Hyperon decays

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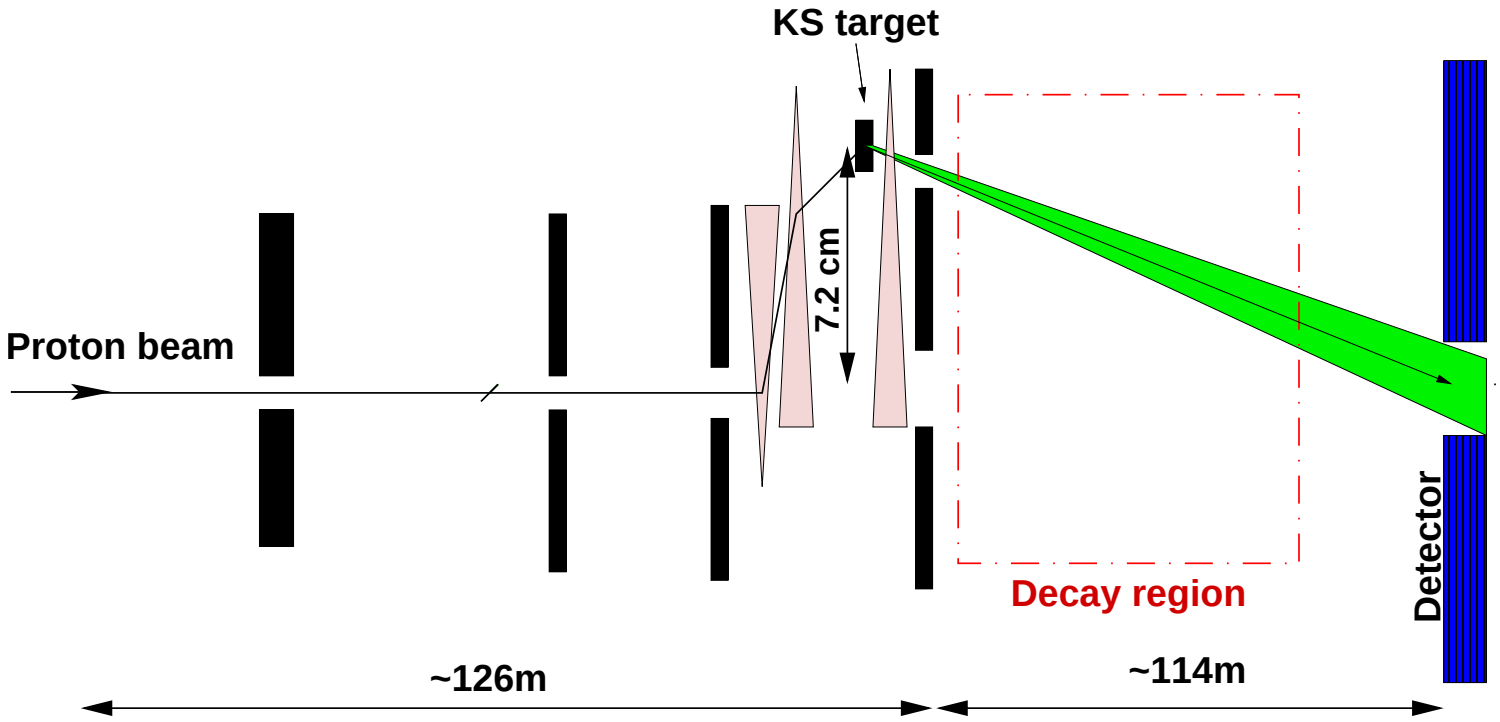
The NA48 simultaneous K_S and K_L beams

400 GeV/c secondary proton beam from the SPS T10 target,
production angle of 4.2 *mrad*



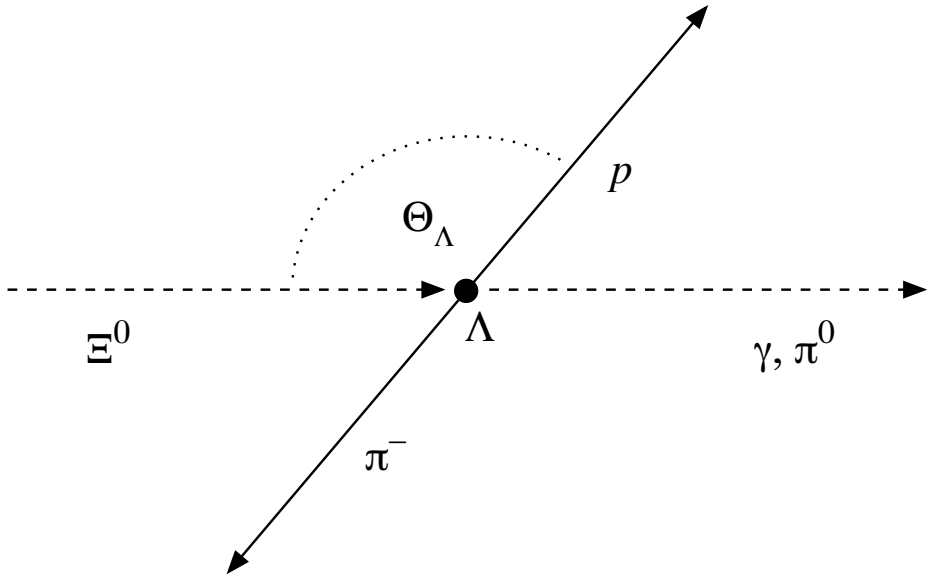
K_S and neutral hyperons decays:
48 h of data taking in 1999, 89 days in 2002

$\approx 200\times$ intensity as $\mathrm{Re}(\varepsilon'/\varepsilon)$

$\Xi^0 \to \Lambda\gamma$ *decay asymmetry*

1999 High Intensity run :
730 $\Xi^0 \to \Lambda\gamma$ events with background of 58.2 ± 7.8 events
$BR(\Xi^0 \to \Lambda\gamma) = (1.16 \pm 0.05_{stat} \pm 0.06_{syst}) \times 10^{-3}$

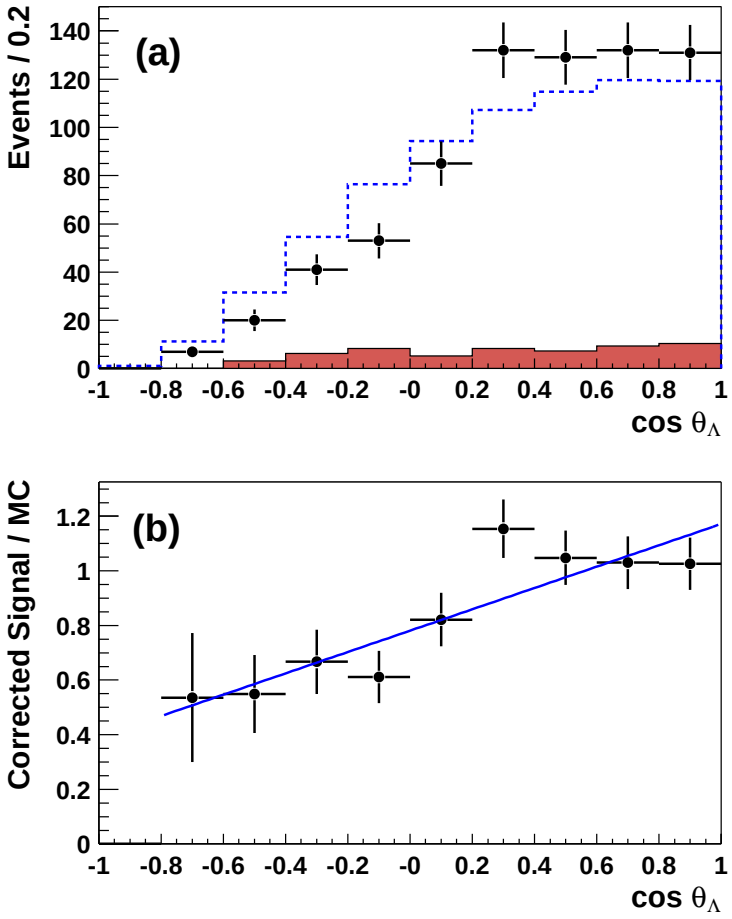
The asymmetry was measured using the angle Θ_Λ between the Ξ_0 and the out-going proton (coming from the decay $\Lambda \to p\pi^-$) in the Λ rest frame



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

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

Data were compared with an isotropic MC distribution:



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

Different predictions:
- pole models, χPT (satysfying the Hara theorem) $\to$ negative
- vector meson dominance models, quark models $\to$ positive

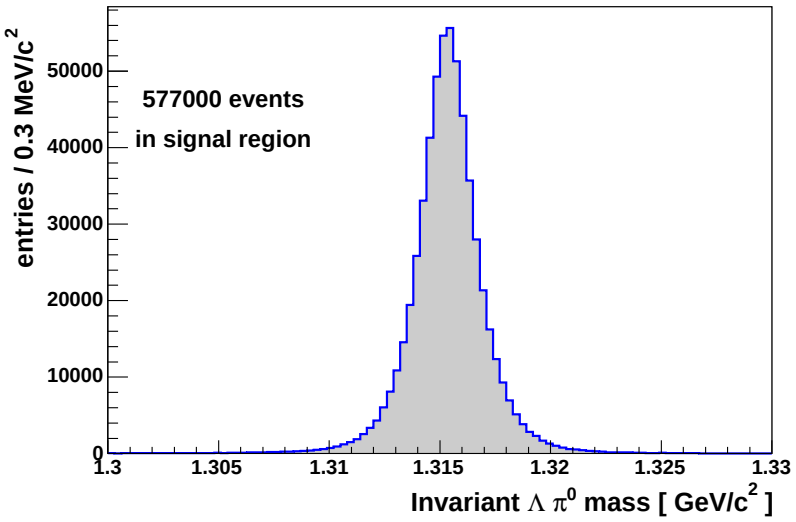
First clear evidence for negative asymmetry

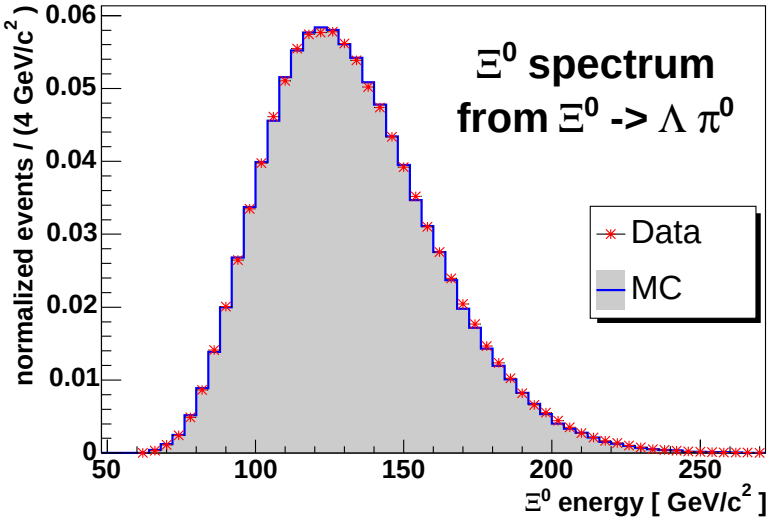
Phys. Lett. B584:251-259, 2004

Ξ^0 *in 2002*

$\approx 2 \times 10^9$ Ξ^0 decays in fiducial volume

From minimum bias trigger (down-scaled by 35):

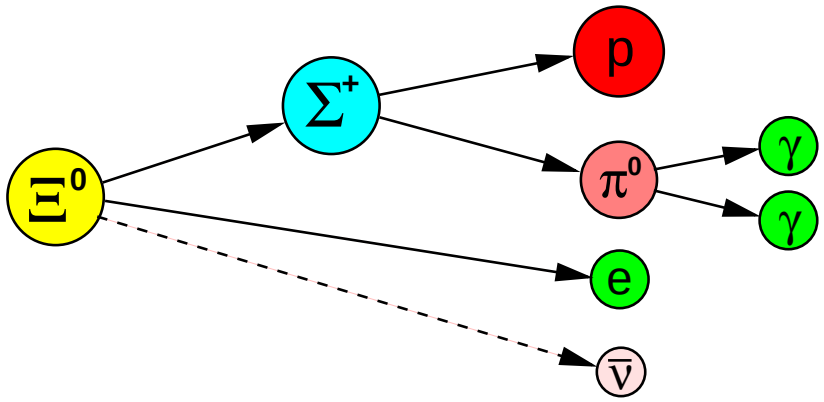




Used for normalisation purposes

Ξ^0 lifetime measurement using $\Xi^0 \to \Lambda\pi^0$ in progress

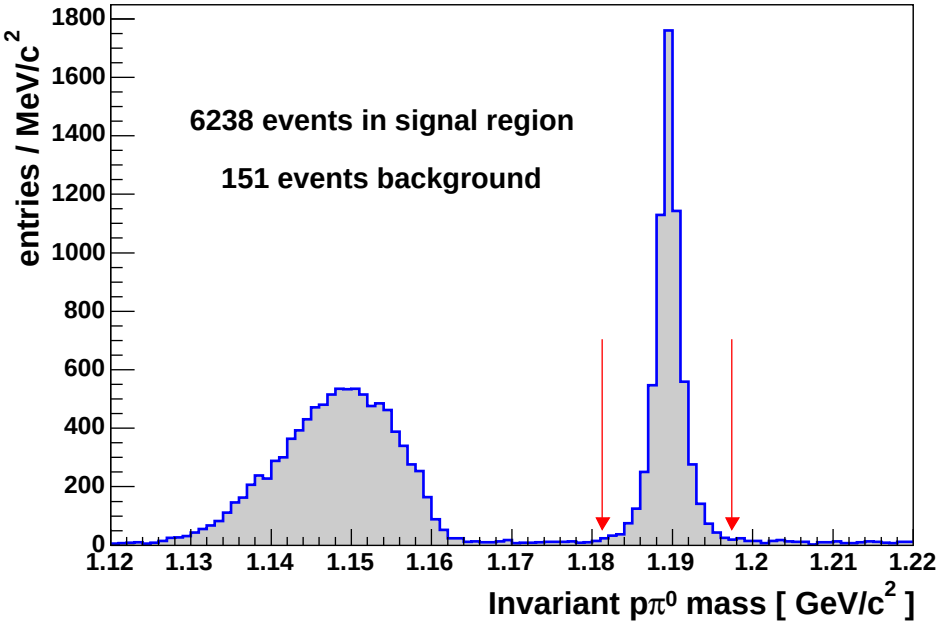
$\Xi^0 \to \Sigma^+ e^- \nu$ *decays*



Reconstruct $\Sigma^+ \to p\pi^0$
and require additional electron

$\Xi^0 \to \Sigma^+ l^- \nu$ decays are only source of Σ^+ in the neutral beam

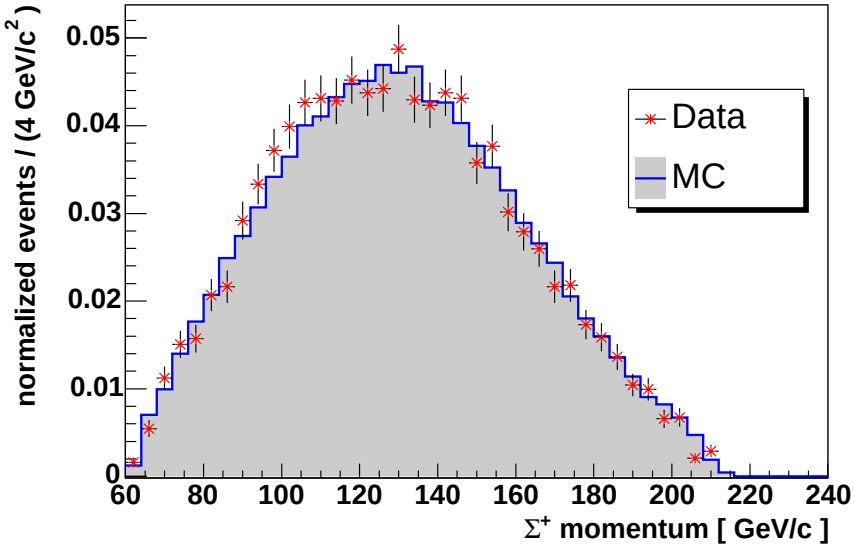
6238 signal events, 2.4% background

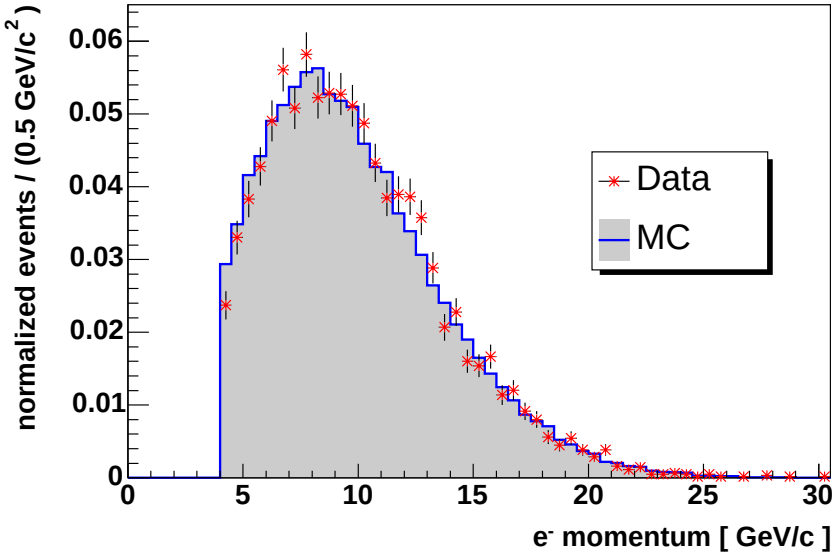


Experimental challenge

- Proton takes most of the hyperon momentum
  $\Rightarrow$ proton line-of-flight close to beam pipe
  $\Rightarrow$ low acceptance, sensitive to detector geometry
  $\Rightarrow$ accurate MC needed

- Triggered by complex algorithm to exclude unwanted K_S and Λ decays
  (use minimum bias trigger to measure trigger efficiency)





$BR(\Xi^0 \to \Sigma^+ e^- \nu)$

Preliminary result on 6238 events:

$$\mathrm{BR}(\Xi^0 \to \Sigma^+ e^- \nu) = (2.51 \pm 0.03_{stat} \pm 0.11_{syst}) \times 10^{-4}$$

Systematics:

Source	σ_{syst}/BR (%)
Trigger efficiency	± 2.6
Detector acceptance	± 3.0
Ξ^0 form factors g_1, f_2	± 1.0
Ξ^0 polarisation	± 1.0
Ξ^0 lifetime	± 0.5
Total systematics	± 4.2
Statistical uncertainty	± 1.2

For comparison:
BR$=(2.71 \pm 0.38) \times 10^{-4}$ KTeV published (176 events, 1999)

$|V_{us}|$ *from* Ξ^0 *beta decays*

Ξ^0 beta decay similar to neutron beta decay:
$\Xi^0(uss) \to \Sigma^+(uus)e^-\nu$ $\qquad$ $n(udd) \to p(uud)e^-\nu$

Decay rate :

$$\Gamma = G_F^2|V_{us}|^2 \frac{\Delta m^5}{60\pi^3}\left[(1-\tfrac{3}{2}\beta)(|f_1|^2+3|g_1|^2)\right]$$

$\Delta m = m_{\Xi^0} - m_{\Sigma^+}$, $\beta = \Delta m/m_{\Xi^0} = 0.095$
(slightly modified by radiative corrections and q^2 dependence)

- f_1 protected by Ademollo-Gatto theorem, $f_1 \approx 1$
- $g_1(\Xi^0) = g_1(neutron)$ if $SU(3)$ symmetry
  $\Rightarrow$ to be measured experimentally
- assume $g_2 = 0$ (non-existing second class currents)

$|V_{us}|$ *from* Ξ^0 *beta decays (cont.)*

Using Ξ^0 lifetime from PDG:
$\Gamma(\Xi^0 \to \Sigma^+ e^- \nu) = (8.66 \pm 0.38_{exp} \pm 0.27_{lifetime}) \times 10^5 s^{-1}$

Using $g_1/f_1 = 1.32^{+0.21}_{-0.17\,stat} \pm 0.05_{syst}$ (KTeV 2000, 494 events), and assuming $f_1 = 1$:

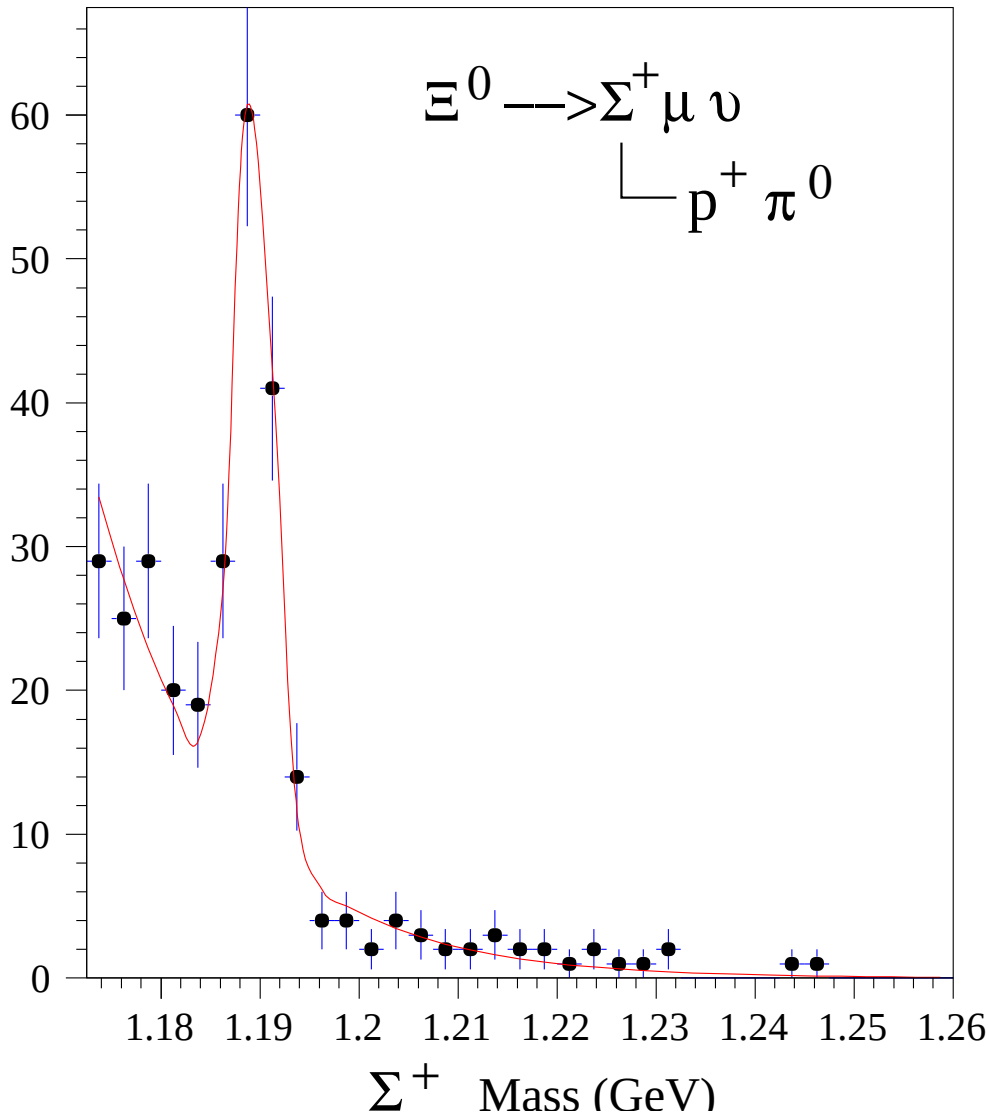
$$|V_{us}| = 0.214 \pm 0.006^{+0.030}_{-0.025\,g_1/f_1} \qquad \text{(preliminary)}$$

(neutron decay + SU(3): $g_1/f_1 = 1.267 \pm 0.0035$, not used here)

$\to$ Agreement with SM expectation of $|V_{us}| = 0.2274 \pm 0.0021$
$\to$ Uncertainty from form factor g_1 still too large -
precise measurement of g_1/f_1 from same data

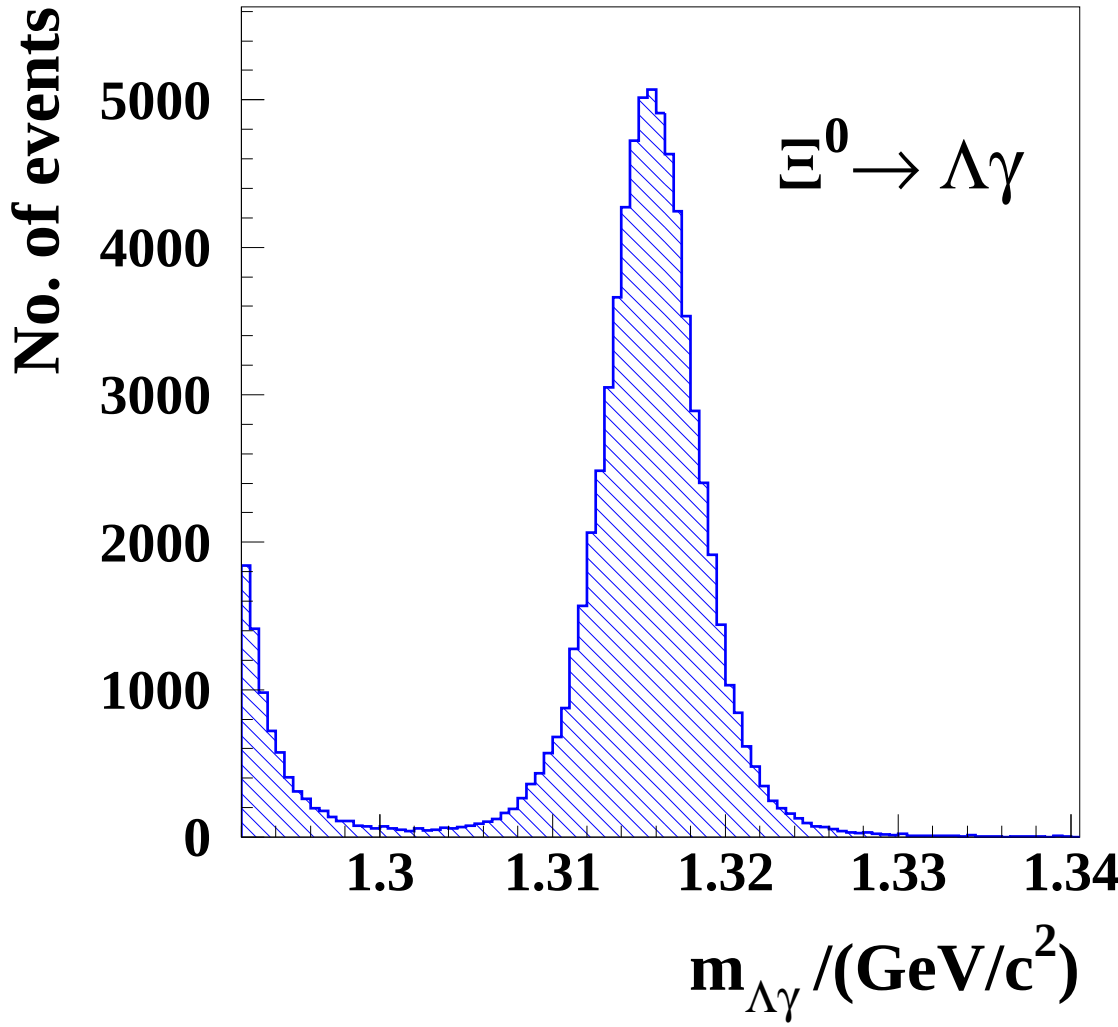
$\Xi^0 \to \Sigma^+ \mu^- \nu$

First clear evidence
for the channel $\Xi^0 \to \Sigma^+ \mu^- \nu$



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

$\approx$ 45000 events



Conclusions

- Published result on decay asymmetry:
  $\alpha(\Xi^0 \to \Lambda\gamma) = -0.78 \pm 0.18_{stat} \pm 0.06_{syst}$

- Preliminary results:

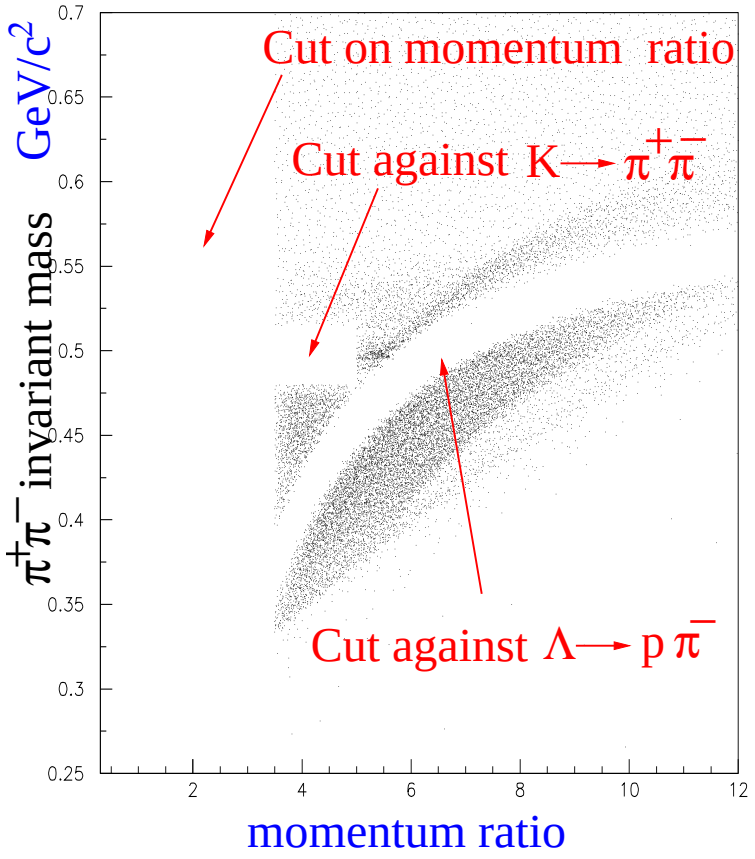
  $|V_{us}| = 0.214 \pm 0.006^{+0.030}_{-0.025\, g_1/f_1}$
  $\mathrm{BR}(\Xi^0 \to \Sigma^+ e^- \nu) = (2.51 \pm 0.03_{stat} \pm 0.11_{syst}) \times 10^{-4}$

- First clear signal for $\Xi^0 \to \Sigma^+ \mu^- \nu$

- More results to come soon:
  - Ξ^0 beta-decay form factors
  - Ξ^0 lifetime
  - improved results on $\Xi^0 \to \Lambda\gamma$ decay asymmetry
  - ....

Spares

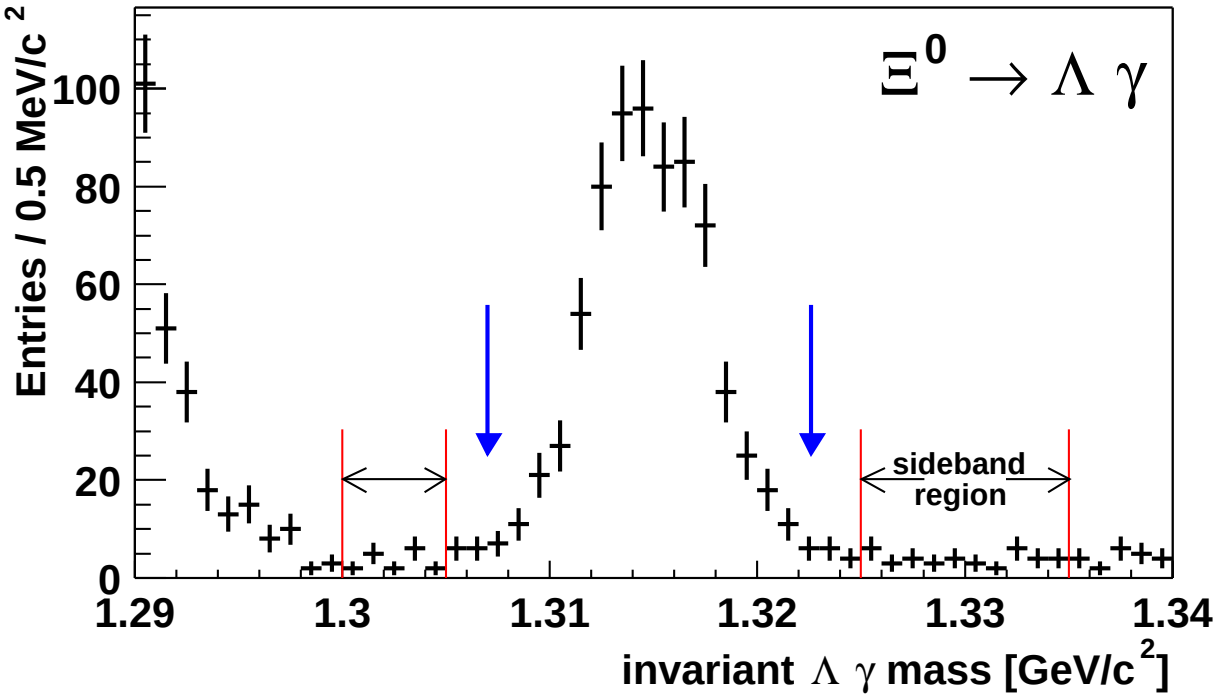
The hyperon trigger



Ξ^0 beta decays : cut on momentum ratio

Ξ^0 radiative decays : cut against low P_t events

$\Xi^0 \to \Lambda\gamma$ *branching ratio*



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

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