Measurement of femtoscopic correlation function between D^0 mesons and charged hadrons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at STAR

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Abstract

Heavy quarks, like charm quarks, are produced early in relativistic heavy-ion collisions and probe all stages of the evolution of the created medium – the Quark-Gluons Plasma (QGP). Femtoscopic correlations are sensitive to the final state interactions and the extent of the region from which correlated particles are emitted. A study of such correlations between charmed mesons and identified hadrons could shed light on their interactions in the hadronic phase and the interaction of charm quarks with the bulk partons. We present an ongoing study of femtoscopic correlations of D^0-π, D^0-K and D^0-proton pairs at mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV using data taken in the year 2014 by the STAR experiment.

I. Motivation

- Charm-hadron correlation can provide information about emission source's length and area of homogeneity

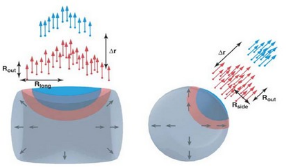


Figure 1: Area of homogeneity

- This length ~ extent of interaction between charm and light quarks in a medium
- Expected source size dependence of correlation function, C(k*)

M. Albaladejo ,J. Nieves, E. Ruiz Arriola, arXiv:2304.03107v1

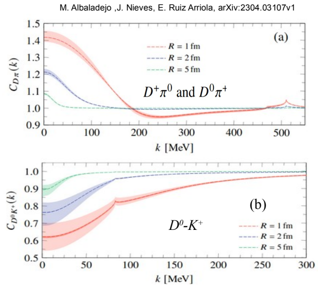


Figure 2: Expected shape of correlation function for (a) attractive and (b) repulsive potential in the vacuum medium

II. Methodology

- Femtoscopic correlation is measured as a function of the reduced momentum difference (k*) of two particles in rest frame
  - From theory, $C(\vec{k}^*) = \int S(\vec{r}^*) \left|\Psi(\vec{k}^*, \vec{r}^*)\right|^2 d^3r^*$,

    where $S(\vec{r}^*)$ → source emission function,
    $\Psi(\vec{k}^*, \vec{r}^*)$ → pair wave function,
    $\vec{r}^*$ → relative separation vector

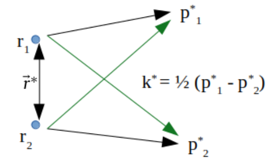


Figure 3: Femtoscopic correlation and k* in pair-rest frame

  - As a function of momentum difference, $C(\vec{k}^*) = \mathcal{N}\frac{A(\vec{k}^*)}{B(\vec{k}^*)}$,

    where $A(\vec{k}^*)$ and $B(\vec{k}^*)$ → k* distribution, respectively, for correlated and uncorrelated pairs in event ensemble, $\mathcal{N}$ → normalization factor
  - *Event mixing* technique to calculate uncorrelated pairs k* using the real events

III. D-hadron femtoscopy

- $D^{\pm}$-π correlation: deviation from only Coulomb interaction (Fig. 4)
- ALICE data suggest small role of D-hadronic re-scattering in heavy-ion collisions
- D^0 v_2 (Fig. 5) and R_{AA} → consistent with model predictions
- D-hadron correlation data from heavy ion collisions → to constrain theoretical models

QM 2022: https://indico.cern.ch/event/895086/contributions/4715876/

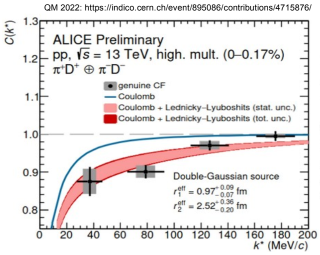


Figure:4: Correlation function for $D^{+/-}$-π

Phys. Rev. Lett. 118 (2017) 212301

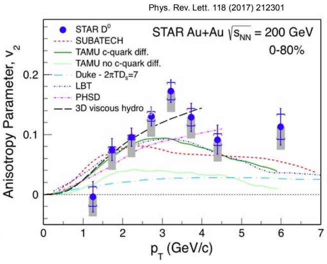


Figure 5: D^0 elliptic flow (v_2) vs p_T

IV. D^0 reconstruction at STAR

STAR: **S**olenoidal **T**racker **A**t **R**HIC

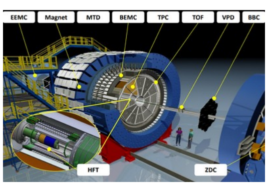


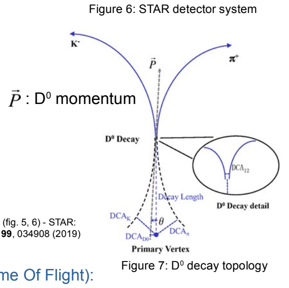
Figure 6: STAR detector system

- HFT (Heavy Flavor Tracker):
  - Directly tracks the decay products of hadrons comprised of charm and bottom quarks
  - Topologically reconstructed secondary D^0 decay vertices

Topological variables:

- Decay length - distance between decay vertex and primary vertex (PV)
- Distance of Closest Approach (DCA) between: a) K^- & π^+ - DCA_{12}
  b) π^+ & PV - DCA_{π}
  c) K^- & PV - DCA_K
  d) D^0 & PV - DCA_{D0}
- θ - angle between $\vec{P}$ & decay length

$\vec{P}$: D^0 momentum



Ref. (fig. 5, 6) - STAR: PRC **99**, 034908 (2019)

Figure 7: D^0 decay topology

- TPC (Time Projection chamber) & TOF (Time Of Flight):

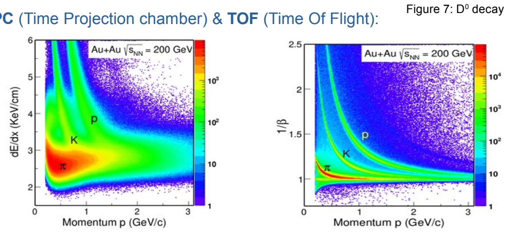


Figure 8: Particle identification (PID) using TPC (left) and TOF (right)

- PID via combined measurement of the ionization energy loss in TPC and the time-of-flight in TOF

V. Analysis & Outcomes

- D^0 invariant mass range: 1.82 – 1.91 GeV/c^2
- Purity of D^0 = signal / (signal + background); signal → Gaussian fit, background → exponential fit

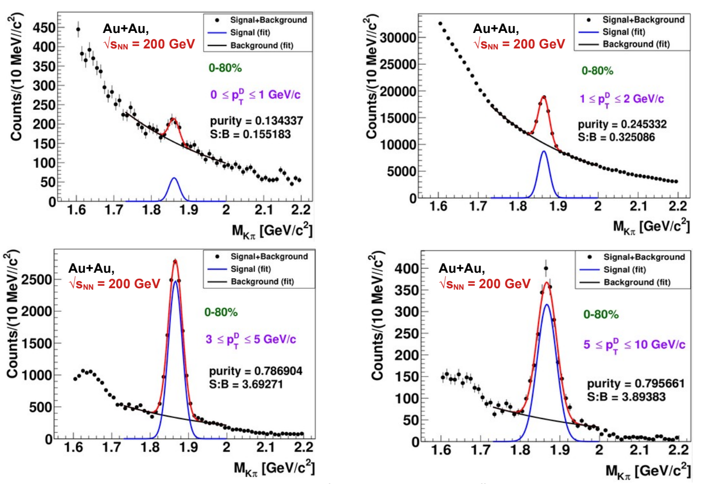


Figure 9: Invariant mass distributions of opposite sign K-π pairs in different p_T intervals

- D^0 signal is predominant over combinatorial background at higher p_T and background is dominant over D^0 signal for p_T < 1 GeV/c

- TPC detector effects corrections:
  - Possible correlation between D^0 candidates and their daughters were removed
  - More than 51% of maximum possible number of TPC hits were required to avoid *track splitting*
  - To avoid *track merging*:
    a) δr(i) < mean TPC distance separation → 'merged' hits, where δr(i) - distance between TPC hits of two tracks
    b) Pair of tracks with fraction of merged hits > 5% were removed as 'merged tracks'

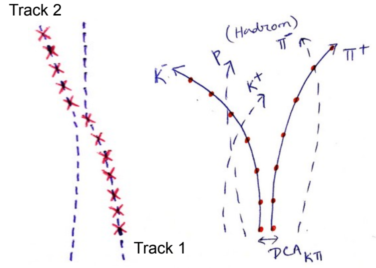


Figure 10: Track splitting (left) & Track merging (right)

VI. Summary

- What is the effect of hot dense QCD medium on the D^0-hadron correlation functions?
- In heavy-ion collisions, the contributions of QGP and hadronic phase to D meson-hadron correlation functions are not well studied
- First measurement of D^0-hadron femtoscopy in Au+Au collisions at STAR is ongoing
- Plan to extract interaction parameters, like emission source size, using Lednický–Lyuboshitz model
- This study can provide additional input to the interactions of charm quarks within the QGP medium
- Theoretical inputs are welcome that include details of charm interactions with the QGP for the interpretation of the results

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