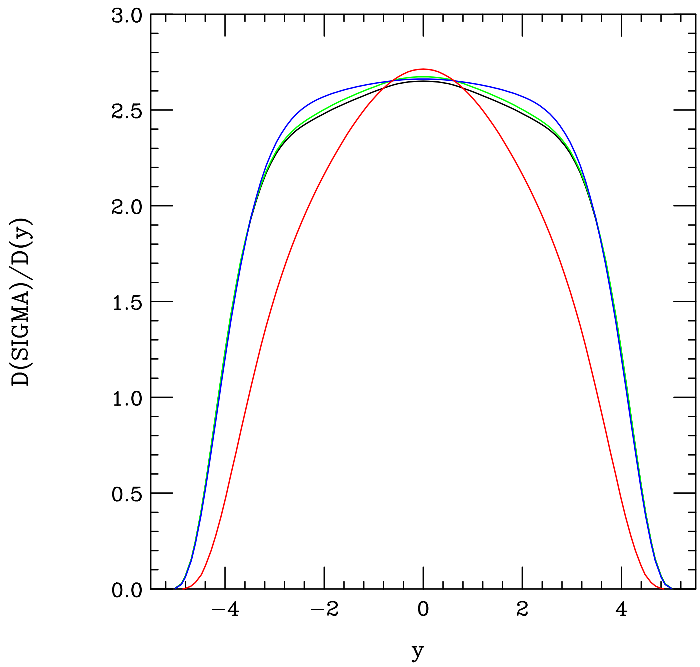
W cross sections and stability with respect to cuts in the PDF global fit

Work in progress (Huston, Pumplin, Stump, Tung) in connection with the Hera/LHC and TeV/LHC workshops.

Predicted W cross sections for LHC



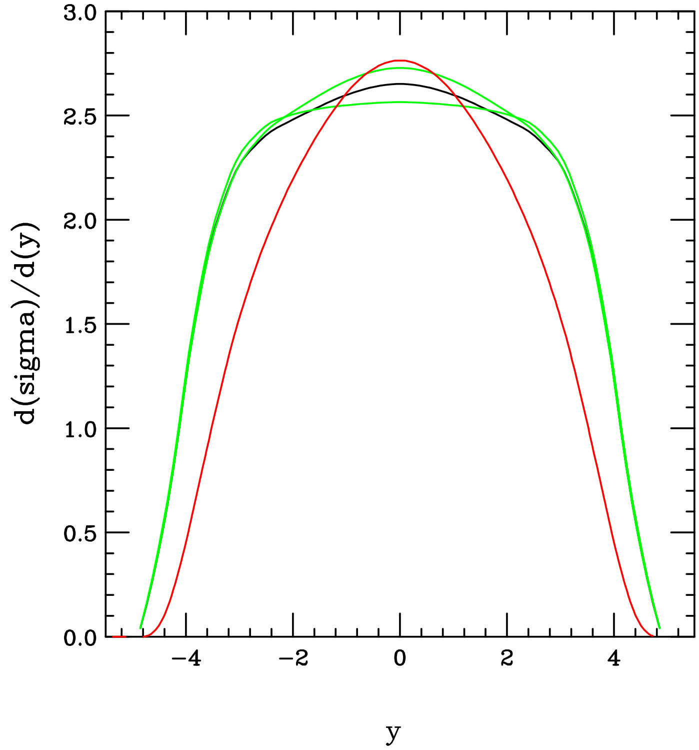
- CTEQ6.1, CTEQ6, MRST2002 yield similar predictions for $d\sigma/dy$ of $W^+ + W^-$ at LHC.
- MRST2003c "conservative" fit is radically different!

If the "conservative" PDF set is an acceptable global fit, the uncertainty in W production is extremely large, making it useless as a partonic luminosity measure. What causes it?

- CTEQ fits use data with $Q > 2\,\mathrm{GeV}$, while MRST2003c only uses data with $Q > 3.162\,\mathrm{GeV}$ and $x > 0.005$.
- MRST2003c allows negative $\bar{M}S$ gluon distribution; finds

$$g(x) < 0 \text{ for } x < 0.0033 \text{ at } Q = 1.3$$
$$g(x) < 0 \text{ for } x < 0.0012 \text{ at } Q = 2.0$$
$$g(x) < 0 \text{ for } x < 0.0005 \text{ at } Q = 3.162$$

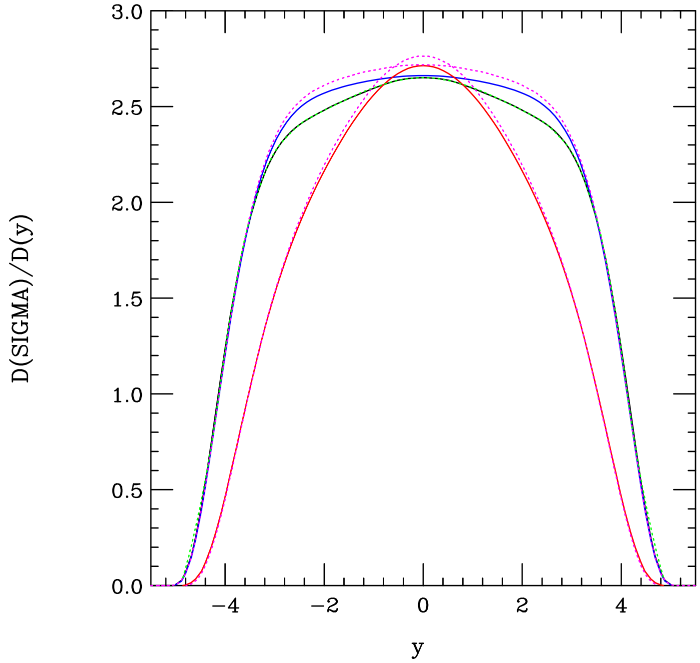
Extremes of predicted shape for W cross section at LHC



CTEQ6.1,
CTEQ6.1 Eigenvector sets with minimum and maximum $\langle y^2 \rangle$,
MRST2003c

This figure shows that the MRST2003c prediction lies far outside the range of predictions that would be expected based on current uncertainty methods.

Using Les Houches Accord interface



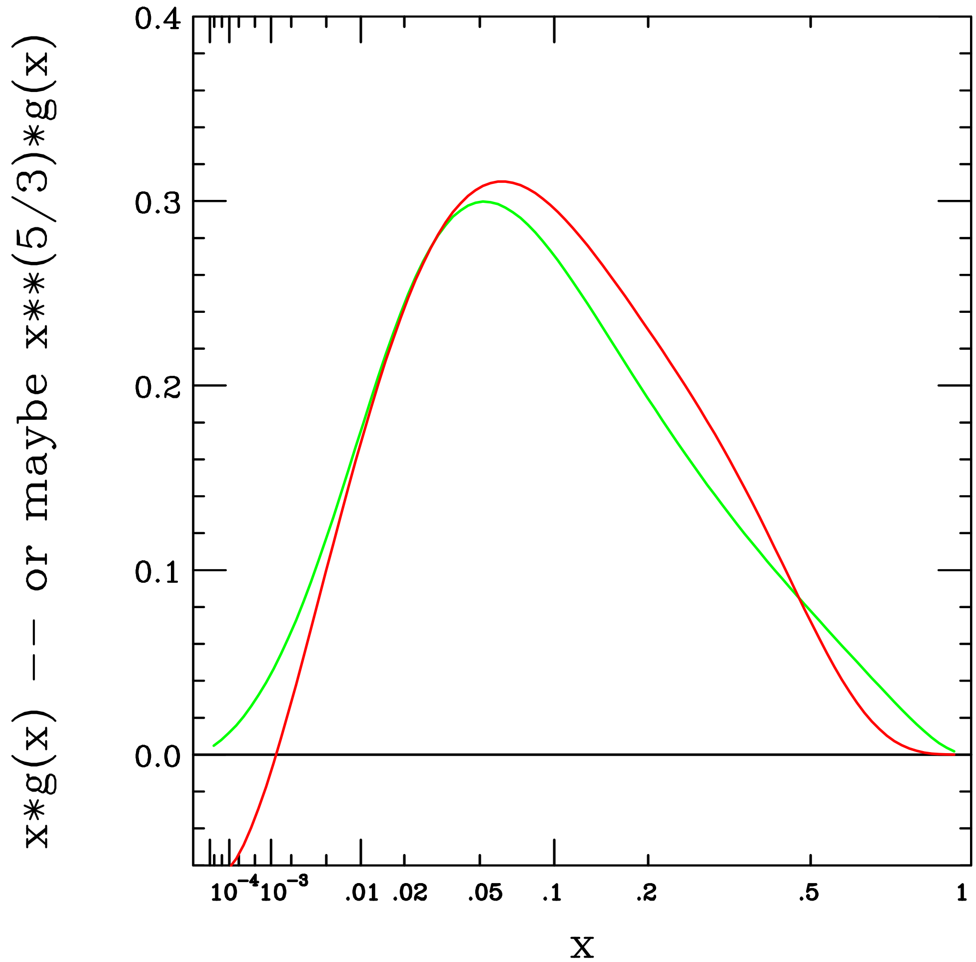
CTEQ6.1, CTEQ6, MRST2002, MRST2003c

MRST curves lifted from PostScript of Fig. 19 in hep-ph/0308087.

Dotted magenta curves calculated using CTEQ codes but with PDFs from http://durpdg.dur.ac.uk/HEPDATA/

- Agreement of CTEQ with CTEQ is excellent (but Durham $\alpha_s(Q)$ needed repair).
- Agreement with MRST with MRST in *shape* is excellent.
- There is a difference of about 3 % in MRST normalization. (Both calculations assume 0.1068 for the W leptonic branching ratio, so that isn't the cause; Dan will discuss the various calculations of the integrated cross section.)

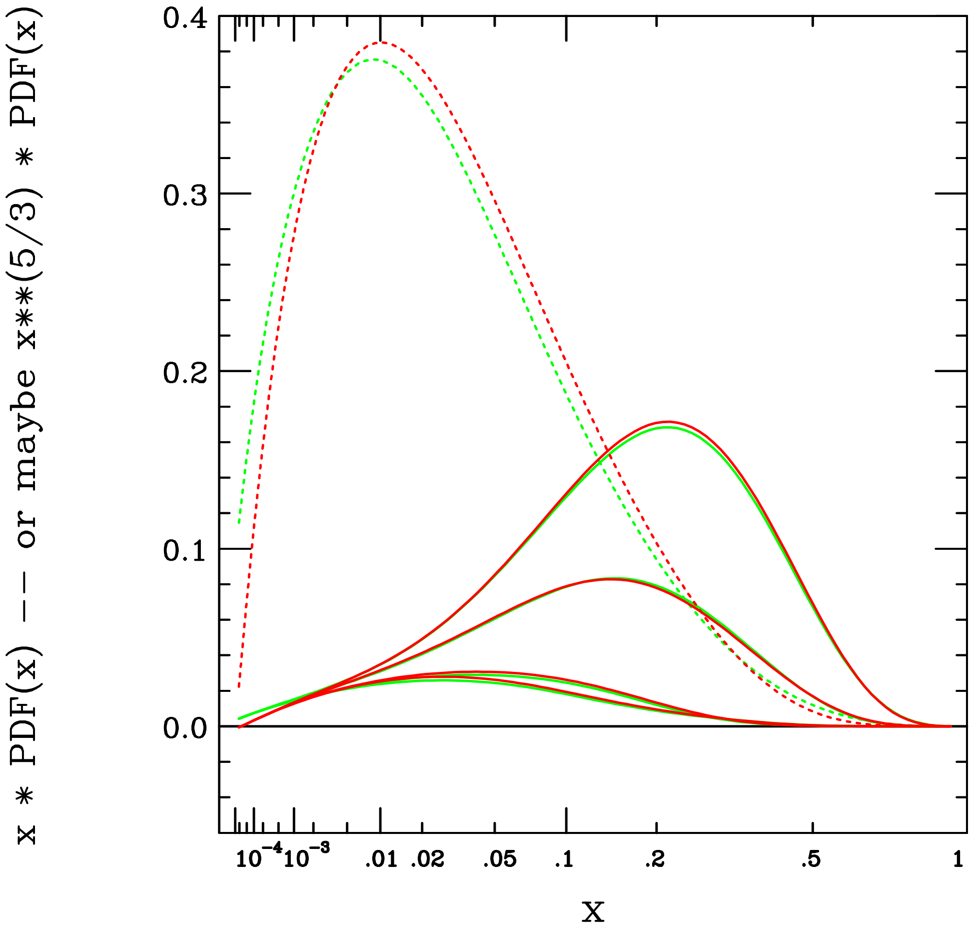
Comparing the gluon PDFs at Small Q



Gluon distribution $x\,g(x)$ at $Q = 2\,\text{GeV}$.
CTEQ6, MRST2003c

- MRST2003c is suppressed at $x \to 1$ by "counting rule" assumption.
- MRST2003c goes negative at $x \to 0$. This is presumably needed to allow large $g(x)$ at moderately large x, to agree with Tevatron jet data, without disturbing the momentum sum rule constraint.

Comparing the PDFs at Large Q



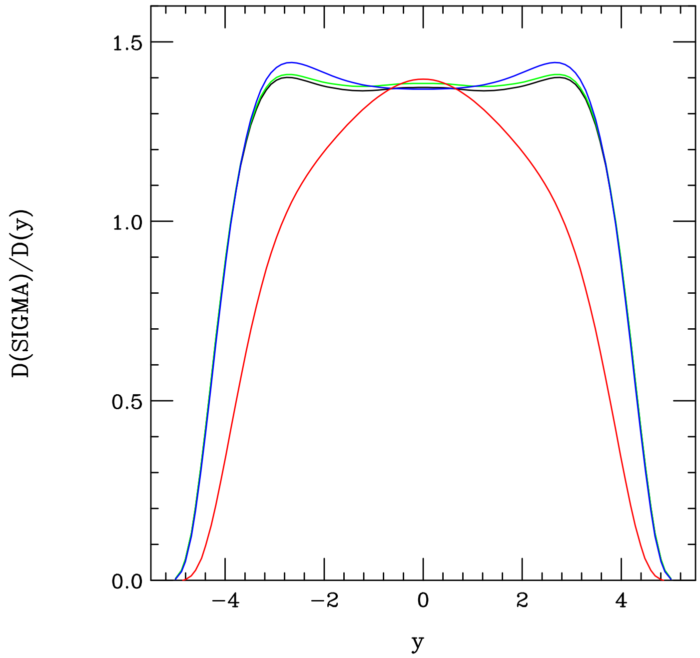
u, d, $\bar{u}$, $\bar{d}$ distributions $x\,pdf(x)$ at $Q = 100\,\mathrm{GeV}$. Gluon (dashed) is also shown. CTEQ6, MRST2003c

- At W mass scale, sea quark distributions in MRST2003c are suppressed at small x as a result of evolution from the suppressed gluons at low Q. This is what makes

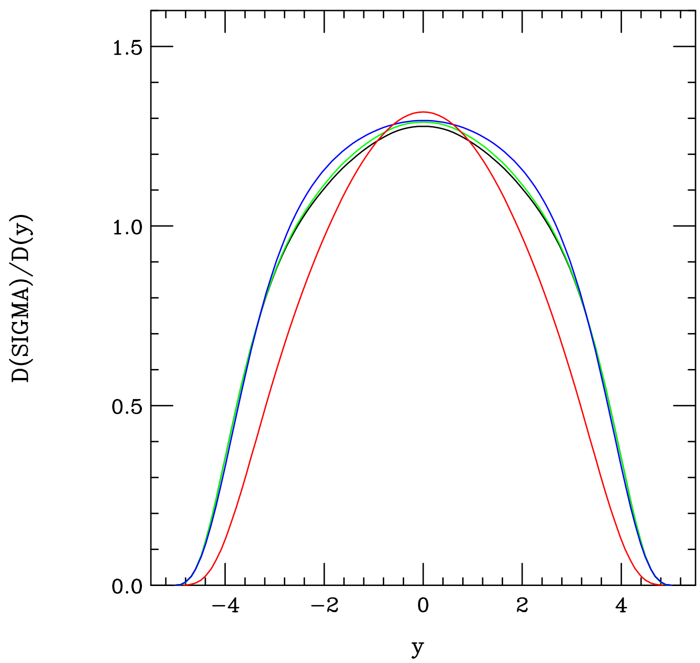
  MRST2003c $<<$ CTEQ6

  for W production at large y.
- CTEQ6 still has stronger gluon at large x, which gives better fit to Tevatron inclusive jet data.

Separated predictions for W^+ and W^-



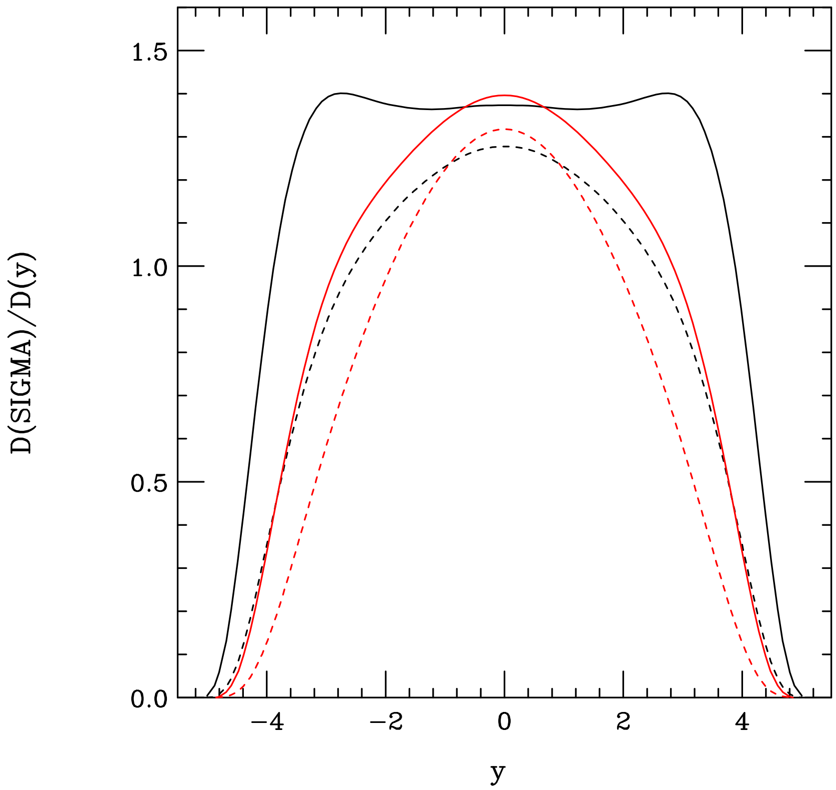
W^+: CTEQ6.1, CTEQ6, MRST2002, MRST2003c



W^-: CTEQ6.1, CTEQ6, MRST2002, MRST2003c

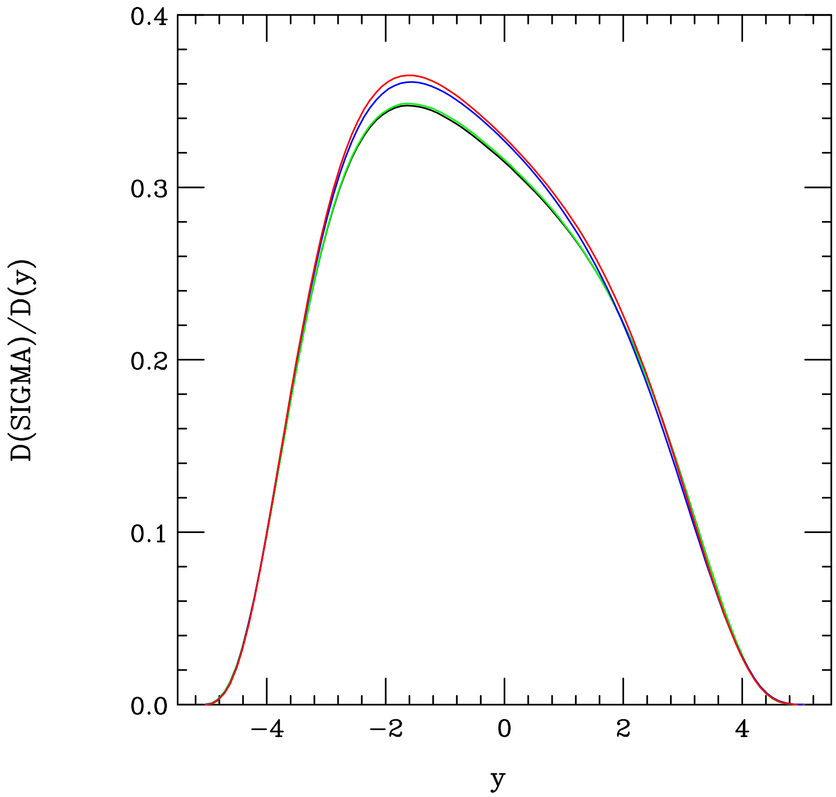
The MRST2003c prediction is anomalous for both W^+ and W^-, because its small or negative $g(x)$ at $Q \sim 1\,\text{GeV}$ evolves to suppressed q and $\bar{q}$ distributions at $Q \sim 100\,\text{GeV}$.

Predictions for W^+ and W^- superimposed



W^+ (Solid) and W^- (Dashed): CTEQ6.1, MRST2003c

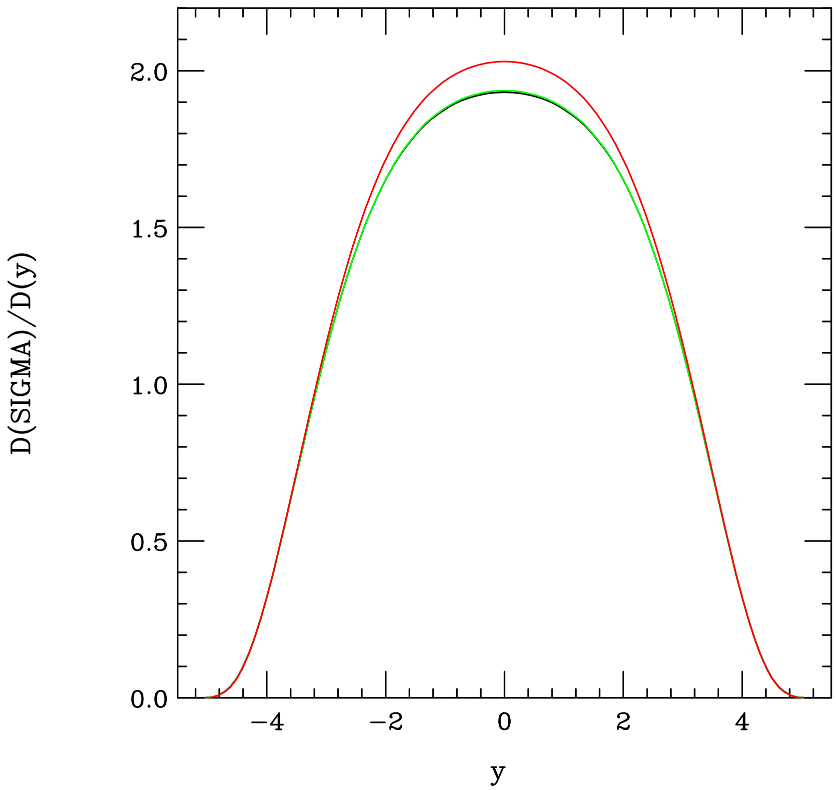
Predictions for W^+ at Tevatron



CTEQ6.1, CTEQ6, MRST2002, MRST2003c

- No big differences in shape, since the small-x region is not probed at Tevatron.
- There is a difference in normalization.
- Perhaps low-mass Drell-Yan pair production would be sensitive enough to small x to settle this matter at the Tevatron.

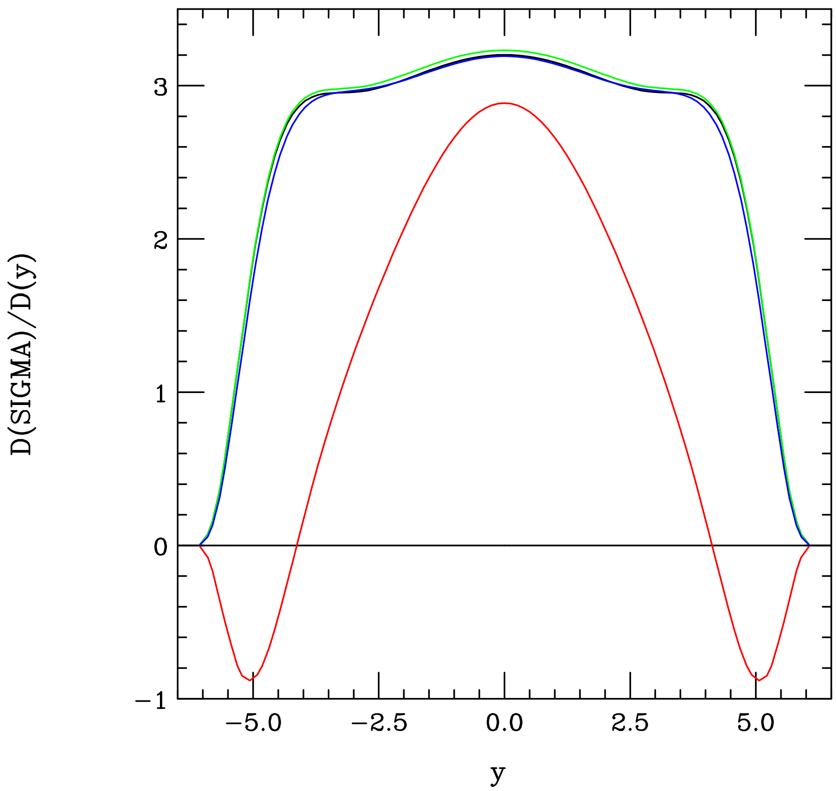
Predictions for Z^0 at Tevatron



CTEQ6.1, CTEQ6, MRST2002, MRST2003c

- Like the $W^{\pm}$ case, there is no big differences in shape, since the small-x region is not probed at Tevatron.
- Like the $W^{\pm}$ case, there is a difference in normalization.

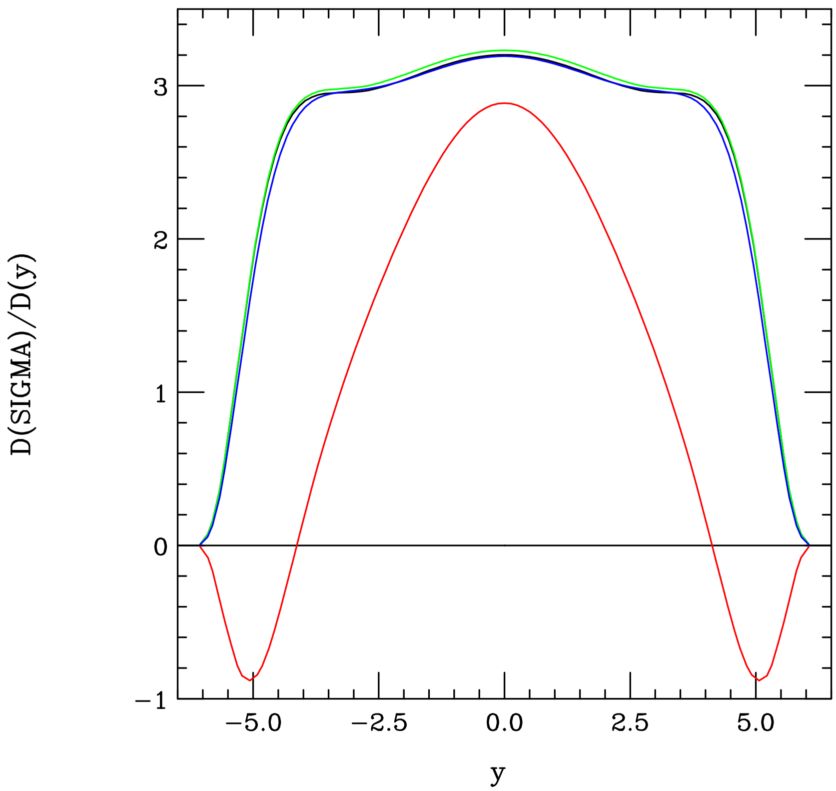
Predictions for W^+ in pp at $\sqrt{s} = 40\,\text{GeV}$



CTEQ6.1, CTEQ6, MRST2002, MRST2003c

- At SSC energy, the "conservative" prediction is even more radical! The negative gluon at small x at $Q = 1.3\,\text{GeV}$ has evolved to produce negative u, $\bar{u}$, d, and $\bar{d}$ at $Q = M_W$, which leads to a negative cross section at NLO.

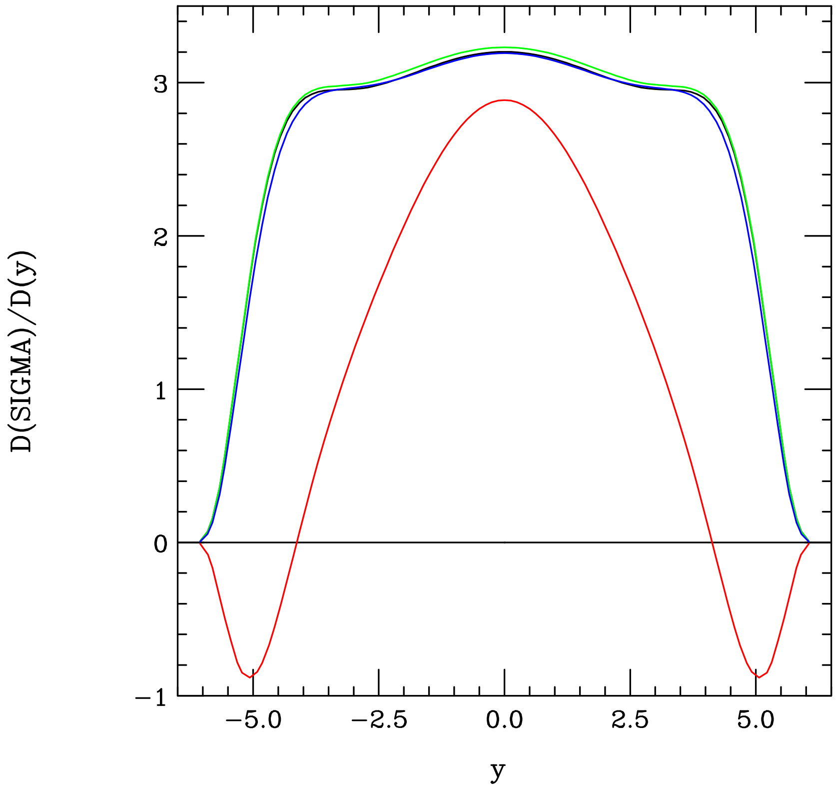
Predictions for W^- in pp at $\sqrt{s} = 40\,\mathrm{GeV}$



CTEQ6.1, CTEQ6, MRST2002, MRST2003c

- W^- has same story as W^+: The negative gluon in MRST2003c at small x at $Q = 1.3\,\mathrm{GeV}$ has evolved to produce negative u, $\bar{u}$, d, and $\bar{d}$ at $Q = M_W$, which leads to a negative cross section at NLO.

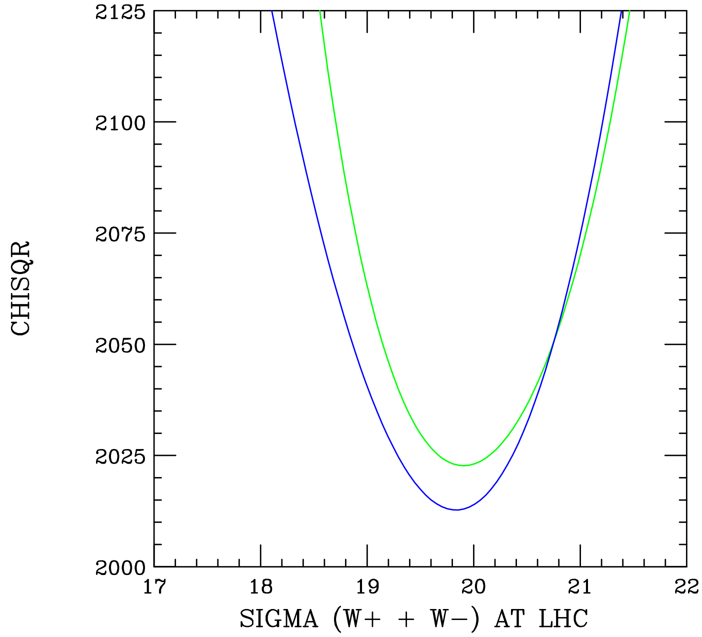
Predictions for Z^0 in pp at $\sqrt{s} = 40\,\text{GeV}$



CTEQ6.1, CTEQ6, MRST2002, MRST2003c

- Z^0 has same story as $W^\pm$: The negative gluon in MRST2003c at small x at $Q = 1.3\,\text{GeV}$ has evolved to produce negative u, $\bar{u}$, d, and $\bar{d}$ at $Q = M_Z$, which leads to a negative cross section at NLO.

χ^2 of Global Fit as fcn of $\sigma_{W^+ + W^-}$ at LHC



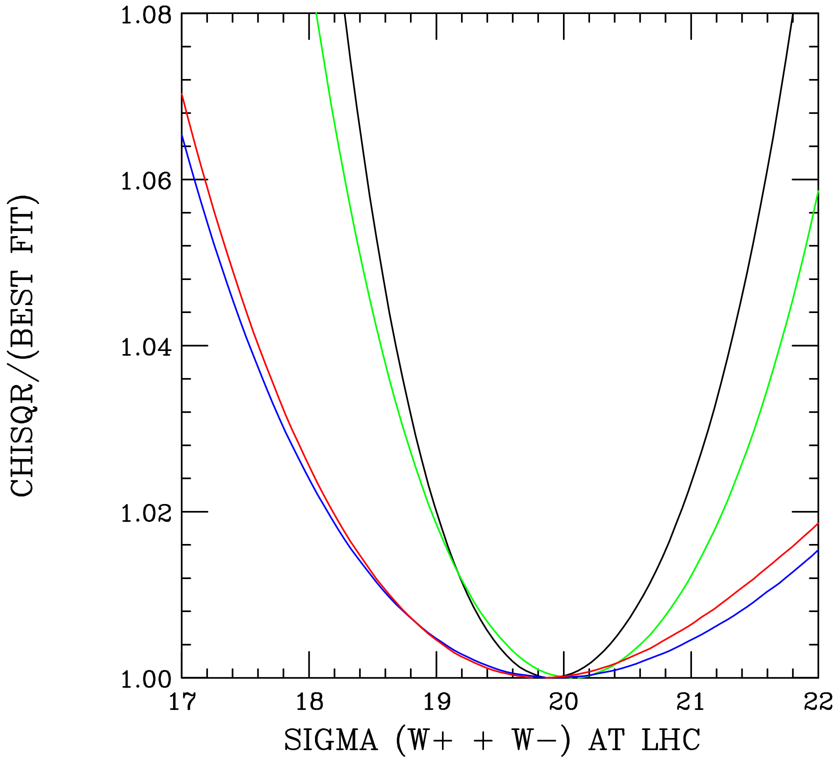
Global fit with standard cuts:

$Q > 2\,\mathrm{GeV}$, $W > 3.5\,\mathrm{GeV}$.

$g(x)$ positive definite. $g(x)$ allowed negative.

- Allowing $g(x) < 0$ can reduce χ^2 by an insignificant amount (~ 10) $\rightarrow$ negative gluon is allowed, but not required.
- Minima occur at approximately the same $\sigma_{W^+ + W^-}$, so allowing negative gluon makes no significant change in the central prediction.
- Allowing negative gluon somewhat expands the uncertainty range – e.g. according to the $\Delta\chi^2 = 100$ criterion, from
  $18.5 < \sigma_{W^+ + W^-} < 21.5$ to
  $18.2 < \sigma_{W^+ + W^-} < 21.5$.

Effect of global cuts (with $g(x) > 0$)



Global fit $\chi^2/\chi^2_{\text{BestFit}}$ as fcn of $\sigma_{W^+ + W^-}$ at LHC.

"Standard" cuts: $Q > 2\,\text{GeV}$.

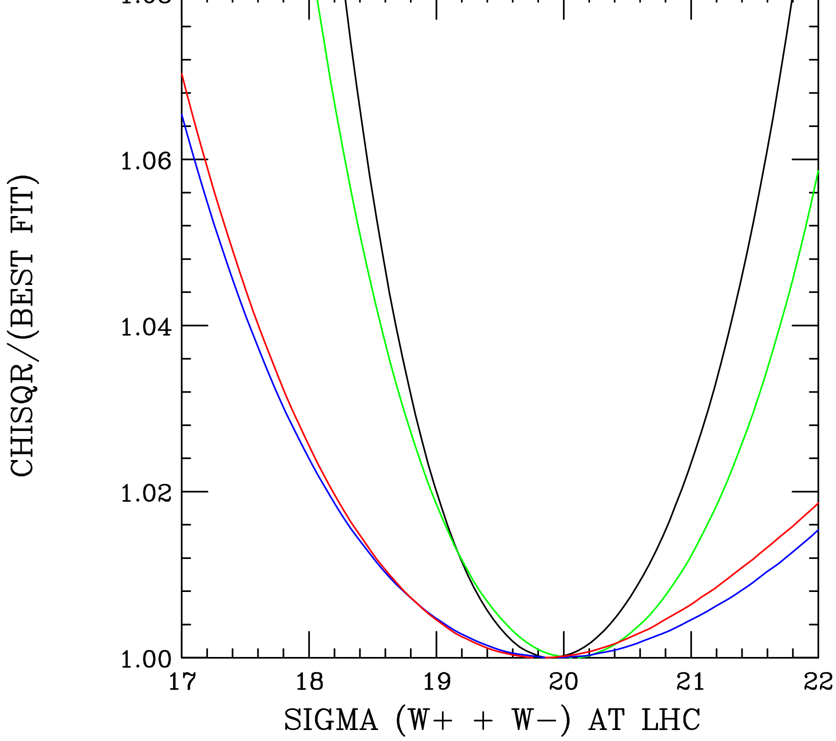
"Intermediate" cuts: $Q > 2.5\,\text{GeV}$, $x > 0.001$.

"Strong" cuts: $Q > 3.162\,\text{GeV}$, $x > 0.005$.

"Very Strong" cuts: $Q > 10\,\text{GeV}$.

($W > 3.5\,\text{GeV}$ imposed always.)

More restrictive cuts make the global fit less sensitive to possible contamination from higher twist (low Q) and non-DGLAP evolution (low x).



"Standard" cuts: $Q > 2\,\text{GeV}$.

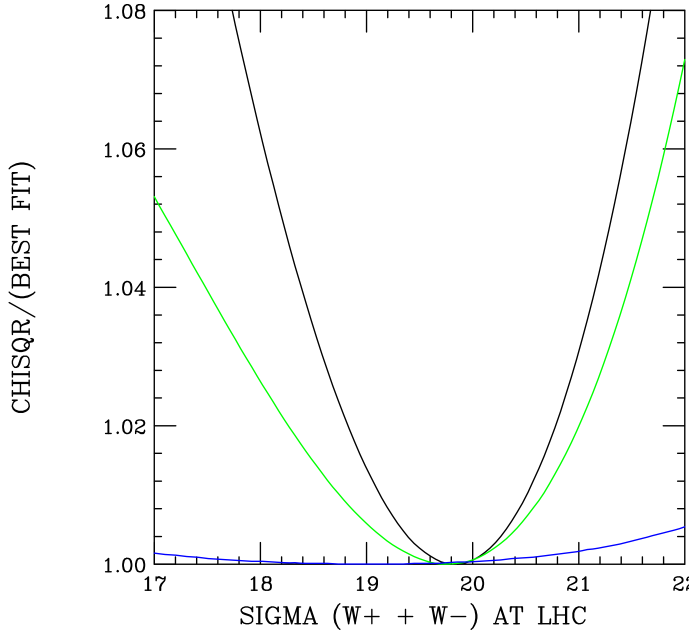
"Intermediate" cuts: $Q > 2.5\,\text{GeV}$, $x > 0.001$.

"Strong" cuts: $Q > 3.162\,\text{GeV}$, $x > 0.005$.

"Very Strong" cuts: $Q > 10\,\text{GeV}$.

- Contrary to MRST, we find no "instability": stronger cuts have little effect on the central value of the predicted $\sigma_{W^+ + W^-}$.
- More restrictive cuts reduce the information included, so expand the allowed uncertainty range.

Effect of global cuts ($g(x) < 0$ allowed)



"Standard" cuts: $Q > 2\,\text{GeV}$.

"Intermediate" cuts: $Q > 2.5\,\text{GeV}$, $x > 0.001$.

"Strong" cuts: $Q > 3.162\,\text{GeV}$, $x > 0.005$.

- Contrary to MRST, we find no "instability": stronger cuts have little effect on the central value of predicted $\sigma_{W^+ + W^-}$.
- With strong cuts and negative gluons, the uncertainty range of σ_W expands considerably toward low values. However, there is no compelling reason to impose the stronger cuts. Also, the extreme low end of the σ_W range comes with a negative gluon distribution at small x and Q, and even negative quark distributions at $x \sim 10^{-4}$ even at $Q = 100\,\text{GeV}$.

Cteq study of Stability of Global fit with respect to cuts

Example:

Normal CTEQ cuts: $Q > 2$, $W > 3.5$, $x > 0$.

Strong cuts: $Q > 3.162$, $W > 3.5$, $x > 0.005$

Compare χ^2 with strong cuts to χ^2 of that subset of the data in the normal fit. Find a difference of only a few units $\rightarrow$ fit is stable.