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Book of Abstracts

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Probing of exotic multiquark states in hadron and heavy ion collisions

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The spectroscopy of charmonium-like mesons with masses above the 2_mD open charm threshold has been full of surprises and remains poorly understood [1]. The currently most compelling theoretical descriptions of the mysterious XYZ mesons attribute them to hybrid structure with a tightly bound cc\bar diquark [2] or cq(cq)\bar tetraquark core [3 - 5] that strongly couples to S-wave DD\bar molecular like structures. In this picture, the production of a XYZ states in high energy hadron collisions and its decays into light hadron plus charmonum final states proceed via the core component of the meson, while decays to pairs of open-charmed mesons proceed via the DD\bar component.
These ideas have been applied with some success to the XYZ states [2], where a detailed calculation finds a cc\bar core component that is only above 5% of the time with the DD\bar component (mostly D0D0\bar) accounting for the rest. In this picture these states are compose of three rather disparate components: a small charmonium-like cc\bar core with r_rms < 1 fm, a larger D+D- component with r_rms = ħ/(2μ+B+)ˆ1/2 ≈ 1.5 fm and a dominant component D0D0 with a huge, r_rms = ħ/(2μ0B0)ˆ1/2 > 9 fm spatial extent. Here μ+(μ0) and B+(B0) denote the reduced mass for the D+D- (D0D0\bar) system and the relevant binding energy |m_D + m_D - M_X(3872)| (B+ = 8.2 MeV, B0 < 0.3 MeV). The different amplitudes and spatial distributions of the D+D- and D0D0 components ensure that the X(3872) is not an isospin eigenstate. Instead it is mostly I = 0, but has a significant (˜ 25 %) I = 1 component.
In the hybrid scheme, XYZ mesons are produced in high energy proton-nuclei collisions via its compact (r_rms < 1 fm) charmonium-like structure and this rapidity mixes in a time (t ˜ ħ/δM) into a huge and fragile, mostly D0D0, molecular-like structure. δM is the difference between the XYZ meson mass and that of the nearest cc\bar mass pole core state, which we take to be that of the χc1(2P) pure charmonium state which is expected to lie about 20 ˜ 30 MeV above M_X(3872) [6, 7]. In this case, the mixing time, cτ_mix 5 ˜ 10 fm, is much shorter than the lifetime of X(3872) which is cτ_X(3872) > 150 fm [8].
The experiments with proton-proton and proton-nuclei collisions with √S_pN up to 27 Gev and luminosity up to 10ˆ32 cmˆ-2sˆ-1 planned at NICA may be well suited to test this picture for the X(3872) and other XYZ mesons [9]. In near threshold production experiments in the √S_pN ≈ 8 GeV energy range, XYZ mesons can be produced with typical kinetic energies of a few hundred MeV (i.e. with γβ ≈ 0.3). In the case of X(3872), its decay length will be greater than 50 fm while the distance scale for the cc\bar → D0D*0 transition would be 2 ˜ 3 fm. Since the survival probability of an r_rms ˜ 9 fm "molecular"inside nuclear matter should be very small, XYZ meson production on a nuclear target with r_rms ˜ 5 fm or more (A ˜ 60 or larger) should be strongly quenched. Thus, if the hybrid picture is correct, the atomic number de-pendence of XYZ production at fixed √S_pN should have a dramatically different behavior than that of the ψ', which is long lived compact charmonium state.
The current experimental status of XYZ mesons together with hidden charm tetraquark can-didates and present simulations what we might expect from A-dependence of XYZ mesons in proton-proton and proton-nuclei collisions are summarized.
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Perspective studies of charmonium, exotics and baryons with charm and strangeness

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The spectroscopy of charmonium-like states together with the spectroscopy of charmed and strange baryons is discussed. It is a good testing tool for the theories of strong interactions, including: QCD in both the perturbative and non-perturbative regimes, LQCD, potential models and phenomenological models [1, 2, 3]. An understanding of the baryon spectrum is one of the primary goals of non-perturbative QCD. In the nucleon sector, where most of the experimental information is available, the agreement with quark model predictions is astonishingly small, and the situation is even worse in the strange and charmed baryon sector. The experiments with antiproton-proton annihilation and proton-proton (proton-nuclei) collisions are well suited for a comprehensive spectroscopy program, in particular, the spectroscopy of charmonuim-like states and flavour baryons. Charmed and strange baryons can be produced abundantly in both processes, and their properties can be studied in detail [1, 2, 3].
For this purpose an elaborated analysis of charmonium and exotics spectrum together with spectrum of charmed and strange baryons is given. The recent experimental data from different collaborations (BaBar, Belle, BES, LHCb,⋯) are analyzed. A special attention was given to the recently discovered XYZ-particles. The attempts of their possible interpretation are considered [4 - 7]. The results of physics simulation are obtained. Some of these states can be interpreted as higher lying charmonium and tetraquarks with a hidden charm [5, 6, 7] and strangeness [8, 9]. It has been shown that charge/neutral tetraquarks must have their neutral/charged partners with mass values which differ by few MeV. This hypothesis coincides with that proposed by Maiani and Polosa [10] and need confirmation nowdays. Many heavy baryons with charm and strangeness are expected to exist. But much more data on different decay modes are needed before firmer conclusions can be made. These data can be derived directly from the experiments using a high quality antiproton beam with √Spp\bar up to 5.5 GeV planned at FAIR and proton-proton (proton-nuclei) collisions with √SpN up to 26 GeV planned at NICA.
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Baryon excited states: quark model versus reality

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Hamiltonian effective field theory (HEFT) provides a powerful method by which we can extract physical information about the nature of baryon excited states, using both experimental data and lattice simulations as a function of quark mass. In particular, we have found that both the $\Lambda(1405)$ [1] and Roper [2] resonances are molecular in nature, with the states expected within the quark model appearing at much higher mass. We will review these two examples as well as more recent applications of the method.

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Hard exclusive reactions beyond DVCS: Compton-like and vector meson production for GPD studies

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The so-called GPDs (Generalized Parton Distributions), sensisitive to the multi-dimensional “position” versus “momentum” of the nucleon’s partonic constituents have been studied for many years at various facilities, for various kinematics. Most of the published measurements and most constraints to GPD models come from the DVCS (Deeply Virtual Compton Scattering) process. There is a growing interest for exploring other reactions, thanks in particular to the perspective of new facilities and upgrades at existing facilities. In this talk, I will discuss the complementarity of Compton-like reactions, such as TCS and DDVCS, to DVCS measurements, in particular for GPD’s fitting and interpretations. I will also discuss what new can be brought with a coherent exclusive meson measurement program, in addition to Compton-like reactions, at the Jefferson Lab Hall C with the recently upgraded 11 GeV beam energy from CEBAF. I will show projections for various reactions, discuss the experimental requirements, what is new in terms of physics, and short term projects for Hall C, including the development of new detectors, and with a particular emphasis on “dilepton” channels and muons.

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Next to SV resummed prediction for pseudoscalar Higgs boson production at NNLO+$\overline{\text{NNLL}}$

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We present the first results on the resummation of Next-to-Soft Virtual (NSV) logarithms for the threshold production of pseudoscalar Higgs boson through gluon fusion at the LHC. These results are presented after resumming the NSV logarithms of the kind $\log^i(1-z)$ to $\overline{\mathrm{NNLL}}$ accuracy and matching them systematically to the fixed order NNLO cross-sections. These results are obtained using collinear factorization, renormalization group invariance, and recent developments in the NSV resummation techniques. The phenomenological implications of these NSV resummed results for 13 TeV LHC are studied and it is observed that these NSV logarithms are quite large. We also evaluate theory uncertainties and find that the renormalization scale uncertainties get reduced further with the inclusion of NSV corrections at various orders in QCD. We further study the impact of QCD corrections on mixed scalar-pseudoscalar states for different values of the mixing angle α.

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Definition of electromagnetic and gravitational local spatial densities

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New relations between the electromagnetic/gravitational local spatial densities and corresponding form factors for various spin systems will be considered. It will be shown how traditional densities in the Breit frame emerge from a static approximation of the matrix element of corresponding local operators. Interpretation, advantages and disadvantages of the new and traditional definitions will be discussed.

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Chiral EFT of deltas, nucleons and pions in the presence of external gravitational field.

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Effective chiral Lagrangian of deltas, nucleons and pions in external gravitational field and the corresponding energy-momentum tensor will be considered. Gravitational form factors of the deltas and their relation to internal forces will be discussed.

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Heavy baryon spectroscopy in a quark-diquark approach

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We present results for the heavy baryon spectrum for ground and excited states with quantum numbers $J^P = 1/2^+$ and $3/2^+$ using functional methods in QCD. To this end, we reduce the three-quark Faddeev equations to two-body equations via the quark-diquark approach, where the baryons are treated as bound states of quarks and effective diquarks. The resulting Bethe-Salpeter equation amounts to a quark ping-pong exchange for the interaction kernel, where the quark and diquark ingredients are determined in a rainbow-ladder truncation. Our results show an overall agreement of the ground state masses with experiment. The single charmed baryon ground state masses agree with lattice QCD and theoretical calculations using QCD potential models. Double and triple charmed baryons were also calculated. A partial wave analysis of the ground and excited states shows that relativistic effects are present in the baryon amplitudes.

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Structure calculations of fully-heavy hexaquarks

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We used a diffusion Monte Carlo technique to describe the properties of fully-heavy compact arrangements (no dibaryon molecules) including six quarks and no antiquarks within the framewok of a constituent quark model. Only arrangements whose wavefunctions were eigenvectors of L^2 with eigenvalue $=0$ were taken into account, what means that we only considered the subset of all the possible color-spin combinations that make the total wavefunctions antisymmetric with respect to the interchange of any two quarks of the same type. This means arrangements with spin $S=0$ for *cccccc*, *bbbbbb*, *cccccb*, *bbbbbc* and *cccbbb* and spin $S=0,1,2$ for the *ccccbb* and *bbbbcc* hexaquarks. In all cases, the masses of the six-quark arrangements are larger that the ones corresponding to the sum of any of the two baryons we can split them into, but smaller that the ones for a set of six isolated quarks, i.e., all them are bound systems. The analysis of their structure indicates that all the hexaquarks considered in this work are compact objects, except the *cccbbb*, that appears to be a loose association of two baryons.

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Intermittency study of charged particles generated in EPOS3 at $\sqrt{s_{NN}}$= 5.02 TeV

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The search for the QCD critical point (CP), and the study of quark-hadron phase transition (and vice-versa), at finite baryon density and high temperature, is the main task in contemporary relativistic ion collision experiments. Fluctuation analysis with global and local measures is the basic tool to achieve this goal. Local density fluctuations are directly related to the critical behaviour in QCD. These fluctuations in the phase space are expected to scale according to universal power-law in the vicinity of critical-point. In practical work, with limited statistics, it is almost always necessary to perform averages over more than a single phase-space cell. In intermittency analysis, phase space volume is divided into non-overlapping cells within a single rapidity interval. This method is used to probe the behaviour of multiplcity fluctuations through the measurement of Normalized Factorial Moments (NFMs) in (η, ϕ) phase space. NFMs have essential properties of Poisson-noise suppression and sensitivity to high density fluctuations. Observations and results from the intermittency analysis

performed for generated charged hadrons in pPb collisions using EPOS3 for transverse momentum bin width dependence will be presented.

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Hidden-charm $P^{\Lambda}_{\psi s}$ pentaquarks in a constituent quark model calculation

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The discovery of pentaquark states by the LHCb [1] revolutionized Hadron Physics, expanding the usual qqq structure to four quarks and an antiquark. The first observations, detected in the $J/\psi p$ mass spectrum, showed two resonances, dubbed $P_c(4380)^+$ and $P_c(4450)^+$, close to $D^{(*)}N$ thresholds, which suggested a baryon-meson molecular nature in contrast to a compact pentaquark core. The existence of such pentaquarks, with minimum $\bar{c}cuud$ quark content, anticipated similar hidden-charm structures with strangeness, i.e., with $\bar{c}cuds$, which were recently confirmed with the discovery of the so-called $P_{cs}(4459)^0$ [2], now called $P^{\Lambda}_{\psi s}(4459)^0$.

In this work, we provide a theoretical description of the $P^{\Lambda}_{\psi s}(4459)^0$ and $P^{\Lambda}_{\psi s}(4338)$ resonances as $\bar{D}^{(*)}\Xi_c^{(\prime)(*)}$ molecular states in the framework of a constituent quark model that has been extensively used to describe hadron phenomenology [3], in particular exotic states in the baryon spectrum as meson-baryon molecules [4,5]. Such $P^{\Lambda}_{\psi s}$ states are found in the $J^P = \frac{1}{2}^-$ channel with masses and widths compatible with the experimental measurements in a coupled-channels calculation with all the parameters constrained from previous studies. Other candidates are explored in the $J^P = \frac{3}{2}^-$ and $\frac{5}{2}^-$ channels. Additionally, $P^{N}_{\psi ss}$ pentaquark states are predicted as $\bar{D}_s\Xi_c$ molecules.

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Strange particle production in Au+Au collisions at √sNN =14.6 GeV using AMPT and UrQMD.

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Production of strange quarks in relativistic heavy-ion collisions is not only used as a signature of QGP formation but also as a diagnostic tool. Strange quarks and antiquarks are produced via strong interactions in the QGP medium and are not present in ordinary matter. The reason is that they promptly undergo decay via weak interactions as soon as they are produced. Additionally, the mass of strange quarks, anti quarks, is below and close to the temperature at which protons, neutrons and other hadrons turn into quarks. Hence, these strange quarks, antiquarks are sensitive to the conditions, structure and dynamics of the deconfined state of matter. It can be said that the deconfined state is reached if there is an abundance of strange quarks. In this poster, I will present the comparison between the invariant mass and yield of different strange particles(Λ, Σ, Ω) at different centralities for the events simulated using AMPT and UrQMD model.

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Δ baryon spectroscopy using Hamiltonian Effective Field Theory and lattice QCD

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Building on previous studies of the nucleon spectrum and the enigmatic Roper resonance, we investigate the closely related Δ baryon spectrum using a combination of lattice QCD and Hamiltonian Effective Field Theory (HEFT). We obtain effective masses for the ground state and first excitation of the spin-3/2 Δ baryon in full QCD using 2+1 flavour PACS-CS gauge field configurations on a $32^3 \times 64$ lattice with a spin projection technique to isolate the spin-3/2 states of interest. In order to compare with experiment, we use HEFT to connect between the finite volume of the lattice and the infinite volume of the real world.

HEFT describes a system with interactions between 3-quark bare basis states and meson-baryon two-particle non-interacting states. We take the relevant two-particle channels to be πN and $\pi\Delta$ in p-wave, and $\pi\Delta$ in f-wave. We constrain the Hamiltonian matrix parameters by fitting the relevant couplings, potentials, bare masses and regulator parameters to experimental phase shifts and inelasticities available through George Washington University's SAID partial waves database. The Hamiltonian can then be solved for its eigenvalues and eigenvectors on a finite volume; the eigenvalues allow us to match to the lattice results while the eigenvectors inform us on how much the bare states and two-particle channels contribute to those energies.

We find evidence to suggest the ground state $\Delta(1232)$ is predominantly a 3-quark state, while the 1st excitation $\Delta(1600)$ appears to be predominantly a dynamical state generated through strong rescattering of πN (p-wave), $\pi\Delta$ (p-wave) and $\pi\Delta$ (f-wave) channels, in contrast to traditional quark model expectations. The next 3-quark dominated state in the spectrum appears to lie around 2 GeV.

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Hidden-charm pentaquarks as hadronic molecules

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In this talk, I will discuss the hidden-charm pentaquarks with and without strangeness from the hadronic molecular point of view. I will show that the LHCb data can be well described under this picture by constructing an effective field theory for the interactions between $\Sigma_c^{(*)}\bar{D}^{(*)}$. Predictions of many more hidden-charm and double-charm molecular pentaquarks will be presented using a simple model for the interaction between a pair of charmed hadrons. I will also briefly discuss the photoproduction of P_c states.

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Mesons, baryons and the phase diagram of QCD

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We summarise recent theoretical results on the QCD phase diagram and the properties of hadrons at finite temperature and chemical potential based on a combination of lattice QCD and Dyson-Schwinger equations. We discuss the silver blaze property of mesons with different quantum numbers along the zero-T-finite-mu-axis and assess the influence of meson and baryon fluctuations on the location of the critical end point.

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Mesons at finite temperature and density from the FRG

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We present recent results on in-medium spectral functions of mesons with a particular emphasis on the rho(770) vector meson and the a1(1260) axial-vector meson in nuclear matter, as well as on the resulting thermal dilepton rate. As an effective description of the thermodynamics and the phase structure of nuclear matter we use a chiral baryon-meson model, taking into account the effects of fluctuations from scalar mesons, nucleons, and vector mesons within the Functional Renormalization Group (FRG) approach. Our results show strong modifications of the spectral functions in particular near the chiral critical endpoint which may lead to an enhanced dilepton yield at low invariant masses in heavy-ion collision experiments. Recent results from transport simulations tend to support this effect and will also be discussed. Our results may therefore well be of relevance for electromagnetic rates in heavy-ion collisions or neutrino emissivities in neutron-star merger events and help to identify phase transitions and the critical endpoint.

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Baryon resonance studies via meson photoproduction at the LEPS2/BGOegg experiment

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Meson photoproduction is a helpful tool for studying baryon resonances thanks to many possibilities of final-state meson-baryon combinations, e.g., πN, ηN, ωN, or multi meson final states.
In addition, the spin information of intermediate resonances can also be obtained by utilizing the high polarization of a photon beam.
The πN final states can couple to both I = 1/2 states (N^* resonances) and I = 3/2 states (Δ resonances).
On the other hand, the ηN and ωN states can couple to only baryons with isospin 1/2, which is called an isospin filter.
Moreover, an eta meson contains $s\bar{s}$ components, and an omega meson has spin 1.
From these features, the η- and ω-meson photoproduction are expected to offer an attractive capability of coupling with the resonances that do not couple well with the πN state.
The differential cross sections measured in past experiments were inconsistent with each other, and the data of photon beam asymmetries were scarce above 2 GeV.
We studied photoproduction reactions of a π^0, η, and ω meson on the proton at the LEPS2/BGOegg experiment using a GeV photon beam produced by the backward Compton scattering.
This photon beam is highly linear polarized, and this polarization degree is
more than 90 % in the highest energy region around the Compton edge.
We measured differential cross sections, photon beam asymmetries, and spin density matrix elements with high statistics and broad angular coverage by using a large acceptance calorimeter (BGOegg) and forward-angle charged-particle detectors.
This calorimeter can identify mesons that decay into multiple γ's, and its energy resolution is the world's best among the experiments conducted in a similar energy range.
A bump-like enhancement of differential cross sections can only be seen at backward angles in the η photoproduction reaction.
Its strength increases as the η emission angles become more backward.
This enhancement indicates the existence of high-spin nucleon resonances that contain a large $s\bar{s}$ component.
We report the photon beam asymmetries and spin density matrix elements in a wide polar angle range for the photon beam energy above 2 GeV for the first time, providing additional constraints to nucleon resonance studies at high energies.

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Hadron-hadron interactions from femtoscopic study

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The two-particle momentum correlation function from high-energy nuclear collisions is beginning to be used to study hadron-hadron interaction. We discuss how the hadron-hadron interaction can be determined from the correlation function data. The experimental and theoretical situation of the baryon-baryon systems are reviewed focusing on the relation to the exotic hadrons. Finally, we discuss the future prospect on the femtoscopic study.

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Spectra and Decay Properties of singly beauty Baryons

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we study the radial and orbital masses of singly beauty baryons. The hypercentral Constituent Quark Model(hCQM) is employed with screened potential. The calculated mass spectra are compared with the latest results of LHCb collaboration and CMS collaboration as well as with the other theoretical approaches and are found to be in good accordance. The single-pion strong decay widths are calculated for P, S and D- wave transitions. The magnetic moments, transition magnetic moments and radiative decays are also determined.

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Proton GPDs from Lattice QCD: Fast and Accurate

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Lattice QCD computations of generalized parton distributions (GPDs) have been traditionally done in the Breit frame, where the transferred momenta is symmetrically distributed between the incoming and outgoing hadron. This set up demands a separate calculation for each momentum transfer value. This talk will outline a Lorentz covariant formalism to carry out lattice QCD computation of GPDs with non-symmetric momentum transfer between the incoming and outgoing hadron. The formalism enables GPD computations at multiple values of momentum transfer within a single calculation and eliminates frame dependent power corrections to the lattice matrix elements, leading to an accurate light-cone GPD at a reduced computational cost. The talk will also demonstrate the efficacy of the formalism through lattice QCD calculations of proton H and E GPDs.

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Bottomonia in QGP: From Excited States to Heavy Quark Interaction

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I will present recent state-of-the-art lattice QCD results on the masses, thermal widths and Bethe-Salpeter amplitudes of up to 3S and 2P bottomonium states in quark gluon plasma (QGP). I will discuss the implications of these lattice QCD results for the in-medium complex heavy quark potential, and supplement these surprising findings from independent lattice QCD calculations of the static quark potential in QGP.

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Pseudoscalar meson dominance and pion-nucleon coupling constant

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Following simple large Nc arguments and perturbative QCD constraints complemented with uncertainty estimates based on the idea of meson dominance and the half-width rule, we describe the pseudoscalar form factors of the nucleon. We analyze their implications in the space-like region at intermediate and low energies and compare to recent lattice QCD determinations. Our analysis allows for a simple determination of the pion-nucleon coupling constant at a precision level that matches the most accurate determination to date based on the analysis of the Granada nucleon-nucleon database (8000 experimental ⊠⊠ scattering data). Based on this we provide a suitable extension to the less accessible SU(3) couplings corresponding to hyperon scattering.

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Extracting nucleon electroweak properties from Lattice QCD using Chiral Perturbation Theory

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The quark mass dependence provided by Lattice QCD results encodes valuable information about hadronic properties. Chiral Perturbation Theory (ChPT) predicts both the low momentum and light quark-mass dependence of hadronic quantities in a model independent way, being therefore well suited to analyze Lattice data. Relying on our calculation of the nucleon isovector axial form factor in relativistic ChPT at next to leading one-loop order we have performed a meta-analysis of an ensemble of recent lattice determinations. We take into account the error associated with the truncation of the perturbative series in the determination of the nucleon axial charge, axial radius (a key ingredient of neutrino-nucleon cross sections) and the low-energy constants such as d16. The later drives the light-quark mass dependence of the axial charge and is a source of uncertainty in the corresponding dependence of nuclear ground state and binding energies. Furthermore, we take advantage of the available determinations of the quark-mass dependence of pion-pion scattering to study the pion mass dependence of the nucleon electromagnetic form factors using dispersion theory with ChPT input.

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Determination of the compositeness of a bound state by a and r_0. The role of the interaction range

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We present an approach that allows one to obtain information on the compositeness of molecular states from
combined information of the scattering length of the hadronic components, the effective range, and the binding
energy. We consider explicitly the range of the interaction in the formalism and show it to be extremely important
to improve on the formula of Weinberg obtained in the limit of very small binding and zero range

interaction.
The method allows obtaining good information also in cases where the binding is not small. We explicitly applyit to the case of the deuteron and the $D^*_{s0}(2317)$ and $D^*_{s1}(2460)$ states and determine simultaneously the value
of the compositeness within a certain range, as well as get qualitative information on the range of the interaction.

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Baryon anticorrelations and the Pauli principle in Pythia

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We present a computational investigation of a problem of hadron collisions from recent years, that of baryon anticorrelations. This is an experimental dearth of baryons near other baryons in phase space, not seen upon examining numerical Monte Carlo simulations.
We have addressed one of the best known Monte Carlo codes, Pythia, to see what baryon (anti)correlations it produces, where they are originated at the string-fragmentation level in the underlying Lund model, and what simple modifications could lead to better agreement with data.
We propose two ad-hoc alterations of the fragmentation code, a "one-baryon" and an "always-baryon" policies that qualitatively reproduce the data behaviour, i.e anticorrelation, and suggest that lacking Pauli-principle induced corrections at the quark level could be the culprit behind the current disagreement between computations and experiment.

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Latest results on hadronic resonance production with ALICE at the LHC

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Hadronic resonances, due to their short lifetimes, are useful to probe the properties of the hadronic phase in ultra-relativistic heavy-ion collisions. Indeed, regeneration and rescattering processes occurring in the hadron gas modify the measured yields of hadronic resonances and can be studied by measuring resonance yields as a function of system size and by comparing to model predictions with and without hadronic interactions. In addition, having different masses, quantum numbers, and quark content, they carry a wealth of information about the processes which determine the shapes of particle momentum spectra, strangeness production, parton energy loss and the possible onset of collective effects in small systems.
With its excellent tracking and particle identification capabilities, the ALICE experiment at the LHC has measured a comprehensive set of both meson and baryon resonances. We present recent results on resonance production in pp, p−Pb, Xe−Xe and Pb−Pb collisions at various centre-of-mass energies, highlighting new results on K*(892)±, Σ(1385) and Λ(1520). The obtained results are used to study the system-size and collision-energy evolution of transverse momentum spectra, yields, mean transverse momentum, yield ratios to stable hadrons, and nuclear modification factors. These results are compared to lower energy measurements and model calculations if available.

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NuMAID: reggeized isobar model for pion neutrinoproduction with unitarity

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We present a new model for electroweak pion production that is an extension of MAID, the unitarized isobar model for pion photo- and electroproduction on the nucleon. At low energy the model includes the most prominent nucleon and Δ resonances, as well as the non-resonant contributions that are unitarized in each partial wave by the respective πN-phase. At high energy we account for dominant Regge trajectory exchanges, and connect the two regimes smoothly at intermediate energy. We compare our new model to the existing ones, and discuss how it contributes the upcoming neutrino oscillation experiments.

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Rotation and vibration in tetraquarks

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Exact solutions for energy spectra and eigenstates for Tetraquarks are found by using an infinite dimensional algebraic method. The Interacting Boson Model, as proposed by Arima and Iachello [1], includes two types of bosons with angular momentum L = 0 (s bosons) and L = 2 (d bosons) in a two-level system. Exact eigen-energies and the corresponding wavefunctions of an interacting four-level pairing in a transitional region of rotation and vibration limits are obtained by using the bethe ansatz method. To analyze the vibration and rotational limits, similar to Refs. [2-4], the SU(1,1) pairing algebra is introduced. The solvable approach presented in this lecture may also be helpful in diagonalizing more general multiquark systems.

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Pentaquarks in a Bethe-Salpeter approach

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In the past two decades there has been tremendous progress in the theoretical and experimental investigation of multiquark states, which has expanded our understanding of what a "hadron"is. Experimental evidence suggests that Nature does not only form "conventional"hadrons such as mesons as quark-antiquark states and baryons as three-quark states, but also more exotic combinations such as tetraquarks and pentaquarks. We present results on pentaquark states in QCD obtained with the Bethe-Salpeter formalism in order to describe the observed LHCb states made of light and charm quarks. We solved the two-body equations for the meson-baryon system which couples the relevant channels in the equation. The interaction that binds such meson-baryon molecules is shaped by one-boson exchanges. Solving the equation allows us to determine the masses of the bound states.

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NP effects in $\Lambda_b \to \Lambda_c^{(*)}$ semileptonic decays.

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In the context of lepton flavor universality violation (LFUV) studies, we study different observables related to the $b \to c\tau\bar{\nu}_\tau$ semileptonic decays. These observables are expected to help in distinguishing between different NP scenarios. Since the τ lepton is very short-lived, we consider three subsequent τ-decay modes, two hadronic $\pi\nu_\tau$ and $\rho\nu_\tau$ and one leptonic $\mu\bar{\nu}_\mu\nu_\tau$. This way the differential decay width can be written in terms of visible (experimentally accessible) variables of the massive particle created in the τ decay. We present numerical results for the observables that can be accessed through the visible kinematics for the $\Lambda_b \to \Lambda_c$ and the $\Lambda_b \to \Lambda_c^*(2595)$ transitions. This work is based on JHEP 10 (2021) 122, JHEP 04 (2022) 026 and arXiv:2207.10529.

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Molecular Ω_{cc} , Ω_{bb} and Ω_{bc} states

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We study the interaction of meson-baryon coupled channels carrying quantum numbers of Ω_{cc} , Ω_{bb} and Ω_{bc} presently under investigation by the LHCb collaboration. The interaction is obtained from one extension of the local hidden gauge approach to the heavy quark sector that has proved to provide accurate results compared to experiment in the case of Ω_c , Ξ_c states and pentaquarks, P_c and P_{cs}. We obtain many bound states, with small decay widths within the energy range containing the chosen coupled channels. The spin-parity of the states are $J^P = \frac{1}{2}^-$ for coupled channels of pseudoscalar-baryon $(\frac{1}{2}^+)$, $J^P = \frac{3}{2}^-$ for the case of pseudoscalar-baryon $(\frac{3}{2}^+)$, $J^P = \frac{1}{2}^-, \frac{3}{2}^-$ for the case of vector-baryon $(\frac{1}{2}^+)$ and $J^P = \frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-$ for the vector-baryon $(\frac{3}{2}^+)$ channels.

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Studies of Excited Nucleon States via Exclusive KY Electroproduction

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Detailed exploration of the spectrum and structure of excited nucleon states from different exclusive reactions in terms of their electro-excitation amplitudes (or $\gamma_v pN^*$ electrocouplings) as a function of four-momentum transfer Q^2 is essential to probe the nature of the non-perturbative strong interaction responsible for their generation. Studies to determine the electrocouplings have been completed from analyses of CLAS πN, ηN, and $\pi\pi N$ data with beam energies up to 6~GeV and $Q^2 < 5$~GeV^2. This work has provided the first and only available results for most N^* states up to 1.8~GeV. Recent and ongoing analyses of these N^* electrocouplings within the continuum Schwinger method have shown a remarkable accord with data, leading to improved insights into the dynamical origins for the emergence of hadron mass. The new experiments with CLAS12 at beam energies up to 11~GeV are expanding the available data to $Q^2 \approx 12$~GeV^2. Advances in understanding the spectrum of N^* states and their structure based on these data, as well as data utilizing the KY channels that couple to higher-lying N^* states, will be discussed. The KY electroproduction data will be analyzed within advanced reaction models to extract the electrocouplings for the most prominent contributing states. The expected results from CLAS12 will allow for the exploration of strong interaction dynamics at distance scales where the transition between quark-gluon confinement and pQCD is expected, and where the dominant part of hadron mass is generated.

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The axial-vector form factor of the nucleon from two flavour Lattice QCD ensembles

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We consider the chiral Lagrangian with nucleon, isobar, and pion degrees of freedom. The baryon masses and the axial-vector form factor of the nucleon are derived at the one-loop level.
We explore the impact of using on-shell baryon masses in the loop expressions. As compared to results from conventional chiral perturbation theory we find significant differences. An application to QCD lattice data is presented. We perform a global fit to the available lattice data sets for the baryon masses and the nucleon axial-vector form factor, and determine the low-energy constants relevant at N^{3}LO for the baryon masses and at N^{2}LO for the form factor. Partial finite-volume effects are considered. We point out that the use of on-shell masses in the loops results in non-analytic behavior of the baryon masses and the form factor as function of the pion mass, which becomes prominent for larger lattice volumes than presently used.

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Study of baryons in a combination of large-N_c QCD and constituent approach

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The large-N_c and constituent approaches are two well-known tools to probe QCD at the hadronic level. In the large-N_c approach, as developed by 't Hooft and Witten, one considers hadrons in the gauge group $SU(N_c)$, with $N_c(\to \infty)$ the number of colour, and where quarks live in the fundamental representation of the group. Then, observables can be expanded in powers of $1/N_c$. In the constituent approach, one describes a baryon as a system of three valence quarks interacting by a potential modelling the exchange of virtual gluons.

Both methods give interesting and concluding results about baryons and other hadrons. It would then seem interesting to combine the two methods. However, in the large-N_c limit, a baryon becomes a state composed of N_c quarks, which implies to deal with an Hamiltonian of N_c particles.

The envelope theory (ET) is a useful approximation method with a nice property: the number of particles N is a simple parameter, which allows to easily deal with large systems. The ET, combined with large-N_c QCD, has already been able to describe baryons as in [1-4]. Recently, the ET has been generalised to systems with N identical particles plus a different one, allowing the study of new states such as baryons with heavy quarks or hybrid baryons. The latter are exotic states composed of three valence quarks and one constituent gluon.

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Nucleon Resonance Electrocouplings and the Emergence of Hadron Mass

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Understanding of the strong interaction dynamics that underlie the emergence of hadron mass (EHM) represents a challenging open problem in the Standard Model. New opportunities for gaining insight into EHM will be presented from the results on the evolution of the nucleon resonance electroexcitation amplitudes (i.e. the gvpN*electrocouplings) with photon virtuality Q2 determined from exclusive meson electroproduction data measured with the CLAS detector. A successful description of the electrocouplings of the Delta(1232)3/2+ and N(1440)1/2+ resonances of different structure has been achieved within the continuum Schwinger method (CSM) with the same momentum-dependent mass of the dressed quarks inferred from the QCD Lagrangian and used for the successful description of the nucleon and pion elastic form factors. This success has conclusively demonstrated the capability of gaining insight into EHM from the resonance electrocoupling studies. Furthermore, the CSM predictions on the electrocouplings of the Delta(1600)3/2+ resonance have been confirmed by still preliminary experimental results determined from pi+pi-p electroproduction data, solidifying evidence for insight into EHM. The CLAS12 detector in Hall B at JLab is the only available and foreseen facility in the world capable of extending information on the �vpN* electrocouplings for most prominent resonances within the almost unexplored range of Q2>5.0 GeV2. Analyses of these results within QCD-rooted approaches will shed light on the strong interaction dynamics in the range of distances where ˜50% of hadron mass is expected to be generated. Studies of the �vpN* electrocouplings at Q2>5.0 GeV2 are of particular importance for insight into the strong interaction mechanisms that underlie the generation of >98% of hadron mass in the Universe.

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CP violation tests of hyperon-antihyperon pairs at BESIII

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CP violation tests of hyperon-antihyperon pairs at BESIII
With the large datasets on ⊠+⊠−-annihilation at the ⊠/⊠ and ⊠(3686) resonances collected at the BESIII experiment, multi-dimensional analyses making use of polarization and entanglement can shed new light on the production and decay properties hyperon-antihyperon pairs. In a series of recent studies performed at BESIII, significant transverse polarization of the (anti)hyperons has been observed in ⊠/⊠ or ⊠(3686) to $\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$, and $\Omega-\bar{\Omega}+$ and the spin of $\Omega-$ has been determined model independently for the first time. The decay parameters for the most common hadronic weak decay modes were measured, and due to the non-zero polarization, the parameters of hyperon and antihyperon decays could be determined independently of each other for the first time. Comparing the hyperon and antihyperon decay parameters yields precise tests of direct, Δ⊠ = 1 CP-violation that complement studies performed in the kaon sector.

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Recent result of nucleon time-like form factors at BESIII

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The BESIII collaboration has studied the time-like form factors of the proton using the energy scan and the ISR technique. The |GE/GM| ratio is obtained with a precision comparable to the investigations of the space-like EMFF in electron proton scattering.
The effective form factor of the neutron is measured with highest precision using the scan method. For both nucleons, an intriguing periodic behavior of effective form factors lineshape is observed. In this presentation the latest results on nucleon form factors at BESIII are discussed.

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Lambda_c+ decays at BESIII

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BESIII has collected 4.5 fbˆ-1 of e+e- collision data between 4.6 and 4.7 GeV. This unique data offers ideal opportunities to study Lambda_c+ decays. We will report the observation of Lambda_c+ -> n pi+, the observation of Lambda_c+->p K- e+ nu, and the form factor measurement in Lambda_c+ -> Lambda e+ nu. Meanwhile, we will report prospect on semileptonic and hadronic decays of Lambda_c+ in the near future.

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Hyperon pair production at BESIII

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Hyperons provide an unique avenue to study the strong interaction in baryon structure.
With the unique data sets obtained by the BESIII collaboration, the pair production cross sections for Lambda, Sigma, Xi, and Lambda_c are studied from threshold, where some abnormal threshold effects are observed. Using the self-analyzing weak decays of the Lambda and Lambda_c, the relative phase between the electric and magnetic form factors is measured. In this presentation the latest results at BESIII are discussed.

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Extracting hadron-hadron interaction from lattice QCD in a small box

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In this talk, I will illustrate an alternative approach to Luscher's formula for extracting the hadron-hadron interaction from finite volume energy levels. The framework includes three ingredients, plane wave basis expansion, effective field theory (EFT) and eigenvector continuation. With the plane wave basis, we can include the partial wave mixing effect in the cubic box more naturally than the Luscher's formula. Using the EFT, the framework will benefit from the known long-range interaction (e.g. one-pion-exchange interaction) and can be used for small box simulations. The eigenvector continuation will accelerate the calculation and provide an easy-to-use interface to the lattice community.

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Theory predictions for the J-PARC E16 experiment

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The status of recent theoretical research related to the behavior of the ϕ meson in nuclear matter is reviewed, focusing on observables that will be measured at the J-PARC E16 experiment, including dilepton and K^+K^- decay modes and their angular distributions.
The relation of these observables to fundamental properties of the strong interaction and nuclear matter, such as chiral symmetry, its partial restauration in nuclear matter, in-medium Lorentz symmetry violation and the resultant modification of hadronic dispersion relations, are also discussed.

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Applications of renormalization group to few-body problems in effective field theory

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Wilsonian renormalization group with a multitude of cutoff parameters will be presented. Applications of Gell-Mann-Low and Winsonian Renormalization groups to problems of baryon-baryon scattering and halo nuclei in low-energy EFT will be considered.

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Accessing the coupled-channels dynamics using femtoscopic correlations with ALICE at LHC

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Systems such as $\mathrm{K^-p}$ and baryon–antibaryon ($\mathrm{B\overline{B}}$) are both characterized by the presence of strong inelastic channels at the production threshold, which can affect the properties and the formation of bound states and resonances.\\
In the $\mathrm{\overline{K}N}$ system, the $\Lambda(1405)$ arises from the interplay between the $\mathrm{\overline{K}N}$ and the coupled $\Sigma\pi$ channel. Experimental constraints on the different $\mathrm{\overline{K}N}$ coupled-channels are needed to provide a full description of the nature and properties of the $\Lambda(1405)$. Similarly, baryon–antibaryon systems are characterised by the dominant contribution of several mesonic channels related to the presence of annihilation processes acting below 1 fm. The possible existence of baryon–antibaryon bound states is still under debate because of the limited amount of data available for the $\mathrm{p - \overline{p}}$ system, and either scarce or absent experimental data for $\mathrm{B\overline{B}}$ systems containing strangeness.
The femtoscopy technique measures the correlation of particle pairs at low relative momentum. This method has been applied in small colliding systems, such as pp and p–Pb collisions at ALICE, and provided high-precision data on several baryon–baryon and meson–baryon pairs, showing a great sensitivity to the underlying strong potential and to the introduction of the different coupled-channels.\\
In this talk, we will present femtoscopic correlations measured by ALICE in pp collisions at $\sqrt{s} = 13$ TeV, separately for data samples obtained with minimum-bias and high-multiplicity triggers, and in peripheral and ultra–peripheral p–Pb and Pb–Pb collisions at $\sqrt{s} = 5.02$ TeV.
In particular, we will show results on the $\mathrm{K^-p}$ correlation function which for the first time provide experimental evidence of the opening of the coupled isospin breaking channel $\mathrm{\overline{K^0} - n}$ and on the $\Sigma\pi$ channel contributions. Finally, results from baryon–antibaryon pairs ($\mathrm{p\overline{p}}$, p- and -) will be shown for the first time. The effect of annihilation channels on the correlation function and a quantitative determination of the inelastic contributions in the three different pairs will be discussed.

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Threshold effects for excited Xi baryons

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While various theoretical studies have been performed for the excited $\Xi(1620)$ and $\Xi(1690)$ states, their nature was not well understood due to the lack of experimental data. Recently, the invariant

mass distribution of the $\Xi_c \to \pi\pi\Xi$ decay was observed by the Belle collaboration. [1]
By fitting the invariant mass spectrum with the Breit-Wigner distribution, the mass and decay width of the $\Xi(1620)$ were obtained as $M_R = 1610$ MeV and $\Gamma_R = 30$ MeV, respectively. This result provides precise spectra of the $\Xi(1620)$ and $\Xi(1690)$ resonances, and therefore it is desired to perform detailed theoretical analysis.
In this talk, we study the excited Ξ states as dynamically generated resonances in the meson-baryon scattering amplitude using the the chiral unitary approach. In the previous study [2], the mass and width of the $\Xi(1620)$ were predicted to be $M_R = 1607$ MeV and $\Gamma_R = 280$ MeV, with the natural values of the subtraction constants.
Because of the difference between the results of Ref. [2] and those by Belle, it is required to improve the model of $\Xi(1620)$. By adjusting the subtraction constants of $\pi\Xi$ and $\bar{K}\Lambda$ channels, we successfully reproduce the mass and width of $\Xi(1620)$ by Belle. We, however, find that the threshold effect shifts the resonance peak near the threshold, by comparing the coupled channels meson-baryon scattering amplitude with the Breit-Wigner distribution. We conclude that the cation must be paid to determine the resonance pole near the threshold.
While there is one threshold $\bar{K}^0\Lambda$ near the $\Xi(1620)$, there are two thresholds $\bar{K}^0\Sigma^0$ and $K^-\Sigma^+$ near the $\Xi(1690)$ due to the isospin symmetry breaking.
Here, we analyze the $\Xi(1690)$ using the model in Ref. [3], which is based on the Belle data of the Λ_c decay, and includes the isospin symmetry breaking effect. Then, we show that the $\Xi(1690)$ spectrum is affected by two thresholds $\bar{K}^0\Sigma^0$ and $K^-\Sigma^+$ due to the isospin symmetry breaking.
In future, studying the invariant mass distribution of the $\Xi_c \to \pi\pi\Xi$ decay in comparison with the Belle data, we aim at the determination of the spin and parity of the Ξ resonances.

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TMDs in dijet production in SIDIS

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We discuss the measurement of gluon transverse momentum distribution (TMD) in dijet and heavy hadron pair (HHP) production in semi-inclusive deep inelastic scattering. The factorization of these processes in position space shows the appearance of a specific new soft factor matrix element on top of angular and complex valued anomalous dimensions. We show in detail how these features can be treated consistently and we discuss a scale prescription for the evolution kernel of the dijet soft function. As a result we obtain phenomenological predictions for unpolarized and angular modulated cross-sections for the electron-ion collider (EIC) using current available information on unpolarized TMD.

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Explicit renormalization of nuclear chiral EFT and non-perturbative effects

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Nucleon-nucleon interaction is studied within chiral effective field theory at next-to-leading order in the chiral expansion.
The leading order interaction is resummed non-perturbatively,
whereas the next-to-leading-order terms are taken into account in a perturbative manner.
Explicit renormalizability of such a scheme is analyzed in several important cases. The possibility to absorb the power-counting
breaking terms originating from the integration regions with large momenta is studied for both perturbative and non-perturbative regimes.
A comparison of the schemes with a finite and an infinite
cutoff is performed.

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Consistency of the molecular picture of $\Omega(2012)$ with the latest Belle results

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We study the $\Omega(2012)$ which was measured in the Belle experiment. We conduct a study of the interaction of the $\bar{K}\Xi^*$, $\eta\Omega$(s-wave) and $\bar{K}\Xi$(d-wave) channels within a coupled channel unitary approach. We also present a mechanism for $\Omega_c \to \pi^+\Omega(2012)$ production through an external emission Cabibbo favored weak decay mode, where the $\Omega(2012)$ is dynamically generated from the above interaction. The picture has as a consequence that one can evaluate the direct decay $\Omega_c^0 \to \pi^+K^-\Xi^0$ and the decay $\Omega_c^0 \to \pi^+\bar{K}\Xi^*$, $\pi^+\eta\Omega$ with direct coupling of $\bar{K}\Xi^*$ and $\eta\Omega$ to $K^-\Xi^0$. We find that all data including the Belle experiment on $\Gamma_{\Omega^*\to\pi\bar{K}\Xi}/\Gamma_{\Omega^*\to\bar{K}\Xi}$, are compatible with the molecular picture stemming from meson baryon interaction of these channels. I will give a presentation based on Refs. [1]-[3].

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On the recent states Zcs(3985) and X(3960)

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In this talk we will discuss our recent works (2201.08253 and 2207.08563) in which we make analyses of several X and Z states. In the first part of the talk, we present a combined study of the BESIII spectra in which the Zc(3900) and Zcs(3985) states are seen, assuming that both are SU(3) partners. In the second part, a step further is taken and we analyze the full heavy quark spin and light flavor multiplets arising by considering as inputs the X(3872), Zc(3900), and the X(3960) recently claimed by LHCb in the D+s D-s spectrum.

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Information entropy in fragmentation functions and their relation to pdfs

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The flow of information in high-energy collisions has been recently investigated by various groups. Entanglement entropy of the proton becoming classical information entropy of pdfs, jet splitting affecting entropy, or the entropy in hadron decays have already been reported in the literature. Here we examine aspects of fragmentation functions in this context, including their entropy as probability distributions and the relation of Barone, Drago and Ma between FFs and pdfs.

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The study of P-wave strange mesons in coupled channel framework

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In this talk, I will discuss a novel framework to extract resonant states from finite-volume energy levels of lattice QCD and apply it to elucidate structures of the positive parity Ds resonant states nearby the DK and D*K thresholds. In the framework, the Hamiltonian effective field theory is extended by combining it with the quark model. The Hamiltonian contains the bare mesons from the quark model, its coupling with the threshold channels described by quark-pair-creation (QPC) model, and the channel-channel interactions induced by exchanging light mesons. A successful fit of the finite-volume energy levels of lattice QCD with the Hamiltonian model is made. The extracted masses and the predication for an additional state, Ds(2573), are well consistent with experimental measurements. The same framework has also be extended to the P-wave B_s states.

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Nature of Tcc with effective field theory

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The exotic hadrons have a different internal structure from the ordinary hadrons with qqq or $q\bar{q}$. T_{cc}, observed by the LHCb Collaboration last year, is considered as the exotic state with $cc\bar{u}\bar{d}$ [1]. One of the possible internal structures of the exotic hadron is the hadronic molecule state which is a weakly bound state of hadrons. The weight of the hadronic molecule component in a hadron wavefunction is quantitatively expressed as the compositeness [2]. We discuss the internal structure of T_{cc} by calculating the compositeness with the effective field theory.

We construct a model to reproduce the mass of T_{cc} with the scattering of D^0D^{*+} coupled with the compact four-quark state. The model parameters are the cutoff Λ, coupling constant g_0 and energy of the compact four-quark state ν_0 measured from the threshold of the D^0D^{*+} scattering. We employ $\Lambda = 0.14$ [GeV] based on the pion exchange interaction. The relation between g_0 and ν_0 is obtained from the bound-state condition with the binding energy $B = 0.36$ [MeV] of T_{cc}. We vary ν_0 in the region $-B \leq \nu_0 \leq \Lambda^2/(2\mu)$ which is the allowed region in this model. We show that T_{cc} is hadronic molecule dominant for almost all region of ν_0 even without D^0D^{*+} direct interactions.

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Radial excitation of Ω_{cc} baryon using relativistic formalism

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The doubly heavy Ω_{cc} baryon represents a distinctive three quark system because they contain a strange light quark in the combination of two charm quarks. There are new decay modes and excited states seen in doubly charmed baryons by CLEO, LHCb and many other experiments and they have attempted to identify the doubly heavy baryons, but only a few states have been discovered so far. Here, The mass spectra of radially excited states of doubly heavy baryons are calculated under a mean field confinement of Martin-like potential with a parametric centre of weight mass correction in an independent quark model with Dirac relativistic formalism. We have predicted the ground state masses as well as radial excitation of Ω_{cc} baryon using the optimized fitted potential parameters which are found to be in good agreement with other theoretical predicted data. For predicting $(\frac{3}{2}^+)$ and $(\frac{1}{2}^+)$ states, we have incorporated the $j-j$ coupling in this study.

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S-Wave spectroscopy of Ω_c^0 baryon in a relativistic Dirac formalism using the independent Quark model.

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Ω_c^0 baryon is the center of attraction for many researchers after the discovery of different states all together in the single decay $\Omega_c^0 \rightarrow \Xi_c^+ K^-$. These states are $\Omega_c^0(2695)$, $\Omega_c^0(2770)$, $\Omega_c^0(3000)$, $\Omega_c^0(3050)$, $\Omega_c^0(3067)$, $\Omega_c^0(3090)$ & $\Omega_c^0(3120)$. Thus, we investigate the S-wave of $\Omega_c^0(ssc)$ in the relativistic Dirac formalism. The spectroscopy is performed using the independent quark model in which the spin-average masses are obtained by summing the individual Dirac energy of the constituent quarks under the mean field confinement of Martin-like potential with a parametric center of mass correction. We find the spin-average masses of low-lying S-wave. the spin degeneracy is removed by considering the spin-spin($j \cdot j$) interaction. The best-fitted potential parameters yielded the estimation of the ground state masses in very good agreement with experimental data. The computed masses of $1S(\frac{3}{2}^+)$, $2768.84\ MeV$ and $1S(\frac{1}{2}^+)$, $2698.14\ MeV$ are very close to the experimentally observed states $\Omega_c^0(2770)$ and $\Omega_c^0(2695)$ respectively. We also predict the experimentally observed state $\Omega_c^0(3120)$ is 3119 MeV as 2S($\frac{3}{2}^+$) state and the 2S($\frac{1}{2}^+$) at 3047 MeV which is identified here as $\Omega_c^0(3050)$. Higher S state doublets are also predicted which will be useful for the identification of future experimental data. Other states may be related to the orbital excited states and will be estimated by incorporating the spin-orbit and tensor interactions among the confined quarks.

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Hamiltonian effective field theory with the nucleon excitations and kaonic atoms

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We have studied the low-lying nucleon resonances N(1530), N(1440), and Lambda(1405) and the relevant interactions with Hamiltonian effective field theory. Combined with the meson-nucleon scattering data and the lattice QCD simulations, and even the S11 pion photoproduction data, we obtain different structures of these resonances. Furthermore, we investigate the kaonic hydrogen and deuteron with the same framework and notice the life of kaonic deuteron would become much short by considering the recoil effect of nucleon in deuteron, which may result from the existence of Lambda(1405) near threshold.

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Antikaon-nucleon interactions and the momentum correlation functions in high-energy collisions

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The strong interaction between an antikaon and a nucleon is at the origin of various interesting phenomena in kaon-nuclear systems [1]. In particular, the interaction in the isospin $I = 0$ channel is sufficiently attractive to generate a quasi-bound state, the $\Lambda(1405)$ resonance, below the $\bar{K}N$ threshold. Based on this picture, it may be expected that the $\bar{K}N$ interaction also generates quasi-bound states in kaon-nuclear systems, sometimes called kaonic nuclei. At the same time, the $\bar{K}N$ quasi-bound picture of the $\Lambda(1405)$ is also related to the discussion of hadronic molecules in hadron spectroscopy.

Femtoscopic study of the two-particle momentum correlation functions in high-energy collisions has become a new method to extract the hadron-hadron interactions. We study the two-particle correlation function of a K^-p pair from high-energy collisions in the $\bar{K}N$-$\pi\Sigma$-$\pi\Lambda$ coupled-channels framework [2]. The effects of all coupled channels together with the Coulomb potential and the threshold energy difference between K^-p and $\bar{K}^0n$ are treated completely. Realistic potentials based on the chiral SU(3) dynamics are used which fit the available scattering data [3]. We discuss the resulting K^-p correlation functions in comparison with the recent measurements by the ALICE collaboration with various collision conditions [4].

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Meson structures at EicC

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The status and the project of a low-energy Chinese electron-ion collider (EicC) is briefly introduced. Measurements of pseudoscalar meson structures are important for the fully understanding of the emergent hadron mass problem. The leading baryon tagged DIS process and the Sullivan process are the useful tools to obtain the form factor and structure function information of the pion (and the kaon). The simulation results of the pion (and the kaon) structure experiments at the future EicC are presented.

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Heavy-light exotics: old laces and new pieces

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I will compare, in a pedagogical way, the traditional approach to heavy-lighty hadrons based on effective models of QCD,
to recent developments for heavy-light hadrons based on string theory. In particular, I will present

predictions for the properties of recently discovered heavy-light tetraquarks and pentaquarks, based on the series of works [1-6].

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Radiative corrections to neutron beta decay from low-energy effective field theory

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We study radiative corrections to neutron beta decay within heavy-baryon chiral perturbation theory. As it was recently shown, a few electromagnetic and electroweak low-energy effective couplings are not known in the literature. We relate these low-energy constants to correlation functions of vector and axial-vector currents. Such relations allow us to demonstrate explicitly scheme and scale dependence of standard treatments of radiative corrections and to provide more robust prediction of leading in the electromagnetic coupling constant corrections.

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Structure of X(3872) with hadronic potentials coupled to quarks

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The inter-quark potentials diverge at large distance because of the color confinement of quarks. The inter-hadron potentials, on the other hand, vanish at large distance, because the interaction range is limited by the inverse pion mass.
What then is the effect of the coupling to the inter-hadron potentials in the inter-quark potentials and vice versa?

We consider, in this talk, the channel coupling between the inter-quark and inter-hadron potentials. We then derive the effective potential of hadrons by eliminating the quark channel in the Feshbach method [1]. In the case of the Yukawa type transition potential, we obtain the effective potential of hadrons,
\begin{align}
V(\mathbf{r},\mathbf{r'},E)
&= \frac{g_0^2}{E-E_0}\frac{e^{-\mu r}}{r}\frac{e^{-\mu r'}}{r'}, \tag{1}

\end{align}
where g_0 is the coupling constant of the channel transition between quarks and hadrons, E_0 is the energy of the bound state of the quark degrees of freedom.
We show that the effective potential has non-locality and depends on the energy E.

There are two methods of converting non-local potentials into local ones. A formal derivative expansion decomposes directly a non-local potential in terms of the derivatives of the local potential. In the HAL QCD method, one derives the local potential from the wave function $\psi_k(r)$ at a momentum $k = \sqrt{2mE}$ which is obtained by the non-local potential.
In the case of potential (1), we obtain at leading order,
\begin{align}
V_0^{\rm{{formal}}}(r,{E}) &= \frac{4\pi g_0^2}{\mu^2(E-E_0)}\frac{e^{-\mu r}}{r}, \\
V_0^{{\rm{HAL}}}(r,E) &= \frac{1}{2mr\psi_{{k}}(r)}\frac{d^2}{dr^2}\left[r\psi_{{k}}(r)\right] .
\end{align}

Finally, we take $c\bar{c}$ as the quark channel and $D\bar{D}^*$ as the hadron channel to apply this study to $X(3872)$.
We construct the effective local $D\bar{D}^*$ potentials which reproduce the observed mass of $X(3872)$.
By analyzing properties of these local potentials, we discuss the structure of $X(3872)$.

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Nucleon-nucleon interaction in manifestly Lorentz-invariant chiral effective field theory

Authors: Xiu-lei Ren[1]; Evgeny Epelbaum[2]; Jambul Gegelia[3]; Vadim Baru[4]

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We propose a systematic approach to study the nucleon-nucleon interaction by applying time-ordered perturbation theory (TOPT) to covariant chiral effective field theory. Diagrammatic rules of TOPT, for the first time, are worked out for particles with non-zero spin and interactions involving time derivatives. They can be applied to derive chiral potentials at any chiral order. The effective potential, as a sum of two-nucleon irreducible time-ordered diagrams, and the scattering equation (Kadyshevsky equation) are obtained within the same framework. According to the Weinberg power counting, at leading order, we find that NN potential is perturbatively renormalizable, and the corresponding integral equation has unique solutions in all partial waves. Through evaluating the two-pion exchange contribution at the one-loop level, we formulate the NN interaction up to NNLO. A good description of phase shifts and the deuteron properties is achieved by treating the full NNLO potential non-perturbatively.

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Pole determination of $P_{\psi s}^{\Lambda}(4338)$ and possible $P_{\psi s}^{\Lambda}(4254)$ in $B^- \to J/\psi\Lambda\bar{p}$

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First hidden-charm pentaquark candidate with strangeness, $P_{\psi s}^{\Lambda}(4338)$, was recently discovered in $B^- \to J/\psi\Lambda\bar{p}$ by the LHCb Collaboration. $P_{\psi s}^{\Lambda}(4338)$ shows up as a bump at the $\Xi_c\bar{D}$ threshold in the $J/\psi\Lambda$ invariant mass ($M_{J/\psi\Lambda}$) distribution. The $M_{J/\psi\Lambda}$ distribution also shows a large fluctuation at the $\Lambda_c\bar{D}_s$ threshold, hinting the existence of a possible $P_{\psi s}^{\Lambda}(4254)$. In this work, we determine the $P_{\psi s}^{\Lambda}(4338)$ and $P_{\psi s}^{\Lambda}(4254)$ pole positions for the first time. For this purpose, we fit a $B^- \to J/\psi\Lambda\bar{p}$ model to the $M_{J/\psi\Lambda}$, $M_{J/\psi\bar{p}}$, $M_{\Lambda\bar{p}}$, and $\cos\theta_{K^*}$ distributions from the LHCb simultaneously; $\chi^2/\mathrm{ndf} \sim 1.29$. Then we extract $P_{\psi s}^{\Lambda}$ poles from a unitary $\Xi_c\bar{D}$-$\Lambda_c\bar{D}_s$ coupled-channel scattering amplitude built in the model. The $P_{\psi s}^{\Lambda}(4338)$ pole is found at $(4339.2\pm1.6)-(0.9\pm0.4)\,i\tilde{}$MeV while the $P_{\psi s}^{\Lambda}(4254)$ pole at $4254.4\pm0.9\tilde{}$MeV. Without the coupled-channels, $P_{\psi s}^{\Lambda}(4338)$ is a bound $\Xi_c^+ D^-$-virtual $\Xi_0^+\bar{D}^0$ state while $P_{\psi s}^{\Lambda}(4254)$ is a $\Lambda_c\bar{D}_s$ virtual state. The data disfavors a hypothesis of $P_{\psi s}^{\Lambda}(4338)$ as merely a kinematical effect. This pole determination, which is important in its own right, sets a primary basis to study the nature of the $P_{\psi s}^{\Lambda}$ states.

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Dielectron measurements with the HADES at GSI

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The High Acceptance DiElectron Spectrometer (HADES) is a versatile detector with particular focus on dielectron measurements in pion, proton, deuteron and (heavy-) ion-induced reactions using proton or nuclei targets and SIS-18 beams with energies of up to 4.5 GeV/nucleon. Its excellent particle identification capabilities also allow for the investigation of hadronic observables.
The excess of dileptons above the contributions from initial state processes and late meson decays serve as messengers of the dense medium created in heavy-ion collisions and reveal the thermal properties and the lifetime of the medium but also give insight into meson properties at high densities.
In this contribution dielectron measurements with the HADES in various heavy-ion collision systems, $Ar + KCl$, $Au + Au$, $Ag + Ag$, are presented. The recently upgraded detector combines a high electron detection efficiency, impressive pion suppression and high-level conversion recognition allowing to study dielectron production with unprecedented precision, also as a function of centrality and pair-momentum with a signal up to the ϕ meson mass region. The obtained dilepton spectra show strong excess radiation and suggest a substantial modification of the mesons.
Information on the ρ-meson in cold nuclear matter has also been obtained in $p + Nb$ reactions at $3.5\,GeV$. The dilepton production rates in $p + p$ reactions at the same kinetic beam energy serve as reference for the study of vector meson production in p+Nb reactions. This program is continuing and a first glimpse on new results from the recent p+p beamtime at $E_{beam} = 4.5\,GeV$ will also be discussed.

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Optimization of distillation profiles for charmonium spectroscopy in lattice QCD

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An improvement to the widely used distillation technique for hadron spectroscopy is presented in the context of meson spectroscopy. Introducing meson profiles in distillation space and optimizing them for the different operators and states of interest significantly increases the overlap between the created states and the energy eigenstates at no considerable extra cost. We show results including the effects of the disconnected diagrams, which lead to mass shifts and mixing with glueballs.

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Baryon masses estimate in heavy flavor QCD

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We apply the renormalization group procedure for effective particles (RGPEP) to the eigenvalue problem in QCD for only heavy quarks. We derive the effective Hamiltonian that acts on the Fock space by solving the RGPEP equation up to second order in powers of the coupling constant. The eigenstates that contain three quarks and two or more gluons are eliminated by inserting a gluon-mass term in the component with one gluon.
We estimate masses for bbb and ccc states and find that the results match estimates obtained in lattice QCD and in quark models.
Masses of ccb and bbc states are also estimated and discussed.

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Experimental study of in-medium spectral change of vector mesons in nuclear medium at J-PARC

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Spontaneous breaking of the chiral symmetry plays a major role in generation of the hadron mass. It is predicted that the broken symmetry is partially restored even at normal nuclear density, and results in a measurerable difference in hadron mass.
J-PARC E16 has been proposed to measure such a change of vector mesons in nuclear medium at J-PARC Hadron Experimental Facility. It will measure dilelectron decay of ρ, ω and ϕ in 30 GeV pA reactions.
We've executed three comissoining runs in 2020 and 2021, and we are preparing for one planned in 2023 with upgraded accelerator and detectors. The first physics run is anticipated in 2024.

In this talk we present the achievement and findings of the commissioning runs and prospects of the experiment.

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Experimental access to the three-body forces between hadrons with ALICE.

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Measurements of correlations between particle pairs with low relative momentum via femtoscopy in pp collisions have been recently demonstrated to be very sensitive to the effects of the final-state strong interaction. Such studies face now a new challenge with the extension for the first time to three-body systems. The presented results are obtained using high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV recorded by ALICE at the LHC.

The first measurement of the genuine three-body effects obtained from p–p–p, p–p–Λ, p–p–K^+ and p–p–K^- correlation functions are obtained by utilising the formalism of the three-particle cumulants. Such measurements provide information on the genuine three-particle interaction and constitute important inputs for the calculation of the equation of state of neutron stars and the formation of kaonic nuclei.

In the studies of the strong interaction among hadrons, ALICE has flared out its femtoscopic studies to nuclei with the measurement of the proton-deuteron correlation function. The data that cannot be reproduced by simple two-body calculations considering p-d scattering parameters, and the necessity of using full three-body calculations is demonstrated. The obtained results bring also valuable information on the mechanism of formation of light nuclei in hadron-hadron collisions.

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Study of static properties of Δ Baryon resonances in the relativistic potential model formalism

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A relativistic model of independent quarks based on Dirac equation with an equally mixed scalar-vector square root confining potential is used to compute the quark core contributions to study the static properties like magnetic moments and charge radii of the Δ baryons with spin $\frac{1}{2}$ and spin $\frac{3}{2}$. The results obtained with inclusion of appropriate centre-of-mass motion corrections agree well with experimental values. The model is also extended to the study of magnetic moments of the quark core of baryons in the charmed and b-flavoured sectors and the overall predictions so obtained compare well with other model predictions. The outcomes from this study is expected to inspire for progresses and further unravelling other light baryons additionally to experimental facilities PANDA-GSI.

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Approaching Near-threshold Resonances by Analytic Maps of the S-matrix: Uniformization, and Mittag-Leffler Expansion of 2 and 3-channeled Systems

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Excited states, which show up as resonances embedded in the continuum spectrum and their structure, are primary issues in the study of hadron physics. In particular, many candidates of exotic hadrons have recently been found near the threshold of hadronic channels [1, 2]. Extraction of such resonance information is an essential and challenging task. However, many of the existing analyses of the spectra assume a Breit-Wigner form [3] to a peak structure situated near the thresholds, which cannot appropriately incorporate the threshold behaviors.

We focus on the analytic structure of the multi-channel S-matrix by the introduction of uniformization[4, 5]. As a function of center-of-mass energy, the S-matrix has branch points at the corresponding channel thresholds, and thus its Riemanan Surface has a multi-sheeted structure [5]. This non-trivial structure in the vicinities of the thresholds makes it particularly challenging to extract resonance information of near-threshold resonances. The key idea of uniformization is to find a kinematic variable such that the S-matrix can be expressed single-valued. Under the uniformized-variable parameterization, the Mittag-Leffler theorem is applicable so that the S-matrix can be expressed by a simple pole expansion which we call the Uniformized Mittag-Leffler Expansion. The expansion exhibits the appropriate threshold behaviors of the multi-channel spectrum and is model-independent, simple, and suited for the extraction of the pole properties. In addition, the uniformized-variable parameterization explicitly clarifies the contribution of a pole situated on an arbitrary sheet to the observed spectrum. For the single-channel S- matrix, the center-of-mass momentum can serve as the uniformization variable (assuming the absence of left-handed cuts). Its Mittag-Leffler Expansion has already been studied in Ref. [6, 7]. Naturally, an extension of the Uniformized Mittag-Leffler program to the two-channel and three-channel S-matrix is a pivotal step forward for the analysis of multi-channel scattering.

In this presentation, we extend the Uniformized Mittag-Leffler Expansion to the two-channel case by the use of the uniformization variable introduced in Ref.[5, 8], and study the pole properties of Λ(1405) in a model-independent manner considering the $\pi\Sigma$, $\bar{K}N$ channels[9, 10]. Moreover, we report our two-channel analyses concerning Z_c(3900)[11] and point out that the lattice QCD results in Ref.[12] indicate the existence of an unusual S-matrix pole with a positive imaginary part in complex energy near the $\bar{D}D^*$ threshold, which is most likely the origin of the 'enhanced cusp'found in the near-threshold spectrum. Then, we investigate the analytic structure of the three-channel S-matrix in detail and illustrate that the three-channel S-matrix is topologically equivalent to a torus [5, 13], unlike the two-channel S-matrix which is equivalent to a Riemann Sphere. We show that an explicit form of the three-channel uniformization variable can be given by the inverse of the Jacobi elliptic function. Also, we show that the double-periodicity of the torus plays a vital role in the contributions of the S-matrix poles. This results in an explicit form of the Uniformized Mittag-Leffler expansion of the three-channel S-matrix, which is given by a series of Weierstrass zeta functions (Details regarding the formalism of the three-channel uniformization and the Mittag-Leffler expansion are shown in Ref. [14]). In addition to a demonstration with a simple non-relativistic effective field theory model with contact interaction for the $S=-2, I=0, J^P=0^+$, $\Lambda\Lambda$-$N\Xi$-$\Sigma\Sigma$, analyses with the three-channel Uniformized Mittag-Leffler expansion applied to the invariant-mass distributions of $\pi_L^+\Xi^-$ in the $\Xi_c^+ \to \pi^+\pi^+\Xi^-$ decay measured with the Belle detector[15], and pJ/ψ from the $\Lambda_b^0 \to K^-pJ/\psi$ decay measured by the LHCb collaboration [16] are presented.

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Latest results from Kaon experiments at CERN

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The NA62 experiment at CERN collected the world's largest dataset of charged kaon decays in 2016-2018, leading to the first measurement of the branching ratio of the ultra-rare K+ –> pi+ nu nu decay, based on 20 candidates.
The radiative kaon decay K+ ⟶ pi0e+vg (Ke3g) was studied with a data sample of O(100k) Ke3g candidates with sub-percent background contaminations recorded in 2017-2018. The most precise measurements of the branching ratio and of T-asymmetry are achieved.
An analysis of the flavour-changing neutral current K+ -> pi+ mu+ mu- decay, based on about 27k signal events with negligible background contamination collected in 2017 and 2018 with a dedicated pre-scaled di-muon trigger, leads to the most precise determination of the branching ratio and of the form factor.
New preliminary results are obtained from an analysis of the K+ -> pi+ gamma gamma decay using data collected in 2016—2018 with a minimum-bias trigger. The sample, about 15 times larger than the previous largest one, leads to an unprecedented sensitivity. This analysis can be naturally extended to search for the K+ -> pi+ a, a -> gamma gamma process, where a is a short-lived axion-like particle.
Dedicated trigger lines were employed to collect dilepton final states, which allowed establishing new stringent upper limits on the rates lepton flavor and lepton number violating kaon decays.
NA62 can also be run as a beam-dump experiment, by removing the Kaon production target and moving the upstream collimators into a "closed" position. Analyses of the data taken in beam-dump

mode were performed to search for visible decays of exotic mediators, with a particular emphasis on Dark Photon Models.
An overview of the latest NA62 results and the future prospect of the experiment are presented.
The first observation of the decay $K\pm \longrightarrow \pi 0\ \pi 0\ \mu\pm\ \nu$ (K00μ4) by the NA48/2 experiment at the CERN and the preliminary measurement of the branching ratio are also presented. The result is converted into a first measurement of the R form factor in Kl4 decays and compared with the prediction from 1-loop Chiral Perturbation Theory.

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Emergence of mass in the gauge sector of QCD

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It is widely accepted nowadays that gluons, while massless at the level of the fundamental QCD Lagrangian, acquire an effective mass through the non-Abelian implementation of the classic Schwinger mechanism. The key dynamical ingredient that triggers the onset of this mechanism is the formation of composite massless poles inside the fundamental vertices of the theory. These poles enter in the evolution equation of the gluon propagator, and affect nontrivially the way the Slavnov-Taylor identities of the vertices are resolved, inducing a smoking-gun displacement in the corresponding Ward identities. In this talk I will present a comprehensive review of the pivotal concepts associated with this dynamical scenario, emphasizing the synergy between functional methods and lattice simulations, and highlighting recent advances that corroborate the action of the Schwinger mechanism in QCD.

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Multiquark states

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Exotic spectroscopy is a hot topic. In this review talk, the last main experimental discoveries will be presented and then the main theoretical interpretations will be discussed.
Finally, some results of which I am also one of the authors will be presented and discussed.

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Baryon spectroscopy and properties: Measurement of polarization observables in photoproduction of mesons on nuclei

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During the last decades, numerous experiments were performed with the aim of understanding meson photoproduction on light and heavy nuclei. Meson production on light nuclei, such as the deuteron or helium isotopes, allows one to access the baryon resonances produced on the nucleon.

Photoproduction on heavier targets is well-suited for the understanding of possible modifications of hadrons, including baryon resonances, in the nuclear medium. In this talk, the recent results on polarization observables (measured with linearly or circularly polarized photons) in meson photoproduction on various nuclear targets will be discussed.

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Femtoscopy of the Origin of the Nucleon Mass

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I will address the prospects of using femtoscopy in high-energy proton-proton and heavy-ion collisions to learn about the low-energy J/ψ-nucleon interaction. This interaction is relevant to the problem of the origin of nucleon's mass. Femtoscopy is a technique that makes it possible to obtain spatio-temporal information on particle production sources at the femtometer scale through measurements of two-hadron momentum correlation functions. These correlation functions also provide information on low-energy hadron-hadron forces as final-state effects. In particular, such correlation functions give access to the forward scattering amplitude. One can express the forward amplitude as the product of the J/ψ chromopolarizability and the nucleon's average chromoelectric gluon distribution; the latter accounts for most of the nucleon's mass. I will present the results of a recent study using the information on the J/ψ-nucleon interaction from lattice QCD simulations to compute J/ψ-nucleon correlation functions. The calculated correlation functions show evident sensitivity to the final-state interaction.

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Hidden-charm pentaquarks in the molecular picture: effective field theory and phenomenological considerations

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During the last few years the LHCb collaboration has detected a series of hidden-charm pentaquarks, the most recent one being the $P_{\psi s}^{\Lambda}(4338)$, which has the quantum numbers of a Λ baryon. Most of these pentaquarks are close to a meson-baryon threshold and have been readily interpreted as bound (or molecular) states. Here we explore what are the consequences of the molecular hypothesis, particularly when constrained by heavy-quark spin symmetry [1,2,3,4]. We argue, for instance, that if the $P_{\psi s}^{\Lambda}(4338)$ is to be interpreted as a $\bar{D}\Xi_c$ bound state, this will imply the existence of a $\bar{D}_s\Lambda_c$ partner state with a mass close to 4250 MeV [5]. Finally, we confront predictions coming from effective field theory with phenomenological models, to find what are the converging points between these two approaches.

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GTMDs and the factorization of exclusive double Drell-Yan

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In this talk we will give a short overview of multi-dimensional parton distributions (TMDs, GT-MDs…) and Soft Collinear Effective Theory (SCET). This will be used to explain the factorization process of the cross-section of an exclusive Double Drell-Yan and to show how this leads to the appearance of GTMDs.

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Semileptonic decays of heavy+light and heavy+heavy mesons

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Dyson-Schwinger equations (DSEs) is employed successfully to provide a unified explanation for the properties of hadrons with $0-3$ heavy quarks, viz. from the lightest (almost) Nambu-Goldstone bosons to triply heavy baryons, e.g.. Each semileptonic transition is conventionally characterized by the value of the dominant form factor and we present predictions for transition form factors and decay widths for heavy+light mesons, including $B_{(s)} \to \pi(K)$,$D_s \to K$; $D \to \pi, K$ and $B_c \to \eta_c, J/\Psi$. The form factors are a leading source of uncertainty in all such calculations: our results agree quantitatively with available data and provide benchmarks for the hitherto unmeasured $D_s \to K^0, \bar{B}_s \to K^+$form factors. The analysis delivers a value of $|V_{cs}| = 0.974(10)$ and also predictions for all branching fraction ratios in the pseudoscalar meson sector that can be used to test lepton flavour universality. Quantitative comparisons are provided between extant theory and the recent measurement of $\mathcal{B}_{B_s^0 \to K^- \mu^+ v_\mu}$. Here, further, refined measurements would be useful in moving toward a more accurate value of $|V_{ub}|$.

Working with branching fractions calculated from $B_c \to \eta_c, J/\Psi$, the following values of the ratios for τ over μ final states are obtained:

$R_{\eta_c} = 0.313(22)$ and $R_{J/\psi} = 0.242(47)$.

Combined with other recent results, our analysis confirms a 2σ discrepancy between the Standard Model prediction for $R_{J/\psi}$ and the single available experimental result.

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Going to the light-front 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), 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 and yield, for instance, the hadron's Bethe-Salpeter wave functions. The main problem is then to project these Bethe-Salpeter wave functions onto the light front.

We present a new method to compute the light-front wave functions using contour deformations, which we illustrate for a simple system of two interacting scalar particles of equal mass. After solving the two-body Bethe-Salpeter equation, the projection onto the light front is done through a combination of contour deformations and analytic continuation methods, and shown to be in agreement with the commonly used Nakanishi method. After showing that the contour deformation method can be used for particles of unequal masses and complex conjugate propagator poles, we explore the extension of this method to the calculation of more general parton distributions, such as transverse momentum distributions (TMDs) and generalized parton distributions (GPDs), from the projection of the hadron-hadron correlator, built from elementary n-point functions, such as the quark propagator and 4-point function.

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Nucleon self-energy including two-loop contributions

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The nucleon self-energy is calculated in SU(2) covariant chiral perturbation theory to study the pion mass dependence of the nucleon mass up to chiral order $O(q^6)$, i.e., including two-loop diagrams.
The contributions of the diagrams are expressed by a small set of (scalar) master integrals, which are evaluated by means of the chiral expansion in d dimensions, using the strategy of regions to differentiate between the infrared singular and regular part.
The extended on-mass-shell renormalization scheme is applied, making the renormalized expressions consistent with the power counting.
In addition, the renormalization is discussed in the off-shell case, taking the nucleon mass in the chiral limit as renormalized nucleon mass.
For the final result not to rely on the chiral ($1/m$) expansion, the master integrals are computed numerically.

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Baryon structure from a light-front Hamiltonian approach

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We solve the structure of baryons in a nonperturbative approach in the framework of light-front Hamiltonian, named Basis Light-front Quantization (BLFQ). We apply BLFQ to study the structure of

the nucleon and the heavy baryons containing one strange or charm quark. I will show the resulting observables such as the form factors and various parton distribution functions characterizing the three dimensional structure of the baryons. Finally I will report the preliminary results on the gluon distribution in the nucleon and its contribution to the nucleon spin.

98

Quarkonium production to probe TMDs

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I will discuss how quarkonium production can be used to probe transverse-momentum-dependent functions (TMDs), both in pp and ep, paying spacial attention to the role played by a new type of non-perturbative functions, the so-called TMD shape functions.

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Deuteron VVCS and two-photon exchange effects in (muonic) deuterium in pionless EFT

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We report on our studies of the forward virtual Compton scattering (VVCS) off a deuteron and the two-photon-exchange corrections to the S-levels in muonic (μD) and ordinary (D) deuterium within the pionless effective field theory (EFT). The spin-independent deuteron VVCS amplitudes are evaluated up to next-to-next-to-next-to-leading order (N3LO) for the longitudinal and next-to-leading order (NLO) for the transverse amplitude. The only unknown low-energy constant enters at N3LO in the former, and describes the coupling of a longitudinal photon to the nucleon-nucleon system. It is extracted using the information about the hydrogen-deuterium isotope shift.
Considering the elastic contribution to the two-photon-exchange in μD, we emphasize the role of the low-virtuality properties of the deuteron, and identify a correlation between the deuteron charge and Friar radii, which can help one to judge how well a form factor parametrisation describes the aforementioned properties. We also quantify the higher-order two-photon-exchange contributions in μD, generated by the single-nucleon structure and expected to be the most important terms beyond N3LO.
With the respective two-photon-exchange effects evaluated in a unified pionless EFT approach, the resulting extractions of the deuteron charge radius from the μD Lamb shift, the $2S - 1S$ transition in D, and the $2S - 1S$ hydrogen-deuterium isotope shift, are in perfect agreement.

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Probing the Path-Length Dependence of Parton Energy Loss in Quark-Gluon Plasma

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The scaling property of large-$p_\perp$ hadron suppression, $R_{\rm AA}(p_\perp)$, measured in heavy ion collisions at RHIC and LHC allows for the determination of the average parton energy loss $\langle\epsilon\rangle$ in quark-gluon plasma produced in a variety of collision systems and centrality classes. Rescaling $\langle\epsilon\rangle$ by the particle density allows for the determination of the effective path length dependence of parton energy loss. We find that $\langle\epsilon\rangle \propto L^\beta$ with $\beta = 1.03\pm^{0.09}_{0.06}$, which is consistent with pQCD expectation of parton energy loss in a longitudinally expanding quark-gluon plasma. We demonstrate that the azimuthal anisotropy coefficient v_2 divided by the collision eccentricity follows the same scaling property as $R_{\rm AA}$, which is observed in data. Finally, a simply relation between $v_2(p_\perp)$ and $R_{\rm AA}(p_\perp)$ is found and confirmed by the correlation of the two independent measurements. This offers a new way to probe the L dependence of parton energy loss using high-statistics measurements from the coming LHC Run 3.

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Mott-polarimeter for electron transverse spin component in the BRAND experiment

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Exotic, BSM components of the weak interaction will be probed in the BRAND experiment via measurement of correlation coefficients of neutron β-decay. Ultimately, the BRAND detection setup will be able to provide precisely measured eleven correlation coefficients (*a, A, B, D, H, L, N, R, S, U, V*). Among them, seven (*H, L, N, R, S, U, V*) are dependent on the transverse electron polarization, which vanishes in the Standard Model. Coefficients *H, L, S, U* and *V* were never measured before.
Both electrons and protons from β-decay of polarized, free neutrons will be registered in the detection system, permitting the determination of complete kinematics of the decay. Electrons'energy, momentum and transverse spin component are measured in the Mott polarimeter which consists of the Multi-Wire Drift Chamber, a set of scintillation detectors and the Mott scattering target. The electron detection setup is optimized for the low-energy β-particles. The detection of low-energy protons from the β-decay is realized with a system that involves the acceleration and subsequent conversion of protons into bunches of secondary electrons.
In this contribution, results of the first pilot run of the BRAND experiment performed in September-October 2021 at the polarized, cold neutron beam facility PF1B at the Laue-Langevin Institute (ILL) in Grenoble, France will be reported. The emphasis will be put on the description and the performance of the electron detection system.

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Vector meson-proton scattering lengths from omega to upsilon

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High-accuracy upsilon photoproduction data from EIC and EicC experiments will allow the measurement of the near-threshold total cross section of the reaction gamma + p −> upsilon + p, from which the absolute value of the upsilon-p-scattering length can be extracted using a vector-meson dominance model. For this evaluation, we used upsilon-meson photoproduction quasidata from the QCD approach (the production amplitude can be factorized in terms of gluonic generalized parton distributions and the quarkonium distribution amplitude). A comparative analysis of vector meson-proton with the recently determined scattering lengths for omega-p, phi-p, and J/psi-p using the A2, CLAS, and GlueX experimental data are performed. The role of the "young"vector meson effect is evaluated.

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Smoking gun signals of the Schwinger mechanism in QCD from lattice simulations

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In QCD, gluons acquire an effective mass through the Schwinger mechanism, which is triggered by the dynamical formation of longitudinally coupled massless bound-state poles. The presence of these poles leaves smoking gun signals in the fundamental Ward identities, which are displaced by contributions of the Bethe-Salpeter amplitudes of the massless bound states. This displacement can be determined by combining lattice data for the QCD propagators and vertices, and a derivative of the ghost-gluon kernel computed from a Schwinger-Dyson equation. To control the latter's truncation error, we employ lattice results directly for the transversely projected three-gluon vertex in general kinematics that contributes to the ghost-gluon kernel equation. We obtain a clearly nonvanishing displacement of the ward identity, which agrees strikingly with predictions based on the analysis of the Bethe-Salpeter equation governing the formation of the massless bound states. Our study further strengthens the evidence for the realization of the Schwinger mechanism in QCD.

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Study of charmed baryons via their strong decay widths and mass spectra

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The total decay widths of charmed baryons, including all the possible open-flavor decay channels, are calculated through the $^3P_0$ model. Furthermore, we calculate the masses of the charmed-baryon up to the D-wave in a constituent quark model, using the three-quark and quark-diquark schemes.

We use a Hamiltonian model based on a harmonic oscillator potential plus a mass splitting term that encodes the spin, spin-orbit, isospin, and flavor interactions.
We have thoroughly propagated these uncertainties into our predicted charmed baryon masses and decay widths via a Monte Carlo bootstrap approach, which is often absent in other theoretical studies on this subject.
Our quantum number assignments and predictions of mass and strong-decay widths are in agreement with the available data. Thus, our results show the ability to guide future measurements in LHCb, Belle, and Belle II experiments.

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Hadron structure and spectroscopy with functional methods

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I will summarize advances on calculations of hadron spectrum and structure observables using functional methods such as Dyson-Schwinger and Bethe-Salpeter equations. Systematic improvements in this approach have made it possible to address a wide range of problems from the baryon excitation spectrum to multiquark spectroscopy, form factors, parton distributions and other areas. I will make a survey through some open questions in QCD, with an emphasis on the structure of exotic hadrons and multiquarks, and connect them with key underlying phenomena such as mass generation for quarks and gluons.

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Three-gluon vertex: planar degeneracy and emergence of gluon mass

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We shall discuss novel results for the three-gluon vertex, based on the analysis of recent, extensive lattice quenched simulations, featuring a singular kinematical property of its dominant form factor that we denominated “planar degeneracy”. On the ground of this property, one can apply to three-gluon vertex to unveil a distinctive signature of the mass generation mechanism in the QCD gauge sector.

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Production of P_c states in Lambda_b decays

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We develop a model for the production of the P_c states observed at LHCb in $\Lambda_b \to J/\psi p K^-$ decays. With fewer parameters than other approaches, we obtain excellent fits to the $J/\psi p$ invariant mass spectrum, capturing both the prominent peaks, and broader features over the full range of invariant

mass. A distinguishing feature of our model is that whereas $P_c(4312)$, $P_c(4380)$ and $P_c(4440)$ are resonances with $\Sigma_c^{(*)}\bar{D}^{(*)}$ constituents, the nature of $P_c(4457)$ is quite different, and can be understood either as a $\Sigma_c\bar{D}^{(*)}$ threshold cusp, a $\Lambda_c(2595)\bar{D}$ enhancement due to the triangle singularity, or a $\Lambda_c(2595)\bar{D}$ resonance. We propose experimental measurements that can discriminate among these possibilities. Unlike in other models, our production mechanism respects isospin symmetry and the empirical dominance of colour-enhanced processes in weak decays, and additionally gives a natural explanation for the overall shape of the data. Our model is consistent with experimental constraints from photoproduction and $\Lambda_b \to \Lambda_c\bar{D}^{(*)0}K^-$ decays and it does not imply the existence of partner states whose apparent absence in experiments is unexplained in other models.
https://arxiv.org/abs/2112.11527
https://arxiv.org/abs/2207.00511
https://arxiv.org/abs/2208.05106

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Baryon spectrum with a contact interaction

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We present the spectrum of positive-parity baryons composed of light and heavy quarks. Our analysis is provided by a symmetry preserving Schwinger-Dyson Bethe-Salpeter Equation (SDBSE) approach of a vector-vector contact interaction model. Our computations include the results using two different sets of parameters: one used to compute observables of light quarks, where the QCD-coupling is strong; and other considering the fact that in the reign of heavy quarks, the QCD coupling constant becomes smaller.

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Measurement of charm baryon lifetimes at Belle II

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Outstanding vertexing performance and low-background environment are key enablers of a systematic Belle II program targeted at measurements of charm baryon lifetimes. Recent results from measurements of the Λ_c and Ξ_c baryon lifetimes are presented. The former result is the most precise to date.

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Exploring Neutron stars EoS with coherent π0 π0 photoproduction at A2@MAMI

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A recent measurement of coherent π^0 photoproduction on Pb leads to a most accurate determination of the neutron skin, constraining nuclear matter Equation of State (EoS) at around $\rho \sim 1\rho_0$. A natural next step is elucidating the nuclear EoS at higher densities to tune our understanding of the most violent process in the Universe - neutron stars mergers. It was demonstrated that at densities above $\sim 3\rho_0$ dibaryonic degrees of freedom come into play [1]. The work presented in this talk is aiming to improve our knowledge of dibaryon behavior in dense nuclear matter by measuring coherent $\pi^0\pi^0$ photoproduction off Ca-40/48 nuclei. The experiment was performed at the A2@MAMI facility in Mainz (Germany). The goal of the analysis is to identify the first genuine hexaquark, the $d^*(2380)$, photoproduction on nuclei. We are expecting to determine the medium modifications of the $d^*(2380)$ in nuclear matter and constrain its couplings [2]. These new results will further improve our understanding of the neutron stars equation of state and allow precise determination of the maximum neutron star mass as well as provide key ingredients for calculation of the neutron stars merger dynamics. Also, an interplay between the hexaquark, quark-gluon and hyperon degrees of freedom in the EoS of a dense nuclear matter will be discussed. The effective coupling constants obtained in this experiment can further constrain the possibility of hexaquark condensate dark matter [3].

[1] I. Vidana, M. Bashkanov, D.P. Watts, A. Pastore, Phys. Lett. B 781, 112-116 (2018)
[2] A. Mantziris, A. Pastore, I. Vidana, D.P. Watts, M. Bashkanov, A.M. Romero, Astronomy & Astrophysics A40, ISSN 0004-6361 (2020)
[3] M. Bashkanov, D.P. Watts 2020, J. Phys. G: Nucl. Part. Phys. 47 03LT01 (2020)

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Search for Hidden Sector New Particles in the 3-60 MeV Mass Range Focusing on the Hypothetical X17 Particle

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The search for new particles in the low mass range is motivated by new hidden sector models and dark matter candidates introduced to account for a variety of experimental and observational puzzles: the small-scale structure puzzle in cosmological simulations, anomalies such as the 4.2σ disagreement between experiments and the standard model prediction for the muon anomalous magnetic moment, and the excess of e^+e^- pairs from the ^{8}Be and ^{4}He nuclear transitions to their ground states observed by the ATOMKI group. In these models, the 1–100 MeV mass range is particularly well-motivated, and the lower part of this range still remains unexplored. Our PRad collaboration developed an experimental proposal to search for these particles by direct detection of all three final state particles in the electroproduction experiment allowing for an effective control of the background. It will cover the 3 - 60 MeV mass range, focusing on the detection of hypothetical X17 particle. This experiment was fully approved by the recent JLab's PAC50 with a highest scientific rating (A). Currently the collaboration is preparing this experiment to be performed as early as next year. The current status of this experiment will be presented and discussed in this talk.

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Hadron induced Charmonium production

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We study the excitation function of the low-lying charmonium states: J/ψ, $\psi(3686)$ in p, π and $\bar{p}$, Au collisions taking into account their in-medium propagation. The time evolution of the spectral functions of the charmonium state is studied with a BUU type transport model. We calculated the charmonium contribution to the dilepton spectrum. We study how the short range correlations in nuclei effect the excitation function of J/ψ and show that for $\psi(3686)$ production there is a good chance to observe its in-medium modification with good resolution detectors. The energy regime will be available in JPARC, PANDA and CBM.

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Definite Orbital Angular Momentum Nucleon GPD Contributions via Light Front Wave Function Overlap

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While hadronic structure is experimentally probed by processes such as DIS and DVCS, both lattice and continuum techniques are employed to corroborate such results from a theoretical perspective. On the continuum side, the Fadeev equations provide a fully covariant approach to three body interactions convenient for describing three quark hadronic states. However, the four-spacetime-dimensional nature of the corresponding Fadeev wave functions precludes a probabilistic interpretation, encouraging our use of their 3-spacetime-dimensional light cone projections, Light Front Wave Functions (LFWFs). An intuitional advantage of LFWFs is their role as coefficients in Fock expansions of hadronic states. We first define nucleon Fadeev wave functions in terms of off-diagonal nucleon matrix elements, and subsequently express the corresponding definite orbital angular momentum (OAM) nucleon LFWFs. With these definite quark helicity LFWFs in hand we calculate GPDs as linear combinations of their overlaps, and isolate definite OAM contributions to nucleon GPDs, PDFs, Form Factors (FFs) and the electric nucleon radius. Looking forward, this work will allow us to map dynamical effects underlying the computation of Fadeev wave functions to the multimensional structure of the nucleon.

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The three-gluon vertex from quenched lattice QCD in Landau gauge

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The three-gluon vertex plays a central role in the infrared dynamics of Quantum Chromodynamics (QCD). Gluon self-interaction is the main difference between this theory and others like quantum electrodynamics (QED); namely its non-abelian nature. The appearance of a three-gluon vertex in the QCD Lagrangian is intimately linked to both asymptotic freedom and confinement in QCD. The study of its non-perturbative features has attracted attention for the last decades in both Dyson-Schwinger and lattice simulations [Alkofer:2004it, Cucchieri:2006tf].

The three gluon vertex depends on the incomimg momenta, q, r and p, with the kinematical constrain $q + r + p = 0$. Most lattice studies focus in the symmetric ($q^2 = r^2 = p^2$) and soft-gluon ($p = 0$, and thus $q^2 = r^2$) cases where there is a single momentum scale [Boucaud:2017obn, Aguilar:2021lke, Aguilar:2021okw]. Both kinematics exhibit an infrared zero-crossing which can be understood as a consequence of the gluon-mass generation while the ghost remains massless [Aguilar:2021uwa].

In this work, we present recent results [Pinto-Gomez:2022brg] for the three-gluon vertex from quenched lattice-QCD in extended kinematics, i.e., beyond the limiting symmetric and soft-gluon

ones. We have employed a special tensorial basis, whose form factors are naturally parametrized in terms of individually Bose-symmetric variables, in order to study both, the previously studied kinematics and the new ones, including the bisectoral case ($q^2 = r^2$) and the completely general case.

From our lattice results, two outstanding features of the non-perturbative three-gluon vertex emerge:

- the form-factor associated to the tree-level tensor is clearly dominant over the others.
- the scalar form factors depend almost exclusively on the symmetric variable $s^2 = (q^2+r^2+p^2)/2$. Thus, all kinematical configurations lying on a plane with constant s^2 in the coordinate system (q^2, r^2, p^2) share, to a high degree of accuracy, the same values of the form factors, a property that we denominate planar degeneracy.

Being its study of paramount theoretical relevance by itself, the three-gluon vertex is also a central component in a variety of phenomenological studies in the continuum. In particular, the outstanding feature of infrared suppression [Cucchieri:2006tf, Huber:2012zj] displayed by its main form factors is instrumental for the formation of bound states with the right physical properties. This ongoing search, based on the profitable synergy between lattice simulations and continuum methods, has afforded a firmer grip on delicate underlying patterns, establishing prominent connections with the emergence of a mass-scale in the gauge sector of the theory [Aguilar:2021okw, Aguilar:2008xm, Boucaud:2008ky].

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Study of quarkonium in QGP from unquenched lattice QCD

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We present full QCD correlator data and corresponding reconstructed spectral functions charmonium and bottomonium. Correlators are obtained using clover-improved Wilson fermions on $N_f = 2 + 1$ HISQ lattices. We use gradient flow to check whether it reduces cut-off and mixed action effects. Valence quark masses are tuned to their physical values by comparing the mass spectrum obtained from the lattice QCD with experimental values at each flow time. For the spectral reconstruction, we use models based on perturbative spectral functions from different frequency regions like resummed thermal contributions around the threshold from pNRQCD and vacuum contributions well above the threshold. We show preliminary results of the reconstructed spectral function obtained for the first time in our study for full QCD. In addition, we compare the results with the previous continuum extrapolated results in the quenched approximation.

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Chiral spin symmetry and the QCD phase diagram

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During the last few years, an unexpected emergent approximate symmetry has been observed in Euclidean correlation functions computed on the lattice. This chiral spin synnetry, once combined with isospin symmetry, is larger than the well-known chiral symmetry, and emerges dynamically in a range between the chiral crossover and roughly three times the crossover temperature. This can only happen if colour-electric quark gluon interactions dominate the quantum effective action in that temperature range, and suggests that chiral symmetry is restored, but quarks are still strongly

bound in hadron-like objects. I summarise lattice evidence from space-like and time-like correlators, as well as screening masses. Furthermore, a calculation of the pion spectral function is presented, that shows clearly discernible peaks for the pion as well as its first excitation in some temperature range above the chiral transition.

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Future EIC at Brookhaven National Laboratory

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Meson structures at EicC

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Pion and Kaon structure

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Generalised Parton Distributions at the time of high precision experiments

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Baryon structure from a light-front Hamiltonian approach

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Probing CP symmetry with polarised and entangled hyperons

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Measurement of charm baryon lifetimes at Belle II

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Heavy quark masses with calibrated uncertainties

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Search for Hidden Sector New Particles in the 3-60 MeV Mass Range Focusing on the Hypothetical X17 Particle

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Investigating the Structure of Matter with the AMBER Experiment

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Baryon resonance studies via meson photoproduction at the LEPS2/BGOegg experiment

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Experimental access to the three-body forces between hadrons with ALICE

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Latest results on hadronic resonance production with ALICE at the LHC

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Accessing the coupled-channels dynamics using femtoscopic correlations with ALICE at LHC

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Emergence of mass in mesons and its relation with their parton distribution functions

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Heavy-light exotics: old laces and new pieces

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Latest results from Kaon experiments at CERN

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Semileptonic decays of heavy+light and heavy+heavy mesons

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Overview of Lattice-QCD calculations of Baryons

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Hidden-charm pentaquarks in the molecular picture: effective field theory and phenomenological considerations

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Pole determination of $P_{\psi s}^{\Lambda}(4338)$ and possible $P_{\psi s}^{\Lambda}(4254)$ in $B^- \to J/\psi \Lambda \bar{p}$

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Structure calculations of fully-heavy hexaquarks

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Study of charmed baryons via their strong decay widths and mass spectra

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Lambda(1405) and Kbar-N and Kbar-D scattering lengths

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Antikaon-nucleon interactions and the momentum correlation functions in high-energy collisions

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The study of P-wave strange mesons in coupled channel framework

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Extracting hadron-hadron interaction from lattice QCD in a small box

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Hidden-charm pentaquarks as hadronic molecules

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Hadron-hadron interactions from femtoscopic study

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Production of P_c states in Lambda_b decays

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Molecular states of Ω⊠,Ω⊠,Ξ⊠⊠,Ξ⊠⊠,Ξ⊠⊠ type

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Hidden-charm ⊠Λ⊠⊠ pentaquarks in a constituent quark model calculation

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Plans for the JLab12 era and beyond

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Baryon Spectroscopy at GlueX

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Overview of lattice results for hadron structure

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Overview of CSM results for hadron structure

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dbar/ubar from SeaQuest and recent and future Drell-Yan results / MARATHON

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Mesons, baryons and the phase diagram of QCD

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Mesons at finite temperature and density from the FRG

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Study of quarkonium in QGP from unquenched lattice QCD

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Chiral spin symmetry and the QCD phase diagram

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Hadron properties in nuclear medium (QCD sum rules)

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Hadron induced Charmonium production

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Theory predictions for the J-PARC E16 experiment

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Dielectron measurements with the HADES at GSI

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Experimental study of in-medium spectral change of vector mesons in nuclear medium at J-PARC

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Topological screening and sphaleron transitions in polarized deeply inelastic scattering at the Electron-Ion Collider

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Electromagnetic form factor of vector meson

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Baryon masses estimate in heavy flavor QCD

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Δ baryon spectroscopy using Hamiltonian Effective Field Theory and lattice QCD

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Emergence of mass in the gauge sector of QCD

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Femtoscopy of the Origin of the Nucleon Mass

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Smoking gun signals of the Schwinger mechanism in QCD from lattice simulations

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Three-gluon vertex: planar degeneracy and emergence of gluon mass

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Going to the light-front with contour deformations

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Large-Q2 nucleon's (hadron) form factors in Lattice QCD

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Dynamical diquarks and baryon transition form factors

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TMDs in dijet production in SIDIS

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Definite Orbital Angular Momentum Nucleon GPD Contributions via Light Front Wave Function Overlap

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Effective field theories and phenomenology for electron and neutrino-induced processes

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Extracting nucleon electroweak properties from Lattice QCD using Chiral Perturbation Theory

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NuMAID: reggeized isobar model for pion neutrinoproduction with unitarity

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Radiative corrections to neutron beta decay from low-energy effective field theory

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Deuteron VVCS and two-photon exchange effects in (muonic) deuterium in pionless EFT

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Nucleon Resonance Electrocouplings and the Emergence of Hadron Mass

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The incredible shrinking proton and the proton radius puzzle

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Determination and status of the light baryon spectrum (Overview talk on partial-wave analysis)

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Dynamical Coupled Channels theory for nucleon resonances and other excited/unusual states

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Hadron structure and spectroscopy with functional methods

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Exploring the potential role of diquarks in hadronization using SIDIS on nuclear targets

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Probing the Path-Length Dependence of Parton Energy Loss in Quark-Gluon Plasma

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Pentaquarks in a Bethe-Salpeter approach

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Molecular Ω⊠⊠ , Ω⊠⊠ and Ω⊠⊠ states

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GFMC studies of nucleus and Neutrino-nucleus interaction

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Vector meson-proton scattering lengths from omega to upsilon

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Pseudoscalar meson dominance and pion-nucleon coupling constant

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Generalized parton distribution of pions at the forthcoming electron-ion collider

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Theory of Dispersion relations and scattering matrix

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Approaching Near-threshold Resonances by Analytic Maps of the S-matrix: Uniformization, and Mittag-Leffler Expansion of 2 and 3-channeled Systems

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Determination of the compositeness of a bound state by a and ⍰0. The role of the interaction range

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Study of baryons in a combination of large-⍰⍰ QCD and constituent approach

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Forging a Path for Understanding Nuclear Structure from Strong QCD

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Recent hadronic physics with astrophysical implications

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Short range correlations and EMC effect

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Baryon spectroscopy and properties: Measurement of polarization observables in photoproduction of mesons on nuclei

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Electroexcitation of Bound Nucleons and What We Have Learnt from Free Protons

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Evaluating evidence for baryons with light quark content

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b-baryons at the LHCb experiment

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Studies of baryon-baryon interaction at J-PARC

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Lüscher formalism and extraction of resonances

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Baryon-baryon interactions from Lattice-QCD

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Proton's radii overview

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Nucleon self-energy including two-loop contributions

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The axial-vector form factor of the nucleon from two flavour Lattice QCD ensembles

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Proton GPDs from Lattice QCD: Fast and Accurate

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Quantum tomography of nucleons, with some focus on TMDs (and PDFs)

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Information entropy in fragmentation functions and their relation to pdfs

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Hard exclusive reactions beyond DVCS: Compton-like and vector meson production for GPD studies

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Chiral EFT of deltas, nucleons and pions in the presence of external gravitational field

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Definition of electromagnetic and gravitational local spatial densities

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Prospects to access N to N* transition GPDs

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Explicit renormalization of nuclear chiral EFT and non-perturbative effects

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Applications of renormalization group to few-body problems in effective field theory

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Nucleon-nucleon interaction in manifestly Lorentz-invariant chiral effective field theory

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Multiquark states

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Rotation and vibration in tetraquarks

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Nature of Tcc with effective field theory

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Heavy baryon spectroscopy in a quark-diquark approach

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Radial excitation of Ω[illegible] baryon using relativistic formalism

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Lattice-QCD studies of nuclei, and their electromagnetic properties

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Exploring Neutron stars EoS with coherent π0 π0 photoproduction at A2@MAMI

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NP effects in Λ▯→Λ(*)▯ semileptonic decays

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CP violation tests of hyperon-antihyperon pairs at BESIII

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Studies of Excited Nucleon States via Exclusive KY Electroproduction

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Consistency of the molecular picture of Ω(2012) with the latest Belle results

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Baryon excited states: quark model versus reality

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Baryon spectrum with a contact interaction

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On the recent states Zcs(3985) and X(3960)

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Generalized parton distribution of pions at the forthcoming electron-ion collider.

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The advent of the Electron-Ion Collider (EIC) is pushing the frontiers of hadron physics. Importantly, generalized parton distributions are expected to be accessible within an unprecedented accuracy. This work takes advantage of this context to present the first exploratory study on the access of pion GPDs at the EIC. Relying on state-of-the-art models for the pion's GPDs, we tackle the effect of scale-evolution up to a Q2-regime accessible in experiment, and elaborate on its manifestations in observable quantities. More precisely, we compute event-rates and beam-spin asymmetries for the Sullivan process. The analysis of these results confirms the expectation for pion GPDs to be accessible at the EIC. Remarkably, we find evidence on the dominant role played by gluons in the description of pion's structure and identify a sign inversion in the beam-spin asymmetries to be clear manifestation of this phenomenon both at an
experimental and theoretical level.

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Dynamical diquarks and baryon transition form factors

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Based upon a continuum Schwinger approach, which employs a Poncaré-covariant Faddeev equation to describe baryons as composite states, we shall present recent calculations of electromagnetic transitions involving baryon ground states and their corresponding parity partners, namely \gamma^{(*)}p->N(1535) and \Delta(1232)-> \Delta(1700) transition form factors. The role and impact of dynamical diquark correlations that appear within the baryon bound state, owing largely to the mechanisms responsible for the emergence of hadron mass, will be discussed in detail. Although limited to a contact interaction model, the results herein shown serve as benchmarks for future more sophisticated calculations.

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Gravitational form factors of a quark in a dressed quark model.

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We calculate the gravitational form factors (GFFs) and mechanical properties of a quark for a dressed quark state. We obtain all the form factors in terms of overlap of the light front wavefunctions (LFWFs). We compare the D-term obtained in our model with the dressed electron state at one loop in the QED result obtained by Metz et al., by setting the
model parameters to the QED domain.

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The incredible shrinking proton and the proton radius puzzle

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For nearly half a century the charge radius of the proton had been obtained from measurements of the energy levels of the hydrogen atom or by scattering electrons from hydrogen atoms. Until recently the proton charge radius obtained from these two methods, agreed with one another within experimental uncertainties. In 2010 the proton charge radius was obtained for the first time by precisely measuring the energy levels of an exotic kind of hydrogen atom called muonic hydrogen. The charge radius of the proton obtained from muonic hydrogen was found to be significantly smaller than those obtained from regular hydrogen atoms. This was called the proton charge radius puzzle" and led to a rush of experimental as well as theoretical efforts to understand why the size of the proton appears to be different when measured in regular hydrogen vs. muonic hydrogen. Many physicists were excited by the possibility that thepuzzle" was an indication of a possible new force that acted differently on electrons and muons.

The Proton Charge Radius (PRad) experiment at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) was one such major new effort which used electron scattering from a regular hydrogen atom, but with several innovations that made it the highest precision electron scattering measurement. These innovative methods have allowed us to measure the size of the proton more precisely than it has been measured before using electron scattering. I will provide a brief review of the techniques used to measure the proton's size and introduce the proton radius puzzle", and the world-wide effort to resolve this puzzle. I will discuss the PRad experiment, the new results from this experiment, the current status of thepuzzle" and future prospects.

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Quantum tomography of nucleons, with some focus on TMDs (and PDFs)

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Building 3D maps of the internal structure of the proton allows us to explore the inner structure of matter and and to learn about the dynamics its fundamental constituents.

I will give a brief overview of tcollinear and TMD factorization theorems, which are at the basis of the predictive power of QCD, and an overview of the state of the art of TMD phenomenology, focusing on a personal selection of challenging issues. I will then highlight some of the future perspectives in this field.

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Effective field theories and phenomenology for electron and neutrino-induced processes

Author: Astrid Hiller Blin[1]

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Obtaining a physically well-founded theoretical description of hadrons across energy scales is of high importance for the extraction of precision quantities such as hadronic contributions to the Lamb shift or the impact of neutrino-nucleon interactions on neutrino oscillation experiments. However, the strong force behaves remarkably differently at high and low energies: effective field theories (EFTs) are called for for the description in the different regimes.

When probing hadrons with electron or neutrino beams, at high energies the underlying physics is well understood in terms of perturbative QCD, as well as Regge phenomenology. At low energies, the connection to the physics of the constituents becomes obscured and it becomes justified to use chiral perturbation theory (ChPT) or pionless EFT.

Moreover, to connect the low and high-energy regimes, the wealth of resonances appearing in the spectrum needs to be accounted for, whose description is highly convoluted. Many of them, the exotic resonances, do not even follow the usual 2 or 3-valence-quark picture.

I present an overview of low-energy processes described in ChPT, as well as advances towards connecting low-energy and resonance regimes to high-energy processes with the help of phenomenological frameworks and Regge theory.

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Hadron properties in nuclear medium

Author: Su Houng Lee[None]

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I will discuss the effects of chiral symmetry breaking in the hadron masses. This is accomplished by separating the four quark operators appearing in the vector and axial vector meson sum rules into chiral symmetric and symmetry breaking parts. We then identify each part from the fit to the rho and a1 meson masses, which form chiral partners. By taking the chiral symmetry breaking part to be zero while keeping the symmetric operator to the vacuum value, we find that the chiral symmetric part of the rho and a1 meson mass to be between 550 and 600 MeV. Similar calculation for the chiral partner (K*,K1) as well as other non chiral partners are discussed. I will also discuss how present and future experiments on hadron masses can provide insights into the origin of hadron masses and their relation to chiral symmetry breaking.

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Paving a way for understanding nuclear structure from strong QCD [Part 1 (JLab 2019) to Part 2 (2022)]

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Sending abstract by end of this week

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Dynamical Coupled Channels theory for nucleon resonances and other excited/unusual states

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Data on the photo- and electroproduction of different hadrons provide access to the spectrum of excited baryons and its properties. Recent results from the Julich-Bonn-Washington model will be presented, including extensions to the electroproduction of pions and η mesons. The amplitudes and resonance properties obtained through this phenomenological analysis can serve as a point of comparison for theories and models of excited baryons and their dynamics. Three-body dynamics plays an important role for excited baryons, so the first calculation of a three-body resonance from lattice QCD, the a1(1260), is presented and put into context with baryons.

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Determination and status of the light baryon spectrum (Overview talk on partial-wave analysis)

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I give an overview of (some of) the different analysis tools and PWA approaches used to extract the spectrum of N^* and Δ^* states from experimental data. Differences and similarities, e.g. in the construction of the amplitude, will be illustrated and I will show selected recent results.

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Structure and dynamics of the proton using light-front dynamics

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Understanding the structure and dynamics of the proton constitute an important remaining challenges in hadron physics. From the theory side, one of the challenges is to extract from Lattice QCD calculations, performed in Euclidean space, Minkowskian quantities such as the proton parton distribution function. It is difficult to do the inversion of Euclidean quantities back to the corresponding Minkowskian ones, and thus important to have a solution defined directly in Minkowski space for calculations of dynamical observables such as momentum distributions.

We present results for the proton calculated using a simple although dynamical model defined in Minkowski space [1]. Our starting point is the Bethe-Salpeter-Faddeev equation for a system of three spin-less bosons interacting through a contact interaction. Recently, the general properties of the solution to this equation was studied in great detail in the papers [2, 3, 4]. In the present work, the equation is solved in the valence approximation (i.e. only the first Fock component is kept) and the parameters of the model are set by comparing the calculated Dirac form factor with experimental data. The single- and double parton distributions of the proton are then computed. The proton image in coordinate space in terms of the transverse coordinates and the Ioffe times \tilde{x}_{1,2} is also studied, by performing numerically the Fourier transformation of the distribution amplitude.

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The BGOOD experiment at ELSA - exotic structure in the light quark sector?

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The recent discoveries of the pentaquark, P_C, states and XYZ mesons in the charmed quark sector has initiated a new epoch in hadron physics. The existence of exotic multi-quark states beyond the conventional three and two quark systems has been realised. Such states could manifest as single colour bound objects, or evolve from meson-baryon and meson-meson interactions, creating molecular like systems and re-scattering effects near production thresholds. Intriguingly, similar effects may be evidenced in the light, uds sector in meson photoproduction. Access to a low momentum exchange and forward meson production region is crucial. The BGOOD photoproduction experiment is uniquely designed to explore this kinematic region; it is comprised of a central calorimeter complemented by a magnetic spectrometer in forward directions.

Our results indicate a peak-like structure in the $\gamma n \to K^0\Sigma^0$ cross section at $W \sim 2$ GeV consistent with a meson-baryon interaction model which predicted the charmed P_C states. The same $K^*\Sigma$ molecular nature of this proposed N*(2030) is also supported in our measurement of $\gamma p \to K^+\Lambda(1405)(\to \pi^0\Sigma^0)$, where it is predicted to drive a triangle mechanism. Additionally, a sharp drop in the $\gamma p \to K^+\Sigma^0$ cross section at very forward angles at $W \sim 1.9$ GeV is observed.

In the non-strange sector, coherent meson photoproduction off the deuteron enables access to proposed dibaryon states, including the recently discovered $d^*(2380)$. Data will be presented which support recent experimental claims of higher mass isoscalar and isovector dibaryons.

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Towards the measurement of electromagnetic dipole moments of strange and charm baryons at LHC

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Electric dipole moments (EDM) of fundamental particles provide powerful probes for physics beyond the Standard Model. Magnetic dipole moments (MDM) of baryons provide further information on the baryon substructure and represent experimental anchor points for tests of low-energy QCD models, related to non-perturbative QCD dynamics. These have not been experimentally accessible to date for the case of heavy baryons, due to the difficulties imposed by their short lifetimes. In the recent years, novel experimental techniques have been proposed to extend the worldwide intense experimental program of electromagnetic dipole moments measurement to heavy baryons. The technique is based on the spin precession in the LHCb dipole magnet (for the Lambda baryon) and in a bent crystal installed in the insertion region IR3 at LHC (for charmed baryons). Feasibility studies of the proposed experiment in IR3 will be discussed, along with the demonstration to reconstruct Lambda baryons with tracking stations downstream the LHCb dipole magnet. Perspectives of the dipole moments measurement during LHC Run3 will be outlined.

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b-baryons at the LHCb experiment

Author: Luis Miguel Garcia Martin[1]

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The study of b-baryon decays are sensitive probes of New Physics through the study of branching fractions, CP asymmetries and angular measurements. Additionally, measurements of spectroscopy can provide valuable experimental input for QCD. The LHCb experiment has collected a large dataset and features excellent detector performance. This provides the LHCb with unprecedented capabilities of providing the world's most precise measurements of properties and production of known baryons, as well as discovering many new unobserved states. In this talk, the latest results on spectroscopy and decays of b-baryons at LHCb will be shown.

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Hadron structure and spectroscopy with functional methods

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I will summarize advances on calculations of hadron spectrum and structure observables using functional methods such as Dyson-Schwinger and Bethe-Salpeter equations. Systematic improvements in this approach have made it possible to address a wide range of problems from the baryon excitation spectrum to multiquark spectroscopy, form factors, parton distributions and other areas. I will make a survey through some open questions in QCD, with an emphasis on the structure of exotic hadrons and multiquarks, and connect them with key underlying phenomena such as mass generation for quarks and gluons.

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Properties of Pseudoscalar Mesons in a Contact Interaction

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We study pseudoscalar meson properties and compute the $\gamma^*\gamma \to \pi^0, \eta, \eta'$ transition form factor in the framework of the Dyson-Schwinger equations (DSE) and Bethe-Salpeter equations (BSE), using a momentum-independent contact interaction. The contact interaction is capable to describe the observable properties, but produce a transition form factor whose evolution for large Q^2 disagrees with experiment, as well as its asymptotic power-law behavior conflicts with pQCD. Moreover, we explore the influence of the pseudovector components of the Bethe-Salpeter amplitude, $F_{PS}(P)$, on the static properties and transition form factor.

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Electroexcitation of Bound Nucleons and What We Have Learnt from Free Protons

Author: Ralf Gothe[None]

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Single and double pion electroproduction results off bound nucleons will be presented and the path from exclusive to quasi-free cross sections will be laid out. Their impact on guiding us towards a comprehensive QCD theory will be highlighted by recent and anticipated results as well as potentially available opportunities in the near future.

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Overview of Lattice-QCD calculations of Baryons

Author: Ying CHEN[None]

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The talk will review recent lattice spectroscopic studies of baryons, such as the calculation of the spectrum of heavy flavored baryons, the meson-nucleon scatterings related to Delta baryon and nucleon excited states, as well as new calculations of the pion-nucleon sigma term and the nucleon mass structure. The progress in studying diquarks in baryons will also be introduced.

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Measuring the Production Cross Sections of the Ground State Cascade in Photoproduction

Author: Jesse Hernandez[1]

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For decades an assortment of quark models and more recently lattice QCD calculations have predicted many more Cascade baryon states than have been experimentally observed. Furthermore, SU(3) flavor symmetry indicates that there should be a Cascade partner for every N^*- and Δ^*- resonance. The spectrum of the doubly strange Ξ baryons is poorly known and only a few states have been experimentally observed. Moreover, the photoproduction mechanism for these states is not well understood. It is assumed that Ξ resonances are photoproduced in the strong decay of intermediate highly excited singly strange hyperons.

The GlueX experiment in Hall D at Jefferson Lab has accumulated high-statistics samples of photoproduction data. Using these high-statistics data and the fact that the lowest-lying Cascade states are expected to have very narrow widths, GlueX will be able to shed light on the systematics of the spectrum. In addition, the high statistics data in conjunction with the linearly polarized photon beam at GlueX makes it possible to measure the differential cross section and various polarization observables with high accuracy. Consequently, the measurement of these observables will allow for the composition of a full partial wave analysis to fully understand the production mechanism.

I will give a broad overview of the Cascade physics program being conducted using GlueX data. Furthermore, I will report the preliminary differential cross section for $\Xi(1320)^-$ in the exclusive t-channel production reaction $\gamma p \to K^+Y^* \to K^+(K^+\Xi^-)$ where $\Xi^- \to \Lambda\pi^-$.

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Hadron Spectroscopy from Lattice QCD

Author: Robert Edwards[None]

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There has been recent, significant, advances in the determination of the hadron spectrum. Current efforts have focused on the development and application of finite-volume formalisms that allow for the determination of scattering amplitudes as well as resonance behavior in coupled channel systems. I will review some of these recent developments and outline future directions of research.

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Generalised Parton Distributions at the time of high precision experiments

Author: Cédric Mezrag[None]

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Introduced more than two decades ago, Generalised Parton Distributions (GPDs) have been deeply studied theoretically as they offer the unique opportunities to i) probe the multidimensional structure of the nucleon in coordinate space, and ii) collect experimental information regarding the energy-momentum tensor of hadrons. Thus, high-precision facilities such as Jefferson Lab present dedicated experimental program on GPDs, and one expects a large amount of experimental data of unmatched precision to be released in the near future. However, extracting GPDs from these data is a challenge. I will explain why and show how integrated software such as the PARTONS project will play a key role in the future of GPD phenomenology.

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Recent Progress in Lattice Parton-Distribution Calculations

Author: Huey-Wen Lin[None]

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In recent years, a breakthrough was made in calculating the Bjorken-x dependence of PDFs in lattice QCD by using large-momentum effective theory
(LaMET) and other similar frameworks. The breakthrough has led to the emergence and rapid development of direct calculations of Bjorken-x dependent structure. In this talk, I will review the recent progress made in lattice QCD and future challenges.

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Molecular states of Ω□,Ω□,Ξ□□,Ξ□□,Ξ□□ type

Author: Jorgivan Dias[None]

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By exploring the interactions among mesons and baryons, in a coupled-channels approach, for the heavy-quark sector (charm and bottom), we investigate the dynamical generation of singly Ωc/Ωb and doubly Ξcc, Ξbc, and Ξbb heavy-quark baryon resonances. The interactions describing the meson-baryon transitions among the relevant channels are evaluated considering the vector meson exchange mechanism. For that, we extend the Local Hidden Gauge approach to the heavy-quark sector and show that the dominant terms come from the exchange of light vector mesons, with the heavy-quarks as spectators. Consequently, the heavy-quark spin symmetry is preserved for the dominant terms in 1/MQ counting, and the Chiral Lagrangians describe the interaction. The amplitudes obtained are then unitarized through the Bethe-Salpeter equation, according to the Chiral Unitary approach, with its solutions interpreted as physical states, i. e. bound/resonances. For the singly-charmed system case, we obtain two states with JP = 1/2− and 3/2− with an excellent agreement with the experimental Ωc(3050), Ωc(3090) and Ωc(3119) structures, recently reported by the LHCb collaboration [Phys. Rev. Lett. 118, 182001 (2017)]. Furthermore, for the bottom case, we found four states with a good matching with the four peaks seen in the high-energy part of the LHCb data [Phys. Rev. Lett 124, 082002 (2020)] report for the experimental Ωb states. In addition, we also present predictions for the doubly-heavy quark baryons Ξcc(bb) and Ξbc resonances.

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Topological screening and sphaleron transitions in polarized deeply inelastic scattering at the Electron-Ion Collider

Author: Raju Venugopalan[None]

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We employ a powerful worldline formalism to uncover the role of the chiral anomaly in polarized deeply inelastic scattering in QCD at high energies and demonstrate simply that the anomaly dominates the proton's helicity in both Bjorken and Regge asymptotics. We independently confirm Veneziano's argument that the physics underlying topological mass generation in QCD (the UA(1) problem) is also the physics that explains the "spin crisis" demonstrating the failure of the relativistic quark model. We go further and suggest that measurements of polarized structure functions at an Electron-Ion Collider can uncover first evidence for topological "Sphaleron-like" transitions in nature.

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Baryon-baryon interactions from Lattice-QCD

Author: Sinya Aoki[None]

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I review the current status on baryon-baryon interactions such as nuclear forces in lattice Quantum ChromoDynamics (QCD), using the HAL QCD potential method. I first show results on HAL QCD potentials between nucleons (proton and neutron, denoted by N) in various cases, including preliminary results at the almost physical pion and kaon masses and exploratory studies on three-nucleon potentials. Secondly I discuss interactions between generic baryons including hyperons. Universal properties of potentials between baryons become manifest in the flavor SU(3) symmetric limit, where masses of three quarks, up, down and strange, are all equal. In particular, one bound state, traditionally called the H-dibaryon, appears in the flavor singlet representation of SU(3). A fate of the H dibaryon is also discussed with flavor SU(3) breaking taken into account at the almost physical point. Finally, I present latest results on various kinds of dibaryons, bound or resonate states of two baryons, including charmed dibaryons at the almost physical point.

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Investigating the Structure of Matter with the AMBER Experiment

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The M2 beamline at the CERN/SPS can provide both muon and hadron beams with energy up to few hundred GeV. A new fixed-target experiment, AMBER (Apparatus for Meson and Baryon Experimental Research), explores this versatility by addressing several aspects of the so-called Emergence of Hadron Mass mechanism. The experimental program, started in 2021, includes in its already approved phase-I: the charge radius of the proton, measured in muon-proton elastic scattering; the parton momentum distributions in the pion, accessed from Drell-Yan and charmonia production; and the measurement of the antiproton production cross section in proton-helium collisions, a valuable input for Dark Matter search studies. The feasibility studies for an even more ambitious second phase of measurements are presently ongoing, that include the measurement of pion, kaon and antiproton charge radii; the kaon polarizability; a vast program addressing light meson spectroscopy, in particular in the strange sector; and the kaon parton distribution functions.

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Measurable Expressions of Emergent Hadron Mass

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The vast bulk of visible mass emerges as a consequence of nonperturbative dynamics within the strong interaction sector of the Standard Model. The past decade has revealed the three pillars of this emergent hadron mass (EHM); namely, a nonzero gluon mass-scale, a process-independent effective charge, and dressed-quarks with constituent-like masses. Contemporary theory is now exposing their manifold and diverse expressions in hadron observables and highlighting the types of measurements that can be made in order to validate the EHM paradigm. In sketching these developments, this presentation will highlight the role of EHM in forming baryon spectra and structure.

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Baryon Spectroscopy at GlueX

Author: Volker Crede[1]

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High-energy electrons and photons are a remarkably clean probe of hadronic matter, essentially providing a microscope for examining atomic nuclei and the strong nuclear force. One of the most striking phenomena of Quantum Chromodynamics (QCD) is the formation of the nucleon out of massless gluons and almost massless quarks. This system of confined quarks and gluons serves as the basic constituent of ordinary baryonic matter and exhibits the characteristic spectra of excited states, which are sensitive to the details of quark confinement. Complementary to nucleon structure studies in deep inelastic scattering experiments, nucleon excitations provide the unique opportunity to explore the many aspects of non-perturbative QCD.

While the last few years have seen significant progress toward the mapping of the nucleon and Δ spectrum, experimental information on the spectrum, structure, and decays of strangeness -2 Ξ baryons remains sparse compared to non-strange and strangeness -1 baryons. Moreover, the photoproduction mechanism for these so-called Cascade resonances is not well understood and expected to proceed via highly excited intermediate singly strange hyperons in reactions such as $\gamma p \longrightarrow K\, Y*\, (\Lambda*, \Sigma*) \longrightarrow KK\, \Xi\, (*)$.
The GlueX experiment in Hall D at Jefferson Lab has accumulated high-statistics samples of photoproduction data in recent years. Since the lowest-lying Cascade states are expected to have narrow widths (as compared to the broad and overlapping N ∗ states), GlueX will be able to shed more light on the systematics of the spectrum of excited states and their properties. Copious data for excited strangeness -1 baryons have also been collected with GlueX, e.g. for the Λ(1405) and Λ(1520), along with the data for Cascade baryons in this experimental hyperon program. In this talk, I will discuss preliminary GlueX results on photoproduced Cascade baryons, including differential cross section measurements for the Ξ(1320) – octet ground state, recent results for excited strangeness -1 baryons, including spin-density matrix measurements for the Λ(1520), and give a brief outlook on the GlueX potential for a spectroscopy program on excited Λ baryons.

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Neutrino-nucleus scattering from a quantum Monte Carlo perspective

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Theoretical calculations of neutrino-nucleus scattering cross sections are critical for the success of the accelerator neutrino program, as experiments use nuclear targets in their detectors. I will present a nuclear quantum Monte Carlo protocol suitable to compute quasi-elastic lepton-nucleus inclusive scattering for moderate momentum transfer accurately. To tackle the high-momentum regime, I will discuss the development of an "extended factorization scheme"based on realistic spectral functions computed within quantum Monte Carlo that includes two-nucleon current and single-pion-production amplitudes. Finally, I will discuss their interplay with ACHILLES, a novel neutrino event generator we contribute to developing.

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Probing CP symmetry with polarised and entangled hyperons

Author: Karin Schönning[None]

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Why does our Universe contain so much more matter than antimatter? If not fine-tuned in the Big Bang, the abundance of matter must have been dynamically generated, e.g. through Baryogenesis. This, however, requires the existence of processes that violate charge conjugation and parity symmetry (CP). Hyperon decays have been proven a powerful diagnostic tool to study CP violation, thanks to the traceable spin. In particular, spin polarised and entangled hyperon-antihyperon pairs allow for high precision CP tests. However, since hadron decays occur through a complex interplay of strong CP conserving processes on the one hand and weak, possibly CP violating processes on the other, the latter may be diluted or completely hidden by the former. In a recent paper from the BESIII collaboration, a new method is outlined where sequentially decaying double-strange hyperon decays are utilized to separate strong and weak contributions. This method increases the sensitivity to CP violation by up to two orders of magnitude. In this talk, I will demonstrate this method and present the results when applied to data from BESIII. In addition, I will discuss the possibilities that come with the advent of the future PANDA experiment at FAIR.

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Evaluating evidence for baryons with light quark content

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Progress in understanding any aspect of nature is a "conversation" between measured quantities and theoretical models. As experiments get more accurate and sophisticated, models describing their results require to be more accurate and sophisticated; as new models are conceived, new experiments require to be performed to confirm or falsify predictions. Light baryon spectroscopy is no exception to this; what is notable in this field is that data have been collected over several decades from a wide variety of experiments, and the development of theoretical models in this period has undergone significant evolution. The resulting heterogeneity has a potential to lead to spurious results, so the time is now right to evaluate the available experimental evidence with the full power of modern statistical methodologies. This talk will discuss the available data for learning about the spectrum of baryons, and whether this data can be made self-consistent, such that comparison with theoretical models delivers the cleanest inference of the physics.

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Studies of baryon-baryon interaction at J-PARC

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Recent results and future plans at J-PARC on baryon-baryon interaction studies are presented.

We recently observed several new events of double-strange hypernuclei in the emulsion-counter hybrid experiment (E07) [1]. Observed events indicate a rather deep binding energy of Ξ in the ^{14}N nucleus. One of the events is interpreted as a bound state of Ξ in the nuclear 0s orbit, suggesting

that the ΞN-$\Lambda\Lambda$ interaction is unexpectedly weak [2]. Further Ξ-hypernuclear studies by missing mass spectroscopy of the (K^-, K^+) reaction (E70) will be conducted soon.

We also successfully carried out a high-statistics $\Sigma^{\pm}$-p scattering experiment (E40) [3]. In the $\Sigma^+ p$ channel, the obtained cross section was converted to the phase shift, showing that the $\Sigma^+ p$ interaction has a much stronger repulsive core than the NN interaction, which is interpreted as a result of Pauli principle in the quark level [4].

In the future, we plan to investigate the ΛNN three-body force via high-resolution Λ-hypernuclear spectroscopy. Together with high quality Λ-p scattering experiments, it allows us to solve the "hyperon puzzle"in neutron stars. Such studies will be performed using new secondary beam lines in the J-PARC Hadron Facility extension project [5].

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Exploring the potential role of diquarks in hadronization using SIDIS on nuclear targets

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Semi-Inclusive Deep Inelastic Scattering on nuclei offers a new way to gain microscopic information about the mechanisms of parton propagation and hadron formation in QCD. The interactions with the nuclear medium of the partonic and hadronic participants in the hadronization process can reveal features of that process at the femtometer distance scale. New data from CLAS on baryon hadronization in nuclei for the lambda baryon and for the proton may offer the potential of understanding more about the role of diquark correlations as a feature of nucleon structure, and more generally the in-medium interaction of colored qq pairs in the final state. Comparisons of the new data to the predictions of the GiBUU model, which generally describes meson production from nuclei quite well, intriguingly suggest that our picture of baryon production from nuclei is incomplete.

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Recent hadronic physics with astrophysical implications

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This talk will present some recent hadron physics results obtained from the MAMI (Germany) and JLAB (USA) intense photon beam facilities. New data which constrains our understanding of the hyperon-nucleon interaction will be presented, obtained via photoproduction and rescattering processes in light nuclear targets. In addition, the current status and future plans of the programme aiming to elucidate the nature of the d*(2380) hexaquark in photoproduction from deuterium targets will be presented. The potential implications of the new data for the study of astrophysical systems will be outlined.

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Plans for the JLab12 era and beyond

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During this talk, I will describe the research of Thomas Jefferson National Accelerator Facility (TJNAF, or JLab) where we explore the nature of QCD and matter at its most fundamental level of quarks and gluons. Understanding the amazing world inside a nucleon requires tremendous technical capabilities embodied in the large accelerator facility and advanced detector technology known as CEBAF (the Continuous Electron Beam Accelerator Facility). These capabilities allow us to peer inside the proton to understand the motion and structure of the quarks within. I will describe recent results coming from the 12 GeV era, and also our plans for new experimental capabilities at the facility. The versatility of CEBAF also allows for investigations that touch on other fields of science. For example, the MOLLER experiment will measure the parity-violating asymmetry in electron-electron scattering which will accurately determine the electroweak mixing angle. JLab also recently focused attention on astrophysical phenomena: for example, a precise measurement of the thickness of the neutron skin in Pb has implications in the astrophysics associated with neutron-star mergers. This interplay is but one demonstration of how the world of the small, even at the sub nuclear level, affects the most violent of collisions in the universe.

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Forging a Path for Understanding Nuclear Structure from Strong QCD

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The focus of our program –and hence this contribution –is to recast lessons learned over the last half of the 20th Century regarding the structure of atomic nuclei (primarily a particle-based picture) into a forward leaning 21st Century (field-theory-based framework) in anticipation that this will encourage the establishment of a natural bridge between the low-energy and medium-to-high energy nuclear physics communities. This has been and continues to be enabled by two major developments, the first technical (high-end computational facilities of the 90s) and the other analytical (underpinned by the so-called no-core ab initio –from first principles –shell-model theories). Early successes of the latter rest upon a realization that special symmetries and the associated algebraic methods that this enables are far better than previously anticipated. Consequently, this presentation includes a shallow dive into some key group theoretical concepts, and also shows some published results that exposes "simplicity within complexity" in atomic nuclei that has, until now, been under appreciated!

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Lattice-QCD studies of nuclei, and their electromagnetic properties

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The search for predictive capabilities in the study of hadronic reactions and nuclear structure from the Standard Model, which describes the strong and electroweak interactions in nature, is a defining challenge that bridges nuclear and particle physics. In this talk I will present some of the progress made in that direction by calculations using Lattice QCD (LQCD), a systematically improvable numerical technique based on solving the fundamental theory of the strong interaction, quantum chromodynamics, in a finite volume.

Within this framework, nuclear systems up to atomic number A = 5, including systems with non-zero strangeness, have been studied over the past decade, with a range of unphysically-large values of the quark masses. These LQCD calculations have been used to provide phenomenologically-important results and to constrain nuclear effective field theories, allowing constraints on larger nuclei and on the quark-mass dependence of nuclear forces and bindings.

With LQCD studies of nuclei progressing, the first attempts to investigate nuclear structure directly from the dynamics of quarks and gluons have also been made, complementing the existing body of experimental data, phenomenological modeling, and EFT analyses. The simplest aspects of the structure of nuclei are revealed through their static responses to external probes. During the last few years, we have performed a series of calculations of the responses of light nuclei to electromagnetic and weak fields, which define the most basic aspects of nuclear structure, at heavier than physical quark masses.

In this talk, I will report on the results obtained by the Nuclear Physics with LQCD collaboration on the structure and interactions of nuclei using LQCD.

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Towards the measurement of electromagnetic dipole moments of strange and charm baryons at LHC

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Baryon anticorrelations and the Pauli principle in Pythia

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Measuring the Production Cross Sections of the Ground State Cascade in Photoproduction

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Gravitational form factors of a quark in a dressed quark model.

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Definite Orbital Angular Momentum Nucleon GPD Contributions via Light Front Wave Function Overlap

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Properties of Pseudoscalar Mesons in a Contact Interaction

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The three-gluon vertex from quenched lattice QCD in Landau gauge

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Break between in-person and on-line contributions

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S-Wave spectroscopy of Ω0□ baryon in a relativistic Dirac formalism using the independent Quark model

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Flash-Talks Session / 284

Mott-polarimeter for electron transverse spin component in the BRAND experiment

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Perspective studies of charmonium, exotics and baryons with charm and strangeness

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Next to SV resummed prediction for pseudoscalar Higgs boson production at NNLO+NNLL

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Threshold effects for excited Xi baryons

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Study of static properties of Δ Baryon resonances in the relativistic potential model formalism

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Structure of X(3872) with hadronic potentials coupled to quarks

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Spectra and Decay Properties of singly beauty Baryons

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Strange particle production in Au+Au collisions at √sNN =14.6 GeV using AMPT and UrQMD.

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Emergence of mass in mesons and its relation with their parton distribution functions

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The proton mass is an emergent feature of QCD, as is the mass of the meson. Emergence of hadron mass provides the basic link between theory and observables. This presentation will sketch some of the theoretical developments in the use of Continuum Schwinger methods on mesons, focusing mainly on their parton distribution functions.