Search for CP Violation in Hyperon Decays with the *HyperCP* Spectrometer at Fermilab

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*for the HyperCP collaboration*

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Why Search for \( CP \) Violation in Hyperon Decays?

- After 40 years of intense experimental effort — and many beautiful experiments — we still know little about \( CP \) violation: the origin of \( CP \) violation remains unknown and there is little hard evidence that it is explained by the Standard Model.

- The asymmetry can be relatively large: up to \( 1 \times 10^{-2} \).

- The price is modest:
  - No new accelerators needed.
  - Apparatus is modest in scope and cost.

- Hyperons are sensitive to sources of \( CP \) violation that, for example, kaons are not.

- \( CP \) violation is too important, and experimental evidence is too meagre, not to examine every possible manifestation of the effect.

“We are willing to stake our reputation on the prediction that dedicated and comprehensive studies of \( CP \) violation will reveal the presence of New Physics.”

*Bigi and Sanda, CP Violation*
How to Search for $CP$ Violation in $\Lambda$ Decays

Due to parity violation the proton likes to go in the direction of the $\Lambda$ spin:

$$\Lambda \rightarrow p\pi^- : \quad \frac{dN(p)}{d\cos \theta} = \frac{N_0}{2} (1 + \alpha_\Lambda P_\Lambda \cos \theta) \quad \alpha = \frac{2 \text{Re}(S^*P)}{|S|^2 + |P|^2}$$

Under $CP$ the antiproton likes to go in the direction opposite to the $\bar{\Lambda}$ spin:

$$\alpha_\Lambda \xrightarrow{CP} \bar{\alpha}_\Lambda = -\alpha_\Lambda$$
Problem: Producing $\Lambda$’s of Known Polarization

$\Lambda/\bar{\Lambda}$’s of known polarization can be produced through the decay of unpolarized $\Xi^-/\Xi^+$’s:

$$\Xi^- \rightarrow \Lambda\pi^- \quad \Xi^+ \rightarrow \bar{\Lambda}\pi^+$$

If the $\Xi$ is produced unpolarized — which can simply be done by targeting at 0 degrees — then the $\Lambda$ is found in a helicity state:

$$\vec{P}_\Lambda = \alpha_\Xi \hat{p}_\Lambda$$

$$\vec{P}_\bar{\Lambda} = \bar{\alpha}_\Xi \hat{p}_\bar{\Lambda}$$

$$\frac{dN(p)}{d\cos\theta} = \frac{N_0}{2}(1 + \alpha_\Lambda \alpha_\Xi \cos\theta)$$

$$\frac{dN(\bar{p})}{d\cos\theta} = \frac{N_0}{2}(1 + \bar{\alpha}_\Lambda \bar{\alpha}_\Xi \cos\theta)$$

If $CP$ is good, the slopes of the proton and antiproton $\cos\theta$ distributions are identical, and:

$$\alpha_\Xi \alpha_\Lambda = \bar{\alpha}_\Xi \bar{\alpha}_\Lambda$$

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

slope = $\alpha_\Lambda \alpha_\Xi$

$$\Xi^+ \rightarrow \bar{\Lambda}\pi^+ \rightarrow \bar{p}\pi^+ \pi^+$$

slope = $\bar{\alpha}_\Lambda \bar{\alpha}_\Xi$
We are sensitive to both $\Xi$ and $\Lambda$ CP violation

$$A_{\Xi\Lambda} = \frac{\alpha_{\Xi}\alpha_{\Lambda} - \overline{\alpha}_{\Xi}\overline{\alpha}_{\Lambda}}{\alpha_{\Xi}\alpha_{\Lambda} + \overline{\alpha}_{\Xi}\overline{\alpha}_{\Lambda}} \approx A_{\Xi} + A_{\Lambda}$$

where: $A_{\Xi} = \frac{\alpha_{\Xi} + \overline{\alpha}_{\Xi}}{\alpha_{\Xi} - \overline{\alpha}_{\Xi}}$ and $A_{\Lambda} = \frac{\alpha_{\Lambda} + \overline{\alpha}_{\Lambda}}{\alpha_{\Lambda} - \overline{\alpha}_{\Lambda}}$

What we experimentally measure is the slope of the proton (antiproton) $\cos(\theta)$ distribution in the special $\Lambda$ rest frame where the $\Lambda$ momentum direction in the $\Xi$ rest frame defines the polar axis: the Lambda Helicity Frame.
Phenomenology of CP Violation in \(\Xi\) and \(\Lambda\) Decay

- CP violation in \(\Xi\) and \(\Lambda\) decays is manifestly direct with \(\Delta S = 1\).
- Three ingredients are needed to get a non-zero asymmetry:
  1. At least two channels in the final state: the \(S\)-and \(P\)-wave amplitudes.
  2. The CP violating weak phases must be different in the two channels.
  3. There must be unequal final-state scattering phase shifts in the two channels.

\[
A_\Lambda = \frac{(\alpha_\Lambda + \alpha_\Lambda)}{(\alpha_\Lambda - \alpha_\Lambda)} \cong - \tan(\delta_P - \delta_S) \sin(\phi_P - \phi_S),
\]

\[
A_\Xi = \frac{(\alpha_\Xi + \alpha_\Xi)}{(\alpha_\Xi - \alpha_\Xi)} \cong - \tan(\delta_P - \delta_S) \sin(\phi_P - \phi_S).
\]

- Asymmetry greatly reduced by the small strong phase shifts.
  - The \(p\pi\) phase shifts have been measured to a precision of about one degree:
    \[
    \Lambda \left\{ \begin{array}{c}
    \delta_P = -1.1 \pm 1.0^\circ \\
    \delta_S = 6.0 \pm 1.0^\circ
    \end{array} \right. 
    \]
  - The \(\Lambda\pi\) phase shifts can’t be measured, and theoretical predictions disagree.
    \[
    \Xi^- \left\{ \begin{array}{c}
    \delta_P = -2.7^\circ \\
    \delta_S = -18.7^\circ
    \end{array} \right. \text{ 1965 } \left\{ \begin{array}{c}
    = -1^\circ \\
    = 0^\circ
    \end{array} \right. \text{ recent } \chi PT
    \]

HyperCP has measured the \(\Lambda\pi\) phase shift: \((4.6 \pm 1.4 \pm 1.8)^\circ\)
What do we Expect: Theoretical Predictions

- Standard Model predictions range from about $10^{-4}$ – $10^{-5}$. Beware
  
  "Given our crude estimate of the hadronic matrix elements involved, all our numerical results should be viewed with caution.”


- Beyond-the-standard-model predictions larger, and not well constrained by kaon CP measurements: hyperon CP violation probes both parity conserving and parity violating amplitudes.

  Recent preprint by Tandean (hep-ph/0311036) shows that the upper bound on $A_{\Xi A}$ is $\sim 100 \times 10^{-4}$.

- For example, some supersymmetric models that do not generate $\epsilon'/\epsilon$ can lead to $A_\Lambda$ of $O(10^{-3})$. 

He et al., PRD 61 (2000) 071701(R).
What is the experimental situation?

- There are no limits on $A_\Xi$.
- $A_A$ has been measured to $2 \times 10^{-2}$.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Method</th>
<th>Limit</th>
<th>Exp</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_A$</td>
<td>$p \bar{p} \rightarrow \Lambda X$, $p \bar{p} \rightarrow \bar{\Lambda} X$</td>
<td>$-0.02 \pm 0.14$</td>
<td>R608</td>
<td>1985</td>
</tr>
<tr>
<td>$A_A$</td>
<td>$e^+e^- \rightarrow J/\psi \rightarrow \Lambda \bar{\Lambda}$</td>
<td>$0.01 \pm 0.10$</td>
<td>DM2</td>
<td>1988</td>
</tr>
<tr>
<td>$A_A$</td>
<td>$p \bar{p} \rightarrow \Lambda \bar{\Lambda}$</td>
<td>$0.010 \pm 0.022$</td>
<td>PS185</td>
<td>1998</td>
</tr>
</tbody>
</table>

- There is a recent measurement of $A_{\Xi A}$, based on the $HyperCP$ technique.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Method</th>
<th>Limit</th>
<th>Exp</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{\Xi A}$</td>
<td>$pN \rightarrow \Xi \pi \rightarrow \Lambda \pi \rightarrow p \pi \pi$</td>
<td>$0.012 \pm 0.014$</td>
<td>E756</td>
<td>2000</td>
</tr>
</tbody>
</table>

- This measurement of $A_{\Xi A}$ can be used with measurements of $A_A$ to infer a limit on $A_\Xi$.
- None of these measurements is in the regime of testing theory.
- $HyperCP$ is pushing two orders of magnitude beyond the best limit, to $\sim 10^{-4}$. 
New High-Rate Spectrometer Built

- 800 GeV/c incident proton beam.
- 10–15 MHz, 167 GeV/c secondary beam.
- Low-mass, high-rate, narrow-pitch wire chambers.
- Very high-rate DAQ:
  - 50-80 KHz evts/spill/s to tape.
  - 27 MB/s on 27 Exabyte 8705 tape drives.

- Simple, low-bias trigger using hodoscopes and calorimeter.
  \[ SS(\geq 1 \text{ hit}) \cdot OS(\geq 1 \text{ hit}) \cdot Cal(\geq 40 \text{ G eV}) \]
- Muon system for rare and forbidden hyperon and kaon decays.


HyperCP Yields

- In 12 months of data taking we recorded one the largest data samples ever by a particle physics experiment: 231 billion events, 29,401 tapes, and 119.5 TB data.

Events

<table>
<thead>
<tr>
<th>Year</th>
<th>Trigger</th>
<th>1997</th>
<th>1999</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cascade</td>
<td>$39 \times 10^9$</td>
<td>$81 \times 10^9$</td>
<td>$120 \times 10^9$</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>$58 \times 10^9$</td>
<td>$173 \times 10^9$</td>
<td>$231 \times 10^9$</td>
</tr>
</tbody>
</table>

Reconstructed Events

<table>
<thead>
<tr>
<th>Channeled beam polarity</th>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Xi \rightarrow \Lambda \pi$</td>
<td>$+ $</td>
<td>$458 \times 10^6$</td>
</tr>
<tr>
<td>$K \rightarrow \pi \pi \pi$</td>
<td>$- $</td>
<td>$391 \times 10^6$</td>
</tr>
<tr>
<td>$\Omega \rightarrow \Lambda K$</td>
<td>$\pm$</td>
<td>$4.9 \times 10^6$</td>
</tr>
<tr>
<td>$\Omega \rightarrow \Lambda K$</td>
<td>$\mp$</td>
<td>$4.9 \times 10^6$</td>
</tr>
</tbody>
</table>
Care Taken to Mimimize Differences in + and − Running

- Target length changed to equalize channeled beam rates.
  - + polarity: 2.0 cm Cu
  - − polarity: 6.0 cm Cu
- When flipping polarity, field magnitude kept within $\sim 2\times 10^{-4}$.
- This corresponds to a $\sim 0.3$ mm deflection difference at 10 m for the lowest momentum ($\sim 10$ GeV/c pions).
Little Difference in PWC Efficiencies from + and – Running

- data: solid line
+ data: dashed line

<table>
<thead>
<tr>
<th>C2X wire number</th>
<th>Efficiency</th>
<th>Difference (Neg. - Pos.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>-0.004</td>
</tr>
<tr>
<td>100</td>
<td>1.00</td>
<td>-0.003</td>
</tr>
<tr>
<td>200</td>
<td>1.00</td>
<td>-0.002</td>
</tr>
<tr>
<td>300</td>
<td>1.00</td>
<td>-0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C5X wire number</th>
<th>Efficiency</th>
<th>Difference (Neg. - Pos.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>-0.004</td>
</tr>
<tr>
<td>100</td>
<td>1.00</td>
<td>-0.003</td>
</tr>
<tr>
<td>200</td>
<td>1.00</td>
<td>-0.002</td>
</tr>
<tr>
<td>300</td>
<td>1.00</td>
<td>-0.001</td>
</tr>
<tr>
<td>400</td>
<td>1.00</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Two Different CP Analyses Being Done

Hybrid Monte Carlo Method:

- Compare corrected $\cos \theta$ distributions.
- Take a real $\Xi \rightarrow \Lambda \pi$, $\Lambda \rightarrow p\pi$ event, discard proton and pion, generate 10 new unpolarized $\Lambda$ decays.
- **Advantage:** Absolute measurement of $\alpha_{\Lambda}\alpha_{\Xi}$.
- **Disadvantage:** Monte Carlo must be very, very good, and fast: $\sim$20 billion events needed.

Weighting Method:

- Compare uncorrected $\cos(\theta)$ distributions.
- Force the $\Xi^-$ and $\Xi^+$ events to have similar momentum and spatial distributions by appropriate weighting.
- **Advantage:** No Monte Carlo needed to measure apparatus acceptance, smaller statistical error.
- **Disadvantage:** inflexible, event-size dependent analysis.
Weighting Technique

- **Problem:** Geometrical acceptance identical for $\Xi^-$ and $\Xi^+$ decay products only if parent $\Xi^-$ and $\Xi^+$ have same momentum and inhabit the same phase space exiting the collimator.
- **Solution:** Weight the $\Xi^-$ and $\Xi^+$ events to force the two distributions to be identical.

![Diagram showing data processing steps](Image)

- **Pass 1**
  - Bin data in $p, y, dy/dz$ 100$^3$ bins
  - Calculate + weights
  - Fill + histograms using + weights

- **Pass 2**
  - Bin data in $p, y, dy/dz$ 100$^3$ bins
  - Calculate + weights
  - Fill + histograms using + weights
\( \Xi^- \) and \( \Xi^+ \) x Slopes and Positions not Weighted

- Distributions almost identical ⇒ cut out regions where they are not.
- \( \Xi^- \): Solid lines
- \( \Xi^+ \): Dashed lines
Proton, $\Lambda$-pion, $\Xi$-pion Momenta Before/After Weighting

- Solid lines
- dashed lines

Events/(5.5 GeV/c) x 10^3

Proton z momentum (GeV/c)

Ratio

Events/(1.95 GeV/c) x 10^2

$\Lambda$ pion z momentum (GeV/c)

Ratio

Events/(2.75 GeV/c)

$\Xi$ pion z momentum (GeV/c)

Ratio

±: before weighting
= after weighting
Extracting the $CP$ Asymmetry

- Determine weighted proton and weighted antiproton $\cos \theta$ distributions.

\[
\frac{dN_-}{d \cos \theta_-} = A_\frac{N_-}{2} (1 + \alpha \Xi \alpha \Lambda \cos \theta_-)
\]

\[
\frac{dN_+}{d \cos \theta_+} = A_\frac{N_+}{2} (1 + \bar{\alpha} \Xi \bar{\alpha} \Lambda \cos \theta_+)
\]

- Take the ratio of $\cos \theta$ distributions and fit to:

\[
R(\theta, \delta) = C \frac{1 + \alpha \Xi \alpha \Lambda \cos \theta}{1 + (\alpha \Xi \alpha \Lambda - \delta) \cos \theta}
\]

to extract asymmetry $\delta$:

\[
\delta = \alpha \Xi \alpha \Lambda - \bar{\alpha} \Xi \bar{\alpha} \Lambda
\]

\[
A_{\Xi \Lambda} = \frac{\delta}{\alpha \Xi \alpha \Lambda + \bar{\alpha} \Xi \bar{\alpha} \Lambda} \approx \frac{\delta}{2 \alpha \Xi \alpha \Lambda}
\]

- Note: acceptances cancel out!

Proton $\cos \theta$ ratio before before (●) and after (△) weighting.
Monte Carlo Tests

Important! Monte Carlo only used to:
- Verify code and algorithm.
- Study a few systematics.

Problem: How do you generate $\sim 1$ billion MC events?

Solution:

Real + data  $\rightarrow$ Take $\Xi$ momentum and xy position at collimator exit  $\rightarrow$ Store in intermediate files  $\rightarrow$ Simulate 5 $\Xi$ decays for each real event  $\rightarrow$ CHMC + data

Real - data  $\rightarrow$ CHMC - data

We get the input asymmetry back $\implies$

$$\delta = (-0.73 \pm 0.64) \times 10^{-4}$$
$$A_{\Xi\Lambda} = (1.24 \pm 1.09) \times 10^{-4}$$
The CP Asymmetry $A_{\Xi\Lambda}$ from Weighting Method

- Data broken up into 18 sets of positive and negative data.
- No acceptance corrections.
- No efficiency corrections.
- No background subtraction.

Proton cos $\theta$ ratio before (●) after (△) weighting, from Analysis Set 1

Weighted average of all 18 data sets:

$$\delta = (-1.3\pm3.0) \times 10^{-4}$$

$$A_{\Xi\Lambda} = (2.2\pm5.1) \times 10^{-4}$$

$$\chi^2 = 24$$
Background Subtraction Has Little Effect

- Triple Gaussian fit with fourth-order polynomial for background.
- Background fraction:
  \[\Xi^-: 0.43\% \text{ (lines)}\]
  \[\Xi^+: 0.41\% \text{ (circles)}\]

Low mass: \[\delta = (-2.2\pm0.5) \times 10^{-2}\]
High mass: \[\delta = (-3.8\pm0.7) \times 10^{-2}\]

- Weighted background asymmetry:
  \[A_{\Xi\Lambda(bs)} = (0.0\pm5.1) \times 10^{-4}\]
Helicity Frame Analysis Naturally Minimizes Biases

- The helicity frame axes changes from event to event since we always define the polar axis to be the direction of the $\Lambda$ momentum in the $\Xi$ rest frame.

- Acceptance differences localized in a particular part of the apparatus do not map into a particular part of the proton (antiproton) $\cos \theta$ distribution.

Important! Overall acceptance differences do not cause any biases.
## Weighted Analysis Bias Error Summary

<table>
<thead>
<tr>
<th>Systematic</th>
<th>Method</th>
<th>$\delta A_{\Xi\Lambda} \times 10^{-4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing Magnets field uncertainties</td>
<td>Data</td>
<td>2.8</td>
</tr>
<tr>
<td>Calorimeter inefficiency uncertainty</td>
<td>Data</td>
<td>2.1</td>
</tr>
<tr>
<td>Validation of analysis code</td>
<td>CHMC</td>
<td>1.9</td>
</tr>
<tr>
<td>Collimator exit $x$ slope cut</td>
<td>Data</td>
<td>1.4</td>
</tr>
<tr>
<td>Collimator exit $x$ position cut</td>
<td>Data</td>
<td>1.2</td>
</tr>
<tr>
<td>PWC inefficiency uncertainty</td>
<td>CHMC</td>
<td>1.0</td>
</tr>
<tr>
<td>Hodoscope inefficiency uncertainty</td>
<td>Data</td>
<td>0.3</td>
</tr>
<tr>
<td>Particle/antiparticle interaction differences</td>
<td>MC</td>
<td>0.9</td>
</tr>
<tr>
<td>Momentum weights bin size</td>
<td>Data</td>
<td>0.4</td>
</tr>
<tr>
<td>Background subtraction uncertainty</td>
<td>Data</td>
<td>0.3</td>
</tr>
<tr>
<td>Error on $\alpha\alpha_{PDG}$</td>
<td>Data</td>
<td>0.03</td>
</tr>
<tr>
<td>Polarization</td>
<td>MC</td>
<td>negligible</td>
</tr>
<tr>
<td>Earth’s magnetic field</td>
<td>CHMC</td>
<td>negligible</td>
</tr>
<tr>
<td>Total systematic error</td>
<td></td>
<td>4.2</td>
</tr>
</tbody>
</table>
Results from \textit{CP} Violation Search

**Weighting Technique:**
- \(\sim 10\%\) total data sample
- selected from end of 1999 run
- 118.6 million \(\Xi^-\)
- 41.9 million \(\Xi^+\)
- no acceptance or efficiency corrections

\[ A_{\Xi\Lambda} = [0.0\pm5.1(\text{stat})\pm4.2(\text{syst})] \times 10^{-4} \]

**Check with HMC Technique:**
- \(\sim 5\%\) of the total data sample
- prescaled selection of 1997 and 1999
- 15 million \(\Xi^-\)
- 30 million \(\Xi^+\)

\[ A_{\Xi\Lambda} = [-7\pm12(\text{stat})\pm6.2(\text{syst})] \times 10^{-4} \]

\(\Rightarrow 20\times\) improvement on previous result.
Measuring the $\Lambda-\pi$ Strong Phase Shift

- This is done by analyzing the $\Lambda$ decay distribution from polarized $\Xi^-$'s.
- Polarized $\Xi^-$'s are produced by targeting at nonzero angles.
- A polarized $\Xi^-$ decay produces a $\Lambda$ with three components of polarization:

$$\vec{P}_\Lambda = \frac{(\alpha_{\Xi} + \vec{P}_{\Xi} \cdot \hat{p}_\Lambda) \hat{p}_\Lambda + \beta_{\Xi} (\vec{P}_{\Xi} \times \hat{p}_\Lambda) + \gamma_{\Xi} (\hat{p}_\Lambda \times (\vec{P}_{\Xi} \times \hat{p}_\Lambda))}{(1 + \alpha_{\Xi} \vec{P}_{\Xi} \cdot \hat{p}_\Lambda)}$$

where:

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

- Measuring $\beta_{\Xi}$ allows the phase shift to be extracted:

$$\frac{\beta_{\Xi}}{\alpha_{\Xi}} = \tan(\delta_P - \delta_S) \approx \delta_P - \delta_S$$
Measurement of the $\Lambda-\pi$ Phase Shift

- From 144 million polarized $\Xi^-$ decays:
  \[
  \beta_\Xi = -0.037\pm0.011\text{(stat)} \pm0.010\text{(syst)} \\
  \gamma_\Xi = 0.888\pm0.0004\text{(stat)}\pm0.006\text{(syst)}
  \]

- Using the known value of $\alpha_\Xi$ ($-0.456\pm0.008$), the strong phase shift is:
  \[
  \delta_P - \delta_S = \tan^{-1}\left(\frac{\beta_\Xi}{\alpha_\Xi}\right) = (4.6\pm1.4\pm1.2)^\circ
  \]

- First non-zero measurement of phaseshift.
- This is about the same magnitude as the $p-\pi$ phase shift:
  \[\Rightarrow\] CP equally likely to be seen in $\Xi \to \Lambda\pi$ decays.
  \[\Rightarrow\] CP predictions underestimated,
  \[\Rightarrow\] $\chi$PT calculations off.
Search for Parity Violation in $\Omega^- \to \Lambda K^-$ Decays

$\Omega^- \to \Lambda K^-$  \  $\Lambda \to p\pi^-$

- Although spin-3/2, $\Omega^- \to \Lambda K^-$ decay goes much like the other hyperon two-body decays:
  \[
  \frac{dP}{d\cos \theta} = \frac{1}{2}(1 + \alpha \Omega P \cos \theta)
  \]

- Here:
  \[
  \alpha = \frac{2\text{Re}(P^*D)}{|P|^2 + |D|^2}
  \]

- A non-zero $\alpha$ indicates parity violation.
- All other hyperons have non-zero $\alpha$ parameters; only the $\Omega^-$ has resisted efforts to find an asymmetrical decay distribution.
- HyperCP is measuring $\alpha$ using unpolarized $\Omega^-$'s through the polarization given to the daughter $\Lambda$, which is $\alpha$:
  \[
  \frac{dP}{d\cos \theta} = \frac{1}{2}(1 + \alpha \alpha \Lambda \cos \theta)
  \]

- Large data sample, little background.
Preliminary Measurement of $\alpha_{\Omega}$ and $\overline{\alpha}_{\Omega}$ in $\Omega^-$ → $\Lambda K^-$ Decays

1999 : $\alpha_{\Omega} = [1.78 \pm 0.19\text{(stat)} \pm 0.10\text{(syst)}] \times 10^{-2}$

1999 : $\overline{\alpha}_{\Omega} = [-1.81 \pm 0.28\text{(stat)}] \times 10^{-2}$

- First evidence of parity violation in $\Omega^-$ decays.
- Can search for CP violation in $\Omega^- / \overline{\Omega}^+$ decays.
Conclusions and Outlook

- Analyzing by far the largest sample of hyperons ever recorded, we have assaulted \( CP \) violation from a different direction than the kaon and B experiments.

- We find no evidence of \( CP \) violation in \( \Xi^\pm \) and \( \Lambda \) decays:
  \[
  \delta A_{\Xi\Lambda} = (0.0 \pm 5.1 \pm 4.2) \times 10^{-4}
  \]

- This result is constraining some SUSY models of \( CP \) violation.

- Shortly we will push our statistical limit to \( \delta A_{\Xi\Lambda} \approx 2 \times 10^{-4} \) two orders of magnitude better than the present limit.

- We have the first evidence of parity violation in \( \Omega^- \to \Lambda K^- \) decays.

- A preliminary analysis shows no evidence of \( CP \) violation in \( \Omega^- \to \Lambda K^- / \Omega^+ \to \Xi K^+ \) decays.