Report from the
Fermilab HyperCP Experiment

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E871 (HyperCP) Collaboration

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The HyperCP Experiment is at the Fermi National Accelerator Laboratory.

- The experiment took data in the 1997 fixed target run at Fermilab.
- Results presented here are PRELIMINARY ≈ 8% of sample.
- The HyperCP Experiment's primary physics goal is to look for CP violation in the decays of Ξ hyperons.

$$\begin{array}{llll} \Xi^- \to \Lambda\pi^- & & \overline{\Xi}^+ \to \overline{\Lambda}\pi^+ & \\ \quad\;\; \Lambda & \to p\,\pi^- & \quad\;\; \overline{\Lambda} & \to \overline{p}\pi^+ \end{array}$$

CP violation has only been observed in the decays of K^o's. And recently CDF observed indications of CP violation in B$^o_d \to J/\psi K^o_s$ decays.

- Other physics to be explored by the HyperCP Experiment include:
  - Search for CP violation in $K^\pm \to \pi^+\pi^-\pi^\pm$ decays,
    W. S. Choong QB08.08 3/24/99 (Wednesday) 11:00 AM.
  - Search for rare decays:

$$\left.\begin{array}{l} \Sigma^+ \to p\mu^+\mu^- \\ K^+ \to \pi^+\mu^+\mu^- \end{array}\right\}\text{FCNC}$$

$$\left.\begin{array}{ll} \Xi^- \to p\mu^-\mu- & \text{Later this session} \\ & \text{D. Rajaram, JB08.07} \\ \Sigma^- \to p\mu^-\mu^- & \\ K^+ \to \pi^-\mu^+\mu^+ & \end{array}\right\}\begin{array}{l}\text{Lepton}\\ \text{number}\\ \text{violation}\end{array}$$

  - Measurement of hyperon decay parameters.
  - Measurement of hyperon polarization.
  - Measurement of production cross sections.

Physics of CP Violation in Ξ decays

- The non-leptonic decay of the Ξ hyperon is described in terms of the Lee-Yang variables:

$$\alpha = \frac{2Re(S^*P)}{|S|^2+|P|^2} \ , \ \beta = \frac{2Im(S^*P)}{|S|^2+|P|^2} \ , \ \gamma = \frac{|S|^2-|P|^2}{|S|^2+|P|^2}$$

This is a parity violating decay, so S is the S wave amplitude and P is the P wave amplitude.

- Under CP operation, α and β change signs, γ is unchanged.
- The decay distribution for the daughter spin $\frac{1}{2}$ baryon in the rest frame of the parent hyperon is:

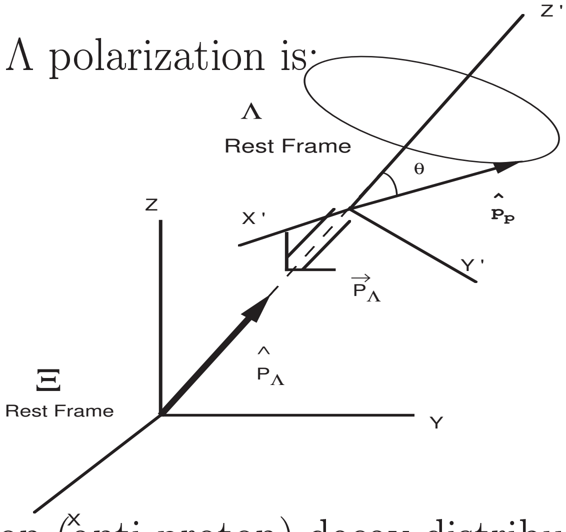
$$\frac{dP}{d\Omega} = \frac{1}{4\pi}(1 + \alpha\vec{P}_p \cdot \hat{p}_d)$$

- Where in the rest frame of the parent:
  - $\vec{P}_p$ is the parent hyperon polarization.
  - $\hat{p}_d$ is the daughter baryon momentum direction.
- The daughter baryon is polarized according to:

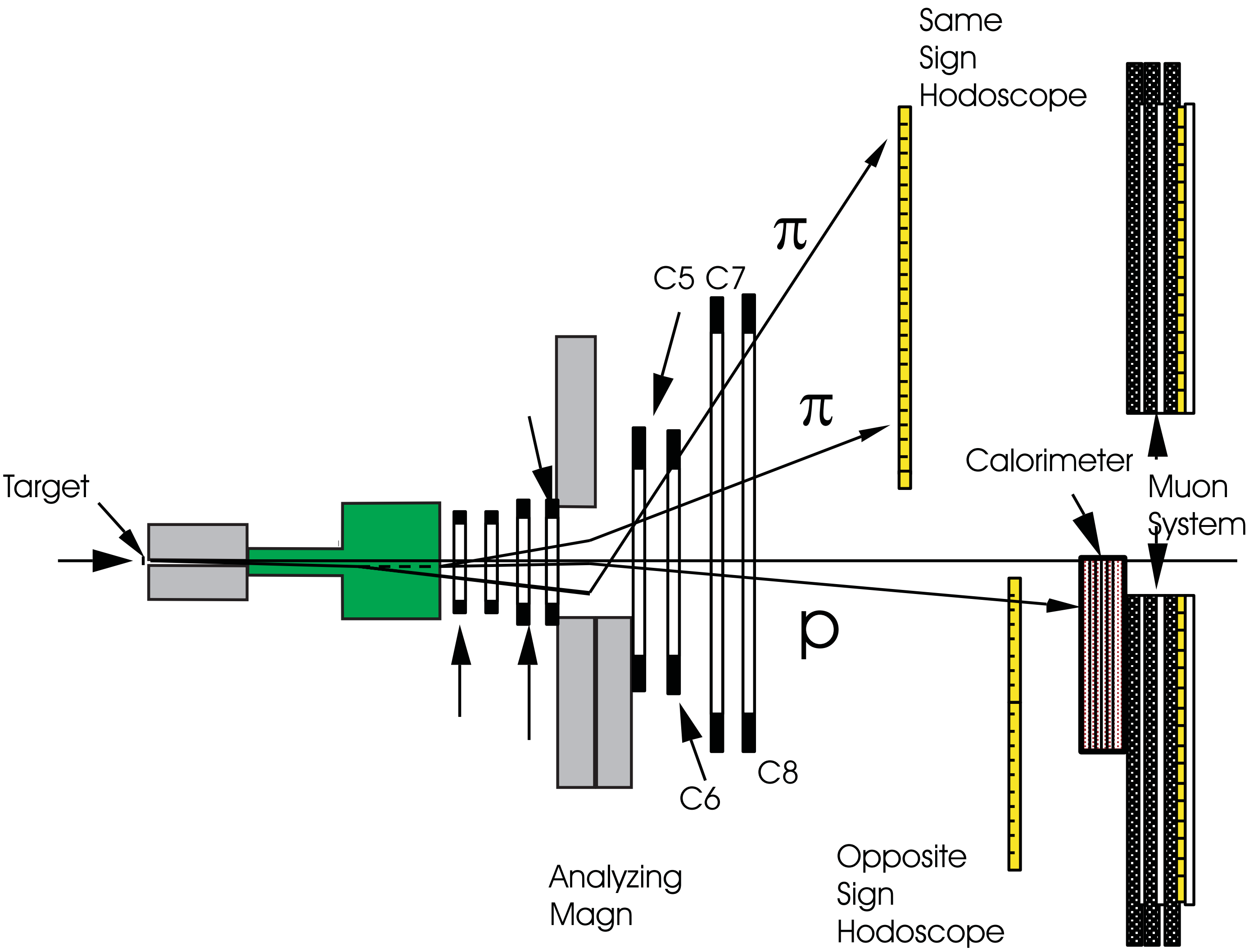
$$\vec{P}_d = \frac{(\alpha + \vec{P}_p \cdot \hat{p}_d)\hat{p}_d + \beta(\vec{P}_p \times \hat{p}_d) + \gamma(\hat{p}_d \times (\vec{P}_p \times \hat{p}_d))}{(1 + \alpha\vec{P}_p \cdot \hat{p}_d)}$$

- Where:
  - α, β, γ are the Lee-Yang variables of the parent.

The HyperCP Experiment uses unpolarized Ξ particles (O^o production angle).
As a result the daughter Λ polarization is:
$\vec{P}_\Lambda = \alpha_\Xi \hat{p}_\Lambda$



- The normalized proton (anti-proton) decay distribution is: $$\frac{\mathbf{dP}}{\mathbf{d}(\cos(\theta))} = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{1} + \alpha_{\boldsymbol{\Lambda}} \alpha_{\boldsymbol{\Xi}} \cos(\theta))$$
- Note the "Z" axis in the Λ rest frame is defined by the Λ direction in the Ξ rest frame.
- "θ" is the polar angle of the proton (or anti-proton) in the Λ rest frame.
- Any differences in the angular distributions of the proton from Ξ^- decays and anti-proton from $\overline{\Xi}^+$ decays is a signature of CP Violation.
- A CP asymmetry variable may be constructed: $$\mathcal{A}_{\Xi\Lambda} = \frac{\alpha_\Lambda \alpha_\Xi - \alpha_{\overline{\Lambda}} \alpha_{\overline{\Xi}}}{\alpha_\Lambda \alpha_\Xi + \alpha_{\overline{\Lambda}} \alpha_{\overline{\Xi}}} \approx A_\Xi + A_\Lambda$$
- The CP violating asymmetry is measuring the difference in the parity violation between particle and anti-particle.


Same
Sign
Hodoscope
π
C5 C7
π
Calorimeter
Muon
System
Target
p
C8
C6
Analyzing
Magn
Opposite
Sign
Hodoscope