QCD dijet analyses at DØ

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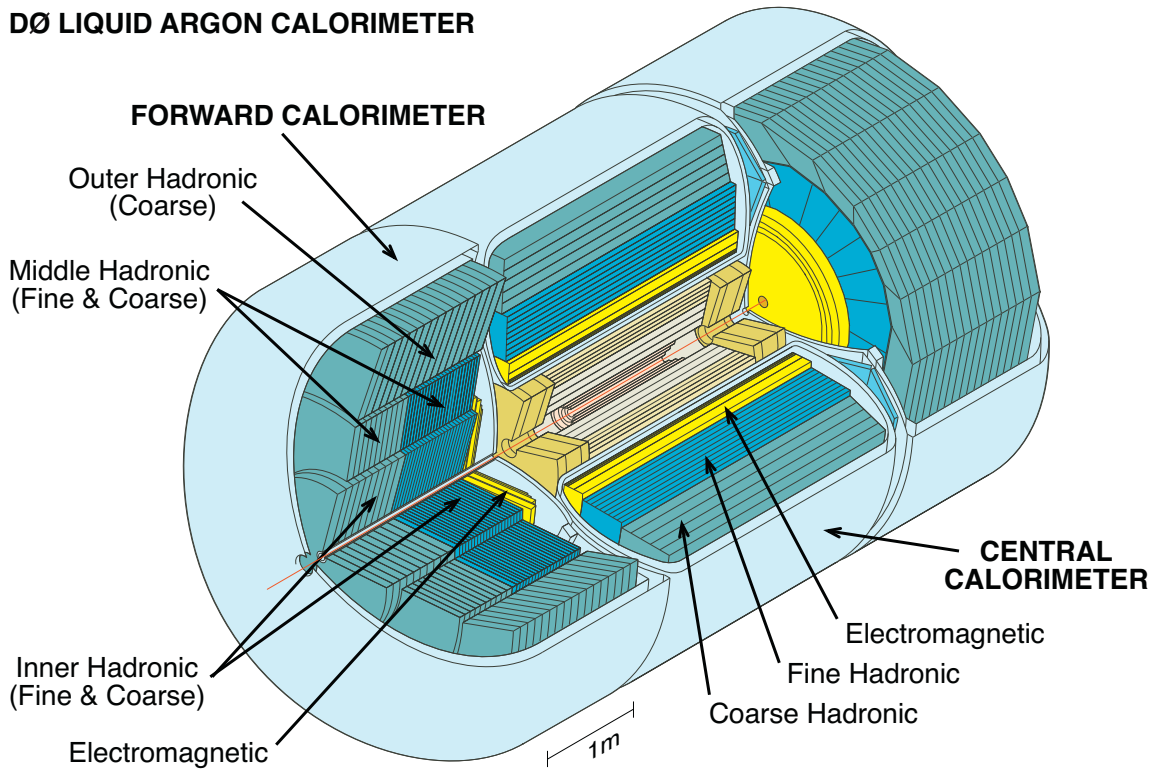
DØ Calorimeter



- uniform and hermetic
- coverage up to $|\eta| < 4.2$
- compensating ($e/\pi \sim 1$)
- fine segmentation:
  $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$
  (3rd EM layer: 0.05×0.05)

- Changes from Run I $\rightarrow$ 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 = 0.7 cone
  - Use the four vector of every tower 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
- Jets:
  - E-scheme recombination

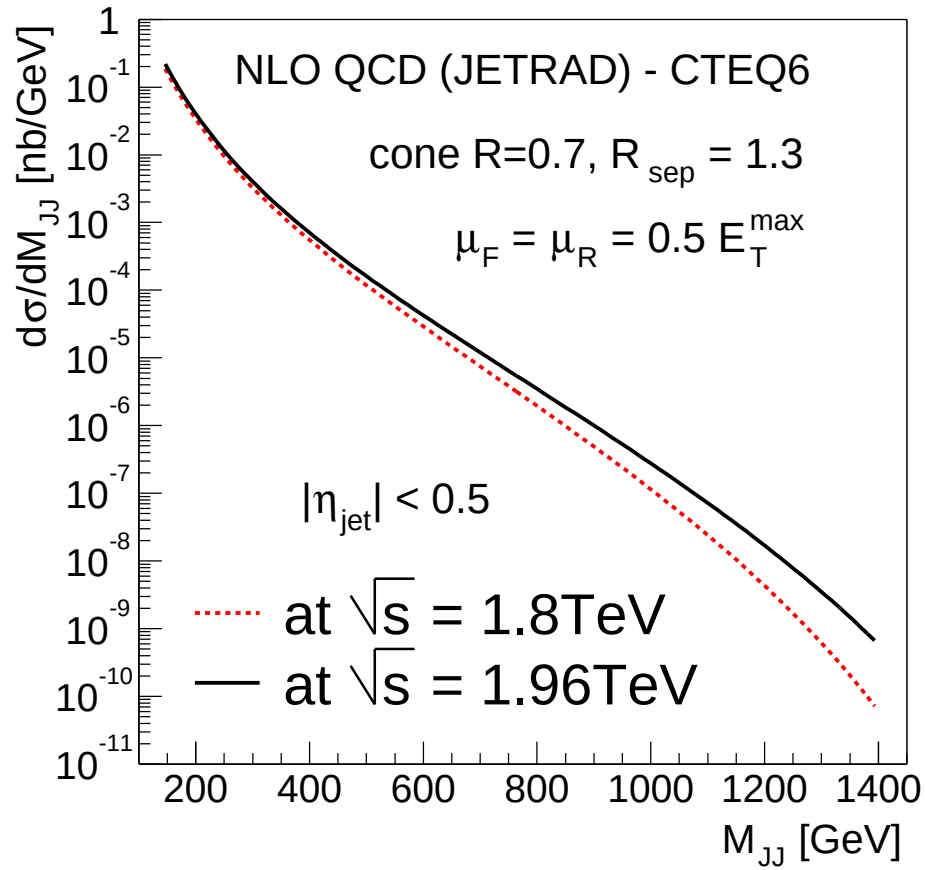
$$p^J = (E^J, \mathbf{p}^J) = \sum_{i \subset J = C} (E^i, p_x^i, p_y^i, p_z^i) \tag{1}$$

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

$$y^J = \frac{1}{2} \ln \frac{E^J + p_z^J}{E^J - p_z^J} \qquad \phi^J = \tan^{-1} \frac{p_y^J}{p_x^J} \tag{3}$$

Dijet mass measurement

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

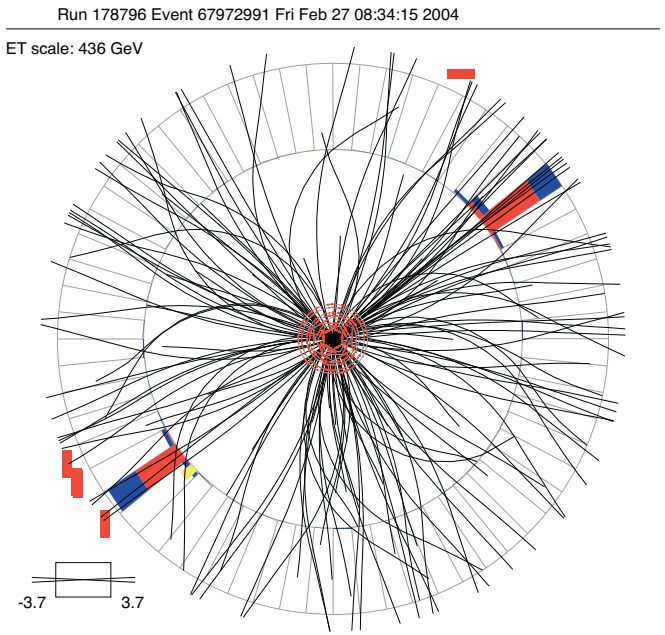


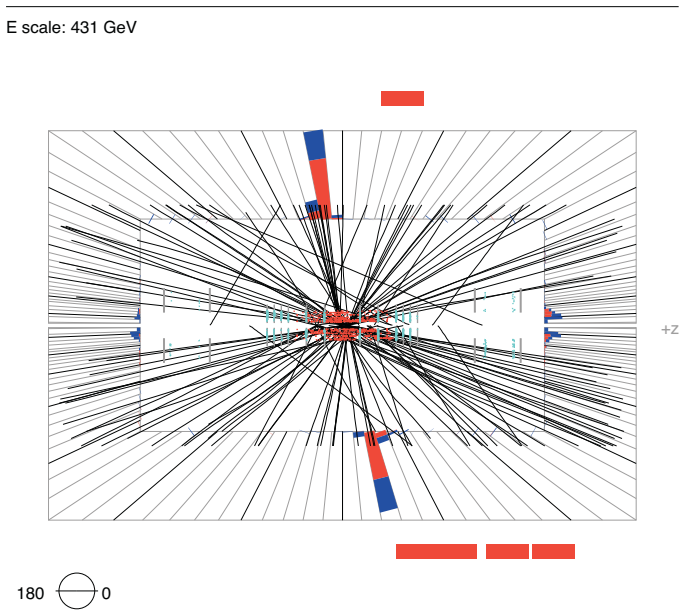
twice the σ at 1.96 TeV

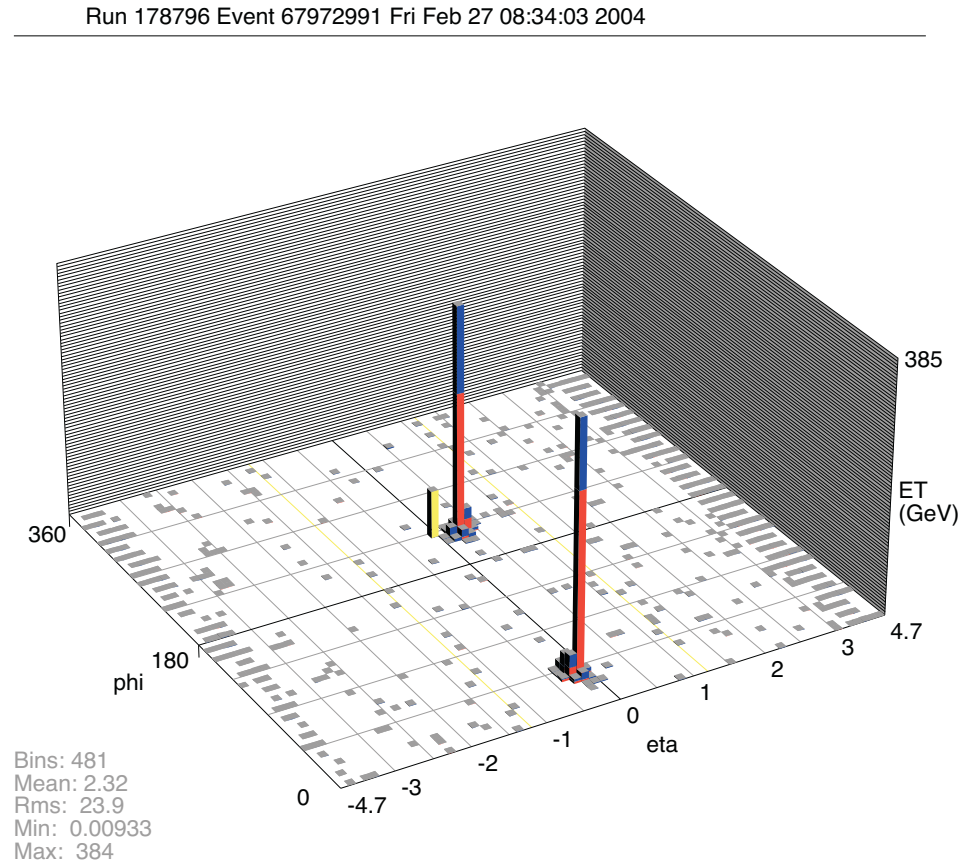
- master formula:

$$\left\langle \frac{\mathrm{d}\sigma}{\mathrm{d}M_{JJ}\mathrm{d}y} \right\rangle = \frac{N_{evt}}{L} \cdot \frac{C_{unsmear}}{\varepsilon_{eff}} \cdot \frac{1}{\Delta M_{JJ}\Delta y}$$

Highest dijet mass event

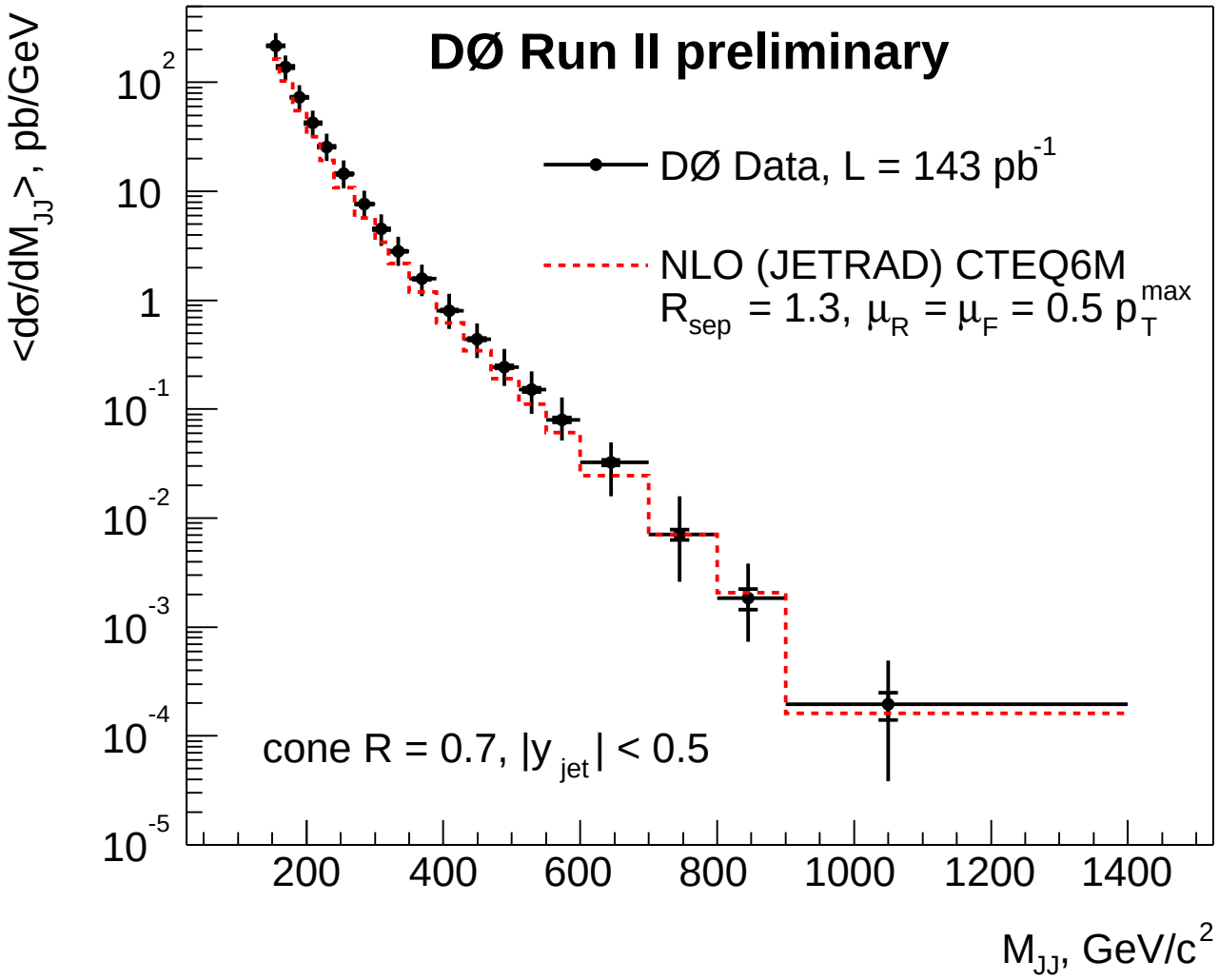






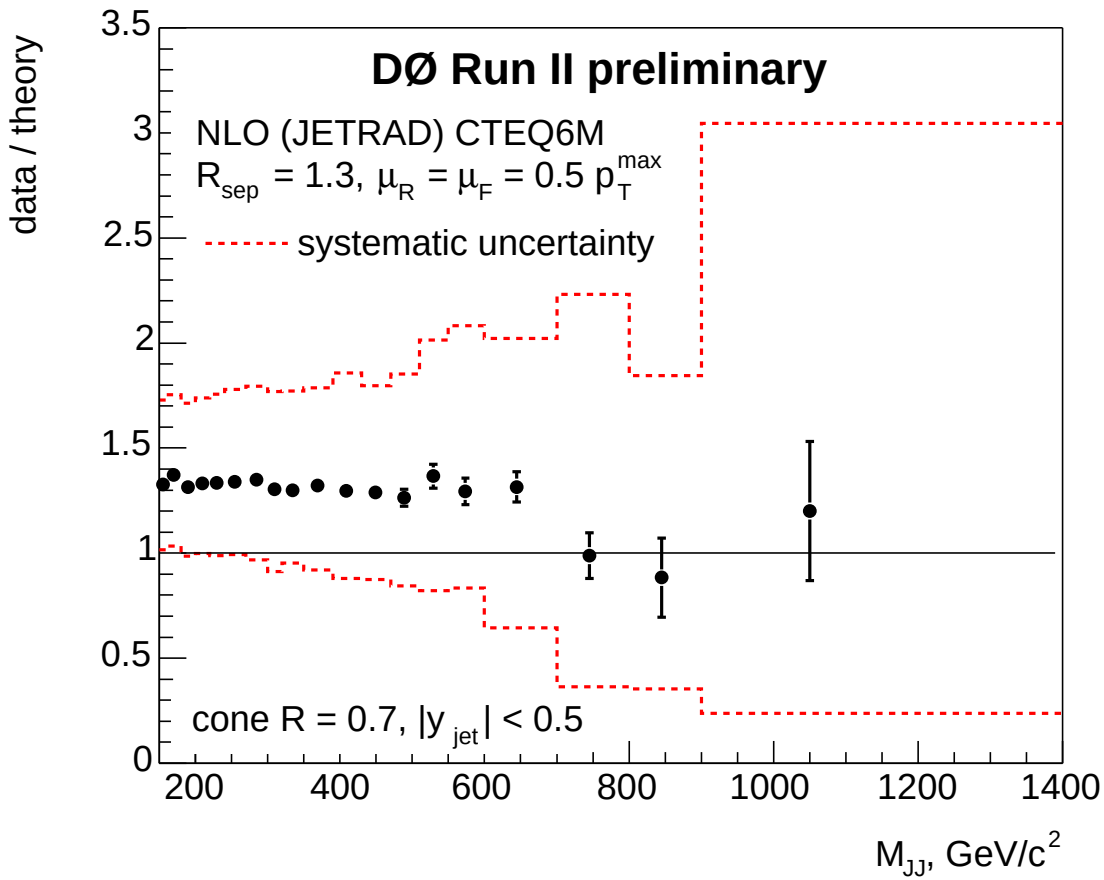
jet_1	jet_2
$p_T = 616$ GeV/c $\eta = -0.19$ $\phi = 0.65$	$p_T = 557$ GeV/c $\eta = 0.25$ $\phi = 3.78$
$m_{J_1 J_2} = 1206$ GeV/c^2	

Dijet cross section: result



agreement with NLO QCD over 7 orders of magnitude

Dijet cross section: compare to NLO

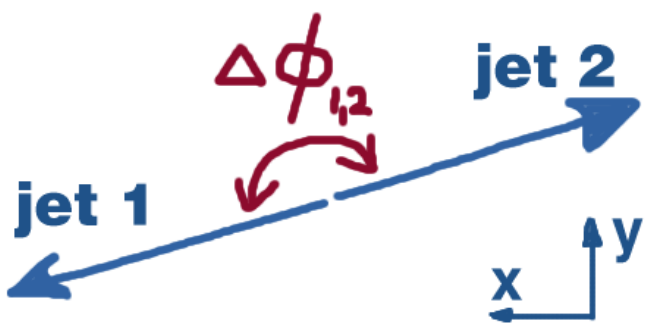


- agrees within uncertainty with NLO QCD calculations
- systematic uncertainty is dominated by jet energy scale error:
  - 150 – 160 GeV: $+30\,\%$ $-23\,\%$
  - 800 – 1400 GeV: $+120\,\%$ $-68\,\%$

Dijet azimuthal angle decorrelation

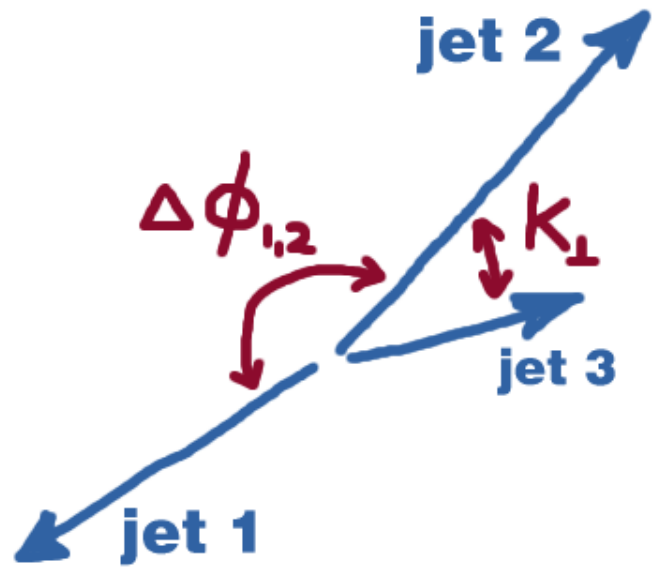
- $\Delta\phi$ between two leading jets provides a clean laboratory for testing QCD
- simple to define and understand
- much easier to measure a jet direction than its energy
- $\Delta\phi$ distribution is directly sensitive to higher-order QCD radiation without explicitely measuring a third jet

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)
($k_\perp \to 0$) $\Rightarrow$ $\Delta\phi_{1,2} \to \pi$

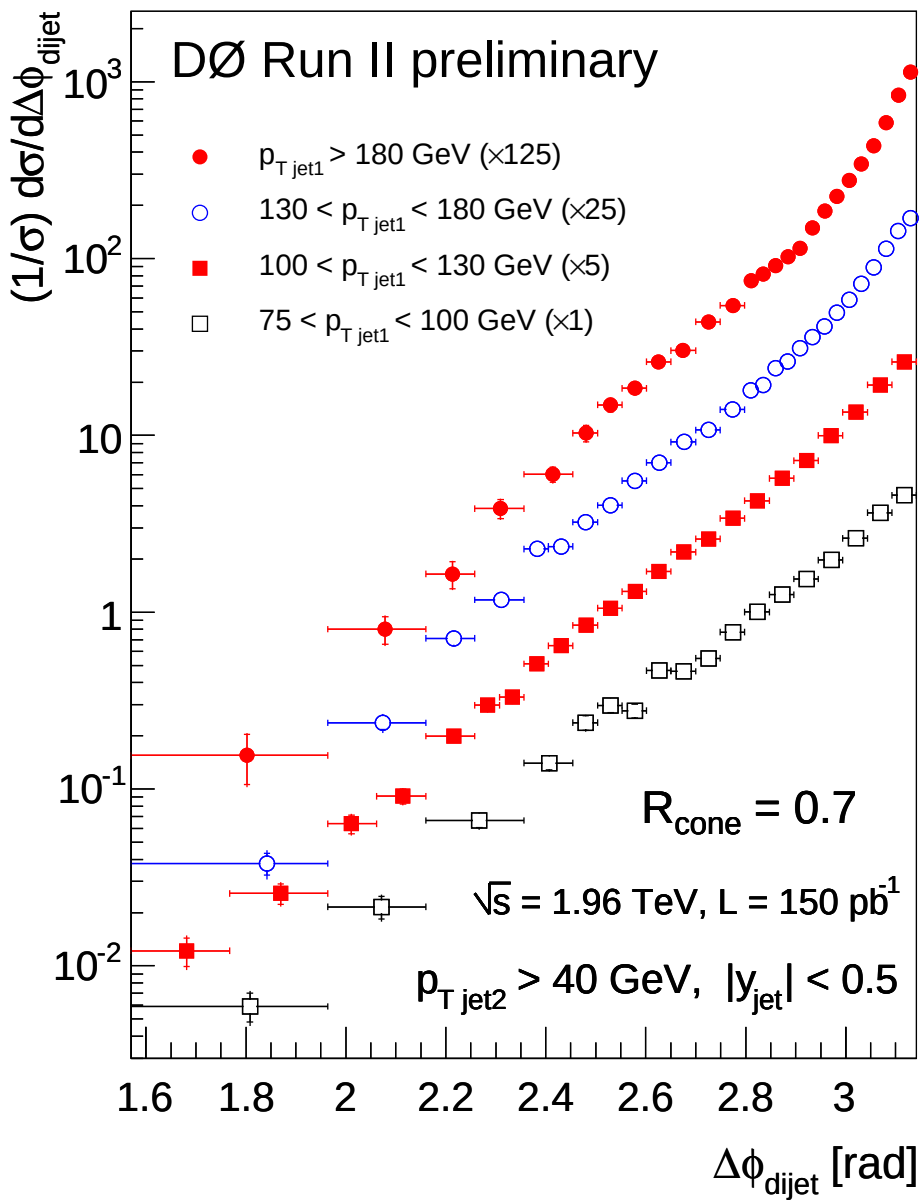
Dijet $\Delta\phi$ decorrelation: measurement

- dijet azimuthal angle defined as $\Delta\phi = |\phi_{jet1} - \phi_{jet2}|$
- master formula for the $\Delta\phi$ distribution

$$\frac{1}{N}\left\langle\frac{\mathrm{d}N}{\mathrm{d}\Delta\phi}\right\rangle_{bin} = \frac{1}{\sum_{bins} C_i \tilde{N}_i} \cdot \frac{C_{bin}\tilde{N}_{bin}}{\Delta\phi_{bin\ width}}$$

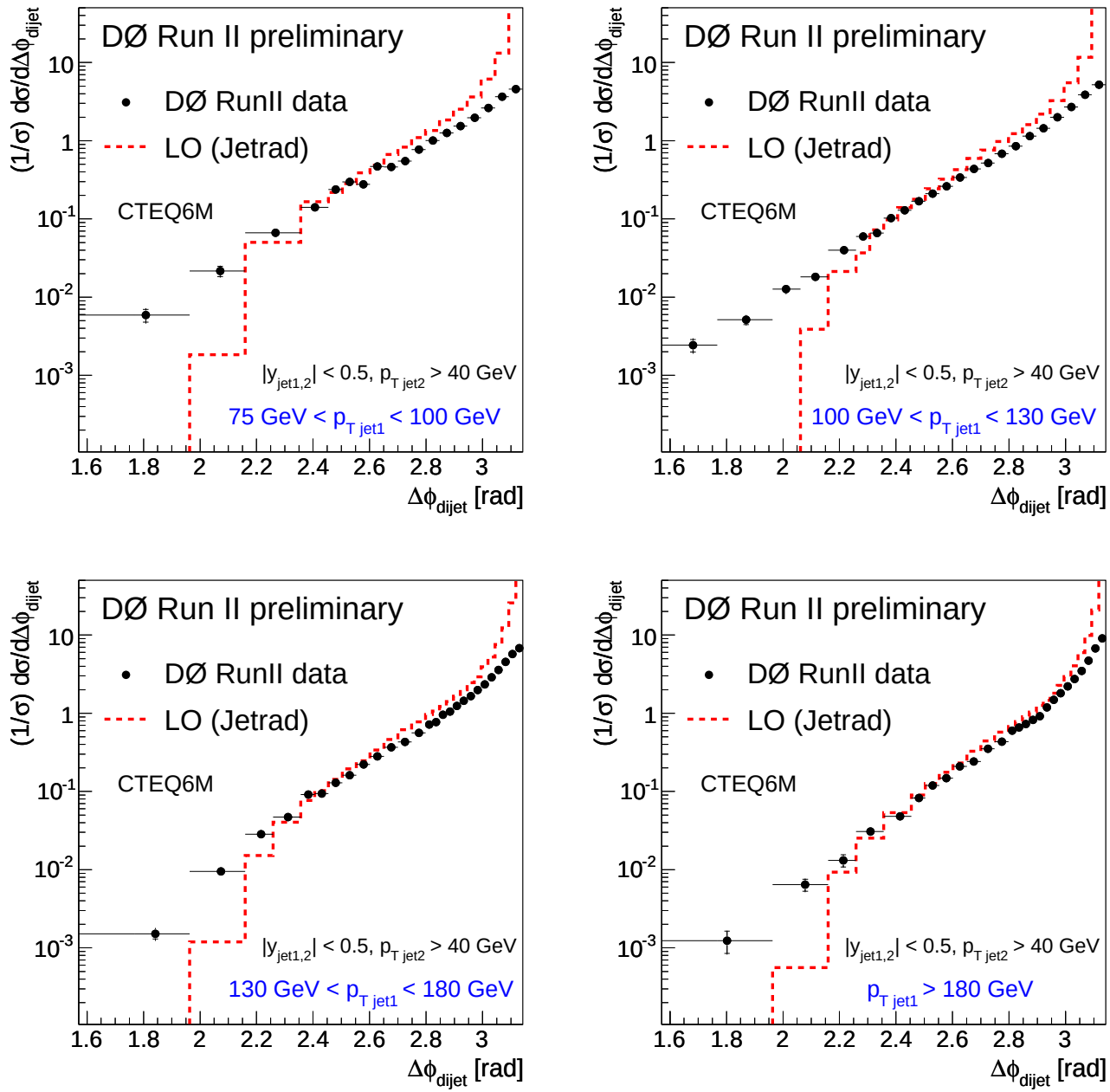
  - $\Delta\phi_{bin\ width}$ – $\Delta\phi$ bin width
  - $\tilde{N}_{bin}$ – sum of number of events corrected for efficiency
  - C_{bin} – unfolding correction
- the $\Delta\phi$ distribution measured only for $\Delta\phi > \pi/2$
  - to avoid $\Delta\phi \lesssim 2 \cdot R_{\mathrm{cone}}$ (overlapping jets)

Dijet $\Delta\phi$ decorrelation: result



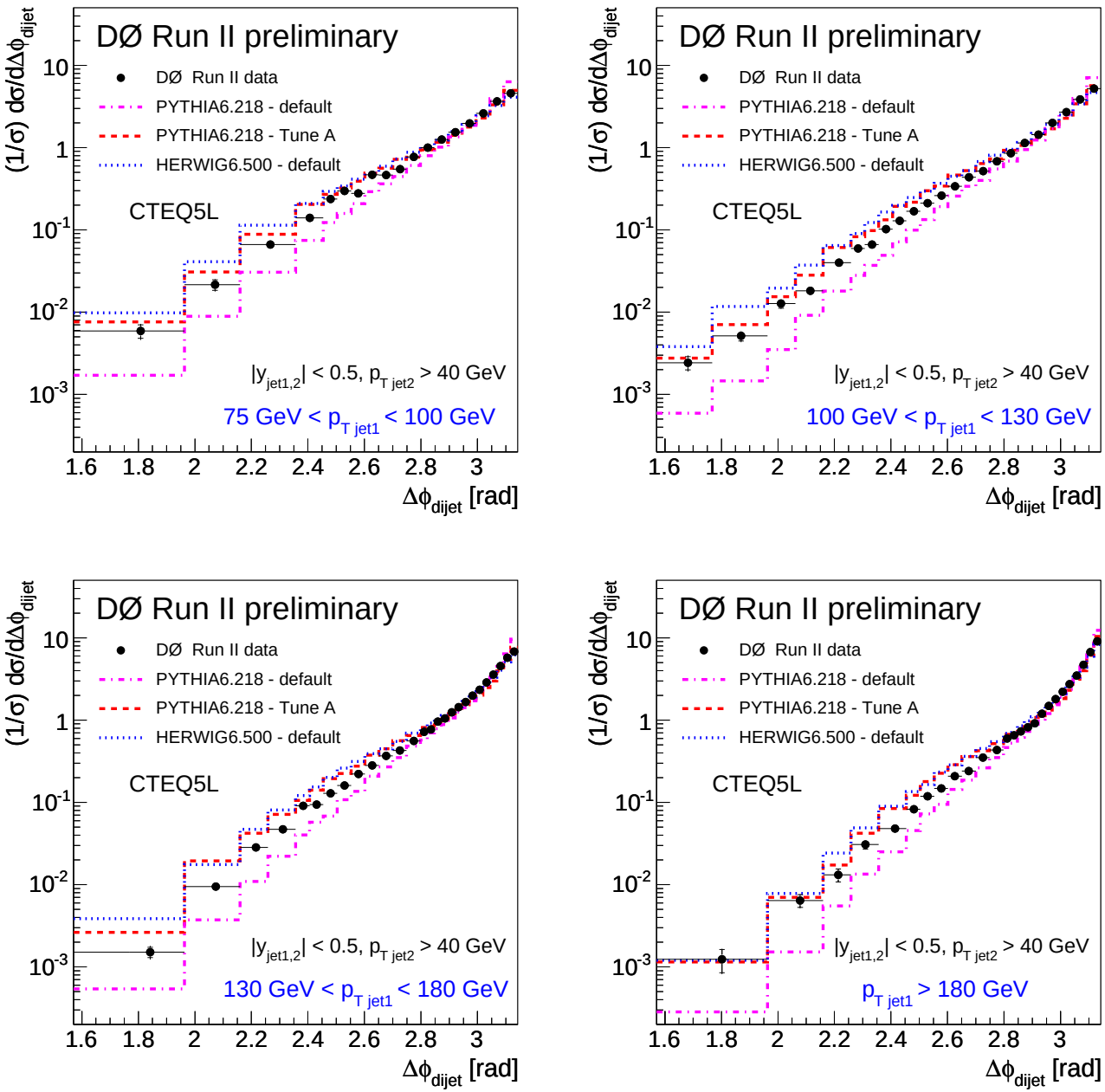
- change in the shape of the $\Delta\phi$ distribution
- proportion of back-to-back jets is higher for higher p_T

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



- JETRAD normalized by $\sigma_{\rm LO}$
- last bin at $\Delta\phi \sim \pi$ is poorly described by JETRAD
- poor fit to data at low p_T, better at higher p_T

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



- HERWIG & PYTHIA have better description
- PYTHIA "Tune A" reproduces data best

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
  - results agree within uncertainties with NLO QCD calculations
  - systematic uncertainty is dominated by jet energy scale error
- Dijet azimuthal angle decorrelation (first time at the Tevatron):
  - $\Delta\phi$ distribution was measured for cone $R = 0.7$ jets in the central region of the calorimeter ($|y_{jet}| < 0.5$) for four different bins of transverse momentum of the leading jet
  - `HERWIG` & `PYTHIA`, MC generators that models parton shower evolution, give better description of the data. However, the difference from the data is still significant
  - `PYTHIA` "Tune A" (by Rick Field) on the Run I data is reproducing data well