Rapidity acceptance and higher moments

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The crucial issue for the dependence of a fluctuation signal on the width Δy of rapidity acceptance window is the range of the correlations $\Delta y_{\rm corr}$. The argument below generalizes the discussion in Ref.[1] from quadratic to higher-order cumulants.

If $\Delta y \ll \Delta y_{\rm corr}$, the critical point contribution to the n-th order cumulant κ_n of the fluctuations grows as $(\Delta y)^n$. This is because the n-th cumulant measures the strength of an n-particle correlation and, therefore, if all particles in the acceptance are correlated, the signal is proportional to the number of possible n-plets, which is roughly $M^n \sim (\Delta y)^n$, where M is the multiplicity.

When $\Delta y \gg \Delta y_{\rm corr}$, all cumulants grow linearly with Δy, as uncorrelated contributions are additive in a cumulant. It is convenient to remove this trivial volume dependence by normalizing cumulants to their uncorrelated, Poisson value (M, for cumulants of M), defining $\omega_n \equiv \kappa_n/M$. The critical contribution $(\omega_n^{(\Delta y)} - 1)$ grows as $(\Delta y)^{n-1}$ for $\Delta y \ll \Delta y_{\rm corr}$ and then saturates at a constant value.

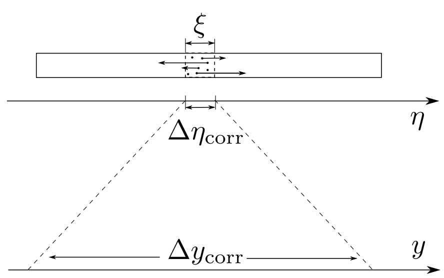

FIG. 1. Spatial (Bjorken's) vs kinematic rapidity.

What determines $\Delta y_{\rm corr}$? Consider the boost-invariant scenario with correlation length in comoving coordinates at freezeout given by ξ (Fig. 1). This translates into Bjorken rapidity correlation length $\Delta\eta_{\rm corr} = \xi/\tau_{\rm f}$. With ξ ranging from 1 fm typically to about $2-3$ fm near the critical point [2] and with freezeout Bjorken time $\tau_{\rm f} \sim 10$ fm one estimates $\Delta\eta_{\rm corr} \sim 0.1-0.3$.

Detectors do not measure the spatial (Bjorken) rapidity η, but the kinematic rapidity y of the particles. Within the spatial correlation volume $\Delta\eta_{\rm corr}$ thermal distribution of particle rapidities y_p in the comoving frame ranges roughly from -1 to 1. The observed rapidity $y = \eta + y_p$ of the particles from the correlated volume is then spread over an interval of order $\Delta y_{\rm corr} \sim 2$ (Fig. 1). Because $\Delta y_{\rm corr} \gg \Delta\eta_{\rm corr}$, the value of $\Delta y_{\rm corr}$ is not sensitive to ξ (in contrast to the magnitude of κ_n [3] — larger ξ means more correlated particles in the same $\Delta y_{\rm corr}$).

To make this argument more quantitative, consider

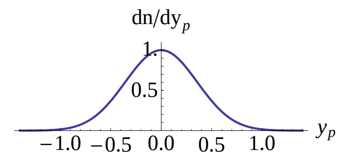

FIG. 2. Thermal proton rapidity distribution.

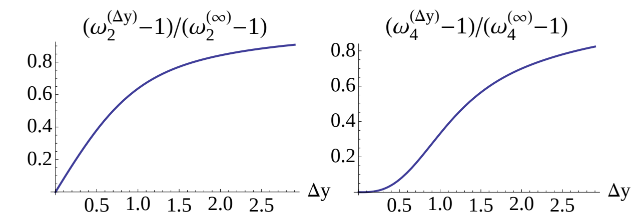

FIG. 3. Critical contributions to normalized 2nd and 4th order cumulants vs acceptance.

thermal distribution of proton rapidities at freezeout conditions $(T, \mu_B)_{\rm f} \approx (140, 400)$ MeV shown in Fig.2. Using the expression for the critical contribution to the correlator in momentum space from Ref.[3], boosting it by η and integrating over η and particle momenta within the acceptance, one then finds the dependence of proton $\omega_4^{(\Delta y)}$ on Δy plotted in Fig.3 alongside $\omega_2^{(\Delta y)}$ obtained similarly (see also Ref.[4]) for comparison. For example, the value of $(\omega_4^{(\Delta y)} - 1)$ changes from 0.33 to 0.60 of its $\Delta y \to \infty$ limit between $\Delta y = 1$ and 1.6.

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[2] B. Berdnikov and K. Rajagopal, Phys. Rev. D **61**, 105017 (2000) [hep-ph/9912274].

[3] M. A. Stephanov, Phys. Rev. Lett. **102**, 032301 (2009) [arXiv:0809.3450 [hep-ph]].

[4] M. A. Stephanov, Phys. Rev. D **65**, 096008 (2002) [hep-ph/0110077].