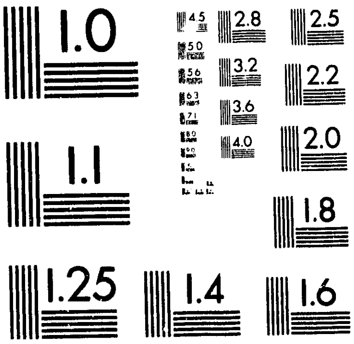
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

ANL-HEP-CP-93-61
For the Proceedings of the International Conference
(19th Blois Vth Workshop) on Elastic and
Diffractive Scattering, Brown University
Providence, Rhode Island, 8-12 June 1993

FNAL POLARIZED BEAMS AND SPIN DEPENDENCE AT RHIC

A. YOKOSAWA
High Energy Physics Division
Argonne National Laboratory, Argonne, Illinois 60439

ABSTRACT

We review activities with experiments using polarized protons and polarized antiprotons at Fermilab. For future high-energy spin physics we describe an experimental program with polarized collider at RHIC.

1. FNAL Polarized Beam

In order to avoid possible complications involving depolarization at high energies, polarized protons can be produced from decaying lambdas. The Fermilab polarized-beam facility was constructed and was operational in 1987.

An extracted beam (800 GeV/c) from the Tevatron is delivered to the Meson Detector Building where a 0.73-interaction-length Be target is utilized to produce Λ and $\bar{\Lambda}$ at $\theta_{c.m.} \approx 0°$. Protons and antiprotons from the Λ and $\bar{\Lambda}$ decays respectively are brought to a final target position in the MP hall through the experimental secondary beam (200 GeV/c) line.

Polarized protons from the virtual sources are focused in the tagging section, where both the momentum and polarization are selected.

The typical beam flux ($\Delta p/p = \pm 5\%$) for 3×10^{12} incident protons per 20-sec spill at 200 GeV/c were: (P_{av} is average polarization)

	Tagged Beam (Pav = 45%)	Total Particles	Background π's
Protons	1.0×10^7	2.0×10^7	2.0×10^6
Antiprotons	5.0×10^5	1.0×10^6	5.0×10^6

The following measurements were carried out with the polarized beams:

i) Hadron Production with 200-GeV/c Polarized Beams

Single-Spin Asymmetry in $p^{\uparrow}p \rightarrow (\pi^\circ, \eta)$ and $\bar{p}^{\uparrow}p \rightarrow \pi^\circ X$ at high $p_\perp$,
x_F Dependence of Single-Spin Asymmetry in $p^{\uparrow}p \rightarrow \pi^\circ X$ and $\bar{p}^{\uparrow}p \rightarrow \pi^\circ X$,
x_F Dependence of Single-Spin Asymmetry in $p^{\uparrow}p \rightarrow \pi^\pm X$ and $\bar{p}^{\uparrow}p \rightarrow \pi^\pm X$, and
Double-Spin Asymmetry in π° Production.

ii) One-Spin and Two-Spin Measurements in Λ Production.
iii) Difference in Total Cross Section, $\Delta\sigma_L(pp)$ and $\Delta\sigma_L(\bar{p}p)$.

In general, data analyses are in progress. Here we will discuss the results of x_F dependence of asymmetry in the pion production.

Single-spin asymmetries were measured in $\pi^{\pm}$ production at 200 GeV/c.[1] The asymmetry values (A_N) in the $p^{\uparrow}p$ reaction are shown in Fig. 1 as a function of x_F for π^+ and π^- data over a $p_{\perp}$ range of 0.2 - 2.0 GeV/c. Further study of these data shows a threshold effect in which A_N increases dramatically above $p_{\perp}$ = 0.7 GeV/c. The A_N values in the $\bar{p}^{\uparrow}p$ reaction[2] are shown in Fig. 2 for the π^+ and π^- data. We observe a similar behavior on A_N magnitude with respect to x_F but the sign of A_N is positive for the π^- data and negative for the π^+ data.

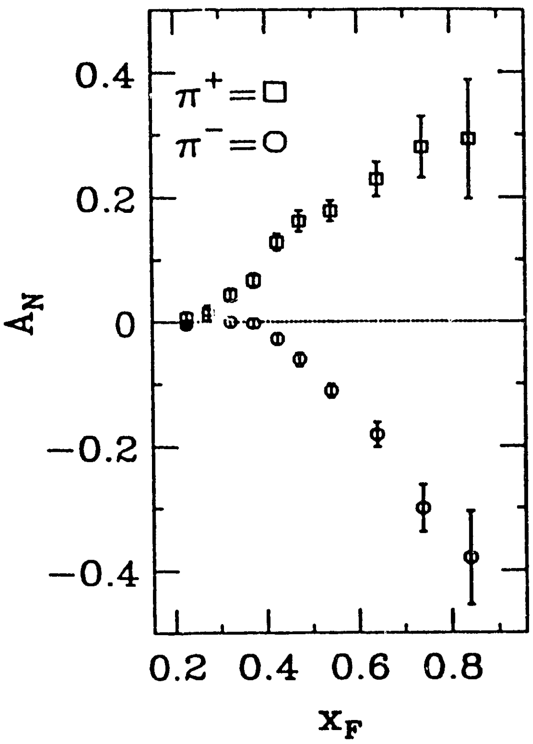

Fig. 1 A_N for π^+ and π^- production versus x_F integrated over pT.

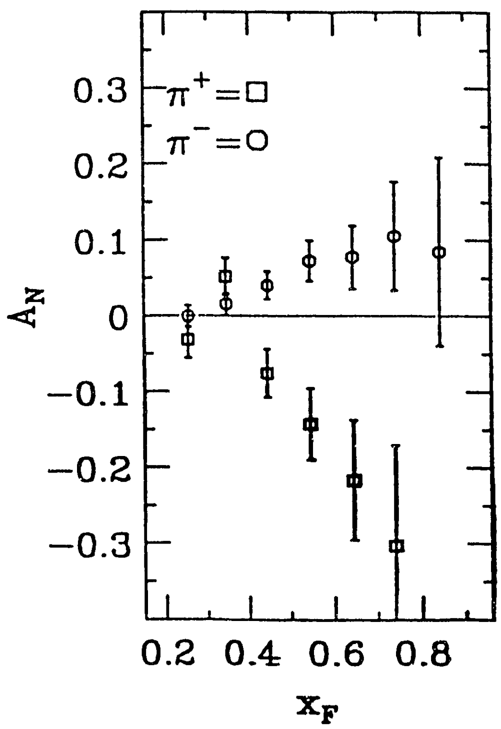

Fig. 2 A_N for π^+ (squares) and π^- (circles) in the $\bar{p}^{\uparrow}p$ reaction.

These results were explained in the following two papers thus far. The first one[3] uses the model which relates $pp \rightarrow \pi^{\pm}X$ scattering to the πp backward scattering. The antiprocess of $\pi^+p \rightarrow p\pi^+$ and $\pi^- p^{\uparrow} \rightarrow p\pi^-$ are $\pi^- \bar{p} \rightarrow \bar{p}\pi^-$ and $\pi^+ \bar{p} \rightarrow \bar{p}\pi^+$ respectively. Thus we have opposite signs for $p^{\uparrow}$ and $\bar{p}^{\uparrow}$ beams. The second one[4] discusses that these experimental results provide crucial tests for the existence of orbiting valence quarks. These asymmetries are expected to exist when annihilation of orbiting valence quarks takes place. The effective orbital motion is counter clock wise to the polarization axis. For π^+, orbiting u quarks pick up $\bar{d}$ and for π^-, orbiting of d quark picks up $\bar{u}$. In this model, the valence quark contributes to the proton spin and therefore there is no "proton spin crisis".

From this mirror-symmetry effect in π^+ and π^-, one may speculate $A_N = 0$ for π° production. By applying isospin relations for single-particle distributions,[5] $\sigma^+ A_N^+ + \sigma^- A_N^- = 2\sigma^\circ A_N^\circ$, where σ^+ and A_N^+ are for the cross section and analyzing power in $p^\uparrow p \rightarrow \pi^\circ X$ respectively, σ and A_N^- in $p^\uparrow p \rightarrow \pi^- X$, and σ° and A_N° in $p^\uparrow p \rightarrow \pi^\circ X$, we can conclude the following: experimental data show $\sigma^+ > \sigma^-$ and $A_N^+ \approx - A_N^-$ therefore we expect $A_N^\circ > 0$. Asymmetry measurements, A_N, in $p^\uparrow p \rightarrow \pi^\circ X$ and $\bar{p}^\uparrow p \rightarrow \pi^\circ X$,[6] on the x_F dependence at 200 GeV/c covering $p_\perp$ up to 2 GeV/c were carried out. A_N values are consistent with zero up to xF = 0.3 and 0.4, and then linearly increase to + 20% near $x_F = 1.0$ as shown in Fig. 3. Since π° has $u\bar{u}$ and $d\bar{d}$ terms, we expect to see similar behavior in $p^\uparrow p \rightarrow \pi^\circ X$ and $\bar{p}^\uparrow p \rightarrow \pi^\circ X$.

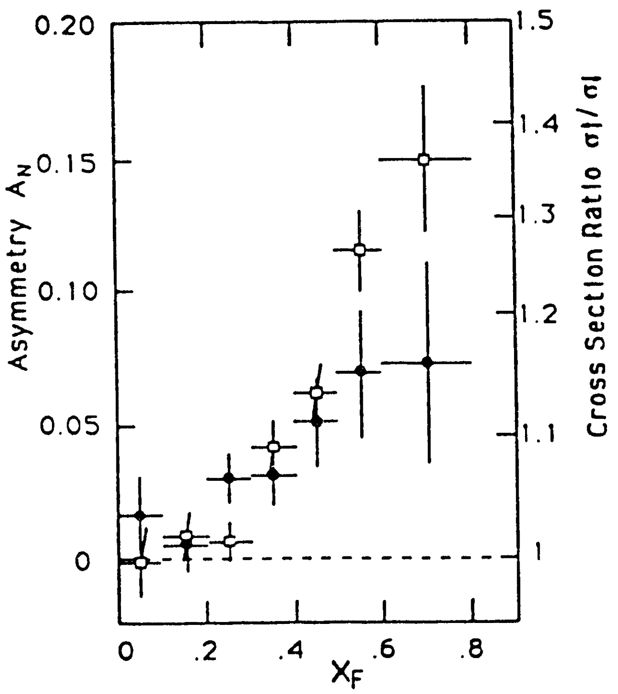

Fig. 3 x_F dependence of A_N at $p_\perp = 0.5$ to 2.0 GeV/c in the reaction $p^\uparrow p \rightarrow \pi^\circ X$ (open squares and $\bar{p}p \rightarrow$ (closed circles).

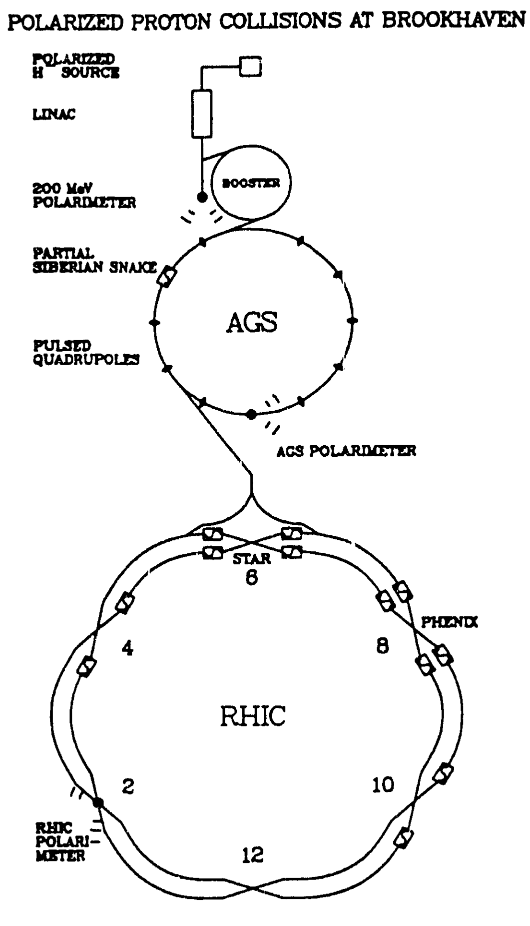

Fig. 4 Polarized collider at RHIC

2 RHIC Polarized Collider

The RHIC Spin Collaboration (RSC) has proposed various spin physics experiments with the RHIC polarized collider.[7] Polarized ion source, AGS, transfer of the polarized beam to RHIC, siberian snakes, and spin rotations are shown in Fig. 4.[8]

Physics issues for the polarized collider include:

i) Parton helicity distribution in a polarized proton (spin structure of the proton) by gluon and sea-quark measurements in direct-gamma, jet, single high-p_T particle production, and Drell-Yan process,

ii) Measure parity violation of real W and Z production in proton collisions,

iii) Quark transversity distribution in a polarized proton Drell-Yan process, and

iv) Tests of perturbative QCD predictions.

The RHIC spin program offers unique opportunities with high energy $\sqrt{s} = 50$ to 500 GeV, high luminosity reaching $\mathcal{L} = 2 \times 10^{32}\ \mathrm{cm^{-2}\ sec^{-1}}$, and high polarization. We will be able to study high-p_T events to which QCD would be applicable.

We illustrate measurements of parton helicity distribution in a polarized proton. Let us consider the hadronic reaction, pp $\rightarrow$ (hadron or gauge boson) + X. When both initial protons are longitudinally polarized, we measure an observable A_{LL} defined as:

$$A_{LL} = \left(1/P^2\right)\left(N^{++} - N^{+-}\right) / \left(N^{++} + N^{+-}\right).$$

If one QCD subprocess is dominant:

$$A_{LL} \sim P_a P_b\ \hat{a}_{LL}\ (a + b \rightarrow c + d),$$

in where we can determine the product of parton polarization P_a and P_b. In the case of quark-gluon Compton process ($qg \rightarrow \gamma q$), by knowing the quark polarization one can determine the gluon polarization; by detecting direct-γ at x_a and "away-side" jet at x_b one can determine the spin-dependent gluon structure function (x).

We now discuss parity-violating asymmetry in W and Z production. W and Z production with polarized protons is a totally unexplored area. The predictions for asymmetries, in particular, for the parity nonconservation ones, are expected to be large.

The observable A_L^{PV} is defined as:

$$A_L^{PV} = \left(N^- - N^+\right)/\left(N^- + N^+\right).$$

W's are predicted to be produced by a parity-violating mechanism, using standard model couplings.[9]

For W^+:

$$A_L^{PV} = \frac{\Delta u(x_1)\,\bar{d}(x_2) - \Delta\bar{d}\,(x_1)\,u(x_2)}{u\,(x_1)\,\bar{d}(x_2) + \bar{d}\,(x_1)\,u(x_2)}\,\hat{a}_L\,,$$

which contains information of sea-quark polarization.

When the helicities of both beams are the same, we define another observable as:

$$A_{LL}^{PV} = \left(N^{--} - N^{++}\right)/\left(N^{--} + N^{++}\right).$$

where -(+) are minus (plus) helicity, respectively.

Our present plan includes experiments with two major RHIC detectors (PHENIX and RHIC). We present the estimations on the acceptances of one of the detectors and the expected event rates for various reactions discussed earlier. This is to show our ultimate goals for experimental achievements.

The integrated luminosities used are:

$$\mathcal{L}dt = 8 \times 10^{38}\ cm^{-2}\ \text{at } 500\ GeV = 800\ pb^{-1}$$

$$\mathcal{L}dt = 3.2 \times 10^{38}\ cm^{-2}\ \text{at } 200\ GeV = 320\ pb^{-1}$$

which means 100 days of running ($4 \cdot 10^6$ sec, 50% eff.).

We present proposed experiments with STAR using the barrel EM calorimeter and shower maximum detector as i) for direct-γ production, the estimated statistical error in A_{LL} at $\sqrt{s} = 200$ GeV, is $\delta A_{LL} \sim \pm (1/P^2)\ (0.003\sqrt{3.2 \times 10^{38} cm^{-2} / \int \mathcal{L}dt})$ for $\Delta y = \pm 1$, $p_T = 10$ to 20 GeV, ($\delta A_{LL} \sim \pm 0.006$ with beam polarization, P = 70% and $\int \mathcal{L}dt = 1$) and ii) for W production we estimate 61,000 events for W^+ and 22,000 for W^-.

* Work supported by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.

3. References

1. D. L. Adams et al., *Phys. Lett.* B264 (1991) 462.
2. E-704 preliminary data.
3. J. Soffer and N. A. Tornquist, *Phys. Rev. Lett.* 68 (1992) 907.
4. C. Boros, Liang Zuo-tang, and Meng Ta-chung, *Phys. Rev. Lett.* 70 (1993) 1751.
5. J. Soffer and D. Wray, Wis-72/31-ph, unpublished.
6. D. L. Adams et al., *Phys. Lett.* B261 (1991) 201.
7. BNL RHIC Proposal, R5 (1992).
8. K. Brown et al., *Conceptual Design for the Acceleration of Polarized Protons at RHIC*, May 1993.
9. C. Bourrely and J. Soffer, *Phys. Lett.* to appear.

DATE

FILMED

10/20/93

END