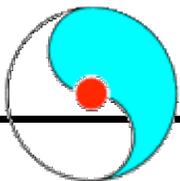

Measurements & Detector at eRHIC

Abhay Deshpande
SUNY-Stony Brook
RIKEN BNL Research Center

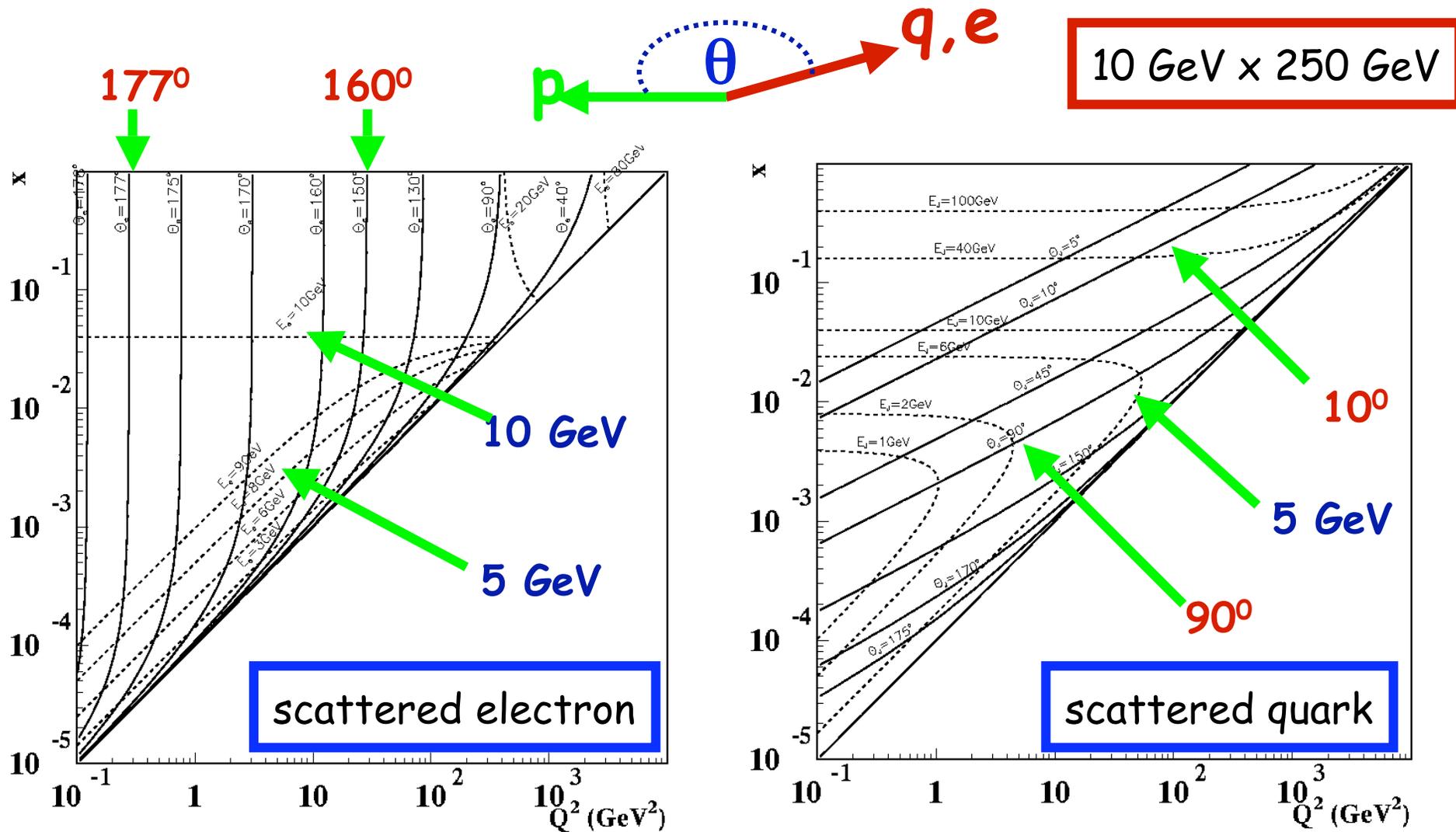
NSAC Subcommittee meeting at BNL
June 4, 2004



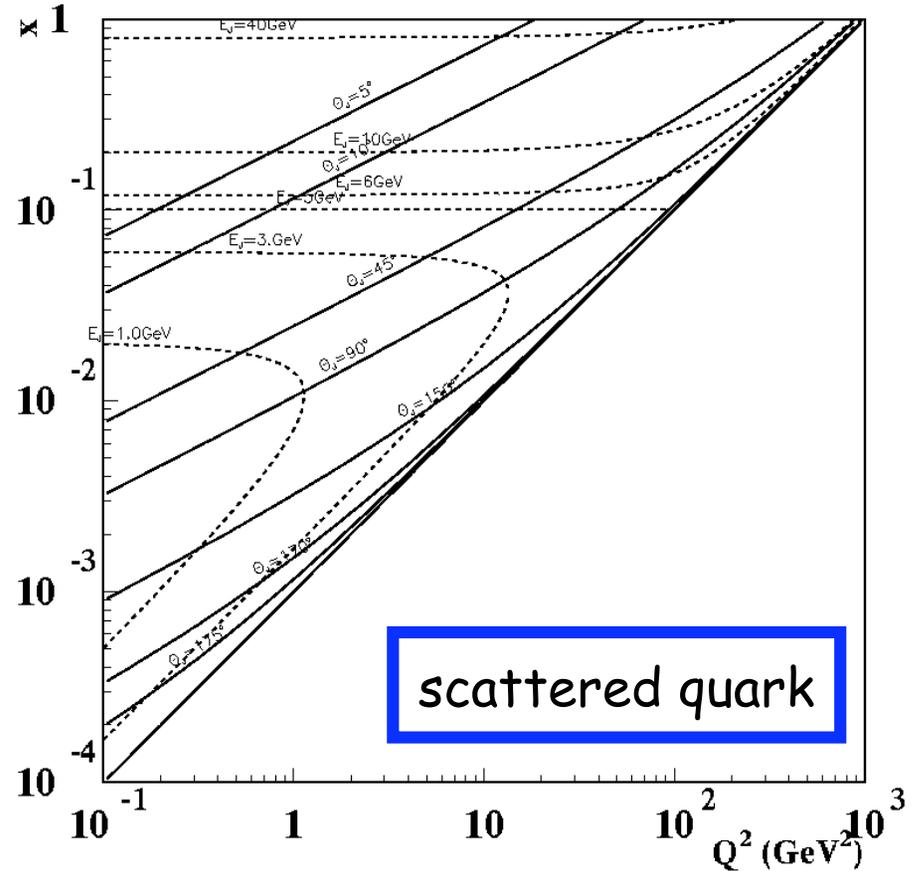
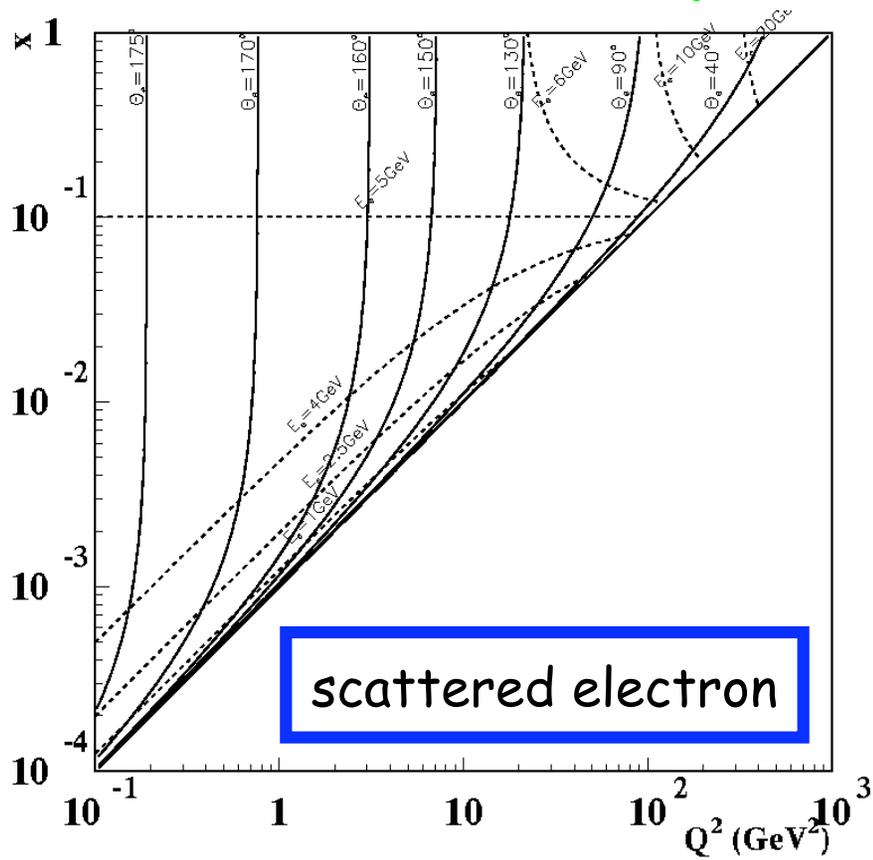
Many involved....

- The **eRHIC steering committee** (Richard M.'s talk)
 - **The eRHIC Accelerator Group:** BNL, MIT/Bates, DESY, PNPI
>> Accelerator ZDR: Ed. V. Ptitsyn (BNL)
M. Farkondeh (MIT/Bates)
and ~40 other collaborators... (see ZDR front page)
 - **Monte Carlo Simulation & Detector Group** (meets every 3-4 months)
A. Bruell (Jlab), A.D.(Stony Brook/RBRC), R. Ent (Jlab), E. Kinney (Colorado), N. Makins (UIUC), E. Sichtermann(LBL), B. Surrow (MIT) and a special mention for Grad. Student Joe Seele (Colorado)
- “Collaboration:”
+ ~100 or so people who contributed to the Whitepaper 2001/2
- **Friendly Theorists:** L. McLerran (BNL), R. Venugopalan (BNL), W. Vogelsang (BNL), M. Stratmann (Regensburg) M. Strikmann(PSU), X. Ji(Maryland), S.Kretzer(BNL)

Where do electrons and quarks go?



Electron, Quark Kinematics



A Detector for eRHIC → A 4π Detector

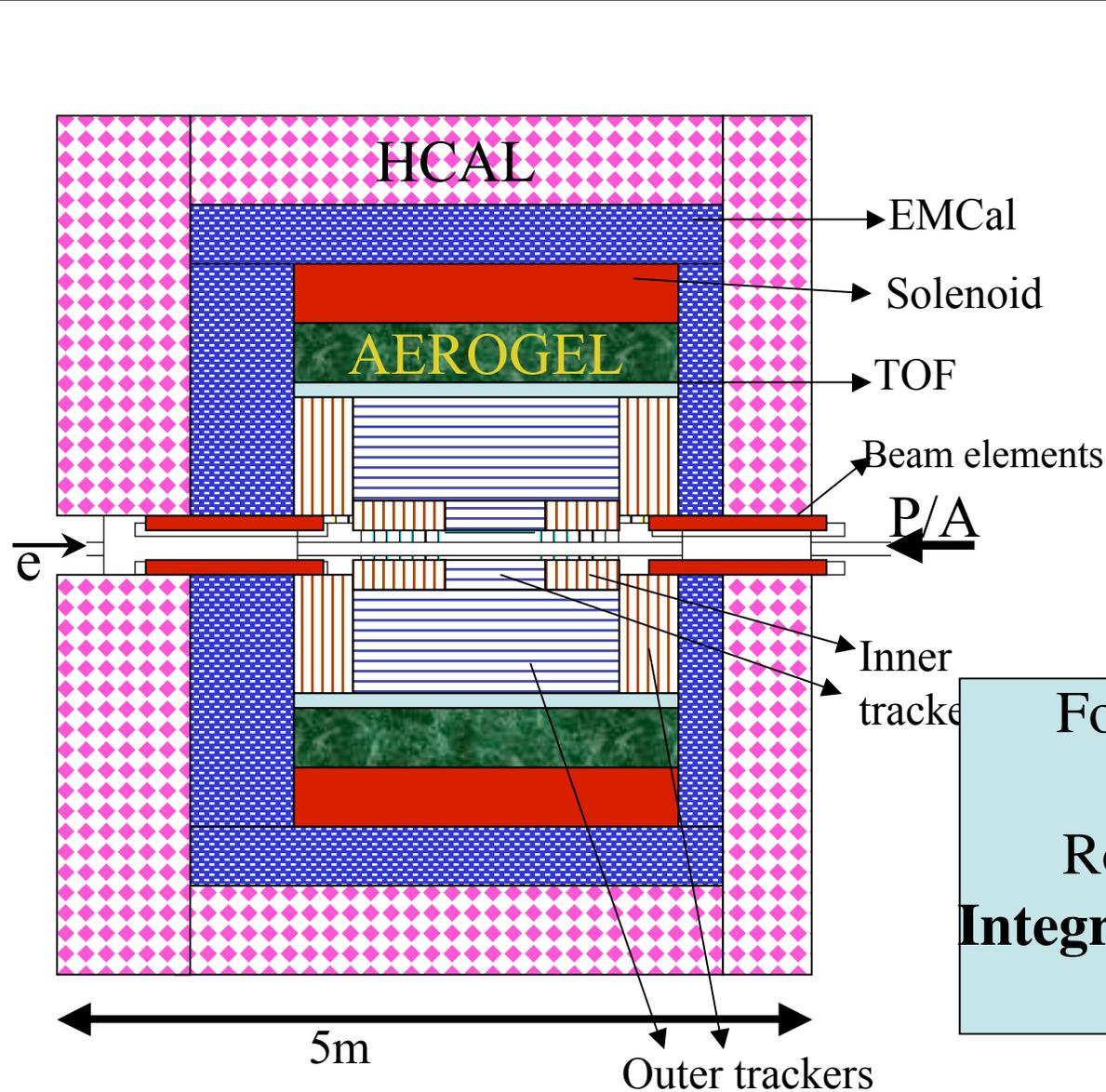
- Scattered electrons to measure kinematics of DIS
- Scattered electrons at small (\sim zero degrees) to tag photo production
- Central hadronic final state for kinematics, jet measurements, quark flavor tagging, fragmentation studies, particle ID
- Central hard photon and particle/vector detection (DVCS)
- \sim Zero angle photon measurement to control radiative corrections and in e-A physics to tag nuclear de-excitations
- Missing E_T for neutrino final states (W decays)
- Forward tagging for 1) nuclear fragments, 2) diffractive physics

- ***Lot of experience from HERA... use it!***
 - What was good about HERA detectors?
 - What was bad? How/What can we improve?

- eRHIC will provide: 1) Variable beam energies 2) different hadronic species, some of them polarization, 3) high luminosity

Detector Design HERA like...+ PID

(Not to scale)



A HERA like
Detector with
dedicated PID:
>> Time of flight
>> Aerogel Ckov

AND

Forward detectors
including
Roman Pots etc...
**Integrated in to the beam
Elements!**

Scientific Frontiers Open to the eRHIC

- **Nucleon structure, role of quarks and gluons in the nucleons**
 - Unpolarized quark and gluon distributions, confinement in nucleons
 - Polarized quark and gluon distributions
 - Correlations between partons
 - Exclusive processes--> Generalized Parton Distributions
 - Understanding confinement with low x /low Q^2 measurements
- **Meson Structure:**
 - Goldstone bosons and play a fundamental role in QCD
- **Nuclear Structure, role of partons in nuclei**
 - Confinement in nuclei through comparison e-p/e-A scattering
- **Hadronization in nucleons and nuclei & effect of nuclear media**
 - How do knocked off partons evolve in to colorless hadrons
- **Partonic matter under extreme conditions**
 - For various A , compare e-p/e-A

Polarized DIS at eRHIC

- Spin structure functions g_1 (p,n) at low x, high precision
 - g_1 (p-n): Bjorken Spin sum rule better than 2% accuracy [1]
- Polarized gluon distribution function $\Delta G(x, Q^2)$ ★ [1]
 - at least three different experimental methods
- Precision measurement of $\alpha_s(Q^2)$ from g_1 scaling violations
- Polarized s.f. of the photon from photo-production [1]
- Electroweak s. f. g_5 via $W^{+/-}$ production ★ [1]
- Flavor separation of PDFs through semi-inclusive DIS [1,2]
- Deeply Virtual Compton Scattering (DVCS) [1]
- >> Generalized Parton Distributions (GPDs) [1,2]
- Transversity ★ [3]
- Drell-Hern-Gerasimov spin sum rule test at high ν [1]
- Target/Current fragmentation studies
- ... etc.... [2,3]

★ Also at RHIC SPIN; [1] --> inclusive, [2]--> semi-inclusive

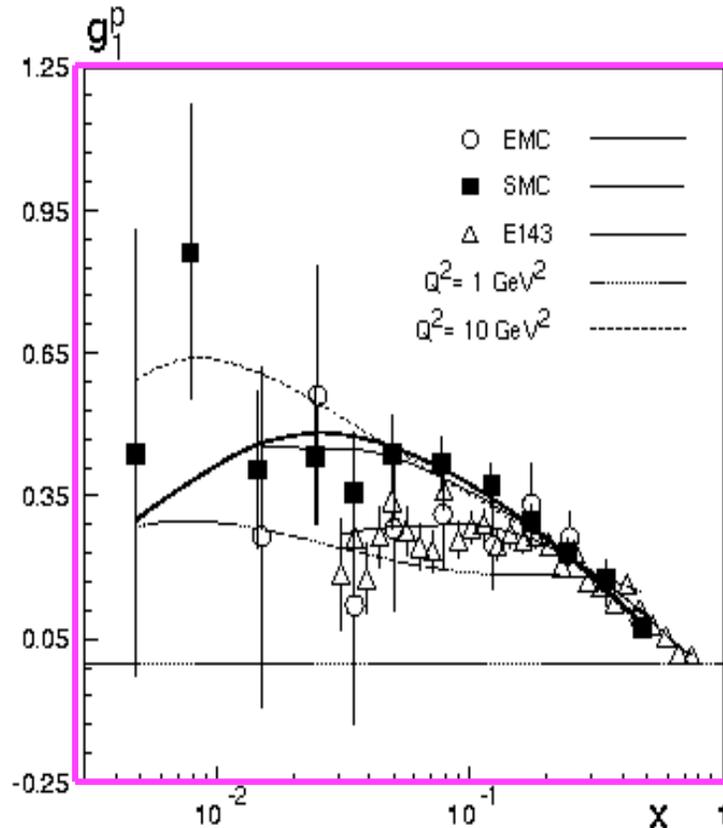
[3] --> exclusive measurements

Luminosity
Requirement

Proton Spin Structure at Low x

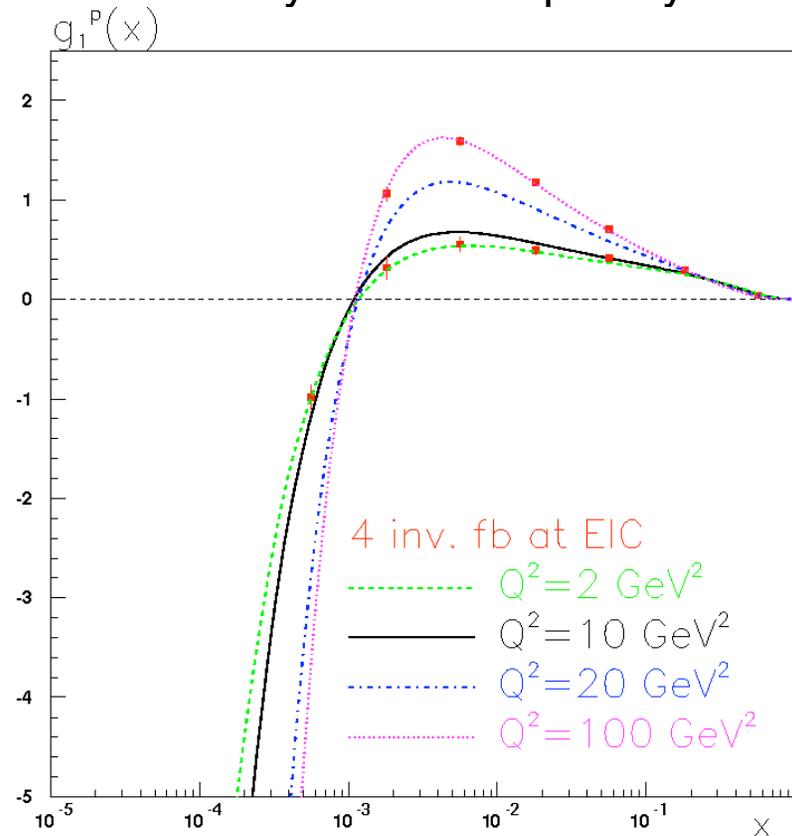
Fixed target experiments

1989 – 1999 Data



eRHIC 250 x 10 GeV

Luminosity = ~ 85 inv. pb/day



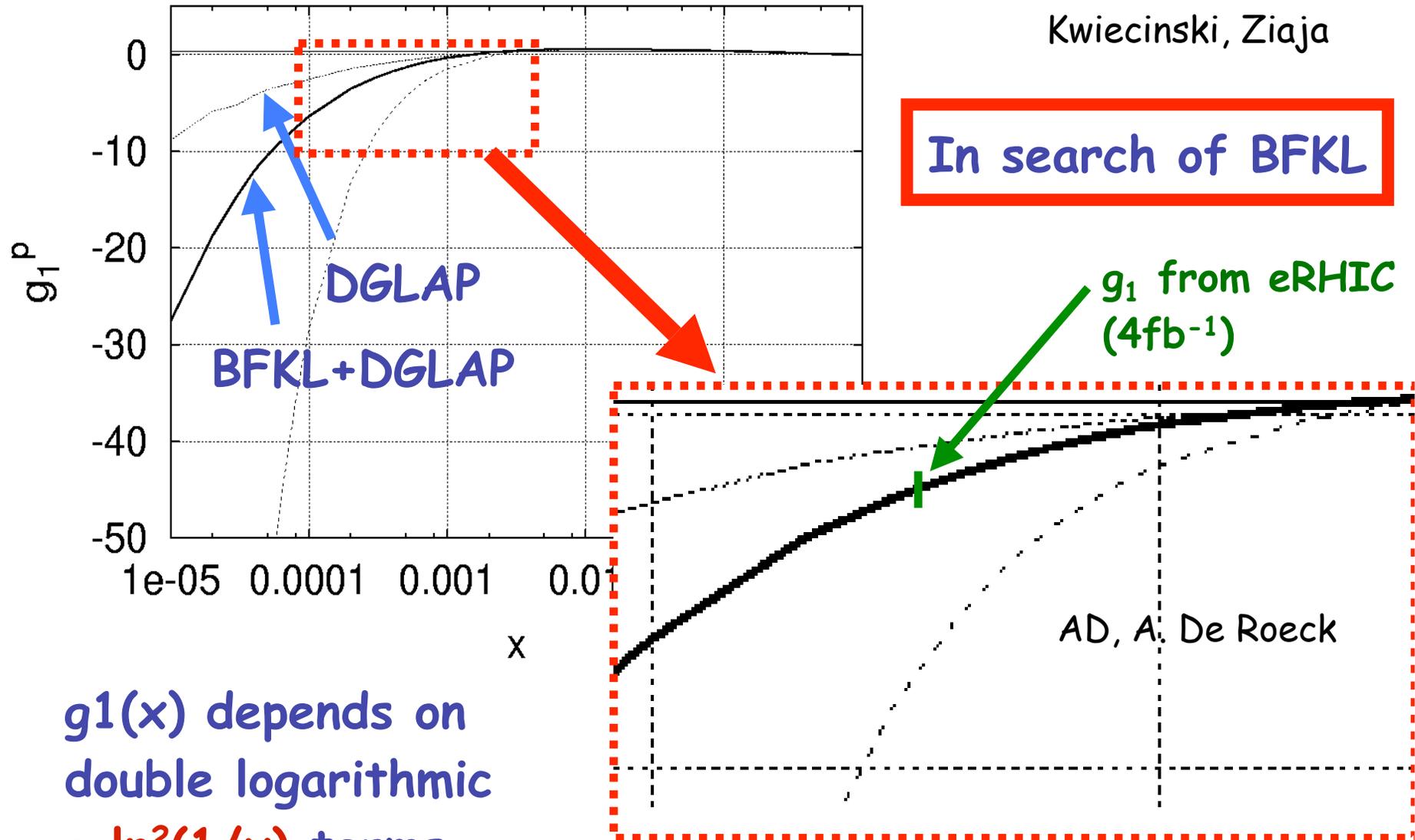
Studies included statistical error & detector smearing to confirm that asymmetries are measurable. No present or future approved experiment will be able to make this measurement

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

Low-x measurements

Kwiecinski, Ziaja

In search of BFKL



$g_1(x)$ depends on
double logarithmic
 $\alpha_s \ln^2(1/x)$ terms

Fits of $g_1(x, Q^2)$ +jets

J. Lichtenstadt

AD, A.De Roeck, V. Hughes, G.Radel

Constrain better the shape and the first moment

ΔG determined from the Scaling violations of g_1

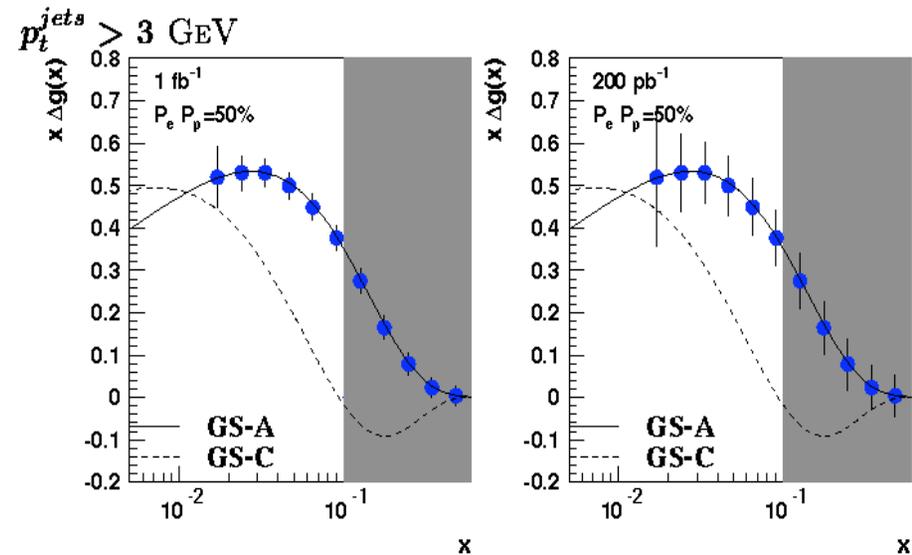
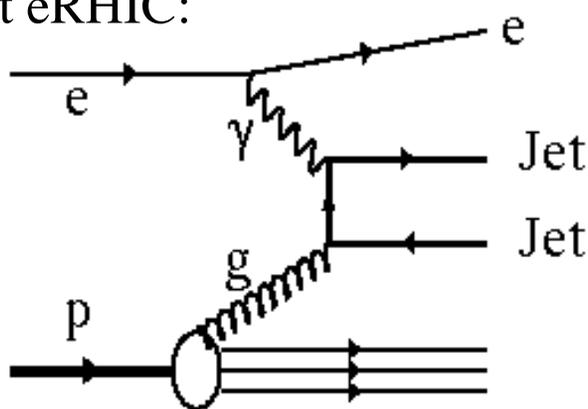
SMC Published 1998: First Moment of $\Delta G(x)$

$$\int \Delta G(x) dx = 1.0 \pm 1.0 \text{ (stat)} \pm 0.4 \text{ (exp.syst)} \pm 1.4 \text{ (theory)}$$

-- one week eRHIC reduces statistical & theory errors by factors 3-5

-- low x --> strong coupling, functional form at low x , renorm. & fact. scales

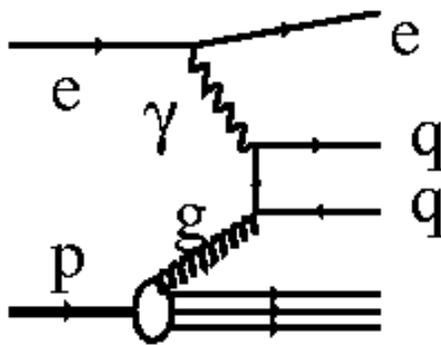
Di-Jet at eRHIC:



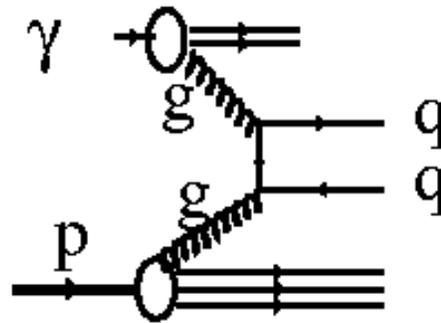
Polarized PDFs of the Photons

- Photo-production studies with single and di-jet

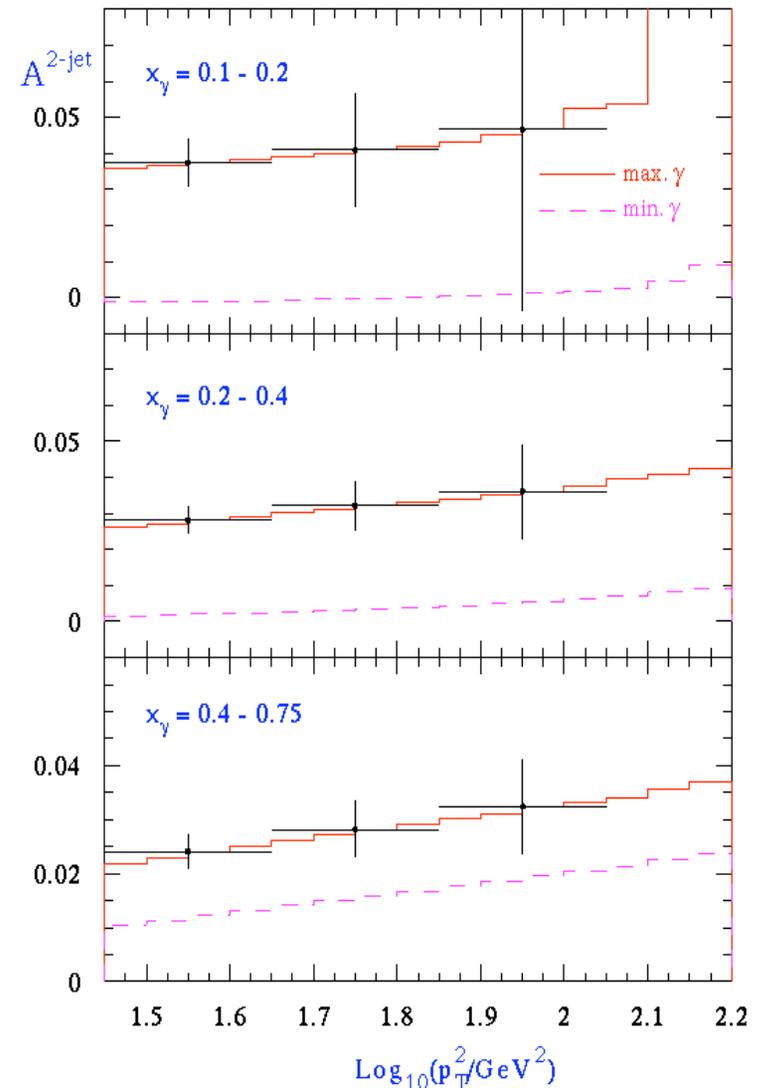
Direct Photon



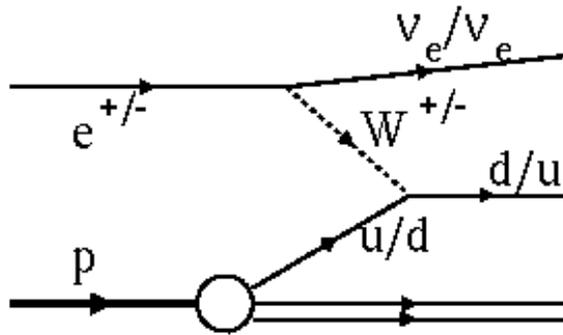
Resolved Photon



- Photon Gluon Fusion or Gluon Gluon Fusion (Photon resolves in to its partonic contents)
- Resolved photon asymmetries result in measurements of spin structure of the photon
- 1 fb⁻¹ data, ZEUS acceptance: ample data to explore the QCD/spin structure of the photon

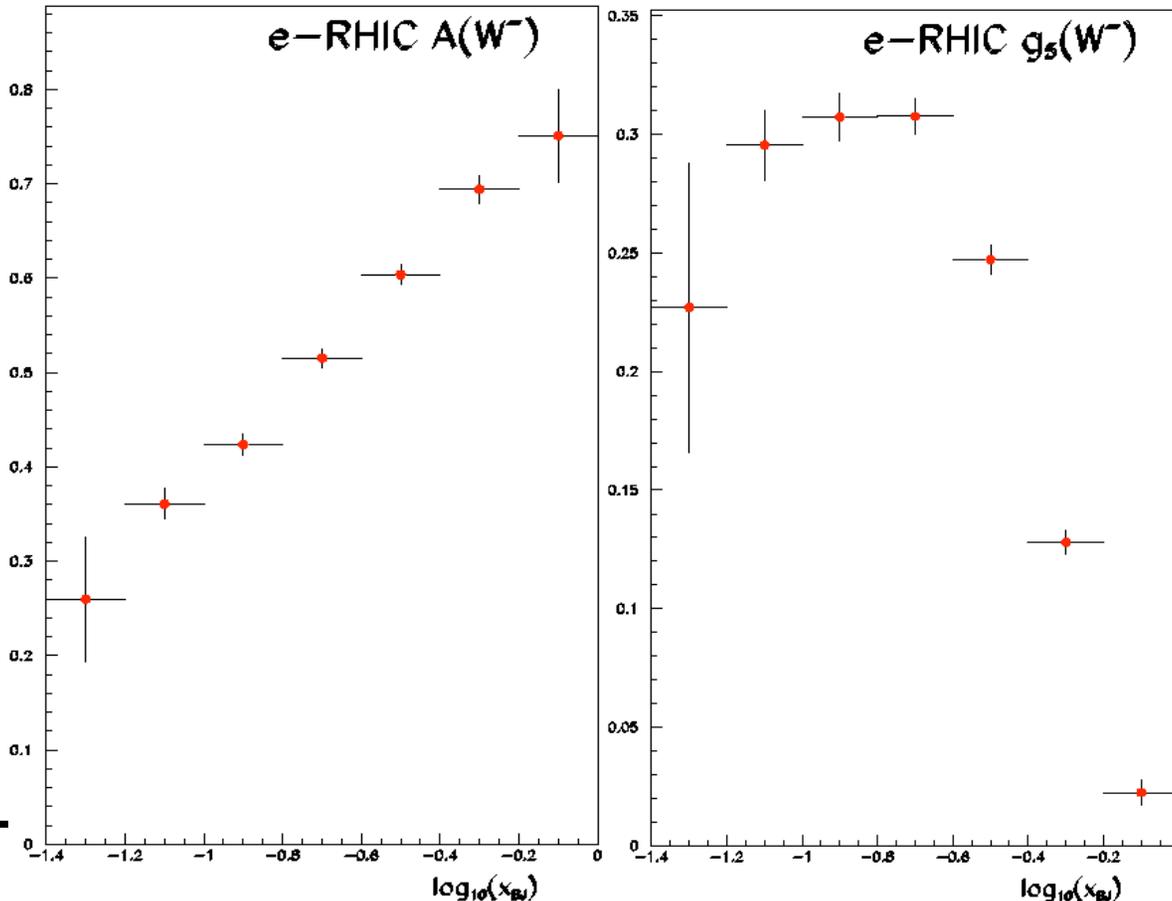


Measurement Accuracy PV g_5 at eRHIC



$$g_5^{W^-} = \Delta u + \Delta c - \Delta \bar{d} - \Delta \bar{s}$$

$$g_5^{W^+} = \Delta d + \Delta s - \Delta \bar{u} - \Delta \bar{c}$$



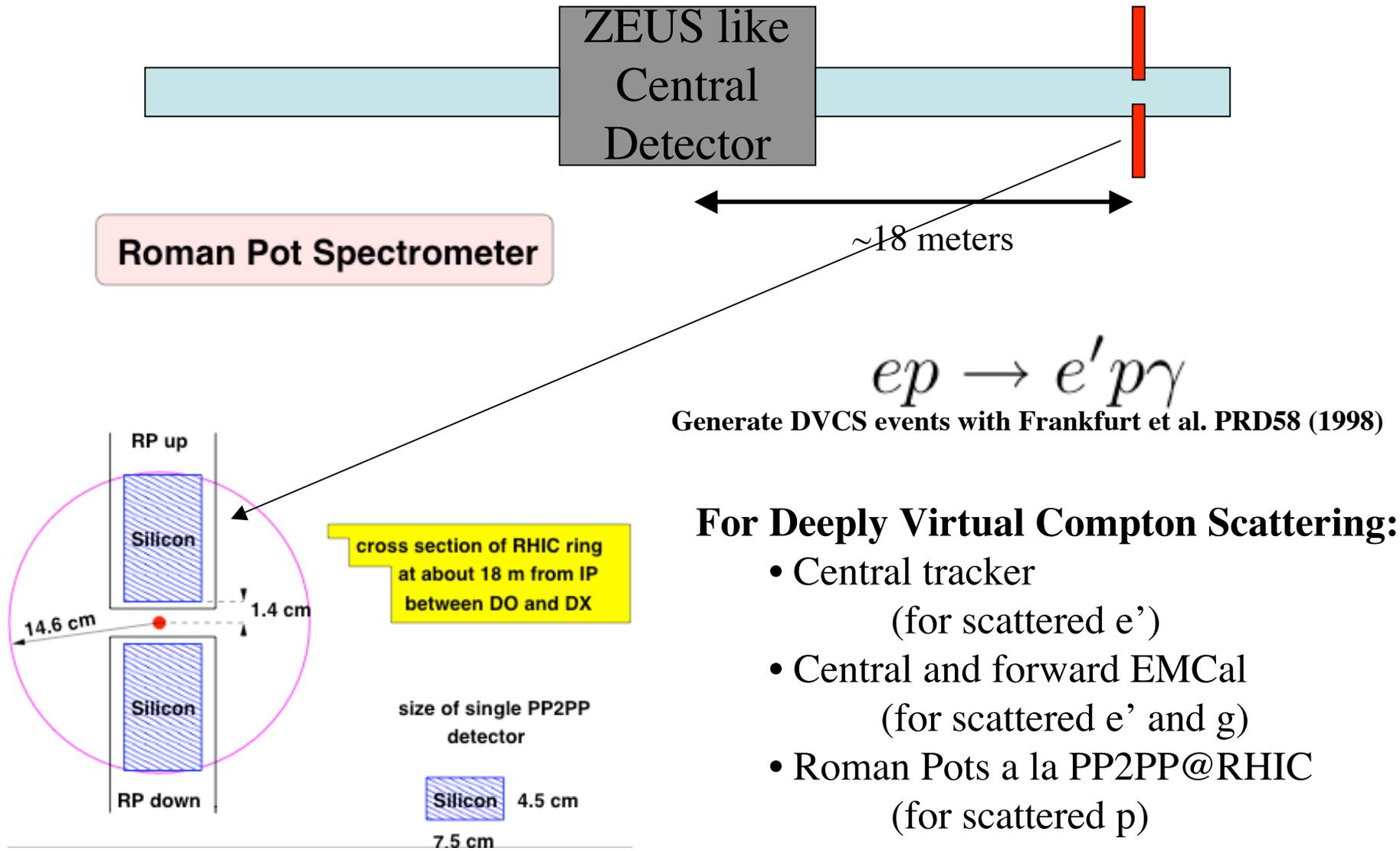
Assumes:

1. Input GS Pol. PDFs
2. $x F_3$ measured
3. 4 fb^{-1} luminosity

Positrons & Electrons in eRHIC $\rightarrow g_5(+)$

\gg reason for keeping the option of positrons in eRHIC

Roman Pots for eRHIC



Study DVCS acceptance

Central Detector Acceptance

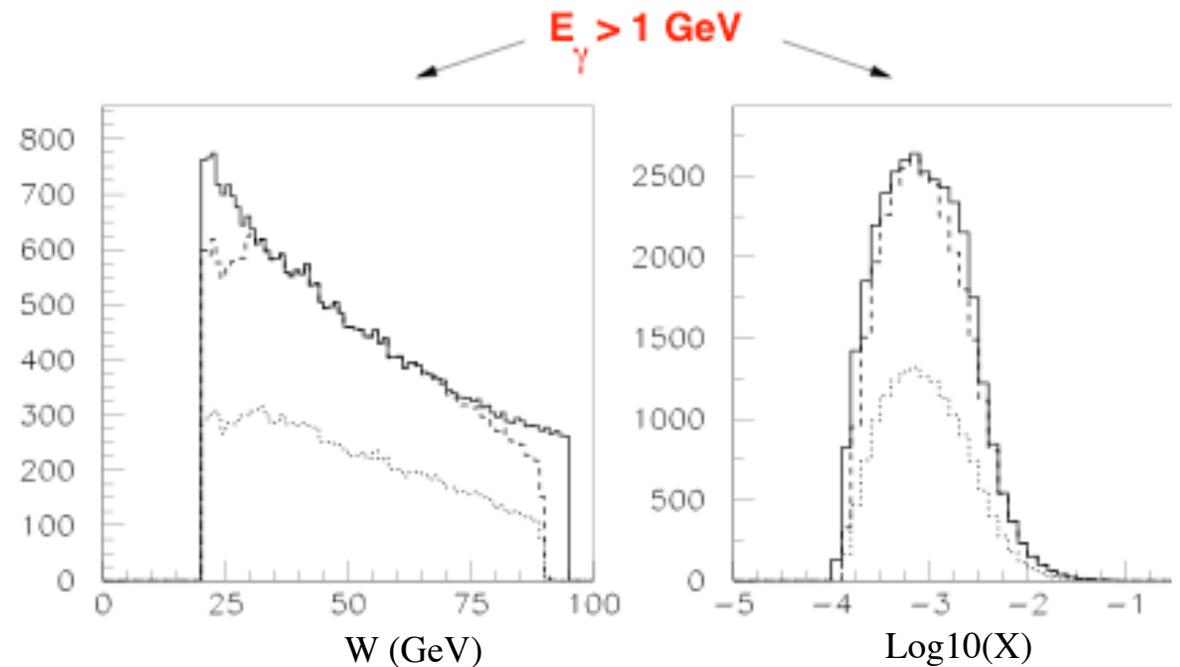
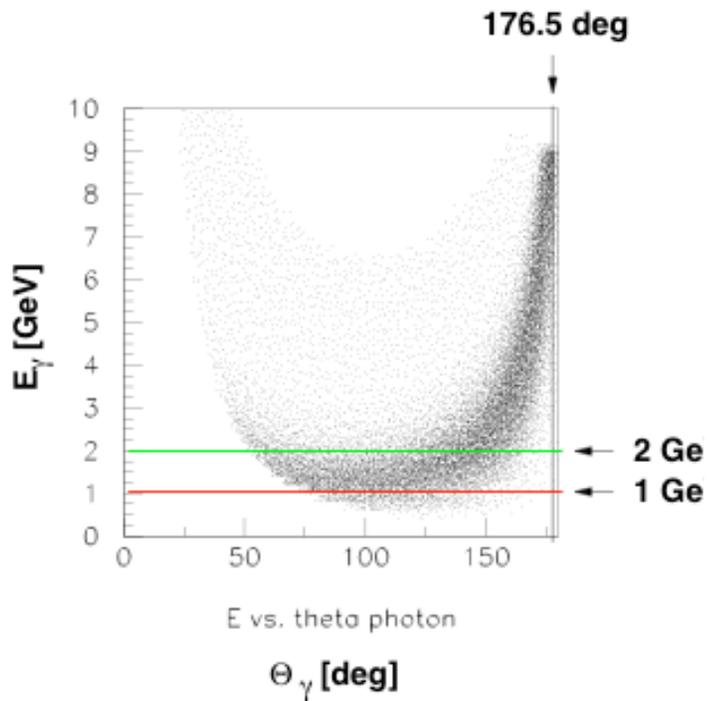
$$2.2 < \Theta_{e'} < 176.5 \text{ deg}$$

$$2.2 < \Theta_{\gamma} < 176.5 \text{ deg}$$

$$\Theta_{e'\gamma} > 3.1 \text{ deg}$$

$$E_{e'} > 2 \text{ GeV}$$

$$E_{\gamma} > 1 \text{ GeV}$$



Signatures of Novel Small x Physics (I)

Inclusive measurements:

Structure functions $F_2(x, Q^2)$, $dF_2/d\ln Q^2$, $dF_2/d\ln x$

- $dF_2/d\ln Q^2$ at fixed x at high Q^2 is the gluon distribution
>> CGC vs. conventional pQCD predict very different
- Quark shadowing ($F_2^A/A * F_2^N$) in fixed target experiments observed
- Gluon shadowing ($G^A/A * G^N$) indirect evidence only... pQCD at NLO
- Gluon measurements using semi-inclusive... **di-jet final states**
- eRHIC collider-detector ideal

Longitudinal structure function $F_L = F_2 - 2xF_1$

- Provide independent gluon distribution measurement
- Needs variable electron beam (\sqrt{s}) energy → Possible at eRHIC

Signatures of Novel Small x Physics (II)

DIFRACTION at eRHIC:

Shadowing and diffraction:

- Measurements of diffractive structure functions F2D and F2L as functions of $(x, Q^2, t, x_{\text{pomeron}})$ --> Examine relation to shadowing (Gribov)
>> Will need good acceptance/tracking in "forward/backward" acceptance regions

Hard Diffraction $e + A \rightarrow e' + \gamma^* + A \rightarrow e' + X + A; M_X^2 \gg \Lambda_{QCD}^2$

- Large rapidity gap between current and target fragmentation region. At HERA 7-10% cross section diffractive.

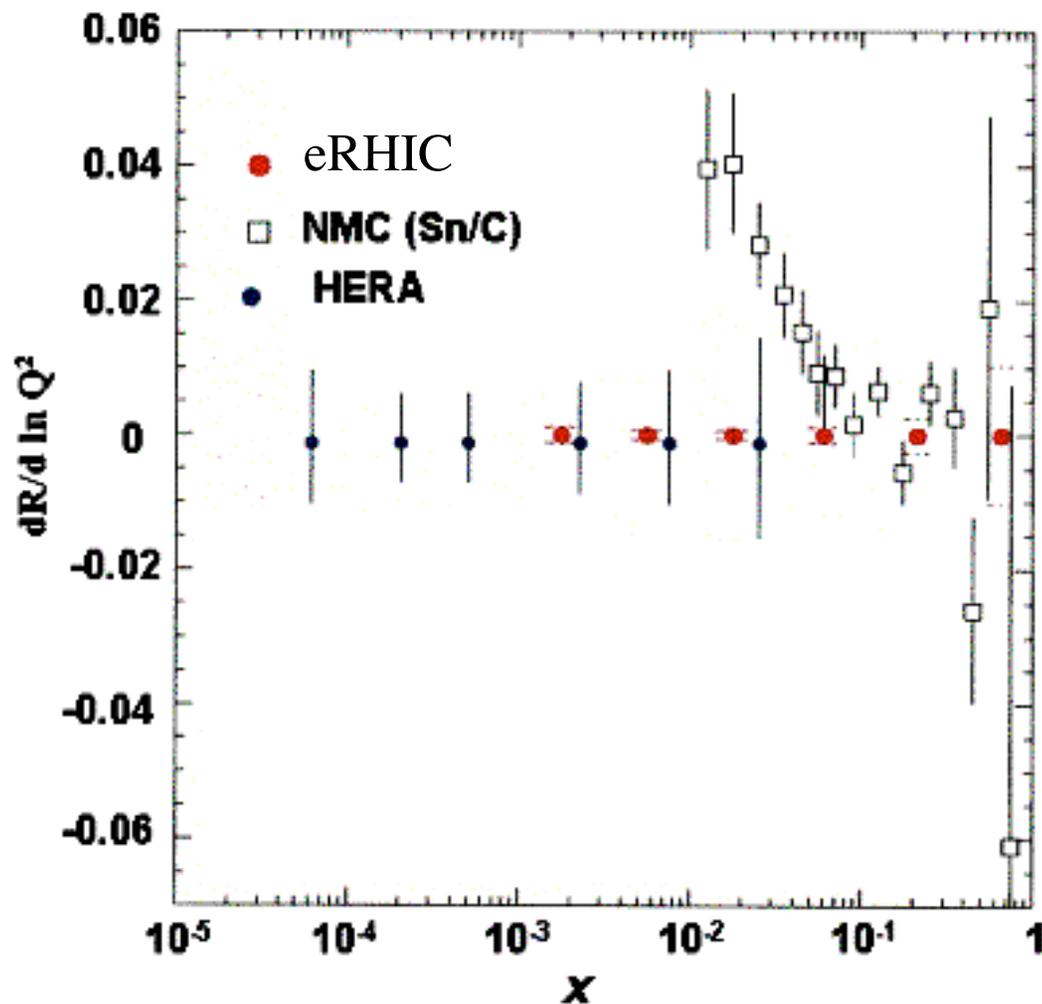
In e-A at eRHIC, diffractive processes may contribute 30-40% to the total cross section.

>> Also good acceptance/tracking in "forward & backward" regions

Coherent & Inclusive vector meson production:

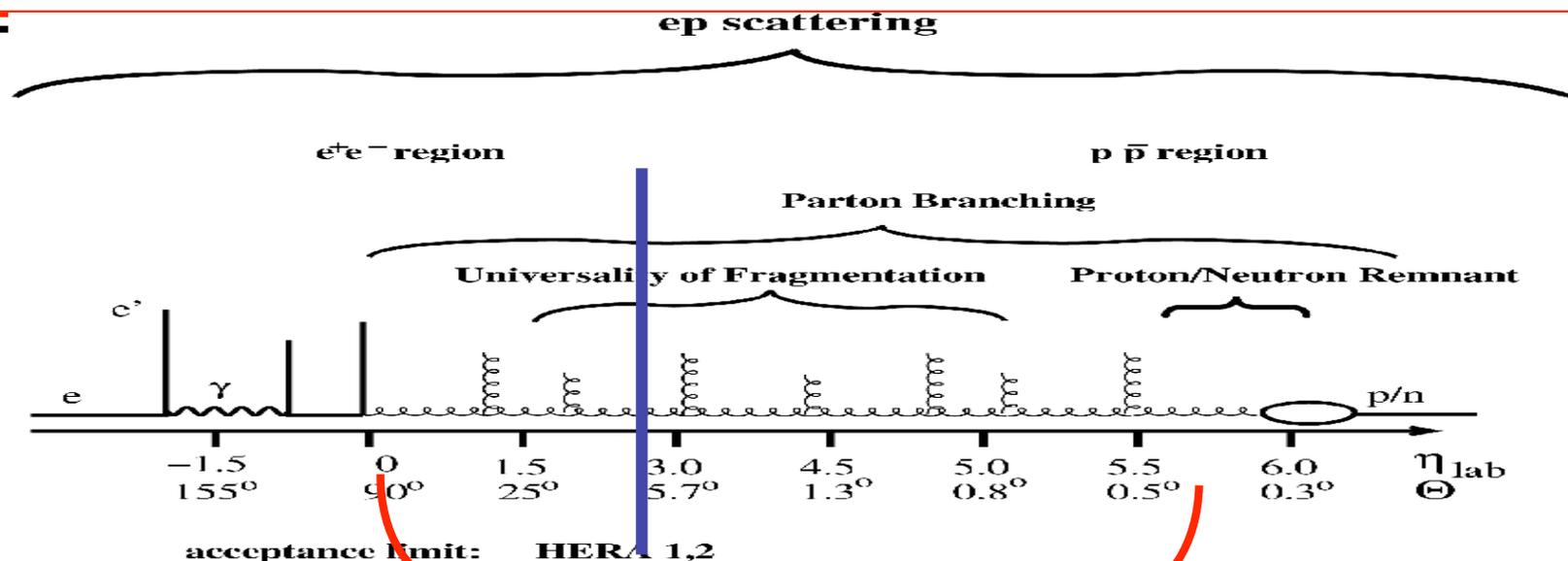
- For light vector mesons diff. Cross section. = 0.5 (inclusive)
Heavy vector mesons this decreases...finally reaching $1/\ln Q^2$
eRHIC will measure for different nuclei, $\rho, \omega, \phi, J/\psi, Y$ cross sections

Statistical Precision at eRHIC for e-A



- High precision at eRHIC shown statistical errors for 1 pb^{-1}
- Recall: eRHIC will $\sim 85 \text{ pb}^{-1}$ per day
- NMC data $R = F_2(\text{Sn})/F_2(\text{D})$
- eRHIC's Q^2 range between 1 and 10 GeV^2
- Will explore the interesting low x region!

More detailed tests of radiation in QCD: forward jets



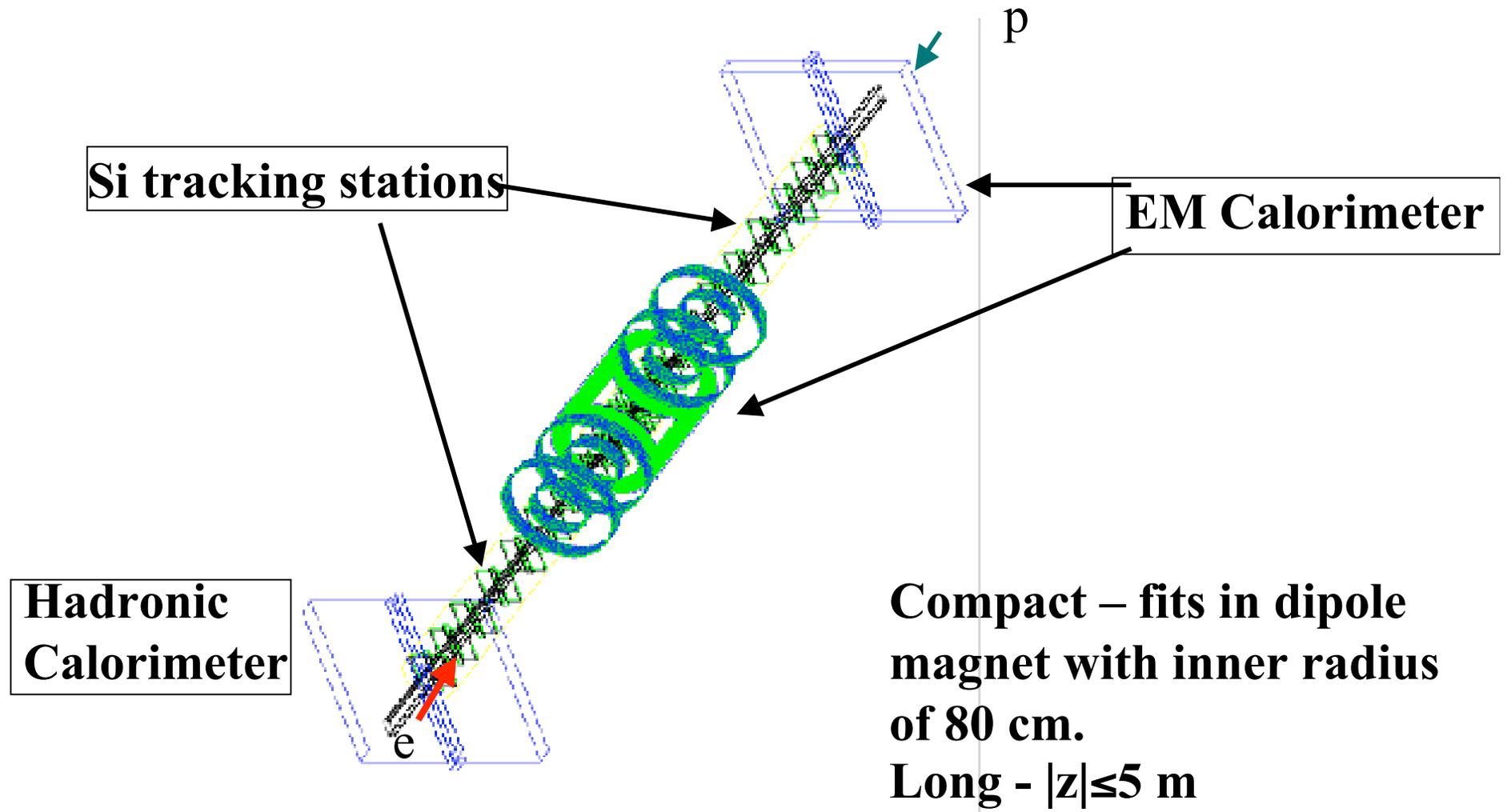
Investigate this region

Large effects are expected in Forward jet cross sections at high rapidities (also for forward particle production (strange, charm, ...))

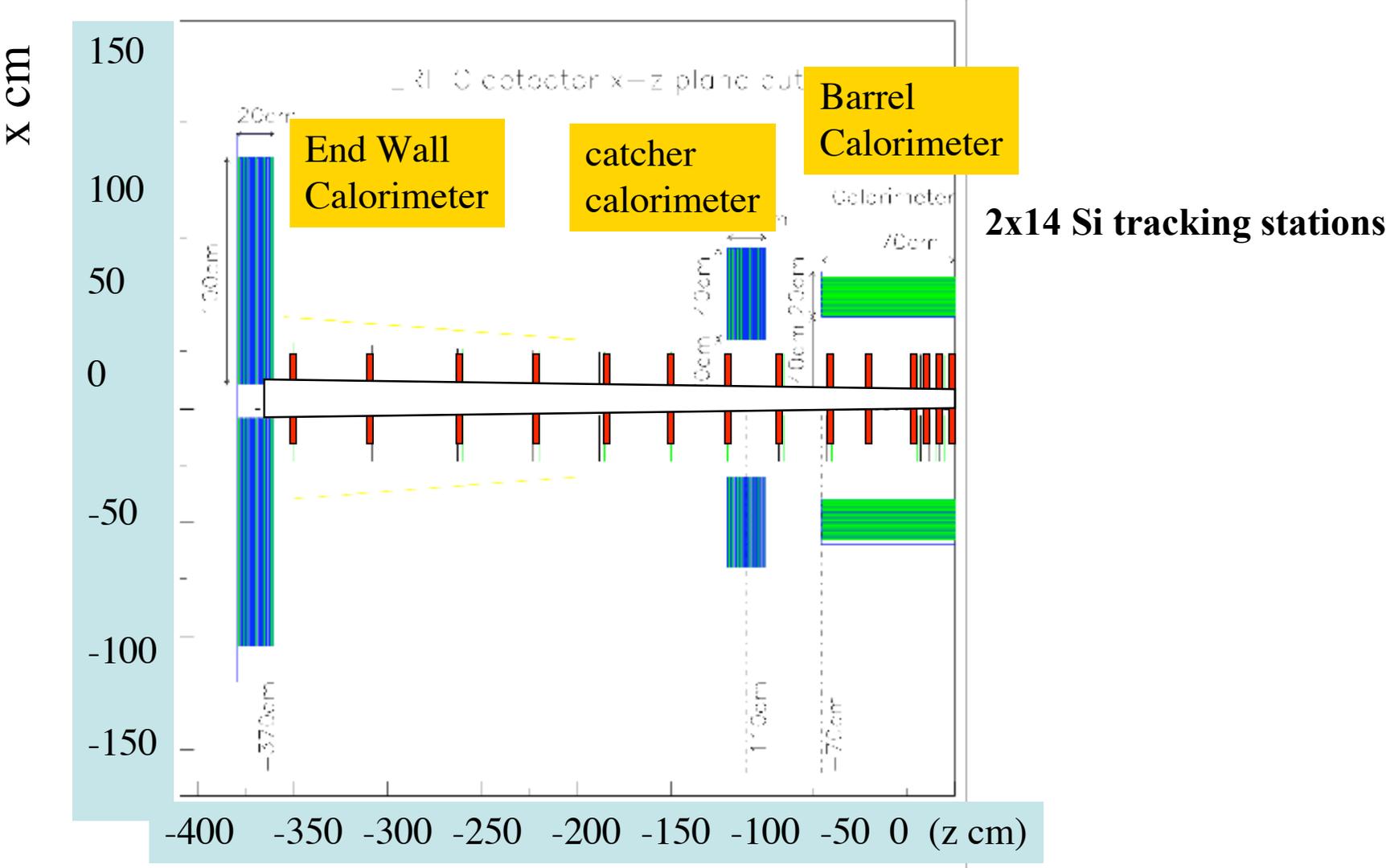
A. Caldwell et al.

A new detector to study strong interaction physics

A. Caldwell et al.

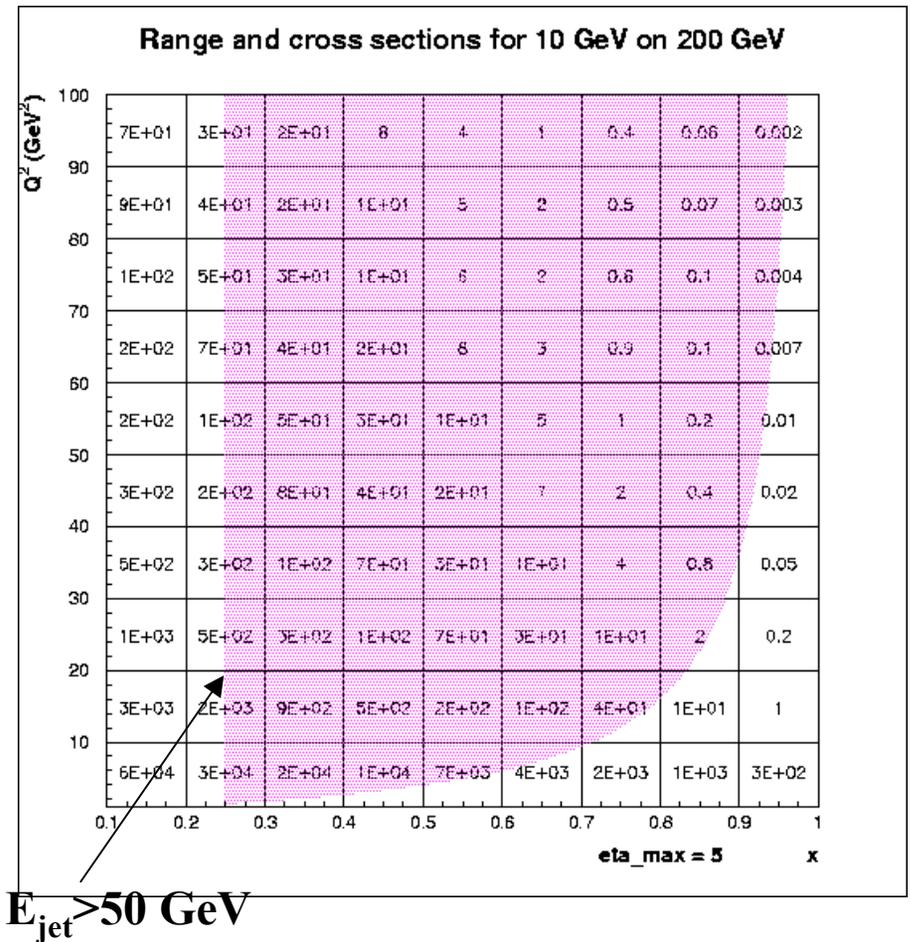
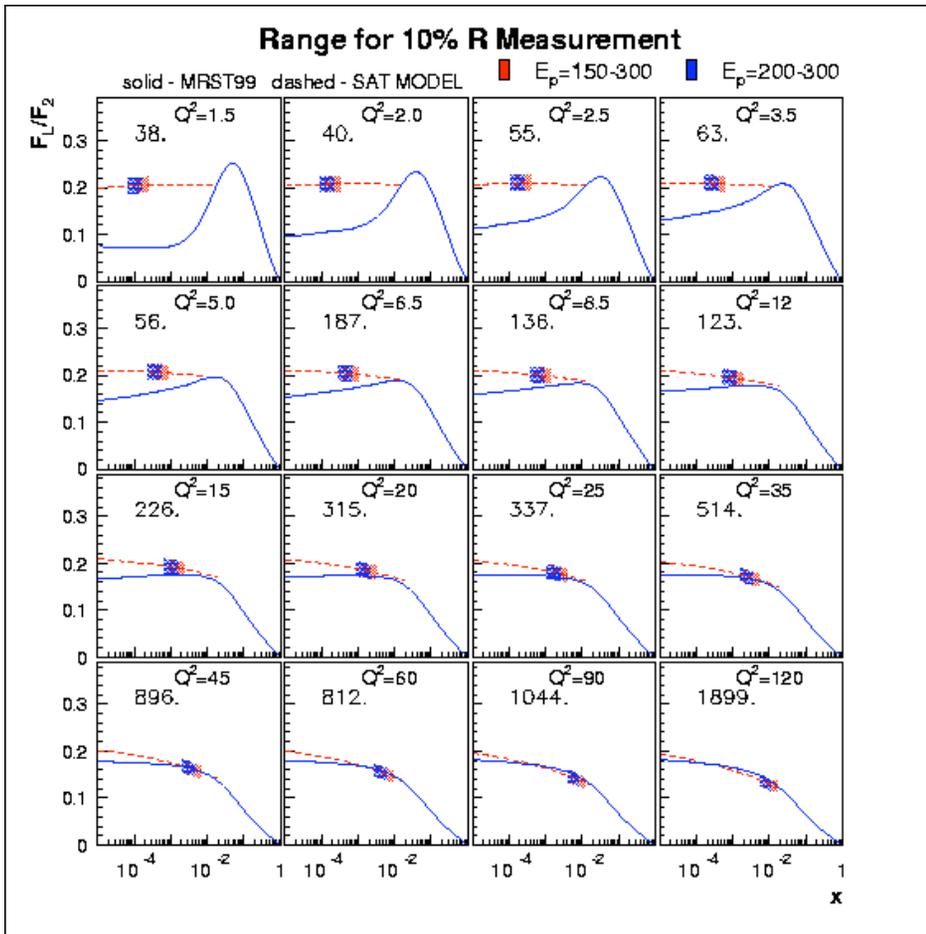


Low x Detector studies for eRHIC



F_L/F_2 vs. x for different Q^2

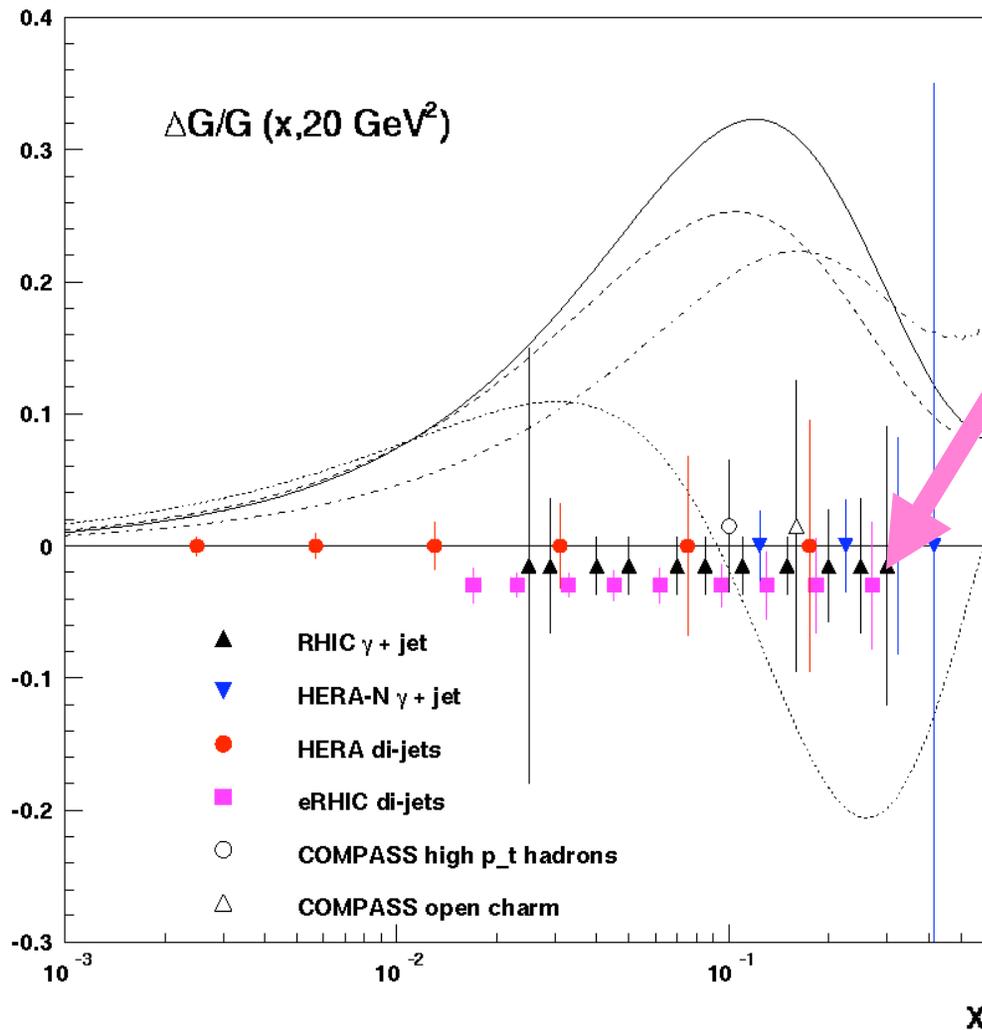
High x measurement $W^2 > 5 \text{ GeV}^2$
 Cross sections in pb



Summary:

- eRHIC promises to be truly a next generation collider experiment
 - detector ideas dictated by the physics are developing
 - over the next year, the focus will be to refine them and come up with a “conceptual design”
- Many technical challenges, but none deemed unsolvable
- Critical issues of integration of detector + interaction region being looked in to **now**
 - >> Experience at HERA helps on accelerator/IR design as well as detector ideas
- *To fully realize the fruits of these ideas:*
 - Need keep on a **fast path towards realization**
 - Next Step 1: NSAC 2005/6 long range plan approval
 - Technically driven schedules (Milner, Aronson, Kirk)
 - We do not want to explore “how late” is “too late”!

Di-Jet at eRHIC vs. World Data for $\Delta G/G$



eRHIC Di-Jet
DATA 2fb^{-1}
(half a run)

(RHIC at 200 GeV CM Only...)

Good precision

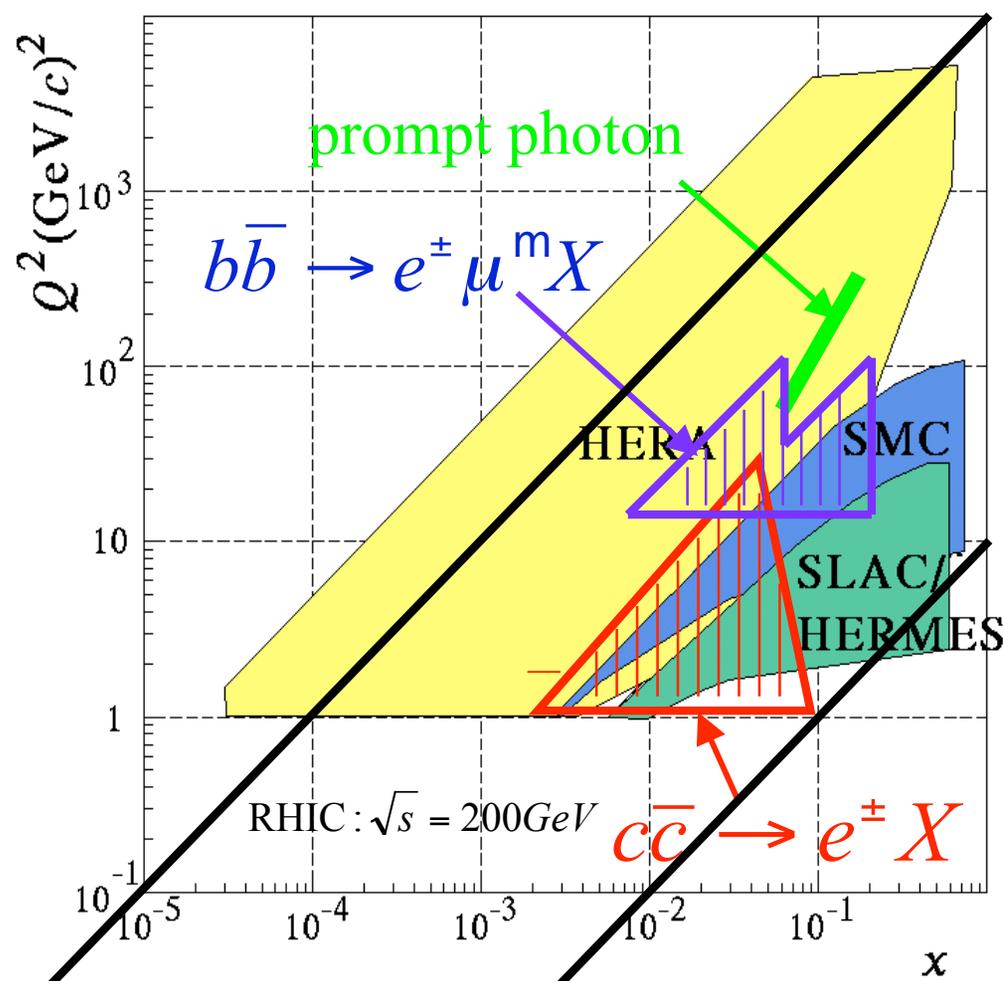
Clean measurement in x
range $0.01 < x < 0.3$

Constrains shape of $\Delta G(x)$

Polarization in HERA will
not happen!

ΔG from scaling violations
 $> x_{\min} \sim 10^{-4}$ at eRHIC

RHIC vs. eRHIC extension



NOTE:

- RHIC/PHENIX plots for 200 GeV CM
- At 500 GeV these will increase low x reach by $\sim 1/2$ a decade in low x

eRHIC region denoted by two Dark black lines.

- Continuous coverage