Prof. dr hab. Wojciech Florkowski
Institute of Theoretical Physics
Jagiellonian University

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Review of the Doctoral Dissertation by Mr. Rupam Samanta

"Study of the hottest droplet of fluid through correlations and fluctuations of collective variables"

1. GENERAL CHARACTERISTICS OF THE THESIS

The submitted PhD Thesis reports on theoretical studies of fluctuations and correlations of collective variables used to characterize the behavior of matter produced in ultrarelativistic heavy-ion collisions. Such variables include mainly the mean transverse momentum per particle [p_T] and harmonic flow coefficients v_n. These quantities exhibit event-by-event fluctuations mostly determined by the fluctuations of the initial state geometry. In this way, the problems studied in the Thesis become connected with the intriguing issues of early thermalization and early hydrodynamization of matter produced in heavy-ion collisions.

The first contact with the work shows the great care with which it was prepared, as well as its large volume. The Thesis has 193 pages, excluding introductory pages containing the lists of figures and tables, as well as the explanations of symbols. The main part of the Thesis is divided into 7 Chapters, with the first two of them being the introduction to the Thesis and introduction to the physics of ultrarelativistic heavy-ion collisions, respectively.

Most of the results presented in the Thesis have been already published in six Physical Review C articles that appeared within less than three years (Refs. [125-130]). These articles have at the moment altogether about 50 citiations in the INSPIRE database, which indicates that they have already brought significant attention of the heavy-ion community.

2. NEW RESULTS PRESENTED IN THE THESIS

The presentation of new results starts in **Chapter 3** that is partially based on Ref. [125]. After a concise discussion of the phenomenon of

ul. St. Łojasiewicza 11
PL 30-348 Kraków
tel. +48(12) 664-47-26
+48(12) 664-46-77
e-mail:
sekret@th.if.uj.edu.pl

anisotropic flow, the Author argues that the fluctuations of the harmonic flow coefficients can be very conveniently probed by constructing the factorization-breaking coefficients in different transverse momentum bins.

In **Chapter 4** the topic of the Thesis changes to ultracentral Pb+Pb collisions. The transverse-momentum fluctuations are studied and the Author shows that a sudden fall of the variance with centrality in the ATLAS data can be explained by the specific correlation between multiplicity and mean transverse momentum. I find the discussion of the fluctuations at small values of the impact parameter presented in this Chapter as very illuminating and giving a very convincing physics picture of many observed effects. Many of the results presented in this Chapter were published before in Refs. [126] and [127].

In **Chapter 5**, the Author discusses the correlations between mean transverse momentum [p_T] and the harmonic flow coefficients squared v_n^2 (in some way, it is an interplay of the effects studied in the two earlier chapters). The Pearson coefficient proposed first by prof. Piotr Bożek in Ref. [95] is used, and the model calculations are compared to the ATLAS data for v_2^2 and v_3^2 in Figs. 5.1 and 5.2, respectively, indicating a good qualitative agreement. In the same chapter, new higher-order normalized and scaled symmetric cumulants are proposed that can be used to introduce additional constraints on the measured correlations. In this case, some of the results were published in Refs. [128] and [129].

Finally, the effects of nuclear deformation are discussed in **Chapter 6**. As the standard way of determination of nuclear structure is low energy electron scattering, a new perspective of getting additional information on nuclear structure from high-energy collisions has become a very fascinating topic. It is shown in the Thesis that the deformation parameter beta of ^{238}U nucleus can be constrained by studying correlations between [p_T] and v_n^2 , and also by symmetric cumulants. This was reported before in Refs. [128] and [130].

The main findings of the work, plans for future investigations are outlined in **Chapter 7**. The Authors emphasizes here the role played by relativistic hydrodynamic expansion and event-by-event fluctuations that determine main features of the experimentally studied observables.

3. **CRITICAL COMMENTS**

i) In Sec. 1.5, in the list of six published papers, two of them have the same title – the title of the fourth paper is wrongly given.

ii) A ``sudden fall'' in the ATLAS data is frequently mentioned in the introductory parts of the Thesis, which does not mean much without further explanations of the character of this observable (an additional note that one has in mind the fall with centrality would be useful).

iii) The statement ``the contribution from intrinsic and impact parameter fluctuations" in the caption of Fig. 4.1 is not clear for me. What does ``intrinsic'' in this context mean?

iv) Unfortunately, there are many typos in the text. They should be eliminated with standard tools before the Thesis is submitted for publication (for example as a review article, which is suggested below).

4. **SUMMARY**

The minor critical comments listed above do not affect my very positive opinion about the doctoral Thesis of Mr. Rupam Samanta. As I mentioned above, the Thesis is very well organized, clearly written and contains a lot of general information about fluctuations and correlations studied in heavy-ion collisions, hence, it may serve as a review or introduction to this topic for all who want to start such investigations. Because of this character of the Thesis and new important physics results obtained, I recommend the Thesis for distinction. As far as I know there is no comparable reference in the current literature that deals with fluctuations and correlations (analyzed in heavy-ion collisions) in such a complete way.

5. **SUMMARY in POLISH**

Podsumowując stwierdzam, że recenzowana rozprawa spełnia wymagania ustawy o stopniach naukowych i tytule naukowym oraz stopniach i tytule w zakresie sztuki określonej w art. 187 ustawy z dnia 20 lipca 2018 r. *Prawo o szkolnictwie wyższym i nauce* (z późn.zm.) i wnioskuję o jej dopuszczenie do dalszych etapów postępowania o nadanie stopnia doktora w dziedzinie nauk ścisłych i przyrodniczych w dyscyplinie nauki fizyczne.

Wojciech Florkowski

Podpisany elektronicznie przez
Wojciech Florkowski
24.09.2024
12:09:01 +02'00'