The 21st International Conference on QCD in Extreme Conditions

Report of Contributions

https://indico.cern.ch/e/xqcd2025

Contribution ID: **1** Type: **Talk**

Universal Real-Time Dynamics in Diffusive Systems

Friday 4 July 2025 17:10 (20 minutes)

The search for the QCD critical point in heavy-ion collisions requires the inclusion of fluctuations in hydrodynamic simulations of Quark-Gluon Plasma (QGP). Schwinger-Keldysh Effective Field Theory (SK-EFT) systematically incorporates these fluctuations, extending beyond classical hydrodynamics, which accounts only for dissipation. After a brief review of SK-EFT, we discuss how linear response results obtained from experimental data can be incorporated into this framework to predict nonlinear response in diffusive systems. This is closely related to the emergence of a universal scaling function in the structure of real-time correlation functions. Furthermore, we argue that this universality persists even in a causal diffusive system. Finally, we comment on the relevance of these results to QGP dynamics near the QCD critical point.

Author: ABBASI, Navid

Presenter: ABBASI, Navid

Track Classification: Fluid dynamics and collectivity

Contribution ID: **2** Type: **Poster**

Heavy Quark Polarization in a QCD Plasma

Thursday 3 July 2025 19:40 (20 minutes)

We investigate the rotational Brownian motion of heavy quarks in a QCD medium and present predictions for the polarization of open heavy-flavor hadrons. Specifically, we derive expressions for vector and tensor polarization, which correspond to baryon spin polarization and meson spin alignment, respectively. Furthermore, we suggest that the transverse momentum dependence of heavy quark polarization could serve as a unique indicator of the strong initial magnetic field produced in off-central relativistic heavy-ion collisions.

Authors: Dr JAISWAL, Amaresh (National Institute of Science Education and Research); DEY, Sourav (National Institute of Science Education and Research(INDIA))

Presenter: Dr JAISWAL, Amaresh (National Institute of Science Education and Research)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **3** Type: **Poster**

On the local thermodynamic relations in relativistic spin hydrodynamics

Thursday 3 July 2025 19:40 (20 minutes)

In this talk, I will present our latest research building upon the findings of PLB 850 (2024) 138533, which demonstrated that the entropy current can be derived from first principles using the quantum statistical method, bypassing the need for assumed traditional local thermodynamic forms. Our study uncovers that the local thermodynamic relations, which have been conventionally used as educated guesses in relativistic hydrodynamics with spin based on global thermodynamic equilibrium, are generally inadequate. We will present two specific examples to illustrate this: a system of massless and massive free fermions under rotation and acceleration at global thermodynamic equilibrium. Our findings reveal that the traditional local thermodynamic relations are incomplete when the spin tensor is considered. Notably, we show that the derivative of the pressure function with respect to the spin potential deviates from the spin density, acquiring corrections due to acceleration and rotation. These results suggest that for an accurate derivation of constitutive relations in relativistic spin hydrodynamics, the traditional thermodynamic relations must be extended.

Authors: BECATTINI, Francesco; Dr SINGH, Rajeev (West University of Timisoara, Romania)

Presenter: Dr SINGH, Rajeev (West University of Timisoara, Romania)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **4** Type: **Talk**

Guiding center hydrodynamics with spin

Friday 4 July 2025 16:30 (20 minutes)

We build upon the recently formulated guiding-center kinetic theory for guiding-center plasma by incorporating spin degrees of freedom in the presence of electromagnetic fields. This approach yields a streamlined set of equations for guiding-center ideal hydrodynamics with spin–fewer than those in traditional spin hydrodynamics–owing to a restriction on motion perpendicular to the magnetic field. We propose that this framework offers a promising tool to comprehending how matter behaves under the influence of intense magnetic fields, such as spin polarization effects observed in experimental measurements.

Author: Dr SINGH, Rajeev (West University of Timisoara, Romania)

Presenter: Dr SINGH, Rajeev (West University of Timisoara, Romania)

Track Classification: Dense QCD

Contribution ID: **5** Type: **Talk**

The finite-temperature QCD static potential: a higher order calculation

Wednesday 2 July 2025 12:20 (20 minutes)

We calculate the leading and subleading corrections to the real-time static potential in a high-temperature quark-gluon plasma for distances smaller than the screening length. The calculation involves one-loop 2- and 4- point functions in the hard-thermal-loop effective theory. We use our results to estimate the binding energy, the decay width, and the dissociation temperature of the bottomonium ground state. We compare with recent lattice results in the literature.

Author: CARRINGTON, ME (Brandon University)

Presenter: CARRINGTON, ME (Brandon University)

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **7** Type: **Talk**

Welcome by the Rector of the University of Wroclaw, Prof. Robert Olkiewicz & Opening

Wednesday 2 July 2025 08:50 (15 minutes)

Contribution ID: **11** Type: **Poster**

Non-perturbative behavior of thermal QCD up to the electroweak scale: computational strategy and screening masses

Thursday 3 July 2025 19:40 (20 minutes)

The predictions of QCD at temperatures ranging from 1 GeV up to 160 GeV have recently become accessible from first-principles, non-perturbative lattice simulations owing to a novel computational strategy. Among the quantities that are being investigated in the ongoing program, hadronic screening masses - i.e. inverse correlation lengths - offer crucial insight into the properties of the QCD medium at extreme temperatures. Physically, they characterise the length scales over which strong interactions are screened in the plasma and the response of the medium when a given hadron is placed in it. On the theory side, these can be computed also as a weak-coupling series in the three-dimensional EFT describing high temperature QCD.
After reviewing the strategy to simulate lattice QCD at temperatures up to 160 GeV, in this talk I will report on recent and ongoing lattice determinations of hadronic screening masses - including for the first time those of non-static mesonic fields - and their comparison with the complementary perturbative computations, highlighting clear signs of significant non-perturbative contributions to these quantities persisting even at such high temperatures.

Author: RESCIGNO, Pietro (University of Milano-Bicocca, INFN Milano-Bicocca)

Co-authors: LAUDICINA, Davide (Ruhr Universitaet Bochum); GIUSTI, Leonardo (University of Milano-Bicocca, INFN Milano-Bicocca); CÈ, Marco (University of Milano-Bicocca, INFN Milano-Bicocca); PEPE, Michele (INFN Milano-Bicocca)

Presenter: RESCIGNO, Pietro (University of Milano-Bicocca, INFN Milano-Bicocca)

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **12** Type: **Talk**

Equation of State of QCD with $N_f = 3$ flavours up to the electroweak scale

Friday 4 July 2025 12:00 (20 minutes)

The Equation of State of Quantum Chromodynamics with $N_f = 3$ flavours is determined non-perturbatively with a precision of about 0.5%-1.0% in the range of temperatures between 3 GeV and 165 GeV. The computation is carried out by means of numerical simulations of the gauge theory discretized on the lattice. At each given temperature the entropy density is computed at several lattice spacings in order to extrapolate the results to the continuum limit. The pressure and energy density are then determined by integrating the entropy density with respect to the temperature. The numerical data show a linear behaviour in the strong coupling constant squared, which points to the Stefan-Boltzmann limit at infinite temperature. They are also compatible with the known perturbative formula supplemented by higher order terms in the coupling constant, containing non-perturbative contributions. This parametrization describes well our data together with those present in the literature down to 500 MeV.

Authors: GIUSTI, Leonardo (University of Milano-Bicocca, INFN Milano-Bicocca); BRESCIANI, Matteo; DALLABRIDA, Mattia; Dr PEPE, Michele (INFN - National Institute for Nuclear Physics)

Presenter: BRESCIANI, Matteo

Track Classification: Lattice QCD

Contribution ID: **13** Type: **Talk**

Equation of state of finite-density 2color QCD at lower temperature from lattice simulations

Friday 4 July 2025 11:00 (20 minutes)

We investigate the equation of state (EoS) of two-color QCD at low temperature and high density using lattice Monte Carlo simulations. Our results show that the speed of sound exceeds the relativistic limit (cˆ2_s/cˆ2= 1/3) after the BEC–BCS crossover in the superfluid phase. We also discuss the temperature dependence of the EoS within the superfluid phase. This talk is based on arXiv:2207.01253, 2405.20566, and work in progress.

Author: ITOU, Etsuko

Presenter: ITOU, Etsuko

Track Classification: Lattice QCD

Contribution ID: **14** Type: **Poster**

Transport coefficients of anisotropic quark matter

Thursday 3 July 2025 19:00 (20 minutes)

We investigate the transport properties of quark matter under conditions of momentum anisotropy using the Polyakov chiral quark mean-field (PCQMF) model. Momentum anisotropy naturally arises in systems out of equilibrium, such as the early stages of relativistic heavy-ion collisions or the interior of compact stars. Understanding the impact of such anisotropy on transport coefficients is essential for accurately describing the evolution of these systems. We focus on calculating the shear and bulk viscosities, which are crucial for characterizing the dissipative dynamics of the medium. The PCQMF model, incorporating features of chiral symmetry breaking, confinement, and the Polyakov loop, is employed to evaluate these viscous coefficients at finite temperature and chemical potential.

Authors: KUMAR, Arvind (Dr B R Ambedkar National Institute of Technology Jalandhar India); Mr SINGH, Dhananjay (National Institute of Technology Jalandhar)

Presenter: Mr SINGH, Dhananjay (National Institute of Technology Jalandhar)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **15** Type: **Poster**

Λ transverse polarization in p+p interactions within NA61/SHINE at the CERN SPS

Thursday 3 July 2025 18:00 (20 minutes)

The observation of significant Λ hyperon transverse polarization, i.e. the polarization in the direction transverse to the Λ production plane, in inclusive p+p and p+A collisions using unpolarized beams triggered theoretical efforts to describe this effect. Numerous models have been proposed to explain the origin of hyperon polarization. Several models have successfully explained the behavior of some hyperons, but none have been able to account for the behavior of the entire hyperon family.
NA61/SHINE is a fixed-target experiment with large acceptance and high particle identification capabilities at the CERN SPS. The first feasibility studies have shown that the properties of the magnetic field used by NA61/SHINE, together with high statistics of collected p+p collisions at beam momentum 158 GeV/c, offer possibilities to study Λ polarization in several bins of p_{T} and x_{F}. This work will contain a description of the methodology of our studies and will present preliminary results on Λ transverse polarization in Feynman-x $x_{\mathrm{F}} \in$ (-0.3,0.2) and $p_{\mathrm{T}} \in$ (0.2,1.2) GeV/c compared with results from other experiments and predictions of DeGrand - Miettinen model.

Author: BONDAR, Yehor (Jan Kochanowski University (PL))

Presenter: BONDAR, Yehor (Jan Kochanowski University (PL))

Session Classification: Poster Session

Track Classification: Other

Contribution ID: **18** Type: **Talk**

Topological observables and θ dependence in high temperature QCD from lattice simulations

Friday 4 July 2025 11:40 (20 minutes)

We discuss topology in Quantum Chromodynamics at high temperatures T
$gtrsim$ 180 MeV obtained from lattice simulations. Our setup consists of $N_f = 2 + 1 + 1$ Wilson twisted mass fermions with physical quark masses and results are extrapolated to the continuum limit. We compare the results for the topological susceptibility obtained with the field-theoretic definition with those obtained from an observable constructed with the disconnected part of the chiral susceptibility, and we confirm their agreement on our range of temperatures. We also study the topological charge distribution, the next order cumulant b_2 and, for the first time, the Free Energy as a function of the θ angle.
We find a rapid crossover to the Dilute Instanton Gas behaviour above $T \simeq 300$ MeV for all the observables we have considered.

Authors: KOTOV, Andrey; TRUNIN, Anton; LOMBARDO, Maria Paola (INFN)

Presenter: KOTOV, Andrey

Track Classification: Lattice QCD

Contribution ID: **19** Type: **Talk**

Exploring Color-Superconducting Phases in Hybrid Star Models Using an RG-Consistent NJL Approach

Thursday 3 July 2025 11:20 (20 minutes)

We present a comprehensive investigation of color-superconducting phases in compact stars using the renormalization group-consistent Nambu–Jona-Lasinio (RG-NJL) model [1]. By systematically varying vector and diquark coupling constants, we analyze their effects on the equation of state, speed of sound, and resulting mass-radius relations. Our models demonstrate that stable color-flavor-locked (CFL) phases can exist in maximum-mass star configurations, typically extending several kilometers in radius. At neutron-star densities, we observe the speed of sound squared reaching values up to $c_s^2 \approx 0.6$ and CFL gaps up to $\Delta \approx 250$ MeV [2]. The parameter constraints are derived from the $2.0\,M_\odot$ observational limit. We further explore the viability of hybrid-star configurations by combining our quark-matter model with a hadronic equation of state through Maxwell construction. Our results indicate several possible compositional scenarios for hybrid stars that remain consistent with current astrophysical constraints while demonstrating that early hadron-quark transitions can significantly affect tidal deformability measurements at $1.4\,M_\odot$ [3].

References

[1] H. Gholami, M. Hofmann, and M. Buballa, Phys. Rev. D 111, 014006 (2025).
[2] H. Gholami, I. A. Rather, M. Hofmann, M. Buballa, and J. Schaffner-Bielich, (2024), arXiv:2411.04064 [hep-ph].
[3] J. E. Christian, I. A. Rather, H. Gholami, & M. Hofmann, (2025), arXiv:2503.13626 [astro-ph.HE]

Author: Dr RATHER, Ishfaq Ahmad (Institute for Theoretical Physics, Goethe University, 60438 Frankfurt am Main, Germany)

Co-authors: GHOLAMI, Hosein (TU Darmstadt); HOFMANN, Marco; CHRISTIAN, Jan-Erik (Goethe Uni Frankfurt); BUBALLA, Michael (TU Darmstadt); SCHAFFNER-BIELICH, Juergen

Presenter: Dr RATHER, Ishfaq Ahmad (Institute for Theoretical Physics, Goethe University, 60438 Frankfurt am Main, Germany)

Track Classification: Nuclear astrophysics

Contribution ID: **20** Type: **Poster**

Transport properties of the strongly interacting quark-gluon plasma

Thursday 3 July 2025 18:40 (20 minutes)

An understanding of the properties of the quark-gluon plasma (QGP) is important for the interpretation of experimental data on the bulk observables, as well as on jet and heavy-quark attenuation in heavy-ion collisions. However, gaining this knowledge is a challenging task, since it pertains to the non-perturbative regime of QCD, for which only limited information from lattice QCD is currently available.

To overcome these difficulties, we employ the dynamical quasi-particle model (DQPM), which describes the non-perturbative nature of the strongly-interacting QGP at finite temperature and baryon chemical potential based on a propagator representation of massive off-shell quarks and gluons, the properties of which are adjusted to reproduce the lattice QCD equation of state for the QGP in thermodynamic equilibrium. From the DQPM propagators, we can explicitly derive the scattering amplitudes for both elastic ($2 \to 2$) and inelastic ($2 \to 3$) interactions (without resorting to additional approximations), allowing us to investigate not only the properties of the thermalized medium itself, but also jet and heavy-quark energy loss.

In this work, we present several key findings. First, we show how total elastic and radiative cross sections vary with energy and temperature, highlighting the dominance of elastic scattering at low energies and high temperatures, while radiative processes become increasingly relevant at high energies and low temperatures. Second, we obtain the interaction rate and relaxation time in the QGP and show that their values are primarily governed by elastic scatterings. Third, we evaluate the jet transport coefficient $\hat{q}$ and reveal its strong dependencies on the medium temperature, jet momentum and the choice of the strong coupling in thermal, jet-parton, and radiative vertices. We also examine the ratio of $\hat{q}$ to shear viscosity η, identifying regimes in which the commonly used scaling $\eta/s \approx 1.25T^3/\hat{q}$ either holds or is violated. Finally, we obtain the heavy-quark diffusion coefficient and explore its temperature and mass dependencies.

References:
1. I. Grishmanovskii et al, Phys.Rev.C 106, 014903
2. I. Grishmanovskii et al, Phys.Rev.C 109, 024911
3. I. Grishmanovskii et al, Phys.Rev.C 110, 014908
4. I. Grishmanovskii et al, arXiv:2503.22311

Authors: GRISHMANOVSKII, Ilia (ITP, Frankfurt); SONG, Taesoo; GREINER, Carsten (University of Frankfurt); BRATKOVSKAYA, Elena

Presenter: GRISHMANOVSKII, Ilia (ITP, Frankfurt)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **22** Type: **Talk**

Temperature and Magnetic Field effects on Isospin equilibration via Urca processes in Neutron Star Mergers.

Thursday 3 July 2025 10:05 (20 minutes)

Isospin-equilibrating weak processes, called "Urca" processes, are of fundamental importance in astrophysical environments like proto-neutron stars, neutron star mergers, and supernovae. In these environments, matter can reach high temperatures of tens of MeVs and be subject to large magnetic fields. We thus investigate Urca processes at different temperatures and field strengths by performing the full temperature and magnetic-field dependent integrals of rates of Urca processes for different equations of state. I will present the finite temperature and magnetic field effects on the Isospin equilibrium condition. We find that the magnetic fields play an important role at temperatures of a few MeV, especially close to or below the direct Urca threshold, which is softened by the magnetic field. At higher temperatures, the effect of the magnetic fields can be overshadowed by the thermal effects. We observe that the magnetic field more strongly influences the neutron decay rates than the electron capture rates near the direct-Urca threshold density, leading to a shift in the isospin equilibrium condition.

Author: TAMBE, Pranjal (Inter-University Centre for Astronomy and Astrophysics)

Co-authors: Prof. CHATTERJEE, Debarati (Inter-University Centre for Astronomy and Astrophysics); Prof. ALFORD, Mark (Washington University, St Louis); Dr HABER, Alexander (University of Southampton)

Presenter: TAMBE, Pranjal (Inter-University Centre for Astronomy and Astrophysics)

Track Classification: Nuclear astrophysics

Contribution ID: **23** Type: **Poster**

D meson in isospin asymmetric Δ resonance matter at finite temperature and density

Thursday 3 July 2025 19:40 (20 minutes)

We present the in-medium mass modification of D (D^+, D^0) and $\bar{D}$ (D^-, $\bar{D^0}$) mesons when immersed in isospin asymmetric Δ resonance matter by using the chiral SU(3) hadronic model extended to the SU(4) sector.
The interactions of D and $\bar{D}$ mesons with decuplet baryons ($\Delta^{++,+,0,-}$) are explicitly taken into account in the dispersion relations in addition to nucleons. The properties of D ($\bar{D}$) mesons are modified at finite density and temperature of asymmetric resonance matter through the exchange of scalar fields σ, ζ and δ and the vector fields ω and ρ.
At finite temperatures, the effective masses of D ($\bar{D}$) mesons undergo substantial modifications due to the presence of Δ resonance baryons within the medium. The significance of isospin-dependent medium effects is especially important for future asymmetric HIC studies.

Author: KAUR, Manpreet (Dr. B R Ambedkar National Institute of Technology Jalandhar (144008), Punjab, India)

Co-author: Dr KUMAR, Arvind (Department of Physics, Dr. B R Ambedkar National Institute of Technology Jalandhar, 144008, Punjab, India)

Presenter: KAUR, Manpreet (Dr. B R Ambedkar National Institute of Technology Jalandhar (144008), Punjab, India)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **24** Type: **Talk**

Chiral anomaly: from vacuum to Columbia plot

Wednesday 2 July 2025 10:10 (20 minutes)

First, the importance of the chiral anomaly in the QCD vacuum is briefly reviewed. Besides pseudoscalar mesons, it may affect other resonances. To this end, a mathematical object called 'polydeterminant' is introduced. Next, the role of the chiral anomaly at nonzero temperature is investigated. In particular, the Columbia plot (the order of the phase transition in dependence of the quark masses) is strongly affected by the precise realization of the chiral anomaly.

Authors: RENNECKE, Fabian (Justus Liebig University Giessen); Prof. GIACOSA, Francesco (Kielce University); KOVACS, Gyozo (University of Wrocław, Wigner RCP); Dr KOVÁCS, Péter (Wigner Research Centre for Physics); PISARSKI, rob

Presenter: Prof. GIACOSA, Francesco (Kielce University)

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **25** Type: **Poster**

Hot and dense perturbative QCD in a very strong magnetic background

Thursday 3 July 2025 19:40 (20 minutes)

We compute the pressure, chiral condensate and strange quark number susceptibility from first principles within perturbative QCD at finite temperature and very high magnetic fields up to two-loop and physical quark masses. We also discuss cold and dense quark matter in the presence of a very strong magnetic field using perturbative QCD at finite density. The effectively negligible contribution of the exchange diagram allows for building a simple analytic model for the equation of state for pure quark magnetars at extremely large fields. Finally, we consider the Taylor coefficients for the pressure in magnetic QCD. Our results for the chiral condensate, strange quark number susceptibility and Taylor coefficients can be directly compared to recent lattice QCD data away from the chiral transition. Even though current lattice results do not overlap with the region of validity for perturbation theory, perturbative results seem to be in the same ballpark.

Authors: FRAGA, Eduardo (Instituto de Física, Universidade Federal do Rio de Janeiro); PALHARES, Leticia; RESTREPO MEDINA, Tulio Eduardo (University of Houston)

Presenter: FRAGA, Eduardo (Instituto de Física, Universidade Federal do Rio de Janeiro)

Session Classification: Poster Session

Track Classification: QCD in external fields

Contribution ID: **26** Type: **Poster**

Universal scaling properties of the chiral phase transition in (2+1)-flavor QCD

Thursday 3 July 2025 18:20 (20 minutes)

The chiral phase transition in (2+1)-flavor QCD is expected to be of second order, if the breaking of axial anomaly remains sufficiently strong at the chiral phase transition temperature T_c [1]. This observation is supported by the lattice QCD calculations [2]. However, the FRG model calculations suggest that the scaling window may be small [3], within which the universal scaling relations hold true and remain valid. Furthermore, whether or not the $U_A\,(1)$ symmetry gets effectively restored at $T = T_c$ remains to be controversial. These suggest that a more detailed analysis of universal critical behaviour close to $T = T_c$ is needed, as well as one also requires a direct determination of the relevant universality class for the chiral phase transition [1,4] in (2+1)-flavor QCD.

In this talk, we present new results from a study of the scaling behaviour of an improved order parameter $M = M_\ell - H\,\chi_\ell$ for chiral symmetry restoration in the light 2-flavor sector of (2+1)-flavor QCD. Here M_ℓ and χ_ℓ are multiplicatively renormalised light quark chiral condensate and chiral susceptibility respectively, with $H = m_\ell\,/\,m_s$ being the light-to-strange quark mass ratio.

We construct ratios of M for two different values of the light quark mass, m_ℓ (or H equivalently) at T close to T_c. In the scaling region, we find a unique intersection point for these ratios at $T = T_c$, which allows us not only to determine T_c but also the underlying universality class of the chiral phase transition, from the knowledge of the critical exponent δ.

The approach followed here in this work, will allow one to further constrain the influence of axial anomaly on the universal critical behaviour in (2+1)-flavor QCD. It also provides a new way of determining the chiral phase transition temperature T_c, which strengthens the upper bound on the temperature range, within which a critical end point in QCD for non-vanishing chemical potential values can possibly be found in heavy-ion experiments.

[1] R. D. Pisarski and F. Wilczek, Phys. Rev. D 29 (1984) 338
[2] H. T. Ding et al. [HotQCD], Phys. Rev. Lett. 123 (2019) 062002
[3] J. Braun et al., Phys. Rev. D 102 (2020) 056010
[4] A. Pelissetto and E. Vicari, Phys. Rev. D 88 (2013) 105018

Author: Dr MITRA, Sabarnya (Bielefeld University)

Co-authors: Prof. KARSCH, Frithjof (Bielefeld University); Dr SARKAR, Mugdha (National Taiwan University); Dr SHARMA, Sipaz (TuM Munich)

Presenter: Dr MITRA, Sabarnya (Bielefeld University)

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **27** Type: **Poster**

Effective Chiral Lagrangian including thermal fluctuations and scale symmetry breaking

Thursday 3 July 2025 19:40 (20 minutes)

We analyze the finite-temperature equation of state (EOS) within the framework of an effective Lagrangian, where a dilaton field encodes the breaking of scale invariance in QCD. The present work extends a previous study in the pure gauge SU (3)c sector [1], in which the dynamics of the gluon condensate are described through a dilaton Lagrangian. Below the critical temperature, the condensate is dominated by the dilaton field, while above it, it evaporates into quasi-free gluons. As a new feature, we incorporate for the first time the lightest excited glueball, i.e. J = 2, into the thermodynamic description, assuming its mass lies on a linear Regge trajectory. The mass of the excited glueball is further affected by a string tension term. In this context, we investigate the impact of thermal fluctuations of the dilaton field by employing the method developed in Refs. [2, 3], which has been shown to reproduce lattice QCD results for thermodynamic quantities such as the pressure and energy density. We further extend the analysis to an EOS that includes additional hadronic degrees of freedom, namely the σ, π, ω, and ρ mesons, as well as nucleons, at finite chemical potential. This extension is realized within an effective Lagrangian that incorporates both spontaneously broken scale symmetry and explicitly broken chiral symmetry. Going beyond the mean-field approximation, we include the effects of thermal fluctuations of the scalar glueball and of the mesonic fields to gain further insight into the thermodynamic properties of the phase transition.

References

[1] A. Drago, M. Gibilisco, and C. Ratti, "Evaporation of the gluon condensate: a model for pure gauge su(3)c phase transition,"Nuclear Physics A, vol. 742, no. 1, pp. 165–181, 2004.
[2] G. W. Carter, O. Scavenius, I. N. Mishustin, and P. J. Ellis, "Effective model for hot gluodynamics,"Phys. Rev. C, vol. 61, p. 045206, Mar 2000.
[3] A. Mocsy, I. N. Mishustin, and P. J. Ellis, "Role of fluctuations in the linear σ model with quarks," Phys. Rev. C, vol. 70, p. 015204, Jul 2004.

Authors: PASSARELLA, LUCA; LAVAGNO, ANDREA; DRAGO, Alessandro

Presenter: PASSARELLA, LUCA

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **29** Type: **Talk**

Towards an optimally sensitive temperature probe in heavy-ion collisions

Wednesday 2 July 2025 12:00 (20 minutes)

The high-precision heavy quarkonium data from LHC Run 2 and the ongoing Run 3 provide a unique window into the properties of hot nuclear matter and the Quark-Gluon Plasma (QGP). To make full use of this data, it is crucial to go beyond traditional observables such as the nuclear modification factor R_{AA} and elliptic flow v_2, and instead develop new probes that are more directly sensitive to the characteristics of the medium.
We adopt the open quantum systems perspective for in-medium quarkonium and take inspiration from cold atom metrology techniques to construct observables with optimal sensitivity to specific QGP parameters. Focusing on the bulk temperature, we develop such optimal observables based the Caldeira-Leggett master equation as a simplified setup, with the goal of extending it to a full Quantum Brownian Motion Lindblad equation.

Authors: Prof. ROTHKOPF, Alexander (University of Stavanger); LÓPEZ PARDO, Víctor

Presenter: LÓPEZ PARDO, Víctor

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **30** Type: **Poster**

Probing degeneracies between dark matter and dense nuclear matter in compact stars

Thursday 3 July 2025 19:40 (20 minutes)

We study the impact of asymmetric fermionic and bosonic dark matter on neutron star properties, including tidal deformability, maximum masses, radii, thermal evolution, moment of inertia, etc. The conditions under which dark matter particles tend to condense in the core of the star or create an extended halo are presented. We show that dark matter condensed in a core leads to a decrease of the total gravitational mass and tidal deformability compared to a pure baryonic star, which we will perceive as an effective softening of the equation of state. On the other hand, the presence of a dark matter halo increases those observable quantities. Thus, observational data on compact stars could be affected by accumulated dark matter and, consequently, constraints we put on strongly interacting matter at high densities. We will discuss how the ongoing and future X-ray, radio, and GW observations could shed light on dark matter admixed compact stars and put multi-messenger constraints on its effect. A special emphasis will be given to the next-generation gravitational wave detectors.

Author: Dr SAGUN, Violetta (University of Southampton)

Co-authors: GIANGRANDI, Edoardo (University of Coimbra / University of Potsdam); CIPRIANI, Lorenzo (University of L'Aquila /Gran Sasso National Laboratory); IVANYTSKYI, Oleksii (University of Wroclaw)

Presenter: Dr SAGUN, Violetta (University of Southampton)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **31** Type: **Talk**

QCD at finite isospin density and pion condensation

Wednesday 2 July 2025 16:50 (20 minutes)

In this talk I will discuss QCD at finite isospin density at zero temperature and zero baryon density. This is system is of particular interest since there is no sign problem and one can perform lattice simulations. I will present results for the speed of sound from NLO chiral perturbation theory (chipt) and the quark-meson model in the Bose-condensed phase. The latter is able is in good agreement with chipt for small values of mu_I and with lattice data
over a large range iospin densities. I also present results for the pion condensate in chipt and it compares favorably with lattice simulations for small mu_I.

Authors: Prof. ANDERSEN, Jens Oluf; Mr NØDTVEDT, Mathias (NTNU)

Presenter: Prof. ANDERSEN, Jens Oluf

Track Classification: Dense QCD

Contribution ID: **32** Type: **Talk**

Are there indications for quark deconfinement in fastly spinning massive neutron stars?

Thursday 3 July 2025 11:00 (20 minutes)

We study rotating hybrid stars, with a particular emphasis on the effect of a deconfinement phase transition on their properties at high spin. Our analysis is based on a hybrid equation of state with a phase transition from hypernuclear matter to color-superconducting quark matter, where both phases are described within a relativistic density functional approach. By varying the vector meson and diquark couplings in the quark matter phase, we obtain different hybrid star sequences with varying extensions of the quark matter core, ensuring consistency with astrophysical constraints from mass, radius, and tidal deformability measurements. We test whether the early deconfinement phase transition is consistent with the present observational data. We show how the fastest spinning pulsars and the appearance of the quasi-radial oscillations and non-axisymmetric instabilities constrain the strongly interacting matter equation of state at zero temperature. Our findings reveal that incorporating the hybrid equation of state into the analysis of pulsars has significant implications for the constraints on the properties of strongly interacting matter and neutron stars.

Author: Dr SAGUN, Violetta (University of Southampton)

Co-authors: GÄRTLEIN, Christoph (IST, University of Lisbon / University of Coimbra / University of Wroclaw); BLASCHKE, David; PEREIRA LOPES, Ilídio (CENTRA-IST); IVANYTSKYI, Oleksii (University of Wroclaw)

Presenters: GÄRTLEIN, Christoph (IST, University of Lisbon / University of Coimbra / University of Wroclaw); Dr SAGUN, Violetta (University of Southampton)

Track Classification: Nuclear astrophysics

Contribution ID: **33** Type: **Talk**

Berry curvature and spin-one color superconductivity

Wednesday 2 July 2025 17:30 (20 minutes)

We explore the interplay between Berry curvature and topological properties in single-flavor color superconductors, where quarks form spin-one Cooper pairs. By deriving a new relation, we connect the topological nodal structure of the gap function in momentum space to the (non-Abelian) Berry flux associated with paired quarks. This generalizes the early work by Li and Haldane [1] to systems with additional internal quantum numbers, such as color. In the ultra-relativistic limit, we uncover rich topological structures driven by the interplay of spin, chirality, and color. Specifically, we identify chirality-induced topological nodes in the transverse (opposite chirality pairing) polar and A-phases. In contrast, the color-spin-locking phase lacks these nodes due to a non-trivial color Berry flux, which in turn induces gapless excitations with total Berry monopole charges of ±3/2–differing from conventional Weyl fermions. Our findings can be potentially extended to other fermionic systems carrying additional internal degrees of freedom. This work has been published in Physical Review Letters [2].

[1] Y. Li and F. Haldane, Phys. Rev. Lett. **120**, 067003 (2018).
[2] N. Sogabe and Y. Yin, Phys. Rev. Lett. **134**, 171903 (2025).

Authors: SOGABE, Noriyuki (University of Illinois Chicago); Dr YIN, Yi (Chinese University of Hong Kong (Shenzhen))

Presenter: SOGABE, Noriyuki (University of Illinois Chicago)

Track Classification: Dense QCD

Contribution ID: **34** Type: **Talk**

Color-superconducting strange quark matter formation in compact stars

Thursday 3 July 2025 11:40 (20 minutes)

An intriguing hypothesis states that ordinary hadronic matter in bulk is a metastable state (i.e., a local minimum) of strongly interacting matter, while strange quark matter (SQM) is absolutely stable (i.e., the global minimum) in bulk. A potential barrier that prevents a spontaneous deconfinement transition of ordinary hadronic matter into SQM would separate these two phases.
Our work aims to determine the conditions under which this barrier can be overcome and to assess whether such conditions may occur in high-energy astrophysical phenomena, such as core-collapse supernovae and binary compact star mergers. In these scenarios, the formation of a critical SQM seed could ultimately lead to the conversion of a hadronic star into a strange quark star.
It is usually assumed that the local flavor composition remains fixed during the initial formation of the SQM seed, given that the weak interactions are too slow to change it significantly. However, the composition fluctuates around its average equilibrium values at the typical temperatures of high-energy astrophysical processes. I will address this effect by considering the local thermal fluctuations of the hadronic composition, showing that they make the formation of SQM much easier. This result is also relevant in the standard one-family and twin-star scenarios, leading to a much smaller finite-size effect-mediated delay in the deconfinement than the ones estimated in previous works. Moreover, I will discuss the role of color-superconductivity in such a phenomenon. Finally, some possible associated phenomenology, such as the explosion of massive progenitor stars, will be presented.

Authors: LAVAGNO, ANDREA; DRAGO, Alessandro; PAGLIARA, Giuseppe; GUERRINI, Mirco (University of Ferrara and INFN Ferrara)

Presenter: GUERRINI, Mirco (University of Ferrara and INFN Ferrara)

Track Classification: Nuclear astrophysics

Contribution ID: **35** Type: **Poster**

Stochastic dynamics and diffusion models: a generative AI approach for lattice field theory

Thursday 3 July 2025 19:40 (20 minutes)

Diffusion models are currently one of the leading generative AI approaches for image generation used by e.g. DALL-E and Stable Diffusion. A formulation familiar to physicists uses stochastic differential equations. We review this formulation and relate it to stochastic quantisation in quantum field theory. We demonstrate the approach for scalar and abelian gauge fields in two dimensions and end with some speculation on further applications in physics.

Authors: Prof. AARTS, Gert (Swansea University); Mr HABIBI, Diaa (Swansea University); Dr WANG, Lingxiao (RIKEN); Prof. ZHOU, Kai (Chinese University of Hong Kong - Shenzhen (CUHK-Shenzhen)); Mr ZHU, Qianteng (Shanghai Jiao Tong University)

Presenter: Prof. AARTS, Gert (Swansea University)

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **36** Type: **Poster**

Non-equilibrium Chiral Magnetic Effect from lattice QCD simulations

Thursday 3 July 2025 19:40 (20 minutes)

First-principle lattice QCD studies of the Chiral Magnetic Effect (CME) have so far been mostly carried out in a thermal equilibrium state with background magnetic field and an artificial "chiral chemical potential". In this case, Bloch theorem prohibits any nonvanishing conserved currents in equilibrium, and the CME current vanishes identically.

In this talk, I introduce a novel formalism to measure the out-of-equilibrium Chiral Magnetic Effect in standard lattice QCD simulations of thermal equilibrium state with background magnetic field. The formalism captures time-like correlations between the axial charge density and the conserved electric current without any need for the "chiral chemical potential".

For free fermions, the axial-vector correlator only receives contributions from the lowest Landau level, and exhibits a linear dependence on both magnetic field and temperature with a universal coefficient. With an appropriate regularization, nonvanishing axial-vector correlator is compatible with the vanishing of the CME current in thermal equilibrium state with nonzero "chiral chemical potential".

The real-time axial-vector correlator is intimately related to the real-time form of the axial anomaly equation, which strongly limits possible corrections to out-of-equilibrium CME in full QCD. We present numerical results for the Euclidean-time axial-vector correlator in SU(2) lattice gauge theory with Nf=2 light quark flavors, demonstrating its closeness to the free fermion result on both sides of the chiral crossover. The proposed methodology can be used to interprete experimental data on CME in heavy-ion collisions (e.g. in the RHIC isobar run).

Author: BUIVIDOVICH, Pavel

Presenter: BUIVIDOVICH, Pavel

Session Classification: Poster Session

Track Classification: Non-equilibrium dynamics/non-equilibrium aspects of QCD

Contribution ID: **37** Type: **Poster**

Determination of the curvature of the QCD pseudo-critical line using hadronic observables

Thursday 3 July 2025 19:40 (20 minutes)

In this talk I will present a new method to study the QCD phase diagram at finite baryon chemical potential, using hadronic correlators. Specifically, the approach exploits the degeneracy between the vector and axial vector channels upon chiral symmetry restoration. The temperature at which this degeneracy occurs shifts as μ_B is increased, allowing us to follow the change of T_c along the pseudo-critical line in the $T - \mu_B$ plane. The curvature of this line is encapsulated in the second-order coefficient kappa and our results are in good agreement with kappa values obtained using thermodynamic quantities. This work employs lattice QCD ensembles produced by the FASTSUM collaboration on anisotropic lattices, using an improved Wilson action for the fermions.

Author: SMECCA, Antonio (Swansea University)

Co-authors: JÄGER, Benjamin; ALLTON, Chris (Swansea University); Prof. AARTS, Gert (Swansea University); SKULLERUD, Jon-Ivar; WU, Liang-Kai (Jiangsu University); BIGNELL, Ryan (Trinity College Dublin); NAM, Seung-il; KIM, Seyong (Unknown)

Presenter: SMECCA, Antonio (Swansea University)

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **38** Type: **Poster**

Properties of the Object HESS J1731-347 as a Twin Compact Star

Thursday 3 July 2025 19:40 (20 minutes)

By consideration of the Compact object HESS J1731-347 as a hybrid twin compact star, i.e., a more compact star than its hadronic twin of the same mass, its stellar properties are derived. Besides showing that the properties of compact stars in this work are in good agreement with state-of-the-art constraints both from measurements carried out in laboratory experiments as well as by multi-messenger astronomy observations, the realization of an early strong hadron-quark first order phase transition as implied by the twins is discussed.

Author: Dr ALVAREZ CASTILLO, David Edwin (Institute of Nuclear Physics PAS)

Presenter: Dr ALVAREZ CASTILLO, David Edwin (Institute of Nuclear Physics PAS)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **39** Type: **Talk**

QCD in strong magnetic fields: fluctuations of conserved charges and EoS

Friday 4 July 2025 12:20 (20 minutes)

Strong magnetic fields, attaining magnitudes comparable to the QCD scale, can significantly affect the equilibrium properties and bulk thermodynamics of strongly interacting matter. While such strong fields are expected in off-central heavy-ion collisions, directly measuring their imprints, such as chiral magnetic effects, remains challenging.

In this talk, we propose the baryon-electric charge correlations χ_{11}^{BQ} and the chemical potential ratio $\mu_{\mathrm{Q}}/\mu_{\mathrm{B}}$ 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.

Extending our investigation into the QCD equation of state (EoS), we examine the behavior of bulk thermodynamic expansion coefficients under extremely strong magnetic fields [3]. Our current eB window spans up to $0.8\ \mathrm{GeV}^2 \sim 45m_\pi^2$, revealing intriguing non-monotonic behaviors in the T-eB dependence of pressure and number density, which are absent at vanishing and relatively weak magnetic fields. The HRG model and the magnetized ideal gas serve as useful references for the low-T, weak-eB and high-T, strong-eB regimes, respectively. Furthermore, we also discuss higher-order thermodynamic observables, energy and entropy density, highlighting the significant impact of magnetic fields.

[1] Heng-Tong Ding, Jin-Biao Gu, Arpith Kumar, Sheng-Tai Li, Jun-Hong Liu, Phys. Rev. Lett. 132, 201903 (2024)

[2] Heng-Tong Ding, Jin-Biao Gu, Arpith Kumar, Sheng-Tai Li, arXiv:2503.18467 [hep-lat]

[3] Heng-Tong Ding, Jin-Biao Gu, Arpith Kumar, Sheng-Tai Li, PoS LATTICE2024 (2025) 175, and work in progress

Authors: KUMAR, Arpith (Central China Normal University); DING, Heng-Tong (Central China Normal University); GU, Jin-Biao (Central China Normal University); LI, Sheng-Tai (Central China Normal University)

Presenter: KUMAR, Arpith (Central China Normal University)

Track Classification: Lattice QCD

Contribution ID: **41** Type: **Poster**

Color superconductivity and non-strange hybrid stars

Thursday 3 July 2025 19:40 (20 minutes)

In this talk I will discuss the three-flavor quark-meson model including color superconductivity, with emphasis on the 2SC and CFL phases. We extend the quark-meson model to the quark meson diquark model. This is a renormalizable low energy effective model that describes the superconductive phases of QCD. We calculate the thermodynamic potential including quark loops. We map out the phase diagram in the μ_B - T plane and sketch how one can apply this model to compact stars. We will present results for the speed of sound, mass-radius relationship, and tidal deformability of non-strange hybrid stars.

Author: NØDTVEDT, Mathias Pavely (NTNU)

Co-author: Prof. ANDERSEN, Jens Oluf

Presenter: NØDTVEDT, Mathias Pavely (NTNU)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **42** Type: **Talk**

Glasma as a fluid

Thursday 3 July 2025 17:40 (20 minutes)

At the earliest stage of ultrarelativistic heavy-ion collisions the produced matter is a highly populated system of gluons called glasma which can be approximately described in terms of classical chromodynamic fields. Although the system's dynamics is governed by Yang-Mills equations, glasma evolution is shown to strongly resemble hydrodynamic behavior. We discuss glasma collective flow and we check how well the glasma energy-momentum tensor can be represented by a hydrodynamic energy-momentum tensor. Keeping in mind the recently discovered polarization phenomena of hyperons and vector mesons, we study the global angular momentum of the glasma, which is perpendicular to the reaction plane, and the local angular momentum along the beam direction. The vorticity of the glasma fluid is discussed as well.

Author: MROWCZYNSKI, Stanislaw

Presenter: MROWCZYNSKI, Stanislaw

Track Classification: Fluid dynamics and collectivity

Contribution ID: **43** Type: **Poster**

Hypernuclear Matter in Neutron Stars Using Realistic Lambda Hyperon potentials

Thursday 3 July 2025 19:40 (20 minutes)

The extraordinary densities achieved in the cores of neutron stars make them ideal astrophysical laboratories for investigating hypernuclear matter. Recent multi-messenger observations impose stringent constraints on the neutron star equation of state, allowing for tests of models that incorporate exotic components such as hyperons. For example, precise measurements of neutron star masses—such as PSR J0740+6620 with a mass of approximately $2.08\,M_\odot$ —along with tidal deformability constraints from the binary neutron star merger GW170817, significantly narrow the range of viable EoSs. In this work, we explore the presence of Λ hyperons in β-stable matter within neutron star cores using a potential-based ab initio approach. For both Λ–nucleon and Λ–Λ interactions, we employ spin- and parity-dependent potentials with parameters phenomenologically tuned to reproduce experimental data from hypernuclei. Special emphasis is placed on addressing the long-standing hyperon puzzle within this framework.

Author: SHAHRBAF MOTLAGH, mahboubeh (University of Wroclaw)

Co-authors: Mr MOHAMMAD ALI LOOEE, Ali (University of Tehran); MOSHFEGH, Hamidreza (University of Tehran and Centro Brasileiro de Pesquisas Fısicas, Brazil)

Presenter: SHAHRBAF MOTLAGH, mahboubeh (University of Wroclaw)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **44** Type: **Poster**

Sound velocity peak driven by the chiral partner in dense two-color QCD

Thursday 3 July 2025 19:40 (20 minutes)

Recent studies suggest that the presence of a peak structure in the sound velocity would be essential for reproducing the observed mass-radius relation of neutron stars. To investigate the existence of the sound velocity peak in baryonic dense matter, the chemical potential dependence of the sound velocity has recently been evaluated via lattice simulations of two-color QCD, rather than simulations of real-world QCD with three colors. The results indicate the emergence of a peak in the sound velocity. However, the chiral perturbation theory (ChPT), which serves as a low-energy effective model for the lightest hadrons, fails to reproduce this peak at finite quark chemical potential in two-color QCD with two quark flavors.
In this talk, I present an effective model to describe the sound velocity peak. I first extend the ChPT to incorporate excited hadrons into the effective theory by employing the linear sigma model, where the sigma meson is identified as the chiral partner of pions. Within the mean field approximation, I show that the contribution from the chiral partner leads to the sound velocity peak. In addition, I discuss the correlation between the sound velocity and the trace anomaly in dense two-color QCD.

Author: KAWAGUCHI, Mamiya

Co-author: SUENAGA, Daiki (Nagoya University)

Presenter: KAWAGUCHI, Mamiya

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **45** Type: **Poster**

Quark matter at four loops

Thursday 3 July 2025 19:40 (20 minutes)

Major progress has been made in recent years toward computing the four-loop perturbative pressure of cold and dense quark matter (QM) [1,2], a key ingredient in constraining the equation of state of neutron-star matter. What remains to be computed is the contribution from hard-momentum gluons in dense QCD, encoded in the sum of 52 four-loop vacuum Feynman diagrams at finite baryon chemical potential.

In this talk, we present recent advances in tackling this challenging calculation [3]. Our approach involves classifying the distinct contributions, isolating a subset of graphs responsible for infrared divergences, and demonstrating the feasibility of the novel dense Loop-Tree Duality (dLTD) method in the numerical evaluation of dense integrals at the four-loop level [4]. This will ultimately lead to the first completed loop order in almost five decades, a milestone result with significant impact in constraining the neutron-star-matter equation of state.

[1] Phys.Rev.Lett. 127 (2021) 16, 162003
[2] Phys.Rev.Lett. 131 (2023) 18, 181902
[3] arXiv:2501.17921
[4] Phys.Rev.D 110 (2024) 9, 094033

Author: NAVARRETE, Pablo (University of Helsinki)

Co-authors: KÄRKKÄINEN, Aapeli (University of Helsinki); NURMELA, Mika (University of Helsinki); Dr PAATELAINEN, Risto (University of Helsinki); SEPPÄNEN, Kaapo (University of Helsinki); Prof. VUORINEN, Aleksi (University of Helsinki)

Presenter: NAVARRETE, Pablo (University of Helsinki)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **46** Type: **Talk**

Nonlocal Operators on the Lattice for the Higgs-Confinement Phase Transition

Friday 4 July 2025 09:45 (20 minutes)

In this talk, I will report our recent achievements based on ref. [1].

Quark-Hadron Continuity on QCD and Gauge-Higgs model
A big puzzle of QCD and its phase diagram is whether quark matter at high density and hadronic matter are smoothly connected or separated by the phase transition. On the one hand, since both phases have the same symmetry, the continuity between hadrons and quark matter (**quark-hadron continuity**) seems to be realized. On the other hand, intuitively, the two phases are distinguished by the presence or absence of the color charge, and the phase transition seems to exist. To settle this issue, the color charge needs to be calculated numerically from **nonlocal operators** such as the Wilson loop and **Aharonov–Bohm phase**. We have examined the usefulness of nonlocal operators in analyzing the behavior of the phase transition by using an Abelian Higgs model as a testing ground. This model does not have the sign problem and has the same continuity problem as QCD if the gauge group is extended.

Phase Diagram of Abelian Higgs model
We calculated the **Polyakov loop** and **'t Hooft loop** of the charge-2 Abelian Higgs model on the lattice. These nonlocal operators are order parameters of confinement. We confirmed the phase transition lines of the theory and obtained the phase diagram. Furthermore, the Higgs and Coulomb deconfined phases were distinguished.

Aharonov–Bohm Phase on Lattice
We also calculated the Wilson loop and the **Aharonov–Bohm phase** on the lattice. A vortex of the Higgs field is generated, and several size loops are considered. We found the first-order phase transition on the Wilson loop, but phase values become difficult to read at the confined phase.

[1] Yusuke Shimada and Arata Yamamoto, "Analyzing the Higgs–Confinement Transition with Nonlocal Operators on the Lattice", *Progress of Theoretical and Experimental Physics*, Volume 2025, Issue 4, April 2025.

Author: SHIMADA, Yusuke (U Tokyo)

Co-author: YAMAMOTO, Arata

Presenter: SHIMADA, Yusuke (U Tokyo)

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **47** Type: **Talk**

Particle-theory input for neutron-star physics

Thursday 3 July 2025 12:20 (20 minutes)

Different parts of neutron stars (NSs) probe all fundemantal interactions of particle physics: the strong nuclear force is behind the bulk thermodynamic properties of their constituent matter, electroweak interactions are needed to describe equilibration and transport phenomena during binary NS mergers, and information on QED scattering processes at ultrastrong magnetic fields is required to properly understand the NS magnetosphere. Corresponding to these three topics, I will discuss three topical problems within NS physics: inferring a model-independent equation of state for NS matter, determining the bulk viscosity of quark matter, and accounting for the full effects of background magnetic fields in QED scattering processes using Schwinger's proper time formalism. A common denominator in all cases is the need to perform high-precision calculations using resummed (thermal) field theory, the recent results of which I will showcase within each of the three categories.

Author: VUORINEN, Aleksi (University of Helsinki)

Presenter: VUORINEN, Aleksi (University of Helsinki)

Track Classification: Dense QCD

Contribution ID: **48** Type: **Talk**

Columbia plot, critical point and bound states in dense QCD

Wednesday 2 July 2025 09:05 (45 minutes)

Converging results from different approaches locate the critical end point (CEP) of QCD at large chemical potential, i.e. in the realm of dense QCD. We summarise recent theoretical results within functional methods on the location of the CEP and its variation under systematic changes of the light and strange quark masses. We furthermore discuss the physics at large chemical potential including the properties of bound states and the possible appearance of interesting new phases.

Author: FISCHER, Christian (University of Giessen, Germany)

Presenter: FISCHER, Christian (University of Giessen, Germany)

Track Classification: Dense QCD

Contribution ID: **49** Type: **Poster**

Impact of Bosonic Dark Matter on Neutron Star Structure and X-ray Pulse Profiles

Thursday 3 July 2025 19:40 (20 minutes)

We study neutron stars (NSs) admixed with self-interacting bosonic dark matter (DM), motivated by recent observational data from NICER and LIGO/Virgo. In this framework, sub-GeV bosonic DM can accumulate as a dense core or form an extended halo around the NS, significantly affecting its mass, radius, and tidal deformability. By varying the DM particle mass, self-coupling strength, and its fraction within the NS, we place constraints on the allowed DM parameter space in light of current astrophysical limits.

A key focus of our work is on how a DM halo can alter X-ray pulse profiles of rotating NSs. The presence of DM modifies the external space-time geometry, which in turn affects photon trajectories and light bending near the NS. Through detailed pulse profile modeling, we show that changes in compactness due to DM can lead to significant variations in the observed flux, particularly in the minimum flux levels of the light curve. This effect provides a novel and sensitive probe of DM halo structures, positioning pulse profile analysis as a powerful observational tool in future missions like NICER and STROBE-X.

Author: Mr RAFIEI KARKEVANDI, Davood (University of Wroclaw, Institute of Theoretical Physics)

Presenter: Mr RAFIEI KARKEVANDI, Davood (University of Wroclaw, Institute of Theoretical Physics)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **50** Type: **Talk**

Approaching the continuum with anisotropic lattice thermodynamics

Friday 4 July 2025 10:05 (20 minutes)

The FASTSUM collaboration has a long-standing programme of using anisotropic lattice QCD to investigate strong interaction thermodynamics, and in particular spectral quantities. Here we present first results from our new ensemble which has a temporal lattice spacing $a_\tau = 15$ am and anisotropy $a_s/a_\tau = 7$, giving unprecedented resolution in the temporal direction. We show results for the chiral transition, parity doubling of baryons, and heavy quarkonium, and compare them with earlier results on coarser lattices.

Author: SKULLERUD, Jon-Ivar

Presenter: SKULLERUD, Jon-Ivar

Track Classification: Lattice QCD

Contribution ID: **51** Type: **Talk**

Using net quark number gain to probe the phases of QCD

Wednesday 2 July 2025 11:20 (20 minutes)

We propose an observable to probe the content of a bath of quarks and gluons at finite temperature and chemical potential, the net quark number gain ΔQ. QCD is controlled by different degrees of freedom in the various sections of its phase diagram, notably hadrons at low temperatures (and chemical potentials) and quarks and gluons at high temperatures. However, studying the relevant content of a QCD medium across the phase diagram is challenging.

To this end, we correlate the Polyakov or anti-Polyakov loops to the medium's net quark number Q. This gives the net quark number gain ΔQ, which provides information on how the thermal bath reacts to adding a static quark or antiquark probe. While insignificant at high temperatures, it shows the bath's tendency to form hadron-like configurations at low temperatures, which would screen the probe's color charge. Interestingly, ΔQ allows one to distinguish meson-like and baryon-like configurations as a function of the chemical potential and for the different probes. This net quark number gain also helps explain how a single quark/antiquark can be added to a supposedly hadronic medium in the first place: the latter provides the missing quarks/antiquarks to form hadron-like states.

We sketch the derivation of this general result for temperatures much smaller than the quark masses and in the limits of large temperature or chemical potential, where perturbative QCD works. We discuss possible further applications to study the various features of the QCD phase diagram, like critical points or color superconductivity.

arXiv: 2504.06459 [hep-ph]

Authors: MARI SURKAU, Tomas; REINOSA, Urko (CPHT - Ecole Polytechnique - CNRS)

Presenter: MARI SURKAU, Tomas

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **52** Type: **Poster**

Studying the interaction between charm and light-flavor mesons

Thursday 3 July 2025 19:40 (20 minutes)

In the last years, several exotic states have been observed in the charm sector; such particles cannot be interpreted as baryons or mesons and are thought to be either quark bags or molecular states. To unveil the nature of those states, it is crucial to experimentally constrain the strong force that governs the interaction between the charmed hadrons and other hadrons, e.g. via the measurement of the scattering parameters.

The knowledge of the charmed-hadron interactions is also essential for the study of ultrarelativistic heavy–ion collisions; in fact, during the hadronic phase of the fireball expansion, the charmed hadrons can interact with the other particles produced in the collision, mainly light hadrons, via elastic and inelastic processes. These interactions modify the heavy-ion observables, and to disentangle this effect from the signatures of the quark–gluon plasma formation, the scattering parameters of charmed hadrons with light flavours are required.

Despite the importance of constraining the charmed-hadron interactions, the available experimental knowledge is very scarce: so far, only the D-proton system was investigated. This contribution extends these studies to the open-charm and light-flavor meson systems. The final-state strong interaction is accessed using the femtoscopy method applied to high-multiplicity proton-proton collisions at $\sqrt{s} = 13$ TeV, collected by the ALICE Collaboration. Projections of the ALICE 3 performance for femtoscopic studies are also presented.

Author: BATTISTINI, Daniel (Technische Universität München (DE))

Presenter: BATTISTINI, Daniel (Technische Universität München (DE))

Session Classification: Poster Session

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **54** Type: **Talk**

Bulk viscous dissipation in strange quark stars and mergers

Thursday 3 July 2025 09:45 (20 minutes)

In the coalescence of neutron stars the bulk viscous dissipation offers a potential opportunity to infer properties of neutron star matter by estimating its effect on the gravitational wave emission. To this end, we compute the bulk viscosity in unpaired quark matter considering the electroweak processes allowed in the neutrino-transparent regime at low temperatures. Using the equations of state of bag models and perturbative QCD, we analyze the dependence of our results on the density, temperature and strange quark mass. Finally, we study relevant phenomena in the merger of binary compact stars where the bulk viscosity plays a significant role. First, the damping of baryon density oscillations in quark matter and its importance in the postmerger phase after the collision of two neutron stars if deconfined matter is achieved in the process. Further, the tidal heating induced by the companion in the binary inspiral of strange quark stars and its effect on the gravitational wave form.

References

1. Damping of density oscillations from bulk viscosity in quark matter, José Luis Hernández; Cristina Manuel; Laura Tolos, Phys. Rev. D 109, 123022 (2024)
2. Damping of density oscillations from bulk viscosity in quark matter, José Luis Hernández; Cristina Manuel; Laura Tolos, PoS QNP2024, 175 (2025)
3. Tidal heating in binary inspiral of strange quark stars, Suprovo Ghosh; José Luis Hernández; Bikram Keshari Pradhan; Cristina Manuel; Debarati Chatterjee, Laura Tolos, arXiv:2504.07659, (2025)

Author: HERNÁNDEZ, José Luis (Institut de Ciències de l'Espai, Institut d'Estudis Espacials de Catalunya (IEEC))

Presenter: HERNÁNDEZ, José Luis (Institut de Ciències de l'Espai, Institut d'Estudis Espacials de Catalunya (IEEC))

Track Classification: Nuclear astrophysics

Contribution ID: **55** Type: **Talk**

Novel early time hydrodynamic attractor in ultracold quantum gases

Friday 4 July 2025 17:30 (20 minutes)

Hydrodynamic attractors were first studied in conformal Bjorken flow in the context of heavy ion collisions to discuss how the fireball of strongly interacting matter approaches hydrodynamic behaviour. Recently, a hydrodynamic attractor has also been constructed for the case of ultracold atom gases, meaning it now has a second real world application and may soon be measured directly in experiment. Interestingly, the newly discovered instance of this behaviour has some significant differences to Bjorken flow: it appears in a deeply nonrelativistic, nonconformal and isotropically contracting system. This suggests that the phenomenon is universal to all dynamical systems where equilibration competes with expansion. Through more general studies of how the behaviour plays out in different situations, one might eventually be able to construct an effective dynamical description that would supercede hydrodynamics.
We take a first step in this direction by examining continuous modifications of conformal Bjorken flow. In some scenarios, the competition between equilibration and expansion can play out very differently, even leading to long term stable states of coexistence. We discuss how concepts from the known case transfer to the new case, for example the scaling variable and the distinction between the early time and late time attractors, and propose a modification of how to identify the behaviour that we believe to be a more accurate representation.

Author: WERTHMANN, Clemens (Ghent University)

Presenter: WERTHMANN, Clemens (Ghent University)

Track Classification: Fluid dynamics and collectivity

Contribution ID: **56** Type: **Poster**

Hadron resonance gas in a magnetic field with physical magnetic moments of hadrons

Thursday 3 July 2025 19:40 (20 minutes)

We study the magnetic properties of the Hadron Resonance Gas (HRG) (which is created in ultra-relativistic heavy-ion collisions or studied on the lattice) in the presence of a constant magnetic field. Instead of the simplified approach[1,2] of taking the gyromagnetic ratio of a hadron as $g = 2|Q|$, we consider the physical value of g as measured in experiments or estimated theoretically. By considering this, we also take into account the paramagnetic contributions from the spin magnetic moments of neutral hadrons, missed in past studies. We evaluate the conserved charge susceptibilities and correlations describing fluctuations in HRG, both in the absence and presence of a magnetic field. We quantify the sizable effects of the physical values of g. Additionally, we also discuss the instability and the dominance of the Δ baryons in strong magnetic fields, and propose how to tackle it phenomenologically. We compare our model results with the lattice data from various collaborations[3]. For not too strong magnetic fields, the approach can reasonably describe the features of the lattice data related to the baryon, strangeness, and charge susceptibilities and correlations, highlighting the importance of the physical anomalous magnetic moments and a proper treatment of the Δ. (Based on the work in progress)

References:

1. M. Marczenko, M. Szymanski, P. M. Lo, B. Karmakar, P. Huovinen, C. Sasaki, and K. Redlich, Phys. Rev. C 110, 065203 (2024), arXiv:2405.15745 [hep-ph].

2. V. Vovchenko, Phys. Rev. C 110, 034914 (2024), arXiv:2405.16306 [hep-ph].

3. Bollweg et al. Phys. Rev. D 104, 074512 (2021), arXiv:2107.10011 [hep-lat], Ding et al. (2025), arXiv:2503.18467 [hep-lat], Astrakhantsev et al. Phys. Rev. D 109, 094511 (2024), arXiv:2403.07783 [hep-lat].

Author: Dr SAMANTA, Rupam (Institute of Nuclear Physics (IFJ, PAN), Poland)

Presenter: Dr SAMANTA, Rupam (Institute of Nuclear Physics (IFJ, PAN), Poland)

Session Classification: Poster Session

Track Classification: QCD in external fields

Contribution ID: **57** Type: **Poster**

Color-superconducting quarkyonic matter

Thursday 3 July 2025 19:40 (20 minutes)

We explore the role of color superconductivity in quarkyonic matter under the conditions of electric and charge neutrality at β-equilibrium, as relevant for neutron stars. By explicitly incorporating color-superconducting pairing gap into the phenomenological model of a crossover transition from hadron to quark matter, we extend the known quarkyonic framework suggested by McLerran and Reddy to include this essential aspect relevant at high densities. We demonstrate that reaching the conformal limit of QCD within the proposed model is provided by the proper momentum dependence of the pairing gap, motivated by effective chiral quark approaches with nonlocal interaction among quarks. We utilize the flexible metamodelling approach to nuclear matter, analyze the structure of the shell of hadrons in momentum space and focus on the effects of color superconductivity in quarkyonic matter. Similarly to the effects caused by the onset of quarkyonic phase, color superconductivity leads to stiffening of the equation of state of the neutron star matter. This causes a significant impact on observable properties of neutron stars, which are analyzed and confronted to recent astrophysical and theoretical constraints. We argue that the developed model of color-superconducting quarkyonic matter provides a new consistent tool for studying the scenario of smooth quark-hadron crossover in neutron stars.

Author: GÄRTLEIN, Christoph (IST, University of Lisbon / University of Coimbra / University of Wroclaw)

Co-authors: PEREIRA LOPES, Ilídio (CENTRA-IST); IVANYTSKYI, Oleksii (University of Wroclaw); Dr SAGUN, Violetta (University of Southampton)

Presenter: GÄRTLEIN, Christoph (IST, University of Lisbon / University of Coimbra / University of Wroclaw)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **58** Type: **Poster**

Relativistic dissipative hydrodynamics for particles of arbitrary mass

Thursday 3 July 2025 19:40 (20 minutes)

Employing a kinetic framework, we calculate all transport coefficients for relativistic dissipative (second-order) hydrodynamics for arbitrary particle masses in the 14-moment approximation. Taking the non-relativistic limit, it is shown that the relativistic theory reduces to the Grad equations computed in the "order-of-magnitude"approach.

Authors: WAGNER, David (Florence University); POTESNOV, Semyon (Institute for Theoretical Physics, Goethe-University Frankfurt)

Presenter: POTESNOV, Semyon (Institute for Theoretical Physics, Goethe-University Frankfurt)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **59** Type: **Poster**

Chiral Properties of (2+1)-Flavor QCD in Strong Magnetic Fields at Zero Temperature

Thursday 3 July 2025 19:40 (20 minutes)

We present a lattice QCD study of light pseudoscalar meson masses and decay constants in strong background magnetic fields, using three different lattice sizes. Our simulations employ (2+1)-flavor ensembles using the highly improved staggered quark (HISQ) action with physical quark masses and three values of the lattice spacing ($a \approx 0.067$, 0.084, 0.112 fm) to enable a controlled continuum extrapolation. We utilized seven different values of the magnetic field strength, reaching up to $\sim 1.22\mathrm{GeV}^2 (\sim 66 M_\pi^2)$ in the vacuum. The meson masses and decay constants were extracted from the exponential decay and amplitudes of two-point correlation functions. Finally, we analyze how these quantities depend on the magnetic field, providing insight into mesonic behavior in strong magnetic backgrounds.

Authors: ZHANG, Dan; DING, Heng-Tong

Presenter: ZHANG, Dan

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **61** Type: **Talk**

Analytic calculation of quark-number susceptibilities in heavy-quark QCD

Wednesday 2 July 2025 11:40 (20 minutes)

We investigate the thermodynamics of heavy-quark QCD in the hopping-parameter expansion (HPE) in an analytic manner. We develop a procedure to calculate the grand potential of heavy-quark QCD in the HPE using a technique based on the cumulant expansion. Applying this method to the analysis of thermodynamics, we derive the formula for the grand potential expressed in terms of the cumulants of the Polyakov loop and loop operators with windings along the temporal direction. These results immediately lead to the fact that the ratio of quark-number cumulants at even orders is unity in the deconfined phase and nine in the confined phase at leading order in the HPE. We also explore properties of excitations carrying quark number in both phases, such as their excitation energies.

Author: TOHME, Kei (Kyoto University)

Co-authors: SASAKI, Chihiro; REDLICH, Krzysztof (University of Wroclaw); KITAZAWA, Masakiyo; DOI, Takahiro (Japan/Kyoto University)

Presenter: TOHME, Kei (Kyoto University)

Track Classification: Lattice QCD

Contribution ID: **62** Type: **Poster**

Imprint of nuclear structure on identified particles in high energy heavy ion collisions

Thursday 3 July 2025 19:40 (20 minutes)

The encoded nuclear structures related to flow fluctuations can be investigated at a fixed impact parameter in ultra-relativistic ion collisions through the concept of factorization breaking. This phenomenon is explored by analyzing momentum-dependent correlations among flow harmonics across distinct kinematic bins, specifically in terms of pseudorapidity (η)1 or transverse momentum (pT)[2]. The influence of various β deformations on these momentum-dependent coefficients has been observed previously [3]. Our findings indicate a sensitivity to triaxiality for $pT > 1.5$ GeV in ultra-central U+U collisions. Notably, we find that the imprint of deformation is evident in the behavior of identified particles. We report a significant shift in the crossing point of observable ratios, specifically $\pi^{\pm}/p(\bar{p})$ and $\pi^{\pm}/K^{\pm}$. This new observable reveals that the crossing point occurs at higher p_T values for quadrupole-deformed nuclei and higher ratio values for triaxiality in U+U and Au+Au collisions, as determined using the TRENTO+VISH(2+1D) framework. Furthermore, the structural effects can also be observed in lighter nucleus collisions, such as O+O and Ne+Ne (as well as O+Pb and Ne+Pb), which we propose for future LHC runs. Our analysis demonstrates that factorization breaking effectively differentiates between the structures of ^{16}O and ^{20}Ne, as derived from the Nuclear Lattice Effective Field Theory (NLEFT) model, utilizing 3D-MCGlauber+Music simulations. It is noteworthy that the tendencies of identified particles exhibit significant differences compared to heavier nuclei, such as ^{238}U and ^{197}Au.
1 P. Bozek, W. Broniowski, and J. Moreira, Phys. Rev. C 83, 034911 (2011).
[2] F. G. Gardim, F. Grassi, M. Luzum, and J.-Y. Ollitrault, Phys. Rev. C 87, 031901 (2013).
[3] R. Samanta and P. Bozek, Phys.Rev.C 107 (2023) 5, 5.

Author: MEHRABPOUR, Hadi (Peking Univresity)

Presenter: MEHRABPOUR, Hadi (Peking Univresity)

Session Classification: Poster Session

Track Classification: Phenomenology & Experiment

Contribution ID: **63** Type: **Poster**

Lattice QCD constraints on the critical point from an improved precision equation of state

Thursday 3 July 2025 19:40 (20 minutes)

We employ lattice simulations to search for the critical point of quantum chromodynamics (QCD). We search for the onset of a first order QCD transition on the phase diagram by following contours of constant observables (e.g. entropy density) from imaginary to real chemical potentials under conditions of strangeness neutrality. We scan the phase diagram and investigate whether these contours meet to determine the probability that the critical point is located in a certain region on the T–μBT–μB plane. To achieve this we introduce a new, continuum extrapolated equation of state at zero density with improved precision using lattices with $N_\tau = 8, 10, 12, 16$ timeslices, and supplement it with new data at imaginary chemical potential. The current precision allows us to exclude, at the 2σ level, the existence of a critical point at $\mu_B < 450$ MeV.

Authors: GUENTHER, Jana N. (University of Wuppertal); BORSANYI, Szabolcs Istvan; FODOR, Zoltan (Deutsches Elektronen-Synchrotron (DE)); PAROTTO, Paolo; PASZTOR, Attila (Eötvös University); RATTI, Claudia; Dr VOVCHENKO, Volodymyr (University of Houston); Dr WONG, Chik Him

Presenter: GUENTHER, Jana N. (University of Wuppertal)

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **65** Type: **Talk**

Nontrivial topology in gauge theories, and time dependent Dark Energy of the Universe.

Wednesday 2 July 2025 17:50 (20 minutes)

We discuss the dynamics of the topologically nontrivial sectors with non-trivial holonomy in strongly coupled QCD in the background of the expanding universe characterized by the Hubble scale $H \ll \Lambda_{QCD}$. We argue that the vacuum energy and the de Sitter phase emerge dynamically with the scale $\rho_{DE} \approx H\Lambda_{QCD}^3 \approx (10^{-3}eV)^4$, which is amazingly close to the observed value. We argue that the key element for this idea to work is the presence of nontrivial holonomy in strongly coupled gauge theories. The effect is global in nature and cannot be formulated in terms of a gradient expansion in an effective local field theory. We explain the idea in exactly solvable 2d Schwinger model and we also test these ideas with solvable models for QCD being formulated on Hyperbolic space. We also comment on some lattice QCD results when the system is formulated on a curved background modelling the expanding Universe with nonzero H. We also comment on recent DESI (Dark Energy Spectroscopic Instrument) results which are consistent with our findings.

Author: Prof. ZHITNITSKY, Ariel (UBC)

Presenter: Prof. ZHITNITSKY, Ariel (UBC)

Track Classification: Nuclear astrophysics

Contribution ID: **66** Type: **Poster**

Chiral symmetry restoration, the $U(1)_A$ and thermal resonances

Thursday 3 July 2025 19:40 (20 minutes)

We review recent progress towards the understanding of the QCD phase diagram using tools based on effective theories, Ward Identities (WI) and resonances at finite temperature and chemical potentials.
Various relevant observables such as scalar and topological susceptibilities can be obtained within this framework and are consistent with recent lattice analyses. In particular, we show that for the isospin channels $I = 0$ and $I = 1/2$, the $f_0(600)/\sigma$ and the $K_0^*(700)/\kappa$ thermal resonances, generated respectively from $\pi\pi$ and πK scattering at finite temperature, are essential to describe chiral symmetry and $U(1)_A$ restoration of scalar and pseudoscalar susceptibilities consistently both with lattice and WI. In turn, WI imply scaling laws around T_c which can be checked with lattice screening masses.
This approach allows to control in a systematic and consistent way the dependence on temperature, quark masses and strangeness. We have also derived novel results for effective theories at nonzero isospin density and nonzero chiral imbalance.

Author: Prof. GOMEZ NICOLA, ANGEL (Universidad Complutense Madrid)

Co-authors: VIOQUE RODRIGUEZ, ANDREA; RUIZ DE ELVIRA CARRASCAL, JACOBO (Complutense University of Madrid and IPARCOS)

Presenter: Prof. GOMEZ NICOLA, ANGEL (Universidad Complutense Madrid)

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **67** Type: **Poster**

Perturbative evaluation of adjoint correlators of chromoelectric fields at NLO in finite T

Thursday 3 July 2025 19:40 (20 minutes)

Heavy quarkonium serves as an excellent probe to study the properties of the Quark-Gluon Plasma (QGP). The physics of quarkonium created in heavy-ion collisions is intrinsically connected to the correlation functions of adjoint chromoelectric fields in quantum chromodynamics. Such correlation functions are vital in determining transport coefficients that govern the evolution of heavy quarkonium inside the QGP.

I will identify three distinct gauge-invariant correlators and present their next-to-leading order (NLO) perturbative calculation in a weak-coupling expansion in a thermal medium. Interestingly, two of the resulting correlators turn out to be asymmetric and the results are shown to be in excellent agreement with recent lattice calculations at high temperatures. Finally, I will also outline how these correlators can be used to extract transport coefficients.

Authors: Prof. VAIRO, Antonio (Technical University of Munich); Prof. BRAMBILLA, Nora (Technical University of Munich); PANAYIOTOU, Panayiotis (Technical University of Munich); Dr SÄPPI, Saga (CSIC)

Presenter: PANAYIOTOU, Panayiotis (Technical University of Munich)

Session Classification: Poster Session

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **68** Type: **Talk**

3D Pion crystal from the chiral anomaly

Wednesday 2 July 2025 15:15 (20 minutes)

Including the effects of the chiral anomaly in Chiral Perturbation Theory at finite baryon chemical potential, it has been shown that neutral pions form an inhomogeneous phase dubbed the "Chiral Soliton Lattice" (CSL) above a certain critical magnetic field. Above a second, even higher critical field, the CSL becomes unstable to fluctuations of charged pions, implying they condense.

I will point out the similarity of this second critical field to the upper critical magnetic field in conventional type-II superconductors, suggesting that an inhomogeneous phase of superconducting charged pion exists beyond this point. Applying similar methods originally used by Abrikosov, I will present results where we've constructed such a phase and show the region where it is preferred in the baryon chemical potential-magnetic field phase diagram at zero temperature. This new phase has a non-zero baryon number density which is periodic in all three spatial dimensions.

Authors: SCHMITT, Andreas (University of Southampton); EVANS, Geraint (Academia Sinica)

Presenter: EVANS, Geraint (Academia Sinica)

Track Classification: Dense QCD

Contribution ID: **70** Type: **Poster**

Magnetized by Rotation: The Role of Axial Vector Fields in the rotating NJL-model

Thursday 3 July 2025 19:40 (20 minutes)

Rotation is known to restore chiral symmetry at high angular velocities, but it is also expected that rotation can induce an axial-vector condensate. This condensate, often overlooked, can significantly alter the behavior of the chiral condensate, potentially enhancing it under rapid rotation. To investigate this interplay, we compute the phase diagram of the chiral and axial vector condensates within a NJL-model in a rigidly rotating frame in the mean field approximation.

Our results indicate that when chiral symmetry is fully restored, the axial vector condensate vanishes. Conversely, in regimes where chiral symmetry is spontaneously broken, a finite axial vector condensate emerges. Notably, at low temperatures and moderate angular velocities, the chiral condensate is enhanced in the same region where the axial vector condensate becomes finite. At high temperatures, both condensates vanish, consistent with theoretical expectations.

Our findings reveal novel phases with implications for the physics of neutron stars, where rapid rotation can generate axial vector condensates. The axial vector condensate, closely linked to magnetization, provides a compelling framework to explain the extreme magnetization observed in neutron stars.

Authors: DASH, Ashutosh; KIEFER, Lutz (Goethe University Frankfurt)

Presenter: KIEFER, Lutz (Goethe University Frankfurt)

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **72** Type: **Talk**

Out-of-equilibrium CME conductivity from lattice QCD

Thursday 3 July 2025 17:00 (20 minutes)

In this talk, we present a study of the out-of-equilibrium CME conductivity via Kubo formulas using lattice QCD simulations. We present an analytic study of the CME Kubo formula in 1-loop perturbation theory, which sheds light on the nature of the CME in a system of non-interacting fermions. We then determine the Euclidean correlator as a function of the (imaginary) time using full dynamical simulations at the physical point, analyzing some of its characteristics and how they can be directly related to the conductivity. Finally, we extract the spectral function from the Euclidean correlator using well-known spectral reconstruction methods, discussing the temperature dependence of the determined conductivity in QCD.

Authors: BRANDT, Bastian (University of Bielefeld); ENDRŐDI, Gergely; GARNACHO VELASCO, Eduardo; MARKO, Gergely (University of Bielefeld); MARQUES VALOIS, Adeilton Dean

Presenter: GARNACHO VELASCO, Eduardo

Track Classification: Lattice QCD

Contribution ID: **73** Type: **Talk**

Color Superconductivity in two-flavor QCD and its role in neutron stars

Thursday 3 July 2025 12:00 (20 minutes)

We investigate color superconductivity in two-flavor QCD and its impact on the equation of state for dense matter in neutron stars. Employing a quark-meson-diquark model truncation within the functional renormalization group framework, we analyze the formation of diquark and chiral condensates and characterize the resulting superconducting phase at high baryon densities.
Our results provide insights into the phase structure of QCD under extreme conditions and suggest that color-superconducting quark matter may play a significant role in the composition of neutron star cores and other astrophysical phenomena.

Author: SCHAEFER, Bernd-Jochen

Presenter: SCHAEFER, Bernd-Jochen

Track Classification: Dense QCD

Contribution ID: **75** Type: **Poster**

Probing Nuclear Structure Using Event Topology: A Spherocity-Based Study of Deformation Effects

Thursday 3 July 2025 19:40 (20 minutes)

We investigate the influence of nuclear structure on transverse spherocity (S_0) distributions in ^{238}U +^{238} U collisions at $\sqrt{S_{NN}}$ = 193 GeV. The initial spatial anisotropy of colliding nuclei is expected to imprint distinct signatures on final-state event topology. Hydrodynamic evolution translates these initial geometric anisotropies into momentum-space correlation via collective flow. S_0 integrates over these correlations, making it a sensitive probe of both initial geometry and nuclear structure.

Our results demonstrate a strong dependence of S_0 on the quadrupole deformation β_2, with larger deformations shifting the distribution toward more anisotropic (jet-like) events. In contrast, no significant effects are observed for triaxiality (γ), octupole (β_3), and hexadecapole (β_4)deformations when using the standard S_0 definition. However, by isolating p_T fluctuations through $\delta p_T = (p_T - \langle p_T \rangle)/\langle p_T \rangle$ and δp_T^2, we uncover subtle but systematic variations in distribution for different and values. These results demonstrate that while β_2 dominantly modulates global event isotropy, higher-order deformations (β_3, β_4) manifest only when S_0 is generalized to incorporate p_T-fluctuation-driven observables. These findings establish a new connection between initial-state nuclear structure and final-state momentum anisotropies. We propose this fluctuation-sensitive S_0 as a novel tool for heavy-ion experiments to constrain nuclear deformation parameters through event-shape engineering, complementing traditional flow measurements.

Author: Mr SAHA, Abhisek (Peking University)

Co-author: MEHRABPOUR, Hadi (Peking Univresity)

Presenter: Mr SAHA, Abhisek (Peking University)

Session Classification: Poster Session

Track Classification: Phenomenology & Experiment

Contribution ID: **76** Type: **Talk**

Cold quark matter: Renormalization group improvement

Wednesday 2 July 2025 16:30 (20 minutes)

We will discuss the recent developments in renormalization group improvements of the cold and dense QCD pressure (Phys. Rev. D 111, 034020 and Phys. Rev. Lett. 129, 212001) at next-to-next-to leading order (NNLO) through the renormalization group optimized perturbation theory (RGOPT) and at all-order resummation of the soft modes. RGOPT applied for the very first time at NNLO displayed a significant reduction in sensitivity to variations of the arbitrary renormalization scale as compared to the state-of-the-art NNLO results. This confirms previous NLO investigations that the RGOPT resummation scheme provides improved convergence properties and reduced renormalization scale uncertainties, thus being a promising prescription to improve perturbative QCD at high and mid range baryonic densities.

Author: FERNANDEZ, Loïc (Helsinki Institute of Physics, University of Helsinki)

Co-author: Prof. KNEUR, Jean-Loïc (Laboratoire Charles Coulomb)

Presenter: FERNANDEZ, Loïc (Helsinki Institute of Physics, University of Helsinki)

Track Classification: Dense QCD

Contribution ID: **77** Type: **Poster**

The (2+1)-dimensional Gross-Neveu-Yukawa Model in large magnetic fields with the Functional Renormalization Group

Thursday 3 July 2025 19:40 (20 minutes)

In this work, we calculate the phase diagram of the (2+1)-dimensional Gross-Neveu-Yukawa (GNY) model under strong magnetic fields at finite temperature and density. Large magnetic fields result in magnetic catalysis, a dimensional reduction of the system and enhancement of the chiral symmetry breaking. Using the functional renormalization group (FRG) in a hydrodynamic approach allows us to solve for the full effective potential at constant flavor numbers.

Author: MAULDIN, Justin (Frankfurt University)

Presenter: MAULDIN, Justin (Frankfurt University)

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **78** Type: **Poster**

Exploring charm-quark hadronization via charm-tagged jet and correlation measurements using machine learning with ALICE

Thursday 3 July 2025 19:40 (20 minutes)

Fragmentation functions are fundamental components of the factorization approach which is used to calculate the production cross sections of heavy-flavor hadrons within QCD. Due to their non-perturbative nature, they cannot be computed a priori and are typically extracted from measurements in clean environments such as electron-positron (e^+e^-) or electron-proton (e^-p) collisions. However, recent measurements of the relative abundances of various charmed hadrons in proton-proton (pp) collisions have questioned the universality of charm fragmentation across leptonic and hadronic collision systems.

In this contribution, we present measurements that consider not only heavy-flavor hadrons but also the surrounding charged particles, as angular correlations between charm hadrons and charged particles, and charm-tagged jets.

These observables enable a closer connection to charm fragmentation functions and provide stronger constraints on the hadronization process in hadronic collisions. A Boosted Decision Tree (BDT) classifier is employed to reconstruct charm hadrons in pp collisions at $\sqrt{s} = 13.6$ TeV using data recorded by the ALICE during the Run 3 of the LHC. The FAIR Spoke 6 Project, funded by the NextGenerationEU program in Italy, supports these studies as a valuable use-case to find efficient computing solutions for AI-oriented applications. We report measurements of the fraction of jet longitudinal momentum carried by D^0 and Λ_c^+ baryons. Additionally, we present azimuthal correlation distributions of D_s^+, D^+, D^0 mesons, and Λ_c^+ baryons with charged particles. Further insight into the correlation patterns is obtained through the extraction of quantitative observables such as the near- and away-side peak integrals and widths. The results are compared to state-of-the-art theoretical predictions to improve our understanding of charm-quark fragmentation and hadronization in hadronic environments. Finally, an outlook on the status of the analysis of D_s^+-meson and charged particles correlation in central and semicentral Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 5.36$ TeV will be presented.

Author: Mr KUMAR, Shyam (Universita e INFN, Bari (IT))

Presenter: Mr KUMAR, Shyam (Universita e INFN, Bari (IT))

Session Classification: Poster Session

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **79** Type: **Talk**

First Demonstration that Quark-Gluon Plasma has a Nonzero Resolution Length

Friday 4 July 2025 15:15 (20 minutes)

We begin by using Hybrid Model calculations to reproduce experimental results published by ATLAS in 2023 on R_{AA} for $R = 1$ jets in Pb+Pb collisions. These jets are identified by first reconstructing anti-k_t $R = 0.2$ subjets and then re-clustering them. Following ATLAS, we investigate how R_{AA} for these jets depends on the angle between the two subjets involved in the final clustering step of the $R = 1$ jet. We also study the dependence of R_{AA} for these jets on the resolution length of quark-gluon plasma (QGP), defined such that the QGP-medium can only resolve partons in a jet shower that are separated by more than this length. We demonstrate that this measurement pioneered by ATLAS rules out any picture in which an entire parton shower loses energy coherently as a single entity.

We further use this setup of $R = 1$ jets reclustered from $R = 0.2$ skinny subjets to evaluate the soft drop angle, notated as dR_{12}, using all charged-particle tracks that are associated with each $R = 1$ jet. Following another ATLAS measurement published in 2025, we use Hybrid Model calculations to investigate the dependence of $R = 1$ jet R_{AA} on the soft drop angle dR_{12}. We demonstrate that this new measurement from ATLAS rules out any picture in which all partons in a shower lose energy fully incoherently. Therefore, our analysis demonstrates, for the first time, that the QGP has a finite nonzero resolution length.

Authors: KUDINOOR, Arjun Srinivasan (Massachusetts Institute of Technology); Dr PABLOS, Daniel (INFN Torino); RAJAGOPAL, Krishna (Massachusetts Inst. of Technology (US))

Presenter: KUDINOOR, Arjun Srinivasan (Massachusetts Institute of Technology)

Track Classification: Phenomenology & Experiment

Contribution ID: **80** Type: **Poster**

Born rate equivalence for the kinetic theory and quantum field theory approach

Thursday 3 July 2025 19:40 (20 minutes)

Dileptons are considered to be an important observable, in the context of studying the characteristics of the deconfined phase of quark gluon plasma (QGP). Historically, the dilepton production rates (DPR) from the QGP have been studied using two different approaches. In the quantum field theory (QFT) approach, the DPR is expressed in terms of the thermal expectation value of the current-current correlator 1 or the imaginary part of the photon self energy [2]. On the other hand, the kinetic theory (KT) framework assumes the QGP to be sufficiently weakly coupled, such that the quarks can be considered as quasiparticles and the DPR is computed based on a collision kernel for an inelastic scattering process. We discuss the equivalence of the two approaches at the Born level, where the QFT and KT frameworks give identical results.

Keywords: Dilepton production rate, Kinetic theory, Quark gluon plasma.

References:

1. D. McLerran and T. Toimela, Phys. Rev. D 31, 545 (1985).
2. H. A. Weldon, Phys. Rev. D 42, 2384 (1990).
3. K. Kajantie, J. I. Kapusta, L. D. McLerran, and A. Mekjian, Phys. Rev. D 34, 2746 (1986)

Author: KUNDU, Moulindu (West University of Timisoara)

Co-authors: BANDYOPADHYAY, Aritra; Dr AMBRUS, Victor (West University of Timişoara)

Presenter: KUNDU, Moulindu (West University of Timisoara)

Session Classification: Poster Session

Track Classification: QCD in external fields

Contribution ID: **81** Type: **Talk**

Results on magnetohydrodynamics simulations with BHAC-QGP

Friday 4 July 2025 16:50 (20 minutes)

We present BHAC-QGP, a numerical framework for simulating the evolution of quark-gluon plasma (QGP) in relativistic heavy-ion collisions under strong magnetic fields. Based on the general-relativistic magnetohydrodynamics code BHAC, originally developed for astrophysical applications, BHAC-QGP incorporates finite electrical conductivity and uses Adaptive Mesh Refinement (AMR) to capture QGP dynamics across multiple scales with high precision. Simulations of Au+Au collisions at RHIC energies demonstrate excellent agreement with established results and improved resolution of electromagnetic effects. Furthermore, we show that causality and a consistent treatment of Ohm's law are essential for modeling early-time electromagnetic fields in such collisions. In particular, finite electrical conductivity plays a critical role in describing the directed flow recently measured by the STAR experiment. These features make BHAC-QGP a valuable tool for studying magneto-hydrodynamic effects in heavy-ion collisions.

Authors: DASH, Ashutosh; RISCHKE, Dirk; Dr INGHIRAMI, Gabriele (Darmstadt University); ELFNER, Hannah; REZZOLLA, Luciano; Mr MAYER, Markus (Goethe University, Frankfurt)

Presenter: DASH, Ashutosh

Track Classification: Fluid dynamics and collectivity

Contribution ID: **82** Type: **Poster**

Energy Density Functional of Confined Quarks

Thursday 3 July 2025 19:40 (20 minutes)

We present an improved ansatz for the self-energy of confined quarks within a density functional formalism in order to investigate the thermodynamics of dense matter, particularly, the speed of sound and baryon fluctuations, including studying their approach toward the conformal limit. The formulation offers insight into how characteristic scales inherent to a theory lead to mimicking confinement, as well as how asymptotic freedom and confinement have different origins. By incorporating asymptotic freedom, our model addresses the long-standing problem of non-conformality of speed of sound observed in many equations of state (EoS) in the COMPOSE database that also either lack confinement or rely on ad hoc modifications to capture it.

Reference - U. Shukla and P. M. Lo. Energy Density Functional of Confined Quarks: an Improved Ansatz. 4 2025

Author: Ms SHUKLA, Udita (University of Wroclaw)

Co-author: Prof. LO, Pok Man (University of Wroclaw)

Presenter: Ms SHUKLA, Udita (University of Wroclaw)

Session Classification: Poster Session

Track Classification: Dense QCD

Contribution ID: **83** Type: **Talk**

Signatures of local acceleration of quark-gluon plasma in the dilepton production

Friday 4 July 2025 15:35 (20 minutes)

Dilepton emissions represent a key probe for characterising the Quark-Gluon Plasma (QGP). A central role in computing dilepton yields is played by the imaginary part of the electromagnetic current-current correlation, or equivalently, of the photon polarisation tensor 1. In this work, we investigate the influence of local acceleration on dilepton production. We compute this quantity in a thermal medium subject to acceleration. We assume the acceleration is sufficiently small so that it can be treated as a perturbation. We employ the thermal Dirac propagator in an accelerated frame, recently formulated within the imaginary-time formalism in [2]. Using a small acceleration expansion, we evaluate the imaginary part of the photon polarization tensor. Our perturbative results are then compared with the case of vanishing acceleration, allowing us to clearly isolate and identify the effects introduced by local acceleration.

Keywords: Dilepton production rate, Accelerated medium, Quark gluon plasma.

References:
1 L. D. McLerran and T. Toimela, Phys. Rev. D 31, 545 (1985).
[2] V. E. Ambruș and M. N. Chernodub, Phys. Lett. B 855, 138757 (2024).

Authors: BANDYOPADHYAY, Aritra; Dr AMBRUS, Victor (West University of Timişoara); Dr CHERNODUB, Maxim ((i) Institut Denis Poisson, Tours, France and (ii) West University of Timişoara, Romania); KUNDU, Moulindu (West University of Timisoara)

Presenter: BANDYOPADHYAY, Aritra

Track Classification: QCD in external fields

Contribution ID: **84** Type: **Talk**

Finite-size scaling analysis of cumulants of net proton number and the QCD critical point

Wednesday 2 July 2025 11:00 (20 minutes)

We explore the validity of finite-size scaling of net-proton number cumulants as a tool to search for evidence of a critical point in the QCD phase diagram. We show that in central Au+Au collisions at $\sqrt{s_{\rm NN}} = 7.7$ GeV and above, the second cumulant C2 as a function of rapidity bin width follows a power-law consistent with scale invariance. We then show that for any bin width, C2 increases as a power-law with baryon chemical potential μ_B. This behavior is consistent with scaling near a critical point, and our analysis identifies a range of plausible critical exponents, including mean field and 3-D Ising model critical exponents, as well as critical μ_B values, ranging between 500 MeV and 615 MeV which is consistent with recent theoretical expectations. To understand the origin of this apparent scale-free, power-law behavior, we perform the same analysis on simulation data from SMASH hadronic transport in the cascade mode.

Authors: SORENSEN, Agnieszka (Facility for Rare Isotope Beams); SORENSEN, Paul (DOE)

Presenter: SORENSEN, Agnieszka (Facility for Rare Isotope Beams)

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **86** Type: **Poster**

Spin hydrodynamics: the hybrid approach

Thursday 3 July 2025 19:40 (20 minutes)

We propose a hybrid approach, which may help to establish consistency between different formulations of spin hydrodynamics. The perfect fluid is described in the framework of kinetic theory of particles with spin 1/2 following the Fermi-Dirac statistics. The baryon number, energy, linear momentum, the spin part of angular momentum, as well as entropy are conserved, although in the presence of spin degrees of freedom the expressions for the baryon current, the energy-momentum tensor and the spin tensor contain terms whose mathematical form is seemingly typical of dissipative corrections. Genuinely dissipative terms are introduced in our approach via the Israel-Stewart method, using the condition of positive entropy production, which allows for transfer between the spin and orbital parts of angular momentum.
Based on: Zbigniew Drogosz, Wojciech Florkowski, Mykhailo Hontarenko, Hybrid approach to perfect and dissipative spin hydrodynamics, Phys. Rev. D 110, 096018 (2024)

Author: DROGOSZ, Zbigniew (Jagiellonian University)

Co-authors: HONTARENKO, Mykhailo (Jagiellonian University); FLORKOWSKI, Wojciech (Jagiellonian University)

Presenter: DROGOSZ, Zbigniew (Jagiellonian University)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **87** Type: **Poster**

Thermodynamics of QCD with 8 flavors

Thursday 3 July 2025 19:20 (20 minutes)

We explore the phase diagram of 8 flavor QCD by lattice simulations, using a stout improved staggered fermion action and a tree-level Symanzik improved gauge action. At small masses we observe an intermediate phase between the strong coupling and the weak coupling phases, aligning with results from previous studies. We also investigate the effect of adding an imaginary chemical potential.

Authors: ZAMBELLO, Kevin (University of Pisa and INFN, Sezione di Pisa); D'ELIA, Massimo (University of Pisa); NACCI, Marco (University of Pisa)

Presenter: ZAMBELLO, Kevin (University of Pisa and INFN, Sezione di Pisa)

Session Classification: Poster Session

Track Classification: Lattice QCD

Contribution ID: **88** Type: **Talk**

Finite spin density effects on the QCD phase transition in the linear sigma model

Wednesday 2 July 2025 17:10 (20 minutes)

The experimental observation of the spin polarisation of the outgoing hadrons in non-central heavy ion collisions implies the existence of a strongly vortical QGP medium with finite spin density. We consider the effect of finite spin density on the QCD phase diagram using the Linear Sigma model coupled to quarks (LSMq). In our approach, we introduce the finite spin density via a quark spin potential (μ_s) in the canonical formulation of the spin operator, leading to a nonlinear modification of the energy dispersion relation. Besides an expected effect on the thermal fermion loop, the spin potential also enters non-trivially in the zero-point, temperature-independent part of the fermion loop. Employing renormalization techniques 1, we observe a substantial influence of this term on the phase structure of the system at nonnegligible μ_s/T. Taking both the thermal and the zero-point terms into account, we find the expectation value of the sigma condensate by minimizing the thermodynamic potential of the system. Our findings indicate that, starting from a chiral symmetry broken phase at small T and μ_s, the minima of the thermodynamic potential moves towards lower values of σ with increasing μ_s, indicating the restoration of chiral symmetry. This behaviour is consistent with the results from the first principle lattice simulations [2].

Keywords: Quark-Gluon-Plasma, chiral phase transition, spin potential.

References:
1 A. Ayala, L.A. Hernandez, M. Loewe, J.C. Rojas, R. Zamora, Eur. Phys. J. A 56 (2020)71.
[2] V.V. Braguta, M.N. Chernodub, A.A. Roenko, arXiv:2503.18636

Author: SINGHA, Pracheta (west university of Timisoara)

Co-authors: BANDYOPADHYAY, Aritra; Dr CHERNODUB, Maxim ((i) Institut Denis Poisson, Tours, France and (ii) West University of Timişoara, Romania); Dr BUSUIOC, Sergiu (West University of Timişoara); Dr AMBRUS, Victor (West University of Timişoara)

Presenter: SINGHA, Pracheta (west university of Timisoara)

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **89** Type: **Poster**

Exact Wigner function for chiral spirals

Thursday 3 July 2025 19:40 (20 minutes)

At present, our understanding of the non-equilibrium aspects of a relativistic spin fluid is derived from the study of Wigner function coupled with the semiclassical expansion. In our work, we present an exact computation (up to quantum loop corrections) of the Wigner functions for quarks in a field of oscillating pion condensate. The oscillating pion condensate enters the equation of motion as a mean field, allowing for an exact solution. The spinors thus obtained are used to compute all components of the Wigner functions. Our findings indicate that some of the resulting coefficients of the Wigner function are incompatible with the standard semiclassical expansion. Furthermore, the axial vector component of the Wigner function is used to study spin polarization effects and illustrate connections between the spin density matrix and axial current. In particular, we find that during an adiabatic change of the periodic potential into a uniform one, the polarization vector is twisted from its original direction.

Authors: Mr BHADURY, Samapan (Jagiellonian University); FLORKOWSKI, Wojciech (Jagiellonian University); KAR, Sudip Kumar; MYKHAYLOVA, Valeriya (University of Wrocław)

Presenter: KAR, Sudip Kumar

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **90** Type: **Talk**

Spin density and local equilibrium Wigner function for spin-half particles

Wednesday 2 July 2025 15:35 (20 minutes)

Analyzing the connections between the spin density matrix and the Wigner function for spin-half particles, we propose a new form of the local equilibrium Wigner function that solves the long-standing problem related to normalization of mean spin polarization. Interestingly, this new proposal for the local equilibrium Wigner function coincides with the recently developed generalized thermodynamic relations for perfect spin hydrodynamics using classical spin. The expressions of the conserved currents of the theory, obtained from the new Wigner function and the classical spin, match up to the second order in the spin polarization tensor. However, as expected, the two approaches fail to coincide at large values of the mean polarization.

Authors: Mr BHADURY, Samapan (Jagiellonian University); KAR, Sudip Kumar; MYKHAYLOVA, Valeriya (University of Wrocław); FLORKOWSKI, Wojciech (Jagiellonian University)

Presenter: Mr BHADURY, Samapan (Jagiellonian University)

Track Classification: Other

Contribution ID: **91** Type: **Poster**

The moat regime in the quark meson model with the FRG

Thursday 3 July 2025 19:40 (20 minutes)

We use the functional renormalization group in the local potential approximation, with the full effective potential, to investigate the quark meson model for the presence of inhomogenious phases. To this end, we solve the flow equation for the bosonic two point function, to investigate if the two point function shows a negative wave function renormalization or even a zero crossing. Furthermore we observe the necessity of employing the correct numerical procedure to avoid oscillations in the higher derivatives of the effective potential which appear in the flow equation of the two point function.

Author: PÖPLAU, Johannes

Co-author: Mr KIEFER, Lutz (Goethe University Frankfurt)

Presenter: PÖPLAU, Johannes

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **92** Type: **Talk**

Flux tube structure in finite temperature QCD

Friday 4 July 2025 11:20 (20 minutes)

We present a study of the structure of the chromoelectrical field created by a static quark-antiquark pair in lattice QCD with 2+1 flavours of dynamical quarks, where the quark masses are set to their physical values. The analysis covers a wide range of temperatures both above and below the chiral crossover, and explores varying quark-antiquark distances, with the aim of identifying signals of deconfinement and string breaking in the field structure. To this end we apply the zero-curl perturbative field subtraction method, developed in our earlier studies of pure gauge SU(3) theory and of full QCD at zero temperature.

Authors: BAKER, Marshall (Department of Physics, University of Washington); CEA, Paolo (INFN - Sezione di Bari); CHELNOKOV, Volodymyr (Institut für Theoretische Physik, Goethe Universität); COSMAI, Leonardo (INFN - Sezione di Bari); PAPA, Alessandro (Dipartimento di Fisica dell'Università della Calabria and INFN - Gruppo collegato di Cosenza)

Presenter: CHELNOKOV, Volodymyr (Institut für Theoretische Physik, Goethe Universität)

Track Classification: Lattice QCD

Contribution ID: **93** Type: **Talk**

QCD transition line up to μ_B=400 MeV from finite volume lattice simulations

Wednesday 2 July 2025 09:50 (20 minutes)

The QCD cross-over line in the temperature (T) - baryo-chemical potential (μ_B) plane has been computed by several lattice groups by calculating the chiral order parameter and its susceptibility at finite values of μ_B . In this work we extract from the peak position of the static quark entropy ($S_Q(T, \mu_B)$) in T, which is based on the renormalized Polyakov loop. This observable was proved to have a peak in the vicinity of the chiral transition temperature, as was illustrated in arXiv:1603.06637, and has smaller volume effects, as was shown in arXiv:2405.12320. The small volume is here useful to mitigate the effects of the sign problem in the cancellations inside the Taylor coefficients of the Polyakov loop. We extrapolate $S_Q(T, \mu_B)$ based on high statistics finite temperature ensembles on a $16^3 \times 8$ lattice to finite density by means of a Taylor expansion to eighth order in μ_B (NNNLO) along the strangeness neutral line. For the simulations the 4HEX staggered action was used with 2+1 flavors at physical quark masses. In this setup the phase diagram can be drawn up to unprecedentedly high chemical potentials. Our results are in rough agreement with phenomenological estimates of the freeze-out curve in relativistic heavy ion collisions. In addition, we study the width of the crossover. We show that up to $\mu_B \approx 400$ MeV, the transition gets broader at higher densities, disfavoring the existence of a critical endpoint in this range. Finally, we examine the transition line without the strangeness neutrality condition and observe a hint for the narrowing of the crossover towards large μ_B.

Authors: BORSANYI, Szabolcs Istvan; FODOR, Zoltan (BUW); GUENTHER, Jana N. (University of Wuppertal); PAROTTO, Paolo; PASZTOR, Attila (Eötvös University); PIRELLI, Ludovica (Bergische Universität Wuppertal); SZABO, Kalman; Dr WONG, Chik Him

Presenter: PIRELLI, Ludovica (Bergische Universität Wuppertal)

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **97** Type: **Poster**

Role of isospin asymmetry in the onset of quark matter in neutron stars

Thursday 3 July 2025 19:40 (20 minutes)

While symmetric nuclear matter has been studied in laboratories, neutron star matter is characterized by high asymmetry. Therefore, by examining the strongly interacting matter properties in a wide range of densities and isospin asymmetry we confront two regimes to understand how the enforced electric neutrality and beta equilibrium alter the onset density of quark matter. Particularly, we demonstrate the dependence of the onset density of deconfined quarks in the electrically neutral beta-equilibrated matter on the onset density for symmetric matter. This allows us to map the phase diagram of cold strongly interacting matter in the plane of baryon density vs isospin asymmetry which is important in modeling hybrid stars based on the nuclear and low-energy heavy-ion collision experiments.

Authors: BLASCHKE, David; IVANYTSKYI, Oleksii (University of Wroclaw); PANASIUK, Pavlo; Dr SAGUN, Violetta (University of Southampton)

Presenter: PANASIUK, Pavlo

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **98** Type: **Poster**

Non-relativistic stochastic hydrodynamics

Thursday 3 July 2025 19:40 (20 minutes)

Stochastic hydrodynamics provides a dynamical framework for the evolution of fluctuations in heavy-ion collisions. Due to the small volume of the system, thermal fluctuations can become sizeable and probe the equation of state of the system, being particularly sensitive to a possible QCD critical endpoint.
Our present numerical setup can simulate stochastic non-relativistic hydrodynamics in a box, taking only equations of state and transport coefficients as input parameters. Fluctuations are sampled in a Metropolis update step. Since the acceptance probability depends specifically on the change in entropy, the setup is particularly stable and robust to the typical problem of unphysical entropy production. Additionally, approximations or microscopic assumptions about the fluctuations are not necessary.
Apart from the details of the numerical setup, we discuss the connection to Model H in the classification by Halperin & Hohenberg and present macroscopic and microscopic numerical test cases for equilibration properties and fluctuation-dissipation relations. We present lattice calculations of the renormalization of transport coefficients and give an outlook to relativistic hydrodynamics.

Author: HARHOFF, Mattis (Universität Bielefeld)

Presenter: HARHOFF, Mattis (Universität Bielefeld)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **99** Type: **Poster**

Dissecting the moat regime

Thursday 3 July 2025 19:40 (20 minutes)

Dense QCD matter can feature a moat regime, where the static energy of mesons is minimal at nonzero momentum. We elucidate various features of this regime in this work. To capture the main effects, we use a two-flavor quark-meson model and put forward an efficient renormalization scheme to account for the nontrivial momentum dependence of meson self-energies in the moat regime.
We show that the extent of the moat regime critically depends on the interaction of quarks and mesons, and analyze quark and meson correlation functions in this regime. Since it arises from particle-hole fluctuations of quarks in a dense medium, the resulting spatial modulations manifest in various different meson correlations, including scalar, pseudoscalar, vector and axialvector mesons. We clarify the nature of these modulations based on the analytic structure of meson self-energies, demonstrating in particular their distinction from Friedel oscillations which also occur in the presence of a Fermi surface. In contrast, while quark correlations are enhanced in the moat regime, they do not show oscillatory behavior.

Authors: RENNECKE, Fabian (Justus Liebig University Giessen); YIN, Shi (Institute for Theoretical Physics, Justus Liebig University Giessen)

Presenter: YIN, Shi (Institute for Theoretical Physics, Justus Liebig University Giessen)

Session Classification: Poster Session

Track Classification: Phase diagram and critical behaviour in QCD/QFT

Contribution ID: **100** Type: **Poster**

The rho-pi puzzle and vector glueball mixing

Thursday 3 July 2025 19:40 (20 minutes)

The $\psi(3686)$ is identified as the radial excitation of the J/ψ. Based on perturbative QCD, the branching ratio of the $\psi(3686)$ into some final hadron state should be approximately 13\% of the branching ratio of the J/ψ to that same hadron final state. This is called the "13\% rule". However, certain decay channels such as the $\rho\pi$ severely violate this 13\% rule. Using the extended Linear Sigma Model, we study the effect a small mixing angle between the $\psi(3686)$ and the vector glueball can have on the 13\% rule. It turns out that both electromagnetic decay channels and a mixing with the vector glueball are necessary to match experimental data in this setup.

Author: VEREIJKEN, Arthur (UJK Jan Kochanowski University Kielce)

Presenter: VEREIJKEN, Arthur (UJK Jan Kochanowski University Kielce)

Session Classification: Poster Session

Track Classification: Correlations, bound states and hadron spectroscopy

Contribution ID: **101** Type: **Poster**

Hydrodynamic spin feedback in boost-invariant expansion

Thursday 3 July 2025 19:40 (20 minutes)

A recently formulated extension of perfect spin hydrodynamics, which includes second-order corrections in the spin polarization tensor to the energy-momentum tensor and baryon current, is studied in the case of a one-dimensional boost-invariant expansion. The presence of second-order corrections introduces feedback from spin dynamics on the hydrodynamic background, constraining possible spin polarization configurations. However, as long as the magnitude of the spin polarization tensor remains small (below unity in natural units), the permitted spin dynamics differs very little from that found in the case without the second-order corrections.

Based on: Z.Drogosz, W.Florkowski, N.Łygan, R.Ryblewski, Boost-invariant spin hydrodynamics with spin feedback effects, arXiv:2411.06154 [hep-ph].

Presenter: ŁYGAN, Natalia (Jagiellonian University)

Session Classification: Poster Session

Track Classification: Fluid dynamics and collectivity

Contribution ID: **102** Type: **Poster**

Bulk viscosity of two-colour superconducting quark matter in neutron star mergers

Thursday 3 July 2025 19:40 (20 minutes)

We study the bulk viscosity of moderately hot and dense, neutrino-transparent colour superconducting quark matter arising from weak-interaction-driven direct URCA processes. The quark matter is modeled using the Nambu-Jona-Lasinio model extended to include both vector interactions and the ʻt Hooft determinant term. The superconducting phase is described by using the two-flavour red-green paired colour-superconducting (2SC) phase, while allowing for the presence of unpaired strange quarks and blue colour light flavours. We compute the relaxation rates associated with d and s-quark decay and electron capture processes on u quark for blue colour, the associated bulk viscosity, as well as the damping timescales in the frequency range 1-10 kHz, relevant to binary neutron star mergers. Our results show that the damping of density oscillations in 2SC phase can be a leading mechanism of dissipation in merging hybrid stars containing colour-superconducting cores and is quantitatively similar to that predicted for nucleonic matter.

Presenter: Mr TSIOPELAS, Stefanos (University of Wrocław)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **103** Type: **Talk**

Nuclear chiral density wave in neutron stars?

Wednesday 2 July 2025 14:30 (45 minutes)

Cold and dense QCD matter may break rotational invariance spontaneously. One candidate phase is the chiral density wave, which exhibits an anisotropic chiral condensate, and which is conjectured to occur in the vicinity of the quark-hadron transition. I will employ a nucleon-meson model that allows for a chiral phase transition to explore the possibility of a chiral density wave in nuclear matter and throughout the transition. Besides the simplest case of isospin-symmetric matter, I will discuss the fate of the chiral density wave under neutron star conditions. I will show that the chiral density wave is only favored for model parameters that result in very soft matter, too soft to allow for realistic neutron stars.

Presenter: SCHMITT, Andreas (University of Southampton)

Track Classification: Dense QCD

Contribution ID: **104** Type: **Talk**

Isotropization in heavy ion collisions in the 2PI formalism

Thursday 3 July 2025 17:20 (20 minutes)

An important question in heavy-ion collisions is how the initial far-from-equilibrium medium evolves and thermalizes while it undergoes a rapid longitudinal expansion. In this presentation, I will show how to use the two-particle irreducible (2PI) effective action to address this question, focusing on phiˆ4 scalar theory truncated at three loops. I will present numerical results for quantities such as the occupation number, the thermal mass, and the number density.

Author: GELIS, Francois

Presenter: GELIS, Francois

Track Classification: Non-equilibrium dynamics/non-equilibrium aspects of QCD

Contribution ID: **105** Type: **Talk**

Pi in the sky: Axion condensation in neutron stars

Thursday 3 July 2025 09:00 (45 minutes)

The QCD axion, originally proposed nearly five decades ago as a solution to the strong CP problem, remains one of the most compelling dark matter candidates. In this talk, I will explore the possibility that axions may undergo Bose-Einstein condensation in the dense cores of neutron stars, where extreme baryon densities could facilitate such a phase. Employing Chiral Perturbation Theory in conjunction with nuclear forces derived from Chiral Effective Field Theory, I will present evidence that axion condensation is not only theoretically plausible but may have astrophysically relevant consequences. Detecting - or definitively excluding - axion condensation in neutron star interiors would allow us to probe previously inaccessible regions of axion parameter space, with potentially far-reaching implications for both axion phenomenology and the microphysics of dense nuclear matter.

Presenter: REDDY, Sanjay (University of Washington)

Track Classification: Nuclear astrophysics

Contribution ID: **106** Type: **Talk**

How to explain the unreasonable success of hydrodynamics in heavy-ion collisions

Friday 4 July 2025 14:30 (45 minutes)

Relativistic hydrodynamics is the covariant generalization of a classical (non-relativistic, non-quantum) model. Recent developments in the field can explain how it is possible for relativistic hydrodynamics to be predictive in a very small system, in which quantum effects like diffraction and discrete (rather than continuous) spin states are not suppressed. This can be particularly surprising, if one considers that the gradients, as well as the non-ideal corrections are large, especially during the initial stages. This is in contrast to the classical requirements for the applicability of viscous hydrodynamics.

Author: Dr TINTI, Leonardo (Uniwersytet Jana Kochanowskiego w Kielcach)

Presenter: Dr TINTI, Leonardo (Uniwersytet Jana Kochanowskiego w Kielcach)

Track Classification: Fluid dynamics and collectivity

Contribution ID: **107** Type: **Talk**

Exploring QCD phase diagram at finite temperature and density via lattice calculations

Friday 4 July 2025 09:00 (45 minutes)

In recent years, lattice QCD calculations have significantly advanced our understanding of the QCD phase diagram at finite temperature and baryon density. In this talk, I will discuss the QCD equation of state at finite baryon chemical potential, with particular emphasis on the Taylor expansion method used to extend lattice results to nonzero chemical potentials. I will highlight the role of cumulants of conserved charge fluctuations as essential probes of the properties of hot and dense QCD matter.
Additionally, I will review the current understanding of the curvature of the chiral phase transition lines as functions of the baryon chemical potential, both for physical light and strange quark masses and in the (2+1)-flavor chiral limit. Throughout the talk, I will continuously draw connections between these lattice results and the experimental efforts to locate the QCD critical point.

Author: SHARMA, Sipaz (Technische Universitat Munchen)

Presenter: SHARMA, Sipaz (Technische Universitat Munchen)

Track Classification: Lattice QCD

Contribution ID: **108** Type: **Talk**

Nonequilibrium dynamics in QCD and Holography

Thursday 3 July 2025 16:15 (45 minutes)

The plasma generated in heavy ion collisions goes through different phases in its time evolution. While early times right after the collision are governed by far-from equilibrium dynamics, later times are believed to be well described by near-equilibrium dynamics. While these regimes of nonequilibrium are complicated to describe within QCD, effective descriptions such as hydrodynamics provide a viable approach. In addition, holographic descriptions allow access to the full nonequilibrium dynamics. In this presentation, we review three examples of such hydrodynamic approaches and corresponding holographic descriptions: 1) nonequilibrium shear viscosity, 2) propagation of nonequilibrium sound waves, and 3) the nonequilibrium chiral magnetic effect.

Author: KAMINSKI, Matthias

Presenter: KAMINSKI, Matthias

Track Classification: Non-equilibrium dynamics/non-equilibrium aspects of QCD

Contribution ID: **109** Type: **Poster**

Primordial black-hole formation and heavy r-process element synthesis from the cosmological QCD transition. Two aspects of an inhomogeneous early Universe

Thursday 3 July 2025 19:40 (20 minutes)

We review the role of primordial black holes (PBHs) for illuminating the dark ages of the cosmological evolution and as dark matter candidates. We elucidate the role of phase transitions for primordial black hole formation in the early Universe and focus our attention to the cosmological QCD phase transition within a recent microscopical model. We explore the impact of physics beyond the Standard Model on the cosmic equation of state and the probability distribution for the formation of primordial black holes which serve as dark matter (DM) candidates. We argue that besides primordial black holes also droplet-like quark-gluon plasma inhomogeneities may become gravitationally stabilized for a sufficiently long epoch to distill baryon number and form nuclear matter droplets which upon their evaporation may enrich the cosmos locally with heavy r-process elements already in the early Universe.

Authors: BLASCHKE, David; Prof. RÖPKE, Gerd; Prof. HASINGER, Günther; GONIN, Mael; IVANYTSKYI, Oleksii (University of Wroclaw)

Presenter: BLASCHKE, David

Session Classification: Poster Session

Contribution ID: **110** Type: **Poster**

Hybrid Nuclear Matter EOS with Color Superconducting Quark Phase: Bayesian Constraints from Observations

Thursday 3 July 2025 19:40 (20 minutes)

We perform a Bayesian analysis of the equation of state (EOS) constraints using recent observational data, including pulsar masses, radii, and tidal deformabilities. Our focus is on a class of hybrid neutron star EOS that incorporates color superconducting quark matter, based on a recently developed nonlocal chiral quark model. The nuclear matter phase is described using a relativistic density functional approach within the DD2 class, while the phase transition between nuclear and quark matter is described using a Maxwell construction.
Our analysis identifies a region within the two-dimensional parameter space, defined by the vector meson coupling and scalar diquark coupling, where the observational constraints are met with the highest probability (90% of the maximum). We present the overlap of this region with those where other properties are fulfilled:
1. A strong phase transition that produces a third family of compact stars.
2. A maximum mass of the hybrid neutron star that exceeds that of the purely nucleonic star.
3. An onset mass for quark deconfinement below one solar mass.

Author: Dr AYRIYAN, Alexander (University of Wroclaw & AANL)

Presenter: Dr AYRIYAN, Alexander (University of Wroclaw & AANL)

Session Classification: Poster Session

Track Classification: Nuclear astrophysics

Contribution ID: **111** Type: **Talk**

Announcement of the XXIVth Conference on Quark Confinement and the Hadron Spectrum

Friday 4 July 2025 12:40 (5 minutes)

Presenter: BLASCHKE, David