Abstract

In the collisions of heavy ions the nuclear matter can undergo a phase transition from hadrons to a state of deconfined quarks and gluons, the Quark-Gluon Plasma (QGP). Femtoscopic measurements of two-particle correlations at small relative momenta reveal information about the space-time characteristics of the system at the moment of particle emission. The correlations result from quantum statistics, final-state Coulomb interactions, and the strong final-state interactions (FSI) between the emitted particles. It has been predicted [1] that correlations due to the strong FSI in a system where a narrow resonance is present will be sensitive, in the region of the resonance, to the source size and momentum-space correlations. Such a measurement can provide complementary information to the measurements at the very low relative momenta. This poster presents a status report of a STAR analysis of unlike-sign kaon femtoscopic correlations in Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV, including the region of \( \phi(1020) \) resonances. The experimental results are compared with HYDJET++ simulations and to a theoretical prediction that includes the treatment of resonance formation due to the final-state interactions [1].

Motivation

The formalism of femtoscopic measurement at very low momentum is well understood. The formalism proposed in [1] allows to use strong FSI going through a narrow resonance at higher \( Q^2 \).

The system of unlike-sign kaons is ideally suited for testing this extension of femtoscopic formalism as it contains narrow \( \phi(1020) \) resonance.

Use strong FSI in region of resonance:

- More sensitive
- Statistically advantageous
- High statistics
- Low feed down
- Source well known from imaging

Unlike-sign kaon correlation function:

- \( \phi(1020) \) resonance: \( k^\perp = 126 \) MeV/c, \( T = 4.3 \) MeV
- Narrow separation of emission and FSI

Challenges - femtoscopic formalism at higher \( Q^2 \):

- Possibility of breakdown of basic assumptions
- Smoothness assumption
- Equal-time approximation

The Solenoidal Tracker at RHIC (STAR)

- 2π azimuthal coverage
- Pseudorapidity \( |\eta| < 1 \)

Main subdetectors used for this analysis are:

- Time Projection Chamber (TPC)
- Particle identification via specific ionization energy loss dE/dx
- Charged particle tracking and momentum reconstruction

Time of Flight (TOF)

- Particle identification via \( 1/\beta \)
- Timing resolution < 100 ps
- Separation of charged kaons from other hadrons up to momentum \( -1.5 \) GeV/c

Data selection and construction of correlation function

- Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV, taken in 2011

Track selection

- Primary track with signal from TOF
- \( |\eta| < 1 \) and (TOF) < 3 ps
- \( 0.15 < p < 1.55 \) GeV/c
- \( 0.21 < m^2 < 0.28 \) (GeV/c)^2
- \( \mid\mathbf{r}_{\text{TPC}}\mid < 3 \) cm

where \( \mathbf{r}_{\text{TPC}} \) is the distance from the expected dE/dx for kaons expressed in terms of standard deviation units

Correlation function:

\[ C(\beta_1,\beta_2) = \int dE \psi_e\psi_k \psi_{\phi}() \]

where \( \psi_\ell() \) is emission source function and \( \psi_{\phi}() \) wave function describing interaction

Experimentally:

\[ C(\phi_{1020}) = \frac{\text{mean pairs}}{\text{phase space cross section}} \]

Event mixing

To obtain uncorrelated two-particle distributions \( \rho_{\phi_{1020}}() \). In order to remove non-femtoscopic correlations, events are divided into sub-classes according to primary vertex position along the beam direction and multiplicity

Unlike-sign 1D correlation function

- Correlation functions are sensitive in the region of the \( \phi \) resonance to the source size and momentum-space correlations

Centrality dependence

- Centrality dependence
- Star preliminary
- STAR preliminary

Like-sign 1D correlation function and fitting

- Used for extraction of kaon emission source size \( R_{\text{em}} \) and lambda parameter \( \lambda \)
- Fitting function:
  \[ CF(\theta) = \left( 1 - \lambda \right) + \left( \lambda \right) \frac{T_{\text{Coulomb}}}{N_{\text{fsi}}} \]
  where \( \lambda \) - correlation strength, \( k_{\phi} = \frac{\phi(1020)}{\phi(1020)} \)

- Narrow separation of emission and FSI

- The source radii \( R_{\text{em}} \) increase with the centrality and decrease with pair transverse momentum \( k_T \)
- Only statistical errors shown; systematic error is underway

Comparison of unlike-sign 10 correlation function with HYDJET++ simulations

- HYDrodynamics + JETS - Monte Carlo heavy ion AA collisions generator [2]
- HYDJET++ captures only thermal production of \( \phi \) no Quantum statistics, Coulomb, Strong and FSI
- Experimental correlation function is corrected via \( C^{\text{corr}} = \frac{C^{\text{data}}}{\sum_{\text{RMS}}^{\text{data}}} \), where \( \lambda \) parameter is from fitting like-sign correlation function

Comparison of unlike-sign 1D correlation function to Lednicky model

- Lednicky model [1] - includes the treatment of \( \phi \) resonance due to the FSI as well as generalized smoothness approximation
- Gaussian source sizes \( R_{\text{em}} \), used for calculation of theoretical CF are extracted from fitting like-sign CF
- Clean theoretical function is transformed to a raw one via: \( CF^{\text{raw}} = \left( \frac{CF^{\text{corr}} - \lambda 1}{\lambda} \right) + 1 \), in order to compare to an experimental correlation function

Conclusion

- Measurement of K+K- correlation function in Au+Au collisions
- Extraction of \( \lambda \) parameter and source radii \( R_{\text{em}} \) from fitting like-sign correlation function
- HYDJET++ model reproduced the correlation functions well especially in the phi-mass region, final comparison will be done after the efficiency correction is applied to the data
- Studies of 3D correlation function underway

References:


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