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Monopoles, instantons, and eta-prime meson in external magnetic fields

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Magnetic monopoles are essential ingredients for explaining the color confinement mechanism, and instantons induce chiral symmetry breaking. The magnetic monopoles and instantons are closely tied to one another in the QCD vacuum. Furthermore, the eta-prime meson is closely related to the topology of the QCD vacuum. However, it is difficult to demonstrate the relations among them by perturbative calculations because of the strong interaction in the low-energy region of the QCD. Therefore, we perform simulations of lattice gauge theory and reveal the relations.

In this research, the Pisa group generates gauge field configurations with $N_f = 2 + 1$ dynamical fermions at the physical pion mass under the Pisa-Dubna collaboration. The standard configurations and the configurations to which uniform magnetic fields are applied are prepared at low and finite temperatures. The intensity of the uniform magnetic fields varies from $e|B| = 0.7$ to 1.1 [GeV^2]. We calculate the eigenvalues and eigenvectors of the overlap Dirac operator that holds the exact chiral symmetry using these configurations.

First, we compute the monopole density. Second, we compute the topological charges and the number of instantons and anti-instantons and compare the distributions of the eigenvalues of the overlap Dirac operator with the predictions of random matrix theory. Third, we estimate the eta-prime meson mass from the disconnected contribution of the quark bilinear operator for the pseudoscalar density. Finally, we demonstrate the impact of the external magnetic fields on the monopoles, instantons, spectrum of the overlap Dirac operator, and eta-prime meson mass.

In my talk, I will present the preliminary results obtained using the small lattice volumes.

Primary author: HASEGAWA, Masayasu (JINR, BLTP)

Presenter: HASEGAWA, Masayasu (JINR, BLTP)

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