Light-Cone 2023: Hadrons and Symmetries

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Hydrodynamics in small systems in ultra-relativistic hadron collisions

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I will give an outline of the evidence of the formation of a "fluid" in small systems in ultra-relativistic hadron collisions (p-p and pA), and argue that this forces us to radically rethink our view of hydrodynamics as an effective theory. I will argue that a re-derivation of hydrodynamics as a field theory can help us in understanding how a system with as few as 20 degrees of freedom can appear hydrodynamic.
I conclude proposing to test the hydrodynamic hypothesis "to the limit", using the hydrodynamic initial state to characterize initial state quark wavefunctions of the hadron

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cos(2ϕ) and sin(2ϕ-ϕs) azimuthal spin asymmetries in the pion induced Drell-Yan process

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The Drell-Yan process, involving the annihilation of a quark and an antiquark into a lepton-antilepton pair, provides valuable insights into the structure and dynamics of hadrons. In this study, we focus on the investigation of azimuthal angular asymmetries, specifically the cos(2ϕ) and sin(2ϕ-ϕs) asymmetries, which probe the spin and transverse momentum-dependent properties of the initial-state hadrons. The cos(2ϕ) asymmetry arises from the convolution of two Boer-Mulders functions in an unpolarized π-p Drell-Yan process. It reflects the polarization of the initial-state quarks and antiquarks, providing information on the distribution of quark spins inside the hadrons. Similarly, the sin(2ϕ-ϕs) asymmetry (with ϕs , the azimuthal angle of target transverse spin) can be obtained through the convolution of the Boer-Mulders function of the pion and the transversity distribution of the proton. By analyzing the sin(2ϕ-ϕs) asymmetry, one can extract valuable information about the transverse spin structure of the nucleons and study the role of spin-orbit correlations. We discuss the theoretical framework and formalism employed for the calculation of these asymmetries, taking into account the pion parton distribution functions from the light-front holographic QCD and proton parton distribution functions from light-front quark-diquark model, and we show the comparison with the COMPASS (2017) and other theoretical studies.

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Gluon saturation: toward precision using light front and covariant approaches

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We use the Color Glass Condensate effective theory of QCD at small x to calculate fully inclusive structure functions as well as single and double inclusive hadron production in DIS at small x at the Next to Leading Order (NLO). We show that calculations of NLO corrections in light front perturbation theory and the traditional covariant perturbation theory agree for processes that have been computed in both approaches. We elucidate the need for and outline an approach for going beyond the small x approximation which may be more convenient in light front perturbation theory.

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Light Front Puzzles

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I discuss some of the apparent inconsistencies in canonical, covariant and light-front formulations of quantum field theory and the resolution of these inconsistencies. The topics that will be discussed are (1) the problem of inequivalent representations (2) the problem of the trivial vacuum (3) the problem of ill-posed initial value problems (4) the problem of rotational covariance (5) the problem of zero modes and (6) the problem of spontaneously broken symmetries.

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Valence and sea parton correlations in double parton scattering from data

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Numerous experiments have yielded diverse results when measuring the effective cross section of double parton scattering during proton collisions. This wide range motivated us to assume that parton correlations in the transverse plane vary depending on whether we are dealing with valence or sea partons. Adopting this approach allowed us to fit available data and found that sea parton pairs show a higher correlation in the transverse plane compared to valence-sea parton pairs.

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Fourier Coefficients in PNJL Model with Vector Interaction at Imaginary Chemical Potential: A Comparison with Lattice QCD Results

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One of the biggest challenges for lattice quantum chromodynamics (LQCD) at finite baryon densities is the so-called sign problem which prevents evaluations to be reliably performed within this domain. A possible technique to circumvent this problem is to perform an extrapolation from real to imaginary chemical potential, where the sign problem is overcome. An effective way to implement a finite chemical potential into the equation of state is to perform a Taylor series expansion in the chemical potential. Then, after analytically continuing the chemical potential, the main task is to obtain the Fourier coefficients, b_k, of the series expansion representing the first order baryon susceptibility, $\chi_1^B(T,\mu) = \sum_k b_k(T)\sinh(k\mu_B/T)$. In the present work, we consider the Polyakov–Nambu–Jona-Lasinio model (PNJL) with a repulsive vector interaction, parametrized by G_V, which is an essential ingredient to describe *in medium* properties. In order to do an optimal fitting we compare the PNJL b_k coefficients, obtained at the mean-field level, with those predicted by LQCD to analyze if G_V should eventually also depend on the temperature and/or chemical potential.

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Exploring the pion condensation using the Functional Renormalization Group

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The full description of strongly interacting matter requires complete knowledge of the phase structure generated by a quantum field theory. In many cases, analyzing the fundamental theory that describes their interactions in a medium is quite complicated, so that it becomes interesting to use alternative theories that reproduce at least part of the physical characteristics of the fundamental theory. Effective theories provide us with a powerful mathematical and physical tool for the limit in which the application of the fundamental theory - Quantum Chromodynamics (QCD) in the case of Strong Interactions –becomes extremely complex. In the dense regime of matter, the main non-perturbative technique, lattice Monte Carlo simulations, presents an open problem called the Sign Problem due to the coupling of a specific chemical potential. However, in some situations, Monte Carlo simulations do not present such a problem, providing satisfactory results for various observable physical phenomena such as, for example, the dense isospin matter that could exist inside compact stars. Thus, the study of effective theories in environments with non-zero chemical potentials is even more relevant because it presents systems in which the Sign Problem is not present. In this work, we will investigate, using non-perturbative techniques, the phase transition of Bose-Einstein condensation in an effective theory for bosons at finite density and zero temperature. We will construct a toy model based on the Linear σ Model and implement the Functional Renormalization Group (FRG) to estimate the influence of non-perturbative effects on the critical parameters of the model.

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Superconductivity in a confining field-theory model

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Many models of superconductivity are already present in high energy physics, since the end of last century, mainly in the study of color superconductivity in Quantum Chromodynamics and in other effective models of Strong Interactions at high densities. These models use in general a gluon propagator with specific electric and magnetic effects, resulting in an integral gap equation whose solutions are frequency dependent and could reach gaps of the order of 100 MeV. In this work, we will investigate a simple superconductivity model by changing the usual propagator of the mediator to a confining propagator, with a structure similar to that encountered in Gribov-Zwanziger and Refined Gribov-Zwanziger theories. In these theories, the gluon has an explicit mass parameter that is related with the phenomenon of confinement. Through this modification we try to explore the superconductivity of confined particles with a simple toy model with a Yukawa-type interaction. We present results for the full integral gap equations as well as for differential gap equations that arise under a series of approximations and investigate the effect of corrections originated from the new propagators. Two mass limits in the bosonic propagator must be reached: the high mass limit, reproducing the behavior of the "point like" approximation, making the gap function behave like a usual BCS superconductivity and the small mass, making the gap function behave similar to early results in color superconductivity. Solving numerically the integral gap equation, we can calculate the gap in function of the mass parameter. These calculations were performed too with improved gluon propagators, suche as the ones appearing in the Gribov-Zwanziger and Refined Gribov-Zwanziger theories. These results allow us to understand how the introduction of the explicit mass parameter to the gluon can affect the phenomenon of superconductivity in high energies. This study could be a first step towards assessing how nonperturbative confinement effects might affect the phenomenon of color superconductivity at intermediate densities.

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Exploring the covariant form factor for spin-1 particles

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The spin-1 particles is an admirable two quarks bound state
system to understand electromagnetic properties from hadronic states.
These systems are generally relativistic, and therefore,
need an approach using quantum field theory. In the present work, we will use both the
quantum field theory at the instant form, as well,
quantum field theory on the light-front~(LFQFT).
In general, it is used to calculate the electromagnetic properties of
spin-1 vector particles in the LFQFT formalism, with the plus
component of the electromagnetic current. In the present work, we used, in addition to
the plus component of the electromagnetic current; the minus component
of the current, and we use that
components o the current, to extract the covariant form factors; showing that
to have an equivalence between these we need to add non-valence terms
to the electromagnetic current, in order to restore the covariance, and obtain
exactly the same results when using the instant form quantum field theory.

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The proton gluonic gravitational form factors

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I will be discussing the proton gluonic gravitational form factors, in particular, those extracted from the J/ψ-007 performed in Hall C at Jefferson Lab. In this experiment, the elastic photoproduction of a small dipole (J/ψ) is used to probe the gluonic structure of the proton. The gluons' contribution to the mechanical properties of the proton (mass density, pressure, and shear forces) will be presented in several frames (Breit, lightcone). A comparison to lattice calculations will also be presented. The experimental uncertainties as well as the theoretical caveats of this extraction in a nonperturbative region of photon-nucleon center of mass will be considered and discussed. Projections of these form factors with better statistical precision using the SoLID detector in Hall A will be shown.

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Quark Scattering and Confinement Effects

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The work aims to investigate possible non-perturbartive effects of gluon confinement in the infrared regime on cross-section calculations.
As a result of net simulations, we know that the gluon propagator in the Landau gauge reaches nonzero and finite values at low momentum, which suggests that the gluon generates mass dynamically in the IR. Therefore, it is used in this work an effective theory with a mass term added through Proca lagrangian to describe this massive gluon.
Another important result from studies of the Landau propagator is that the coupling constant remains finite and even decreases at deep IR. Such result is gotten from numerical calculations of pure Yang-Mills theories. Thus, this allows us to use perturbartives methods in the IR regime.
Therefore, it is used a Landau gauge propagator with a mass term to describe the gluon in the calculation of the cross-section of a quark-antiquark scattering. All that is achieved using perturbartive method. The main goal is to compare the results with experiments and establish limits to the values of the gluon mass at high energies.

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Dynamical mass generation constrained by gauge symmetries

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A nonperturbative approach to derive the dressed quark-gluon vertex is based on longitudinal and transverse Slavnov-Taylor identities, rather than on perturbative dressing or solving the inhomogeneous Bethe-Salpeter equation. The adequate manipulation of these identities with projections leads to the functional form of all form factors of the vertex.

This novel vertex is used in the Dyson-Schwinger (DSE) equation of the quark with lattice QCD simulations for the gluon and ghost propagators. The dynamical chiral symmetry breaking this vertex induces is very large and gives rise to a realistic mass gap for all quark flavors, compatible

with those of the usual phenomenological interaction models in DSE calculations. Finally, we test the gauge covariance of our DSE kernel by studying the gauge dependence of the quark mass and wave renormalization function as well as of the quark condensate and the anomalous chromomagnetic moment.

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Two boson interaction in high energy physics with dipole formalism

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In the high energy regime, in light cone coordinates it is possible to calculate the probability of bosons ($\gamma, W^{\pm}, Z, g$) floating in a quark-antiquark pair, which in turn can be approached through of the dipole formalism in the high energy regime. In this work we present important observables that will be essential to study the background contributions of future electron-positron accelerators, such as contributions from interactions between two bosons in ultraperipheral collisions measured at the LHC.

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Quantum stress on the light front

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We investigate the gravitational form factors of a strongly coupled scalar theory in the light front Hamiltonian approach. The theory can be used to mimic the non-perturbative interaction between the nucleon and the pion. We renormalize the energy-momentum tensor with a Fock sector dependent scheme. We also systematically analyze the Lorentz structure of the energy-momentum tensor and identify the suitable hadron matrix elements to extract the form factors, avoiding the contamination of spurious contributions. We present results up through the 3-parton Fock sector (i.e bare mock nucleon plus up to two mock pions) for the gravitational form factors of the mock nucleon at strong coupling and over a large range of four-momentum transfer squared. We verify that the extracted form factors obey momentum conservation as well as von Laue's mechanical equilibrium condition. From the gravitational form factors, we compute the energy and pressure distributions of the system. Furthermore, we show that utilizing the Hamiltonian eigenvalue equation, the off-diagonal Fock sector contributions from the interaction term can be converted to diagonal Fock sector contributions, yielding a systematic non-perturbative light-front wave function representation of the energies and forces inside the system.

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Exotic Baryons in Hot Neutron Stars

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We study the nuclear isentropic equation of state for a stellar matter composed of nucleons, hyperons, and Δ-resonances. We investigate different snapshots of the evolution of a neutron star, from its birth as a lepton-rich protoneutron star in the aftermath of a supernova explosion to a lepton-poor regime when the star starts cooling to a catalyzed configuration. We use a relativistic model within the mean-field approximation to describe the hot stellar matter and adopt density-dependent couplings adjusted by the DDME2 parameterization. We use baryon-meson couplings for the spin-$1/2$ baryonic octet and spin-$3/2$ decuplet determined in a unified manner relying on $\mathrm{SU}(6)$ and $\mathrm{SU}(3)$ symmetry arguments. We observe that Λ is the dominant exotic particle in the star at different entropies for both neutrino-free and neutrino-trapped stellar matter. For a fixed entropy, the inclusion of new particles (hyperons and/or delta resonances) in the stellar matter decreases the temperature. Also, an increase in entropy per baryon (1 to 2) with decreasing lepton number density (0.4 to 0.2) leads to an increase in stellar radii and a decrease in its mass due to neutrino diffusion. In the neutrino transparent matter, the radii decrease from entropy per baryon 2 to $T = 0$ without a significant change in stellar mass.

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Studying the gluon mass from bound states of heavy quarks

Auteur: Florencia Benitez Martinez[1]

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One of the main goals of QCD is to recover hadronic properties from the interaction between quarks and gluons. The Faddeev-Popov Lagrangian has been successful in predicting strong interactions at high energy scales. In this regime (UV) the strong interaction becomes less intense which allows perturbative calculations. However, at low energies (IR), the Faddeev-Popov method fails.

The calculation of the coupling constant in the lattice gives a hopeful result: its value does not diverge at low energies. In addition, when calculating the gluon propagator, its behavior at low energies (in Landau gauge) corresponds to that of a massive particle. This differs substantially from what was observed by Faddeev-Popov, who considers the gluon to be a massless boson. This led to retaking the idea that G.Curci and R.Ferrari presented in the 70s, about a Yang Mills theory with massive mediating particles.
In this work we present the preliminary results of the study of nonrelativistic bound states of heavy quarks, where we calculate the spectrum of mesons solving Schrodinger equation with corrections obtained from the one-(massive gluon) exchange potencial.

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Abnormal states with unequal constituent masses

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The Bethe-Salpeter equation for system of two oppositely charged particles not only reproduces the Coulomb spectrum, but, for enough large coupling constant $calC > \frac{\pi}{4}$, predicts additional levels [1,2] not covered by the Schroedinger equation. These relativistic states (called abnormal) are dominated, for more than 90-99 percent, by the exchanged photons [3] (which are scalar in the model [1,2]), while contribution of two massive charged particles themselves is rather small (1-10 percent). These predictions and theoretical clarification of the nature of the abnormal states put on the agenda their experimental detection. Since the carrier of a large (positive) charge is a heavy ion, and the negative charge is provided by electron, the masses of particles, capable of forming the abnormal systems and available in laboratory, are very different. We show that in a system with so different masses the abnormal states still exist. Moreover, the effect of unequal masses is attractive. From the Bethe-Salpeter amplitude we extract the two-body light-front wave function and calculate the balance between contribution to the state vector of two charged constituents and photons. It is weakly sensitive to the mass ratio. The photons still predominate.

[1] G.C. Wick, Phys. Rev. 96, 1124 (1954).
[2] R.E. Cutkosky, Phys. Rev. 96, 1135 (1954).
[3] J. Carbonell, V.A. Karmanov, H. Sazdjian, Eur. Phys. J. C (2021) 81:50.

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Bridge between QCD and LFQM

Auteur: Chueng Ji[1]

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I will discuss the link between the QCD and the light-front quark model (LFQM) utilizing the interpolation between the instant form dynamics (IFD) and the light-front dynamics (LFD). In the ʻtHooft model, the mass gap solutions, vacuum condensation, spontaneous symmetry breaking of the chiral symmetry and the mass spectra of mesons bearing the feature of the Regge trajectories are found and the Gell-Mann-Oakes-Renner relation for the pionic ground-state in the zero fermion mass limit is confirmed both in IFD and LFD as well as in-betweens. The implication of the link between QCD and LFQM will be discussed for the consistency in the framework of analyzing simultaneously both the mass spectra and the wave-function related physical observables. Independence of current components, polarization vectors, and reference frames will be exemplified in recent LFQM analyses of meson decay constants.

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A confining holographic QCD model for vector mesons and nucleons

Auteur: Alfonso Ballon Bayona[1]

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We present a minimal holographic QCD model that allows for a description of asymptotically linear Regge trajectories for vector mesons and nucleons in a way consistent with confinement. We

consider a 5d background where the dilaton is quadratic in the infrared (far from the boundary). The background is a solution of 5d Einstein-dilaton gravity and satisfies the confinement criterion. The vector mesons and nucleons are described by a 5d Yang-Mills action and a generalized 5d Dirac action respectively. In our framework all hadron masses depend on a single mass scale related to the infrared parameter of the dilaton. We calculate masses and decay constants and compare our results against experimental data finding a good agreement.

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Abnormal solutions with massive exchanges

Auteur: Jaume Carbonell[1]

Co-auteurs: Ekatherina Kupriyanova [2]; Hagop Sazdjian [3]; Vladimir Karmanov [4]

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We will summarize the main properties of the so called "abnormal solutions"of the Wick-Cutkosky model [1, 2], i.e. scalar particles interacting via massless exchange, within the Bethe-Salpeter equation [3]. These solutions have the property of not existing in the non-relativistic limit, despite of having very small binding energies, and present a genuine many-body character with a vanishing two-body norm in the zero binding limit. These states have already been obtained and discussed in previous works, including previous LCM [4, 5, 6, 7]
We will present in the LCM 2023 new results concerning the massive exchange case, in particular determine under which conditions it is possible to obtain such peculiar solutions without spoiling the model by tachyonic states (M2 < 0).
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Enhanced Charm CP Asymmetries from Final State Interactions

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[2] *Elisa Carmen Hickman de Bediaga*

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Precision CP violation (CPV) measurements are widely recognized as a highly sensitive probe of the Standard Model with new sources needed to account for the mater-antimatter asymmetry observed

in the Universe. There is a long-term discussion involving the source of the strong phase needed to generate direct CPV in charmless B and D decays. I will show that the final state interactions (FSI) can be the source needed to explain some observed asymmetries in B ⟶ hhh (h = π, K). I will also show in more detail a recent result where FSI and CPT symmetry constraint, one can enhance the charge-parity (CP) violation difference between D0 ⟶ π−π+ and D0 ⟶ K−K+ decay up to the current experimental value recently observed by the LHCb collaboration.

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Entanglement Entropy in the Quadratic Sector of Gribov-Zwanziger Theory

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In this work, we discuss the concept of entanglement entropy and its application to the realm of quantum field theory, with a focus on the quadratic sector of the Gribov-Zwanziger Theory. We obtained a general expression for the entanglement entropy of this theory by using the Euclidean formalism approach. We observed and interpreted that the restriction to the Gribov region affects the entanglement of the field configurations of the two considered regions.

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Photoproduction of light vector mesons and the nuclear shadowing

Auteurs: Emmanuel de Oliveira[1]; Haimon Otto Melchiors Trebien[1]

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In this work we study the photoproduction of ρ mesons considering the proton and the nucleus as the target. Utilizing the dipole picture and the wave functions obtained via AdS/QCD, we were able to describe the HERA ρp data and extend the formalism to the nuclear case considering the Glauber-Gribov model. The preliminary results obtained in the nuclear regime are compared to the recent LHC PbPb ⟶ ρPbPb data and suggest the presence of a nuclear effect called shadowing.

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Charmonium production in high multiplicity pp collisions and the structure of the proton

Auteur: Ríchard Terra[1]

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In this work we study charmonium production in high multiplicity proton-proton collisions. We investigate the role of the spatial distribution of partons in the protons and assume that the proton

has a Y shape. In this configuration quarks are more at the surface and gluons in the inner part of the proton. Going from peripheral to more central and then to ultra-central proton-proton collisions, we go from quark-quark collisions to gluon-gluon collisions. Since gluons are much more abundant, the cross sections grow. In the case of charm production this growth is enhanced by the fact that, $\sigma(g+g \to c+\bar{c}) >> \sigma(q+\bar{q} \to c+\bar{c})$. These effects can explain the growth seen in the data.

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Confirming the action of the Schwinger mechanism in QCD

Auteur: Arlene Cristina Aguilar[1]

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In this talk, we present a short review of the emergence of a dynamical gluon mass through the action of the Schwinger mechanism. The linchpin of this mechanism is the dynamical formation of longitudinally coupled massless bound-state poles in the vertices of the theory, and especially in the three-gluon vertex. The presence of these poles, in addition to causing the infrared saturation of the gluon propagator, also induces a modification ("displacement") to the Ward identity of the three-gluon vertex, proportional to the form factor associated with the pole. Here we will show how this displacement signal has been confirmed through a suitable combination of inputs obtained from lattice QCD.

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Refined Gribov-Zwanziger theory coupled to scalar fields in the Landau gauge

Auteurs: Gustavo Pazzini de Brito[1]; Philipe De Fabritiis[2]; Antonio Pereira[3]

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The Refined Gribov-Zwanziger (RGZ) action in the Landau gauge accounts for the existence of infinitesimal Gribov copies as well as the dynamical formation of condensates in the infrared of Euclidean Yang-Mills theories. We couple scalar fields to the RGZ action and compute the one-loop scalar propagator in the adjoint representation of the gauge group. We compare our findings with existing lattice data and also comment on a previous proposal for a non-minimal coupling between matter and the RGZ action. We find good agreement with the lattice data of the scalar propagator for the values of the mass parameters that fit the RGZ gluon propagator to the lattice. This suggests that the non-perturbative information carried by the gluon propagator in the RGZ framework provides a suitable mechanism to reproduce the behavior of correlation functions of colored matter fields in the infrared.

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Multigluon correlation functions from lattice QCD

Auteur: Orlando Oliveira[1]

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The lattice computation of multigluon correlation functions, namely two, three and four point functions, is reviewed exploring its implications to the QCD dynamics.

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POLE APPROXIMATION FOR PSEUDOSCALAR PARTICLES

Auteurs: J. P. Paschoal[1]; G. A. P. Vaccani[2]; João Pacheco de Melo[3]

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Exploring the quantum field theory within light-front dynamics, the work
carefully studies the electromagnetic form factors of pseudoscalar mesons using a symmetric vertex function and the pole approximation approach. Furthermore, other observables can be built from these electromagnetic form factors studies, for example, the mean-square charge radius and decay constant. Moreover, this work investigates the reliability of the pole approximation approach to the exact values of electromagnetic form factors using only a few poles of the Feynman amplitudes, simplifying the calculations without the direct dependence of external propagators. The consequences of that approach for all the observables are also compared with the experimental data.
Once calculations of the observables and the pole approximation approach
studies have been satisfactory for the pion experimental data, the work is implemented for other more complex meson structures. In this way, the pole approximation approaches can simplify calculations of electromagnetic form factors, at first, for more complex pseudoscalar meson structures, other types of regulator vertex functions, or more sophisticated dynamical models based on solutions of a Bethe-Salpeter equation.

Keywords: Form Factors, Decay Constant, Light-Front Dynamics, Charge
Radius, Bethe-Salpeter equation.

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The search for glueballs

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While the Higgs mechanism might be responsible for the masses of the elementary particles, the mass-creation mechanism for hadrons is quite different. Less than 1% percent of the mass of the proton is due to the Higgs mechanism. Particles solely composed of gluons are at the center of the strong interaction. Glueballs themselves would be massless without the strong interaction and their predicted masses arise solely from the strong interaction. Glueballs thus offer a unique way to study the mass creation of strongly interacting particles. In the past years, a new relation between modern superstring theory and QCD has been developed by the AdS/CFT (Anti-de Sitter space/conformal field theory) correspondence. Several groups have studied in the Witten-Sakai-Sugimoto model of

strings to investigate glueballs and their behavior. Modern stringy hadron models attempt not only to make predictions for glueballs but also describe and predict other hadronic states including their decay dynamics. This talk describes the experimental situation and the experimental perspectives to provide more information on glueballs and their structure.

Plenary / 177

Nuclear Hadronization Studies at JLab: Present and Future

Auteur: Hayk Hakobyan[1]

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In 2004, the CLAS detector at Jefferson Lab collected experimental data on a broad range of nuclear targets, from heavy nuclei like Lead to lighter ones such as Carbon or Deuterium, employing a 6 GeV electron beam. These data enabled us to investigate various facets of nuclear phenomena, encompassing the nuclear hadronization process, nuclear color transparency, short-range nuclear collations, and two-pion correlations. Notably, the varying sizes of nuclei facilitated an exploration of the phenomenon of nuclear hadronization in relation to nuclear medium size. The studied final hadron types included charged and neutral pions, protons with substantial statistics, and, with fewer statistics, kaons, etas, omegas, and lambdas. Moving forward to the first quarter of 2024, the experiment will be replicated on CLAS12 with CEBAF12, offering higher energy, an expanded kinematic range, and increased statistical precision for diverse types of hadrons. Within the presentation, I will outline the previous experiment, delve into the impending 12 GeV experiment, and elucidate the perspectives and scientific significance of the envisioned 24 GeV experiment.

Plenary / 178

Study of Kaon Structure with Light Front Approach in Nuclear Medium

Auteur: George Yabusaki[1]

Co-auteurs: João Pacheco de Melo [2]; Kazuo Tsushima [3]; Tobias Frederico [4]; Wayne de Paula [4]

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We study the properties of the K^+-meson in nuclear medium within
the framework of light-front field theory, such as the electromagnetic form factors (EMFF), charge radius, decay constant and probability of the kaon valence component η, where the kaon (K^+-meson) structure in nuclear medium is described using the light-front K^+ meson wave function based on a Bethe-Salpeter amplitude model for the quark-anti-quark bound state. The K^+-meson model we adopt is well constrained by previous studies to explain its properties in vacuum. The in-medium K^+-meson properties is evaluated for the plus-component of the electromagnetic current, J^+, in the Breit frame with Drell-Yan conditions. In order to consistently incorporate the constituent up and anti-strange quarks of the K^+-meson in symmetric nuclear matter, we adopted the "quark-meson coupling (QMC) model", which has been widely applied to various hadronic and nuclear phenomena in a symmetric nuclear medium. We predict the in-medium modification of the K^+-meson properties in symmetric nuclear matter. It is found that, after a fine tuning of the regulator mass, the

model can describe the available experimental data in vacuum within the theoretical uncertainties, and based on this we predict the in-medium modification of the K^+-meson properties.

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Effective models for heavy mesons in a plasma inspired by gauge gravity duality

Auteur: Nelson Braga[1]

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The advent of the AdS/CFT correspondence led to the development of phenomenological models aimed at describing the behavior of hadrons in non-perturbative regimes of QCD. In particular, the so-called holographic models allow the description of the behavior of quarkonium in a thermal medium, such as the plasma of quarks and gluons formed in heavy ions collisions. We will discuss how quasi-states of bottomonium and charmonium inside a thermal medium can be described holographically in such a way that one can study the effects of temperature, density and presence of magnetic fields on dissociation in the thermal medium. We will also present a recent result on how rotation, which occurs when ion collisions are not frontal, affects the deconfinement temperature.

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Klein-Gordon Effective Equation for Yang-Mills SU(2) Classical Theory

Auteurs: Ederson Staudt[1]; Jorge Zabadal[2]; Josenilson Adnei Oliveira Marinho[3]

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[3] *Universidade Federal Rural da Amazonia*

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The Faddeev-Niemi representation prescription for the Yang-Mills SU(2) gauge theory is explored through a Gauge Induced Variable technique which render the topology implied both interesting and rich on new consequences: effective modes in the classical solutions of the theory emerge in the context of a generalized Klein-Gordon Equation. Traces of mass intervals and fundamental scales appears in the treatment as long as electroweak charge screening.

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Much ado about nothing. The light front vacuum

Auteur: Matthias Burkardt[1]

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In naive light front quantization the vacuum is trivial. I will discuss how proper inclusion of zero modes leads to a consistent formulation and how this affects hadron structure.

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Light-Front Distribution Amplitudes and Strong Couplings

Auteurs: Bruno El-Bennich[1]; Eduardo Rojas[2]; Fernando Serna Algarín[None]; J. J. Cobos-Martínez[3]; Roberto Correa da Silveira[4]

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We use the framework of the Dyson Schwinger and Bethe-Salpeter equations to compute Light-Cone Distribution Amplitudes of heavy-light mesons and quarkonia. The corresponding heavy-light Bethe-Salpter amplitudes are projected onto the light front and we reconstruct the distribution amplitudes of the mesons in the full theory.
Also we calculate the strong decay couplings for $\rho\to\pi\pi$, $\phi\to KK$, $K\to K\pi$, *and* $D\to D\pi$ in a unified and consistent approach based on the impulse approximation, nonperturbative solutions of the quark-gap equation and the Poincaré invariant Bethe-Salpeter amplitudes of vector and pseudoscalar mesons.

Plenary / 183

Spectra, from factors and hadronic structure functions from a deformed AdS model

Auteurs: Henrique Boschi-Filho[1]; Miguel Angel Martin Contreras[2]; Eduardo Capossoli[3]; Alfredo Vega[4]; Danning Li[5]

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[2] *U. South China, Hengyang*

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[4] *Valparaiso U.*

[5] *Jinan U.*

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In this talk, I will present recent results from an AdS/QCD model, inspired by AdS/CFT correspondence. In this model, the IR mass scale is introduced in a quadratic exponential deformation of the AdS metric. In contrast with the hard and soft wall models, there is no cut in the AdS space nor any dilaton field in the action. This model proves effective for obtaining discrete spectra for hadrons of any spin, from glueballs to scalar and vector mesons as well as baryons of spins 1/2, 3/2 and 5/2. From this model, we also obtain the pion and nucleon form factors and the structure functions of the proton. These results are compared with the literature and experimental data.

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B^+ decay to $K^+\eta\eta$ with ($\eta\eta$) from the $D\bar{D}(3720)$ bound state

Auteurs: Eulogio Oset[1]; Jing Song[2]; Luciano Abreu[3]; Pedro Carvalho Santos Brandão[4]

[1] *Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC Institutos de Investigación de Paterna*

[2] *School of Physics, Beihang University*

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Auteur correspondant pedro.brandao@ufba.br

We search for a B decay mode where one can find a peak for a $D\bar{D}$ bound state predicted in effective theories and in Lattice QCD calculations, which has also been claimed from some reactions that show an accumulated strength in $D\bar{D}$ production at threshold. We find a good candidate in the $B^+ \to K^+\eta\eta$ reaction, by looking at the $\eta\eta$ mass distribution. The reaction proceeds via a first step in which one has the $B^+ \to D_s^{*+}\bar{D}^0$ reaction followed by D_s^{*+} decay to D^0K^+ and a posterior fusion of $D^0\bar{D}^0$ to $\eta\eta$, implemented trough a triangle diagram that allows the $D^0\bar{D}^0$ to be virtual and produce the bound state. The choice of $\eta\eta$ to see the peak is based on results of calculations that find the $\eta\eta$ among the light pseudoscalar channels with stronger coupling to the $D\bar{D}$ bound state. We find a neat peak around the predicted mass of that state in the $\eta\eta$ mass distribution, with an integrated branching ratio for $B^+ \to K^+$ ($D\bar{D}$, bound) ; ($D\bar{D}$, bound) $\to \eta\eta$ of the order of 1.5×10^{-4}, a large number for hadronic B decays, which should motivate its experimental search.

Plenary / 185

Basis Light-Front Quantization: Foundations, Recent Results and Plans

Auteur: James Vary[1]

[1] *Iowa State University*

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Basis Light Front Quantization (BLFQ) provides a foundation for the development of Hamiltonians and numerical methods to solve both relativistic bound state and scattering applications in QED and QCD. For QCD applications in limited Fock spaces, one assumes a form of confinement based on light-front holography along with an additional longitudinal confinement. For applications limited to valence quarks, an effective one-gluon exchange interaction in light front gauge is employed. Recent developments include expanding Fock spaces beyond valence fermions to include the dynamical gauge degrees of freedom which provide direct access to gluonic contributions to amplitudes and distribution functions. Since the light front wave functions are interpreted as appropriate to a low-resolution scale, calculated observables such as parton distribution functions (PDFs) can be QCD-evolved to higher scales for comparison with experiments. I will survey recent applications to mesons and baryons and discuss prospects for future developments.

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Comparison Between Holographic Deformed AdS and Soft Wall Models for Fermions

Auteurs: Ayrton Nascimento[1]; Henrique Boschi-Filho[1]

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We compare the holographic dressed soft wall and the exponentially deformed AdS models for spin 1/2 fermions. We present the dressed soft wall model and its analytical solutions for the left and right modes, and the corresponding spectra, also including modifications considering hyperfine spin-spin and meson cloud interactions, as well as anomalous dimensions. Then, we discuss the deformed AdS model for spin 1/2 fermions and present their effective Schrödinger equations for the left and right modes, for which only numerical solutions are available. Then, we consider a polynomial expansion of the effective potential of the deformed AdS model and show that in the quadratic approximation it leads to exact analytical solutions comparable with the dressed soft wall model and obtain the corresponding spectra for left and right modes. We show a numerical comparison of the mass spectra of spin 1/2 baryons for the dressed soft wall and the deformed AdS models. We present a detailed relation between the quadratic approximation of the deformed AdS and the dressed soft wall models. We find that the left and right modes of these two models can be related with appropriate choice of the parameters in both cases.

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Pion Transverse Momentum Distribution in Minkowski space.

Auteur: Wayne de Paula[1]

Co-auteurs: Tobias Frederico [1]; Giovanni Salme' [2]

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[2] *Istituto Nazionale di Fisica Nucleare*

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I will discuss the pion structure within a dynamical model based on the solution of the Bethe-Salpeter equation in Minkowski space.
The model consider the pion as quark anti-quark bound state, interacting through a one-gluon exchange. The inputs of the model are the quark and gluon masses, and a scale parameter related to the extended quark-gluon vertex. Within this model, we obtain the full parton distribution function, its contribution due to light-front valence wave function and a comparison with experimental data, after the aplication of a NLO evolution[1]. We also present the unpolarized transverse-momentum dependent quark distributions. In addition, I will show that the model is able to compute other hadronic observables as pion weak decay constant, the valence probability, the LF-momentum distributions, the distribution amplitudes, the probability densities both in the LF-momentum space and the 3D space given by the Cartesian product of the covariant Ioffe-time and transverse coordinates [2]. Finally, we calculated the pion electromagnetic form factor with a good agreement with available experimental data [3].

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3. E. Ydrefors, W. de Paula, J. H. A. Nogueira, T. Frederico and G. Salme, Phys. Lett. B 820 (2021), 136494

Plenary / **188**

Hot perturbative QCD in a very strong magnetic background

Auteurs: Eduardo Fraga[1]; Leticia Palhares[2]; Tulio Eduardo Restrepo Medina[3]

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[2] *Departamento de Física Teórica, UERJ*

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We compute the pressure, chiral condensate and strange quark number susceptibility from first principles within perturbative QCD at finite temperature and very high magnetic fields up to next-to-leading order and physical quark masses. We study the convergence of the perturbative series for the pressure for different choices of renormalization scale in the running coupling. Our results for the chiral condensate and strange quark number susceptibility can be directly compared to recent lattice QCD data away from the chiral transition.

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Positronium structure from a basis light-front approach

Auteur: Kaiyu Fu[1]

Co-auteurs: Xingbo Zhao [1]; Yang Li [2]; James Vary [3]

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In this talk I report our recent progress on solving the postronium system in a basis light-front Hamiltonian approach with the light-front QED Hamiltonian as input. Both the leading Fock sector ($|e^+e^-\rangle$) and the higher sector containing one dynamical photon ($|e^+e^-\gamma\rangle$) are included in the basis. We found that the rotation symmetry of the positronium system provides natural cutoffs in momentum space for the particles in the basis. We performed the calculation at the physical electromagnetic coupling. We obtained the mass spectrum and charge radii of the low-lying states which reasonably agree with the results from non-relativistic quantum mechanics. The subleading helicity components of the postronium states naturally appear due to relativistic effects. Finally I will report the photon distribution in the positronium states.

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Anomalous Holographic Hard Wall Model for Glueballs and the Pomeron

Auteurs: Rafael A. Costa Silva[1]; Henrique Boschi-Filho[1]

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In this work we consider the inclusion of anomalous dimensions in the dual operators that describe glueballs in the holographic hard wall model, inspired by the AdS/CFT correspondence. The anomalous dimensions come from well known string theory analysis showing a dependence with the spin of the hadronic state. We show that this inclusion improves the glueball spectra and Regge trajectory when compared to lattice data and to the soft pomeron. We also consider a phenomenological

motivated expression for the anomalous dimensions such that the glueball Regge trajectory becomes asymptotically linear with good masses and fitting the pomeron trajectory.

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Valence and sea parton correlations in double parton scattering from data

Auteur: Emmanuel de Oliveira[1]

Co-auteurs: EDGAR HUAYRA PAITAN [1]; João Vitor Costa Lovato [2]

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[2] *Universidade Federal de Santa Catarina*

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The effective cross section of double parton scattering in proton collisions has been measured by many experiments with rather different results. Motivated by this fact, we assumed that the parton correlations in the transverse plane are different whether we have valence or sea partons. With this simple approach, we were able to fit the available data and found that sea parton pairs are more correlated in the transverse plane than valence–sea parton pairs.

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Beyond Valence Distributions in meson with Basis Light-Front Quantization

Auteurs: Jiangshan Lan[1]; Xingbo Zhao[1]; Chandan Mondal[2]; Zhimin Zhu[3]; Jiatong Wu[3]; Kaiyu Fu[1]; Ziqi Zhang[3]; Jialin Chen[3]

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We explore light mesons beyond valence structure in the Basis Light-front Quantization (BLFQ) approach, comprising the quark-gluon interactions from the light-front quantum chromodynamics (QCD) on the Hamiltonian. After fitting the light meson mass spectroscopy, the Hamiltonian eigenvectors provide a good description of the pion and the kaon Decay constants, Electromagnetic Form factor, and Parton distribution function. We will also discuss the parton distributions going beyond the leading twist.

Plenary / 193

The electron-ion collider – A world wide unique collider to unravel the mysteries of visible matter

Auteur: Elke Aschenauer[1]

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Understanding the properties of nuclear matter and its emergence through the underlying partonic structure and dynamics of quarks and gluons requires a new experimental facility in hadronic physics known as the Electron-Ion Collider (EIC). The EIC will address some of the most profound questions concerning the emergence of nuclear properties by precisely imaging gluons and quarks inside protons and nuclei such as their distributions in space and momentum, their role in building the nucleon spin and the properties of gluons in nuclei at high energies. In January 2020 the EIC received CD-0 and Brookhaven National Laboratory was selected as site, and June 2021 CD-1. This presentation will give highlights on the EIC science program, introduce the experimental equipment and its integration into the accelerator and give the status of the EIC project, as well what are the next major steps.

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Proton gravitational form factors with basis light-front quantization

Auteur: Sreeraj Nair[1]

Co-auteurs: Chandan Mondal [2]; James Vary [3]; Siqi Xu [4]; Xingbo Zhao [5]

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We study the gravitational form factors (GFFs) and the mechanical properties like the pressure and shear distribution of quarks using the light-front wave functions (LFWFs) of the nucleon from a basis light-front quantization (BLFQ) approach in the leading Fock-sector representation. Our analysis further expands to include an extra Fock sector, which integrates three quarks and an active gluon. This leads to the study of gluon GFFs and their respective mechanical features. We compare our results with existing experimental data and Lattice outcomes.

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Structure of spin-1 QCD systems using light-front Hamiltonian approach

Auteurs: Satvir Kaur[1]; Jiatong Wu[1]; Zhi Hu[None]; Jiangshan Lan[2]; Chandan Mondal[2]; Xingbo Zhao[2]; James Vary[3]

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We investigate the structure of the spin-1 hadron system, particularly the ρ-meson, through the leading-twist momentum-dependent parton distribution functions. We employ the light-front wavefunctions generated from the Basis Light-Front Quantization approach to compute the quark and gluon distribution functions (PDFs), and the transverse momentum-dependent quark distribution

functions (TMDs). To extract the wavefunctions, we truncate the Fock space to consider the states of the valence quark-antiquark and quark-antiquark-gluon. Our predictions follow the positivity bounds implied on the PDFs and TMDs of both the quark and the gluon. Further, we evolve the unpolarized and helicity PDFs to a higher scale in order to compare the moments of PDFs with the other theoretical approaches.

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Glue and sea inside proton: A light-front Hamiltonian approach

Auteurs: Chandan Mondal[1]; Siqi Xu[2]; Xingbo Zhao[1]; James Vary[3]

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Basis Light-Front Quantization (BLFQ) provides a nonperturbative framework to solve relativistic many-body bound state problems in quantum field theories. We report our recent progress in applying BLFQ to reveal structure of the nucleon going beyond to its leading Fock sector. We produce the light-front wave functions of the nucleon from the light-front QCD Hamiltonian, determined for its constituent $|qqq\rangle$, $|qqqg\rangle$, and $|qqqq\bar{q}\rangle$ Fock components. The eigenvectors of the light-front QCD Hamiltonian have been successfully employed to compute a wide class of different and related nucleon observables. We discuss the generalized parton distributions functions (GPDs) and the transverse momentum dependent distribution functions (TMDs) of the gluon and sea quarks inside the nucleon.

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Evolution of GPDs as a tool for their extraction

Auteur: Herve Dutrieux[1]

Co-auteurs: Cédric Mezrag [2]; Hervé Moutarde [3]; Kostas Orginos [1]; Pawel Sznajder [4]; Valerio Bertone [5]

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[5] *IRFU, CEA, Université Paris-Saclay*

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I will present how perturbative evolution offers in theory the possibility of a model independent extraction of generalized parton distributions (GPDs) from exclusive processes such as deeply virtual Compton scattering (DVCS), but falls short of its promises practically at moderate skewness – a problem illustrated through the concept of shadow GPDs. However, perturbative evolution provides crucial insights to the modeling of GPDs at small x. I will open up on the perspectives provided by non-perturbative evolution computed in lattice QCD.

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Studying chiral pions with massive gluons.

Auteur: Marcela Peláez[None]

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We will show how to obtain a closed expression for the
the calculation of the pion decay constant in the chiral case.
The expression is obtained by using the Curci-Ferrari model which
includes massive gluons. This model also allows to find an infrared safe
trajectory of the renormalisation group. With
which the results of the numerical simulations can be reproduced with good accuracy ussing perturbation theory. This leads to the interpretation that the
development parameter associated with the ghost-gluon coupling constant is a small parameter.
This small parameter allows for a better understanding of which diagrams has to be considered when calculating, for example, the pion decay constant. The numerical solution of the expression gives the region of gluon masses that well reproduce the pion decay constant.

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Towards a Hamiltonian first principle approach for baryons

Auteur: Siqi Xu[1]

Co-auteurs: Chandan Mondal [2]; James Vary [3]; Sreeraj Nair [4]; Xingbo Zhao [2]; Yang Li [5]

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Basis light-front quantization (BLFQ), as a fully relativistic and nonperturbative approach based on a light-front quantized Hamiltonian with Quantum Chromodynamics (QCD) input, has the potential to achieve the first principle calculation. For QCD applications in limited Fock spaces, we implement a form of confinement based on light-front holography and additional longitudinal confinement in our Hamiltonian. Consequently, BLFQ results agree with the global fitting and experimental data. Recent developments include expanding the Fock spaces to the five-particle Fock sectors, such as the five-quark and three-quark-two-gluon Fock sectors, and implementing the relevant QCD interaction to replace the effective confining potential. Using the light-front wave functions produced by BLFQ, one can calculate observables such as parton distribution functions (PDFs) of the gluon and sea quarks at a low-resolution scale and implement QCD-evolved to higher scales for comparison with experiments. At the end of this talk, I also discuss prospects for future developments.

Plenary / **200**

Double Parton Scattering in Ultraperipheral Collisions

Auteur: Bruna de Oliveira Stahlhofer[1]

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Double Parton Scattering (DPS) is a important way for which we can investigate the parton distributions of the proton and the nucleus. Although, we know that such scatterings should occur in high energy collisions, the formalism to describe it lack of answers to questions like — is there a universal effective cross section? In direction to explore such questions, we investigate DPS in ultraperipheral collision (UPC) where the effective cross section is not a constant as usually is in the central collisions, as we point in our results. Furthermore, once we allow the nucleus to break in a ultraperipheral proton–nucleus collision, we provide insights concerning the photon distribution of the nucleus. Also, as the effective cross section have a complex dependence with the longitudinal fraction energy carrying by the photon in the initial state, we evaluate cross sections with photon and gluons in the initial state producing quark–antiquark pairs or dilepton and quark–antiquark in the final state.

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Exclusive production of excited light vector mesons with a holographic wave function model

Auteur: Cheryl Henkels de Souza[1]

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The exclusive photo- and electroproduction of the light vector mesons ρ, ω and ϕ are studied within the color dipole picture as function of the center-of-mass energy of the γp collision and the momentum transfer squared $|t|$. The corresponding vector meson wave functions have been computed with the relativistic AdS/QCD holographic approach. This enabled us to obtain a good description of all available data for the ground-state light mesons $\rho(1S)$, $\omega(1S)$, and $\phi(1S)$ as well as to make predictions for the excited states $\rho(2S)$, $\omega(2S)$, and $\phi(2S)$ with the same formalism. This study revealed the existence of a sizeable theoretical uncertainty coming from modeling the partial dipole amplitude in the non-perturbative kinematical domain. These uncertainties could be deeply investigated with measurements of the light vector meson cross sections in future hadron colliders.

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Pole structure of the three-gluon vertex: connecting symmetry and dynamics

Auteur: Bianca Maria Silveira de Oliveira[1]

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In QCD, the gluons acquire a dynamical mass through the Schwinger mechanism. When the Schwinger mechanism is activated, the fundamental vertices of the theory acquire massless poles. This effect is entirely nonperturbative, in which the three-gluon vertex has a dominant contribution. In this work, we analyze the patterns of the pole structure of the three-gluon vertex using two different approaches: the Slavnov-Taylor identity satisfied by the three-gluon vertex and the Schwinger-Dyson equation that governs the dynamical evolution of this vertex. From the symmetry perspective of the theory, we show that the STI imposes constraints on these pole structures, preventing them from vanishing. On the other hand, we also check that the SDE governing the dynamical evolution of the three-gluon vertex reproduces the same constraints, disclosing the deep connection between the symmetry and dynamics of the theory, favoring the scenario of dynamical mass generation.

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The transversely projected three-gluon vertex and its planar degeneracy

Auteur: Leonardo Santos[1]

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We analyze in detail the key features of the transversely-projected three-gluon vertex based on the corresponding Schwinger-Dyson equation. In particular, we aim to scrutinize the property denominated "planar degeneracy" recently established by lattice simulations. This property states that the vertex is well approximated by a single Bose-symmetric variable, which defines a plane in momentum space. Our analysis indicates that this property is particularly accurate for the form factor associated with the classical tensor structure in general kinematics, while deviations are observed for the remaining three form factors. Furthermore, we demonstrate that the classical form factor has a clear numerical dominance over the other three. The outcome is the emergence of a very compact description for the three-gluon vertex in general kinematics, which may simplify significantly nonperturbative applications involving this vertex.

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Electric and magnetic susceptibilities of a hot and dense medium of massive fermions

Auteurs: Osvaldo Ferreira[1]; Eduardo Fraga[2]

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In this work we calculate the electric and magnetic susceptibilities of a hot and dense medium in equilibrium up to order $\mathcal{O}(\frac{m^4}{T^4})$ $\mathcal{O}(\frac{m^2}{T^2})$, respectively. These susceptibilities are associated with $\mathcal{O}(k^2)$ terms (power corrections) of the photon polarization tensor, which are computed here for a hot and dense medium of fermions with a small but nonzero mass, i.e., $0 < m \ll T, \mu$. Our calculations are performed within the hard thermal loop approximation in the real-time formalism. In the high temperature and small chemical potential limit, our results are compared with previous calculations.

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Positronium in quantum electrodynamics of effective particles

Auteur: Kamil Serafin[1]

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We study numerically spectrum of positronium using effective (and renormalized) Hamiltonian obtained from QED by means of the renormalization group procedure for effective particles

(RGPEP). The basis light-front quantization (BLFQ) provides the framework for numerical computations. Positronium is chosen as the testing ground for our method and a stepping stone for future studies in QCD, which is the intended application area of the method. We obtain reasonable agreement between our and the well-known perturbative results with controllable uncertainties. The dependence on the renormalization scale parameter is also studied.

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Resummation in JIMWLK Hamiltonian

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The JIMWLK Hamiltonian governs evolution of high energy collision processes. At next-to-leading order, the Hamiltonian features large logarithms, which have to be resummed. We discuss partial resummation of these logarithms into running coupling and DGLAP-like resummation.

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Cooling of quark stars from perturbative QCD

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Since Witten's proposal that symmetric deconfined u, d, and s quark matter might be the true absolute ground state, properties of quark stars have been extensively studied. By choosing an equation of state to describe the matter inside these stars, it is possible to solve the Tolman-Oppenheimer-Volkoff equations to obtain the mass and radius of the star. However, it has become clear that measuring solely the mass and radius will not be sufficient to distinguish between neutron stars, hybrid stars and quark stars. Therefore, it is necessary to take into account other observables that are closely related to microscopic physics. One possibility is the thermal evolution of these stars. The general relativistic equations of energy balance and energy transport that are solved in a numerical cooling simulation involve both microscopic (neutrino emissivity, heat capacity, thermal conductivity) and macroscopic (metric function, mass, radius) quantities. In this work, we study the structure and thermal evolution of quark stars employing equations of state from perturbative QCD. We build the framework for acquiring cooling solutions and discuss the consequences arising from the application of different equations of state to describe the properties of quark matter.

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The three- and four-gluon vertices from lattice QCD in Landau gauge

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We present our latest results from lattice-QCD simulations concerning the three-gluon vertex in scenarios beyond the conventional symmetric and soft-gluon situations. These outcomes stem from extensive quenched lattice simulations with high statistical accuracy. To analyze these outcomes, we adopt a tensorial basis that eneables the representation of the three-gluon form factors using momentum variables that exhibit Bose symmetry. Our data highlights a significant prevalence of the tree-level tensor element.

We also present our current preliminary results on the four-gluon vertex form factors obtained also from quenched lattice QCD simulations with a large set of configurations for different values of the lattice spacing. As in the three-gluon vertex, it is expected a clear dominance of the form factor associated with the tree-level tensor.

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Radiative Corrections to the Gribov-Zwanziger Effective Model for QCD

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Given the well-known limitations of the perturbative approach to Yang-Mills theories in the infrared regime, it is often interesting to resort to nonperturbative methods, such as Lattice QCD, Schwinger-Dyson equations, Renormalization Group Methods, and effective models. In particular, the so-called Refined Gribov-Zwanziger (RGZ) effective model has successfully described a nontrivial infrared behavior of gauge field propagators, being very close to the ones observed in numerical lattice gauge field theory simulations.

We discuss the one-loop correction to the the ghost-anti-ghost-gluon interaction vertex, in the RGZ theory. Our analytical results are fairly compatible with lattice YM simulations. We also discuss our current efforts to calculate the one-loop correction to the RGZ gluon propagator.

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The EMC effect within the light-front Hamiltonian dynamics for few-nucleon bound systems

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We present the description of light-nuclei, in valence approximation, within a rigorous Light-Front (LF) approach. The latter, fulfills Poincaré covariance, macroscopic locality,number of particles and momentum sum rules. We applied the analysis to electron deep inelastic scattering (DIS) on ^{3}He, ^{3}H and ^{4}He targets, in the Bjorken limit. For details about the ^{3}He case, see Ref. [1]. Within the present framework, the main theoretical ingredient is the LF nuclear spectral function which can be related to the nuclear momentum distribution. The latter quantity has been calculated within the phenomenological Av18 + UIX potential and the chiral potentials called NVIa +3N and NVIb +3N. The evaluated momentum distribution has been used to calculate the structure functions of the considered nuclei. As discussed in Ref. [1], also for ^{3}H and ^{4}He, our analysis predicts a sizable European Muon Collaboration (EMC) effect [2]. Let us remark that, in the valence region, results are rather independent with respect to the use of different parametrizations of the nucleon DIS structure functions and the nuclear potentials. This investigation represents the first realistic calculations of the EMC effect, for different targets, which fulfills Poincaré covariance and thus preserving all the fundamental sum rules. Therefore, this a relevant study also in view of the present and future experimental scenarios.

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Spectral analysis of the gauge invariant quark propagator

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We explore the Dirac decomposition of the gauge invariant quark propagator, shedding light on the hadronization of a quark as this interacts with the vacuum. Using the spectral representation of the quark propagator, we link the coefficients of the Dirac decomposition of the gauge invariant quark propagator to sum rules governing the chiral-odd and chiral-even quark spectral functions.

In particular, in light-like axial gauges, we obtain a novel sum rule for the quark spectral function associated to the gauge-fixing vector. Based on the gauge invariance of the gauge invariant quark propagator, we demonstrate the formal gauge invariance of the so called jet mass, a color-screened gauge-invariant dressed quark mass) that can be expressed in any gauge as the first moment of the chiral-odd quark spectral function. Lastly, we also present a gauge-dependent formula that connects the second moment of the chiral-even quark spectral function to invariant mass generation and final state rescattering in the hadronization of a quark.

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Light-front subtleties: zero modes, operator solutions, correlation functions

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A novel approach to the dynamical light-front (LF) zero modes is presented. It is based on quantization of the two-dimensional LF gauge field $A^\mu(x)$ in the covariant (Feynman) gauge. The $A^\pm$ components are obtained as a massless limit of the massive vector field and contain an infinite set of dynamical zero modes with finite LF energy. We argue that the same zero modes are present in realistic gauge theories like LF QED(3+1). Its covariant-gauge formulation is briefly described and a few general comments concerning the LF zero modes are presented. Next, operator solution and axial anomaly of the LF Thirring-Wess and Schwinger models is discussed. Finally, we show that contradictions related to the $x^+ = 0$ restriction of the two-point and Pauli-Jordan functions are removed if the scalar field contains regularization terms in the plane-wave factors. The value of the two-point function at coinciding points is then also correctly obtained in the Hamiltonian approach.

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Training the machine for learning how to predict the infrared gluon two-point correlation function

Auteur: Rodrigo Carmo Terin[1]

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We exploit the use of one of the specific tools of Artificial Intelligence, the Machine Learning setup, to apply it in the infrared quantum chromodynamics context. We display all the required phases that the machine needs to learn to discover how it behaves the already existing gluon two-point correlation function provided by lattice numerical simulations starting from computing error metrics, training instances, and the use of the cross-validation method and then through the previous knowledge acquired by our built-up machine, it can predict in the unseen data the boot samples values in a lattice infrared phantom zone.

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The quark-photon vertex in confining models

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We present one-loop results for corrections from Strong Interactions to the quark-photon vertex using different confining models for the exchanged gluon. This calculation allows for the prediction of confinement effects in form factors and observables like the proton anomalous magnetic moment. We show that a range of confining models with dynamical gluon masses and even complex-conjugated poles present predictions that are fully compatible with observables and discuss to what extent model parameters may be constrained by this comparison.

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The bound state formation in Minkowski space: A study about the effect of dressing the quark propagator

Auteur: Abigail Castro[1]

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This work analyzes the effect of dressing the quark propagator in the bound state formation in Minkowski space. Through the Bethe-Salpeter approach, a 0- fermion-antifermion bound state is studied. The considered system is characterized by two quarks interacting through a vector boson exchange in the ladder approximation. Especially, the dressed quark propagators with a phenomenological running mass function fit to Lattice QCD calculations. The developed model contains three gluonic scales: the effective gluon mass ~ ⊠QCD, the size of the extended quark-gluon vertex ~2fm, and the dressing of the quark propagator. Static and dynamical quantities that characterize the bound state are calculated and the effects of those scales in the dynamics of the bound system are discussed. In particular, the light-front amplitudes and the longitudinal and transverse valence momentum distributions are analyzed for two bound state masses, M = 653 MeV and M = 447 MeV, with or without dressing effects.