Femtoscopic correlations of D^0 mesons with identified hadrons in Au-Au collisions at √sNN = 200 GeV at STAR

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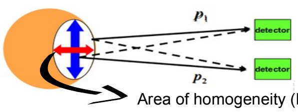
Abstract

Heavy quarks, like charm quarks, are produced early in the relativistic heavy-ion collisions and probe all stages of the evolution of the created medium – the Quark Gluons Plasma. Two-particle correlations at low relative momentum (the femtoscopic correlations) are sensitive to the interactions in the final state and the extent of the region from which correlated particles are emitted (so-called region of homogeneity). A study of such correlations between charmed mesons and identified hadrons could shed light on their interactions in the hadronic phase and interaction of charm quarks with the bulk partons.

We will present a study of femtoscopic correlations of D^0-π, D^0-K, 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. D^0 mesons are reconstructed via the $K^-\pi^+$ decay channel using topological criteria enabled by the excellent track pointing resolution provided by the Heavy Flavor Tracker.

I. Motivation

- Charm-hadron correlation can provide information about the length of homogeneity of emission source.
- One could interpret this distance as a measure of how far the interaction between charm quarks and light quarks extends in a medium.



Area of homogeneity (Fig. 1)

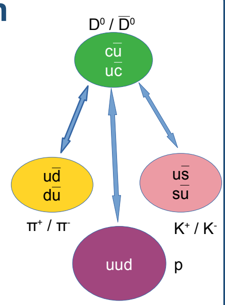


Fig. 2: Interaction between charm and light quarks within Quark-Gluon-Plasma

II. Methodology

Femtoscopic correlation is measured as a function of the reduced momentum difference (k*) of the pair 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, $S(r^*)$ is the source emission function, $\psi(k^*, r^*)$ is the pair wave function, and r^* is the relative separation vector

Applied mathematical formula of correlation function: $C(\vec{k}^*) = \mathcal{N}\frac{A(\vec{k}^*)}{B(\vec{k}^*)}$.

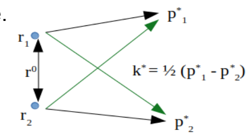


Fig 3.: k^* in pair-rest frame

where, A(k*) and B(k*) are respectively k* distribution for correlated and uncorrelated pairs. N is the normalization factor.

- *Event mixing* technique was applied to calculate k^* for uncorrelated pairs
- K^* was calculated for D^0 transverse momentum p_T > 1 GeV/c in the 0-80% centrality

III. Experiment

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

STAR was created focusing on the study of Quark-Gluon-Plasma (QGP) state of matter which allows us to understand better the universe in the moments after the Big Bang

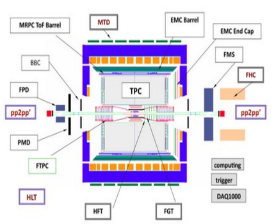
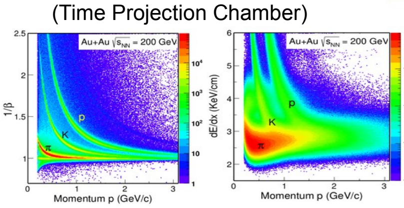


Fig. 4: STAR detector system

- **TOF** (Time of Flight) & **TPC** (Time Projection Chamber)



Plot 1, 2: Particle identification (PID) using TOF and TPC respectively

Ref. (plot 1,2 and fig. 6): PHYSICAL REVIEW C 99, 034908 (2019)

- **HFT** (Heavy Flavor Tracker)

HFT is the latest addition in the STAR detector system. HFT makes it possible for the first time to directly track the decay products of hadrons comprised of charm and bottom quarks.

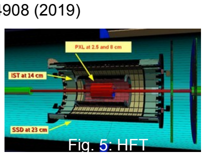


Fig. 5: HFT

Topological cuts for D^0 reconstruction:

1. Decay length (cm.) = {0.0145, 0.0181, 0.0212, 0.0247, 0.0259}
2. DCA_{12} (cm.) = {0.0084, 0.0066, 0.0057, 0.0050, 0.0060}
3. DCA_π (cm.) = {0.0110, 0.0111, 0.0086, 0.0081, 0.0062}
4. DCA_K (cm.) = {0.0103, 0.0091, 0.0095, 0.0079, 0.0058}
5. DCA_{D0} (cm.) = {0.0061, 0.0049, 0.0038, 0.0038, 0.0040}
6. cos(pointing angle θ) >0.95 & 7. 1.6 < D^0 mass <2.2 GeV/c^2

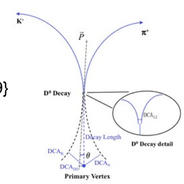
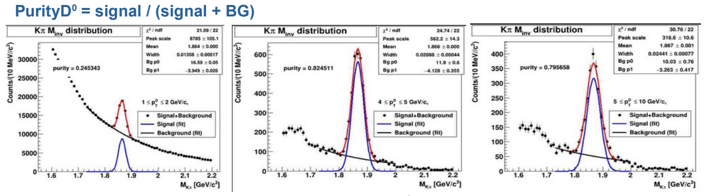


Fig 6: D^0 decay channel

IV. Analysis & Outcomes

PurityD^0 = signal / (signal + BG)



Plot 3-5: p_T dependence of D^0 invariant mass

D^0 signal is predominant over combinatorial background at higher p_T and for p_T < 1 GeV, background is dominant over D^0 signal.

- Invariant mass used for D^0 signal extraction is 1.82 – 1.91 GeV/c^2

Correction of $C(k^*)$ due to D^0 signal purity: $C^{corr}_{measured}(k^*) = \frac{C_{measured}(k^*) - 1}{PairPurity} + 1$,

Detector effects corrections:

Self-correlation: Track id (Hadron) ≠ Track id ($D^0{}_{K^-/\pi^+}$)
Track splitting: No. of hits / Max no. of hits > 0.51
Track merging: Distance between hits of two tracks (δr(i)) were calculated from reconstructed helix
δr(i) < mean TPC distance separation → 'merged' hits
Pair of tracks with fraction of merging > 5% were removed. We will check the effect with variation of this cut.

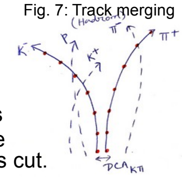


Fig. 7: Track merging

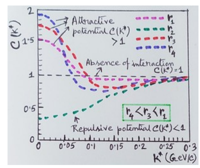


Fig. 8: Shape of $C(k^*)$

How the correlation functions should look like?

Calculation of $C(k^*)$ is ongoing. We can't predict the shape because this kind of analysis hasn't done before. Moreover, there is no known theory which says what are the effects of hadronization on the correlated pairs emitting from QGP to the final state.

V. Summary

- This is the first ever experimental analysis of D^0-hadron femtoscopy in Au+Au at STAR. Theoretical or simulation studies are not available.
- Model study (ex. Lednický–Lyuboshitz) is required to extract interaction parameters, like emission source size. This can lead us to make conclusion about screening length of charm quarks within QGP medium.

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