Jet results from the Tevatron

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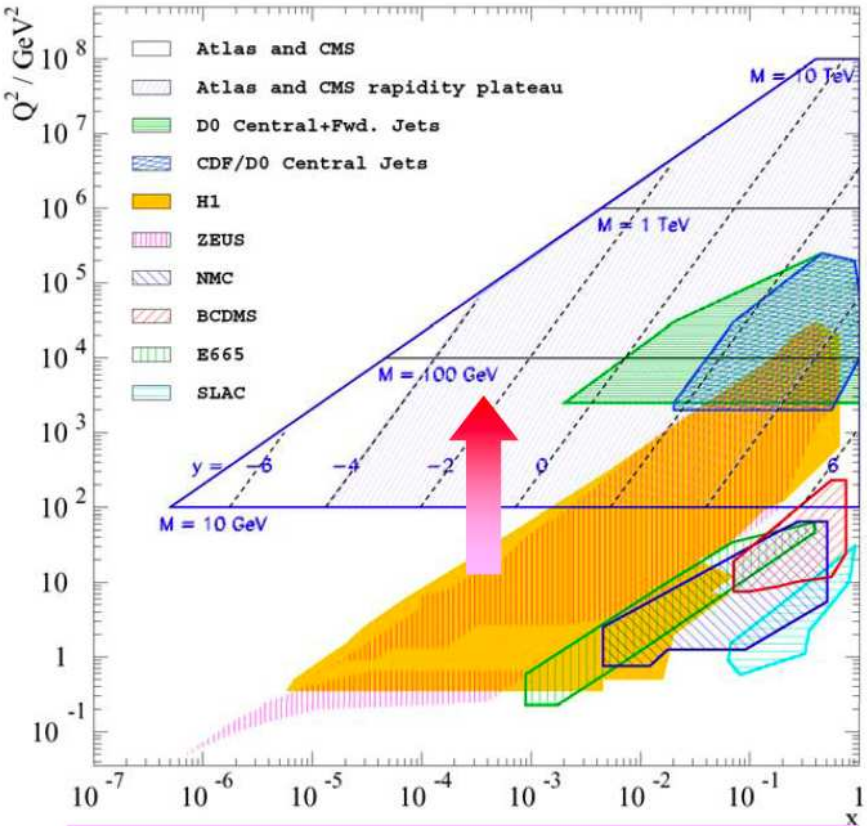
On behalf of the D0 and CDF collaborations

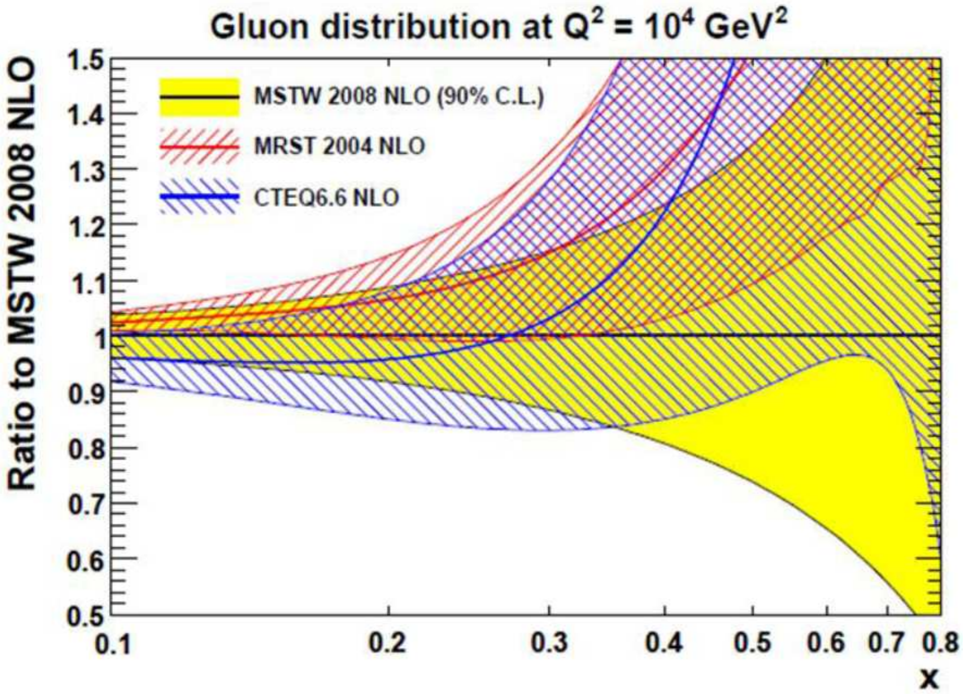
Contents:

- Inclusive jet cross section
- α_S measurement
- Dijet mass and sensitivity to new physics
- Dijet angular distributions
- Three-jet mass
- Mass of high p_T jets

Motivations

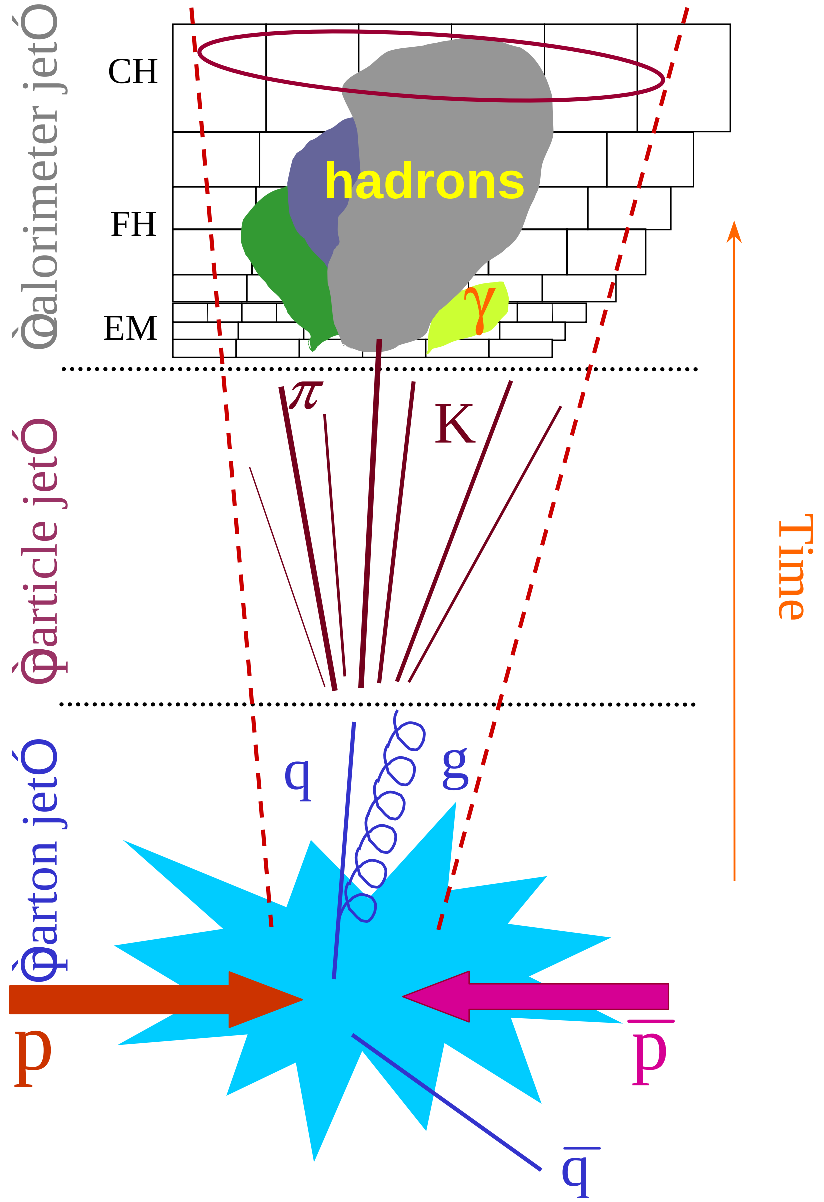
- Kinematical plane at HERA, Tevatron and LHC in (x, Q^2) compared to fixed target experiments: reach at high energy and high x
- Jets at Tevatron are sensitive to new physics and allow to constrain PDFs, specially the gluon density at high x
- Impact on searches: searches for new phenomena limited without a proper understanding of QCD background





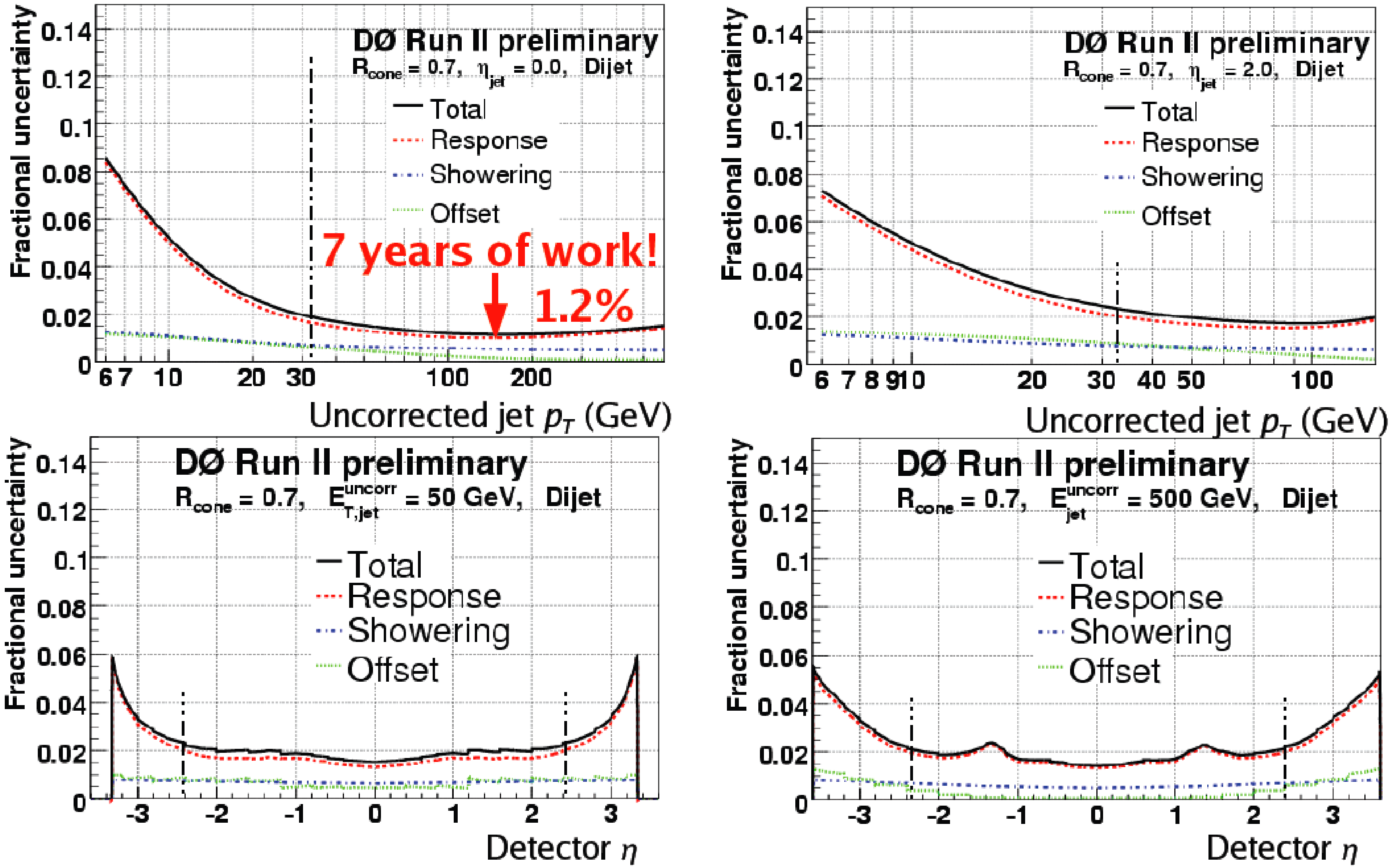
Jets at the Tevatron (and the LHC)

Dominant uncertainty: Determination of jet energy scale in calorimeter: use γ+jet, Z+jets at Tevatron and LHC



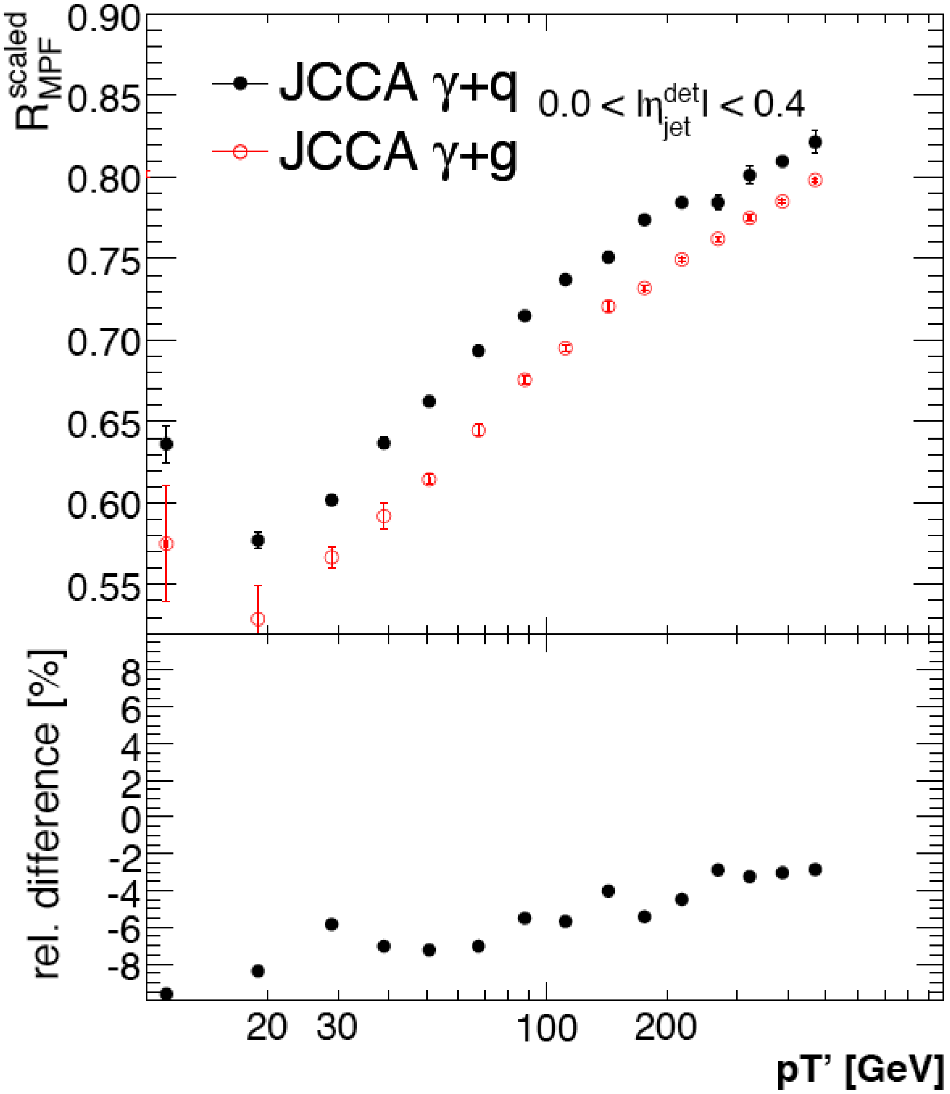
Jet Energy Scale (D0)

- “Standard” JES determined using p_T balance in clean γ+jet events
- Corrections for JES for QCD jets obtained using inclusive jet sample and p_T balance between dijets
- Uncertainties of the order of 1.2% for central jets and $p_T \sim 100$ GeV



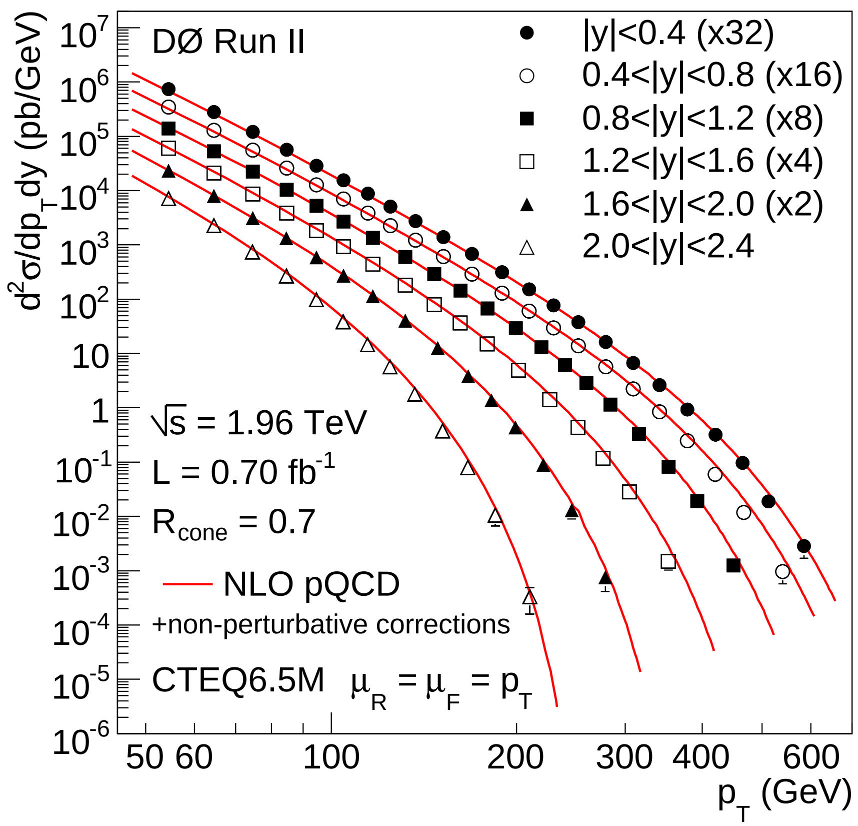
Differences between quark and gluon responses

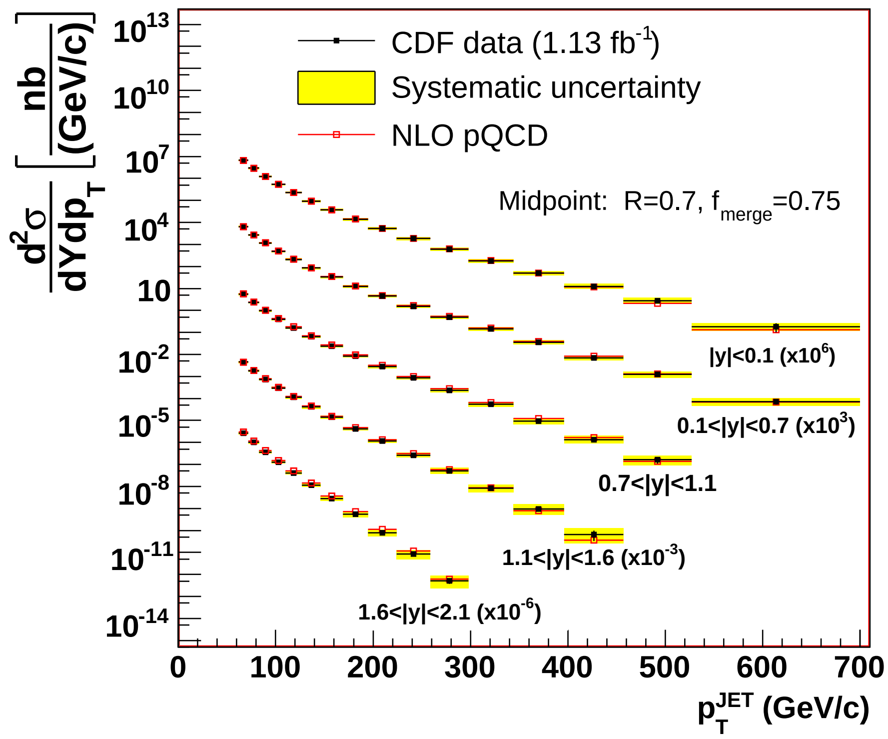
- Different quark and gluon jet responses (measure jet responses in γ+jet and inclusive jet samples)
- Means different corrections depending on physics: QCD jets (gluon dominated), $t\bar{t}$ events (quark dominated)...



Jet inclusive p_T cross section (D0 and CDF)

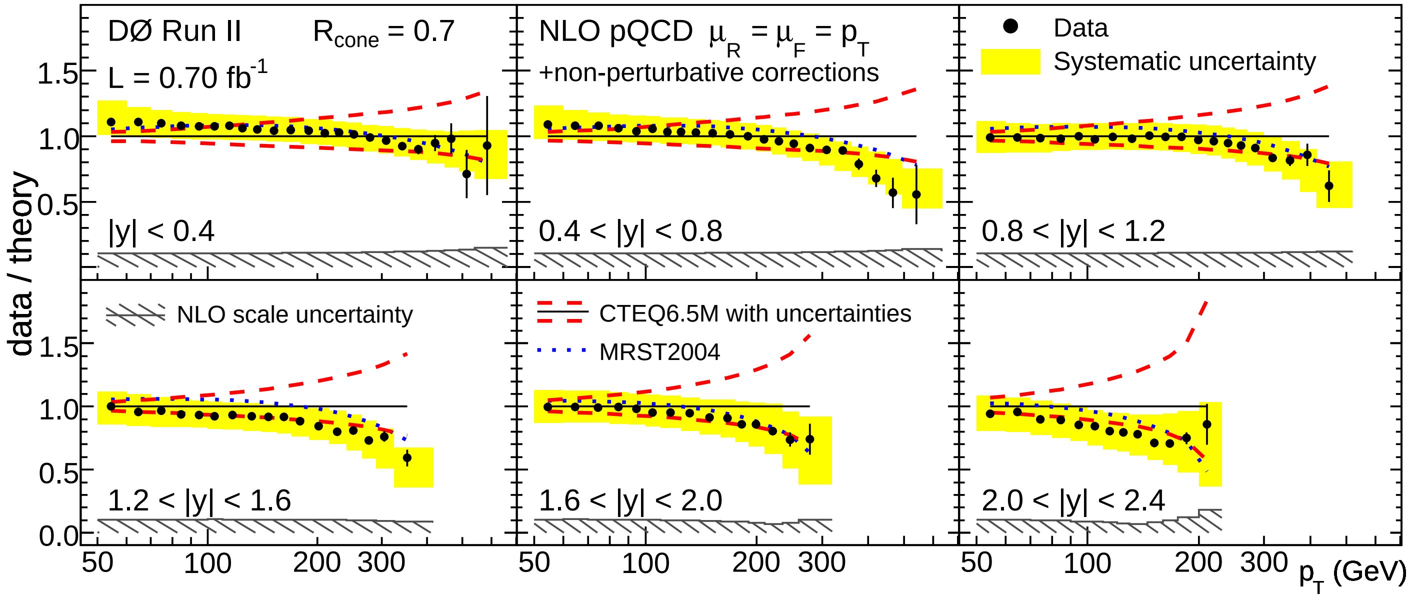
- Measurement of the inclusive jet cross section: Test of QCD over 8 orders of magnitude
- Comparison with NLO QCD calculation (CTEQ6.5M for D0, CTEQ6.1 for CDF with uncertainties $\sim$ two times larger): Good agreement over six orders of magnitude
- CDF uses both midpoint cone jet and k_T algorithms

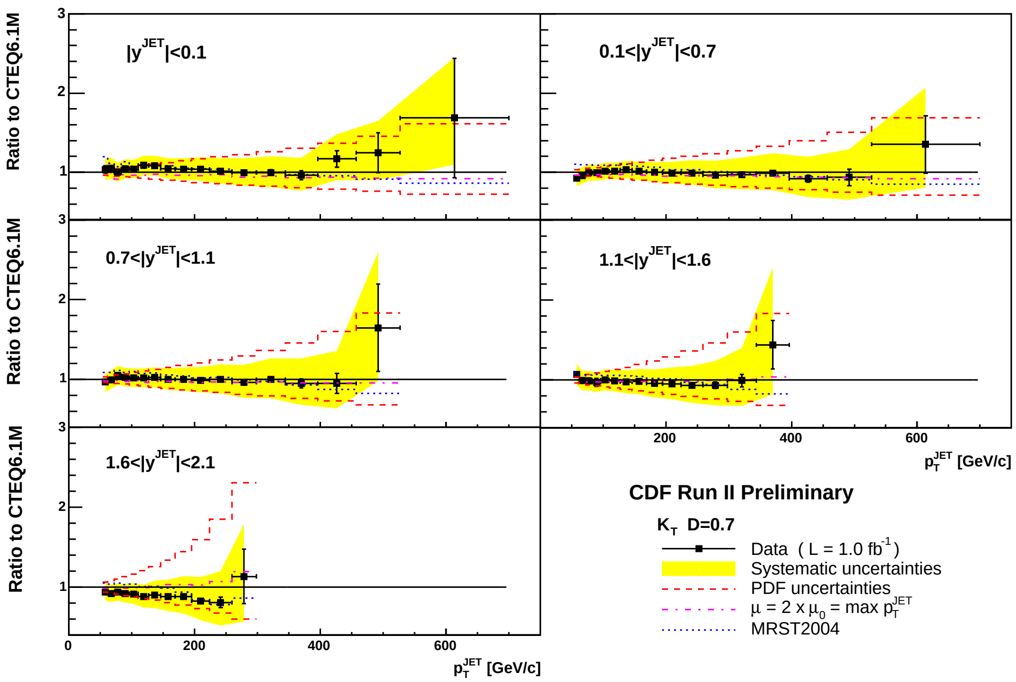




Data/Theory for inclusive jet cross section

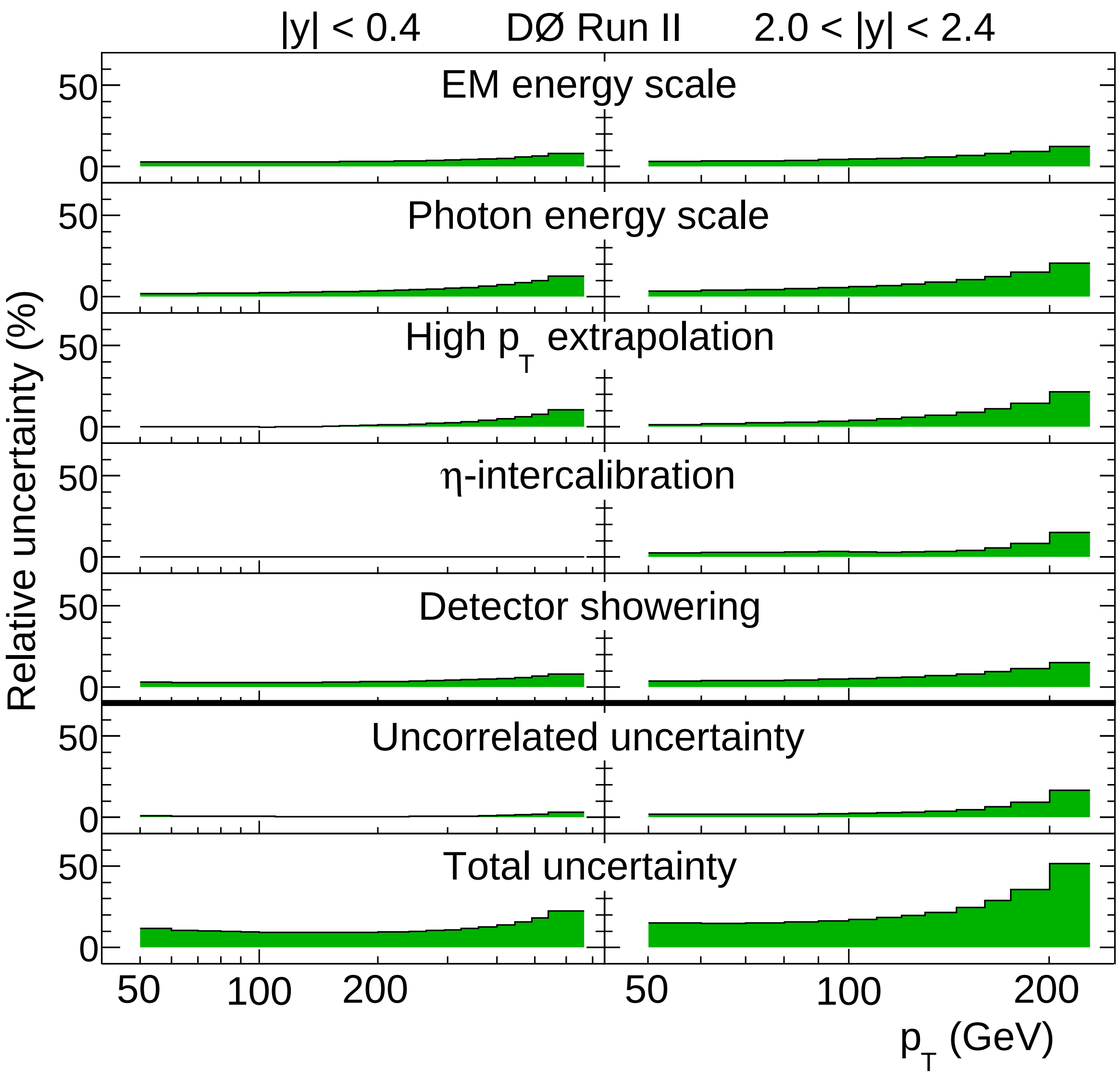
- CDF and D0 measurements in agreement with NLO calculations
- Data favour lower bound of theoretical predictions with smaller gluon densities at high x





Correlation studies for jet inclusive p_T cross section (D0)

- Full correlation studies: give the effects of 24 sources of systematics in data
- Possibility to constrain further PDFs using correlation matrices

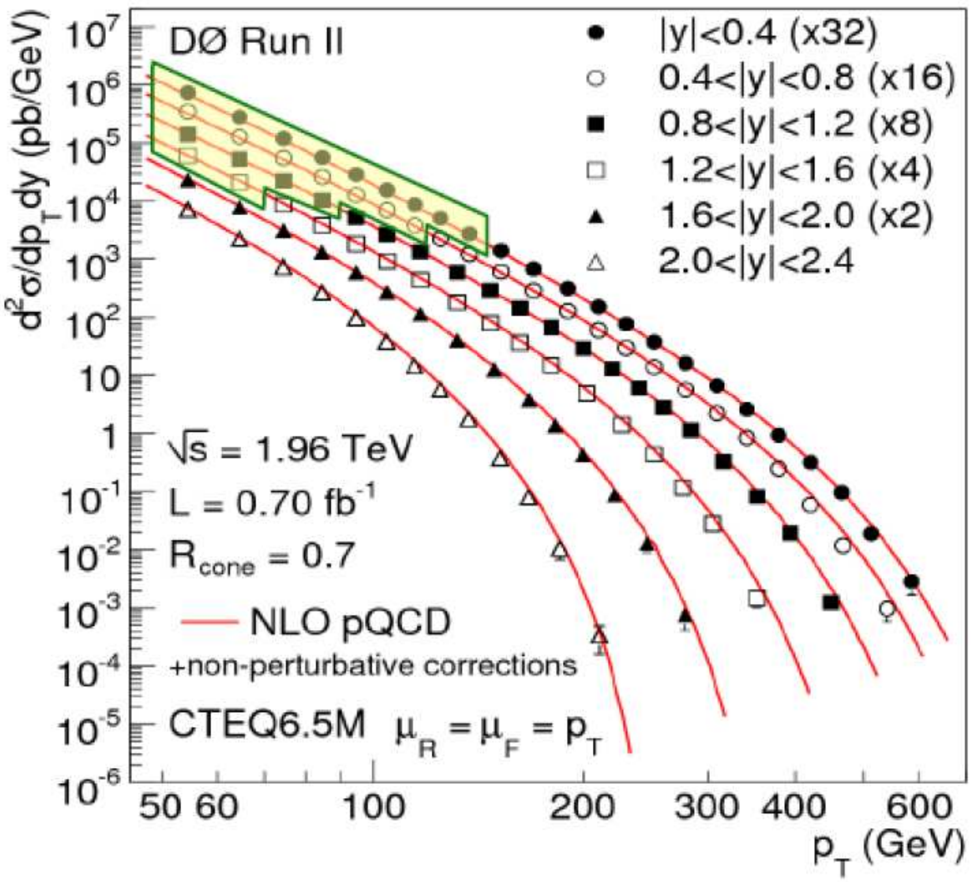


α_S measurement using inclusive jet cross sections (D0)

- Inclusive jet cross section directly related to α_S measurement

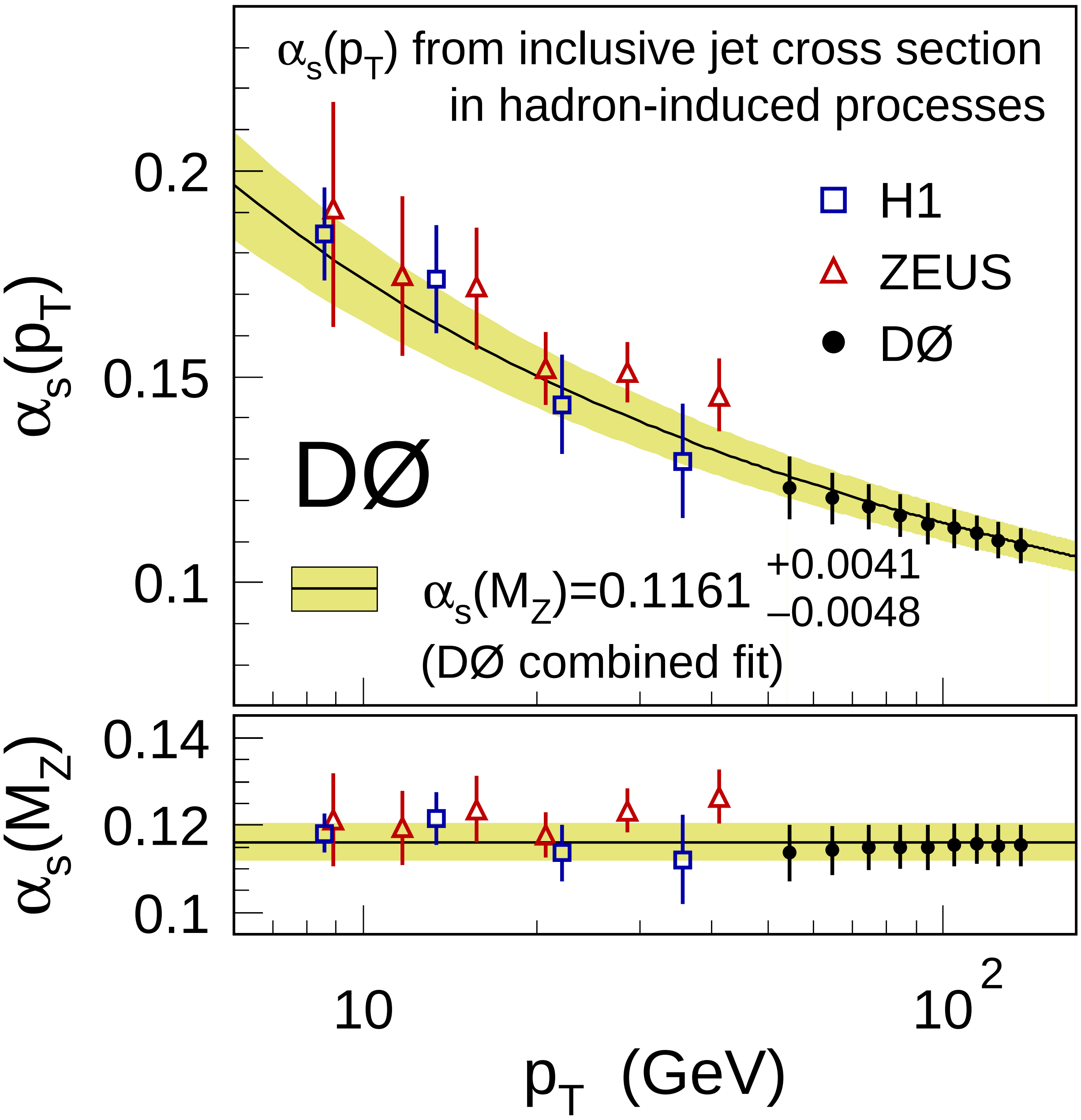
$$\sigma_{pert}(\alpha_S) = (\Sigma_n \alpha_S^n c_n) \otimes f_1(\alpha_S) \otimes f_2(\alpha_S)$$

- RGE equations relates $\alpha_S(\mu_R)$ for an arbitrary scale to $\alpha_S(M_Z)$
- c_n known from NLO QCD
- f_1 and f_2 dependence on α_S known from PDFs: use MSTW 2008 which provides fits for 21 values of $\alpha_S(M_Z)$ in the range 0.110-0.130
- Minimize correlations between data and PDFs by restricting analysis to kinematic regions where Tevatron data do not dominate in PDF determination: keep 21 data points



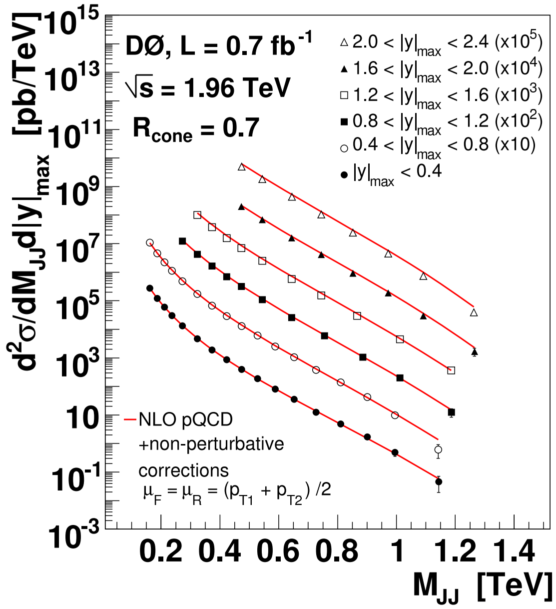
α_S measurement using inclusive jet cross sections (D0)

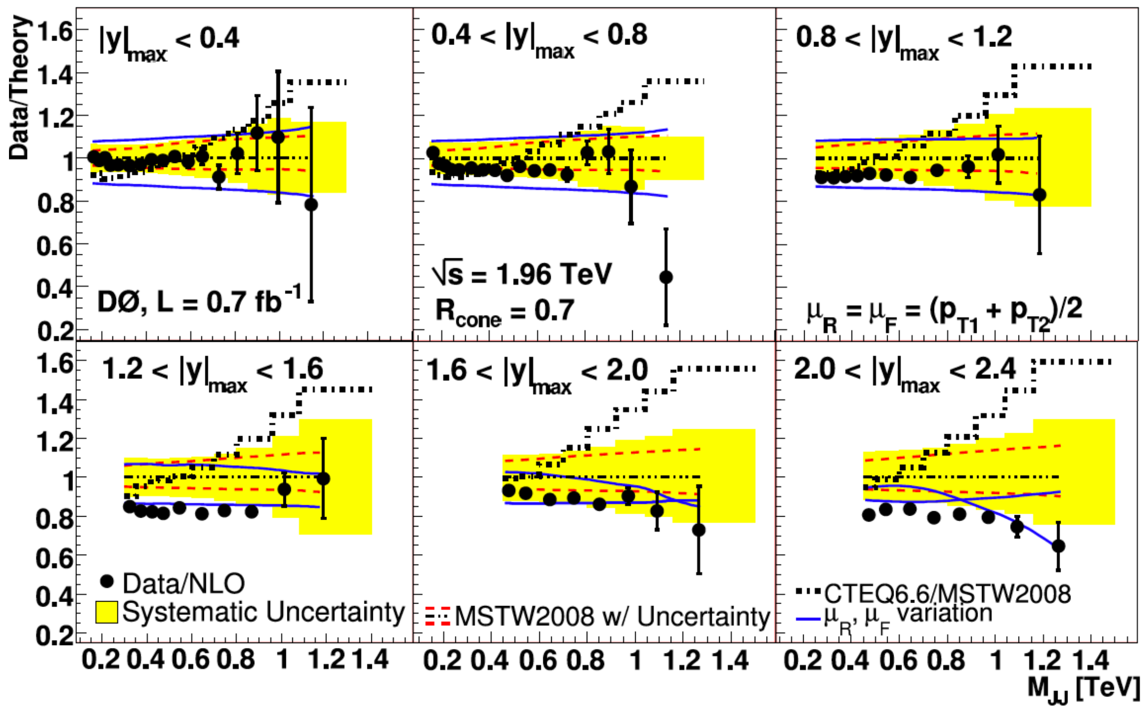
- Together with CDF run I measurement, highest p_T measurements of running α_S to date
- Most precise determination of α_S from a hadron collider: $\alpha_S(M_Z) = 0.1161^{+0.0048}_{-0.0041}$



Dijet mass cross section measurement (D0)

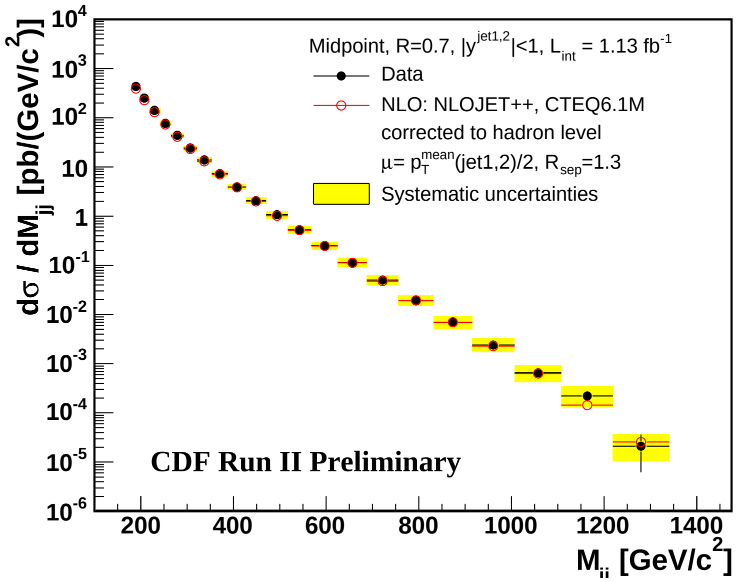
- Measurement of the dijet mass cross section in 6 rapidity bins where $|y|_{max} = max(|y_1|, |y_2|)$
- Data and QCD in good agreement in central region, data lower than QCD at higher rapidities

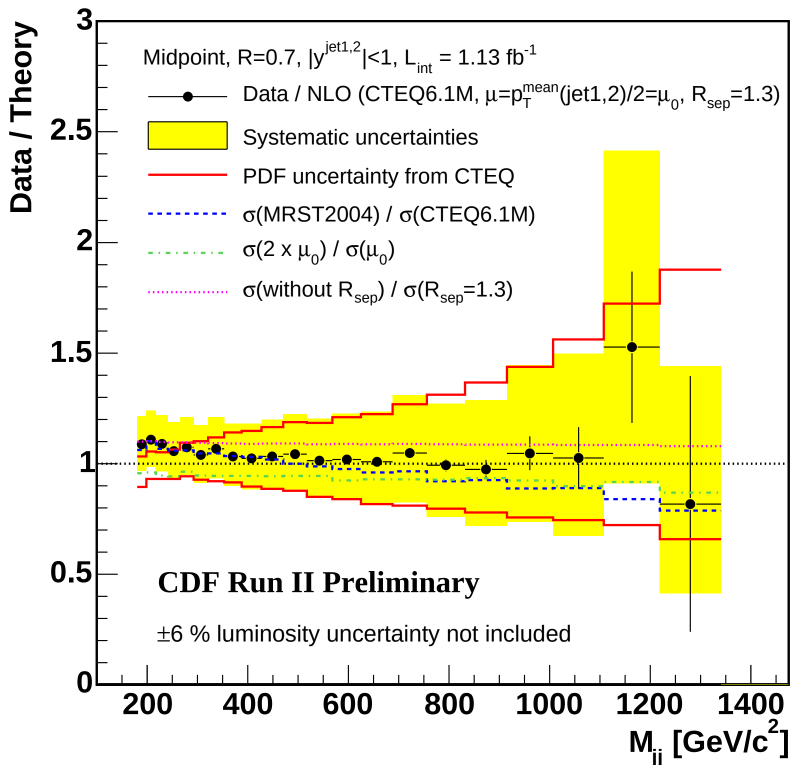




Dijet mass cross section measurement (CDF)

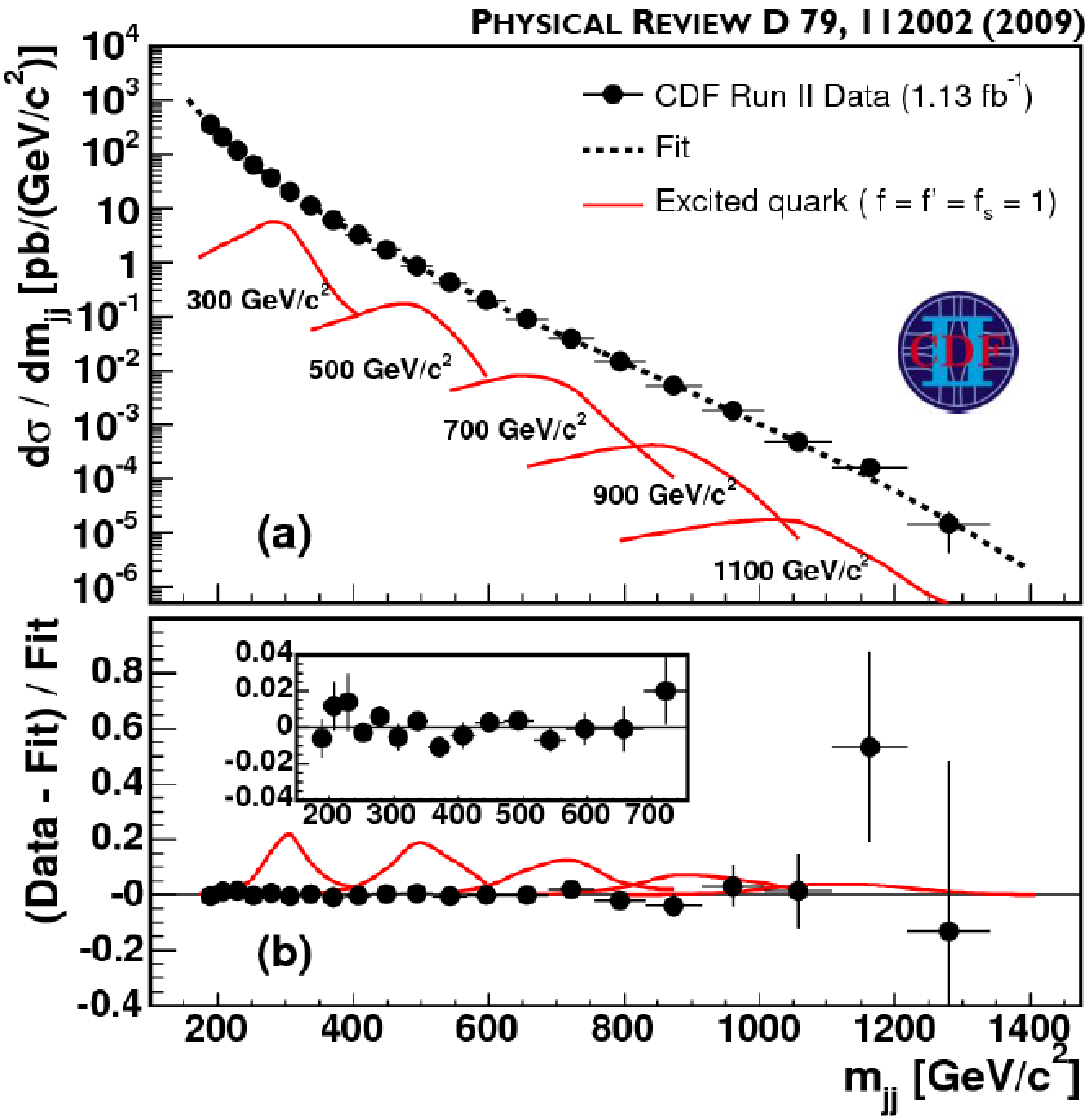
- Dijet mass distribution for jet rapidities $|y| < 1$
- New physics expected to be produced more centrally
- NLO pQCD fits to data: $\chi^2/\text{ndf} = 21/21$





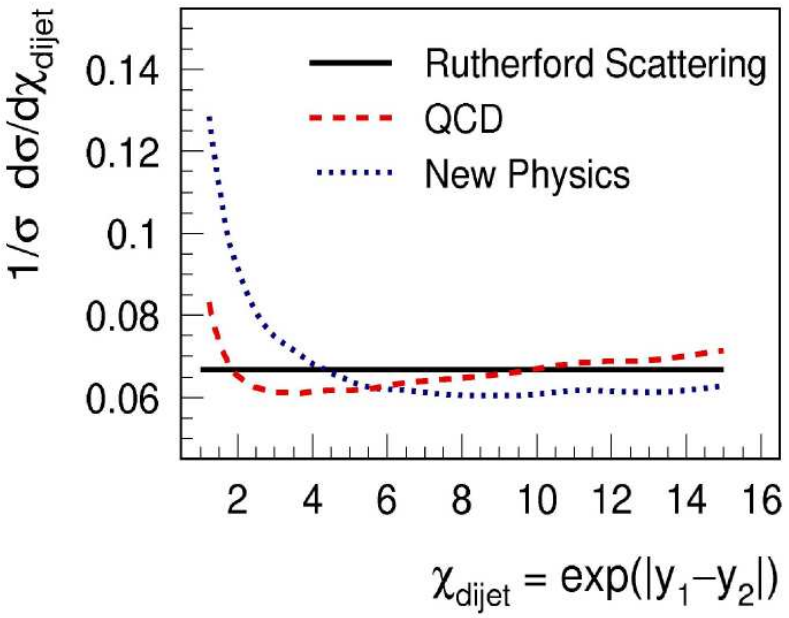
Dijet mass: searches for new physics (CDF)

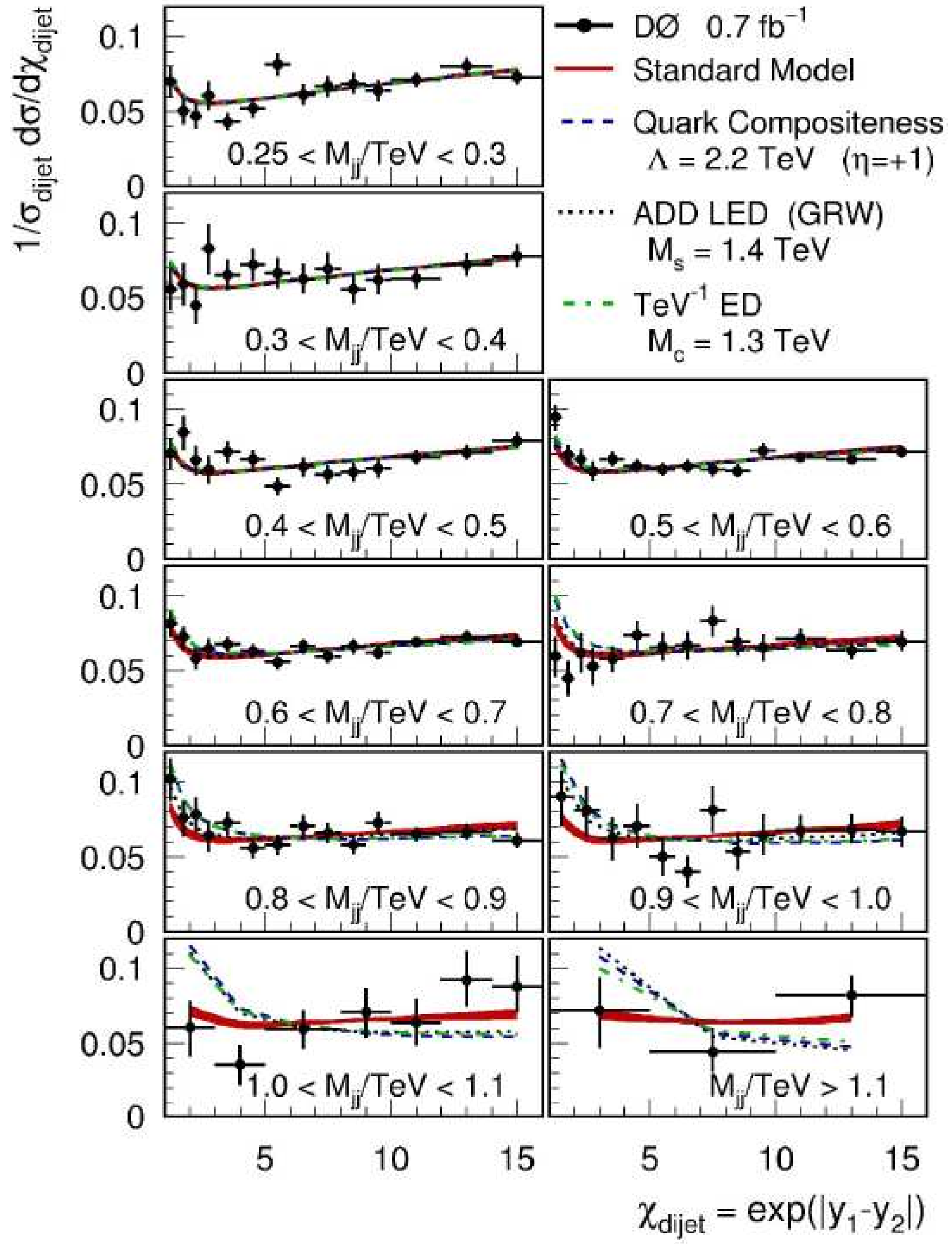
- Dijet mass measurements sensitive to new physics: mass reach up to 1.2 TeV
- No indication of resonances: Provides most stringent limits on many new heavy particles (as examples: 260-870 GeV for excited quarks, 2600-1100 GeV for technirho, 260-1250 GeV for axigluon/coloron...)



Angular distribution - dijet χ (D0)

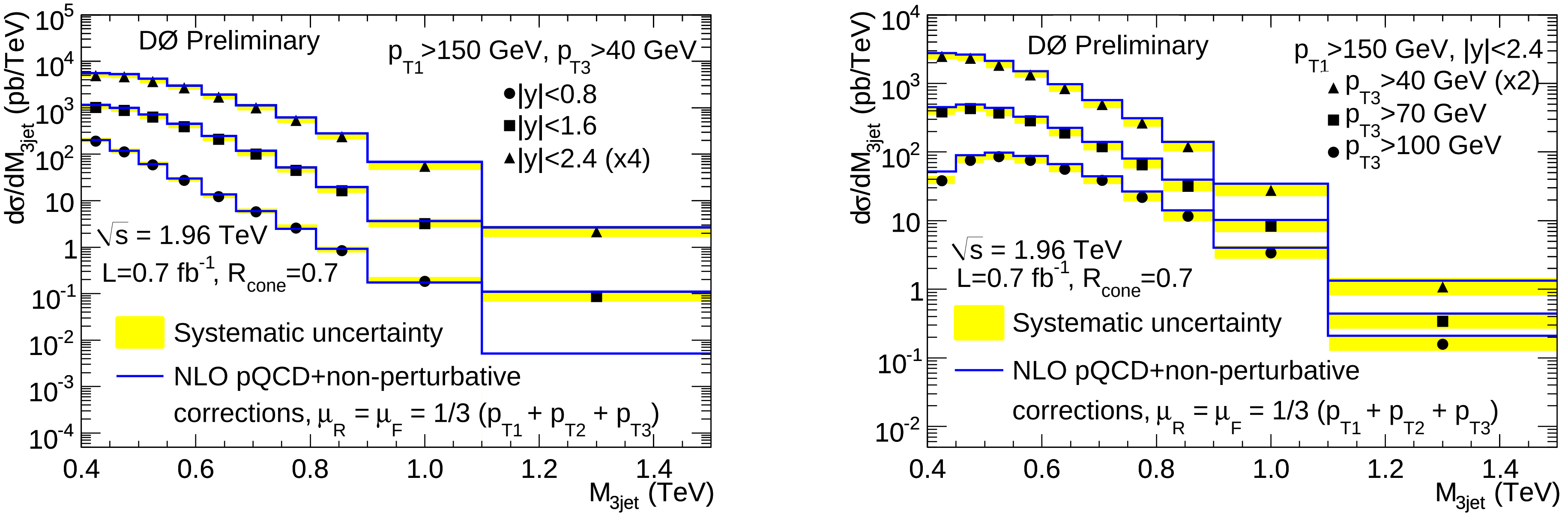
- Measure $\chi = \exp(|y_1 - y_2|)$ in 10 regions of dijet mass M_{JJ} >250 GeV
- Sensitity to new physics and comparisons with NLO QCD: best limits on quark compositeness ($\sim$ 3 TeV), extra-dimensions (1.3-1.9 TeV)





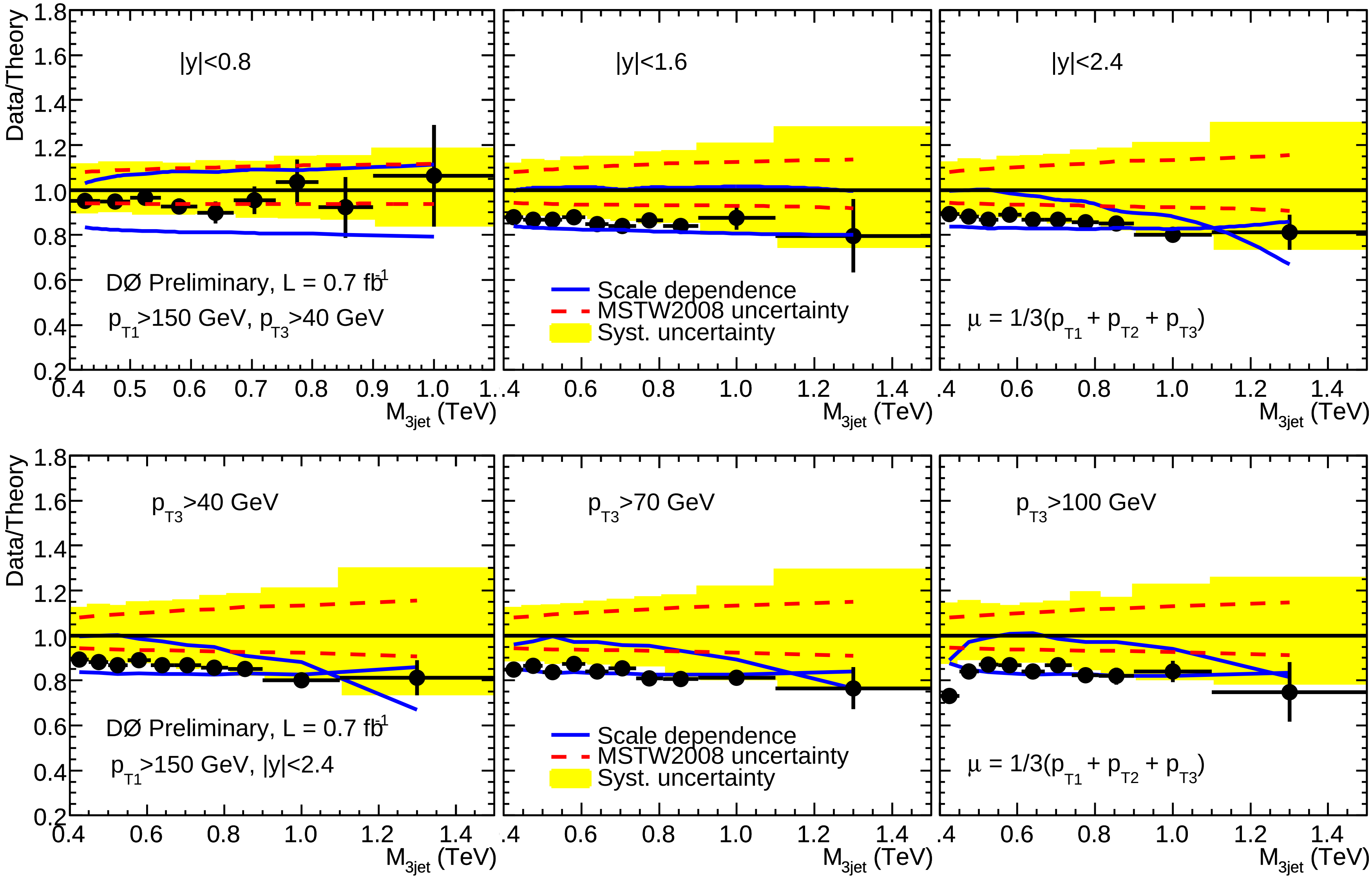
Three jet mass measurements (D0)

- Differential measurements of three jet mass: p_T^{lead} >150 GeV, $p_T^{3rd} > 40$ GeV, ΔR_{jj} >1.4, allow to study invariant masses > 1 TeV
- Comparison with NLO calculations with MSTW08
- Total systematic uncertainties: 20-30%, dominated by JES, jet p_T resolution and luminosity



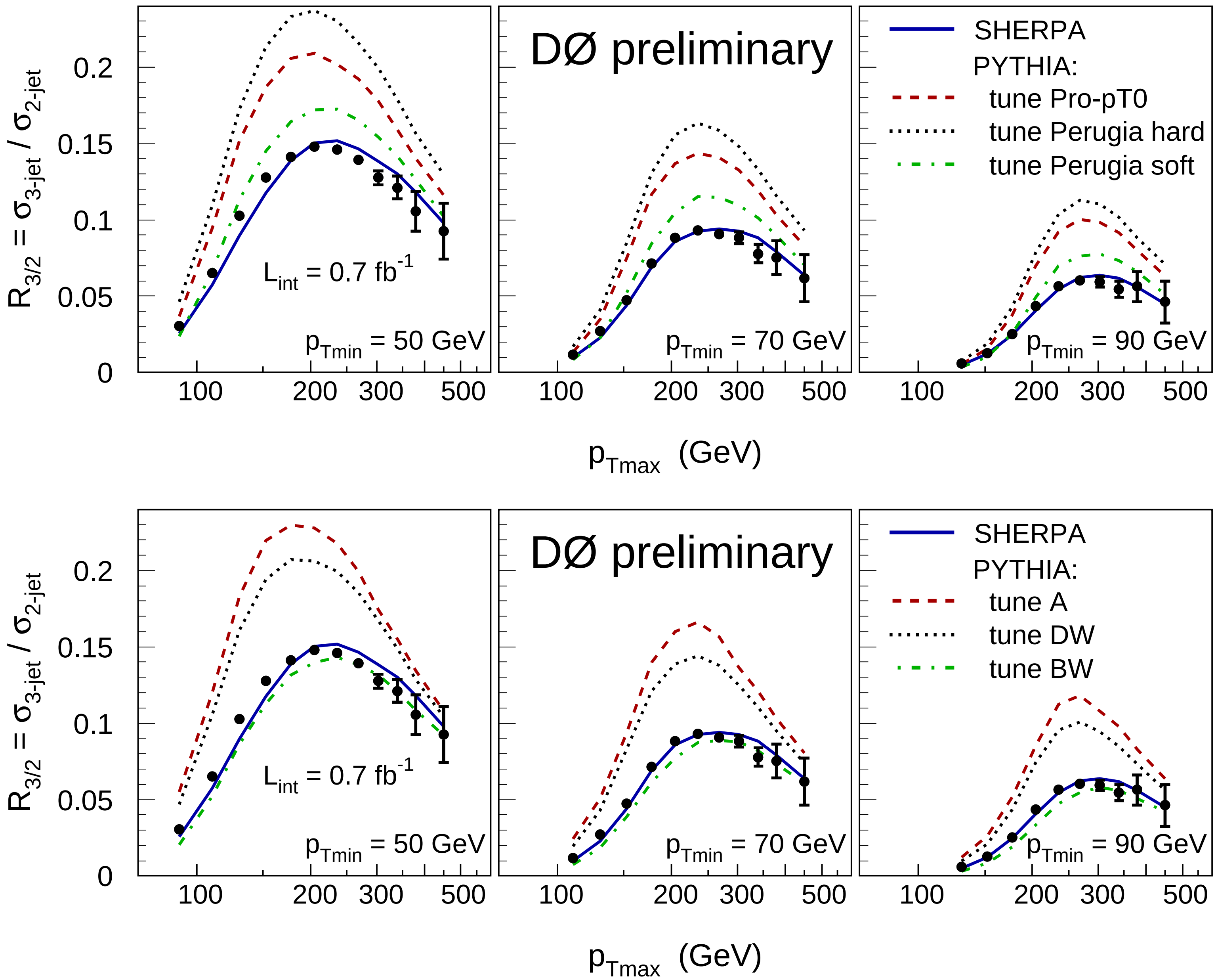
Three jet mass measurements (D0)

Reasonable agreement between data and NLO



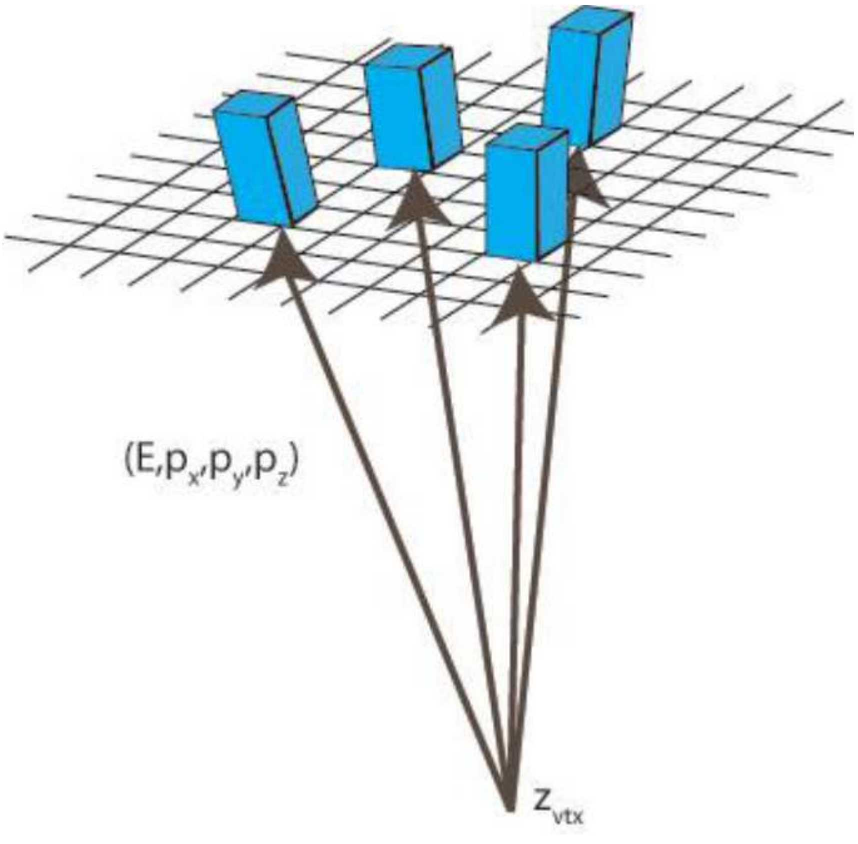
Ratio of 3 to 2 jet inclusive cross sections (D0)

- First measurement of ratios of multijet cross sections at Tevatron: Test QCD more independent of PDFs (residual dependence due to 2/3 jet subprocess composition), probes α_S
- Good agreement with Sherpa 1.1.3 (MSTW2008), PYTHIA tunes too high (except BW)



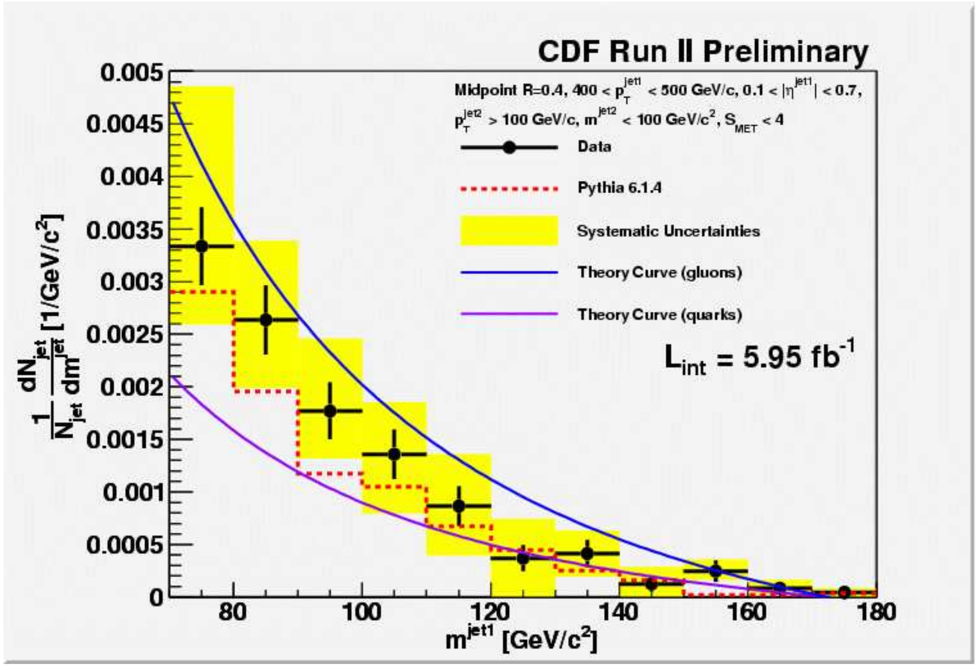
Mass of high p_T jets (CDF)

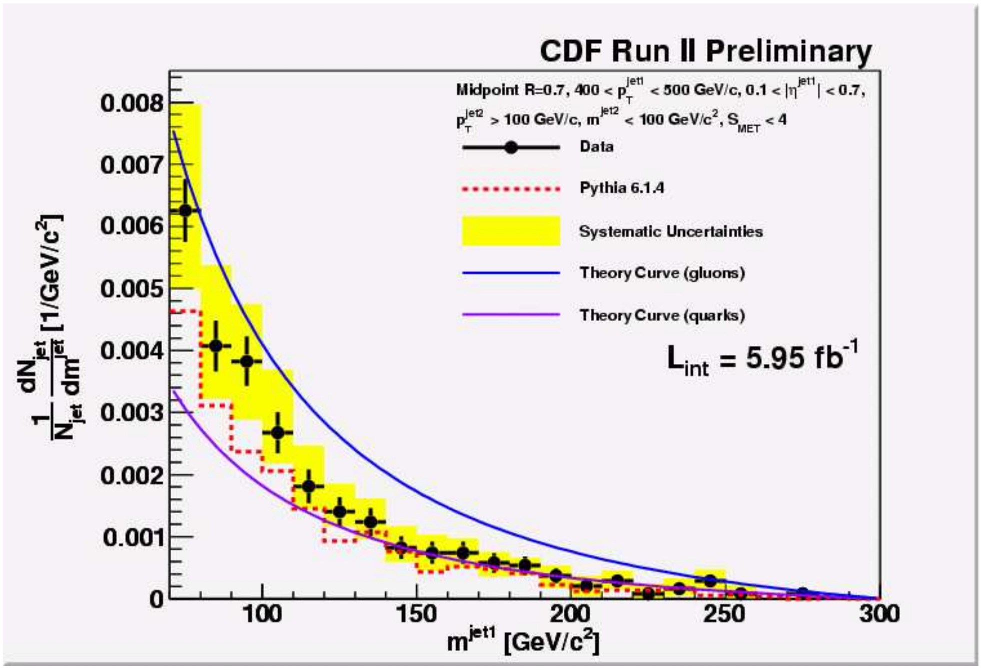
- Motivation of mass measurement of high-p_T jets: such jets form significant background to new physics searches (Higgs, neutralinos, high p_T tops...)
- Angularity and planar flow variables: variables allowing to test QCD, quite robust against soft radiation, less dependent on the jet algorithm used
- Use standard E-scheme for mass calculation: 4-vector sum over towers in jets (each tower is a particle with $m = 0$), the vector sum gives (E, p_x, p_y, p_z)



Comparison between mass and QCD expectations (CDF)

- Good agreement between data and QCD prediction (also with Pythia) over the jet mass range 70 to 250 GeV
- Data interpolate between quark and gluon predictions: about 80% of jets arise from quark showering





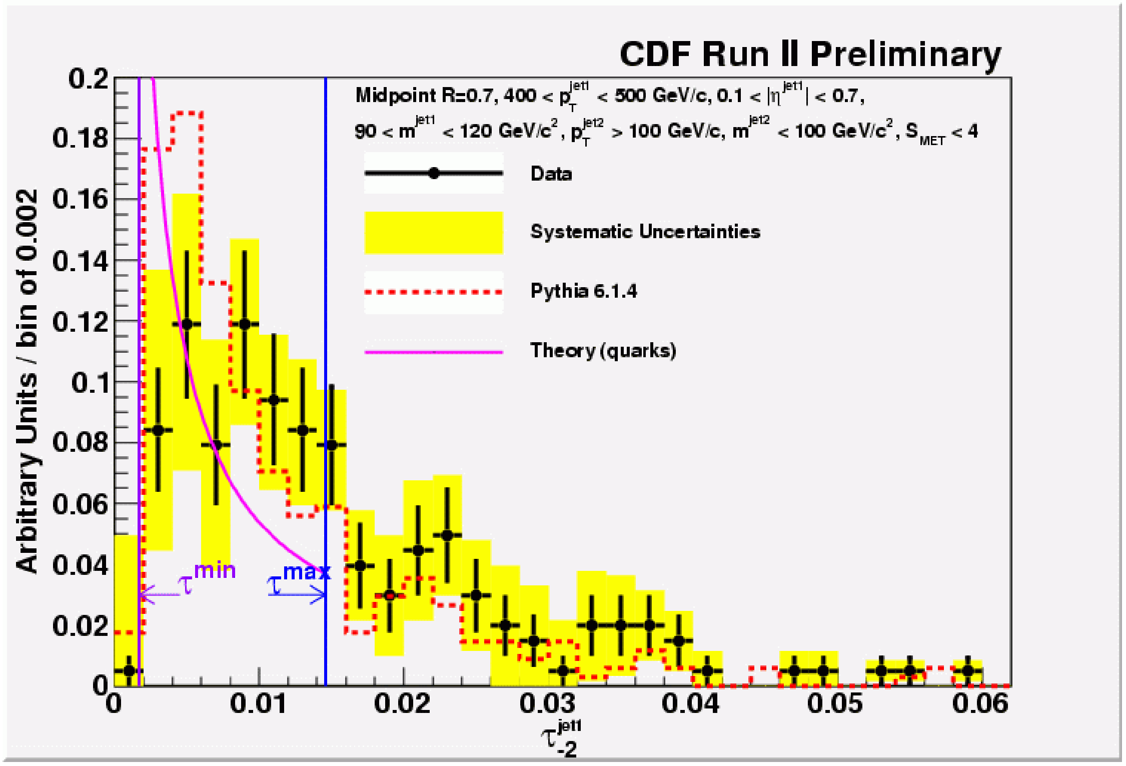
Angularity and planar flow (CDF)

- Angularity: (sum over calorimeter towers)

$$\tau_a(R, p_T) = \frac{1}{m_J} \Sigma_i \omega_i \sin^a \theta_i \, [1 - \cos \theta_i]^{1-a}$$

where ω_i is the energy of a component inside the jet (for instance, calorimeter tower)

- measures the energy distribution inside a jet
- sensitive to the degree of symmetry in the energy deposition: can distinguish QCD jets from quarks/gluons and boosted heavy particle decays
- fewer jets at low angularity, data show more spherical jets



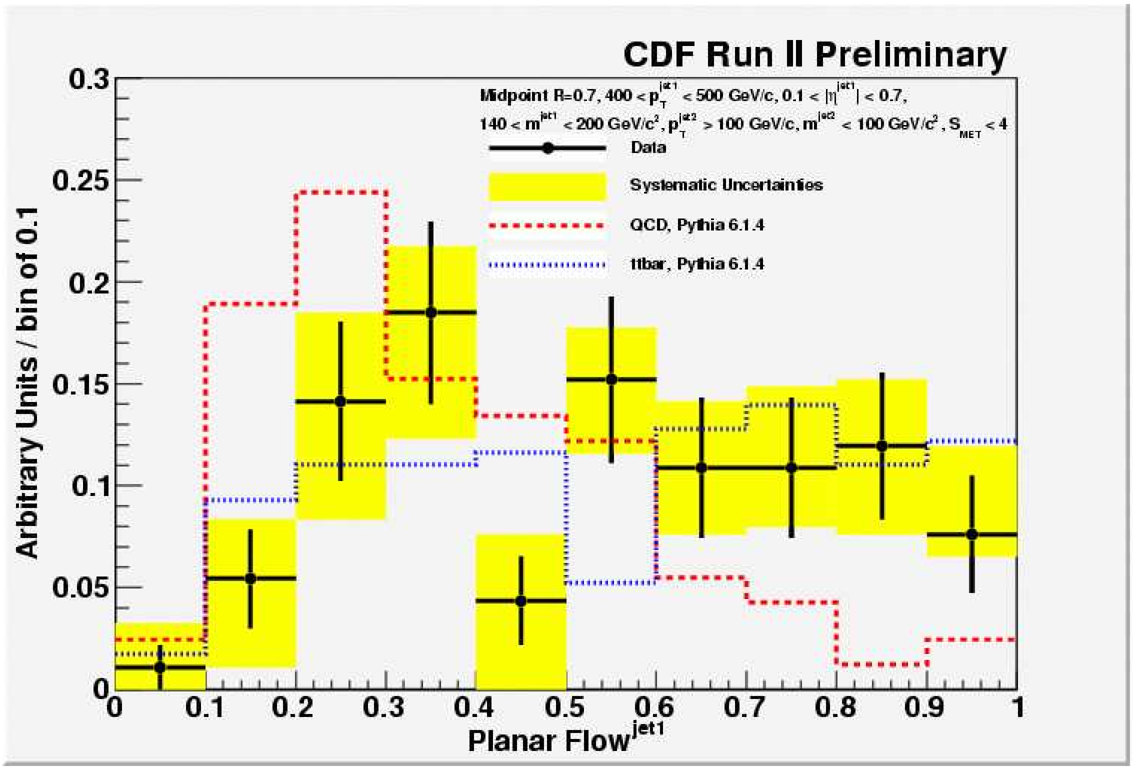
Angularity and planar flow (CDF)

- Planar flow: additional jet substructure variable

$$I_w^{kl} = \frac{1}{m_{jet}} \Sigma_i \frac{p_{ik}}{w_i} \frac{p_{il}}{w_i} \qquad P_f = \frac{4\lambda_1\lambda_2}{(\lambda_1+\lambda_2)^2}$$

where w_i is the energy of particle i, p_{ik} is the k^{th} component of the transverse momentum relative to the jet momentum axis and λ_1. λ_2 are eigenvalues of I_w^{kl}

- P_f vanishes for linear shape and approaches unity for isotropic deposition of energy
- Reasonable agreement but data prefer more aplanar configuration than QCD



Conclusion

- Measurement of the inclusive jet cross section: high precision measurement due to high precision on jet energy scale (1.2% for D0 for a wide region in jet p_T and rapidity)
- Extraction of α_S from jet inclusive measurements: $\alpha_S(M_Z) = 0.1161^{+0.0048}_{-0.0041}$
- Dijet mass measurements (cross sections and angular distributions): good agreement with QCD, leads to best limits on quark compositeness, extra-dimensions
- 3-jet mass measurements: reasonable agreement with NLO QCD
- Ratio 3 to 2 jet cross sections: Good agreement with Sherpa, Pythia does not lead to a good description (ratio less dependent on PDFs)
- Mass of high p_T jets: data show more spherical jets than QCD prediction