ATLAS Jet Reconstruction Capabilities in Heavy Ion Collisions

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Motivation

• In nuclear collisions jets provide powerful tool for understanding medium
  • Jet not thermalized, can be used as “external” probe to measure thermal properties of medium
  • Energy loss, fragmentation functions and $J_T$ distributions modified

Explore jet structures discovered at RHIC by doing full jet reconstruction in ATLAS
ATLAS Acceptance

Full $\phi$ coverage

Jets measurable over 10 units in $\eta$
Clusters all fragments in fixed size

\[ \Delta = \sqrt{(\eta_{jet} - \eta)^2 + (\phi_{jet} - \phi)^2} < R \]

Not infrared/collinear safe

Problems with overlapping jets (Split/Merge)

For HI events background subtraction required

- Exclude actual jets from background
- Subtract mean \( E_T \) (\( \eta \) dependent)
Central HIJING Pb+Pb Events at 5.5 TeV with embedded PYTHIA jets

Before Subtraction
Central HIJING Pb+Pb Events at 5.5 TeV with embedded PYTHIA jets

After Subtraction
**k_{T}** Algorithm

- Cluster fragments with smallest weight

\[ d_{ij} = \min(k_{Ti}, k_{Tj}) \frac{\Delta^2}{R^2} \]

- Ordering mimics angular ordering in QCD fragmentation processes

- Infrared/collinear safe

- All fragments associated with a jet

- Use discriminant to determine “background jets” for background subtraction
Simulation Studies

- Central HIJING Pb+Pb Events at 5.5 TeV with embedded PYTHIA jets
- Truth jets defined as algorithm run on PYTHIA particle output
- Reconstructed jets matched to truth for $R<0.5$
- Extensive studies conducted
  - efficiency, fake rate, position resolution
Both algorithms show efficiency above 95% for $E_T > 120$ GeV. $k_T$ gives better energy resolution.
Reconstructed $k_T$ jets tend to have systematically lower energy.

Missing fragments, present in truth jets but not reconstructed, mostly come from periphery.

Competition from background jets can cause depletion of fragments from real jet. These occasionally cut into jet core, taking significant fraction of energy.

$k_T$ jet size determined by background!
Anti-$k_T$ Algorithm

- Clustering algorithm like $k_T$ but composes fragments with weight $k_T^{-2}$
  - Cacciari et al., arXiv:0802.1189v2
- Gives cone-like shape, but provides better boundary definitions for overlapping jets
- IR “insensitive” and IR safe
- Contrast with $k_T$ where jet shape highly sensitive to soft fragments (background)
- Has not been studied in HI backgrounds
PYTHIA PP at 5.5 TeV
Summary

• ATLAS jet studies in HI backgrounds using cone and $k_T$ algorithms show excellent performance

• New Anti-$k_T$ study underway

• Availability of several algorithms provides detailed description of jet behavior
  • Gives multiple approaches to complicated problem of subtracting HI background
Backup Slides
Anatomy of Anti-$k_T$ Algorithm

- Due to inverse weighting soft fragments more likely to be clustered with a hard fragment than another soft one
- Hard fragments with no hard neighbors ($\Delta > 2R$) will accumulate soft fragments, resulting in cone
- Neighboring hard fragments ($R < \Delta < 2R$) will share boundary of overlapping cones based on hardness
- Hard fragments close together will be merged into single jet ($\Delta < R$)