Global Fits for PDFs

at

Large-x

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Outline

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Introduction

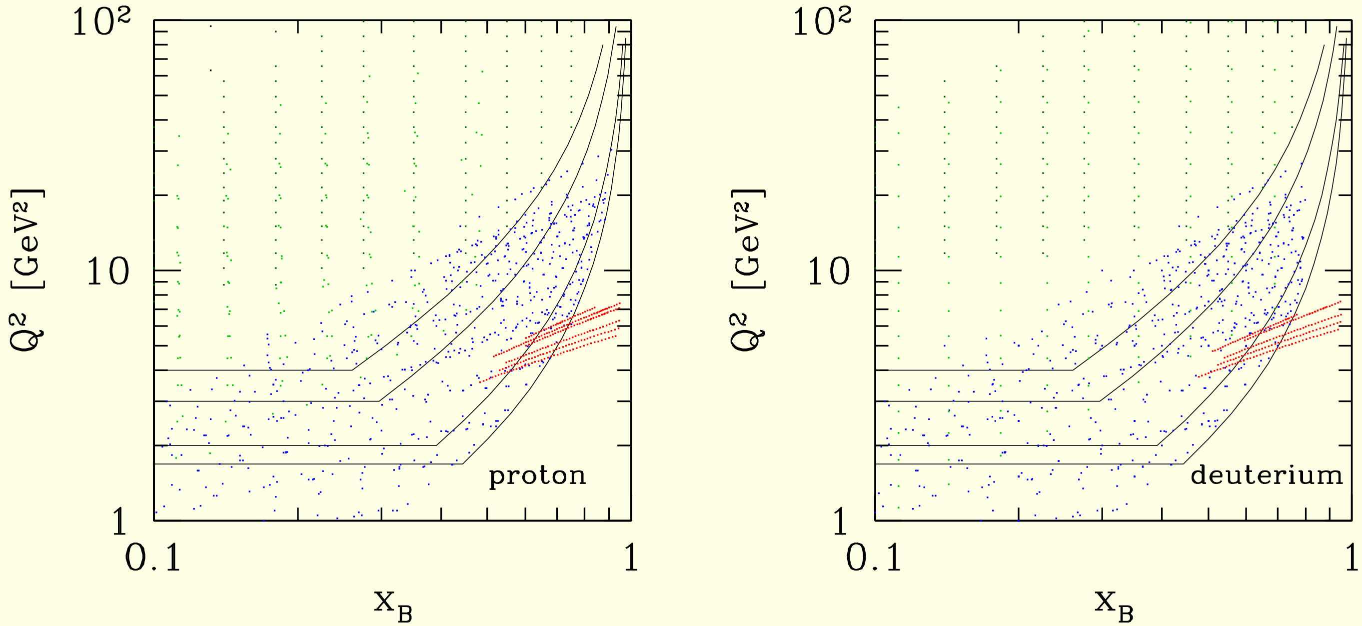
Cast of characters - Alberto Accardi, Eric Christy, Cynthia Keppel, Wally Melnitchouk, Peter Monaghan, Jorge Morfín, JFO, and Lingyan Zhu

Goals:

- Extend PDF fits to larger values of x and lower values of Q
- Wealth of data from older SLAC experiments and newer JLAB experiments
- Study effects of different target mass correction methods
- Explore role of higher twist contributions

Motivation

- Traditional global fits focus on leading twist PDFs convoluted with hard scattering partonic cross sections
- For DIS require cuts on Q and W to avoid regions with contributions from higher twist terms and target mass corrections
- $W^2 = m^2 + Q^2(\frac{1}{x} - 1)$ limits $x \leq \frac{Q^2}{W_{min}^2 - m^2 + Q^2}$
- Need large Q^2 in order to get near $x \approx 1$ with $W \geq W_{min}$
- Lower energy fixed target experiments - run out of Q
- Higher energy experiments - run out of statistics
- Typically use $Q > 2$ GeV and $W > 3.5$ GeV
- When applied to existing DIS data sets this results in $x \lesssim .7$



- Red = JLAB, Blue = Slac, Green = BCDMS and NMC
- Four boundaries correspond to four sets of (W, Q) cuts to be discussed later
- Top boundary is the one used in previous fits
- Lower boundary is the one used for the results to be shown in this talk

Question - how does one constrain PDFs in regions which are excluded by kinematic cuts?

- Use momentum sum rule and quantum number sum rules for PDFs
- Rely on evolution equations - high x, low Q feeds lower x, higher Q
- Both provide indirect constraints on the PDFs as one integrates over a larger region than is covered by data

But, one would also like a direct comparison - requires a lowering of the cuts on W and Q.

- Target mass corrections and higher twist contributions will become important
- Fermi motion smearing for deuterium targets becomes important at high x

Other Hard Scattering Processes

Lepton Pair Production

- $x_1 x_2 = \frac{M^2}{s}$ and $x_F = x_1 - x_2$
- Can get to large x_1 if high-x_F data are available
- E-866 reaches to $x \approx .8$

W asymmetry

- $x_{1,2} = \frac{M_W}{\sqrt{s}} e^{\pm y}$
- W asymmetry directly sensitive to large x d/u at large y
- Effect is reduced if decay lepton asymmetry is used
- Newer data reach to $x \approx .8$

DIS Target Mass Corrections

Several different methods available

- Standard Georgi-Politzer method
- Collinear Factorization
  - Jianwei Qiu and Alberto Accardi - arXiv:0805.1496 [hep-ph], JHEP 0807:090, 2008.
  - See also Jianwei's talk at the 2005 JLAB meeting/workshop on the CTEQ web page
- Naive TMC - to be defined below

Some comments on TMCs

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

  - In the standard GP formalism $\xi < 1$ when $x_B = 1$
  - Leads to non-zero structure functions at $x_B \geq 1$

- Collinear factorization gives structure functions as a convolution which respects the kinematic boundaries

$$F_{T,L}(x_B, Q^2, m_N^2) = \int_{\xi}^{\xi/x_B} \frac{dx}{x} h_{f|T,L}(\xi/x_B, Q^2)\phi_f(x, Q^2)$$

  where h_f is a parton-level helicity structure function and ϕ is the respective PDF

- Naive

$$F_{T,L}(x_B, Q^2, m_n^2) = F_{T,L}(\xi, Q^2)$$

Higher Twist parametrization

Parametrize the higher twist contribution by a multiplicative factor

$$F_2(data) = F_2(TMC) * (1 + C(x)/Q^2)$$

where

$$C(x) = a * x^b (1 + c * x + d * x^2)$$

Comments:

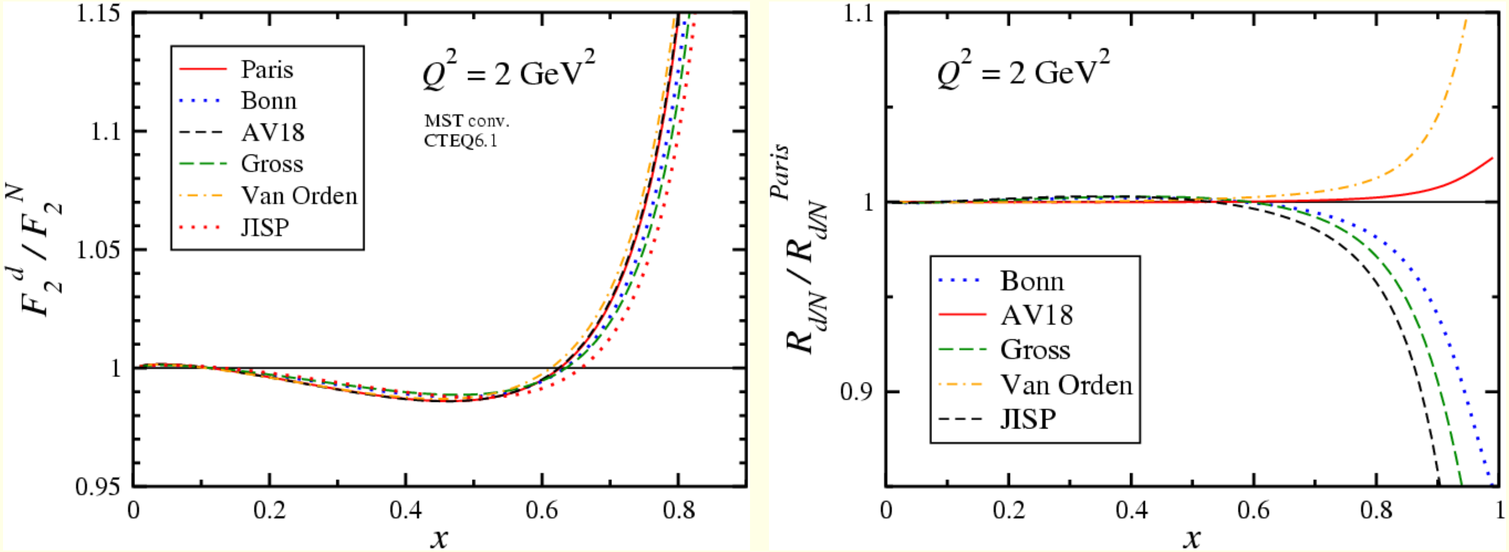
- Parametrization is sufficiently flexible to give a good fit to the data
- Parameter d not really needed since for x near 1 there is not a lot of difference between x and x^2

Nuclear Smearing Corrections

Use a convolution formalism wherein

$$F_2^d(x, Q^2) \;=\; \sum_{N=p,n} \int_x^{M_d/M} dy\; f_{N/d}(y,\gamma)\; F_2^N\left(\frac{x}{y}, Q^2\right) , \qquad (1)$$

- The smearing function $f_{N/d}(y,\gamma)$ gives the distribution of nucleons in the deuteron as a function of the lightcone momentum fraction y and a finite Q^2 correction factor $\gamma = \sqrt{1 + 4x^2M^2/Q^2}$
- Use the Paris wavefunction for the deuteron
- Have also compared the effects of other non-relativistic wavefunctions (CD-Bonn and AV-18)



- Similar results from Paris, CD-Bonn, and AV18 wavefunctions
- Variations between these three for F_2^d/F_2^p are less than 5% for $x \lesssim .9$

Fitting Package

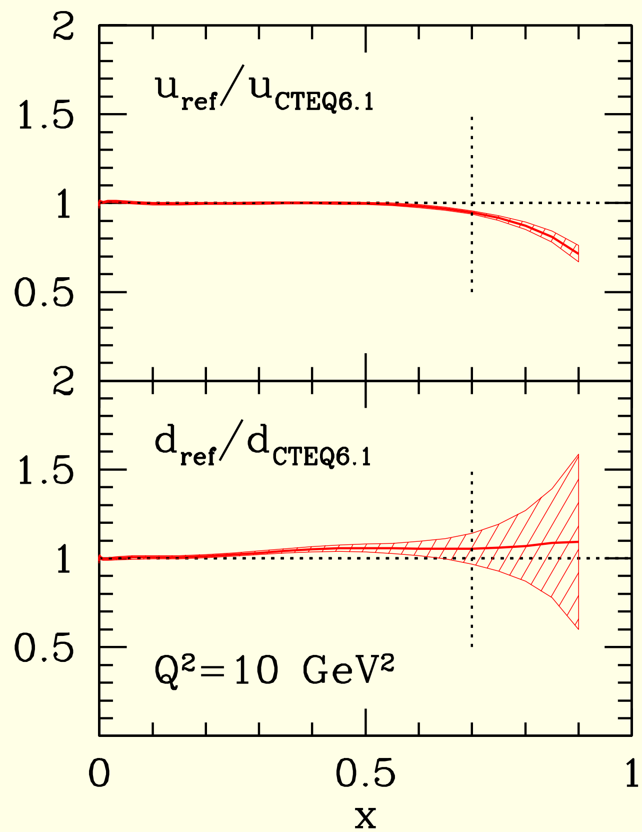
We are using my NLO DGLAP fitting package which I have continued to update and extend

- Can fit DIS, Drell-Yan, W lepton asymmetry, jets, and γ + jet
- Routines for the DØ γ+ jet data recently added
- W lepton asymmetry routine allows for a single p_T cut, but a generalization to allow for multiple p_T cuts has been developed
- Added PDF errors (Hessian method)
- Multiple TMC and HT terms added (Alberto Accardi)
- Some correlated errors added
- Options for nuclear corrections added (Wally Melnitchouk, Alberto Accardi)

Procedure

Reference fit

- Perform a conventional PDF fit in order to have a baseline for comparisons as new contributions are added
  - $Q > 2$ GeV and $W > 3.5$ GeV
  - No TMC, no higher twist, no nuclear corrections
  - BCDMS, SLAC, NMC, H1, Zeus DIS data
  - E-605 and E-866 lepton pair data
  - CDF and D0 jet data
  - W asymmetry and W-lepton asymmetry data
  - DØ γ + jet data
- Data sets similar to those used in CTEQ6.1 except CCFR removed, E-866 added, DØ γ + jet added, and some new W asymmetry data added



- Reference fit is similar to CTEQ6.1
- DIS data coverage for $x \lesssim .7$
- u-quark PDF slightly reduced at larger x values reflecting the effect of E-866
- W-lepton asymmetry data wants a slight increase in d/u, so d stays about the same while u decreases

Next, define a series of standard cuts on Q^2 and W^2

- Cut00: $Q^2 > 4$ GeV^2 , $W^2 > 12.25$ GeV^2
- Cut01: $Q^2 > 3$ GeV^2 , $W^2 > 8$ GeV^2
- Cut02: $Q^2 > 2$ GeV^2 , $W^2 > 4$ GeV^2
- Cut03: $Q^2 > 1.69$ GeV^2 , $W^2 > 3$ GeV^2

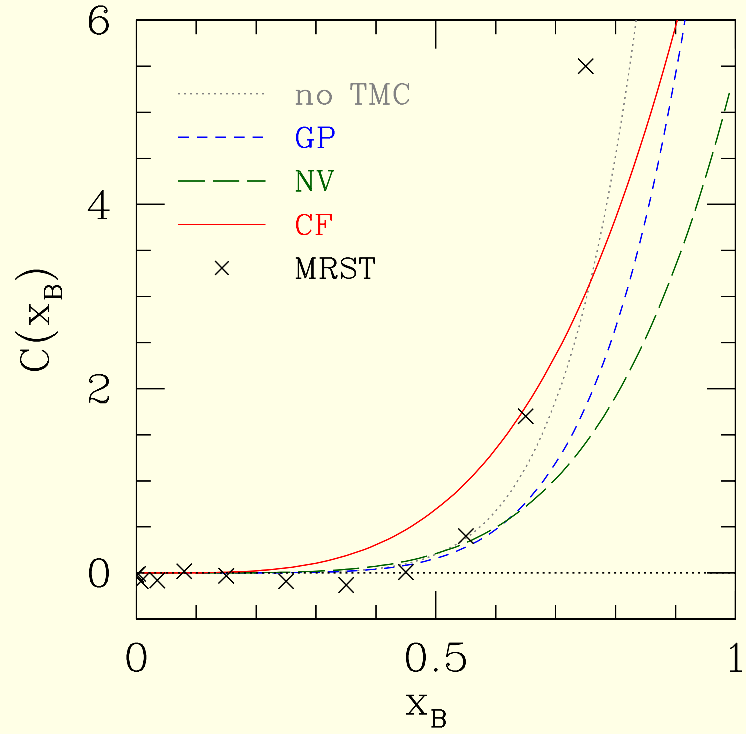
Add nuclear smearing corrections for deuterium, target mass corrections, and higher twist terms

Repeat fits and compare to the reference fit

Note: error bands are calculated using the Hessian method with a χ^2 tolerance of one. Intent is to compare the relative sizes of the error bands as the cuts are varied.

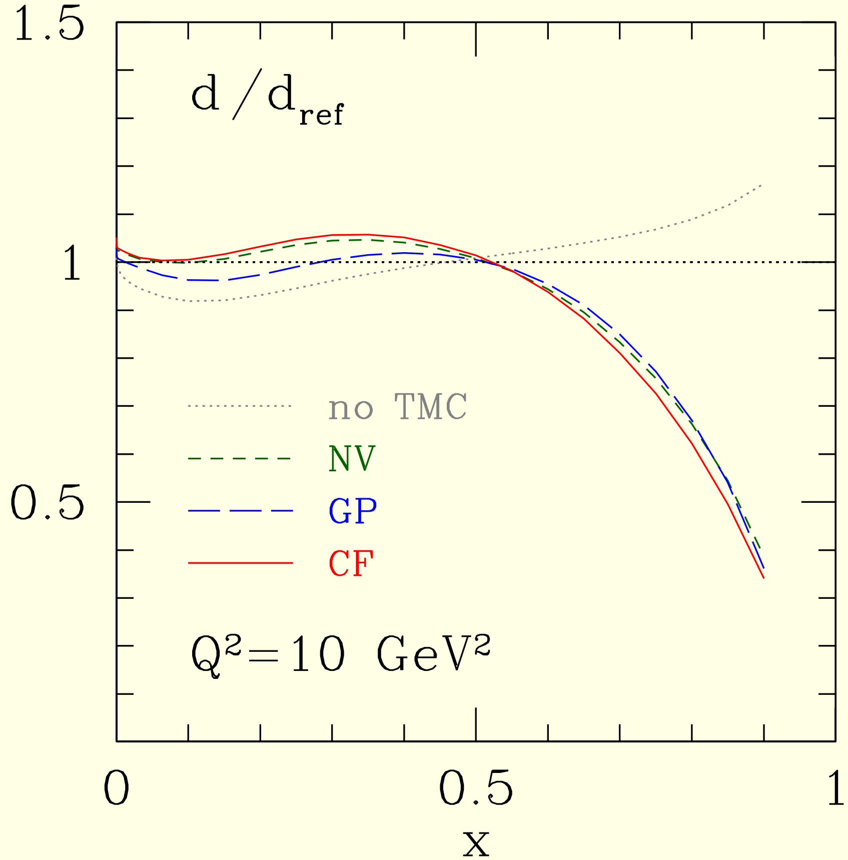
Preliminary Results

Extracted higher twist term depends on the type of TMC used

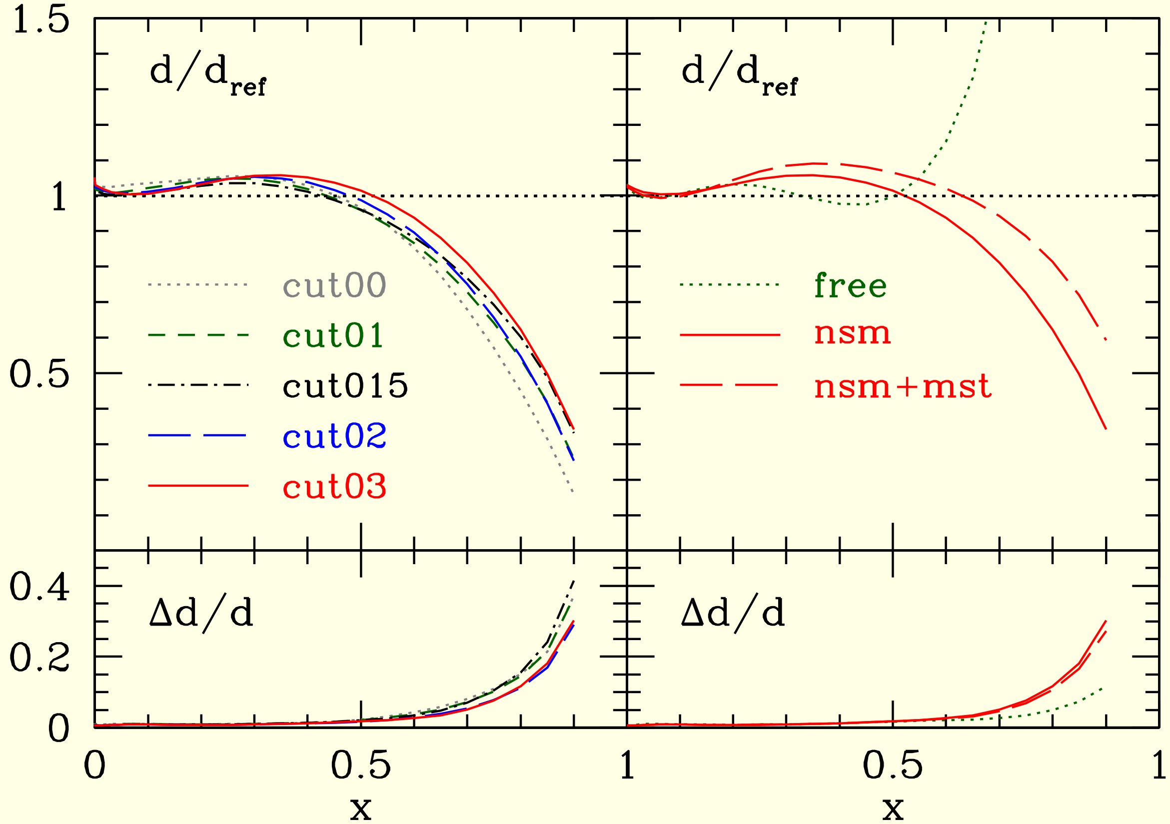


- Cut03: $Q^2 > 1.69$ GeV^2 and $W^2 > 3$ GeV^2
- Grey curve has no TMC (compare to MRST)
- Significant variations observed depending on which TMC model is used

- Extracted twist-2 PDFs much less sensitive to the choice of TMC
- Fitted higher twist function compensates the TMC so that the twist-2 PDFs are relatively stable
- Plots are relative to the Reference Fit
- Largest effect is on the d distribution



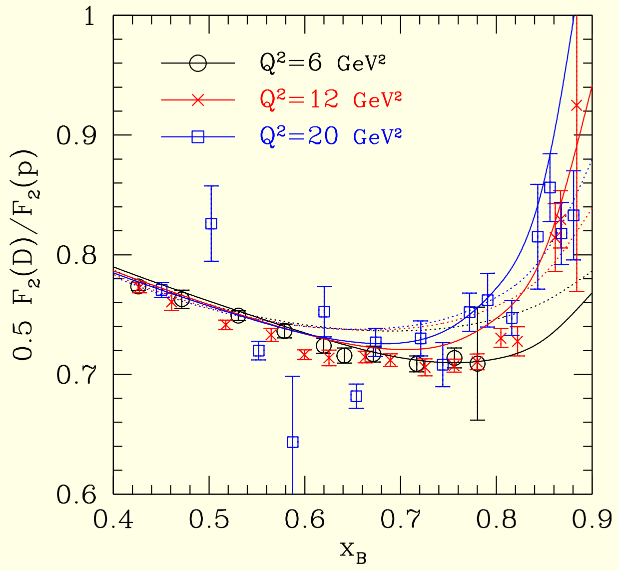
Effects of Cuts



- Decrease in d PDF is slightly moderated as the cuts are decreased
- Decrease is totally driven by the nuclear smearing corrections for deuteron targets
- Relative errors on d PDF decrease slightly as more data are added

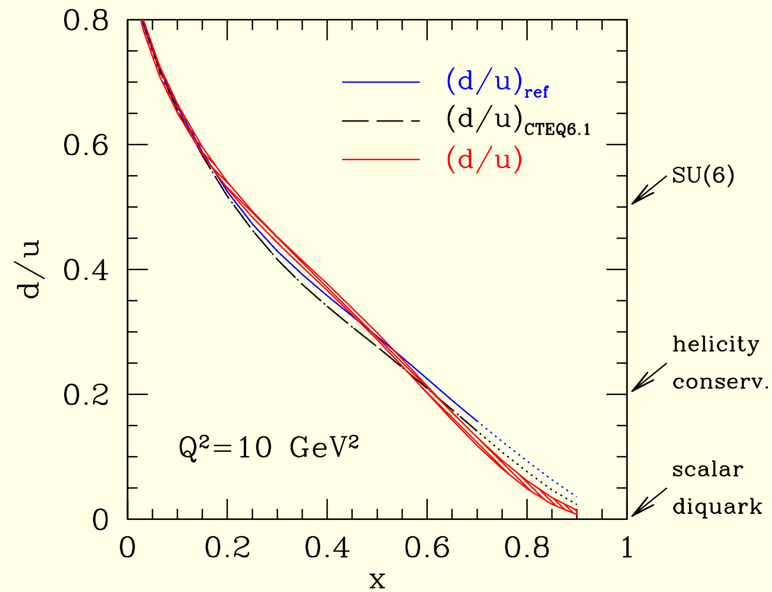
Discussion

Results depend on the deuteron nuclear correction model used. As a cross check, look at F_2^d/F_2^p.



- Solid curves have nuclear corrections included, dashed curves do not
- Q^2 dependence is well described in the smearing formalism.

d/u ratio



- d/u ratio is reduced at large values of x
- Reflects inclusion of nuclear corrections
- Previous fits ignored nuclear corrections, used cuts to restrict the x range to below .7 or so and then *extrapolated* the result to higher values of x.

Conclusions

- A new series of fits is underway with an expanded kinematic range and enlarged data set
- Preliminary indications suggest that the d/u ratio will be decreased from previous fits in the large x region
- Stable twist-2 PDFs can be extracted provided that both TMC and HT terms are included
- It appears to be possible to use an extended kinematic range of DIS data in order to better constrain large-x PDFs