MITP Mandelstam Institute for Theoretical Physics

NITheCS National Institute for Theoretical and Computational Sciences

INTERNATIONAL YEAR OF Quantum Science and Technology

S E M I N A R

QCD in strong magnetic fields: fluctuations of conserved charges and equation of state

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Dr Kumar is a postdoctoral fellow at CCNU. He received his PhD in 2023 from the Indian Institute of Science Education and Research in India. he is studying QCD thermodynamics in strong magnetic fields – relevant to the early universe, neutron-star interiors, and heavy-ion collisions – by exploring fluctuations of conserved charges and equation of state at nonzero baryon chemical potentials. He is also working on the applicability and reliability of complex Langevin dynamics to field-theoretic systems plagued by sign problem, relevant to lattice QCD studies at high baryon densities.

Date:
Tuesday, 21 October 2025

Time:
13h15-14h15 SAST

Venues:
- P213, Physics Building, East Campus, WITS
- Online

Who should attend?
All are welcome!

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ABSTRACT:
Strong magnetic fields – attaining magnitudes comparable to the characteristic interaction scales – can significantly affect the equilibrium properties and bulk thermodynamics of strongly interacting quantum chromodynamics (QCD) matter relevant to the early universe, neutron-star interiors, and heavy-ion collisions. In off-central heavy-ion collisions, a short-lived and strong magnetic field is expected to be generated; however, directly measuring their imprints, such as chiral magnetic effects, remains challenging.

In this talk, we propose baryon-electric charge conserved charges correlations $\chi^{\rm BQ}_{11}$ and the chemical potential ratio $\mu_{\rm Q}/\mu_{\rm B}$ as effective probes for magnetic fields in heavy-ion collisions [1, 2]. This is based on our (2+1)-flavor QCD lattice simulations at physical pion masses, focusing on the pseudocritical temperature regime. To bridge theoretical predictions with experiment, we construct proxy observables and implement systematic kinematic cuts within the hadron resonance gas (HRG) framework to emulate detector acceptances of the STAR and ALICE experiments.

Furthermore, extending this investigation, we discuss the QCD equation of state and examine the leading-order thermodynamic coefficients for strangeness-neutral scenarios up to $eB =\simeq 0.8 GeV^2 \sim 45 M_\pi^2$, revealing intriguing non-monotonic structures [3].

References:

1. Baryon Electric Charge Correlation as a Magnetometer of QCD, *Phys.Rev.Lett.* 132 (2024) 20, 201903
2. Second order fluctuations of conserved charges in external magnetic fields, *Phys.Rev.D* 111 (2025) 11, 114522
3. Leading-Order QCD Equation of State in Strong Magnetic Fields at Nonzero Baryon Chemical Potential, arXiv:2508.07532 [hep-lat], accepted, to soon appear in *Phys.Rev.D*.

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