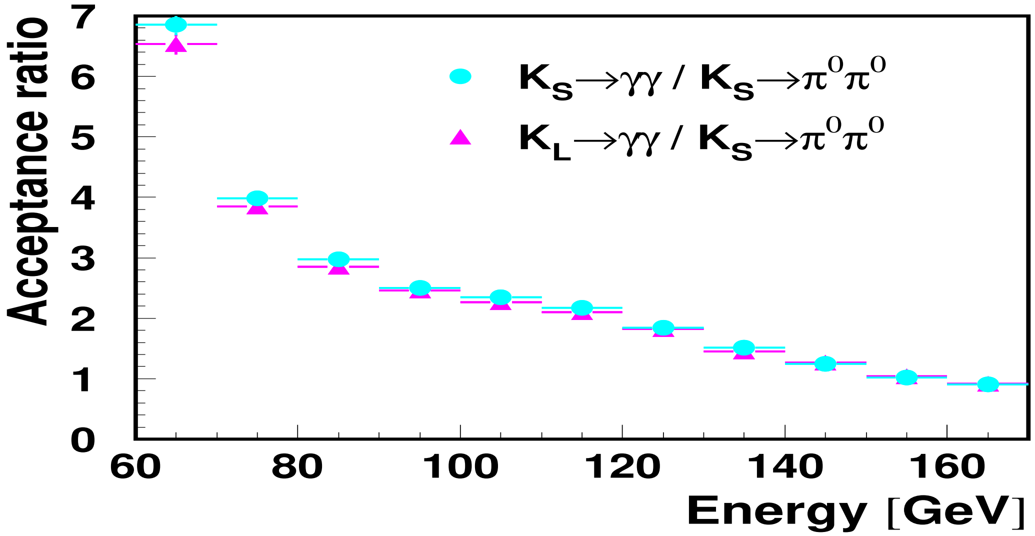
$K_S \to \gamma\gamma$ Background Contribution

- Neutral hadronic contribution $\simeq 14$ events; $E_{HADRONIC} > 3\ GeV$



- $K_S \to \pi^0\pi^0 \simeq 2$ events
- $K_L \to \gamma\gamma$ (294 events) using relative acceptances and efficiencies:

$$N_L = N_{2\pi^0} \cdot \frac{A(K_L \to \gamma\gamma)}{A(K_S \to \pi^0\pi^0)} \cdot \frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_S \to \pi^0\pi^0)} \cdot \frac{1}{\epsilon_{2\pi^0}}$$



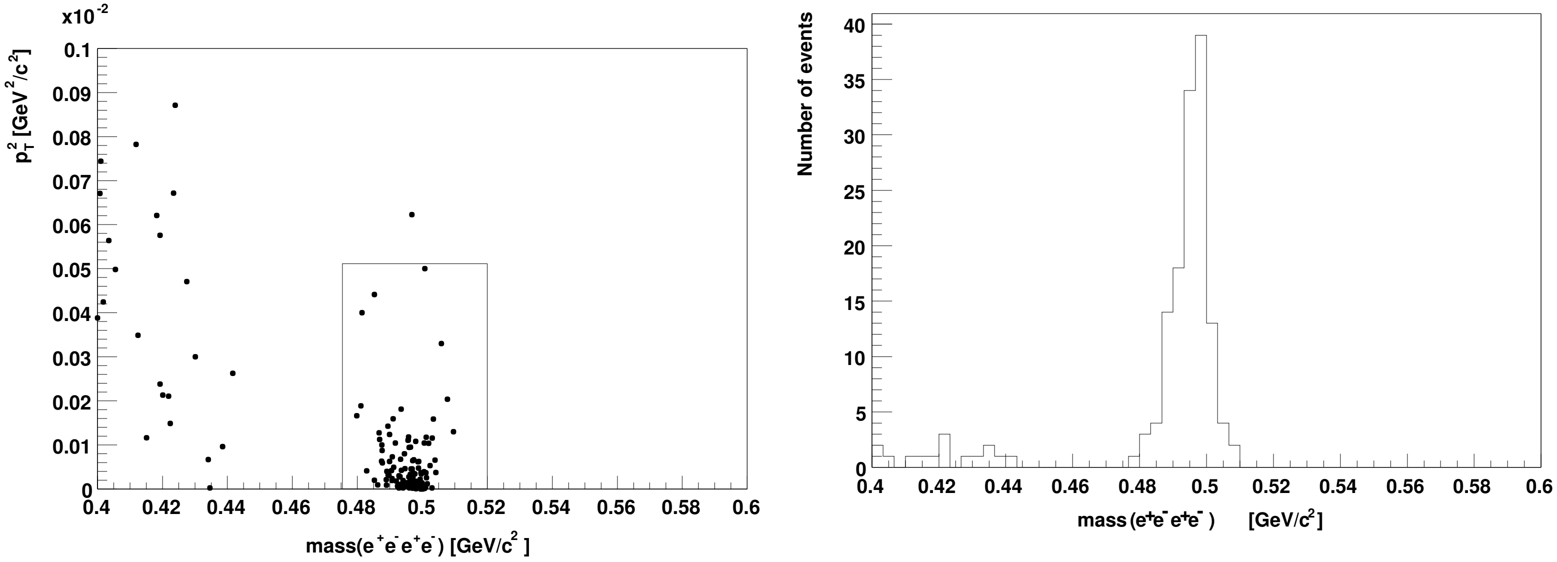
Systematics:

Source	contribution to γ (%)
Background	3
$\Gamma(K_L \to \gamma\gamma)$	5
MC simulation	2
2π trigger efficiency	$1 - 2$
cuts	4

Result:

$$\Gamma(K_S \to \gamma\gamma) = (2.6 \pm 0.4_{STAT} \pm 0.2_{SYST}) \times 10^{-6}$$

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



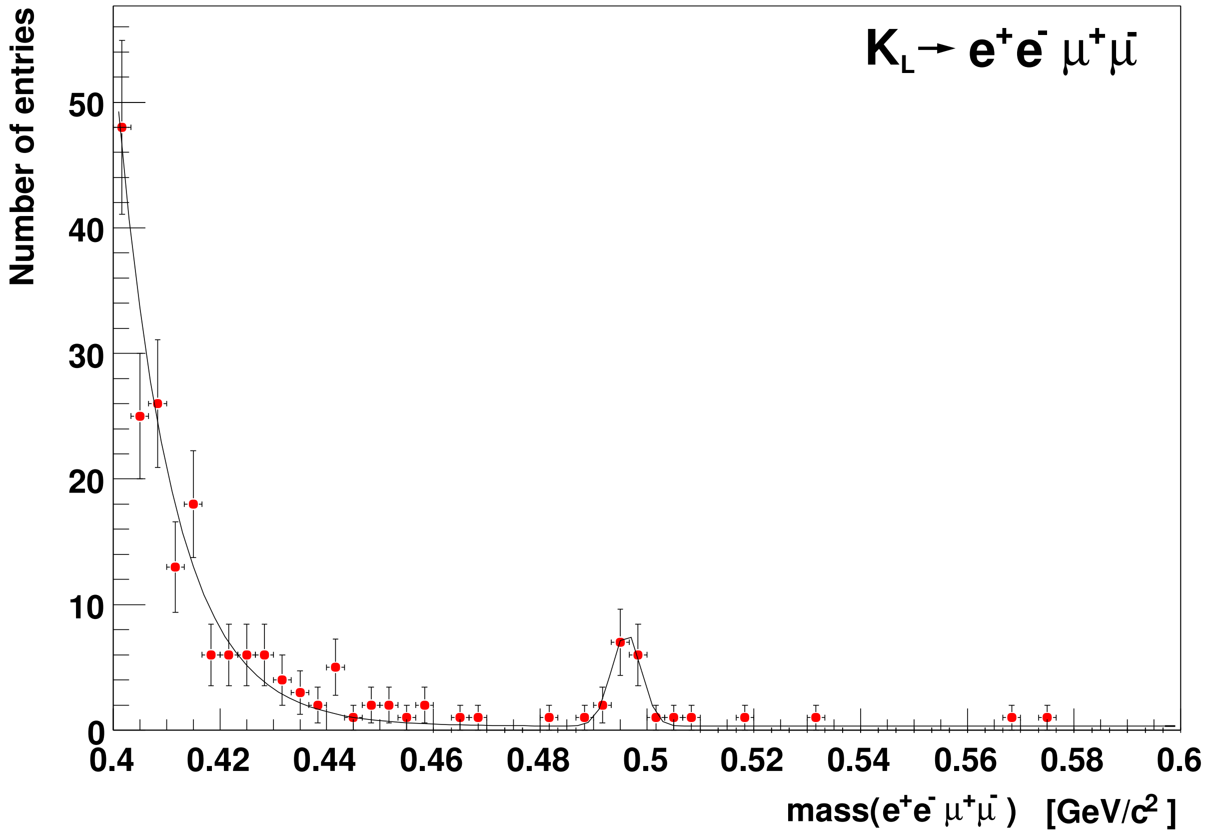
Motivation; $\gamma^\star\gamma^\star$ vertex structure; model dependent tests

132 candidate events in 1999 data

$$\Gamma(K_L \to e^+e^-e^+e^-) =$$
$$(3.67 \pm 0.32_{STAT} \pm 0.23_SYST \pm 0.08_{NORM}) \times 10^{-8}$$

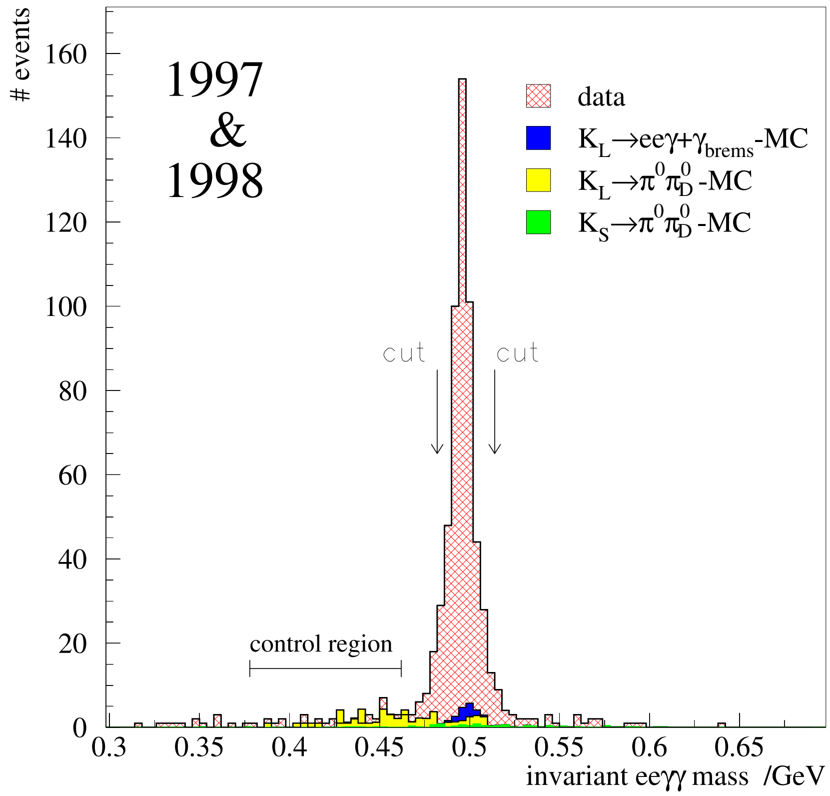
$$K_L \rightarrow \mu^+\mu^-e^+e^-$$

Motivation; $\gamma^\star\gamma^\star$ vertex structure; model dependent tests



21 candidate events have been observed in the 1999 data set

$K_L \rightarrow e^+e^-\gamma\gamma$ (final result from 98 + 99 data)



492 events observed in the 1998 and 1999 data with a total background of 25.1 ± 3.7 events mainly from from $K_L \rightarrow e^+e^-\gamma+$ external brems and $K_S \rightarrow \pi^0\pi^0{}_D$.

$$\Gamma(K_L \rightarrow e^+e^-\gamma\gamma; M_{\gamma^\star}) > 5\ MeV) = (6.32 \pm 0.31_{STAT} \pm 0.20_{SYST} \pm 0.29_{NORM}) \times 10^{-7}$$

Summary of recent results; Kaons

- $\Gamma(K_S \to \pi^0 e^+ e^-; M_{ee} > 165\ MeV) < 8.3 \times 10^{-8}$ $(90\% C.L.)$.
- $\Gamma(K_S \to \gamma\gamma) = (2.6 \pm 0.4_{STAT} \pm 0.2_{SYST}) \times 10^{-6}$.
- $\Gamma(K_L \to \pi^0 \gamma\gamma; a_v = -0.45) = (1.51 \pm 0.05_{STAT} \pm 0.20_{SYST}) \times 10^{-6}$.

  1397 events.
- $\Gamma(K_S \to \pi^+ \pi^- e^+ e^-) = (5.1 \pm 0.9_{STAT} \pm 0.3_{SYST}) \times 10^{-5}$.
- $\Gamma(K_L \to e^+ e^- e^+ e^-) =$

  $(3.67 \pm 0.32_{STAT} \pm 0.23_{SYST} \pm 0.08_{NORM}) \times 10^{-8}$, 132 events.
- 21 candidate $K_L \to \mu^+ \mu^- e^+ e^-$ events have been observed.
- $\Gamma(K_L \to e^+ e^- \gamma\gamma; M_{\gamma^\star} > 5 MeV) =$

  $(6.32 \pm 0.31_{STAT} \pm 0.20_{SYST} \pm 0.29_{NORM}) \times 10^{-7}$, 492 events.

Summary of recent results; Hyperons

- $\Gamma(\Xi^0 \to \Lambda\gamma) = (1.9 \pm 0.1 \pm 0.2) \times 10^{-3}$, 497 events.
- $\Xi^0 \to \Sigma^0\gamma$, observed $\sim$ 380 signal events above a background of about 50 events.
- $\Xi^0 \to \Sigma^+ e^- \overline{\nu_e}$, observed $\sim$ 60 events. Should lead to $O(15\%)$ measurement.
- $\Gamma(\Xi^0 \to p\pi^-) < 3.7 \times 10^{-5}$ (90 % C.L.). Expect an order of magnitude improvement over this when all data are analyzed.
- Further work is required to finish analysis of the 1999 Hyperon data.
- The planned high intensity K_S run will give NA48 at least 40 times the statistics obtained in the 2 day run in 1999.