Generalized angularities measurements from STAR at $\sqrt{s} = 200$ GeV

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for the STAR Collaboration

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Outline

1. Introduction
2. Analysis
3. Results

Generalized angularities

$\lambda_\beta^1 \to$ Infra-red and collinear (IRC) safe angularities

$$\lambda_\beta^\kappa = \sum_{\mathrm{const}\in\mathrm{jet}} \overbrace{\left(\frac{p_{\mathrm{T,const}}}{p_{\mathrm{T,jet}}}\right)^\kappa}^{\text{soft/hard radiation}} \times \overbrace{r(\mathrm{const},\mathrm{jet})^\beta}^{\text{collinearity sensitive}}$$

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$\implies \langle \lambda^1_{\beta>0} \rangle_{\text{gluon jets}} > \langle \lambda^1_{\beta>0} \rangle_{\text{quark jets}}$
$\implies$ quark-gluon discrimination

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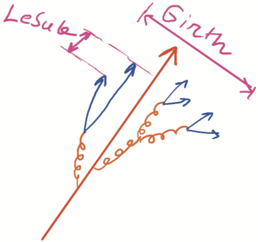
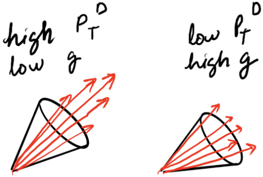
$\implies$ quark-gluon discrimination

- **Jet girth/broadening:** $\mathrm{g} = \lambda^1_1 = \frac{\sum_{\mathrm{trk}\in\mathrm{jet}} p_{\mathrm{T,trk}} \Delta R}{p_{\mathrm{T,jet}}}$
- **Momentum dispersion :** $\mathrm{p_T^D} = \frac{\sqrt{\sum_{\mathrm{trk}\in\mathrm{jet}} (p_{\mathrm{T,trk}})^2}}{\sum_{\mathrm{trk}\in\mathrm{jet}} p_{\mathrm{T,trk}}}$

  soft/hard fragmentation $\implies$ low/high p_T^D
- **LeSub** $= p^{\mathrm{Leading}}_{\mathrm{T,const}} - p^{\mathrm{Subleading}}_{\mathrm{T,const}}$, proxy for hardest splitting in jet

$\lambda^1_\beta \rightarrow$ Infra-red and collinear (IRC) safe angularities





Motivation

- Angularities are **IRC safe** (for $\kappa = 1$), **tunable** in their sensitivity to different aspects of jet fragmentation, probe the modification of radiation pattern of jets in medium

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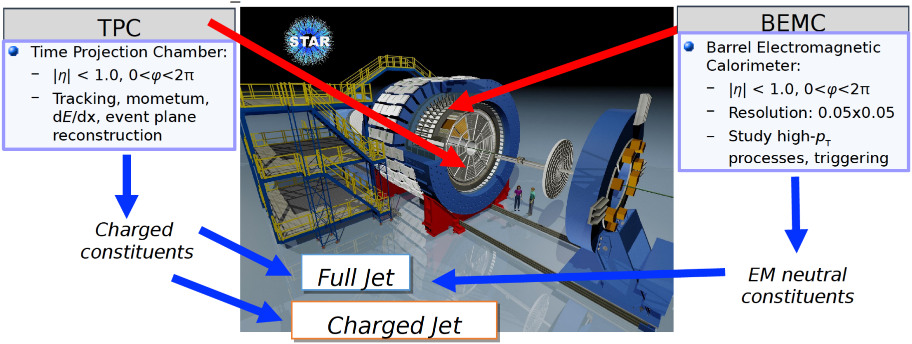
- Angularities are **IRC safe** (for $\kappa = 1$), **tunable** in their sensitivity to different aspects of jet fragmentation, probe the modification of radiation pattern of jets in medium
- These measurements will help **constrain theoretical descriptions** of jet-medium interactions
- **Generalized angularities measured at LHC, but lower energies at RHIC**→ opportunity to further study medium effects using jets from phase space region **complementary to LHC**

Solenoidal Tracker At RHIC (STAR)



TPC

- Time Projection Chamber:
  - $|\eta| < 1.0$, $0<\varphi<2\pi$
  - Tracking, mometum, dE/dx, event plane reconstruction

Charged constituents

BEMC

- Barrel Electromagnetic Calorimeter:
  - $|\eta| < 1.0$, $0<\varphi<2\pi$
  - Resolution: 0.05x0.05
  - Study high-p_T processes, triggering

EM neutral constituents

Full Jet

Charged Jet

- The Time Projection Chamber (TPC) used to detect charged tracks
- The Barrel Electomagnetic Calorimeter (BEMC) measures energy deposited by electomagnetic constituents

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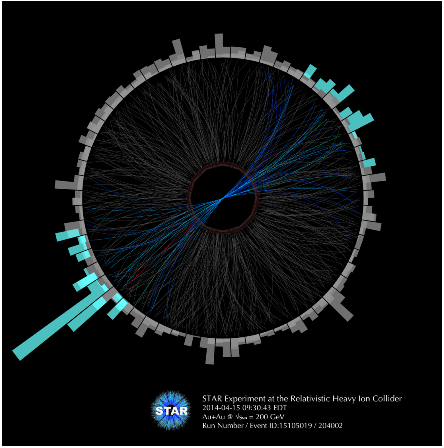
Dataset and Simulations

- **System:** Au+Au @ $\sqrt{s_{\mathrm{NN}}} = 200\mathrm{GeV}$ (2014)
- **High Tower (HT) triggered** events ($\exists$ tower with $E_{\mathrm{tower}} \geqslant 4$ GeV) to enhance jet signal
- **Embedding simulation:**
- GEN: PYTHIA-6 Perugia-STAR dijet events (arXiv:1907.11233)
- RECO: PYTHIA-6 Perugia-STAR + GEANT3 + STAR Au+Au Run14 MinBias



Jet Reconstruction

- Jets reconstructed by clustering **TPC tracks** and **calorimeter energy depositions** after **full hadronic correction** using the **anti-k_T algorithm** with a **resolution parameter** $R = 0.4$ and using the FASTJET library [1]
- **Hard-core constituent cut** of 2 GeV was applied on tracks and tower depositions for jet reconstruction i.e., $p_{\mathrm{T,trk}}(E_{\mathrm{T,tower}}/c) \geq 2$ GeV/c
- Jet area > 0.4 to **suppress fake jets**
- $N_{con,charged} \geq 2$ for non-trivial values of observables
- These selections **bias** the jet sample to the **hardest fragmented** (**quark-like**) jets produced in an event

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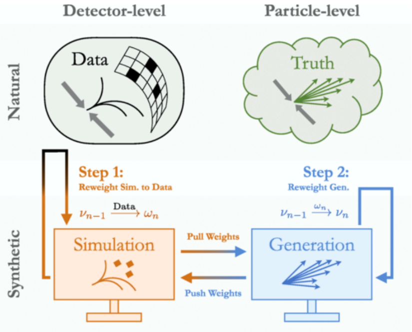
[1] M. Cacciari, G. Salam, G. Soyez, JHEP 04 (2008) 06

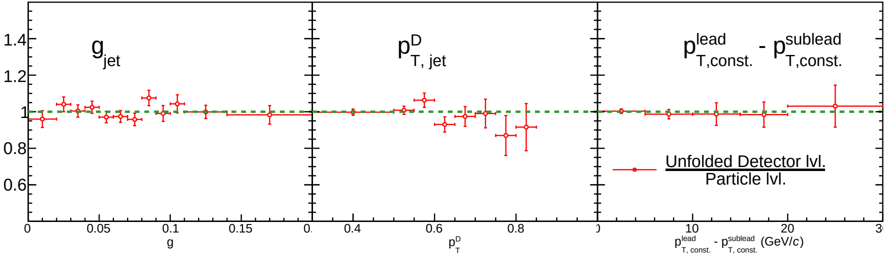
Uncovering the truth - MultiFold



- Removing background and detector effects by mapping RECO → GEN using embedding simulation
- Simultaneously unfolding $p_{\mathrm{T,jet}}$,η_{jet}, ϕ_{jet}, $N_{con,charged}$, p_T^D, LeSub and Girth through Multifolding (Phys. Rev. Lett. 124, 182001)
- Multifolding uses Dense Neural Networks (DNNs) trained on full embedding sample at the detector level and the generator level
- DNNs were implemented using Energyflow package (JHEP 04 (2018) 013)

Closure test for 0-20% centrality

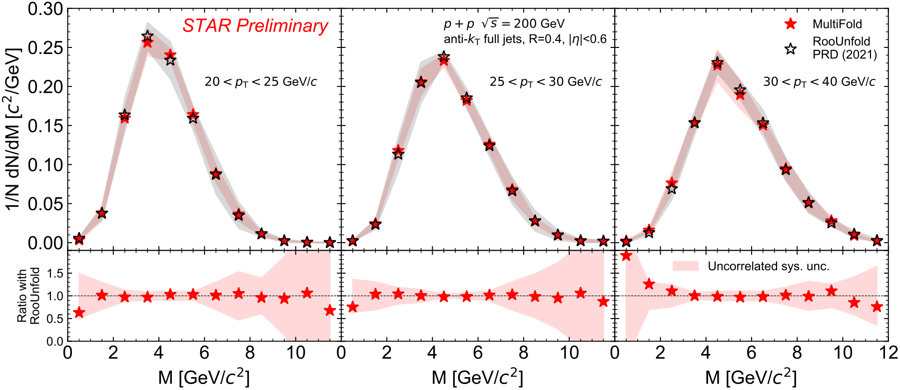
Multifolding implementation closes well for central and peripheral bins



+ 4 more observables for a net **7D unfolding**

Multifold vs RooUnfold

Multifold is shown to compare well with RooUnfold for p+p collisions at $\sqrt{s} = 200$ GeV in previous jet-mass measurements



Y. Song (for the STAR Collaboration) arXiv:2307.07718

Comparisions between the two methods ongoing for Au+Au collisions

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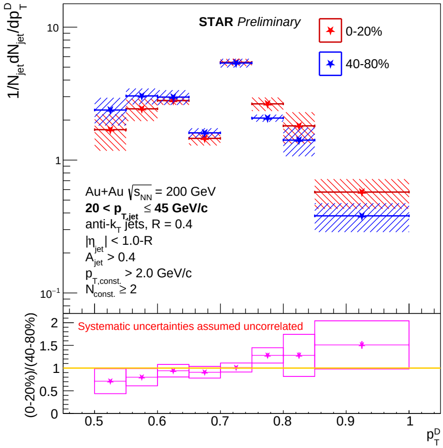
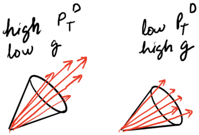
Results - p_T^D

$$p_T^D = \frac{\sqrt{\sum_{\mathrm{trk}\in\mathrm{jet}} (p_{\mathrm{T,trk}})^2}}{\sum_{\mathrm{trk}\in\mathrm{jet}} p_{\mathrm{T,trk}}}$$





- p_T^D consistent within systematic uncertainties between central, peripheral collisions

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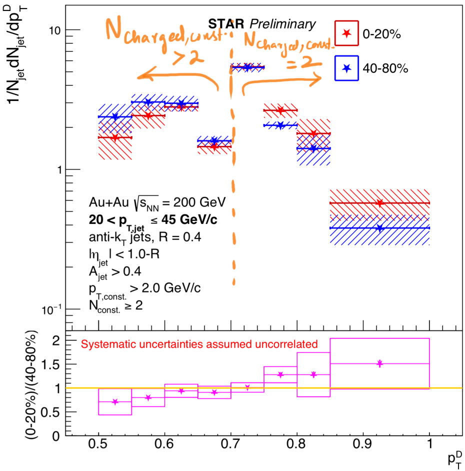

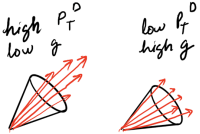

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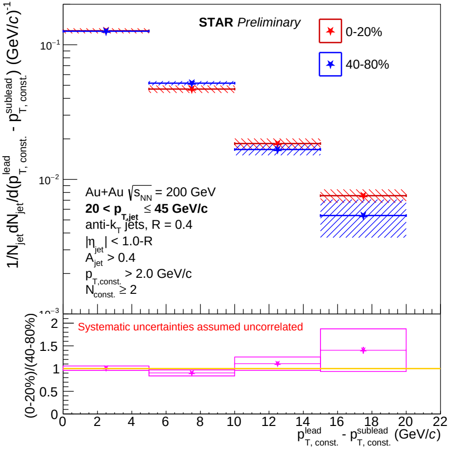
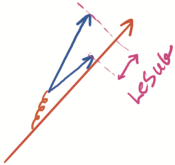
Results - LeSub

$$\text{LeSub} = p_{\mathrm{T,const.}}^{\mathrm{lead}} - p_{\mathrm{T,const.}}^{\mathrm{sublead}}$$

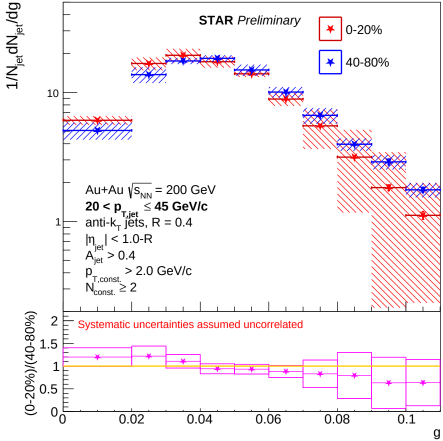


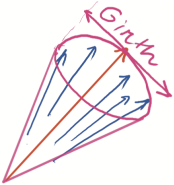


- p_T^D, LeSub consistent within systematic uncertainties between central, peripheral collisions

Results - Girth

$$g = \frac{\sum_{\mathrm{trk}\in\mathrm{jet}} p_{\mathrm{T,trk}}\Delta R}{p_{\mathrm{T,jet}}}$$





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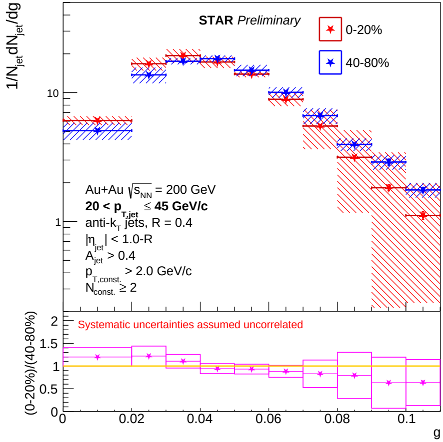

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Further analysis ongoing to improve systematic uncertaities

Conclusions and Outlook

- **First fully corrected** observations of p_T^D, Girth and LeSub from **hard-core jets** in heavy-ion collisions at RHIC presented

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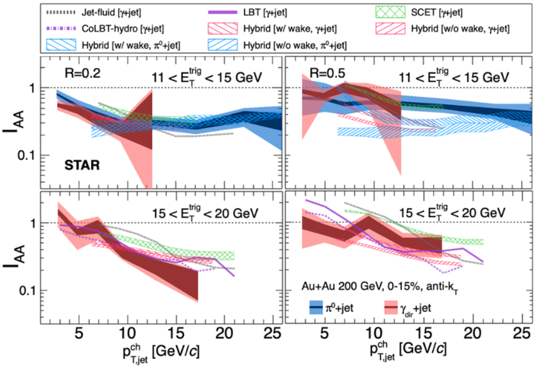
- Central and Peripheral collisions are compared by taking ratios with systematic uncertainties assumed to be uncorrelated
  - **Room to improve** by studying systematic uncertainties in more detail
- Further investigation with simultaneous comparisions to MC simulations (e.g. JEWEL)

γ+jet and π^0 + jet measurements at STAR

How does the jet-energy move around during propagation in medium?

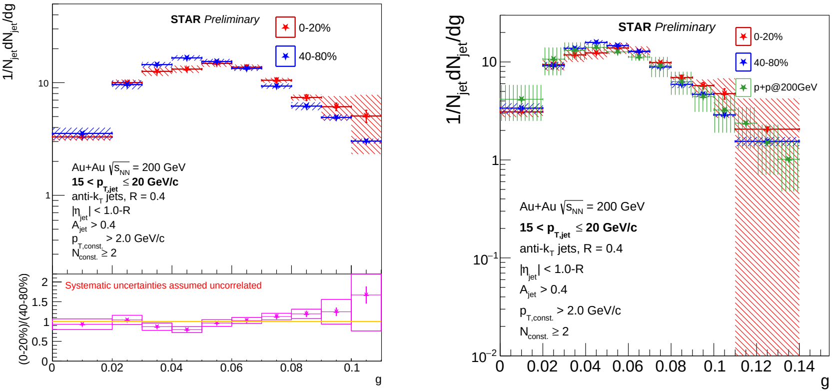


- Significant medium-induced recoil jet yield suppression for R = 0.2 than for 0.5
- Evidence of significant medium- induced intra-jet broadening at angular scales less than 0.5 radians

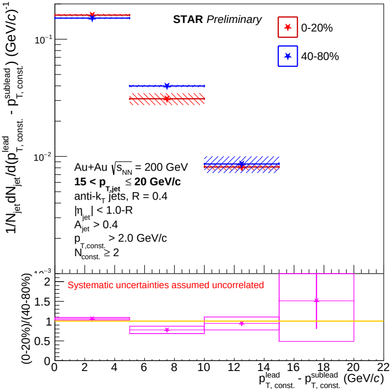
Short paper arXiv: 2309.00156 [nucl-ex]
Long paper arXiv: 2309.00145 [nucl-ex]

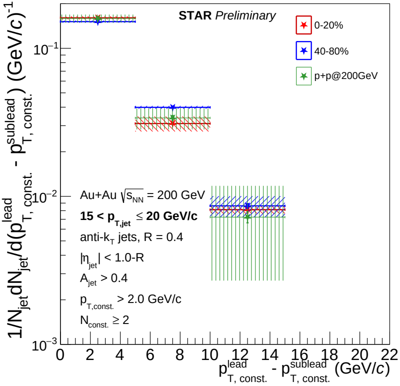
BACK UP...

Girth, $15 < p_{T,jet} < 20$ GeV/c

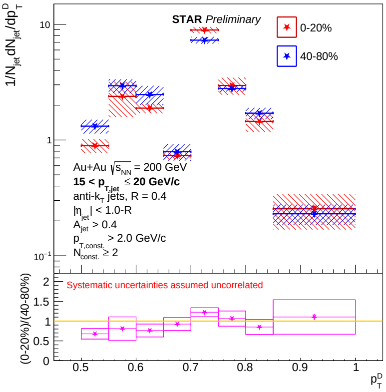


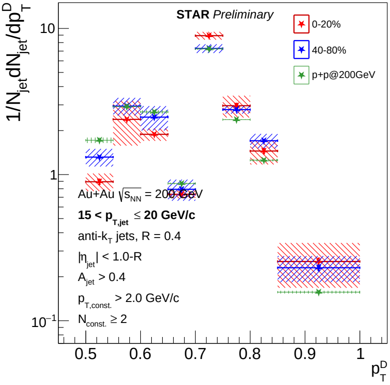
LeSub, $15 < p_{T,jet} < 20$ GeV/c



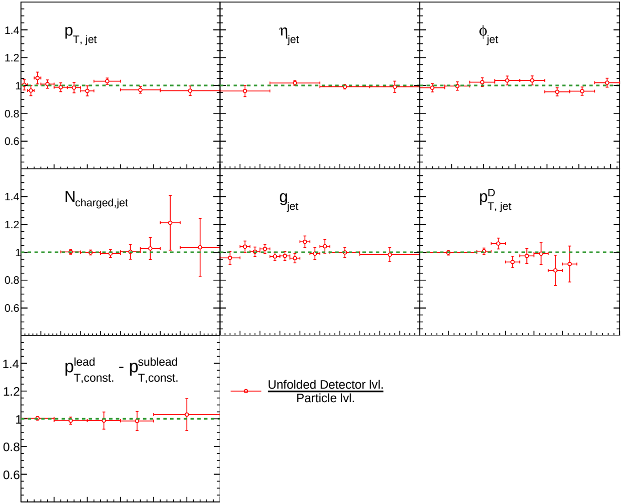


PtD, $15 < p_{T,jet} < 20$ GeV/c

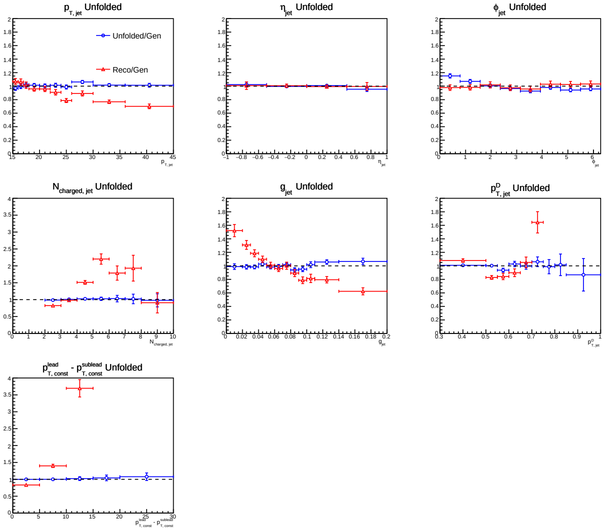




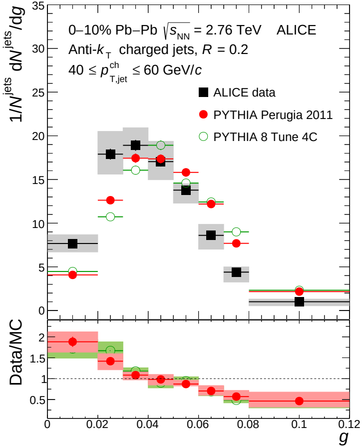
Closure 0-20%

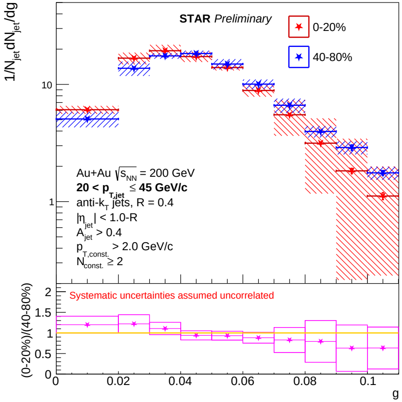

$p_{T,\text{ jet}}$
η_{jet}
ϕ_{jet}
$N_{\text{charged,jet}}$
g_{jet}
$p^{D}_{T,\text{ jet}}$
$p^{\text{lead}}_{T,\text{const.}} - p^{\text{sublead}}_{T,\text{const.}}$
1.4
1.2
1
0.8
0.6
Unfolded Detector lvl. / Particle lvl.

Closure 40-80%



Comparision with ALICE





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