Parton Distribution Topics

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JLAB CTEQ meeting   11–12 November 2005

- New PDF fits: α_s series

- Light-cone models for intrinsic charm and bottom

- The road to CTEQ7 (talk this afternoon)

CTEQ6AB PDFs: α_s scans

CTEQ6, including the 40 eigenvector uncertainty sets, uses $\alpha_s(m_Z) = 0.118$ based on data (mainly from LEP) that is not otherwise included in the Global Analysis.

The actual uncertainty of $\alpha_s(m_Z)$ is around ± 0.002. To explore the effect of this additional uncertainty, a new series of PDF fits has been made, and is in the process of being made public via the Durham LHAPDF website.

20 new PDF sets:
$\alpha(m_Z) = 0.110, \ldots, 0.128$ with DefA for $\alpha(\mu)$.
$\alpha(m_Z) = 0.110, \ldots, 0.128$ with DefB for $\alpha(\mu)$.

Outline:

- Definitions for $\alpha(\mu)$
- χ^2 vs. $\alpha(\mu)$
- Applications
  - W and Z cross sections
  - Inclusive jet cross sections
  - Higgs boson production

Definitions for $\alpha_s(\mu)$

Dependence of $\alpha_s(\mu)$ on momentum scale μ is governed by renormalization group RGE

$$\mu \, d\alpha/d\mu = c_1\alpha^2 + c_2\alpha^3 + \ldots$$

When truncated at $\mathcal{O}(\alpha^3)$ there are infinitely many definitions of $\alpha_s(\mu)$ that are formally equivalent because they differ only in higher orders. Two standard choices:

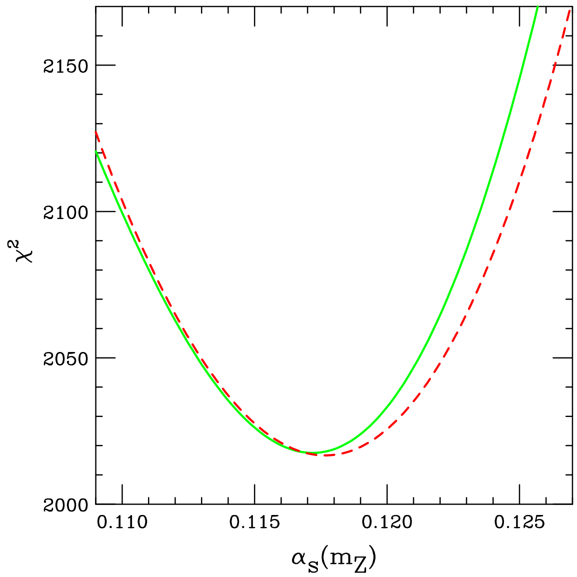
- DefA: The original NLO definition (traditionally used in CTEQ distributions)

$$\alpha(\mu) = c_3 \, [1 - c_4 \ln(L)/L]/L \ ,$$

- DefB: Exact solution of the truncated RGE equation (used in QCDNUM and by the HERA groups)

Form used by MRST is different from both of these, but numerically close to DefB.)

Global ChiSqr vs. $\alpha_s(m_Z)$



Goodness-of-fit vs. $\alpha_s(m_Z)$ using DefA and DefB

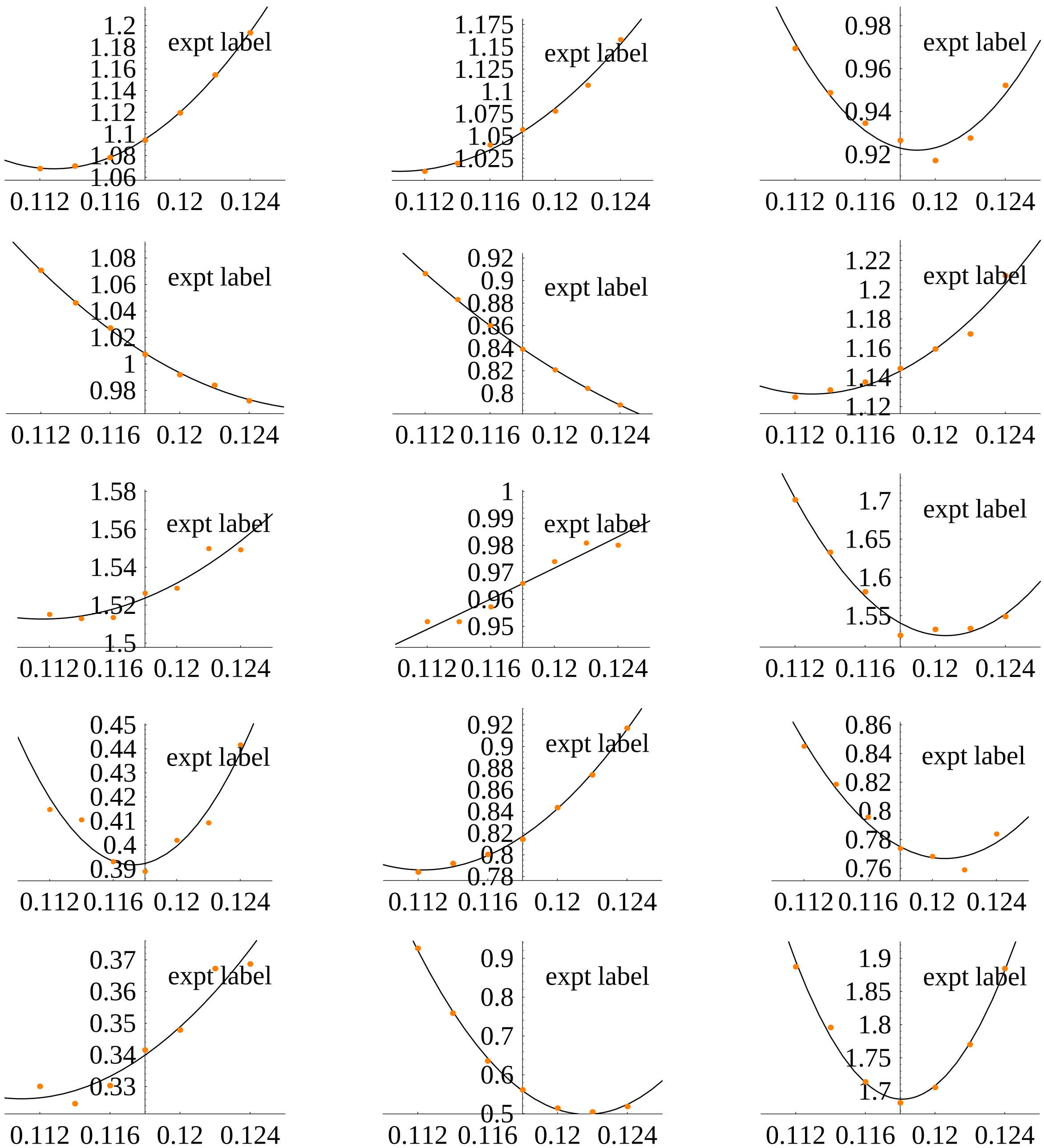
Very similar, but DefA slightly narrower and farther left because it has more rapid variation of $\alpha_s(\mu)$.

Minima at $\alpha_s(m_Z) = 0.1172$ and 0.1176, very close to the world average (0.1187 ± 0.0020)

If treat as a measurement, error on $\alpha_s(m_Z)$ is roughly ± 0.004 from PDF fit, i.e., twice the World Average error.

New fits span a very wide range $\approx \pm 0.008$ by popular demand.

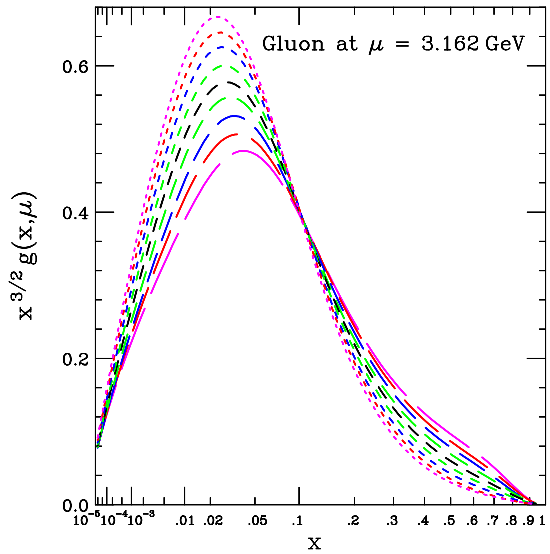
χ^2/Npt vs. $\alpha_s(m_Z)$ for each experiment

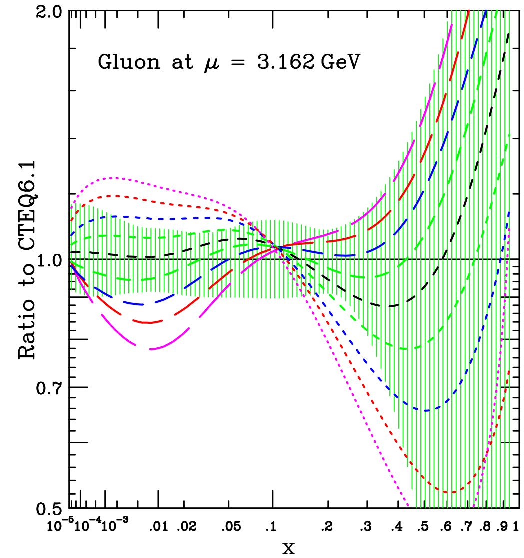


These plots show the danger of “measuring” α in one experiment

They also remind us why $\Delta\chi^2 \approx 100$.

Gluon Distributions

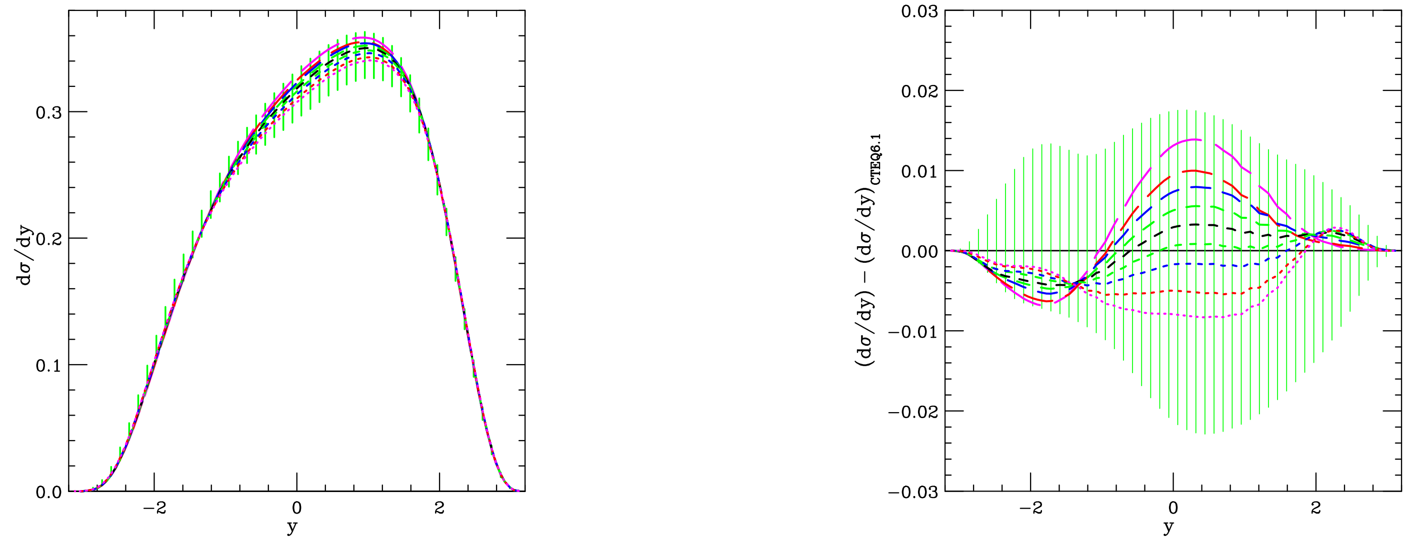




When α_s is made larger, $g(x)$ becomes smaller at small x to maintain agreement with the large amount of small-x data. At large x, $g(x)$ then becomes larger because $\int g(x)\, x\, dx$ is constrained by momentum sum rule.

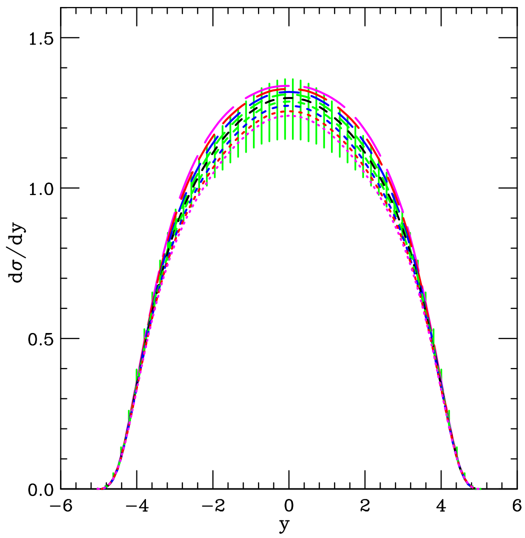
The uncertainty of $g(x,\mu)$ due to α_s is comparable to its uncertainty from other sources at $x < 0.02$
$\Rightarrow$ increased uncertaintes at LHC.

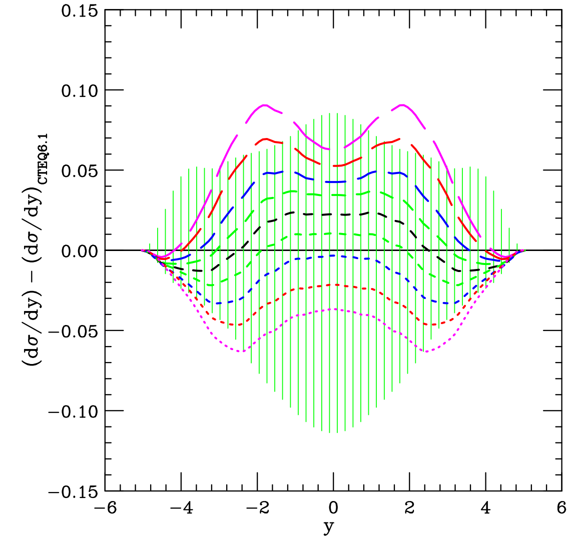
W and Z production



(a) $d\sigma/dy_W$ for W^- at Tevatron (b) Same with the CTEQ6.1 prediction subtracted.

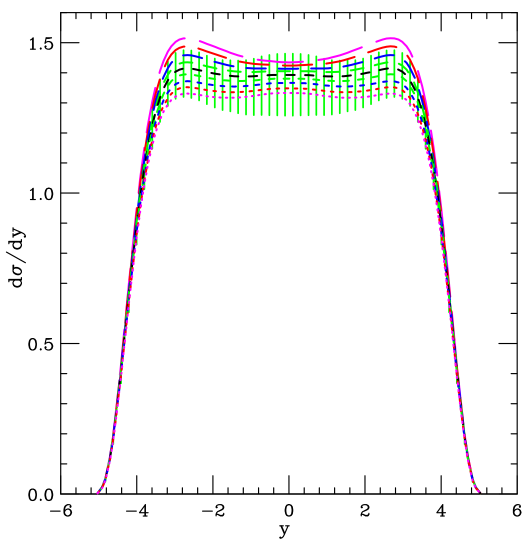
- Uncertainty due to α_s is small
- $\alpha_s = 0.118$ fit is slightly different from CTEQ6.1 (slightly improved data set.)

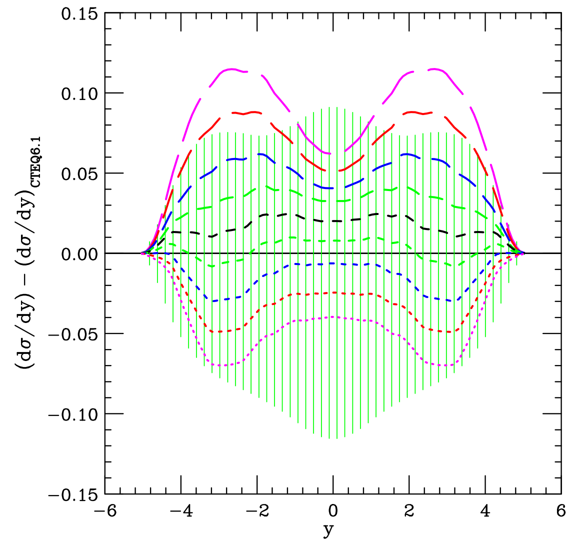




(a) Production of W^- at the LHC.

(b) Same with CTEQ6.1 subtracted.

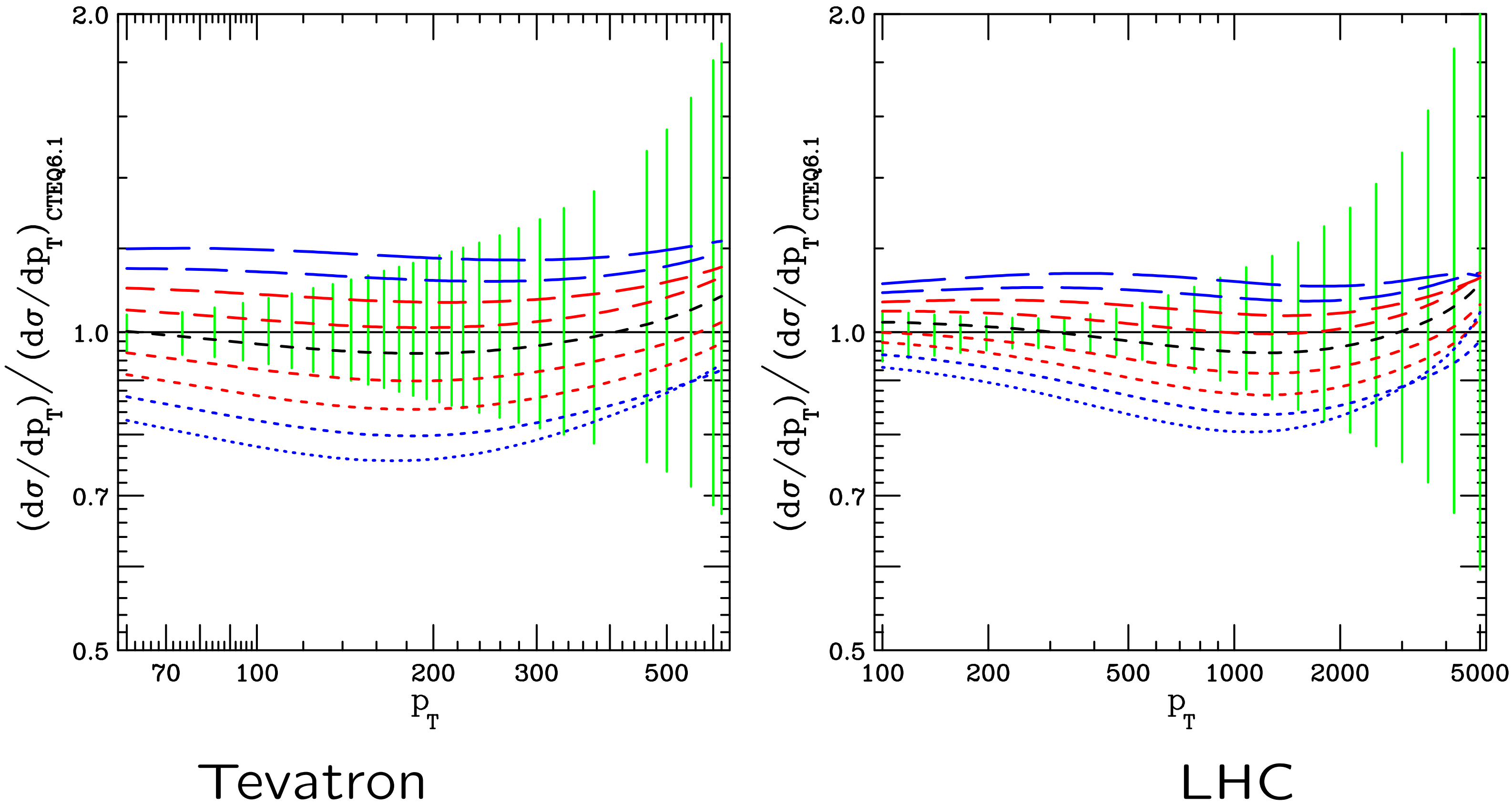




(a) Production of W^+ at the LHC.

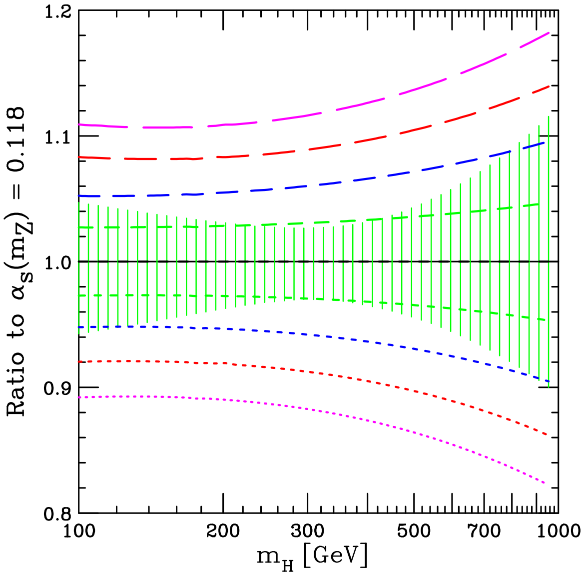
(b) Same with CTEQ6.1 subtracted.

$\alpha_s(m_Z)$ dependence of Inclusive Jets

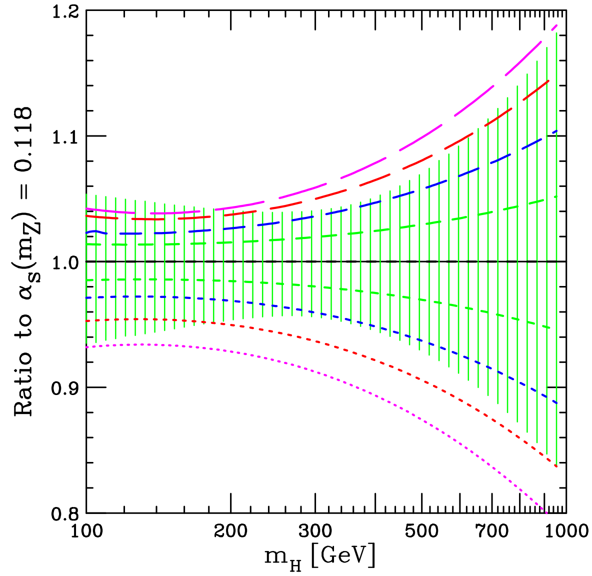


- Increased uncertainty at low p_T
- Preliminary: used CTEQ6.1 K-factors.

Higgs cross sections at LHC



SM



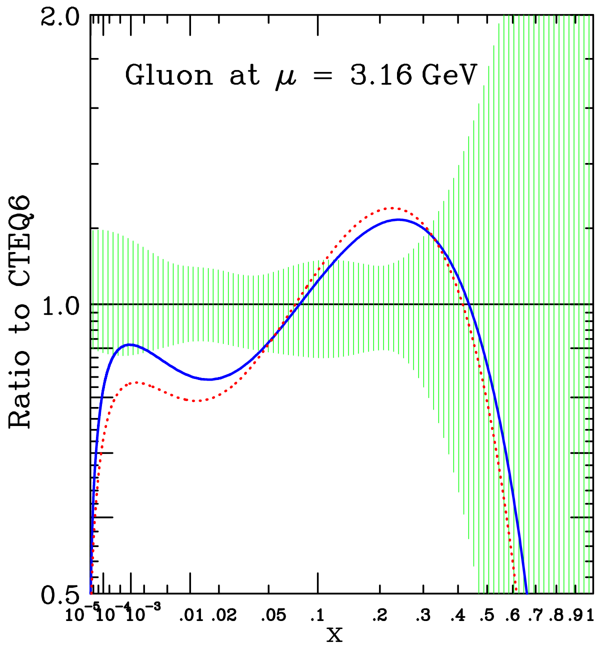
MSSM ($\tan\beta = 50$)

- Uncertainty in $\alpha_s(m_Z)$ $\sim$doubles uncertainty in σ_H.

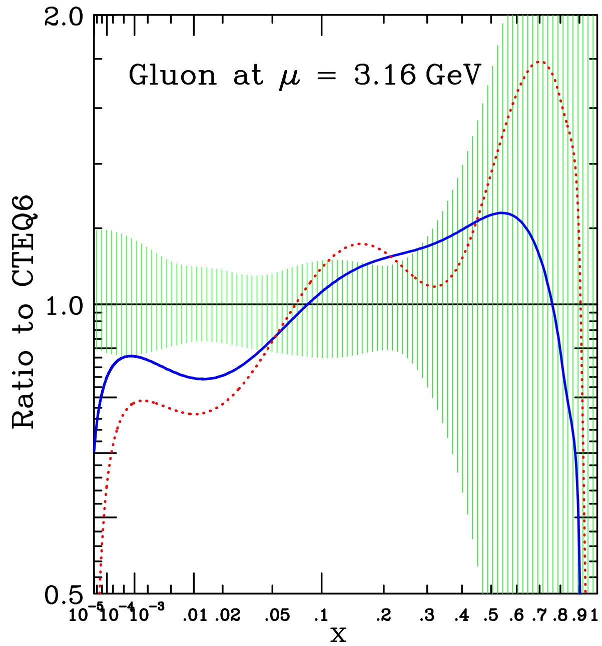
- Large additional uncertainty due to α_s is not surprising in view of the natural α_s^3 behavior of the leading order process $gg \rightarrow H$.

NLO vs. NNLO

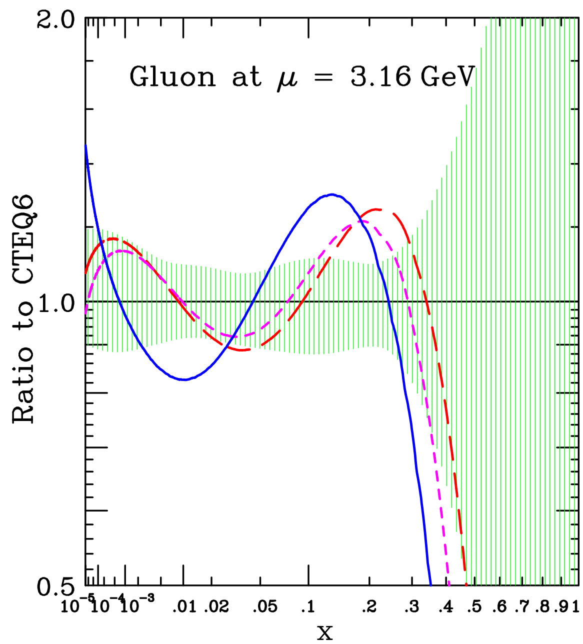
Difference between NLO and NNLO analysis is small compared to current PDF uncertainty. Hence full NNLO fitting is desirable but not urgent.



MRST2002NLO, NNLO



MRST2004NLO, NNLO



Zeus2005zj, Alekhin02NLO, Alekhin02NNLO

Code speed issues

Skip redundant calculations when successive calls to PDF are at same X and/or same Q:

```
      FUNCTION PARDIS (iflavor, x, q)
      if(x .eq. xlast) goto 100
      xlast = x
...lots of stuff...
100   continue
      if(q .eq. qlast) goto 110
      qlast = q
...lots of stuff...
110   continue
```

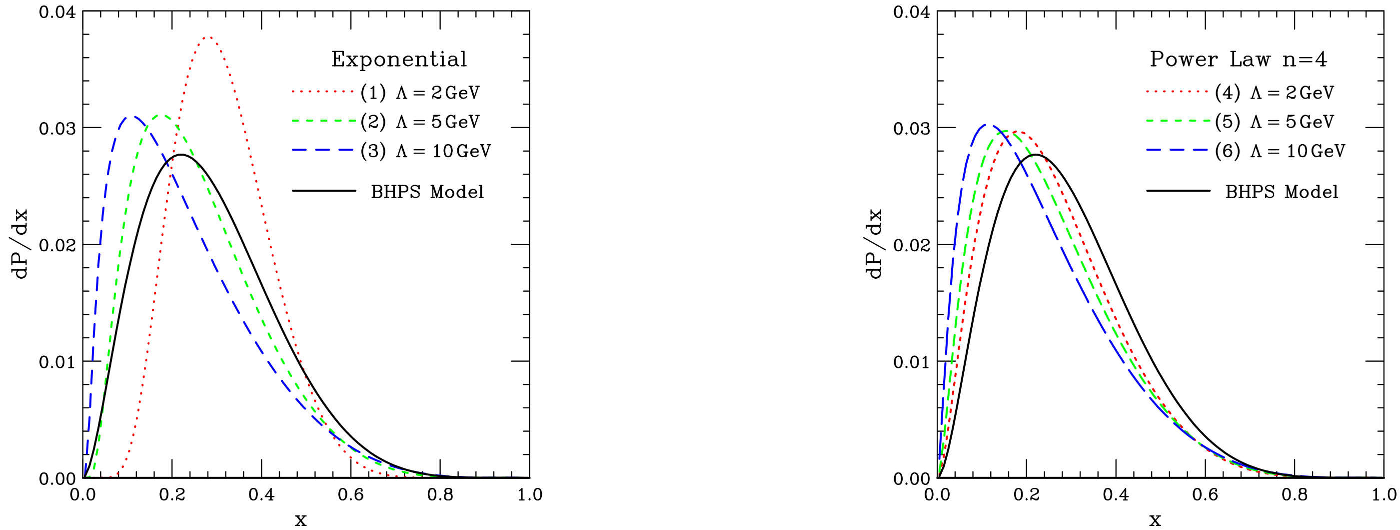
Wrong way:

```
  Do I= -MaxParton, MaxParton
     Parton(I,1) = PDF(Iset,Hadron1,I,x1,Mu,Ir)
     Parton(I,2) = PDF(Iset,Hadron2,I,x2,Mu,Ir)
  EndDo
```

Right way:

```
  Do I = -MaxParton, MaxParton
     Parton(I,1) = PDF(Iset,Hadron1,I,x1,Mu,Ir)
  EndDo
  Do I = -MaxParton, MaxParton
     Parton(I,2) = PDF(Iset,Hadron2,I,x2,Mu,Ir)
  EndDo
```

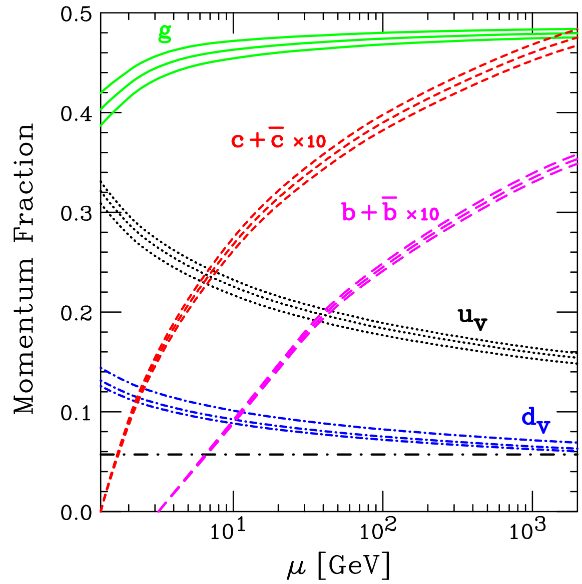
Intrinsic c and b



Momentum distribution of c or $\bar{c}$ from the 5-quark model with (a) Exponential suppression, or (b) Power Law suppression of high-mass configurations.

Solid curve is Brodsky et al.

Intrinsic c and b

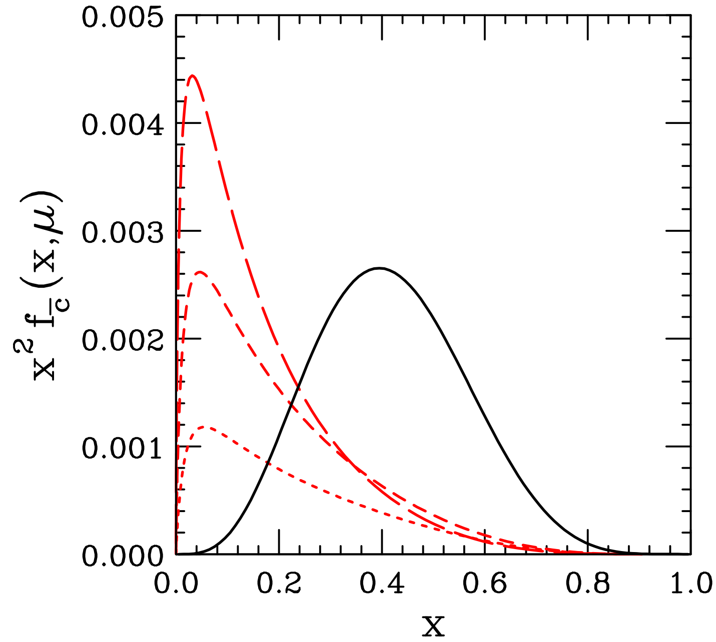


Fraction of proton momentum carried by valence quarks, gluon, $b + \bar{b}$, and $c + \bar{c}$ as a function of scale μ, with uncertainty bands.

The $b + \bar{b}$ and $c + \bar{c}$ curves were multiplied by 10 for clarity. Dot-dash line is the level of intrinsic $c + \bar{c}$ predicted by BHPS, also multiplied by 10.

Very rapid rise of perturbative contribution exaggerated by zero-mass approximation.

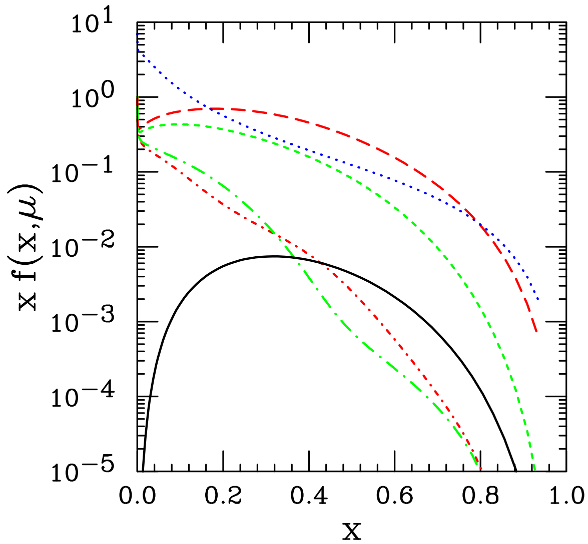
Intrinsic c dominant at large x



Distribution $x^2 f_{\bar{c}}(x)$ from CTEQ6.1 at $\mu = 2$, 5, 100 GeV (short, medium, long dash) compared to Brodsky et al. solid).

The intrinsic charm model is dominant at large x.

Large x behavior of c and g



Parton distributions for u (long dash), d (short dash), $\bar{u}$ (long dash dot), $\bar{d}$ (short dash dot), and g (dotted) at $\mu = 2\,\text{GeV}$, compared with $\bar{c}$ from the BHPS model (solid).

The $\sim (1-x)^2$ behavior of $g(x)$ is an incidental artifact in CTEQ6 fits. Intrinsic charm doesn't cure it, but it can be removed at $\Delta\chi^2 \approx 5$.