Abstract booklet for XQCD 2013

Workshop on QCD under extreme conditions

Bern, 5-7 August 2013

Oscar Akerlund
Scale hierarchy in high-temperature QCD
Talk

Because of asymptotic freedom, QCD becomes weakly interacting at high temperature: this is the reason for the transition to a deconfined phase in Yang-Mills theory at temperature T_c. At high temperature $T >> T_c$, the smallness of the coupling g induces a hierachy betwen the 'hard', 'soft' and 'ultrasoft' energy scales $2\pi T$, gT and g^2T. This hierarchy allows for a very successful effective treatment where the 'hard' and the 'soft' modes are successively integrated out. However, it is not clear how high a temperature is necessary to achieve such a scale hierarchy. By numerical simulations, we show that the required temperatures are extremely high. Thus, the quantitative success of the effective theory down to temperatures of a few T_c appears surprising a posteriori.

Andrei Alexandru
QCD at imaginary chemical potential with Wilson fermions
Talk

The phase diagram for QCD at non-zero baryon density is difficult to explore using lattice QCD techniques due to the sign problem. One possible avenue to constrain the features in this diagram is through simulations at imaginary chemical potential where numerical simulations are possible. Most numerical investigations in this region use staggered fermions, which are problematic for systems where the number of flavors is not a multiple of four. In this study, we use Wilson fermions to investigate the phase diagram for QCD with three degenerate flavors of quarks. We use a determinant compression method to perform a multi-histogram reweighting in both temperature and imaginary chemical potential, which allows us to smoothly map out this region. We identify the endpoint of the Roberge-Weise transition line and determine its relation to the pseudo-critical curve that intersects the zero-density line. We compare these results with results from another study at real chemical potential.

Alessandro Amato
Transport coefficients of the QGP
Poster

A lattice calculation is presented for the electrical conductivity of the QCD plasma at finite temperature, using a tadpole improved clover action with $2 + 1$ dynamical flavours and conserved currents. The behaviour of this transport coefficient is shown over a wide range of temperatures, across the deconfining transition. The spectral functions relevant for the analysis are extracted using the MEM algorithm, and with a detailed investigation of its systematics.

Georg Bergner
The strong coupling expansion of the effective Polyakov loop action and the free energy of the static quark-antiquark pair
Poster

Effective Polyakov loop models are a useful tool for an investigation of pure Yang-Mills theory and full QCD. A systematic derivation of the effective action can be done in a strong coupling expansion. Quite accurate predictions for phase transition have been obtained with this approach. As a further test of this approach the free energy of the static quark-antiquark pair in the effective theory is compared with the results in full Yang-Mills theory. In a different approach the a non-perturbative determination of the effective theory can be done up to a certain truncation. In a comparison between this non-perturbative estimation the validity of the strong coupling approach and the truncation is tested.

Wolfgang Bietenholz, Ivan Hip and David Landa-Marban
Dirac Spectrum of a 2d IR Conformal Theory
Poster TBA

Jacques Bloch
Solving the sign problem in one-dimensional QCD
Talk

We present a subset method to solve the sign problem for QCD at nonzero quark chemical potential in 0+1 dimensions. The subsets of gauge configurations are constructed using the center symmetry of the SU(3) group. This subset construction completely solves the sign problem when the number of flavors ranges from one to five. For a larger number of flavors we propose an extension of the subsets that also solves the sign problem for these cases. The subset method allows for numerical simulations of the model at nonzero chemical potential.

Igor Bogolubsky
On 2D and 3D localized solutions with nontrivial topology
Poster

Localized topological field distributions can be divided into 2 classes: topological solitons (TS) and topological defects (TDs). We exemplify and compare stationary TSs and TDs in bosonic models including Maxwell and Yang-Mills fields in 2 and 3 spatial dimensions.

Bastian Brandt
QCD thermodynamics with O(a) improved Wilson fermions at Nf = 2
Talk

We explore the phase diagram of two flavour QCD at vanishing chemical potential using dynamical $O(a)$ improved Wilson quarks. All simulations are done on lattices with a temporal extent of $N_t = 16$ and spatial extent $L = 32, 48$ and 64, ensuring that discretisation effects are small and finite size effects can be conrolled. In the approach to the chiral limit we currently have two scans along lines of constant physics at $m_\pi = 290$ and 200 MeV. In addition to Polyakov loop and chiral condensate, we also use spectroscopic observables, such as screening masses, to investigate the pattern of chiral symmetry restoration. Furthermore, we measure temporal correlation functions to extract information about spectral functions in confined and deconfined phases and to learn about plasma properties close to the critical temperature.

Falk Bruckmann
Thermodynamic properties of QCD in external magnetic fields
Invited Talk

I review recent results about the effect of external magnetic fields on thermodynamic properties of QCD, such as chiral condensate, Polyakov loop and gluonc action, from lattice simulations in comparison with model calculations. Observables quantifying the induced anisotropy are also discussed.

Shailesh Chandrasekharan
Fermion bag solutions to sign problems
Talk

We argue that a variety of sign problems in lattice field theories containing interacting fermions and bosons are solvable if one considers the path integral from the point of view of fermion bags. In the traditional formulation these sign problems look very similar to the sign problem in QCD at finite baryon density. In addition to solving the sign problems, the fermion bag approach also allows for efficient Monte Carlo calculations. Using this powerful approach we are able to compute for the first time, the quantum critical behavior in four-fermion field theories that were plagued by sign problems.

Jingyi Chao
An inverse magnetic catalysis effect induced by sphalerons
Poster

We find that the barrier between topologically in-equivalent vacua is lowered at the presence of external magnetic field. As a consequence, the imbalanced chiral quark density arises due to the sphaleron transition at finite temperatures. It quantitatively explains and describes the unusual phenomena of the inverse magnetic catalysis, which was numerically found to happen at the transition between the hadron, low-temperature phase and hot, magnetized quark-gluon plasma. We also propose relevant signatures of this effect to be experimentally accessible in the magnetised plasma environment created in noncentral heavy-ion collisions at the LHC.

Ting-Wai Chiu
Chiral symmetry and axial U(1) symmetry in finite temperature QCD with domain-wall fermion
Talk

We study the restoration of the spontaneously broken chiral symmetry and the anomalously broken axial U(1) symmetry in finite temperature QCD at zero chemical potential. We use 2 flavors lattice QCD with optimal domain-wall fermion on the $16^3 \times 6$ lattice,with the extent $N_s = 16$ in the fifth dimension, in the temperature range $T = 150-250$ MeV. To examine the restoration of the chiral symmetry and the axial $U(1)$ symmetry, we use diluted Z_2 noises to calculate the chiral condensate, and the chiral susceptibilities in the scalar and pseudoscalar meson channels, for flavor singlet and non-singlet respectively. From the degeneracy of the chiral susceptibilities around T_c, it suggests that the axial $U(1)$ symmetry is restored in the chirally symmetric phase. Moreover, we examine the spectral density $\rho(\lambda)$ of the overlap Dirac operator, which is obtained by computing zero modes plus 400 low-lying modes for each gauge configuration. The existence of a gap in the spectral density around $\lambda = 0$ for $T \simeq T_c$ provides a consistency check of the restoration of axial $U(1)$ symmetry in the chirally symmetric phase.

Saumen Datta
Bottomonia correlators from lattice QCD
Poster

Quarkonia are among the most important probes of the medium formed in relativistic heavy ion collisions. In particular, interesting results on bottomonia have been seen in LHC. Here we present results of a lattice study of bottomonia in gluonic plasma. We use relativistic framework for the b quarks, and examine the correlation functions in various quantum number channels.

Ydalia Delgado
Simulating Abelian Gauge-Higgs models using the worm algorithm
Poster

We present the surface worm algorithm (SWA), which is a generalization of the Prokof'ev Svistunov worm algorithm concept to simulate abelian Gauge-Higgs models on a lattice which can be mapped to systems of surfaces and loops (dual representation). First we assess the performance of the SWA using a U(1) Gauge-Higgs model and compare it with a local update in the dual representation. Then we also perform simulations of scalar electrodynamics with two flavors at finite density, where the sign problem is overcome in the dual representation.

William Detmold
QCD at nonzero isospin density
Invited Talk

QCD at nonzero isospin density is an interesting system both from a theoretical point of view and from a phenomenological perspective. On the one hand, it is presents new fundamental phases of matter that we seek to understand and on the other hand nonzero isospin density occurs, albeit in combination with baryon density, in both heavy ion collisions and in dense astrophysical environments. QCD at nonzero isospin density is also appealing as it is a system that can be studied efficiently using standard Monte-Carlo techniques. I will outline various different approaches to isospin density and chemical potential in lattice QCD and highlight recent results that have been obtained.

Heng-Tong Ding
QCD transition at finite temperature with domain wall fermions
Talk

We present recent studies on the fate of chiral and axial symmetries at finite temperature in 2+1 flavor QCD using Domain Wall fermions having lattice spacings corresponding to the temporal extent of Nt=8 and various volumes. Domain Wall fermions is a realization of chiral fermions on the lattice that preserves the exact chiral symmetry and reproduces the correct axial anomaly even at a finite lattice spacing. We investigate the nature of QCD transition by performing calculations with two pion masses, namely with a physical pion mass and also with a slightly heavier pion mass of 200 MeV. We explore the restoration of chiral and axial symmetries at finite temperature by studying the relations among various appropriate susceptibilities. We also investigate the role of Dirac eigenvalue spectrum in understanding the underlying mechanism of the axial symmetry breaking in the chirally restored phase. We also present comparisons of various observables with those using non-chiral fermions namely Highly Improved Staggered Quarks.

Michael Endres
Unitary fermions
Invited Talk

Since their first physical realization in ultra-cold atom experiments over a decade ago, unitary Fermi gases remain the subject of intense study from both an experimental and theoretical standpoint. The system is generically defined as a dilute mixture of nonrelativistic spin-1/2 fermions interacting via an attractive short-range two-particle interaction tuned to a resonance. In the limit of infinite scattering length and vanishing effective range, the properties of the Fermi gas become universal in the sense that they are insensitive to the details of the interaction potential. Because of this universality, unitary fermions are relevant for describing physical systems in widely varied disciplines beyond that of ultra-cold atoms, including dilute neutron matter in neutron stars. In this talk, I will discuss some of the fascinating low-temperature properties of unitary fermions, review some of the current theoretical tools used for exploring such systems nonperturbatively, and present qualitative and quantitative results produced from the application of these methods thus far.

Leonard Fister
Gluondynamics in 2-colour matter at high density Talk

We study aspects of gluodynamics of QCD with two colours at both zero and non-zero chemical potential on the lattice. In contrast to other quantities the medium effects on correlation functions of quarks and gluons in two-colour QCD may provide a reliable guideline for full QCD. Here we present results on the gluon propagator in Landau gauge as a function of both temperature and chemical potential. With increasing temperature and chemical potential we find strong screening in the electric gluon, whereas the magnetic gluon shows little sensitivity to temperature, and exhibits a mild enhancement at intermediate chemical potential before being suppressed at large densities.

Rajiv Gavai
Quark number susceptibility divergence can be subtracted off
Talk

We proposed earlier a faster method to evaluate the coefficients of the series for baryonic susceptibility which could potentially permit access to higher orders than so far. It consists of adding the chemical potential linearly as a Lagrange multiplier, and does even exhibit full chiral invariance on the lattice for the overlap Dirac operator at finite density. Using lattices with varying N_t such that T/T_c is held fixed, we demonstrate at many different temperatures the absence of any diverging terms in the quark number susceptibility by using a subtraction of the corresponding ideal gas term . Moreover, the continuum limit in each case is found to be in very good agreement with the existing results obtained by using the exponential μ-term.

Pietro Giudice
Thermodynamics of dense 2-color matter
Poster

We study two-color QCD with two flavors of Wilson fermion as a function of quark chemical potential and temperature. We find evidence of three distinct phases at low temperature, namely a vacuum/hadronic phase, a superfluid phase, where the quark number density and diquark condensate are both very well described by a Fermi sphere of nearly-free quarks disrupted by a BCS condensate, and a deconfined phase. We present our recent results supporting this picture, focusing on the equation of state, the quark number susceptibility and the chiral condensate.

Jeff Greensite
Effective Polyakov line actions and the sign problem
Talk

There are indications that the sign problem is tractable in effective Polyakov line actions; the problem is then to derive such actions from the underlying lattice gauge theory. We present a new technique for extracting the effective Polyakov line theory corresponding to a given lattice gauge theory, and test the validity of the effective theory by comparison of Polyakov line correlators in the effective theory and the underlying gauge theory. It is found that the effective action in the confined phase includes non-nearest neighbor couplings, up to a maximum separation which increases with temperature.

Sourendu Gupta
The QCD critical point
Talk

We present results on the position of the QCD critical point from lattice simulations of QCD at three different lattice spacings. We also present results on the construction of physical measurables and their extrapolation to accessible parts of the phase diagram from their measurement at vanishing chemical potential.

Masanori Hanada
A new look at instantons at large N
Talk

In particle physics, when one considers 'large-N', it almost automatically means the 't Hooft large-N limit, in which the 't Hooft coupling g^2N is fixed. I point out, however, a large-N limit with g^2 fixed ('the very strong coupling large-N limit') is as useful as (or sometimes more useful than) the 't Hooft limit, especially when one considers the instanton effect. This is so because the instanton effect, which is typically suppressed in the 't Hooft limit, remains finite in the very strongly coupled limit. After showing that the relationship between the 't Hooft limit and the very strongly coupled large-N limit, I will show several applications, including (1) a novel large-N equivalence in the instanton sectors and the derivation of the instanton partition function of a class of nonsupersymmetric gauge theories, (2) holographic description by the eleven dimensional supergravity,(3) instanton gas in the large-N QCD.

Simon Hands
A strongly-interacting Fermi surface? Voltage-biased bilayer graphene
Talk

I present simulation results for a lattice theory with Nf=4 relativistic 2+1d fermions which models bilayer graphene near a quantum critical point. A bias voltage between the layers is equivalent to an isospin chemical potential and the resulting system can be simulated using orthodox HMC without a Sign Problem. An excitonic condensate forms between electrons in one layer and holes in the other. The scaling of both condensate and carrier density is not in accord with expectations based on a weakly-interacting BCS picture, but assuming Luttinger's theorem could be taken as evidence in support of a strongly-interacting degenerate system. New results for the quasiparticle dispersion will be presented to test this picture.

Tim Harris
Bottomonium at finite temperature
Poster

I will present some updated results from the FASTSUM collaboration on the bottomonium spectrum at finite temperature from lattice QCD. Bottomonium may serve as a cleaner probe of a hot medium than in the charmonium system as there are fewer effects competing with suppression. In this work we use a new ensemble of anisotropic gauge configurations with 2+1 flavours of Wilson quark with a finer spatial lattice spacing than used previously. The heavy valence quarks are treated using an improved NRQCD action. I will compare the analysis of the Υ and χ_{b1} correlators on the new ensemble with the earlier results which suggested the survival of the S-wave states and melting of the P-wave states at accessible temperatures above the deconfinement transition temperature. Further insight can be gained by computing the associated spectral functions using the maximum entropy method. I will include some preliminary results on the bottomonium spectral functions at finite temperature.

Matti Jarvinen
Finite-temperature holographic QCD in the Veneziano limit
Talk

I discuss the finite-temperature phase structure in a class of holographic models for QCD. The models are defined in the Veneziano limit of large number N_c of colors and N_f flavors, and with $x_f = N_f/N_c$ fixed. They contain a 5-dimensional metric and two scalars, a dilaton sourcing Tr F^2 and a tachyon dual to $\bar{q}q$, with full backreaction of the flavor dynamics to the glue. Various phases with and without chiral symmetry or confinement can be identified on the (x_f,T)-plane, separated by 1st or 2nd order transitions or crossovers. In the simplest case, for x_f up to the critical x_c 4 there is a 1st order transition on which chiral symmetry is broken and the energy density jumps. I will also comment on turning on finite chemical potential.

Kazuhiko Kamikado
Effects of baryon number density fluctuation around QCD critical point
Poster

Many chiral effective model calculations suggest that there is a QCD critical point on temperature and baryon chemical potential plane. The QCD critical point is a point at which second order phase transition occurs and some of physical values show critical behaviors. In contrast to zero chemical potential case, the chiral order parameter is coupled with baryon-number density fluctuation. Thus it is essential to consider the effects of mixing between chiral condensate and baron number density fluctuation around the CP. We calculate effective potential with the fluctuation of these modes by solving the functional renormalization group equation and reveal the phase structure around the CP. We will show that how the critical region is sensible to the strength of the mixing between sigma and density fluctuation mode.

Nikhil Karthik
Improved hadronic screening at zero baryon density
Poster

We present our results on hadronic screening correlators and masses in finite temperature two flavor QCD using optimally smeared staggered valence quarks and staggered thin-link sea quarks. In the transition region, we find clear signal for chiral symmetry restoration immediately above the cross over temperature, T_c. We also find evidence for rapid opening of spectral gap between 1 to 1.06 T_c. In the high temperature phase above 1.5 T_c, we resolve the apparent disagreement between staggered meson screening masses and weak coupling predictions.

Kouji Kashiwa
Phase diagram and Hosotani mechanism in QCD-like theory with compact dimensions
Talk

We investigated the phase structure of SU(3) gauge theory in four and five dimensions with one compact dimension by using perturbative one-loop and PNJL-model-based effective potentials. The effect of the adjoint and fundamental fermion is investigated and then rich phase structure in the quark-mass and compact-size space with gauge-symmetry-broken phases is realized. We also study chiral properties in these theories. Our results are qualitatively consistent with the recent lattice calculations and clearly show that the calculations can be understood from Hosotani mechanism.

Seyong Kim
Lattice NRQCD study of bottomonium around the deconfinement temperature
Talk

Using lattice NRQCD method on $48^3\times12$ HotQCD HiSQ configurations with light dynamical $N_f = 2+1$ ($m_l/m_s = 0.05$) staggered quarks, we study bottomonium state correlators at non-zero temperature, $140.4(\beta = 6.664) \geq T \geq 221(\beta = 7.280)$ (MeV), where the transition temperature is 154(9) (MeV). Zero temperature behavior of bottomonium correlators is compared based on 32^4 ($\beta = 6.664, 6.800$ and 6.950) and $48^3 \times 64$ ($\beta = 7.280$) lattices to understand finite temperature effect. It is found that temperature effects on S-wave bottomonium states are small but P-wave bottomonium states show a noticeable temperature dependence above the transition temperaure.

Thomas Kloiber
Dual methods for lattice field theories at finite density
Talk

When studying (lattice) field theories at finite densities, the notorious complex action or sign problem arises, i.e, the action becomes complex for non-vanishing chemical potential. Therefore the Boltzmann factor also becomes complex, which spoils a probabilistic interpretation. To get rid of complex contributions to the partition function we reformulate the theory in terms of new degrees of freedom – so-called dual variables. In this representation the partition function consists of real, non-negative contributions only, such that a probabilistic interpretation is feasible. The fundamental degrees of freedom are then integer-valued and constrained. Here we treat a complex (charged) ϕ^4 theory, i.e., the relativistic Bose gas. We show how the dual representation is derived and discuss its numerical simulation which generates only admissible configurations. This is achieved with a generalized version of the Prokof'ev-Svistunov worm algorithm. Physical phenomena like the Silver Blaze problem and Bose condensation can then be studied efficiently. In addition, we present a method to extract n-point functions from the dual ensemble. Results for the field correlators and finite chemical potential spectroscopy calculations are shown.

Chris Korthals Altes, Alfonso Sastre
What drives the departure from the Stefan-Boltzmann gluon gas?
Poster

The effective action of the Polyakov loop is since long known at asymptotic temperatures. It is given by the one loop fluctuations around a constant Polyakov loop. At its minima the Stefan- Boltzmann gas realizes. We pose the question: by what mechanism is this minimum destabilized? We have scrutinized the one loop fluctuations around the caloron, and how the minima start to move to the Z(2) invariant confining minimum. We compare our result to earlier work.

Dean Lee
Lattice effective field theory for nuclear physics
Invited Talk

I review recent results in lattice effective field theory applied to nuclear structure and many-body physics. I emphasize connections to lattice QCD both at the level of algorithms and underlying physics questions. I also preview ongoing work to calculate inelastic nuclear reactions on the lattice.

Heiri Leutwyler
The mass of the two lightest quarks
Invited Talk

Among the parameters occurring in the Lagrangian of QCD, the masses of the u- and d-quarks are subject to the largest uncertainties. I intend to review the current state of our knowledge.

Keh-Fei Liu
Origin of sign problem and noise filtering
Poster

The origin of the sign problem in the canonical ensemble approach to finite density in lattice QCD and the O(4) is studied. We consider an idea of filtering out the noise to ameliorate the sign problem in the charmonium correlators with finite momenta.

Yu Maezawa
Meson screening masses at finite temperature with highly improved staggered quarks
Talk

We study meson screening masses at finite temperature in 2+1 flavor QCD using the Highly Improved Staggered Quarks (HISQ) action. The screening masses are obtained from spatial meson propagators and enable us to probe the sensitivity of hadronic correlation functions to the quark structure in thermal matter. We calculate the meson screening masses on lattices with aspect ratio $N_s/N_t = 4$ in a larger temperature interval of 140–250 MeV for N_t=12 and 250–740 MeV for N_t=4–10. We focus on the strange and charmed flavor sectors and find that significant modifications of thermal masses in the strange quark sector appear even below the critical temperature (Tc), whereas for charmonium states modifications become significant only for T ¿ 1.2Tc. We also present several other properties of meson states at finite temperature, e.g. modifications of amplitudes and the onset of spin and parity degeneracy at high temperature.

Nilmani Mathur
Nucleons near the QCD deconfinement transition
Poster

We present results of a lattice study of hadronic screening correlators above and immediately below the deconfinement transition temperature, Tc, in the quenched approximation. Simulations were performed at temperatures T /Tc = 0, 0.95 and 1.5. Mesonic screening correlators show no statistically significant thermal effects below Tc, and clear evidence for weakly interacting quarks above Tc . Baryon screening correlators yield similar physics above Tc, but show precursor effects for chiral symmetry restoration below Tc.

Harvey Meyer
Non-perturbative approaches to transport properties and spectral functions in hot QCD
Invited Talk

I review the progress made in non-perturbative techniques to compute transport coefficients and spectral functions. After describing the nature of the problem in general, I discuss more specifically the derivation and use of exact sum rules and new insight into the vector and axial-vector spectral functions.

Guy Moore
NLO calculations at finite temperature and the lightcone
Invited Talk

Using photon production from QCD as an example, we present the methodology to compute transport phenomena at next-to-leading order in the gauge coupling. The key physics involves soft correlators at lightlike separated points, which are characterized by condensates which can be computed via Euclidean methods. We illustrate how this physics arises and how it allows relatively simple calculations of NLO transport phenomena.

Joyce Myers
Large N relationship of weakly coupled QCD on the hypersphere with strongly coupled lattice QCD
Talk

We consider the action of QCD at large Nc and large Nf at weak coupling, from continuum one loop perturbation theory on $S^1 \times S^3$, for small S^3, and compare with that of lattice QCD at strong coupling and large quark mass from a combined strong coupling and hopping expansion. In the lattice theory we build on previous results, calculating up to order $\beta^{(2Nt)}$ in the inverse coupling, using the character expansion to obtain the contributions to the pure gauge action, and at second order in the hopping parameter for the quark contribution to the action. We find that at this order, the equation of motion can still be matched to that of continuum QCD on $S^1 \times S^3$ at weak coupling for a suitably truncated action, allowing for observables calculated in one theory to be converted to the other under suitable transformations.

Keitaro Nagata
Eigen spectrum of Wilson fermions in finite isospin chemical potential
Poster

QCD with finite isospin chemical potential is known to be free from the sign problem, and is a testing ground for examining properties of QCD at finite density. Based on lattice QCD simulations with finite isospin chemical potentials, we will discuss the eigen-spectrum of a Dirac matrix and of a reduced matrix for Wilson fermions.

Atsushi Nakamura

What can we learn from RHIC proton multiplicity distributions on QCD phase diagram?

Poster

We show that we can construct the canonical partition functions, Z_n, from the net-proton number distributions at RHIC assuming that the proton number is approximately conserved after the freeze-out. We construct then the grand partition function Z(mu) from the Z_n. We calculate the moments such as the susceptibility and the kurtosis not only on the experimentally measured (T,mu) points, but also at larger mu regions. We construct also Lee-Yang zeros. From these analyses, we estimate the QCD phase transition line regions in (T,mu) plane. We construct the Lee-Yang zeros also from our lattice QCD simulation data. We see the different features of Lee-Yang zero distribution below and above the phase transition temperature. We find a Roberge-Weise phase transition structure in the Lee-Yang zero structure at high temperature, which can be observed also in future baryon number distribution at heavy-ion collision experiments.

Tiago Nunes

Probing the conformal window on the lattice

Talk We present a summary of our study on the conformal window: using lattice techniques we have studied the properties of the theories inside the window and in the quasi-conformal region. Our current ongoing project will allow us sharpen the evidence of the singularity that signals the opening of the window. We also comment on the role of improvement away from the perturbative limit.

Kari Rummukainen

Qhat from EQCD

Talk

The bremsstrahlung energy losses of high energy partons in hot QCD plasma modify the jet momentum broadening coefficient $\hat{q}$. Perturbatively, the effects are seen to be large, even at weak coupling. Following the suggestion by Caron-Huot, we measure $\hat{q}$ using lattice simulations of dimensionally reduced effective theory of high temperature QCD (EQCD).

Yuji Sakai

Analytic continuation in two color QCD with clover-improved Wilson fermion at finite density

Talk

We test the method of analytic continuation from imaginary to real chemical potential in two-color QCD, which is free from the sign problem. We employ a clover-improved Wilson fermion action of two-avors and a renormalization-group improved gauge action. In particular, we consider the analytic continuation of the critical line, the quark number density and meson correlations.

Takahiro Sasaki

Constraints on quark-hadron transition from lattice QCD and neutron-star observation

Poster

We investigate constraints on the QCD phase diagram given by the solid information. Particularly, measurement of two-solar-mass neutron star gives a strong constraint to the equation of state at vanishing temperature. We make a simple quark-hadron transition model which is consistent with both of lattice QCD simulations and neutron-star mass measurements. The model tells a lower limit of critical chemical potential, and it is consistent with recent analysis of baryon multiplicity distribution.

Daisuke Satow
Quasi-Nambu-Goldstone fermion in QGP and cold atom system
Poster

It was suggested that supersymmetry (SUSY) is broken at finite temperature, and as a result of the symmetry breaking, a Nambu-Goldstone fermion (goldstino) related to SUSY appears. Since dispersion relations of quarks and gluons are almost degenerate at extremely high temperature, quasi-zero energy quark excitation was suggested to exist though QCD does not have exact SUSY. As for the condensed matter system, a setup of cold atom system in which the Hamiltonian has SUSY was proposed, the goldstino was suggested to exist, and the dispersion relation of that mode at zero temperature was obtained recently. In this presentation, we obtain the expressions for the dispersion relation of the goldstino in cold atom system at finite temperature, and compare it with the dispersion of the quasi zero-mode in QCD. Furthermore, we show that the form of the dispersion relation of the goldstino can be understood by using an analogy with a magnon in ferromagnet. We also discuss on how the dispersion relation of the goldstino is reflected in observable quantities in experiment.

Hans-Peter Schadler
New developments in the fugacity expansion approach to finite density QCD
Poster

We calculate the projection of the fermion determinant on fixed quark numbers, i.e., the canonical determinants. These canonical determinants are expansion coefficients in the fugacity series and observables related to quark numbers can be written in terms of their moments. In this talk we discuss the technical challenges and show results for various observables at small chemical potential and temperatures below and above the crossover.

Christian Schmidt
The strange degrees of freedom in QCD at high temperature
Talk

We use appropriate combinations of conserved charge fluctuations up to the fourth order to probe the strangeness carrying degrees of freedom in QCD at high temperature. In particular, we use diagonal fluctuations of net strangeness as well as their correlations with net baryon number and net electric charge, which we have obtained from lattice QCD calculations using 2+1 flavor of highly improved staggered quarks (HSIQ) on Nt=6 and 8 lattices. We show that up to the chiral crossover temperature (Tc) strange mesons and baryons, can be well described by an uncorrelated gas of hadrons. On the other hand, the strangeness carrying degrees of freedom inside the quark gluon plasma can be described by a weakly interacting gas of quarks only for temperatures larger than 2 Tc. In the intermediate temperature window these observables show considerably richer structures, indicative of the strongly interacting nature of the quark gluon plasma.

Denes Sexty
Simulations of full QCD using the complex Langevin equation
Talk

We employ a new method, "gauge cooling", to stabilize complex Langevin simulations of QCD. First the heavy quark approximation is investigated, where results are checked against results obtained with reweigthing; then the method is extended to full QCD with light quarks. The method allows us to go to previously unaccessible high densities.

Sayantan Sharma

Investigation of the axial anomaly in high temperature QCD on the lattice

Poster

In this work we study the effects of the $U_A(1)$ anomaly for $2+1$-flavour QCD at high temperature. We apply the overlap operator as a tool to probe the topological properties of gauge field configurations which have been generated within the Highly Improved Staggered Quark (HISQ) discretization scheme on lattices of size $32^3 \times 8$ with $m_l/m_s = 1/20$, commonly used for the study of QCD thermodynamics. The distribution of the low-lying eigenvalues of the overlap operator suggests that the $U_A(1)$ is not restored effectively even at 1.5 times the pseudo critical temperature. We also study the localization properties of the lower eigenmodes as a function of temperature to gain a better understanding of the underlying topological structure of QCD.

Kim Splittorff

The QCD sign problem as a total derivative

Talk

We consider the distribution of the complex phase of the fermion determinant in QCD at nonzero chemical potential and examine the physical conditions under which the distribution takes a Gaussian form. We then calculate the baryon number as a function of the complex phase of the fermion determinant and show 1) that the exponential cancellations produced by the sign problem take the form of total derivatives 2) that the full baryon number is orthogonal to this noise. These insights allow us to define a self-consistency requirement for measurements of the baryon number in lattice simulations.

Nucu Stamatescu

Progress in complex Langevin simulation for lattice gauge models at non-zero chemical potential

Poster

At nonzero chemical potential the numerical sign problem in lattice field theory limits the use of standard algorithms based on importance sampling. Complex Langevin dynamics provides a possible solution, but it has to be applied with care. We here summarise our current understanding of the approach, combining analytical and numerical insight. We introduce methods for controlling the Langevin simulation for complexified variables and present results for lattice gauge models.

Shinji Takeda

Exploring finite density QCD with Nf=3 and 4 by Wilson-type fermions

Poster

We investigate the critical end-point of QCD with zero and finite density by using Wilson-clover fermions and the Iwasaki gauge action. In the case of the finite density, we employ the grand canonical approach combined with the phase reweighting method. We use the Binder cumulant intersection method to identify the location of the critical end-point.

Wolfgang Unger

The phase diagram of QCD in the strong coupling limit and its O(beta) corrections

Poster

The strong coupling limit of staggered lattice QCD has been studied since decades, both via Monte Carlo and Mean field theory. In this model, the finite density sign problem is mild and the full phase diagram can be studied, even in the chiral limit. It is however desirable to understand the effect of a finite lattice coupling on the phase diagram in the μ_B-T plane in order to see how it might be related to the phase diagram of continuum QCD. Here we present how to compute O(β) corrections of fermionic observables like the chiral susceptibility and the baryon density, and discuss the effect of the phase diagram

Mithat Unsal
Center symmetry, neutral bions and (a tiny little bit of) resurgence theory
Invited Talk

Recently, it is understood that an interesting class of QCD-like gauge theories does not undergo a center-symmetry changing phase transition once compactified to a spatial (non-thermal) circle on R^3xS^1. The same class of theories, at finite N, possess a semi-classical non-perturbatively calculable domain continuously connected to R^4, and in the large-N limit, they satisfy volume independence (solution of the Eguchi-Kawai problem). Because of large-N orbifold equivalences, these theories also have some relevance to ordinary QCD. This set-up provides opportunity to make progress in non-perturbative gauge dynamics from first principles where we have control over non-perturbative aspects. I will discuss a non-perturbative mechanism of center-stabilization (neutral bions), and provide evidence that it provides a microscopic/semi-classical interpretation of the elusive renormalons of 't Hooft. At the end, I will point out briefly that this framework has the potential to lead to a non-perturbative definition of QFT in continuum via resurgence theory. My talk will provide a summary of the program I am pursuing with my collaborators Poppitz, Schaefer, Argyres, and Dunne.

Urs Wiedemann
News and theoretical challenges from recent heavy ion experiments
Invited Talk
TBA

Masanobu Yahiro
Differences and similarities between fundamental and adjoint fermions in SU(N) gauge theories
Poster

We investigate differences and similarities between fundamental fermions and adjoint fermions in SU(N) gauge theories. The gauge theory with fundamental fermions possesses ZN symmetry only in the limit of infinite fermion mass, whereas the gauge theory with adjoint fermions does have the symmetry for any fermion mass. The flavor-dependent twisted boundary condition (FTBC) is then imposed on fundamental fermions so that the theory with fundamental fermions can possess ZN symmetry for any fermion mass. We show similarities between FTBC fundamental fermions and adjoint fermions, using the Polyakov-loop extended Nambu-Jona- Lasinio (PNJL) model. In the mean-field level, the PNJL model with FTBC fundamental fermions has dynamics similar to the PNJL model with adjoint fermions for the confinement/deconfinement transition related to ZN symmetry. The chiral property is somewhat different between the two models, but there is a simple relation between chiral condensates in the two models. As an interesting high-energy phenomenon, a possibility of the gauge symmetry breaking is studied for FTBC fundamental fermions.

Arata Yamamoto
Strong external electric fields in lattice QCD
Poster

We study particle generation by a strong electric field in lattice QCD. To avoid the sign problem of the Minkowskian electric field, we adopt the 'isospin' electric charge. When a strong electric field is applied, the insulating vacuum is broken down and pairs of charged particles are produced by the Schwinger mechanism. The competition against the color confining force is also discussed.