SEMESTER REPORTS

1. Semester

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PhD Thesis Title: Precision investigation of femtoscopic correlation functions and their implications in heavy-ion physics

Introduction

I conducted femtoscopic studies, concretely, I investigated the Bose -Einstein correlation of identically charged pion pairs. This methodology yields knowledge about the femtometer scale phenomena happening in heavy-ion collisions. From the phenomenological side, a goal of my study was to investigate the pair source function in the EPOS event generator, in order to compare these with experimental findings. I also made preparatory steps towards experimental study of Bose-Einstein correlations at the STAR experiment at the RHIC accelerator.

Description of research work carried out in current semester

I continued the analyses I started during my Msc years. I used the EPOS event generator, widely employed in high-energy heavy-ion physics, to study the pair correlation function of same-charge pion pairs, approximating the functional form with a Lévy distribution. The aim of the research was to to obtain refined results on the source parameters that can be directly compared with the experimental results of Ref. [1]. This experimental analysis also used Lévy distributions, with two main parameters: the Lévy exponent (α), which is related to the shape of the source, and the Lévy scale (R), which is basically the geometric size of the distribution, and also a third parameter, the strength of the correlation function (λ). This latter one is an important observable because is connected to the ratio of pions produced directly in the collision zone as compared to those produced from resonance decays, so knowing its behavior makes indirect investigation of such resonances and their decays possible. Our previous analysis based on the EPOS generator was performed on an event-by-event basis (to rule out event averaging as a possible contributing factor), so the investigation could only be carried out for the most central (0–30%) collisions. The new goal was to develop a method that would allow us to present results for a wider centrality range (0–60%), similar to that of the experimental results. Another important improvement compared to earlier results is that now we were also able to reproduce the third fit parameter of the source, the λ.

One of my tasks during the analysis was to investigate the dependence of the fitted parameters on the integration range used for normalization, as well as on the fit limits, and then to determine the systematic uncertainties arising from these choices for both aspects. I did not perform the normalization based on the sum over all particle pairs; instead, I defined a range within which I then integrated the histograms. With this method, particle pairs produced at very large separations were excluded, which are not relevant in experiments anyway due to the parameters of the detector system. Based on these investigations, I found that although most parameters vary only negligibly with the choice of the upper integration limit, the λ parameter depends strongly on it. For comparison purposes, I therefore chose the range that is closest to the maximum measurable particle-pair separation based on the physical parameters of the detector system (PHENIX) described in the paper presenting the experimental results.

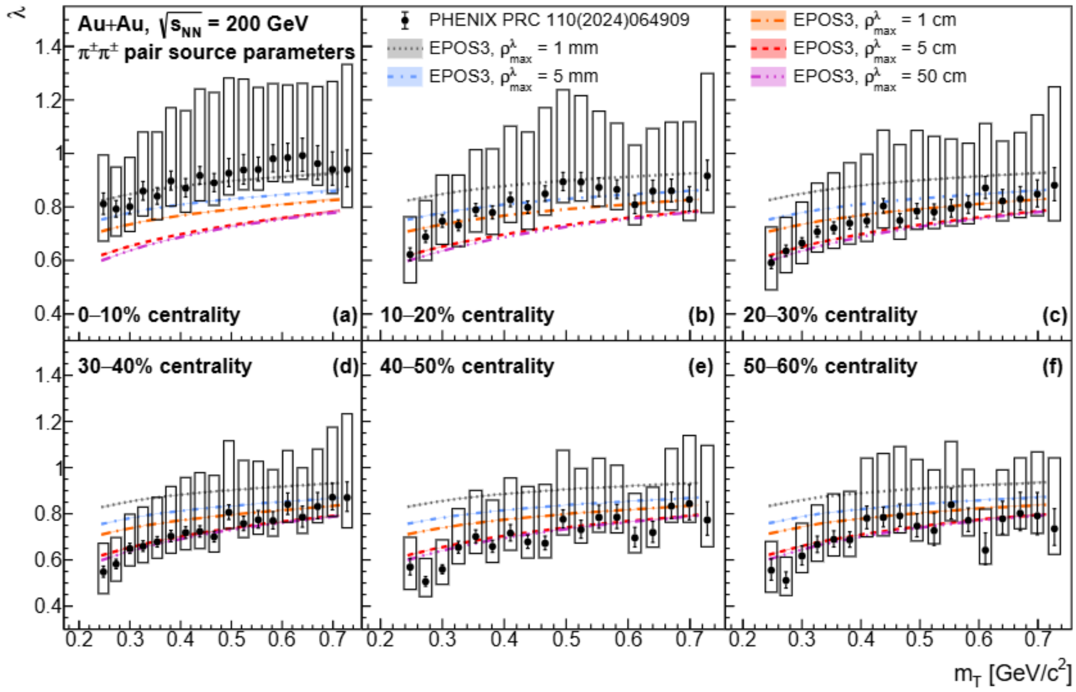

Figure 1: The dependence of the λ parameter from the choice of the integration limits.

During the fitting procedure, I also examined the dependence on the upper limit of the fitting range and the resulting systematic uncertainty. The pair-distribution analysis was performed for different centrality ranges; in addition, for each centrality I also studied the transverse mass dependence of the parameters. In general, for the parameters of the correlation function it can be stated that the Lévy scale (i.e., the geometric properties of the distribution) shows a strong dependence on transverse mass. Taking this property into account, I made the choice of the upper limit of the fitting range dependent on transverse mass: $\rho_{\max} = {}^{B}\!/\!_{\sqrt{m_T}}$. The parameter B was a value chosen arbitrarily by me (while, of course, taking the shape of the distribution into account); to determine the systematic uncertainty, I varied this chosen value in both directions for the fit and calculated the uncertainty accordingly.

Publications

During the semester, a manuscript, based on the results of the analyses described above, was submitted for publication, with title: *"Three-dimensional sizes and shapes of pion emission in heavy-ion collisions"* and is currently under full consideration for publication in *The European Physical Journal C*. The preprint is available on arXiv:2511.01808.

Studies and teaching in current semester

I completed two courses during this semester:

- Experimental Methods in Particle Physics II (FIZ/2/004E)
- Phase Diagram of the Strongly Interacting Matter (FIZ/2/024E)

In this semester, I taught the Classical Physics Laboratory practical course for BSc students, which represents 4 hours per week student contact hours.

Conferences in current semester

I participated in two conferencies:

- The Day of Femtoscopy, held in Gyöngyös, where I presented my results, mentioned above, in a talk.
- The 25th Zimányi School Winter Workshop, where I presented a poster with my results.

Professional activities

In this semester, I participated in the organisation of the 25th Zimányi School Winter Workshop, as a member of the local organisor commitee.

References

[1] Abdulameer, N.J., et al.: PHENIX PCR 110(2024)064909) arXiv:2407.08586 [nucl-ex]

[2] arXiv:2511.01808