ADVANTAGES OF POLARIZATION EXPERIMENTS AT RHIC*

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ABSTRACT

We point out various spin experiments that could be done if the polarized beam option is pursued at RHIC. The advantages of RHIC for investigating several current and future physics problems are discussed. In particular, the gluon spin dependent structure function of the nucleon could be measured cleanly and systematically. Relevant experience developed in conjunction with the Fermilab Polarized Beam program is also presented.

Some people may think that the primary advantage of polarized colliding beams is to eliminate the unpolarized background which is present with solid fixed targets. The newer polarized target materials such as Li^6D make this less of an advantage than it used to be, but in any case, the biggest advantage is in the cm energy and luminosity available to do the appropriate experiments for structure functions and particle searches.

For structure functions, RHIC seems to have a unique advantage in the root-S and luminosity. These allow one to do 2 to 2 physics with observation of the final two jets or gamma plus jet for applying kinematic constraints to determine x_1 and x_2 . The use of such kinematic constraints is problematic for fixed target, even at 2 or 3 TeV. Also, the root-S at RHIC is lower than at SSC so that the moderate x_{BJ} values are attainable, not just very low x .

Having the kinematic constraints is important for several reasons. In a fixed target experiment such as a direct gamma experiment one generally does not measure the away side jet well if at all. At Fermilab fixed target polarized beam energies and luminosities an experiment would then measure the spin structure function over a region around x of .2 or .3, weighted in x by the usual structure functions and cross section. The same x coverage is true of experiments which depend on gluon-gluon fusion to produce x_2 . One depends on the physics process to choose the gluon as opposed to the quark. With kinematic constraints from well measured jets, one has an extra handle as well as being able to measure as a function of x . The extra handle comes from the fact that the valance quark densities are higher than the gluon densities at large x and smaller at low x . Furthermore, the polarization of valance quarks has been measured to increase with x and is almost .4 at x of 0.2.

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So at RHIC,

- 1) One measures the structure function as a function of x ,
- 2) In some kinematic regions one is allowed a kinematic choice of gluon vs. quark since x_1 and x_2 are determined and quark and gluon densities have different x dependence, and
- 3) In some regions a valence quark of known high polarization can be chosen to investigate the low x gluon region where some of the physics questions reside at present.

A simple and illuminating way to compare physics coverage of different facilities is to use a kinematics program for 90 degree parton-parton scattering with event weighting using structure functions and parton cross sections, and to plot contours of constant event probability. We have done this for Fermilab and RHIC energies and luminosities and have used EHLQ structure functions. As an example we find that a Fermilab fixed target direct gamma experiment could get 5% error bars for a two spin measurement at $x_1 \approx x_2 \approx 0.2$, $pt = 5$, luminosity 5×10^{29} . At RHIC we can measure as a function of x from $x_1 = x_2 = .1$, $pt = 25$, $\eta = 0$ to $x_1 = .5$, $x_2 = .02$, $pt = 25$, $\eta = 2.3$ with about 5% error bars on direct gamma plus jet at luminosity of about 5×10^{31} . As pointed out by others at this workshop, one could get very small error bars at $pt = 20$ and luminosity of 1×10^{32} .

Another point is that at large rapidity, small x of gluon, where it may be difficult to do a direct gamma experiment, it is probably not necessary to use direct gammas. Due to the distributions of quarks and gluons two jet events with both jets at large rapidity are mainly from a quark at large x and a gluon at small x and the use of the physics process to select gluons is not necessary. Also, one may do a poor-man's jet experiment with π^0 's as the leading particles of jets.

Apparently, protons on deuterons is not possible for the machine, but perhaps one could do deuterons on deuterons after the nucleon-nucleon is understood.

Having polarized protons on polarized deuterons would allow comparison of gluon spin distributions for protons vs. neutrons similar to the comparisons of quarks for checking the Bjorken sum rule, etc. According to some people, one should think about such comparisons for the distributions of polarization of strange sea quarks also.

A separate issue discussed at this workshop was measurement of the beam polarization. In our experiments we have established that three physics processes are suitable for polarimeters in this energy range. These are Coulomb-Nuclear interference, inverse Primakoff effect, and pion inclusive production at large x_F . All of these

involve very forward particles, and some probably are best done from a gas jet target, although this should be studied.

The analyzing power of Coulomb-Nuclear interference⁶ is calculated from scattering amplitudes. It involves the dominant imaginary strong amplitude and the real part of the EM spin flip amplitude. The peak analyzing power is about 5% and in a real experiment with resolution and acceptance, the effective analyzing power may be 3%. The advantage of C-N for RHIC is that the scattered particle would go down the beam pipe to Roman Pot detectors and the recoil from a gas jet target could be measured with silicon detectors. It may be that beam-beam collisions are also suitable, as elastic events are sufficiently clean at small angle to have been measured in SPS.

The Primakoff polarimeter⁷ has a very high analyzing power which is related to measured asymmetries in low energy π^0 photoproduction. It may be a mismatch to RHIC unless one has close to 50 meters in a straight section for measuring forward protons outside the beam pipe. Also, a lead target must be used, possibly lead evaporated onto a carbon filament which would pass through the beam. Can one do proton-lead collisions in RHIC?

The large x pion inclusive polarimeter⁸ ($x > .5$) might be viable with forward electromagnetic detectors near a standard collider detector. The analyzing power grows with x and is on the order of 10%.

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Table I

A TABLE OF INTERESTING POLARIZED COLLIDING PHYSICS

NUCLEON SPIN STRUCTURE FUNCTIONS:

GLUON

2-SPIN EXPERIMENTS:

DIRECT GAMMA + JET

JET-JET

DRELL-YAN + JET

(ALSO, P-D BEAMS)

ORBITAL ANGULAR MOMENTUM

1-SPIN AND 2 SPIN EXPERIMENTS:

JET OR PI-ZERO

NEW IDEAS

STRANGE QUARK

?

SEARCHES

SUPER SYMMETRY

2-SPIN, 2 TO 2 PROCESSES:

JET-JET

LEPTON?

RIGHT HANDED W, ETC.

OTHER PHYSICS:

ELASTIC SCATTERING

ODDERON WITH POMERON ?

TOTAL CROSS SECTION

RELATE $\Delta\sigma_L$ TO RISING CROSS SECTION ?

PARITY VIOLATION

LARGE DUE TO NON-VALANCE QUARK CONTRIBUTION ?

SPIN OF JETS

STUDY FRAGMENTATION

LOOK AT ACAUSAL CORRELATIONS A LA BELL'S THEOREM

All of these topics have been treated in papers or conferences Refs. 1-5.

TABLE II

Comparison of Some Polarized Facilities

Laboratory	Momentum	Beam	Root-S	L Pol.	Target Junk	2-Spin	Direct gam. pt for 5% A_N A_{LL}		Typical x Coverage
AGS	20 + fix	PP	6		YES	YES			
FNAL	200 fix	PP	19	2E29	YES	YES			
	200 fix	PP-	19	1E28	YES	YES			
	500 fix	PP	30	6E29	YES	YES	5	4-5	.2 $\pm$.1
KEK			38						
CERN/ SPS	315 gas	PP	24	>4E29	NO	NO	4-7	---	.2 $\pm$.1
		PP-	24	>2E29	NO	NO			
UNK/ POLEX	2000 fix 700	PP	61	>1E30	YES	YES	7	4-7	.1 $\pm$?
		PP-		5E28	YES	YES			
RHIC	250 + 250	PP	500	2E32	NO	YES	25	5-25	.02 to .1
FNAL	900 + 900	PP-	1800	1E31	NO	NO	30	---	
SSC	20T + 20T	PP	40T	1E33	NO	YES?	?	?	Very Low

Note that RHIC is the only place to do a clean 2-spin experiment as a function of x_1 and x_1 in the relevant x region for the gluon spin distribution function.

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