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# Rare $\Xi^0$ Decays

## New Results from NA48

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on behalf of the

**NA48 Collaboration**

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Saclay, Siegen, Torino, Vienna, Warsaw)

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## Overview and Motivation

### Radiative Decays $\Xi^0 \rightarrow \Lambda \gamma / \Sigma^0 \gamma$

Theoretical understanding poor:

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

Experimental data not conclusive:

$\text{Br}(\Xi^0 \rightarrow \Lambda \gamma)$ :

Fermilab (1990):  $(1.06 \pm 0.16) \times 10^{-3}$

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

$\text{Br}(\Xi^0 \rightarrow \Sigma^0 \gamma)$ :

Fermilab (1989):  $(3.6 \pm 0.4) \times 10^{-3}$

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

### Beta Decay $\Xi^0 \rightarrow \Sigma^+ e^- \bar{\nu}$

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

$\rightarrow$  study flavor symmetry violation.

### $\Xi^0 \rightarrow p \pi^-$

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

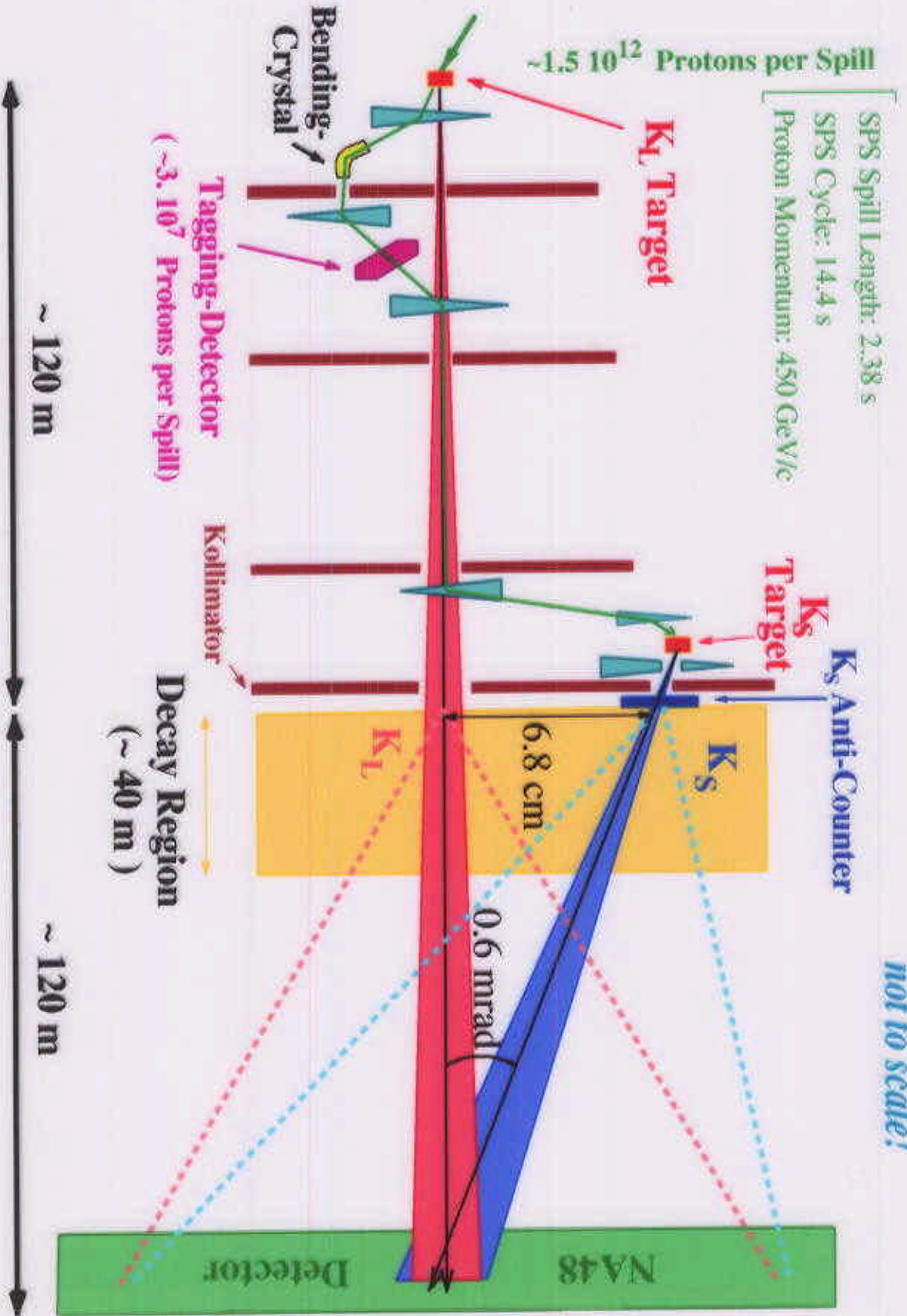
(X.-G. He, G. Valencia, 1997)

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

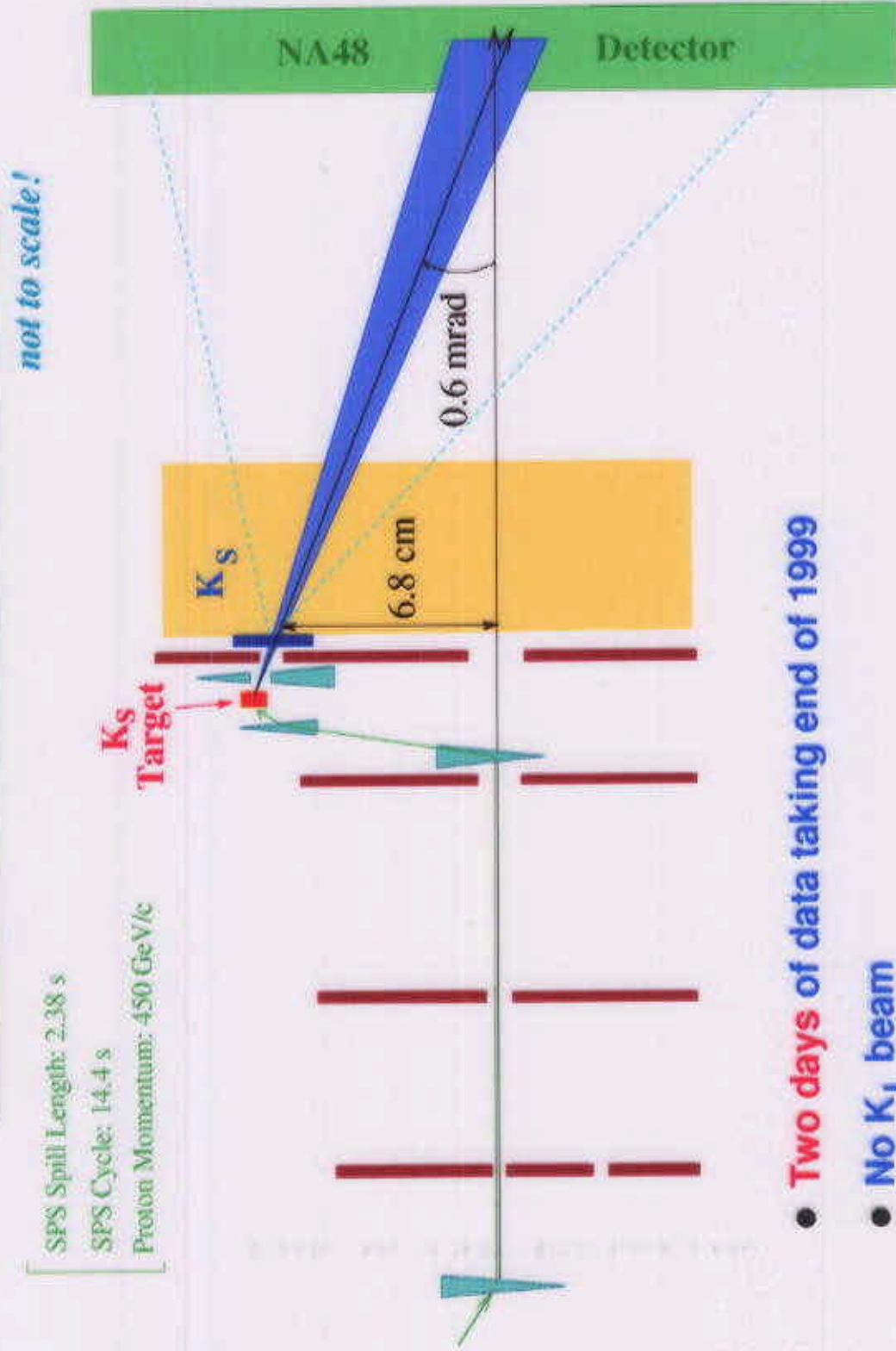
(Geweniger et. al., 1975)

# The NA48 Kaon Beams

*not to scale!*

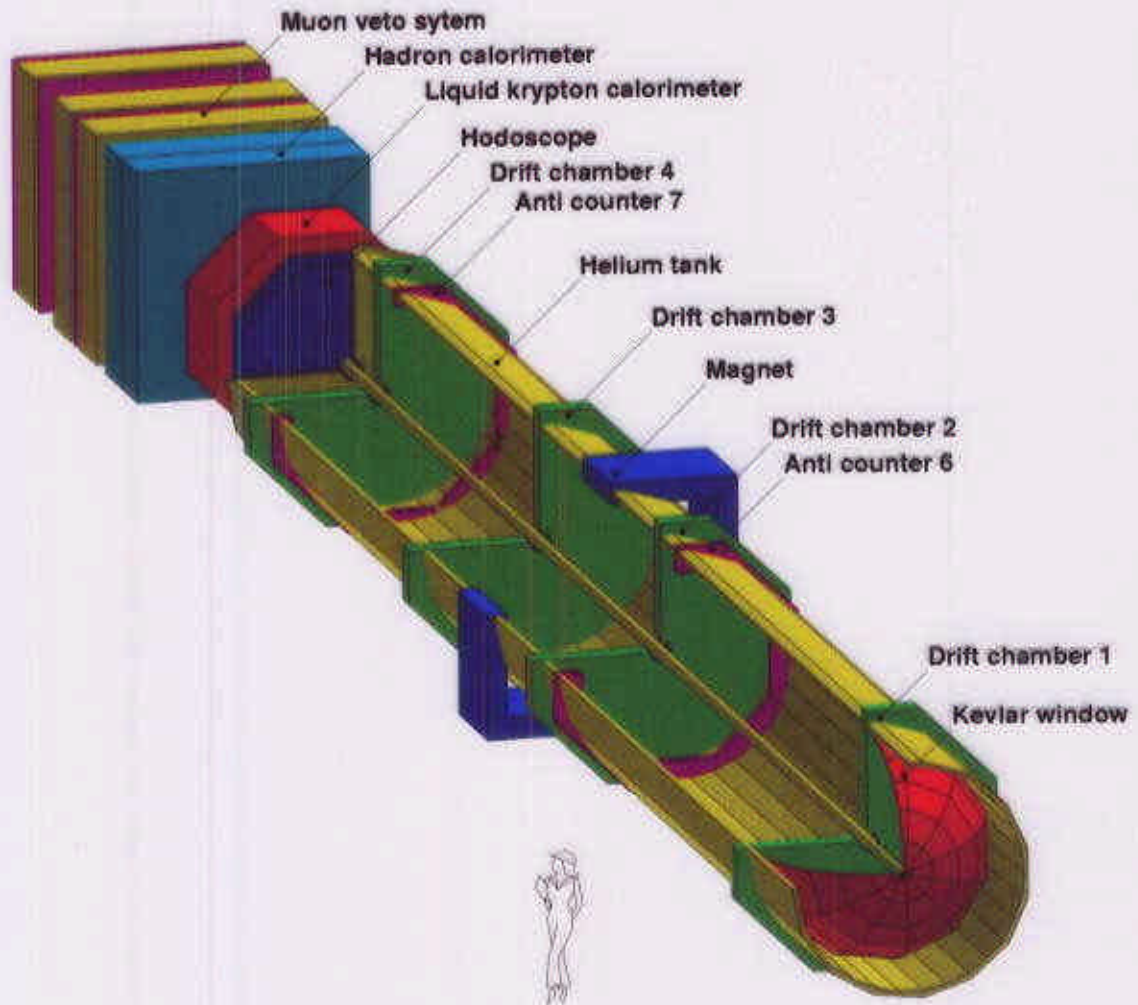


# Hyperon and $K_S$ Running in 1999



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

# The NA48 Detector



## Magnetic Spectrometer:

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

## Liquid Krypton Calorimeter:

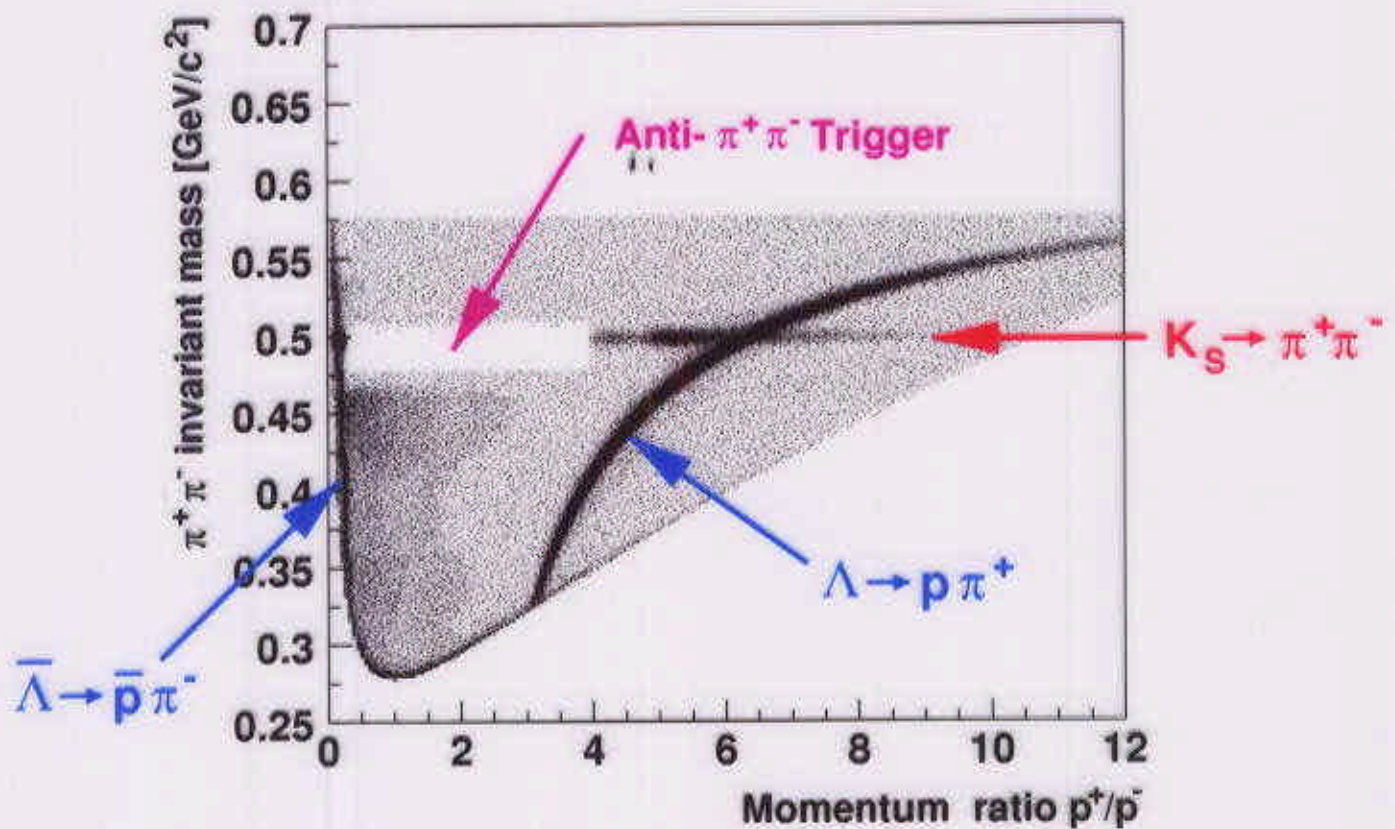
$$\Delta E/E = 3.2\% / \sqrt{E [\text{GeV}]} \oplus 100 \text{ MeV}/E \oplus 0.5\%$$

## Trigger Conditions

### Hyperon Trigger:

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

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



- ⇒
- $41 \times 10^6$  2-track events
  - $17 \times 10^6$   $\Lambda \rightarrow p \pi^-$  events
  - $2 \times 10^6$   $\bar{\Lambda} \rightarrow \bar{p} \pi^+$  events

# Hyperon Selection

## Charged Tracks:

- Two tracks form vertex
- Time difference  $< 4.5$  ns

## Photons and $\pi^0$ 's:

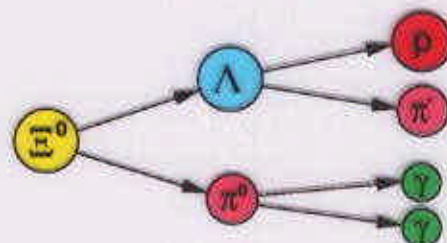
- $\gamma$ 's well separated from tracks and LKr calorimeter edges
- Time difference to tracks  $< 3$  ns
- $|m(\gamma\gamma) - m(\pi^0)| < 10 \text{ MeV}/c^2$   
( $\cong 3\sigma$  in  $\Xi^0 \rightarrow \Lambda \pi^0$ )

## Hyperon candidates:

- No  $K_L \rightarrow \pi^+ \pi^- \pi^0$  candidate
- $z$ -vertex  $< 40$  m  
(mean  $\Xi^0/\Lambda$  decay length  $\approx 10$  m)
- $|m(p\pi^-) - m(\Lambda)| < 2.5 \text{ MeV}/c^2$  ( $\cong 3\sigma$ )

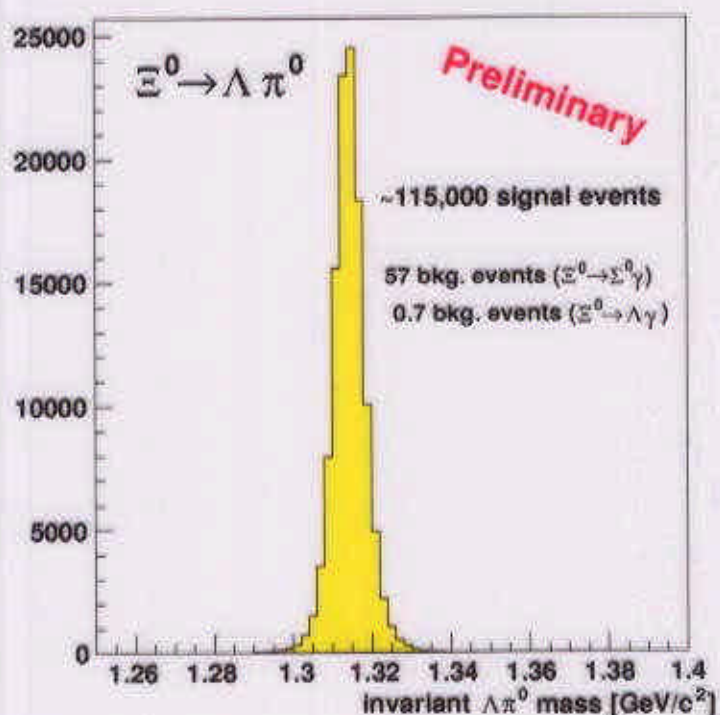
## Normalization: $\Xi^0 \rightarrow \Lambda \pi^0$

$\Xi^0 \rightarrow \Lambda \pi^0$  is used for normalization of all modes.



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

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

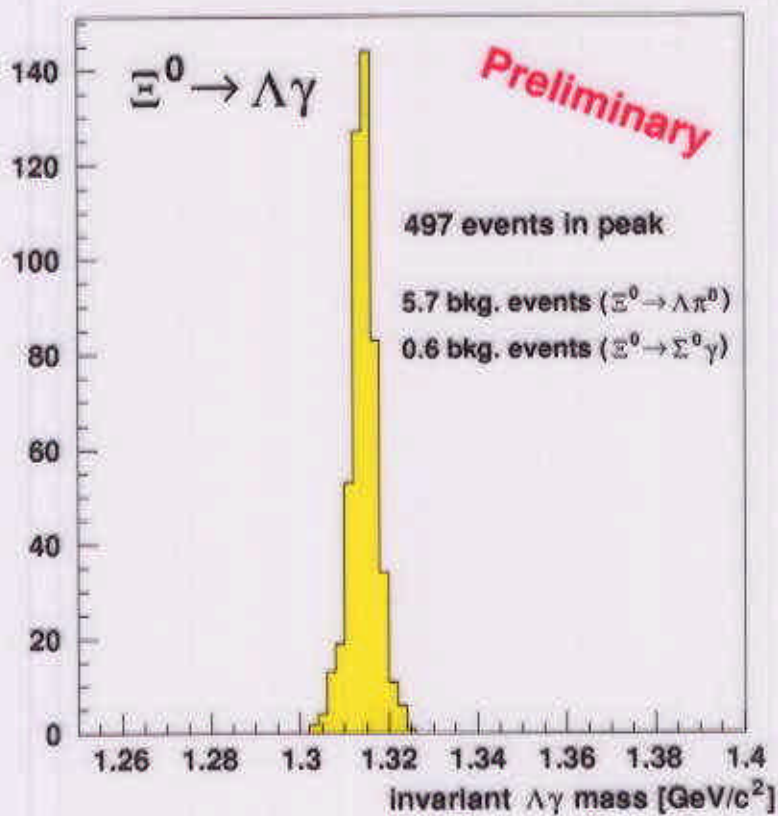
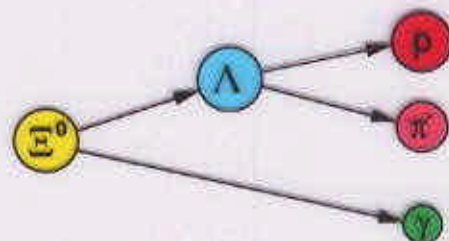






We find  $\sim 500$  signal candidates.

Expected background:  $\approx 1\%$ .



Preliminary result:

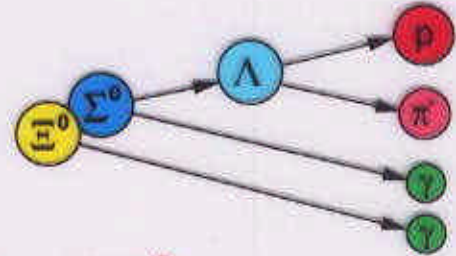
$$\text{Br}(\Xi^0 \rightarrow \Lambda \gamma) = (1.9 \pm 0.1 \pm 0.2) \times 10^{-3}$$

Main systematics:  $\Xi^0$  polarization and asymmetry.



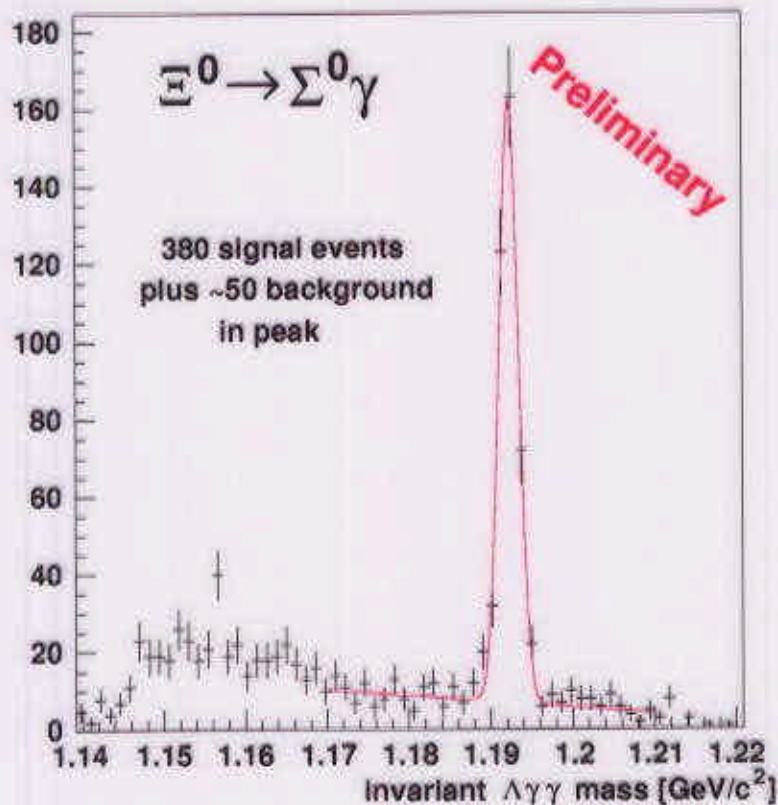
$\Sigma^0$  lifetime  $\sim \mathcal{O}(10^{-10} \text{ s})$

→ Almost same signature  
as  $\Xi^0 \rightarrow \Lambda \pi^0$ .



⇒ Main background from  $\Xi^0 \rightarrow \Lambda \pi^0$ .

We find a signal of  $\sim 380$  events  
over a  $\Xi^0 \rightarrow \Lambda \pi^0$  background of  $\sim 50$  events.

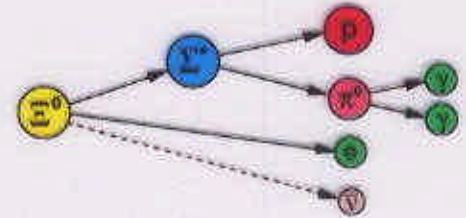


⇒ Expect a measurement with  
 $\sim 5\%$  accuracy soon!

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

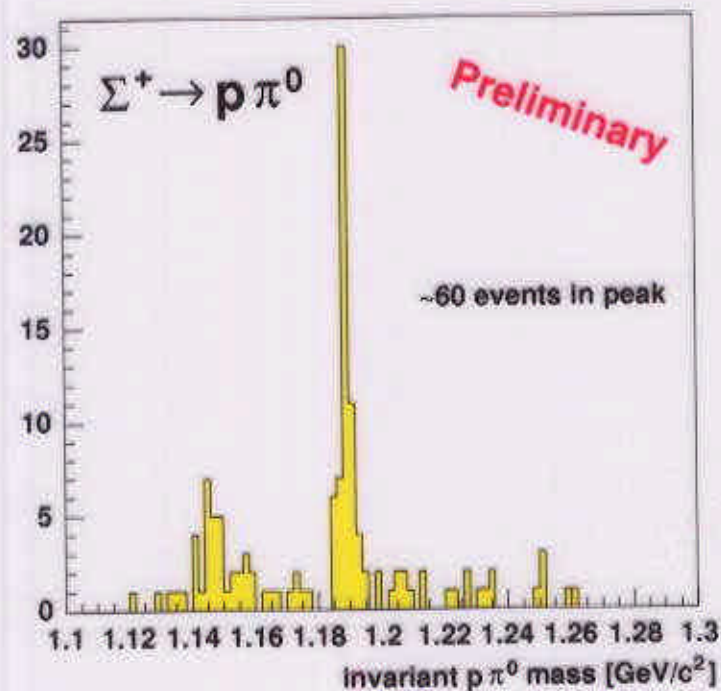
## Signature:

Find  $\Sigma^+ \rightarrow p \pi^0$  with an additional **electron**.



Severe background from  $\Xi^0 \rightarrow \Lambda \pi^0$  with

- $\Lambda \rightarrow p \pi^-$  ( $\rightarrow$  cut against  $\Lambda$  mass)
- $\Lambda \rightarrow p e^- \bar{\nu}$  ( $\rightarrow$  cut on  $\Sigma^+$  mass)



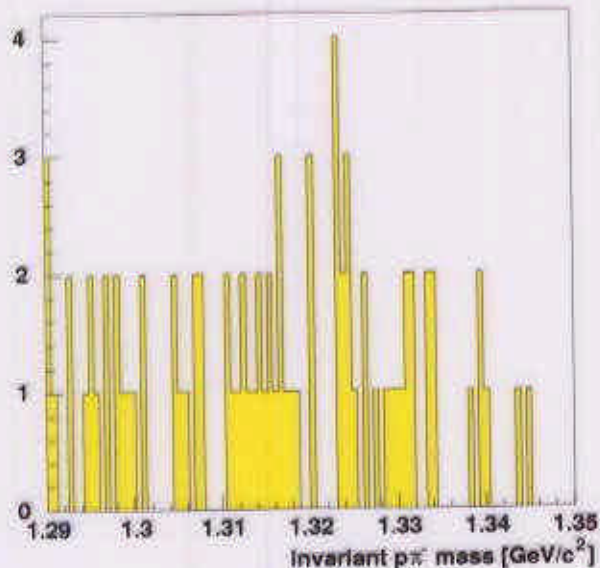
$\Rightarrow$  From  $\sim 60$  signal candidates we will be able to perform a measurement with  $\sim 15\%$  accuracy.

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

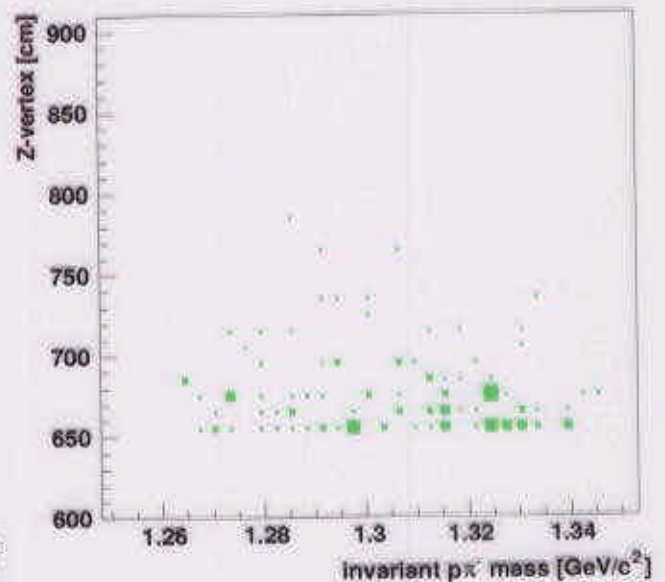
Background only at small decay lengths.

⇒ Require  $z$ -vertex  $> 10$  m.

Before final  
 $z$ -vertex cut



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



⇒ No signal candidate found.

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

(Geweniger et al. (1975):

$Br < 3.7 \times 10^{-5}$  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  $\Xi^0$  decay modes.

$$\Xi^0 \rightarrow \Lambda \gamma$$

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

$$\Xi^0 \rightarrow \Sigma^0 \gamma$$

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

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

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

$$\Xi^0 \rightarrow p \pi^-$$

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

## Outlook

**2000:**

Further work on the 1999 NA48 hyperon data.

**2001:**

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

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