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Net-proton high-order cumulants in event-by-event studies in high energy A+A collisions at NICA energies

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The region of nucleus-nucleus collision energies $\sqrt{s_{NN}} \approx$ 2-10 GeV is very attractive for the detailed study of the phase diagram of strongly interacting matter, where the first-order phase transition and the existence of the critical endpoint (CEP) are predicted by the QCD. So far, the experimental investigations carried out in this energy range at SPS and at RHIC have shown no convenient evidence for the critical phenomena. The non-Gaussian fluctuations [1] of conserved quantities, like net electric charge Q, net strangeness S, net baryon number B, near the QCD critical point", could be very sensitive to the proximity of the critical point. Studies of the energy dependence of higher-order cumulants of net-protons (as a proxy for net baryon number) were started in BES-I and are in progress in BES-II programs at RHIC [2,3]. In particular, recent precision measurement for net-proton cumulant ratios vs. centrality across Au+Au collision energies at RHIC showed some hints of the non-monotonic energy dependence [2,3]. However, the non-dynamical contributions to fluctuations of protons and net-protons could be large [4]. These trivial volume fluctuations are to be carefully taken into account before comparison to theory.
In this report we argue that the current experimental approaches are still lacking the proper event-by-event estimate of the interaction volume. Assumption of the mean value of the interaction volume for the given class of selected events, including the case of Centrality Bin Width Correcrition (CBWC) procedure, used by STAR at RHIC, is introducing the bias into the values of net-proton cumulant ratios due to the inevitable mixture of the events with different impact parameters. We focus in this report on the minimization of the role of trivial volume fluctutions that should be under strict control in data analysis in order to reval the dymanical physics fluctuations effects of interest. We propose to use the reduced cumulants, where both the cumulants and the volume of interaction are defined for each event. The last procedure requires the event-by-event estimates of the most probable value of number of participation nucleons (Npart) by using such approach as [5] or the ML technique [6] that is in currently in progress.

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