Pion-kaon femtoscopy in Au+Au collisions at STAR

Katarzyna Poniatowska*
For STAR Collaboration

*Warsaw University of Technology
Faculty of Physics
Outline

- Motivation
- Space-time asymmetry
- Data selection
- Comparison of correlation functions for
  \( \sqrt{s_{NN}} = (130, 39, 7.7) \) GeV
- Comparison of asymmetry for \( \sqrt{s_{NN}} = (130, 39, 7.7) \) GeV
- Summary
The Solenoidal Tracker At RHIC (STAR)
Analyze all Beam Energy Scan (BES) energies and find answers:

If or how pion-kaon source changes with energy?

If or how pion-kaon asymmetry in emission process looks for all BES energies?

If or how the flow affects the pion-kaon system, consisting of particles of different masses?
**Space-time asymmetry**

\[ C(p_1, p_2) = \frac{P_2(p_1, p_2)}{P_1(p_1)P_1(p_2)} \]

- the probability of observing two particles with momentum \( p_1 \) and \( p_2 \) at the same time and the same place.
- \( P_1(p_1), P_1(p_2) \) – the probability of observing two particles with momentum \( p_1 \) and \( p_2 \) separately.

**cos(Ψ) > 0**
Catching up
Long time of effective interaction.
Strong correlation.

**cos(Ψ) < 0**
Run away
Short time of effective interaction.
Weak correlation.

\( v_1, v_2 \) - 1\(^{st}\), 2\(^{nd}\) particle velocity.
\( v = v_1 + v_2 \)

Double ratio
Sensitive for space-time asymmetry in emission process.

---

28 July - 6 August 2014  Kolymbari, Greece  ICNFP 2014  Katarzyna Poniatowska
Data selection

<table>
<thead>
<tr>
<th></th>
<th>7.7 GeV</th>
<th>39 GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>analyzed</td>
<td>5.7 mln events</td>
<td>91.2 mln events</td>
</tr>
<tr>
<td>π momentum</td>
<td>[0.1, 1.2] GeV/c</td>
<td>[0.15, 0.7] GeV/c</td>
</tr>
<tr>
<td>K momentum</td>
<td>[0.1, 1.2] GeV/c</td>
<td>[0.3, 0.8] GeV/c</td>
</tr>
<tr>
<td>N σ for π and K</td>
<td>&lt; 3.0</td>
<td>&lt; 3.0</td>
</tr>
<tr>
<td>π m²</td>
<td>[0.0176, 0.022] GeV²/c⁴</td>
<td>[0.017, 0.026] GeV²/c⁴</td>
</tr>
<tr>
<td>K m²</td>
<td>[0.23, 0.26] GeV²/c⁴</td>
<td>[0.22, 0.27] GeV²/c⁴</td>
</tr>
<tr>
<td></td>
<td>η</td>
<td></td>
</tr>
<tr>
<td>DCA</td>
<td>&lt; 3cm</td>
<td>&lt; 3cm</td>
</tr>
</tbody>
</table>

Centrality definition:
- central: 0-10%
- minimum bias: 0-80%

28 July - 6 August 2014  Kolymbari, Greece  ICNFP 2014  Katarzyna Poniatowska
Comparison of Au+Au data for $\sqrt{s_{NN}}=130\text{GeV}$ and $\sqrt{s_{NN}}=39\text{GeV}$

Au+Au collision at $\sqrt{s_{NN}}=130\text{GeV}$ (central)

*Phys. Rev. Lett. 91 (2003) 262302*

Au+Au collision at $\sqrt{s_{NN}}=39\text{GeV}$ (central)

28 July - 6 August 2014  Kolymbari, Greece  ICNFP 2014  Katarzyna Poniatowska
Comparison of Au+Au data for $\sqrt{s_{NN}}=130\text{GeV}$ and $\sqrt{s_{NN}}=39\text{GeV}$

Trends of correlation functions for both energies are the same.

The correlation functions for 39GeV are stronger than the correlation functions for 130GeV.

Au+Au collision at $\sqrt{s_{NN}}=130\text{GeV}$ (central)

Au+Au collision at $\sqrt{s_{NN}}=39\text{GeV}$ (central)
Comparison of Au+Au data for $\sqrt{s_{NN}}=(130, 39, 7.7)$ GeV

Au+Au collision at $\sqrt{s_{NN}}=130$ GeV (central)


Au+Au collision at $\sqrt{s_{NN}}=39$ GeV
and $\sqrt{s_{NN}}=7.7$ GeV (minimum bias)
Comparison of Au+Au data for $\sqrt{s_{NN}}=(130, 39, 7.7)\, \text{GeV}$

Trends of correlation functions for all energies are the same.

The correlation functions for $39\, \text{GeV}$ and $7.7\, \text{GeV}$ looks the same within error bars.

Au+Au collision at $\sqrt{s_{NN}}=130\, \text{GeV}$ (central)

Au+Au collision at $\sqrt{s_{NN}}=39\, \text{GeV}$ and $\sqrt{s_{NN}}=7.7\, \text{GeV}$ (minimum bias)
Comparison of Au+Au data for $\sqrt{s_{NN}}=130\text{GeV}$ and $\sqrt{s_{NN}}=39\text{GeV}$

Au+Au collision at $\sqrt{s_{NN}}=130\text{GeV}$ (central)


Au+Au collision at $\sqrt{s_{NN}}=39\text{GeV}$ (central)

STAR preliminary

28 July - 6 August 2014  Kolymbari, Greece  ICNFP 2014  Katarzyna Poniatowska
Comparison of Au+Au data for \( \sqrt{s_{NN}} = 130 \text{GeV} \) and \( \sqrt{s_{NN}} = 39 \text{GeV} \)

**Au+Au collision at \( \sqrt{s_{NN}} = 130 \text{GeV} \) (central)**

**Au+Au collision at \( \sqrt{s_{NN}} = 39 \text{GeV} \) (central)**

*Phys. Rev. Lett. 91 (2003) 262302*

**STAR preliminary**

Stronger asymmetry effect.
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}} = 39 \text{GeV}$
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}} = 39\text{GeV}$

"Double ratio" for all particle combinations for side and long directions are flat for $k^* > 0.02\text{[GeV/c]}$. 

STAR preliminary
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}} = 39\text{GeV}$

"Double ratio" for all particle combinations for side and long directions are flat for $k^* > 0.02\,[\text{GeV/c}]$.

Trends for "double ratio" functions for same sign (different sign) particle combinations for out direction are similar.
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}} = 7.7$GeV

Minimum bias data.

Same sign particles sys. @ 7.7GeV
- out
- side
- long

Different sign particles sys. @ 7.7GeV
- out
- side
- long

STAR preliminary

$CF_+(k^*)/CF_-(k^*)$
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}}=7.7\text{GeV}$

Minimum bias data.

"Double ratio" for all particle combinations for side and long directions are flat in respect of error bars.
Asymmetry for Au+Au collisions at $\sqrt{s_{NN}}=7.7\text{GeV}$

Minimum bias data.

"Double ratio" for all particle combinations for side and long directions are flat in respect of error bars.

Trends for "double ratio" functions for same sign (different sign) particle combinations for out direction deviated from the unity – we observe the asymmetry.
Comparison of Au+Au data for $\sqrt{s_{NN}}=39\text{GeV}$ and $\sqrt{s_{NN}}=7.7\text{GeV}$

Minimum bias data.

STAR preliminary

Same sign particles sys.
- STAR 7.7GeV
- STAR 39GeV

Different sign particles sys.
- STAR 7.7 GeV
- STAR 39 GeV

Out direction

$CF_{+(k^*)}/CF_{-(k^*)}$

$k^*[\text{GeV/c}]$
Comparison of Au+Au data for $\sqrt{s_{NN}} = 39 \text{GeV}$ and $\sqrt{s_{NN}} = 7.7 \text{GeV}$

Minimum bias data.

We observe the same tendency in asymmetry for 7.7 GeV as for 39 GeV.
• Correlation functions and “double ratio” functions for minimum bias Au+Au collisions at 39GeV and 7.7GeV are calculated.

• Trends of correlation functions and “double ratio” functions for Au+Au collisions at 39GeV, 7.7GeV and 130GeV are the same.

• Pions are emitted closer to the system's center or/and later than kaons in systems created in collisions for 7.7GeV, 39GeV and 130GeV.

• Source size is bigger in Au+Au collisions at 130GeV than at 39GeV and 7.7GeV.

• The asymmetry in emission process in “double ratio” functions for 39GeV are stronger than for 130GeV.

• The correlation functions for 39GeV and 7.7GeV are stronger than the correlation functions for 130GeV.

• Due to small statistics we can only say, that source size in Au+Au collision at 7.7GeV are close to source size in Au+Au collision at 39GeV.
Thank you for your attention!
Back up
Comparison of Au+Au data for $\sqrt{s_{NN}}=39\text{GeV}$ and $\sqrt{s_{NN}}=7.7\text{GeV}$

Minimum bias data.

STAR preliminary
Comparison of Au+Au data for $\sqrt{s_{NN}}=39\,\text{GeV}$ and $\sqrt{s_{NN}}=7.7\,\text{GeV}$

Minimum bias data.

The data from 39GeV and 7.7GeV Au+Au collisions are consistent within errors
Comparison of Au+Au data for $\sqrt{s_{NN}}=39\text{GeV}$ and $\sqrt{s_{NN}}=7.7\text{GeV}$

We cannot devide data into 4 systems

The data from 39GeV and 7.7GeV Au+Au collisions are consistent within errors