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Dynamics of particle emission probed by femtoscopic correlations in the STAR experiment

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Abstract

One of methods to study the properties of hot and dense nuclear matter created in high-energy nuclear collisions is femtoscopic measurements. This method provides information about space-time characteristics of the particle emission region, which has a size and lifetime of the order of 10^{-15} m and 10^{-23} s, respectively. From non-identical particle correlations, one can obtain information about asymmetry in the emission process between those two kinds of particles [1]. Such an emission asymmetry gives knowledge on geometric and dynamic (times of emission) properties of the particle emitting source. Such investigation could provide information about differences between the emission of light mesons (pions), strange mesons (kaons) and baryons (protons).

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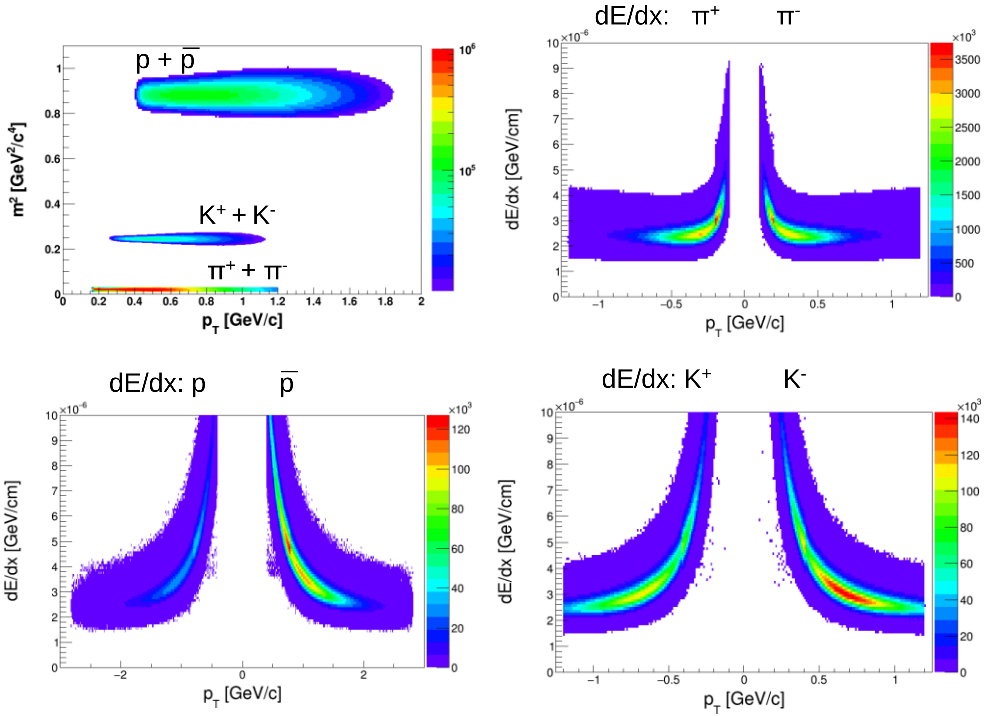
The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations

STAR

Particle identification

	π	K	p
p_T [GeV/c]	[0.1 - 1.2]	[0.1 - 1.2]	[0.4 - 2.5]
p [GeV/c]	[0.1 - 1.2]	[0.1 - 1.2]	[0.4 - 3.0]
Momentum threshold [GeV/c]	0.2	0.41	0.8
Mass squared window [GeV²/c⁴]	[0.01 - 0.03]	[0.21 - 0.28]	[0.76 - 1.03]
|Nσ|	≤ 3.0		
Pseudorapidity |η|	≤ 0.5		
Distance of closest approach (DCA) [cm]	≤ 3.0		



Femtoscopy

Theoretical correlation function can be described by the Koonin-Pratt formula [2, 3]:

$$C(\boldsymbol{k}^*) = \int d\boldsymbol{r}\, |\boldsymbol{\psi}(k^*, r)|^2\, S(\boldsymbol{r})$$

where $\Psi(\mathbf{k^*},\mathbf{r})$ is a pair wave function that expresses interactions between particles, and $S(\mathbf{r})$ is the source function – distribution of relative positions of particles.

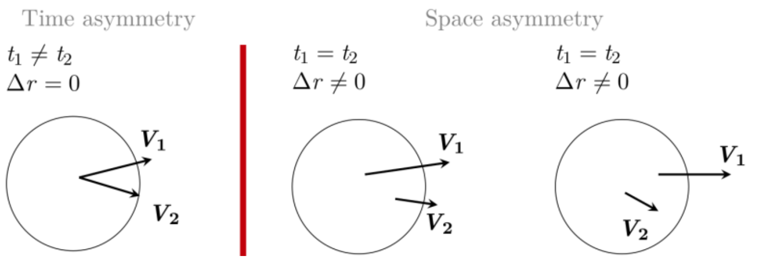
The source of non-identical particles is assumed by 3-dimensional Gauss distribution with sizes R in *out*, *side* and *long* directions, and the mean μ value corresponding to the emission asymmetry:

$$S(\boldsymbol{r}) \propto \exp\left(-\frac{(r_{out}-\mu)^2}{2R_{out}^2} - \frac{r_{side}^2}{2R_{side}^2} - \frac{r_{long}^2}{2R_{long}^2}\right)$$

Emission asymmetry

Asymmetries in the emission process may arise from long-lived resonances, bulk collective effects, or differences in the freeze-out scenario for different particle species [4].

The separation comes from:
• space asymmetry (flow) • emission time difference



t – emission time, r – emission point distance from center, V_1, V_2 – velocity of the particle

- Moving away scenario – faster particle is emitted earlier (or closer to the edge of the source)
- Catching up scenario – faster particle is emitted later (or closer to the center of the source)

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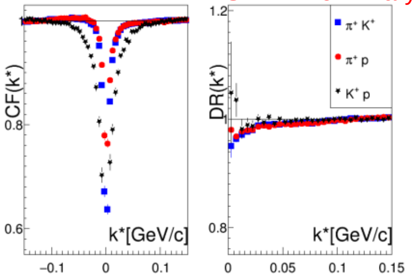
Double ratio function

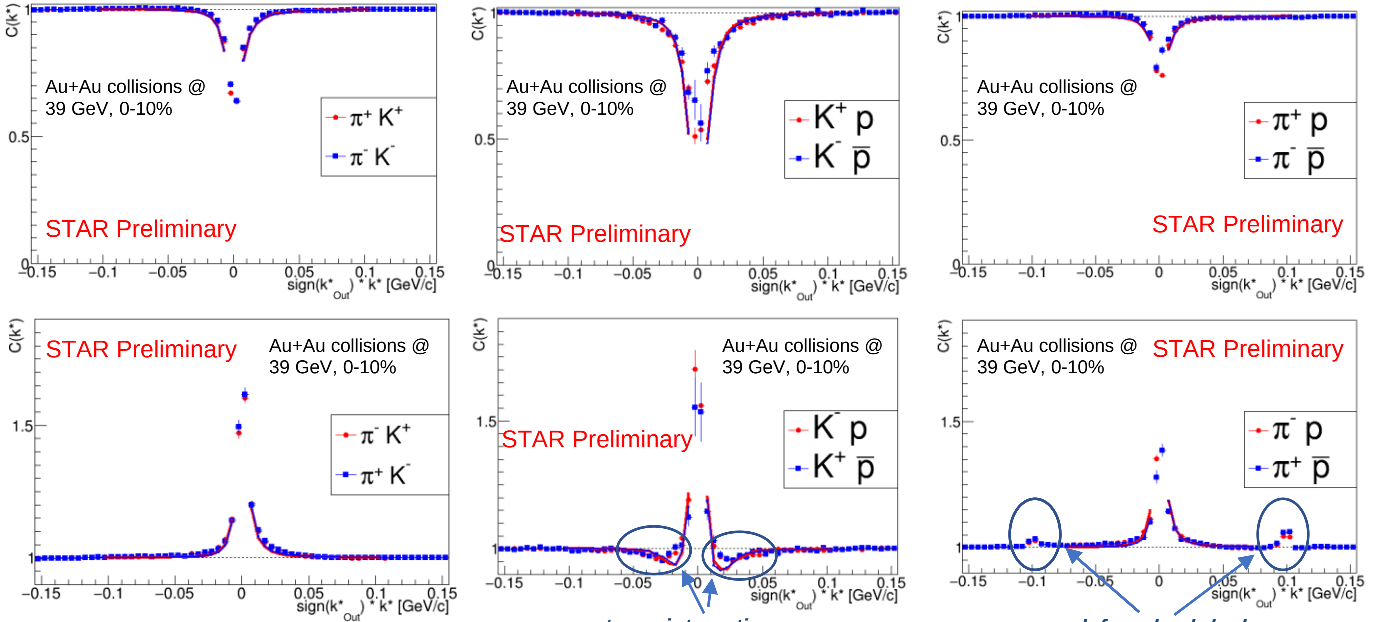
Correlation functions are caluclated for two groups of pair:

- $C_{+}(k^{*})$ - first (lighter) particle is faster
- $C_{-}(k^{*})$ - second (heavier) particle is faster

Double ratio is definied as a ratio C+ to C- and it is sensitive to the average separation of particles.



*solid lines represent theoretical fits of the correlation function.



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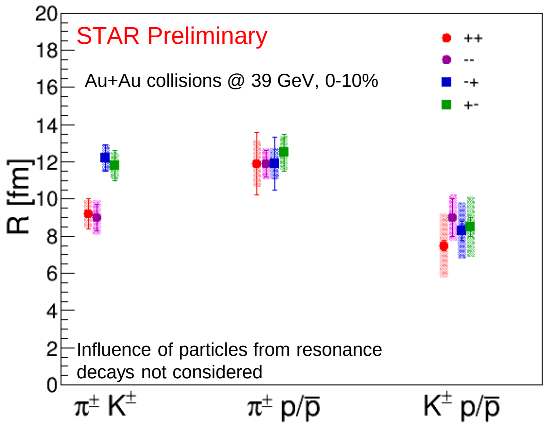

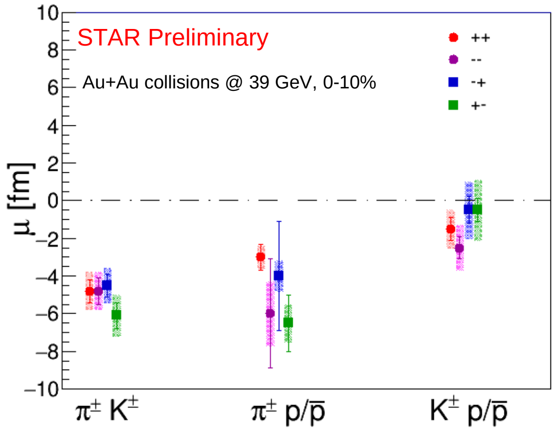

Summary:

- Asymmetry is visible in each kind of analyzed pair,
- Lighter particles are emitted closer to the center and/or later,
- Pairs from lambda resonance have a negligible impact on the correlation effect,
- Only KP pairs have visible, significant strong interaction.

References

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