Event-shape engineering of charged-hadron spectra in heavy-ion collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV at STAR

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Abstract

Partonic scatterings with high momentum transfer occur before the formation of the quark-gluon plasma (QGP) in heavy-ion collisions and result in collimated collections of hadrons, called jets. The modification of the high-virtuality parton shower in the QGP compared to that in proton-proton collisions offers insight into the nature of colored probes' interaction with the medium. To study the path-length-dependent effects on high-momentum partons traveling through the QGP, we apply a technique known as event-shape engineering to data from Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV at STAR. Charged-hadron spectra are compared within a given eccentricity and centrality class. By selecting on the centrality, we minimize the effect from variation in energy density. Work is ongoing to compare charged-hadrons traveling in the event-plane direction (having shorter path length) to those traveling perpendicular to it (having longer path length) in different eccentricity classes to access the dependence of energy loss on the collision geometry.

Motivation

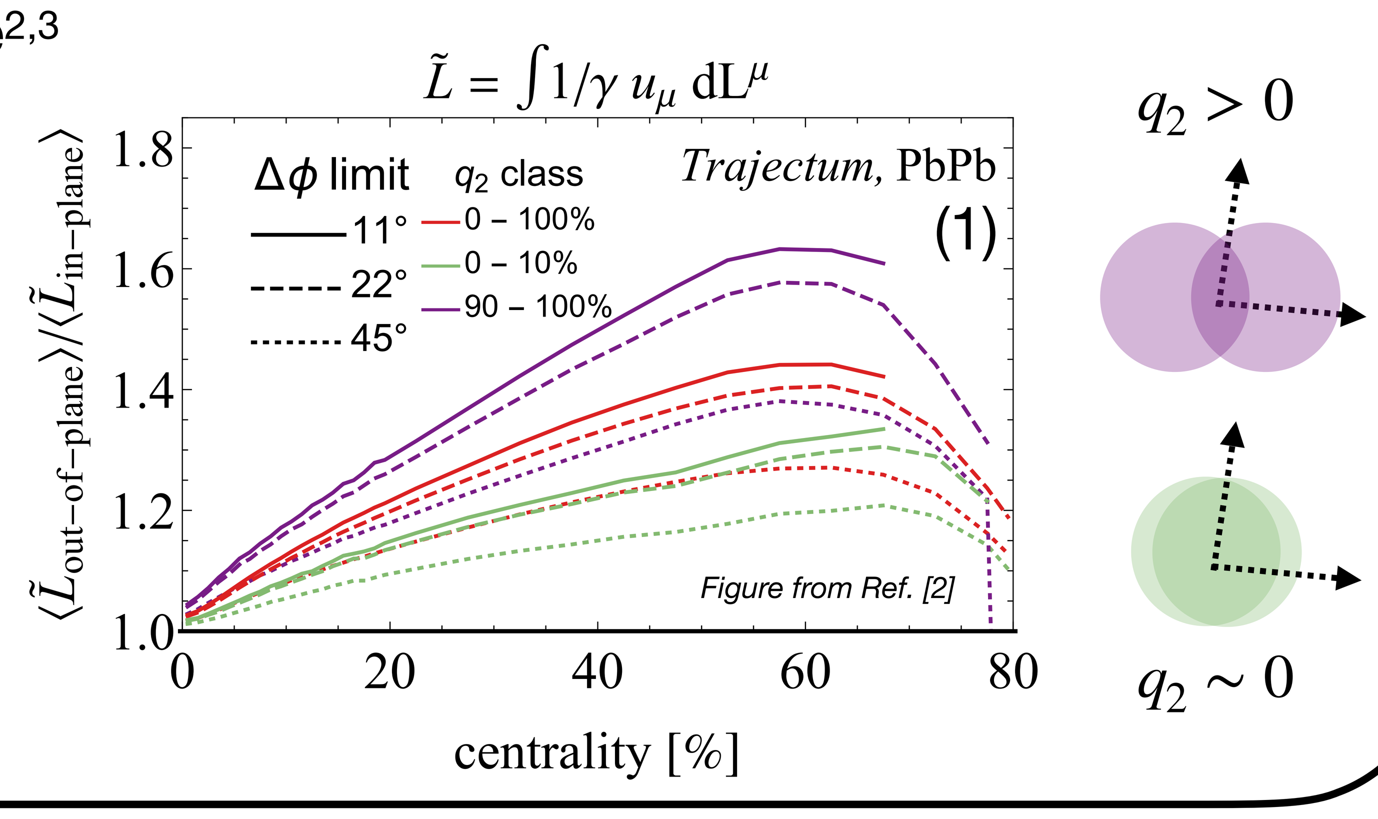
Jet-medium interaction influenced by **path length**, L

Goal: control system **geometry** at fixed energy density.

→ fix centrality, vary geometry with "event shape engineering"[1]

Possible by relation between final-state flow (q_2, 2nd order reduced flow vector) and initial-state eccentricity (ε)

Access path-length dependence: comparing yields in/out of event plane[2,3]

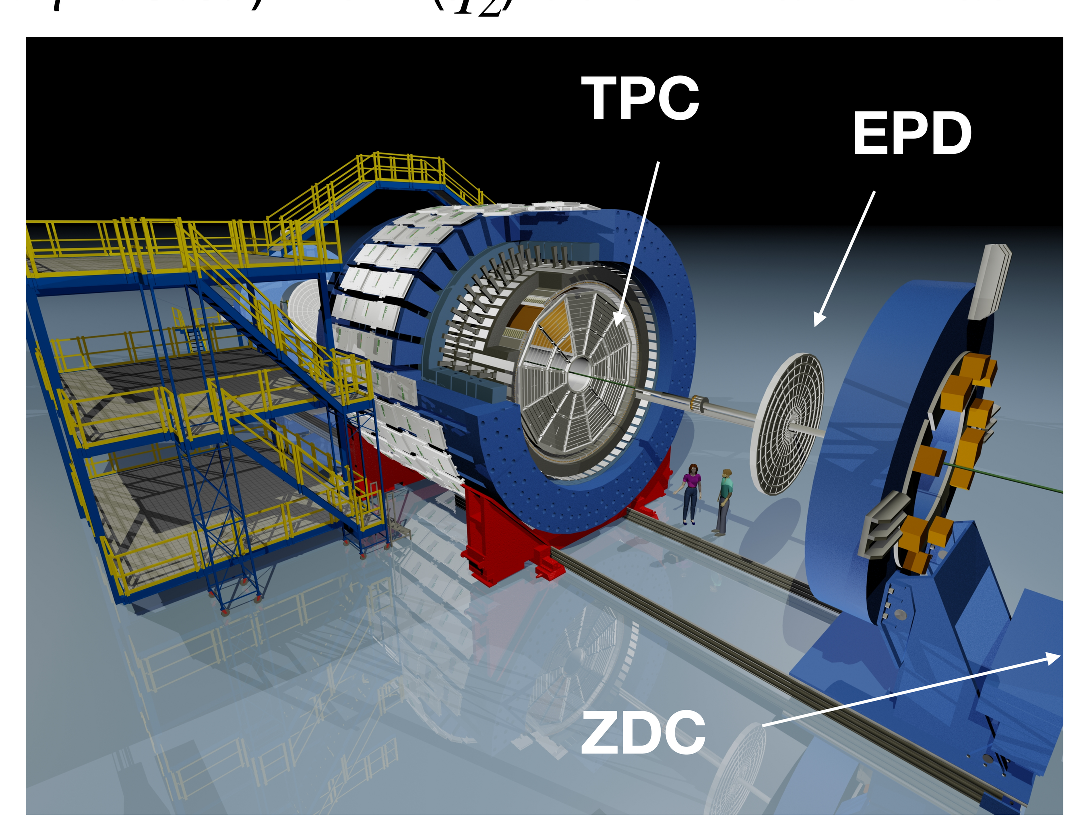


The STAR Experiment

Time Projection Chamber (**iTPC**) ($|\eta| < 1.5$):
Charged-track POI (particles of interest) reconstruction + momentum determination

Zero Degree Calorimeter (**ZDC**) (18 m): Triggering

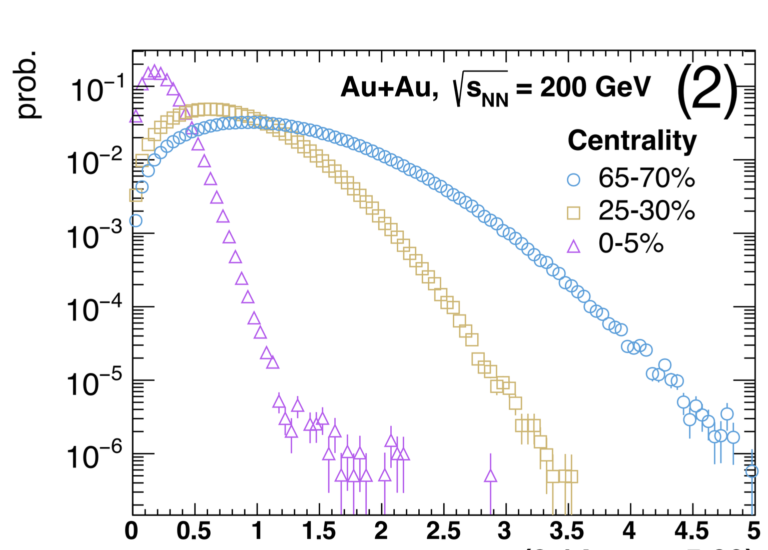
Event Plane Detector (**EPD**):
West ($2.15 < \eta < 5.09$): flow (q_2) determination *East*: EP angle (Ψ_2)

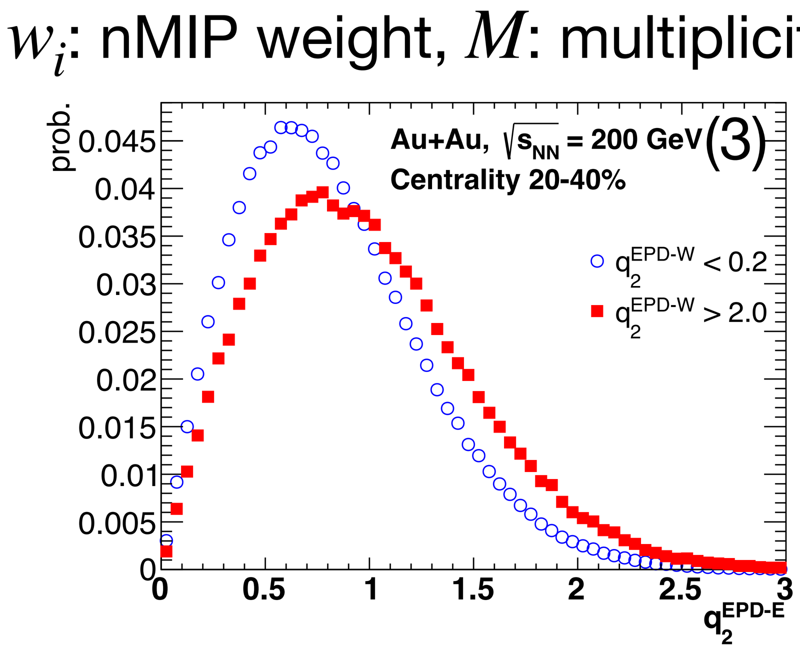


Event characterization

$$Q_2 = \left(\sum_{i=1}^{M} w_i \cos(2\phi_i), \sum_{i=1}^{M} w_i \sin(2\phi_i)\right),\ q_2 = |Q_2|/\sqrt{M},$$

w_i: nMIP weight, M: multiplicity

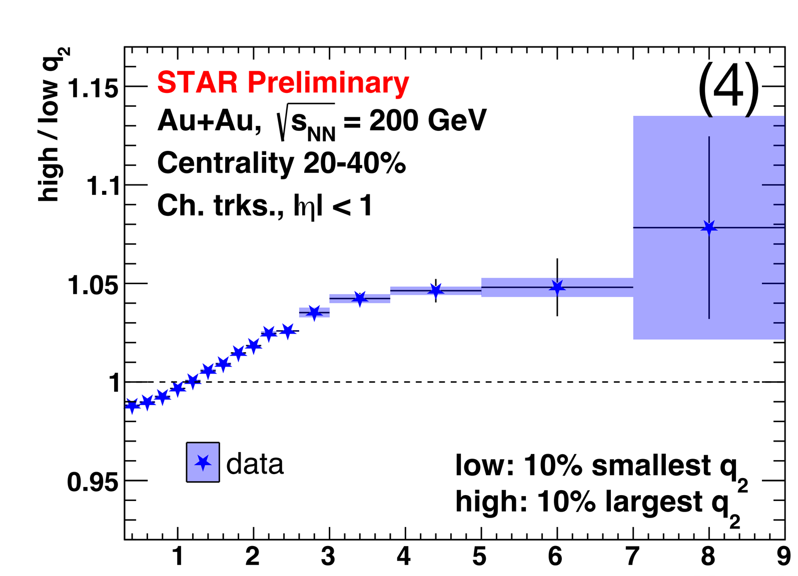


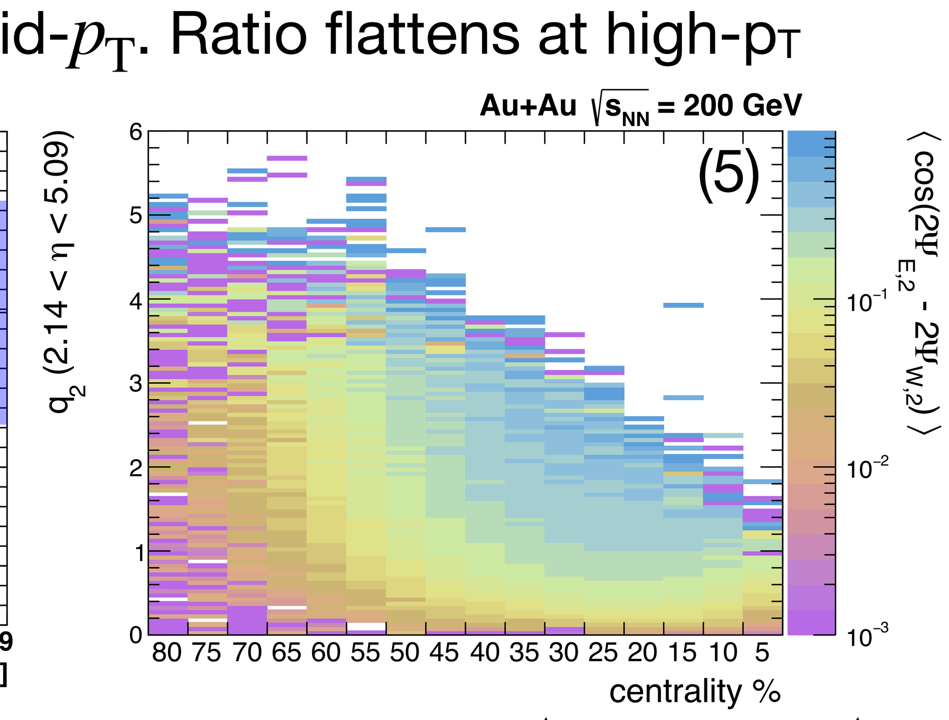


- Centrality and $\langle q_2 \rangle$ are correlated. For given centrality, large variation in event shapes (*fig. 2*).
- Avoid autocorrelation: EPDW (q_2), TPC (POI), EPDE (Ψ_2)
- Select on 10% highest/lowest q_2 (eccentricity) events, and compare charged-hadron spectra
- Systematic uncertainty on spectrum ratio (switch East, West q_2; correlation observed — *fig. 3*)

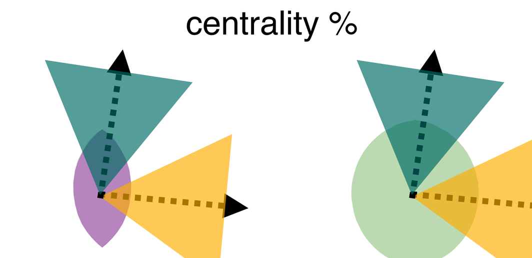
Charged-hadron spectra comparisons

- *Fig. 4*: Interplay between elliptic and radial flow → hardening of spectra at mid-p_{T}. Ratio flattens at high-p_{T}





- Analysis steps to access L dependence:
- Flatten EP distribution, divide spectra: $\phi_{\mathrm{EP}} \pm \pi/6$ ('in'), $(\phi_{\mathrm{EP}} + \pi/2) \pm \pi/6$ ('out')
- Apply resolution correction (based on *fig. 5*)
- Determine full set of systematics (3-subevent[5], etc.)
- Outlook: out/in ratio for mid-central low- vs. high-q_2 events: difference in ratio would indicate path-length-dep. E_{loss}



- Results: hardening of spectra in high-q_2 events; flatten at high-p_{T} where differential quenching expected to be minimal by average path-length argument. Consistent with ALICE 2.76 TeV[4].
- Work ongoing to select on the event plane angle to allow for comparison between longer and shorter path length

[1]Schukraft, Timmins, Voloshin, PLB 719 (2013), 394-398 [2]Beattie, Nijs, Sas, van der Schee, PLB 836 (2023), 137596 [3]ALICE, PLB 851 (2024), 138584 [4]ALICE, PRC 93 (2016) 3, 034916 [5]Festanti, PhD thesis

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