New results on rare decays and on future NA48

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On behalf of the NA48 Collaboration

(Cagliari, Cambridge, CERN, Dubna, Edinburg, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna, Warsaw)

Overview

$$\boxed{K_S \to \gamma\gamma}$$

Theory: Br($K_S \to \gamma\gamma$)=$(2.3 \pm 0.2) \times 10^{-6}$

Br($K_S \to \gamma\gamma$)=$(2.6 \pm 0.2) \times 10^{-6}$ NA31, 1995

Br($K_S \to \gamma\gamma$)=$(2.58 \pm 0.36_{sta} \pm 0.22_{sys}) \times 10^{-6}$

Published in PL B493(2000) 29

$$\boxed{K_S \to \pi^0 e^+ e^-}$$

Theory: Br($K_S \to \pi^0 e^+ e^-$)$\sim$few $\times 10^{-9}$

Br($K_S \to \pi^0 e^+ e^-$) $< 1.1 \times 10^{-6}$ NA31, 1993

Br($K_S \to \pi^0 e^+ e^-$) $< 1.4 \times 10^{-7}$ 90% CL

Published in PL B514(2001) 253

$$\boxed{K_L \to \pi^+ \pi^- e^+ e^-}$$

Theory: $A^L_{\pi\pi ee} \approx 14\%$

$A^L_{\pi\pi ee} = (13.6 \pm 2.5_{sta} \pm 1.2_{sys})\%$ KTeV

Published in PRL 84(2000) 408

$A^L_{\pi\pi ee} = (13.9 \pm 2.7_{sta} \pm 2.0_{sys})\%$ Preliminary

$$\boxed{K_S \to \pi^+ \pi^- e^+ e^-}$$

$Br(K_S \to \pi^+ \pi^- e^+ e^-) = (4.3 \pm 0.2_{sta} \pm 0.3_{sys}) \times 10^{-5}$

$Br(K_L \to \pi^+ \pi^- e^+ e^-)_{IB} = (1.3 \pm 0.1) \times 10^{-7}$

$A^S_{\pi\pi ee} = (-0.2 \pm 3.4_{sta} \pm 1.4_{sys})\%$ No asymmetry

Results are preliminary

Contents

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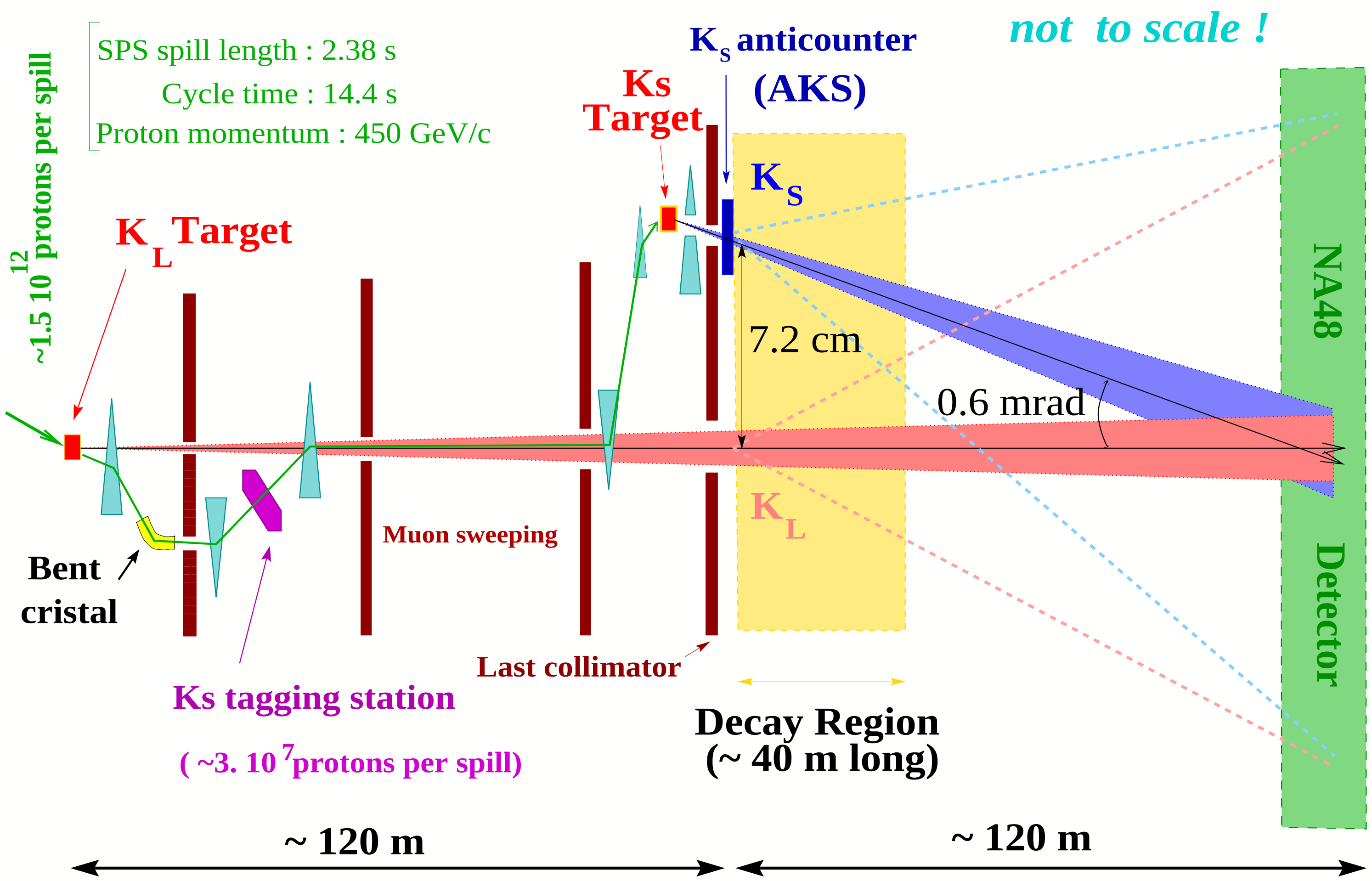
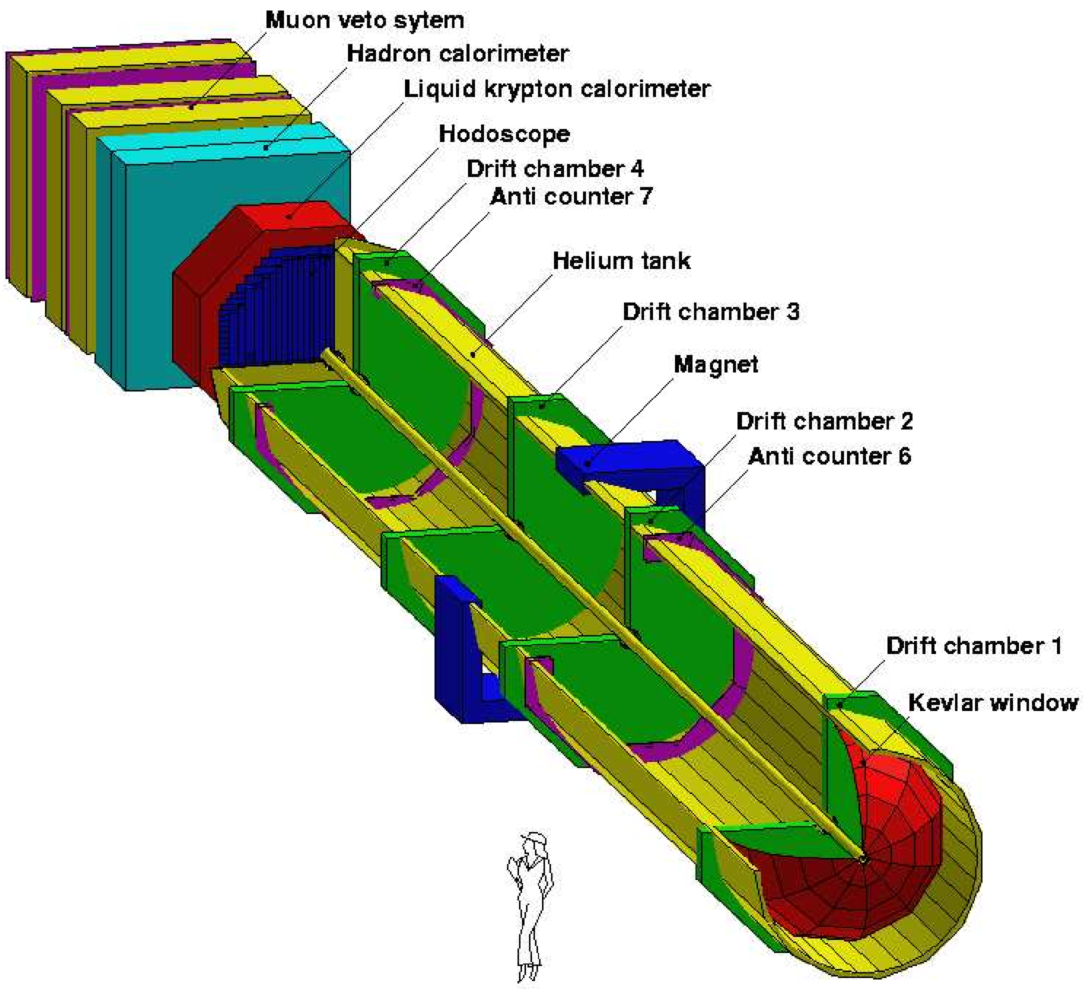
   - $\Xi^0 \rightarrow \Sigma^0\gamma$
   - $\Xi^0 \rightarrow \Lambda^0\gamma$
3. NA48/1: High intensity K_S run (2002)
4. NA48/2: Charged kaon run (2003)

NA48 K_L and K_S beams



NA48 Detector



Magnetic spectrometer:

$$\sigma(p)/p \simeq 0.5\% \oplus 0.009\% \times p[GeV/c]$$

Liquid Krypton Calorimeter:

$$\sigma(E)/E \simeq 3.2\%/\sqrt{E[GeV]} \oplus 9\%/E \oplus 0.42\%$$

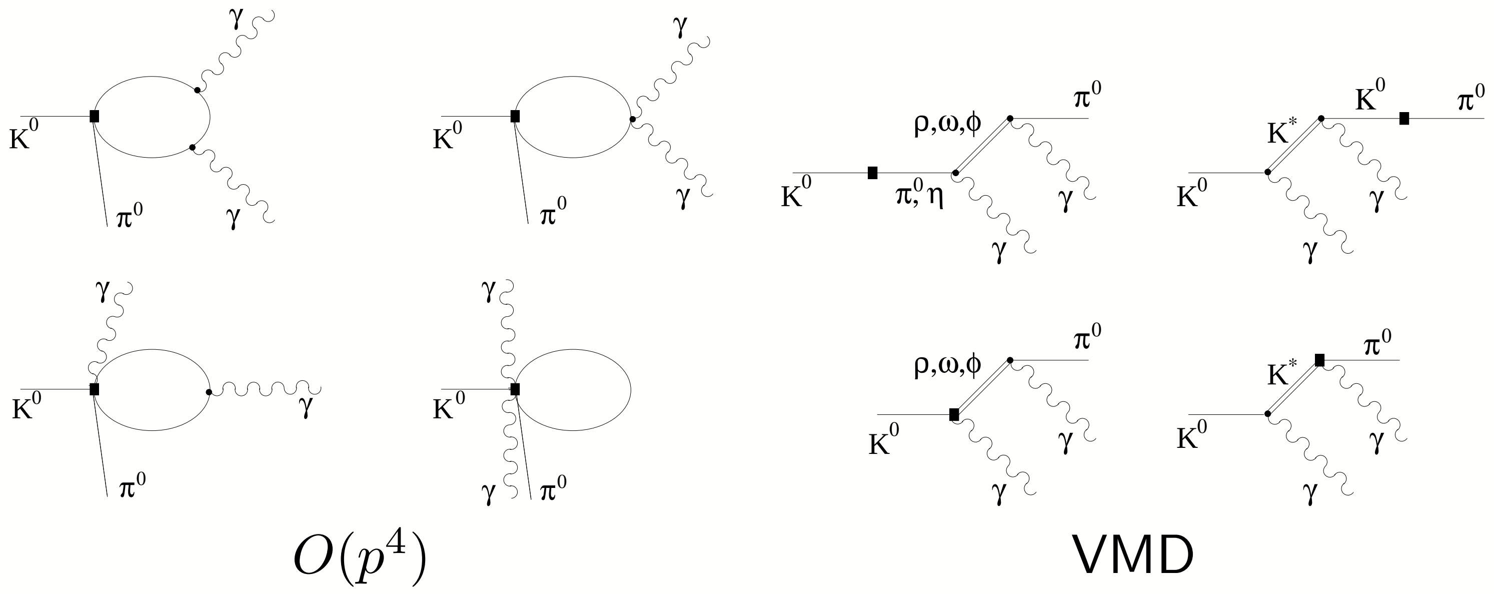
$$\sigma(x) \simeq \sigma(y) \simeq 0.4cm/\sqrt{E} \oplus 0.05cm$$

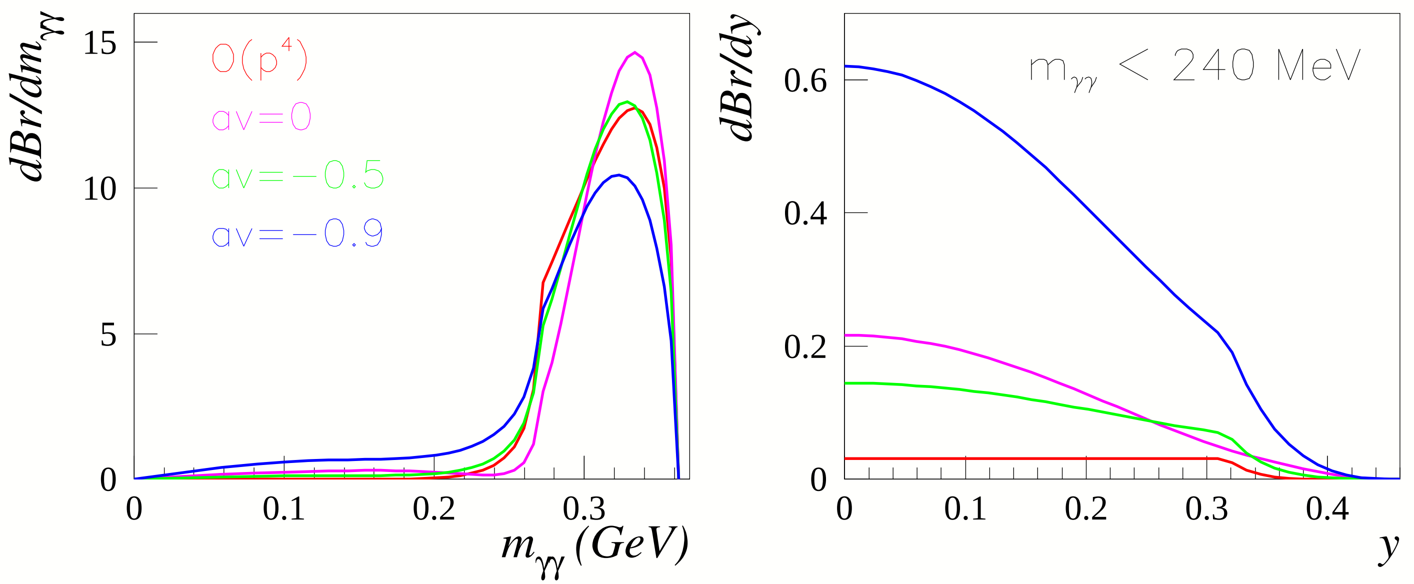
$K_L \to \pi^0\gamma\gamma$

Physics motivation

- The decay rate is finite at one loop Chiral Perturbation Theory (χPT)
- The χPT calculation at $O(p^4)$ predicts only 1/3 of the measured rate
- $O(p^6)$ calculation including VMD contibution parametrised by a_V can reproduce the rate and predict a tail at low $m_{\gamma\gamma}$
- The difference y between the energy of the two non-π^0 photons in the kaon rest frame is also sensitive to a_v
- The a_V contribution leads to a CP conserving component to $K_L \to \pi^0 e^+ e^-$, e.g.:
  BR$(K_L \to \pi^0 e^+ e^-)_{CPC} = 1.24 \times 10^{-12}$ for $a_V =$ -0.7
  (G.D'Ambrosio, J.Portoles, NP B492 417)

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





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

Trigger requirements

- At maximum 5 peaks in each projection;
- Total energy $(E_{tot}) > 50GeV$
- The center of gravity $(COG) < 15cm$
- The decay lifetime $(\tau) < 4.5\tau_s$

Event selection

- Only tagged K_L decays ($\approx 11\%$ good K_L are disregarded)
- At least four clusters in time and inside the LKR acceptance
- Cluster energy $3GeV < E_\gamma < 100GeV$
- Kaon energy $70GeV < E_K < 170GeV$

Background sources

- $K_L \to \pi^0\pi^0$ decays misreconstructed and/or with γ conversion in the spectrometer
- $K_L \to \pi^0\pi^0\pi^0$ decays with missing and/or overlapping photons
- Pile up events due to the high rate environment

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

$2\pi^0$ rejection

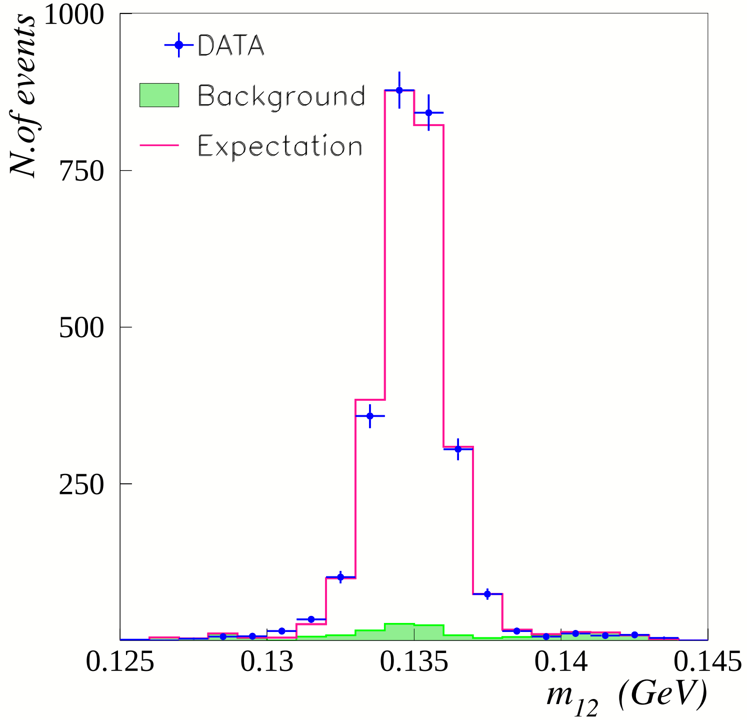
- $[\frac{(m_{1,2}+m_{3,4})/2-m_{\pi^0}}{\sigma_+}]^2 + [\frac{(m_{1,2}-m_{3,4})/2}{\sigma_-}]^2 > 300$
- $|m_{1,2} - m_{\pi^0}| < 3MeV/c^2$ and $m_{3,4}$ not in the $(110 \div 160)MeV/c^2$ range
- DCH in veto (against conversion and Dalitz decays)
- $p_{T,4} > 40MeV/c$, $p_{T,4}$ is the transverse momentum of the lowest energy γ of the unpaired photons.

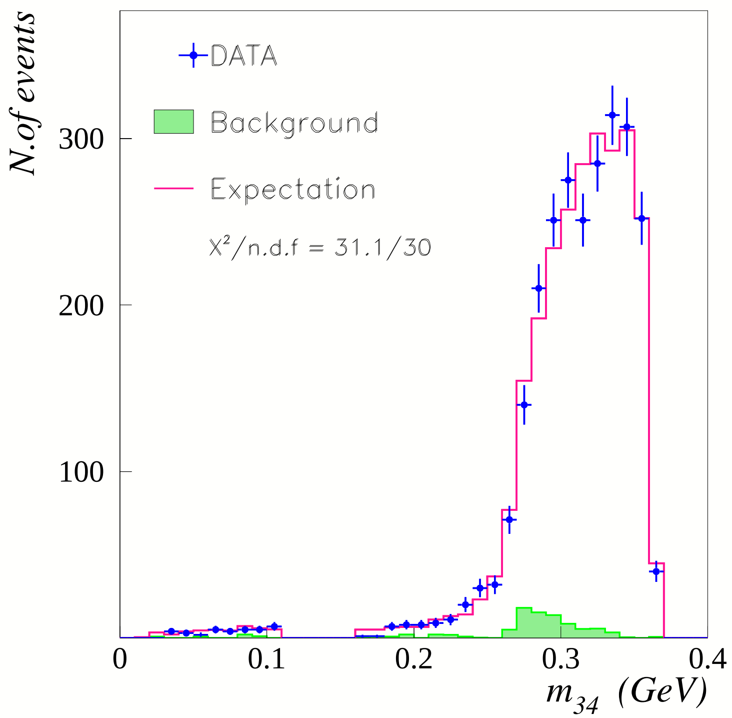
$3\pi^0$ rejection with missing and overlapping photons

- Only four clusters
- AKL veto
- Decay region $z_K < 3000cm$
- $R_{COG} < 4cm$
- Reject events if 2 γ reconstruct Z_π or 3 γ reconstruct $Z_{\pi\pi}$ more then 6 m upstream of K decay vertex
- Cut on cluster width

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

1998 + 1999 data





$m_{\gamma\gamma}$ for the π^0 candidates

$m_{\gamma\gamma}$ for the non-π^0 photons

2588 $K_L \to \pi^0\gamma\gamma$ events have been observed in the signal region $132 MeV/c^2 < m_{1,2} < 138 MeV/c^2$ with background $\approx$ 80 events (3.3%)

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

To define the coupling constant a_V a fit of the bidimensional distribution of the two relevant kinematic variables $m_{3,4}$ and $y = |E_3 - E_4|/m_K$ was performed, defining a likehood function as follows:

$$\ln L = \sum_{i,N_{bins}} [N_i(y, m_{\gamma\gamma}) \cdot \ln E_i(y, m_{\gamma\gamma}) - E_i(y, m_{\gamma\gamma})],$$

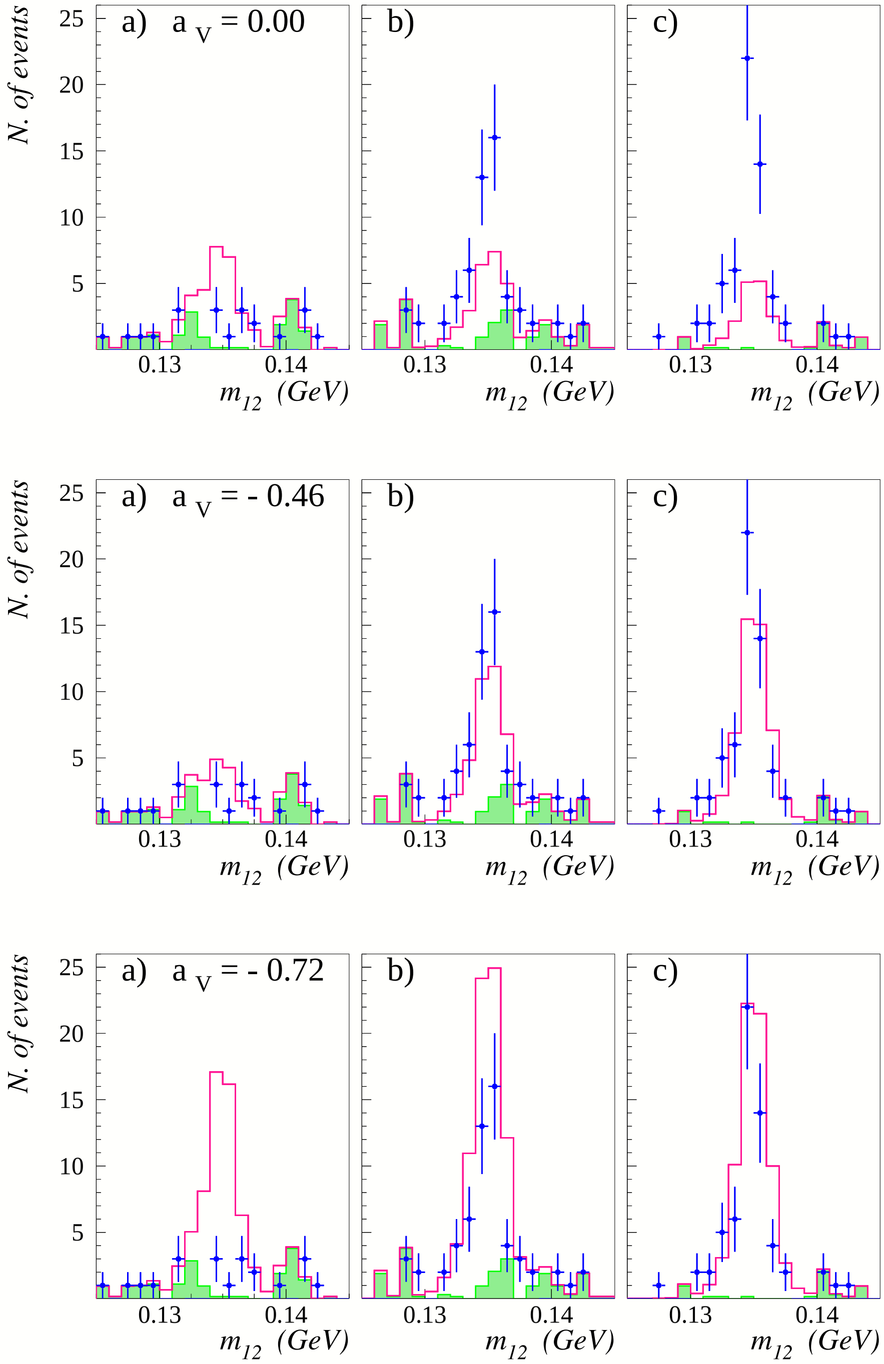
where $N_i(y - m_{\gamma\gamma})$ is the measured number of events in the i-th bins, $E_i(y, m_{\gamma\gamma})$ is expectation value given by the simulated $K_L \to \pi^0\gamma\gamma$ plus background.

For the best fit, with a χ^2 of 71.6 for 54 degrees of freedom, it was obtained:

$$a_v = -0.46 \pm 0.03_{(stat)} \pm 0.03_{(syst)} \pm 0.02_{(theo)}.$$

Systematic error is dominated by uncertainty in the background evaluation. We quote as a separate error the uncertainty from $O(p^4)$ χPT parametrisation of the $K_L \to 3\pi$ vertex.

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



$$a)30MeV/c^2 < m_{3,4} < 135MeV/c^2$$
$$b)135MeV/c^2 < m_{3,4} < 240MeV/c^2$$
$$c)240MeV/c^2 < m_{3,4} < 260MeV/c^2$$

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

From the whole $\pi^0\gamma\gamma$ candidates sample and with the obtained value of a_v, using the $K_L \to \pi^0\pi^0$ decay as a normalisation channel, we find the branching ratio to be:

$$BR(K_L \to \pi^0\gamma\gamma) = (1.36 \pm 0.03_{(stat)} \pm 0.03_{(syst)} \pm 0.03_{(norm)}) \times 10^{-6}.$$

The uncertainty related to the knowledge of the experimental $K_L \to \pi^0\pi^0$ branching ratio is quoted separately. The systematic error comes from the residual background estimate (1.5%), the a_V fit (2.3%) and the acceptance calculation (3.2%).

For $m_{3,4}$ there is no evidence of a signal and the branching ratio upper limit for $y < 0.2$ can be computed in a model independent way:

$$BR(K_L \to \pi^0\gamma\gamma)|_{m_{34}\in[30\div110],y\in[0\div0.2]} \leq 6 \times 10^{-9}\ 90\%\ CL.$$

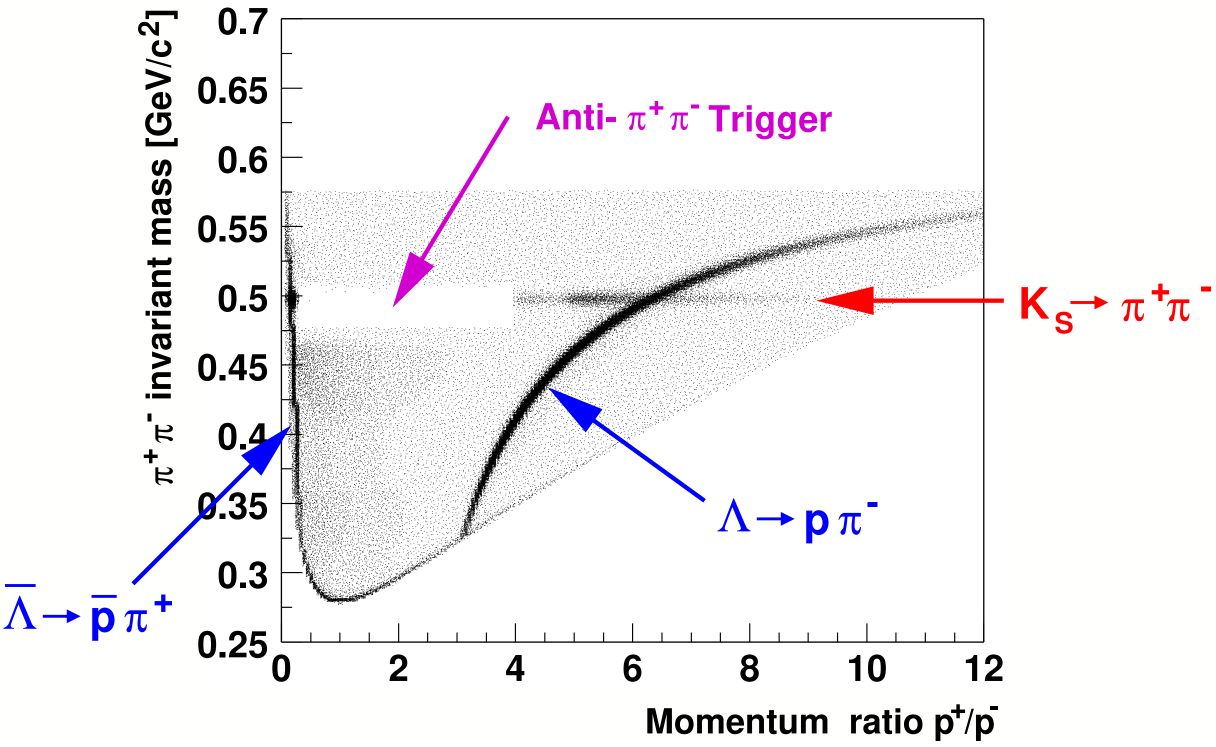
KTEV has published: BR$(K_L \to \pi^0\gamma\gamma) = (1.68 \pm 0.07 \pm 0.08) \times 10^{-6}$
$a_V = -0.72 \pm 0.05 \pm 0.06$ (PRL 83 (1999),917)

Hyperon decays

Hyperon trigger:

- Two tracks (one positive, one negative)
- "Anti $K_s \to \pi^+\pi^-$" trigger:

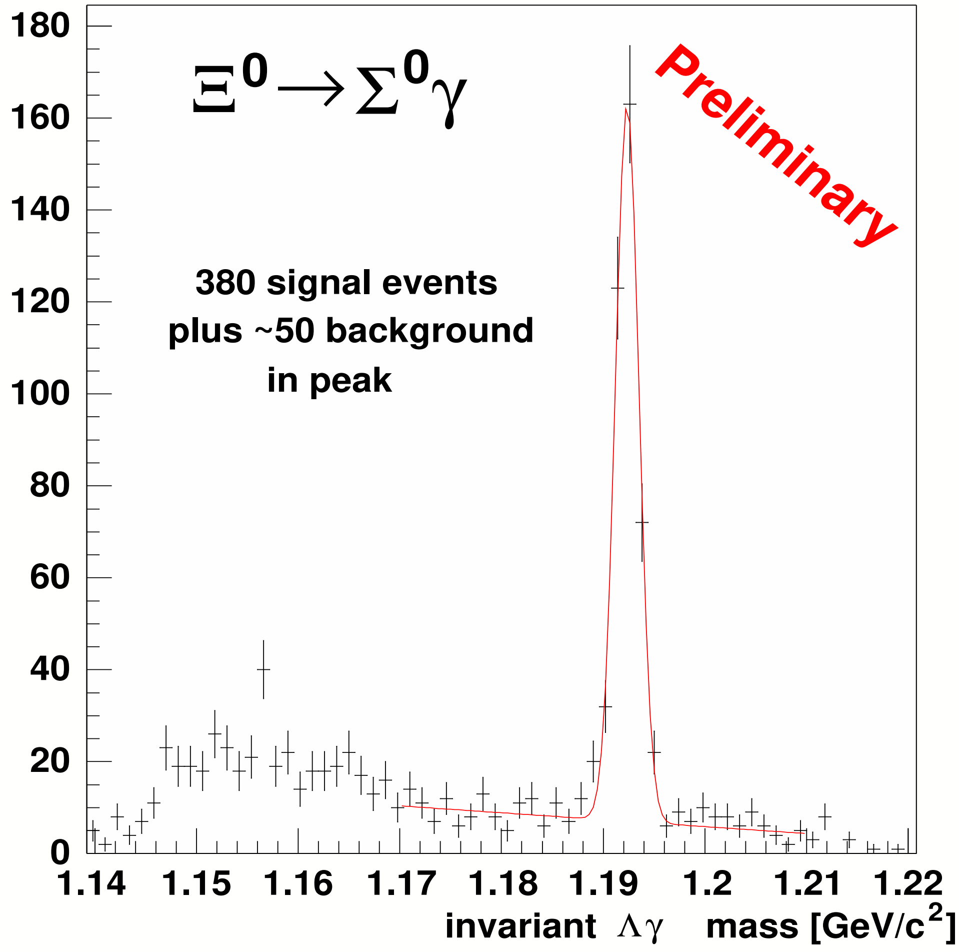
Combined cut on kaon mass and momentum ratio $p_+ p_-$.



- 41×10^6 2-track events
- 17×10^6 $\Lambda^0 \to p\pi^-$ events
- 2×10^6 $\bar{\Lambda}^0 \to \bar{p}\pi^+$

$\Xi^0 \to \Sigma^0\gamma$

Σ^0 lifetime $\approx 10^{-10}$ s
$\to$ Almost same signature as $\Xi^0 \to \Lambda\pi^0$
$\to$ Main background from $\Lambda\pi^0$
We find a signal of $\approx$ 380 events
over $\Xi^0 \to \Lambda\pi^0$ background of $\approx$ 50 events.



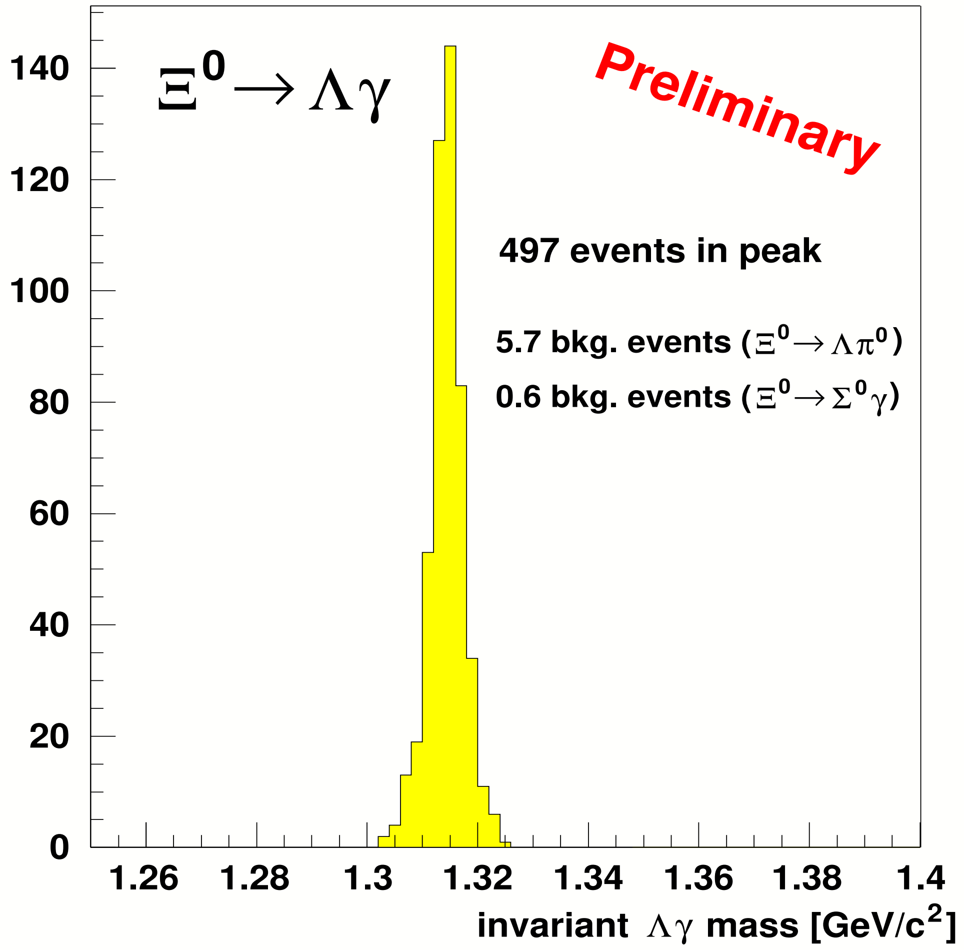
Preliminary result:

$\mathrm{Br}(\Xi^0 \to \Sigma^0\gamma) = (3.7\pm0.5)\times10^{-3}$

$\Xi^0 \to \Lambda\gamma$

We find $\sim$ 500 signal candidates

Expected background: $\approx 1\%$



Preliminary result:

Br($\Xi^0 \to \Lambda\gamma$) $= (1.9 \pm 0.1_{stat} \pm 0.2_{syst}) \times 10^{-3}$

Main systematics: Ξ^0 polarisation and asymmetry.

NA48/1

- High intensity K_S and neutral hyperon data taking

- We expect $50\times$ the statistics of 1999 high intensity data (much more in some channels using improved triggers)

- Observation of $K_S \to \pi^0 e^+ e^-$

- $50\times$ more $K_S \to \gamma\gamma$

- Much more $K_S \to 3\pi^0 \Rightarrow$ measurement of η_{000}

- Neutral hyperon decays:
  we expect ~ 30000 Ξ^0 semileptonic decays $\Rightarrow$ possible measurements of Ξ^0 form factors and the Cabbibo angle

Precision measurement of charged kaon decay parameters

- Direct CP violation in $K^{\pm} \rightarrow (3\pi)^{\pm}$ decays
  - CP violation $\Rightarrow$ asymmetry in $K^{+} \rightarrow (3\pi)^{+}$ and $K^{-} \rightarrow (3\pi)^{-}$ matrix elements:

$$|A\,(K \rightarrow 3\pi)|^2 \propto 1 + gu + jv + hu^2 + kv^2$$

$$A_g = (g^{+} - g^{-})/(g^{+} + g^{-}) \neq 0$$

  - Measurement of the ratio $R(u) \equiv N^{+}(u)/N^{-}(u)$ $\neq$constant
  - Simultaneous K^{+} and K^{-} beams
  - Alternating magnetic field in spectrometer and analysis in kaon energy bins $\Rightarrow$ equalised and cancelled acceptances
- Study of $Ke4$ decay

Expected results for 1 year data taking

❖ CP violation in $K^{\pm} \rightarrow (3\pi)^{\pm}$:

- We expect to collect $\approx 10^{10}$ $K^{\pm} \rightarrow \pi^{\pm}\pi^{\pm}\pi^{\mp}$
- Stat.error of $A_g < 10^{-4}$
- Very low systematic error ($< 5 \times 10^{5}$) $\Rightarrow$ only statistical limitation on accuracy

❖ Ke4:

- We expect to collect 10^{6} decays
- Stat. error of $a_0^0 < 0.01$