Rare Kaon Decays From NA48

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on behalf of the NA48 Collaboration:

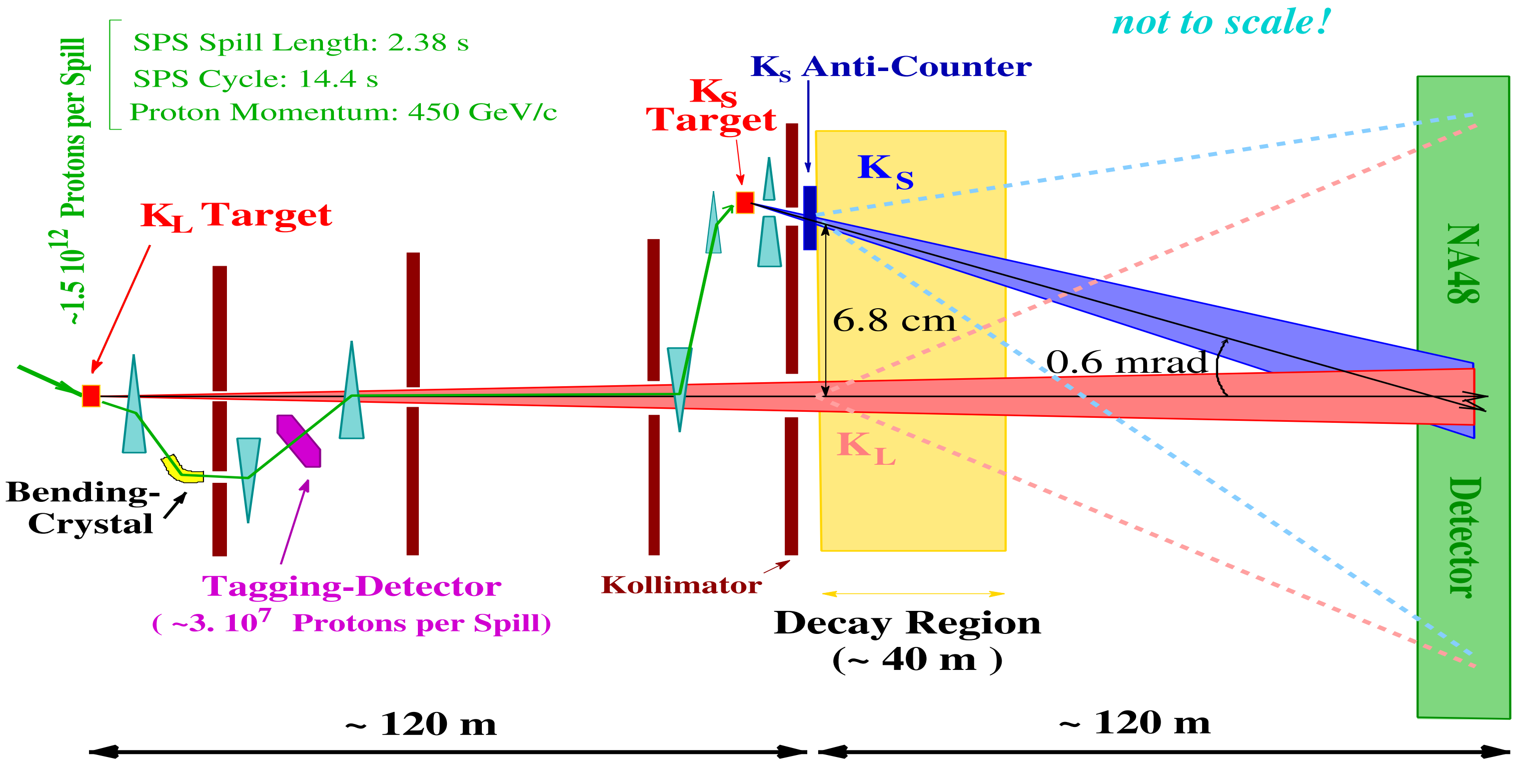
Cagliari, Cambridge, CERN, Dubna, Edinburgh, Ferrara, Florence, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna, Warsaw

Outline

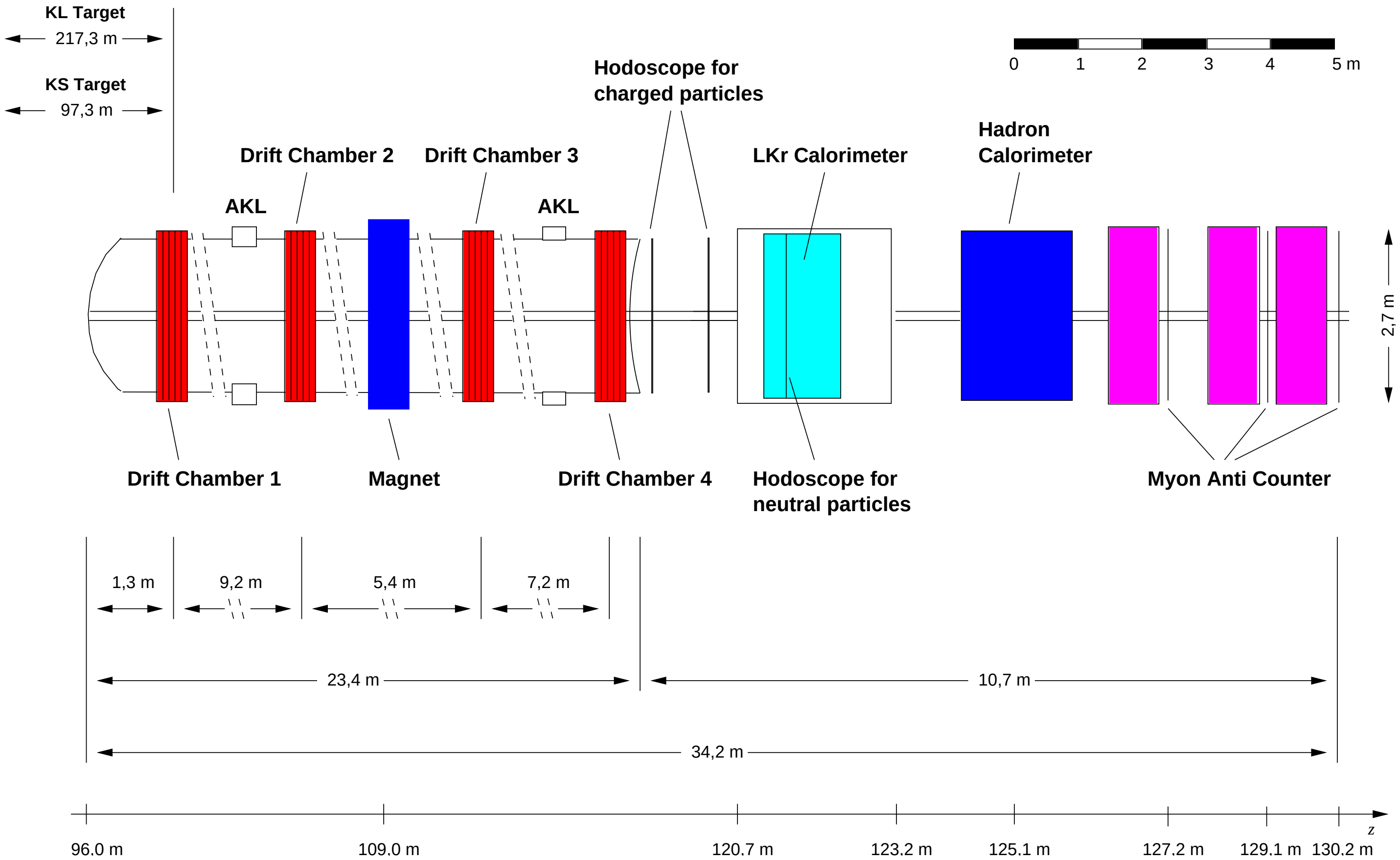
- NA48 Beam Line & Detector
- $K_L \to \pi^0\gamma\gamma$
- $K_S \to \gamma\gamma$

The NA48 Experiment

Designed for precision measurement of the CP violation parameter ϵ'/ϵ

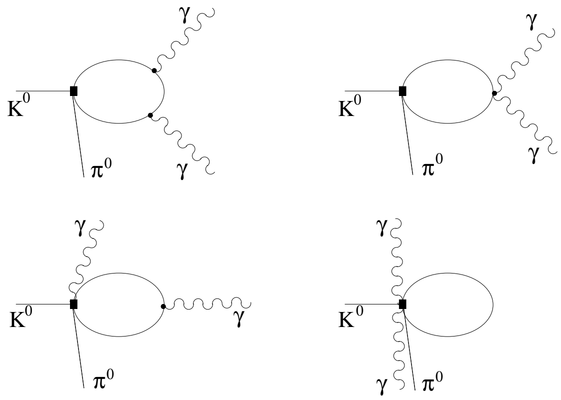


The NA48 Detector



$K_L \to \pi^0\gamma\gamma$: Motivation & Theory

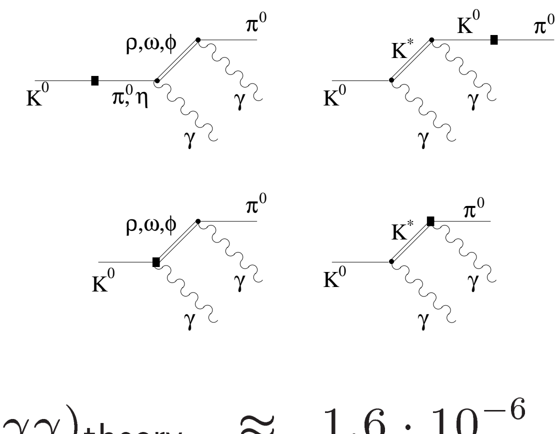
- calculation up to O(p^4) does not explain previously measured branching ratio



$$\text{BR}(K_L \to \pi^0\gamma\gamma)_{\text{theory}} \approx 0.8 \cdot 10^{-6} \quad (a_v = 0)$$

$$\text{BR}(K_L \to \pi^0\gamma\gamma)_{\text{exp}} = (1.7 \pm 0.3) \cdot 10^{-6} \quad \text{NA31}$$

- add O(p^6) calculation, especially VMD contributions

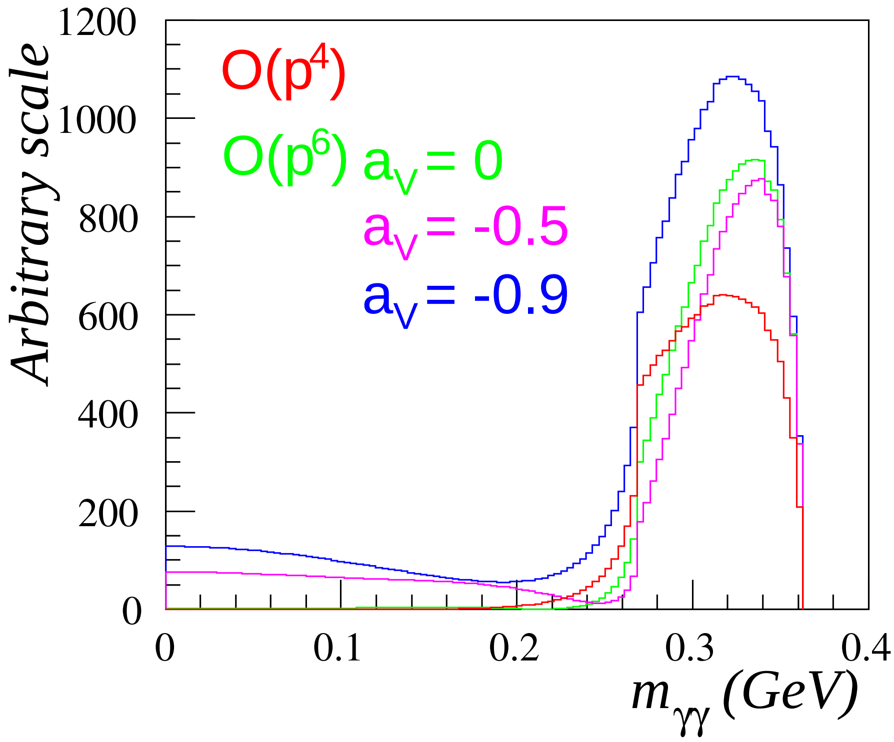


$$\text{BR}(K_L \to \pi^0\gamma\gamma)_{\text{theory}} \approx 1.6 \cdot 10^{-6} \quad (a_v = -0.9)$$

- $\rightsquigarrow$ good test of χPT up to O(p^6)

$K_L \to \pi^0\gamma\gamma$: Motivation & Theory

- a_v not given by theory, to be determined by experiments
- spectra depend on a_v:



- if $a_v < 0 \leadsto$ events with $m_{\gamma\gamma} < 240$ MeV
- estimate of CP conserving amplitude in $K_L \to \pi^0 e^+ e^-$ (via intermediate state $\pi^0\gamma^*\gamma^*$)

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

Data sample: 1998 and 1999 data

Online selection: $2\pi^0$ trigger (efficiency: 99.95%)

Normalisation channel: $K_L \to \pi^0\pi^0$

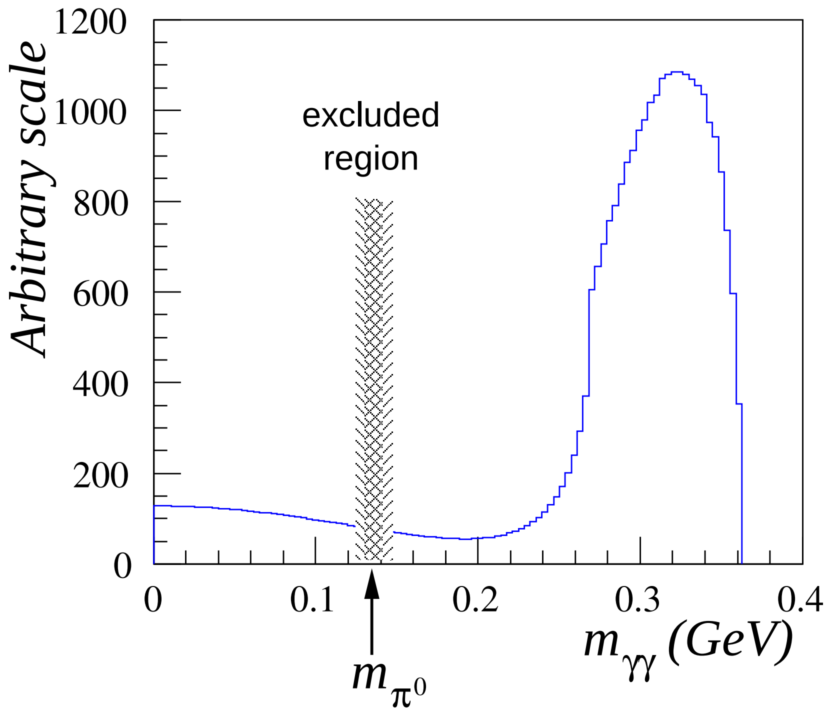
Offline selection:

- K_L identification by **tagging system**
- $E_{\text{shower}} > 3$ GeV
- 70 GeV $< E_{\text{LKr}} <$ 170 GeV
- 4 “good” clusters within 10 ns
- no tracks in **drift chambers**

$K_L \to \pi^0\gamma\gamma$: Background Rejection

Background from $K_L \to \pi^0\pi^0$ (BR $= 9.4 \cdot 10^{-4}$)

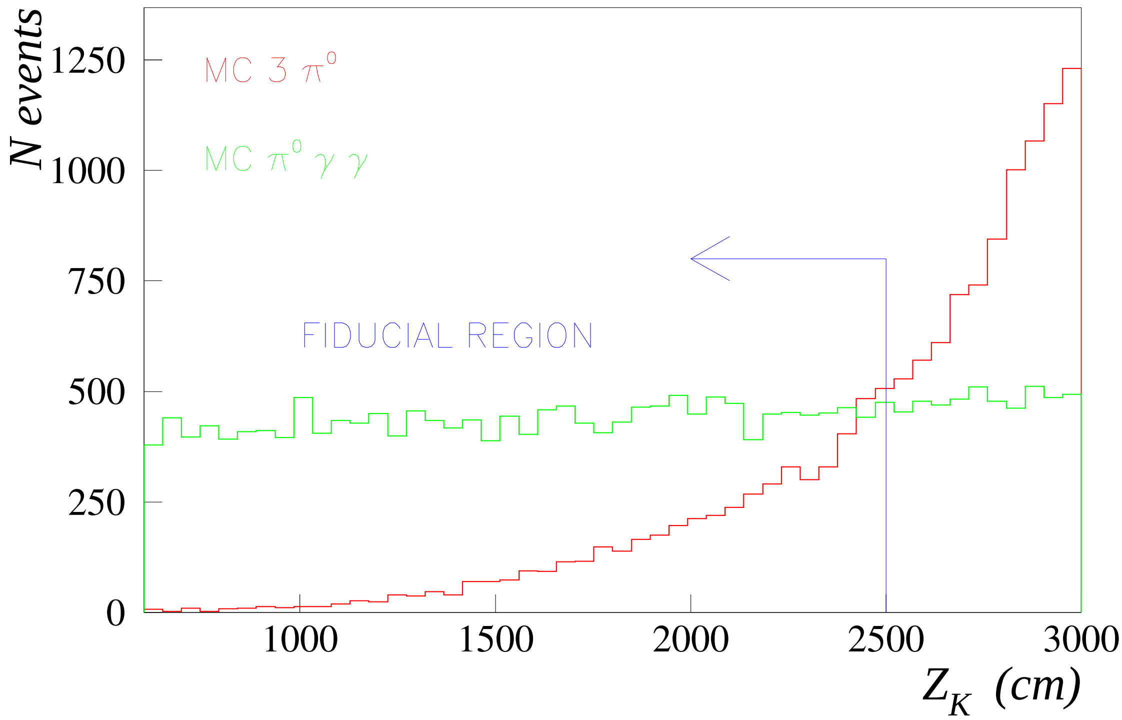
- $m_{\pi^0} < 125$ MeV || $m_{\pi^0} > 145$ MeV (preselection)
- $m_{\gamma\gamma} < 130$ MeV || $m_{\gamma\gamma} > 140$ MeV (preselection)
- $\chi^2(K_L \to \pi^0\pi^0) > 100$
- no drift chamber hit in time (conversions)



$K_L \to \pi^0\gamma\gamma$: Background Rejection

$K_L \to \pi^0\pi^0\pi^0$ background: lost photons

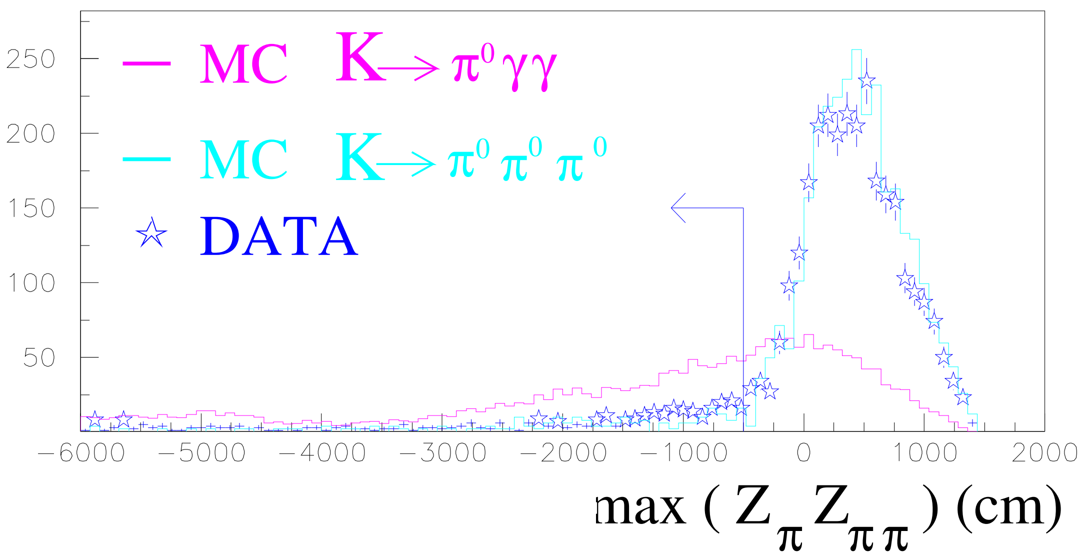
- require no hit in ring veto counters (2 ns window)
- lost photon
  $\leadsto$ vertex shift towards detector (by > 6 m)
  $\leadsto$ hard vertex cut: $z_{coll} < z < 25$ m



$K_L \to \pi^0\gamma\gamma$: Background Rejection

$K_L \to \pi^0\pi^0\pi^0$ background: photon loss and shower overlap

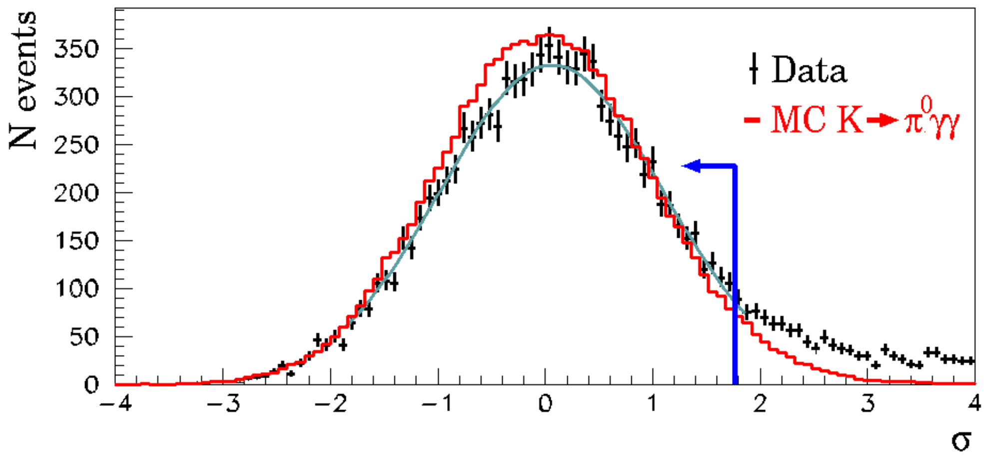
1. two photons overlap, one photon lost
   - reconstruct $K_L \to \pi^0\gamma\gamma$ vertex
   - attempt reconstruction of
     $\pi^0 \to \gamma\gamma$ or $\pi^0\pi^0 \to \gamma(\gamma\gamma)\gamma$ (all comb.)
     $\rightsquigarrow z_\pi/z_{\pi\pi} < z_K - 6$ m
     $\rightsquigarrow$ tight cuts on $max(z_\pi, z_{\pi\pi}) < -5$ m



$K_L \to \pi^0\gamma\gamma$: Background Rejection

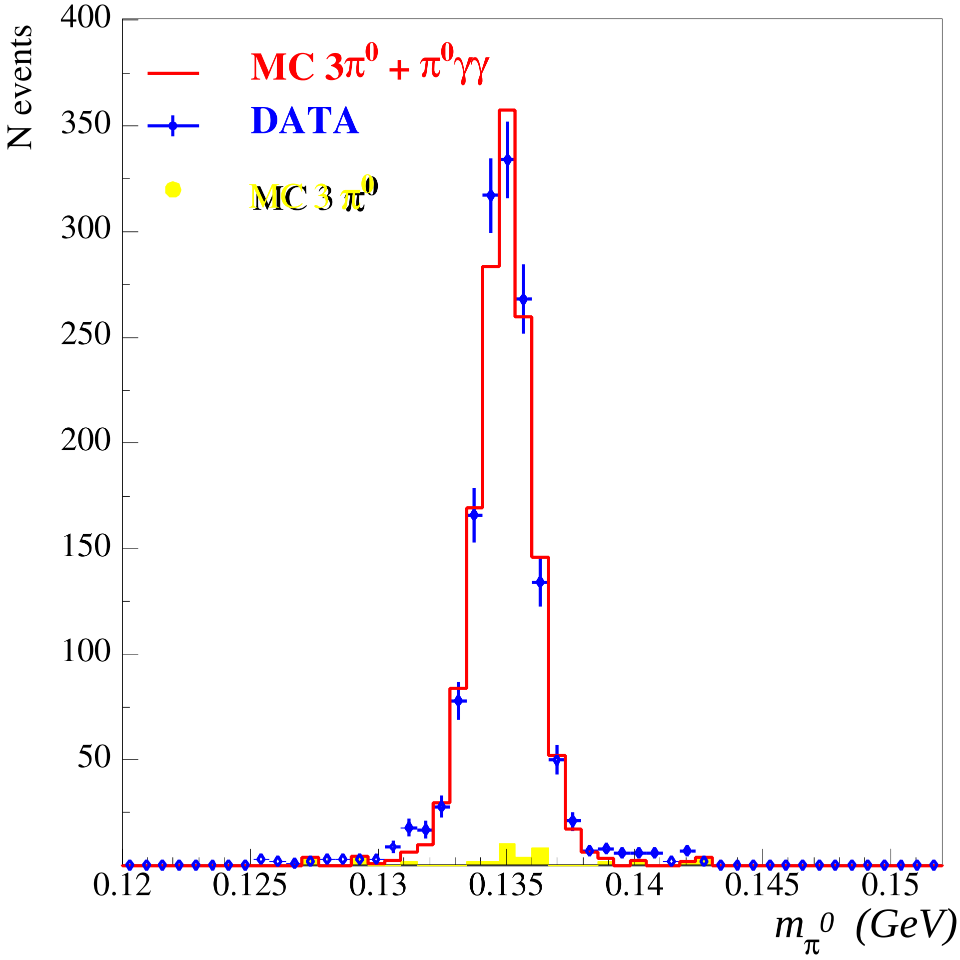
$K_L \to \pi^0\pi^0\pi^0$ background: photon loss and shower overlap

2. $2 \times$ two photons overlap, no photon lost
   - all γs detected, no vertex shift
   - use shower width
     $\rightsquigarrow$ overlapping showers are broader in LKr
     $\rightsquigarrow$ cut on shower width: rms$_{Cluster} < 1.8\sigma$



$K_L \to \pi^0\gamma\gamma$: Branching Ratio

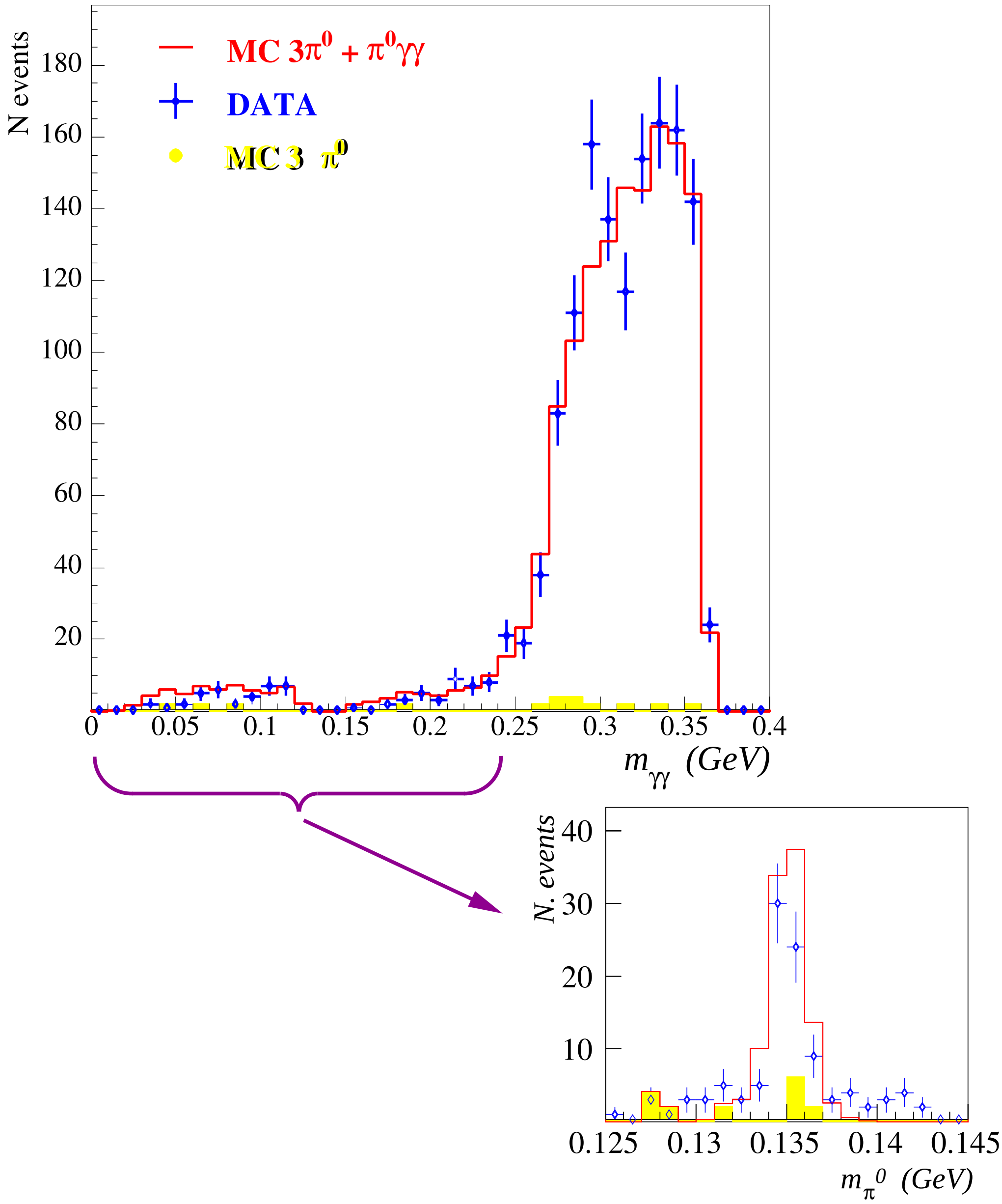
1397 candidates ($\sim$30 background)



Preliminary result ('99 and fraction of '98 data):

$$\mathrm{BR}(K_L \to \pi^0\gamma\gamma)|_{a_v=-0.45} = (1.51 \pm 0.05 \pm 0.20) \cdot 10^6$$

$K_L \to \pi^0\gamma\gamma$: $m_{\gamma\gamma}$ Spectrum

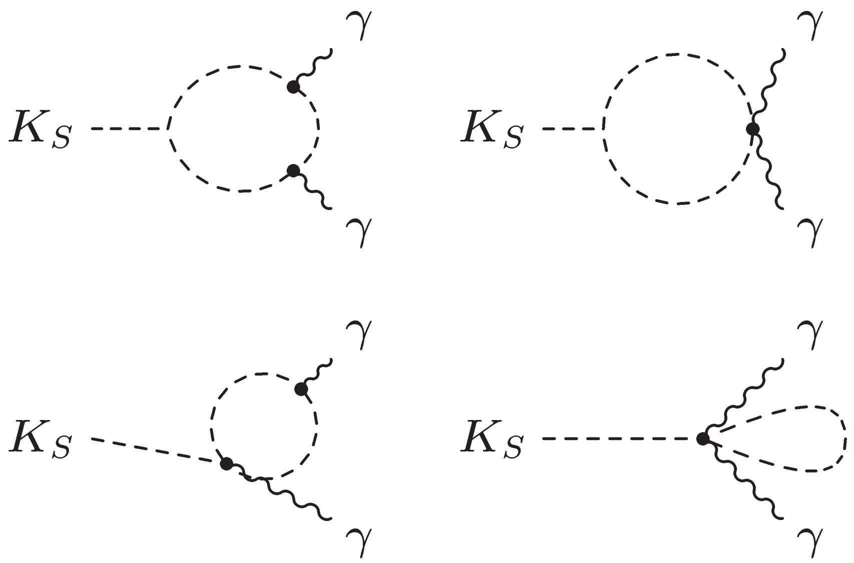


Clear evidence for events with $m_{\gamma\gamma} < 240$ MeV

$\rightsquigarrow$ O(p^6) with VMD contribution

$K_S \to \gamma\gamma$: Motivation & Theory

- again, O(p^2) and tree level O(p^4) contributions vanish
- lowest order diagrams:



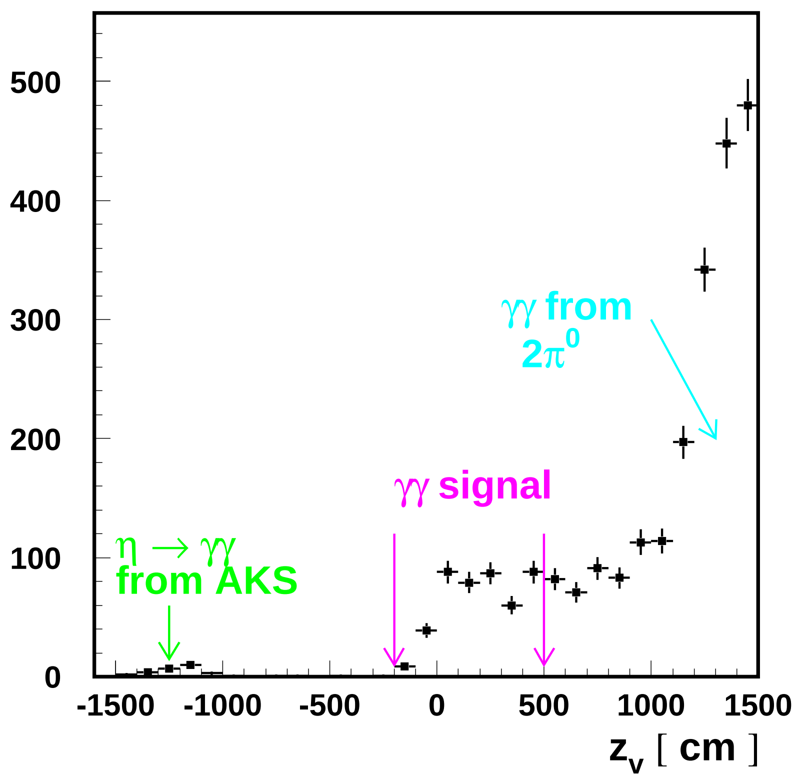
- prediction and previous measurement:

$$\mathrm{BR}(K_S \to \gamma\gamma)_{\text{theory}} = (2.3 \pm 0.2) \cdot 10^{-6}$$

$$\mathrm{BR}(K_S \to \gamma\gamma)_{\text{exp}} = (2.4 \pm 0.9) \cdot 10^{-6} \quad \text{NA31}$$

$K_S \to \gamma\gamma$: Selection & Decay Region

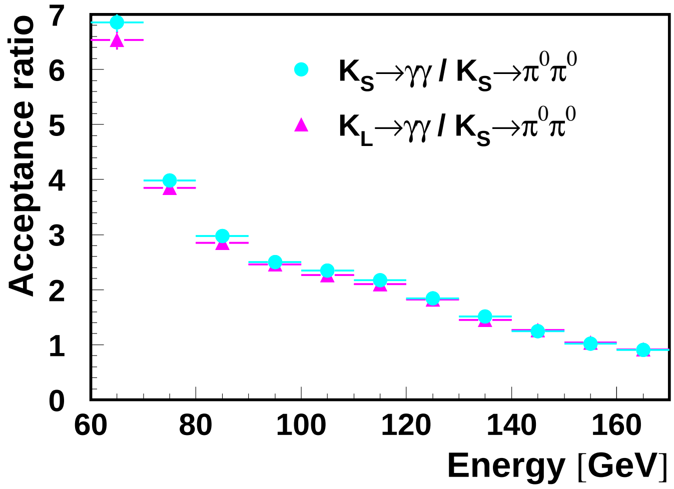
- K_S beam only (high intensity K_S run)
- 3 GeV $< E_{\text{shower}} >$ 100 GeV
- $d_{\text{shower}} >$ 10 cm
- 60 GeV $< E_{\text{LKr}} <$ 170 GeV
- "good" clusters within 5 ns
- $r_{\text{COG}} <$ 7 cm
- no extra cluster with $E >$ 1.5 GeV within 3 ns



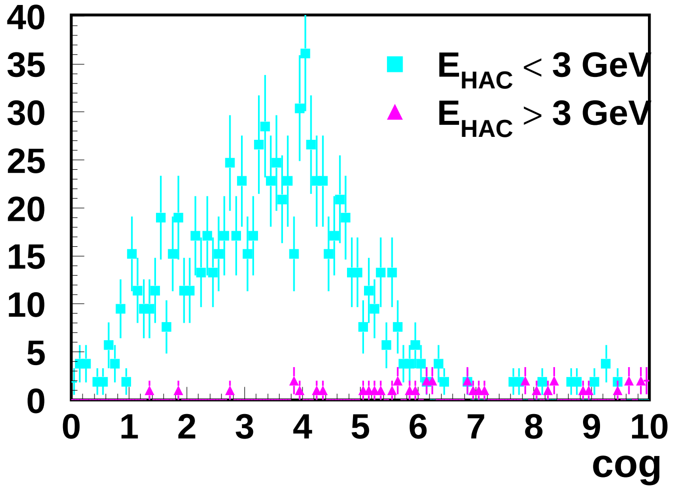
- no $K_S \to \pi^0\pi^0$ below 9 m (kinematics)
- MC studies (overlapping clusters):
  $z_{coll} < z_v < z_{coll} +$ 5 m

$K_S \to \gamma\gamma$: Background

- $K_L \to \gamma\gamma$: Compute N_L from known flux
  $\rightsquigarrow N_L \approx 294$ events

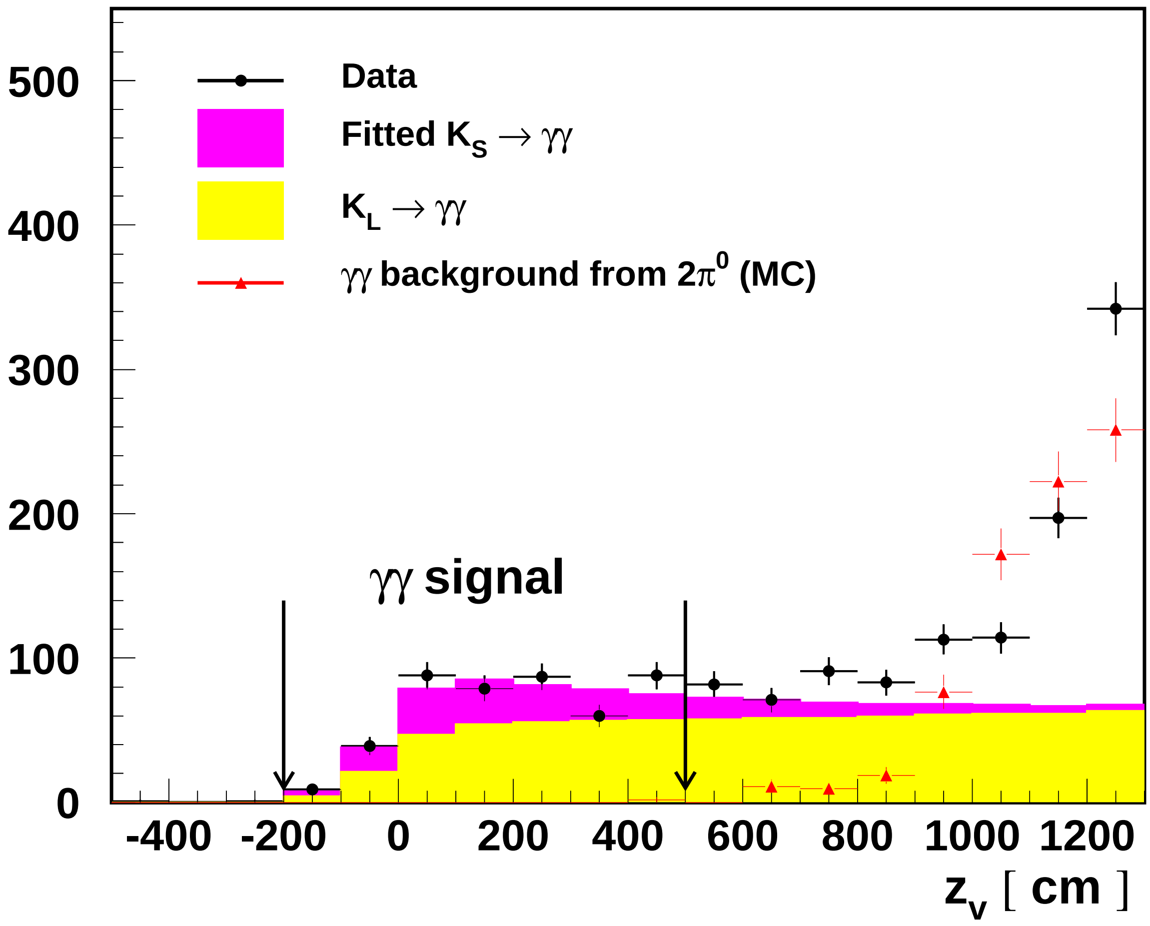


- $\Lambda \to n\pi^0$: cluster rms, in time cluster in HAC, r_{cog}
  $\rightsquigarrow N_\Lambda \approx 14$ events



- $K_S \to \pi^0\pi^0$: MC studies to estimate background from overlapping showers
  $\rightsquigarrow N_{2\pi^0} \approx 2$ events

$K_S \to \gamma\gamma$: Branching Ratio

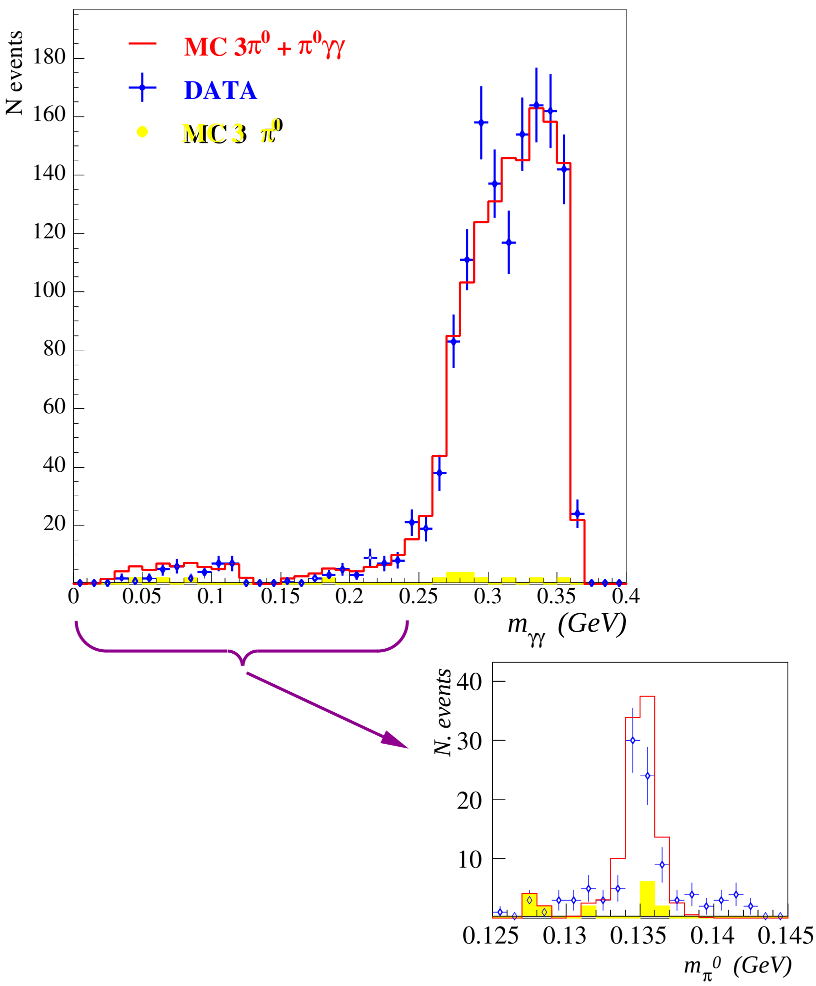


148 $K_S \to \gamma\gamma$ events

$$\boxed{\mathrm{BR}(K_S \to \gamma\gamma) = (2.6 \pm 0.4 \pm 0.2) \cdot 10^{-6}}$$

Rare Kaon Decays From NA48: Summary

- $\text{BR}(K_L \to \pi^0\gamma\gamma)|_{a_V=-0.45}$
  $$= (1.51 \pm 0.05 \pm 0.20) \cdot 10^6$$

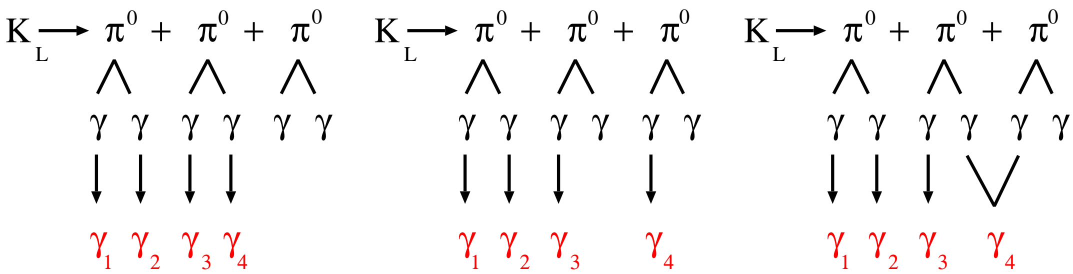


- Clear evidence for events with $m_{\gamma\gamma} < 240$ MeV $\rightsquigarrow$ O(p^6) with VMD contribution
- $\text{BR}(K_S \to \gamma\gamma) = (2.6 \pm 0.4 \pm 0.2) \cdot 10^{-6}$

$K_L \to \pi^0\gamma\gamma$: Background Rejection

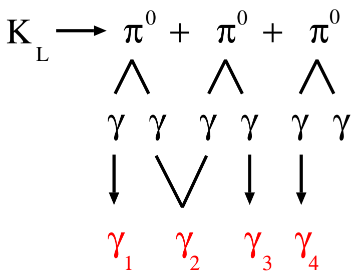
4 cases of photon loss / overlap from $K_L \to \pi^0\pi^0\pi^0$

Case 1: at least one π^0 fully contained, non-overlapping π^0



Calculate $z_\pi = z_{lkr} - \frac{\sqrt{E_1 E_2 d_{12}}}{m_\pi}$, require $z_\pi^{max} < z_{lkr}$ − 6 m

Case 2: two π^0 fully contained, but overlapping

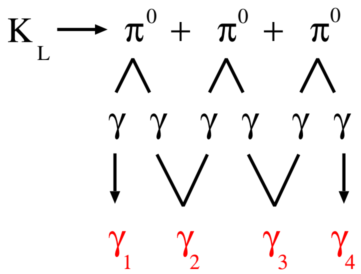


Calculate $z_{\pi\pi} = z_{lkr} - \frac{1}{m_\pi \sqrt{\frac{1}{E_1 E_2 d_{12}} + \frac{1}{E_3 E_2 d_{32}}}}$

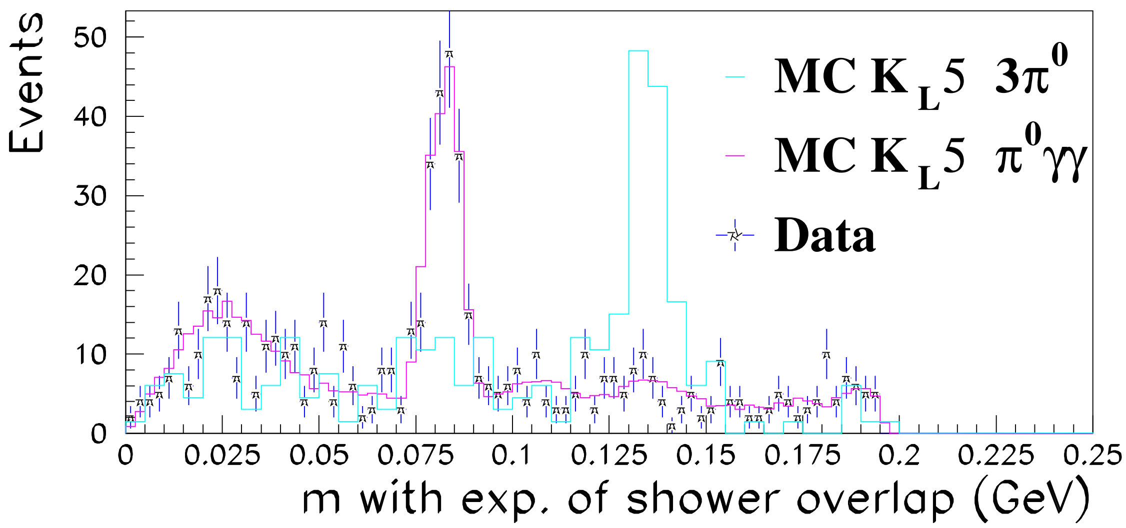
require $z_{\pi\pi}^{max} < z_{lkr}$ − 6 m

$K_L \to \pi^0\gamma\gamma$: Background Rejection

Case 4: all π fully contained, all overlapping



One true π^0 “hidden” within two clusters:
$m = (m_{12} - m_\pi) + (m_{34} - m_\pi)$



$\rightsquigarrow$ no significant background left