Future Prospects on Polarized Parton Distributions

Johannes Blümlein, DESY

- Theory Needs
- Prospects for $g_1(x, Q^2)$
- Valence Distributions
- The polarized Gluon
- Light Sea & Charm
- Diffraction
- $g_2(x, Q^2)$
- $\Lambda_{\rm QCD}$ & $\alpha_s(M_Z^2)$

- EIC Working Group White Paper, April (2007)
- A. Deshpande, R. Millner, R. Venugopalan, W. Vogelsang, Annu. Rev. Nucl. Part. Sci. 55 (2005) 165.
- J. Blümlein, arXiv:0708.1474

Theory Results Needed

- 3 Loop anomalous dimensions

S. Moch, M. Rogal, J. Vermaseren, A. Vogt, upcoming

- 3 Loop Heavy Flavor Wilson coefficients

JB, I. Bierenbaum, S. Klein, upcoming

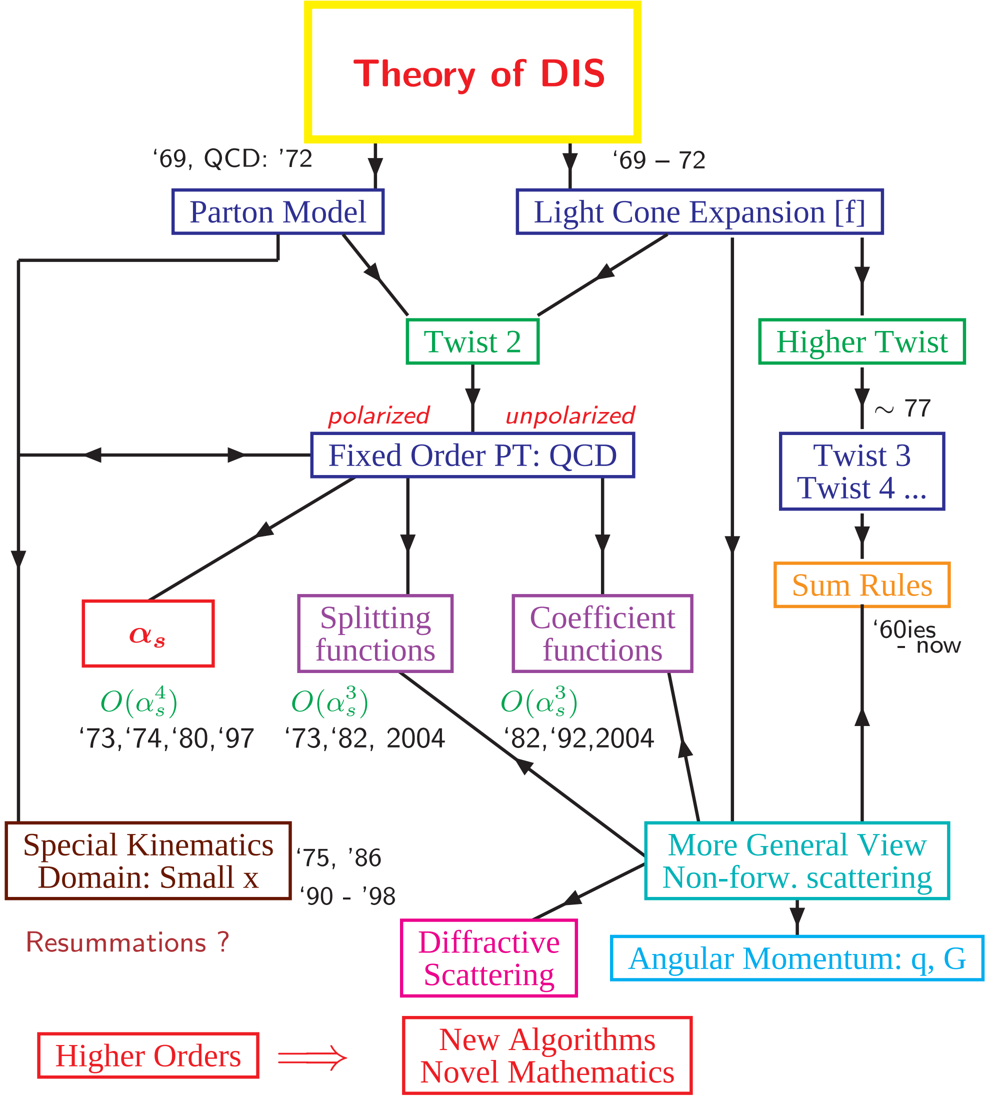
- Moments from Lattice calculations

different groups, upcoming

- Anything special at small x ?

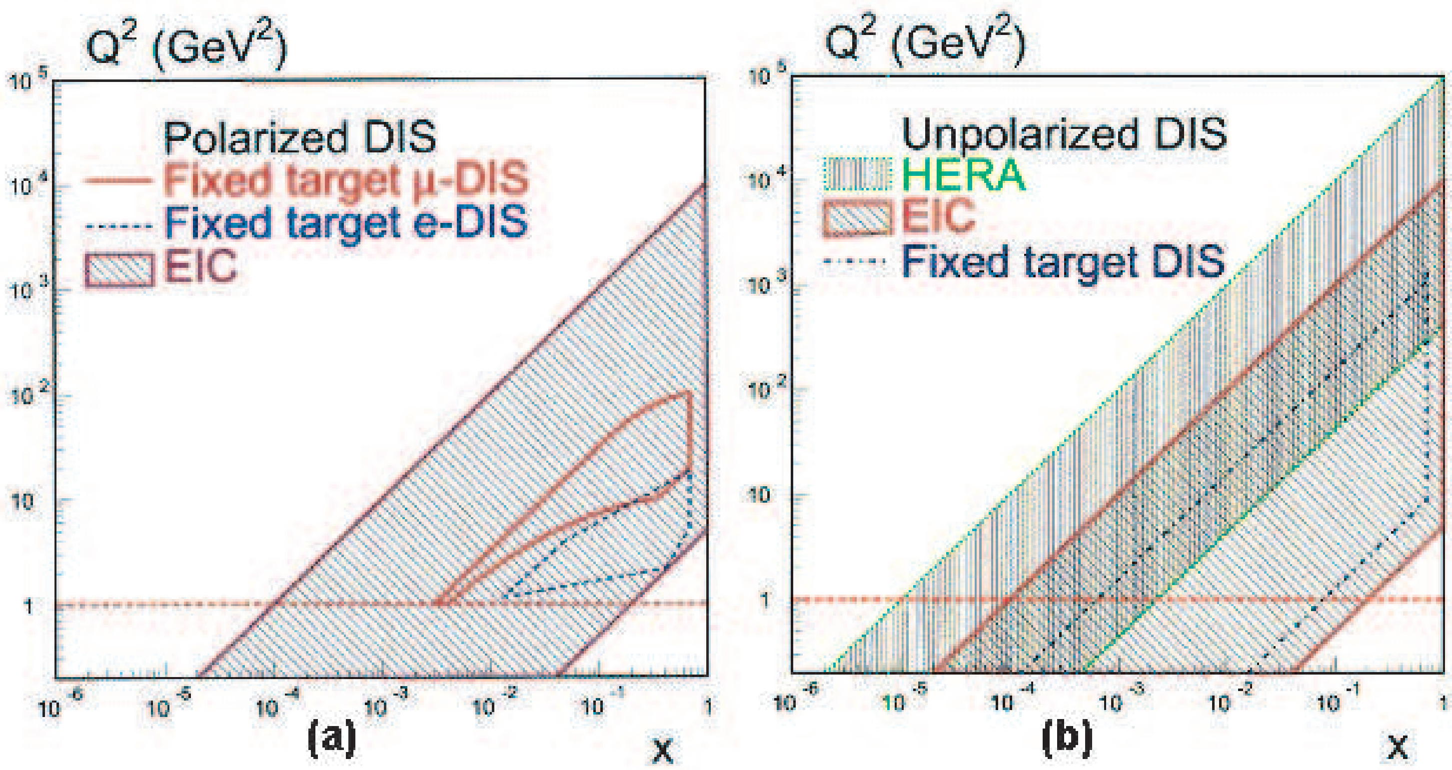
- Twist 3 and Higher ...

- ... need precise data first.

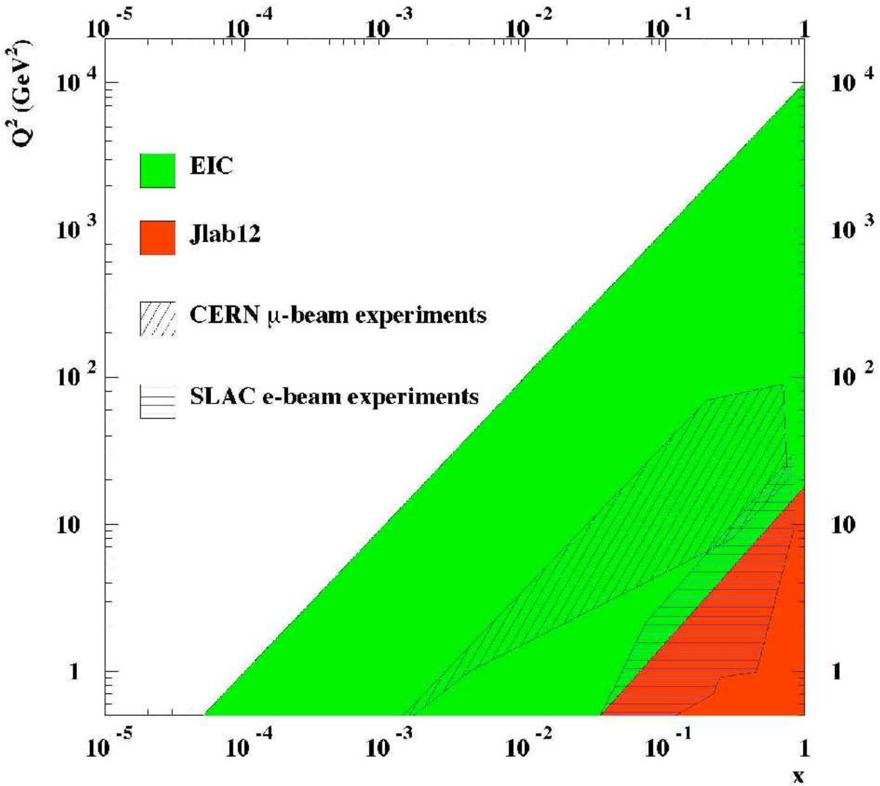


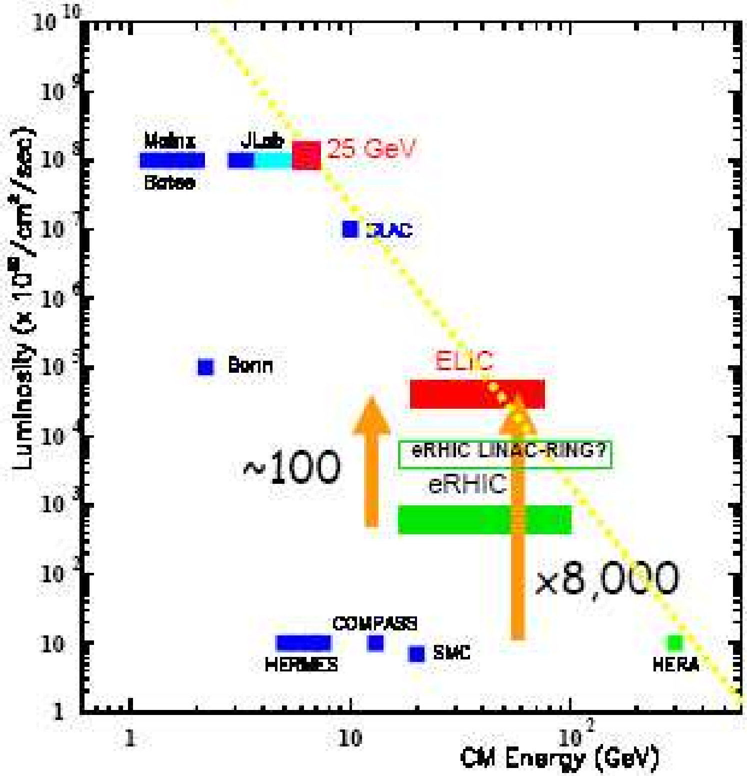
Theory of DIS
'69, QCD: '72
'69 – 72
Parton Model
Light Cone Expansion [f]
Twist 2
Higher Twist
polarized
unpolarized
Fixed Order PT: QCD
~ 77
Twist 3
Twist 4 ...
Sum Rules
α_s
Splitting functions
Coefficient functions
'60ies - now
$O(\alpha_s^4)$
'73,'74,'80,'97
$O(\alpha_s^3)$
'73,'82, 2004
$O(\alpha_s^3)$
'82,'92,2004
Special Kinematics Domain: Small x
'75, '86
'90 - '98
More General View Non-forw. scattering
Resummations ?
Diffractive Scattering
Angular Momentum: q, G
Higher Orders
New Algorithms Novel Mathematics

Kinematic Range



Luminosity & Kinematic Range

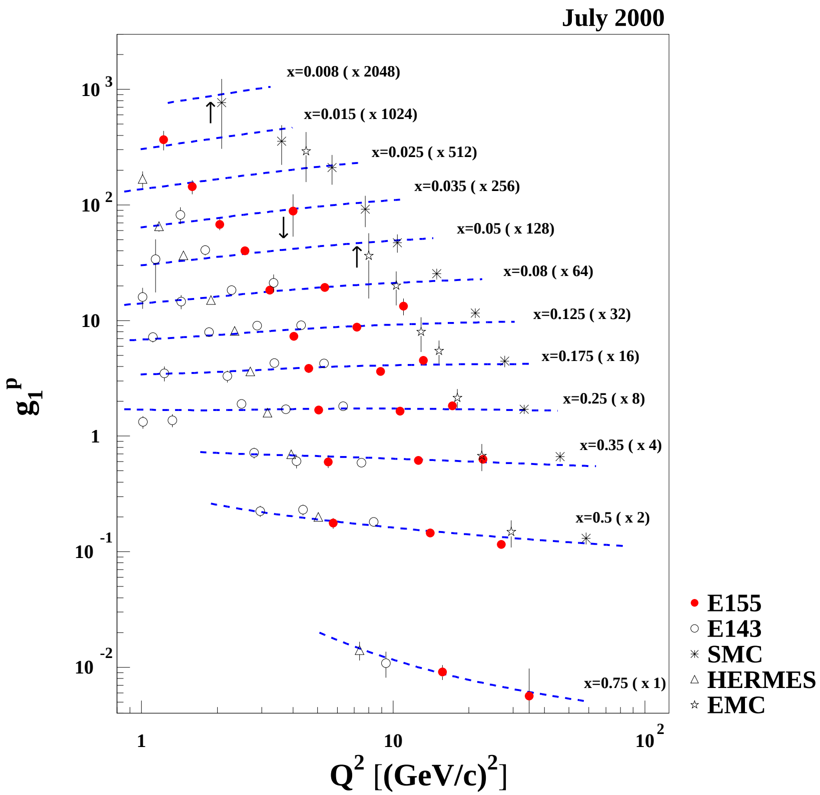


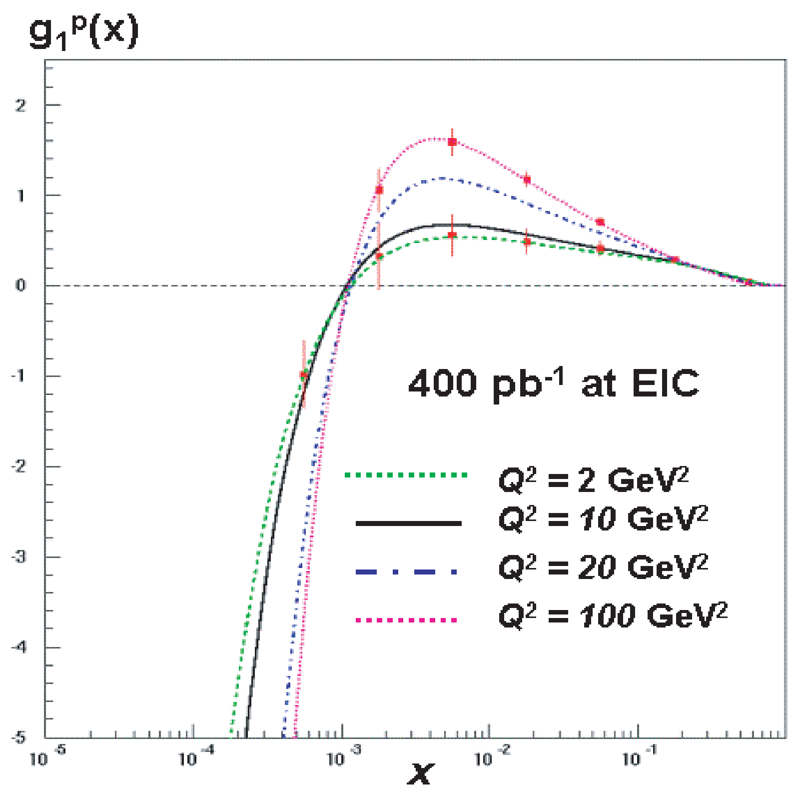


High Luminosity is most important:

Various precision measurements.

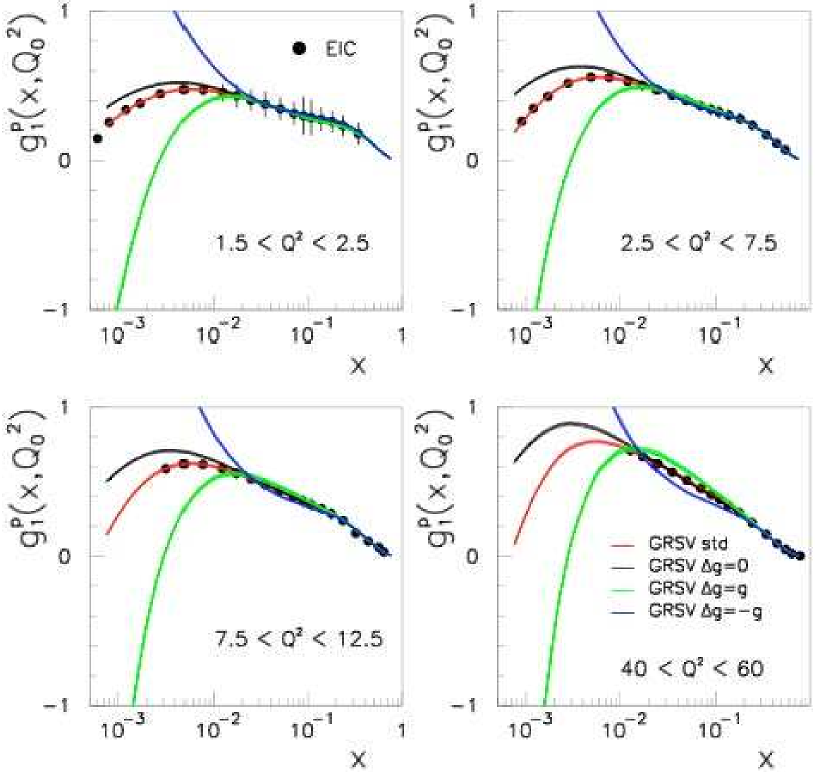
The polarized Structure Function Now & Then

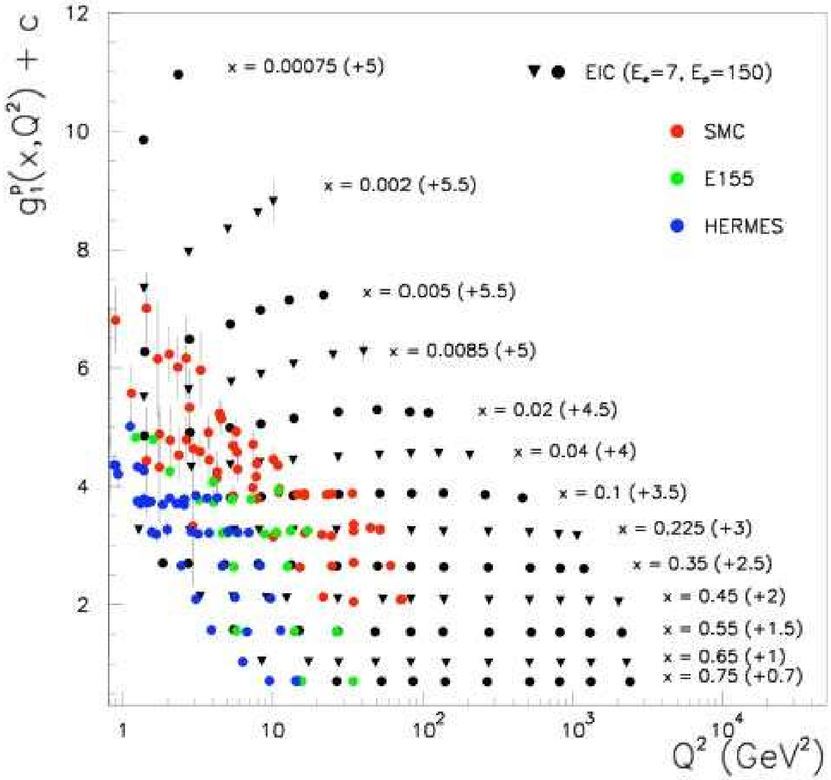




Lower values of x are reached, improving accuracy in the medium and large x region.

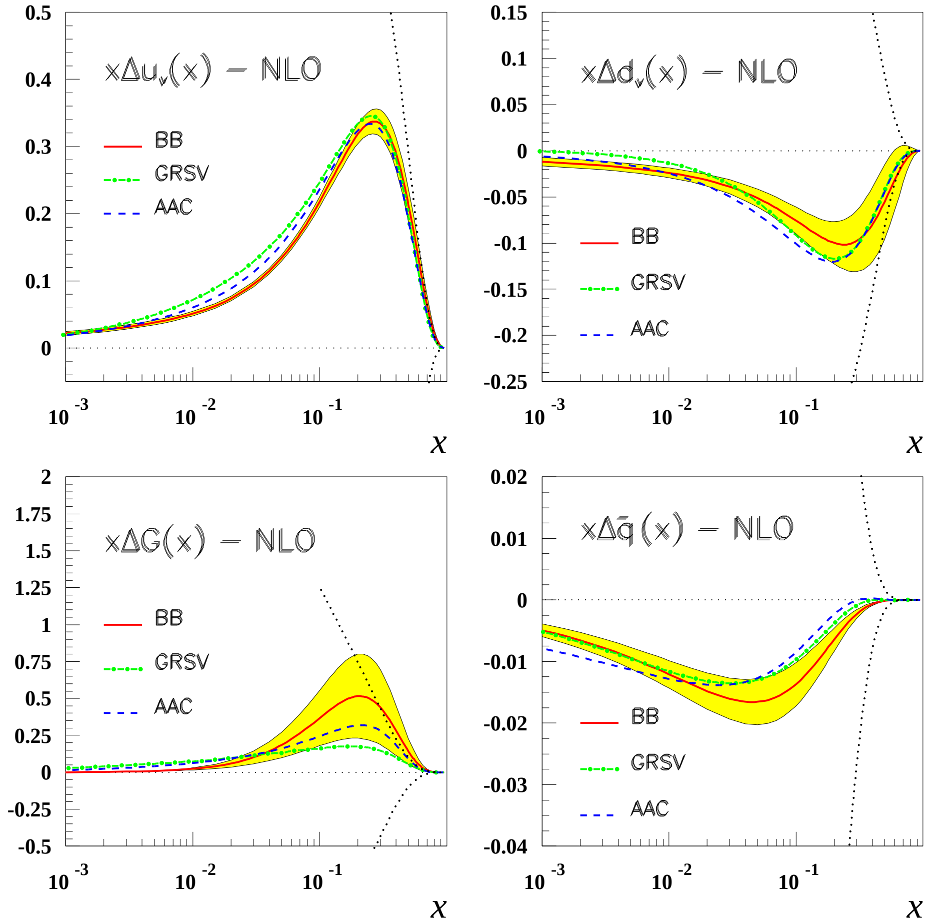
The polarized Structure Function Now & Then





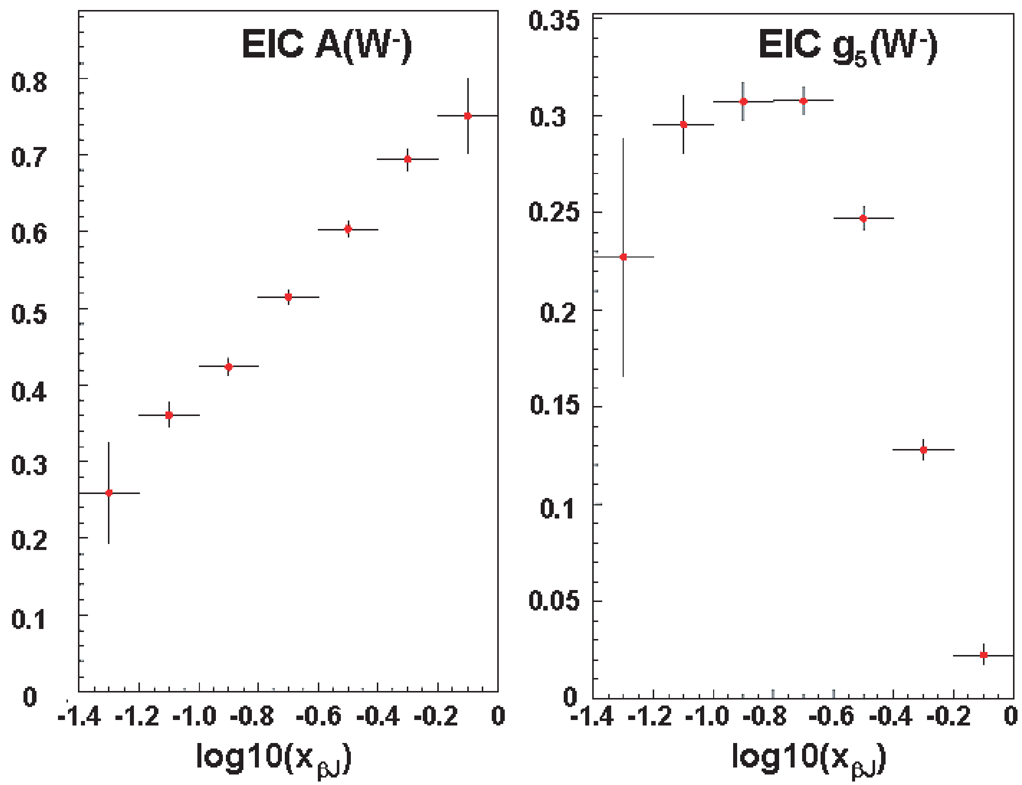
How does $g_1(x, Q^2)$ behave at small x ? $\Longrightarrow$ Sufficiently wide slopes in $\ln(Q^2)$.

Polarized Parton Densities at Present



JB, H. Böttcher (2002)

The W-Asymmetry A_{W^-} and $g_5(x, Q^2)$



$$A^{W^-} = \frac{2b(y)g_1^{W^-} + a(y)g_5^{W^-}}{a(y)F_1^{W^-} + b(y)F_3^{W^-}}$$

$$g_5^{W^+,p} + g_5^{W^-,p} = \Delta u_v + \Delta d_v, \qquad g_5^{W^+,p} - g_5^{W^-,n} = -[\Delta(u+\bar{u}) - \Delta(d+\bar{d})]$$

Measurement of a polarized electro-weak structure function at high Q^2.

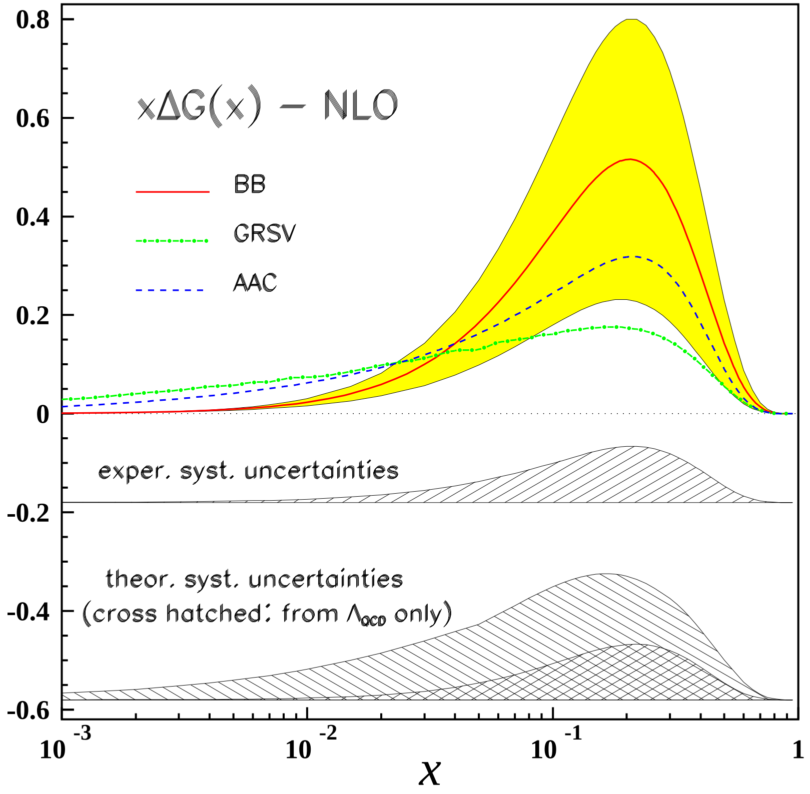
Moments of Polarized Parton Densities

	Moment	BB, NLO
Δu_v	0	0.926
	1	0.163 ± 0.014
	2	0.055 ± 0.006
Δd_v	0	-0.341
	1	-0.047 ± 0.021
	2	-0.015 ± 0.009
$\Delta u_v - \Delta d_v$	0	1.267
	1	0.210 ± 0.025
	2	0.070 ± 0.011

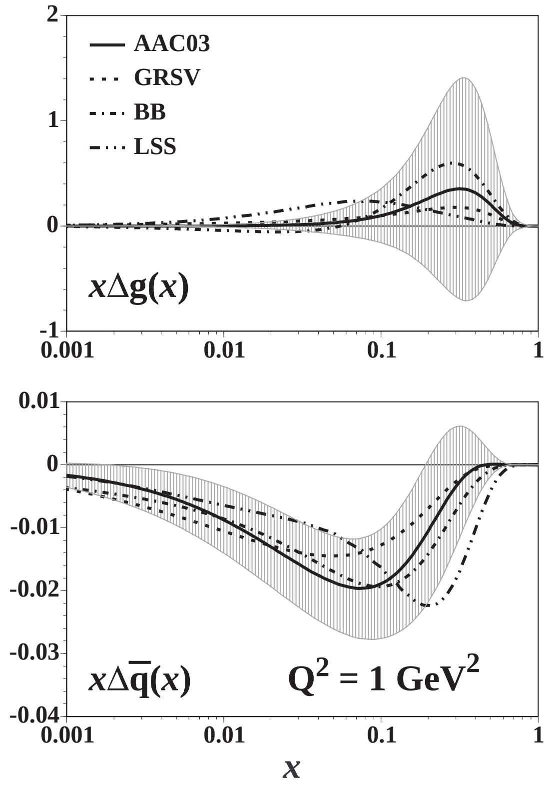
J.B., H. Böttcher (2002)

More Lattice Results: upcoming; different (dynamical) fermion-types studied. Low values of m_π crucial. m_π 270 MeV at present.

Polarized Gluon Density at Present



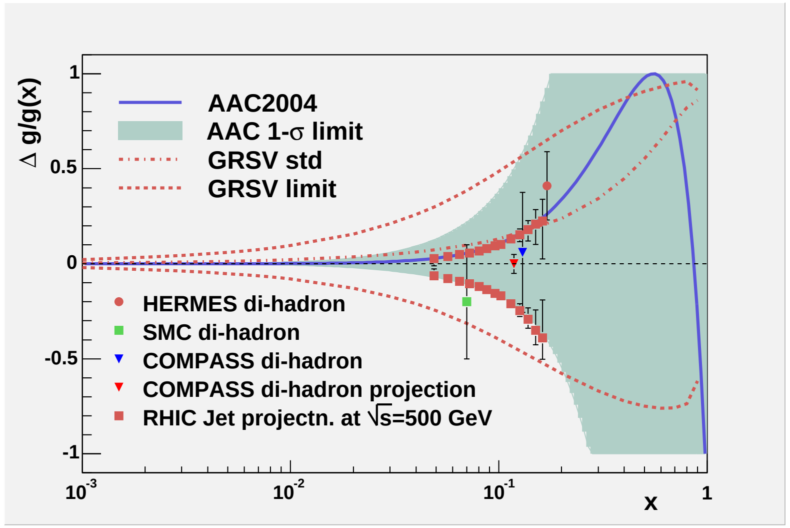
J.B., H. Böttcher (2002)

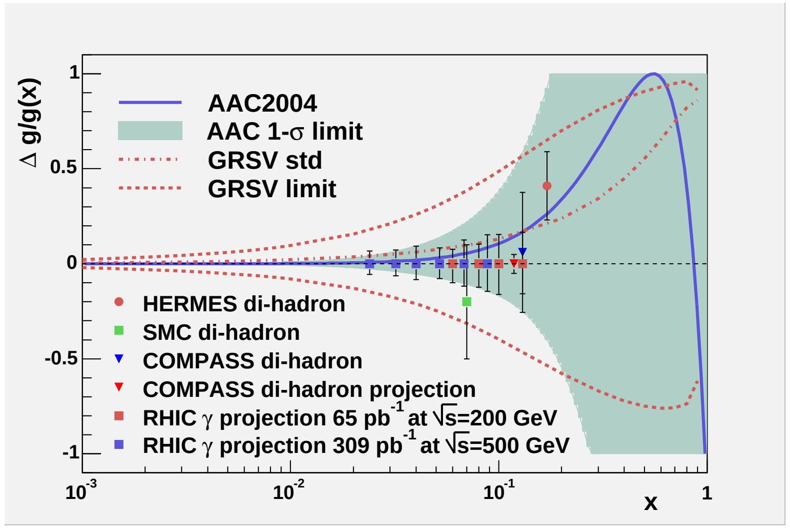


AAC

$\Longrightarrow$ Currently slight move of ΔG towards lower values

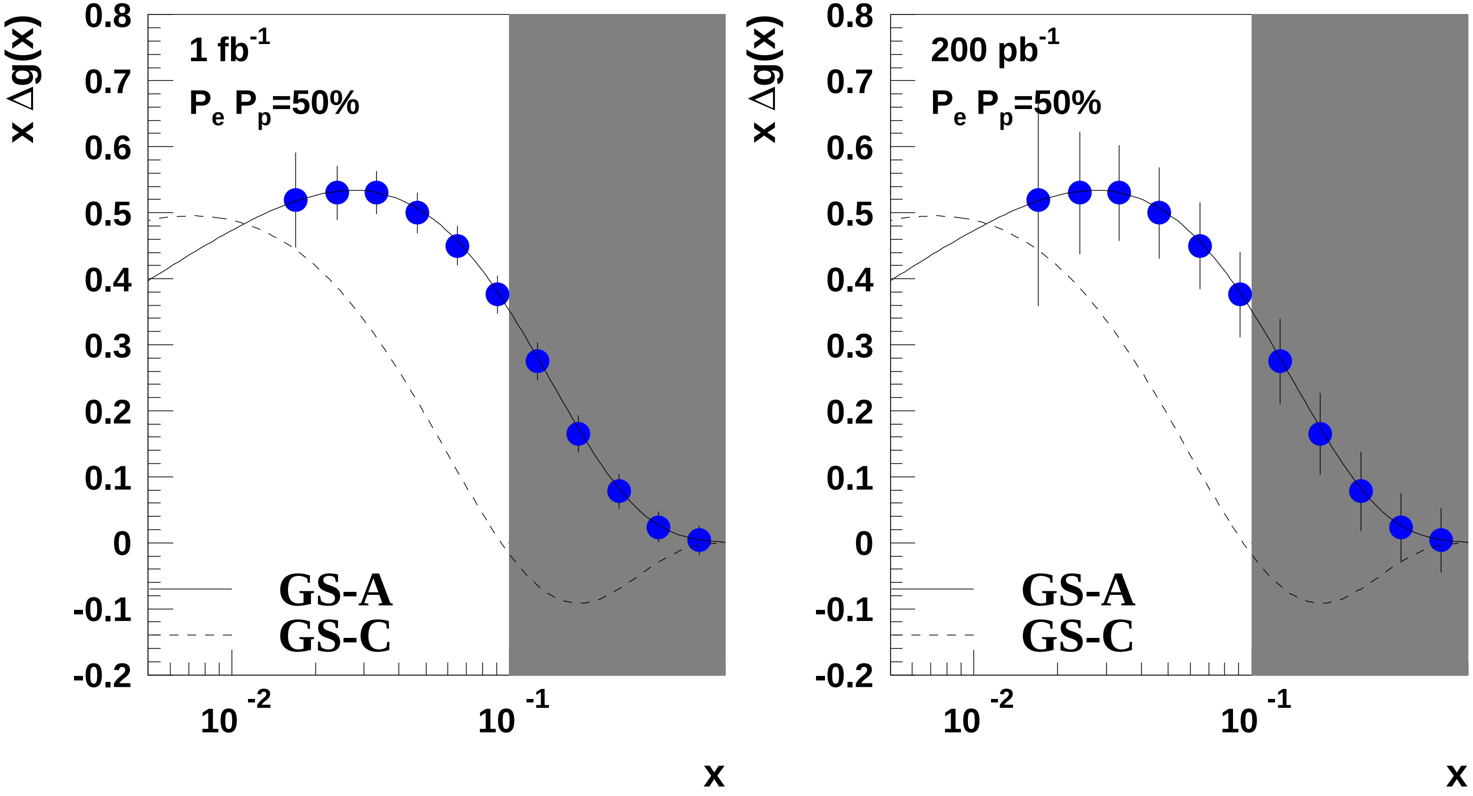
Polarized Gluon Density at RHIC





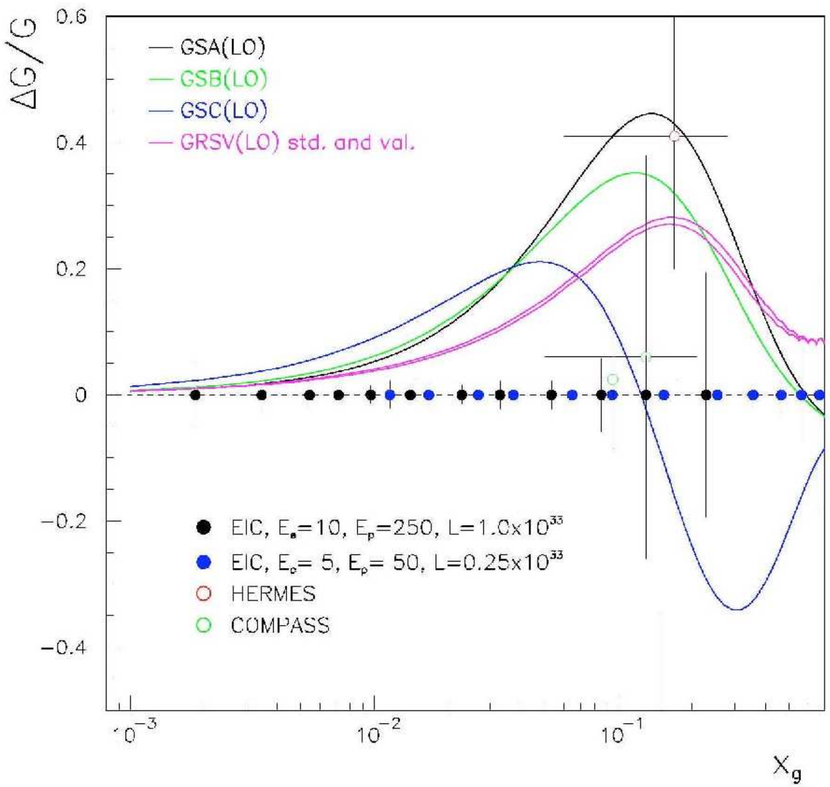
Accuracies for ΔG, which may be reached at RHIC

Polarized Gluon Density at EIC



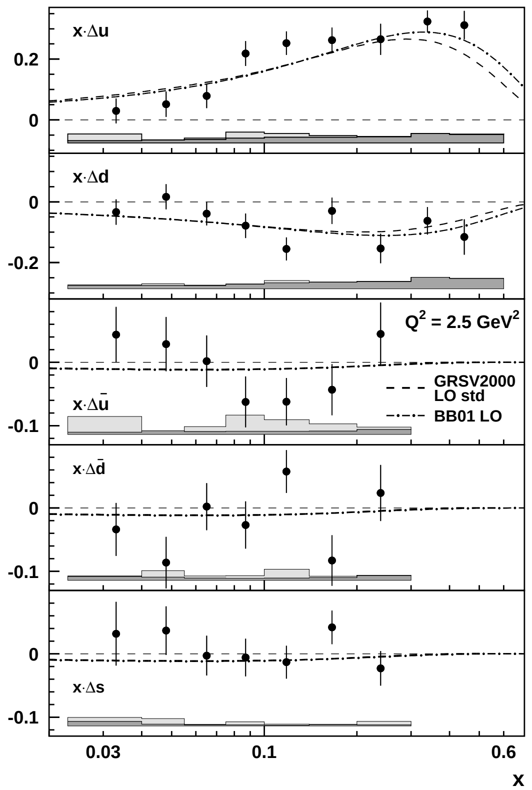
Excellent Resolution for ΔG at EIC

Polarized Gluon Density at EIC

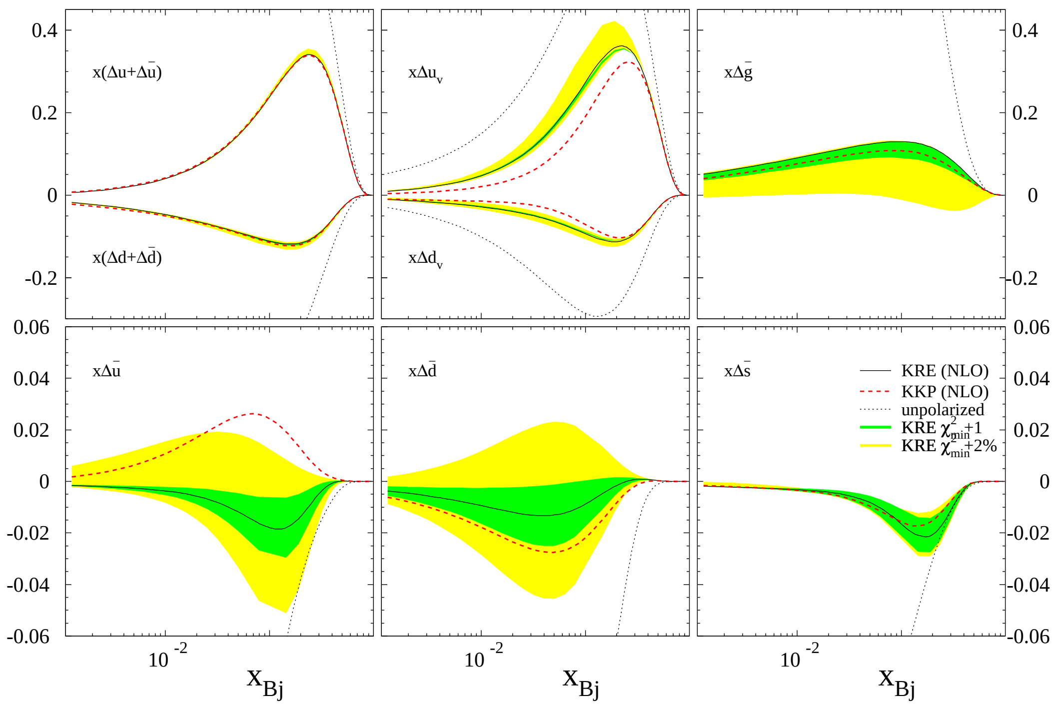


Accuracy for ΔG from Open Charm Production at EIC

Unfolding the Sea Quarks

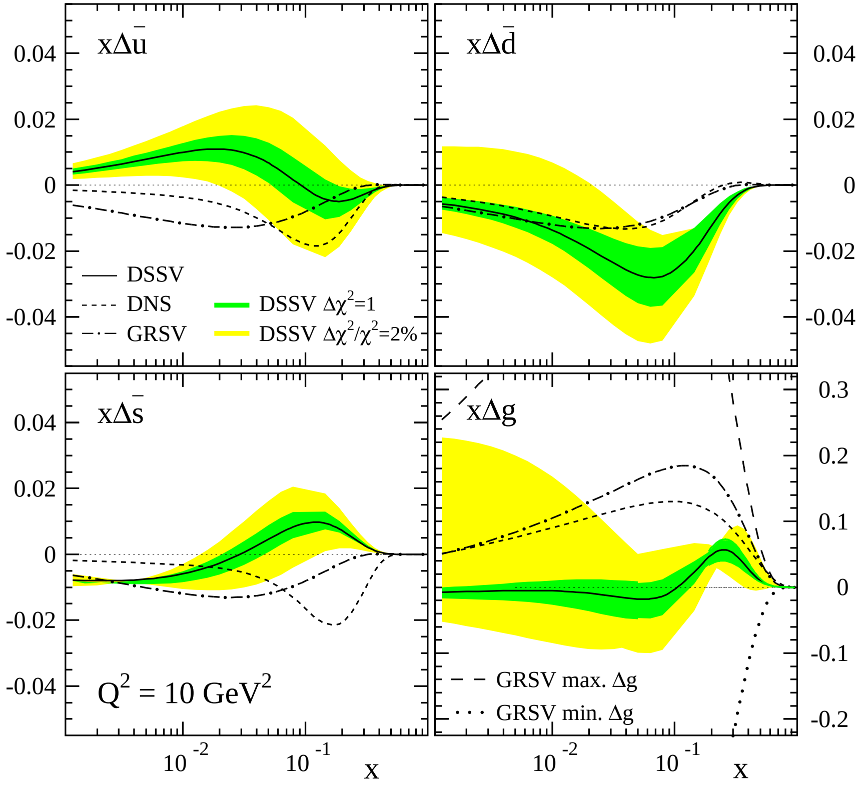


HERMES, 2004



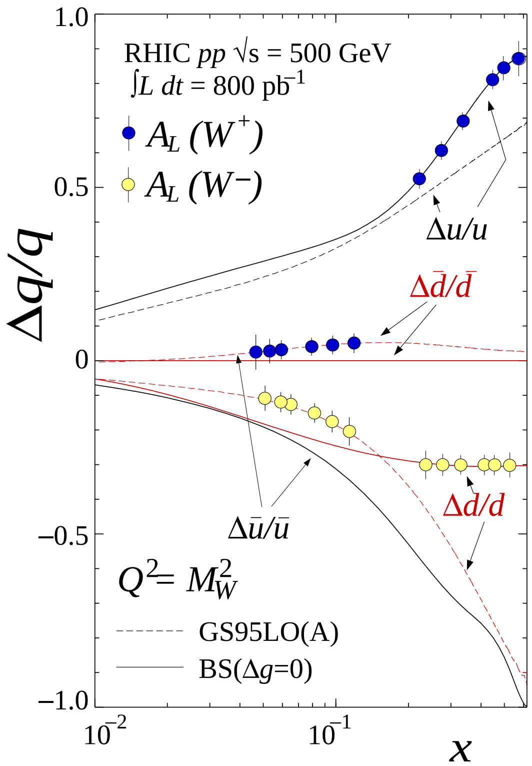
De Florian & Sassot, 2005

Unfolding the Sea Quarks

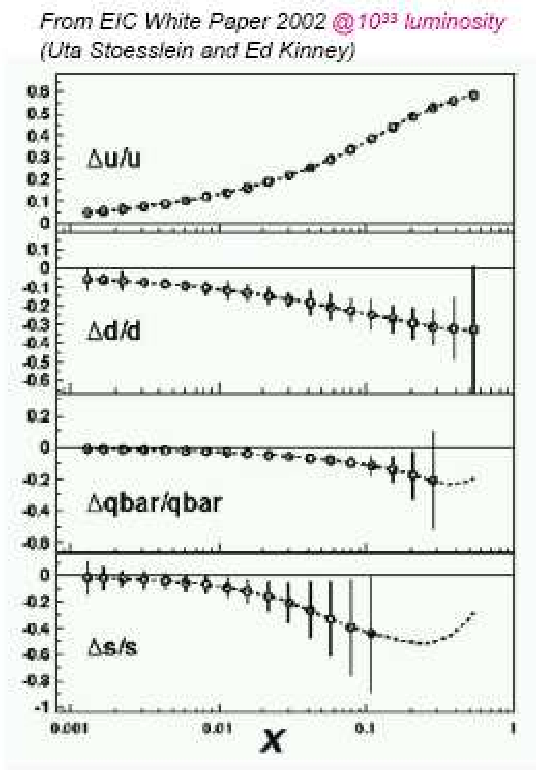


De Florian, Sassot, Stratmann, Vogelsang, 2008

Unfolding the Sea Quarks

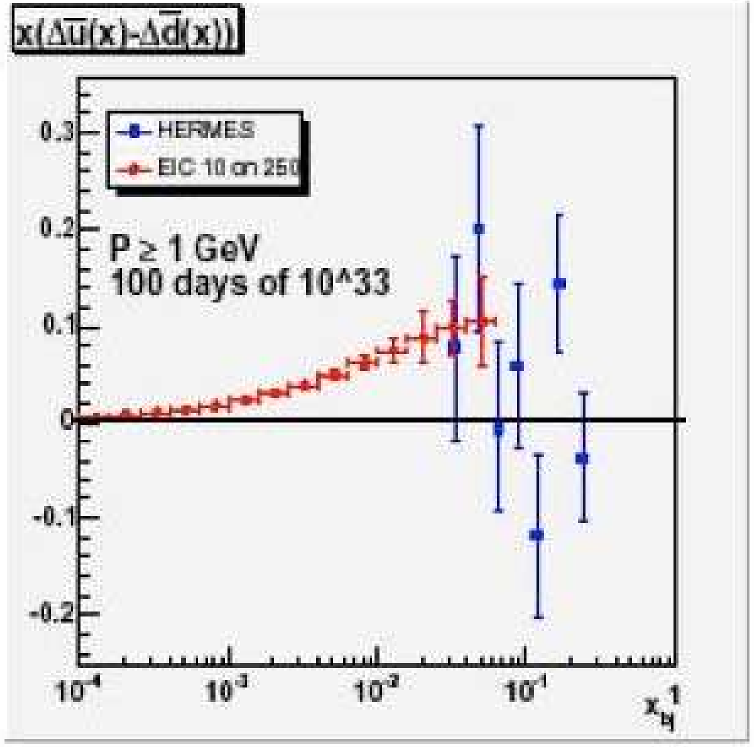


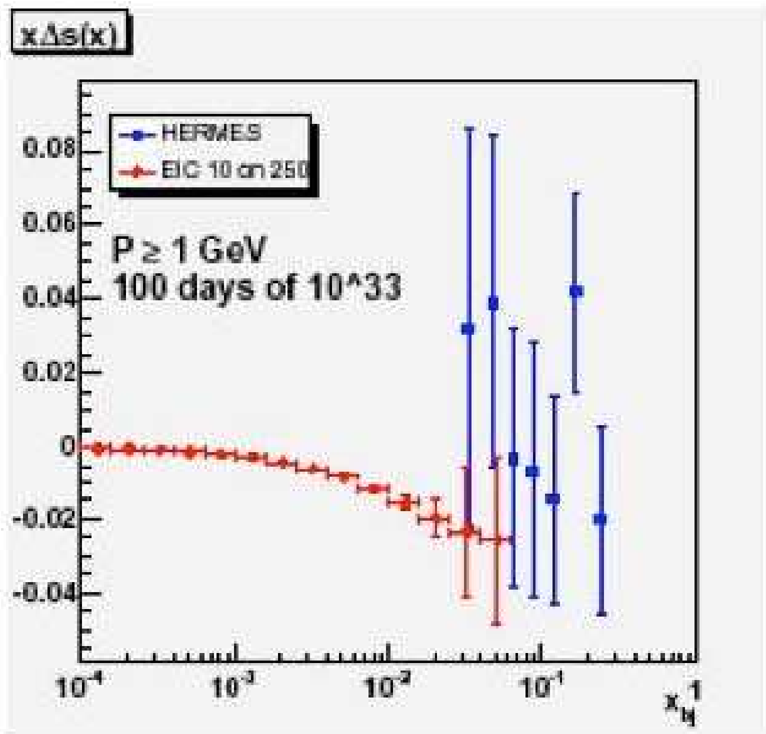
RHIC, G. Bunce et al. 2000



EIC

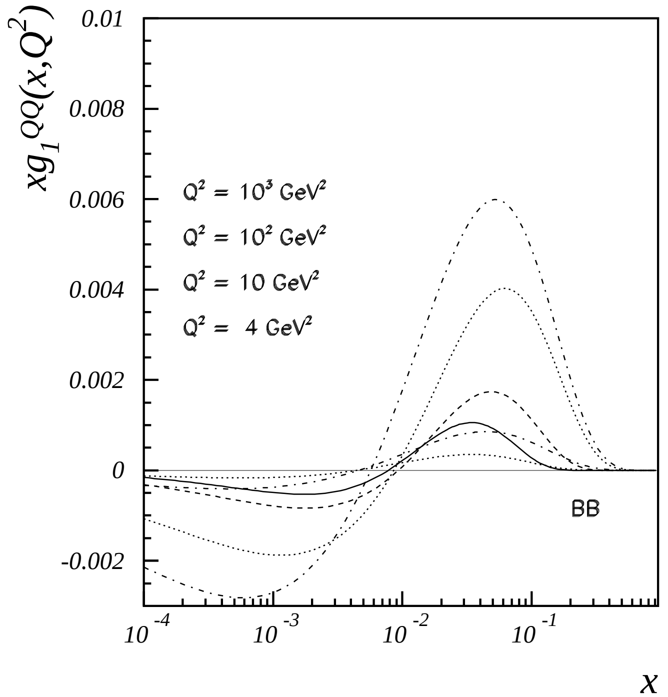
Unfolding the Sea Quarks

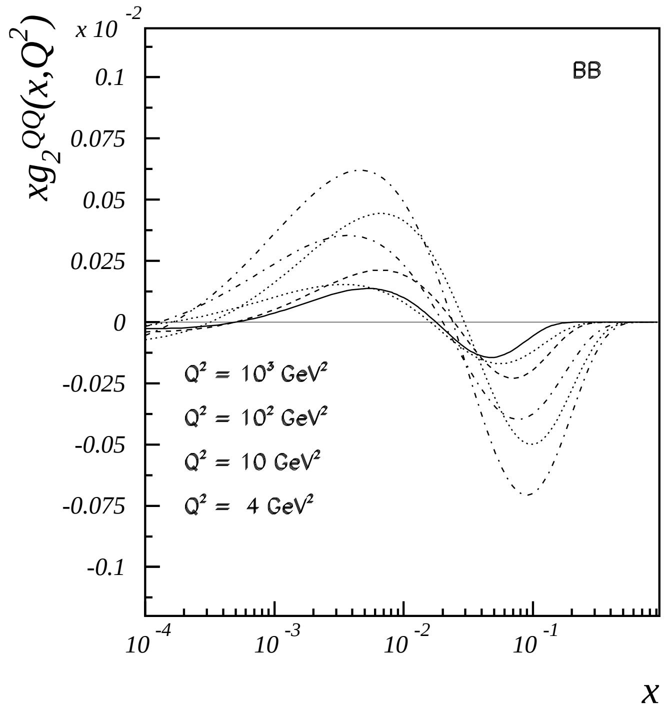




Comparison of the Sensitivity at HERMES and at EIC

Charm Contributions

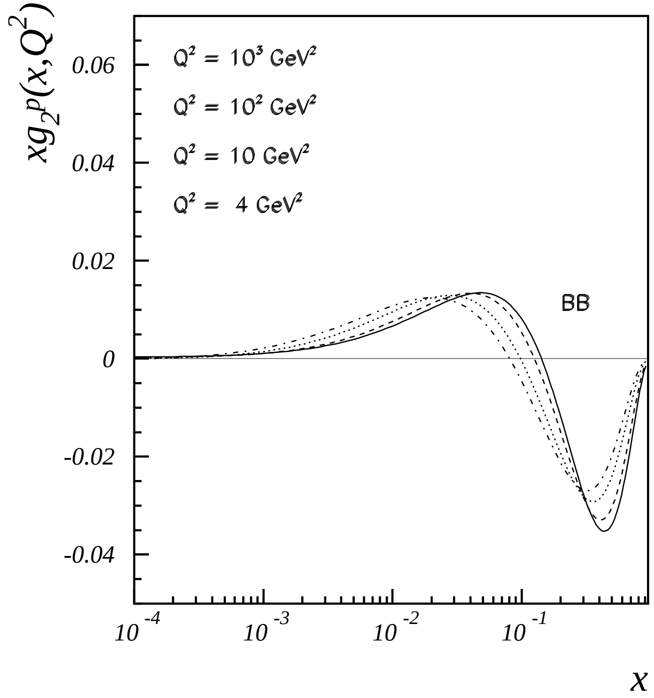




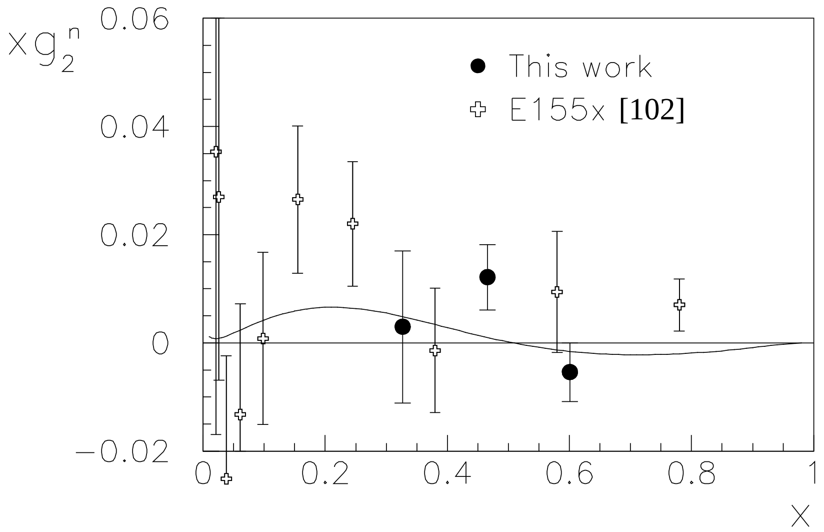
JB, Ravindran, van Neerven (2003): $g_{1,2}^{c\bar{c}}(x, Q^2)$

$\Longrightarrow$ **to be measured at EIC**

$g_2(x, Q^2)$ - a Window to Higher Twist



$g_2^{\tau=2}(x, Q^2)$ (light partons)

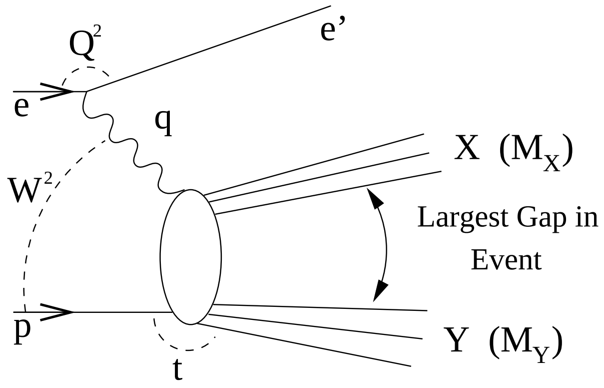


JLAB Hall A, 2004

Accurate measurement highly desired.

How big is the $\tau = 3$ contribution ?

Polarized Diffraction @ EIC



As in the unpolarized case, diffractive scattering is there for DIS off polarized targets.
EIC could unravel that.
Gluon or Quark dominated ?
Test of WW-Relation possible;
[JB, D. Robaschik, 2002]

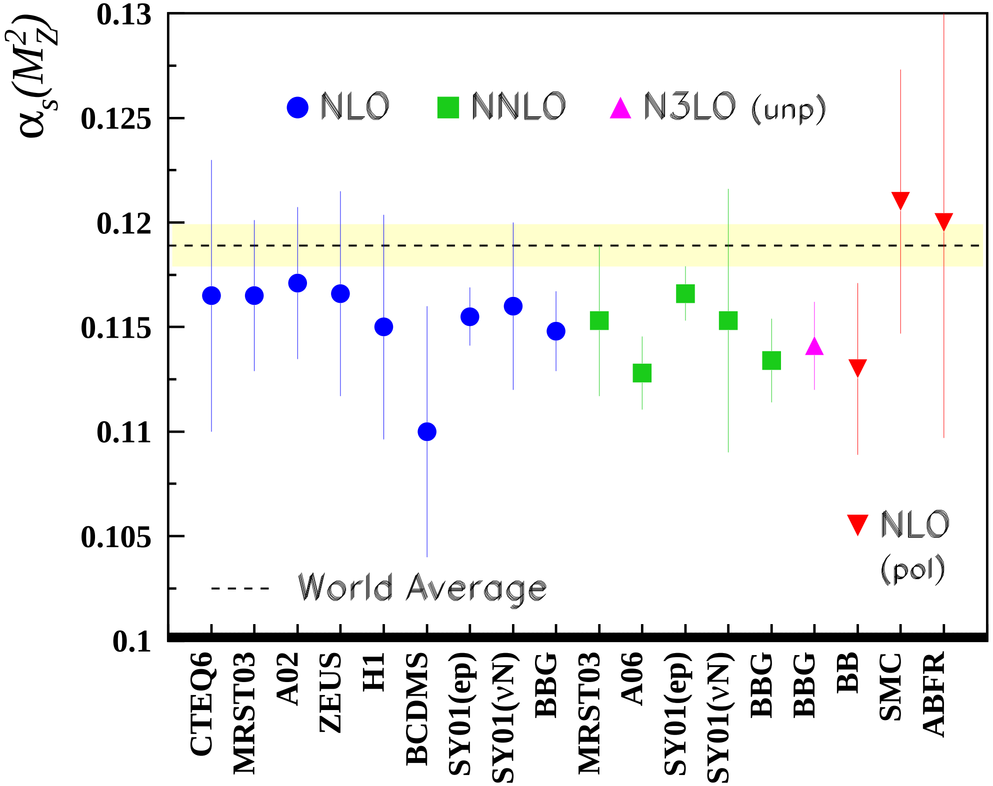
4 structure functions contribute in general.

$$g_{1,2}^D(\beta, Q^2), \qquad \beta = x/x_P$$

evolve in the same way as the DIS structure function replacing $x \to \beta$.

$$g_2^D(\beta, Q^2) = -g_1^D \beta, Q^2) + \int_\beta^1 \frac{dy}{y} g_1^D(y, Q^2)$$

$\alpha_s(M_Z^2)$ & $\Lambda_{\rm QCD}$



Less precise values if compared to the unpolarized case:

NLO: $\alpha_s(M_Z^2)|_{\rm pol} = 0.113 \pm 0.004 \pm 0.008 \Longrightarrow$ Considerable improvement at EIC

NLO: $\alpha_s(M_Z^2)|_{\rm unp} = 0.1148 \pm 0.0019$

N^{3}LO: $\alpha_s(M_Z^2)|_{\rm unp} = 0.1134 \pm 0.0019$ [good agreement with Lattice values ($N_f = 2$)]

Conclusion

- EIC allows to perform missing central high-precision Measurements for DIS off polarized targets.
- These are needed to perform further detailed QCD Tests.
- Key objectives are :
    - Precise valence, sea quark and gluon densities
    - $\Longrightarrow$ Comparison with Lattice Moments
    - Decomposiotion of the light polarized sea
    - Polarized charm & beauty quark distributions
    - Discovery of polarized diffractive scattering
    - More detailed measurement of $g_2(x, Q^2)$: Size of the $\tau = 3$ part ?
    - $\Longrightarrow$ Testing QCD @ the Twist 3 Level
    - $\Longrightarrow$ 3–loop Extraction of $\Lambda_{\rm QCD}$ using very precise $g_1(x, Q^2)$ data.

EIC would be a unique facility in this respect.