THE CHARGE

* present a plenary talk on the subject of "Nucleon Helicity Structure".

* give a perspective on which challenges still remain after the RHIC and fixed-target spin programs will have been largely completed.

* consider the importance and impact of ep collider measurements in polarized DIS at small x, Q2 evolution, the Bjorken Sum Rule, the large x valence region, semi-inclusive DIS/sea polarization, ~~parity-violating DIS~~, further measurements of delta G, etc.

NUCLEON HELICITY STRUCTURE

* 10 years ago ... 1 slide
* Today
* 10 years from now
* 20 years from now

Emlyn Hughes
Jlab
March 17, 2004

THE PROTON SPIN

$$S = \tfrac{1}{2} = \tfrac{1}{2}\Delta q + L_q + \Delta G + L_G$$

orbital angular momenta

~10 years ago...

* $\Delta q = 0$

* QCD might be wrong

→ CERN, SLAC, DESY, FERMILAB

SLAC E143 Collaboration

P.L. Anthony, R.G. Arnold, T. Averett, H.R. Band, M.C. Berisso, H. Borel, P.E. Bosted, S.L. Bultmann, M. Buenerd, T. Chupp, S. Churchwell, G.R. Court, D. Crabb, D. Day, P. Decowski, P. DePietro, Robin D. Erbacher, R. Erickson, A. Feltham, H. Fonvieille, E. Frlez, R. Gearhart, V. Ghazikhanian, J. Gomez, K.A. Griffioen, C. Harris, M.A. Houlden, E.W. Hughes, C.E. Hyde-Wright, G. Igo, S. Incerti, J. Jensen, J.R. Johnson, P.M. King, Yu.G. Kolomensky, S.E. Kuhn, R. Lindgren, R.M. Lombard-Nelsen, J. Marroncle, J. McCarthy, P. McKee, W. Meyer, G.S. Mitchell, J. Mitchell, M. Olson, S. Penttila, G.A. Peterson, G.G. Petratos, R. Pitthan, D. Pocanic, R. Prepost, C. Prescott, L.M. Qin, B.A. Raue, D. Reyna, L.S. Rochester, S. Rock, O. Rondon-Aramayo, F. Sabatie, I. Sick, T. Smith, L. Sorrell, F. Staley, S. St. Lorant, L.M. Stuart, Z. Szalata, Y. Terrien, A. Tobias, L. Todor, T. Toole, S. Trentalange, D. Walz, R.C. Welsh, F.R. Wesselmann, T.R. Wright, C.C. Young, M. Zeier, H. Zhu, B. Zihlmann

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Fermilab E581/E704

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TODAY

quark $\Delta q \approx 0.25 \pm 0.1$

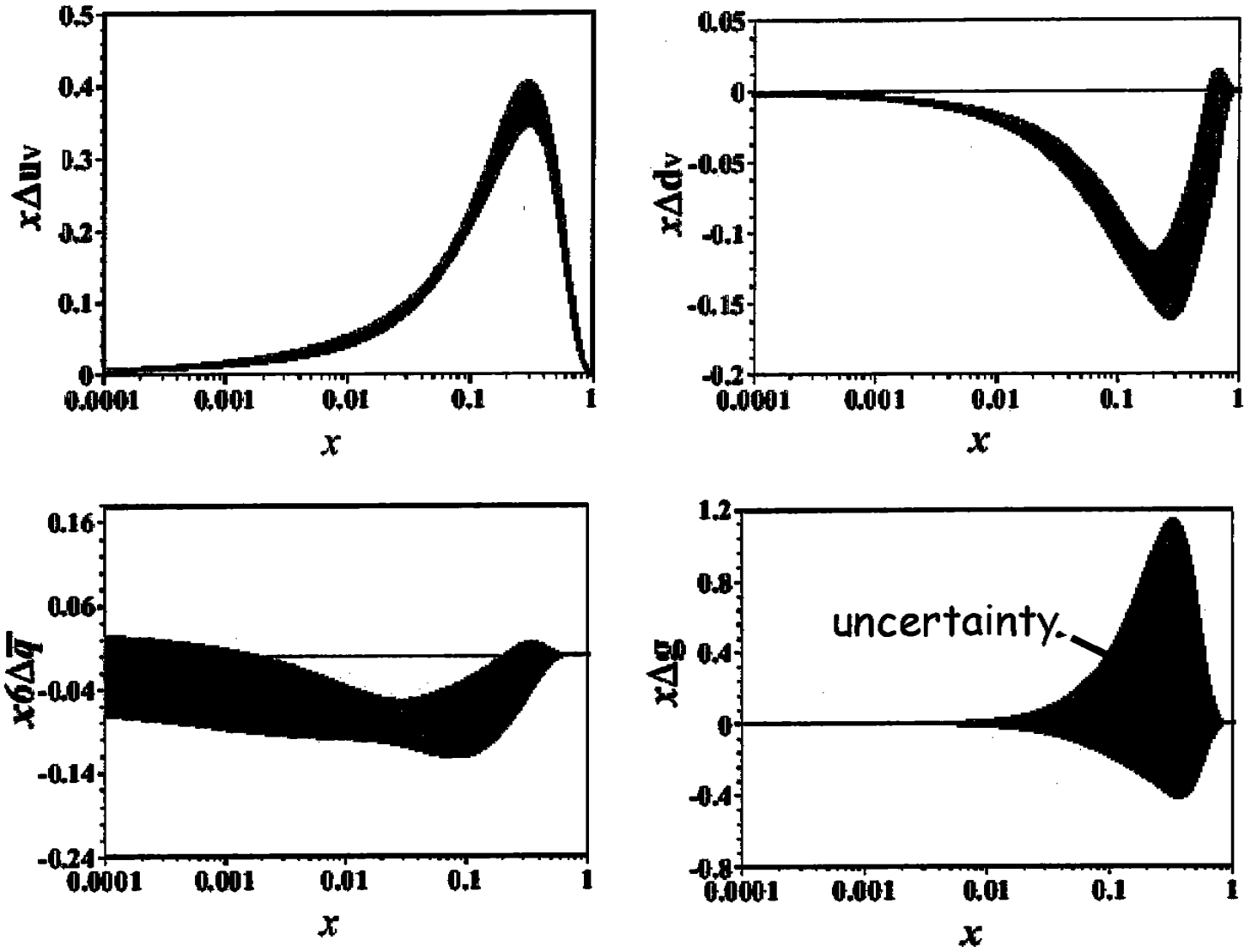
gluon $\Delta G \approx 0.5 \pm \sim 1.$

NLO
pQCD

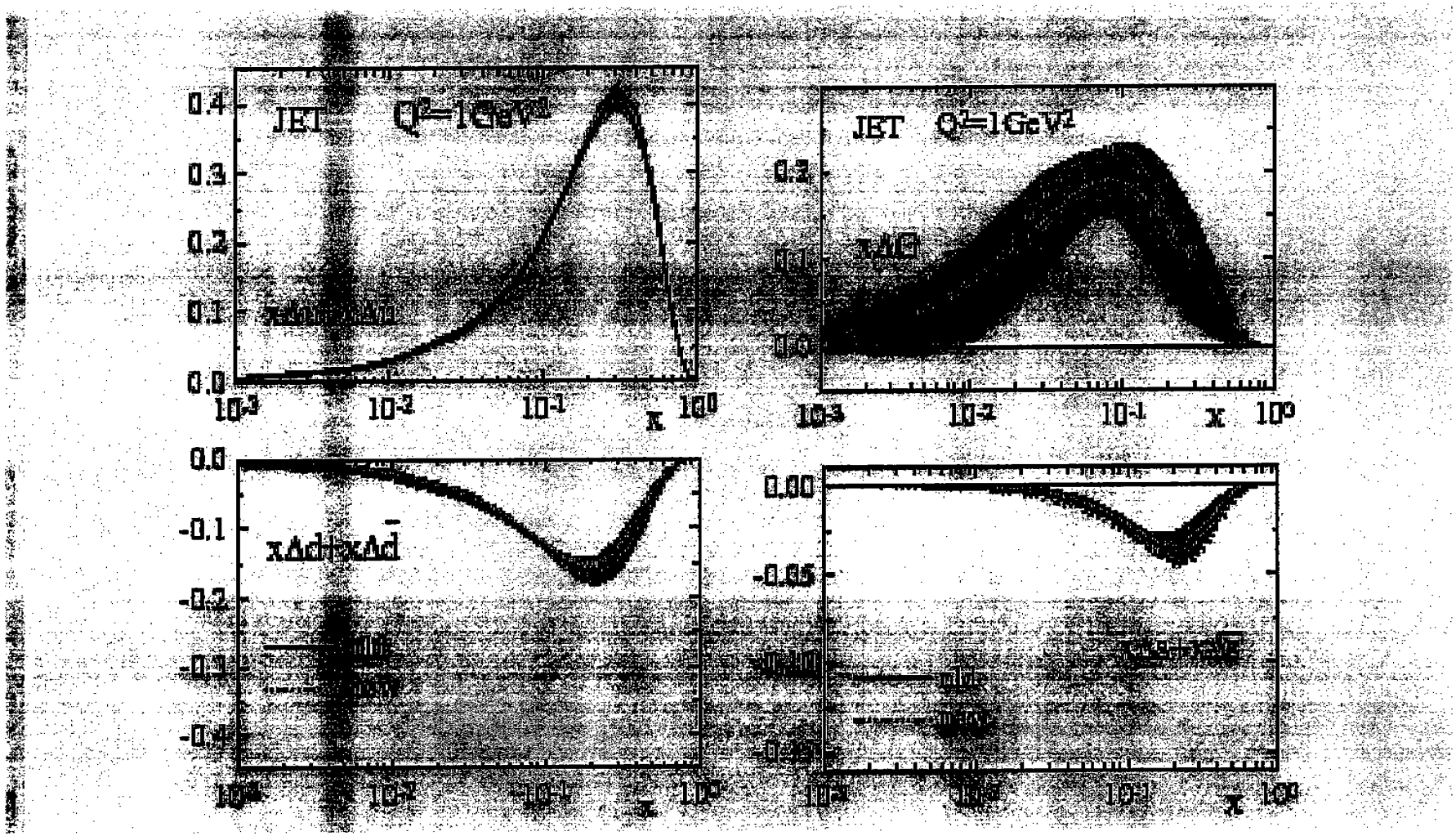
L_q = ???

L_G = ???

Fits to polarized DIS data



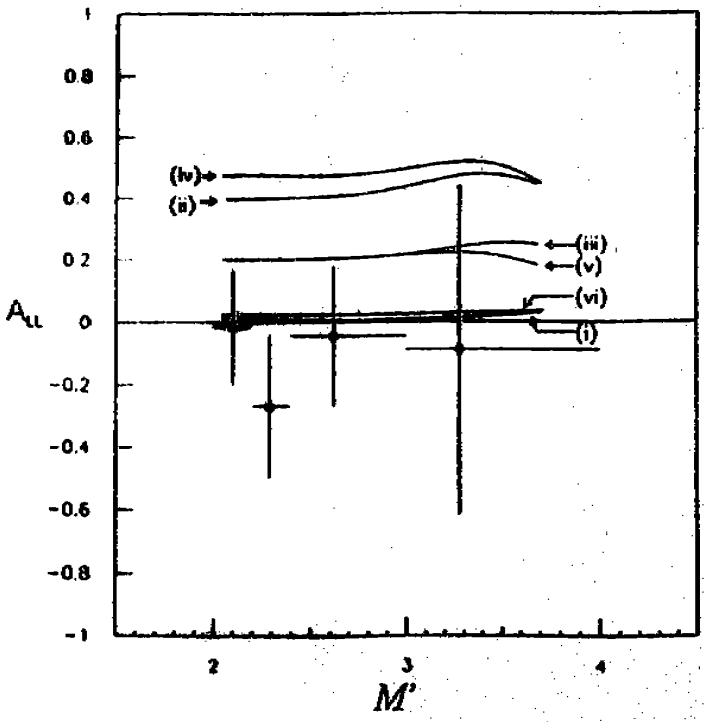
M. Hirai et al., Int. Jour. Mod. Phys. A 18 (2003) 1203

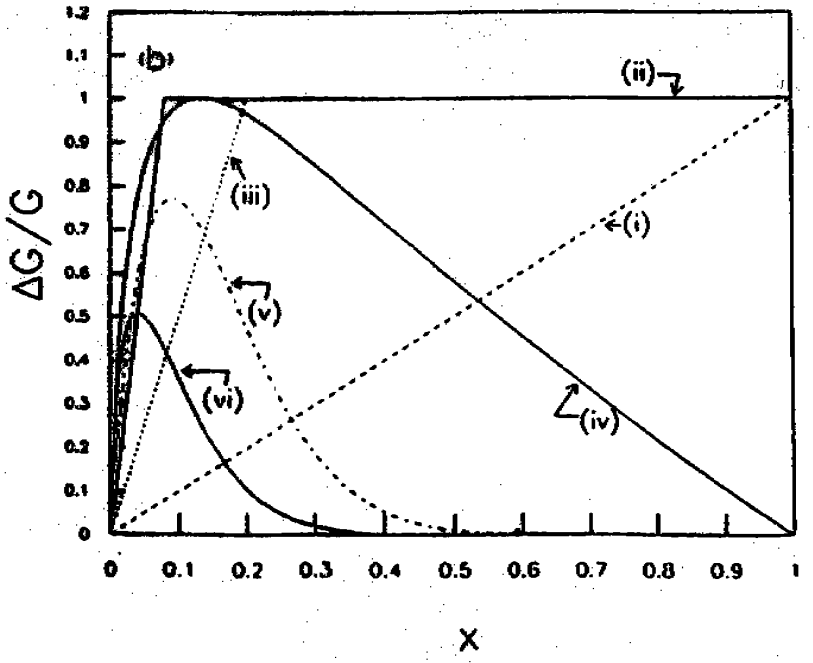


E. Leader, A. Siderov, D.B. Stamenov PR D67, 074017 (2002)

Fermilab E704

...10 years ago





...excludes large values of ΔG

ΔG Measurements.....

* COMPASS $\vec{\mu}\,\vec{N}$ in progress

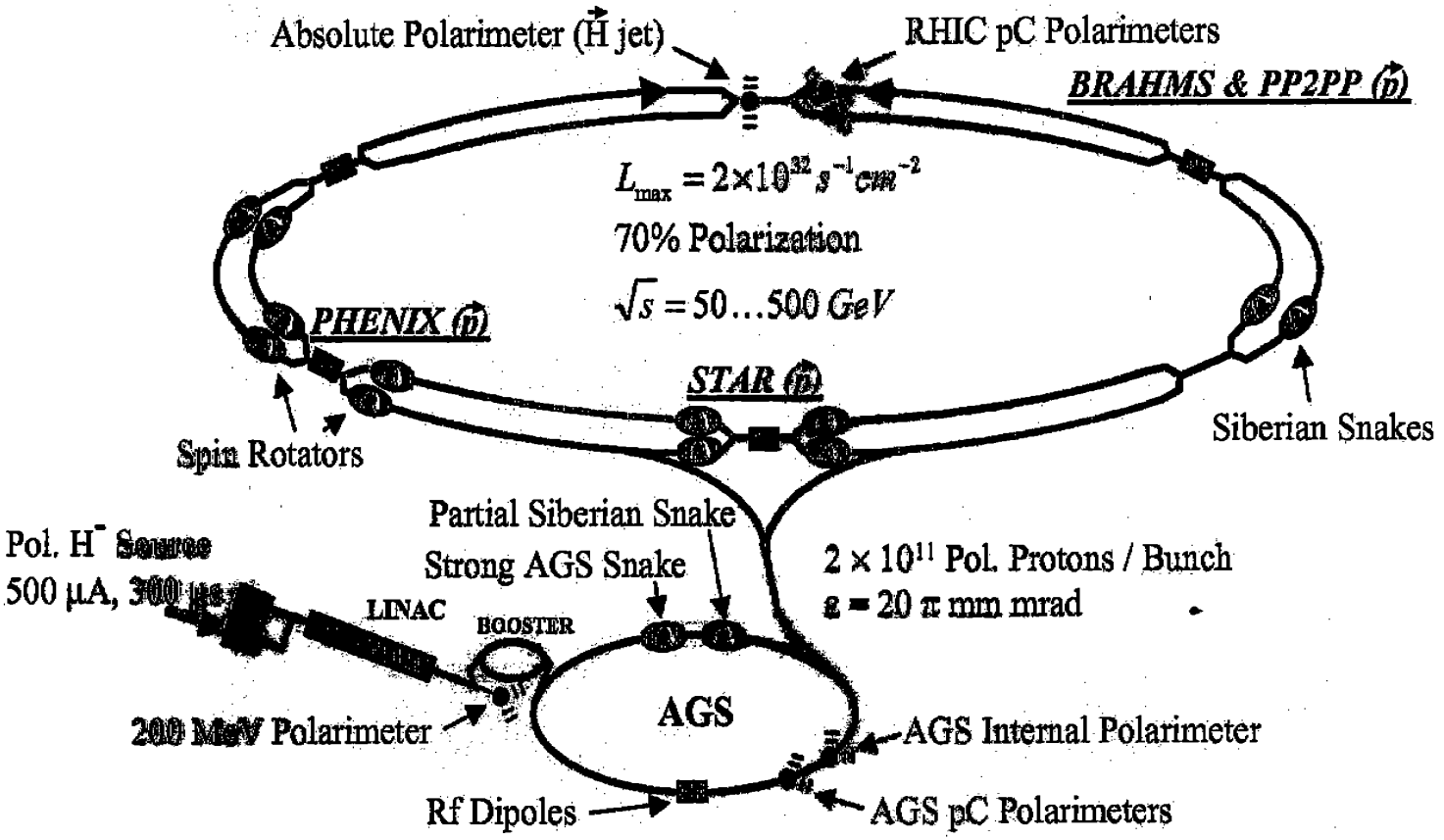
* RHIC Spin $\vec{p}\,\vec{p}$ in progress

  → PHENIX & STAR

* HERMES $\vec{e}\,\vec{N}$ - probably over?

* SLAC E161 $\vec{\gamma}\,\vec{N}$ unfunded

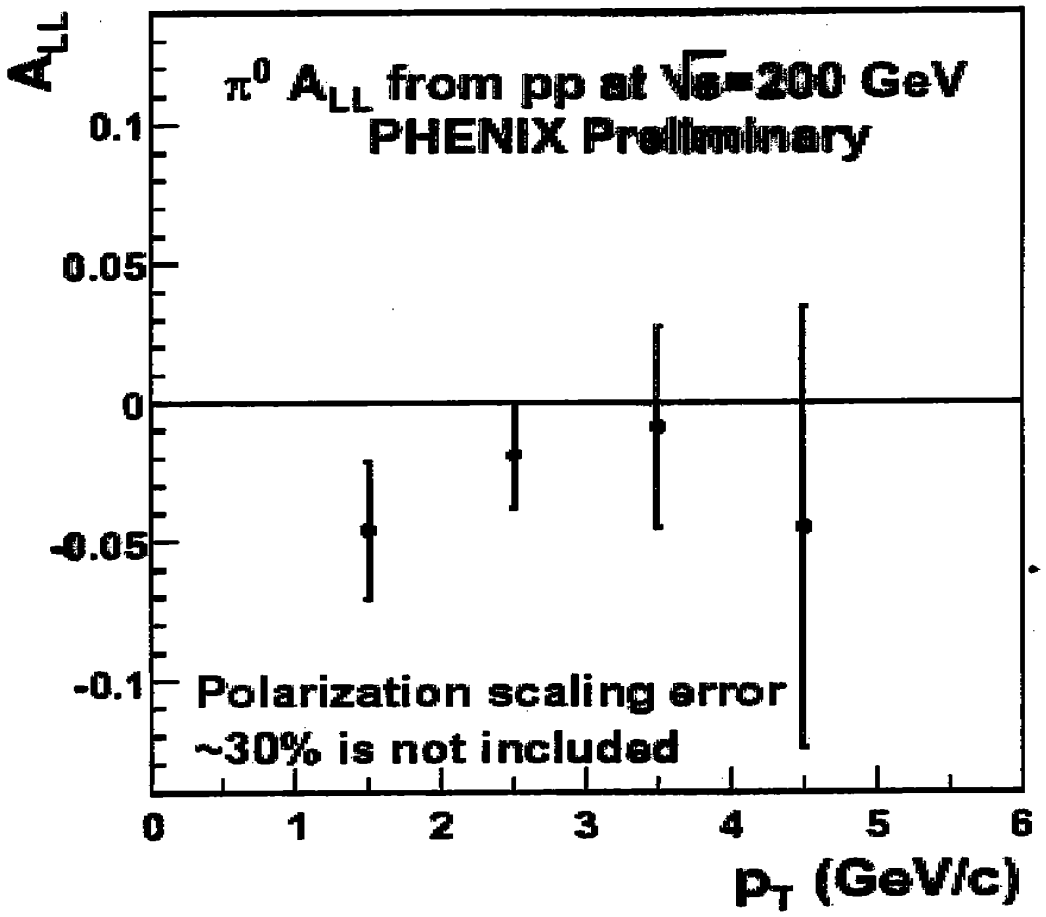
RHIC Spin -- Polarized proton scattering



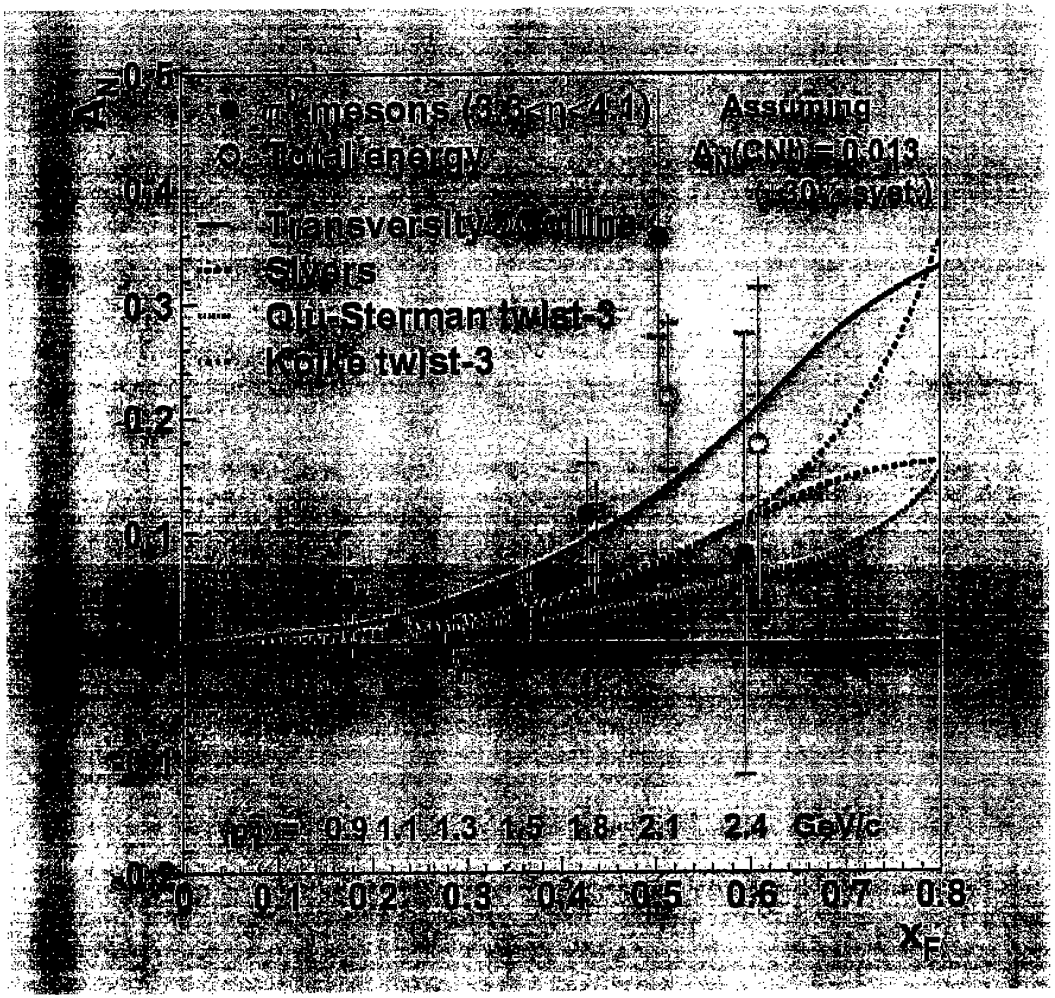
TODAY's Asymmetry Results

→ Hunt for ΔG

PHENIX π^0 measurement from p-p

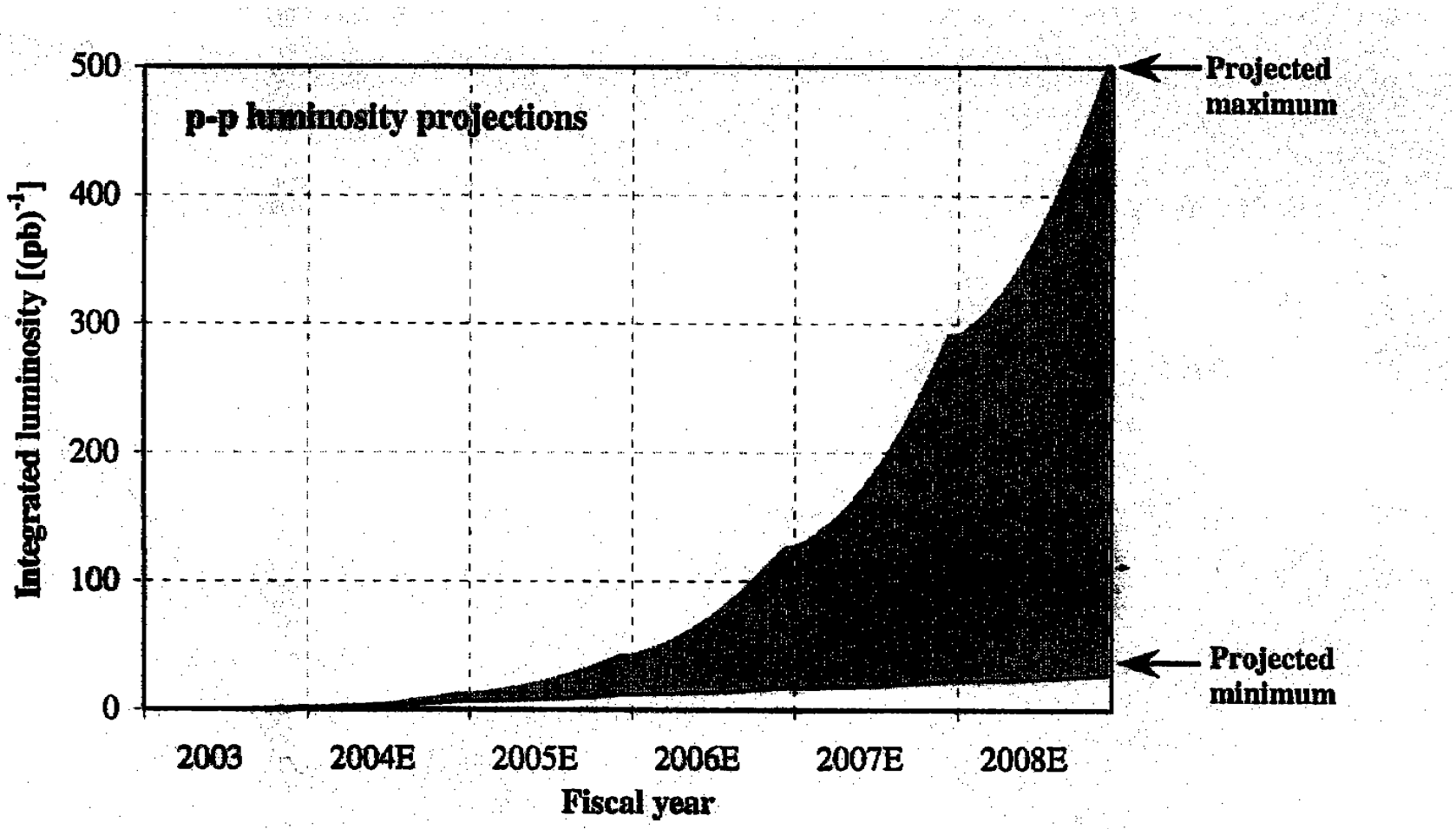


Transverse polarized p + p results on π^0 production from STAR

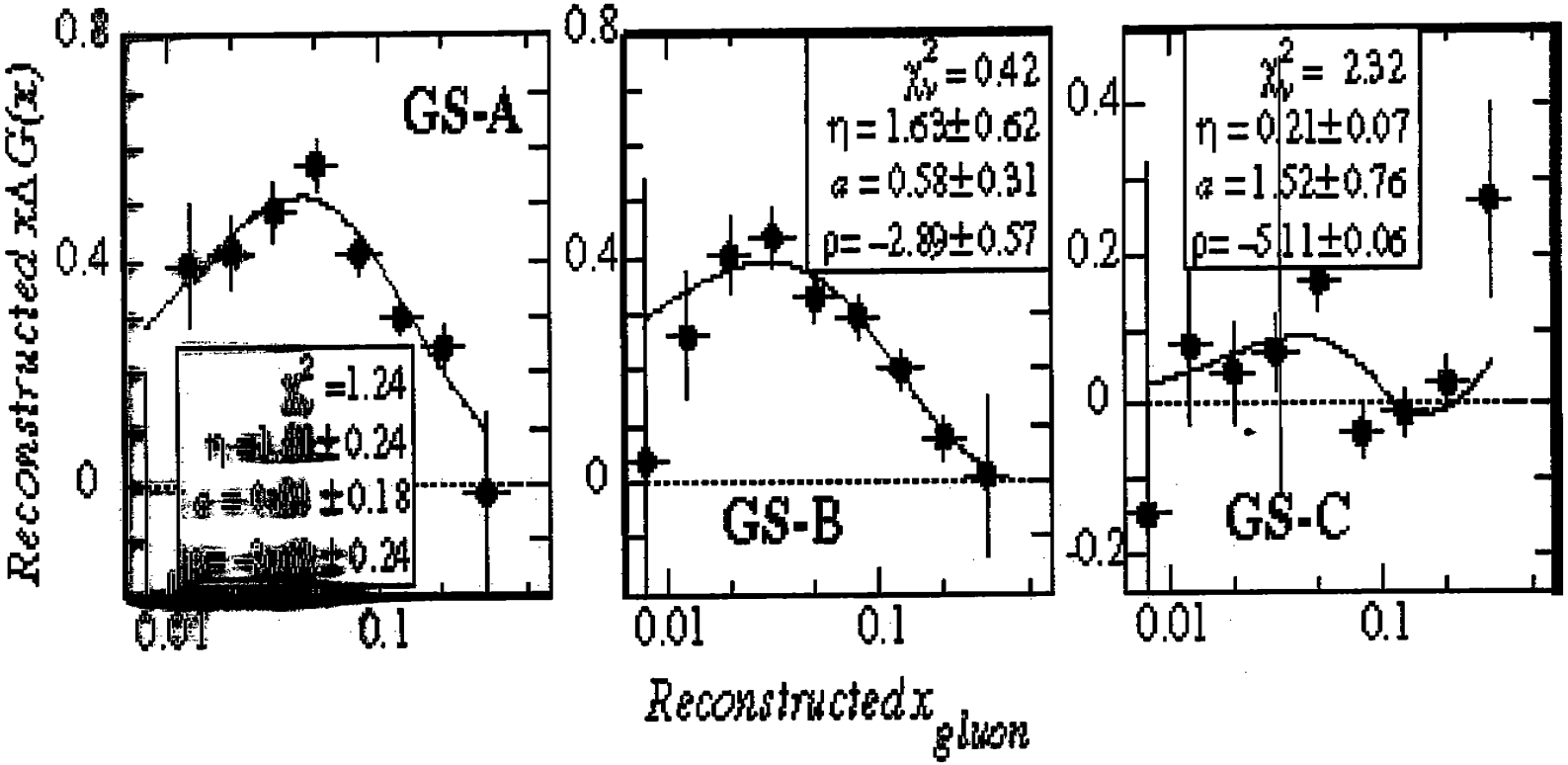


10 YEARS from NOW...

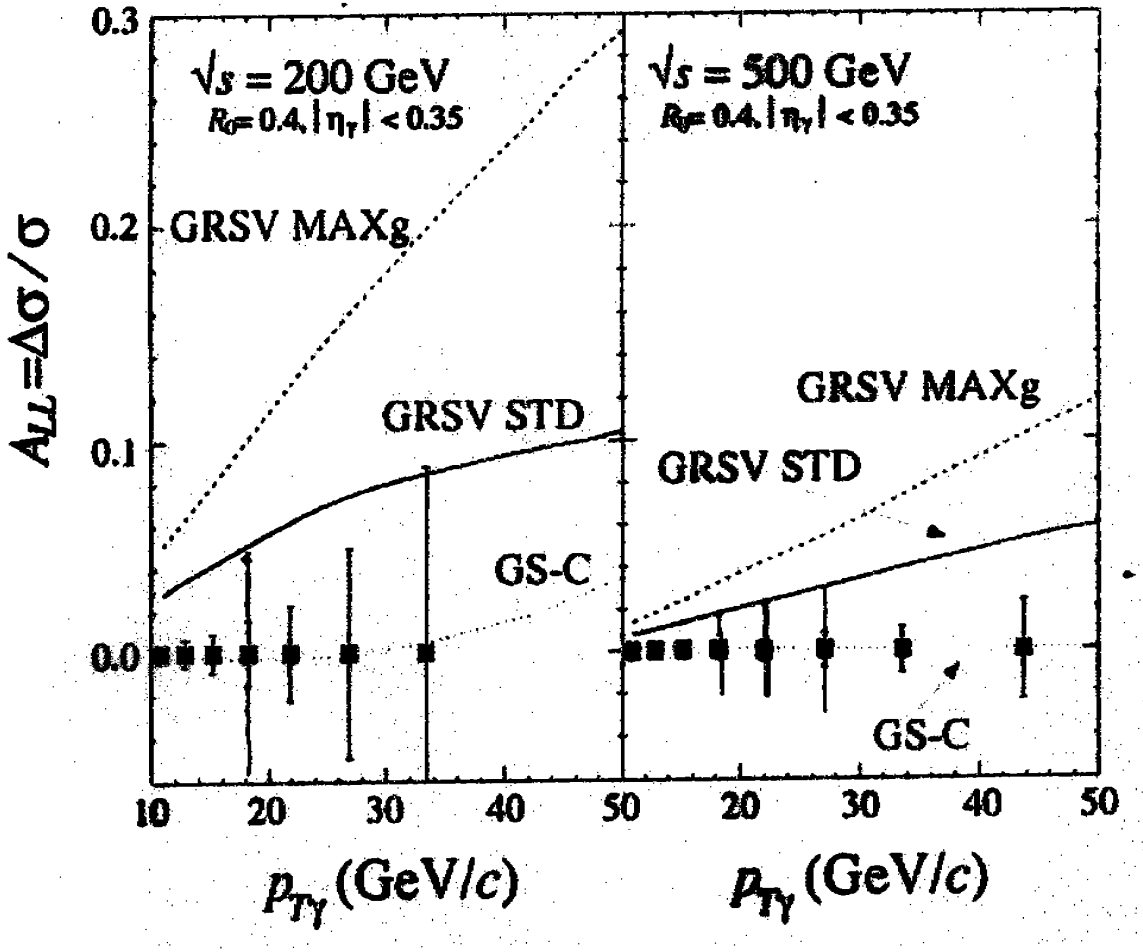
RHIC proton-proton collider



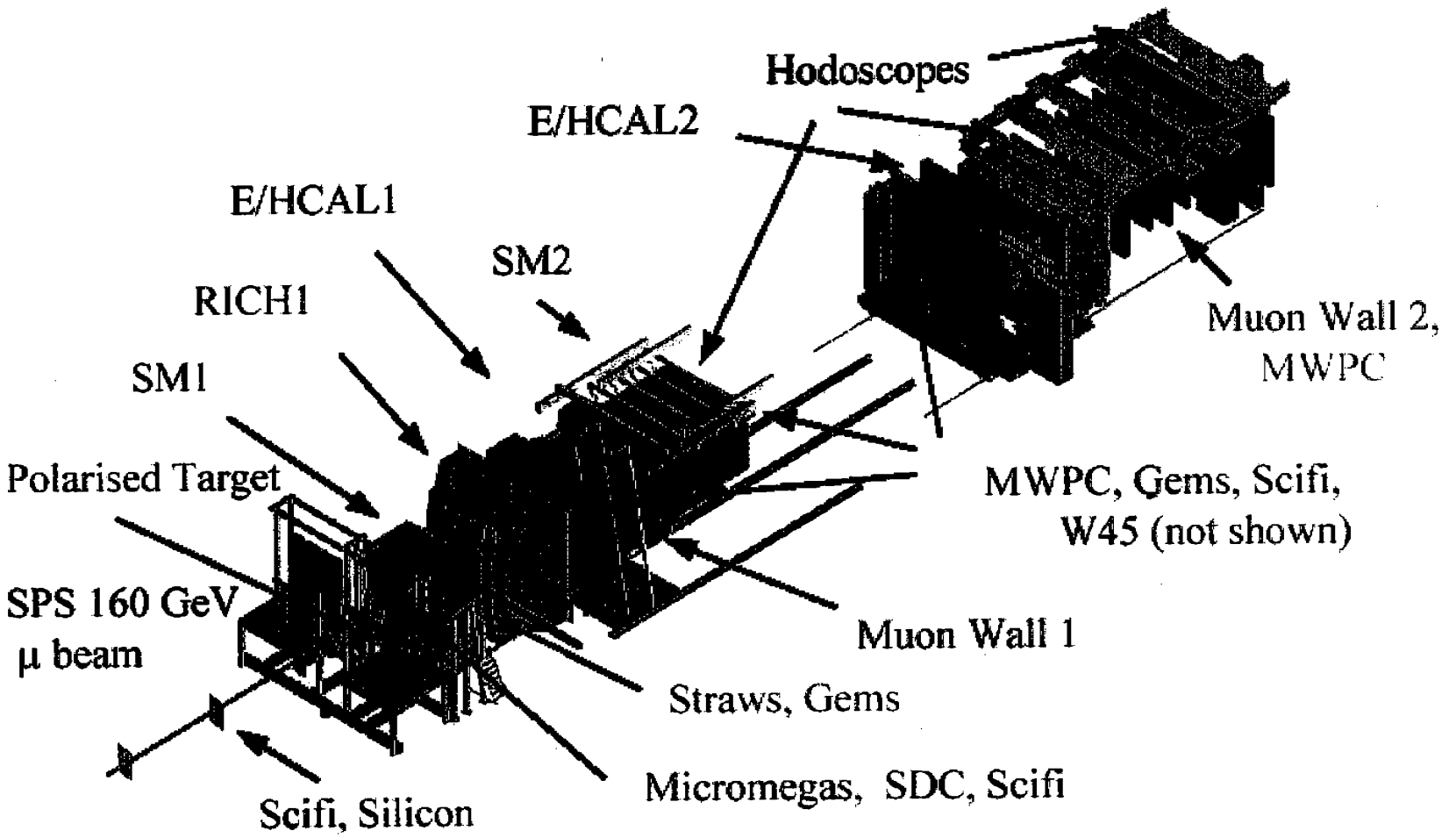
Proposed Sensitivity to ΔG from direct photon production at STAR



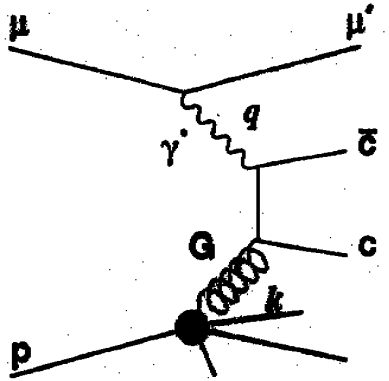
PHENIX direct photon production



COMPASS Experiment at CERN



Photon-Gluon Fusion



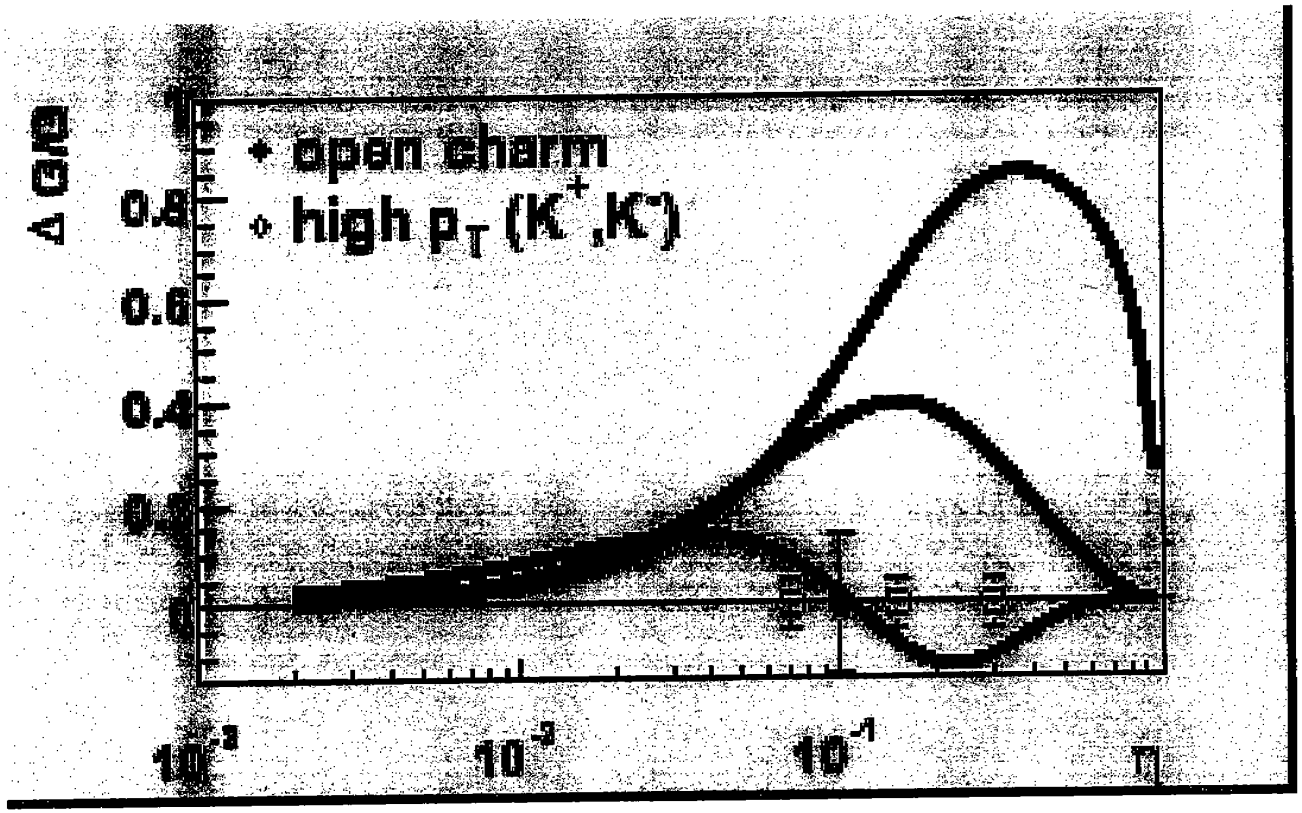
Rate $N^{S}_{D^{*+}} = 300\ \text{day}^{-1}$

Total 22,000 events

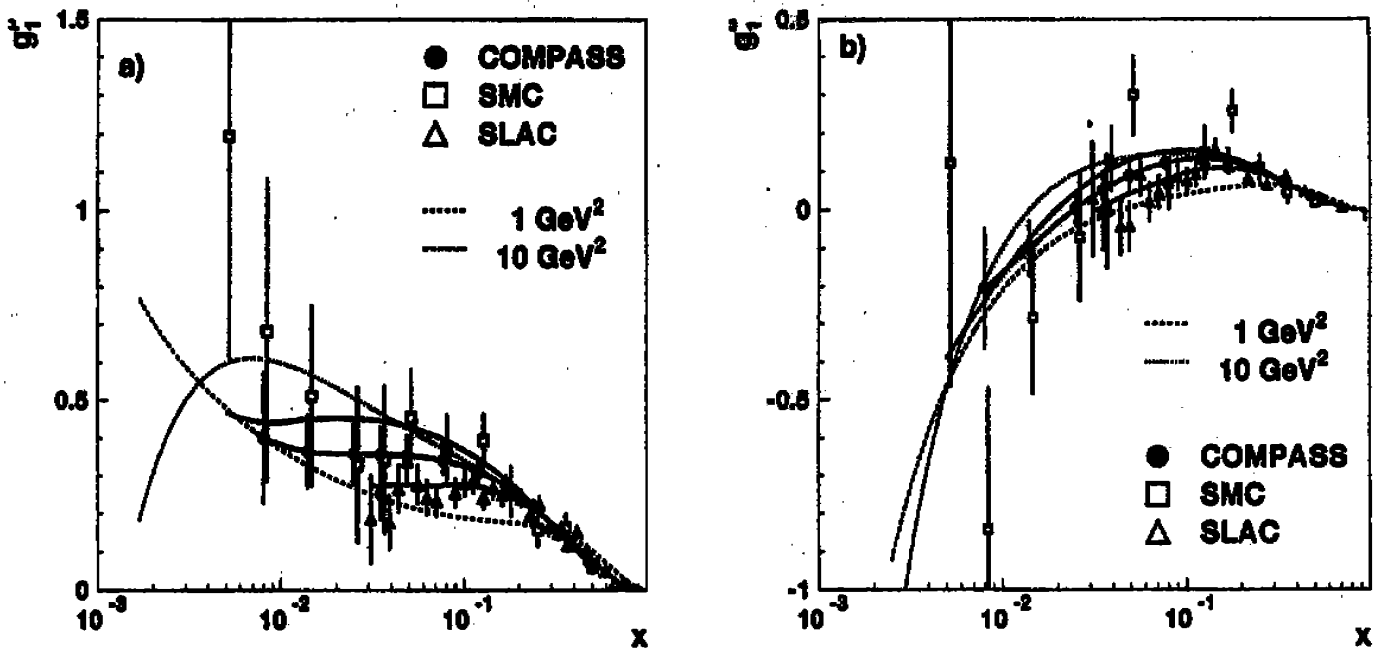
$\Delta A^{c\bar{c}}_{\gamma N}$ ± 6%

$\Delta G/G \sim 10\%$

Compass Projections



Proton and Deuteron Spin Structure Functions g_1



Comparison to SMC today:

Note x-range and precision

Generalized Parton Distributions

Jlab 12 GeV program

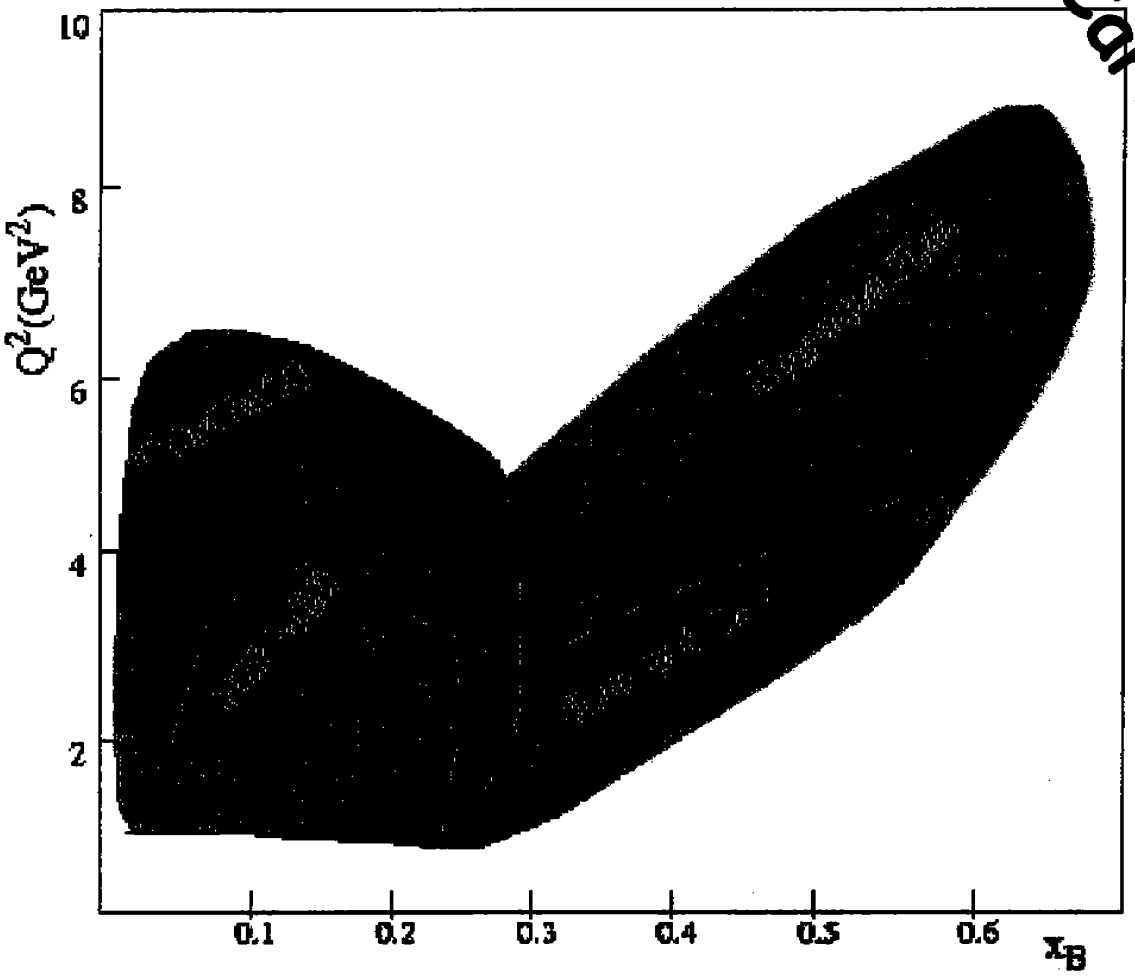
The Dream ...
Quark Orbital Angular Momentum

$$J_q = \int_{-1}^{1} x dx \left[H_q(x,\xi,0) + E_q(x,\xi,0) \right]$$

Generalized Parton Distributions

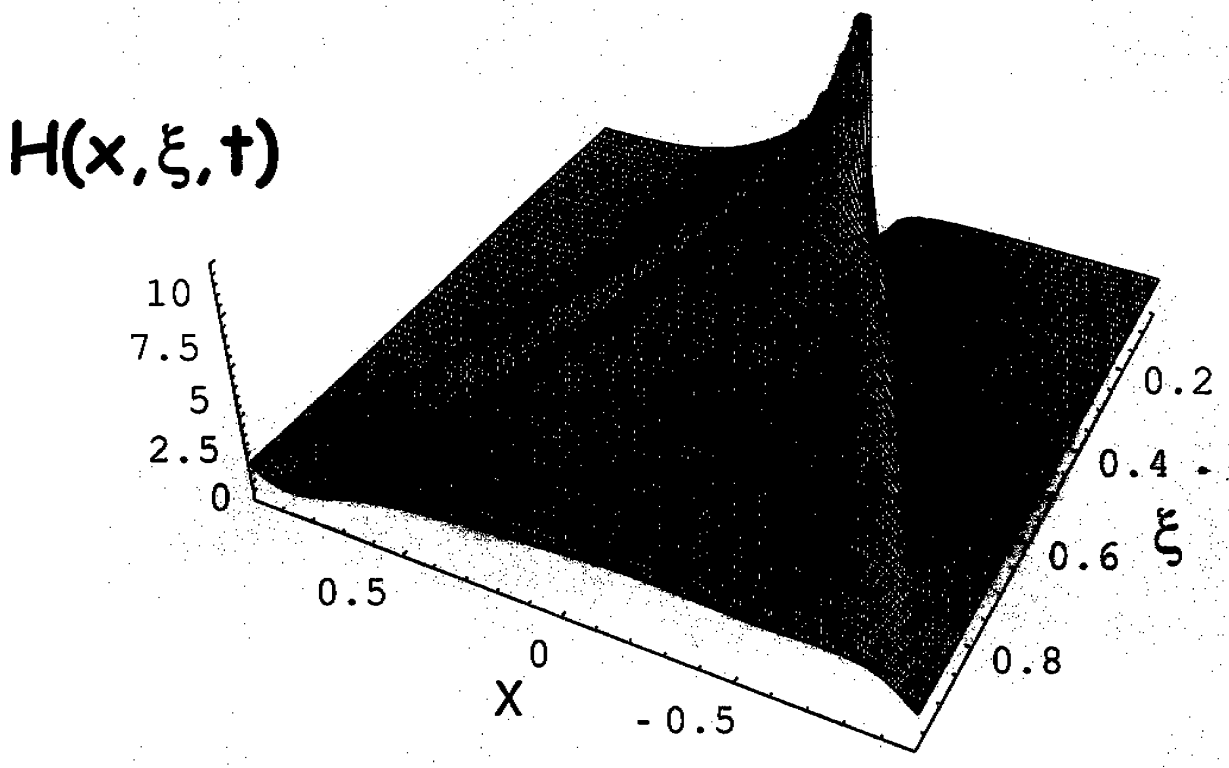
...functions of x, ξ, t

Kinematic range of the various lepton scattering labs

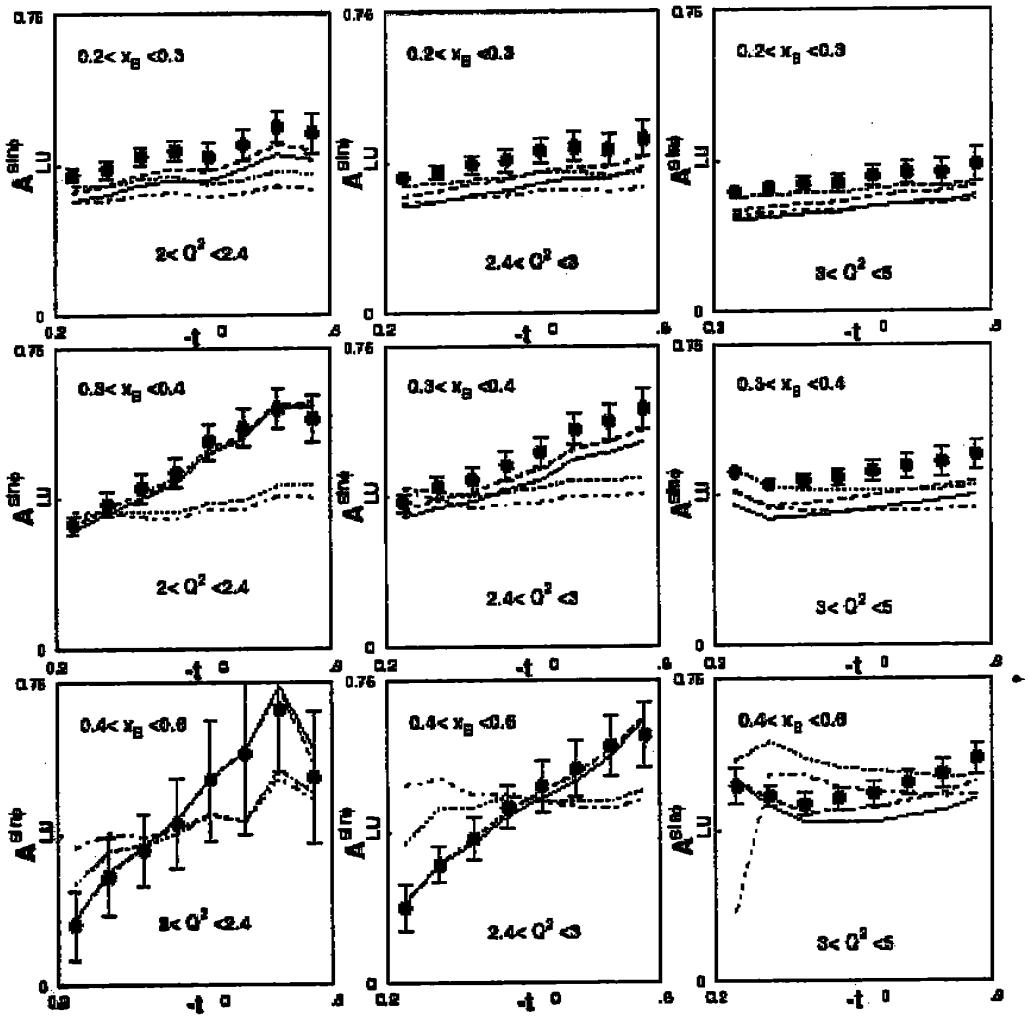


Careful with such plots!!!

You know that you are in trouble when theorists do this...



Future 12 GeV measurements...



Quark Orbital Angular Momentum

→ Still a long way from estimating an uncertainty on L_q

→ Need a long program to map out these new structure functions to see if they develop into insight

20 YEARS from NOW...

MAINLINE EIC Physics Topics:

1. Polarized Gluon Distribution
2. Angular momentum of quarks and gluons inside the proton
3. Gluon Saturation (unpolarized)
4. Precision electroweak

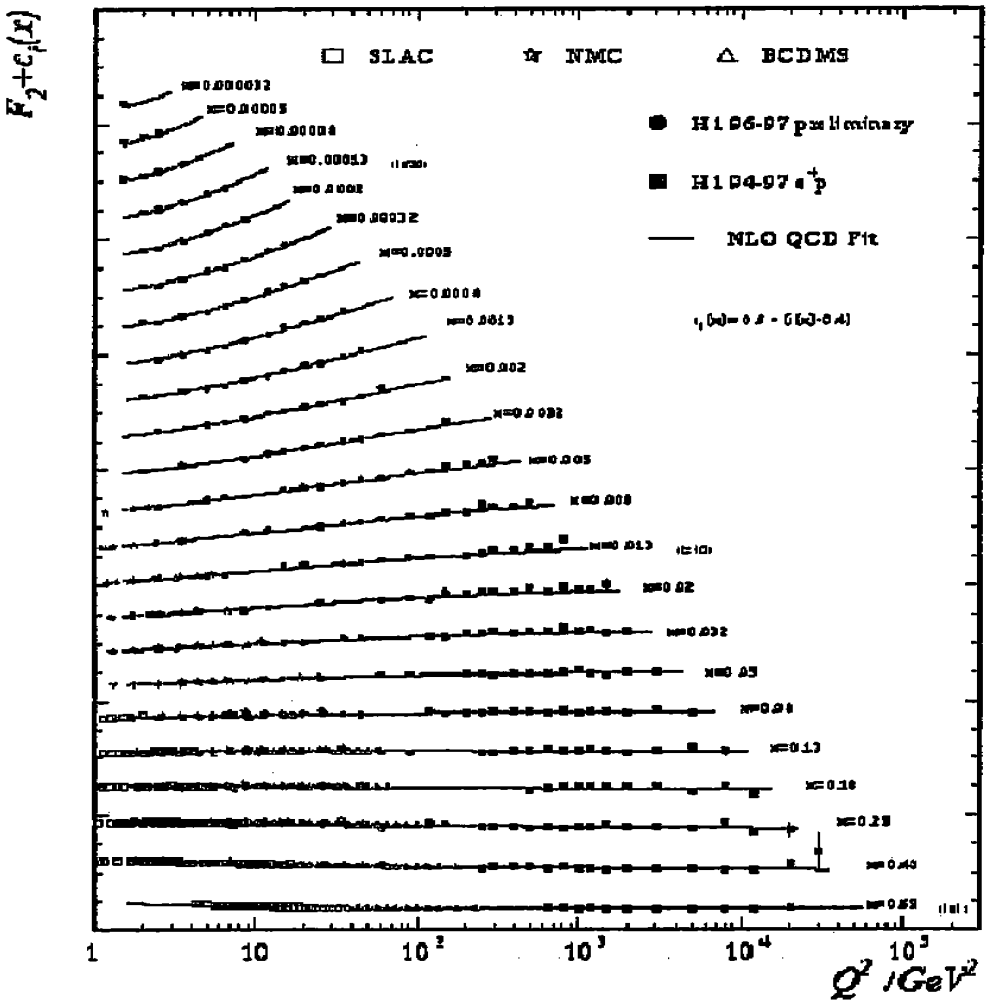
Polarized Electron-Ion Colliders

→ eRHIC ΔG machine

→ ELIC L_q machine

unpolarized

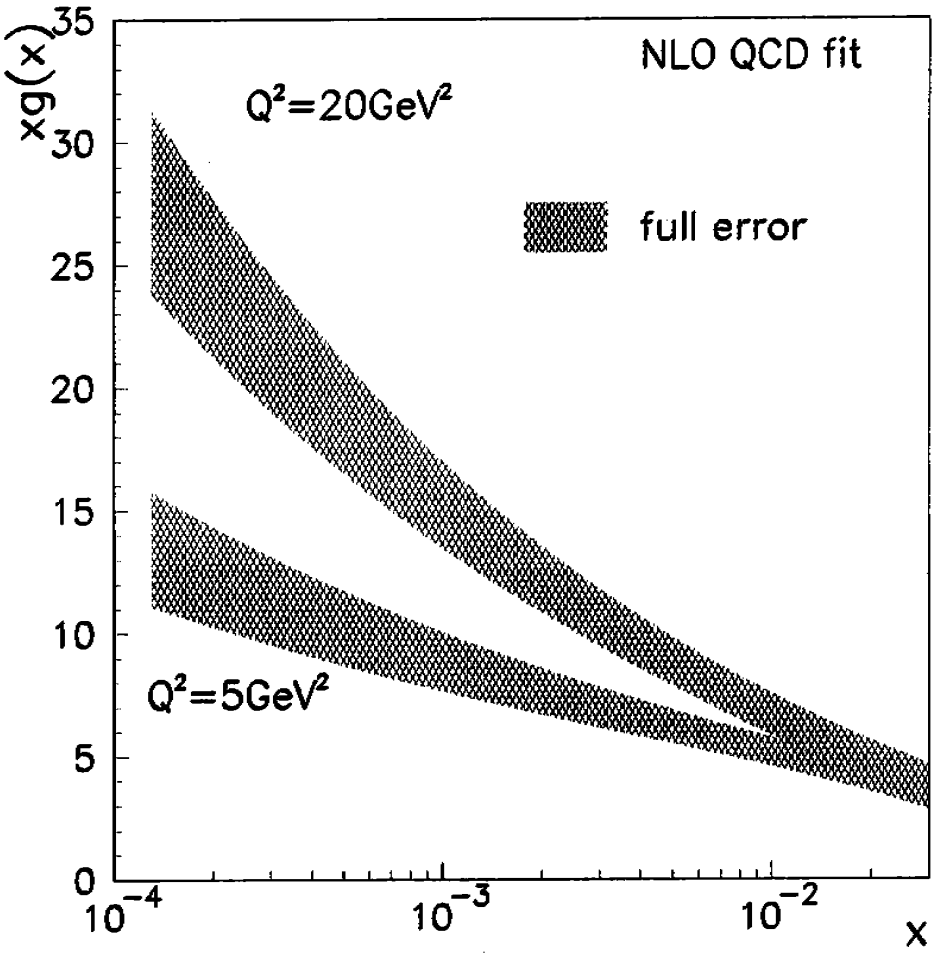
After ~12 years...



HERA

Gluon Distribution

unpolarized

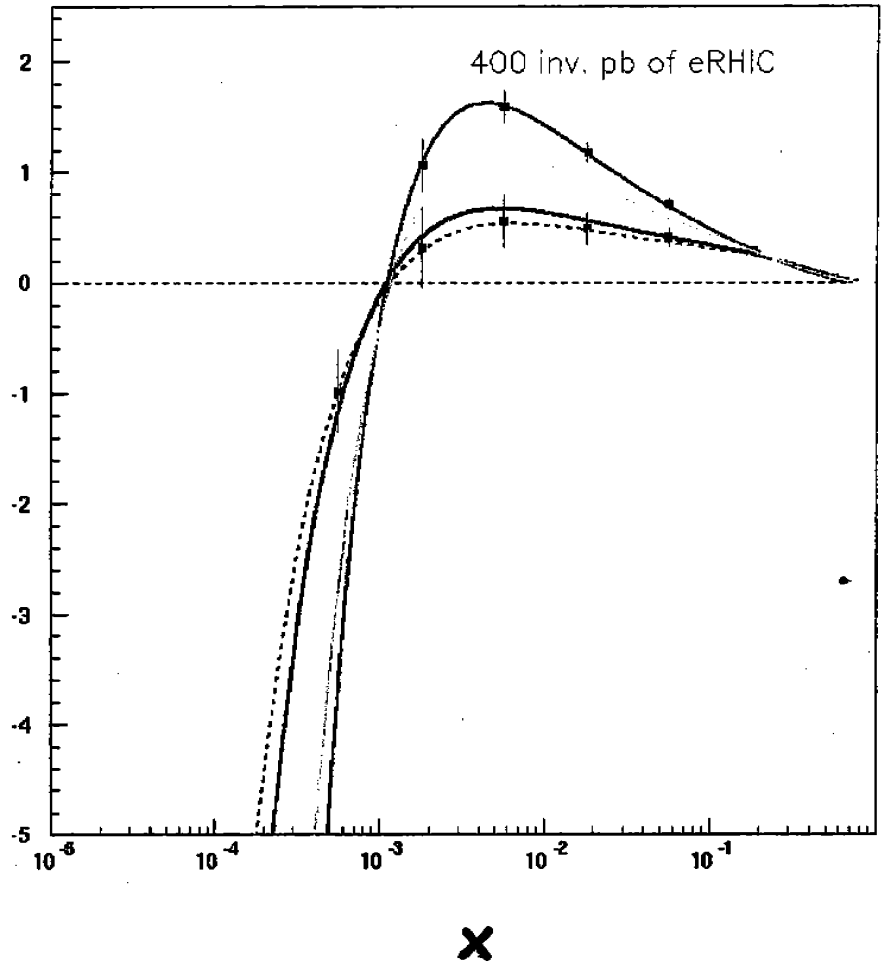


HERA

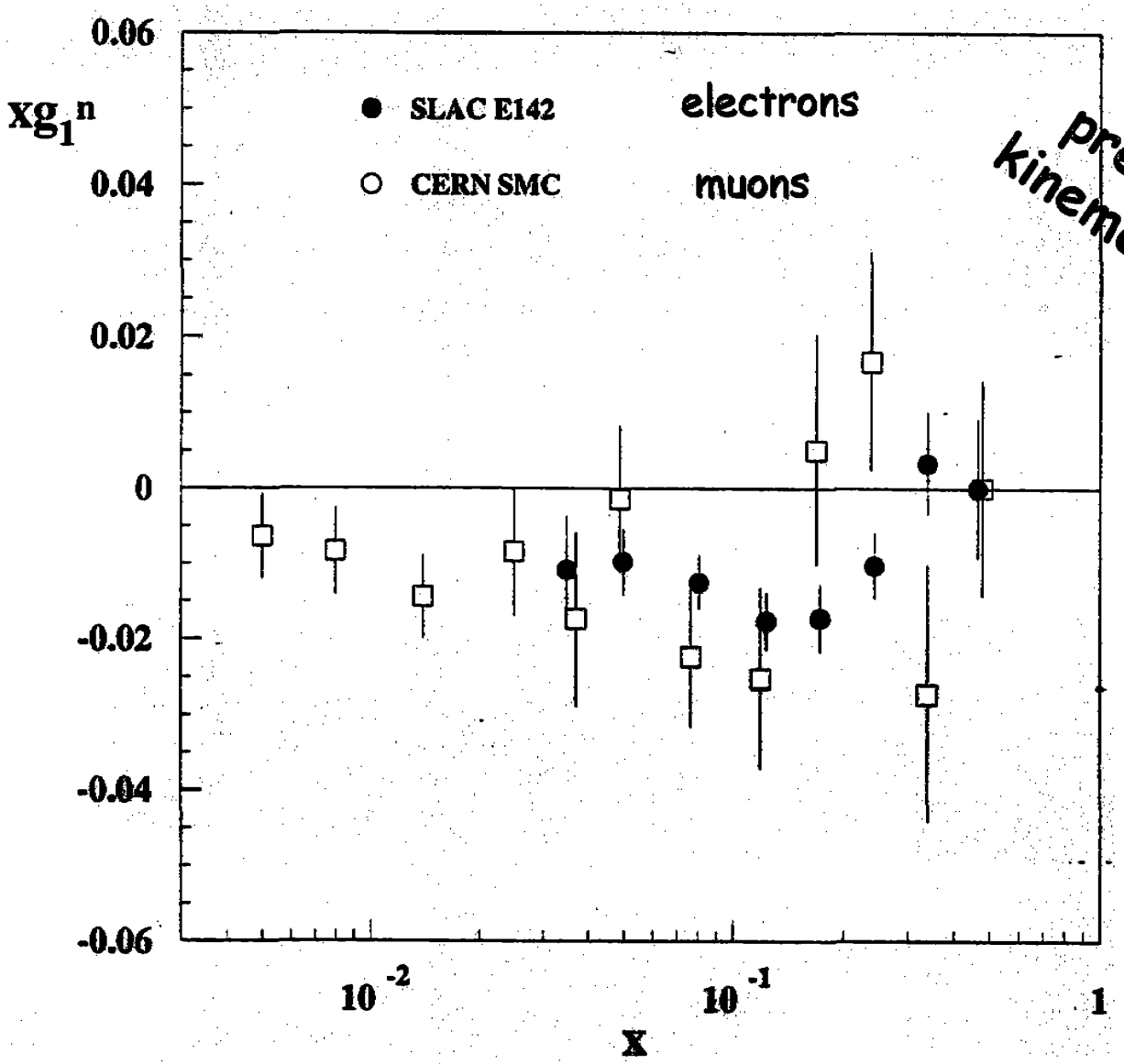
Proton spin structure function measurement

maps out $x \sim 10^{-3}$

eRHIC



1992-1995 Neutron Measurements

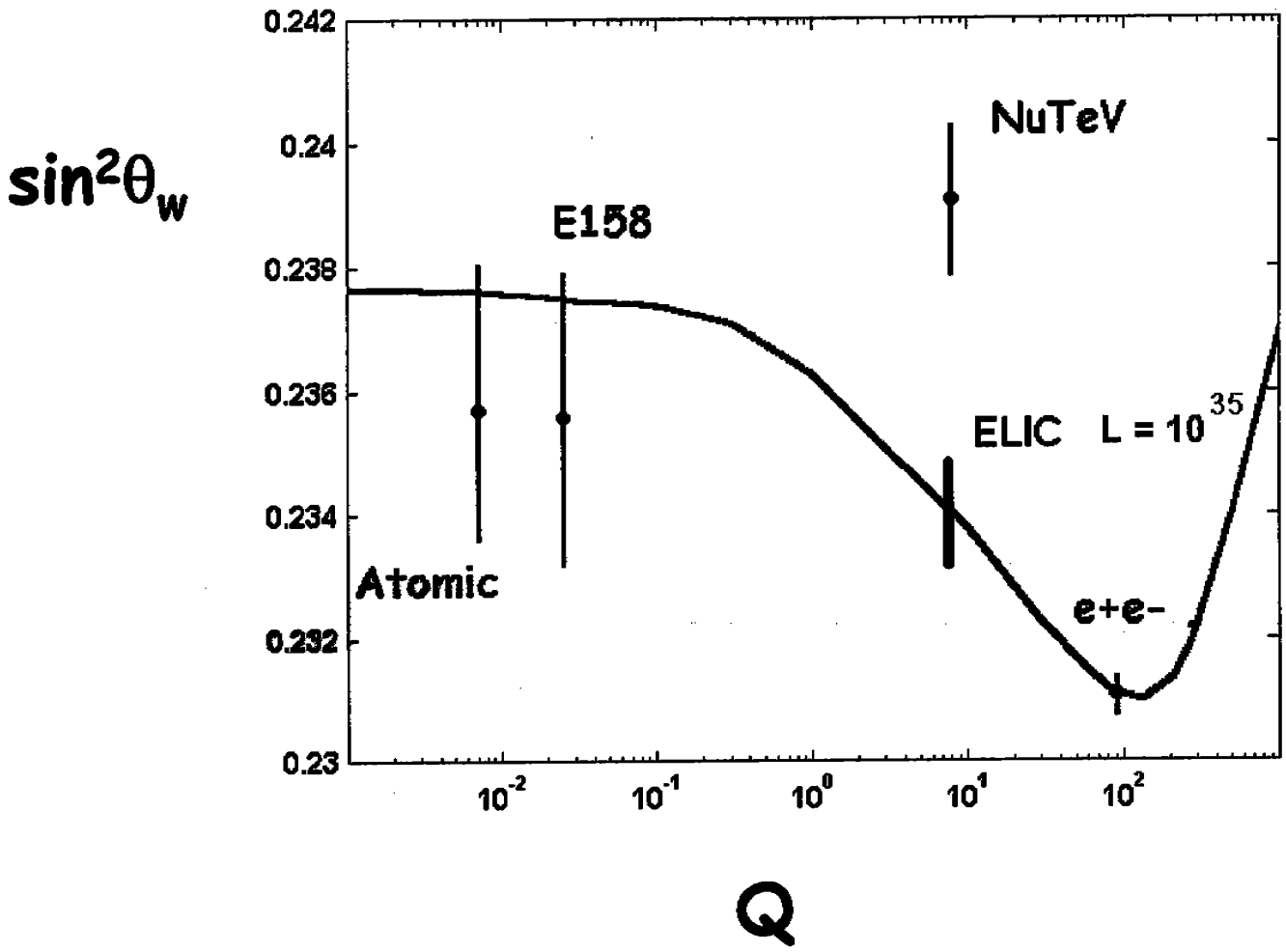


precision vs. kinematic reach

TOPIC IV...

PRECISION ELECTROWEAK

Precision Electroweak Physics



Further testing the BJ Sum Rule

$$\int_0^1 g_1^p(x)dx - \int_0^1 g_1^n(x)dx = \frac{1}{6}\left(\frac{g_A}{g_V}\right)\left(1 - \frac{\alpha_S(Q^2)}{\pi} - \ldots\right)$$

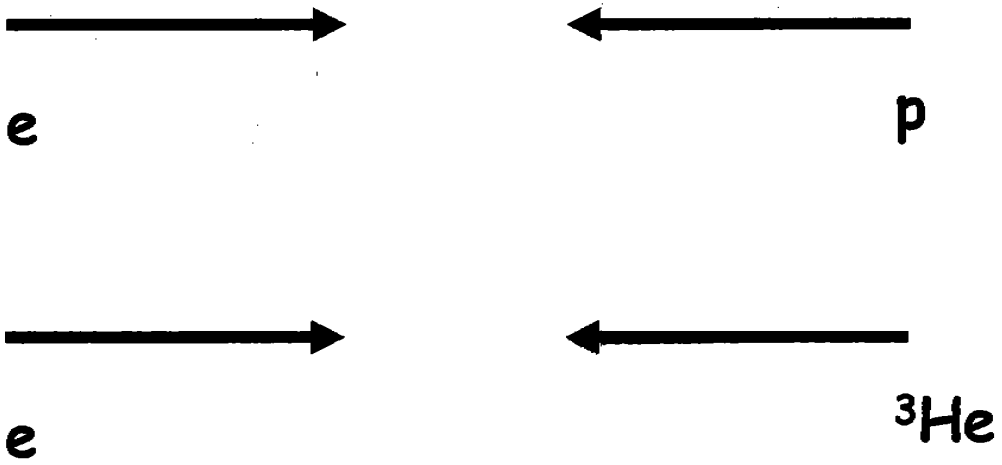
proton **neutron**

Today → **measured to ~10% precision**

... dominated by systematic uncertainties

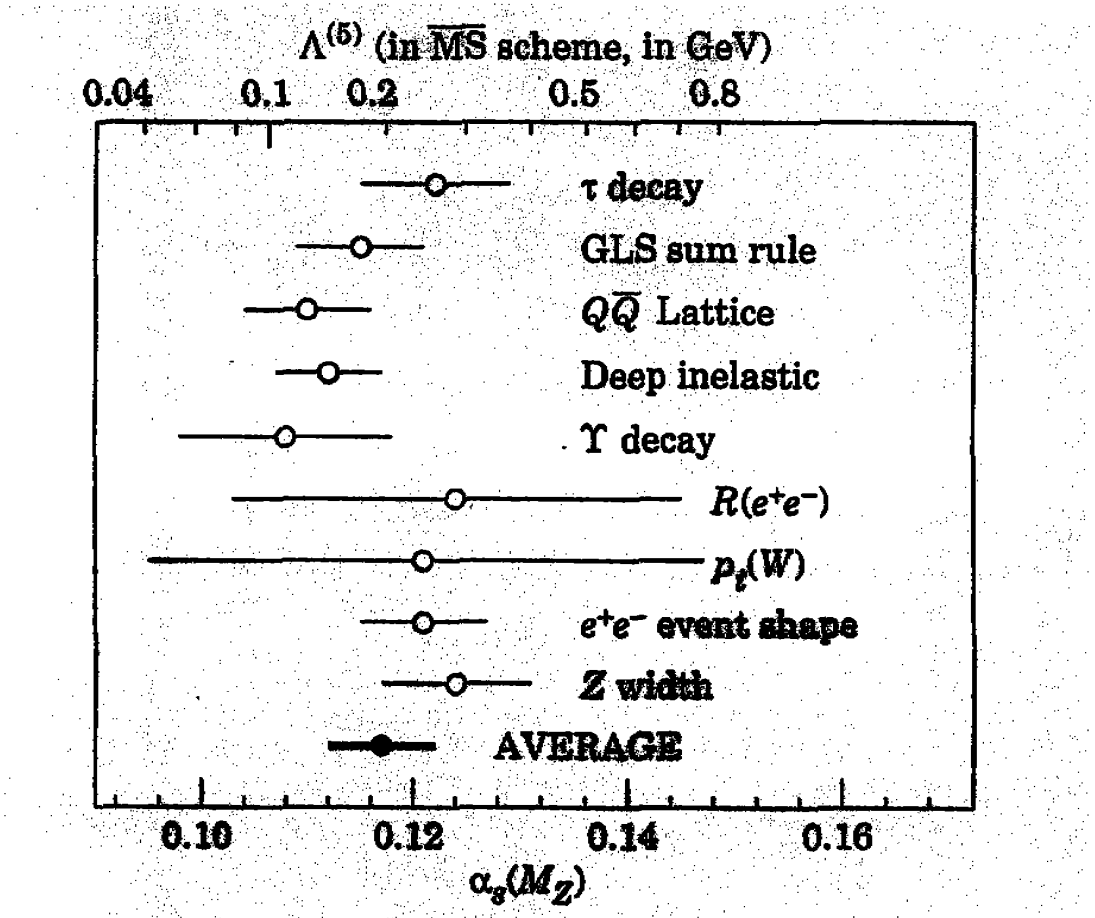
SMC, SLAC, HERMES

Everything polarized, of course



Can you beat down systematic uncertainties?

Precision measurement of α_s



SMC quotes 0.002 (stat) and 0.006 (syst)

CONCLUSION

Don't trust anyone who believes they can predict 20 years ahead