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

**Priyanka Roy Chowdhury** (priyanka.roy_chowdhury.dokt@pw.edu.pl), Warsaw University of Technology (for the *STAR collaboration*)

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## Abstract

Heavy quarks are produced in hard partonic scatterings at the very early stage of heavy-ion collisions and they experience the whole evolution of the Quark-Gluon Plasma medium. Femtoscopic correlations, i.e. two-particle correlations at low relative momentum, are sensitive to the final-state interactions as well as to the extent of the region from which the correlated particles are emitted. A study of such correlations between charmed mesons and identified charged hadrons could shed light on their interactions in the hadronic phase and the interaction of charm quarks with the medium.

In this poster, we will present the first measurement of femtoscopic correlations between $D^0$-$K$ pairs at mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV using the 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 Heavy Flavor Tracker with excellent track pointing resolution. We will present the femtoscopic correlation function for $D^0$ transverse momentum above 1 GeV/c and $K$ momentum < 1 Gev/c in the 0-80 % centrality. We will also compare the experimental results with available theoretical models and discuss physical implications.


## I. Motivation

- Charm-hadron correlations can provide information about the emission source's length and 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*)

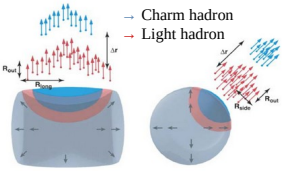


Figure 1: Area of homogeneity

## II. D-hadron femtoscopy

- $D^*$-π correlation: deviation from only Coulomb interaction in pp collisions (Fig. 2)
- ALICE data suggest small role of D-hadronic re-scattering in heavy-ion collisions
- $D^0$ $v_2$ (Fig. 3) and $R_{AA}$ → are consistent with model predictions
- D-hadron correlation data from heavy ion collisions → can constrain theoretical models

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

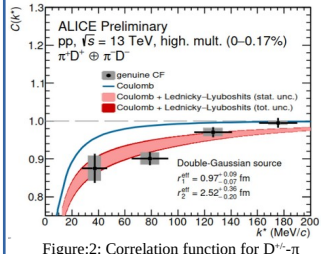


Figure:2: Correlation function for $D^{+/-}$-π

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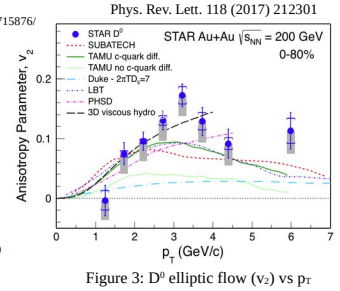


Figure 3: $D^0$ elliptic flow ($v_2$) vs $p_T$

## III. $D^0$ reconstruction at STAR

**STAR**: **S**olenoidal **T**racker **At** **R**HIC

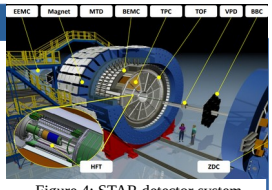


Figure 4: STAR detector system

**HFT** (Heavy Flavor Tracker):

- Directly tracks the decay products of hadrons comprised of charm and bottom quarks
- Topologically reconstructed secondary $D^0$ decay vertices

Topological variables:

- Decay length - distance between decay vertex and primary vertex (PV)
- Distance of Closest Approach (DCA) between:

a) $K^-$ & $\pi^+$ - $DCA_{12}$ , b) $\pi^+$ & PV -$DCA_\pi$
c) $K^-$ & PV - $DCA_K$ , d) $D^0$ & PV - $DCA_{D0}$

θ - angle between $\vec{P}$ & decay length

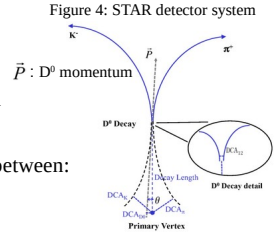


Figure 5: $D^0$ decay topology

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

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

STAR: PRC **99**, 034908 (2019)

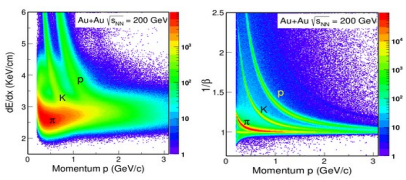


Figure 6: Particle identification (PID) using TPC (left) and TOF (right)

## IV. Methodology

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

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

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

$\mathcal{N}$ → Normalization factor
$A(\vec{k}^*)$ & $B(\vec{k}^*)$ → k* distribution, respectively, for correlated and uncorrelated pairs in event ensemble,

- *Event mixing* technique to calculate uncorrelated pairs k* using the real events

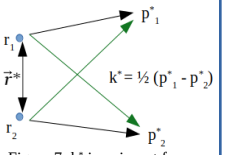


Figure 7: k* in pair-rest frame

## 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

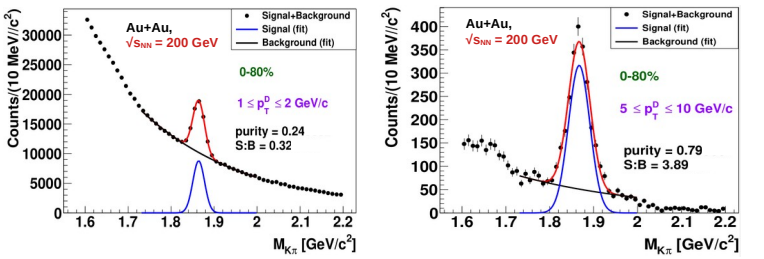


Figure 8: Invariant mass distributions of opposite sign K-π pairs in different $p_T$ intervals

- $D^0$ 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: Self correlation between $D^0$ daughters and track splitting [NOTE: Track merging effect is negligible for the dataset]
- Systematic Uncertainties: Variation in topological cut for $D^0$ reconstruction + $D^0$-K pair purity correction (using following formula)

$$C^{corr}_{measured}(k^*) = \frac{C_{measured}(k^*) - 1}{\text{PairPurity}} + 1$$ , $C_{measured}(k^*)$ is correlation function after detector effects removal

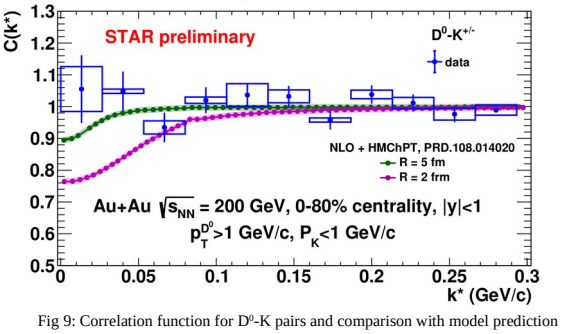


Fig 9: Correlation function for $D^0$-K pairs and comparison with model prediction

- The results are consistent with **no correlations**, but also with **emission source size of 5 fm or larger**
- Theoretical inputs are welcome that include details of charm interactions with the QGP for the interpretation of the results

## VI. Summary

- First measurement of $D^0$-hadron femtoscopy in Au+Au collisions at STAR
- 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

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