Recent results from NA48/1

Cristina Lazzeroni

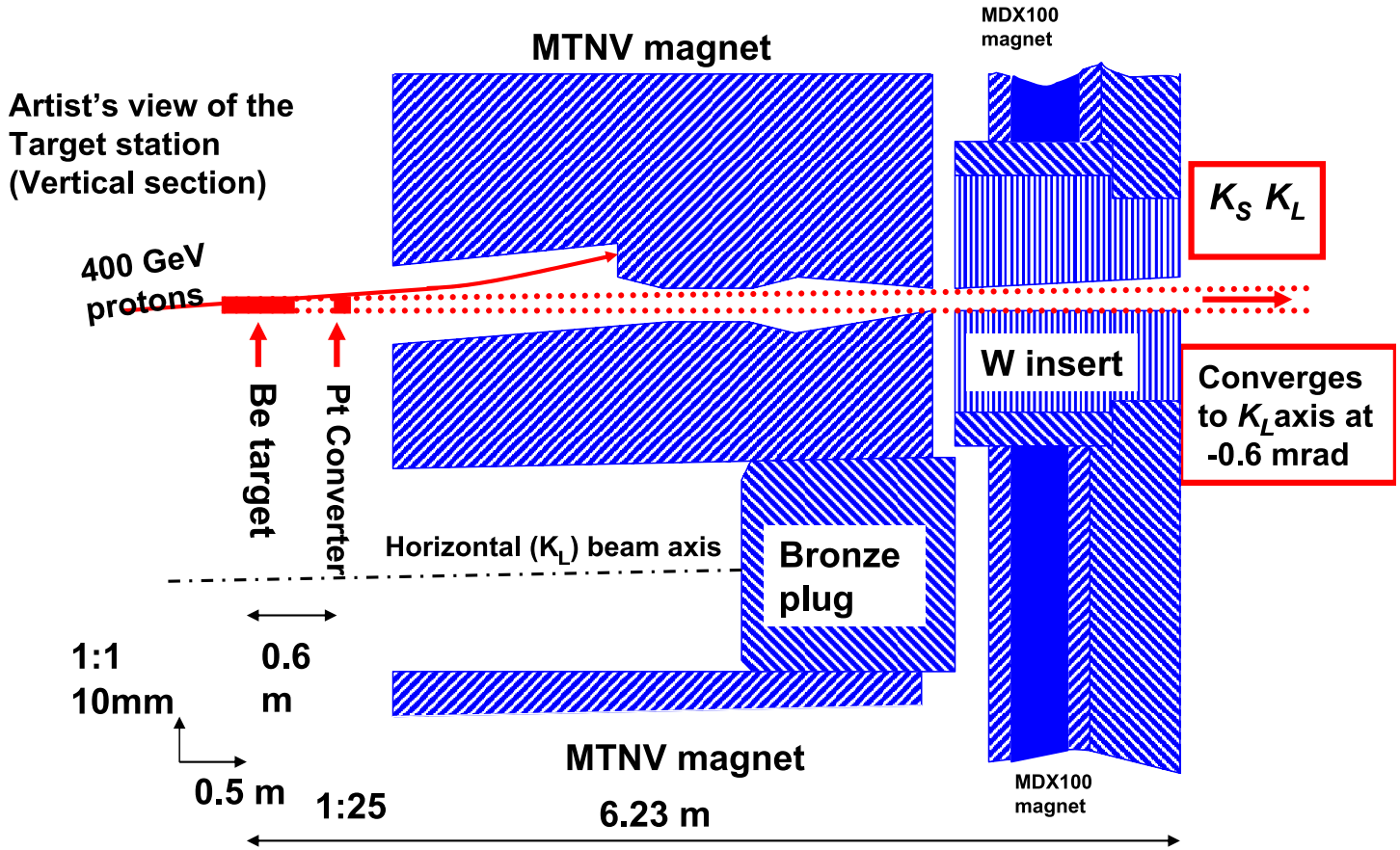
Kaon Mini Workshop

Cern, 5th May 2004

Overview

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

2002 Beam line - High intensity K_S



$\sim 4\times10^{10}$ K_S decays in 89 days
in $40 < E_K < 240\,\mathrm{GeV}$, $0 < c\tau < 2.5 c\tau_{K_S}$

Results from 2000 data

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

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

- $K_S \to \pi^0\pi^0\pi^0$:
  $Re(\eta_{000}) = -0.026 \pm 0.010_{stat} \pm 0.005_{syst}$
  $Im(\eta_{000}) = -0.034 \pm 0.010_{stat} \pm 0.011_{syst}$
  Preliminary

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

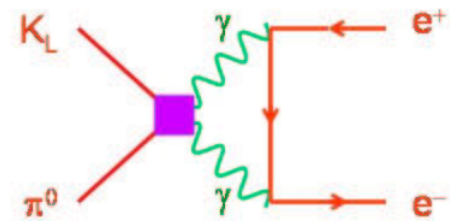
- CP conserving

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

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

  [PL B536 229]

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

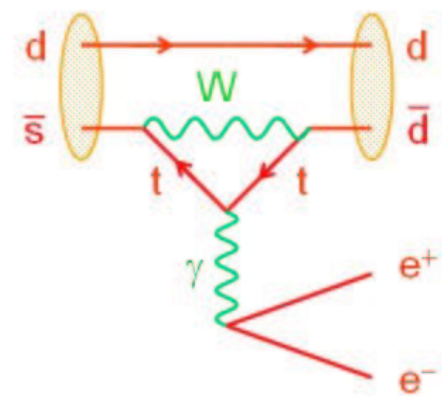


- direct CP violating

  Proportional to η or $\mathcal{I}m(\lambda_t)$

  $\mathcal{I}m(\lambda_t) = \eta A^2 \lambda^5 \qquad \lambda_t = V_{ts}^* V_{td}$

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



- indirect CP violating

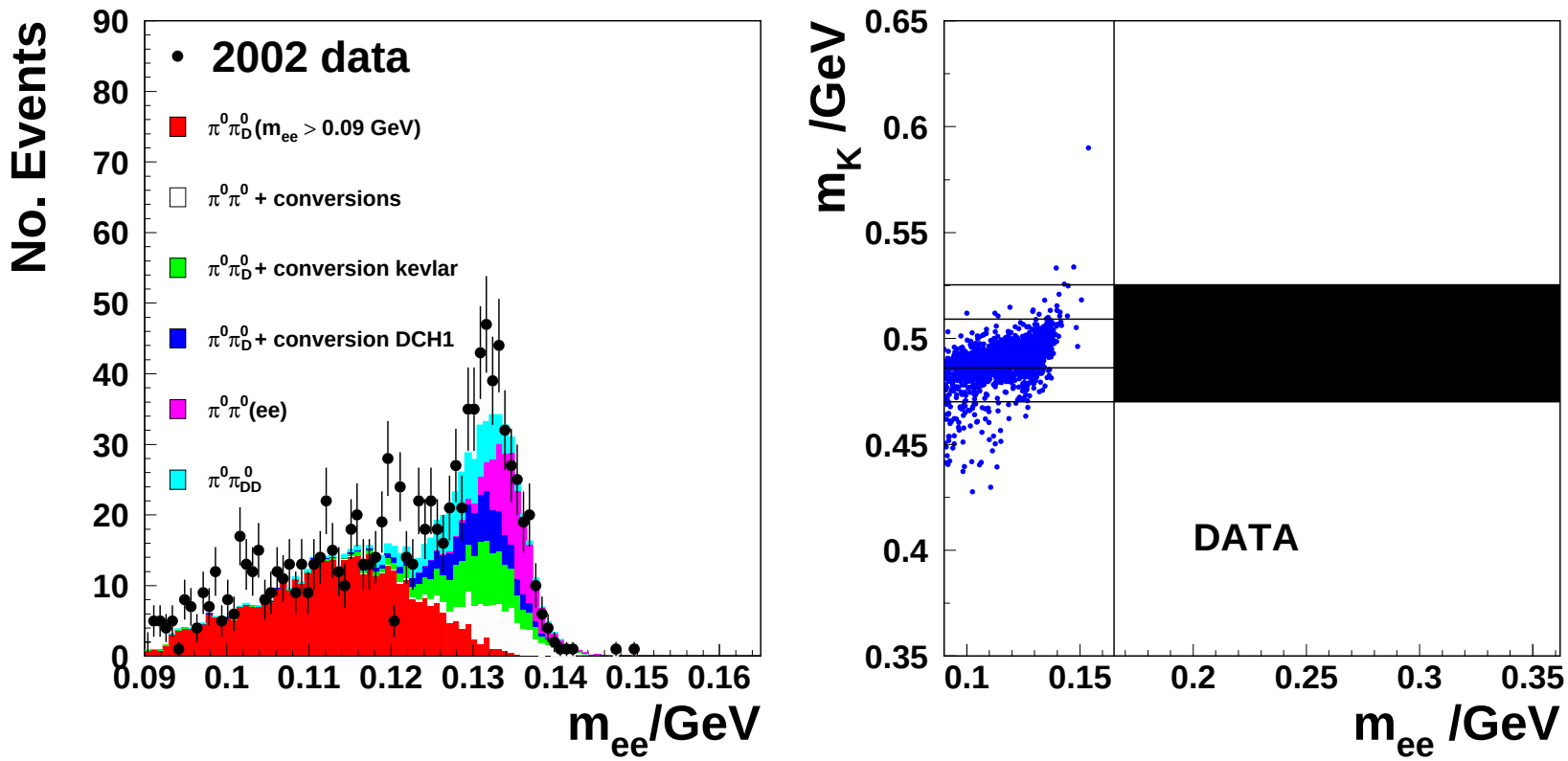
  $\to BR(K_L \to \pi^0 l^+ l^-)_{ind} = |\epsilon|^2 (\frac{\tau_L}{\tau_S}) BR(K_S \to \pi^0 l^+ l^-)$

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

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

$K_S \to \pi^0 e^+ e^-$: *Background from* $K_S \to \pi^0 \pi^0_D$

Blind analysis: Control and Signal regions masked

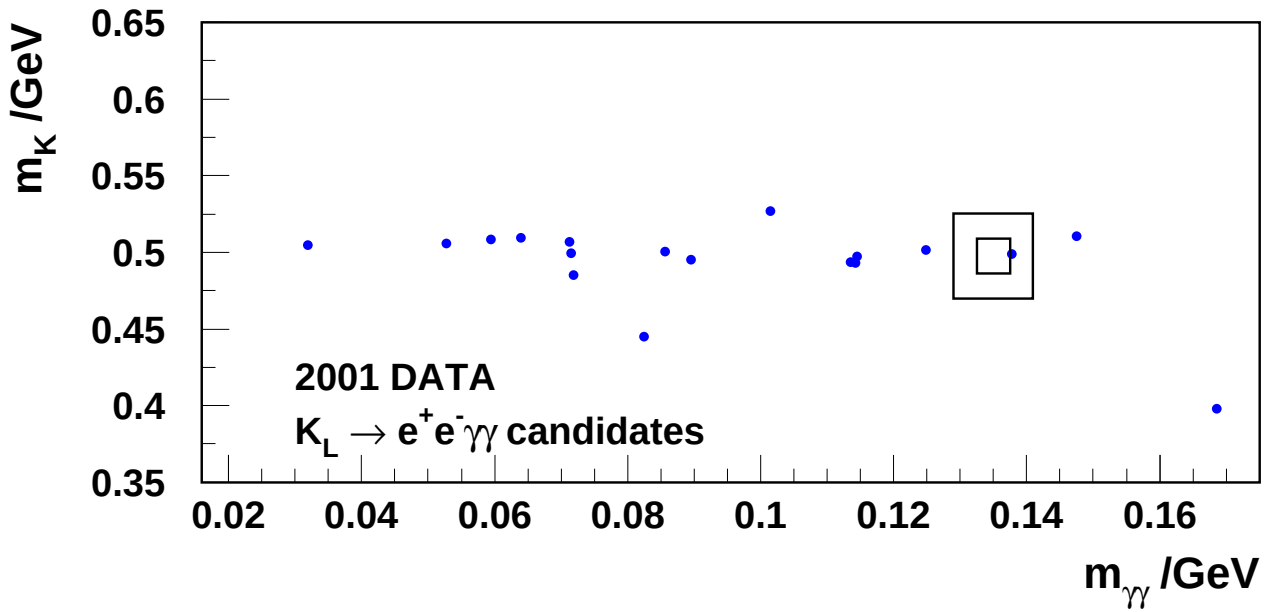


Events with m_{ee} mis-measured : $m_{ee} > m_{\pi^0} \to m_{ee\gamma\gamma} > m_K$

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

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

$\sim 5\times10^8$ K_L decay in the $0 < \frac{c\tau}{c\tau_S} < 2.5$ fiducial region
$\Rightarrow$ 300 $K_L \to ee\gamma\gamma$ decays ($BR = 6\times10^{-7}$)
2001 data with K_L beam used to estimate background
(10 $\times$ number of K_L decays in 2002 data)



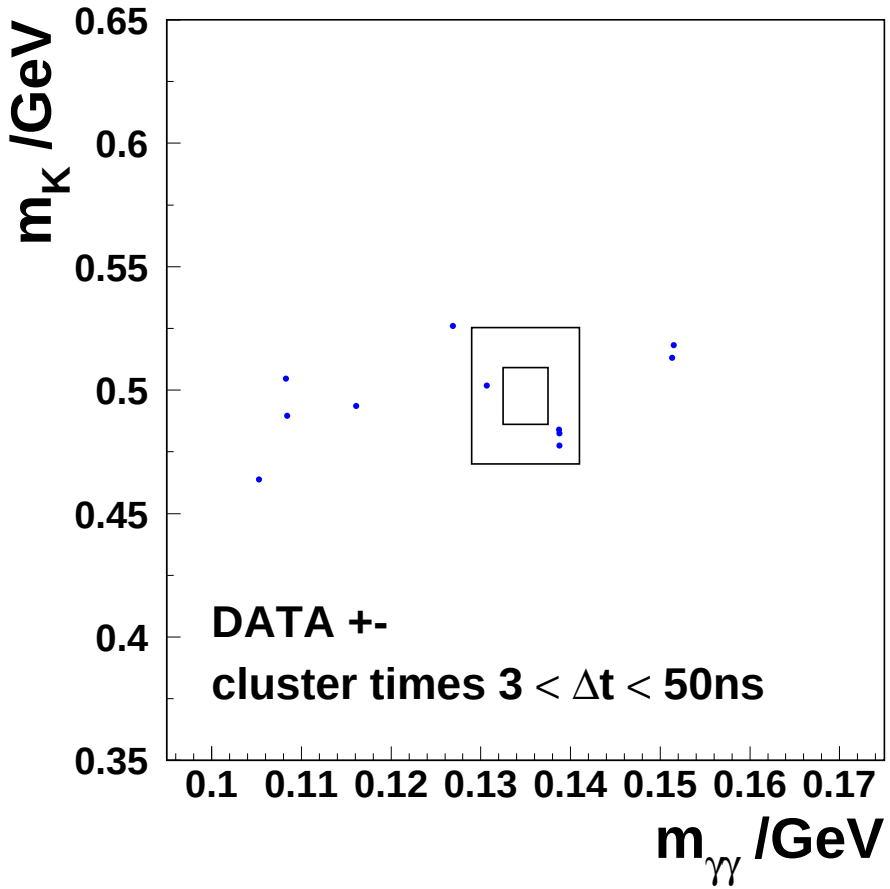
Extrapolate from low $m_{\gamma\gamma}$ region to signal region
$\to$ Background 0.075 events in signal region

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

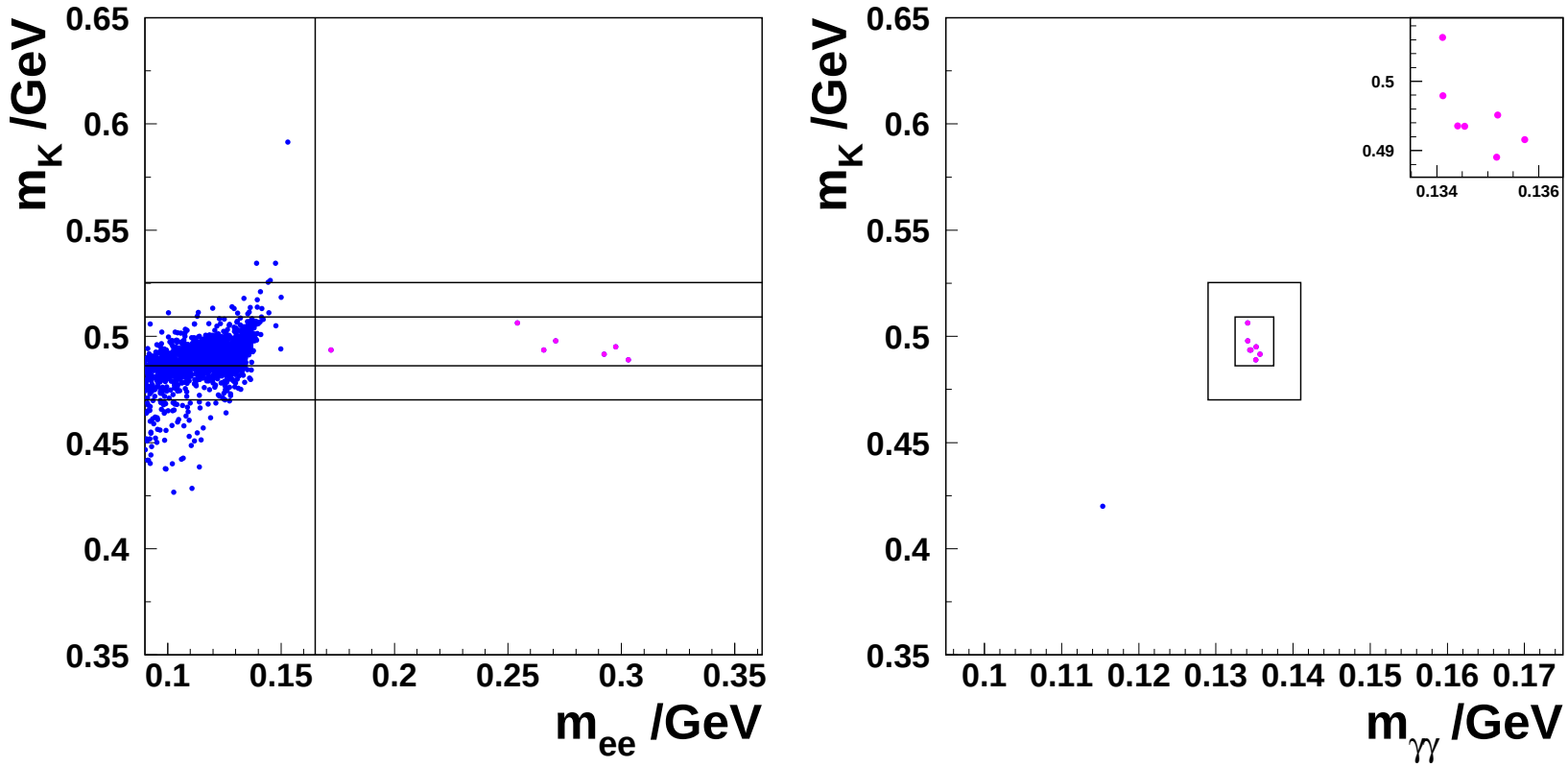
Δt = time between fragments
Control region : $3 < \Delta t < 50\,\mathrm{ns}$
Signal region : $\Delta t < 3\,\mathrm{ns}$

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



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

$\to$ presence of signal well established

$K_S \to \pi^0 e^+ e^-$ *branching ratio*

$$BR(K_S \to \pi^0 e^+ e^-)_{(m_{ee}>0.165\ \mathrm{GeV})} =$$

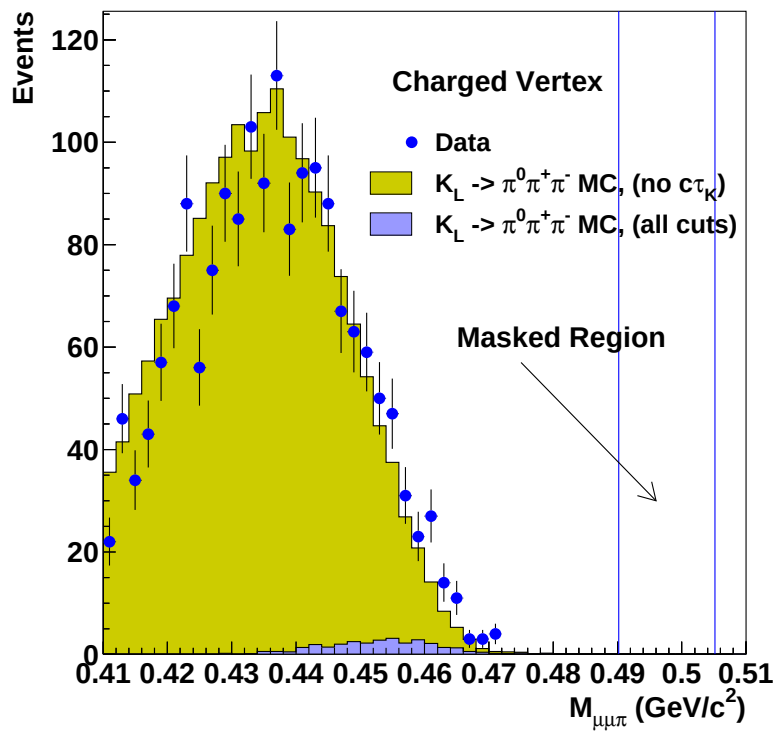
$$(3.0^{+1.5}_{-1.2}(stat) \pm 0.2(syst)) \times 10^{-9}$$

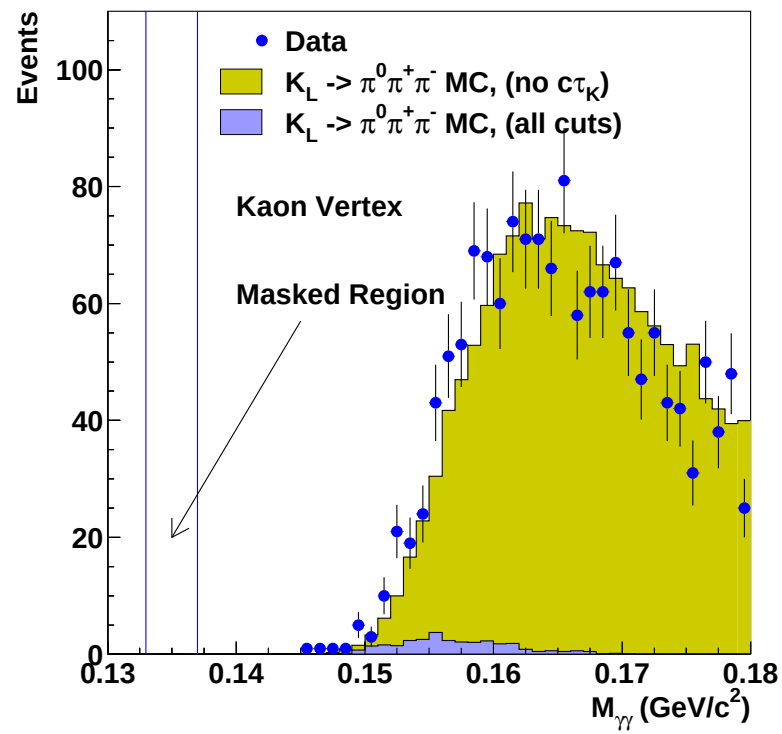
Published in Physics Letters B576 (2003) 43

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

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

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

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

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

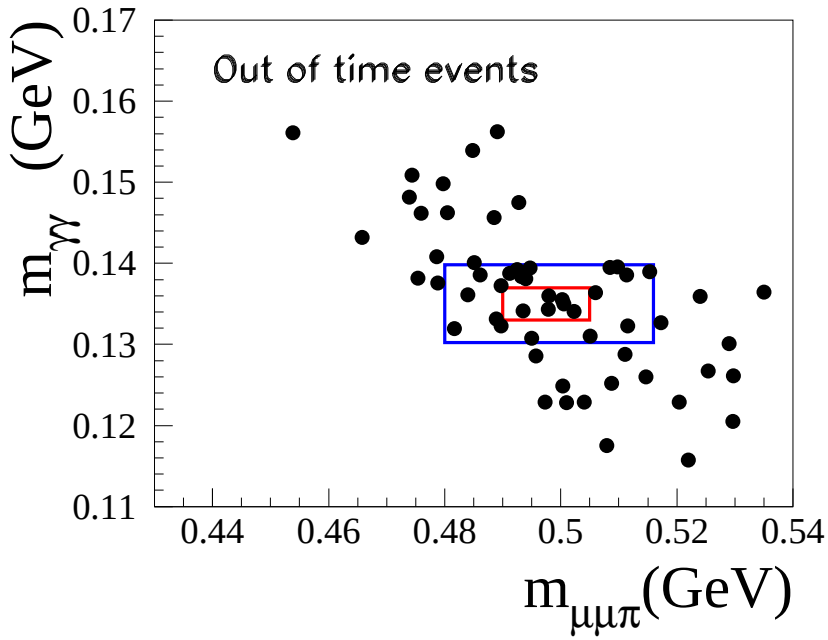
0.04 ± 0.04 events expected in signal region

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

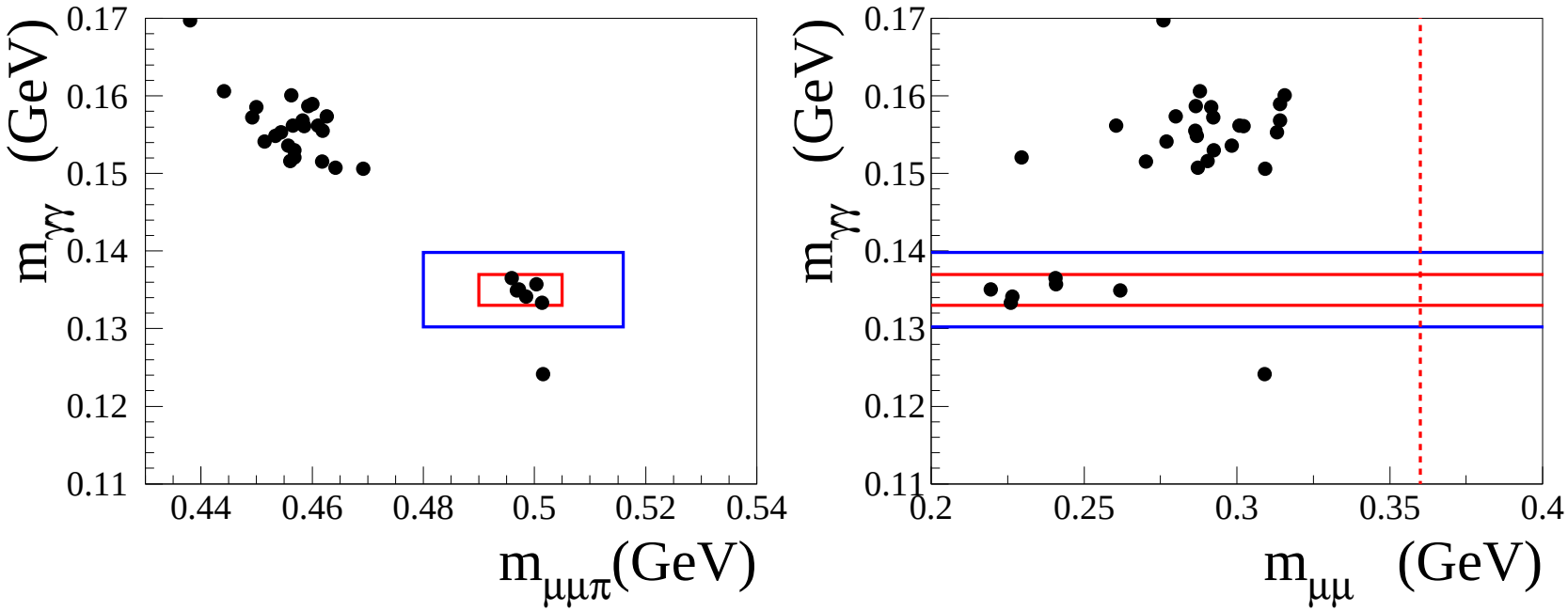
Dominated by:

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

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



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



Presence of signal well established:

6 events found with a background $0.22^{+019}_{-0.12}$

$K_S \to \pi^0 \mu^+ \mu^-$ *Branching ratio*

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

$$(2.8^{+1.5}_{-1.2}(stat) \pm 0.3(syst) \pm 0.8(theor)) \times 10^{-9}$$

Preliminary result

Implication of results

Assuming vector interaction and a unit form factor:
$BR(K_S \to \pi^0 e^+ e^-) = (5.8^{+2.8}_{-2.3}(stat) \pm 0.3(syst) \pm 0.8(theor)) \times 10^{-9}$

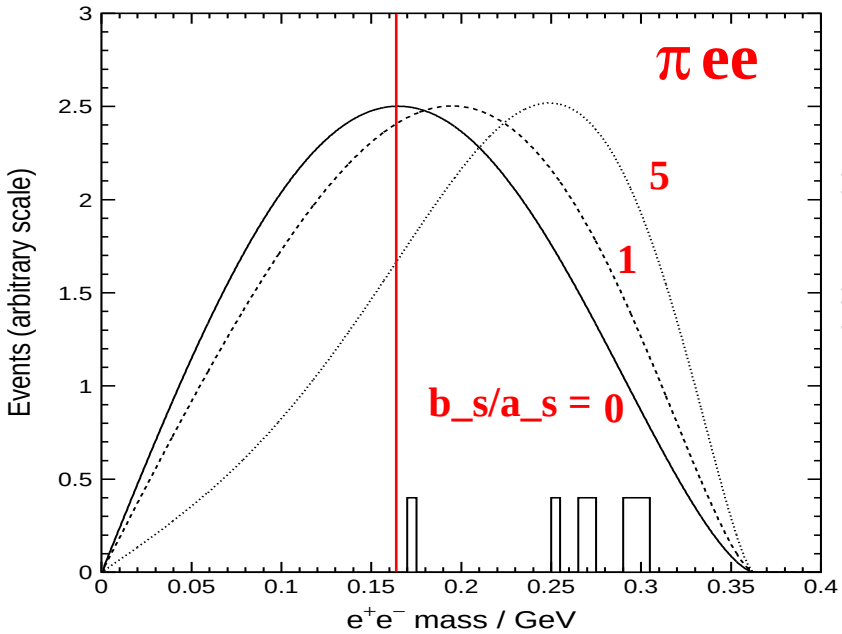
$BR(K_S \to \pi^0 l^+ l^-) \propto |W(z)|^2 \qquad W(z) \sim (a_s + b_s\ m_{ll}^2/m_K^2)$

Assuming Vector Meson Dominance: $b_s/a_s = m_K^2/m_\rho^2 = 0.4$
D'Ambrosio, Ecker, Isidori, Portoles JHEP08 (1998) 004

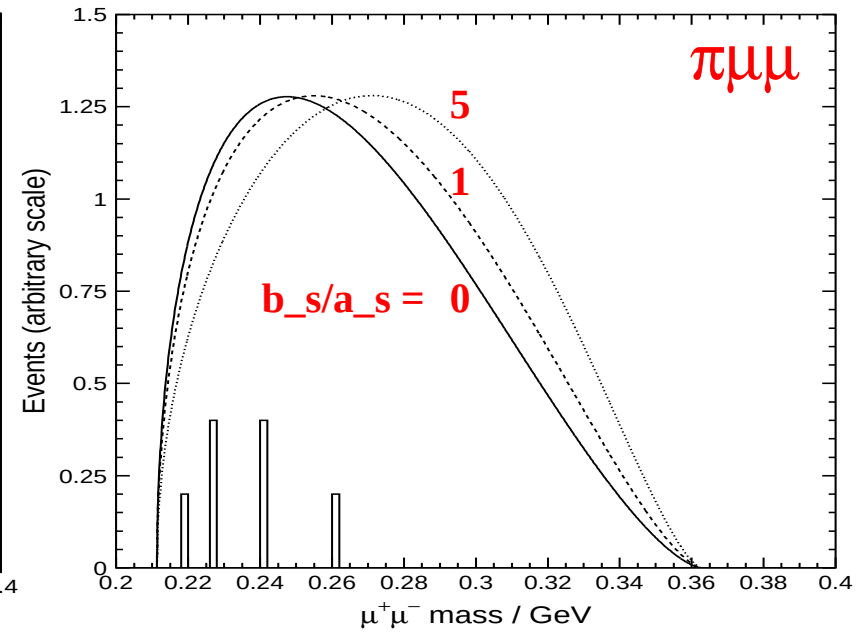
$BR(K_S \to \pi^0 e^+ e^-) = 5.2 \times 10^{-9} |a_s|^2 \Rightarrow |a_s| = 1.08^{+0.26}_{-0.21}$
$BR(K_S \to \pi^0 \mu^+ \mu^-) = 1.2 \times 10^{-9} |a_s|^2 \Rightarrow |a_s| = 1.53^{+0.38}_{-0.32}$

Dilepton mass distributions

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



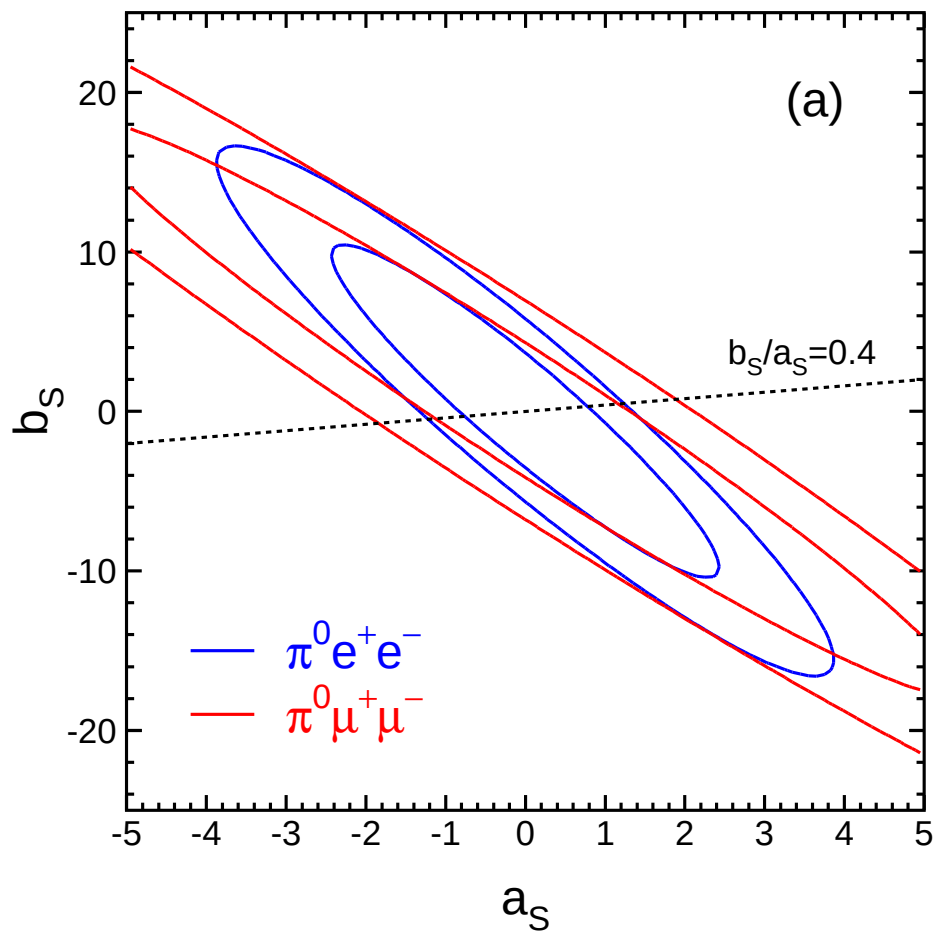
$K_S \to \pi^0 \mu^+ \mu^-$



Shape determined by ratio b_s/a_s

Determination of a_s and b_s

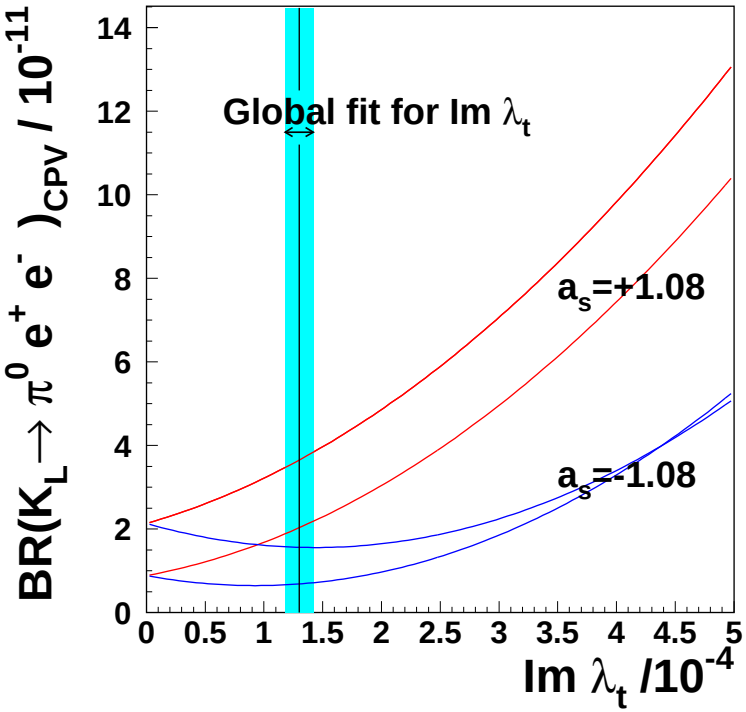
Combining both $K_S \to \pi^0 l^+ l^-$results in a log-likehood fit:

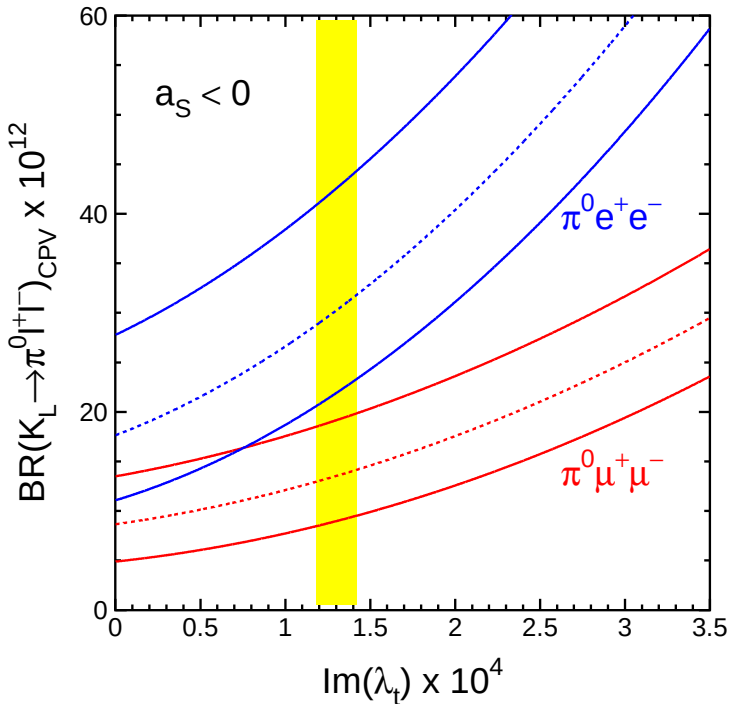


Curves compatible with each other and VMD

Statistics too low to determine b_s

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





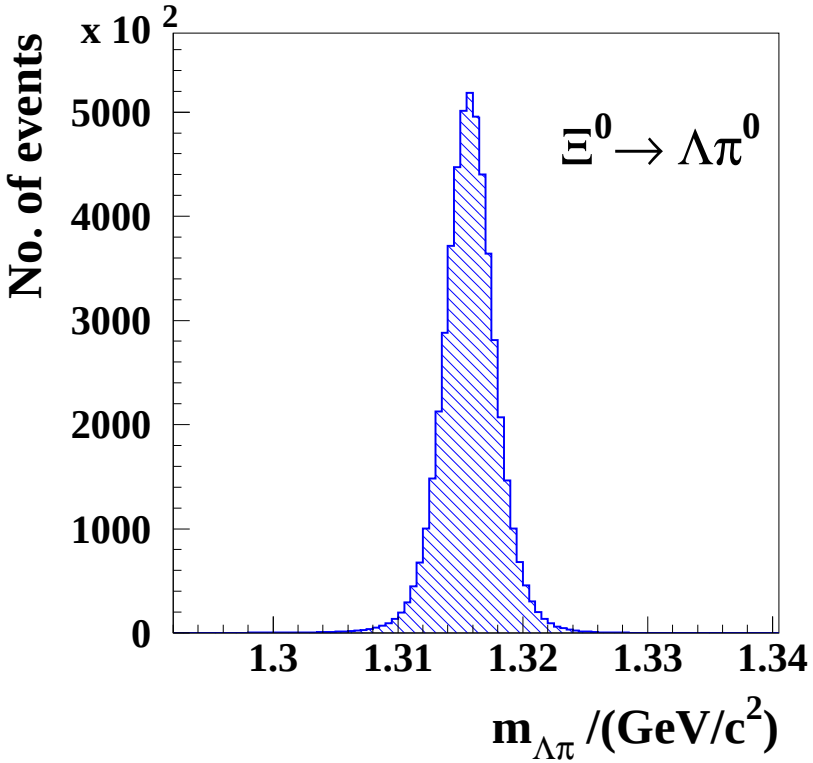
Construct. interf.

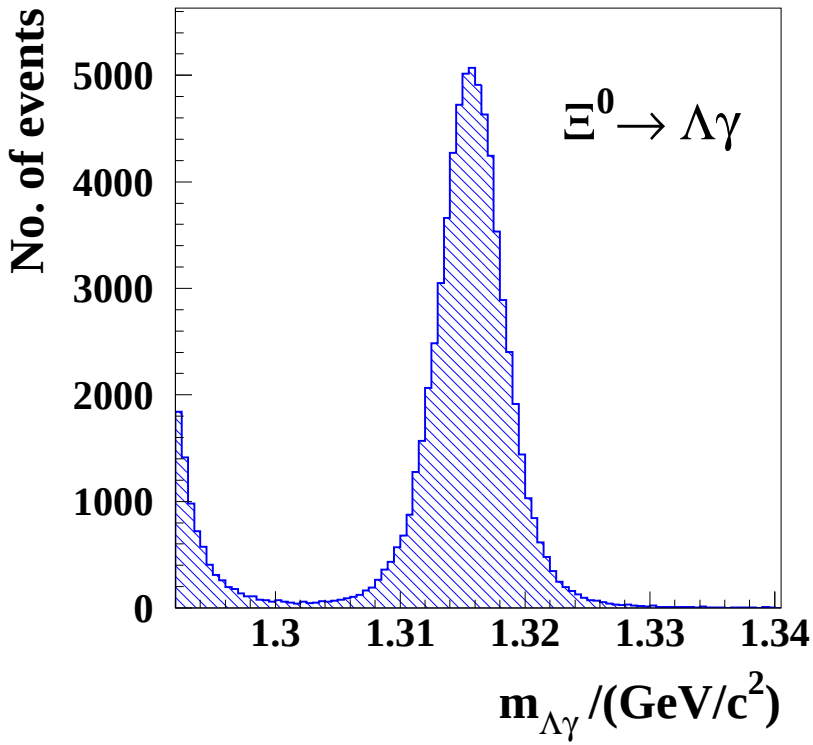
Other analyses

- $K_S \to \pi^+\pi^-\pi^0$
- $K_S \to \pi e \nu$
- $\Xi^0 \to \Lambda\gamma$
- $\Xi^0 \to \Sigma^+ e^- \nu$, $\Sigma^+ \mu^- \nu$
- $\Xi^0 \to \Lambda e^+ e^-$

Ξ^0 *radiative decays*

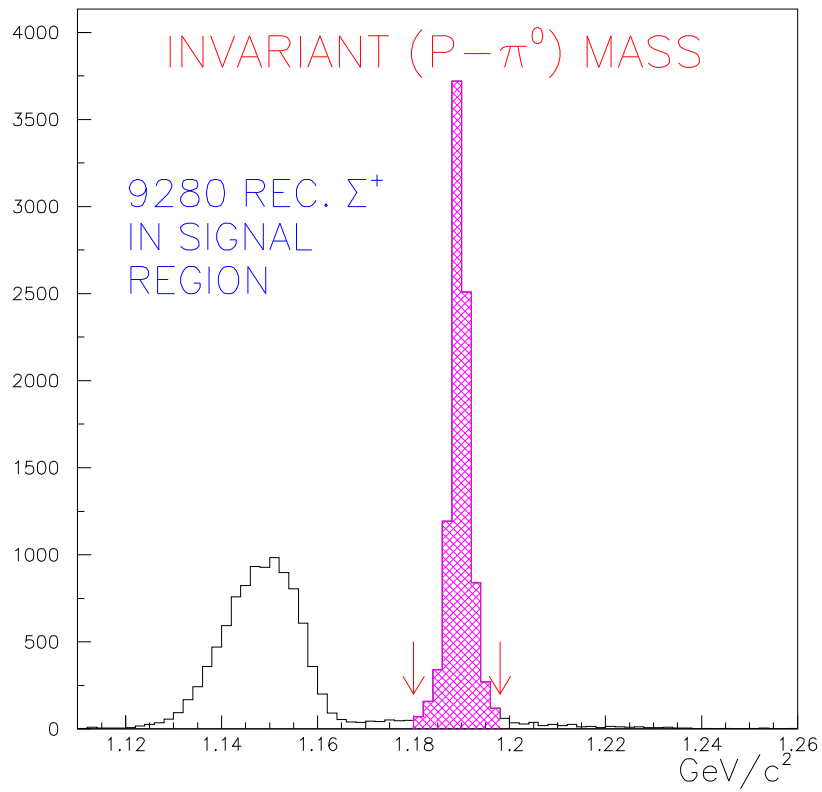
2002 data:

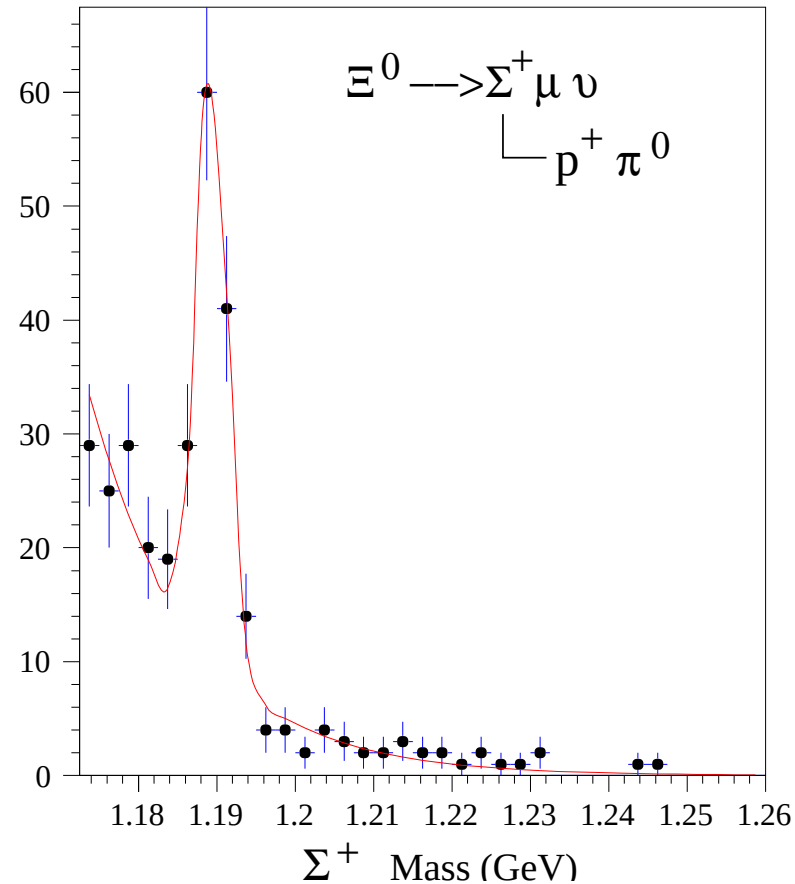




(Published paper from 99 HIKS data)

Ξ^0 *semileptonic decays*





First clear evidence for the muon channel

Conclusions

- Main goal of NA48/1 reached:
  - First observation of $K_S \to \pi^0 e^+ e^-$ Published
  - First observation of $K_S \to \pi^0 \mu^+ \mu^-$ Preliminary
- Clear signal from Ξ^0 decays
- Many analyses in progress, both K_S and Ξ^0