Hyperon physics in the experiment NA48/I at CERN

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On behalf of the NA48/I Collaboration

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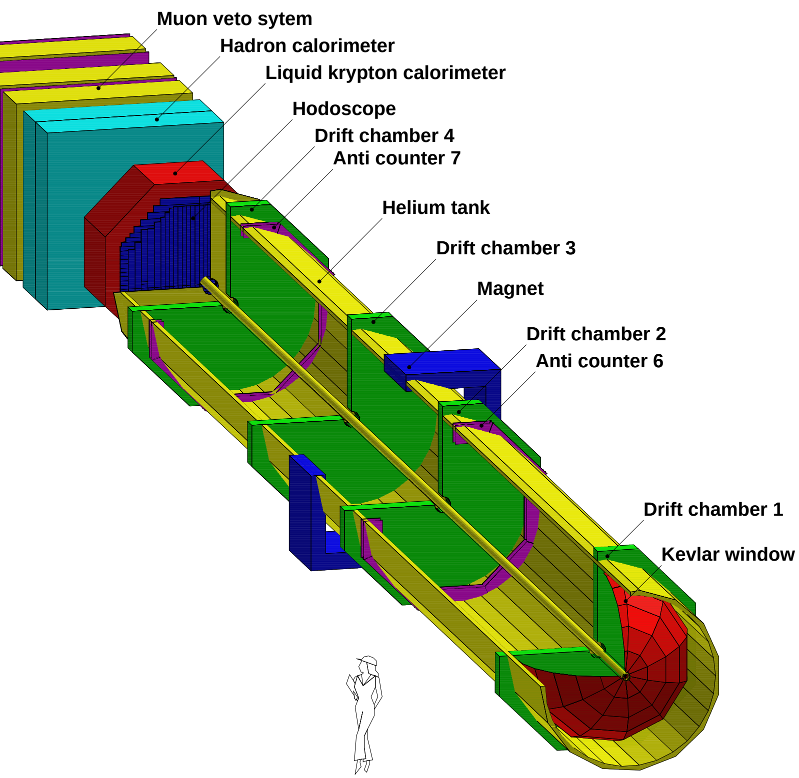
Outline

- The NA48 detector
- The Beam (2002 Configuration)
- Recent results from NA48 on Hyperon Physics:
  - Decay asymmetry on $\Xi^0 \to \Lambda\gamma$
  - BR of the decay $\Xi^0 \to \Lambda\gamma$
- Status and perspectives on the study of Ξ^0 beta decays
  - V_{us} extraction
  - Form factor studies
- Other on-going analyses for Hyperon studies in NA48/I

The NA48 detector



CHARGED DECAYS:

magn. spectrometer and scintillator hodoscope ($p_T^{kick} \simeq 265\ MeV/c$)

$$\frac{\sigma(p)}{p} \simeq 0.5\% \oplus 0.009\%\ p\ (GeV/c)$$

$$\sigma_{x,y}^{hit} \simeq 90\ \mu m$$

$$\sigma_{x,y}^{vtx} \simeq 2\ mm$$

$$\sigma_t \simeq 200\ ps$$

NEUTRAL DECAYS:

Quasi homogeneous Liquid Krypton electromagnetic calorimeter (LKr)

$$\frac{\sigma(E)}{E} = \frac{3.2\%}{\sqrt{E}} \oplus \frac{0.10}{E} \oplus 0.5\%\ (E\ in\ GeV)$$

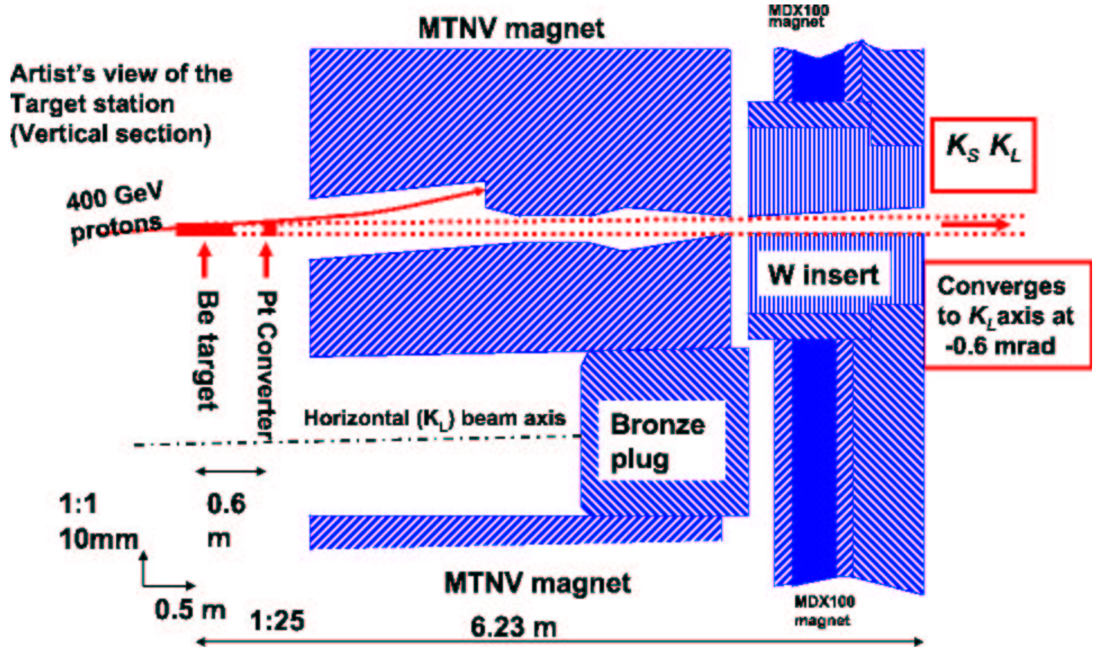
$$\sigma_{m_{\pi^0}} \simeq 1\ MeV/c^2$$

$$\sigma_{x,y} < 1.3\ mm$$

$$\sigma_t < 300\ ps\ above\ 20\ GeV$$

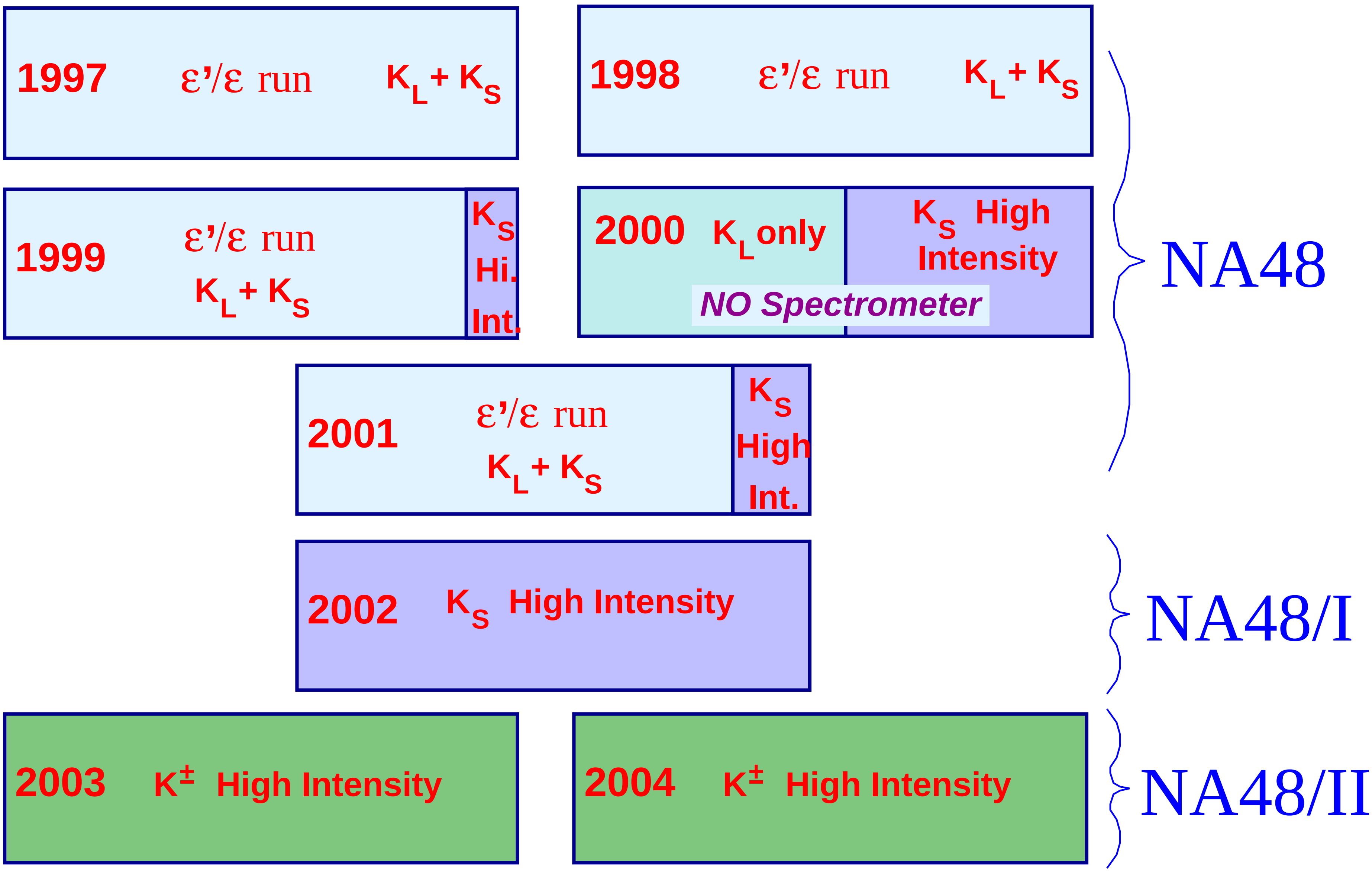
The NA48 beam

DETAIL OF THE K_S TARGET STATION (2002 conf.)



SPS proton momentum	400 GeV/c
Duty Cycle	4.8 s/16.8 s
Protons per pulse on target	$5 \cdot 10^{10}$
Production angle	-4.2 $mrad$

Data taking periods



Data taking periods

1997 ε'/ε run $K_L + K_S$

1998 ε'/ε run $K_L + K_S$

1999 ε'/ε run $K_L + K_S$ | K_S Hi. Int.

2000 K_L only | K_S High Intensity

NO Spectrometer

2001 ε'/ε run $K_L + K_S$ | K_S High Int.

→ NA48

2002 K_S High Intensity

→ NA48/I

2003 $K^{\pm}$ High Intensity

2004 $K^{\pm}$ High Intensity

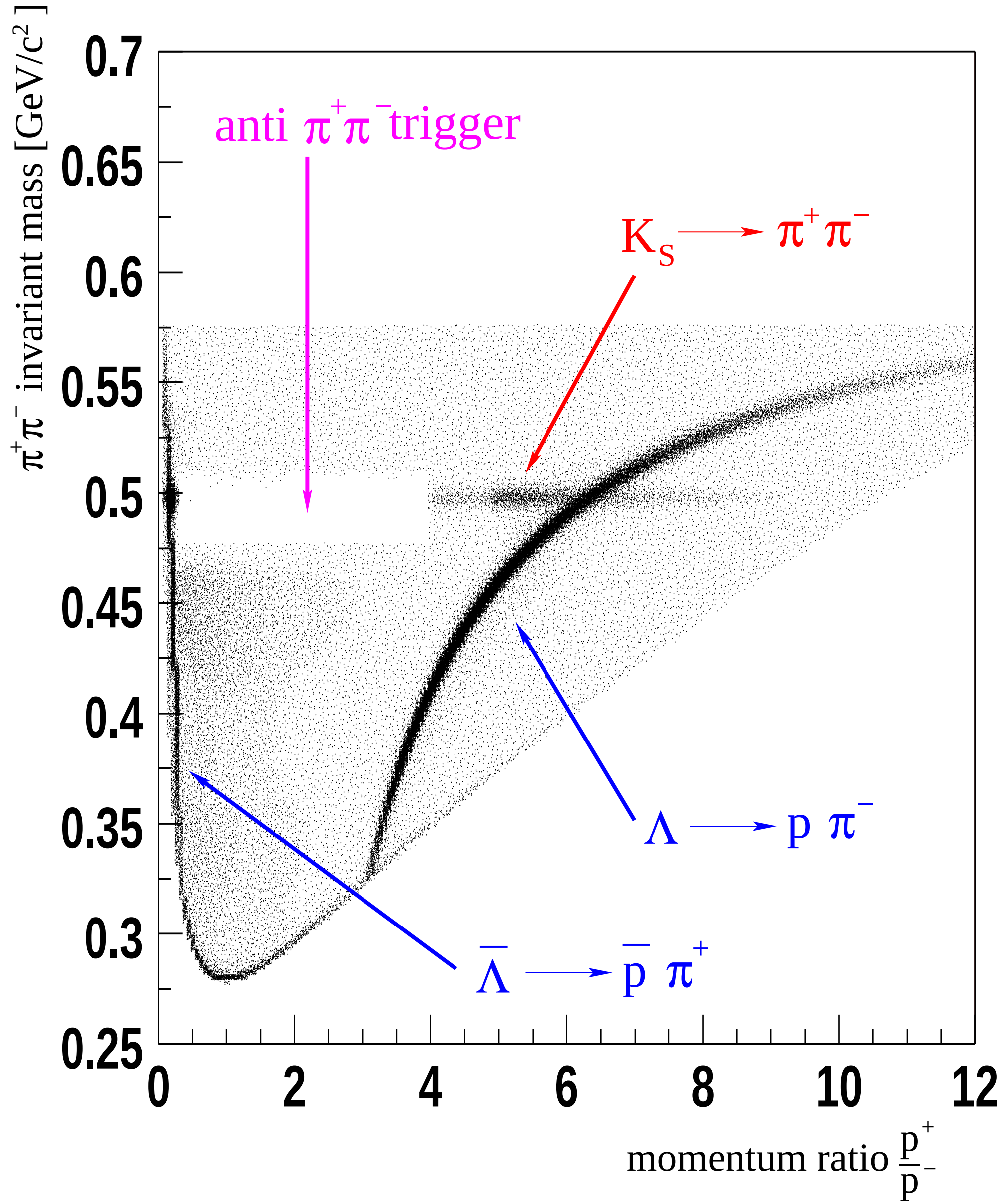
→ NA48/II

The hyperon trigger in 1999

- The K_S target is also a source of hyperons
- The main difficulty for the acquisition of events from hyperon decays was the rejection of K_S decay into two charged pions

HYPERON TRIGGER

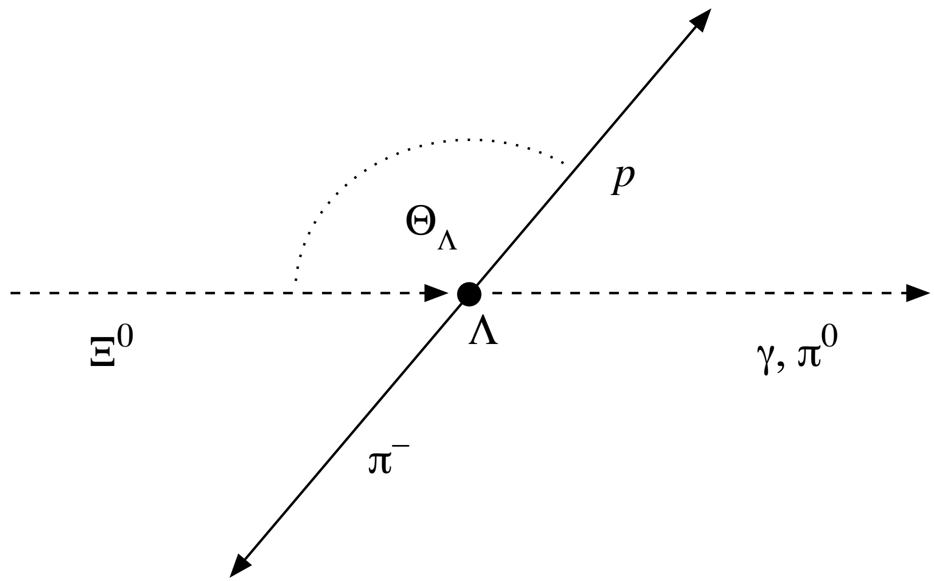
Cut against $K_S \to \pi^+\pi^-$ using mass and momentum ratio (downscaling=5)



Asymmetry on $\Xi^0 \to \Lambda\gamma$ from 1999 data

In 1999 High Intensity K_S run (48 h of data taking) 730 $\Xi^0 \to \Lambda\gamma$ events were recorded with a background of 58.2 ± 7.8 events.

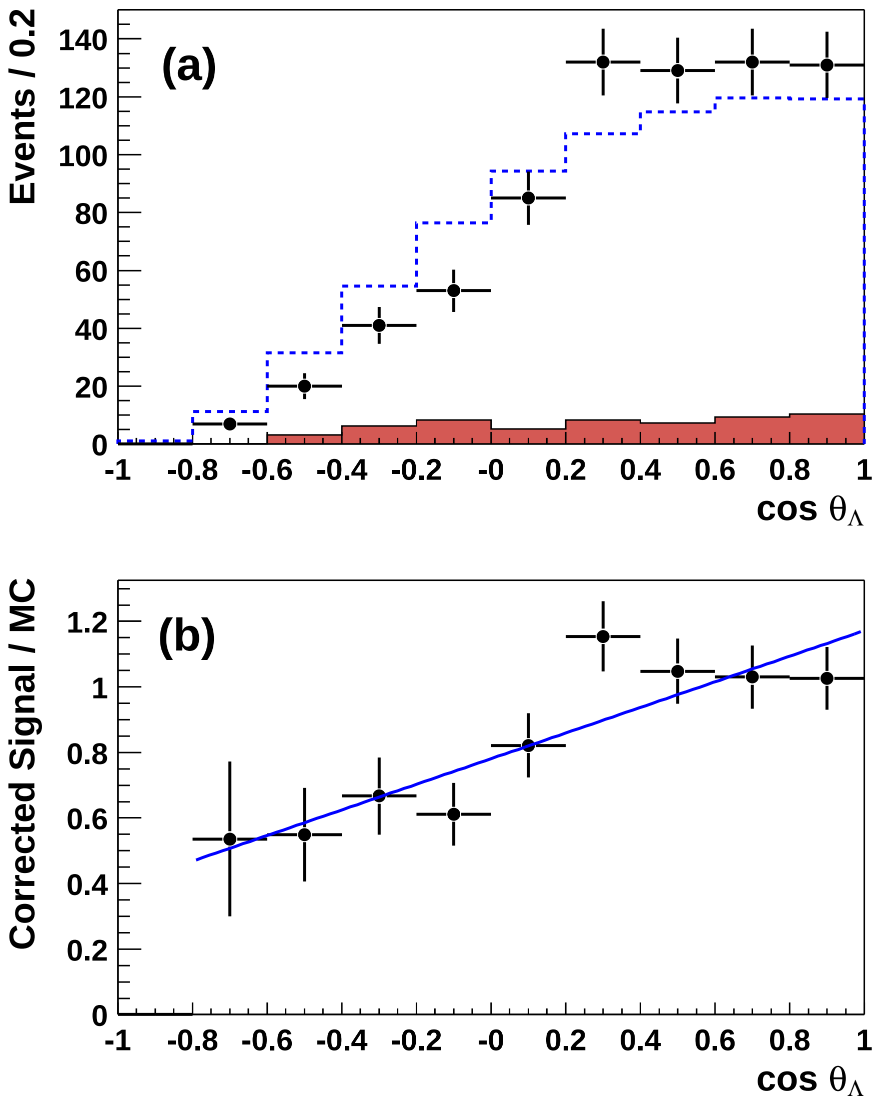
The asymmetry was measured using the angle Θ_Λ between the Ξ_0 and the out-going proton (coming from the decay $\Lambda \to p\pi^-$) in the Λ rest frame



The MC and the measurement technique were first tested measuring the decay asymmetry in the non-leptonic decay $\Xi^0 \to \Lambda\pi^0$

Asymmetry on $\Xi^0 \to \Lambda\gamma$ (cont.)

We compare the data with an isotropic MC distribution.



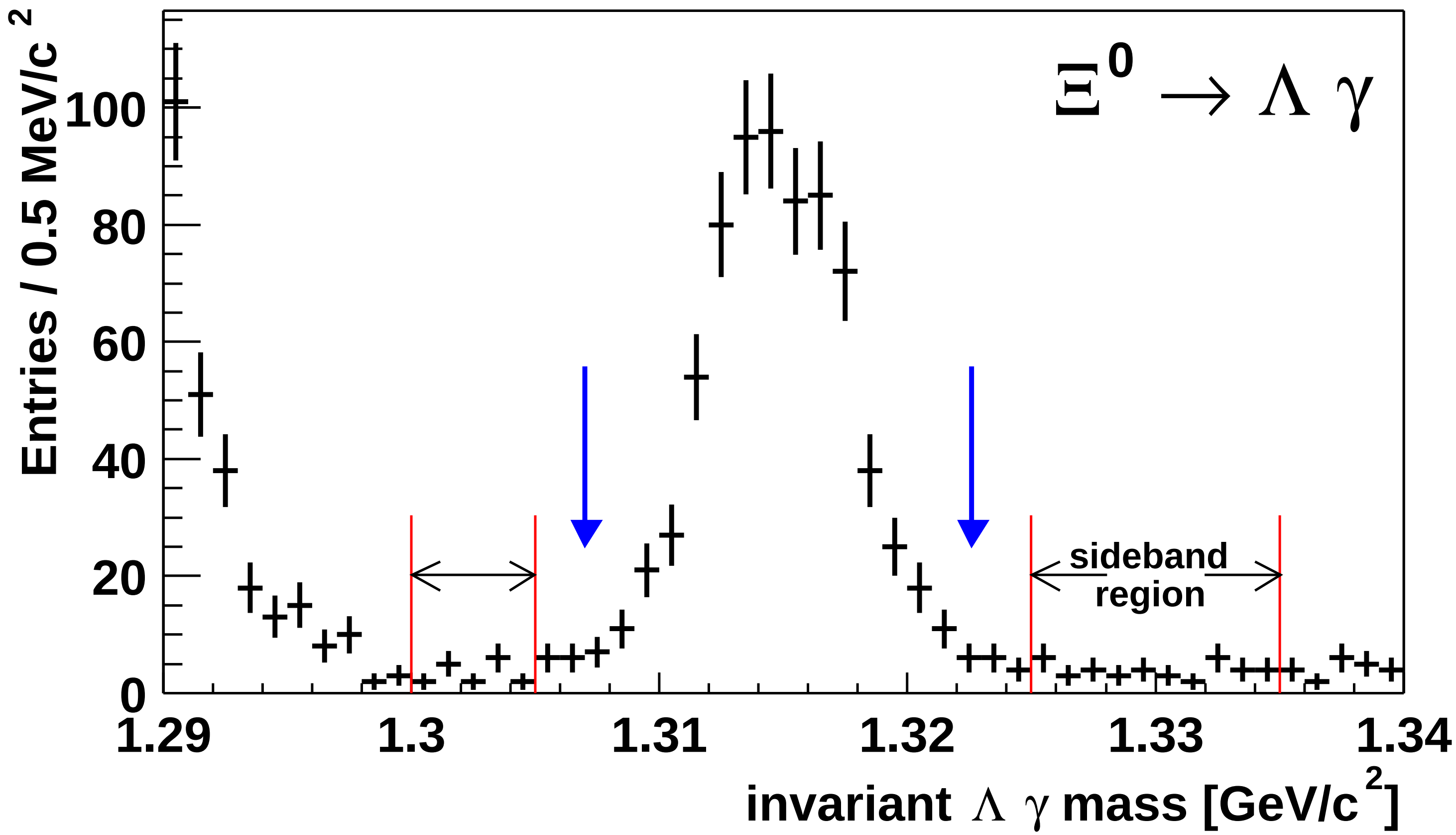
$\alpha(\Xi^0 \to \Lambda\gamma) =$
$-0.78 \pm 0.18_{stat} \pm 0.06_{syst}$

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

First clear evidence for negative asymmetry on this Ξ^0 radiative decay

The main systematic uncertainty comes from background subtraction

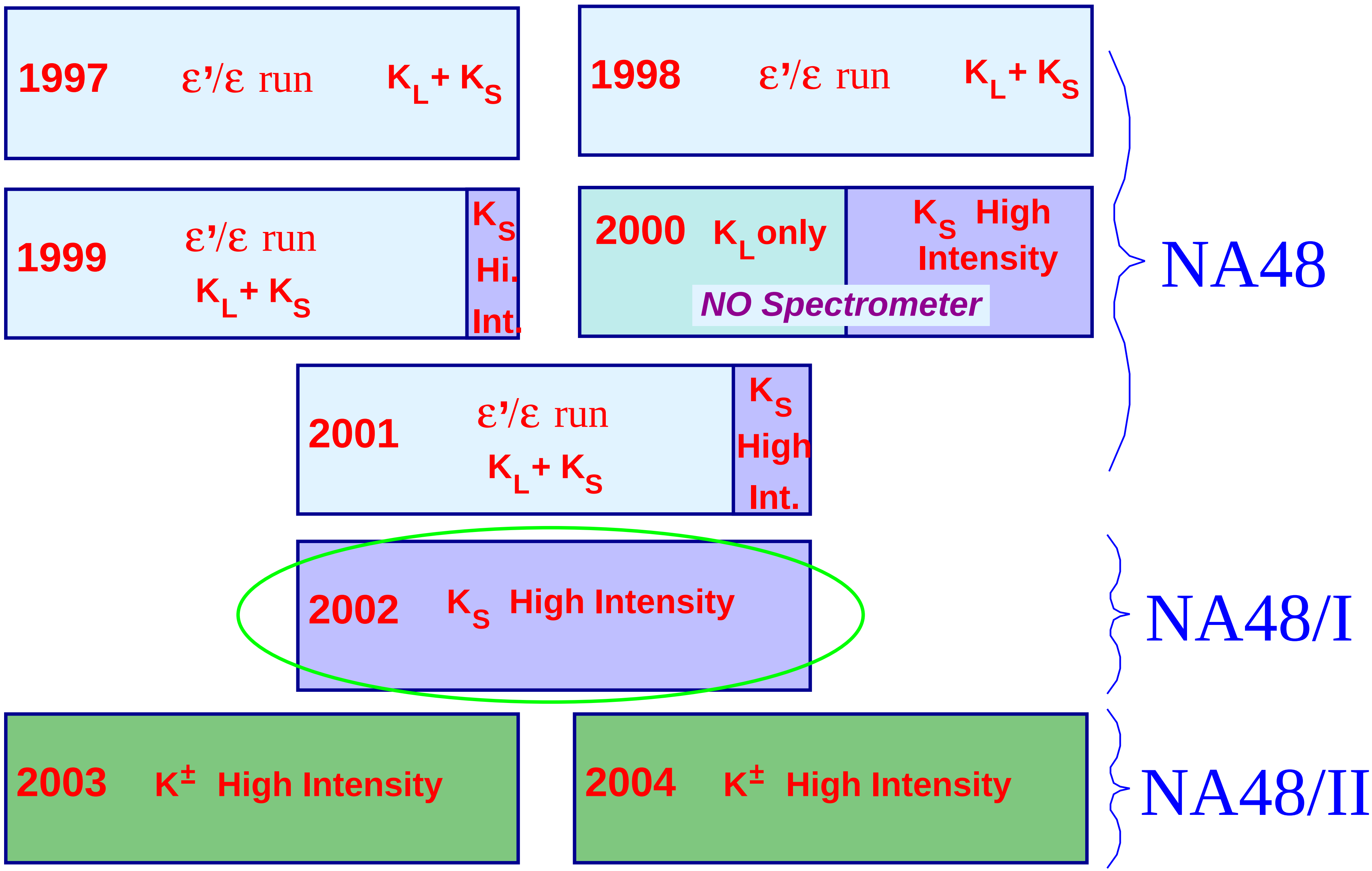
Branching Ratio for $\Xi^0 \to \Lambda\gamma$



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

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

Data taking periods



The Ξ^0 β-decay:

- ⋆ In 2002 NA48 has collected the largest world sample of events in this channel
- ⋆ The $\Xi^0 \to \Sigma^+ e^- \overline{\nu_e}$ doesn't suffer for the background from the corresponding 2 body decay ($\Xi^0 \to \Sigma^+ \pi^-$)

Good perspectives for:

- ⋆ Form factors measurement
  $\Rightarrow$ study of SU(3) breaking
- ⋆ BR measurement
  $\Rightarrow$ V_{us} extraction (test of V_{CKM} unitarity)

More information from:

- ⋆ $\Xi^0 \to \Sigma^+ \mu^- \overline{\nu}_\mu$
- ⋆ $\overline{\Xi}^0$ β-decay ($\overline{\Xi}^0$ are unpolarized)

V_{us}

The sine of Cabibbo's angle V_{us} can be extracted from the BR measurement

Open item: The unitarity of CKM matrix

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 \simeq |V_{ud}|^2 + |V_{us}|^2 = 1$$

in fact $|V_{ub}|^2 \sim 10^{-5}$

Measured V_{us} values (PDG 2002):

$$(V_{us})_{ke3} = 0.2196 \pm 0.0023 \ \Rightarrow \ V_{ud}^{U} = 0.9756 \pm 0.0005$$

$$(V_{us})_{Hyp} = 0.2250 \pm 0.0027 \ \Rightarrow \ V_{ud}^{U} = 0.9744 \pm 0.0007$$

Measured V_{ud} values (PDG 2002):

$$(V_{ud})_{n \rightarrow p e^- \overline{\nu}} = 0.9728 \pm 0.0012$$

$$(V_{ud})_{nuclei} = 0.9740 \pm 0.0005$$

New results on V_{us} from E865, KLOE and KTEV

Form factors

Within of SU(3) validity the form factors for Ξ^0 β-decay are equal to the form factors for neutron β-decay.
Some theories explaining SU(3) breaking, give significant differences for the axial-vector form factor g1.
Current status:

$$\left(\frac{g_1}{f_1}\right)_{n\rightarrow pe^-\overline{\nu}} = 1.267 \pm 0.0035$$

$$\left(\frac{g_1}{f_1}\right)_{\Xi^0\rightarrow\Sigma^+e^-\overline{\nu}} = 1.32 \pm^{0.21}_{0.17} \pm 0.05 \qquad (KTEV)$$

No evidence for SU(3) breaking

Hyperon semileptonic trigger on 2002

In 1999 run the trigger rate was dominated by the $\Lambda \to p\,\pi^-$

In order to recover the downscaling factor 5 with respect to 1999 run, in 2002 we split the hyperon trigger into 2 new triggers:

Hyperon semiletonic trigger:

Cut against $K \to \pi^+\pi^-$

Cut against $\Lambda \to p\pi^-$

Cut on the momentum ratio

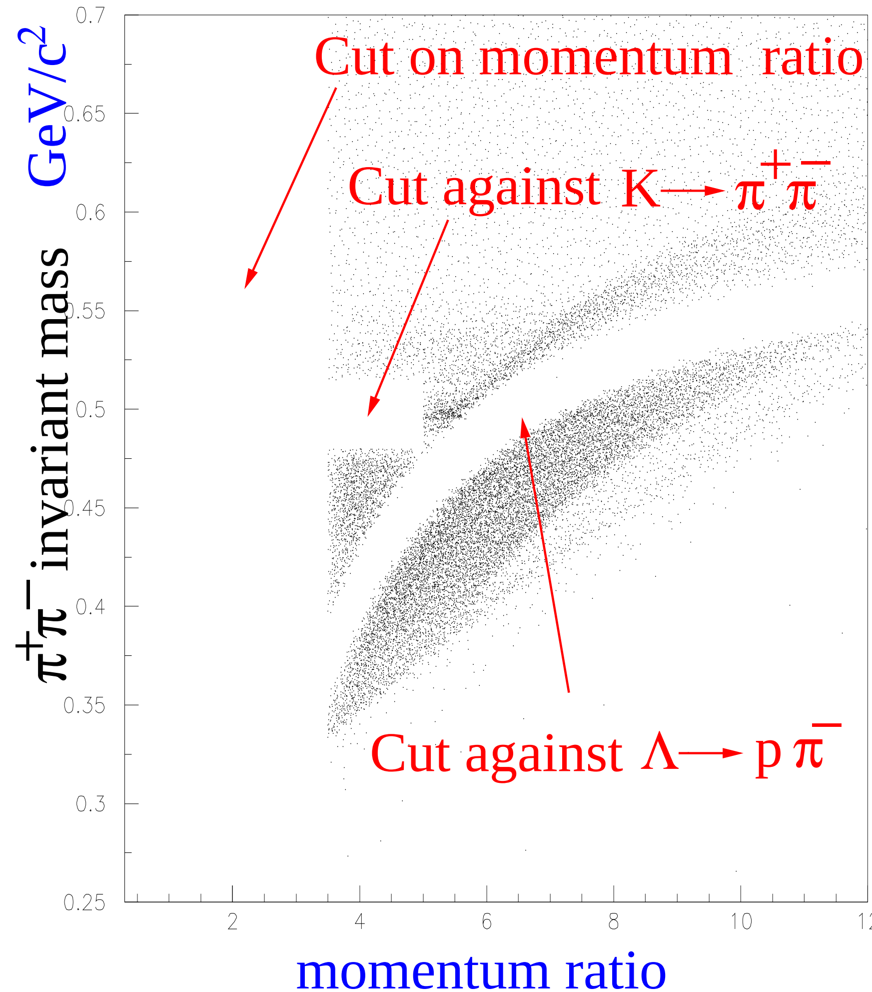
Hyperon radiative trigger:

Cut against $K \to \pi^+\pi^-$

$\Lambda \to p\,\pi^-$ asked

Cut against low p_t events

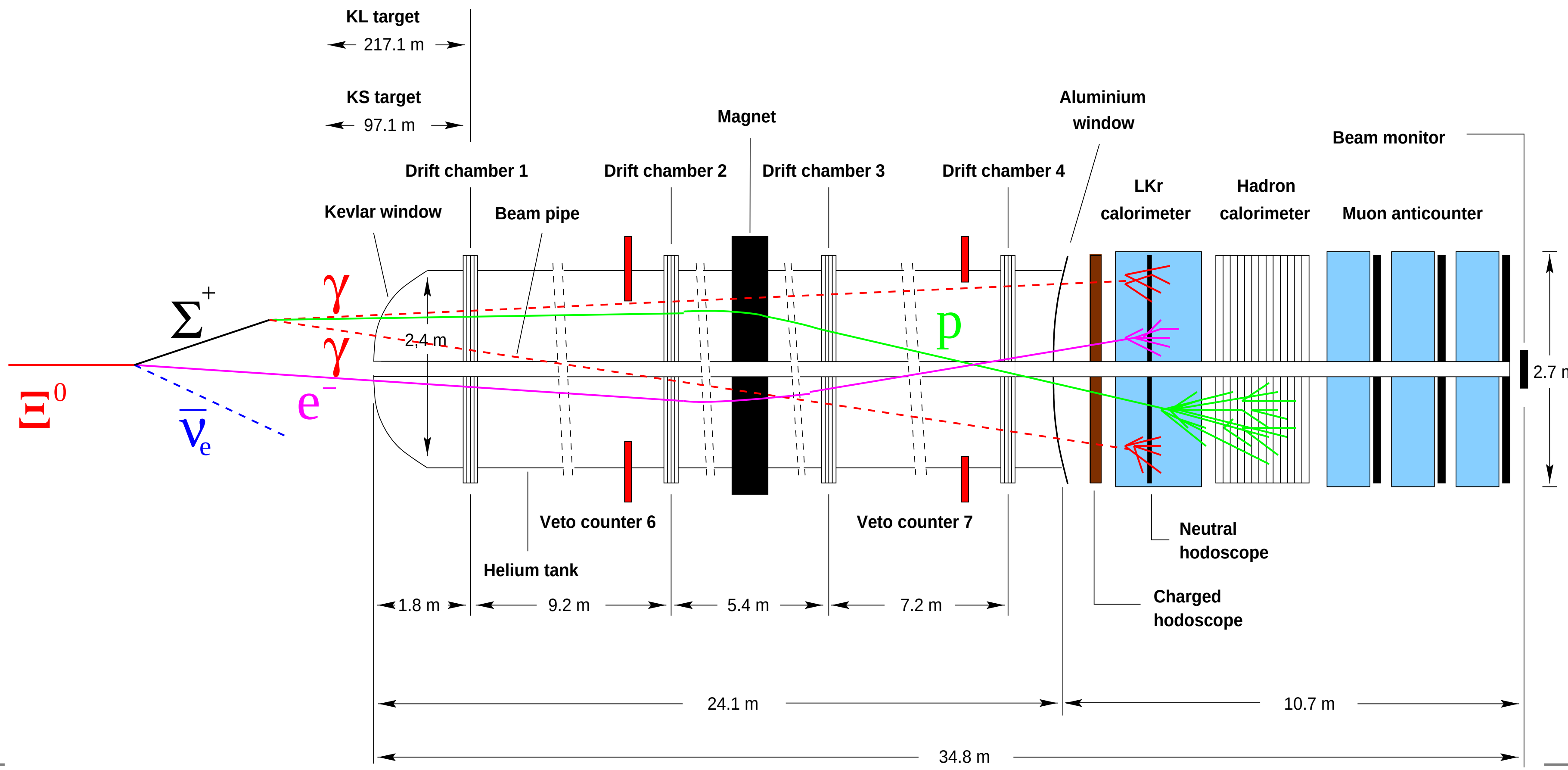
(considering only charged particles)



Detection

$$\Xi^0 \rightarrow \Sigma^+ e^- \overline{\nu_e}, \qquad \Sigma^+ \rightarrow p\pi^0, \qquad \pi^0 \rightarrow \gamma\gamma$$

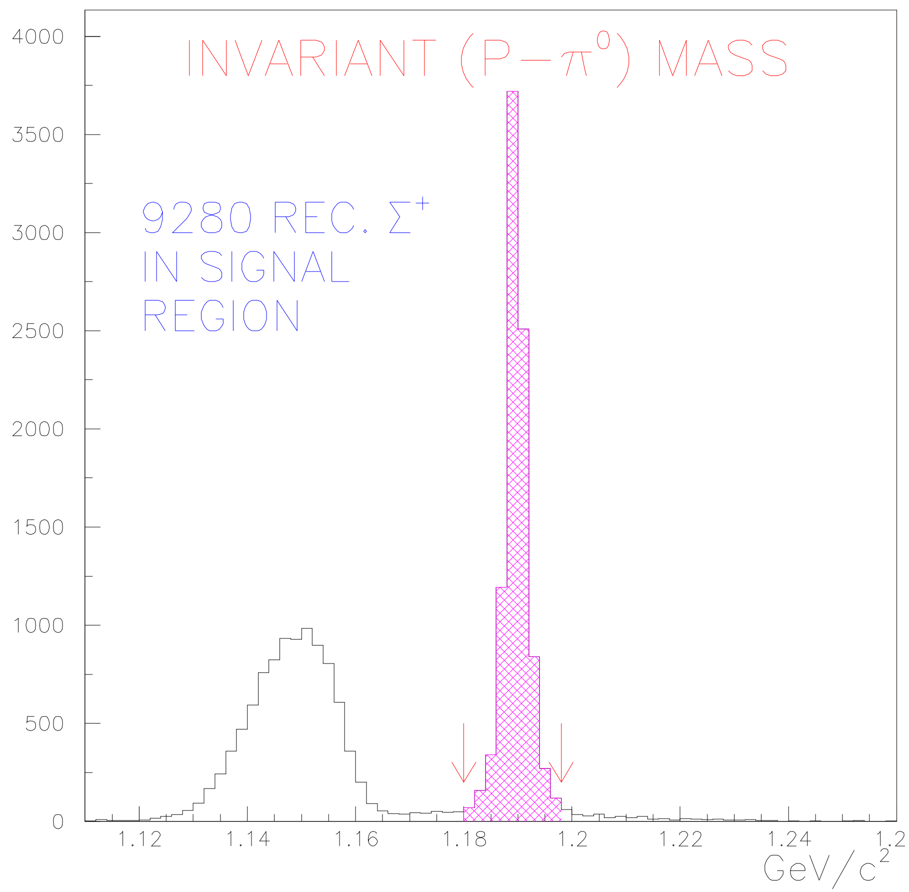
$\Rightarrow$ 2 tracks and 2 photons to be detected



2002 DATA

Data collected during 89 days in 2002

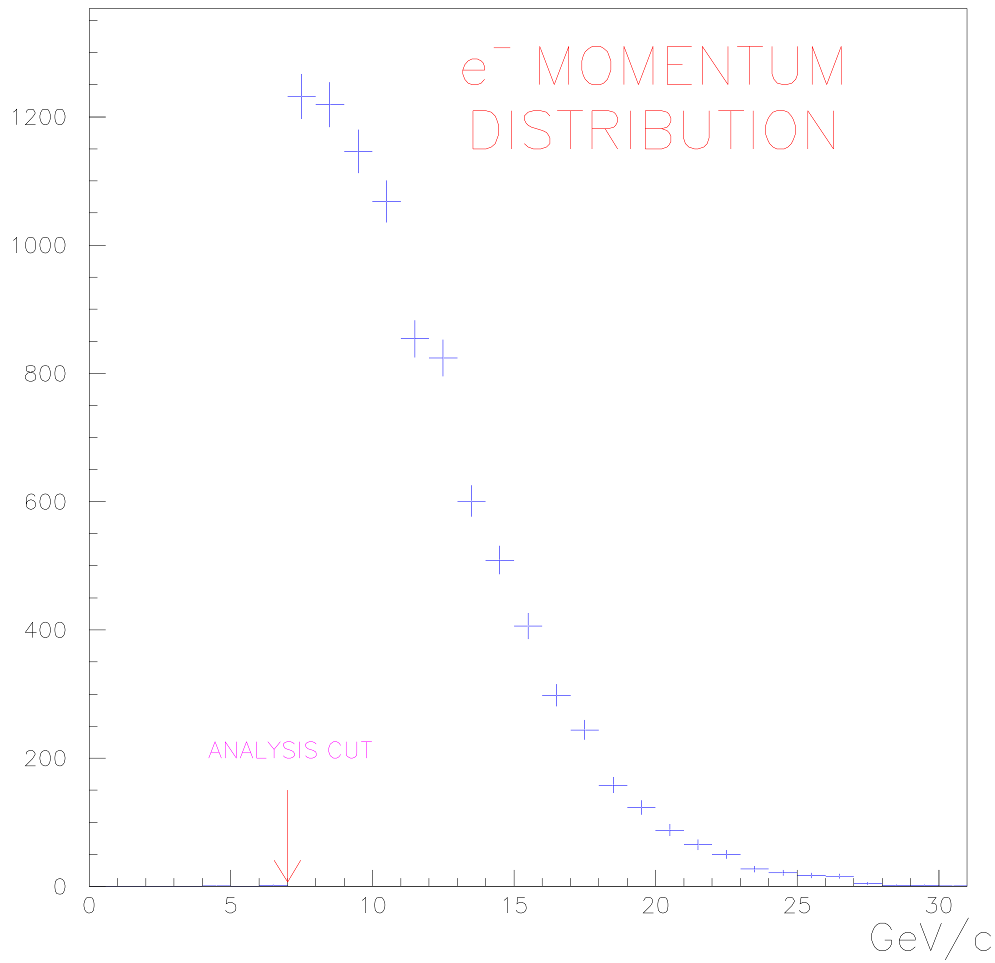
~ 9000 events in the signal region (background $\sim 3\%$)



Signal region: $|M_{\Sigma^+}^{rec} - M_{\Sigma^+}^{pdg}| \leq 10\ MeV$

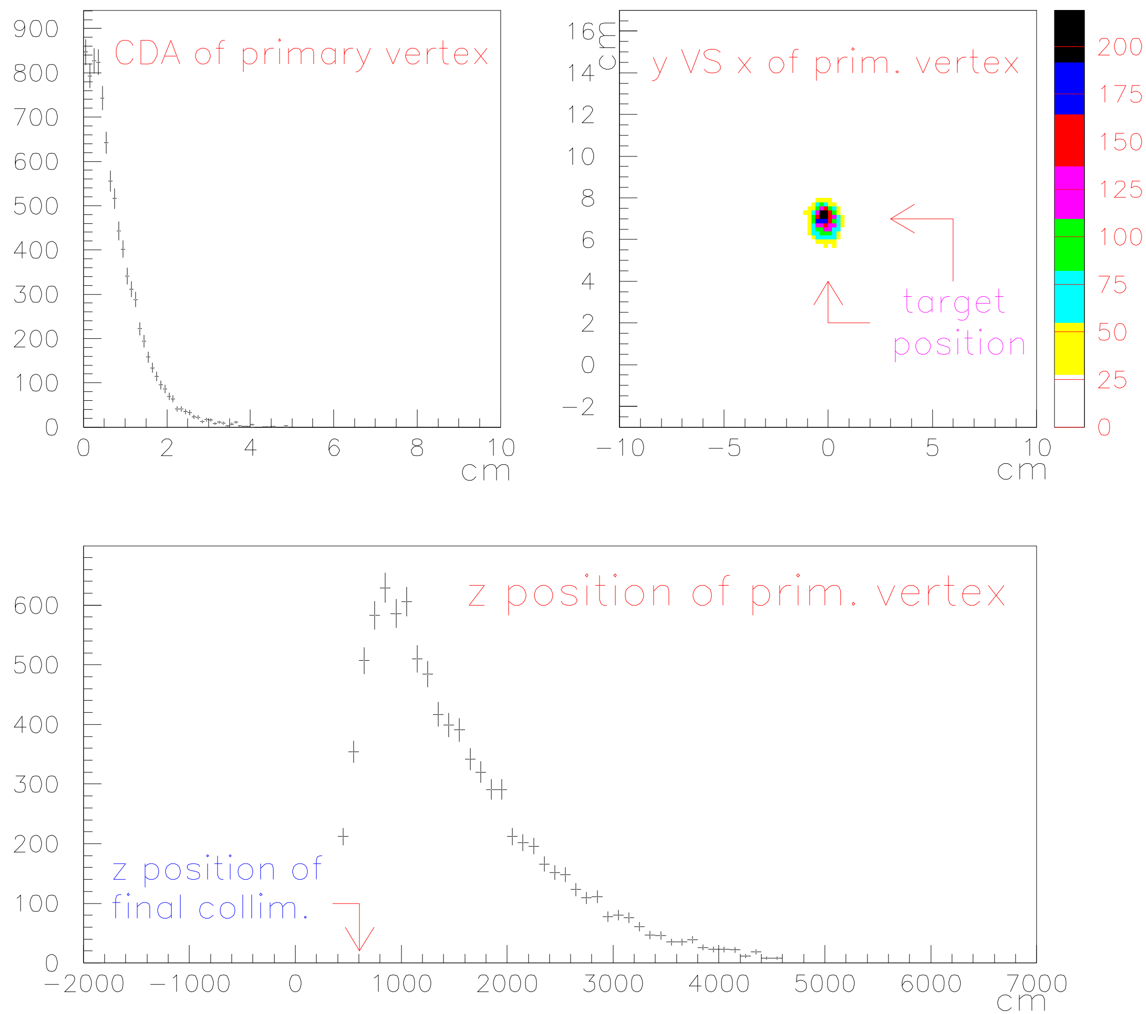
Electron spectrum

In addition presence of electron is required



Ξ^0 vertex

Then Ξ^0 vertex is reconstructed



Remark on the sample statistics

The trigger efficiency is the critical point of the analysis

$\Rightarrow$ The main source of systematic uncertainty

(Principal contribution comes from the cut against Λ)

In fact we decide to measure the effect of trigger efficiency on data, using a downscaled minimum bias trigger (control trigger).

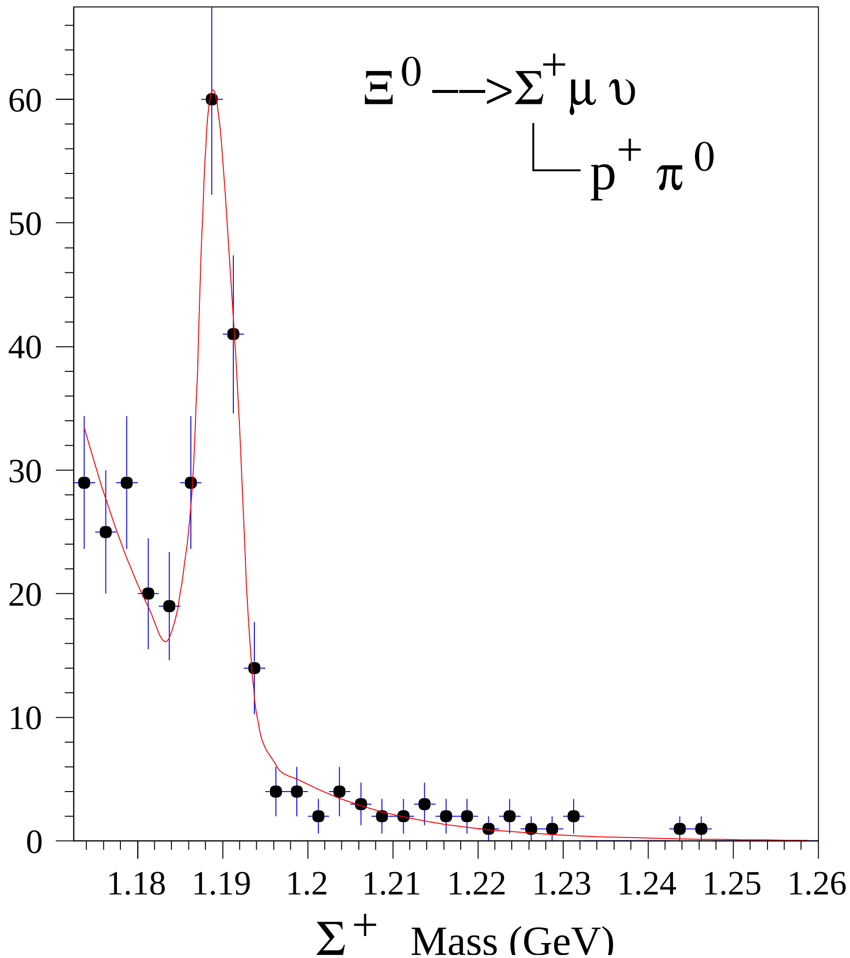
But we are limited by the statistics on this control sample

Final cuts are chosen in order to minimize the overall uncertainty

$\Rightarrow$ The statistics shown might be different from the final one

$$\Xi^0 \to \Sigma^+ \mu^- \overline{\nu_\mu}$$

In 2002 run we also collect $\sim$ 100 events for Ξ^0 muonic decay



Clear evidence for this decay

Other studies on Ξ^0 physics

On 2002 many other analyses are in progress

- Ξ^0 lifetime
- $\Xi^0 \rightarrow \Lambda\gamma$ (enlarged stat.)
- $\Xi^0 \rightarrow \Sigma^0\gamma$, $\Sigma^0 \rightarrow \Lambda\gamma$
- $\Xi^0 \rightarrow \Lambda e^+ e^-$
- Limit on $\Xi^0 \rightarrow p\pi^-$ (ΔS=2)

Already published results on hyperon physics from NA48:

- Measurement of the $\Xi^0 \rightarrow \Lambda\gamma$ decay asymmetry and branching fraction. (Phys.Lett.B584:251-259,2004)
- Precision measurement of the Ξ^0 mass and the branching ratios of the decays $\Xi^0 \rightarrow \Lambda\gamma$ and $\Xi^0 \rightarrow \Sigma^0\gamma$ (Eur.Phys.J.C12:69-76,2000)

Conclusions

- The NA48 collaboration has recently published new results on Ξ^0 physics:
  - Measurement of the decay asymmetry in $\Xi^0 \to \Lambda\gamma$
    $\Rightarrow$ First clear evidence for a negative value of the asymmetry
  - Measurement of the Branching ratio for $\Xi^0 \to \Lambda\gamma$
- The studies on the Ξ^0 semileptonic decays are well advanced, soon new results on:
  - Branching ratio measurement and V_{us} extraction
  - Form factors
- The NA48 collaboration is also active on the study of other Ξ^0's decay channel

Stay tuned

Effect of cut against Λ on signal sample