Femtoscopy and correlations at MPD: physics case, people, projections

within the RFBR Mega Grant # 18-02-40044
"Study of strongly interacting matter properties at the energies of the NICA collider using the methods of femtoscopy and factorial moments"

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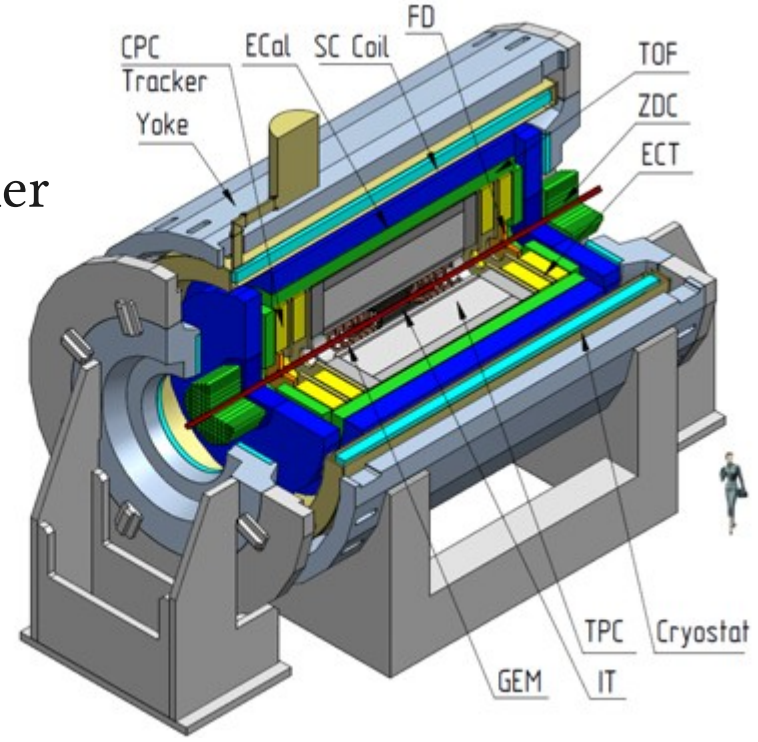


MPD Physics Seminar
Apr, 2020

Femtoscopy & correlations activities within RFBR mega grant "Study of strongly interacting matter properties at the energies of the NICA collider using the methods of femtoscopy and factorial moments"

Aim of the project:

Study of collective effects and dynamics of quark-hadron phase transitions via femtoscopic correlations of hadrons and factorial moments of particle multiplicity at NICA energies

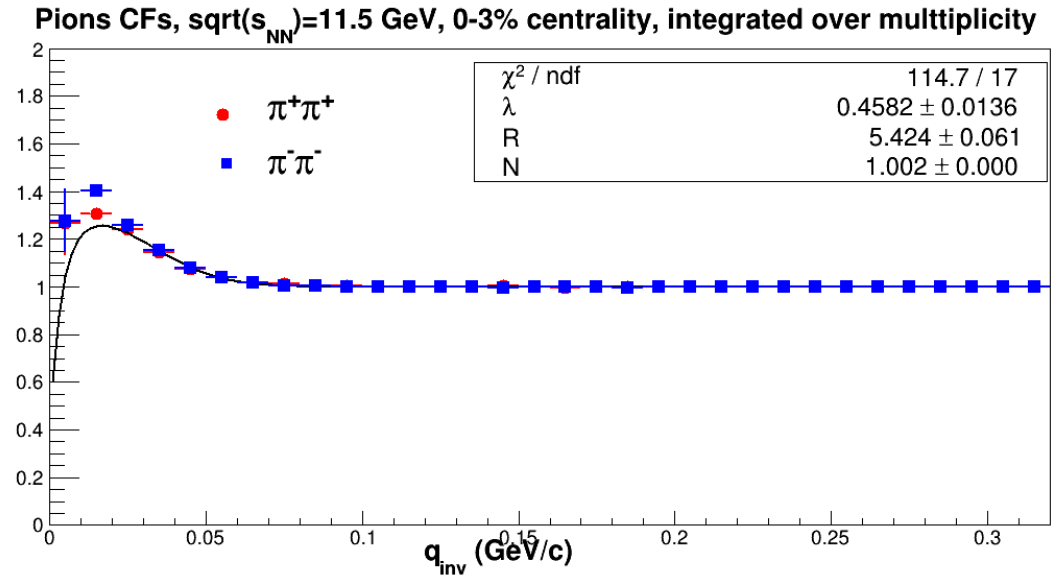
Goals:

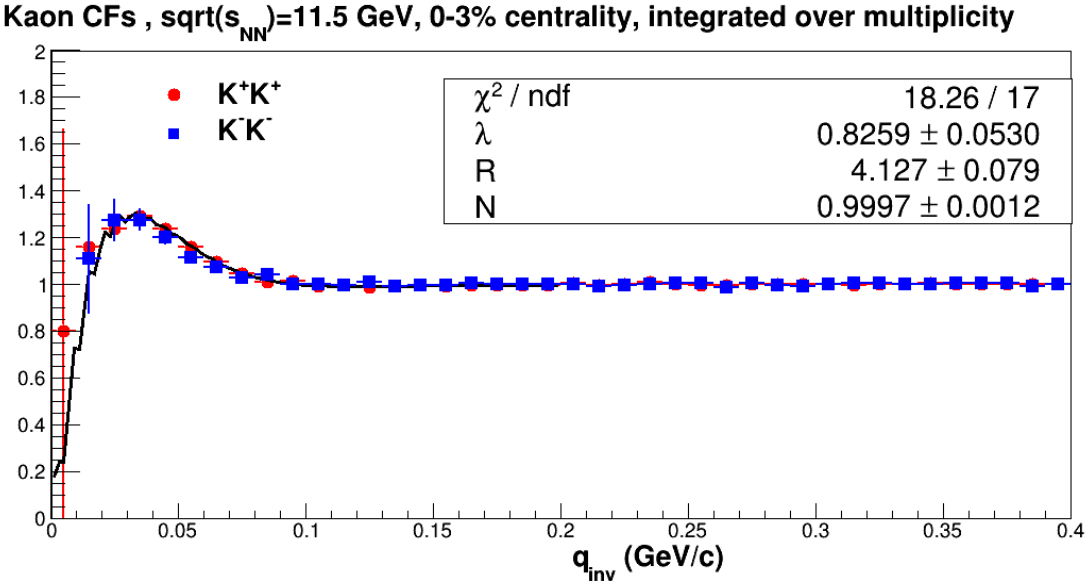
- Development of the data analysis methods and software that will be integrated in the Multi-Purpose Detector (MPD) software environment
- Analysis of the simulated with different event generators (in particular, UrQMD and vHLLE) Au+Au collisions at NICA energies
- Study the dependence of femtoscopic radii and scaled factorial moments of particle multiplicity on the initial conditions and properties of nuclear matter equation of state

Plans for 2019:

- Simulation of Au+Au collisions with UrQMD and vHLLE+UrQMD models for different collision energies (done)
- Software development for: (done)
  - femtoscopic analyses
  - factorial moments of multiplicity distributions
  - other activities
- Femtoscopic analysis (at one collision energy) and extraction of source functions for pions and kaons for models with different Equation of State (EoS): first-order phase transition (1PT), crossover (XPT), no phase transition. (done)
- Investigation of the detector effects (track-merging and track-splitting in TPC) on femtoscopic measurements (done)

CF of π and K, vHLLE+UrQMD (11.5GeV) MPD FEMTO





- Example $\pi^{\pm}\pi^{\pm}$ and $K^{\pm}K^{\pm}$ CFs calculated with MPD FEMTO
- Bose-Einstein enhancement and Coulomb FSI seen in drop at low *q*
- Bowler-Sinyukov formula:

$$C(q) = N\left[1-\lambda+\lambda\, K(q)\left(1+\exp\left(-R_{inv}^2 q^2\right)\right)\right],$$

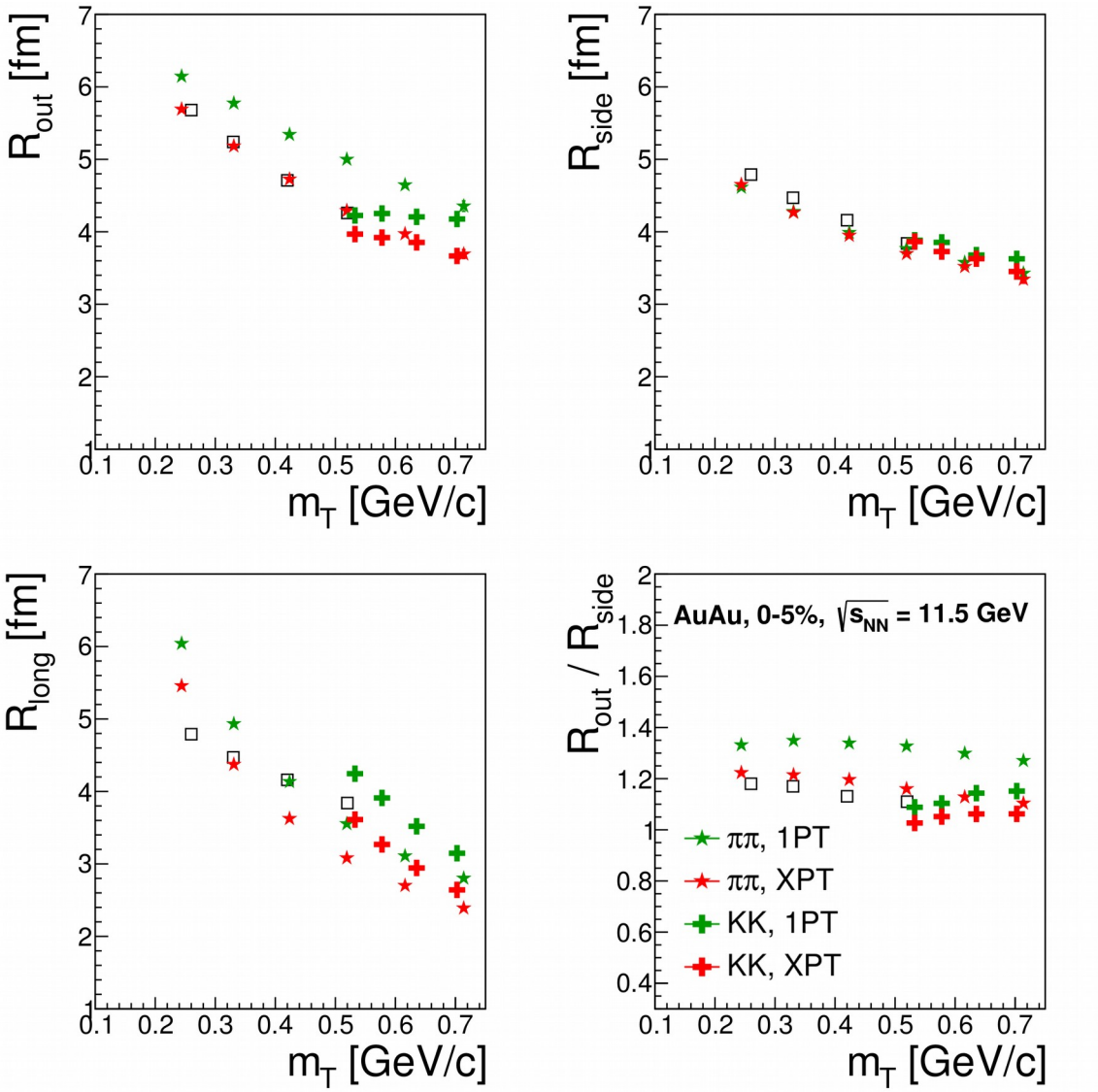
N norm. factor, λ correlation strength, *K(q)* symmetrized Coulomb factor

- Package works well !
- FSI weights for different particle types looks reasonably
- kT/mT – dependencies and
- 3D analysis – study are under way

Additional slides

Radii π and K vs. mT with vHLLE+UrQMD (11.5GeV)

1PT -green dots; XPT – red dots



- Au+Au, $\sqrt{s_{NN}}$ = 11.5 GeV
- 0-5% centrality

- As well as for π, kaon out and long radii greater for 1PT than for XPT

- Approximate m_T-scaling for pions and kaons observed only for "side" radii

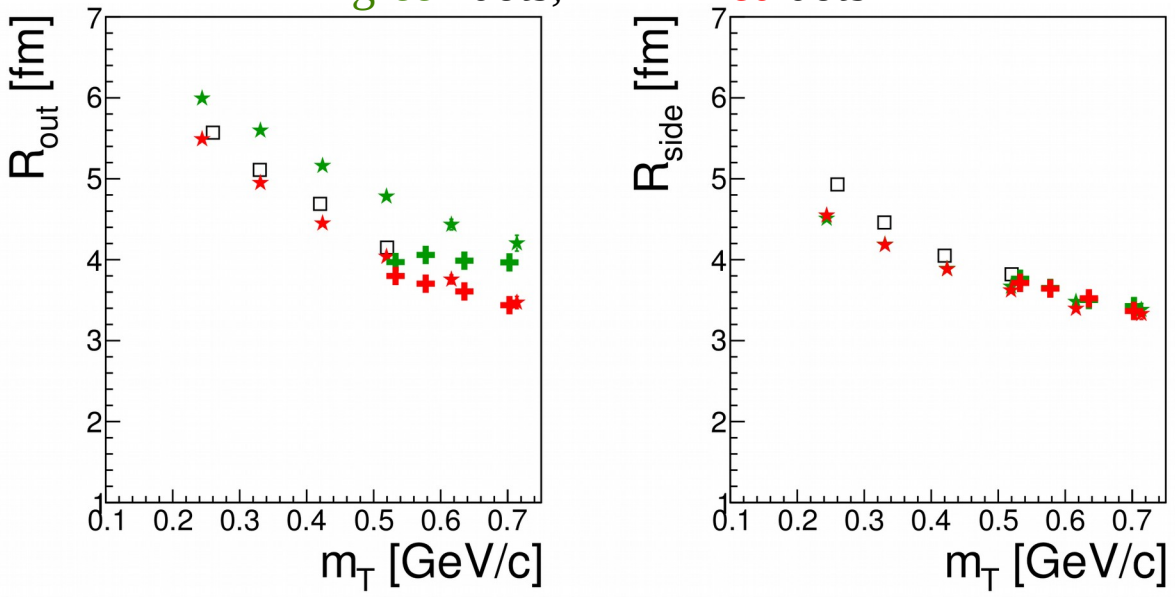
- R_{out} almost flat for 1PT

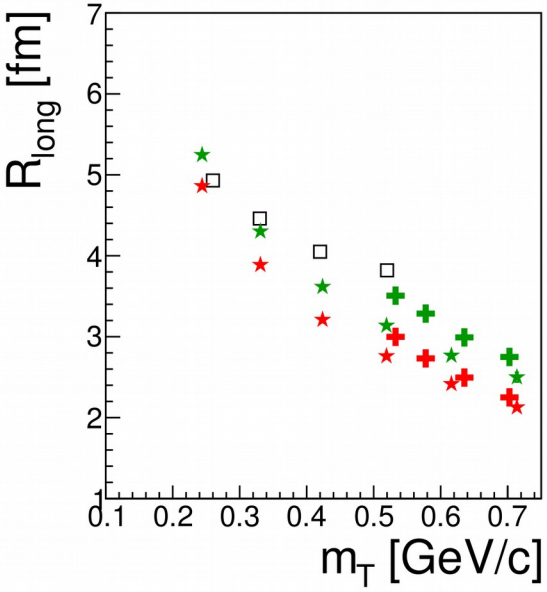
- R_{long}(KK) is greater than R_{long}(ππ) kaons on average emitted later than pions

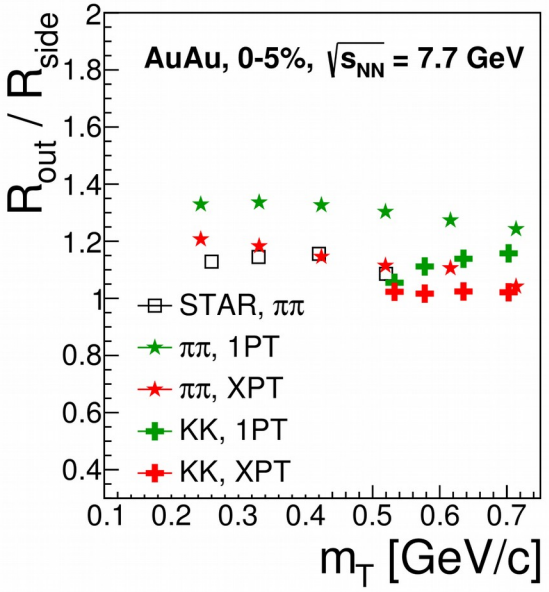
- Rout/Rside(KK) for kaons is less than for pions

Radii π and K vs. mT with vHLLE+UrQMD (7.7GeV)

1PT -green dots; XPT – red dots







- AuAu, $\sqrt{s_{NN}}$ = 7.7 GeV
- 0-5% centrality

- **All as for 11.5 AGeV (slide 11) and model does not predict significant differences.**

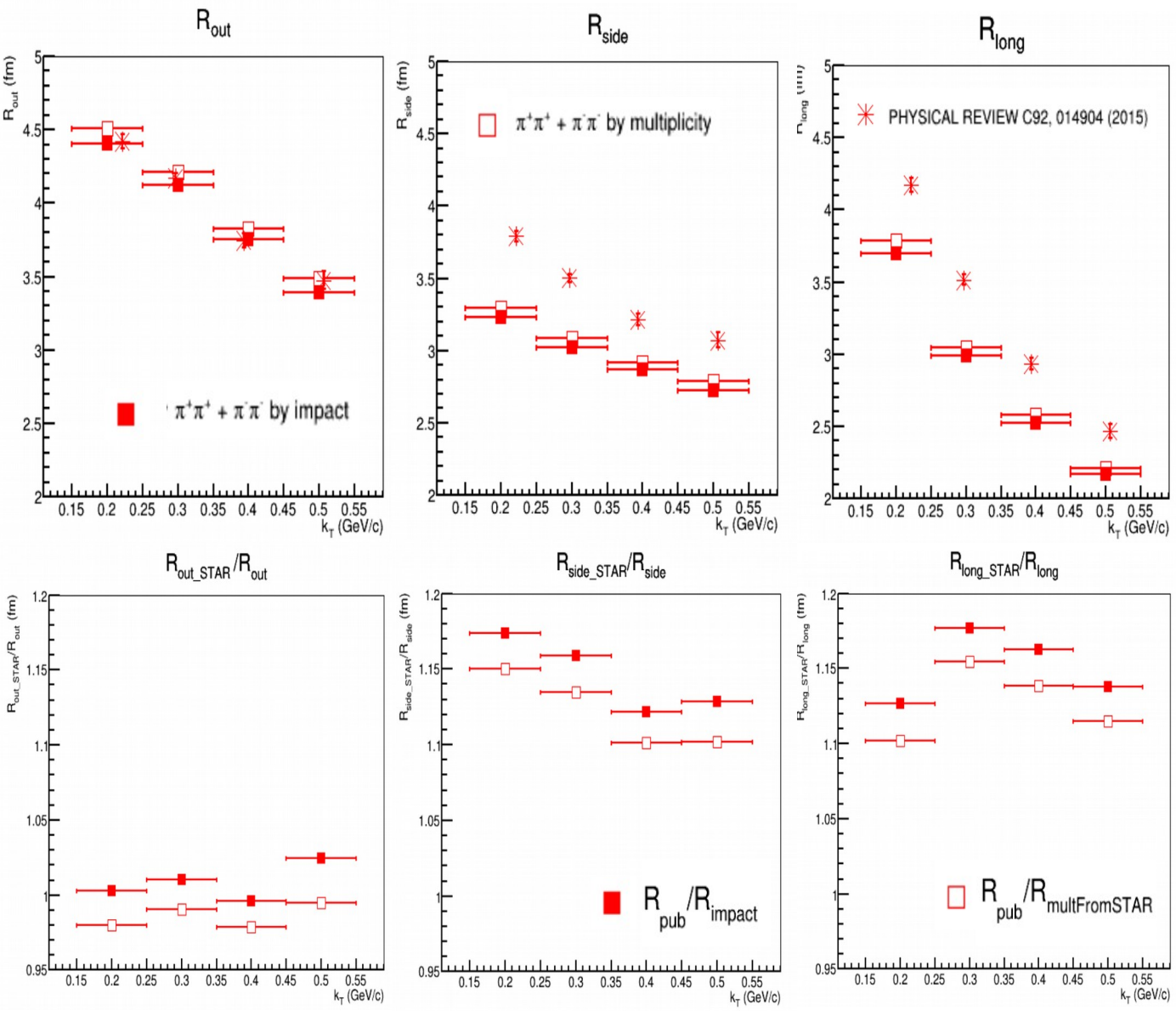
- As well as for π kaon out and long radii greater for 1PT than for XPT

- Approximate m_T scaling for pions and kaons observed only for "side" radii

- It is important to measure both kaons and pions

Pion R(kT) with UrQMD (7.7GeV)

- Analysis was performed using the MpdFemto package developed by our group



- Femtoscopic weigths were estimated using R. Lednicky codes incorporated in MpdFemto
- Centrality bin (20-30%) was estimated by:
  - Impact parameter: 6.6 — 8.1 fm (solid markers)
  - Reference multiplicity range (charged particles with pT > 0.1 GeV/c and η<0.5): 72 — 106 (open markers)
- Both centrality definitions give similar results (< 5% difference)
- Both agree with STAR data **PHYSYCAL REVIEW C92, 014904 (2015)**

Other activities we do:

Package for Femtoscopy analyses:

- ✔ Inherited from STAR (StHbtMaker) and ALICE (AliFemto)
- ✔ Keeps the same hierarchy as in ALICE (PckgName/, PckgNameUser/, macros/)
- ✔ Works with ROOT 5 and 6
- ✔ Lighter than ancestors:
  - ✔ Most of STAR-developed classes replaced with ROOT ones
  - ✔ Better compression, smaller sizes
- ✔ Implemented running options (INDEPENDENT on experiment-dependent software):
  - ✔ Standalone mode – compile with g++ (clang) and run on your “laptop”
  - ✔ Maker; Tasks will be also implemented

Factorial moments:

Factorial moments analysis code inherited from Mirabel experiment is written

Data formats (DST):

- ✔ General-purpose data format for Monte Carlo generators - McDst
  (https://github.com/nigmatkulov/McDst)
  - ✔ Similar to UniGen (developed at GSI)
  - ✔ Lighter, faster, easy expandable, works with ROOT 5 and 6, g++ (clang)
  - ✔ Possibility to add converters from other generators: Terminator, EPOS, AMPT, etc...
- ✔ Group has positive experience on the data format developments:
  - ✔ (St)PicoDst format in STAR (standard data format for physics analysis)

Mini DST format:

Output data format derived from STAR has been incorporated to MpdRoot.

VHLLE interface software:

Allows to perform simulations with vHLLE+UrQMD model by simple and understandable way (vHLLE_package/README.md)

Conclusions

- Study of collective effects and dynamics of quark-hadron phase transitions via femtoscopic correlations of hadrons and factorial moments of particle multiplicity at NICA energies was performed
- First results look promising and this study is planned to be continued.
- Development of the data analysis methods and software integrated in the Multi-Purpose Detector (MPD) software environment was performed and will be continued

- Our studies were presented in the MPD Physics Seminars on and in internatinal conferences WPCF2019 and QFTHEP 2019