Fermilab Proposal No. 441

Scientific Spokesman:

L. Pondrom
Department of Physics
University of Wisconsin
Madison, Wisconsin 53706

PH: 608 - 262-3077

A Proposal to Study Λ^0 Polarization in the Inclusive Reaction $p + p \rightarrow \Lambda^0$ + Anything with a Liquid Hydrogen Target

G. Bunce, L. Pondrom, R. March
University of Wisconsin

T. Devlin, R. Edwards
Rutgers University

K. Heller, O. Overseth
University of Michigan

September 1975

A Proposal to Study Λ° Polarization in the Inclusive Reaction $p + p \rightarrow \Lambda^\circ$ + Anything with a Liquid Hydrogen Target

G. Bunce, L. Pondrom,* R. March,
R. Handler, and M. Sheaff

Department of Physics
University of Wisconsin
Madison, Wisconsin 53706

T. Devlin and R. Edwards

Department of Physics
Rutgers University
New Brunswick, New Jersey 08903

K. Heller and O. Overseth

Department of Physics
University of Michigan
Ann Arbor, Michigan 48104

Abstract

It is proposed that the Λ° polarization recently observed in inclusive production of Λ° by 300 GeV protons on beryllium be studied with 400 GeV protons in liquid hydrogen. A range of scaling variables $0 \leq p_+ \leq 2.3$ GeV/c and $.1 \leq X \leq 1$ will be covered with good statistics. A total run of 150 hours is requested.

*Spokesperson

I. Introduction

Relatively little is known about baryon polarization effects due to strong interactions in inclusive production at high energies. Rather large polarization has recently been reported for $X = p/p_{max} > .8$ in $p + p \rightarrow \Lambda^\circ$ + anything at 6 GeV.[1] This effect is consistent with a large polarization observed in the exclusive channel $p + p \rightarrow \Lambda^\circ K^+ p$ at 6 GeV some years ago.[2] In the analysis of those data the authors found that a one pion exchange model fitted the production adequately, and described the polarization in terms of the known polarization in $\pi p \rightarrow \Lambda K$ at the ΛK production vertex. Inclusive Λ° production at 25 GeV by protons on platinum has been studied in the 80" bubble chamber.[3] A limit on the polarization $|\alpha P_\Lambda| < .1$ is quoted in this case. Similarly, in the CERN hyperon incident on a tungsten target, Λ° observed at 75 mrad are found to have a polarization $|\alpha P_\Lambda| = .039 \pm .015$.[4]

In general the polarization seems to decrease with increasing energy. Elastic πp scattering serves as an example, where the polarization of the recoil proton drops from a maximum of 57% at 6 GeV[5] to 7% at 40 GeV.[6] One might imagine that an inclusive process at 300 GeV would be unlikely to produce a net polarization, since any effect is the result of interference between amplitudes in a particular channel, and so many channels are open with such high particle multiplicities that a polarization would be completely washed out. Nevertheless, as shown in Fig. 1, a polarization has been observed in the reaction $p + Be \rightarrow \Lambda^\circ$ + anything with 300 GeV protons.[7] Within the accuracy of the data, the Λ° polarization is independent of the scaling variable $X = p_\parallel/p_{max}$ in the

range $.25 \leq X \leq 1$, and depends only on p_+ in the manner shown. At $p_\perp = 1.6$ GeV/c, $\langle \alpha P_\Lambda \rangle = .17 \pm .05$, where α is the helicity of the proton in $\Lambda^\circ \to p\pi^-$, with the experimental value $\alpha = .647 \pm .013$. The polarization is therefore $P_\Lambda = .26 \pm .08$, which is a surprisingly large number. The direction of the Λ° spin is along $\hat{n} = (\vec{p}_\Lambda \times \vec{p}_p)/|\vec{p}_\Lambda \times \vec{p}_p|$. The experimental evidence is consistent with the polarization being due to strong interactions.

Only the complex nucleus beryllium has been used as a target to produce polarized Λ° so far. This leaves open the possibility of complex nuclear effects contributing to the Λ° polarization - either increasing or diminishing it. For example the outgoing Λ° could be rescattered by target nucleons, or secondary pions made by the primary proton in the nucleus could be responsible for producing the Λ° polarization. Although the $(x, p_\perp)$ dependence of the data discriminate against such secondary processes (the polarized Λ°'s always have high energy), they cannot be conclusively ruled out. Complex nuclear effects such as those which give rise to anomolous multiplicities of charged secondaries, discussed for example by Van Hove,[8] must be eliminated experimentally by studying the production of polarized Λ° in hydrogen before the problem of describing the phenomenon is clearly defined. Within the statistical accuracy of the present data, the polarization increases monotonically with $p_\perp$. It would be most interesting to follow the curve in Fig. 1 out to higher $p_\perp$ in search of a turn over in $\langle \alpha P_\Lambda \rangle$. Such a turn over might be a clue to the mechanism which produces the polarization - a decaying intermediate N* state, for example. The measurements proposed here will study the $(X, p_\perp)$

dependence of the Λ° polarization in inclusive production by 400 GeV protons in hydrogen over as wide a range of kinematic variables as is practical with the present set-up.

II. Experimental Procedure

Running time with a 50cm long liquid hydrogen target and a 400 GeV proton beam in the M-2 line can be estimated from the measured rates from beryllium and a 300 GeV proton beam. The Λ° yield is described by the formula

$$\Lambda^\circ \rightarrow p\pi \text{ yield} \simeq 3.6e^{-.39\theta}/10^6 \text{ protons}, \qquad (1)$$

where θ is in milliradians. The actual trigger rate is 1.66 times as large. The extra triggers arise from $K_S^\circ \rightarrow \pi^+\pi^-$, neutron stars, and γ ray conversions in the material in the neutral beam. Table I shows the proposed division of running time at each angle, assuming a maximum proton flux of 4×10^8/pulse and a machine cycle time of 13 seconds. The longest run is of course at 12 mrad. An error of $\pm$ .05 on the Λ° polarization should be achieved at $p_+ =$ 2.3 GeV/c. Transverse momenta out to $p_\perp \simeq 3$ GeV/c will be available, but with larger statistical error. It is proposed that 8 tapes with 80,000 events each be recorded at each angle. One tape will be taken for each of two sweeping magnet polarities, two analyzing magnet polarities, and two signs of the production angle in order to eliminate all geometrical biases. Figure 2 shows the proposed geometry. The 50 cm cryogenic target should be placed as near the upstream collimator opening as possible. The production angle will be varied in a vertical plane $-$ 12 mrad $\leq \theta \leq +$ 12 mrad. The precession of the Λ° spin in the sweeping magnet is shown schematically in the bottom drawing.

Table I

Trigger rates expected for 400 GeV protons on hydrogen in the reaction $p + p \rightarrow \Lambda^\circ$ + anything. A 5-cm long H_2 production target is assumed, together with a maximum proton intensity of 4×10^8/ 13 sec. A total yield of 380,000 Λ's, or 640,000 triggers, is needed at each angle.

θ	Triggers/10^6 protons	Time/.64M Triggers
0	6	3 hours
4	1.3	4.5 hours
8	.26	22 hours
12	.06	96 hours
		125.5 hours

Time required to tune all angles and for contingency	25 hours
Total requested	150 hours

III. Requests Made of the Laboratory

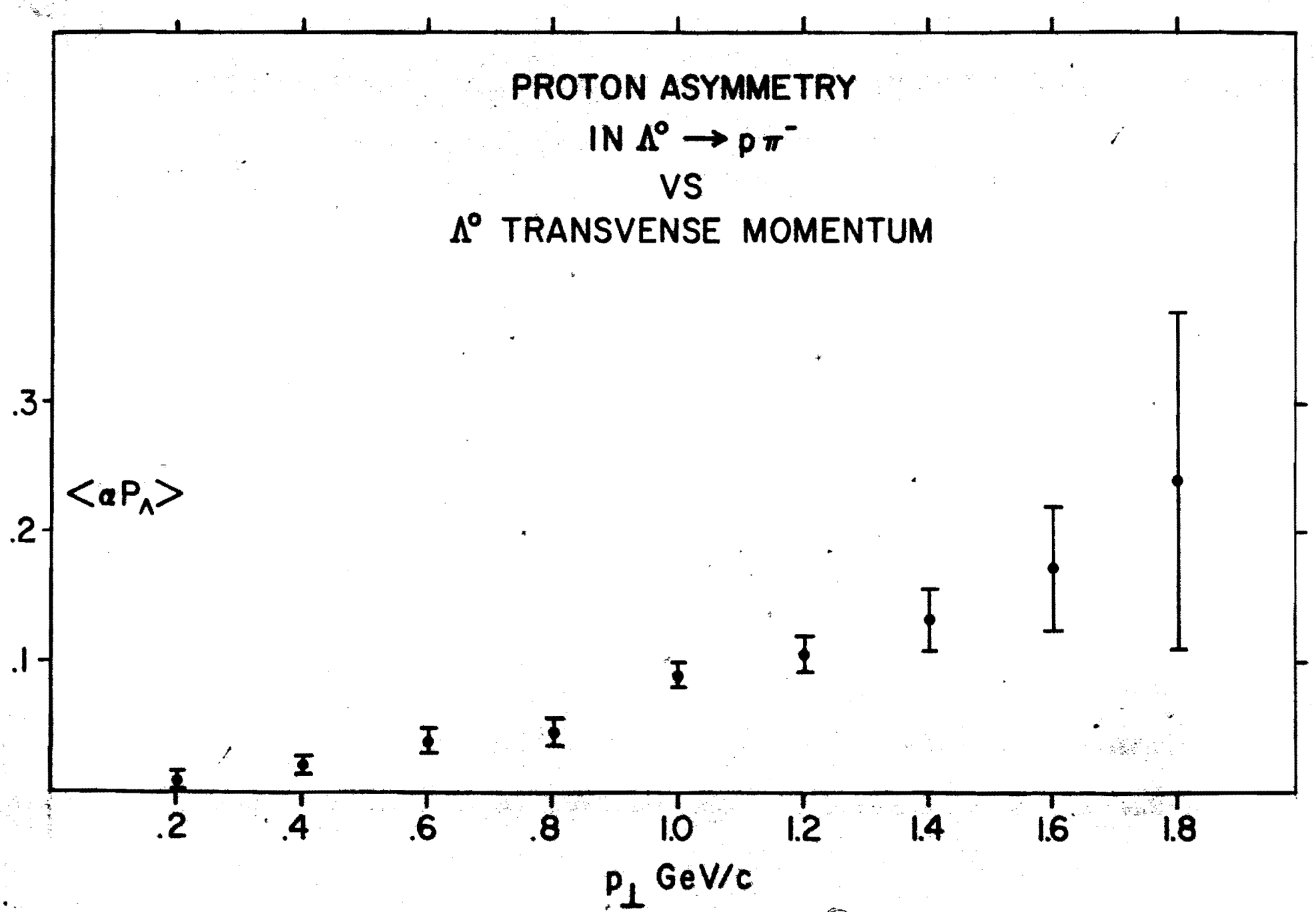
1. 150 hours running at 400 GeV in the M-2 line with a proton intensity up to 4×10^8.
2. A 50cm long 2cm diameter liquid hydrogen target.
3. 1 1/2 main ring dipoles (30 feet of magnet) mounted immediately upstream of the liquid hydrogen target with horizontal magnetic field. The magnets will have to be moved vertically by about 10cm to achieve both signs of the production angle. This could be done with jacks.

References

1. Lesnik, et al., Phys. Rev. Letters 35, 770 (1975). The authors are grateful to Professor R. Winston for discussions regarding these measurements.
2. Chinowsky, et al., Phys. Rev. 165, 1466 (1968).
3. Anderson, et al., Phys. Rev. D11, 473 (1975).
4. CERN-Heidelberg collaboration, private communication.
5. Borghini, et al., Physics Letters 31B, 405 (1970).
6. Gaidot, et al., Physics Letters 57B, 389 (1975).
7. G. Bunce, et al., submitted to Phys. Rev. Letters.
8. L. Van Hove in Particle Interactions at Very High Energies, editied by Halzen, Speiser, and Weyers, Plenum Press, N. Y., 1974.

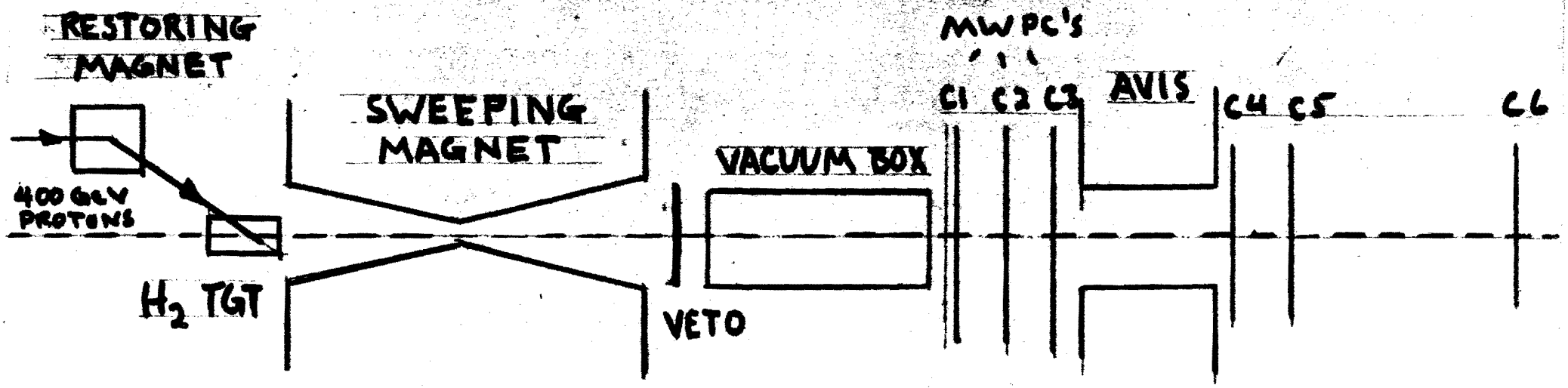
Figure Captions

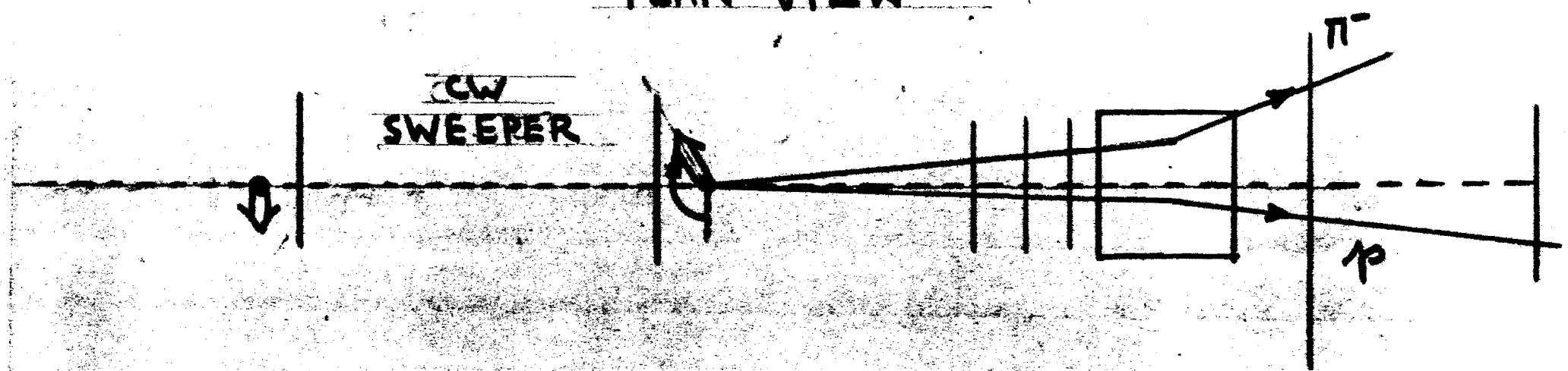
1. Observed $\langle \alpha P_\Lambda \rangle$ for Λ° produced inclusively by 300 GeV protons on beryllium.
2. Proposed experimental set-up. There are two modifications to the previous apparatus. First the restoring magnet must be increased from 20' long to 30' long to bend 400 GeV through a net angle of 12 mrad. Second the usual beryllium or other solid target must be replaced by a 50cm long liquid hydrogen target. The downstream equipment is the usual E-8 Λ° spectrometer. The plan view sketch shows how the Λ° spin rotates in the sweeping magnet for clockwise polarity.


PROTON ASYMMETRY
IN Λ° → pπ⁻
VS
Λ° TRANSVENSE MOMENTUM
<αP_Λ>
.3
.2
.1
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
p⊥ GeV/c

5 1

ELEVATION VIEW



NOT TO SCALE

PLAN VIEW