CRITICAL PHENOMENA SUMMARY

Fabian Rennecke, Laurin Pannullo, Sipaz Sharma

CRC Retreat 2024,
K6 Seminarhotel Halberstadt

CRC-TR 211
Strong-interaction matter under extreme conditions

Relevant directions of QCD

- Information comes from the universality class.
- $O(4)$ has two relevant directions. Any stable fixed point with more than two relevant directions is unstable.
- A fixed point with three relevant directions allows system to fluctuate. WFF becomes unstable and flows towards strong scaling fixed point. How is this related to static $O(4)$?

Universality classes of chiral phase transitions

- Universality class of (2+1)-flavor theory $3d$-$O(4)$?
- Universality class of 3-flavor theory?
- Likely stable fixed points for $SU(N_f)_L \times SU(N_f)_R \times U_A(1)$, for $N_f = 2, 3$
- Likely no stable fixed point for $SU(3)_L \times SU(3)_R$. It should be possible to do a lattice Monte-Carlo calculation.

Status of $U_A(1)$

- Two point functions can provide information about $U_A(1)$ breaking in the chiral limit of (2+1)-flavor theory at T_c.
- Calculation of three point functions in 3-flavor theory?
- Remark 1: In the chiral limit, topological susceptibility goes to zero, and correlators becomes insensitive to $U_A(1)$ breaking. This should lead to an effective restoration of $U_A(1)$.
  Remark 2: In the chiral limit, it should be possible to connect different topological sectors, and construct observables sensitive to $U_A(1)$. How to do this on lattice?
- What about $N_f = 1$ case? If $U_A(1)$ remains broken, one should see a sharp crossover. However, if all anomalous couplings vanish at T_c, one could see an emergent $U_A(1)$ symmetry at T_c.

Yang-Lee edge singularities

- YLE singularities as a probe to locate CEP. There are a few practical challenges:
- YLE could be really close to the real axis but might not touch it – high precision is required.
- At high T, disentangling CEP scaling from Roberge-Weiss scaling.
- Are there any other techniques to construct zeroes of partition function other than Pade (or Multi-Pade)?
- Current ansatz assumes there is a CEP.
- Lattice data can benefit from information about non-universal aspects such as knowing the scaling window. This could help in determing the sensitivity of CEP to subleading corrections. Could classical statistical simulations help with this issue?
- Possibility of obtaining information about the first-order transition line?

Criticality and Experiments

- χ_4/χ_2 is a widely accepted probe for CEP. It is based on net-baryon fluctuations instead of net-proton – which experiments measure.
- Corrections at low energies due to particle conservation are known.
- Non-monotonicity is sufficient but maybe not be a necessary condition for the existence of CEP.
- Kibble-Zurek mechanism: third scaling direction. How to control this direction? Locally changing μ? Volume quenching? Boundary conditions become important. Domain size related to how fast the system quenches. Already some study with expanding statistical mechanical system.

Scaling Window

- fRG : $m_\pi \approx 5$ MeV; lattice: some studies see it beyond physical m_π.
- Need a definition for scaling window based on percentage of contribution from regular terms.
- Effective potential has a sixth order term. Could this be an unlucky coincidence? Precise determination of critical exponents from lattice data is mandatory to settle this.
- Physical implication of scaling window? Enhancement of pion yields at low momenta?

Neutron stars

- Pick an EOS which favors CEP. Sort of reverse engineering?
- Possible to determine the existence of transition but not the order?
- During merger, which phases could the system evolve through?

Unconventional scenarios

- If CEP is in a moat, modified dispersion relation and the universality class.
- Alternative investigation strategies are needed.
- Two particle correlations could be an observable.
- Dileptons could also be a probe.