Jet Results from DØ

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for the DØ collaboration

Introduction

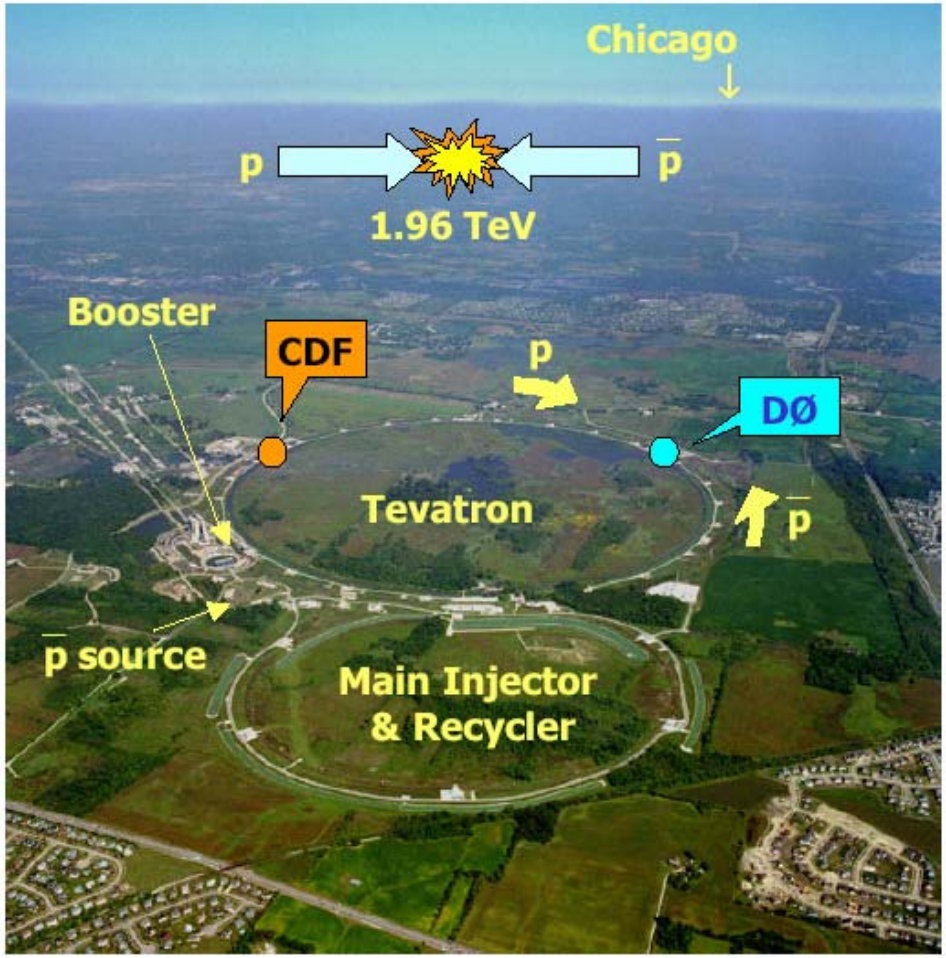
- We present the following measurements:
  1) Inclusive jet cross section
  2) Dijet cross section
  3) Dijet azimuthal decorrelation

- These measurements improve our understanding of the strong interactions
- Sensitive to quark and gluon densities at large X
- As high Q^2 processes => good place to look for new physics (compositeness, ressonances ...)

Fermilab Acelerator(Tevatron)

- Highest energy (1.96TeV) collider until LHC

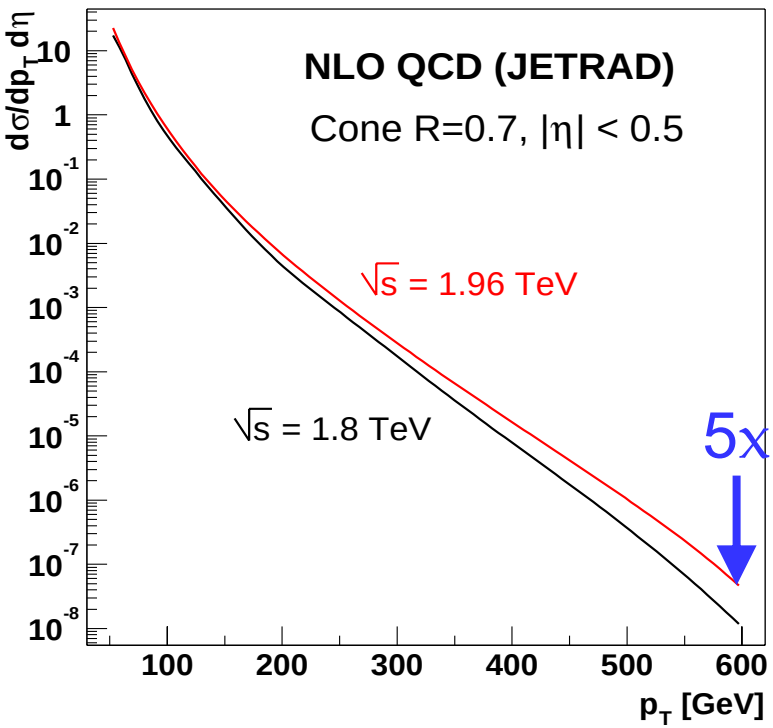
- Luminosity:
  - Run I (1992-1995) ~0.1 fb^{-1}
  - Run IIa (2001~2005) ~1 fb^{-1}
  - Run IIb (2006-2009) ~4-8 fb^{-1}



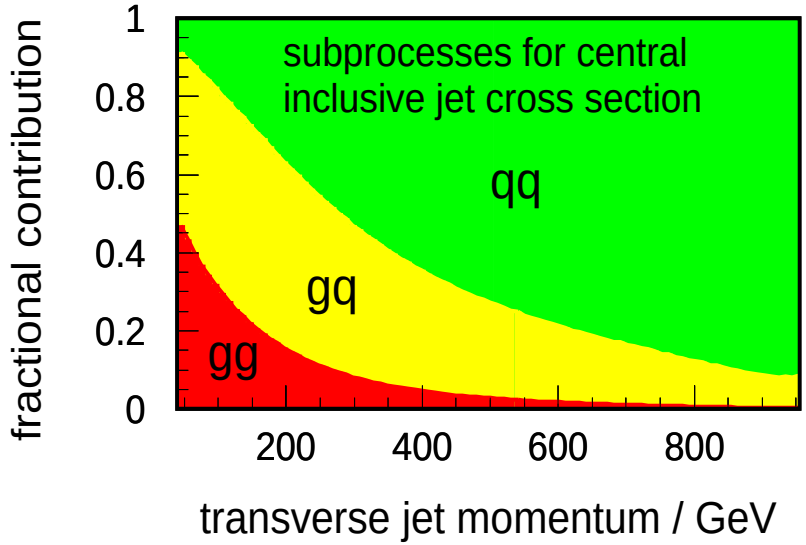
Jet Physics at Tevatron

Going from 1.8TeV to 1.96TeV increases statistics up to 5x

Inclusive jet spectrum

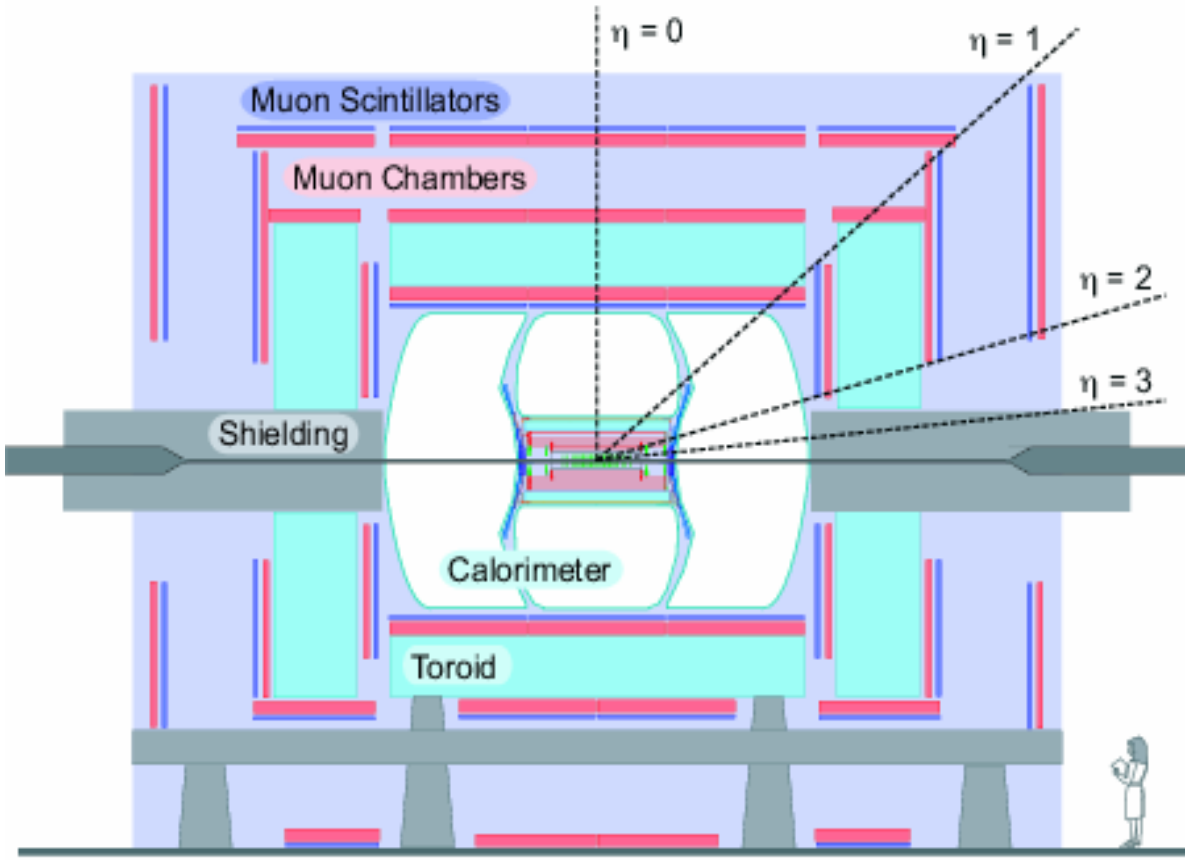


Partonic subprocess contributions to the inclusive jet cross section (significant gluon contribution at high Pt)



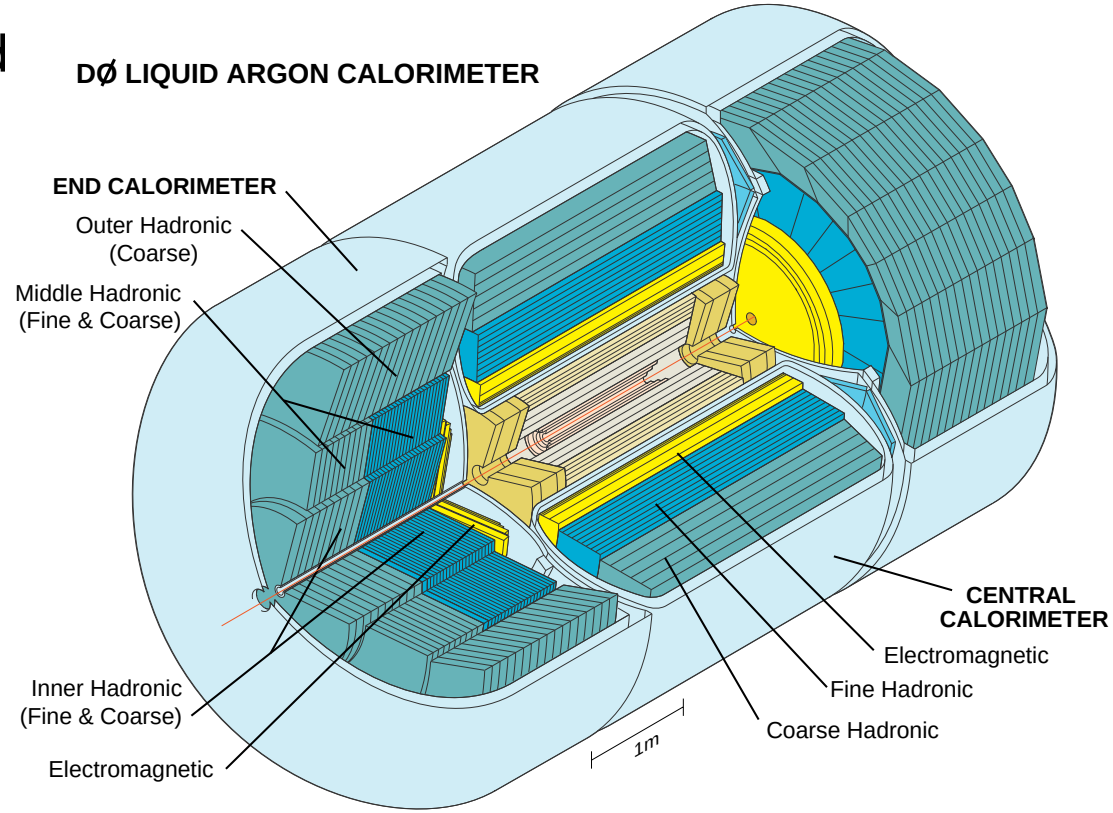
DØ Detector(Run II)

- New detectors: silicon and fiber tracker
- Solenoid (2 Tesla)
- Calorimeter pre-showers and new electronics
- Upgraded muon system (forward mini drift tubes and scintilators)
- Upgraded Trigger/DAQ



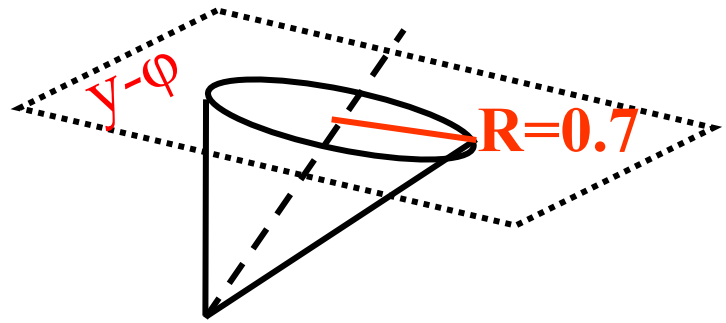
DØ Calorimeter

- Uranium-Liquid Argon Calorimeter with a stable and uniform response
- Compensating: $e/\pi \approx 1$
- Hermetic coverage $|\eta| \leq 4.2$
- Longitudinal Segmentation
  - 4 EM Layers (2,2,7,10) X_o
  - 4–5 Hadronic Layers (6λ)
- Transverse Segmentation
  - $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$ in EM
  - $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$ otherwise



Run II Jet Algorithm(hep-ex/0005012)

- 4-vector cone algorithm with a 0.7 radius in y-φ space
  - Identify a seed calorimeter tower
  - Using the event vertex, assign a four-vector to that seed
  - Add all other other four-vectors inside the cone to generate the jet's four-vector
  - Iterate until stable solution is found (jet axis = cone axis)
- Changes from Run I algorithm
  - Use of midpoints between jets as additional seeds for new jets (infrared safety)
  - Use of 4-vectors instead of scalar quantities



Jet 4-vector

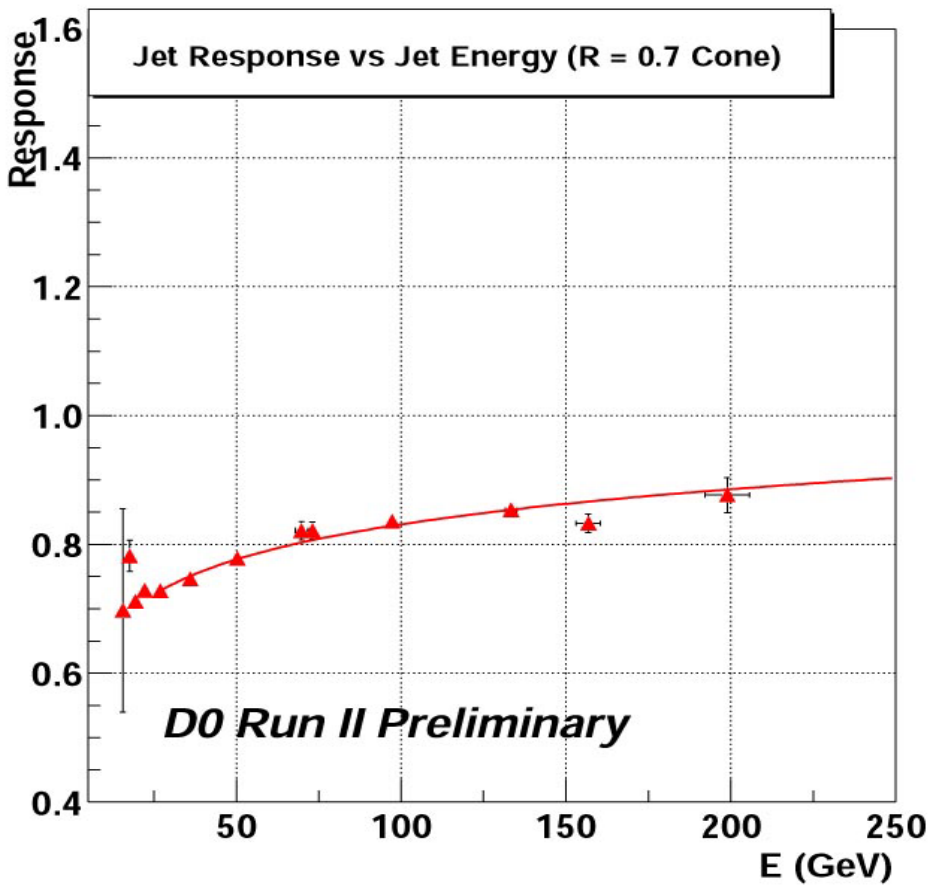
$$p^J = (E^J, \vec{p}^J) = \sum_{i \subset J} (E^i, p_x^i, p_y^i, p_z^i)$$

Jet Properties

$$p_T^J = \sqrt{\left(p_x^J\right)^2 + \left(p_y^J\right)^2}$$

$$y^j = \frac{1}{2}\ln\left(\frac{E^J + p_z^j}{E^J - p_z^j}\right) \qquad \varphi^J = \arctan\left(p_y^J / p_x^J\right)$$

Jet Energy Scale Correction



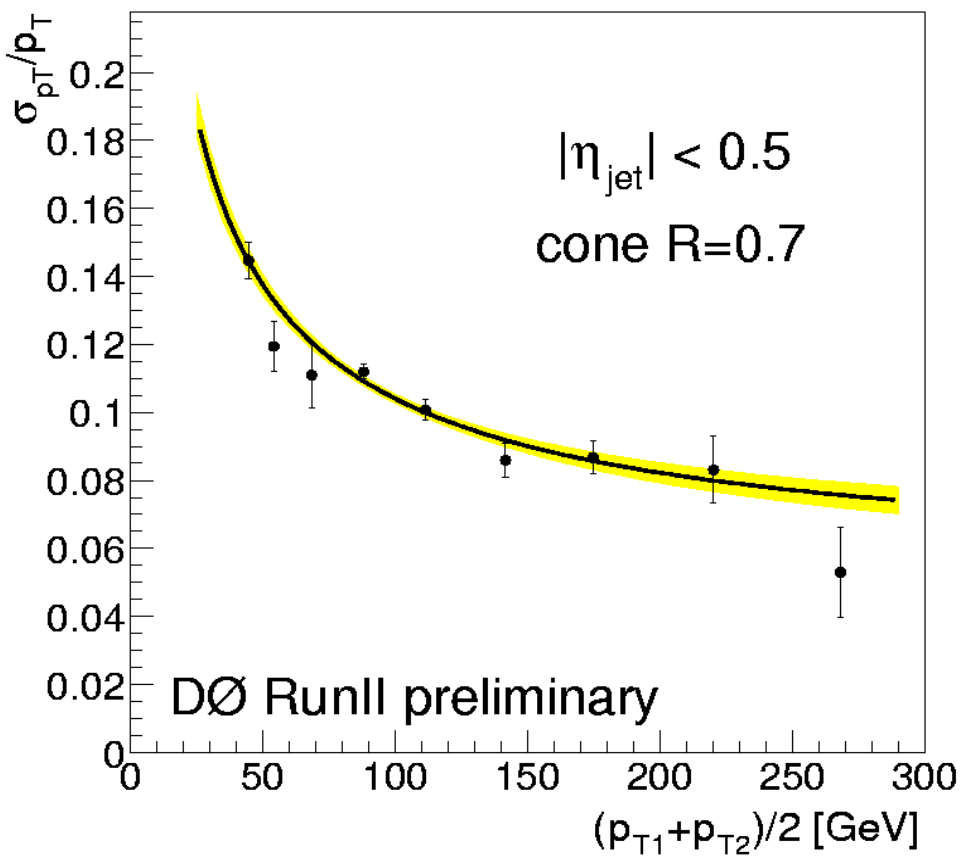
- Measured jet energy is corrected to particle level

$$E_{\text{corr}} = \frac{E_{\text{uncorr}} - O}{R \cdot S}$$

- O = offset energy
  - Energy not associated with the hard interaction (calorimeter noise and pile-up)
- R = calorimeter response
  - EM calibrated on Z->ee peak
  - calibrated from energy balance in γ+ jet events (up to 200GeV) => extrapolation
- S = showering correction
  - energy losses due to showering outside the reconstruction cone

Jet Momentum Resolution

Jet p_T Resolution



- The Jet Resolution is measured by studying dijet asymmetry

$$A = \frac{p_T^{jet1} - p_T^{jet2}}{p_T^{jet1} + p_T^{jet2}} \qquad \frac{\sigma_{p_T}}{p_T} = \sqrt{2}\sigma_A$$

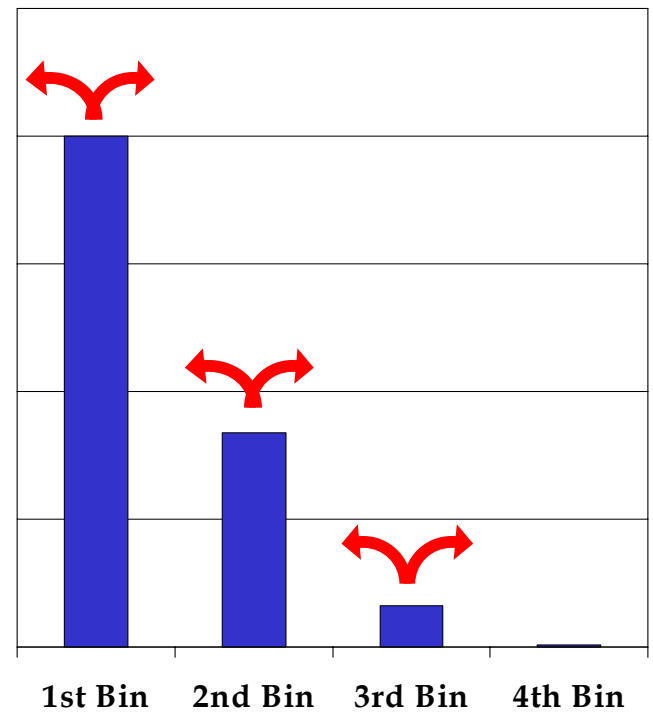
- We use this resolution to unsmear our data

Unsmearing

- Steeply falling cross section + jet energy resolution => cross section shift to the right

- Unsmearing procedure:
  - guess an ansatz function **f** for the true cross section
  - smear f with the jet resolution
  - fit the smeared ansatz **F** to the data
  - correct data by the ratio **f / F**

Steeply Falling Spectrum



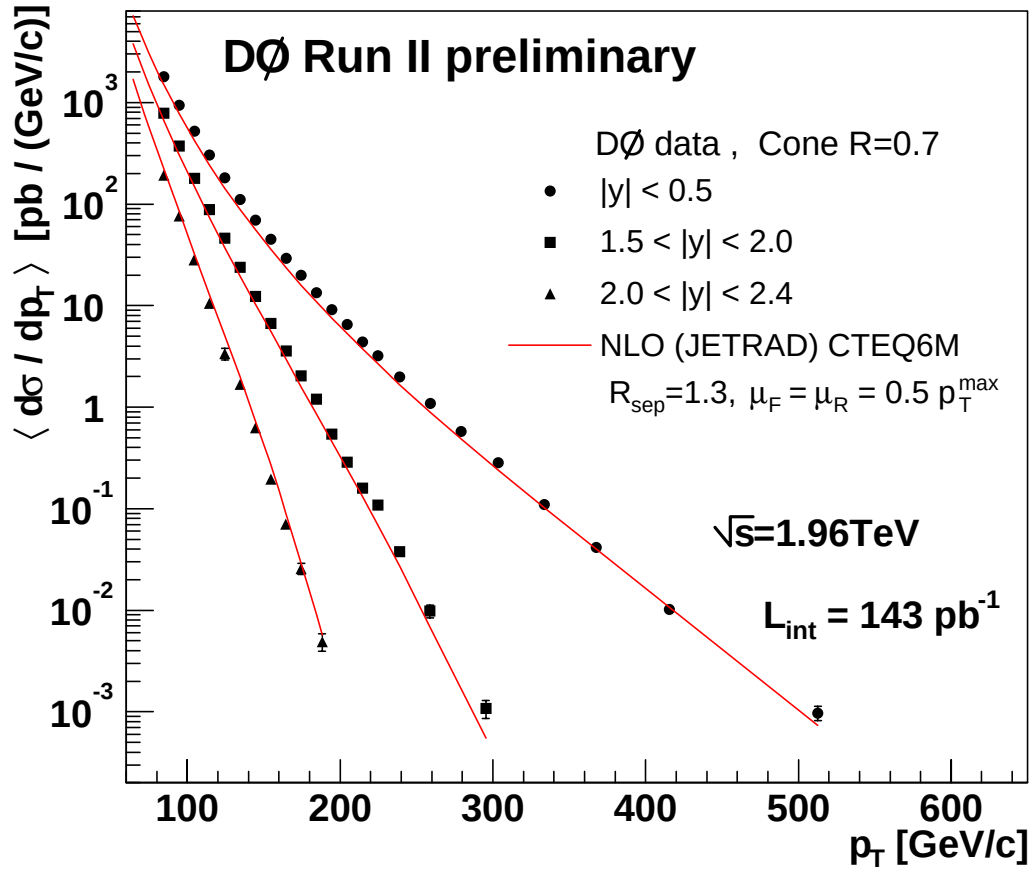
$$F(M_{JJ}) = f(M'_{JJ}) \otimes smearing$$
$$= \int_0^{\sqrt{s}} dM'_{JJ} \cdot f(M'_{JJ}) \cdot G(M'_{JJ} - M_{JJ}, M'_{JJ})$$

Inclusive Jet Cross Section

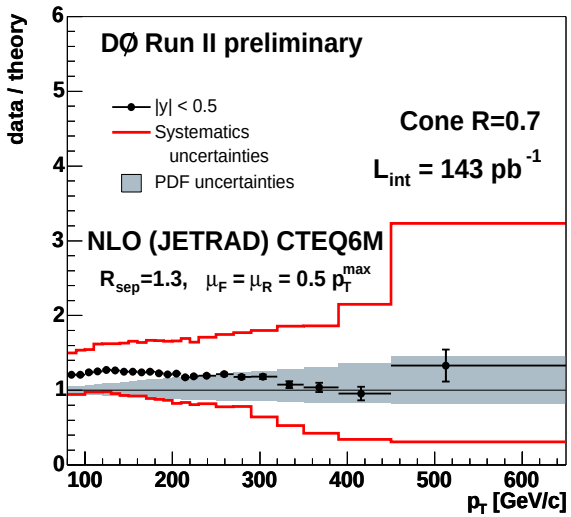
$$\left\langle \frac{d\sigma}{dp_t} \right\rangle = \frac{N_{event}}{L \cdot \Delta p_T} \times \frac{C_{unsmear}}{\varepsilon_{eff}}$$

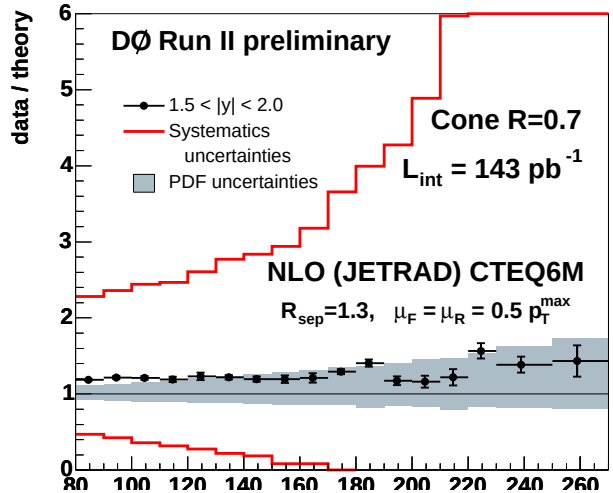
- Data sample:
  - L ~ 143pb-1
  - |yjet| < 0.5
  - ΔR = 0.7 cone jets

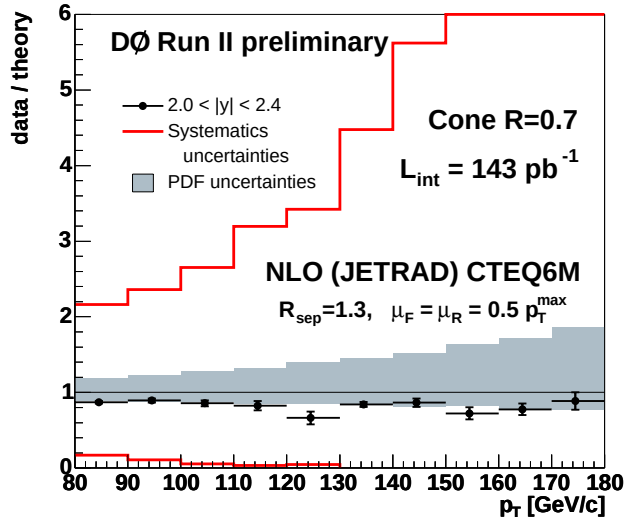
- Efficiencies estimated from data
- Strong rapidity dependence
- Agreement with NLO QCD(JETRAD) over 6 orders of magnitude



Inclusive Jet Cross Section





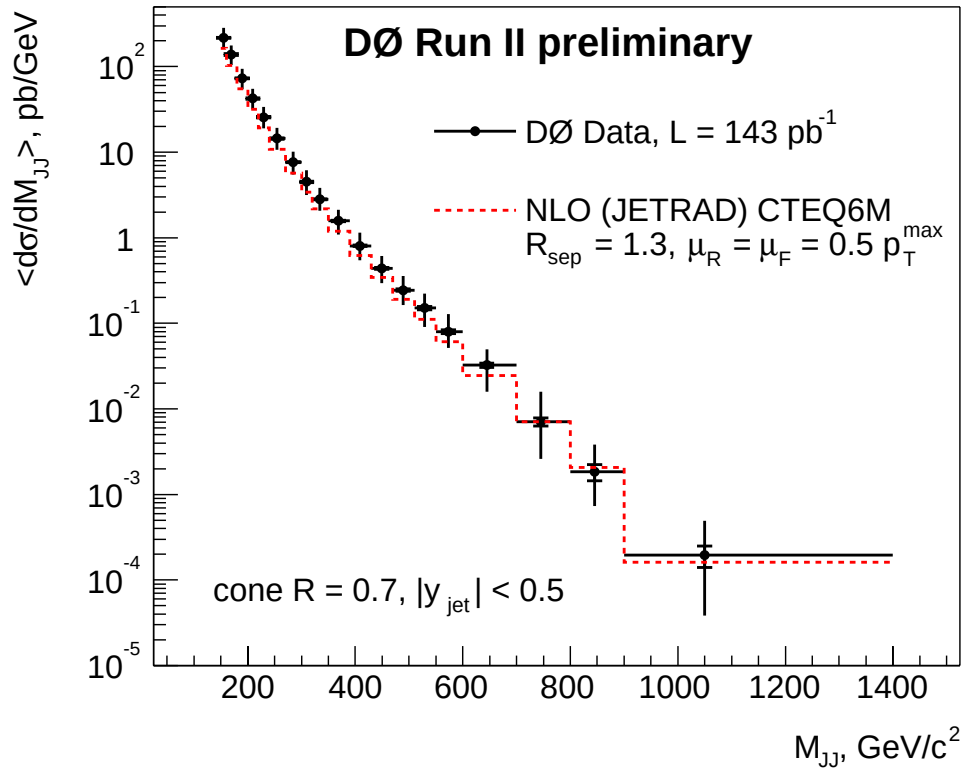


- Good agreement between data and theory at all rapidities
- Increased theory uncertainty in forward region due to PDFs
- Large uncertainty due to jet energy scale

Dijet Cross Section

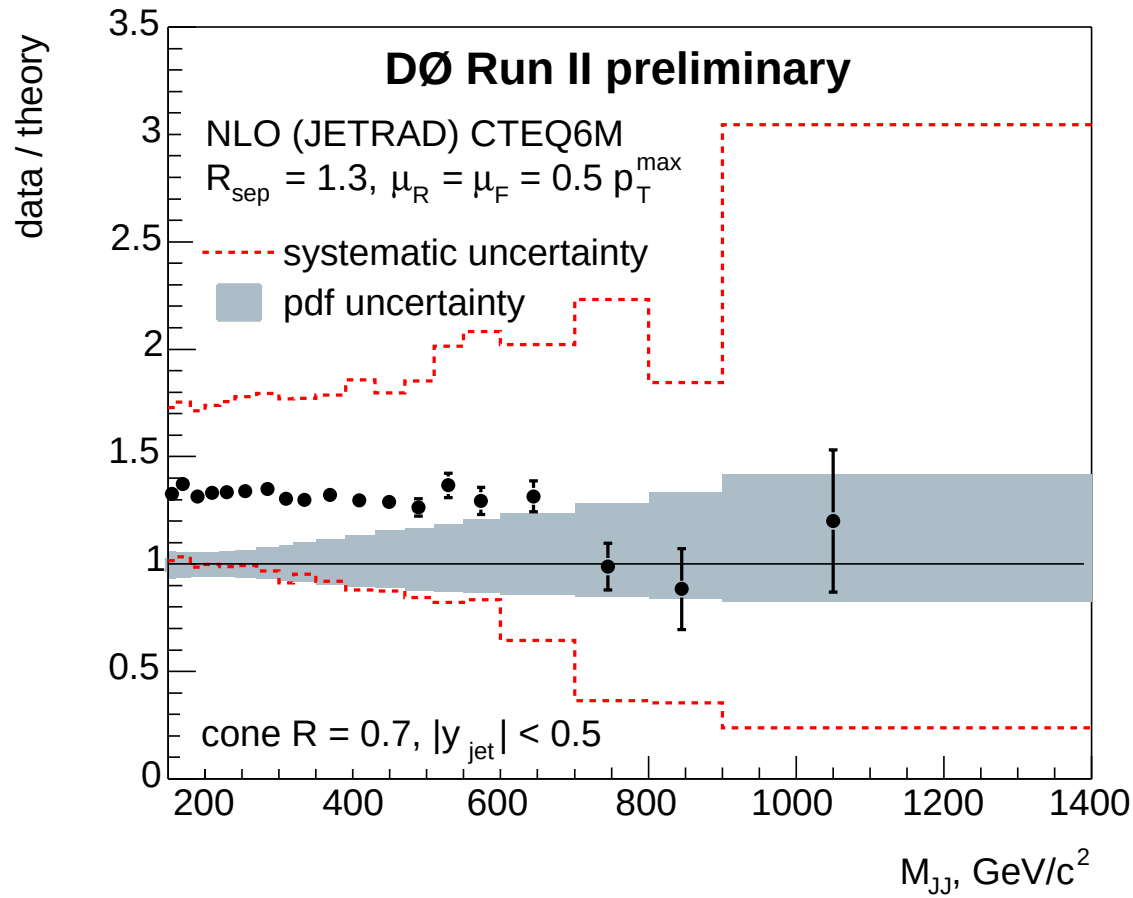
$$\left\langle \frac{d\sigma}{dM_{JJ}} \right\rangle = \frac{N_{event}}{L \cdot \Delta M_{JJ}} \times \frac{C_{unsmear}}{\varepsilon_{eff}}$$

- Data sample:
  - L ~ 143pb^{-1}
  - $|y_{jet}| < 0.5$
  - $\Delta R = 0.7$ cone jets
- Probe for QCD, quark compositness, ressonances ...
- Agreement with NLO QCD(JETRAD) over 6 orders of magnitude



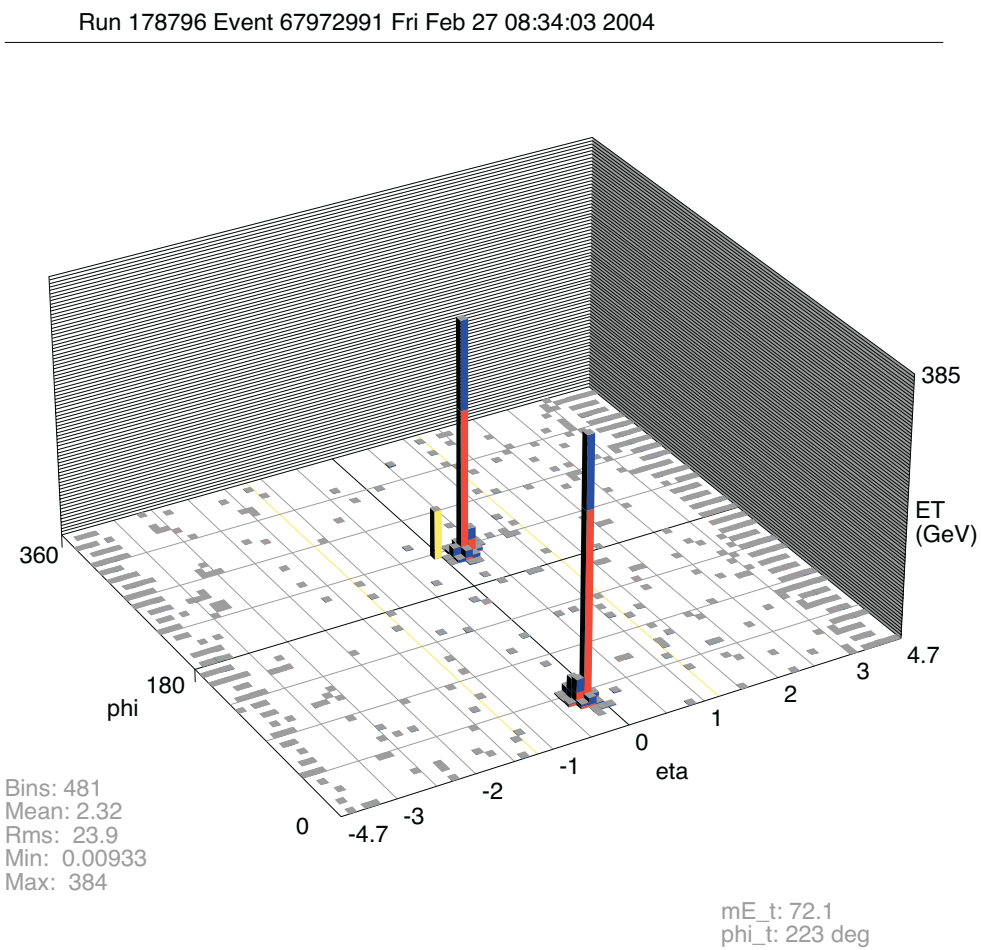
Dijet Cross Section

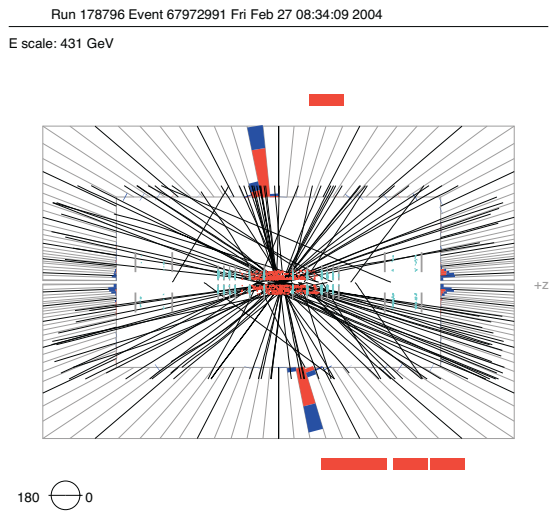
- Systematic uncertainty dominated by jet energy scale

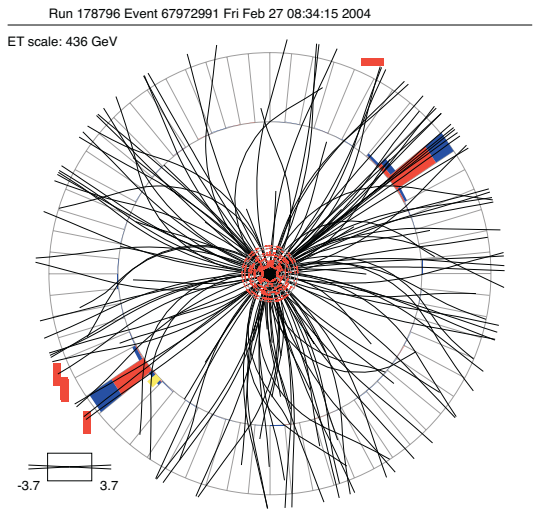


Highest Mass Dijet Event

Dijet mass M_{JJ} = 1206 GeV



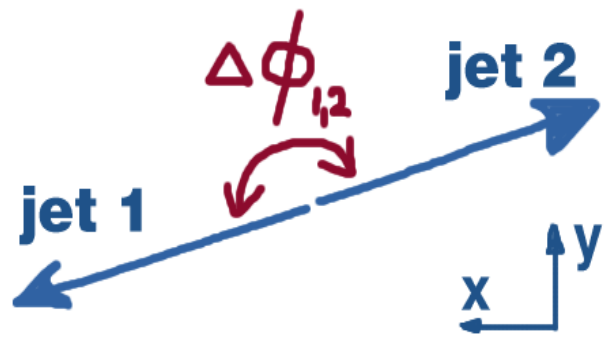




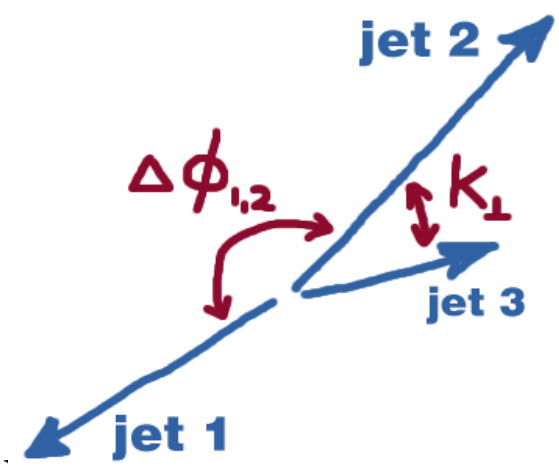
Dijet Azimuthal Decorrelations

- In 2→2 scattering, partons emerge back-to-back
- Additional radiation introduces decorrelation in ΔΦ between the two leading partons(jets)
- ΔΦ distribution is sensitive to higher-order QCD radiation without explicitly measuring a third jet

Dijet production in LO pQCD

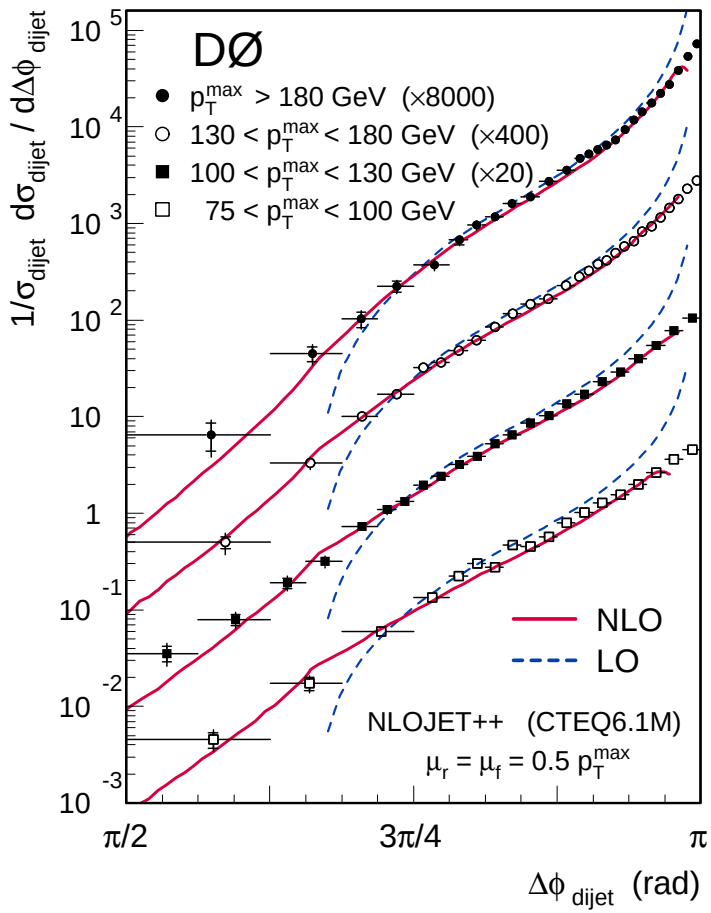


3-jet production in LO pQCD



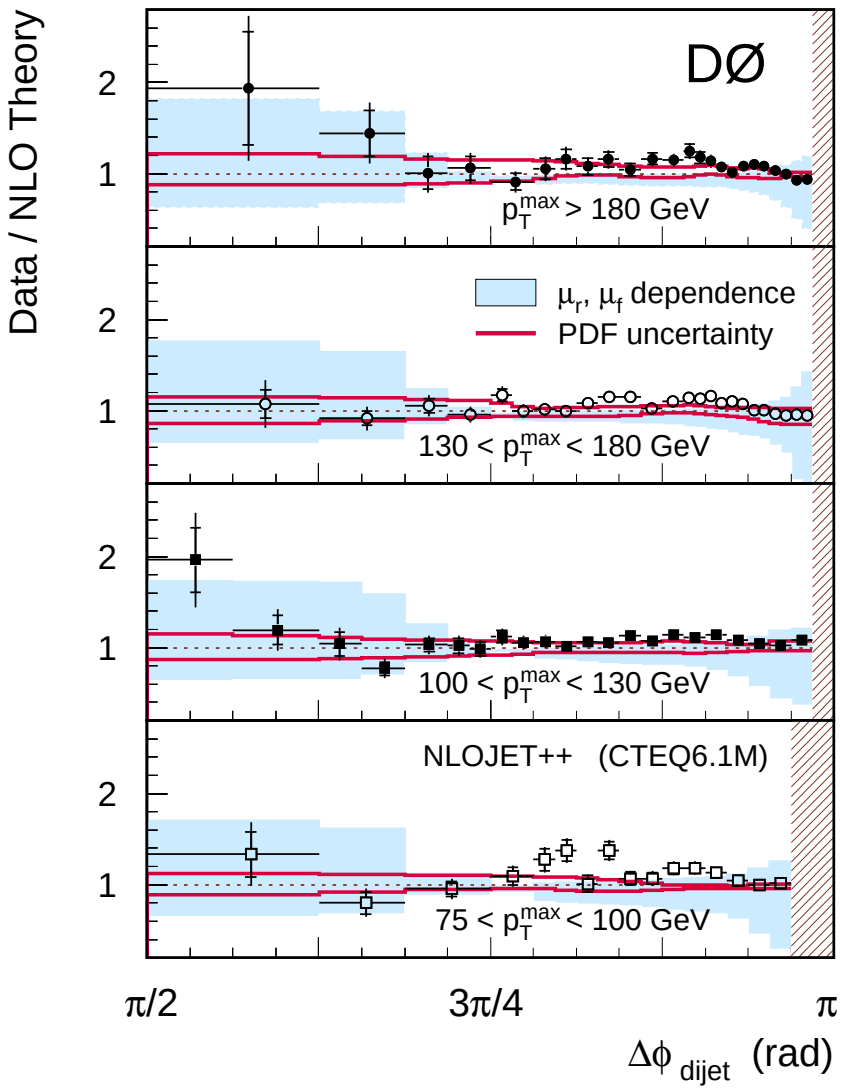
ΔΦ: Comparison to Fixed-Order pQCD

$$\frac{1}{\sigma_{\text{dijet}}} \cdot \frac{d\sigma_{\text{dijet}}}{d\Delta\Phi}$$



- ΔΦ distribution has reduced sensitivity to jet energy scale
- Data set ~150 pb^{-1}
  - Central jets |y| < 0.5
  - Second-leading jet p_T > 40 GeV
- **Leading order (dashed blue curve)**
  - Divergence at ΔΦ = π dominated by soft processes => resummation needed
  - No phase-space at ΔΦ<2π/3 (only three partons)
- **Next-to-leading order (red curve)**
  - Good description except at large ΔΦ => resummation needed

ΔΦ: Comparison to Fixed-Order pQCD

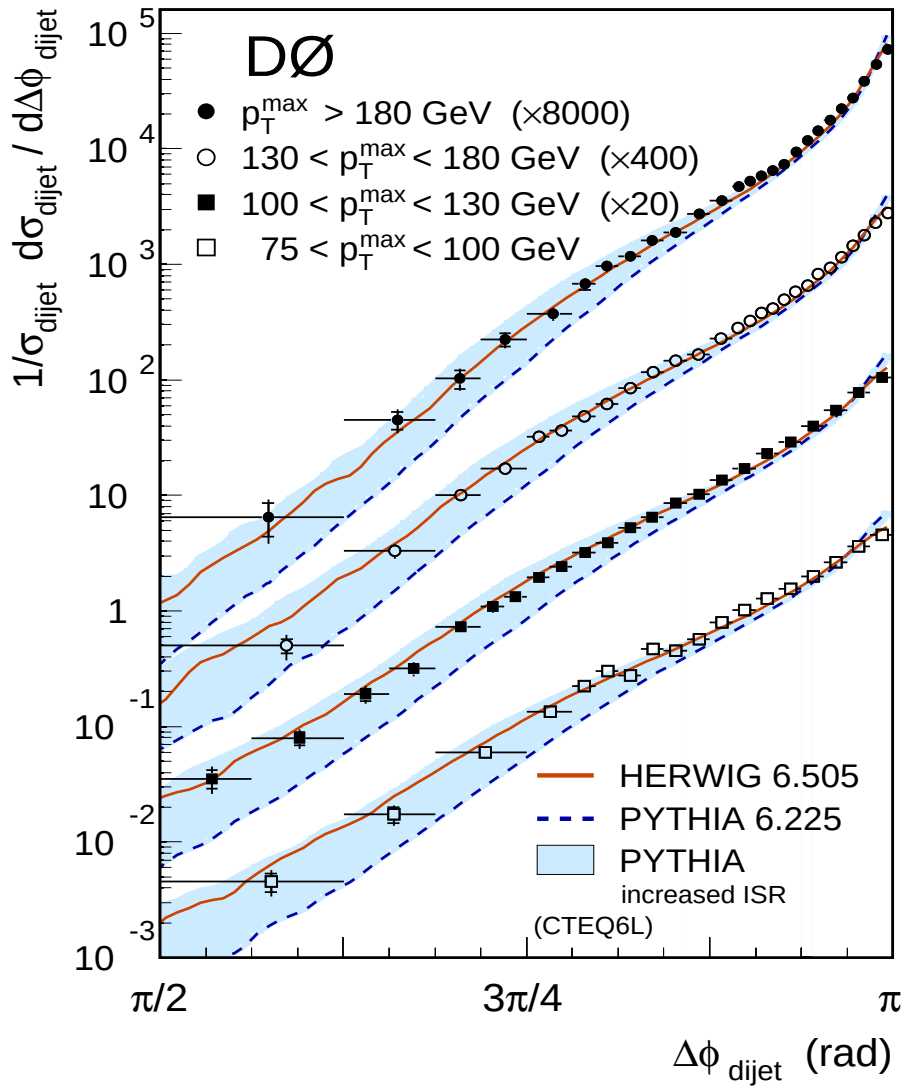


- Data at large ΔΦ excluded because calculation is non-physical near the divergence at π

- Large scale dependency near ΔΦ=2π/3 since NLO calculation only receives contribution from tree-level four parton final states in this regime

ΔΦ: Comparison to Parton Shower MC

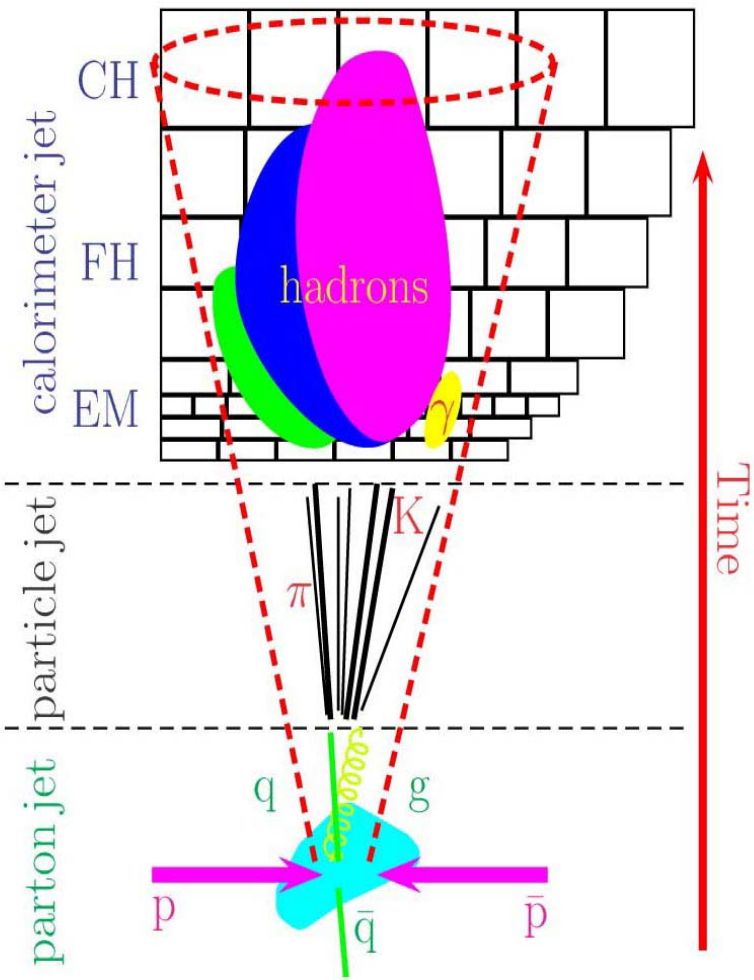
- Herwig 6.505 (default)
  - Good overall description!
  - Slightly high at intermediate ΔΦ
- Pythia 6.223 (default)
  - Very different shape
  - Too strongly peaked
  - Underestimates low ΔΦ(5x)
- ΔΦ distribution is sensitive to the amount of initial-state radiation
  - Plot shows in blue the variation of Pythia's PARP(67) from 1.0 (default) to 4.0 (Tune A)
  - With more ISR Pythia is much closer to data (2.5 gives best fit)



Summary

- Tevatron Run II program is on the way (present results corresponds to L ~150pb^{-1})
- Inclusive and dijet cross section have a larger reach than Run I due to larger statistics
- Good agreement between theory and data (large systematics due to energy scale)
- With more statistics, our large energy scale uncertainties will come down
- Dijet azimuthal decorrelations allows a direct test of three-jet NLO QCD

Jets



- Our model says the hard interaction occurs between partons. The resulting partons constitute the "parton jet"
- Partons hadronize and turn into observable particles, like π and K, which constitute the "particle jet"
- Our data is a "calorimeter jet" made of energy deposition in the detector
- We correct to the energy of the calorimeter jet to match it to particle jets