Kaon femtoscopy in STAR

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Beam Energy Scan program

Beam Energy Scan (BES) – a comprehensive program conducted by all experiments of the RHIC complex, launched in 2010 to study the Quantum Chromodynamics Phase Diagram at different chemical potential (μ_B) and temperature (T) values using collisions of Au ions at collision energies **from 7.7 GeV to 200 GeV** [1, 2].

The main goals:

- to study the QCD Phase Diagram at different collision energies and to find areas in which QGP signatures are turned off,
- to find a Critical Point between crossover and the first-order phase transition,
- to examine the area between the hadronic and Quark Gluon Plasma matter.

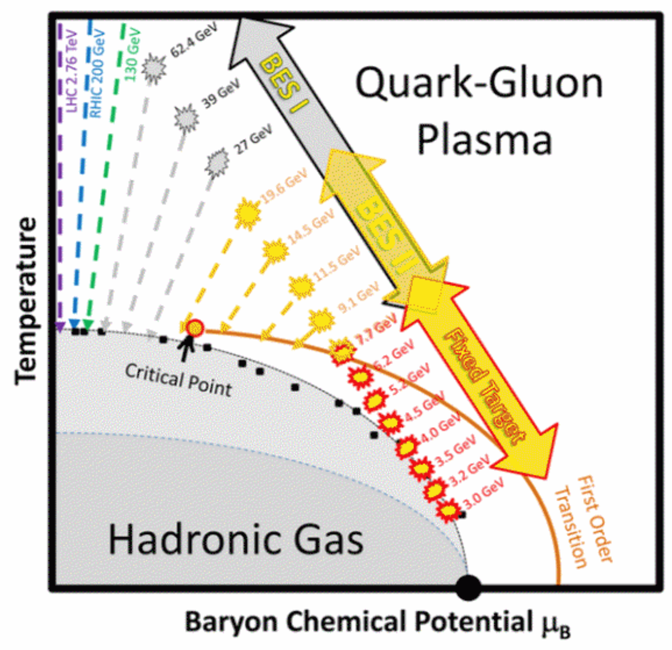


Fig. 1 The Quantum Chromodynamics Phase Diagram [3].

Femtoscopy

Femtoscopy - a method to examine **the particle emitting source** sizes (of the order of 10^{-15} m) by measurements of relative momentum characteristics [4].

The correlation function (CF) - the ratio of probability of observing two particles with specific momenta p_1 and p_2 at the same place and time to the product of probabilities to find them separately [5]:

$$CF(\vec{p}_1,\vec{p}_2)=\frac{P_2(\vec{p}_1,\vec{p}_2)}{P_1(\vec{p}_1)P_1(\vec{p}_2)}$$

The experimental correlation function:

$$CF(q_{inv})=\frac{A(q_{inv})}{B(q_{inv})}$$

$A(q_{inv})$ - the signal distribution,
$B(q_{inv})$ - the background distribution.

Kaon correlation function

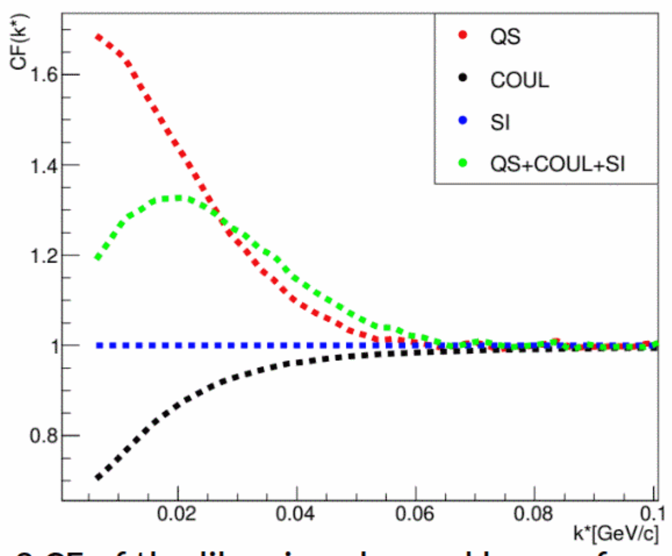


Fig. 2 CF of the like-sign charged kaons from the Therminator model for central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

The correlation function depends on:

- **Quantum statistics (QS)**
- **Final state interactions (FSI):**
  - **Coulomb interaction (COUL)**
  - **Strong interaction (SI)**

Like-sign charged kaons -> dominant quantum statistical effects together with Coulomb interaction
Neutral kaons -> absent Coulomb interaction but strong interaction need to be taken into account together with quantum statistical effects

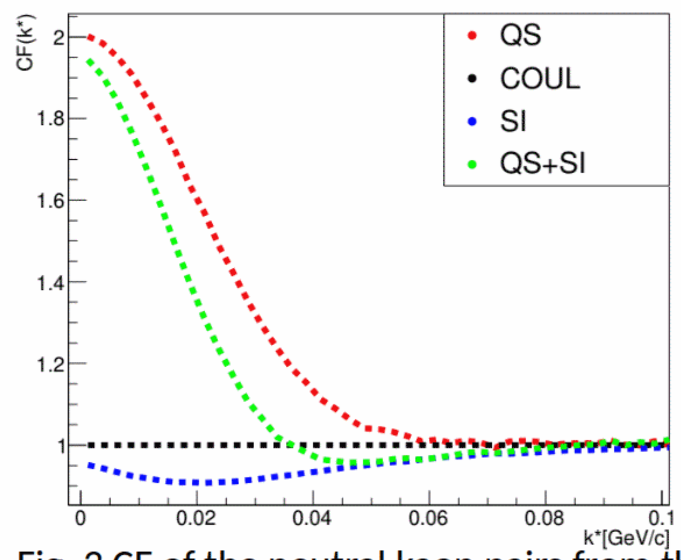


Fig. 3 CF of the neutral kaon pairs from the Therminator model for central Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV.

Parametrization

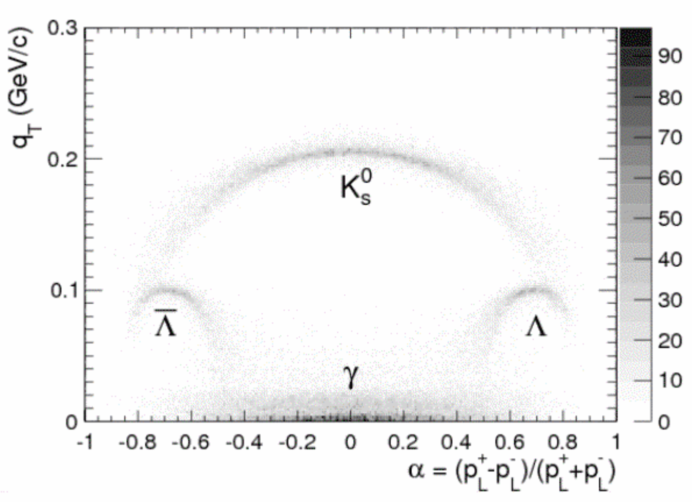
Gaussian density distribution (includes only QS effects):

$$CF(q_{inv})=1+\lambda\exp(-R_{inv}q_{inv})$$

λ – the correlation strength
R_{inv} – the size of the particle-emitting source

Lednicky and Lyuboshitz model includes strong FSI was also using to fit the K^0K^0 correlation functions [6].

Armenteros-Podolanski plot



The kinematic properties of the V^0 candidates.

$$K^0_S \rightarrow \pi^+ + \pi^-$$

π^+ and π^- have the same mass and their momenta are distributed symmetrically on average

Charged kaons results

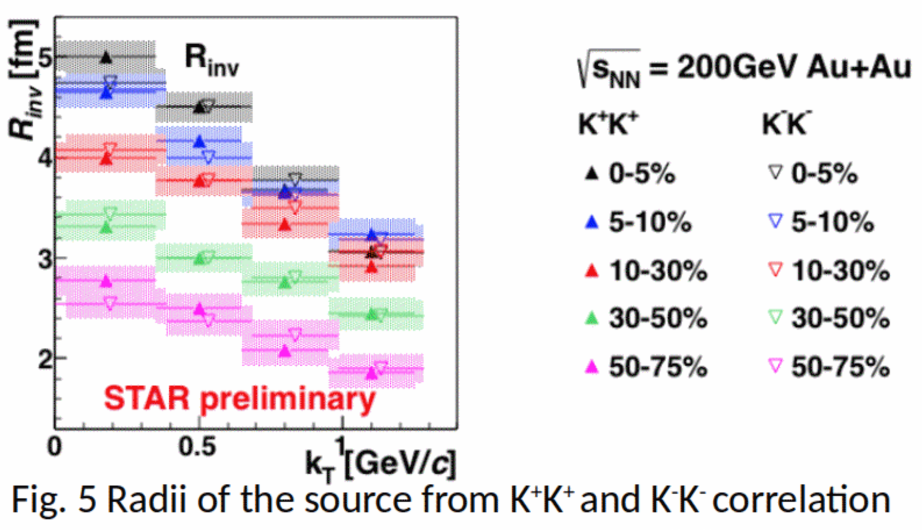


Fig. 5 Radii of the source from K^+K^+ and K^-K^- correlation function in different k_T ranges [8].

- k_T and centrality dependence of HBT radii observed
- source sizes increase with the centrality and decrease with the pair transverse momentum

Neutral kaon results

p_T [GeV/c]	0.2-1.5
|η|	< 0.5
DCA V^0 to the PV [cm]	< 0.3
DCA of daughter [cm]	< 0.3
decay length [cm]	> 2
mass range [GeV/c²]	0.488 – 0.51

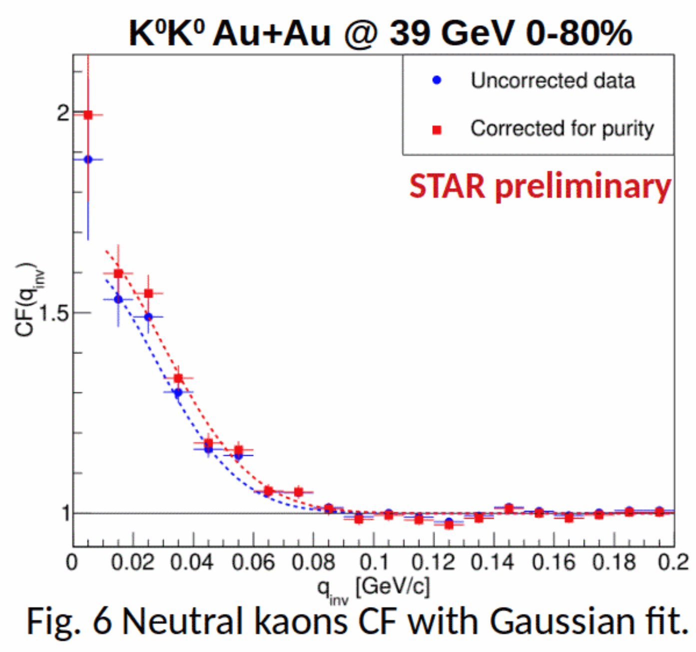


Fig. 6 Neutral kaons CF with Gaussian fit.

Before purity correction:

R = 5.08 ± 0.19 fm
λ = 0.630 ± 0.051

After purity correction:

R = 4.72 ± 0.20 fm
λ = 0.701 ± 0.056

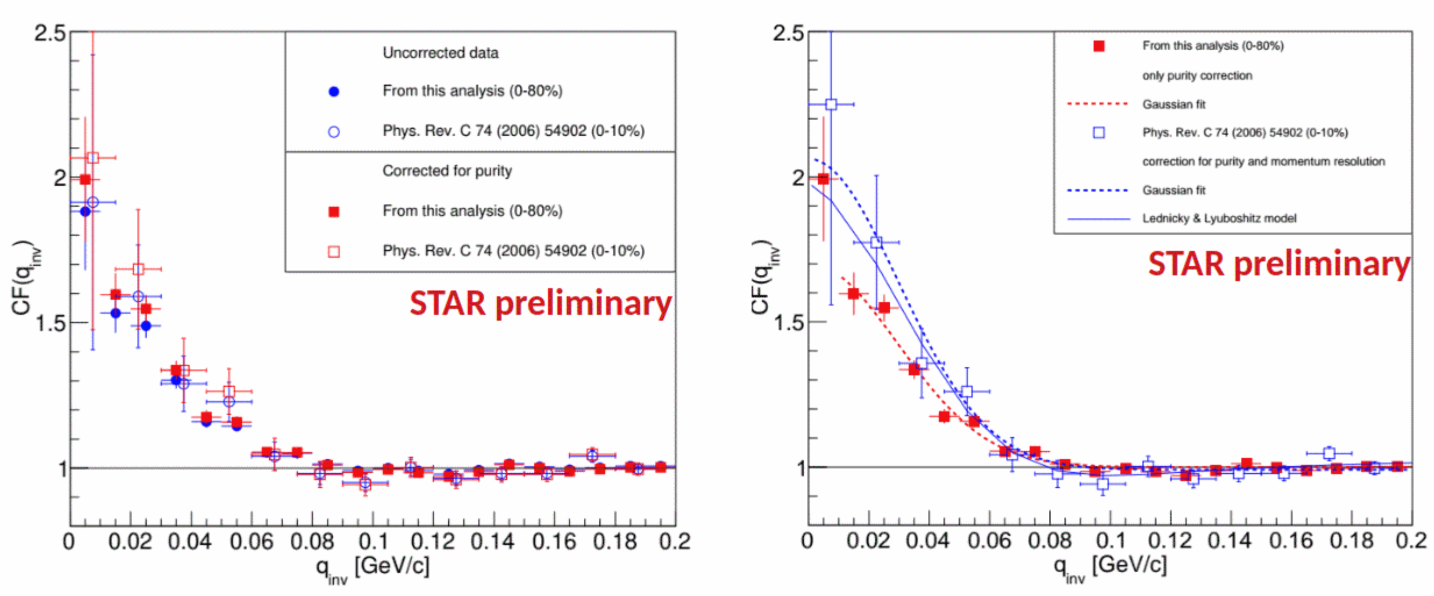


Fig. 7 Comparison with previous STAR result.

References

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[3] Meehan, K., "STAR Results from Au+Au Fixed-Target Collisions at at $\sqrt{s_{NN}}$ = 4.5 GeV," Nucl.Phys. A (2017).
[4] Hanbury Brown, R. and Twiss, R., "A new type of interferometer for use in radio astronomy," Phil. Mag. (1954).
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[6] Lednicky, R. and Lyuboshitz, V., "Final-state interaction effect on pairing correlations between particles with small relative momenta," Sov.J.Nucl.Phys (1982).
[7] Aamodt, K., et al., "Strange particle production in protonproton collisions at $\sqrt{s_{NN}}$ = 0.9 TeV with ALICE at the LHC," Eur. Phys. J. C (2011)
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Summary

- Kaon femtoscopy – a complementary method to pion femtoscopy
- Less affected by resonance decays than pions
- Allows one to learn about the final state interaction
- Source size ~5fm for the most central collisions

STRANGENESS IN QUARK MATTER
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