The 11th International Workshop on Chiral Dynamics

Monday, 26 August 2024 - Friday, 30 August 2024

Ruhr University Bochum, Germany

Book of Abstracts

Version: 16.08.2024

ID: 101, Plenary session, Monday 26 August

C and CP violation in effective field theories and applications to η-meson decays

Bastian Kubis (HISKP, Bonn University), Hakan Akdag, Andreas Wirzba

The quest for sources of the simultaneous violation of C and CP symmetry was popular in the 1960s and has since been mostly neglected. We revisit the operators that break C and CP for flavor-conserving transitions in both the Standard Model effective field theory and the low-energy effective field theory. Subsequently, we match these quark operators to light-meson physics using chiral perturbation theory. Applications in particular to C-odd Dalitz-plot asymmetries in $\eta \to 3\pi$ and long-distance contributions to the rare semileptonic decays $\eta \to \pi^0\ell^+\ell^-$ are also discussed.

ID: 75, Plenary session, Monday 26 August

Measurements of the chiral anomaly at COMPASS

Andrii Maltsev (TUM)

The chiral symmetry of QCD can be exploited to build an effective field theory, called Chiral Perturbation Theory (χPT), which allows to describe the interactions of light mesons at low energies, where the standard perturbative expansion in the strong coupling constant α_s is no longer possible. Verification of the predictions of such models, such as the $\pi\gamma \to \pi\pi$, $\pi\gamma \to \pi\eta$, $K\gamma \to K\pi$ and other couplings arising as a consequence of the chiral anomaly, is important for understanding the low-energy interactions of hadrons.
This talk will focus on the experimental verification of the so-called anomalous couplings, in particular the result on the $F_{3\pi}$ constant describing the $\pi\gamma \to \pi\pi$ coupling, as well as other possible measurements aimed at testing the predictions of the chiral anomaly.

ID: 108, Plenary session, Monday 26 August

Nucleon resonances from lattice QCD

Colin Morningstar (Carnegie Mellon University)

Recent progress in studying nucleon resonances using lattice QCD is presented. Systems involving meson-baryon scattering, such as the Lambda(1405) resonance, and baryon-baryon scattering are discussed.

ID: 13, Plenary session, Monday 26 August

Roy–Steiner equations for pion–nucleon scattering and nucleon resonances

Jacobo Ruiz de Elvira (Complutense University of Madrid), Bastian Kubis, Martin Hoferichter, Ulf-G. Meißner

We review the determination of the low-energy pion-nucleon scattering amplitude using Roy-Steiner equations. In particular, we focus on the extraction of nucleon resonances and address some of the most frequently asked questions regarding our analysis. Finally, we also discuss the phenomenological determination of the pion-nucleon σ-term, derived in combination with modern precision data on pionic atoms, applications to nucleon form factors, and the determination of low-energy constants in chiral perturbation theory.

ID: 90, Plenary session, Monday 26 August

Two-pole structures in QCD

Li-Sheng Geng (Beihang University)

Two-pole structures refer to the fact that two dynamically generated states are located close to each other between two coupled channels and have a mass difference smaller than the sum of their widths. Thus, the two poles overlap in the invariant mass distribution of their decay products, creating the impression that only one state exists. This phenomenon was first noticed for the Lambda(1405) and the K1(1270), and then for several other states. This report explicitly shows how the two-pole structures emerge from the underlying universal chiral dynamics describing the coupled-channel interactions between a heavy matter particle and a pseudo-Nambu-Goldstone boson. Furthermore, we show how the latest lattice QCD simulations of the trajectories of the two poles of the Lambda(1405) can be described in the chiral unitary approach without any fine-tunings.

ID: 56, WG1 parallel session, Monday 26 August

Review of the ɣ3π chiral anomaly

Bai-Long Hoid (University of Bern)

In this talk, we will review the theory underlying the chiral anomaly $\gamma\pi \to \pi\pi$. This includes its extractions based on dispersion relations, lattice QCD and the constraints from the crossed channel $\gamma^* \to 3\pi$.

ID: 78, WG3 parallel session, Monday 26 August

Criteria of Renormalizability in Effective Field Theories

Ashot Gasparyan (Ruhr University Bochum), Evgeny Epelbaum

Any effective field theory relies on a certain power counting that allows one to perform a systematic expansion of calculated quantities in terms of some soft scales. However, a naive power counting can be violated due to the presence of various hard scales in the scheme. A typical example of such a scale is an ultraviolet regulator. This issue is particularly challenging when the interaction is nonperturbative. The power counting is expected to be restored in the course of renormalization, that is by redefining bare low energy constants in the effective Lagrangian. Whether this procedure works is not a priory obvious. We discuss various criteria of renormalizability and applications to the few-body physics.

ID: 117, WG2 parallel session, Monday 26 August

Recent and future experiments exploring Nucleon-to-Delta transition form factors at Jefferson Lab

Michael Paolone (New Mexico State University)

The first excited state of the nucleon dominates many nuclear phenomena at energies above the pion-production threshold and plays a prominent role in the physics of the strong interaction. The study of the N to Δ transition form factors (TFFs) allows to shed light on key aspects of the nucleonic structure that are essential for the complete understanding of the nucleon dynamics. In this talk we will discuss collected and proposed measurements of the TFFs in Hall C at JLab, utilizing the SHMS and the HMS spectrometers, that focus on low four-momentum transfer squared where the mesonic cloud dynamics are dominant and rapidly changing. Possible future experiments pursuing bound neutron excitation with the CLAS12 and ALERT detectors, as well as large Q2 measurements with SoLID and beam energy upgrades at Jefferson Lab will also be discussed.

ID: 9, WG1 parallel session, Monday 26 August

Measurements of the Pion Electromagnetic Polarizabilities at Jefferson Lab

Rory Miskimen (University of Massachusetts, Amherst)

Electromagnetic polarizabilities are fundamental properties of composite systems, and measure the 'stiffness' of a system to electromagnetic deformation. Measurements of hadron polarizabilities provide a test of effective field theories, dispersion theories, and lattice calculations. While significant progress has been made in measuring proton polarizabilities, with uncertainties at the level of +/- 0.4 x 10-4 e fm2, experimental constraints on the charged and neutral pion polarizabilities (CPP and NPP) are much weaker, +/- 2 x 10-4 for the charged pion and no measurement for the neutral pion. The CPP/NPP experiment at the Jefferson Lab GlueX detector utilizes a new technique to measure pion polarizability, Primakoff photo-production of charged and neutral pion pairs using linearly polarized 6 GeV photons on a nuclear target, 208Pb. The CPP/NPP experiment finishing data taking at JLab in summer 2022. In this talk the experimental setup and preliminary physics distributions will be presented.

ID: 55, WG3 parallel session, Monday 26 August

The Unitarity Limit of the NN System with Perturbative Pions

Harald Griesshammer (Institute for Nuclear Studies, George Washington University)

Theorists love the unitarity limit: the NN S-wave binding energies are zero, the scattering lengths infinite, and one has more symmetries. In "pionless" EFT, Efimov's $3N$ scale sets the only low-energy scale of all observables for a convergent, perturbative expansion around the unitarity limit. There are strong hints that Nuclear Physics resides indeed in a sweet spot: bound weakly enough to be insensitive to the details of the nuclear interaction; but dense enough that the NN scattering lengths are perturbatively close to the unitarity limit. In this paradigm change, details of two-nucleon interactions are less important than three-nucleon interactions to explain the complexity and patterns of the nuclear chart.

This presentation explores quantitatively the corrections to this picture when pions are included perturbatively. Their mass and decay constant provide dimensionful scales already in the NN system, and thus explicitly break the unitarity symmetries. The "KSW" version of Chiral EFT has a well-defined power counting. Its leading order is identical to pionless EFT, so unitarity is broken "weakly". Utilising the work by Fleming, Mehen and Stewart up to next-to-next-to-leading order, one finds that perturbative pions describe the NN system well in the range in which pionless EFT applies as well. Beyond that, the series converges up to momenta of about 200 MeV in the ${}^1\mathrm{S}_0$ channel, while the ${}^3\mathrm{SD}_1$ channel appears to show strong fine-tuning. Consequences and possible remedies are discussed.

Work in collaboration with Y.-P. Teng (GW and U. of Wisconsin).

ID: 122, WG2 parallel session, Monday 26 August

Gravitational form factors of hadrons within chiral EFT

Herzallah Alharazin (Ruhr-Universität Bochum)

In this talk we discuss how the chiral effective Lagrangian is generalized systematically to curved spacetime and how the corresponding energy-momentum tensor (EMT) is obtained. As next, we discuss the nucleon and delta gravitational form factors, which are described by the diagonal hadronic matrix elements of the EMT at low energies. Furthermore, we discuss the transition gravitational form factors corresponding to the one pion graviproduction off the nucleon, in which the initial nucleon scatters on external gravitational field and emits a pion in the final state. This process is described by the non-diagonal hadronic matrix elements of the EMT at low energies. Moreover, we discuss how various non-diagonal matrix elements of the EMT can be parametrized in terms of independent and conserved Lorentz invariant structures.

ID: 28, WG1 parallel session, Monday 26 August

The sign of the neutral pion electric polarizability

Volodymyr Biloshytskyi (Johannes Gutenberg University Mainz), Marc Vanderhaeghen, Vladimir Pascalutsa

One of the most preplexing predictions of Chiral Perturbation Theory is the negative electric polarizability of the neutral pion. We revisit this problem and argue that in an ultraviolet-complete calculation the polarizabilty is positive. A novel light-front QCD calculation will be presented, corroborating this point.

ID: 42, WG3 parallel session, Monday 26 August

Perturbation theories for chiral nuclear forces

Bingwei Long (Sichuan University)

The chiral Lagrangian provides a modern paradigm to build nuclear forces and nuclear currents for external probes. Higher-order chiral forces tend to have more complicated structures despite their smaller effects. We present our recent results in developing perturbatiion theories for higher-order chiral forces while iterating the leading-order interactions nonperturbatively. In particular, we discuss the issues arising from renormalizing one-pion exchange and possible solutions to resolve them.

ID: 104, WG2 parallel session, Monday 26 August

Proton leading scalar and spin polarisabilities from proton Compton scattering data

Timon Esser (Johannes Gutenberg University Mainz), Franziska Hagelstein, Vadim Lensky

We present the results of a partial wave analysis of the global real Compton scattering (RCS) database, extracting the leading scalar and spin polarisabilities of the proton.

Exploring the nucleon using electromagnetic probes reveals a fine and intricate interplay between its various structural properties. As an example, the nucleon polarisabilities encode the two-photon response, such as measured in RCS [1, 2]. On the other hand, their precise knowledge is very important for the analysis of atomic spectra, especially in muonic atoms [3], which serves to constrain the details of the nucleon charge distribution such as the charge radius.

The polarisabilities are introduced as the coefficients in the low-energy expansion (LEX) of the RCS amplitudes, and can, in principle, be extracted using the LEX to analyse the RCS data [1, 4]. However, the energies where quality experimental data are available are too high to use the LEX for an analysis, forcing one to use a more sophisticated framework such as effective field theories [5, 6], dispersion relations [7], or partial wave analysis [8]. We use the latter framework here, include the most recent RCS data from MAMI [9] and HIGS [10], and introduce a few further modifications in the formalism. The results of our refined analysis are presented in this contribution.

[1] D. Babusci et al., Phys. Rev. C 58, 1013–1041 (1998).
[2] B. R. Holstein et al., Phys. Rev. C 61, 034316 (2000).
[3] K. Pachucki et al., Rev. Mod. Phys. 96, 015001 (2024).
[4] N. Krupina and V. Pascalutsa, Phys. Rev. Lett. 110, 262001 (2013).
[5] H. W. Griesshammer et al., Prog. Part. Nucl. Phys. 67, 841–897 (2012).
[6] V. Lensky and J. A. McGovern, Phys. Rev. C 89, 032202 (2014).
[7] E. Mornacchi et al., Phys. Rev. Lett. 129, 102501 (2022).
[8] N. Krupina et al., Phys. Lett. B 782, 34–41 (2018).
[9] E. Mornacchi et al. (A2 Collaboration at MAMI), Phys. Rev. Lett. 128, 132503 (2022).
[10] X. Li et al., Phys. Rev. Lett. 128, 132502 (2022).

ID: 3, WG2 parallel session, Monday 26 August

Recent results on Hyperon-Nucleon interactions from BESIII

Jielei Zhang (Henan University), Beijiang Liu

With the existing 10 billion J/psi events accumulated at BESIII, the high production of long-lived baryons in J/psi decays serves as a novel source of hyperon beams, which open a unique opportunity for exploring the hyperon-nucleon interactions. By studying these hyperons with the beam pipe and the inner tube of the MDC detector, the recent results, including interactions of Λp, Σp and Ξn, achieved at BESIII will be presented in this talk. Also the perspectives at the future tau-charm factory is presented.

ID: 35, WG1 parallel session, Monday 26 August

Weak decays and finite-volume QED

Nils Hermansson-Truedsson (University of Edinburgh), Antonin Portelli, Matteo Di Carlo, Maxwell Hansen

Precision calculations of flavour physics processes such as leptonic decays of pions and kaons allow for indirect searches of new physics. For instance, the Cabibbo-Kobayashi-Maskawa matrix elements $|V_{ud}|$ and $|V_{us}|$ accessible in these decays satisfy a unitarity relation within the Standard Model that can be probed with lattice QCD simulations. With a goal of (sub-)percent precision, isospin-breaking effects from quark-mass differences and electromagnetism have to be taken into account. The long-range nature of the electromagnetic force introduces systematic effects in the finite-volume lattice calculations, which have to be under good control for precision tests of the Standard Model. Motivated by recent results on weak decays of pions and kaons, we here present a finite-volume formulation of electromagnetism constructed to improve the associated systematic uncertainties in modern lattice simulations.

ID: 47, WG3 parallel session, Monday 26 August

Modified Power Counting in Chiral Effective Field Theory up to N3LO

Oliver Thim (Chalmers University of Technology), Andreas Ekström, Christian Forssén

Chiral effective field theory (χEFT) is an approach to describe the force between nucleons as arising from the more fundamental principles of quantum chromodynamics. A vital part is to have a power counting (PC) that quantifies the relative importance of the EFT order-by-order contributions to nuclear observables. The definition of the PC is not unique, and the fact that nuclear systems are non-perturbative makes finding a proper PC a non-trivial problem. We are investigating a PC [1] that is constructed to possess an infinite limit for the momentum cutoff, where sub-leading contributions to the interaction are treated in perturbation theory. In [2] we investigate this PC at leading order (LO) by analyzing the posterior probability densities of low-energy constants (LECs) in a Bayesian framework. In recent works, [3,4], we added up to third-order corrections to LO perturbatively and found a good description of both neutron-proton scattering cross sections and S-wave low-energy theorems. I will present these promising results and discuss our next steps towards a robust Bayesian inference of the LECs as well as the prospect of predicting properties of atomic nuclei.

[1] B. Long, C.J. Yang, Phys. Rev. C 86, 024001 (2012)
[2] O. Thim, E. May, A. Ekström, C. Forssén, Phys. Rev. C 108, 054002 (2023)
[3] O. Thim, A. Ekström, C. Forssén, arXiv:2402.15325 (2024)
[4] O. Thim, arXiv:2403.10292

ID: 45, WG1 parallel session, Monday 26 August

Radiative modes $K^+ \to \pi^+\gamma^*\gamma^{(*)}$ and $K^+ \to \pi^+\ell^+\ell^-(\gamma)$ decays

Tomáš Husek (Charles University and University of Birmingham)

The rare radiative $K^+ \to \pi^+\ell^+\ell^-$ decays ($\ell = e, \mu$) provide experimental access to the $K^+ \to \pi^+\gamma^*$ transition. The relevant form factor is conventionally written in terms of two hadronic parameters, a_+ and b_+, which are being measured by NA62 in both electron and muon channels. Comparing the two channels allows for a stringent test of lepton-flavor universality. However, appropriate experimental analysis requires adequate theory inputs: Although the $K^+ \to \pi^+\gamma^*$ conversion has been studied extensively, radiative corrections involve the $K^+ \to \pi^+\gamma^*\gamma^{(*)}$ transitions (with up to two virtual photons), not fully addressed in the literature. At the same time, the $K^+ \to \pi^+\gamma^*\gamma^*$ transition is essential for the description of the $K^+ \to \pi^+e^+e^-\ell^+\ell^-$ decays, which represent a background to new-physics searches.

ID: 62, WG3 parallel session, Monday 26 August

Three-pion exchange potential using the method of unitary transformation

Victor Springer (Ruhr University Bochum), Evgeny Epelbaum, Hermann Krebs

The leading and subleading three-pion exchange potentials have so far only been derived in chiral EFT by Norbert Kaiser using S-matrix matching. However, nuclear potentials are scheme-dependent quantities, and it is not a priori clear if the available results are consistent with the interactions and currents derived by the Bochum group using a different technique, the so-called Method of Unitary Transformation (MUT). Here, we re-calculate the leading and subleading three-pion exchange potentials using the MUT. We indeed find deviations from the previously obtained results for selected classes of reducible-like diagrams. We present analytical expressions for the three-pion exchange potential consistent with the interactions used by the Bochum group and discuss the numerical importance of the observed differences.

ID: 98, WG2 parallel session, Monday 26 August

Structure of the Λ(1405) from Photoproduction at GlueX

James Ritman (RUB and GSI), Reinhard Schumacher, Nilanga Wickramaarachchi, Peter Hurck

The well-established $\Lambda(1405)$ hyperon with $J^\pi = \frac{1}{2}^-$ may be a dual structure consisting of two overlapping $I = 0$ resonances. Each resonance may couple to $\Sigma\pi$ and $N\overline{K}$ final states, but a direct measurement of these two decays for each resonance has not previously been done. Using the GlueX detector system at Jefferson Lab we have obtained high statistics samples for the $\Lambda(1405)$ structure decaying to both final states. The photoproduction measurement in the beam energy range $6.5 - 11.6$ GeV used a liquid hydrogen target together with a large-acceptance charged particle tracking and electromagnetic calorimeter system. The experiment obtained the differential cross sections $d\sigma/dM_{\Sigma^0\pi^0}$ and $d\sigma/dM_{pK^-}$ in the $-(t-t_{min})$ range $0.0-1.5$ (GeV/c)^2 from analyzing the reaction $\gamma p \to K^+\Lambda^*$, collected during the first phase of GlueX running. The $\Sigma^0\pi^0$ data exhibited both the dual $\Lambda(1405)$ states and the $\Lambda(1520)$ hyperon. The pK^- data were dominated by the $\Lambda(1520)$ hyperon sitting atop the tails of the $\Lambda(1405)$ states decaying to the pK^- final state. The data were subjected to K-matrix fits to both final state channels from one or two $\Lambda(1405)$ plus the $\Lambda(1520)$ resonances. The two-resonance hypothesis for the $\Lambda(1405)$ region resulted in much better matching to the experimental results. The complex T-matrix pole positions of the dual $\Lambda(1405)$ resonances as well as the $\Lambda(1520)$ were extracted, and the results will be presented. The results also include first-time measurements of the mass- and beam-energy- integrated photoproduction cross sections in the stated energy range for the dual $\Lambda(1405)$ and the $\Lambda(1520)$ states. Within the framework of the K-matrix fits to the $\Lambda(1405)$ states, the branching ratio and branching fractions to the $N\overline{K}$ and $\Sigma\pi$ final states were obtained for the first time and will also be presented.

ID: 57, WG3 parallel session, Monday 26 August

Nucleon-nucleon interaction in manifestly Lorentz-invariant ChEFT

Xiu-Lei Ren (Helmholtz Institute Mainz), Evgeny Epelbaum, Jambul Gegelia

We study nucleon-nucleon interaction up to next-to-next-to-leading order (NNLO) 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. We define the effective potential as a sum of two-nucleon irreducible contributions of time-ordered diagrams and derive the NN scattering equation, i.e. the Kadyshevsky equation, for the scattering amplitude. 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 deuteron properties is achieved by treating the full NNLO potential non-perturbatively.

ID: 33, WG1 parallel session, Monday 26 August

Light Meson Decays at Jefferson Lab

Liping Gan (University of North Carolina Wilmington)

The decays of the light meson $\pi 0$, η and η' offer a flavor-conserving laboratory to assess the low-energy QCD and to search for new physics Beyond the Standard Model. The QCD symmetries and symmetry breakings at low-energy, such as the chiral symmetry or the axial anomalies, are manifested in their most unambiguous form in the sector of light pseudoscalar mesons. An experimental study of various decays will yield light on our understanding of the origin and the dynamics of QCD confinement. In addition, the η/η' meson has quantum numbers of vacuum (except parity) with its strong and electromagnetic decays being either anomalous or forbidden to the lowest order due to symmetries or angular momentum conservation. This enhances the relative importance of higher order contributions, making the rare η/η' decays a sensitive hadronic probe for weakly-coupled new forces. Searching for sub-GeV dark gauge boson candidates, and the C-violating, P-conserving interactions in various η/η' decays will extend our knowledge of the dark sector and explore new sources of CP violation to explain the observed matter and anti-matter asymmetry in the universe. The status of experimental activities at JLab and the future new opportunities will be discussed.

ID: 60, WG3 parallel session, Monday 26 August

Application of chiral 2- and 3-baryon interactions to light hypernuclei

Andreas Nogga (Forschungszentrum Jülich)

Hypernuclei provide important information to constrain the hyperon-nucleon (YN) and three-baryon (YNN) interactions. In this contribution, we will discuss our recent results obtained using chiral YN [1,2] and chiral YNN interactions for light hypernuclei up to $A = 8$.

We use the hypernuclei data to determine the charge-symmetry breaking (CSB) of YN interactions and for exploring the results using and isospin multiplets of hypernuclei [3,4]. We then employ the results of different chiral orders to reliably estimate the theoretical uncertainty [5]. Finally, we use the separation energies of light hypernuclei to pin down the leading chiral YNN interaction.

[1] J.Haidenbauer, U.G.Meißner and A.Nogga, Eur. Phys. J. A 56 (2020) no.3, 91 [arXiv:1906.11681 [nucl-th]].

[2] J.Haidenbauer, U.G.Meißner, A.Nogga and H.Le, Eur. Phys. J. A 59 (2023), 63 [arXiv:2301.00722 [nucl-th]].

[3] J.Haidenbauer, U.G.Meißner and A.Nogga, Few Body Syst. 62 (2021), 105 [arXiv:2107.01134 [nucl-th]].

[4] H.Le, J.Haidenbauer, U.G.Meißner and A.Nogga, Phys. Rev. C 107 (2023), 024002 [arXiv:2210.03387 [nucl-th]].

[5] H.Le, J.Haidenbauer, U.G.Meißner and A.Nogga, Eur. Phys. J. A 60 (2024), 3 [arXiv:2308.01756 [nucl-th]].

ID: 110, WG2 parallel session, Monday 26 August

Computing scattering amplitudes on the lattice involving Goldstone bosons

Ferenc Pittler (The Cyprus Institute)

Whether one is interested in measuring transition matrix elements or extracting scattering parameters, a common requirement is to constrain and determine an analytical expression for the scattering amplitude. A systematically improvable, well developed theoretical method is to determine the finite volume spectrum using lattice QCD and connect it to the infinite volume scattering amplitude through the Luescher formalism. In the present talk I will review current investigations that follow this approach for the study of mesonic and baryonic systems with two and three hadrons.

ID: 66, WG1 parallel session, Monday 26 August

Review of lattice results on eta, eta'

Konstantin Ottnad (Johannes Gutenberg University Mainz)

The pseudoscalar η and η' mesons play a special role in the context of chiral dynamics as their physics properties are intimately linked to the chiral anomaly. While the η meson would be a massless state in a $SU(3)$ flavor symmetric world like the other pseudoscalar octet mesons, the η' remains massive even in the chiral limit due to the anomalous breaking of the axial $U(1)$ symmetry. Still, corrections due to $SU(3)$ flavor symmetry breaking are known to be large in the physical world, giving rise to a peculiar mixing pattern between flavor octet and singlet states.
Lattice calculations involving η and η' mesons are notoriously difficult due to large contributions of quark-disconnected diagrams and the resulting signal-to-noise problem particularly for the η' state. However, there has been tremendous progress in recent years towards obtaining physical results with controlled systematics. Therefore, it has become feasible to reproduce the physical masses and mixing of η and η' mesons from first principles using lattice QCD. Beyond masses and mixing, η and η' mesons contribute in various processes of phenomenological interest such as e.g. $\eta, \eta' \to \gamma\gamma$ that can studied using lattice QCD. In this talk I review the current status and results for lattice calculations of η and η' mesons.

ID: 102, WG2 parallel session, Monday 26 August

Role of the three-body and left-hand cut on the pole extraction of the Tcc(3875)

Meng-Lin Du (University of Electronic Science and Technology of China), Arseniy Filin, Vadim Baru, Xiang-Kun Dong, Evgeny Epelbaum, Feng-Kun Guo, Christoph Hanhart, Alexey Nefediev, Juan Nieves, Qian Wang

A coupled-channel approach is applied to the charged tetraquark state T_{cc} discovered by the LHCb Collaboration and the lattice data. Special attention is paid to the three-body and left-hand cut for the physical and unphysical pion mass cases, respectively. We discuss the lattice data to stress a potentially strong impact of left-hand cuts from the one-pion exchange on the pole extraction for near-trehshold exotic states. In particular, if the left-hand cut is located close to the two-particle threshold, which happens naturally in the DD^* system for the pion mass exceeding its physical value, the effective-range expansion is valid only in a very limited energy range up to the cut and as such is of little use to reliably extract the poles. Then, an accurate extraction of the pole locations requires the one-pion exchange to be implemented explicitly into the scattering amplitudes. Our findings are general and potentially relevant for a wide class of hadronic near-threshold states.

ID: 109, WG3 parallel session, Monday 26 August

Experiments with RI-beam populating tetra-neutron system

Susumu Shimoura (RIKEN Nishina Center)

Study of isolated multi-neutron systems is one of fundamental subjects in nuclear physics. In several decades, experimental attempts have made with a particular focus on the tetra-neutron system. Among them, two experiments, the double-charge exchange reaction on ^{4}He and the alpha-particle knockout reaction from the ^{8}He, show a sharp peak structure just above the threshold in the four-neutron spectra, which could be a signature of a strong correlated state. Both the experiments have been realized by using the ^{8}He beam above 150 A MeV at the RIKEN RI Beam Factory. Production mechanisms with kinematical considerations are introduced, where impulse natures and amount of the transferred energies and momenta of the reactions are emphasized. The relevant reaction processes are discussed and corresponding analysis procedures on the four-body continuum system taking into account the final-state interactions in the di-neutrons are presented.

ID: 29, WG1 parallel session, Monday 26 August

Semileptonic eta(') decays in the Standard Model

Hannah Schäfer (University of Bonn), Marvin Zanke, Bastian Kubis, Yannis Korte

We performed a theoretical analysis of the semileptonic decays $\eta^{(\prime)} \to \pi^0\ell^+\ell^-$ and $\eta' \to \eta\ell^+\ell^-$, where $\ell = e, \mu$, via a charge-conjugation-conserving two-photon mechanism. The underlying form factors are modeled using vector-meson dominance, phenomenological input, and $U(3)$ flavor symmetry. We considered both a monopole and a dipole model, the latter tailored such that the expected high-energy behavior is ensured. Furthermore, we benchmarked the effect of S-wave rescattering contributions to the decays. We inferred significant effects of the form factors neglected in the literature so far, still finding branching ratios of the various decays well below the current experimental upper limits.

ID: 73, WG3 parallel session, Monday 26 August

Recent results of $\Sigma^{\pm}p$ scattering experiment at J-PARC

Takuya Nanamura (RIKEN, Japan), J-PARC E40 Collaboration, Koji Miwa

Hyperon-proton scattering experiment is one of the most direct methods to study the hyperon-nucleon interaction, as in the case of the NN interaction. Although it had been experimentally difficult for a long time due to short lifetime of hyperons, we successfully performed novel high-statistics $\Sigma^{\pm}p$ scattering experiment at J-PARC (J-PARC E40 experiment). The main physics motivation was verification of a strong repulsive force due to Pauli effect in the quark level (quark Pauli effect) in $\Sigma N(I = 3/2)$ system by measuring the differential cross sections of the $\Sigma^{+}p$ elastic scattering. Measurements of the differential cross sections of the $\Sigma^{-}p$ elastic and $\Sigma^{-}p \to \Lambda n$ inelastic scattering also provide systematic information on ΣN interaction.
The experiment was performed at the K1.8 beam line in the J-PARC Hadron Experimental Facility by June 2020.
Both of the incident $\Sigma^{\pm}$ production via the $\pi^{\pm}p \to K^{+}\Sigma^{\pm}$ reaction and the $\Sigma^{\pm}p$ scattering occurred in a liquid hydrogen (LH_2) target. The $\Sigma^{\pm}$ production reaction was analyzed using the two spectrometers and the momentum of the $\Sigma^{\pm}$ was tagged event by event. The recoil proton from the $\Sigma^{\pm}p$ scattering was measured using CATCH, detector system surrounding the LH_2 target. The $\Sigma^{\pm}p$ scattering was identified by checking the kinematical consistency for the recoil proton. We identified thousands of scattering events for each channel and obtained the differential cross sections with good precisions. Their uncertainties were typically 10-20 $\%$ with an angular step of $\Delta \cos\theta_{\mathrm{CM}} = 0.1$ and the data quality was drastically improved in comparison with past experiments. These data is reliable input for theoretical models describing the baryon-baryon interactions (BB interatcions), such as χEFT.
Moreover, owing to the precise data points and the simple representation of the $\Sigma^{+}p$ system with respect to the multiplets of the BB interaction, we could perform phase-shift analysis and obtain the $^3S_1$ and $^1P_1$ phase shifts of the $\Sigma^{+}p$ elastic scattering. Especially, S-wave phase shift can be compared with lattice QCD calculations such as HALQCD, where a calculation of higher partial-wave contribution is still difficult.
In this talk, I will introduce the J-PARC E40 experiment and results, mainly focusing on the $\Sigma^{+}p$ elastic scattering. There are plans of further hyperon-nucleon scattering (Λp and $\Sigma^{\pm}p$) experiments at J-PARC.I would like to mention them.

ID: 86, WG2 parallel session, Monday 26 August

Charmonium scalar and tensor resonances in coupled channel scattering from lattice QCD

David Wilson (University of Cambridge)

I will discuss scalar and tensor charmonium resonances determined using lattice QCD. Working at $m_\pi \approx 391$ MeV, more than 200 finite-volume energy levels are computed and these are used in extensions of the Lüscher formalism to determine infinite volume scattering amplitudes. Working in the approximation where charm-annihilation is forbidden, the ground state $\chi_{c0}(1P)$ and $\chi_{c2}(1P)$ states are stable. Below 4000 MeV we find a single χ_{c0} and a single χ_{c2} resonance, both strongly-coupled to several decay channels consisting of pairs of open-charm mesons. Both resonances are found on the closest unphysical sheet just below 4000 MeV with a widths of $\approx$ 60 MeV. The largest couplings are to the closed $D^*\bar{D}^*$ channels in S-wave, but several open-charm channels are also found to be large and significant in both cases. All closed-charm channels are found to be approximately decoupled. No additional states are found beyond what would be expected from quark-model-like $c\bar{c}$ excitations.

ID: 37, WG3 parallel session, Monday 26 August

Structure of multi-neutron system and future study

Emiko Hiyama (Tohoku Univ./RIKEN)

It is important to study multi-neutron system for T=3/2 three nucleon force. For this purpose, I have been studying tetra neutron system, 7H etc. In this talk, I introduce recent study of these study. I also introduce my future study: up to 10-body system calculation with chral EFT force.

ID: 50, WG1 parallel session, Monday 26 August

Dispersive determination of the eta/eta' transition form factors

Simon Holz (University of Bern), Bastian Kubis, Martin Hoferichter, Bai-Long Hoid

The uncertainty of the Standard Model prediction of the anomalous magnetic moment of the muon $g-2$ is dominated by hadronic contributions. As part of these hadronic inputs, the pseudoscalar-pole contribution in hadronic-light-by-light scattering plays a vital role. The currently sought precision of the Standard Model prediction of $(g-2)$ requires a careful evaluation not only of the pion-pole contribution but also of the η and η'.
We report on progress towards a dispersive, data-driven determination of the η and η' transition form factors in the space-like regime, which can be unambiguously related to their pole contributions. The analysis takes into account all of the lowest-lying singularities and encapsulates factorization-breaking effects by means of a left-hand-cut contribution due to the impact of the $a_2(1320)$ tensor meson.

ID: 120, WG2 parallel session, Monday 26 August

Internal structure of the Tcc(3875) from its light-quark mass dependence

Michael Abolnikov (Ruhr University Bochum), Vadim Baru, Evgeny Epelbaum, Arseniy Filin, Christoph Hanhart, Lu Meng

We employ a chiral effective field theory-based approach to connect DD^* scattering observables at the physical and variable pion masses accessible in lattice QCD simulations. We incorporate all relevant scales associated with three-body $DD\pi$ dynamics and the left-hand cut induced by the one-pion exchange for pion masses higher than the physical one, as required by analyticity and unitarity. By adjusting the contact interactions to match experimental data at the physical pion mass and lattice finite-volume energy levels at $m_\pi = 280$ MeV, we predict the trajectory of the T_{cc} pole as a function of the pion mass, finding it consistent with the hadronic-molecule scenario. In particular, we find that the explicit treatment of the one-pion exchange has a pronounced effect on the pole trajectory for $m_\pi \gtrsim 230$ MeV by pushing it into the complex energy plane.

ID: 21, WG1 parallel session, Monday 26 August

Application of Bayesian statistics to the sector of decay constants in three-flavour χPT

Jaroslav Říha (Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University, Prague), Marián Kolesár

The sector of decay constants of the octet of light pseudoscalar mesons in the framework of 'resummed' $SU(3)$ chiral perturbation theory is investigated. A theoretical prediction for the decay constant of η-meson is compared to a range of available determinations. Compatibility of these determinations with the latest fits of the $SU(3)$ low energy coupling constants is discussed. Using a Bayesian statistical approach, constraints on the low energy coupling constants L_4^r and L_5^r, as well as higher order remainders to the decay constants F_K and F_η, are extracted from the most recent experimental and lattice QCD inputs for the values of the decay constants.

ID: 38, WG2 parallel session, Monday 26 August

ChPT and Lattice QCD studies of doubly charmed baryons

De-Liang Yao (Hunan University)

The scattering lengths on the interactions between the spin-1/2 doubly charmed barons and Nambu-Goldstone bosons are of great importance for the investigation of the spectroscopy of the doubly charmed baryons. On the one hand, the S- and P-wave scattering lengths are predicted in a manifestly relativistic baryon chiral perturbation theory at leading one-loop order. On the other hand, results of the S-wave scattering lengths for the elastic scattering channels are obtained in lattice QCD for the first time.

ID: 69, WG3 parallel session, Monday 26 August

Faddeev Calculation of Hypertriton Including with YNN Three-Body Force

Hiroyuki Kamada (Osaka University, Research Center for Nuclear Physics), Kazuya Miyagawa, Michio Kohno

We have been performing calculations [1] using the SMS chiral potential [2] for NN interactions, the Juelich NLO19 chiral potential [3] for YN interactions, and the YNN three-body force [4] as inputs for the Faddeev three-body equations of Hypertriton. For the YNN three-body force, not only a two-pion exchange type but also one-pion exchange and contact types were adopted. Partial wave expansion [5] was performed to examine [6] the effects of each type. It is known that in chiral NLO order, it is not possible to determine the low-energy coefficients (LECs) of the three-body force, but the range dependence of the high momentum cutoff is examined.

[1] H. Kamada, M. Kohno and K. Miyagawa, Phys. Rev. C 108, no.2, 024004 (2023)
[2] P. Reinert, H. Krebs and E. Epelbaum, Eur. Phys. J. A 54, no.5, 86 (2018)
[3] J. Haidenbauer, U.-G. Meißner and A. Nogga, Eur. Phys. J. A 56, no.3, 91 (2020)
[4] S. Petschauer, N. Kaiser, J. Haidenbauer, U.-G. Meißner and W. Weise, Phys. Rev. C 93, no.1, 014001 (2016)
[5] M. Kohno, H. Kamada and K. Miyagawa, Phys. Rev. C 106, no.5, 054004 (2022)
[6] M. Kohno, H. Kamada and K. Miyagawa, Phys. Rev. C 109, no.2, 024003 (2024)

ID: 70, WG2 parallel session, Monday 26 August

Vector-meson exchange vs chiral dynamics at both quark and hadron levels

Bing-Song Zou (Tsinghua University)

Vector-meson exchange can be naturally introduced for both quark and hadron interactions in the framework of the hidden local symmetry (HLS) for the chiral dynamics. In the studies of Pc hadronic molecules [1,2] and whole spectrum of hadronic ground states [3,4], the vector meson exchanges are found to play more important role to reproduce the data than pseudoscalar meson exchanges, with many predictions to be checked by future experiments [4-6].
[1] J.J.Wu, R.Molina, E.Oset, B.S.Zou, Phys. Rev. Lett. 105 (2010) 232001.
[2] N.Yalikun, Y.H.Lin, F.K.Guo, Y.Kamiya, B.S.Zou, Phys. Rev. D104 (2021) 094039.
[3] B.R.He, M.Harada, B.S.Zou, Phys. Rev. D108 (2023) 054025.
[4] B.R.He, M.Harada, B.S.Zou, Eur. Phys. J. C83 (2023) 1159.
[5] X.K.Dong, F.K.Guo, B.S.Zou, Progr. Phys. 41 (2021) 65.
[6] X.K.Dong, F.K.Guo, B.S.Zou, Commu. Theor. Phys. 73 (2021) 125201.

ID: 79, WG1 parallel session, Monday 26 August

Triangle Singularities in a Hilbert's House

Ajay Shanmuga Sakthivasan (University of Bonn), Akaki Rusetsky, Maxim Mai

Our current understanding of hadrons is through QCD, and confinement in QCD leads to a rich spectrum of hadrons. Experimentally, hadronic resonances can appear as peaks in the invariant mass distributions. However, universal parameters of hadronic resonances are encoded theoretically in the poles of the S-matrix. Still, not all observed peaks necessarily correspond to hadronic resonances.
For example, the kinematical singularities, that correspond to intermediate particles going on shell and producing a peak in the invariant mass distributions, without any correspondence to a pole in the S-matrix. This was originally identified by Landau, and has been recently used to explain the $a_1(1420)$. We re-examine this scenario in the full three-body unitary formalism, utilising a recent approach, and extending it to the relevant coupled-channel system. We show the pattern and mechanism leading to the triangle singularity to all orders in exchange diagrams.

ID: 87, WG3 parallel session, Monday 26 August

Truncation uncertainty of chiral EFT for two-nucleon scattering from marginalizing over higher order contributions

Sven Heihoff (Ruhr University Bochum), Arseniy Filin, Evgeny Epelbaum

A reliable estimation of the accuracy of theoretical calculations is crucial for meaningful comparisons with experimental data. In the framework of chiral Effective Field Theory (EFT), one significant source of theoretical error stems from truncating the EFT expansion, which accounts for the impact of neglected higher-order terms. Past studies have typically estimated truncation uncertainty by analyzing the convergence pattern of lower-order terms. This requires certain assumptions about the expansion pattern for an observable of interest. In particular, one usually assumes that the chiral EFT expansion for the nuclear Hamiltonian directly translates into the analogous expansion for observables, which might not be the case for fine-tuned nuclear systems. In this study, we explicitly incorporate and quantify the contributions from the neglected next higher-order terms in the Hamiltonian. We compute the truncation error by explicitly marginalizing over the parameters associated with the next-higher order in the EFT expansion across a natural range of values. The resulting truncation errors are then compared with those obtained through conventional methods, and various criteria for assessing naturalness are explored. Our research enhances the understanding of the convergence patterns within chiral EFT, pinpointing configurations where the theory exhibits the highest precision and identifying areas with potential for refinement.

ID: 111, Plenary session, Tuesday 27 August

Left-hand branch cuts in lattice QCD scattering calculations

Maxwell Hansen (University of Edinburgh)

The abstract will be added later

ID: 10, Plenary session, Tuesday 27 August

Three-hadron dynamics from lattice QCD

Fernando Romero-Lopez (Uni Bern)

Studying three hadron dynamics using lattice QCD enables first-principles predictions of various hadronic resonances, including the Roper and the doubly-charmed tetraquark. To achieve this, substantial progress has been made in developing, implementing, and applying theoretical tools that connect finite-volume quantities to infinite-volume amplitudes involving three particles. In this presentation, I will discuss recent theoretical developments in formulating a framework for generic three hadrons and present numerical results focusing on three mesons at maximal isospin.

ID: 113, Plenary session, Tuesday 27 August

High-Precision Electron Scattering Experiments at the MESA Accelerator

Sören Schlimme (Johannes Gutenberg University Mainz)

In this talk, I will discuss the physics program of the low-energy, high-intensity electron accelerator MESA, currently under construction at the Institute for Nuclear Physics in Mainz. Designed to support a comprehensive physics program, MESA will facilitate three distinct experiments. An external beamline will deliver spin-polarized electrons to the P2 experiment, with the major goal of achieving a precision measurement of the weak mixing angle via parity-violating electron scattering at a low energy scale. Positioned downstream of P2, the DarkMESA beam dump experiment is dedicated to the search for light dark matter particles.

The main focus of my presentation will be on the multi-purpose MAGIX experiment, which features a windowless gas-jet target as a key component. This target's relatively low density allows MESA to operate in energy-recovery mode, an innovative technique that enables the generation of very high beam intensities, compensating for the low target thickness in terms of luminosity. This setup permits high-precision electron scattering experiments in the low-energy region ($E \leq 105$ MeV), where both electrons and low-energy recoil particles, such as protons or alphas, can be detected without traversing thick target material.

The MAGIX physics program encompasses dark sector searches, studies of hadron structure, and investigations of reactions relevant to nuclear astrophysics. Moreover, the experimental conditions are particularly ideal for studying light nuclei as strongly interacting systems. By using different targets such as deuterium or helium, both inclusive and exclusive measurements aim to systematically explore various aspects of low-energy theories, such as chiral effective field theory. Planned experiments include measurements of monopole transition form factors on helium and carbon at very low momentum transfers, deuteron electrodisintegration at forward angles, and exclusive reactions using a helium target.

ID: 34, Plenary session, Tuesday 27 August

Studying electroweak few-body observables in chiral effective field theory

Alex Gnech (Old Dominion University and JLab)

In recent years the use of nuclei has become increasingly relevant for experiments studying fundamental parameters of electroweak interactions. For experimental success, reliable theoretical inputs with well-controlled errors are required. Currently chiral effective field theory is one of the most adept theory fulfilling this requirement. In order to use this theory as a tool for studying electroweak interactions with nuclei, it is crucial to validate it on light nuclear systems for which the numerical calculation is well under control. In this talk, I will present some recent calculations of electromagnetic and electroweak processes involving few-body nuclei. The aim is to discuss how we can test the reliability of chiral effective field theory for these processes when we are computing few-body observables.In this context, we will focus on how to determine the free parameters of the currents as well as the computation of the theoretical truncation errors and how these can help to identify limitations and issues in the theory. Moreover, we will give a prospect on the calculation of some of these observables in heavier systems that are more relevant for future experiments.

ID: 88, Plenary session, Tuesday 27 August

Advances in Quantum Monte Carlo Studies of Nuclear Systems with Chiral Effective Field Theory Interactions

Maria Piarulli (Washington University)

A central goal of nuclear theory is to comprehensively explain the diverse phenomena and unique characteristics observed in nuclear systems through a microscopic framework. In this framework, nucleons interact with each other via two and many-body effective interactions, and with external electroweak probes via effective current operators. These interactions and currents form the core inputs for ab initio methods, which aim to solve the many-body Schrödinger equation for the nuclear system under study. In this talk, I will highlight the recent advancements in Quantum Monte Carlo methods for calculating the low-energy spectra and electroweak properties of light nuclei, as well as the equation of state for nucleonic matter. A special focus will be given to the calculations based on chiral effective field theory, which has significantly enhanced our understanding and predictive capabilities in these areas.

ID: 67, WG3 parallel session, Tuesday 27 August

Few-Nucleon Scattering Experiments to Explore the Three-Nucleon Forces

Yuko Saito (Tohoku University)

Necessity of the three-nucleon forces (3NFs) have come to light in various nuclear phenomena, for example, binding energies of nuclei, and equation of state in nuclear matters. As numerically exact solutions of the Faddeev equations using 2N- and 3N-forces are now attainable for observables in nucleon-deuteron (Nd) scattering, intricate information of the 3NFs can be extracted by directly comparing high precision data obtained in Nd experiments and theoretical calculations. Various performances of deuteron-proton (d-p) elastic scattering experiments at 70-300 MeV/nucleon (MeV/N) have confirmed clear signatures of 3NF effects in results of the cross sections below 135 MeV/N, whereas data of spin observables and cross sections at 250 MeV/N or above have suggested deficiencies in the spin dependent parts and high momentum transfer regions of current 3NF models.

In view of determining the 3NFs, we plan to measure the spin correlation coefficients in d-p elastic scattering at 100 MeV/N and see how the observables are described by potentials based on chiral effective field theory. The experiment will be performed at RIKEN RIBF facility, employing the polarized deuteron beam provided via the polarized ion source, in combination with the polarized proton solid-state target and the detector system, both of which have been newly developed for this experiment.

We also focus on proton-3He (p-3He) scattering experiments, with the aim to observe 3NFs effects such as the iso-spin channels of T=3/2. Data of differential cross sections, analyzing powers, and spin correlation coefficients at intermediate energies have been taken at RCNP and CYRIC, employing polarized beam and target systems.

In this conference, detailed explanations and future plans on the new d-p and p-3He scattering experiments will be given.

ID: 72, WG1 parallel session, Tuesday 27 August

Stringy Methods for Pion Amplitudes

Christoph Bartsch (Charles University, Prague)

In this talk I review established as well as recently uncovered connections between string-derived scalar amplitudes (Z-theory) and amplitudes of pions in the chiral non-linear sigma model (NLSM). Non-abelian Z-theory [1] amplitudes generalize the open string Veneziano amplitude and represent a stringy completion (including corrections in the string scale α') of a cubic bi-adjoint field theory of scalars (BAS). Abelian Z-theory [2] amplitudes on the other hand describe string-completed NLSM amplitudes of pions, and can be obtained from their non-abelian counterparts by a straightforward combinatoric procedure. Therefore pion amplitudes are encoded in the structure of the much simpler BAS theory.

A recent discovery [3] established an even more immediate connection between field theory BAS amplitudes and those of the NLSM using a simple kinematic shift which remarkably extends to loop-level integrands.

In this context I will formulate new Berends-Giele-like recursion relations for NLSM amplitudes and planar integrands that leverage the close tie to the BAS theory. The recursive procedure is highly efficient as its input are large building blocks in the form of mixed amplitudes coupling pions and bi-adjoint scalars. Furthermore the recursion requires only a single cubic vertex to build NLSM amplitudes with any number of legs and loops and naturally generalizes the well-known Adler zero of tree amplitudes to loop integrands [4].

[1] arXiv:1609.07078 [hep-th]
[2] arXiv:1608.02569 [hep-th]
[3] arXiv:2401.05483 [hep-th]
[4] arXiv:2401.04731 [hep-th]

ID: 115, WG2 parallel session, Tuesday 27 August

Low-energy constants from baryon masses on Lattice QCD ensembles

Matthias F.M. Lutz (GSI)

In this talk I discuss Low-Energy Constants (LEC) in the chiral Lagrangian with three light flavors from current Lattice QCD data. The LEC are adjusted to describe the baryon octet and decuplet masses from a large set of lattice ensembles at N3LO, where finite-box and discretization effects are considered. Faithful results require in particular accurate baryon masses on flavor symmetric ensembles. The analysis is performed for all ensembles with pion and kaon masses smaller than 550 MeV where our loop contributions are evaluated systematically in terms of on-shell meson and baryon masses. The set of LEC is most relevant for meson-baryon scattering processes as computed from the chiral Lagrangian in coupled-channel approaches.

ID: 36, WG2 parallel session, Tuesday 27 August

J/Ψ N scattering length

Bing Wu (Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing, China), Xiang-Kun Dong, Meng-Lin Du, Feng-Kun Guo, Bing-Song Zou

Our work focused on studying the scattering length of $J/\psi N$ under gluon exchange via dispersion relations and compared the results with contributions from existing coupled-channel processes. Starting from the SU(3) tree-level chiral amplitudes of $N\bar{N} \to \pi\pi/K\bar{K}$, we obtained the S-wave amplitude considering the final state interactions of the $\pi\pi$-$K\bar{K}$ coupled channels through the Muskhelishvili-Omnès representation. Using the amplitudes for the $J/\psi J/\psi \to \pi\pi/K\bar{K}$ processes from the literature and the crossing relations, we calculated the scattering length of $J/\psi N$ without considering the rescattering effects. Finally, by applying the Schwartz inequality satisfied by the chromopolarizability, we further refined this result, providing that the product of the scattering lengths of $J/\psi N$ and $\psi(2S)N$ satisfies $a^{J/\psi N}a^{\psi(2S)N} \geq 0.06\ \mathrm{fm}^2$. Furthermore, both of these S-wave scattering lengths are spin-independent. Given that the coupled-channel mechanism yields a $J/\psi N$ scattering length of less than 10 am, we can conclude that the contribution from gluon exchange is qualitatively much larger than that from the coupled channels.

ID: 94, WG3 parallel session, Tuesday 27 August

Chiral three-nucleon force in many-nucleon systems

Tokuro Fukui (Kyushu University)

Three-nucleon systems offer fundamentals to determine the basic properties of three-nucleon forces (3NFs), such as the strength of the force. In contrast, many-nucleon systems are major playground of three-nucleon forces, as evidenced by, for example, spectroscopic properties of light nuclei, dripline determination, and nuclear-matter saturation.

In this presentation, we delve into the intricate relationship between spin-orbit (SO) splitting and 3NFs derived from chiral effective field theory. While the influence of 3NFs on enhancing SO splitting is well-documented, the precise mechanisms underlying this enhancement have remained elusive. Through a meticulous decomposition of the chiral 3NF, our investigation reveals that the rank-1 component emerges as the primary driver behind the enlargement of SO splitting in light nuclei.

Of particular interest is the antisymmetric nature of the rank-1 3NF, prompting intriguing parallels with phenomena observed in other domains, such as the spin canting caused by the Dzyaloshinsky-Moriya interaction in magnetic ions. Furthermore, we explore the implications of this antisymmetry in relation to the quantum entanglement of two-nucleon spin states.

By elucidating these intricate connections, our findings not only deepen our understanding of nuclear dynamics but also pave the way for future investigations into the broader implications of 3NFs.

ID: 105, WG1 parallel session, Tuesday 27 August

Gauge Theory Bootstrap: Pion amplitudes and low energy parameters

Yifei He (Ecole Normale Superieure, Paris), Martin Kruczenski

We propose the Gauge Theory Bootstrap — a method to compute the pion S-matrix that describes the low energy physics of the strong interaction and other similar gauge theories. Using this method, we compute pion scattering phase shifts for all partial waves with angular momentum $\ell \leq 3$ up to 2 GeV and calculate the low energy χPT coefficients $L_{1,2,4,6}$. The method looks for the most general S-matrix that matches at low energy the tree level amplitudes of the non-linear sigma model and at high energy, QCD sum rules and form factors. This is a theoretical/numerical calculation that uses as only data the pion mass m_π, pion decay constant f_π and the QCD parameters $N_c = 3$, $N_f = 2$, m_q and α_s. All results are in reasonable agreement with experiment. In particular, we find the $\rho(770)$, $f_2(1270)$ and $\rho(1450)$ resonances and some initial indication of particle production near the resonances. The interplay between the UV gauge theory and chiral dynamics is an example of a general situation where we know the microscopic theory as well as the effective theory of long wavelength fluctuations but we want to solve the strongly coupled dynamics at intermediate energies. The bootstrap builds a bridge between the low and high energy by determining the consistent S-matrix that matches both and provides, in this case, a new direction to understand the strongly coupled physics of gauge theories.
Based on 2309.12402 and 2403.10772.

ID: 20, WG1 parallel session, Tuesday 27 August

Subthreshold parameters of pipi scattering revisited

Marián Kolesár (Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University, Prague), Jaroslav Říha

Using the most recent experimental data and lattice calculations of scattering lengths of $\pi\pi$ scattering and employing dispersive representation of the amplitude based on Roy equations, we compute the subthreshold parameters of this process. We use Monte Carlo sampling to numerically model the probability distribution of the results based on all uncertainties in the inputs. In the second part of the analysis, we use the new results for the subthreshold parameters to obtain constraints on the leading order low energy constant B_0 in the context of three-flavour chiral perturbation theory.

ID: 39, WG3 parallel session, Tuesday 27 August

Sensitivity of the nucleon-deuteron scattering observables to N4LO contact terms of three-nucleon force

Roman Skibiński (Jagiellonian University), Henryk Witała, Jacek Golak

The ongoing progress in derivation the chiral two- and many-nucleon forces in the framework of chiral perturbation theory (χPT) [1,2] gives better and better understanding of nuclear phenomena, but also brings many challenges for application of these forces beyond the two-nucleon (2N) system. While general operator form of three nucleon force (3NF) is currently known up to N4LO [3-6], its practical implementation to the bound systems and to the scattering problems is delayed. The main obstacles are necessity of consistent, with what is used in 2N force, regularization of the 3NF, performing partial wave decomposition of 3NF, and last but not least fixing it's free parameters. It is expected that at N4LO there are thirteen free parameters to be fixed from data. Due to the computational complexity of 3N calculations it is unpractical to apply standard fitting methods in that case.

In this contribution, we focus on the latter problem and propose fast and efficient way to obtain approximated solution of 3N scattering problem [7-9] within the Faddeev approach. We apply that new emulator to investigate the importance of the 3NF N2LO and N4LO contact terms in elastic nucleon-deuteron (Nd) scattering. Specifically, we use the N4LO+ chiral semilocal momentum space regularized 2N chiral potential [10] supplemented by N2LO 3NF [11] and all subleading N4LO 3NF contact terms [5-6]. Inclusion of the N4LO 3NF contact terms yields an improved description of the elastic Nd scattering observables in a wide range of incoming nucleon energies up to 250 MeV. We will shortly discuss the equations forming the emulator, the procedure for establishing the LEC values, and last but not least, not shown before, the uncertainties of predictions related to uncertainty of these LEC values.

[1] E.Epelbaum, H-W.Hammer, and U-G.Meiβner, Rev Mod Phys 81 (2009) 1773.
[2] R.Machleidt and D.R.Entem, Phys. Rep. 503, 1 (2011).
[3] H.Krebs, A.Gasparyan, and E.Epelbaum, Phys. Rev. C 85, 054006 (2012).
[4] H.Krebs, A.Gasparyan, and E.Epelbaum, Phys. Rev. C 87, 054007 (2013).
[5] L.Girlanda, A.Kievsky, and M.Viviani, Phys. Rev. C 84, 014001 (2011).
[6] L.Girlanda, A.Kievsky, and M.Viviani, Phys. Rev. C 102, 019903(E) (2020).
[7] H.Witała, J.Golak, R.Skibiński, and K.Topolnicki, Few-Body Syst. 62, 23 (2021).
[8] H.Witała, J. Golak, and R. Skibiński, Eur. Phys. J. A 57, 241 (2021).
[9] H.Witała, J. Golak, and R. Skibiński, Phys. Rev. C105, 054004 (2022).
[10] P.Reinert, H.Krebs, and E.Epelbaum, Eur. Phys. J. A 54, 86 (2018).
[11] E.Epelbaum et al., Phys. Rev. C 66, 064001 (2002).

ID: 85, WG2 parallel session, Tuesday 27 August

Baryon-meson scattering amplitude in the 1/Nc expansion of QCD

Johann Hernández (Universidad Autónoma de San Luis Potosí), Rubén Flores-Mendieta, Víctor Miguel Banda Guzmán

The baryon-meson scattering amplitude is calculated under the formalism of $1/N_c$ expansion of QCD. The obtained results consider the effects of the decuplet-octet baryon mass difference and perturbative flavor $SU(3)$ symmetry breaking in the complete computation for the first time. Since the resulting expressions can be applied to any baryons and mesons, when the Gell-Mann - Nishijima scheme is fulfilled, the $N\pi$ scattering processes are analyzed. In addition, the reported results have been verified with some isospin relations at the physical value $N_c = 3$.

ID: 61, WG2 parallel session, Tuesday 27 August

Neutrino-induced pion-production off the nucleon in chiral effective field theory

Niklas Döpper, Norbert Kaiser

In this talk, our analysis of neutrino-induced single pion production off the nucleon within the framework of manifestly Lorentz-invariant chiral perturbation theory is presented. We consider tree and one-loop diagrams up to and including third chiral order, explicitly incorporating the $\Delta(1232)$ resonance. To handle terms breaking the power counting between loop and small momentum expansion, we employ the extended on-mass-shell scheme. First results for the total cross-section are shown.

ID: 65, WG1 parallel session, Tuesday 27 August

Six-meson scattering and three pions on the lattice

Mattias Sjö (CPT, Aix-Marseille University), Fernando Romero-Lopez, Johan Bijnens, Jorge Baeza-Ballesteros, Stephen Sharpe, Tomáš Husek

Three-hadron systems are an active topic in lattice QCD, primarily due to their relevance to the study of hadronic resonances with three-body decays. The systematics of such challenging systems – finite-volume effects and the pion-mass dependence – can be connected to the elastic three-to-three scattering amplitude, which can in turn be computed in chiral perturbation theory. I describe a series of works in which we calculate this six-point amplitude to next-to-leading order and then relate it to the lattice, covering *all* cases involving only pions and setting the stage for further developments. In the maximum-isospin channel, our results resolve most of the tension previously seen between lattice QCD and the leading-order amplitude.

ID: 76, WG3 parallel session, Tuesday 27 August

Dynamics of 3-nucleon systems studied in proton-induced deuteron breakup reaction.

Elżbieta Stephan (Institute of Physics, University of Silesia, Poland), Adam Kozela, Nasser Kalantar-Nayestanaki, Stanisław Kistryn

Scattering experiments in systems of three nucleons provide particularly rich and sensitive data for testing the state-of-the-art potentials of nuclear interactions. Experimental studies of the deuteron breakup reaction demonstrated sensitivity of the observables to three-nucleon force (3NF) and but also the importance of the Coulomb interaction between protons even at beam energies close to 200 MeV/nucleon. Because of the momentum continuum of the three free nucleons in the output channel, experiments investigating this reaction in a wide range of phase space have been a very useful tool for searching for dynamical effects.
The results of such experiments conducted over a wide range of beam energies, between 50 and 200 MeV/nucleon, will be shown, with particular emphasis on the observed effects, as well as local discrepancies between experiment and theoretical description. Current and planned experiments in this area will also be presented.

ID: 27, WG2 parallel session, Tuesday 27 August

Nucleon Self-Energy at Two-Loop Level

Nils Dirk Conrad (Ruhr University Bochum), Ashot Gasparyan, Evgeny Epelbaum

The nucleon self-energy is calculated in SU(2) covariant chiral perturbation theory (ChPT) to analyze the pion mass dependence of the nucleon mass up to chiral order $\mathcal{O}(q^6)$, i.e., including two-loop diagrams. In a first step, all diagrams are expressed by a small set of (scalar) master integrals. The extended on-mass-shell (EOMS) renormalization scheme is applied, where (next to the divergent pieces) certain infrared regular parts of the integrals are systematically subtracted, gaining renormalized expressions consistent with the power counting. The master integrals are dimensionally regularized and calculated in two ways: Firstly, a $1/m_0$ expansion (with m_0 being the nucleon mass in the chiral limit) is performed, using the strategy of regions to differentiate between the infrared singular and regular part. The corresponding result is in agreement with the results from heavy-baryon ChPT and infrared renormalization. Secondly, the master integrals are solved numerically (using the sector decomposition method) to obtain a fully covariant result that is to be compared to the lattice data.

ID: 52, WG3 parallel session, Tuesday 27 August

Non-perturbative three-nucleon simulation using chiral lattice EFT

Lukas Bovermann (Ruhr University Bochum), Evgeny Epelbaum, Hermann Krebs, Dean Lee

We consider the three-nucleon system non-perturbatively in the framework of chiral effective field theory (EFT) on the lattice at next-to-next-to-next-to-leading order ($\mathrm{N^3LO}$). For the two-nucleon force, a lattice version of the successful semilocal momentum-space regularized (SMS) potential is employed. In the three-nucleon sector, we determine the two low-energy constants (LECs) in the $\mathrm{N^2LO}$ contact interactions by adjusting the smallest Hamiltonian eigenvalues to the binding energies of triton and helion-3. Additionally, the charge radii of these nuclei and the half-life of the beta decay between them are computed, where the latter is based on the nuclear axial current at leading order in chiral EFT. We compare our results with a recent perturbative lattice-EFT calculation that uses the wave-function-matching technique to circumvent the Monte-Carlo sign problem.

ID: 74, WG1 parallel session, Tuesday 27 August

Multi-Higgs production and chiral effective Lagrangians

Juan Jose Sanz-Cillero (Universidad Complutense de Madrid and IPARCOS), Alexandre Salas-Bernardez, Felipe J. Llanes-Estrada, Javier Martinez-Martin, Rafael L. Delgado, Raquel Gomez-Ambrosio

We discuss various aspects of (multi-) Higgs boson production from longitudinal electroweak gauge bosons $W_LW_L \to n\times h$ in the TeV region as the necessary information to characterise the Flare function, $\mathcal{F}(h)$, which determines whether the Standard Model EFT (SMEFT) or the Higgs EFT (HEFT -also sometimes referred as the EW Chiral Lagrangian-) is the appropriate description. We show a set of new correlations among BSM corrections to the HEFT coefficients that help decide, from experimental data, whether we have a viable SMEFT low-energy scenario. We present an effective field theory study of W_LW_L scattering into two, three and four Higgs bosons in the final state. We consider the general HEFT approach and then particularize it for SMEFT scenarios. We make use of the equivalence theorem and improve previous results on $W_LW_L \to n \times h$ cross sections, showing several important cancellations and simplifications which allows us to display these amplitudes in a very compact form. We show that for a growing number of Higgs bosons in the final state, SMEFT leads to an important suppression of the cross sections with a large number of Higgses, while this does not happen for general HEFT low-energy scenarios (which do not accept a SMEFT description). We provide some numerical estimates of these multi-Higgs cross sections based on current experimental bounds.

ID: 48, WG2 parallel session, Tuesday 27 August

Weak nonleptonic hyperon decays in relativistic ChiPT

Nora Salone (National Centre for Nuclear Research - NCBJ), Stefan Leupold, Fernando Alvarado

Nonleptonic hyperon transitions are studied in a relativistic framework of chiral perturbation theory (χPT). Previously, one-loop corrections to parity-violating and -conserving partial-wave amplitudes S and P have been computed in a nonrelativistic approach, focusing on the leading chiral logarithms [1]. This study concluded that a satisfying agreement with data and reasonable convergence is reachable for the S waves, but not for the P waves. In light of significant updates of asymmetry parameters on the experimental side (see [2] and references therein), we attempt a (re)calculation of one-loop corrections in relativistic χPT in the EOMS renormalization scheme [3, 4]. Following the suggestion of [5], the unknown low-energy constants are estimated using explicit resonances corresponding to the chiral order of the one-loop corrections. We present our results for the combined fit to S- and P-wave amplitudes, as well as the relative importance of the considered contributions, such as the role of resonances and decuplet baryons as intermediate states. To summarize, our goal is to provide an updated theoretical description of weak nonleptonic hyperon decays in χPT up to one-loop corrections, based on the most recent data and theoretical framework.

References
[1] E. Jenkins, Nucl. Phys. B 375 (1992), 561-581.
[2] Phys. Rev. D 105 (2022) 11, 116022.
[3] Phys. Rev. D 68 (2003), 056005.
[4] Front. Phys. 8 (2013), 328–348.
[5] Phys. Rev. D 59 (1999), 094025.

ID: 82, WG3 parallel session, Tuesday 27 August

Studies of A>3 few-nucleon systems within next-to-leading order Pionless Effective Field Theory

Martin Schäfer (Nuclear Physics Institute of the Czech Academy of Sciences)

Pionless effective field theory (EFT) represents a highly convenient tool that allows the description of nuclear interaction at very low energies. This theory, at its leading order, has been used to study various systems up to ^{16}O; however, only with limited success, rendering $A > 4$ nuclei unbound in the large cutoff limit. Higher orders of the theory have been mostly tested in $A \leq 3$ nuclear systems. At the three-body level, it has been shown that considering sub-leading terms systematically improves the theory's predictive power. Whether experimentally observed binding of $A > 4$ nuclei might be restored at higher orders remains an open question.
In my contribution, I will show how a few-body approach based on the Stochastic Variational Method with a correlated Gaussian basis and a harmonic oscillator trap enables studying nuclear systems with A > 3. In particular, I will present the microscopic predictions of s-wave low-momentum n-d, n-3H, n-3He, and n-4He elastic scattering within perturbative next-to-leading order Pionless EFT [1,2]. The corresponding results will be compared to available experimental data.
[1] M. Schäfer and B. Bazak, Phys. Rev. C 107 (2023) 064001.
[2] M. Bagnarol, M. Schäfer, B. Bazak, and N. Barnea, Phys. Lett. B 844 (2023) 138078.

ID: 103, WG1 parallel session, Tuesday 27 August

Hypergeometric function theory and Feynman Integrals at the interface: some recent Mathematica implementations

Balasubramanian Ananthanarayan (Indian Institute of Science)

Hypergeometric function theory and Feynman Integral calculus go hand in hand. A series of recent investigations that culminated in the construction of several Mathematica packages that are based on Mellin-Barnes techniques, Method of Regions, hypergeometric function theory, etc., is reviewed in this talk to encourage the community to explore the use of these packages. Two-loop integrals appearing in chiral perturbation theory are a typical example that will be used for purposes of illustration.

ID: 26, WG3 parallel session, Tuesday 27 August

Ab initio predictions of heavy atomic nuclei

Takayuki Miyagi (University of Tsukuba)

One of the fundamental problems in nuclear physics is to understand the properties of nuclei based on underlying nuclear interactions. The nuclear interactions determined with the few-body data can be tested by computing the heavier systems. The tested interactions can be used to predict the experimentally yet unknown properties. For this purpose, developing many-body techniques for heavier systems is important. The applicability of nuclear ab initio calculation has been expanding in the past few decades, and systematic calculations can be performed up to mass number ~ 100. However, the applications for heavier systems are limited primarily due to the memory-expensive three-nucleon (3N) interaction matrix elements. Modern nuclear ab initio calculations begin with the nucleon-nucleon (NN) and 3N interactions, benefitting from chiral effective field theory. For medium- and heavy-mass nuclei, one can apply basis expansion methods such as the coupled-cluster method, self-consistent Green's function method, many-body perturbation theory, and in-medium similarity renormalization group, starting from the NN and 3N matrix elements expressed with the spherical harmonic-oscillator (HO) basis set, where a typical calculation is performed within 13 or 15 major-shell space. The memory requirement of the 3N matrix elements in such space will exceed 10 TB, and one needs another truncation for 3N matrix elements, known as $E_{3\mathrm{max}}$ defined by the sum of 3N HO quanta. It turned out that the current $E_{3\mathrm{max}}$ limit does not allow us to obtain converged results for nuclei heavier than $A \sim 100$. To overcome the limitation, we proposed a new storage scheme for the 3N matrix elements, where we exploit the feature of the normal-ordered two-body approximation widely used in the basis expansion methods. This new scheme enables us to compute the known heaviest doubly magic nucleus ^{208}Pb. In this presentation, I will show recent ab initio results for some heavy mass nuclei, including a prediction for the neutron-skin thickness of ^{208}Pb.

ID: 64, WG1 parallel session, Tuesday 27 August

Long-range forces in a finite volume

Akaki Rusetsky (University of Bonn), Fabian Müller, Hans-Werner Hammer, Jia-Jun Wu, Jin-Yi Pang, Rishabh Bubna

The presence of the long-range forces brings novel aspects in the formulation of the finite-volume two-body quantization condition, which relates the lattice spectrum with the infinite-volume scattering phase shifts. In particular, the higher partial waves start to contribute substantially to the quantization condition that makes the analysis more complicated. Furthermore, the so-called t-channel cut in the scattering amplitude moves very close to the unitarity cut, rendering the use of the standard formalism impossible just below the physical threshold. In my talk, I will review different solutions to the problem that are available in the literature. In particular, I shall concentrate on the recent proposal, based on the finite-volume version of the modified effective-range expansion.

ID: 77, WG2 parallel session, Tuesday 27 August

Status of the PrimEx-eta experiment at Jefferson Lab

Alexander Somov (Jefferson Lab)

The GlueX detector in the experimental Hall-D at Jefferson Lab offers a unique opportunity to perform a measurement of the decay width of eta mesons through the Primakoff effect. The experiment complements the physics program at Jefferson Lab on measuring the decay width of light pseudoscalar mesons via the Primakoff process. The goal of the experiment is to measure differential cross sections of η mesons at forward angles using a beam of tagged photons incident on a liquid ^{4}He target, which will be used for the extraction of the decay width. This measurement is vital for understanding fundamental properties like the ratios of the light quark masses and the η-η' mixing angle, and will provide an important test of chiral symmetry breaking in QCD. Our experimental results will help reduce uncertainties on partial widths of all other η decays. The experiment collected data during three physics runs between 2019 and 2022. We will give an overview of the PrimEx-eta experiment and the current status of our data analyses. We will also discuss the feasibility of conducting future Primakoff measurements in light of the recent upgrade of the GlueX forward calorimeter.

ID: 4, WG2 parallel session, Tuesday 27 August

Fragmentation function studies at BESIII

Christoph Redmer (Johannes Gutenberg University Mainz), Beijiang Liu

Fragmentation Function (FF) plays a crucial role in describing the hadronization process. We report the measurements of normalized differential cross sections of inclusive pi0, Ks, and eta production as a function of hadron momentum at six energy points with q^2 transfer from 5 to 13 GeV^2 at BESIII. The results of pi0 and Ks with a relative hadron energy coverage from 0.1 to 0.9 significantly deviate from several theoretical calculations based on existing fragmentation functions.

ID: 30, WG1 parallel session, Tuesday 27 August

Left-hand cut problem in lattice QCD and an EFT-based solution

Lu Meng (Ruhr University Bochum), Evgeny Epelbaum, Arseniy Filin, Ashot Gasparyan, Vadim Baru

In this talk, I will present a novel effective-field-theory-based approach for extracting two-body scattering information from finite volume energies. By explicitly incorporating one-pion exchange, we overcome the challenging left-hand cut problem in Lüscher's method and can handle finite volume energy levels both below and above the left-hand cut. Additionally, we utilize the plane wave basis instead of the conventional partial wave expansion to account for partial wave mixing effects resulting from rotational symmetry breaking in a cubic box. Applied to the lattice data for DD^* scattering at a pion mass of 280 MeV, it reveals the significant impact of the one-pion exchange interaction. This study demonstrates, for the first time, that two-body scattering information can be reliably extracted from lattice spectra including the left-hand cut.

ID: 68, WG3 parallel session, Tuesday 27 August

Recent progresses in few-nucleon structure and dynamics in chiral effective field theory

Laura Elisa Marcucci (University of Pisa)

We present in this talk the most recent progresses made within the framework of chiral effective field theory for few-nucleon structure and low-energy reactions, especially those of astrophysical interest. We will first review the studies of the A=2 proton-proton fusion [1], as well as the muon capture on deuteron [2]. Furthermore, using the Hyperspherical Harmonics ab-initio method, we will present results for some A=4 observables, as the 4He monopole form factor, the d(d,n)3H and d(d,p)3He reactions [3], and the 3He($\vec{n}$,p)3H parity-conserving asymmetry.

References

[1] B. Acharya et al., J. Phys. G 50 (2023), 095102

[2] A. Gnech et al., Phys. Rev. C 109 (2024), 035502

[3] M. Viviani et al., Phys. Rev. Lett. 130 (2023), 122501

ID: 16, WG2 parallel session, Tuesday 27 August

Mixing interactions and effects in the NJL-model

Fabio Braghin (Federal University of Goias)

By considering the one loop background field method for the quark-antiquark interaction mediated by non perturbative one-gluon exchange, U(3) flavor dependent corrections to the NJL-model coupling constant are derived in the local limit. Meson and quark mixing(s) are discussed, basically emerging due to the different representations in which quarks and quark-antiquark meson are defined. These mixing(s) induce a sizeable role of the sea quark-antiquark states by means of the quark condensates of all flavors. Due to this, it is possible to show a strangeness (and heavier flavor) content of light mesons such as pions and scalar quark-antiquark states. Consequences for observables usually calculated with the NJL-model are presented by neglecting the mixing interactions. The 6th order interactions for the scalar and pseudoscalar quark currents are of the same shape of the 't Hooft determinantal interactions for the flavor U(3) model. However, further structures emerge from vacuum polarization.

ID: 31, WG3 parallel session, Tuesday 27 August

Short range correlations in light nuclei

Eleonora Proietti (Università di Pisa, INFN sezione di Pisa), Laura Elisa Marcucci, Michele Viviani

Within the Generalized Contact Formalism [1], I will present a study of short-range correlations and contact coefficients [2], utilizing realistic chiral potentials, derived either in coordinate-space, and therefore local, or in momentum-space, and therefore non-local. Additionally, we employ the Hyperpherical Harmonics method [3] to calculate the two-body momentum distribution with virtually any potential[4]. Specifically, I will present results for A=2, 3, and 4 nuclei, in order to address the model-independent behavior of the contact coefficient ratio across various spin and isospin channels. We will verify whether the contact coefficient ratio between different nuclei exhibits minimal dependence on the nuclear interaction model, thus extending the results presented in Ref. [2], when these coefficients were obtained using only local interactions.
[1] R. Weiss, Cruz-Torres R. et al., "The nuclear contacts and short-range correlations in nuclei", Phys. Lett. B 780, 211-215 (2018).
[2] Cruz-Torres R., Lonardoni, D., Weiss, R. et al., "Many-body factorization and position–momentum equivalence of nuclear short-range correlations", Nat. Phys. 17, 306–310 (2021).
[3] L. E. Marcucci et al., "The Hyperspherical Harmonics Method: A Tool for Testing and Improving Nuclear Interaction Models", Front. in Phys 8, 69 (2020).
[4] L. E. Marcucci et al., "Momentum distributions and short-range correlations in the deuteron and 3He with modern chiral potentials", Phys. Rev. C 99, 034003 (2019).

ID: 92, WG1 parallel session, Tuesday 27 August

A Novel Method for Determining Resonance Positions in Finite Volume

Congwu Wang (Ruhr University Bochum/Fudan Univ.), Dean Lee, Evgeny Epelbaum, Hermann Krebs, Lukas Bovermann

We introduce a novel method that utilizes the overlaps between test states and Hamiltonian eigenstates to determine resonance positions, applicable both in lattice and in finite-volume continuum calculations. We demonstrate the efficiency of this method through explicit examples. Using simple spatially compact test states, we obtained Breit-Wigner peaks in the energy distribution for the overlaps (which we call the "spectral overlap function") as anticipated. The extrapolated resonance positions in the infinite-volume and continuum limit compare well with the exact values. The Monte-Carlo version of this technique for nuclear lattice EFT is currently under development.

ID: 44, WG3 parallel session, Tuesday 27 August

Radiative corrections for the two-nucleon interaction in effective field theory

Immo Christopher Reis (Johannes Gutenberg University Mainz), Thomas Richardson

We use a combination of effective field theory and the renormalization group to determine the impact of radiative corrections on the nucleon-nucleon potential. In order to do so, we present a modified version of pionless effective field theory inspired by earlier work in nonrelativistic quantum electrodynamics. We investigate the effect of the corrections on the binding energy, electromagnetic form factors and photodisintegration of the deuteron.

ID: 81, WG1 parallel session, Tuesday 27 August

Three-body analysis of Tcc+(3875)

Sebastian Dawid (University of Washington), Fernando Romero-Lopez, Stephen Sharpe

During the talk, I will discuss progress in applying the relativistic three-particle scattering formalism of Hansen and Sharpe to systems of non-degenerate mesons of arbitrary angular momenta. For concreteness, I will focus on the $DD\pi$ system in the charm $C = 2$ and isospin $I = 0$ sectors, where the doubly charmed tetraquark $T_{cc}^{+}(3875)$ should appear as a pole in the elastic $3 \to 3$ scattering amplitude. After a short overview of the tetraquark physics, finite-volume results, and the three-body formalism, I will describe solutions to the relativistic integral equations describing this three-body process. I will focus on systems with heavier than physical pion masses and present several three-body models of the state proposed to explain the available and future lattice data. In particular, I will advocate for the importance of partial S- and D-wave mixing in this system and describe its implications for the finite-volume $DD\pi$ energy levels.

ID: 123, WG2 parallel session, Tuesday 27 August

Trace anomaly and gravitational form factors in the QCD instanton vacuum

Christian Weiss (Jefferson Lab)

The breaking of conformal and chiral symmetry determine the structure of the QCD vacuum and condition the emergent properties of light hadrons. We review recent efforts in studying these phenomena in the instanton liquid model of the QCD vacuum, a semiclassical picture abstracted from lattice QCD calculations. Chiral symmetry breaking is caused by the fermionic zero modes induced by the topological gauge fields of the instantons. Conformal symmetry breaking is encoded in the fluctuations of the number of instantons dictated by the renormalization properties of QCD [1]. An effective theory is derived in the $1/N_c$ expansion, describing massive quarks with chiral spin-flavor interactions. Gluonic operators such as the trace anomaly F^2 are represented by effective operators. Hadronic matrix elements of the trace anomaly are obtained in accordance with low-energy theorems. We summarize recent results for the mass decomposition and gravitational form factors of the pion [2] and the nucleon and their mechanical interpretation. We also present predictions for instanton-induced quark-gluon correlations in the twist-3 generalized parton distributions [3].
[1] D. Diakonov, M.V. Polyakov, C. Weiss, Nucl. Phys. B 461, 539 (1996)
[2] W.Y. Liu, E. Shuryak, C. Weiss, I. Zahed, arXiv:2405.14026 [hep-ph]
[3] J.Y. Kim, C. Weiss, Phys. Lett. B 848, 138387 (2024)

ID: 32, WG1 parallel session, Tuesday 27 August

Advances in the finite-volume three-particle formalism

Stephen Sharpe (University of Washington), Fernando Romero-Lopez, Sebastian Dawid

I describe recent advances in the development and application of the three-particle formalism that connects the finite-volume spectrum of three (and two) particles to infinite volume three- (and two-) particle scattering amplitudes. Specifically, I will present results from applying this formalism to systems of three pions and/or kaons at maximal isospin at near physical quark masses (work with Sebastian Dawid, Zack Draper, Andrew Hanlon, Ben Horz, Colin Morningstar, Fernando Romero-Lopez, and Sarah Skinner), and will present the generalization of the formalism needed in the presence of multiple three particle channels, focusing on pi+pi+eta and K+Kbar+pi (work with Zack Draper).

ID: 40, WG2 parallel session, Tuesday 27 August

Possible scenario of dynamical chiral symmetry breaking in the instanton liquid

Yamato Suda (Tokyo Institute of Technology), Daisuke Jido

We examine a pattern of dynamical chiral symmetry breaking making use of the vacuum energy density as a function of the quark condensate. We compute the vacuum energy density and the quark condensate in the interacting instanton liquid model (IILM) with three-flavor quarks. These computations are performed by using a numerical simulation of the canonical IILM, i.e., the number of instantons and anti-instantons are fixed. We find that chiral symmetry is broken in the $U(1)_A$ anomaly assisted way in the IILM with three-flavor dynamical quarks. Comparing the full and the quenched IILM calculations, we also find the instanton-quark interaction included in the IILM plays a crucial role for the chiral symmetry breaking.

ID: 49, WG3 parallel session, Tuesday 27 August

Nuclear structure effects on two-photon exchange in muonic deuterium

Vadim Lensky (Johannes Gutenberg University Mainz), Franziska Hagelstein, Vladimir Pascalutsa

Nuclear structure effects on the energies of light (ordinary and muonic) atoms are the dominant source of uncertainty in the determination of the nuclear charge radii and other properties of light nuclei [1], [2]. The most important of these effects are the two-photon exchange (TPE) contributions. The present method of choice for studying them is ab initio theoretical calculations. In this talk, I will consider TPE contributions to the energy spectra of muonic deuterium, concentrating on recent results obtained within the framework of chiral [3] and pionless effective field theories [4,5].

[1] K. Pachucki, V. Lensky, F. Hagelstein, S. Li Muli, S. Bacca, R. Pohl, Rev. Mod. Phys. 96 (2024), 015001 [arXiv:2212.13782 [physics.atom-ph]]

[2] A. Antognini, F. Hagelstein and V. Pascalutsa, Ann. Rev. Nucl. Part. Sci. 72 (2022) 389 [arXiv:2205.10076 [nucl-th]]

[3] B. Acharya, V. Lensky, S. Bacca, M. Gorchtein, M. Vanderhaeghen, Phys. Rev. C 103 (2021), 024001 [arXiv:2010.11155 [nucl-th]].

[4] V. Lensky, F. Hagelstein and V. Pascalutsa, Eur. Phys. J. A 58 (2022), 224 [arXiv:2206.14756 [nucl-th]]

[5] V. Lensky, F. Hagelstein and V. Pascalutsa, Phys. Lett. B 835 (2022), 137500 [arXiv:2206.14066 [nucl-th]]

ID: 97, WG3 parallel session, Tuesday 27 August

Precision theory for electromagnetic observables of light nuclei

Arseniy Filin (Ruhr University Bochum), Vadim Baru, Evgeny Epelbaum, Christopher Körber, Hermann Krebs, Daniel Möller, Andreas Nogga, Patrick Reinert

Charge, magnetic and Zemach radii of light nuclei characterize the distribution of electromagnetic charge inside the corresponding nuclei and are a perfect tool to test modern high-precision nuclear forces. Experimentally, these radii can be extracted from electron scattering and the laser spectroscopy of normal and muonic atoms with precision often reaching sub-percent level. Theoretical description with a similar accuracy level requires a very good understanding of two- and three-body forces, two-body electromagnetic currents, and various relativistic effects.
We present a high-accuracy calculation of electromagnetic form factors of A=2,3,4 nuclei based on the latest two- and three-nucleon forces, electromagnetic current operators derived up through the fifth order in the chiral effective field theory. We predict electric and magnetic structure radii and perform a comprehensive and systematic analysis of various sources of uncertainty. Using the predicted values of the ^{2}H and ^{4}He structure radii combined with the spectroscopic measurements of the deuteron-proton charge radius difference and ^{4}He charge radius we extract the neutron and proton charge radii.

ID: 114, Plenary session, Wednesday 28 August

New insights into the nucleon's electromagnetic structure

Hans-Werner Hammer (TU Darmstadt)

We present a combined analysis of the electromagnetic form factors of the nucleon in the space- and time-like regions using dispersion theory. Our framework provides a consistent description of the experimental data over the full range of momentum transfer, in line with the constraints from analyticity and unitarity. The statistical uncertainties of the extracted form factors are estimated using the bootstrap method, while systematic errors are determined from variations of the spectral functions. From the form factors, we determine precise values for the nucleon radii and comment on their puzzling status.

ID: 100, Plenary session, Wednesday 28 August

Review of JLab and Mainz experimental results for spin-independent generalized nucleon polarizabilities

Nikos Sparveris (Temple University)

The polarizabilities of a composite system such as the proton are elementary structure constants. They describe it's response to an external electromagnetic (EM) field and quantify the deformation of the charge and magnetization distributions inside the proton caused by the electric or magnetic field, respectively. When studied through the virtual Compton scattering process, the virtuality of the photon gives access to the generalized polarizabilities that open a powerful path to study the internal structure of the proton. They map out the spatial distribution of the polarization densities in the proton, they provide access to key dynamical mechanisms that contribute to the electric and the magnetic polarizability effects, and allow to determine fundamental characteristics of the system, such as the electric and the magnetic polarizability radii. Of particular interest are puzzling measurements of the proton's electric generalized polarizability, that have challenged the theoretical predictions in recent years. This talk will present an overview on the topic, followed by a discussion that emphasizes the recent developments and findings of the Virtual Compton scattering experiments and future perspectives on the topic.

ID: 116, Plenary session, Wednesday 28 August

Fifty Years of Quantum Chromodynamics

David Gross (UC Santa Barbara)

I shall discuss the past, present and future of this remarkable theory.

ID: 118, Plenary session, Wednesday 28 August

Chiral Dynamics: Quo vadis?

Ulf-G. Meißner (University of Bonn)

I review some developments in chiral dynamics and pose some questions that remain to be answered.

ID: 121, Plenary session, Wednesday 28 August

Quantum Simulations of Fundamental Physics

Martin Savage (University of Washington)

Robustly simulating the nature and dynamics of non-equilibrium matter in extreme conditions of energy and density lies beyond the capabilities of classical computation alone. Toward realizing Feynman's vision, the remarkable advances in quantum information science and technology during the last thirty years continue to profoundly change how we understand and explore fundamental quantum many-body systems, and have brought us to the point where we are working toward simulating essential aspects of such systems using quantum computers (embedded in large HPC systems). I will discuss this progress, along with the opportunities and challenges ahead.

ID: 107, Plenary session, Thursday 29 August

Dispersive approach to hadronic contributions to the Muon g-2

Gilberto Colangelo (University of Bern)

I will review the status of the dispersive approach to the two hadronic contributions (vacuum polarization and light-by-light) to the Muon g-2 and give an update on the current puzzles concerning the HVP.

ID: 24, Plenary session, Thursday 29 August

The puzzles of the muon anomalous magnetic moment

Hartmut Wittig (Johannes Gutenberg University Mainz)

The anomalous magnetic moment of the muon, also called the muon $g-2$, is a sensitive probe of the Standard Model. Any evidence for a non-zero deficit between experimental measurement and theoretical prediction would be ascribed to contributions from physics beyond the SM. While the latest experimental average displays a tension of 5.1σ with the SM estimate as published in a White Paper in 2020, a straightforward interpretation of this result is precluded by a significant tension between lattice QCD calculations of the hadronic vacuum polarisation contribution and the corresponding estimates based on the traditional "data-driven" method employing experimental hadronic cross section data. In this contribution, I review the current status of different evaluations of the hadronic contributions to the muon $g-2$ and discuss their implications for the running of the electromagnetic coupling and the consistency of global fits using electroweak precision data.

ID: 46, Plenary session, Thursday 29 August

Interactions between two hadrons in lattice QCD

Sinya Aoki (Yukawa Institute for Theoretical Physics, Kyoto Unversity)

In this talk, I review recent results on hadron interactions in lattice QCD, mainly those obtained by the HAL QCD method. In particular, I consider two hadron systems including strange, charm and bottom quarks such as H dibaryon, $\Omega\Omega$, $\Omega_{ccc}\Omega_{ccc}$, $N\phi$, NJ/ψ, and tetra quark states T_{cc} and T_{bb}. I emphasize the importance of the two-pion exchange contributions in $\Omega\Omega$, $\Omega_{ccc}\Omega_{ccc}$, $N\phi$, NJ/ψ and T_{cc} systems. I also report on experimental studies concerning some of these interactions. Finally I briefly discuss an issue of the left hand cut, which may become relevant in particular for T_{cc}.

ID: 12, Plenary session, Thursday 29 August

Status of two-baryon scattering in lattice QCD

Jeremy Green (DESY)

Lattice QCD calculations of baryon-baryon scattering will be reviewed. In the last few years, there has been a new generation of calculations with increased focus on controlling systematic uncertainties. I will discuss the challenges and recent developments in these calculations.

ID: 83, Plenary session, Thursday 29 August

Recent Applications of Nuclear Lattice Effective Field Theory

Dean Lee (Michigan State University)

This talk discusses recent applications of nuclear lattice simulations using chiral effective field theory. Some of the topics to be discussed are accelerated perturbation theory using wavefunction matching, seeing and measuring nucleonic correlations with the pinhole algorithm, intrinsic shapes, nuclear clustering, thermodynamics, and superfluidity.

ID: 99, Plenary session, Thursday 29 August

ChPT with axions

Feng-Kun Guo (Institute of Theoretical Physics, CAS)

In this talk, I will discuss chiral perturbation theory with axions, including the axion potential, axion mass, axionic couplings to photons and nucleons, and so on.

ID: 112, Plenary session, Thursday 29 August

Neutrinoless double beta decay and chiral effective field theory

Jordy de Vries (University of Amsterdam)

Next-generation neutrinoless double-beta decay (0vbb) experiments aim to discover lepton number violation in order to shed light on the nature of neutrino masses. A non-zero signal would have profound implications by demonstrating the existence of elementary Majorana particles and possibly pointing towards a solution of matter-antimatter asymmetry in the universe. However, the interpretation of the experimental signal (or lack thereof) requires care as complicated hadronic and nuclear input is required to connect the experimental data to a fundamental description of lepton-number violation. In this talk I will discuss the tremendous progress that has been made in recent years by using the framework of chiral effective field theory to systematically describe lepton number violation in nuclear systems.

ID: 8, WG3 parallel session, Thursday 29 August

Study of dark matter scattering off 2H and 4He nuclei within chiral effective field theory

Elena Filandri (Università di Pisa, INFN sezione di Pisa), Michele Viviani

We study dark matter, assumed to be composed by weak interacting massive particles (WIMPs), scattering off ^{2}H and ^{4}He nuclei. In order to parameterize the WIMP-nucleon interaction the chiral effective field theory approach is used. Considering only interactions invariant under parity, charge conjugation and time reversal, we examine five interaction types: scalar, pseudoscalar, vector, axial and tensor. Scattering amplitudes between two nucleons and a WIMP are determined up to second order of chiral perturbation theory. We apply this program to calculate the interaction rate as function of the WIMP mass and of the magnitude of the WIMP-quark coupling constants. From our study, we conclude that the scalar nuclear response functions result much greater than the others due to theirs large combination of low energy constants. We verify that the leading order contributions are dominant in this low energy processes. We also provide an estimate for the background due to atmospheric neutrinos.

ID: 15, WG2 parallel session, Thursday 29 August

Gravitational local spatial densities for hadrons

Iuliia Panteleeva (Ruhr University Bochum), Evgeny Epelbaum, Jambul Gegelia, Ulf-G. Meißner

The issue of proper definition of spatial densities through matrix elements of local operators has attracted much attention in the last few years. In this talk, the novel definition of gravitational local spatial densities of hadrons using sharply localised wave packets will be discussed. We will show how the traditional densities in the Breit frame appear and how they differ from densities in the sharp localisation approach. We will also discuss the interpretation of these densities and applications using the ChEFT.

ID: 23, WG1 parallel session, Thursday 29 August

New pi0->ee result from NA62

Michal Koval (Charles University)

The NA62 experiment at CERN collected the world's largest dataset of charged kaon decays in 2016–2018. In this talk, we report a new preliminary result of the $\pi^0 \to e^+e^-$ branching fraction measurement at NA62. The result is based on a sample of signal decay candidates collected using a dedicated scaled-down di-electron trigger. Other recent NA62 results with analyses of rare kaon decays $K^+ \to \pi^+\gamma\gamma$, $K^+ \to \pi^0 e^+ \nu\gamma$, and $K^+ \to \pi^+\mu^+\mu^-$ are also presented.

ID: 22, WG3 parallel session, Thursday 29 August

μ → e conversion in nuclei and nuclear charge distributions

Frederic Noël (Uni Bern, ITP, AEC), Martin Hoferichter

$\mu \to e$ conversion in nuclei gives one of the leading limits on BSM lepton-flavor violating (LFV) processes. Upcoming measurements call for a more consistent theoretical description of $\mu \to e$ conversion. This can be done model independently using an effective field theory framework in terms of effective BSM operators, which however crucially depends on hadronic and nuclear matrix elements.

In particular, the uncertainties inherent in these non-perturbative inputs, limit the discriminating power that can be achieved. In order to quantify the associated uncertainties, we revisit nuclear charge densities and propagate uncertainties from elastic electron scattering experiments. These charge densities, parametrized in terms of Fourier-Bessel series, can be correlated with results from modern ab-initio methods and will thus allow for the evaluation of general $\mu \to e$ conversion rates with quantified uncertainties.

The resulting description of $\mu \to e$ conversion enables improved studies of the appearing effective operators, which can also be related to LFV pseudoscalar decays.

partly based on: Phys.Rev.Lett. 130 (2023) 13, 131902

ID: 54, WG2 parallel session, Thursday 29 August

The Transition Density Formalism in the First Compton Computation on 4He, and Beyond

Harald W. Griesshammer (Institute for Nuclear Studies, George Washington University)

The transition-density formalism is highly efficient for interactions with perturbative probes in few-nucleon systems. One- and two-body transition densities that encode the nuclear structure of the target are evaluated once per nucleus and stored. They are then convoluted with an interaction kernel to produce observables. The same densities can be used with different kernels. This method exploits factorisation between nuclear structure and interaction kernel in Chiral EFT. It takes full advantage of the numerical power of modern few-nucleon methods, is markedly more computationally efficient and applicable to a wide array of nuclei and reactions. In this contribution, the formalism is first introduced and then applied to present the first theory description of 4He Compton scattering. It uses the same Compton kernels familiar from proton, deuteron and 3He Compton scattering in Chiral Effective Field Theory with explicit Delta degrees of freedom, applicable between about 50 and 130MeV. The result compares well to data from HIγS, MAXlab and Illinois. Particular attention is devoted to the sensitivity of the cross section and beam asymmetry on the (static) scalar-isoscalar polarisabilities of the nucleon which parametrise the stiffness of charge distributions against deformations. The project is part of the synergetic international effort of experimentalists and theorists in Compton scattering on one- and few-nucleon systems.
Work in collaboration with A. Long (GW), J. A. McGovern (U. of Manchester), A. Nogga, X. Sun (FZ Juelich) and D. R. Phillips (Ohio U.).

ID: 91, WG1 parallel session, Thursday 29 August

Lattice calculation of K→ππ decay and ππ scattering

Masaaki Tomii (RBRC)

$K \to \pi\pi$ decay amplitudes and the measure of its direct CP violation, ε', are expected to play a key role in searching for new physics beyond the Standard Model because of the highly suppressed value of ε'. While, NA48 and KTeV experiments gave a well-resolved result, $\mathrm{Re}(\varepsilon'/\varepsilon) = 16.6(2.3) \times 10^{-4}$, there have been tremendous obstacles to reaching this level of precision in theoretical calculations. One lattice group, the RBC and UKQCD collaborations, is now overcoming these difficulties after a few decades of their efforts and further improving the precision. In this talk, we will mainly discuss the past challenges, current status, remaining challenges and future prospects of lattice QCD calculations of ε'. Since understanding two-pion system in a finite box is essential for lattice calculation of $K \to \pi\pi$ decay, $\pi\pi$ scattering will also be discussed.

ID: 7, WG1 parallel session, Thursday 29 August

Chiral extrapolation of the pion scattering amplitudes and the hadronic vacuum polarization

Jacobo Ruiz de Elvira (Complutense University of Madrid), Bastian Kubis, Gilberto Colangelo, Martin Hoferichter

In this talk, we provide compact analytic expressions for the one- and two-loop pion-pion partial-wave ChPT amplitudes for $J = 0, 1, 2$. We use these results to analyze lattice-QCD data of the $\pi\pi \longrightarrow \pi\pi$ P wave obtained at unphysical-high pion masses using the inverse-amplitude method at next-to-leading order and next-to-next-to-leading order. We then extrapolate to the physical pion mass and determine the properties of the ρ meson from its pole in the complex plane. By comparing both orders, we estimate the systematic error associated with the truncation. Finally, we study the pion-mass dependence of the two-pion channel in the hadronic-vacuum-polarization contribution to the anomalous magnetic moment of the muon. These results constrain the dominant isospin-1 part of the isospin-symmetric light-quark contribution and should thus allow one to better control the chiral extrapolation of HVP required for lattice-QCD calculations performed at larger-than-physical pion masses.

ID: 14, WG3 parallel session, Thursday 29 August

Manifestly Lorentz invariant formulation of chiral EFT for neutrinoless double beta decay

Yilong Yang (Peking Univeristy), Pengwei Zhao

The neutrinoless double beta decay $0\nu\beta\beta$ is of fundamental importance for particle physics, nuclear physics, and cosmology. The amplitude for the $0\nu\beta\beta$ decay of the two-neutron system $nn \to ppe^-e^-$ is a key building block to calculate the $0\nu\beta\beta$ decay in nuclei employed in large-scale experimental searches. Assuming that $0\nu\beta\beta$ decay is mediated by a light-Majaorana-neutrino exchange, an analysis based on the standard nonrelativistic chiral effective field theory (EFT) shows that already at leading order (LO) a contact decay operator is required to ensure renormalizability. So far, the size of this contact operator is still uncertain and has only been estimated by a generalized Cottingham model.

In this presentation, we will show that such a LO contact operator is not needed for renormalizability in the manifestly Lorentz invariant formulation of chiral EFT. We will present, for the first time, the predictions of $nn \to ppe^-e^-$ amplitude up to the next-to-leading order, where to this order no uncertain contact operators appear. We will discuss the validation of the present approach, and compare the results with the previous estimation from the generalized Cottingham model.

ID: 53, WG2 parallel session, Thursday 29 August

Using the Nucleus Density Formalism to Analyze Pion-Photoproduction and Other Reactions on Light Nuclei

Alexander Long (The George Washington University)

Pion-Photoproduction and other elastic processes are analyzed in chiral effective field theory around threshold. We extend the work by Lenkewitz et. al. to include the chiral SMS potential with uncertainty estimation based on cutoff variation. In particular we consider as targets ^{3}He, ^{4}He and ^{6}Li which enter through their probability density amplitudes which are calculated separately and reused for different processes.

The computational complexity of probability density calculations for $A \geq 5$ body systems requires the use of a similarity renormalization group transform and a corresponding back transform, the details of which are discussed.

This work is conducted in collaboration with Harald Griesshammer (GW), Andreas Nogga, and Xiang-Xiang Sun (FZ Julich).

ID: 2, WG2 parallel session, Thursday 29 August

Electromagnetic form factors of nucleons from SU(3) chiral effective field theory

Lingyun Dai (Hunan University)

In this talk, we will discuss a recent study on the electromagnetic form factor of nucleons from our group. The SU(3) chiral effective field theory is applied to calculate the potential of nucleon anti-nucleon scatterings up to the next-to-leading order. The potentials are then input into the Lippmann-Schwinger equation, and the scattering amplitudes are solved. These potentials are input as the kernel to study the nucleon anti-nucleon FSI. With distorted-wave Born approximation, we study the processes of electron-positron annihilation into nucleon-antinucleon. The separated EMFFs are extracted, and the oscillation of the subtracted formfactors is discussed. An attractive model is proposed and needs further study. We will also discuss the possibility of combining the quark model and chiral effective field theory to describe strong interactions in a wider range.

ID: 5, WG1 parallel session, Thursday 29 August

R value measurements at BESIII

Frederic Stieler (Johannes Gutenberg University Mainz), Beijiang Liu

The R value, defined as the ratio of inclusive hadronic cross section over dimu cross-section from electron-positron annihilation, is an important quantity that contributes to the SM prediction of the muon anomalous magnetic moment, and in the determination of the QED running coupling constant evaluated at the Z pole. At BESIII, the R value is measured with a total of 14 data points with the corresponding c.m. energy going from 2.2324 to 3.6710 GeV. The statistical uncertainty of the measured R is less than 0.6%. Two different simulation models, the LUARLW and a new Hybrid generated, are used and give consistent detection and initial-state-radiation corrections. An accuracy of better than 2.6% below 3.1 GeV and 3.0% above is achieved in the R values.

ID: 93, WG3 parallel session, Thursday 29 August

Neutrinoless double beta decay rates and the 3+2 scenario

Vaisakh Plakkot (University of Amsterdam), Daniel Castillo, Emanuele Mereghetti, Guanghui Zhou, Javier Menendez, Jordy de Vries, Juraj Klaric, Marco Drewes, Pablo Soriano, Wouter Dekens, Yannis Georis

Neutrino oscillation measurements hint at non-zero neutrino masses, and the addition of gauge singlet right-handed neutrinos to the SM field content conveniently provides masses to the active neutrinos. A byproduct of this mechanism is the possible Majorana nature of neutrinos, which leads to lepton number violating effects, such as neutrinoless double beta decay. The standard study of these effects involves mass-dependent nuclear matrix elements which, although easy to use, might be missing important effects, especially in the light neutrino regime where the ultrasoft contributions become important. A fresh look at the different momentum regions leads us to an effective practical parametrisation for the decay amplitude that can show significant differences in the light-to-medium mass range of neutrinos compared to the standard parametrisation. The differences are compared for ^{136}Xe and ^{76}Ge, and as a concrete realisation of a UV model leading to Majorana neutrinos, the testability of a 3+2 model with two sterile neutrinos is discussed.

ID: 6, WG1 parallel session, Thursday 29 August

Short-distance contributions to Hadronic-light-by-light for the muon g-2

Johan Bijnens (Lund University), Antonio Rodriguez-Sanchez, Nils Hermansson-Truedsson

I will present the work on short-distance contributions to the hadronic light-by-light part of the muon g-2 as in the Standard Model. Work done since the previous chiral dynamics is working out how to calculate in principle the higher order corrections to the Melnikov-Vainshtein result, published in JHEP 02 (2023) 167 [2211.17183 [hep-ph]]. In addition I will preesent the sofar unpublished gluonic corrections to the next-order and nonperturbative estimates.

ID: 17, WG2 parallel session, Thursday 29 August

Gravitational p $\longrightarrow \Delta$+ transition form factors in chiral perturbation theory

Bao-Dong Sun (Ruhr University Bochum), Herzallah Alharazin, Evgeny Epelbaum, Jambul Gegelia, Ulf-G. Meißner

The electromagnetic form factors of the nucleon have been widely used for exhibiting how the charge and magnetization distributions are spatially distributed inside a nucleon in the Breit frame. Similarly, the Energy-Momentum-Tensor form factors (i.e. gravitational form factors, GFFs) characterize the mechanical properties, such as the three-dimensional distributions of mass, angular momentum, pressure, and shear-force densities inside particles.

In this talk, I will first briefly introduce GFFs for particles with different spins and their interpretations in the Breit frame. I will also mention current experimental measurements or lattice QCD calculations on GFFs. Next, I will present our recent studies on Delta GFFs, N-Delta transitional GFFs, and one-pion graviproduction FFs using the chiral perturbation theory (ChPT) in curved spacetime. Since the validity of the definitions of local densities in the Breit frame has been questioned, a new definition using sharply localized wave packet states is proposed, and I will demonstrate its application to spin-3/2 systems. The long-range behaviors of the densities under our newly proposed definition are obtained with the ChPT results for Delta GFFs.

ID: 18, WG3 parallel session, Thursday 29 August

Parity and time-reversal violating nuclear forces with explicit delta excitations

Lukas Gandor (Ruhr University Bochum), Evgeny Epelbaum, Hermann Krebs

Parity-violating and time-reversal-violating (PVTV) nuclear interactions govern electric dipole moments of nuclei and play an important role in searches for beyond-Standard-Model physics. Recently, PVTV two- and three-nucleon potentials have been worked out to next-to-next-to-leading order in the chiral effective field theory (EFT) expansion based on pions and nucleons as the only explicit degrees of freedom. We emphasize the usefulness of the explicit treatment of the delta resonance for describing PVTV interactions by performing calculations using the delta-full formulation of chiral EFT. Compared with the delta-less approach, the explicit inclusion of the delta isobar allows one to resum certain types of contributions to the PVTV two-pion exchange two- and three-nucleon potentials without introducing any unknown parameters. We provide the corresponding expressions for the delta contributions in momentum and coordinate spaces and compare the convergence of the EFT expansion in both formulations.

ID: 11, WG1 parallel session, Thursday 29 August

Coupled-channel dispersive analysis of the πη/KK scattering and its application to $(g-2)_\mu$

Igor Danilkin (Johannes Gutenberg University Mainz), Marc Vanderhaeghen, Oleksandra Deineka

A dispersive implementation of the $\pi\eta/K\bar{K}$ scattering to $(g-2)_\mu$ requires the knowledge of the double-virtual S-wave $\gamma^*\gamma^* \to \pi\eta/K\bar{K}_{I=1}$ amplitudes. To obtain these amplitudes we used a modified coupled-channel Muskhelishvili–Omnes formalism, with the input from the left-hand cuts and the hadronic Omnes function. The latter were obtained using a data-driven N/D method in which the fits were performed to the different sets of experimental data on two-photon fusion processes with $\pi\eta$ and $K\bar{K}$ final states. The preliminary dispersive estimate $(g-2)_\mu^{\rm HLbL}[a_0(980)]_{\rm resc.}$ will be shown.

ID: 63, WG3 parallel session, Thursday 29 August

Anthropic Considerations for Big Bang Nucleosynthesis

Helen Meyer (University of Bonn), Bernard Ch. Metsch, Ulf-G. Meißner

In this talk I will discuss the dependence of the primordial nuclear abundances as a function of fundamental physical constants like the electromagnetic fine-structure constant α and the Higgs VEV v. We updated the leading nuclear reaction rates and used more recent results for the electromagnetic and strong contribution to the neutron-proton mass difference. For the α-dependence of the light element primordial abundances we included the temperature-dependence of the leading nuclear reactions rates and assessed the systematic uncertainties by using four different publicly available codes for Big Bang nucleosynthesis (BBN). I will present bounds on the α-variation that we derived from comparing our results to measurements.

The Higgs VEV variation was studied using the newly published PRyMordial code. I will explain how we improved existing methods to treat a possible variation of the Higgs VEV in BBN and derive new (stricter) constraints.

Finally, I will give an outlook on work in progress, e.g. computing dd reaction rates within the nuclear lattice effective field theory (NLEFT) framework.

ID: 80, WG2 parallel session, Thursday 29 August

Inelastic two-photon exchange correction to near-forward lepton-proton scattering

Vladyslava Sharkovska (Paul Scherrer Institute, University of Zurich), Franziska Hagelstein, Vadim Lensky

In this talk, we will present a first leading-order baryon chiral perturbation theory (BChPT) estimate of the inelastic two-photon exchange (TPE) correction to elastic lepton-proton (lp) scattering. The presented estimate is limited to near-forward kinematics, where the TPE correction to the unpolarized lp scattering cross section can be approximated through the unpolarized forward doubly-virtual Compton scattering (VVCS) amplitudes, or, via dispersion relations, through the proton structure functions [1]. In an earlier calculation, the LO BChPT predictions of the non-Born VVCS amplitudes [2] have been successfully applied to evaluate the proton-polarizabilty correction to the Lamb shift in muonic hydrogen [3], originating from forward TPE. In the forward limit, the BChPT prediction is in good agreement with data-driven dispersive evaluations. Our results for the inelastic TPE are compared to the next-to-next-to-leading-order QED corrections in low-energy scattering experiments [4].
[1] Tomalak et al., Phys. Rev. D 93, 013023 (2016)
[2] Alarcon et al., Phys. Rev. D 102 (2020) 1, 014006
[3] Alarcon et al., Eur. Phys. J. C 74 (2014) 4, 2852
[4] Engel et al., Eur.Phys.J.A 59 (2023) 11, 253

ID: 19, Plenary session, Friday 30 August

Light Meson decays at BESIII

Xiaolin Kang (China University of Geosciences (Wuhan))

The world's largest sample of J/psi events accumulated at the BESIII detector offers a unique opportunity to investigate eta and eta' physics via two body J/psi radiative or hadronic decays. In recent years the BESIII experiment has made significant progresses in eta/eta' decays. A selection of recent highlights in light meson spectroscopy at BESIII are reviewed in this report, including observation of the cusp effect in eta'→pi0 pi0 eta, transition form factor measurements, as well as the search for rare/forbidden decays of eta/eta'.

ID: 25, Plenary session, Friday 30 August

Semileptonic kaon decays and the precise determination of Vus

Chien Yeah Seng (University of Washington), Daniel Galviz, Mikhail Gorchtein, Ulf-G. Meißner

I will describe our recent effort on the precise calculation of the radiative correction to semileptonic kaon decays that leads to an improved determination of the CKM matrix element Vus and further sharpens the so-called "Cabibbo angle anomaly".

ID: 51, Plenary session, Friday 30 August

Nucleon structure in light muonic atoms

Franziska Hagelstein (JGU Mainz and PSI Villigen), Vadim Lensky, Vladimir Pascalutsa

Laser spectroscopy of muonic atoms has been recently used to probe the low-energy properties of the proton and light nuclei with unprecedented precision [1]. In the future, measurements of the Lamb shift in muonic hydrogen and helium isotopes are supposed to improve by up to a factor 5. Furthermore, there is an ongoing effort to perform a first-time measurement of the ground-state hyperfine splitting in muonic hydrogen with ppm accuracy. In order to extract with high precision nuclear radii or polarizability effects from the spectroscopy measurements, the experimental accuracy has to be matched by the corresponding theoretical predictions. Thus, it is a timely task to refine the theoretical predictions [2], and in particular, the nucleon-structure contributions.
After a brief overview of the theory of light muonic atoms and related experiments, I will discuss the effect of the nucleon polarizabilities on the spectra of muonic atoms through forward two-photon exchange. I will present the recent NLO baryon chiral perturbation theory prediction of doubly-virtual Compton scattering and the nucleon polarizabilities [3], as well as the proton polarizability contribution to the Lamb shift [4] and hyperfine splitting [5] of muonic hydrogen. Some ideas to further reduce uncertainty on the nucleon structure contributions will be discussed [6,7].
[1] Antognini et al., Ann. Rev. Nucl. Part. Sci. 72 (2022) 389
[2] Pachucki et al., Rev. Mod. Phys. 96 (2024) 1, 015001
[3] Alarcon et al., Phys. Rev. D 102 (2020) 11, 114026 and Phys. Rev. D 102 (2020) 1, 014006
[4] Alarcon et al., Eur. Phys. J. C 74 (2014) 4, 2852
[5] Hagelstein et al., Eur. Phys. J. C 83 (2023) 8, 762
[6] Hagelstein et al., Nucl. Phys. A 1016 (2021) 122323
[7] Biloshytskyi et al., Phys. Rev. D 109 (2024)

ID: 71, Plenary session, Friday 30 August

Nucleon form factors from lattice QCD

Sara Collins (University of Regensburg)

Through the calculation of nucleon matrix elements in the off-forward limit, a wealth of information on the structure of the nucleon can be accessed using lattice QCD. This includes the determination of the electromagnetic form factors, the axial form factors and moments of generalised parton distribution functions, such as the gravitational form factors. Significant progress has been made in addressing sources of systematic uncertainty in lattice calculations, with simulations now performed at physical light quark masses and on fine lattices. Recent highlights in lattice calculations of nucleon form factors will be presented and the remaining challenges will be discussed.

ID: 84, Plenary session, Friday 30 August

Low-Q2 Spin Structure Data from Jefferson Lab

David Ruth (University of New Hampshire)

High precision data in the Low-Q2 regime is crucial for the study of effective theories such as chiral perturbation theory, which collectively remain the best treatment of QCD in the non-perturbative regime. Measurements of the nucleon spin structure functions and their moments provide a very useful means to directly test the predictions of effective theories. The Jefferson Lab community has been highly active in experimentally measuring these spin structure functions in the low-Q2 regime for both the proton and neutron using inclusive electron scattering. In this talk I will discuss and review recent results from several completed low-Q2 spin structure experiments at Jefferson Lab. These results are compared to predictions of chiral perturbation theory at the level of moments and polarizabilities. I will also discuss future plans and prospects for the next generation of JLab spin structure experiments.