Towards Higher Precision PDFs at Large x

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Deep Inelastic Scattering 2009
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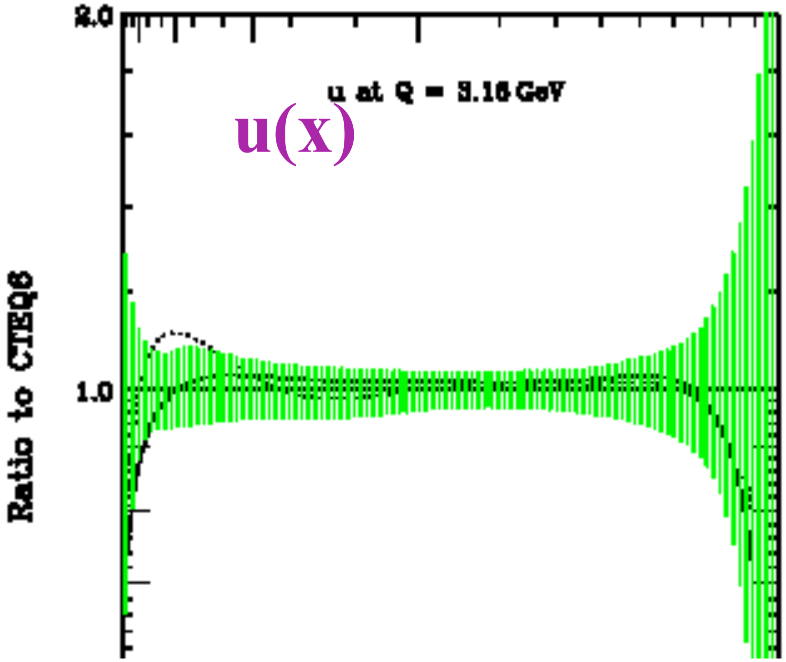
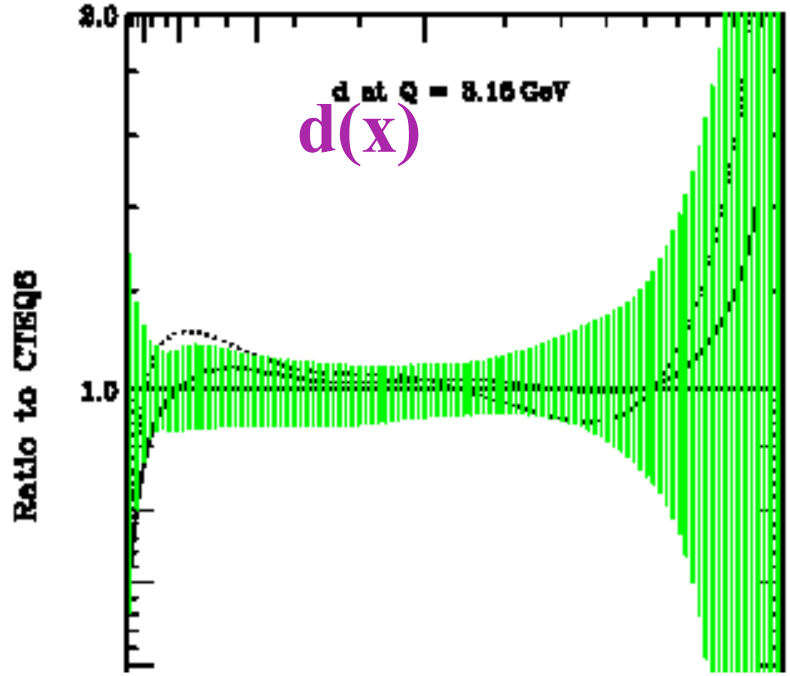
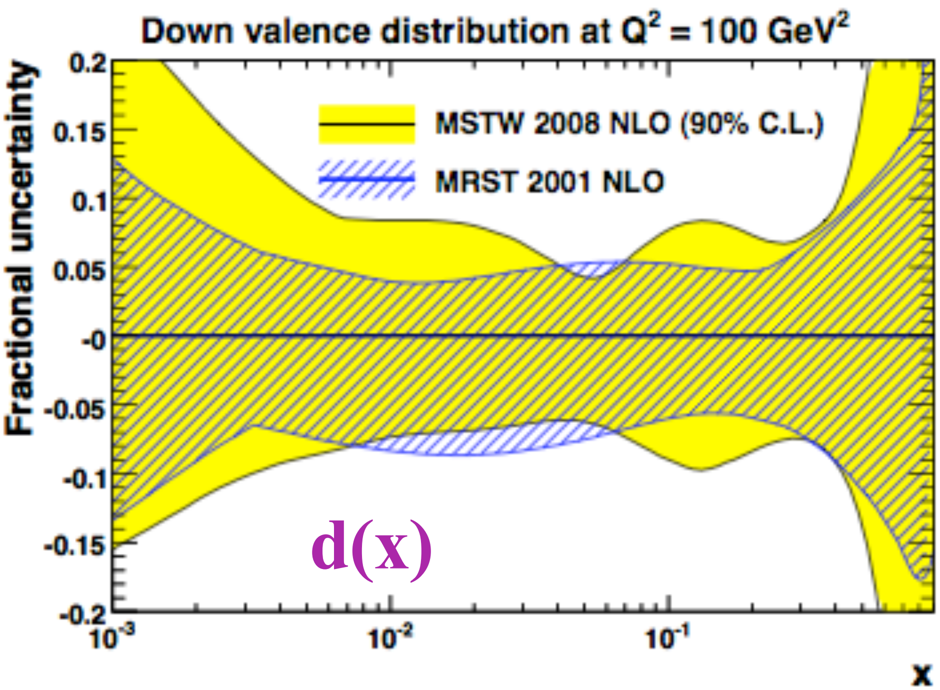
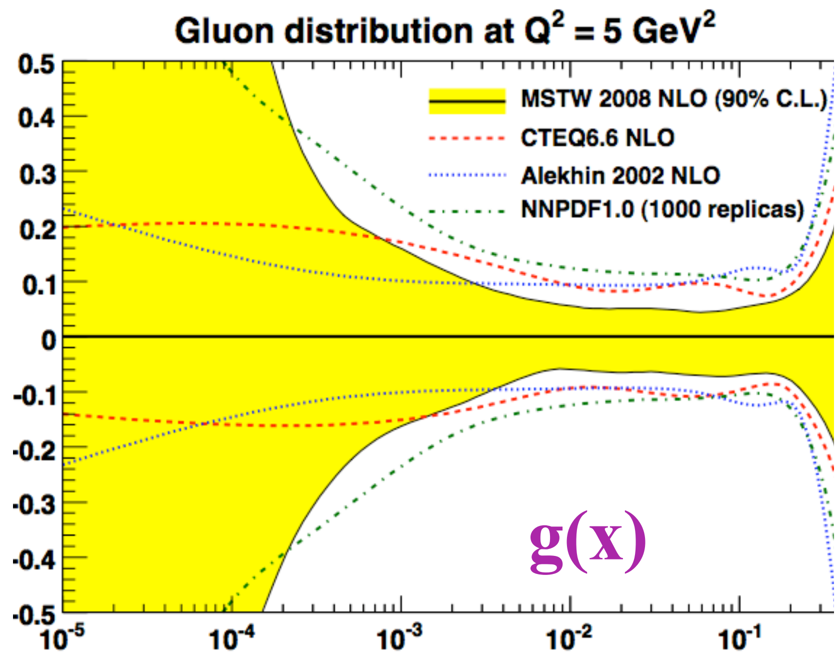
Large x (x > 0.1) -> Large Uncertainties





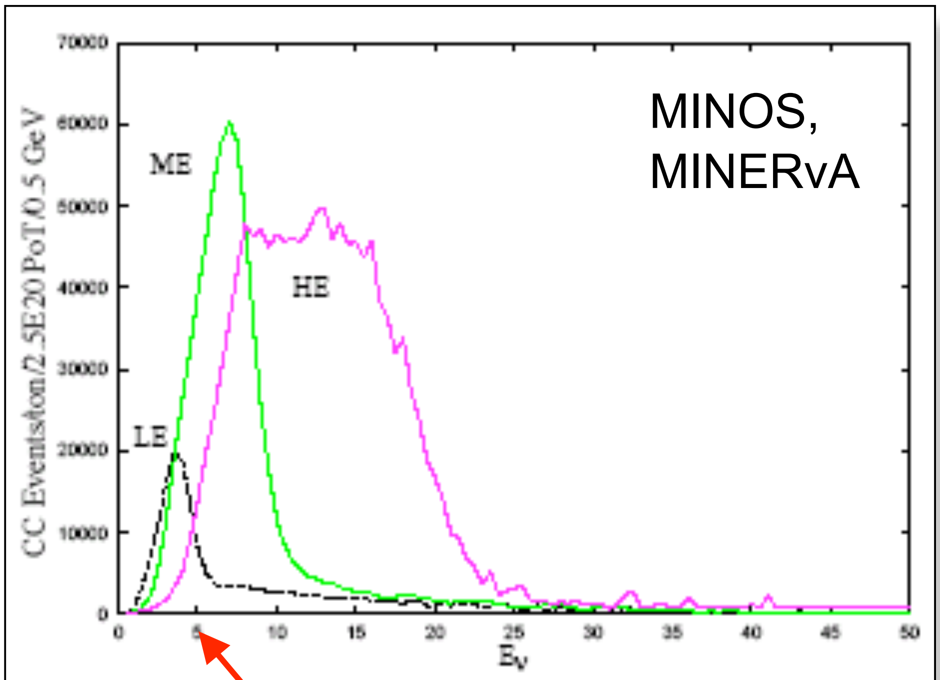


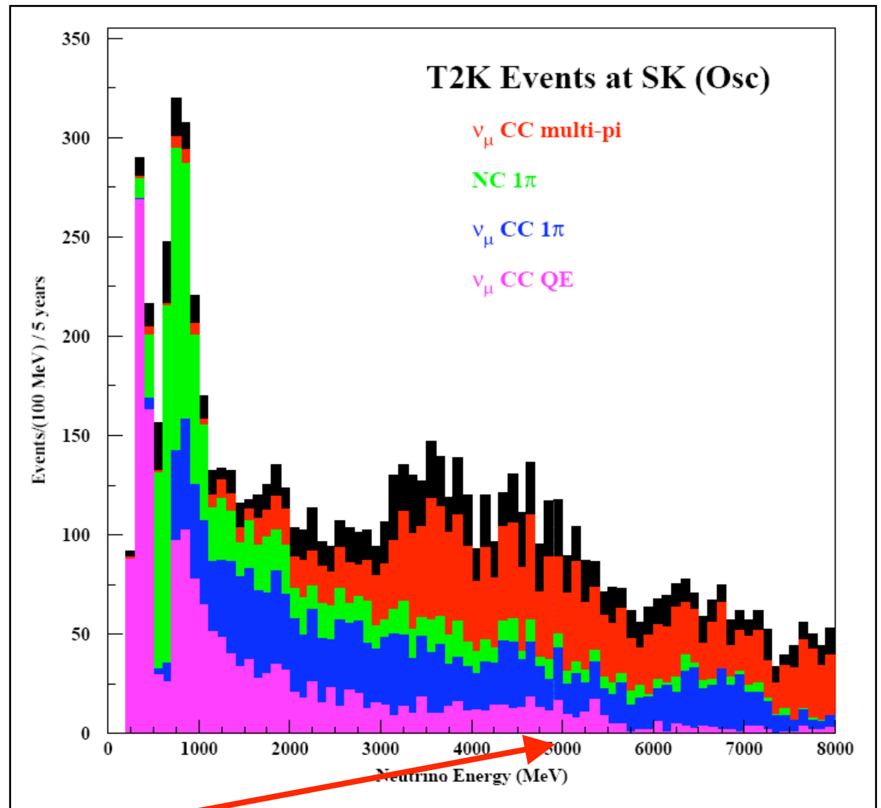


Why improve large x PDFs ?

- Precise PDFs at large *x* are / will be needed for:

  - Current and upcoming neutrino oscillation experiments





5 GeV (Large x, Low Q^2!)

Why improve large x PDFs ?

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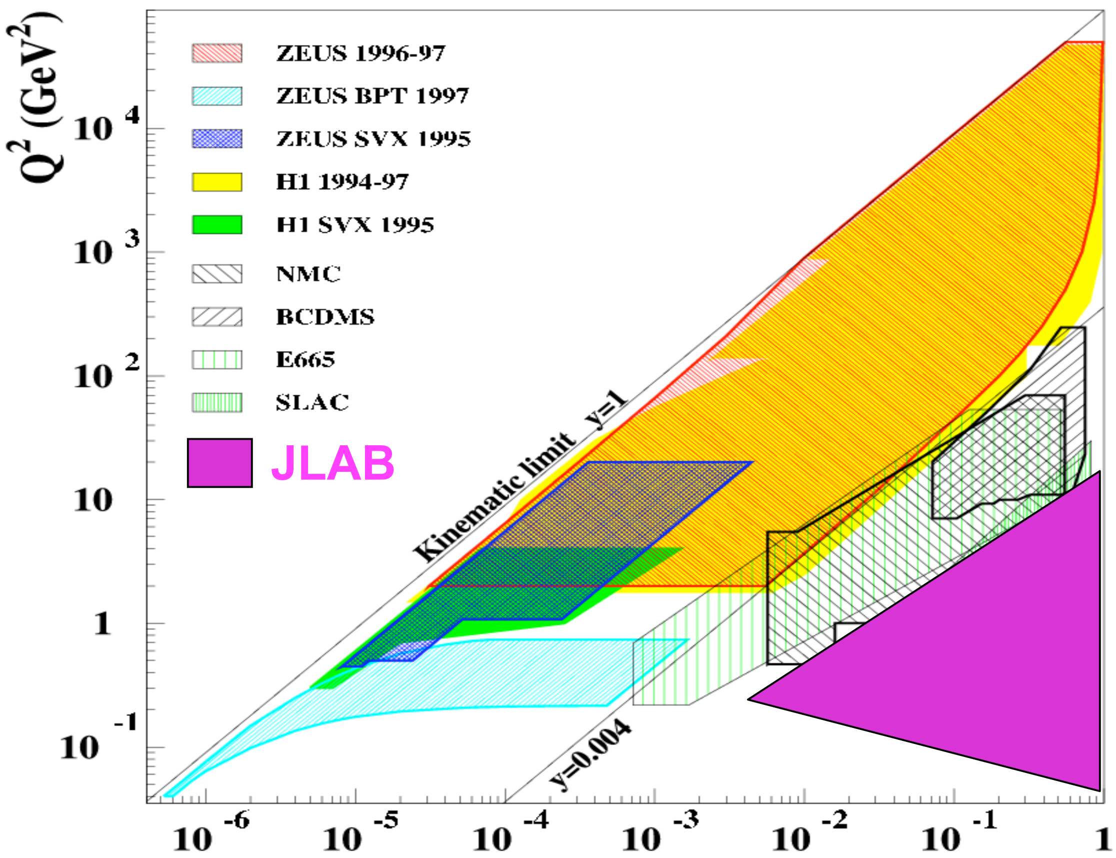
  - Current and upcoming neutrino oscillation experiments
  - A host of results from Jefferson Lab (now and at 12 GeV) F_L, semi-inclusive flavor decomposition, generalized parton distributions,……



Also HERMI
Drell-Yan,
COMPASS,
many
experiment

Why improve large x PDFs ?

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  - Current and upcoming neutrino oscillation experiments
  - A host of results from Jefferson Lab (now and at 12 GeV) F_L, semi-inclusive flavor decomposition, generalized parton distributions,……
  - Can also be relevant to heavy particle production in a colli

Mass M , center-of-mass energy $\sqrt{s}$, rapidity Y

$x_a = (M/\sqrt{s})e^Y$
$x_b = (M/\sqrt{s})e^{-Y}$
$(x_a)(x_b) = M^2/s$

$M^2/s \le x_i \le 1$
Factorization scale (“Q”) ~ M

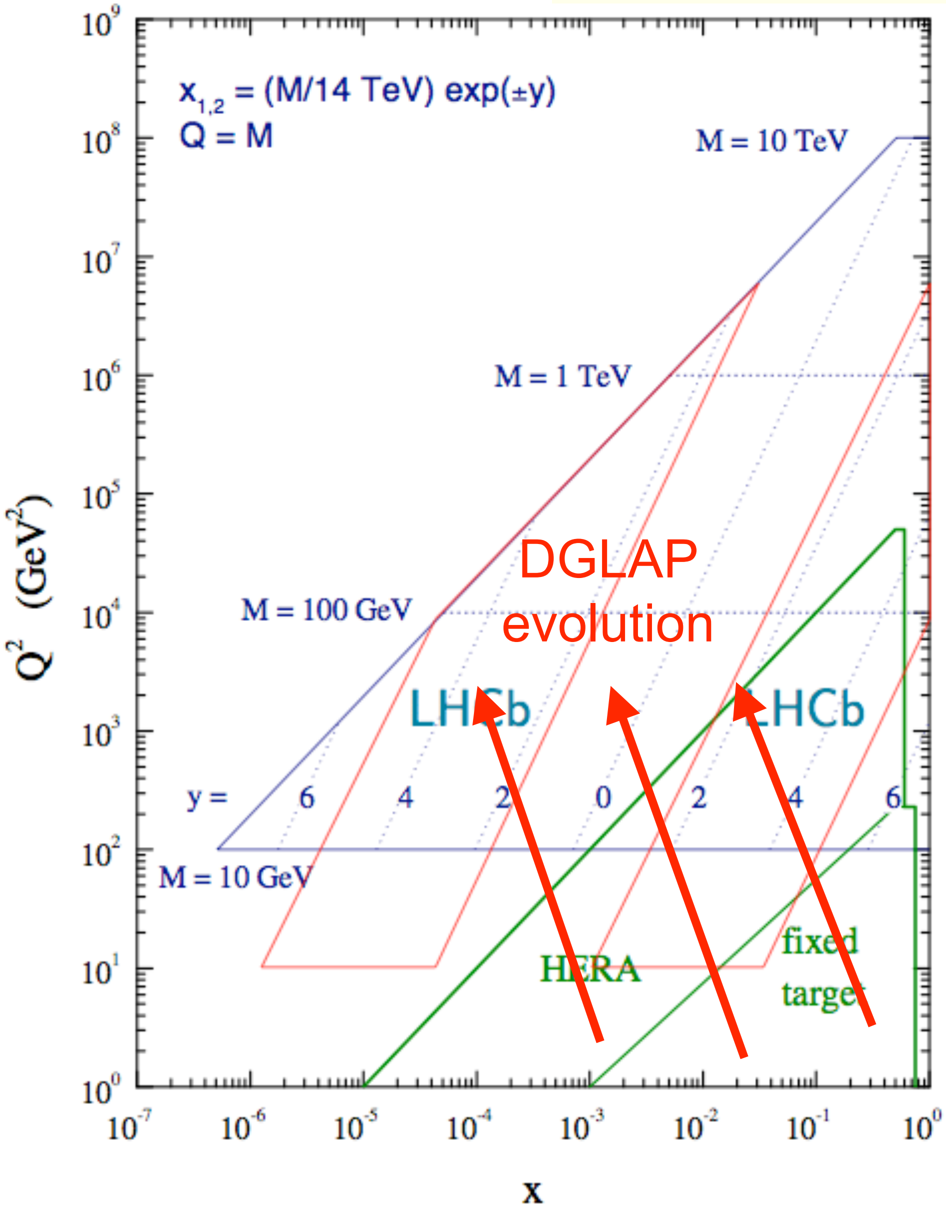
Large Y with large M means one x is small, the other large.

For a $q\bar{q} \rightarrow M + X$ subprocess at the LHC, one could have one q at small x and a valence q at large x

More generally...

$$\frac{dq_i(x,t)}{dt} = \frac{\alpha_s(t)}{2\pi}\int_x^1 \frac{dy}{y}\left[P_{qq}\left(\frac{x}{y}\right) q_i(y,t) + P_{qg}\left(\frac{x}{y}\right) g(y,t\right.$$

$$\frac{dg(x,t)}{dt} = \frac{\alpha_s(t)}{2\pi}\int_x^1 \frac{dy}{y}\left[\sum_{i=1}^{n_f} P_{gq}\left(\frac{x}{y}\right) q_i(y,t) + P_{gg}\left(\frac{x}{y}\right) g\right.$$



DGLAP evolution allows high Q pd
to be generated from those at lower

Evolution at a value x_0 only require
knowledge of the pdfs at values of x
x_0

As a result, high-x, low-Q feeds low
x, higher-Q

Knowledge of the pdfs at some start
value Q_0 is, in principle, sufficient t
calculate the pdfs at all higher value
Q

Wide kinematic range over which p
must be known

Collaboration and Goals

A. Accardi, E. Christy, C. Keppel, W. Melnitchouk, P. Monaghan,
J. Morfín, J. Owens

CTEQ, JLab

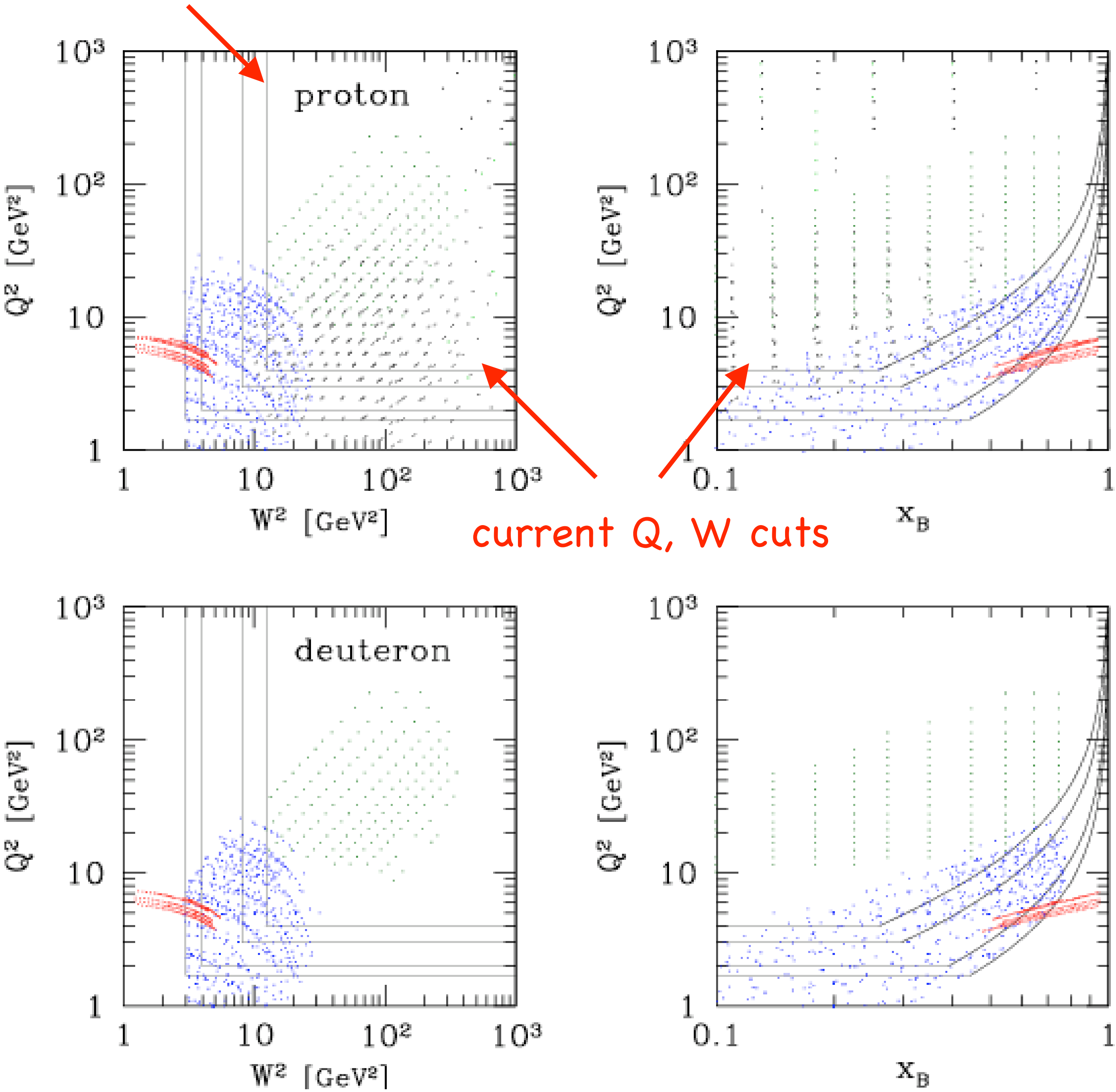
Initial Goals:

- Extend CTEQ PDF global fit to larger values of x_B and lower values of Q:

  $$Q^2 > 4\ \mathrm{GeV}^2,\ W^2 > 12.25\ \mathrm{GeV}^2$$

- Incorporate data from large x and new experiments

First, need to reduce typical W, Q cuts....



Lots of (new) da available

BUT, need of theoretical cont on DIS over *at least:*

target mass corrections (
$\propto x_B^2 m_N^2 / Q$

higher twist $\propto$
Q^2

deuterium nuc corrections

Target Mass Corrections - There are options!

A Review of Target Mass Corrections, Ingo Schienbein et al., J.Phys.G 35:053101 (200

- Nachtmann variable $\xi = 2x\left[1 + (1 + 4M^2x^2/Q^2)^{1/2}\right]$
- **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

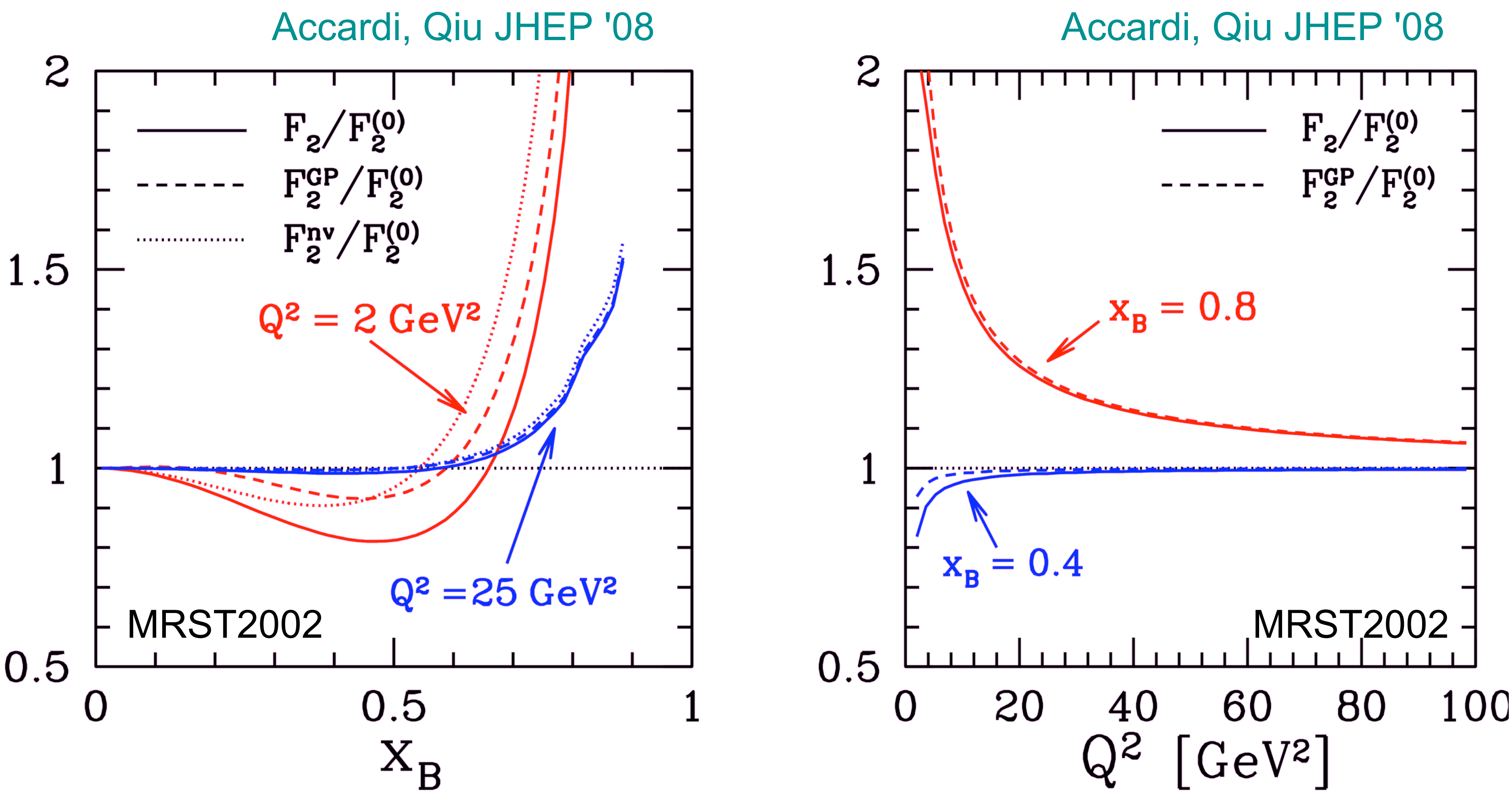
$$F_{T,L}(x_B, Q^2, m_N) = \sum_f \int_\xi^{\frac{\xi}{x_B}} \frac{dx}{x}\, h^f_{T,L}\left(\frac{\xi}{x}, Q^2\right) \varphi_f(x, Q^2)$$

  - 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 (!)

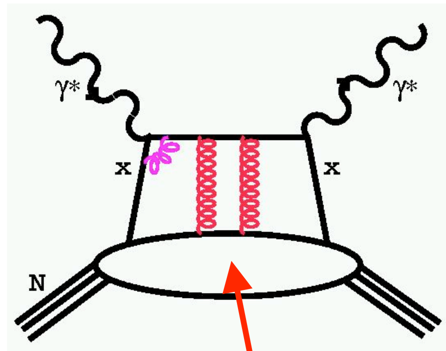
Target mass corrections – F_2 at NLO



Crucial at low Q^2, large x

Crucial *even at high Q^2* at high x – not taken into account in current pdf analyses

Higher-Twist Parameterization



Parameterize the higher-twist contributions by a multiplicative factor:

$$F_2(\text{data}) = F_2(\text{TMC})\,(1+C(x)/Q^2)$$

$$C(x) = a\,x^b\,(1 + cx)$$

SIMPLE parametrization is sufficiently flexible to good fits to data *(except when no TMCs are included)*

Deuteron Nuclear Corrections

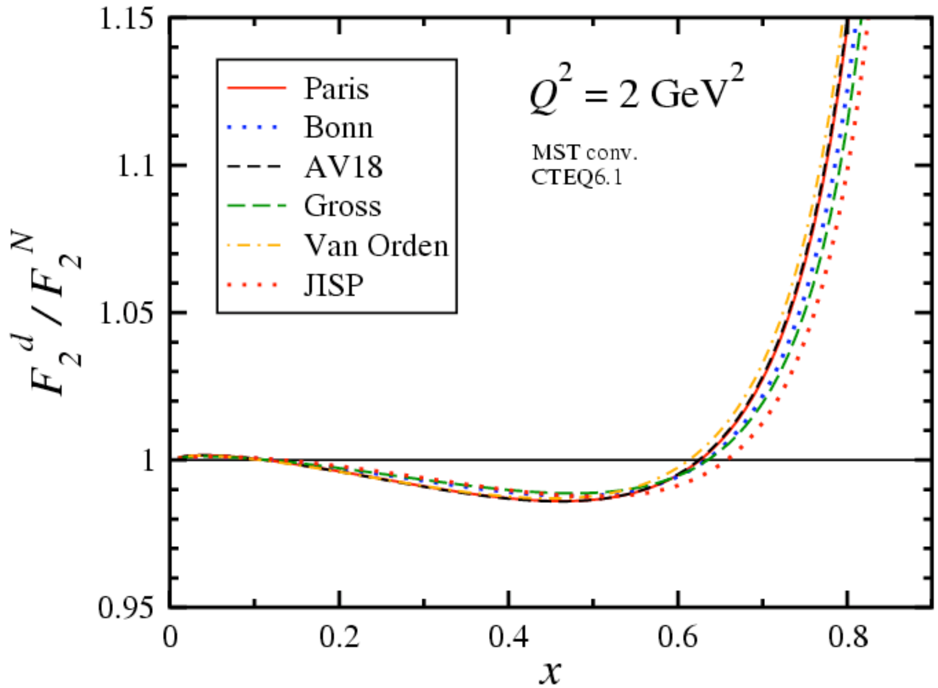
Nucleon Smearing Model, Fermi motion and binding energy [Kahn et al., arXiv:0809.4308; Accardi et al., *in preparation*]

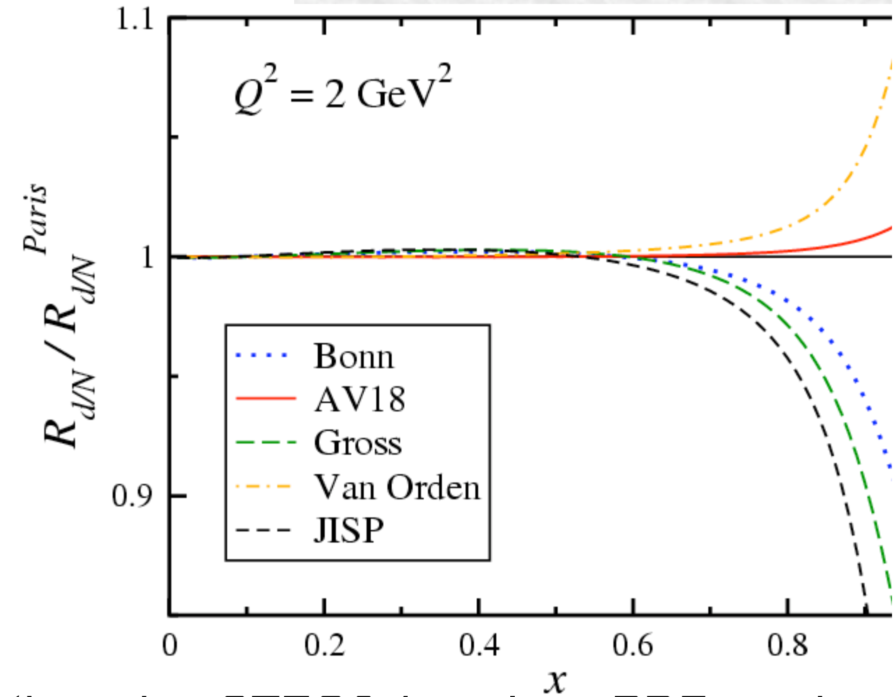
Important to go beyond Bjorken limit, allows finite-Q^2 corrections

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

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

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





LEFT Deuteron to nucleon structure function ratio, using CTEQ6.1 nucleon PDFs and va smearing functions

RIGHT The same, relative to that for the Paris wave functions. The effects are of the orde 5% at x ~ 0.8

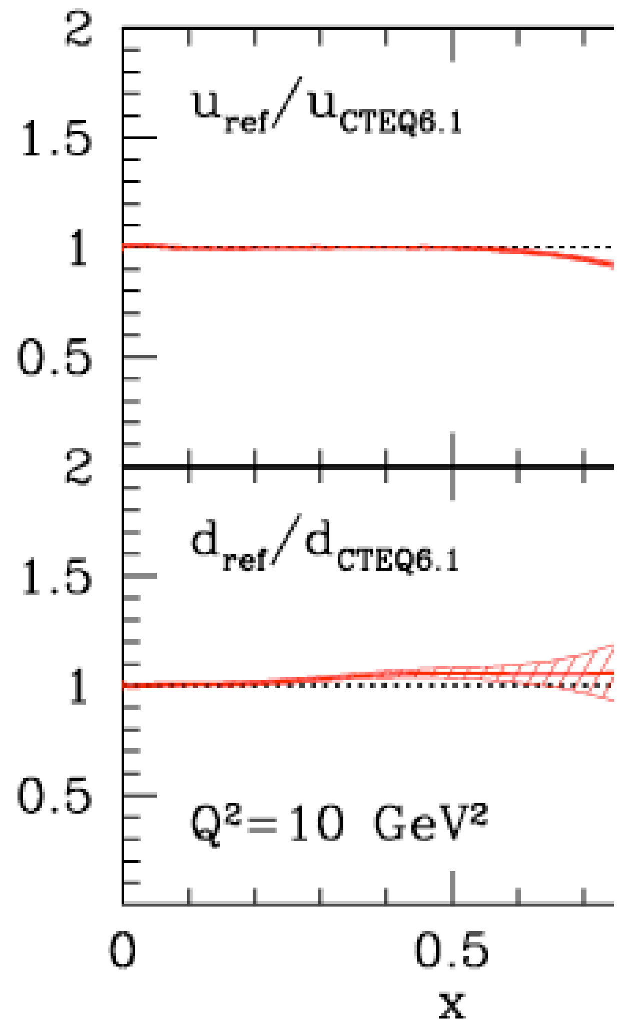
Global Fitting

We are using Jeff Owens' (CTEQ) NLO DGLAP fitting package

- Fit DIS *(including SLAC and JLab!)* proton and deuteron, E866 Drell-Yan, CDF W lepton asymmetry, jets (and γ+jet)
- First, compare "Reference Fit" to CTEQ6.1 parameterization of PDFs at Q^2=1.69 GeV^2

  u-quark suppression, d-quark enhancement

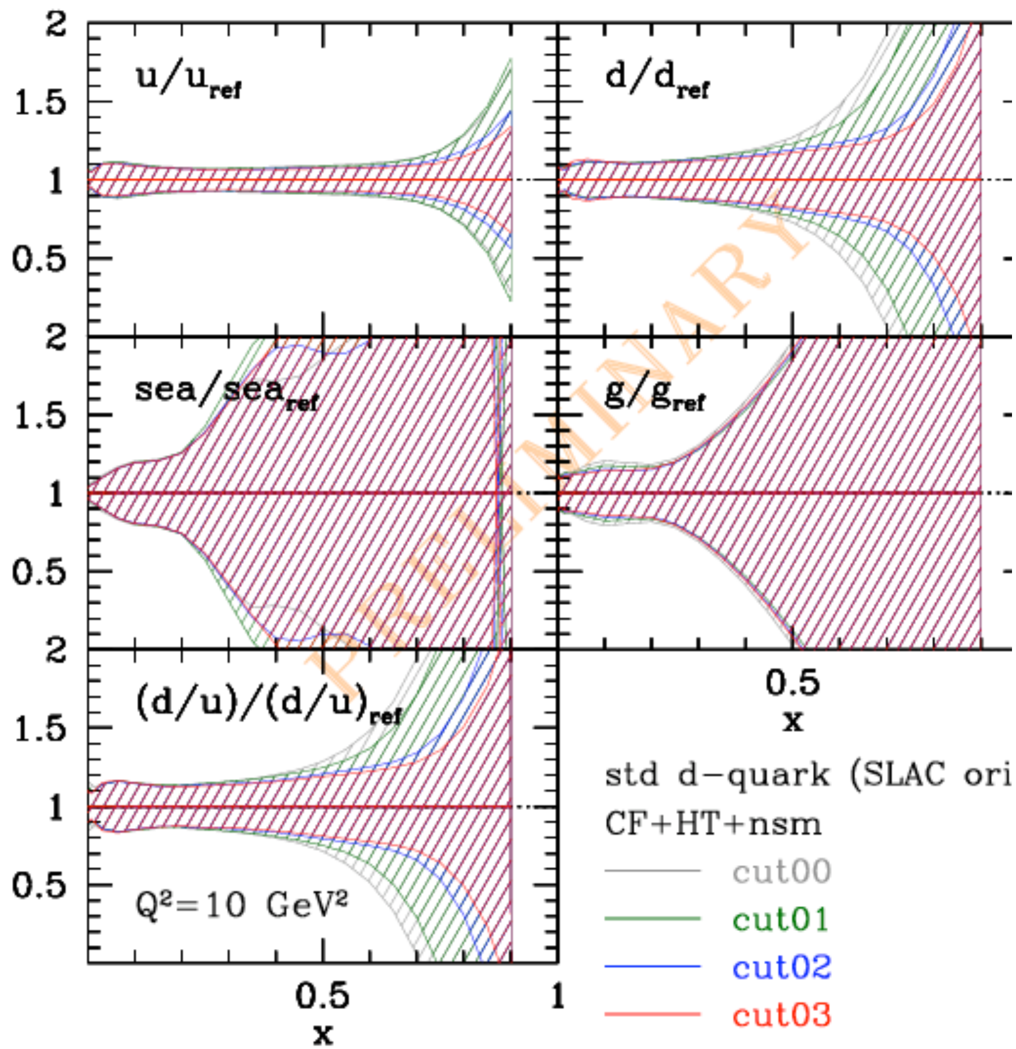
  mainly due to E866 DY and SLAC DIS data
- Next: Systematically reduce Q, W (x) cuts:
- Multiple TMC terms added
- Higher-twist contributions by a multiplicative factor
- Nuclear corrections for deuteron targets added
- PDF errors computed by the Hessian method, with $\Delta\chi^2$=1



Preliminary Results

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

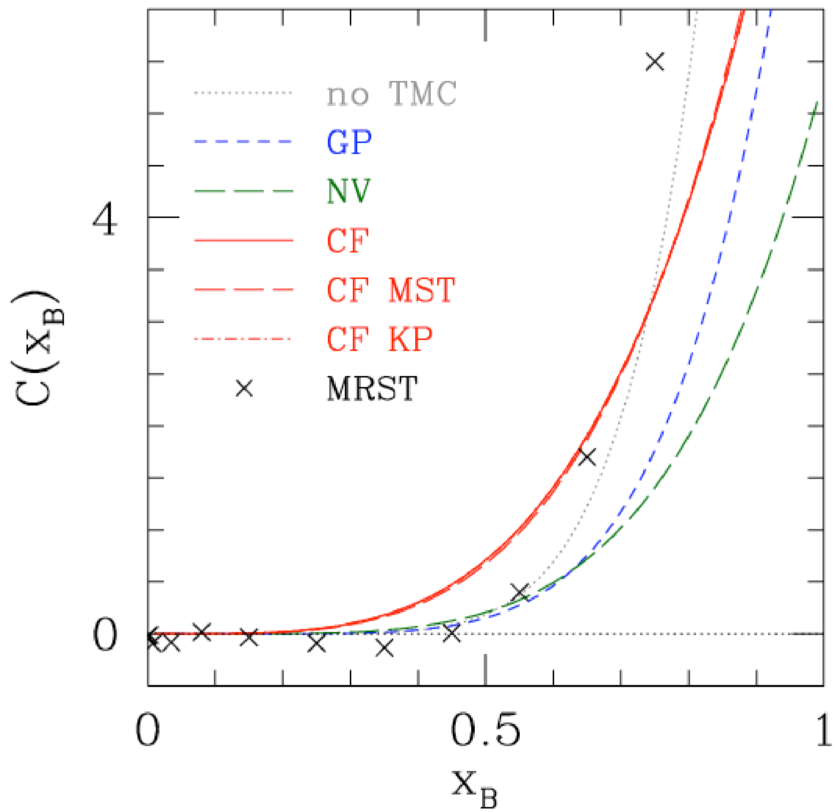
	Q^2 [GeV^2]	W^2 [GeV^2]
cut00	4	12.25
cut01	3	8
cut02	2	4
cut03	1.69	3



Glue, sea not constrained by the new data

Preliminary Results

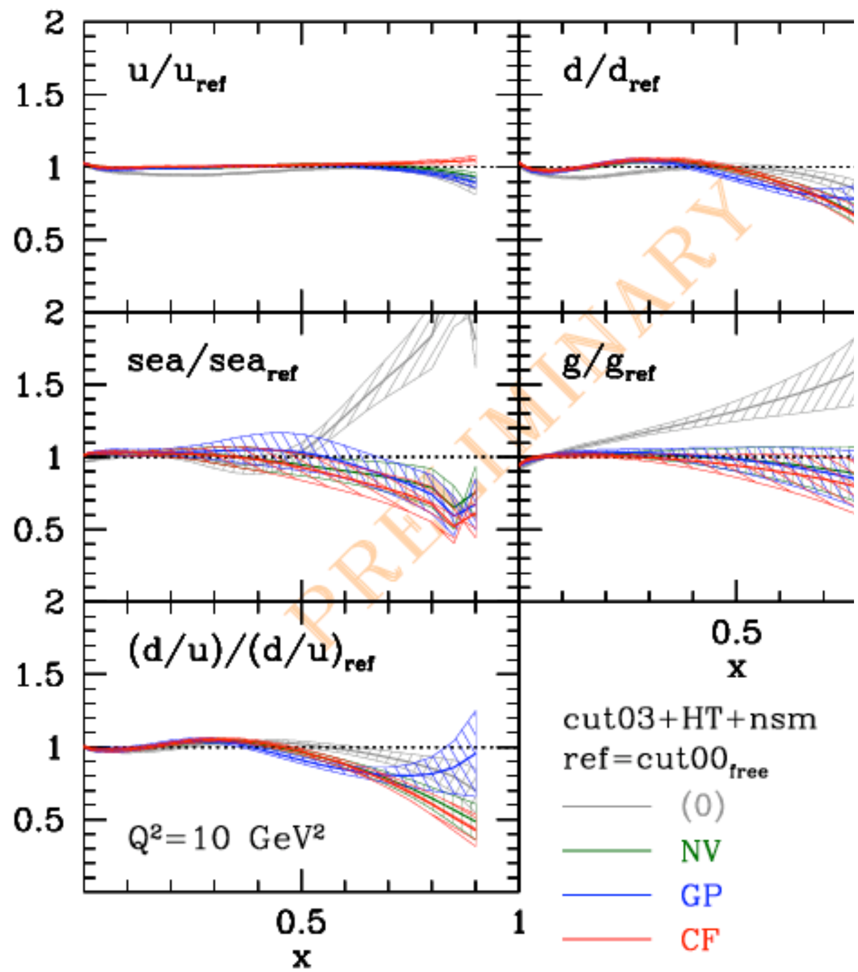
Extracted higher-twist term depends on the type of TMC used



- $Q^2 > 1.69$ 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 small errors on HT coefficients *a, b*, and *c*

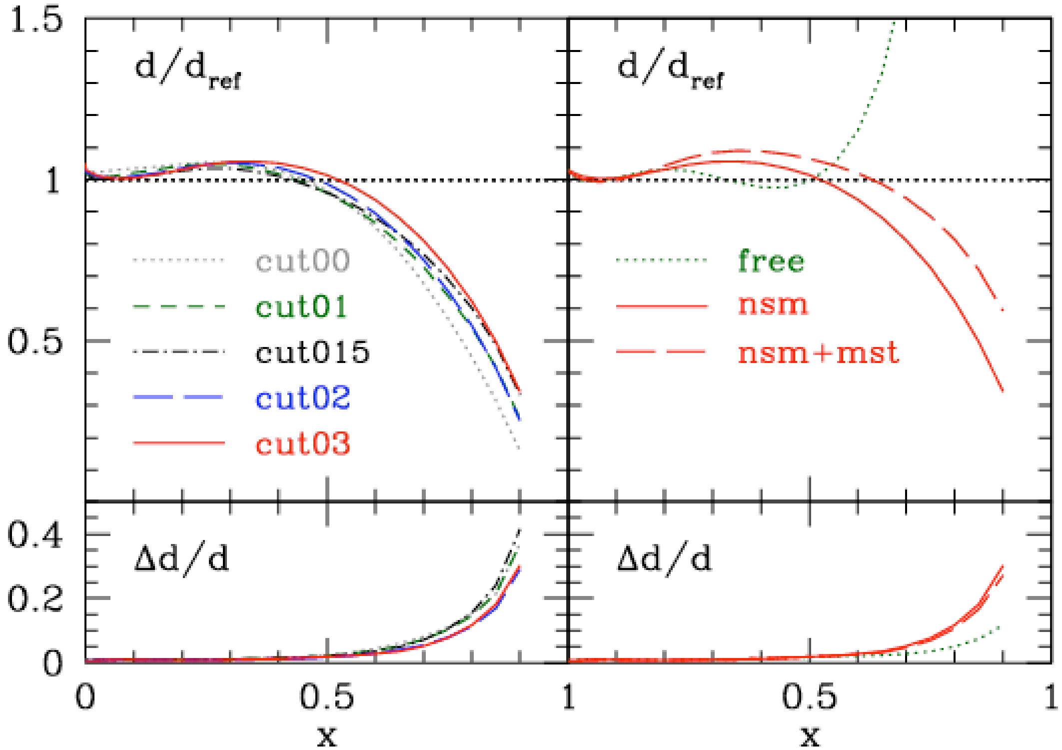
Preliminary Results - Good News!

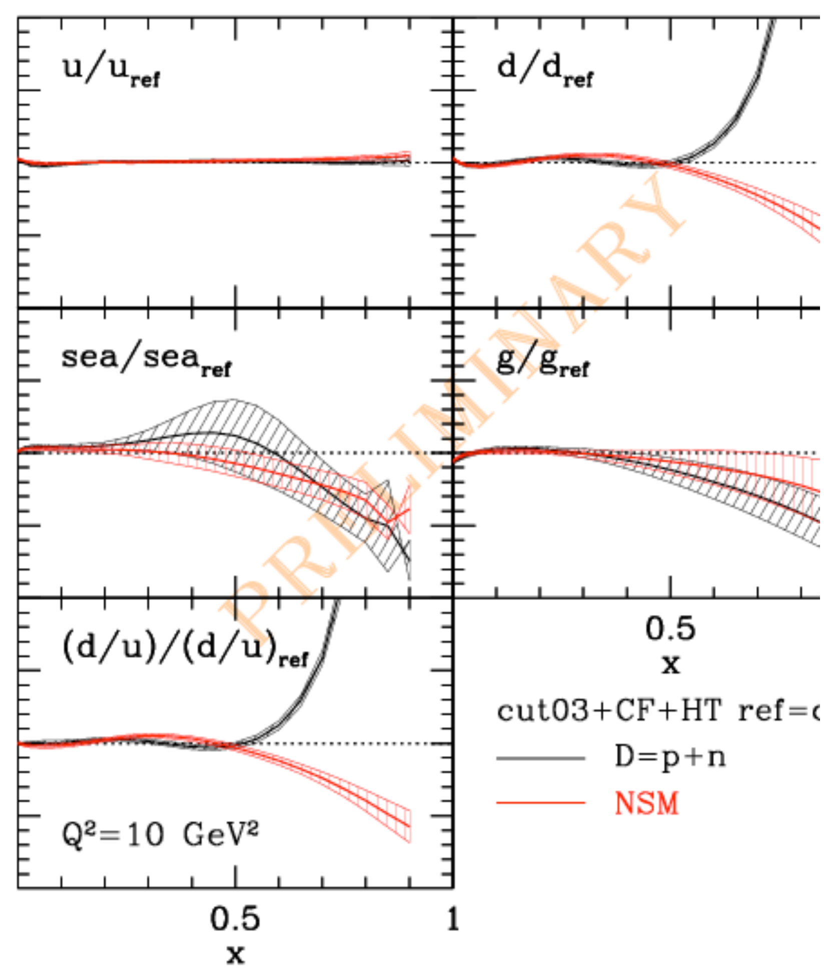
- **Extracted twist-2 PDF *much less sensitive* to choice of TMC!**
  - fitted HT function compensates the TMC
  - except when no TMC is included
- **Largest effect on *d*-quark**
- $Q^2 > 1.69$ GeV^2, $W^2 > 3$ GeV^2 (referred to as 'cut03')
- plots relative to fit with
  - $Q^2 > 4$ GeV^2, $W^2 > 12.25$ GeV^2 ("cut00" ≡ CTEQ6.1 cuts)
  - no TMC, no HT, no nuclear correction



Preliminary Results

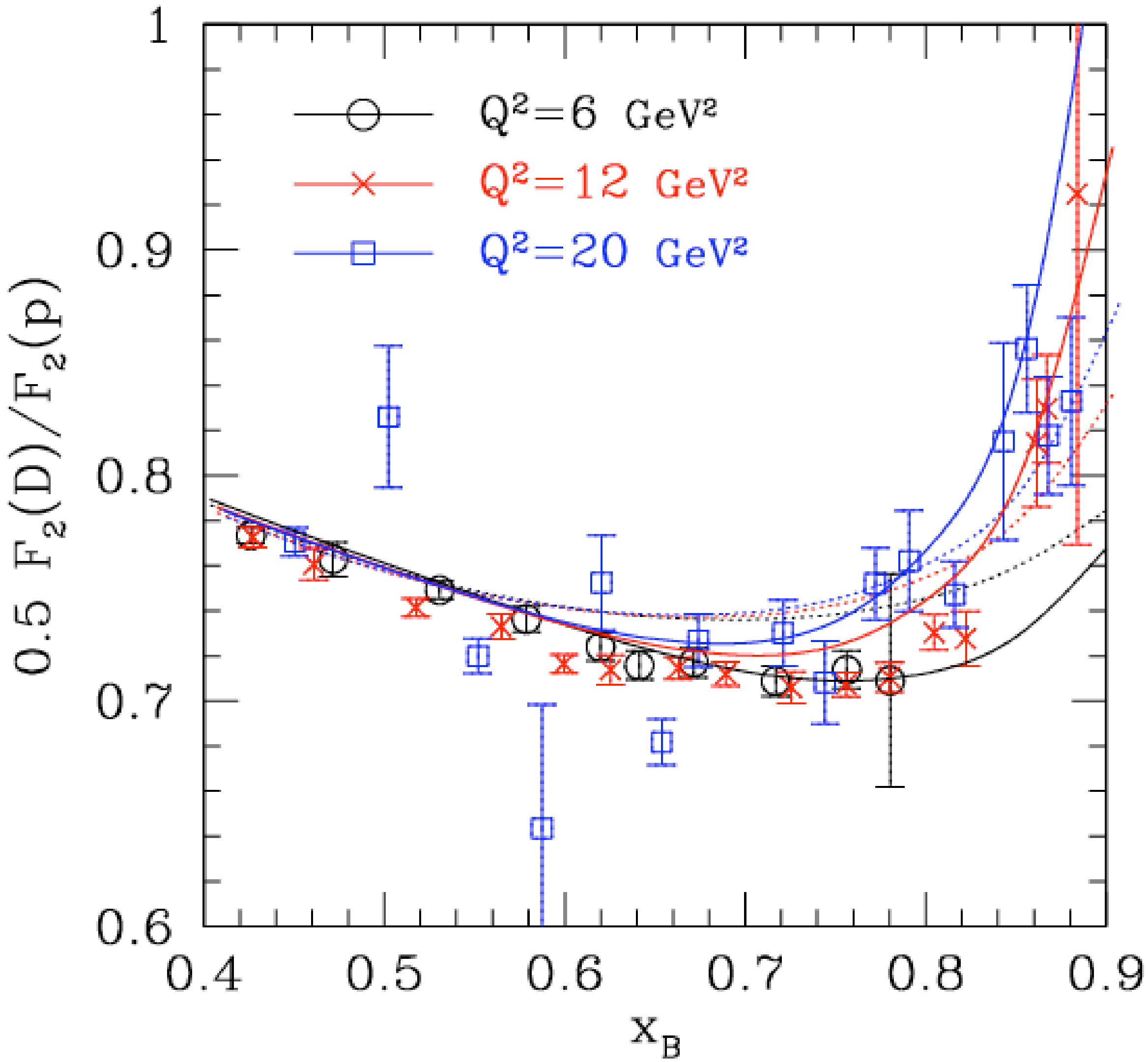
- **Deuterium corrections have large effect on *d*-quark**





- Lower d (and d/u) at large x
- Slightly higher d in "moderate" x region

Nuclear correction convoluted with target mass - models well the Q^2 dependence of the data



SLAC dat

New pdfs, nuclear model for D

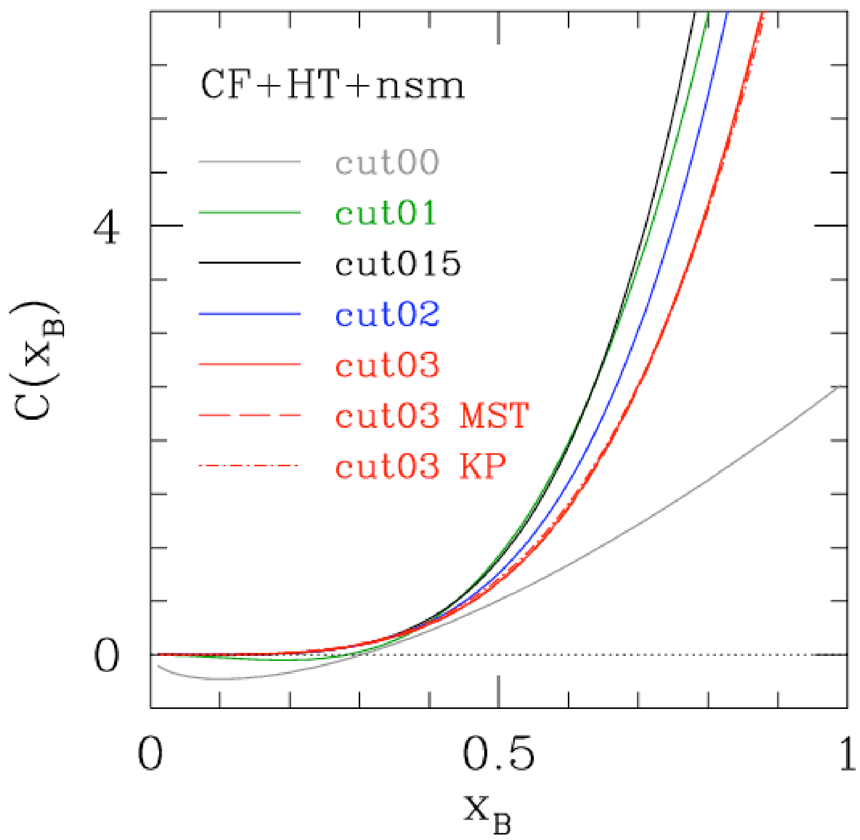
Conclusions

- A new series of global PDF fits is *underway* with expanded kinematic range and an enlarged data set
  - PDFs relatively insensitive to higher twist, target mass so long as bc are taken into account
  - PDF errors are reduced by the expanded large-x_B data set
  - Preliminary indications suggest a suppressed *d(x)* at large *x*
  - Large effect of deuterium corrections under study (on-shell extrapolation)

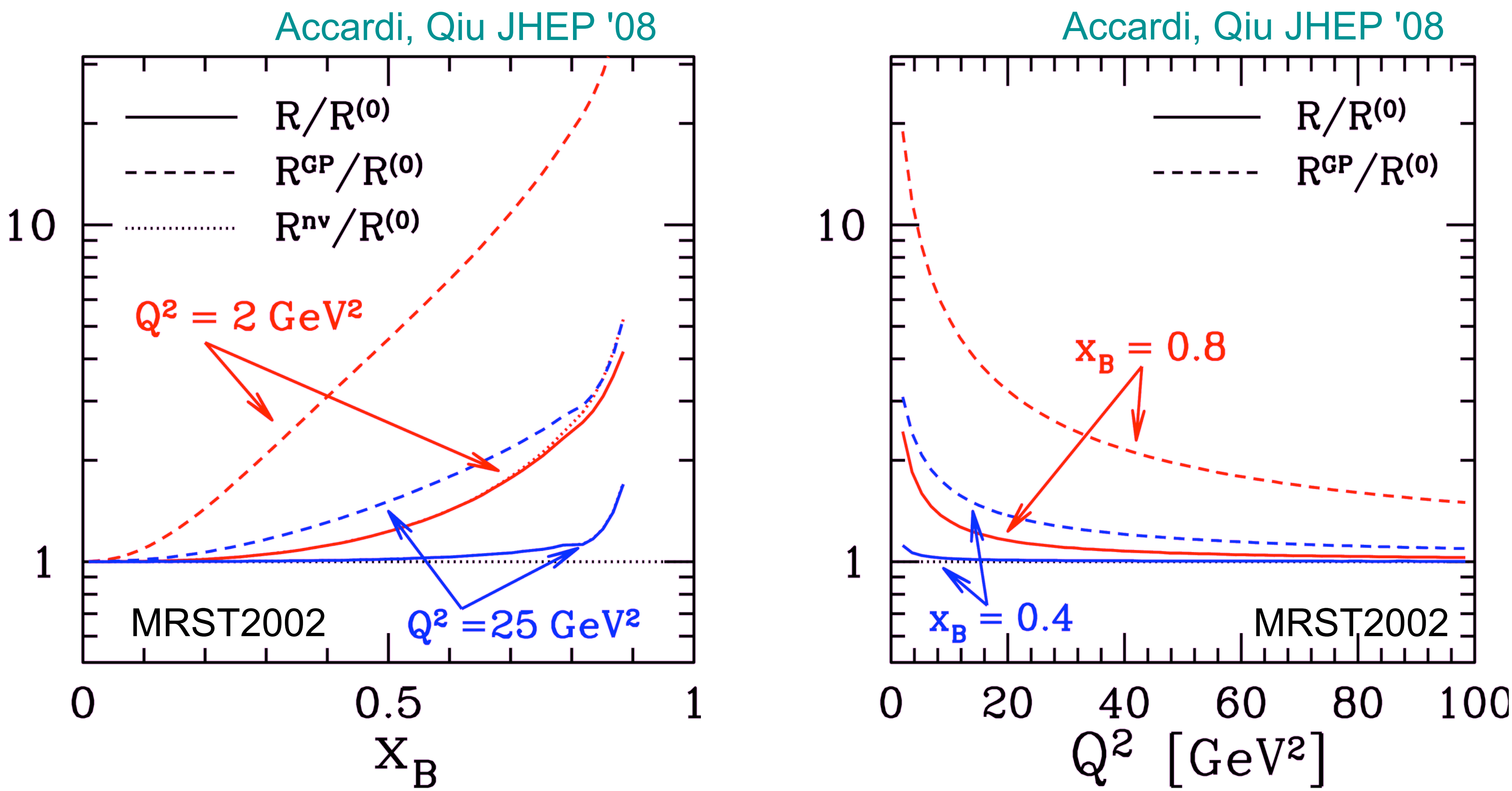
- In near future, use JLab data to
  - Constrain the gluons using F_L
  - Incorporate d/u at large x from BONUS

- Additional theoretical effects to be included:
  - Large-x resummation
  - Effect of Jet Mass Corrections
  - Parton-hadron duality – further reduce kinematic cuts

extra slides



Target mass corrections, $R = \sigma_L/\sigma_T = F_L/F_1$ at NL



Still crucial at low Q^2, large x

May be crucial *even at high Q^2* at high x

May be crucial *even at low Q^2* at low x