Hyperon physics in NA48

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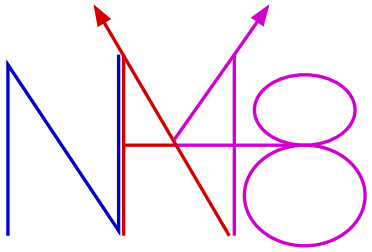
Aachen - Germany, 17-23 July 2003

HEP2003 Aachen - Germany



On behalf of the NA48/I Collaboration

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

Outline:

- The Ξ^0 beta decay
- An interesting decay to study:
  - CKM unitarity
  - Form factors and SU(3) breaking
- The opportunity to collect that decay: NA48/I
  - NA48 story
  - NA48 apparatus
  - NA48 results on hyperon physics
  - Progress report on 2002 run
- conclusions

The Ξ^0 beta decay:

- Until few years ago there was a lack of data for this decay (First evidence from KTEV in 1999)
- The $\Xi^0 \to \Sigma^+ e^- \overline{\nu_e}$ doesn't suffer of the background from the corresponding 2 body decay ($\Xi^0 \to \Sigma^+ \pi^-$)

$\Rightarrow$ A new and good chance for:

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

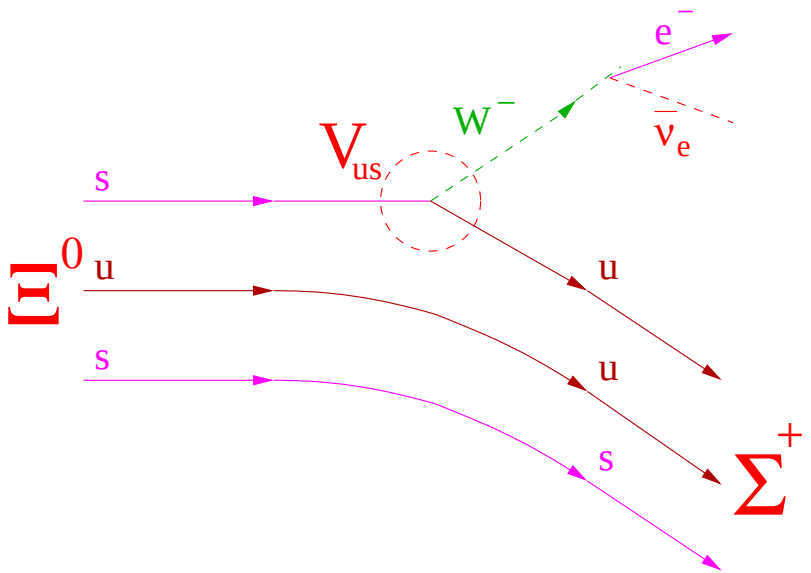
In 2002 NA48 has collected the largest world sample of events in this channel

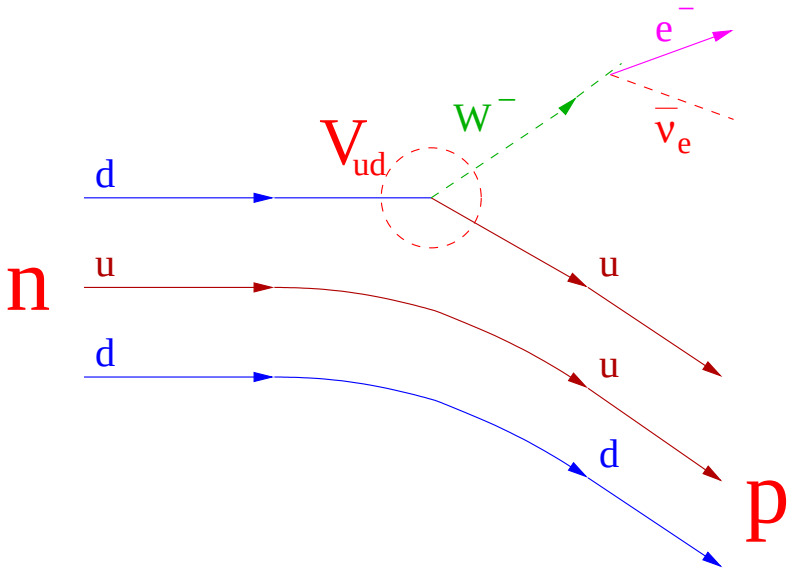
More informations from:

- $\Xi^0 \to \Sigma^+ \mu^- \overline{\nu}_\mu$
- $\overline{\Xi}^0$ beta decay (The $\overline{\Xi}^0$ should be unpolarized)

decay mechanisms

$$\Xi^0 \longrightarrow \Sigma^+ e^- \overline{\nu_e}$$





$$n \longrightarrow p e^- \overline{\nu_e}$$

V_{us}

The sine of the Cabibbo angle V_{us} can be extracted from the following relation:

$$Rate = \frac{BR}{\tau} \propto G_\mu^2 |V_{us}|^2 |f_1|^2 \left[1 + 3\left(\frac{g_1}{f_1}\right)^2\right]$$

Open issue: 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:

$$(V_{us})_{Ke3} = 0.2196 \pm 0.0023 \Rightarrow V_{ud}^U = 0.9756 \pm 0.0005$$
$$(V_{us})_{Hyp} = 0.2250 \pm 0.0027 \Rightarrow V_{ud}^U = 0.9744 \pm 0.0007$$

Measured V_{ud} values:

$$(V_{ud})_{n \to pe\overline{\nu}} = 0.9728 \pm 0.0012$$
$$(V_{ud})_{nuclei} = 0.9740 \pm 0.0005$$

New measurement on Ke3 from E865 apparently removes the discrepancy, hep-ex/0305042

Form factor

Within the SU(3) framework, the form factors for Ξ^0 beta decay are equal to the form factor for neutron beta decay.

Some theories explaining SU(3) breaking, give significant differences for the axial-vector form factor g_1.

Current status:

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

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

No evidence for SU(3) breaking

NA48 can also measure g_2 (second class current)

Useful variables for form factors exctraction

Due to the lack of neutrino energy we can't recostruct the Ξ^0 energy and we can't work in Ξ^0 RF.

Two RF are useful for the form factors studies:

- The Σ^+ Rest Frame
- The Q Rest Frame

Q RF is obtained boosting the measured quantities with the momentum:

$\vec{p}_Q = \vec{p}_{\Sigma^+} + \vec{p}_e$
(overall measured momentum of the event)

Interesting quantities:

1) Electron energy in Σ^+ RF
2) Angle between electron and proton in Σ^+ RF

If we define the $\vec{p}^{\,\nu}_{\perp LAB}$ as: $\vec{p}^{\,\nu}_{\perp LAB} = -\vec{p}^{\,e}_{\perp LAB} - \vec{p}^{\,\Sigma^+}_{\perp LAB}$
We have two extra-quantities:

3) Angle between $p^{\nu}_{\perp Q}$ and electron in Q RF
4) Angle between $p^{\nu}_{\perp Q}$ and proton in Q RF

The way to do it: NA48

- NA48, the past:

  Main goal: measurement of direct CP violation

  $$Re(\epsilon'/\epsilon) = (14.7 \pm 2.2) \cdot 10^{-4}$$

  (1997+1998+1999+2001 data)

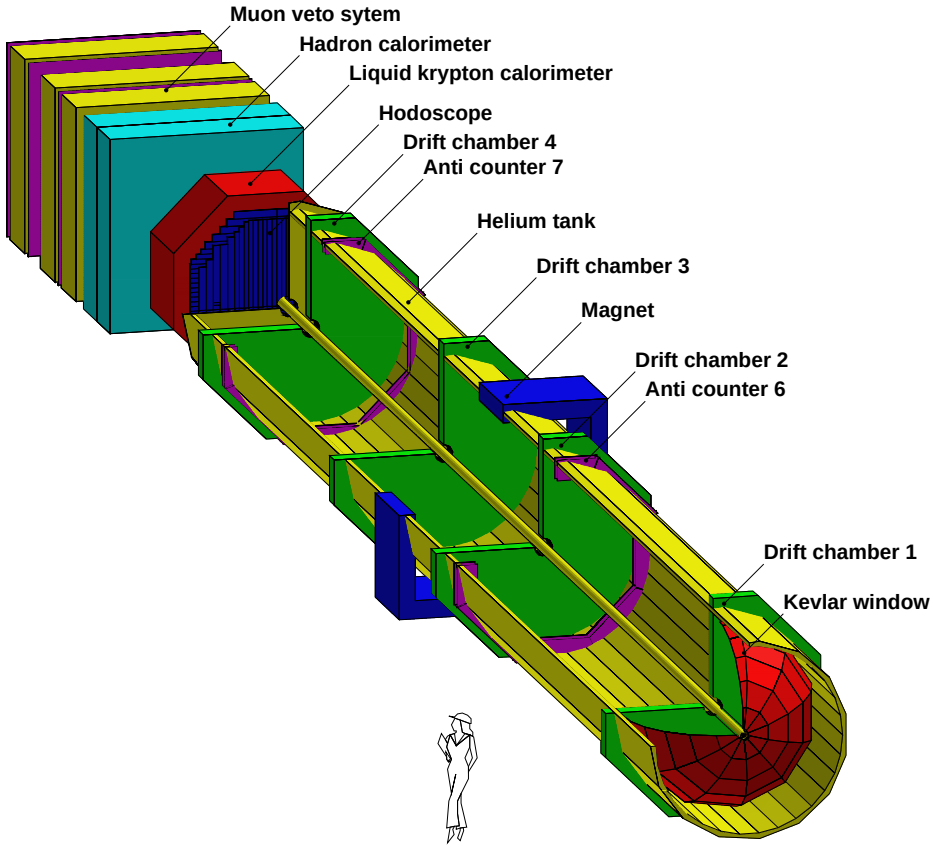
  Other results on $\mathrm{K_S}$, $\mathrm{K_L}$ and neutral hyperon rare decays

  NA48/I: a high sensitivity investigation of $\mathrm{K_S}$ and neutral hyperon decays using a modified $\mathrm{K_S}$ beam (2000+2002)

- NA48, the present:

  NA48/II: a precision measurement of charged kaon decay parameters with an extended NA48 setup (2003)

The NA48 detector



✦ CHARGED DECAYS:

magnetic 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:

High granularity, quasi homogeneous Liquid KRypton electromagnetic calorimeter (LKR)

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

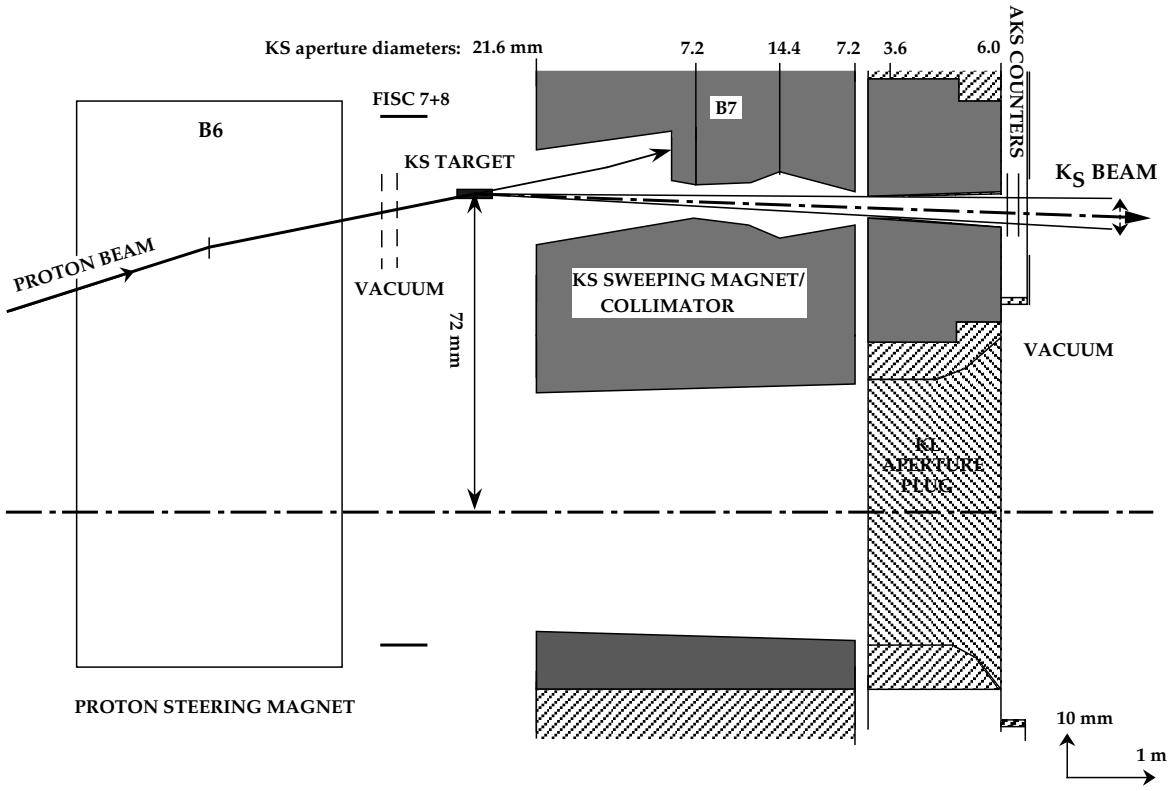
$$\sigma_{m_{\pi^0}} \simeq 1\ MeV/c^2$$

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

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

The NA48 beam characteristics

DETAIL OF THE K_S TARGET STATION (2002 conf.)

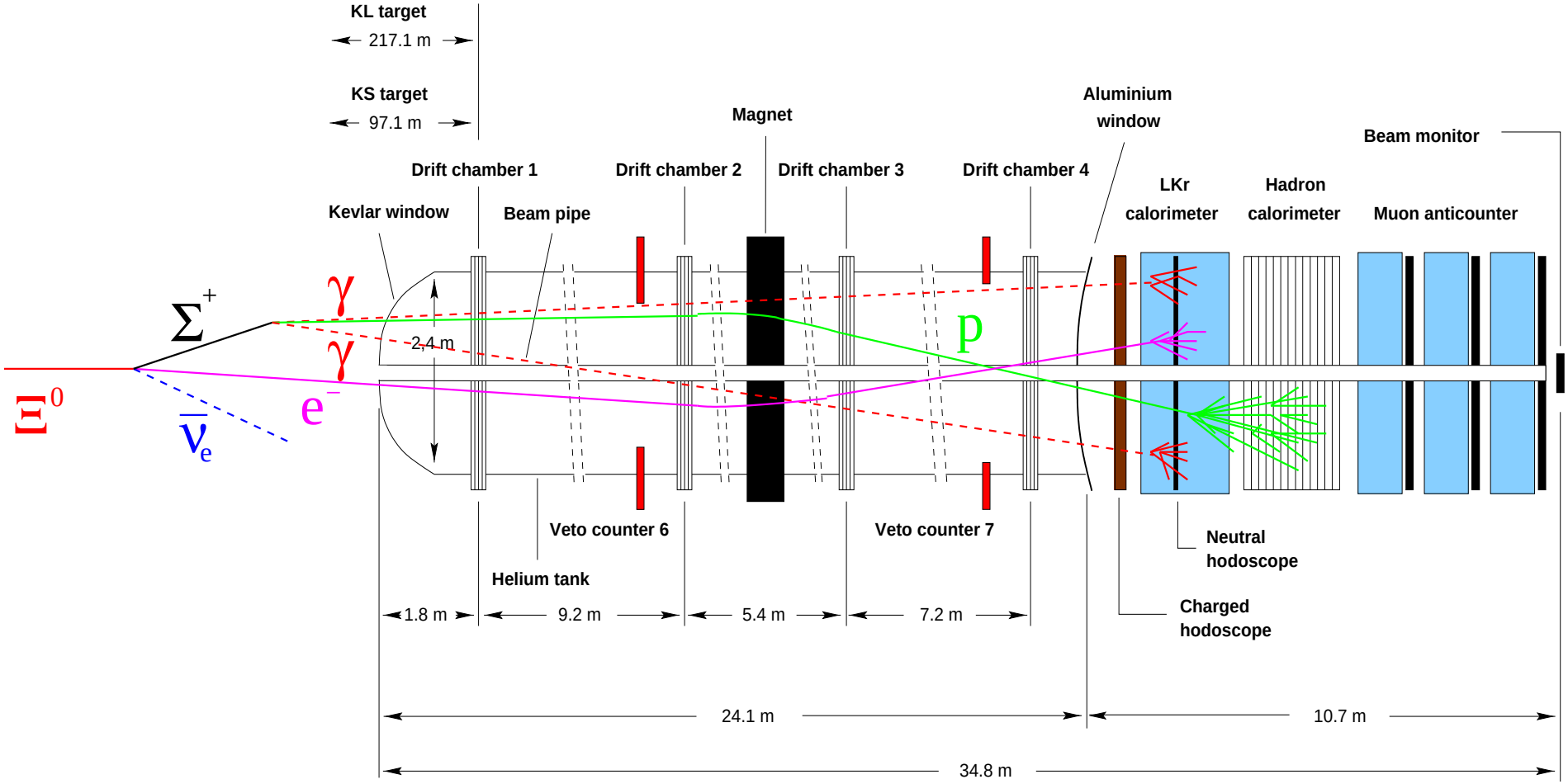


SPS proton momentum	400 GeV/c
Duty Cycle	4.8 s/16.8 s
Protons per pulse on target	5×10^{10}
Production angle	4.2 $mrad$

Detection

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

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



The hyperon trigger

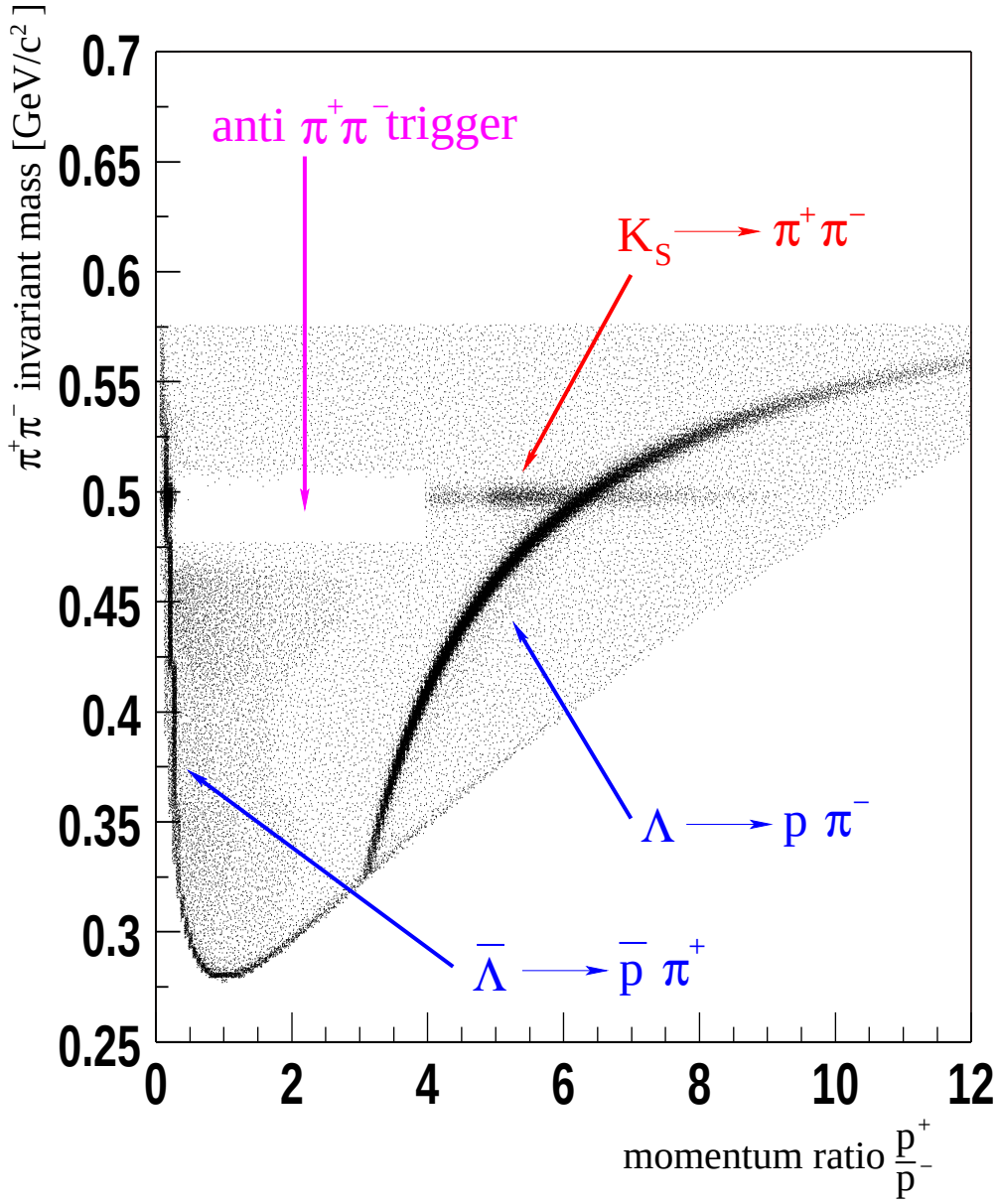
- The K_S target is a source of hyperons
- The main difficulty for the acquisition of events from hyperon decays is the rejection of K_S decay into two charged pions

$\Rightarrow$ HYPERON TRIGGER

apply cuts on:

anti–$[K_S \rightarrow \pi^+\pi^-]$ mass

& p^+/p^- momenta ratio



NA48 results on hyperon physics

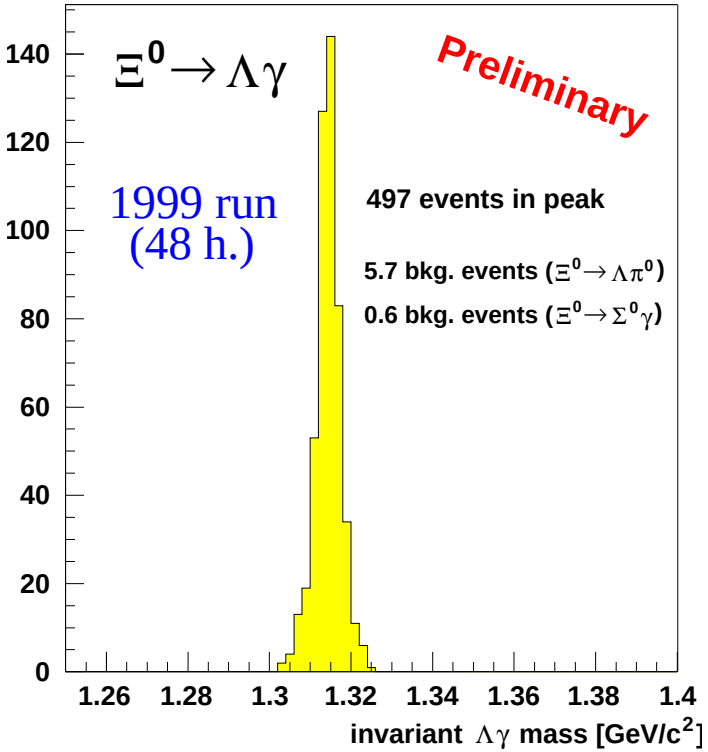
NA48 collaboration has already published results on hyperon physics:

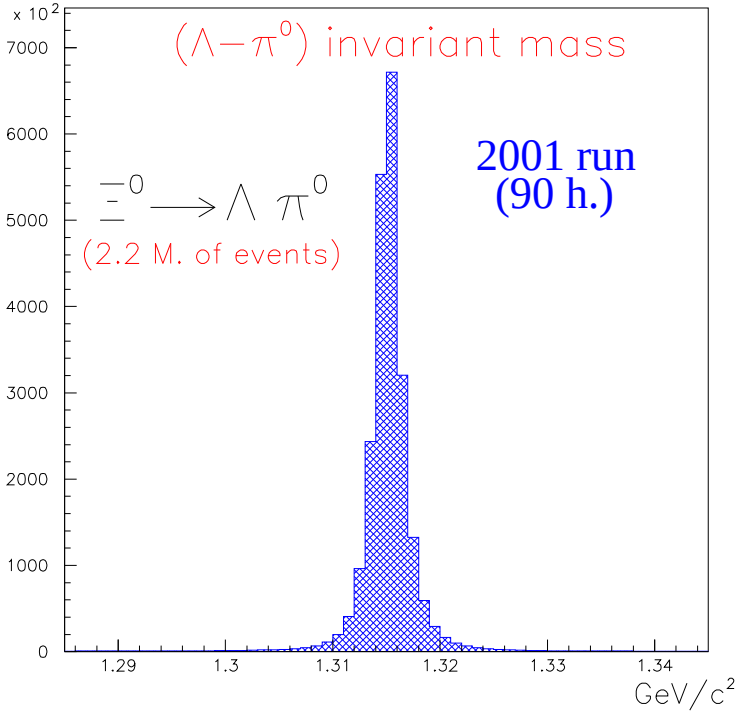
$$m(\Xi^0) = [1314.82 \pm 0.06(stat.) \pm 0.20(syst.)] MeV/c^2$$

$$BR(\Xi^0 \to \Lambda\gamma) = [1.90 \pm 0.34(stat.) \pm 0.19(syst.)] \times 10^{-3}$$

$$BR(\Xi^0 \to \Sigma^0\gamma) = [3.14 \pm 0.76(stat.) \pm 0.32(syst.)] \times 10^{-3}$$

Big improvements with KSHI run and dedicated hyperon trigger

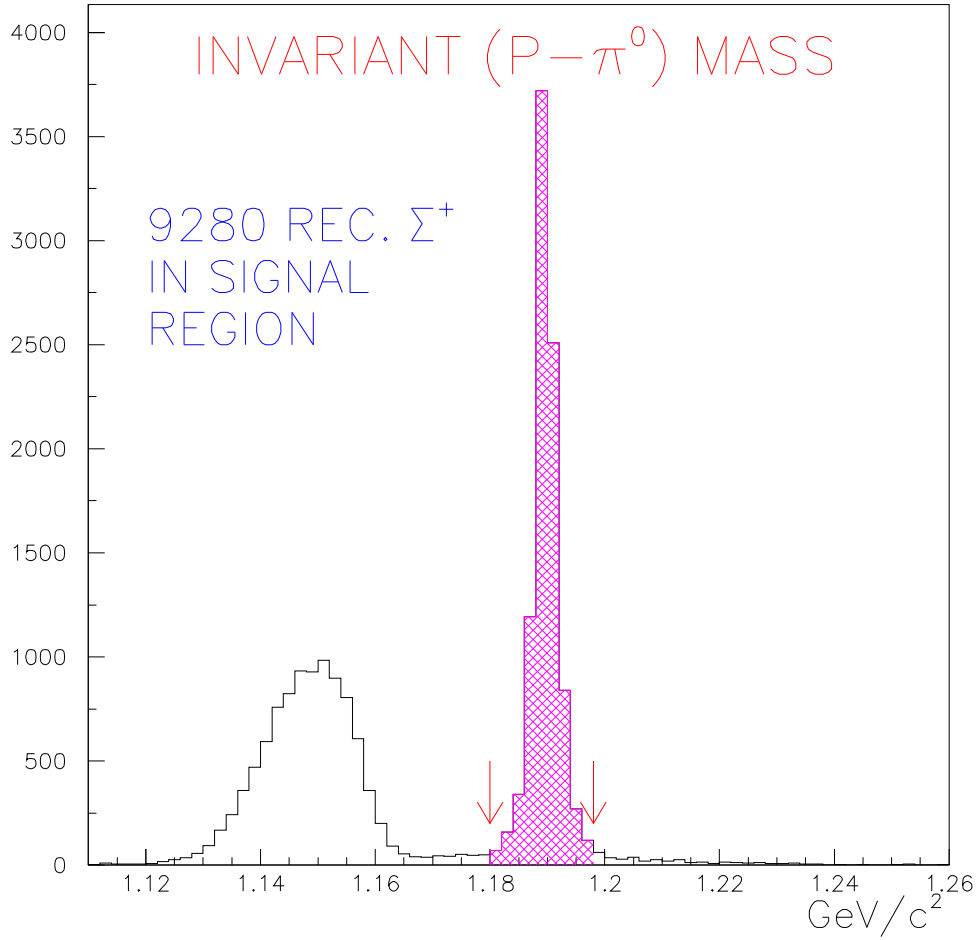




Results on $\Xi^0 \to \Sigma^+ e^- \overline{\nu_e}$: The 2002 DATA

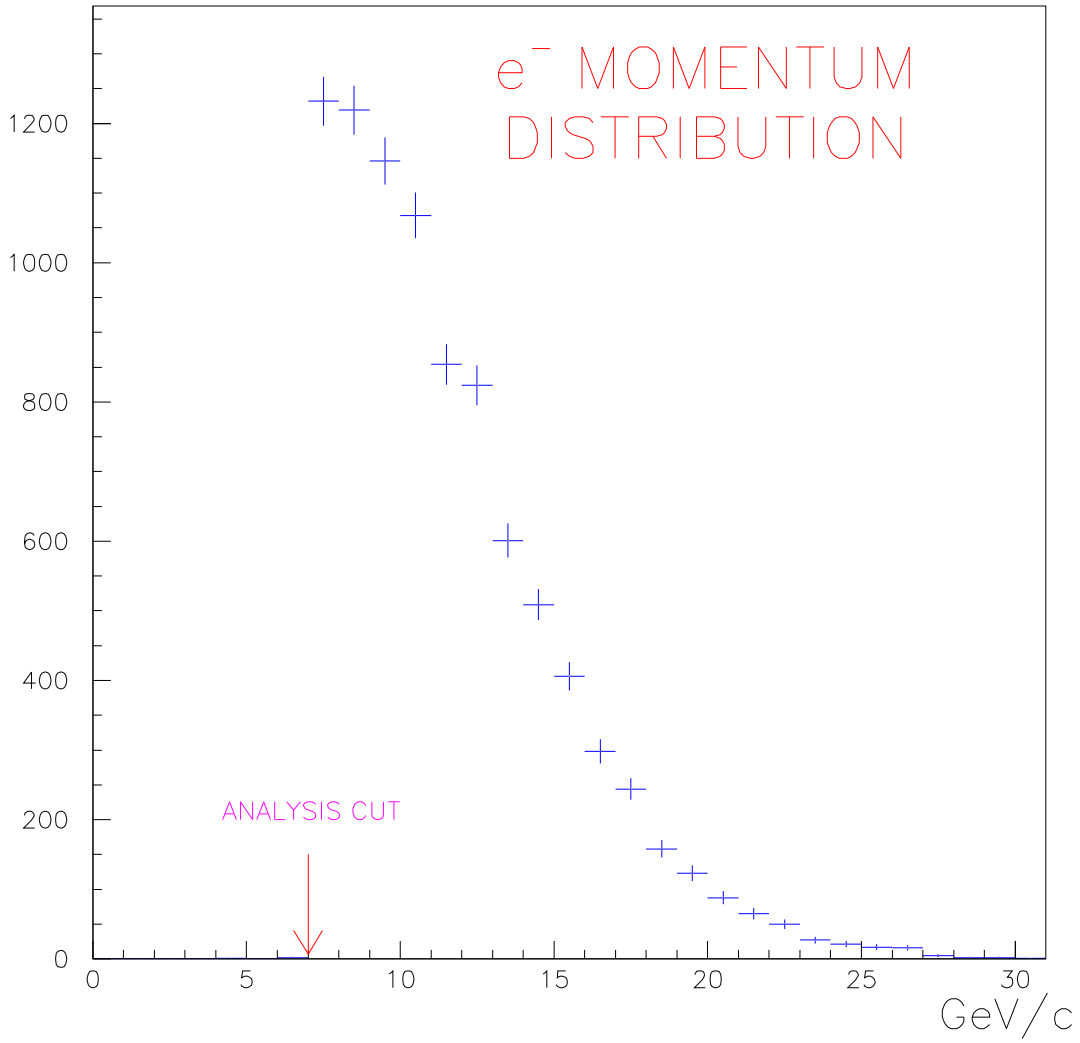
Data collected during 89 days in 2002

More then 9000 events in the signal region (background $\sim 3.\%$)

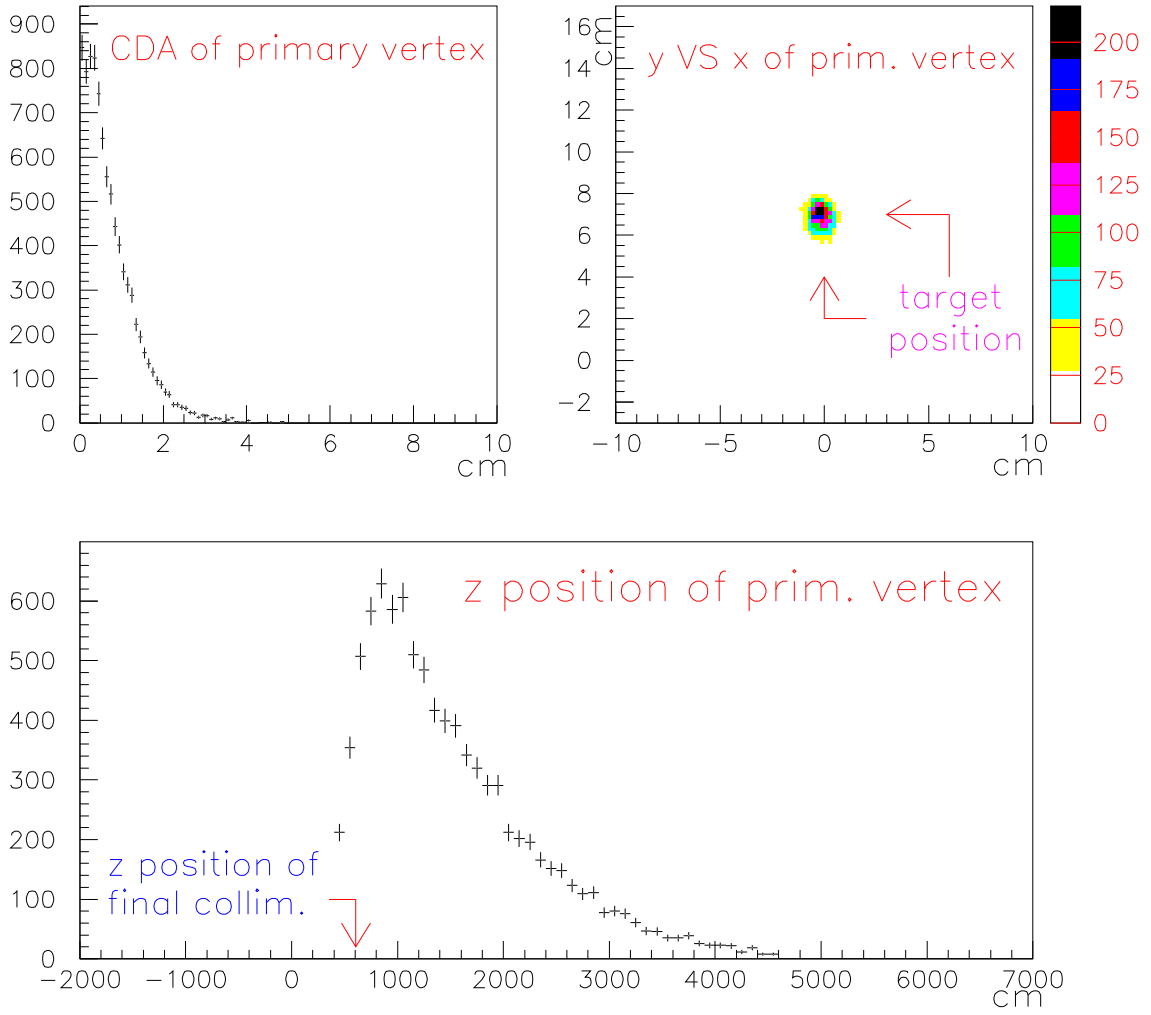


Signal region: $|M^{rec}_{\Sigma^+} - M^{pdg}_{\Sigma^+}| \leq 10\ MeV$

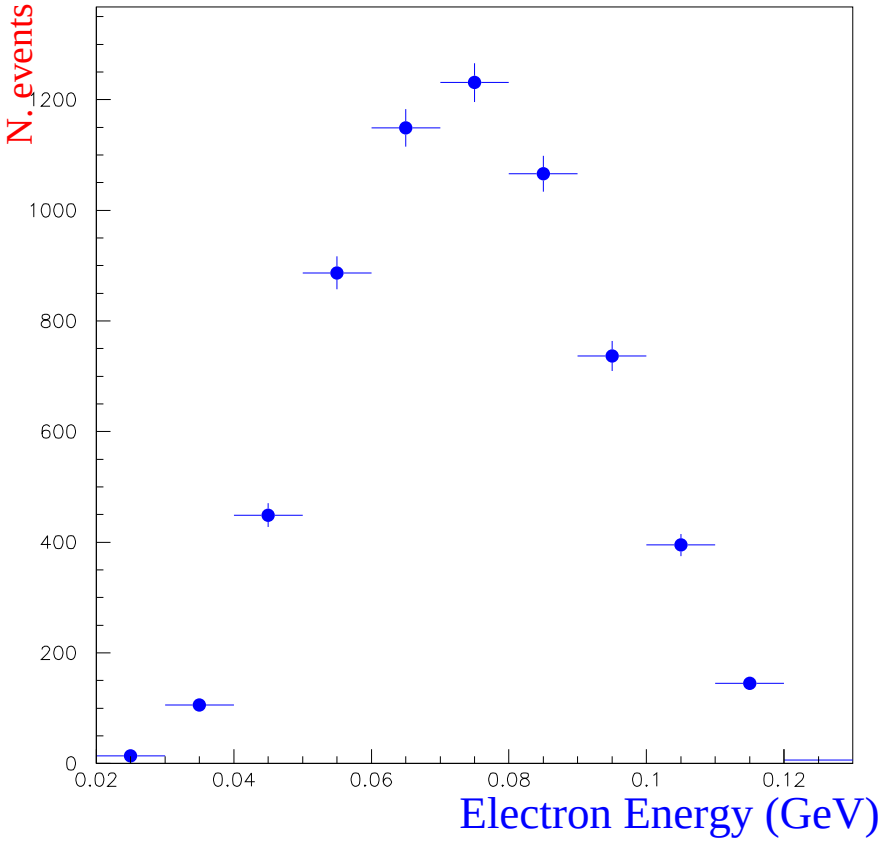
Electron spectrum

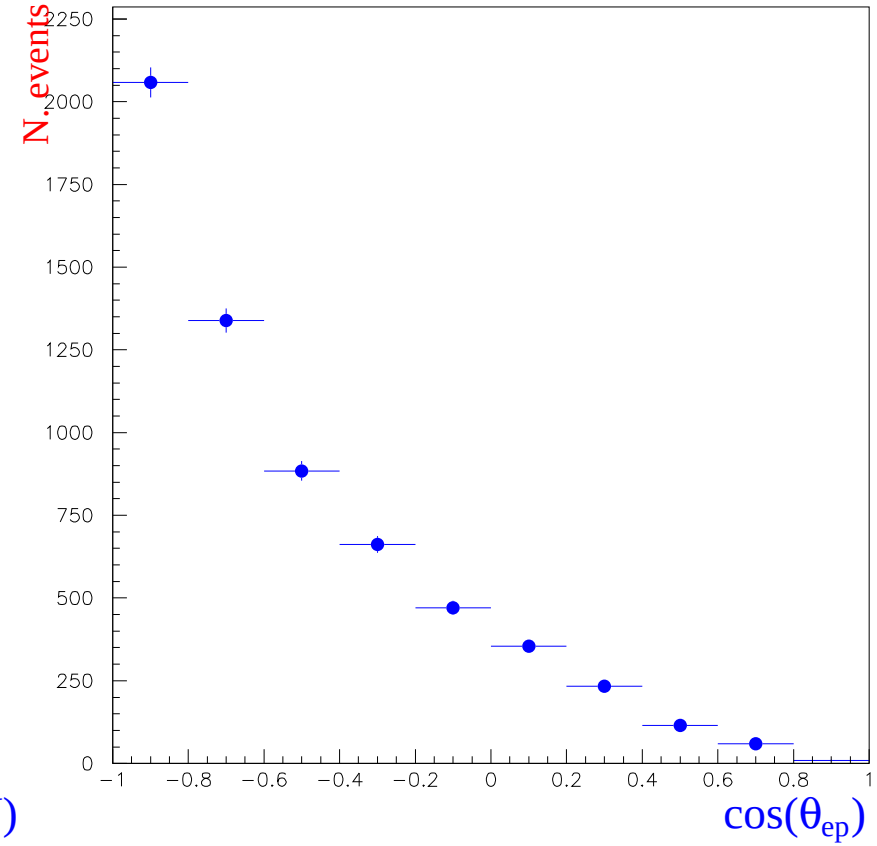


Primary vertex

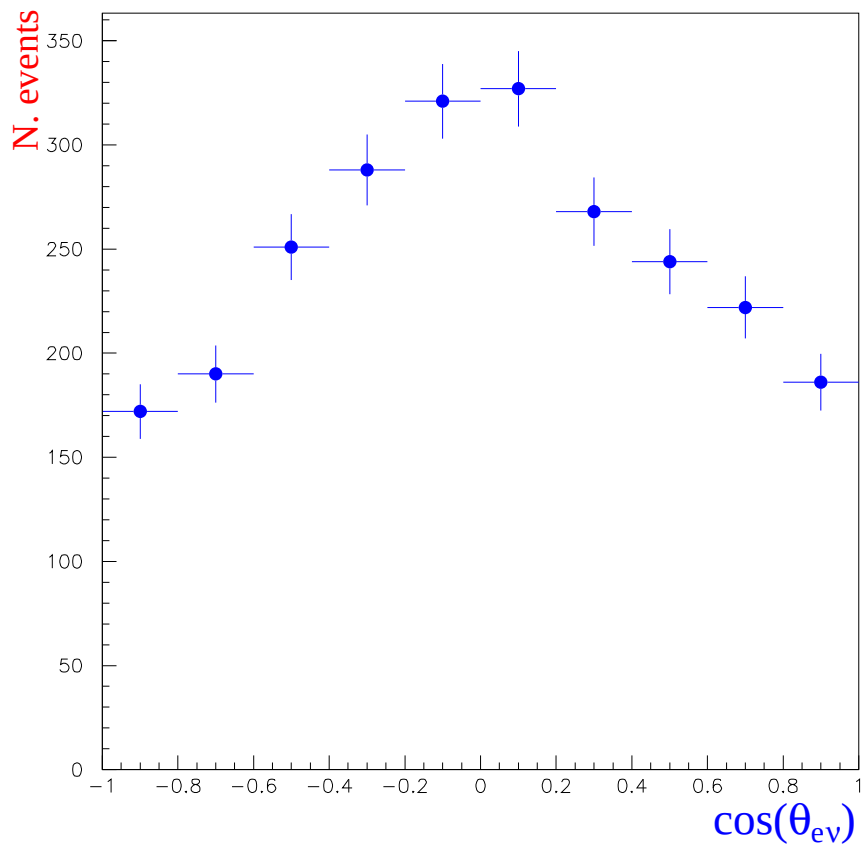


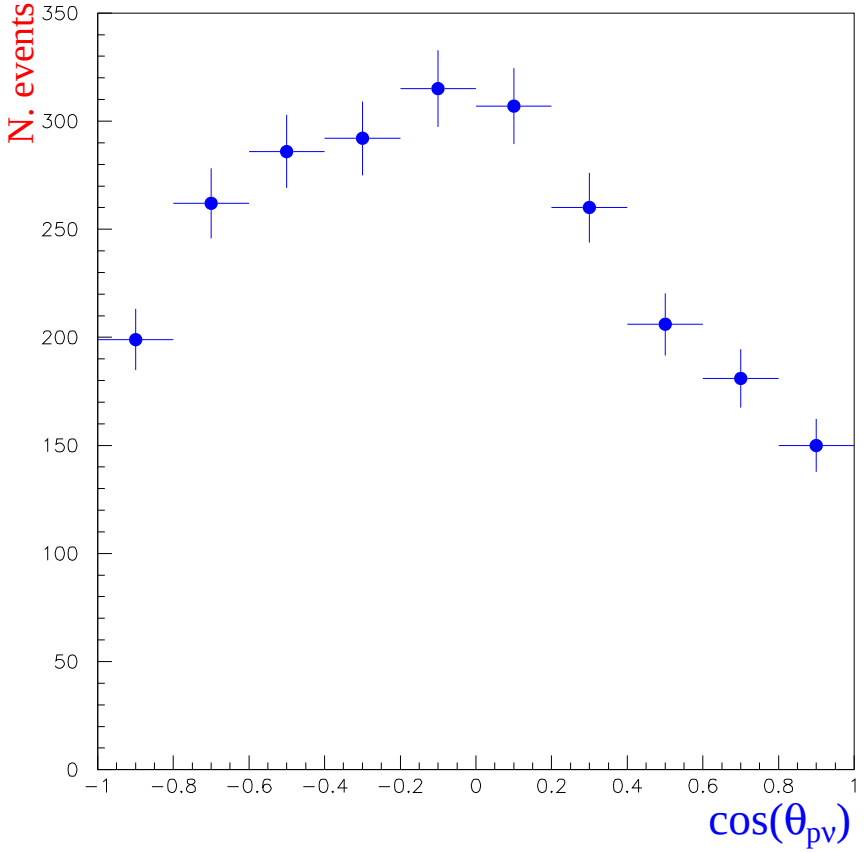
kinematical quantities in the Σ^+ RF for data





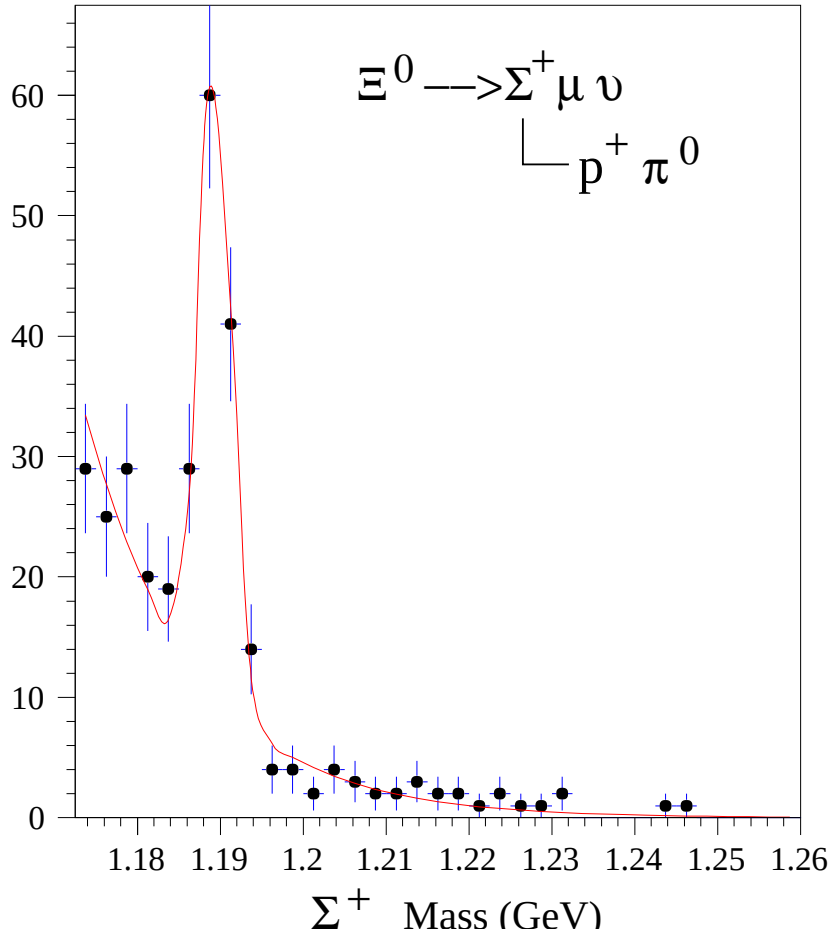
kinematical quantities in the Q RF for data





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

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



The sample represents the first clear evidence for this decay

Conclusions:

- The Ξ^0 beta decay represents a new chance for fundamental studies
- During 2002 run NA48 collected the largest world sample for this decay
- NA48 had also collected data samples to study:

  Ke3, ke4 and kμ3 form factors

  Ξ^0 radiative decays asimmetry
- All the analyses are going on, soon new results!