# Femtocopic measurements of strange hadrons in Au+Au collisions at the STAR experiment

**Diana Pawłowska**
(diana.pawlowska.dokt@pw.edu.pl),

Warsaw University of Technology,
*for the STAR Collaboration*

## Abstract

Relativistic heavy-ion collisions can study properties of nuclear matter in high-energy experiments like the STAR experiment. Femtoscopy, which relies on information carried by the particles produced in the collisions, is one of methods to learn about the bulk matter. By studying the quantum statistical effects and final state interactions between two particles, one can study spatial and temporal extents of particle emitting source. For the case of kaons, the correlation functions are sensitive to the early stage of the collision evolution and provide different information about particle-emitting sources compared to pions. Information on the final state interactions amongst the particles under study can also be extracted from the measurement. Especially, in the case of strange particle correlations, one could investigate hyperon-nucleon interactions which is little known.

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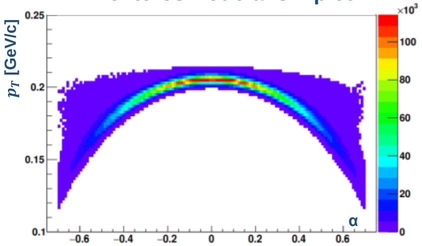
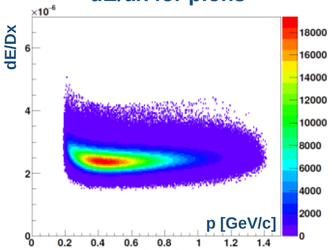
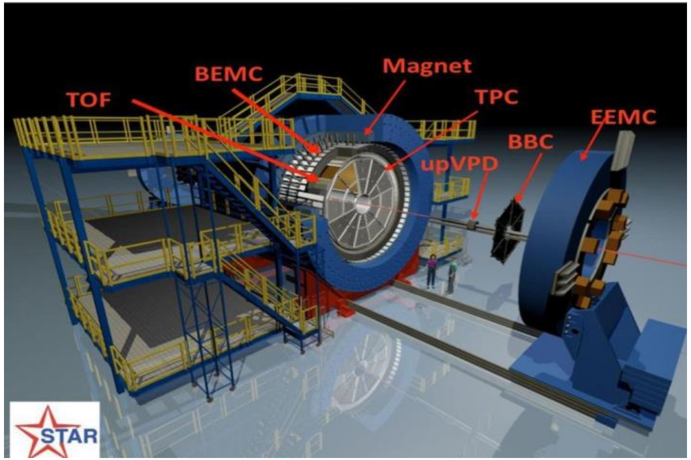
# The STAR experiment

## Neutral kaon selection criteria

| Cuts | 200 GeV | 39 GeV |
|---|---|---|
| $p_T$ [GeV/c] | 0.4 - 2.0 | |
| \|η\| | < 0.5 | |
| DCA $V^0$ to PV [cm] | 0.0 – 0.3 | |
| DCA of daughters [cm] | 0.6 | 0.8 |
| decay lenght [cm] | 3 | 2 |
| Armenteros $q_T$ [GeV/$c$] | 0.12 – 0.22 | |
| Armenteros \|α\| | < 0.7 | |
| mass range [GeV/$c^2$] | 0.488 – 0.51 | 0.475 - 0.525 |


**Armenteros-Podolanski plot**


**dE/dx for pions**



## Numbers of events

| Energy/centrality | 0-10% | 10-70% | 0-70% |
|---|---|---|---|
| 200 GeV | ~107M | ~154M | ~261M |
| 39 GeV | ~12M | ~71M | ~83M |

# Basics of femtoscopy

**Femtoscopy** – method to examine **the particle emitting source** sizes (of the order of $10^{-15}$ fm and lifetime $10^{-23}$s) by measurements of relative momentum characteristics.

**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:

$$CF(\overrightarrow{p_1},\overrightarrow{p_2}) = \frac{P_2(\overrightarrow{p_1},\overrightarrow{p_2})}{P_1(\overrightarrow{p_1})P_1(\overrightarrow{p_2})}$$

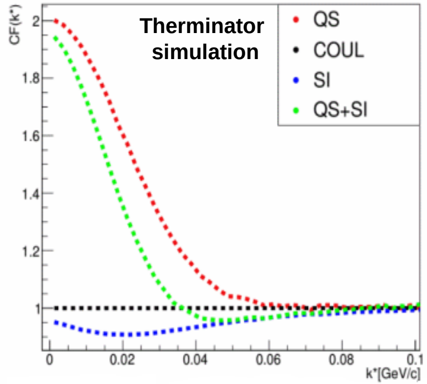
**The experimental correlation function:**

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

$$q_{inv} = \sqrt{(p_1 - p_2)^2 - (E_1 - E_2)^2}$$

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

## Neutral kaons correlations



The correlation function depends on:

- **Quantum statistics (QS)**
- **Final State Interactions (FSI)**
  **~~- Coulomb Interaction (COUL)~~**
  **- Strong Interaction (SI)**

# Parametrizations

**Gaussian density distribution** (includes only QS effects): $CF(q_{inv}) = 1 + \lambda e^{[-R_{inv}^2 q_{inv}^2]}$

$\lambda$ – the correlation strenght, $R_{inv}$ - the size of the particle-emitting source.

**Lednicky and Lyuboshitz model** includes strong FSI: Sov. J. Nucl. Phys. 35, 770 (1982)

$$CF(q_{inv}) = 1 + \lambda\left(\underbrace{\boxed{e^{[-R_{inv}^2 q_{inv}^2]}}}_{\text{QS effects}} + \underbrace{\boxed{\frac{1}{2}\left[\left|\frac{f(k^*)}{R_{inv}}\right|^2 + \frac{4\Re f(k^*)}{\sqrt{\pi}R_{inv}}F_1(q_{inv}R_{inv}) - \frac{2\Im f(k^*)}{\sqrt{\pi}R_{inv}}F_2(q_{inv}R_{inv})\right]}}_{\text{strong FSI through the } f_0(980) \text{ and } a_0(980) \text{ resonances}}\right)$$

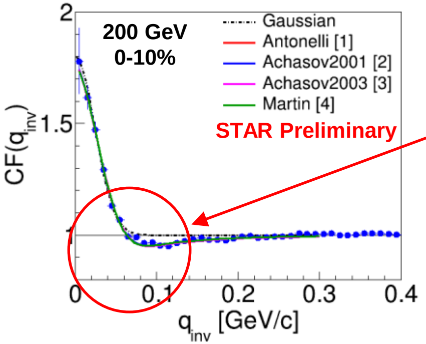
$$F_1(z) = \int_0^z dx\,\frac{e^{x^2} - z^2}{z}, \quad F_2(z) = \frac{1 - e^{-z^2}}{z}$$

$$f(k^*) = \frac{1}{2}[f_0(k^*) + f_1(k^*)], \quad f_I(k^*) = \frac{\gamma_r}{m_r - s - i\gamma_r k^* - i\gamma_r' k_r'}, \quad s = 4(m_K^2 + k^{*2})$$

| | $m_{f_0}\,[\frac{\mathrm{GeV}}{\mathrm{c}^2}]$ | $\gamma_{f_0K\bar{K}}$ | $\gamma_{f_0\pi\pi}$ | $m_{a_0}\,[\frac{\mathrm{GeV}}{\mathrm{c}^2}]$ | $\gamma_{a_0K\bar{K}}$ | $\gamma_{a_0\pi\pi}$ |
|---|---|---|---|---|---|---|
| Antonelli [1] | 0.973 | 2.763 | 0.5283 | 0.985 | 0.4038 | 0.3711 |
| Achasov2001 [2] | 0.996 | 1.305 | 0.2684 | 0.992 | 0.5555 | 0.4401 |
| Achasov2003 [3] | 0.996 | 1.305 | 0.2684 | 1.003 | 0.8365 | 0.4580 |
| Martin [4] | 0.978 | 0.792 | 0.1990 | 0.974 | 0.3330 | 0.2220 |

[1] eConf C020620, THAT06 (2002), [2] Phys. Rev. D 63, 094007 (2001)
[3] Phys. Rev. D 68, 014006 (2003), [4] Nucl. Phys. B 121, 514–530 (1977)

# Results



**strong FSI through the $f_0(980)$ and $a_0(980)$ resonances**

**Summary:**

- The strong final-state interaction has a significant effect on the $K_s^0 K_s^0$ correlation due to the near-threshold $f_0(980)$ and $a_0(980)$ resonanses
- The radii of the source depend on centrality and increase with increasing collision energy
- Comparison with model calculations shows better compability for UrQMD model

**Future plans:** $K_s^0 K^{ch}$ correlation functions