Femtoscopy with unlike-sign kaons at STAR in 200 GeV Au+Au collisions

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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 q_{inv} is well understood. The formalism proposed in [1] allows to use strong FSI going through a narrow resonance at higher q_{inv}.

The system of unlike-sign kaon pairs is ideally suited for testing this extension of femtoscopy formalism as it contains narrow ϕ(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:
  $k^* = 126$ MeV/c, $\Gamma = 4.3$ MeV
- Narrow – separation of emission and FSI

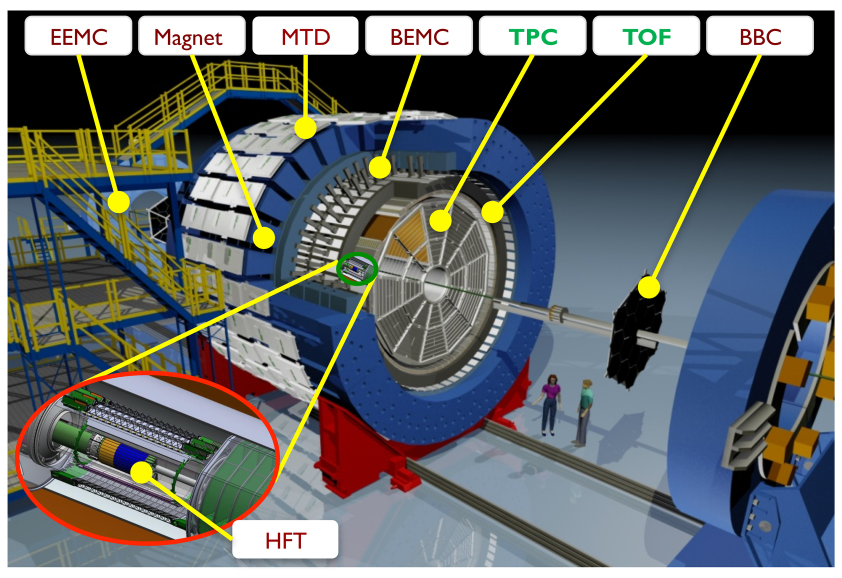
Challenges - femtoscopy formalism at higher q_{inv}

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

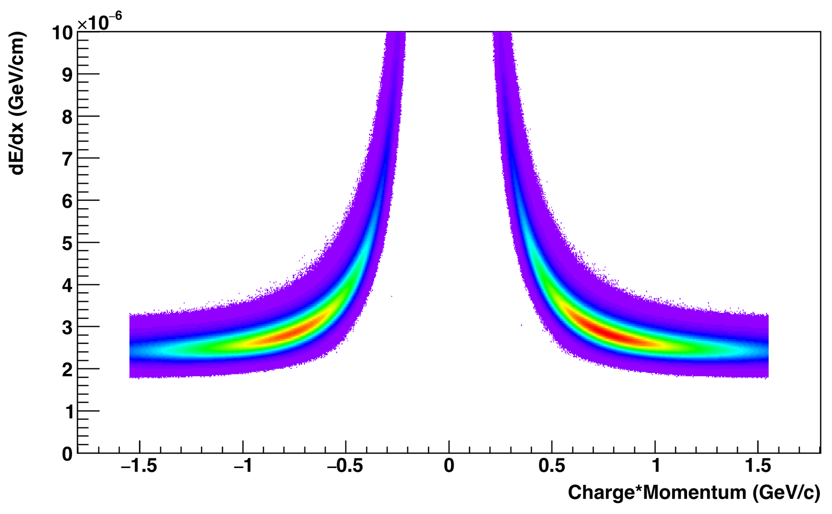
Data selection and construction of correlation function

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

Track selection

- Primary track with signal from TOF
- $|\eta| < 1$ and $|DCA| < 3$ cm
- $0.15 < p < 1.55$ GeV/c
- $0.21 < m^2 < 0.28$ (GeV/c^2)^2
- $|n\sigma_{kaon}| < 3$,

where $n\sigma_{kaon}$ is the distance from the expected dE/dx for kaons expressed in terms of standard deviation units



Correlation function:

Koonin-Pratt eq.: $C(p_1, p_2) = \int d^3 r S(r,k) |\psi_{1,2}(r,k)|^2$,

where $S(r,k)$ is emission source function and $\psi_{1,2}(r,k)$ is wave function describing interaction

Experimentally: $C(q_{inv}) = \frac{N_{same}(q_{inv})}{N_{mixed}(q_{inv})} = \frac{real\ pairs}{mixed\ pairs}$

$q_{inv} = p_1 - p_2 = 2k^*$, $k_T = \frac{p_{1,T} + p_{2,T}}{2}$

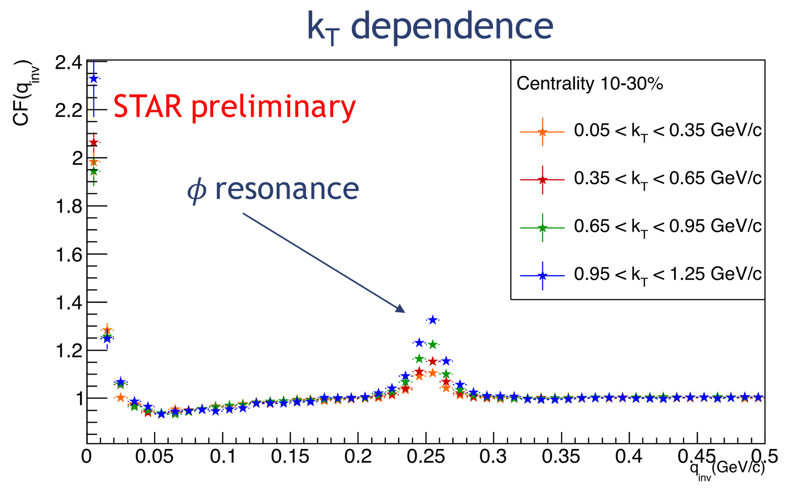
Event mixing

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

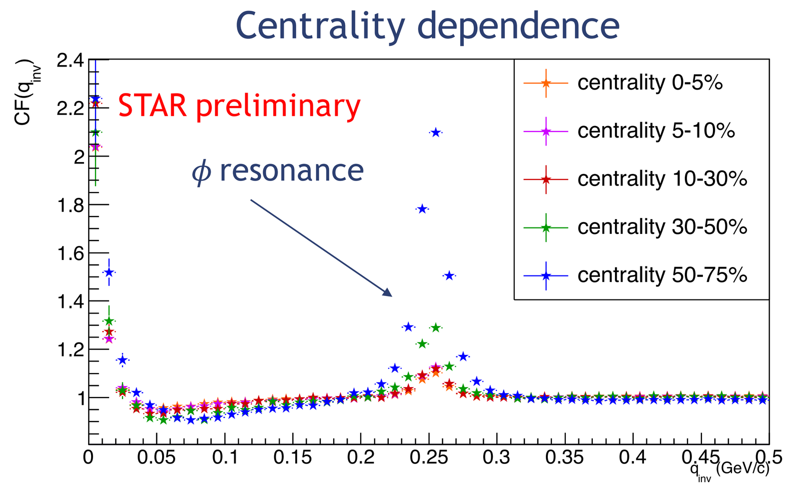
Unlike-sign 1D correlation function

- Correlation functions are sensitive in the region of the ϕ resonance to the source size and momentum-space correlations

k_T dependence



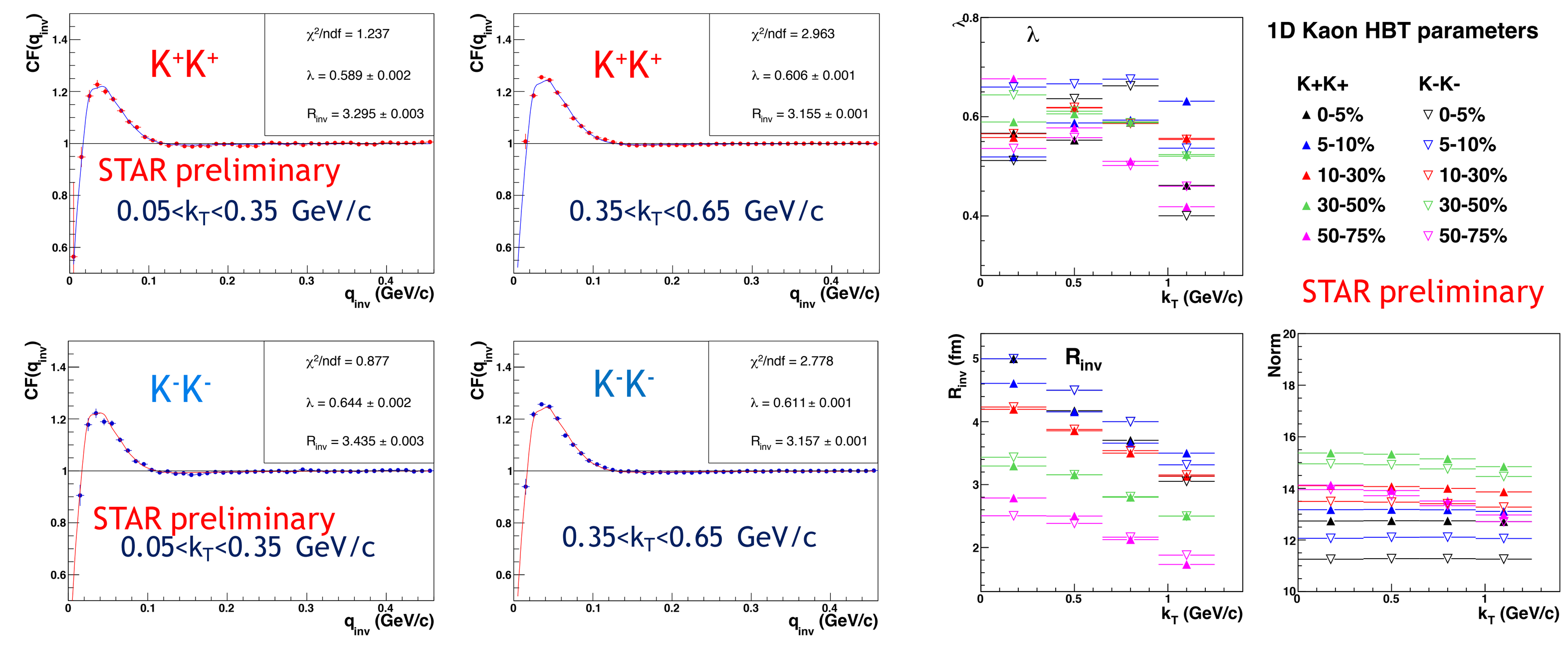
Centrality dependence



Like-sign 1D correlation function and fitting

- Used for extraction of kaon emission source size R_{inv} and lambda parameter λ
- Fitting function: $CF(q_{inv}) = \left[(1-\lambda) + \lambda K(q_{inv}) e^{-R_{inv}^2 q_{inv}^2}\right] N$,

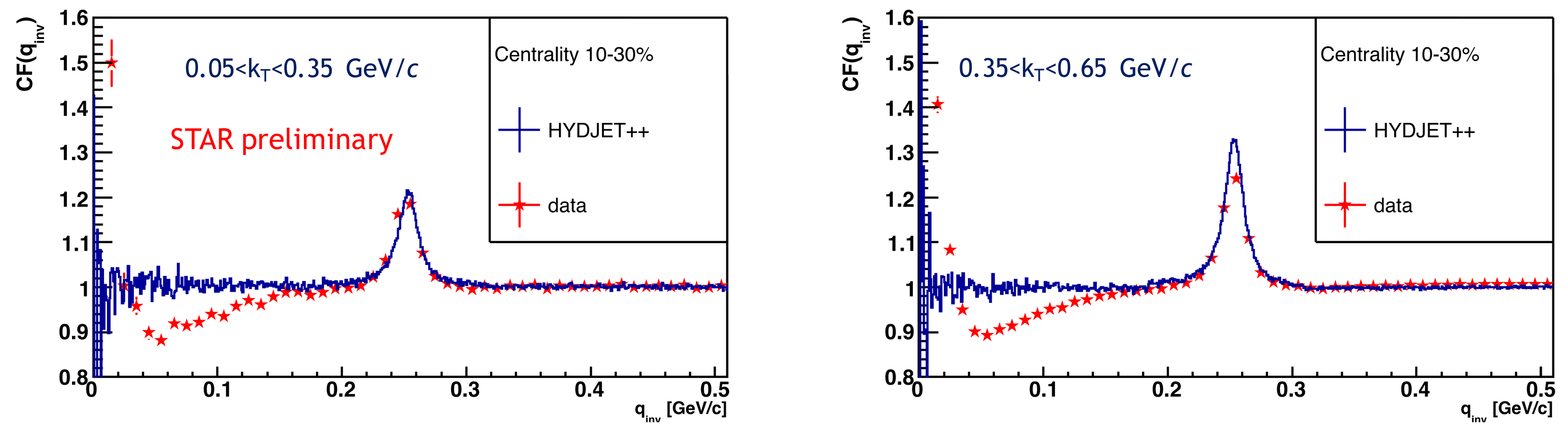
  where λ - correlation strength, $K(q_{inv})$ - Coulomb function and N - normalization



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

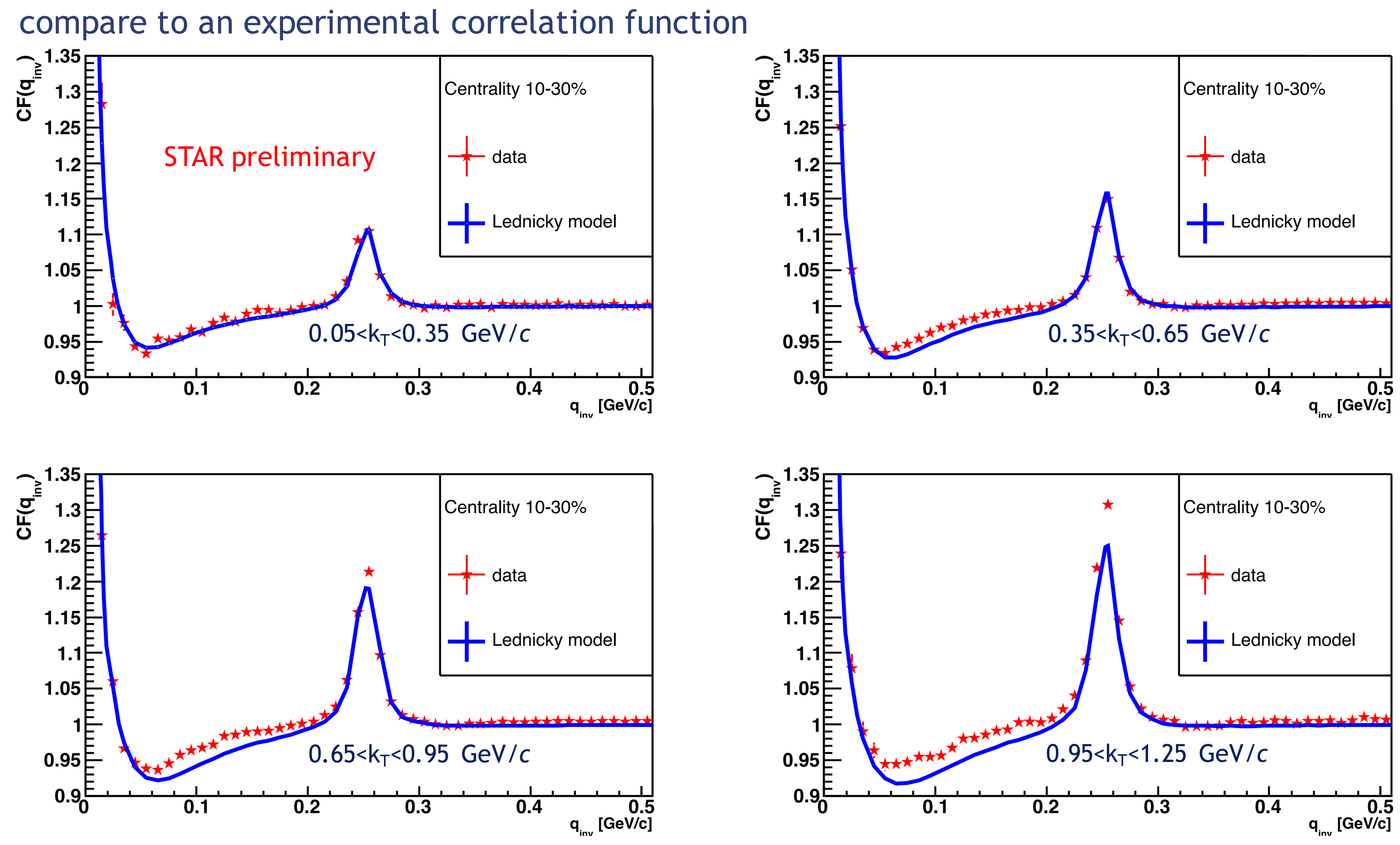
Comparison of unlike-sign 1D correlation function with HYDJET++ simulations

- HYDrodynamics plus JETs – Monte-Carlo heavy ion AA collisions generator [2]
- HYDJET++ contains only thermal production of ϕ, no Quantum statistics, Coulomb, Strong and FSI
- Experimental correlation function is corrected via $CF^{corr} = \frac{CF^{raw} - 1}{\lambda} + 1$, where λ 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 ϕ resonance due to the FSI as well as generalized smoothness approximation
- Gaussian source sizes R_{inv} used for calculation of theoretical CF are extracted from fitting like-sign CF
- Clean theoretical function is transformed to a raw one via: $CF^{raw} = (CF^{corr} - 1)\lambda + 1$, in order to compare to an experimental correlation function



Conclusion

- Measurement of K+K- correlation function in Au+Au collisions
- Extraction of λ parameter and source radii R_{inv} 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

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References:

[1] R.Lednicky, Phys.Part.Nucl.Lett. 8 (2011) 965-968

[2] I.P. Lokhtin et al., Comp.Phys.Comm 180 (2009) 779-799