Rare Ξ^0 Decays

New Results from NA48

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on behalf of the

NA48 Collaboration

(Cagliari, Cambridge, CERN, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Vienna, Warsaw)

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Overview and Motivation

Radiative Decays $\Xi^0 \to \Lambda\,\gamma \,/\, \Sigma^0\,\gamma$

Theoretical understanding poor:

Variety of models $\longrightarrow$ Predictions vary over an order of magnitude.

Experimental data not conclusive:

$\mathrm{Br}(\Xi^0 \to \Lambda\,\gamma)$:

Fermilab (1990):	$(1.06 \pm 0.16) \times 10^{-3}$
NA48 (1997 data):	$(1.9 \pm 0.4) \times 10^{-3}$

$\mathrm{Br}(\Xi^0 \to \Sigma^0\,\gamma)$:

Fermilab (1989):	$(3.6 \pm 0.4) \times 10^{-3}$
NA48 (1997 data):	$(3.1 \pm 0.8) \times 10^{-3}$

Beta Decay $\Xi^0 \to \Sigma^+\,e^-\,\bar{\nu}$

Direct analogue to $n \to p\,e^-\,\bar{\nu}$.

$\longrightarrow$ study flavor symmetry violation.

$\Xi^0 \to p\,\pi^-$

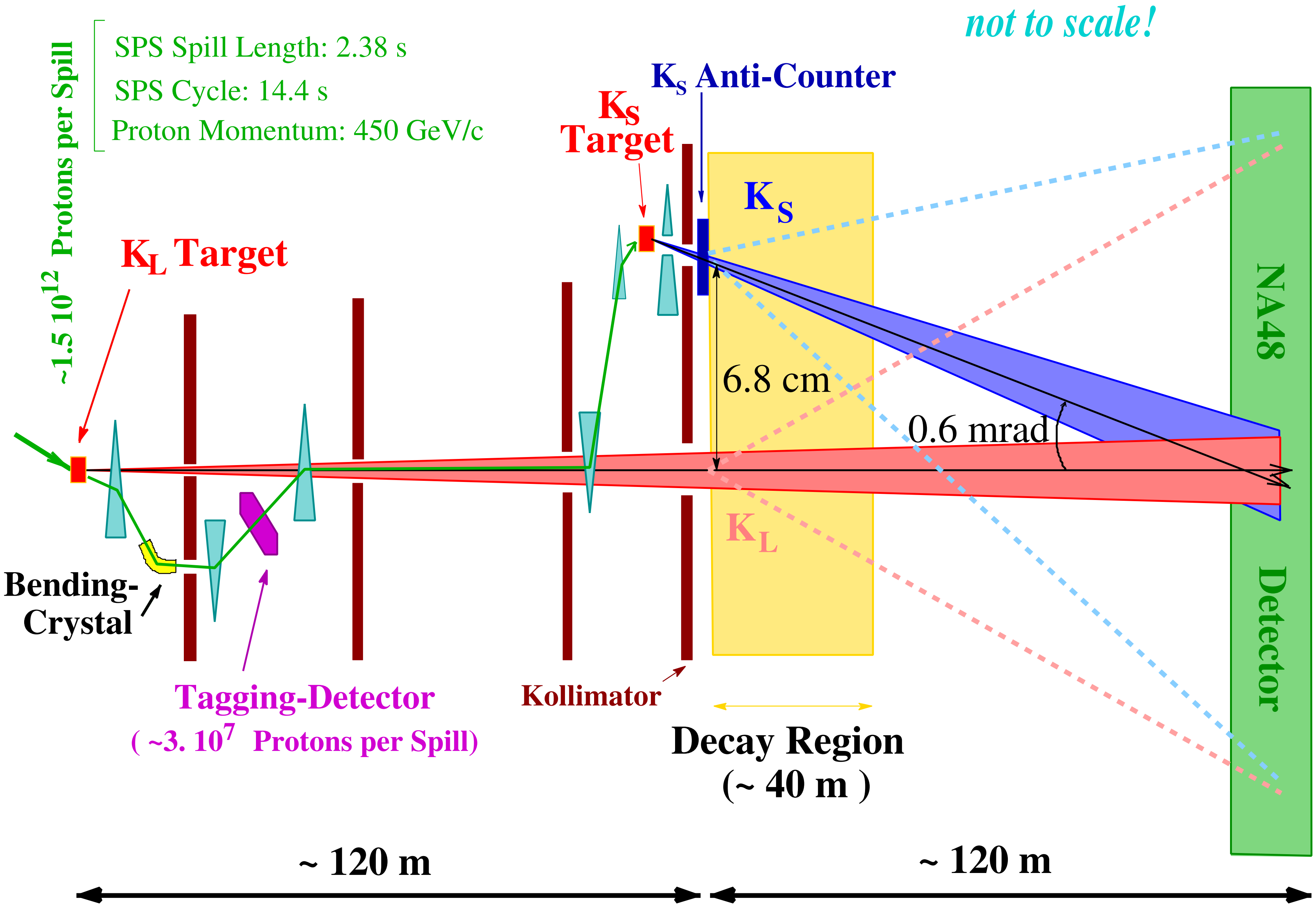
$\Delta S = 2$ transition, predicted $\mathrm{Br} \sim 10^{-17}$

(X.-G. He, G. Valencia, 1997)

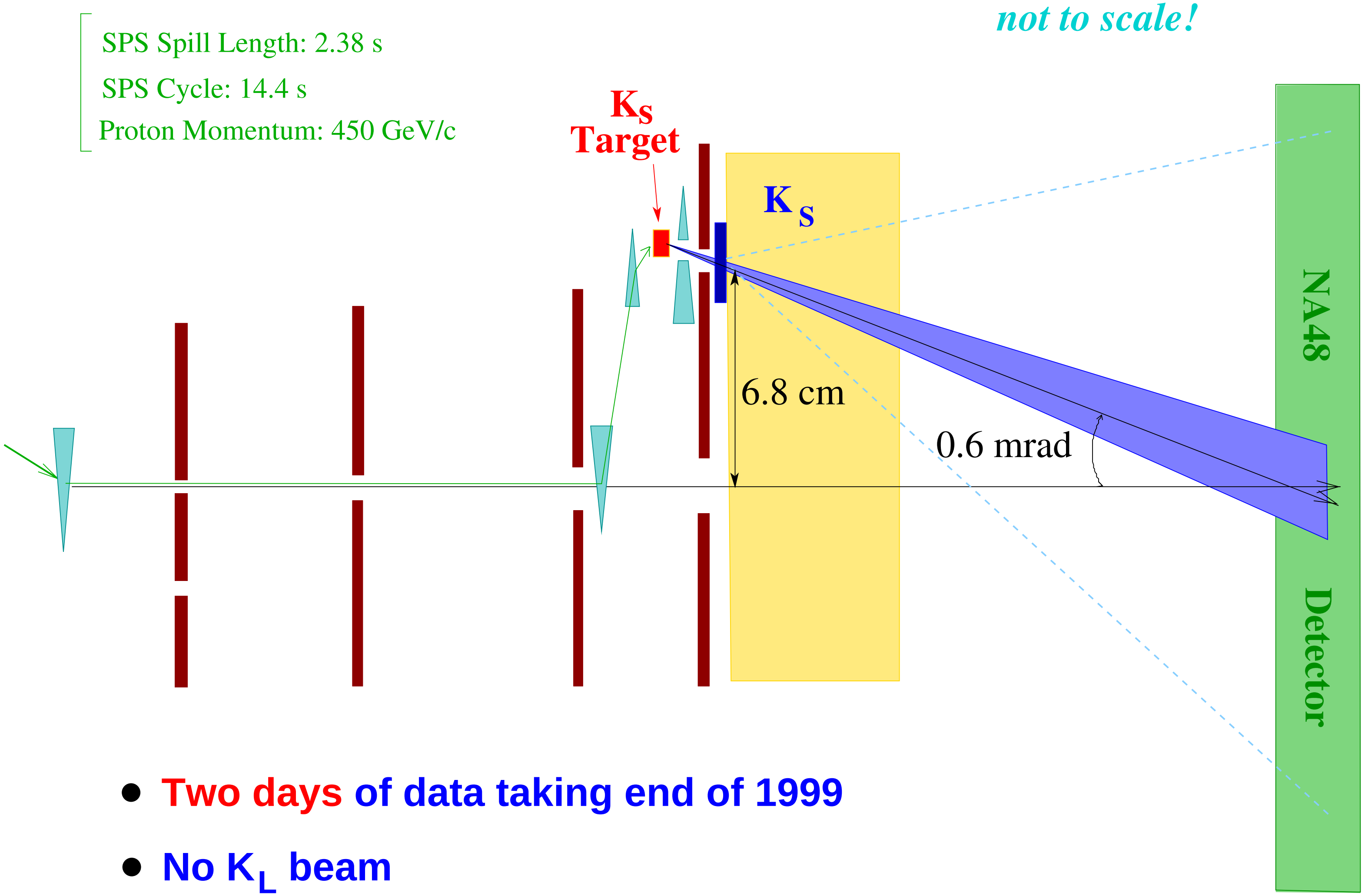
Best limit so far: $\mathrm{Br} \sim 3.7 \times 10^{-5}$ at 90% CL.

(Geweniger et. al., 1975)

The NA48 Kaon Beams

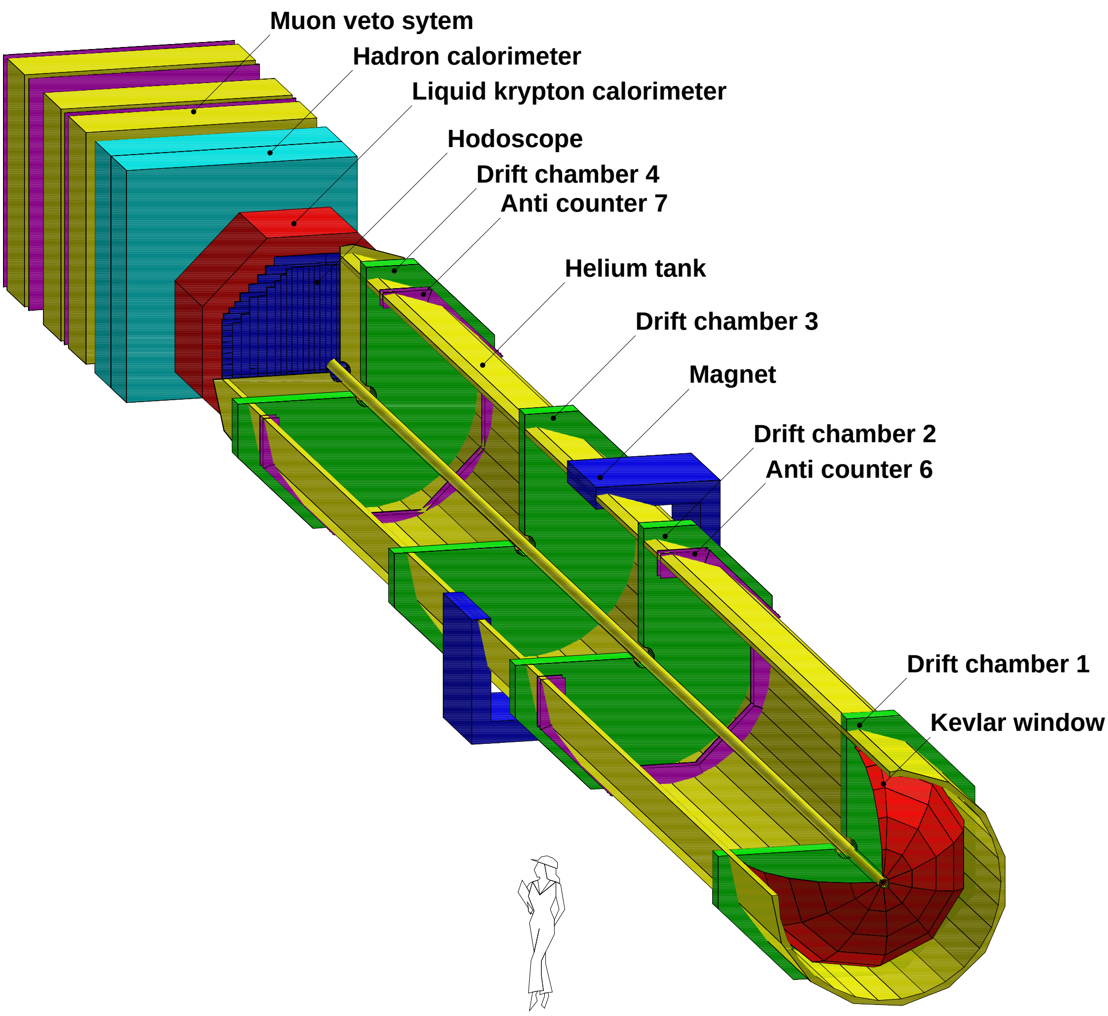


Hyperon and K_S Running in 1999



- **Two days of data taking end of 1999**
- **No K_L beam**
- **7 x 10^9 protons per spill on K_S target (200 times ε'/ε intensity)**

The NA48 Detector



Magnetic Spectrometer:

$$\Delta p/p \simeq 0.5\% \oplus 0.009\% \times p\,[\mathrm{GeV/c}]$$

Liquid Krypton Calorimeter:

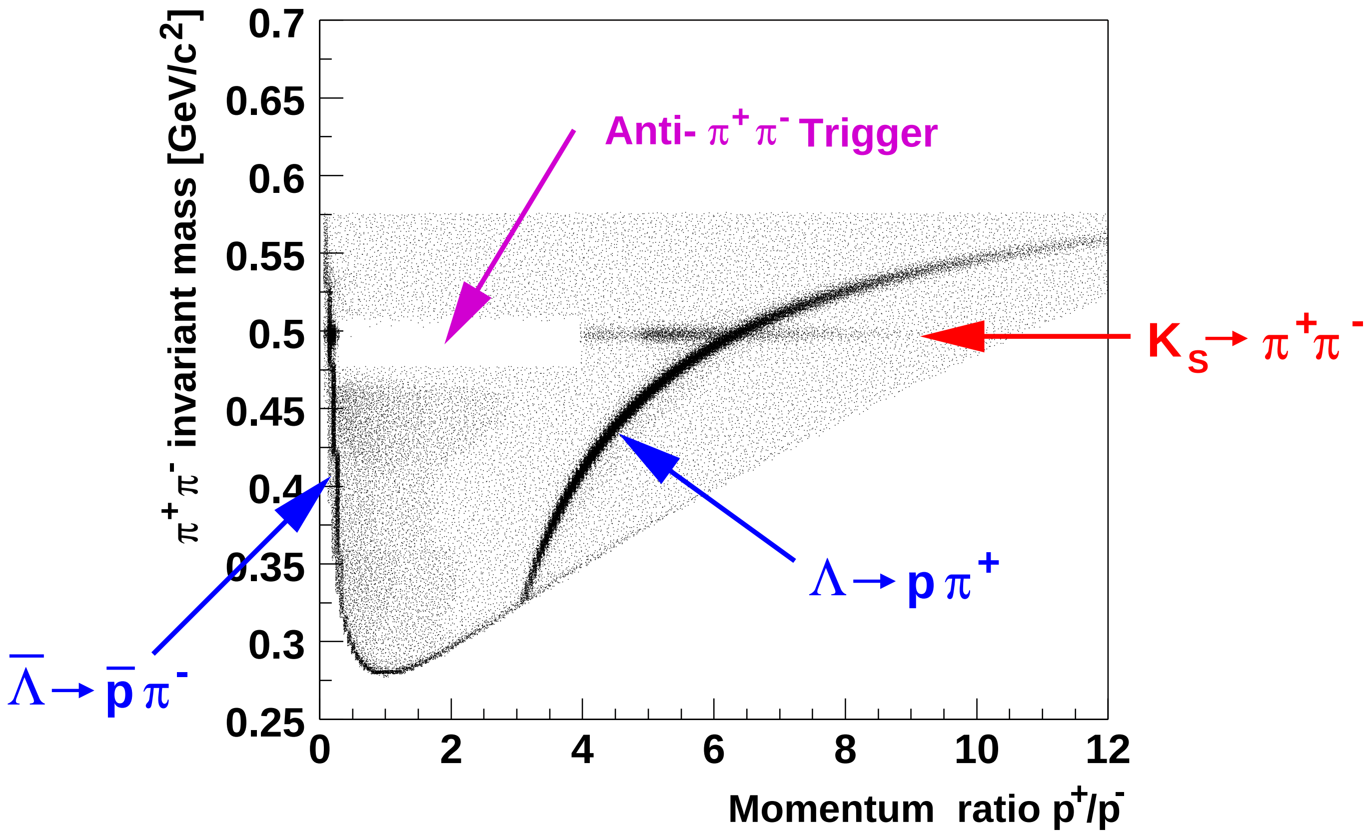
$$\Delta E/E = 3.2\%/\sqrt{E[\mathrm{GeV}]} \oplus 100\ \mathrm{MeV}/E \oplus 0.5\%$$

Trigger Conditions

Hyperon Trigger:

- Two tracks (one positive, one negative)
- "Anti $K_S \to \pi^+\pi^-$ trigger":

  Combined cut on kaon mass
  and momentum ratio p_+/p_-.



$\Longrightarrow$
- 41×10^6 2-track events
- 17×10^6 $\Lambda \to p\,\pi^-$ events
- 2×10^6 $\bar{\Lambda} \to \bar{p}\,\pi^+$ events

Hyperon Selection

Charged Tracks:

- Two tracks form vertex
- Time difference < 4.5 ns

Photons and π^0's:

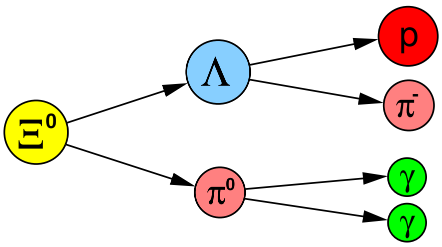
- γ's well separated from tracks and LKr calorimeter edges
- Time difference to tracks < 3 ns
- $|m(\gamma\gamma) - m(\pi^0)| < 10$ MeV/c^2 ($\cong 3\sigma$ in $\Xi^0 \to \Lambda\,\pi^0$)

Hyperon candidates:

- No $K_{\rm L} \to \pi^+\pi^-\pi^0$ candidate
- z-vertex < 40 m (mean Ξ^0/Λ decay length ≈ 10 m)
- $|m(p\pi^-) - m(\Lambda)| < 2.5$ MeV/c^2 ($\cong 3\sigma$)

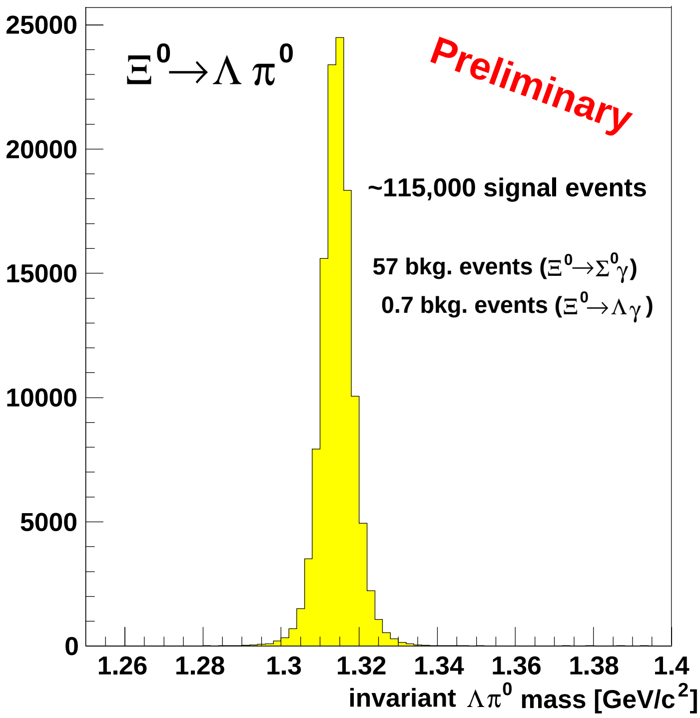
Normalization: $\Xi^0 \to \Lambda\,\pi^0$

$\Xi^0 \to \Lambda\,\pi^0$ is used for **normalization** of all modes.



- $\mathrm{Br}(\Xi^0 \to \Lambda\,\pi^0) = 99.5\%$
- Similar topology as most decays (2 tracks + LKr activity)
- Virtually background-free

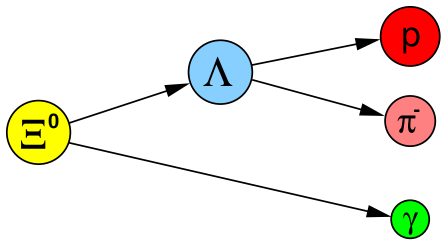
We find 115,000 events in the accepted vertex and energy region.

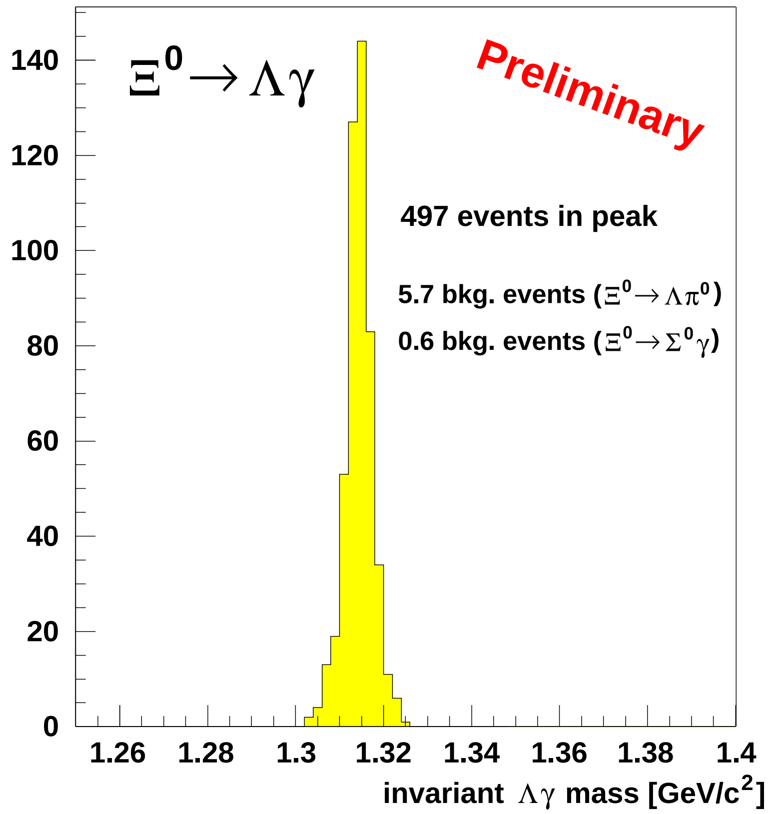


$\Xi^0 \to \Lambda\,\gamma$

We find ~ 500 signal candidates.

Expected background: $\approx 1\%$.





Preliminary result:

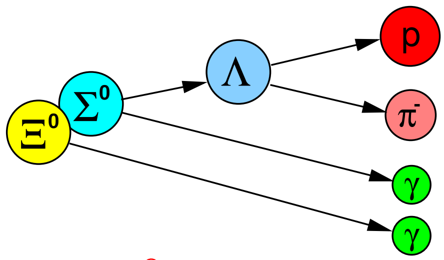
$$\mathrm{Br}\,(\Xi^0 \to \Lambda\,\gamma) \;=\; (1.9 \pm 0.1 \pm 0.2) \times 10^{-3}$$

Main systematics: Ξ^0 polarization and asymmetry.

$$\boxed{\Xi^0 \to \Sigma^0\,\gamma}$$

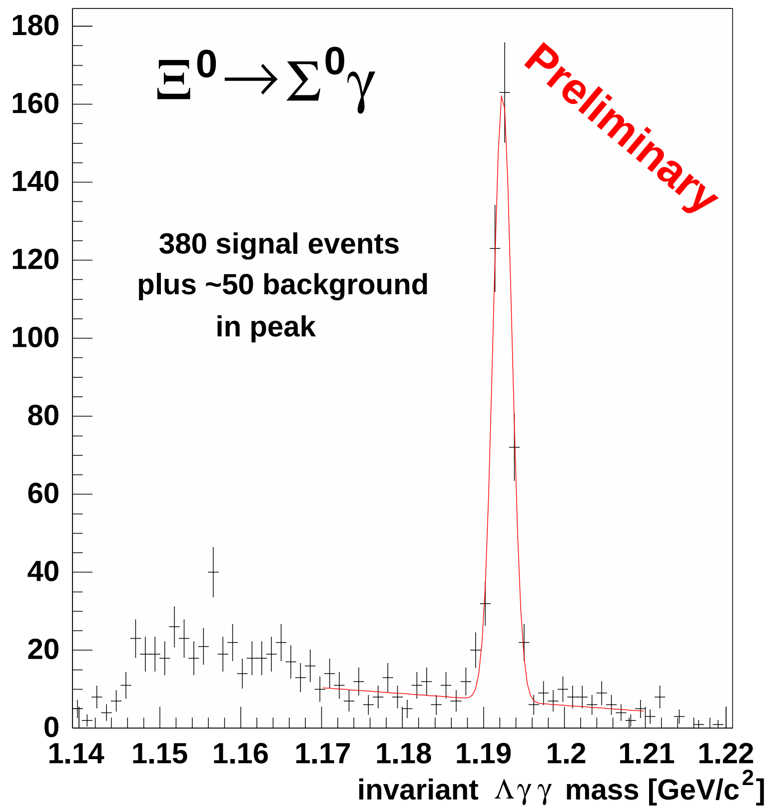
Σ^0 lifetime $\sim \mathcal{O}(10^{-10}$ s)

$\longrightarrow$ Almost same signature as $\Xi^0 \to \Lambda\,\pi^0$.



$\Longrightarrow$ Main background from $\Xi^0 \to \Lambda\,\pi^0$.

We find a signal of ~ 380 events over a $\Xi^0 \to \Lambda\,\pi^0$ background of ~ 50 events.

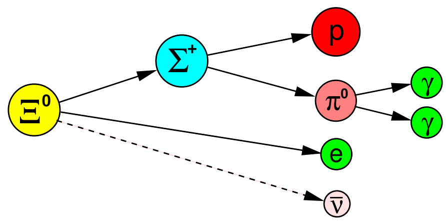


$\Longrightarrow$ Expect a measurement with $\sim 5\%$ accuracy soon!

Ξ^0 Beta Decay: $\Xi^0 \to \Sigma^+ e^- \bar{\nu}_e$

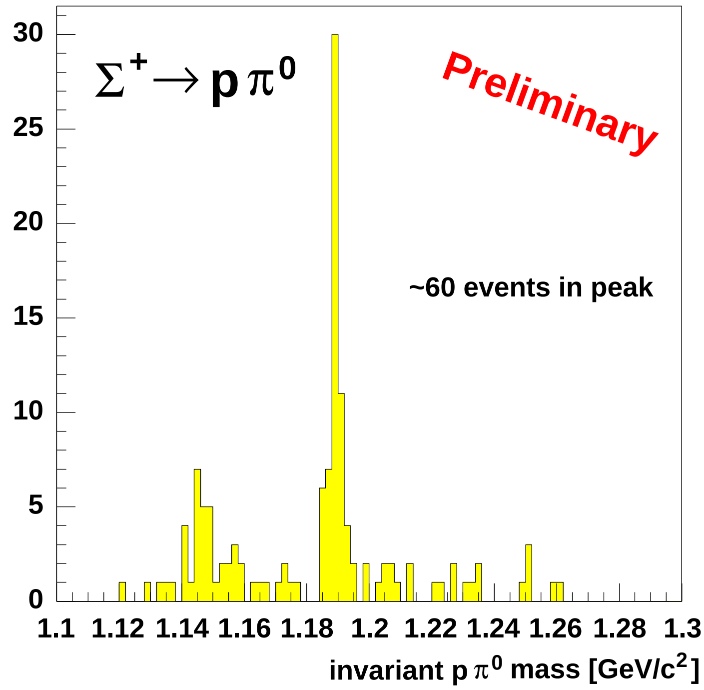
Signature:

Find $\Sigma^+ \to p\,\pi^0$ with an additional electron.



Severe background from $\Xi^0 \to \Lambda\,\pi^0$ with

- $\Lambda \to p\,\pi^-$ ($\longrightarrow$ cut against Λ mass)
- $\Lambda \to p\,e^-\,\bar{\nu}$ ($\longrightarrow$ cut on Σ^+ mass)



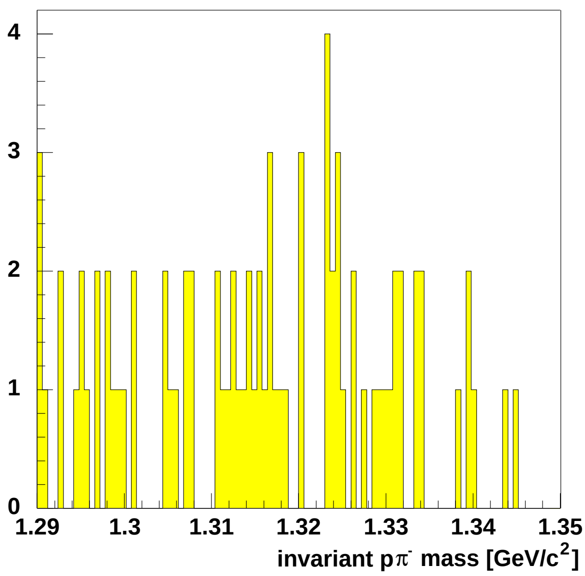
$\Longrightarrow$ From ~ 60 signal candidates we will be able to perform a measurement with $\sim 15\%$ accuracy.

$\Delta S = 2$ **Transition:** $\Xi^0 \rightarrow p\,\pi^-$

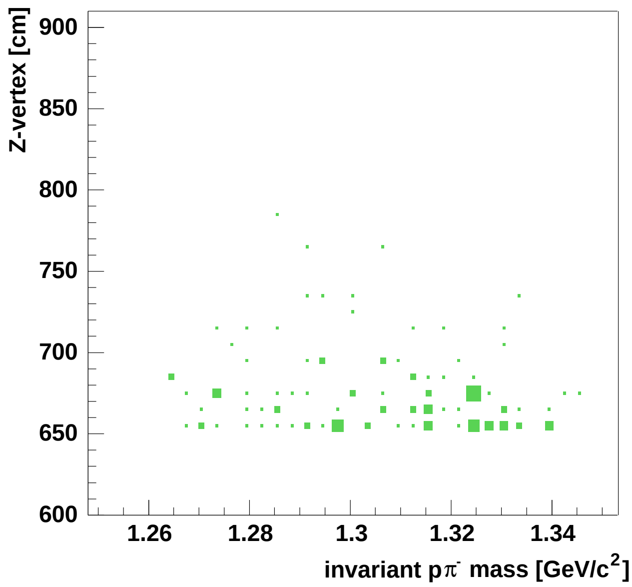
Background only at small decay lengths.

$\Longrightarrow$ Require z-vertex > 10 m.

Before final z-vertex cut



z-vertex vs. $m(p\,\pi^-)$



$\Longrightarrow$ No signal candidate found.

We expect to improve the upper limit by a factor of 10.

(Geweniger et al. (1975): $\mathrm{Br} < 3.7 \times 10^{-5}$ at 90% CL.)

Summary

From 2 days of special high-intensity data taking for rare K_S and hyperon decays, we obtain *preliminary* results for a variety of Ξ^0 decay modes.

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

From 497 signal candidates, we measure
$\mathrm{Br}(\Xi^0 \to \Lambda\,\gamma) = (1.9 \pm 0.1 \pm 0.2) \times 10^{-3}$

$\Xi^0 \to \Sigma^0\,\gamma$

We find $\approx$ 380 signal events above a background of about 50 events.

$\Xi^0 \to \Sigma^+\,e^-\,\bar{\nu}_e$

About 60 signal candidates are seen
$\Longrightarrow$ Expect $\sim 15\%$ accuracy on measurement.

$\Xi^0 \to p\,\pi^-$

No signal event is found
$\Longrightarrow$ Upper limit will improve by an order of magnitude.

Outlook

2000:

Further work on the 1999 NA48 hyperon data.

2001:

NA48 will finish the $\mathrm{Re}(\epsilon'/\epsilon)$ measurement.

2002:

One full year of high-intensity K_{S} and hyperon data taking proposed.
We would expect to collect at least 40 times the statistics of the 1999 hyperon data.

$\Longrightarrow$

- Several new decay modes accessible.
- High precision measurements of the "old ones" are possible.