A Jet Shape Study with the STAR Experiment

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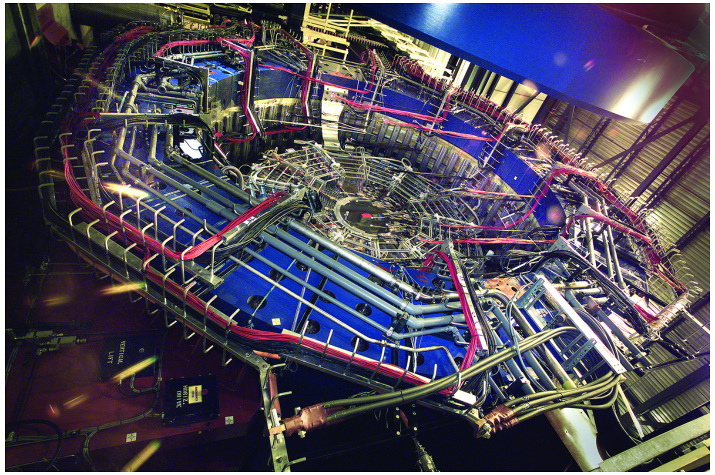
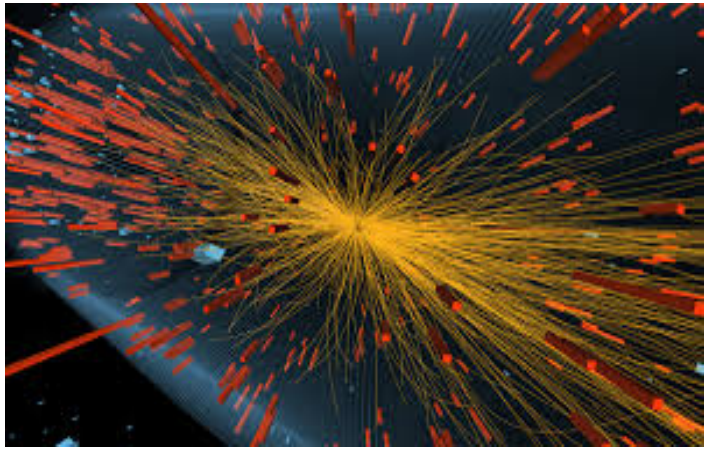
Introduction

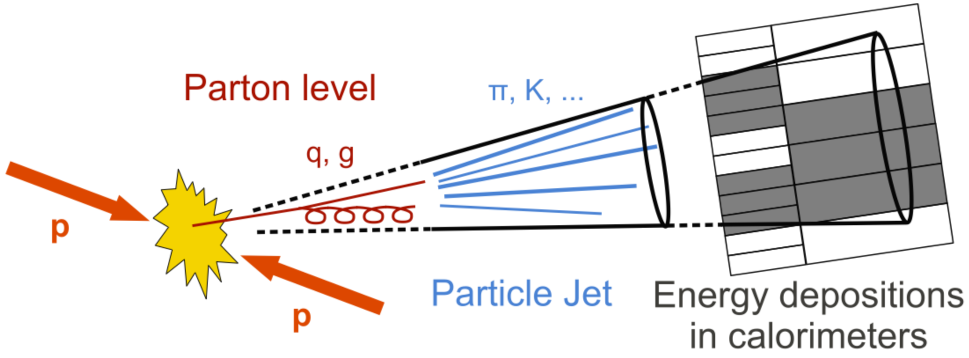


- Analysis on QGP and jets in relativistic heavy-ion collisions at the relativistic heavy-ion collider (RHIC), at Brookhaven National Laboratory (BNL)



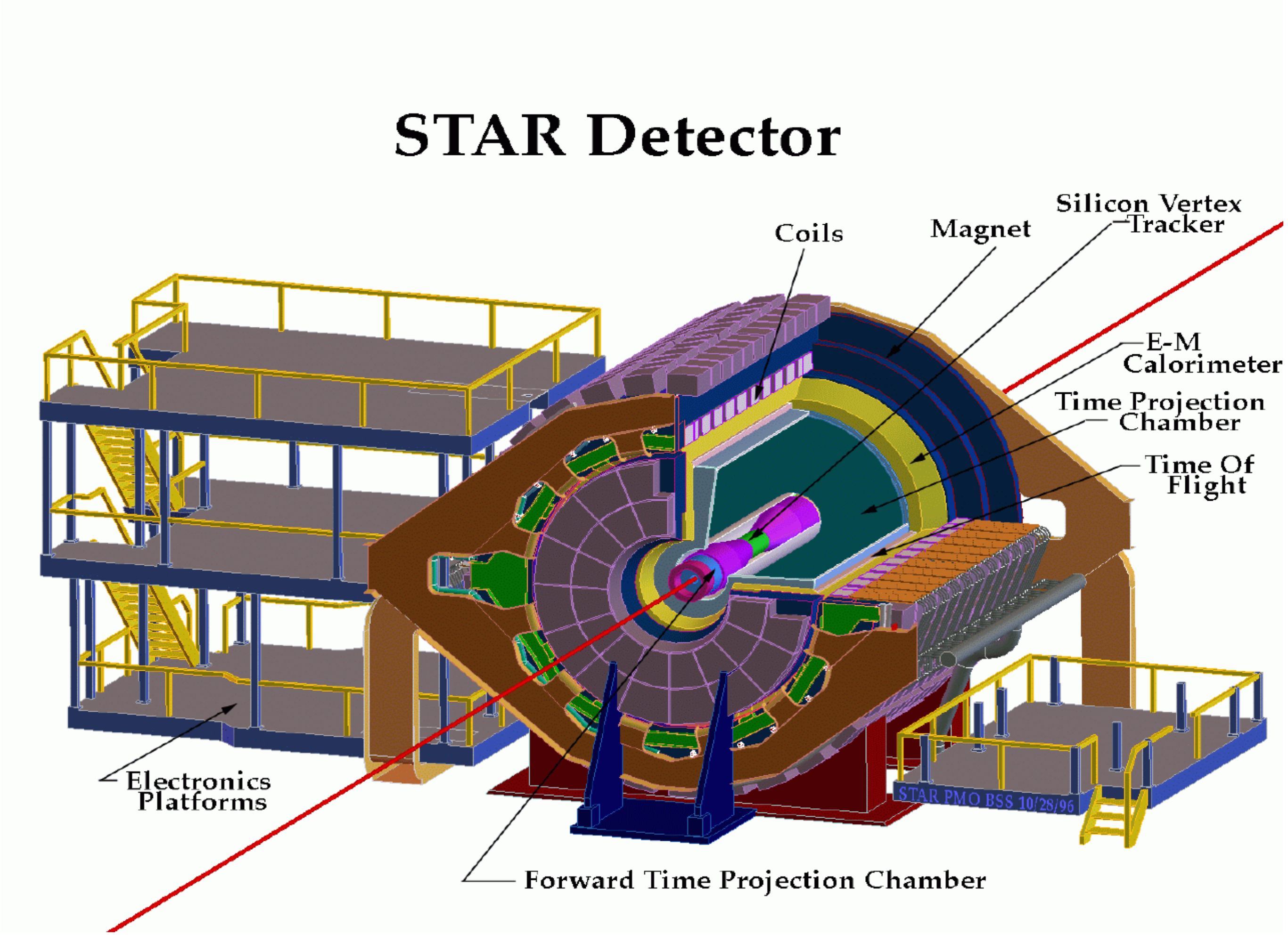
- Quark-gluon plasma (QGP) is a form of matter that existed moments (10^{-6} s) after the Big Bang
  - Allows us to study the evolution of the universe
  - Can be recreated at both RHIC and the LHC

Jets and Jet Quenching



- Jets are a stream of particles coming from the scattering of partons
- For this analysis, the anti-k_T algorithm was used
- Only examined jets can be made up of both charged constituents
- Wish to observe the jet quenching phenomenon: parton energy loss due to interaction with QGP
- Comparison of Au+Au to p+p allows for comparison between jets interacting with the QGP medium (Au+Au) and those in vacuum (p+p)

STAR Experiment



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

$$p_\mathrm{T}D = \frac{\sqrt{\sum_{i\in\mathrm{jet}} p_{\mathrm{T},i}^2}}{\sum_{i\in\mathrm{jet}} p_{\mathrm{T},i}}$$

- *LeSub* is defined as the p_T difference between the leading and sub-leading constituent track in a jet

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

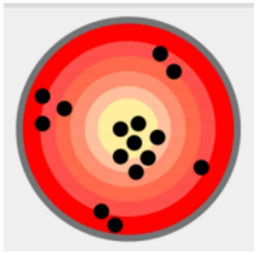
- Angularity (g) is defined as the first radial moment of the jet

$$g = \sum_{i\in\mathrm{jet}} \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}} \Delta R_{\mathrm{jet},i}$$

Jet Shapes (cont.)

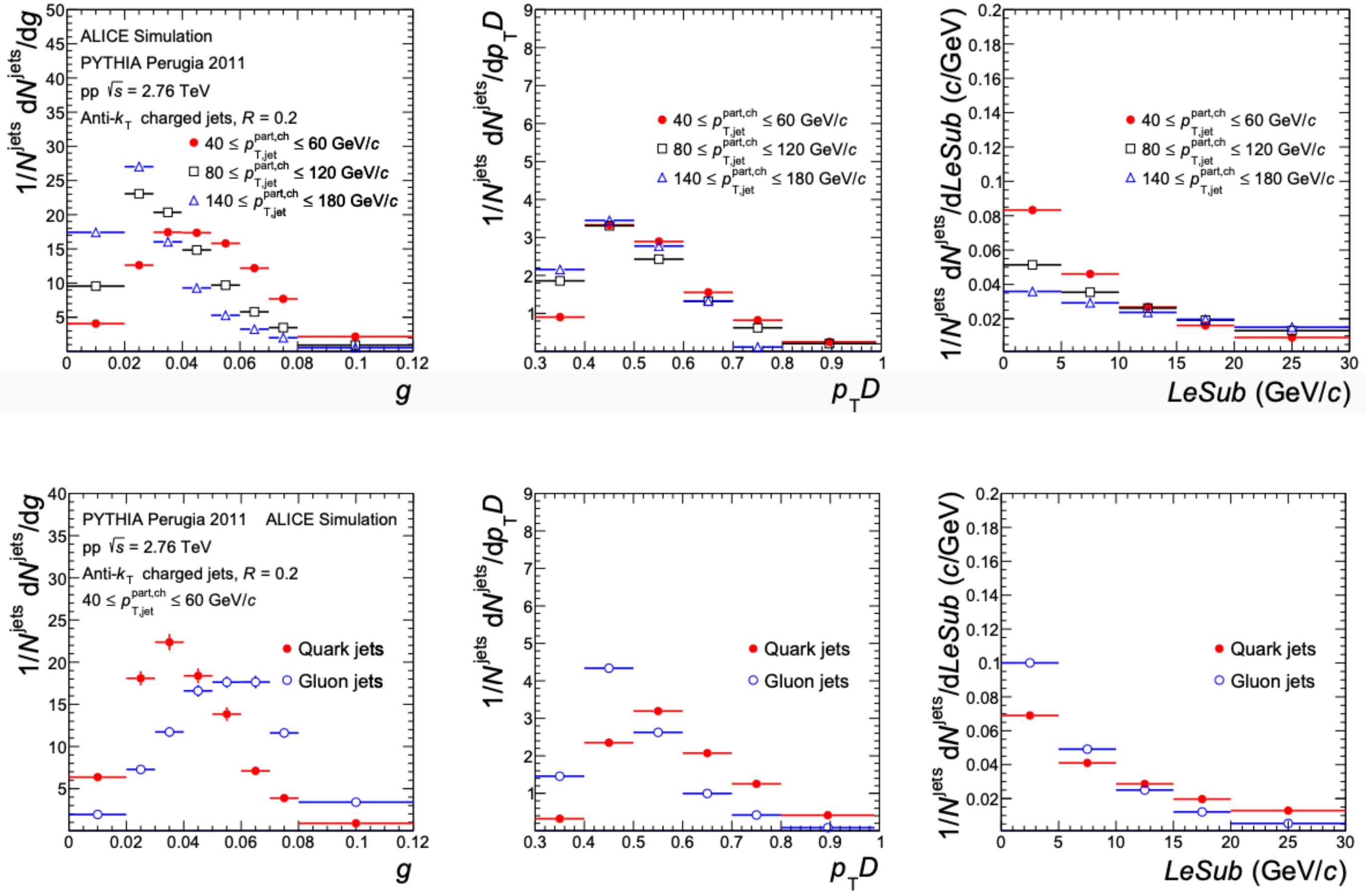
- $p_T D$ is sensitive to hard or soft scattering of the jet fragmentation
  - Hard scattering gives values close to 1; soft is closer to 0
- *LeSub* is sensitive to hard scattering
  - Hard scattering can give large *LeSub* values

- g is sensitive to broadening of the p_T distribution
  - See where jet p_T is centered relative to the jet axis



ALICE Results

- Previous study by ALICE measured these jet shapes at LHC energies
- We can see differences between quark/gluon jets and jets of different momenta (PYTHIA simulation)
- Collisions at RHIC energies produce more quark jets than those at the LHC, and thus there is the potential to measure QGP effects LHC energies are not sensitive to



Kinematic Selections

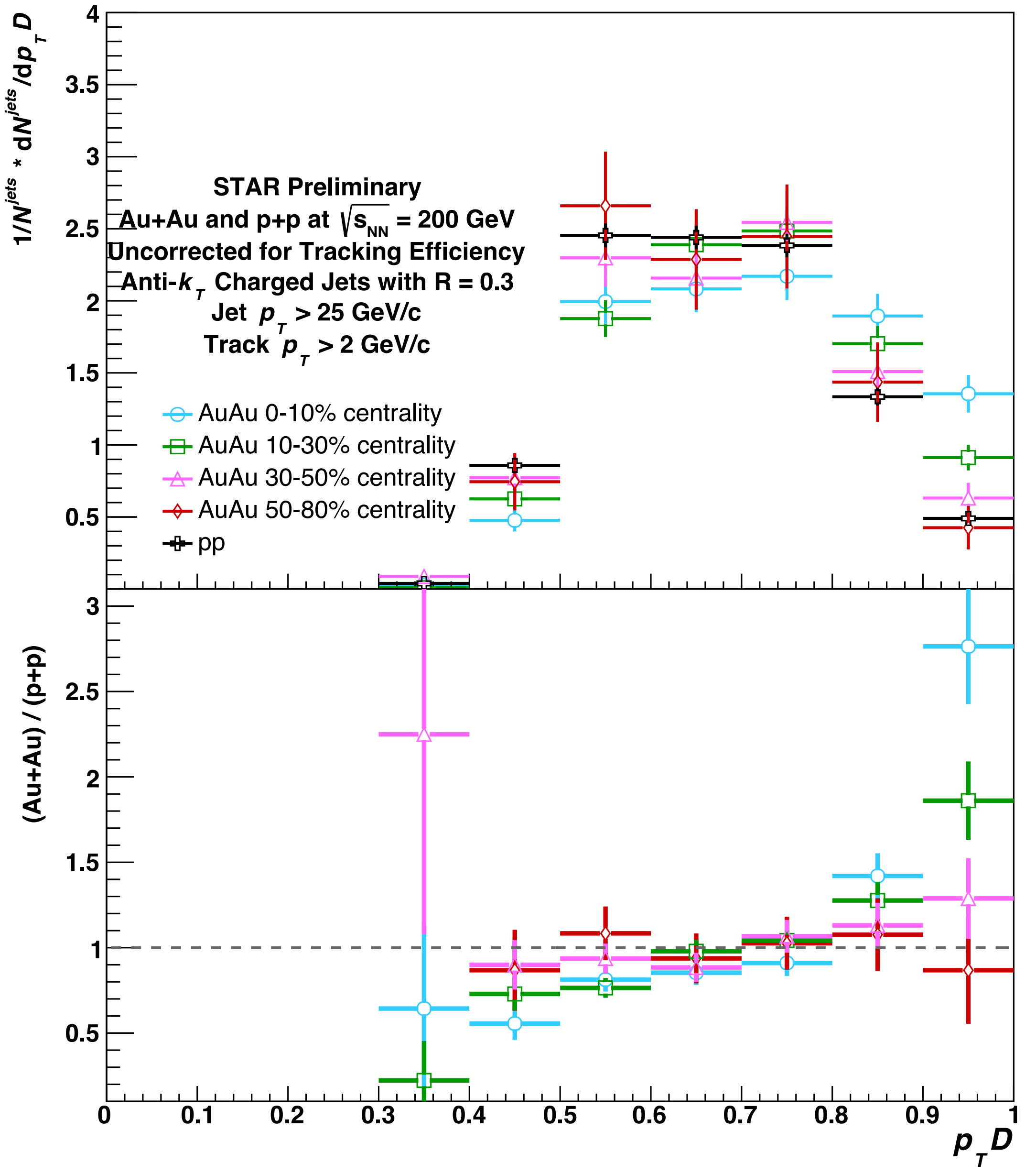
- Need to make several selections to ensure a proper signal
- Jet resolution (jet R) = 0.3
- Pseudorapidity of the jets: -0.7 < jet η < 0.7
- Overall Jet p_T > 25 GeV/c
- Jet constituent (track) p_T > 2 GeV/c
- Overall track p_T > 2 GeV/c
- Only examining charged constituents; **uncorrected** for tracking efficiency
- Au+Au data is split into centrality ranges: 0-10%, 10-30%, 30-50%, 50-80%
- Using 2014 Au+Au and 2012 p+p collision data at energy of $\sqrt{s_{NN}} = 200$ GeV

Background Subtraction

- Used a constituent matching method to subtract the background (constituent subtractor)
- Estimates a fractional background energy for the event and subtracts this off each individual track
  - Example: if the estimate for a given event was 20%, then a 1 GeV/c track would be corrected to 0.8 GeV/c
- Tracks given to the jet algorithm are thus already background subtracted
- Background subtraction only needed for Au+Au

Momentum Dispersion

- Results for all centralities
- Cutoff in small bins due to kinematic selections
- Most central distributions have and increasing trend
- Ratio value increases with higher $p_T D$ values
- Harder-scattered jets appear to survive in more central collisions, producing higher $p_T D$ values

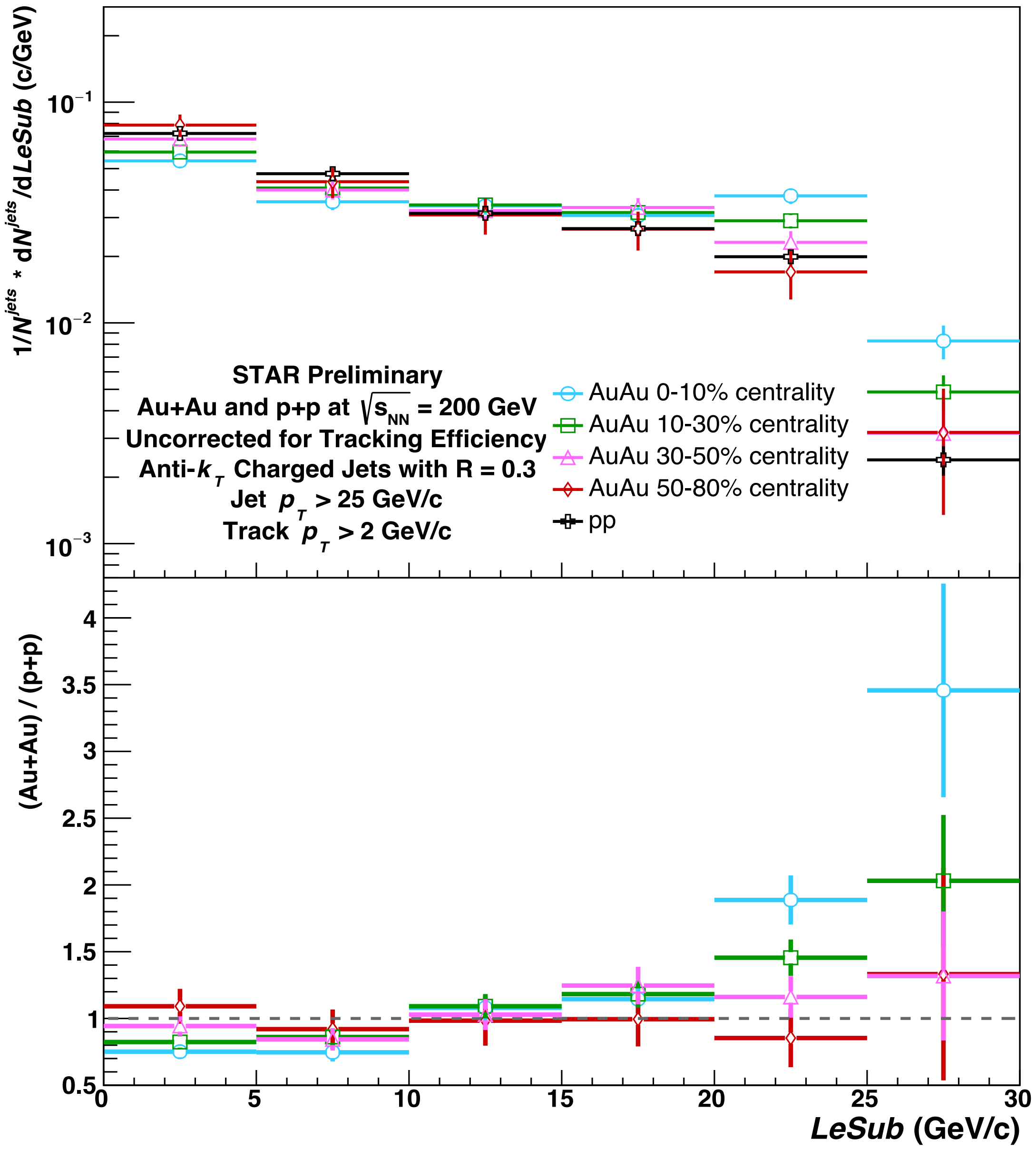


$$p_T D = \frac{\sqrt{\sum_{i \in \text{jet}} p_{\text{T},i}^2}}{\sum_{i \in \text{jet}} p_{\text{T},i}}$$

LeSub

- Little changes in the ratio at low values of *LeSub*
- Ratio value increases with higher *LeSub* values
- Implies that high centrality jets have more momentum concentrated in a single constituent
- Effect not observed in the ALICE study

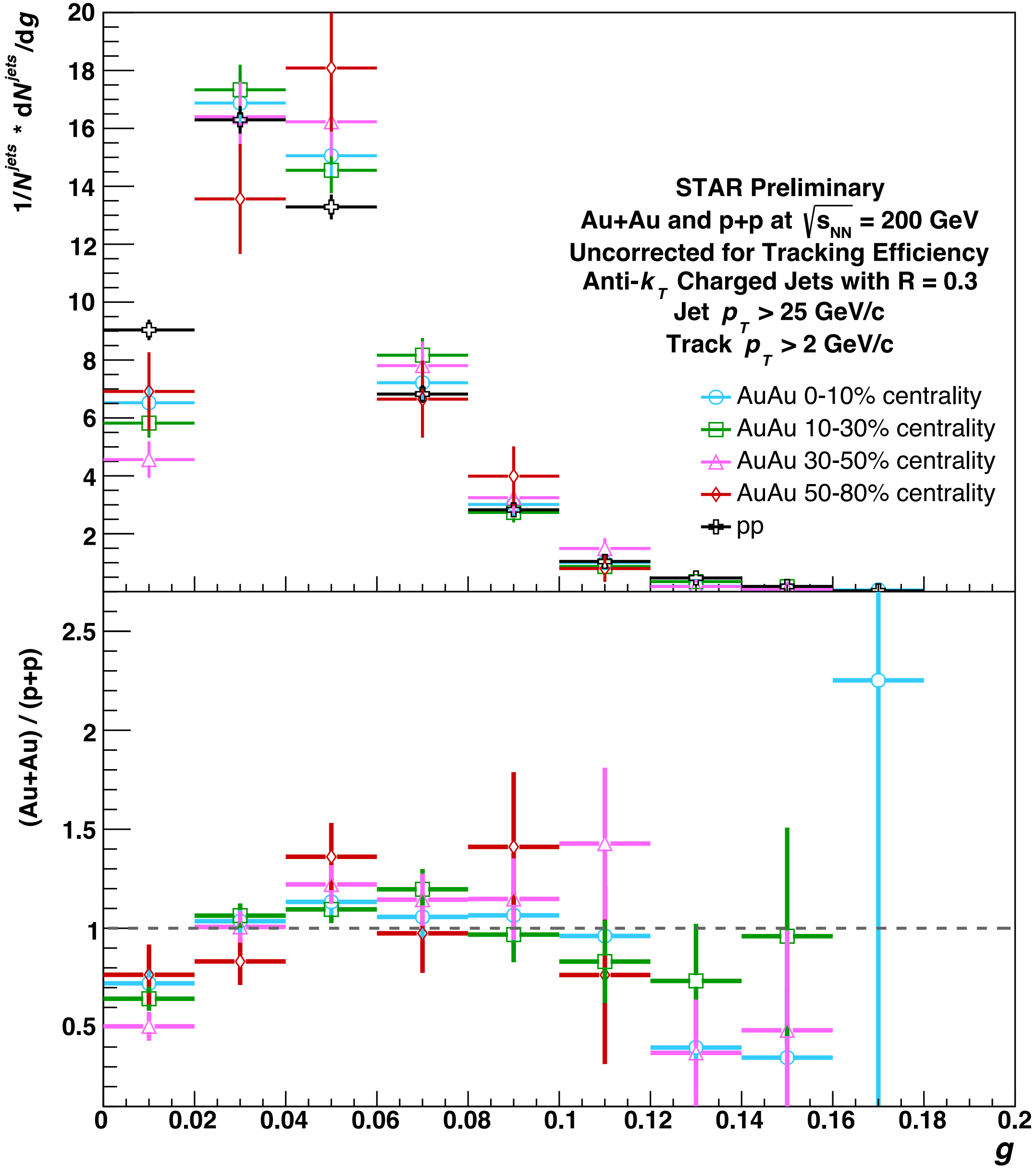
$$LeSub = p_{\mathrm{T,track}}^{\mathrm{lead}} - p_{\mathrm{T,track}}^{\mathrm{sublead}}$$



Angularity

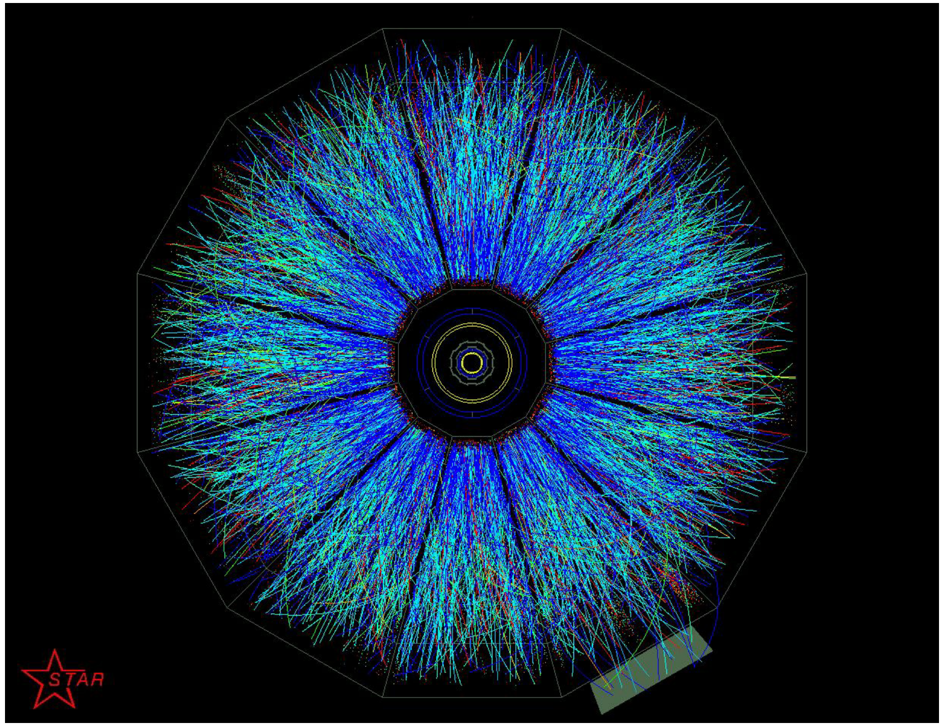
- Distribution of the shape resembles that of the fully corrected ALICE study
- Not much of a trend with the ratio
  - Uncertainty range of most points falls within 1
- Would indicate that the radial moment is not as affected by QGP
- The shape perhaps most effected by the tracking efficiency corrections

$$g = \sum_{i \in \mathrm{jet}} \frac{p_{\mathrm{T},i}}{p_{\mathrm{T,jet}}} \Delta R_{\mathrm{jet},i}$$



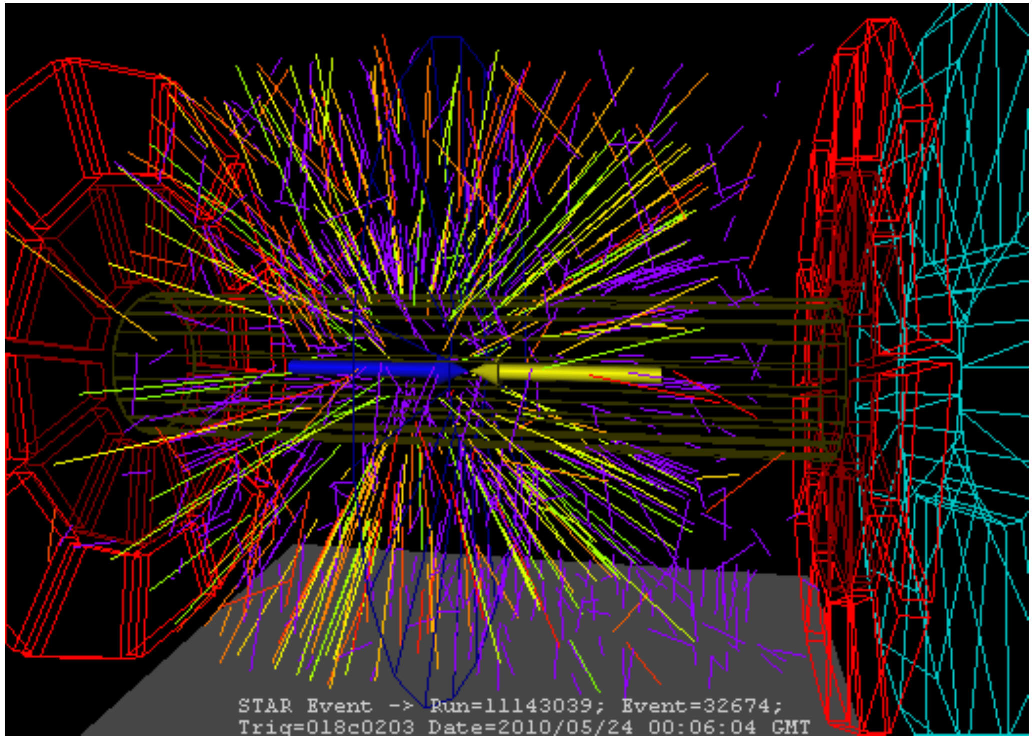
Conclusions

- First (!) measurements of the $p_T D$, *LeSub*, and g observables at RHIC energies
- (Very) preliminary results show effects of QGP on the observables which LHC energies are not sensitive to
  - Especially notable *LeSub* result
- Further corrections needed to confirm conclusions



Future Outlook

- Next main step is to implement the tracking efficiency
- Correct for underlying fluctuations
- Cross check with PYTHIA and other heavy-ion Monte Carlo simulations



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Questions?

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