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Baryon electric charge correlation as a magnetometer of QCD

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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 $\chi_{11}^{\rm BQ}$, can serve as a magnetometer of QCD. At pseudocritical temperatures the $\chi_{11}^{\rm BQ}$ starts to increase rapidly with magnetic field strength eB
$gtrsim 2M_\pi^2$ 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 $\chi_{11}^{\rm BQ}$ is mainly due to the doubly charged $\Delta(1232)$ baryon. Although the doubly charged $\Delta(1232)$ could not be detected experimentally, its decay products, protons and pions, retain the eB dependence of $\Delta(1232)$'s contribution to $\chi_{11}^{\rm BQ}$. Furthermore, the ratio of electric charge chemical potential to baryon chemical potential, $\mu_{\rm Q}/\mu_{\rm B}$, 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 $\chi_{11}^{\rm BQ}$ and $\mu_{\rm Q}/\mu_{\rm B}$ 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.

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