A Jet Shape Study with the STAR Experiment

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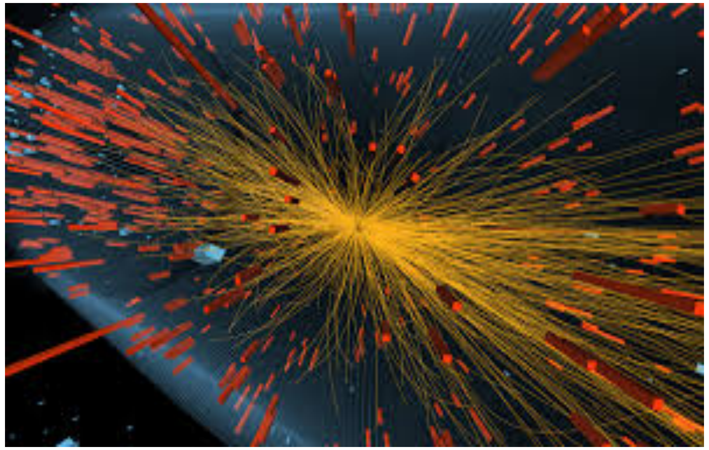
Introduction

- Analysis on QGP and jets in relativistic heavy-ion collisions at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory (BNL)
- Quark-gluon plasma (QGP) is a form of matter that existed moments (10^{-6} s) after the Big Bang
  - Allows us to study the state of matter of the early universe
  - Can be recreated at both RHIC and the LHC



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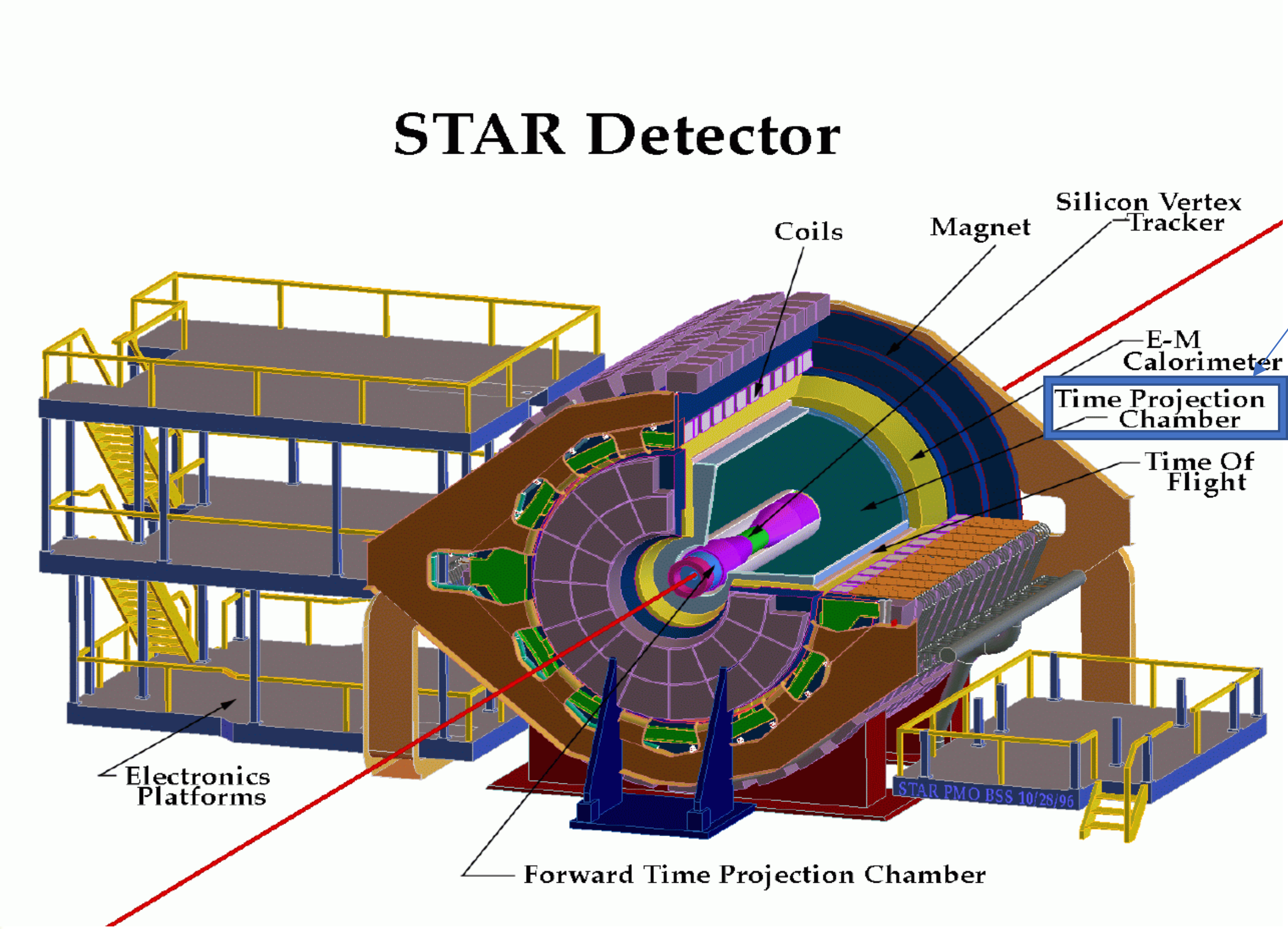
Jets and Jet Quenching

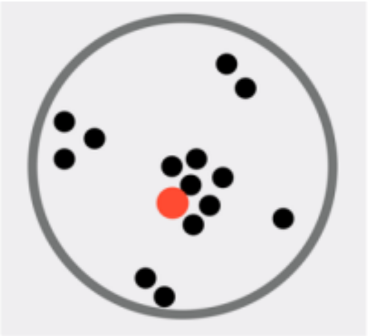
- Jets are a stream of particles originating from the scattering of partons
- Wish to observe the jet quenching phenomenon: parton energy loss and modification of jet substructure due to interaction with QGP
- Comparing Au+Au to p+p collisions allows one to examine jets interacting with the QGP medium (Au+Au) and those in vacuum (p+p)
- For this analysis, jets are reconstructed using an anti-k_T algorithm only considering charged particles reconstructed by STAR

STAR Experiment



Charged particles reconstructed in the TPC

The charged particle ionizes gas in the TPC, sending electrons to the detector from which the original particle's path is reconstructed



Jet Shapes

- Jet shape in general refers to a series of different observables that describe how energy is distributed throughout a jet (on average); we examine 3 such observables
- Momentum dispersion ($p_T D$) is defined as the dispersion of the jet p_T among its constituent tracks
- *LeSub* is defined as the p_T difference between the leading and sub-leading constituent tracks in a jet
- Girth (g) is defined as the first radial moment of the jet

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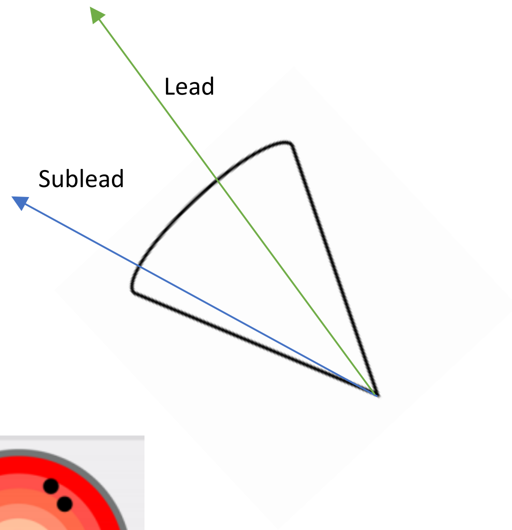
$$p_T D = \frac{\sqrt{\sum_{i \epsilon \mathrm{jet}} p_{\mathrm{T},i}^2}}{\sum_{i \epsilon \mathrm{jet}} p_{\mathrm{T},i}} \qquad LeSub = p_{\mathrm{T,track}}^{\mathrm{lead}} - p_{\mathrm{T,track}}^{\mathrm{sublead}} \qquad g = \sum_{i \epsilon \mathrm{jet}} \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}} \Delta R_{\mathrm{jet},i}$$

Jet Shapes (cont.)

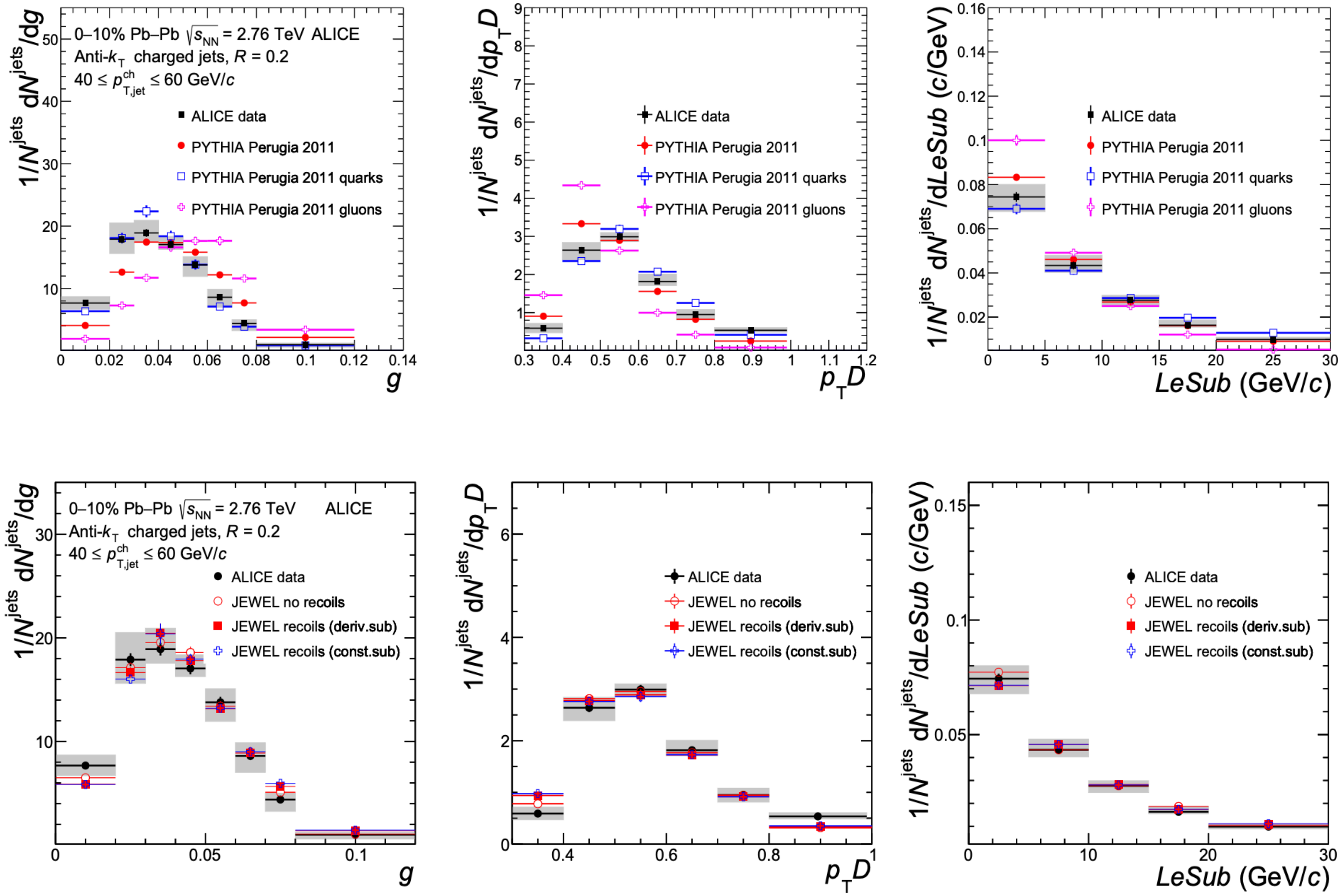
- $p_T D$ is sensitive to hard or soft jet fragmentation
  - ➢Hard fragmentation gives values close to 1; soft is closer to 0
- *LeSub* is sensitive to hard fragmentation
  - ➢Hard fragmentation can give large *LeSub* values
  - ➢Robust but not IRC-safe



- g is sensitive to broadening of the p_T distribution

ALICE Results

- Previous study by ALICE measured these jet shapes at LHC energies
- We can see differences between different PYTHIA and JEWEL simulations as well as the ALICE data measurements
- Since RHIC energies are different from those at the LHC, we can possibly observe different features of these observables



ALICE, JHEP 10 (2018) 139

Kinematic Selections

- Jet resolution (jet R) = 0.3
- Pseudorapidity of the jets: $-0.7 < \text{jet } \eta < 0.7$
- Jet $p_T > 25$ GeV/c
- Jet constituent (track) $p_T > 2$ GeV/c
  - Selects hard fragmented and hard scattered jets
  - Ensures combinatorial background suppression

- Only examining charged constituents; **uncorrected** for tracking efficiency
- Using Au+Au and p+p collision data collected in 2014 and 2012, respectfully, at energy of $\sqrt{s_{NN}} =$ 200 GeV

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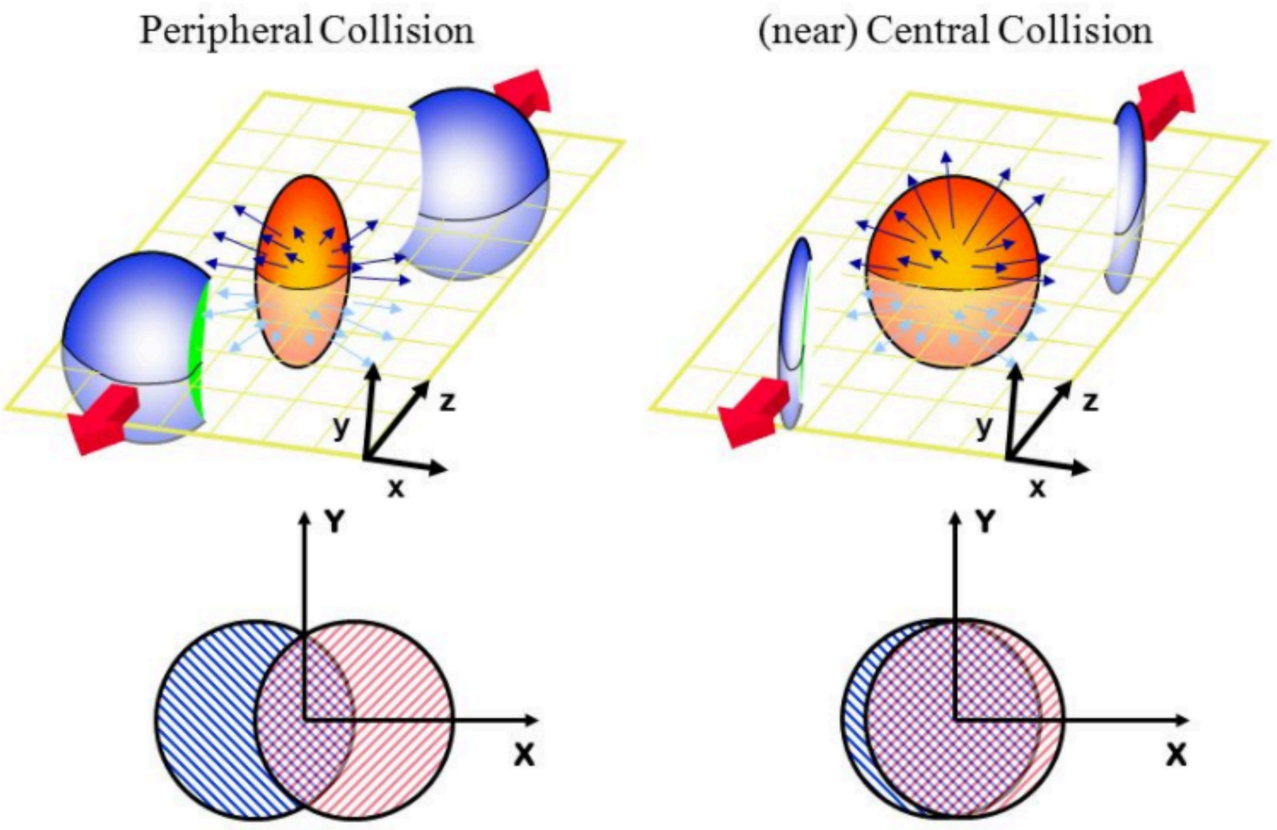
Au+Au Collision Centrality

- Au+Au collisions are separated into different centrality ranges
- Centrality describes how “head-on” the collision system is
- The most central collisions have the highest volume of QGP
- Used 4 different centrality ranges for this analysis: 0-10%; 10-30%; 30-50%; and 50-80%



50-80% centrality

0-10% centrality

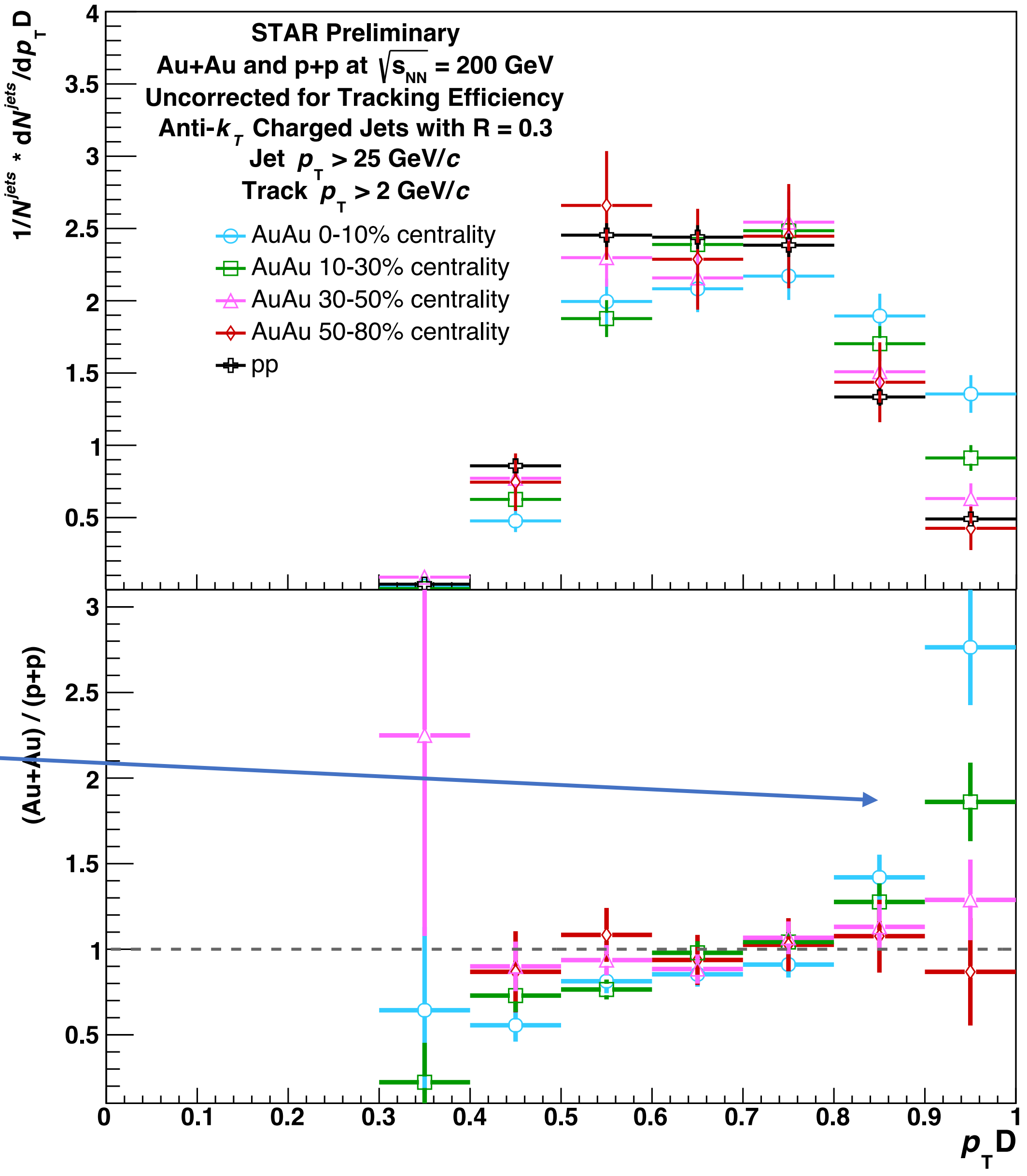
Correcting for Au+Au Underlying Event

- Used a constituent matching method for background subtraction (Berta et. al JHEP 1406 (2014) 092)
- Removes underlying events by matching them with artificial particles created from an estimation of the background energy
- Objects provided to the jet algorithm are thus already background subtracted

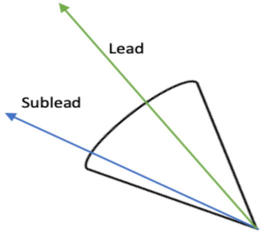
Momentum Dispersion ($p_T D$)

- Compare p+p to Au+Au in various centralities
  - ➢Results not corrected for detector effects such as tracking efficiency
- Cutoff in small $p_T D$ due to kinematics
- Shift in $p_T D$ to larger values for central collisions
- Harder-fragmented jets appear to survive in more central collisions, producing higher $p_T D$ values

$$p_T D = \frac{\sqrt{\sum_{i \epsilon \text{jet}} p_{T,i}^2}}{\sum_{i \epsilon \text{jet}} p_{T,i}}$$

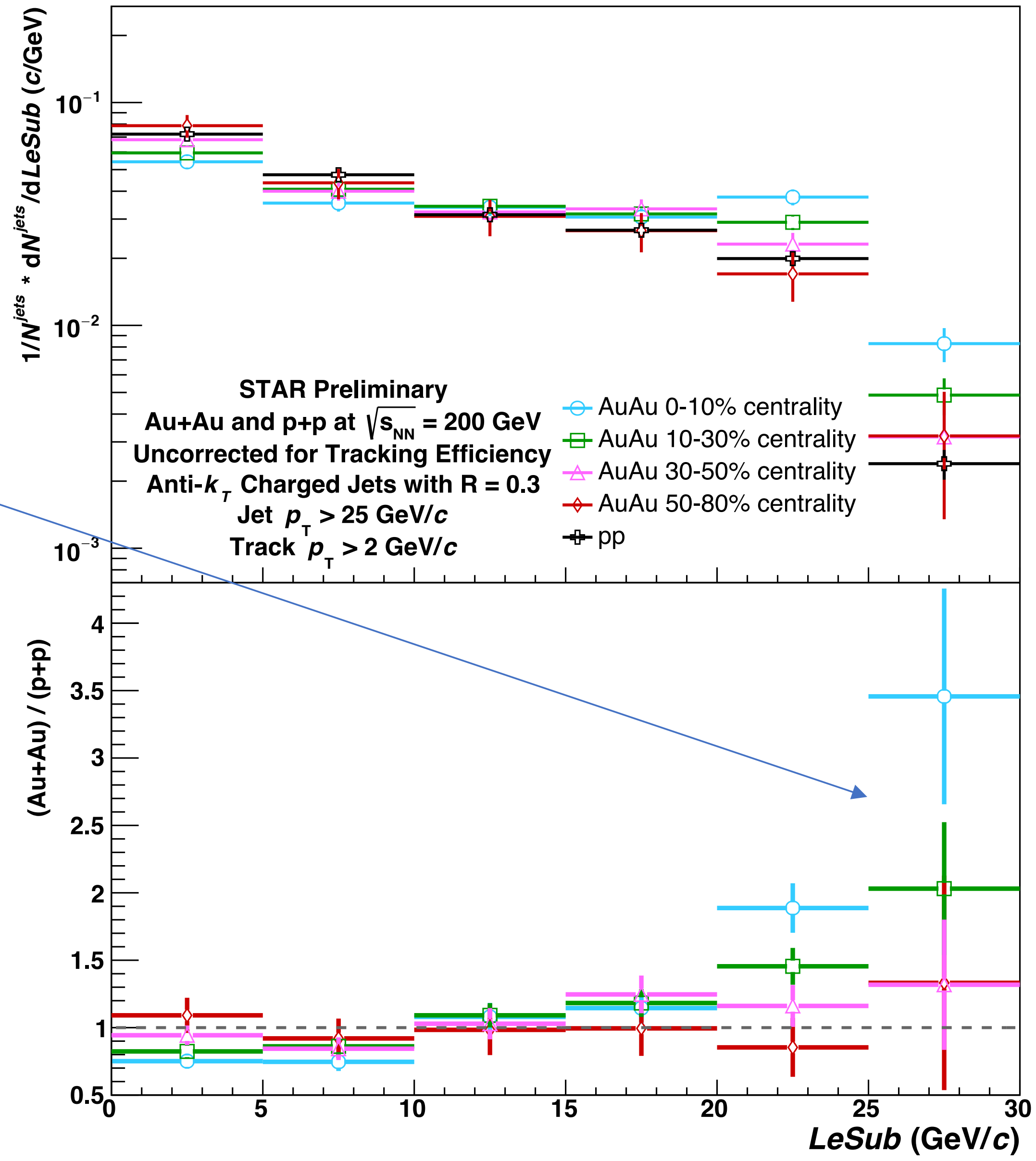


LeSub



- Shift in *LeSub* to larger values for central collisions
- Au+Au/p+p > 1 for the most central collisions at large values of *LeSub*
- Results may imply that most central jets have more momentum concentrated in a single constituent
- Interesting complementary effect in comparison with the ALICE measurement

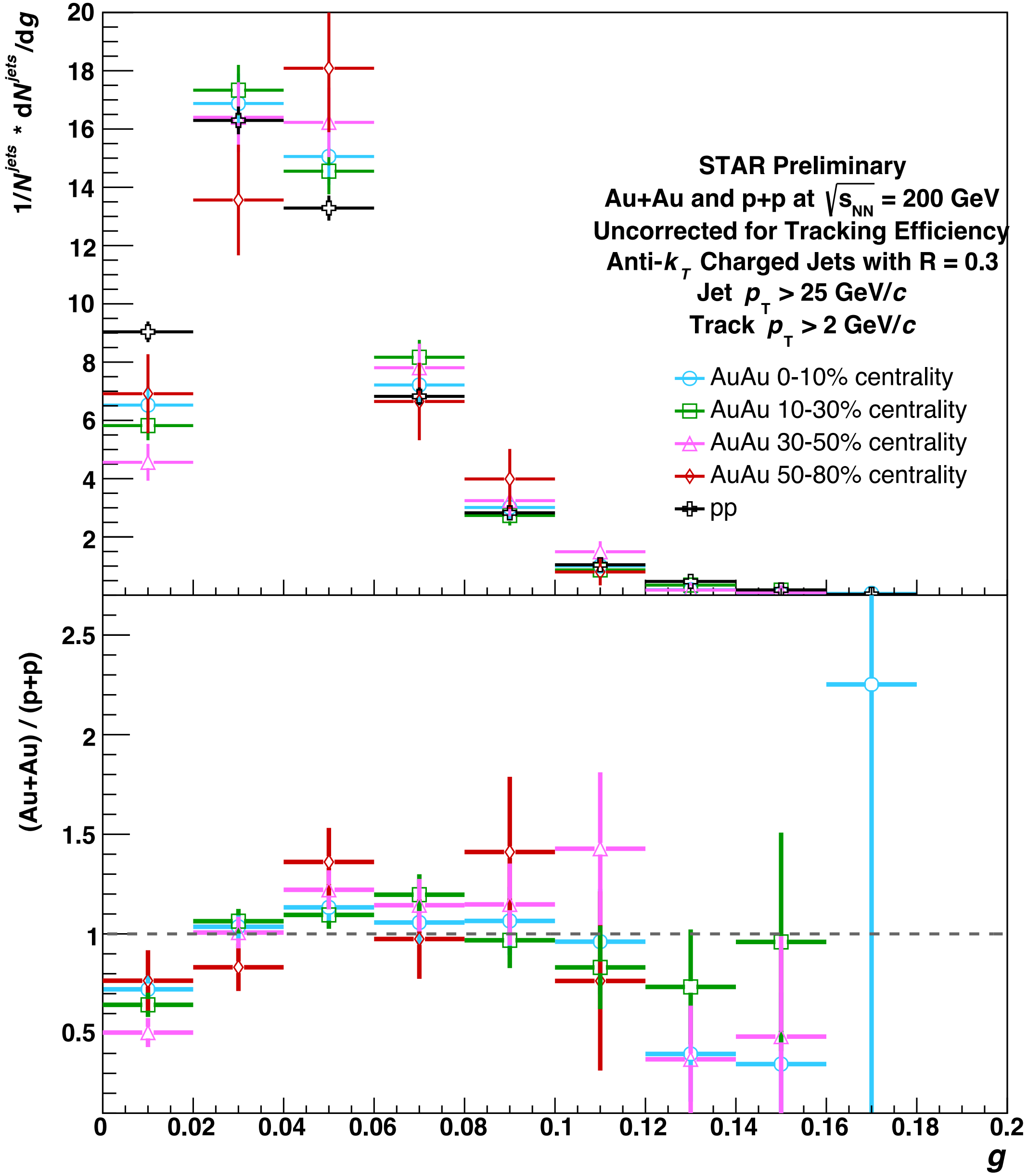
$$LeSub = p_{\mathrm{T,track}}^{\mathrm{lead}} - p_{\mathrm{T,track}}^{\mathrm{sublead}}$$



Girth (g)

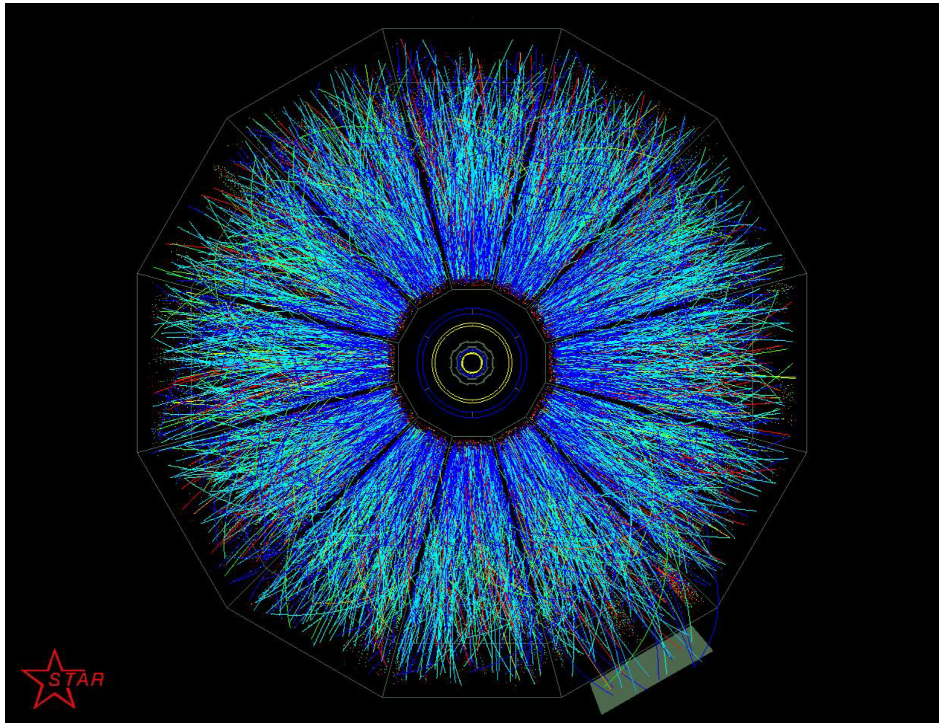
- Distribution of the girth resembles that of the fully corrected ALICE study
- Might be a trend with the ratio, but it is unclear
  - ➢Uncertainty range of most points falls within 1
- Results could possibly show limited effects of QGP on the radial moment, but require further corrections and a better control of systematic uncertainties (not shown here)

$$g = \sum_{i\epsilon \text{jet}} \frac{p_{\text{T},i}}{p_{\text{T,jet}}} \Delta R_{\text{jet},i}$$

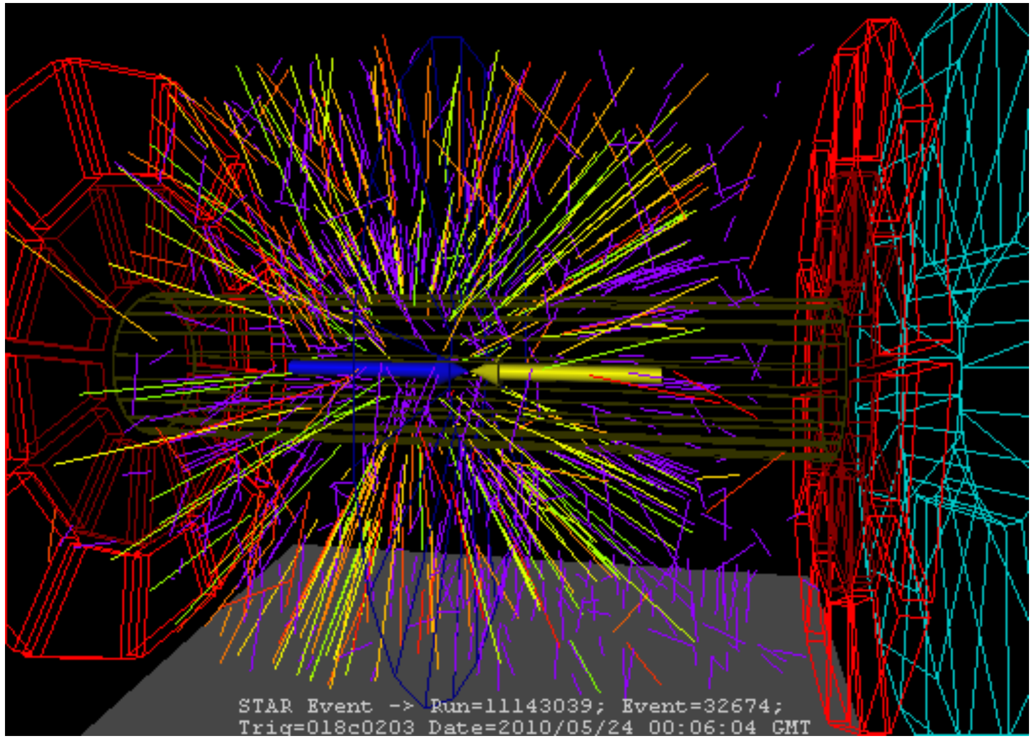


Conclusions

- First preliminary measurements of the $p_T D$, *LeSub*, and g observables at RHIC energies
- Preliminary results show we might have measurements of effects of QGP on the observables not measured at LHC energies
  - Especially noticeable with *LeSub*
- Actively working on corrections for detector effects
  - Aim for publication in the future



Future Outlook



- Next main step is to implement corrections for detector effects
- Also correction for underlying fluctuations
- Cross check with PYTHIA and other heavy-ion Monte Carlo simulations

References

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Questions?

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