Status of Run II* Jet Production Measurements at DØ & Selected Run I# Curiosities

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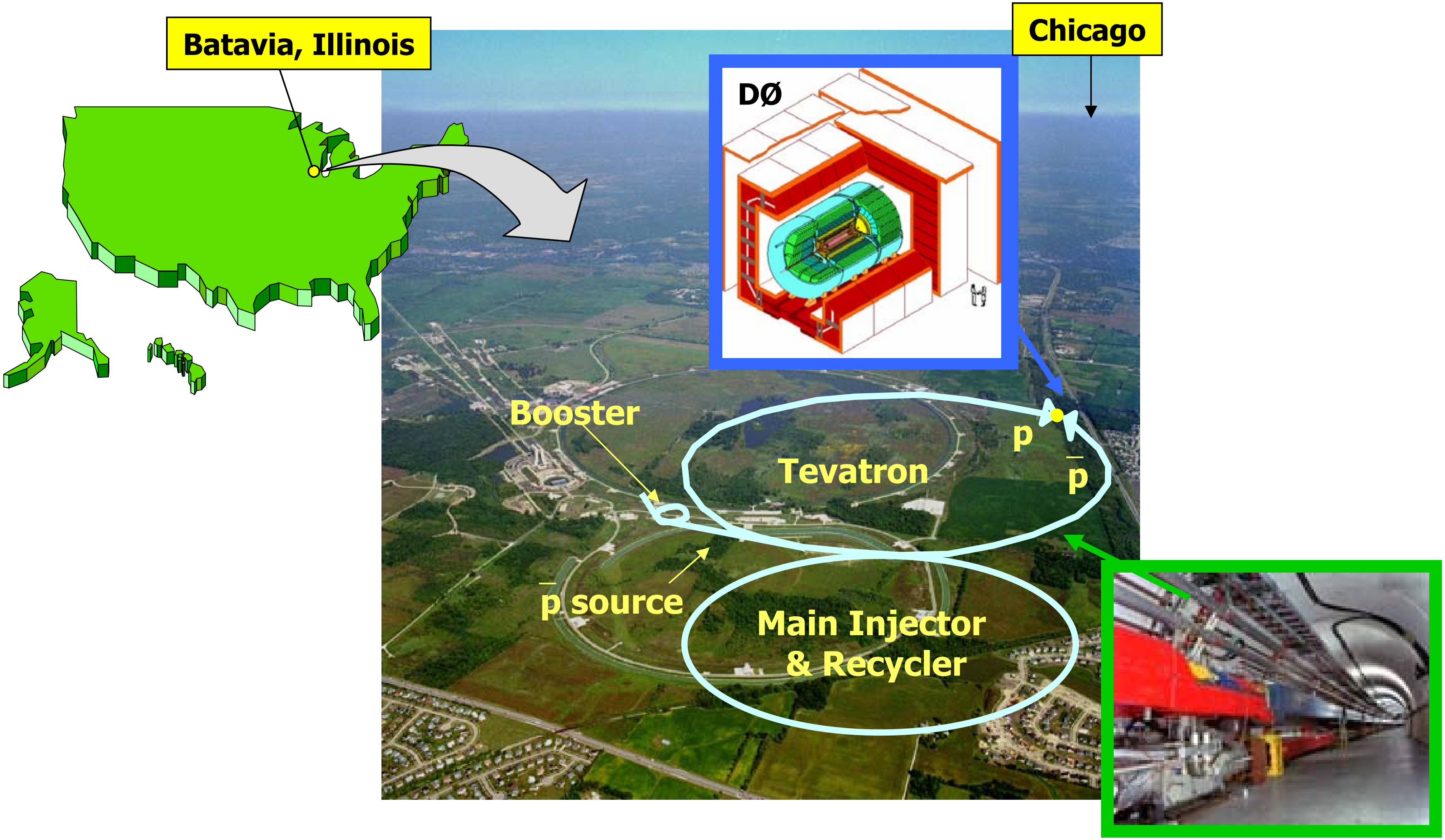
LOW X 2003

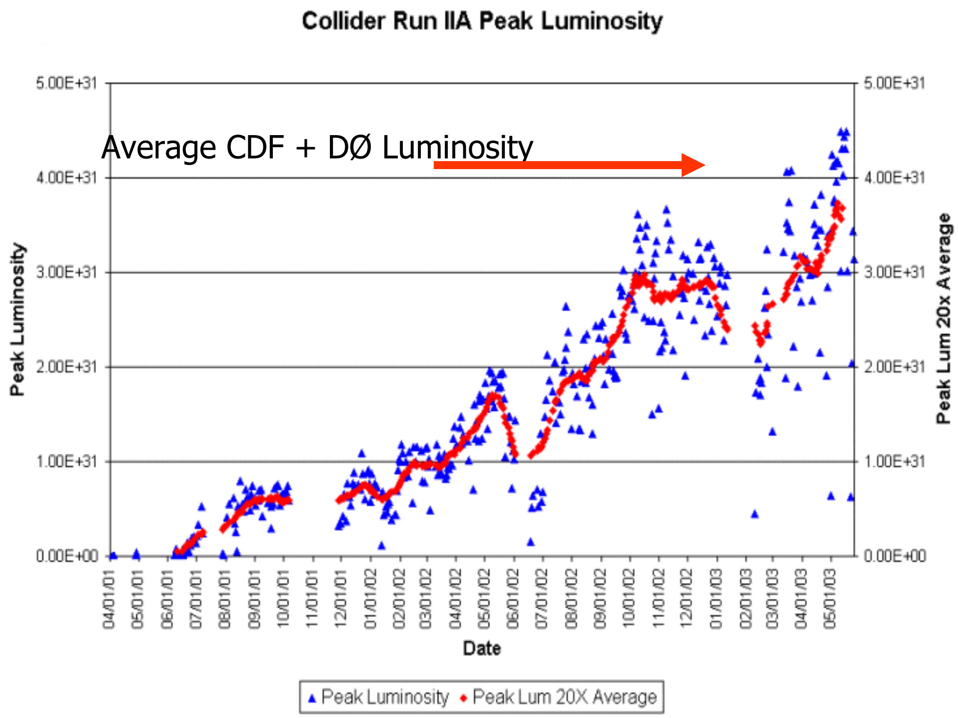
***1.96 TeV, #1.80 TeV**

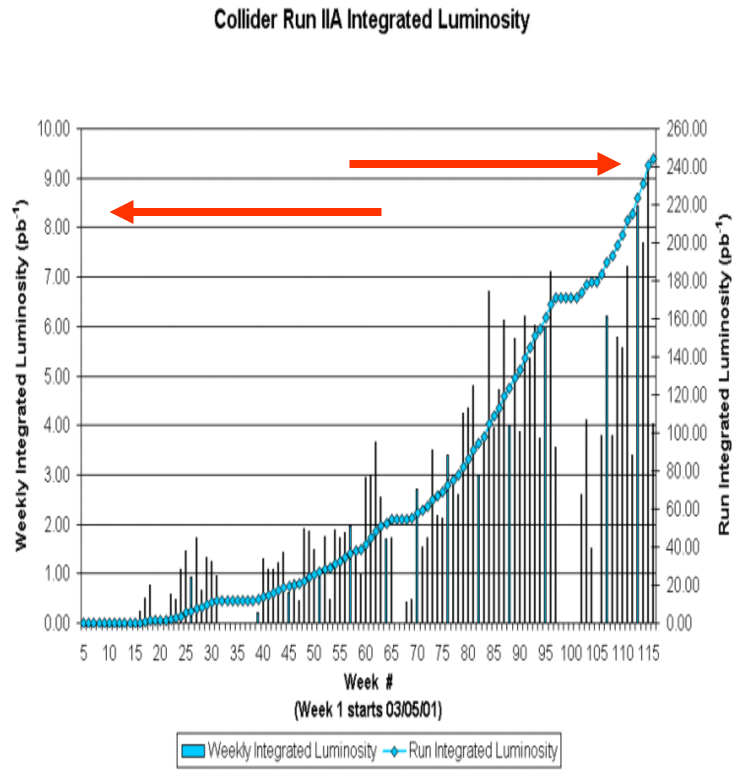
DØ

Fermilab Proton-Antiproton Collider



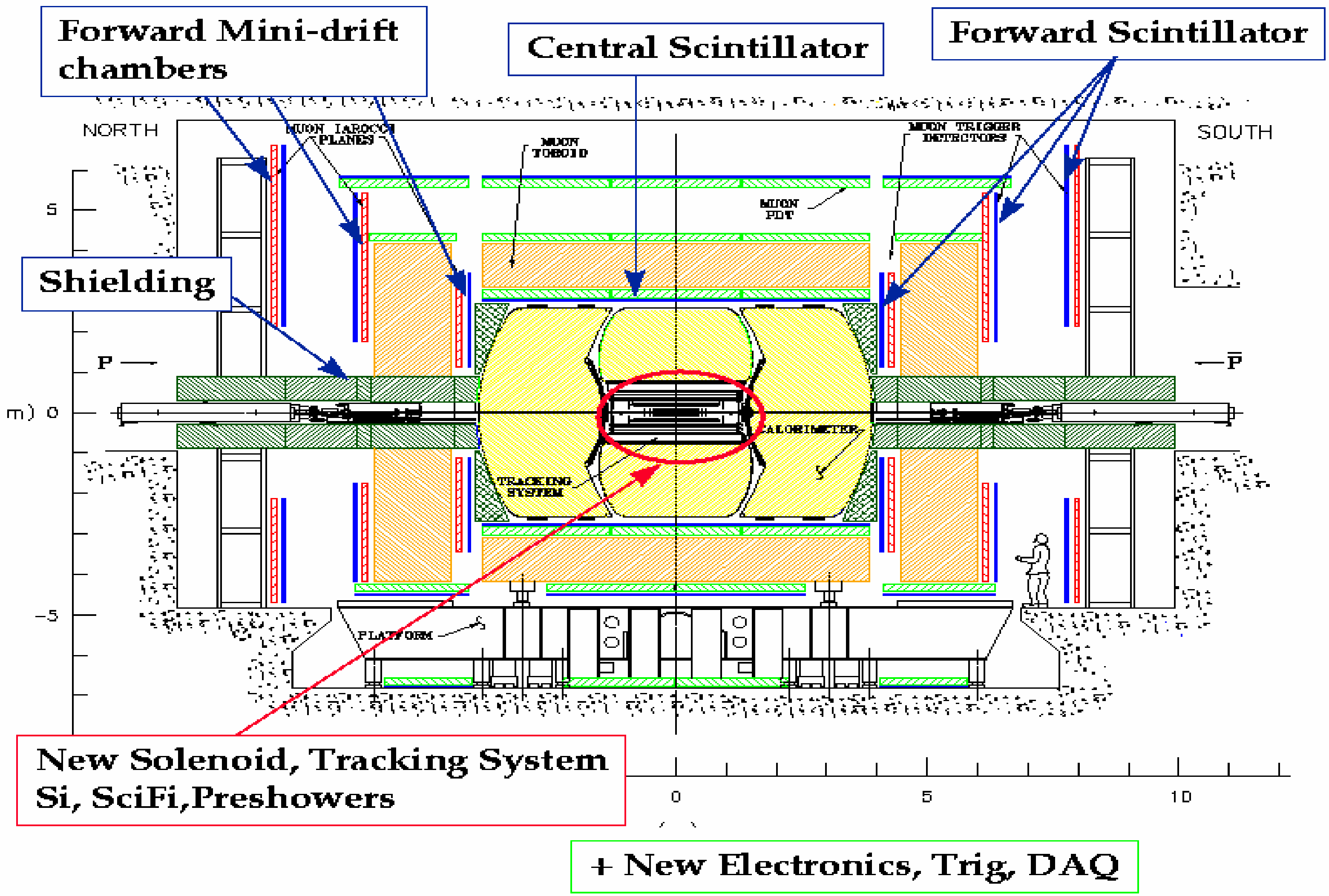
Run II Tevatron Performance



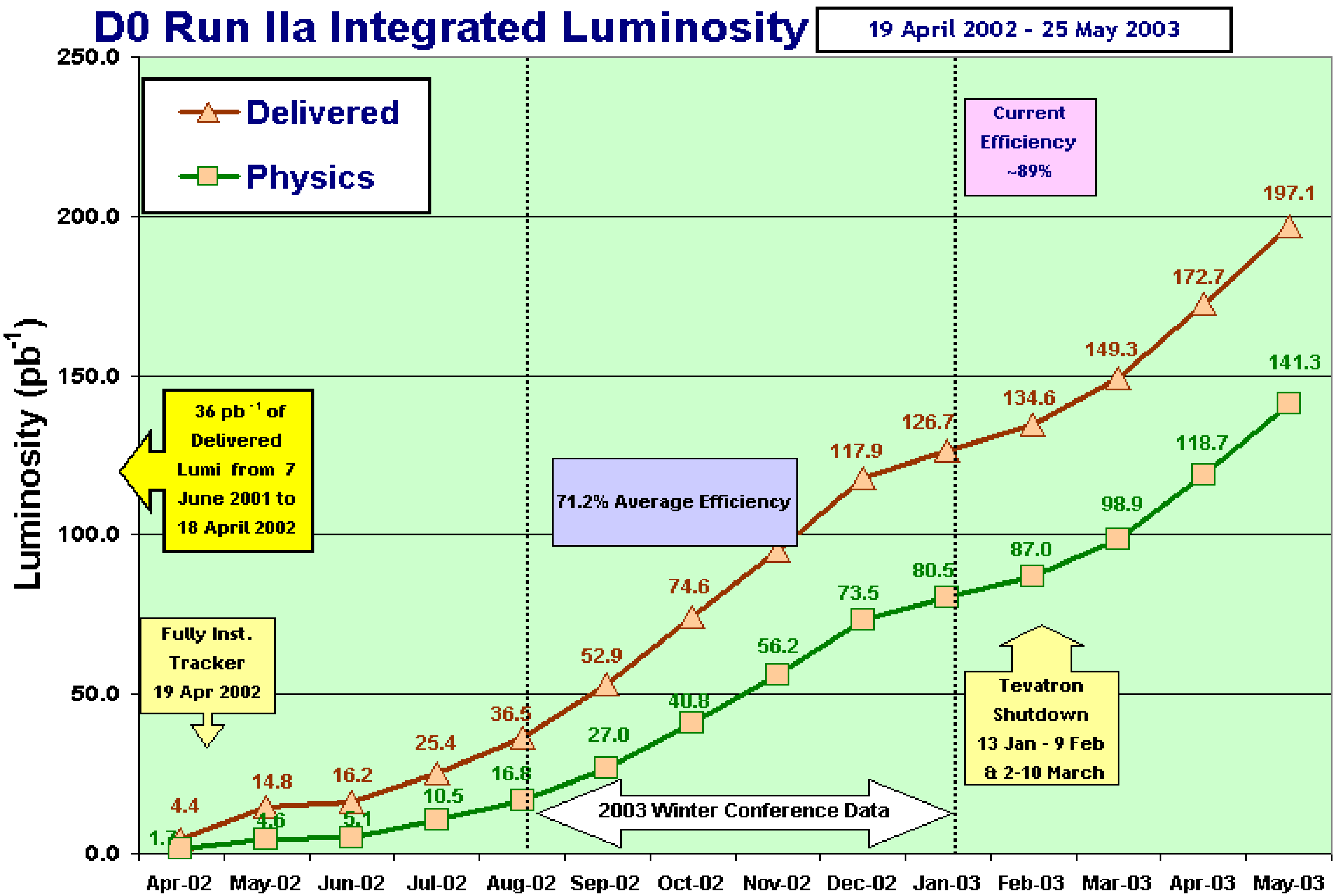


- Average Peak Instantaneous Luminosity: 44E30 cm-2s-1
- Typical Integrated Luminosity: ~8 pb-1/wk
- Total Delivered: 240 pb-1 (6/1/2001)

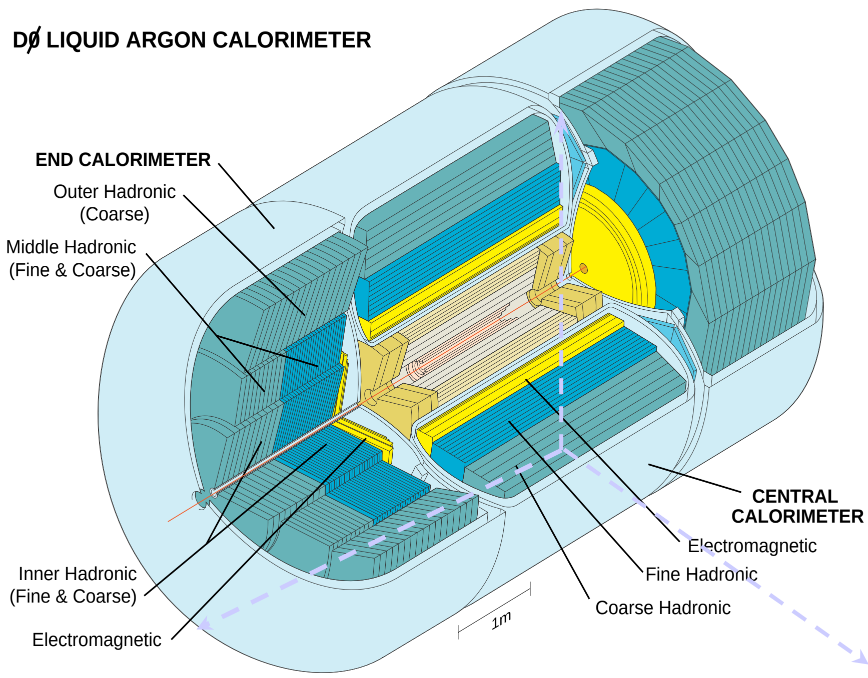
Run II DØ Detector



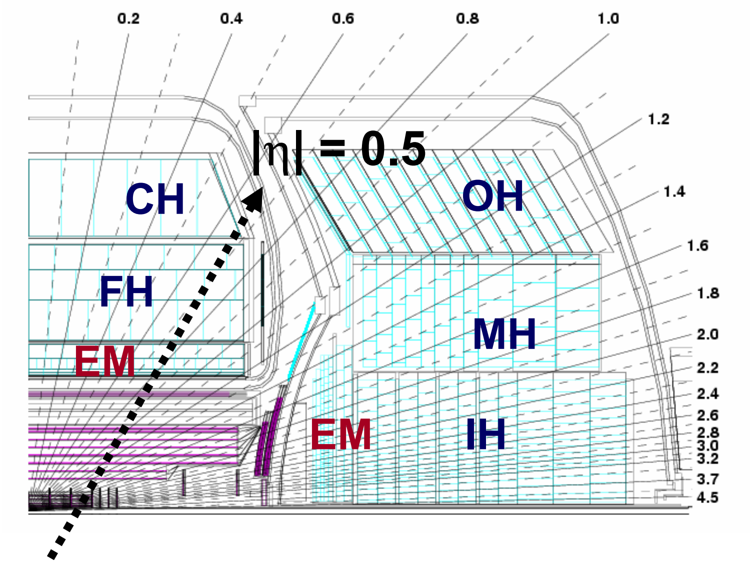
Run II Performance



Calorimetry



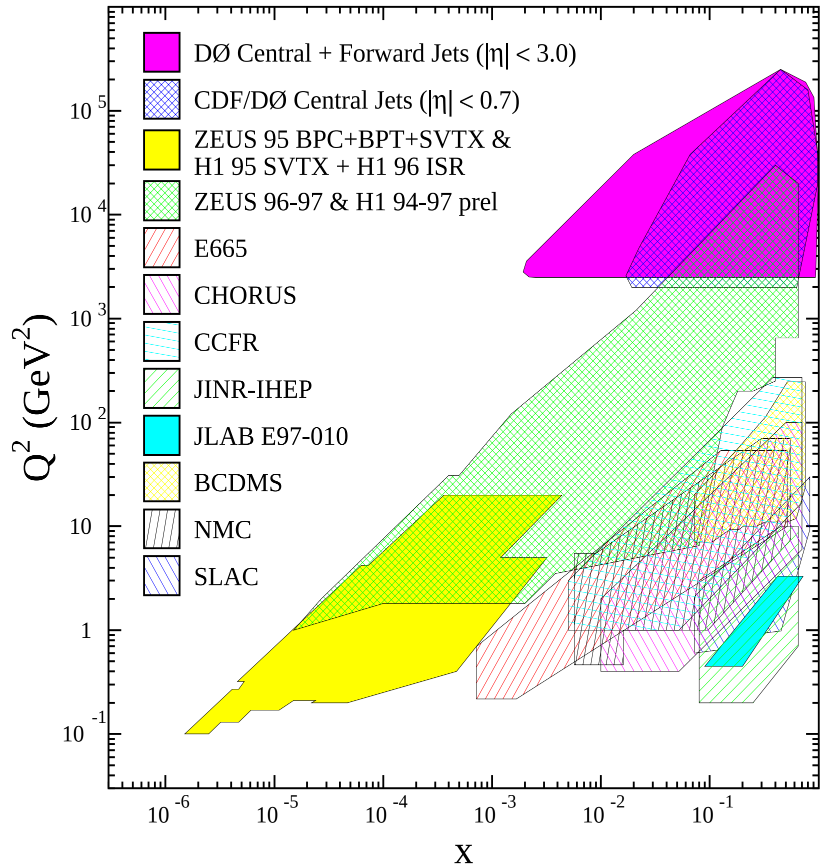
- Fine segmentation
  - Transverse:
    - 5000 pseudo-projective towers
    - $\eta \times \phi = 0.1 \times 0.1$
  - Longitudinal:
    - 4 EM layers
    - 4/5 Hadronic
- L1/L2 fast Trigger readout towers



- Uniform, hermetic with full coverage
  - $|\eta| < 4.2$ ($\theta \approx 2^o$), $\lambda_{int} \sim 7.2$ (total)
- Single particle energy resolution
  - e: $\sigma/E = 15\% / \sqrt{E} \oplus 0.3\%$
  - π: $\sigma/E = 45\% / \sqrt{E} \oplus 4\%$

Jet Production

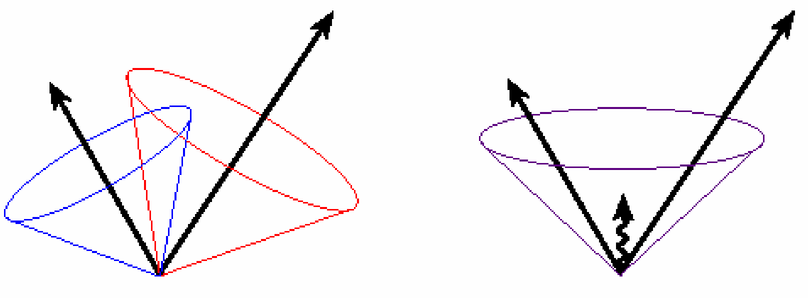
- **Probe of QCD over wide x-Q^2 region**
- **Sufficiency of NLO QCD**
- **Search for new phenomena**
- **Tune perturbative calculations in preparation for LHC era**



Run I/Run II Jet Cone Algorithms

Run I Legacy Algorithm:

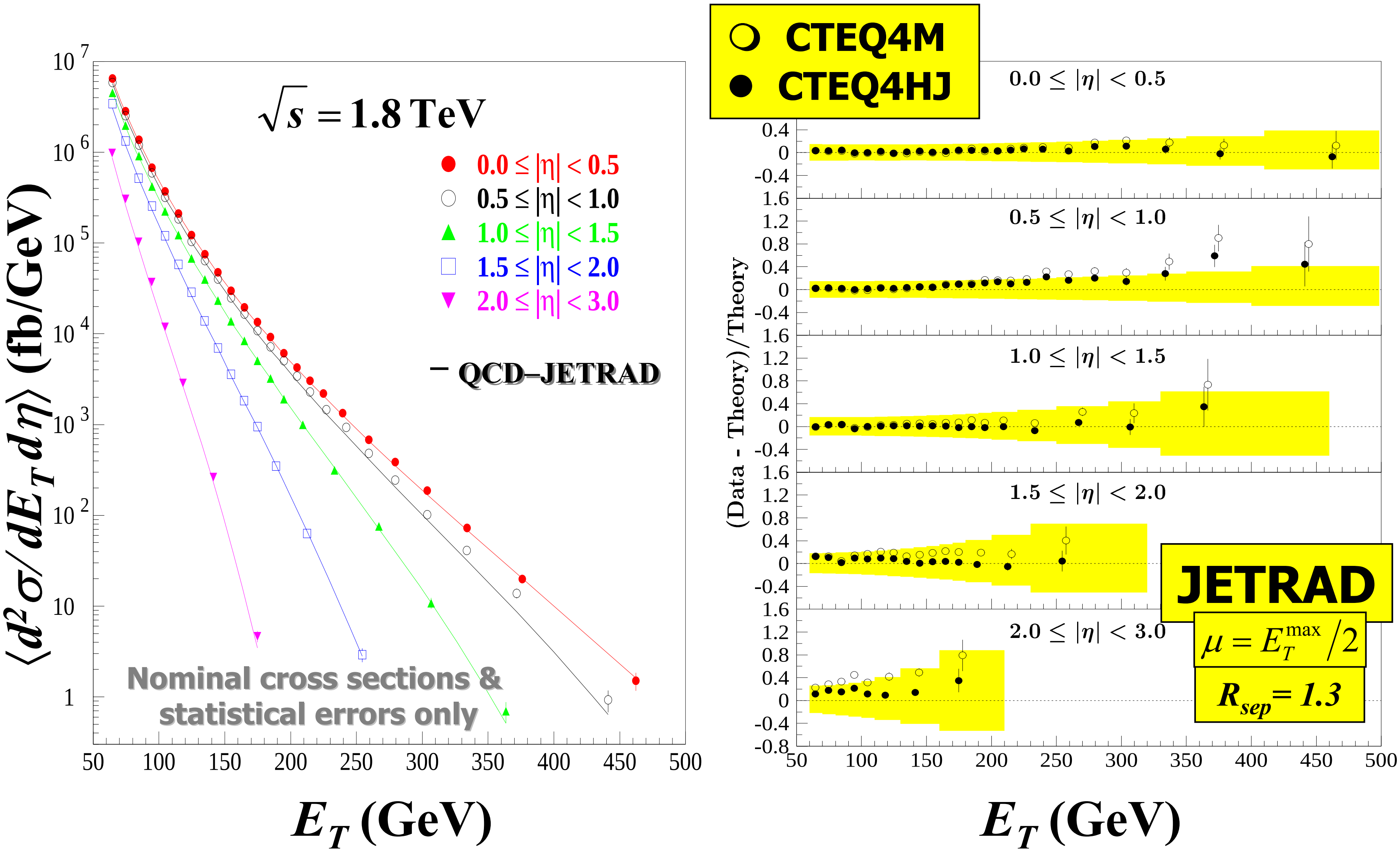
- Draw a cone of fixed size in $\eta-\phi$ space around a seed
- Compute jet axis from E_T-weighted mean and jet ET from ΣE_T
- Draw a new cone around the new jet axis and recalculate axis and new E_T
- Iterate until stable
- Split/Merge
- Algorithm is sensitive to soft radiation



Improved Run II Cone :

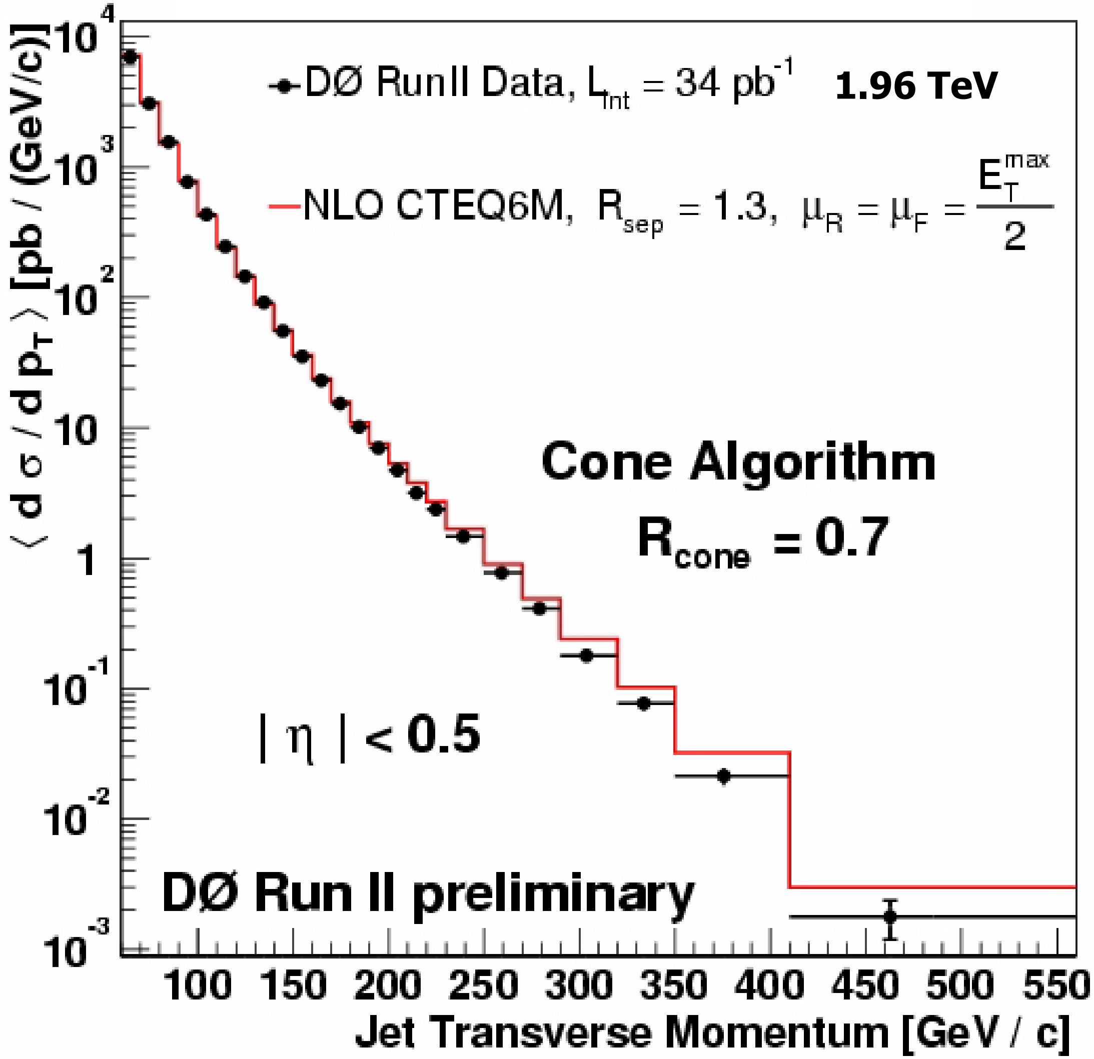
- "Joint CDF/DØ/Theory Jet Working Group"
- Use 4-vectors instead of E_T
- Add additional midpoint seeds between pairs of close jets
- Split/merge after stable protojets found
- Improved infrared safety at NLO

DØ Run I Inclusive Jet Cross Sections

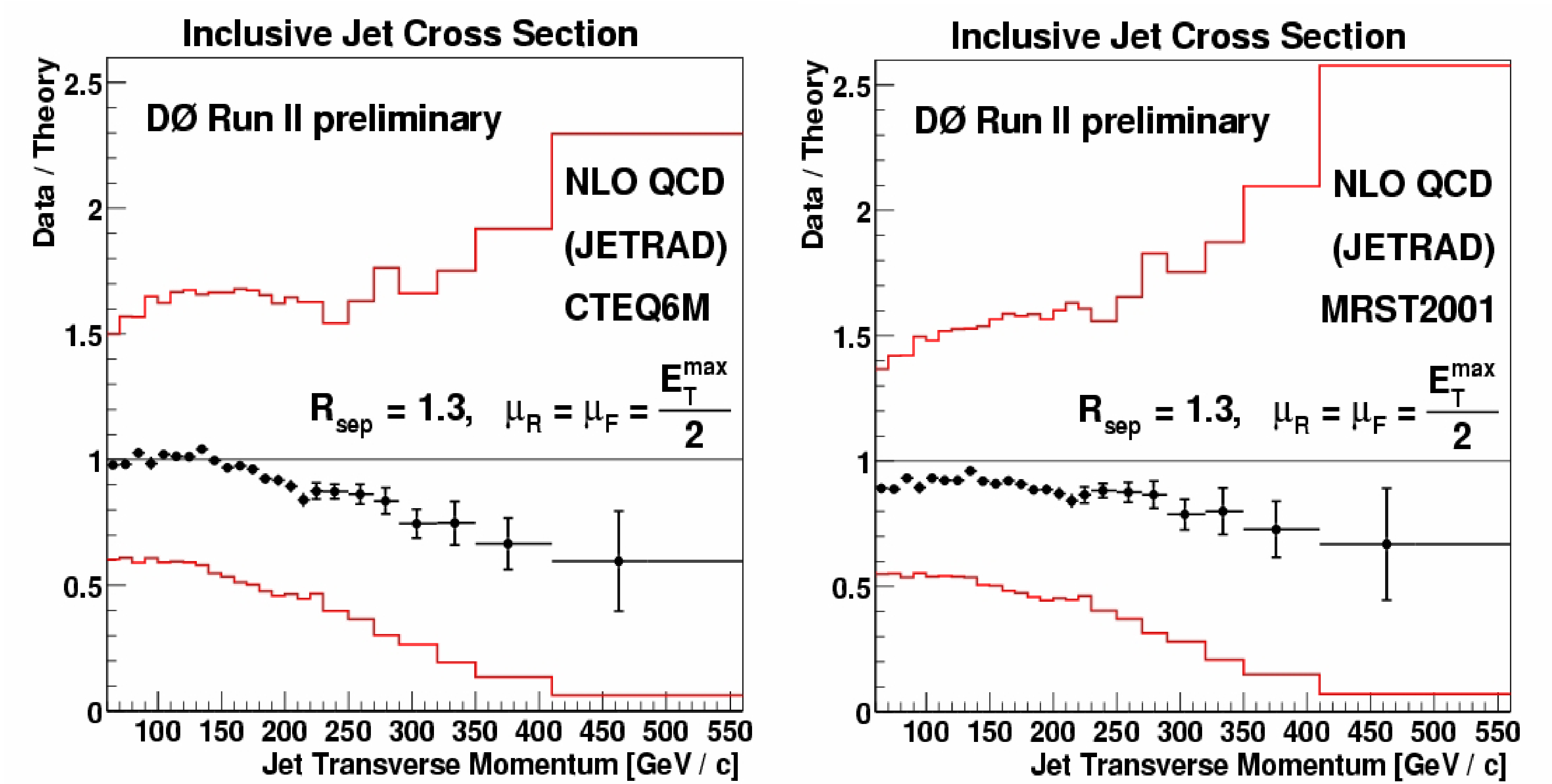


Phys. Rev. Lett. {86} 1707 (2001)

DØ Run II Inclusive Jet Cross Section



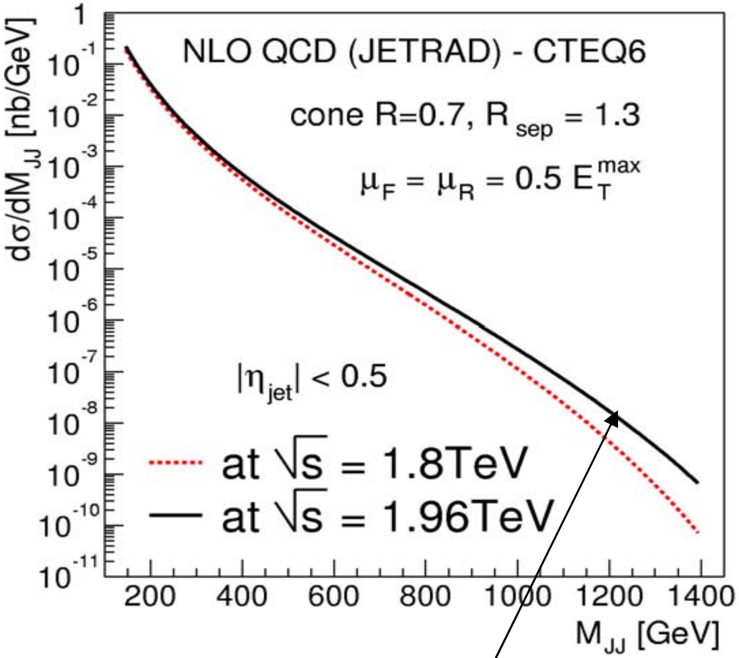
Comparison with Theory



Consistent with Run I & expectations
Uncertainties are large and statistically limited
(dominated by jet energy calibration)

QCD: Dijet Mass Cross Section

- **Probe of**
  - **proton structure at large x**
  - **hunting for resonances**
  - **quark compositeness**
- **Data sample:**
  - **34 pb^{-1}**
  - **DR = 0.7 cone jets**
  - **$|\eta_{jet}| < 0.5$**



Twice the σ at 1.96 TeV

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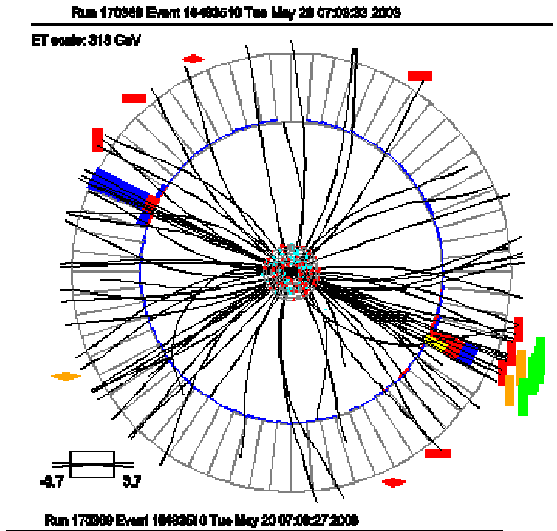
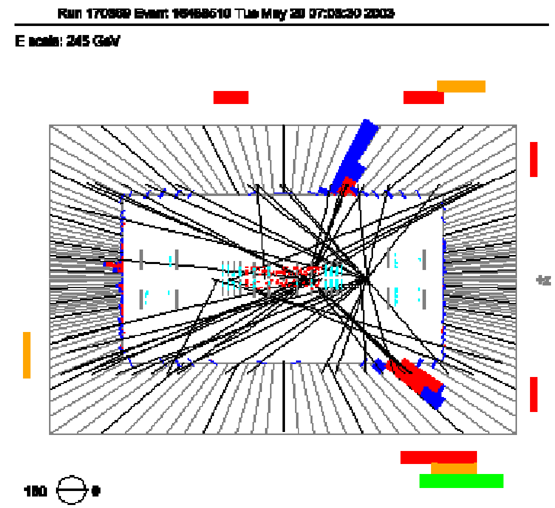
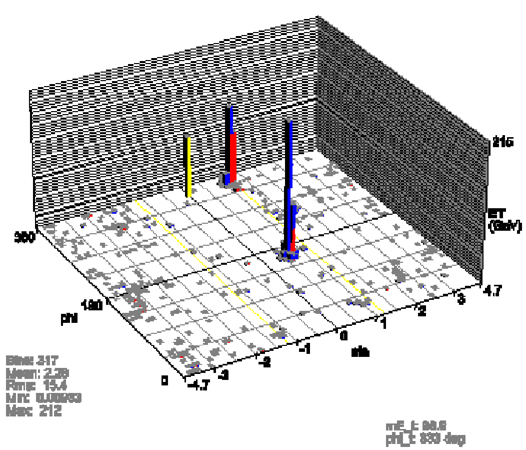
$M_{JJ} = 1120\ GeV$

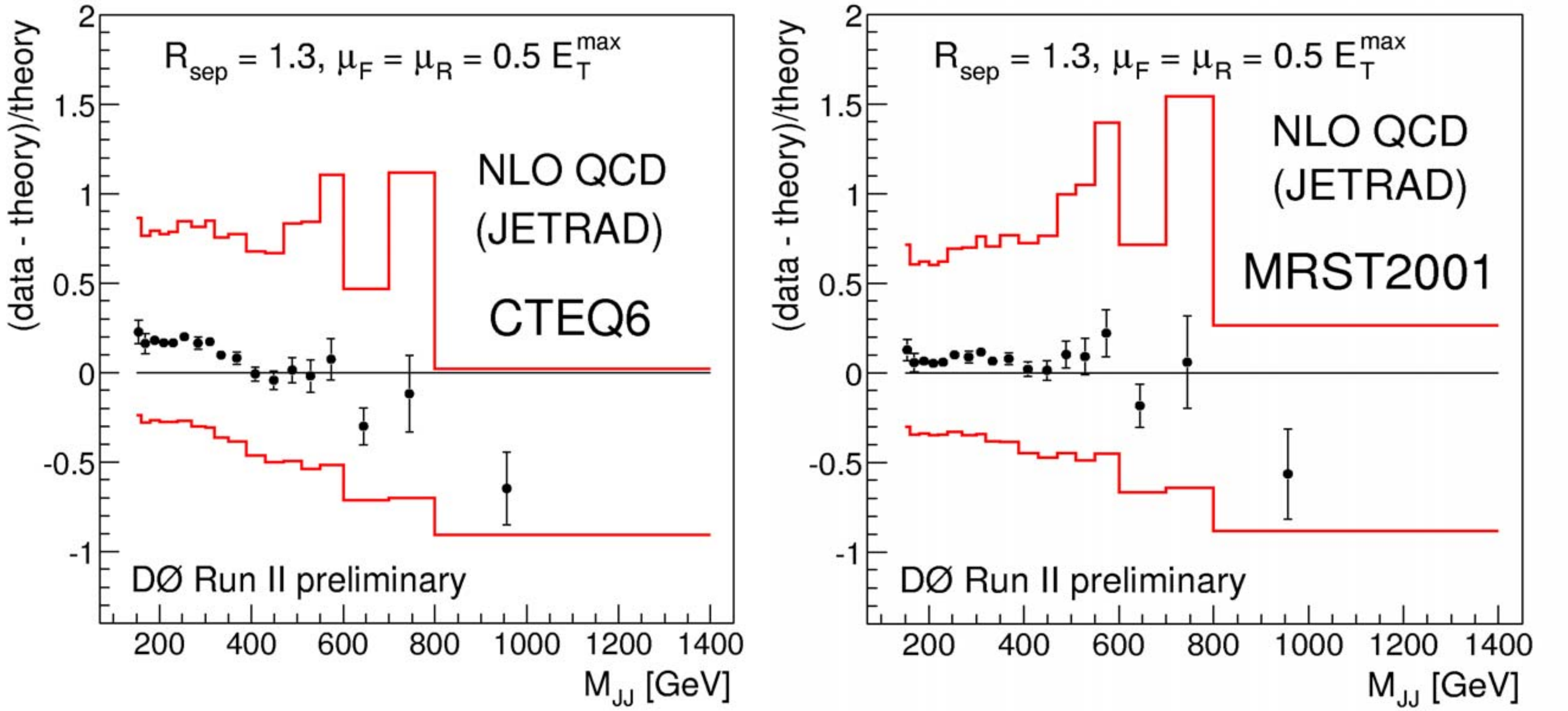






jet_1	jet_2
$p_T = 539$ GeV/c	$p_T = 538$ GeV/c
$\eta = 0.9$	$\eta = 0.4$
$\varphi = 5.8$	$\varphi = 2.7$
$M_{JJ} = 1120$ GeV/c^2	

Dijet Mass Distribution



Consistent with Run I & expectations
Uncertainties are large and statistically limited

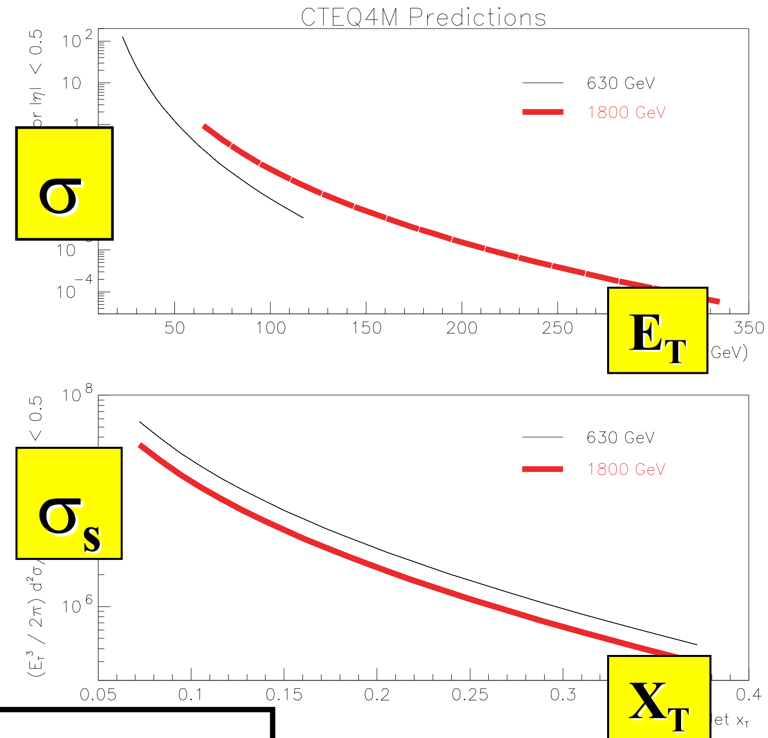
Curiosity I: Ratio of Cross Sections at Different Beam Energies

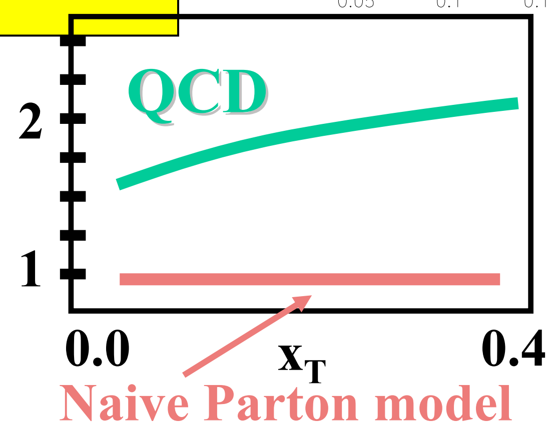
The ratio of the scale invariant cross sections :

$$\sigma_s = (E_T^3/2\pi)\,(d^2\sigma/dE_T d\eta)$$
$$\text{vs} \qquad X_T = E_T / (\sqrt{s}/2)$$

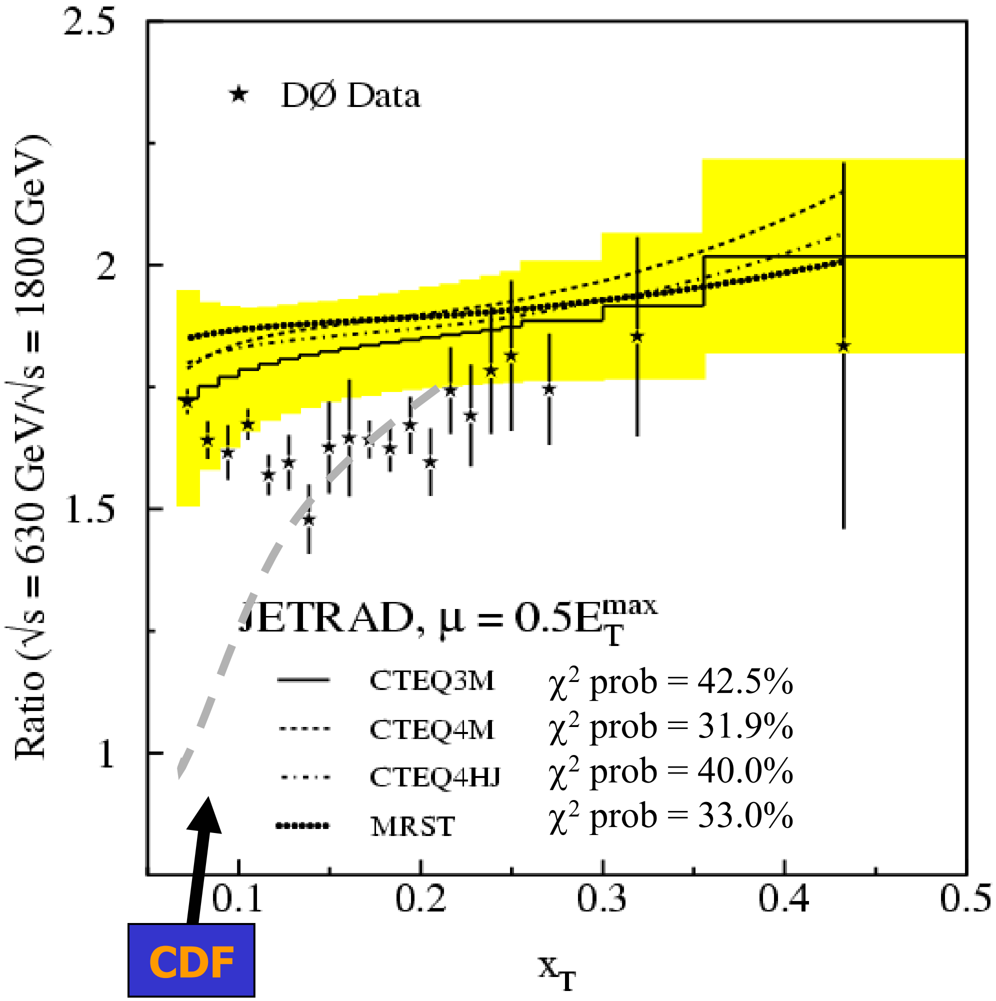
at different beam energies allows substantial reduction in theoretical and experimental uncertainty. And provides a look at

- **Scaling behavior**
- **Terms beyond LO (α_s^2)**



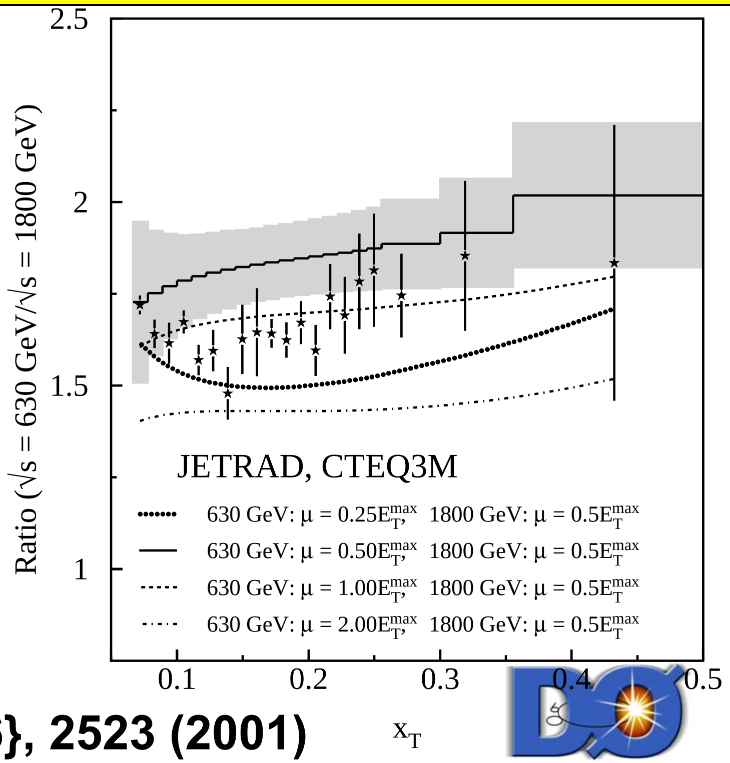


630/1800 inclusive jet ratio



Two Interesting features:

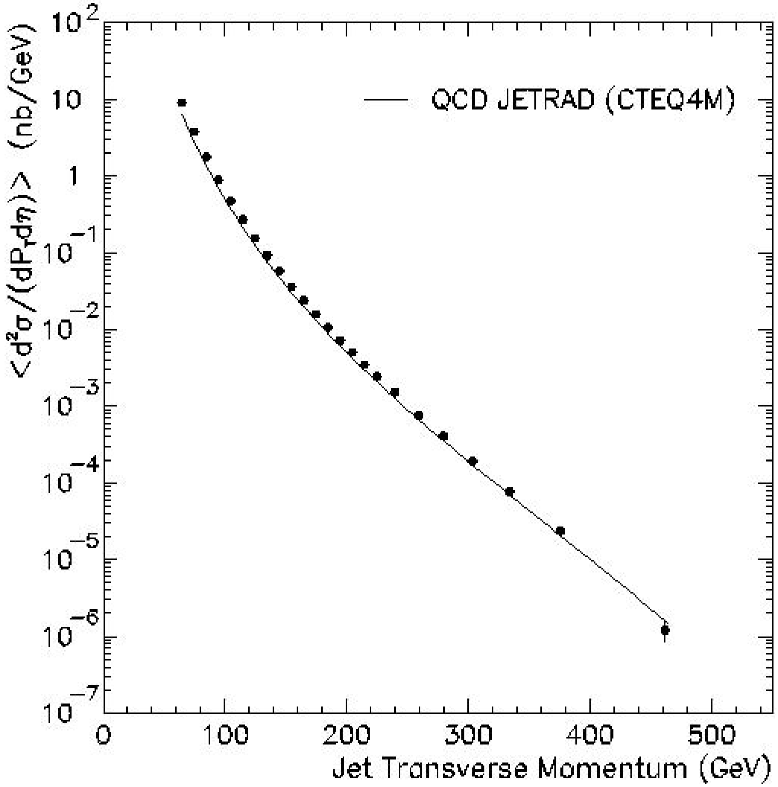
- **The results from CDF are much lower in the X_T~0.1 region**
- **QCD prediction is satisfactory (~1σ)**
- **Better description with different renormalization scales for the 630 and 1800 cross sections. (But Esthetically unattractive!)**
- **Suggests higher orders**



Phys. Rev. Lett. {86}, 2523 (2001)

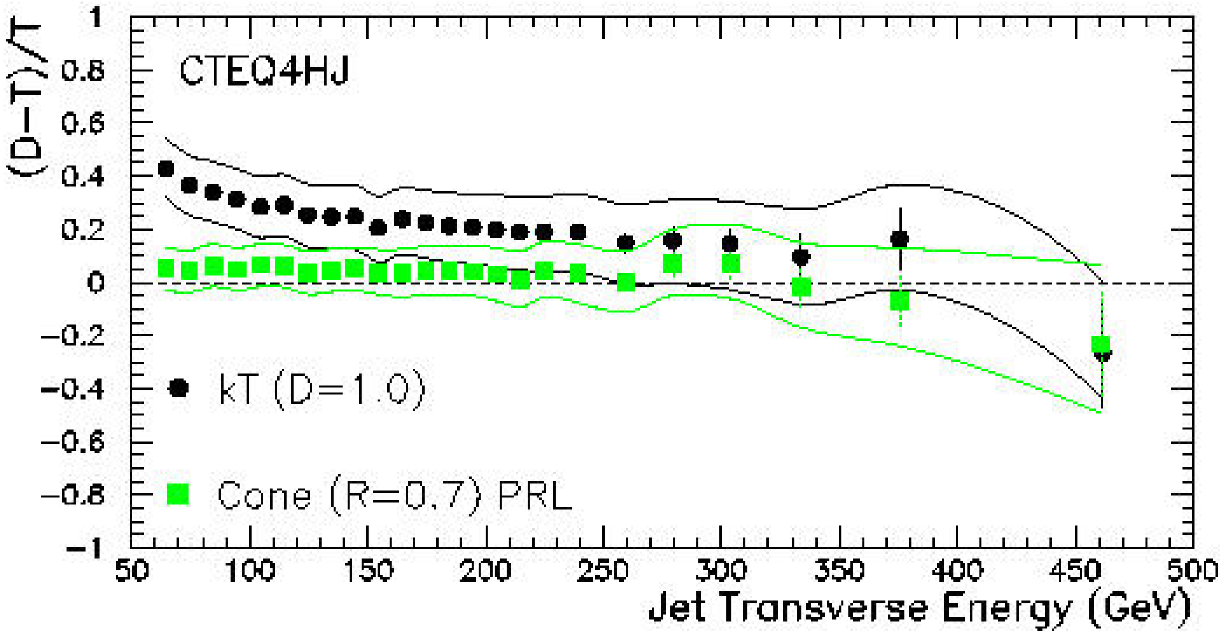
Curiosity II: K_T-Cone Discrepancy

- k_T recombinant algorithm, definition highly-desirable, popular at HERA, elsewhere
  - IR safe
  - Small hadronization effects
- For NLO predictions, Cone R=0.7 » k_T D=1.0
- Should have been a well described as cone….



Phys. Lett. B525, 211 (2002)

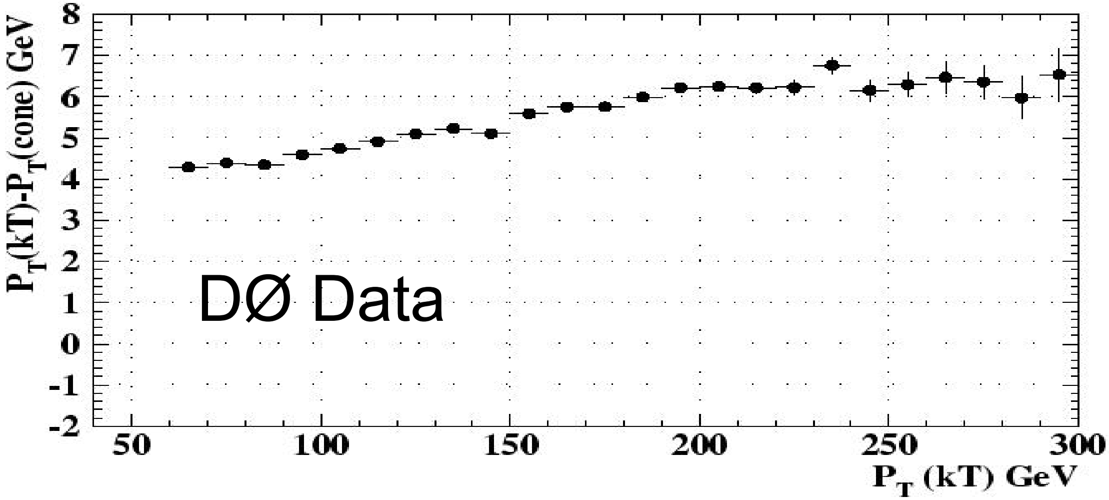
Comparison of k_T and cone

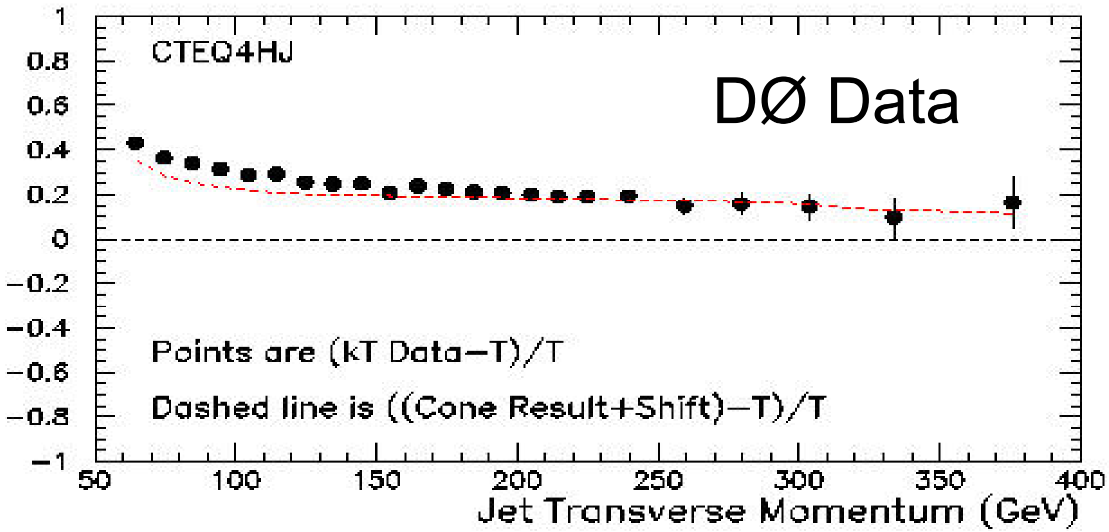


- **Each distribution compared to its own prediction**
- **Uncertainties highly- correlated from one bin to the next → normalization not well-determined, but shape is**
- **Unexpected 1-2σ deviation from cone and from predictions, mostly at low-p_T**

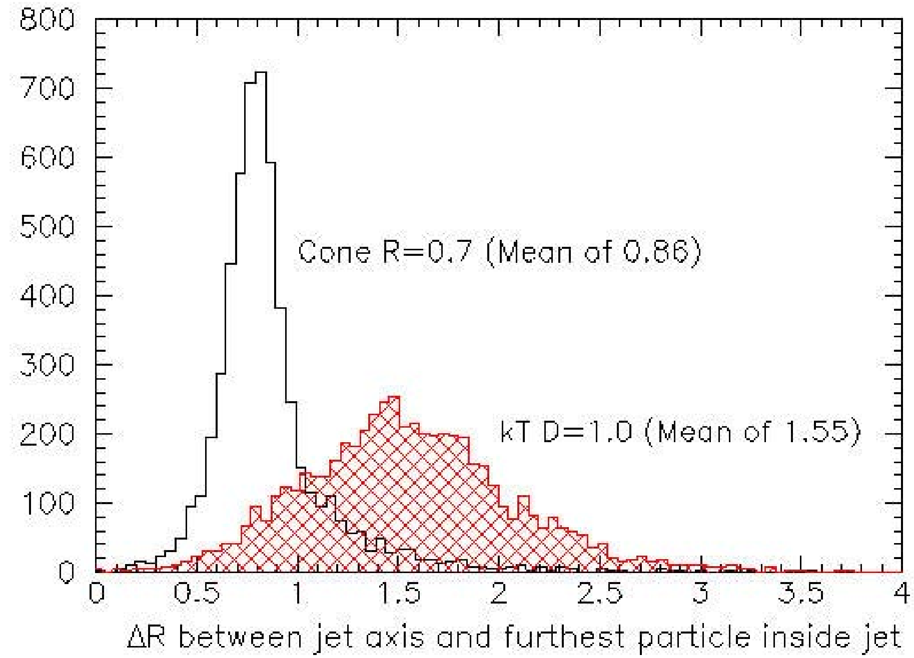
What causes this low p_T difference?

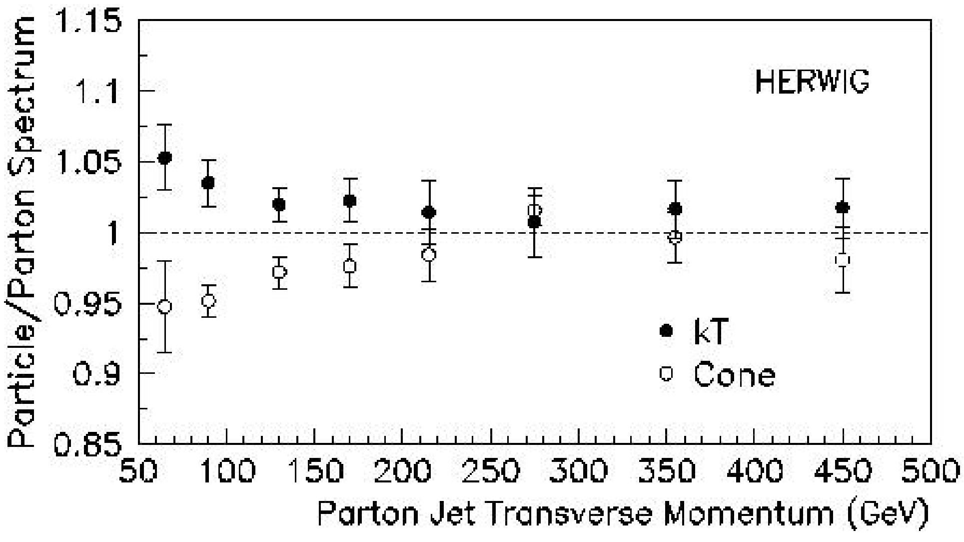
- Match k_T and cone jets in space:
- k_T jets include more energy than cone
- Insert this difference into the cross section and they match!





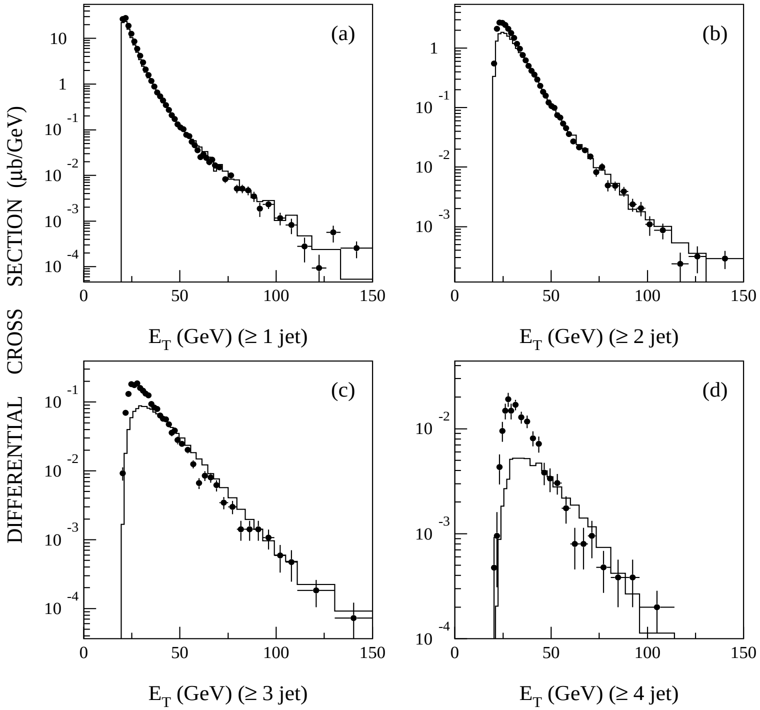
- Explanation may be associated with hadronization:
  - k_T seeks and finds hadronization products
  - Cone gives up quite a bit of energy during hadronization
- MC energy difference is half the size, accounts for half the shift. Needs tuning?
- Or a signal of <u>higher order corrections</u> < 0.2 that can bring Kt and cone in simultaneous agreement?





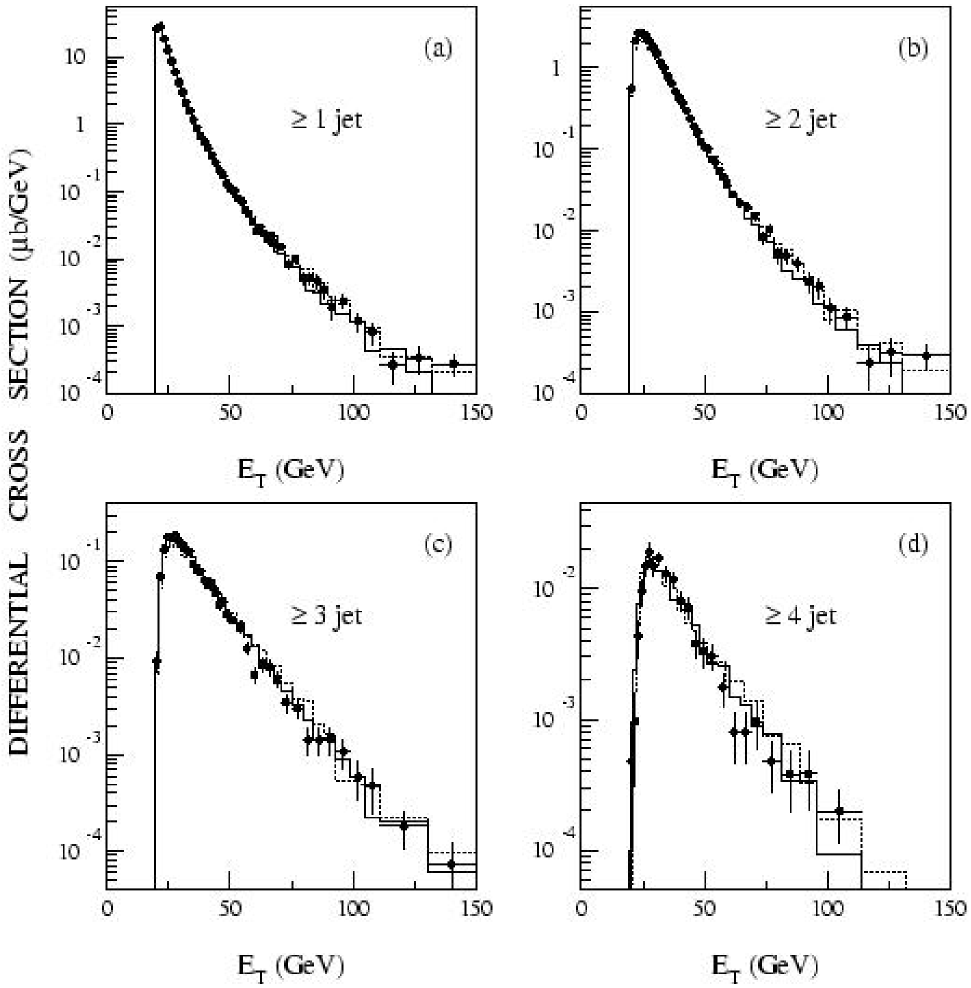
Curiosity III: Low-p_T multijet cross sections

- **Simple cross section study of exclusive jet final states**
- **Data shown with symbols**
- **Neither Pythia (histogram) nor Herwig (not shown) reproduce data without tuning**



Low-p_T multijet cross section

- After tuning, both MCs agree with data, but have not checked consistency with world's data
- Pythia: PARP(83)=0.4 "hard core" of proton, multiple-parton scatter
- Herwig: PTMIN=3.7 should not make a difference but appears to modulate underlying event
- Another manifestation of higher orders at X<.05?



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Curiosity IV: R_{32}

(The ratio of multijet cross sections)

Measure the ratio

$$R_{32} = \frac{\sigma_3(p\overline{p} \to 3+ \ \text{jets})}{\sigma_2(p\overline{p} \to 2+ \ \text{jets})} \ \text{vs.} \ H_T$$

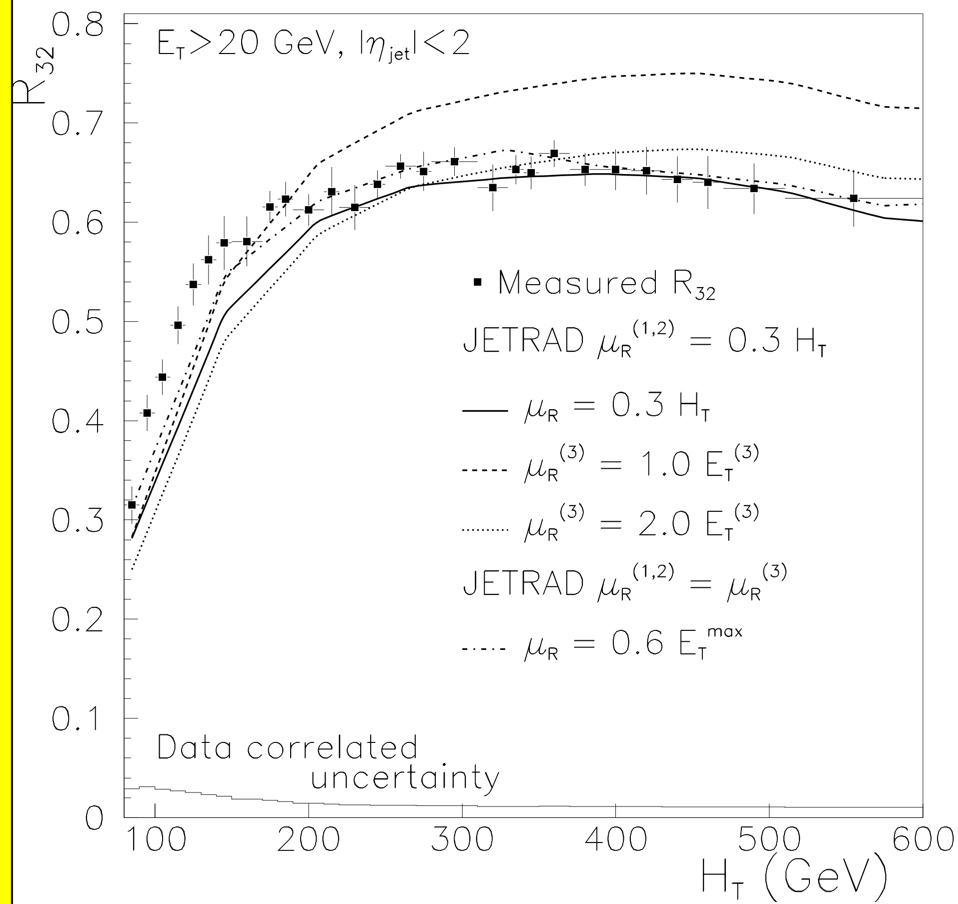
with

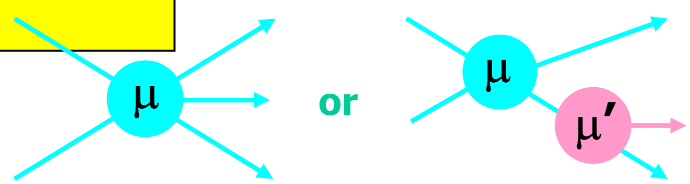
$$H_T = \sum_{\text{jets}} E_T$$

- **Improve understanding of the limitations of pQCD.**
  - **Identify renormalization sensitivity**
  - **Does the introduction of additional scales improve agreement with data ?**
- **QCD multijet production - background to interesting processes**
- **Predict rates at future colliders (Zeppenfeld/Summers)**

Measurement/Predictions for R_{32}

- Compare to pQCD JETRAD
- Prediction independent of pdf
- Sensitive to μ_R
- Jet emission best modeled using the same scale $\propto$ the hard scale for all jets rather than softer scale for additional jets
- Introduction of additional scales to predict the rate of additional jet production - unnecessary and leads to poorer agreement with data.
- Need higher order terms to fully explain shape.





Closing Comments

- **Tevatron and D0 running well and physics programs well established**
  - High transverse momentum inclusive jet cross section
  - Dijet cross section
- **Some interesting departures/results from NLO QCD at "lowish" x require progress**
  - Scaled cross sections at different energies
  - Recombinant algorithms
  - R_{32}
  - Multi-jet production low transverse energy.

  } **Limitations of NLO QCD?**
- **Expect exciting results in QCD as luminosities reach 1-2 fb^{-1} in the next few years. New summer results will be ~100 pb^{-1}.**