Experimental Status of RHIC Spin & eRHIC

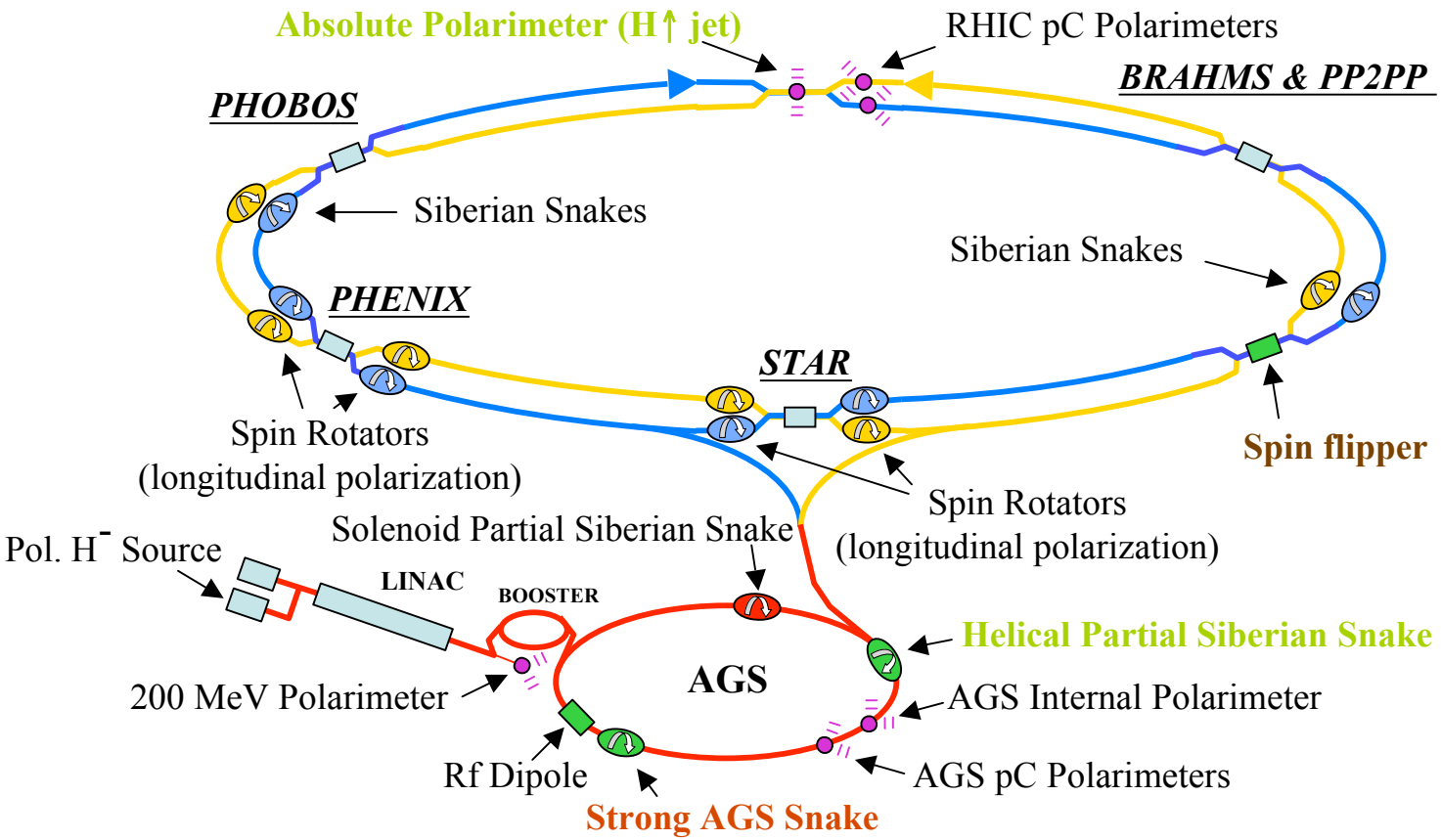
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

0.2!

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

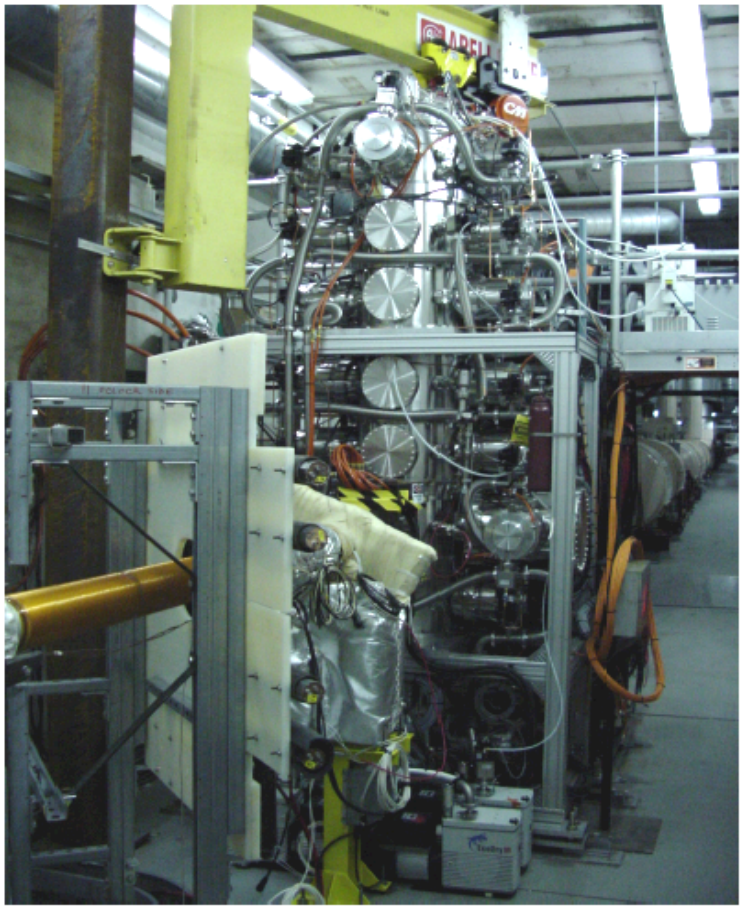
STONY BROOK
STATE UNIVERSITY OF NEW YORK

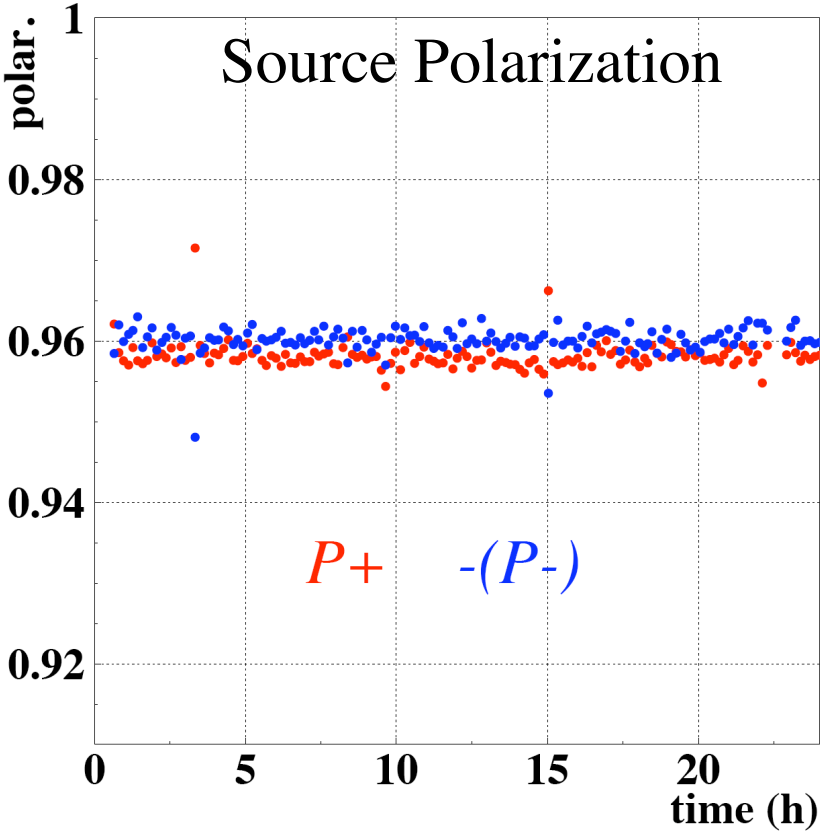
RHIC Polarized Collider



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

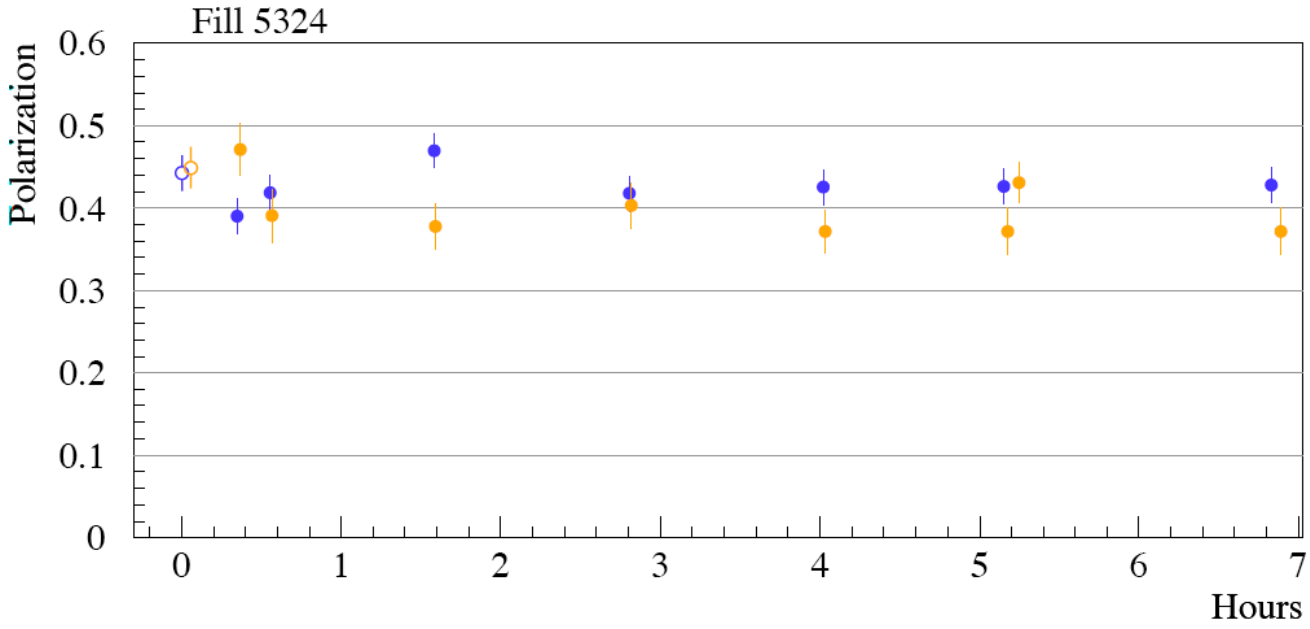
RHIC Polarimetry





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

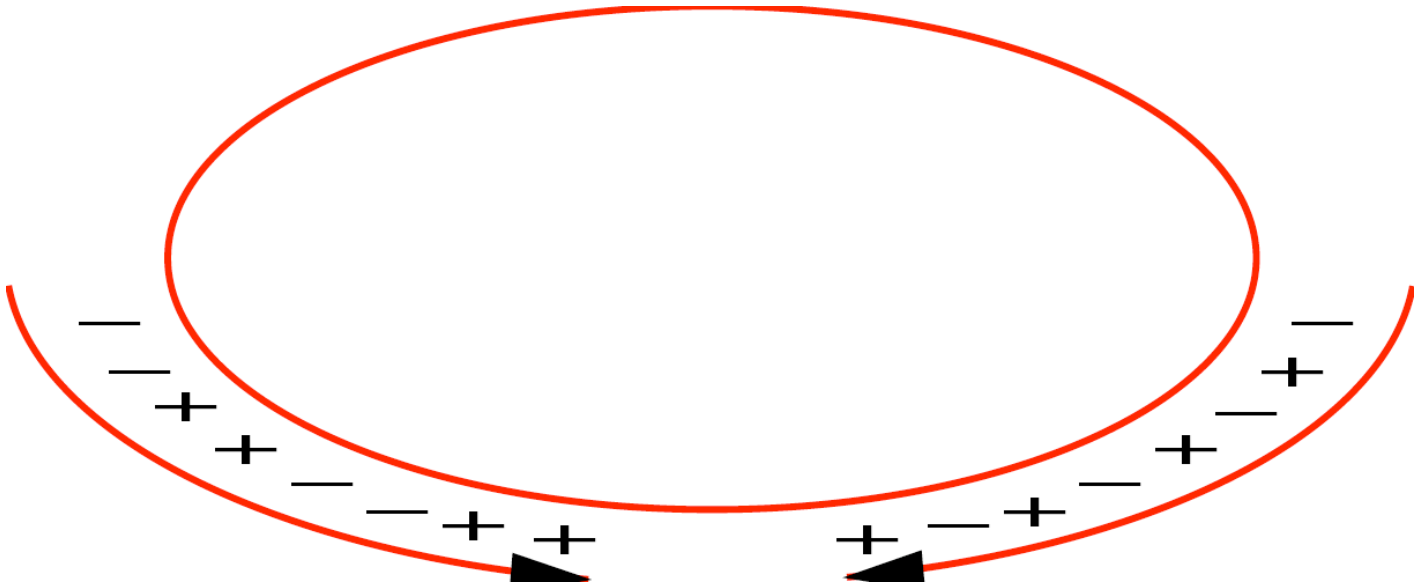
Polarization in RHIC

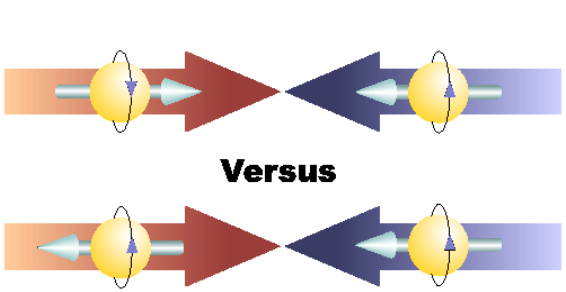


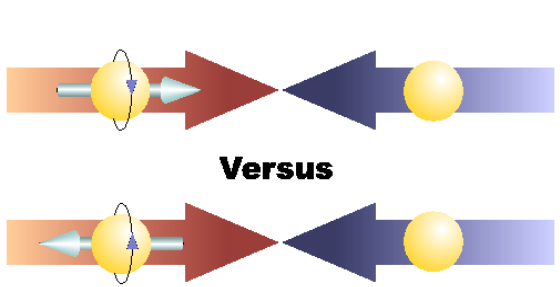
RUN4

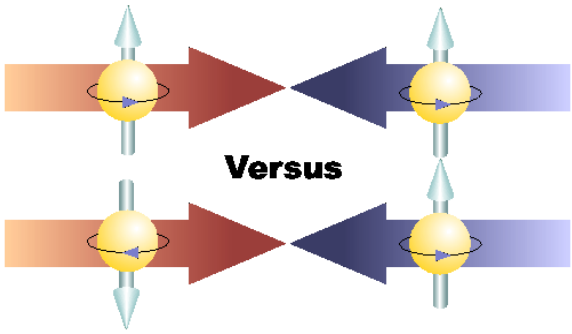
- RUN 4 RHIC pp average polarization (0.39 +/- 0.03)
- AGS cold snake installed last week:
  - Commissioning in Run-5
  - Expected polarization in Run-6 for Physics >65%

Exquisite Control of Systematics







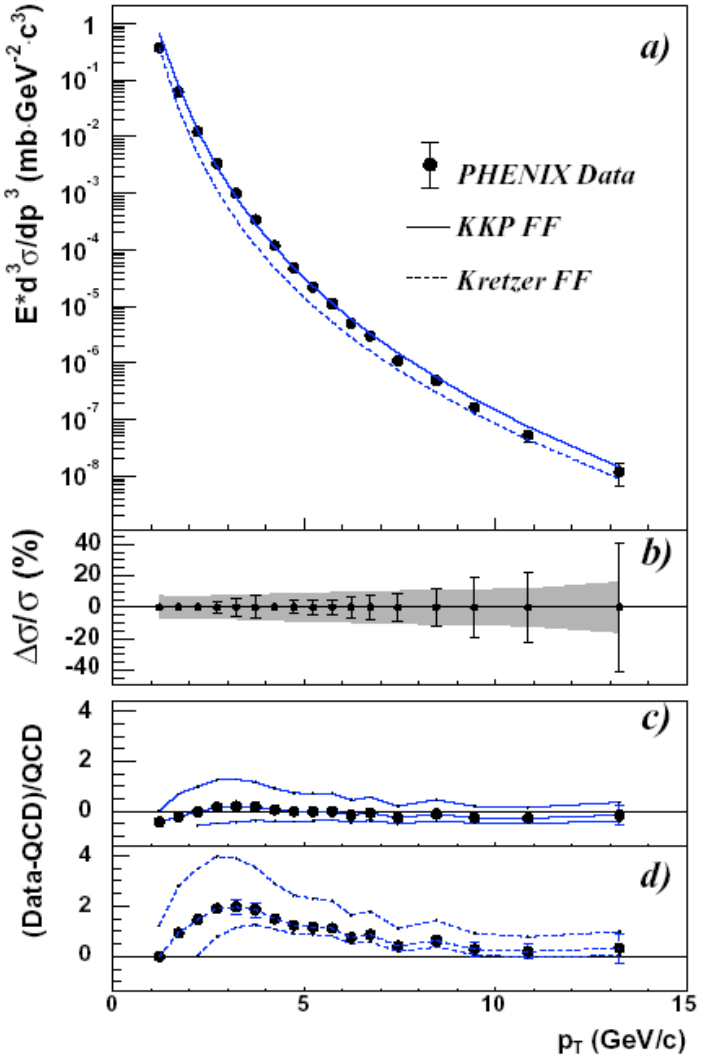


RHIC Spin Physics Program

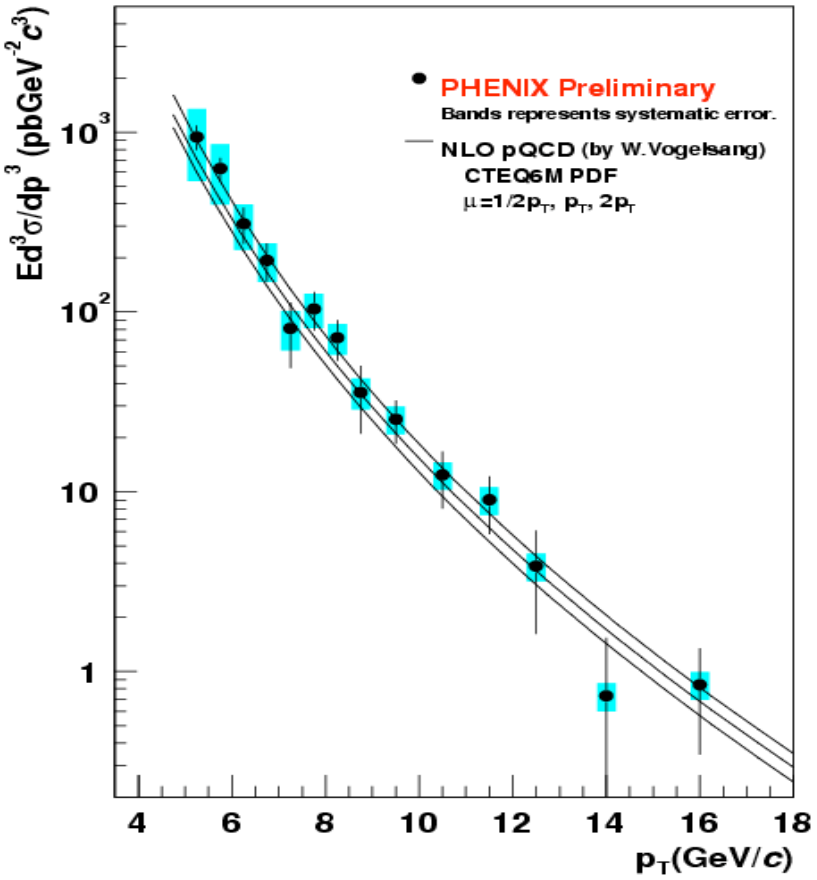
- *Direct measurement* of polarized gluon distribution *using multiple probes (R. Jaffe's talk)*
- Direct measurement of *anti-quark polarization* using parity violating production of $W^{+/-}$
- Transverse spin: Transversity & transverse spin effects: possible connections to orbital angular momentum?

Cornerstone to the RHIC Spin program

$pp \rightarrow \pi X$

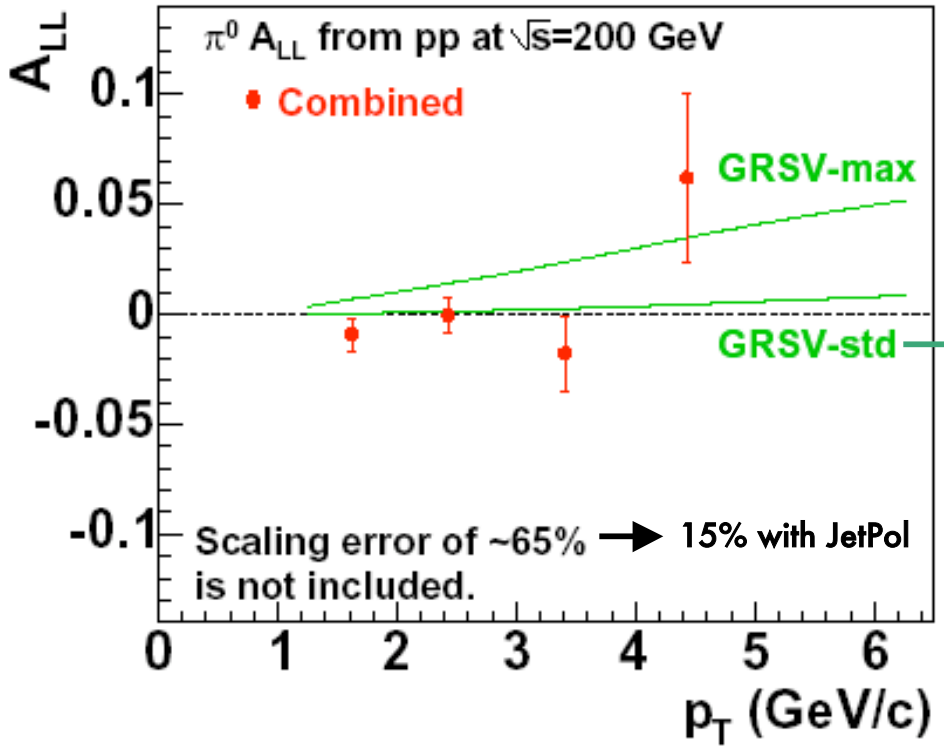


$pp \rightarrow \gamma X$

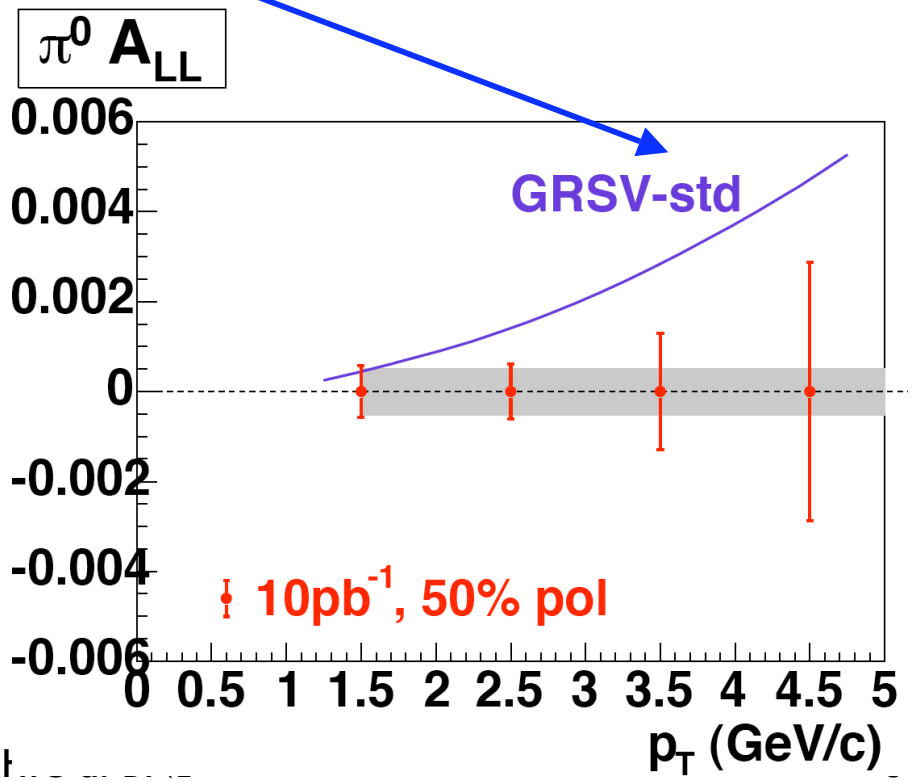


Unpolarized data are well described by NLO

ΔG/G: Measurements have begun!

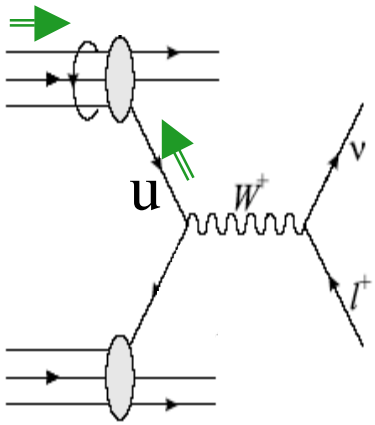


PHENIX data
Run-3 & 4 combined
~200nb^{-1}, 16% pol
~100nb^{-1}, 26% pol



Run 5 starting
next week

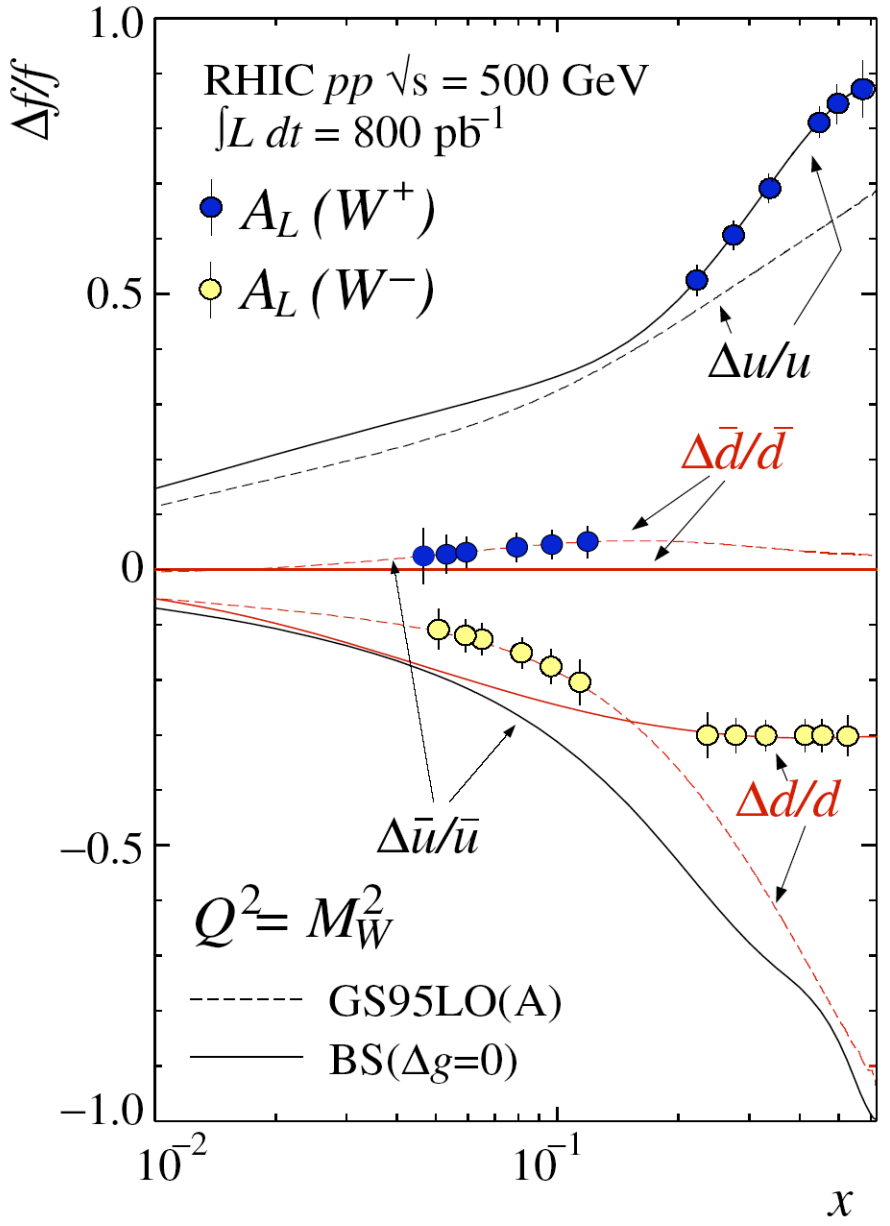
Δq-$\Delta\bar{q}$ at RHIC via W production



unpol.

$$\Delta d + \bar{u} \rightarrow W^-$$
$$\Delta \bar{u} + d \rightarrow W^-$$
$$\Delta \bar{d} + u \rightarrow W^+$$
$$\Delta u + \bar{d} \rightarrow W^+$$

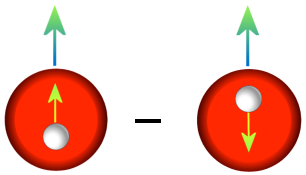
$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$



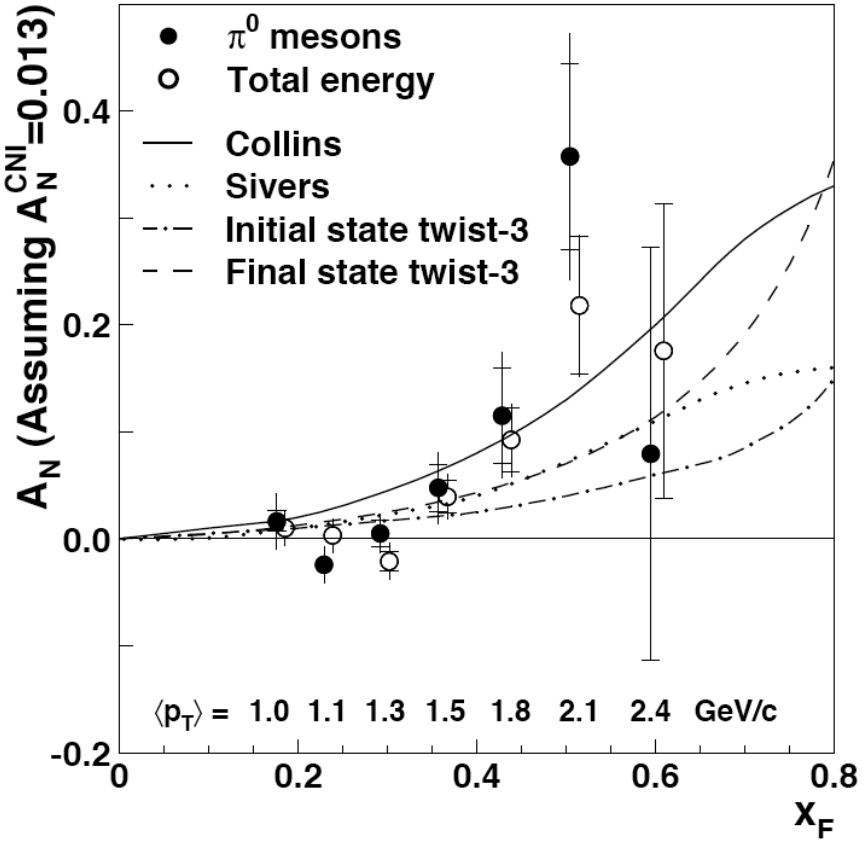
PHENIX & STAR Upgrades:
Axel Drees's talk

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

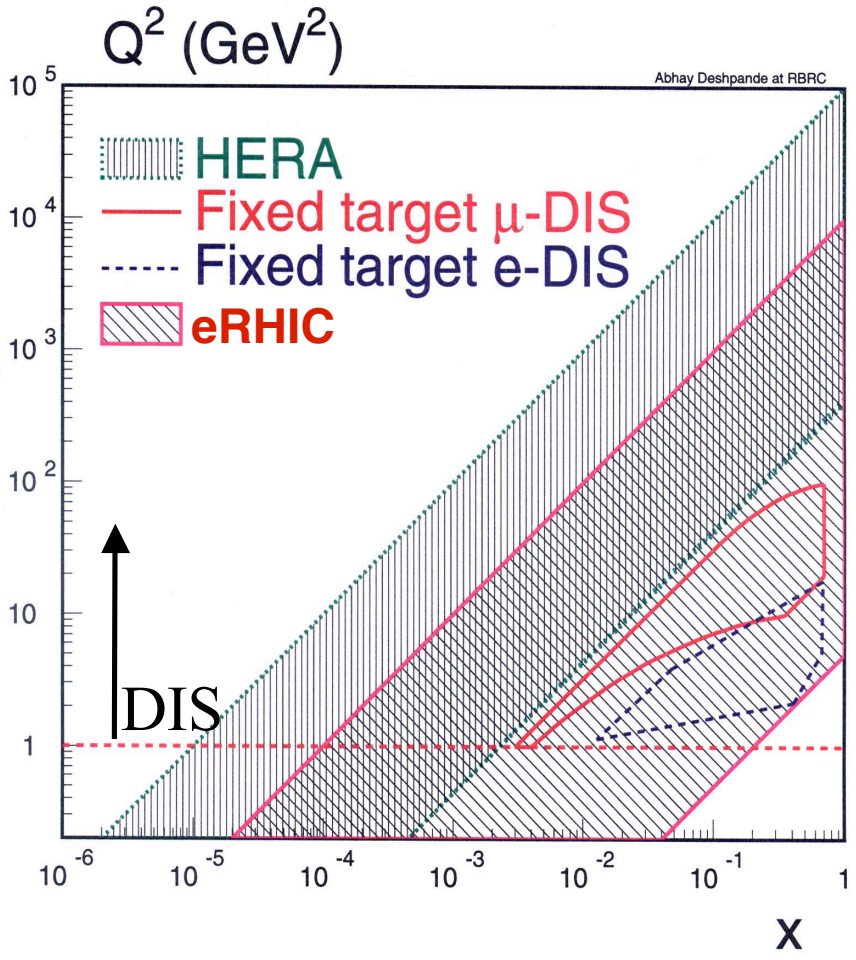
fundamental and universal aspects of QCD

• 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

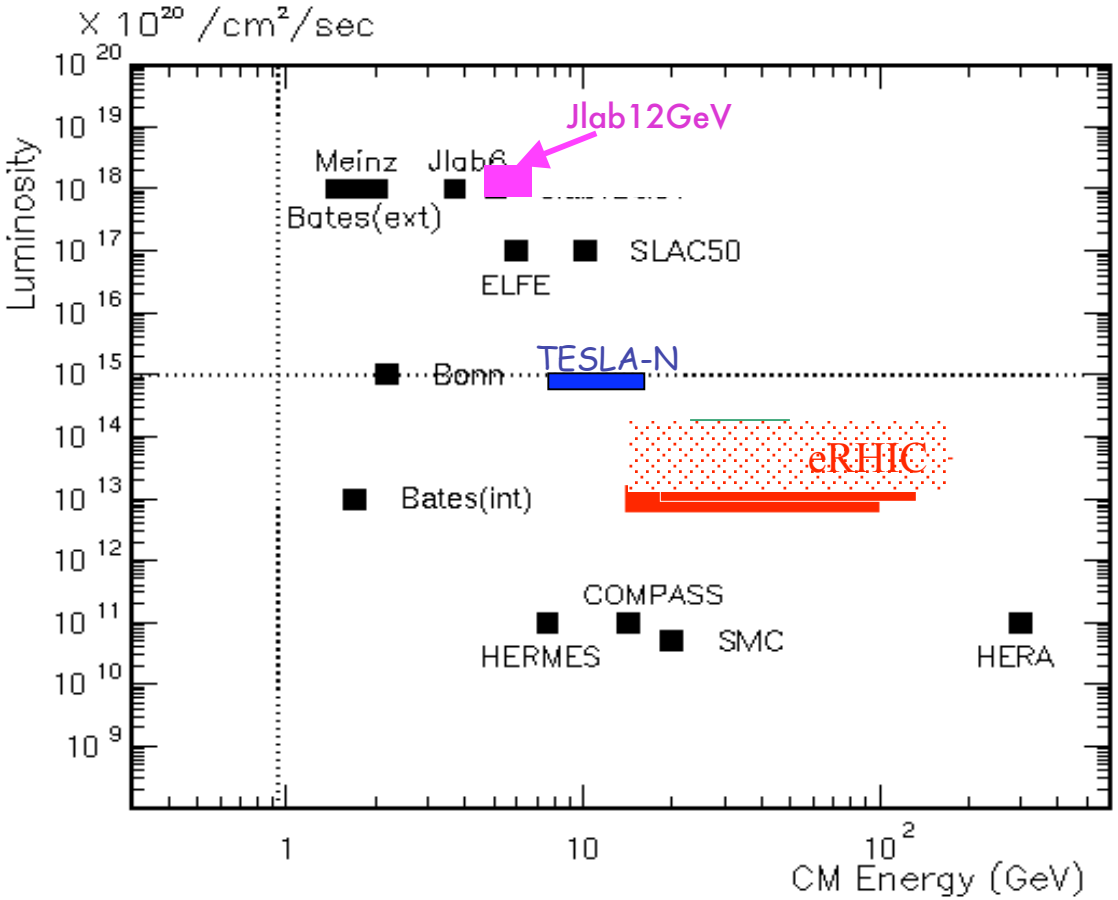
Precision tool to study & understand QCD

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

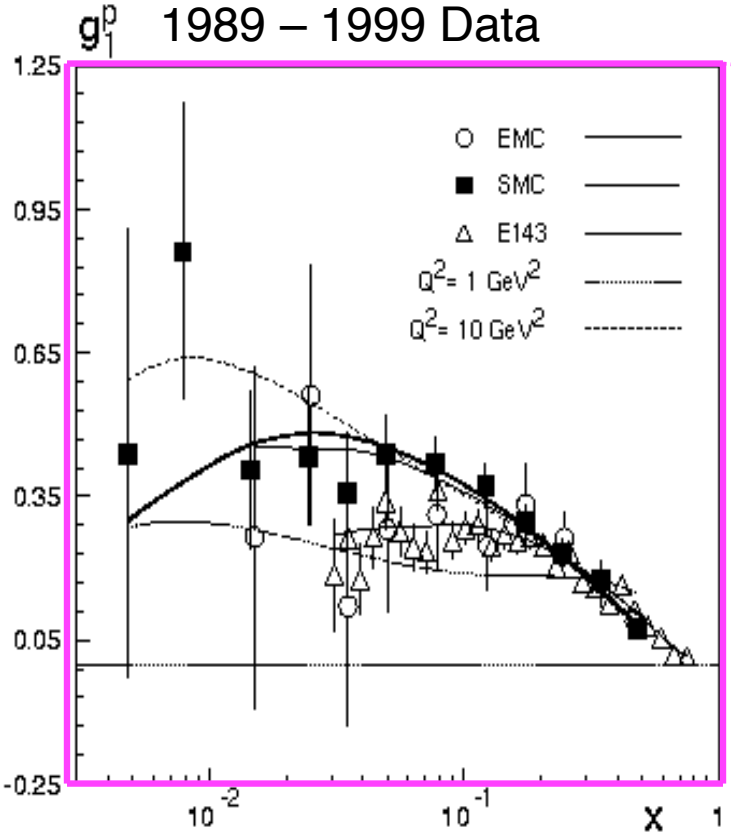
Scientific Frontiers for eRHIC

- 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

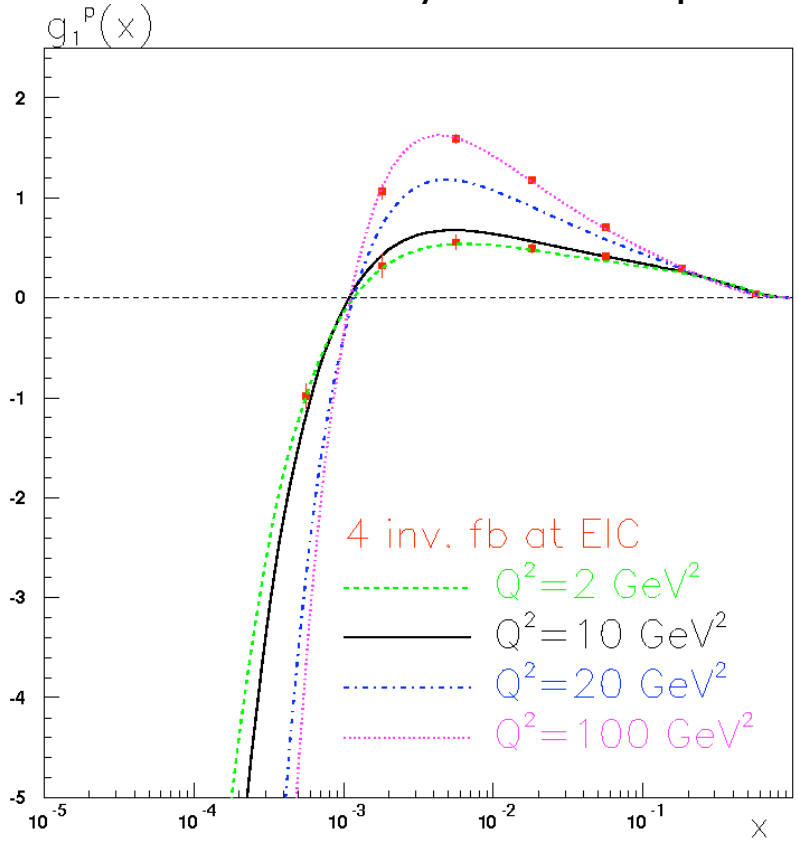
Spin structure & evolution: Precision Measurement

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:

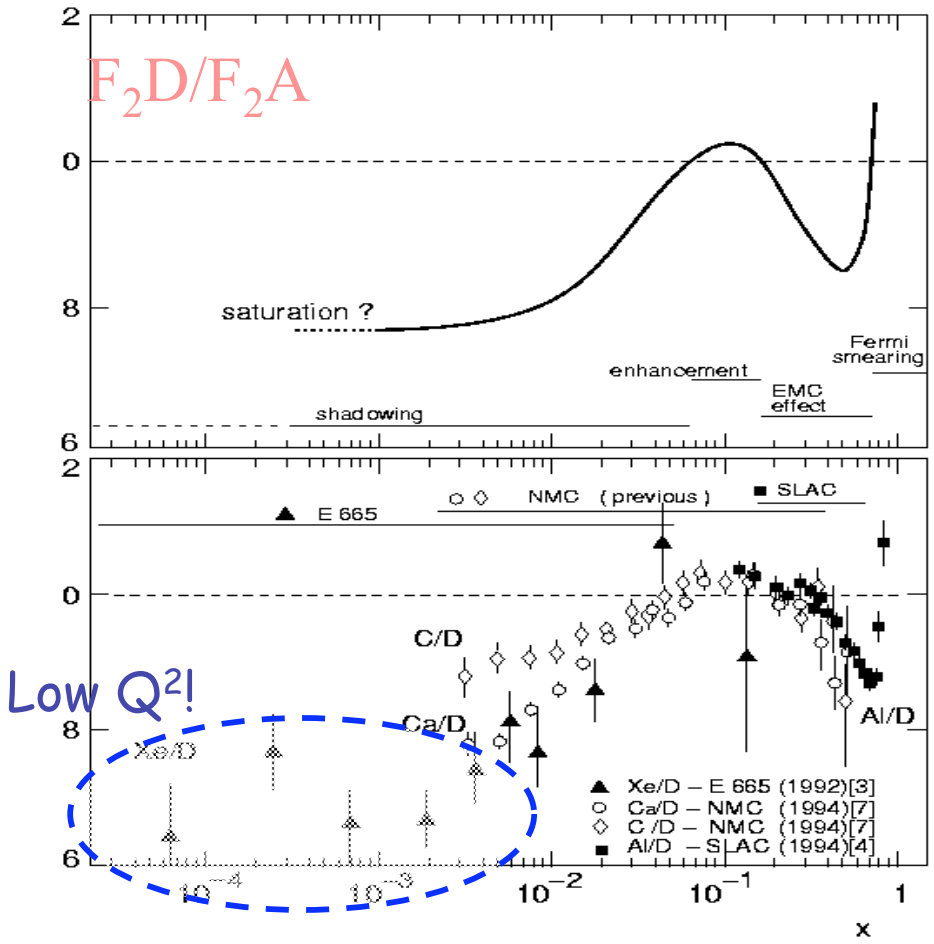
+/- 0.004 (experimental)

+/- 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

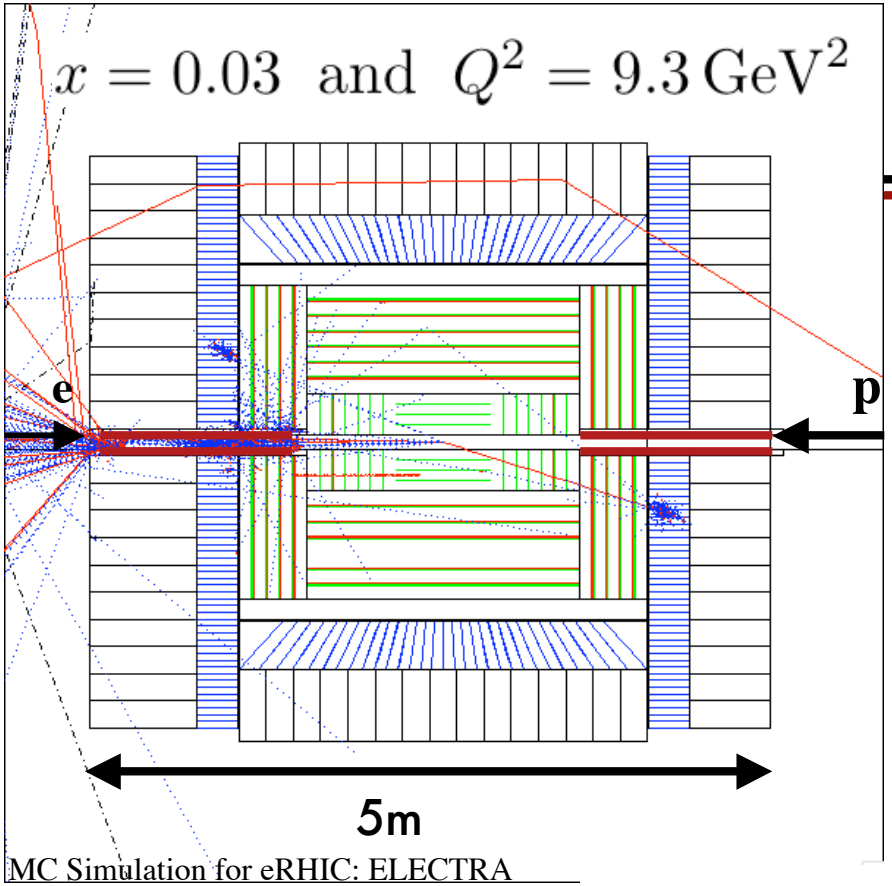
Already hints of exciting physics in this from: HERA, RHIC d-A; eRHIC will allow precision measurements

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:

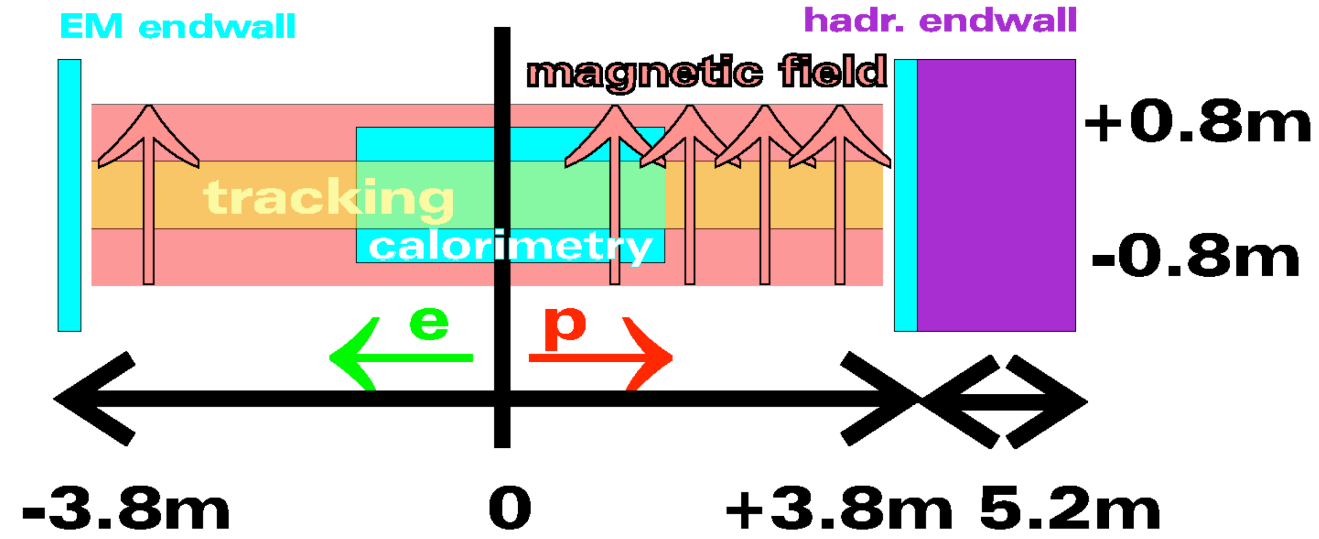


MC Simulation for eRHIC: ELECTRA

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 Strongly interacting probes
- eRHIC DIS at collider energies

QCD & the structure of matter including its spin

A unique laboratory for precision QCD