A Jet Shape Study with STAR

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Abstract

Quark-Gluon Plasma (QGP) is a state of matter comprised of quarks and gluons that are not confined within any particular hadrons. QGP is expected to be produced in ultra-relativistic heavy ion collisions at RHIC and the LHC. In this analysis, we study properties of the QGP produced in these collisions with jets, which are collimated sprays of hadrons that originate from hard scatterings of quarks and gluons (partons). Modification of the jets has been observed in heavy ion collisions as jets traverse the medium before reaching our detectors. To study this in detail, we utilize data collected by the STAR experiment located at RHIC, and we compare jets produced in Au+Au collisions to those created in *p+p* collisions. Specifically, we look at three complementary jet shape observables: *LeSub*, *g*, and $p_T D$ to get a comprehensive picture of how the medium modifies the jet.

Introduction

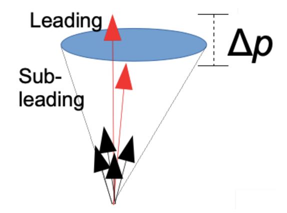
When the universe was just 10^{-6} seconds old, it was filled with a soup of quarks and gluons known as Quark-Gluon Plasma (QGP).

- Relativistic heavy ion collisions are expected to reproduce QGP
- To study the QGP we utilize jets, which are collimated sprays of hadrons resulting from the fragmentation of hard-scattered partons
- As jets traverse the QGP, their energy profile is modified by the medium

We analyze this modification using three jet shape observables:

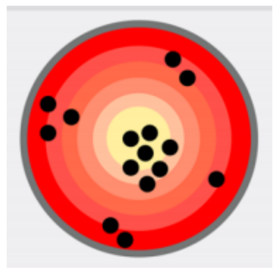
- *LeSub* is the difference in p_T of the leading (i.e. highest p_T) jet constituent, and the sub-leading jet constituent

$$LeSub = p_{T,track}^{lead} - p_{T,track}^{sublead} \quad (1)$$



- Girth (g) is defined in equation (2). It is large when the jet's momentum is "spread out", and small when the momentum is concentrated close to the jet axis

$$g = \sum_{i \in jet} \frac{p_{T,i}}{p_{T,jet}} \Delta R_{jet,i} \quad (2)$$



- Momentum Dispersion ($p_T D$) is defined in equation (3). It is close to 1 when the momentum of the jet is concentrated in a small number of constituents, and close to 0 when the momentum is distributed among a large number of constituents

$$p_T D = \frac{\sqrt{\sum_{i \in jet} p_{T,i}^2}}{\sum_{i \in jet} p_{T,i}} \quad (3)$$

By comparing the jet shape distributions of Au+Au collisions to those of *p+p* collisions, we can determine the effect that the QGP has, since *p+p* collisions are not expected to produce QGP. These observables were originally introduced by the ALICE collaboration at the LHC [1]. By measuring these jet shapes at RHIC, we hope to complement their results.

Analysis

Data from $\sqrt{s_{NN}}$ = 200 GeV Au+Au and *p+p* collisions, collected by the STAR detector [2], are used. Inclusive anti-k_T [3] jets with *R*=0.3 are reconstructed, using the FASTJET [4] software package. We limit our jets to those with p_T>25 GeV/c and $|\eta|$<0.7. Additionally, we impose the constraint that all jet constituents have p_T>2 GeV/c and $|\eta|$<1. We run a constituent background subtractor [5], to remove the effect of the underlying background on the signal. For each of the resulting jets we calculate the jet shapes. We then split our resulting jet shape distributions into four centrality ranges, 0-10%, 10-30%, 30-50%, and 50-80%. We do this to get a more detailed view of how the distributions in Au+Au collisions differ from those in *p+p* collisions.

Results

In Fig. 1, we show raw LeSub distributions, uncorrected for detector effects. There is an observed difference between the raw distributions from *p+p* collisions and the most central Au+Au collisions. This gives a hint of jet shape modification in central Au+Au collisions, and will be further investigated. Next are the uncorrected results for $p_T D$ (Fig. 2). Again we see a difference between the *p+p* distribution and the most central Au+Au distributions (but again these are uncorrected results). Finally, we look at raw *g* distributions (Fig. 3). Here it is harder to see any trend relative to the *p+p* distribution.
It is worth noting that the upward trend seen in the *LeSub* ratio plots was not observed in the ALICE study. However, these results are not conclusive, and corrections must be applied before we can be definitive.

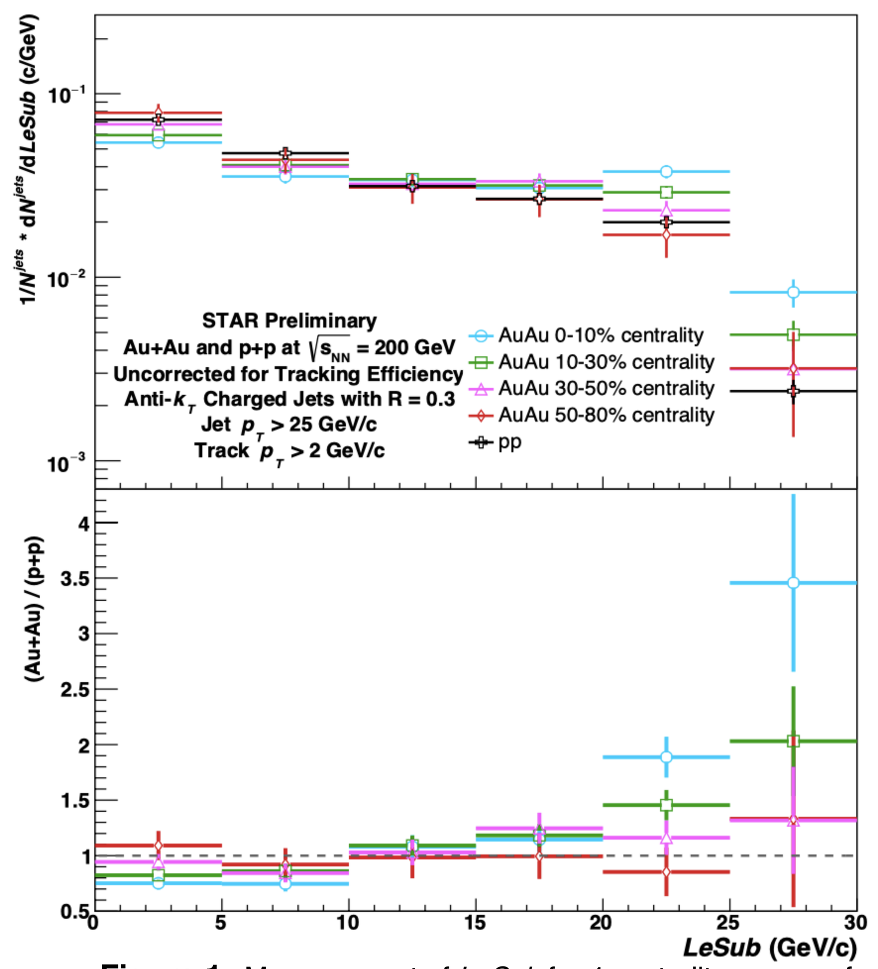


Figure 1: Measurement of *LeSub* for 4 centrality ranges of Au+Au collisions, as well as for *p+p* collisions (upper panel). Ratio of Au+Au distributions to *p+p* distribution for 4 centrality ranges (lower panel).

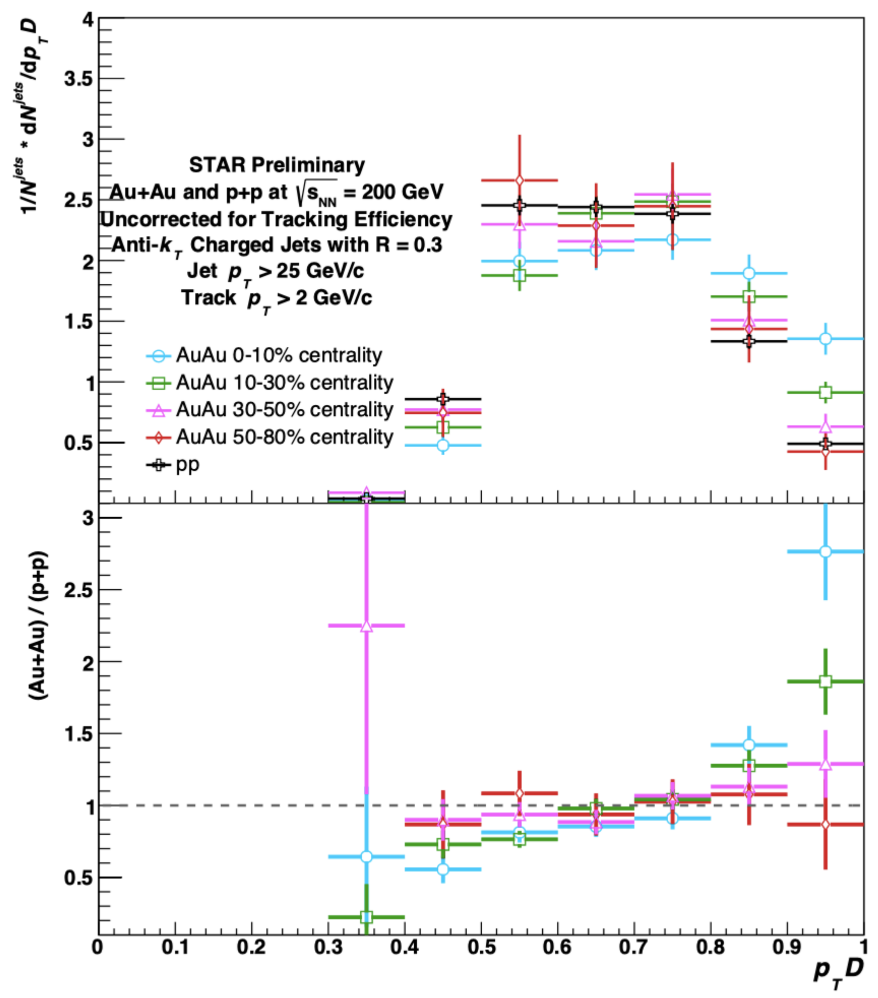


Figure 2: Measurement of $p_T D$ for 4 centrality ranges of Au+Au collisions, as well as for *p+p* collisions (upper panel). Ratio of Au+Au distributions to *p+p* distribution for 4 centrality ranges (lower panel).

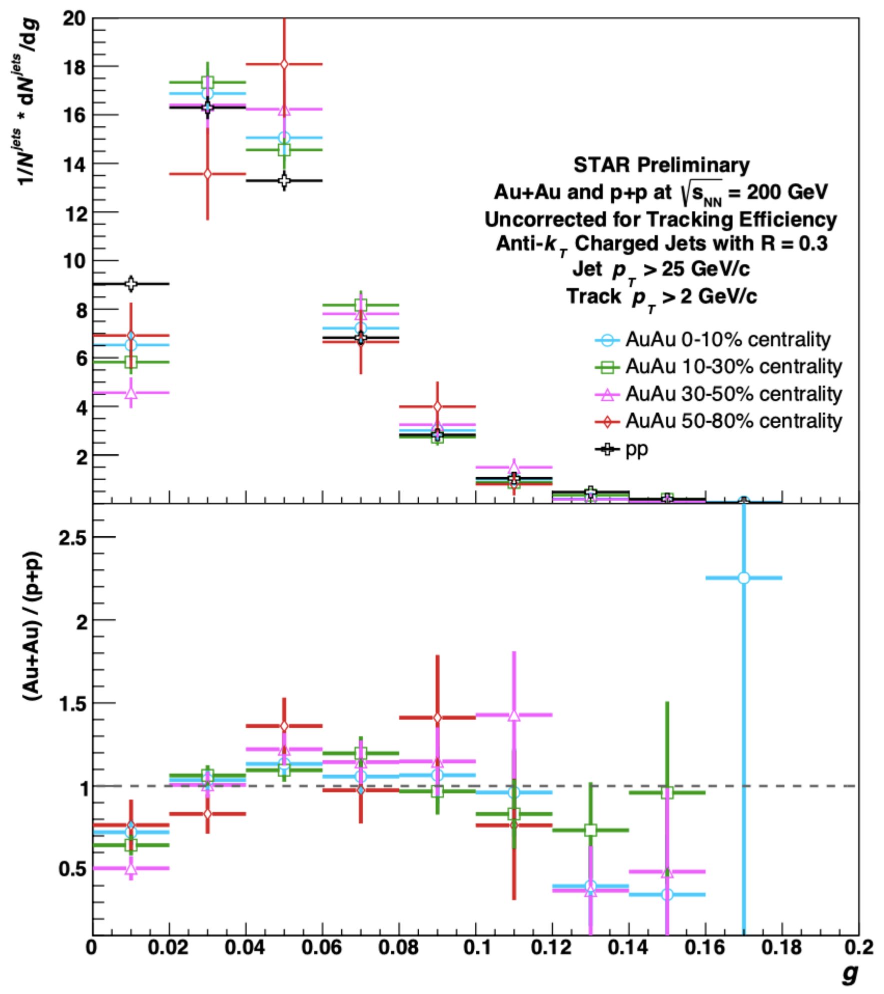


Figure 3: Measurement of *g* for 4 centrality ranges of Au+Au collisions, as well as for *p+p* collisions (upper panel). Ratio of Au+Au distributions to *p+p* distribution for 4 centrality ranges (lower panel).

Conclusion

These results are the first measurements of *LeSub*, *g*, and $p_T D$ at RHIC energies. We have seen that in highly central collisions the QGP possibly has an effect on these observables, particularly *LeSub* and $p_T D$. However, these measurements are not corrected for detector efficiency and acceptance. Moving forward, these corrections will be implemented. We will also examine the dependence of these measurements on jet p_T (in addition to the centrality dependence), in order to get a more detailed picture of how the medium modifies the jet.

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https://drupal.star.bnl.gov/STAR/presentations