Summer Study on Jet Physics and Beyond!

REU-Final Presentation
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Inclusive Jet and Dijet Cross-sections from √s = 7 TeV pp collision

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Exchange to UC Berkeley next semester for 1 year!
Outline

• Why study Jet?
  a. QCD
  b. New physics hidden behind
  c. Early Universe- QGP

• Project goal!
  a) Inclusive and Dijet? Why?
  b) Atlas vs CMS
  c) LO/NLO vs Data
  d) QCD Fit
  e) Factorization/Renomalization

• Future Outlook

From Prof. Gavin Salam ‘s lecture
New Physics Hides here
Jet quenching illustration from CMS artist/analyst
Quark-Gluon Plasma / Early Universe

Jet quenching in the CMS detector
Inclusive and Dijet: The Data

- From pp collision of $\sqrt{s} = 7$ TeV

- **ATLAS**: 2010 data of a total integrated luminosity of 37 inverse picobarns. Anti-kT algorithm with area parameter $R=0.4$ and $R=0.6$

- **CMS**: 34 inverse picobarns, $R=0.5$ for CMS.

- Jet rapidity range $|y|<4.4$, covering $p_T$ from 20 GeV to 1.5 TeV and dijet invariant masses from 70 GeV to 5 TeV. (for ATLAS, CMS is slightly different)
Why *Inclusive Jet* and *Dijet*?

- Not process/model dependent research
- Convenient for theorists and experimentalists (no worries on background)
- **Simple** and **relevant**
- Best for *QCD interests*
- **Know how far we can go to go beyond**
Why anti-K$_T$?

• Collinearly safe
• Soft/infrared Safe
• Regular Jet Area-

look at that Fantastic Shape!

Based on the following distance measures:

★ distance $d_{ij}$ between two particles $i$ and $j$:

$$d_{ij} = \min \left( k_{T_i}^{2p}, k_{T_j}^{2p} \right) \Delta_{ij} \frac{\Delta_{ij}}{D}$$

\[ \Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2 \]

★ distance between any particle $i$ and the beam (B) $d_{iB}$:

$$d_{iB} = k_{Ti}^{2p}$$

Compute all distances $d_{ij}$ and $d_{iB}$, find the smallest

★ if smallest is a $d_{ij}$, combine (sum four momenta) the two particles $i$ and $j$, update distances, proceed finding next smallest

★ if smallest is a $d_{iB}$, remove particle $i$, call it a jet
**ATLAS vs CMS:**

Inclusive Jet Cross section

- **Data Comparison**
- **Red:** ATLAS, Ro.6/CMS
- **Middle:** CMS self divided
- **Green:** ATLAS, Ro.4/CMS

\[ \sqrt{s} = 7 \text{ TeV} \]
LO for inclusive Jet cross section

- Eight relevant QCD $2 \rightarrow 2$ parton-parton scattering
  
  \[
  qq' \rightarrow qq' \\
  q\bar{q} \rightarrow q'\bar{q}' \\
  qq \rightarrow qq \\
  q\bar{q} \rightarrow q\bar{q} \\
  gg \rightarrow g\bar{g} \\
  qg \rightarrow qg \\
  gg \rightarrow gg 
  \]

- Leading order **Theory**:
  - Almost **identical** for three
  - Because only **2 jet** event!
LO/NLO Calculation and Comparisons

- Ratio between LO and Data!
- Three should come closer to 1 in NLO!
- Working on scales and error bar...

ridiculous error bar...
What does that mean NLO?

**Anatomy of a NLO calculation**

- Loop Corrections
- 2 Jets to 2 or 3 Jets (Extra External Leg)
- Need to consider renormalization and hence $\mu_r$ comes into play
Factorization . Cross Section . PDF .

Cross section for some hard process in hadron-hadron collisions

\[ \sigma = \int dx_1 f_{q/p}(x_1, \mu^2) \int dx_2 f_{\bar q/p}(x_2, \mu^2) \hat{\sigma}(x_1 p_1, x_2 p_2, \mu^2), \quad \hat{s} = x_1 x_2 s \]

Total cross section can be described by parton distribution function and hard process-> where the **factorization scale** \( \mu_f \) comes into play!
Renormalization scale illustrated

QCD corrections can be expressed as an power series:

$$\Delta_{QCD}(\mu_r) = \frac{\alpha_s(\mu_r)}{\pi} + [1.4092 + 1.9167 \ln \frac{\mu_r^2}{s}] \left(\frac{\alpha_s(\mu_r)}{\pi}\right)^2$$

$$+ [-12.805 + 7.8179 \ln \frac{\mu_r^2}{s} + 3.674 \ln^2 \frac{\mu_r^2}{s}] \left(\frac{\alpha_s(\mu_r)}{\pi}\right)^3 + \ldots$$

- In lowest order we have no clue what the scale is.
- In higher orders both $\alpha_s$ and the coeff. fct. depend logarithmically on the scale: cancellations & $\mu_r$ should be of the order of $s$. 

July, 25-28 2005

PHENIX Spin Fest @ RIKEN Wako
Future Outlook

• non-purturbative correction - Shower, Underlying Events...
• QCD fit: parameters in the PDF
• Determine factorization/renormalization scales

...I also spend my time talk to these guys, to know my future study...
Apparently not the best of times...

- No major deviation from the Standard Model
- Harder to build new **discovery machine**
- SUSY and **Extra dimensions** haven’t showed up maybe in TeV region?

- Too many ideas, constraints, less surprising
  - hard time for Phenomenologist
Also not the worst of times ...

- Wait for **next February (spin)** and **years to come (couplings)**
- **LHC, ILC and CLIC** – precision time again
- Still super exciting to be a **HEP Experimentalist**
- **Cosmological** observations thriving

- Eying ILC and Cosmology
It is our time
Let’s get the party started
Know how far we can go to go beyond!
Thanks, REU group!