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What are multiplicity distributions telling us on QCD phase diagram?

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We report a new way to extract the QCD phase transition from the net baryon multiplicity. The method provides us not only a freeze-out temperature-density point, but also the neighbour of the point. In other words, Beam Energy Scan explores not only points, but also regions with the finite spreads in μ-T plane, where μ is the chemical potential, and T is the temperature.

First, we develop a formula in which canonical partition functions are constructed from multiplicities data
for a conserved quantity. From the canonical partition functions, we construct the grand partition functions as a function of the fugacity, $\exp(\mu/T)$, from which we can investigate the system when it goes near to the QCD phase transition line. We discuss the applicability limit that comes from the maximum number of the multiplicity measured in experiments.

We extend the fugacity to the complex number region, and show the Lee-Yang zero structure, which allows us to see the statistical nature of the system.
We calculate the Lee-Yang zero structure by the lattice QCD simulations, and find a very striking feature, i.e., the Roberge-Weiss transition at the deconfinement regions.

We investigate the net-proton multiplicity data at RHIC, although it is not a conserved quantity. Using the proposed method, we calculate the susceptibility and kurtosis as a function of μ/T for each T, and the Lee-Yang zeros, and compare them with those of the lattice QCD results.

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