Recent QCD Results from DØ

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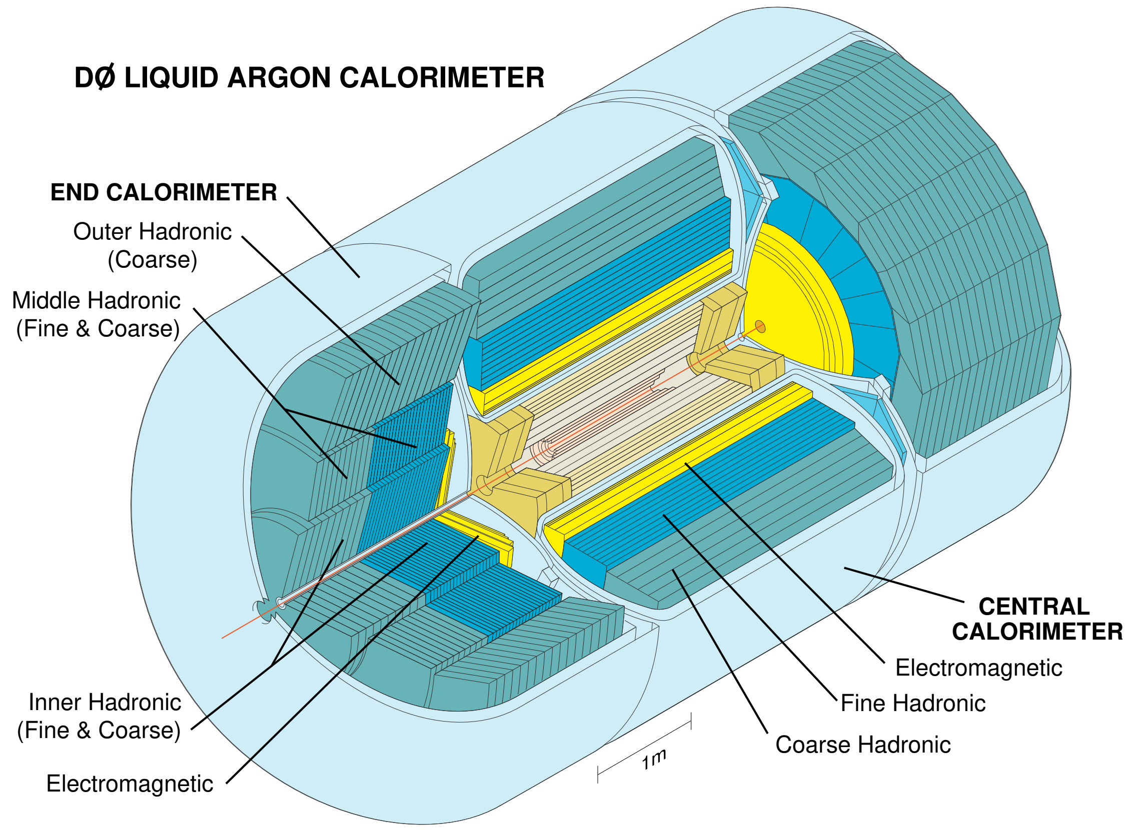
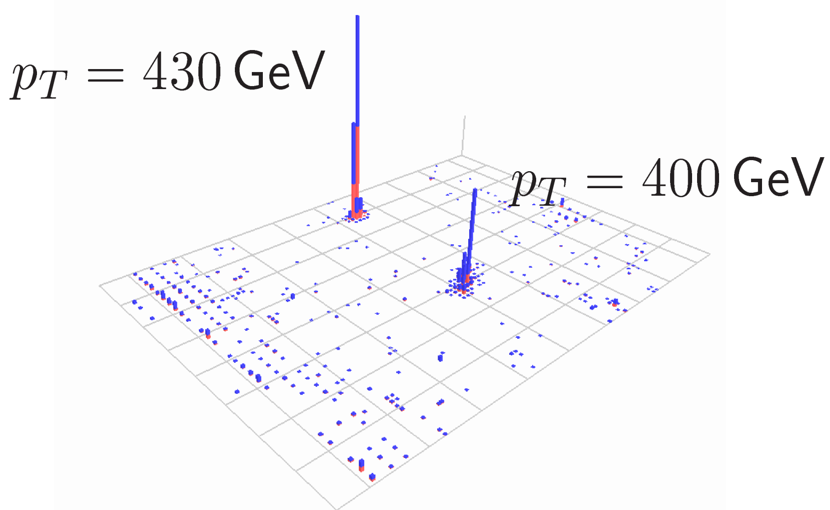
Calorimeter



- 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)



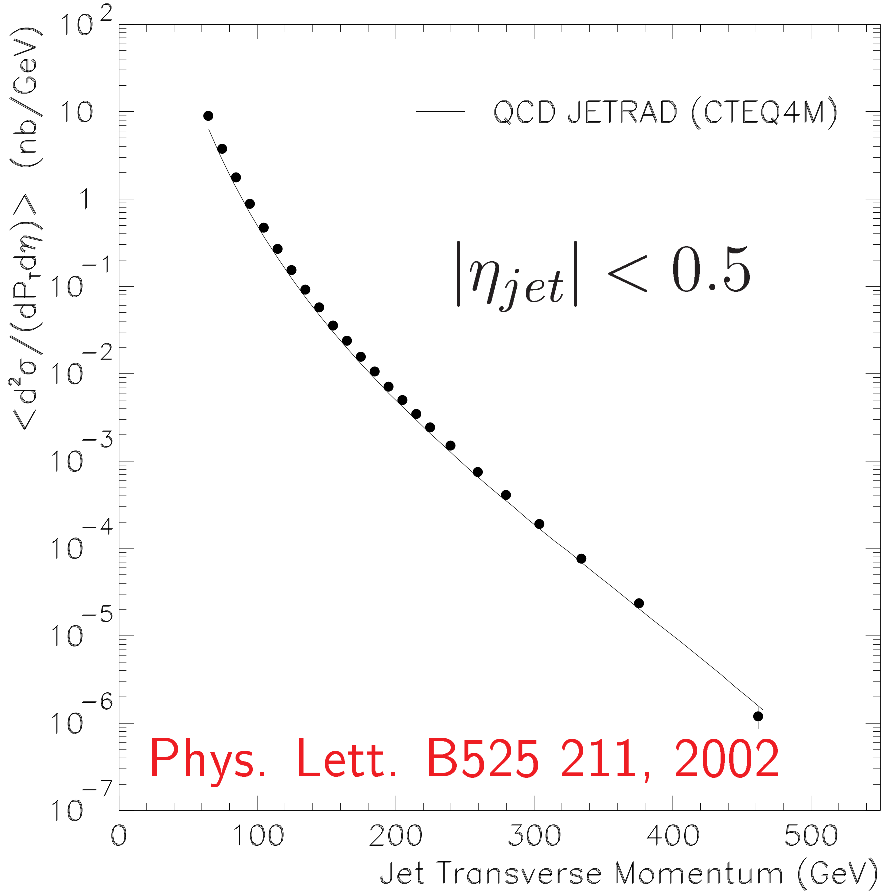
RunII upgrade

- 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

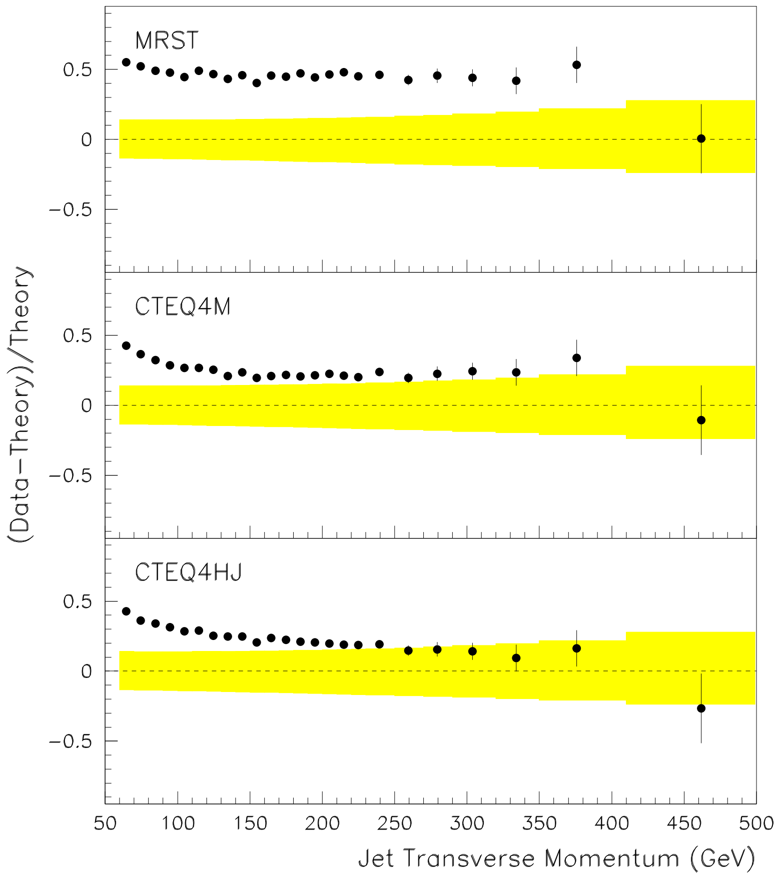
k_T jet inclusive cross section

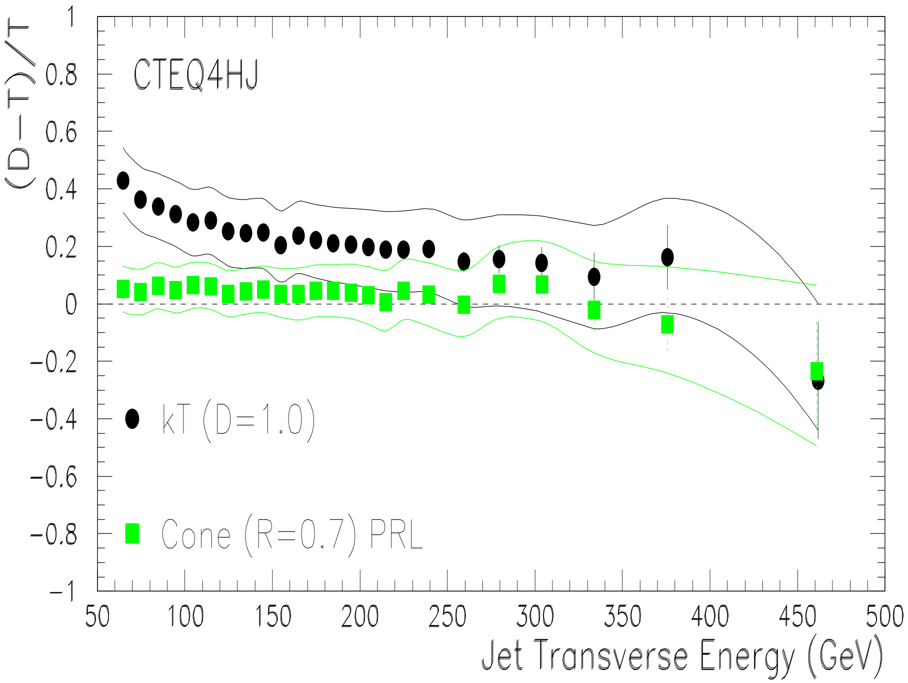
- DØ RunI data at $\sqrt{s} = 1.8\,\text{TeV}$, $\mathcal{L} = 88\,\text{pb}^{-1}$
- $D = 1$ (within 1% the same NLO cross section as cone with R=0.7)

main uncertainties: jet energy scale and luminosity



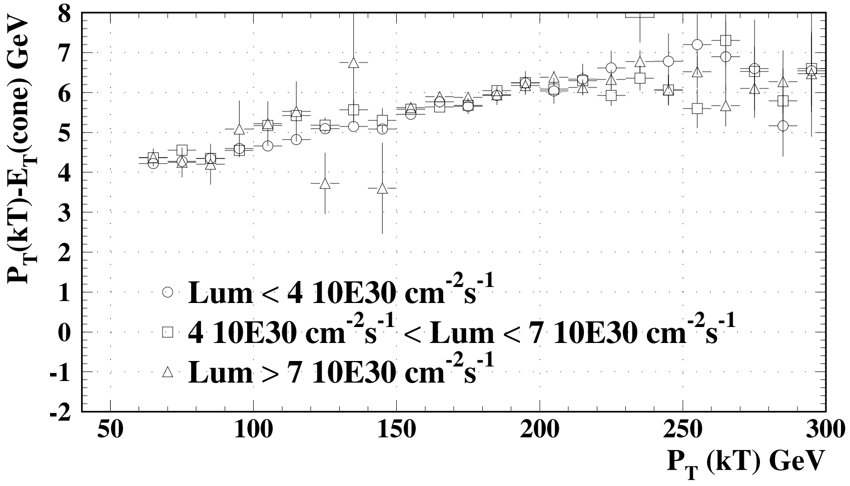
only statistical errors





- error bands without error on luminosity
- systematic errors almost **uncorrelated**

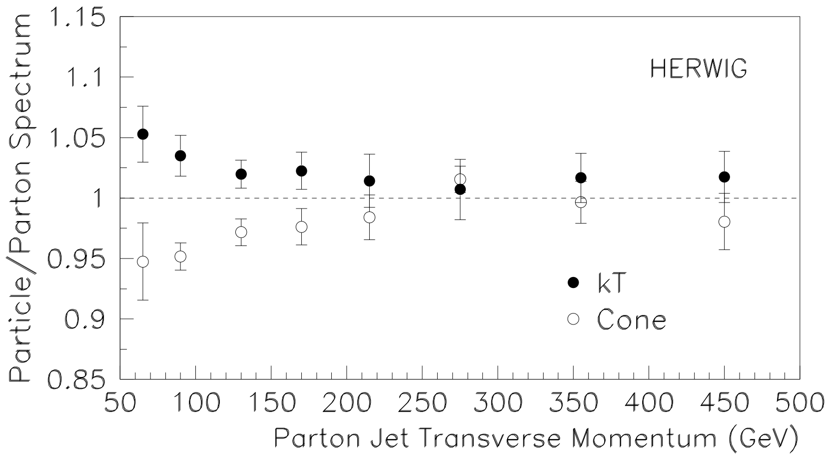
- k_T jets are more energetic

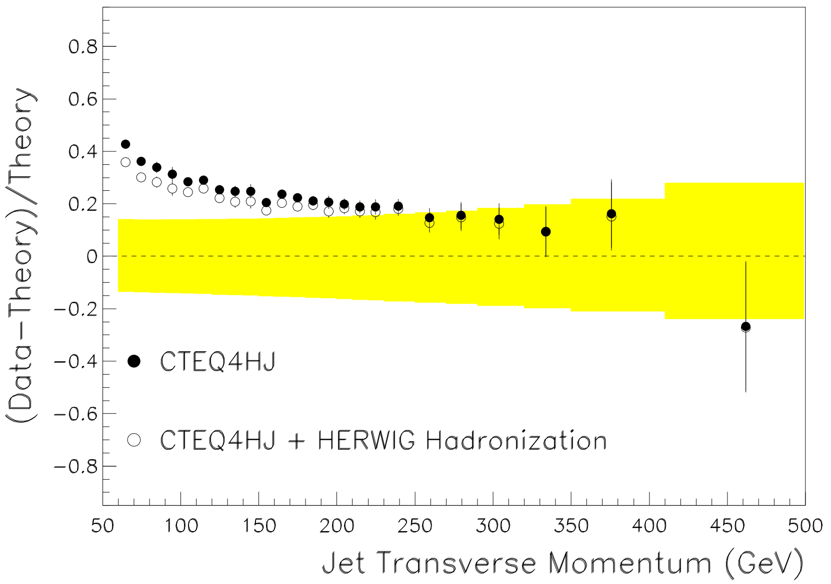


- independent on luminosity

- reasonable agreement, marginal at low p_T
- corrected to particle level but theory is NLO at parton level

hadronization effects



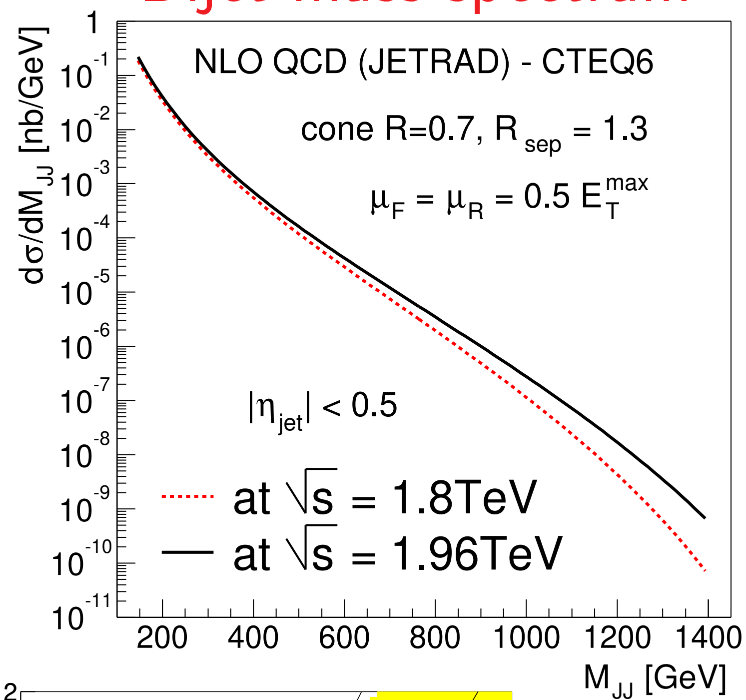


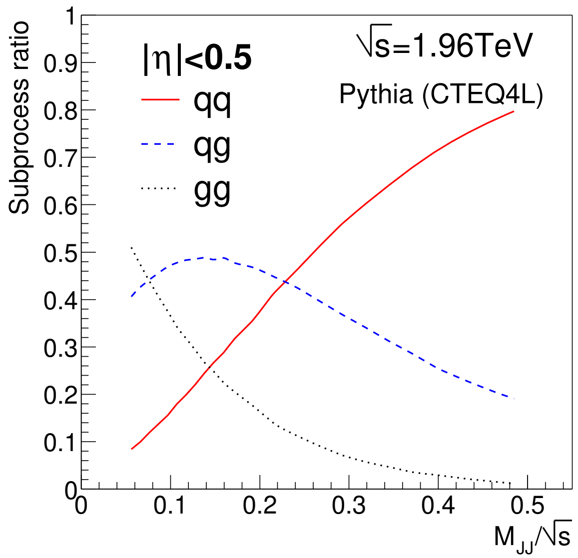
- studied on MC (Herwig 5.9)
- cone jets are less energetic on particle level than on parton level
  - out of cone radiation
- k_T jets are more energetic
  - nearby particles are merged into a jet
- the same trend as in data but smaller

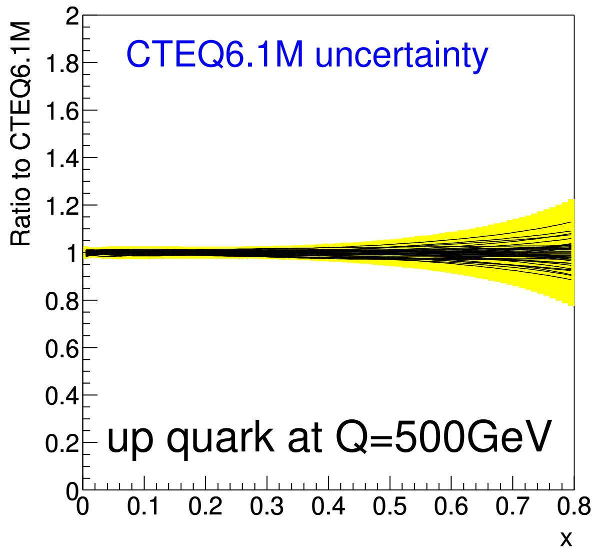
High pT jets in RunII

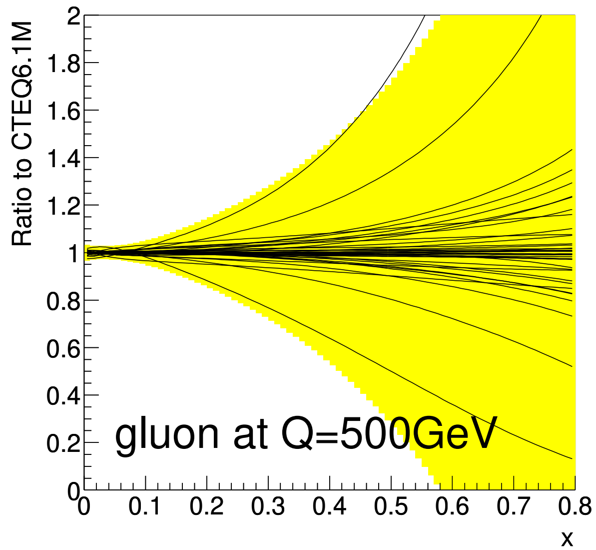
- ▷ **slightly higher CMS energy**
  - cross section at 1.96 TeV 2 times larger for dijet masses above 800 GeV than at 1.8 TeV
- ▷ **higher statistics for high p_T jets**
  - proton structure at large x
  - searches for new physics
    (quark compositeness, excited quarks, Z′, W′, . . .)

Dijet mass spectrum









Jet triggers

Level 1

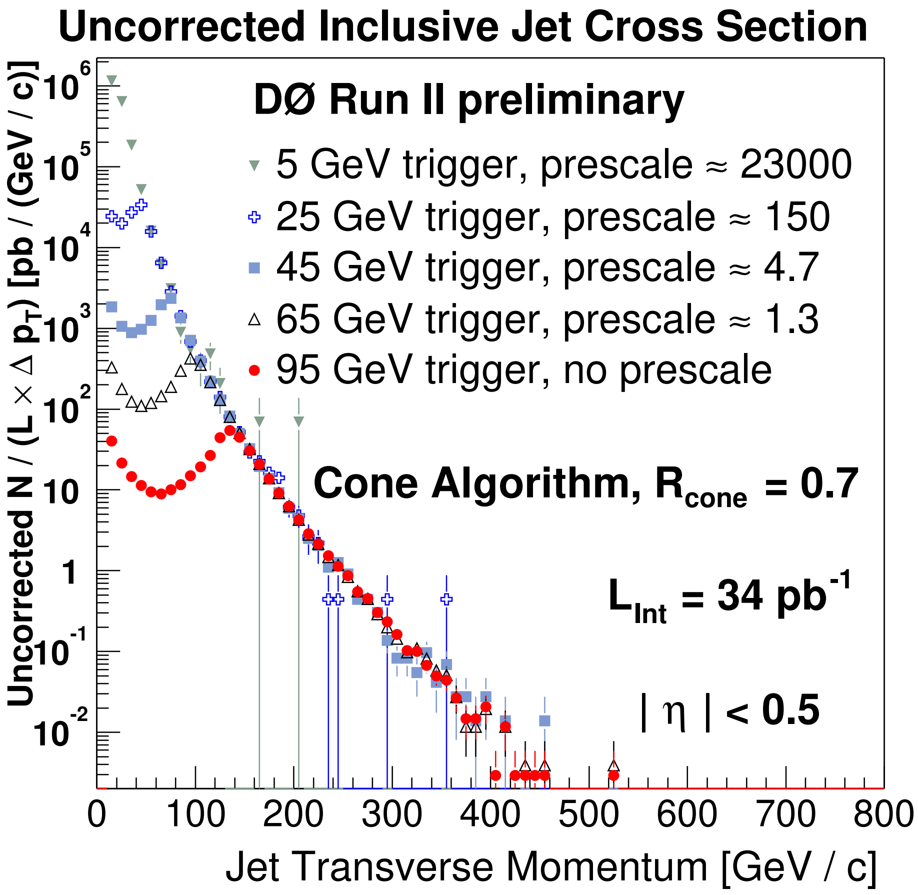
- hardware trigger
- fast calorimeter readout
- $\Delta\phi \times \Delta\eta = 0.2 \times 0.2$ L1 towers
- coverage $|\eta| < 2.4$
  (now extended up to 3.2)
- ability to prescale the trigger

Level 2

- software running on special hardware
- 3×3 or 5×5 square jets

Level 3

- software trigger
- simple cone run on precision readout
- no splitting and merging



Jet energy scale

correction of the jet energy measured on the detector level to the jet energy on the particle level

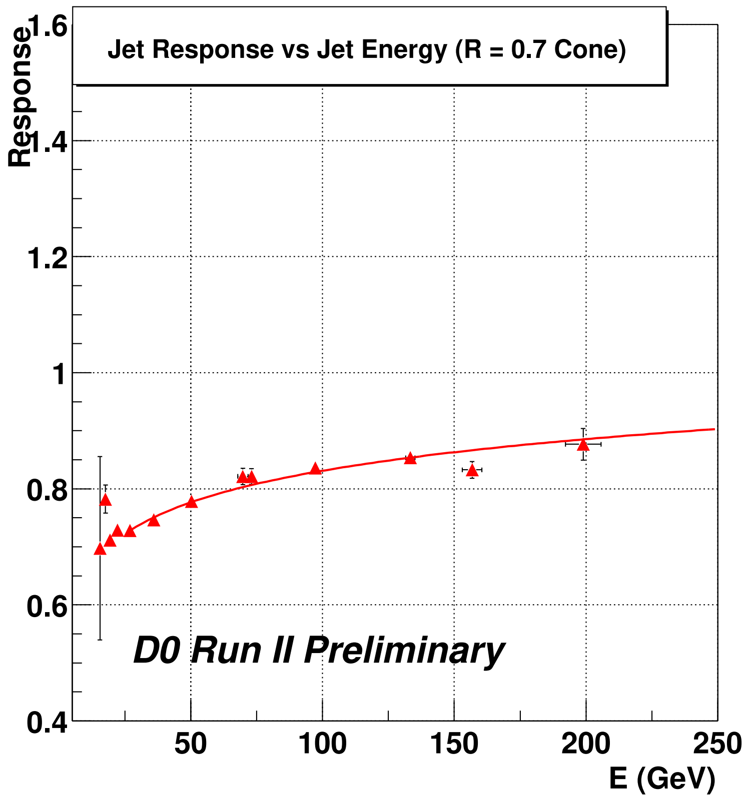
$$E_{ptcl}^{jet} = \frac{E_{det}^{jet} - \mathcal{O}}{R_{jet}\, S}$$

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 $Z \to ee$ mass peak
- measured from E_T balance in $\gamma +$ jet events

Showering (S) - losses due to showering the energy in the calorimeter out of the jet cone



- Response measured for energies up to 200 GeV

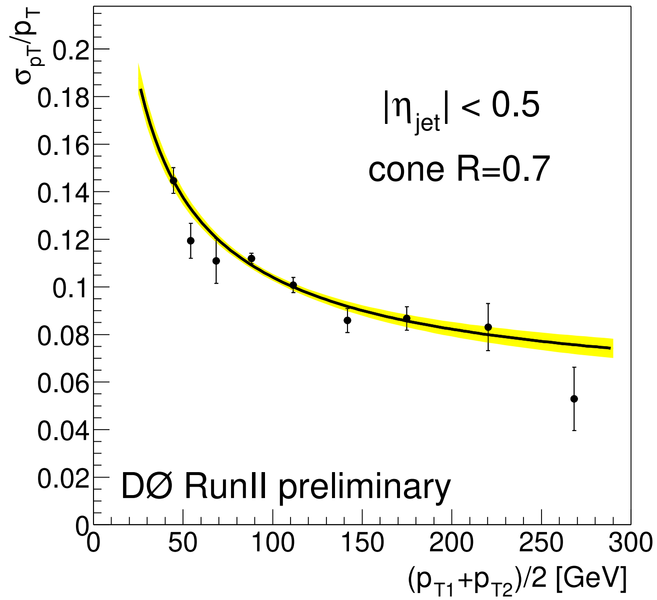
Jet resolutions

Jet p_T resolution

- measured from dijet imbalance in p_T

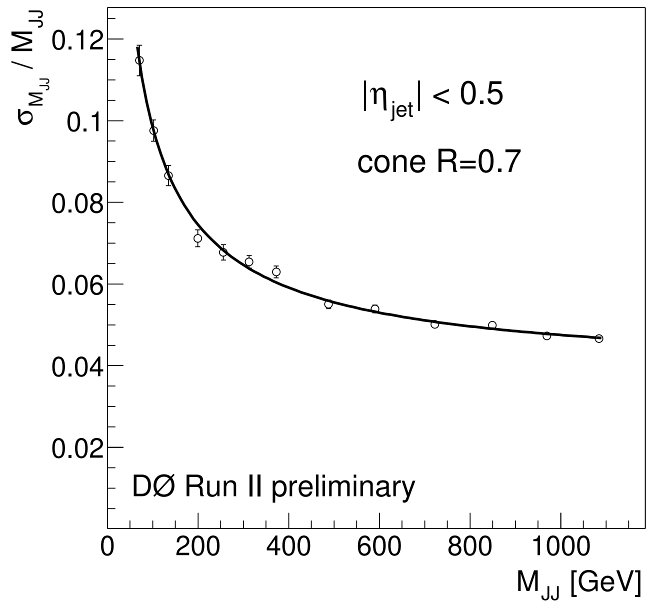
$$\mathcal{A} = \frac{p_T^{jet1} - p_T^{jet2}}{p_T^{jet1} + p_T^{jet2}}$$

- raw resolution: $\sigma_{p_T}/p_T = \sqrt{2}\sigma_{\mathcal{A}}$
- corrected for soft radiation and particle jet p_T imbalance



Dijet mass resolution

- smearing MC (Pythia) particle jet momenta



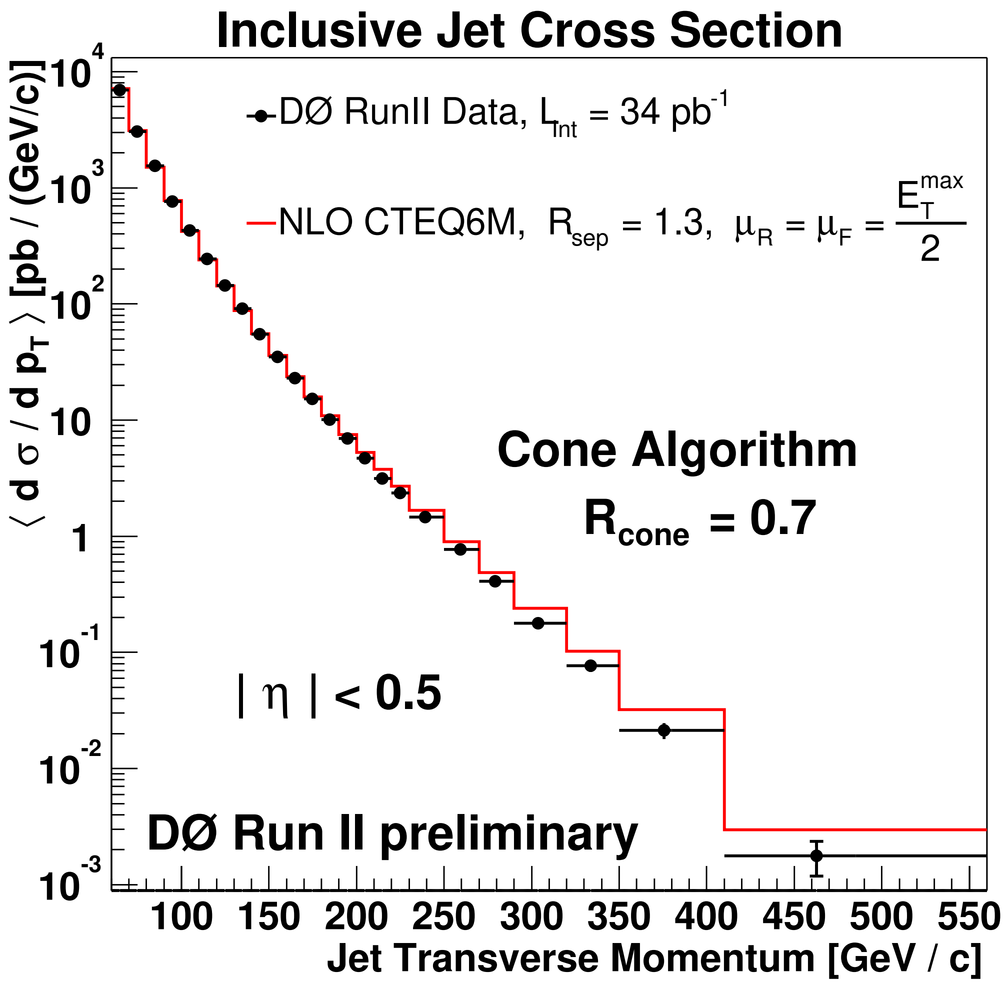
Unsmearing corrections

- inclusive p_T spectrum: $\sim$0.82–0.87
- dijet mass spectrum: $\sim$0.90–0.95

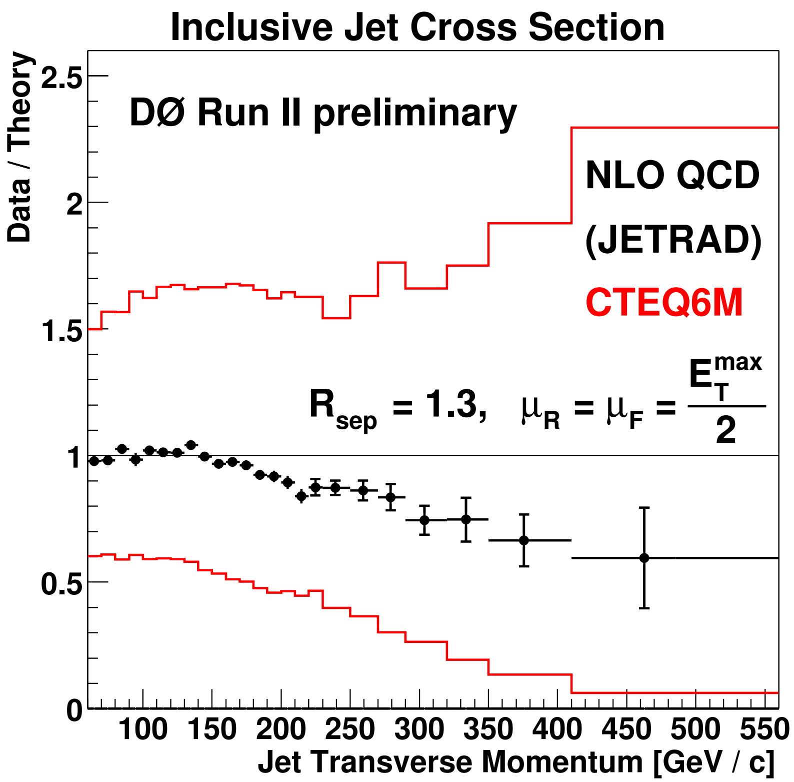
Inclusive jet p_T spectrum

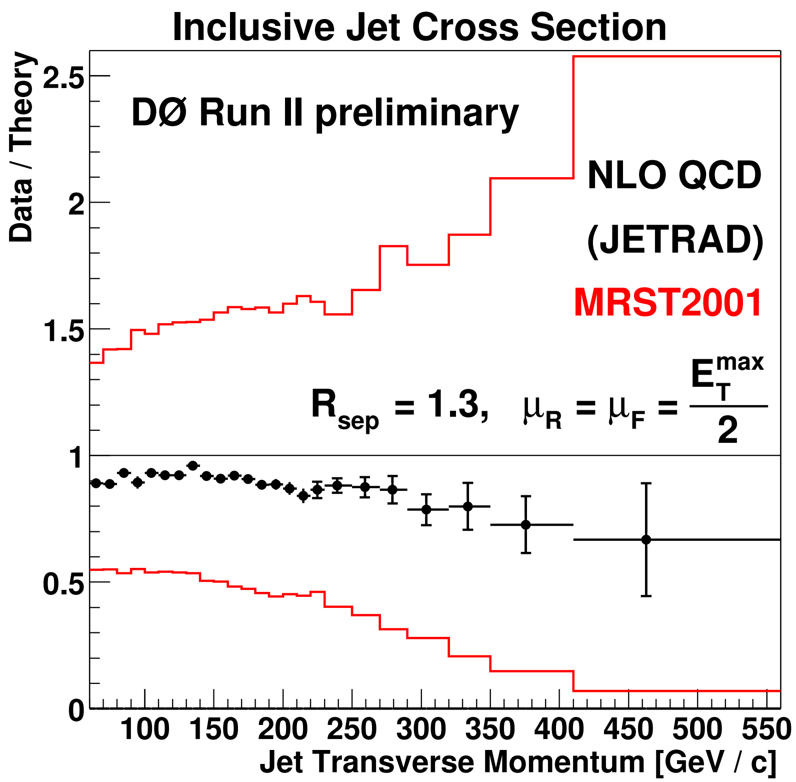
$$\left\langle \frac{d\sigma}{dp_T} \right\rangle_{bin} = \frac{N_{evt}}{\mathcal{L}} \frac{1}{\varepsilon_{eff}} C_{unsmear} \frac{1}{\Delta p_T}$$

- central calorimeter: $|\eta_{jet}| < 0.5$
- vertex cut: $|z| < 50$ cm, $N_{track} > 4$
  - efficiency $\sim 78\%$
- jet identification cuts
  - efficiency $\sim 97\%$
- luminosity: $\mathcal{L} = 34\,\text{pb}^{-1}$
- only statistical errors
- NLO QCD prediction
  - JETRAD (parton level)



Inclusive jet p_T spectrum, part II

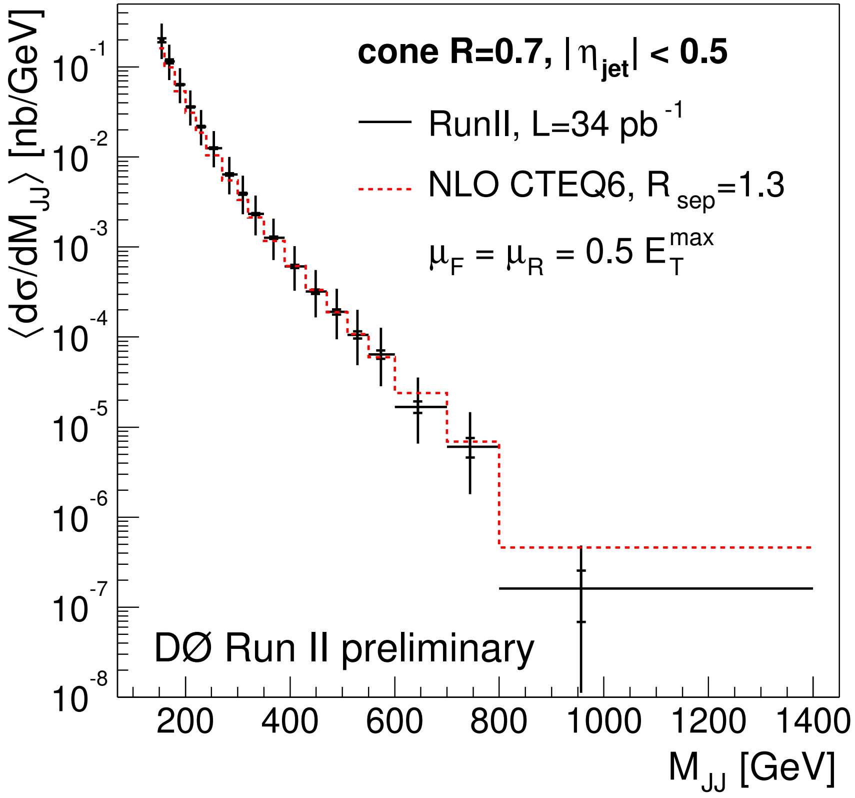


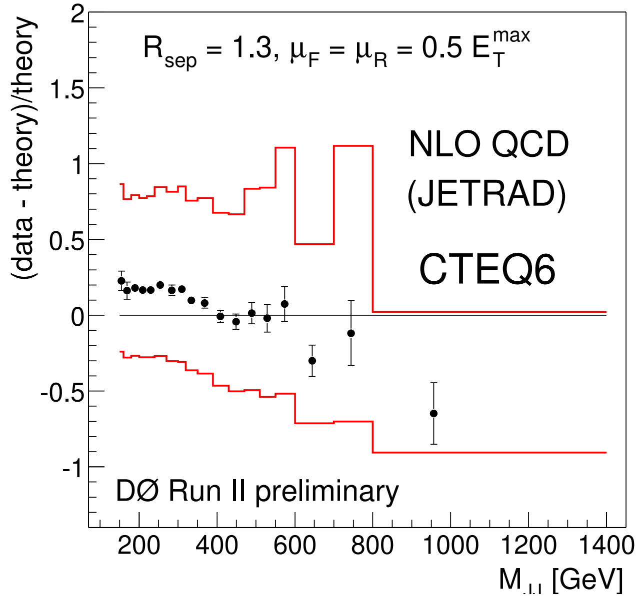


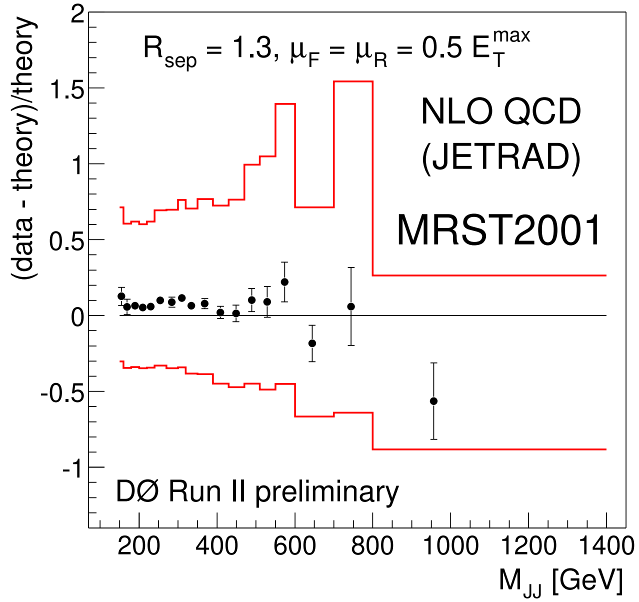
- $\sim 10\%$ in normalization not shown
- systematics: dominated by jet energy scale
- NLO QCD agrees with the data
- large error does not allow us to make quantitative statements about PDF

Dijet mass spectrum

$$\left\langle \frac{d\sigma}{dM_{JJ}} \right\rangle_{bin} = \frac{N_{evt}}{\mathcal{L}} \frac{1}{\varepsilon_{eff}} C_{unsmear} \frac{1}{\Delta M_{JJ}}$$







- $\sim 10\%$ normalization error not shown
- systematics dominated by jet energy scale

Summary and Outlook

k_T algorithm in Run I

▷ jet p_T cross section

- in agreement with NLO QCD (marginal at low p_T)
- different hadronization effects for cone and k_T jets

▷ other RunI k_T results

- subjet multiplicity (Phys. Rev. D65 052008, 2002)
- dijet thrust cross section (publication in preparation)

▷ the first measurements in hadron-hadron collider using k_T algorithm

Jets in Run II

▷ preliminary results on the central inclusive jet p_T and dijet mass spectra were presented

- agreement with NLO QCD over 7 orders of magnitude

▷ next steps

- extend the measurement to the forward region
- reduce the error on jet energy scale and understand the correlations

▷ other analysis

- dijet angular distribution
- dijet $\Delta\phi = |\phi_1 - \phi_2|$ distribution

RunI k_T algorithms

- ▷ first introduced in e^+e^- interactions, inspired by pQCD
- ▷ additional partons are mostly radiated along the direction of the original parton or they are soft

Ellis-Soper

- k_T algorithm for hadron colliders with one parameter D
- introduce the *distance* between two particles

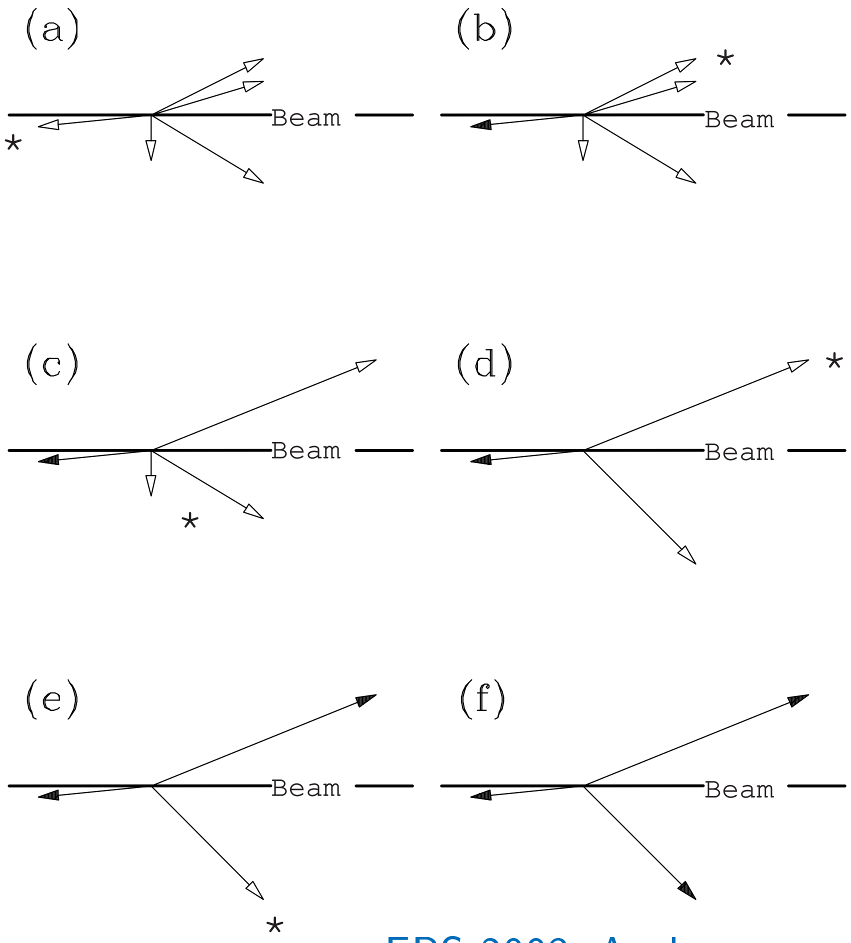
$$d_{ij} = \min\left(p_{T_i}^2, p_{T_j}^2\right) \Delta R_{ij}^2 / D^2$$

and between particle and beam

$$d_i = p_{T_i}^2$$

- $d_{ij} \sim k_\perp^2$ when $\Delta R_{ij}^2 \ll 1$

Iterative procedure



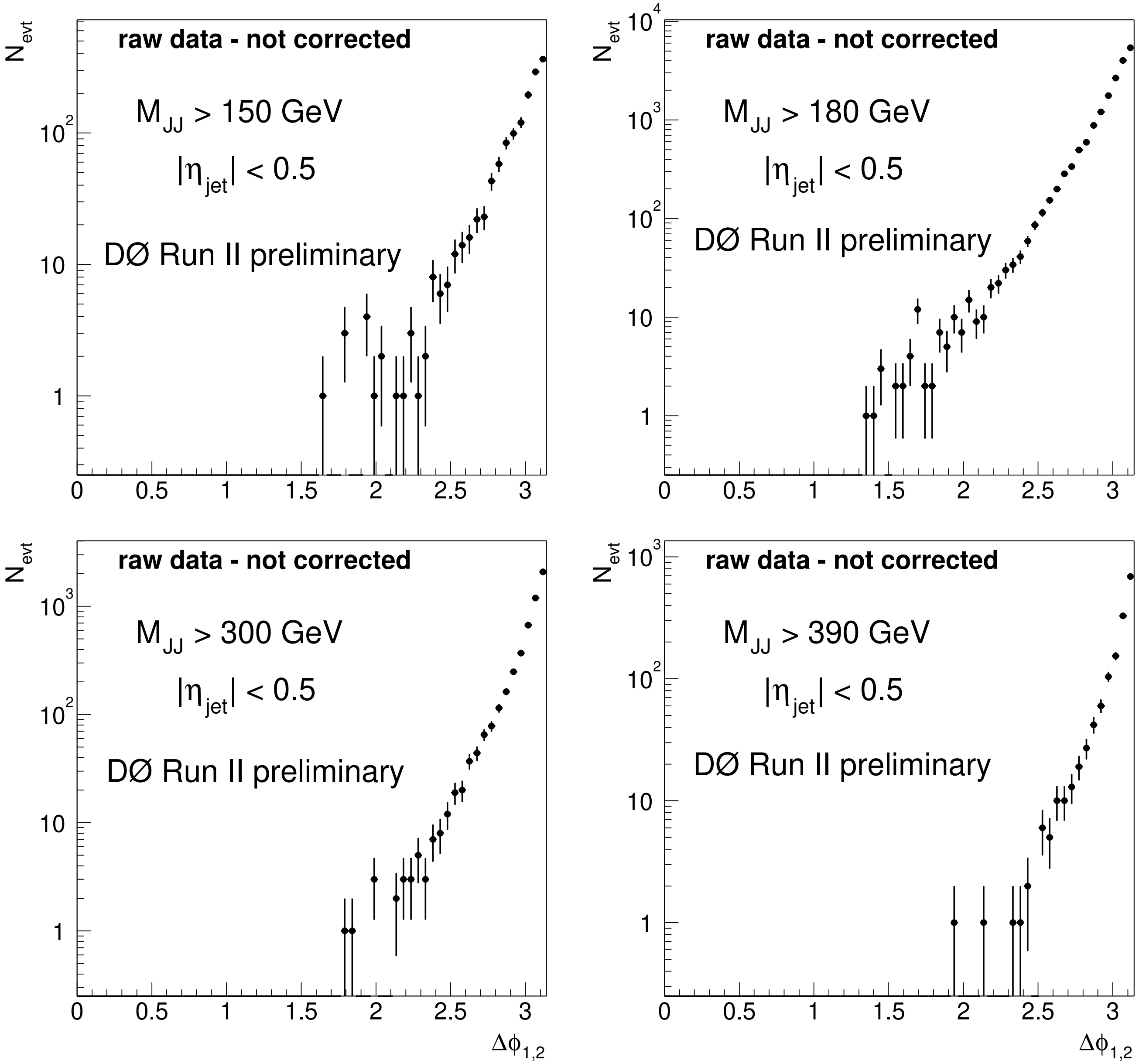
RunII jet algorithms

- ▷ RunII Jet Algorithm Working Group (FERMILAB-Conf-2000-092-E)
- ▷ Les Houches Jet Working Group
- ▷ propose jet algorithms suitable for experiments and theoretical calculation
  - reduce the error connected with jet algorithm

Cone algorithm

- ▷ midpoint algorithm (Improved Legacy Cone Algorithm)
  - add midpoints $(p_i + p_j, p_i + p_j + p_k, \ldots)$ after cone clustering
  - essentially remove infrared sensitivity
- ▷ use E-scheme for recombination and for reported kinematic variables
  - simple, manifestly Lorentz invariant ($\Rightarrow$ jets are massive)
  - jets satisfy **boundary stability** condition $(E_T^{jet} \leq \sqrt{s}/2)$ - important for soft gluon resummation

$\Delta\phi_{1,2} = |\phi_1 - \phi_2|$ distribution



- same sample as in case of dijet mass analysis
- only JES correction

LO $2 \to 3$ - problems at

▷ $\Delta\phi_{1,2} \sim \pi$
  - soft and collinear re-summation needed

▷ $\Delta\phi_{1,2} < 2\pi/3$
  - four partons are needed