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Book of Abstracts

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Theoretical description of candidate chiral doublet bands in Ag isotopes

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The nearly degenerate doublet bands in odd-A nuclei Ag-105,107 and odd-odd nuclei Ag-104,108 are studied via the relativistic mean field (RMF) theory and multi-particle plus rotor model (PRM). From the configuration-fixed constrained triaxial RMF calculations, the favorable configurations and triaxial deformation for nuclear chirality are searched. Adopting PRM, the data available are reproduced for the doublet bands. Chiral geometry is further checked by analyzing the angular momentum components.

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Renormalization and power counting of chiral nuclear forces

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While applications of chiral perturbation theory (ChPT) to low-energy mesonic and meson-baryon systems have been understood very well and have led to fruitful results in explaining related phenomenology, the nonperturbative nature of low-energy nuclear physics very much obscures the way to implement a ChPT-based, model-independent effective theory for few-nucleon systems. Despite a couple of decades of endeavor, there yet exists a consistent chiral nuclear theory that is widely accepted. I will discuss our efforts to develop such a theory, emphasizing the constraints on power counting imposed by renormalization-group invariance.

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Recent progress towards a chiral effective field theory for the NN system

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Since Weinberg's proposal two decades ago, chiral effective field theory in the NN sector has been developed and applied up to order O((Q/M_hi)^4). In principle it could provide a model-independent description of nuclear force from QCD. However, in spite of its huge success, some open issues such as the renormalization group invariance and power counting, still remain to be solved. In this talk we refine the chiral effective field theory approach to the NN system based on a renormalization group analysis. Our results show that a truly model-independent description of NN system can be obtained by a new power counting which treats the subleading order corrections perturbatively.

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Symmetry breaking and determination of parton distributions of the nucleon

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Parton models of the nucleon predict several symmetries for the parton distribution functions of the nucleon, including flavour symmetry, charge symmetry, and quark-antiquark symmetry. We review theoretical calculations and experimental measurements for the breaking of these symmetries. We discuss implications of symmetry breaking studies on the determination of parton distribution functions of the nucleon.

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Roy-Steiner equations for pi N scattering

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Starting from hyperbolic dispersion relations for the invariant amplitudes of pion–nucleon scattering together with crossing symmetry and unitarity, we derive a closed system of integral equations for the partial waves of both the s-channel (\pi N->\pi N) and the t-channel (\pi\pi→\bar N N) reaction, called Roy–Steiner equations. We also solve the t-channel subsystem by means of Muskhelishvili–Omnès techniques and present preliminary results on the solution of the s-channel problem.

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Recent results from QCD sum rule analyses based on the maximum entropy method

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The maximum entropy method has recently been applied to QCD sum rules as a novel tool for extracting spectral functions without any artificial assumptions. After briefly outlining the essential features of this method, the results that have been obtained so far will be reviewed and the status of

ongoing studies will be presented. In this talk, a special focus will be laid on the behavior of various hadronic systems at high temperature or density.

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Studies of hypernuclei with the AMD method

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In this talk, we will discuss structure of Λ hypernuclei with mass number $A \simeq 20$, so called $p-sd$ shell Λ hypernuclei based on the antisymmetrized molecular dynamics (AMD) calculation.
One of the unique and interesting aspects of hypernuclei is structure change caused by hyperons as an impurity in nuclei. In p-shell Λ hypernuclei, experimental and theoretical studies have revealed a couple of interesting structure changes such as changes of deformation and shrinkage of the inter-cluster distance.
In sd-shell Λ hypernuclei, we can expect various structure changes depending on the structure of the core nuclei, since sd-shell normal nuclei have various structure such as pronounced cluster structure, triaxial deformation and coexistence of shell-model like and cluster structure in ground and low-lying states.
To reveal such phenomena, we have extended the AMD to hypernuclei. The AMD can describe various nuclear structures without any assumption on clustering and deformation of nuclei. In this talk, we will discuss possible structure changes by adding Λ in Be and Ne hypernuclei based on the AMD calculation. Furthermore, we will show a possibility to study the nuclear (triaxial) deformation of Mg by using Λ as a probe.

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Updated study of meson-baryon dynamics with strangeness -1 in a chiral framework

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I discuss the meson-baryon scattering processes with strangeness -1 within the unitarized chiral perturbation theory. Ten coupled channels are included in the discussion. By performing several sophisticated fits to a large amount of data, it enables us to give a strong constraint on the free parameters and the meson-baryon scattering amplitudes. We then study the uncertainty that is caused by using different strategies in the fits. We find that large error bars in the sub-threshold region of the K- p amplitude show up by either employing one weak pseudo-Goldstone decay constant or distinguishing between the decay constants of pi, K and eta. Finally, we study the poles from the S-wave amplitudes and pay special attention to the Lambda(1405) resonance.

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Compositeness of hadron resonances in chiral dynamics

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The structure of hadron resonances attracts much attention, in conjunction with recent observations of various exotic hadrons which are not well described in the conventional picture. However, it is a subtle problem to define a proper classification scheme for hadron structure, and the finite decay width of hadron resonances makes the analysis complicated. In this talk, we summarize recent developments in the investigations of structure of resonances, focusing on the notion of the compositeness of particles.

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Hyperon-nucleon interaction and baryonic contact terms in SU(3) chiral effective field theory

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We present results for hyperon-nucleon interactions at next-to-leading order in SU(3) chiral perturbation theory. The potential includes contributions from one- and two-meson exchange diagrams as well as contact terms with SU(3) symmetric low-energy constants. These results provide a new basis for studies of hypernuclei or hyperons in nuclear matter. In more detail we explain the construction of the four-baryon contact Lagrangian within SU(3) chiral perturbation theory up to order q^2 in a covariant power counting. The constructed terms are invariant under charge conjugation, parity transformation, Hermitian conjugation and local chiral transformations. Terms including Goldstone bosons as well as external fields are considered. Furthermore we derive the leading order six-baryon contact terms in the non-relativistic limit and study their contribution to ΛNN three-body contact forces.

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Hyperfine Structure of Ground-State Nucleon in Chiral Quark Model

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The hyperfine structure of ground-state nucleon is studied in chiral quark model with nonlinear pion interaction in which
quarks move in the potential of Coulomb-like plus linear form. The mass splitting of ground-state nucleon is
reproduced by taking into account the colour magnetic interaction between quarks and found to be in agreement with data. The
connection of the model with the bag models is discussed

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New Hidden beauty molecules predicted by the local hidden gauge approach and heavy quark spin symmetry

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Using a coupled channel unitary approach, combining the heavy quark spin symmetry and the dynamics of the local hidden gauge, we investigate the meson-meson interaction with hidden beauty and obtain several new states. Both I=0 and I=1 states are analyzed and it is shown that in the I=1 sector, the interactions are too weak to create any bound states within our framework. In total, we predict with confidence the existence of 6 bound states, and weakly bound 6 more possible states. The existence of these weakly bound states depend on the influence of the coupled channel effects.

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Thermodynamics of hadrons using the Gaussian functional method in the linear sigma model

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We investigate thermodynamics of hadrons using the Gaussian functional method (GFM) at finite temperature. Since the interaction among mesons is very large, we take into account fluctuations of mesons around their mean field values using GFM. We obtain the ground state energy by solving the Schroedinger equation. The meson masses are obtained using the energy minimization condition. The resulting mass of Nambu-Goldstone (NG) boson is not zero even in the spontaneous chiral symmetry broken phase due to the non-perturbative effect. We consider then the bound state of mesons using the Bethe-Salpeter equation and show the NG theorem is recovered. We investigate further the behavior of the meson masses and the mean filed value as functions of temperature for the cases of chiral limit and explicit chiral symmetry breaking.

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The new charged charmonium state Zc(3900) from BES and Belle

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Recently BESIII and Belle collaborations working independently at two different particle accelerators have found evidence of what appears to be a four-quark particle that has come to be called Zc(3900). Both their research findings have been published in separate papers in the journal Physical Review Letters. In my this report, I will show the experimental details on Zc(3900) from BESIII and Belle measurements; at the same time, I will give a summary of its possible theoretical explanation up to now.

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Regge trajectory of the f0(500) resonance from a dispersive connection to its pole

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Our results on obtaining the Regge trajectory of a resonance from its pole in a scattering process and from analytic constraints in the complex angular momentum plane will be presented. The method, suited for resonances that dominate an elastic scattering amplitude, has been applied to the rho(770) and the f0(500) resonances. Whereas for the former we obtain a linear Regge trajectory, characteristic of ordinary quark-antiquark states, for the latter we find a non-linear trajectory with a much smaller slope at the resonance mass. We also show that if a linear trajectory with a slope of typical size is imposed for the f0(500), the corresponding amplitude is at odds with the data. This provides a strong indication of the non-ordinary nature of the sigma meson.

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Present status of light scalars

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I will review the status of light scalars, paying particular attention to the precision dispersive determinations of their parameters and the dramatic changes in the latest edition of the PDG for the f0(500) or sigma meson.

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Exotic dibaryons with a heavy antiquark

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The hadron-nucleus systems are interesting and important topics in the hadron and nuclear physics. Recently, there have been many studies for the hadronic few-body states in light flavor sector, and these interesting phenomena caused by the impurity effects, e.g. glue-like effects and high-density states, have been discussed.

We discuss the possible existence of exotic dibaryons with a heavy antiquark,
and investigate three-body systems, Dbar()*NN and B()*NN.
The specific feature of such Dbar (B) nuclei is the exotic flavor
structure.
These bound states are genuinely exotic states with no quark-antiquark annihilation.
We emphasize that there is no corresponding states in strangeness sector, e.g. KNN, because the interaction between a K meson and a nucleon is repulsive.
We consider the one pion exchange potential (OPEP) between a heavy meson P(*) and a nucleon N, where P()*=Dbar(*) and B()*.
Thanks to the mass degeneracy between P and P*mesons, the OPEP is enhanced and produces a strong attraction.
As for the NN interaction, we employ the Argonne v'_8 potential.
By solving the coupled channel equations for PNN and P**NN channels,
we obtain bound and resonant states.
As a consequence, we find bound states for (I,J^P)=(1/2,0^-) as well as resonant states for (I,J^P)=(1/2,1^-) both in Dbar()*NN and B()*NN systems.
It is turned out that the tensor force of OPEP mixing PN-P*N channels plays an important role to yield a strong attraction.

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$rhoK\bar{K}$ system within the Framework of the Fixed Center Approximation to Faddeev equations

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We perform a calculation for three body $\rho K\bar{K}$ scattering amplitude by using the fixed-center approximation to Faddeev Equations, taking the interaction between ρ and $\bar{K}$, ρ and K from the chiral unitary approach. We find a peak in the modulus squared of the three-body scattering amplitude, indicating the existence of resonance which can be associated to $\rho(1700)$. The mass is around 1700 MeV, and the width is smaller because we do not explicitly consider possible two body decay channels, which, as in other three body states studied along the same lines, play a small role in the structure of the states, but provide the natural decay channels because of the available phase space to produce these decay states.

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Few-body structure of light hypernuclei

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One of the main goals of hypernuclear physics is to investigate the hyperon-nucleon (YN) and hyperon-hyperon(YY) interactions. Interesting and important hypernuclear few-body problems contribute. To solve the three- and four-body problem precisely, we employ Gaussian Expansion method (GEM) [1], which has been successfully applied to calculate
properties of various bound three- and four-body systems. The basis fucntions describe well both short-range correlations and the long-range tail. Here we emphasize what is interesting and important from the view point of hypernuclear physics.

(i) It is one of important subject to discuss about ΛN charge symmetry breaking effect. For this purpose, the binding energies of $^{10}_{\Lambda}$Be and $^{10}_{\Lambda}$B are calculated with the framework of $\alpha + \alpha + \Lambda + N$ four-body model.

(ii) Recently, it was observed a neutron-rich Λ hypernuclues, $^{6}_{\Lambda}$H [2].
To structure of this hypernucleus, we performed four-body calculation of $t + \Lambda + n + n$. In the conference, we discuss about our result and new experimental data.

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Understanding the new hidden heavy flavor states in a chiral quark model

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We report results from our recent systematic study of the systems of DDbar, BBbar, BB*bar, B*B*bar,* *DD*bar, D*D*bar et. al. in a chiral quark model. The possiblity of the existences of bound states or molecular stats of those meson-meson systems will be discussed, and the possible explanation for the structures of Zb(10610), Zb(10650), X(3872), Y(3940), Y(4260), Zc(3900) will be addressed.

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Ab initio no core shell model for light nuclei

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Using one of the latest chiral N-N potentials, we study the properties of 6Li in the frame work of ab initio no core shell model.

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Two-nucleon scattering in effective field theory: searching for the power counting.

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In this talk I consider the two-nucleon system from the effective field theory viewpoint. In particular, I address the problem of constructing a sensible expansion of the scattering amplitude that is able to reconcile the requirements of (i) renormalizability, (ii) the existence of a well-defined power counting at the level of observable quantities and (iii) phenomenological success. Using the proposal of Nogga, Timmermans and van Kolck [1] as a starting point, I show how these conditions can be met by perturbatively renormalizing the chiral two pion exchange contributions to the nuclear force [2,3]. The explicit next-to-next-to-leading order computations show that the present scheme leads to a good description of the phase shifts, comparable with the results obtained in the Weinberg counting at the same order [4,5], but free of the usual inconsistencies generated by the full iteration of chiral nuclear forces [6]. Further aspects of the theory, such as the convergence rate, the expansion parameter, or the power counting
in deuteron reactions, will be briefly discussed [7].

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[7.] M. Pavon Valderrama, D.R. Phillips (in preparation)

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Search for deeply-bound $\bar{K}$-nuclear states via the $^3He(inflght - K^-, N)$ reaction at J-PARC

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As the latest effort to search for deeply-bound $\bar{K}$-nuclear states, E15 experiment has been carried out at K1.8 branch beam line at J-PARC. $^3He(inflght - K^-, N)$ reaction was employed to search for the simplest K-nuclear bound state, K−pp. An exclusive measurement is performed with the in-flight 3He(K−, n) reaction, which allows us to investigate the K−pp bound state both in the formation via missing-mass spectroscopy and its decay via invariant-mass spectroscopy using the emitted neutron and the expected decay, K−pp → Λp → π−pp, respectively. In additon to the 3He(K-,n), the 3He(K-,p) reactions was also measured with the K1.8BR spectrometer to investigate the isospin dependence of the kaon-nucleus K-NN interaction. In this presentation, preliminary results of 3He(K-,N) spectra obtained in the first physics-run will be presented.

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100MeV/u 12C+12C scattering

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Recently theoretical development of optical potential suggests a method to study the repulsive nature due to the three-body-force. Thus it is important to explore the repulsive nature of nucleus-nucleus interaction experimentally. The repulsive nature of the interaction can be observed as a change of diffraction pattern of the elastic scattering. We have finished the experiment of 100MeV/u 12C+12C to measure the angular distributions of elastic and inelastic scattering by using the magnetic spectrometer "Grand Raiden" at RCNP, Osaka University. We observed the angular distributions of ground states and three excited states. By comparing the theoretical results, maybe we found the obvious three-body-force effect.

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Phase transition into spontaneous chiral symmetry breaking

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Exploration of spontaneous time-reversal symmetry breaking in nuclear physics –widely known as nuclear chirality –is the subject of intensive theoretical as well as experimental study since more than
one decade. At the beginning of the present century structures resembling theoretically predicted chiral partner bands were identified in several nuclei with help of gamma correlation measurements[1,2]. The origin of these bands have been than verified by applying lifetime
measurements methods [3,4,5, 6] leading to discovery of first chiral nuclei in nature[3].
At present the gamma spectroscopy focuses its interest in search of new mass regions where appearance of nuclear chirality is pronounced as well as in study of electromagnetic features of chiral nuclei like –gamma selection rules[7, 8] and search for chiral phase transition in form of critical rotational frequency. The letter one will be the main subject of the presentation.

Summary:

It is expected that the transition into the chiral configuration happens rapidly as a function of total angular momentum at some critical rotational frequency[9]. Some experimental premises like staggering of energies of partner bands levels indicating existence of chiral phase transition will be discussed.

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The Proton Spin Problem; Measurements of Octet Spin Fractions from Lattice QCD

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The 1987 discovery by the European Muon Collaboration, that only a small fraction of the spin of the proton may be attributed to the spin of its three constituent quarks, sparked decades of careful experimental investigation of the phenomenon. Despite extensive efforts, there is no consensus that the so-called 'proton spin crisis' has been adequately resolved.
The fraction of the spin of the proton carried by its quarks currently stands at 33 ± 3 ± 5%, if one relies on SU(3) symmetry for the octet axial charge. This is a dramatic suppression with respect to the value of 100% expected in a naive quark model, or even the 65% expected in a relativistic quark model.
A number of possible theoretical explanations have been offered for the observed suppression, ranging from a key role for the axial anomaly, to the effect of gluon exchange currents, chiral symmetry and, in the light of insights gained from lattice QCD studies, a combination of both of these effects. It is clearly of great use to be able to place some constraint on candidate explanations of this remarkable phenomenon.
We discuss recent work based on lattice QCD simulations from the QCDSF/UKQCD Collaboration. The quark spin content of the octet baryons extracted from the lattice results displays striking variation across the baryon octet. Within the relatively large uncertainties, this observation is supported by the predictions of a model that incorporates the relativistic motion of valence quarks, the pion cloud required by chiral symmetry and an exchange current contribution associated with the one-gluon-exchange hyperfine interaction.
The results do not support the hypothesis that the spin suppression observed for the proton is a universal property. It is therefore of considerable interest to investigate further the predictions of models in which the suppression of the spin carried by quarks is dependent on baryon structure.

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Analysis of strong decays of the charmed mesons $D_J(2580)$, $D_J^*(2650)$, $D_J(2740)$, $D_J^*(2760)$, $D_J(3000)$, $D_J^*(3000)$

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In this article, we tentatively identify the charmed mesons $D_J(2580)$, $D_J^*(2650)$, $D_J(2740)$, $D_J^*(2760)$, $D_J(3000)$, $D_J^*(3000)$ observed by the LHCb collaboration according to their spin, parity and masses, then study their strong decays to the ground state charmed mesons plus light pseudoscalar mesons with the heavy meson effective theory in the leading order approximation, and obtain explicit expressions of the decay widths. The ratios among the decay widths can be used to confirm or reject the assignments of the newly observed charmed mesons. The strong coupling constants in the decay widths can be fitted to the experimental
data in the future at the LHCb, BESIII, KEK-B and PANDA.

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Dynamically generated resonances from the vector octet-baryon octet interaction in the strangeness zero sector

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The interaction potentials between vector mesons and baryon octet are calculated explicitly with a summation of t-, s-, u- channel diagrams and a contact term originating from the tensor interaction. Some resonances are generated dynamically in different channels of strangeness zero by solving the Bethe-Salpeter equation in a coupled-channel unitary approach, and their masses, decay widths, isospins and spins are determined. Some of them are well fitted with their counterparts listed in the newest review of Particle Data Group, while others might stimulate the experimental observation in these energy regions in the future.

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The predictions of Psi(nS) and Upsilon(nS) decays based on the molecular structure

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Based on previous studies that support the vector-vector molecular structure of some tensor states generated dynamically from the interaction of pairs of more elementary hadrons,we firstly study the J/Psi decay and compare with the experimantal data available, then we make some predictions for Psi(nS) and Upsilon(nS) decays.

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Heavy quark spin structure in hidden charm molecules

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Recent observations of exotic charmonium-like mesons above the $D\bar{D}$ threshold triggered heated discussions on their inner structures. The meson-antimeson molecule is a popular picture in understanding their properties. It has been proposed that the X(3872) is an S-wave $D\bar{D}^*$ molecule since its extreme closeness to the threshold. Although the charm quark and the anti-charm quark belong to different mesons, their total spin is one, which is called "heavy quark spin selection rule". We extend the study to general meson-antimeson case. In the heavy quark limit, we construct explicitly the spin wave function of an S-wave meson-antimeson system. By recoupling the wave function, we find that there are two cases that the $c\bar{c}$ spin cannot be 0: (a) the total spin of the system is larger than the maximum value of the total angular momentum of the light degree of freedom or smaller than the minimum one; (b) the spin and C-parity of the system are odd and positive, or even and negative, respectively, if the two mesons are different but belong to the same doublet. The heavy quark spin symmetry implies that the $c\bar{c}$ spin is conserved in the strong decay of the system, which may give some constraints on the decay channels.

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Double Lambda hypernuclei at J-PARC

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Double Lambda(L) hypernuclei at J-PARC

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Double-L hypernuclei give us information about the L-L interaction which is valuable for unified understanding of Baryon-Baryon interaction in SU(3)-flavor symmetry. Nuclear physics with double strangeness also guides us to multi-strangeness systems such as "strange matter" and is closely related to the H-dibaryon. However experimental knowledge is very limited so far.
Recently, we have succeeded to detect nearly one thousand events with Xi- hyperon capture at rest in nuclear emulsion. Among them, production and decay topology of double-L hypernucleus has been shown in 7 events. Regarding uniquely identified Nagara event (LL6He), although it was published in PRL(2001) [1], the binding energy (B_LL) and the interaction energy (DB_LL) of two Lambda hyperons should be revised due to the change of the mass of Xi- hyperon by 0.4 MeV in Particle Data (2008). Under the check of the consistency of the DB_LL with that of Nagara event, other three events, named Mikage, Demachi-yanagi and Hida event, were found to be LL6He, LL10Be and (LL11Be or LL12Be) as the most probable nuclear species, respectively [2, 3].
We developed a fast system for overall scanning of the emulsion to detect more events of double-L hypernuclei, very recently. The system consists of taking microscope image in whole area of the emulsion and the image processing so as to pick up the topologies of production and the decay of double-L hypernuclei with multi-vertices. The scanning is on-going for the emulsion of the E373 experiment and we detected some new events with double units of strangeness.
At J-PARC, we will carry out the E07 experiment which can provide nearly 10ˆ2 double-L hypernuclei with newly developed hybrid-emulsion method. In the experiment, we will use 2.1 t emulsion gel and measure X rays from Xi-atom to study Xi-N interaction for the first time.
In our contribution, we will discuss the B_LL and the DB_LL using data of the above nuclei and newly found candidate events of double-L hypernuclei which are introduced in International Symposium for the first time. Brief introduction of E07 at J-PARC shall be also discussed.

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Reanalysis of the $e^+e^- \to (D^*\bar{D}^*)^\pm\pi^\mp$ reaction and the claim for the $Z_c(4025)$ resonance.

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In this paper we study the reaction $e^+e^- \to (D^*\bar{D}^*)^\pm\pi^\mp$ in which the BESIII collaboration has claimed the existence
of a 1^+ resonance, named $Z_c(4025)$, in the $D^*\bar{D}^*$ invariant mass spectrum with a mass around 4026

MeV and width close to 26 MeV . We determine the $D^*\bar{D}^*$ invariant mass distribution and find that although the explanation considered by the BESIII collaboration is plausible, there are others which are equally possible, like a 2^+ resonance or a bound state. Even more, we find that the data can be explained without the existence of a resonance/bound state. In view of the different possible interpretations found for the BESIII data, we try to devise a strategy which could help in identifying the origin of the signal reported by the BESIII collaboration. For this, we study the dependence of the $D^*\bar{D}^*$ spectrum considering the different options as a function of the total center of mass energy. We arrive to the conclusion that increasing the center of mass energy from 4.26 GeV to 4.6 GeV can be useful to distinguish between a resonance, a bound state or just a pure background as being responsible for the signal found. This information should be useful for future experiments.

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The $f_0(1790)$ and $f_0(1800)$ puzzle

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I will present the results of our works on f_0 mesons with mass around 1700-1800. From some recent results available from the BES collaboration, it seems that two new f_0 resonances exist with masses around 1800 MeV. One of them has been found in the two pion mass spectrum and the decay of the same has been found to be suppressed to K anti-K system. While the other has been found in the $\phi\omega$ mass spectrum in the process $J/\Psi \to \gamma\phi\omega$. I will discuss that the first one is indeed a new state which can be understood as a \pi\pi f_0(980) resonance, while the other is a manifestation of the well known f_0(1710) resonance.

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Recent developments on LQCD studies of nuclear force

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Nuclear force is one of the fundamental problems in physics even though it has been recognized that quantum chromodynamics (QCD) is the theory of the strong interaction. Although nucleons are not true fundamental building blocks of atomic nuclei but compositions of quarks and gluons, the description of nuclei in terms of nucleonic degrees of freedom provides successful results. The hyperon-nucleon (YN) and hyperon-hyperon (YY) interactions are fundamental inputs to study the properties of hypernuclei and the hyperonic matter inside the neutron stars. However, in contrast to the normal nuclear force where the modern nucleon-nucleon (NN) potentials together with three-nucleon forces have been used for precise calculations of light nuclei, scattering experiments for YN and

YY are either difficult or impossible due to the short life-time of hyperons. Phenomenological YN and YY potentials are not well constrained from experimental data. Under these circumstances, the lattice QCD would be a valuable theoretical tool to make a first-principle calculation of nuclear forces. In this contribution, we would like to present the lattice QCD calculation to study the baryon-baryon interaction of the strangeness S=-1 system.
We would also like to present a stochastic variational calculation for four-nucleon bound state problem by using a lattice nucleon-nucleon interaction comprising the central and the tensor potentials.

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Decays of doubly charmed meson molecules

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Several observed states close to the $D\bar{D}^*$ and $D^*_{(s)}\bar{D}^*_{(s)}$ thresholds, as the X(3872) and some XYZ particles can be described in terms of a two-meson molecule. Furthermore, doubly charmed states are also predicted. These new states are near the D^*D^* and $D^*D^*_s$ thresholds, and have spin-parity $J^P = 1^+$. Their natural decay modes are $D_{(s)}D^*$, $DD_{(s)}\pi$ and $DD_{(s)}\gamma$ and $D^*D_{(s)}\gamma$. We evaluate the widths of these states, named here as $R_{cc}(3970)$ and $S_{cc}(4100)$, and obtain 44 MeV for the non-strangeness, and 24 MeV for the doubly charm-strange state. Essentially, the decay modes are $DD_{(s)}\pi$ and $DD_{(s)}\gamma$, being the $D\pi$ and $D\gamma$ emitted by one of the D^* meson which forms the molecule.

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A study of $\eta K\bar{K}$ and $\eta' K\bar{K}$ with the fixed center approximation to Faddeev equations

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In the present work we investigate the three-body systems of $\eta K\bar{K}$ and $\eta' K\bar{K}$, by taking the fixed center approximation to Faddeev equations. We find a clear and stable resonance structure around 1490 MeV in the squared $\eta K\bar{K}$ scattering amplitude, which is not sensitive to the renormalization parameters. Conversely, we get only an enhancement effect of the threshold in the $\eta' K\bar{K}$ amplitude that indicates the difficulty to bind the $\eta' K\bar{K}$ system as a consequence of a weaker $\eta' K$ interaction than the ηK one. We associate the $\eta K\bar{K}$ state found to the $\eta(1475)$.

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Scattering lengths of Nambu-Goldstone bosons off D mesons and dynamically generated heavy-light mesons

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Recent lattice QCD simulations of the scattering lengths of Nambu-Goldstone bosons off the D mesons are studied using unitary chiral perturbation theory. We show that the LQCD data are better described in the covariant formulation than in the heavy-meson formulation. The $D^*_{s0}(2317)$ can be dynamically generated from the coupled-channels DK interaction without a priori assumption of its existence. A new renormalization scheme is proposed which manifestly satisfies chiral power counting rules and has well-defined behavior in the infinite heavy quark mass limit. Using this scheme we predict the heavy-quark spin and flavor symmetry counterparts of the $D^*_{s0}(2317)$.

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Parity violation in proton-proton scattering in chiral effective field theory

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The observation of parity violation in the weak interaction is one of the pillars on which the Standard Model of particle physics was built. Despite the solid theoretical foundation, the manifestation of parity violation in hadronic and nuclear systems is not fully understood. This problem mainly arises due to the nonperturbative nature of QCD at low energies. In the last decades tremendous progress has been made in understanding low-energy strong interactions by use of effective field theories. This understanding has made it possible to calculate hadronic and nuclear observables in a controlled fashion.

In this talk, I will present a recent calculation of the parity-violating longitudinal asymmetry in proton-proton scattering. The calculation is performed in the framework of chiral effective field theory which is applied systematically to both the
parity-conserving and parity-violating interactions. By careful comparison to the existing low- and medium-energy data, it is possible to model-independently pin down an allowed range for the not-well-known, but important, parity-odd pion-nucleon
coupling constant h_π. I will discuss how this range compares to theoretical limits and limits obtained from different experiments.

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The high order chiral Lagrangian

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Chiral Lagrangian is a very effective tool to deal with the low-energy pseudoscalar mesons where the low-energy constants (LECs) play the important role and very difficult to be estimated. To increase the precision of chiral Lagrangian, we need to manage the high orders, which include hundreds of LECs. There are numerous operators and constraint conditions in the high orders. Up to now, all of the p6 order structures of the chiral Lagrangian have been given, including the two and three flavors, the normal and anomalous parts, and the tensor sources parts. We review the main methods to search these constraint conditions, emphasis the method to obtain the high orders of chiral Lagrangian, introduce our method to compute all the LECs up to order of p6, with Schwinger-Dyson proper time method and some approximations, including the large-Nc limit, the improved, ladder approximation, and the leading order in dynamical perturbation theory. All the LECs are expressed in terms of the quark self-energy. Finally, we compare our results with others.

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Massive Hybrid Stars with Strangeness

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Recent observations of the $2M_{sun}$ mass neutron stars (NSs; e.g. PSR J1614-2230, PSR J0348+0432) present a challenging problem how to explain the existence of such massive NSs. This problem is serious since massive NSs demand a very stiff equation of state (EOS) of underlying dense matter and on the contrary every transition to the exotic new phases proposed so far, including pions, kaons, hyperons or quarks in dense matter, leads to a remarkable softening of the EOS, clearly contradicting observations. In particular, the strangeness degrees of freedom (namely hyperon (Y) mixing) in NS cores causes a dramatic softening of the EOS and thereby the corresponding NS maximum-mass (M_{max}) fails to exceed even by far smaller mass, 1.44 solar mass observed for PSR 1913+16.
In this paper, we address how $M_{max}\gsim 2M_{sun}$ is made possible by introducing a new degrees of freedom, i.e., the hadron (H)-quark (Q) transition in NS cores and by a new approach not restricted to the conventional Gibbs or Maxwell condition. Our new strategy is to divide the EOS into three density (ρ) regions [1] [2], i.e., H-EOS for $\rho\lsim\rho_H$, HQ-EOS for $\rho_H\lsim\rho\lsim\rho_Q$ and Q-EOS for $\rho\gsim\rho_Q$ characterized as three-window model. This is motivated by the consideration that pure hadronic EOS becomes uncertain with increasing ρ because of finite size hadrons composed quarks and also pure quark matter EOS gets unreliable due to the deconfined-confined transition with decreasing ρ. Therefore, to discuss the HQ transition by extrapolating the pure H-EOS from lower density side and Q-EOS from higher density side is not necessarily justified. Our basic idea is to supplement the very poorly known HQ-EOS by sandwitching it in between the relatively certain H-EOS and Q-EOS and construct the HQ-EOS by a phenomenological interpolation. We use a realistic H-EOS from a G-matrix-based effective interaction including Y and take the Q-EOS from NJL model with repulsion from a vector interaction.
It is found that $M_{max} \sim (2\text{-}3)M_{sun}$ is possible as far as $\rho_H \sim 2\rho_0$, $\rho_Q \sim (5\text{-}7)\rho_0$ ($\rho_0=0.17$ fm^{-3} being the nuclear density) and Q-EOS is stiff. To be more realistic, we try to construct the EOS in a same manner but with a crossover HQ transition from a percolation picture, finding $M_{max}\gsim 2M_{sun}$ is possible [2].

[1] T. Takatsuka, T. Hatsuda and K. Masuda, AIP Proceedings 1484 (NY, 2012) 406.
[2] K. Masuda, T. Hatsuda and T. Takatsuka, ApJ. 794 (2013) 12; Prog. Theor. Exp. Phys. 073D01 (2013).

Summary:

1. To summarize,
(1) The EOS with hadron-quark transition is constructed by a new approach characterized as the 3-window model (H, HQ, Q regions) and applied to hybrid stars.
(2) The EOS brings about M_{max}\gsim2M_{sun}, almost irrespectively to the interpolation function for HQ region.
(3) Hybrid star as massive as M\gsim2M_{sun} is possible under the condition:
· Hadron (H)-quark (Q) transition sets on at relatively low density (about 1.5×nuclear density).
· Strongly correlated quark matter with the repulsion from a vector type interaction is existent.
(4) Realization of a large mass is caused by a stiffened EOS at \rho ~ (2-5)\rho_0 due to the HQ transition.
(5) Quite similar results are obtained by a more plausible case where the HQ transition is assumed to occur as a smooth crossover transition from a percolation picture.

2. In an extended framework of H plus Q degrees of freedom, hybrid stars based on the EOS with HQ transition are found to be as massive as M\gsim2M_{sun}, which opens the possibility to reconcile a current viewpoint of a softened EOS (due to the transition to a new phase with exotic components) with the stiff EOS demanded from observations.

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Studies of Chirality in the mass 80,100 and 190 regions

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[1] *iThemba LABS*

Recent results from investigations into nuclear chirality based on experimental work at iThemba LABS is reviewed. New results[1], obtained using the AFRODITE array, for 194Tl show a pair of four-quasiparticle bands featuring what is perhaps the best example so far of chiral energy degeneracy. In the mass 100 region, the nucleus 106Ag has been revisited with extensive additions to the level scheme and measurements of transition rates. Like 134Pr, it is a case where a crossing occurs between chiral candidate bands. In this case, gamma-softness was conjectured to play a role[2]. Our results suggest a completely different interpretation, where the excited partner band is actually of four-quasiparticle structure, itself a member of a chiral-vibrational structure.

[1] P.L. Masiteng et al, PLB 719, 83 (2013)
[2] P. Joshi et al PRL 98, 102501 92007)

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Tensor force and Deltas for the structure of light nuclei

Author: Kaori Horii[1]

Co-author: Hiroshi Toki [2]

[1] *Research Center for Nuclear Physics, Oska University*

[2] *RCNP, Osaka University*

It is important to understand the structure of nuclear many-body systems in terms of the bare nucleon-nucleon interactions. In addition, it is necessary to include the effects of three-body force in many-body nucleon system. In this study we treat explicitly Δ(1232) isobar degrees of freedom in the bare interaction, which can be the origin of the three-body forces via the pion exchange. We adopt the Argonne delta model potential(AV28) and study the explicit role of Δ in nuclei. It is surprising that the additional Δ states generate strong tensor interactions though the transitions between N and Δstates, and change various matrix elements from the results of the only nucleon space.

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Strongly tensor correlated Hartree-Fock theory on finite nuclei and nuclear matter

Author: Hiroshi Toki[1]

[1] *RCNP, Osaka University*

We have developed a new framework for the treatment of tensor interaction in the Hartree-Fock (HF) theory for nuclear many body system. The tensor interaction plays an important role for the formation of nuclei. However, we cannot include the tensor interaction in the HF space. We extend the HF space by including two particle- two hole states (2p-2h) for the tensor interaction to provide finite and essential contributions. We name this framework as strongly tensor correlated Hartree-Fock (STCHF) theory and apply it to nuclear matter and finite nuclei. We get good results for nuclear matter when treated in the relativistic framework.

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Rotation induced Chirality in Triaxial Nuclei

Author: Stefan Frauendorf[1]

[1] *Department of Physics, University Notre Dame*

The emergence of chirality in rotating triaxial nuclei will be discussed based the concept of spontaneous symmetry breaking. Differences and similarities with the chirality of molecules will be exposed. Microscopic mean field approaches for identifying chiral configurations (TAC, CRMF) will be reviewed. Using examples of observed chiral partner bands, the dynamical character of nuclear chirality will be demonstrated. New developments for describing the large-amplitude tunneling mode will be discussed.

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Charge symmetry violation in moments of the nucleon PDFs

Author: Ross Young[1]

[1] *The University of Adelaide*

TBA

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Recent theoretical developments in chirality in atomic nuclei

Author: Shuangquan Zhang[1]

[1] *School of Physics, Peking University*

TBA

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Quantum kinetic approach to chiral magnetic effect

Author: Qun Wang[1]

[1] *Univ. of Science and Tech. of China*

We derive a relativistic chiral kinetic equation with manifest Lorentz covariance from Wigner functions of spin-1/2 massless fermions in a constant background electromagnetic field. It contains vorticity terms and a 4-dimensional Euclidean Berry monopole which gives axial anomaly. By integrating out the zero-th component of the 4-momentum p, we reproduce the previous 3-dimensional results derived from the Hamiltonian approach, together with the newly derived vorticity terms. The phase space continuity equation has an anomalous source term proportional to the product of electric and magnetic fields ($F_{\sigma\rho}\tilde{F}^{\sigma\rho} \sim E_\sigma B^\sigma$). This provides a unified interpretation of the chiral magnetic and vortical effects, chiral anomaly, Berry curvature, and the Berry monopole in the framework of Wigner functions.

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How to distinguish a molecular state from an ”elementary particle”

Author: Hanqing Zheng[1]

[1] *Peking University*

TBA

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From QCD to Nuclear Physics

Author: Andre Walker-Loud[1]

[1] *The College of William and Mary*

Lattice QCD offers the promise of quantitatively connecting low-energy nuclear physics with the fundamental theory of strong interactions. Significant progress in achieving this goal has been made in the last few years, with, for example, the first definitive calculations of light nuclei recently appearing. There remain significant challenges which must be overcome to connect these calculations to experimental results, including the ability to perform calculations with physical pion masses. I will review lattice QCD calculations of multi-hadron systems, providing a status report as well as future prospects.

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Effect of the tensor force in nuclei

Author: Isao Tanihata[1]

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The tensor force is included in a large amplitude in pion exchange interactions. The importance of the tensor force is known in light nuclei where ab-initio type calculation of nucleus can be made. However the mean field model or the shel model that describe the heavier nuclei do not include the tensor force explicitly. One of the most important effect of the tensor force is the creation of the large momentum nucleons in a nucleus that gives a large binding energy. Recently we have studied a neutron pick up reaction at high energy and observed an evidence of the high momentum component related to the tensor force. Relation between tensor forces and nuclear structure and the new measurement will be presented.

63

Spectroscopy of Heavy Quark Hadrons

Author: Makoto Oka[1]

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Recent developments of heavy hadron spectroscopy have revealed existence of new types of hadrons, which are not simply accounted as qqbar or qqq. I focus on a few topics of heavy hadron spectroscopy, i.e., heavy baryon spectroscopy and its significance in QCD, and heavy quark exotic hadrons.

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Recent progress on dynamically generated meson and baryon resonances

Author: Eulogio Oset[1]

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A sort review is made of the local hidden gauge approach to hadron interactions, extrapolating the chiral Lagrangians to the vector sector and showing how mesonic and baryonic resonances are generated. Then I shall discuss a new BES reaction on J/psi -> eta K*K*bar, from where evidence is obtained of one h_1 resonance predicted from the vector-vector interaction. Similarly, I shall discuss an new ELSA reaction, gamma p -> K^0 Sigma^0, which provides evidence for one of the baryon resonances predicted from the vector-baryon interaction. Then I shall discuss the generation of resonances in the charm and beauty sectors.

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Life on Earth - an accident?

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In this talk, I discuss the generation of carbon as a function of the parameters of QCD+QED. First, in the framework of chiral effective field theory, the quark mass dependence of the nuclear forces and the constraints on possible quark mass variations from Big Bang Nucleosynthesis are discussed. Second, using nuclear lattice simulations, I investigate the fine-tuning of the fundamental parameters of QED+QCD that is consistent with the bounds on carbon production through the triple-alpha process in stars.

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Low energy reaction K^-p and the negative parity resonances

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The reaction K−p → η at low energies is studied with a chiral quark model approach. Good descriptions of
the existing experimental data are obtained. It is found that (1670) dominates the reaction around threshold.
Furthermore, u- and t-channel backgrounds play crucial roles in this reaction as well. The contributions from
the D-wave state (1690) are negligibly small for its tiny coupling to η. To understand the strong coupling
properties of the low-lying negative parity resonances extracted from the ¯KN scattering, we further study their
strong decays. It is found that these resonances are most likely mixed states between different configurations.
Considering these low-lying negative parity resonances as mixed three-quark states, we can reasonably understand
both their strong decay properties from Particle Data Group and their strong coupling properties extracted
from the ¯K N scattering. As a byproduct, we also predict the strong decay properties of the missing D-wave
state |3
2
−i3 with a mass of ~ 1.8 GeV. We suggest our experimental colleagues search it in the (1385)π and π channels.

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Hadronic Form Factors From Schwinger-Dyson Equations

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Abstract: Experimental efforts like the ones in Jefferson Laboratory, Babar Experiment and Belle Experiment have contributed importantly in the last few years towards our improved understanding of the mesonic form factors. The 12 GeV upgrade of the Jefferson Laboratory holds further promise to chart out mesoninc as well as baryonic form factors in a wide range of probing momenta, hopefully providing glimpses of a transition from the non perturbative regime of QCD to
its perturbative domain. Starting from QCD' s fundamental degrees of freedom, namely quarks and gluons and map out their imprint on the hadronic form factors is a challenging task. In continuum, I argue that Schwinger-Dyson equations hold the promise to successfully undertake this challenge.

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Chiral symmetry breaking and restoration with mixing between quarkonium and tetraquark

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In the framework of two flavor quark-meson model we study the effect of mixing between effective quarkonium and tetraquark fields on chiral phase transition. The physical mass spectrum of mesons put a tight constraint on the parameter set of our model. We find a sufficiently strong cubic self interaction of the tetraquark field can drive the chiral phase transition to first order even at zero quark chemical potential. Weak or absence of the cubic self interaction term of the tetraquark field make the chiral pahse transition crossover at vanishing density.

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Dynamical holographic QCD model for chiral symmetry breaking and confinement

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A dynamical soft-wall model would be introduced, which could cover the gluon condensate and chiral condensate simultaneously and realize linear confinement and chiral symmetry breaking simultaneously. Furthermore, the meson spectra in this model fit the experimental data quite well.

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Octet baryon masses in covariant baryon chiral perturbation theory

Author: Xiulei Ren[1]

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We have performed a comprehensive study of the lowest-lying octet baryon masses and sigma terms in the covariant baryon chiral perturbation theory (BChPT) with the extended-on-mass-shell (EOMS) renormalization scheme up to next-to-next-to-next-to-leading order (N3LO). We fix the relevant low-energy constants by a simultaneous fit of all the publicly available LQCD data. Finite volume and discretization effects on the LQCD simulations are taken into account self-consistently.
Our main results are
(1)The N3LO EOMS BChPT can give a reasonable description of the LQCD data with a χ2/d.o.f. = 1.0 and the various lattice simulations seem to be consistent with each other.
(2) The predicted values of the pion- and strangeness-nucleon sigma terms are σπN = 43(1)(6) MeV and σsN = 126(24)(54) MeV, respectively.
(3) The virtual decuplet effects on the baryon masses cannot be distinguished from those of the virtual octet baryons and the tree level diagrams.
(4) The finite-volume corrections to the octet baryon masses are important and can be useful to help constrain some relevant low-energy constants.
(5) Up to O(a2), the discretization effects on the LQCD baryon masses are shown to be small and can be safely ignored.

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Light quark mass dependence of the $X(3872)$ in XEFT

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The quark mass dependence of hadrons is an important input for lattice calculations. We investigate the light quark mass dependence of the binding energy of the $X(3872)$ and the $\bar{D}^0 D^{0*}$ scattering length in the $C = +1$ channel in the framework of XEFT. We find a moderate dependence of the binding energy for quark masses up to twice the physical value while the scattering length is much more sensitive. The treatment of infrared divergences due to on-shell pions in XEFT is discussed in detail.

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Future projects at J-PARC

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TBA

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Antimagnetic rotation in nuclei: a microscopic description

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TBA

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Collective Hamiltonian for chiral modes

Author: Qibo Chen[1]

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Since the occurrence of chirality was originally suggested in 1997 by Frauendorf and Meng [1] and the corresponding experimental signals, chiral doublet bands, were observed in 2001 [2], the study of chiral symmetry in atomic nuclei has become one of the intriguing topics in nuclear physics. More than thirty candidate chiral doublet bands have been reported in the A˜80, A˜100, A˜130, and A˜190 mass regions, see e.g. Refs. [3-5]. Theoretically, chiral doublet bands have been extensively studied in terms of tilted axis cranking (TAC) [6-8] approach and particle rotor model (PRM) [9-11]. However, it is imperative to search a unified microscopic method for studying both chiral rotation and vibration.

Recently, we develop a collective model to describe the chiral rotation and vibration and apply this model to investigate a system with one h11/2 proton particle and one h11/2 neutron hole coupled to a triaxial rigid rotor [12]. In this framework, it goes beyond the mean-field approximation, includes the quantum fluctuation in the chiral degree of freedom, and restores the chiral symmetry. The collective Hamiltonian is constructed from the potential energy and mass parameter obtained in the TAC approach. By diagonalizing the collective Hamiltonian with a box boundary condition, it is found that for the chiral rotation, the partner states become more degenerate with the increase of the cranking frequency, and for the chiral vibrations, their important roles for the collective excitation are revealed at the beginning of the chiral rotation region. Furthermore, the collective Hamiltonian reasonably reproduces the exact results calculated by PRM. The success of the collective Hamiltonian here guarantees its application for realistic TAC calculations.

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Search for the chiral doublet bands in odd-odd nucleus 78Br

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The fusion-evaporation reaction 70Zn(12C, 1p3n) at beam energies of 60 and 65 MeV was used to populated the excited states in 78Br. The previously known level scheme has been extended and two new rotational bands have been identified. The triaxial particle-rotor model (PRM) was used for the analysis of the positive parity doublet bands in 78Br. The energy spectra E(I), energy staggering parameter S(I) = [E(I) − E(I − 1)]/2I and the intraband B(M1)/B(E2) ratios of the doublet bands have been calculated. Good agreement has been obtained between the calculated results and the available data. The positive parity doublet bands in 78Br have been tentatively interpreted as a pair of chiral bands based on the πg9/2⊗νg9/2 configuration.

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O16 in relativistic Brueckner-Hartree-Fock theory

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We study the properties of O^{16} in relativistic Brueckner-Hartree-Fock equations with realistic nucleon-nucleon interaction. No additional approximation is used and no parameters are needed to calculate the ground state properties of finite nuclei. The whole system is solved in Harmonics oscillator basis. The resulting ground state properties, such as binding energies and charge radii of O^{16}, are largely improved as compared with non-relativistic Brueckner-Hartree-Fock results and more close to the experimental data. It becomes feasible to use this framework also for ab initio investigations of heavy nuclei.

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Nuclear chirality in the context of possible future scientific applications.

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A hypothesis of the chiral symmetry breaking opened a new opportunity for the study of spontaneous time-reversal symmetry breaking in an atomic nucleus. A connection between the chirality phenomenon and the time-reversal symmetry will be shown. A possibility of using chiral doublets for studies of time reversal symmetry beyond the nuclear structure boundaries will be introduced. This idea relay on well known phenomenon of doublet state mixing in frame of first order perturbation theory, see for example N. Auerbach, Nucl. Phys. A787, 532c (2007). Although the theoretical basics are not complicated there is no straight-forward experimental technique applicable for this kind of time-reversal symmetry breaking measurements with help of the chiral doublets. As a starting point for the discussion a gamma-gamma correlation and polarization experiments will be introduced as possible candidates.

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Nuclear shpae phase transition and effective interactional strength in SD-pair shell model

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TBA

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Shape-phase transitions in very neutron-rich nuclei from 40Zr to 46Pd

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Chirality in atomic nuclei: 2013

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Panel Discussions —Nuclear chirality in the context of possible future scientific applications.

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Review of theoretical prescriptions for the charged heavy quarkonium states

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How to distinguish a molecule from an "elementary" particle?

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Compositeness of hadron resonances in chiral dynamics

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