Strangeness and Charm in PDFs

Jon Pumplin

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Global Analysis to measure Parton Distributions

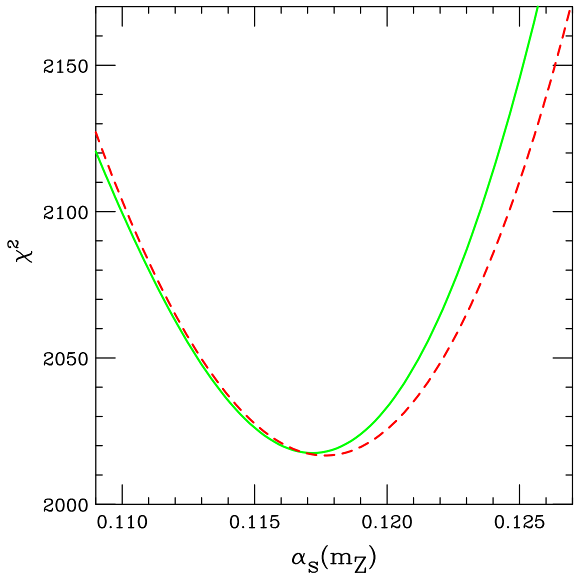
Recent work by Tung, Stump, Huston, Pumplin, Yuan, Lai, Belyaev

- Improved theory: ZM $\rightarrow$ GM
- Improved data sets: all HERA run I data
- Study of Strangeness uncertainty
- Study of Charm uncertainty

Light Cone Theory for Intrinsic Charm

(Portions of a talk for next week at LC2006.)

Global ChiSqr vs. $\alpha_s(m_Z)$

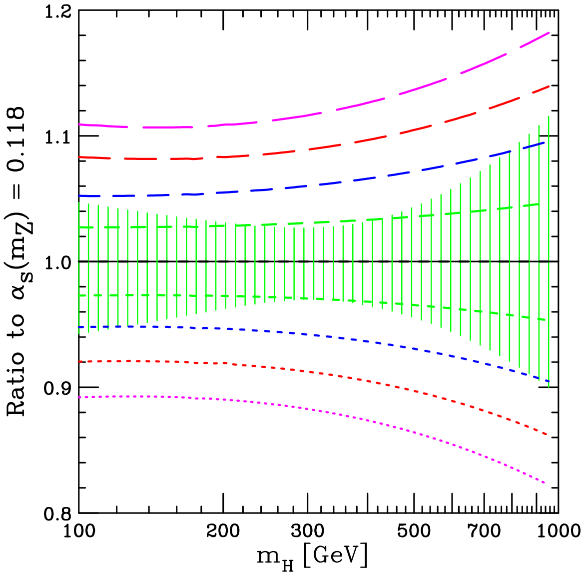


Goodness-of-fit vs. $\alpha_s(m_Z)$ using two NLO-equivalent forms for $\alpha_s(\mu)$.

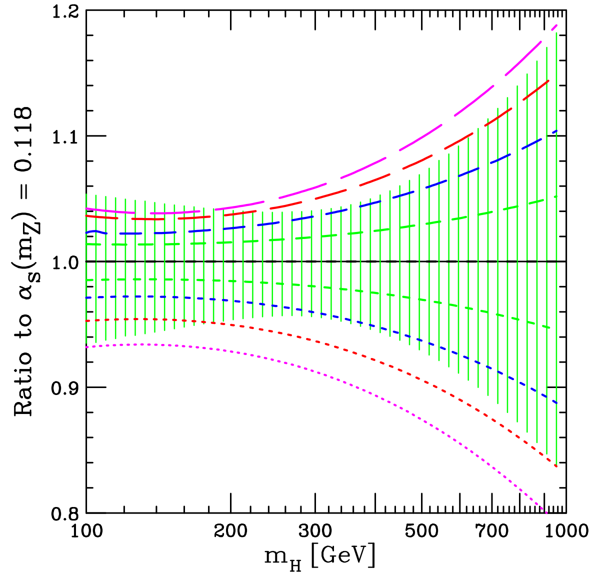
CTEQ6AB series of fits at $\alpha_s(m_Z) = 0.110$, 0.112,. . . ,0.124 were shown at CTEQ JLAB meeting last November.

Minima at $\alpha_s(m_Z) = 0.1172$ and 0.1176, very close to the world average (0.1187 ± 0.0020) and to the value 0.1180 assumed in CTEQ6M and CTEQ6.1M.

Higgs cross sections at LHC



SM



MSSM ($\tan\beta = 50$)

- Uncertainty in $\alpha_s(m_Z) \sim$ doubles uncertainty in σ_H. The large uncertainty due to α_s is not surprising in view of the natural α_s^3 behavior of the leading order process $gg \to H$.

Updates in Global Analysis

Theory update:

- Remove Zero-Mass approximation for c and b quarks. (Tung, Lai, Yuan) — see Wu-Ki's talk.

Experimental update:

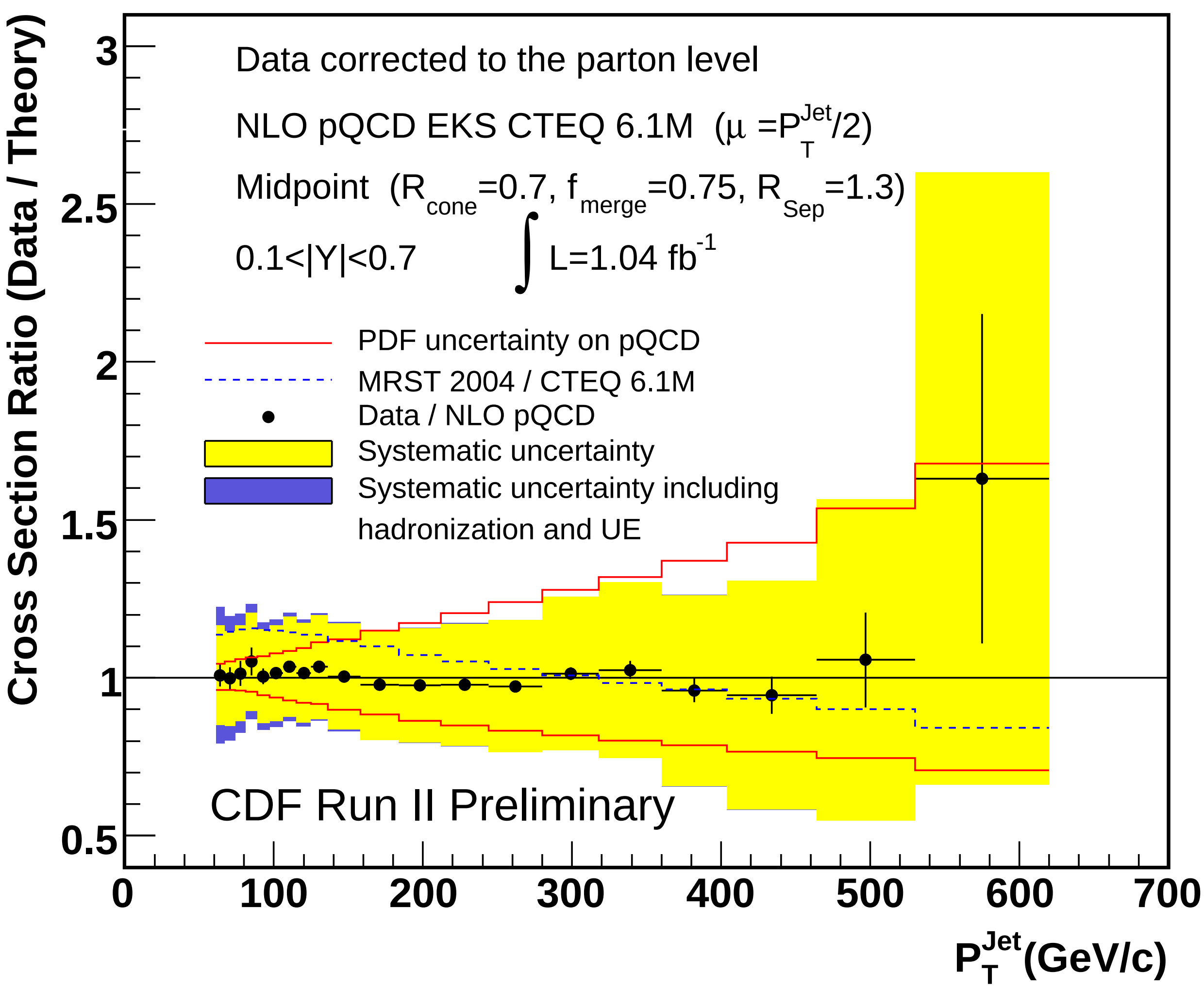
- Full DIS data sets from HERA I (1994–2000). (Some ZEUS run II data expected in Fall – MD)
  - Include Charged Current ($e\,p \to \nu X$) data.
  - Fit measured cross sections instead of F_2.
  - Include experimental systematic errors.
  - (Don't yet include DIS + Jet data)

Still need some Fixed Targed data:

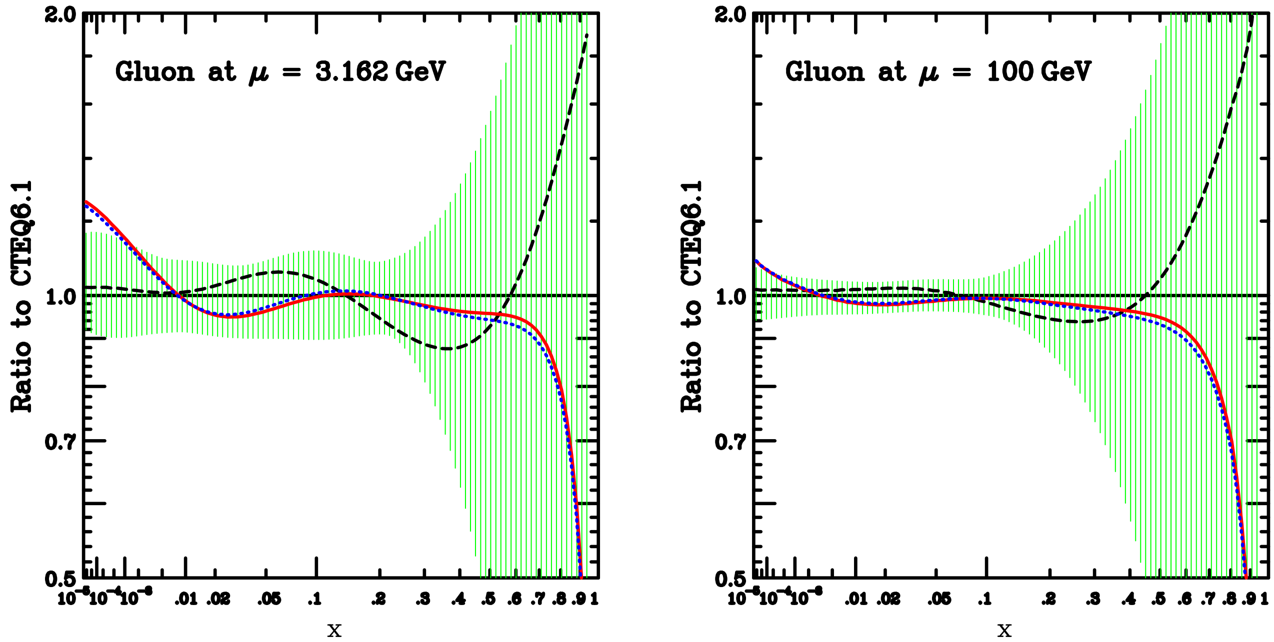
- NuTeV (nukyular corrections)
- E866
- NuTeV dimuon data

Tevatron data not yet included:

- Run II Jet data (consistent with CTEQ6.1, so won't produce any big change.)
- W and W-lepton asymmetry (in P_T bins).
- y and p_T dependences of W, Z production.
- $W/Z/\gamma$ + Jet cross sections.



Comparison with CTEQ6.1



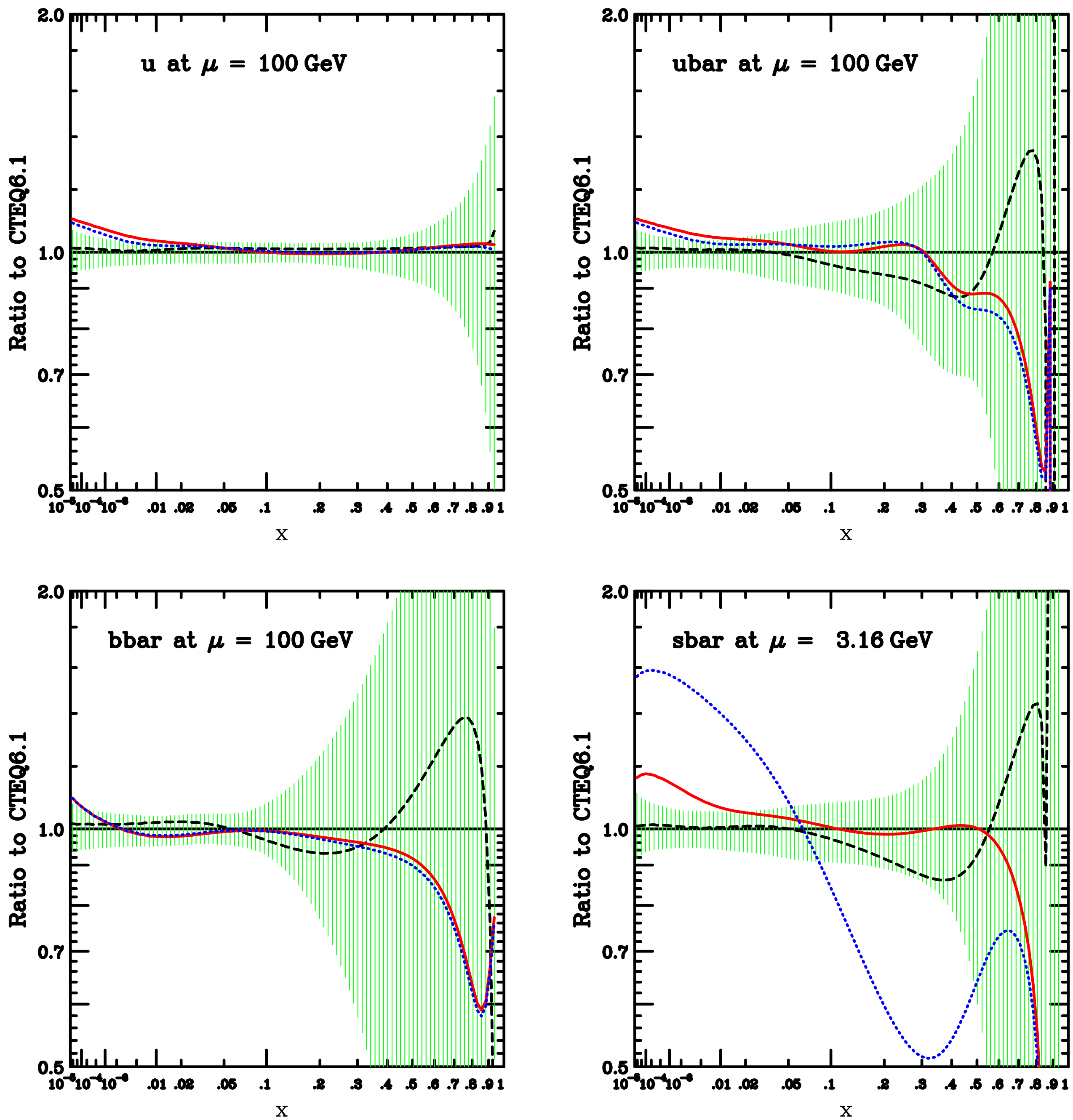
Green: Uncertainty from CTEQ6.1 40 ev sets.
Black: CTEQ6A118
Red, Blue: Candidates for new "Best Fit"

- CTEQ6.1 uncertainty estimate was about right: the new PDFs are more-or-less within the expected (90% confidence) range.

- PDFs are somewhat larger at small $x \Rightarrow$ somewhat larger cross sections predicted for LHC.

- Gluon smaller (well within old errors) at $x \to 1$ by choice of parametrization: $(1-x)^{A_2}$ with A_2 moved from ~ 1.9 to 3.0 based on quark counting.

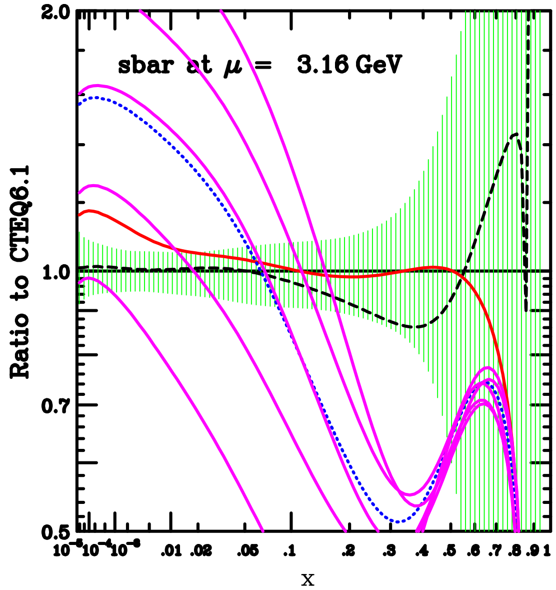
Further comparison with CTEQ6.1



Green: Uncertainty from CTEQ6.1 40 ev sets.
Black: CTEQ6A118
Red, Blue: Candidates for new "Best Fit"

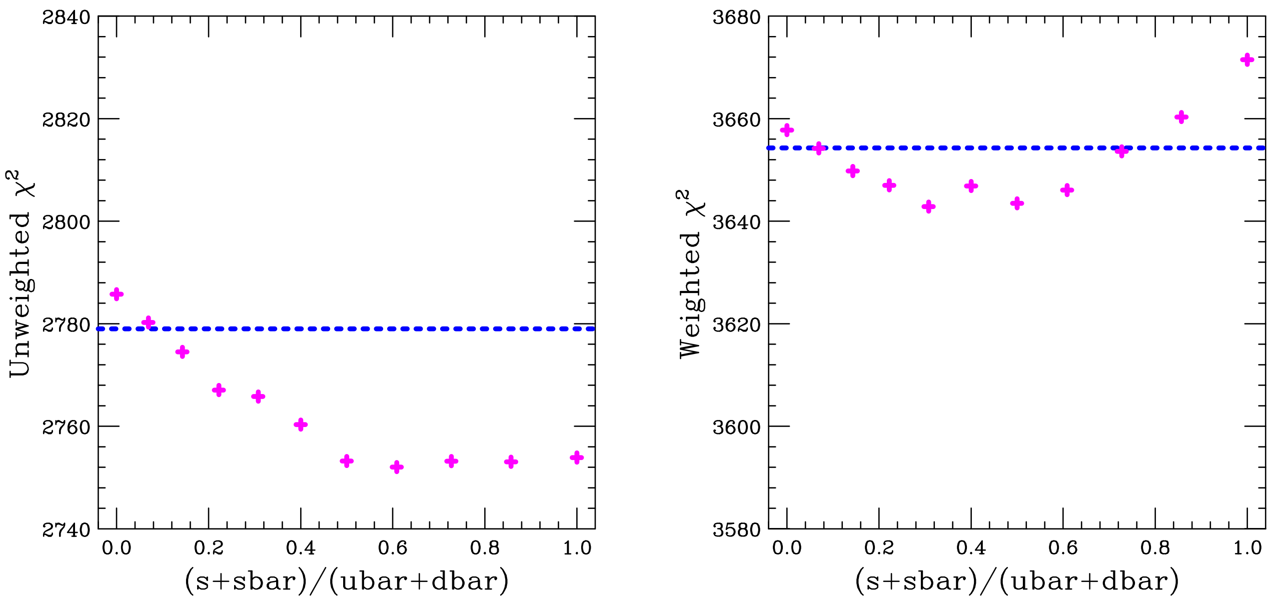
- Blue curve has $s(x) = \bar{s}(x) = A_0\, x^{A_1}\, (1-x)^{A_2}$ — NOT forced $\propto \bar{u}(x) + \bar{d}(x)$.

Fits with strangeness fraction free



Green: Uncertainty from CTEQ6.1 40 ev sets.
Black: CTEQ6A118
Red, Blue: Candidates for new "Best Fit"
Magenta: "Kappa" series

Kappa series



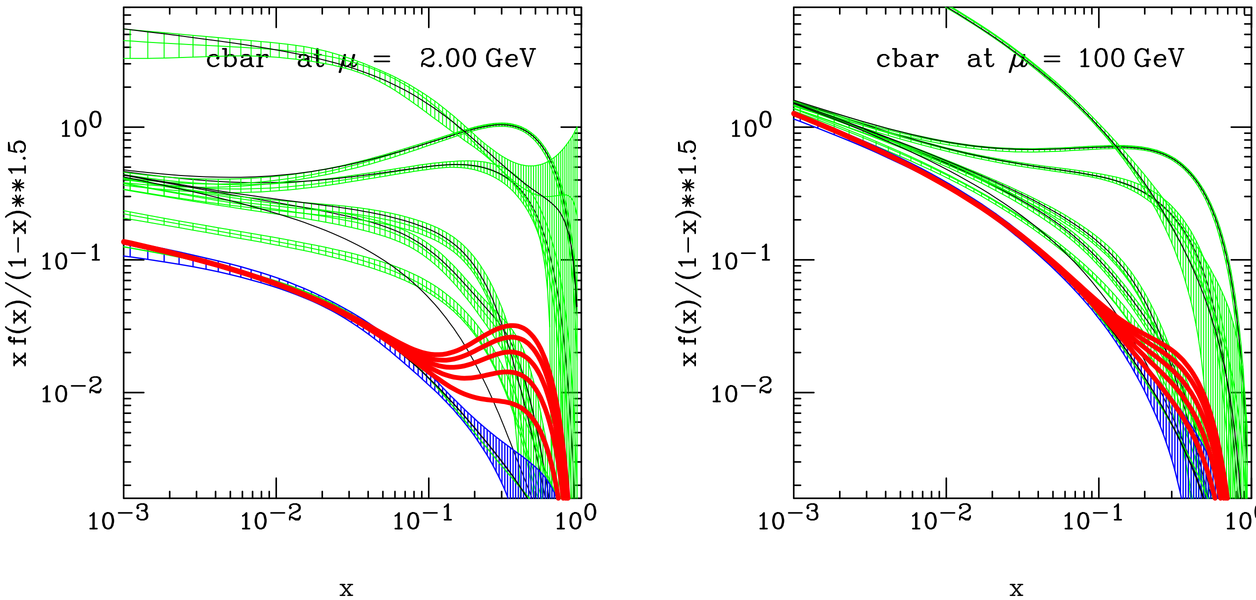
χ^2 of Global Fit vs.

$R = \int_0^1 [s(x) + \bar{s}(x)]\, x\, dx \;/\; \int_0^1 [\bar{d}(x) + \bar{u}(x)]\, x\, dx$

$\kappa = 3 * R/(2 + R)$

- Very little constraint on $s(x) + \bar{s}(x)$, even with the CC DIS data emphasized by weight factor 5.
- Still consistent with $s(x) + \bar{s}(x) \propto \bar{u}(s) + \bar{d}(s)$ (dashed constant values).
- Need to include dimuon data explicitly!
- Have not investigated $s(x) - \bar{s}(x)$ with the new data set.

PDFs with Intrinsic Charm: Brodsky model



Green: g, u, d, $\bar{u}$, $\bar{d}$, $s = \bar{s}$ (Quiz: Which is which?)

Black: Candidate for new "Best Fit" (Prefers $s(x) = \bar{s}(x)$ equal to $\bar{u}(x) = \bar{d}(x)$ (built in) at $x \to 0$.

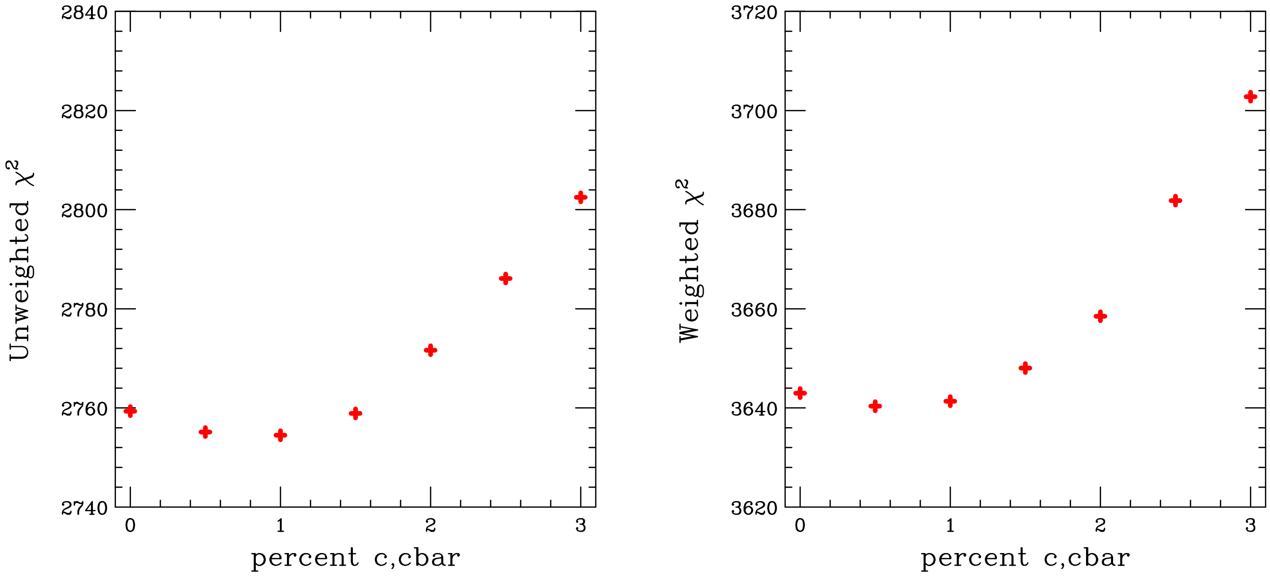
Blue: Charm from gluon splitting

Red: Intrinsic Charm using Brodsky's Light-Cone form at $Q_0 = 1.3\,\text{GeV}$, normalized to probability 0.5%, 1.0%, 1.5%, 2.0%, 2.5% for $c\bar{c}$.

- Typical estimate 1.0%; $> 2.5\%$ ruled out by Global Fit.

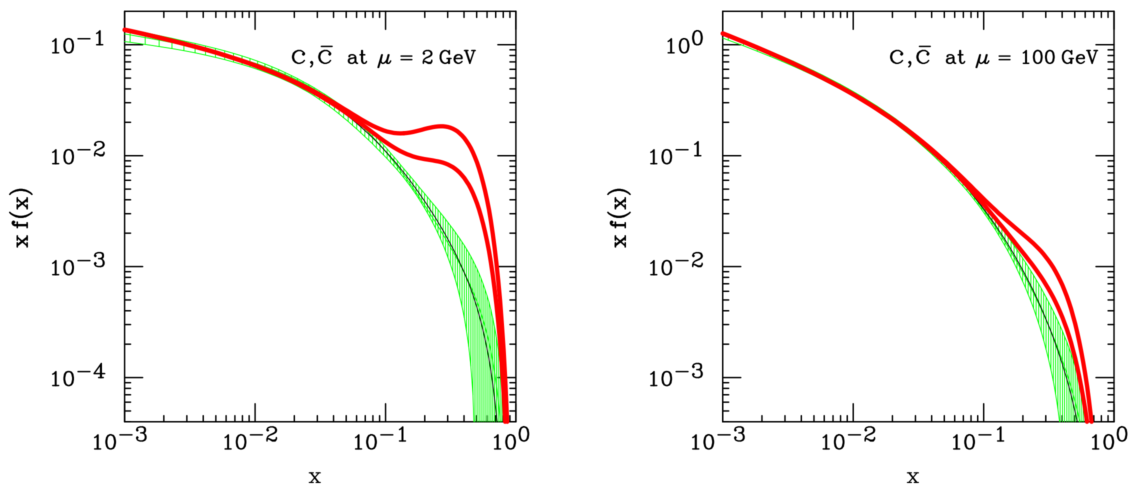
- IC may be "large" ($\bar{c} > \bar{u}, \bar{d}$) for $x > 0.2$. How to observe??

Intrinsic Charm: BHPS model

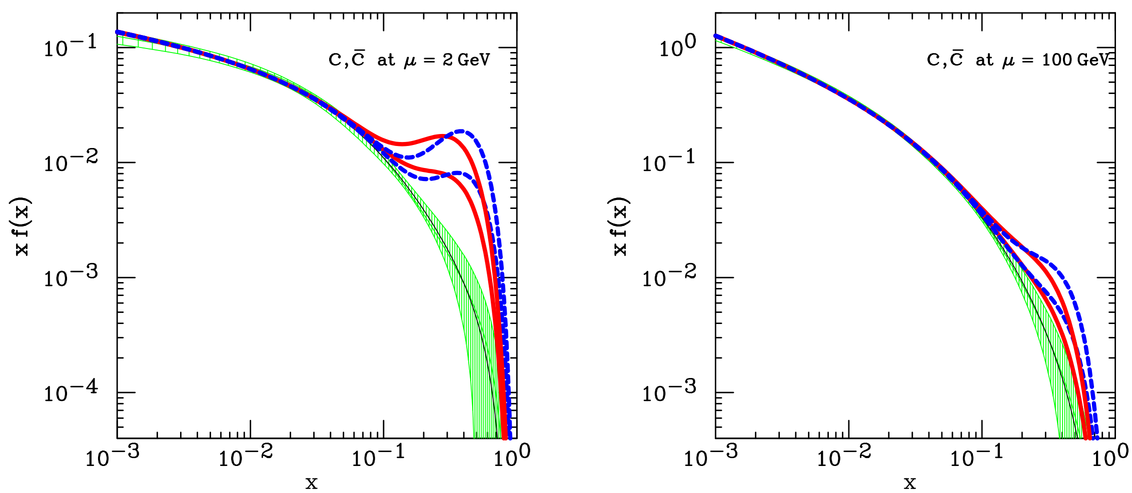


Allowing 1% intrinsic charm improves the fit by an insignificant amount. Roughly 1–3% can be tolerated by the global fit.

Other Light-Cone models for IC

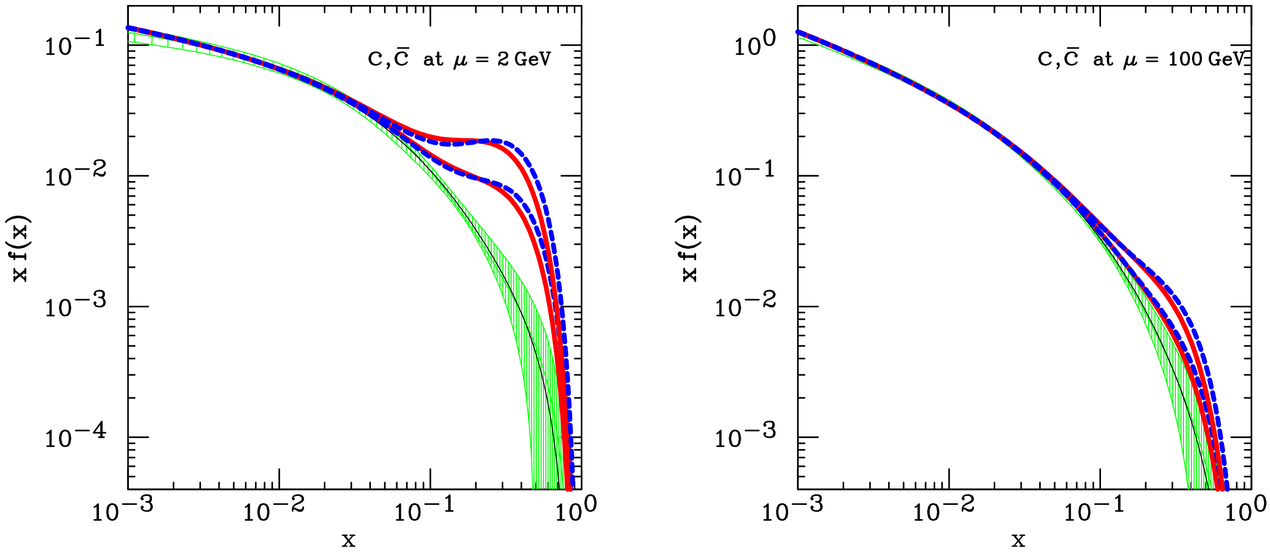


Brodsky model ($c, \bar{c}$ probability 1.0%, 2.5% $\rightarrow$ $\int_0^1 [c(x) + \bar{c}(x)]\, x\, dx = 0.00571,\ 0.01429$.



$D_0\, \Lambda_c^+$ model with $\int_0^1 [c(x) + \bar{c}(x)]\, x\, dx = 0.00571,$ 0.01429.

Another Light-Cone model: (udc)(ubar c)



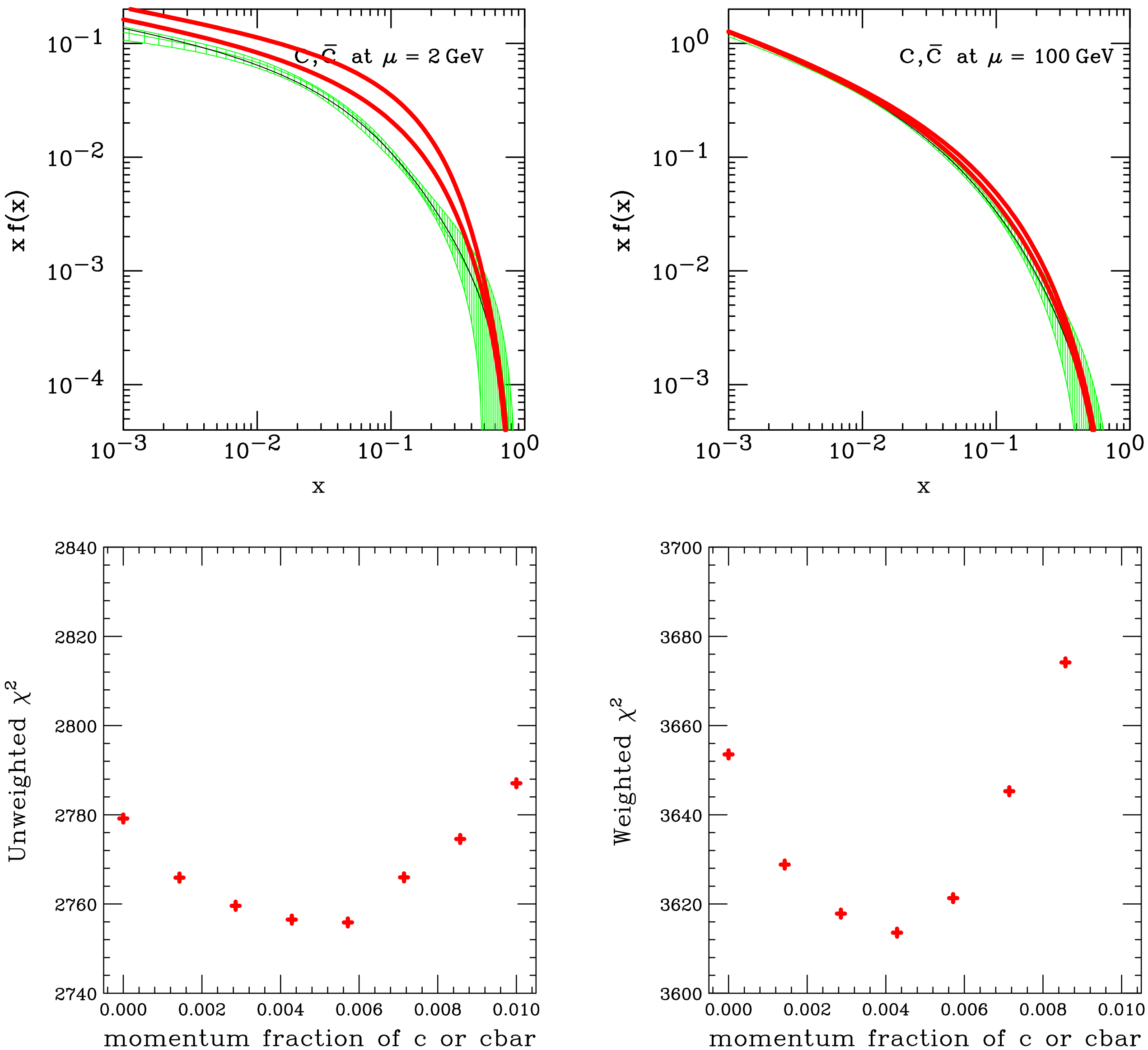
$(udc)(u\bar{c})$ model with
$\int_0^1 c(x)\, x\, dx = 0.00264$, $\int_0^1 \bar{c}(x)\, x\, dx = 0.00307$, total 0.00571
$\int_0^1 c(x)\, x\, dx = 0.00660$, $\int_0^1 \bar{c}(x)\, x\, dx = 0.00768$, total 0.01429

Again

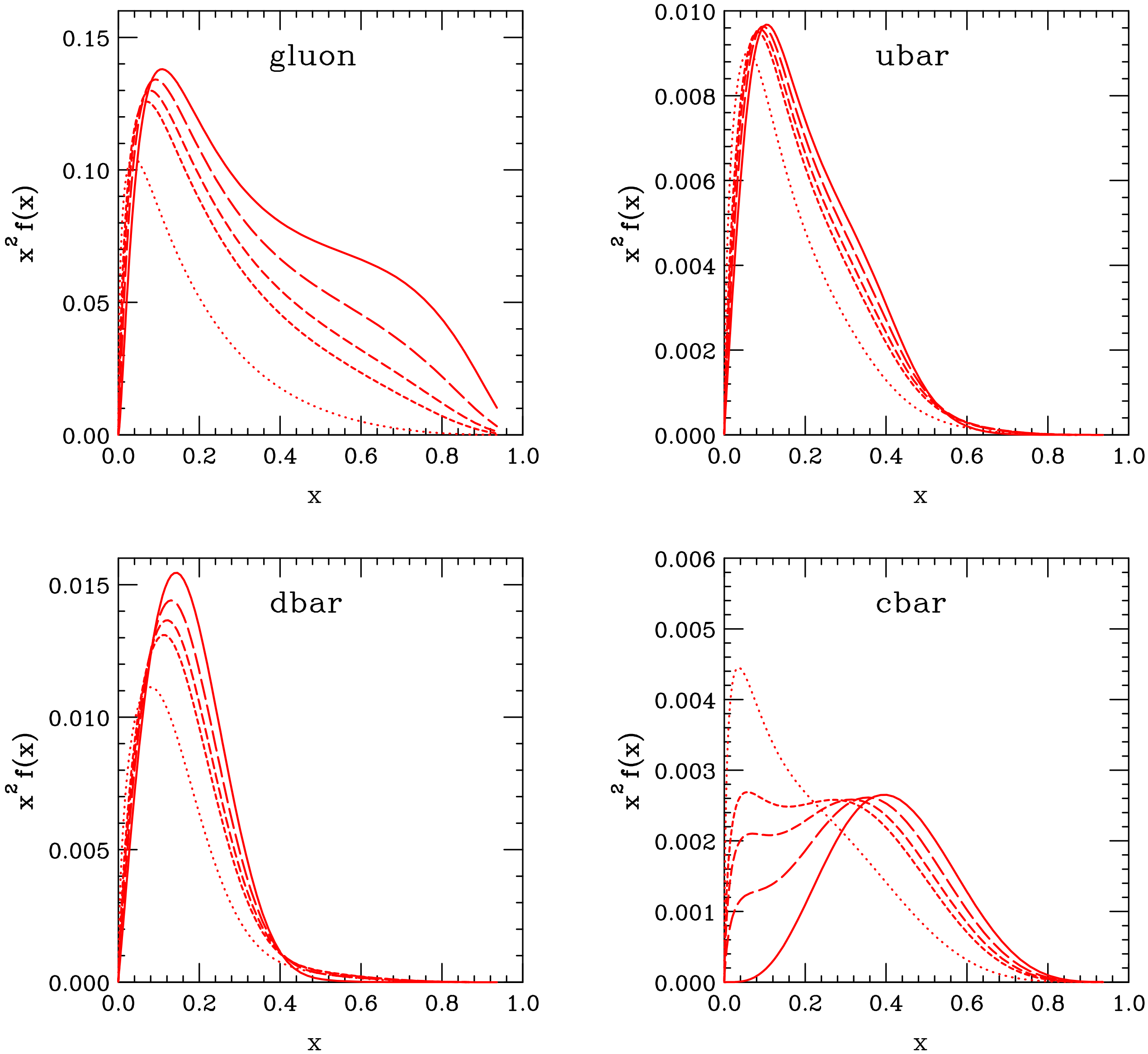
- $c + \bar{c}$ momentum fraction up to 0.015 allowed by Global Fit.
- IC may be very important for $x > 0.2$.
- Difference between $c(x)$ and $\bar{c}(x)$ is not large. Sign is $\bar{c}(x) > c(x)$ at $x \to 1$.
- All of the Light-Cone models are similar to

Intrinsic Charm at small x?

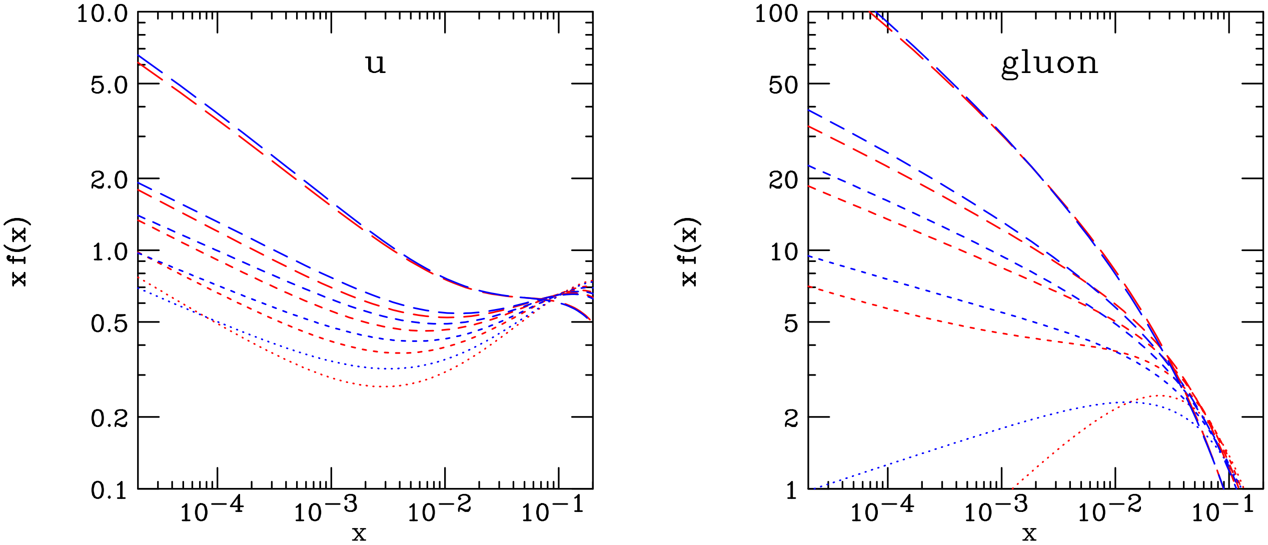
Try $c(x) = \bar{c}(x) \propto [s(x) + \bar{s}(x)]$



More “Movies”

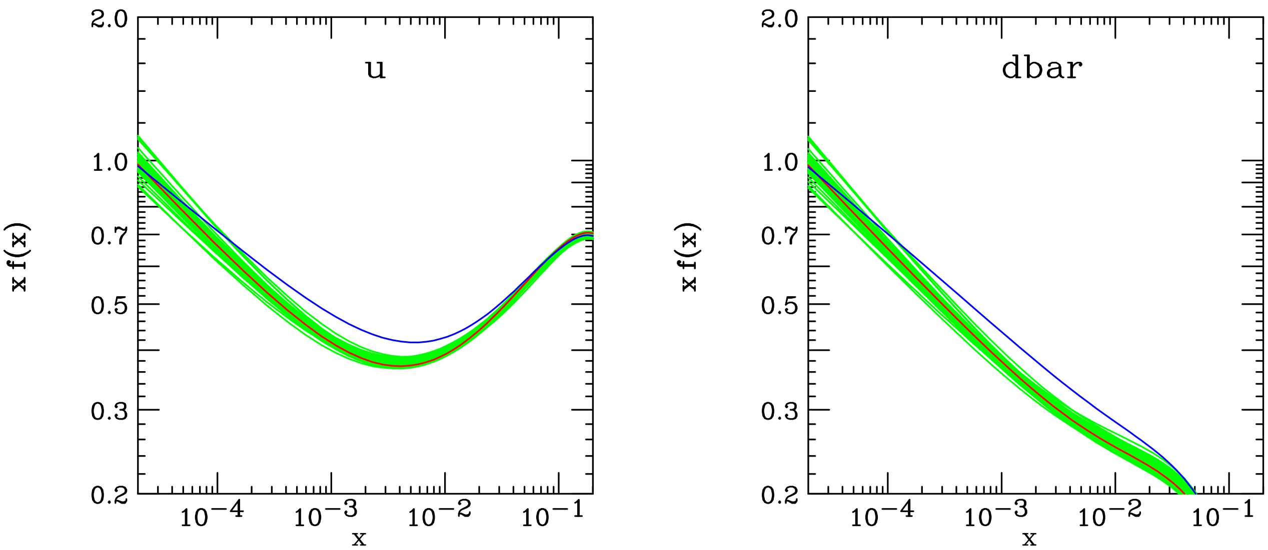

gluon
ubar
dbar
cbar
$x^2 f(x)$
x
0.15
0.10
0.05
0.00
0.010
0.008
0.006
0.004
0.002
0.000
0.015
0.010
0.005
0.000
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0.0
0.2
0.4
0.6
0.8
1.0

Systematic non-perturbative behavior at small x?



Curves show $Q = 1.3,\ 2,\ 3.16,\ 5$ and $100\,\mathrm{GeV}$.

- Parton density $\sim A_0\, x^{A_1}$ at $x \to 0$ with A_1 reasonably independent of scale Q at small Q for u, d, $\bar{u}$, $\bar{d}$ (all the same); but *NOT* for gluon.



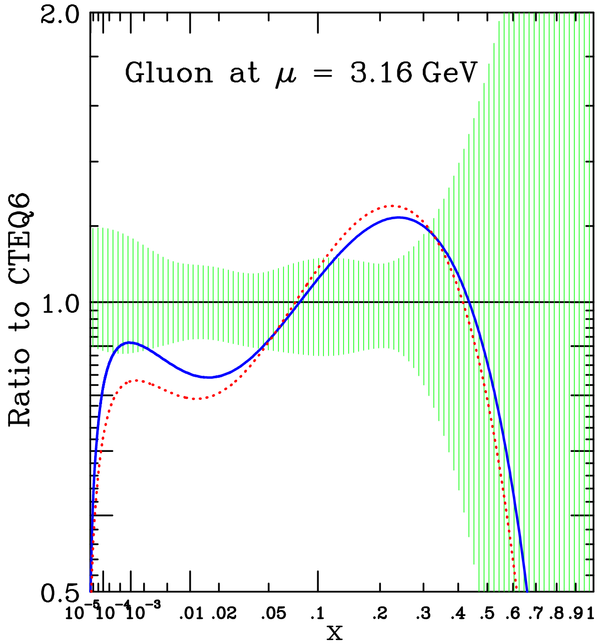
Green: The 40 ev sets of CTEQ6.1
Red, Blue: Candidates for new "Best Fit"

- The value of A_1 is reasonably well determined by the fit. Predictions from Regge theory or other non-perturbative physics?

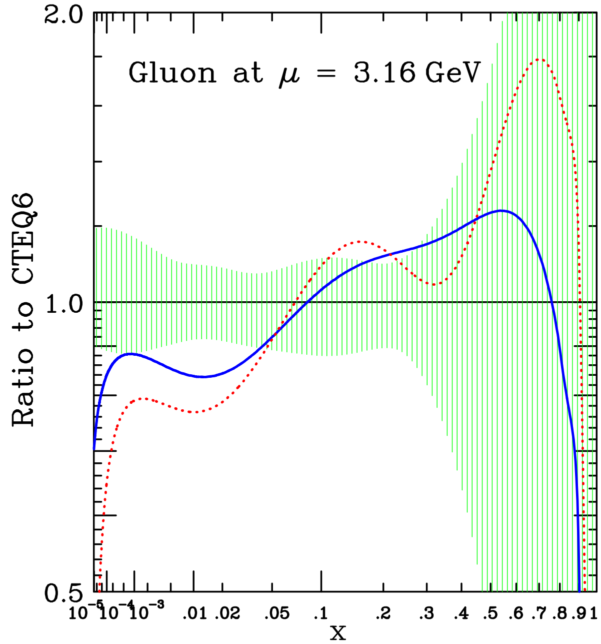
Extra Slides

NLO vs. NNLO

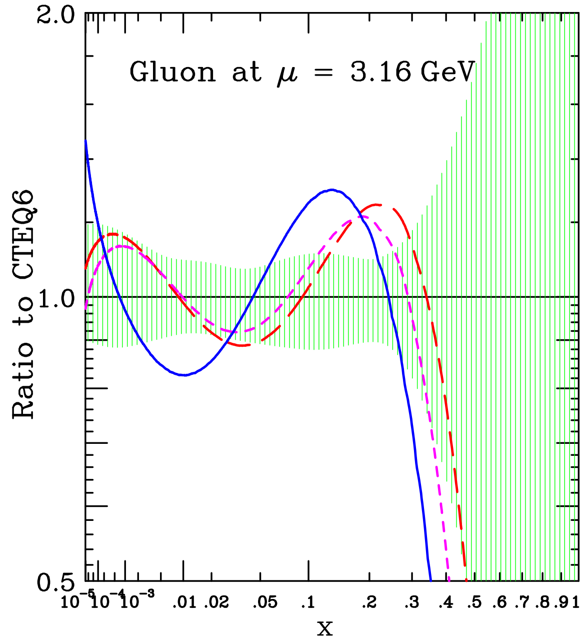
Difference between NLO and NNLO analysis is small compared to current PDF uncertainty. Hence full NNLO fitting is desirable but not urgent.



MRST2002NLO, NNLO



MRST2004NLO, NNLO



Zeus2005zj, Alekhin02NLO, Alekhin02NNLO