Femtoscopic correlations of D^0 mesons with identified 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 the relativistic heavy-ion collisions and probe all stages of the evolution of the created medium – the Quark Gluons Plasma. Femtoscopic correlations are sensitive to 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 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 the length of homogeneity of emission source
- One could interpret this length as a measure of how far the interaction between charm quarks and light quarks extends in a medium
- Expected source size dependence of correlation function

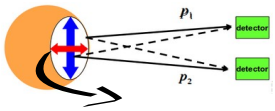

Figure - 1: Area of homogeneity

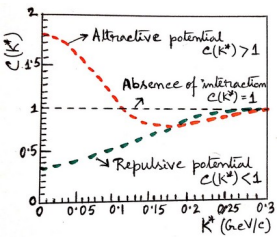

Figure - 2: Expected shape of C(k*) for attractive and repulsive potential

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

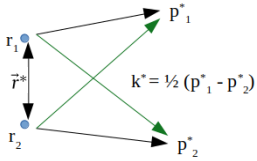

Figure - 3: Femtoscopic correlation and k* in pair-rest frame

- 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 k* for uncorrelated pairs using the real events

III. D^0 reconstruction at STAR

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

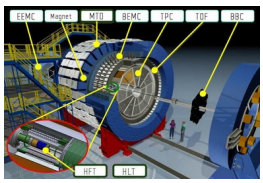

Figure - 4: STAR detector system

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

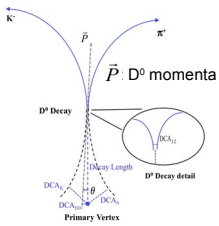

Figure - 5: D^0 decay channel

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

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

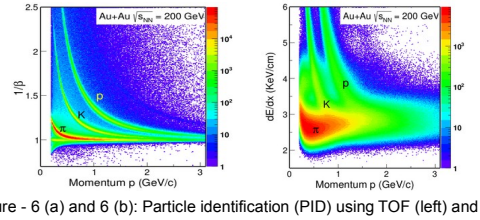

Figure - 6 (a) and 6 (b): Particle identification (PID) using TOF (left) and TPC (right)

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

IV. Analysis & Outcomes

- 2014, Au+Au at $\sqrt{s_{NN}}$ = 200 GeV

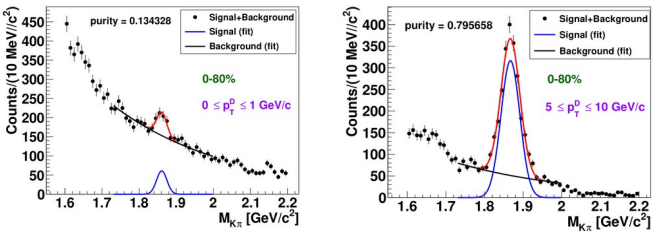

Figure - 7 (a) & 7 (b): K-π invariant mass distributions in different p_T intervals

- Purity of D^0 = signal / (signal + background)
- D^0 invariant mass range: 1.82 – 1.91 GeV/c²
- 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

- Detector effects corrections:
  - Possible correlation between D^0 candidates and their daughters were removed
  - More than 51% of max. possible no. 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'

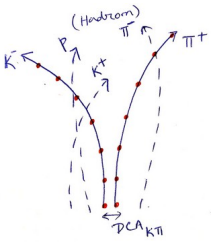

Figure - 8: Track merging

- **How should the correlation functions look like?**
  - No prediction on the correlation shape is available so far and it will be the first measurement
  - QGP and hadronic phase effects are unknown

V. Summary

- First experimental analysis of D^0-hadron femtoscopy in Au+Au collisions at STAR is ongoing.
- Model study (ex. Lednický–Lyuboshitz) is ongoing to extract interaction parameters, like emission source size. This can lead us to measure screening length of charm quarks within QGP medium.
- Theoretical inputs are needed to explore the nature of interaction.

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