$\Xi^- \to p\mu^-\mu^-$

Search for $\mid \Delta L \mid = 2$ Hyperon Decay

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Lepton-Number Conservation

- Experimentally observed :

  conservation of Lepton-Family ($L_{e,\mu,\tau}$) Number

  conservation of Total Lepton-Number

- *Reason ?*

  not fully understood

- Related issues :

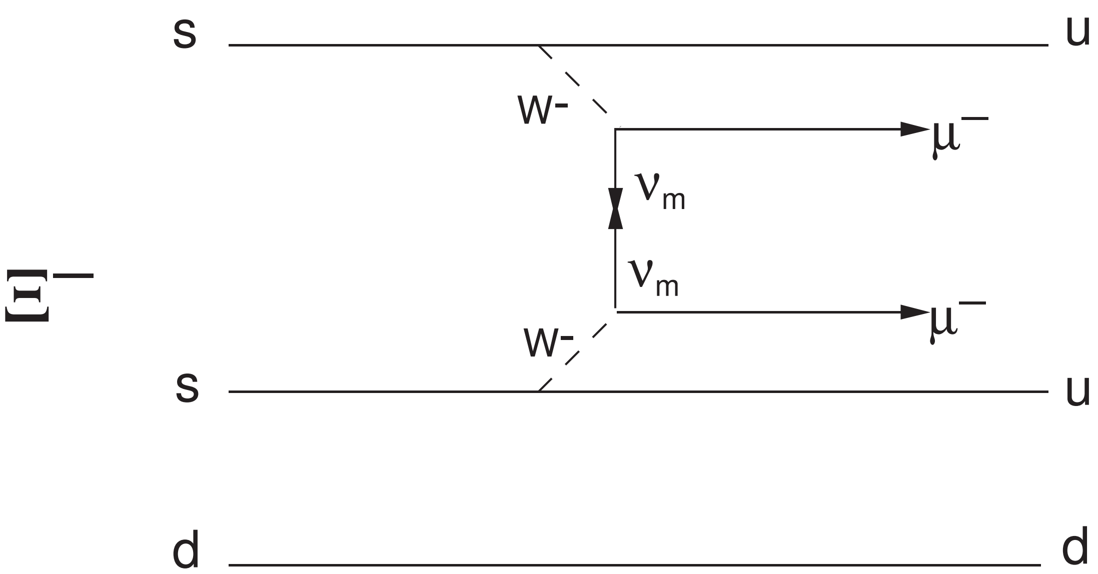
  Neutrino mass

  Lepton mixing

- Lepton-number violation could :

  imply the existence of a new ν type (Majorana)

  probe physics beyond the SM



s
u
W-
μ⁻
ν m
ν m
μ⁻
W-
s
u
d
d
Ξ⁻

Lepton-Number Violation in Hyperon Decays

- Only one reported search :

  1974 Experiment

  based on 6200 $\Xi^- \rightarrow \Lambda\pi^-$ events

  – *from retroactive analysis of data*

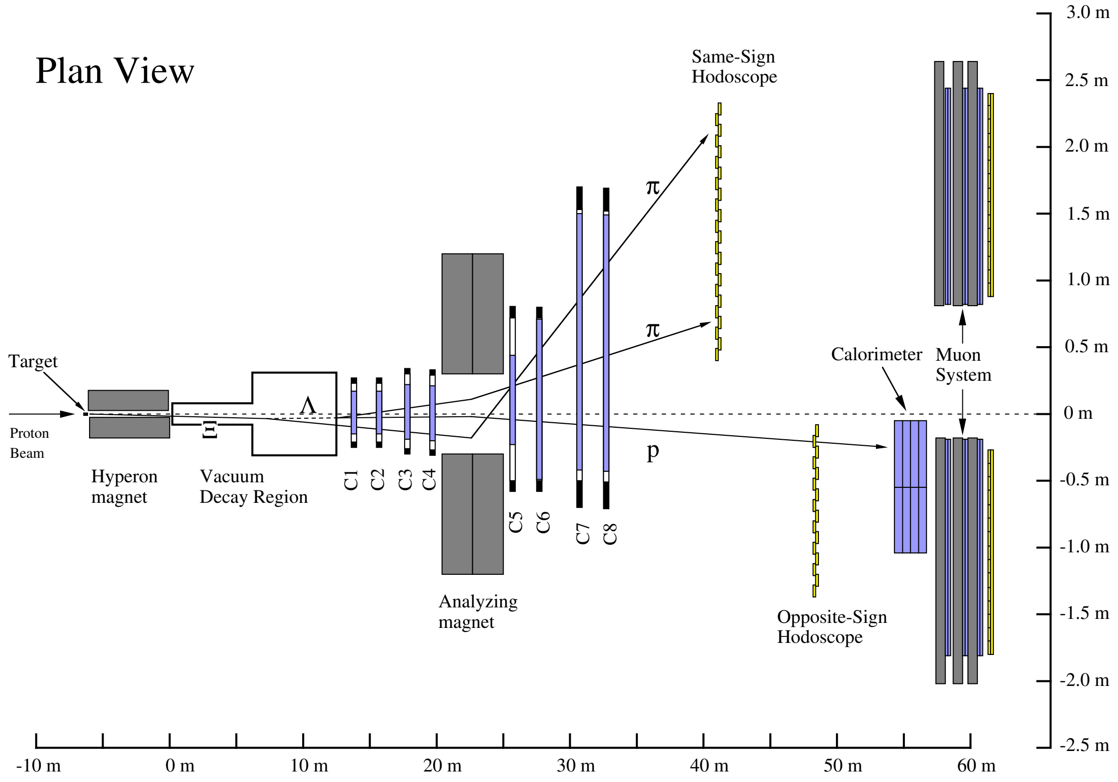
  Upper limit: $< 4 \times 10^{-4}$ @ 90% CL

- HyperCP – data-set *much larger*

  $\sim 2.5 \times 10^9$ $\Xi^- \rightarrow \Lambda\pi^-$ events

- Very sensitive search.

  Orders of magnitude better than existing limit



- HyperCP spectrometer: Plan View
- 800 GeV/c primary proton beam
- 160 GeV/c secondaries exit the Hyperon magnet
  - Negative-mode secondary beam contains Ξ^-
  - Positive-mode secondary beam contains $\overline{\Xi}^+$
- Four PWCs upstream of analysis magnet, four PWCs downstream
- Two trigger hodoscopes to form "left–right" trigger
- Muon station with μ trigger hodoscopes

Selection cuts

- final state must have 2 identified μ^-
- require 120 GeV/c $< p_{total} <$ 220 GeV/c
- $p_{proton} > \frac{1}{2}\, p_{total}$
- Ξ^- production must be from target
- exclude $\Xi^- \to \Lambda\pi^-, K^- \to \pi^-\pi^+\pi^-$ (eliminate π^- misidentified as μ^-)
- decay from a single vertex
- decay vertex must be within vacuum decay region
- no ghost tracks

Identifying muons

- Track extrapolated to muon station must:

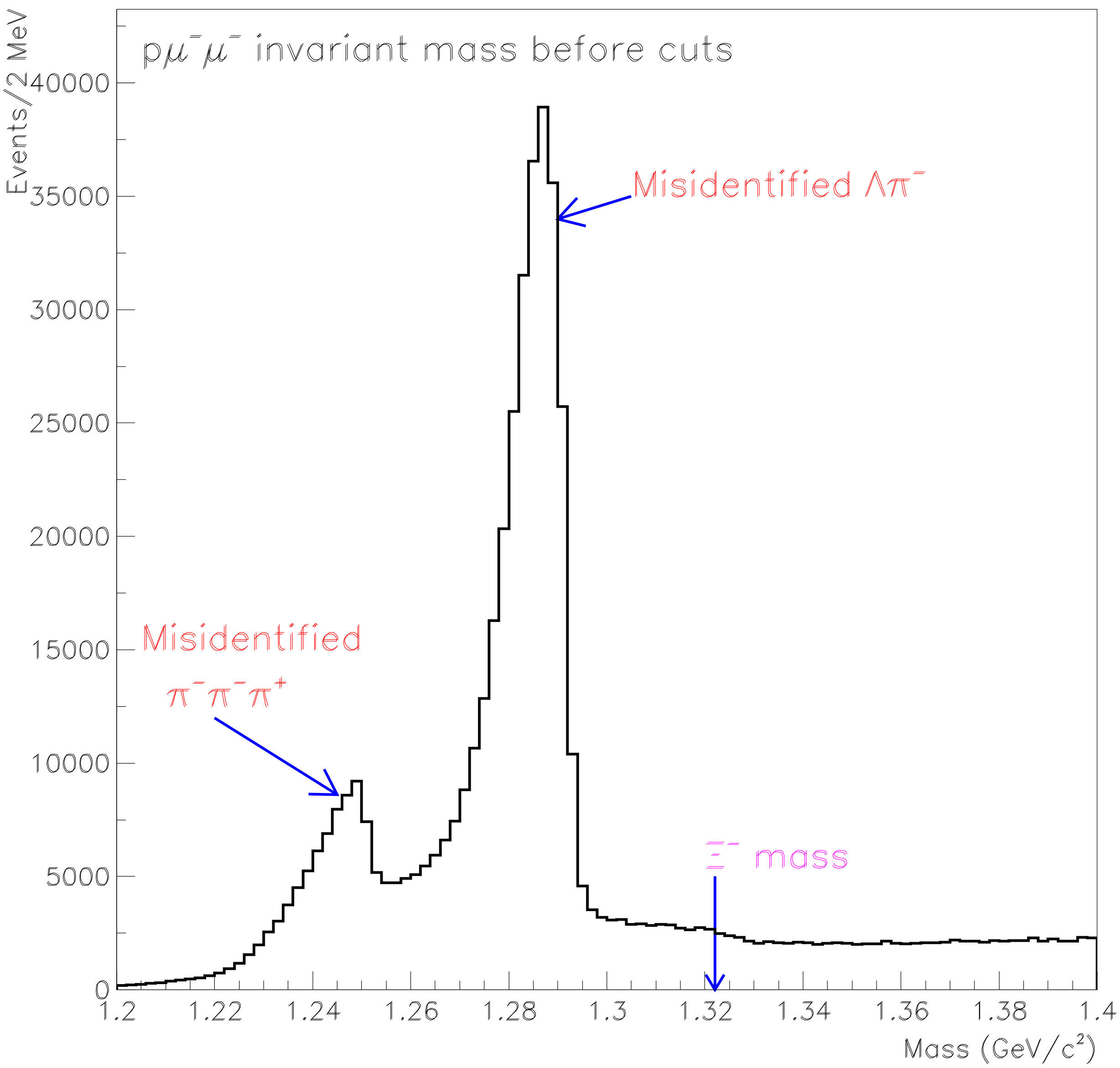
  have hits in x and y views

    in at least 2 of 3 chambers

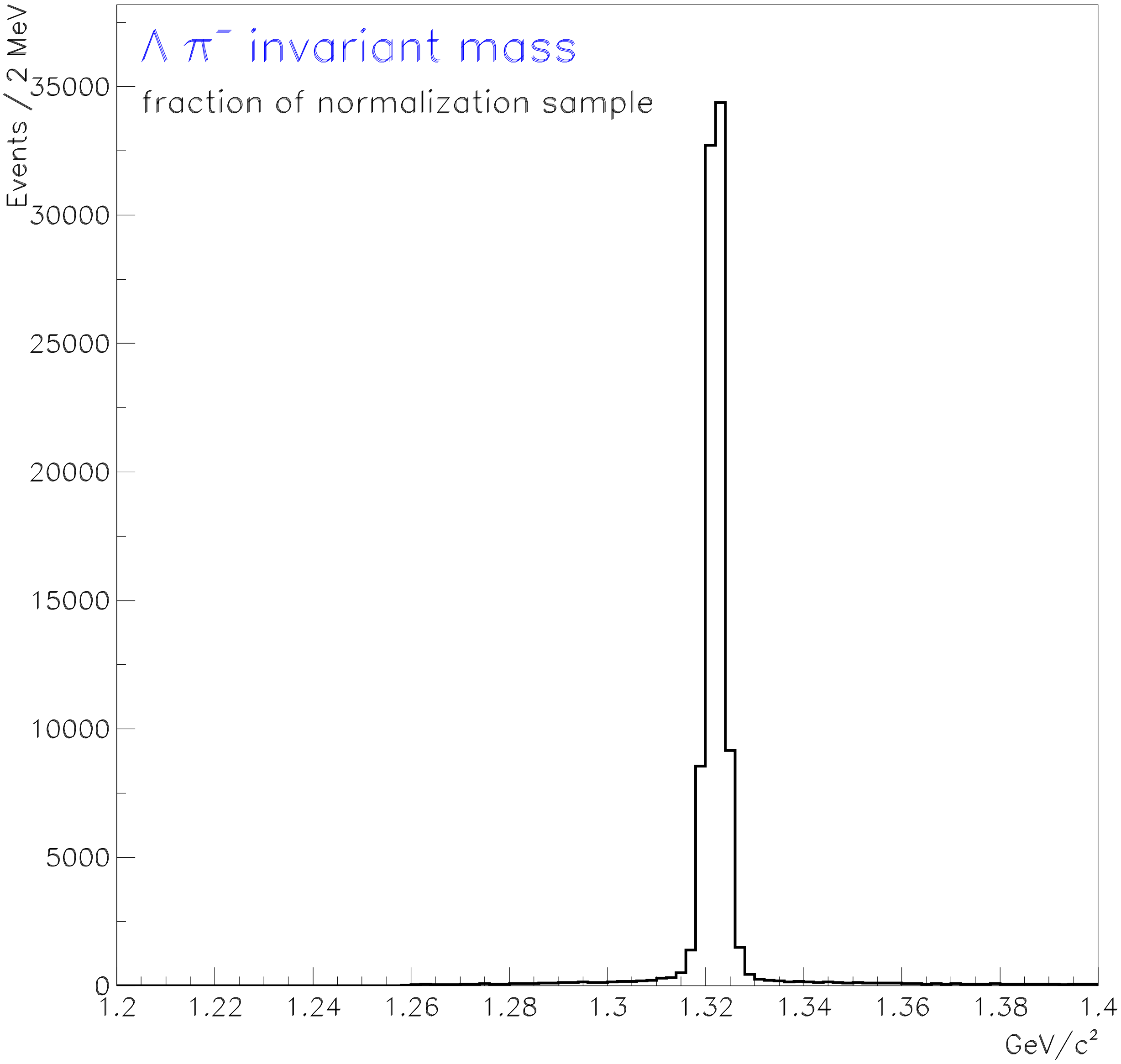
    hit must be $\pm$ 4.5 cm of track projection

  have hits in the muon hodoscope

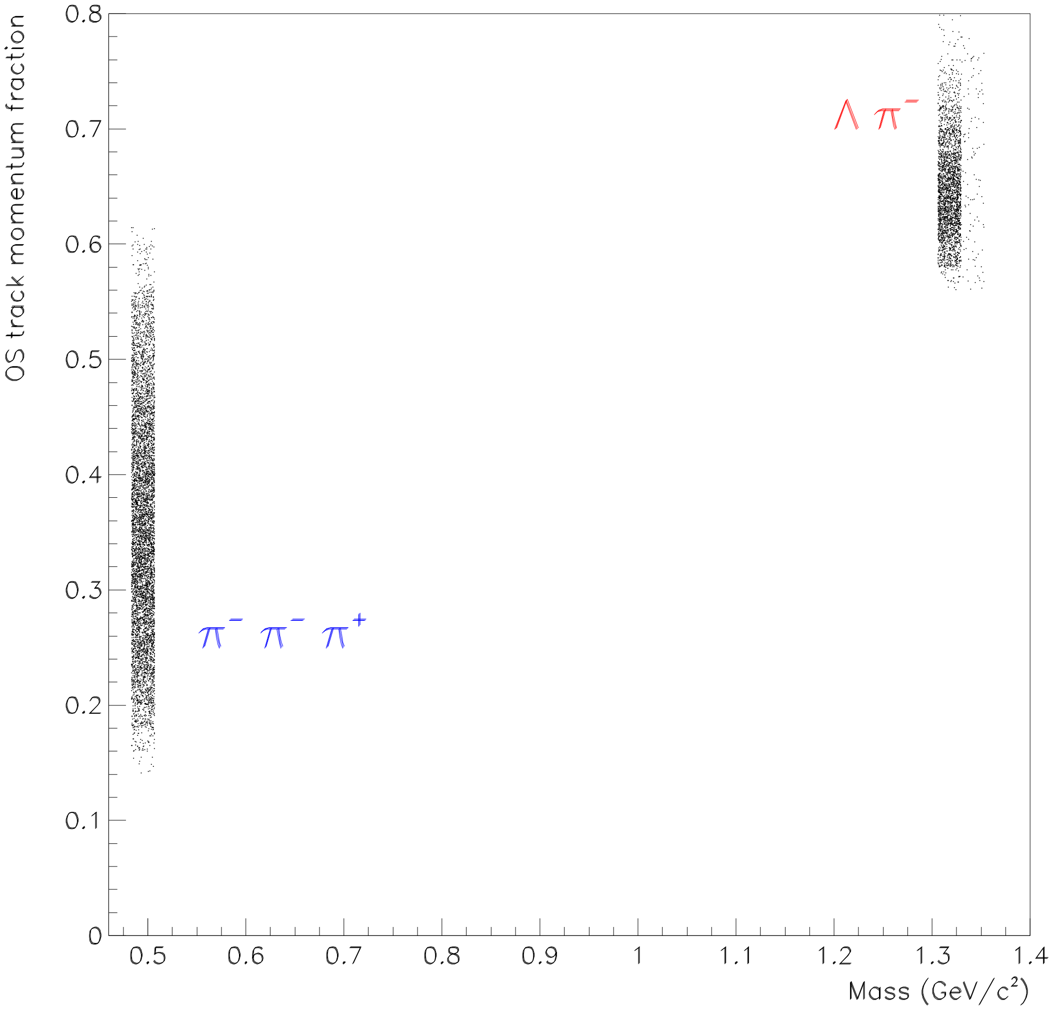
    x and y hits must be $\pm$ 10 cm of track projection



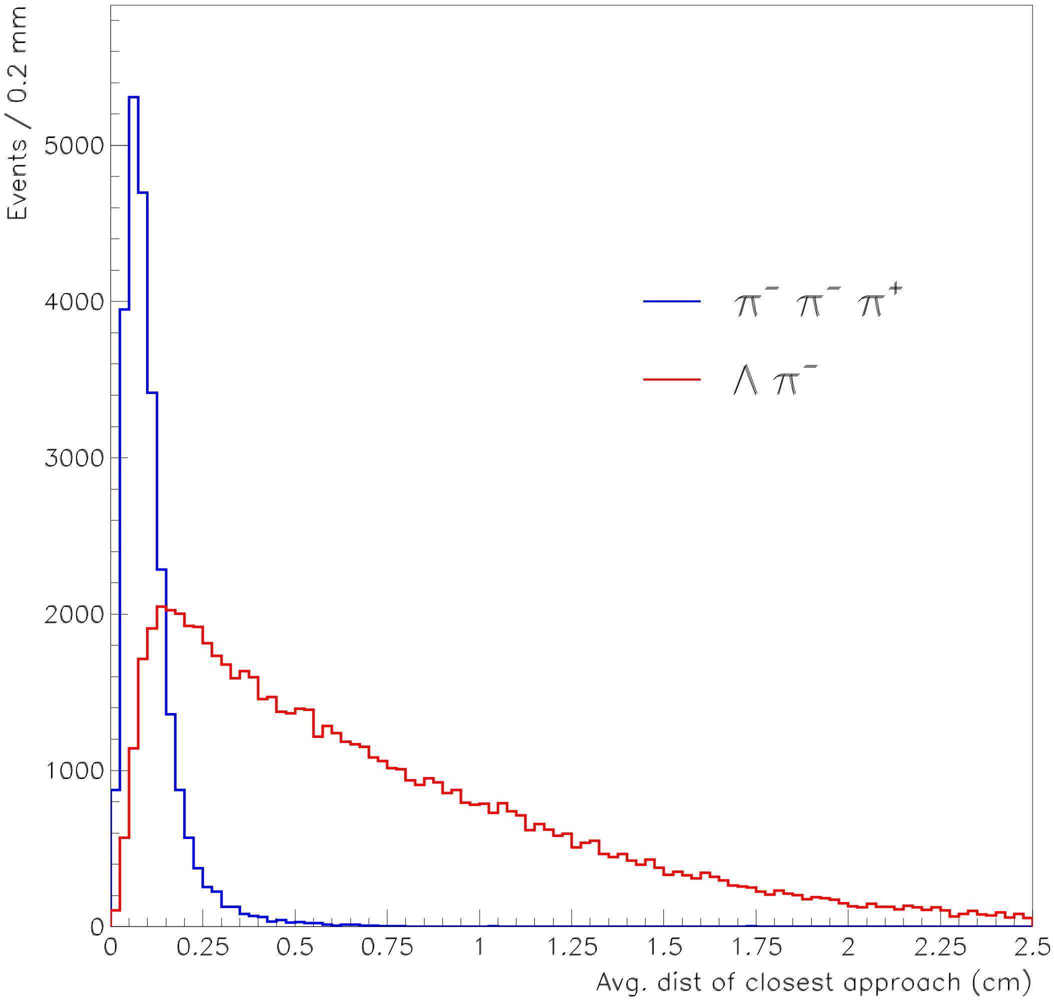
$p\mu^-\mu^-$ invariant mass before cuts
Events/2 MeV
Misidentified $\Lambda\pi^-$
Misidentified
$\pi^-\pi^-\pi^+$
Ξ^- mass
Mass (GeV/c^2)
0
5000
10000
15000
20000
25000
30000
35000
40000
1.2
1.22
1.24
1.26
1.28
1.3
1.32
1.34
1.36
1.38
1.4

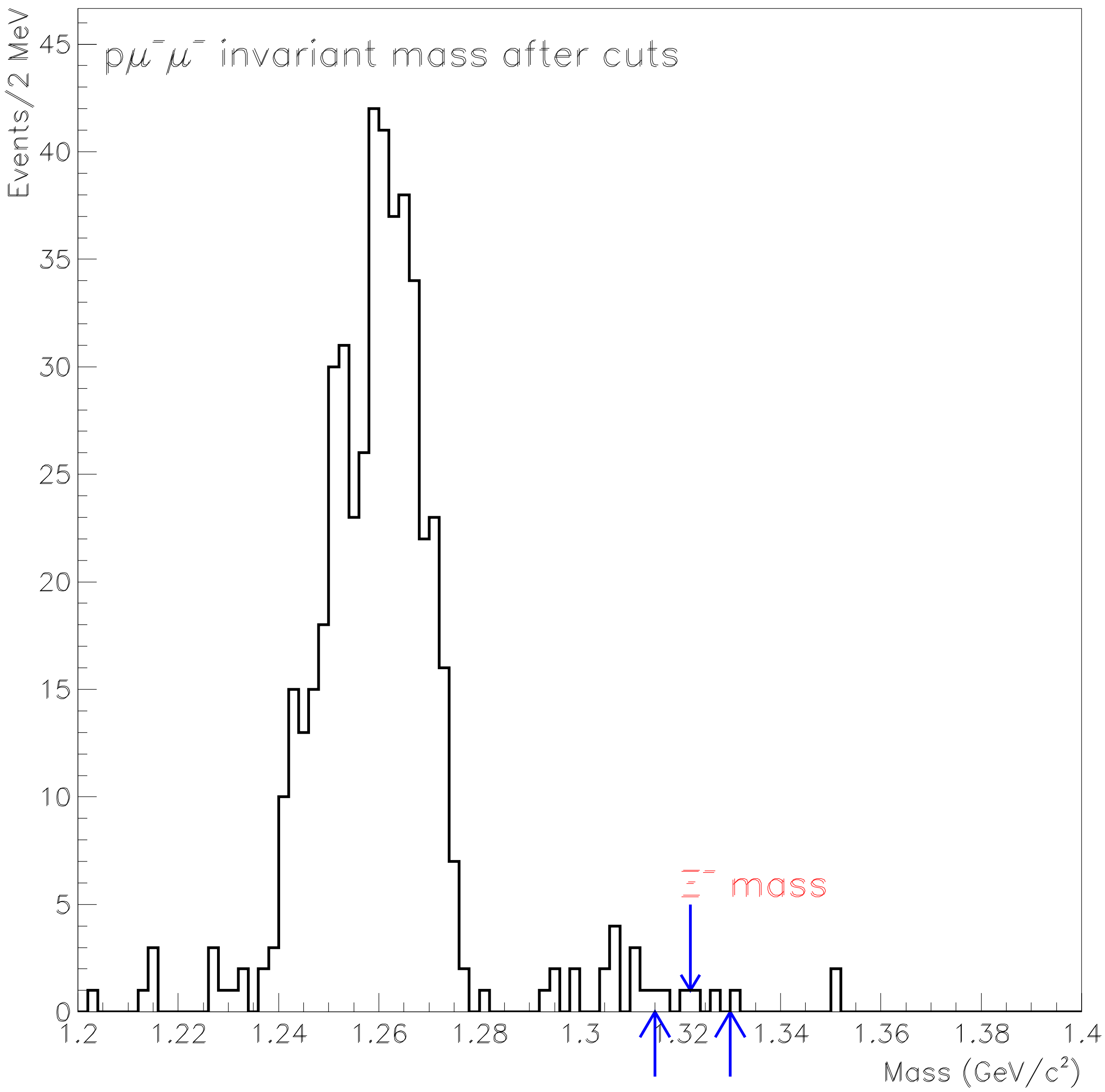


Λ π⁻ invariant mass
fraction of normalization sample
Events / 2 MeV
35000
30000
25000
20000
15000
10000
5000
0
1.2
1.22
1.24
1.26
1.28
1.3
1.32
1.34
1.36
1.38
1.4
GeV/c²



OS track momentum fraction
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Mass (GeV/c²)
$\Lambda\ \pi^-$
$\pi^-\ \pi^-\ \pi^+$


Events / 0.2 mm
0
1000
2000
3000
4000
5000
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Avg. dist of closest approach (cm)
$\pi^- \pi^- \pi^+$
$\Lambda \pi^-$



Events/2 MeV
$p\mu^-\mu^-$ invariant mass after cuts
0
5
10
15
20
25
30
35
40
45
1.2
1.22
1.24
1.26
1.28
1.3
1.32
1.34
1.36
1.38
1.4
Mass (GeV/c^2)
Ξ^- mass

Upper Limit

$$\frac{B(\Xi^- \to p\mu^-\mu^-)}{B(\Xi^- \to \Lambda\pi^-)} = \frac{n_{\Xi^- \to p\mu^-\mu^-}}{n_{\Xi^- \to \Lambda\pi^-}} \times (Relative\ Acceptance) \times \frac{1}{B(\Lambda \to p\pi^-)}$$

$$\frac{n_{p\mu^-\mu^-}}{n_{\Lambda\pi^-}} = \frac{5}{5.3 \times 10^8}$$

Relative Acceptance:

Geometric:

$$\frac{G_{\Lambda\pi^-}}{G_{p\mu^-\mu^-}} = \frac{28\%}{9.3\%}$$

Cuts:

$$\frac{C_{\Lambda\pi^-}}{C_{p\mu^-\mu^-}} = \frac{83\%}{27\%}$$

μ selection:

$$\frac{\epsilon_{\Lambda\pi^-}}{\epsilon_{p\mu^-\mu^-}} = \frac{1}{89\%}$$

Preliminary Upper Limit: $< 1.53 \times 10^{-7}$ @ 90% CL

Preliminary study of systematic effects

- Targeting in x and y:

  from Monte Carlo: $\sim 2\%$

- Muon selection:

  $\sim 1\%$

  run-by-run study incomplete

- Simulation of data:

  Ξ^- production parameters: $\sim 2\%$

Conclusion

HyperCP Preliminary Upper Limit:

$$\frac{B(\Xi^- \to p\mu^-\mu^-)}{B(\Xi^- \to \Lambda\pi^-)} < (1.53 \pm .05_{syst}) \times 10^{-7} \ @\ 90\% \ CL$$

PDG limit: $< 4{\times}10^{-4}$ @ 90% CL

PDG limit on $K^- \to \pi^+\mu^-\mu^-$: $< 1.5 \times 10^{-4}$