Estimation of pion emission source in symmetric and asymmetric collision using the UrQMD model

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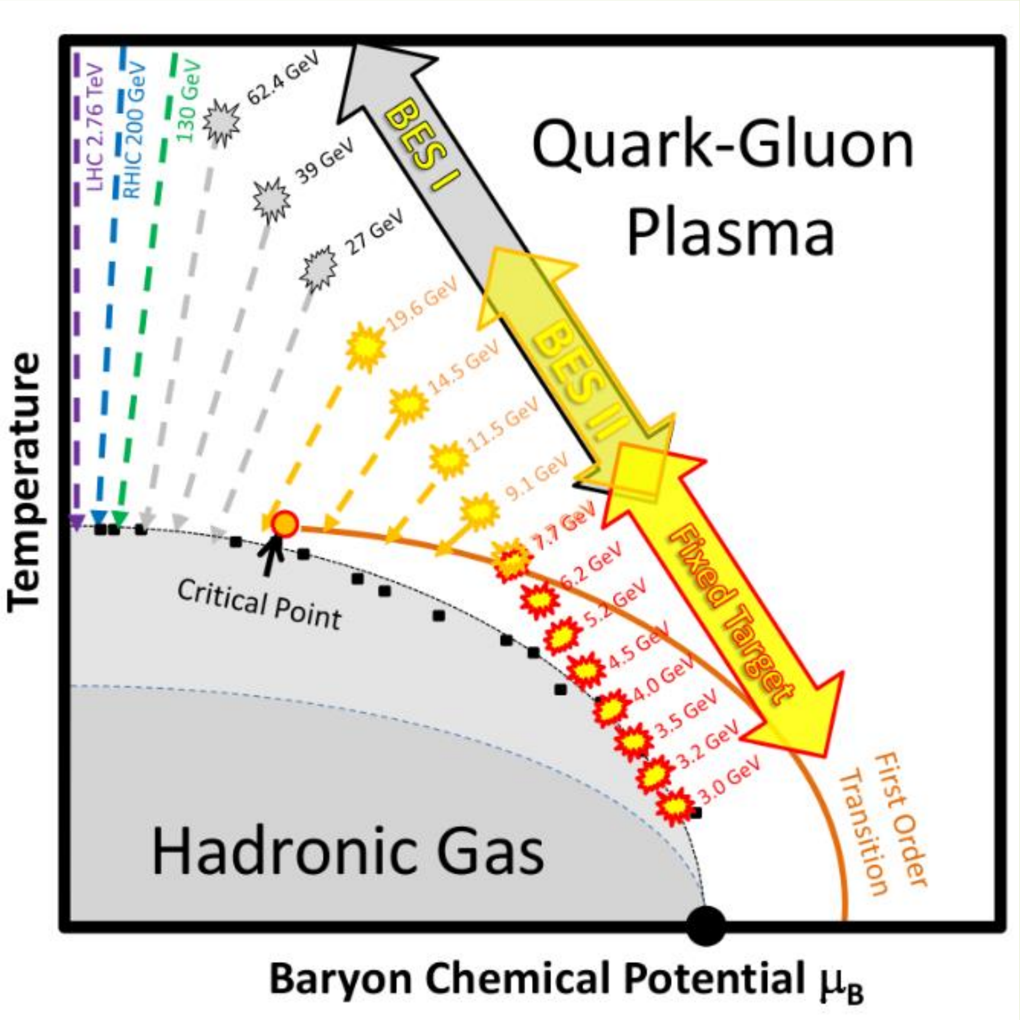
Outline

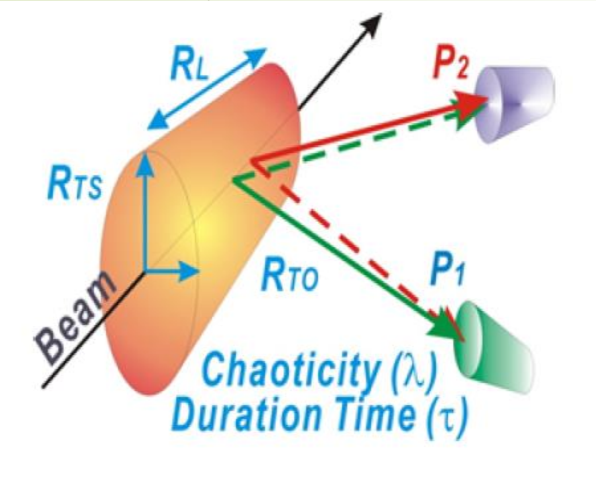
- Correlation femtoscopy
- Correlation function
- First part: HBT in asymmetric $\mathrm{d} + \mathrm{Au}$ and $\mathrm{He}^3 + \mathrm{Au}$ at 200 GeV collision system
- Second part: Azimuthally sensitive HBT in $\mathrm{Cu} + \mathrm{Au}$ and $\mathrm{Au} + \mathrm{Au}$ at 200 GeV collision system
- Conclusion

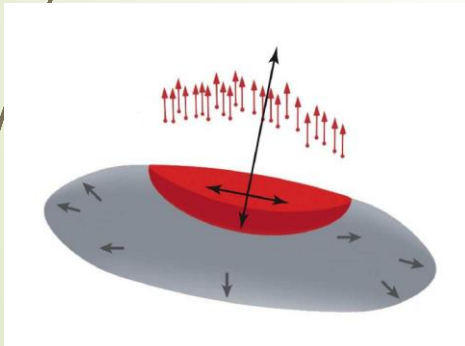
Motivation

- In order to make predictions, the **U**ltra **r**elativistic **Q**uantum **M**olecular **D**ynamics was used



Correlation femtoscopy

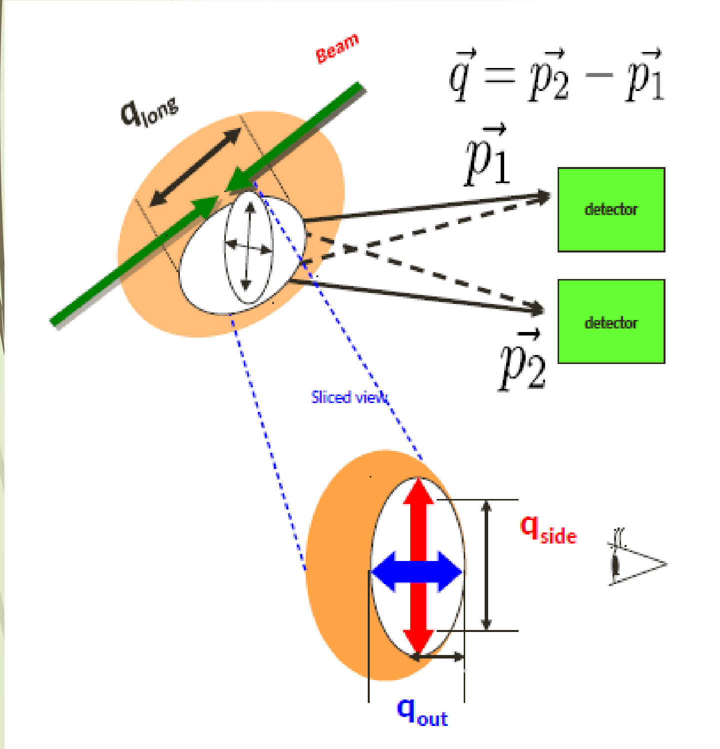




- **Femtoscopy allows to measure:**
  - Size of the emission source
  - Source shape & orientation
  - Lifetime & Emission duration
- **System expansion dynamics are influenced by:**
  - Transport properties
  - Phase transition/Critical point
  - Initial-state event shape

Extracted radii measure the homogeneity lengths of the source

Longitudinally Co-Moving System (LCMS)



- **The Bertsch-Pratt parameterization:**
  - q_{long} (R_{long})→ along the beam direction
  - q_{out} (R_{out})→ direction of average transverse momentum of the pair
  - q_{side} (R_{side})→ perpendicular to the out and long directions

$$R^2_{out} = R^2_{side} + \beta^2_T(\Delta\tau)^2 - 2\beta_T\Delta x_{out}\Delta\tau$$

$$R^2_{long} = \lambda^2\tau^2(1 + \frac{3}{2}\lambda^2);$$

$$where \quad \lambda^2 = \frac{T}{m_T}(1 - (\beta^2_T))^{\frac{1}{2}}$$

$$R^2_{side} = \frac{R^2_{geo}}{1 + \frac{m_T}{T}\beta^2_T}$$

- [Yu. M. Sinyukov et al. Nucl.Phys. A946 (2016) 227-239]

- Emission Duration $\Delta\tau$
- Lifetime τ
- Transverse geometric source size R_{geo}
- **r** vector component in Cartesian coords x_{out}
- Transverse velocity of pair β_T

Correlation function

Simulations were performed with the Ultra Relativistic Quantum Molecular Dynamics (UrQMD 3.4) transport model.

[M. Bleicher et al. J. Phys. G25 (1999) 1859–1896]

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

- *A(q)* – *q* distribution with $Weight = 1 + \cos(\Delta x \Delta p)$
- *B(q)* – *q* distribution with $Weight = 1$

1-D Fit function

$$C(q_{inv}) = 1 + \lambda G(q_{inv})$$

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

and

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

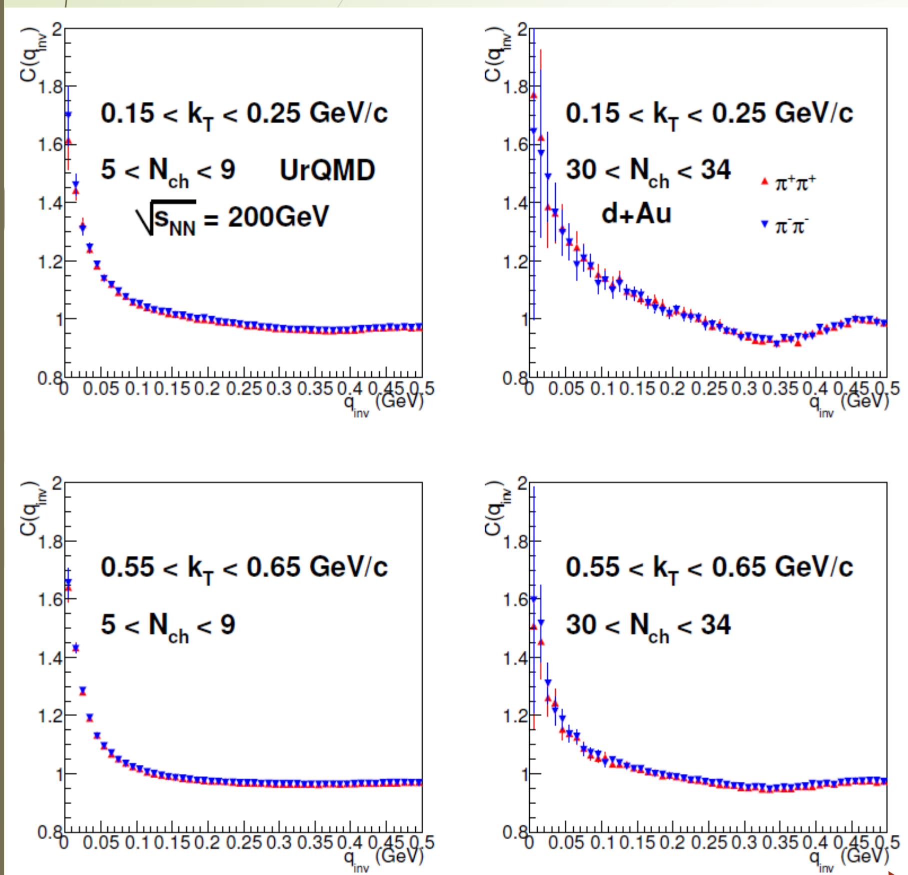
3-D Fit function

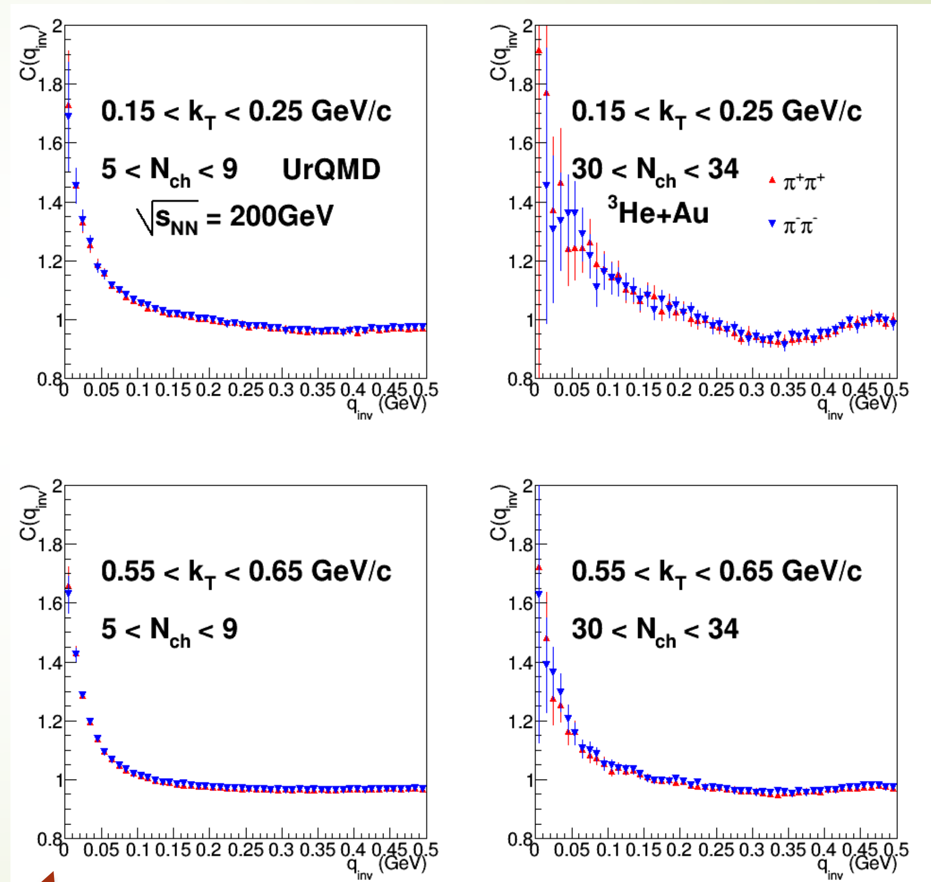
$$C(q, \Delta\varphi) = 1 + \lambda G(q, \Delta\varphi)$$

$$\begin{aligned} G(q_{out}, q_{side}, q_{long} \Delta\varphi) &= \exp(-q_{out}^2 R_{out}^2(\Delta\varphi) - q_{side}^2 R_{side}^2(\Delta\varphi) \\ &- q_{long}^2 R_{long}^2(\Delta\varphi) - 2 q_{out} q_{side} R_{os}^2(\Delta\varphi) \\ &- 2 q_{side} q_{long} R_{sl}^2(\Delta\varphi) - 2 q_{out} q_{long} R_{ol}^2(\Delta\varphi)) \end{aligned}$$

First part: HBT in asymmetric $\mathrm{d} + \mathrm{Au}$ and $\mathrm{He}^3 + \mathrm{Au}$ at 200 GeV system

1. Correlation function for positive and negative pions



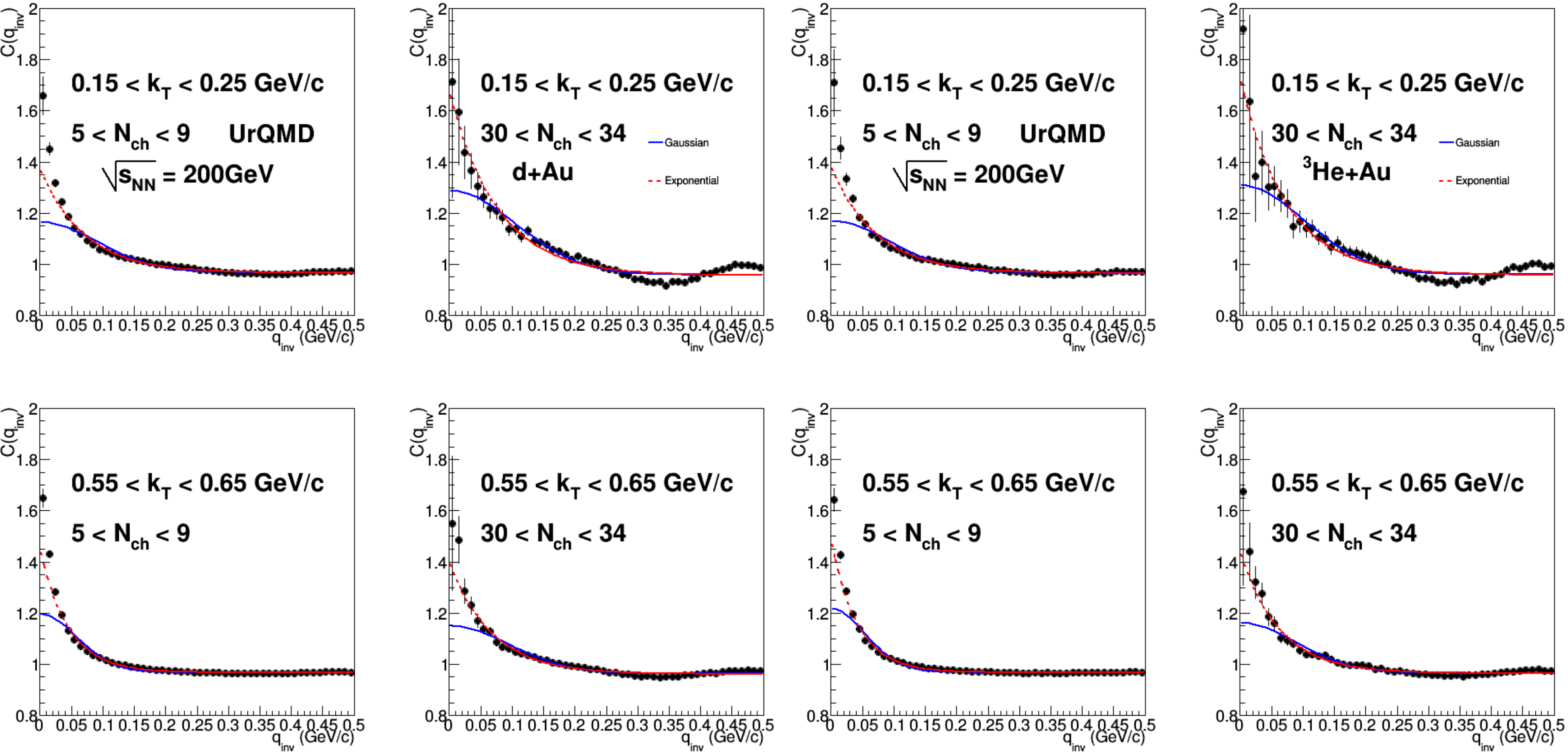


$d + Au$ for $\pi^+\pi^+$ and $\pi^-\pi^-$

$^3He + Au$ for $\pi^+\pi^+$ and $\pi^-\pi^-$

CF look similar, so we can combine $\pi^+\pi^+$ and $\pi^-\pi^-$ and increase our statistics

2. Fit of correlation functions

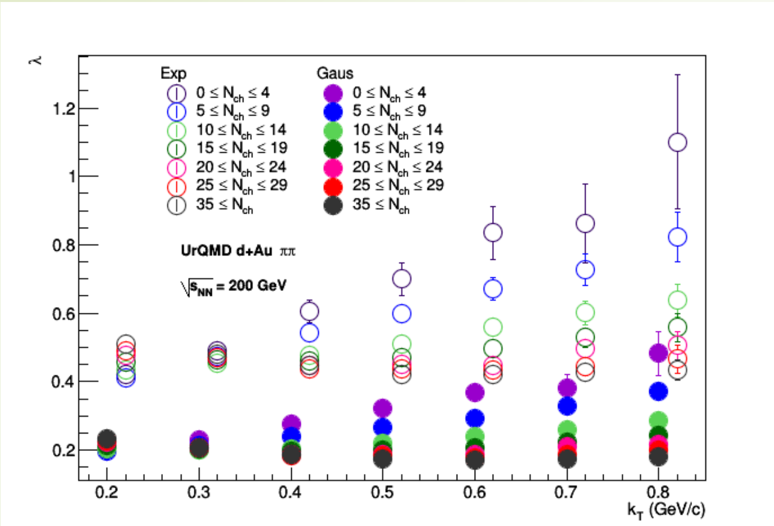


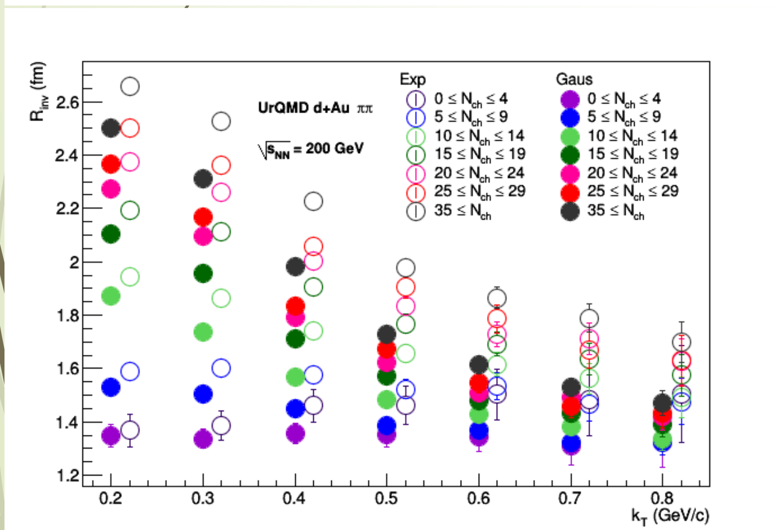
$d + Au$ for $\pi^+\pi^+ + \pi^-\pi^-$ **$^3He + Au$ for $\pi^+\pi^+ + \pi^-\pi^-$**

Exponential fit gives better description that the Gaussian one

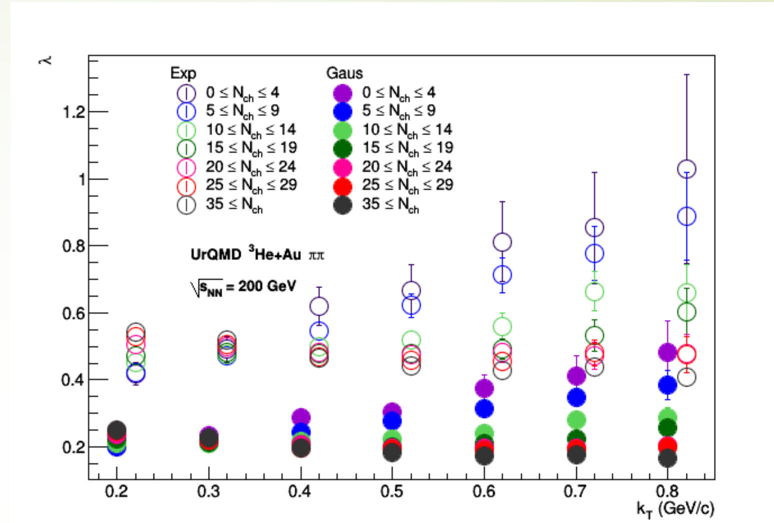
3. Exp. Vs. Gauss function for fit

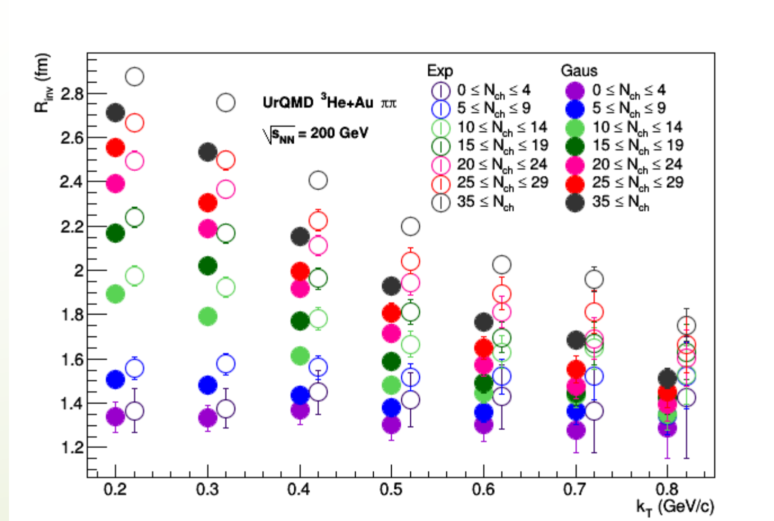
$d + Au$





$^3He + Au$

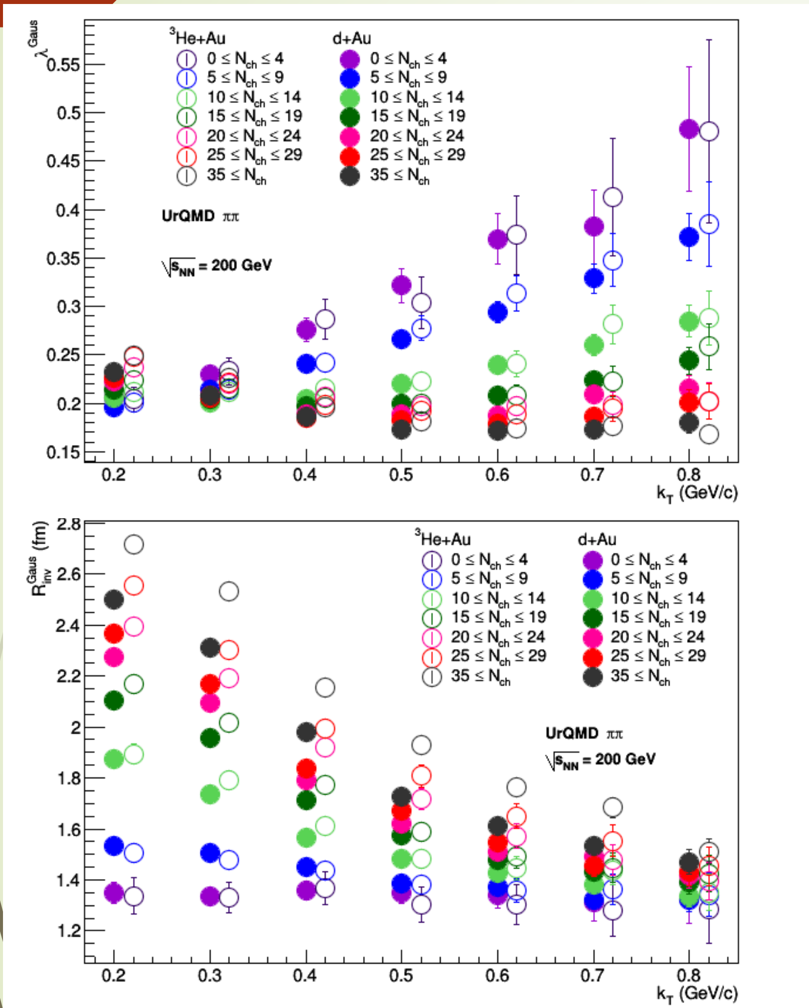




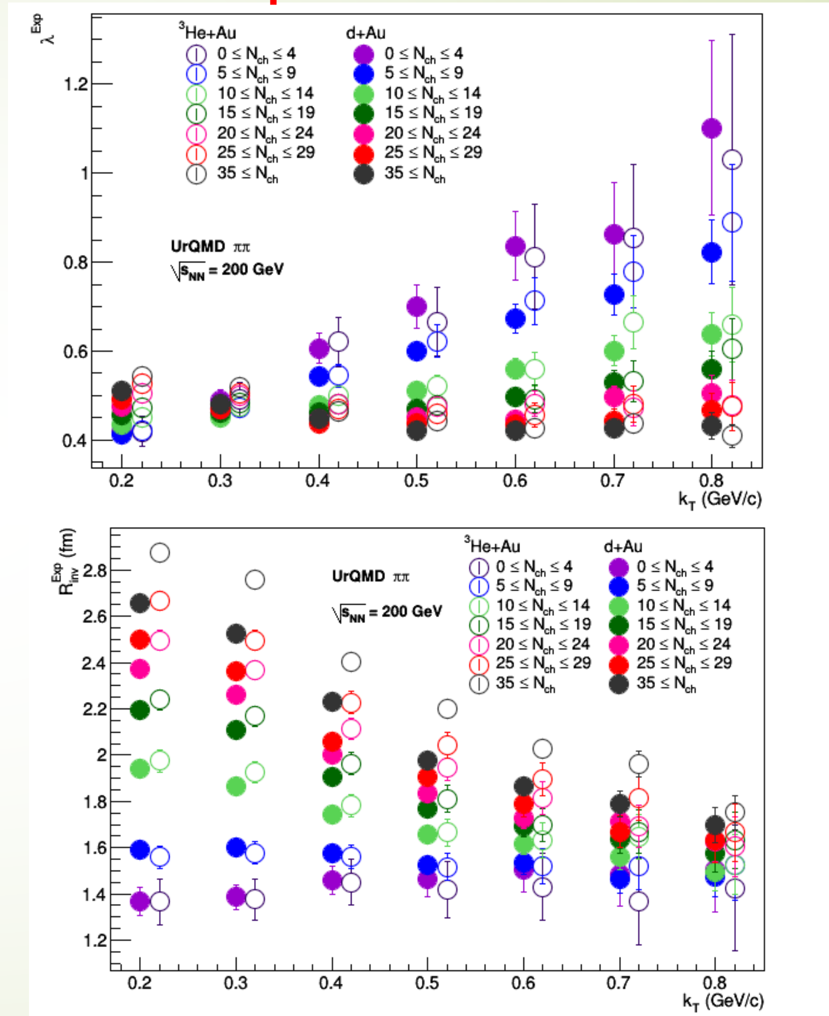
Femtoscopic parameters obtained from expo fits are systematically larger than those for Gaussian fit

4. Radii dependence of transverse momentum for different multiplicity

Gauss fit



Exponential fit



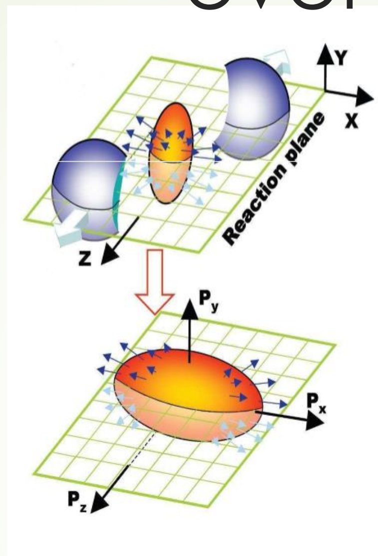
Flow multiplicity events (Nch < 20) femtoscopic parameters obtained for $He^3 + Au$ and $d + Au$ are consistent within uncertainties

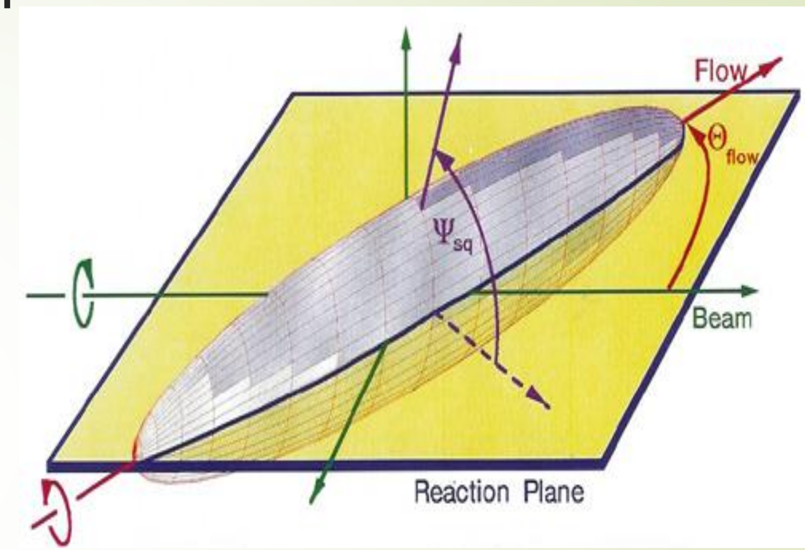
For larger multiplicities femtoscopic radii obtained for $He^3 + Au$ are systematically larger than those for $d + Au$

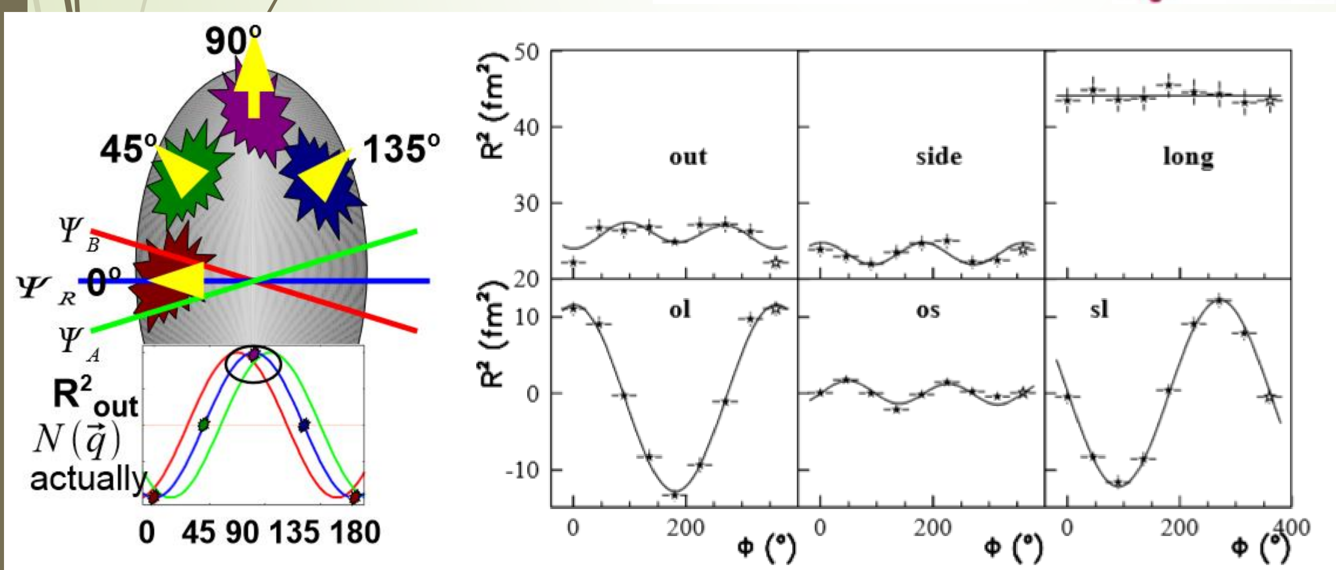
Second part: Azimuthally sensitive HBT in $\mathrm{Cu} + \mathrm{Au}$ and $\mathrm{Au} + \mathrm{Au}$ at 200 GeV

Azimuthally sensitive HBT wrt. To the event plane

In heavy ion collision spatial anisotropy lids to momentum anisotropy. In non-central collisions created medium can be tilted in reaction plane



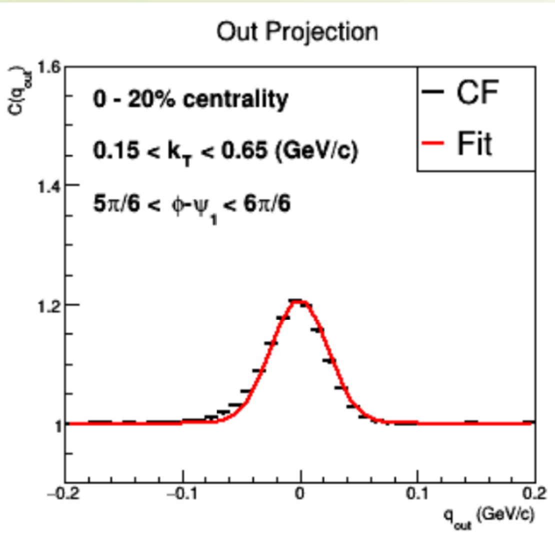


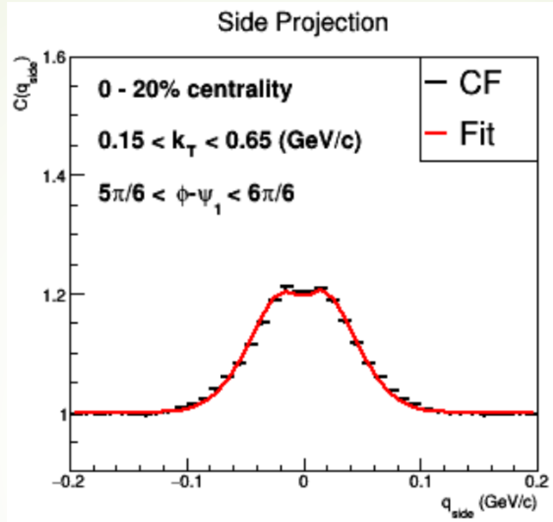


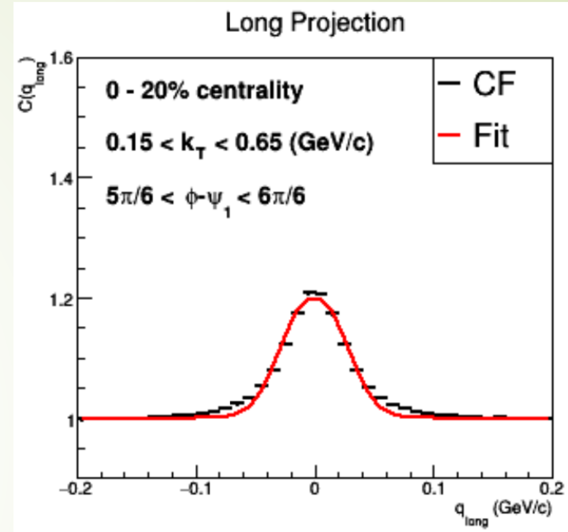
Azimuthally sensitive HBT measurements allow us to probe shape and orientation of emission source

1.Correlation functions and their fits

Au+Au@200 GeV

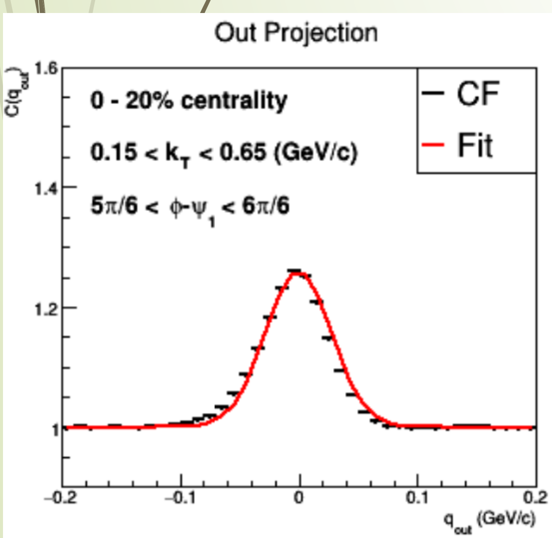


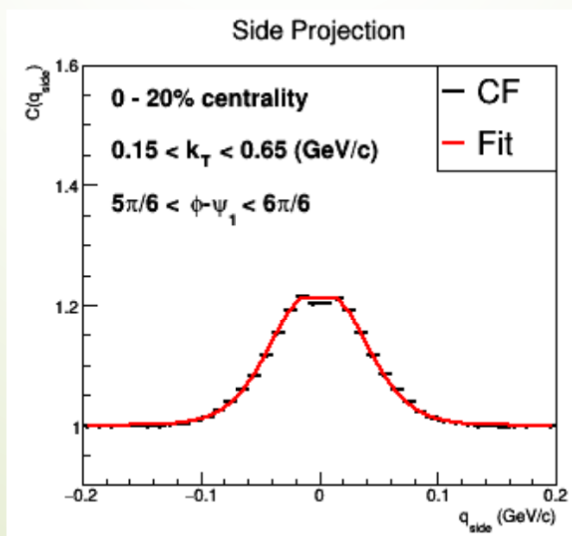


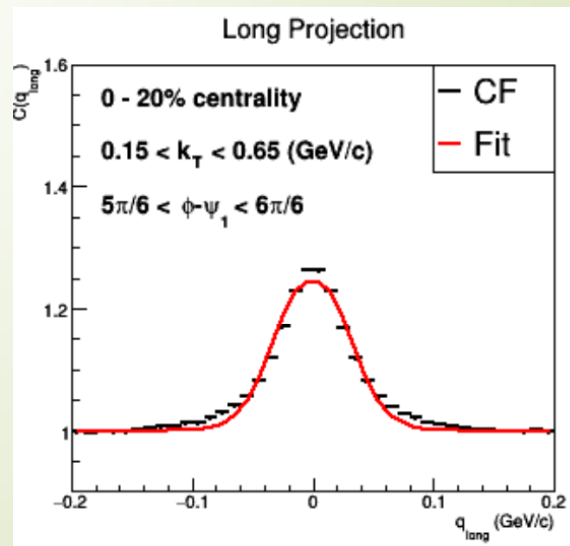


Cu+Au@200 GeV

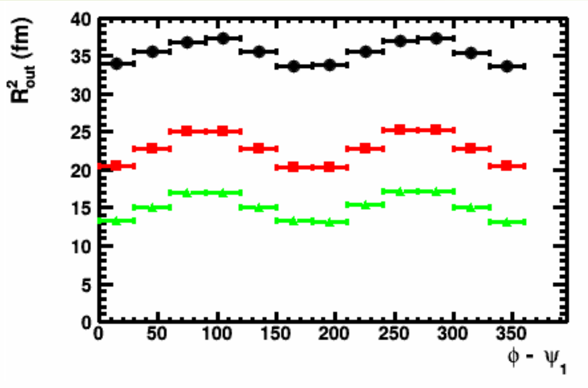
All fits of CFs look good

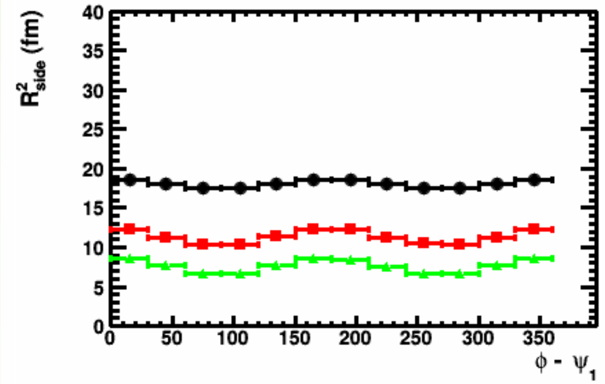


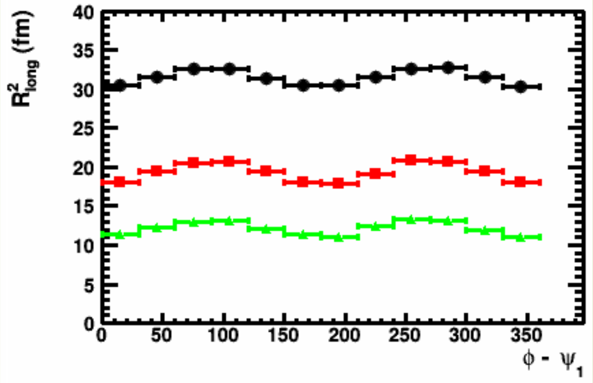


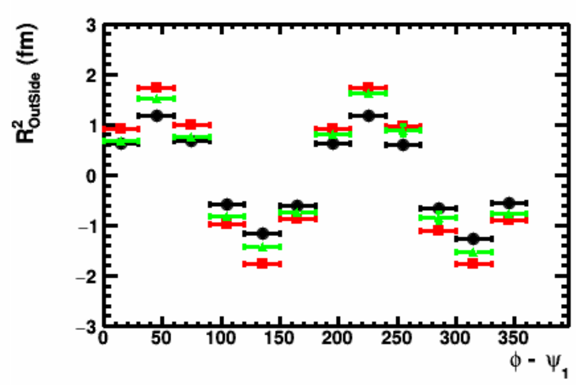


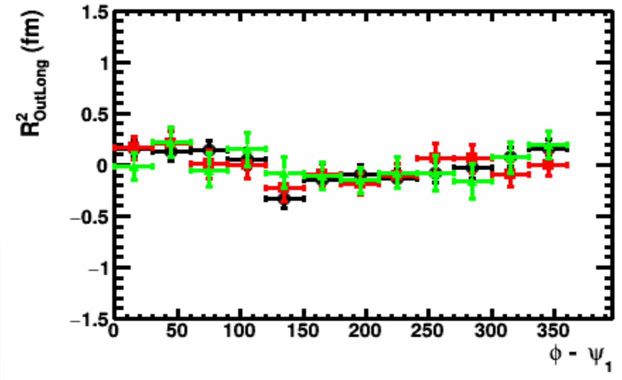
2. Au+Au@200GeV: azimuthally differential femtoscopic mesurements

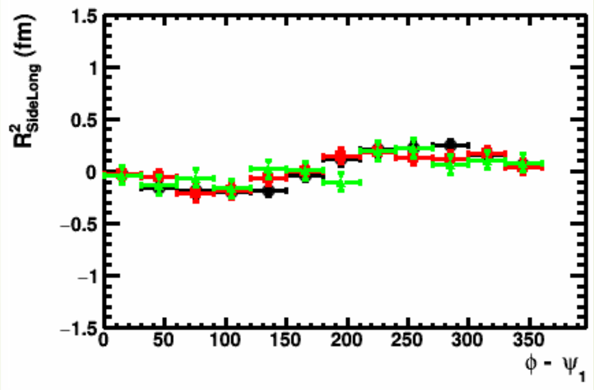


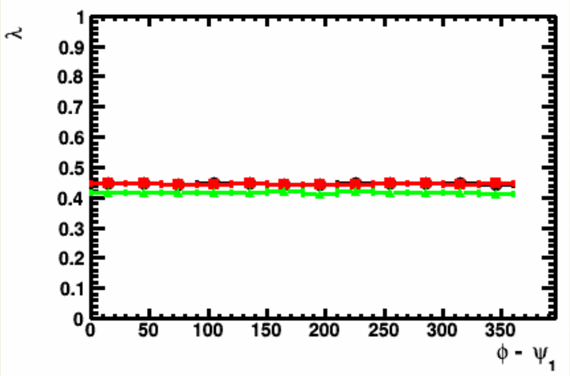


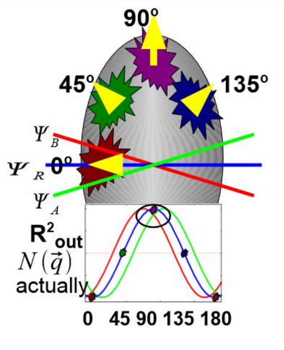








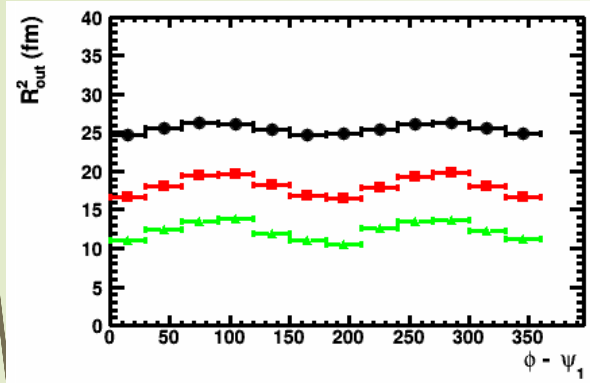


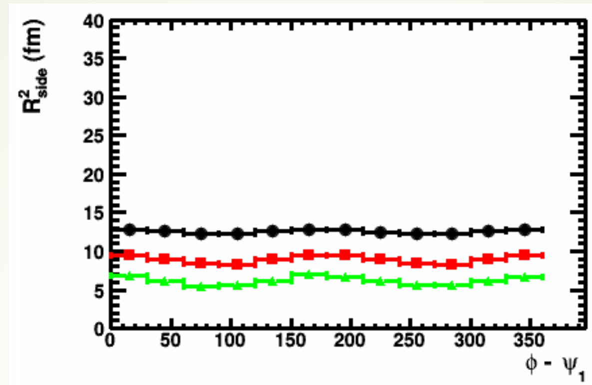


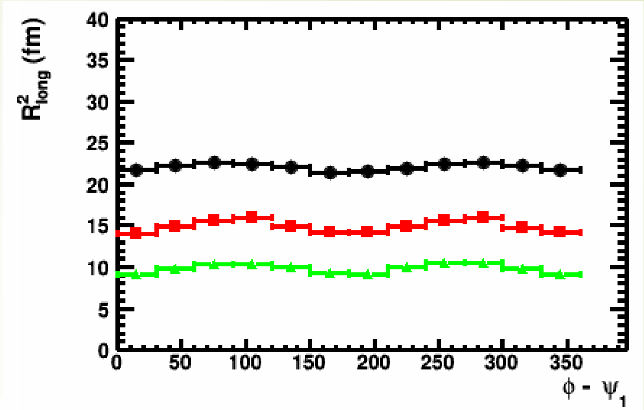
10M events

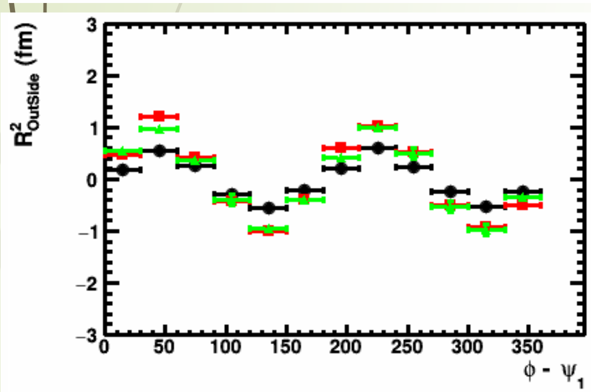
- ● 0 - 20% centrality $\pi^+\pi^+ + \pi^-\pi^-$
- ■ 20 - 40% centrality $\pi^+\pi^+ + \pi^-\pi^-$
- ▲ 40 - 80% centrality $\pi^+\pi^+ + \pi^-\pi^-$

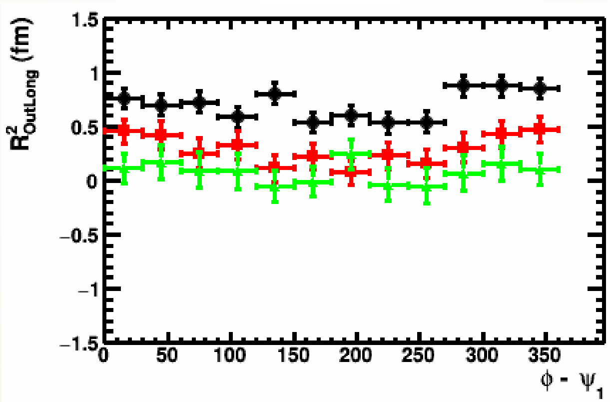
3. Cu+Au@200GeV: azimuthally differential femtoscopic mesurements

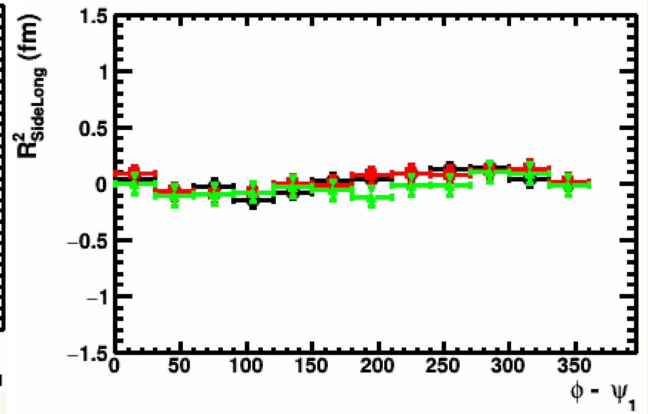


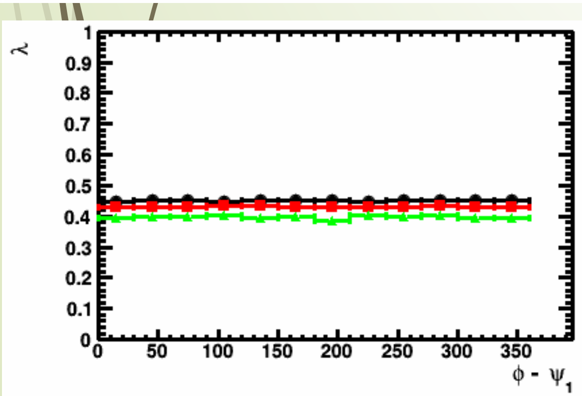


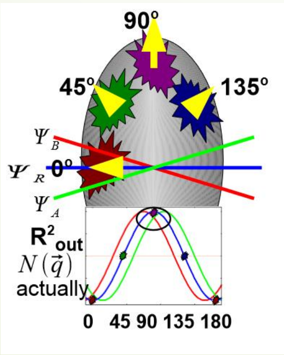












10M events

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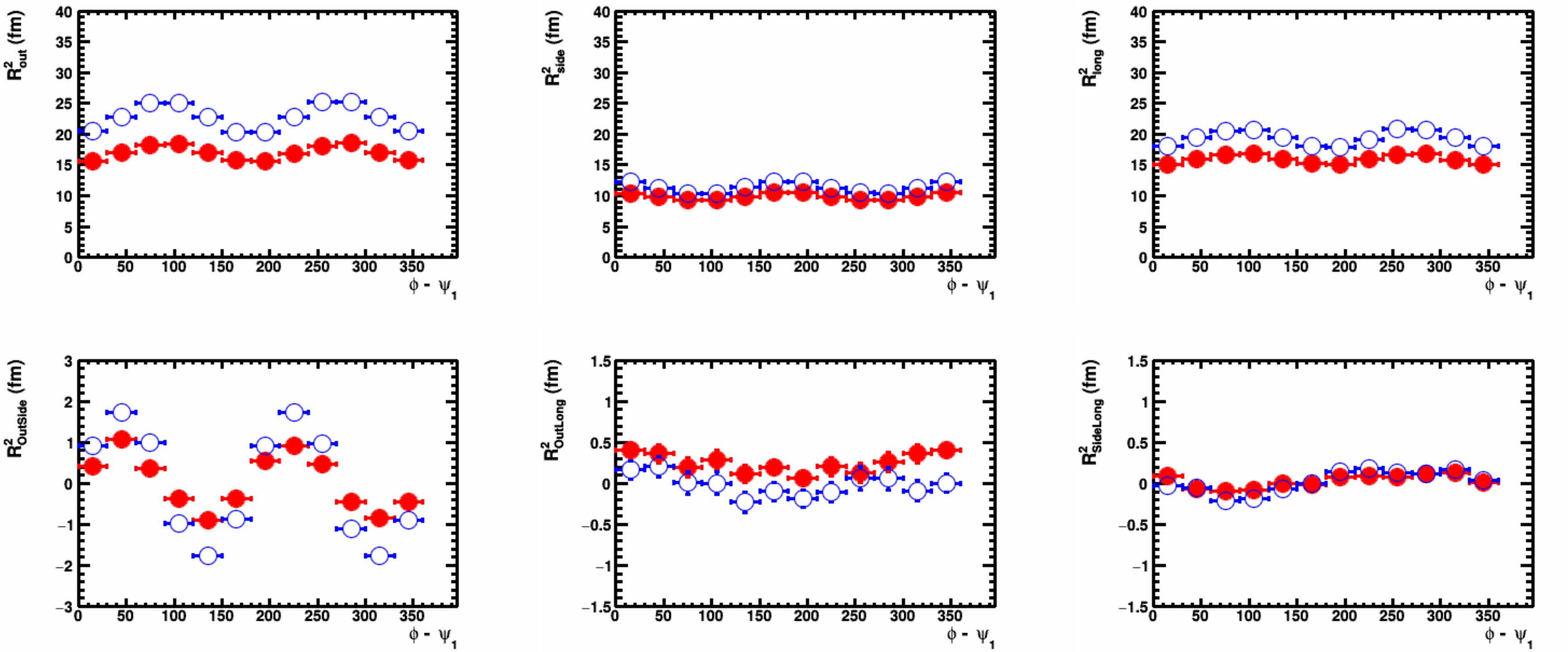
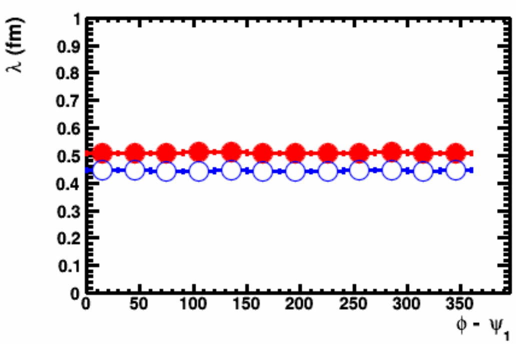
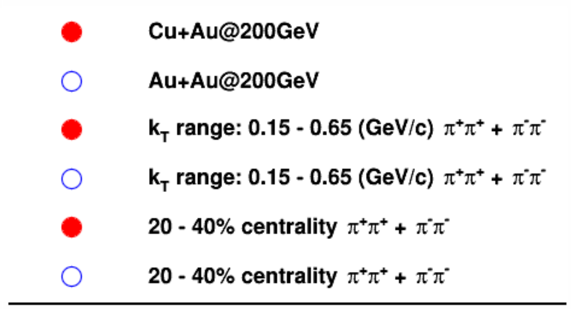
4. Cu+Au Vs. Au+Au@200GeV





Femtoscopic radii measured for AuAu collisions are systematically larger those fore Cu+Au



Summary

- Pion femtoscopy in $\mathrm{d}+\mathrm{Au}$ and $\mathrm{He}^3+\mathrm{Au}$ collisions at 200 GeV
  - Correlation functions for positive and negative pion pairs are the same within the statistical uncertainties
  - Gaussian Vs. Exponential source:
    - Exponential fit gives better description that the Gaussian one
    - The femtoscopic radii for exponential fits as compared to Gaussian fits systematically larger
  - Extracted femtoscopic radii decrease with increasing k_T and decreasing multiplicity
- Azimuthally sensitive HBT in $\mathrm{Cu}+\mathrm{Au}$ and $\mathrm{Au}+\mathrm{Au}$ at 200 GeV
  - In 3D analysis with respect to the first-order event plane the oscillations of the radii were observed as the function of azimuthal angle
  - The extracted radii for Au+Au collisions are systematically larger than those for Cu+Au at the same centrality and pair transverse momentum

Thank you for attention!