Experimental Status of RHIC Spin & eRHIC

\[ \frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_q + L_g \]

Cold Siberian snake in AGS
March 31, 2005

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SUNY–Stony Brook & RBRC
NSAC Subcommittee, April 4, 2005
RHIC Polarized Collider

- Absolute Polarimeter (H↑ jet)
- RHIC pC Polarimeters
- PHOBOS
- BRAHMS & PP2PP
- PHENIX
- STAR
- AGS
- Pol. H⁻ Source
- LINAC
- Booster
- 200 MeV Polarimeter
- Rf Dipole
- Strong AGS Snake
- Spin Rotators
  (longitudinal polarization)
- Siberian Snakes
- Spin flipper
- Helical Partial Siberian Snake
- AGS Internal Polarimeter
- AGS pC Polarimeters

- Installed and commissioned during FY04 run
- Plan to be commissioned during FY05 run
- Installed and plan to be commissioned during FY05 run
$P_{Beam} = P_{Jet} \times \frac{\epsilon_{Beam}}{\epsilon_{Jet}}$  

where $\epsilon = \frac{N_{up} - N_{down}}{N_{up} + N_{down}}$
Polarization in RHIC

- **RUN 4 RHIC pp average polarization (0.39 +/- 0.03)**

- **AGS cold snake installed last week:**
  - Commissioning in Run-5
  - **Expected polarization in Run-6 for Physics >65 %**
Exquisite Control of Systematics
RHIC Spin Physics Program

- Direct measurement of polarized gluon distribution using multiple probes (R. Jaffe’s talk)
- Direct measurement of anti-quark polarization using parity violating production of $W^{+/−}$
- Transverse spin: Transversity & transverse spin effects: possible connections to orbital angular momentum?
Cornerstone to the RHIC Spin program

Unpolarized data are well described by NLO
$\Delta G/G$: Measurements have begun!

PHENIX data
Run-3 & 4 combined
- 200nb$^{-1}$, 16% pol
- 100nb$^{-1}$, 26% pol

Run 5 starting next week

$\pi^0 A_{LL}$ from $pp$ at $\sqrt{s}=200$ GeV
- Combined
- GRSV-max
- GRSV-std

Scaling error of ~65% 15% with JetPol is not included.
$\Delta q - \overline{\Delta q}$ at RHIC via W production

unpol.

$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

PHENIX & STAR Upgrades:
Axel Drees’s talk
Physics with transverse spin at RHIC

\[ A_N = \frac{\sigma_{\uparrow \downarrow} - \sigma_{\downarrow \uparrow}}{\sigma_{\uparrow \uparrow} + \sigma_{\downarrow \downarrow}} \]

\[ \delta q(x) = \]

- **Transverse Physics:** Measurement of transversity and study of other transverse spin effects with possible connections to orbital angular momentum

STAR data

- \( \pi^0 \) mesons
- Total energy
- Collins
- Sivers
- Initial state twist-3
- Final state twist-3

\[ \langle p_T \rangle = 1.0 \ 1.1 \ 1.3 \ 1.5 \ 1.8 \ 2.1 \ 2.4 \ \text{GeV/c} \]
eRHIC at BNL

Construction of a high energy, high intensity polarized electron (and positron) beam to collide with the existing heavy ion and polarized proton beam would significantly enhance RHIC’s ability to probe fundamental and universal aspects of QCD.

- \( E_e = 10 \text{ GeV} \) (~5–12 GeV variable) TO BE BUILT
- \( E_p = 250 \text{ GeV} \) (~50–250 GeV variable) EXISTS
- \( E_A = 100 \text{ GeV/nucleon} \) EXISTS

A new detector for ep & eA
Precision tool to study & understand QCD
eRHIC vs. Other DIS Facilities

- First Polarized DIS collider

- New kinematic region

- Polarization of $e^+p$ and light ion beams at least $\sim 70\%$ or better

- Heavy ions of ALL species at RHIC
  - High gluonic densities

- High Luminosity:
  - $L(ep) \sim 10^{33-34} \text{ cm}^{-2} \text{ sec}^{-1}$
CM vs. Luminosity

- eRHIC
  - Variable beam energy
  - Proton-to-Uranium ion beams!
  - Proton, $\text{He}^3$(EBIS) polarization
  - Huge luminosity
Scientific Frontiers for eRHIC

- Understand nucleon structure and its spin, role of quarks & gluons in the nucleons, issues of confinement, low-x & DVCS ...

- Exploration meson structure

- Understand the role of partons in nuclei to understand confinement in nuclei

- Understand hadronization in nucleons & nuclei in nuclear media

- Explore and study partonic matter under extreme conditions with e-A
  - Large “A” at RHIC: very high gluon densities
  - Saturation/Color Glass Condensate
Spin structure & evolution: Precision Measurement

Fixed target experiments

1989 - 1999 Data

Luminosity = \approx 85 \text{ inv. pb/day}

Studies included statistical error & detector smearing to confirm that asymmetries are measurable. No present or future approved experiment will be able to make this measurement.

\Rightarrow \text{ Bjorken sumrule } \int_0^1 dx (g_1^p - g_1^n)(x, Q^2) \approx 1-2\% \text{ precision at eRHIC}
Bj Sum Rule & Determination of $\alpha_s$

$\alpha_s(M_Z)$ has been determined from Bj spin sum rule by:


Values range from 0.114–119 with uncertainties:

- $\pm 0.004$ (experimental)
- $\pm 0.010$ (theory/low x extrapolation)

Particle Data Book, Extended version:

"Theoretically, this sum rule is better for determining $\alpha_s$ because perturbative QCD result is known to higher order ($\mathcal{O}(\alpha_s^4)$), and these terms are important at low $Q^2$. Should data at lower x become available, so that the low x extrapolation is more tightly constrained, the Bj sum rule method could give the best determination of $\alpha_s$"
DIS in Nuclei is Different!

Regions of:
- Fermi smearing
- EMC effect
- Enhancement
- Shadowing
- Saturation?

Regions of shadowing and saturation mostly around $Q^2 \sim 1$ GeV$^2$

An e–A collision at eRHIC can be at significantly higher $Q^2$

Already hints of exciting physics in this from: HERA, RHIC d-A; eRHIC will allow precision measurements
Some probes of Gluon Saturation/CGC

- How does high density gluonic matter affect quark & gluon distributions?
  - $F_2$ measurements at low $x$ for $eA$ (for different $A$)
    - $d\ln F_2/d\ln Q^2, d\ln F_2/d\ln x$: high precision measurements
  - $F_L$ measurements
    - Energy variability of hadron beam essential & available

- How does nuclear matter become opaque?
  - CGC expects large fractions of diffractive cross sections in $eA$
    - Diffractive cross section in $eA$
    - Detector capabilities in the high rapidity region crucial
    - Interaction point and detector need to be developed together
A Detector for eRHIC:

Single detector for ep and eA

HERA-Like design being studied as start-up
- Calorimetry & tracking
- Add PID

HERA-III like ideas for eRHIC:
A strong European interest!
Summary:

- **RHIC Spin** promises an interesting and exciting time in the next few years in our pursuit of **understanding nucleon spin**.

- **eRHIC** will be the next generation precision tool for **understanding QCD & the structure of matter including its spin**.
A unique laboratory for precision QCD

ep/ep/eA

AA/pA/pp

PHENIX+

STAR+