JET SHAPES AT D0

presented by

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December 7, 1995

Introduction

- Motivation
- Data Analysis
    - -- Data Sample
    - -- Cuts
    - -- Corrections
- Results
- Comparison to Monte Carlo
- Comparison to NLO predictions

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Jet Shape Analysis
Test of QCD

- jet shape due to:

  -- gluon radiation

  -- fragmentation

- measure E_T flow in jets as a function of radial distance $R = (\Delta\eta^2 + \Delta\phi^2)^{1/2}$ from jet axis

- measure dependence of jet shape on E_T and η of jets

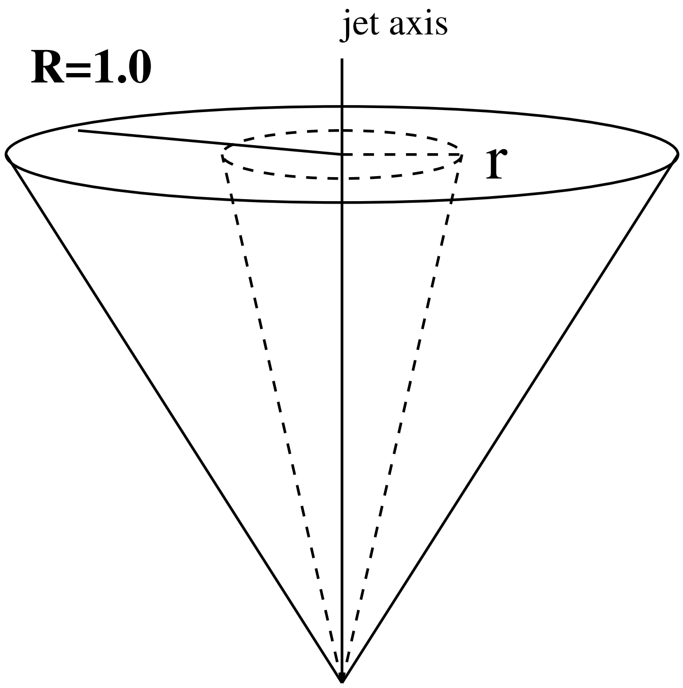
- compare data to QCD predictions:

  -- NLO calculations at the parton level

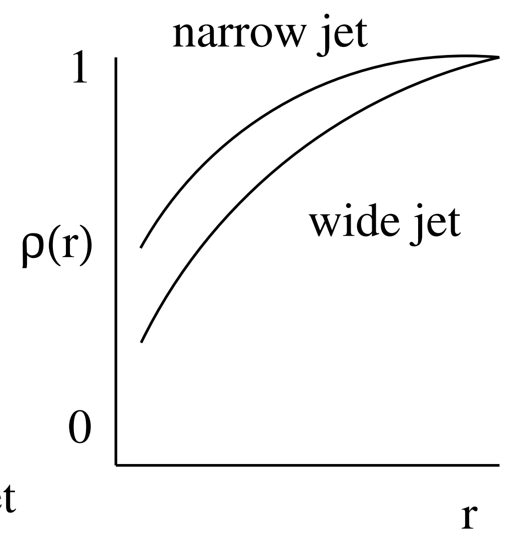
  > LO - 2 partons in final state
  - jets have no shape (no substrucure)

  > NLO - 2 or 3 partons in final state
  - first order a jet shape prediction can be made

Jet Shape Measurement



Measure radial E_T flow in 10 subcones around jet axis in $\Delta r = 0.1$ increments



Calculate average integrated jet E_T fraction as a function of radial distance from jet axis:

$$\rho(r) = 1/N_{jets}\left[\Sigma_{jets}\left(E_T(r)/E_T(R)\right)\right]$$

Jet Shape Measurement

- jets measured using calorimeter energy deposition and event vertex

- jet shape obtained from calorimeter energy deposition (charged and neutral particles)

- previous measurement by CDF

  -- jet shape obtained using tracking chamber information
  (charged particles only)
  --> **PRL,** Vol 70, p. 717 (1993)

- previous measurement by OPAL

  -- jet shape obtained using calorimeter and charged tracking chamber information
  --> **Z. Phys. C**63 (1994) 197.

Data Sample

- Data from Run 1a of Fermilab Tevatron (1992-1993)
- use 3 pb^{-1} in this analysis (out of 14 pb^{-1})
- select data using calorimeter based trigger with trigger towers 0.2 x 0.2 in $\Delta\eta \times \Delta\phi$

	L1 Trigger (hardware)	L2 Trigger (software)
	x/y -> x towers above y GeV	single jet above threshold
-- Jet Min	1/3	20
-- Jet Low	1/7	30
-- Jet Med	2/7	50
-- Jet High	3/7	80

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Offline Analysis - D0 Jet Algorithm

- find jets with cone-based algorithm using calorimeter tower information and event vertex:
  - -- calorimeter towers (0.1 x 0.1 in $\Delta\eta$ x $\Delta\phi$) with energy > 1 GeV used as seeds to define preclusters (formed by adding neighboring towers within radius 0.3)
  - -- cone of radius R = 1.0 is drawn around each precluster and the jet center calculated:

$$\eta = \Sigma \eta_i E_{Ti} / \Sigma E_{Ti} \quad \text{and} \quad \phi = \Sigma\phi_i E_{Ti} / \Sigma E_{Ti}$$

  - -- interate to find stable jet then redefine jet center:

$$\eta = -\ln(\tan(\theta_j/2))$$

$$\text{where } \theta_j = \tan^{-1}[(\Sigma E_{xi})^2 + (\Sigma E_{yi})^2]^{1/2} / \Sigma E_{zi}$$

and $\phi = \tan^{-1} (\Sigma E_{yi} / \Sigma E_{xi})$

  - -- E_{Tjet} is sum of E_T of calorimeter towers in jet
- if 2 jets overlap:
  - -- if they share >50% of lower jet's E_T then they are merged - jet direction redefined
  - -- otherwise they are split - calorimeter cells energies reassigned
- keep all jets with E_T > 8 GeV

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Cuts on Data

- Event Cuts

  — E_T of leading jet in region of full trigger efficiency

  -- |z-vertex| < 30 cm

- Jet Cuts - quality cuts

  ••● fraction of E in outer calorimeter < 0.4

  ••● 0.05 < EM fraction < 0.95

  ••● ratio of energies of calorimeter cell with most energy to cell with 2nd most energy < 10

➧ all jets passing above cuts included in sample

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MEASUREMENT REGION

- regions populated:

→ 2 η regions: $0.0 < |\eta| < 0.2$

$2.5 < |\eta| < 3.0$

→ 4 E_T regions

E_T = 45 - 70 GeV

70 - 105 GeV

105 - 140 GeV

140 - 300 GeV

★ Regions chosen consistent with 4 triggers used

Corrections to Data

- 2 processes cause jet to have larger energy than due to hard scatter:

    -- zero suppression effects

        > due to uranium noise and asymmetric electronics shaping (gives asymmetric pedestal)

    -- underlying event

        > due to spectator interactions

- Apply energy scale correction to jet
- Jet energy lost due to out-of-cone showering:

    -- effect < 2% in central and forward regions
    --> Data not corrected for this

Corrections to Data

- E_T in each subcone corrected for:
  - -- underlying event
    - > 0.55 +- 0.1 GeV $E_T/\eta\phi$ - constant in E_T
  - -- uranium noise/pedestal bias - Zero Suppression
    - > 1.36 +- 0.2 GeV/$\eta\phi$ – constant in E
  - ➨ above measured from minimum bias runs
- jet E_T corrected for: (~ 15 to 20 %)
  - -- underlying event
  - -- zero suppression
  - -- energy scale
  - ➨ jet E_T used just for binning

Correct to Particle Level

- want jet shape measurement **due just to particles in jet,** before comparing different regions and to theory

- correct for effects on jet shape by measurement using calorimeter:

  -- remove showering and non-linear response effects due to calorimetric measurement

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> **Showering** -> widens jets

* particles shower in physical space whereas jets measured in $\eta-\phi$ space

* effect larger in forward region where physical cell sizes smaller

> **Non-linear response of low energy particles** -> narrows jets

* low E particles on outer edge of jet

+

decreased response to low E particles

= less energy measured on outer edge of jet (narrower)

-- use MC (Pythia, Isajet, Herwig) at particle and calorimeter level (before and after detector simulation by Geant) to obtain correction factors

> assumes MC describe distribution of particles in jet well & Geant models calorimeter response well

> largest difference in correction factors obtained from the different MC = 3%

Sizes of Corrections to Data

- Corrections to subcones (largest in inner subcones)

  -- Underlying event

  > 1-3% in inner subcones

  -- Uranium Noise / Hardware subtraction and suppression of asymmetric pedestal

  > max 2-4% in inner subcones

  -- calorimeter to particle level correction

  > ~9% in inner subcone in central region

  > ~28% in inner subcone in forward region

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Errors

<u>Error in shape in first subcone:</u>

- **underlying event 0.5%**
- **uranium noise / pedestal bias 0.5%**
- **jet energy scale 1%**
- **uncertainty in low energy response 3%**
- **jet quality cuts 1%**
- **calorimeter to particle level correction 3%**
- **statistics 0.5%**

★ errors calculated for each jet E_T and η region and for each subcone separately and added in quadruture

Data Summary

☞ jets narrow with increasing jet Et
-- central and forward

☞ central wider than forward
-- for jets at same E_T

★ now how well does MC do?

-- compare D0 data to leading log parton shower Monte Carlo --- HERWIG

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NLO Theoretical Predictions

- Compare data to theoretical predictions
  - -- NLO loop and tree level QCD prediction
  - -- parton level - no fragmentation
  - -- 1 gluon radiating gives jet shape
  - -- first order jet shape prediction can be made

  - -- parton clustering methods not uniquely defined

➧ Giele, Glover, Kosower --> JETRAD
FNAL-Pub-94/070-T

-- use CTEQ2M structure functions

➧ Ellis, Kunszt, Soper --> **PRL,** Vol. 69, p. 3615 (1992)

-- use HMRSB structure functions

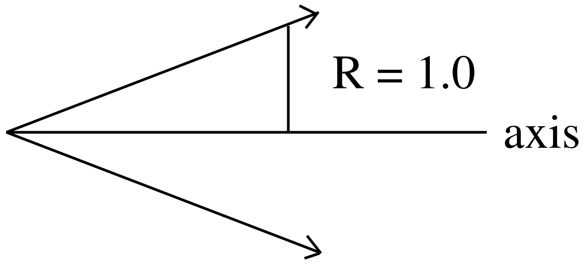
Clustering Algorithms used in Theoretical Predictions

- Method 1

  -- take jet axis along energy weighted center of partons

  -- draw cone (R=1) around jet axis - the two partons are clustered if they are within the cone

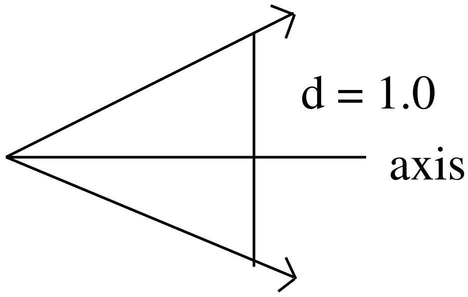
  -- partons required to be within Rsep<1.3 (Ellis)



- Method 2

  -- if the two partons are within R=1 of each other, then they are clustered into a jet

  -- jet axis is along energy weighted center of partons



Dependence on Jet Direction Definitions

- 2 parts in jet algorithm:
  - -- step 1 where jets are found - iterations
  - -- step 2 where final jet direction calculated

- can use Snowmass or D0 in either stage:

  -- Snowmass

  $\eta = \Sigma \eta_i E_{Ti} / \Sigma E_{Ti}$ and $\phi = \Sigma\phi_i E_{Ti} / \Sigma E_{Ti}$

  -- D0

  $\eta = -\ln(\tan(\theta_j/2))$

  where $\theta_j = \tan^{-1}[(\Sigma E_{xi})^2 + (\Sigma E_{yi})^2]^{1/2} / \Sigma E_{zi}$

  and $\phi = \tan^{-1}(\Sigma E_{yi} / \Sigma E_{xi})$

- compare JETRAD predictions using clustering Method 1 and different jet direction definitions:
  - -- D0 - use D0 in step 1 & Snowmass in step 2 (this is what D0 does)
  - -- Snowmass - use Snowmass in step 1 & 2
  - -- D0 Modified - use D0 in step 1 & 2

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Conclusions

➡ **We have measured jet shape for different jet E_T's for central and forward jets**

We Find:

- **jets narrow with increasing jet E_T in both the central and forward regions**
- **jets with the same E_T narrow going from central to forward regions**
- **HERWIG is narrower than data in central and forward regions, but describes trend of data well**
- **NLO predictions at parton level**

  -- very sensitive to renormalization scale μ and to parton clustering algorithm choice and to jet axis definition

  -- do not consistently describe data in all regions