Jet shapes in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV

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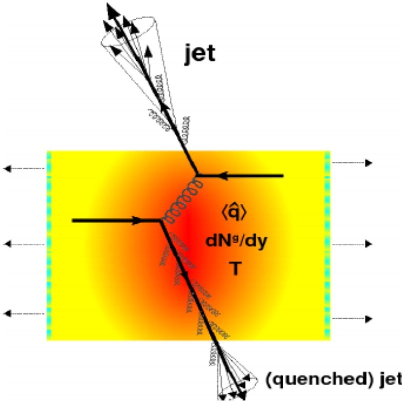
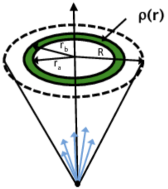
Introduction

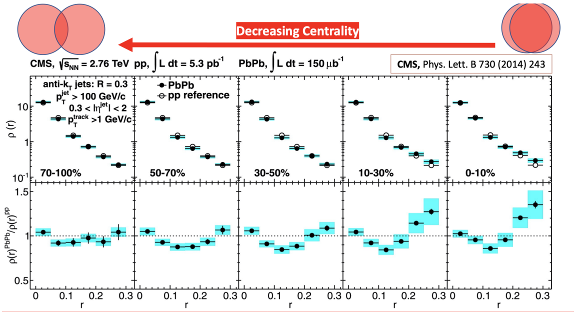
- Jets are collimated sprays of particles from hard interactions between pairs of partons.
- These interactions happen at the early stages of a heavy ion collision.
- Jets travel through the Quark Gluon Plasma (QGP) medium and get modified relative to those in vaccum.
- Observables related to distribution of energy inside jets are important probes to study QGP.



Differential jet shape (ρ)

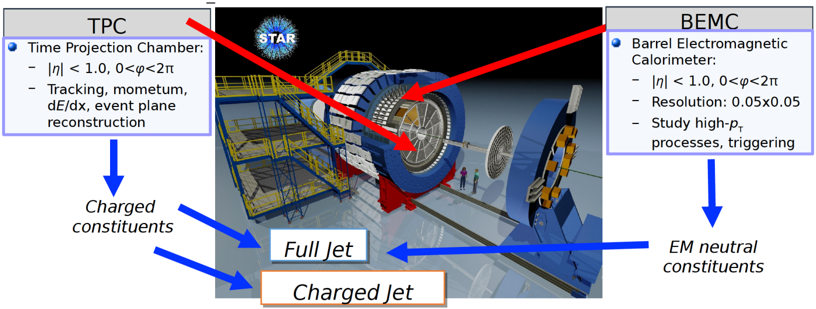
- $\rho(r) = \frac{1}{\delta r}\frac{1}{N_{\text{jet}}}\sum_{\text{jet}} \frac{\sum_{\text{trk}\in(r-\delta r/2, r+\delta r/2)} p_{\mathrm{T,track}}}{p_{\mathrm{T,jet}}}$
  $r = \sqrt{(\varphi_{\text{track}} - \varphi_{\text{jet}})^2 + (\eta_{\text{track}} - \eta_{\text{jet}})^2}$ and
  δr is the width of radial bins.
- $\rho(r)$ = charged momentum fraction as a function of radial distance from the jet axis.





- LHC results show more modification in central events relative to *pp* baseline compared to peripheral events
- Jet energy redistributed inside the jet-cone in presence of QGP

Solenoidal Tracker At RHIC (STAR)



- The Time Projection Chamber (TPC) is used for detecting charged particle tracks and particle identification.
- The Barrel Electomagnetic Calorimeter (BEMC) gives us the energy deposited by neutral electomagnetic constituents, e.g. π^0, γ, etc.

Events, tracks and jets

Event Selection:

- **System:** Au+Au @ $\sqrt{s_{\mathrm{NN}}} = 200$GeV (2014)
- Minimum bias + High tower triggered event
- Centrality $\in [20, 50]\%$
- $|z_{\mathrm{vtx}}| < 28$ cm

Track selection:

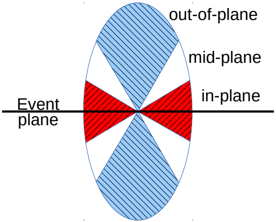
- $1.0 < p_{\mathrm{T,track}} < 30.0$ GeV/c

Jet Selection:

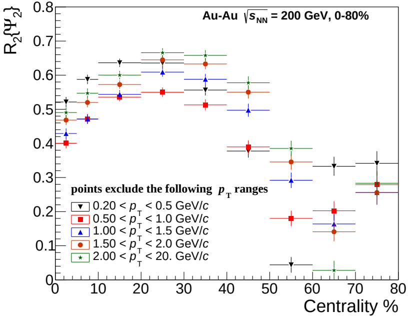
- We use anti-k_{T} jets of radius 0.4, with a **hard-core** requirement of $p_{\mathrm{T,track}}$ ($E_{\mathrm{T,tower}}$) > 2.0 GeV/c for the constituents to reduce combinatorial background. (*STAR, Phys. Rev. Lett. 119 (2017) 062301*)

Event plane reconstruction

- Azimuthal orientation + Centrality $\iff$ Path length dependence.
- Event plane (EP) estimated using 2nd-order azimuthal correlations among TPC tracks with $0.2 < p_{\mathrm{T,track}} < 2.0$ GeV/c (*STAR, Phys. Rev. C89 (2014) 041901*)
- Based on the azimuthal orientation of the jet axis w.r.t. the event plane:
  - In-plane: $0^\circ \leq |\varphi_{\text{jet}} - \Psi_{\mathrm{EP}}| < 30^\circ$
  - Mid-plane: $30^\circ \leq |\varphi_{\text{jet}} - \Psi_{\mathrm{EP}}| < 60^\circ$
  - Out-of-plane: $60^\circ \leq |\varphi_{\text{jet}} - \Psi_{\mathrm{EP}}| < 90^\circ$



Event plane resolution



- Due to finite multiplicity and detector effects we have disparity between the calculated event plane and underlying symmetry plane.
- $R_n =< \cos(n(\psi_{n,true} - \psi_{n,reco})) >$
- $R_2\{\Psi_2\}$ calculated using modified reaction-plane (MRP) method, an improvement over typical EP measurements with the TPC and BBC. (*STAR, Phys. Rev. C89 (2014) 041901*)
- Best resolution in 20-40% centrality.

Results from data

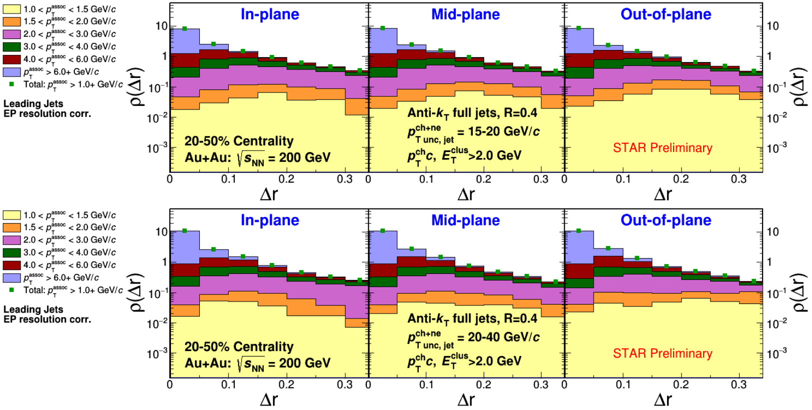


Figure: *Top plot is in $p_{\mathrm{T,jet}}$ selection of 15-20 GeV/c and the bottom plot is in 20-40 GeV/c*

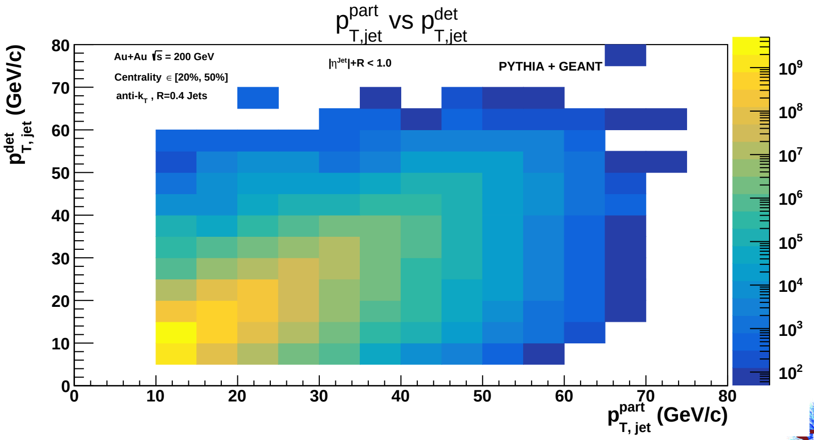
- Low p_{T} particles are relatively homogenous in a jet, while the high p_{T} particles are concentrated closer to the jet axis.
- Low p_{T} particles are pushed to the edge of the jet as we go from in-plane to out-of-plane jets. This hints at path length dependence.

Corrections

- Background subtraction in jet-shape measurement is done using a mixed-event technique. (*STAR, Phys. Rev. C 96 (2017) 024905*)
- In addition to the background, we also need to correct for the smearing of jet observables due to detector effects.
- To study the detector effects on our jet shape observables, we generate PYTHIA-6 events and run through a GEANT-3 simulation of the STAR detector
- To include the effects of the run conditions, these simulated PYTHIA-6 + GEANT-3 events are embedded into real data (Minimum bias Au+Au events)

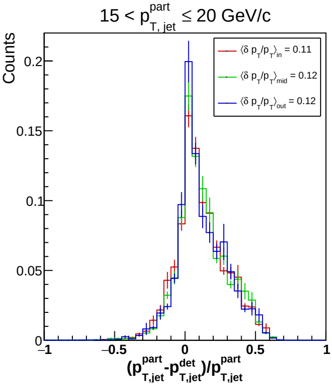
Response matrix

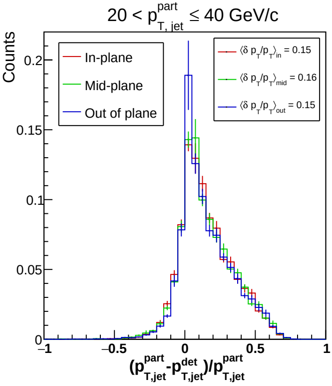
Comparisions are done between the jets from the input PYTHIA-6 tracks (particle-level jets) and the jets from the tracks reconstructed by GEANT (detector-level jets).



$p_{\mathrm{T,jet}}$ resolution

We see an average of 11-16% resolution of $p_{\mathrm{T,jet}}$ and it doesn't vary significantly as a function of event plane orientation in both $p_{\mathrm{T,jet}}^{\mathrm{part}}$ selections.





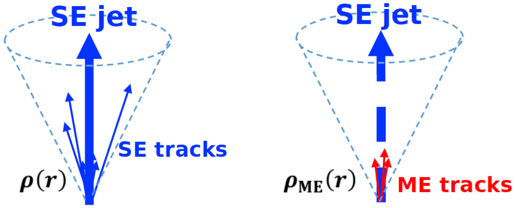
Summary and outlook

- Background corrected, event plane dependent differential jet shape functions in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV are shown differentially in $p_{\mathrm{T}}^{\mathrm{assoc}}$ bins.
- We see a concentration of high p_{T} particles closer to the jet axis and an enhancement of low p_{T} particles further from the jet axis in out-of-plane jets relative to the in-plane jets.
- No event plane dependence is observed in $p_{\mathrm{T,jet}}$ resolution in any $p_{\mathrm{T,jet}}^{\mathrm{part}}$ selection.
- To finalize the jet-shape study corrections on $p_{\mathrm{T,jet}}$ and r will be performed.

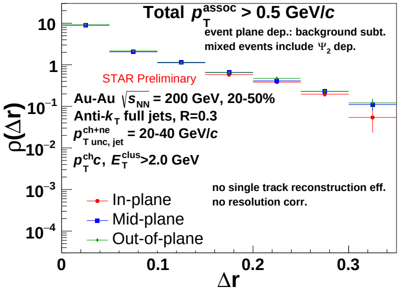
BACK-UP

Mixed events background subtraction

- Background contributions in $\rho(r)$ are estimated by placing same-event jets ($p_{T,jet}$ and jet axis) into mixed-events.
- Background jet shape, $\rho_{ME}(r)$, is calculated and then subtracted from $\rho(r)$, accordingly



Results from data



- Figure to the left shows differential jet shape measurement summed over all p_T^{assoc} bins.
- Dependence with jet orientation w.r.t. to the event plane is shown.