

CHARGE CONSERVATION EFFECTS FOR
HIGH-ORDER FLUCTUATIONS*

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The exact charge conservation significantly impacts multiplicity fluctuations. The result depends strongly on the part of the system charge carried by the particles of interest. Along with the expected suppression of fluctuations for large systems, charge conservation may lead to negative skewness or kurtosis for small systems.

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The STAR Collaboration observes the non-monotonous behavior of the net-proton normalized kurtosis [1]. This might be an indication of the critical point of strongly interacting matter. The NA61/SHINE Collaboration performs the system size and energy scan in order to find the critical point and study its properties [2]. Electric charge Q , baryon number B , and strangeness S are conserved exactly in strong interactions. This may change the expected background fluctuations in high-energy collisions¹.

For illustration purposes, the system with only one conserved charge in CE Hadron Gas model for primary particles (no resonance decays) is considered in the system with the total charge $Q = 2$. The straightforward calculations using [3] allow to obtain fluctuations for different amount of charge carried by the particles, $k = z_j/z$, where $z = \sum_j z_j$, and j is the type of hadron, and z_j is the one-particle partition function [3]. The $k = 0.95$ means that the particles contain 95% of the electric charge $Q = 2$ of the system, which may correspond to pions created in $p+p$ reactions. Let us also consider the case $k = 0.5$, in order to check the importance of this parameter. The normalized skewness, $S \cdot \sigma = m_3/m_2$, where m_i are central moments,

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¹ The grand canonical statistical ensemble (GCE), where charges are conserved on average, is equivalent to the canonical ensemble (CE), where charges are conserved exactly, only for mean multiplicities and only for large systems. Multiplicity fluctuations in CE and GCE for both small and large systems are different [3].

and normalized kurtosis, $\kappa \cdot \sigma^2 = (m_4 - 3m_2^2)/m_2$, are considered. They are calculated for plus, minus, net, and total number of charged particles. The results are shown as a function of the mean number of neutral particles $\langle N_0 \rangle$, which is the same in GCE and CE.

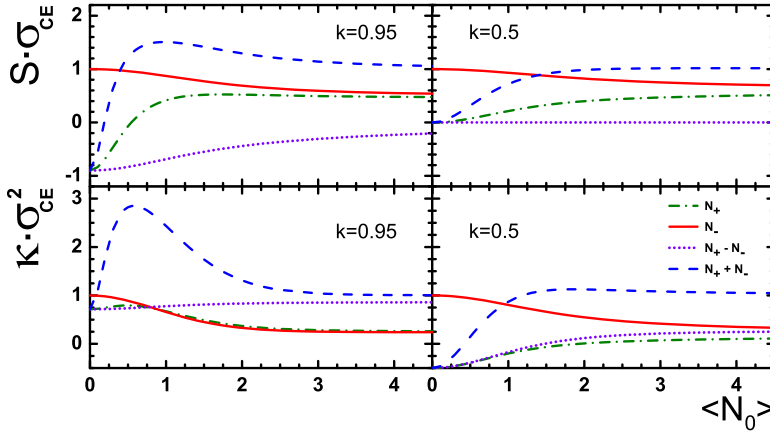


Fig. 1. The normalized skewness (top row) and the normalized kurtosis (down row) for different amount k of the system charge carried by the particles of interest.

One can see that all observables have a non-trivial behavior in CE². Since $Q = N_+ - N_- = 2 > 0$, fluctuations of N_+ and $N_+ + N_-$ are suppressed for small systems, while N_- fluctuate as by Poisson. For large systems, $\langle N_0 \rangle \gg Q$, “+” and “-” become equivalent. The net charge $N_+ - N_-$ is always special. The $S \cdot \sigma_{\text{CE}}$ can be negative for $k = 0.95$, and $\kappa \cdot \sigma_{\text{CE}}^2$ can be negative for $k = 0.5$, while they have positive values in other cases. Thus, the calculations and interpretation of high moments should be performed with a great care.

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² GCE values of $S \cdot \sigma$ and $\kappa \cdot \sigma^2$ are either 1 for Poisson, or 0 for Gauss distribution.