Estimation of the isotopic spin influence on femtoscopic correlations of identical pions in Au+Au collisions in the UrQMD model

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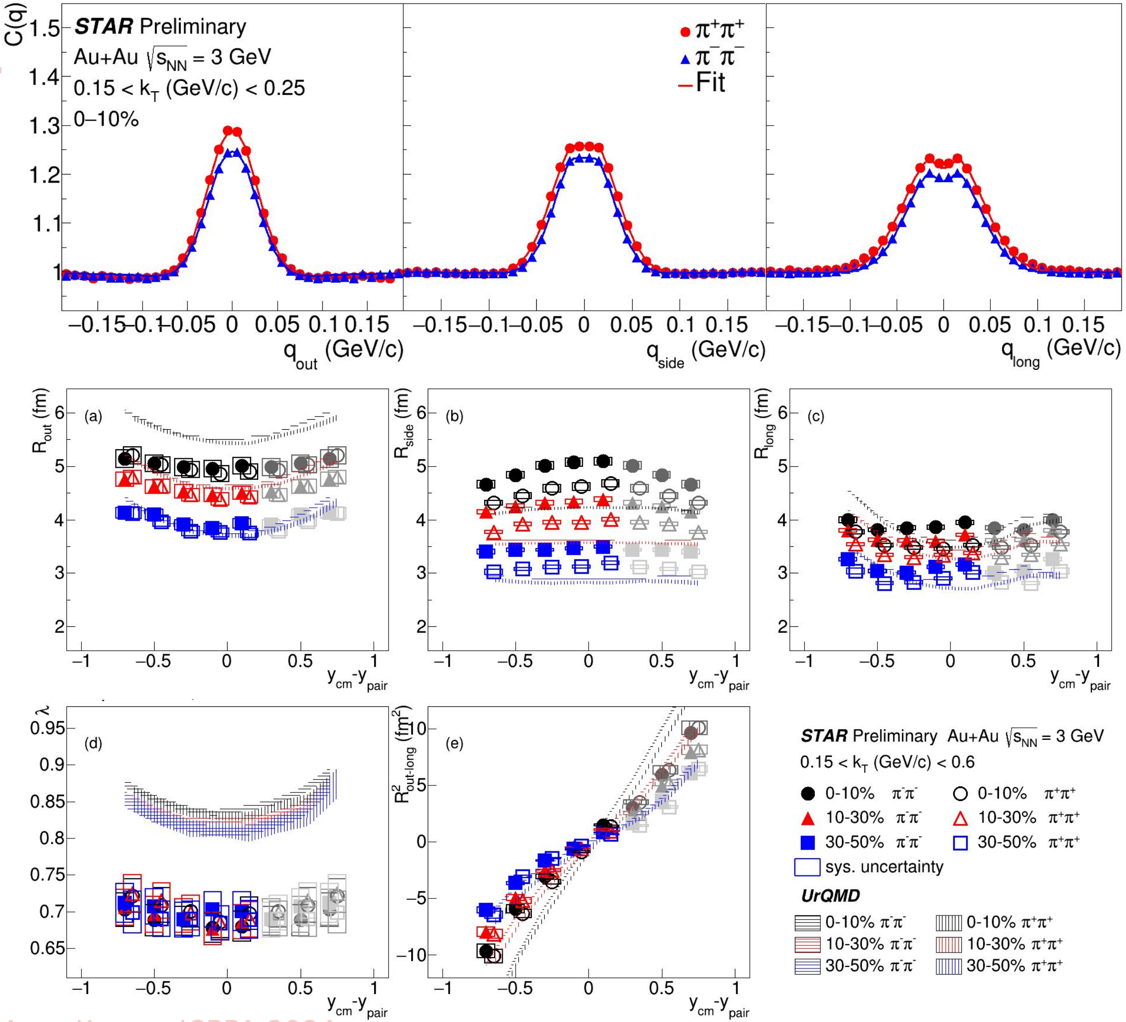
Motivation

- The isospin dependence of the nuclear equation of state (ES) is indefinite for describing neutron-rich matter. It's necessary for understanding asymmetric nuclei.
- In last preliminary plots there is a difference between the CFs and radii for $\pi^+\pi^+$ and $\pi^-\pi^-$ due to the isospin and residual electric charge due to Coulomb interaction.
- Studies of such effects on the reaction dynamics can provide a clearer estimation of the temporal characteristics of the particle emission processes.



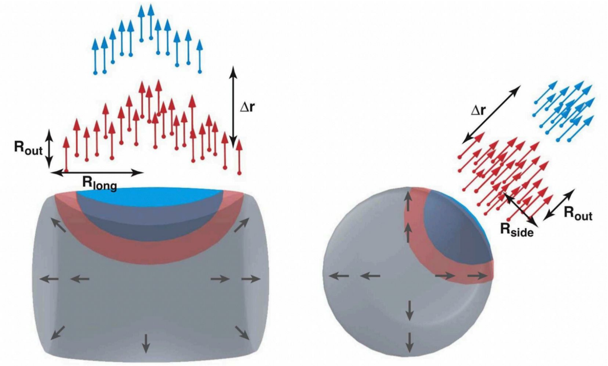
Construction two-particle correlation function (CF)

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

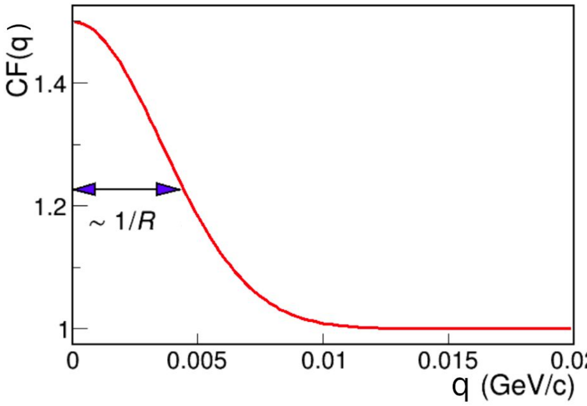
$A(q)$ - formed using pairs, where both tracks are from the same event. It contains quantum-statistical correlations (QS)

$B(q)$ - formed using pairs, where QS are absent

q - relative momentum



MC generators do not contain QS correlations.
Femtoscopic weight could be added as: $1 + \cos(q\Delta r)$
where Δr is a relative four-coordinate of particles from a pair.



The relative pair momentum can be projected onto the Bertsch-Pratt, out-side-long system:
q_{long} - along the beam direction,
q_{out} - along the transverse momentum of the pair,
q_{side} - perpendicular to longitudinal and outward directions

S. Pratt. Phys. Rev. D 33 (1986) 1314
G. Bertsch, Phys. Rev. C 37 (1988) 1896

CF are constructed in Longitudinally Co-Moving System (LCMS), where $p_{1,z} + p_{2,z} = 0$

Femtoscopic radii are extracted by fitting C(q) with Bowler-Sinyukov

$$C(q) = N[(1-\lambda) + \lambda K(q)(1+G(q))]$$, where
$$G(q) = \exp(-q_{out}^2 R_{out}^2 - q_{side}^2 R_{side}^2 - q_{long}^2 R_{long}^2 - 2q_o q_l R_{ol}^2)$$

N - normalization factor,

K(q) - Coulomb correction factor,

λ - correlation strength,

R_{side} ~ geometrical size of the particle emission source,

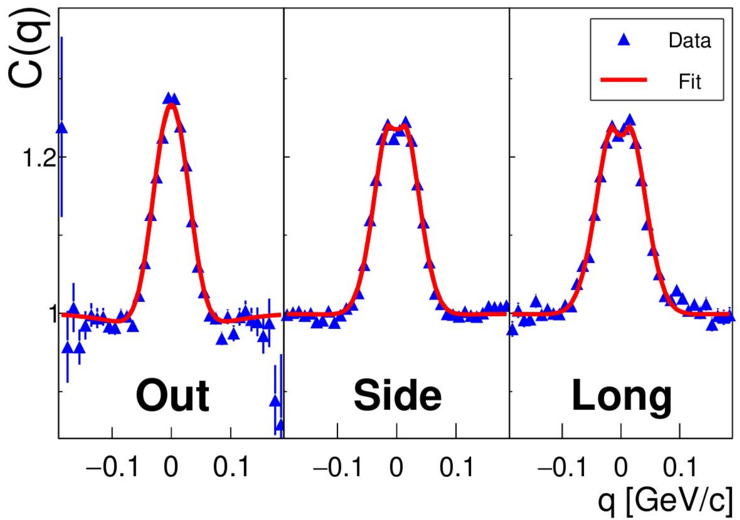
R_{out} ~ geometrical size + particle-emitting duration

R_{long} ~ medium lifetime,

$R^2_{out\text{-}long}$ – twist of the CF in the $q_{out} - q_{long}$ plane, depending on the degree of asymmetry of the rapidity acceptance w.r.t. midrapidity.

Yu. Sinyukov et al. Phys. Lett. B 432 (1998) 248
M. Bowler Phys. Lett. B 270 (1991) 69

Fit example:

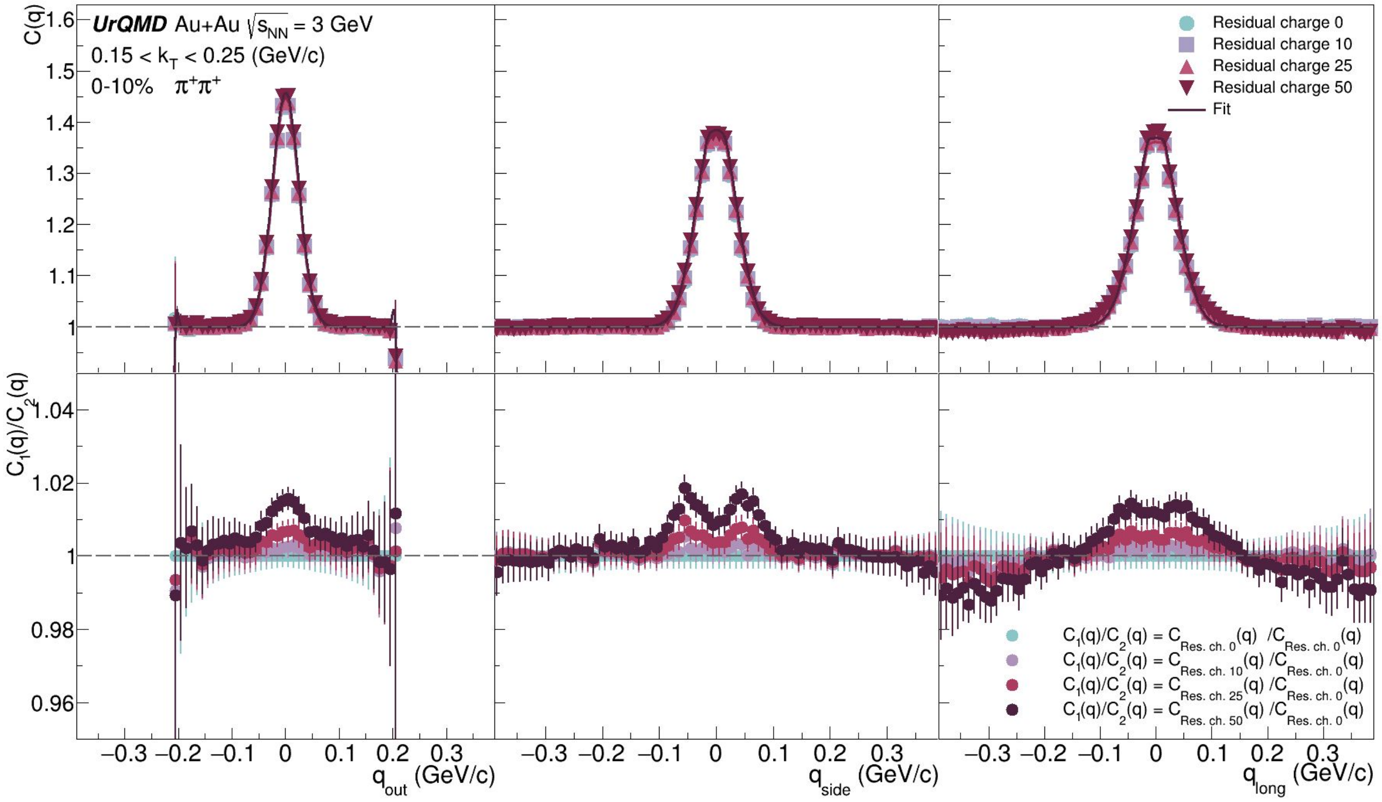


Fit using Log-likelihood method: Phys. Rev. C 66 (2002) 054906

$$\chi^2 = -2\left[A\, ln\left(\frac{C(A+B)}{A(C+1)}\right) + B\, ln\left(\frac{A+B}{B(C+1)}\right)\right], C = \frac{A}{B}$$

Influence of residual electric charge on the CFs

For the initial estimation of the residual electric charge, the charges was taken in range from 0 to 50



- The 3-body effect on the CF was added in UrQMD
- With residual charge increasing the CF width becomes larger and the radii slowly decreases for $\pi^+\pi^+$.
- The ratio of CFs before and after adding residual charge does not exceed 2%

https://arxiv.org/abs/nucl-th/0501065

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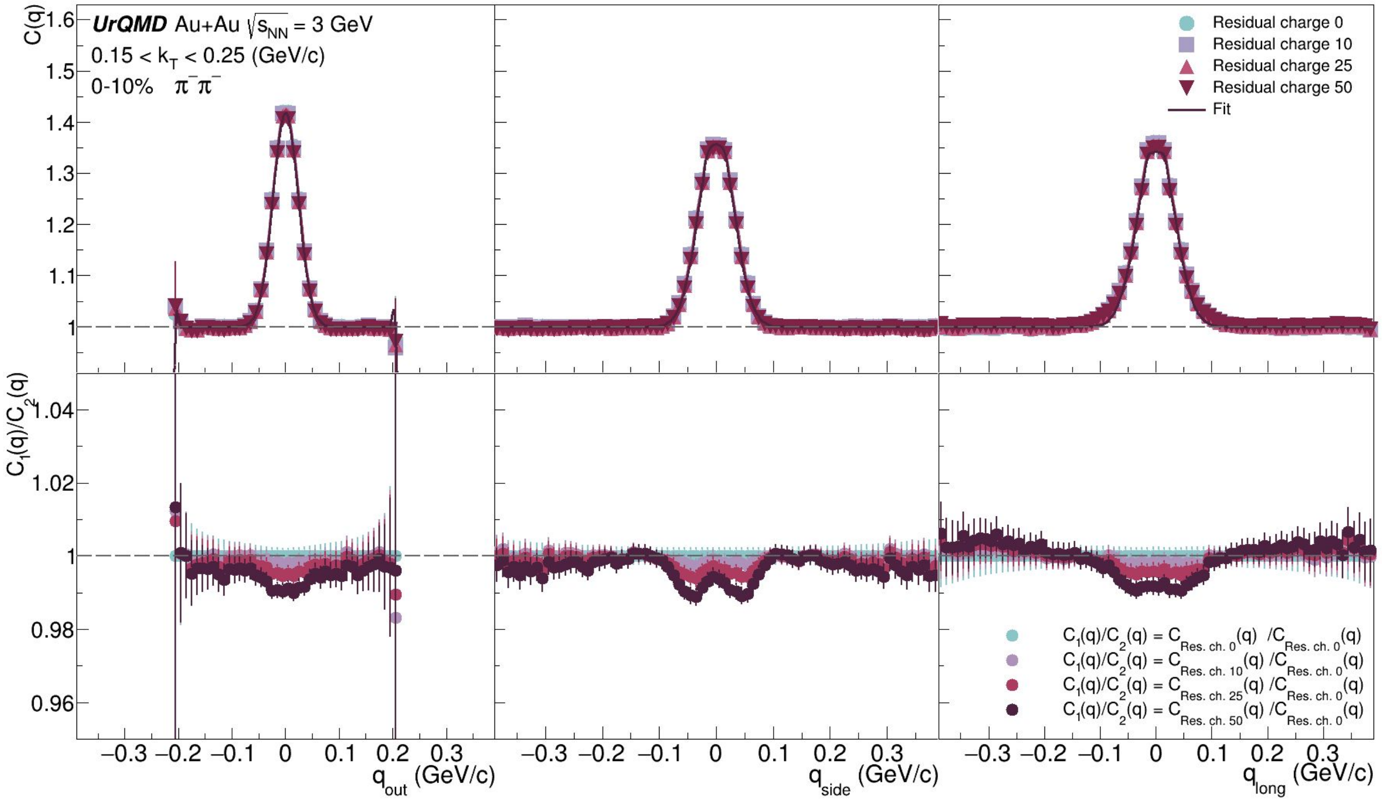

- The 3-body effect on the CF was added in UrQMD
- With residual charge increasing the CF width becomes smaller and the radii slowly increases for $\pi^-\pi^-$.
- The ratio of CFs before and after adding residual charge does not exceed 2%

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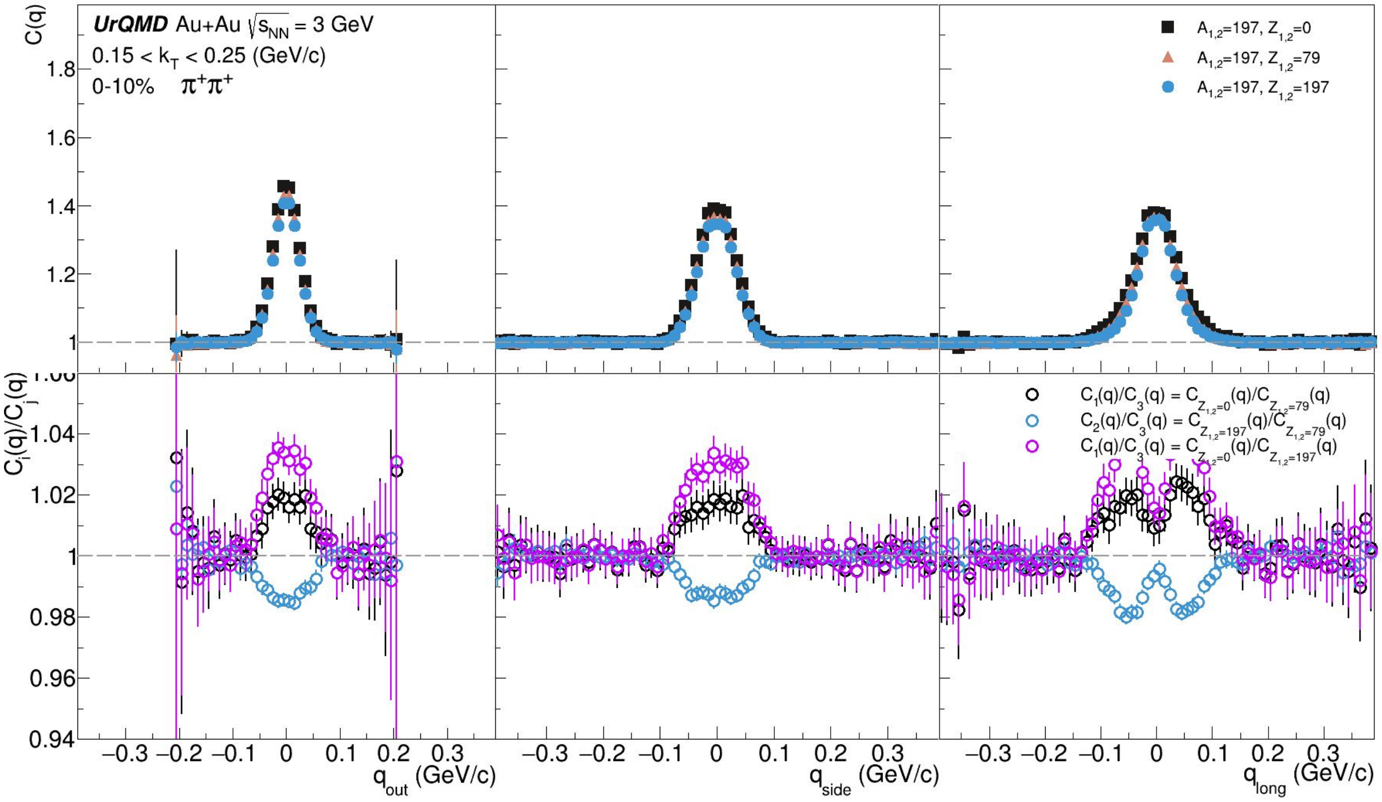
Influence of initial charge on the CFs

To estimate the influence of the initial charge “proton”, “neutron” and “usual” gold were used.



- The influence of the initial proton number in ion on the CF is observed
- With Z_{Au} increasing the CF width becomes smaller and the radii increases for $\pi^+\pi^+$.
- The ratio of CFs before and after changing Z_{Au} does not exceed 4%

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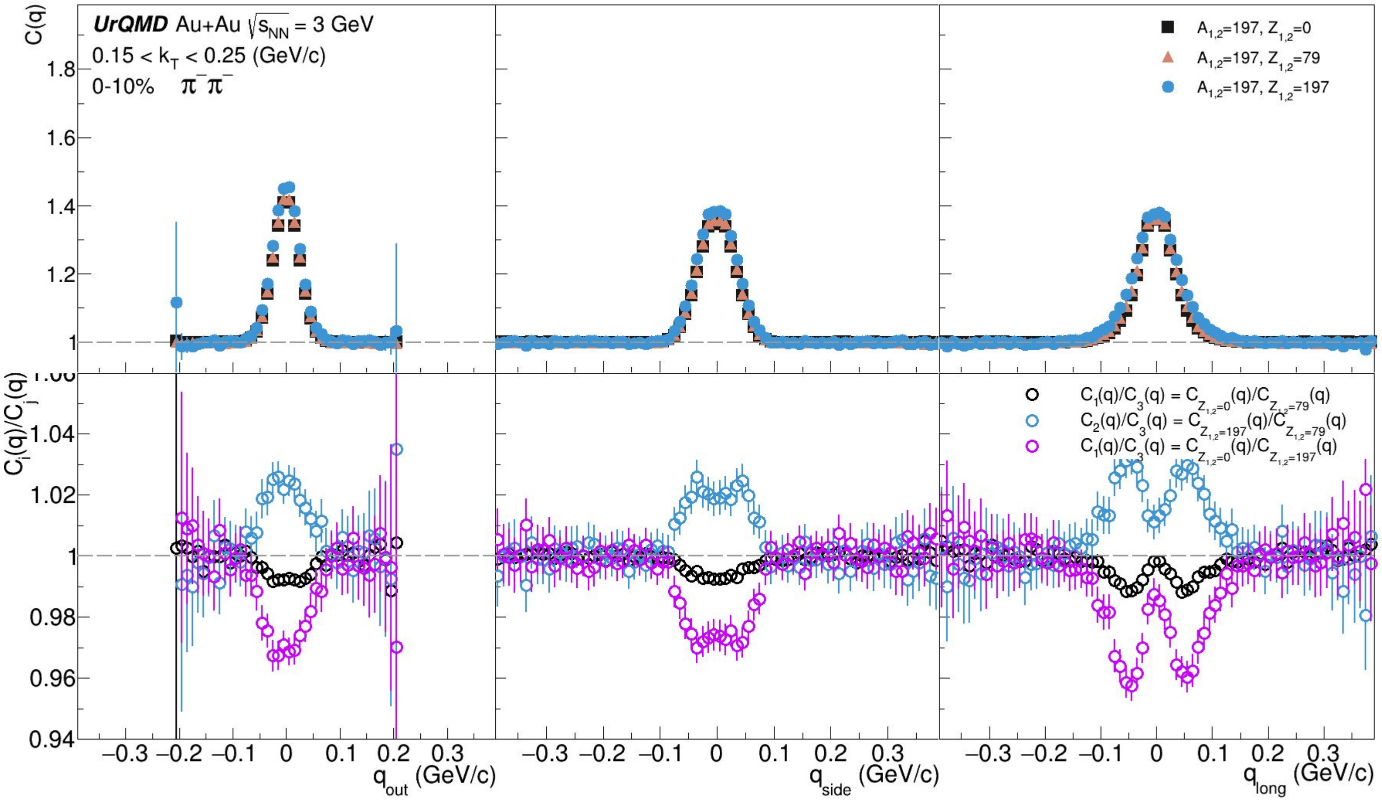

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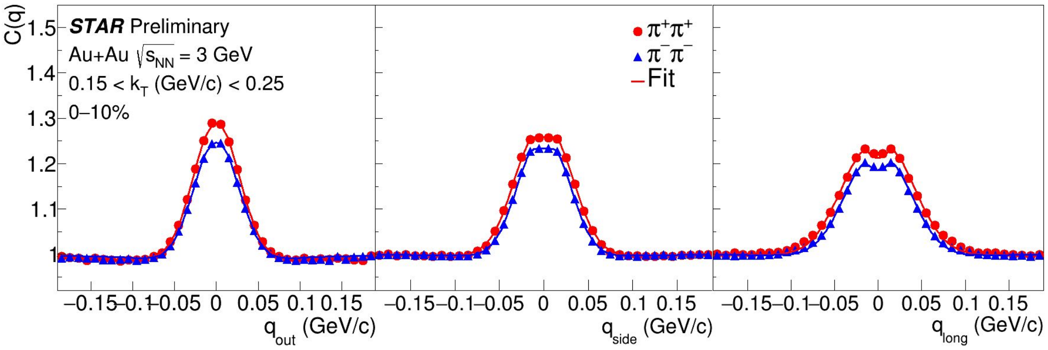
How to correct the three-body effect?

- We have a significant difference between the CFs for pions in the STAR experiment. This difference includes the isospin effect and the third-body effect.
- Firstly, we estimate the third body effect in UrQMD.

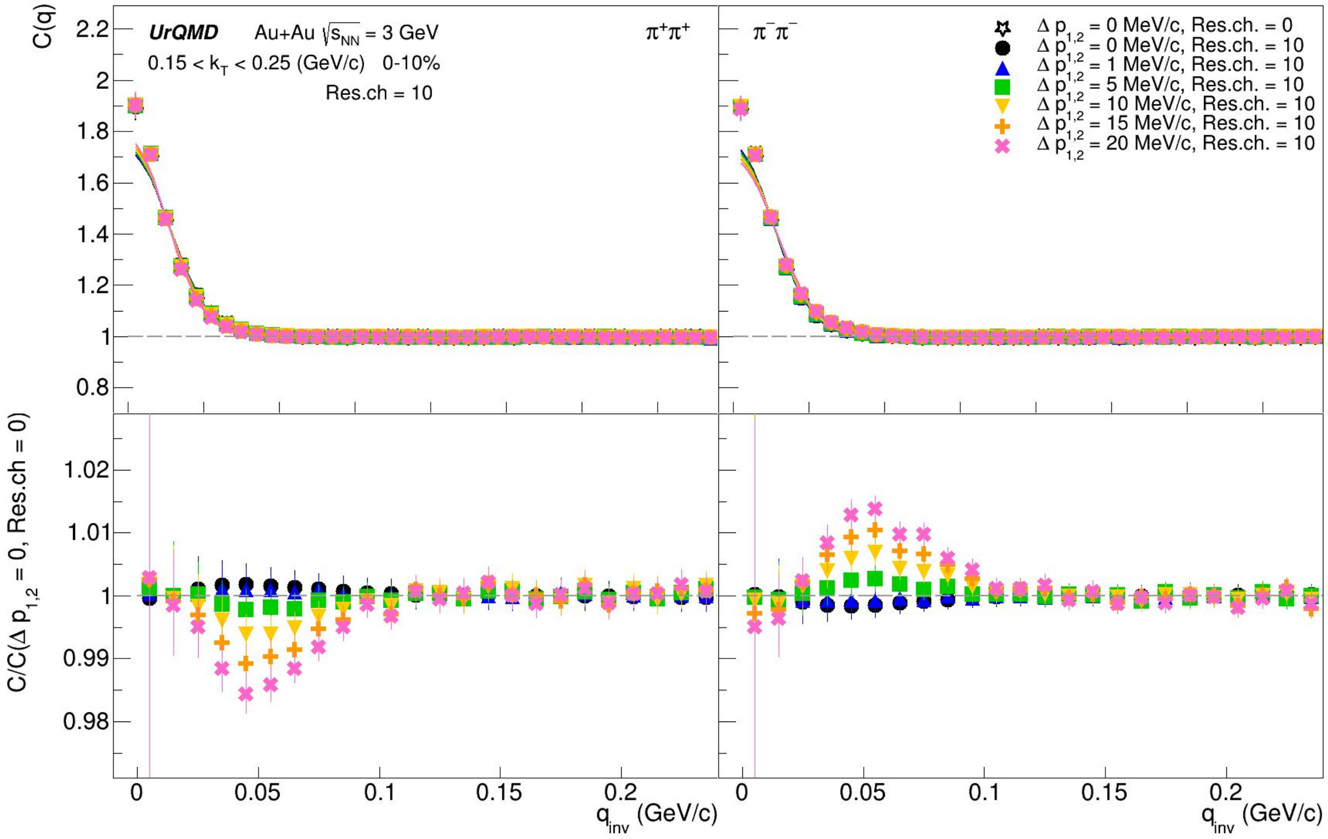


- Correction of the CF consists of:
  - Push π^- outward: $\mathbf{p}'_1 = \mathbf{p}_1 + |\Delta p|$
  - Pull π^+ back: $\mathbf{p}'_2 = \mathbf{p}_2 - |\Delta p|$
  - Direction of $|\Delta p|$ is chosen to be along particle's $\mathbf{p}$

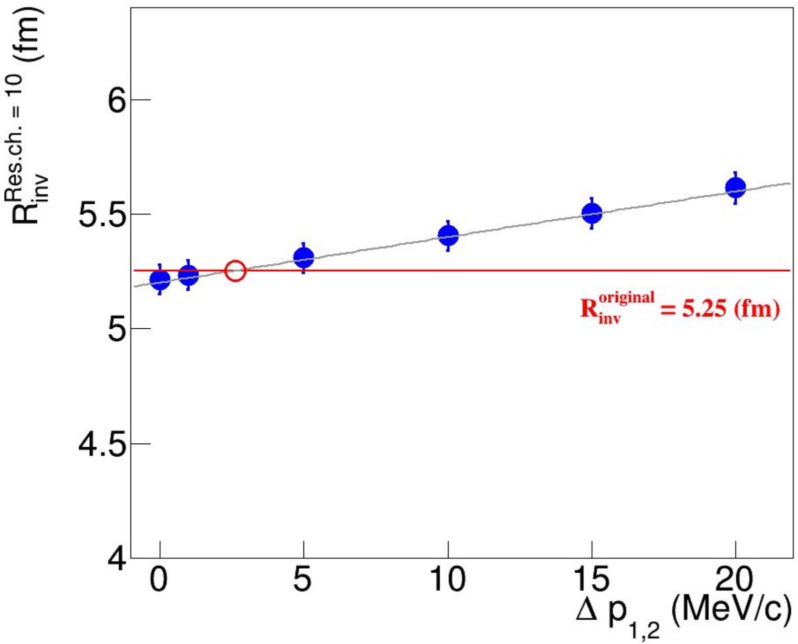
- For the estimation three-body effect in UrQMD we used:
  - $|\Delta p|$ = 1, 5, 10, 15, 20 MeV/c
  - Electric residual charge = 10, 20, 30, 40, 50

ππ correlations with dif. Δp and Residual charge = 10

Difference between 1D CFs with different |Δp| is observed



Δp dependence of femtoscopic radii for Residual charge = 10, $\pi^+\pi^+$



UrQMD Au+Au $\sqrt{s_{NN}}$ = 3 GeV

$0.15 < k_T < 0.25$ (GeV/c) 0-10%

$\pi^+\pi^+$

$\Delta p_{Res.ch. = 10} = 2.61$ (MeV/c)

$$R_{inv}^{\Delta p_{1,2} = 0,\ Res.ch. = 0} = R_{inv}^{original}$$

- Colored markers - radii at charge 10 for $\Delta p_{1,2} = \{0, 1, 5, 10, 15, 20\}$ MeV/c
- Red line - radius at charge 0 for $\Delta p_{1,2}$ = 0 MeV/c
- Empty red circle is intersection point. This point means $\Delta p_{1,2}$ = 2.61 MeV/c for charge 10 for $\pi^+\pi^+$

Using calculated Δp for Residual charge = 10

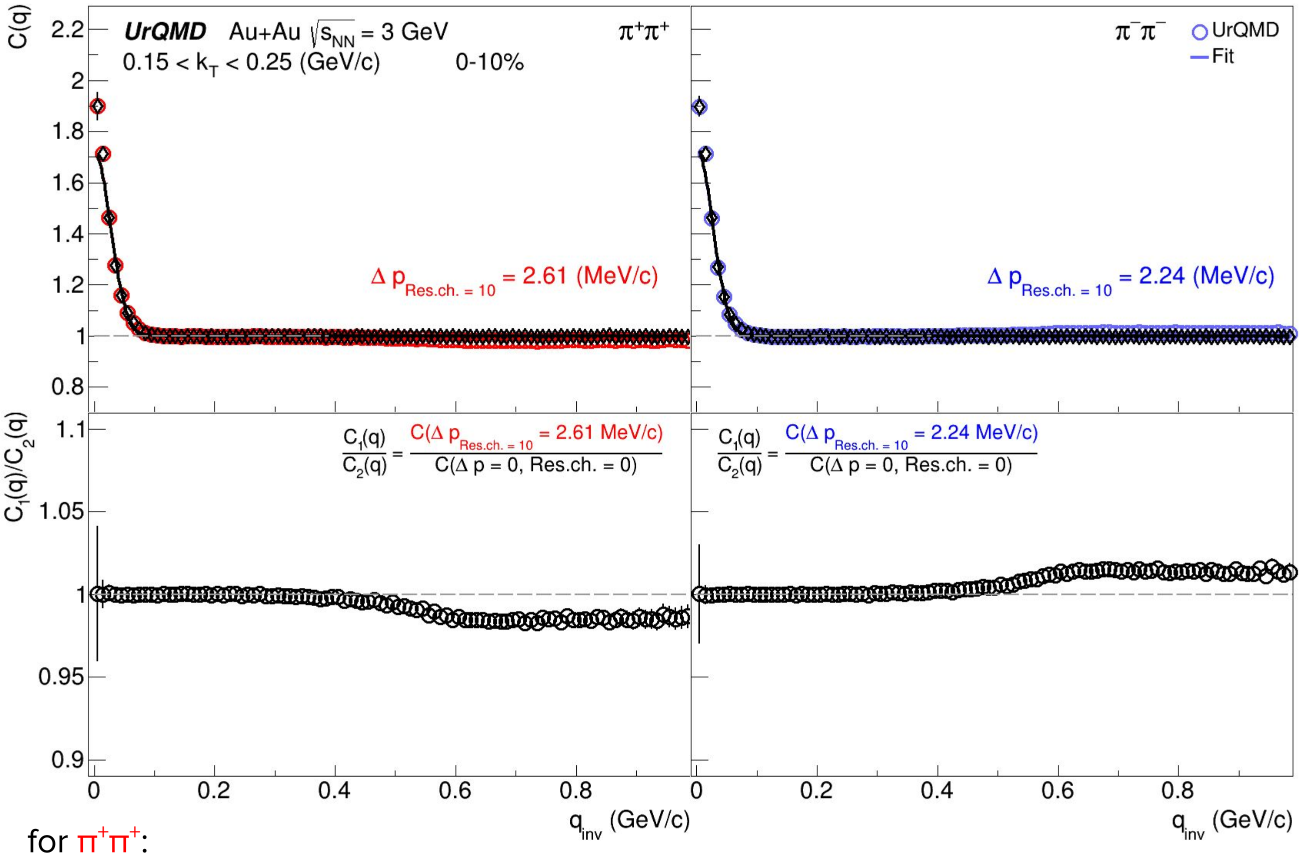
$\Delta p_{1,2}$ = 2.61 MeV/c for charge 10 for $\pi^+\pi^+$ ($\Delta p_{1,2}$ = 2.24 MeV/c for $\pi^-\pi^-$) was used for the calculation

C (q) = A (q' $_{inv}$*, weight* $_{QS}$*) / B (q'* $_{inv}$*, 1)*, where q'_{inv} is shifted q_{inv}

It means
for π^+ : $p'_{1,2} = p_{1,2} - 2.61$ (MeV/c)
for π^- : $p'_{1,2} = p_{1,2} + 2.24$ (MeV/c)

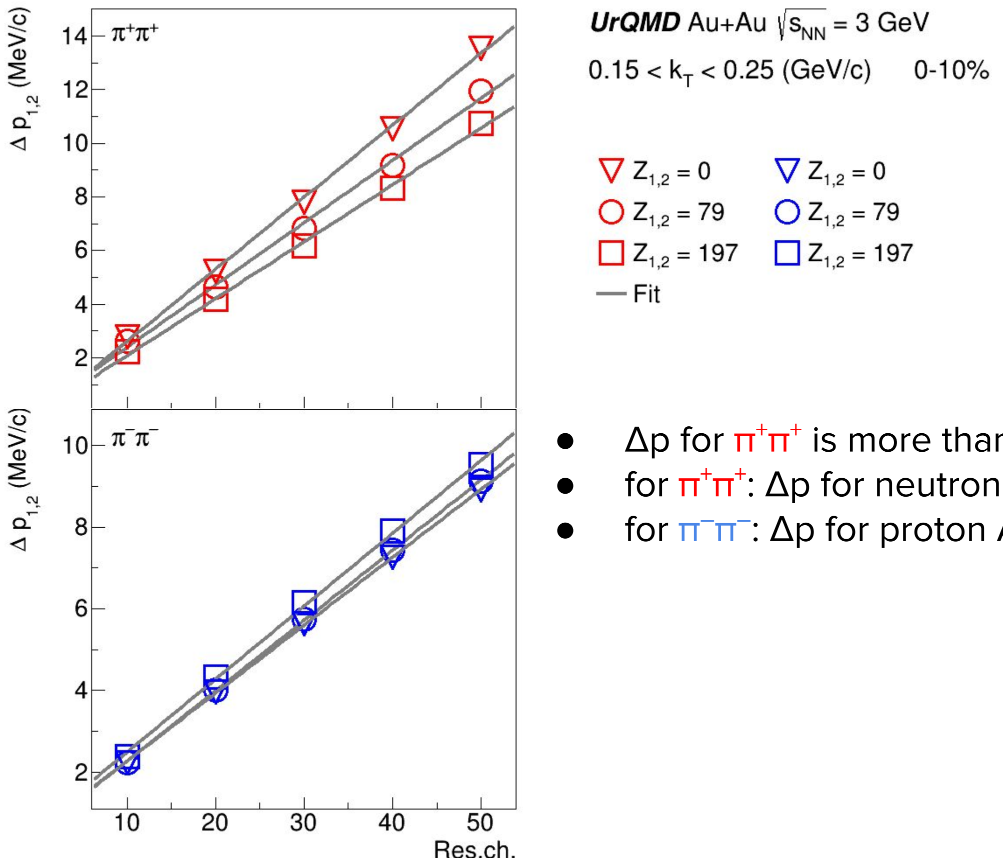
Fit range: [0, 0.25] GeV/c
Deflection of the CF from 1 is observed (about 2%)

After the using $\Delta p_{1,2}$ = 2.61 MeV/c for $\pi^+\pi^+$ ($\Delta p_{1,2}$ = 2.24 MeV/c for $\pi^-\pi^-$) for the construction CFs radii for charge 10 was obtained:



for $\pi^+\pi^+$:
$R_{inv}^{Res.ch.=10}$ ≃ 5.26 ± 0.03 fm *($R_{inv}^{original}$ = 5.25 ± 0.03 fm)*
for $\pi^-\pi^-$:
$R_{inv}^{Res.ch.=10}$ ≃ 5.37 ± 0.02 fm *($R_{inv}^{original}$ = 5.38 ± 0.02 fm)*

Res.ch. dependence of Δp for different Initial Charges for $\pi^+\pi^+$, $\pi^-\pi^-$



- Δp for $\pi^+\pi^+$ is more than for $\pi^-\pi^-$
- for $\pi^+\pi^+$: Δp for neutron Au is more than for proton Au
- for $\pi^-\pi^-$: Δp for proton Au is more than for neutron Au

Table of $\Delta p_{Res.ch.}$ for different Initial and Residual charges

		$\Delta p_{Res.ch.}$ (MeV/c)				
	$Z_{1,2}$ / Res. Ch.	10	20	30	40	50
$\pi^+\pi^+$	0	2.80	5.23	7.81	10.55	13.55
	79	2.61	4.66	6.82	9.18	11.94
	197	2.23	4.18	6.17	8.33	10.75
$\pi^-\pi^-$	0	2.24	3.96	5.64	7.26	8.91
	79	2.24	4.02	5.75	7.43	9.14
	197	2.38	4.34	6.16	7.91	9.53

Conclusion

- 1D correlation functions were constructed for different **Residual Charges** and **|Δp| shifts**
  - CFs are different for several |Δp| for each Residual Charge
- 1D correlation functions were constructed for different Δp shifts, Residual and **Initial Charges**
  - CFs are different for several Initial Charge
- |Δp| were calculated for each electric residual charge, electric residual and initial charge
  - 1D CFs was corrected

To do:

- Cross-check the developed approach with the toy model
- Corrections for 3D CFs in UrQMD
- Corrections for experimental data