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Spin Physics at E-704 and RHIC*

David G. Underwood

High Energy Physics Division
Argonne National Laboratory, Argonne, IL 60439 USA

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Abstract

Results from the E704 polarized beam program at Fermilab as well as the future measurements in the RHIC SPIN program are presented. These are in the context of possible spin measurements at HERA. The emphasis is on how to obtain spin dependent gluon and sea quark distributions. There are references for other topics such as twist-3, supersymmetry, and beam polarimeters.

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E704 was the highest energy polarized beam experiment done to date. It actually consisted of several experiments run more or less simultaneously, some with polarized target and some with hydrogen target. It utilized 200 GeV polarized Protons obtained from the parity violating decays of Lambdas. This was to some extent a survey experiment. It established polarimetry and a number of spin related phenomena at high energy. Proposals to exploit it more fully for pursuing the gluon polarization in the nucleon and polarization of sea quarks were not approved. There were proposals for direct photon experiments, χ_2 and J/ψ , and Drell–Yan.

The beamline allowed simultaneous tagging of two polarization directions, and unpolarized beam. The spin precession system allowed periodic flipping of the polarization directions for either transverse or longitudinal directions at the experiment.

1 E704 Summary

Results have been published on a number of topics including: The Beamline and the spin rotator [1, 2], Processes that were specifically proposed as high energy polarimeters, Coulomb Nuclear Interference [3, 4] and the Inverse Primakoff Effect Polarimeter. [5]

There are results that are relevant to the polarization of the gluon in the nucleon, δG, although they cannot provide tight constraints. These are A_{ll} in π^0 production [6] and A_{ll} in Multi–Photon production [7].

There are large asymmetries in π^+, π^- and π^0 production at large x_f for $p_t > 0.7$. These are quite similar to the asymmetries observed at 6, 12, and 18 GeV. They will be extremely useful for a fast polarimeter at RHIC. They have been measured with both polarized p and $\bar{p}$ beams. [8, 9, 10]

There were also results at moderately high p_t, mainly single spin asymmetries. These are relevant to twist–3 processes. The experiments were prototypes for the proposed high p_t two–spin experiments which were to investigate δs, δG. There was A_n in π^0 production at large $p_t, x_f = 0$ [11] and A_n in direct γ production [12].

Further results are forthcoming on the following topics: $\Delta\sigma_l$ for(pp) and $(\bar{p}p)$. This is the total cross section difference with both beam and target polarized. It is parity conserving. There are contributions from unnatural exchange like A_1, from "mini–jets" and in the case of $\bar{p}$, from valence quark annihilation. Also, Parity Violation in (pp) and $(\bar{p}p)$. This is the highest energy result, and the only result with anti–protons on protons. And, the parameters D_{nn} and A_n for Λ production are being analyzed to understand better the role of di–quarks in the nucleon, Thomas precession, exchange models, and other factors.

2 RHIC

The spin related experiments at RHIC will address many issues, some of which have been of interest for more than a decade, [13, 14, 15] and some of which were clarified when RHIC was considered.[16, 17, 18] The programs presently approved for the two large detectors, STAR and PHENIX, [18] will focus on the contribution of gluons and sea quarks to the spin of the proton, and on another aspect of using perturbative QCD to investigate non–perturbative QCD, the h_1 structure function.[19, 20, 21, 22]

The spin distribution of the gluon as a function of x_{bj} will be measured both with direct γ plus jet from the Compton diagram, and with gluon–gluon scattering as observed in jet–jet events.[23] These provide relatively direct measurement of the gluon, with small modifications

calculated at next to leading order.[24] In contrast, the efforts to access this information by means of deep inelastic scattering are through the Q^2 evolution. Both STAR and PHENIX can do simplified measurements with inclusive direct photons to get some measure of the gluon polarization at some average x_{bj} near 0.1.

The polarization of $\bar{u}$ and $\bar{d}$ can be measured using the W's. This will be done by looking for the electron from W decay at central rapidity in the case of STAR, and by looking at muons at relatively high rapidity in the case of PHENIX.[25, 18]

So far there is no official approval for twist-3 [26, 27] or for searches for supersymmetry.[15] In considering HERA, it seems that the Drell–Yan measurements using both longitudinal and transverse spin would be better done at lower $\sqrt{s}$ than RHIC, due to the cross section falling at high mass, and the x_{bj} being related to the mass. STAR and PHENIX will cover some of the same physics as Drell–Yan utilizing either the Z^0 or di–jets, but these are not quick or simple experiments.

Table 1: Examples of Expected Measurement Errors for Some Parts of the STAR SPIN Program:

Process	$\sqrt{s}$	$\delta_{measurement}$ δA_{ll}	$\delta_{physics}$ $\delta(\delta G/G)$
$pp \to \gamma$ X	200	~ 0.005	~ 0.035
	500	0.0014	0.01
$pp \to \gamma$ jet	200	0.01	0.07
	500	0.0024	0.016
$pp \to$ jet X	200	0.0015	0.003
$pp \to$ jet jet	200	0.005	0.02
		δA_l	$\delta(\delta\bar{d}/\bar{d})$
$pp \to$ W+ X		~ 0.006	~ 0.03

Working Assumptions for RHIC SPIN used in proposals:

40 Weeks of Heavy Ion Running / Year

10 Weeks of Spin Running / Year

at $\sqrt{s} = 500$ GeV:
Luminosity $= 2 \times 10^{32}$ cm^{-2} sec^{-1}
for 100 days at 50% efficiency
Integrated Luminosity $= 800$ pb^{-1}

at $\sqrt{s} = 200$ GeV:
Luminosity $= 8 \times 10^{31}$ cm^{-2} sec^{-1}
for 100 days at 50% efficiency
Integrated Luminosity $= 320$ pb^{-1}

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