Feasibility of DIS (Polarized e-p Collider) at RHIC

G. Igo, UCLA & T. Sloan, Lancaster U.

The Relativistic Heavy Ion Collider (RHIC) with polarized proton and He^3 beams and with heavy ion beams could support a program of deep inelastic scattering experiments if a low energy beam (~2GeV) of electrons circulated in RHIC. These experiments,which would have a similar center of mass energy to the highest energy fixed target experiments, would allow precision measurements of the polarized proton and neutron structure functions down to Bjorken x of 10^{-5} and permit a precision test of the Bjorken Sum Rule (BjSR) [1]. Collisions of 50 GeV/nucleon polarized protons and He-3 ions with 2 GeV polarized electrons (60 circulating bunches of 10^{11} polarized electrons produced by a SLAC-type [3] polarized electron source) would allow the BjSR integrals to be determined to a statistical precision of 1.4% and 0.8% at Q^2 of 2 and 8 GeV^2 respectively for runs of luminosity of 1000 pb^{-1} for each of e-p and e-He^3 collisions. The BjSR is a deeply fundamental sum rule which, if broken, would imply serious consequences for QCD [5]. The current world data agrees with the BjSR at the level of 10% due to all sources of error [3,4]. Higher precision measurements would provide a more stringent test of QCD. Such an experiment at RHIC would complement those proposed at HERA [6], which would have a much wider Q^2 and higher energy range and hence probe different physics.

The addition of the option of e-p, He^3 collisions to RHIC's arsenal would provide a nice way to measure the absolute polarization of these hadron beams by measuring the elastic scattering asymmetry A_{nn} and by measuring the electron beam polarization with high precision in Moller scattering.

1. J. D.Bjorken, Phys. Rev. **148** (1966) 1467, *ibid* **D1** (1970) 1376.
2. R. Alley et al., Nucl. Instrum.Methods **A365** (1995) 1.
3. B. Adeva et al., submitted to Physical Review D, May 1998.
4. K. Abe et al., Phys. Lett. **B405** (1997) 180.
5. R. P. Feynman, Photon Hadron Interactions (Benjamin Press, 1972).
6. *Future Physics at HERA*, www(http://www.desy.de/~heraws96).

FEASIBLITY OF DIS (POLARIZED e-p COLLIDER) AT RHIC

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HISTORY

SPIN 1/2 $\uparrow$ nucleon = $(\uparrow\downarrow\uparrow)$ i.e. $\Delta\Sigma = \Delta u + \Delta d = 1$

$$\Delta u = \int_0^1 u^{\uparrow}(x) - u^{\downarrow}(x)\ dx$$

$$\Delta d = \int_0^1 d^{\uparrow}(x) - d^{\downarrow}(x)\ dx$$

STRUCTURE FUNCTION $g_1(x) = 1/2\ \Sigma\ e_i^2\ (q_{i(x)}^{\uparrow} - q_{i(x)}^{\downarrow})$

MEASURED IN POLARIZED DIS.

$$A = \frac{d\sigma^{\uparrow\downarrow} - d\sigma^{\uparrow\uparrow}}{d\sigma^{\uparrow\downarrow} + d\sigma^{\uparrow\uparrow}} = (a\, g_1(x,Q^2) + b\, g_2(x,Q^2))$$

KINEMATIC FACTORS: b small for $\uparrow\uparrow$ - a small(ish) for $\uparrow\leftarrow$

ALTERNATIVE NOTATION

VIRTUAL PHOTON ASYMMETRIES $A_1 = \dfrac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$; $A_2 = \sigma_{TL} / \sigma_T$

$$A_1 = g_1 / F_1 \quad \text{(approx)}$$

MEASURE

$$A_m = \frac{N^{\uparrow\downarrow} - N^{\uparrow\uparrow}}{N^{\uparrow\downarrow} + N^{\uparrow\uparrow}} = P_B\, P_T\, f\, D\, A_1$$

$(D \alpha y)$

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$(D \alpha y)$

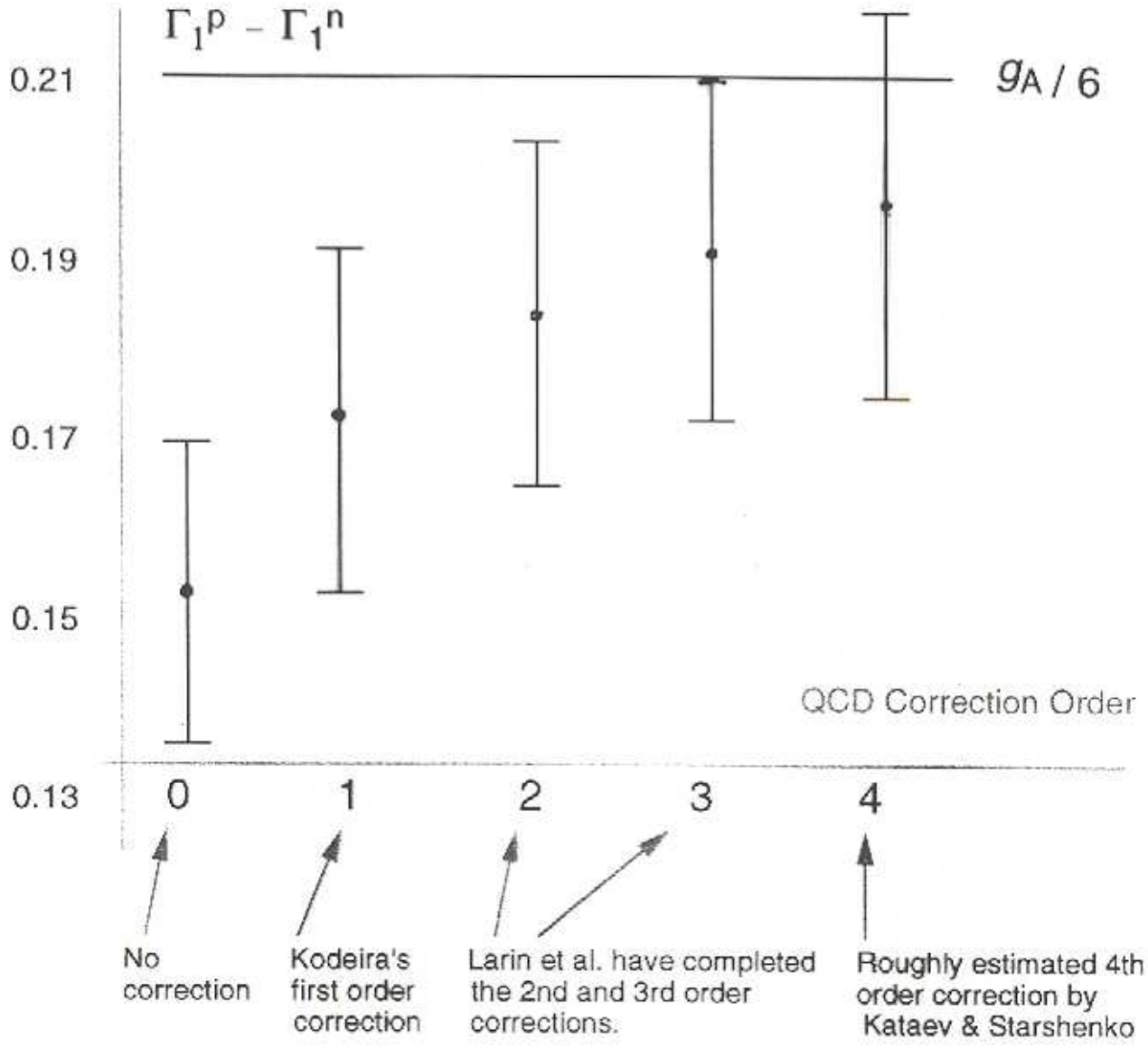
E142 -E143 ($Q^2 \sim 2$ GeV^2) ($\alpha_s = 0.38$)

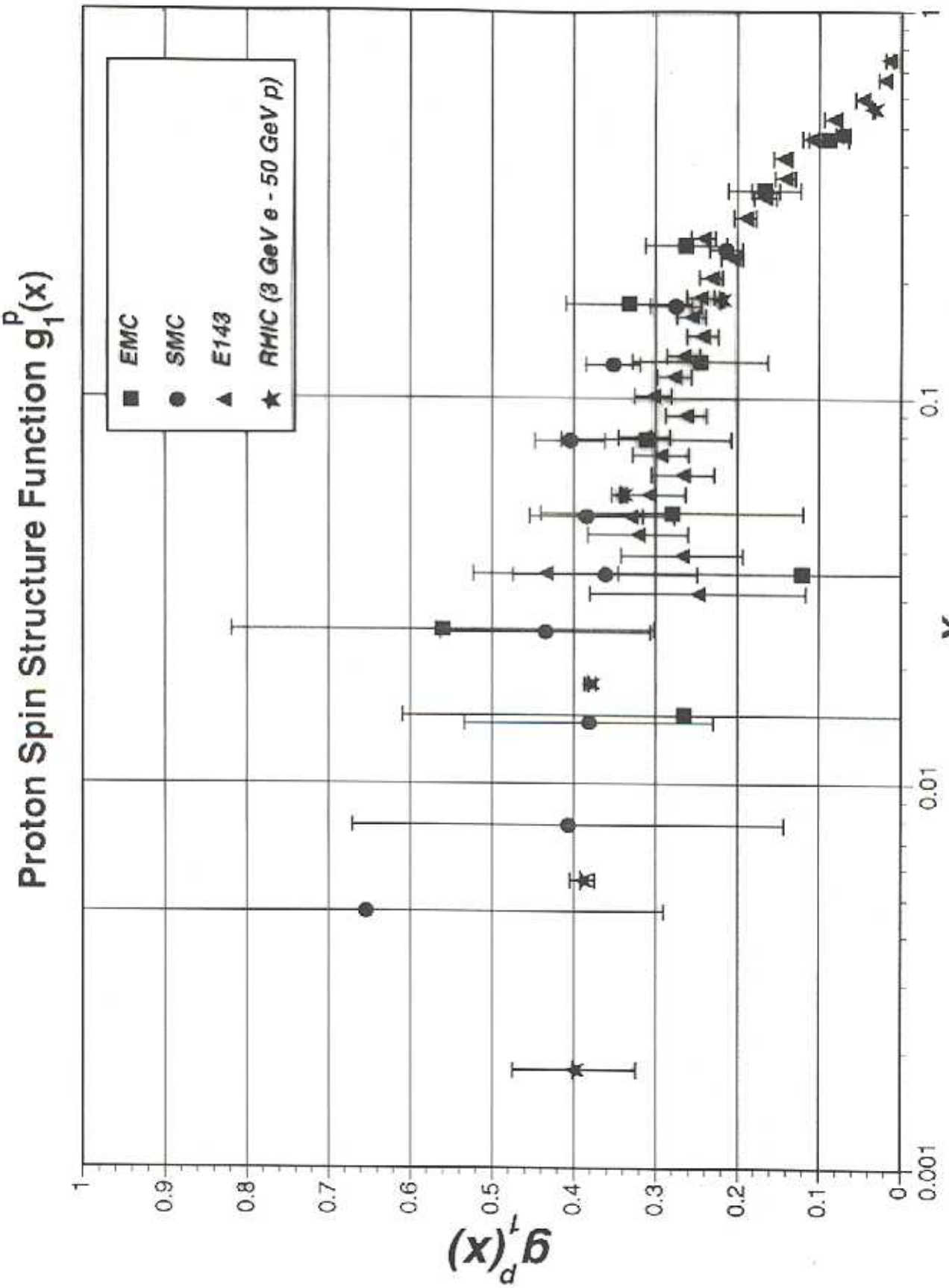
E142 $\Gamma_1^n = -0.022 \pm 0.011$ ←

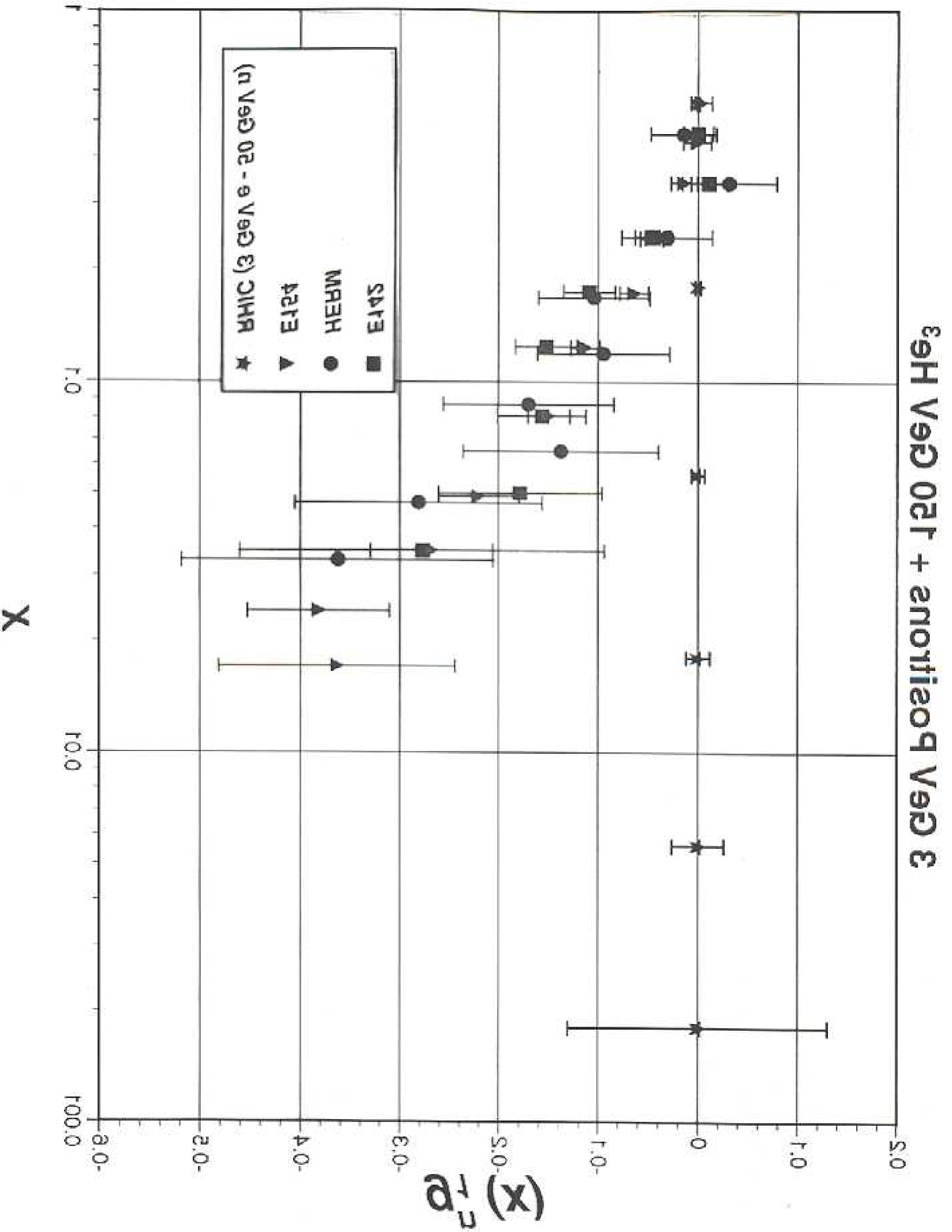
E143 $\Gamma_1^p = 0.129 \pm 0.010$ ← measured values

ie. $\Gamma_1^p - \Gamma_1^n = 0.151 \pm 0.015$ ←

EXPECT $g_A/6$ X QCD Rad. Corr. = 0.21 X QCD Corr.
calculate the QCD corrections to different orders.




Proton Spin Structure Function $g_1^p(x)$
EMC
SMC
E143
RHIC (3 GeV e - 50 GeV p)
$g_1^p(x)$
X
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.001
0.01
0.1
1


3 GeV Positrons + 150 GeV He3
RHIC (3 GeV e - 50 GeV n)
E154
HERM
E142
x
g1n (x)
0.001
0.01
0.1
1
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2

$\Gamma_1^p - \Gamma_1^n$

Nucleon energy	25 GeV	50 GeV	100 GeV
Gamma 1 p at qsq=2	+-.0013	.0023	.0037
Gamma 1 n at qsq=2	+-.0018	.0031	.0050
Bj sum rule at qsq=2	+-.0022	.0039	.0062
% accuracy on Bj SR	1.1	2.0	3.1
Gamma 1 p at qsq=8	+-.00081	.0015	.0025
Gamma 1 n at qsq=8	+-.0011	.0020	.0035
Bj sum rule at qsq=8	+-.0014	.0025	.0043
% accuracy on Bj SR	0.7	1.3	2.2
(taking gamma 1 p - gamma 1 n = 0.2)			

WORLD DATA % accuracy on Bj SR

~3 1/2 % STAT.

± 7% SYST.

Summary

- Rich program at RHIC energies complimentary to Hera program

✓ B_j SR

Important improvement in both statistical and systematic errors is possible.

✓ Variable proton energy

✓ Polarized He^3 Crucial

- Heat load on RHIC
- STAR & PHENIX DETECTORS