Tevatron Jet Physics

Presented for the CDF and DØ Collaborations

by

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Tevatron Run II Results

- Preliminary Results for the Inclusive Jet Cross Section from CDF and DØ
- Preliminary Measurement of Dijet Azimuthal Correlations for Central Rapidities by DØ
- Preliminary Measurement of the Dijet Cross Section from DØ
Studying high energy interactions tests our understanding of the
Standard Model → searches for new physics....

The Tevatron is the world’s highest energy collider
Probing distance scales of $\sim 10^{-17}$ cm

Particle structure is parameterized with Parton Density Functions (PDFs)

→ Gives the probability of probing the constituent quarks

$x$ : momentum fraction carried by struck parton

$Q^2$ : the square of the momentum transferred to the target $p(\bar{p})$

PDFs are fundamental inputs to calculations describing collider phenomenology

Improved PDFs allow more precise calculations that will be needed not only at the Tevatron but also at the LHC and future experiments
The run I inclusive jet cross section was larger than theory expectations at high $E_T$

Run I jet data used in fits resulting in new PDFs having an enhanced gluon density at high $x$

→ Able to accommodate the rise at high $E_T$

Increase center-of-mass energy (1.8 → 1.96 TeV) results in an increased cross section at high $E_T$.

About $2\times$ at 400 GeV and $5\times$ at 600 GeV

→ Probing even higher $E_T$
Improved Jet Clustering Algorithms

JetClu: *Run I Jet Algorithm*

Not infrared safe (at NNLO)

Preclustering and Ratcheting: → *difficult to implement at the parton/hadron level, depends on the detector geometry*

More difficult to compare to theory and between experiments

MidPoint: *Run II Cone Algorithm*

Uses rapidity, $y$, instead of pseudorapidity, $\eta$ and transverse momentum $p_T$ insted of transverse energy, $E_T$

Infrared safe and well defined

No preclustering, no ratcheting

→ *Able to make more direct comparisons with theory and between experiments*

Kt Clustering:

Precluster towers with $p_T > 0.1$GeV

Merge preclusters until all jets are separated by $\Delta R > D$ where $D$ is the scale of the jet.

No use of seeds → infrared and collinear safe

Towers uniquely assigned to jets → no splitting/merging
Inclusive Jet Cross Section

CDF Run II Preliminary
Integrated L = 177 pb\(^{-1}\)
0.1 < |\eta_{\text{Det}}| < 0.7
JetClu Cone R = 0.7

→ Test of QCD over 9 orders of magnitude
→ Extends measurement to higher \(E_T\) by about 200 GeV

Same unsmearing procedure as used in Run I
Jet Et1 = 666 GeV (corr)
583 GeV (raw)
eta1 = 0.31 (detector)
0.43 (corr z)
Jet Et2 = 633 GeV (corr)
546 GeV (raw)
eta2 = -0.30 (detector)
-0.19 (corr z)

Run 152507
Event 1222318
DiJet Mass = 1364 GeV (corr)
z vertex = -25 cm
Ratio of Data over Theory

Run I Tevatron Jet data was used in the fit for CTEQ 6.1 which resulted in an enhanced gluon density at high $x$

Particle level measurement compared with parton level calculation
Uncertainty in the energy scale is the dominant source of systematic error, can expect this to improve...

The effect of a 3% energy scale uncertainty contribution to the total systematic error

For a faster falling $E_T$ spectrum, the error on the measured cross section becomes larger

→ Errors become larger when measuring forward jets
Preliminary Results Using the $K_T$ Clustering Algorithm

Results compared to JETRAD (NLO) with CTEQ6.1

→ Theory does not include effects from hadronization or the underlying event which tends to “raise” the low $E_T$ region

Uses the Run II detector simulation to determine the jet corrections
We now have even more data available (plot includes 353 pb⁻¹)

The increased center-of-mass energy enables us to extend our Run I results by about 200 GeV

→ Able to probe shorter distances with higher precision

→ When including more data, rise at high $E_T$ is not as dramatic

In addition to being able to study the high $E_T$ region we have more data in the low $E_T$ region.
The Tevatron operates in a kinematic region complementing existing and previous experiments and provides unique capabilities.

The parton momentum fraction can be reconstructed from the jet’s transverse energy, $E_T$, and pseudorapidity, $\eta$, by

$$x_1 = \frac{E_T}{\sqrt{s}} (e^+ \eta_1 + e^+ \eta_2)$$

$$x_2 = \frac{E_T}{\sqrt{s}} (e^- \eta_1 + e^- \eta_2)$$

An approximation of the four momentum transfer, $Q^2$, in the interaction is

$$Q^2 = 2E_T^2 \cosh^2 \eta^* (1 - \tanh \eta^*)$$

→ **Best place to study the high $x$ gluon content of the proton**

→ **Kinematic region can be expanded by measuring jets in the forward region**
Forward jet measurements provide additional input for global QCD fits

→ providing better constrained PDFs

Range of uncertainty of the inclusive cross section in different rapidity regions determined for CTEQ6.1.M
Inclusive Jet Cross Section in Different Rapidity Bins from DØ

The MC is only used for a showering correction (about 1-2%). Other corrections are determined from the data.
The rapidity-dependent cross section constrains the gluon PDF at medium to high \(x\)

Energy scale dominates the experimental uncertainty and work in progress on reducing this error
The dijet mass has a greater sensitivity to new phenomena

The analysis has a slight reliance on MC not present for DØ’s inclusive measurement

Agreement with theory given the large experimental uncertainty
Measurement of the correlations between the two leading jets in multijet production is sensitive to the impact of QCD radiation on jet production.

\[ \frac{1}{\sigma_{\text{dijet}}} \frac{d\sigma_{\text{dijet}}}{d\Delta\phi_{\text{dijet}}} \]

Additional jets produced at higher orders result in a decorrelated angle \( (\Delta\phi_{\text{dijet}} < \pi) \) between the lead jets.

Results are compared to pQCD in fixed order \( \alpha_s \) (LO and NLO) and to predictions of PYTHIA and HERWIG.

Based on \( L = 150 \text{ pb}^{-1} \)
Results for two of the measured $p_T$ ranges are compared with HERWIG and PYTHIA.

By increasing the initial state radiation, PYTHIA gives a much better description of the data.

→ **Illustrates the potential for future efforts to tune the event generators.**

MC event generators using parton showers can be tuned to produce the observed correlation over the whole range.

pQCD at NLO provides a very good description of the data.
The performance of the Tevatron is rapidly improving (07/16/2004) Store 3657 set a new luminosity record of $1.1 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$ as measured at CDF.

Tevatron delivered $4.5\text{pb}^{-1}$ in one store!

Both experiments are doing well at collecting physics quality data.

Exceeding four times the Run I dataset.
Summary

- There has been a lot of work on understanding improved clustering algorithms and both experiments are starting to use them → will eventually allow easier comparison with theory and between experiments

- Preliminary results have been presented which exceed the Run I data sample by more than a factor of two
  ...and we now have collected a data sample consisting of more than four times the Run I data sample

- The Tevatron is operating at a higher center-of-mass energy which yields a greater cross section at higher $E_T$ → have extended the high $E_T$ measurements by about 200 GeV

- Results are consistent with the QCD predictions

- Expect an improved understanding of the systematic errors