A Jet Shape Study With the STAR Experiment

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Abstract

Jets are a collection of particles that are emitted from hard scattered partons. In heavy ion collisions, jets are known to strongly interact within quark-gluon plasma (QGP). This is known as jet quenching. It has been observed at the LHC and RHIC that jets' energy deposition and radiation patterns change when they interact with QGP compared to their vacuum baseline. Jet shape observables are sensitive to the changes within a jet and its lateral energy distribution. In this study, we utilize data collected by the STAR experiment at RHIC to compare the evolution of the *LeSub* jet shape observable in $\sqrt{s_{NN}}$ = 200 GeV Au+Au and p+p collisions. *LeSub* is the difference in p_T between the leading and sub-leading constituents in a given jet.

Introduction

In relativistic heavy ion collisions, hard scattering between partons due to large exchanges in momentum can cause jets to form. These collisions are expected to create a novel matter called quark-gluon plasma (QGP). To study QGP, we examine the production of jets, which:

- undergo jet quenching, which represents parton energy loss in the hot and dense QCD medium, considered one of the signatures of the QGP;
- are observed in detectors through fragmentation and hadronization patterns.

As a result, the jet properties will vary in the presence of QGP comparatively to a vacuum reference. Jet shape observables are used to study these differences. In heavy ion collisions, jet shapes are expected to demonstrate how jet energy is redistributed due to QGP, that is, the effects of jet quenching. They measure the energy distribution within a jet on average, either per jet or per event.

We conduct a first principle analysis of a particular jet shape observable, *LeSub*, in $\sqrt{s_{NN}} = 200$ GeV Au+Au and p+p collision data collected by the STAR experiment at the Relativistic Heavy Ion Collider (RHIC). *LeSub* measures the difference in transverse momentum (p_T) of the two highest (leading and sub-leading) p_T constituents of each jet [1]:

$$LeSub = p_{\mathrm{T,track}}^{\mathrm{lead}} - p_{\mathrm{T,track}}^{\mathrm{sublead}}.$$

We examined *LeSub* for different centralities of the Au+Au collisions. At STAR, centrality is related to the impact parameter of the event, determined by event multiplicity. Our results display a centrality dependence in the *LeSub* spectra, suggesting that the presence of QGP causes a larger difference between the two highest p_T constituents of a jet.

Analysis

The data for this project was collected with the Solenoid Tracker at RHIC (STAR), a particle detector on the Relativistic Heavy-Ion Collider (RHIC) at BNL. A schematic of the STAR detector is shown in Figure 1 [2].

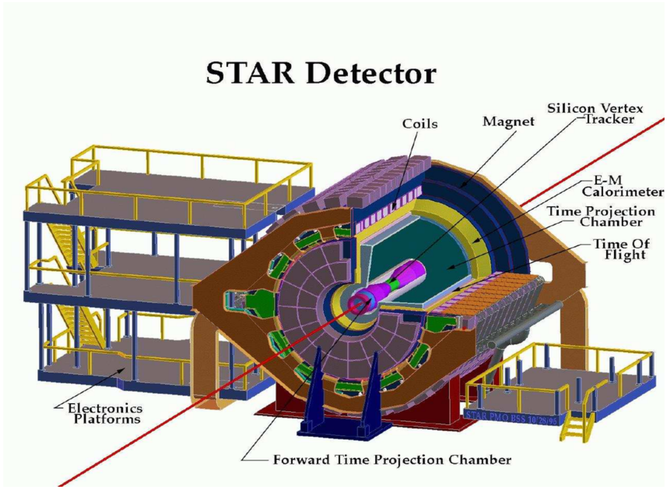

Figure 1: Schematic of the STAR detector and it's various components [2]

An anti-k_T algorithm with an R = 0.3 resolution parameter was used for the jet reconstruction [3, 4]. We only include jets with charged constituents, reconstructed with the Time Projection Chamber (TPC). To ensure the jet constituents are within the TPC acceptance window and to limit the effects of combinatorial jets, we applied the following kinematic selections:

- Constituent track p_T > 2.0 GeV/c;
- Pseudorapidity of -0.7< jet η <0.7;
- Overall jet p_T > 25 GeV/c;

Results

The LeSub measurements for p+p, Au+Au, and their ratio are shown in Figure 2. The upper plot shows the LeSub spectra for p+p and all centralities of Au+Au for jet p_T > 25 GeV/c; the lower plot shows the ratios of LeSub in the Au+Au centralities to that in p+p. Going from most central to most peripheral, the LeSub spectra of Au+Au approach that of p+p. The most central Au+Au case deviates significantly from the reference p+p measurement and there is clear deviation in the second most central range as well. These results are not corrected for detector acceptance and efficiencies.

Conclusions and Future Plans

We measured the *LeSub* observable in p+p and in Au+Au collisions of all centralities for the first time at RHIC kinematics. These preliminary uncorrected measurements indicate possible modifications of the LeSub distributions in the most central Au+Au collisions, and almost no modification in peripheral collisions. ALICE measured *LeSub* for Pb+Pb collisions at LHC energies and observed no centrality dependence within their jet kinematics [1]. This study suggests that RHIC energies are perhaps more sensitive to possible QGP induced modifications to jet shapes. We are exploring the effects of background fluctuations and detector acceptance and efficiency in an upcoming publication.

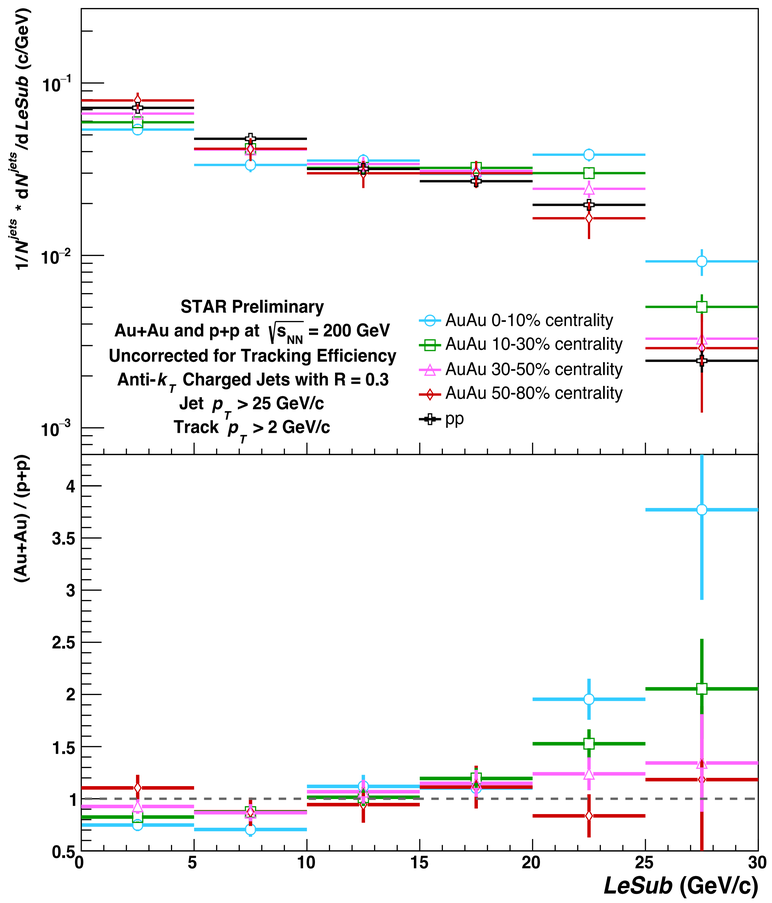

Figure 2: (top) LeSub distributions for R=0.3 anti-k_T jets in p+p and given centrality ranges of Au+Au collisions; (bottom) ratio of Au+Au to p+p for the all centrality ranges

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References

[1] ALICE Collaboration, "Medium modification of the shape of small-radius jets in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV," JHEP 10:139, 2018.
[2] Ackermann et al., "STAR detector overview. Nuclear Instruments and Methods," 499. 624-632. 10.1016/S0168-9002(02)01960-5. (2003).
[3] http://www.fastjet.fr
[4] Cacciari et al., "The anti-k_T clustering algorithm," JHEP 0804:063, 2008.