22nd Zimanyi School
Winter Workshop on Heavy Ion Physics

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Cumulants with global baryon conservation and short-range correlations

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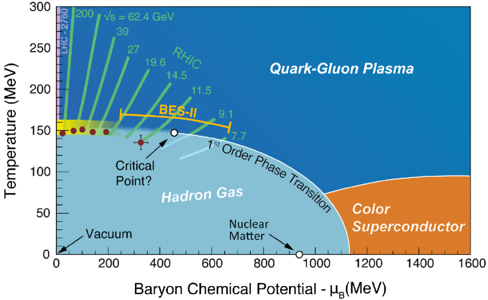
The conjectured QCD phase diagram

- Most of this is only an educated guess based on effective models.
- Search for the critical point - conserved charges fluctuations (cumulants, factorial cumulants).
- Experiments: heavy-ion collisions at different energies.
- Background:
  - small fluctuations of the impact parameter
  - **global baryon number conservation**



A. Bzdak, S. Esumi, V. Koch, J. Liao, M. Stephanov and N. Xu, Phys. Rept. **853**, 1-87 (2020)
A. Aprahamian, A. Robert, H. Caines, *et al.*, *Reaching for the horizon: The 2015 long range plan for nuclear science*

Cumulants with baryon conservation and short-range correlations obtained from the cumulants without baryon conservation.

$$\kappa_n^{(1,B)} \approx \underbrace{\kappa_n^{(1,B,\mathrm{LO})}}_{\substack{\propto B^{1} \\ \text{thermodynamic limit}}} + \underbrace{\kappa_n^{(1,B,\mathrm{NLO})}}_{\propto B^{0}} + \underbrace{\dots}_{O(B^{-1})}$$

$$\kappa_1^{(1,B)} = fB = f\kappa_1^{(G)}$$

$$\kappa_2^{(1,B,\mathrm{LO})} = \bar{f} f \kappa_2^{(G)}$$

$$\kappa_2^{(1,B,\mathrm{NLO})} = \frac{1}{2}\bar{f} f \frac{(\kappa_3^{(G)})^2 - \kappa_2^{(G)}\kappa_4^{(G)}}{(\kappa_2^{(G)})^2}$$

$$\kappa_3^{(1,B,\mathrm{LO})} = \bar{f} f (1-2f)\kappa_3^{(G)}$$

$$\kappa_3^{(1,B,\mathrm{NLO})} = \frac{1}{2} f\bar{f}(1-2f)\frac{\kappa_3^{(G)}\kappa_4^{(G)} - \kappa_2^{(G)}\kappa_5^{(G)}}{(\kappa_2^{(G)})^2}$$

$$\kappa_4^{(1,B,\mathrm{LO})} = f\bar{f}\left[\kappa_4^{(G)} - 3f\bar{f}\left(\kappa_4^{(G)} + (\kappa_3^{(G)})^2/\kappa_2^{(G)}\right)\right]$$

$$\kappa_4^{(1,B,\mathrm{NLO})} = \frac{1}{2} f\bar{f}\left\{\frac{\kappa_3^{(G)}\kappa_5^{(G)} - \kappa_2^{(G)}\kappa_6^{(G)}}{(\kappa_2^{(G)})^2} + 3f\bar{f}\left[\frac{(\kappa_4^{(G)})^2 + \kappa_2^{(G)}\kappa_6^{(G)}}{(\kappa_2^{(G)})^2} + \frac{2(\kappa_3^{(G)})^4 - 5\kappa_2^{(G)}(\kappa_3^{(G)})^2\kappa_4^{(G)} + (\kappa_2^{(G)})^2\kappa_3^{(G)}\kappa_5^{(G)}}{(\kappa_2^{(G)})^4}\right]\right\}$$

LO reproduces net-baryon cumulants from

V. Vovchenko, O. Savchuk, R.V. Poberezhnyuk, M.I. Gorenstein, V. Koch, PLB **811**, 135868 (2020)

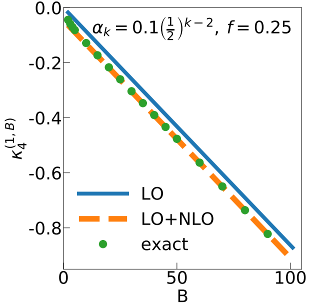
NLO is new.

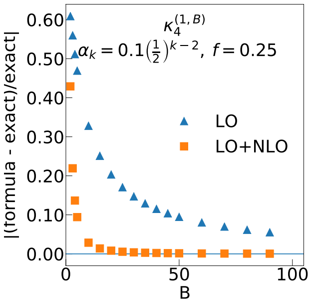
$\kappa_n^{(1,B)}$ - cumulants in the subsystem with the baryon conservation and short-range correlations

$\kappa_n^{(G)}$ - short-range cumulants in the whole system without baryon conservation

f - a fraction of particles in the acceptance, $\bar{f} = 1 - f$

Example





- exact - a straightforward differentiation of the factorial cumulant gen. func.,
- α_k - k-particle short-range correlation strength, $\alpha_k = 0.1\left(\frac{1}{2}\right)^{k-2}$, $k = 2 \ldots 6$, $\alpha_1 = 1$,
- f - a fraction of particles in the acceptance.

- NLO improves the results.

MB and A. Bzdak, PRC 106, no. 2, 024904 (2022)

MB and A. Bzdak, [arXiv:2210.15394 [hep-ph]]