Electric field fluctuations in a self interacting scalar theory

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Motivation

- Our task is to study the impact and effects of electromagnetic (EM) fields and temperature in hadronic matter.

- Particularly, in this project, we study the effects of a weak, noisy electric field on the physical parameters of complex scalar fields ($\lambda\phi^4$ theory).

- We want to compare the effects of the self interaction with the effects of electric field fluctuations on the system, through the RGE for couplings (here are the non perturbative aspects!).

Physical scenario

- In **asymmetric heavy-ion collisions** (nuclei with different sizes) a dipole-like electric field is induced on the collision plane.
- These electric fields are very strong ($\sim 10 m_\pi^2$) with a short life time ($\sim 10^{-15}$)[1][2][3].

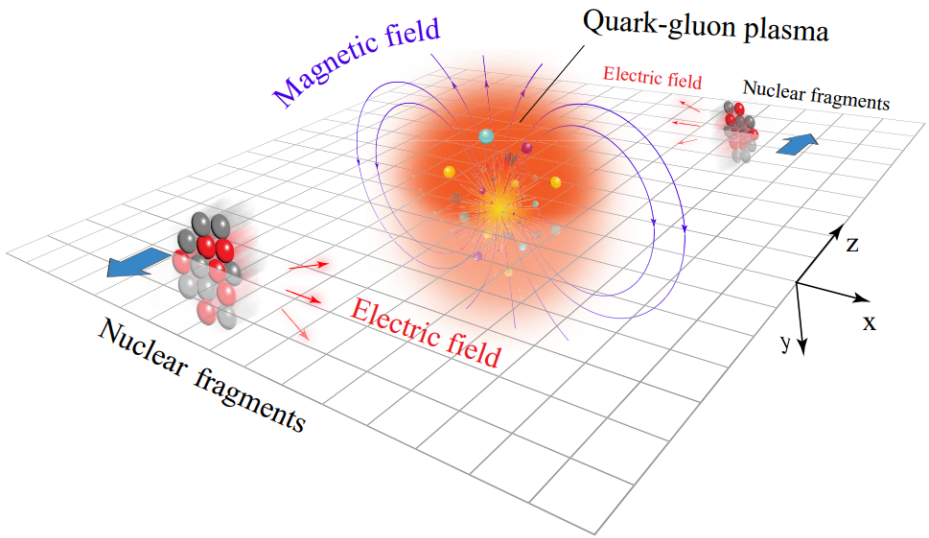

Fig. 1: Sketch of a heavy-ion collision at the lab frame (STAR collaboration, 2024).

[1] Wei-Tian Deng and Xu-Guang Huang. "Electric fields and chiral magnetic effect in Cu + Au collisions". In: *Physics Letters B* 742 (2015)

[2] V. Toneev, O. Rogachevsky, and V. Voronyuk. "Evidence for creation of strong electromagnetic fields in relativistic heavy-ion collisions". In: *The European Physical Journal A* 52.8 (Aug. 2016)

[3] V. V. Skokov, A. Yu. Illarionov, and V. D. Toneev. "Estimate of the magnetic field strength in heavy-ion collisions". In: *International Journal of Modern Physics A* 31 (2009)

The model

- We use Schwinger's propagator[4] as the background propagator (as the "free" propagator in perturbation theory).
- We introduce the fluctuations through the covariant derivative, modeled as white noise, following a Gaussian distribution[5].
- We use the replica method[6] to find $\overline{\ln(Z)}$.

[4] Julian Schwinger. "On gauge invariance and vacuum polarization". In: *Physical Review* 82.5 (1951), p. 664

[5] Jorge David Castaño-Yepes et al. "QED fermions in a noisy magnetic field background". In: *Physical Review D* 107.9 (May 2023). DOI: 10.1103/physrevd.107.096014

[6] Marc Mézard et al. *Spin Glass Theory and Beyond*. 1987

Calculations

- We find the two point (self energy) and four point functions (vertex correction), dressed by the noisy electric field.
- We study the spectral density of the dressed propagator.
- We study the β functions of the couplings.

Results

From the two point function

- We found that the self interaction shifts the pole mass of the field.
- We found that quasi-particle states emerge from the electric field fluctuations.

From the four point function

- We found that the noise works as a damping factor for the self interaction strength.

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