Freeze-out in Au+Au@19.6GeV (UrQMD)

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We do we want to study?

- Emission function and other hypersurfaces for mesons and baryons.
- Particle freeze-out time and compare received results from femtoscopy analysis with time of maximum emission function

Methods of analyzing freeze-out time using femtoscopy analysis is presented in article of Y.M. Sinyukov at al. in 2015

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On m_T dependence of femtoscopy scales for meson and baryon pairs

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Abstract

The m_T-dependencies of the femto-scales, the so-called interferometry and source radii, are investigated within the hydrokinetic model for different types of particle pairs — pion–pion, kaon–kaon, proton–proton and proton–lambda, — produced in Pb+Pb and $p + p$ collisions at the LHC. In particular, such property of the femto-scales momentum behavior as m_T-scaling is studied for the systems with (w) and without (w/o) intensive transverse flow, and also w and w/o re-scattering at the final afterburner stage of the matter evolution. The detailed spatiotemporal description obtained within hydrokinetic model is compared with the simple analytical results for the spectra and longitudinal interferometry radii depending on the effective temperature on the hypersurface of maximal emission, proper time of such emission, and intensity of transverse flow. The derivation of the corresponding analytical formulas and discussion about a possibility for their utilization by the experimentalists for the simple femtoscopy data analysis is the main aim of this theoretical investigation.

Theory of analytical model for the interferometry radii

To get single particle spectra $p_0 d^3N/d^3p$ and the correlation function of bosons C(p,q) we use the generalized Cooper-Frye method

$$p_0 \frac{d^3N}{d^3p} = \int\limits_{\sigma_{m.e.}(p)} d\sigma_\mu p^\mu f_{l.eq.}(x,p), \quad (1)$$

$$C(p,q) \approx 1 + \frac{\left| \int_{\sigma_{m.e.}(k)} d\sigma_\mu k^\mu f_{l.eq.}(x,k) \exp(iqx) \right|^2}{\left(\int_{\sigma_{m.e.}(k)} d\sigma_\mu k^\mu f_{l.eq.}(x,k) \right)^2}, \quad (2)$$

Correlation function in *long* direction depends only on the parameter $\alpha = R_v^2/R_T^2$

and does not depend on the transverse velocity profile at the hypersurface of maximal emission.

Because of this, we will analyze and use only the longitudinal projection of the correlation function.

Then:

$$C(k, q_l, q_s = q_o = 0) = 1 + \frac{\exp\left[\frac{2}{\lambda^2}\left(1 - \sqrt{1 + \tau^2\lambda^4 q_l^2}\right)\right]}{\left[1 + \tau^2\lambda^4 q_l^2\right]^{3/2}} \xrightarrow{k_T \to \infty} 1 + \exp(-\lambda_l^2 q_l^2). \quad (3)$$

Where λ associated with the homogeneity length in longitudinal direction:

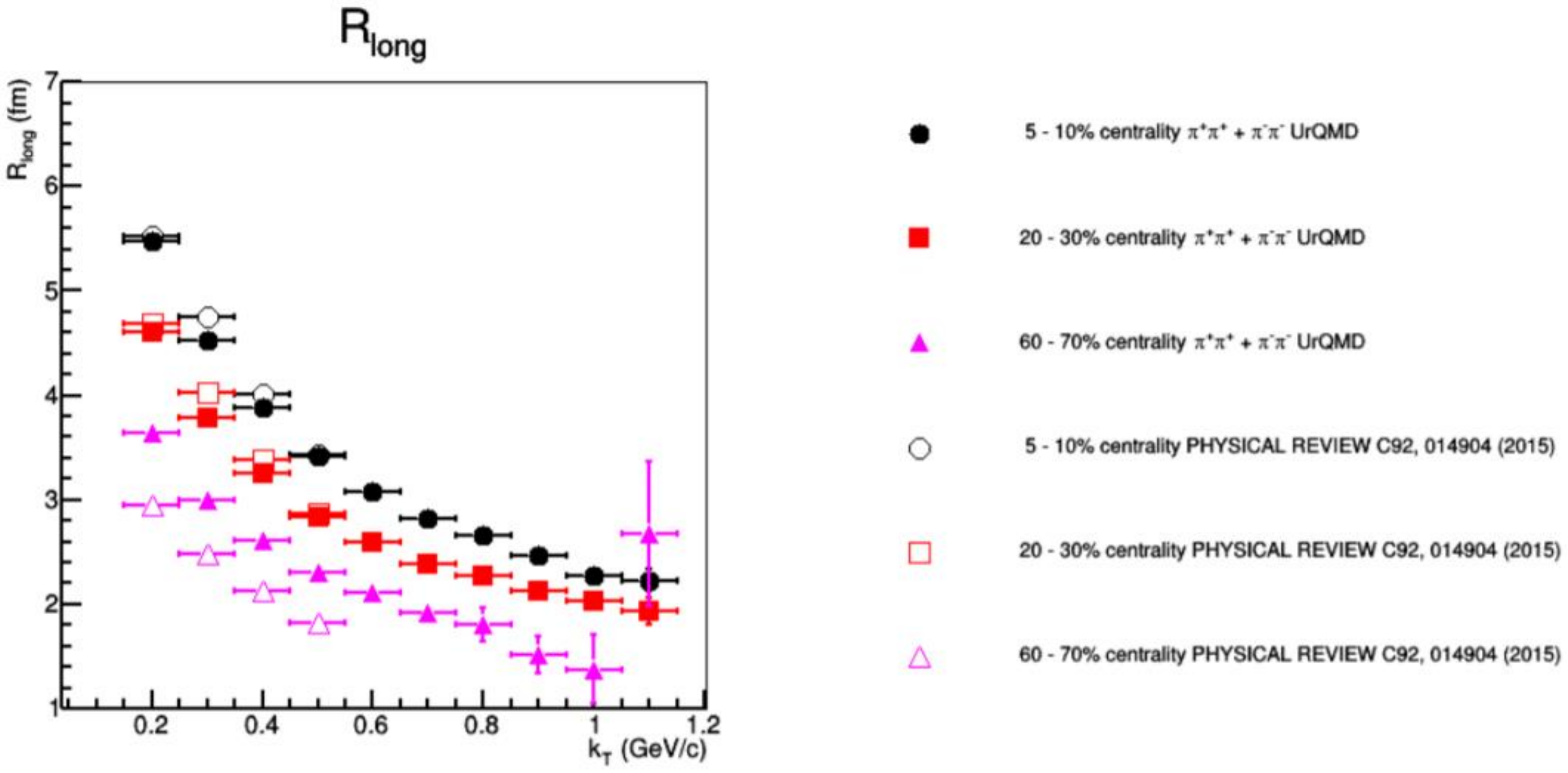
$$\lambda^2 = \frac{\lambda_l^2}{\tau^2} = \frac{T}{m_T}(1 - \bar{v}_T^2)^{1/2} \quad (4)$$, where $\bar{v}_T = k_T/(m_T + \alpha T)$.

The approximation of the correlation function at small q_l leads to the following analytical result for the interferometry radii:

$$R_l^2(k_T) = \tau^2\lambda^2\left(1 + \frac{3}{2}\lambda^2\right) \quad (5)$$

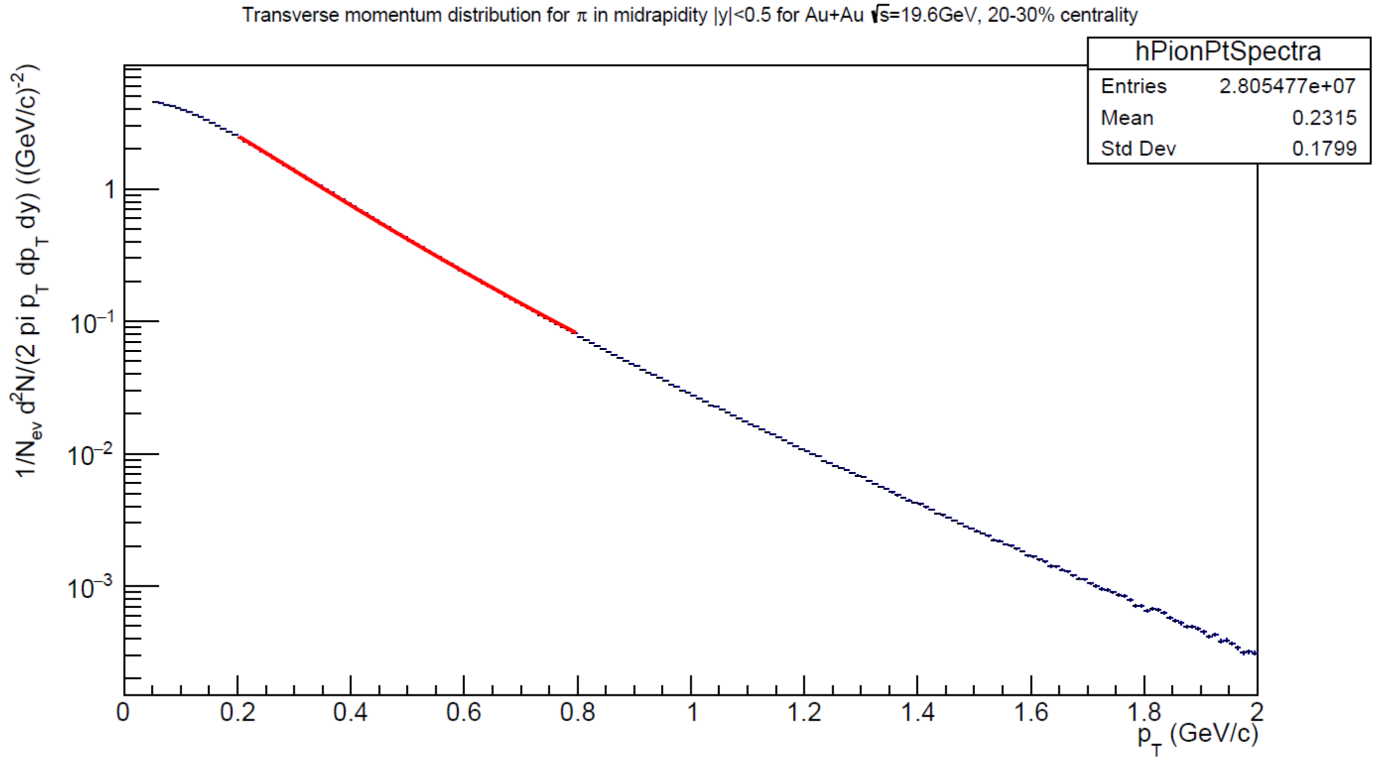
Analytical fitting

Using femtoscopy analysis, Eugenia Khyzhniak had demonstrated radius dependence on transverse momentum of the pair for UrQMD and experimental data



In order to fit m_T dependence of longitudinal femtoscopy radius R_l, using formula (5), and extract τ, is necessary to find Temperature T and parameter α, which could be extracted from fit of pion momentum spectra

$$p_0 \frac{d^3N}{d^3p} \propto \exp[-(m_T/T + \alpha)(1 - \bar{v}_T^2)^{1/2}] \qquad (6)$$

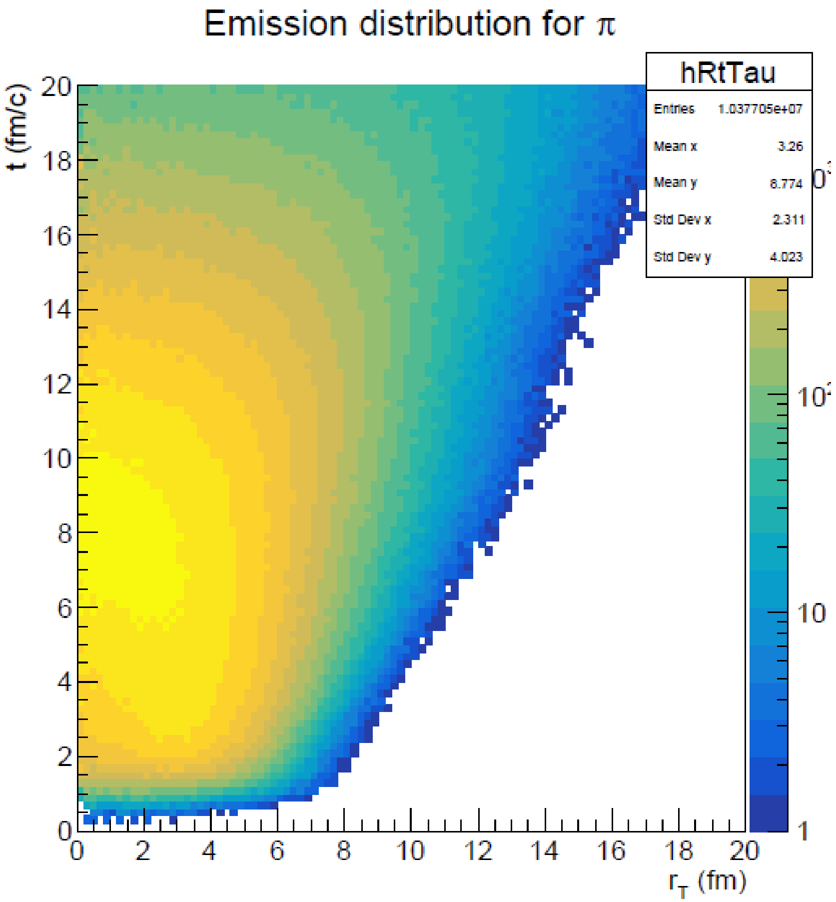


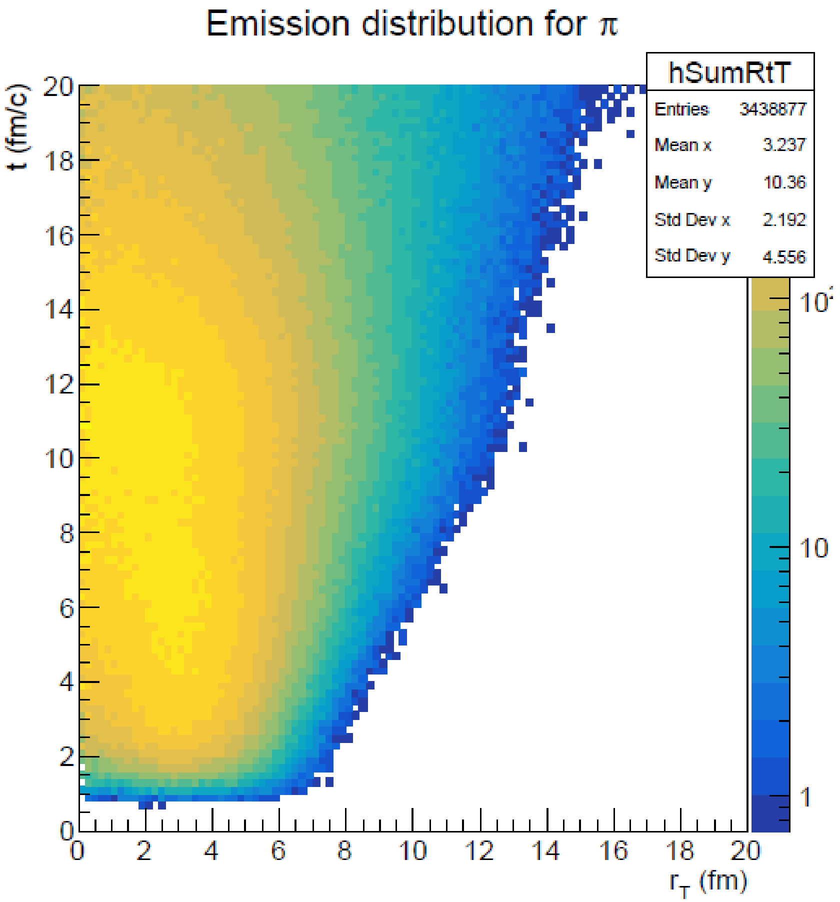
T = 108.9MeV,
α = 7.32

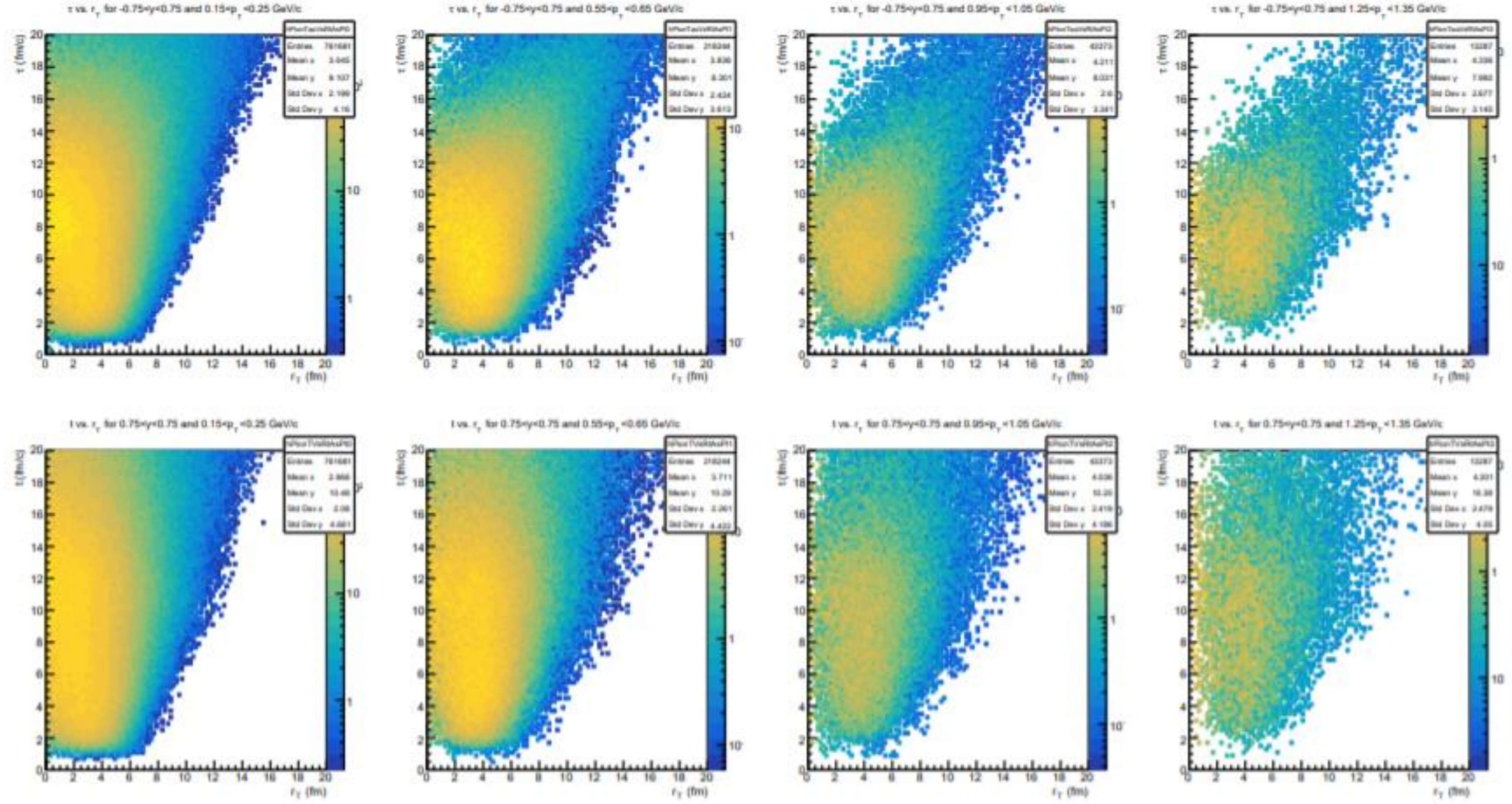
Emission functions for pions

To compare freeze-out time of pions, obtained in different ways, we have to also analyse emission functions.

We studied the dependence of freeze-out time (t in Cartesian and $\tau = \sqrt{t^2 - z^2}$ in hyperbolic coordinates) from transverse position of particle emission $r_T = \sqrt{x^2 + y^2}$ for different p_T and $\cos(p_T, r_T)$

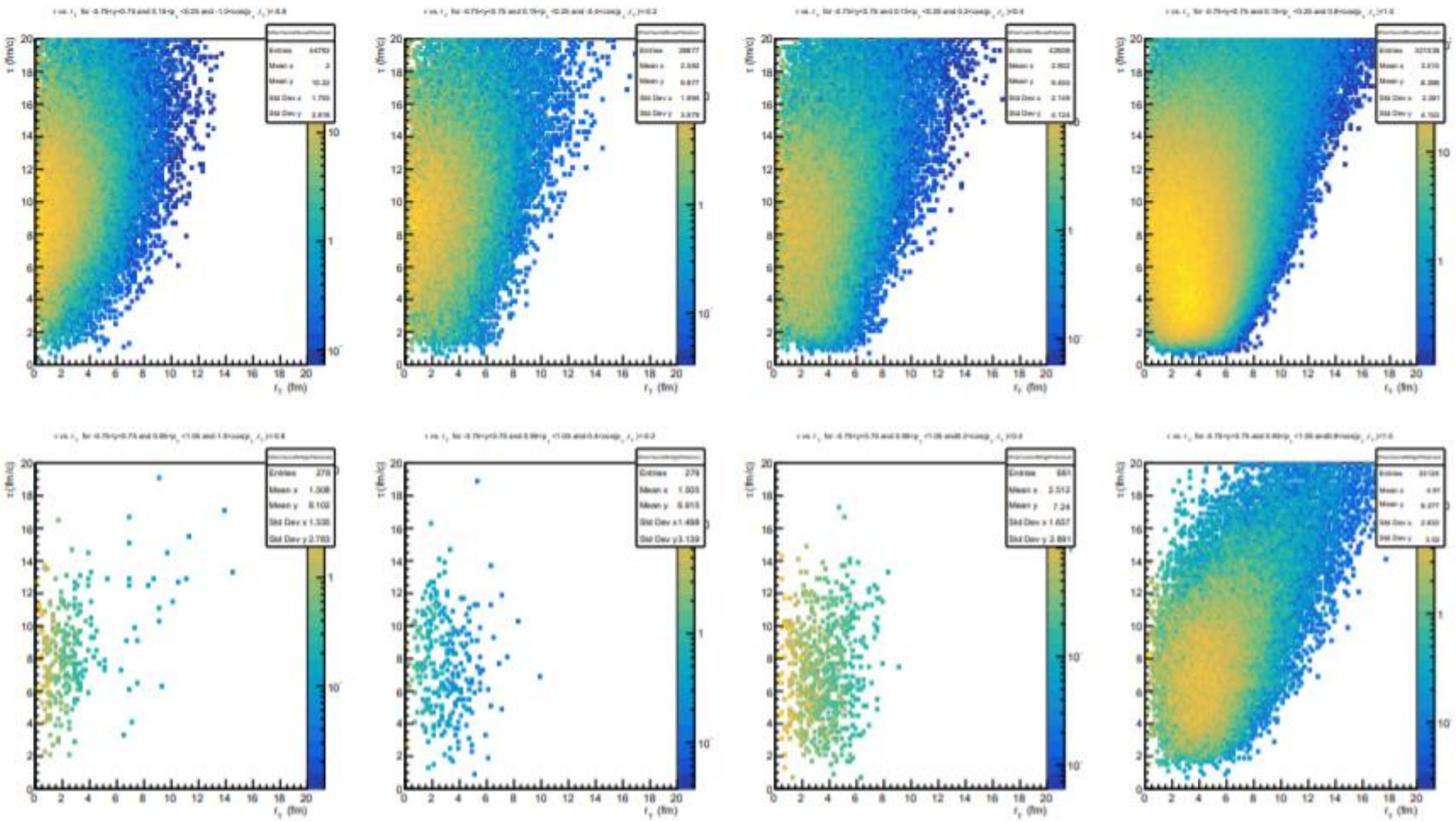






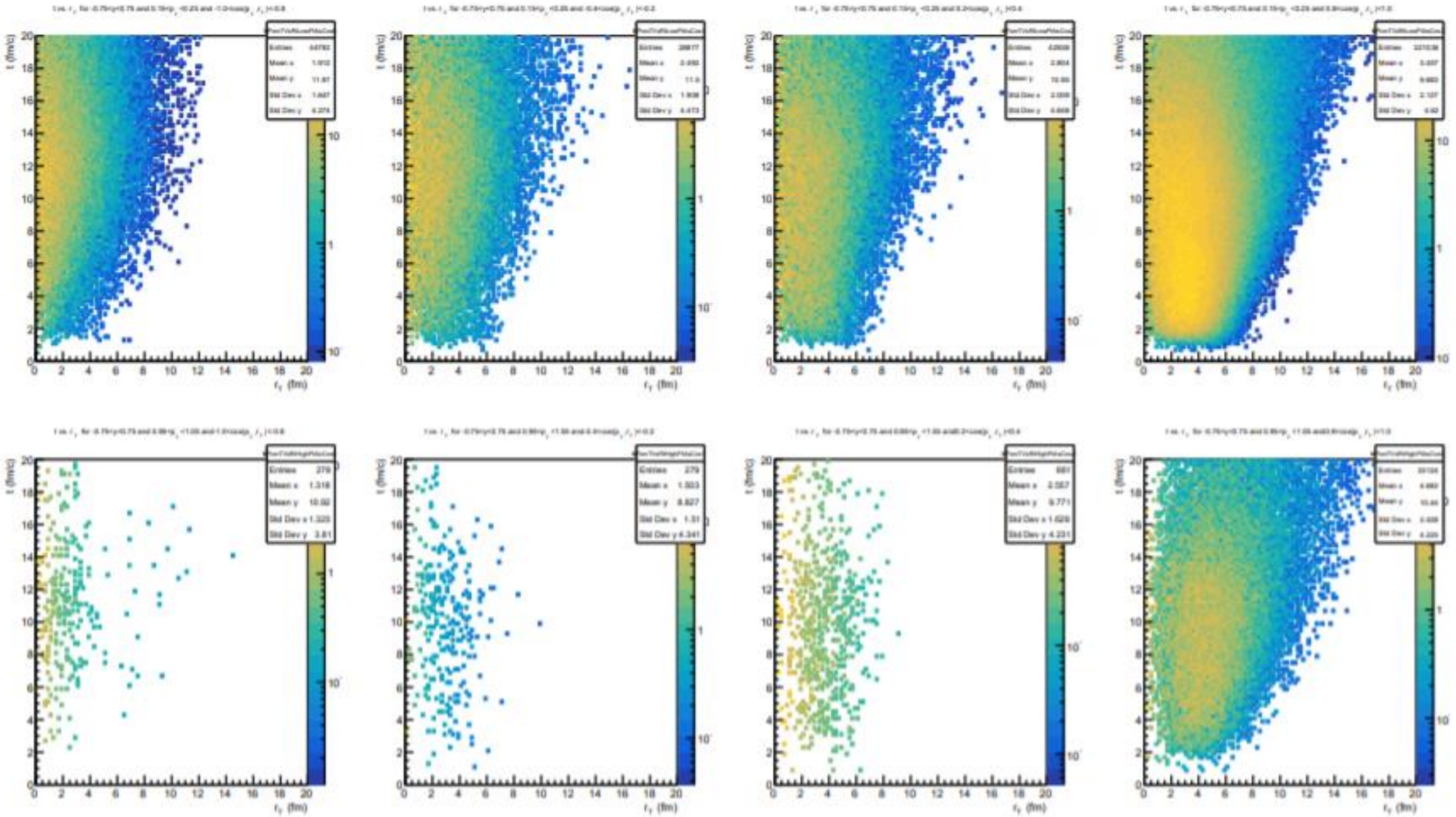
- The pion emission function for $p_T \in (0.15 - 0.25)$, (0.55-0.65), (0.95-1.05), (1.25-1.35) GeV/c

- τ vs r_T



The pion emission function for $cos(p_T r_T) \in (-1; -0.8)$, (-0.4;-0.2), (0.2;0.4), (0.8;1.0) for low $p_T \in (0.15; 0.25)$ and high $p_T \in (0.95; 1.05)$

- t vs r_T



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Summary

- 20-30% most central Au+Au collisions at 19.6 GeV have been simulated using UrQMD model
- Emission function have been studied as a function of p_T and $\cos(p_T, r_T)$
- Lower p_T particles are emitted closer to the center
- Particles that are moving along emission direction are emitted earlier and from the surface
- Necessary parameters for fitting m_T dependence of longitudinal femtoscopy radius R_l have been extracted: T = 108.9MeV, α = 7.32

Outlook

- Simulate Au+Au@19.6 GeV, @11.5GeV, @7.7GeV (9 centrality ranges)
- Extract from fit of m_T dependence of longitudinal femtoscopy radius R_l time and compare this with time of maximum emission function.
- Study other hypersurfaces and particle species

Thank you for your attention!