PHYSICS WITH POLARIZED $p(\bar{p})$ BEAMS

A. Penzo, INFN, Florence, Italy

Summary of Subgroup on Spin Effects - Tevatron Fixed Target Workshop

Participants to subgroup:

R. Ditzler, H. Spinka, D. Underwood, and A. Yokosaw, Argonne National Laboratory; A. Delesquen, DPHPE, Saclay; K. Miyake and N. Tamura, Kyoto University; F. Bradamante, A. Penzo, and P. Schiavon, INFN., Trieste; K. Kuroda, LAPP, Annecy.

With advice from:

E. Berger, J. Collins, J. Owens, and U. Sukhatme.

Detailed write-ups on spin effects in

a) elastic scattering
b) inclusive single particle production
c) "jet"production
and d) dilepton and prompt photon production

are attached.

Introduction

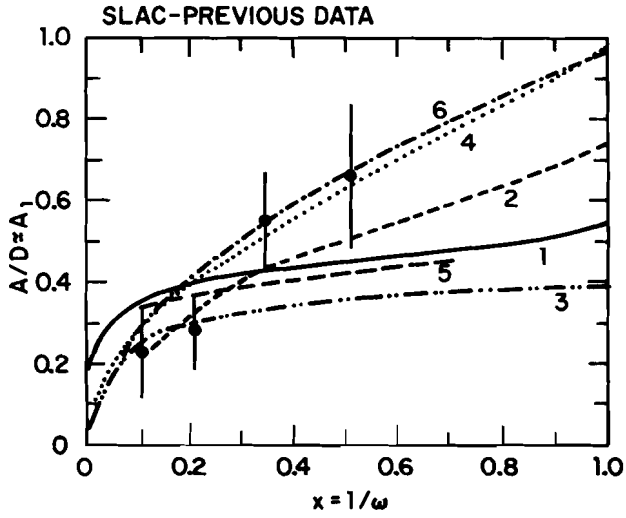
The important merit of Tevatron (Fixed Target) Program (with respect to Collider) is flexibility in beam quantum members; the polarized beam project in Meson Area adds an interesting possibility of also controlling spin orientation.

Experiments with polarized beam (and target) Fig. 1 give access to observables (spin-dependent assymetries) sensitive to interference terms of basic interaction mechanisms. Physics with polarized beams overlaps various areas of studies in this workshop and the working group mainly concentrated on connections with

1) exclusive
2) inclusive
3) jet
4) dilepton (prompt photon)

} processes in a QCD general framework

At the same time experiments with polarized $p(\bar{p})$ beams complement information obtained from other areas, like lepton deep inelastic scattering.


SLAC-PREVIOUS DATA
A/D=A1
x = 1/ω
1.0
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1.0
6
4
2
1
5
3

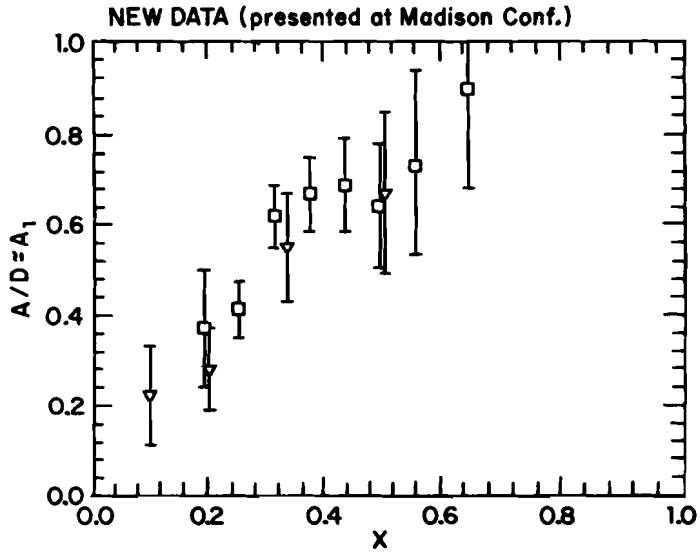

NEW DATA (presented at Madison Conf.)
A/D=A1
X
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

Fig. 1.

Nucleon Spin Composition

Inelastic scattering of leptons gives information on probability distribution function for quarks, both in unpolarized and polarized nucleons

$$2MW_1(\nu,Q^2)\ \nu W(\nu,Q^2) \rightarrow D^i(X,Q^2) = D_+^i(X,Q^2) + D_-i(X,Q^2)$$

$$M^2\nu G_1(\lambda,Q^2),\ M\nu^2 G_2(\lambda_1 Q^2) \rightarrow \delta D^i(X,Q^2) = D_+^i(X,Q^2) - D_-i(X,Q^2).$$

$D_+^i\ (X,Q^2)$ is the probability of finding a valence quark with flavor i with (±) helecity, carrying a longitudinal fraction X in a positive helicity proton, when observed with a probe with momentum transfer $-Q^2$.

Data from SLAC[1] favor the idea that spin of the parent nucleon is communicated to the leading (large X) quarks (Fig. 2 theoretical prediction 4).

Single Spin Asymmetries (A_N Measurements)

A_N is expected to vanish in lowest order QCD[2] (one gluon exchange). Measurements of Λ° production in a wide energy range[3] and π^0 at 24 GeV/c^4 show important spin effects in single spin measurements (Fig. 3); in case such results were confirmed, higher order, gluon or non-pertubative effects should be considered.

Measurements with jets would allow us to study large p_T region where single particle rates are prohibitively low. In case significant single spin effects are observed in pp → jet + X, the nuclear size dependence should be studied; it is suggested[5] that multiple scattering in large nuclei causes gluon processes to dominate.

Single-spin measurements in dilepton production might give a clue on polarization of sea constituents in the nucleon[6] (Fig. 4).

Double-Spin Asymmetries

QCD has predictions[3] for A_{ij} measurements of π^+, π^0 and jets (Figs. 5 and 6) in which should be confronted with accurate experiments.

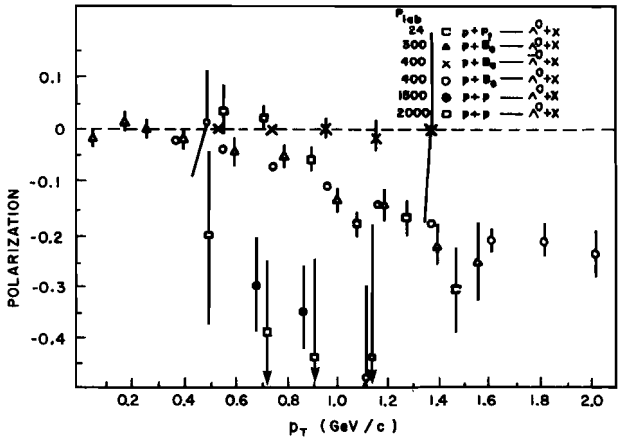


Fig. 2. A polarization on different targets a a function of $p_\perp$ at 24 GeV/c [HEL 77], 300 GeV/c [BUN 76], 400 GeV/c [HEL 78], and 1500 and 2000 GeV/c [ERH 79].

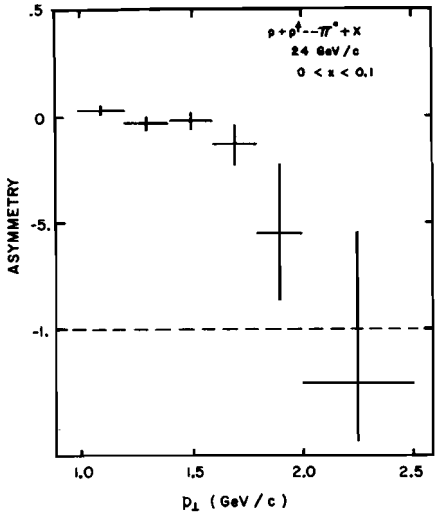


Fig. 3. Asymmetry for $pp^\uparrow - \pi^\circ X$ at 24 GeV/c in the central region [WER 79].

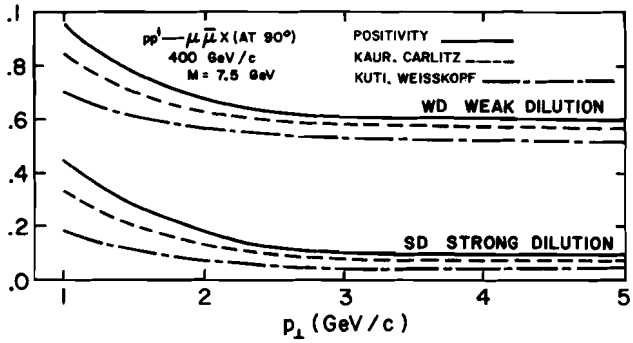


Fig. 4.

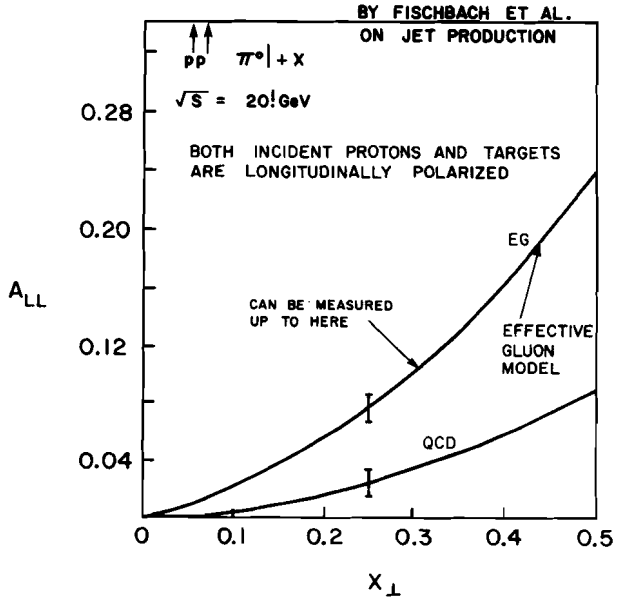


Fig. 5. Predictions of Ref. 7 for A_{LL} based on effective gluon model (EG) and quantum chromodynamics (QCD), shown with expected experimental error bars. Future use of a polarized Li ^{6}D Target and/or jet detector could allow measurements with small statistical errors at even higher $x_\perp$.

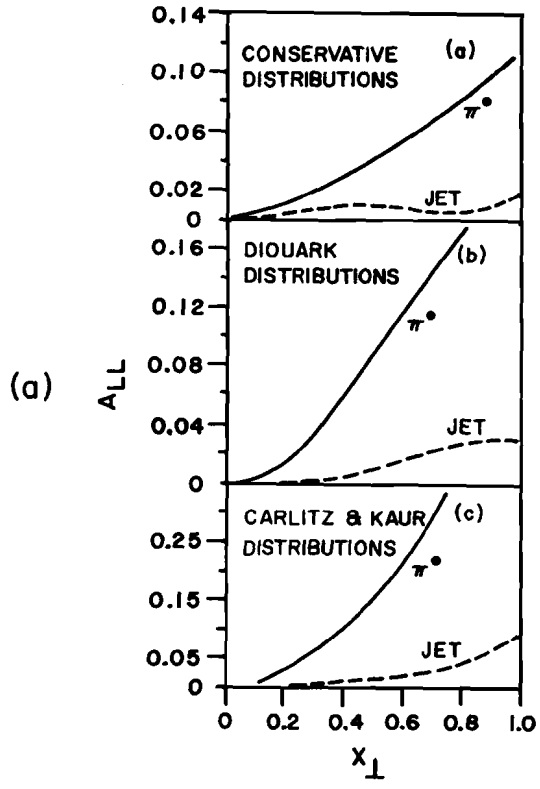


Fig. 6(a). Asymmetry A_{LL} for reactions pp → (π° or jet + X) as a function of $x_\perp = 2p_\perp (s)^{1/2}$ for different quark distribution [BAB 79].

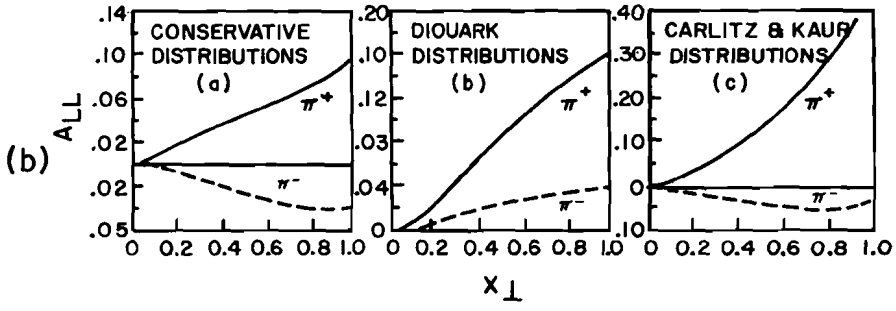


Fig. 6(b). Same as above for the reactions pp → $\pi^\pm$X.

Asymmetries with longitudinal polarization are expected to be larger than with transverse polarization; predictions exist also for dilepton and prompt photon production[8] (Fig. 7). With a detailed study of spin correlations in different kinematical regions it might become possible to appreciate the relative importance of various QCD subprocesses: first-order calculations are now available and comparison with data would indicate the presence of higher order or higher twist effects, which are presumably important and calculable.[9] Measurements of the A_{if} type would give information on spin dependence of quark fragmentation functions and allow to check the consistency of preferred interpretation for A_N and A_{ii} measurements.

A_{if}-type measurements could be performed in Λ^0 inclusive production with polarized beam,[10] and in case of dilepton production, analysis of the lepton pair relative angular distribution would allow one to helicity analyze the original virtual photon. There are also suggestions on the possibility of analyzing the polarization alignment of jets by studying the distribution of jet fragments with respect to suitably defined axis.[2,11]

Low p_T and Exclusive Processes

Considerable effort has been employed in trying to bridge "soft" to hard scattering processes and in pp elastic scattering the amplitude structure, as obtained by measurements of spin-spin correlation parameter[12], seems to indicate that helicity conservation, at quark level, is valid.

Of particular importance in understanding the pp (and $p\bar{p}$) amplitude structure, are also total cross section measurements in pure spin state.

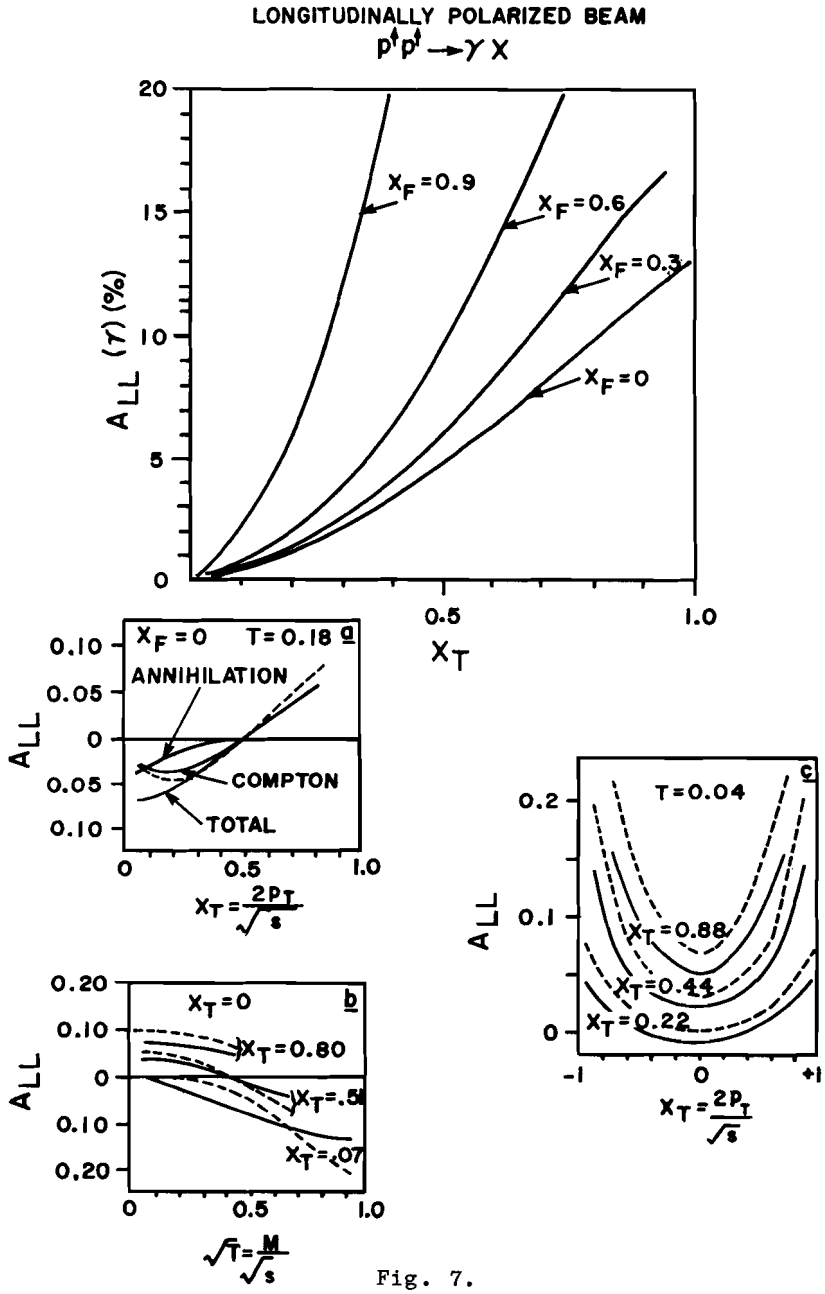

LONGITUDINALLY POLARIZED BEAM
$p^{\uparrow}p^{\uparrow} \rightarrow \gamma X$
$A_{LL}(\gamma)$ (%)
$X_F = 0.9$
$X_F = 0.6$
$X_F = 0.3$
$X_F = 0$
X_T
$X_F = 0$ T = 0.18 a
ANNIHILATION
COMPTON
TOTAL
A_{LL}
$X_T = \frac{2p_T}{\sqrt{s}}$
$X_T = 0$ b
$X_T = 0.80$
$\sqrt{\tau} = \frac{M}{\sqrt{s}}$
T = 0.04 c
$X_T = 0.88$
$X_T = 0.44$
$X_T = 0.22$

Fig. 7.

References

1. M. J. Alguard et al., Phys. Rev. Lett. **41**, 70 (1978).

2. G. L. Kane et al., Phys. Rev. Lett. **41**, 1689 (1978).

3. G. Bruce et al., Phys. Rev. Lett. **36**, 1113 (1976); K. Heller et al., Phys. Rev. Lett. **41**, 607 (1978).

4. J. Antilli et al., CERN Preprint, EP/80-88, June 1980.

5. U. Sukhatme, private communication.

6. C. Bourrely, and J. Soffer, Phys. Lett. **71B**, 330 (1977).

7. J. B. Babcock et al., Phys. Rev. Lett. **40**, 1161 (1978).

8. K. Hidake, Phys. Rev. **D21**, 1316 (1980); R. P. Bajjai et al., Preprint of Indian Institute of Technology, Kanjur, (submitted to Madison Conf.); J. T. Donohue and S. Gottlieb, Argonne Preprint ANL-HEP-PR-80-42, June 1980; K. Hidaka, talk at Moriond Conference 1980.

9. R. Horgan and P. N. Scharbach, CERN Theory Preprint, Ref. TH 2836 CERN.

10. N. S. Craigie et al., ICTP Preprint IC/80/96, July 1980.

11. N. S. Craigie, private communication; A. V. E. Efremov, JINR Preprint, ES 11244, Dubna 1978.

12. I. P. Auer et al., Argonne Preprint ANL-HEP-CP-80-38, submitted to Madison Conference.