QCD dijet analyses at DØ

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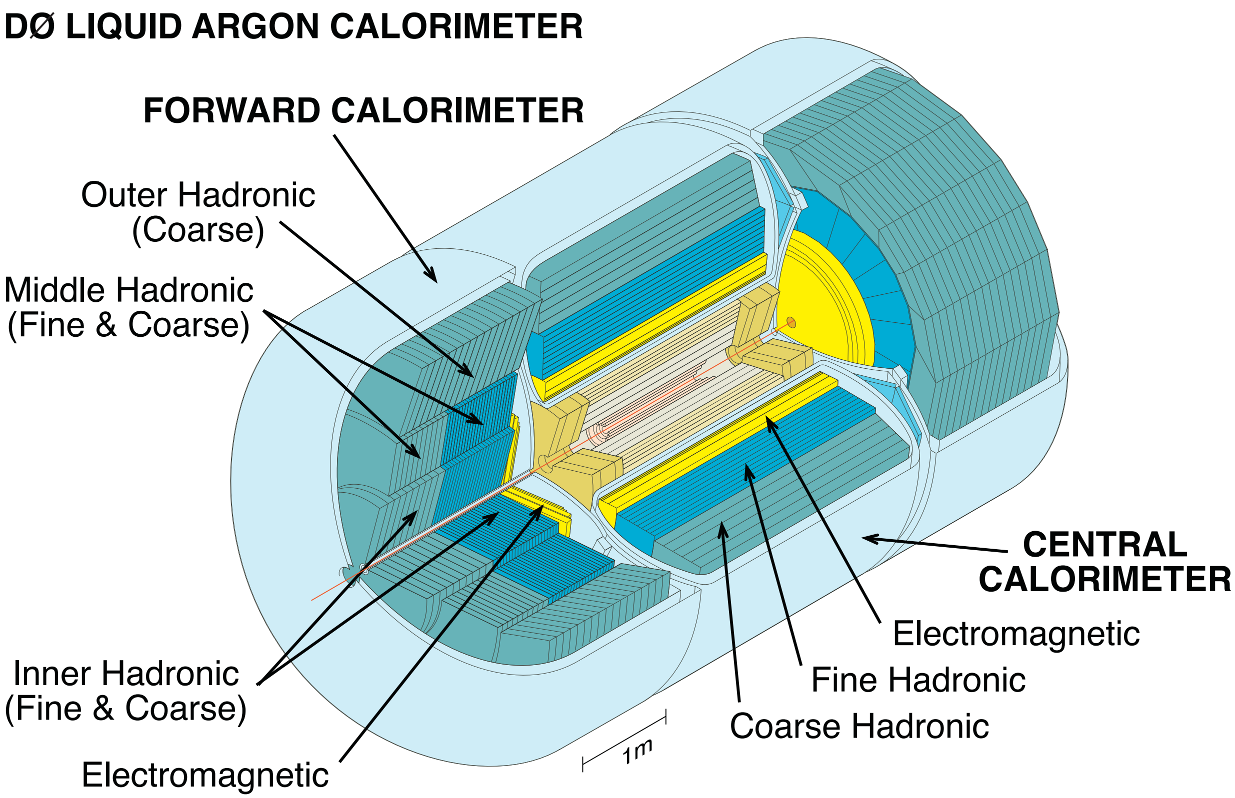
Contents:

- DØ detector
- Jet reconstruction at DØ
- Dijet mass spectrum
- Dijet azimuthal angle decorrelation

XII International Workshop on Deep Inelastic Scattering

DØ Calorimeter



- uniform and hermetic
- full coverage up to $|\eta| < 4.2$
- compensating ($e/\pi \sim 1$)
- fine segmentation:
  $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$
  at EM shower max: 0.05×0.05

- Changes from Run I $\longrightarrow$ Run II:
  - shorter time between bunch crossings (396 ns)
    $\Rightarrow$ faster trigger and readout electronics
  - more material in front of calorimeter (magnet, new tracker)
    $\Rightarrow$ new preshower detector

Jets reconstruction at DØ

- Clusters:
  - Use Run II cone algorithm (G.C. Blazey et al., hep-ex/0005012)
  - Combine particles in a $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ cone
  - Use the 4-vector of every tower with $E_T > 0.5$ GeV as a seed
  - Rerun using the midpoints between pairs of jets as seeds
  - Overlapping jets merged if the overlap area contains more than 50 % of lower p_T jet, otherwise particles assigned to nearest jet
- E-scheme recombination:
  - summing 4-vectors of particles
  - massive jets

$$y^J = \frac{1}{2} \ln \frac{E^J + p_z^J}{E^J - p_z^J} \qquad \phi^J = \tan^{-1} \frac{p_y^J}{p_x^J}$$

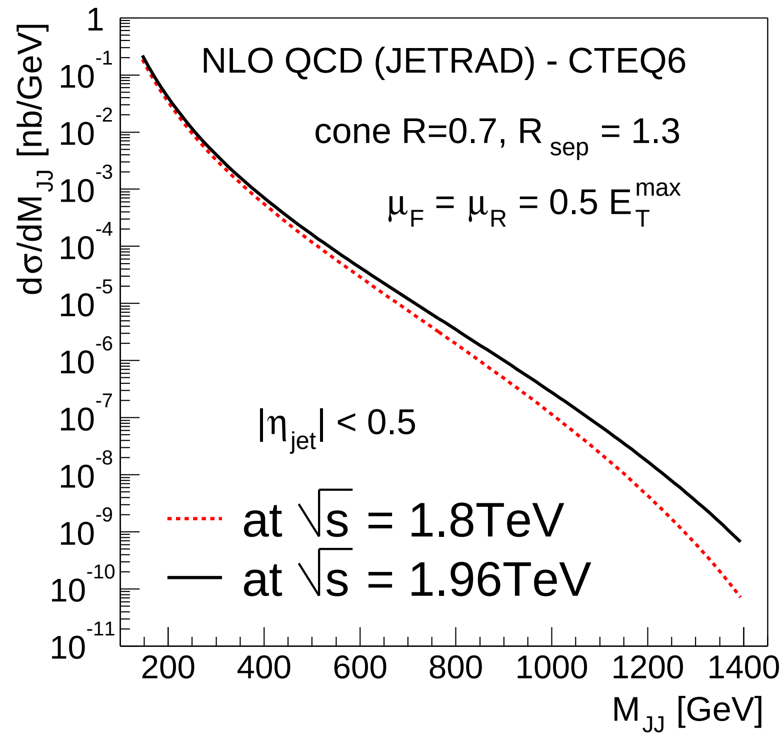
Jet energy scale at DØ

- Correction of the jet energy measured on the detector level to the jet energy on the particle level
  - Offset ($\mathcal{O}$) – energy not associated with the hard interaction (U noise, previous events, additional $p\bar{p}$ interaction)
  - Response (R_{jet})
    - calorimeter response to the jet
    - EM part calibrated on $Z \longrightarrow ee$ mass peak
    - measured from E_T balance in $\gamma +$ jet events
    - measured for energies up to ≈ 250 GeV
  - Showering (S) – losses due to showering the energy in the calorimeter out of the jet cone

$$E_{ptcl}^{jet} = \frac{E_{det}^{jet} - \mathcal{O}}{R_{jet} \cdot S}$$

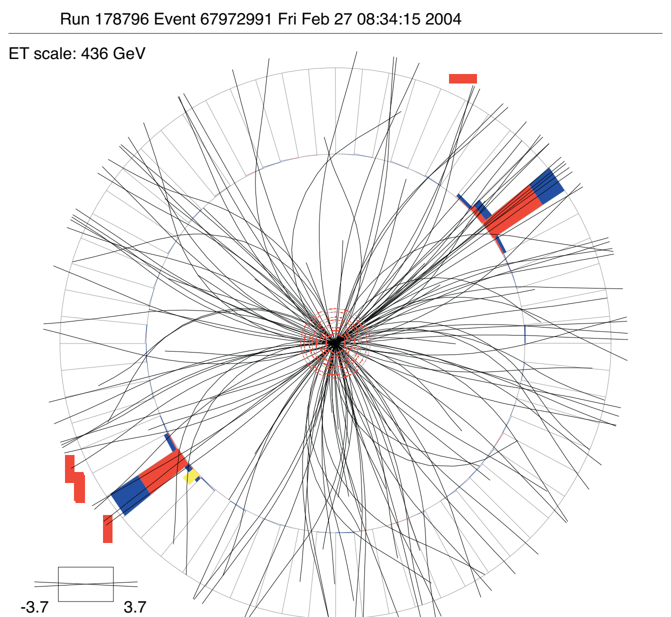
Dijet mass measurement

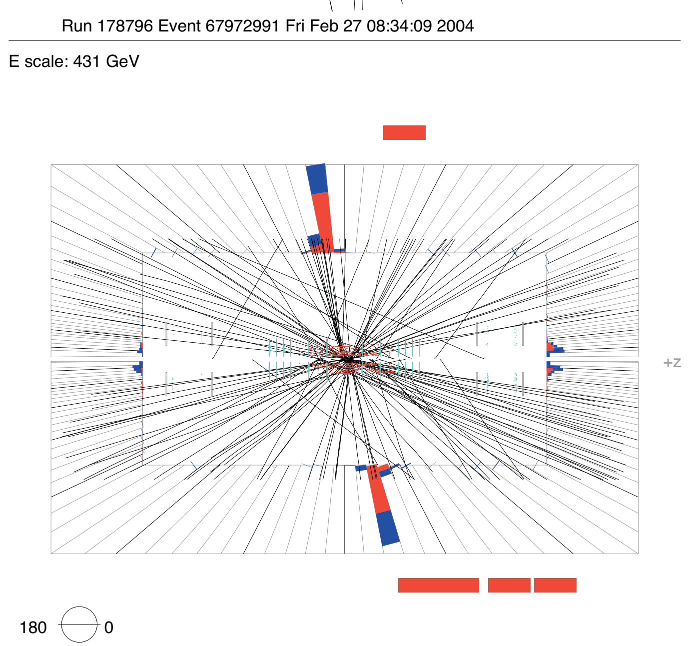
- probe of
  - QCD
  - proton structure at large x
  - resonances existence
  - quark compositeness
- sample definition:
  - $\mathcal{L} \approx 143\ \mathrm{pb}^{-1}\ (\pm 6.5\,\%)$
  - $R = 0.7$ cone jets
  - $|y_{\mathrm{jet}}| < 0.5$

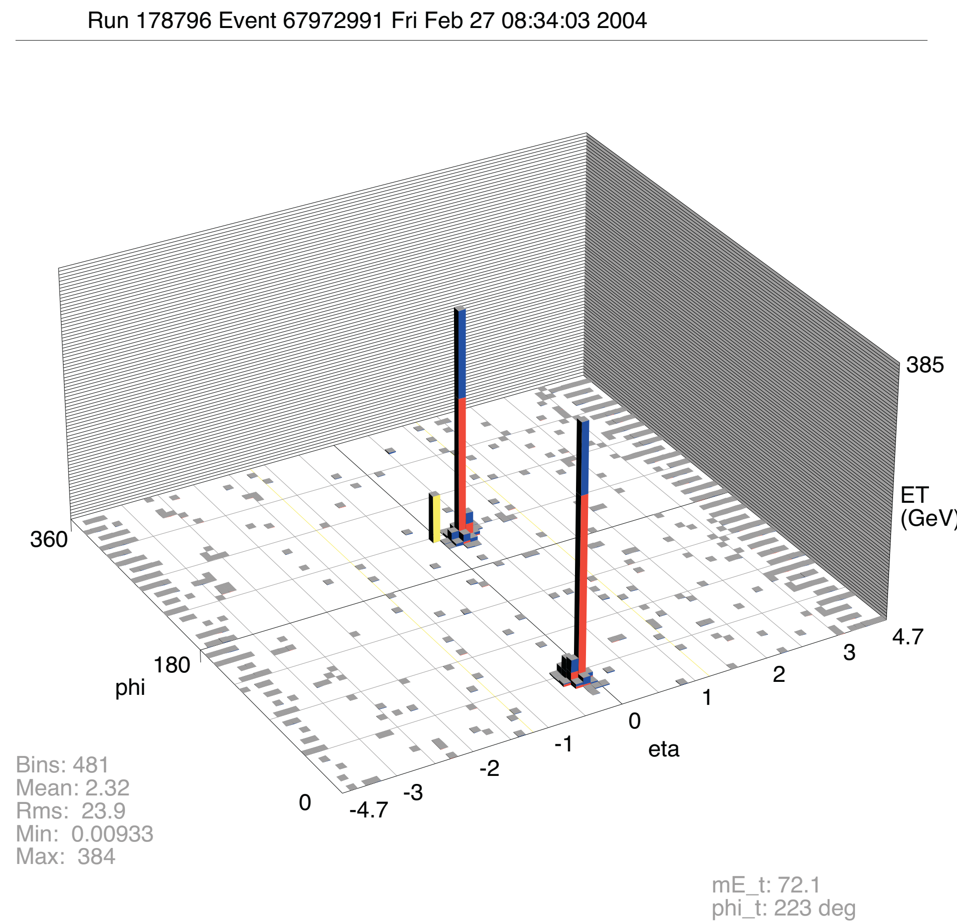


- Jet selection $\varepsilon \approx 98\,\%$:
  based on jet energy fraction in EM and Had. parts of the calorimeter
- Vertex selection $\varepsilon \approx 80\,\%$:

Highest dijet mass event

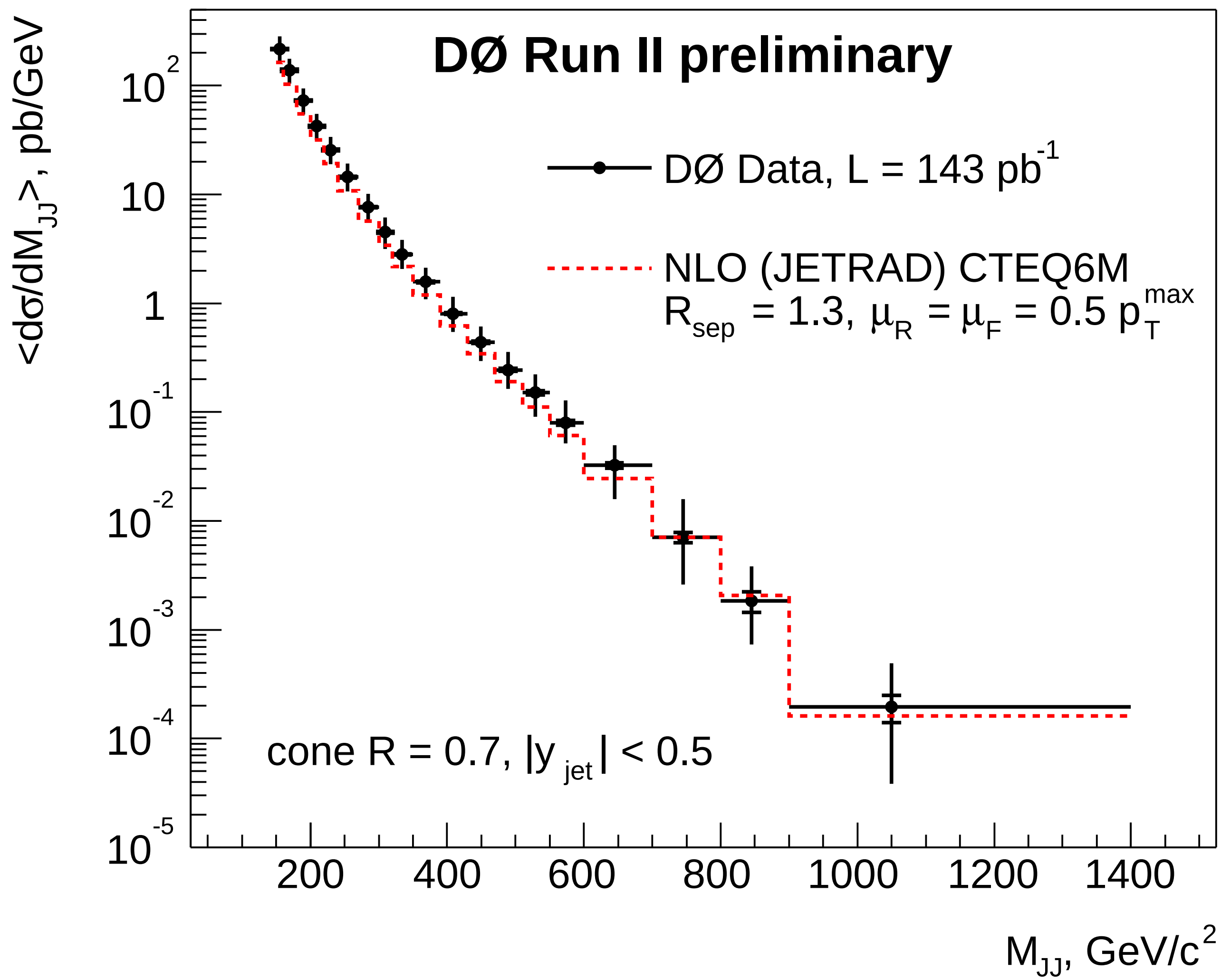






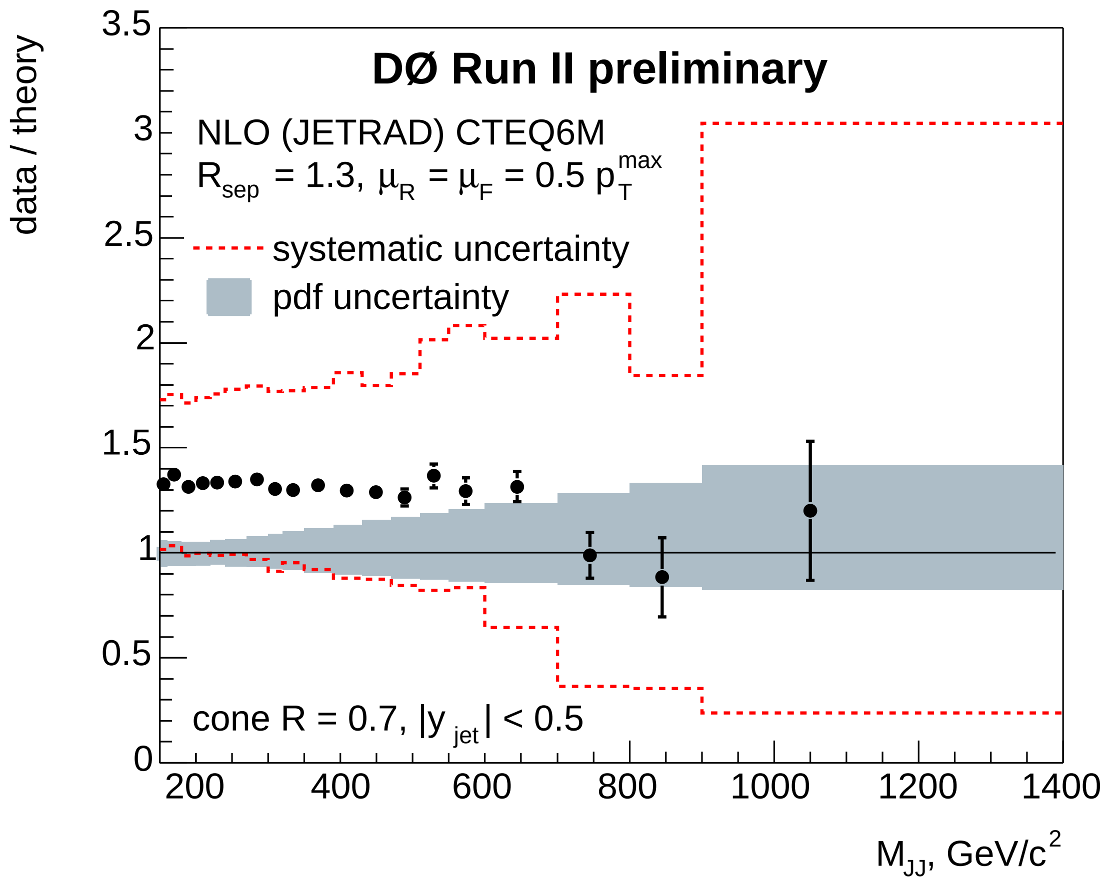
jet_1	jet_2
$p_T = 616$ GeV/c $\eta = -0.19$ $\phi = 0.65$	$p_T = 557$ GeV/c $\eta = 0.25$ $\phi = 3.78$
$M_{J_1 J_2} = 1206$ GeV/c^2	

Dijet cross section: result



NLO pQCD is in agreement with the measurement over 7 orders of magnitude

Dijet cross section: compare to NLO

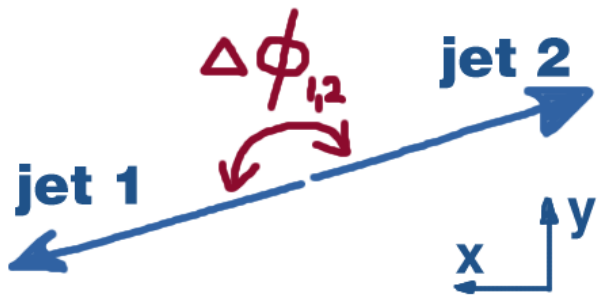


- NLO pQCD calculations agree with the data within uncertainty
- systematic uncertainty is dominated by jet energy scale uncertainty:
  - 150 – 160 GeV: $+30\,\%$ $-23\,\%$
  - 800 – 1400 GeV: $+120\,\%$ $-68\,\%$

Dijet azimuthal angle decorrelation

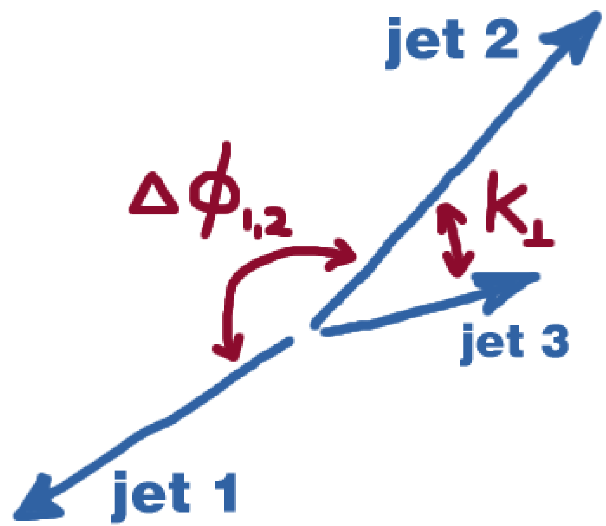
- $\Delta\phi$ between two leading jets provides a clean laboratory for testing QCD
- simple to define and understand
- much easier to measure a jet direction than its energy
- $\Delta\phi$ distribution is directly sensitive to higher-order QCD radiation without explicitely measuring a third jet

Dijet production in lowest order pQCD:



p_T balance $\Rightarrow$ $\Delta\phi_{1,2} = \pi$

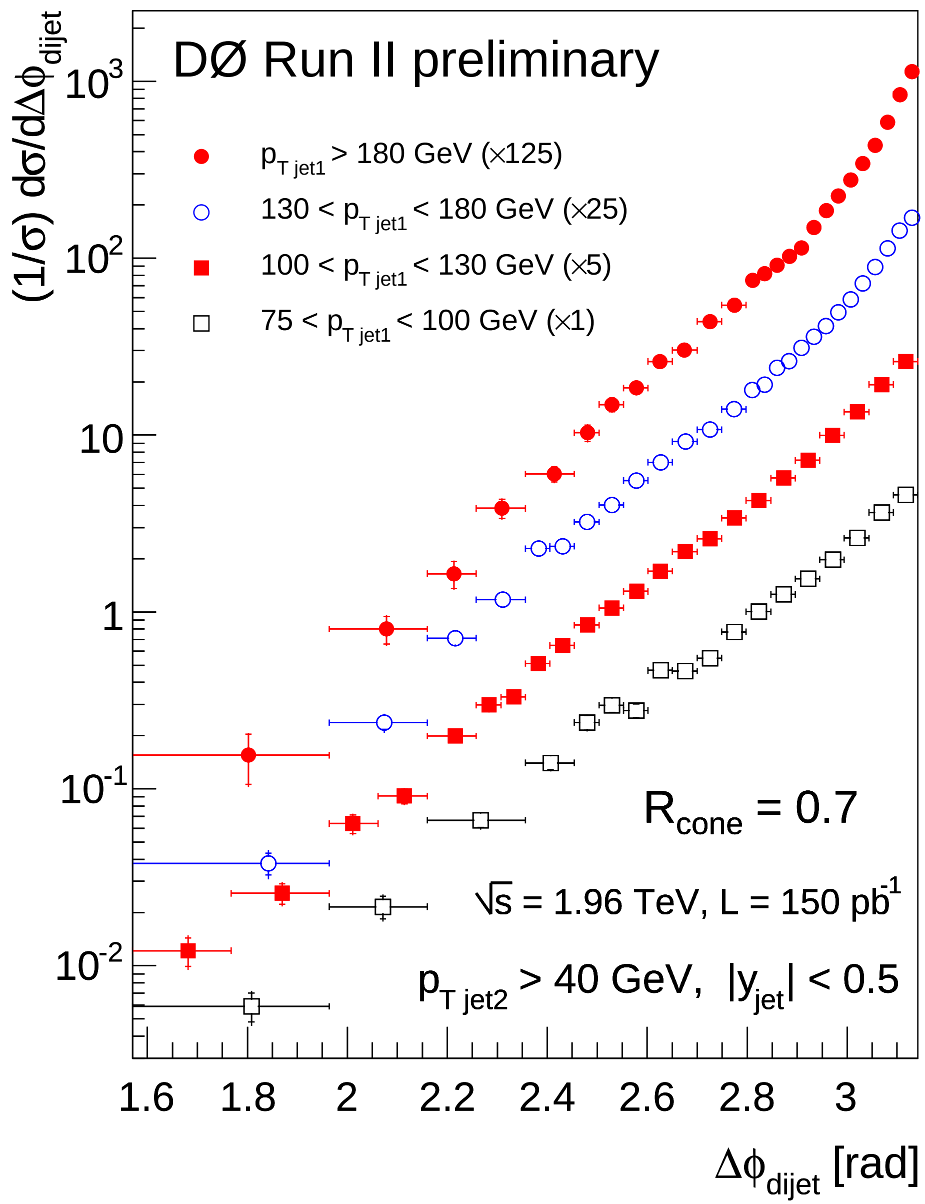
three-jet production in lowest order pQCD:



hard third jet: ($k_\perp$ large) $\Rightarrow$ $\Delta\phi_{1,2} << \pi$

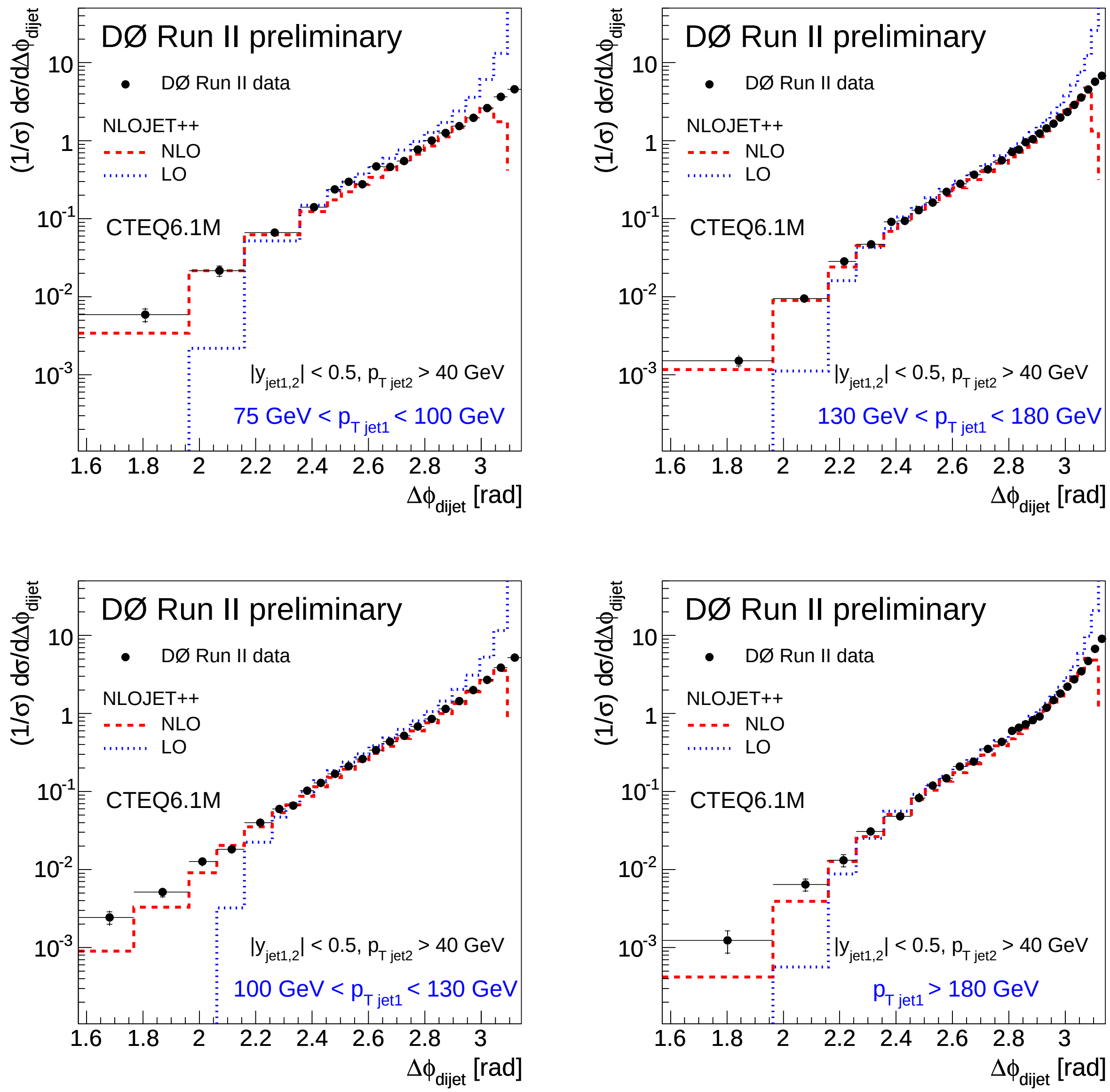
soft third jet: (divergence in LO pQCD)
($k_\perp \rightarrow 0$) $\Rightarrow$ $\Delta\phi_{1,2} \rightarrow \pi$

Dijet $\Delta\phi$ decorrelation: measurement



- dijet azimuthal angle defined as $\Delta\phi = |\phi_{jet1} - \phi_{jet2}|$
- the $\Delta\phi$ distribution measured only for $\Delta\phi > \pi/2$ to avoid $\Delta\phi \lesssim 2 \cdot R_{\rm cone}$ (overlapping jets)
- change in the shape of the $\Delta\phi$ distribution
- proportion of back-to-back jets is higher for higher p_T

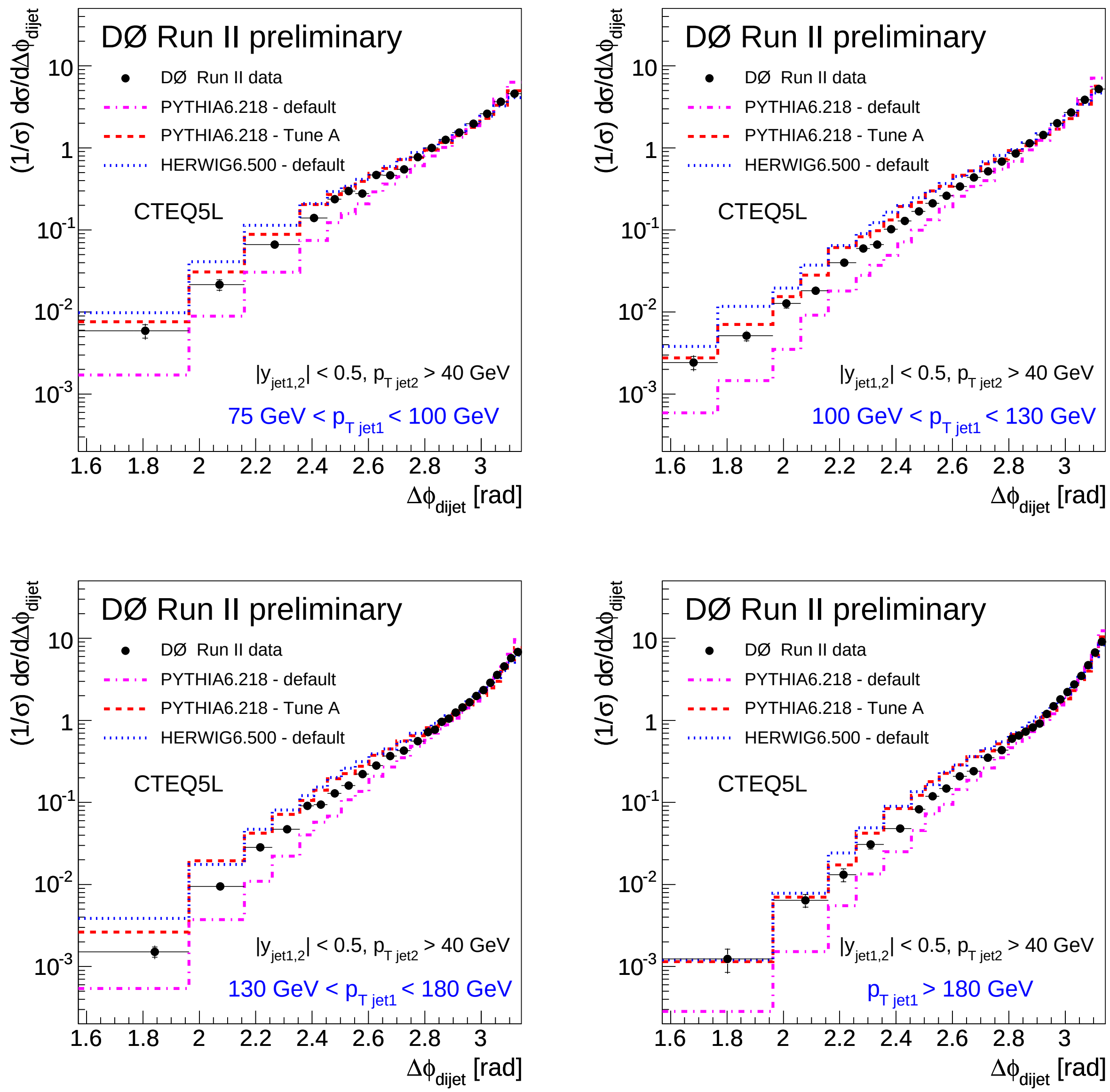
Dijet $\Delta\phi$ decorrelation: compare to LO



- poor overall description by LO
  - divergence towards $\Delta\phi \to \pi$ where third jet is soft: $p_T \to 0$
  - phase space limitation: $\Delta\phi > 2\pi/3$
- very good description by NLO

exceptions: extreme $\Delta\phi$ regions
  - large $\Delta\phi$: third and fourth jets are soft
  - small $\Delta\phi$: no hard phase space restriction, but still limited phase space for four-jet configurations

Dijet $\Delta\phi$ *decorrelation:* HERWIG, PYTHIA



- HERWIG & PYTHIA:
  - different implementations of parton shower
- default versions:
  - not good but reasonable description
  - also for extreme $\Delta\phi$: $\Delta\phi \to \pi/2$ and $\Delta\phi \to \pi$
- PYTHIA "tune A":
  - tuned to CDF data on the underlying event
  - significant improvement over default
  - still not as good as NLO in intermediate $\Delta\phi$ region

Summary

- Dijet mass measurement:
  - dijet mass distribution was measured for cone $R = 0.7$ jets in the central region of the calorimeter ($|y_{jet}| < 0.5$) using 143 pb^{-1} of the DØ Run II data
  - NLO pQCD calculations agree with the measurements within uncertainties
  - systematic uncertainty is dominated by jet energy scale uncertainty
- Dijet azimuthal angle decorrelation:
  - $\Delta\phi$ distribution was measured for cone $R = 0.7$ jets in the central region of the calorimeter ($|y_{jet}| < 0.5$) for four bins of leading jet p_T
  - **HERWIG** & **PYTHIA**, MC generators that model parton shower evolution describe the data better than LO pQCD and can be tuned to improve the agreement
  - NLO pQCD calculations give good description of the data but fails in the largest/smallest $\Delta\phi$ regions