Inclusive Jet Production at CDF

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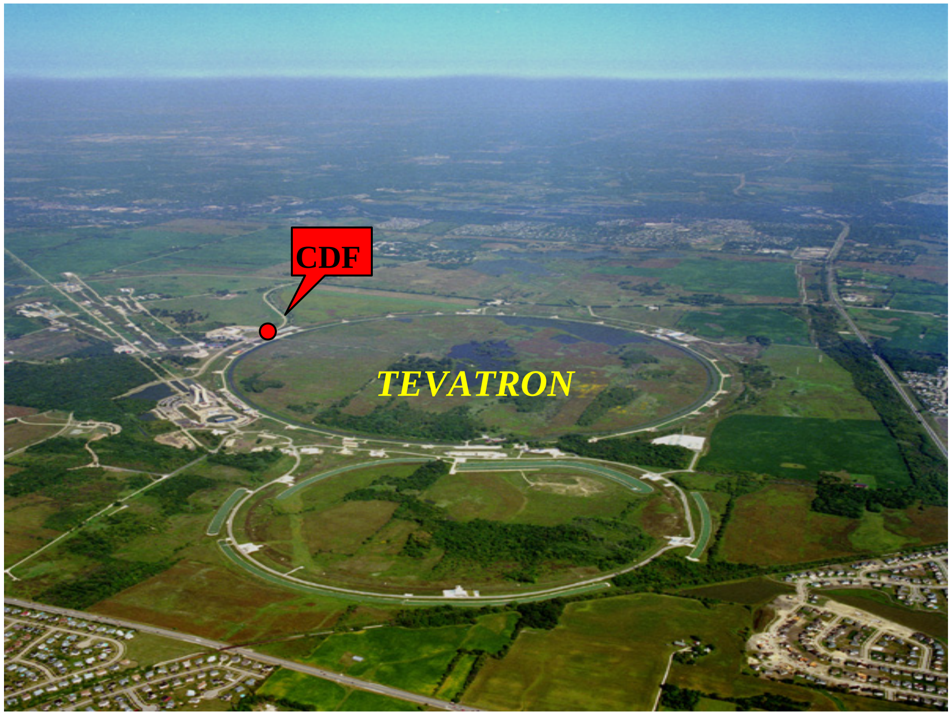
Outline

- TEVATRON and CDF
- Jet Production
- Jet Clustering Algorithms
- Inclusive Jet Cross Section with K_T algorithm
- Inclusive Jet Cross Section with Midpoint algorithm
- Conclusions

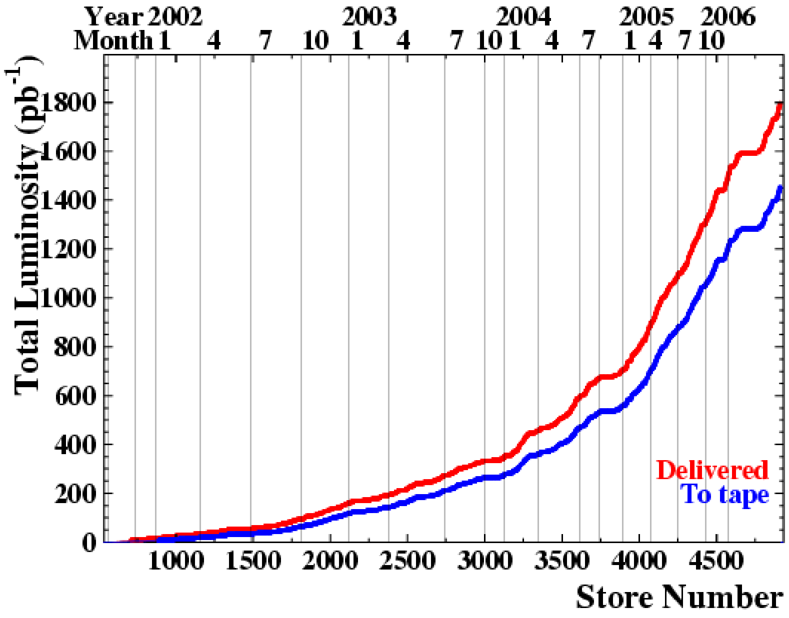
TEVATRON at FNAL



1.8 fb^{-1} of integrated luminosity delivered

1.6 fb^{-1} on tape

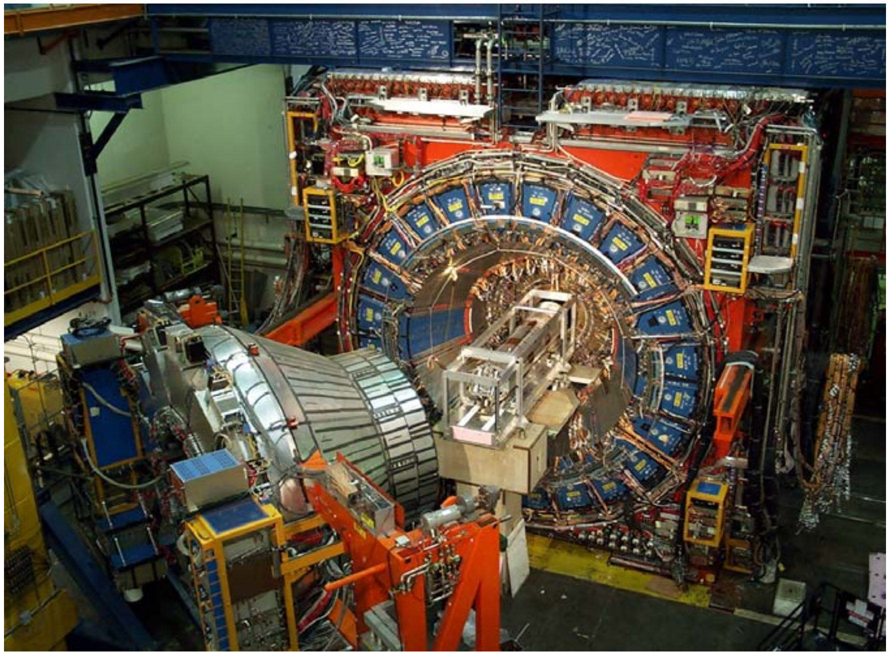
highest peak luminosity - ***1.8*** x ***10***^{32} ***cm***$^{-2}$ ***s***$^{-1}$

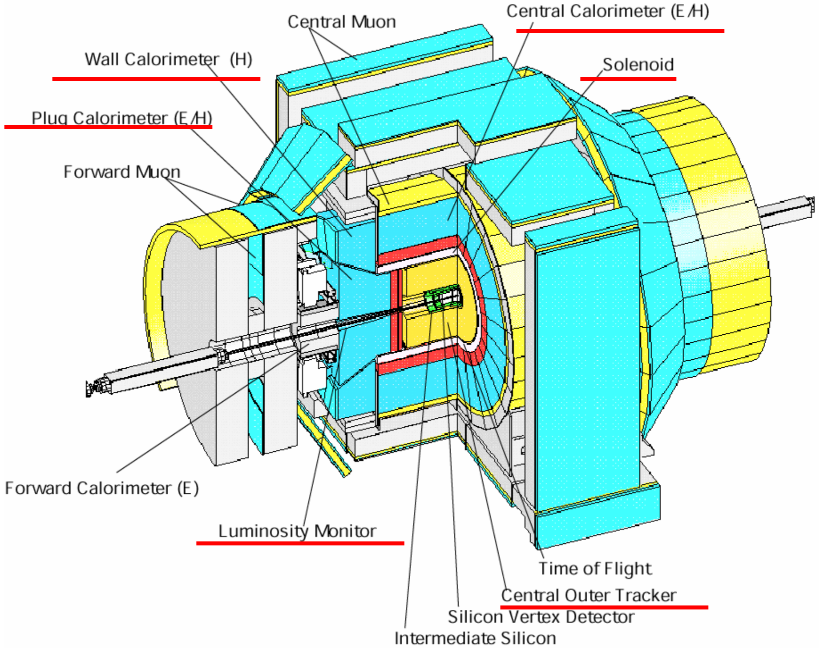


Highest energy proton –antiproton collider in the world

$\sqrt{s} = 1.96\,\text{TeV}$

The CDF Experiment





Detector components crucial for
jet measurements:

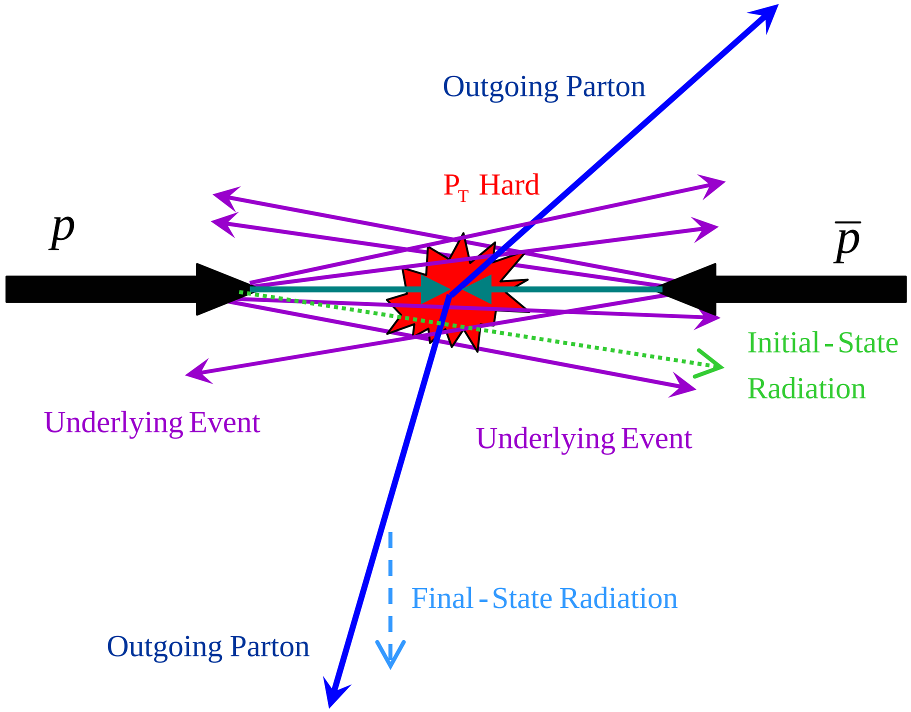
Electromagnetic Calorimeters: jets, e^+e^-, and γ
Hadronic Calorimeters: jets
CLC: luminosity measurements
COT: tracking for vertex reconstruction

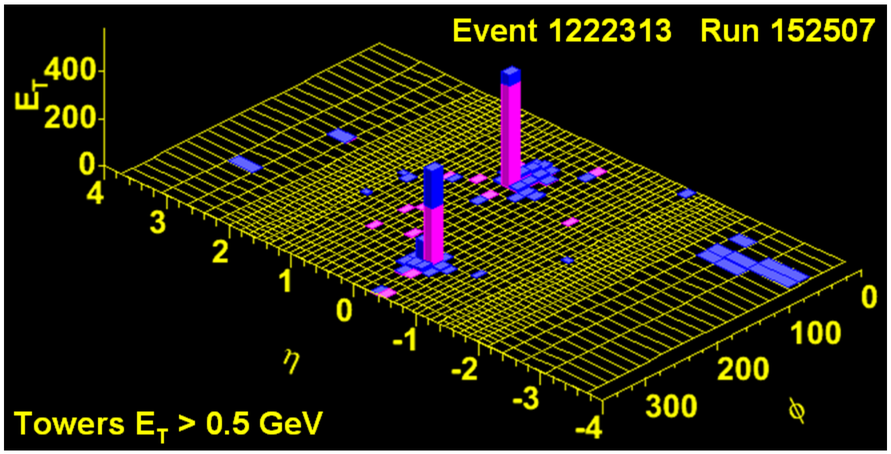
Upgrades for Run II:

- new Silicon tracking, drift chamber, and TOF
- new Plug Calorimeters
- upgraded Muon system
- new DAQ electronics and trigger

Jet Production at the Tevatron

- $2 \rightarrow 2$ hard scattering
  described by pQCD
  dominated by dijet events
  background for many processes
- Initial and Final State Radiation (ISR) and (FSR)
- Underlying Event (UE)
  beam-beam remnants
  multiple parton interactions (MPI)





Jet Physics: Motivation

Fundamental test of QCD

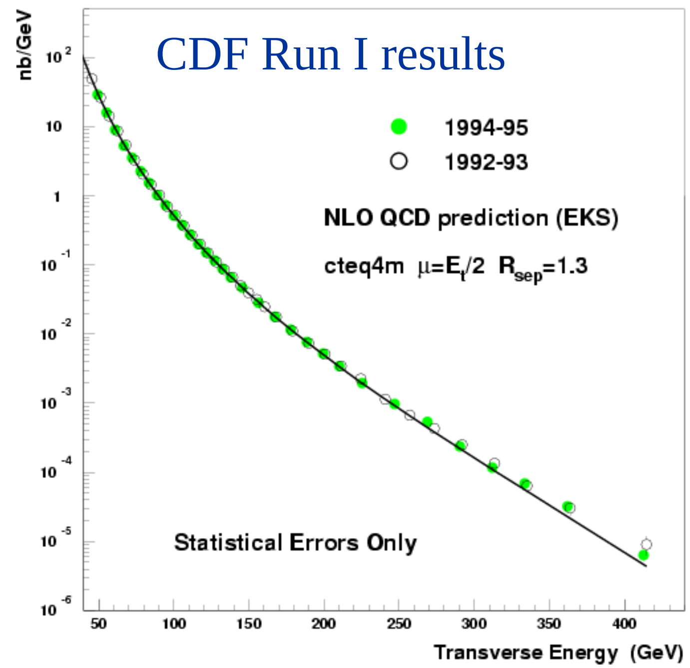
Highest Q^2 scales currently achievable
can probe distance scale of order 10^{-19} m

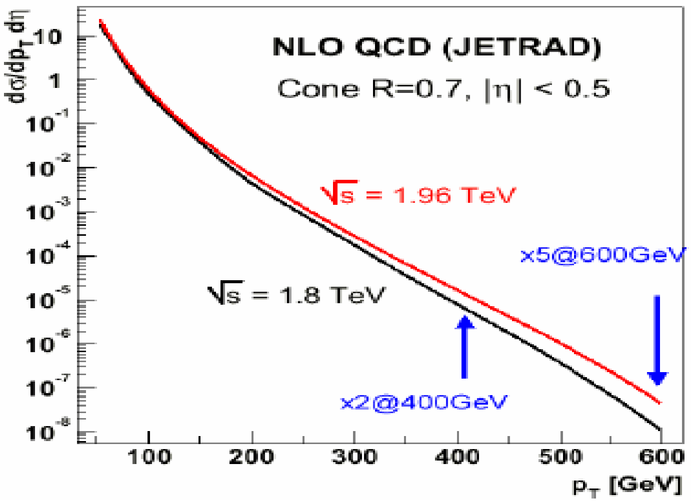
Measurement in wide p_T range $\rightarrow$
probes running of α_S

Sensitivity to parton distributions (PDFs) over a broad kinematic range
measurements at large $x \rightarrow$ constraints on gluon PDFs

Run I legacy – high E_T excess

Increased cms energy $\rightarrow$ increased cross section at high E_T
can probe even higher E_T



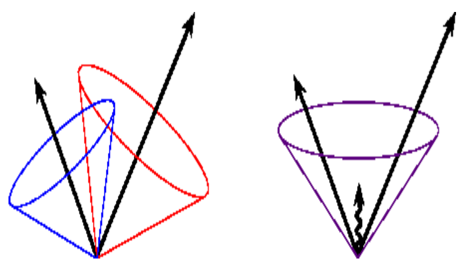


Jet Algorithms

Need common algorithm to reconstruct jets for both theory and experiment

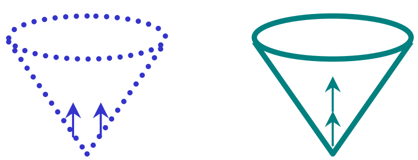
Experiment → hadron level
Theory → parton jets

Theoretically desirable features:



infrared safety

soft parton emission changes jet multiplicity



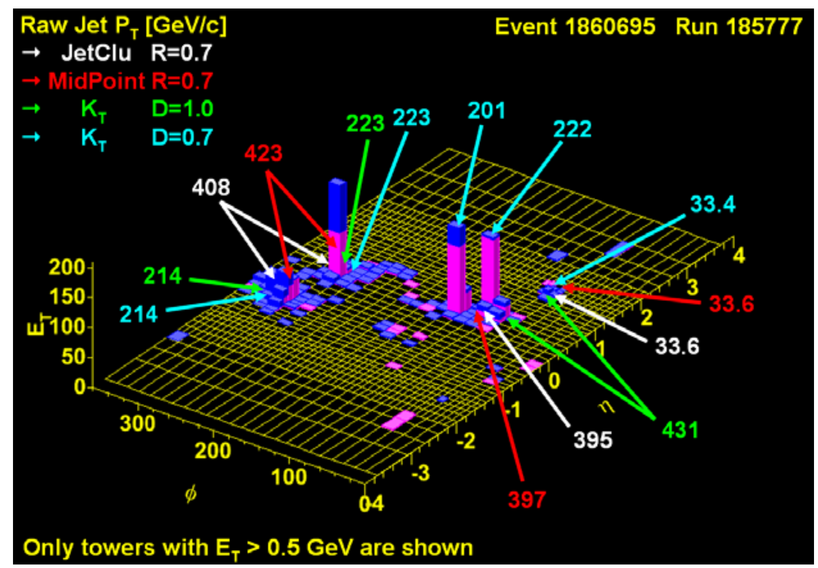
collinear safety

below threshold (no jets) *above threshold (1 jet)*

Jets- composed of partons/hadrons that are "nearby" each other.

cone algorithm - jets are composed of hadrons/partons within a cone in (η,ϕ)

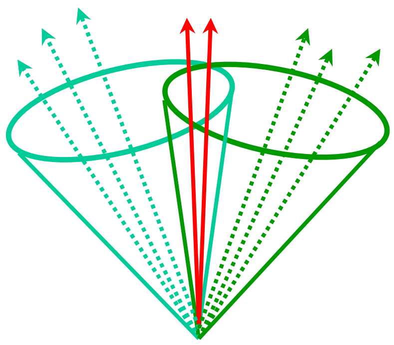
K_T algorithm - jets composed of hadrons/partons being "nearby" in transverse momentum



The Midpoint Algorithm

Midpoint replaced JetClu as the cone algorithm for Run II

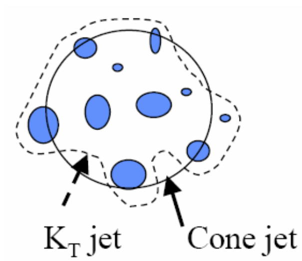
- Using *E* scheme: $E^{jet} = \sum_k E^k, \quad P_i^{jet} = \sum_k P_i^k$
- *Seed* tower -
  start with a calorimeter tower with p_T above certain threshold
- Draw a cone of radius *R* around each seed to form "proto-jet"
- Draw new cones around "proto-jets" and iterate until find
  stable cone
- Add extra seeds at the midpoint *(y-ϕ)*
  between pair of all stable cones separated by less than *2R*
  and iterate for stable cones
- Use R_{sep} parameter at the parton level (NLO) to approximate
  the split-merge step



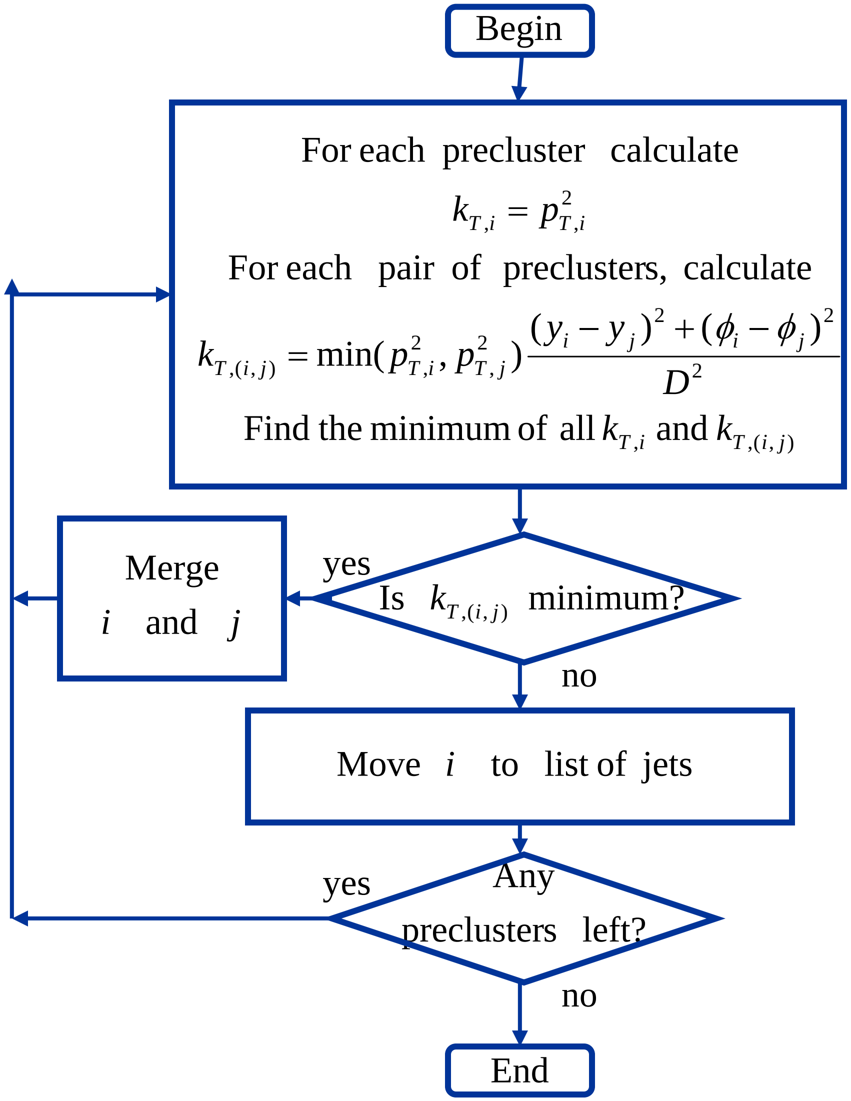
The K_T Algorithm

- Preferred by theorists;

  partons are separated into jets according to their transverse momentum



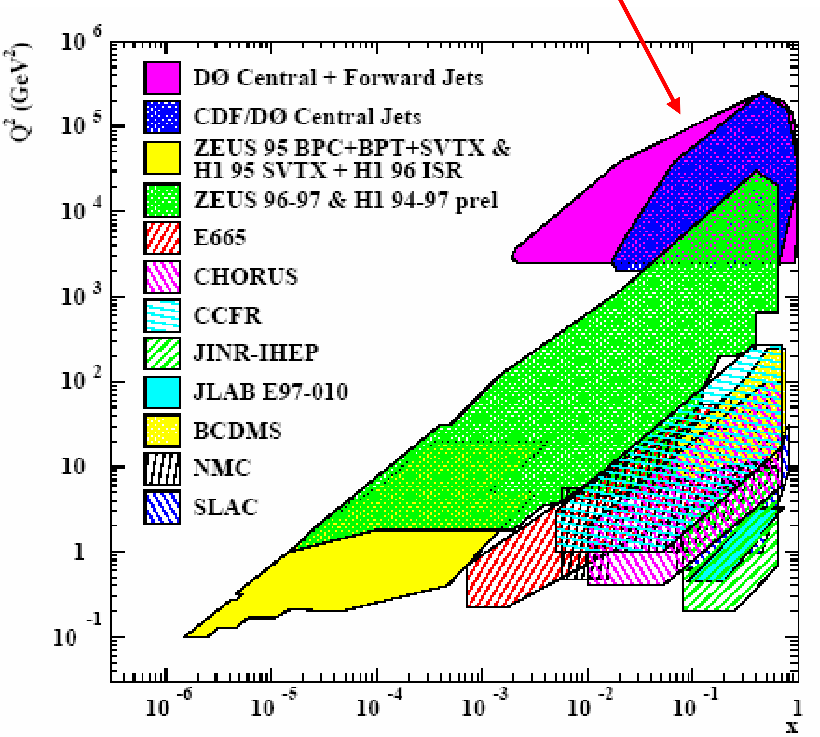
- Infrared/collinear safe to all orders in pQCD
- No merging/splitting parameter needed
- Has been used at ***e***$^+$***e***$^-$ and ***ep*** colliders, new to hadron-hadron colliders
- More sensitive to underlying event and multiple interactions



* *parameter D - controls merging termination and characterizes size of resulting jets*

Forward Jets

region measured in Run I

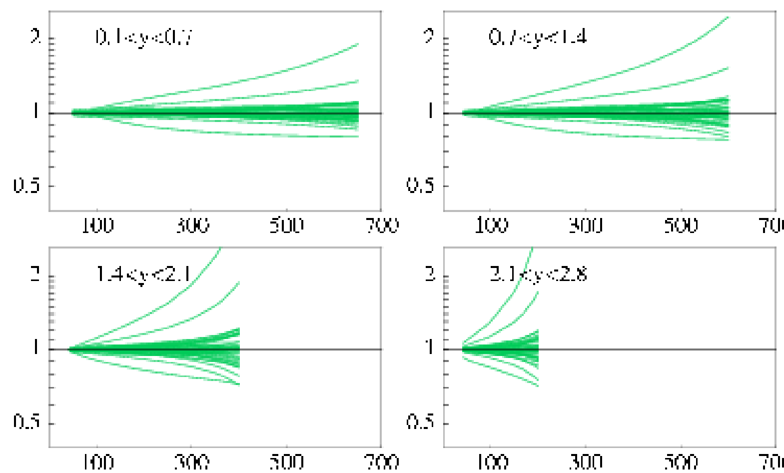


$$x_1 = \frac{E_T}{\sqrt{s}}(e^{+\eta_1} + e^{+\eta_2})$$

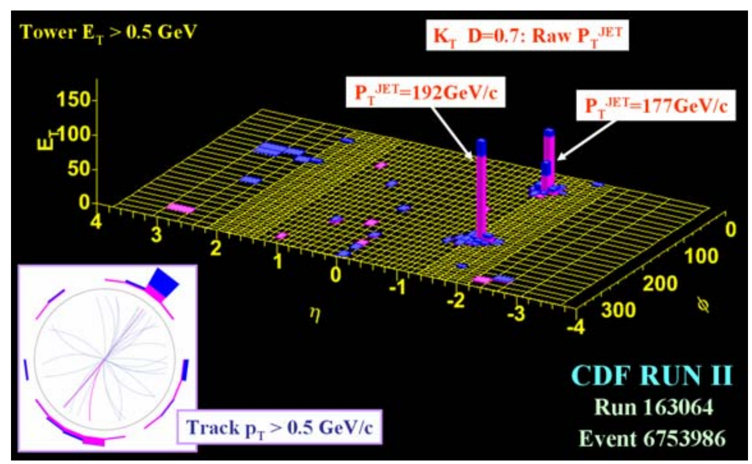
$$x_2 = \frac{E_T}{\sqrt{s}}(e^{-\eta_1} + e^{-\eta_2})$$

Kinematic region can be expanded by measuring jets in the forward region

range of uncertainty of the inclusive cross section in different rapidity regions determined for CTEQ6.1.M



Measurements in the forward region allow to constrain gluon distributions



Jet Energy Corrections

$$P_{T,jet}^{particle} = \left[P_{T,jet}^{measured} \times f_{rel} - MI\right] \times f_{abs}, \quad P_T^{parton} = P_{T,jet}^{particle} - UE + H$$

corrections for detectors effects

corrections for physics effects

f_{rel}: **Relative Correction** – make jet reponse uniform in η - from dijet P_T balance

MI: **Multiple Interaction Correction** – for energy of other pp interactions - from data

f_{abs}: **Absolute Correction** – for calorimeter response to jets – from simulated dijet events, the single particle response in the simulation tuned to *in-situ* single track & test beam data

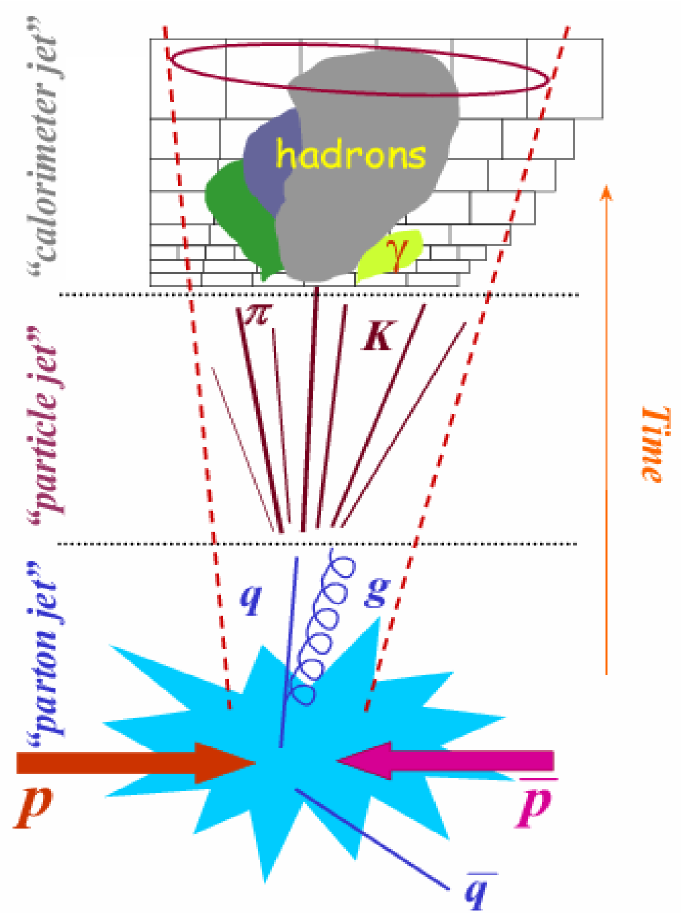
Unfolding Correction – removes smearing effects of the calorimeter, bin-by-bin correction – from data and MC

⇓ **particle jet (including UE)**

UE: **Underlying Event Correction**– for beam remnants, multiple parton scattering - from data

H: **Hadronization Correction** – for energy out of jet cone due to hadronization – based on MC parton shower and hadronization model

⇓ **parton jet**



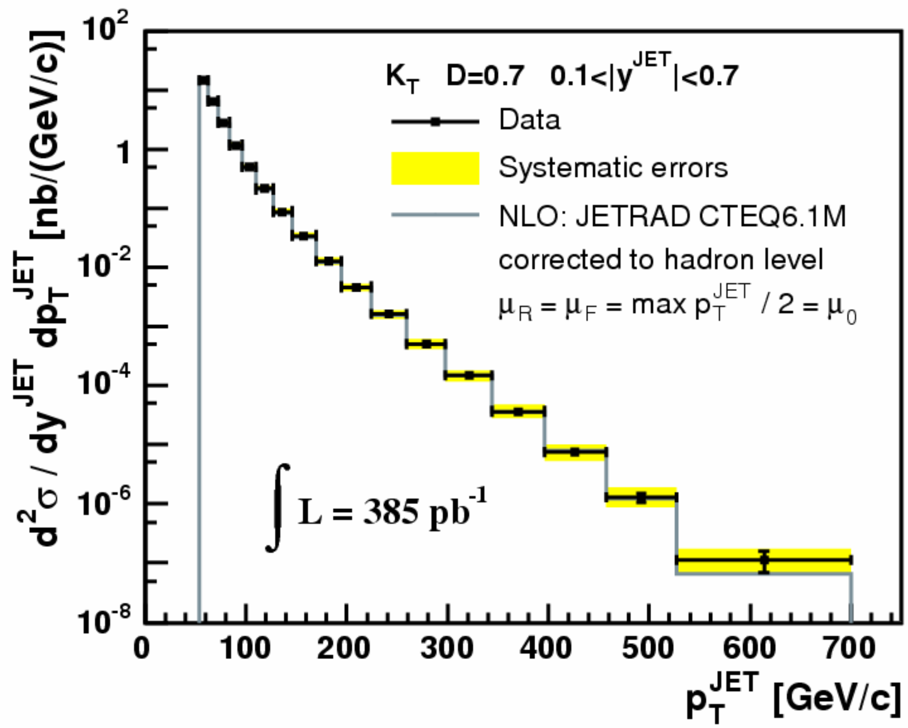
K_T Published Results:

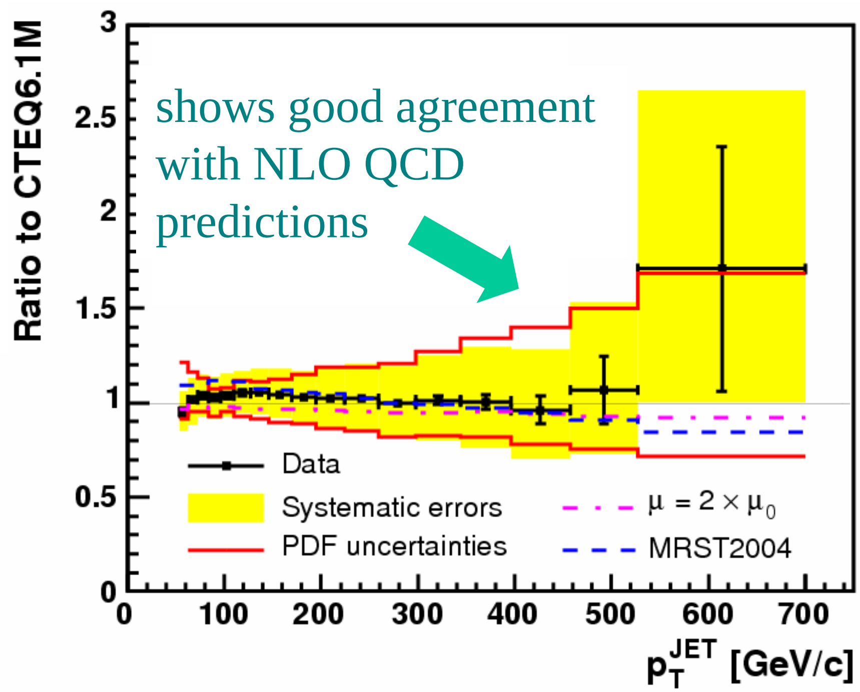
PRL 96, 12201 (2006)

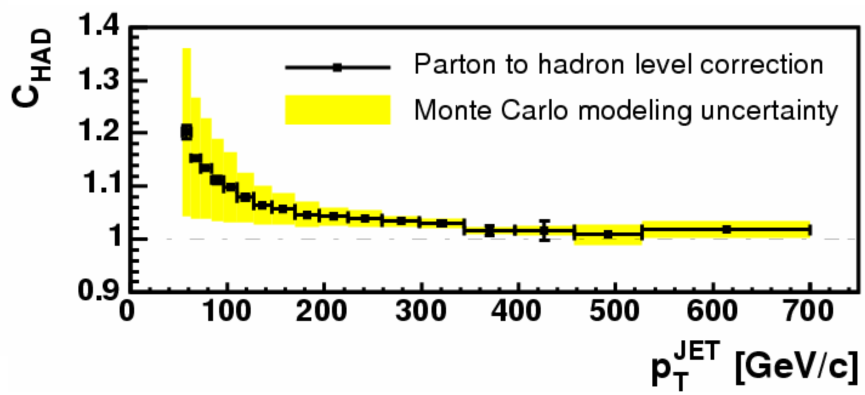
Inclusive jet cross section

0.1< |y| <0.7   D=0.7

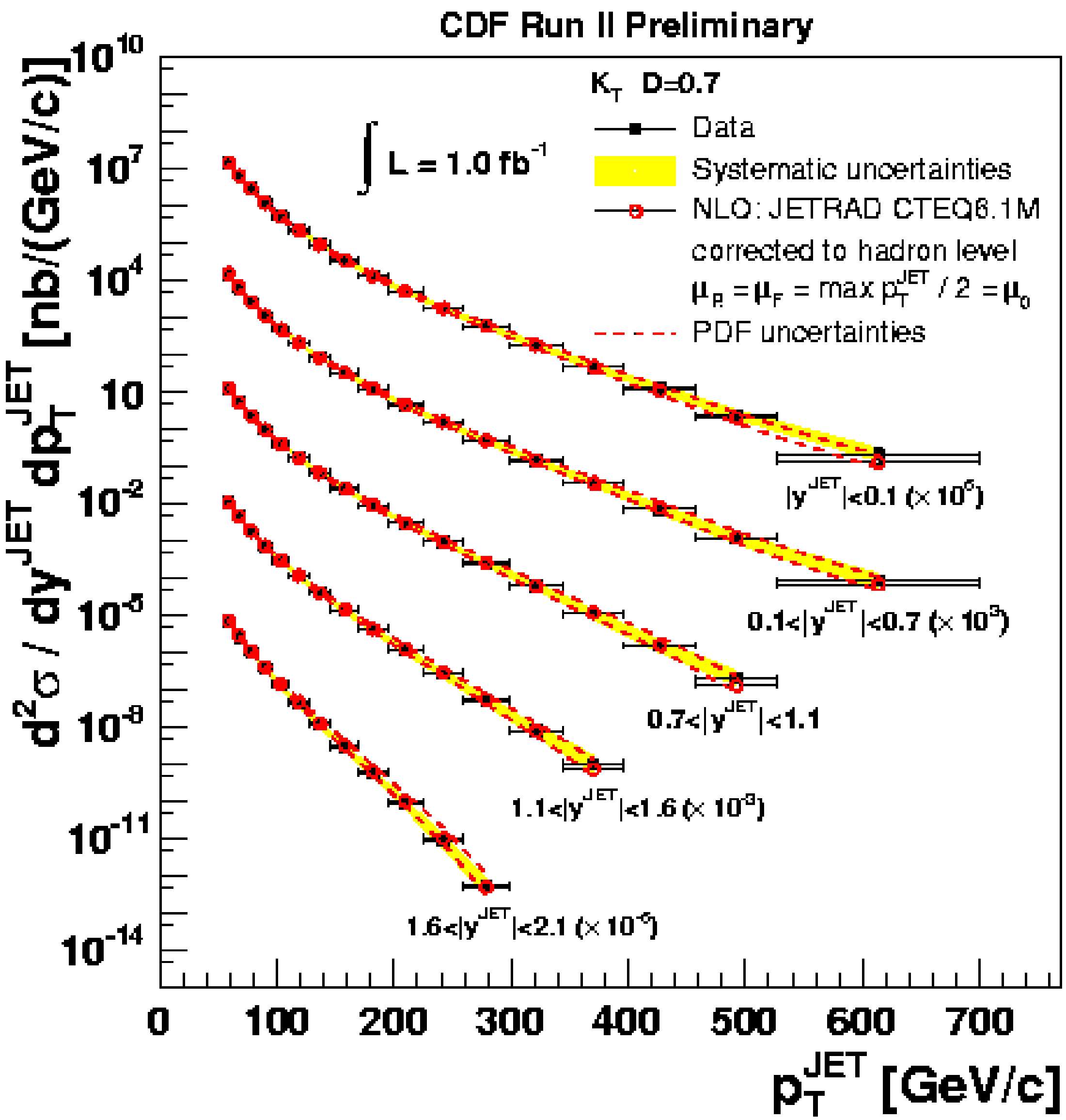
data sample - 385pb^{-1}







K_T Results



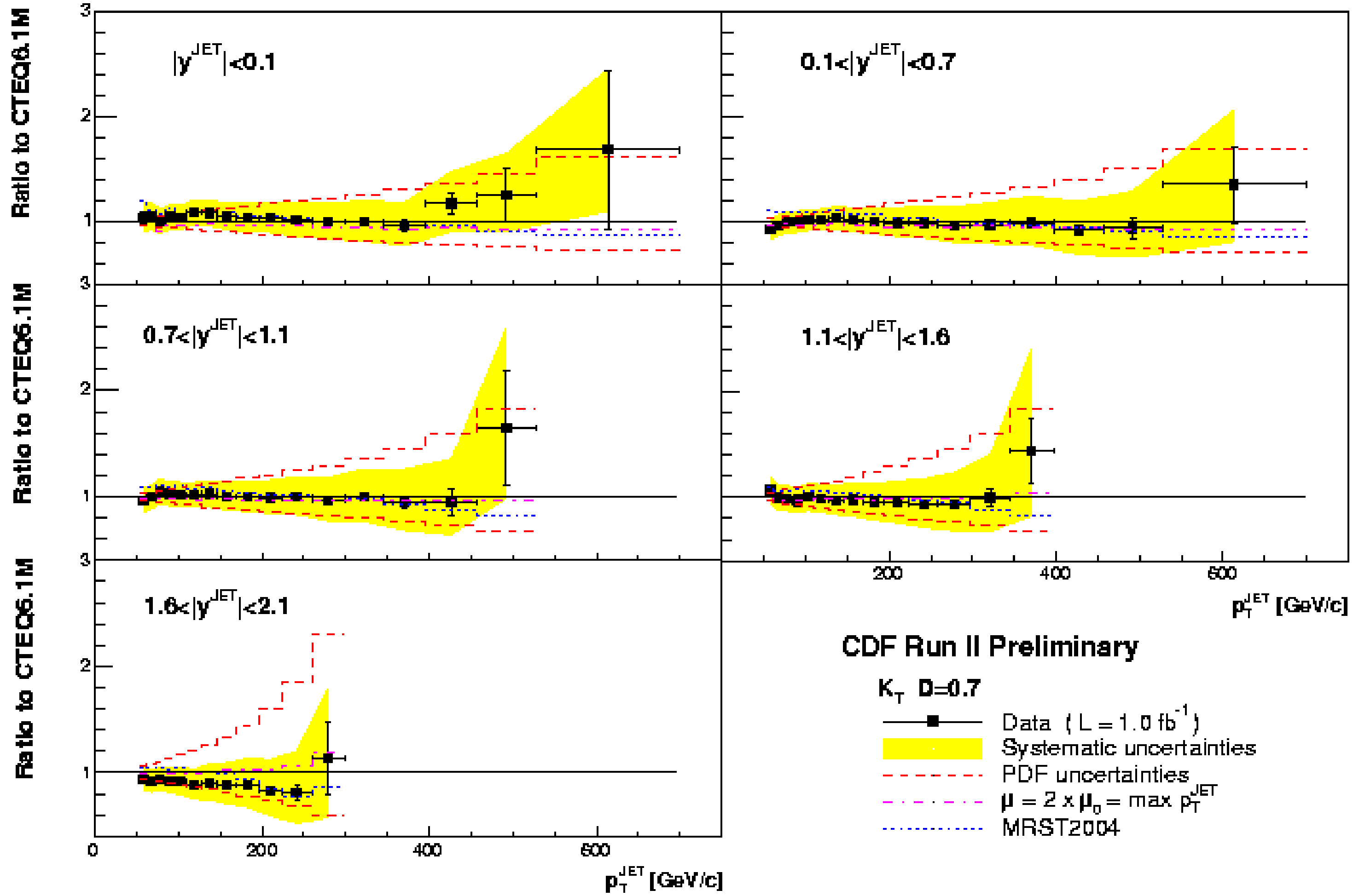
Inclusive Jet Cross Section extended to the forward region $|y^{JET}|<2.1$

1 fb^{-1} of data

Good agreement with NLO QCD

K_T Results

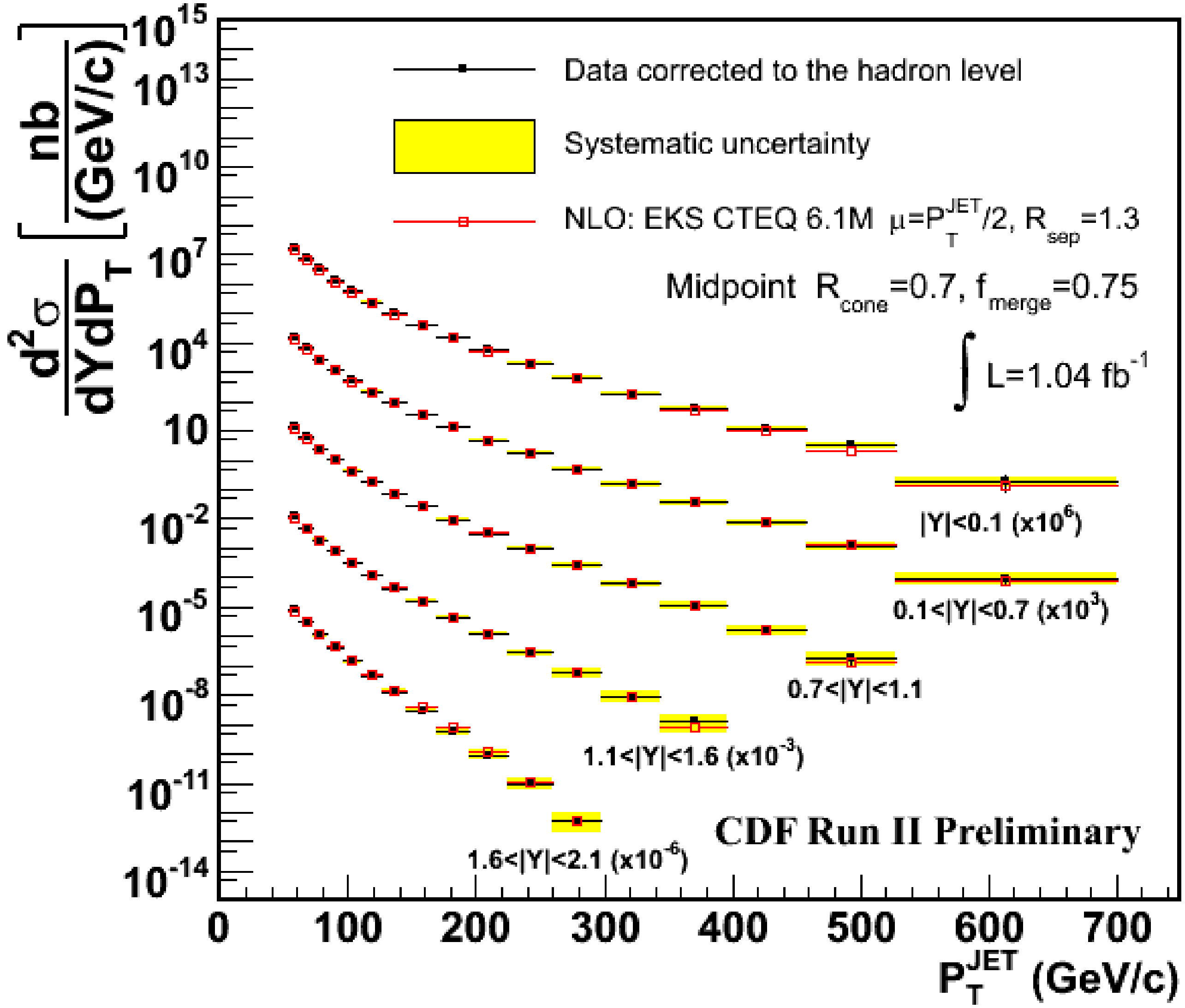
Ratio of Data to Theory



The exp. systematic uncertainty is dominated by uncertainty on the absolute jet energy scale

Midpoint Results

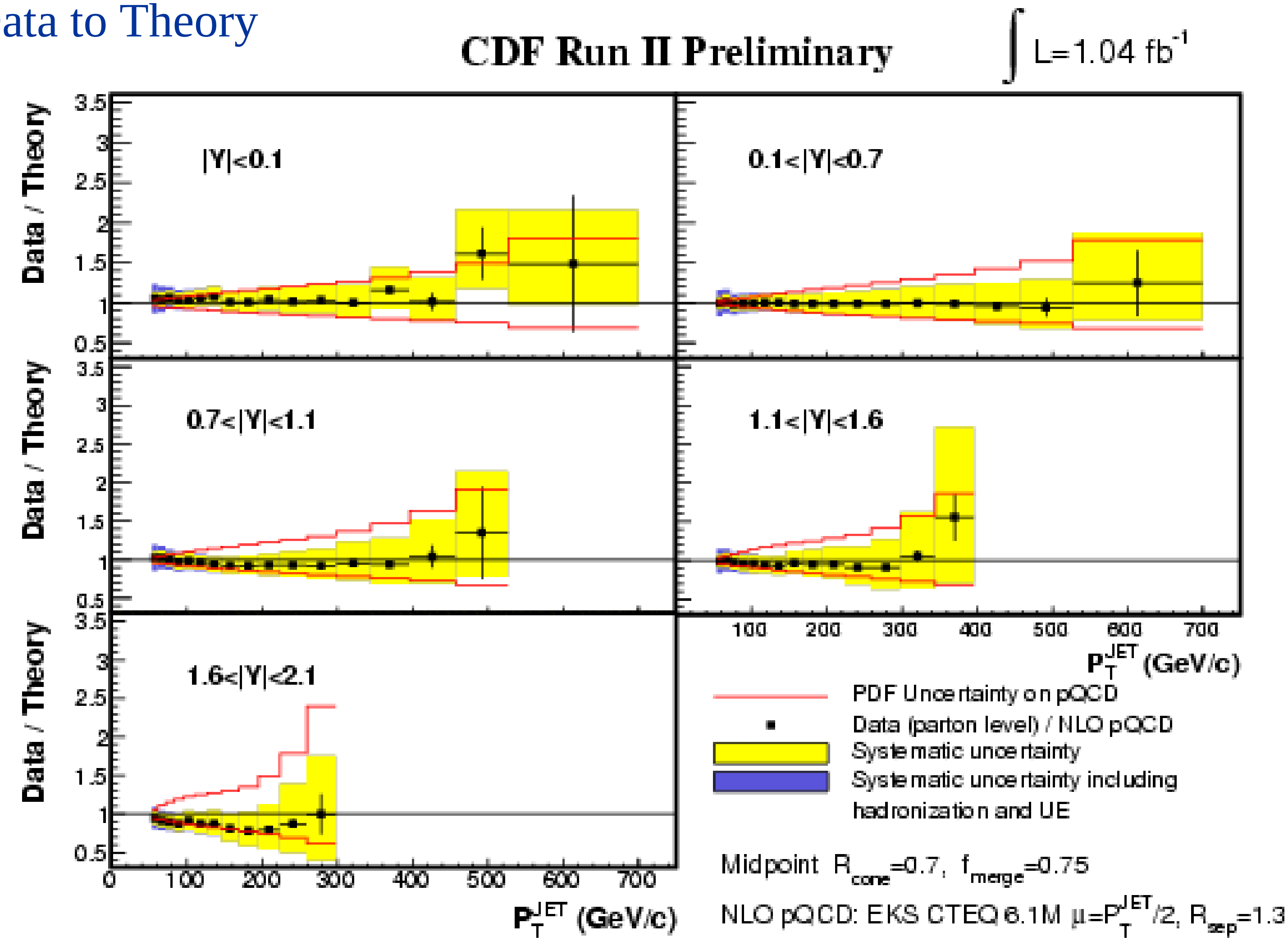
Inclusive Jet Cross Section extended to the forward region



Good agreement with NLO QCD

Midpoint Results

Ratio of Data to Theory



Conclusions

- Inclusive jet cross sections are measured using CDF Run II data:

  jets are clustered using Midpoint and K_T algorithms

  1 fb^{-1} of data

  cross section measurement is extended to the forward region up to $|y^{Jet}|<2.1$

- Measurements are consistent between Midpoint and K_T algorithms.

- Experimental results agree well with NLO QCD predictions.

- K_T algorithm seems to work well in hadron collider environment for high p_T jets above 50 GeV/c

- Results provide important input to constrain gluon densities in PDFs.

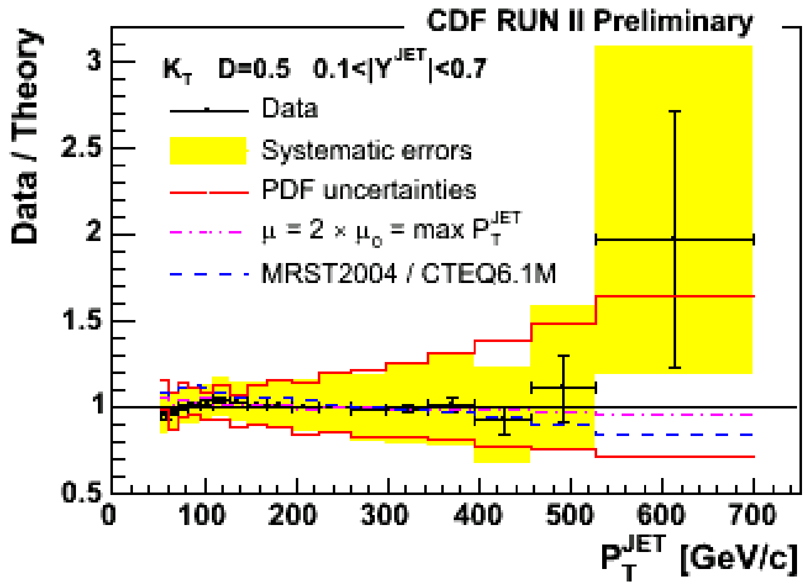
Backup

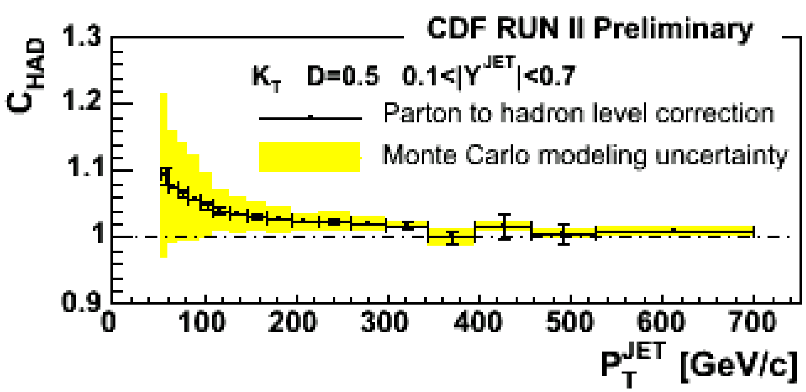
K_T Published Results:

PRL 96, 12201 (2006)

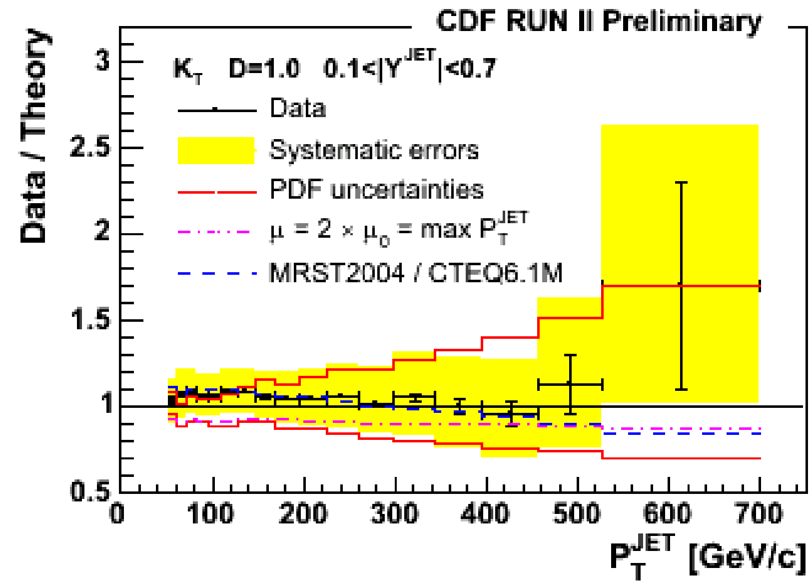
K_T jets for different values of *D*

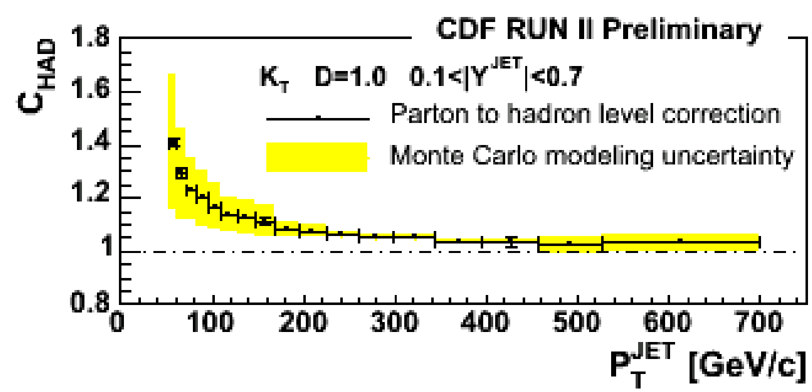
D=0.5



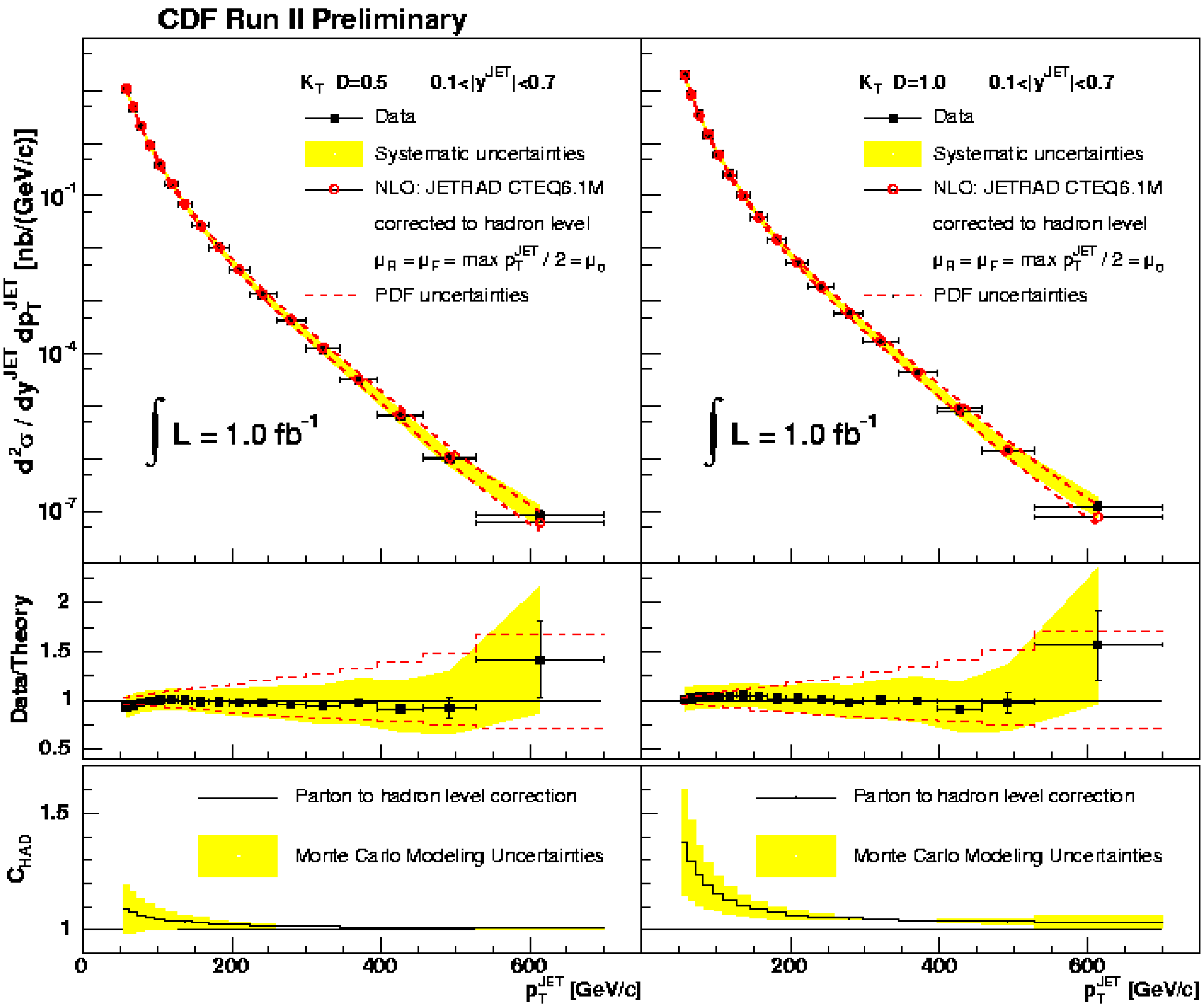


D=0.7





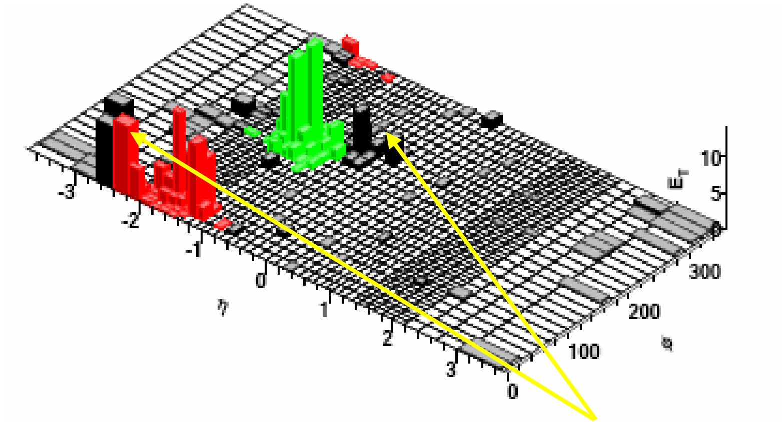
K_T Results

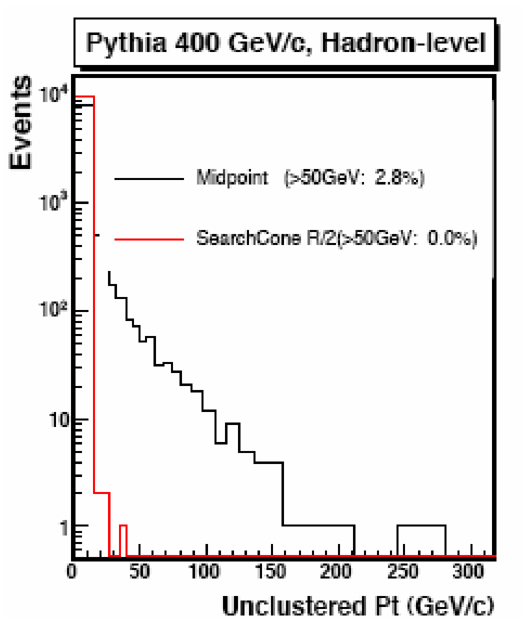

CDF Run II Preliminary
K_T D=0.5 0.1<|y^JET|<0.7
K_T D=1.0 0.1<|y^JET|<0.7
Data
Systematic uncertainties
NLO: JETRAD CTEQ6.1M
corrected to hadron level
μ_R = μ_F = max p_T^JET / 2 = μ_0
PDF uncertainties
∫ L = 1.0 fb^-1
d²σ / dy^JET dp_T^JET [nb/(GeV/c)]
Data/Theory
C_HAD
Parton to hadron level correction
Monte Carlo Modeling Uncertainties
p_T^JET [GeV/c]

Modified Midpoint Algorithm

With midpoint algorithm,
CDF observed "dark towers", significant amounts of energy that remain unclustered in any jet,

for example, ~2% of events with a 400 GeV/c jet have more than 50 GeV/c of unclustered transverse energy





To improve the match between parton, hadron, and detector level jets the search cone was added to minimize this effect.

↓

search for the stable cone with
$R_{cone} = R/2$ then expand to
$R_{cone} = R$
Results in a 5% increase of the jet cross section.

Modified Midpoint Algorithm