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Study of fluctuations and correlations within finite volumes in 2+1 flavor Polyakov—Nambu—Jona-Lasinio Model

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ABSTRACT

The objective is to check the volume scaling of thermodynamic variables for various temperatures and chemical potentials. We observe the possible violation of scaling with system size in a considerable window along the whole transition region in T-μ_q plane.

INTRODUCTION and THE MODEL

➔The matter formed in high-energy heavy ion collision experiments have finite volumes, which depend on the size of the colliding nuclei as well as the center of mass energy and the centrality of collisions.

➔There have been various attempts applying HBT technique, UrQMD etc to estimate the freeze-out volume.

➔Previously in PNJL model the cross-over temperature was observed to decrease with decreasing system's size and the CEP to shift towards lower T and higher μ_B. The possibility of chiral symmetry restoration in a color confined state with finite system size has also been discussed.

➔Fluctuations of conserved charges in this regard are viable indicators for a transition from partonic state to hadronic matter. Alongwith their detailed study, we also intend to focus on the possible volume scalings along the phase transition line within the framework of 2+1 flavor PNJL model.

➔The PNJL model has been formed by a suitable modification of the NJL model through introduction of a background field that mimics the behavior of Polyakov loop in a way that the chiral and confinement properties can be studied under a single framework.

➔ Details of the model and the methodology can be found in [1].

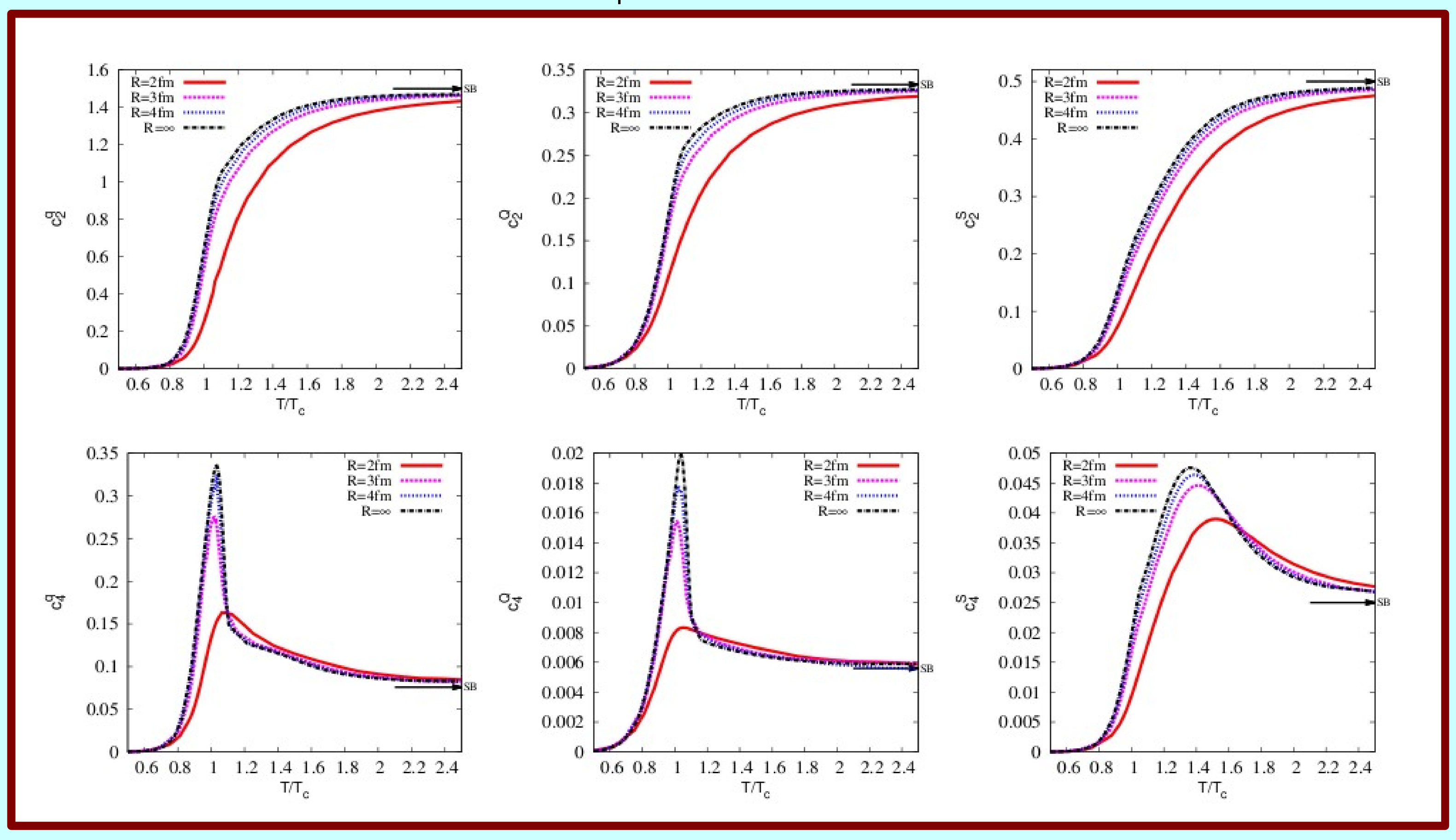
RESULTS AND DISCUSSIONS

R(fm)	2	3	4	∞
T_c(MeV)	160	174	178	181

Cross-over temperatures for various system sizes at vanishing μ_q.

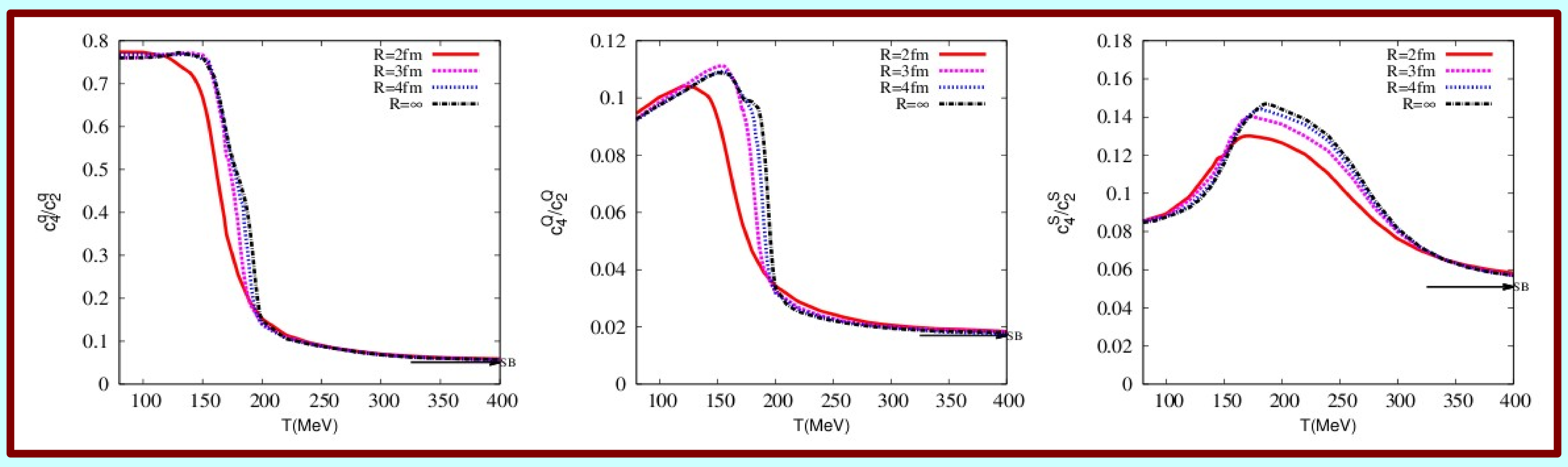
Fluctuations of conserved charges like quark number (q), charge (Q) or strangeness (S) are related to corresponding susceptibilities which are given by,

$$c_n^X(T) = \frac{1}{n!}\frac{\partial^n(-\Omega(T,\mu_X)/T^4)}{\partial(\frac{\mu_X}{T})^n}\Big|_{\mu_X=0}$$



➔Both second and fourth order susceptibilities are found to depend on system's volume indicating the necessity to consider freeze-out volumes as well in the analysis if the experimentally produced fireball thermalizes close to T_c.

➔Now if the multiplicity ratio and ratios of fluctuations are to be employed to match theory and experiment, it is important to study the occurence of volume scaling violation.



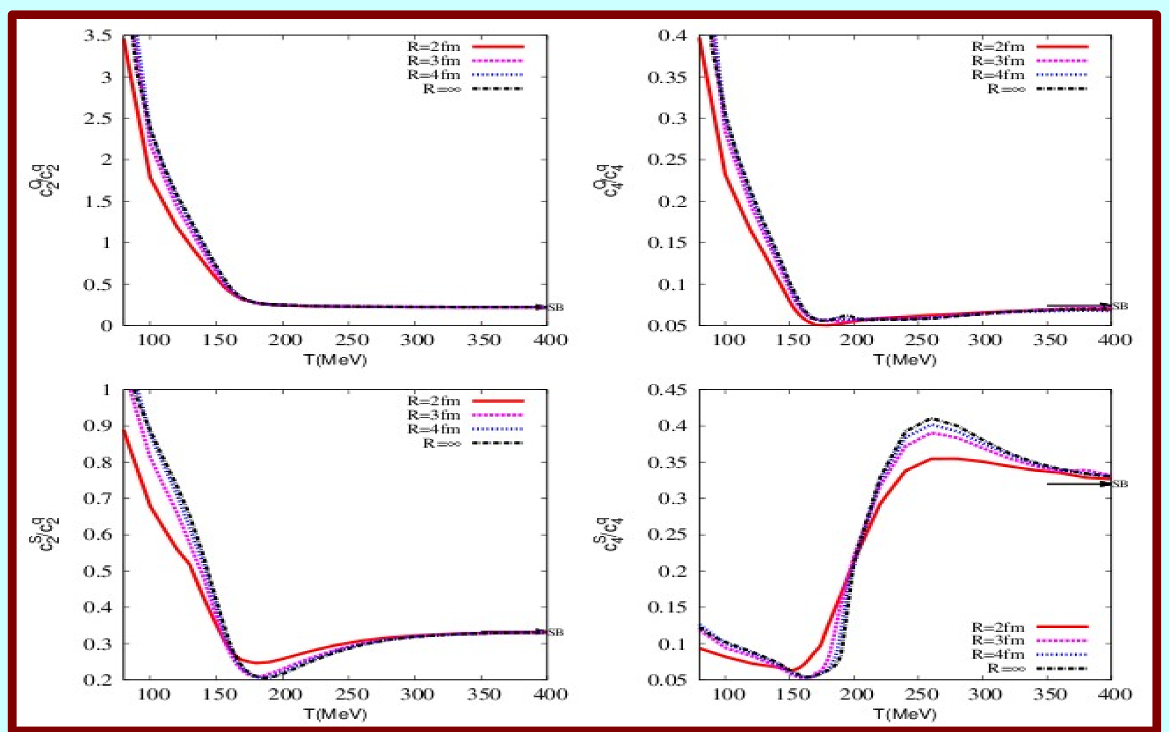
➔We find the susceptibilities themselves are volume dependent and the free energy need not be directly proportional to the volume. So a correlated measurement of the particle multiplicities and the various susceptibilities may provide suitable estimates of the finite sizes of the produced strongly interacting matter.

Correlations among different conserved charges ::

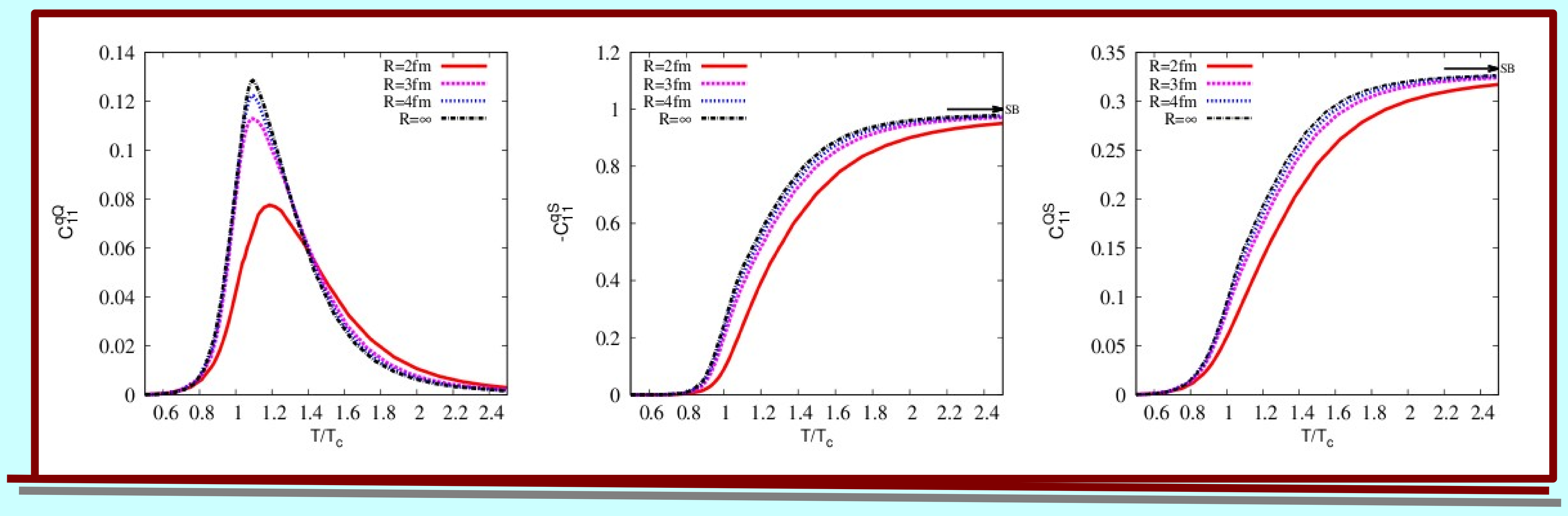
$$C_{i,j}^{X,Y} = \frac{1}{i!j!}\frac{\partial^{i+j}(-\Omega/T^4)}{(\partial(\frac{\mu_X}{T})^i)(\partial(\frac{\mu_Y}{T})^j)}$$

➔Correlations show similar volume dependences like fluctuations.

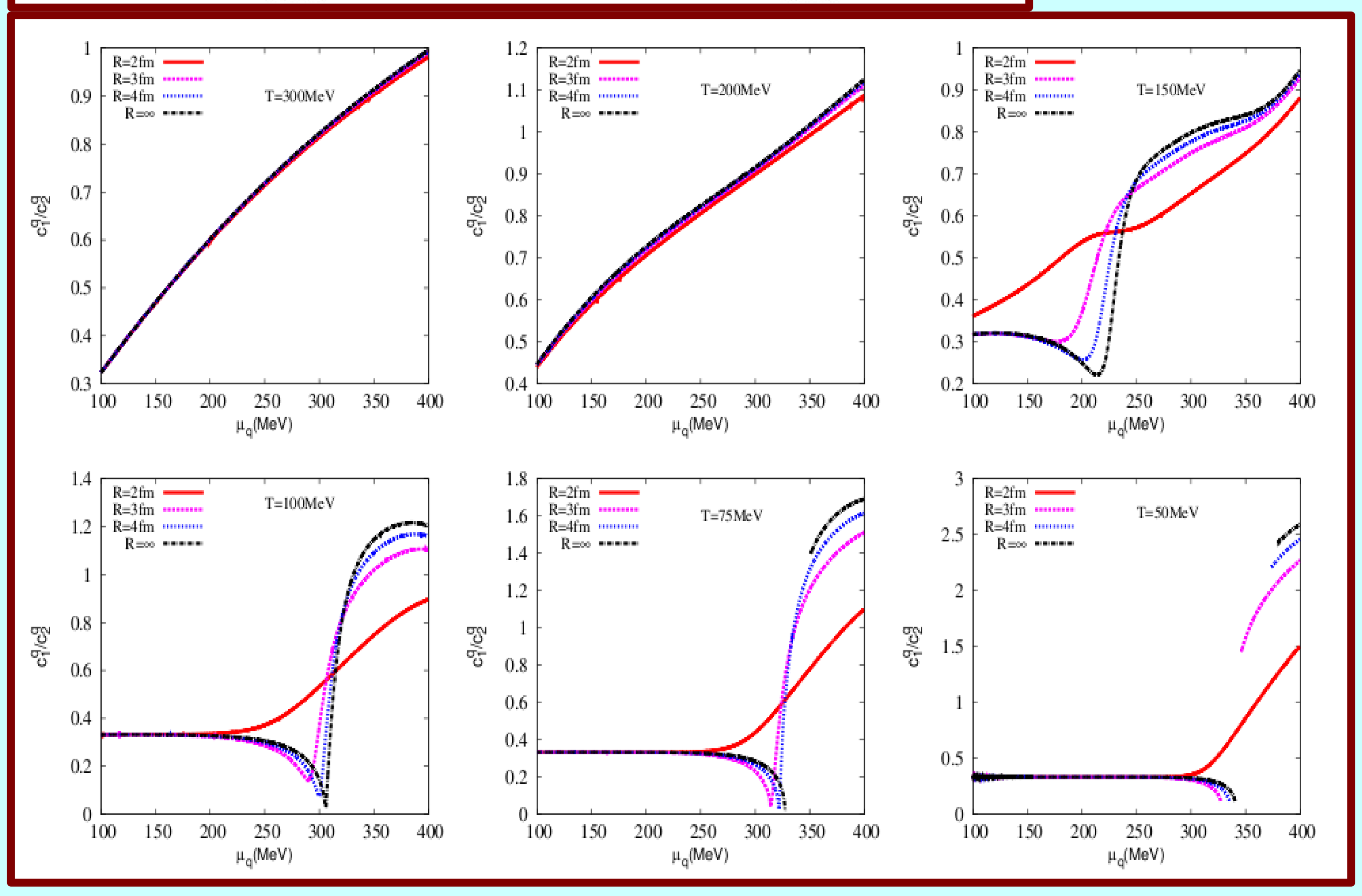
➔The volume scaling violation in correlation to fluctuation ratio happens to be very small.



➔From the ratios of similar order fluctuations, it seems that the large distance behavior of fluctuations change with the order of fluctuations.



➔ To study the scenario at non-zero chemical potential, we have considered net quark density c_1^q and quark number fluctuations c_2^q.



➔For high temperatures the ratio is monotonically increasing.

➔For T < 200 MeV , the dips and subsequent discontinuities eventually correspond to the phase boundary.

➔The violation of volume scaling if any, always occur close to the transition region, where large correlation lengths come into play and lead to the separate finite size behavior of the derivatives of the free energy.

CONCLUSIONS

•The free energy density is itself volume dependent within a certain range of T and μ_q , as given by the behavior of the susceptibilities.

•The ratio of these derivatives themselves show violation of volume scaling in a small window of T and μ_q all along the transition region in phase diagram. The upper limit of the lateral size with violation of volume scaling is found to be 5 fm.

[1] For all relevant references please allude to :: **arXiv:1507.08795**