NA48/1:
K_s rare decays and Hyperons

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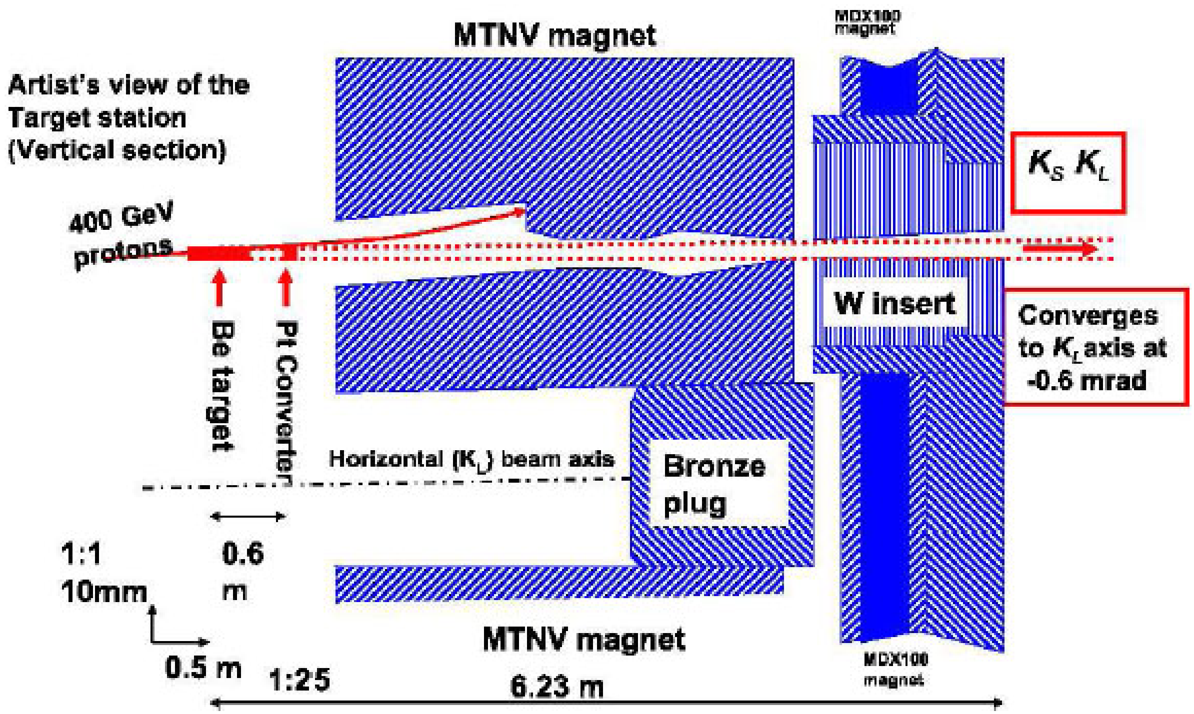
On behalf of the NA48/1 Collaboration:

Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Warsaw, Wien

Outline

- ✓ The NA48/1 beam and detector
- ✓ $K_L \to \pi^0 l^+ l^-$ and CKM matrix
- ✓ First observation of: $K_s \to \pi^0 e^+ e^-$ and $K_s \to \pi^0 \mu^+ \mu^-$
- ✓ BR and decay asymmetry $\Xi^0 \to \Lambda\gamma$
- ✓ Preliminary information on Ξ^0 beta decay
- ✓ Conclusion

The NA48/1 K_S beam line



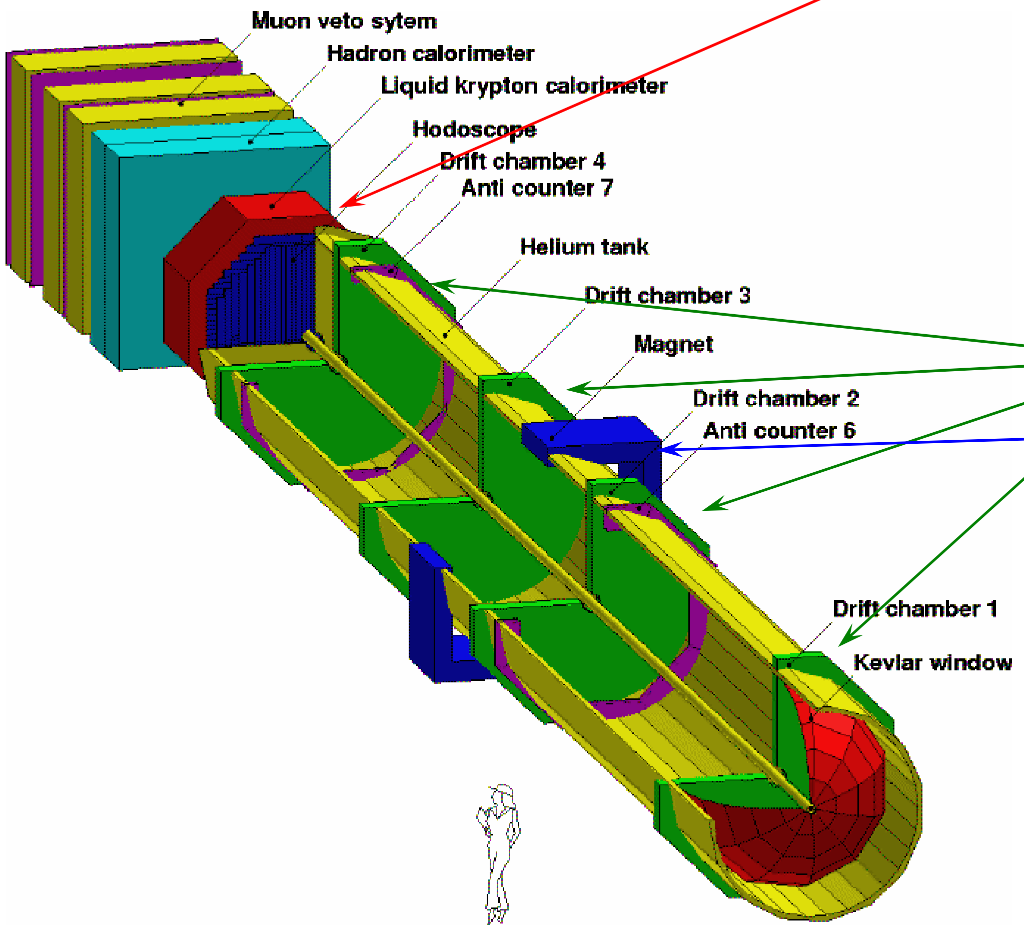
✓SPS protons energy: 400 GeV

✓Duty cycle: 4.8 s/ 16.8 s

✓ Production angle: -4.2 mrad

✓ Proton per pulse on target: $5 \cdot 10^{10}$

The NA48/1 detector



Liquid Kr EM Calorimeter

$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{0.1}{E} \oplus 0.5\%$$

$\sigma_{x,y} < 1.3mm$ E in GeV

Spectrometer

- 4 DCH
- Magnet

$$\frac{\sigma(p)}{p} = 0.48\% \oplus 0.009 \times p$$

$\sigma_{VTX}^{x,y} \sim 2mm$ E in GeV

NA48 data taking periods

- 1997 : ε'/ε run
- 1998 : ε'/ε run
- 1999 : ε'/ε run + 2 days of K_S
- 2000 : K_L only + K_S high intensity → No spectrometer
- 2001 : ε'/ε run + few days of K_S

NA48

- 2002 : K_S High intensity

NA48/1

- 2003 : $K^{\pm}$ High intensity
- 2004 : $K^{\pm}$ High intensity

NA48/2

Interest of $K_L \to \pi^0 l^+ l^-$

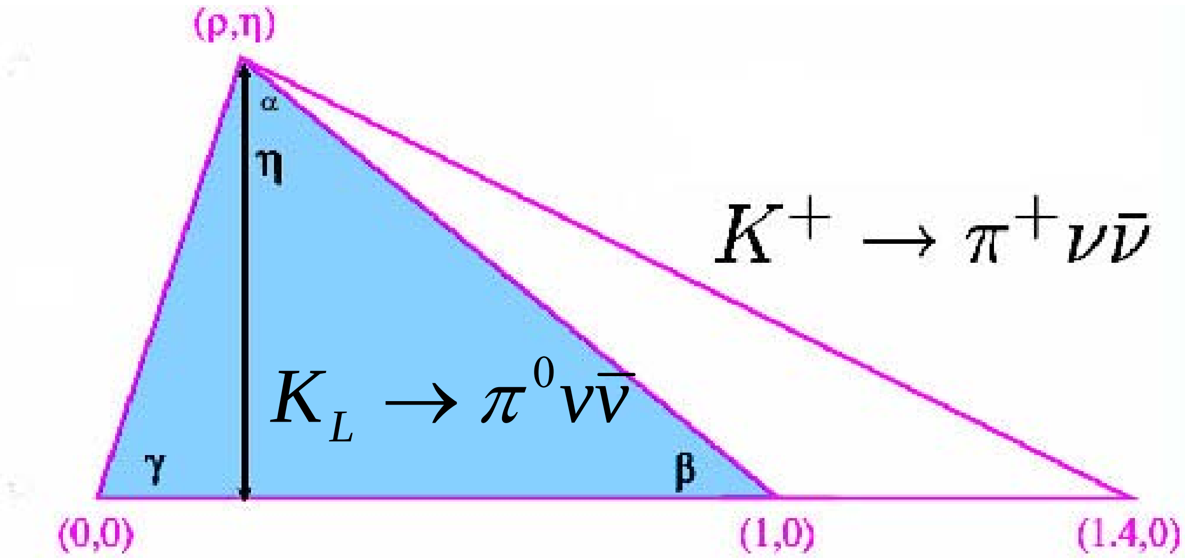
η can be measured using :

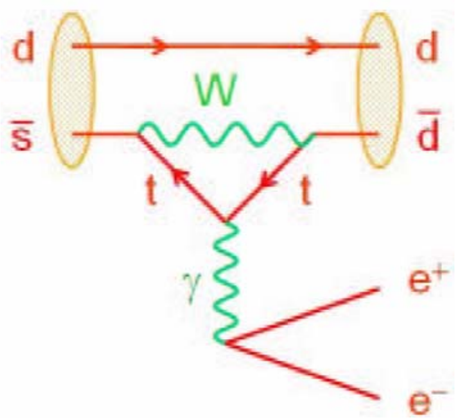
$$K_L \to \pi^0 l^+ l^-$$

ρ can be measured using :

$$K^+ \to \pi^+ l^+ l^-$$

Unitarity triangle





Direct CP violating component is sensitive to Im(λ_t):

$$\mathrm{Im}(\lambda_t) = \eta A^2 \lambda^5 \qquad \lambda_t = V_{ts}^* V_{td}$$

Interest of $K_S \rightarrow \pi^0 e^+ e^-$

$$BR(K_S \rightarrow \pi^0 e^+ e^-) = 5.2 \cdot 10^{-9} a_S^2$$

$$BR(K_L \rightarrow \pi^0 e^+ e^-) = \left(15.3 a_S^2 \pm 6.8 a_S \left(\frac{\mathrm{Im}(\lambda_t)}{10^{-4}} \right) + 2.8 \left(\frac{\mathrm{Im}(\lambda_t)}{10^{-4}} \right)^2 \right) \cdot 10^{-12}$$

Indirect CP violating contribution:
$BR(K_L \rightarrow \pi^0 e^+ e^-)_{IND} = BR(K_S \rightarrow \pi^0 e^+ e^-)/330$

Direct CP violating component

Interference sensitive to $\mathrm{Im}(\lambda_t) = \mathrm{Im}(V_{td} V_{ts}^*)$

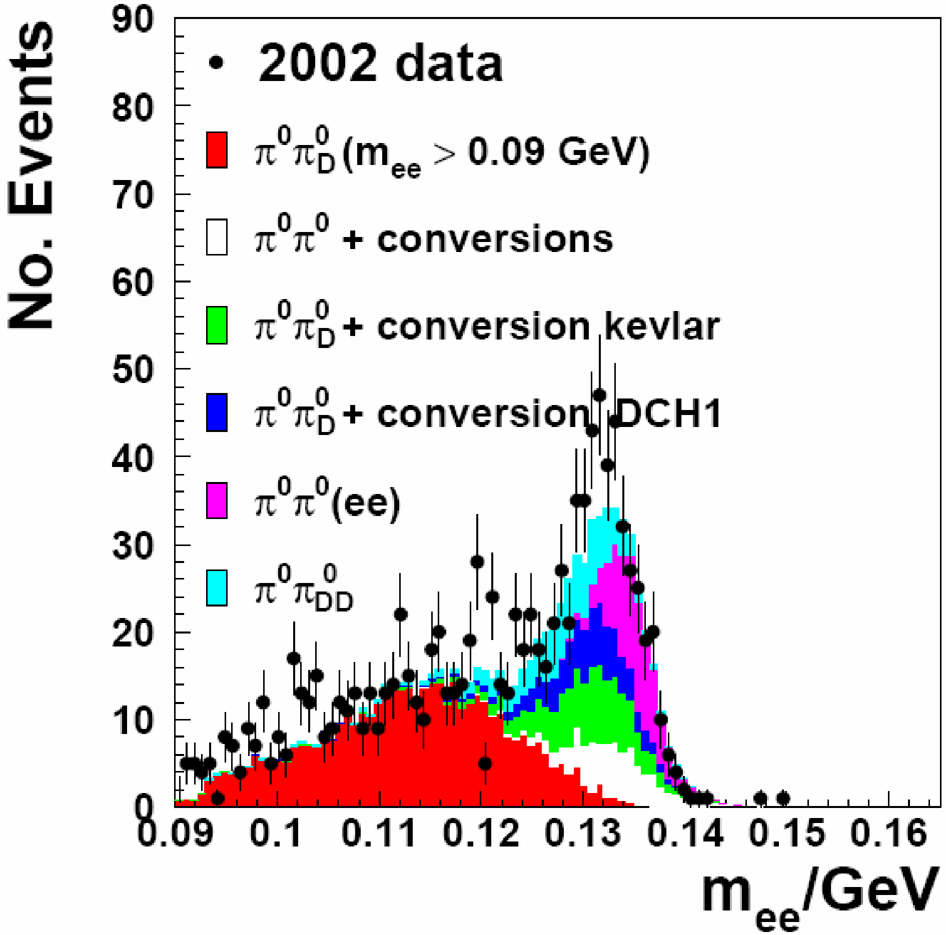
- ✓ Measuring a_s from $BR(K_S)$ you can estimate the $BR(K_L)$
- ✓ The value of the $BR(K_L)$ can give constraints on $\mathrm{Im}(\lambda_t)$

a_s is one of the 2 form factors

$K_S \rightarrow \pi^0 e^+ e^-$: a blind analysis

- ✓ Signal region $|M_{\pi 0rec} - M_{\pi 0}| < 2.5\sigma_{M\pi 0}$ * $|M_{Krec} - M_K| < 2.5\sigma_{MK}$
- ✓ Control region $|M_{\pi 0rec} - M_{\pi 0}| < 6\sigma_{M\pi 0}$ * $|M_{Krec} - M_K| < 6\sigma_{MK}$
- ✓ Large number of possible background were studied:
  - Single Kaon or Hyperon decay
  - Fragment of 2 decay coinciding in time
- ✓ Cuts fixed using MC and data after blinding signal and control region
- ✓ Control region unmasked to check MC background estimate
- ✓ Signal region unmasked to discover signal events

$K_S \rightarrow \pi^0 e^+ e^-$ physical background



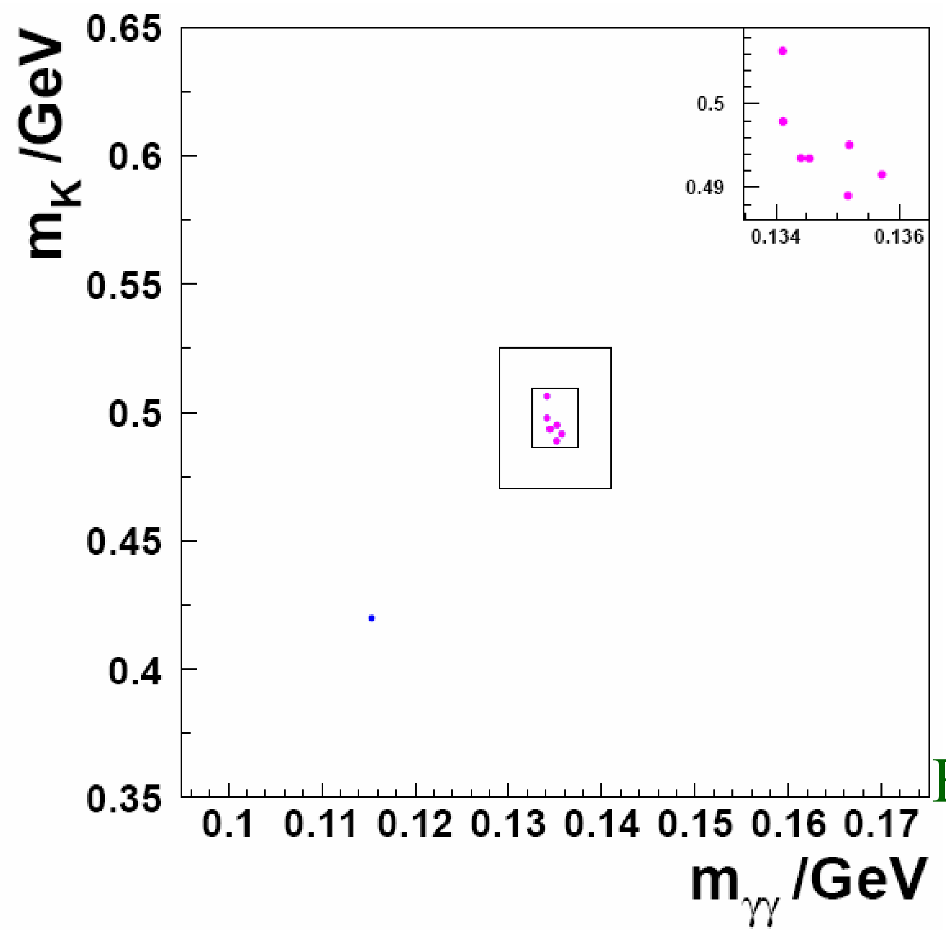
Rejected background

- Main BG: $K_S \rightarrow \pi^0 \pi^0_D$
  - Cut on M_{ee}>165 MeV applied
- $\Xi^0 \rightarrow \Lambda(p\pi^-)\pi^0$
  - Cut on momentum asymmetry

Residual background (MC)

BG source	# ev. sig region
$K_L \rightarrow e^+e^-\gamma\gamma$	$0.08^{+0.03}_{-0.02}$
Accidental	$0.07^{+0.07}_{-0.03}$
Total	$0.15^{+0.10}_{-0.04}$

BR($K_S \to \pi^0 e^+ e^-$)



0 events found in control region
7 events found in signal region

Probability BG only ~10^{-10}

FIRST OBSERVATION OF
$K_S \to \pi^0 e^+ e^-$ with m_{ee}>165 MeV

$$BR(K_S \to \pi^0 e^+ e^-)_{mee>165} = \left(3.8^{+1.5}_{-1.2} \pm 0.2\right) \cdot 10^{-9}$$

Using MonteCarlo with unit form factors

$$BR(K_S \to \pi^0 e^+ e^-) = (5.8^{+2.8}_{-2.3}(stat.) \pm 0.3_{syst} \pm 0.8_{theory}) \cdot 10^{-9}$$

$K_S \rightarrow \pi^0 \mu^+ \mu^-$ physical background

Hyperons background:

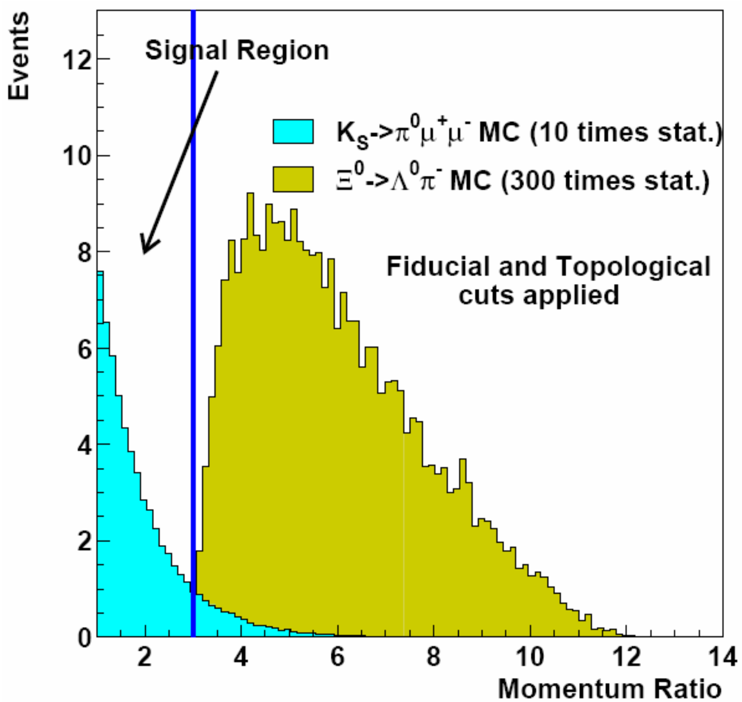
$\Xi^0 \rightarrow \Lambda(p\pi^-)\pi^0$

Kaon background:

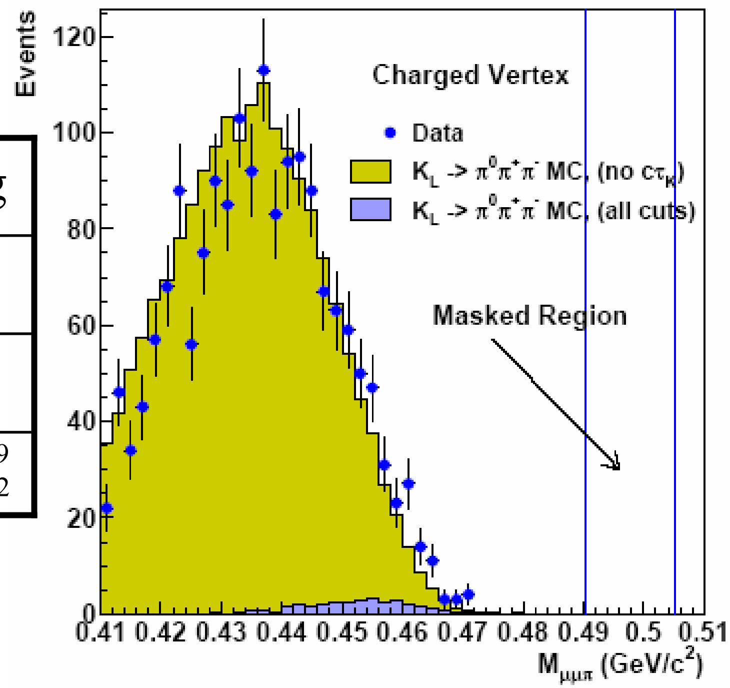
$K_L \rightarrow \pi^0 \pi^+ \pi^-$ with π decay in flight

$K_L \rightarrow \mu^+ \mu^+ \gamma\gamma$

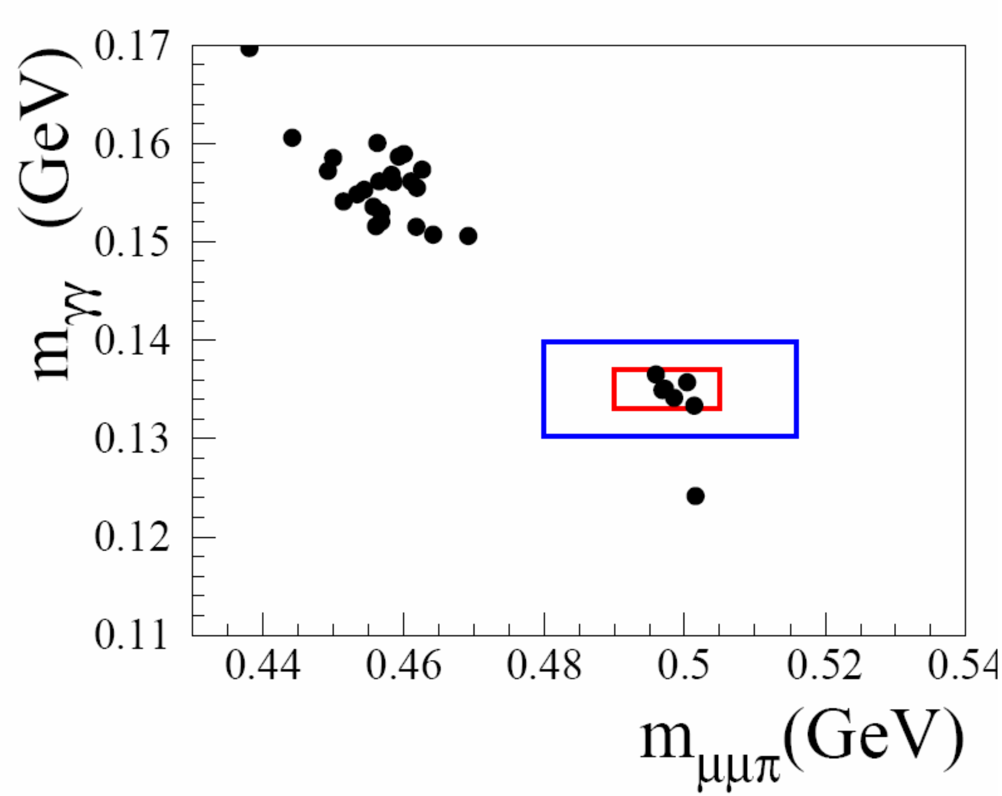
Accidental background



BG	ev. sig
$K_L \rightarrow \mu^+ \mu^- \gamma\gamma$	0.04
Accid.	0.18
Total	$0.22^{+0.19}_{-0.22}$



$BR(K_S \to \pi^0 \mu^+ \mu^-)$



0 events found in control region
6 events found in signal region

FIRST OBSERVATION OF $K_S \to \pi^0 \mu^+ \mu^-$

$$BR(K_S \to \pi^0 \mu^+ \mu^-) = (2.9^{+1.5}_{-1.2}(stat.) \pm 0.2_{syst}) \cdot 10^{-9}$$

a_s and K_L estimates

- ✓ a_s can be extracted using both decays:

$$BR(K_S \to \pi^0 e^+ e^-) = 5.2 \cdot 10^{-9} a_S^2 \Rightarrow |a_s| = 1.06^{+0.26}_{-0.21} \pm 0.07$$
$$BR(K_S \to \pi^0 \mu^+ \mu^-) = 1.2 \cdot 10^{-9} a_S^2 \Rightarrow |a_s| = 1.55^{+0.38}_{-0.32} \pm 0.05$$

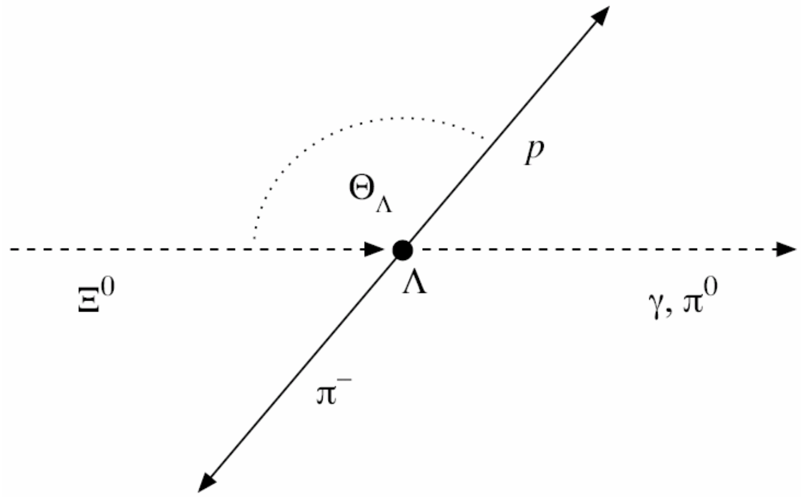
- ✓ The results are compatible taking into account experimental errors
- ✓ Using $|a_s|$ and current value of $\mathrm{Im}(\lambda_t)$

$$BR(K_L \to \pi^0 e^+ e^-)_{CPV} = (17_{IND} \pm 9_{INT} + 5_{DIR}) \cdot 10^{-12}$$
$$BR(K_L \to \pi^0 \mu^+ \mu^-)_{CPV} = (9_{IND} \pm 3_{INT} + 1_{DIR}) \cdot 10^{-12}$$

$\Xi^0 \rightarrow \Lambda\gamma$ decay asymmetry

- ✓ Decay asymmetry in weak radiative hyperons decay was predicted to be small.
- ✓ Discovery of large decay asymmetry α in weak radiative $\Sigma^+ \rightarrow p\gamma$
- ✓ New SU(3) breaking models were developed:
  - Pole models based on χPT approach:
    - ➢ $\alpha < 0$ all weak radiative hyperons decays
  - VMD & quark model:
    - ➢ $\alpha > 0$ only for $\Xi^0 \rightarrow \Lambda\gamma$
- ✓ A measurements of α in $\Xi^0 \rightarrow \Lambda\gamma$ can distinguish between different models

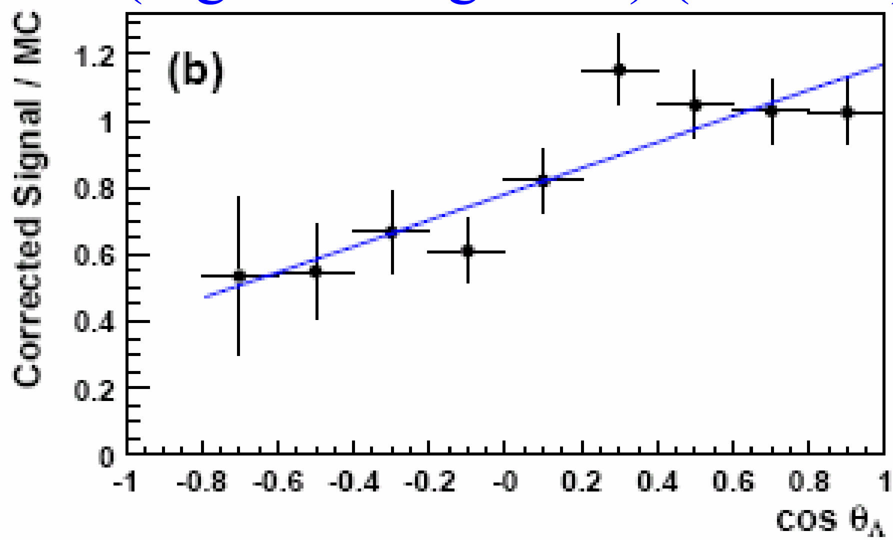
$\alpha(\Xi^0 \rightarrow \Lambda\gamma)$ measurements



Θ_Λ angle between incoming Ξ^0 and outgoing p in the Λ rest frame

$$\frac{dN}{d\cos\Theta_\Lambda} = N_0(1 - \alpha(\Lambda \rightarrow p\pi^-)\alpha(\Xi^0 \rightarrow \Lambda\gamma)\cos\Theta_\Lambda)$$

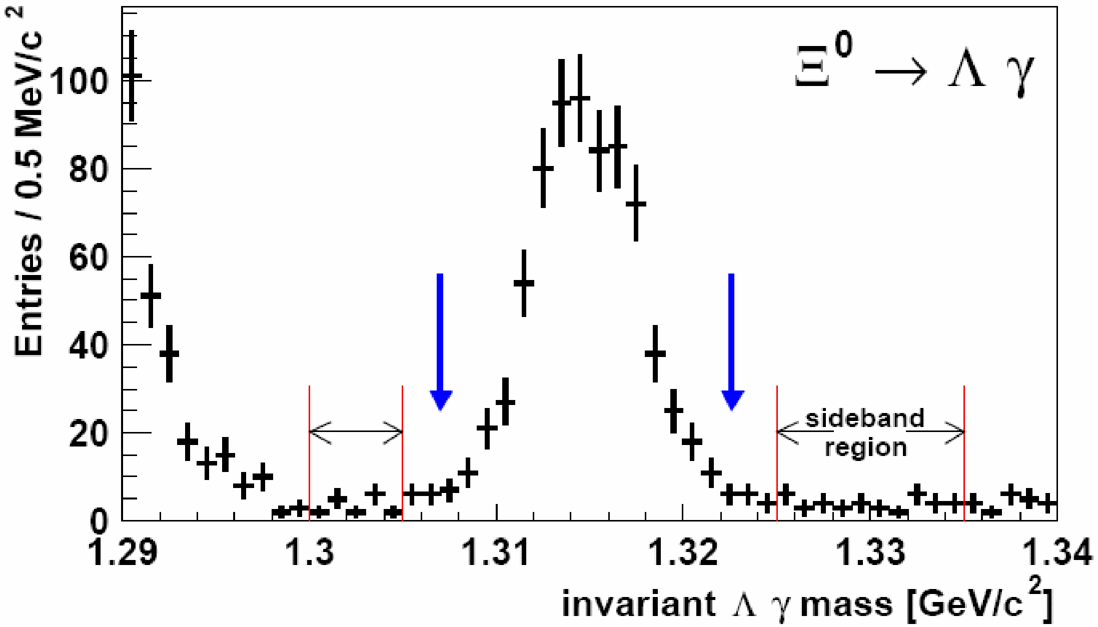
(Signal-background)/(flat MC)



First observation of a negative decay asymmetry for Ξ^0 decay

$$\alpha = -0.78 \pm 0.18_{stat} \pm 0.06_{syst}$$

$BR(\Xi^0 \to \Lambda\gamma)$



2 days of 1999 data

Signal: 730 events

Background: 58.2 ± 7.8 events

$$BR(\Xi^0 \to \Lambda\gamma) = (1.16 \pm 0.05_{stat} \pm 0.06_{syst}) \cdot 10^{-3}$$

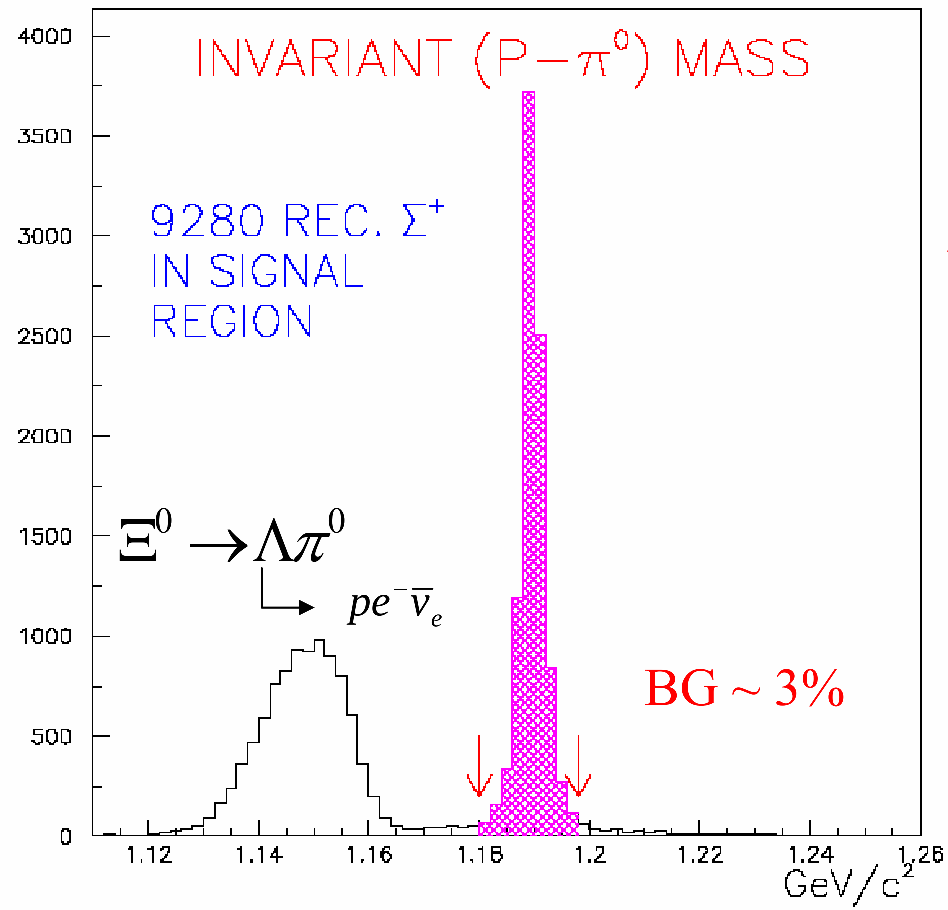
Systematic error dominated by asymmetry measurements

Almost a factor 100 more statistic is expected in 2002 data

Analysis is in progress …

Ξ^0 beta decay: $\Xi^0 \to \Sigma^+ e^- \overline{\nu}_e$

Signal region $\left| M_{\Sigma^+}^{rec} - M_{\Sigma^+}^{PDG} \right| < 10MeV$



$$\Xi^0 \to \Sigma^+ e^- \overline{\nu}_e$$
$$\Sigma^+ \to p\pi^0$$

World largest sample of Ξ^0 β decay

Physics goals:

- V_{us} measurements using BR
- studies of SU(3) breaking in the form factors

Conclusions

- ✓ 2 new rare K decays observed:
  - $K_S \to \pi^0 e^+ e^-$ $\quad BR(K_S \to \pi^0 e^+ e^-) = (5.8^{+2.8}_{-2.3}(stat.) \pm 0.3_{syst} \pm 0.8_{theory}) \cdot 10^{-9}$
  - $K_S \to \pi^0 \mu^+ \mu^-$ $\quad BR(K_S \to \pi^0 \mu^+ \mu^-) = (2.9^{+1.5}_{-1.2}(stat.) \pm 0.2_{syst}) \cdot 10^{-9}$
- ✓ The form factor a_S has been extracted and an estimate of K_L BR was given
- ✓ The $\Xi^0 \to \Lambda\gamma$ decay asymmetry and BR have been measured on 1999 data.
- ✓ World largest sample of Ξ^0 beta decay has been collected and BR ratio measurements will come soon