

K_S and Ξ^0 decays in NA48/1

Cristina Lazzeroni
University of Cambridge

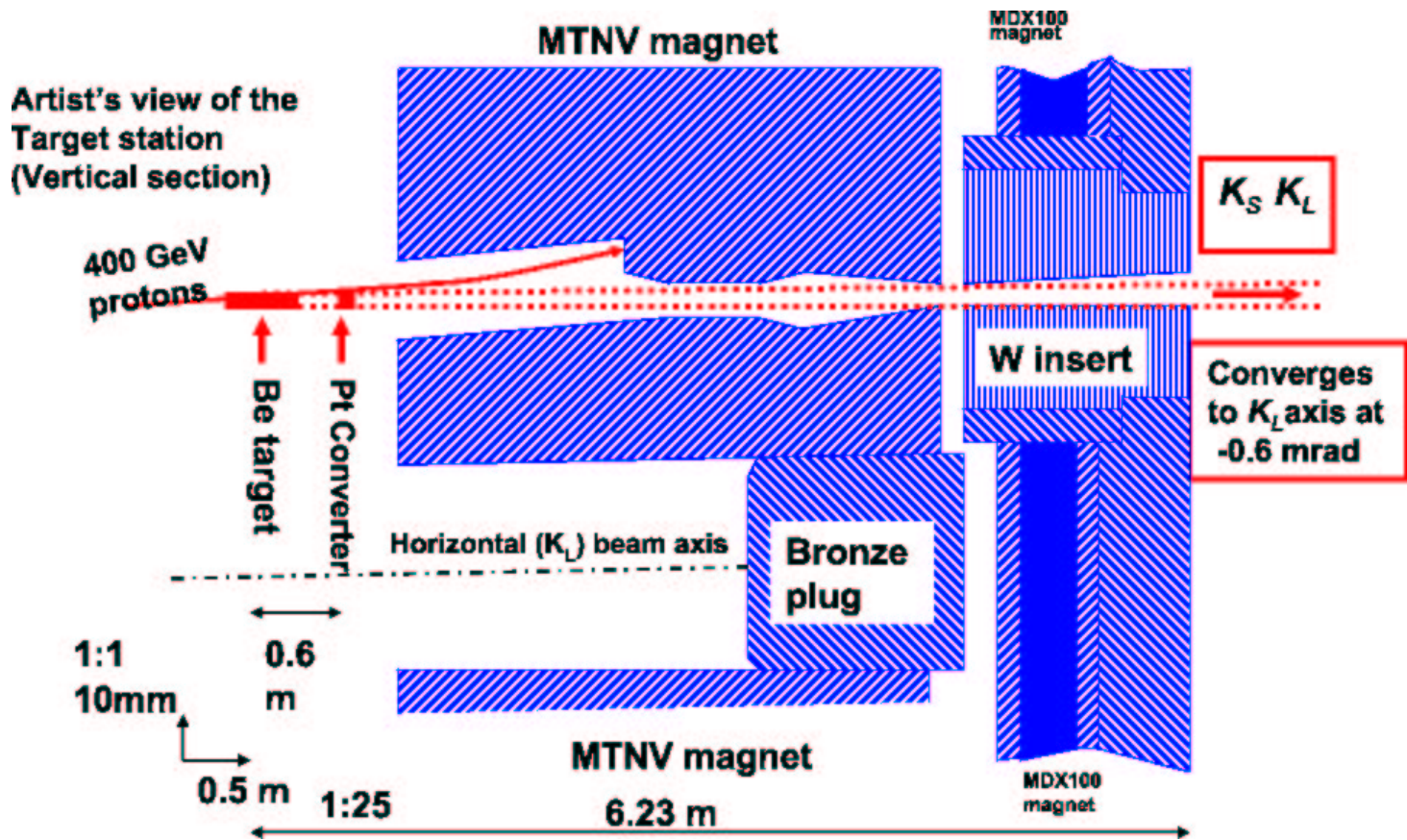
QCD 2004
Montpellier, 8th July 2004

On behalf of the NA48/1 Experiment
Cambridge, Chicago, CERN, Dubna, Edinburgh
Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay,
Siegen, Torino, Warsaw, Wien

Overview

- The NA48/1 beam line in 2002
- Results from 2000 data
- $K_S \rightarrow \pi^0 e^+ e^-$
- $K_S \rightarrow \pi^0 \mu^+ \mu^-$
- $\Xi^0 \rightarrow \Lambda \gamma$
- Prospects for other analyses and Conclusions

2002 Beam line - High intensity K_S



$\sim 4 \times 10^{10}$ K_S decays in 89 days
 in $40 < E_K < 240$ GeV, $0 < c\tau < 2.5c\tau_{K_S}$

Results from 2000 data

- $BR(K_S \rightarrow \gamma\gamma) = (2.78 \pm 0.06_{stat} \pm 0.04_{syst}) \times 10^{-6}$

Published

- $BR(K_S \rightarrow \pi^0\gamma\gamma, m_{\gamma\gamma}^2/m_K^2 > 0.2) = (4.9 \pm 1.6_{stat} \pm 0.9_{syst}) \times 10^{-8}$

Published

- $K_S \rightarrow \pi^0\pi^0\pi^0$:

$$Re(\eta_{000}) = -0.026 \pm 0.010_{stat} \pm 0.005_{syst}$$

$$Im(\eta_{000}) = -0.034 \pm 0.010_{stat} \pm 0.011_{syst}$$

Preliminary

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

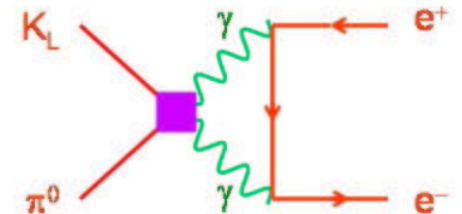
- CP conserving

NA48 measurement $BR(K_L \rightarrow \pi^0 \gamma \gamma)$:

$$\rightarrow BR(K_L \rightarrow \pi^0 e^+ e^-)_{CP\ cons} = 0.47^{+0.22}_{-0.18} \times 10^{-12}$$

[PL B536 229]

$$\rightarrow BR(K_L \rightarrow \pi^0 \mu^+ \mu^-)_{CP\ cons} \approx 10^{-12}$$

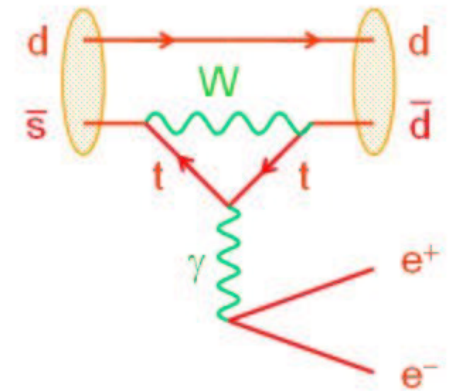


- direct CP violating

Proportional to η or $\text{Im}(\lambda_t)$

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

$$\rightarrow BR(K_L \rightarrow \pi^0 l^+ l^-)_{dir} \sim \text{few} \times 10^{-12}$$



- indirect CP violating

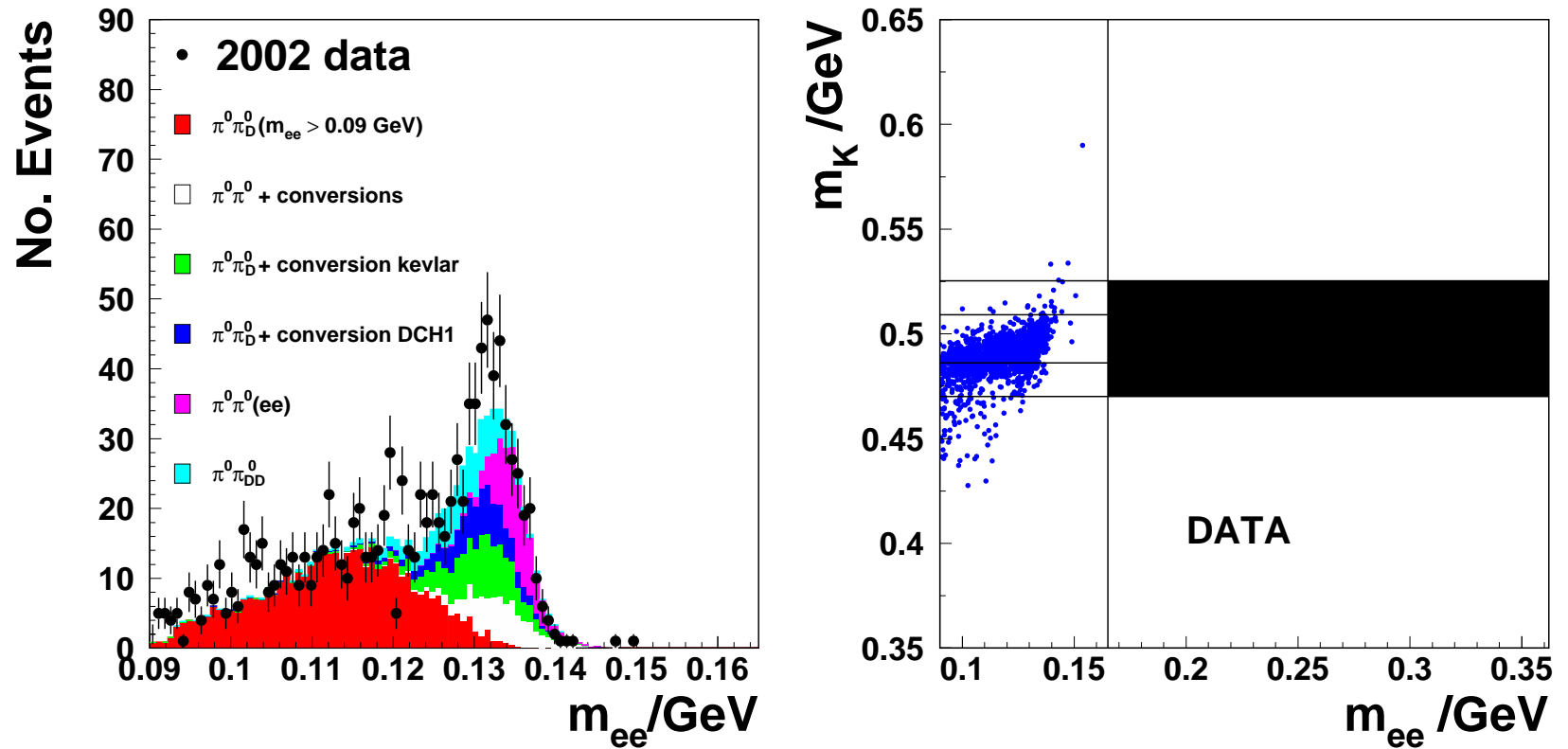
$$\rightarrow BR(K_L \rightarrow \pi^0 l^+ l^-)_{ind} = |\epsilon|^2 \left(\frac{\tau_L}{\tau_S}\right) BR(K_S \rightarrow \pi^0 l^+ l^-)$$

$BR(K_S \rightarrow \pi^0 l^+ l^-)$ and $BR(K_L \rightarrow \pi^0 \gamma \gamma)$ determine whether it will be possible to extract η from a measurement of $BR(K_L \rightarrow \pi^0 l^+ l^-)$

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

$K_S \rightarrow \pi^0 e^+ e^-$: Background from $K_S \rightarrow \pi^0 \pi_D^0$

Blind analysis: Control and Signal regions masked



Events with m_{ee} mis-measured : $m_{ee} > m_{\pi^0} \rightarrow m_{ee\gamma\gamma} > m_K$

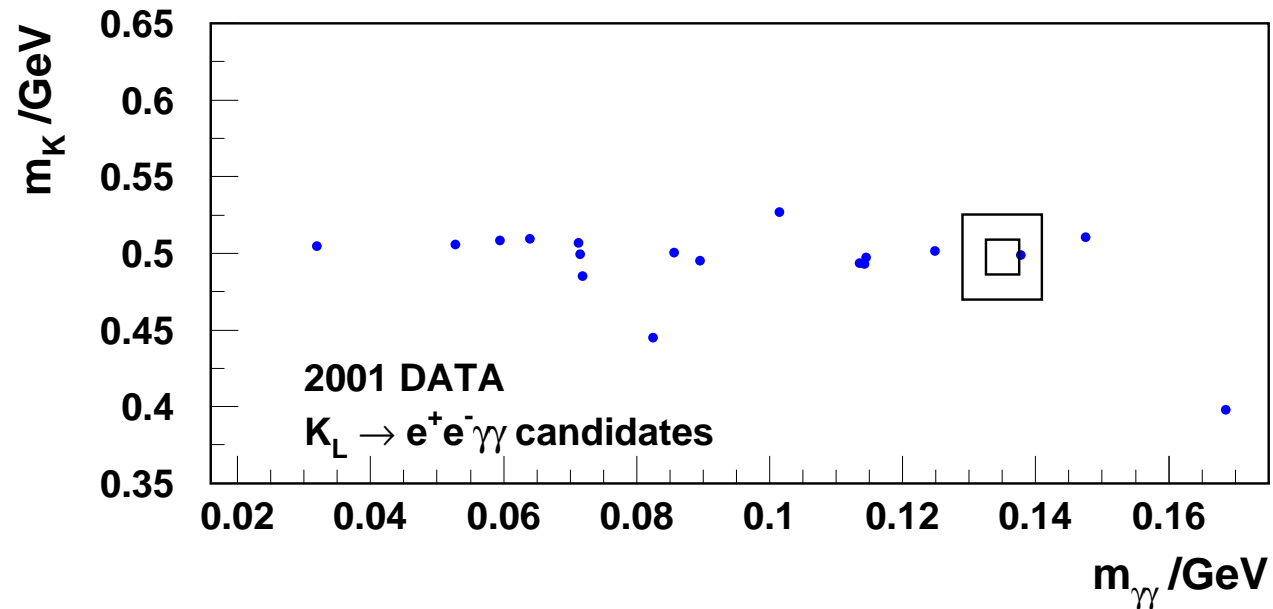
Apply conservative cut $m_{ee} > 0.165 \text{ GeV}$

$K_S \rightarrow \pi^0 e^+ e^-$: Background from $K_L \rightarrow ee\gamma\gamma$

$\sim 5 \times 10^8$ K_L decay in the $0 < \frac{c\tau}{c\tau_S} < 2.5$ fiducial region

$\Rightarrow 300$ $K_L \rightarrow ee\gamma\gamma$ decays ($BR = 6 \times 10^{-7}$)

2001 data with K_L beam used to estimate background
($10 \times$ number of K_L decays in 2002 data)



Extrapolate from low $m_{\gamma\gamma}$ region to signal region
 \rightarrow Background 0.075 events in signal region

$K_S \rightarrow \pi^0 e^+ e^-$: Background from fragments of two decays

Δt = time between fragments

Control region : $3 < \Delta t < 50$ ns

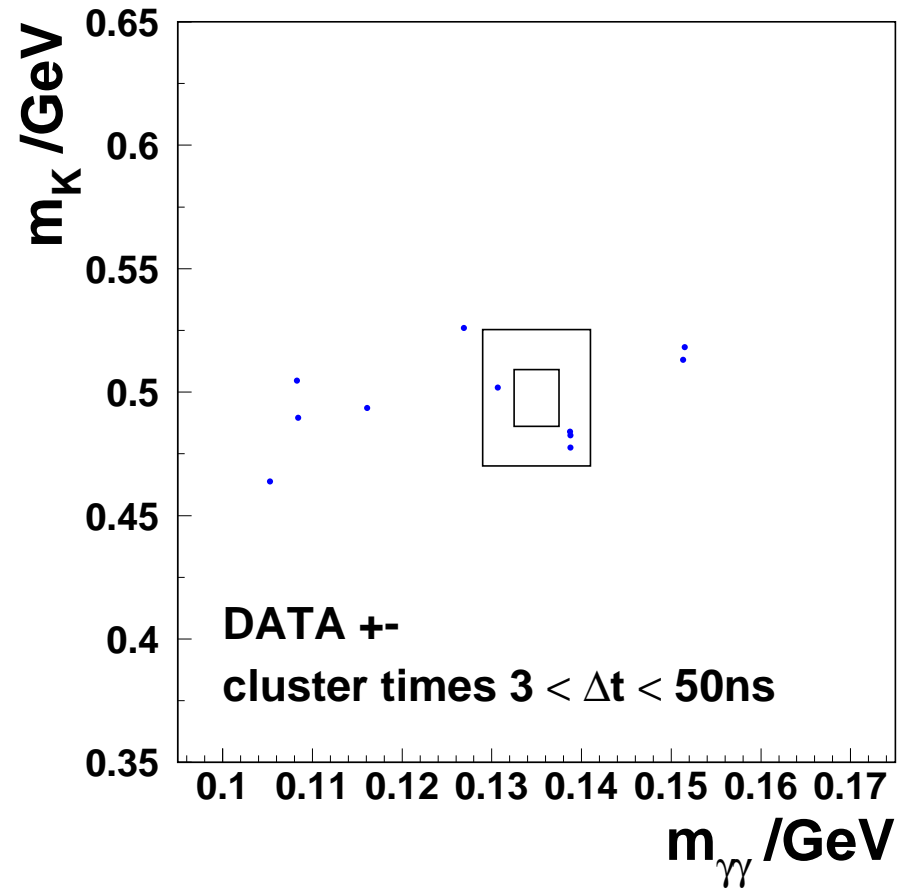
Signal region : $\Delta t < 3$ ns

Dominated by

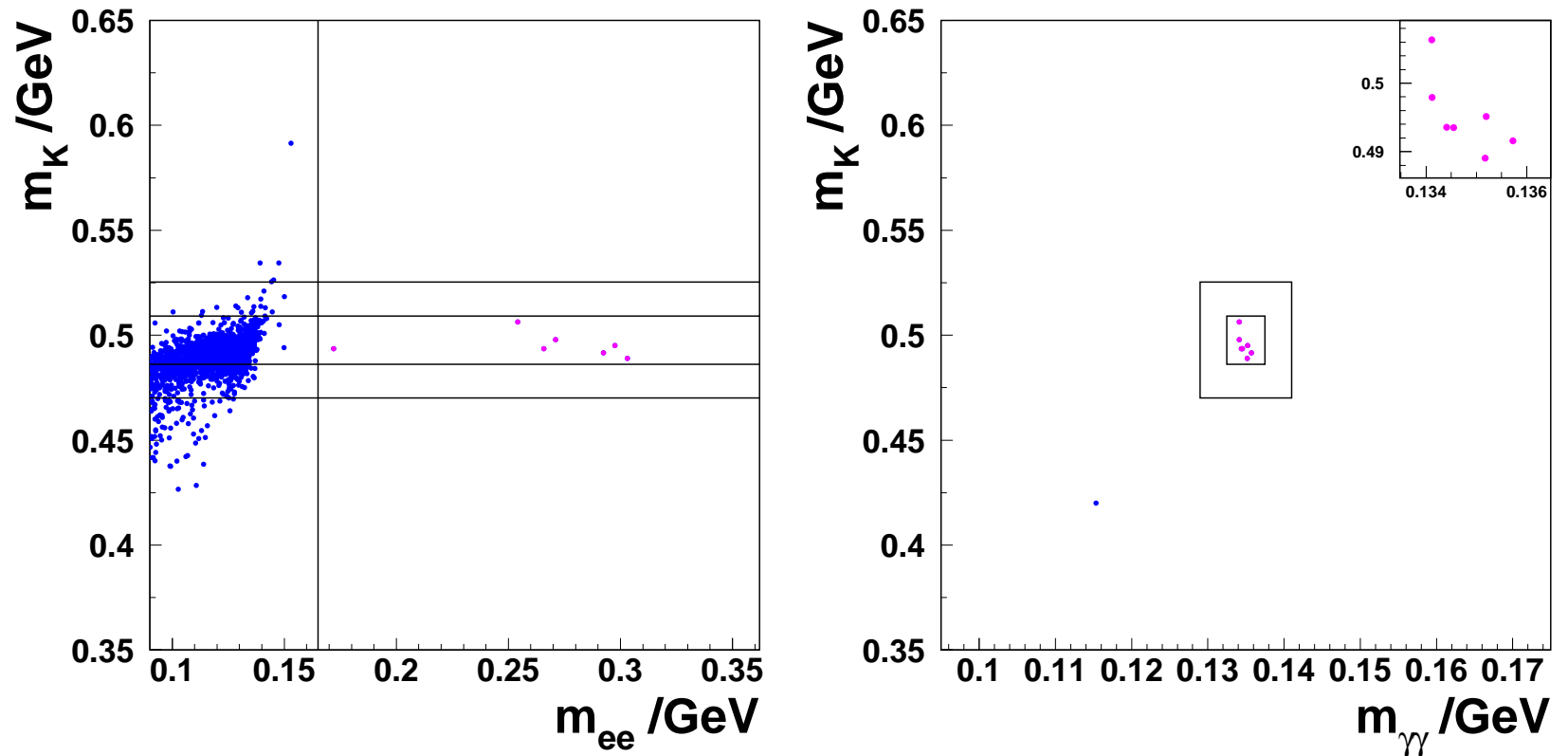
$(\pi^\pm e^\mp \nu) + (\pi^0 \pi^0 (\pi^0))$

confirmed relaxing E/p cut

Extrapolate from out-of-time control region to in-time signal region



First observation of $K_S \rightarrow \pi^0 e^+ e^-$



7 events found in the signal region with a background $0.15^{+0.05}_{-0.04}$

→ presence of signal well established

$K_S \rightarrow \pi^0 e^+ e^-$ branching ratio

$$BR(K_S \rightarrow \pi^0 e^+ e^-)_{(m_{ee} > 0.165 \text{ GeV})} = \\ (3.0_{-1.2}^{+1.5}(\text{stat}) \pm 0.2(\text{syst})) \times 10^{-9}$$

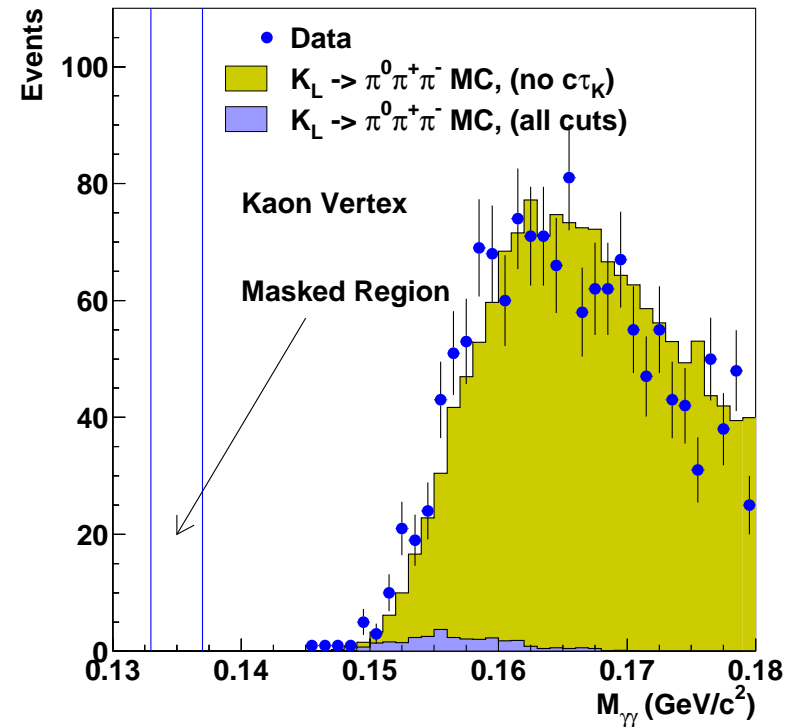
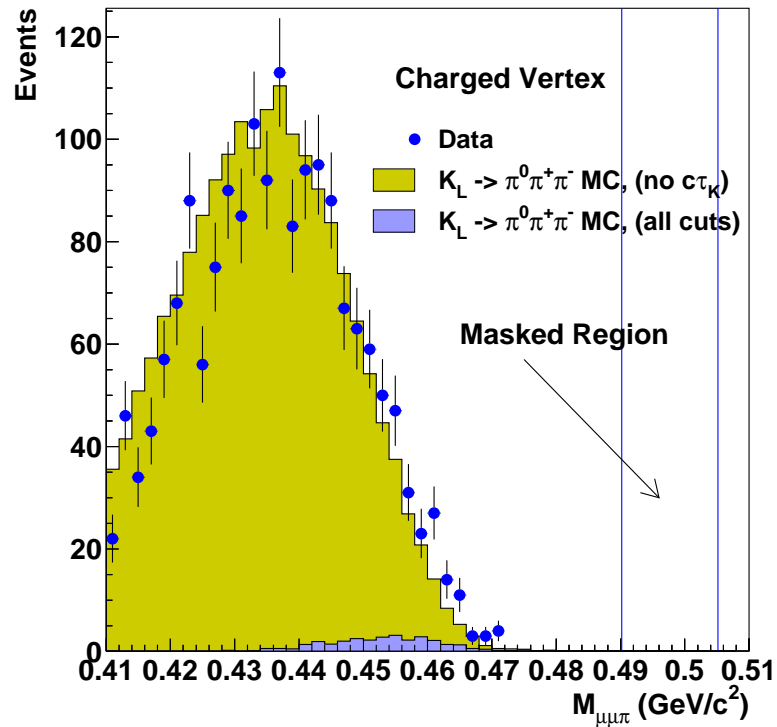
Published in Physics Letters B576 (2003) 43

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

$K_S \rightarrow \pi^0 \mu^+ \mu^-$: Background from $K_L \rightarrow \pi^+ \pi^- \pi^0$

Potential background from pion decay in flight

Studied using Monte Carlo, with τ/τ_S cut removed



$\approx 22 \times 2002$ statistics generated, no MC events found in signal region

$K_S \rightarrow \pi^0 \mu^+ \mu^-$: Background from $K_L \rightarrow \mu^+ \mu^- \gamma \gamma$

- $K_L \rightarrow \mu^+ \mu^- \gamma \gamma$ branching ratio is much smaller (10^{-9}) than in $K_S \rightarrow \pi^0 e^+ e^-$ channel (6×10^{-7})
- Impossible to use 2001 data because of unsuitable trigger
- Studied with Monte Carlo \rightarrow acceptance = 5×10^{-3}
- Mainly suppressed by the pion mass cut

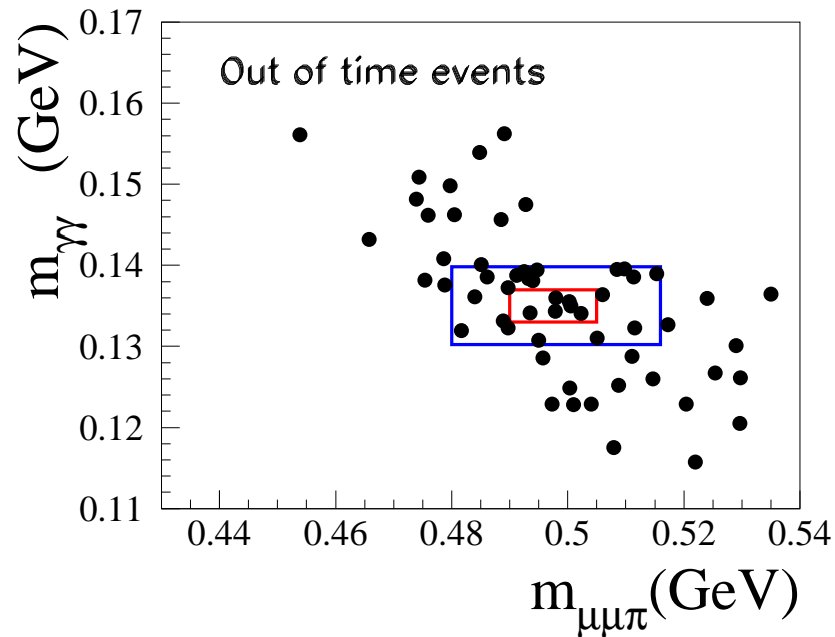
0.04 ± 0.04 events expected in signal region

$K_S \rightarrow \pi^0 \mu^+ \mu^-$: Background from fragments of two decays

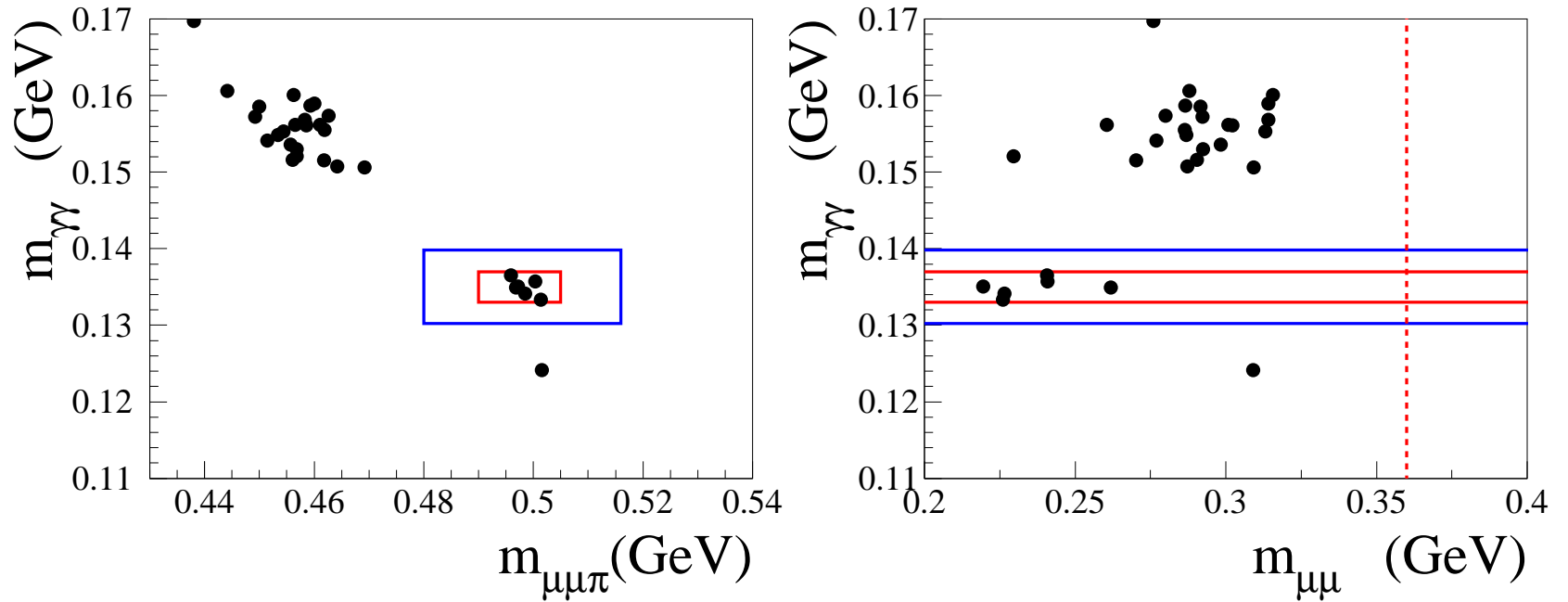
Dominated by:

- $K_L \rightarrow \pi^\pm \mu^\pm \nu + K_S \rightarrow \pi^0(\pi^0)$, $m_{\mu\mu} < 0.3$ GeV
- $K_S \rightarrow \pi^+ \pi^- + K_S \rightarrow \pi^0(\pi^0)$, $0.30 < m_{\mu\mu} < 0.36$ GeV

Control region: $-115 < |\Delta t| < -3$ ns , $3 < |\Delta t| < 60$ ns



First observation of $K_S \rightarrow \pi^0 \mu^+ \mu^-$



Presence of signal well established:

6 events found with a background $0.22^{+0.19}_{-0.12}$

$K_S \rightarrow \pi^0 \mu^+ \mu^-$ Branching ratio

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

Submitted to Physics Letter B

Implication of results

Assuming vector interaction and a unit form factor:

$$BR(K_S \rightarrow \pi^0 e^+ e^-) = (5.8_{-2.3}^{+2.8}(\text{stat}) \pm 0.3(\text{syst}) \pm 0.8(\text{theor})) \times 10^{-9}$$

$$BR(K_S \rightarrow \pi^0 l^+ l^-) \propto |W(z)|^2 \quad W(z) \sim (a_s + b_s m_{ll}^2/m_K^2)$$

Assuming Vector Meson Dominance: $b_s/a_s = m_K^2/m_\rho^2 = 0.4$

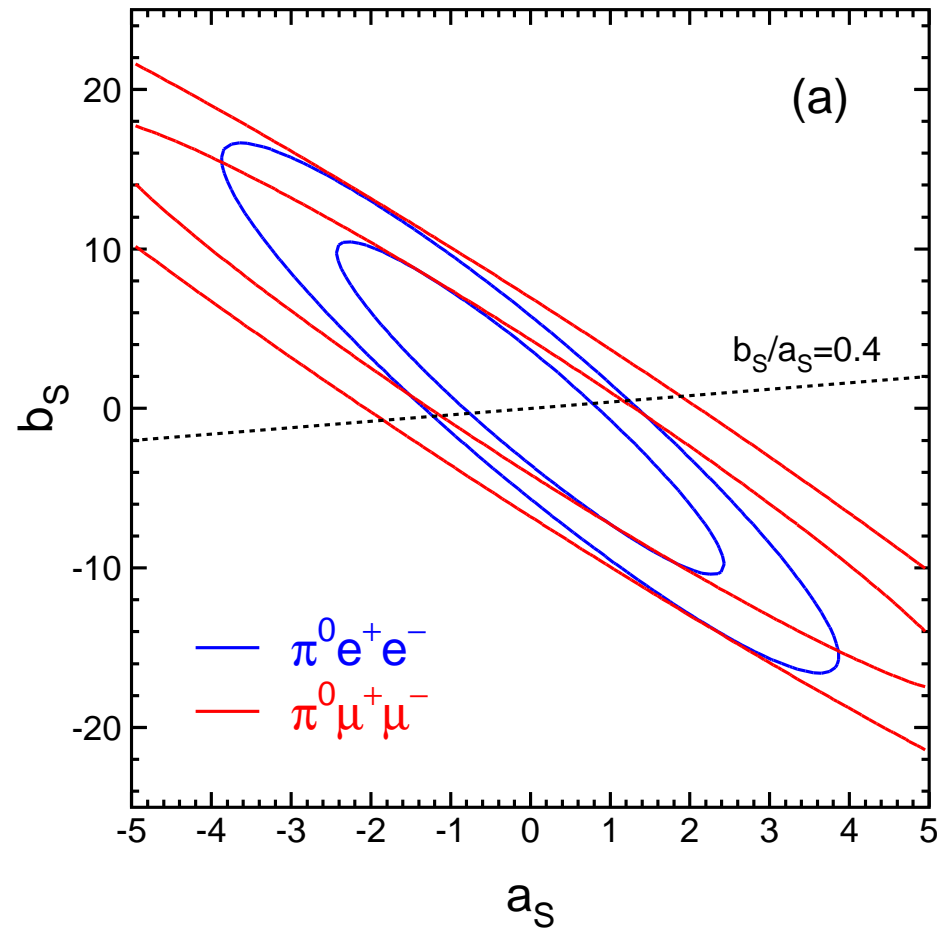
D'Ambrosio, Ecker, Isidori, Portoles JHEP08 (1998) 004

$$BR(K_S \rightarrow \pi^0 e^+ e^-) = 5.2 \times 10^{-9} |a_s|^2 \Rightarrow |a_s| = 1.06_{-0.21}^{+0.26} \pm 0.07$$

$$BR(K_S \rightarrow \pi^0 \mu^+ \mu^-) = 1.2 \times 10^{-9} |a_s|^2 \Rightarrow |a_s| = 1.54_{-0.32}^{+0.40} \pm 0.06$$

Determination of a_s and b_s

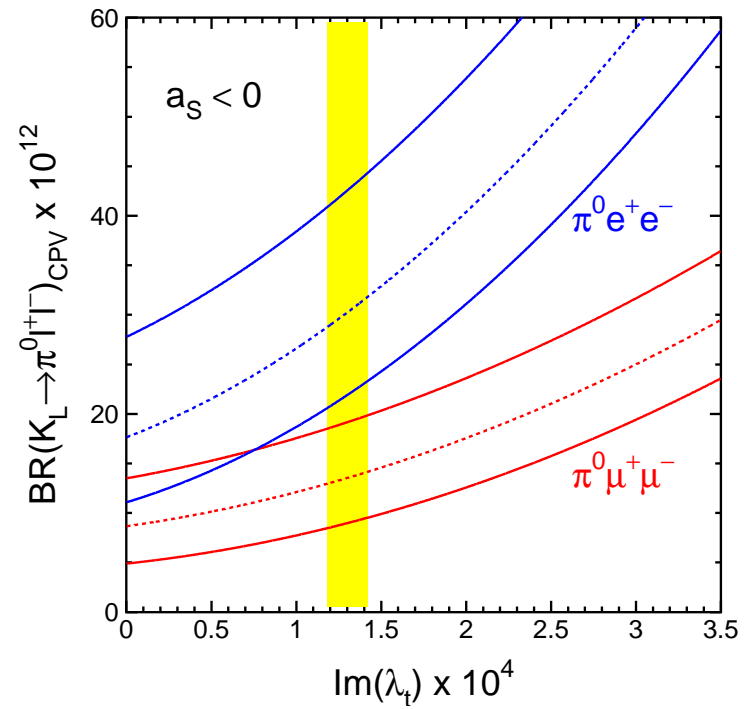
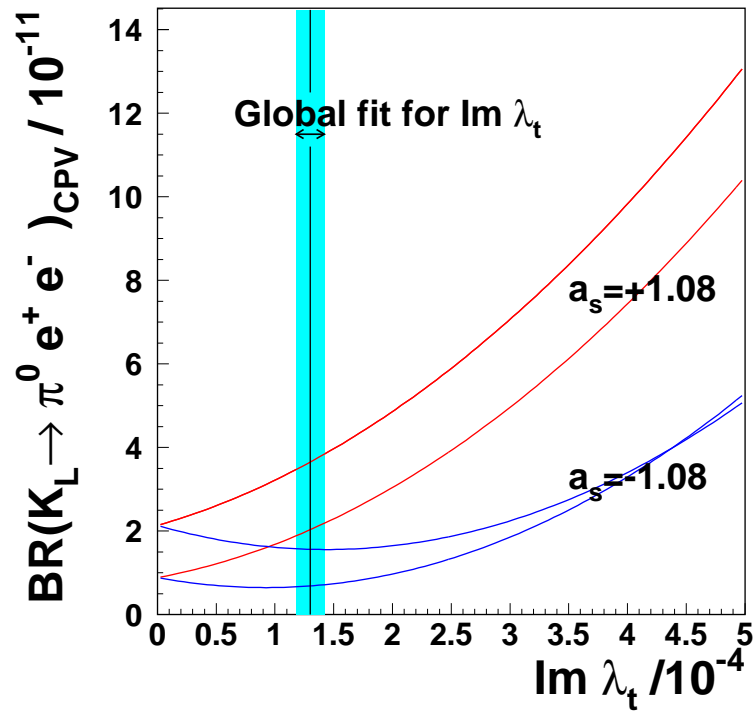
Combining both $K_S \rightarrow \pi^0 l^+ l^-$ results in a log-likelihood fit:



Curves compatible with each other and VMD

Statistics too low to determine b_s

Implications for $K_L \rightarrow \pi^0 l^+ l^-$ CPV



Construct. interf.

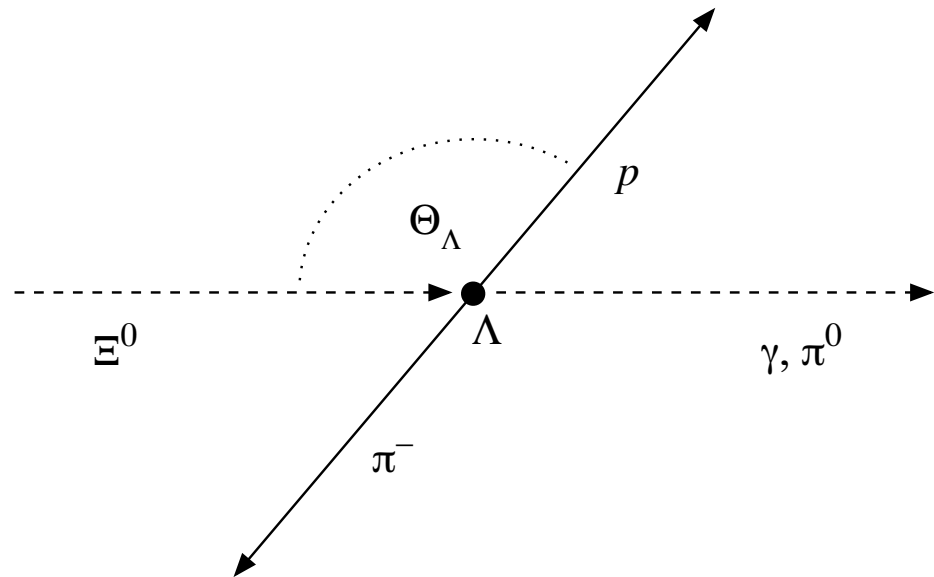
$$\mathbb{E}^0 \rightarrow \Lambda\gamma$$

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

1999 High Intensity K_S run (48 h of data taking):

730 $\Xi^0 \rightarrow \Lambda \gamma$ events with background of 58.2 ± 7.8 events

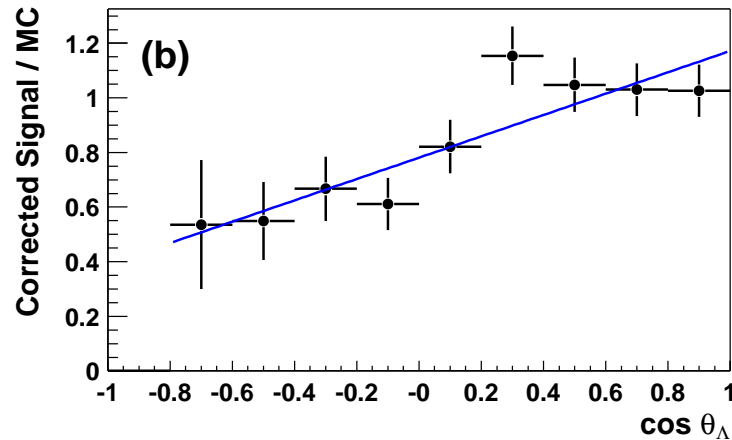
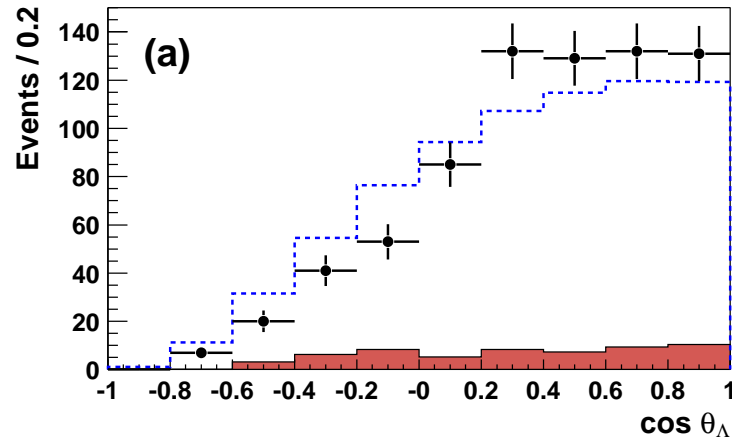
The asymmetry was measured using the angle Θ_Λ between the Ξ^0 and the out-going proton (coming from the decay $\Lambda \rightarrow p\pi^-$) in the Λ rest frame



The MC and the technique were first tested measuring the decay asymmetry in the decay $\Xi^0 \rightarrow \Lambda \pi^0$

$\Xi^0 \rightarrow \Lambda \gamma$ decay asymmetry (cont.)

Data were compared with an isotropic MC distribution:



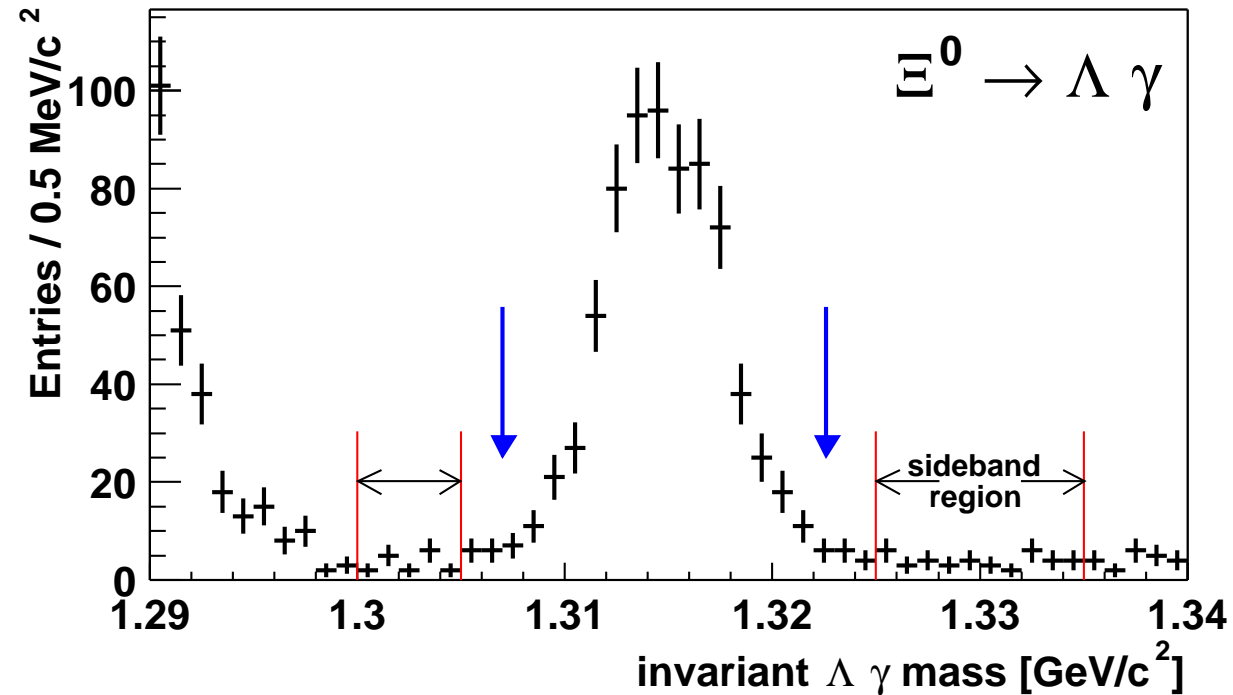
$$\alpha(\Xi^0 \rightarrow \Lambda \gamma) = -0.78 \pm 0.18_{stat} \pm 0.06_{syst}$$

Effect of background on the asymmetry was measured in the mass sidebands

The main systematic uncertainty comes from background subtraction

First clear evidence for negative asymmetry

$\Xi^0 \rightarrow \Lambda \gamma$ branching ratio

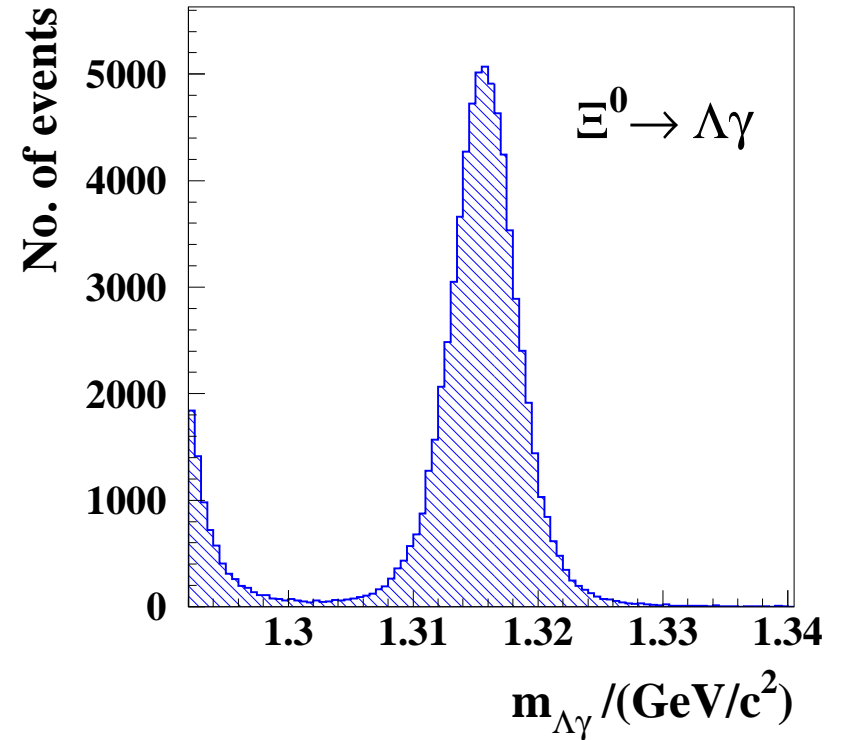
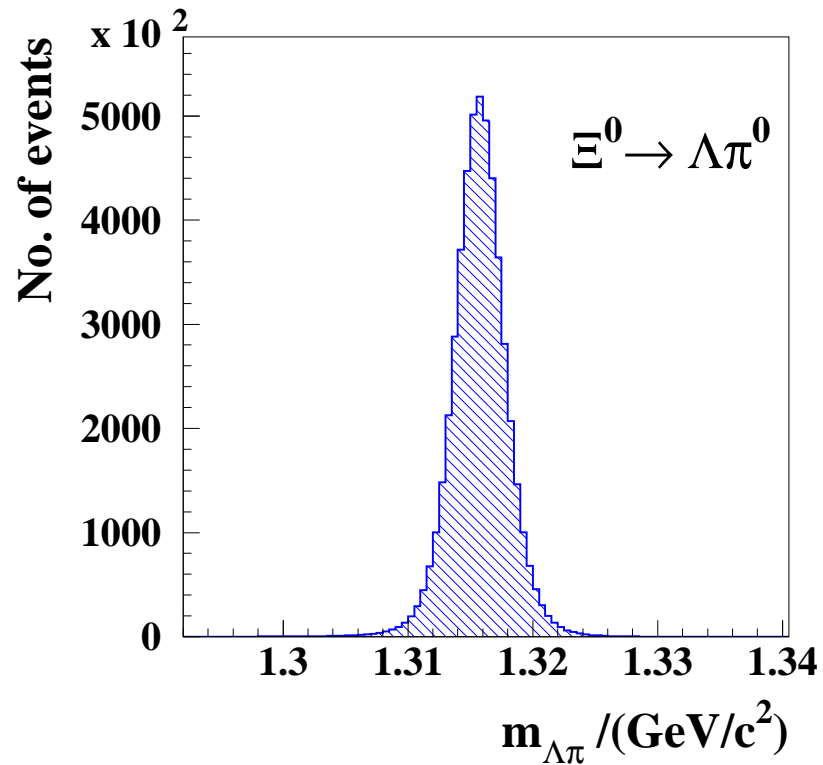


$$BR(\Xi^0 \rightarrow \Lambda \gamma) = (1.16 \pm 0.05_{stat} \pm 0.06_{syst}) \times 10^{-3}$$

The systematic uncertainty is dominated by the error on the asymmetry measurement

Ξ^0 radiative decays

Much larger statistical sample from 2002 data is currently under analysis:



Conclusions

- Main goal of NA48/1 reached:
 - First observation of $K_S \rightarrow \pi^0 e^+ e^-$ Published
 - First observation of $K_S \rightarrow \pi^0 \mu^+ \mu^-$ Submitted
- Clear signal from Ξ^0 decays
- Branching ratio and asymmetry $\Xi^0 \rightarrow \Lambda \gamma$, 99 data
Published
- Many analyses in progress, both K_S and Ξ^0
($K_S \rightarrow \pi^+ \pi^- \pi^0$, $K_S \rightarrow \pi e \nu$,
 $\Xi^0 \rightarrow \Lambda \gamma$, $\Xi^0 \rightarrow \Sigma^+ l^- \nu$, $\Xi^0 \rightarrow \Lambda e^+ e^-$, limit on $\Xi^0 \rightarrow p \pi$,
 Ξ^0 lifetime)