【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Search for a critical point and first order phase transition of high density quark-nuclear matter via higher order fluctuations and particle correlations

ESUMI, Shinichi
(University of Tsukuba, Faculty of Pure and Applied Sciences, Institute of Physics, Associate Professor)

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Keyword : critical point, 1st order phase transition, QCD phase structure, Quark Gluon Plasma

【Purpose and Background of the Research】

High-temperature and/or high-density state of matter in early universe or inside of neutron star is called as Quark Gluon Plasma (QGP) and is being formed and studied in high energy heavy ion collisions in order to reveal the QCD phase diagram of quark-nuclear matter that is governed by Quantum Chromo Dynamics (QCD). The phase transition at high-temperature region is considered as smooth cross-over transition as investigated at RHIC and LHC experiments, while the transition at the high-density region is supposed to be the 1st order that would have dis-continuous boundary between quark and hadron phases. In between these regions, we expect critical point at the end of the 1st order phase transition, however they are not yet experimentally observed. Finding the critical point and the 1st order phase transition is one of the ultimate goals of QGP physics to understand the QCD phase structure.

【Research Methods】

Going from the cross-over phase transition in the high-temperature region of QCD phase diagram towards the rich phase structures in the high-density region, we focus on the critical point and the 1st order phase transition in the high-density area of the phase diagram by scanning the beam energy of heavy-ion collisions around a few 10 GeV per nucleon-nucleon at the center of mass in order to search for a possible existence of the critical point and the 1st order phase transition. The higher order fluctuations of conserved quantities and the multi-particle correlations including directed anisotropic flows will be investigated as they are sensitive to a possible signal from the critical point and the 1st order phase transition.

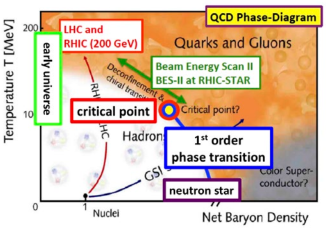

Figure 1: QCD phase diagram

【Expected Research Achievements and Scientific Significance】

The conserved number can also vary within a selected acceptance window, such number fluctuation could be used to measure the correlation length of the system and to search for the critical phenomena. Especially the higher order fluctuations are expected to be more sensitive to the critical point and the phase transition. Figure 2 (left) shows the net-proton 4th order fluctuation as a function of colliding beam energy, and an interesting non-monotonic behavior has been observed around 10-30GeV, which might be a possible indication of the critical point. In order to confirm the possible signature from the critical phenomena, we establish collaboration between experimental and theoretical groups with improved measurements and data analysis methods as well as model calculations. The expected improvement of detection sensitivity from the non-statistical fluctuation can be seen in Figure 2 (right) as a function of |Δη| acceptance.

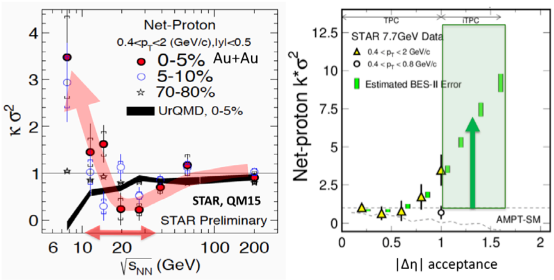

Figure 2: net-proton 4th order fluctuation as a function of energy (left) and expected Δη dependence (right)

【Publications Relevant to the Project】

- Energy dependence of moments of net-proton multiplicity distributions at RHIC, The STAR collaboration, L. Adamczyk, et al., Phys. Rev. Lett. 112 (2014) 32302
- A general procedure for detector–response correction of higher order cumulants, T.Nonaka, M.Kitazawa, S.Esumi, Nucl. Instr. Meth. A906 (2018) 10-17

【Term of Project】 FY2019-FY2023

【Budget Allocation】 79,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.star.bnl.gov
http://www.u.tsukuba.ac.jp/~esumi.shinichi.gn/welcome.html
esumi.shinichi.gn@u.tsukuba.ac.jp