Jet Physics at CDF

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Outline

- CDF Run II and new opportunities
- Run II inclusive jet cross-section
  - Current measurement
  - Leading uncertainties
  - Further improvements
- Understanding fragmentation:
  - Quark and gluon jet differences
    - Multiplicity and Momentum Distributions
    - Comparison to NLLA predictions
    - MC and data comparisons
- Summary
CDF Detector Run II Upgrades

All critical components are working well

7-8 silicon layers
rφ, rz, stereo views

$z_0^{\text{max}} = 45$, $\eta^{\text{max}} = 2$

$2 < R < 30 \text{cm}$

μ coverage extended to $\eta = 1.5$

Tile/fiber endcap calorimeter (faster, larger $F_{\text{samp}}$, no gap)

TOF (100ps@150cm)

μ coverage extended to $\eta = 1.5$

132 ns front end
COT tracks @L1
SVX tracks @L2
40000/300/70 Hz
~no dead time

30240 chnl, 96 layer
drift chamber

$\sigma(1/p_T) \sim 0.1\%/\text{GeV}$
$\sigma(\text{hit}) \sim 150\mu\text{m}$

2 b’s or not 2 b’s?
Double tags essential
for $M_{\text{top}}$, $H \rightarrow \text{bb}$
Jet Production at the Tevatron

- Nowhere else the increase in center of mass energy is appreciated so much

**NLO QCD (JETRAD)**

Cone R=0.7, |η| < 0.5

\[ \sqrt{s} = 1.96 \text{ TeV} \]

\[ \sqrt{s} = 1.8 \text{ TeV} \]

\[ x5@600\text{GeV} \]

\[ x2@400\text{GeV} \]
Jet Triggers at CDF

3-Level Trigger System:
L1: Trigger Tower $E_T$
L2: Continuous Clusters
L3: Cone Algorithm

Jet Clu Cone $R = 0.7$
$0.1 < |\eta_{Det}| < 0.7$

<table>
<thead>
<tr>
<th>Trigger</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>JET 20</td>
<td>ST5 (20)</td>
<td>CL15 (12,25)</td>
<td>J 20 (1)</td>
</tr>
<tr>
<td>JET 50</td>
<td></td>
<td>CL40 (1)</td>
<td>J 50 (1)</td>
</tr>
<tr>
<td>JET 70</td>
<td>ST10 (1)</td>
<td>CL60 (8)</td>
<td>J 70 (1)</td>
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<tr>
<td>JET 100</td>
<td></td>
<td>CL90 (1)</td>
<td>J 100 (1)</td>
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Raw Inclusive $E_T$ Spectrum

- Usable jets up to $\eta \sim 2.8$
- Jet energy corrections are not applied
- $E/P \sim 60\%$ for charged hadrons
Jet cross section in agreement with theoretical prediction within errors

Dominant theoretical error is due to PDF uncertainty

CTEQ6.1 already has an enhanced high $x$ gluon due to influence of Run 1 jet data
Systematic Uncertainties

Energy scale is by far the dominant uncertainty:
- Currently at 3% level, but exponentially falling shape of the ET spectrum results in a large effect
- Goal is ~1%

Next-to-leading uncertainties:
- High ET response
- Fragmentation
Sensitivity to PDF

- Jet cross section in the forward region – work in progress

- Forward regions are highly sensitive to PDFs
  - New Physics is primarily central
  - PDF explanation should work everywhere else
  - Accurate measurement will help constraining PDFs
Looking forward to NNLO

- Further data/study will reduce the PDF uncertainty

Need NNLO jet cross section for useful NNLO PDF’s to be determined
Why Fragmentation?

- Experimental studies of fragmentation test our understanding of QCD, especially at the difficult region of low momentum transfer

- Uncertainty for other QCD studies and new physics searches
  - Improved knowledge will lead to better constraints of SM parameters and new physics

- What can be done:
  - Momentum distributions
  - Track multiplicities
  - Charged/neutral particle fractions
  - Differences of quark and gluon jets
Quark and Gluon Jets

- Historically, proved to be a difficult experimental issue:
  - Many past measurements disagreed with each other
  - Comparisons to theory were often at best controversial (and many eventually incorrect).

- Fragmentation studies at hadron colliders:
  - Obvious difficulties: from underlying event debris to conventional wisdom
  - Important advantage: quark and gluon jets are easy to find in our environment (no need to look for events of complicated topology that can bring biases)
CDF Measurement: Outline

- **Theory side: MLLA-inspired NLLA calculations:**
  - Track Multiplicity and Momentum Distribution if quark and gluon jets

- **Experimental measurement:**
  - Model-independent measurement requires two samples with known fractions of q/g jets
  - Jet-jet vs γ+jet data is one example
  - Properties of q and g jets can be statistically disentangled
  - Compare to theory and available MC
Ratio of Track Multiplicities

- Track multiplicities measured in cones ($\theta$) around the jet axis
- Good agreement with NLLA predictions
- Given uncertainties, hard to compare with OPAL
- Poor agreement with MC: $\sim 1.3$ for both Herwig and Pythia

\[ Q = E_{\text{jet}} \sin(\theta) \]
Track Multiplicity in q/g Jets

- Fit of CDF only Data to NLLA prediction (A. Capella et al.)
- Good agreement with theory and most of recent experimental results
- MC overestimates track multiplicity for quark jets (both Herwig and Pythia)

\[ Q = E_{\text{jet}} \sin(\theta) \]
Momentum Distributions

- Compare momentum distributions to Herwig and Pythia
  - vs MLLA variable $\xi = \log(1/x)$
  - MC overestimates track multiplicity in quark jets
Soft Limit of 9/4

- **MLLA**: soft limit can still be reached for soft partons emitted at large angles.

- **Ratio of track momentum distributions from CDF and OPAL** (similar $E_{\text{jet}}$, $Q$-scales are different):
  - Plateau in the soft part
  - Not 9/4 due to hadronization effects (angles are not necessarily large), but similarities are quite clear.
Conclusions

- By now, we more than doubled the luminosity compared to Run I
- Jet production:
  - Greatly improved access to higher ET domain (higher CM energy)
  - Inclusive Cross-Section agrees with NLO
  - Improvements to systematics are in the works
  - Expect further constraints on PDFs
- Quark/gluon jets:
  - Good agreement with NLLA
  - Herwig and Pythia MC need adjustment
- Stay tuned!