High P_T Jet Physics at the Tevatron Collider

Elizabeth Buckley–Geer

Fermilab

- Inclusive Jet Cross–section at 1800 GeV
- Dijet Mass Distribution
- Dijet Angular Distribution
- Inclusive Jet Cross–section at 630 GeV
- Conclusions

Inclusive Jet Cross–Section at $\sqrt{s}$ = 1800 GeV

$$\frac{1}{\Delta\eta}\int d\eta \frac{d^2\sigma}{dE_T\,d\eta} = \frac{1}{\Delta\eta}\frac{1}{L}\frac{N_{jet}}{\Delta E_T}$$

- *Powerful test of perturbative QCD*

- *High statistics measurement, small systematic uncertainties, wide range of jet E_T*

- *Search for new physics: probes distance scales $\approx 10^{-17}$ cm*

- *Calculated at order α_s^3*

EKS

Ellis et al. Phys. Rev. Lett. 64 (1990) – analytic calculation

JETRAD

Giele et al. Nucl. Phys. B403 (1993) – event generator

Aversa

Aversa et al. Nucl. Phys. B327 (1989) – analytic calculation

Data Samples

Run IA: CDF – 19 pb^{-1}; D0 – 13 pb^{-1}
Run IB: About 90 pb^{-1} for each experiment

- η–ranges for inclusive cross–section:

  D0: $|\eta| \leq 0.5$ CDF: $0.1 \leq |\eta| \leq 0.7$

- Minimum jet E_T:

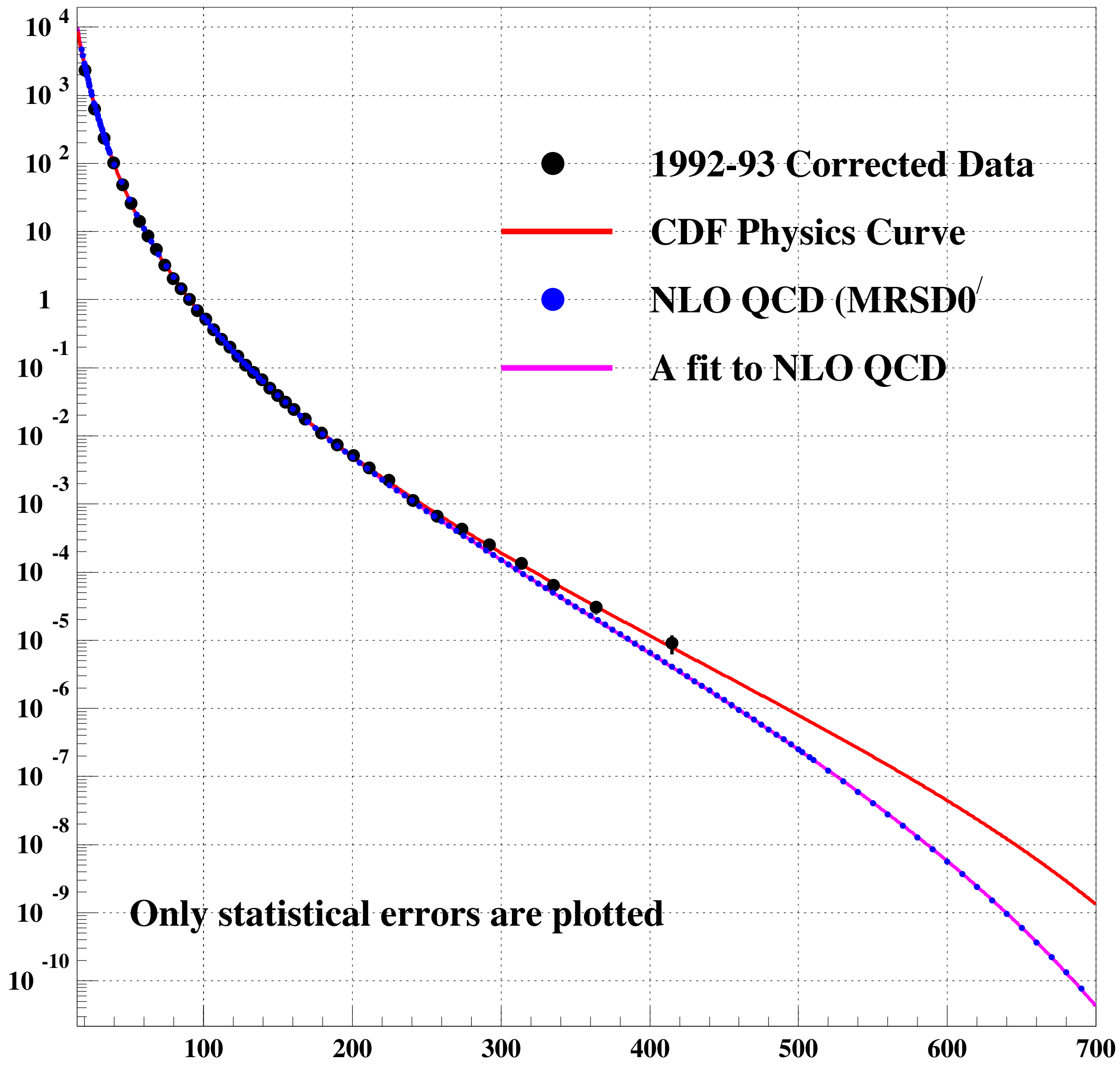
  CDF: 15 GeV D0: 60 GeV

- Data are corrected for detector effects such as energy scale $\approx$ 20%

- Backgrounds are removed with cuts on Missing E_T variables

- Inclusive cross–section is corrected for resolution smearing – convolute "physics curve" with measured jet resolution and fit to data. Iterate until a good fit is obtained.

CDF Inclusive Jet Cross–Section



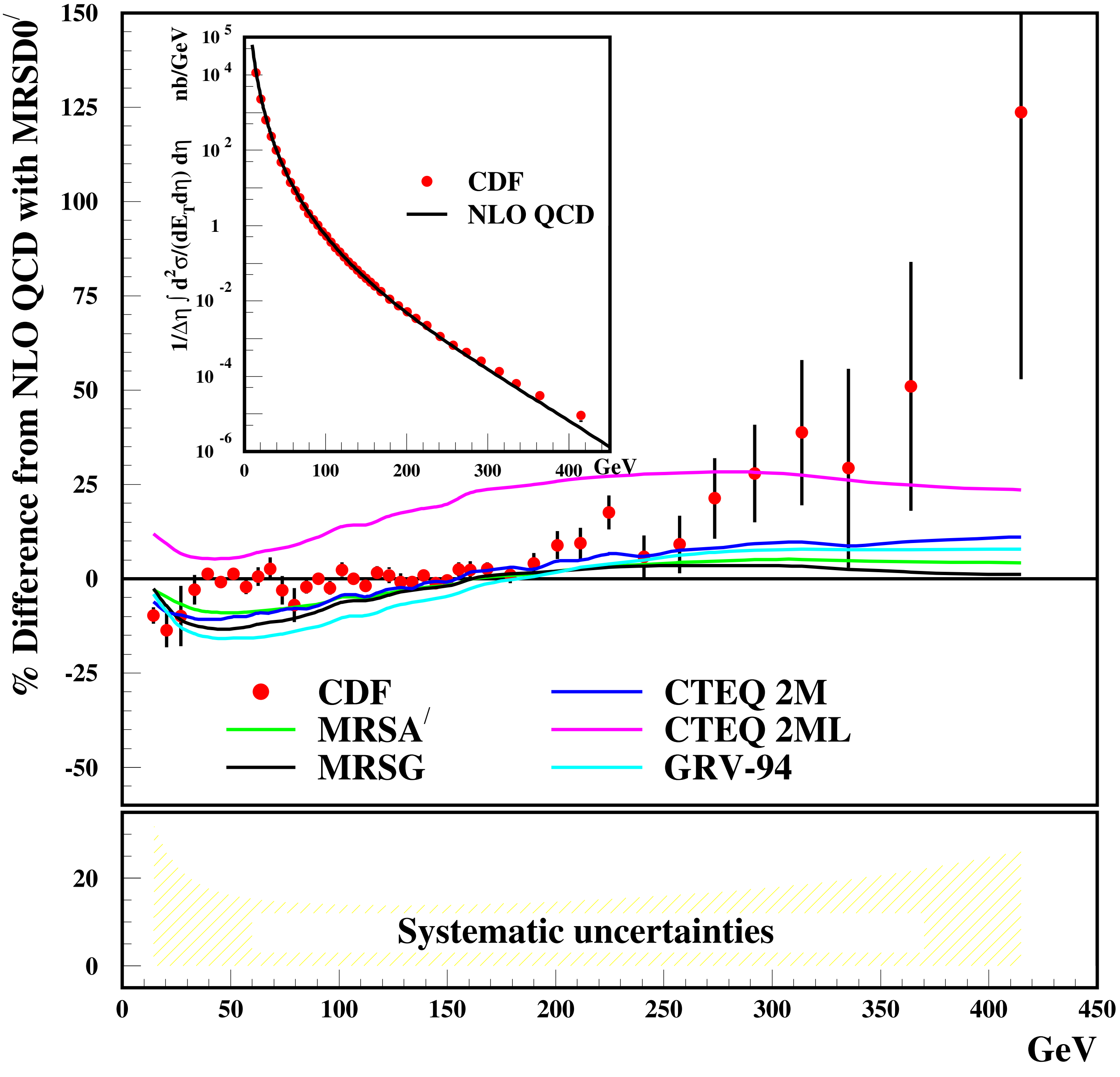
Physics curve is well behaved beyond data

Same parametrization also fits NLO QCD

CDF uses EKS for all theory comparisons

CDF Inclusive Jet Cross–Section

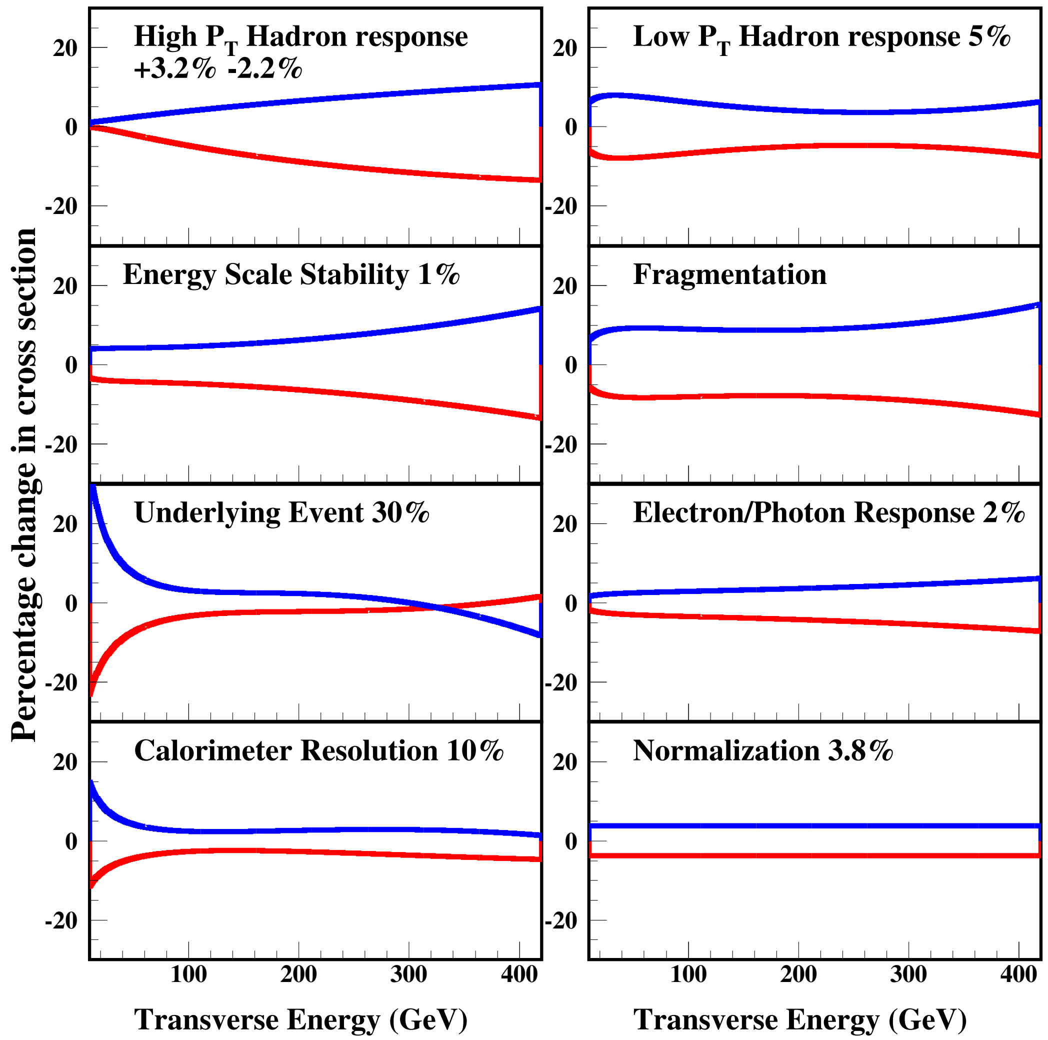
Linear comparison



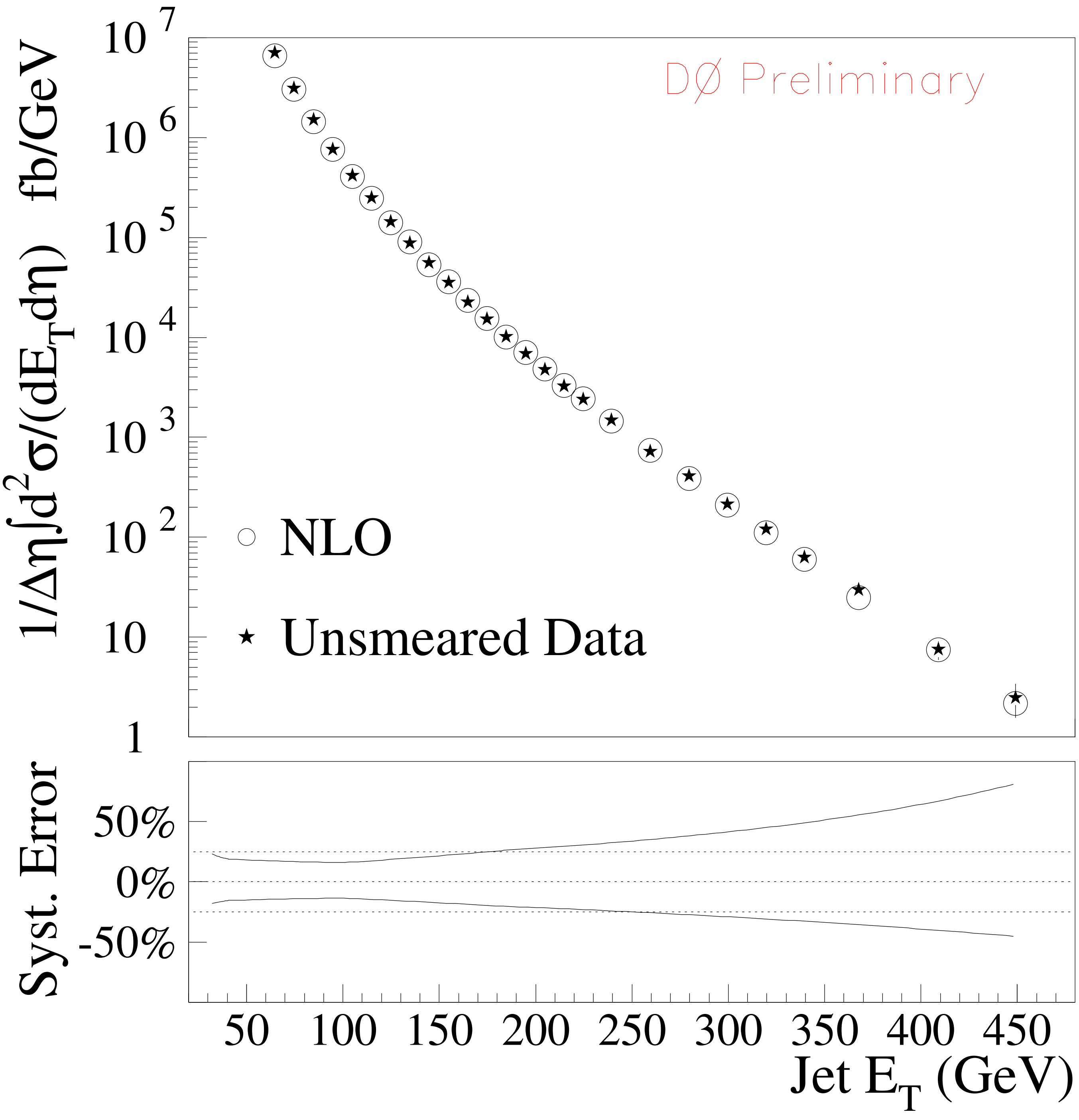
CDF Systematic Uncertainties

- Evaluate change in response functions
- Use new response functions to derive new "physics curve"
- Compare to standard curve
- Overall systematic (added in quadrature)

18% at 50 GeV   22% at 400 GeV



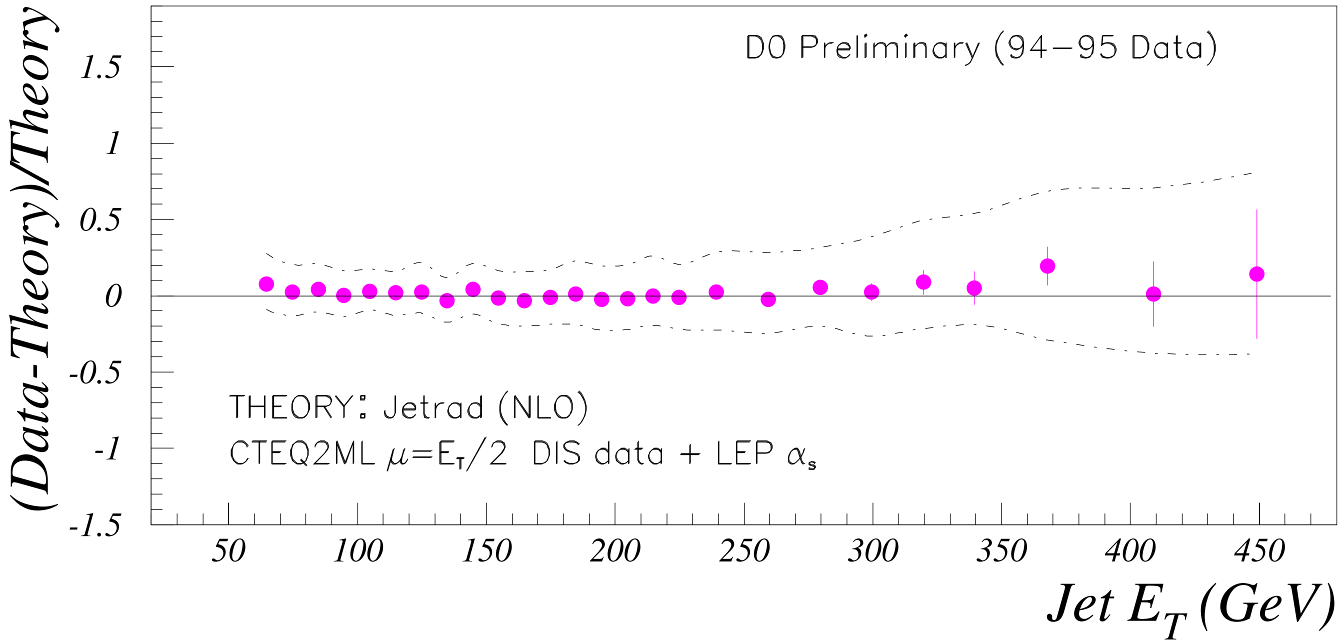
D0 Inclusive Cross–Section

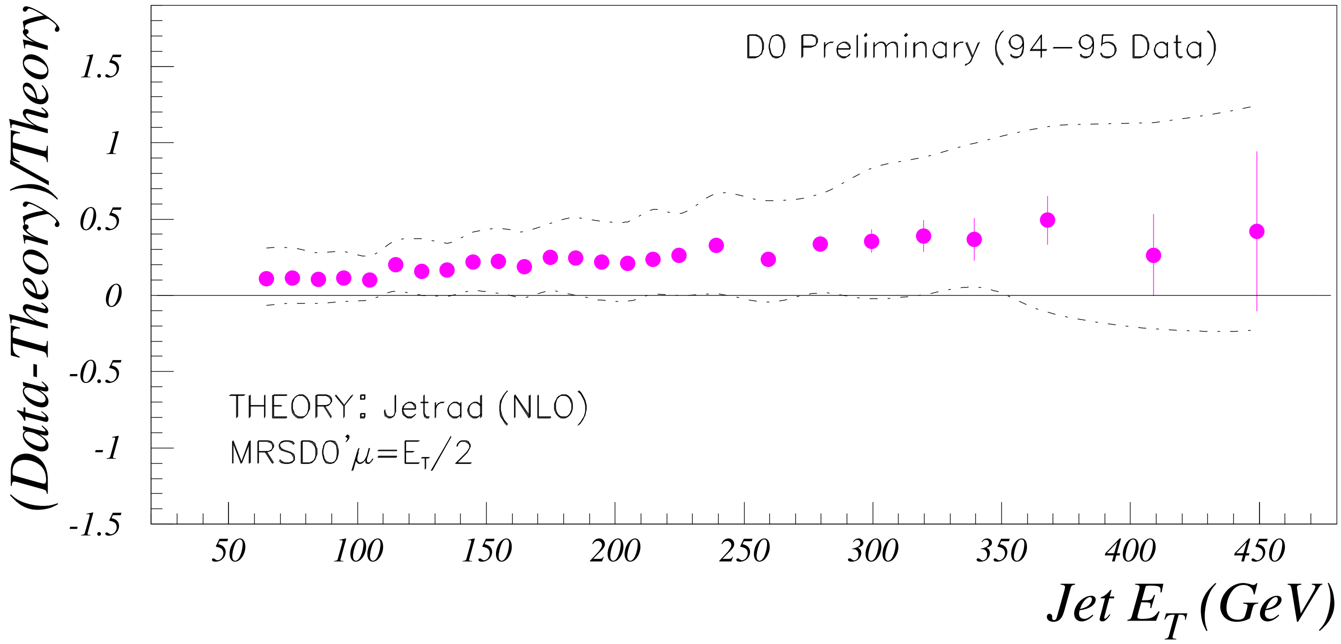


D0 uses JETRAD for all theory comparisons

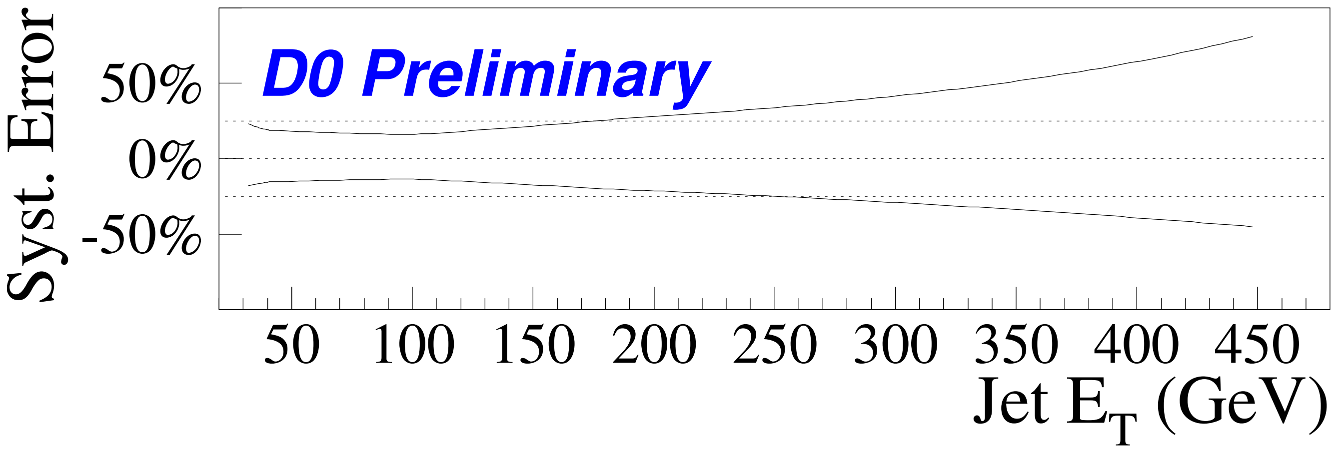
D0 Inclusive Jet Cross–Section

Linear comparison



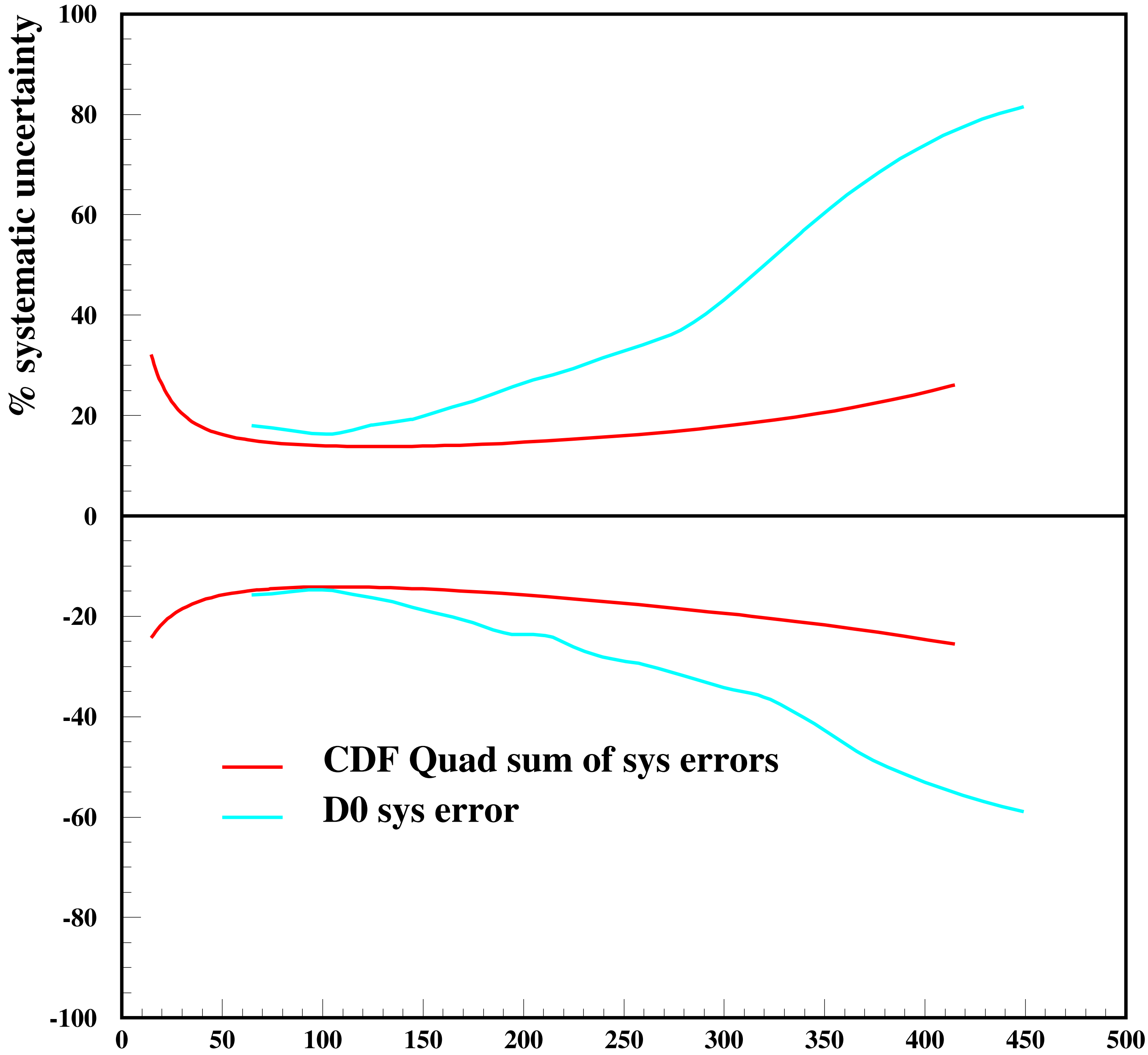


D0 Systematic Uncertainties



Source	% Error
Jet Selection	1
Event Sel.	1
Luminosity	8
Trigger matching	1,2,2
Unsmearing	3–7 (for 100–400 GeV)
Energy Scale	15–45 (for 100–400 GeV)

Comparison of Systematic Uncertainties

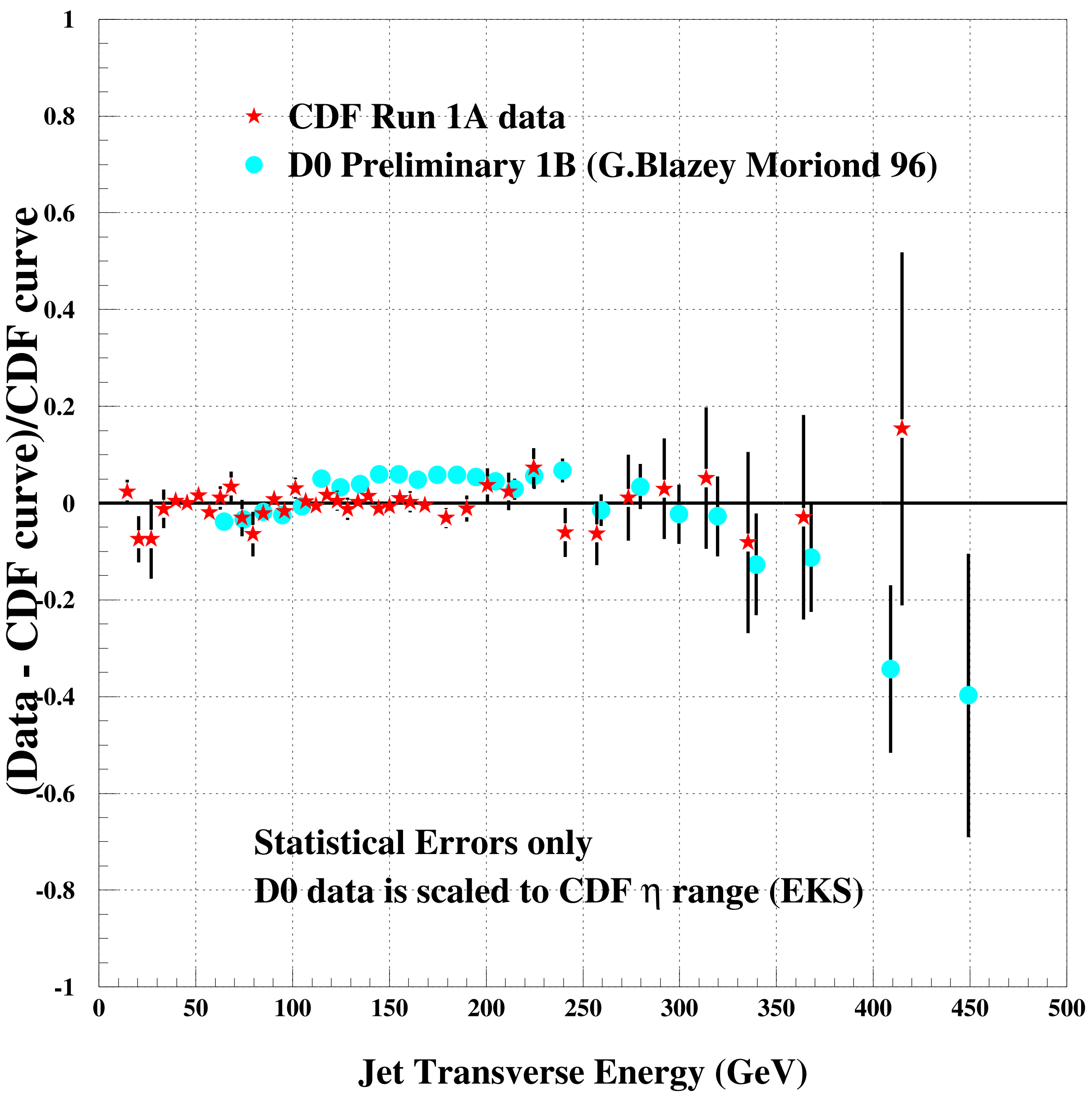


D0 systematic errors expected to shrink

Comparison of CDF and D0 Data

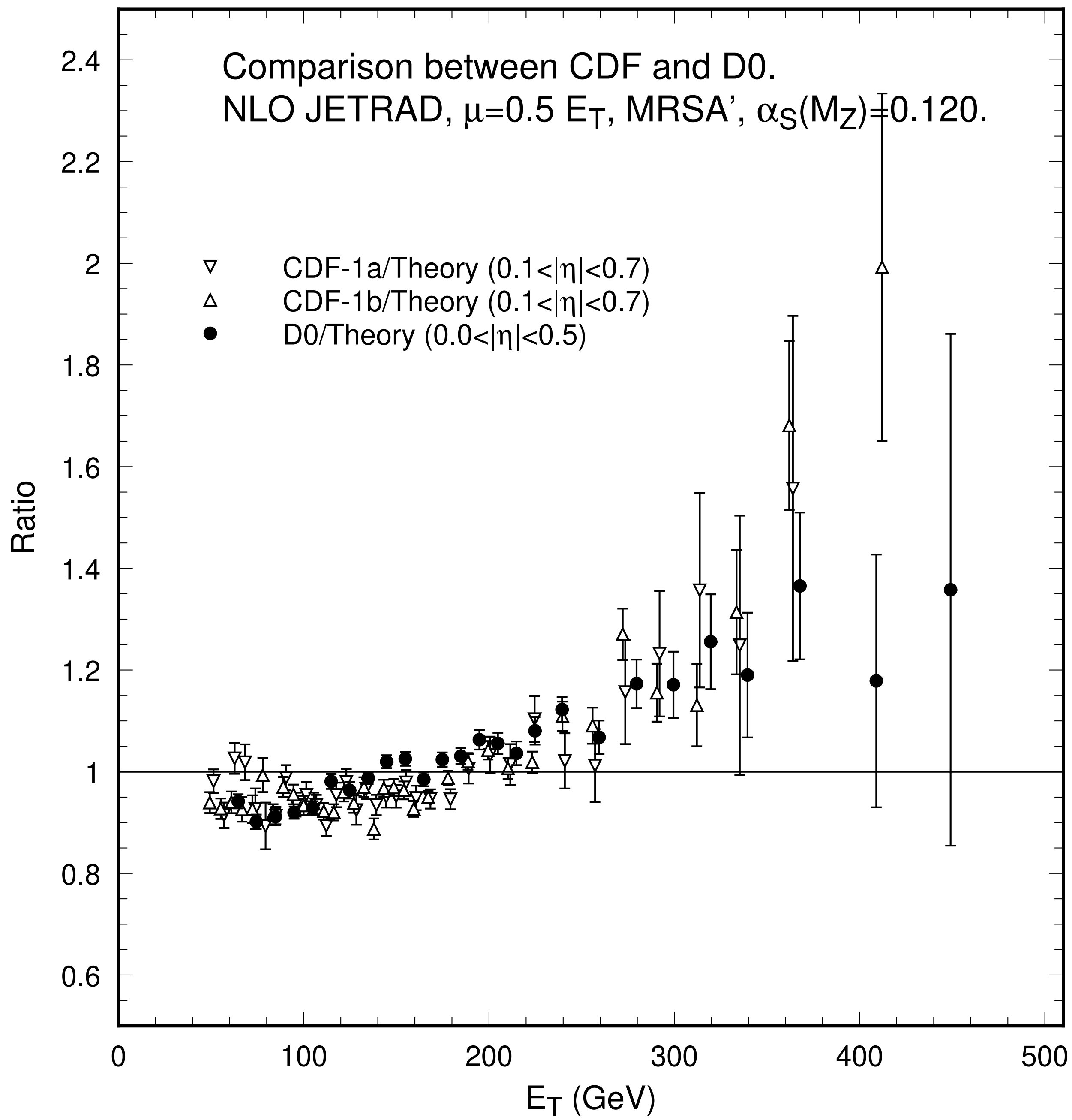
Are the two experiments in agreement?

- ***Use theory predictions to calculate the change in cross–section as a function of E_T for the different η ranges***
- ***Scale the D0 data by this factor***
- ***Plot difference between scaled D0 data and smooth fit to CDF data***



Comparison of CDF and D0 with JETRAD

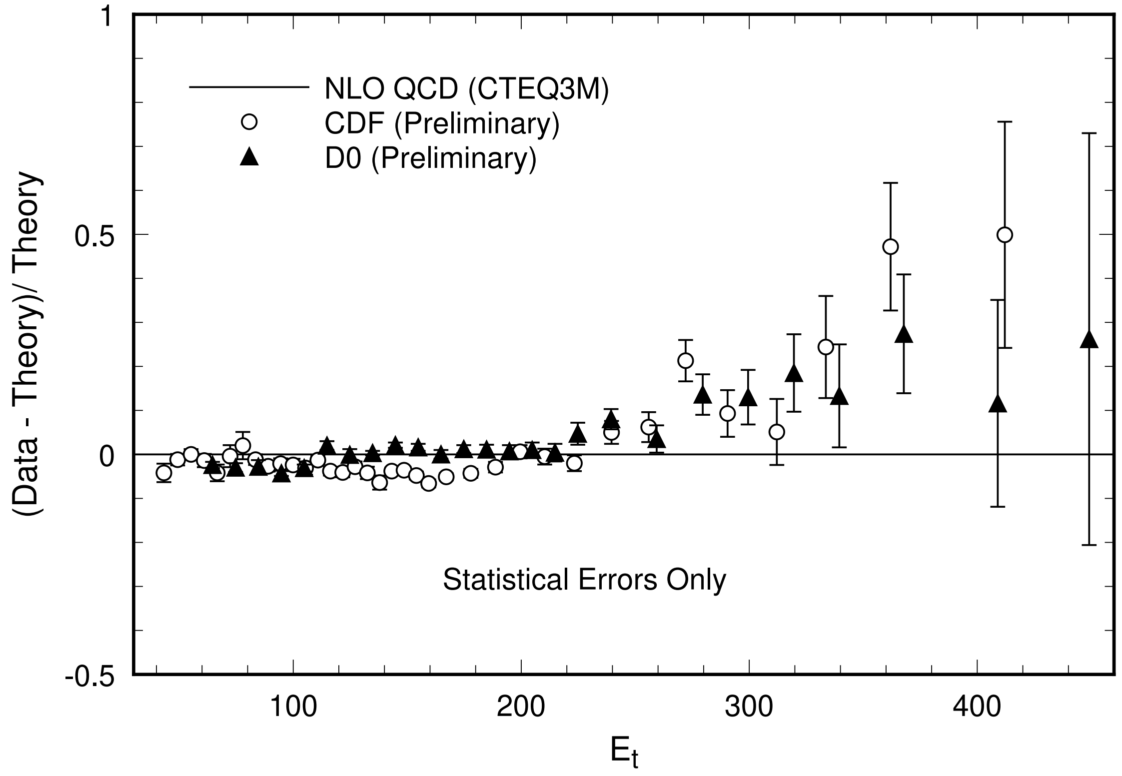
Walter Giele

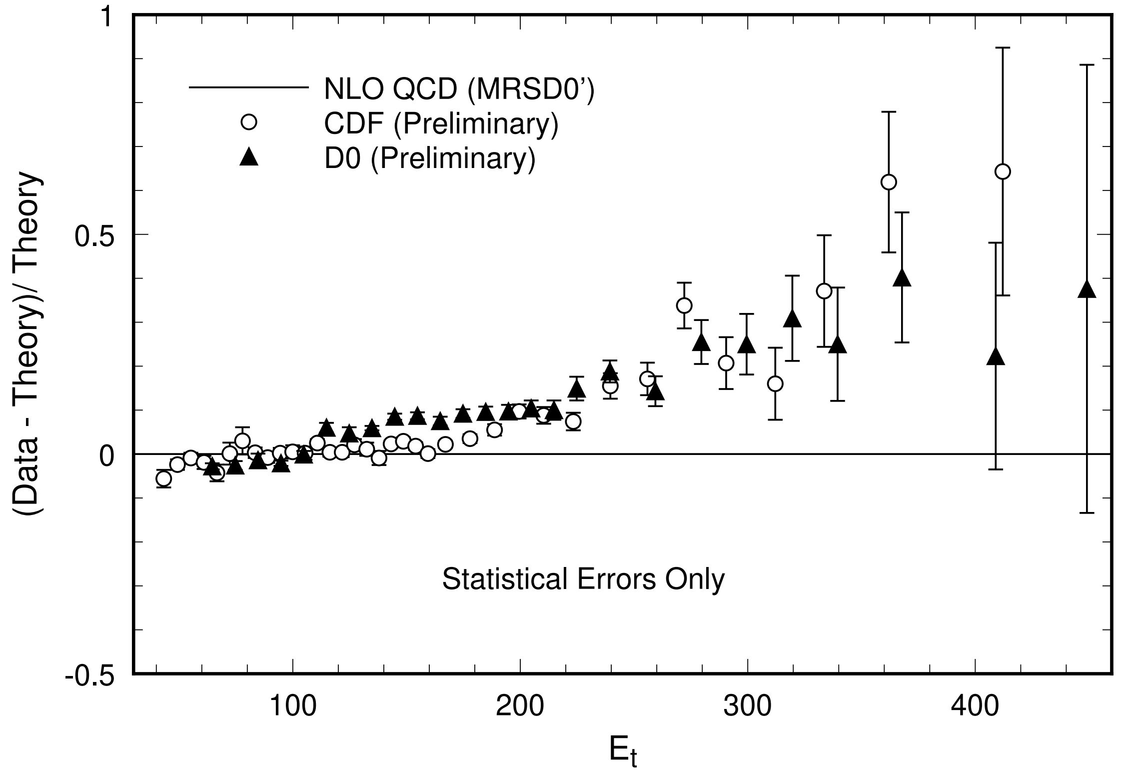


Comparison of CDF and D0 with EKS

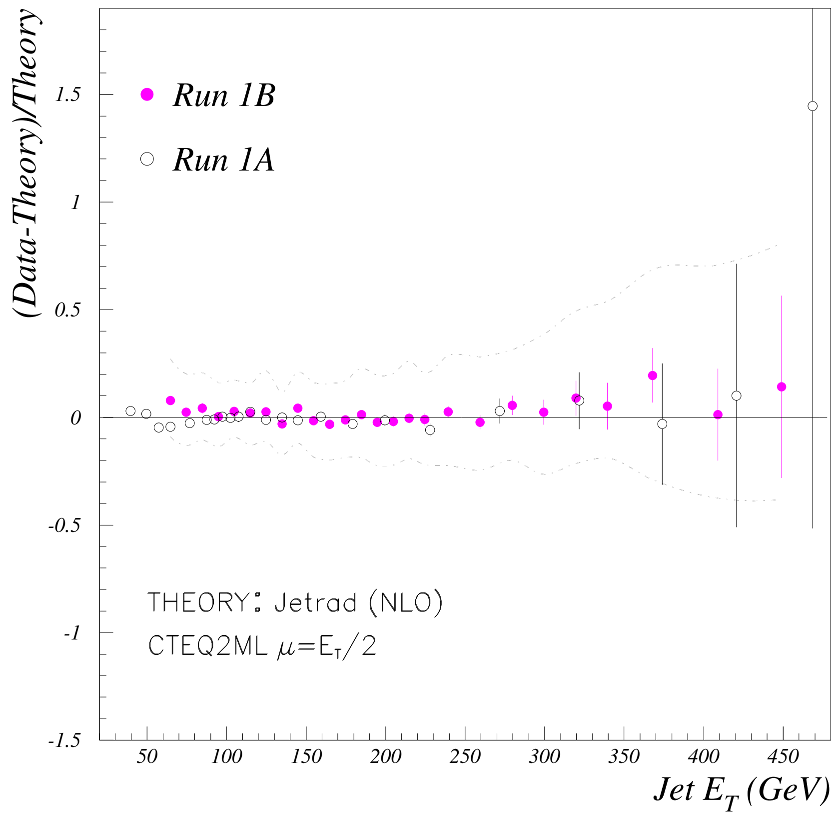
W.K.Tung & H.L.Lai

(hep–ph/9605269)

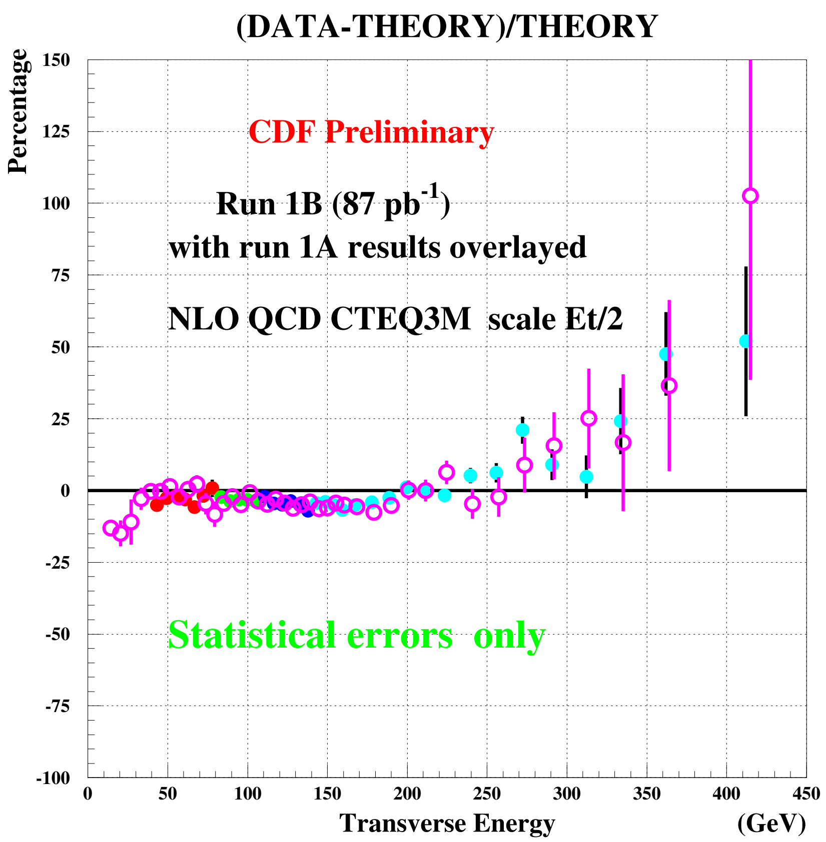




Comparison between Run IA and IB



D0



CDF

● Run 1B

○ Run IA

Comparison of CDF and D0 measurements

Do the data sets agree?

YES!! CDF and D0 data agree within statistics and certainly within systematics

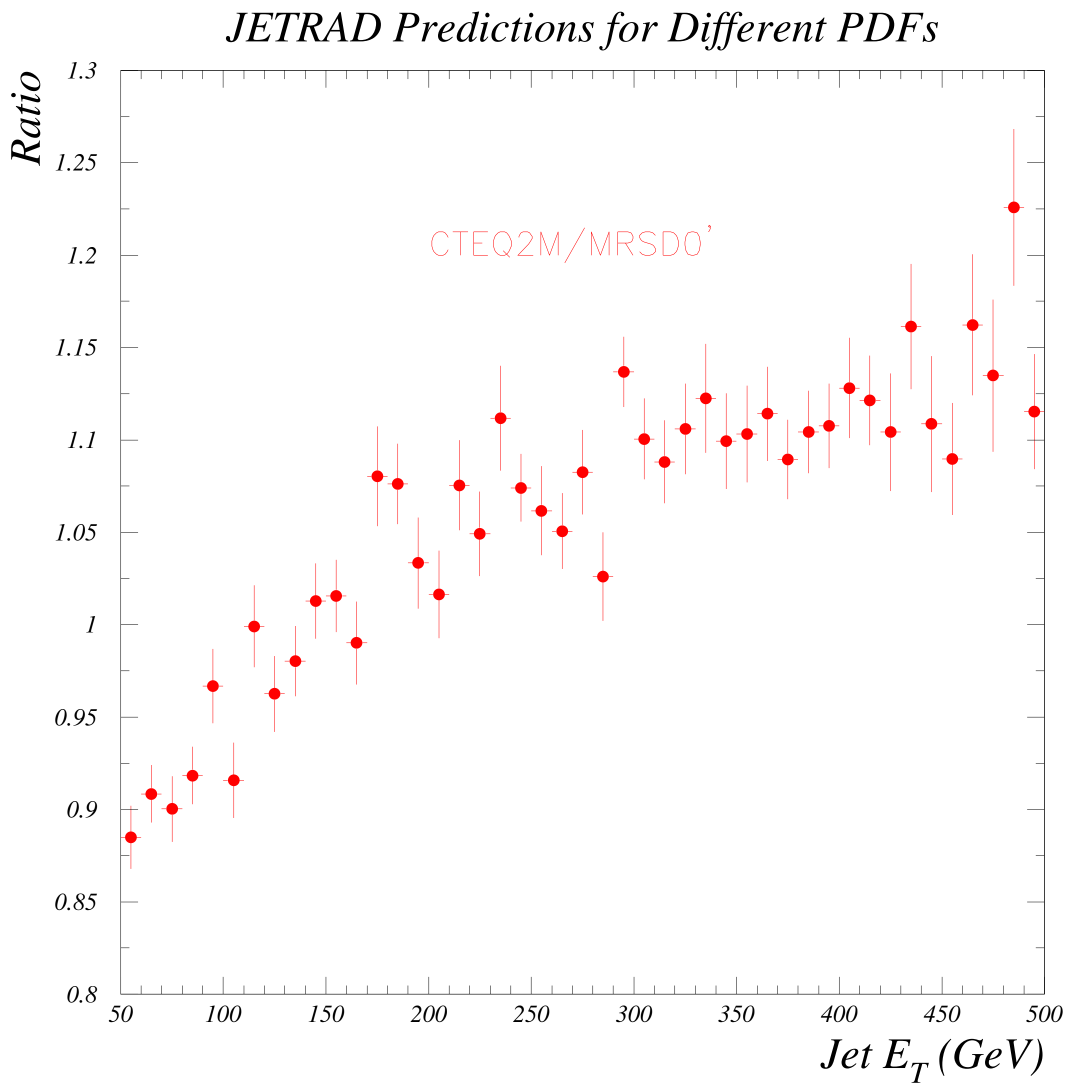
What about the theoretical predictions?

Different theoretical calculations used

Choices:

- *PDFs (~20%)*
- *Renormalization/factorization scale (~10%)*
- *Clustering algorithms (~5%)*

Variation in cross–section due to PDFs

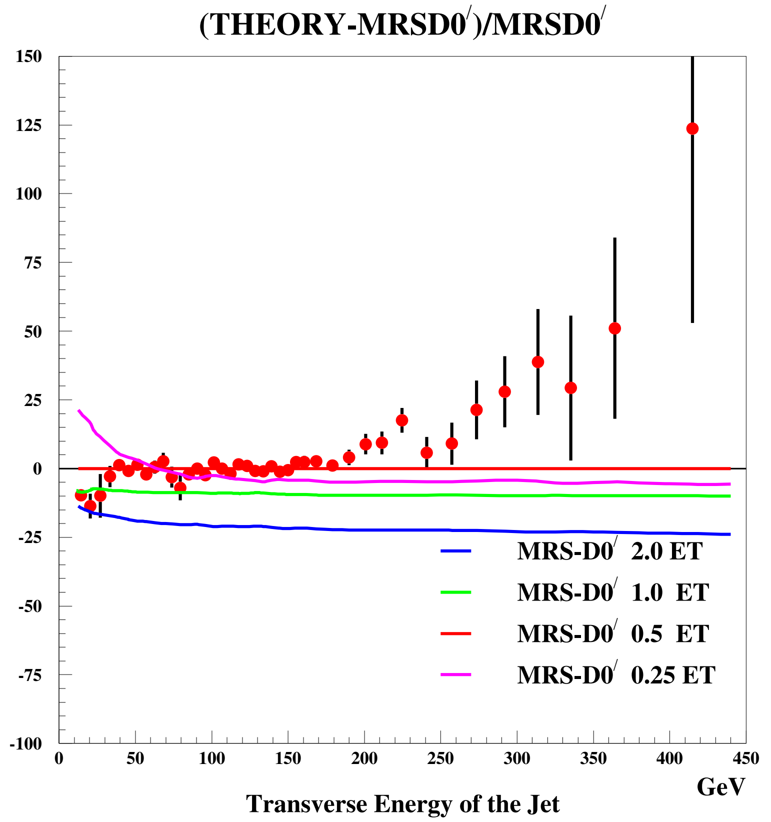


CDF data: statistical tests were performed using different PDFs and including the systematics

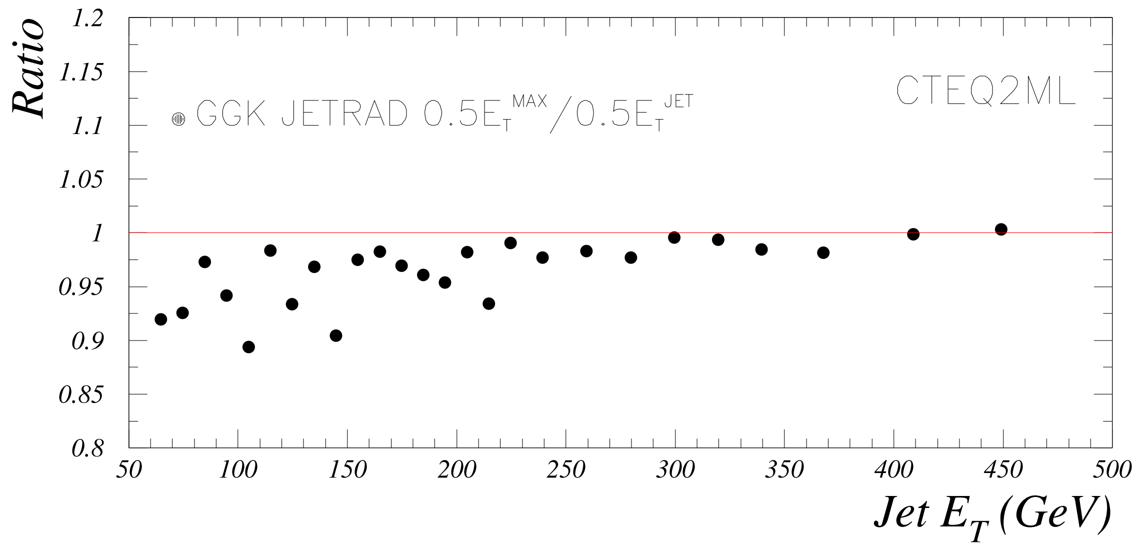
MRSD0′ : E_T = 40 – 150 GeV , > 80%
E_T > 150 GeV , 1%

CTEQ2ML : E_T = 40 – 150 GeV , 23%
E_T > 150 GeV , 8%

Variation of cross–section with μ–scale



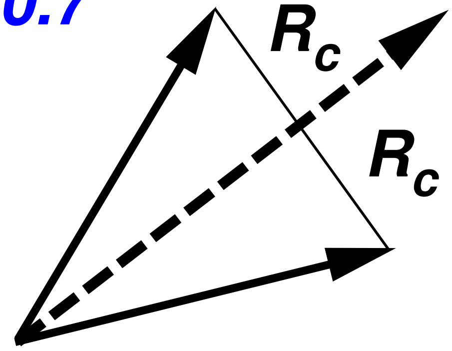
Changes normalization but not shape



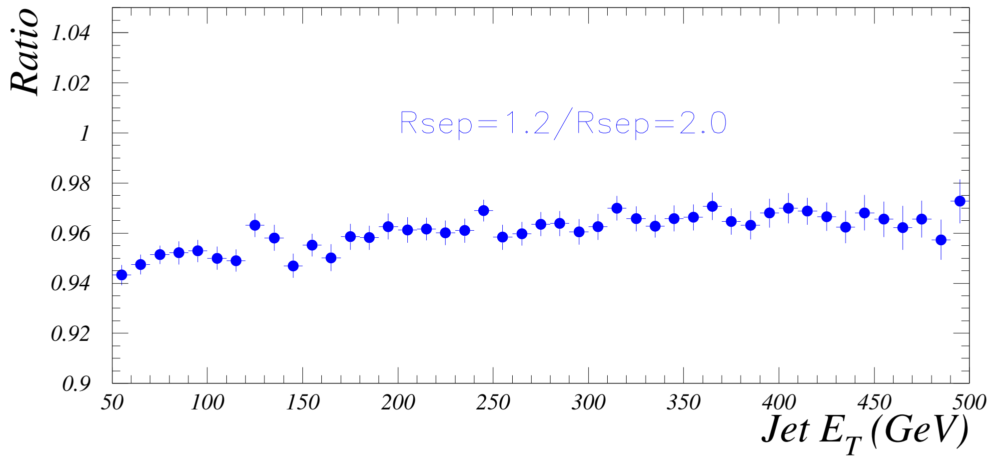
Using E_T(jet) vs E_T(lead jet) results in larger cross–section at low E_T

Variation due to parton clustering algorithms

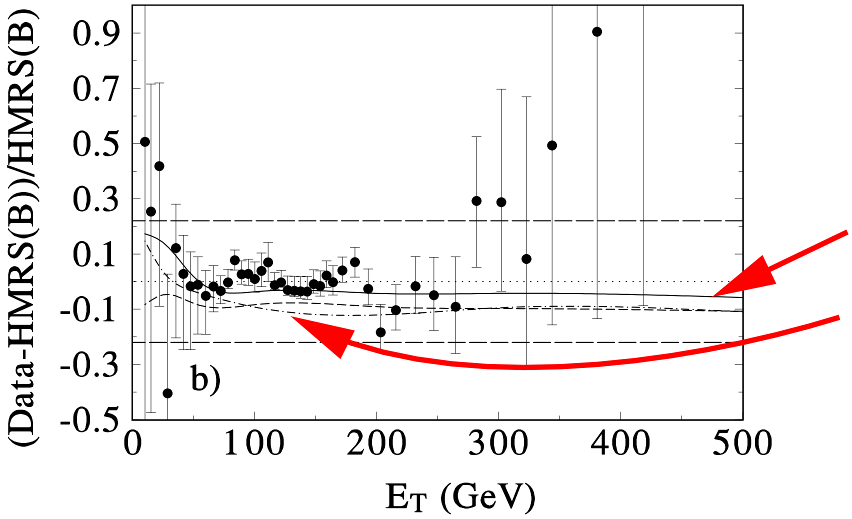
Each parton must be within R_C = 0.7 of jet centroid



But two partons can be resolved if they are within $R_{sep} \times R_C$ of each other.



R_{sep} = 1.3 for CDF and D0.



hep–ph/9306280 (Steve Ellis – Moriond 1993)

solid line $\mu=E_T/4$

dot–dashed line $\mu=E_T/4$, R_{sep} = 1.3

Recent Theoretical Activity

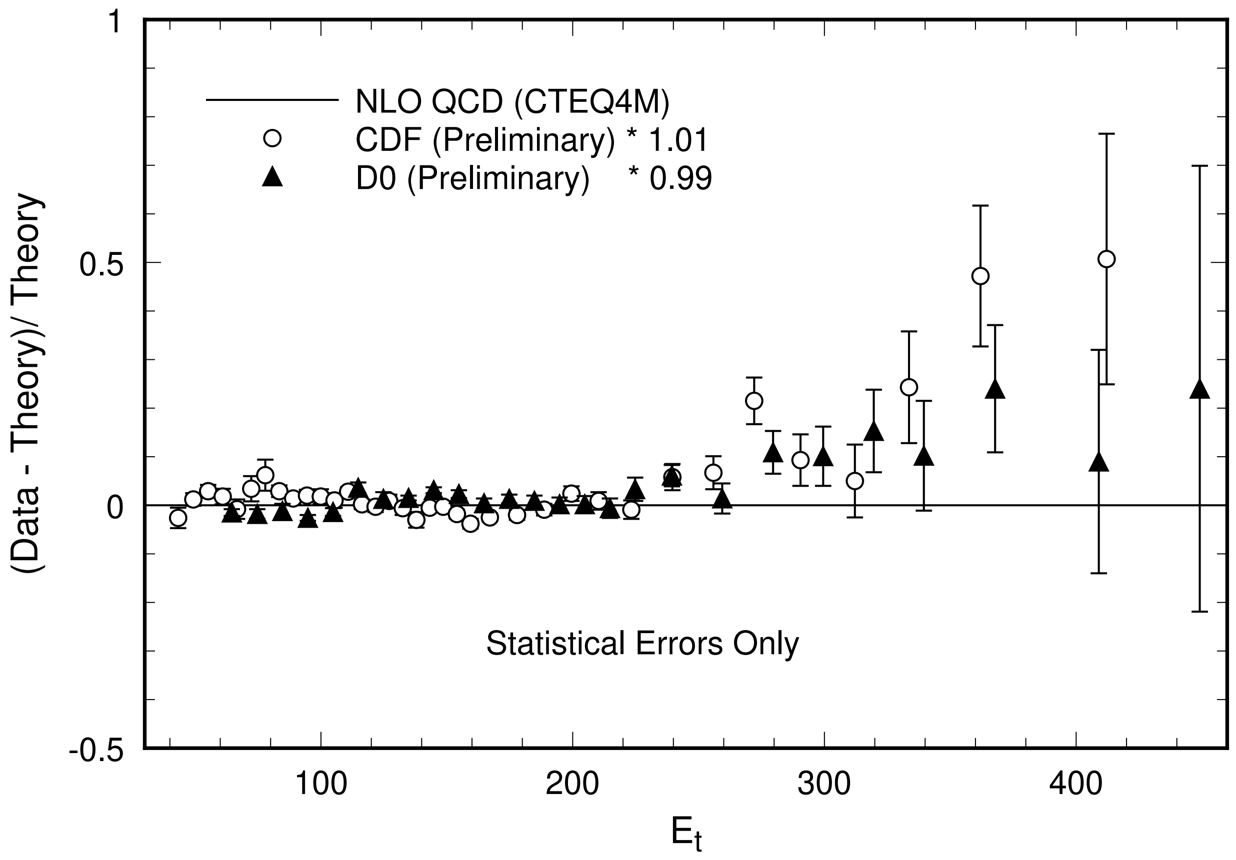
CDF measurement (PRL. 77, 438 (1996)) has stimulated enormous theoretical activity:

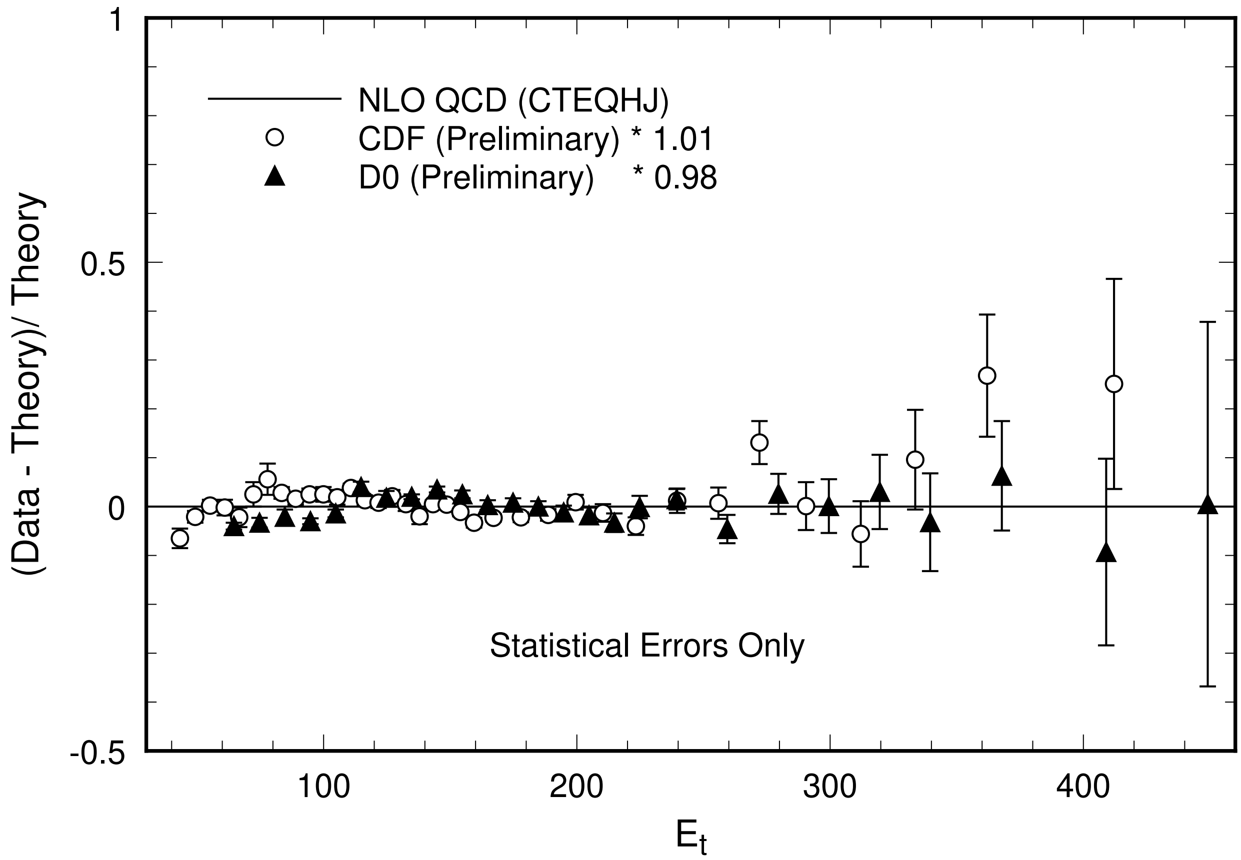
- New PDF's from CTEQ collaboration including CDF and D0 data at intermediate energies (CTEQ4M). Also CTEQHJ that gives more weight to the CDF high–E_T data (E_T > 200 GeV).
- New measurement of α_s (Walter Giele)
- New calculation of the effects of soft–gluon resummation (hep–ph/9604351) (Catani et al.)

More exotic ideas:

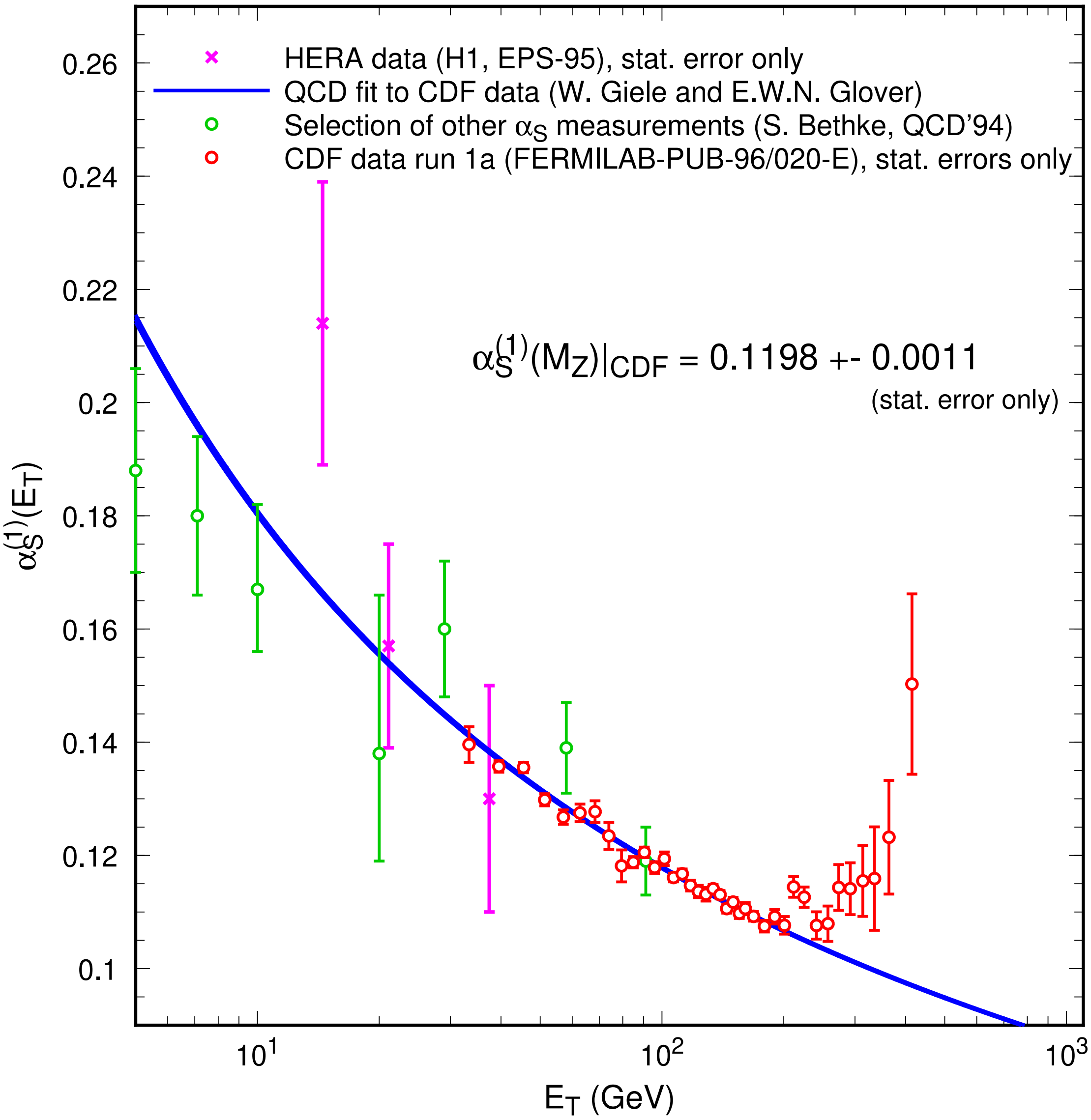
- Composite quarks – Eichten, Lane and Peskin, PRL 50 , 811 (1983).
- α_s stops running – additional SUSY particles increase the number of effective flavors (hep–ph/9512325, hep–ph/96011279); color sextet quarks (Alan White ANL)
- New particles– leptophobic Z' (hep–ph/9601324)

CTEQ Parton Distributions





Measurement of α_s
Walter Giele

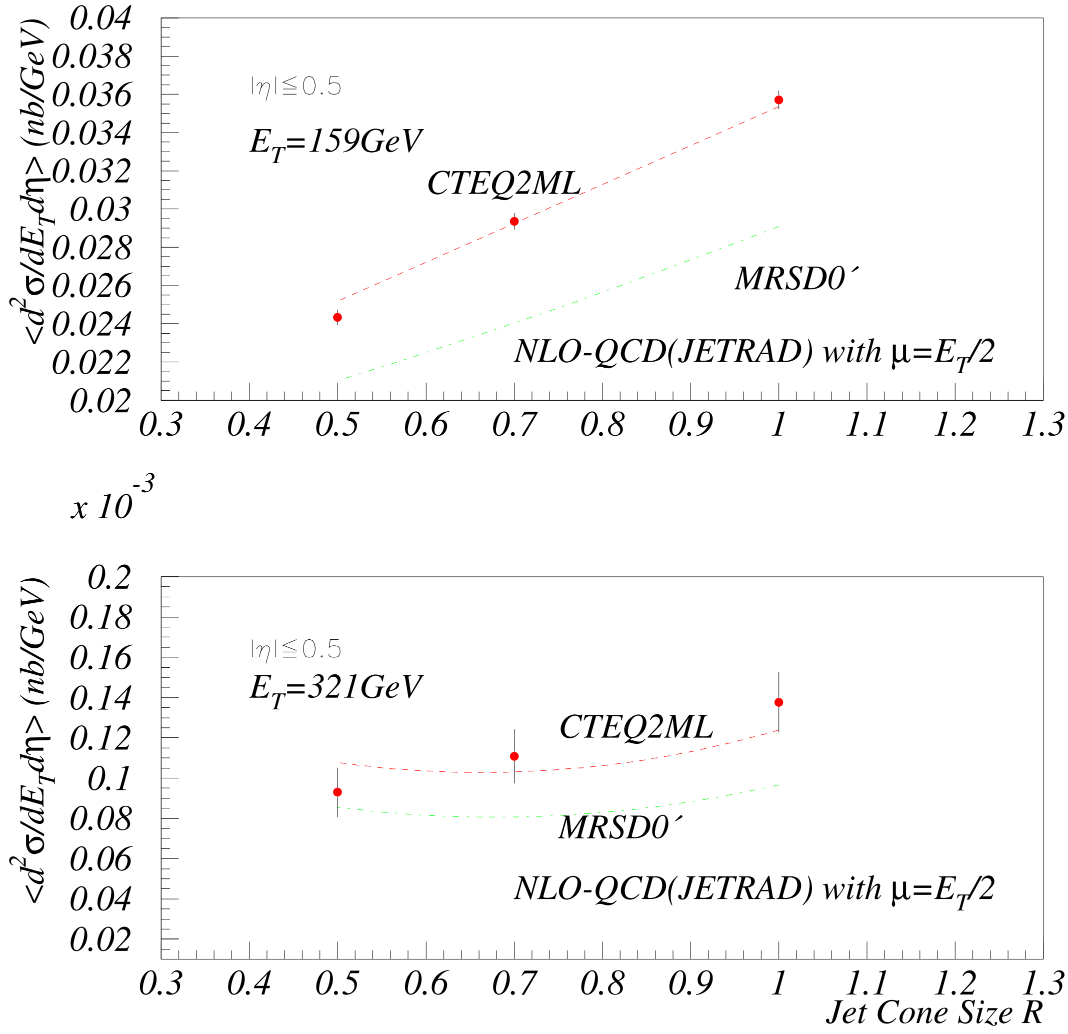


It is clear that the (CDF) data with its small systematic uncertainties is driving the theory. The D0 systematic uncertainties are large at present but are expected to shrink.

Cone–dependence of Inclusive cross–section at fixed Jet E_T

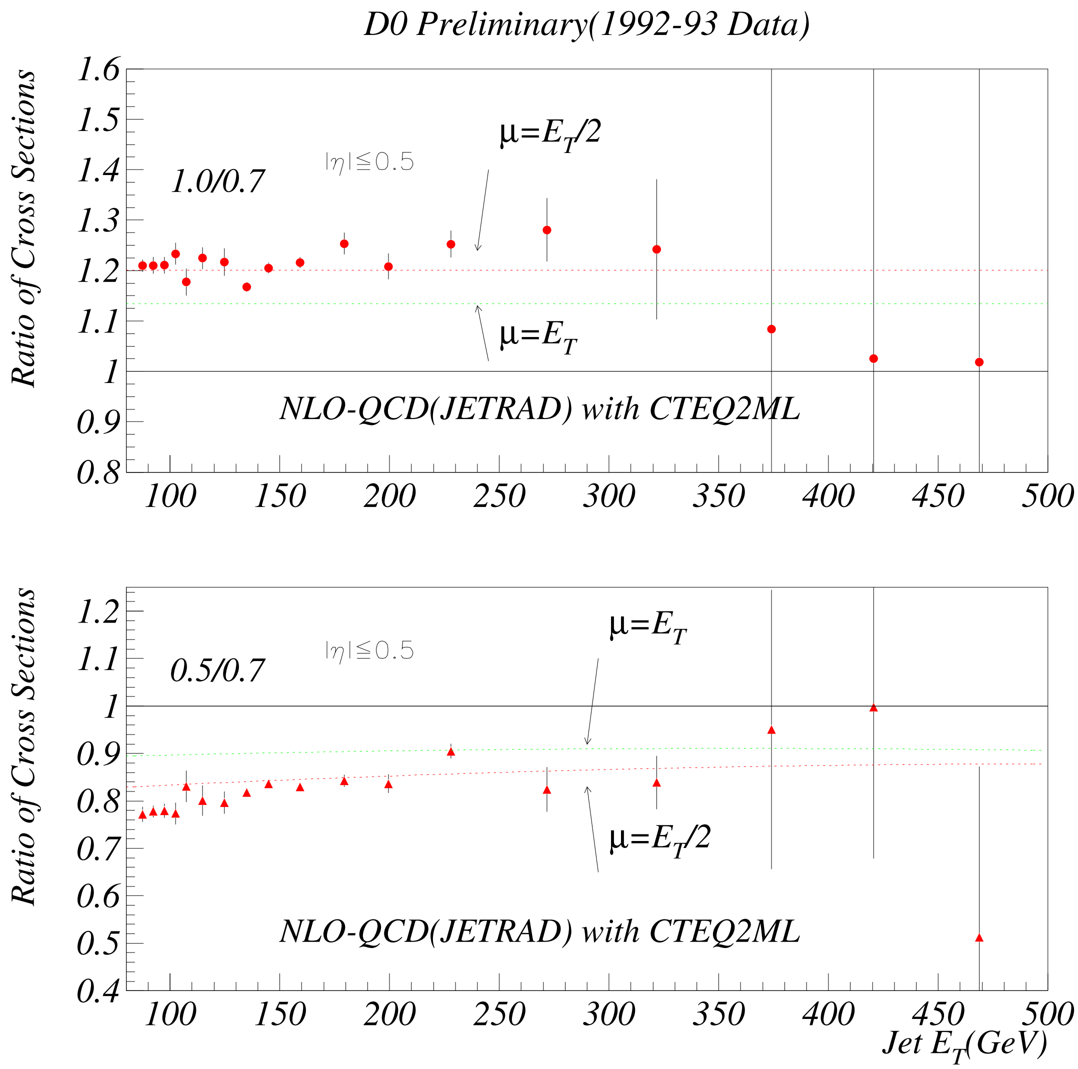
D0 has measured the dependence of the Inclusive cross–section on the cone size

(see also PRL 68 1104 (1992) for CDF measurement from 1989 data sample at E_T = 100 GeV)



Ratio of Inclusive cross–sections at different cone sizes

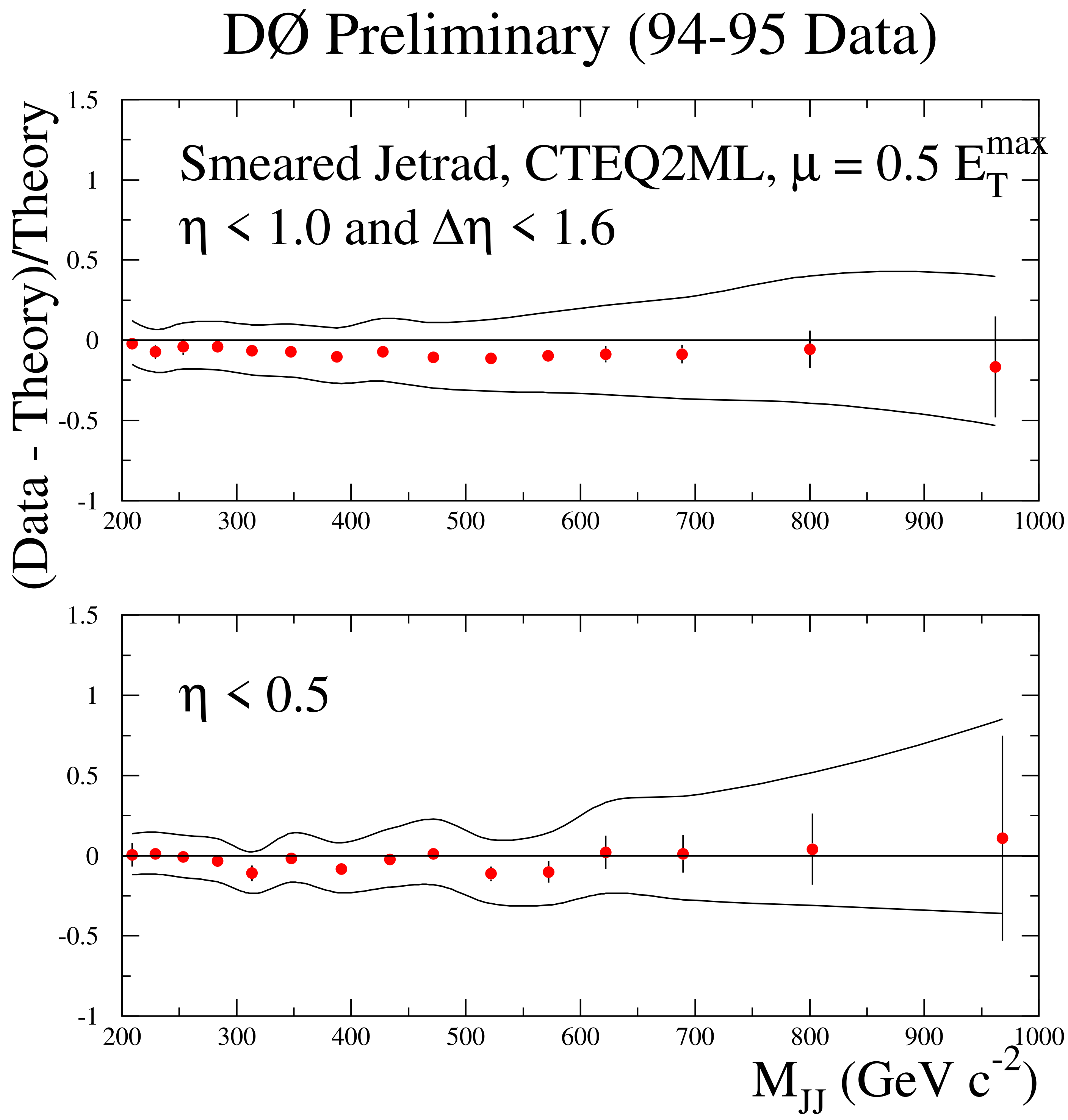
D0 has measured the ratio of the jet cross–sections for different cone sizes.



Systematics tend to cancel in the ratio

Data seem to prefer $\mu = E_T/2$

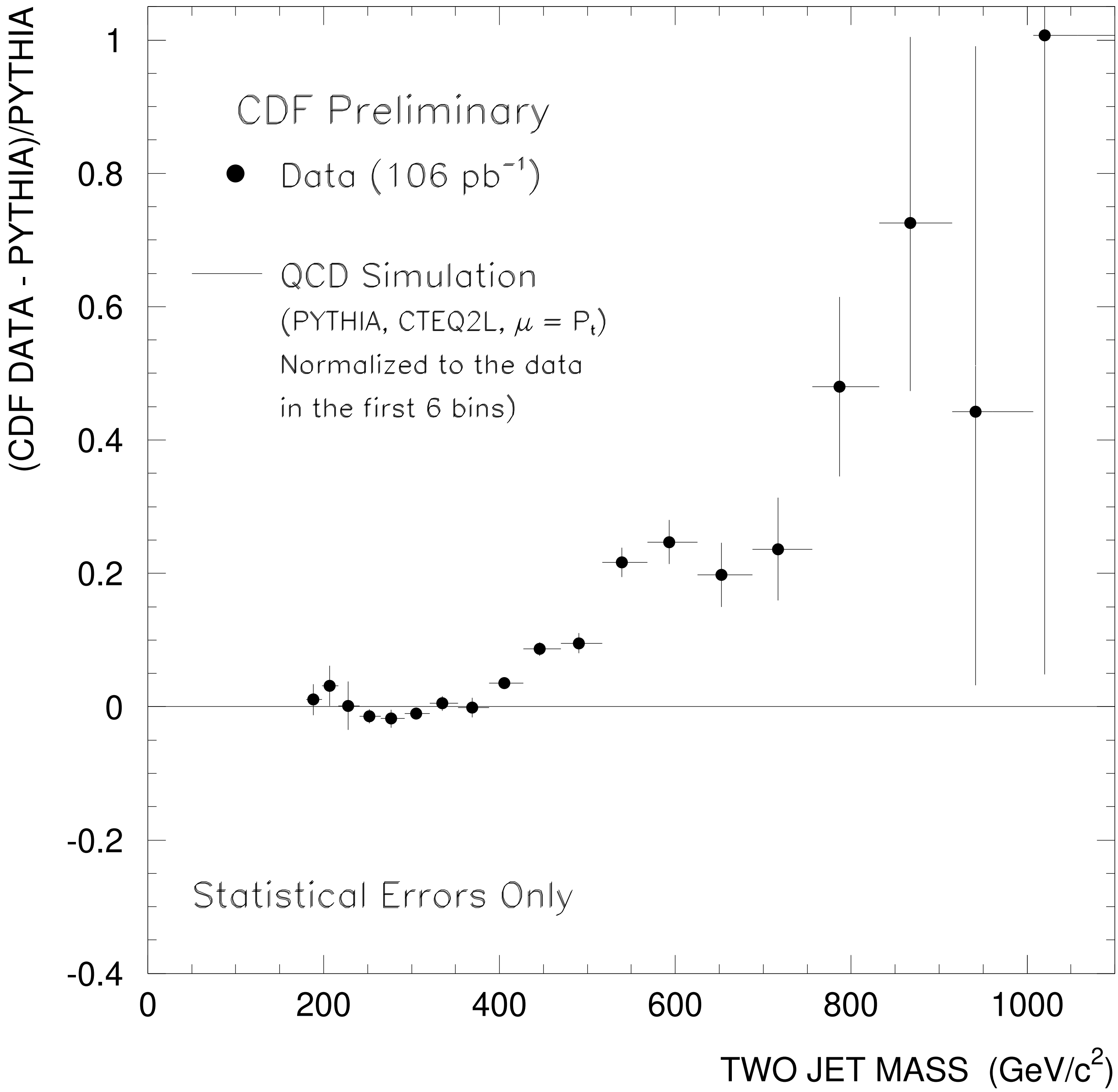
D0 Dijet Mass Distribution



The jet energy scale uncertainty is the dominant systematic: 15% (50%) at M_{jj} = 200 (900) GeV

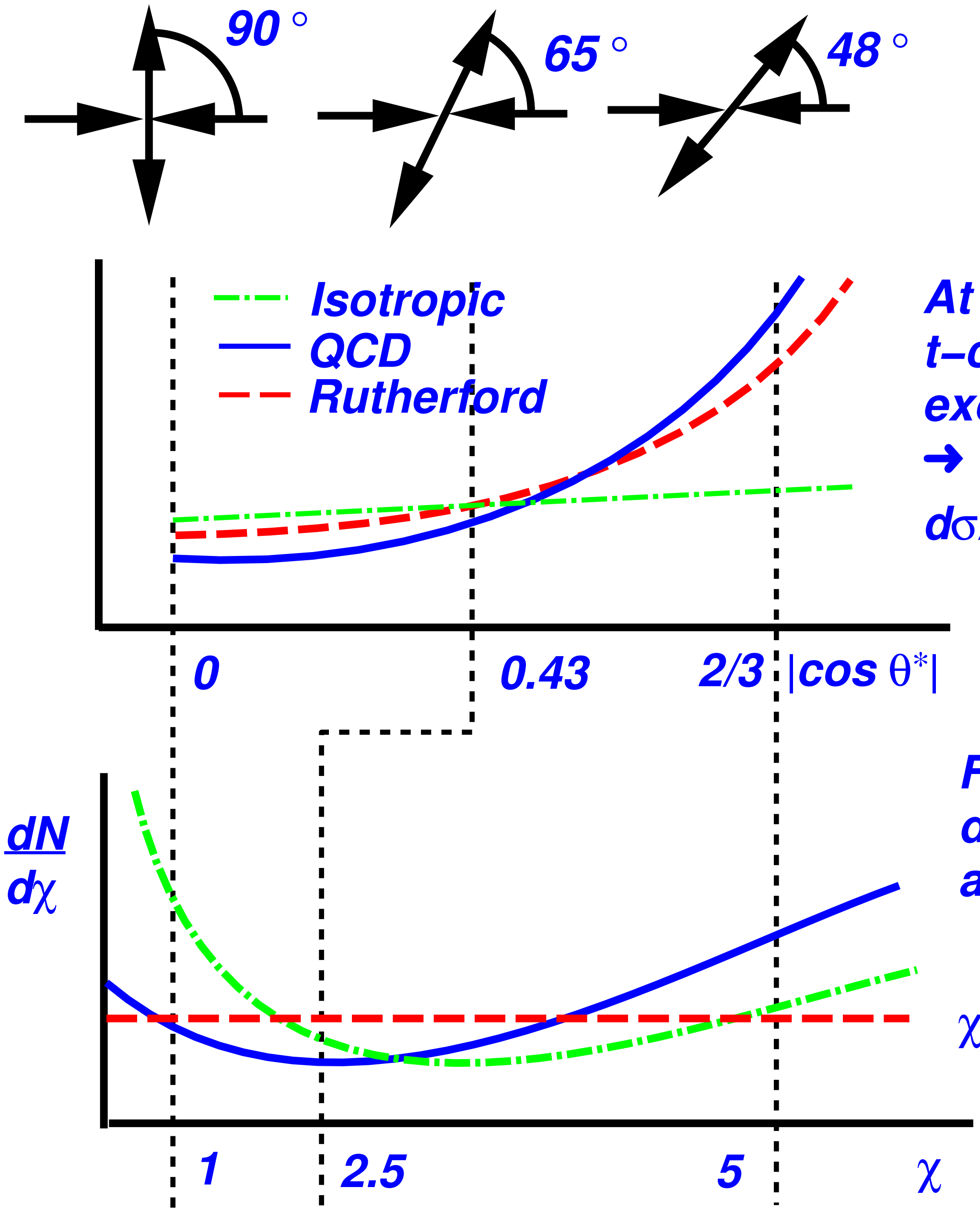
CDF Dijet Mass Distribution

Run 1A+1B



Systematics dominated by energy scale

Dijet Angular Distribution



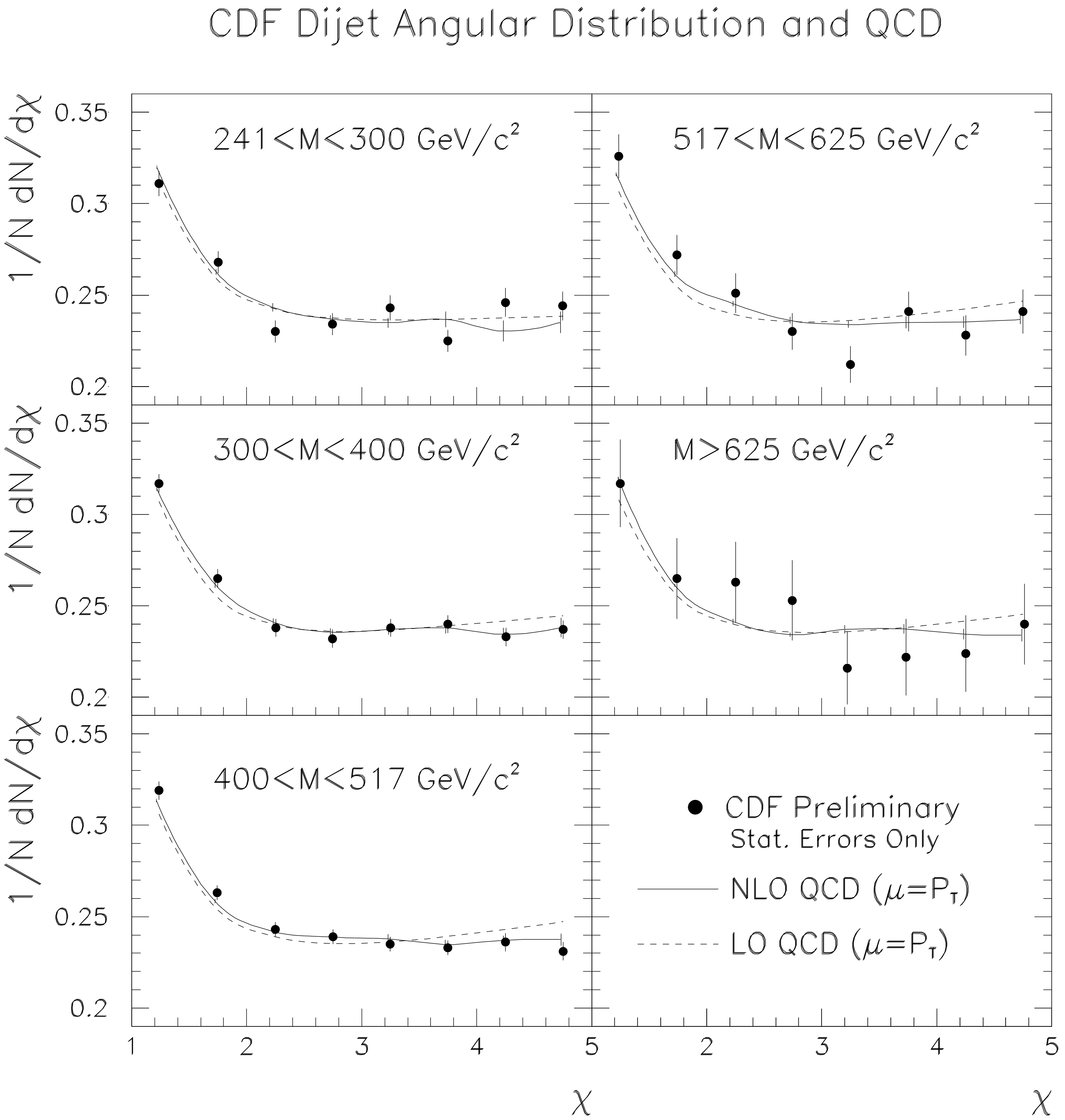
At small angles t–channel gluon exchange dominates
→ Rutherford scattering
$d\sigma/d\cos\theta^* \propto 1/\sin^4(\theta^*/2)$

Flatten out the angular distribution by plotting as a function of χ

$$\chi = \frac{1 + |\cos\theta^*|}{1 - |\cos\theta^*|}$$

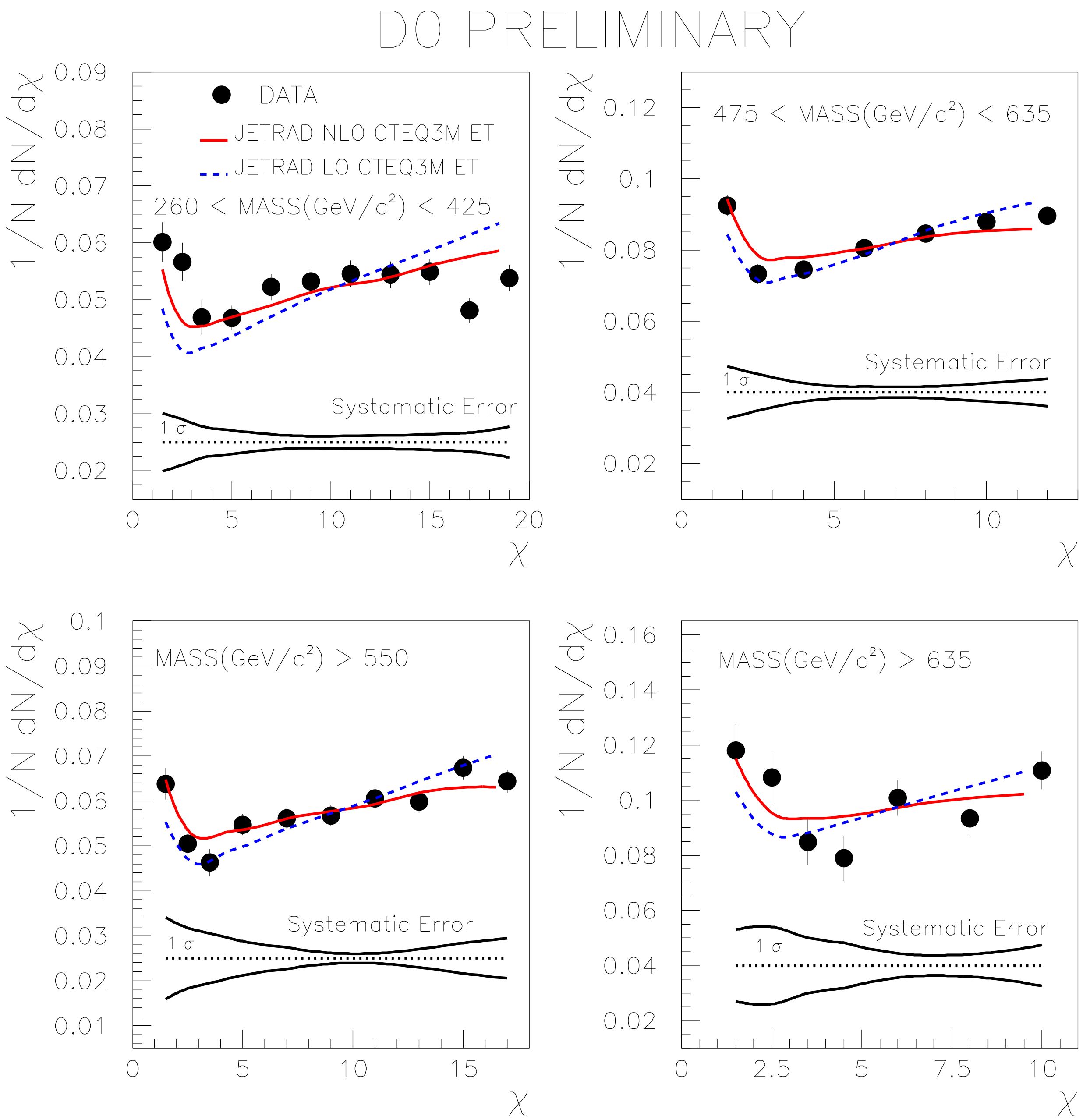
- ***$dN/d\chi$ is sensitive to new physics that has a more isotropic angular distribution than QCD (e.g. compositness). For $\chi < 5$ the most sensitive variable is $R_\chi = N(\chi=1\text{–}2.5)/N(\chi=2.5\text{–}5)$***
- *Insensitive to PDF's*
- *Insensitive to overall energy scale but sensitive to η–dependence of calorimeter response and resolution*

CDF Dijet Angular Distribution



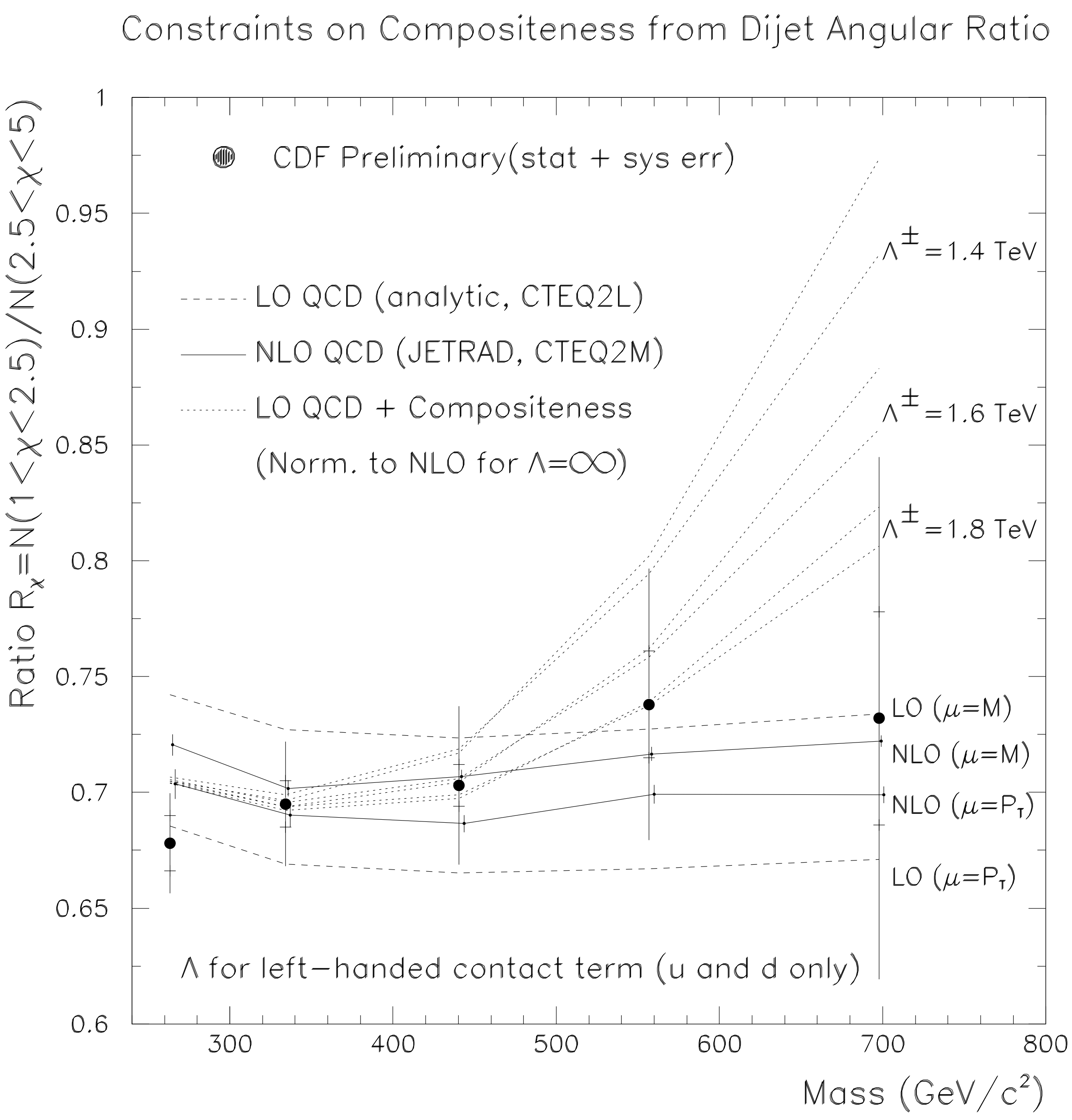
Good agreement with NLO QCD

D0 Dijet Angular Distribution



Good agreement with NLO QCD

R_χ = N(χ = 1–2.5) / (N(χ = 2.5–5)



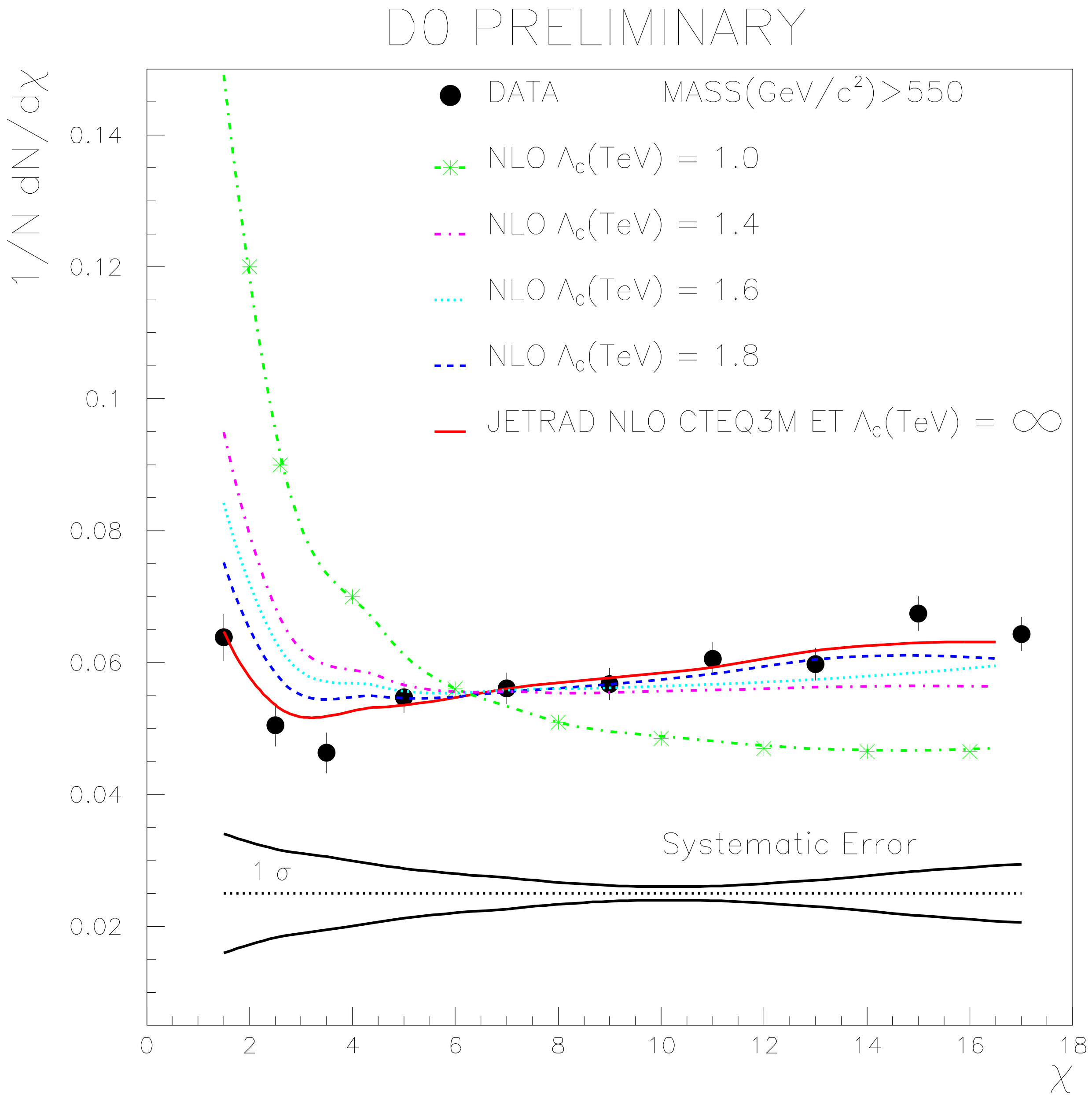
Systematic uncertainties : $\langle M_{jj} \rangle$ **= 263 GeV – 3%**

$\langle M_{jj} \rangle$ **= 698 GeV – 14%**

Compositness limits : $\Lambda^+ \geq 1.6$ **TeV @ 95% CL**

$\Lambda^- \geq 1.4$ **TeV @ 95% CL**

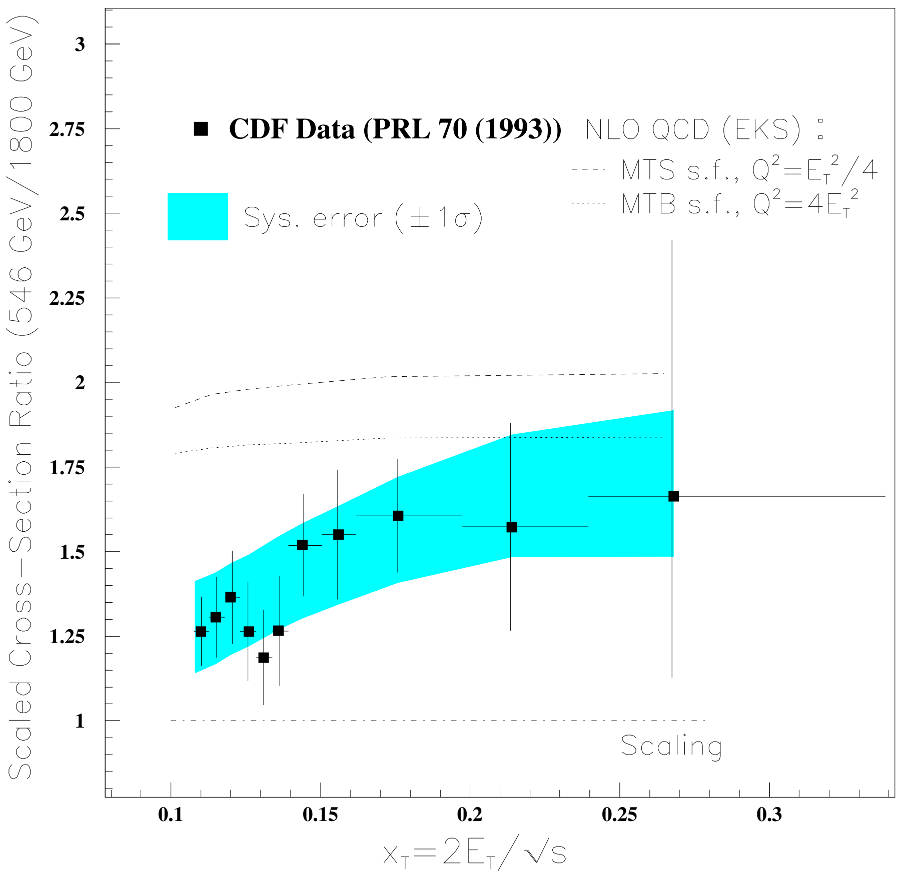
D0 Dijet Angular Distribution
Mjj > 550 GeV



No limits yet

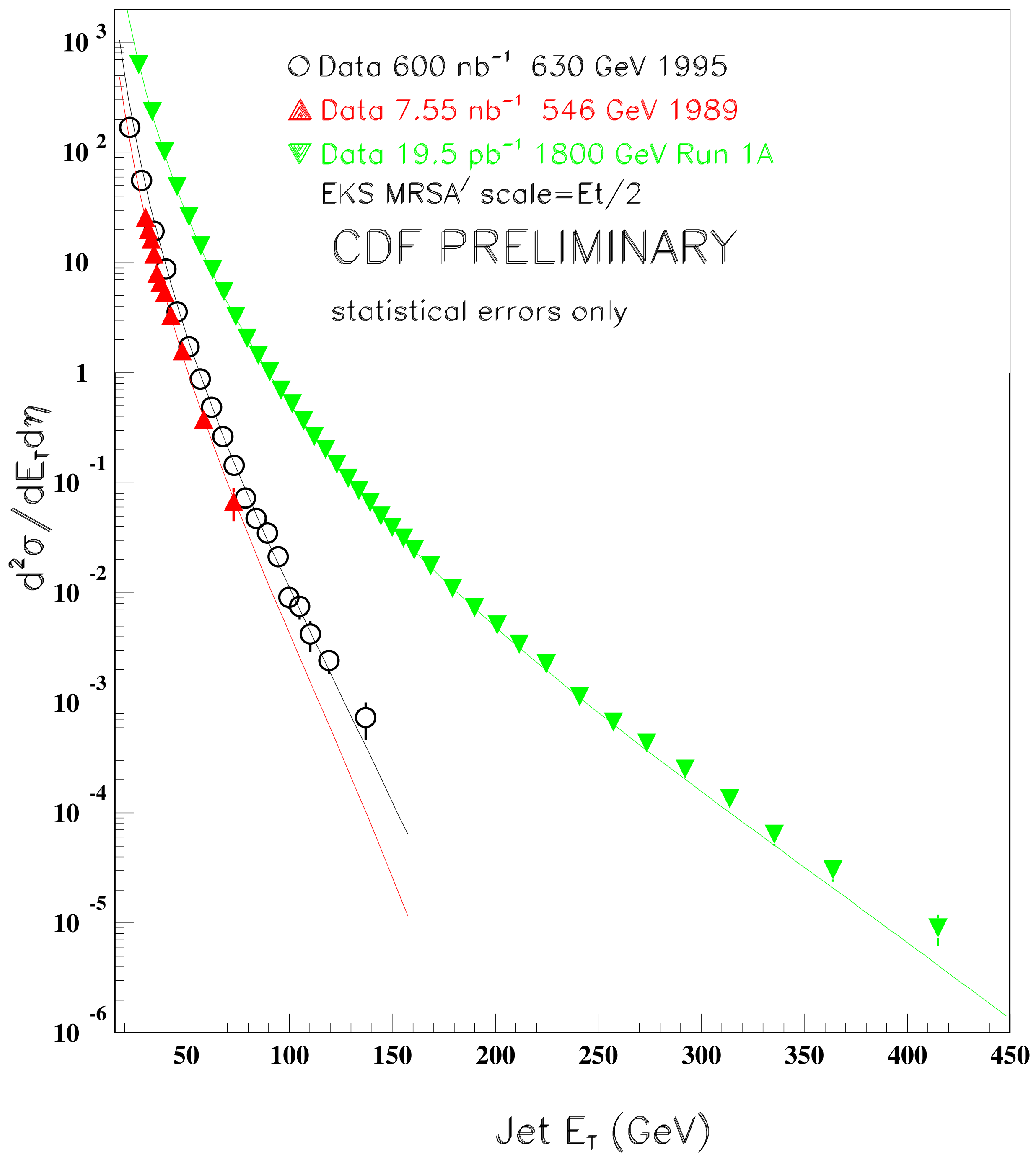
Inclusive Jet Cross–section at $\sqrt{s}$ = 630 GeV

- Test QCD at two different CM energies
- **Scaling hypothesis** predicts that if cross–sections are written in a way that makes them dimensionless then they will be independent of $\sqrt{s}$
- QCD predicts scaling violations due to the evolution of the PDF's with Q^2 and the running of α_s

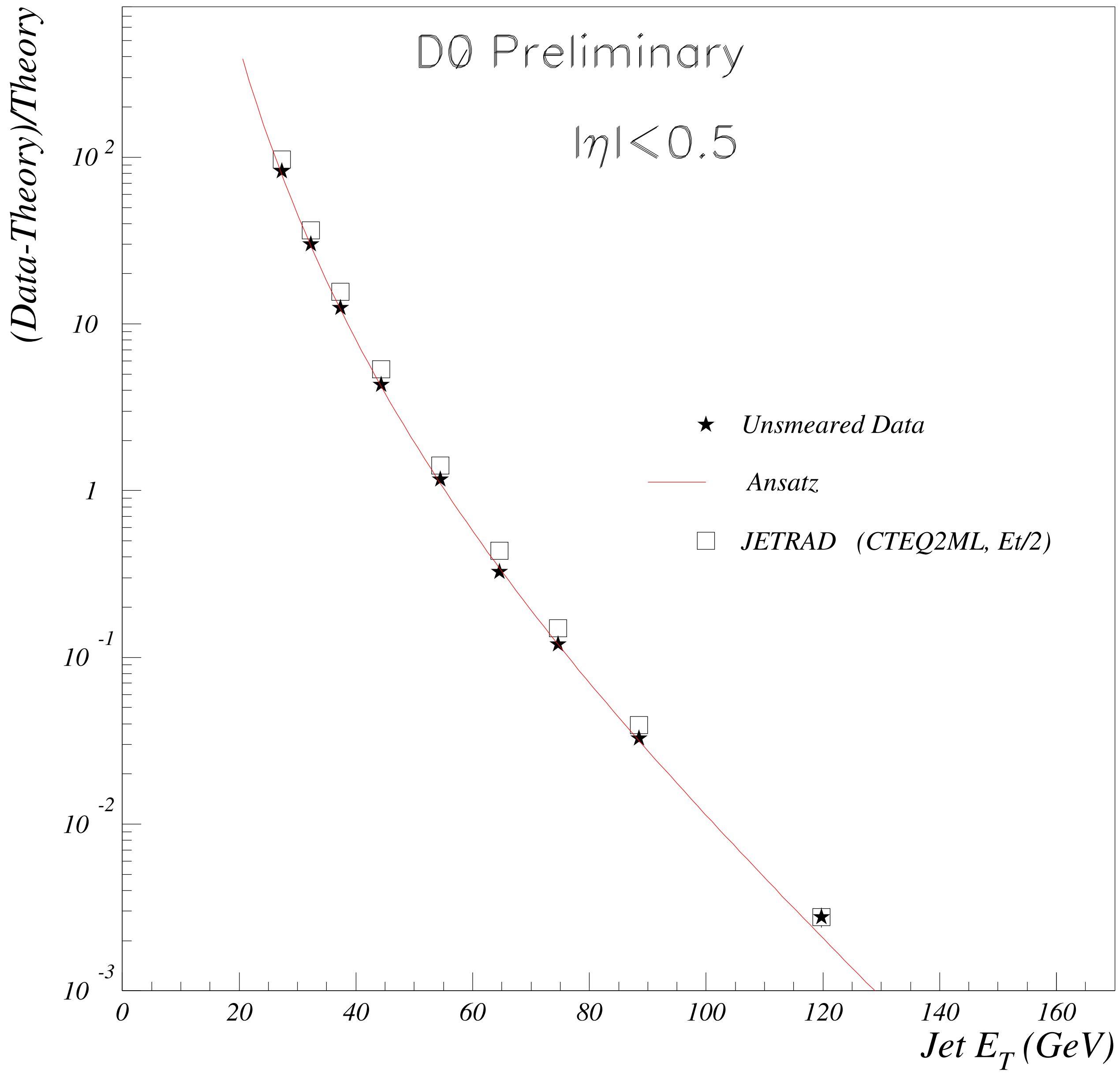


Scaling ruled out at 95% C.L. agreement with NLO QCD at the level of 1.5–2σ at low x_T

CDF Inclusive Jet Cross–section at $\sqrt{s}$ = 546, 630 and 1800 GeV vs E_T

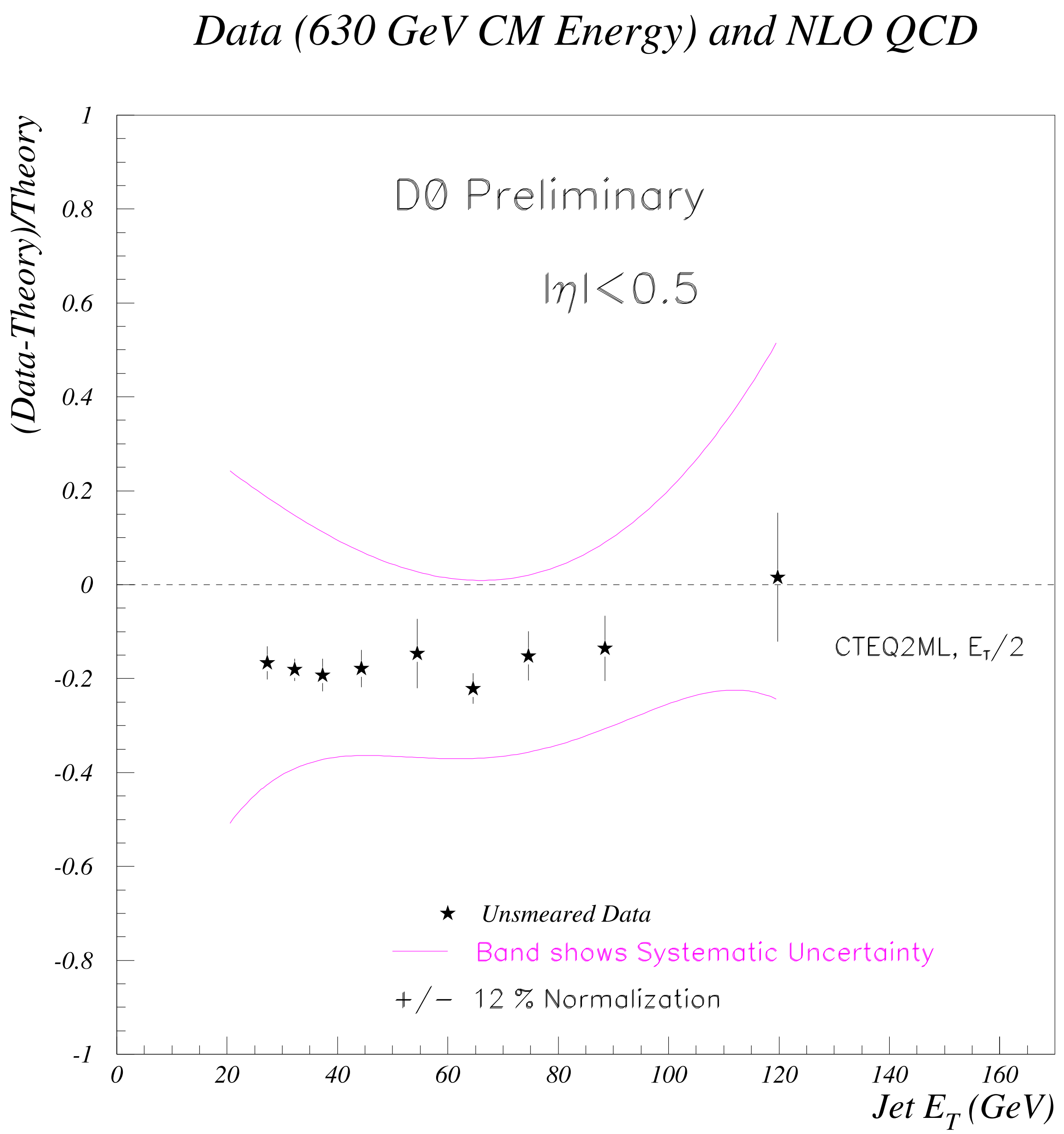


D0 Inclusive Jet Cross–section at $\sqrt{s}$ = 630 GeV vs E_T



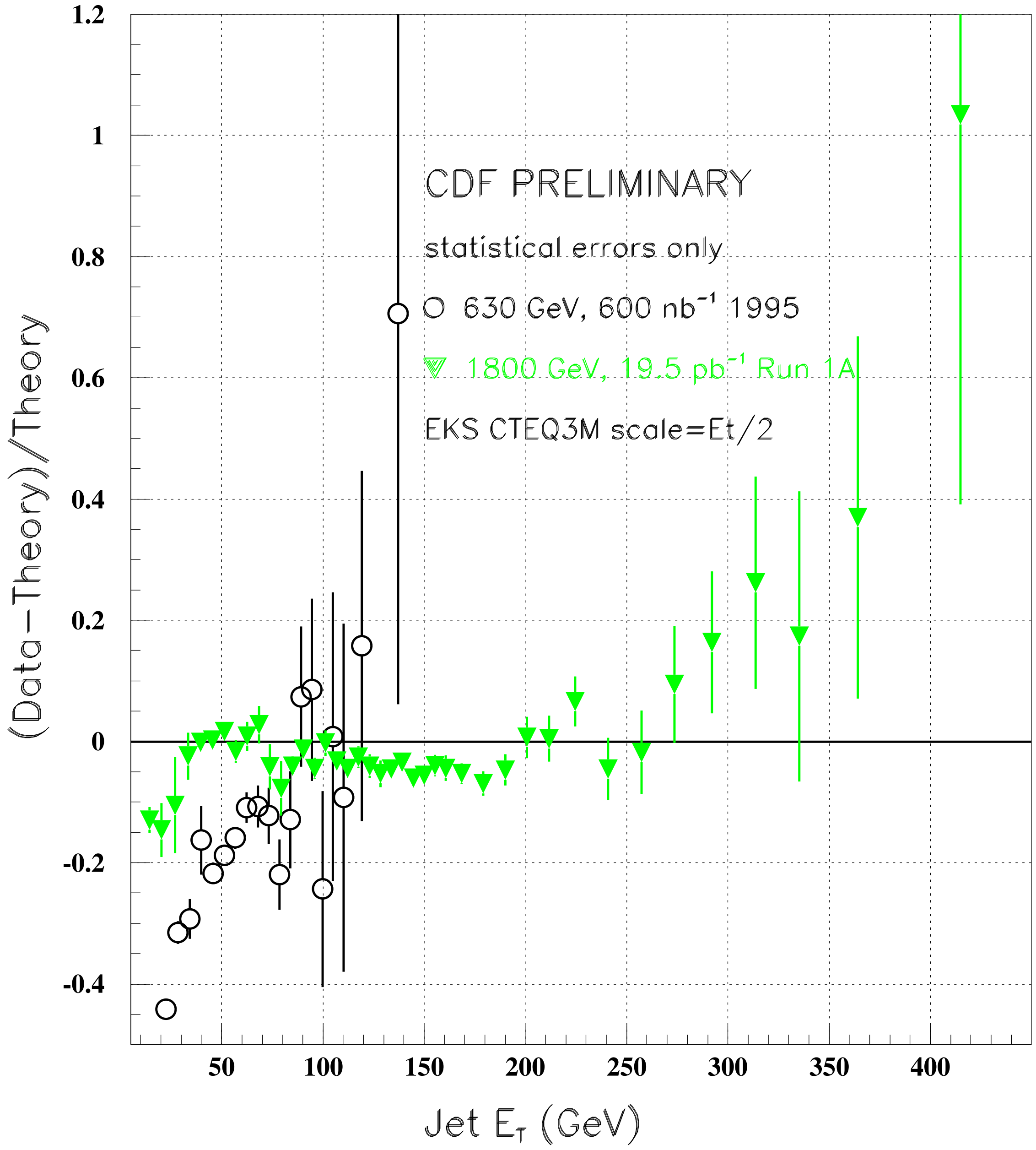
D0 Inclusive Jet Cross–section at $\sqrt{s}$ = 630 GeV vs E_T

Linear scale



Data pretty flat as a function of E_T. Large systematic uncertanties

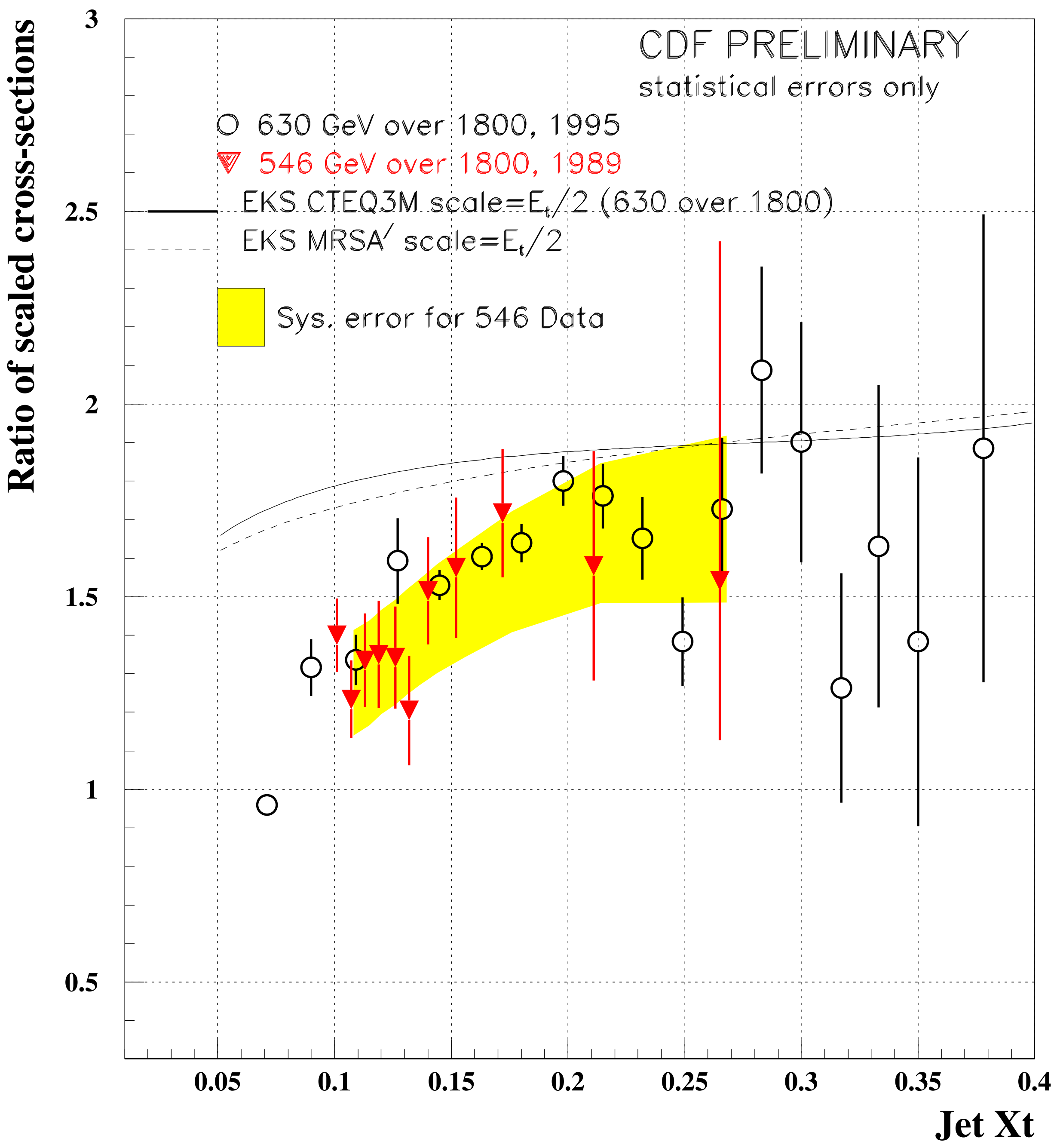
CDF Inclusive Jet Cross–section at $\sqrt{s}$ = 630, 1800 GeV vs E_T



Data at $\sqrt{s}$ = 1800 GeV agree with QCD

Data at $\sqrt{s}$ = 630 GeV at same jet E_T do not.

Scaled Cross–section



Ratio of 630/1800 GeV agrees with previous measurement. Need to redo systematic uncertainties – don't expect them to change very much

Conclusions

- ***Inclusive jet cross–section at 1800 GeV***

  CDF and D0 data are in agreement within statistics and well within the quoted systematics

  Theory issues still need to be resolved

  Note that Run II at $\sqrt{s}$ = 2000 GeV will help to decide whether PDF's are to blame

- ***Dijet Angular distributions (Preliminary)***

  Good agreement with NLO QCD for both experiments.

  CDF: Compositness limits :
  $\Lambda^+ \geq 1.6$ ***TeV @ 95% CL***
  $\Lambda^- \geq 1.4$ ***TeV @ 95% CL***

- ***Inclusive jet cross–section at 630 GeV (Preliminary)***

  New CDF result appears to confirm previous CDF measurement at $\sqrt{s}$ = 546 GeV

  D0 sees no significant shape difference but large systematics and significant normalization uncertainty. Need to compare the experimental data