HK 32: Heavy-Ion Collisions and QCD Phases V

Time: Thursday 13:45–15:45 Location: PHIL C 601

Group Report HK 32.1 Thu 13:45 PHIL C 601

Investigating the properties of (anti-)hypernuclei with the ALICE detector at the LHC — •Carolina Jauch for the ALICE Germany-Collaboration — Universität Heidelberg

Among the thousands of particles produced in high energy heavy-ion collisions at the LHC, light (anti-)hypernuclei are of particular interest. Studying their internal structure provides a unique opportunity to probe the strong interaction between hyperons and nucleons. The lightest known (anti-)hypernucleus, the (anti-)hypertriton, is a bound state of a proton, a neutron, and a Λ hyperon. Several groundbreaking results on its production and properties were reported by ALICE in recent years. The upgraded ALICE detector and the large data sample collected during the ongoing LHC Run 3 enable more precise measurements and the study of rare observables.

This contribution presents the latest ALICE results on (anti-)hypernuclei and outlines prospects for future investigations. In particular, the first measurement of the anti-hypertriton transverse momentum spectrum in pp collisions allows to test different assumptions on its wavefunction. Moreover, the first reconstruction of the (anti-)hypertriton three-body decay in ALICE pp collisions and the measurement of its relative branching ratio, R_3, offer insight into its internal structure. The precision of the recently published measurement of heavier (anti-)hypernuclei, the hyperhydrogen-4 and hyperhelium-4, including the very first observation of the antihyperhelium-4, can be improved using the Run 3 heavy-ion data sample, and a more detailed study of their properties will be feasible.

HK 32.2 Thu 14:15 PHIL C 601

Sexaquark Search in ALICE — •Andrés Bórquez for the ALICE Germany-Collaboration — Heidelberg University

In 2017, G. Farrar proposed the sexaquark, a hypothetical six-quark state with the quark content *uuddss*. This particle is characterized by being neutral, compactly bound, and cosmologically stable within certain mass limits. These unique properties make it a compelling dark matter candidate.

Despite its elusive nature, several experimental collaborations have searched for evidence of its existence. This contribution presents an update on the ongoing search for the sexaquark within the ALICE experiment at the LHC. The strategy focuses on identifying displaced strangeness production caused by the annihilation of anti-sexaquarks with detector material following their potential production in Pb-Pb collisions during LHC Run 2.

HK 32.3 Thu 14:30 PHIL C 601

Measurement of higher-order net-proton fluctuations with ALICE — •Ilya Fokin for the ALICE Germany-Collaboration — Physikalisches Institut, Universität Heidelberg

Fluctuations of conserved charges, such as the baryon number, are a unique tool to study the phase diagram of strongly interacting matter. Cumulants of distributions of conserved charges in heavy-ion collisions can be related to the equation of state in lattice QCD (LQCD) and thus make the calculations from first principle accessible in the experiment. Starting from the fourth-order, these calculations predict a significant difference between the baryon number susceptibilities using the full QCD partition function on the lattice and a hadron resonance gas model.

For a quantitative comparison, correlations from local baryon number conservations must be considered in the theoretical baseline and additional contributions from volume fluctuations must be quantified.

In this contribution, measurements of the higher-order cumulants of the net-proton number up to fourth order in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with the ALICE detector at the LHC are presented as a function of the pseudorapidity acceptance and centrality.

HK 32.4 Thu 14:45 PHIL C 601

Universal scaling of transport coefficients near the QCD critical point — •Johannes Roth[1], Yunxin Ye[2], Sören Schlichting[3], and Lorenz von Smekal[1,4] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Giessen, Germany — [2]Theoretisch-Physikalisches Institut, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — [3]Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld, Germany — [4]Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen

Near a critical point, including the one conjectured in the QCD phase diagram at finite baryon chemical potential, the slow dynamics of long-wavelength modes is expected to become universal. I will review the argument for the associated dynamic universality class being that of Model H in the Halperin-Hohenberg classification, i.e., that of a liquid-gas critical point. Based on a novel real-time formulation of the functional renormalization group, I will present results for universal scaling functions of the thermal diffusivity and the shear viscosity, and discuss their relevance in the ongoing search for the QCD critical point.

HK 32.5 Thu 15:00 PHIL C 601

Out-of-equilibrium scaling in driven first-order phase transitions — •Leon Sieke[1], Jessica Fuchs[1], and Lorenz von Smekal[1,2] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Gießen, Germany — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), Campus Gießen, 35392 Gießen, Germany

First-order and critical phase transitions behave qualitatively different under nearly adiabatic conditions. The former proceed through nucleation and growth, and are accompanied by metastability and hysteresis, while the latter feature diverging correlations and universal scaling. When transitions occur in finite time, non-equilibrium effects gain relevance, and this sharp distinction becomes blurred.

We investigate the real-time dynamics of a Z_2-symmetric scalar field theory in the dynamic universality class of Model A in driven phase transitions across the first-order line using classical-statistical lattice simulations. We find that universal non-equilibrium scaling can emerge even in the first-order region, provided the driving is fast enough to avoid nucleation but slow enough for correlations to form. The resulting scaling behavior is analogous to the Kibble-Zurek mechanism and we compute the associated universal scaling functions for the order parameter.

Our results clarify how universal behavior can arise in driven first-order phase transitions and delineate the conditions under which nucleation, scaling, or trivial mean-field behavior dominate.

HK 32.6 Thu 15:15 PHIL C 601

Critical Behavior of $O(N)$ Model G in the large-N Limit — •Jonas Hirsch[1], Johannes V. Roth[1], and Lorenz von Smekal[1,2] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen, 35392 Giessen, Germany

The chiral phase transition of QCD in the limit of two massless quark flavors is widely believed to be of second order in the $O(4)$ universality class. Since the work of Rajagopal and Wilczek, its dynamic universality class is then expected to be an $O(4)$ extension of the original Model G by Halperin and Hohenberg. The characteristic feature of this dynamic model is the reversible mode coupling between the conserved iso-(axial-)vector charges and the chiral condensate as the order parameter field which all relax at equal rates due to *strong dynamic scaling* [1]. In this talk, we will consider Model G with a generalized N-component order parameter, for which we perform the limit $N \to \infty$. We show exact results for the universal spectral function in the symmetric phase by using large-N counting rules for Dyson-Schwinger equations. Furthermore, we discuss an extension to the broken phase and a nonzero external source, which corresponds to a non-vanishing quark mass. Lastly, we investigate the loss of the strong-scaling fixed point, and how it could be recovered by NLO correction.

[1] J.V. Roth, Y. Ye, S. Schlichting, L. von Smekal, *Dynamic critical behavior of the chiral phase transition from the real-time functional renormalization group*, JHEP, vol. 01, 2025, p. 118

HK 32.7 Thu 15:30 PHIL C 601

Critical dynamics with the analytically continued functional renormalization group — •Patrick Niekamp[1], Johannes Roth[1], and Lorenz Von Smekal[1,2] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität, 35392 Giessen, Germany — [2]Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Giessen, 35392 Giessen, Germany

Euclidean approaches such as the functional renormalization group

(FRG) have been abundantly and successfully used to study the universal static critical behavior of various physical systems near continuous phase transitions. For the study of critical dynamics, on the other hand, one usually relies on real-time methods. Our research aims to connect and relate the two approaches by comparing analytically continued (aFRG) and real-time FRG on the closed time path. In particular, we investigate the dynamic critical behavior of a dissipative open quantum system near equilibrium in the spirit of the Caldeira-Leggett model with the aFRG and compare that with real-time results for the dynamic universality class of the corresponding Model A (according to the classification by Halperin and Hohenberg). The long-term goal of this project is to understand the merits and limitations of studying more complicated critical dynamics, including conservation laws and reversible mode couplings as relevant for QCD, with analytically continued Euclidean versus real-time approaches.