International Journal of Modern Physics A,

SEARCH FOR DIRECT CP VIOLATION IN HYPERON DECAYS

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Fermilab experiment E871, HyperCP, is designed to search for evidence of direct CP violation in Cascade and Lambda hyperon decays. The asymmetry of the angular distribution of the proton in the Lambda helicity frame between $\Xi^- \to \Lambda + \pi^-$, $\Lambda \to p+\pi^-$ and the charge-conjugate decays, will be measured. During the 1997 and 1999 fixed target runs at Fermilab HyperCP collaboration collected billions of Cascade and anti-Cascade decays that would make it possible to probe this asymmetry at the 10^{-4} statistical level. The status of the data analysis is described.

1. Phenomenology of Nonleptonic Hyperon Decays

Parity violating $\Delta S = 1$ decay of spin 1/2 strange baryon into a spin 1/2 baryon and pion, e.g. $\Lambda \to p+\pi^-$, depends on the decay parameter α_Λ that measures the interference between the S-wave and P-wave final states, $\alpha_\Lambda = 2Re(S^*P)/(|S|^2 + |P|^2)$.[1] If CP transformation is conserved then the decay parameter, $\alpha_{\overline{\Lambda}}$, of the charge-conjugate decay, $\overline{\Lambda} \to \overline{p}+\pi^+$, has the same magnitude but reversed sign, $\alpha_{\overline{\Lambda}} = -\alpha_\Lambda$. One can form an asymmetry $A_\Lambda = (\alpha_\Lambda + \alpha_{\overline{\Lambda}})/(\alpha_\Lambda - \alpha_{\overline{\Lambda}})$ to measure the amount of direct CP violation in the decay. The Λ particles produced from the decay of $\Xi^- \to \Lambda + \pi^-$ are longitudinally polarized with the polarization given by the Ξ decay parameter α_Ξ. The angular distribution of the proton in the lambda rest frame is linear with respect to the cosine of the angle θ between the momentum of the proton and the helicity axis of the lambda, $dn/dcos\theta = (1+\alpha_\Lambda\alpha_\Xi \cos\theta)/2$. The asymmetry $A_{\Lambda\Xi}$ in slopes of the distributions for the $\Xi^- \to \Lambda + \pi^-$, $\Lambda \to p + \pi^-$ decay sequence and the charge conjugation of it is sensitive to CP violation in both Ξ and Λ decays, $A_{\Lambda\Xi} = (\alpha_\Lambda\alpha_\Xi - \alpha_{\overline{\Lambda}}\alpha_{\overline{\Xi}}) \,/\, (\alpha_\Lambda\alpha_\Xi + \alpha_{\overline{\Lambda}}\alpha_{\overline{\Xi}}) \approx A_\Lambda + A_\Xi$.

2. Current Experimental Results and Theoretical Predictions

Several experiments have measured the value of the asymmetries A_Λ and $A_{\Lambda\Xi}$. The results are given in Table 1. The measured asymmetries are consistent with zero at

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Table 1. Measurements of direct CP violation in hyperon decays.

Experiment	Decay Mode	A_Λ
R608 at ISR[2]	$pp \to \Lambda X$, $pp \to \bar{\Lambda} X$	-0.02 $\pm$ 0.14
DM2 at Orsay[3]	$e^+e^- \to J/\Psi \to \Lambda\bar{\Lambda}$	0.01 $\pm$ 0.10
PS185 at LEAR[4]	$p\bar{p} \to \Lambda\bar{\Lambda}$	-0.013 $\pm$ 0.022
Experiment	Decay Mode	$A_\Lambda + A_\Xi$
CLEO at CESR[5]	$\Xi \to \Lambda\pi$, $\Lambda \to p\pi$	-0.057 $\pm$ 0.075
E756 at Fermilab[6]	$\Xi \to \Lambda\pi$, $\Lambda \to p\pi$	0.012 $\pm$ 0.014

the 10^{-2} level. Predictions of the Standard Model give $A_{\Lambda\Xi} \approx 10^{-4} - 10^{-5}$ while recent SUSY calculation estimates that A_Λ could be as large as 2 x 10^{-3}.[7,8]

3. HyperCP Experiment

The HyperCP spectrometer was built for measuring $A_{\Lambda\Xi}$ to a precision of 1 x 10^{-4}.[9] The 800 GeV protons are scattered off a copper target. The secondary beam is selected by a collimator placed in 6-m long dipole magnet with a vertical field of 1.67 T. This hyperon channel is followed by a 13-m long vacuum pipe in which most cascades, with a mean momentum of 165 GeV, decay. Eight proportional multi-wire chambers with a pitch ranging from 1 mm at the front to 2 mm at the rear are used to track the charged particles. The momentum is measured by a set of two horizontally bending dipoles located between four front and four rear chambers . The main trigger consisted of two hodoscopes covering the left (SS) and right (OS) parts of the spectrometer and a hadronic calorimeter on the OS side. The cascade trigger required a coincidence of one SS and one OS hodoscope hits, and a minimum energy of $\sim$60 GeV deposited in the calorimeter. The polarities of both the magnetic collimator and the momentum analyzing magnets were reversed between Ξ^- and $\overline{\Xi}^+$ running assuring CP invariant spectrometer and trigger geometries.

The HyperCP experiment collected more than 110 TB of data during the 1997 and 1999 fixed target runs at FNAL. The projected number of reconstructed particles is: 2×10^9 Ξ^- and 0.5×10^9 $\overline{\Xi}^+$, 0.13×10^9 $K^-_{3\pi}$ and 0.32×10^9 $K^+_{3\pi}$, 14×10^6 Ω^- and 5.3×10^6 $\overline{\Omega}^+$. This amount of cascade decays will allow us to probe direct CP violation in terms of asymmetry $A_{\Lambda\Xi}$ with a statistical precision of 1.4 x 10^{-4}.

4. Status of various analyses

Since the end of the 1999 run we have established a consistent alignment of the spectrometer for the 1997 and 1999 runs and have been processing data using the Fermilab Batch System farms. Reconstructed masses of Ξ and Ω of some samples are shown in Figure (1). Several analyses are in progress:
CP violation in Ξ, Λ decays;
CP violation in $K \to 3\pi$ decay;
Measurement of the decay parameter α of $\Omega^- \to \Lambda K^-$;
Measurement of the decay parameter β of $\Xi^- \to \Lambda\pi^-$;
Measurement of production polarization of Ξ and Ω;
Production cross sections;
Searches for rare and forbidden decays (see C. G. White, this proceedings).

The possible systematic effects for the CP measurement have been identified and are under study. These include nonzero production polarization of Ξ^- and $\overline{\Xi}^+$, different interactions between π^+/π^- and $p/\overline{p}$ with the materials in the spec-

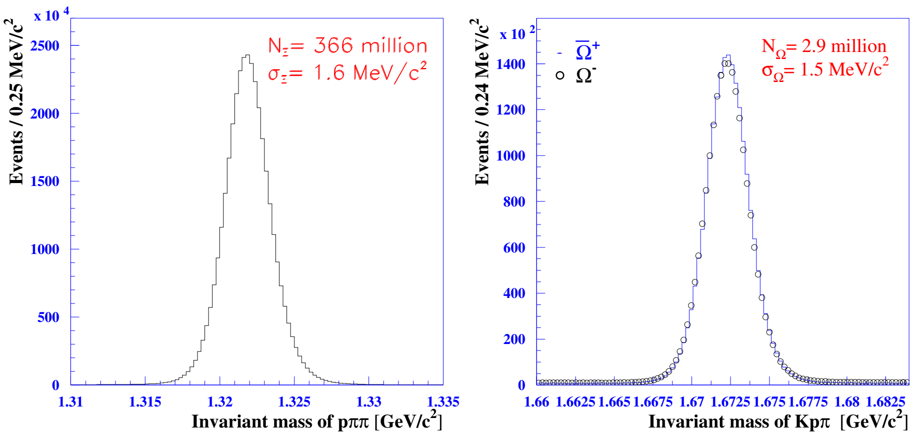

Fig. 1. Reconstructed masses of $\Xi^{\pm}$ and $\Omega^{\pm}$ decays.

trometer, differences in backgrounds for Λ, Ξ^- versus $\overline{\Lambda}$, $\overline{\Xi}^+$, acceptance differences caused by changes in targeting, magnetic field, chamber and trigger efficiencies and production dynamics. All of the above effects could be corrected for, if needed.

5. Summary

The HyperCP experiment, Fermilab E871, ran successfully in 1997 and 1999, and had collected the largest samples of Ξ^- and $\overline{\Xi}^+$ decays in the world. The projected statistical sensitivity of CP asymmetry in Ξ, Λ decays is 1.4 x 10^{-4}, two orders of magnitude better than the present limit and where some theories predict an effect. Processing of data will continue for the next several months. Detailed systematic studies are in progress. The large samples of Ξ, Ω and K decays allow us to make a variety of precise measurements and rare-decay searches.

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