Measurements of jet v_2 in medium-sized systems at STAR

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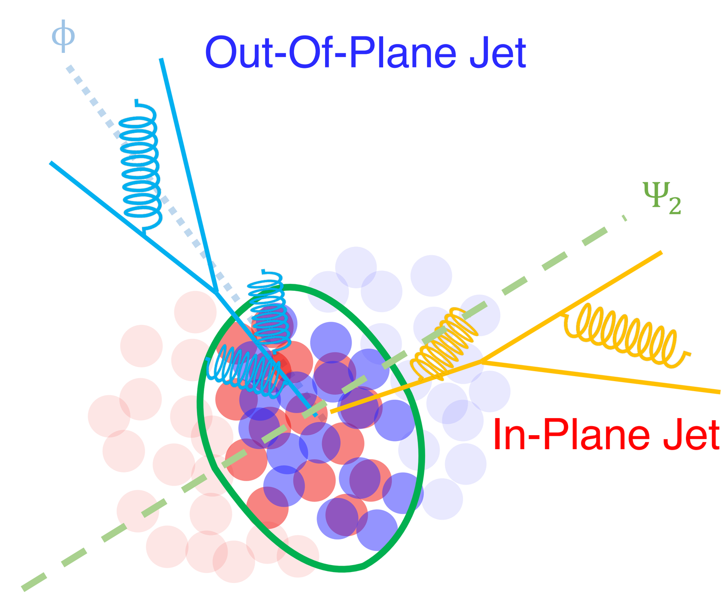
Abstract

Hard partonic scatterings, occurring at the early stages of heavy-ion collisions, produce jets, which experience the full evolution of the quark-gluon plasma (QGP). As they traverse through the QGP, jets lose energy through collisional and radiative processes, collectively known as jet quenching. In semi-central heavy-ion events, the QGP initially takes an approximately elliptical shape in the transverse plane whose mean in-plane and out-of-plane distances differ. This fact can be used to vary the average path length for jets traversing the QGP, and those traveling in-plane should experience less quenching effects than those traveling out-of-plane. This differential quenching manifests as a suppression of jet yield out-of-plane relative to in-plane, quantified by jet v_2, the second order Fourier coefficient. In this poster, charged jet v_2 will be presented from Ru+Ru, Zr+Zr, and O+O collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV with multiple jet resolution parameters. Studying jet v_2 in collision systems of varying sizes may help disentangle path-length dependent quenching effects and other effects which could give rise to anisotropies in systems even smaller than O+O collisions.

Jet v_2

- Semi-central collisions produce an approximately elliptical QGP
  - Orientation defined by second order event plane, Ψ_2
- Jets which travel in-plane will experience a shorter path length through the medium than those which travel out-of-plane
  - The expected in-plane jet yield should be greater than the out-of-plane yield due to path length dependent quenching
- The anisotropy is reported with the second order Fourier coefficient,
  - Though the language is the same, high p_T v_2 (quenching) is driven by different effects than low p_T v_2 (flow)

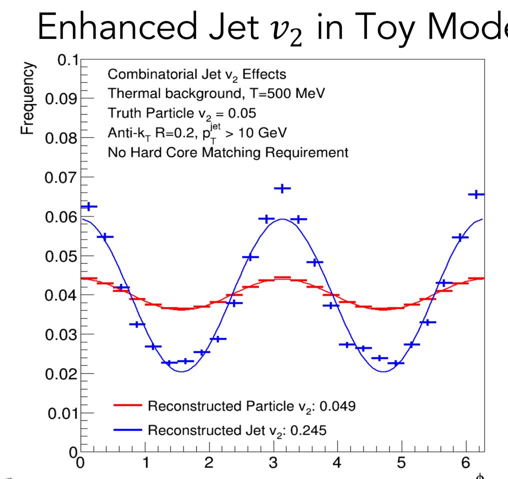


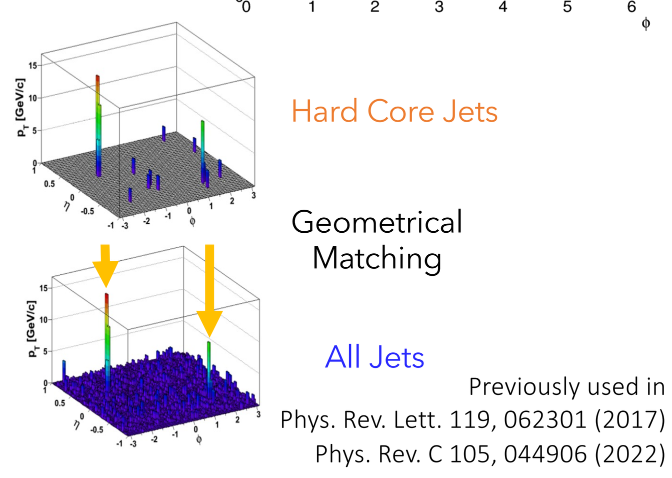
$$\frac{dN}{d\Delta\phi} \propto 1 + 2\,v_2\cos(2(\phi - \Psi_2))$$

Combinatorial jets

- Combinatorial jets were found to significantly enhance the observed jet v_2
  - Demonstrated with toy model featuring no jet-like objects but still yields a large jet v_2
- A hard core matching routine was used to mitigate this
  - Tracks with $p_T > 2$ GeV/c are selected and clustered with anti-k_T algorithm into hard core jets
    - Idea: Cluster only tracks from hard scattering
  - Hard core jets with $p_T > 10$ GeV/c are geometrically matched to jets with constituent $p_T > 0.2$ GeV/c if the jet axis satisfy $\sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < \mathrm{R}$
    - Where R is the jet resolution parameter
- Only jets matched with a hard core jet are analyzed

Enhanced Jet v_2 in Toy Model

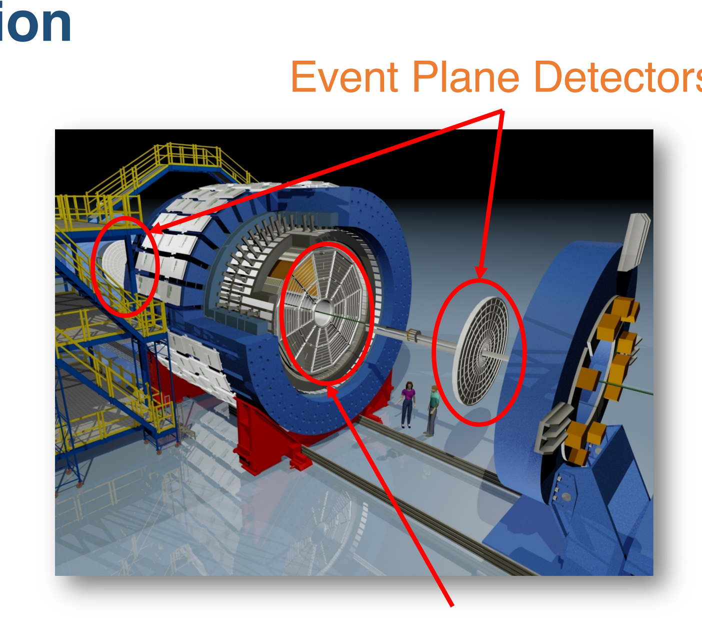


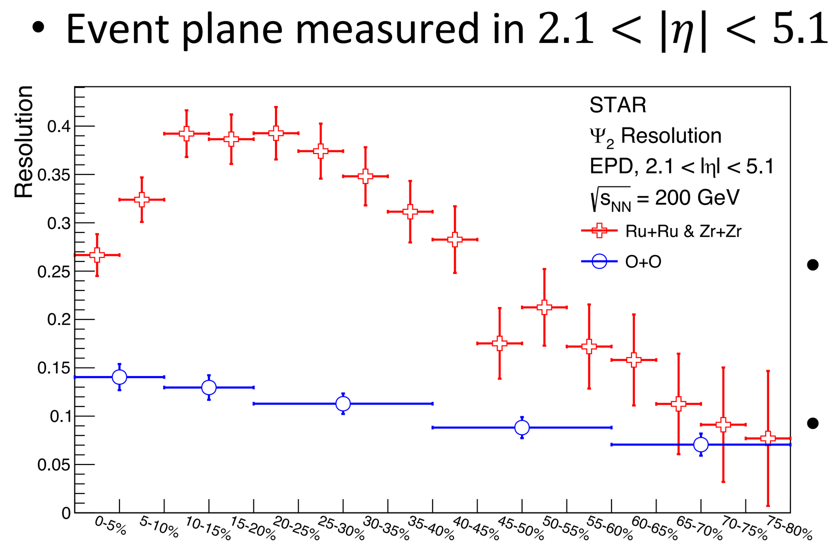


Previously used in Phys. Rev. Lett. 119, 062301 (2017) Phys. Rev. C 105, 044906 (2022)

STAR detector and event plane resolution

- Event Plane Detector upgrade at STAR allows for determination of the event plane at large rapidity
  - Installed in 2018
  - Scintillating hit detector
  - 16 η divisions, 24 ϕ divisions
- Rapidity gap between jet finding and event plane determination avoids autocorrelation
  - Event plane measured in $2.1 < |\eta| < 5.1$

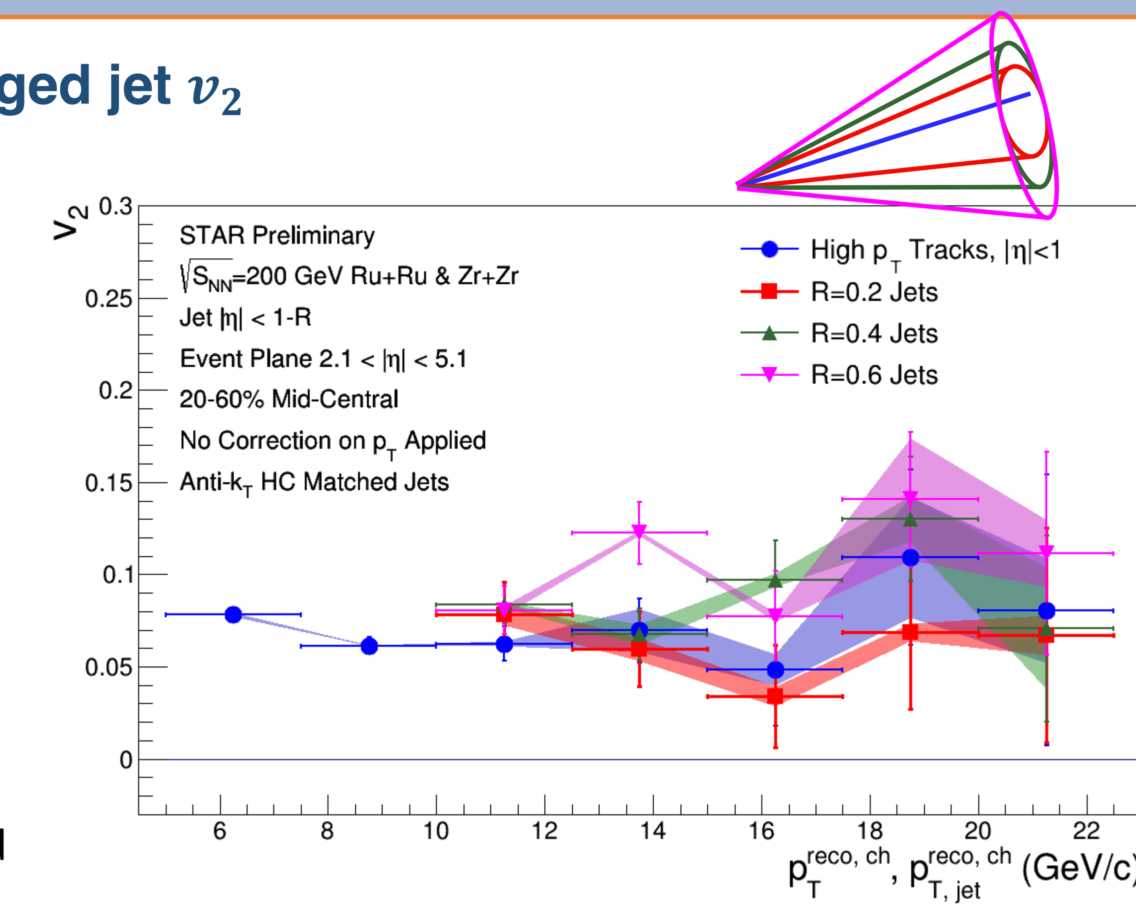




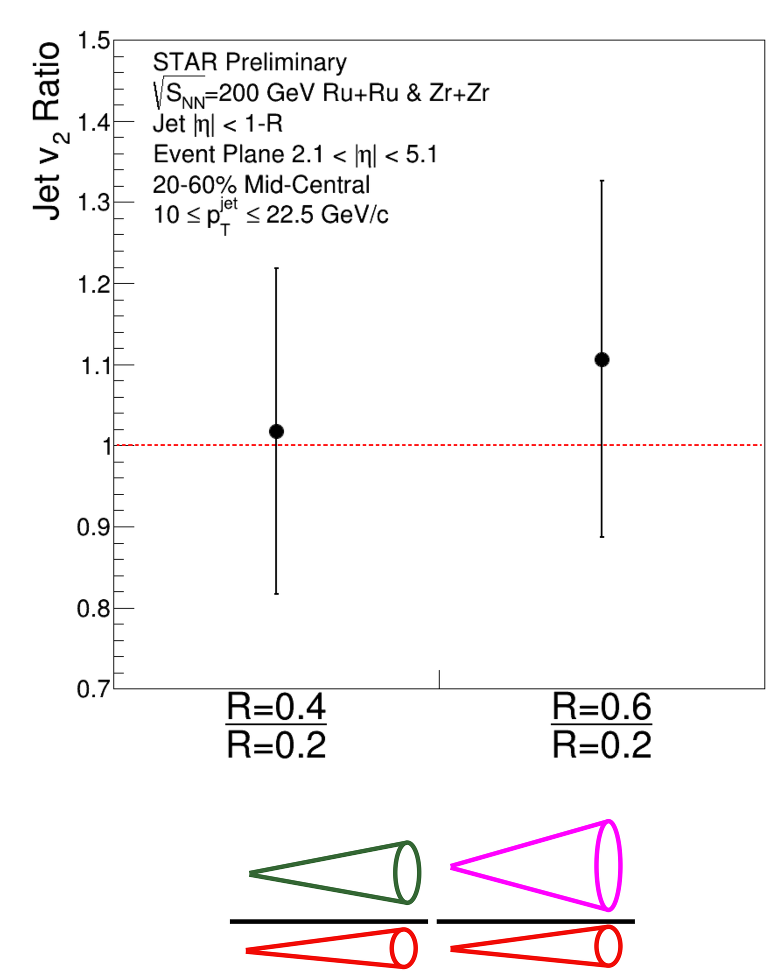
- Charged jets measured in Time Projection Chamber
  - $|\eta| < 1$, full azimuthal coverage
- Analyze electromagnetic calorimeter triggered events
  - $|\eta| < 1$, full azimuthal coverage, $E_T^{\mathrm{trig}} > 3.4$ GeV

Ru+Ru and Zr+Zr charged jet v_2

- Jet energy scale corrected by area-based subtraction
  - $p_T(\phi) = p_T^{\mathrm{measured}} - \rho(\phi)A$
  - Average background density ρ modulated with assumed underlying event flow of 4%
- Positive charged jet v_2 observed for high transverse momentum tracks, R=0.2, R=0.4, and R=0.6 anti-k_T hard core matched jets
- No strong transverse momentum dependence
- Consistent with value observed by ALICE in $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV Pb+Pb collisions [1]



Ru+Ru & Zr+Zr R dependence



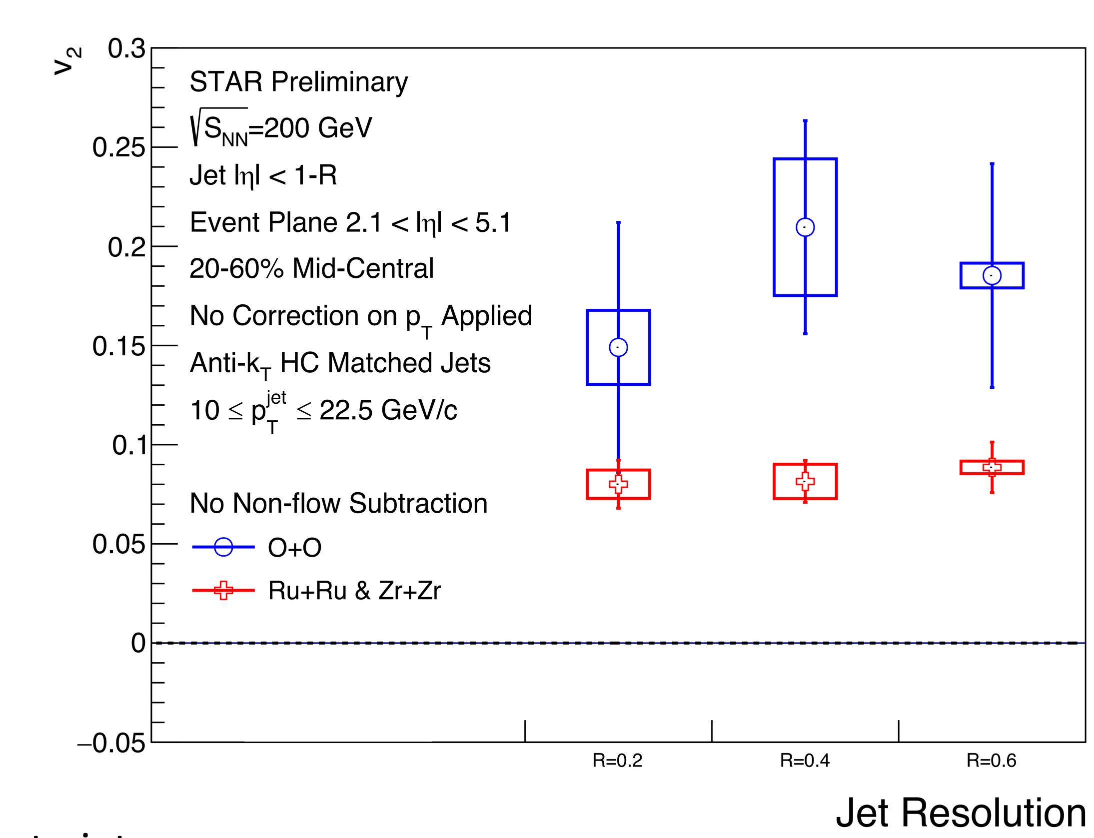
- Under naïve expectation that larger cones capture more radiated energy, we might expect jet v_2 to decrease with increasing R
- To remove correlations in the statistical uncertainties, the dataset was divided in half such that jets of different radii were measured using statistically independent samples
- No evidence for R dependence of jet v_2 for hard core selected jets within large uncertainties
- Hard core selection imposes a fragmentation bias and influences where in the collisional geometry jets are found

O+O charged jet v_2

- O+O is a significantly smaller system than Ru+Ru & Zr+Zr

System	20-60% Central $\langle N_{\mathrm{part}} \rangle$
O+O	10.98
Ru+Ru & Zr+Zr	51.09

- Hints of sizable charged jet v_2 in small systems at RHIC
  - May include significant non-flow contribution – more study needed
- Precision limited by low event plane resolution
- Could this be a similar mechanism to jet v_2 observed by ATLAS in p+Pb? [2]



Summary

- Event geometry information such as centrality class and event plane angle can be used to control the mean path length which jets experience
- A positive jet v_2 is observed in mid-central $\sqrt{s_{\mathrm{NN}}} = 200$ GeV Ru+Ru & Zr+Zr collisions, largely independent of jet transverse momentum or jet resolution parameter
- Hints of a sizable jet v_2 in mid-central $\sqrt{s_{\mathrm{NN}}} = 200$ GeV O+O collisions are observed
- Good understanding of geometry and fragmentation biases must be reached to properly interpret results

[1]: ALICE collaboration, Azimuthal anisotropy of charged jet production in $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV Pb–Pb collisions, Nucl. Phys. A 956 (2016) 629 [1511.05352].

[2]: ATLAS collaboration, Transverse momentum and process dependent azimuthal anisotropies in $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV p+Pb collisions with the ATLAS detector, Eur. Phys. J. C 80 (2020) 73 [1910.13978].

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