Tevatron and CTEQ pdf issues/results …an informal talk

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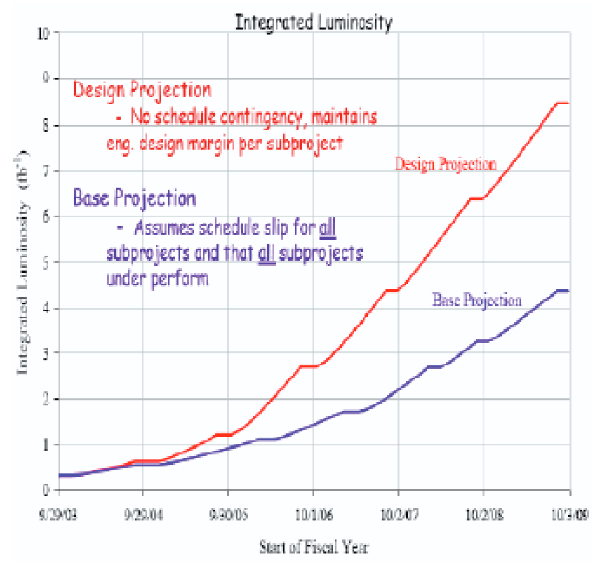
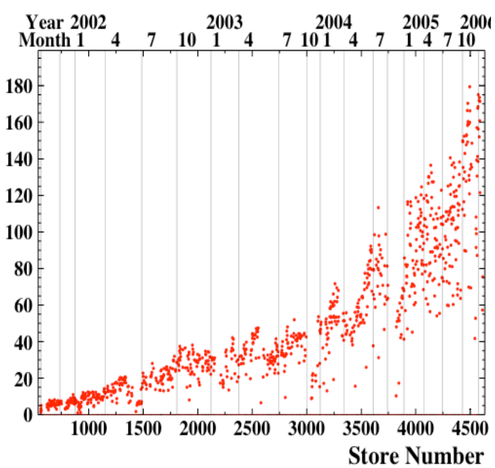
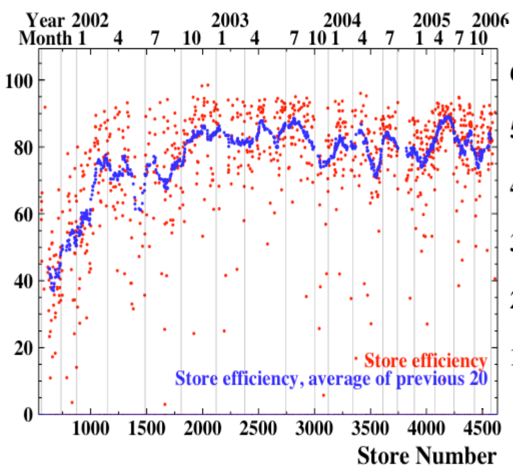
Let me just say

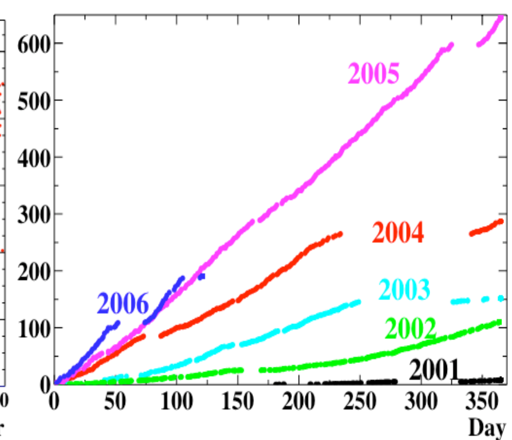
- Tevatron (and CDF and D0) are running well

ultimately 4-9 fb^{-1}





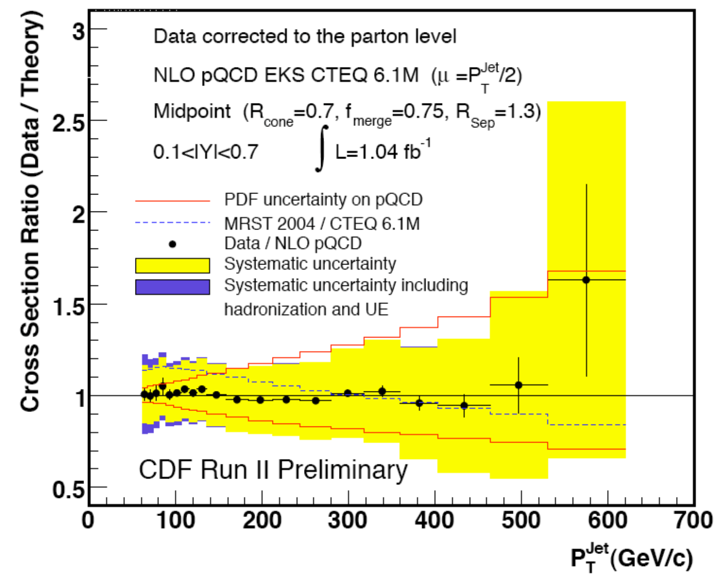


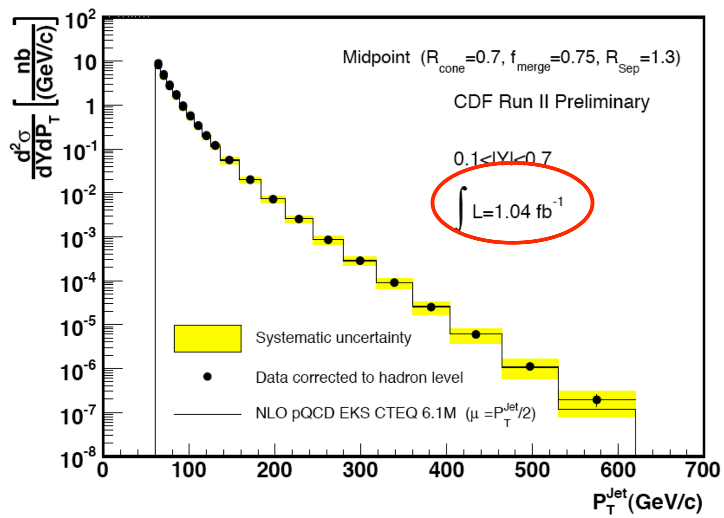


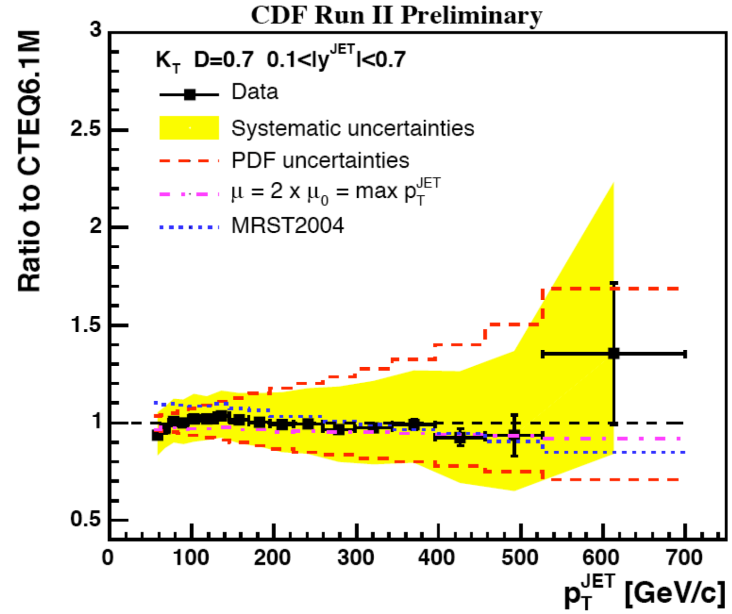
- over 1.2 fb^{-1} on tape
- 1 fb^{-1} analyses presented at Moriond
- coming off of shutdown now
- FY06 design goal = 800 pb^{-1}

CDF Run 2 jet results

- CDF Run II cone result in good agreement with NLO predictions using CTEQ6.1 pdf's
  - enhanced gluon at high x
  - I've included them in the CTEQ fits leading to next CTEQ iteration
- …and with results using k_T algorithm
  - the agreement would appear even better if the same scale were used in the theory
- need to have the capability of using different algorithms in analyses as cross-checks

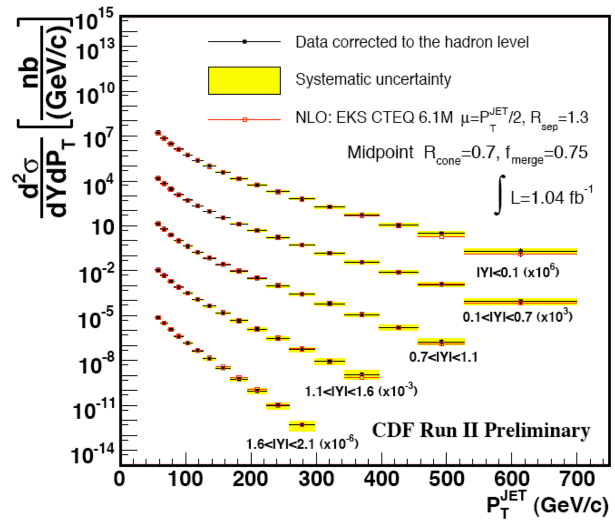


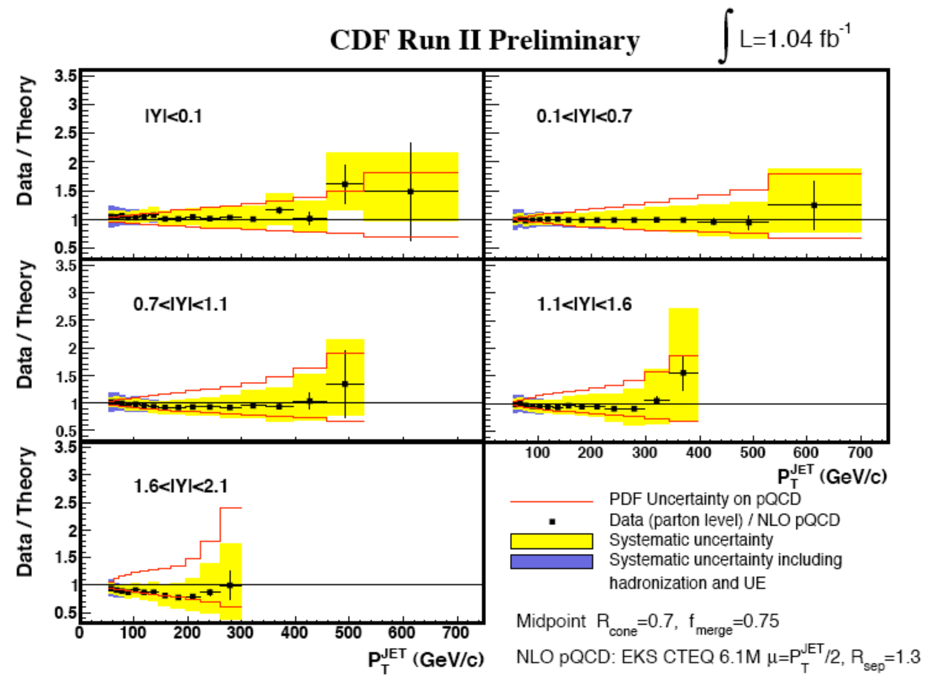




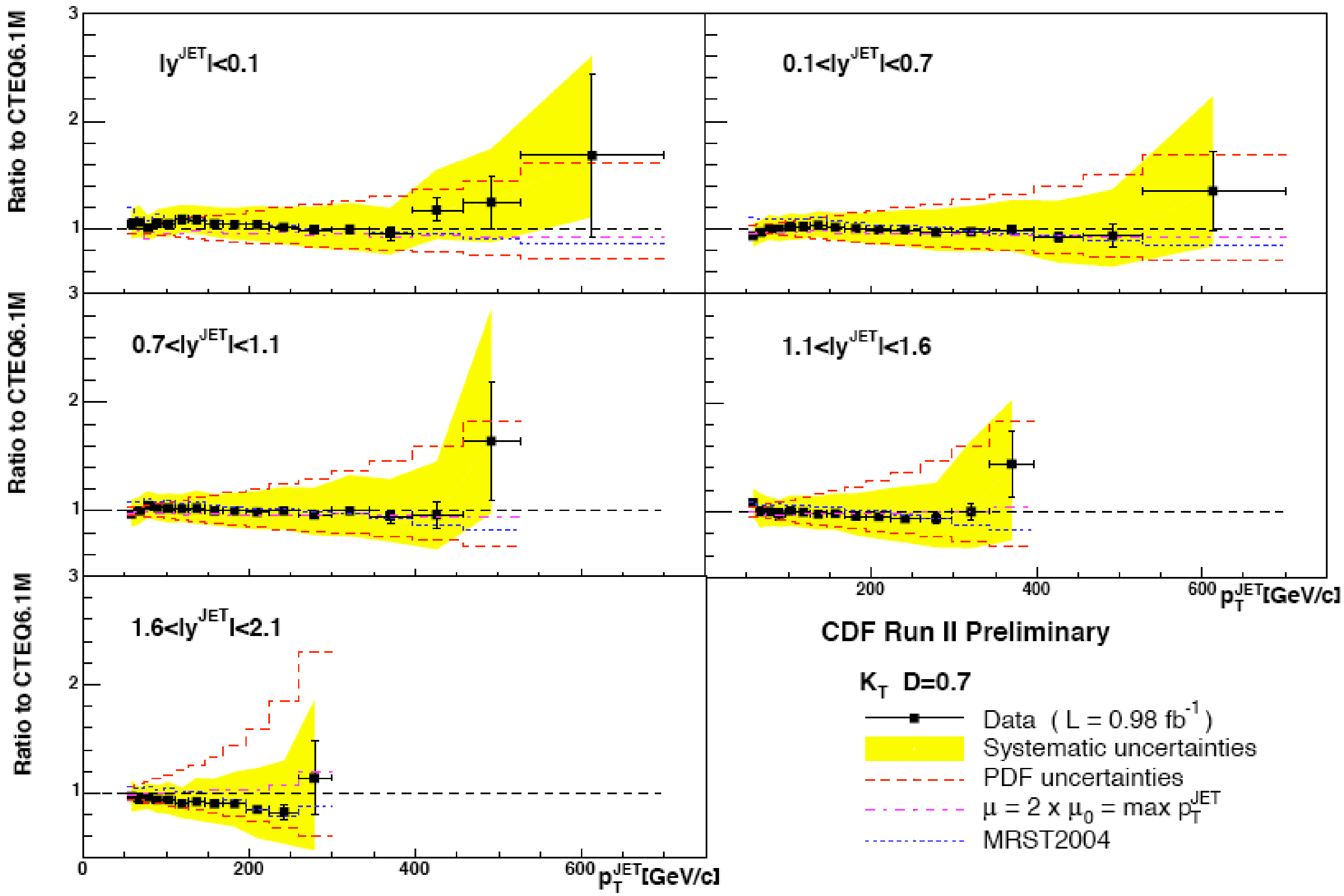
CDF Run 2 cone results

- Precise results over a wide rapidity range
- Good agreement with CTEQ6.1 predictions using CDF midpoint algorithm
  - see more discussion in tomorrow's talk
- PDF uncertainties are on the same order or less than systematic errors
- Should reduce uncertainties for next round of CTEQ fits
  - so long to eigenvector 15?





Forward jets with the k_T algorithm



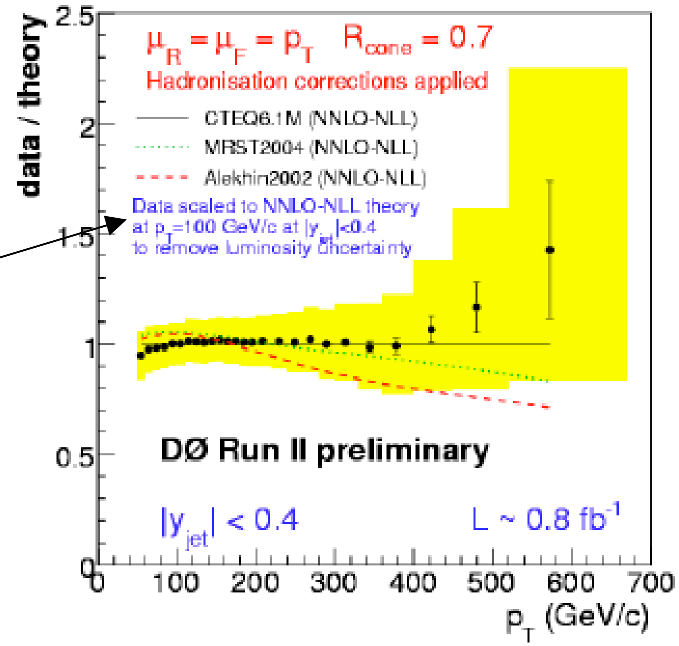
Need to go lower in p_T for comparisons of the two algorithms

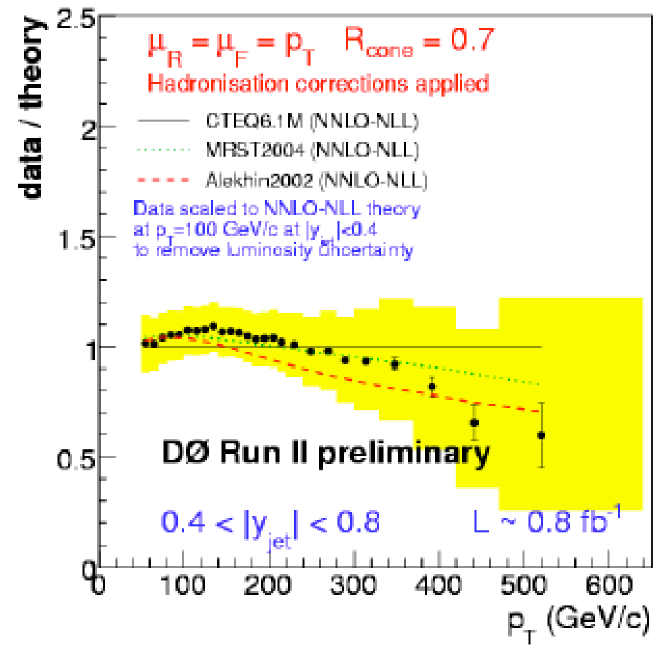
D0 Run 2 jet results

Inclusive Jet Cross Section

- We are also sensitive to different PDF sets (CTEQ, MRST, Alekhin)
- The p_T and rapidity uncertainty correlations to be derived by summer for full PDF sensitivity

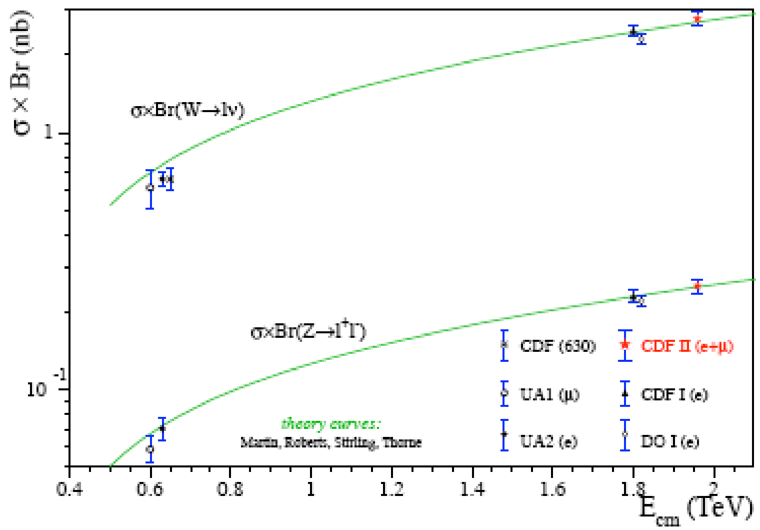
N.B.

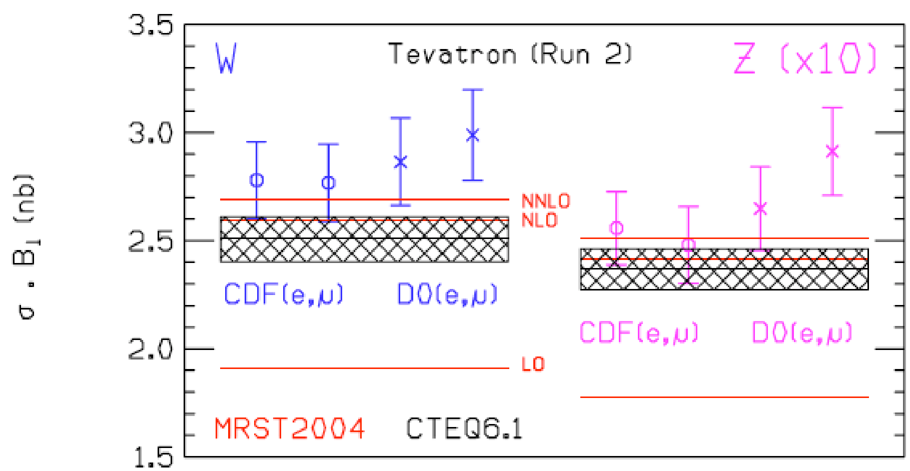




W/Z at the Tevatron

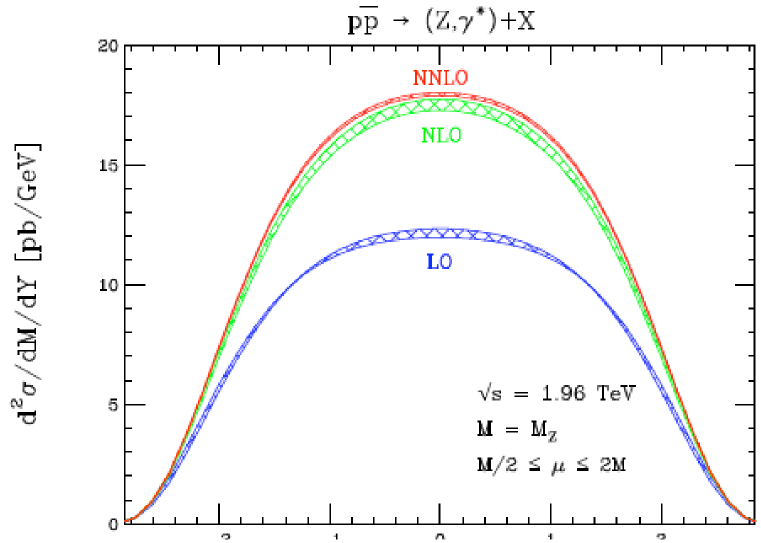
- W/Z cross sections serve as precision physics monitors
- Both experimental and theoretical errors are under control
  - NNLO a small (positive) correction to NLO
- Note that CTEQ and MRST NLO predictions agree within CTEQ6.1 pdf errors (but MRST at edge of CTEQ6.1 error band), but not vice versa
  - for that reason, among others, I don't think the $\Delta\chi^2$ criterion of 100 is unreasonable

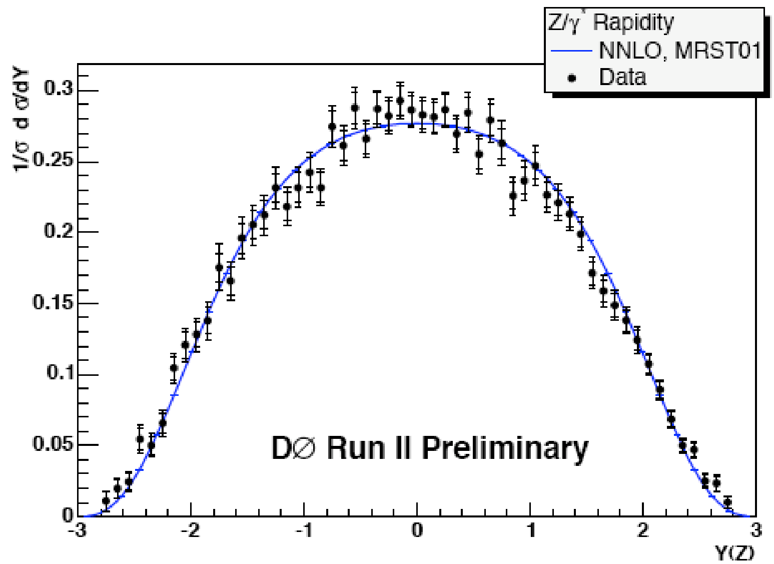




Rapidity distributions

- Little shape difference from NLO to NNLO
  - K-factor should be sufficient
- Z rapidity distributions could/will be used as input for pdf fits





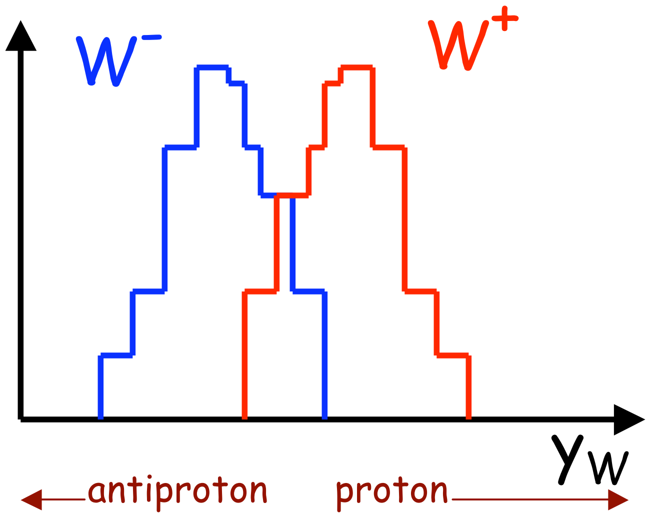
Central-to-Forward W vis. cross section ratio

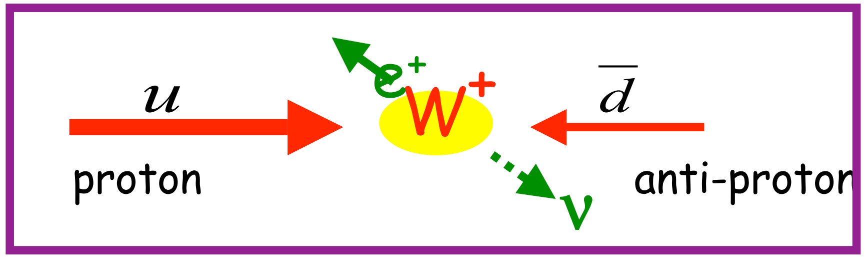
…some slides from Cigdem Issever's talk at DIS06

- σ_{vis}(central) =664.2±11.7 pb (Et_e>25, ETn>25, $|\eta_{ele}|$<1)
- σ_{vis}(forward) =718±21 pb (Et_e>20, ETν>25, 1.2<$|\eta_{ele}|$<2.8)
- **σ_{vis}(central)/σ_{vis}(forward) =0.925±0.033**
  - **1% assigned as luminosity syst. (slightly overestimate)**

- NLO ratios (taking into account correlations between central and forward):
  - **CTEQ= 0.9243±0.037**
  - **MRST01E= 0.94137±0.011**
- **Most uncertainties will go down with more data → useful to constrain PDFs**

W Charge Asymmetry





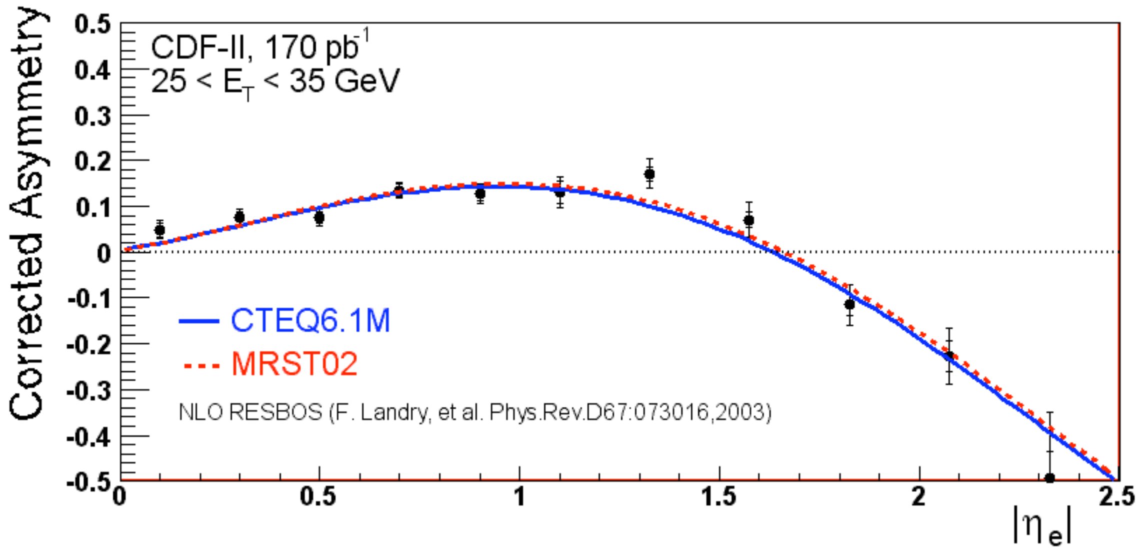
$$A = \frac{d\sigma(W^+)/dy_W - d\sigma(W^-)/dy_W}{d\sigma(W^+)/dy_W + d\sigma(W^-)/dy_W} \approx \frac{d}{u}$$

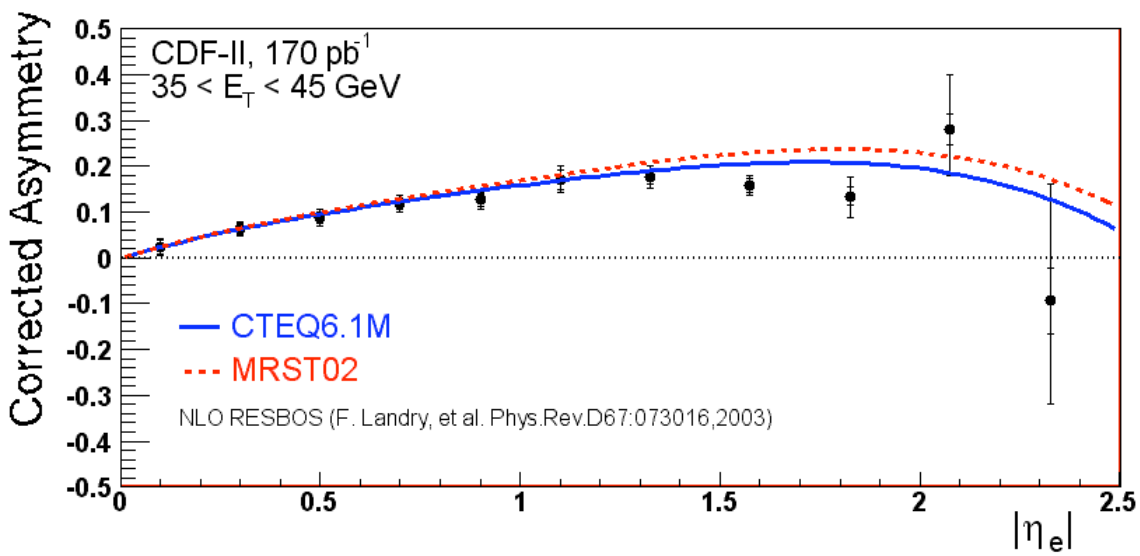
Asymmetry in W production complicated by **unknown ν p_z**
use lepton asymmetry:

$$A_l(\eta) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta} \simeq \frac{\mathrm{d(x)}}{\mathrm{u(x)}}$$

which convolves W production with V-A decay.

W Charge Asymmetry Run II 170pb^{-1}



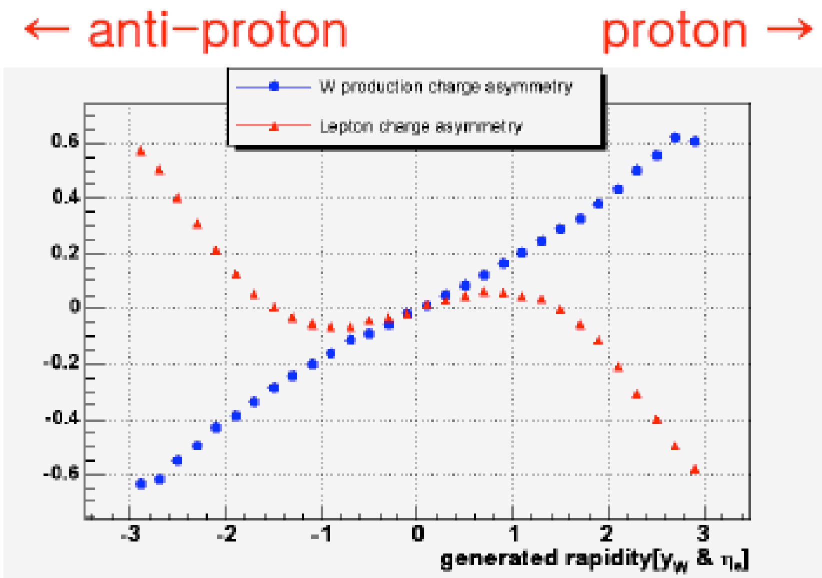


A as function of E_T provides better probe of x dependence.

Statistics allowed two bins.

Will be included into next generation of PDFs.

W Charge Asymmetry – new method



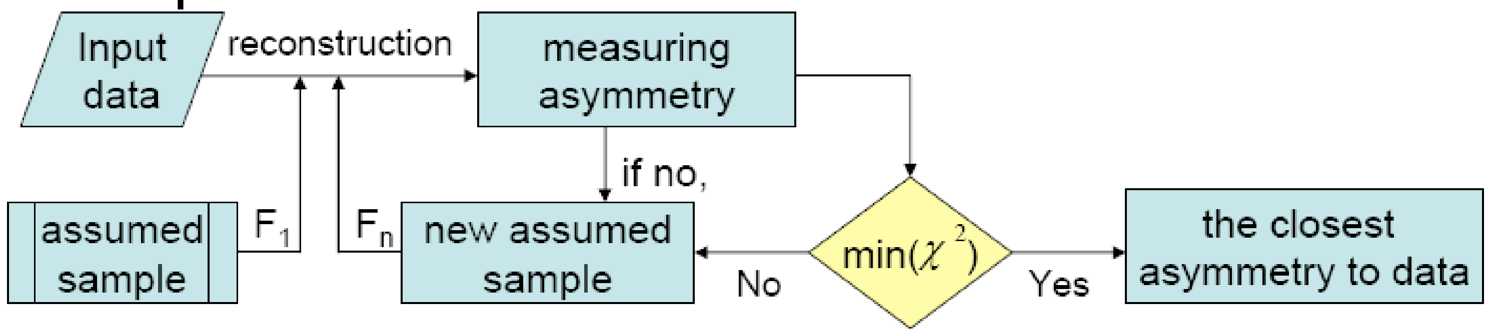
Lepton asymmetry has turn over at high |η| due to V-A

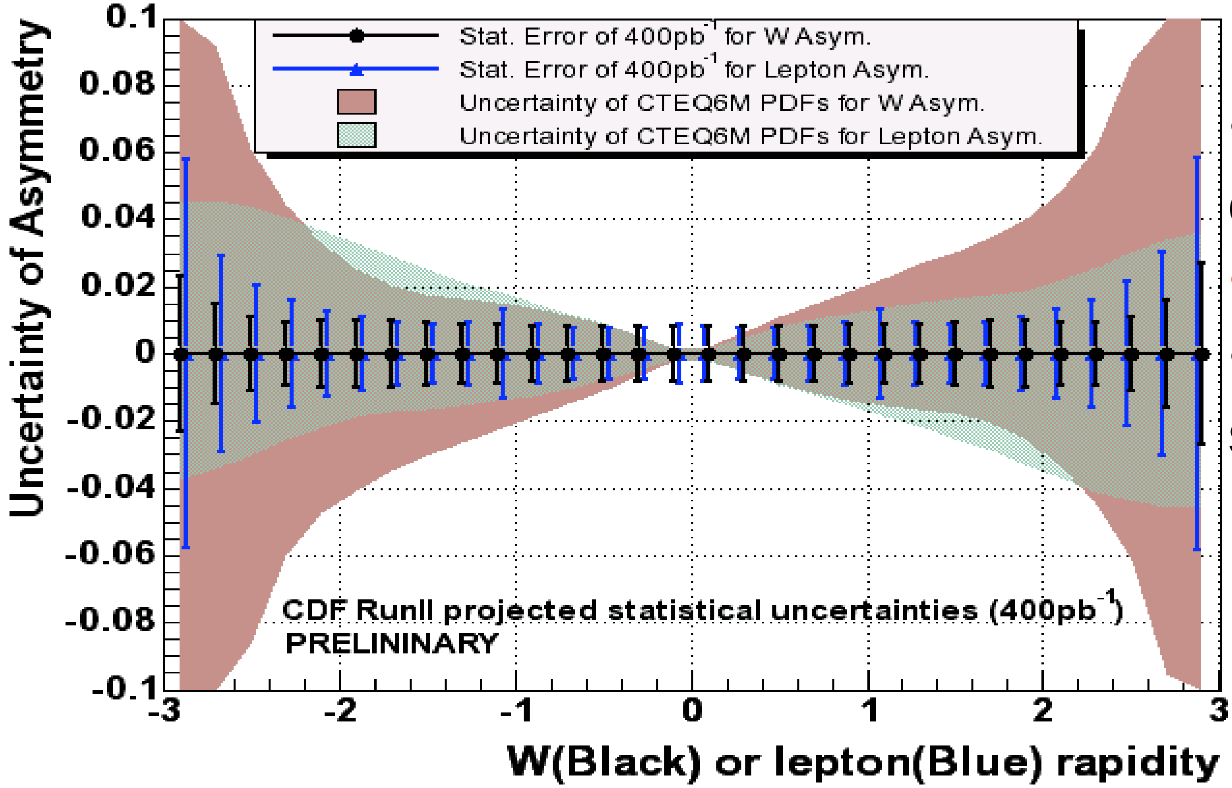
W charge asymmetry does not have this effect, so we don't purely probe high y_W

- **Determination of y_W with W mass constraint gives 2 possible solutions.**
- **Evaluate weight factor $F_{1,2}$ for each $y_{1,2}$ solution.**
- **Parameterize $F_{1,2}$ with**
  1. **the angular distribution of $(1+-\cos\theta^*)^2$**
  2. **with W cross section, _(y_W), but this depends on asymmetry**
- **Iterative procedure!!**

W charge asymmetry – new method

Iterative procedure





- **Smaller statistical errors**
- **Greater sensitivity**
- **No additional systematics due to new method**

Challenges for Global QCD Analysis
—from here to LHC

…slides from Wu Ki's talk at DIS06

In spite of steady progress in over 20 years of global analysis of PDFs, it is surprising how much knowledge is still missing on the parton structure of the nucleon !

- Gluon Distribution;
- Small-x and Large-x behavior of all distributions;
- Strange distribution;
- Charm and bottom distributions;
- Quantifying uncertainties of all PDFs.

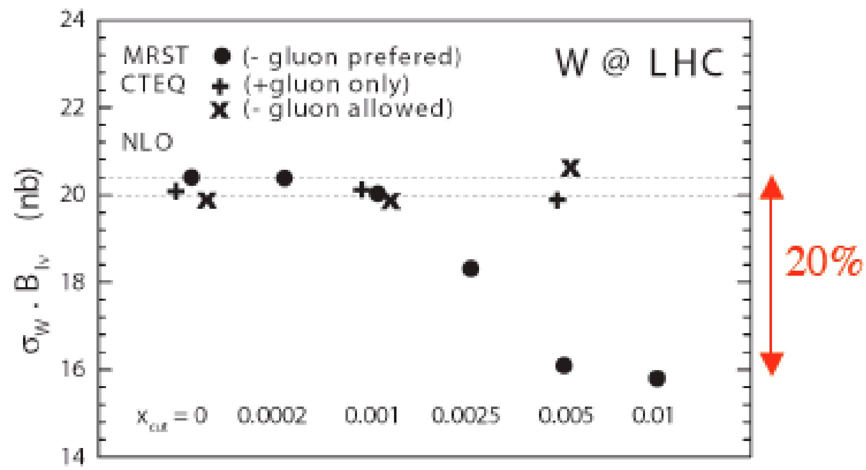
A successful LHC program depends on making substantial improvement on most of these fronts.

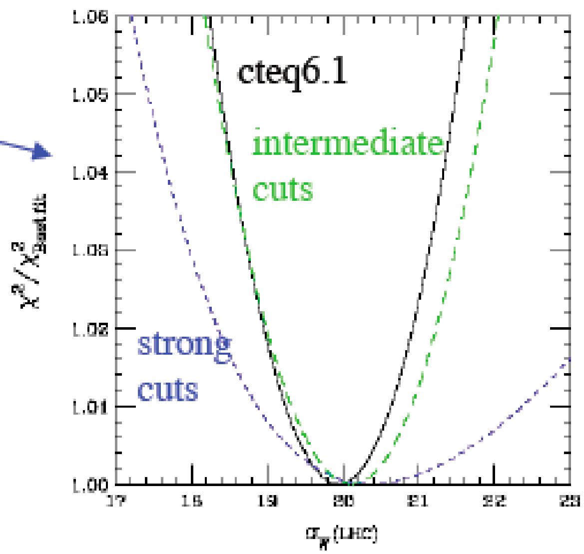
Some recent "CTEQ" work (2005–)

- NLO PQCD is stable for Collider phenomenology, for example W production
  (Huston, Pumplin, Stump, Tung. JHEP 0506:080,2005);
- LHC phenomenology: Uncertainties of the inclusive Higgs production cross section at the Tevatron and the LHC
  (Belyaev, Pumplin, Yuan,Tung. JHEP 0601:069,2006);
  (PDF uncertainties can be larger than commonly estimated "theoretical uncertainties", depending on the Higgs mass.)
- CTEQ6A,B series of PDFs: for physical applications that are sensitive to α_s.
  (Pumplin, Belyaev, Huston, Stump,Tung. JHEP 0602:032,2006)

NLO stability

- Is there a *tension* between HERA and Tevatron data requiring NNLO DGLAP to resolve?
  - MRST study: hep-ph/0308087
  - W cross section at LHC drops 20% when data below x=.005 are removed from fit
  - implications for use of W σ as luminosity benchmark
- Recent CTEQ study indicates as more severe cuts are made in x and Q^2 in global analysis, uncertainty on W cross section at the LHC increases but central value remains relatively constant

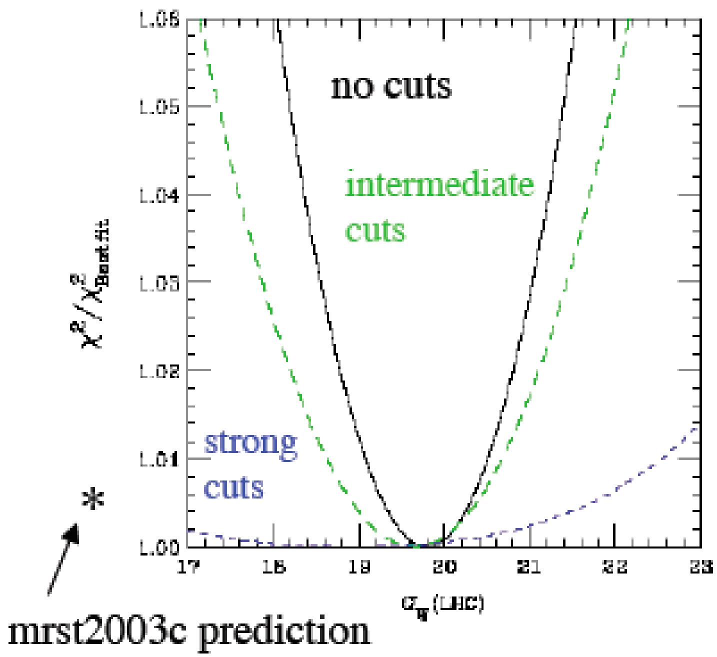




ies 2005

NLO stability

- CTEQ conclusion: if negative gluon allowed, then uncertainty of σ_W increases (dramatically for severe cuts), but again central value remains constant
- No advantage found in fit of allowing negative gluon



hep-ph/0502080

February 3, 2005

MSU-HEP-5
CTEQ-5

Stability of NLO Global Analysis and Implications for Hadron Collider Physics

J. Huston, J. Pumplin, D. Stump, W.K. Tung

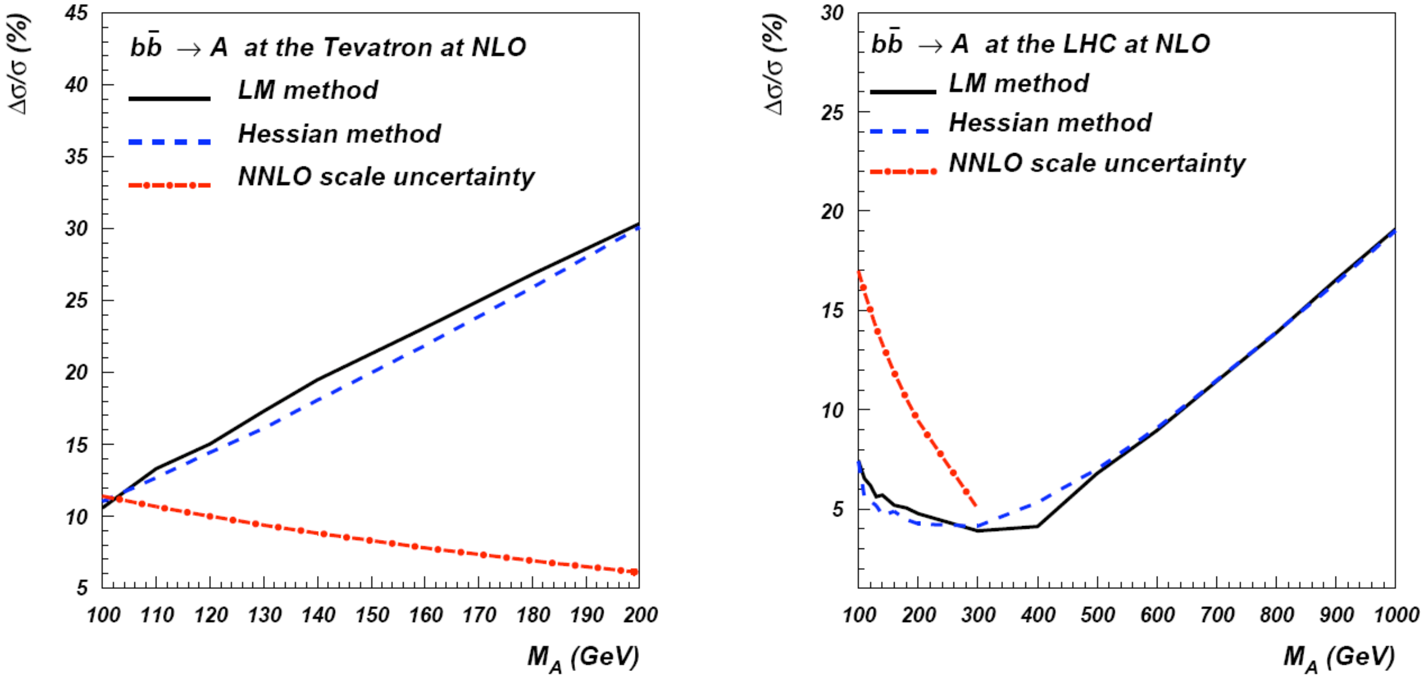
Michigan State University, E. Lansing, MI 48824

Uncertainties of the inclusive Higgs production cross section at the Tevatron and the LHC

(Belyaev, Pumplin, Yuan, Tung JHEP 0601:069,2006)

The relative PDF uncertainty (in percentages) $\delta\sigma^{PDF}_{b\bar{b}\to A}$ vs. scale uncertainty δ^{NNLO} as a function of Higgs boson mass.

Enhanced bbA-coupling in MSSM

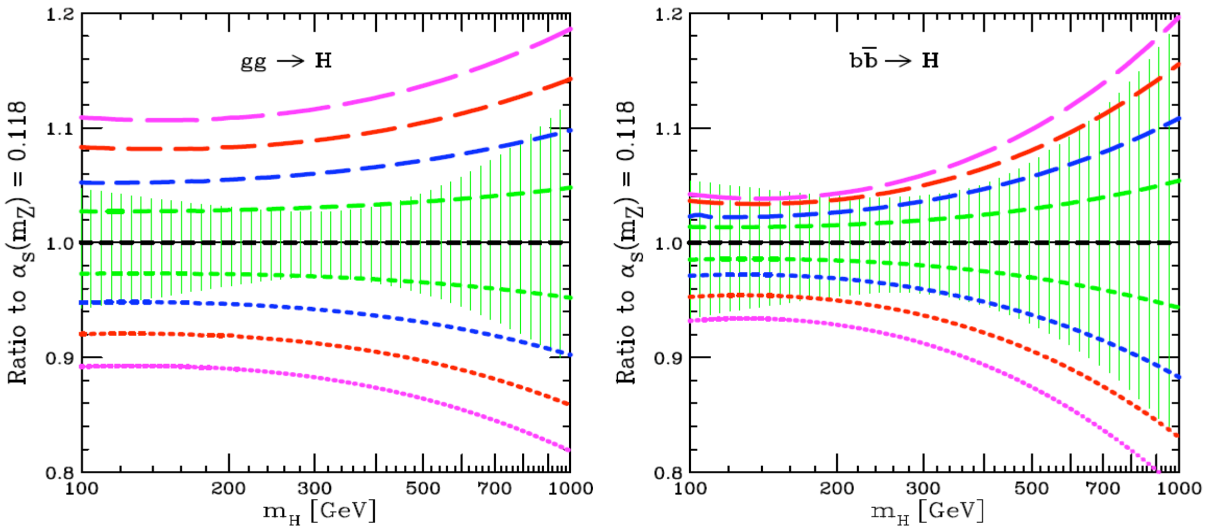


CTEQ6A,B PDFs for a series of α_s

(Pumplin, Belyaev, Huston, Stump, Tung: JHEP 0602:032,2006)

Many applications. One example:

Uncertainty of predictions for Higgs boson production at LHC



* Curves: α_s = 0.110 - 0.126 ; (Realistic range: between blue lines.)

* Shaded areas: uncertainty band based on CTEQ6 error analysis for fixed α_s = 0.118 .

New Experimental Input to Current Global Analysis

- Extensive HERA I data sets (complete?) on
  - total inclusive NC and CC cross sections, covering a wide range of kinematic phase space;
  - semi-inclusive (tagged heavy flavor) cross sections: charm and bottom;
  - semi-inclusive jet cross sections.
- (Note: out go the SFs, $F_{1,2,3}$; in come the xSec's!)
- Fixed-target Experiments (Last of the kind?)
  - NuTeV ν DIS S.F.s and cross sections;
  - E866 DY pp and pd cross sections (finally?).
- New Tevatron Data on W/Z production, jet production, … etc.

Available HERA Data Sets for Current Global Analysis (by our reckoning)

- H1
  - CCe+9497X
  - CCe+9900X
  - CCe-9899X
  - (NCe+9497X ?)
  - NCe+9697X
  - NCe+9900X
  - NCe-9899X
  - NCe-9900X
  - NCe+9697F_2c
  - NCe+9900Xc
  - NCe+9900Xb
- ZEUS
  - CC+9497X
  - CC+9900X
  - CC-9899X
  - NC+9697X
  - NC+9900X
  - NC-9899X
  - NC+9697F_2c
  - NC+9890F_2c

Wow!
(both in coverage and in accuracy.)

Just wait until HERA II data come along!

New Precision Global Analysis

- Data: Full HERA I *total-inclusive* and *semi-inclusive* heavy flavor cross sections *with correlated errors* + F.T. DIS + DY + Tevatron Jet;

- Theoretical tool: New implementation of General Mass Variable-Flavor-Number-Scheme factorization formalism of Collins for consistency + recent SAcot, Acot-χ, … practical prescriptions for efficiency.

- Sorry! DIS jet inclusive not yet implemented. (➔ Jon Pumplin)
- NLO for now. Extension to order α_s^2 is “straightforward”, given the perturbative approach.

Luminosities as a function of y

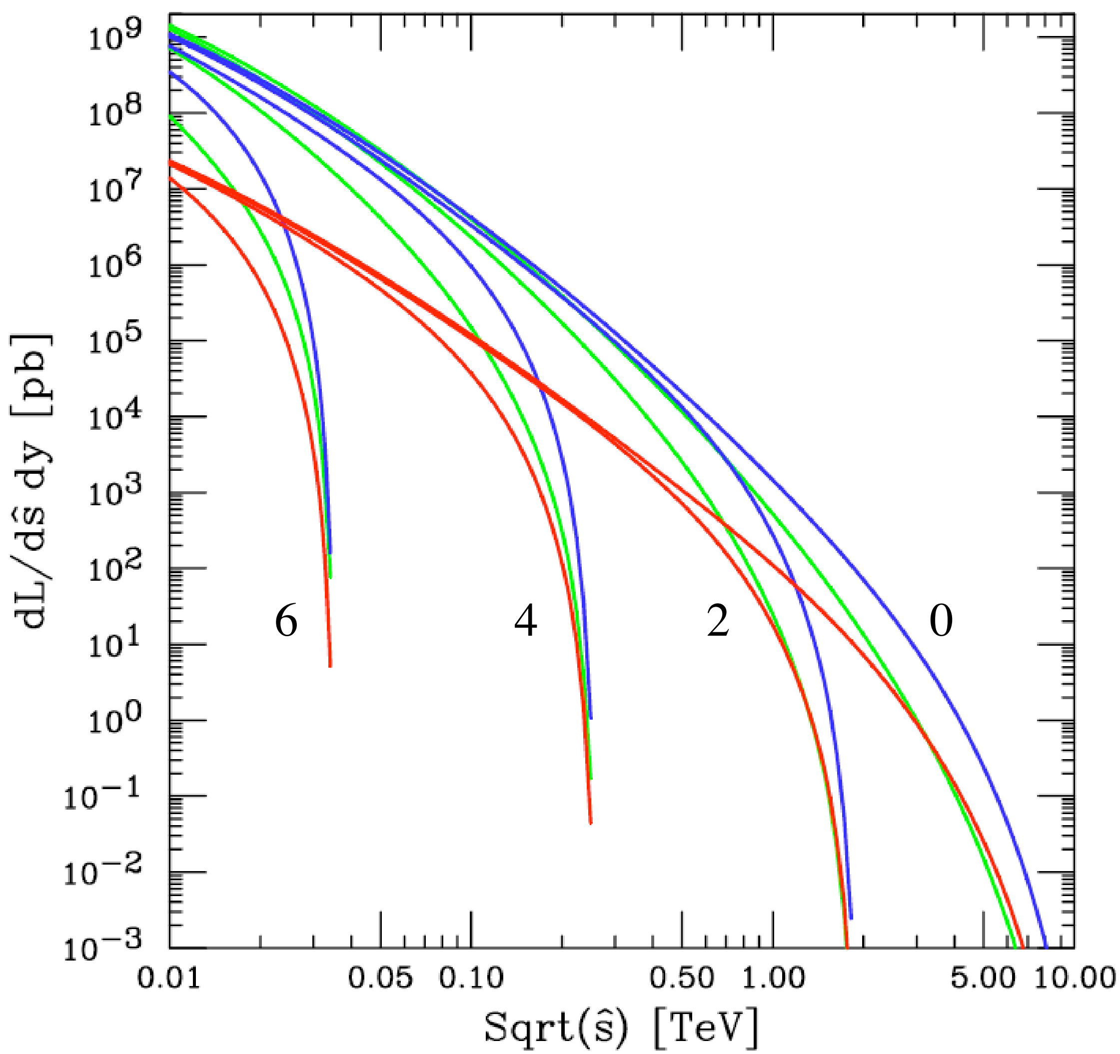


Fig. 3: dLuminosity/dy at $y = 0, 2, 4, 6$. Green=gg, Blue=$g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$, Red=$d\bar{d}+u\bar{u}+s\bar{s}+c\bar{c}+b\bar{b}+\bar{d}d+\bar{u}u+\bar{s}s+\bar{c}c+\bar{b}b$.

LHC to Tevatron pdf luminosities

- Processes that depend on qQ initial states (chargino pair production) have small enhancements
- Most backgrounds have gg or gq initial states and thus large enhancement factors (500 for W + 4 jets for example, which is primarily gq) at the LHC
- Luckily tT has a gg initial state as well as qQ so enhancement at the LHC is a factor of 100
  - but increased W + jets background means that a higher jet cut is necessary at the LHC

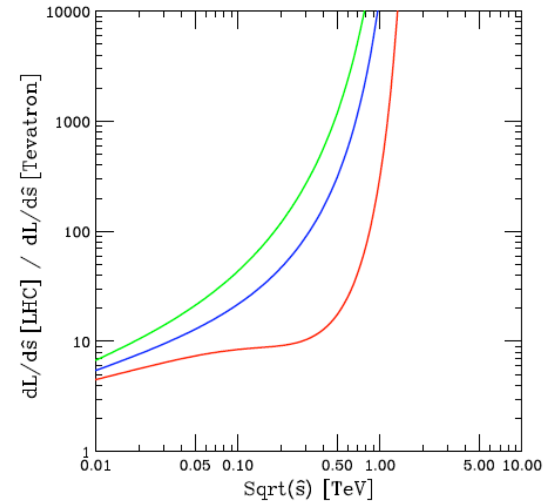


Figure 11. The ratio of parton-parton luminosity $\left[\frac{1}{\hat{s}}\frac{dL_{ij}}{d\tau}\right]$ in pb integrated over y at the LHC and Tevatron. Green=gg (top), Blue=$g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$ (middle), Red=$d\bar{d}+u\bar{u}+s\bar{s}+c\bar{c}+b\bar{b}+\bar{d}d+\bar{u}u+\bar{s}s+\bar{c}c+\bar{b}b$ (bottom).

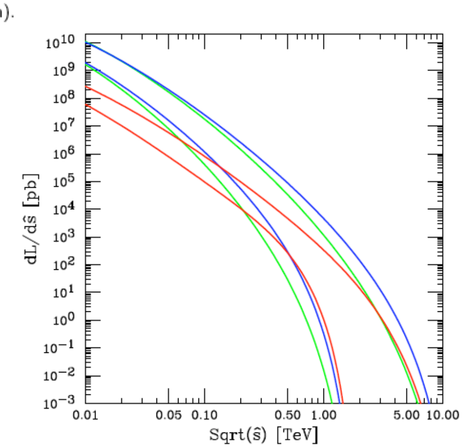


Figure 10. The parton-parton luminosity $\left[\frac{1}{\hat{s}}\frac{dL_{ij}}{d\tau}\right]$ in pb integrated over y. Green=gg, Blue=$g(d+u+s+c+b)+g(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})+(d+u+s+c+b)g+(\bar{d}+\bar{u}+\bar{s}+\bar{c}+\bar{b})g$, Red=$d\bar{d}+u\bar{u}+s\bar{s}+c\bar{c}+b\bar{b}+\bar{d}d+\bar{u}u+\bar{s}s+\bar{c}c+\bar{b}b$. The top family of curves are for the LHC and the bottom for the Tevatron.

Summary and Outlook

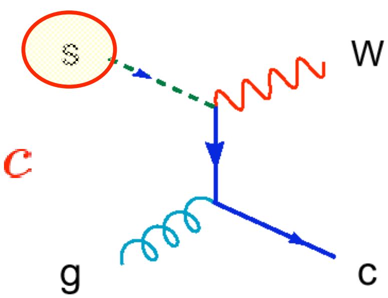
- The impressive consistency between the improved theoretical calculation and much improved experimental input on DIS NC, CC & heavy flavor production (and other F.T. and hadron collider processes) provides a new basis for performing precision phenomenology within and beyond the SM.
- A lot of work remains to be done to pin down the full parton structure of the nucleon (particularly gluon, s, c, b);
- HERA II and Tevatron Run II data can contribute substantially to fill the gaps. More specifically,
- With more accurate data on CC cross sections, we gain additional (clean) handles for differentiating up and down types of quarks;
- Direct F_{Long} measurement in the cards?
- With W/Z/γ + tagged heavy flavor events at the hadron colliders, we can get direct information on s/c/b quark distributions;
- Inclusive jet production at the Tevatron with multi-fb^{-1} data sets

LHC physics is waiting for these advances …

Probing the Sea Quark PDFs: s, c, b using tagged final states $W/Z/\gamma + c/b$?

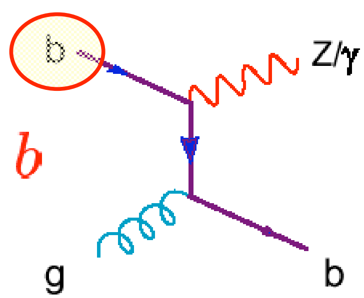
$s(x, Q)$:

$g + s \rightarrow W + c$



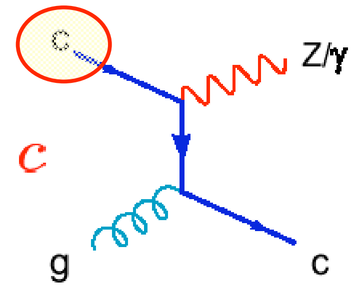
$b(x, Q)$:

$g + b \rightarrow Z/\gamma + b$



$c(x, Q)$:

$g + c \rightarrow Z/\gamma + c$



$g + c \rightarrow W + b$