Contribution ID : **315** Type : **Oral talk**

Influence of Gaussian and non-Gaussian elementary sources on high-order multiplicity cumulants in a toy model of relativistic nucleus-nucleus collisions

Wednesday, 28 October 2026 16:35 (15)

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High-order cumulants of event-by-event multiplicity distributions are widely used in the search for the QCD critical point in relativistic heavy-ion collisions. Their sensitivity to non-Gaussian fluctuations [1] makes them promising observables [2], but at the same time they can be strongly affected by non-critical background effects, in particular by volume fluctuations and by the procedure of centrality class selection[3].

In this work, we study these effects using a simple toy Monte Carlo model of nucleus-nucleus collisions. The collision geometry is described through the impact parameter and the corresponding number of participant nucleons. Particle multiplicity is generated as a superposition of elementary nucleon-nucleon sources. In the first version of the model, the elementary source is assumed to be Gaussian. We show that even in this case nonzero third- and fourth-order cumulants can appear after selecting events by final-state multiplicity, due to the admixture of events with different collision geometry and different effective volume.

The model is then extended to the inclusion of non-Gaussian elementary sources. This allows us to compare two different contributions to high-order cumulants: the intrinsic non-Gaussianity of particle production – in case of proximity to the critical point, and trivial contribution caused by the volume fluctuations. Special attention is paid to the comparison of multiplicity-based event -by-event selection of narrow classes of participating nucleons (Npart).

The results demonstrate that the measured values of high-order cumulants may be significantly distorted by centrality and volume fluctuations even in the absence of critical dynamics. Therefore, careful control of the initial geometry and the use of narrow classes of the number of Npart and relevant reduced cumulants are essential for separating possible critical-point signals from the non-critical background contributions.

The authors acknowledge Saint-Petersburg State University for a research project ID: 153212394

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Session Classification : Heavy ion physics

Track Classification : Heavy ion physics