One-dimensional pion femtoscopy in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR

Eugenia Khyzhniak

(for the STAR collaboration)

National Research Nuclear University MEPhI

NUCLEUS-2020
Outline

- Motivation
- Femtoscoppy
- Correlation functions and their fits
- Systematic uncertainty
- $k_T$ dependence of $R_{inv}$ and $\lambda$
- System comparison
Motivation

Examination of the spatial and temporal scales of the particle-emitting source is one of the ways to study the process of particle production.

M. Podgoretsky 1989 Particles & Nuclei 20 630-68

In small systems (like p+p or d+Au) a collision area size is sensitive to fluctuations of initial conditions. Therefore, the detailed nature of particle production becomes important.

Femtoscopy allows one to measure:
- Size of the emission source
- Source shape & orientation
- Lifetime & Emission duration

System expansion dynamics are influenced by:
- Transport properties
- Phase transition/Critical point
- Initial-state event shape

Extracted radii measure the homogeneity lengths of the source
Analysis technique

Schematic view

Construction of the correlation function:

$$C(Q_{inv}) = \frac{A(Q_{inv})}{B(Q_{inv})}$$

$$Q_{inv} = \sqrt{(\vec{p}_1 - \vec{p}_2)^2 - (E_1 - E_2)^2}$$

$A(Q_{inv})$ – $Q_{inv}$ distribution with Bose-Einstein statistics (and final-state interactions – Coulomb and strong)

$B(Q_{inv})$ – $Q_{inv}$ distribution without it

Fit of the correlation function:

$$C(Q_{inv}) = N \left(1 - \lambda + \lambda K_{Coul}(Q_{inv})(1 + G(Q_{inv}))\right) D(Q_{inv})$$

$$G(Q_{inv}) = e^{-q_{inv}^2 R_{inv}^2}$$

$N$ – normalization factor

$\lambda$ – correlation strength parameter

$K_{Coul}$ - Coulomb correction factor

$D(Q_{inv}) = 1$ (in this analysis) – Non-femtoscopic correlations
The STAR experiment

- **Colliding system:**
  - \(d+Au@200\text{ GeV}\)

- **Pion identification:**
  - Time Projection Chamber (TPC) - main tracking detector, \(|\eta| < 1.0\), full azimuth
Example of the correlation functions and fits

Gaussian fit assumption:
\[ G(Q_{\text{inv}}) = e^{-q_{\text{inv}}^2 R_{\text{inv}}^2} \]

Correlation functions and their fits look reasonable

\[ \vec{k}_T = \frac{\vec{p}_{1T} + \vec{p}_{2T}}{2} \]

Lorentzian fit assumption:
\[ G(Q_{\text{inv}}) = e^{-q_{\text{inv}} R_{\text{inv}}} \]
Statistical and systematic uncertainty

- For almost all cases statistical uncertainty smaller than marker size

- Sources of the systematic uncertainty:
  - Selection criteria of the events (position of the primary vertex): < 5%
  - Selection criteria of the tracks (momentum of the tracks, tracking efficiencies): < 6%
  - Selection criteria of the pairs (two track effects – merging, splitting): < 2%
  - Fit range: < 3%
  - Coulomb radius: < 3%

- Plan to investigate single track momentum resolution
$k_T$ dependence of $R_{inv}$ and $\lambda$

- Radius decreases with increasing $k_T$
- Radius increases with increasing particle multiplicity
- Correlation strength parameter decreases with particle multiplicities
  - Influences of the resonances increases?
Summary

- Femtoscopic parameters were obtained for d+Au colliding system
- The $k_T$ dependence of the $R_{inv}$ shows the dynamic of the system and allows to probe the different regions of the homogeneity in d+Au system
- Radius increases with increasing particle multiplicity
- Correlation strength parameter decreases with particle multiplicities
Thank you for your attention!
Back-up slide
## Selection criteria

<table>
<thead>
<tr>
<th>Event cuts</th>
<th>Track cuts</th>
<th>Pair cuts</th>
<th>Pion TPC cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>Z_{TPC}</td>
<td>$ (cm) &lt; 40</td>
<td>$N_{Hits} &gt; 15$</td>
</tr>
<tr>
<td>$\sqrt{X_{TPC}^2 + Y_{TPC}^2}$ (cm) &lt; 2</td>
<td>$N_{Hits}/N_{HitsFit} &gt; 0.51$</td>
<td>0.15 &lt; $k_T$ (GeV/c) &lt; 1.05</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>Z_{TPC} - Z_{VPD}</td>
<td>$ (cm) &lt; 5</td>
<td>DCA &lt; 2 cm</td>
</tr>
</tbody>
</table>

- $0.15 < p$ (GeV/c) < 0.8