Neutral kaon femtoscopy in STAR

Diana Pawłowska
for the STAR Collaboration

Warsaw University of Technology

Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

STAR

GDRI - International Research Network Meeting
Nantes (France), July 14 - 20, 2019

Outline

- Main goals

Outline

- Main goals

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Outline

- Main goals
- Motivation

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Outline

- Main goals
- Motivation

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Why do we analyse kaons?

Kaons can provide complementary information to pions:

- contain strange quarks
- less affected by the feed-down from resonance decays
- smaller cross section with the hadronic matter

Outline

- Main goals
- Motivation
- The STAR experiment at RHIC

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Why do we analyse kaons?

Kaons can provide complementary information to pions:

- contain strange quarks
- less affected by the feed-down from resonance decays
- smaller cross section with the hadronic matter

Outline

- Main goals
- Motivation
- The STAR experiment at RHIC
- Femtoscopy

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Why do we analyse kaons?

Kaons can provide complementary information to pions:

- contain strange quarks
- less affected by the feed-down from resonance decays
- smaller cross section with the hadronic matter

Outline

- Main goals
- Motivation
- The STAR experiment at RHIC
- Femtoscopy
- Results
  - Analysis details
  - Purity correction
  - Correlation functions
  - Comparison with previous result

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Why do we analyse kaons?

Kaons can provide complementary information to pions:

- contain strange quarks
- less affected by the feed-down from resonance decays
- smaller cross section with the hadronic matter

Outline

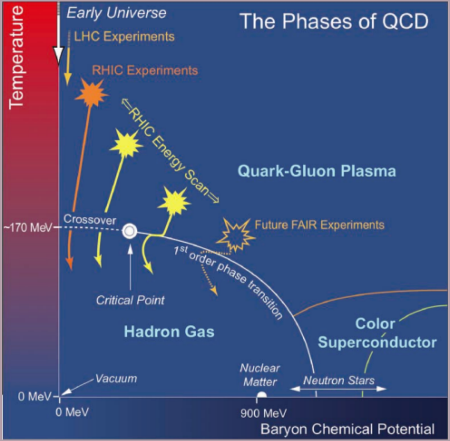
- Main goals
- Motivation
- The STAR experiment at RHIC
- Femtoscopy
- Results
  - Analysis details
  - Purity correction
  - Correlation functions
  - Comparison with previous result
- Conclusions

- study the size of the neutral kaon emitting source
- compare with other kaon systems ($K^{\pm}K^{\pm}$ and $K^0_S K^{\pm}$)

Why do we analyse kaons?
Kaons can provide complementary information to pions:

- contain strange quarks
- less affected by the feed-down from resonance decays
- smaller cross section with the hadronic matter

The STAR experiment at RHIC



- RHIC was built to find QGP (new and complicated phase of matter)
- The main goals of the BES program include:
  - turn-off QGP signature
  - find critical point between crossover and the first-order phase transition
  - examine the area between the hadronic and quark-gluon matter (first order phase transition)

$$\sqrt{s_{NN}} = 7.7 \text{ - } 200 \text{ GeV}$$
$$20 \text{ MeV} < \mu_B < 420 \text{ MeV}$$

Femtoscopy

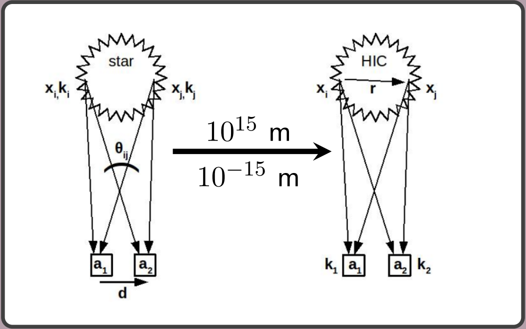
Hanbury Brown and Twiss interferometry

HBT

measure the angular size of astronomical objects through the use of Michelson interferometry

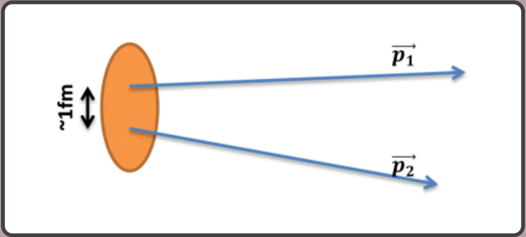
Femtoscopy

examine the particle-emitting source by measuring a momentum distribution



R.Lednicky, Nucl.Phys. A774 (2006) 189-198

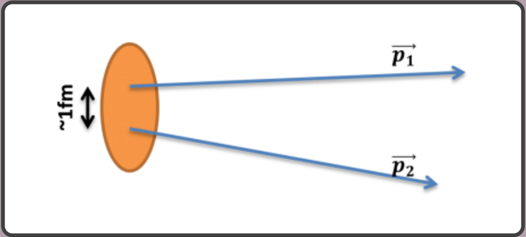
Correlation function



$$C_2(\vec{p_1}, \vec{p_2}) = \frac{P_2(\vec{p_1}, \vec{p_2})}{P_1(\vec{p_1})P_1(\vec{p_2})}$$

P_2 - the probability of finding two particles at the same place and time
P_1 - the probability of finding particle 1 and 2 separately

Correlation function



$$C(\vec{q}) = \frac{A(\vec{q})}{B(\vec{q})}$$

$$\vec{q} = \vec{p_2} - \vec{p_1}$$

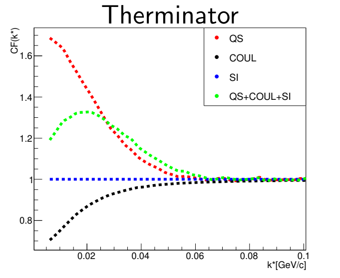
$A(\vec{q})$ - the measured distribution of pairs from the same event
$B(\vec{q})$ - the reference distribution of pairs from mixed events

Correlation function

The shape of the kaon correlation function depends on:

Charged

- Quantum Statistical effects (QS)
- Final State Interactions (FSI)
  - Coulomb Interaction (COUL)
  - Strong Interaction (SI)

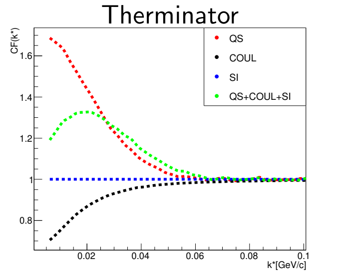


Correlation function

The shape of the kaon correlation function depends on:

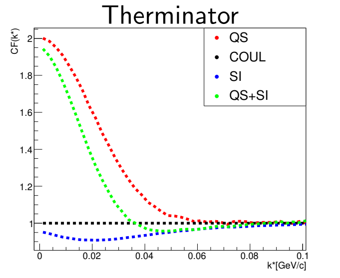
Charged

- Quantum Statistical effects (QS)
- Final State Interactions (FSI)
  - Coulomb Interaction (COUL)
  - Strong Interaction (SI)



Neutral

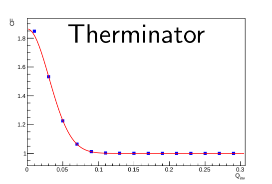
- Quantum Statistical effects (QS)
- Final State Interactions (FSI)
  - ~~Coulomb Interaction (COUL)~~
  - Strong Interaction (SI)



Fitting procedure

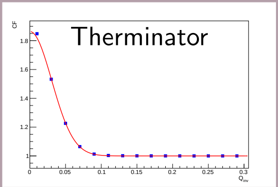
- **The QS correlation function (Gaussian)**

$$C(q_{inv}) = 1 + \lambda \exp[-R_{inv}^2 q_{inv}^2]$$



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

Fitting procedure



- **The QS correlation function (Gaussian)**

$$C(q_{inv}) = 1 + \lambda \exp[-R_{inv}^2 q_{inv}^2]$$

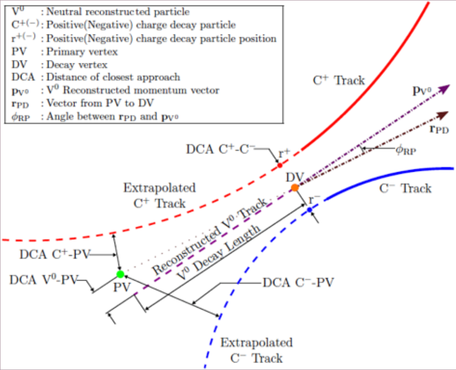
- **Final State Interaction**
  Lednicky & Lyuboshitz model
  R.Lednicky and V.L. Lyuboshitz, Sov.J.Nucl.Phys. 35, 770 (1982)

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

Results

Analysis details

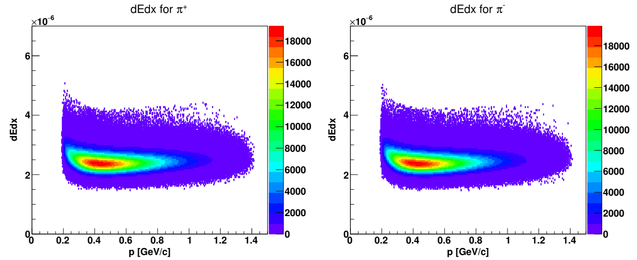
- **1D Femtoscopy of $K^0_S K^0_S$ pairs**
- **Au+Au** collisions at $\sqrt{s_{NN}} = 200$ GeV
- $K^0_S \rightarrow \pi^+ + \pi^-$ (69.20±0.05) %
- **1 centrality** : 0-80% (minimum-bias events)



Daughter track cuts

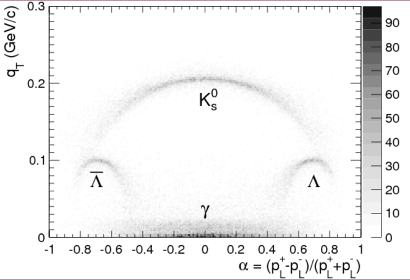
Cut	π^+	π^-
p_T [GeV/c]	0.2-1.2	0.2-1.2
DCA to the primary vertex [cm]	>1.3	>1.3
minimum TPC hits	15	15
$\|N_{\sigma\pi}\|$	<3	<3
$\|N_{\sigma K}\|$	>3	>3
$\|N_{\sigma p}\|$	>3	>3

*DCA - distance of closest approach



Armenteros-Podolanski plot

the kinematic properties of the V^0 candidates



ALICE Collaboration, Eur.Phys.J. C71 (2011) 1594

- decay products of the $K_S^0 \to \pi^+ + \pi^-$ have the same mass and therefore their momenta are distributed symmetrically on average
- for $\Lambda^0 \to p + \pi$ the proton (antiproton) takes on average a larger part of the momentum and as a result the distribution is asymmetric

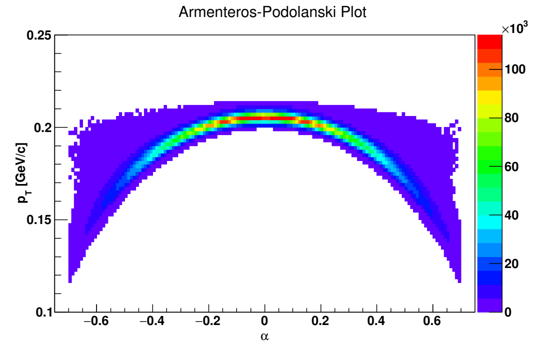
q_T - the relative transverse momentum of decay products
α - the longitudinal momentum asymmetry
p_L^+ and p_L^- - the longitudinal momenta of positive and negative daughter

Neutral kaon selection criteria

Cut	K_s^0
p_T [GeV/c]	0.2-1.5
$\|\eta\|$	<0.5
DCA V_0 to the primary vertex [cm]	0-0.3
DCA of daughters [cm]	0-0.3
decay lenght [cm]	>2
Armenteros q_T [GeV/c]	0.12-0.22
Armenteros $\|\alpha\|$	<0.7
mass range [GeV/c^2]	0.488-0.51
mass from PDG 2016 [GeV/c^2]	0.498$\pm$0.006

*DCA - distance of closest approach

Neutral kaon selection criteria



Signal region is symmetric

Other particles, e.g. Λ and $\overline{\Lambda}$, are not noticeable

Purity correction

The pair purity, $PairPurity(q_{inv})$, is independent of q_{inv} in the range of considered invariant four-momentum difference:

$$PairPurity(q_{inv}) = \frac{S}{S+B}(p_{T,i}) \times \frac{S}{S+B}(p_{T,j}) =\sim 88\%$$

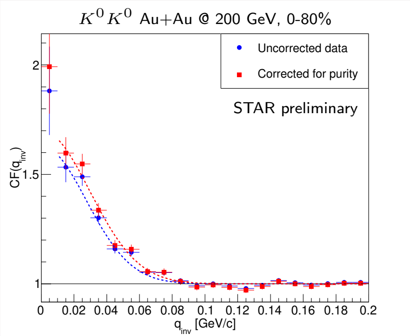
S is the number of K_s^0 in the specific range of distribution of invariant mass,
B is the number of other particles in this range of distribution of invariant mass,
$p_{T,i}, p_{T,j}$ - transverse momentum of first and second in the pair K_s^0

Corrections to the raw correlation functions were applied according to the expression:

$$C_{corrected}(q_{inv}) = \frac{C_{measured}(q_{inv}) - 1}{PairPurity(q_{inv})} + 1$$

Correlation functions

Gaussian fit



Before purity correction

Radius [fm]	λ
5.08 ± 0.19	0.630 ± 0.051

After purity correction

Radius [fm]	λ
4.72 ± 0.20	0.701 ± 0.056

Smaller values of source's radii after corrections (larger statistical uncertainties) and different values of λ parameter (larger for correlations after purity corrections)

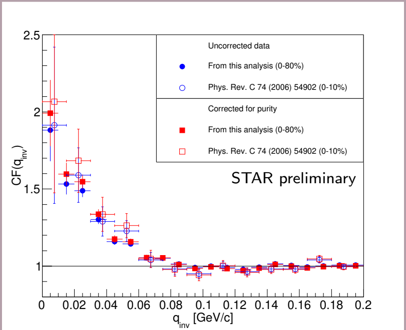
Comparison with previous result

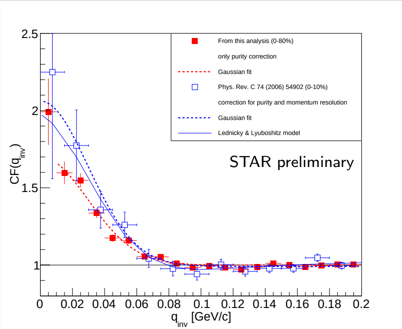
Neutral kaon interferometry in Au+Au collisions at $\sqrt{s_{NN}}$ *= 200 GeV*
Phys. Rev. C 74 (2006) 54902

- Time Projection Chamber (TPC) and Zero Degree Calorimeter (ZDC) central trigger
- only central events 0-10%
- about 3 K_S^0 per event

Cut	
p_T [GeV/c]	0.5-3.5
$\lvert\eta\rvert$	<1.5
DCA V_0 to the primary vertex [cm]	0-0.3
DCA of daughters [cm]	< 0.3 - 0.8
decay lenght [cm]	> 2 - 6
mass range [GeV/c^2]	0.48-0.51

Comparison with previous result





- similar source sizes are determined
- the shape of the correlation functions before and after applying the purity correction is similar

Conclusions

- **the neutral kaon correlations** at $\sqrt{s_{NN}}$ = **200 GeV** in minimum-bias events (0-80%)
- **purity correction** is done
- the source sizes using **Gaussian fit** are obtained
- **comparison with the published data** from 2006
  - similar shape of the correlation functions and extracted femtoscopic parameters

Future plan:

- measure neutral kaon correlation function for BES energies
- measure correlation function for $K_S^0 K^{\pm}$

Thank you for your attention!