Jet Physics and PDFs at the Tevatron

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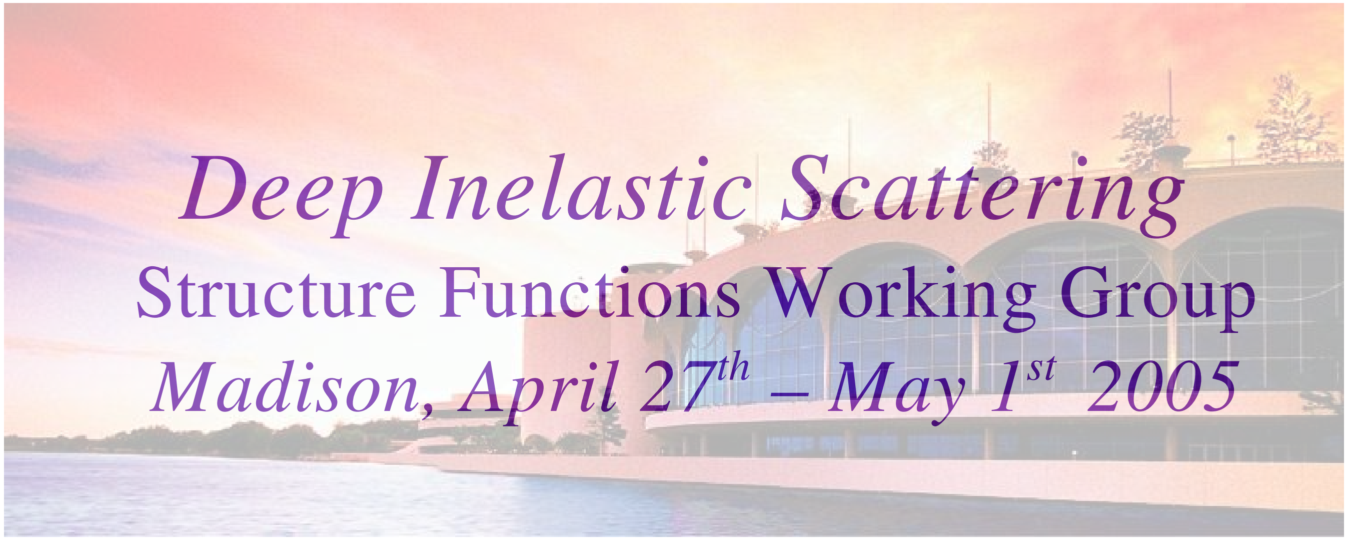
On behalf of CDF & DØ Collaborations



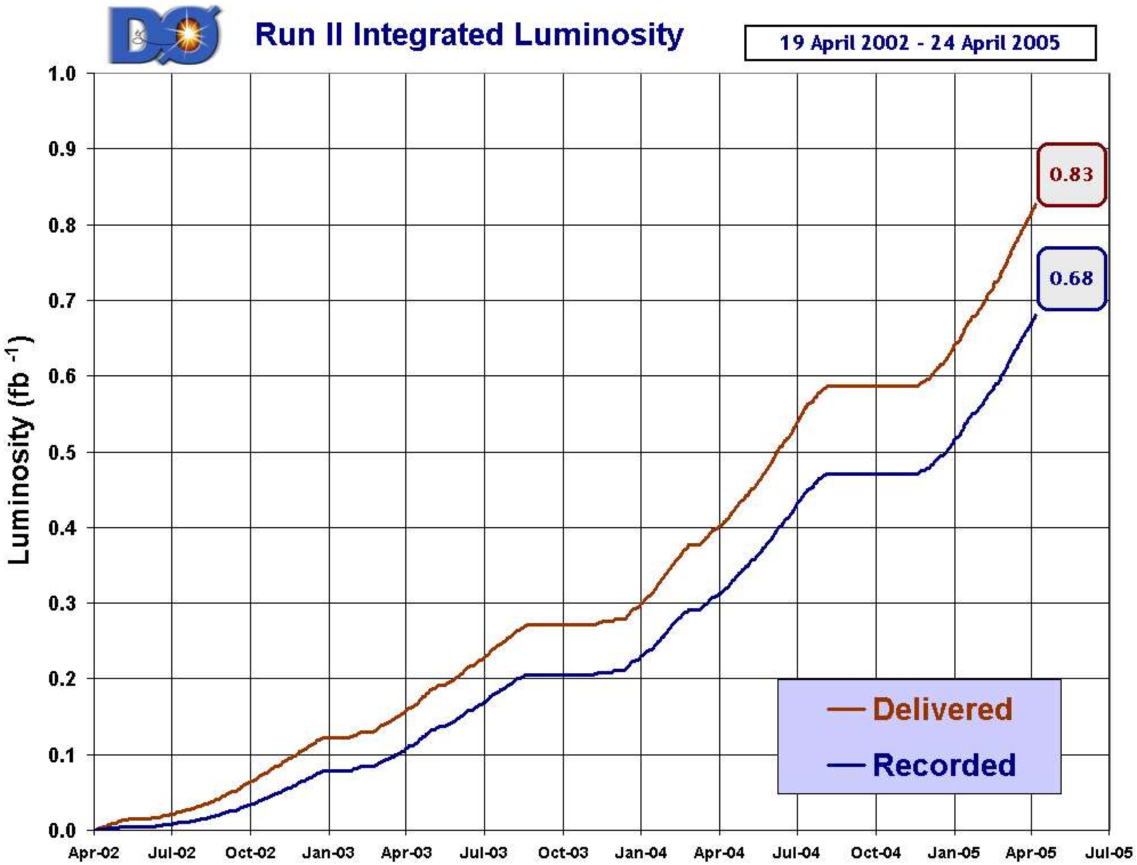
Tevatron Run II

Tevatron Run II began on March 1st 2001.

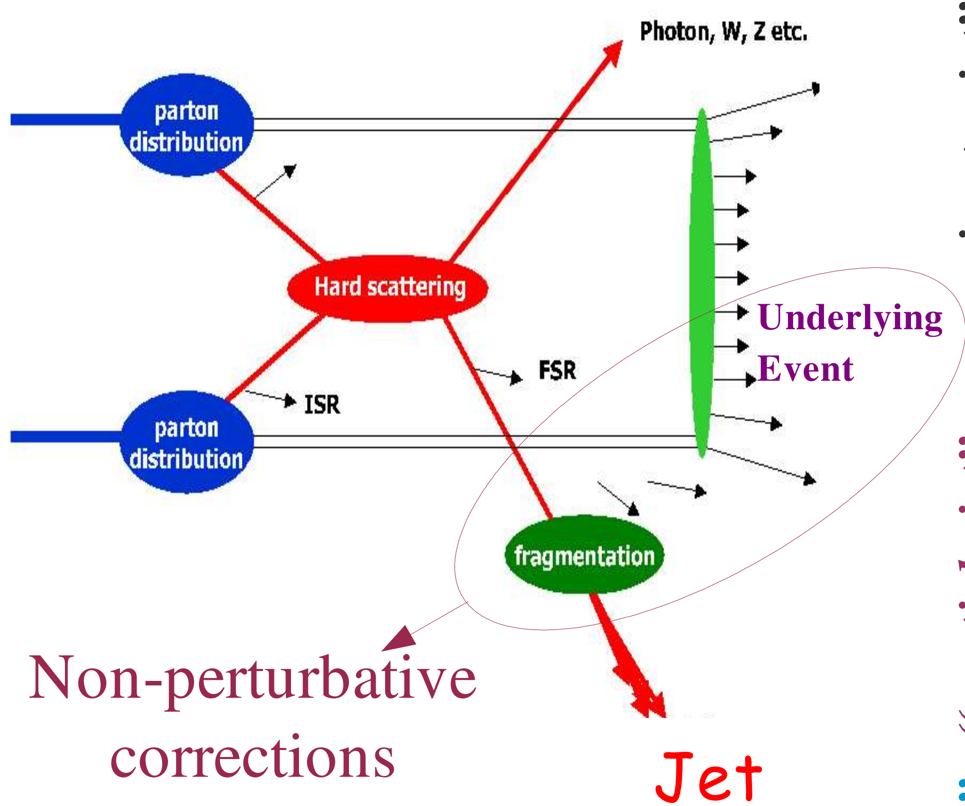
The Tevatron collides protons and antiprotons at a center of mass energy of 1.96 TeV

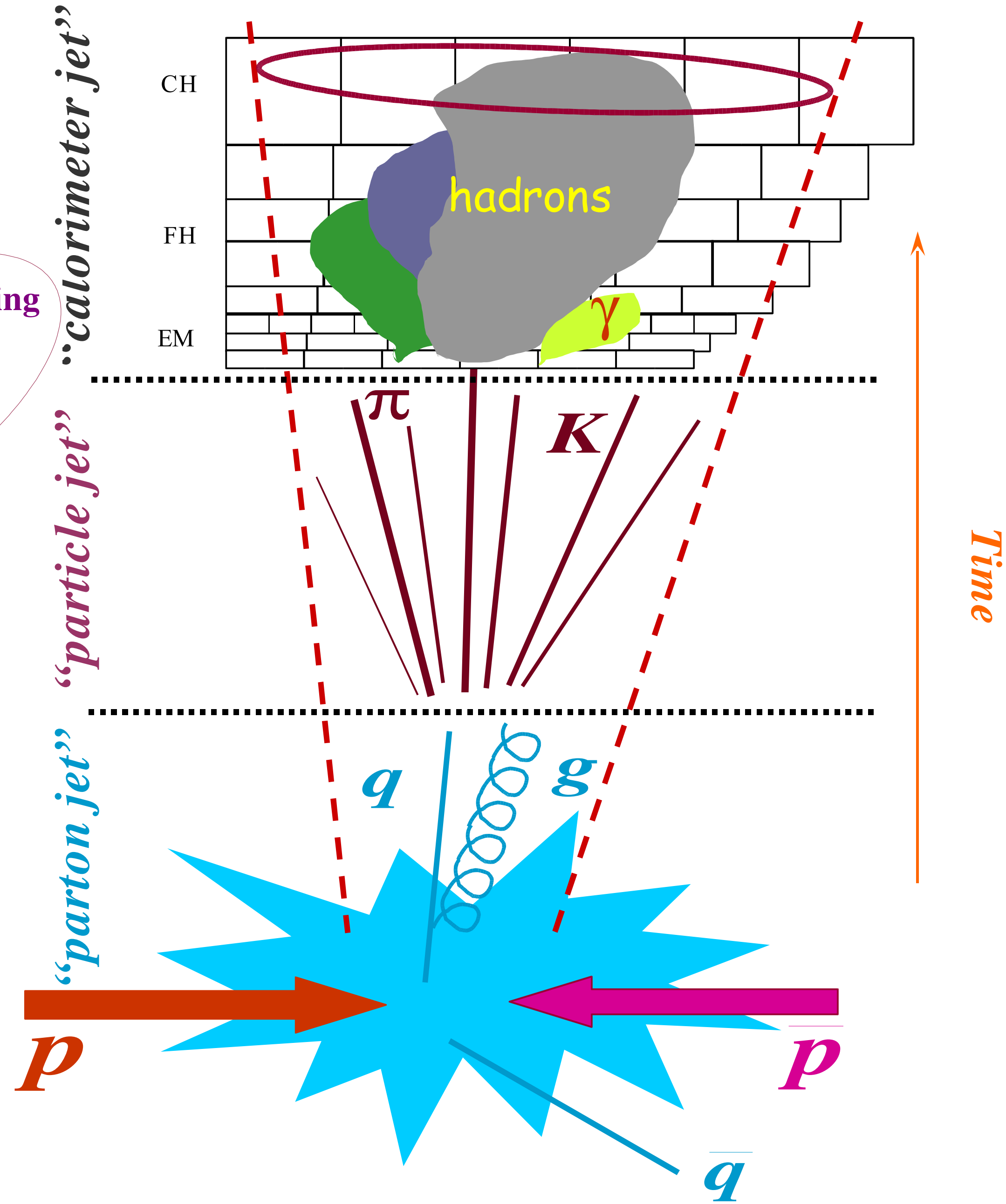
By summer expect 0.8-1.0 fb^{-1} recorded luminosity for each experiment.

Predictions for 2009: between 4 and 8 fb^{-1}



Jets and PDFs





High energy collisions results in collimated particles, which are clustered into jets with various jet algorithms.

The Tevatron jet algorithms are applied to partons, particles and calorimeter towers.

Checking the Prerequisites

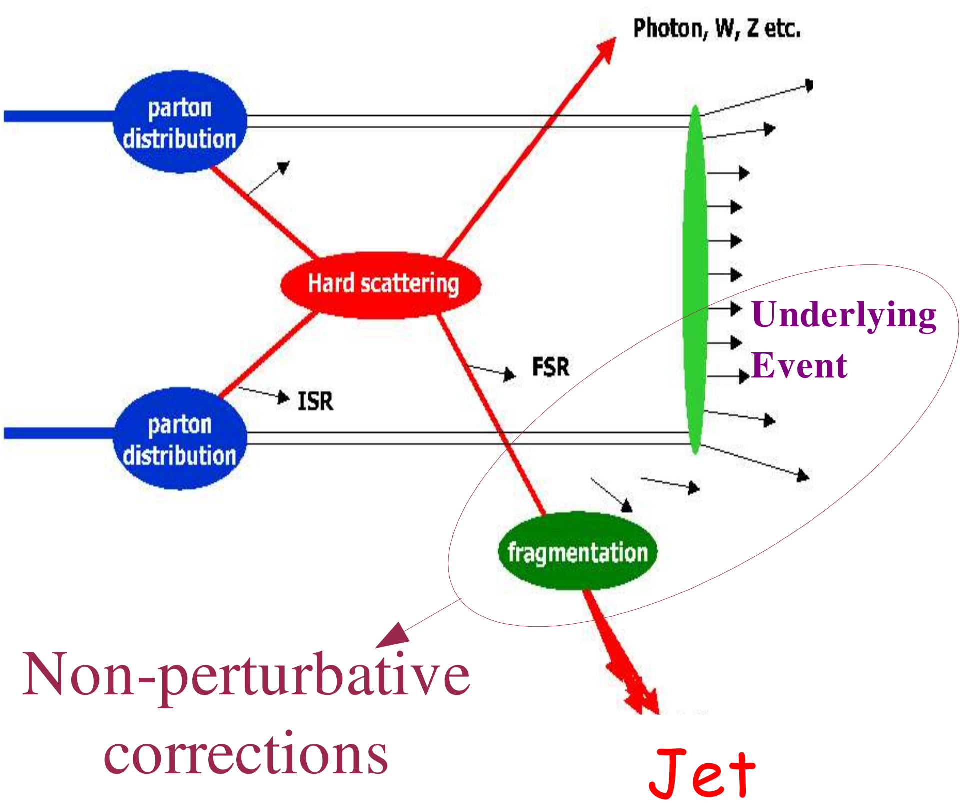
In order to extract the PDFs from the measurements we need a quantitative understanding of the hard scattering matrix elements and the non-perturbative effects, as they all effect the measured observables. Here are Tevatron Jet measurements that let us verify these quantitative understandings:

Checking the matrix elements:

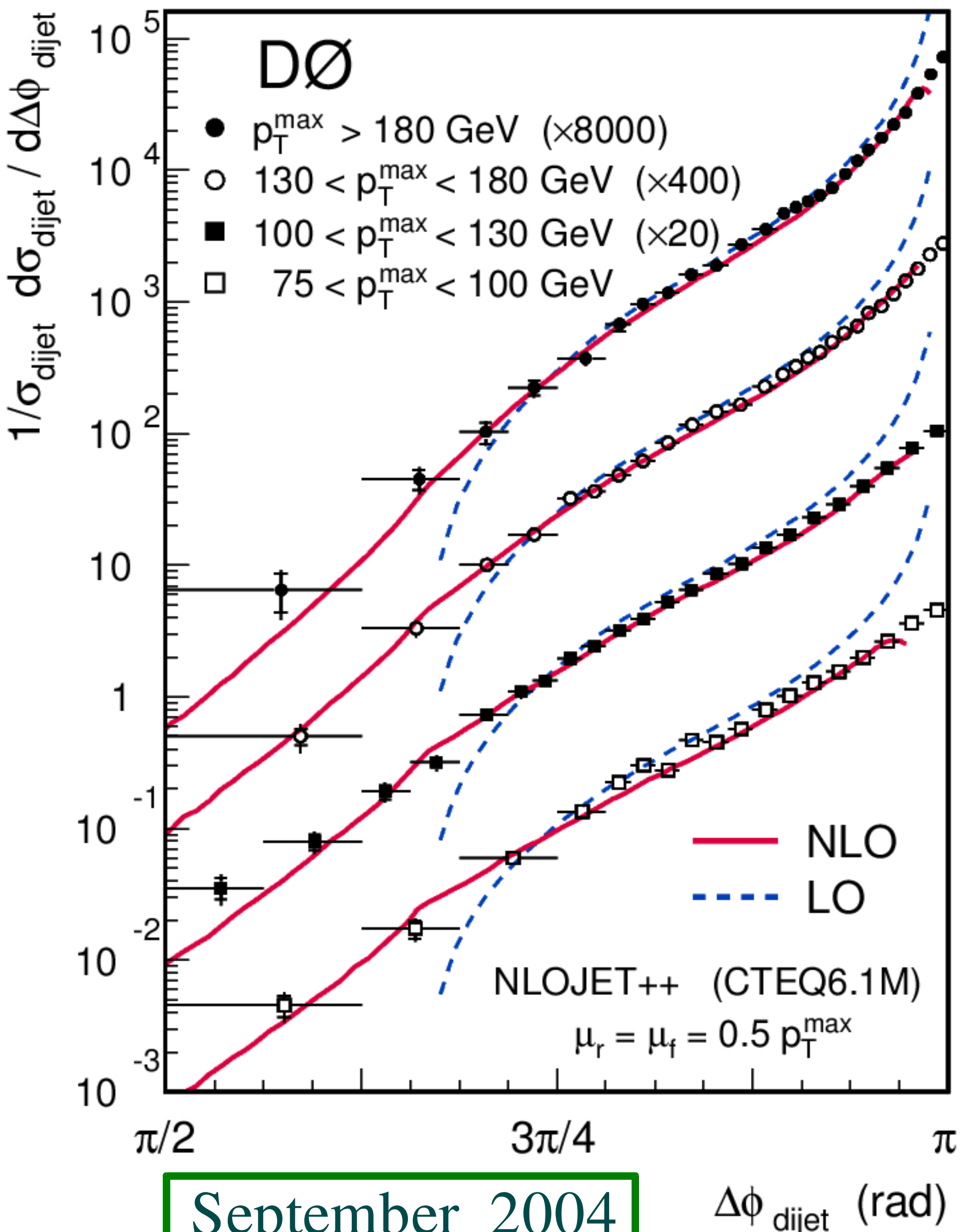
DØ – $\Delta\phi$ Between Di jets

Checking the simulated non-perturbative effects:

CDF - Jet shapes



DØ – Δφ Between Jets



September 2004
hep-ex0409040

This measurement was intended as a test of pQCD. It is sensitive to high order effects (additional jets lower $\Delta\phi$) and to the scales (especially at $\Delta\phi \cong \pi$).

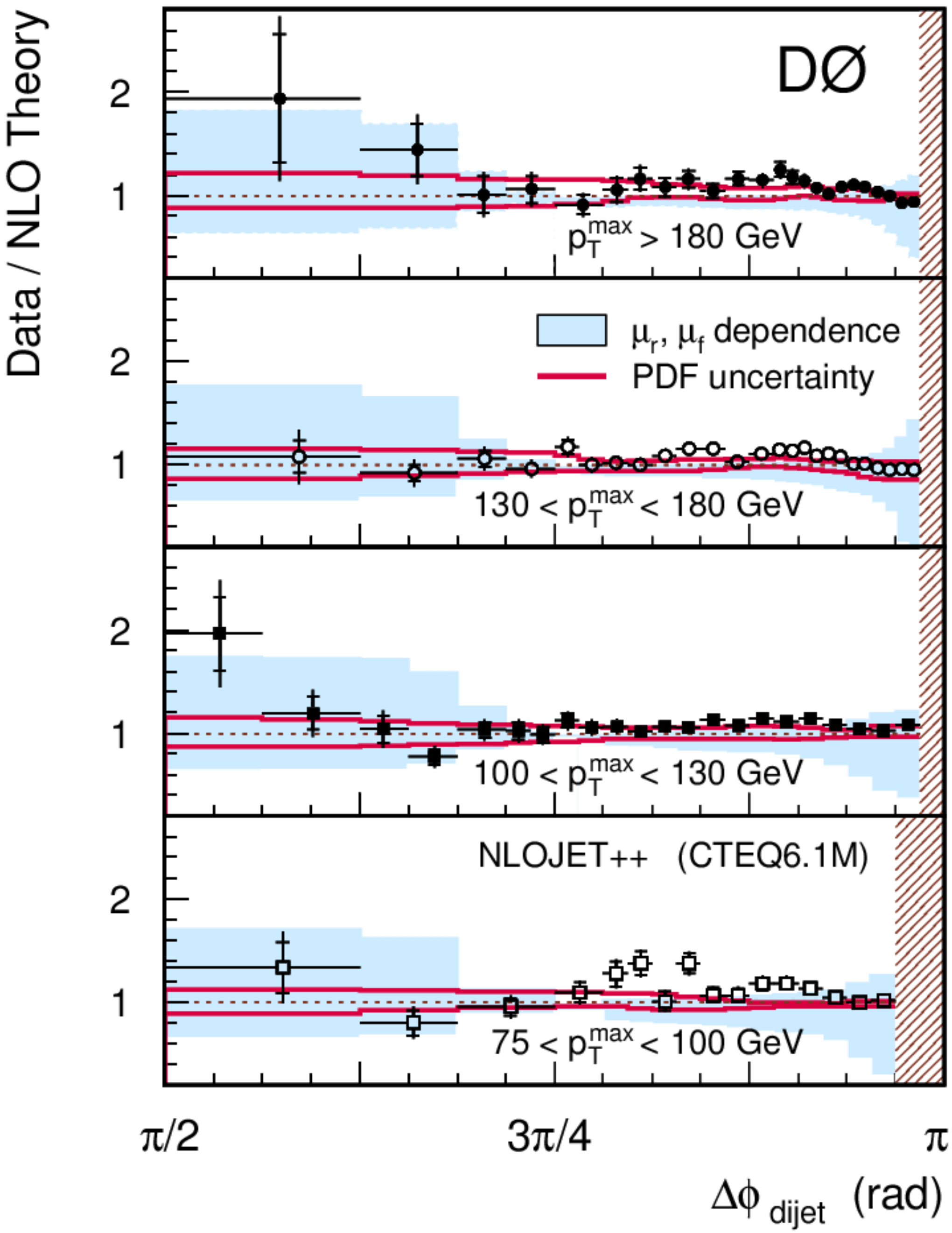
The differential cross section in $\Delta\phi$ is normalized by the total cross section, this reduces the effect of the PDFs and jet energy response, allowing us to check the matrix elements.

The α_s^3 (shown as LO) calculations are limited at soft ($\cong\pi$) and hard ($\cong 2\pi/3$) additional emissions.

The α_s^4 (shown as NLO) calculations are in good agreement with the measurement.

The statistical uncertainties are shown by the inner error bars.

DØ – Di jet Δϕ - Comparisons



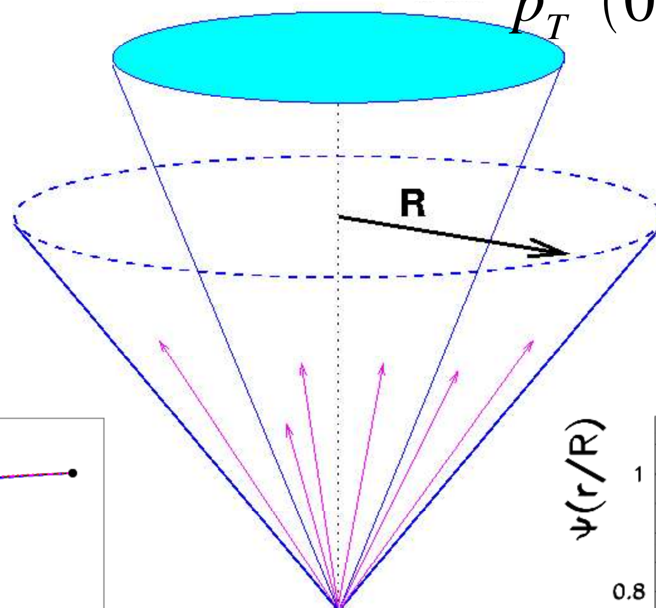
Data and theory agree well.

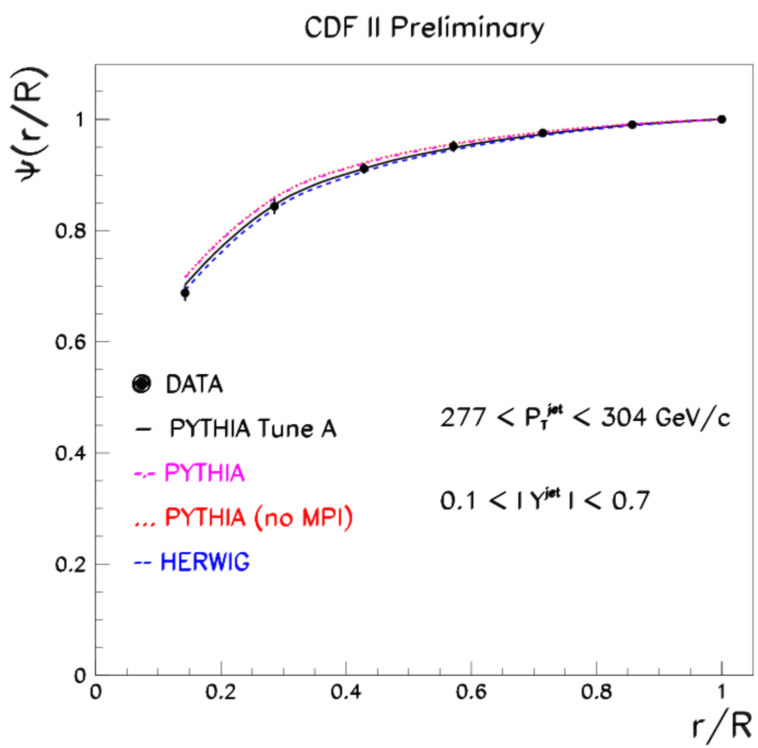
Note the large dependence on the scales below $2\pi/3$, where α_s^4 is only LO.

CDF - Jet Shapes

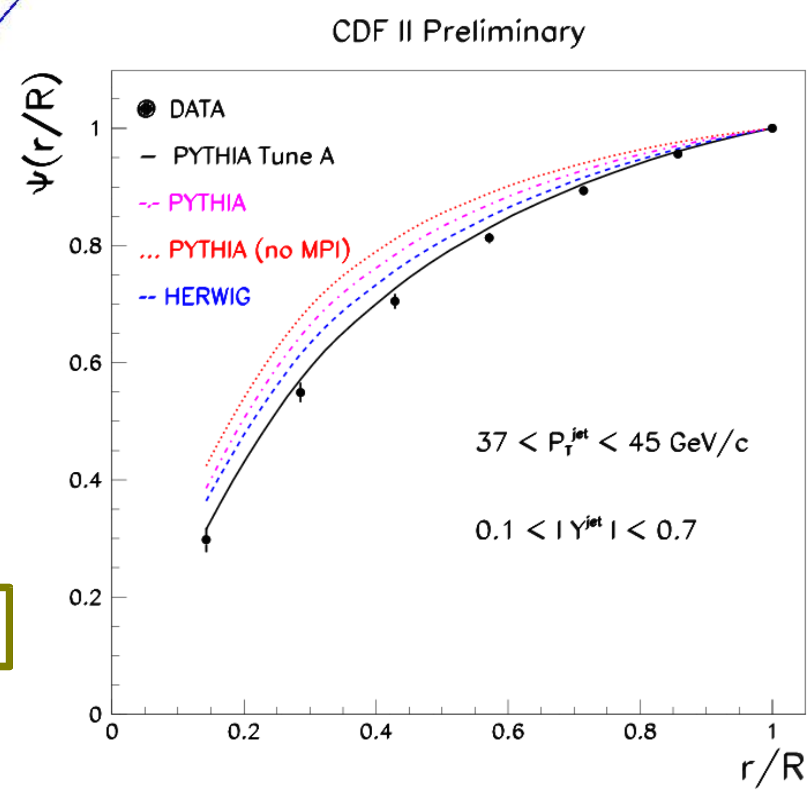
The jet shapes were measured in p_T bins from 37 to 380 GeV.

$$\psi(r) = \frac{p_T^{jet}(0,r)}{p_T^{jet}(0,R)}$$

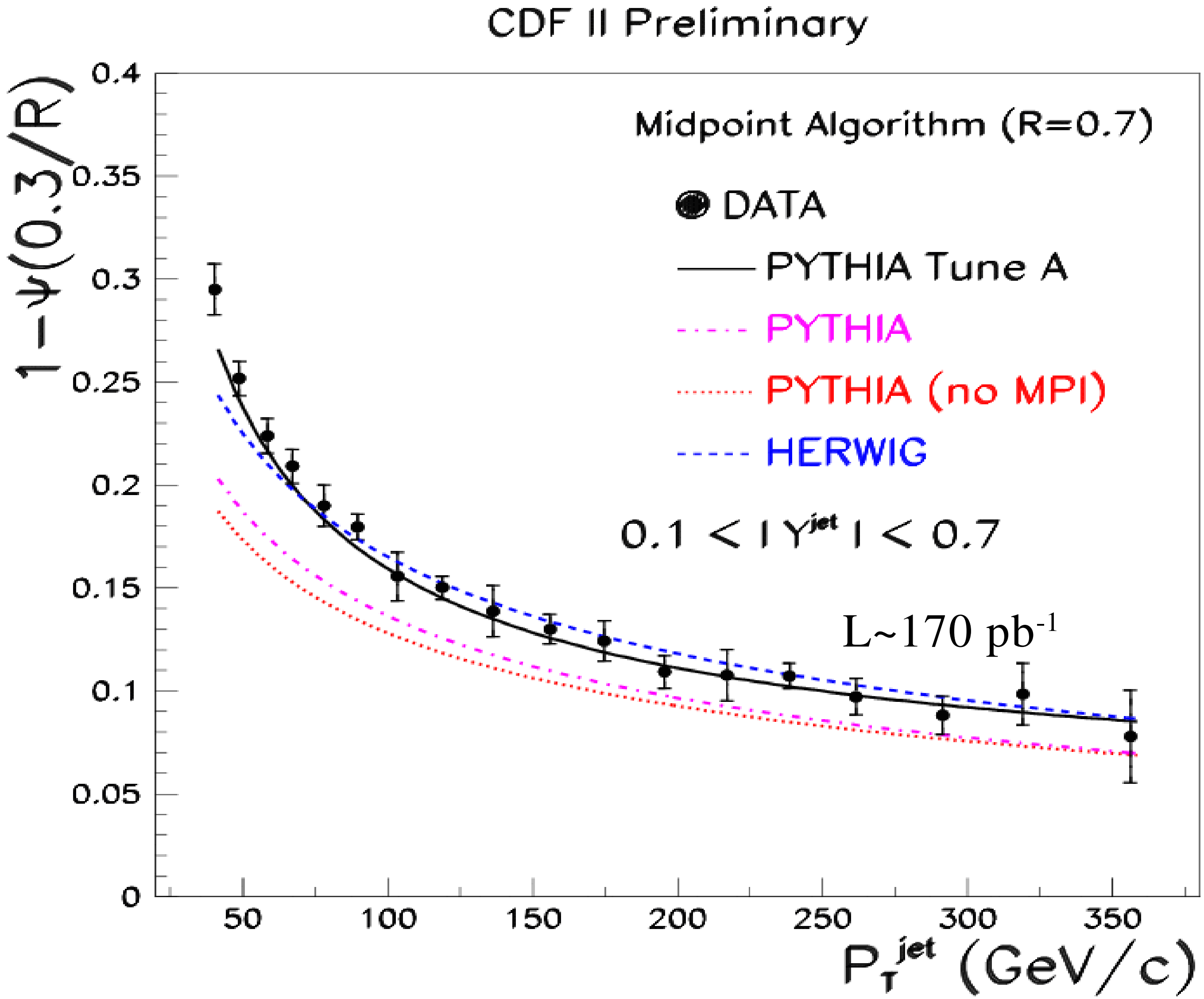




April 2004

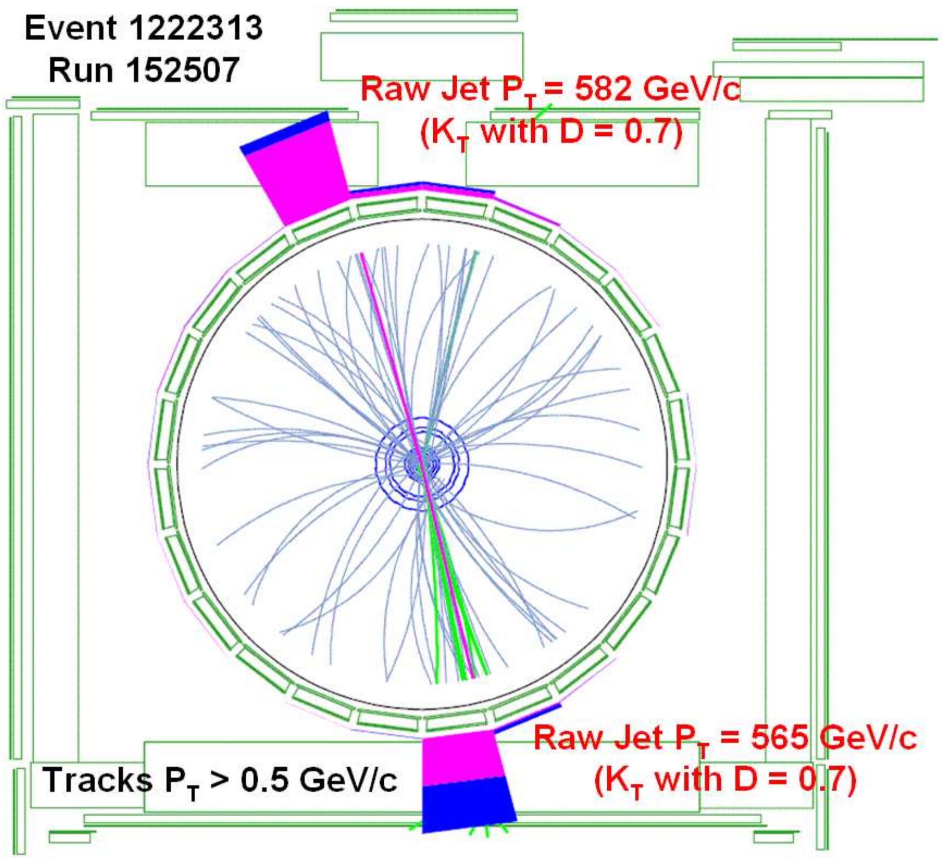


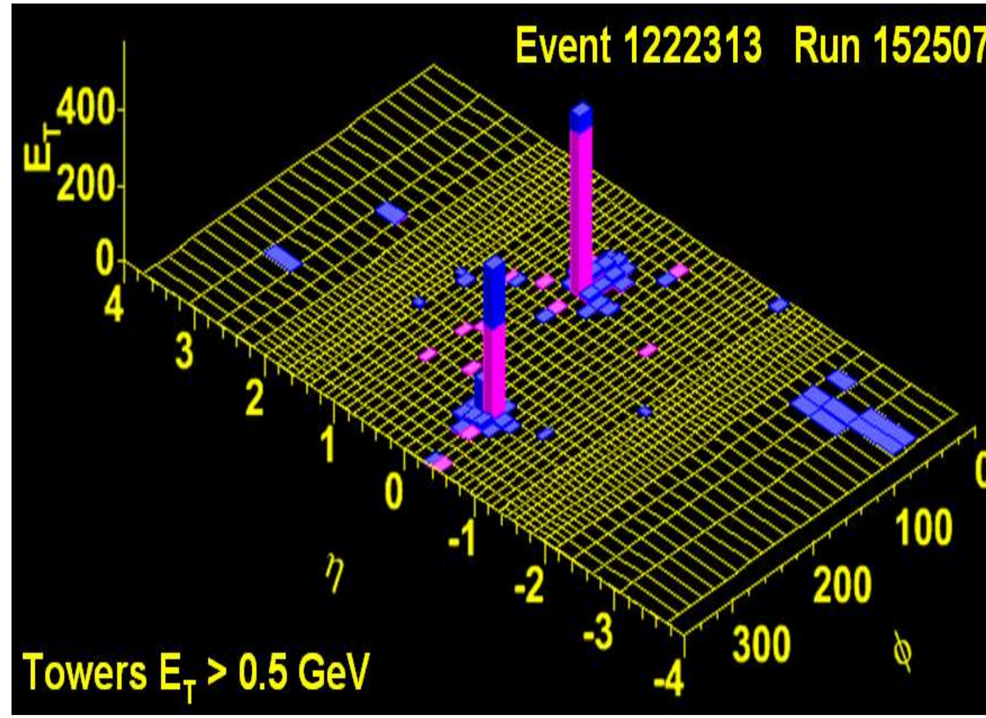
CDF - Jet Shapes



This measurement is sensitive to the underlying event and to fragmentation effects, and we can see that they are well simulated in Pythia tune A.

CDF - Highest p_T Jet Event





The Tevatron run II produces the highest pT jets available.

How can we use them to learn about the proton's PDFs?

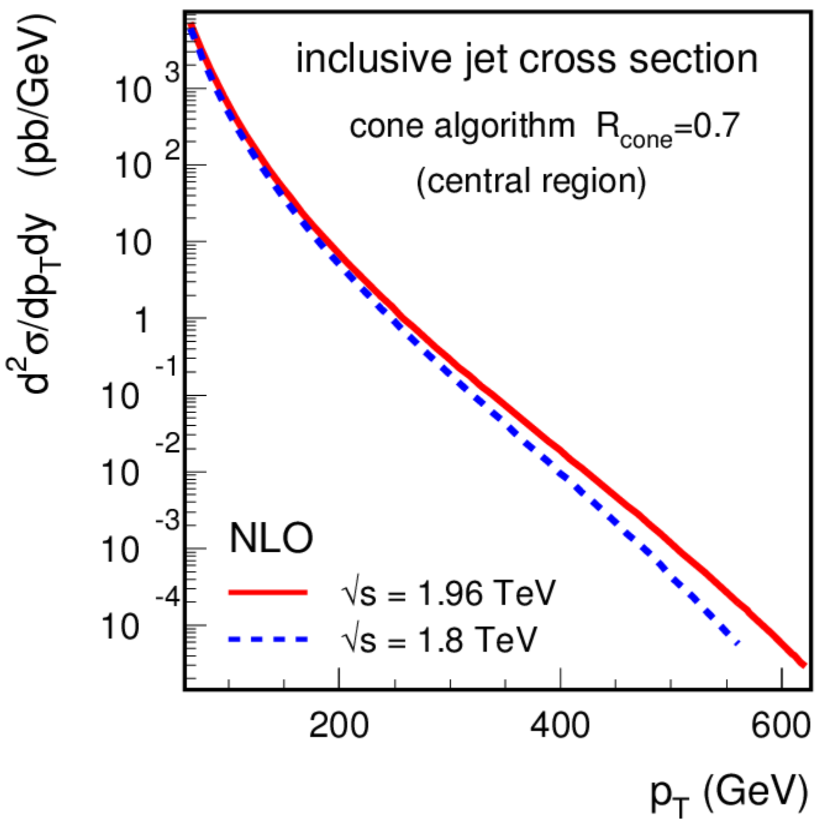
The Basics

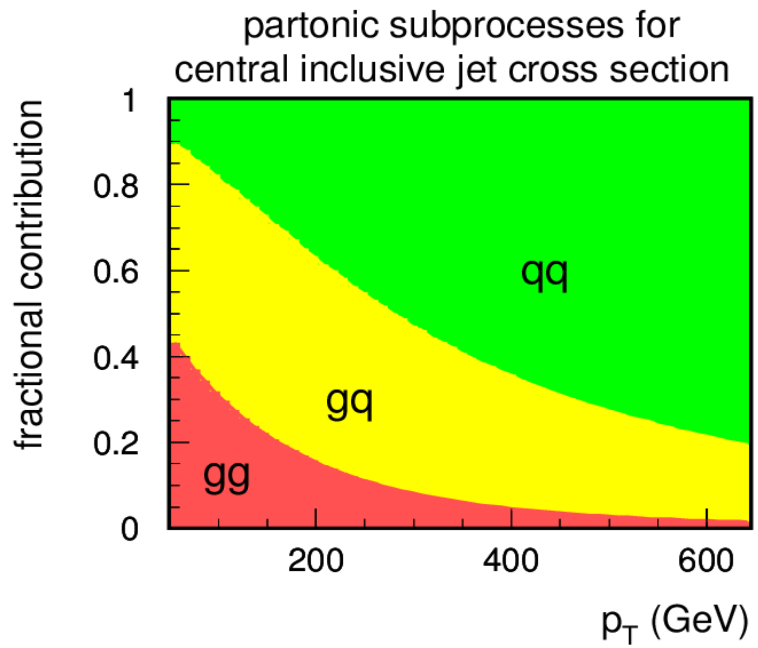
Differential Jet Cross Sections

- New Inclusive Measurements from DØ (Run II cone) and CDF (kT)
- Older results from CDF (Run I cone) and DØ (di jets)
- Back to the future

Inclusive Jet Cross Section

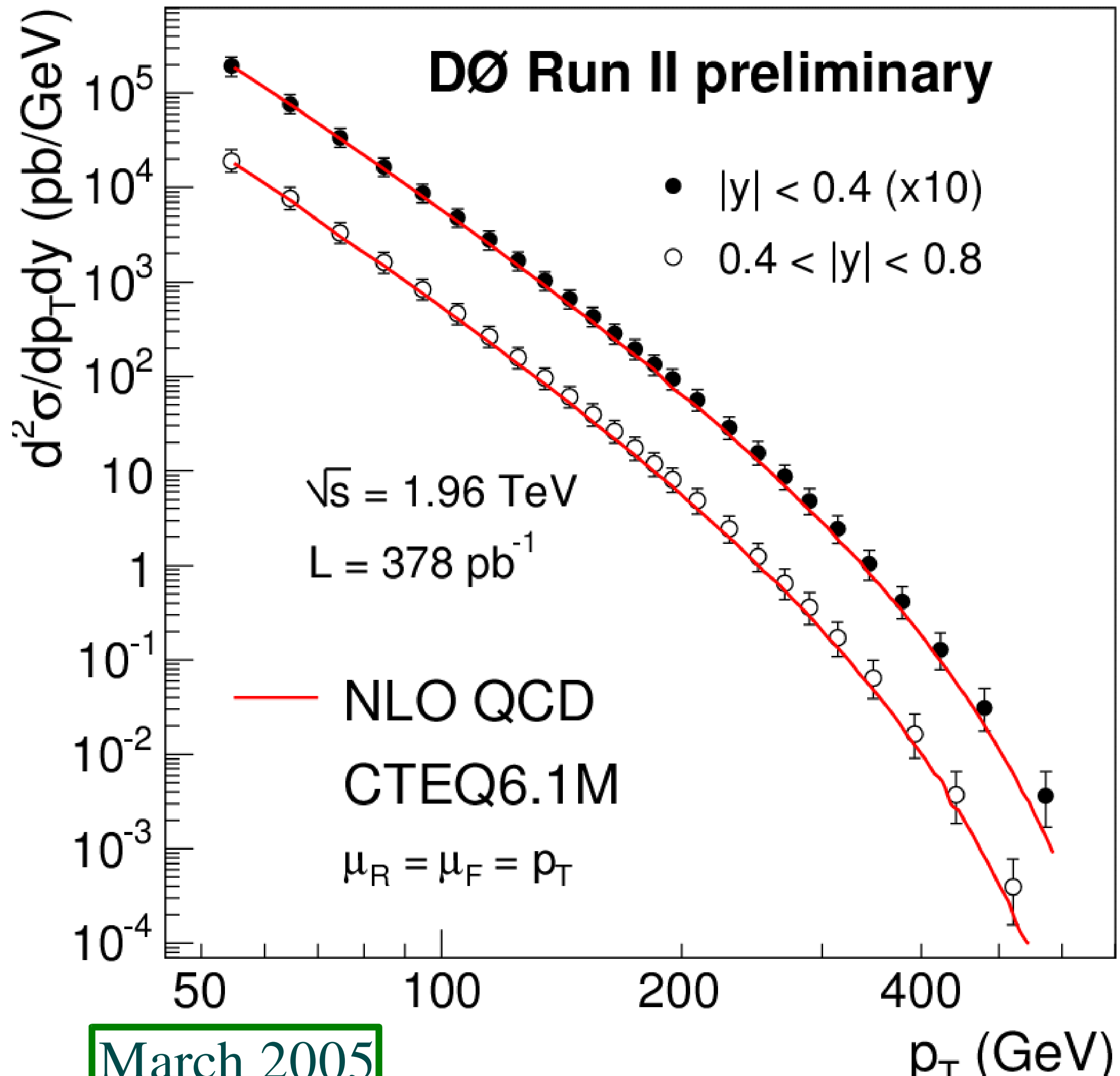
The modest c.m. energy increase results in a factor 5 increase of the cross section at high (~500GeV) p_T.





NLO pQCD predictions using CTEQ6.1M PDFs

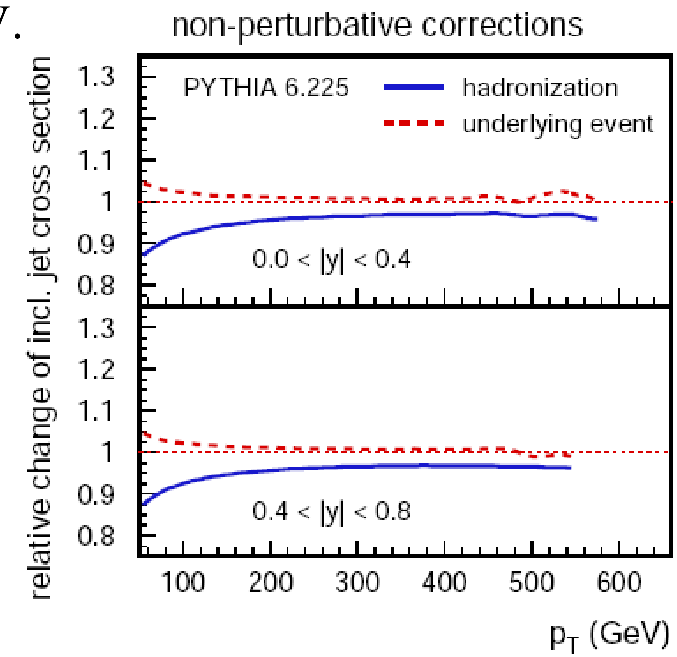
DØ - Inclusive Cone Jet



March 2005

Measurement at central region extends over 8 orders of magnitude.

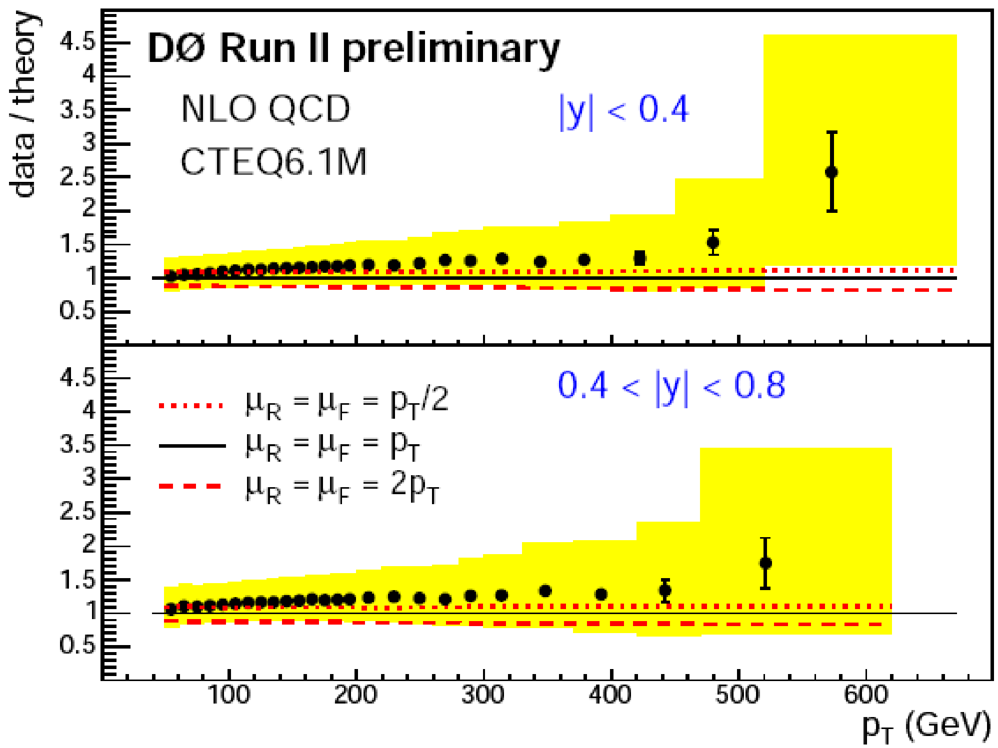
Non-perturbative corrections are not applied and are less than 5% above 100 GeV.



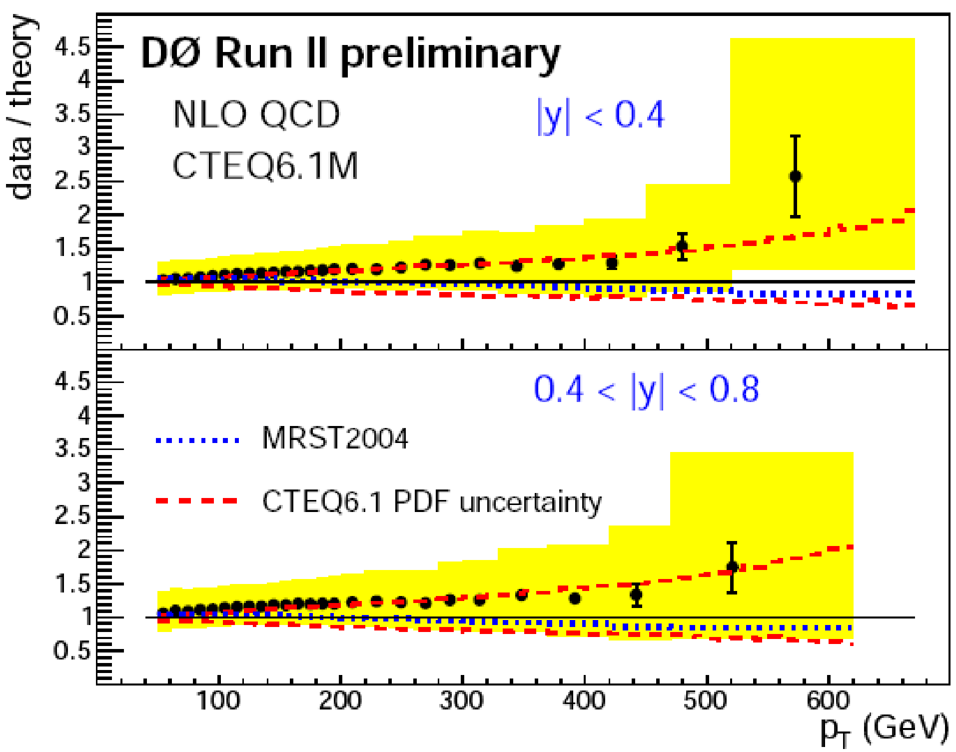
Uses the Run II midpoint cone jet algorithm, which is infrared and collinear safe.

Measurement will be extended to higher rapidities.

DØ - Incl. Jet - Comparisons



The total experimental uncertainty is shown by the shaded band. It is dominated by the uncertainty on the Jet Energy Response (jargon: Jet Energy Scale). As are the uncertainties for all the Tevatron jet measurements.



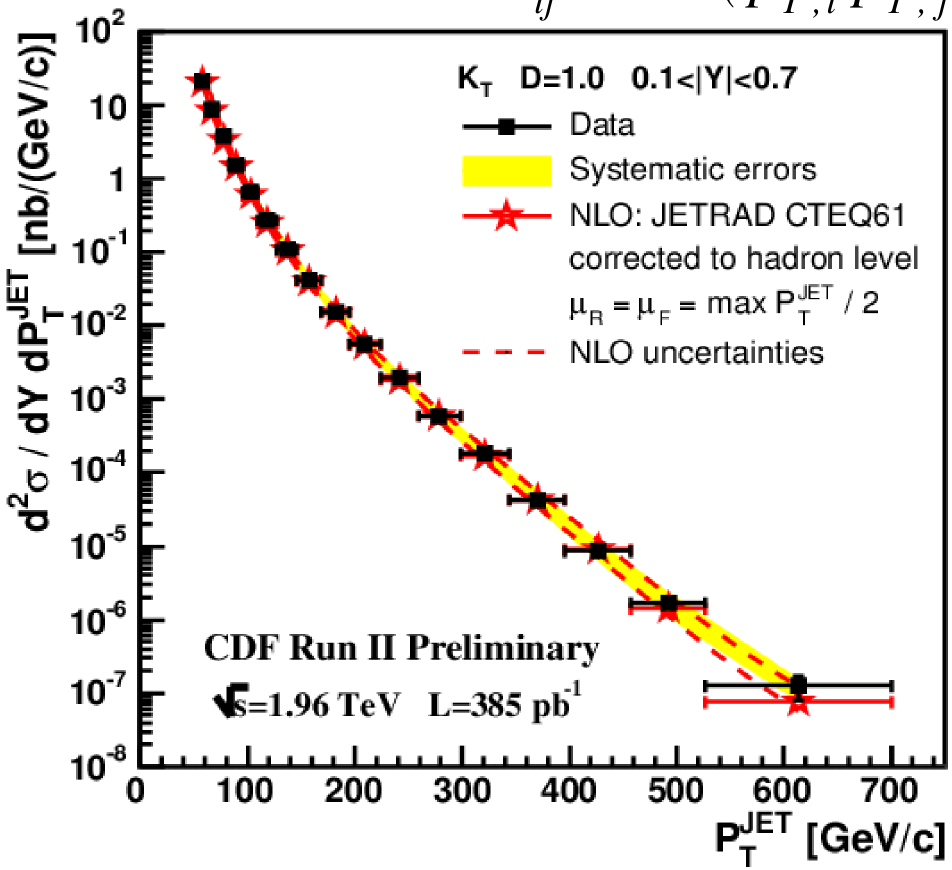
The systematic uncertainties are still too big to constrain the PDFs.

Current results are consistent with CTEQ6.1 within uncertainties.

CDF - Inclusive k_T Jet

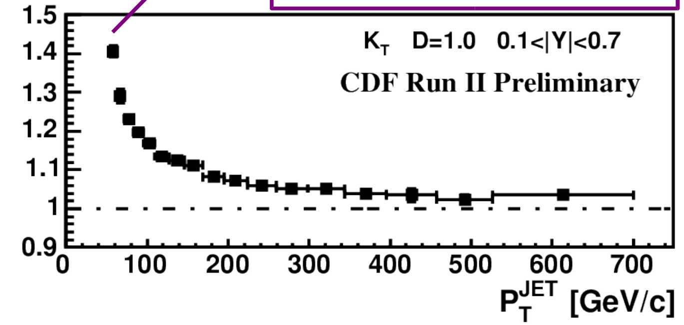
The k_T jet algorithm clusters objects into jets according to:

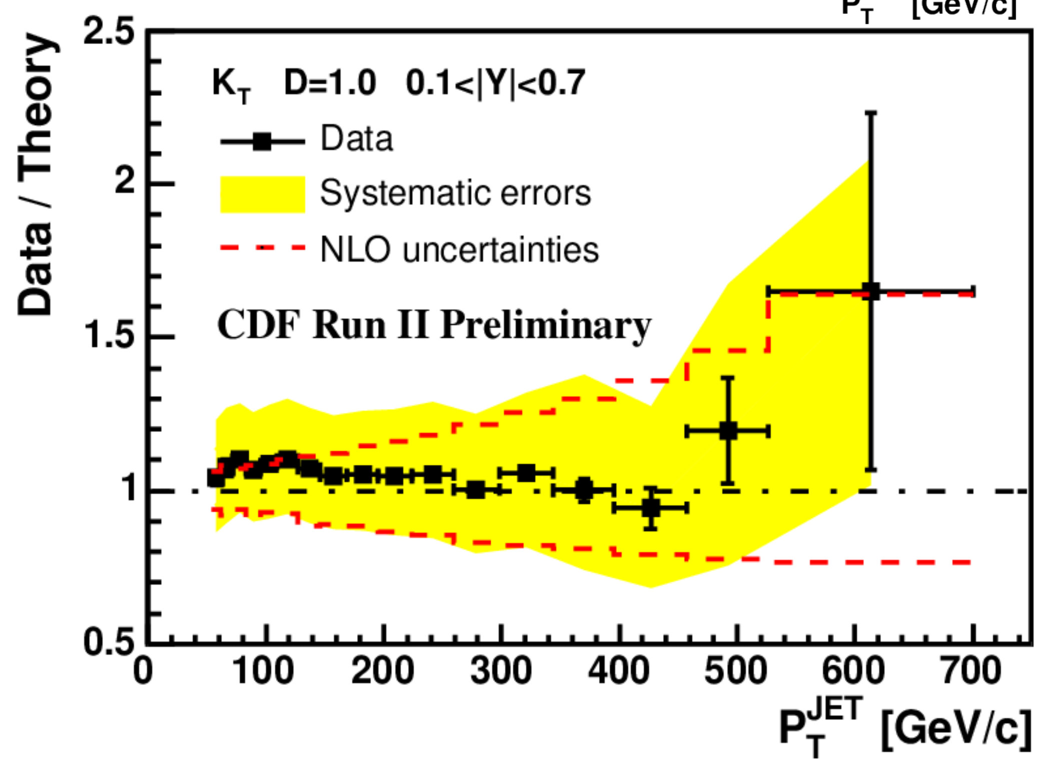
$$d_{ij} = min(p_{T,i}^{2}, p_{T,j}^{2}) \frac{\Delta R^2}{D^2}$$



April 2005

Note large correction due to underlying event

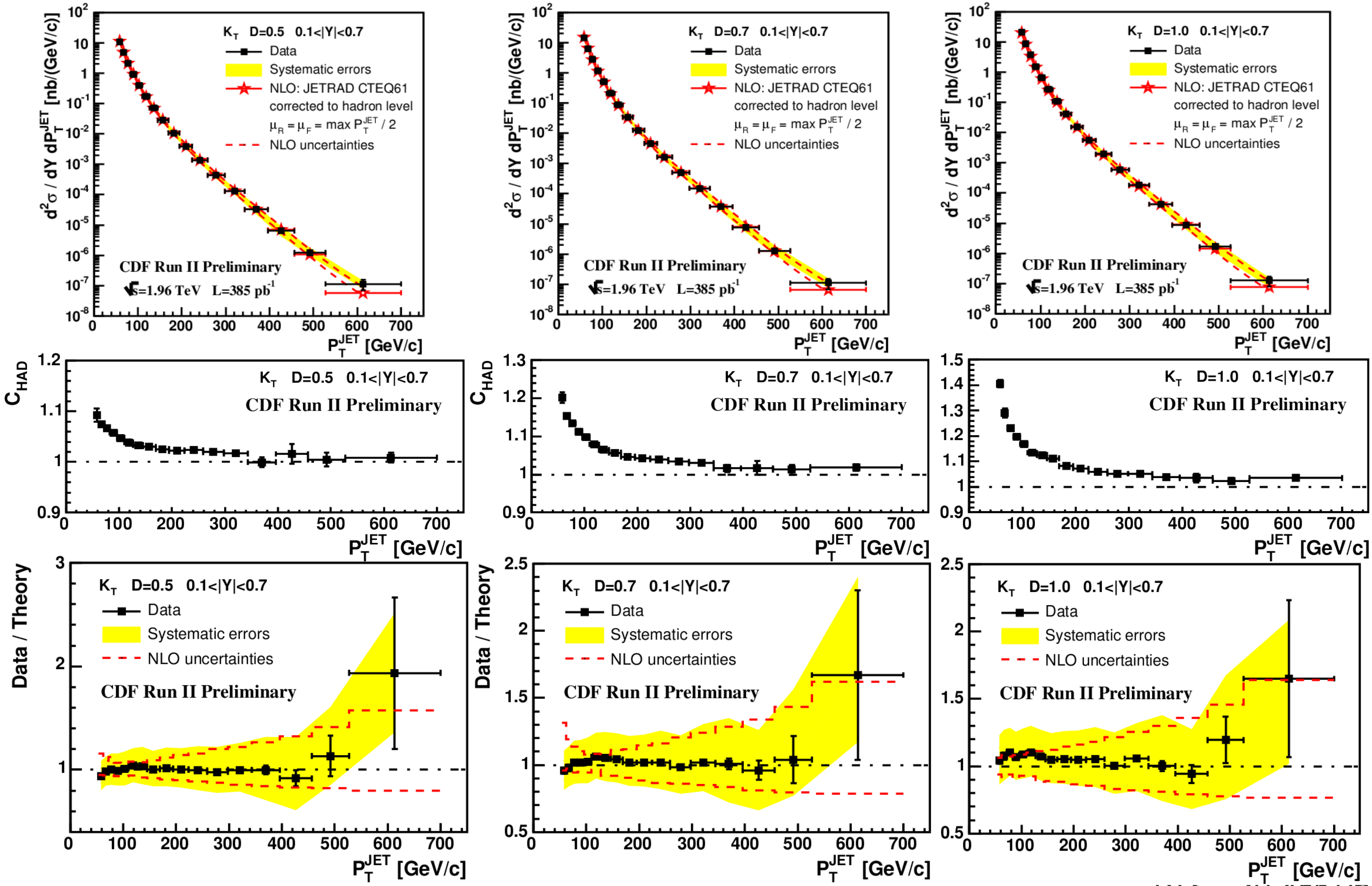




Data and theory agree well.

Experimental uncertainties are comparable to the NLO (PDF+scales) **uncertainties.** Current results confirm CTEQ6.1 within its uncertainties.

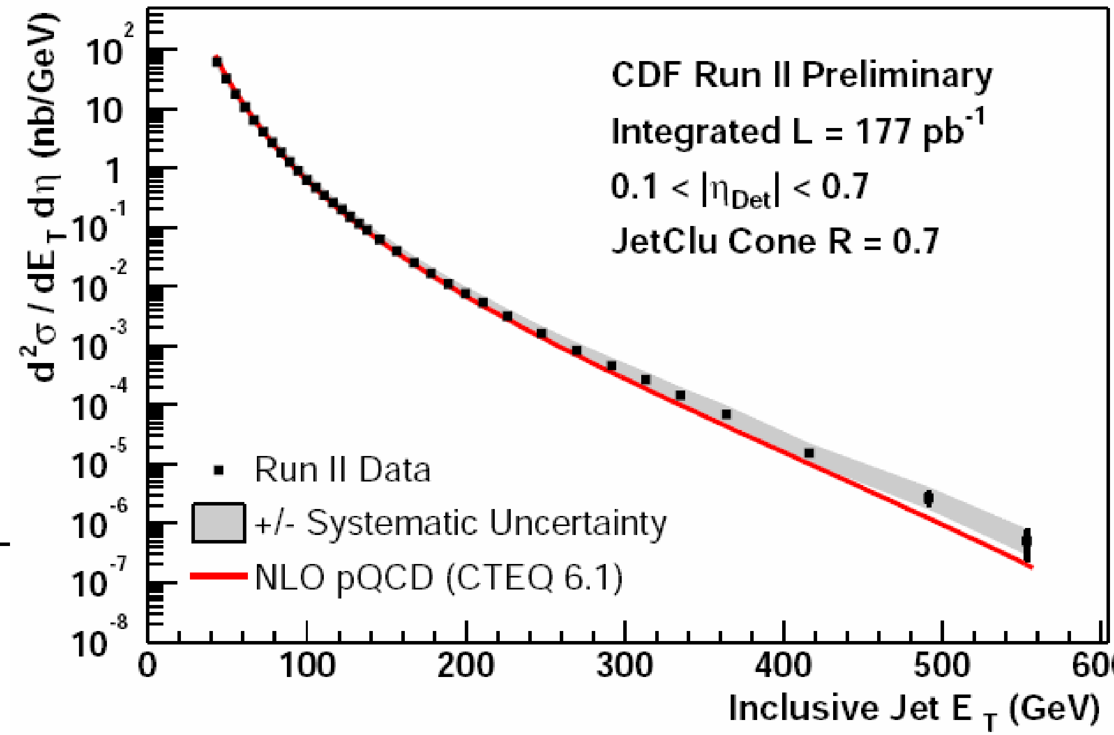
CDF - Inclusive k_T Jet

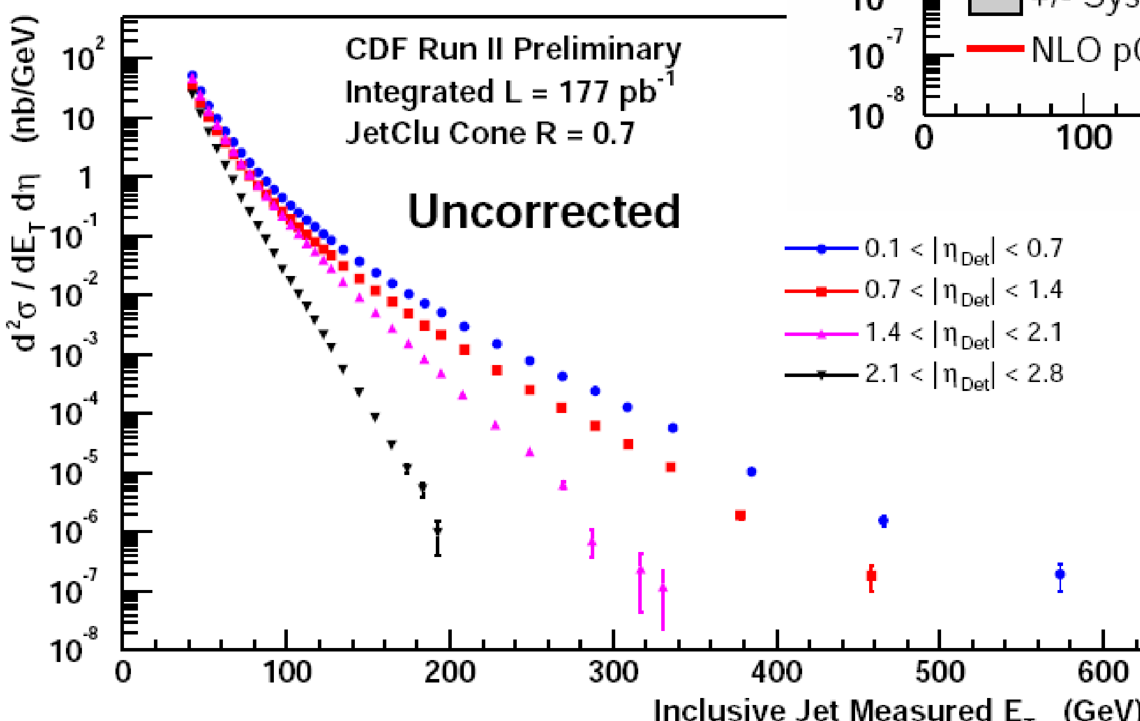


CDF - Inclusive Cone Jet

Measurement extends over 8 orders of magnitude.

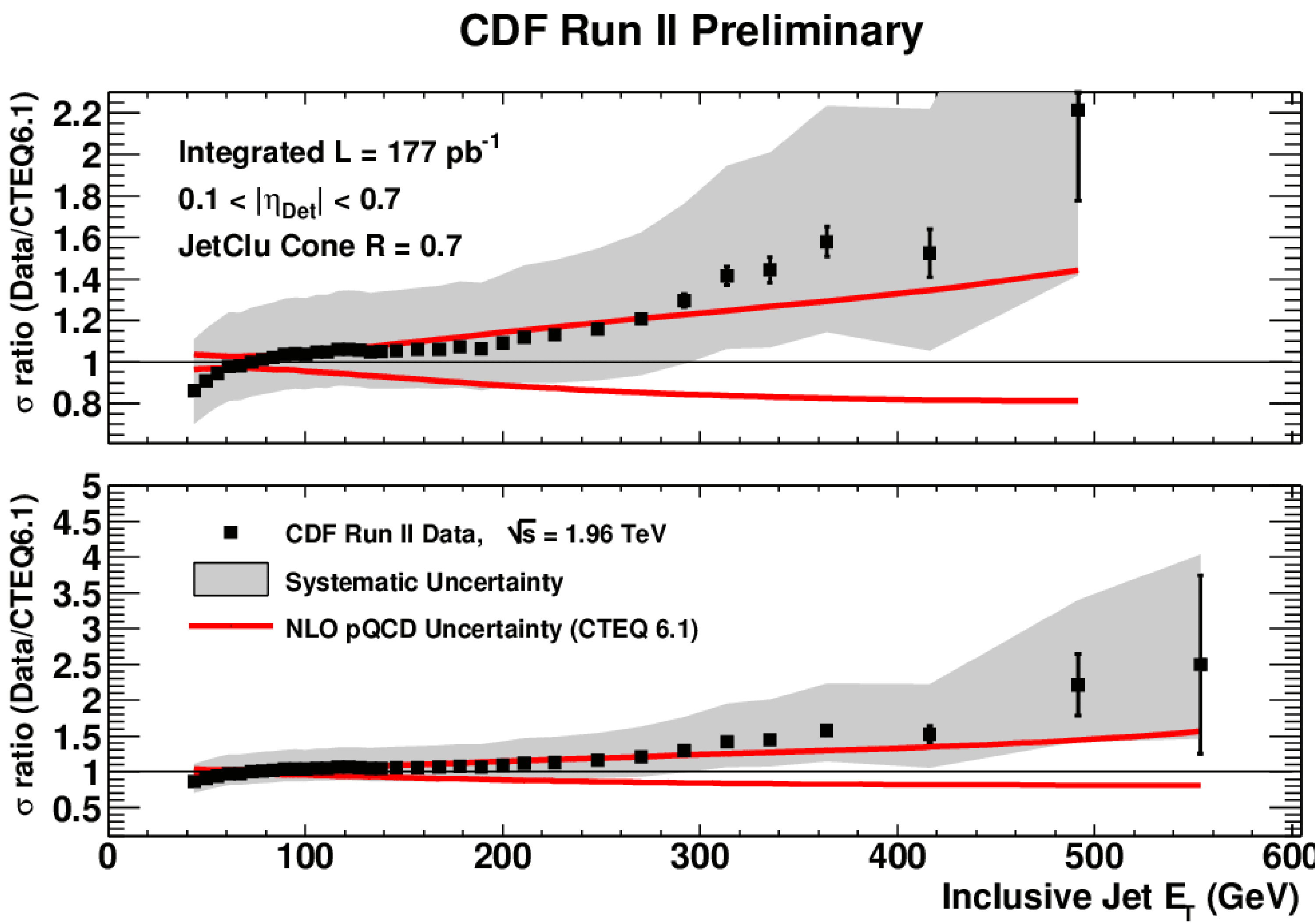
Fully corrected in the central region.





August 2003

CDF - Incl. Cone - Comparisons

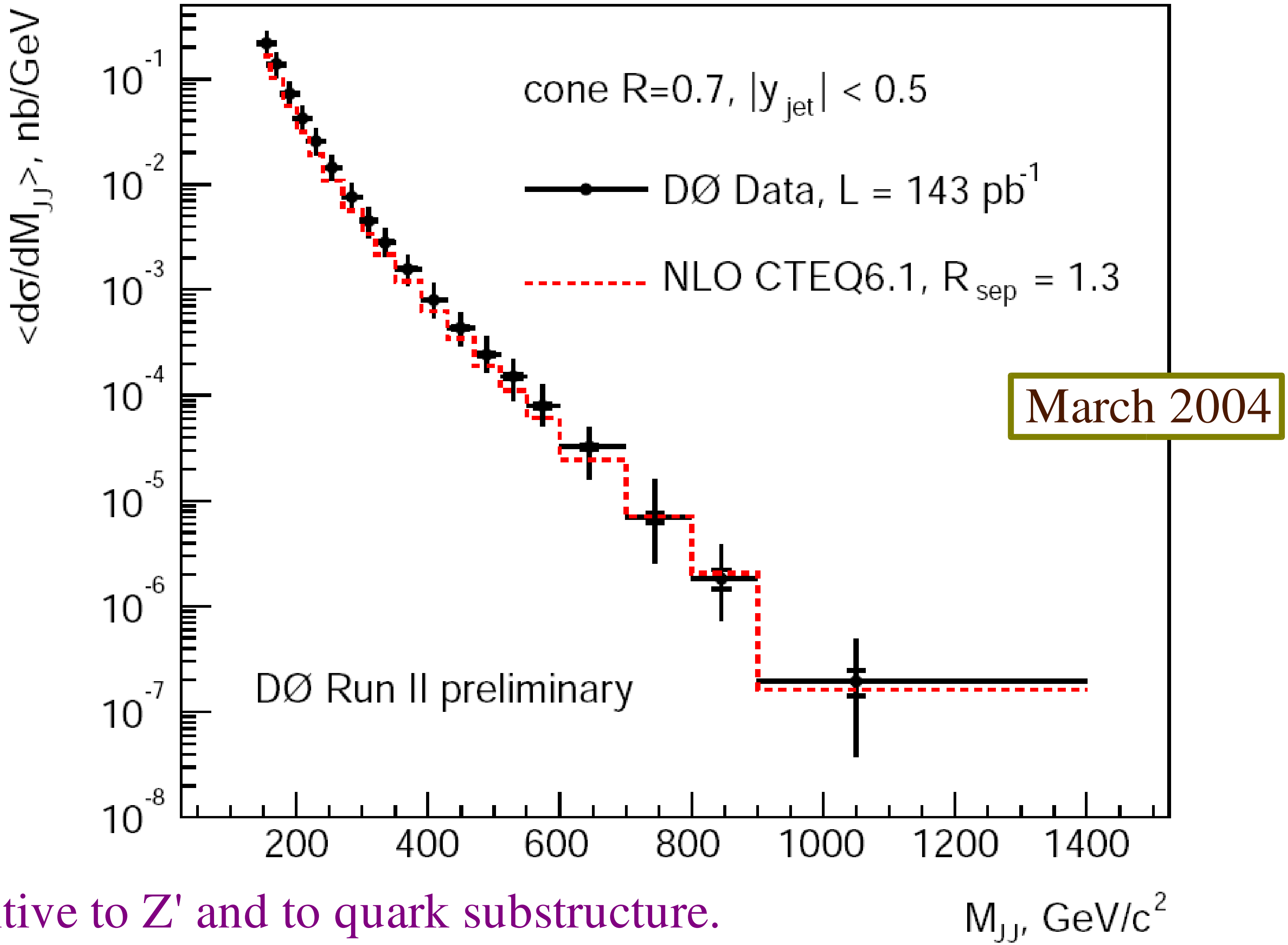


The total experimental uncertainty is shown by the shaded band, and is dominated by the uncertainty on the Jet Energy Response.

The PDF uncertainties are shown by red lines

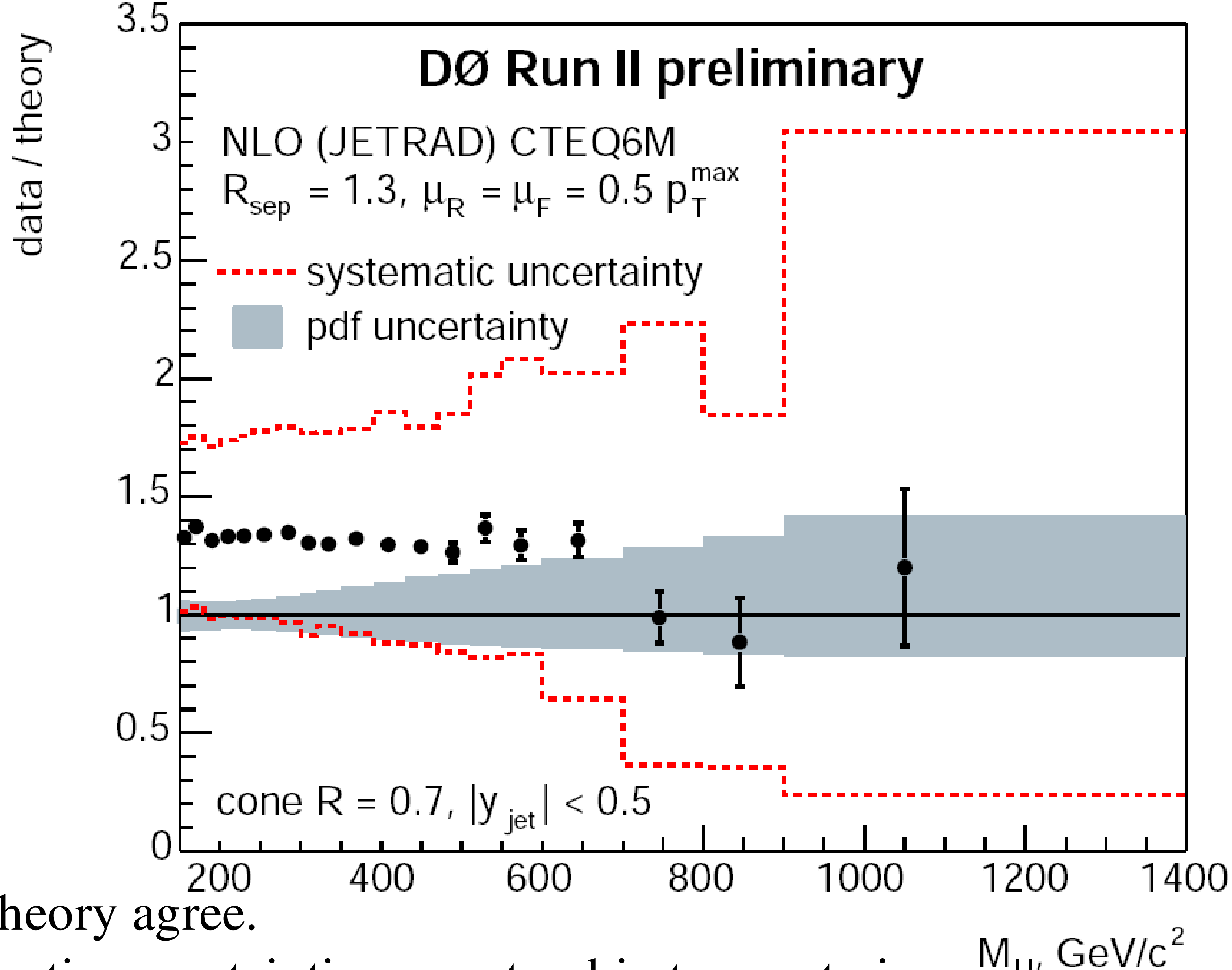
Data and theory agree.
The systematic uncertainties were too big to constrain the PDFs.
The results are consistent with CTEQ6.1 within uncertainties.

DØ - Di jet



Sensitive to Z' and to quark substructure.

DØ – Di jet - Comparisons



Data and theory agree.

The systematic uncertainties were too big to constrain the PDFs, and are being improved as this analysis is being updated.

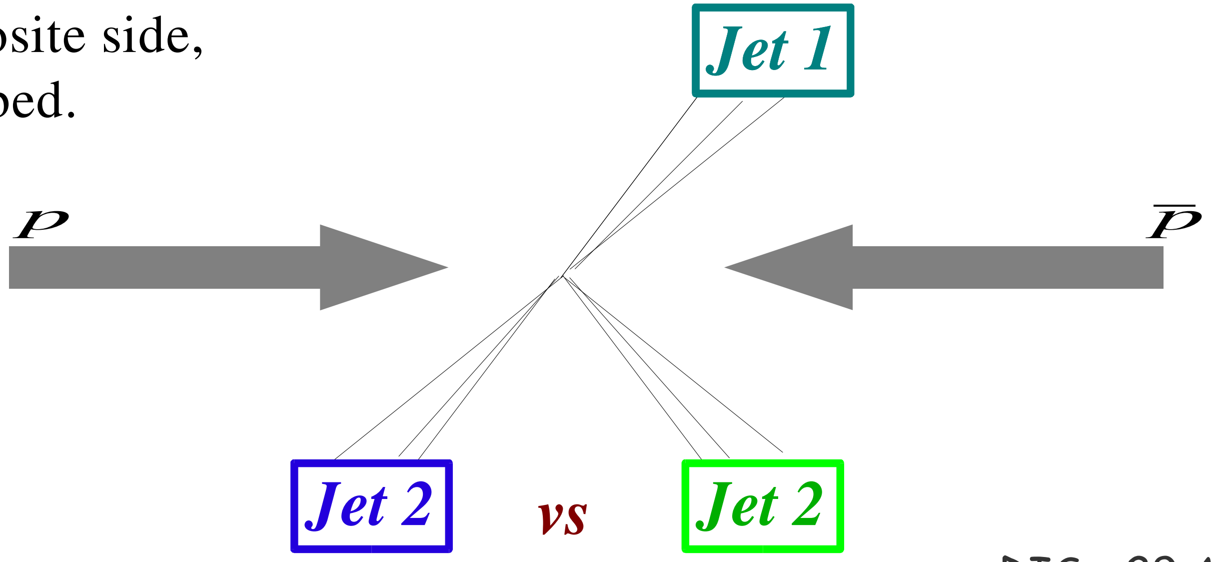
Back to the Future

The main systematic uncertainty in these analysis on the jet's energy response, especially at high rapidities. One way of improving the constraints on the PDFs is to measure relative cross sections:

- Forward over central. Will the correlation between the uncertainties in those regions be high?
- Triple Differential Cross-sections: $$\frac{d\sigma}{d\eta_1 \, d\eta_2 \, dE_T}$$

Two variations in Run I (see DIS 99 talks):

- CDF demanded one central jet, which used the smaller uncertainties in the central region.
- DØ demanded $|\eta_1| \simeq |\eta_2|$, and compared same-sided vs. opposite-sided jets.
  This used the detector's north-south symmetry.
  When the jets are on opposite side,
  a higher value of x is probed.



Beyond Inclusive X-Sections

Other jet measurements at the Tevatron probe the b-quark's PDF

- **Electroweak-boson + b-jet cross section (CDF & DØ)**
- B-jet cross sections

DØ – Z+b-jet cross section

October 2004,
PRL 94, 161801 (2005)

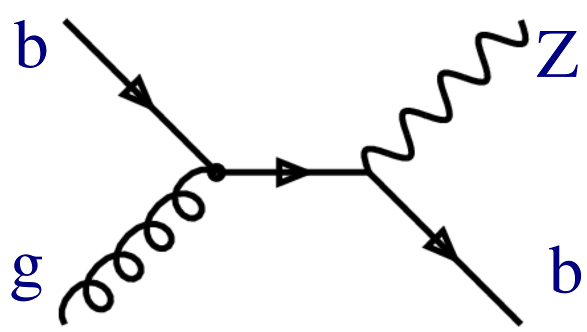
Using ~180 pb^{-1}, DØ measured the cross section ratio

$$\frac{\sigma(Z+b\ jet)}{\sigma(Z+jet)} = 0.023 \pm 0.004(stat)^{+0.002}_{-0.003}(syst)$$

The DØ measurement is in good agreement with the NLO prediction of 0.018±0.004.

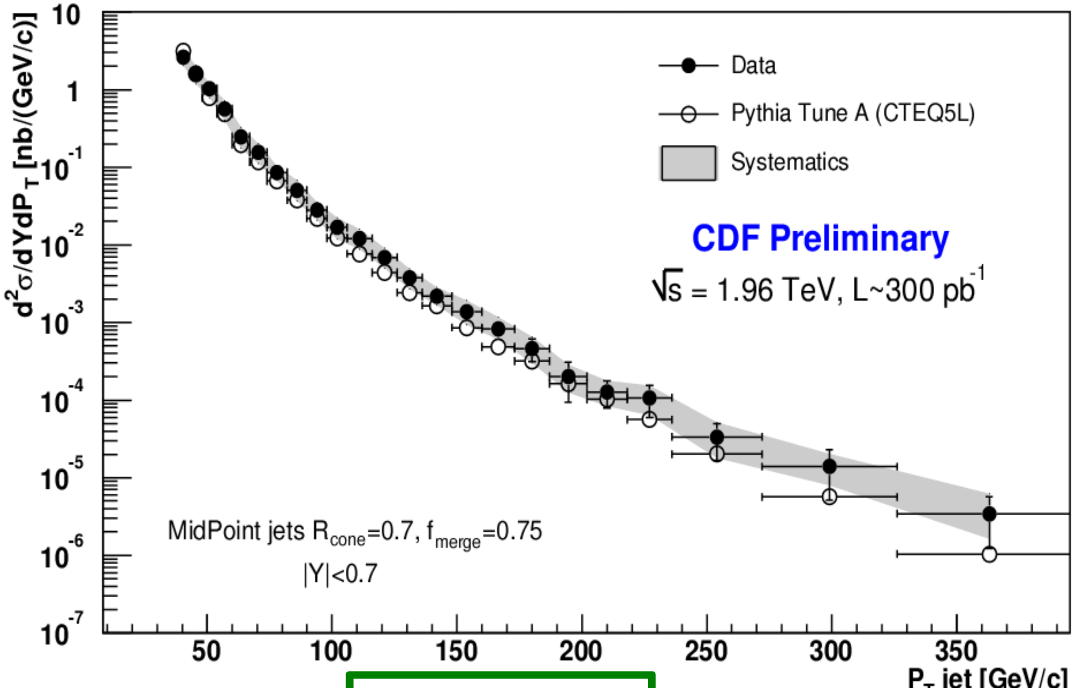
Earlier, Frank Chlebana showed the CDF measurement of the γ+b-jet cross section using ~67pb^{-1}, which similarly probes the b-PDF

The b-PDF is derived from the gluon PDF using theoretical predictions which assume no intrinsic b content and often use the massless gluon splitting approximation. These are the first direct experimental probes of the b-PDF.

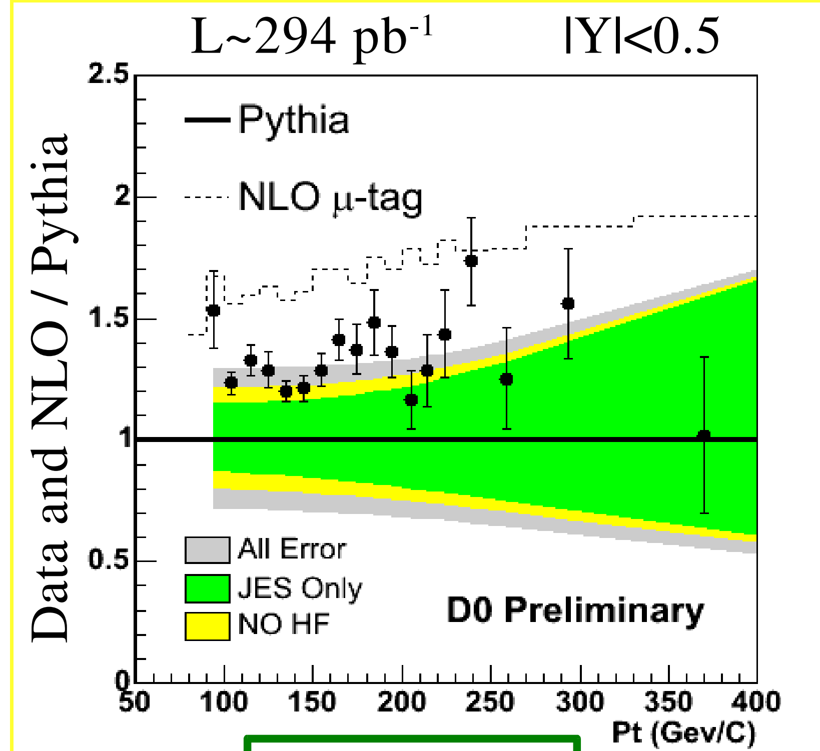


Future measurements with higher statistics and acceptance have great potential to constrain the b-PDF

b-Jet Cross Sections



April 2005



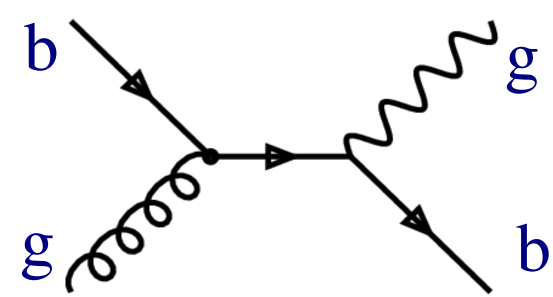
March 2005

There are new measurements of inclusive differential b-Jet cross sections.

Though in the DØ measurement the observable was defined as μ-tagged jets, from which the heavy flavor component was extracted.

The b-PDF comes into play through processes such as this, which may be relevant at low p_T.

How do isolate their contribution from that of other processes (gluon splitting, flavor creation, etc.)?



Conclusions

Tevatron performance very promising.

$\Delta\phi$ and Jet Shape measurements show that we can extract information on PDFs using Tevatron Run II results.

Jet Cross Section Measurements – preliminary measurements are ready and can confirm the high-x gluon PDF. The systematic uncertainties need to be reduced in order to constrain it.

b-Jet measurements can already constrain the b-PDF.