Can MIPP solve the Hyperon Polarization origin?

Ed Hartouni and Nick Solomey

It is not an old out of date subject!

- History of Hyperon Polarization and summary of experimental results
- How to measure Hyperon Polarization
- MIPP can make a series of measurements that can search for a definite answer.

Hyperon Polarization

L. Pondrum discovered Hyperon Polarization, its origin and explanation still remains a theoretical mystery.

Most experiments have measured Hyperons to be highly polarized which increases as a function of the production angle and anti-Hyperons to be unpolarized at all production angles.

Two exceptions to this:

E690 and ISR saw $pp \rightarrow p^+_{fast}\ \Lambda^0\ K^+$ polarization to be a function of the $\Lambda^0\ K^+$ invariant mass.

E761 using a proton beam sees $\bar{\Sigma}^-$ to be polarized, while E756 hyperon channel beam sees $\bar{\Xi}^+$ as polarized.

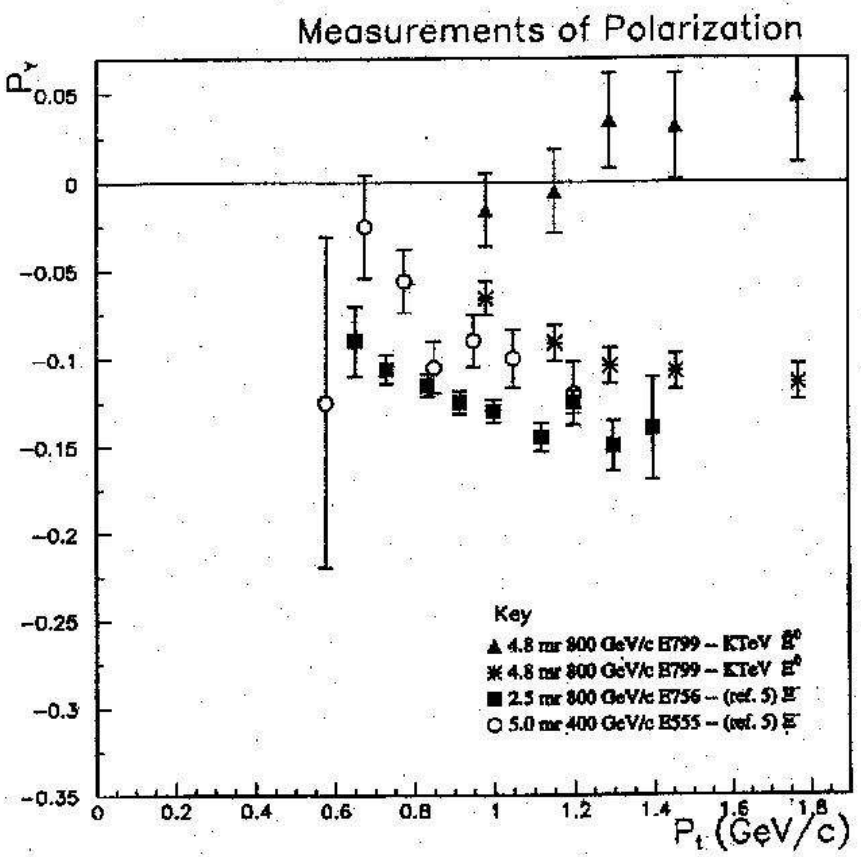
Open Hyperon Polarization Questions:

Why are hyperons produced polarized, while antihyperons mostly unpolarized?

Is there a case when hyperons are produced unpolarized? (yes)

When Hyperons produced at zero production angle

Or at very low P⊥



Are the antihyperon exceptions to this telling us something?

Special E690 Polarization result:

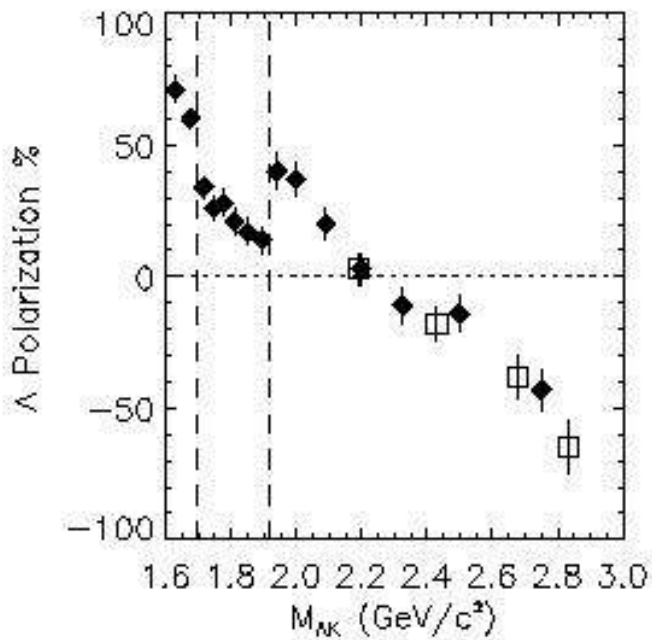


FIG. 6: Λ^0 polarization as a function of $M_{\Lambda K}$. The dashed lines indicate rapid changes in the polarization. Our data is shown as filled diamonds. The data of Reference [3] is shown as the open squares.

Here the Λ^0 polarization can be zero, large negative and large positive.

It depends upon the mass of $\Lambda^0 K^+$.

What is this telling us regarding the origin of Hyperon polarization?

Λ^0K^- Strangeness Associate Production:

Can this result be interpreted as interfering N^* resonances in two different partial wave states summing?

At low Λ^0K^- mass one wave dominates and at high Λ^0K^- mass a different wave dominates; somewhere in between they are equal and completely cancel.

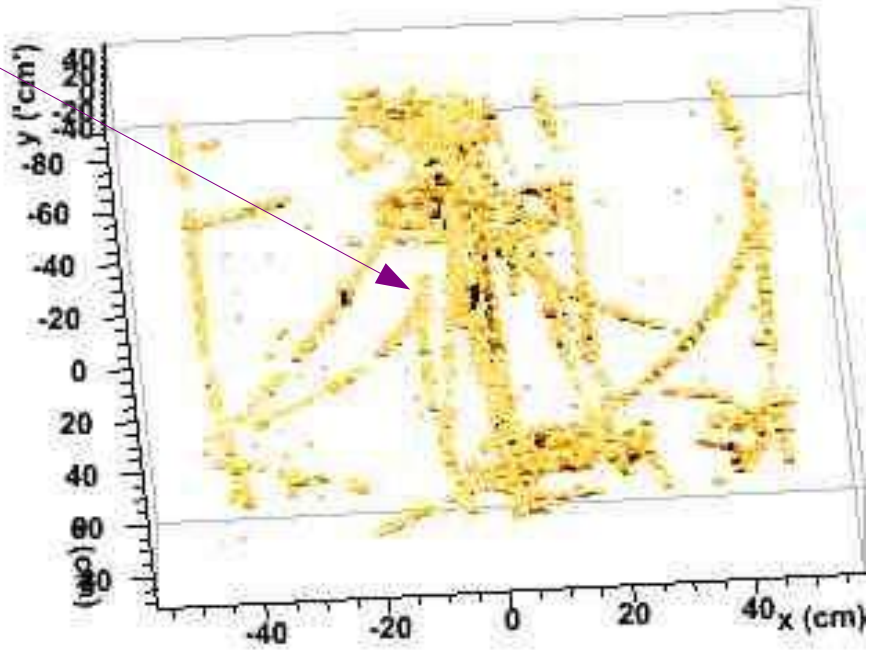
The classical Hyperon Polarization as first observed by Pondrum and others does not tag just one production mechanism.

Their observed polarization with higher beam momentum becomes less polarized. So could the polarization be just a collection of interfering N^* process which gets diluted?

MIPP is observing Λ^0 in TPC

Example of Λ^0 in TPC

It points back to the interaction point



Even in a complicated event, clean Λ^0 with disconnected vertexes at large angles to the beam can be nicely observed, next measure their polarization.

Polarization how-to tutorial:

Observe the Λ^0 decay, generalized as $B_i \rightarrow B_f \pi$

This is a $1/2^+ \rightarrow 1/2^+ \; 0^-$

l=0 s-wave parity violating

l=1 p-wave parity conserving

There will be an observable shift from a flat distribution in the angular distribution of π or B_f in the c. of m. frame of B_i:

$$f(\cos\theta) = dN/d\cos\theta = A\,[1 \pm \alpha P \cos\theta]$$

With α well known, then P can be measured.

Example Measurement

Typical Polarization example from Ed's E690 PRL paper.

We would want to use the Lambda produced off at angles to the beam direction, or bin this result as a function of angular dependence

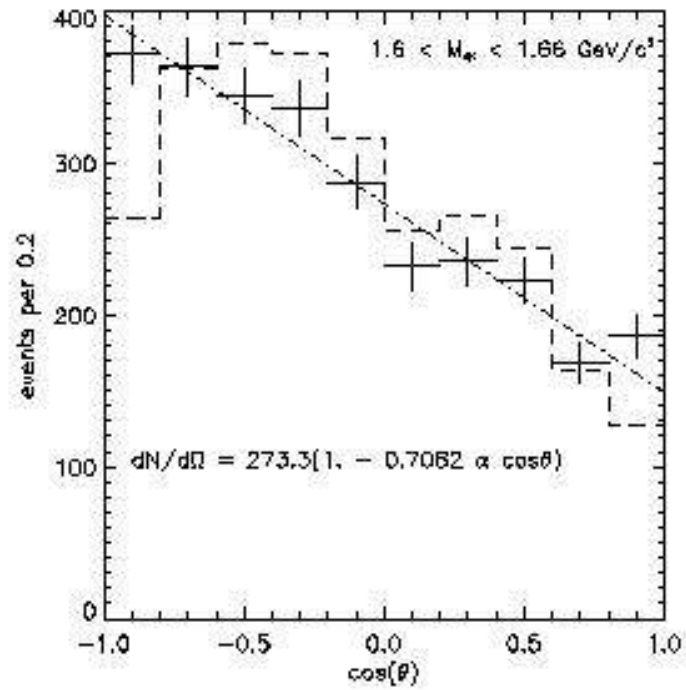


FIG. 5: The proton $\cos\theta$ distribution in the Λ rest frame with respect to the vector normal to the Λ production plane, $\hat{n}$. The dashed histogram is the uncorrected data, the points with error bars are the corrected data, and the dotted line is the result of a fit to equation 4.

MIPP can measure hyperon polarization:

Using our six beam species (p, $\bar{p}$, π^+, π^-, K^+, K^-) MIPP has the unique opportunity to study polarization dependence upon particle species.

This is important because some theorists suggest that the hyperon polarization might be carried from the polarization of the incident beam.

By studying both Λ^0 and $\bar{\Lambda}^0$ particle polarization at various production angles and species of beam particle that produced could we provide new insight to the origin of Hyperon polarization?

What is needed for this study?

$p\ LH \rightarrow \Lambda^0\ X$

$p\ LH \rightarrow \bar{\Lambda}^0\ X$

$\bar{p}\ LH \rightarrow \Lambda^0\ X$

$\bar{p}\ LH \rightarrow \bar{\Lambda}^0\ X$

This will need a lot of beam since there are six beam species and many production angles. It will benefit from the proposed upgrade.

It has to be on Liquid Hydrogen target since on other targets Hyperon production is more difficult

Any beam momentum is fine for this study as long as it produces Hyperon at large production angles.

A MIPP *tour de force* is

continue studies with meson beams

(both Kaon and pion)

$K^+ LH \rightarrow \Lambda^0 X$

$K^+ LH \rightarrow \bar{\Lambda}^0 X$

$K^- LH \rightarrow \Lambda^0 X$

$K^- LH \rightarrow \bar{\Lambda}^0 X$

$\pi^+ LH \rightarrow \Lambda^0 X$

$\pi^+ LH \rightarrow \bar{\Lambda}^0 X$

$\pi^- LH \rightarrow \Lambda^0 X$

$\pi^- LH \rightarrow \bar{\Lambda}^0 X$

Detailed study of Polarization using exclusive processes in symmetry:

$p^+ p^+ \rightarrow p^+ \Lambda^0 K^+$

E690 process

$p^- p^+ \rightarrow p^- \Lambda^0 K^+$

MI PP

$p^- p^+ \rightarrow p^+ \bar{\Lambda}^0 K^-$

$p^- p^- \rightarrow p^- \bar{\Lambda}^0 K^-$

! antimatter on antimatter, would need one of NASA's antimatter traps filled with lots of antiprotons to study the perfect symmetry case with the E690 result, or RHIC using $p^- p^-$ beams?

What would the polarization different be?

Conclusion:

Hyperon Polarization Studies can answer important questions:

Are anti-Lambdas polarized if produced by anti-protons and not when produced by protons? Which is opposite of protons beams and would show the theory that projectile particle plays an important rule.

Does the antiproton beam Hyperon polarization processes behave the same at E690 proton-proton process?

Are Hyperon polarization different when produced by π^+ and π^- or K^+ and K^- meson beams? Minerva plans to study this with ν and $\bar{\nu}$ beams.