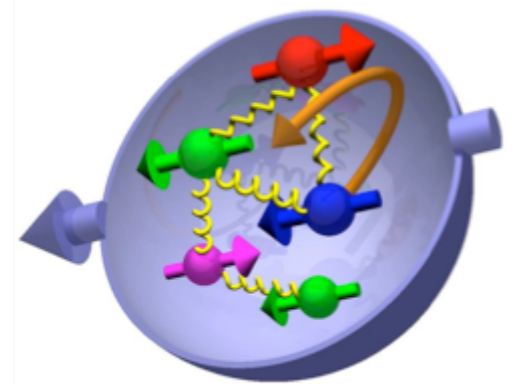# Working group on ep physics

C. Weiss, W. Vogelsang, <u>E. Sichtermann</u>, A. Bruell

Physics:

- Inclusive physics,
  unpolarized, polarized and parity-violating structure functions

- Semi-inclusive physics,
  fragmentation,
  Sivers and Collins effects,
  Transverse-Momentum Dependent parton distributions

- Exclusive processes and diffraction,
  Deeply Virtual Compton Scattering, meson production

- Precision,
  Bjorken Sum, $\alpha_s \cdot \Delta G$, electroweak

Structure
and
Dynamics

Wide kinematic range
and
Precision

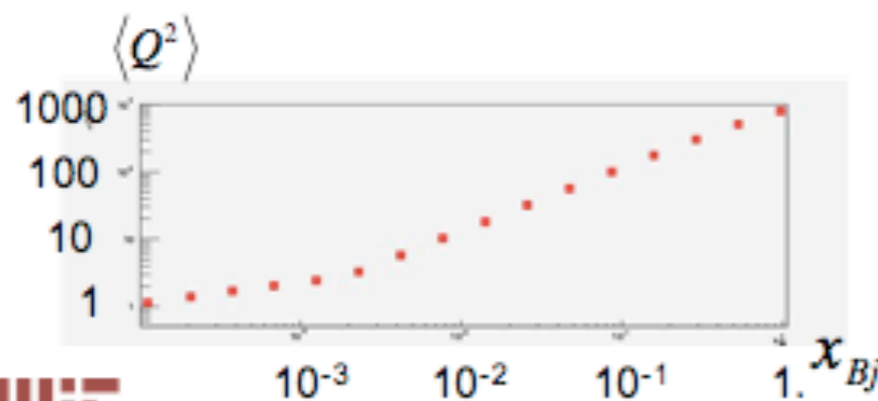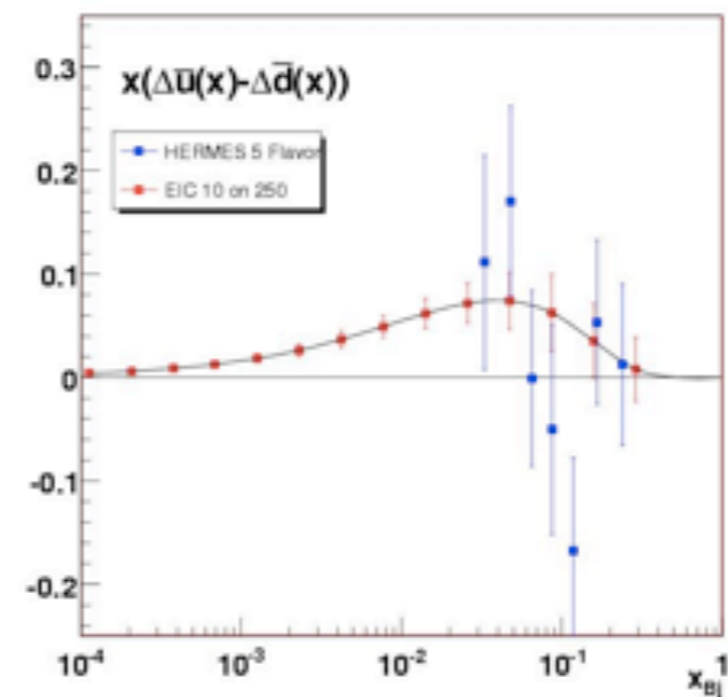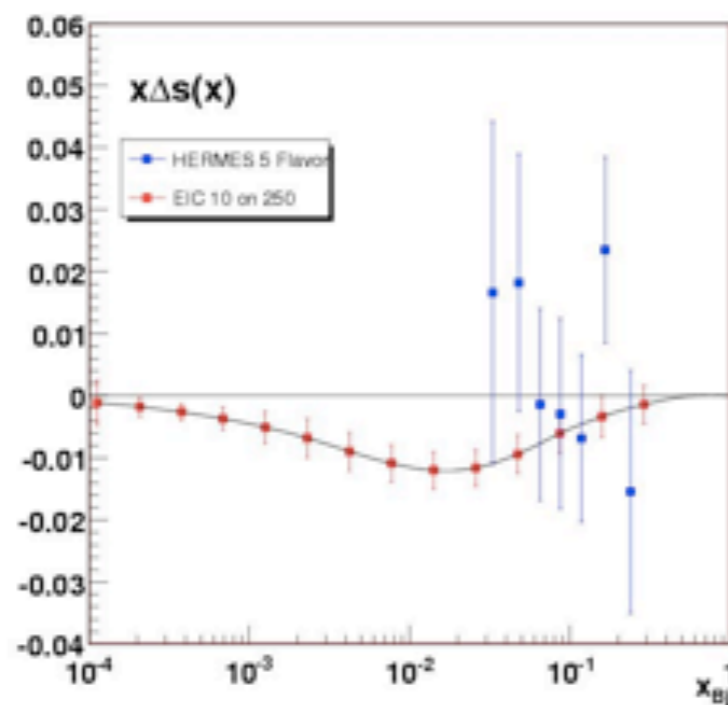## Process: simulations and discussions

ep Physics Working Group

Thursday, December 11, 2008 – building 70, room 191

13:30-14:00	T. Horn	Update on simulations of exclusive meson production
14:00-14:30	J. Seele	Quark helicity distributions from SIDIS
~~14:30-15:00~~	~~X. Jiang~~	~~Enhanced strangeness sensitivity in semi-inclusive phi prod.~~
16:00-16:30	J. Qiu:	Single spin asymmetry in semi-inclusive D meson production
16:30-17:00	M. Strikman	Diffraction in ep at low and intermediate t
17:00-17:30	M. Diehl	Physics in semi-inclusive hadron production at high pT
17:30-18:00		Discussion

Simulations: Joe Seele - SIDIS

10 on 250 Expectations

$x\Delta s(x)$

HERMES 5 Flavor
EIC 10 on 250

$x(\Delta\bar{u}(x)-\Delta\bar{d}(x))$

HERMES 5 Flavor
EIC 10 on 250

$\langle Q^2 \rangle$

Curves are GRSV

Phys. Rev. D63:094005,2001

Simulations: Joe Seele - SIDIS

Future/Plans/Open Questions

- Add detector effects/imperfect PID
- Optimize detector vs. cost for this measurement (-> What can be done with staged implementation?)
- Study accuracy needs of fragmentation functions and pdfs
- Radiative corrections
- Do the study at NLO (-> Plug into a code like DSSV to see effect on uncertainties)

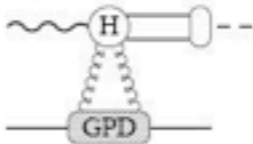# Simulations: Tanja Horn - exclusive meson production

Experimental Challenges

- Exclusivity (channel selection)

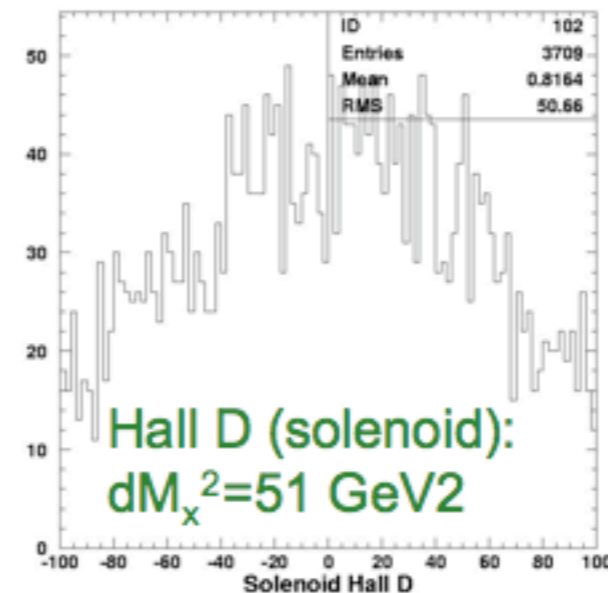- Particle identification

- L/T separations

- Luminosity

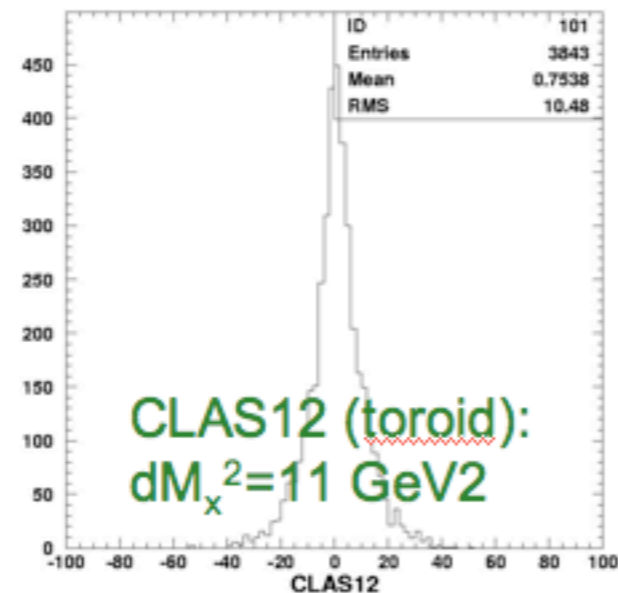Q^2, x

t, φ

e   e'

π

p   n
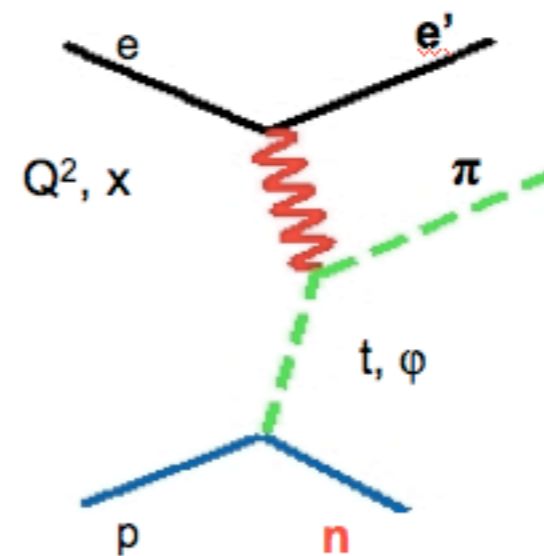
Simulations: Tanja Horn - exclusive meson production

Categories of Exclusive Processes

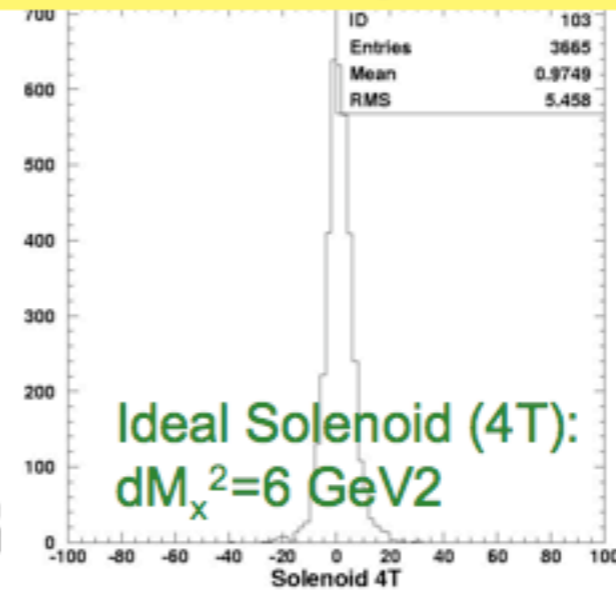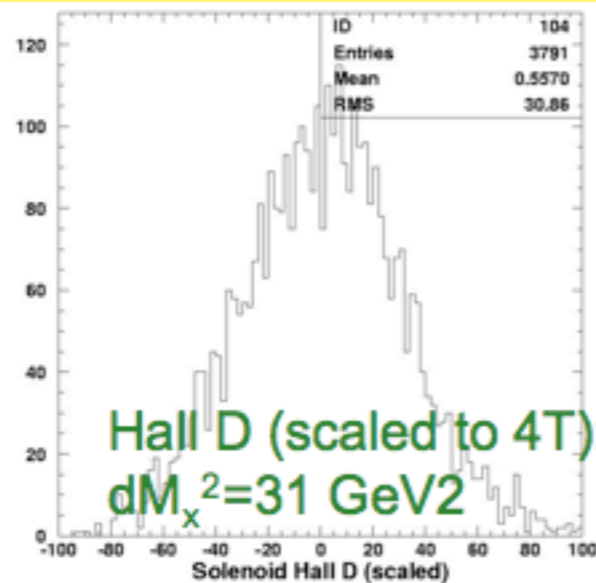|	"diffractive" (vacuum exchange)	"non-diffractive" (quantum number exchange)
Channel	γp, $\rho^0 p$, $J/\psi p$, ...	$\pi^+ p$, $\pi^0 p$, $K\Lambda$, $\rho^+ n$, ...
GPDs	gluon	non-singlet quark
Cross section	rises with energy	drops with energy
Interest	gluon imaging of nucleon	spin/flavor structure of quark GPDs

Simulations: Tanja Horn - exclusive meson production

Simulated dM_x^2 distributions for 5 on 50 kinematics

	ID	101
	Entries	3843
	Mean	0.7538
	RMS	10.48

CLAS12 (toroid):
dM_x^2=11 GeV2

CLAS12

	ID	102
	Entries	3709
	Mean	0.8164
	RMS	50.66

$\Theta_\pi < 30°$

Hall D (solenoid):
dM_x^2=51 GeV2

Solenoid Hall D

Conclusion: missing mass technique will not guarantee exclusivity in these kinematics

	ID	104
	Entries	3791
	Mean	0.5570
	RMS	30.86

Hall D (scaled to 4T):
dM_x^2=31 GeV2

Solenoid Hall D (scaled)

	ID	103
	Entries	3665
	Mean	0.9749
	RMS	5.458

Ideal Solenoid (4T):
dM_x^2=6 GeV2

Solenoid 4T

Jeffers... ...ferson National

Hall C

Simulations: Tanja Horn - exclusive meson production

Conclusion

- Measurements of exclusive reactions face various experimental challenges

- These challenges can be addressed with a different choice of kinematics

- A symmetric collider would offer additional benefits

Theory:

J.W. Qiu   -   Single spin asymmetry in semi-inclusive D meson production

M. Strikman -   Diffraction in ep at low and intermediate t

M. Diehl   -   Physics in semi-inclusive hadron production at high pT

J.W. Qiu   -   Single spin asymmetry in semi-inclusive D meson production

The Question

❑ **How to probe the hadron structure beyond the PDFs?**
beyond the probability distributions?

$$\sigma(Q, s_T) = H_0 \otimes f_2 \otimes f_2 + (1/Q) H_1 \otimes f_2 \otimes f_3 + \mathcal{O}(1/Q^2)$$

Too large to compete!   **Three-parton correlation**

❑ **Idea:**

Take a difference of two cross sections,
whose leading power terms are canceled

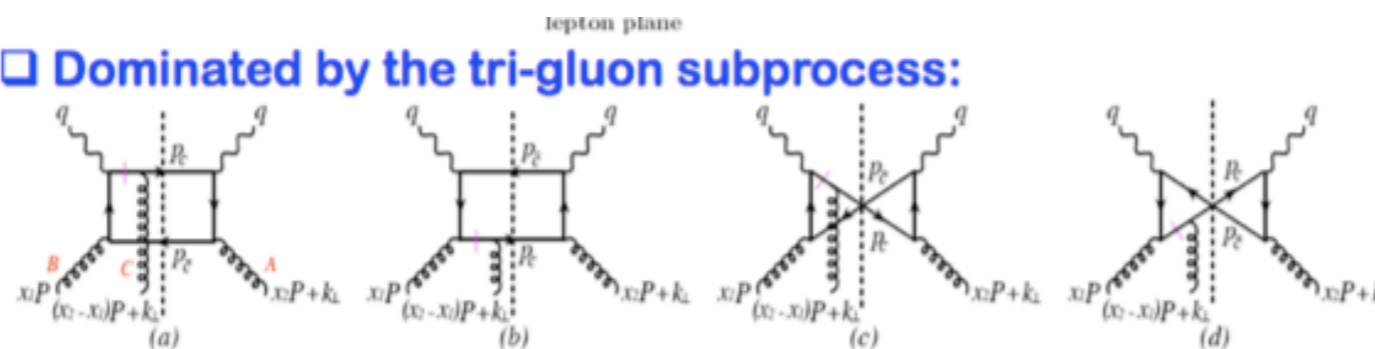$$\Delta\sigma(Q, s_T) \equiv [\sigma(Q, s_T) - \sigma(Q, -s_T)]/2$$

$$= (1/Q)H_1(Q/\mu_F, \alpha_s) \otimes f_2(\mu_F) \otimes f_3(\mu_F) + \mathcal{O}(1/Q^2)$$

lepton plane

❑ **Dominated by the tri-gluon subprocess:**

(a) (b) (c) (d)

Attraction of D-mesons

The physics question:

- ▶ general setting: hard processes with measured transverse momentum q_T in the final state
- ▶ here: semi-inclusive deep inelastic scattering
$$ep \rightarrow e + h + X$$
  transfer results to
  - ▶ Drell-Yan process $pp \rightarrow \ell^+\ell^- + X$
  - ▶ hadron pair production $e^+e^- \rightarrow h_1 + h_1 + X$
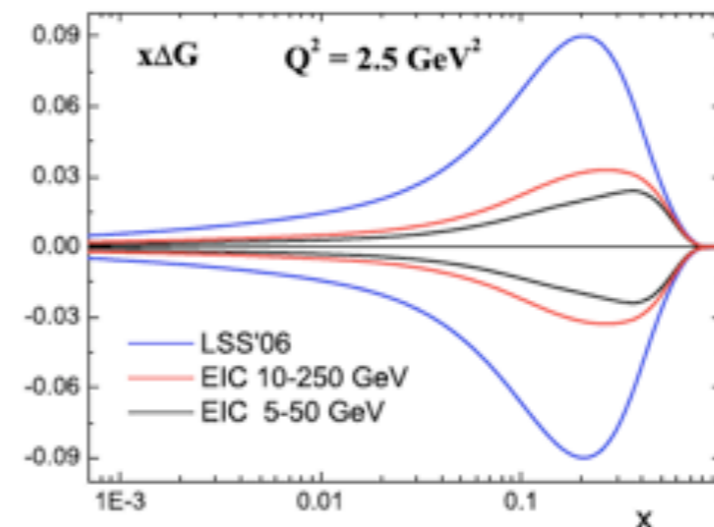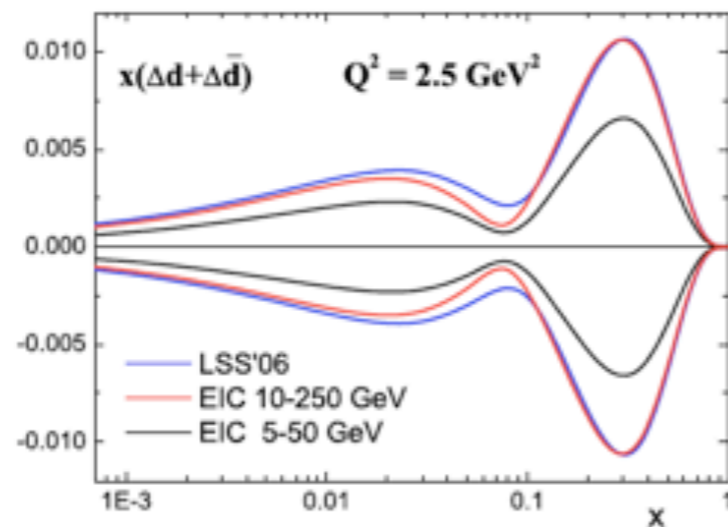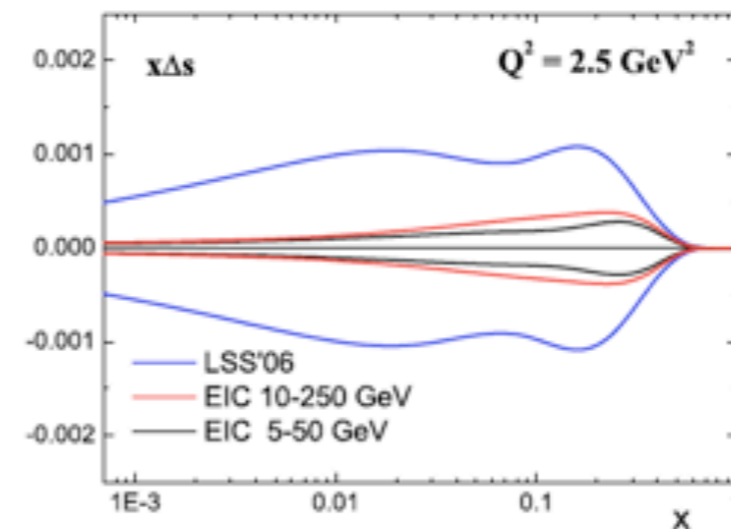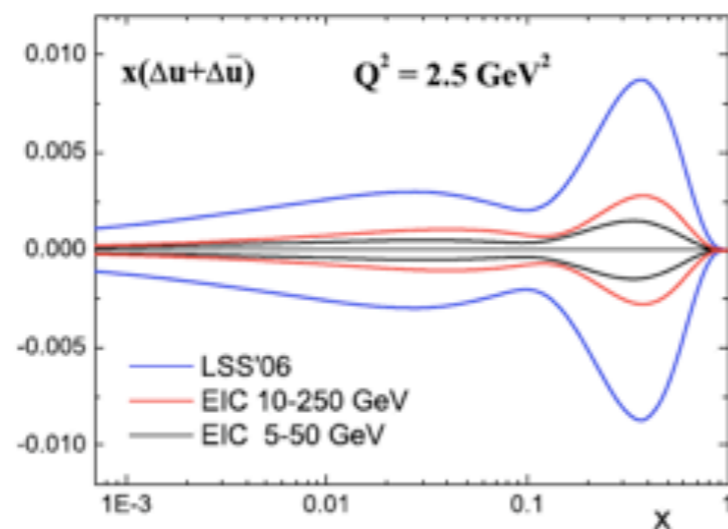
  by crossing symmetry
- ▶ physics motivations:
  - understand a basic feature of QCD final states
  - use as tool for extracting specific parton distributions
- ▶ two different frameworks to describe q_T distribution ⤳

Discussion:

Discussion:
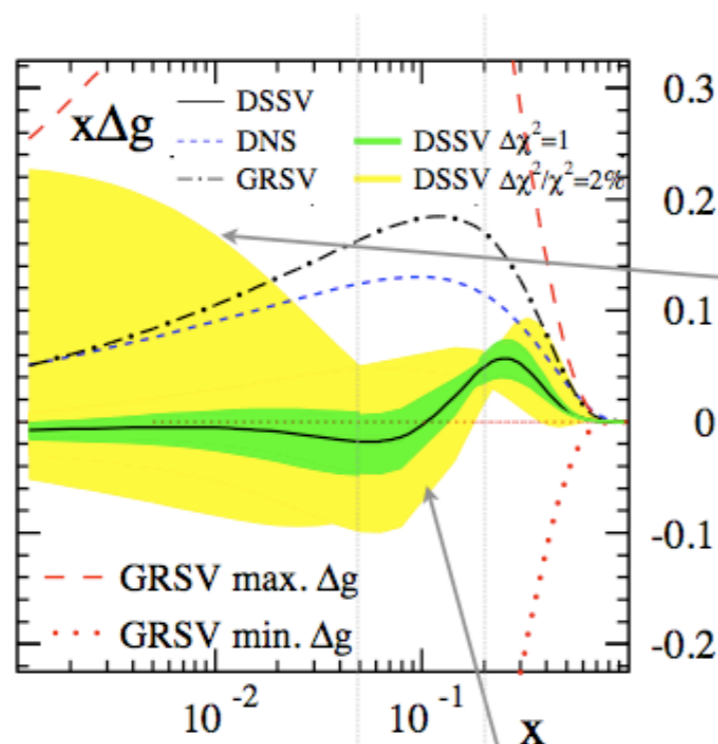

LSS does *not* include RHIC data.

Discussion:

Major step in interpretation

Gluons

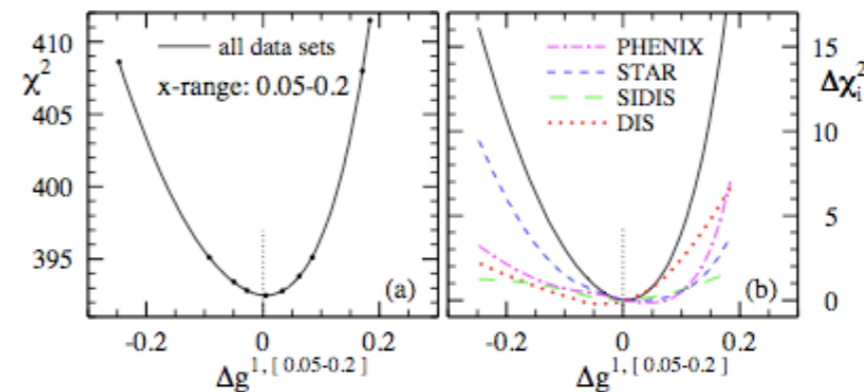$$\Delta f_j^{1,[x_{min}-x_{max}]}(Q^2) \equiv \int_{x_{min}}^{x_{max}} \Delta f_j(x,Q^2)dx$$

Moments $Q^2 = 10\,\text{GeV}^2$

	$x_{min} = 0$ best fit	$x_{min} = 0.001$ $\Delta\chi^2 = 1$	$\Delta\chi^2/\chi^2 = 2\%$
Δg	-0.084	$0.013\,^{+0.106}_{-0.120}$	$0.013\,^{+0.702}_{-0.314}$

Best fit : small first moment ... but..

No clear statement possible for First moment : ~0 but huge uncertainty at small x
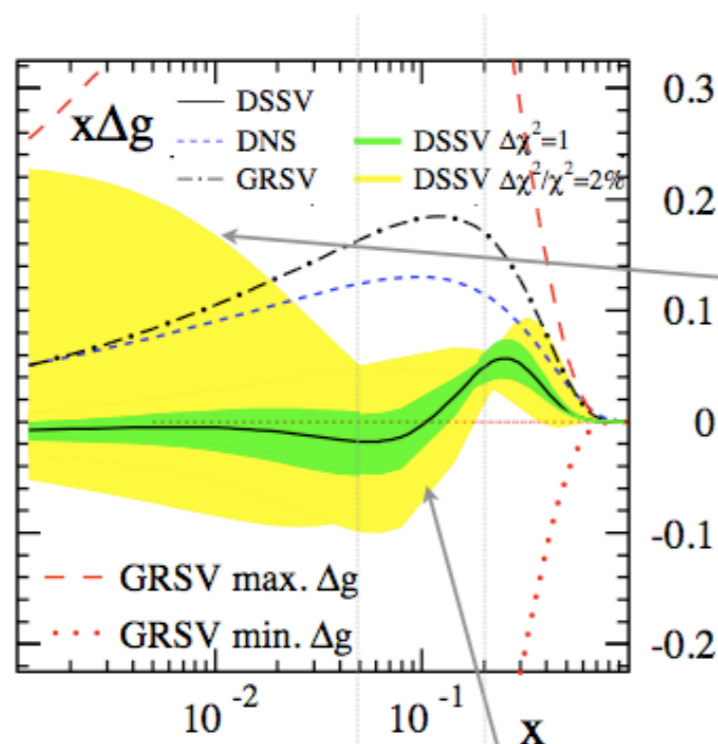
but great improvement at medium x

Complementarity of different data sets RHIC mainly in [0.05-0.2] region

Daniel de Florian - APS Spring Mtg. 2008,
de Florian, Sassot, Stratmann, Vogelsang - Phys.Rev.Lett.101:072001,2008

Discussion:

Major step and task ahead:

Gluons

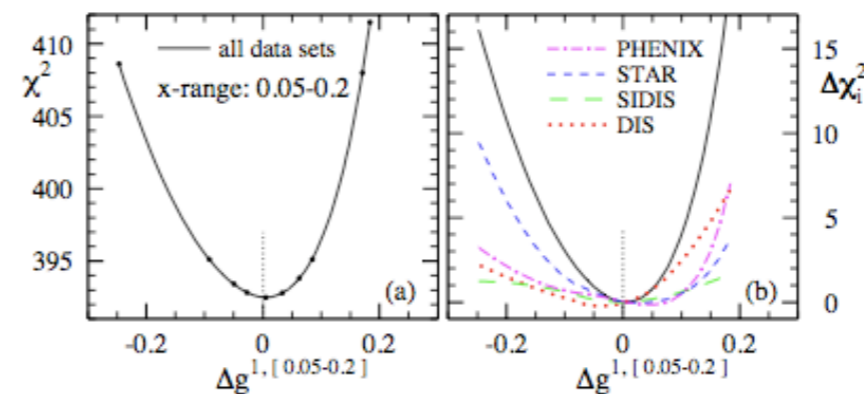$$\Delta f_j^{1,[x_{min}-x_{max}]}(Q^2) \equiv \int_{x_{min}}^{x_{max}} \Delta f_j(x, Q^2)\,dx$$

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Best fit : small first moment ... but..

xΔg

— DSSV
···· DNS — DSSV $\Delta\chi^2=1$
–·– GRSV — DSSV $\Delta\chi^2/\chi^2=2\%$

– – GRSV max. Δg
··· GRSV min. Δg

0.3
0.2
0.1
0
-0.1
-0.2

10^{-2} 10^{-1} **X**

No clear statement possible for First moment : ~0 but huge uncertainty at small x

but great improvement at medium x

410 χ^2 405 400 395

— all data sets
x-range: 0.05-0.2

-0.2 0 0.2
$\Delta g^{1,[0.05-0.2]}$
(a)

···– PHENIX
– – – STAR
– – SIDIS
······ DIS

15 $\Delta\chi_i^2$ 10 5 0

-0.2 0 0.2
$\Delta g^{1,[0.05-0.2]}$
(b)

Complementarity of different data sets
RHIC mainly in [0.05-0.2] region

Precision: sound projections require theory and experiment to proceed hand-in-hand (Deshpande, Vogelsang, et al).

In summary,

- ep parallel session and associated discussions were useful,

- very valuable theory discussion, expect at least one simulation follow-up,

- steps in detector requirements have and are being made,

    need to test *all* (more) channels against a fast-simulator (at minimum),

    investigate resolutions,

A comment,

    set the extra step(s) and document a la Caldwell et al.

BACKUP
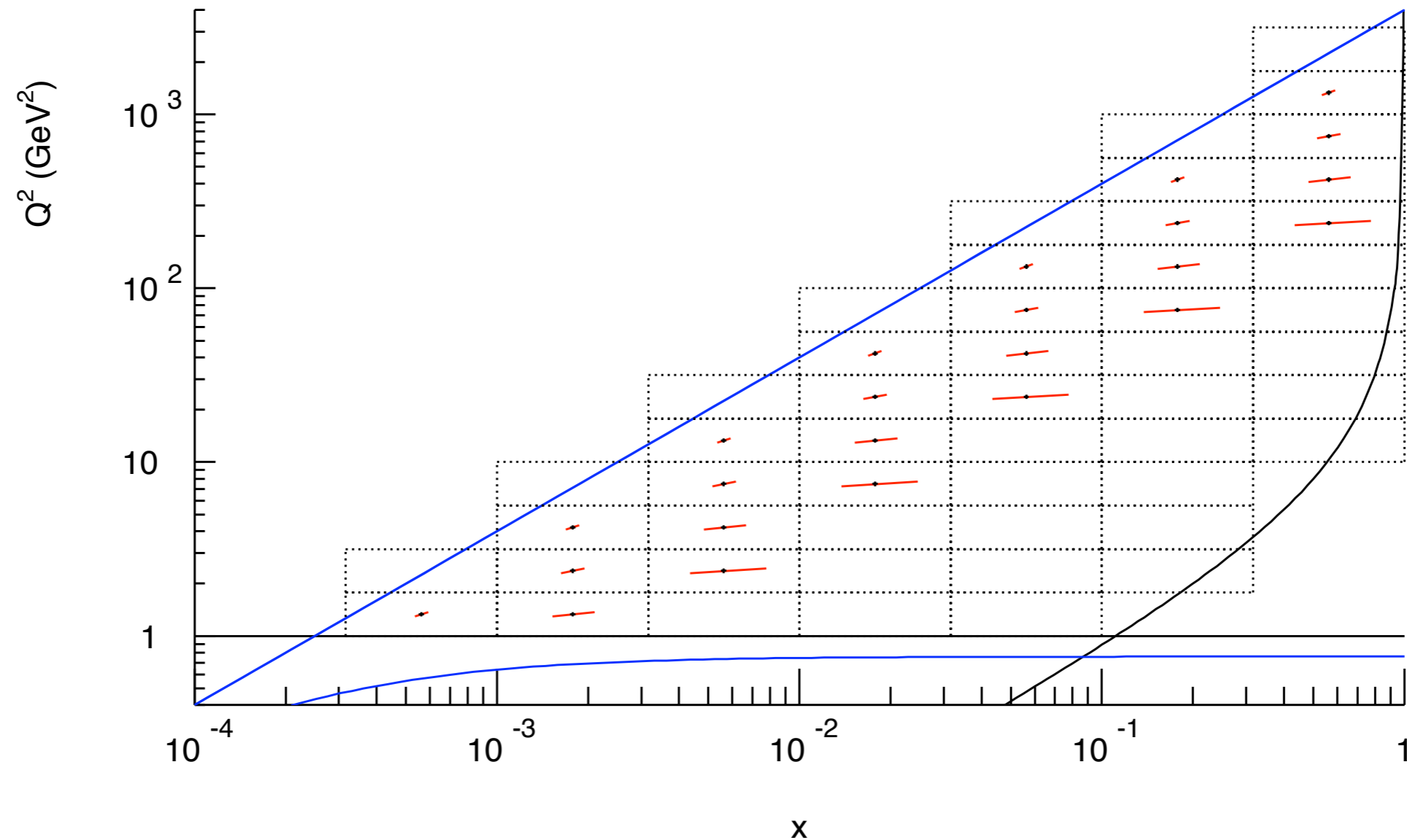
Kinematic smearing at a 10 on 100 GeV EIC collider for a 3% uncertainty in the electron energy measurement for the bin centers of a grid with two intervals per decade in Bjorken-x and four per decade in Q^2. One standard deviation variation is indicated by the read lines, except where it exceeds the bin size. The electron energy is 10 GeV and the proton energy 100 GeV.   J. Reagan (SULI student, Summer 2008) and E.S.