Strong and Electroweak Matter

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Swansea University

Abstracts

Swansea University
Prifysgol Abertawe

Talks

The chiral transition in a magnetic background - finite density effects

Andersen, Jens Oluf

In this talk I will discuss the chiral phase transition in a constant magnetic field, using chiral perturbation theory and functional renormalization group techniques. We map out the phase diagram in the $\mu - T$ plane and locate the critical endpoint. At zero baryon chemical potential, the critical temperature is an increasing function of B. For large values of baryon chemical potential the opposite behaviour is observed.

Coupling dependence of jet quenching in hot strongly-coupled gauge theories

Arnold, Peter

Previous top-down studies of jet stopping in strongly-coupled QCD-like plasmas with gravity duals have been in the infinite 't Hooft coupling limit $\lambda \to \infty$. They have found that, though a wide range of jet stopping distances are possible depending on initial conditions, the maximum jet stopping distance $\ell_{\max}$ scales with energy as $E^{1/3}$ at large energy. But it has always been unclear whether the large-coupling and high-energy limits commute. We use the string α' expansion in AdS-CFT to study the corrections to the λ=∞ result in powers of $1/\lambda$ by assessing the effects of all higher-derivative corrections to the supergravity action for the gravity dual. We find that sometimes $\lambda = \infty$ results can be trusted for jet stopping, but other times the expansion in $1/\lambda$ breaks down.,

Anomaly induced charge dependence of the elliptic flow in heavy ion collisions

Burnier, Yannis

The plasma formed in heavy ion collisions contains charged chiral fermions evolving in an external magnetic field. The electromagnetic triangle anomaly induces a separation of the right and left chiral currents along the magnetic field. In the case of a non-vanishing baryon number density, the additional positive charges move away from the reaction plane so that poles of the fireball acquire an additional positive electric charge. The presence of this electric quadrupole decreases the elliptic flow of positively charged particles. I present an estimate of the produced asymmetry between the elliptic flow of positive and negative pions and compare to the new results from the STAR experiment.

Preliminary results from the 4PI effective action

Carrington, Margaret

We discuss the renormalizability of the 4-Loop 4PI effective action in a symmetric scalar theory with quartic coupling. We show that the self-consistently determined 2-point and 4-point functions can be renormalized using a coupling constant counter-term in the Lagrangian of the original theory. We present the results of a numerical lattice calculation for a toy 2-dimensional model. The self-consistent solutions for the 2-point and 4-point functions agree well with the perturbative ones when the coupling is small. When the coupling is large, perturbative calculations break down, but the self-consistent solution is well behaved.,

A surprise in the phase diagram of many-flavor staggered fermions

de Forcrand, Philippe

It is widely believed that chiral symmetry is spontaneously broken at zero temperature in the strong coupling limit of staggered fermions, for any number of colors and flavors. Using Monte Carlo simulations, we show that this conventional wisdom, based on a mean-field analysis, is wrong. For sufficiently many flavors, chiral symmetry is restored via a bulk, first-order transition. This chirally symmetric phase appears to be analytically connected with the expected conformal window of many-flavor continuum QCD. Indeed, we analyze the Dirac spectrum at strong coupling, and show that the spectral gap associated with chiral symmetry restoration, and the whole infrared spectrum, scale as $1/L$, where L is the system size. L is hence the only length scale in the IR. We conclude that the strong-coupling chirally restored phase appears as a convenient laboratory to study IR conformality.

Jet broadening and a gauge invariant jet quenching parameter with Soft-collinear Effective Theory

Escobedo, Miguel Angel

A useful observable in order to understand the nature of the medium produced in heavy-ion collisions is jet quenching, the energy that is lost by a jet while traversing a medium. Computations of this quantity need information from a related process, jet broadening, that can sometimes be encoded in a so-called jet quenching parameter $\hat{q}$. Jet broadening is the probability that the direction of the jet is changed due to the effect of the medium without modifying its energy, this probability can be computed as the expectation value of two light-cone Wilson lines in a covariant gauge. However, although gauge invariance arguments suggest the existence of two transverse Wilson lines at times going to plus and minus infinity, no explicit computation in a different type of gauge valid to all orders exists. This is an important issue when trying to compute this quantity in a strongly-coupled medium and also in a weakly-coupled one if a high precision is needed. In this talk we will show how this computation can be performed in light-cone gauge and in a general gauge using Soft-collinear Effective Theory, which is a very powerful tool for studying jets in the vacuum and in medium. We will also discuss the relation of the result that we found with the static potential at zero temperature.

Chiral transition and deconfinement in the presence of a magnetic background

Fraga, Eduardo

We discuss the effects of a very strong homogeneous magnetic field B on the thermal deconfinement and chiral transitions using effective models for QCD. In particular, we contrast results obtained using the MIT bag model to those provided by the linear sigma model or to NJL coupled to Polyakov loops. Even though the MIT bag model is known to be crude in numerical precision and misses the correct nature of the (crossover) transition, it provides a simple setup for the discussion of some subtleties of vacuum and thermal contributions in each phase, and should provide a reasonable qualitative description of the critical temperature in the presence of B. In this description, we find that the critical deconfinement temperature decreases and saturates for very large values of the field, in line with recent lattice results and differently from what was found in previous model descriptions. We also present preliminary results for the pressure of QCD in a magnetic background to two loops.

Towards a quantum treatment of leptogenesis

Garny, Mathias

The observed cosmological baryon asymmetry can be dynamically generated in the Early Universe by the out-of-equilibrium decay of right-handed neutrinos via the leptogenesis mechanism. In this talk I will report on some recent progress towards describing the dynamics of leptogenesis within non-equilibrium quantum field theory. A scenario that is of phenomenological interest involves a quasi-degenerate mass spectrum for the Majorana neutrinos, leading to a resonant enhancement of the decay asymmetry. The enhancement is saturated when the mass splitting is of the order of the decay width. The conventional Boltzmann treatment becomes problematic in this limit. By solving a set of Kadanoff-Baym equations, we obtain approximate analytical expressions for the generated asymmetry, and compare them to the Boltzmann result as well as to numerical results.

Preheating with Fermions

Gelfand, Daniil

We show that quantum effects dramatically change our understanding of fermion production following preheating after inflation in the early universe. Standard semi-classical descriptions based on the Dirac equation with a homogeneous background field fail to describe nonequilibrium fermion production in presence of non-perturbatively high inflaton occupation numbers. Our analysis goes beyond this approximation by taking into account quantum corrections including off-shell processes, scattering and decay. This is done by using real-time lattice simulations, which we compare to results from two-particle irreducible (2PI) effective action techniques. We discuss both the weakly and the strongly coupled cases and illustrate the emergence of power-law and Fermi-Dirac distributions of fermion occupation numbers.

Transport Theory of Resonant Leptogenesis from Nonequilibrium QFT

Herranen, Matti

We construct a transport theory of resonant leptogenesis using the Schwinger-Keldysh formalism of nonequilibrium QFT. We consider full flavour-mixing dynamics in the heavy right-handed neutrino sector to find that the dominant wave-function-type contribution to CP-violation arises from the mixing effects at tree level. Our results confirm the general structure of the resonant enhacement of CP-violation reported in refs. arXiv:hep-ph/9710460 and arXiv:hep-ph/0511248, however, novel terms related to flavour oscillations can be important in the resonant regime $|M_i - M_j| \sim \Gamma$. In the non-resonant regime $|M_i - M_j| \gg \Gamma$ we recover the standard perturbative result.

Results from the ANTARES underwater neutrino telescope

James, Clancy

ANTARES is an underwater neutrino telescope located at a depth of 2.5 km in the Mediterranean Sea, 40 km off the Southern coast of France. Twelve detection lines, each equipped with 75 photomultiplier tubes, provide an instrumented volume of order 10 million m^3 for detecting the Cherenkov light produced by energetic charged particles. The primary aim of ANTARES is to identify sources of cosmogenic neutrinos, using the passage of secondary muons produced in charged-current muon-neutrino interactions in the Earth's crust below the ANTARES detector.

In this contribution, the ANTARES underwater neutrino telescope and the detection method are described, and the results of both general and targeted searches for neutrinos from astrophysical phenomena such as AGN and GRBs are presented. Certain models of dark matter predict a neutrino flux from the Sun and/or the Galactic Centre, and corresponding model limits from the non-observation of neutrinos from these sources are shown. Ongoing programs to search for neutrino/gravitational-wave coincidences with LIGO/VIRGO, and for neutrino/supernova coincidences with theTAToO project, are described. Finally, ANTARES is sensitive to a wide-range of other phenomenon, from neutrino oscillations to potential exotics such as nuclearites and magnetic monopoles, and the results of a search for the latter are also presented.

Interweaving Chiral Spirals

Kojo, Toru

Recent studies of cold quark matter at intermediate quark density indicate the importance of the inhomogeneous chiral symmetry breaking as a mechanism to generate the quark mass gap near the quark Fermi surface. Such a mass gap tempers the quark fluctuations near the Fermi surface, shifting the deconfinement transition line toward higher density. We discuss properties of a single chiral spiral as an inhomogeneous chiral condensate, and further demonstrate how to construct the interweaving chiral spirals, that is defined as a superposition of the differently oriented chiral spirals.

Thermalization in collisions at extremely high energies

Aleksi Kurkela

Hydrodynamical analysis of experimental data of ultrarelativistic heavy ion collisions seems to indicate that the hot QCD matter created in the collisions thermalizes very quickly. Theoretically, we have no idea why this should be true. In my talk, I will describe how the thermalization takes place in the most theoretically clean limit – that of large nuclei at asymptotically high energy per nucleon, where the system is described by weak-coupling QCD. In this limit, plasma instabilities dominate the dynamics from immediately after the collision until well after the plasma becomes nearly in equilibrium at time $Q_t \sim \alpha^{-5/2}$.

Heavy quark kinetic and chemical equilibration

Laine, Mikko

The rates at which heavy quarks approach kinetic and chemical equilibrium are well-defined yet non-trivial characteristics of hot QCD. I review recent developments towards a non-perturbative understanding of these observables, and also mention analogous phenomena that play a role in cosmology.

O(2) quantum theory at finite densities and the generalised density of states

Langfeld, Kurt

The O(2) theory in 2+1 dimensions is studied in the scaling limit where the mass gap is the only free parameter. In lattice regularisation, the model can be simulated at finite densities by virtue of the worm algorithm. The magnetic susceptibility and the charge density is studied at finite temperatures and for finite values of the chemical potential. It is shown that the onset chemical potential coincides with the mass gap. We find chemical catalysis: The O(2) symmetry breaks spontaneously if the chemical potential exceeds the onset value. We then modify the recently developed modified WL approach to the density of states to cope with complex action systems. In the context of the O(2) model, we discuss whether first principle simulations at finite densities lie within the remit of the new approach.

Shear viscosity in a superfluid cold Fermi gas at unitarity

Manuel, Cristina

We compute the contribution of small-angle collision processes of Nambu-Goldstone modes to the shear viscosity, η, of a superfluid atomic Fermi gas close to the unitarity limit. Performing a calculation analogous to the one done for superfluid ^{4}He, we show that the low temperature experimental values of the shear viscosity coefficient to entropy ratio, η/s, can be reproduced assuming that η is dominated by small-angle splitting and joining processes, and considering an effective shear viscosity which takes into account the finite size of the experimental system. Our results allow us to constrain the form of the dispersion law of the Nambu-Goldstone bosons and to predict that at very low temperatures η/s should correlate with the size of the optical trap and decrease with decreasing temperature.

Gauge field evolution at high occupancy

Moore, Guy

I will present new results on nonabelian gauge field evolution at high occupation. We solve the classical equations on the lattice and solve the full Boltzmann equations including number-changing processes and the LPM effect. The two results are in good agreement and show a scaling solution which is well described by an exponential tail at large momentum and a power law with power $-4/3$ at small momentum.

Towards hot and cold dense QCD from first principles

Philipsen, Owe

Combined strong coupling and hopping parameter expansions can be used to derive a 3d effective theory for QCD with heavy quarks, which is amenable to economical numerical studies at finite temperature and baryon density. The sign problem of the effective theory is weak enough to be overcome by standard Metropolis methods, or to be solved by flux representations or Langevin methods. As a first application, results for the deconfinement transition at all baryon densities are shown. Furthermore, first numerical studies for cold and dense QCD are presented.

Non-perturbative investigation of conformality in SU(2) gauge theory with two adjoint fermions

Rago, Antonio

In the light of recent lattice results, SU(2) with two Dirac massless fermions in the adjoint representation is believed to be an IR conformal theory. As a result, if perturbed with a mass for the fermions, the theory develops a mass gap and the entire mass spectrum scales with a with a single, well defined, power of the perturbing mass. In this talk I will collect all the evidence for the IR behaviour of the theory that have been proposed by our group during the years. I will discuss the reliability of our findings, and the latest development to investigate the most phenomenologically relevant quantities.

The (better) fate of nonabelian plasma instabilities in 3+1 dimensions with longitudinal expansion

Rebhan, Anton

We present numerical results for the fully 3+1-dimensional evolution of nonabelian plasma instabilities in the presence of a longitudinally expanding background of free streaming particles using the discretized hard loop framework. We find that the transition from exponential to linear growth of plasma instabilities that takes place in the stationary anisotropic background at a scale where the hard-loop approximation is still applicable does not occur in the expanding case. Correspondingly, we find that the energy cascades from small to high momentum scales do not give rise to power-law Kolmogorov-like spectra but instead very rapidly look thermal while remaining anisotropic in momentum space until approximately 5 fm/c.

Low-cost dynamical fermions and electroweak baryogenesis

Saffin, Paul

By modelling the fermions using an ensemble method we explicitly simulate the dynamics of the standard model, including (one family of) the fermions. This allows us to follow the dynamics of the fields through sphaleron processes and explicitly see the baryon anomaly at work. We shall describe the technique, and present results from the first simulations.

Composite Dynamics for the Electroweak theory, Dark Matter and Inflation

Francesco Sannino

New strongly coupled dynamics can lead to natural models of Electroweak symmetry breaking, Dark Matter and Inflation. However to make progress we must advance our understanding of strong dynamics as function of the gauge group, matter representation, finite temperature and matter density. I will show that each of these aspects are of the utter most relevance to coherently explore any of the applications above. I will then outline what are the most relevant future directions which we can envision based on our current experimental knowledge in high energy physics and cosmology as well as the current understanding of strongly coupled dynamics.

Continuity of the Deconfinement Transition in (Super) Yang Mills Theory

Schaefer, Thomas

We study the phase diagram of SU(2) Yang-Mills theory with one adjoint Weyl fermion on $R^3 \times S^1$ as a function of the fermion mass m and the compactification scale β. This theory reduces to thermal pure gauge theory as $m \to \infty$ and to circle-compactified (twisted) susy gluodynamics in the limit $m \to 0$. In the $m - L$ plane, there is a line of center symmetry changing phase transitions. In the limit $m \to \infty$, this transition takes place at $\beta_c = 1/T_c$, where T_c is the critical temperature of the deconfinement transition in pure Yang-Mills theory. We show that near m=0, the critical scale β_c can be computed using semi-classical methods and that the transition is of second order. This suggests that the deconfining phase transition in pure Yang-Mills theory is continuously connected to a phase transition that can be studied in weak coupling. The center symmetry changing phase transition arises from the competition of perturbative effects, fractionally charged instantons, and instanton molecules. The calculation can be extended to higher rank gauge groups and non-zero theta angle. (This is work done in collaboration with M. Unsal and E. Poppitz).

Superfluid components in color-flavor locked quark matter

Schmitt, Andreas

Hydrodynamic simulations are one link between the microscopic physics of ultra-dense matter and astrophysical observations from compact stars. Since dense quark matter in the color-flavor locked (CFL) phase is a superfluid, one needs a formulation of the superfluid hydrodynamics of that matter. I will discuss how the superfluid properties of CFL are changed by kaon condensation and how Landau's two-fluid picture of a superfluid emerges from the field-theoretical description of CFL.

Effective potential for quantum scalar fields on a de Sitter geometry

Serreau, Julien

We study the quantum theory of an O(N) scalar field on de Sitter geometry at leading order in a nonperturbative $1/N$-expansion. This resums the infinite series of so-called superdaisy loop diagrams. We obtain the de Sitter symmetric solutions of the corresponding, properly renormalized, dynamical field equations and compute the complete effective potential. Because of its self-interactions, the field acquires a strictly positive square mass which screens potential infrared divergences. Moreover, strongly enhanced ultralong-wavelength fluctuations prevent the existence of a spontaneously broken symmetry state in any dimension.

Bose condensation far from equilibrium

Sexty, Denes

The formation of Bose condensates far from equilibrium can play an important role in our understanding of collision experiments of heavy nuclei or for the evolution of the early universe. In the relativistic quantum world particle number changing processes can counteract Bose condensation, and there is a considerable debate about the relevance of this phenomenon in this context. We show that the involved question of Bose condensation from initial over-population can be answered for the example of scalar field theories. Condensate formation occurs as a consequence of an inverse particle cascade with a universal power-law spectrum. This particle transport towards low momenta is part of a dual cascade, in which energy is also transfered by weak wave turbulence towards higher momenta. We also study nonequilibrium dynamics of SU(2) pure gauge theory starting from initial over-population. Classical-statistical lattice simulations indicate a quick evolution towards an approximate scaling behavior with exponent 3/2 at intermediate times. Remarkably, the value for the scaling exponent may be understood as arising from the leading $O(g^2)$ contribution in the presence of a time-dependent background field. The phenomenon is associated to weak wave turbulence describing an energy cascade towards higher momenta. This particular aspect is very similar to what is observed for scalar theories, where an effective cubic interaction arises because of the presence of a time-dependent Bose condensate.

Anisotropic Hydrodynamics

Strickland, Michael

One of the chief limitations of viscous hydrodynamical models is that it makes an implicit assumption that the system under consideration is close to being thermal and isotropic in momentum space. I will present a new method to derive hydro-like dynamical equations which do not rely on the assumption that the system is close to being isotropic in momentum space. The resulting partial differential equations can equally well describe the ideal hydrodynamical limit, the free streaming limit, and anything in between. In addition, they can be shown to reduce to the 2nd order viscous hydrodynamical equations in the limit that the system is close to being isotropic in momentum space. I will also present results of the numerical solution of these equations in order to quantitatively describe the collective flow of matter created in heavy ion collisions.

Dynamical Hawking radiation and holographic thermalization

Derek Teaney

Using gauge/gravity duality, we study the thermalization of strongly coupled $N = 4$ supersymmetric Yang-Mills plasma. We determine the dilaton emission rate for an equilibrating density matrix and study the applicability of the fluctuation dissipation theorem. In a holographic setting, the emission rate is determined by the emission of non-equilibrium Hawking radiation from an equilibrating black brane. We contrast the equilibration times of timelike and lightlike modes in the plasma. Hard lightlike modes equilibrate on a parametrically long timescale (in units of the final temperature), while massive timelike modes equilibrate on a timescale of order one. We also compare the equilibration of dilatons to the equilibration of other fields that are more sensitive to the anisotropy of the system, and find that the equilibration of these fields is delayed relative to the dilaton.

Cold Electroweak Baryogenesis with Two Higgses

Tranberg, Anders

We consider the possibility of creating the Cosmological Baryon asymmetry in a cold electroweak spinodal symmetry breaking transition in the Standard Model + extra Higgs field. CP-violation originates from the Higgs-Higgs interaction, but in the bosonized theory an interesting interplay emerges between C and P violating effects to generate the asymmetry. We show simulations of these effects and restrict the parameter space for successful baryogenesis.

2-flavor formulation of Strong Coupling Lattice QCD

Unger, Wolfgang

We present a new framework for lattice QCD with massless staggered fermions in the limit of infinite gauge coupling. The partition function is formulated on a discrete spatial lattice but with continuous Euclidean time. We make use of the exact Hamiltonian, with the inverse temperature beta as the only input parameter. This formulation turns out to be analogous to that of a quantum spin system, which allows us to study the system via quantum Monte Carlo techniques. The sign problem is completely absent. In particular, the method can be applied to QCD with two staggered fields, which previously could not be addressed due to a severe sign problem. We show first results towards the determination of the 2-flavor phase diagram in the $\mu - T$ plane.

Holographic photon and dilepton production in a thermalizing plasma

Vuorinen, Aleksi

I will describe a recent AdS/CFT calculation aimed at determining the production rates of prompt photons and dileptons in strongly coupled $N = 4$ Super Yang-Mills plasma out of thermal equilibrium. Thermalization is described via the gravitational collapse of a thin shell of matter in AdS_5 space as well as the subsequent formation of a black hole. We evaluate the spectral functions relevant for the two processes as well as the quasinormal spectrum of the corresponding U(1) vector field, which display interesting signatures prior to thermalization.

3-loop 3PI effective action for 3D QCD

York, Mark

The 3PI method is a technique to resum an infinite class of diagrams, which may be useful in studying nonperturbative thermodynamics and dynamics in quantum field theory. Until now, it has never been directly applied to Yang-Mills theory. In this talk I will present the results of the computation we performed with QCD in 3 spacetime dimensions. I will highlight a few of the technical challenges that need to be overcome, and I will end with a comparison between our results and those obtained from the lattice.

Posters

Real-time dynamics of heavy quark systems at high temperature

Akamatsu, Yukinao

Single heavy quark system has been considered as a hard probe for dynamical information of quark-gluon plasma (QGP), namely drag force, while heavy quarkonium has been thought to probe static information, such as heavy quark potential. Recent theoretical developments have shown that dynamical feature is also important in the physics of heavy quarkonia through complex heavy quark potential [1]. This complex potential can be understood as stochastic process in the medium [2]. However, as pointed out in [2], complete description must also explain the irreversible process, which results in drag force in the classical limit. In other words, a unified description of heavy quark systems is required. In this presentation, I will develop such a quantum description for heavy quark systems in QGP on the basis of closed-time formalism in non-equilibrium field theory. In this description, I will explain how to obtain the stochastic process and the drag force from the first principle with various approximations and derive the master equation for quantum evolution of the heavy quark systems.

[1] M. Laine et al., JHEP 0703 (2007) 054; JHEP 0705, 028(2007). A. Beraudo, J. P. Blaizot and C. Ratti, Nucl. Phys. A806, 312 (2008). N. Brambilla, J. Ghiglieri, A. Vairo and P. Petreczky, Phys. Rev. D 78, 014017 (2008). A. Rothkopf, T. Hatsuda and S. Sasaki, arXiv:1108.1579 [hep-lat]. [2] Y. Akamatsu and A.Rothkopf, Phys. Rev. D 85, 105011 (2012).

Nonequilibrium quantum meson gas: dimensional reduction

Alvarez-Estrada, Ramon F.

A nonequilibrium quantum gas of interacting relativistic effective mesons, ressembling qualitatively those produced in a heavy-ion collision and described by a scalar ϕ^4 quantum field in (1+3) -dimensional Minkowski space, is studied. In short, we obtain that for high temperature and large temporal and spatial scales and under certain conditions (see below), classical statistical mechanics including quantum renormalization effects describe approximately the dynamics of the gas, and we provide justifications to one-loop order: we shall refer to that simplification as nonequilibrium dimensional reduction (NEDR). At a first stage, and as a source of hints, we treat the quantum gas at equilibrium (without spatial inhomogeneities) in real-time formalism: we obtain simplifications for high temperature and large spatial scales, thereby extending a useful equilibrium dimensional reduction known for the imaginary-time formalism. At a second stage, we proceed to the nonequilibrium quantum gas. By assumption, the nonequilibrium initial state of the gas, not far from thermal equilibrium, includes interactions and spatial inhomogeneities. We use nonequilibrium real-time generating functionals and correlators at non-zero temperature. In the NEDR regime, our arguments yield: 1) renormalized correlators simplify, 2) the perturbative series for those simplified correlators can be resummed into a new nonequilibrium renormalized generating functional $Z'_{r,dr}$, which is super-renormalizable and includes renormalization effects (large position dependent thermal self-energies and effective couplings). We provide detailed justifications of the equilibrium results (first stage) and of the nonequilibrium ones (1) and 2) in second stage), at one-loop order. The nonequilibrium $Z'_{r,dr}$ could enable to study nonperturbatively changes in the phase structures of the field, by proceeding from the nonequilibrium genuine quantum regime to the NEDR one. The references upon which this presentation is based are: R. F. Alvarez-Estrada, European Physical Journal A41 (2009) 53-70, and Annalen der Physik 18 (2009) 391-409.

SU(2) with one Dirac flavour in the adjoint representation

Bennett, Ed

We present an initial investigation into the SU(2) gauge theory with a single adjoint Dirac flavour on the lattice. By a change of basis, we show that this can be reformulated as a theory with two adjoint Majorana flavours, which provides a more convenient framework to discuss the meson mass spectrum. Initial results for the spectroscopy of the theory are shown, including meson and glueball masses.

Pressure of massless hot scalar fields in the boundary effective theory framework

Bessa, Andre

In a recent paper, we have proposed an alternative approach to thermal field theories, denoted by boundary effective theory (BET). The method naturally separates the infrared physics, and is essentially non-perturbative. It is based on the calculation of the density matrix, providing a natural dimensionally-reduced effective theory for the static (boundary) field. We have obtained an expression for the 1-loop effective action for scalar theories with single-well potentials.

In the present work, we use the BET approach in order to calculate the pressure of a system of massless scalar fields with quartic interaction. We derive a resummed pressure, which is in good agreement with recent calculations found in the literature, following a very direct and compact procedure. All these results are intended to be preliminary steps before more realistic calculations in the context of gauge theories.

Temperature dependence of CP violation in the Standard Model

Brauner, Tomas

One of the major unresolved problems in current physics is understanding the origin of the observed asymmetry between matter and antimatter in the Universe. It has become a common lore to claim that the Standard Model of particle physics cannot produce sufficient asymmetry to explain the observation. Our results suggest that this conclusion can be alleviated in the so-called cold electroweak baryogenesis scenario. On the Standard Model side, we continue the program initiated by Smit eight years ago, one derives the effective CP-violating action for the Standard Model bosons and uses the resulting effective theory in numerical simulations. We address a disagreement between two previous computations performed effectively at zero temperature, and demonstrate that it is very important to include temperature effects properly. Our conclusion is that the cold electroweak baryogenesis scenario within the Standard Model is tightly constrained, yet producing enough baryon asymmetry still seems possible.

Spectroscopy of SU(2) with two adjoint fermions on the lattice

Bursa, Francis

I will present a numerical study of spectroscopic observables in the SU(2) gauge theory with two adjoint fermions. I will compare our results using improved source and sink operators with previous determinations of masses that used point sources and sinks and investigate possible systematic effects in both cases. I will discuss the finite volume effects on the spectrum, investigated by varying the size of the lattice and by changing the boundary conditions.

N=4 Super Yang-Mills Plasma

Czajka, Alina

Motivated by the AdS/CFT duality, we systematically compare the $N = 4$ super Yang-Mills plasma to QGP not in a strong but in a weak coupling regime. Collective excitations and collisional processes are discussed. Since the Keldysh-Schwinger approach is used, the collective excitations in both equilibrium and non-equilibrium plasma are under consideration. The dispersion equations of gluon, fermion, and scalar fields are written down and the self-energies, which enter the equations, are computed in the Hard Loop Approximation. The self-energies are discussed in the context of effective action which is also given. The gluon modes and fermion ones appear to be the same as those in the QCD plasma of gluons and massless quarks. The scalar modes are as of free relativistic massive particle. The binary collisional processes, which occur at the lowest nontrivial order of the coupling constant, are reviewed and then the transport properties of the plasma are discussed. The $N = 4$ super Yang-Mills plasma is finally concluded to be very similar to the QCD plasma of gluons and light quarks. The differences mostly reflect different numbers of degrees of freedom in the two systems. For more details see:

A. Czajka and St. Mrowczynski, 'N=4 Super Yang-Mills Plasma', arXiv:1203.1856 [hep-th], to appear in Phys. Rev. D

Energy Loss in Unstable Quark-Gluon Plasma

Deja, Katarzyna

The energy loss per unit path length of a fast parton scattering elastically in a weakly coupled quark-gluon plasma is studied as an initial value problem. The approach is designed to study an unstable plasma but in the case of an equilibrium plasma the well known results are reproduced. As examples of an unstable plasma, the two-stream and extremely prolate systems are considered. The energy loss is then shown to have strong time and directional dependence. Since the magnitude of the energy loss per unit length in an unstable QGP can be much bigger than in an equilibrium plasma, the problem is potentially important for the phenomenon of jet quenching in relativistic heavy-ion collisions. A preliminary account of this study is given in

M.E. Carrington, K.Deja and St. Mrowczynski, 'Parton Energy Loss in an Unstable Quark-Gluon Plasma', arXiv:1110.4846 [hep-ph].

Baryogenesis and Dark Matter from Sterile Neutrinos

Drewes, Marco

We demonstrate that three sterile neutrinos with masses below the electroweak scale can simultaneously explain neutrino oscillations, the observed dark matter and baryon asymmetry of the universe. To identify the range of sterile neutrino properties consistent with this requirement, we study the non-equilibrium processes that lead to their production, oscillations, freezeout and decay in the early universe. Combining our results with bounds from direct searches and BBN, we find that there is a domain of parameters where the sterile neutrinos can be found with present day experimental techniques, using upgrades to existing experimental facilities. Based on arXiv:1204.3902v1 [hep-ph].

Thermalization in classical statistical field theory

Epelbaum, Thomas

The quark gluon plasma thermalization in heavy ion collisions is an open problem that gave rise to many works in recent years. One of the approaches developped to study this QCD non pertubative problem is a resummation scheme that amounts to averaging over classical fields, with random initial conditions. Its numerical implementation is presented here in the case of a scalar field theory with a quartic coupling, that shares some important features with QCD (scale invariance at the classical level and the presence of instabilities). In particular, we will show the relevance of this resummation in capturing the physics relevant for thermalization.

Charmonium Potential at Non-Zero Temperature

Evans, Wynne

Results of the wavefunction and inter-quark potential for charmonium states at non-zero temperature are presented. These are calculated in 2 flavour dynamical lattice QCD using anisotropic configurations with a (fixed) spatial volume of 2fm with temperatures up to 2 T_c. The wavefuncton is extracted from Euclidean correlation functions via two methods. i) by using conventional exponential fits, and ii) by analysing spectral functions obtained from the Maximum Entropy Method. The inter-quark potential is then calculated by assuming that charm quarks are heavy enough to be treated non-relativistically and applying the Schroedinger equation to solve for the potential. Detailed results for the s-wave potentials and preliminary results for p-wave states, using derivative operators, are presented.

Aspects of chiral symmetry restoration from two-flavour lattice QCD correlation functions

Francis, Anthony

We study the temperature dependence of spatial and temporal lattice correlation functions in the vicinity of the deconfinement transition. We use several $N_f = 2$ ensembles on a line of constant quark mass corresponding to $M_\pi \simeq 300$ MeV. From the degeneration pattern of the temporal vector and axial vector currents we find clear signs of chiral symmetry restoration for $T > 210$ MeV. As a consequence we find excellent agreement with the finite temperature Weinberg sum rules.

Baryon Asymmetry from first principles without Boltzmann or Kadanoff-Baym

Gagnon, Jean-Sebastien

We present a formalism that allows the computation of the baryon asymmetry of the universe from first principles of statistical physics and quantum field theory that is applicable to certain types of beyond the Standard Model physics (such as the neutrino Minimal Standard Model – νMSM) and does not require the solution of Boltzmann or Kadanoff-Baym equations. The formalism works if a thermal bath of Standard Model particles is very weakly coupled to a new sector (sterile neutrinos in the νMSM case) that is out-of-equilibrium. The key point that allows a computation without kinetic equations is that the number of particles in this new sector produced during the relevant cosmological period remains small. In such a case, it is possible to expand the formal solution of the von Neumann equation perturbatively and obtain a master formula for the lepton asymmetry expressed in terms of non-equilibrium Wightman functions. These correlation functions can then be evaluated perturbatively; the validity of the perturbative expansion depends on the parameters of the model considered. We illustrate the use of the formalism with a toy model (containing only two active and two sterile neutrinos) and with the more realistic νMSM.

On the Langevin description of non-equilibrium quantum field dynamics

Gautier, Florian

We will adress the non equilibrium dynamics of quantum scalar fields. We will first briefly recall the basic evolution equations for the non equilibrium two point green functions and how they are equivalent to a Langevin process. We will then set up an approximation scheme within which the full non local dynamics can be mimicked by an effective local one. And then we will examine the conditions under which this is true despite the non local behavior of the damping and noise kernels related to the self energies.

Phase transition in the U(N)xU(N) meson model from large-N approximation

Gergely, Fejos

The breaking of the approximate $U(3)\times U(3)$ chiral symmetry of QCD can be efficiently studied in terms of effective chiral meson models. Although the axial anyomaly reduces the symmetry to $SU_A(3)\times SU_V(3)\times U_V(1)$, the investigation of the $U(3)\times U(3)$ symmetric linear sigma model might give phenomenological relevance, if the restoration of the $U_A(1)$ factor is fast enough at finite temperature. It has been known for a long time Pisarski & Wilczek, 1984) that in the system of the $U(N)\times U(N)$ model a first order transition takes place, if $N\geq 2$. This has been verified by Functional Renormalization Group methods (Berges et al., 1997 and Fukushima et. al, 2011), however there is no perturbative treatment which could reproduce the phenomenon of fluctuation induced first order transition. In our study we realized a certain resummation of the perturbative series through the large-N technique, combining it with an approximation based on the existence of heavy scalar particles. We mapped out a large part of the parameter space and found that, first order transition indeed takes place in the system. However, it turned out that, compared to previous studies, in some cases large-N technique predicts a different symmetry breaking scenario: instead of the $U(N)\times U(N)\to U(N)$ breaking, we obtained $U(N)\times U(N)\to U(N-1)$. Properties of the ground state and the finite temperature behavior at $N=3$ was studied in terms of various strengths of the explicit symmetry breaking and couplings.

The photon production rate at NLO

Ghiglieri, Jacopo

We present a calculation of the rate for photon production from a quark-gluon plasma at next-to-leading order in perturbation theory. We first give an overview of the leading-order (e^2g^2) result and show how it decomposes in a region dominated by $2\leftrightarrow 2$ processes ($gq\to\gamma q$ and $q\bar{q}\to\gamma g$) and in one dominated by collinear radiation processes. At NLO (e^2g^3) both regions receive order-g corrections from momenta of order gT, requiring HTL resummation. We introduce light-cone sum rules for the fermion HTL propagators which, together with the known one for the gluon propagator, allow a great simplification of the order-g corrections to the $2\leftrightarrow 2$ region. The calculation has been carried out in collaboration with Juhee Hong, Aleksi Kurkela, Egang Lu, Guy Moore and Derek Teaney.

Debye mass to three-loop order in hot QCD.

Ghisoiu, Ioan

We determine the Debye mass of hot QCD to three-loop order. Being a matching coefficient in the framework of dimensionally reduced Electrostatic QCD, it requires the evaluation of 10^7 vacuum sum-integrals, which are reduced via IBP relations to a small number of master sum-integrals. These are then solved, using methods pioneered by Arnold and Zhai.

New insights into dense two-color matter

Giudice, Pietro

We study SU(2) lattice gauge theory with two Wilson quark flavours at non-zero chemical potential and low temperature. As the baryon chemical potential is varied, we find further evidence of three distinct physical regimes: vacuum/hadronic, quarkyonic and deconfined phases. In this presentation we focus mainly on the following observables: quark number susceptibility, chiral condensate (using naive fermions) and eigenvalues of the Dirac operator.

New Derivation of QCD Sum Rules Based on Commutation Relations

Hayata, Tomoya

QCD sum rules based on the dispersion relation of current correlation function and the operator product expansion (OPE), originally proposed by Shifman-Vainshtein-Zakharov, give relations between condensates (ensemble averages of symmetry breaking operators) to hadronic spectral structure in the presence of medium effects. Thus, we can study relations between the phase diagram of quantum chromodynamics (QCD) and the dynamics of hot (dense) hadronic matter through sum rules. In this talk, we present a new derivation of QCD sum rules by commutation relations (CRs) based on the Kugo-Ojima operator formalism with suitable subtraction of ultra-violet divergences. We do not assume OPE in the presence of the non-perturbative effects. Instead, CRs between currents and the QCD effective Hamiltonian are utilized. We can understand the sum rules by analogy with sum rules involving collective modes in quantum many body physics. We regard hadrons as QCD collective modes and analyze the phase structure through the dynamics of them. However, there is important difference peculiar to quantum field theories and understood as an anomaly in CR. To write down the expectation values of CRs in terms of condensates, we replace CRs with superpositions of local operators which reproduce their matrix elements between asymptotic states. In our approach, leading contributions are given by tree diagrams. They turn out to be the same with those given by the canonical commutation relations (CCRs). There are sub-leading contributions given by loop diagrams which cannot be reduced to the result of CCRs. We find that such anomalous terms in CRs are necessary to be fully consistent with the results of OPE.

Thermal Leptogenesis – Including Gauge Interactions

Huetig, Janine

The observed baryon asymmetry of the universe is well described by the scenario of thermal leptogenesis, where the out-of-equilibrium decay of a heavy majorana neutrino in the plasma of the early universe causes a lepton asymmetry which is later converted to baryons. This picture is consistent with neutrino oscillation experiments and also explains the smallness of the ordinary neutrino masses. Via Kadanoff-Baym equations one can compute the lepton asymmetry completely in a quantum mechanical way. However, the current results have an uncertainty of at least one order of magnitude, since gauge interactions with the thermal bath were not included yet. In this talk the important contributions and the effect of the inclusions of gauge corrections will be shown.

Indistinguishability of particles and thermodynamics

Jakovac, Antal

When are two particles with the same quantum numbers but different mass indistiguishable? This question can be relevant, for example, if we want to construct an effective model for hadrons, and we want to take into account excited particles, too, like in the Hadron Resonance Gas model. We show that if the excitations have finite lifetime, then this question is not simple, and in fact it is a dynamical problem. We provide a method for the correct treatment of this problem, and demonstrate in some examples that it can really give different results than the naive independent particle approach.

Complex Langevin dynamics in the SU(3) spin model at nonzero chemical potential

James, Frank

The three-dimensional SU(3) spin model is an effective Polyakov loop model for QCD at nonzero temperature and density. It suffers from a sign problem at nonzero chemical potential. We revisit this model using complex Langevin dynamics and assess in particular the justification of this approach, using analyticity at small μ^2, an effective toy model and the criteria for correctness developed recently. Our results strongly indicate that complex Langevin dynamics is reliable in this theory in both phases, including the critical region. This is in sharp contrast to the case of the XY model, where correct results were obtained in only part of the phase diagram.

Flavoured quantum transport equations from cQPA

Kainulainen, Kimmo

We derive the propagators and Feynman rules for quantum kinetic theory with flavour and particle-antiparticle coherence based on coherent quasiparticle approximation (cQPA). The statistical cQPA propagators are composites of two spectral functions and an effective two-point interaction vertex, which contains all quantum statistical and coherence information. We emphasize the connection between the singular cQPA approximation in the Wigner space and the two-time formalism in the local limit. Our numerical results show that particle-antiparticle coherence can strongly influence CP-violating flavour mixing even for relatively slowly varying backgrounds, which may be important for asymmetry generation in mass-varying transitions such as EWBG. Finally, we show that the cQPA coherence solutions are related to squeezed states in the operator formalism.

Chiral Superfluidity of the Quark-Gluon Plasma

Kalaydzhyan, Tigran

In this talk I would like to argue that the strongly coupled quark-gluon plasma can be considered as a chiral superfluid. The ”normal” component of the fluid is the thermalized matter in common sense, while the ”superfluid” part consists of long wavelength (chiral) fermionic states moving independently. We use several non-perturbative techniques to demonstrate that. First, we analyze the fermionic spectrum in the deconfinement phase ($T_c < T < 2T_c$) using lattice (overlap) fermions and observe a gap between near-zero modes and the bulk of the spectrum. Second, we use the bosonization procedure with a finite cut-off and obtain a dynamical axion-like field out of the chiral fermionic modes within QCD. Third, we use relativistic hydrodynamics for macroscopic description of the effective theory obtained after the bosonization. Finally, solving the hydrodynamic equations in gradient expansion, we find that in presence of external electromagnetic fields the motion of the ”superfluid” component gives rise to the chiral magnetic, chiral electric and dipole wave effects. Latter two effects are specific for a two-component fluid, which provides us with crucial experimental tests of the model.

Dynamics of mixing fields: a basis-independent analysis

Kartavtsev, Alexander

We use the formalism of non-equilibrium quantum field theory to analyze Boltzmann-like dynamics of a system of mixing fields coupled to a thermal bath in a basis-independent way. In particular, we derive Boltzmann equations for the quasiparticle excitations, analyze temperature dependence of the pole masses in the ’runaway’ and ’avoided level crossing’ regimes, and study the behavior of the Jarlskog invariant at finite temperatures.

Spectral functions of charmonium in 2+1 flavour lattice QCD

Kelly, Aoife

The spectral functions of QCD can give us insight into properties of hadrons, and they are useful in probing the QCD vacuum. I will discuss the correlators and spectral functions of charmonium in high-temperature $2+1$ flavour QCD. The spectral functions have been obtained using the Maximum Entropy Method from anisotropic lattice data.

Heavy quarkonium in two color QCD at non-zero baryon density/temperature

Kim, Seyong

We study heavy quarkonia of Two Color QCD (QC_2D) at non-zero quark chemical potential and non-zero temperature using non-relativistic effective field theory of QC_2D on a lattice. We find that the S-wave bound state spectrum as a function of chemical potential show three distinctly different behaviors: in small chemical potential region, the spectrum decreases as the chemical potential is increased. Then, the spectrum stays roughly constant as the chemical potential is further increased. Finally, the spectrum starts increasing again as the chemical potential is still more increased. This finding strengthens our previous observation that there are three distinct phases at low temperature and high density in QC_2D: hadronic matter, quark/quarkyonic matter, and deconfined matter.

Effective Potential in the boundary effective theory framework

Kroff, Daniel

Using the formalism of the boundary effective theory, we calculate the one-loop effective potential at finite temperature for a system of massless scalar fields with quartic interaction $\lambda\phi^4$. The calculation relies on the solution of the classical equation of motion for the field, and Gaussian fluctuations around it. Our result is non-perturbative and differs from the standard one-loop effective potential for field values larger than $T/\sqrt{\lambda}$. To do the same calculation in the case with spontaneous symmetry breaking, it is necessary to learn how to deal with multiple classical solutions. Therefore we start with the simpler case of a quartic double-well potential in quantum mechanics. In this case one has to deal, due to the bifurcation of solutions, with caustics when calculating the partition function.

Taylor goes imaginary

Laermann, Edwin

In QCD at finite density we compare the Taylor expansion approach with results at non-vanishing imaginary potential and vice versa. The results are based on configurations generated with two plus one flavors at almost physical quark mass values.

Effective lattice theory for hot and/or dense QCD

Langelage, Jens

We derive an effective theory for hot and dense lattice QCD by means of a combined strong coupling and hopping parameter expansion, which correctly reflects the $Z(N_c)$ symmetry resp. its breaking due to finite quark masses. After discussing the derivation for pure gauge theory, we introduce large, but finite, quark masses and put special emphasis on the case of a finite quark chemical potential.

Scaling properties of SU(2) gauge theory with mixed fundamental-adjoint action

Lucini, Biagio

We study the phase diagram of the SU(2) lattice gauge theory with fundamental-adjoint Wilson plaquette action. We confirm the presence of a first order bulk phase transition and we estimate the location of its end point in the bare parameter space. If this point is second order, the theory is one of the simplest realizations of a gauge theory with a non-trivial infrared fixed point at finite bare couplings. All the relevant gauge observables are monitored in the vicinity of the fixed point with very good control over finite-size effects. The scaling properties of the low-lying glueball spectrum are studied while approaching the end point in a controlled manner. We comment on possible implications of near-conformality in SU(2) gauge theory with two flavours of adjoint Dirac fermions.

Nature of the thermal phase transition of the scalar ϕ^4 model at the two-loop approximation of the 2PI formalism

Mark, Gergely

We investigate numerically the temperature phase transition of the Euclidean ϕ^4 theory using the 2PI effective potential truncated at 2-loop order. Fast Fourier Transform algorithms and accelerated Matsubara sums are combined to achieve a well controlled, accurate solution of the fully renormalized coupled set of propagator and field equations. We find that if for a set of mass and coupling parameters a phase transition occures, then it is of second order. Analytical and numerical determination of the static critical exponents give mean field values. However, if we implement some ideas of the renormalization group, by letting the parameters run with the temperature, the values move closer to the true ones.

The Bloch-Nordsieck Model at zero and finite temperature

Mati, Peter

Different levels of resummations of the exactly solvable Bloch-Nordsieck model were performed in order to be able to compare the approximations with the exact result (that was published by B. and N. in 1937). The investigation begins at the one loop perturbation theory, then it continues with 2PI resummation and finally we study the truncated Schwinger-Dyson eq.(+Ward-identities). Perturbation theory doesn't give a good result in the deep infrared regime (actually it's singular), while the 2PI method gives finite result in the IR but it seems to be a poor approximation. The truncated S-D can be solved exactly, and it agrees with the B-N result. The B-N model at finite temperature is going to be discussed as well. Related publication: http://prd.aps.org/abstract/PRD/v85/i8/e085006

On the sign problem in supersymmetric Yang-Mills theories on the lattice

Mehta, Dhagash

In recent years a new class of supersymmetric lattice theories have been proposed which retain one or more exact supersymmetries for non-zero lattice spacing. Possibilities of (fermionic) sign problem for these theories have been intensely debated recently. I will present the latest results in this direction from our simulations for the $Q = 4$ and $Q = 16$ supersymmetric Yang-Mills theories on the lattice.

Off-equilibrium photon production at the chiral phase transition

Michler, Frank

In the early stage of ultrarelativistic heavy-ion collisions chiral symmetry is temporarily restored. During the chiral phase of the fireball, the quark masses change from their constituent values to the bare values. This dynamical mass shift leads to spontaneous pair creation of quarks and antiquarks. We investigate the photon production arising from this pair creation process in a quantum-field theoretical model. The change of the quark mass is modeled by coupling a scalar background field in a Yukawa-like manner to Dirac fermions in the QED-Lagrangian. The quark-antiquark pair creation in this external field is treated exactly to properly take into account the non-perturbative nature of the pair creation process. To assess the photon-momentum spectra we restrict ourselves to a first-order evaluation of the photon polarization tensor. The first-order photon-production processes become kinematically possible since the quarks and antiquarks are rendered offshell by the coupling to the external source field. The photon numbers are extracted in the limit $t \to \infty$ as asymptotically free particles. This procedure eliminates the unphysical contribution from the vacuum polarization. Furthermore, the resulting photon spectra are rendered UV-finite if the time evolution of the quark masses is modeled in a suitable manner.

Thermodynamic Lattice Study for Walking Dynamics in Strongly Flavoured Gauge Theory

Miura, Kohtaroh

Emergence of a conformal symmetry and a preconformal (walking) dynamics in strongly flavoured non-Abelian gauge theories has received much attention. The walking dynamics near the infra-red fixed point has been advocated as a dynamical origin of the electroweak symmetry breaking, which would be responsible for a mass creation in the standard model (except for neutrinos). Lattice Monte-Carlo simulations are expected to provide a solid theoretical base to understand the (pre-)conformal nature in the gauge theory. To investigate the walking nature on the lattice, we extend the technology of the finite temperature lattice QCD to many flavour cases, then a loss of chiral phase transitions at finite temperature with increasing N_f (num. of flavors) indicates the emergence of a conformal phase. By using a functional renormalization group results as an analytic guide, we estimate the lower bound of the conformal window. We also investigate the Miransky-Yamawaki phase diagram, and discuss the emergence of conformal nature on the lattice.

Quark number susceptibilities from different resummed perturbation theories

Mogliacci, Sylvain

In this talk, I will discuss the behaviour of quark number susceptibilities in high temperature QCD using two different schemes of resummed perturbation theory, Hard Thermal Loop perturbation theory (HTLpt) and Dimensional Reduction (DR). In HTLpt, we compute the full leading order result using the branch cuts method. We choose the Debye and thermal quark mass parameters to be evaluated in the weak coupling limit, and at finite chemical potential. In DR, we perform a new resummation of the existing four-loop results, in addition to which we estimate the effects of a non-zero value of the strange quark mass. All results obtained are compared with recent lattice data, showing excellent agreement down to surprisingly low temperatures ($\sim 2-3T_c$).

Deconfinement transitions of large N QCD with chemical potential at weak and strong coupling

Myers, Joyce

We calculate the deconfinement line of transitions for large N_c QCD at finite temperature and chemical potential using two techniques, working in the limit where N_f is of order N_c. First, we extend previous weak-coupling results from one-loop perturbation theory on $S^1 \times S^3$ to higher temperatures and obtain the line of transitions that extends from the $\mu = 0$ axis to the $T = 0$ axis. Second we use the same matrix model to obtain the deconfinement line of transitions as a function of the coupling strength and μ/T from a strong coupling expansion of lattice QCD with heavy quarks, extending previous U(N_c) results to SU(N_c). We show that the result obtained for the Polyakov line from $S^1 \times S^3$ at weak coupling, reproduces the known $\mu = 0$ result from strong coupling lattice QCD, under a certain change of parameters, which is valid for sufficiently low temperatures and chemical potentials.

MSSM Electroweak Baryogenesis and LHC Data

Nardini, Germano

In this talk I will review the general ideas of electroweak baryogenesis in the MSSM. In particular, the model predicts a very heavy left-handed stop, while the right-handed scalar top has to be lighter than the top quark. The cleanest method to probe the model is therefore to look for direct production of the light stop at LHC. An alternative procedure is to study the role that the stops play in the production and decay rates of the Higgs. As it will be explained, a tension between the predictions of the model and the present LHC data is arising.

Confining gauge theories with adjoint Higgs on $R^3 \times S^1$

Nishimura, Hiromichi

We extend recent work on confining gauge theories on $R^3 \times S^1$ with adjoint scalar fields to study the relationship between confinement and the Higgs mechanism. The model allows the deconfining phase transition to be either second-order or first-order depending on the deformation, and it shows a rich phase structure, including a new phase in which the nontrivial Polyakov loop mixes with the Higgs field. This gives rise to topological objects that generalize the instanton constituents of BPS and KK monopoles in the confined phase and are related to Julia-Zee dyons by Poisson duality. We show that Wilson loops orthogonal to the compact direction show area-law behavior due to a dilute gas of the monopoles in a broad region that includes portions of all phases of the model.

Unraveling the conformal window on the lattice

Nunes da Silva, Tiago

Attention has been drawn recently to the possibility of a conformal window in the phase diagram of gauge theories: a region in the diagram where, at zero temperature, chiral symmetry is restored and the theory is deconfined. Theories living inside the window develop a non-trivial infrared fixed point at which they are conformal. The strong coupling nature of this phenomenon requires non-perturbative methods, such as lattice field theory, for its study. I will discuss the strategy we follow on the lattice, based on the Physics of phase transitions, and present our recent advances in the understanding of the phase diagram.

Functional Renormalization Group analysis of relativistic Bose-Einstein Condensation

Palhares, Leticia

We investigate the role of interactions with nonzero momentum exchange in relativistic Bose-Einstein condensation by computing the temperature versus chemical potential phase diagram using the Functional Renormalization Group. In the nonrelativistic case, it was shown that nonperturbative effects associated with interactions with nonzero momentum exchange affect significantly the critical parameters for condensation. Our aim in the present project is to analyze these issues in a relativistic context, with the application to pion Bose-Einstein condensation in isospin-dense QCD media in mind. Initially, we consider a toy model of a complex scalar field theory with U(1) symmetry at finite density using both the Local Potential Approximation (zeroth order of a derivative expansion for the effective action) and the leading correction to it, the so-called LPA' scheme. The generalization of the results to a QCD chiral model for pion condensation at finite isospin density is also planned.

Interface tension in the 3d 4 state Potts model.

Pellegrini, Roberto

We study the interface tension in the four state Potts model in three dimensions. The interface tension is given by the ratio of two partition functions with different boundary conditions. These partition functions are not easily computed by a standard Monte Carlo method. We computed the densities of states and the partition functions with the Wang and Landau algorithm supplemented with a Multicanonical step in order to ensure convergence to the correct densities of states. Preliminary results for the interface tension are shown.

Inverse magnetic catalysis in dense matter

Preis, Florian

Two of the most important “laboratories for QCD - neutron stars and non central heavy ion collisions - exhibit the strongest magnetic fields known to exist in the universe. Therefore, investigating QCD under the influence of a magnetic field might provide new insights into the theory of strong interactions. In several model calculations it was shown that a magnetic field enhances the chiral condensate significantly and thereby increases the critical temperature for chiral symmetry restoration. This feature was termed magnetic catalysis. I will show that at finite chemical potential the opposite effect - inverse magnetic catalysis (IMC) - might occur. Then I present the surface of the chiral phase transition in the parameter space of temperature, chemical potential and magnetic field obtained in the holographic Sakai-Sugimoto model in a limit which is dual to a Nambu - Jona-Lasino (NJL) model. These findings confirm the existence of the IMC scenario and show intriguing similarities with results obtained on the field theory side of the duality. Finally, I will elaborate on how the introduction of large-N_c baryons affects the IMC.

Ultrasoft Fermionic Mode in hot gauge theories

Satow, Daisuke

We analyze the spectral properties of the fermion in the ultrasoft region ($\ll g^2T$) with g being the coupling constant, at the leading order in a plasma of gauge theory including quantum chromodynamics, at so high temperature (T) that all masses are negligible [1]. We establish that a novel fermionic collective mode exists in the ultrasoft region, with the velocity, damping rate and residue being 1/3 of the speed of light, $\sim g^2 T \ln g^{-1}$ and $\sim g^2$, respectively. We need to use the resummed perturbation theory [2] in which we resum the thermal masses and the damping rates of the particles whose momenta are of order T, and sum all the ladder diagrams, instead of the well-established perturbation theory called hard thermal loop approximation to regularize the infrared singularity. We remark that the origin of the infrared singularity is the same as that of the collision term in the Boltzmann equation in the case that the scale of the inhomogeneity has the same order of the magnitude as the damping rate of the particle. We also confirm explicitly that the Ward-Takahashi identity is satisfied.

References [1] Y. Hidaka, D. Satow, and T. Kunihiro, Nucl. Phys. A 876, 93 (2012). [2] V. V. Lebedev and A. V. Smilga, Annals Phys. 202, 229 (1990).

Computation of the 2nd order transport coefficient kappa in the gluon plasma

Schaefer, Christian

From heavy-ion collision experiments we know that the quark-gluon plasma behaves almost like an ideal fluid and can be described by hydrodynamics. The dynamic properties of the quark-gluon plasma are determined by transport coefficients. The second order transport coefficient kappa is related to a momentum expansion of the euclidean energy-momentum tensor correlator at vanishing Matsubara frequency. The computation of the Fourier-transformed correlator in lattice gauge theory allows the determination of kappa from first principles. We present the results obtained by pure Yang-Mills lattice simulations in comparison to a computation in quasi-free lattice perturbation theory.

Pulsars as a probe for dense matter

Schwenzer, Kai

Oscillations of compact stars present a unique way to learn about their interior composition and possible phases of cold dense matter which feature very different mechanical properties. Unstable r-mode oscillations are particularly interesting since they spin down a star by the emission of gravitational waves and thereby connect to precisely measured pulsar timing data and present an interesting source for the detection of gravitational waves. We show that despite the considerable complexity of these systems, the main aspects of the evolution of a young neutron star are well described by simple semi-analytic expressions that prove to be strikingly insensitive to unknown microscopic details. This paves the way for a quantitative comparison with astrophysical data and we substantiate that r-modes are a viable scenario for the spindown of young neutron stars, but very likely no observed young star presently spins down due to gravitational wave emission.

Comparing Models of (Strongly Coupled) Anisotropic Plasma

Steineder, Dominik

Quark-gluon plasma during its initial phase after its production in heavy-ion collisions is expected to have substantial pressure anisotropies which could leave imprints in various observables. We compare two attemps to model this situation at strong coupling by means of AdS/CFT, an anisotropic geometry involving a comparatively benign naked singularity studied by Janik and Witaszczyk, and a regular geometry involving a nontrivial axion dual to a deformation of the gauge theory by a spatially varying theta parameter as introduced by Mateos and Trancanelli. We report on results such as anisotropic shear viscosity, heavy quark potential and jet quenching. Furthermore we consider the weak coupling limit of anisotropic theta-deformed Yang-Mills theory and present its nontrivial phase diagram.

The QCD Phase Transition at High Isopsin Asymmetry

Stiele, Rainer

Dense matter as produced in core collapse supernovae or in particular with Pb or Au beams will be highly asymmetric in isospin. Also in the early universe the poorly constrained lepton asymmetry might be orders of magnitude larger than the baryon asymmetry allowing for a large isospin asymmetry. Hence, for the search of signatures of the QCD phase transition under these extreme conditions, the dependence on finite net isospin densities should be taken into account. We investigate the phase structure of strongly interacting matter within a Polyakov-Quark-Meson model that includes the physics of chiral symmetry breaking and restoration, as well as from the confinement-deconfinement phase transition. We present our results on the QCD phase diagram and equation of state for different asymmetries in isospin and/or lepton number by studying fluctuations and susceptibilities and the equation of state as e.g. the speed of sound and the trace anomaly.

Stochastic Approach for Flat and Non-Flat Direction Systems in Inflationary Universe

Takesako, Tomohiro

We revisit the time evolution of a flat and non-flat direction system in inflationary universe. In order to take into account the quantum noises in the analysis, we base on stochastic formalism and solve coupled Langevin equations numerically. Although the non-flat directions can block the growth of the flat-direction's variance, the blocking effects are suppressed by the effective masses of the non-flat directions. As a consequence, we find that the flat-direction eventually evolves as an exactly flat-direction.

Superconducting properties of the QCD and electroweak vacuum in a strong magnetic background

Van Doorsselaere, Jos

In a very high magnetic background, the vacuum structure changes, both in QCD and the electroweak model. In both models vector bosons condense, rho-mesons in the QCD vacuum and W and Z bosons in the electroweak vacuum. The condensates have the form of an Abrikosov lattice and the detailed structure of all condensates near the transition into this phase can be calculated. We can also show explicitly how superconductivity is established in this vacuum. Similar techniques are used to describe a second phase transition in the electroweak model at an even higher magnetic background field, where the Higgs condensate vanishes. We can also construct an exact analytical solution for the vacuum structure in this regime.

Form factors of a 't Hooft-Polyakov monopole

Weir, David

The formation of 't Hooft-Polyakov monopoles is a consequence of symmmetry breaking phase transitions in the early universe. However, because it is difficult to calculate quantum corrections to the monopole perturbatively, very little is known about how such a monopole would interact with its environment. We show how to study the interactions of the 't Hooft-monopole nonperturbatively in a Monte Carlo simulation. The form factors for the defect-photon and defect-scalar interactions are defined and calculated on the lattice. We discuss the phenomenological consequences of this result for detecting monopoles at (for example) the LHC and applications to monopole pair creation physics.

Modeling Phase Transitions in Dynamical Environments

Yueker, Daniel

An interesting way of testing the standard model is to look for possible consequences of predicted phase transitions in the early universe. Particularly, electro-weak and deconfinement/chiral phase transitions are often discussed in this context. Even stronger dynamical effects are expected in the fireballs created in relativistic heavy-ion collisions. Because of the fast expansion one should expect non-equilibrium effects, such as nucleation, spinodal decomposition, supercooling and reheating, to be important. Due to theoretical uncertainties, we consider different possibilities regarding the type of a phase transition, the mechanism of the phase transformation and dynamics of the expansion. Since the early universe is almost baryon-antibaryon symmetric, its baryochemical potential is close to zero. As well established by lattice calculations, in this case the deconfinement phase transition occurs at a temperature below 200 MeV at time of 10^{-5} seconds after the big bang. We use an effective field-theoretical model to describe the QCD phase transition for different expansion rates. It is assumed that the formation of a new phase proceeds via thermal fluctuations. For the case of cosmological expansion a iterative scheme is formulated where the Hubble parameter is determined self-consistently with the order parameter. A possibility of "small inflation" scenario is discussed.

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