D^0-Hadron Correlations in Azimuth and Pseudorapidity in Au+Au Collisions at $\sqrt{s_{NN}} = 200\ GeV$

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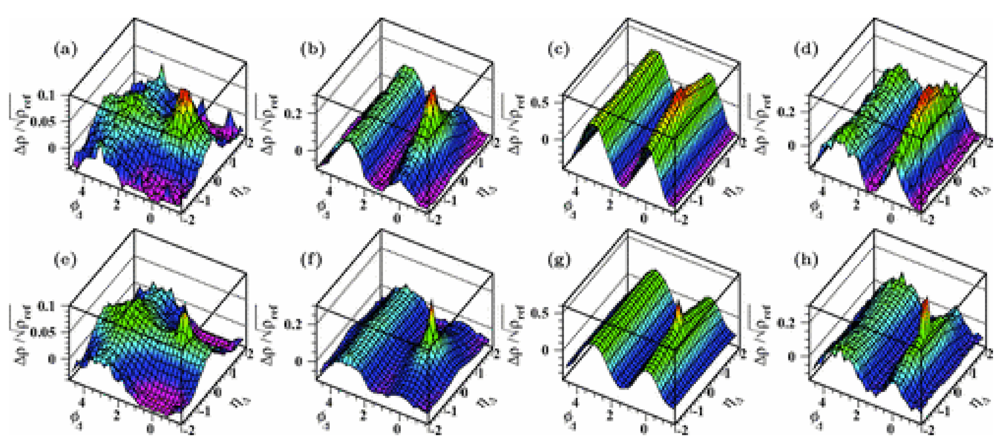
Abstract

Two-particle correlations have been shown to be sensitive to the dynamics of heavy-ion collisions. In particular, angular correlations on relative azimuth and pseudorapidity provide novel information about jet-like and collective behavior in these collisions. They also provide independent measures of important physical quantities, such as the second-order harmonic coefficient (v_2), by separating the quadrupole contribution (related to v_2) from η-dependent contributions such as those coming from jets and jet quenching. These correlations have already been measured for both unidentified and identified light-flavor hadrons. Heavy flavor (HF) quarks (e.g. charm, bottom) are new and ideal probes of these dynamics because they are predominantly formed in the early stage of the collisions, and therefore can be used to study the entire evolution of the hot and dense medium formed in such collisions.

We present here measurements of D^0-hadron angular correlations in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from the Solenoidal Tracker at RHIC (STAR) experiment. The D^0 meson is reconstructed via its hadronic decay channel using the Heavy Flavor Tracker (HFT). The correlation structures are shown as a function of both centrality and D^0 meson transverse momentum, and compared to the correlations for light-flavor hadrons. Using these measurements we will be able to extract physical quantities, such as v_2, and compare these values to model predictions and to results from other experimental methods.

Introduction and Motivation

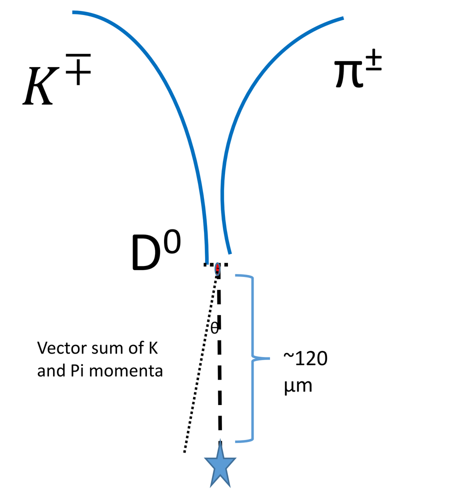
- Correlations allow us to probe the dynamics of heavy-ion collisions.
- Measuring correlations on 2D angular coordinates allows the distinct components related to the jet-like behavior and the quadrupole associated with anisotropy parameter v_2 to be clearly separated, as in the nonidentified di-hadron correlations shown below.
- By comparing measured light-flavor particle correlations with those using heavy flavor particles, we may gain insights into the different behaviors of light and heavy quarks in the medium formed by heavy-ion collisions.

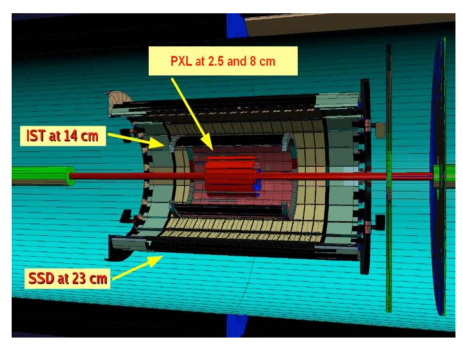


Two-dimensional charge-independent angular correlations $\Delta\rho/\sqrt{\rho_{ref}}$ on relative coordinates $\Delta\eta, \Delta\varphi$ with $p_T > 0.15$ GeV/c for Au-Au collisions at $\sqrt{s_{NN}} = 200$ and 62 GeV (upper and lower rows respectively). Total centrality bins are (from left to right) 84-93%, 55-64%, 18-28% and 0-5% [1].

D^0 Reconstruction

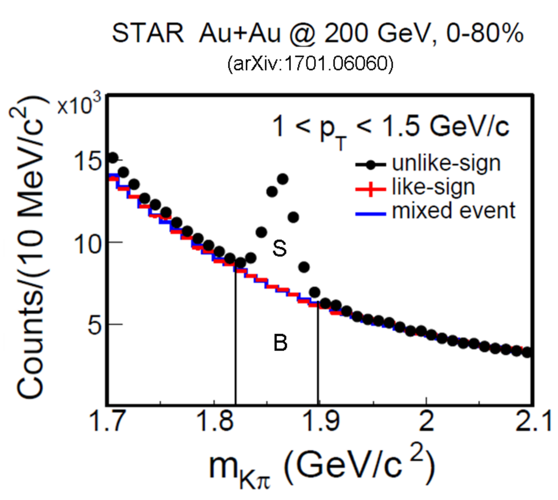
- The D^0 mesons are reconstructed via their hadronic decay channel $D^0 \rightarrow K^{\mp}\pi^{\pm}$.
- This kind of reconstruction would be very challenging using only the STAR Time Projection Chamber (TPC), due to large combinatorial background.
- With the much improved track pointing resolution afforded by the STAR Heavy Flavor Tracker (HFT), topological cuts on the scale of tens of microns can be achieved, resulting in a large reduction in combinatorial background.





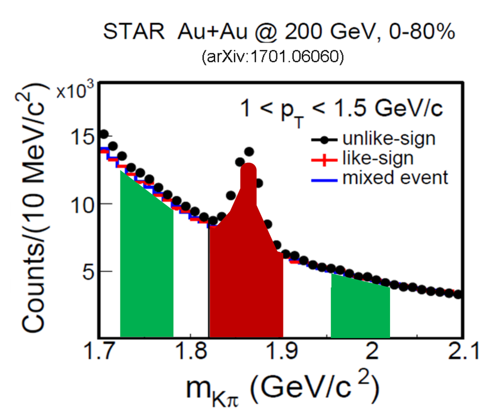
Extracting D^0 Yields and Correlation Scale Factors from Invariant Mass Distributions

- The topological cuts are optimized and the D^0-meson signal (S) yield and background (B) are estimated.
- S and B are found by first subtracting a normalized like-sign invariant mass spectrum from the unlike-sign distribution, and then fitting the residual background with a polynomial function to remove the remainder.
- S and B are used to weight the separate correlations measured for Kπ "parents" in the D^0 and sideband mass ranges, paired with other, non-identified charged hadrons.



Method of Measuring D^0-hadron Correlations

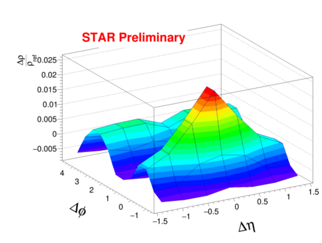
- Pair distributions (ρ_{sib}) are filled on relative angular coordinates ($\Delta\eta \equiv \eta_{D^0} - \eta_h, \Delta\varphi \equiv \varphi_{D^0} - \varphi_h$) formed from unlike-sign Kπ "parents" in the D^0 signal range with other charged hadrons in the same event. The distributions include true D^0-hadron correlations along with background correlations from random Kπ "parents" (denoted [Kπ] in the equation).
- The latter are approximately removed by subtracting the pair distribution using unlike-sign Kπ pairs in the side-band regions with appropriate scaling.
- Detector acceptance is corrected for using mixed-event pair distributions, ρ_{mix}, (Kπ "parent" from one event plus hadrons from different events) for both the signal and sideband regions, scaled by the total number of pairs (N_{sib}, N_{mix}) in those ranges, where $\rho_{ref} = \frac{N_{sib}}{N_{mix}}\rho_{mix}$.
- D^0 and charged hadron reconstruction inefficiencies are accounted for using pair weights.
- Correlation quantities $\frac{\Delta\rho}{\rho_{ref}} = \frac{\rho_{sib} - \rho_{ref}}{\rho_{ref}}$ from the D^0 signal and sidebands are scaled and combined, resulting in the per final-state pair D^0-hadron 2D angular correlations.

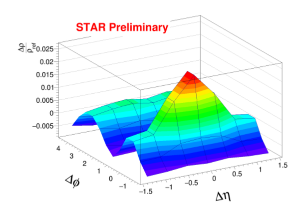


The signal region in red (above) is used to form the signal pairs. The sidebands highlighted in green are used to generate pairs for background estimation.

$$\frac{\Delta\rho^{D^0}}{\rho_{ref}^{D^0}} = \frac{\rho_{ref}^{signal}}{\rho_{ref}^{D^0}}\left[\frac{\Delta\rho^{signal}}{\rho_{ref}^{signal}} - \frac{\rho_{ref}^{[k\pi]}}{\rho_{ref}^{signal}}\frac{\Delta\rho^{[k\pi]}}{\rho_{ref}^{[k\pi]}}\right]$$

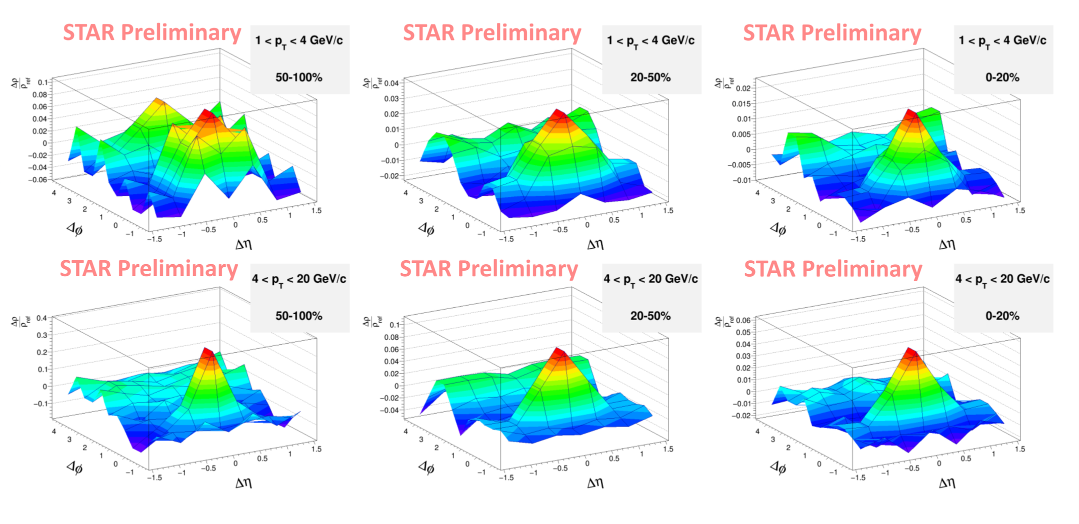
$$\frac{S+B}{S} \qquad \frac{B}{S+B}$$





Corrected D^0-hadron Correlations

- With the RHIC run 14 statistics we are able to measure statistically significant correlation structures for two D^0 p_T bins and three centralities.
- We observe jet-like structure (peak) at small opening angles as well as distinct, harmonic components cos(Δφ) and cos(2Δφ) analogous to those observed in di-hadron correlations [1].
- Interestingly, the elongation of the same-side jet peak along Δη in more-central collisions seen in nonidentified di-hadron correlations with $p_T > 0.15$ GeV/c, is not evident in these data with higher p_T cuts on the "trigger" particle (D^0).



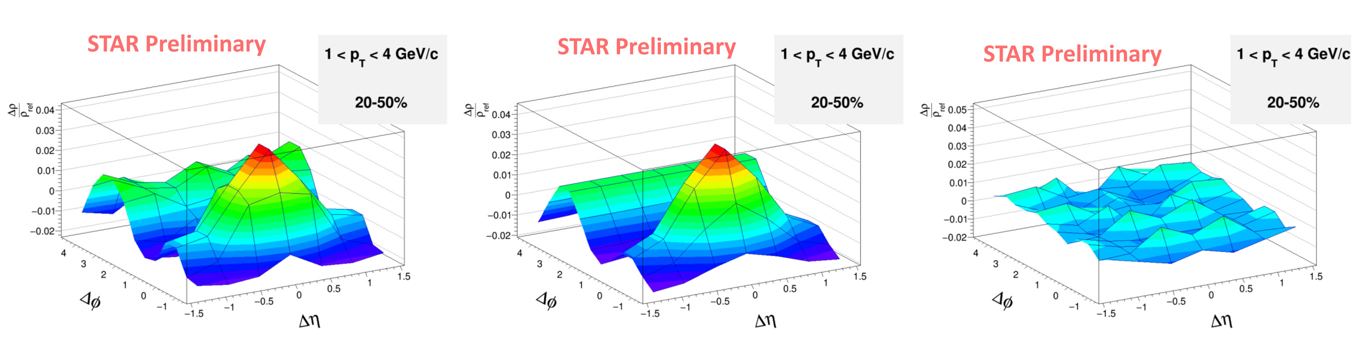
The correlations are arranged in 2 transverse momentum bins, with 1 GeV/c < p_T < 4 GeV/c along the top row and 4 GeV/c < p_T < 20 GeV/c along the bottom. The centrality bins increase from left (peripheral) to right (central). Data are symmetrized on $\pm\Delta\eta$ and $\pm\Delta\varphi$.

Fitting Procedure

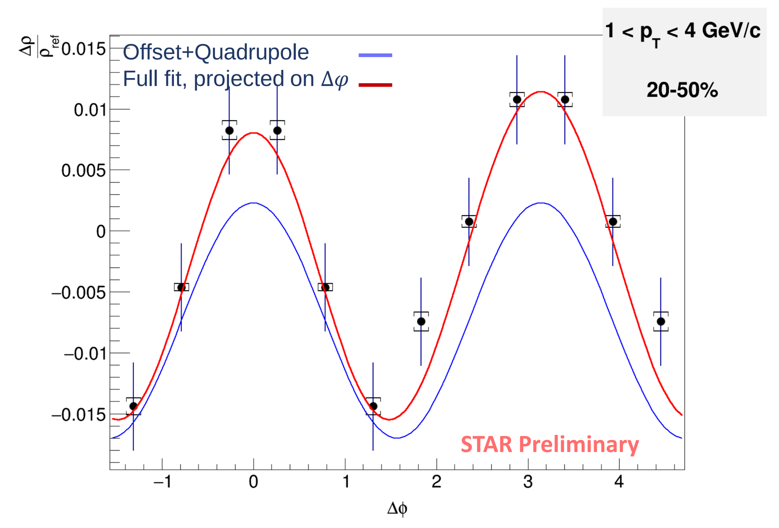
- The corrected correlation distributions are fitted with a functional form consisting of a constant offset term, a dipole term, a quadrupole term and a 2D Gaussian.

$$Fit(\Delta\eta, \Delta\varphi) = A_0 + A_D\cos\Delta\varphi + 2A_Q\cos 2\Delta\varphi + A_1 e^{-\frac{1}{2}\left(\frac{\Delta\varphi}{\sigma_\varphi}\right)^2} e^{-\frac{1}{2}\left(\frac{\Delta\eta}{\sigma_\eta}\right)^2}$$

- The 2D Gaussian term describes the jet-like peak at $\Delta\eta = \Delta\varphi = 0$; the dipole describes the broad away-side correlation.
- The parameter A_Q, which corresponds to the quadrupole component, is related to v_2 by: $A_Q = v_2^{D^0} v_2^{h^{\pm}}$.



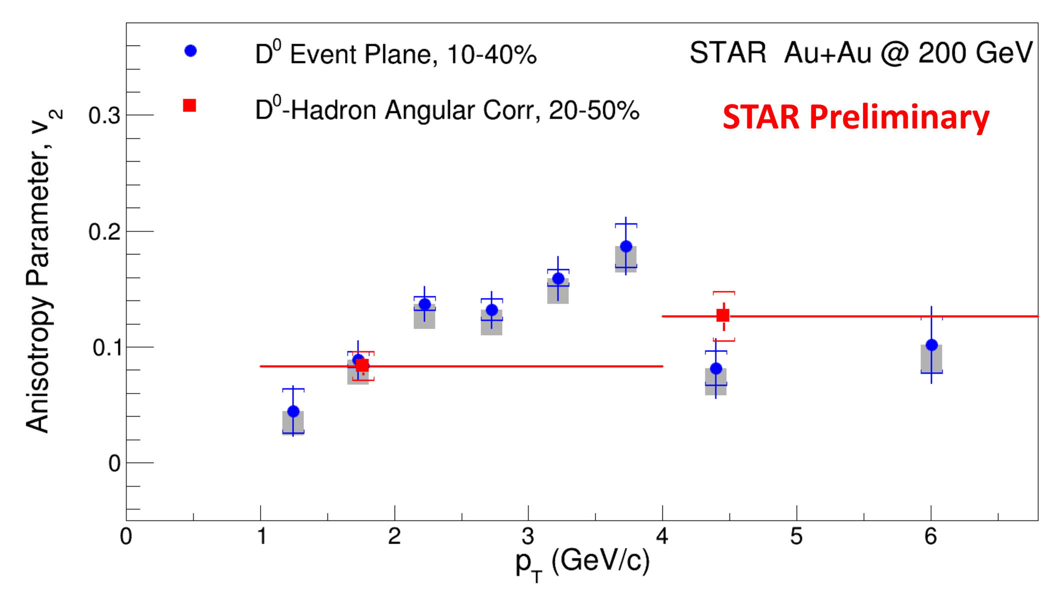
This model fit works well for the mid p_T region (the example above); the same-side peak term (2D Gaussian) needs to be modified for the higher p_T range. The left-most panel is the measured correlation, the middle panel illustrates the function fitted to the data, and the right-most panel is the residual difference between the fit function and the data.



The above figure is a projection of the correlation on Δφ. This figure also includes the quadrupole term from the fit, and the full fit function projected on Δφ. Data points include statistical (vertical lines) and systematic (open brackets) uncertainties.

Conclusions

- The STAR Collaboration reports the first measurements of D^0-hadron 2D angular correlations for Au+Au collisions at $\sqrt{s_{NN}} = 200\ GeV$.
- The data show distinct correlation structures related to jets and v_2.
- These preliminary v_2 measurements (below) are consistent with STAR's recent event-plane results [3].
- The same-side jet peak does not broaden on Δη in more-central collisions as dramatically as was seen in similar nonidentified di-hadron correlations (see figure in motivation pane) [1].
- With the 200 GeV Au+Au data recorded in 2016, we will have enough statistics to further subdivide the data with respect to centrality and p_t in order to better study the evolution of these heavy-flavor correlation structures.



References

[1] G. Agakishiev *et al.* (STAR) 2012, *Phys.Rev.* **C86** 064902
[2] STAR HFT Technical Design Report (STAR)
[3] L. Adamczyk *et al.* (STAR) 2016, arXiv:1701.06060v1 [nucl-ex]