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Baryon electric charge correlation as a magnetometer of QCD

We present the first lattice QCD results of quadratic fluctuations and correlations of conserved charges in (2+1)-flavor lattice QCD in the presence of a background magnetic field. The simulations were performed using the Highly Improved Staggered Quarks with physical pion mass m_π = 135 MeV on $N_\tau = 8$ and 12 lattices. We find that the correlation between net baryon number and electric charge, denoted as χ_{11}^{BQ}, can serve as a magnetometer of QCD. At pseudocritical temperatures the χ_{11}^{BQ} starts to increase rapidly with magnetic field strength $eB2M_\pi^2$ and by a factor 2 at $eB \simeq 8M_\pi^2$.

By comparing with the hadron resonance gas model, we find that the eB dependence of χ_{11}^{BQ} is mainly due to the doubly charged $\Delta(1232)$ baryon. Although the doubly charged $\Delta(1232)$ could not be detected experimentally, the proxy constructed from its decay products, protons and pions, retain the eB dependence of $\Delta(1232)$'s contribution to χ_{11}^{BQ}. Additionally, under the same kinematic cuts as in the ALICE experiment, the proxy for χ_{11}^{BQ} still exhibits a strong dependence on the magnetic field.

Furthermore, the ratio of electric charge chemical potential to baryon chemical potential, $\mu_{\mathrm{Q}}/\mu_{\mathrm{B}}$, shows significant dependence on the magnetic field strength and varies with the ratio of electric charge to baryon number in the colliding nuclei in heavy ion collisions. These results provide baselines for effective theory and model studies, and both χ_{11}^{BQ} and $\mu_{\mathrm{Q}}/\mu_{\mathrm{B}}$ could be useful probes for the detection of magnetic fields in relativistic heavy ion collision experiments as compared with corresponding results from the hadron resonance gas model.

Primary author(s) : GU, Jin-Biao (Central China Normal University); DING, Heng-Tong (Central China Normal University); KUMAR, Arpith (Central China Normal University); Dr LI, Sheng-Tai (Central China Normal University)

Presenter(s) : GU, Jin-Biao (Central China Normal University)