High-order net-proton cumulants and event-by-event volume definition in the A+A collision at NICA energies

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Net-baryon, net-charge and net-strangeness, **are predicted to be sensitive to the correlation length of hot dense matter** created in the collisions [1],

Ratios of cumulants $C_2/C_1=\sigma^2/M$, $C_3/C_2.=S\sigma$, and $C_4/C_2=\kappa\sigma^2$ were used to reduce the volume dependence. **However, the average values of** σ, *S* and *k* **are calculated here assuming the fixed value of volume V in all events!. This is not true.**

- **We propose to use the** reduced cumulants, similar to **[2], but on the event-by-event basis, following the new procedure with volume $(V)^r$ definition [3] in each r^{th} event:**

$$M = \langle N\rangle = C_1,$$
$$\delta N = N - \langle N\rangle$$
$$\sigma^2 = \langle(\delta N)^2\rangle = C_2,$$
$$S = \langle(\delta N)^3\rangle/\sigma^3 = C_3/C_2^{3/2},$$
$$k = \langle(\delta N)^4\rangle/\sigma^4 - 3 = C_4/C_2^2$$

$$c1 = M/V^r = \langle N^r/V^r\rangle,$$
$$\delta N^r = N^r/V^r - \langle N^r/V^r\rangle$$
$$c2 = \sigma_r^2 = \langle(\delta N^r)^2\rangle,$$
$$S_r = \langle(\delta N^r)^3\rangle/\sigma_r^3,$$
$$k_r = \langle(\delta N^r)^4\rangle/\sigma_r^4 - 3$$

- **We assume that for any r^{th} event. in the selected class of centrality, the relevant mean volume V^r is proportional to the mean number of participants $\langle N^r_{part}\rangle$:**

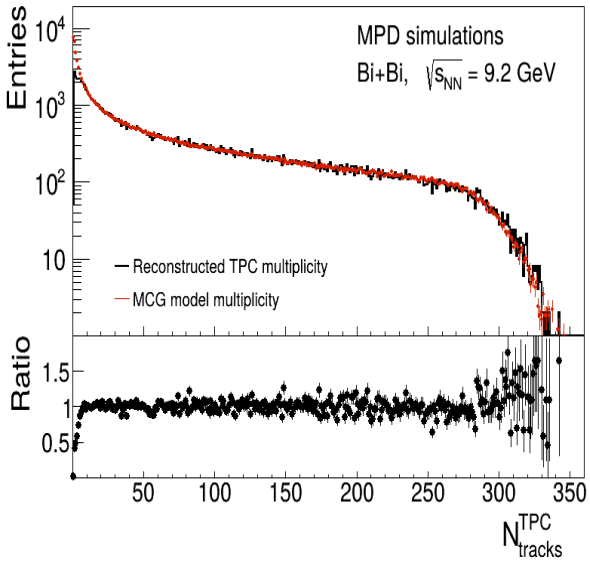
$$V^r = \langle N^r_{part}\rangle V_0$$

Here a volume factor $V_0 = 2.83$ fm^3 (see in [1]).

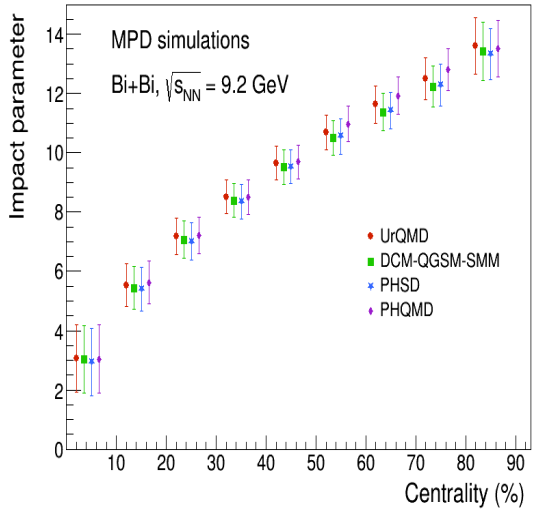
- **Thus we obtain the reduced deviation $\delta N^r = N^r/V^r - \langle N^r/V^r\rangle$ for the relevant distribution of conserved quantity N^r**

[1] [1] M. A. Stephanov, Phys. Rev. Lett. 102, 032301 (2009).
[2] V. Skokov, B. Friman and K. Redlich, "Volume fluctuations and higher order cumulants of the net baryon number". arXiv:1205.4756v2
[3] K. Galaktionov, V. Rudnev , and F. Valiev , "Application of Neural Networks for Event-by-Event Evaluation of the Impact Parameter ", Physics of Particles and Nuclei, 2023, Vol. 54, No. 3, pp. 446–448.

Careful centrality selection



The reconstructed TPC (black) and MCG modeled (red) multiplicity distributions for Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV [1]



Mean impact parameter for 10% centrality intervals for Bi+Bi collisions at $\sqrt{s_{NN}}$ = 9.2 GeV, modeled with the UrQMD, PHSD, DCM-QGSM-SMM, and PHQMD in [1]

- **The width of the class of centrality of A+A collisions is directly related to the unavoidable volume fluctuations [2]: We should select for the analysis of net-proton fluctuations much narrow central classes of multiplicity or in the number of participating nucleons N_{part} [2]**
- **Another approach – to measure spectator fragments with Hadron Calorimeter in parallel with multiplicity**
- **Application of ML to select narrow centrality classes in ToF technique with high timing resolution [3]**

[1] MPD Collaboration, "MPD physics performance studies in Bi+Bi collisions at √1sNN = 9.2 GeV", to be published

[2] T. A. Drozhzhova,V. N. Kovalenko,A. Yu. Seryakov,G. A. Feofilov, Physics of Atomic Nuclei, 2016, V 79, Issue 5, pp 737–748

[3] Galaktionov K., Rudnev V., Valiev F. , Physics of Particles and Nuclei, v54, N3, (2023), 446-448, DOI: 10.1134/s1063779623030152