Rare Hyperon and Kaon Decays from FNAL E871

HyperCP

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for the HyperCP Collaboration

- Physics of Rare or Forbidden Decays
- HyperCP Data Set
- Muon Identification
- Observation of $K^+ \rightarrow \pi^+ \mu^+ \mu^-$
- New Limit for $\Xi^- \rightarrow p\ \mu^- \mu^-$
- Future

Motivation

Test of Conservation Laws

❶ Flavor-Changing Neutral Current:

Neutral current interactions do not change flavor in the SM.

HyperCP is sensitive to $s \rightarrow d + \mu + \mu$ transitions.

❷ Lepton Number Non-Conservation

Total number of leptons remains constant (?)

Total number within a family remains constant

❸ Change of Flavor by Two Units

Requires a second order weak interaction

Search for New Physics

Decays for which we have sensitivity

- FCNC Decays

$$K^+ \rightarrow \pi^+ \mu^+ \mu^-$$
$$\Sigma^+ \rightarrow p\ \mu^+ \mu^-$$

- Lepton Number Violation

$$\Xi^- \rightarrow p\ \mu^- \mu^-$$

- Decays where $\Delta S > 1$

$$\Xi^- \rightarrow p\ \pi^- \pi^-$$
$$\Xi^0 \rightarrow p\ \pi^-$$
$$\Omega^- \rightarrow \Lambda\ \pi^-$$
$$\Omega^- \rightarrow p\ K^- \pi^-$$
$$\Omega^- \rightarrow p\ \pi^- \pi^-$$

Data Set

- 15 MHz secondary beam
- 100 kHz trigger rate
- > 100 Terabytes of data

Number of Reconstructable Decays

- $\sim 10^9$ $\Xi^- \rightarrow \Lambda \pi^-$; $\Lambda \rightarrow p \pi^-$
- $\sim 10^8$ $K^+ \rightarrow \pi^+ \pi^+ \pi^-$
- $\sim 10^7$ $\Omega^- \rightarrow \Lambda K^-$; $\Lambda \rightarrow p \pi^-$

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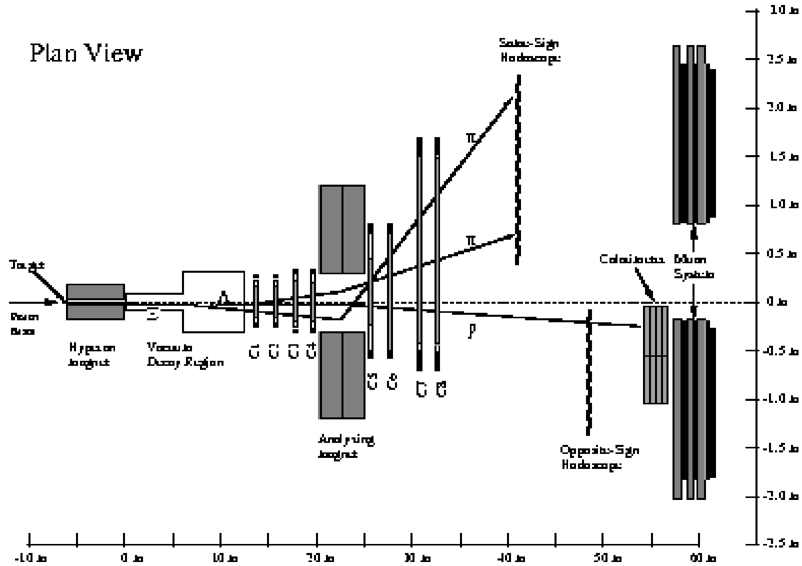
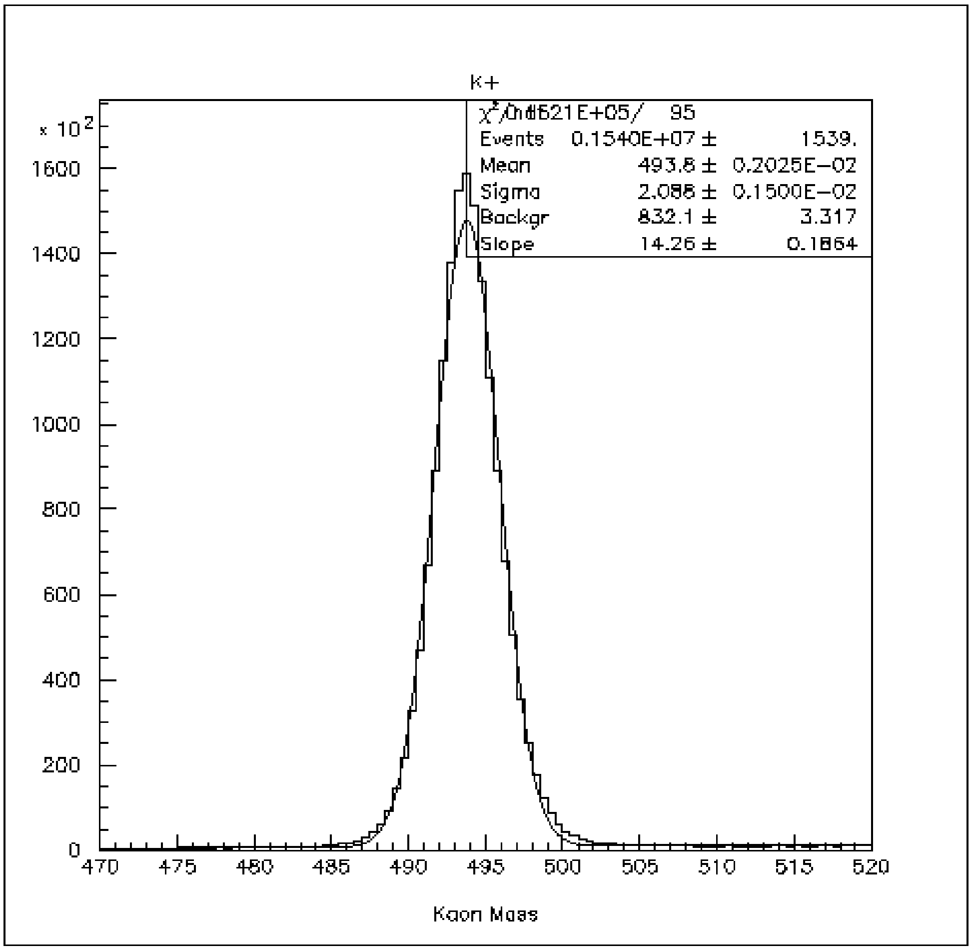


- HyperCP spectrometer: Plan View.
- 800 GeV/c primary proton beam.
- 160 GeV/c secondaries exit the Hyperon magnet.
  - Negative-mode secondary beam contains Ξ^-.
  - Positive-mode secondary beam contains $\overline{\Xi}^+$.
- Four PWCs upstream of analysis magnet, four PWCs downstream.
- Two trigger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

Observation of $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ and $K^- \rightarrow \pi^- \mu^+ \mu^-$

- E787: $(5.0 + 1.0) \times 10^{-8}$
- E865: $(9.2 + 0.8) \times 10^{-8}$
- PDG: $(8.3 + 2.2) \times 10^{-8}$



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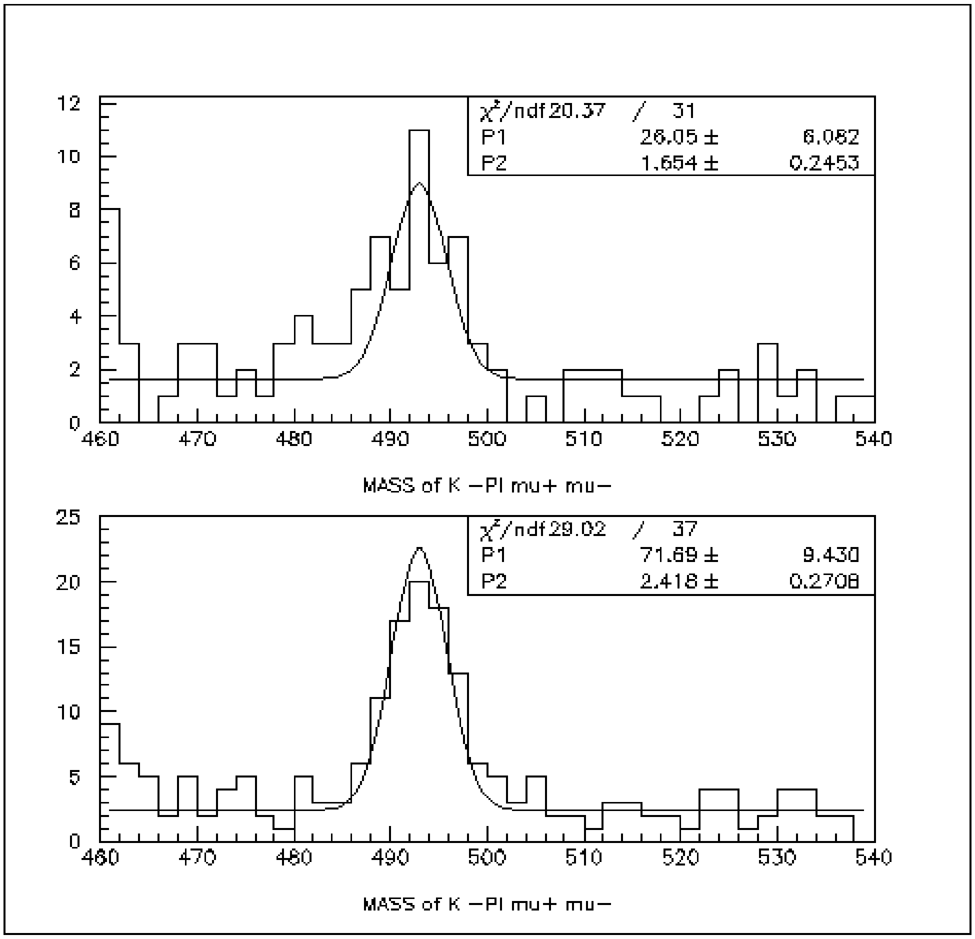

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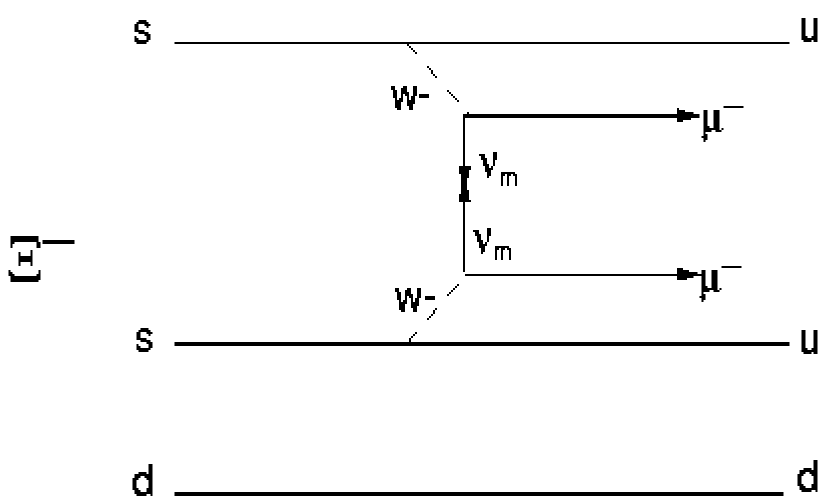
New Limit for $\Xi^- \rightarrow p\ \mu^- \mu^-$

PDG Limit: $< 4 \times 10^{-4}$



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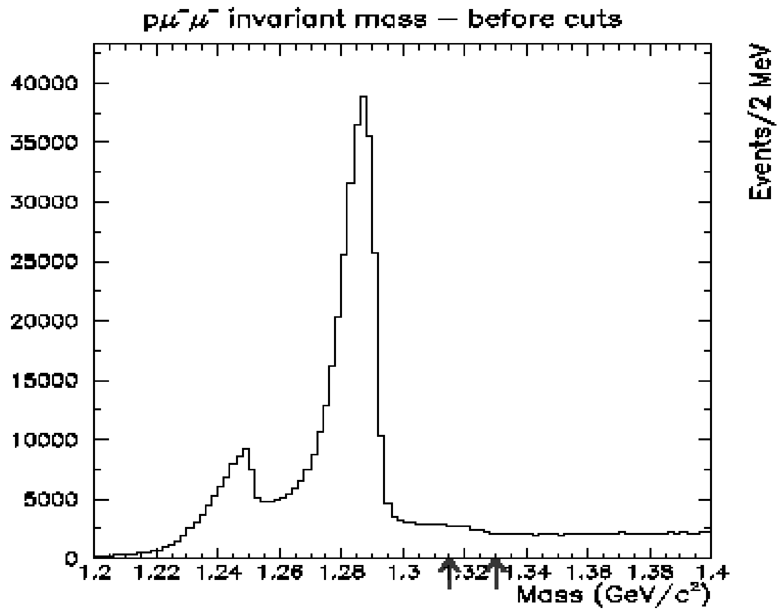

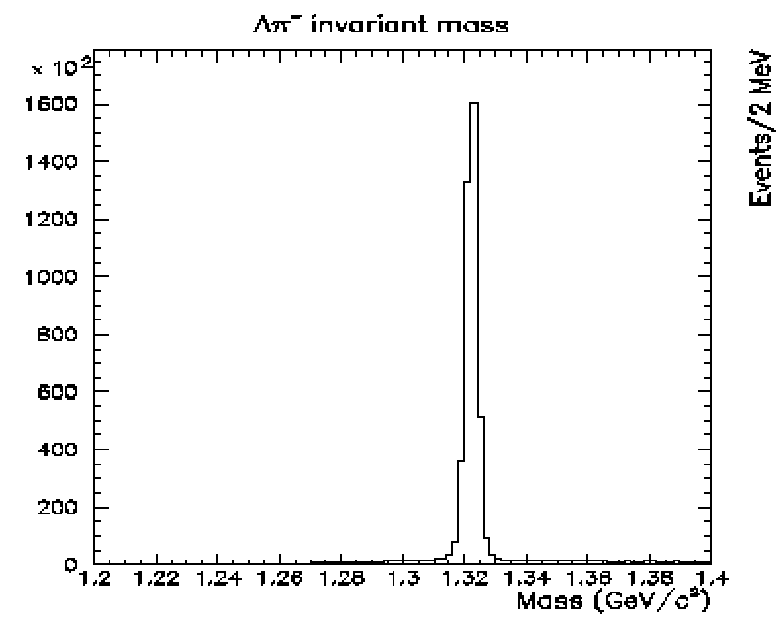

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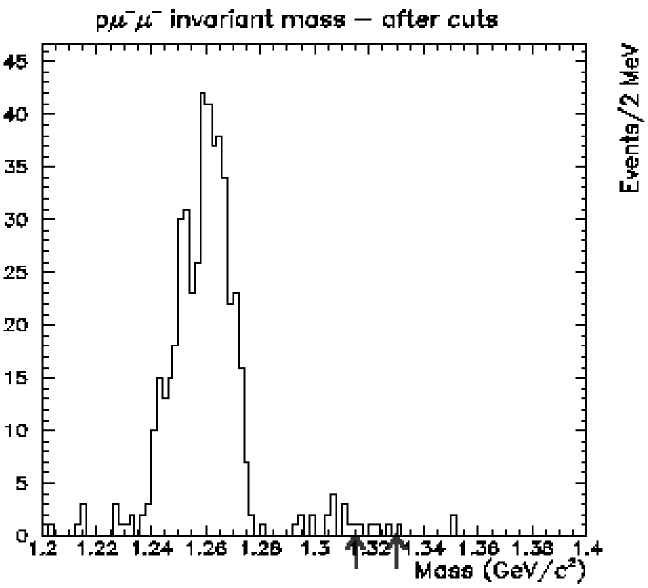

- $120 < p_{total} < 220$ GeV$/c$
- $p_{proton} > 0.6\ p_{total}$
- $50 < z_{vertex} < 1250$ cm
- $\mid x_{tgt} \mid < 0.5$ cm
- $\mid y_{tgt} - 6.55 \mid < 0.5$ cm
- decay from a single vertex
- not $\Lambda \rightarrow p\pi^-$
- not $K^- \rightarrow \pi^+\pi^-\pi^-$

Upper Limit

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

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

Relative Acceptance:

Geometric –

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

Reconstruction –

$$\frac{R_{\Lambda\pi^-}}{R_{p\mu^-\mu^-}} = \frac{94\%}{94\%}$$

Cuts –

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

Hardware –

$$\frac{\epsilon_{\Lambda\pi^-}}{\epsilon_{p\mu^-\mu^-}} = \frac{1}{98\%}$$

$$B(\Lambda \to p\pi^-) = 64\%$$

Preliminary Upper Limit: $< 1.5 \times 10^{-7}$ @ 90% CL

Future

- Complete $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ analysis
- Complete $\Sigma^+ \rightarrow p\ \mu^+ \mu^-$ analysis
- Complete the $\Delta S > 1$

- Additional Searches??

  K Short Decays

  Additional Hyperon Decays

  Additional Charged Kaon Decays