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Book of Abstracts

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3

Quark pairing in sQGP induced by the non-Abelian feature of the interaction

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We solve the coupled Dyson-Schwinger equations for quark propagator and quark gluon vertex in the Nambu-Gorkov basis which is widely applied to study the color superconductivity. After considering the non-Abelian feature in the off-diagonal part of quark gluon vertex, we acquire a quark pairing gap in chiral limit above the chiral phase transition temperature T_c . The gap persists up to $2 - 3 T_c$ and vanishes at higher temperature. Such a quark pairing characterizes the strongly coupled quark gluon plasma phase as a new phase and distinct from the phase with quasi quarks and gluons.

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Universal location of Yang-Lee edge singularity from Functional RG

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Critical points are categorized based on the number of relevant variables. The standard critical point in systems like the Ising model involves two relevant variables, namely temperature and external magnetic field. In contrast, a tricritical point is characterized by four such variables. The protocritical point, widely known as the Yang-Lee edge singularity (YLE), is the simplest form of criticality and has just one relevant variable. Unlike conventional critical points, the YLE singularity occurs at complex values of parameters. When two YLE singularities merge and pinch the real axis of the corresponding thermodynamic variable, a critical point with associated critical scaling emerges. In other words, the location of the YLE singularity is continuously connected to the location of the critical point. In this talk, I explain why conventional methods fail to accurately locate YLE singularity and demonstrate the success of the Functional Renormalization Group approach in determining the universal location of these singularities.

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The θ -angle physics of 2-color QCD at finite density

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Understanding the QCD phase diagram is a major challenge in high-energy physics. To this end, two-color QCD offers an ideal theoretical laboratory since, unlike real-world QCD, its dynamics at finite density can be investigated via lattice simulations. In this talk, I will use chiral perturbation theory to discuss the infrared dynamics of two-color QCD at finite density by focusing on the impact of the θ -angle on the vacuum properties, symmetries, and spectrum. In particular, I will describe the rich phase diagram of the theory for different numbers of flavors. I

will put special emphasis on the diquark condensation phenomenon and the fate of CP symmetry at $\theta=\pi$.
Finally, I will briefly comment on the significance of the results for QCD at finite quark chemical potential.

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Noise-aware variational eigensolvers: a dissipative route for lattice gauge theories

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We propose a novel variational ansatz for the ground-state preparation of the $\mathbb{Z}_2$ lattice gauge theory (LGT) in quantum simulators. It combines dissipative and unitary operations in a completely deterministic scheme with a circuit depth that does not scale with the size of the considered lattice. We find that, with very few variational parameters, the ansatz can achieve >99% precision in energy in both the confined and deconfined phase of the $\mathbb{Z}_2$ LGT. We benchmark our proposal against the unitary Hamiltonian variational ansatz and find a clear advantage of our scheme, especially when focusing on the nature of the confinement-deconfinement transition of the $\mathbb{Z}_2$ LGT. After performing a finite-size scaling analysis, we show that our dissipative variational ansatz can predict critical exponents with reasonable accuracies even for reduced qubit numbers and circuit depths. Furthermore, we investigate the performance of this variational eigensolver subject to circuit-level noise, determining variational error thresholds that fix the error rate p_ℓ below which $p < p_\ell$ it would be beneficial to increase the number of layers $\ell \mapsto \ell' > \ell$. In light of these quantities and for typical gate errors p in current quantum processors, we provide a detailed assessment of the prospects of our scheme to explore the $\mathbb{Z}_2$ LGT on near-term devices.

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Supporting 3P_0 Quark-Pair Creation using Landau Gauge Green's Functions

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Phenomenological evidence suggests that strong decays of low-excitation hadrons often involve the creation of a light quark-antiquark pair with zero angular momentum, known as the 3P_0 mechanism, derived from a scalar bilinear. Despite Quantum Chromodynamics being mediated perturbatively by spin-one gluons and exhibiting chiral symmetry in its Lagrangian, a scalar decay term appears spontaneously upon chiral symmetry breaking. We explore this by employing the quark-gluon vertex in the Landau gauge and the nonperturbative effects recently clarified, alongside a constant chromoelectric field similar to the Schwinger pair production in Quantum Electrodynamics. We compare this to a two-field insertion diagram in QED and argue that the relevant quantum numbers for discussing production are $^3\Sigma_0$, $^3\Sigma_1$, and $^3\Pi_0$, analogous to those in diatomic molecules. Our results indicate significant contributions from the third decay mechanism, supporting the 3P_0 phenomenology at momenta at or below the fermion mass scale. However, ultrarelativistic fermions predominantly exhibit $^3\Sigma_1$ quantum numbers. In QED, $^3\Sigma_0$ is dominant, whereas in QCD, $^3\Pi_0$ prevails at sub-GeV momenta due to the requirement to form a color singlet.

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Towards TMDs with contour deformations

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Hadrons are strongly interacting particles composed of quarks and gluons and described by Quantum Chromodynamics (QCD). Their internal structure can be described in terms of structure functions that encode, for example, the momentum and spin distributions of their constituents. Parton distribution functions (PDFs) and Transverse Momentum Distributions (TMDs), for example, describe the quark and gluon momentum distributions inside a hadron. These distribution functions are, however, not easy to calculate, because they are defined on the light front, whereas most hadron calculations are performed in a Euclidean metric. The main problem is then to go from Euclidean onto the light front.

We are developing a new method to compute the parton distributions (TMDs and PDFs) from hadronic matrix elements using contour deformations. We will illustrate the method for a simple system of two interacting scalar particles of equal mass, using an handbag approximation to the matrix element, that includes the two-body Bethe-Salpeter amplitude as input (calculated from its Bethe-Salpeter Equation). Afterwards, the projection onto the light front is done through a combination of contour deformations and analytic continuation methods. We then explore ways of extending the handbag approximation by adding “quark-quark” interactions via the introduction of the four-point function in the diagram, which, in turn, is calculated self-consistently, from its own scattering equation.

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Conformality, dynamical chiral symmetry breaking and confinement: cartography of strong dynamics

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(Tentative abstract) We study the interplay between colour-confining and chiral symmetry-breaking dynamics in gauge-fermion theories. We target the challenging many-flavour limit of theory space using the non-perturbative functional Renormalisation Group approach. This work connects the QCD-like regime, in quantitative agreement with Lattice data, with the perturbative conformal limit of theory space. Utilising bosonisation techniques, we obtain the theory’s fundamental parameters and the relation between scales purely from first principles. Finally, we investigate interesting near-conformal theories and provide a quantitative estimate for the lower boundary of the Caswell-Bank-Zaks window. This work offers a self-consistent framework for charting the landscape of strongly interacting gauge-fermion theories necessary to reliably study strong extensions of the Standard Model of particle physics.

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Shear and Bulk viscosity for the pure glue theory using an effective matrix model

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At nonzero temperature, the deconfining phase transition and the change in non-trivial holonomy can be analyzed using an effective matrix model. The shear and bulk viscosities are computed in weak coupling but in non-zero holonomy. (shear viscosity/entropy density) decreases as we approach T_d , it is still well above the conformal bound. In contrast, (bulk viscosity/entropy density) is largest at T_d , comparable to (shear viscosity/entropy density), then falls off rapidly with increasing temperature and is negligible by $2T_d$.

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Charge transport in strongly magnetized relativistic matter

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Using the imaginary part of the self-energy function in the Landau-level representation, we derive the fermion damping rate in a hot magnetized plasma at the leading order of coupling. The results are used to investigate the longitudinal and transverse electrical conductivities by employing first-principles quantum field theoretical methods. In the relativistic regime, these conductivities exhibit a scaling behavior expressed in terms of dimensionless functions of eB/T^2 , where T represents the temperature and B is the magnetic field. We demonstrate that the underlying mechanisms governing the transverse and longitudinal conductivities differ significantly, resulting in a substantial suppression of the former compared to the latter. Although the approximation loses validity due to strong coupling in QCD, we extend our analysis to a magnetized quark-gluon plasma.

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The center-symmetric Landau gauge meets the lattice

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We present a lattice implementation of the recently introduced center-symmetric Landau gauge and show that center symmetry imposes constraints on the gauge-link correlators in that gauge. In

particular, we obtain constraints on the local one-link average and on the two-point link correlator which mirror those obtained in the continuum for the gauge-field one- and two-point functions. Then, although link correlators or the associated gauge-field correlators cannot be measured experimentally, they can be used on the theory side as order parameters for the confinement/deconfinement transition. Strictly speaking, this requires the Gribov copies that are present in the center-symmetric Landau gauge to be chosen in specific ways. We discuss to which extent this is realized, at least approximately, in the lattice implementation of the gauge fixing. We also compare this discussion to a similar one within the standard Landau gauge and argue why, in this latter case, link correlators or the associated gauge-field correlators are not good probes for center symmetry breaking.

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Gluon three- and four-point vertices from quenched lattice QCD: planar degeneracy and strong coupling constant.

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We report novel lattice QCD results for the general kinematics three-gluon vertex, focusing in the determination of the three gluon coupling in MOM scheme, α_{3g} , for a wide variety of vertex kinematics. By employing the \textit{planar-degeneracy}, that states that the deep IR running of the vertex does not depend on the particularities of the kinematical configuration chosen to compute it, we propose a definition of the renormalized coupling that exploits this phenomenon.

We furthermore compute for the first time the tree-level component of the four-gluon vertex in non-collinear kinematics, which also exhibits \textit{planar-degeneracy}, and compute the MOM-scheme coupling α_{4g} following the same approach than in the three-gluon case. Strikingly, α_{3g} and α_{4g} seem to coincide with each other in the deep IR, pointing towards the idea of an universal coupling for the gluonic sector of QCD at low momenta.

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Thermodynamics of color-superconducting quark matter

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We investigate the thermodynamic properties of color-superconducting two flavor quark matter at high densities and zero temperature, considering the next-to-leading order (NLO) correction in the strong coupling and the gap. Assuming that the ground state of dense quark matter is a color superconductor, we calculate the pressure and speed of sound for two massless quark flavors. Our results show that the NLO correction is comparable to the leading-order effects, increasing both pressure and speed of sound. Finally, we provide a parameterization of the speed of sound and discuss implications for three-flavor quark matter relevant to neutron stars.

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Quark confinement in the Curci-Ferrari model

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We consider the interaction potential between a static quark and an antiquark forming a singlet in the quenched approximation. For this purpose we work in the Landau-De-Witt gauge and exploit some properties of the Yang-Mills theory in the Landau gauge observed in Monte-Carlo simulations and previously obtained by various semi-analytical methods. In particular, the gluon propagator exhibits massive behavior with positivity violations, the ghost propagator shows a massless behavior and the coupling constant has no Landau pole and remains at moderate values even in the infrared. By means of these properties we show the existence of a solution of the equations of motion in the form of a flux tube in the case of a very distant quark-antiquark pair. The moderate value of the coupling constant allows us to obtain such a solution by a controlled semi-classical approximation which we compare successfully with Monte-Carlo simulations. This solution results in a string tension that also compares well with such simulations. For the purpose of concrete calculations we use the Curci-Ferrari model which has proven to be very efficient in reproducing the infrared behavior of the Yang-Mills theories, but the results obtained do not seem to depend on the details of the precise calculation method as long as it respects the main characteristics of the Yang-Mills correlation functions.

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On the role of truncations of the 3PI effective action for glueball masses

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The last two decades have seen much progress in the calculation of quark and gluon correlation functions using functional methods and in their application to the calculation of hadronic observables. A tantalizing question is that of the systematic error inherent in such methods which is closely related to the stability of the employed truncations with respect to extensions. In this contribution, I will discuss this for the spectrum of glueballs in pure gauge theory calculated from the 3PI effective action. First, its equations of motion are discussed with respect to extensions and in comparison to other methods. Second, I show results for the impact of different truncations of the bound state equations on the masses of several glueballs.

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The high temperature QCD static potential

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It was shown in a certain approximation that dissociation of heavy quark bound states in a quark-gluon plasma occurs due to the emergence of an imaginary part of the potential. We check the robustness of this prediction against corrections. We calculate higher order corrections to the potential in a systematic and rigorous way, in the region where bound states dissociate. This region is dominated by what we call the semi-hard scale, which is smaller than the temperature and larger than the screening mass in natural units. We use a triple expansion in terms of the coupling constant, the semi-hard scale over the temperature, and the screening mass over the semi-hard scale. We have used our result for the beyond leading order potential to calculate the dissociation temperature, and confirmed the validity of the picture that was proposed from the leading order approximation. We compare our results with lattice data.

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Distribution and fragmentation functions of light and heavy mesons

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A more recent approach to light-front wave functions (LFWF) of hadrons consists, in the case of mesons, of projecting their Bethe-Salpeter wave functions on the light front. The latter is obtained within a functional approach to QCD, solving first the quark gap equation within a chiral-symmetry preserving truncation scheme and then the Bethe-Salpeter equation for pseudoscalar and vector mesons. With the LFWF we derive the meson's parton distribution amplitude (PDA), parton distribution function (PDF) and transverse momentum distribution (TMD) for light mesons, D and B mesons, as well as quarkonia. Last not least, I will present recent progress on the calculation of elementary quark-fragmentation functions and their generalization to jet functions.

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Heavy-Light meson spectroscopy beyond rainbow-ladder approach

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We introduce a novel symmetry-preserving approach to the physics of heavy-light mesons, which goes beyond the standard rainbow-ladder approximation. The key element of this method is the

effective incorporation of flavor-dependent contributions into the Bethe-Salpeter kernel describing meson systems. These special terms originate from the quark-gluon vertices appearing in the kernel and the attendant quark-gap equation, and provide a natural distinction between “light” and “heavy” quarks. In its simplest version, this model retains only the classical tensor of the quark-gluon vertex, whose scalar form factor is considered to depend on a single kinematic variable. Then, an abelianized form of the Slavnov-Taylor identity links this form factor to the quark wave-function derived from the corresponding gap equation, allowing for the continuous transition from light to heavy quarks through the variation of the current quark mass.

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Dynamic criticality of chiral transition and QCD critical end point with real-time functional renormalization group

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The dynamic criticality of chiral phase transition and QCD critical end point can be described by model G and model H from Hohenberg and Halperin’s classification. In this talk, I will give an overview about our formulation of real-time functional renormalization group method to study systems of critical dynamics with reversible mode-coupling. Then I will apply such a formulation to study the critical dynamics of chiral transition described by model G and QCD critical end point described by model H. I will also show our resulting dynamic critical exponent and universal scaling function of model G and the dynamic critical exponent of model H obtained from this method.

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Duality and entanglement in lattice gauge theories

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The study of entanglement in quantum field theories provides insight into universal properties which are typically challenging to extract by means of local observables. However, conventional numerical techniques to compute entanglement measures are limited to low-dimensional systems, and, for gauge theories, the definition itself of entanglement is ambiguous due to the non-factorizability of the Hilbert space. On the other hand, Abelian lattice gauge theories are known to admit a dual description in terms of spin models, for which the replica trick and Rényi entropies are well defined. In this talk, I will review recent developments in lattice calculations of Rényi entropies and entropic c-functions using Monte Carlo methods, which allow for large scale simulations of these quantities in arbitrary dimensions. Then, I will discuss how duality transformations can be used as useful tools to unambiguously study entanglement in lattice gauge theories. Finally, I will present a numerical study of the entropic c-function of the (2+1)-dimensional Z₂ gauge theory in the thermodynamic and continuum limits, comparing the results with holographic models.

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The η_c meson in lattice QCD: short-distance factorization and light-cone correlators from Euclidean setups

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The formalism of short-distance factorization connects light-cone correlators with spacelike ones. The later can be computed in Euclidean spacetime, common to many functional approaches to field theory. The former are central objects in the study of hadron structure, entering the definition of parton distributions. In this work we review the application of this formalism, conveyed through the pseudo-distribution approach, to the extraction of parton distribution functions from lattice QCD. As an illustration, we consider the case of a heavy pseudoscalar meson: the η_c . We will present the first model independent extraction of the parton distribution of valence quarks within an η_c meson.

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No planar degeneracy for the Landau gauge quark-gluon-vertex

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Based on a suitable basis system for the quark-gluon vertex' transverse tensor structures and on carefully chosen kinematical variables, the transverse part of the quark-gluon vertex in quenched QCD in the Landau gauge is obtained from a solution of systems of Dyson-Schwinger equations. We demonstrate by analysing this solution that the angular dependence of these transverse quark-gluon vertex' form factors is seemingly very weak. We nevertheless argue that this does not imply a planar degeneracy for this vertex because even this mild dependence cannot be neglected when aiming for reasonably precise results for derived quantities. Furthermore, we provide high-precision fits for the form factors based on sometimes astonishingly simple model functions. Last but not least, we exhibit relations in between the calculated form factors and demonstrate that the core ingredient to dynamical chiral symmetry breaking is the dynamically generated scalar-plus-tensor coupling of glue to quarks which itself is only possible because of chiral symmetry breaking.

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Many-body magic in strongly correlated systems and lattice gauge theory

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Quantum resources have entered the many body stage over the last two decades. Apart from the prototypical case of entanglement, relatively little is known about how such resources relate to physical phenomena, a question that is of pivotal importance for the understanding of quantum simulators and computers as many-body systems.

In this talk, I will show how magic - a type of resource that is fundamental in determining quantum advantage - is directly related to many-body phenomena. First, I will introduce basic theoretical concepts, and explain why magic is the ultimate resource bottleneck for quantum computing applications that utilize error corrections. Then, after a brief review of what is known for conventional statistical mechanics models, I will present a throughout investigation of magic in a one-dimensional $U(1)$ lattice gauge theory. The results indicate that magic is always extensive with volume, and has no direct relation to the presence of critical points. However, its derivatives typically display discontinuities across the latter: this indicates that magic is strongly sensitive to criticality, but in a manner that is very different from entanglement (that, typically, is maximal at critical point). Our results indicate that error-corrected simulations of lattice gauge theories close to the continuum limit have similar computational cost that those at finite correlation length, and provides rigorous lower bounds for quantum resources of such quantum computations.

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Three and four point correlation functions from lattice QCD in the Landau gauge

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On this talk we report on the computation of the four gluon and of the ghost-gluon one-particle irreducible Green functions using lattice QCD simulations performed in the Landau gauge and for pure Yang-Mills $SU(3)$ theory. For the four gluon vertex an update of our previous calculation combining 32^4 and 48^4 results is given for the three form factors published. For the ghost-gluon vertex we report our preliminary results for the soft-gluon limit (zero gluon momentum) using a subset of the ensembles generated to study the four gluon vertex.

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On temporal entanglement and its measures and applications

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Measuring temporal entanglement to identify integrable systems

The temporal entanglement has recently emerged as a new concept in the theory of many-body quantum systems. It is the entanglement computed from the overlap of the half-system right and

half-system left influence functionals for a system evolving in time.

I will review the definition and show how such entanglement i) computed classically, ii) measured in experiments iii) used to distinguish between the dynamics of integrable and non-integrable systems.

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Loschmidt echo, emerging dual unitarity and scaling of generalized temporal entropies after quenches to the critical point

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The dynamics of quantum many-body systems is one of the traditionally most challenging problems to study for classical simulators. Recently, however, the development of novel methodologies based on the concept of temporal entanglement has opened the way to a series of new results, allowing to access dynamical properties of quantum systems with efficient classical algorithms.

In this talk, I will discuss a recent breakthrough in this direction: by considering the return probability of a quantum many-body system to its initial state after out-of-equilibrium evolution in a quench at the critical point, we have been able to build a connection with conformal field theory and provide analytical predictions for the properties of such time evolution and its associated generalized temporal entropies, which have also been recently introduced in the context of holography. The logarithmic growth of these entropies also implies the feasibility of efficient simulations with state of the art tensor network algorithms based on transverse contraction methods, which allowed us to confirm numerically our predictions.

[1] S. Carignano and L. Tagliacozzo, <https://arxiv.org/pdf/2405.14706>

[2] S. Carignano, CR Marimon and L. Tagliacozzo, Phys. Rev. Research 6, 033021 (2024)

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In- and out-of-equilibrium aspects of the Chiral Magnetic Effect

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In this work, we study the Chiral Magnetic Effect (CME) from lattice QCD simulations considering two different scenarios, in particular focusing on the leading-order coefficient of the vector current in a chiral chemical potential expansion. In the first scenario, we consider continuum extrapolated QCD with 2+1 flavors of improved staggered fermions, a system in thermal equilibrium, with a non-uniform magnetic background. We show that local chiral magnetic currents appear in this setup, following non-trivially the magnetic field profile. We check that these currents average to zero in the full volume, confirming that the total CME conductivity vanishes in equilibrium. In the second case, we present the first steps towards studying the out-of-equilibrium aspects of CME on the lattice.

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On the conformal window of $SU(3)$

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There is a flavor number range of $SU(3)$ gauge theory, $N_f^* < N_f < 16.5$, where spontaneous chiral symmetry breaking does not occur and the model is conformal. The upper end 16.5 is determined by the 1-loop β -function but the lower end, N_f^* , may be determined by non-perturbative phenomena. In this contribution a new approach is presented to estimate or constrain N_f^* : high order perturbative results are presented for meson masses and decay constants valid close to the upper end, $N_f \sim 16.5$, and these are matched to continuum extrapolated lattice results in the range $2 \leq N_f \leq 10$. An attempt is made to match them in the intermediate range. It appears a significant qualitative change occurs in the studied quantities at around $N_f \sim 12$.

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Electro-Production of the $\Delta(1700)$ Resonance: Insights from Transition Form Factors in a Contact Interaction Framework

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Modern facilities, with their advanced capabilities, have enabled detailed investigations into the photo- and electro-excitation of nucleon resonances, shedding light on the evolution of their electromagnetic properties. These experimental breakthroughs have, in turn, driven significant progress in theoretical approaches.

In this seminar, I will present preliminary results on the transition form factors associated with the electro-production of the $\Delta(1700)$ resonance from the nucleon, using a vector $\times$ vector contact interaction model. This transition is governed by three key form factors: the magnetic dipole, electric quadrupole, and Coulomb quadrupole, which are often represented through helicity amplitudes. Unlike momentum-dependent interactions, our model exhibits a hard behavior but successfully encodes the dynamical breaking of chiral symmetry within the bound-state problem, resulting in numerical outcomes that align qualitatively with experimental observations. The nucleon and Δ baryons are modeled as quark-diquark bound states, with the electromagnetic transition currents derived self-consistently from the underlying QCD dynamics.

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Gluon mass gap through the Schwinger mechanism

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In QCD, the Schwinger mechanism endows the gluons with a mass gap through the dynamical formation of longitudinally coupled poles at zero momentum in the interaction vertices. In this talk, we review the key aspects of the Schwinger mechanism in QCD, discuss recent evidence for its occurrence, and some of its implications on the infrared behavior of the QCD Green's functions. First, we show how the massless poles arise through the dynamical formation of massless colored bound states, and discuss the Bethe-Salpeter equation governing this process. Next, we demonstrate that the presence of irregularities in the three-gluon vertex modifies the Ward identity that relates it to the gluon propagator and certain ghost sector Green's functions. Importantly, the new term in the Ward identity turns out to be precisely the Bethe-Salpeter amplitude of the massless bound-state. This allows an independent determination of the Bethe-Salpeter amplitude from a certain algebraic combination of two- and three-point sector Green's functions computed with gauge fixed lattice simulations. The results are then contrasted to the prediction based on the Bethe-Salpeter equation, finding excellent agreement.

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Dynamical chiral symmetry breaking and quark-antiquark entanglement in the quark condensate

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I will discuss the prospects of using quantum information concepts to study dynamical chiral symmetry breaking (DCSB) features in quantum chromodynamics (QCD). First, I will present a formalism based on the coherent state representation of Fock-space states, which we developed to compute density matrices and define entanglement measures over partitions of the Fock space. In the sequence, I will present detailed results, obtained within a model Hamiltonian inspired by the QCD Hamiltonian in the Coulomb gauge, for the entanglement entropy associated with the momentum-correlated quark-antiquark pairs in the vacuum. I conclude outlining perspectives for extensions of this study to compute quark-gluon entanglement.

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The quark spectral function and (heavy) quark diffusion coefficients.

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We present our latest results on the quark spectral function in vacuum and at finite temperature, where we use the framework of spectral Dyson-Schwinger equations and a non-trivial but causal and gauge-consistent quark-gluon-vertex based on the respective Slavnov-Taylor identity. We show how the spectral functional approach can be used for the calculation of real-time observables such as the (heavy) quark diffusion coefficient and the computation of bound-state properties at the example of a scalar field in three dimensions.

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Infrared dynamics of the quark-gluon vertex in general kinematics

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In the present work we determine the transversely-projected quark-gluon vertex in the context of unquenched QCD with two degenerate light dynamical quarks in the Landau gauge. This is accomplished by solving the Schwinger-Dyson equation within the 3PI effective action formalism, employing lattice data for the gluon and quark propagators, and the three-gluon vertex. Our findings reveal that the classical form factor displays a significant angular dependence, and is in excellent agreement with recent lattice data in the soft-gluon configuration. The remaining form factors are computed through a single integration, confirming a clear hierarchy, in agreement with previous results.

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The four-gluon vertex in collinear and soft kinematics

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In this talk we present recent results on the transversely-projected four-gluon vertex in two families of kinematic configurations: i) “collinear” where all external momenta are parallel to each other and ii) “soft” with one vanishing and three arbitrary external momenta. The approach is based on the one-loop dressed Schwinger-Dyson equation obtained from the 4PI effective action. The key hypothesis employed in both cases is the property of planar degeneracy of the vertex, simplifying significantly the technical aspects of the underlying equations. The results obtained reveal a considerable suppression with respect to the corresponding tree-level value, and, for the soft configurations, they are in excellent agreement with recent lattice simulations.

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Quantum simulation/computation of non-Abelian gauge theories beyond 1D with finite resources

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Performing gauge theories’ calculations by realizing their Hamiltonians in controllable quantum systems to complement existing methods like perturbation theory and quantum Montecarlo is promising and challenging endeavor. After a brief and partial review of current successes and challenges, I will focus on the task of achieving continuum limit calculation with finite resources. I will present an efficient scheme to allow to determine the running of the coupling in SU(N) gauge theories by computing the expectation value of plaquette operator for any regime of the coupling with finite resources. I will illustrate the results obtaining for pure SU(2) gauge theory on a minimal torus and

discuss the application of the scheme in current quantum computers and tensor-network computations

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The moat regime in QCD

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We study the realtime QCD dynamics underlying the moat behavior in QCD at finite chemical potential, present at baryon chemical potentials with $\mu_B/T \approx 4$. It originates from the Landau damping of quarks scattering in the vicinity of Fermi surface. The moat appears as peaks in the spectral functions for the pion and sigma modes at space-like momenta.

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Lattice gluon propagator in the center-symmetric Landau gauge

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We address the lattice computation of the gluon propagator in the center-symmetric Landau gauge. After discussing a proper lattice implementation of the center-symmetric Landau gauge, we show the first lattice results and study its behaviour with the temperature.

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Fermion doubling in quantum cellular automata for quantum electrodynamics

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Quantum cellular automata (QCA) for quantum electrodynamics (QED) is a quantum algorithm that can be coded on a quantum computer to simulate QED. It is a unitary-based, strictly local discrete space-time formulation of QED. The space-time of the QCA is a square lattice and qubits in the lattice sites encode the information of occupation number of fermions. The dynamics of the QCA is done by quantum gates that simulate the evolution operator of QED. One of the well-known problems of discrete space-time formulation of quantum field theories is fermion doubling. This phenomenon appeared in the context of early lattice gauge theories, their lattice formulation of free fermions suggested that some of the infinite momentum modes contribute to the correlators in the continuum limit as much as the finite ones. To tackle this problem, several strategies have been developed immediately after identifying the doubling but it is shown that these strategies break chirality for non-massive particles. The QCA has less problematic fermion doubling properties than LGT, allowing solutions without breaking the chirality. In this talk, I will introduce the QCA model that we use to simulate QED, give details of the fermion dynamics that QCA for QED has, then I will continue with the analysis of fermion doubling in QCA for QED on 1+1 and 3+1 dimensions which requires considering topological aspects of the corresponding Brillouin zones. I will mention our strategies for solving the problem and give generalizations of the solution.

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QCD in 1+1 dimensions with the FRG: Four-fermion interactions from quark-gluon dynamics

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Two-dimensional QCD was first studied by G. 't Hooft as a model for mesons in the limit of an infinite number of colours where it admits an exact solution. We investigate the model with the FRG at finite number of colours in the vacuum and present the first stages of our study towards dynamical hadronization in this model. In particular, we derive how local four-fermion interactions emerge from the quark-gluon dynamics and study their flow under the FRG in a Fierz-complete ansatz. Emphasizing the importance of Fierz-completeness and the two-dimensional features, we show that the flow equations signal the formation of mesonic bound states.

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Complete analysis of the Landau-gauge three-gluon vertex from lattice QCD

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Several continuum and lattice investigations of the QCD three-gluon vertex have recently exposed its key properties, some intimately connected with the low-momentum behavior of the two-point gluon Green's function and especially relevant for the emergence of a mass scale in this latter, via the Schwinger mechanism. We will report on a complete lattice determination of the Landau-gauge, transversely projected three-gluon vertex, particularly scrutinizing an outstanding one of these properties, termed planar degeneracy, exploring its implications and capitalizing on it to gain further insight on the low-momentum running of both the three-gluon vertex and its associated strong coupling.

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(New) physics from lower dimensions

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Recent years have witnessed impressive progress in the direct numerical study of quantum many-body systems in real-time, from first principles. I will present my perspective on how these methods, combined with insights from quantum information science and the promise of quantum advantage, offer exciting opportunities to learn more about relativistic quantum field theories and how they pave the road to better understanding relevant phenomenology of real-world, 3+1 dimensional theories such as QCD. I will exemplify this view by presenting some of my recent work

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Making Big Lattices Bigger: Bloch's Theorem and The Lattice Gluon Propagator (Part I)

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Exploiting the similarity between Bloch's theorem for electrons in crystalline solids and the problem of Landau gauge-fixing in Yang-Mills theory on a "replicated" lattice allows one to obtain essentially infinite-volume results from numerical simulations performed on regular-size lattices. We review our previous study of this subject, presenting some new preliminary results. A novel interpretation of the method is also proposed, which might improve our understanding of color confinement.

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Making Big Lattices Bigger: Bloch's Theorem and The Lattice Gluon Propagator (Part II)

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We revisit the mathematical formalism involved in the application of Bloch's theorem to non-Abelian gauge theory. In particular, we show how to map numerical simulations performed on the "replicated" lattice to the original (smaller) lattice, or "unit cell". Special emphasis is given to the rôle played by boundary conditions.

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Towards the phase diagram of QCD and its critical endpoint

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I report on technical advancements which are geared towards locating the conjectured critical end-point of QCD using the functional renormalization group. Its use allows to access directly the high-density region, as this approach does not suffer from the sign problem of lattice QCD. In our first-principles setup, one can systematically identify and include all relevant physical degrees of freedom, which is a current work in progress. I discuss both quantitative results in the vacuum as well as preliminary results for the extension to finite temperature and density, including arbitrary-order meson interactions and full momentum dependences. Furthermore, I discuss an analysis of the systematic error of such an fRG calculation of QCD. Finally, for calculations at even higher densities, I discuss future extensions of our setup, such as other potentially relevant composite particles.

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Four-quark scatterings and quasi-PDA for pion from fRG

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In this talk, I would like to discuss recent progress in the construction of functional renormalization group (fRG) approach to first-principles QCD within the four-quark scatterings, and its application to the calculation of quasi-parton distribution amplitudes (PDA) for pions. We investigate dynamical chiral symmetry breaking and the emergence of mesonic bound states from the infrared dynamics of four-quark scatterings. The flows of Fierz-complete four-quark interaction are integrated together with the flow of the quark two-point function. This system can be understood as the fRG analogues of the complete Bethe-Salpeter equations and quark gap equation. A three-momentum channel approximation for the Fierz-complete four-quark vertices is used. We have computed the pion pole mass, pion decay constant, Bethe-Salpeter amplitudes, the quark mass function and wave function. With the Bethe-Salpeter amplitudes and the quark mass function, One is able to compute the pion valence-quark quasi-PDA.

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Feasibility Study of Backward DVCS on Pion

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This work conducts a systematic feasibility study of measuring backward deeply virtual Compton scattering (bDVCS) on the pion in Sullivan processes, within the framework of collinear QCD factorization, where pion-to-photon transition distribution amplitudes (TDAs) describe the photon content of the pion. Using TDAs based on the overlap of light front wave functions, we employ a model for the pion and photon light front wave functions to estimate cross-sections for future measurements at U.S. and China's electron-ion colliders.

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Registration and Welcome

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Synthetic gauge fields in trapped-ion crystals: from background Peierls' phases to Z2 gauge fields

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In this talk, I will describe how trapped-ion crystals can be used as platforms for the quantum simulation of gauge fields. Focusing on the crystal vibrations, I will show how Floquet engineering can be used to control an effective Peierls' phase, and discuss a recent experiment demonstrating where this phase leads to Aharonov-Bohm interference of phonons. I will then discuss how to promote the Peierls' phase to a dynamical gauge field by exploiting also the trapped-ion qubits, which leads naturally to a Z2 gauge theory with bosonic matter particles. I will discuss recent trapped-ion experiments of this scheme, where one can observe how the effective dynamical charges can only move by stretching and compressing the Z2 electric field. Inspired by these quantum simulation toolbox, I will briefly discuss lattice models where Aharonov-Bohm interference can lead to deconfined phases even in the absence of plaquette interactions, a current bottleneck of analog quantum simulators.

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Gauged gaussian PEPS

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A tensor network approach based on sign-problem free Monte-Carlo for studying lattice gauge theories beyond 1+1d"