Status report on large-x PDFs

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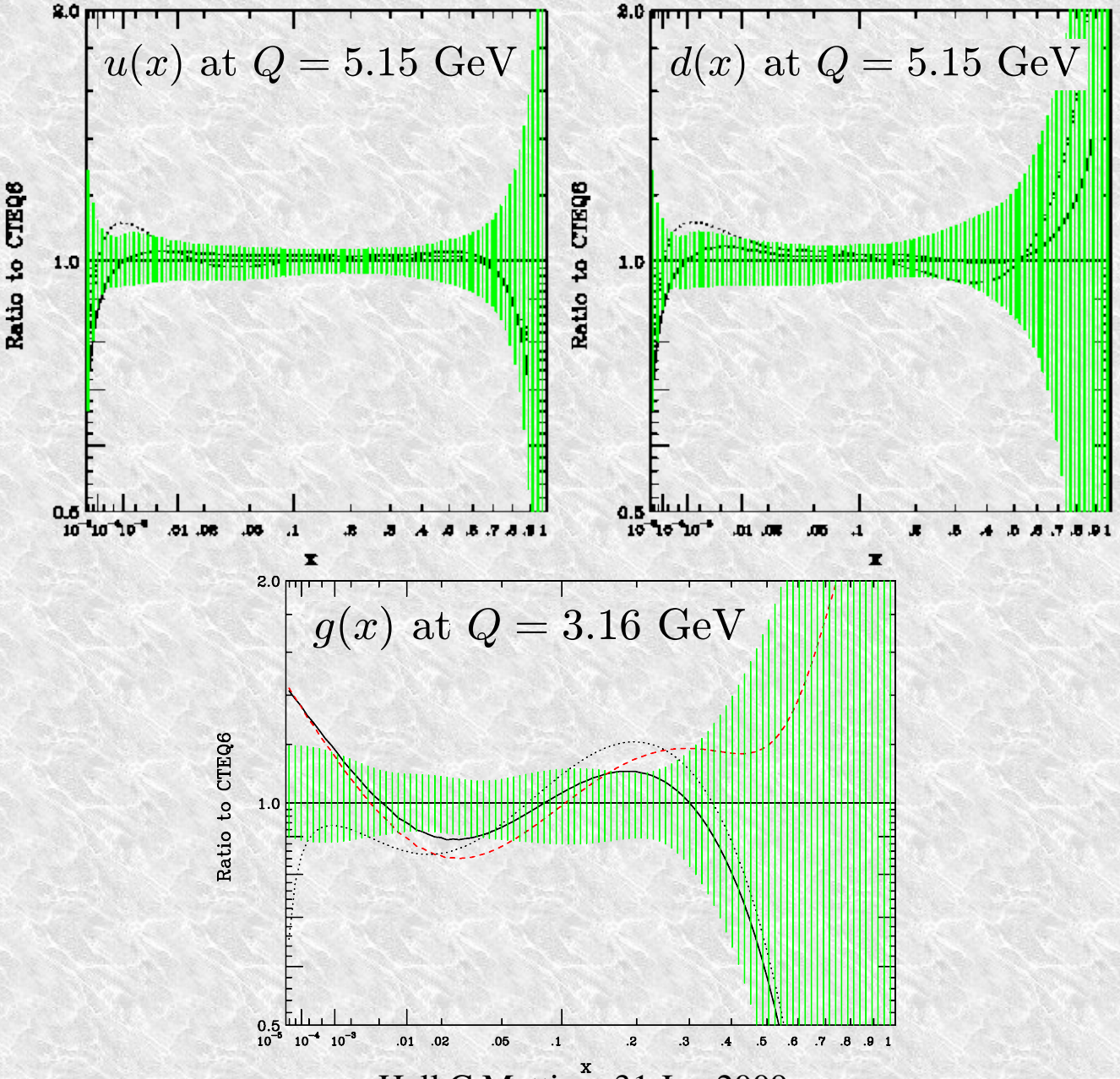
Hall C meeting, 31 January 2009

- **Introduction**
  - why large x and low Q^2 ?
  - collaboration and goals
- **Tools**
- **Preliminary results and comment**
- **Outlook**

Jefferson Lab

Why large x and low Q^2 ?

- Large uncertainties in quark and gluon PDF at $x > 0.5$



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- Precise PDF at large x (and low Q^2) are needed, e.g.,
  - at LHC, Tevatron
    1) New physics as excess in large p_T spectra $\Leftrightarrow$ large x PDF
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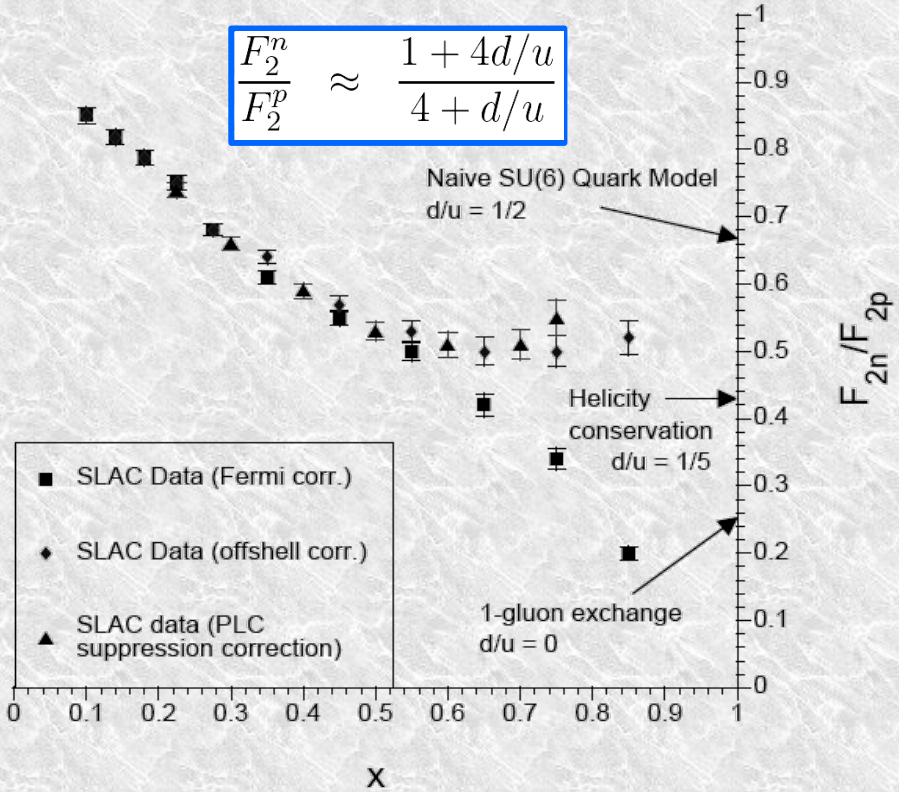

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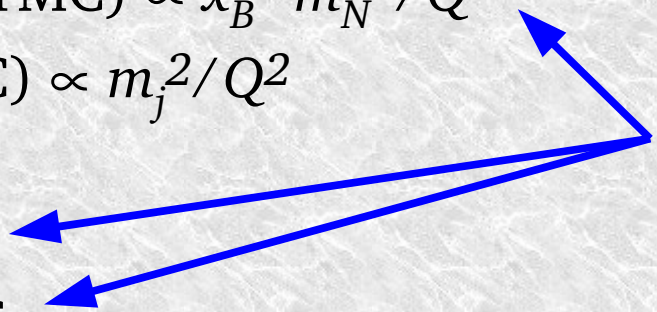
- **Need of theoretical control** on DIS over at least
  1) target mass corrections (TMC) $\propto x_B^2\, m_N^2/Q^2$
  2) jet mass corrections (JMC) $\propto m_j^2/Q^2$
  3) large-x resummation
  4) higher twist $\propto \Lambda^2/Q^2$
  5) nuclear target corrections



Collaboration and goals

- Jefferson Lab/Florida State U./Fermilab collaboration ("cteqX"):
  - A.Accardi, E.Christy, C.Keppel, W.Melnitchouk, P.Monaghan, J.Morfín, J.Owens
- Initial Goals:
  - Extend PDF global fits to larger values of x_B and lower values of Q
  - Wealth of data from older SLAC experiments and newer JLAB
  - Study effects of different target mass correction methods
  - Explore role of higher twist contributions
- Eventually,
  - see if PDF errors can be reduced using new JLAB data
  - determine an optimized set of PDFs at large x_B

Target mass corrections

- Nachtmann variable: $\xi = \dfrac{2x_B}{1+\sqrt{1+4x_B^2 m_N^2/Q^2}} < 1$ at $x_B = 1$

- **Standard Georgi-Politzer** (OPE)
  [Georgi, Politzer 1976; see review by Schienbein et al. 2007]
  - leads to non-zero structure functions at x_B>1 (!)

- **Collinear factorization** [Accardi, Qiu, JHEP 2008; Accardi, Melnitchouk 2008]
  Structure fns as convolutions of parton level structure fns and PDF

$$F_{T,L}(x_B, Q^2, m_N) = \sum_f \int_\xi^{\frac{\xi}{x_B}} \frac{dx}{x}\, h^f_{T,L}\left(\frac{\xi}{x}, Q^2\right) \varphi_f(x, Q^2)$$

  - respects kinematic boundaries

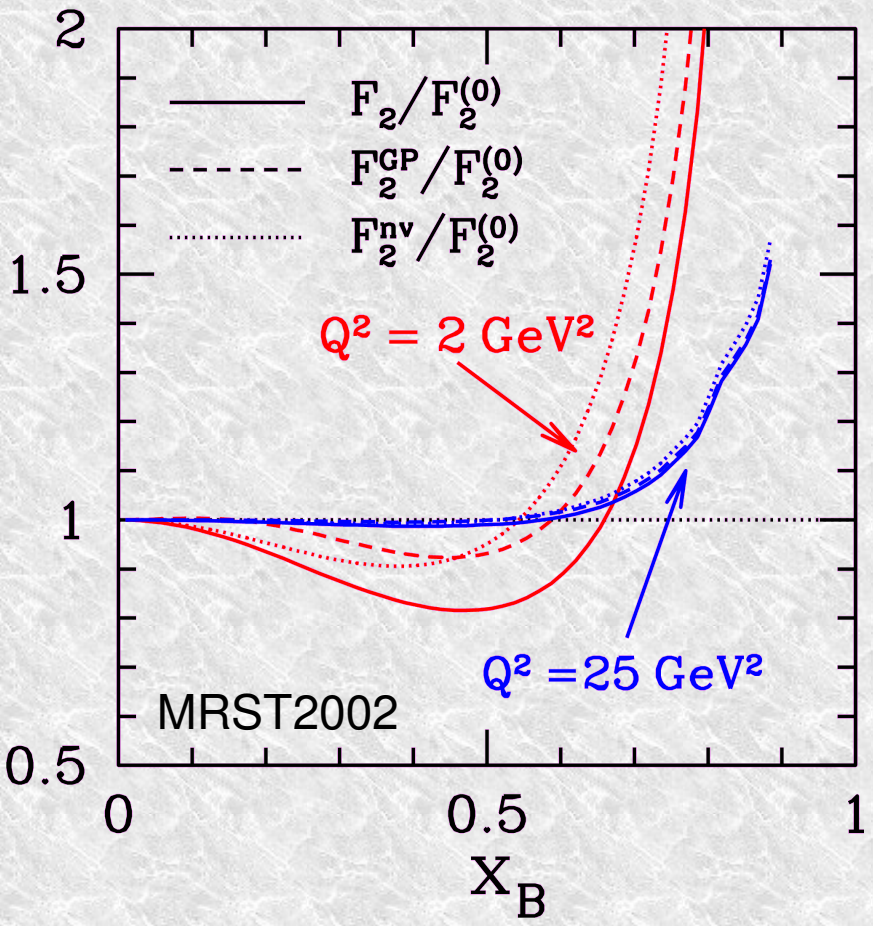
- **Naïve CF**, uses $x_{\max} = 1$ [Aivazis et al '94; Kretzer,Reno '02]

$$F^{nv}_{T,L}(x_B, Q^2, m_N) \equiv F^{(0)}_T(\xi, Q^2)$$

  - leads to non-zero structure functions at x_B>0 (!)

Target mass corrections – F_2 at NLO

Accardi, Qiu JHEP '08



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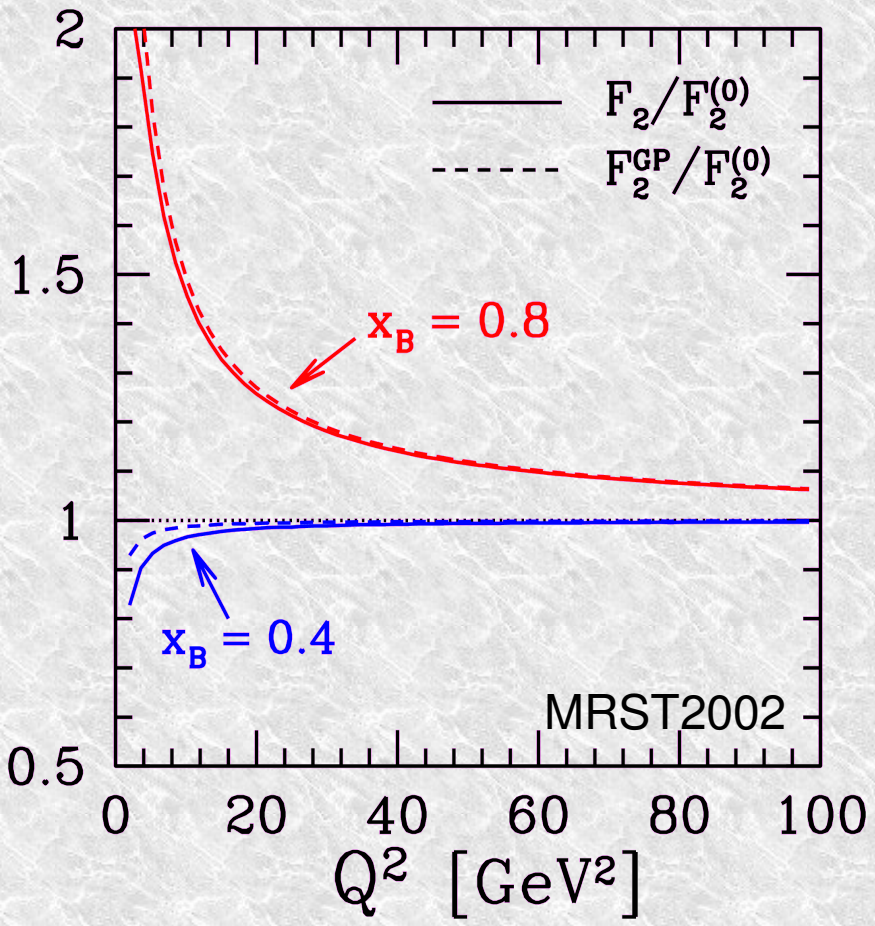
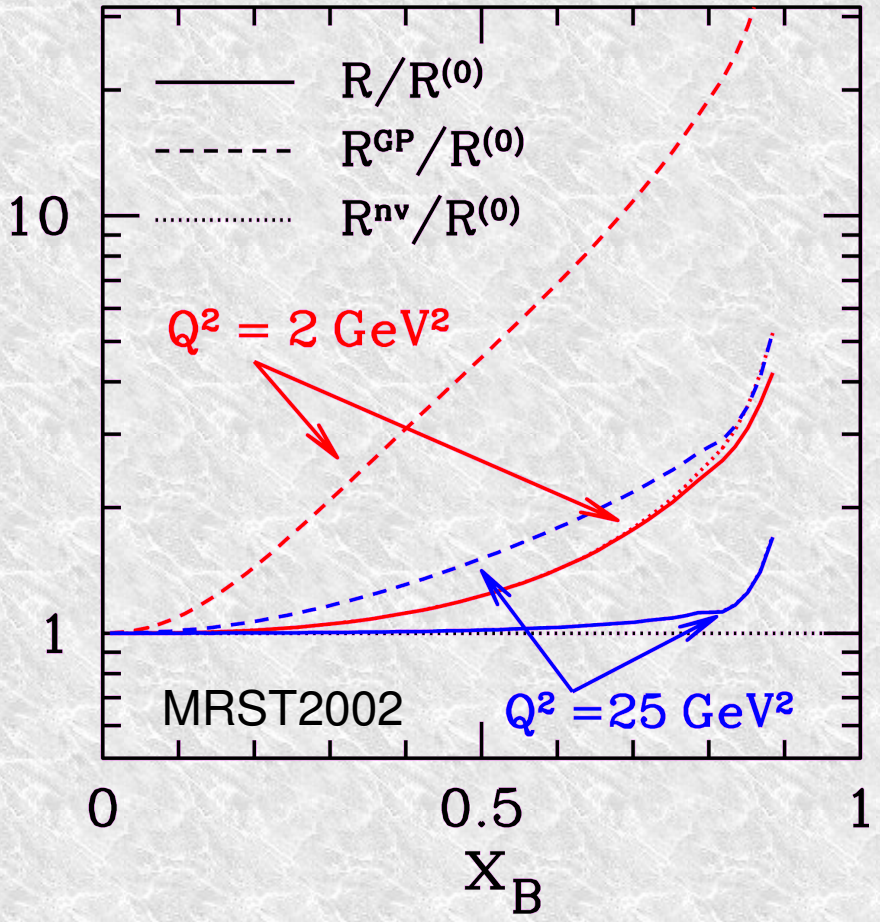


$$F_2^{nv}(x_B) = \frac{1}{1 + 4x_B^2 \frac{m_N^2}{Q^2}} \frac{x_B}{\xi} F_2^{(0)}(\xi)$$

Target mass corrections – σ_L/σ_T at NLO

Accardi, Qiu JHEP '08



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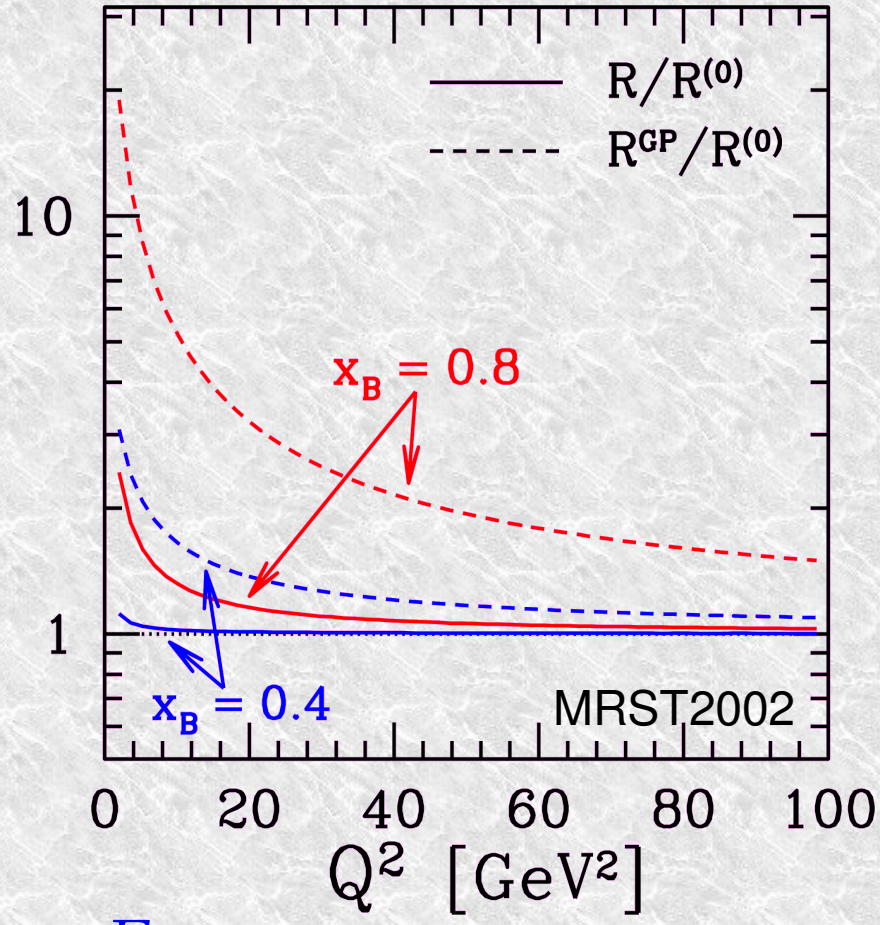
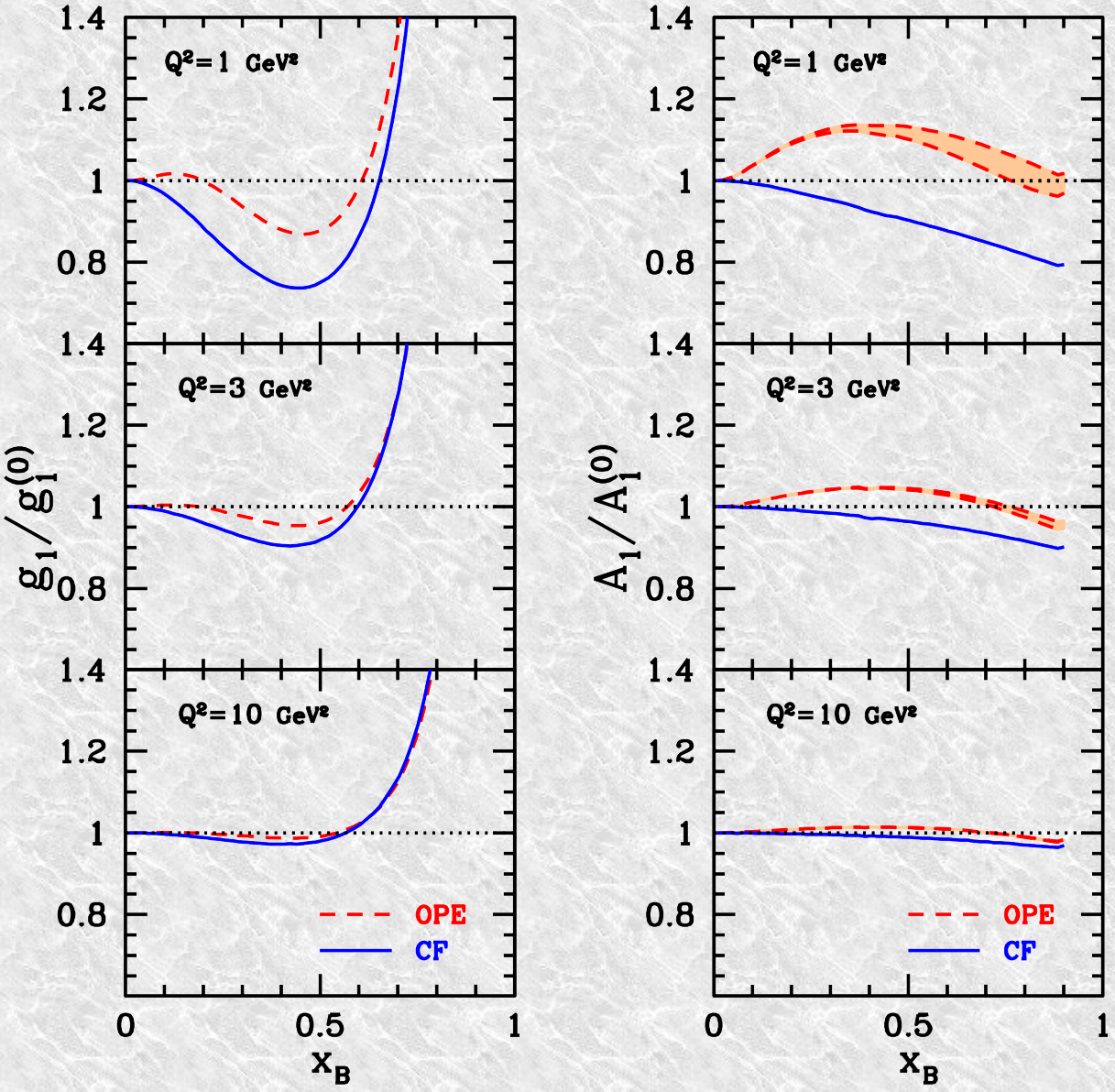


$$R = \frac{\sigma_L}{\sigma_T} = \frac{F_L}{F_1}$$

$$F_{1,L}^{nv}(x_B) = F_{1,L}^{(0)}(\xi)$$

Polarized DIS

Accardi, Melnitchouk PLB '08



- g_1 similar to F_2
- A_1 has smaller corrections
- Common approximation

$$A_1 = (1+\gamma^2)\frac{g_1}{F_1} \approx \frac{A_\parallel}{D}$$

equivalent to

$$A_1 \approx A_1^{(0)}$$

- Self-consistent test for need of $A_\perp$ measurement

Higher-Twists parametrization

- Parametrize the higher-twist contributions by a multiplicative factor:

$$F_2(data) = F_2(TMC) \times \left(1 + \frac{C(x_B)}{Q^2}\right)$$

with

$$C(x_B) = a\, x^b\, (1 + c\, x + d\, x^2)$$

- Comments
  - parametrization is sufficiently flexible to give good fits to data (except when no TMCs are included)
  - typically, the parameter d is not needed since at x_B near 1 there is not a lot of difference between x and x^2

Deuteron corrections

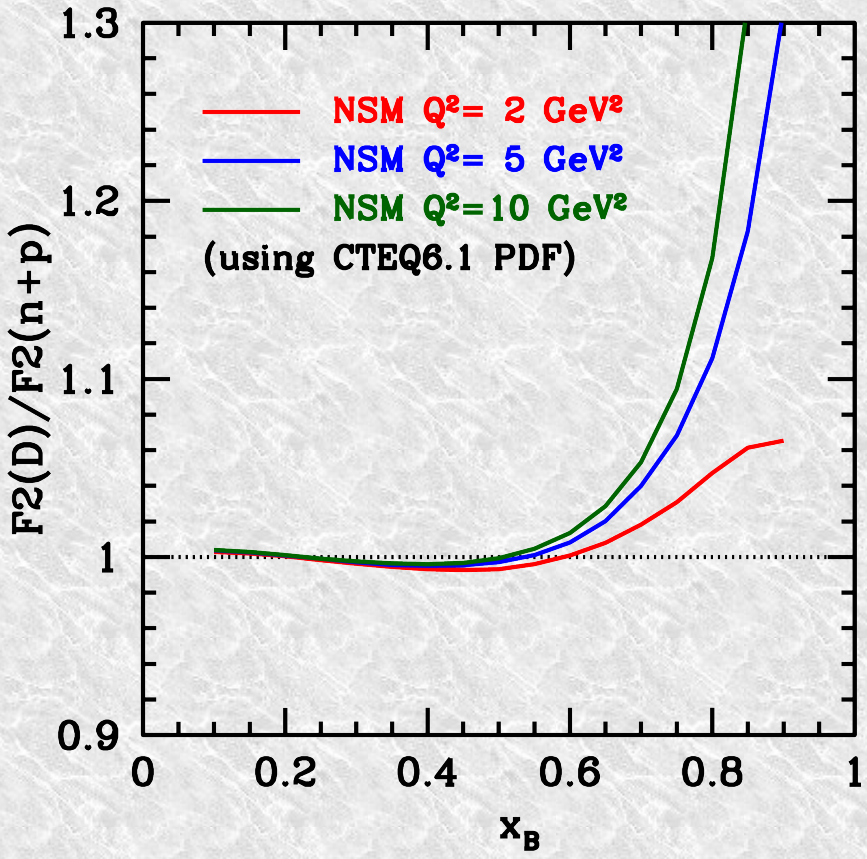
- Nuclear Smearing Model [Kahn et al., arXiv:0809.4308; Accardi et al., *in preparation*]
  - nucleon Fermi motion and binding energy:

$$F_{2A}(x_B) = \int_{x_B}^{\infty} dy \mathcal{S}(y,\gamma) F_2^{TMC}(x_N, Q^2)$$

$$\gamma = \sqrt{1 + 4x_B^2 m_N^2 / Q^2}$$

$$x_N = \frac{p_N \cdot q}{p_D \cdot q} = f(\xi, y, Q^2)$$

- important to go beyond Bjorken limit
  - finite-Q^2 corrections

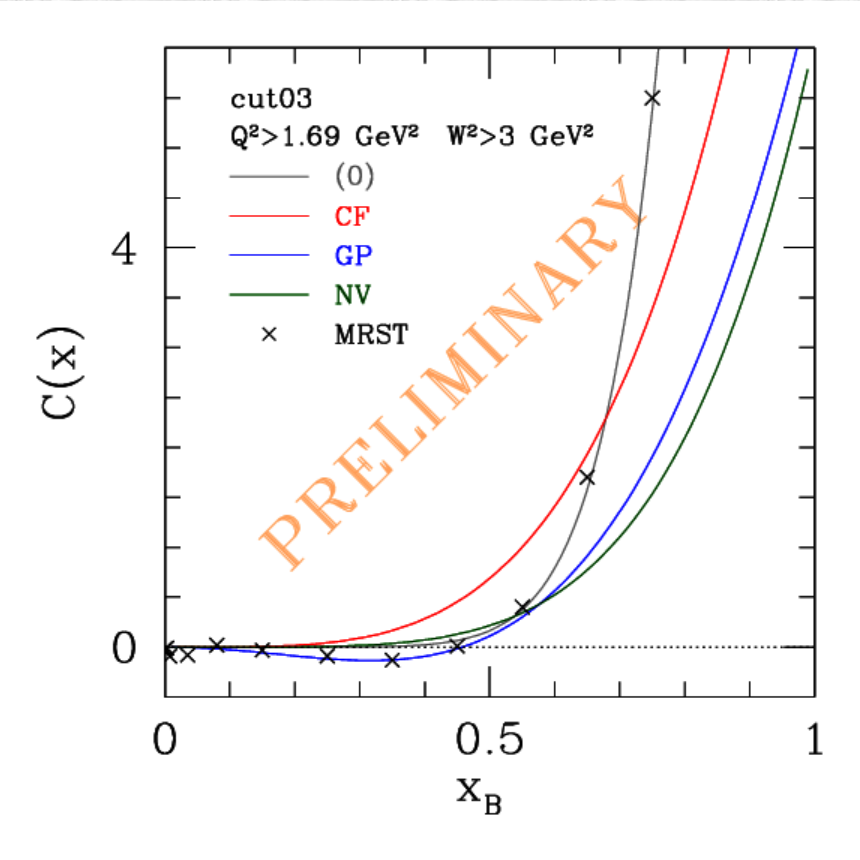


Global Fitting

- We are using Jeff Owens' NLO DGLAP fitting package
  - use CTEQ6.1 parametrization of PDFs at $Q^2=1.69$ GeV^2
  - option for finite d/u at $x \to 1$ is being considered
  - Can fit DIS, Drell-Yan, W lepton asymmetry, jets (and γ+jet)
  - Multiple TMC and HT terms added
  - Higher-twist contributions by a multiplicative factor
  - Nuclear corrections for deuteron targets added
  - PDF errors computed by the Hessian method, with $\Delta\chi^2=1$

Preliminary results

- **Extracted higher-twist term depends on the type of TMC used**



- $Q^2 > 1.69$ GeV^2 and $W^2 > 3$ GeV^2 (referred to as "cut03")
- lower cuts $\Rightarrow x_B < 0.85$ compared to $x_B < 0.65$ in CTEQ/MRST
- curves have $d=0$ and small errors on a, b, and c

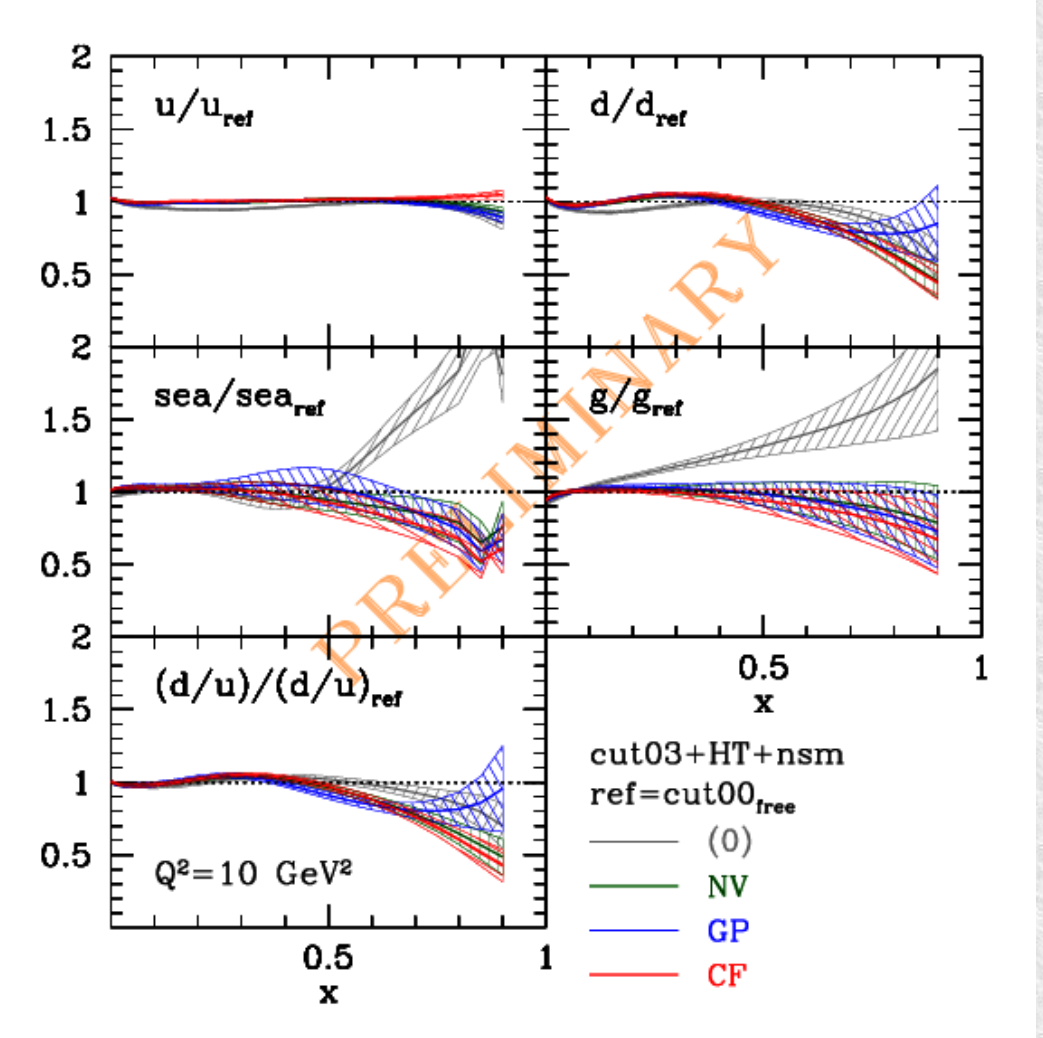
Preliminary results

- **Extracted twist-2 PDF much less sensitive to choice of TMC**
  - fitted HT function compensates the TMC
  - except when no TMC is included

- **Largest effect on *d*-quark**

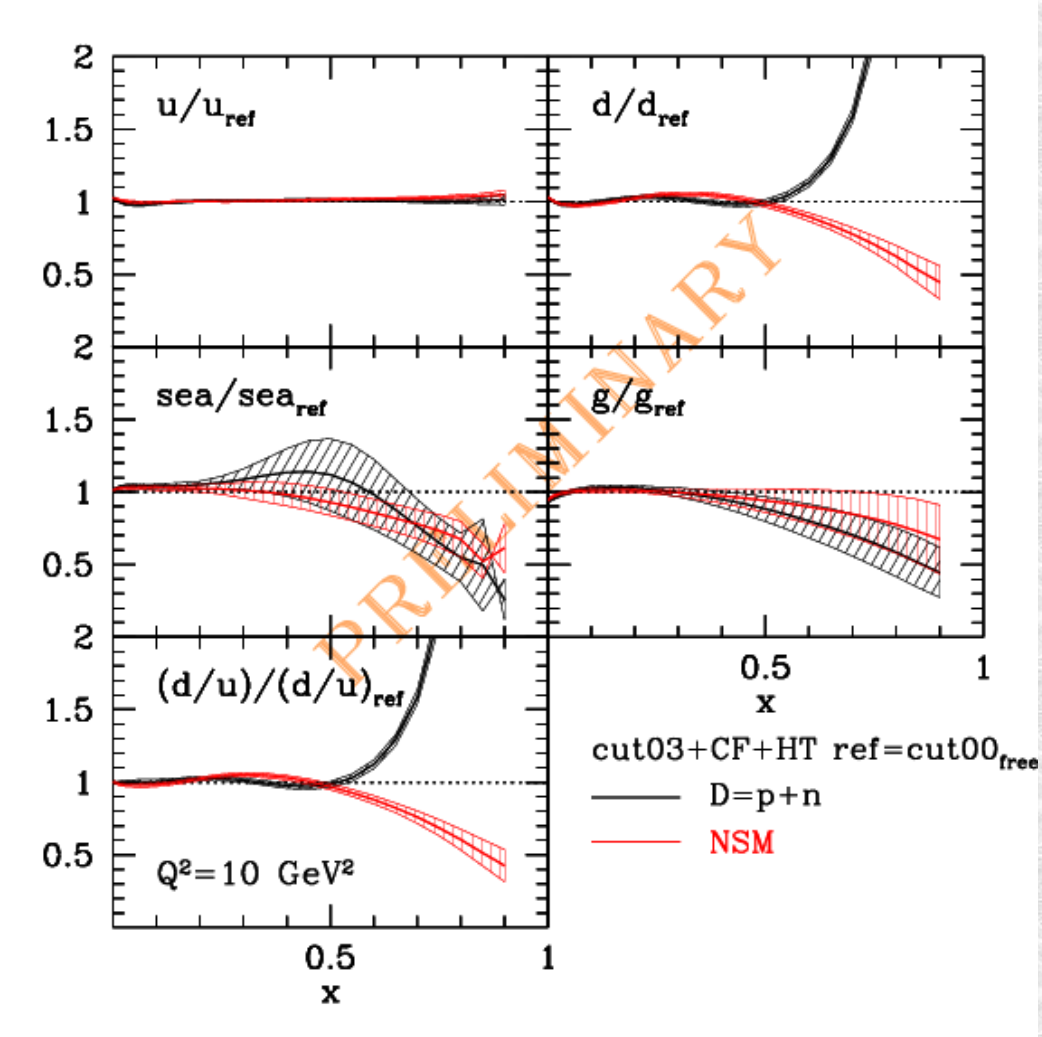
- $Q^2 > 1.69$ GeV^2, $W^2 > 3$ GeV^2 (referred to as 'cut03')

- plots relative to fit with
  - $Q^2 > 4$ GeV^2, $W^2 > 12.25$ GeV^2 ("cut00" ≡ CTEQ6.1 cuts)
  - no TMC, no HT, no deut.cor.



Preliminary results

- Deuterium corrections have large effect on *d*-quark



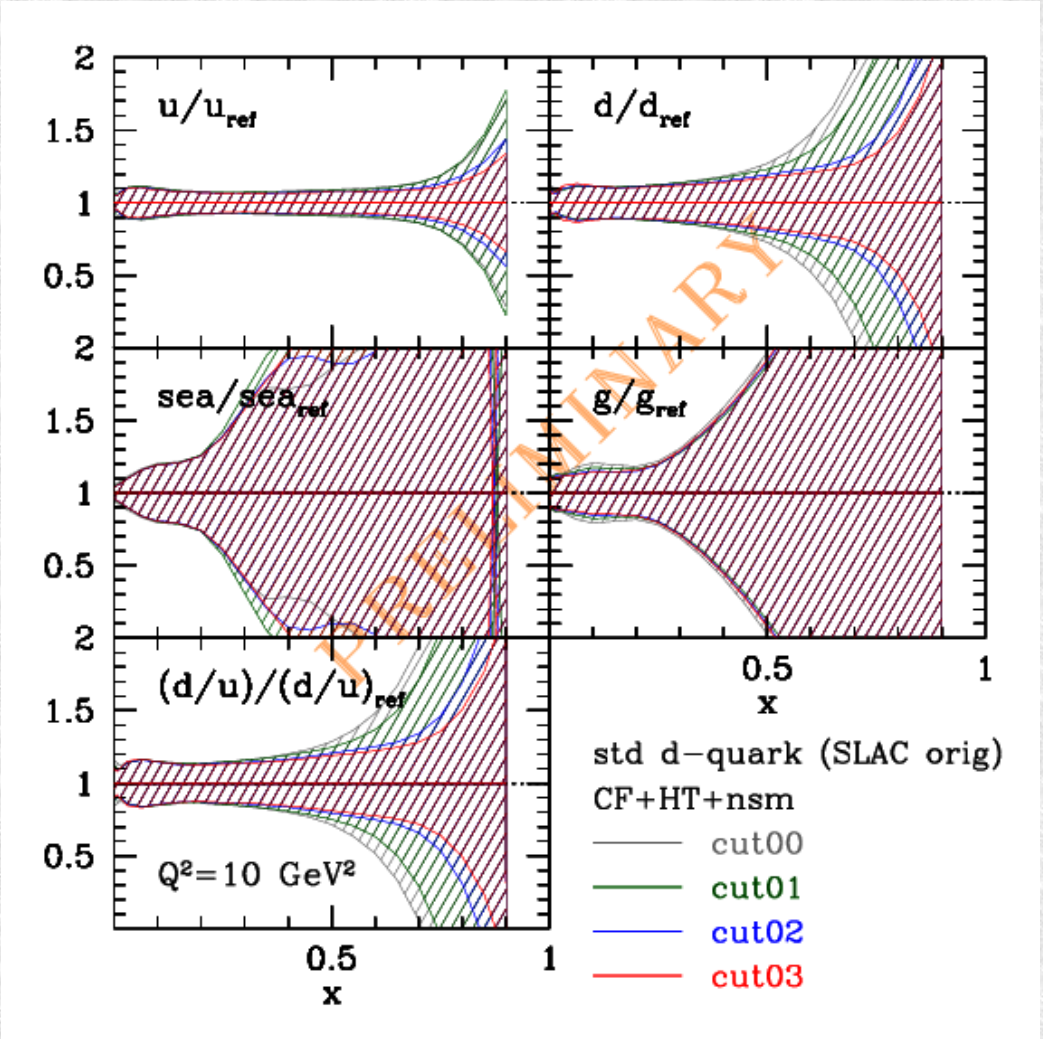
- use WA21 data on ν(νbar)-p to cross-check *d* without Deuterium?
- topic is under study

[w/ L.Y.Zhu]

Preliminary results

- **PDF errors at large *x* are reduced by lowering the cuts**

	Q^2 [GeV^2]	W^2 [GeV^2]
cut00	4	12.25
cut01	3	8
cut02	2	4
cut03	1.69	3



- **Note:** errors multiplied by 10 for rough comparison to CTEQ6.5 errors

Conclusions

- A new series of global PDF fits is underway with expanded kinematic range and enlarged data set
  - Preliminary indications suggest a suppressed d/u ratio at large x
  - Large effect of deuterium corrections under study
- But other analyses and data sets need for increased d/u …
  - Global fit including E-866 lepton pair data and NuTeV, CHORUS neutrino data show enhanced d/u ratios
  - DØ W electron asymmetry lie below predictions of current PDFs suggesting an enhanced d/u ratio for x near 0.4-0.5
- PDF errors are reduced by the expanded large-x_B (SLAC) data set
- Eventually: use JLab data to
  - further reduce PDF errors
  - constrain the gluons using FL

Outlook

- Theoretical effects to be included
  - TMC (and hadron mass corrections) for SIDIS [w/ Hobbs, Melnitchouk]
  - TMC for DY and p+p
  - Large-x resummation
  - Effect of Jet Mass Corrections [Accardi,Qiu '08]

    $\Rightarrow$ new theory, phenomenology, connections to lattice QCD (?), ...
  - Parton-hadron duality – further reduce kinematic cuts

- In the longer run:
  - Polarized QCD fits ?
  - TMDs ?

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