Experimental Status of RHIC Spin & eRHIC

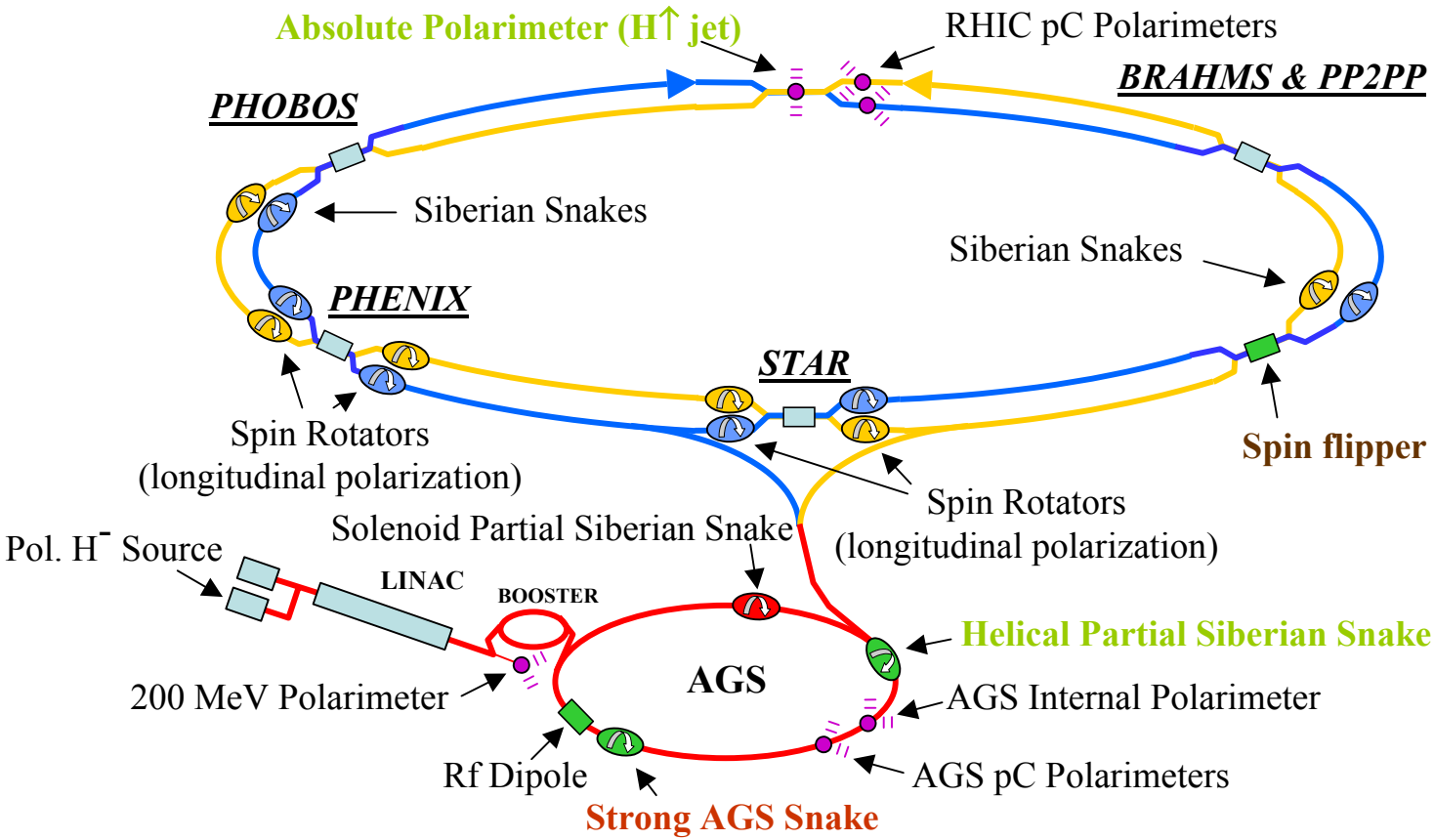
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

0.2!

Abhay Deshpande
SUNY-Stony Brook & RBRC
NSAC Subcommittee, April 4, 2005

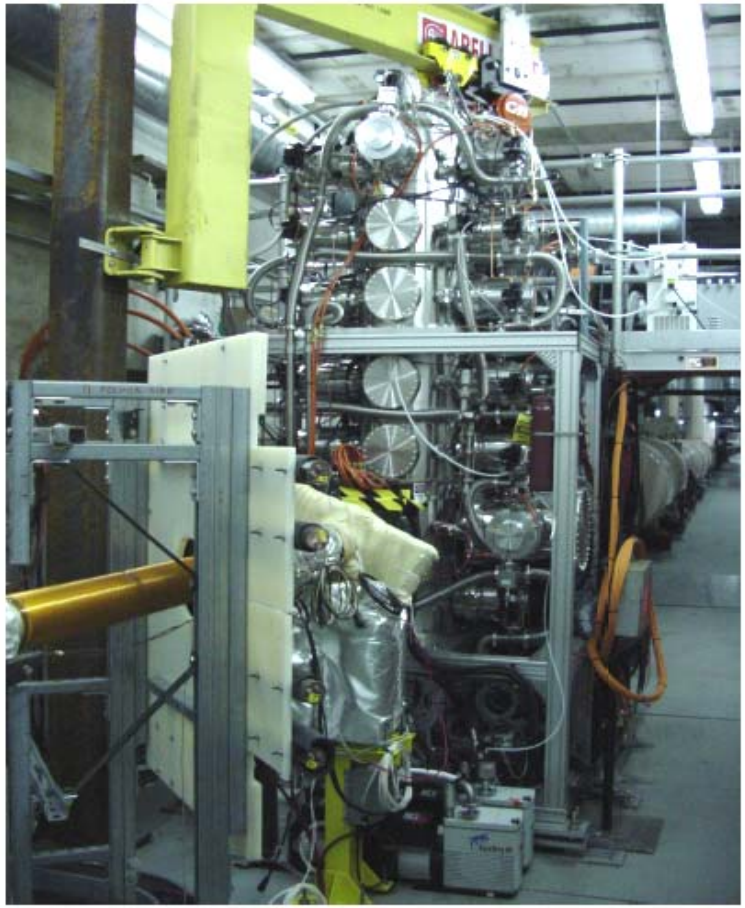
STONY BROOK
STATE UNIVERSITY OF NEW YORK

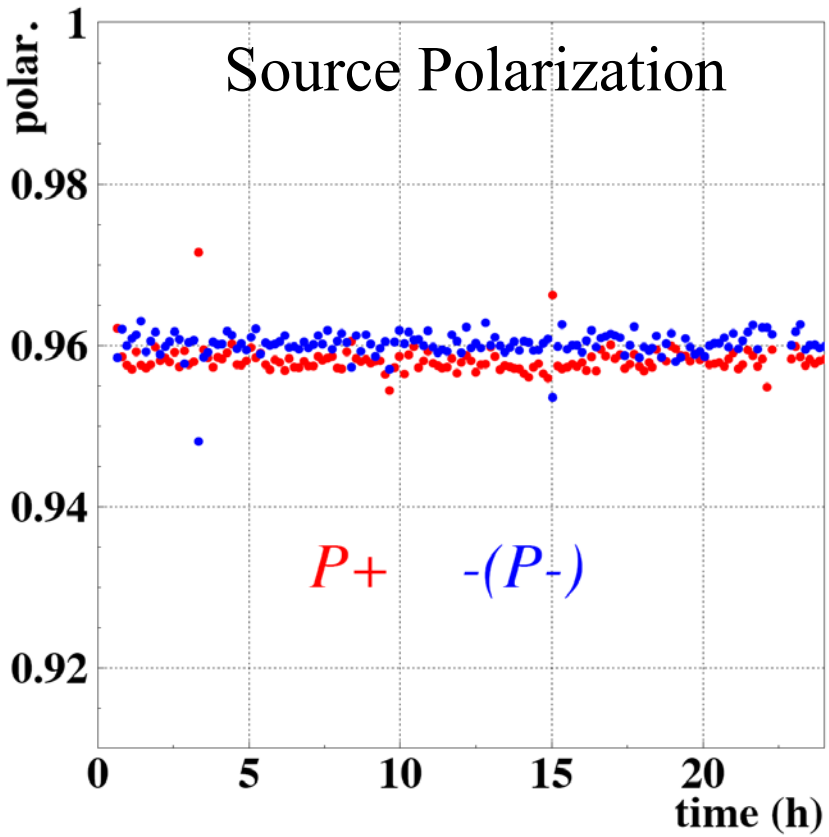
RHIC Polarized Collider



- Installed and commissioned during FY04 run
- Plan to be commissioned during FY05 run
- Installed and plan to be commissioned during FY05 run

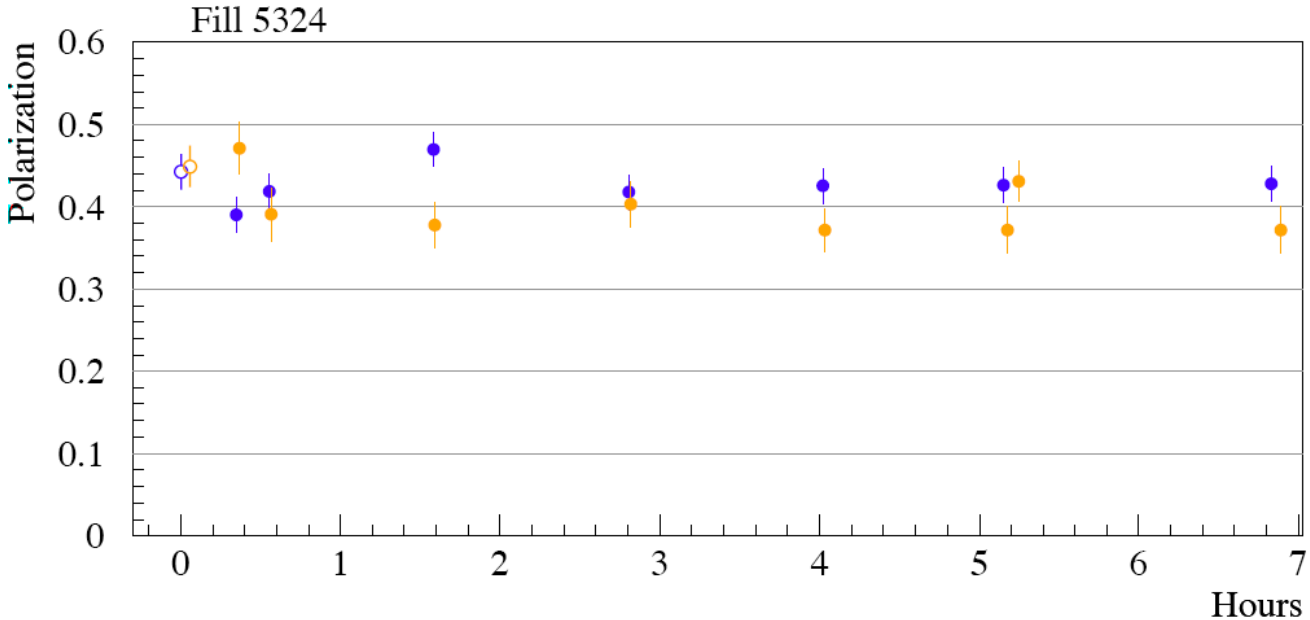
RHIC Polarimetry





$$P_{Beam} = P_{Jet} \times \frac{\epsilon_{Beam}}{\epsilon_{Jet}} \text{ where } \epsilon = \frac{N_{up} - N_{down}}{N_{up} + N_{down}}$$

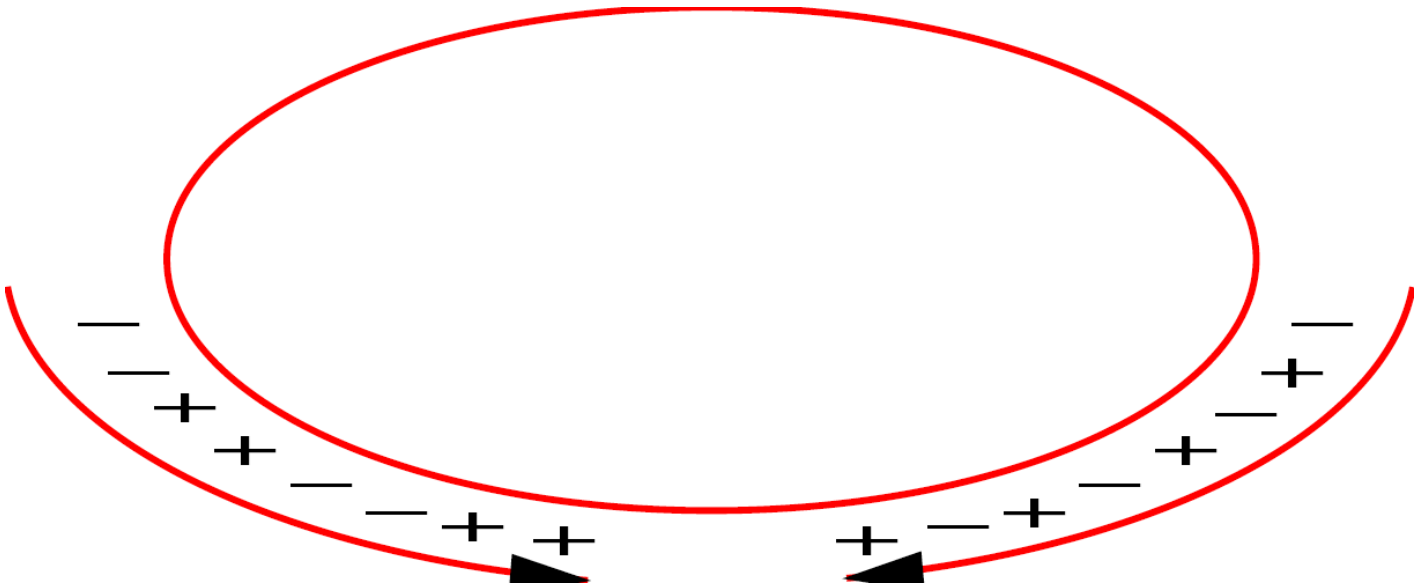
Polarization in RHIC

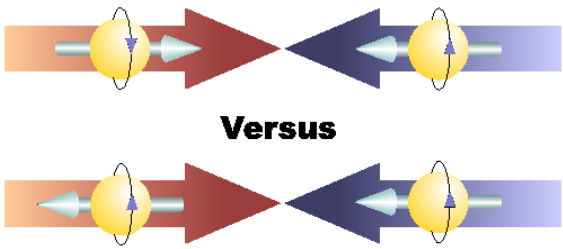


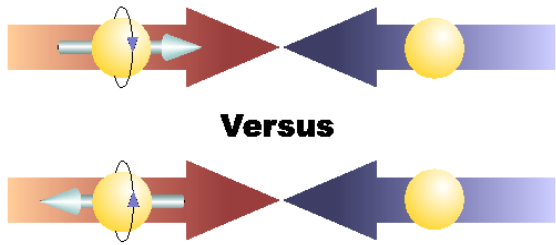
RUN4

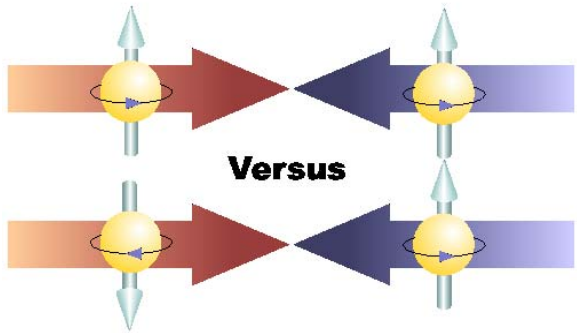
- RUN 4 RHIC pp average polarization (0.39 +/- 0.03)
- AGS cold snake installed last week:
  - Commissioning in Run-5
  - Expected polarization in Run-6 for Physics >65%

Exquisite Control of Systematics







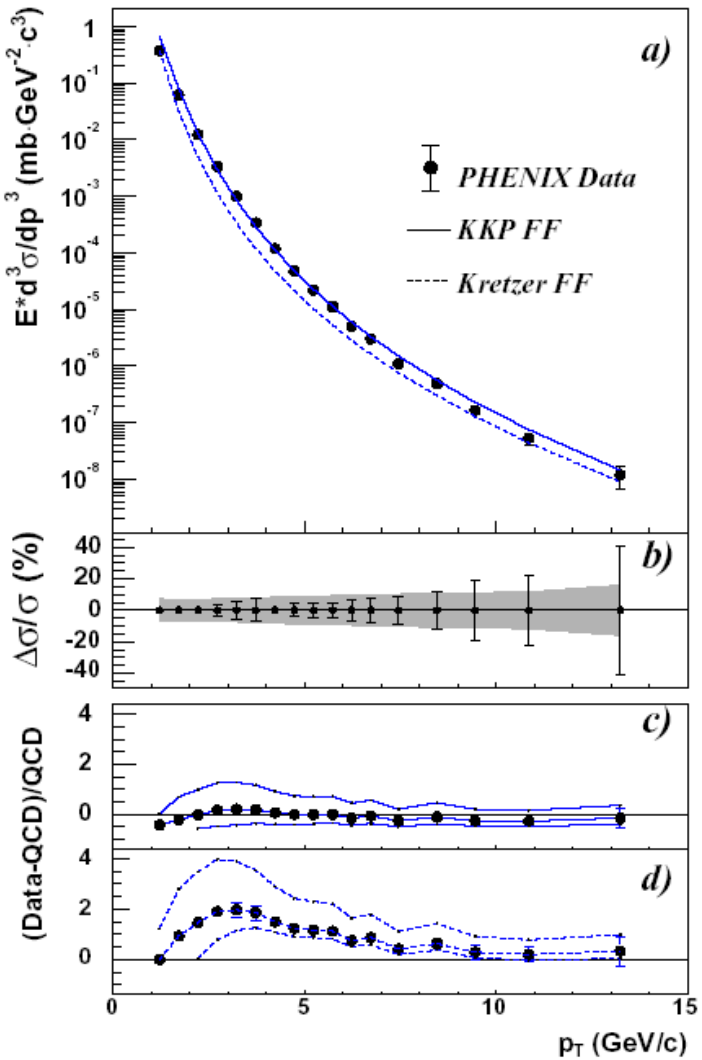


RHIC Spin Physics Program

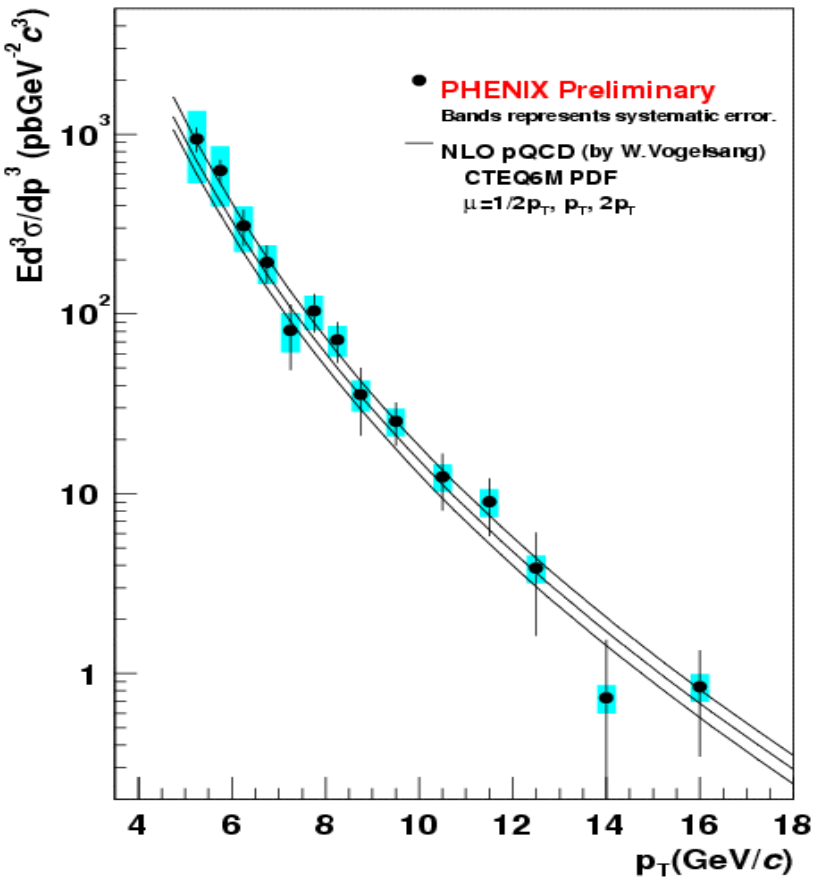
- *Direct measurement* of polarized gluon distribution *using multiple probes (R. Jaffe's talk)*
- Direct measurement of *anti-quark polarization* using parity violating production of $W^{+/-}$
- Transverse spin: Transversity & transverse spin effects: possible connections to orbital angular momentum?

Cornerstone to the RHIC Spin program

$pp \rightarrow \pi X$

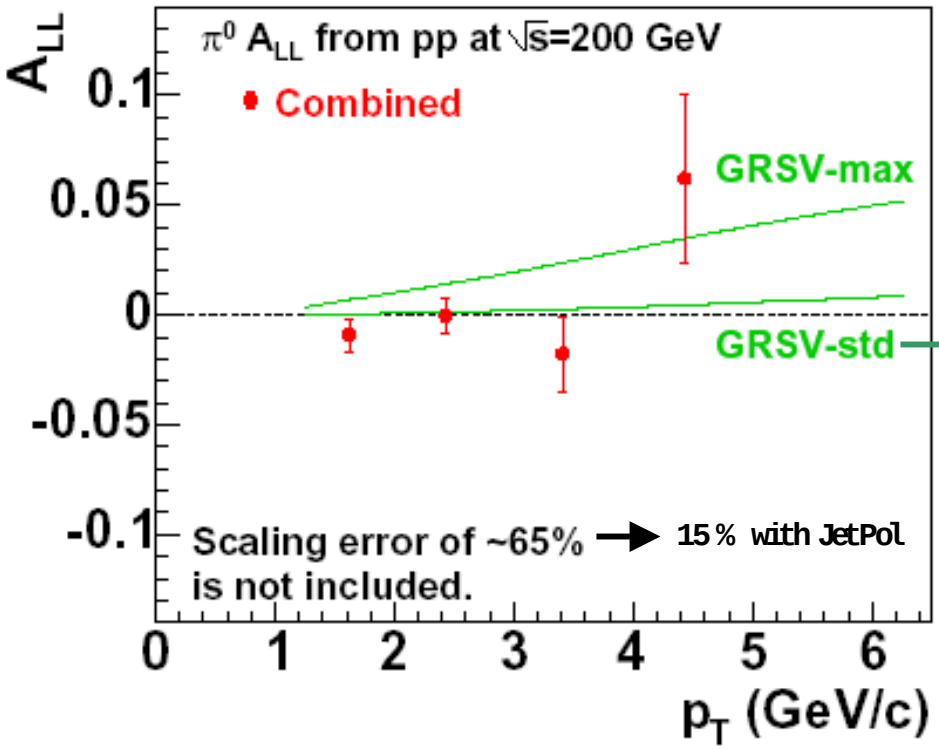


$pp \rightarrow \gamma X$

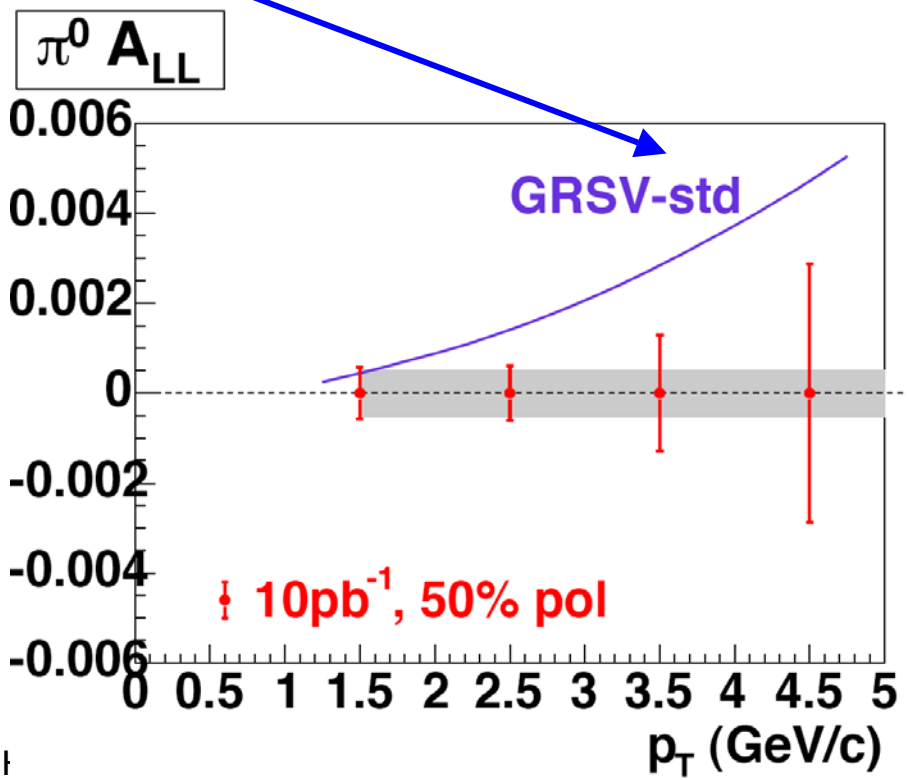


Unpolarized data are well described by NLO

ΔG/G: Measurements have begun!

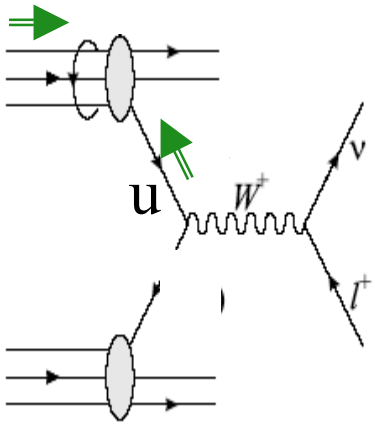


PHENIX data
Run-3 & 4 combined
~200nb^{-1}, 16% pol
~100nb^{-1}, 26% pol



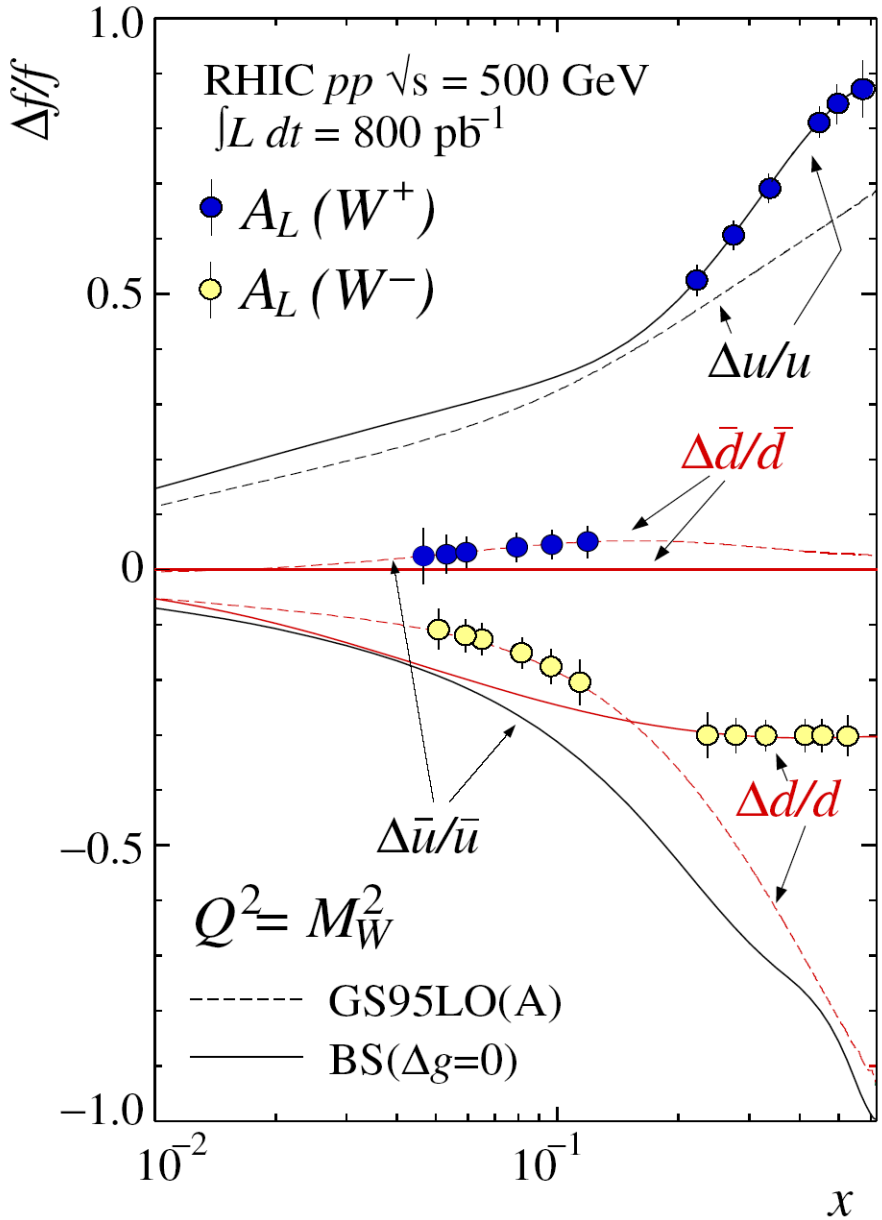
Run 5 starting
next week

Δq-$\Delta \bar{q}$ at RHIC via W production



unpol.

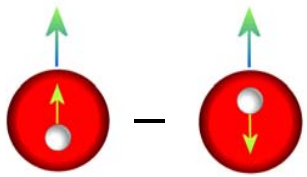
$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$



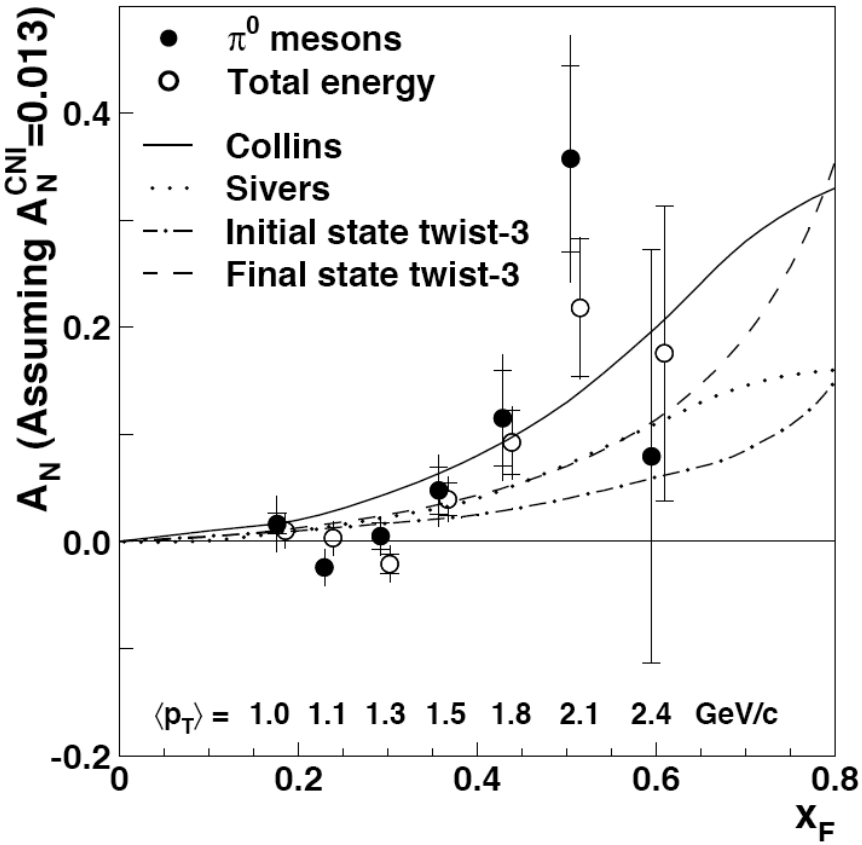
PHENIX & STAR Upgrades:
Axel Drees's talk

Physics with transverse spin at RHIC

$$A_N = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow}$$

$\delta q(x) =$ 

STAR data



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

eRHIC at BNL

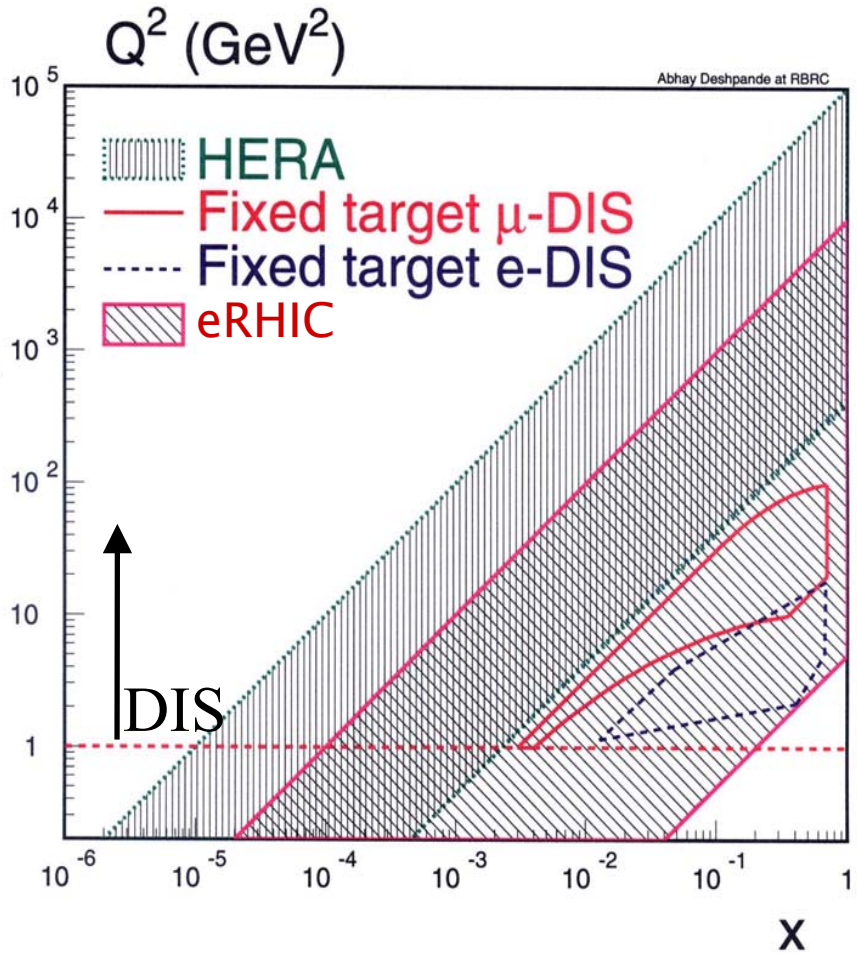
Construction of a high energy, high intensity polarized electron (and positron) beam to collide with the existing heavy ion and polarized proton beam would significantly enhance RHIC's ability to probe **fundamental and universal aspects of QCD**

- E_e = 10 GeV (~5-12 GeV variable) — TO BE BUILT
- E_p = 250 GeV (~50-250 GeV variable) — EXISTS
- E_A = 100 GeV/nucleon — EXISTS

A new detector for ep & eA

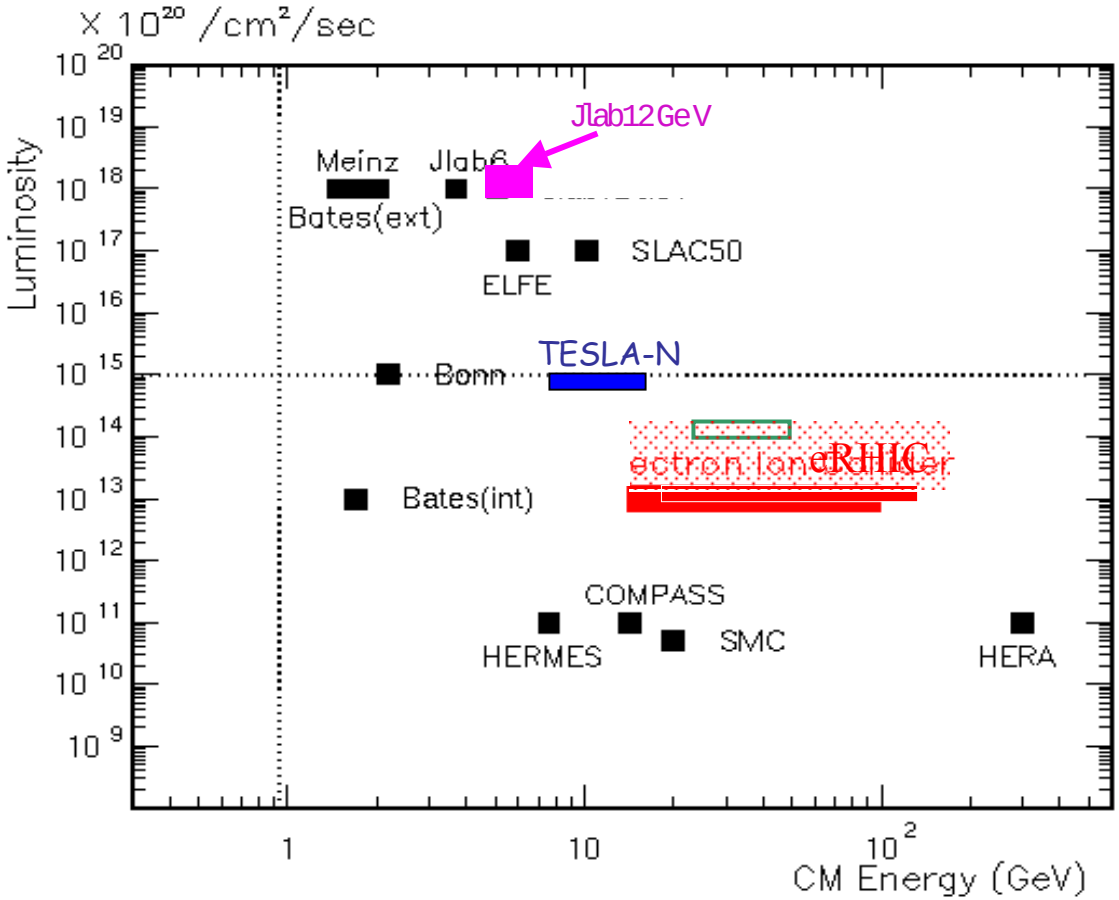
Precision tool to study & understand QCD

eRHIC vs. Other DIS Facilities



- **First Polarized DIS collider**
- **New kinematic region**
- Polarization of e,p and light ion beams at least ~ 70% or better
- Heavy ions of ALL species at RHIC
  - High gluonic densities
- High Luminosity:
  - **L(ep) ~$10^{33\text{-}34}$ cm^{-2} sec^{-1}**

CM vs. Luminosity



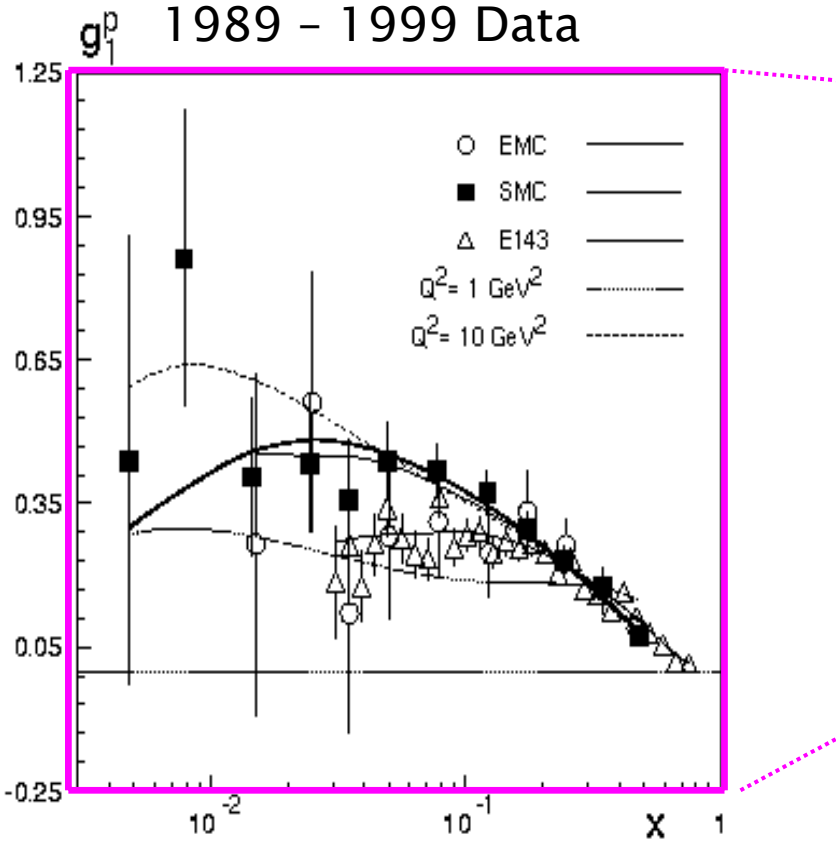
- **eRHIC**
  - Variable beam energy
  - Proton-to-Uranium ion beams!
  - Proton, He^3(EBIS) polarization
  - Huge luminosity

Scientific Frontiers for eRHIC

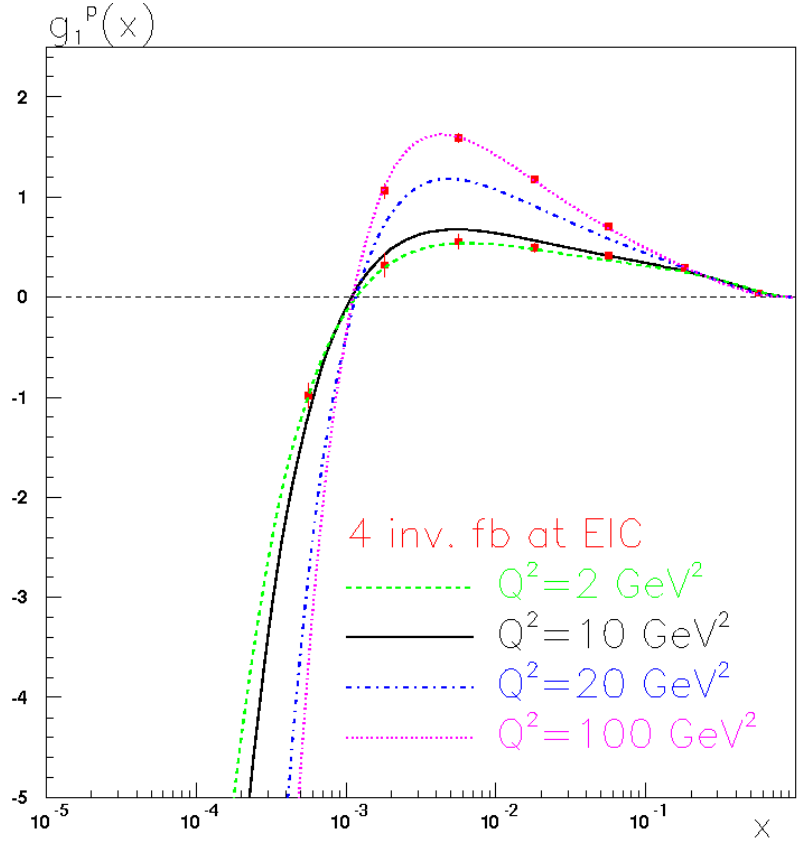
- Understand nucleon structure and its spin, role of quarks & gluons in the nucleons, issues of confinement, low-x & DVCS …
- Exploration meson structure
- Understand the role of partons in nuclei to understand confinement in nuclei
- Understand hadronization in nucleons & nuclei in nuclear media
- Explore 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 = ~85 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

$\Rightarrow$ BJORKEN SUMRULE $\int_0^1 dx(g_1^p - g_1^n)(x, Q^2)$ ~ 1-2% precision at eRHIC

Bj Sum Rule & Determination of α_s

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

1. J. Ellis & M. Karliner, Phys. Lett. B341, 387 (1995)
2. G. Altarelli et al., Nucl. Phys. B496, 337 (1997)
3. B. Adeva et al. SMC Collaboration, Phys. Rev. D58 (1998) 112002

Values range from 0.114-119 with uncertainties:

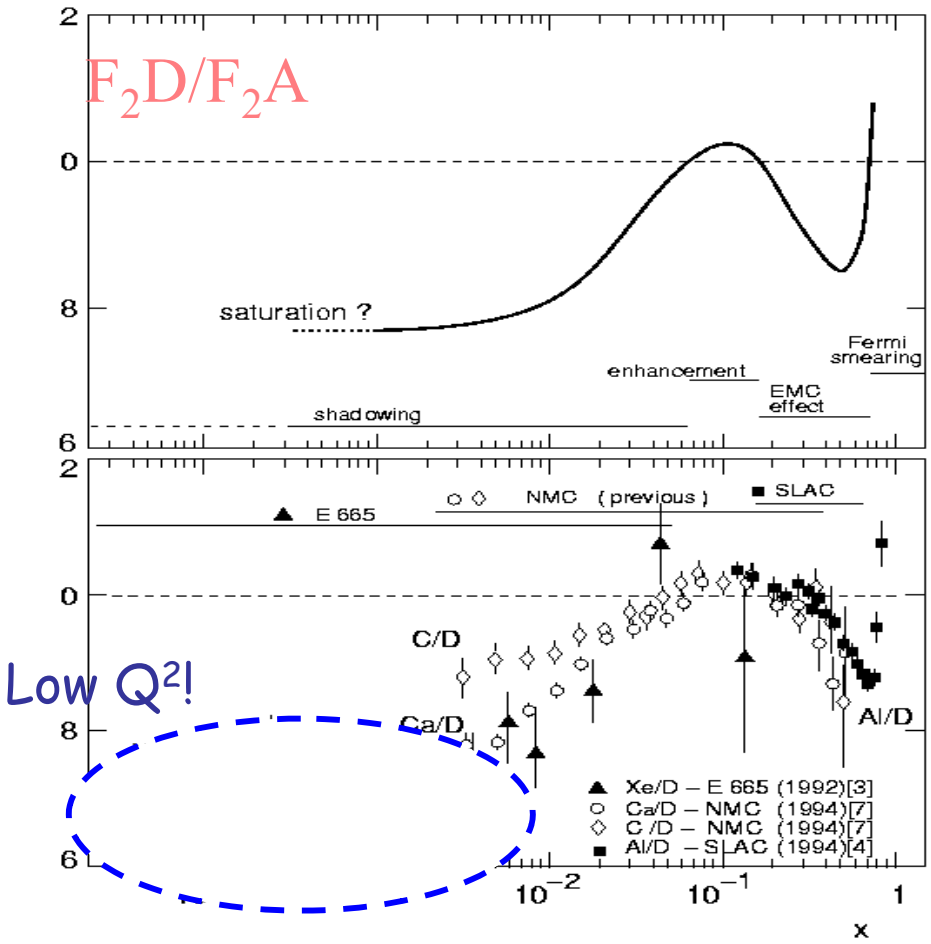
+/- 0.004 (experimental)

+/- 0.010 (theory/ low x extrapolation)

Particle Data Book, Extended version:

"Theoretically, this sum rule is better for determining α_s because perturbative QCD result is known to higher order ($o(\alpha_s^4)$), 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 α_s***"

DIS in Nuclei is Different!



Regions of:

- Fermi smearing
- EMC effect
- Enhancement
- Shadowing
- Saturation?

Regions of shadowing and saturation mostly around Q^2 ~1 GeV^2

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

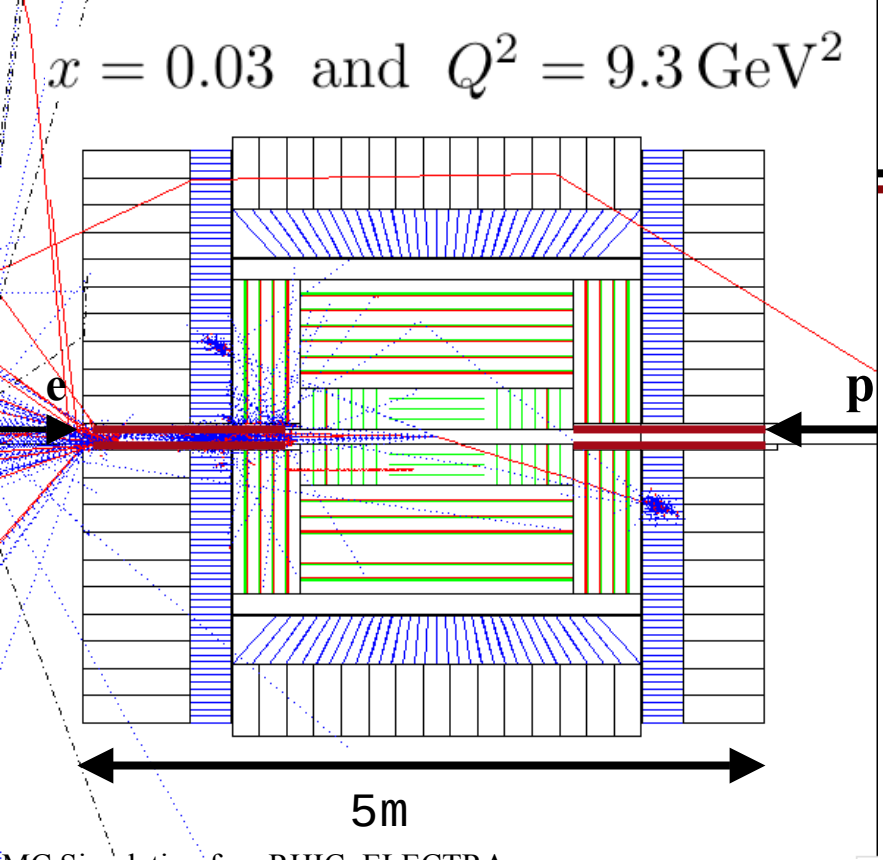
Already hints of exciting physics in this from: HERA, RHIC d-A; eRHIC will allow precision measurements

Some probes of Gluon Saturation/CGC

- How does high density gluonic matter affect quark & gluon distributions?
  - F_2 measurements at low x for e-A (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 e-A
    - Detector capabilities in the high rapidity region crucial
    - Interaction point and detector need to be developed together

A Detector for eRHIC:



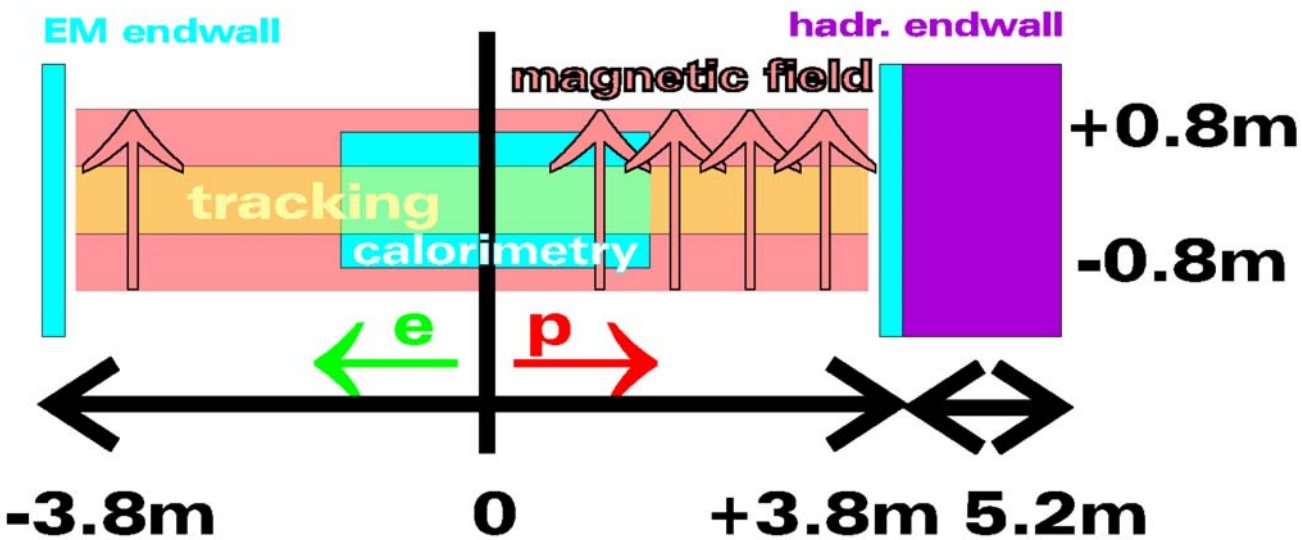
MC Simulation for eRHIC: ELECTRA

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