Részecskekorrelációk az erősen kölcsönható anyagban RHIC-STAR energiákon / Particle correlations in the strongly interacting matter at RHIC-STAR energies

PhD féléves beszámoló / Semester Report
2. félév / 2nd semester

Nuclear and Particle Physics PhD Programme

Mátyás Molnár [molnarmatyas@student.elte.hu]
Supervisor: Máté Csanád

Budapest, June 2025

1 Introduction

During my doctoral studies, I intend to do analysis on RHIC–STAR experimental data, do phenomenological studies in order to better understand the underlying effects from a theoretical point of view, and also contribute to applied research in the field of medical physics.

2 Description of research and related work carried out in current semester

During this semester, I continued my theoretical work on Lévy femtoscopy, using multiple Monte Carlo event generators. In collaboration with Balázs Kórodi, I contributed to the progress of publishing the RHIC STAR charged particle pseudorapidity analysis results. I also continued the applied medical physical research, progressing each week as in the first semester [1].

2.1 Theoretical and Phenomenological Research in High-Energy Physics

During the semester, made a lot of corrections to my theoretical source function analysis using the EPOS4 framework [2]. Run a lot of consistency checks with earlier analyses done by other colleagues within the research group. Increased the statistics by an order of magnitude on the simulated samples, and also added a lot of more energies within the 7.7 GeV–200 GeV range. To extend the energy range even further down, I started working with another Monte Carlo event generator, the UrQMD (Ultrarelativistic Quantum Molecular Dynamics) package [3] and merged the same analysis done on the UrQMD data I simulated with the EPOS4 results.

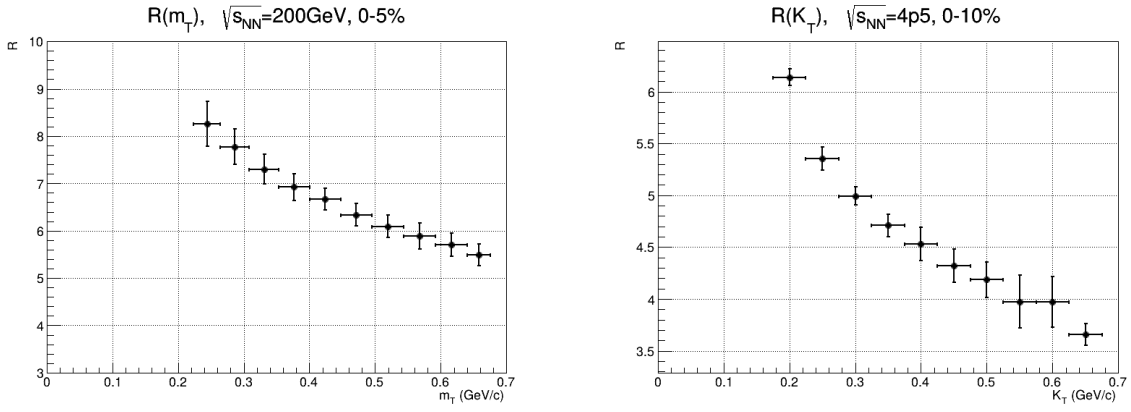

Figure 1: The Lévy parameter R both in EPOS4 (left) and UrQMD (right) showing a strong dependence as a function of transverse momentum, probably due to a hydrodynamical scaling behaviour.

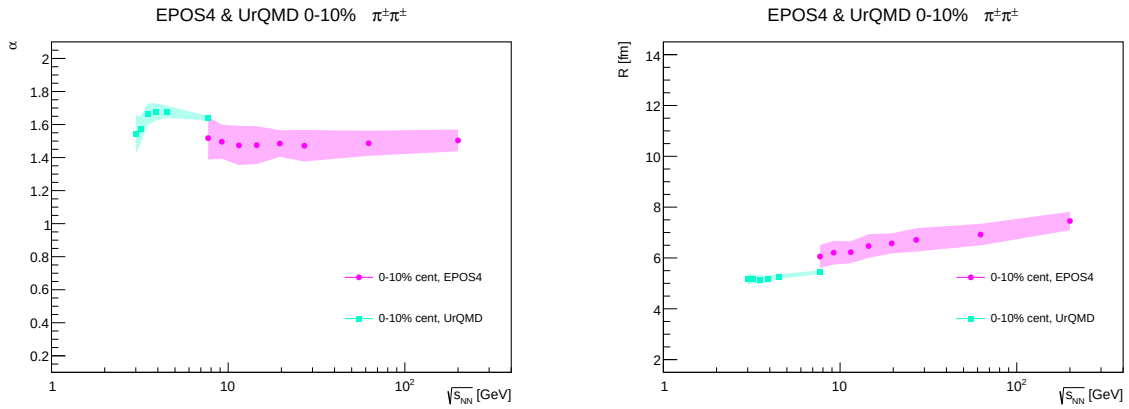

Figure 2: The Lévy parameter α and R as a function of beam energy. Note that the errorbars do NOT represent a systematic nor statistic error, but are simply the standard deviation of the transverse momentum-averaged results.

2.2 Experimental research

When the theoretical results compared to already available experimental data, it could be seen that the trends are different, perhaps indicating a shortcoming in the theoretical framework used in both of the event generators.

With respect to the experimental research, I started working on a way to define the centrality of the simulated events to match the method used in the STAR experiment. Currently, I developed the necessary tools to define the centrality bins, but much larger simulated sample is needed, the preparation is in progress.

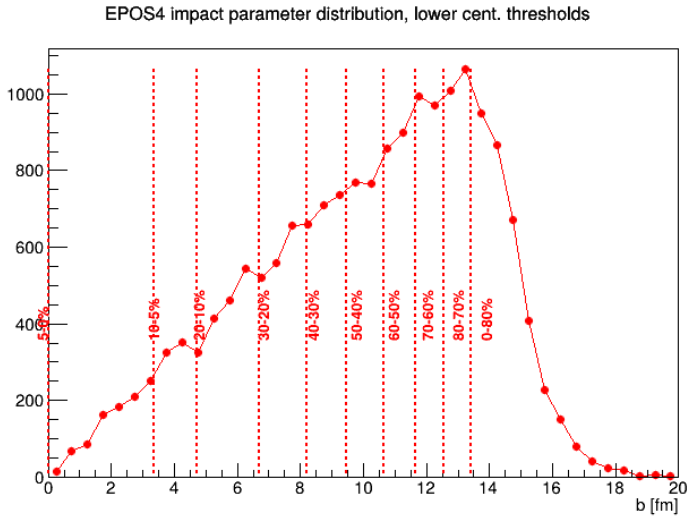

Figure 3: Current progress in defining the centrality bins based on charged particle multiplicity.

In case of the charged particle pseudorapidity measurement ($\mathrm{d}N_{ch}/\mathrm{d}\eta$) analysis, I provided the wording of the theoretical description of the relativistic hydrodynamics part and the unfolding method used in the analysis.

2.3 Applied Medical Physics Research

As detailed in my 1st semester report [1], I worked in collaboration with Norma Instruments Zrt., within the Geant4 framework to model a blood cell counting device in development. I worked on developing several properties of a toy model, and then implementing the full 3D model of the instrument, including adding the optical properties to its elements in Geant4, an analysis to get rid of CCD image asymmetries, implementing an extended light source based on a measured beam profile and similar tasks.

This semester's research work corresponded to registering for FIZ/S1-S4/K18 *Guided research work 1., 2., 3., 4. semesters* subject.

3 Publication

Writing the conference proceedings based on my poster and flash talk from the 24th Zimányi Winter School, titled *Pion emission source and femtoscopic correlation functions from EPOS4 via CRAB*, is still in progress.

The theoretical paper on the phenomenological research and the experimental paper on the 3-dimensional analysis that should be in preparation during the current year are pending as well, new results are being obtained to be included in them.

4 Studies in current semester

During the semester, I attended the following courses:

- FIZ/5/025 *The Structure of Compact Stars (Kompakt csillagok szerkezete)*
- FIZ/2/022 *Experimental Methods in Nuclear Physics (A magfizika kísérleti eljárásai)*
- FIZ/2/023E *Jet Physics in Hadron-Hadron and Heavy-Ion Collisions (Jet-fizika hadron-hadron és nehézion ütközésekben)*

and scored a mark "excellent" from all three of them.

(Furthermore, although not strictly related to my doctoral studies, I finished the parallel Physics teacher's training, obtaining Physics teacher master's degree. I also attended the class Solitons and Instantons I., but decided not to take the exam due to accumulation of my other responsibilities.)

5 Conferences in current semester

Using the corrected and expanded results from the theoretical research, I held a talk at the conference *ACHT 2025: Non-perturbative methods in strongly interacting quantum many-*

body systems, titled *Emission shape evolution in the Monte-Carlo models of heavy-ion collisions*.

I also held a talk during the New Talents session of *2025 International School of Subnuclear Physics in Erice* titled *Femtometer-scale geometry of quark matter*, with the same results in content but in a more refined manner suitable for an audience from a wider range of branches of Physics.

6 Teaching activity

Even though in this semester I did not carry out teaching activity related to university studies, after obtaining the aforementioned teacher's degree, I voluntarily continued teaching in the secondary school I did my teaching practice in the previous semester, preparing students for the school-leaving exam in Physics.

References

[1] M. Molnár, "Particle correlations in the strongly interacting matter at RHIC-STAR energies," *Semester report for 1st semester*, 2025.

[2] K. Werner, "Core-corona procedure and microcanonical hadronization to understand strangeness enhancement in proton-proton and heavy ion collisions in the epos4 framework," *Physical Review C*, vol. 109, no. 1, p. 014 910, 2024.

[3] H. Petersen, M. Bleicher, S. A. Bass and H. Stöcker, "Urqmd-2.3-changes and comparisons," *arXiv preprint arXiv:0805.0567*, 2008.