Use of LO and NLO pdf’s

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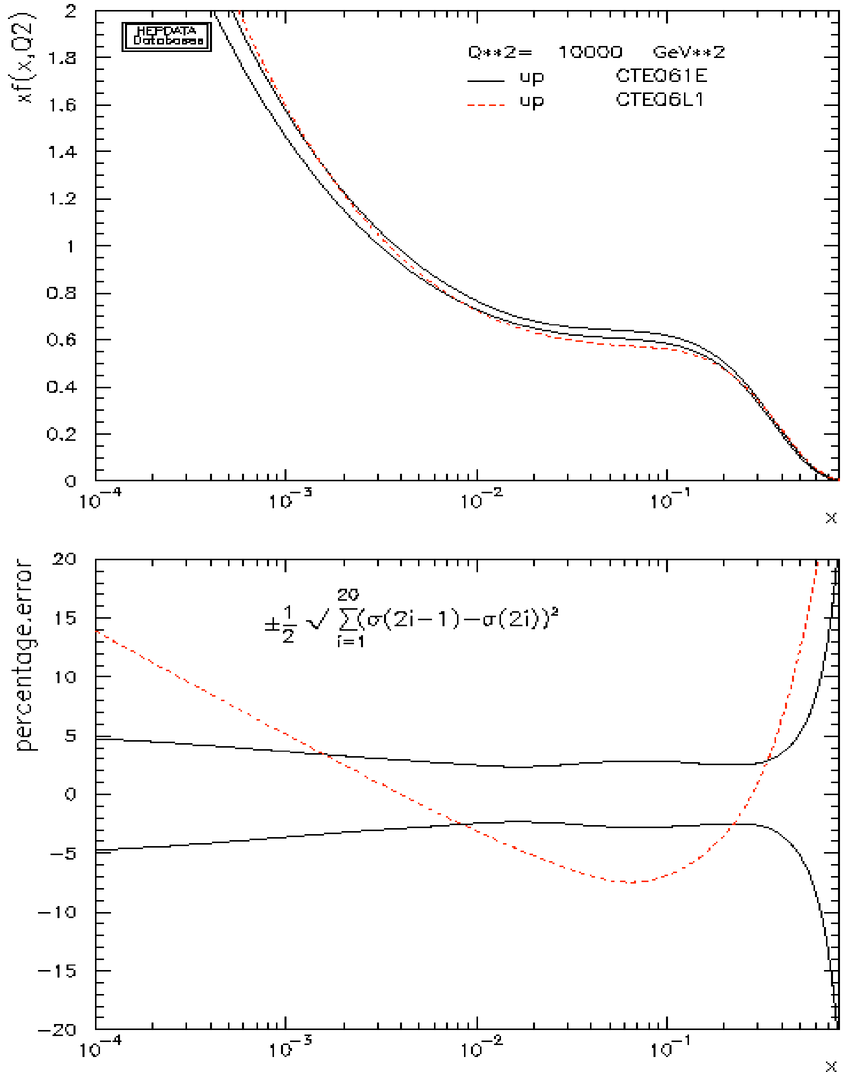
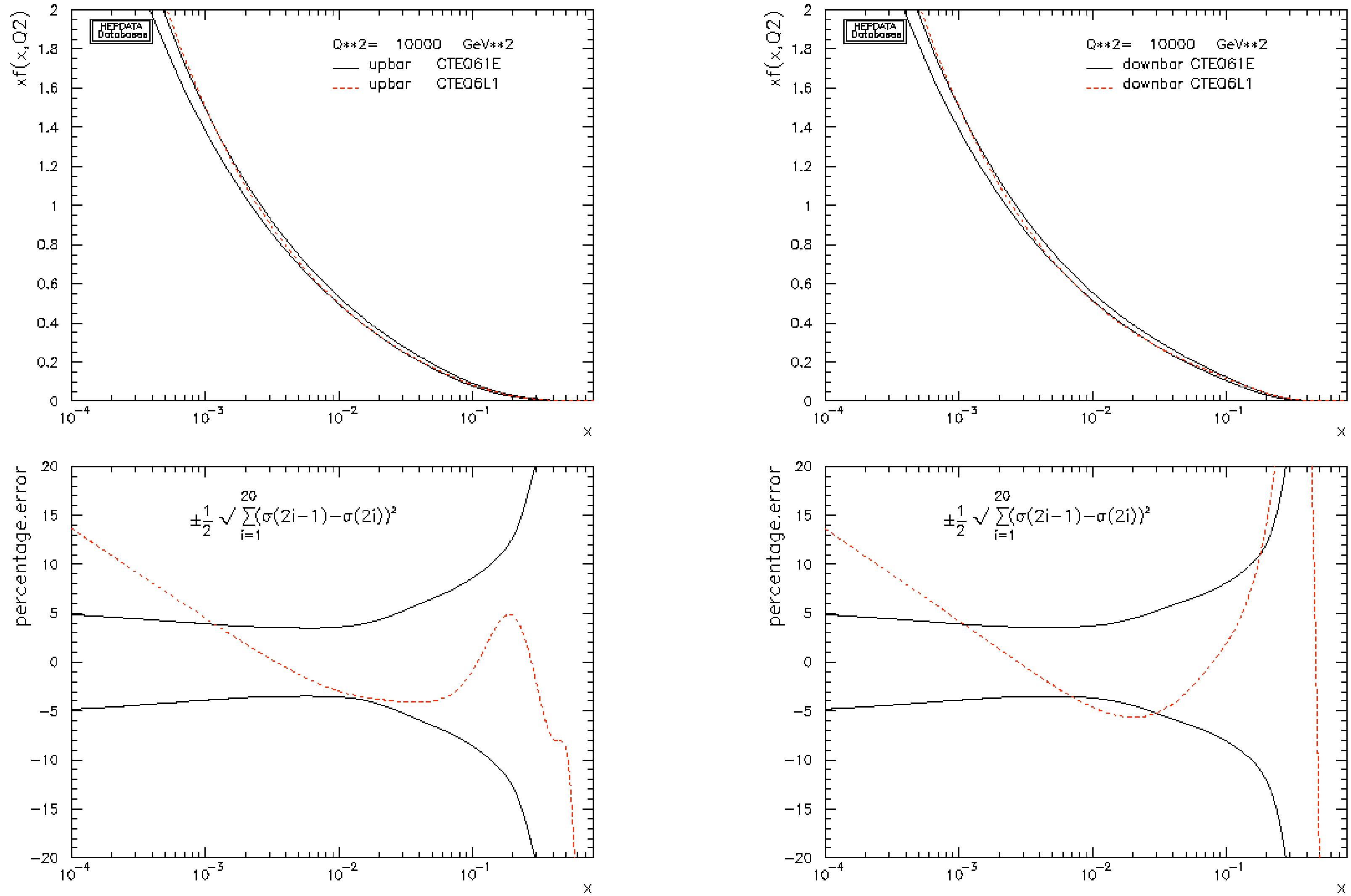
LO vs NLO pdf's for parton shower MC's

- For NLO calculations, use NLO pdf's (duh)
- What about for parton shower Monte Carlos?
  - somewhat arbitrary assumptions (for example fixing Drell-Yan normalization) have to be made in LO pdf fits
  - DIS data in global fits affect LO pdf's in ways that may not directly transfer to LO hadron collider predictions
  - LO pdf's for the most part are outside the NLO pdf error band
  - LO matrix elements for many of the processes that we want to calculate are not so different from NLO matrix elements
  - by adding parton showers, we are partway towards NLO anyway
  - any error is formally of NLO
- (my recommendation) use NLO pdf's
  - pdf's must be + definite in regions of application (CTEQ is so by def'n)
- Note that this has implications for MC tuning, i.e. Tune A uses CTEQ5L
  - need tunes for NLO pdf's



. . .but at the end of the day this is still LO physics;
There's no substitute for honest-to-god NLO.

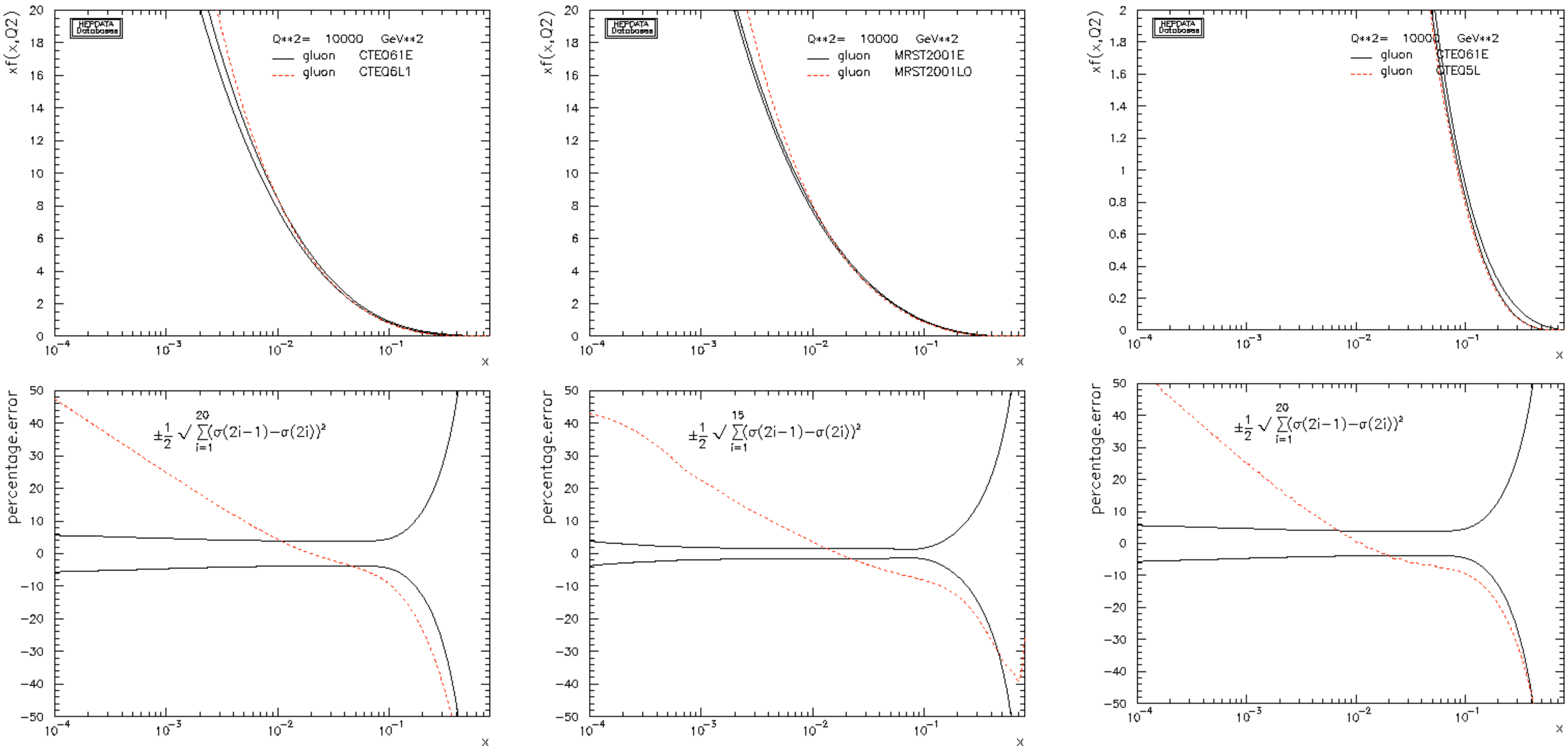
upbar/downbar



gluon

similar for MRST

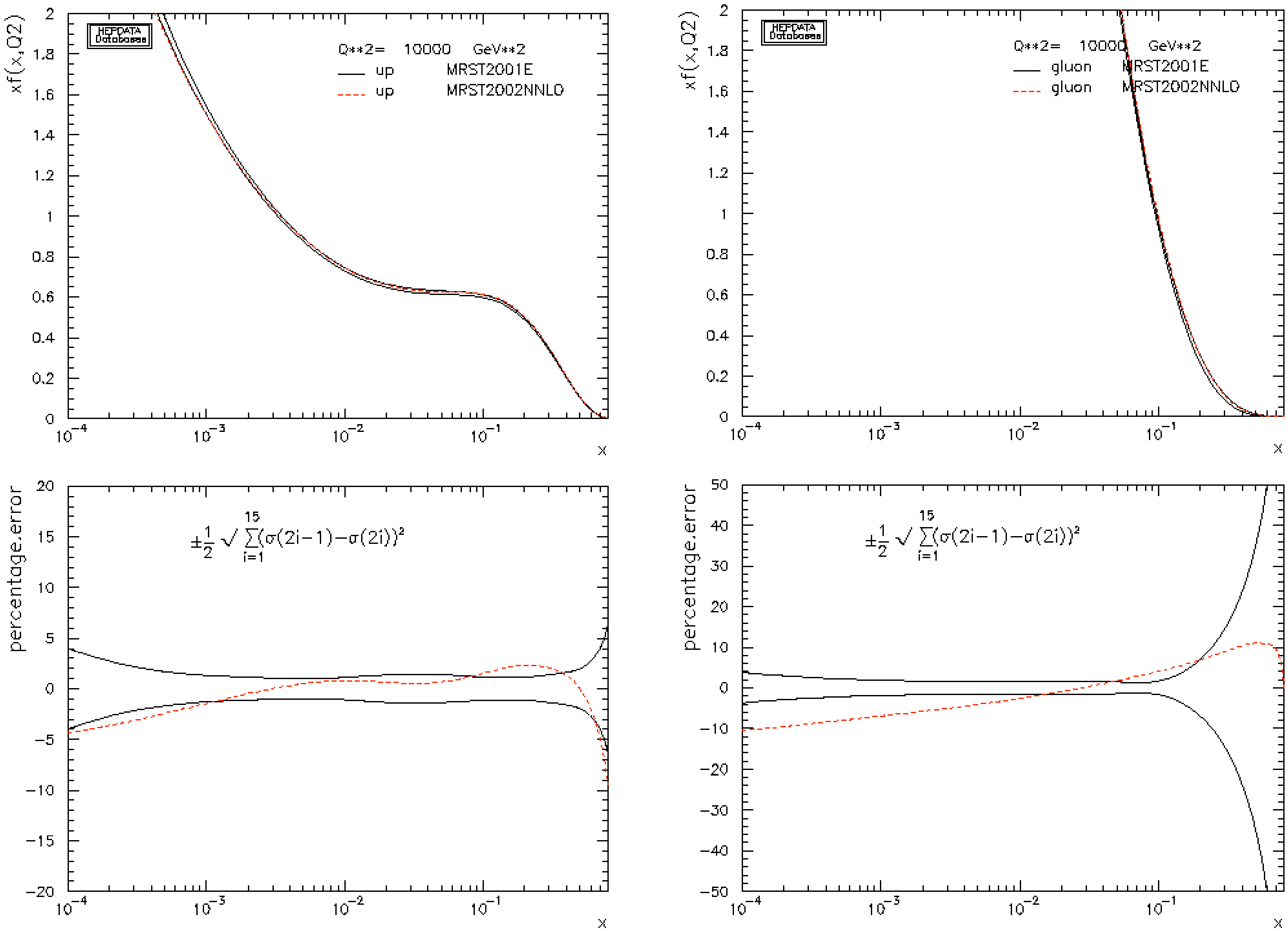
compare to CTEQ5L,
used for most MC's



Comparisons

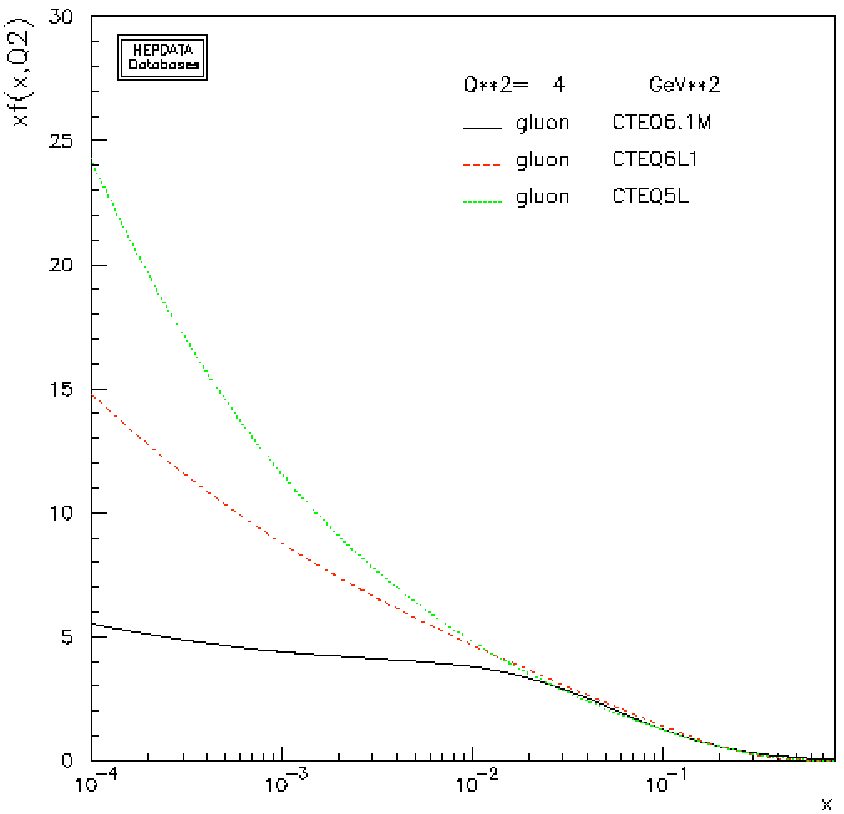
- For the TeV4LHC (Les Houches) writeup, I'm going to try a comparison for a number of processes whose cross sections at known at NLO
  - NLO cross section with CTEQ6.1M
  - LO cross section with CTEQ6L
  - LO cross section with CTEQ6.1M
- …to try to quantify this statement

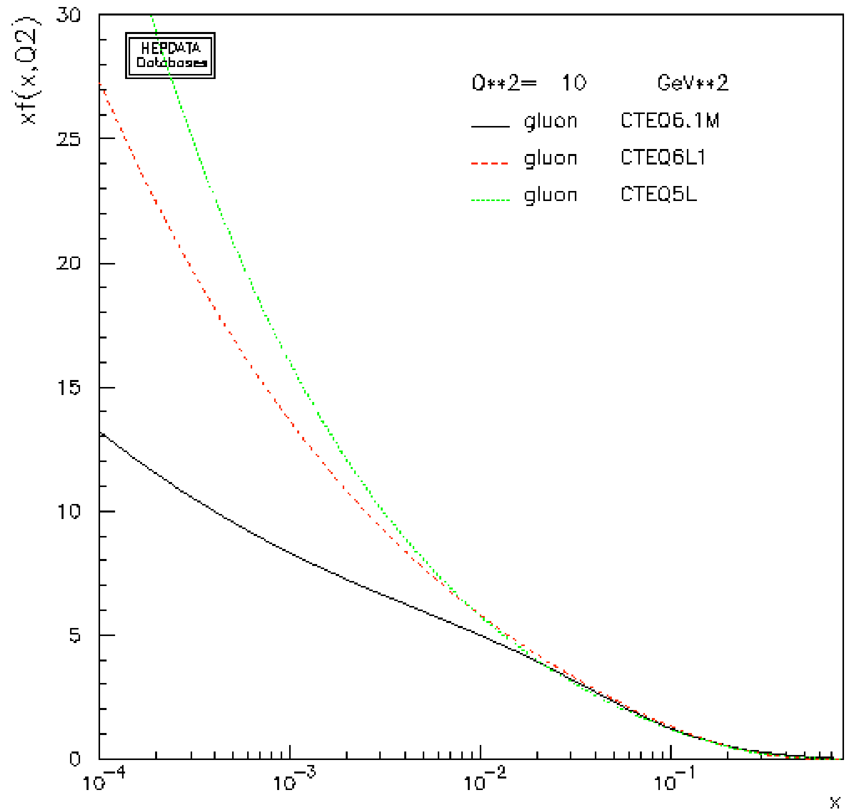
Less difference between NLO and NNLO pdf's



Impact on UE tunes

- 5L significantly steeper at low x and Q^2



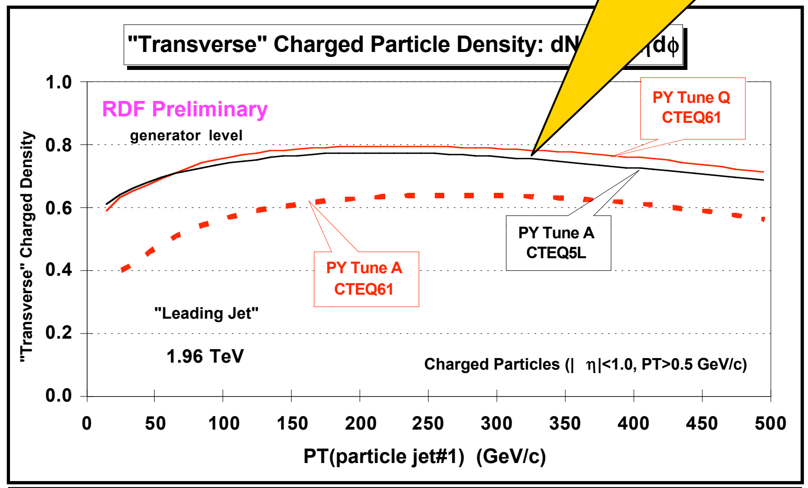


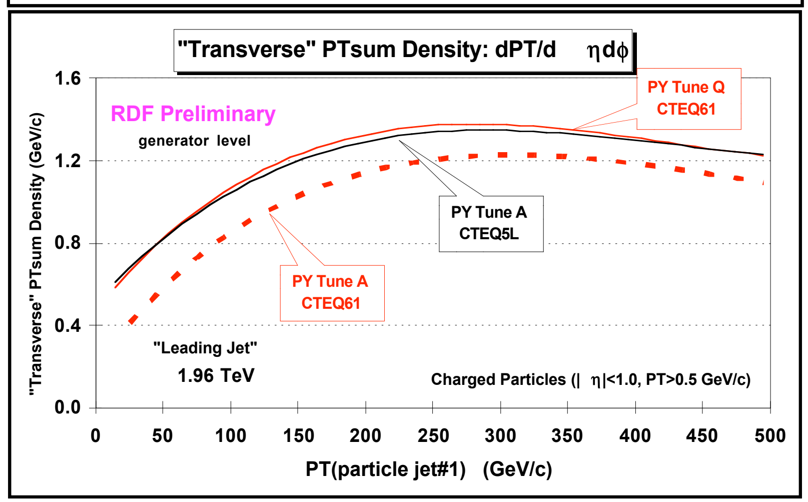
CTEQ6.1 Tune

I used LHAPDF! See the next talk by Craig Group!

PYTHIA 6.2 CTEQ6.1

	Parameter	Tune Q	Tune QW
UE Parameters	MSTP(81)	1	1
	MSTP(82)	4	4
	PARP(82)	1.2 GeV	1.2 GeV
	PARP(83)	0.5	0.5
	PARP(84)	0.4	0.4
	PARP(85)	0.9	0.9
	PARP(86)	0.95	0.95
	PARP(89)	1.8 TeV	1.8 TeV
	PARP(90)	0.25	0.25
ISR Parameters	PARP(62)	1.0	1.25
	PARP(64)	1.0	0.2
	PARP(67)	4.0	4.0
Intrensic KT	MSTP(91)	1	1
	PARP(91)	1.0	2.1
	PARP(92)	5.0	15.0



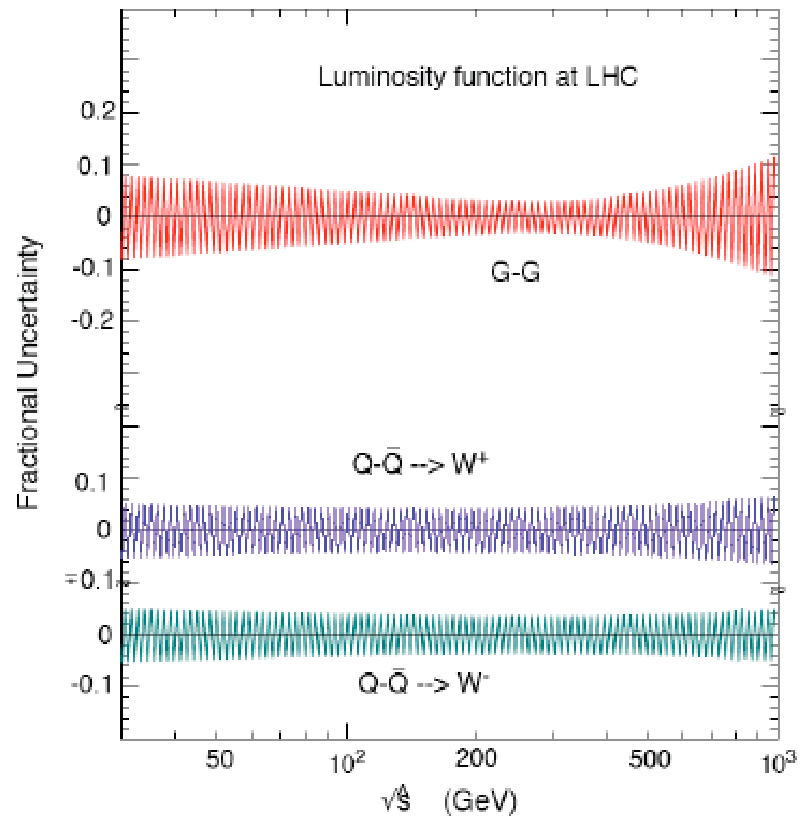


PDF uncertainties

- In most kinematic regions of interest at the Tevatron/LHC, pdf uncertainties are small
  - one exception is high E_T jet production

- Using LHAPDF, can easily calculate pdf uncertainties for any observable using pdf weights

Note that you can roughly estimate pdf uncertainties for many processes using plots like the one below. I'll produce more.



- NLO predictions for LHC under good control if NLO formalism is adequate for LHC

Les Houches 2005

C. Group: LHAPDF

LHAPDF/LHAGLUE

- The Les Houches Accord PDF library is replacement for PDFLIB.
- LHAGLUE is a “PDFLIB-like” interface for HERWIG and PYTHIA

$\longrightarrow$ See talk by J. Huston (Dec.1 2005 QCD working group) for summary of LHAPDF and LHAGLUE.

LHAPDF V5 coming soon!

- Will be possible to keep PDFs from multiple sets stored in memory.
- Feedback from Tevatron experiments implemented
  - pftopdg.f added from PDFLIB.
    - Some CDF and D0 programs use this.
    - pftopdg converts flavor convention of PDFLIB to PDG convention
  - Various generic names changed to be unique to LHAPDF

    These are only internal names which do NOT affect the average user.
- NEW: LHAPDF v5 available ups/upd at FNAL...
  - "lhapdf" "v5_0_0_beta" "Linux+2.4-2.3.2" "GCC3_4_3" "development"
  - "lhapdf_source" "v5_0_0_beta" "NULL" "" "development"

  → Thanks to Lynn Garren!
- Please check v5! Your suggestions/problems can still be dealt with in v5.

→ CDF and D0 use will help validate and develop tools and ideas that will also be useful to the LHC. This is important!

LHAPDF

Implementing the weighting technique for PYTHIA

- Two options for using the weight technique
  - Store 40 weights for each event (we do it this way).
  - Store X_1, X_2, F_1, F_2, and Q^2 and calculate the weights "offline".
- Momentum fractions for the 2 initial partons from the hard scattering.

$$X_1 = PARI(33) \text{ and } X_2 = PARI(34)$$

- Flavor type of 2 initial partons

$$F_1 = MSTI(15) \text{ and } F_2 = MSTI(16)$$

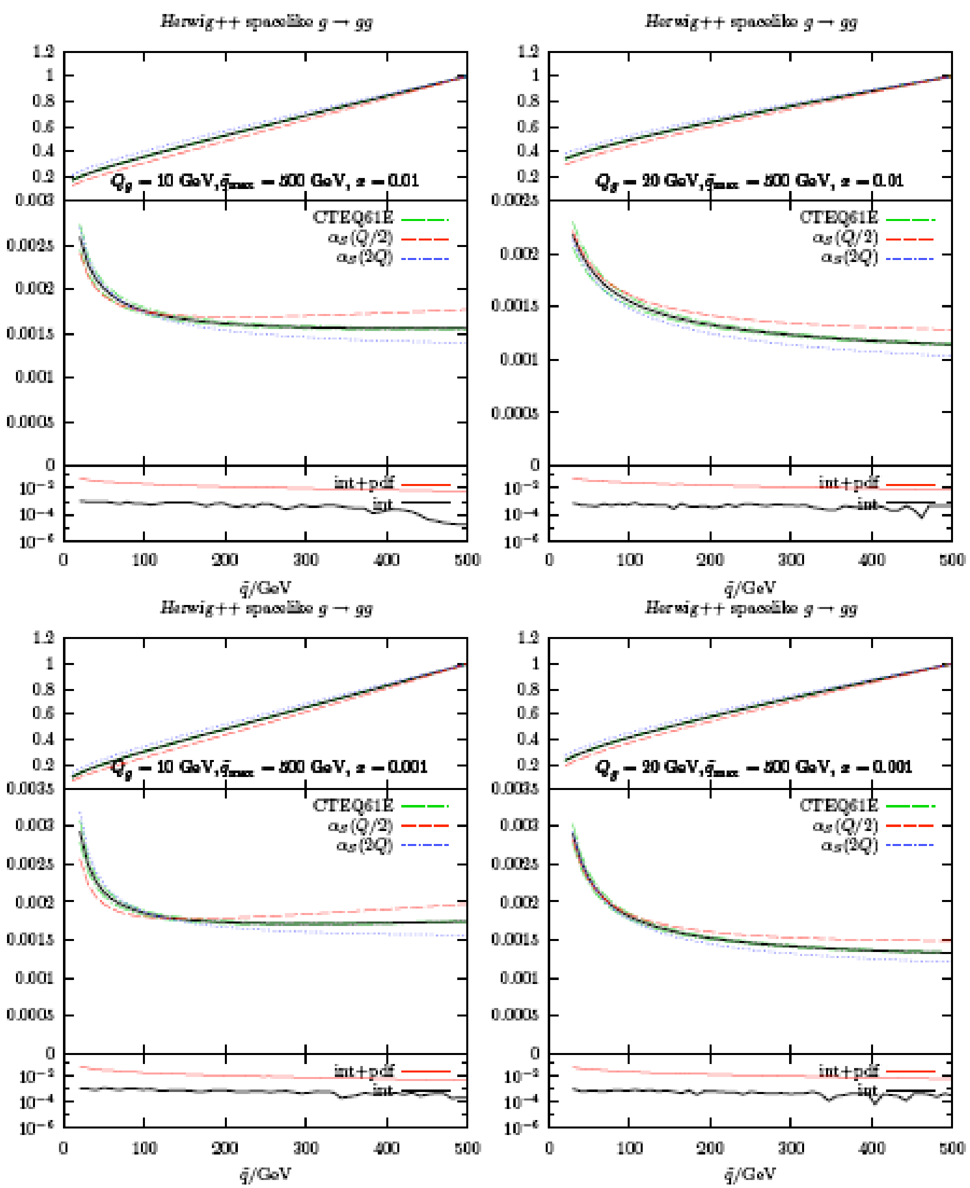
- Q^2 for the hard scattering

$$Q^2 = PARI(24)$$

This is everything you need to calculate PDF weights using LHAPDF, but we are in the process of writing a general robust code for all users, so you won't have to.

$\longrightarrow$ Thanks to Torbjörn Sjöstrand for the PYTHIA help!

Uncertainties on Sudakov form factors



- Stefan Gieseke showed that the Sudakov form factors have very little dependence on the particular pdf's used
  - hep-ph/0412342
- So pdf weighting works for parton shower Monte Carlos as well as fixed order calculations

To be discussed in TeV4LHC report

1. Introduction/motivation
2. PDF's:tools and issues
    1. fastNLO
    2. LHAPDF
        1. pdf reweighting techniques
        2. Sudakov FF's
    3. CTEQ α_s series and CTEQ7
    4. use of NLO pdf's (MC's)
3. Monte Carlo parameters
    1. underlying event tuning at the Tevatron
        1. Pythia and Jimmy
        2. CTEQ6.1
    2. extrapolation to the LHC: predictions and uncertainties
5. Matrix element/parton shower tools
    - W+jets: CKKW/MCFM comparisons to data
    - extrapolation to the LHC: backgrounds to VBF
    - Samper case study: Higgs + 2 jets
6. Jet production
    - MC@NLO: inclusive jet production
    - jet algorithms:advice for the LHC
7. Diffraction
8. White paper on remaining measurements at the Tevatron
9. SM Benchmarks for the LHC
    - relation to Tevatron measurements
10. Conclusions

Outline for review article I'm writing: suggestions welcome

1. Introduction and Framework
2. 2->1 and 2->2 hard subprocesses at hadron colliders
   a. W/Z/Drell-Yan/Higgs
   b. High pT photon, jet, heavy flavor
3. Adding extra partons, real and virtual; cross sections and jet structures
   a. at LO (tree-level scattering amplitudes)
      i. increasing complexity of 2->n processes as n increases, # of diagrams, color factors
      ii. numerical implementations – Madevent, Alpgen, Sherpa
      iii. new techniques – MHV rules, recursion relations
   b. at NLO (K-factors, singularity cancellations, scheme dependence)
      i. loop and real diagrams, toy model for singularity cancellation
      ii. origin of reduced scale dependence
      iii. complexity of analytical calculations, dependence on # of legs, masses, tensor structure
      iv. new numerical methods (sector decomposition, numerical reduction ...)
      v. new analytical methods (cutting rules, sewing amplitudes)
      vi. examples
   c. at NNLO
      i. different contributions (2-loop, 1-loop/1 unresolved, 2 unresolved)
      ii. 2-loop calculations of 2->2 processes
      iii. bottleneck: generic integration of 2-unresolved contribution; solution for DY is to convert real integrals -> loop integrals
      iv. works for total inclusive, simple cuts on rapidity
      v. example (or already in Sec.2, 5?)
   d. at all orders (parton showers; analytic resummation)
   e. jet algorithms
   f. fragmentation and hadronization
   g. merging fixed order and parton shower predictions
      i. CKKW
      ii. mlm
      iii. connections between parton showers and NLO

general points:

-power counting (in alpha_s)

-where do logs come from? What are LL? NLL? What calculation has what?

-exact, leading pole and eikonal approximations

-color flow: different color flows interfere with each other giving rise to 1/Nc^2 terms that don't correspond to a unique color flow; interference terms not present in parton shower Monte Carlos

Outline, continued

4. Parton distribution functions
   a. basics (symmetries, sum rules, small and large x behavior)
   b. global fits (LO, NLO, NNLO)
   c. uncertainties

5. Cross sections and uncertainties
   a. "rules of thumb"
      i. parton-parton luminosities and uncertainties for LHC
      1. effects of evolution
      2. LHAPDF and effective use of pdf uncertainties
      ii. LO vs. NLO vs. parton showers, e.g. regions of applicability
      iii. NLO corrections (K-factors); generalizations; edges of distributions where perturbation theory breaks down
   b. comparisons to Tevatron data
      1. W/Z sigma, y distributions
      a. LO, NLO, NNLO
      2. W/Z + jets
      a. LO+PS, NLO
      b. Zeppenfeld plots
      3. inclusive jet production
      a. jet algorithms revisited
      b. feedback to global fits
      c. fragmentation/UE corrections

c. SM benchmarks for the LHC – where appropriate, include best theoretical cross sections, error estimates
   1. W/Z/DY as luminosity monitors
   2. UE predictions/uncertainties
   3. inclusive jet production
   4. W/Z + jets
   5. top
   6. Higgs
      a. gg->H
      b. WW->H

d. new physics signatures and Standard Model backgrounds

6. Outlook: theory and experiment
a. LHC
b. NNLO
c. Samper
d. twistors