Jet and Photon Physics at DØ

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(For the DØ Collaboration)

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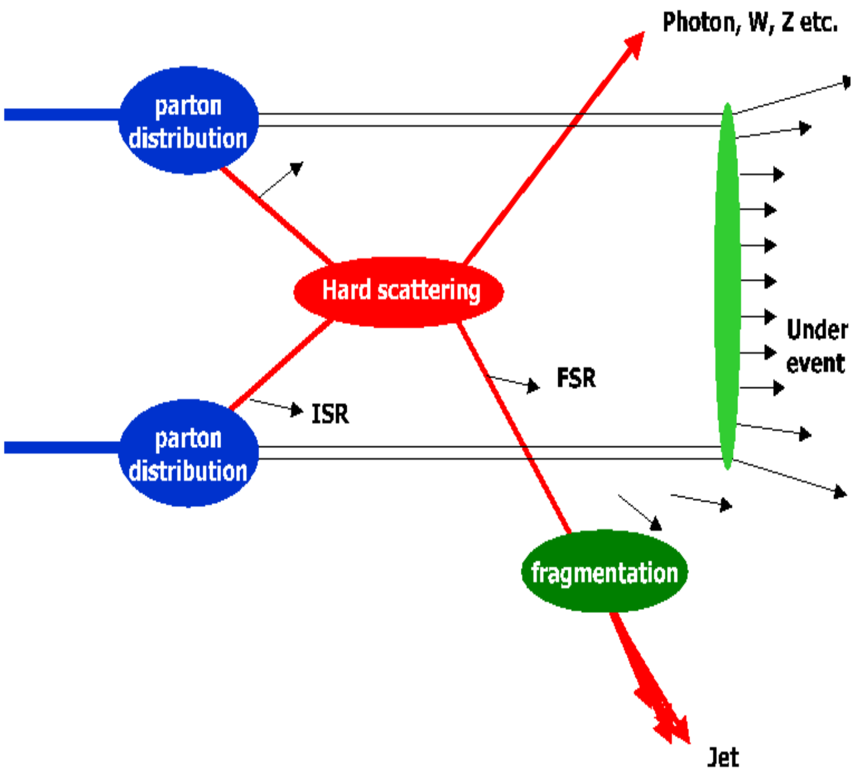
Outline

- Introduction
- Jet cross sections
  - ➔ inclusive results
  - ➔ multi-jet results
- Photon cross sections
- Diffractive W and Z production
- Run 2
  - ➔ status
  - ➔ first jet results
- Summary

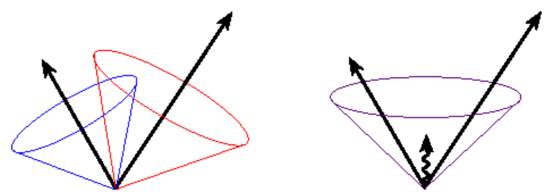


Jets at the Tevatron

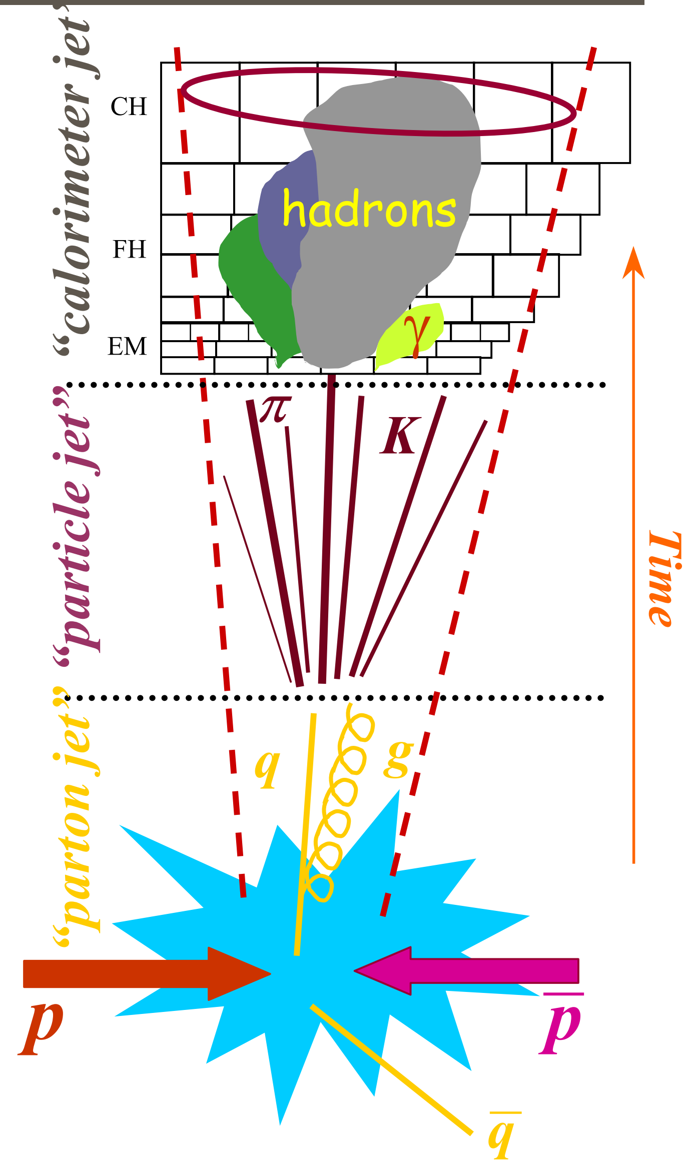
- Here, jets of fixed cone size
  - ➔ k_T-jet results in the talk by U. Bassler
- Run 1:
  - ➔ Add up towers around a “seed”
  - ➔ Iterate until stable
  - ➔ Jet quantities: E_T, η, ϕ

$$E_T^{jet} = \sum_{R_i \le 0.7} E_T^{tower}$$

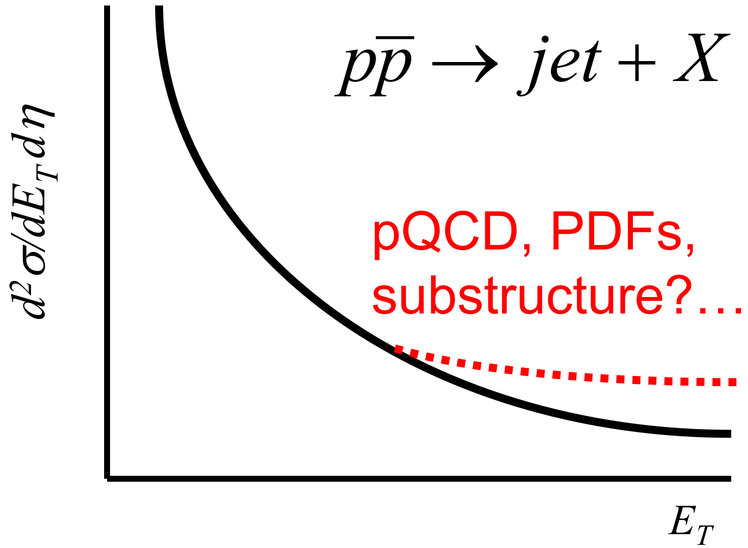
- Modifications for Run 2:
  - ➔ Use 4-vector scheme, p_T instead of E_T
  - ➔ Add midpoints of jets as additional starting seeds
  - ➔ Infrared safe



- Correct to particles
  - ➔ Underlying event, previous/extra $p\bar{p}$ interactions, energy loss out of cone due to showering in the calorimeter, detector response, E_T resolution



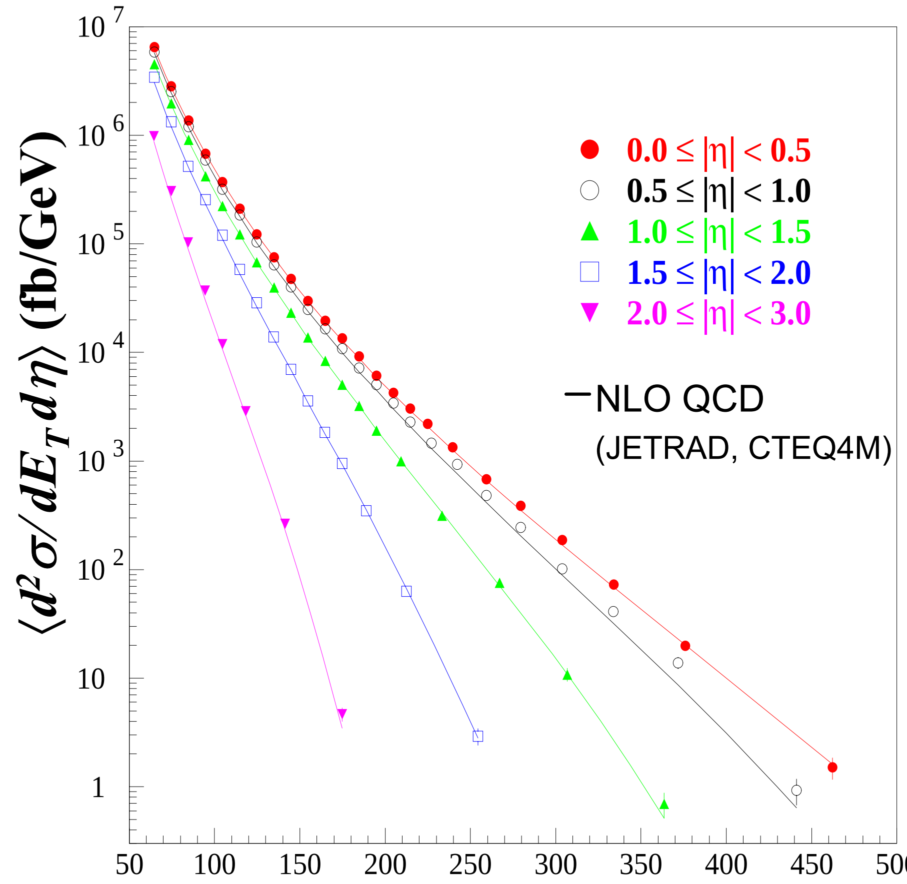
Inclusive Jet Cross Section at 1800 GeV



- How well do we know proton structure (PDFs) ?
- Is NLO (α_s^3) QCD "sufficient" ?
- Are quarks composite ?

$$\frac{d^2\sigma}{dE_T d\eta} = \frac{N_{jet}}{\Delta E_T \Delta \eta \varepsilon L} \text{ vs. } E_T$$

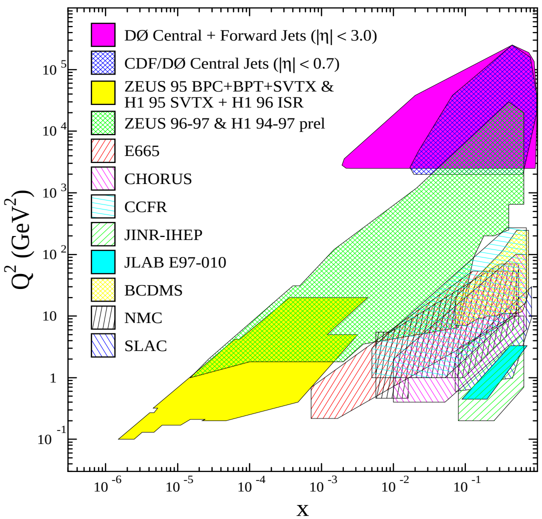
- PRL 86, 1707 (2001)



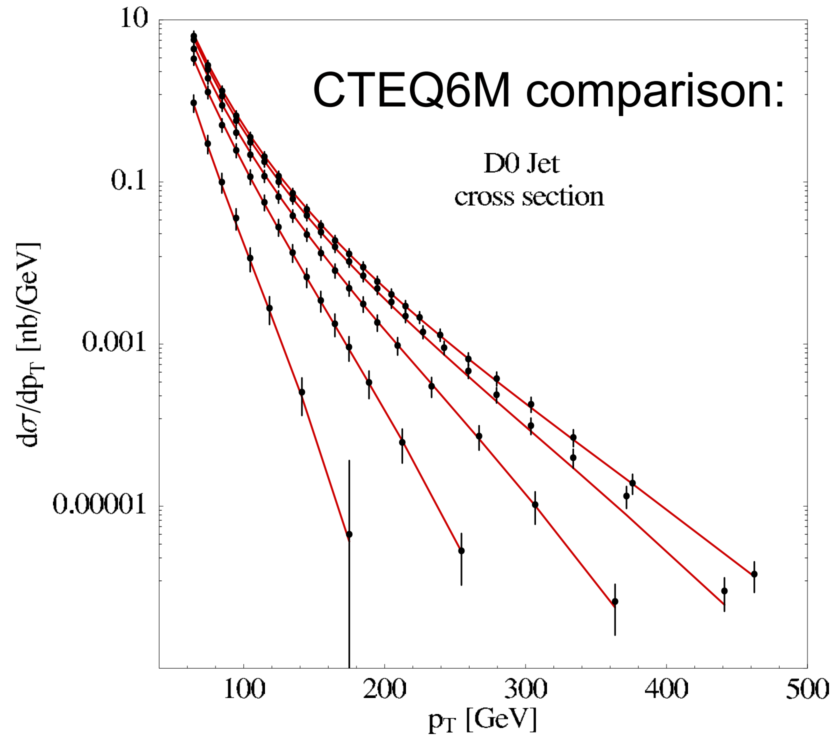
Good Agreement with NLO QCD

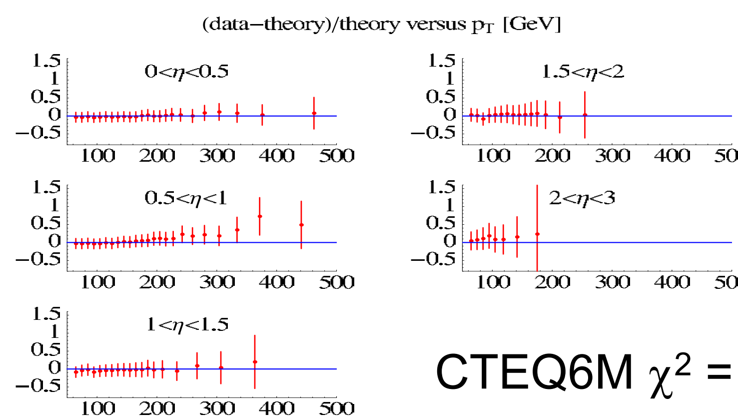
Rapidity-Dependent Inclusive at 1800 GeV

- DØ's most complete cross section measurement
  - ➔ covers $|\eta| < 3.0$
  - ➔ complements HERA x-Q^2 range



- 90 data bins
  - ➔ Full correlation of uncertainties
- Used in CTEQ6 and MRST2001 fits to determine gluon at large x "better than ever before"
  - ➔ **Enhanced gluon at large x**





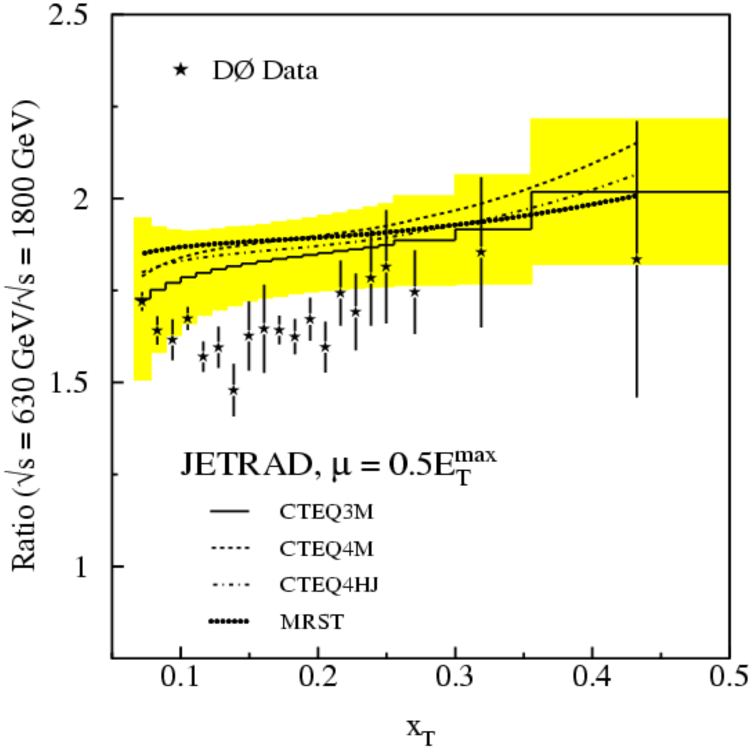
CTEQ6M $\chi^2 = 65$

Marek Zieliński, University of Rochester

Ratio of Cross Sections: 630 GeV / 1800 GeV

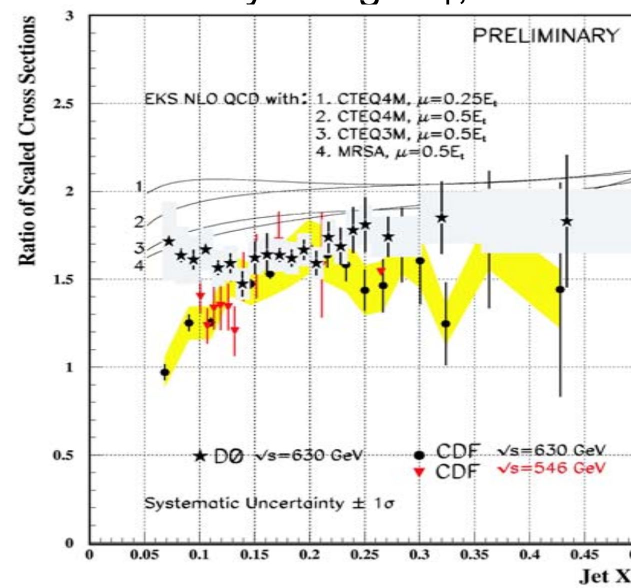
$$\frac{E_T^3}{2\pi}\frac{d^2\sigma}{dE_T d\eta}$$ vs. $$x_T = \frac{2E_T}{\sqrt{s}}$$

- Various theoretical and experimental uncertainties tend to cancel in the ratio



- **PRL 86, 2523 (2001)**

- Data 10-15% below NLO QCD
  - ➔ Agreement Probability (χ^2 test) with CTEQ4M, CTEQ4HJ, MRST: 25-80%
- Comparison with CDF
  - ➔ Consistency at high x_T, but not at low x_T



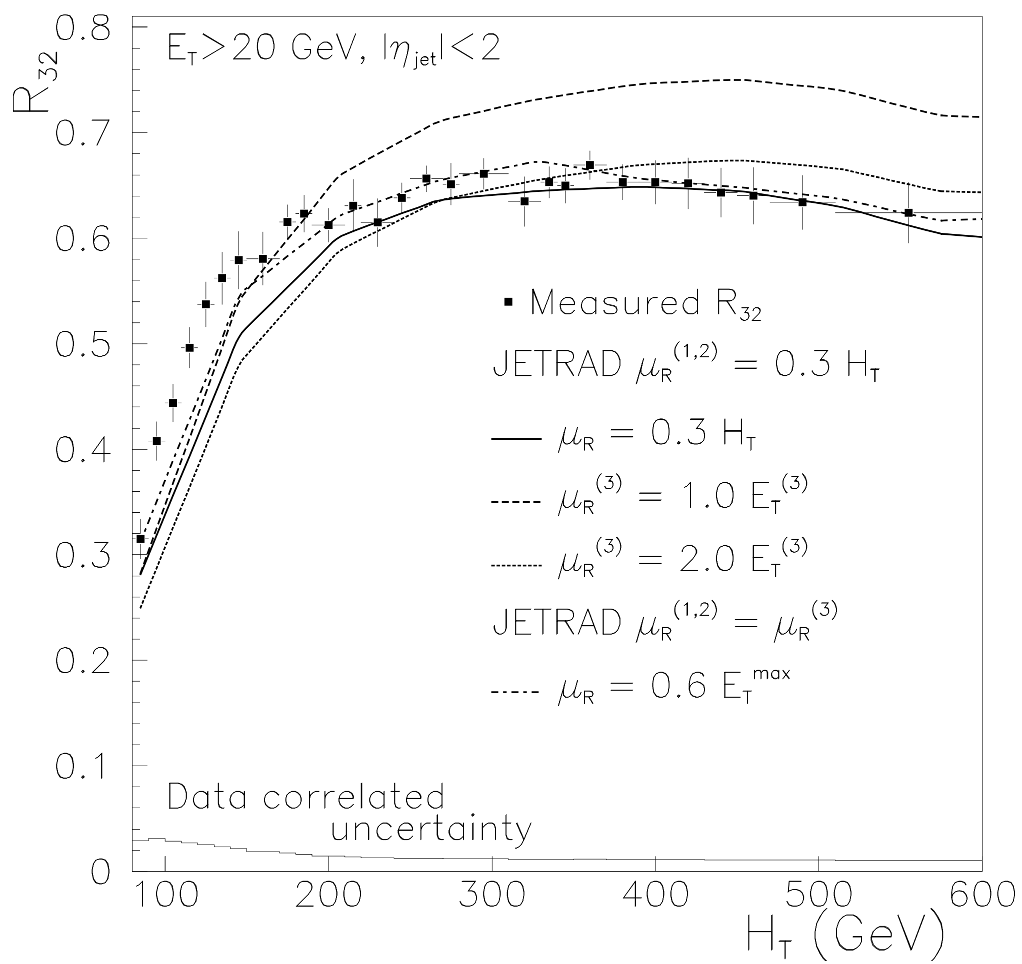
- A ~3 GeV shift in jet energies could account for the discrepancies
  - ➔ corrections for underlying event, showering in calorimeter, parton k_T…?
  - ➔ larger than experimental uncertainty…

Inclusive R_{32}: 3 Jets / 2 Jets at 1800 GeV

$$R_{32} = \frac{\sigma_{\geq 3\ \text{Jets}}}{\sigma_{\geq 2\ \text{Jets}}} \quad vs \quad H_T = \sum_{\text{Jets}} E_T$$

- A study of soft jet emission
  - ➔ 70% of high-E_T jet events have a 3rd jet above 20 GeV
  - ➔ 50% have a jet above 40 GeV
- Ratios provide reduced systematic uncertainties
- We observe very little sensitivity to PDFs
- Using JETRAD, investigate sensitivity to scale μ_R
  - ➔ **Single-scales ($\mu \approx 0.3 H_T$) seem better than mixed-scales**

PRL 86, 1955 (2001)

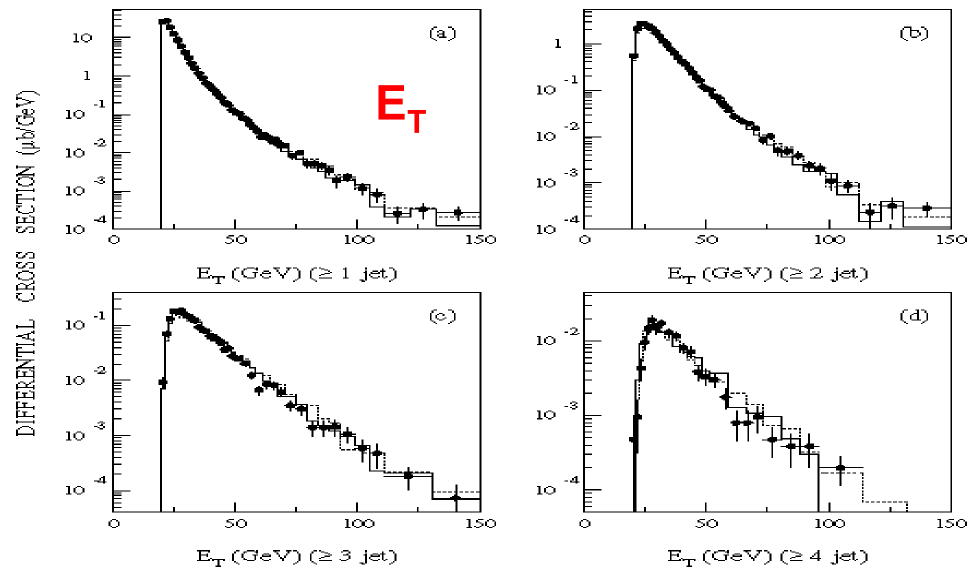


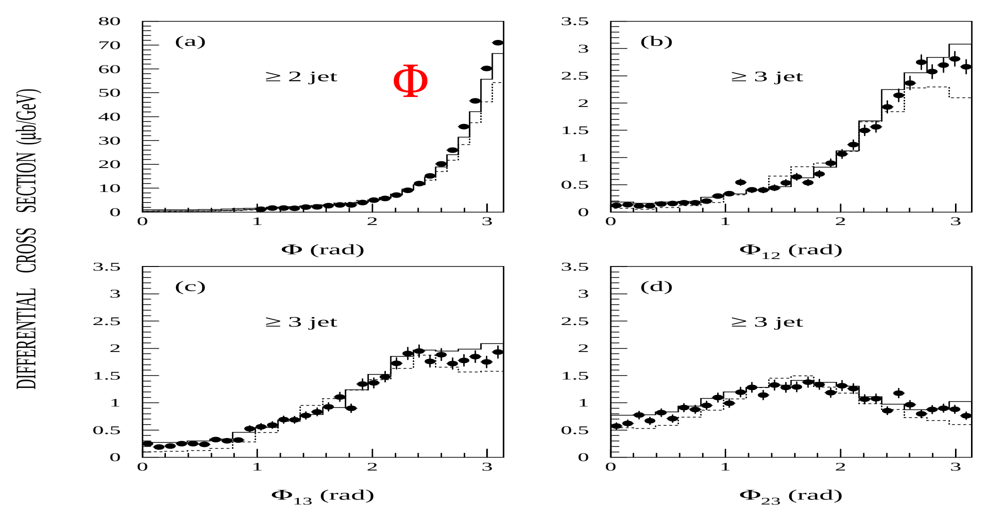
Low-E_T Multi-jet Production at 1800 GeV

- Now looking at multi-jets at low $E_T \approx 20$ GeV …
- This region is sensitive to gluon radiation and multiple parton interactions
- E_T distribution of $\geq$ 1, 2, 3, and 4 jet events compared with MC predictions (Pythia – solid, Herwig -- dotted)
  - ➔ Without tuning, the MC predictions do not match the data:
    - ❖ excess of events for $\geq$3 and 4 jets at low-E_T end
    - ❖ wrong Φ distributions
  - ➔ Tune Pythia PARP(83) = 0.32 (fraction of core region of hadronic matter distribution)
  - ➔ Tune Herwig P_T^{min} to 3.7 GeV (minimum P_T of hard processes)

DØ preliminary, hep-ex/0207046

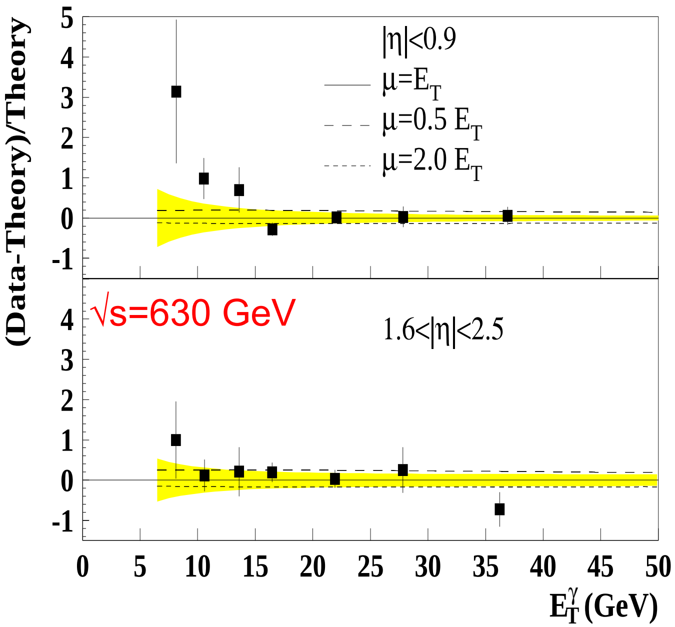
Each jet's E_T>20 GeV, $|\eta|$<3

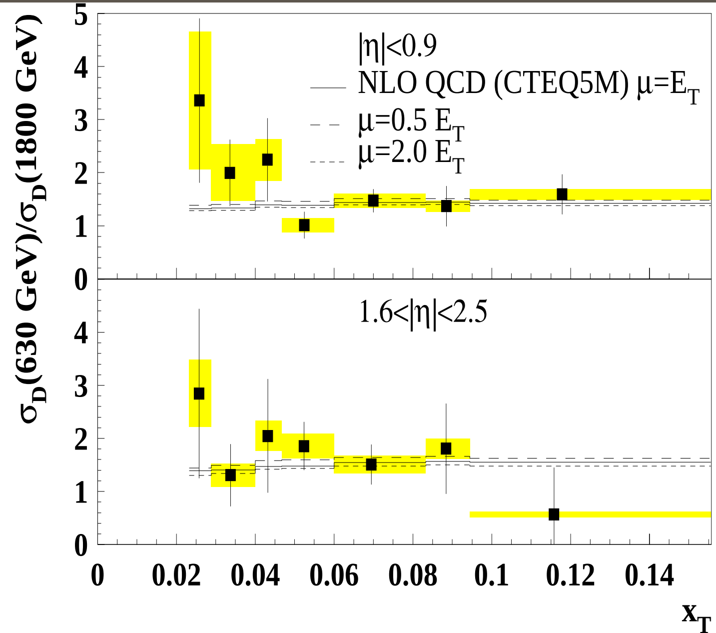




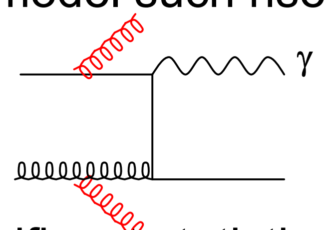
Photons at 630 and 1800 GeV

- Probe pQCD without the complication from jet identification and hadronization
  - ➔ DØ and CDF previously reported an excess of γ production for $p_T<30$ GeV at 1800 GeV (DØ: PRL 84, 2786 (2000))





- Slight excess at low x_T?
  - ➔ Smearing of the transverse momenta of initial partons by a few GeV can model such rise at low E_T



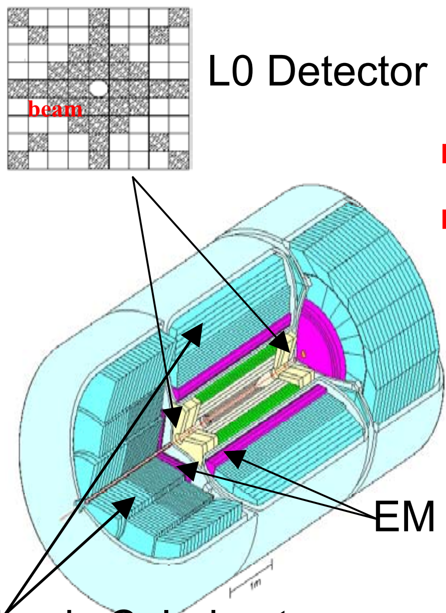
  - ➔ But: insignificant statistically
  - ➔ Good agreement with NLO QCD

First measurement at forward rapidities

PRL 25, 251805 (2001)

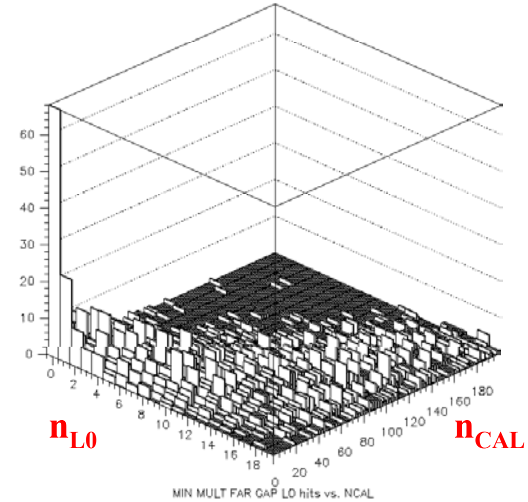
Diffractive W and Z Production at 1800 GeV

- Probe quark content of Pomeron
- Measurement: look for rapidity gaps



n_{L0} = # hit tiles in L0 detector

n_{CAL} = # towers with energy above threshold in forward calorimeters



Peak at (0,0) indicates diffractive process

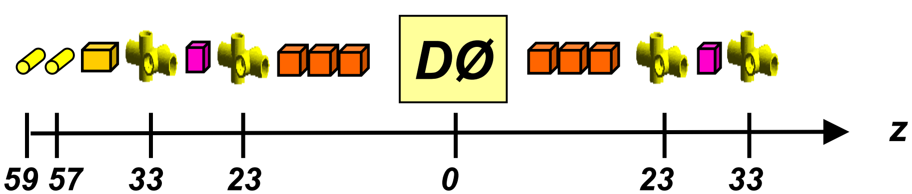
W sample: 91 of 12622 events in (0,0) bin

Z sample: 9 of 811 events in (0,0) bin

- New definitive observation of diffractive W signal:
  $R_W=(0.89 + 0.20 - 0.19)\%$
- First observation of diffractive Z:
  $R_Z=(1.44 + 0.62 - 0.16)\%$

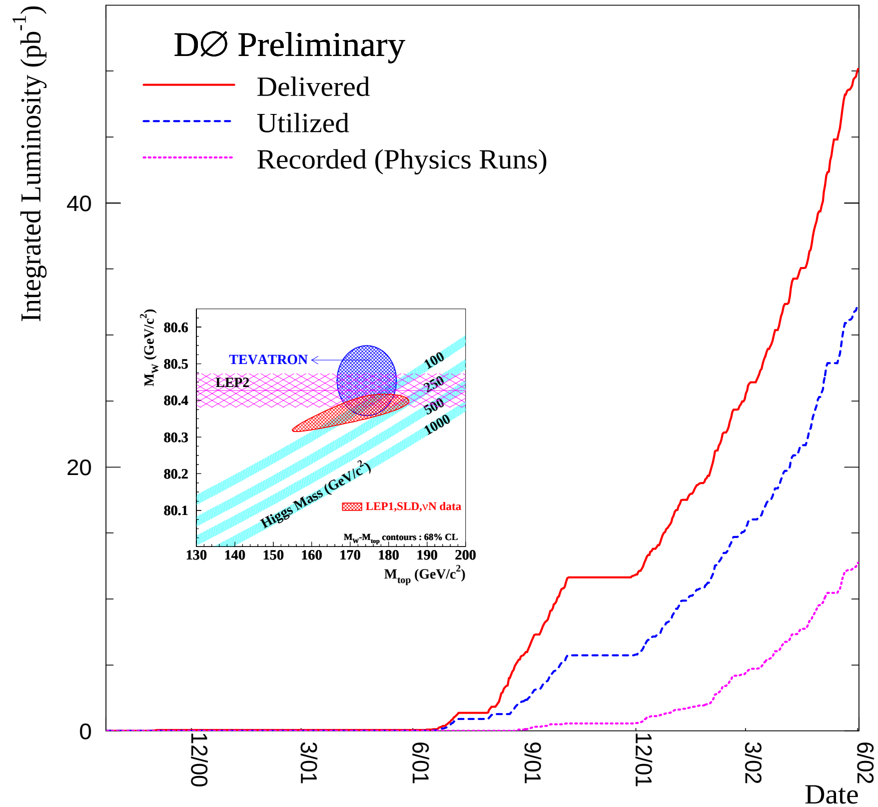
DØ preliminary, paper in preparation

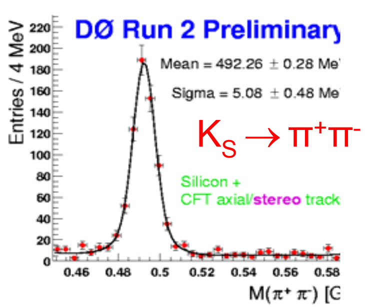
- In Run 2 we will be able to measure the scattered proton using the Forward Proton Detector:

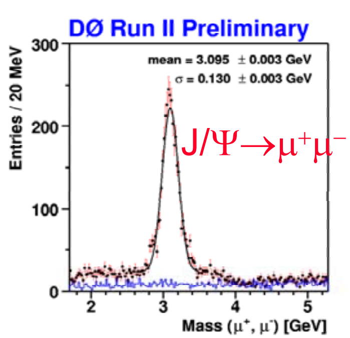


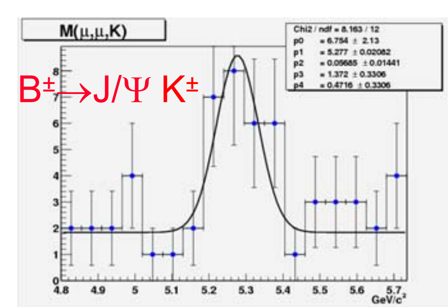
Start of Run 2

- Run 2 of the Tevatron started in March 2001
  - ➔ Running at $\sqrt{s}$=1.96 TeV
- Considerable fraction of collected luminosity devoted to the commissioning of the detector
- Significant progress in establishing and refining "physics objects": e, μ, jets, EM and jet energy scale…
- **6 pb^{-1} used for jet results (March-May 2002)**

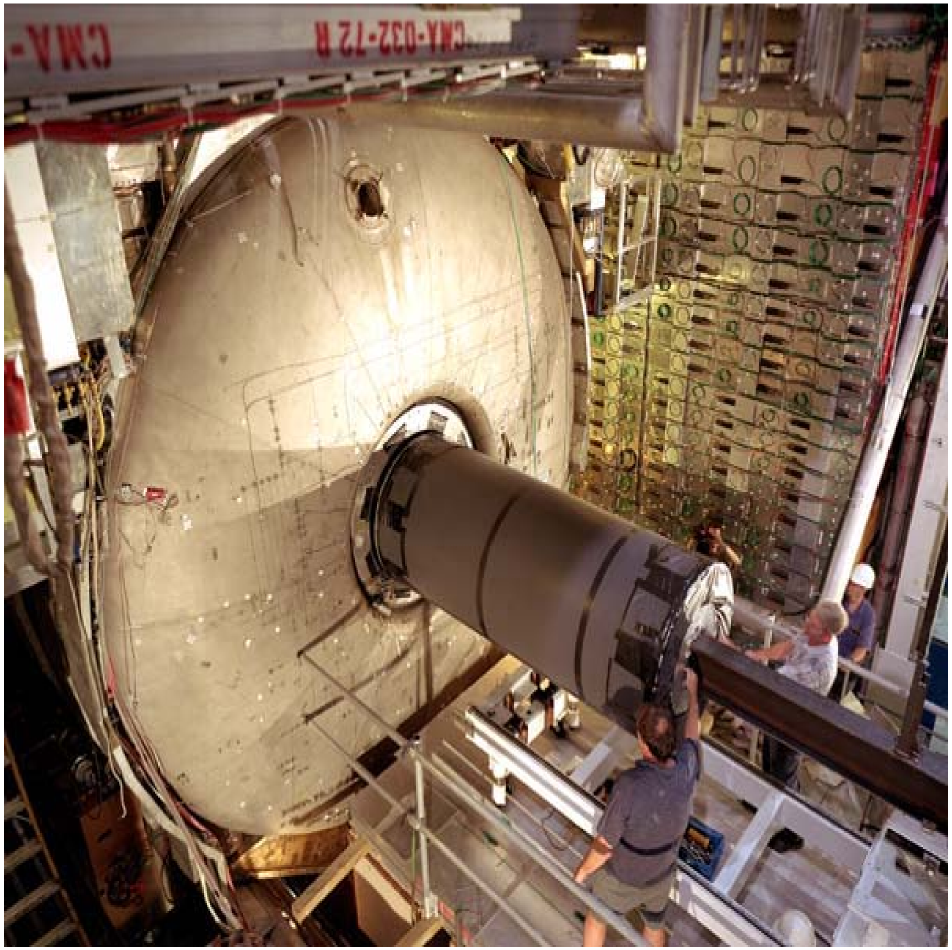








Run 2: Calorimeter



- Using Run 1 calorimeter
- Uranium-Liquid Argon
  - ➔ stable, uniform response, radiation hard, fine segmentation
- Uniform, hermetic, coverage $|\eta| < 4.2$
- Compensating ($e/\pi \sim 1$)
- Good energy resolution

- New readout electronics to operate in Run 2 environment

Very stable running

~50 bad channels (0.1%)

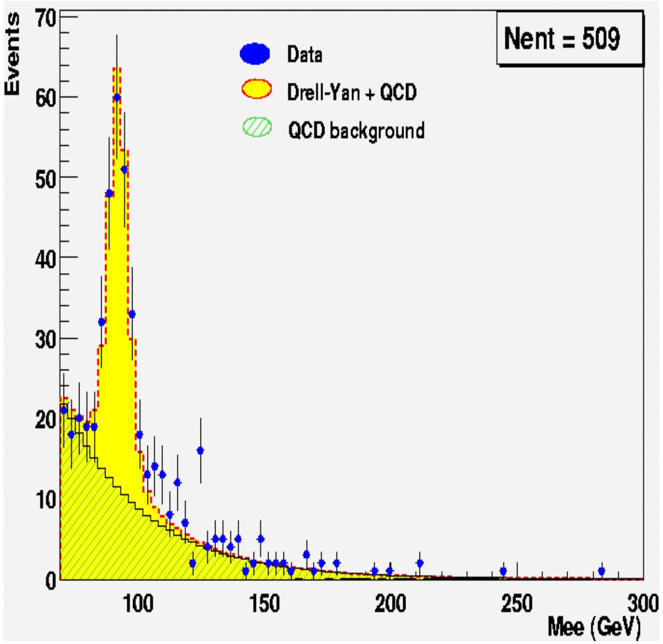
Jet Energy Scale

- Measured jet energy is corrected to particle level

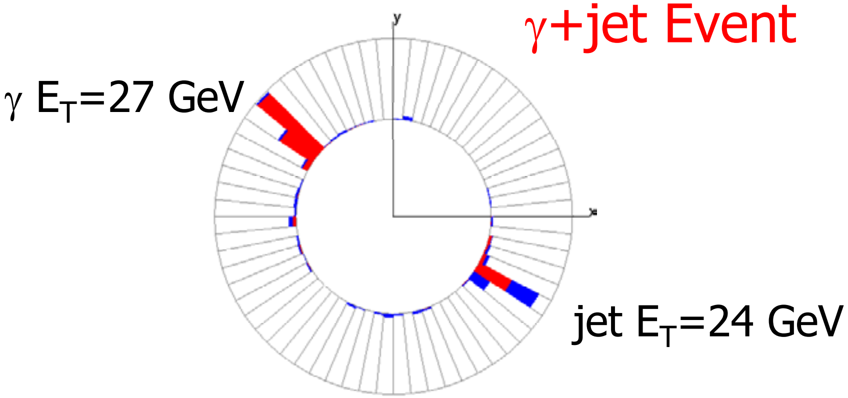
$$E_{ptcl}^{jet} = \frac{E_{det}^{jet} - E_O}{R_{jet} S}$$

- Detector $\boldsymbol{E_{det}}$: jet energy in the detector, reconstructed with a cone algorithm
- Offset $\boldsymbol{E_O}$: energy due to previous events, multiple interactions, noise etc.
- Response $\boldsymbol{R_{jet}}$: calorimeter response to hadrons, measured from E_T imbalance in γ+jet events
- Showering $\boldsymbol{S}$: net fraction of particle-jet energy that remains inside jet cone after showering in the calorimeter

Z→ee signal (Calorimeter only)



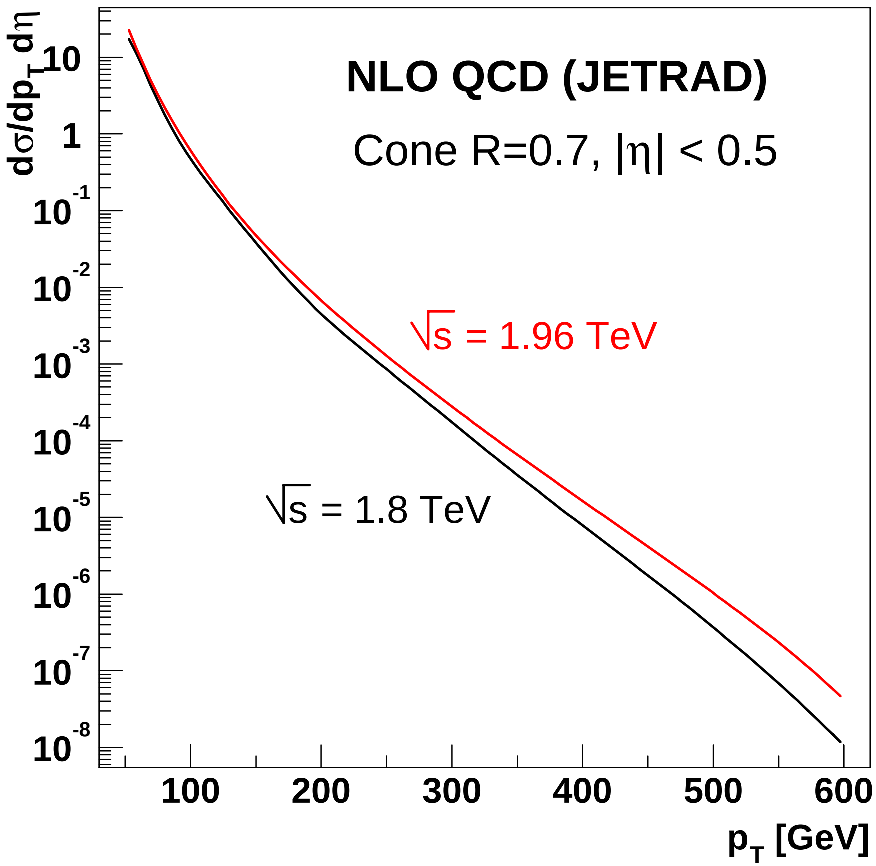
γ+jet Event



Jets Physics in Run 2

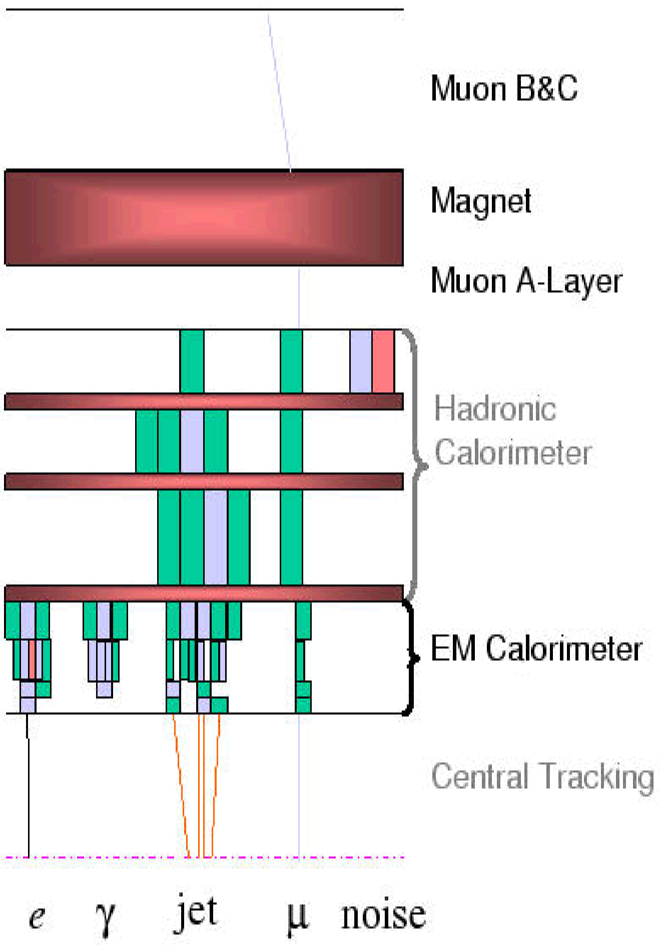
- At $\sqrt{s}$=1.96 TeV, cross section 2x larger compared to Run 1 for jets with p_T > 400 GeV
- Higher statistics will allow:
  - ➔ better determination of proton structure at large x
  - ➔ testing pQCD at a new level (resummation, NNLO theory, NLO event generators)
  - ➔ continued searches for new physics (compositeness, W', Z', extra dimensions etc…)
- New algorithms:
  - ➔ midpoints
  - ➔ massive jets, using jet p_T

Inclusive jet spectrum

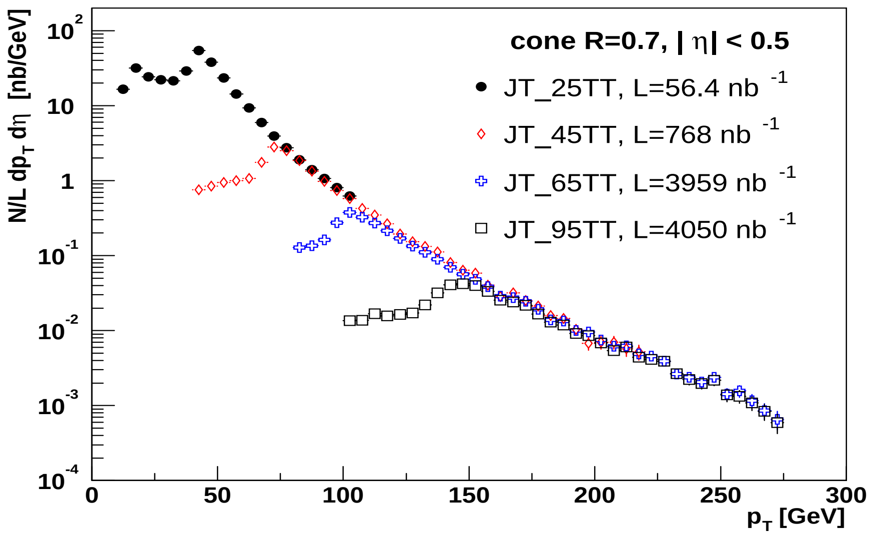


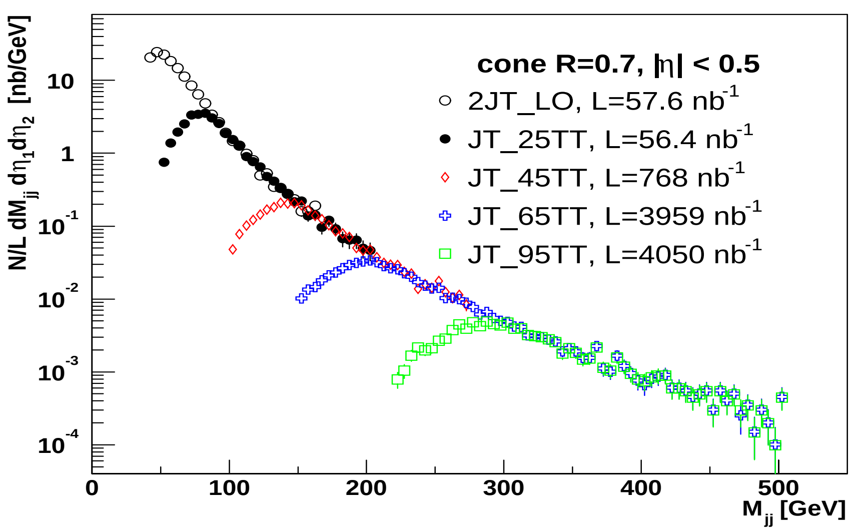
Selecting Jets in Run 2

- Jet sample:
  - ➔ Data taken during March-May 2002 period
  - ➔ Cone size R=0.7
  - ➔ $|\eta|<0.7$
  - ➔ Run selections based on hardware status, missing E_T
  - ➔ Jet selection based on several calorimeter characteristics
  - ➔ Missing $E_T < 0.7\, p_T^{jet1}$
  - ➔ $|z_{VTX}| < 50$ cm
  - ➔ $E_{CAL} < 2$ TeV

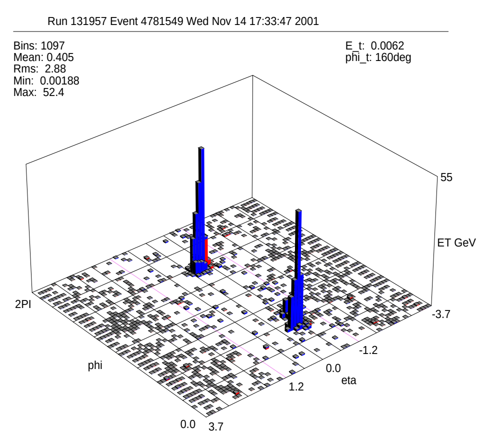


Jet Triggers in Run 2





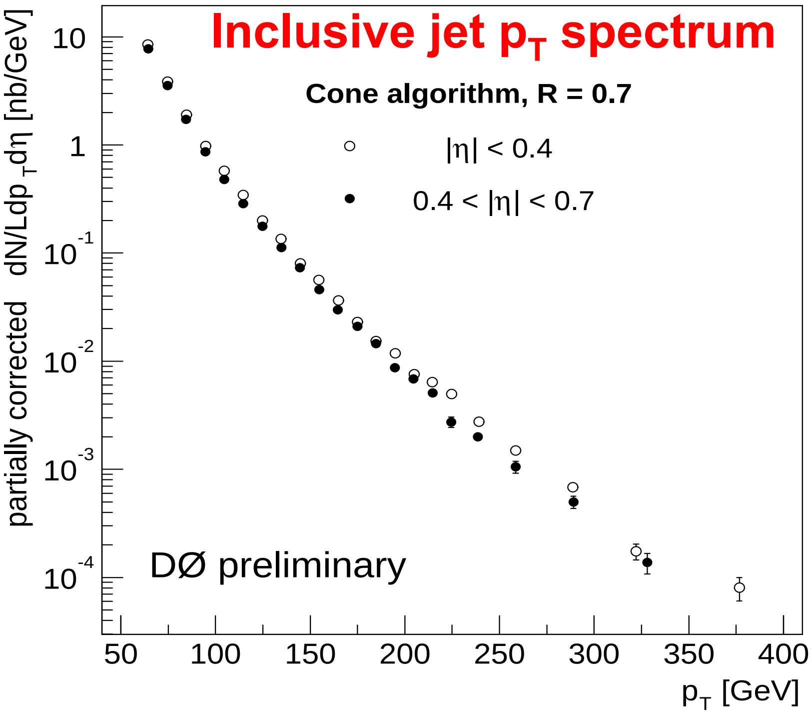
- Hardware trigger (L1)
  - Triggers on calorimeter towers
  - Fast readout
  - Multi-tower triggers
  - Trigger coverage $|\eta| < 0.8$ for this data
    - **Expanded to $|\eta| < 2.4$ in June!**
- Software trigger (L3)
  - Simple and fast jet algorithm on precision readout
    - **Improved turn-on**

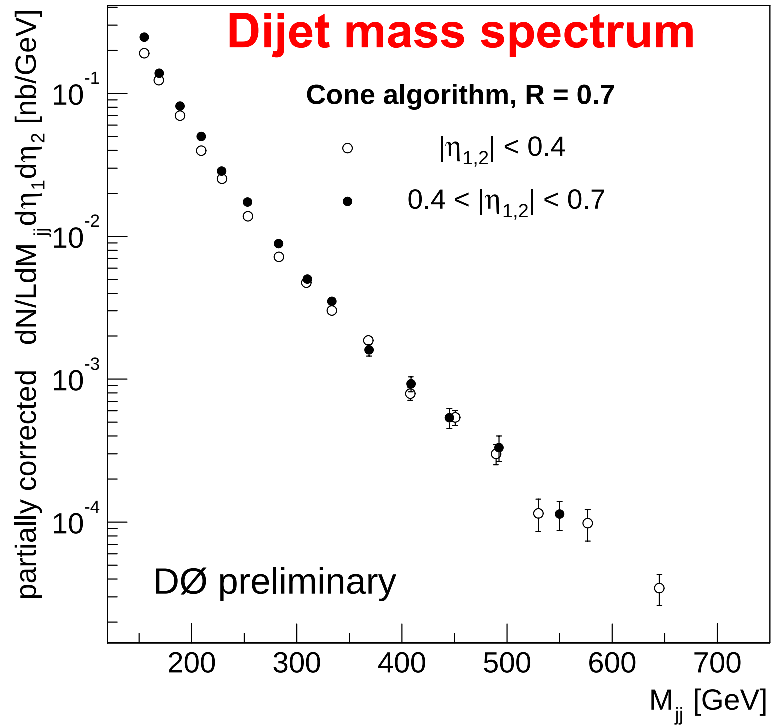


2-jet event

- E_T^{jet1}~230 GeV
- E_T^{jet2}~190 GeV

Run 2 Jet Results





- Only statistical errors
- Luminosity L = 5.8 pb^{-1} (±10%)
- Preliminary jet energy scale
  - ➔ 30-50% syst. error in cross section
- Not fully corrected
  (for unsmearing, efficiencies)

- Coming shortly:
  - ➔ Much expanded η range
  - ➔ L2 triggers, L1 large tiles
  - ➔ Improved energy scale
  - ➔ Efficiency corrections
  - ➔ Ever increasing lumi…

Summary

- **Run 1:**
  - Jet results in good agreement with NLO QCD
  - Good understanding of systematics, correlations
  - Strong constraints on PDF's, especially high-x gluon
  - Photon results consistent with NLO QCD
    - a hint of discrepancy at low p_T?
  - Clear observation of diffractive W production, first for the Z
- **Run 2:**
  - DØ detector is working well after upgrade
  - Jet measurements are well underway
  - First results available for
    - Inclusive jet p_T spectrum $60 < p_T < 410$ GeV
    - Dijet mass spectrum $150 < M_{jj} < 750$ GeV
  - Many precision measurements possible

Looking forward to more data!