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SPATIOTEMPORAL STRUCTURE OF THE PION EMISSION IN AU+AU COLLISIONS AT $\sqrt{s_{NN}}$ = 19.6 GEV IN THE URQMD MODEL

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Motivation

Time/hypersurface of pions maximum emission could be analyzed within the two methods.

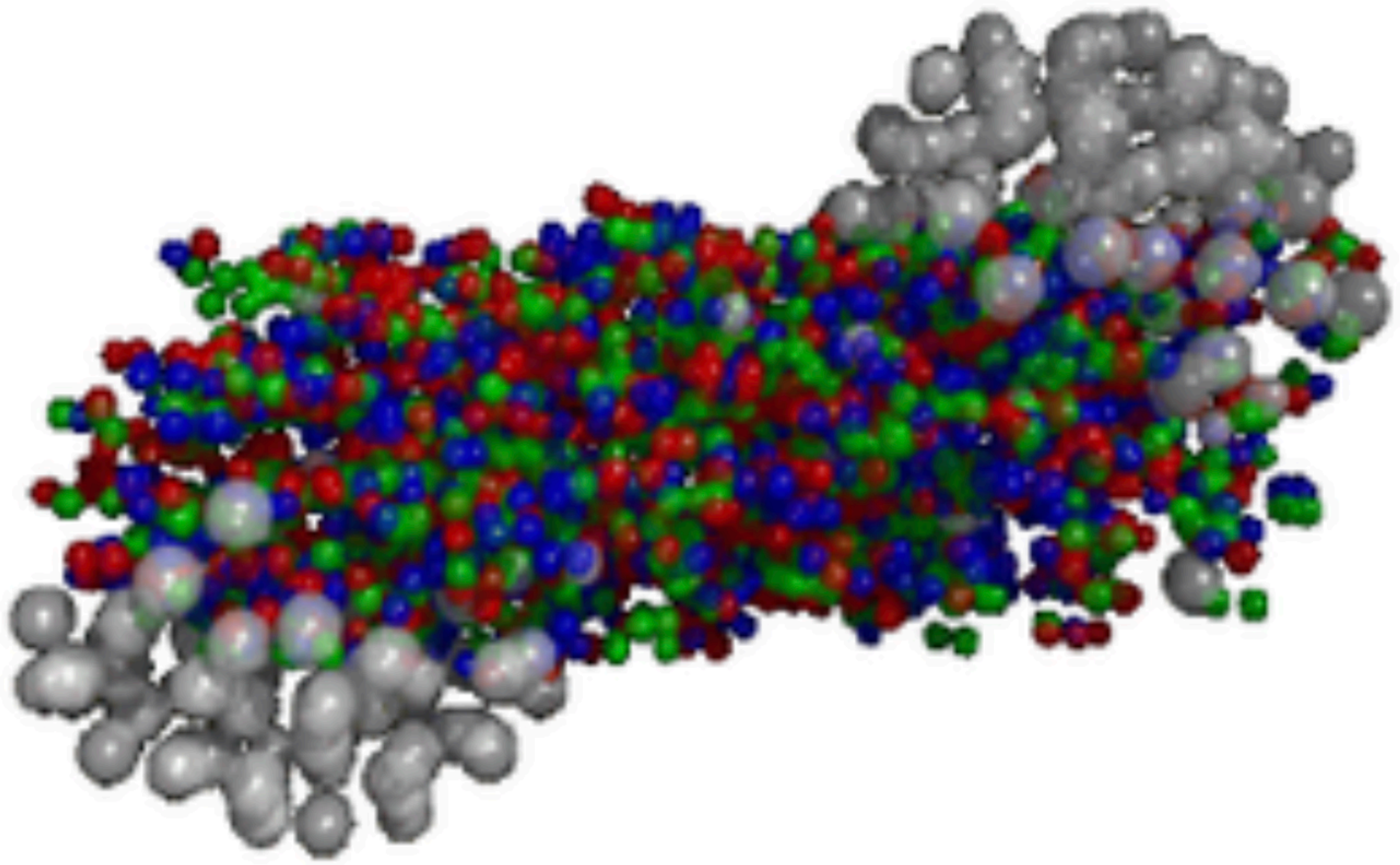
- The first one utilizes the specific approach for correlation femtoscopy analysis, developed and applied earlier for ultrarelativistic A+A collisions.

- The second one is based on the direct study of the pion kinetic freeze-out in UrQMD.

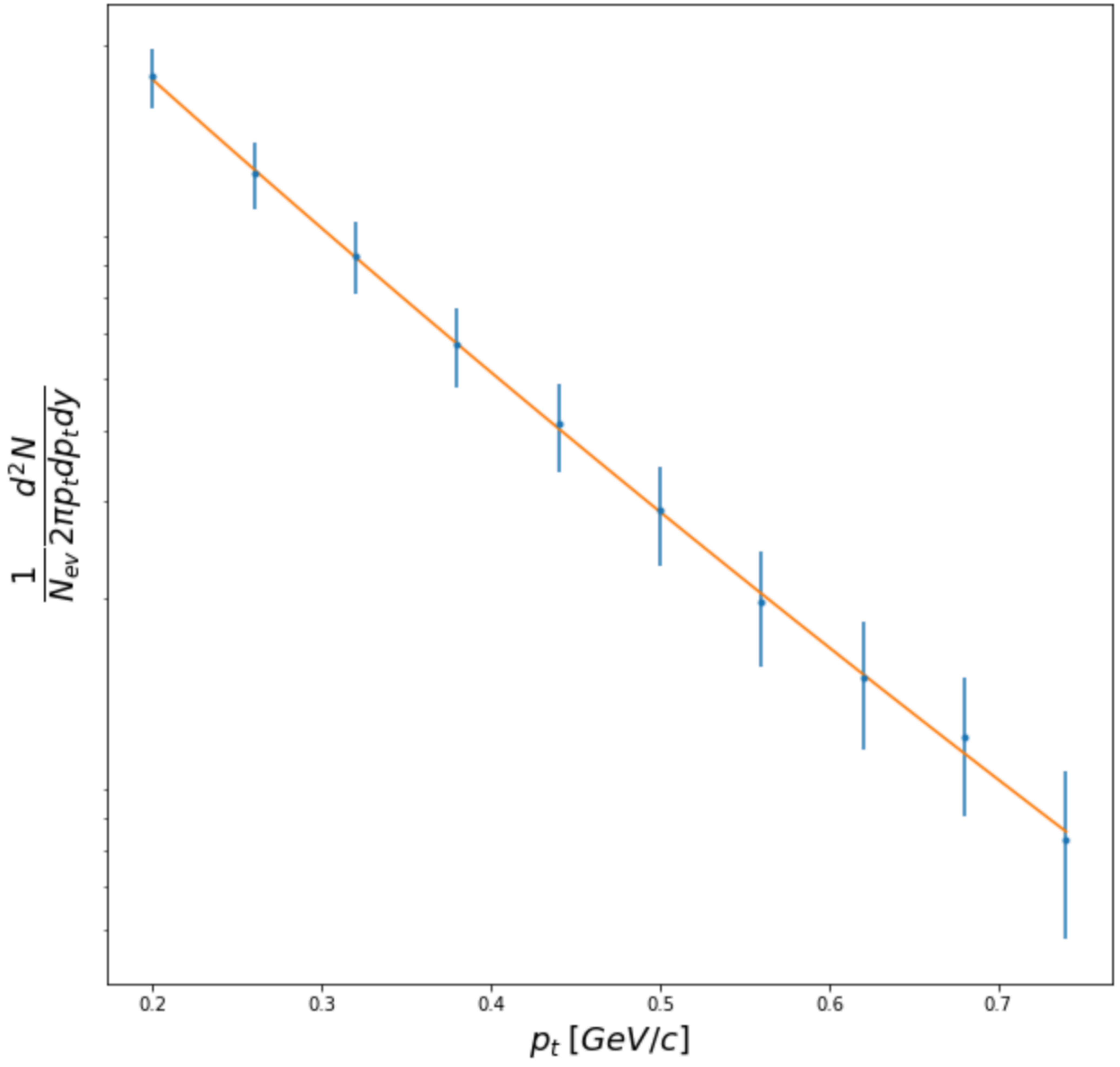
Main purpose of this research - to examine the consistency of the two methods also at moderate energies of nuclear collisions.

Collisions

- Were considered Au+Au collisions with energy $\sqrt{s_{NN}} = 19.6\ GeV$
- Selected events with $0 - 5\ \%$ centrality
- Experimental cuts $0.05 < p_t < 1.5\ GeV/c$ and $|\eta| < 0.5$



Temperature from transverse momentum distribution



Distribution over p_t in log scale with $y \in [-0.1,\ 0.1]$

$$\frac{p_0 d^3N}{d^3p} = \frac{1}{N_{ev}} \frac{d^2N}{2\pi p_T dp_T dy} \sim e^{-(\frac{m_T}{T}+\alpha)(1-v_T^2)^{1/2}}$$

Where:

$$m_T = \sqrt{m^2 + p_T^2}$$

$$v_T = \frac{k_T}{m_T + T * \alpha}$$

The following temperature was obtained from the fit:

$$T = 148 \ \pm 1 \ MeV$$

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Correlation functions

- Charged pions were considered

- Correlation functions built as ratio of distributions with and without weight:

$$C(q_{long}, q_{out}, q_{side}) = \frac{A(q_{long}, q_{out}, q_{side}; w)}{B(q_{long}, q_{out}, q_{side})}$$

$$w = 1 + cos(q \cdot r)$$

q - pair relative 4-momentum,

r - pair relative 4-coordinates

$q_{long}, q_{out}, q_{side}$ - in Bertsch-Pratt parametrization

- Analysed independently pion pairs with $k_T = \frac{|\overrightarrow{p}_{T1} + \overrightarrow{p}_{T2}|}{2}$ in ranges:

  [0.05,0.15], [0.15,0.25], [0.25,0.35], [0.35,0.45], [0.45,0.55], [0.55,0.65], [0.65,0.75] GeV/c

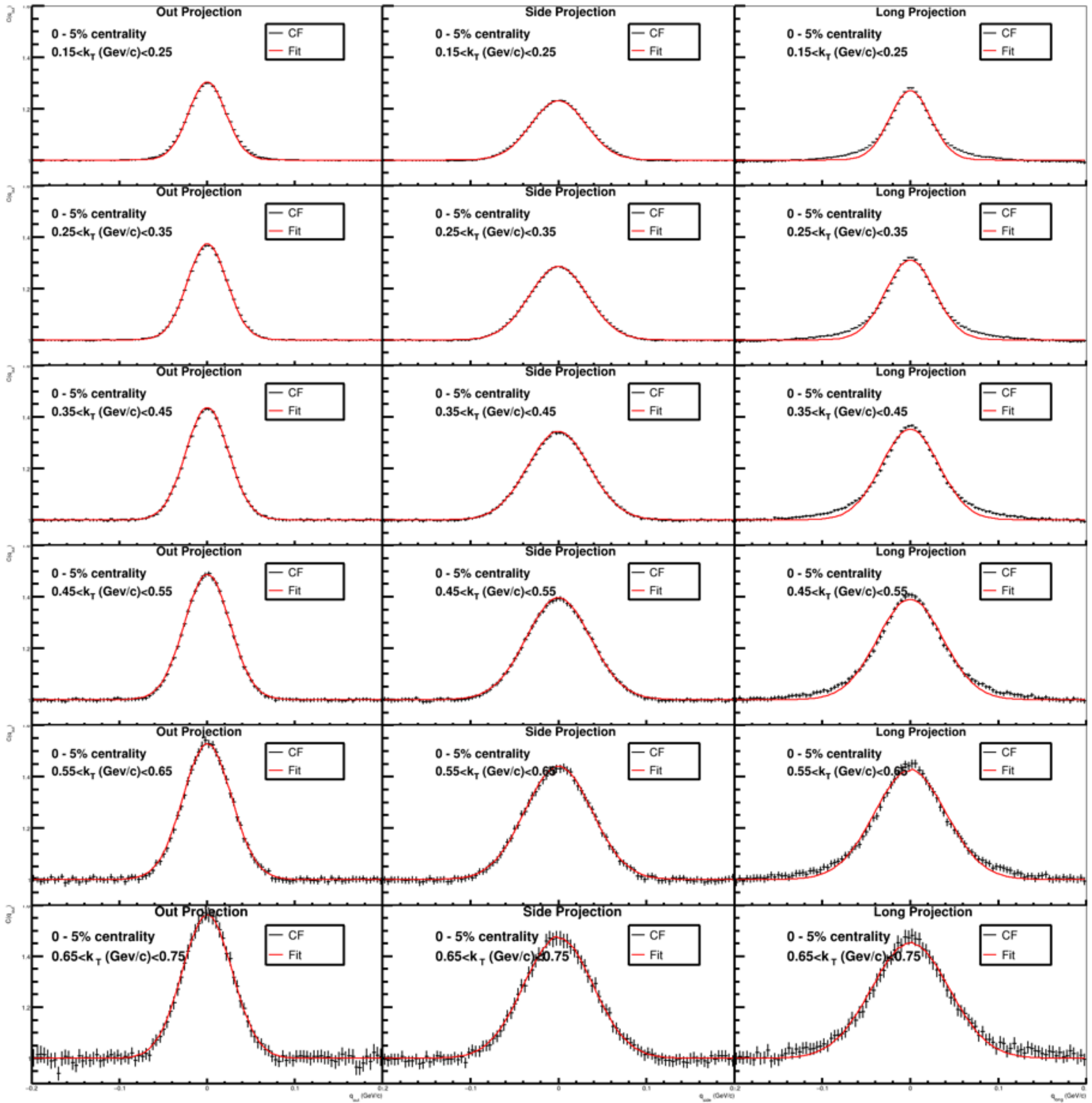
The following transformations of relative momentum were applied:

- Lorentz boost into the system of the pair`s center of mass along the Z axis.

- Coordinate rotation according to Bertsch-Pratt parametrization:
  - Long direction - parallel to the beam (z axis)
  - Out direction - parallel to $\overrightarrow{k_T}$
  - Side direction - perpendicular to long and out

Correlation function fit

$$C(q_{long}, q_{out}, q_{side}) = 1 + \lambda \cdot e^{-R_{long}^2 q_{long}^2 - R_{out}^2 q_{out}^2 - R_{side}^2 q_{side}^2}$$


Out Projection
0 - 5% centrality
0.15<k$_T$ (Gev/c)<0.25
CF
Fit
Side Projection
0 - 5% centrality
0.15<k$_T$ (Gev/c)<0.25
CF
Fit
Long Projection
0 - 5% centrality
0.15<k$_T$ (Gev/c)<0.25
CF
Fit
Out Projection
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0.35<k$_T$ (Gev/c)<0.45
CF
Fit
Side Projection
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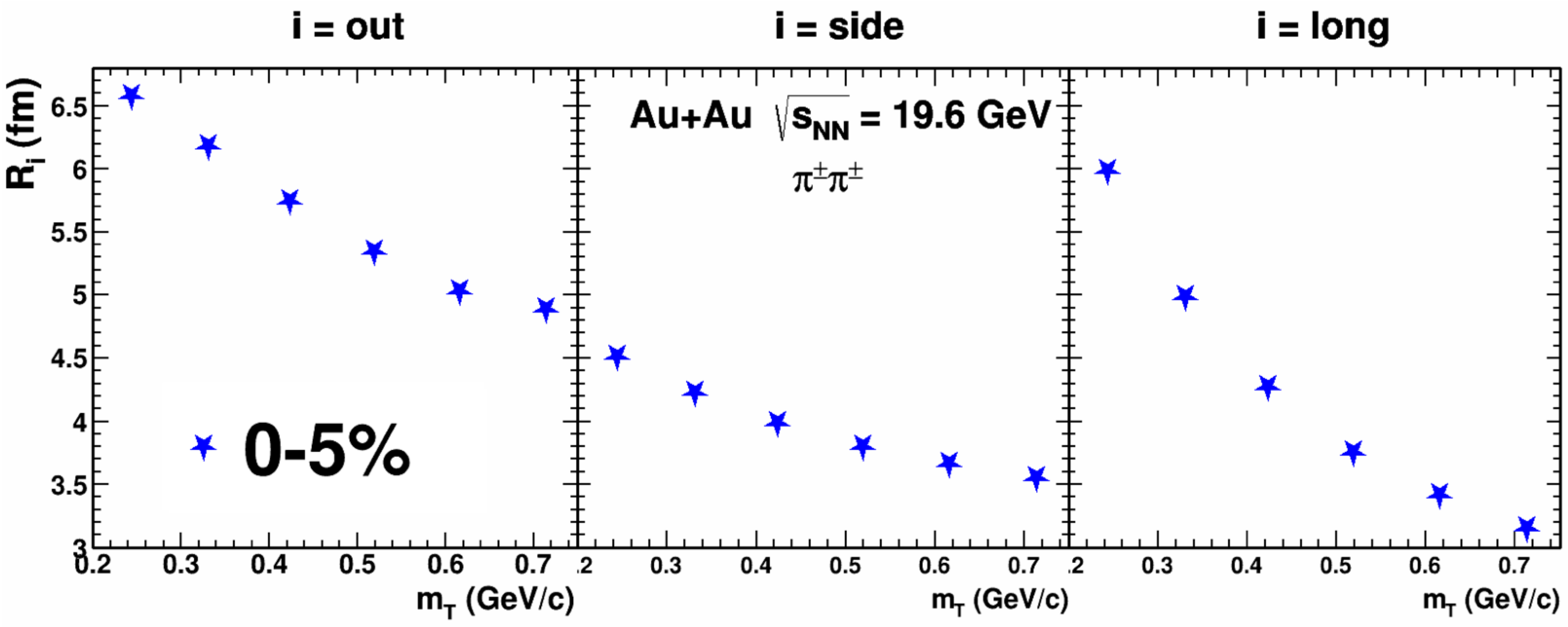
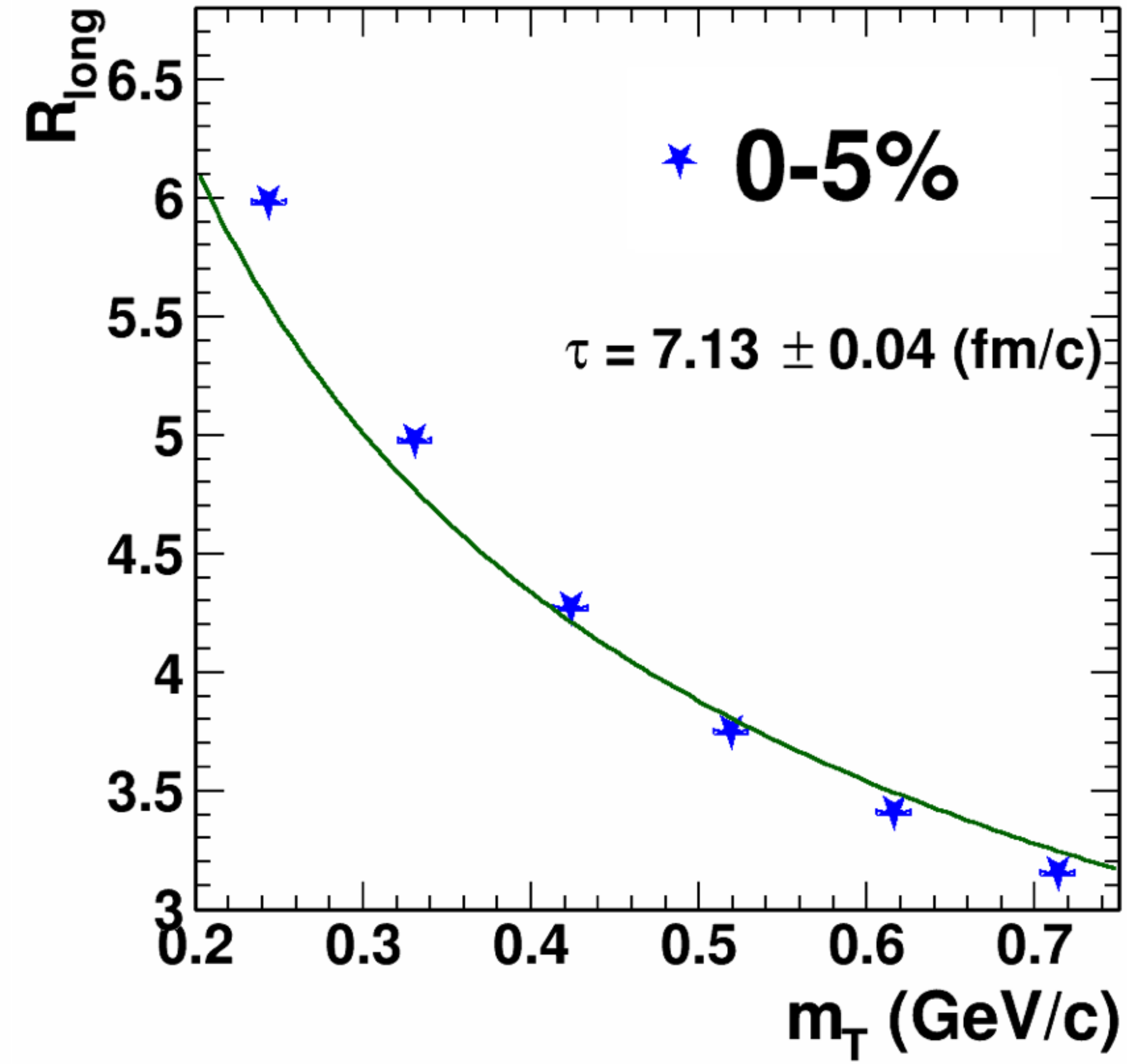
CF
Fit
Out Projection
0 - 5% centrality
0.65<k$_T$ (Gev/c)<0.75
CF
Fit
Side Projection
0 - 5% centrality
0.65<k$_T$ (Gev/c)<0.75
CF
Fit
Long Projection
0 - 5% centrality
0.65<k$_T$ (Gev/c)<0.75
CF
Fit

m_T dependence of correlation radii



Obtaining τ from R_{long} fit

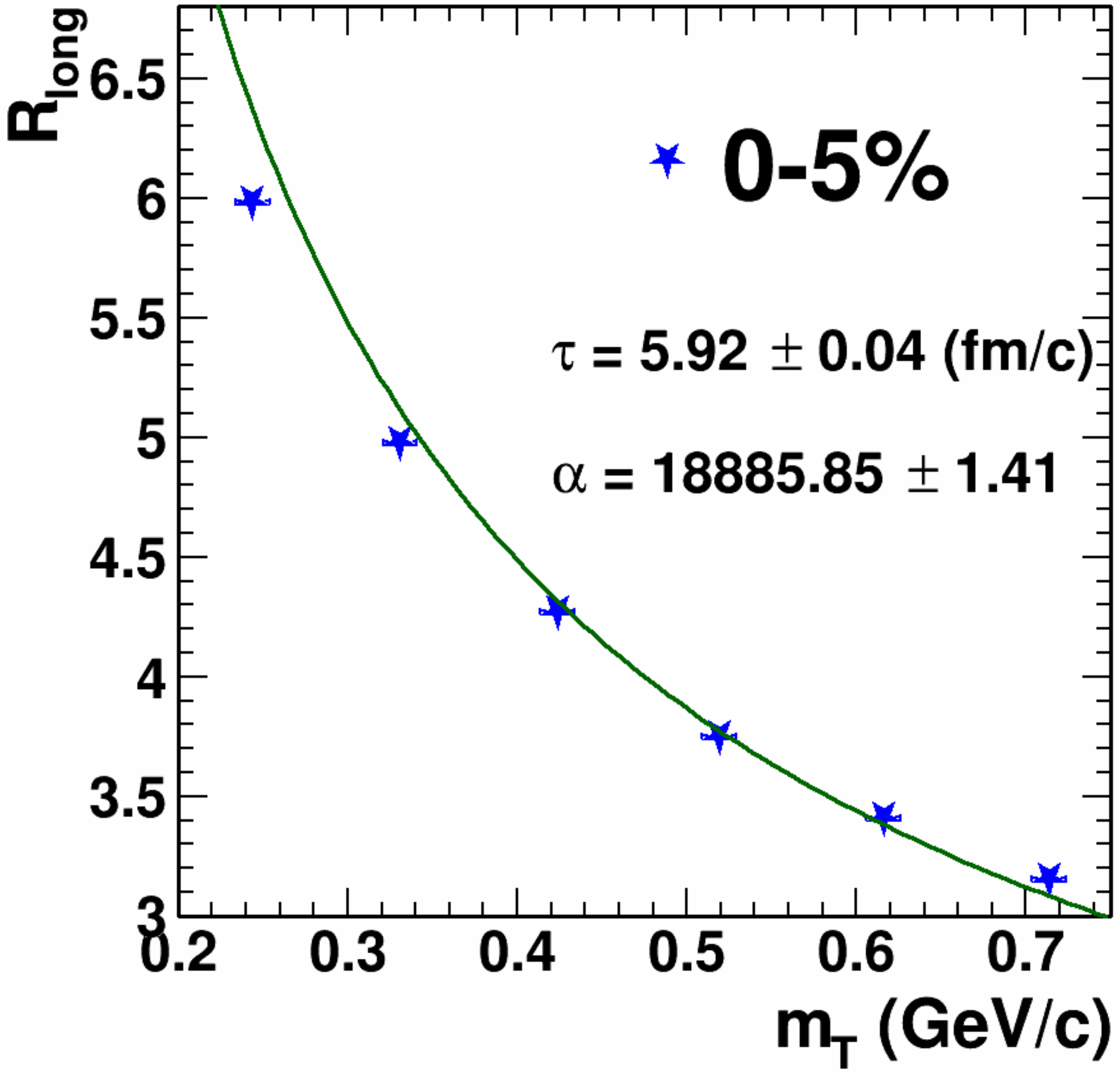


Dependency of R_{long} fitted with:

$$R_{long} = \tau \cdot \sqrt{\frac{T}{m_T}}$$

$$\tau = 7.13 \pm 0.04\ fm/c$$

Obtaining τ from R_{long} fit



Dependency of R_{long} fitted with:

$$R_{long} = \tau \cdot \lambda \sqrt{1 + \frac{3}{2}\lambda^2}$$

where:

$$\lambda^2 = \frac{T}{m_T}\sqrt{1 - v_T^2}$$ - homogeneity length in longitudinal direction

$$v_T = \frac{k_T}{m_T + \alpha T}$$ - transverse velocity in the saddle point

$$\tau = 5.92 \pm 0.04\ fm/c$$

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Emission function distribution

The second approach is based on a direct analysis of the last collision points. In UrQMD full information about last collision points is available, that allows studying the spatiotemporal structure of emission function straightforwardly.

Considered distribution of π^+ kinetic freeze-out:

$$\frac{dN^2}{r_T \cdot d\tau dr_T}$$

Where:

$$\tau = \sqrt{t^2 - z^2}$$

$$r_T = \sqrt{r_x^2 + r_y^2}$$

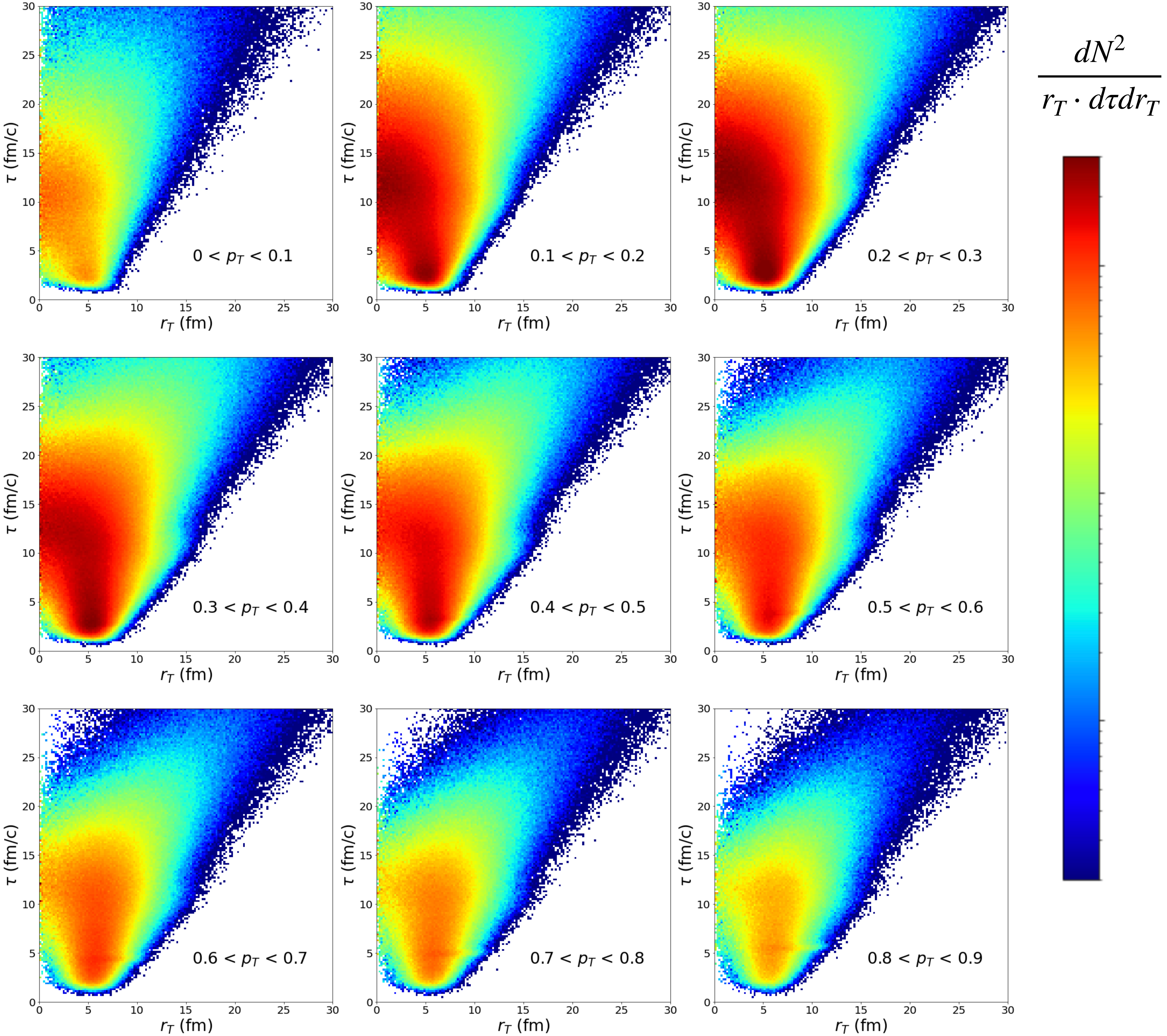
With the following cuts:

Time-space rapidity: $|\frac{1}{2} \cdot ln\frac{t+z}{t-z}| < 0.5$

Momentum rapidity: $|\frac{1}{2} \cdot ln\frac{E+p_z}{E-p_z}| < 0.5$

Distributions built separately for p_T in ranges:

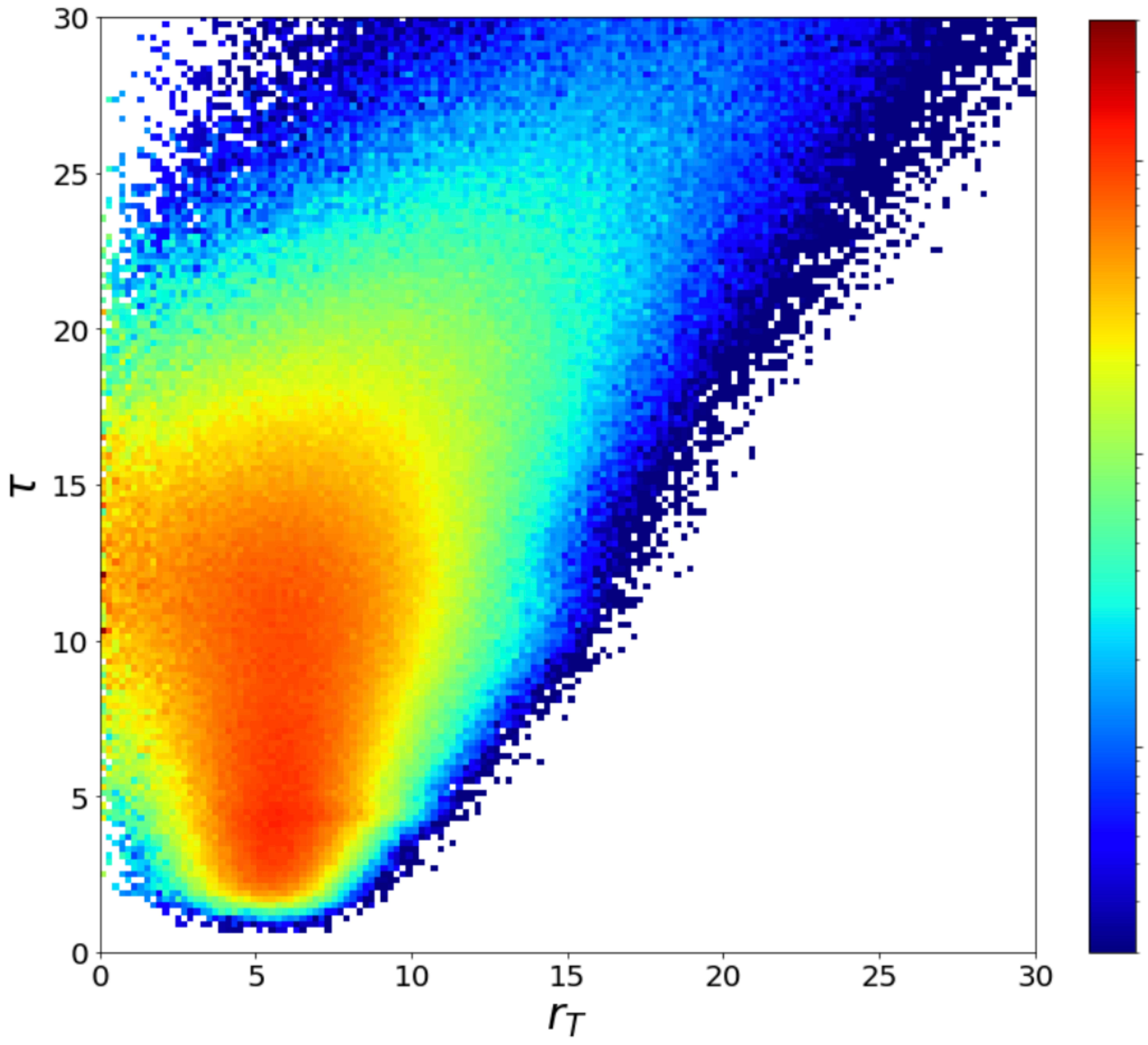
[0,0.1], [0.1,0.2], [0.2,0.3], [0.3,0.4], [0.4,0.5], [0.5,0.6], [0.6,0.7], [0.7,0.8], [0.8,0.9]



$0 < p_T < 0.1$
$0.1 < p_T < 0.2$
$0.2 < p_T < 0.3$
$0.3 < p_T < 0.4$
$0.4 < p_T < 0.5$
$0.5 < p_T < 0.6$
$0.6 < p_T < 0.7$
$0.7 < p_T < 0.8$
$0.8 < p_T < 0.9$
τ (fm/c)
r_T (fm)
$\frac{dN^2}{r_T \cdot d\tau dr_T}$

To the accordance with asymptotic formulas, high-p_T will be considered further.

In the area of $p_T > 0.4$ GeV/c maximum absolute value is observed in the interval of [0.6, 0.7] GeV/c



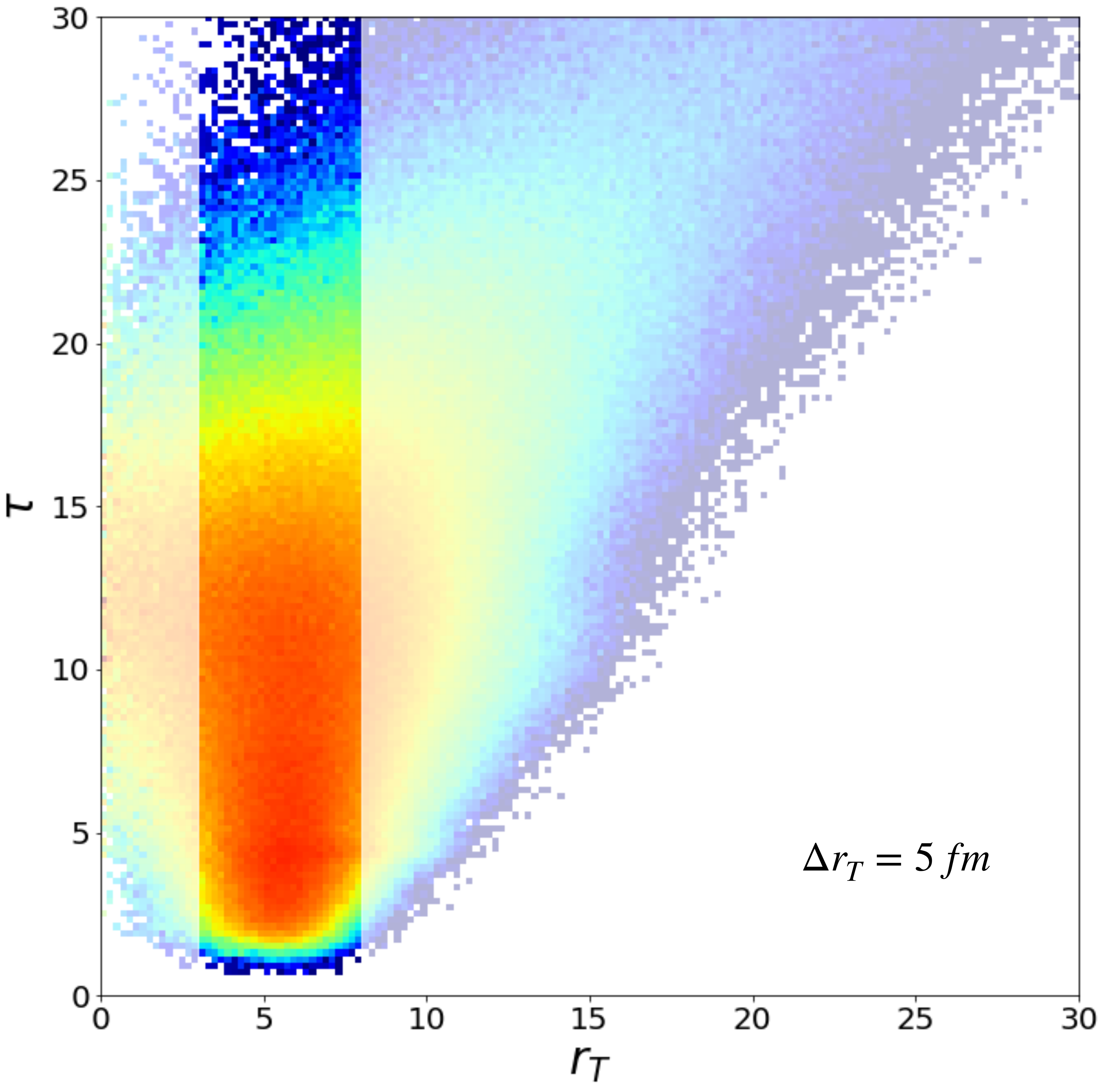
Maximum emission, τ_{max}, could be obtained from the fit:

$$g(\tau) \sim e^{-\frac{(\tau - \tau_{max})^2}{2 \cdot d^2}}$$

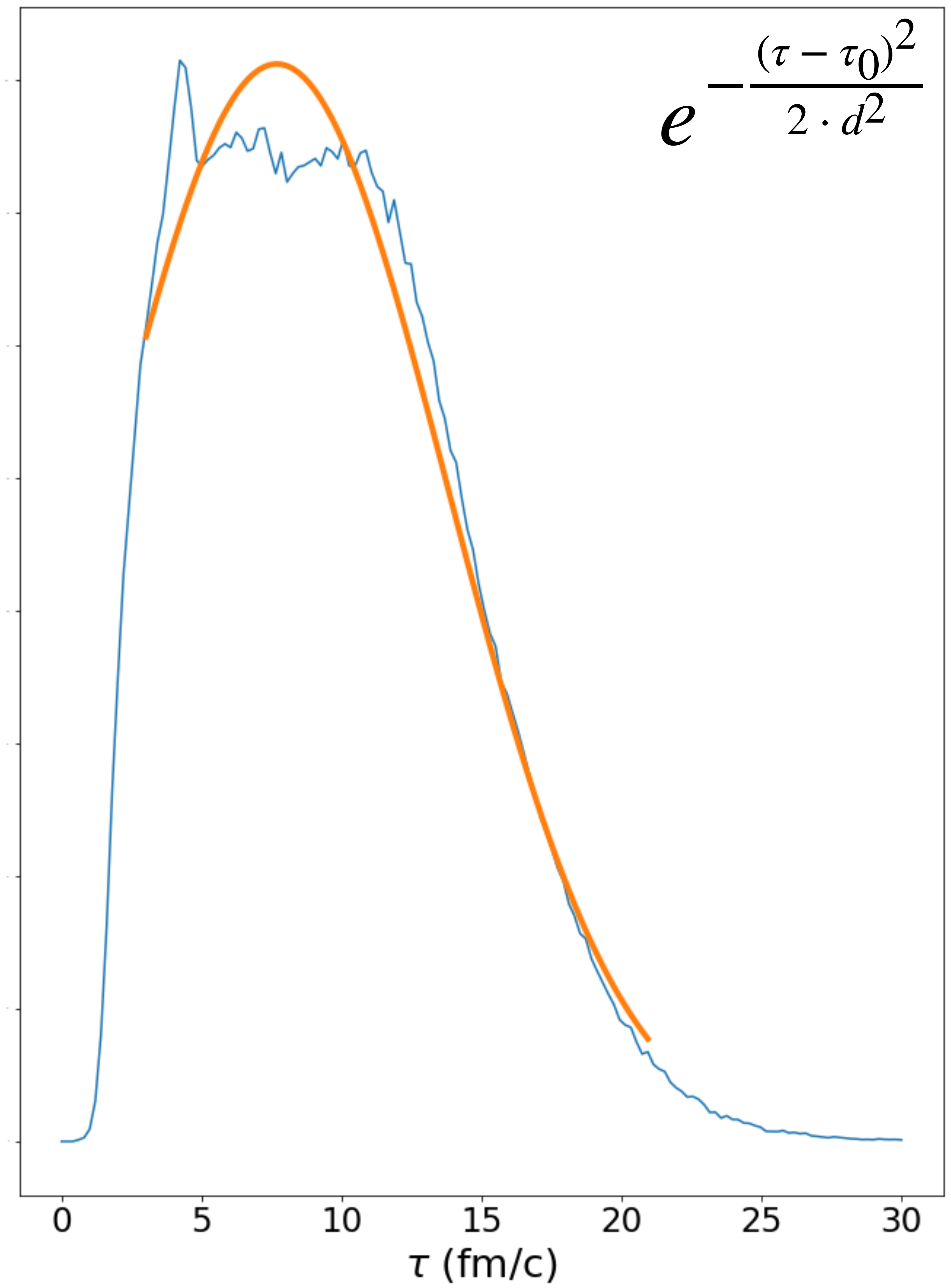
where d - emission duration

To move to the distribution over τ, the r_T integration interval has to be selected

Interval over r_T is centered around the point of distribution maximum value



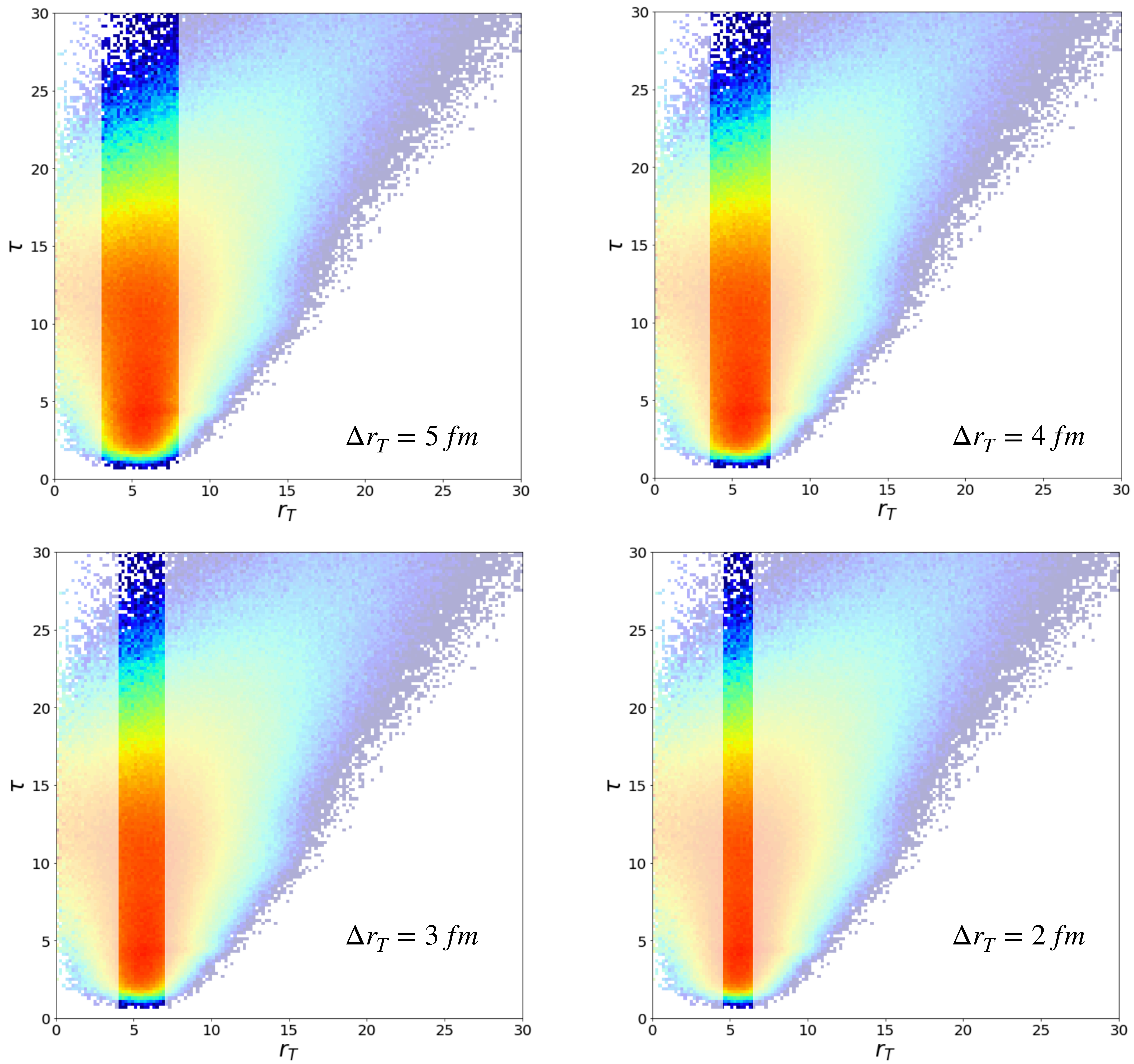
The 10% and 30% of points were truncated from the left and right distribution edge correspondingly, due to asymmetry of the distribution



Different width of r_T regions were considered for extraction of τ.

r_T variation defines the uncertainty of the final value:

$$\tau = 7.03 \pm 0.88\ fm/c$$



Comparison

Maximum emission time from correlation femtoscopy:

Fitting $R_{long} = \tau \cdot \sqrt{\frac{T}{m_T}}$

$$\tau = 7.13 \pm 0.04\ fm/c$$

Fitting R_{long} accordingly to Yu.Sinyukov et al., NPA 946 (2016) 227

$$\tau = 5.92 \pm 0.04\ fm/c$$

Maximum emission time from distribution of emission function:

$$\tau = 7.03 \pm 0.88\ fm/c$$

Conclusions

To compare approaches to pions emission analysis at moderate energies of nuclear collisions, Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 GeV in the UrQMD model were considered.

- Temperature was obtained from the spectrum over p_T
- Correlation function in Bertsch-Pratt parametrization was built
- τ was extracted from $R_{long}(m_T)$ dependency
- Kinetic freeze-out distribution was considered directly and τ obtained

Correlation femtoscopy approach has shown consistency with straightforward kinetic freeze-out analysis

Thank you!