CTEQ

CTEQ pdf parametrization*

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*not an expert on this subject, just filling in, so this will be brief

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CTEQ parametrization

- PDF's ($f_a(x,Q)$) are parametrized with a flexible form motivated by physics considerations (Regge behavior, spectator counting, for example) at fixed small Q_o (1.3 GeV for CTEQ) and then evolved for $Q>Q_o$ by DGLAP
  - assume for most of the general analyses that the c and b distributions are zero at scales below their masses and are generated by QCD evolution above
- Parametrization of parton distributions at Q_o used to obtain the CTEQ5 and CTEQ6 parton distributions contained 5 shape parameters (apart from normalization) for each flavor
  - global analysis data sets not sufficiently constraining to determine all of the parameters, so a number are frozen at some particular (motivated) values
  - 20 free parameters for CTEQ6.1/6.5 (22 for CTEQ6.6 (see next slide))
- For CTEQ6.5/6.6, adopt a simpler form with 4 shape parameters for the valence quarks $u_v(x)$, $d_v(x)$ and the gluon $g(x)$

$$f(x) = a_o x^{a_1} (1-x)^{a_2} e^{a_3 x + a_4 x^2}$$

  - a reasonable generalization of the conventional minimal form

$$f(x) = a_o x^{a_1} (1-x)^{a_2}$$

  - which combines Regge behavior at x->0 and spectator counting at x->1
- Both forms above are positive definite and have simplified logarithmic derivatives

CTEQ parametrization

- Is this form flexible enough?
- Remember the lesson of Tevatron jets, where low x and high x can easily be (artificially) tied together through the parametrization
- We find that significantly better fits cannot be achieved by introducing additional parameters or changing the functional form
  - NB: prior to CTEQ6.6, the analysis generally assumed

$$s(x) = \bar{s}(x) \propto \bar{d}(x) + \bar{u}(x)$$

  - that ansatz has been dropped in CTEQ6.6

W/Z cross sections at the LHC

- CTEQ6.1 and MRST2004 NLO predictions in good agreement with each other
- NNLO corrections are small and negative
- NNLO mostly a K-factor; NLO predictions adequate for most predictions at the LHC

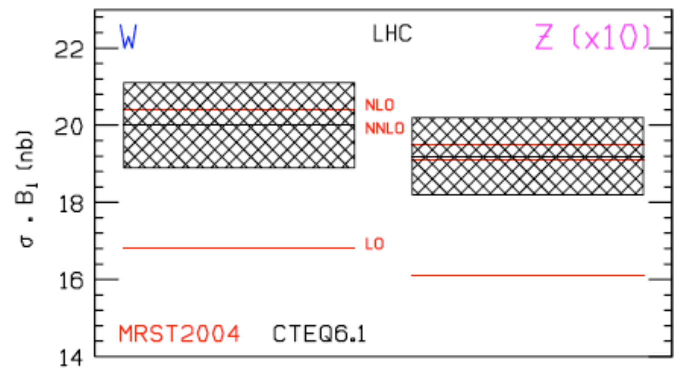
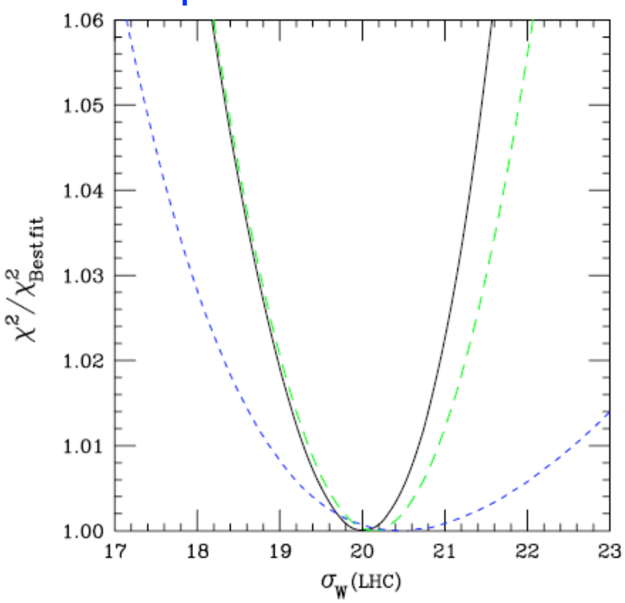
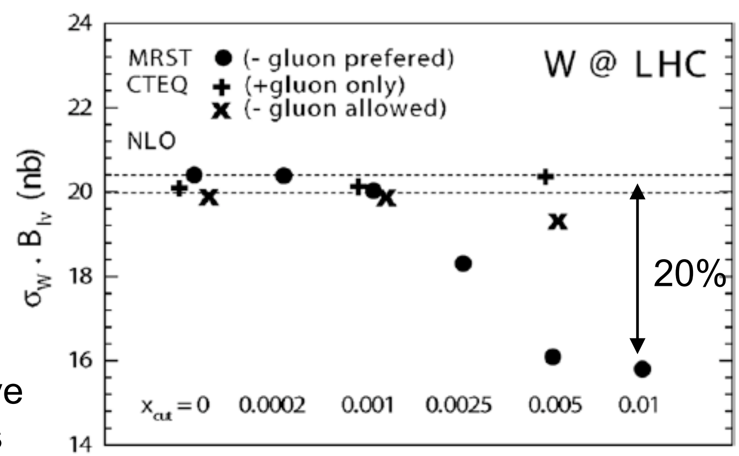


Figure 80. Predicted cross sections for W and Z production at the LHC using MRST2004 and CTEQ6.1 pdfs. The overall pdf uncertainty of the NLO CTEQ6.1 prediction is approximately 5%, consistent with figure 77.



removing low x data from global fits increases uncertainty but does not significantly move central answer; negative gluon increases uncertainty even more

Figure 82. Lagrange multiplier results for the W cross section (in nb) at the LHC using a positive–definite gluon. The three curves, in order of decreasing steepness, correspond to three sets of kinematic cuts, standard/intermediate/strong.



tension between low x and high x data?; not a big effect in CTEQ analysis

Figure 81. Predicted total cross section of $W^+ + W^-$ production at the LHC for the fits obtained in the CTEQ stability study, compared with the MRST results. The overall pdf uncertainty of the prediction is ~5%, as observed in figure 77.

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Errors in parton distribution functions

- CTEQ/MSTW/HERA provide ways to estimate the error on the central pdf
  - Hessian methodology enables full characterization of parton parametrization space in neighborhood of global minimum

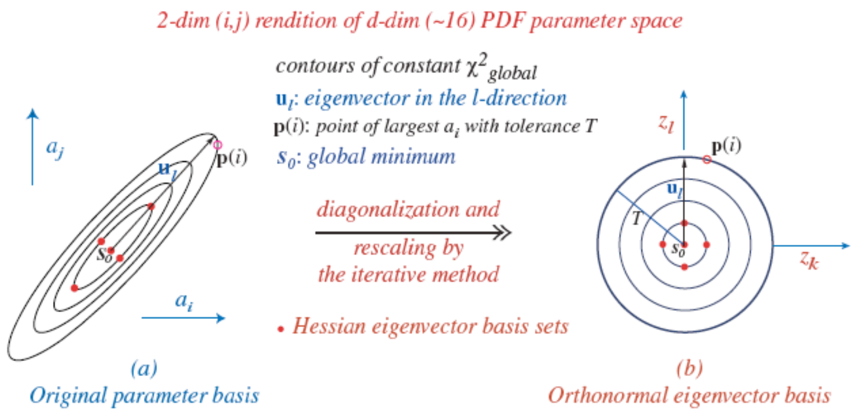

Figure 28. A schematic representation of the transformation from the pdf parameter basis to the orthonormal eigenvector basis.

Inclusive jets at the Tevatron

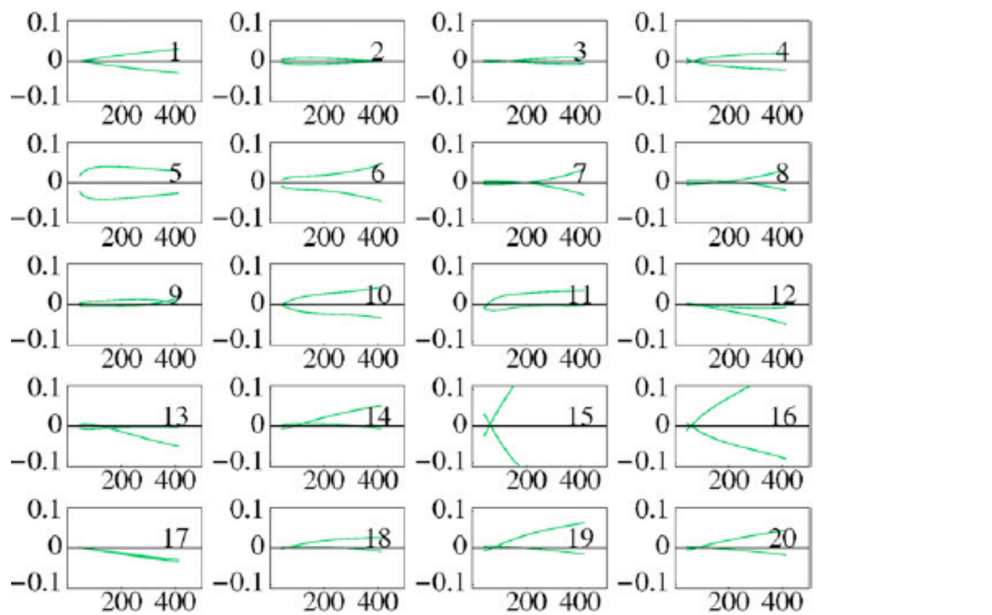

Figure 29. The pdf errors for the CDF inclusive jet cross section in Run 1 for the 20 different eigenvector directions. The vertical axes show the fractional deviation from the central prediction and the horizontal axes the jet transverse momentum in GeV.

- CTEQ6.1 has 20 free parameters so 20 directions in eigenvector space

40 error pdfs

$$\Delta X^{+}_{\max} = \sqrt{\sum_{i=1}^{N} [\max(X^{+}_{i} - X_0, X^{-}_{i} - X_0, 0)]^2},$$

$$\Delta X^{-}_{\max} = \sqrt{\sum_{i=1}^{N} [\max(X_0 - X^{+}_{i}, X_0 - X^{-}_{i}, 0)]^2}.$$

•CTEQ6.6 has 22 free parameters so 22 directions in eigenvector space and 44 error pdf's
•Of order of a factor of 1E6 between largest (best determined directions) and smallest (least well-determined directions) eigenvalues

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Eigenvector directions (CTEQ6.1)

Eigenvector 1: primarily a_1 of u valence

Sets	Shape Parameter	Component
1, 2	BP(2, 1)	0.057911
1, 2	BP(2, 2)	-0.022688
1, 2	BP(2, 3)	0.015496
1, 2	BP(2, 4)	0.035277
1, 2	BP(2, 5)	frozen
1, 2	BP(1, 1)	0.888833
1, 2	BP(1, 2)	-0.161942
1, 2	BP(1, 3)	0.118204
1, 2	BP(1, 4)	0.268405
1, 2	BP(1, 5)	0.276392
1, 2	BP(0, 1)	0.038555
1, 2	BP(0, 2)	-0.006610
1, 2	BP(0, 3)	frozen
1, 2	BP(0, 4)	-0.017717
1, 2	BP(0, 5)	frozen
1, 2	BP(-1, 1)	-0.007668
1, 2	BP(-1, 2)	0.012745
1, 2	BP(-1, 3)	0.001851
1, 2	BP(-1, 4)	frozen
1, 2	BP(-1, 5)	0.001004
1, 2	BP(-2, 1)	0.117517
1, 2	BP(-2, 2)	-0.008357
1, 2	BP(-2, 3)	0.006504
1, 2	BP(-2, 4)	frozen
1, 2	BP(-2, 5)	frozen

Eigenvector 20: high x sea quark

Sets	Shape Parameter	Component
39, 40	BP(2, 1)	0.000248
39, 40	BP(2, 2)	0.069038
39, 40	BP(2, 3)	0.173137
39, 40	BP(2, 4)	-0.029044
39, 40	BP(2, 5)	frozen
39, 40	BP(1, 1)	0.000920
39, 40	BP(1, 2)	-0.001493
39, 40	BP(1, 3)	0.008380
39, 40	BP(1, 4)	0.000153
39, 40	BP(1, 5)	-0.008078
39, 40	BP(0, 1)	0.003339
39, 40	BP(0, 2)	-0.010965
39, 40	BP(0, 3)	frozen
39, 40	BP(0, 4)	0.008411
39, 40	BP(0, 5)	frozen
39, 40	BP(-1, 1)	0.479314
39, 40	BP(-1, 2)	0.190673
39, 40	BP(-1, 3)	0.796917
39, 40	BP(-1, 4)	frozen
39, 40	BP(-1, 5)	-0.131794
39, 40	BP(-2, 1)	-0.000408
39, 40	BP(-2, 2)	0.136504
39, 40	BP(-2, 3)	0.163995
39, 40	BP(-2, 4)	frozen
39, 40	BP(-2, 5)	frozen

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Extrapolations

- How reasonable are extrapolations, say to low x?
- Of course, in the absence of data, you may be constrained by the parametrization (and momentum sum rule) and are probably underestimating the uncertainty
- See, for example, Ubiati presentation at La Thuile