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Chiral properties of (2+1)-flavor QCD in strong magnetic fields at zero temperature

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We have performed (2+1)-flavor QCD lattice simulations using the Highly Improved Staggered Quarks (HISQ) action on $N_\sigma = 32$ and $N_\tau = 96$ lattices. In our lattice simulations the strange quark mass is fixed to its physical quark mass $m_s^{\rm phy}$ and light quark mass is set to $m_s^{\rm phy}/10$ which corresponds to $M_\pi \approx 220$ MeV at zero temperature. We have studied the masses and magnetic polarizabilities of light and strange pseudo-scalar mesons, chiral condensates, decay constants of neutral pion and neutral kaon in the presence of background magnetic fields with eB ranging up to around 3.35 GeV^2 ($\sim 70\ M_\pi^2$) in the vacuum. We find that the masses of neutral pseudo-scalar mesons monotonously decrease and then saturate at a nonzero value as the magnetic field strength grows, while there exists a non-monotonous behavior of charged pion and kaon masses as magnetic field grows. We observe a qB scaling of the up and down quark flavor components of neutral pion mass, neutral pion decay constant as well as the quark chiral condensates in the magnetic field strength window (0.05GeV^2, 3.35 GeV^2). We show that the correction to the Gell-Mann-Oakes-Renner relation involving neutral pion is less than 6\%, and the correction for the relation involving neutral kaon is less than 30\% as eB up to 3.35 GeV^2. The validity of 2-flavor GMOR suggests that neutral pion is still the Goldstone boson, the mass reduction of neutral pion explains the reduction of the critical temperature of chiral symmetry breaking. And we further find that the reconciliation of magnetic catalysis and reduction of pion mass intrinsically lies in the Ward identity. This talk is based on Phys.Rev.D 104 (2021) 1, 014505.

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