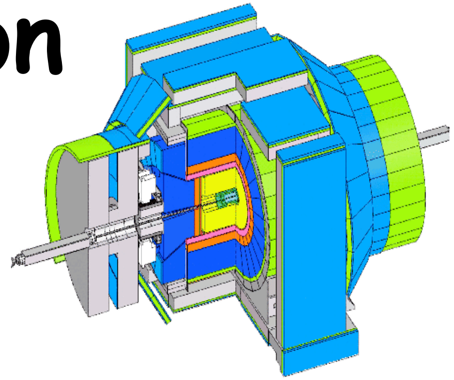
Measurements of the Inclusive Jet and Dijet production cross sections at CDF



M. Martínez

(ICREA/IFAE-Barcelona)

On behalf of the CDF Collaboration

DIS09, Madrid, April 2009

Outline

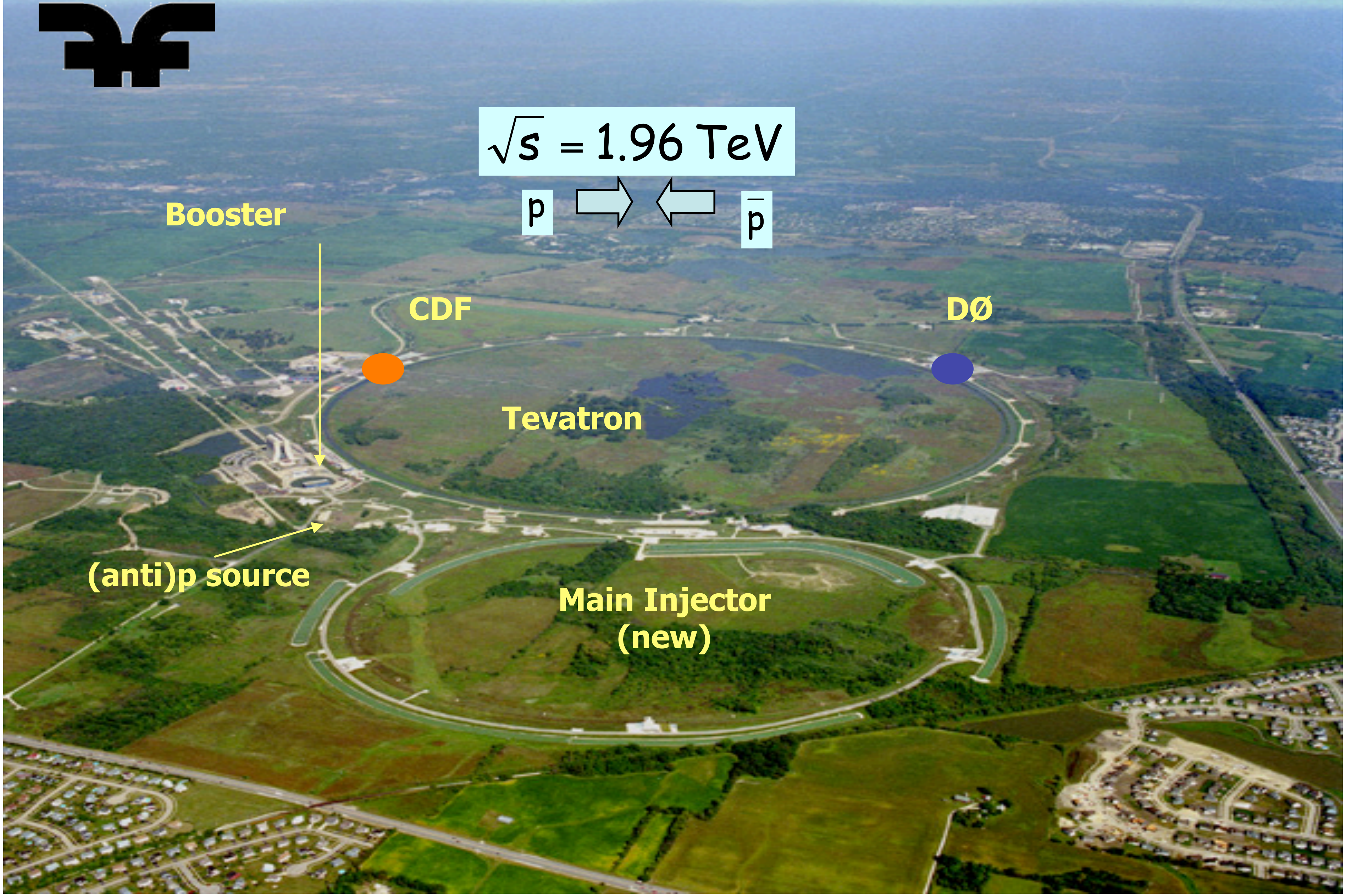
- Tevatron, CDF/D0
- Inclusive Jet Production
- Underlying Event/Jet Shapes
- Dijet Production
- New Gluon PDF
- B-jet Production
- Final Remarks

Not included in this talk:

Prompt γ production [C. Deluca]
Z/W +jets production [Tara Shears]
Soft QCD/Underlying Event [C. Mesropian]

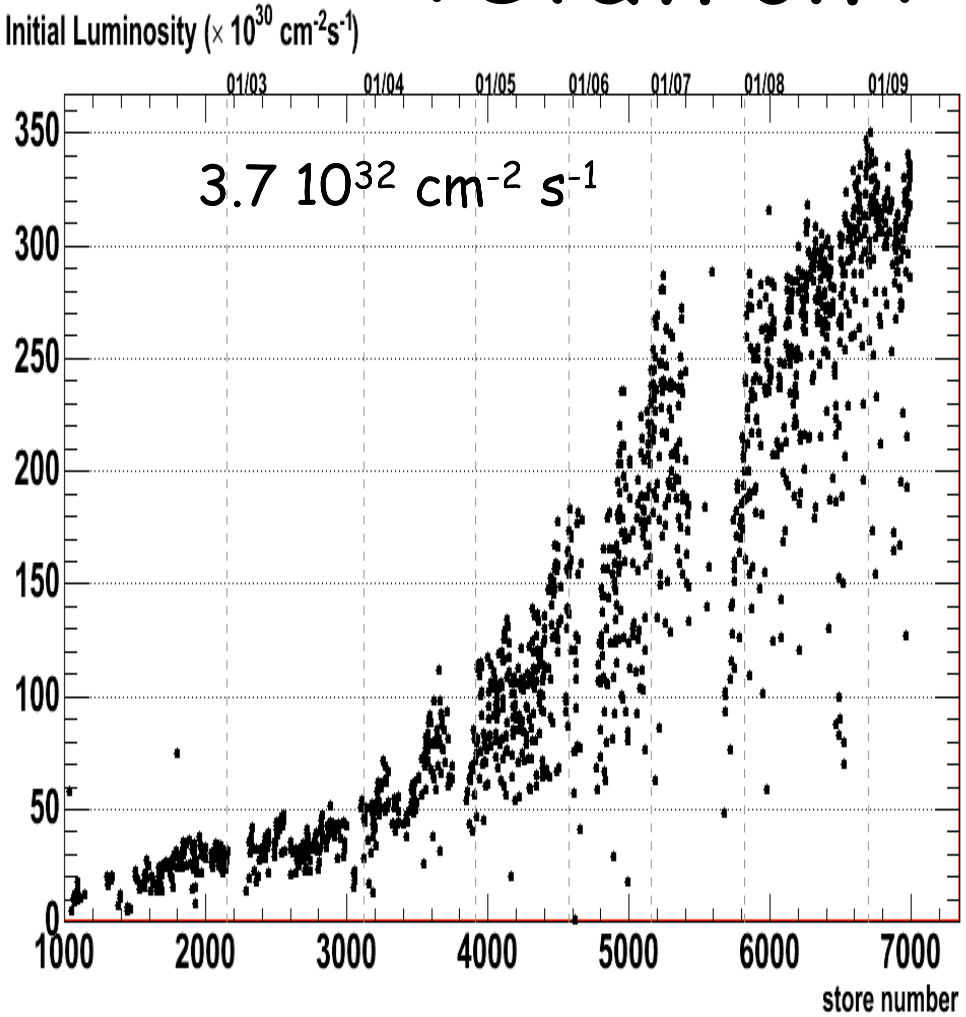
..see other related talks in this Conference...

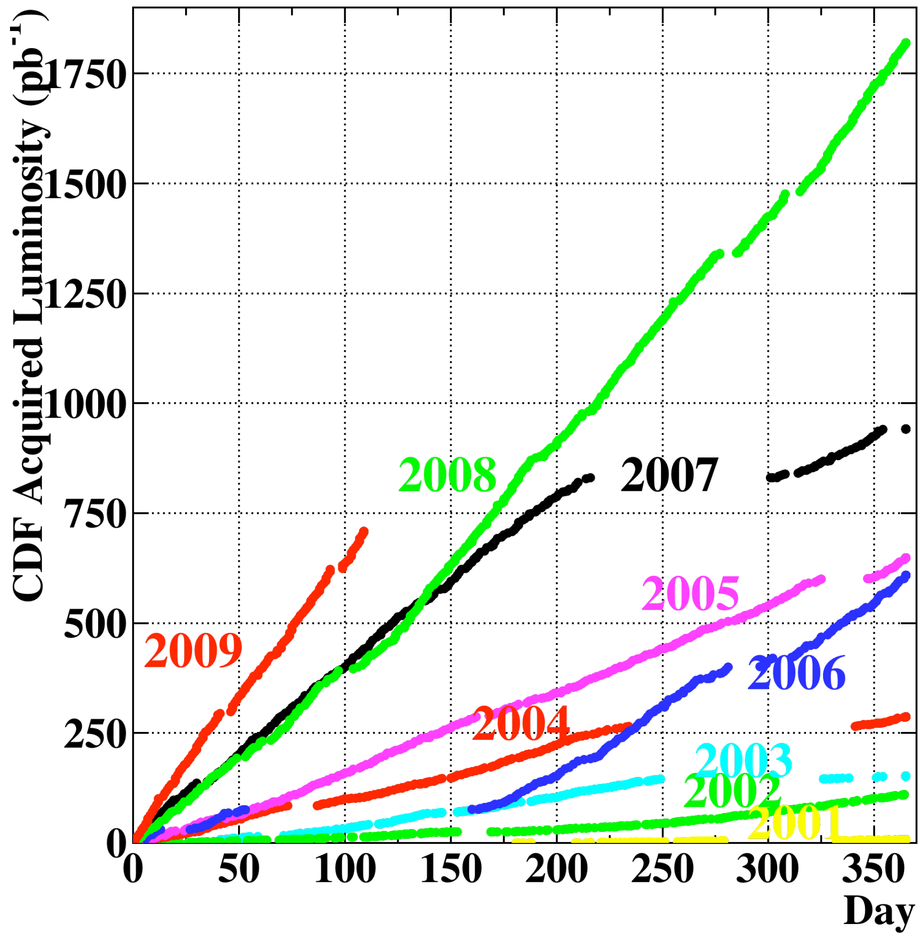
Tevatron



Chicago
$\sqrt{s} = 1.96$ TeV
p
$\bar{p}$
Booster
CDF
DØ
Tevatron
(anti)p source
Main Injector
(new)

Tevatron Performance

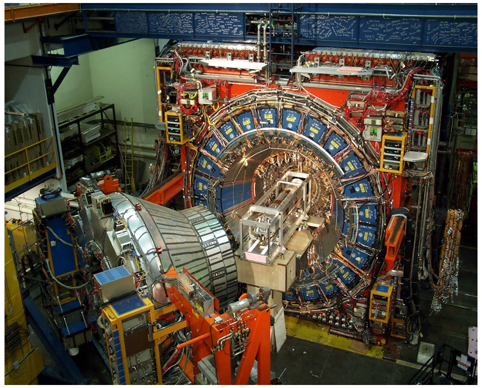




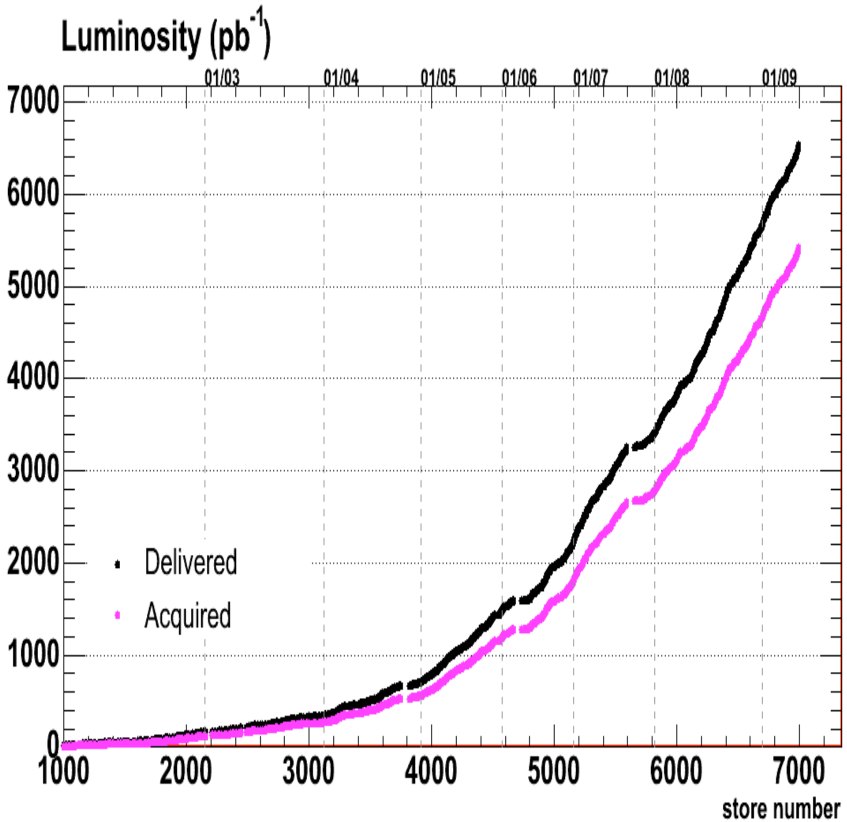
Tevatron delivered > 6 fb^{-1}
(8 fb^{-1} expected by end FY09)

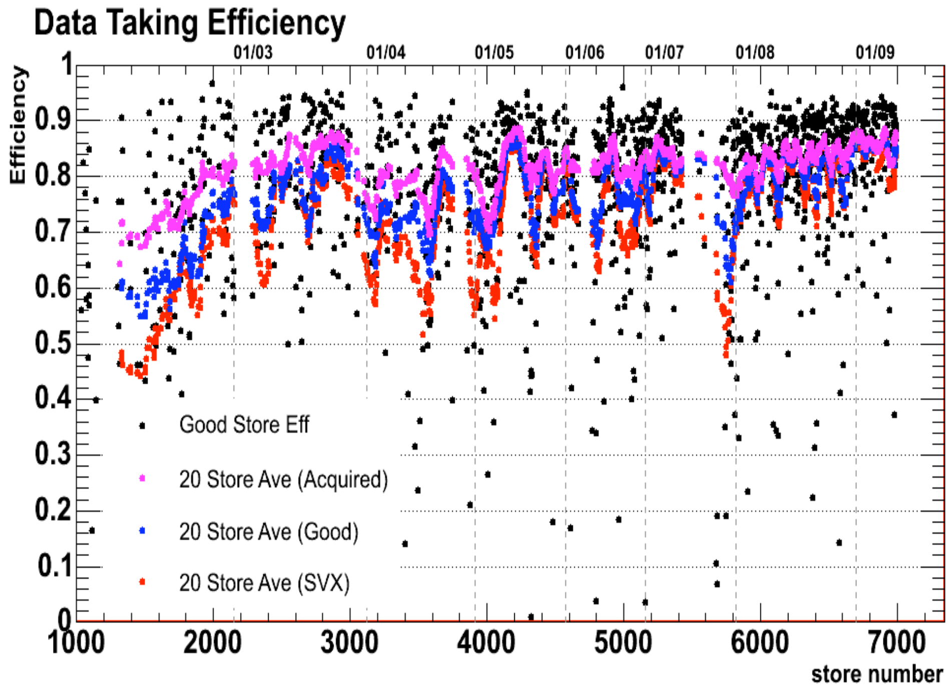
Ongoing discussion for FY2011
(we could sum up more than 10 fb^{-1})

(Run I : 120 pb^{-1})



CDF Performance

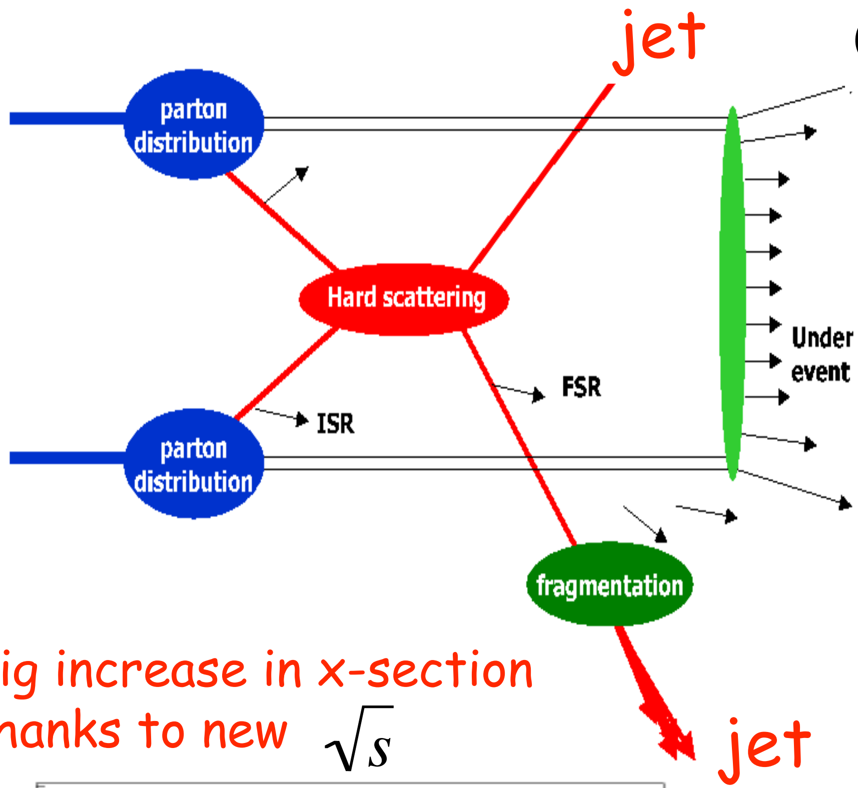


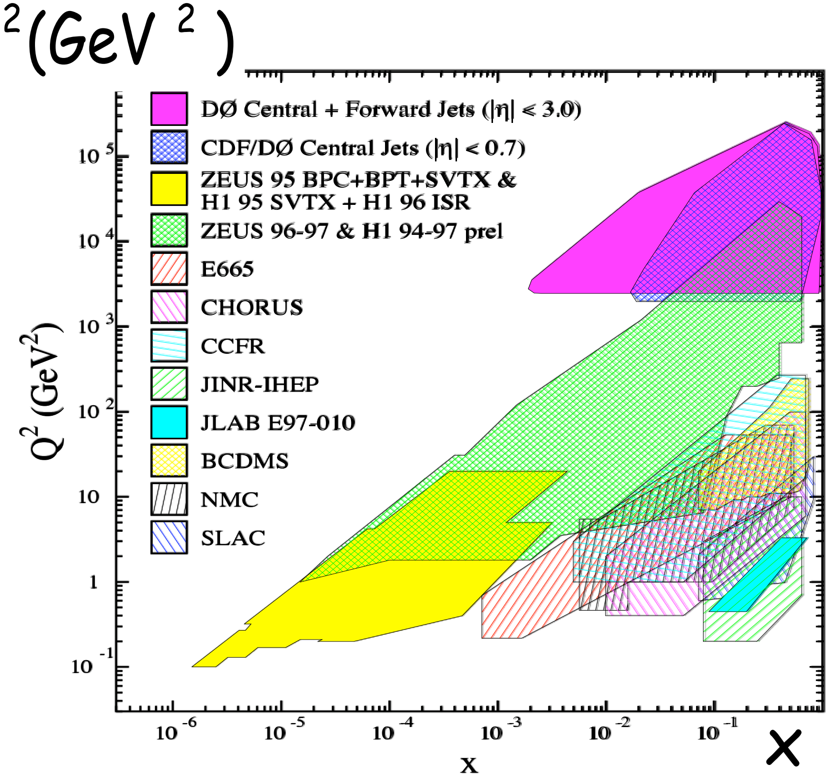


CDF has already collected more than 5 fb^{-1} on tape

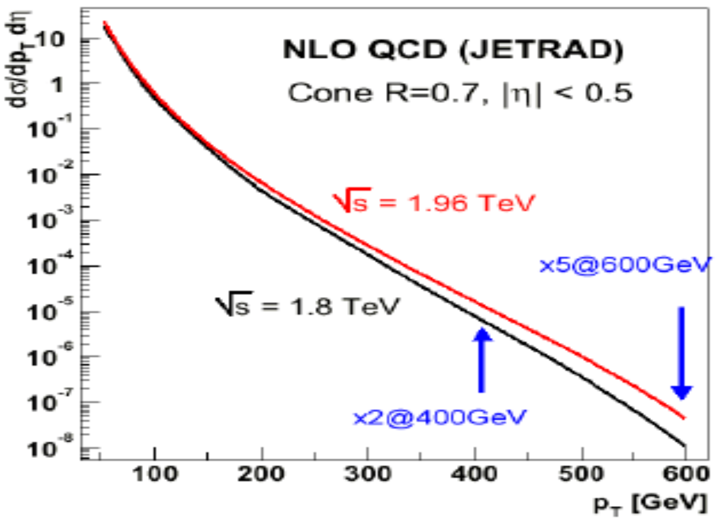
CDF operating well and recording physics quality data with very high efficiency (~85%)

High Pt Jet Physics at 2 TeV





Big increase in x-section thanks to new $\sqrt{s}$



Huge step forward in Run II

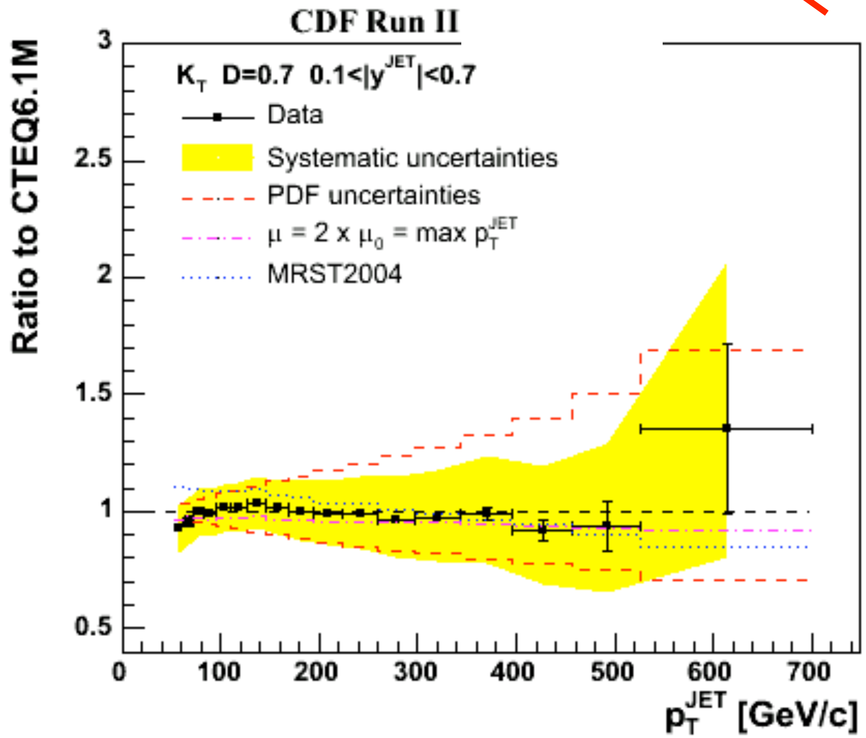
- Pt range increased by 150 GeV/c
- Measurements in wide rapidity region
- Use of K_T and cone jet algorithms
- Inclusion of non-pQCD contributions

Inclusive Jet Production

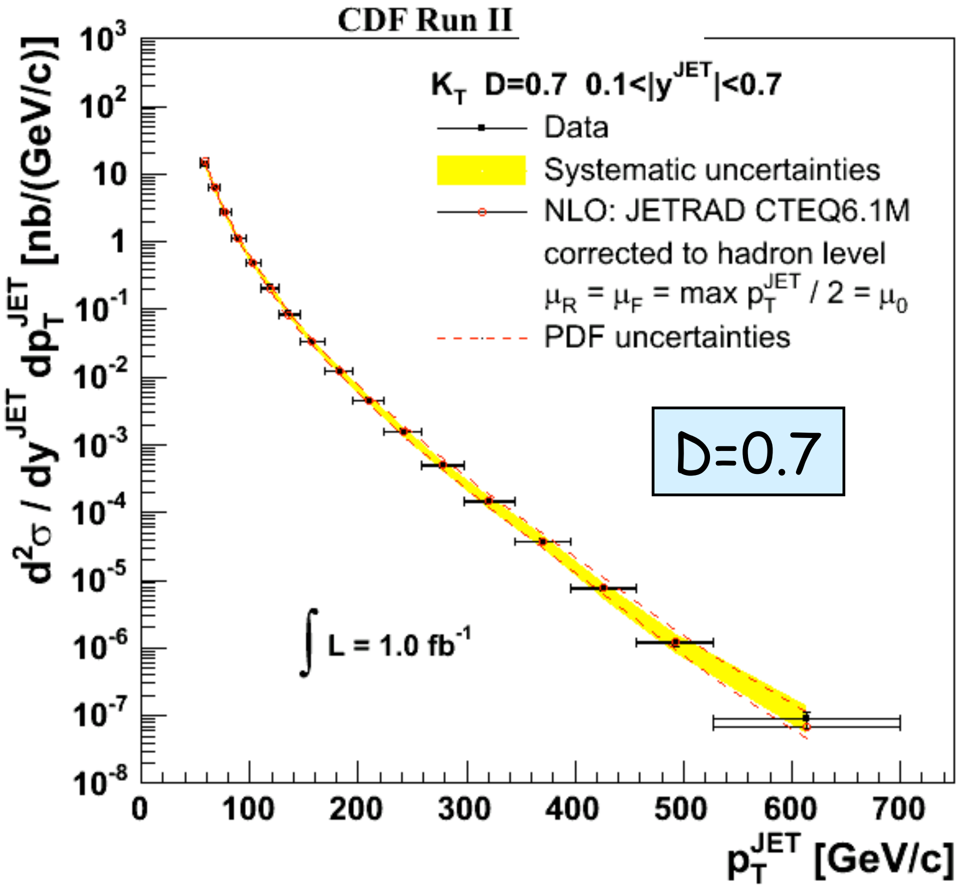
- Inclusive K_T algorithm

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

$$d_i = (P_{T,i})^2$$



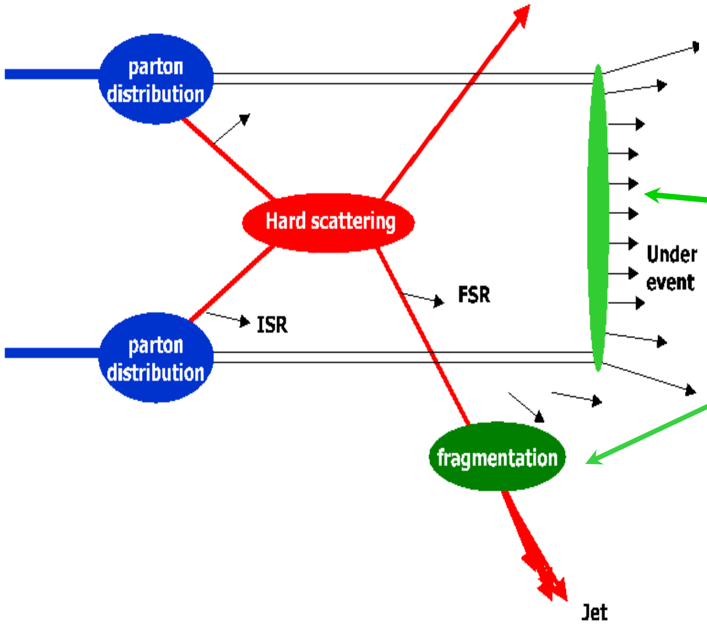
NLO pQCD is corrected for Hadronization & Underlying Event (this is important at low Pt)



- Good agreement Data vs Theory
  - Data uncertainty -> 2-2.7% e-scale
  - pQCD uncertainty -> PDFs
- K_T robust in hadron collisions

→ relevant for LHC strategies

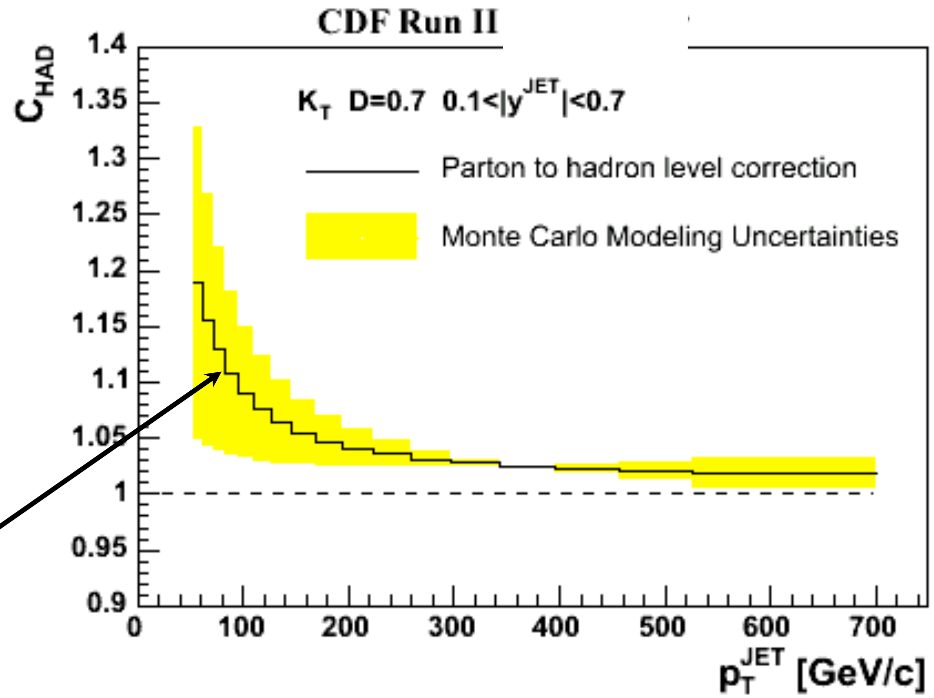
Non-pQCD Contributions



- Non-pQCD contributions
- Underlying Event

(remnant-remnant interactions)

- Fragmentation into hadrons



Underlying Event and Fragmentation contributions must be considered before comparing to NLO QCD predictions
(only way to perform a fair comparison)

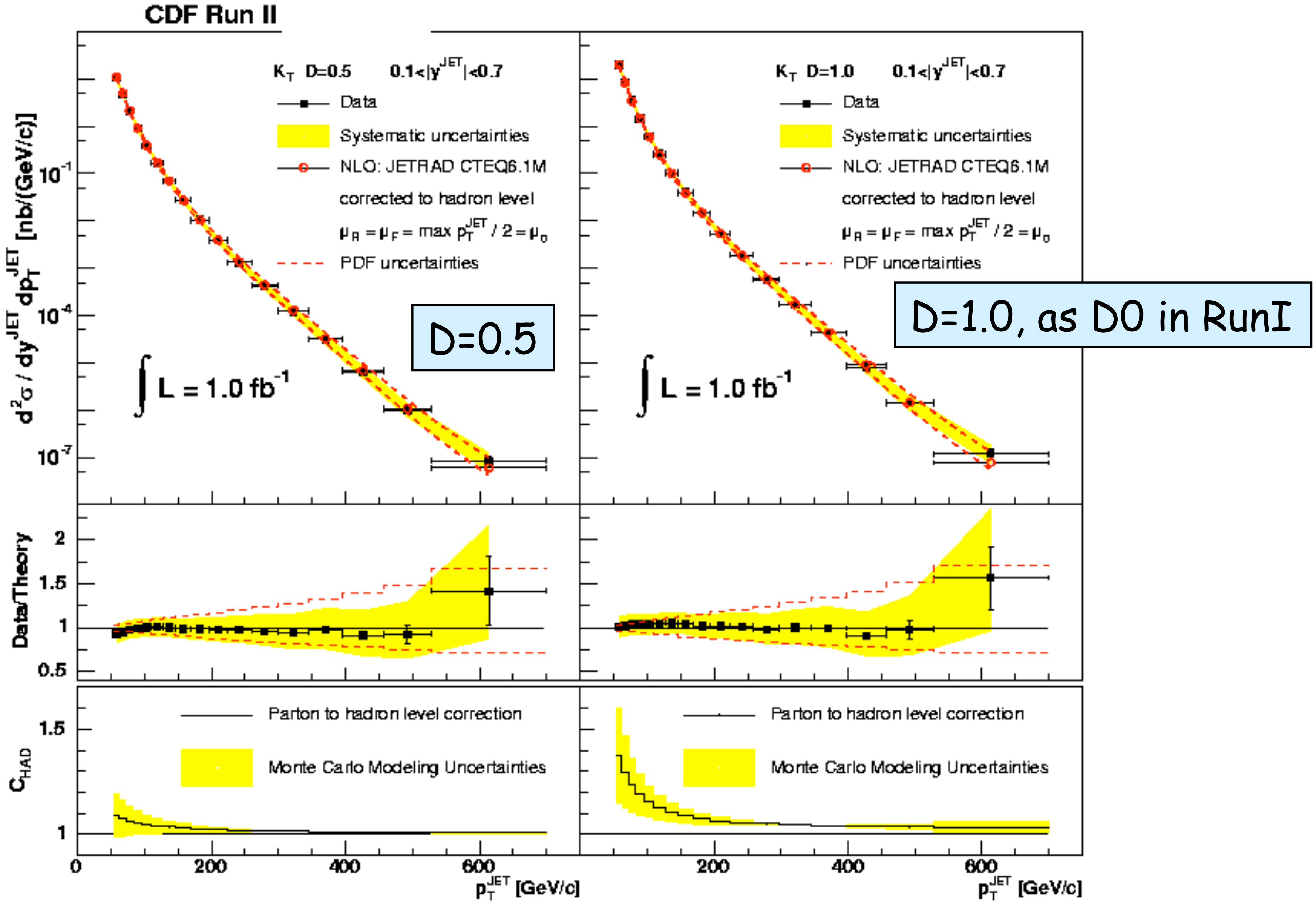
Precise measurements at low Pt require good modeling of the non-pQCD terms

Dedicated measurements are needed to validate the Monte Carlo modeling

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

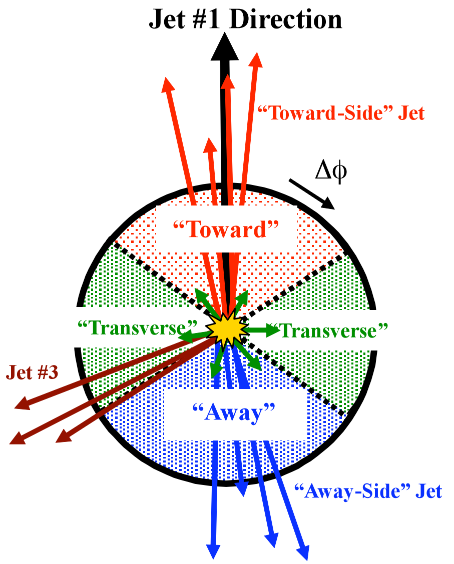
K_T Jets vs D

1 fb^{-1}



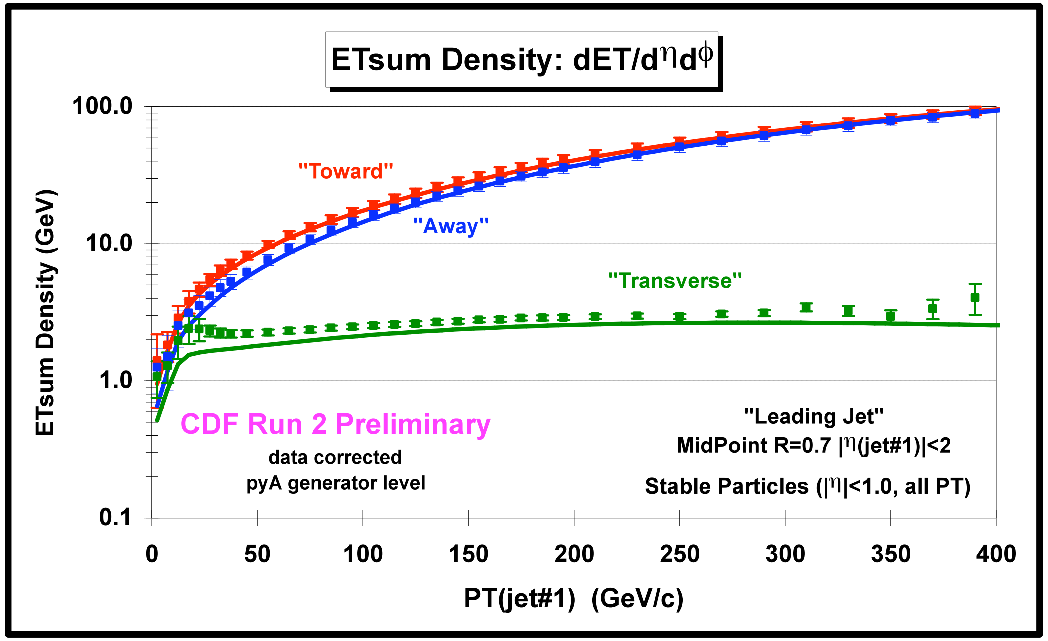
As D increases the required non-perturbative corrections increase at low P_T

Underlying Event Studies



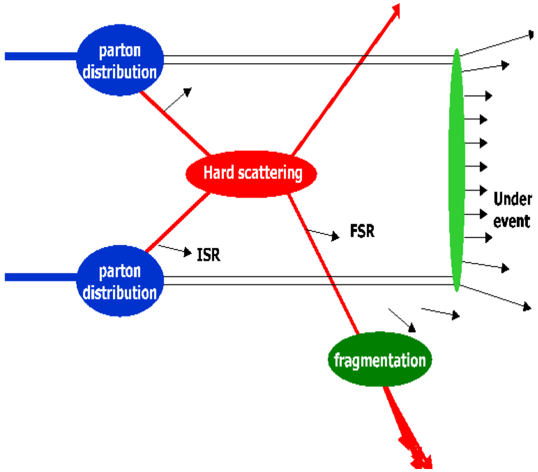
$p_T^{track} > 0.5\,\text{GeV}, \quad |\eta^{track}| < 1$

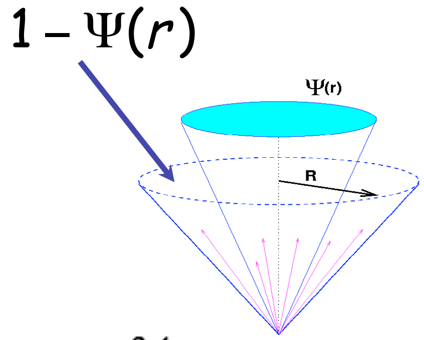
transverse region sensitive to soft underlying event activity

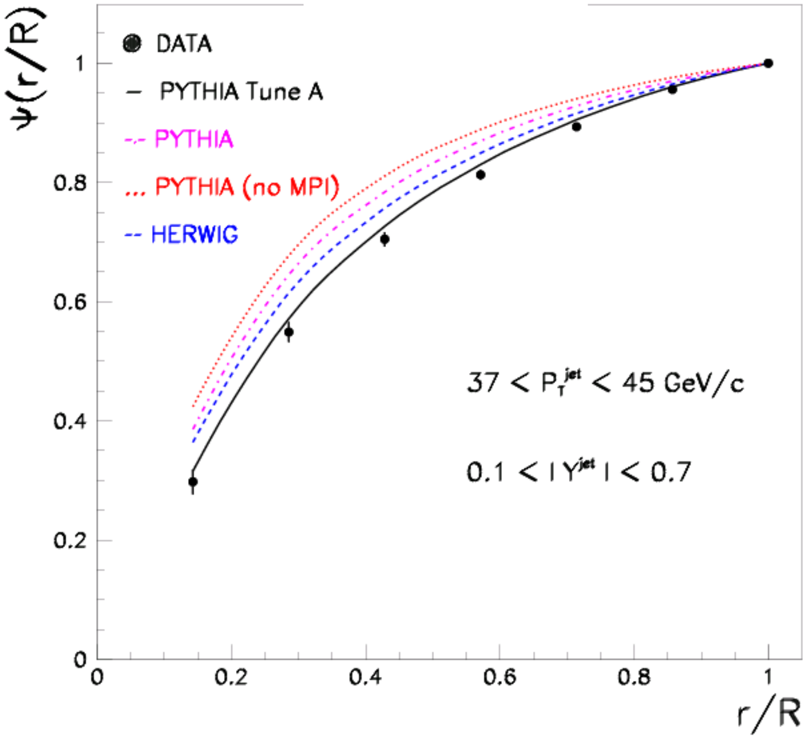


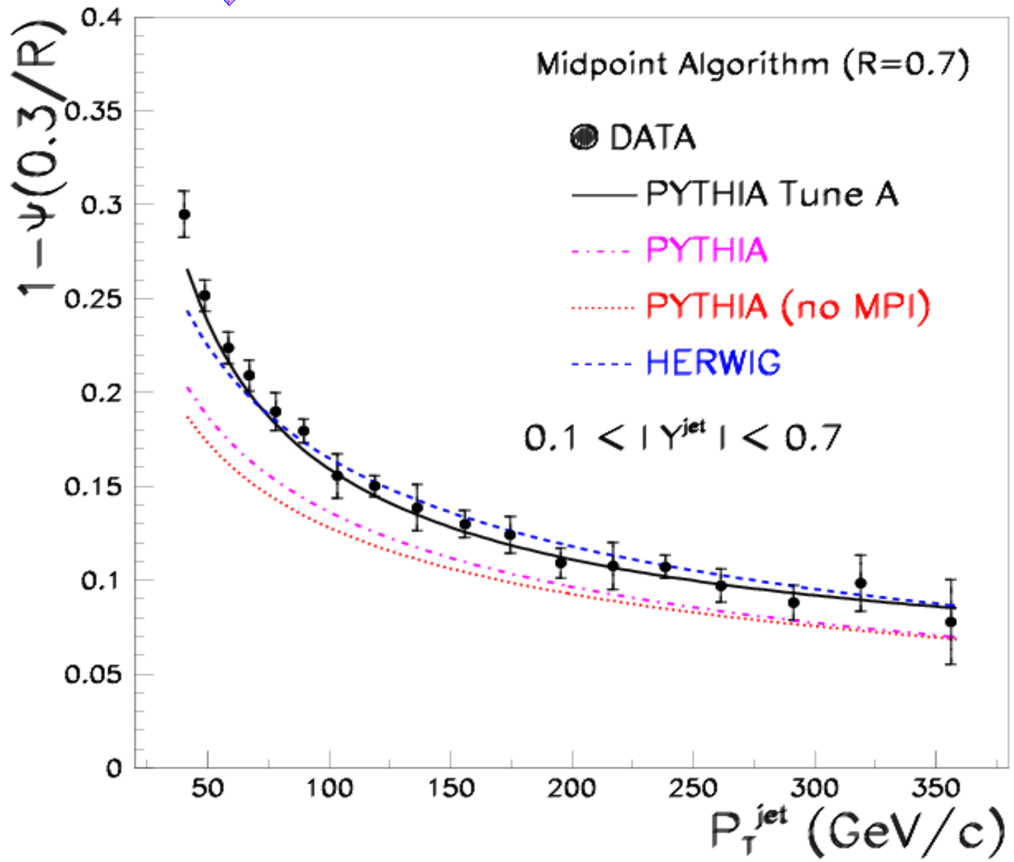
Good description of the underlying event by PYTHIA after tuning the amount of initial state radiation, MPI and selecting CTEQ5L PDFs (known as PYTHIA Tune A)

Jet shapes





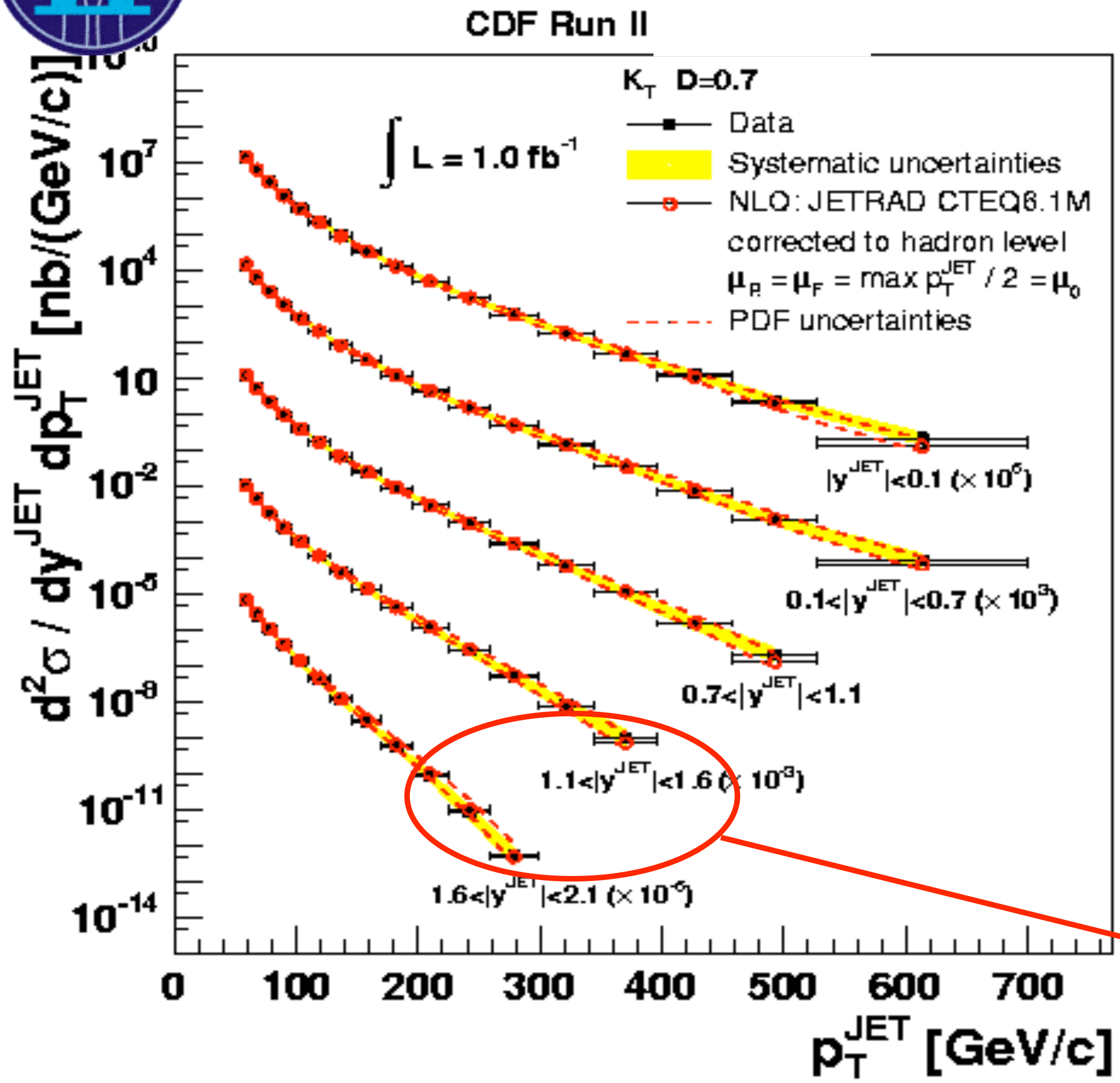


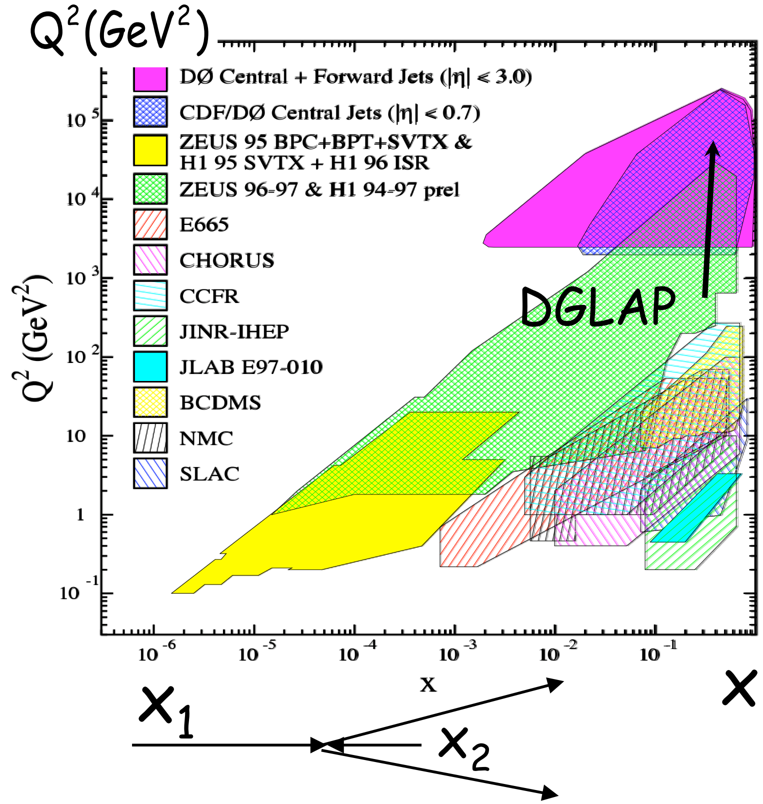


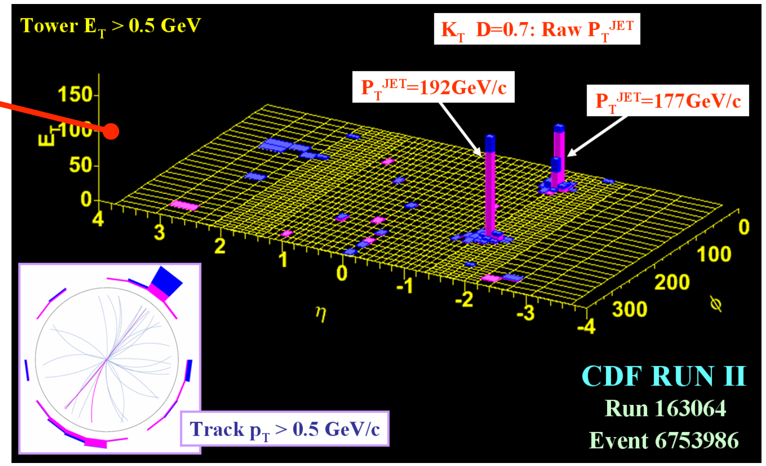
- PYTHIA Tune A describes the data (enhanced ISR + MPI tuning)
- PYTHIA default too narrow
- MPI are important at low Pt
- HERWIG too narrow at low Pt

We know how to model the UE at 2 TeV for QCD jet processes

Measurement in five $|y^{jet}|$ ranges

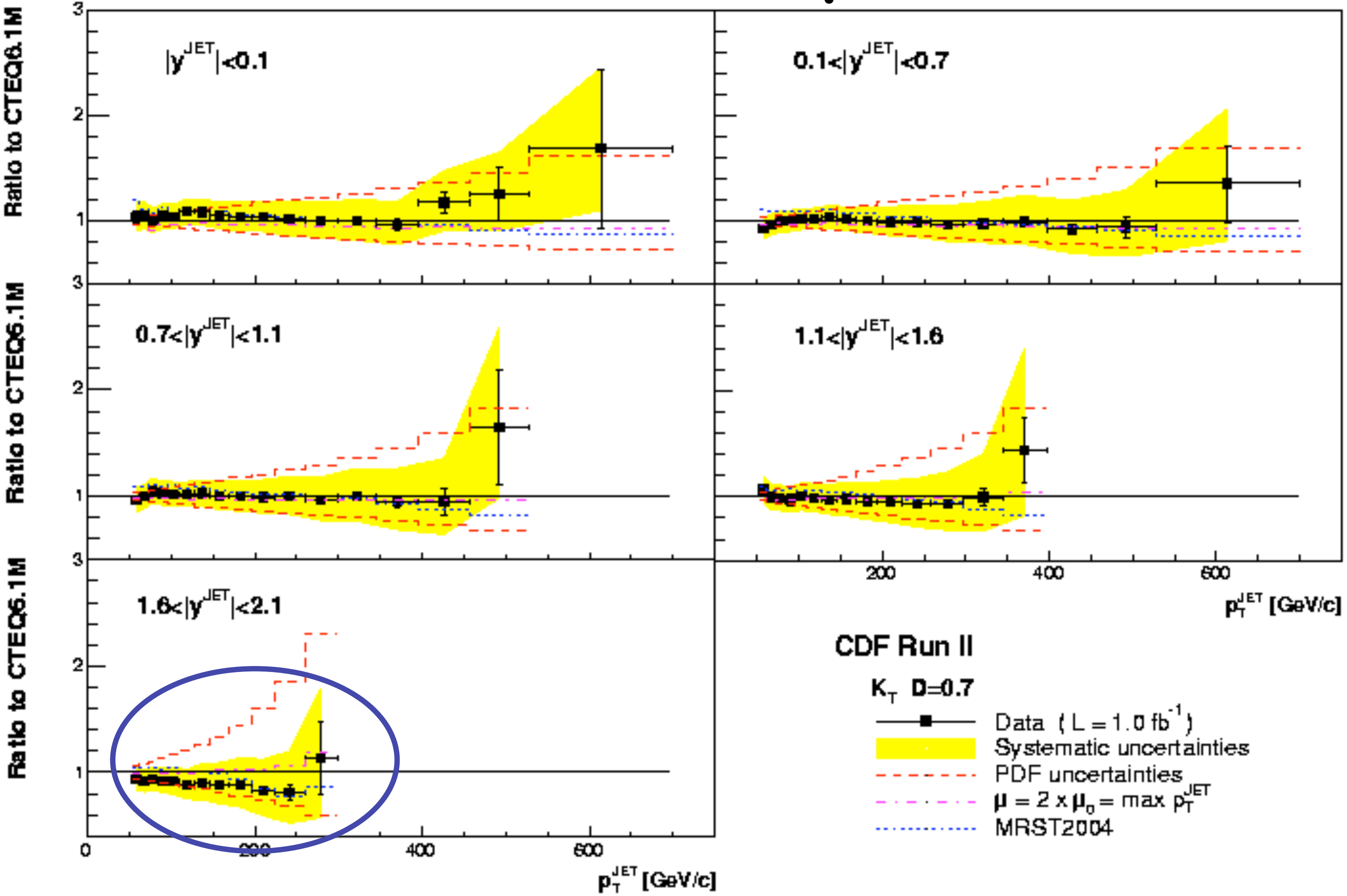






Forward jet measurements further constrain the gluon PDF in a region in P_T where no new physics is expected

Ratio Data/pQCD NLO



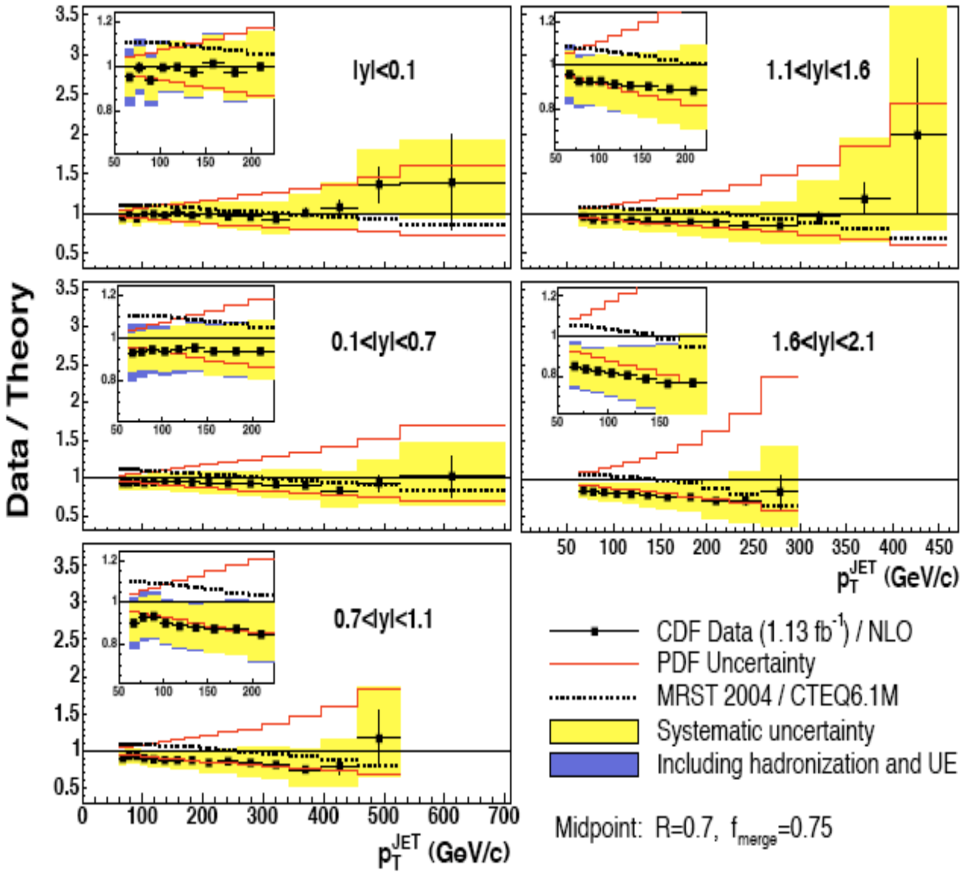
Data uncertainty smaller than that on pQCD NLO

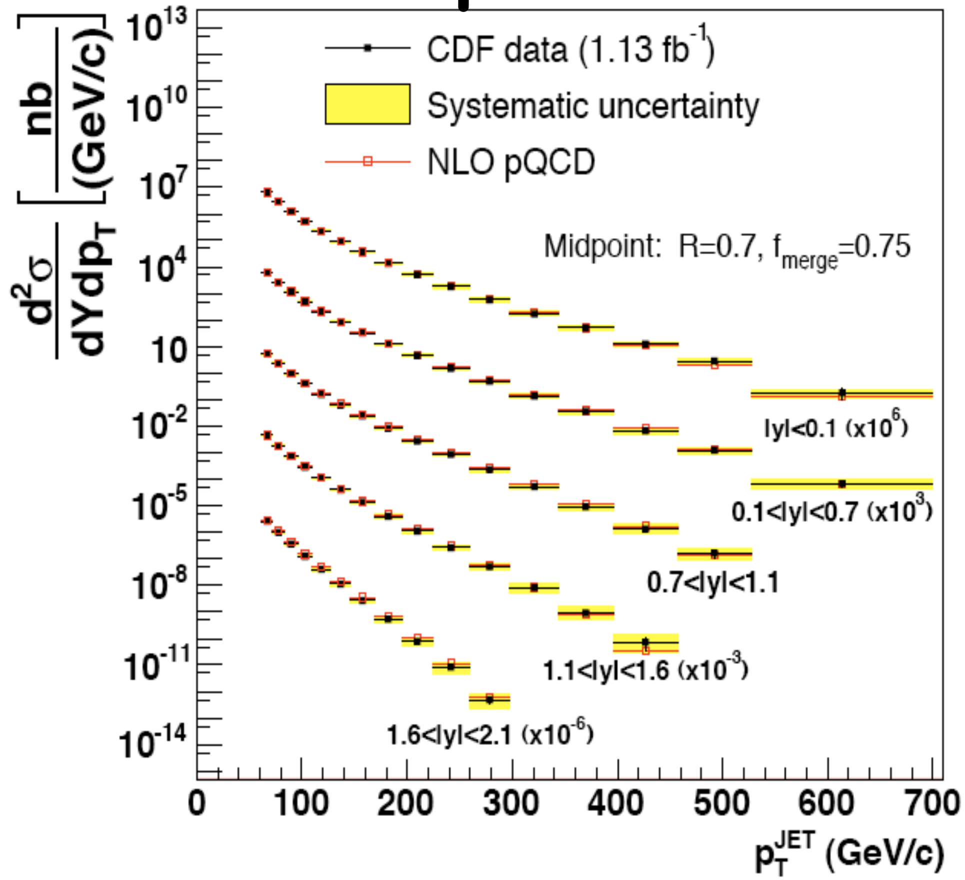
CDF contribution to a better knowledge of gluon PDF

Inclusive jets with midpoint

CDF performed a second parallel measurement using a cone-based Midpoint algorithm with R = 0.7

In same bins in P_T^{jet} and Y^{jet}

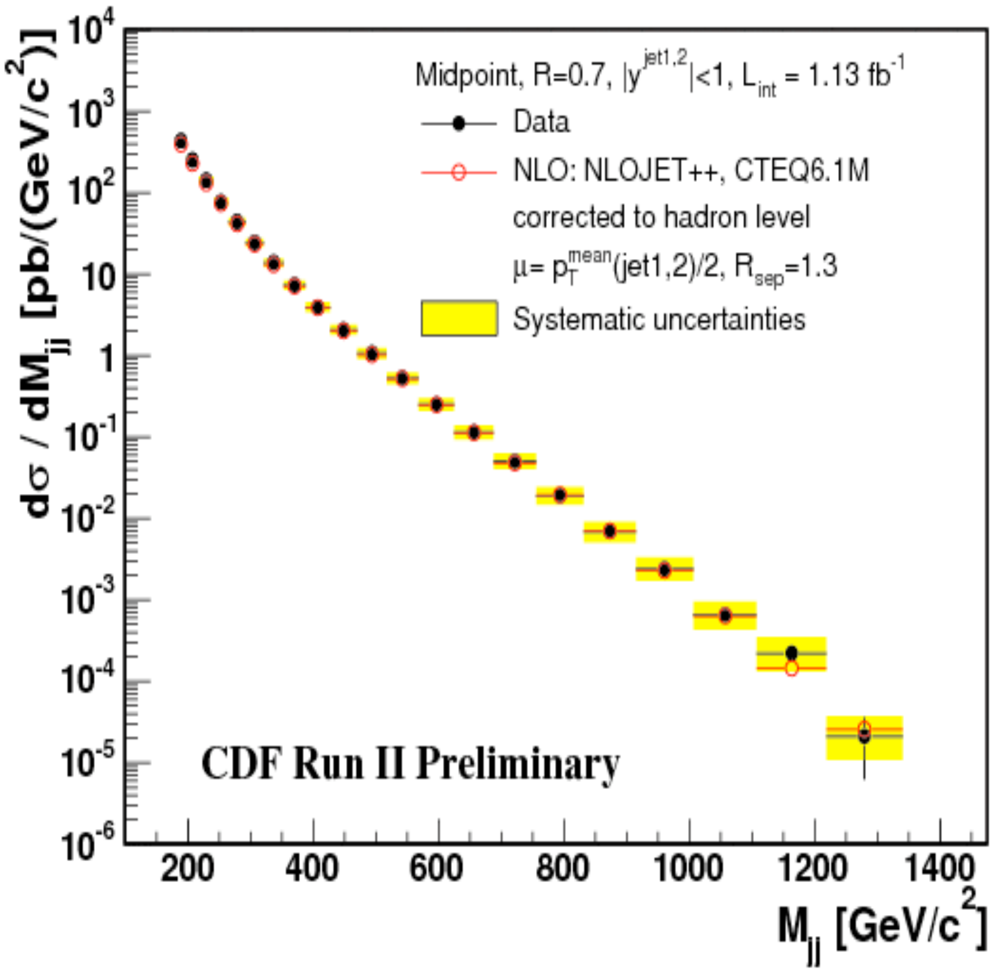


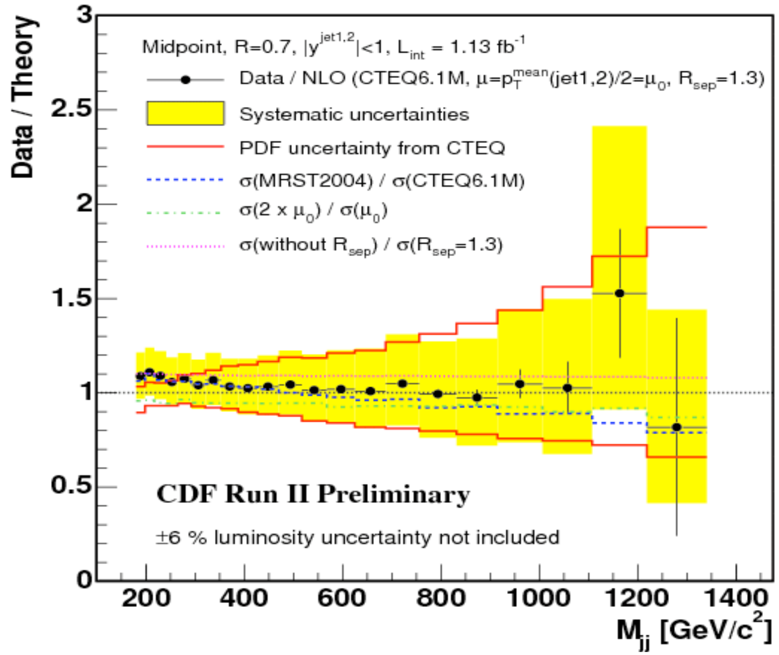


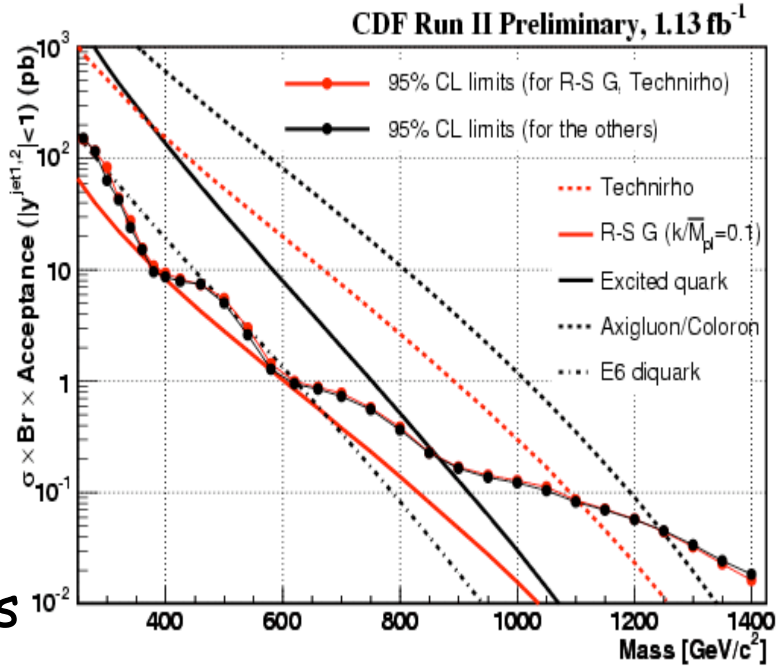
Agreement with NLO pQCD predictions….

MC study indicates that SISCone would give same conclusion

Dijet Mass







Dijet Mass distribution in good agreement with NLO pQCD predictions

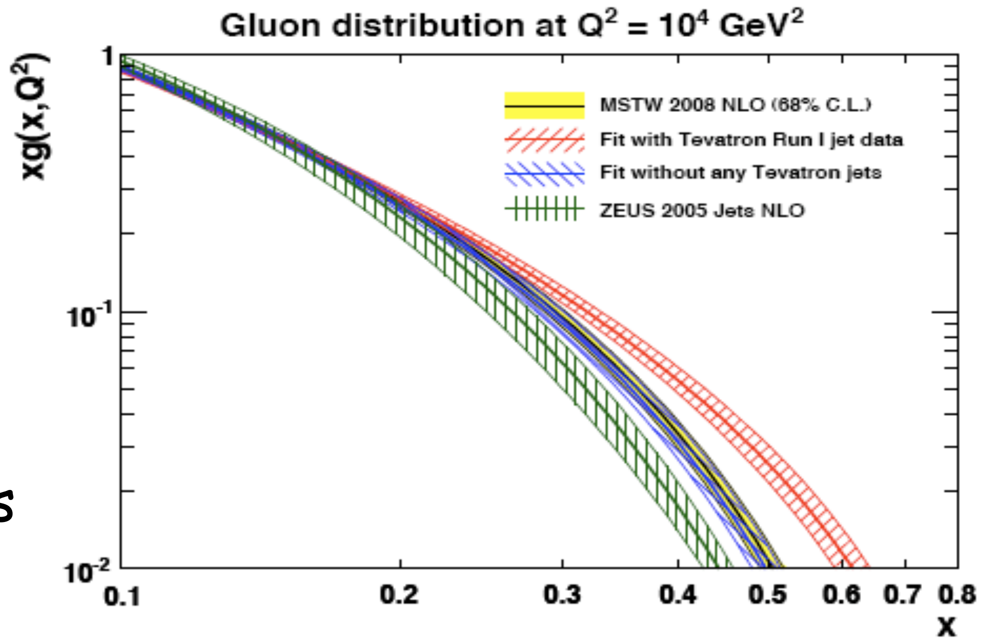
→ Limits on new particles decaying into jets

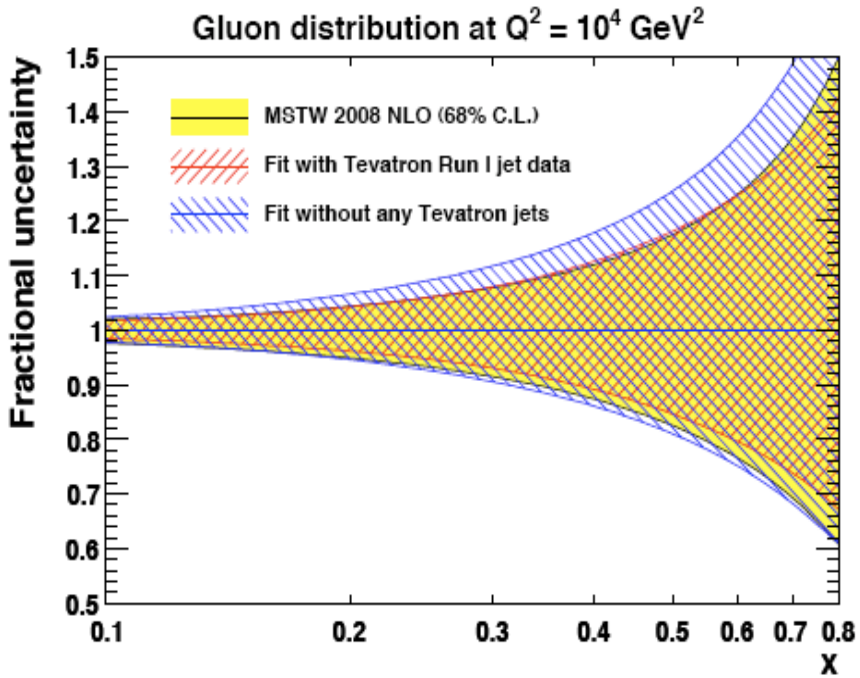
New Gluon (MSTW08) (hep-ph:09010002)

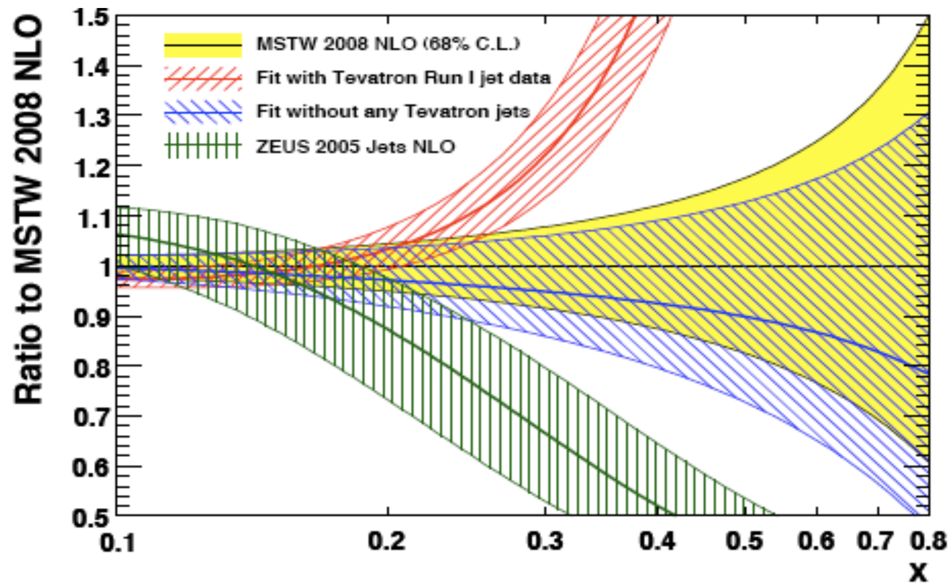
New MSTW analysis:

- Using CDF K_T and D0 Midpoint
- CDF and D0 data consistent

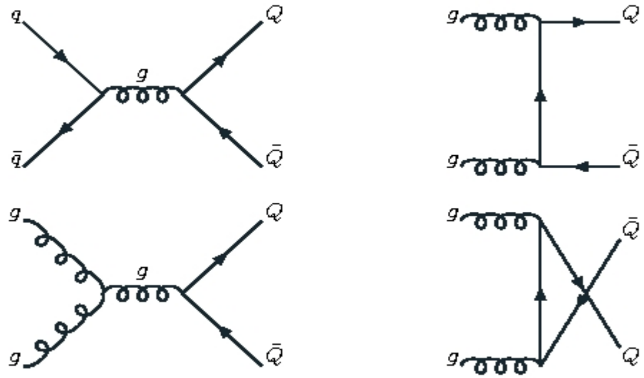
- Data dictate less gluons at high-x
- Reduced gluon PDF uncertainty
- already input to H → WW analysis

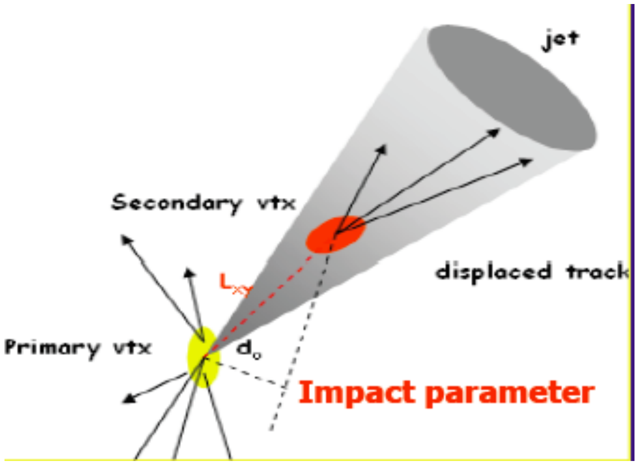






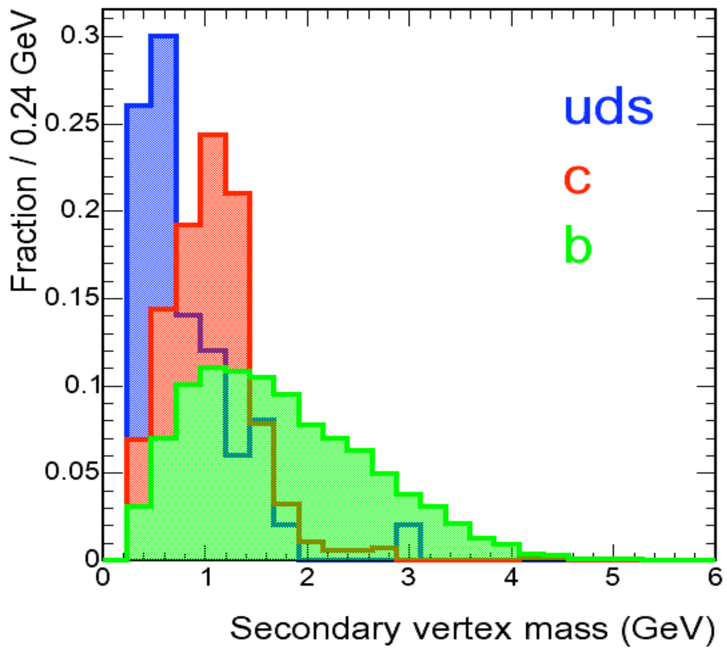
Dijet Production ($b\bar{b}$)

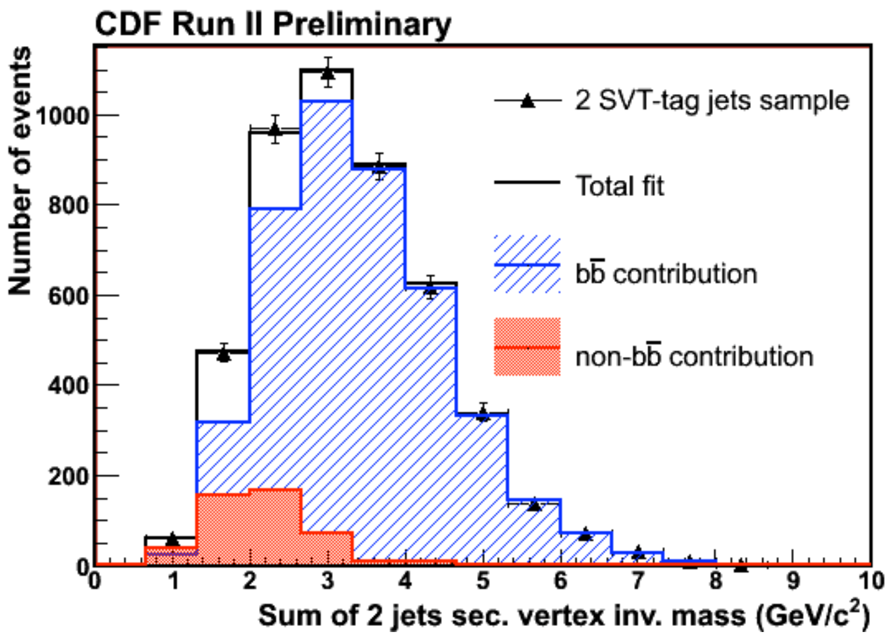




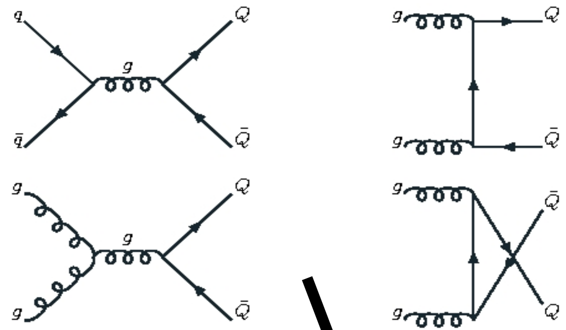
2 jets with $E_T^{jet} >$ 35 (32) GeV and $|\eta^{jet}| < 1.2$
Identified secondary decay vertex (b-tagged)

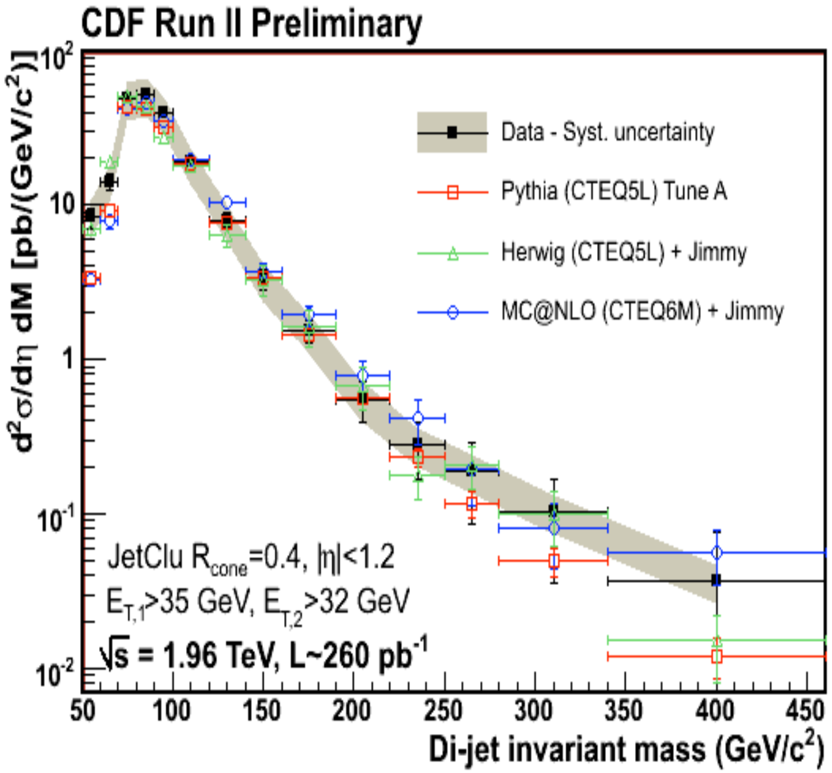
Secondary vertex mass used to separate bottom from (uds + c) contributions

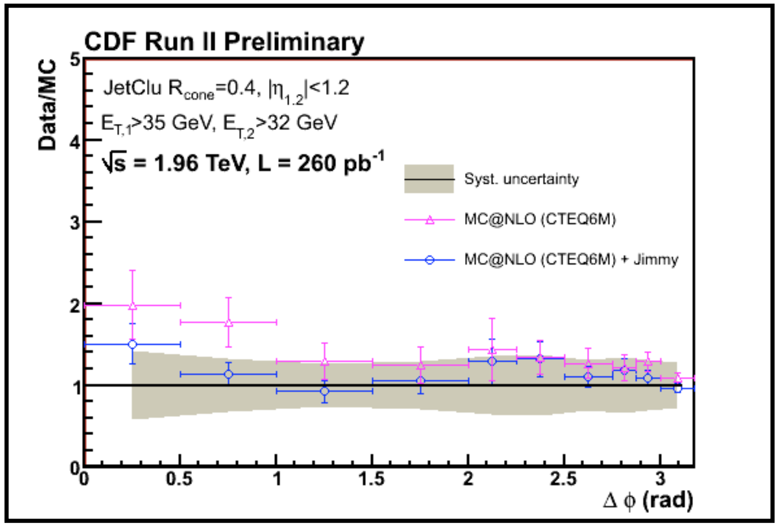


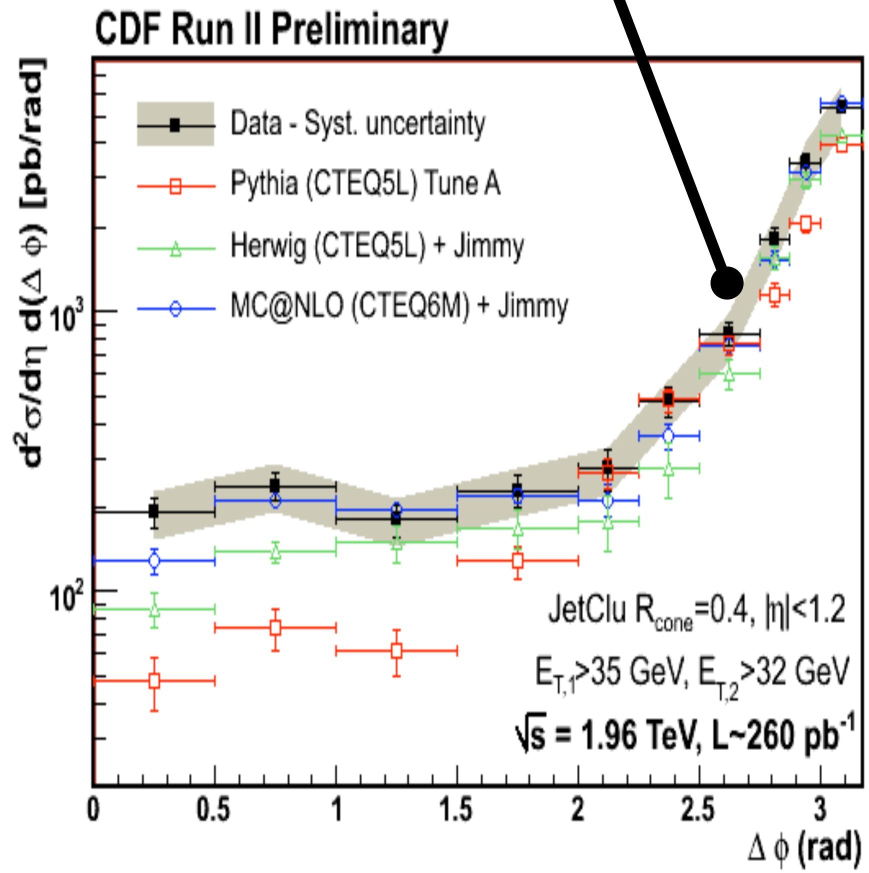


Dijet Production ($b\bar{b}$)

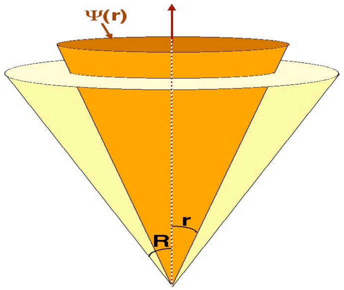








NLO prediction closest to the data
(once again one needs UE contribution to
bring NLO predictions to the data)



Inclusive B-jet Shapes

Study of B-jet shapes for (300 pb^{-1})

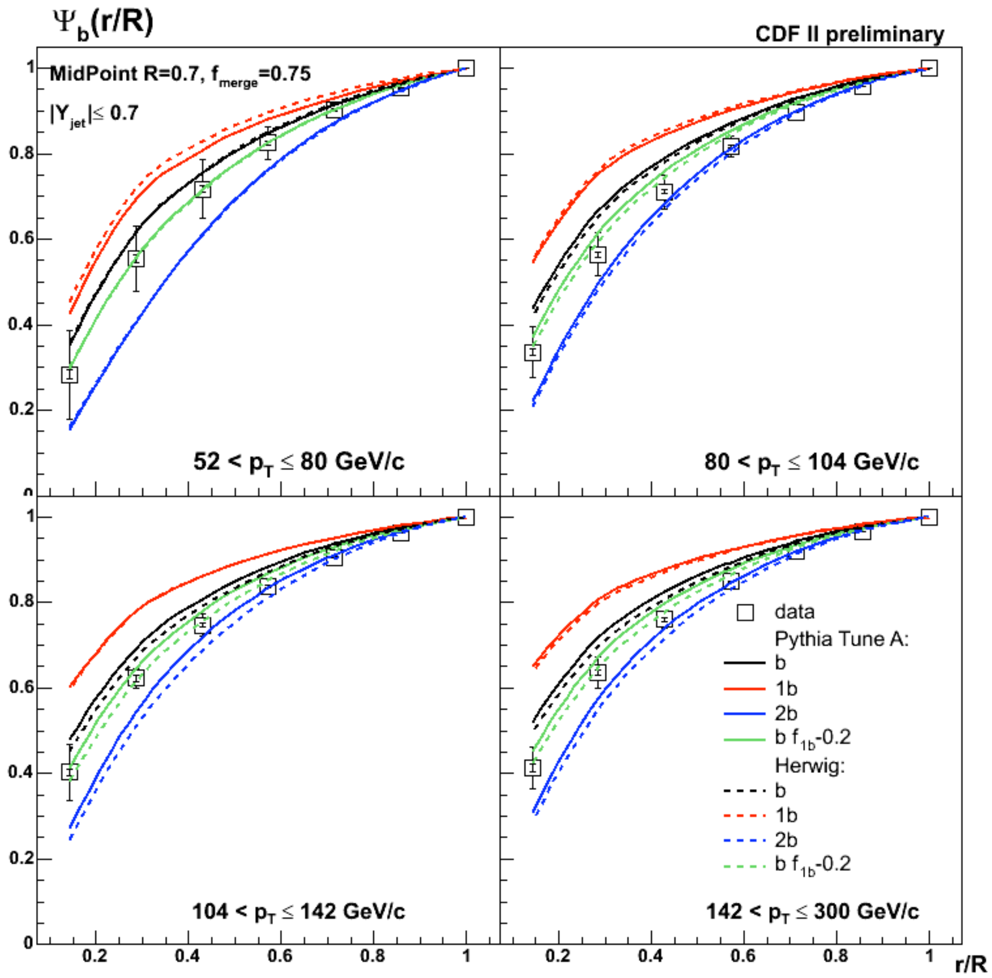
P_T^{jet}> 52 GeV/c , $|Y^{jet}|$ < 0.7

- It contains contributions from g→bb processes identified as one jet

- PYTHIA and HERWIG inclusive b-jets slightly narrower than the data

- Observable sensitive to the fraction of gluon→ bb inside the jet…

→caution: does not mean you can simply determine g→ bb fraction from here.. (one can also tune UE, parton-shower..)



… more precise data in the B-jet sector will definitively help us at the LHC…

Final Notes

- Jet measurements in Run II contributed to a better understanding of the gluon PDF
  → less gluons now preferred at large X
  → already included in H→WW results
  → will decrease all large-X gluon driven cross sections (Tevatron and LHC..)

- Modeling of UE contributions essential

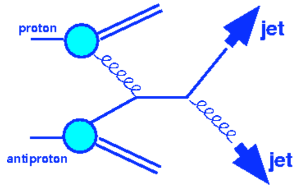
- Dijet Production studies lead to new limits on quark compositeness and Eds

- New B-jet studies using full CDF sample would be very important for the future…

"Just checking."

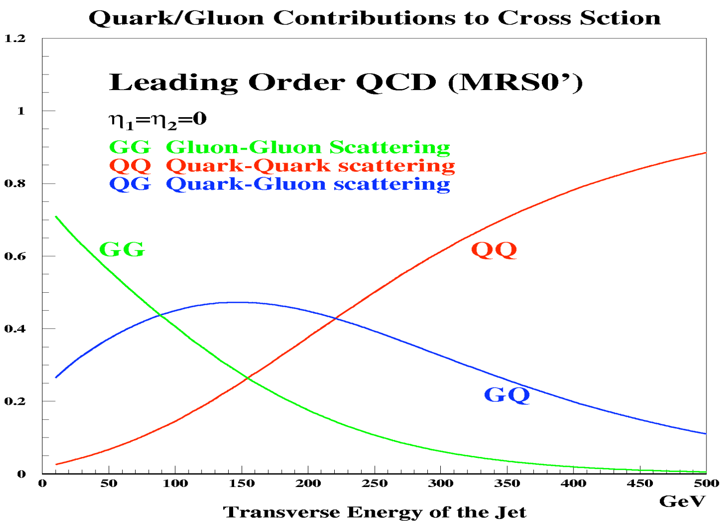
- Tevatron promises 8 fb^{-1} by end 2009
- First LHC physics data by this Fall

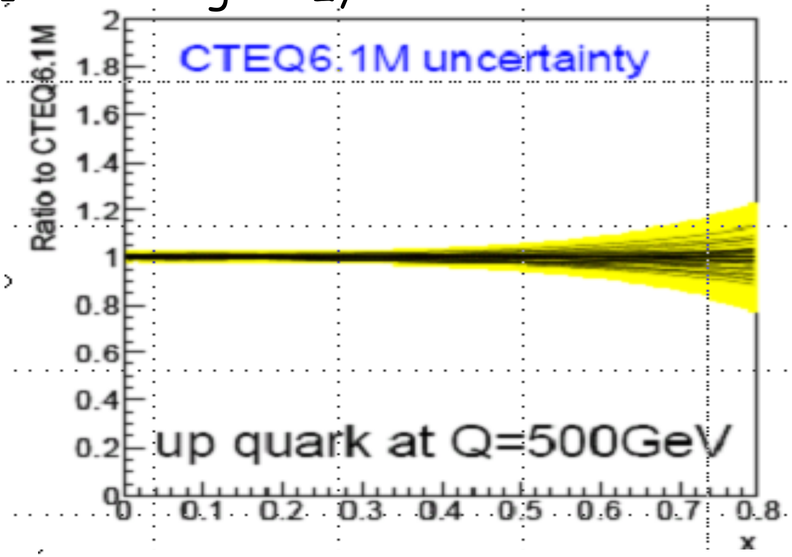
Backup Slides

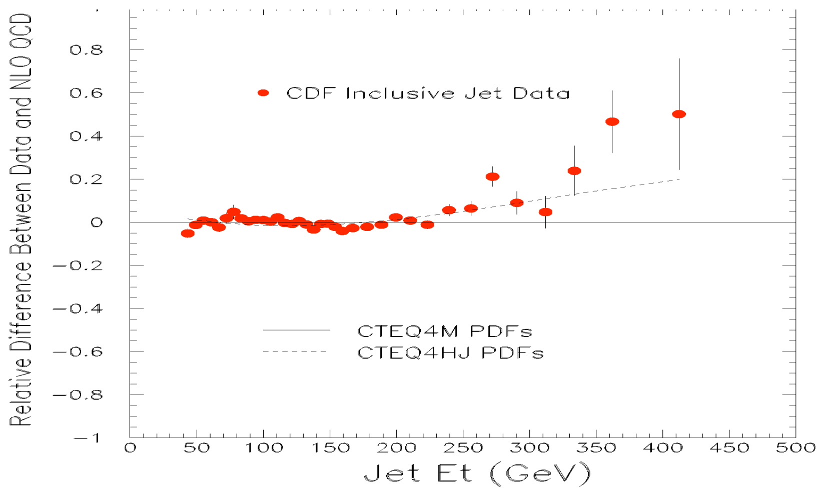


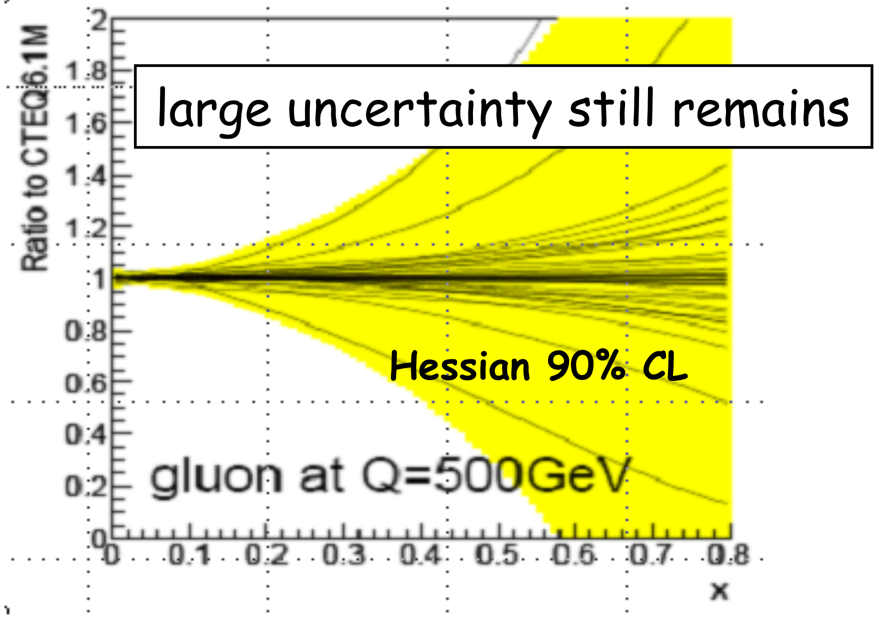
gluon PDFs at high-x

$$\sigma^{total} = \sum \int dx_1 dx_2 f_q(x_1, Q^2) f_g(x_2, Q^2) \sigma^{parton}$$









Important GG and GQ contrib. at high-E_T

...room for SM explanation....

Inclusive K_T Algorithm

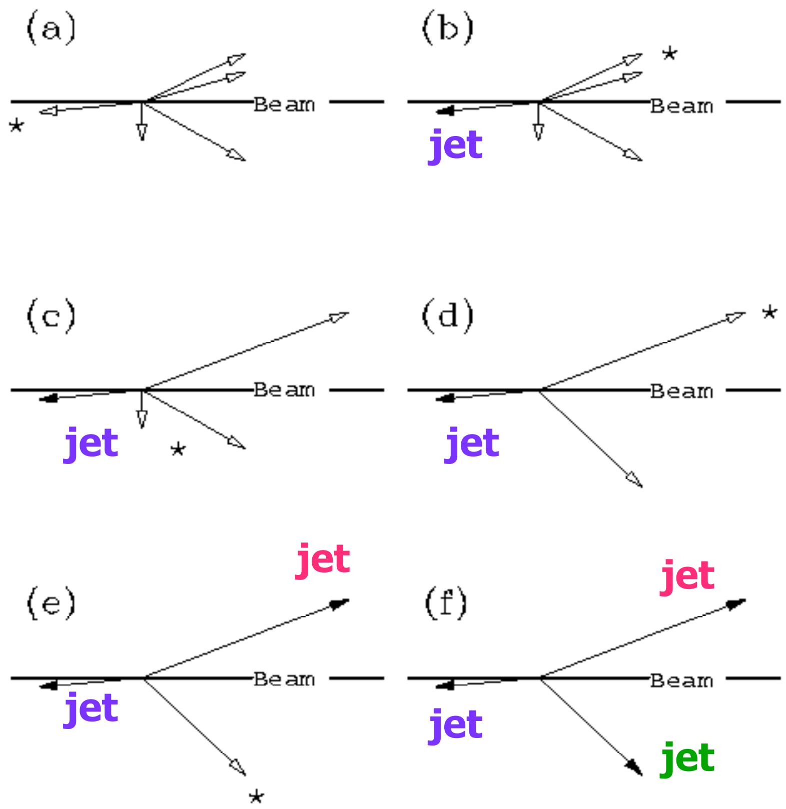
1. Compute for each pair (i,j) and for each particle (i) the quantities:

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

$$d_i = (P_{T,i})^2$$

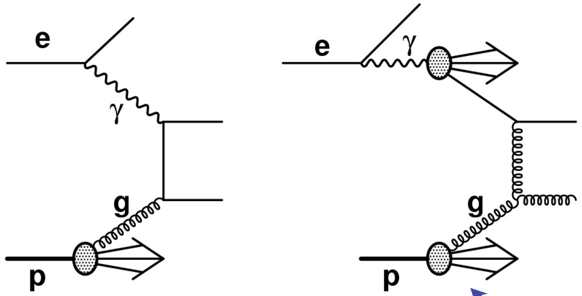
2. Starting from smallest {d_ij ,d_i}:
3. If it is a d_i then it is called a jet and is removed from the list
4. If it is a d_ij the particles are combined in "proto-jets" (E scheme)
5. Iterate until all particles are in jets

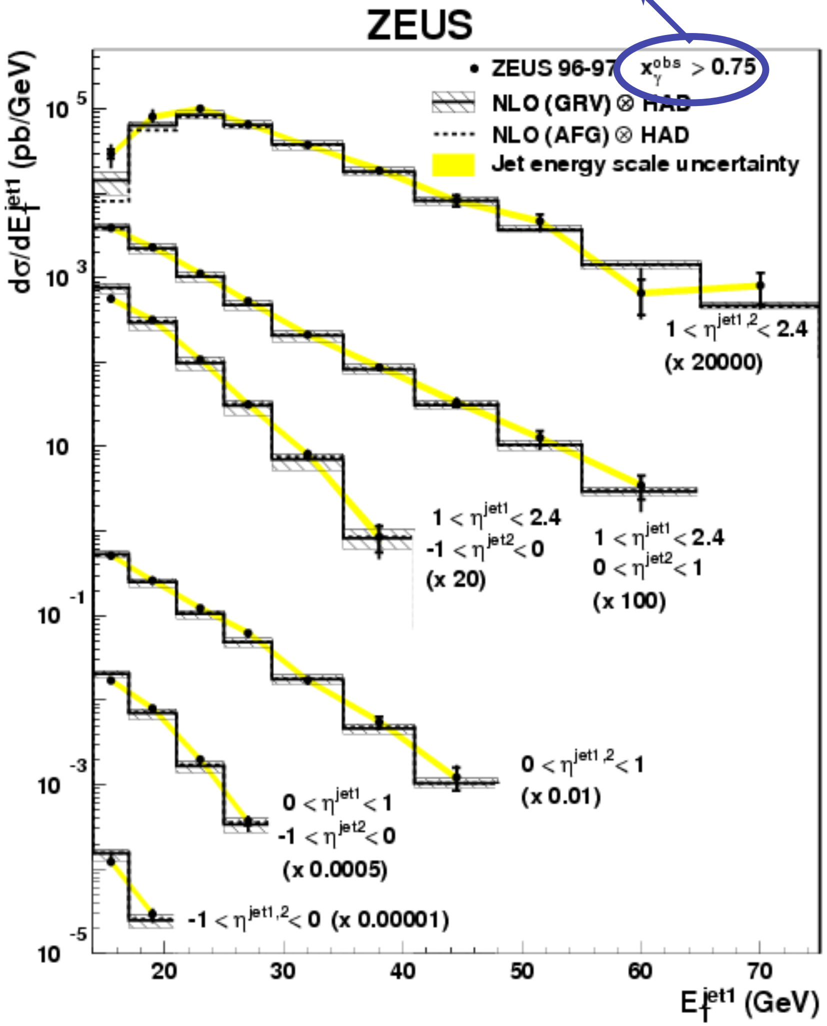
Separation in transverse momentum…
Inspired by pQCD gluon emissions.



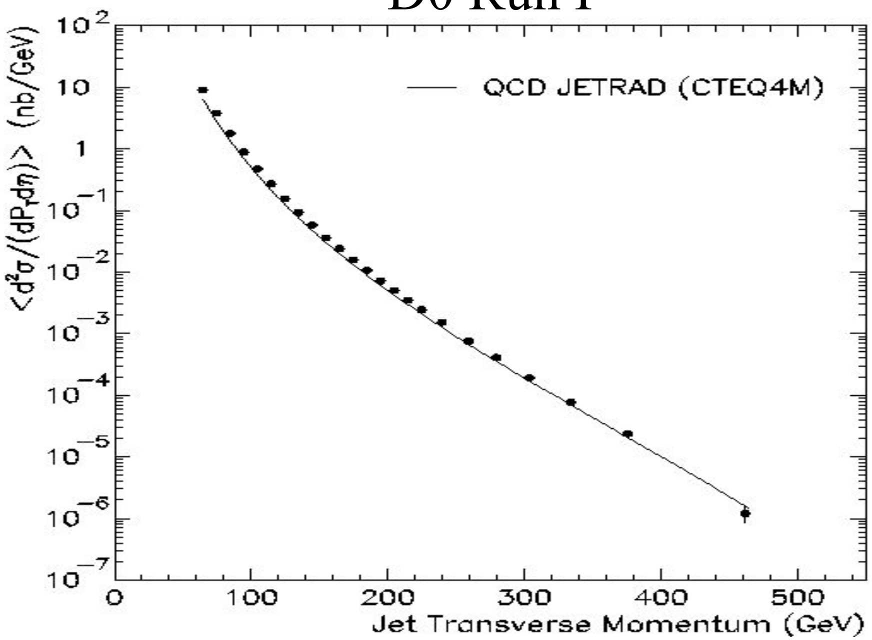
☺ No merging/splitting needed! Infrared and Collinear safe to all orders in pQCD!

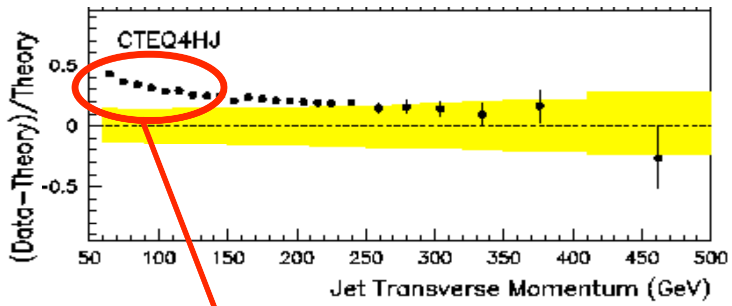
Results from ZEUS / D0 Run I





D0 Run I

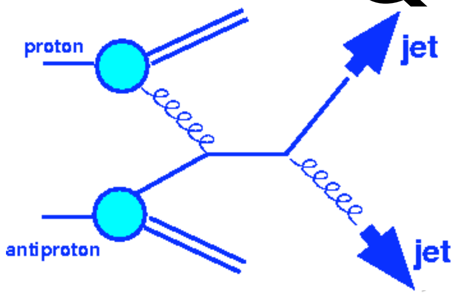


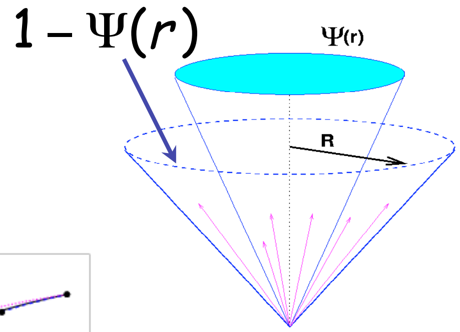


Disagreement at low p_T

↳ Suggests Underlying Event not properly accounted for

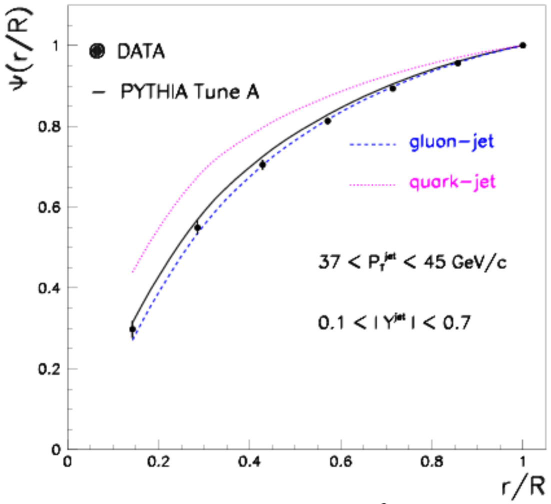
Quark and Gluon Jets

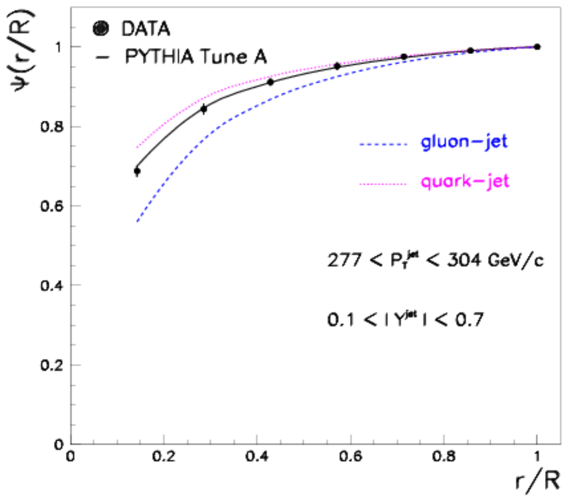


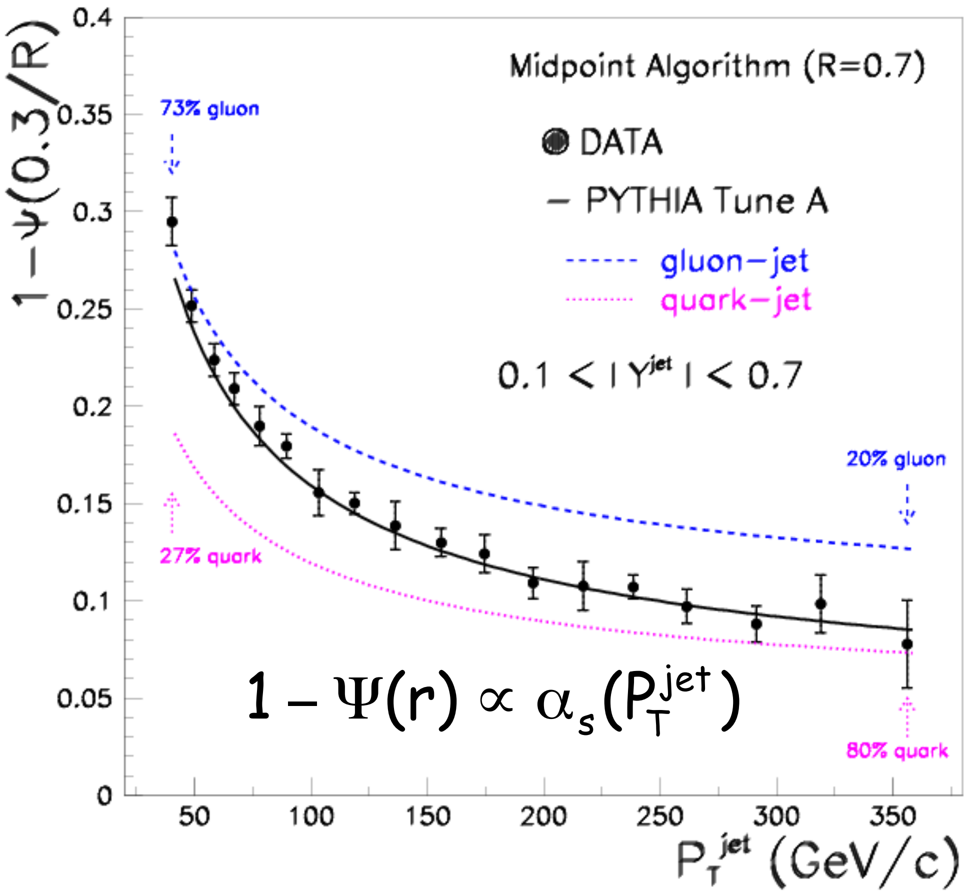


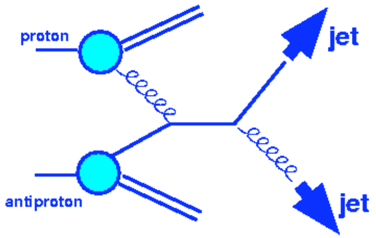
Jet narrows as Pt increases

- gluon/quark mixture
- running coupling



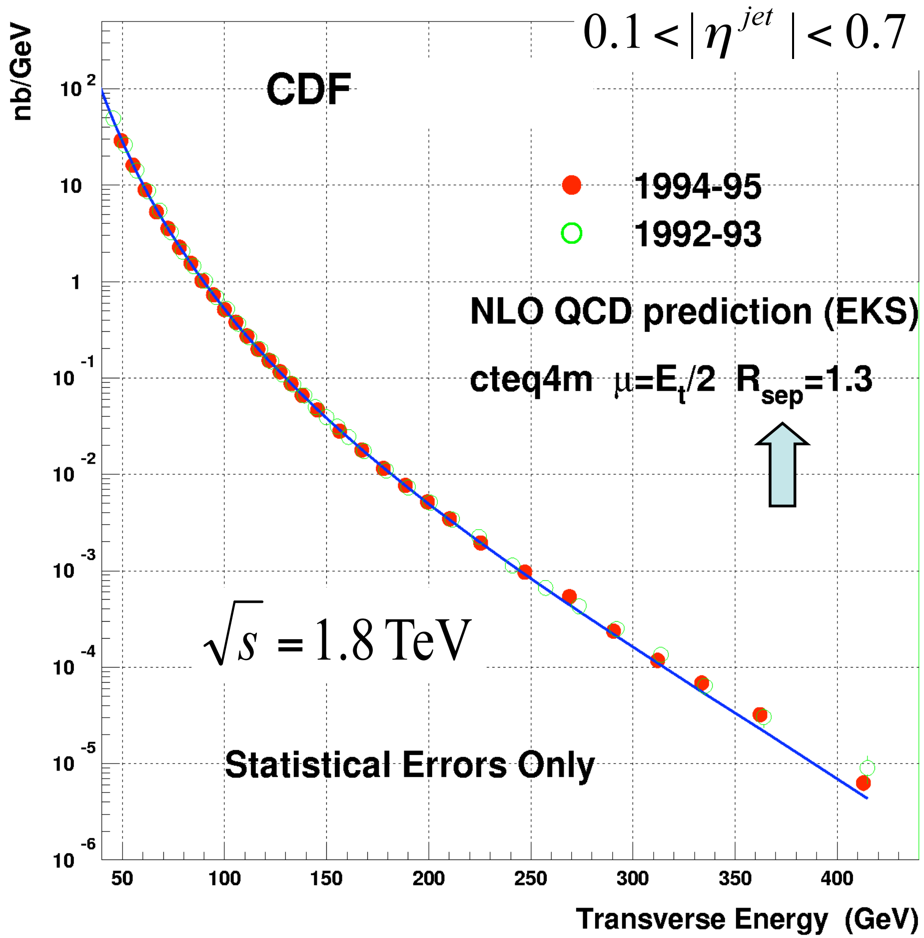


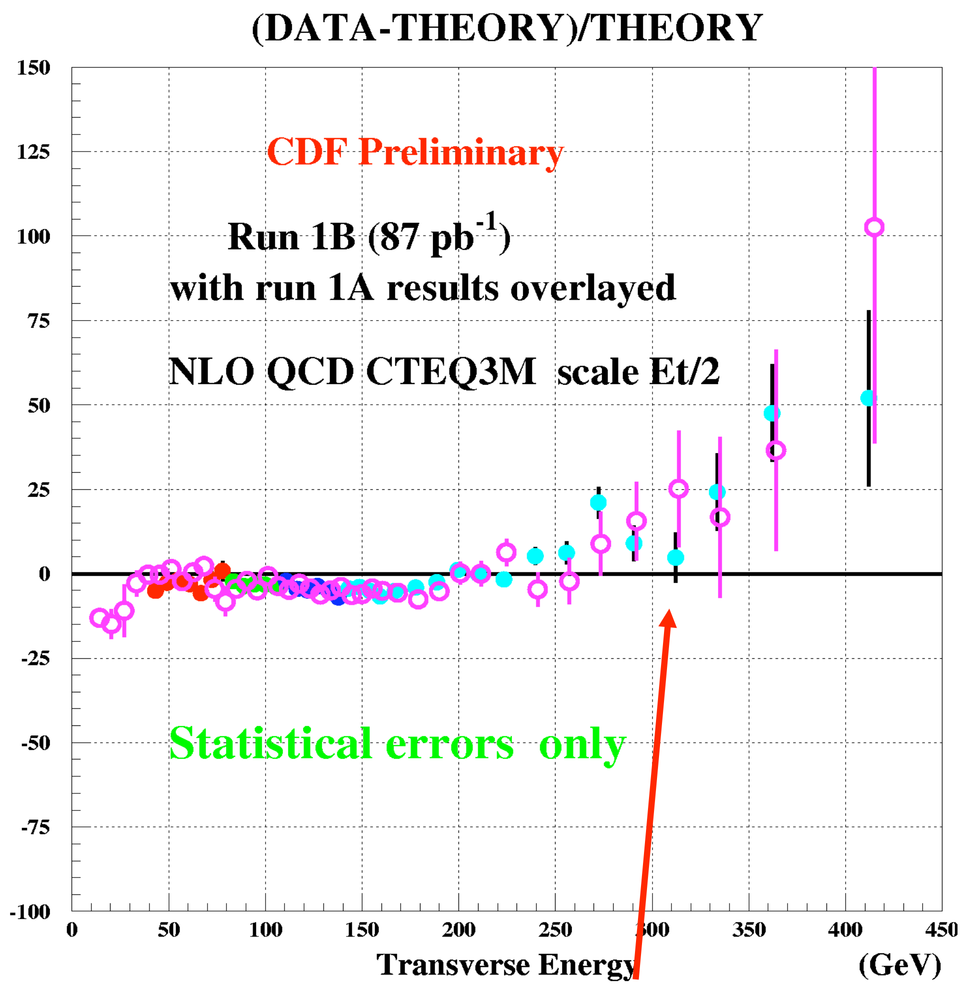




Run I $\frac{d\sigma}{dE_T^{JET}}$ Results

Inclusive Jet cross section



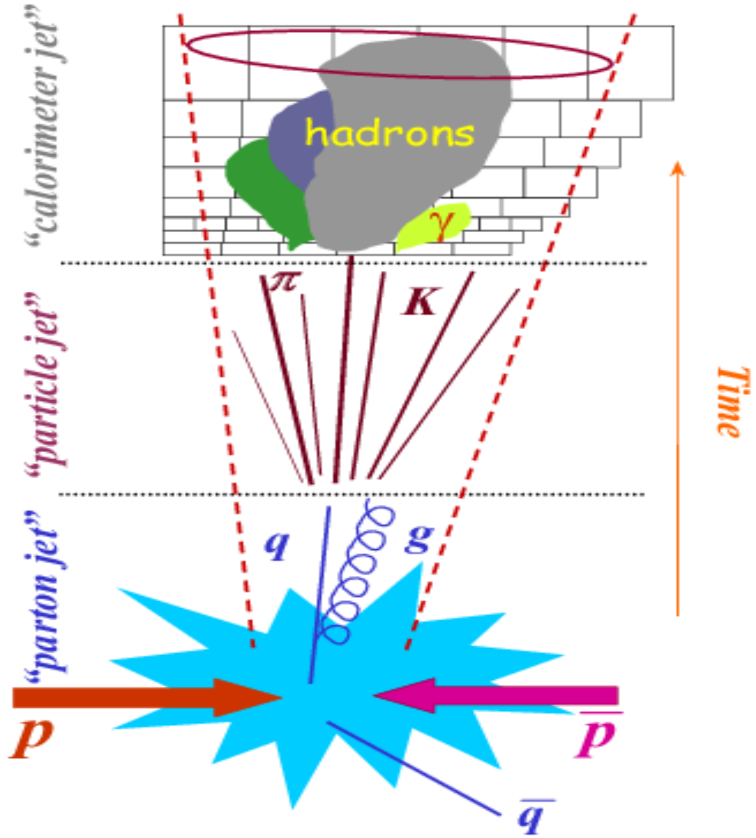


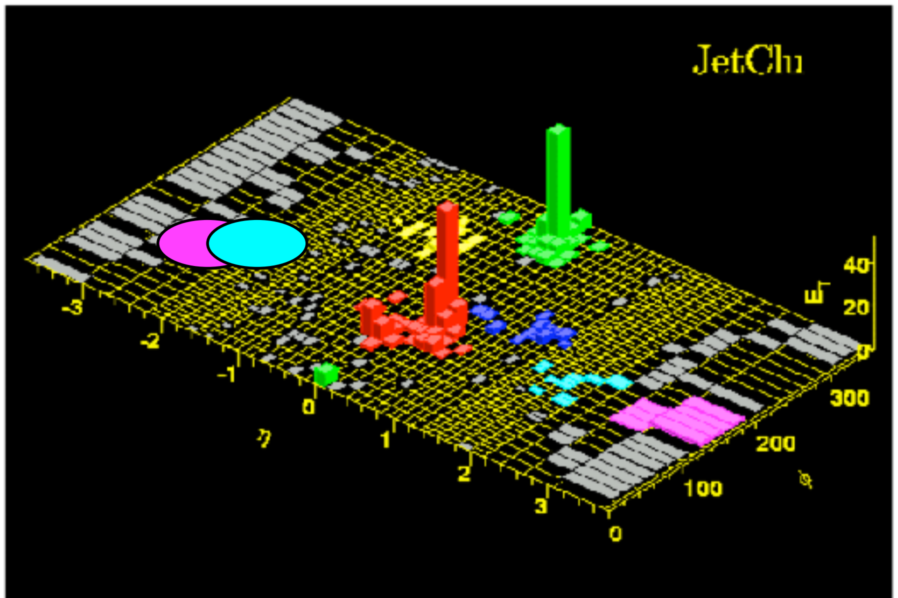
Run I data compared to pQCD NLO

Now absorbed in gluon PDFs !

Motivation for the K_T algorithm

- Run I cone-based algorithms is not infrared/collinear safe → Midpoint
- Cone-based jet algorithms include an "experimental" prescription to resolve situations with overlapping cones
- This is emulated in pQCD theoretical calculations by an arbitrary increase of the cone size : R → R' = R * 1.3 ☹





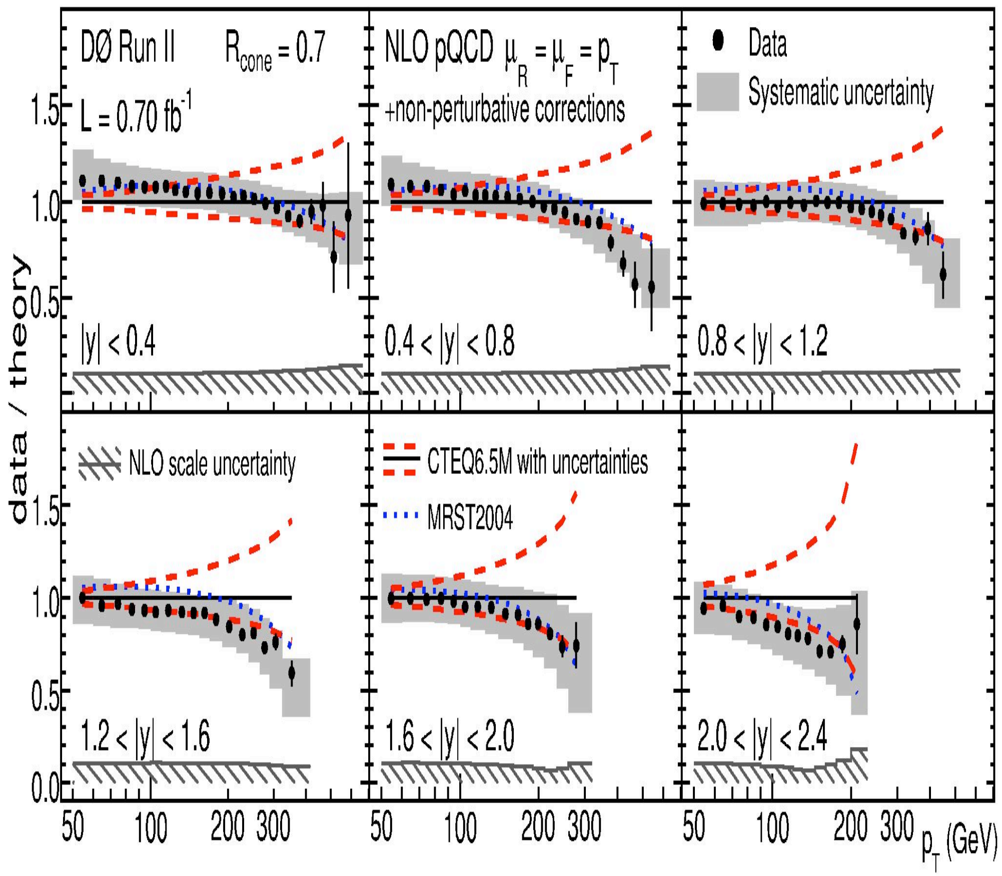
Nature (QCD ?) prefers to separate partons into jets according to their relative transverse momentum

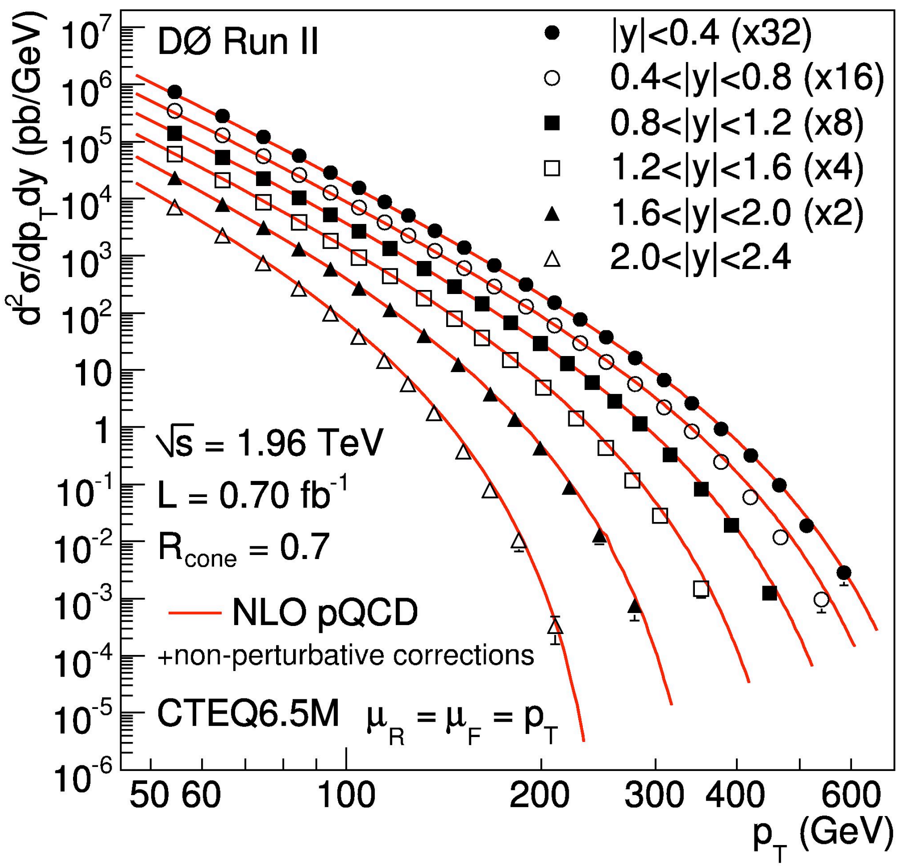
⇩

K_T algorithm preferred by theory

Latest D0 Jet Results

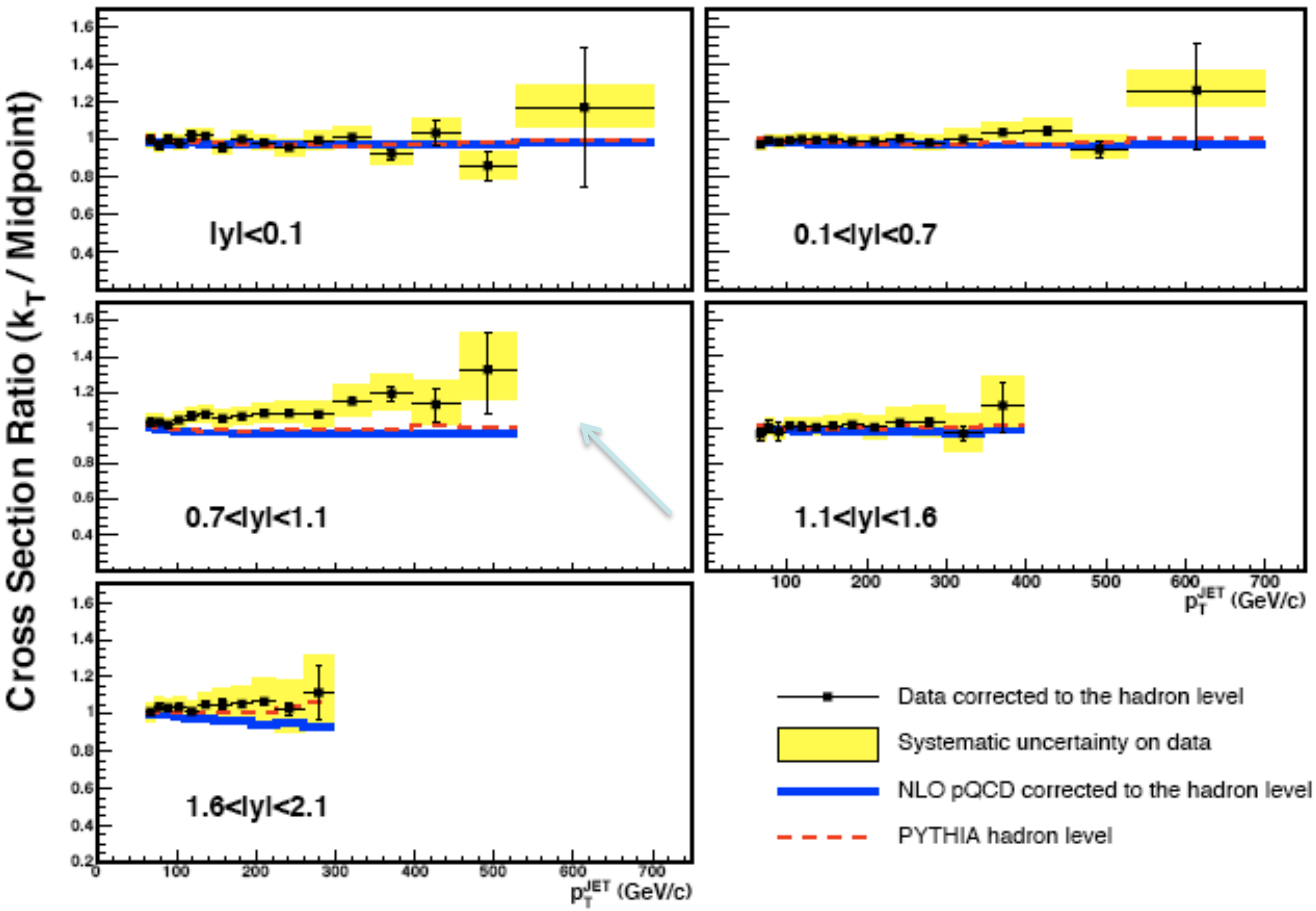
Using cone-based Midpoint Algorithm (R=0.7)





Similar conclusions using the midpoint algorithm ....and reduced systematic uncertainties on the absolute jet energy scale (1.2% - 2%)

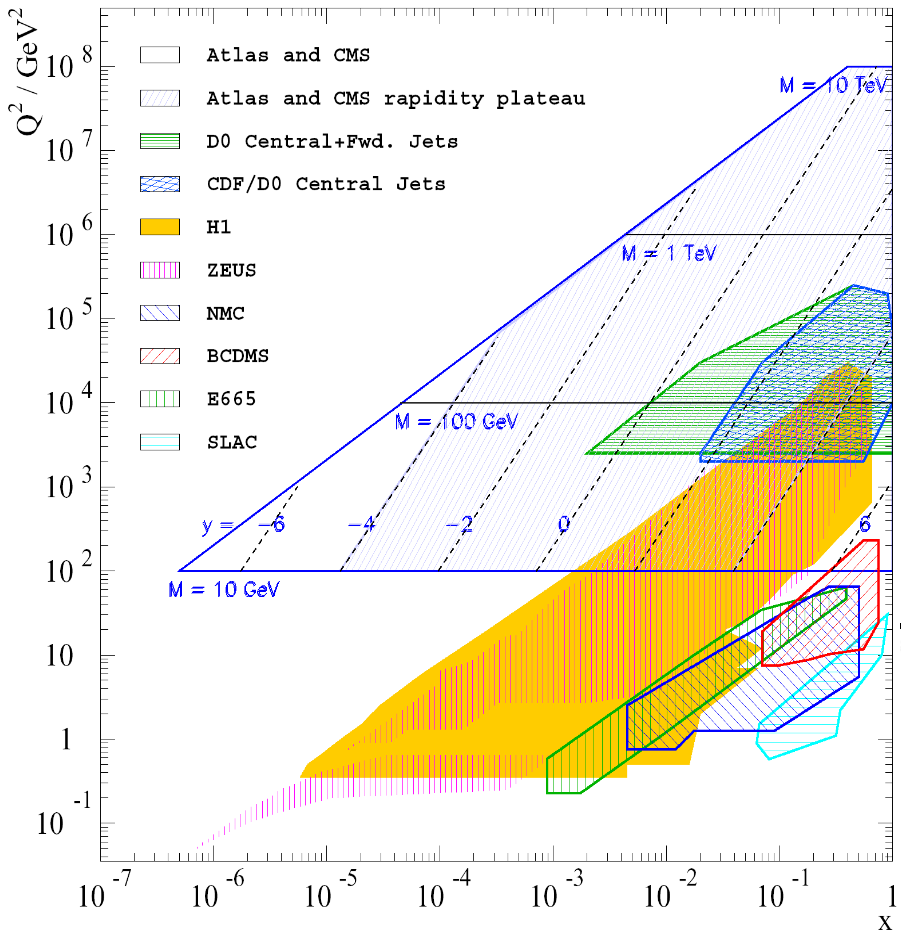
CDF K_T vs Midpoint

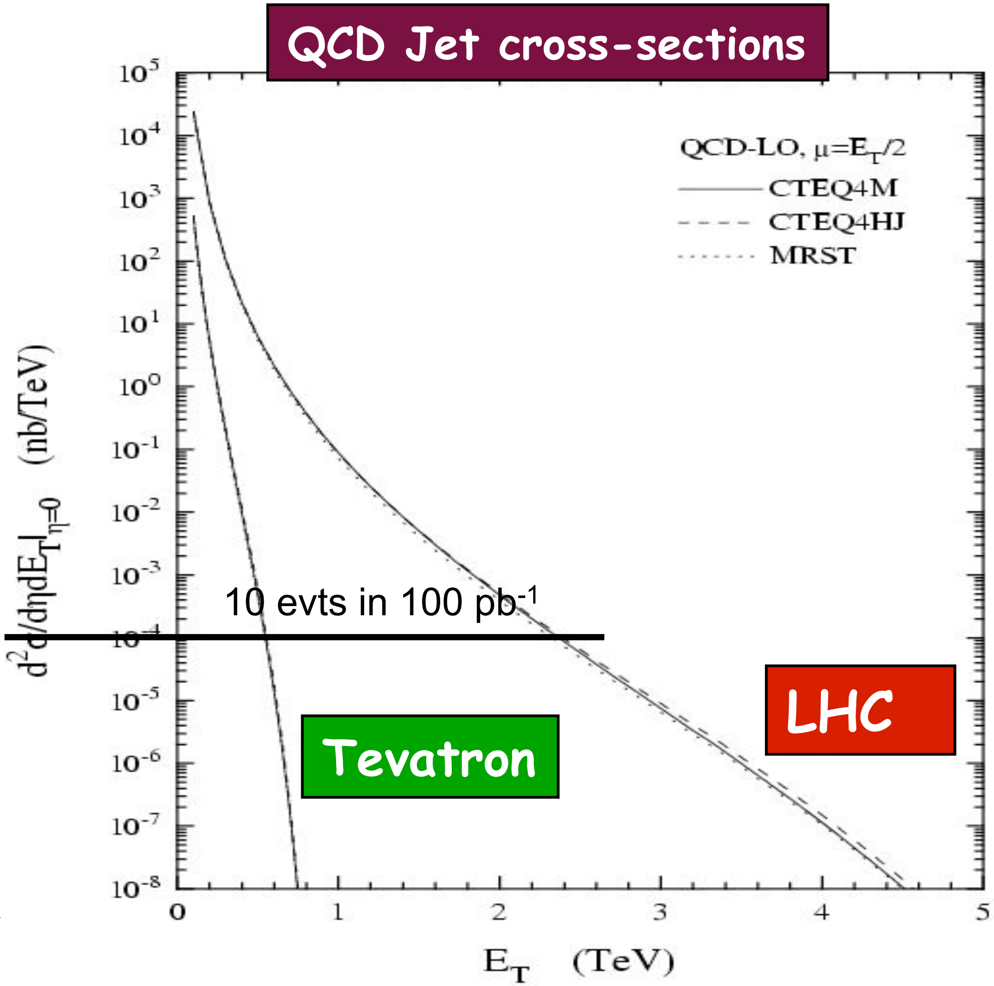


90% overlap between samples… careful study of correlations in systematics

→ Broadly consistent (Some tension with K_t results in $0.7 < |y^{jet}| < 1.1$)

Jets at LHC

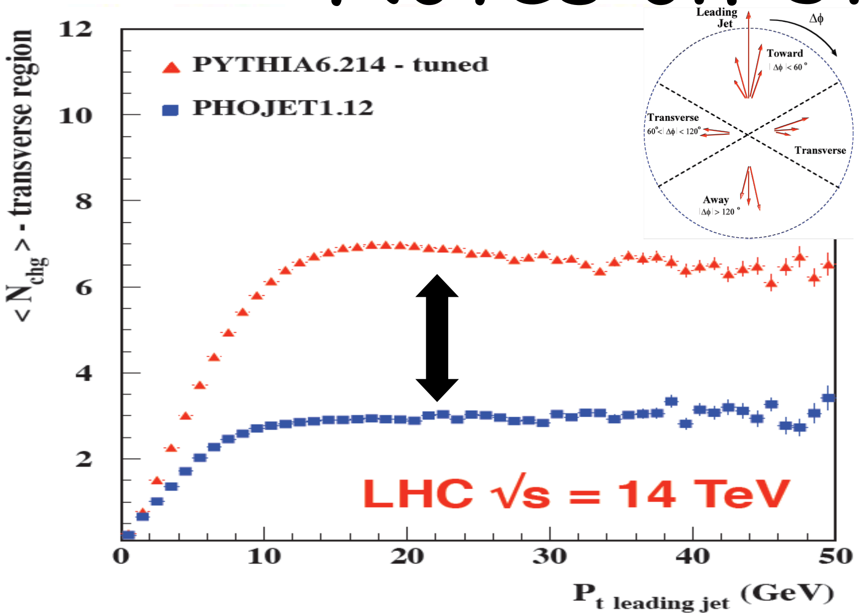


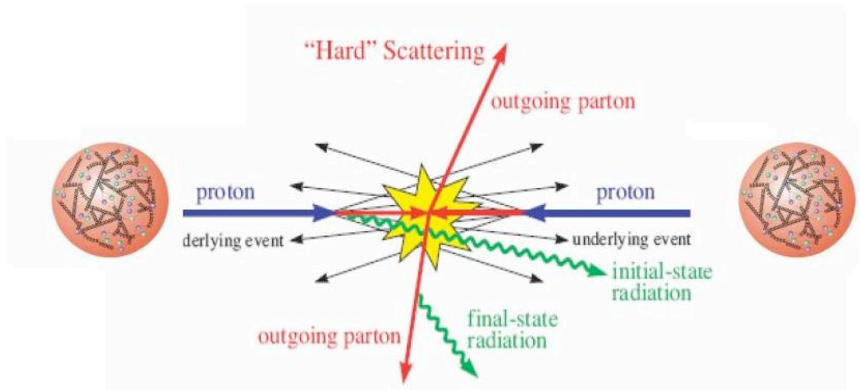


It is clear that LHC will explore 2-3 TeV jets rather soon…

(~5-10% (?) uncertainty on jet energy scale expected on day 1…lots of work ahead of us)

Notes on Underlying Event





This is a clear unknown at LHC energies

- Dependence with physics process
- How "hard" will be ?