2.6 JET PHYSICS IN THE FERMILAB POLARIZED PROTON BEAM

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Why look at jet spin-dependence?

Jets allow us to study the high-p_T region where single-particle rates are prohibitively low. This is the region where simple hard-scattering processes are expected to dominate the cross section. QCD-based models make unambiguous predictions for the spin-dependence of these processes. A hadron calorimeter experiment in the polarized beam line therefore can test these models.

What are the predictions?

1. qq scattering by one-gluon exchange has **zero** asymmetry in a single-spin experiment (polarized beam, unpolarized target). There are upper bounds on the asymmetry possible in qq process. Nevertheless, large asymmetries in pion production have recently been observed at CERN.[1]

2. Double-spin asymmetries (polarized beam and target) are directly related to the distribution of spin inside the nucleon. SLAC deep-inelastic results suggest that the leading quark carries all the spin as $x \to 1$.

The predicted asymmetries for longitudinal polarization are about 10x larger than those for transverse beam and target polarization[2] and are rising functions of $X_\perp$ (see Fig. 1).

2a. The process $p\bar{p} \to$ jet + X is dominated by $q\bar{q}$ scattering at high p_T and should show very small 2-spin asymmetry, unlike $pp \to$ jet + X.[3]

3. If a significant single-spin asymmetry (item 1) is observed in $pp \to$ jet + X, the nuclear-size dependence of the asymmetry should be studied. Sukhatme suggests that multiple scattering in large nuclei causes gluon processes to dominate even at large p_T.

What about the apparatus?

The polarized beam now planned has a maximum momentum of 450 GeV/c. It can deliver 3×10^7 p/spill at 45% polarization (see Fig. 2). Studies at Saclay on a polarized Li_6D target appear promising. This target would have ~30% average nucleon polarization. ($Li_6 = \alpha + D$). Otherwise, an NH_3 target with 15% average polarization will be used.

Reducing unpolarized background material in the target is crucial for measurement of inclusive asymmetries; the true spin-dependence is diluted by a factor of the average

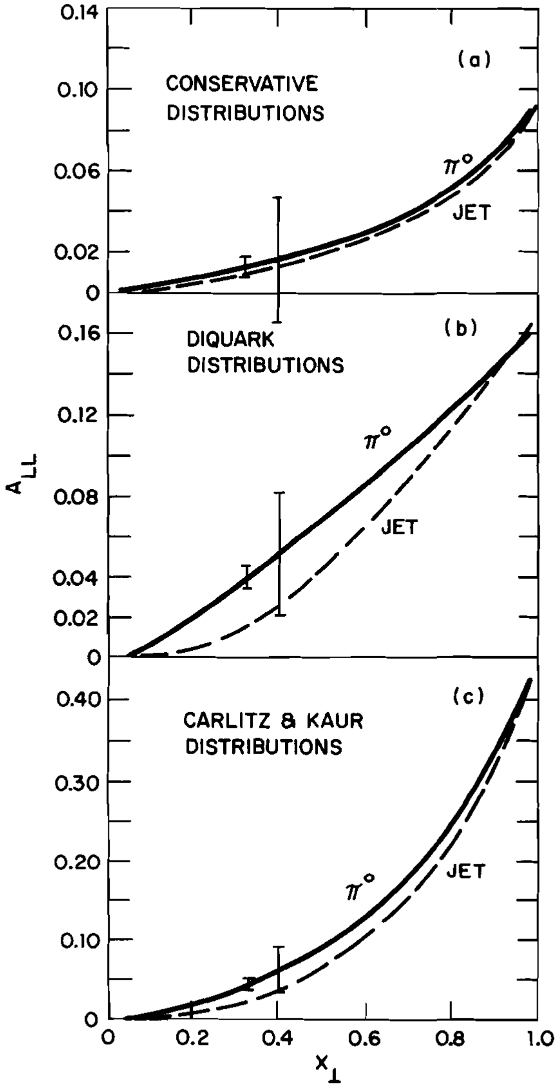

Fig. 1. 2-spin asymmetries for several models.

From Babcock, Monsay, and Sivers (Ref. 3).
Statistical errors shown for $p_T = 5$ and $p_T - 6$ at 450 GeV.

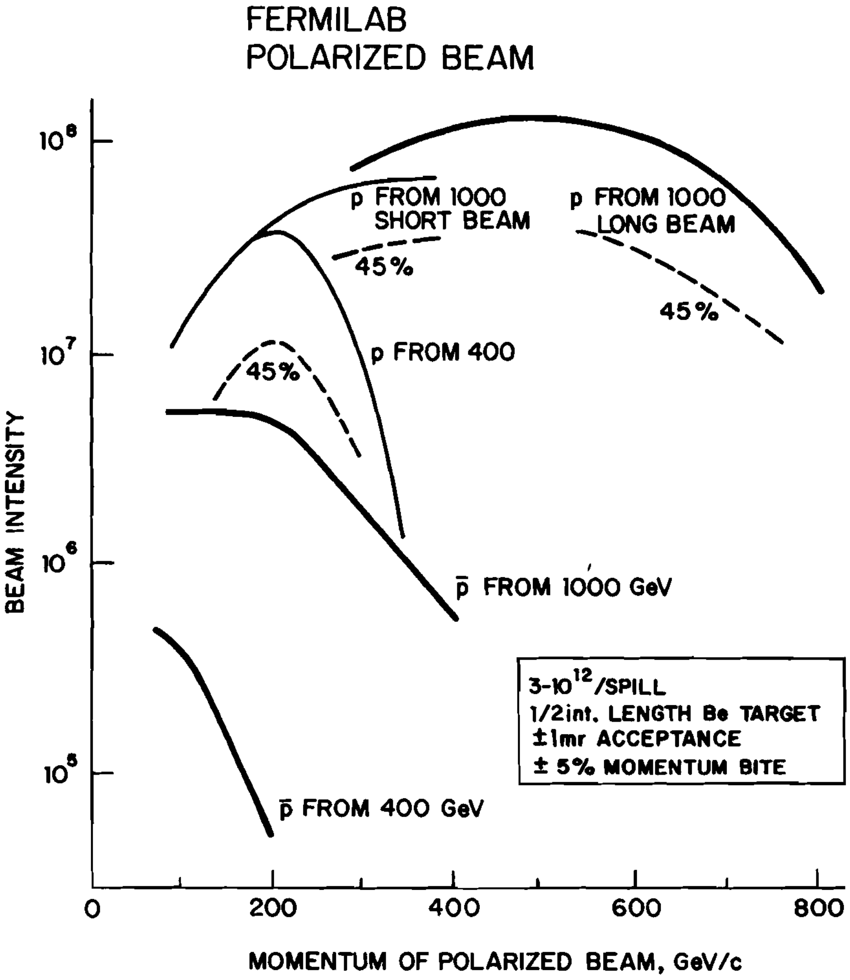

Fig. 2. Estimated polarized-proton and- antiproton intensities.

polarization per nucleon--assuming **linear** A-dependence. Anomalous A-dependence at high p_T makes the factor even larger.

For accurate measurement of asymmetries, large calorimeter solid angle is essential. Let us assume the calorimeter array of E-609, which has a **fiducial** acceptance of ~2 sr centered on 90° $_{c.m.}$ and 2π coverage in ϕ. Drift chambers and analyzing magnet as in E-609 allow charge identification and some momentum analysis of charged particles.

$$\text{Rate} = N_{beam} \cdot \rho_{tgt} \cdot \Delta\Omega \cdot \Delta p_{lab} \cdot \left(\frac{d^3\sigma}{d\Omega dp}\right)_{lab}$$

$$\Big\uparrow$$

$$\Delta\theta_{lab} = 0.03 \text{ sr}$$

$$\Delta p_{lab} \cong 15 \cdot \Delta p_T = 7.5 \text{ GeV/c} \qquad \frac{p_{lab}^2}{\underbrace{E_{lab}}} \left(E \frac{d^3\sigma}{dp^3}\right) \text{inv.}$$

$$N_{beam} = 4 \times 10^{10} \text{ per day} \qquad \approx p_{lab} \approx 15\, p_T$$

$$\rho_{tgt} = 4 \times 10^{24}/\text{cm}^2 \text{ (15\% collision length).}$$

From E-395, $Ed^3\sigma/dp^3(\text{jet}) \approx 10^{-28-1.5(p_T-3)}$ at 400 GeV[5]

so evts/day = $5.4 \times 10^7\, p_T \cdot 30^{-(p_T-3)}$

p_T	events/day
3	5.4×10^7
4	1.8×10^6
5	6×10^4
6	2×10^3
7	60
8	2

Assume a 20-day run--then error in **raw** asymmetry measurement will be ~$(20 \times \text{evts/day})^{-1/2}$, but true asymmetry is $1/(p_{beam} \cdot p_{tgt})$ times raw mesurement.

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p_T	Raw Error	True Error
3	3 E-5	2 E-4
4	1.7 E-4	1.1 E-3
5	9 E-4	6 E-3
6	5 E-3	3.3 E-2
7	3 E-2	0.2

(assuming an LiD target; double true errors for NH_3)

Thus we can reach X_T values of ~0.4 with adequate statistics.

References

1. C. Bourrely and J. Soffer, Phys. Lett., **71B**, 330 (1977).
2. K. Hiduka, E. Monsay, and D. Sivers, ANL-HEP-PR-78-47.
3. J. Babock, E. Monsay, and D. Sivers, ANL-HEP-PR-78-39.
4. U. Sukhatme, (private communication).
5. W. Selove, UPR-70E.