ROCKSTAR: Towards a ROadmap of the Crucial measurements of Key observables in Strangeness reactions for neutron sTARs equation of state

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ECT*

Book of Abstracts

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Welcome

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Session I / 31

The European Networking Activity THEIA: achievements and prospects

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The cooperation of world-leading experimentalists and theoreticians in the field of strangeness nuclear physics with experts of the neutron star community is the aim of the networking activity THEIA. The main objectives of THEIA were
• the hypertriton puzzle and its implication for fragment formation in heavy ion reactions.
• the study of antihyperons in nuclei by antiproton nucleus collisions
• theoretical and experimental studies of bound mesonic systems
• the organization of (annual) workshops to bring together scientists and students with complementary expertise
I will discuss the achievements of THEIA and the aims for the remaining funding period. Finally I will address some open questions in the field of strangeness nuclear physics and point to possible avenues for future research.

Session I / 24

Application of SMS chiral interactions to light hypernuclei

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Recently, a new generation of chiral hyperon-nucleon interaction has been developed [1]. In this contribution, I will discuss the properties of these interactions and apply them to light hypernuclei. A special focus will be put on using different chiral orders to obtain reliable uncertainty estimates [2].

[1] J. Haidenbauer, U.-G. Meißner, A. Nogga and H. Le,
Hyperon-nucleon interaction in chiral effective field theory at next-to-next-to-leading order,
Eur. Phys. J. A 59 (2023), 63 [arXiv:2301.00722 [nucl-th]].
[2] H. Le, J. Haidenbauer, U.-G. Meißner and A. Nogga,
Separation energies of light Lambda-hypernuclei and their theoretical uncertainties, [arXiv:2308.01756 [nucl-th]].

Session I / 40

Welcome from ECT* Director

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Session I / 22

Light hypernuclei in the frameworkd of J-NCSM and χ EFT

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We study s- and light p-shell Λ hypernuclei from a microscopic level based on the ab initio Jacobi no-core shell model (J-NCSM) in combinations with
baryon-baryon interactions derived in the frame work of chiral effective field theory. The employed potentials are softened with similarity renormalization group evolution in order to speed up the convergence of the NCSM calculations. We discuss in details impact of the evolution and of the two phase-equivalent YN potentials on the Λ separation energies in $A = 4 - 8$. Consequently, the possible contribution of chiral YNN forces to these light systems is investigated. We further explore the charge symmetry breaking (CSB) effect in the $A = 7, 8$ isospin multiplets employing the YN interactions that include also the leading CSB potential. Finally, the predictions of the chiral YY potentials for the s-shell $\Lambda\Lambda$ hypernuclei are briefly discussed.

Session I / 23

Dense nuclear matter with phenomenological short distance repulsion

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The possibility of short distance repulsion applicable inside the cores of neutron stars is incorporated into the hadron equation of state generated by the quark-meson coupling model. Whilst obtaining an incompressibility compatible with data on giant monopole resonance, neutron stars are predicted to have a maximum mass in excess of 2.1 $M_\odot$, even when hyperons are included under β-equilibrium. Radii and tidal deformations are also consistent within the current experimental constraints.

Session II / 5

Search for the Kbar-NN state in photoproduction with LEPS2 spectrometer

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The behavior of kaon and anti-kaon in dense matter is an important topic, as their nature is closely related to symmetry breaking in low-energy QCD.
The interaction of kaons and anti-kaon with nucleon has been extensively studied with various experiments.These studies found that the Kbar-N interaction in the isospin I=0 channel is sufficient to produce the quasi-bound state Λ(1405).
This strong attractive interaction predicts the existence of a bound state known as a kaonic nucleus.

In particular, Kbar-NN is gaining attention as the simplest kaonic nucleus.
Recently, a clear peak has been observed in the E15 experiment. So there is growing interest in the properties of Kbar-NN.
In this presentation, I will discuss the studying of Kbar-NN in the ongoing hadron photoproduction experiment known as the LEPS2 solenoid Experiment and compare it with previous experiments.The LEPS2 solenoid experiment is a project aimed at investigating various hadron photoproduction reactions. It uses high-energy and high-intensity gamma beam and the solenoid spectrometer that covers large angles. The experiment is carried out at SPring-8, one of the large synchrotron radiation facilities in Japan.
Since 2022, the LEPS2 solenoid experiment has collected the physics data.In my talk,I would like to report on its current status and expected future results.

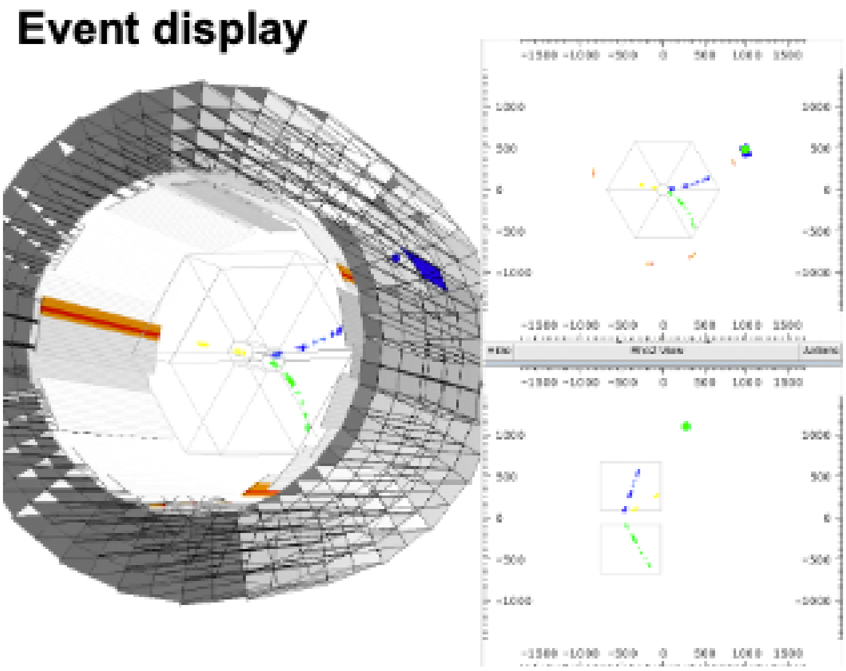

Figure 1: The Event Display of the LEPS2 Experiment

Session II / 15

Study of mesonic decay of KbarNN using J-PARC E15 data

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The lightest kaonic nuclear bound state, $\bar{K}NN$, was observed by measuring a non-mesonic decay of $\bar{K}NN \rightarrow \Lambda p$ in the J-PARC E15 experiment. The obtained binding energy, $B.E. \sim 40$ MeV

is compatible with those of theoretical predictions. On the other hand, the obtained decay width, $\Gamma_{\bar{K}NN} \sim 100$ MeV, is rather larger than the predictions. It is also noticeable that $\Gamma_{\bar{K}NN}$ is $\sim$ twice larger than the decay width of $\Lambda(1405)$ ($\equiv \bar{K}N$ quasi-bound system). To understand why the $\Gamma_{\bar{K}NN}$ is large, it is essential to measure other decay modes of $\bar{K}NN$, in particular, mesonic decay modes which are considered to be major decay branch of $\bar{K}NN$. Therefore, we analyzed data obtained in the J-PARC E15 to measure the $K^-{}^3\mathrm{He} \rightarrow \pi YNN'$ reactions, specifically $\pi^\mp\Sigma^\pm pn'$, $\pi^+\Lambda nn'$, and $\pi^-\Lambda pp'$. The invariant mass and momentum transfer distributions of πYN were well reproduced by employing model fitting functions for $\bar{K}NN$ production and quasi-free $\bar{K}$ absorption processes. We obtained cross-sections for four $\bar{K}NN \rightarrow \pi YN$ decay branches, and the decay branching ratios of $\bar{K}NN$ were found to be $\Gamma_{\pi YN}/\Gamma_{YN} = \mathcal{O}(10)$ and $\Gamma_{\pi\Lambda N} \sim \Gamma_{\pi\Sigma N}$. This indicates that the $\pi\Lambda N$ decay mode, which involves mesonic $\bar{K}N$ absorption with $I_{\bar{K}N} = 1$, significantly contributes to the $\bar{K}NN$ decay, making the $\bar{K}NN$ state approximately twice as unstable as $\Lambda(1405)$.

Session II / 14

Development of large acceptance spectrometer for systematic study of kaonic nuclei at J-PARC

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Bound states caused by attractive $\bar{K}N(I=0)$ interaction, such as $\Lambda(1405)$ and kaonic nuclei, are interesting systems with strangeness.
Many experimental attempts have tried to establish an existence of the lightest kaonic nuclei, "K^-pp". However, no clear conclusion was reached. Recently, J-PARC E15 collaboration searched for "K^-pp", using the in-flight $K^- +^3$ He reaction with an exclusive analysis of the Λpn final state. By reconstructing not only the Λp invariant-mass but also the momentum transfer to the Λp system, they definitely showed event concentration interpretted as "K^-pp" bound state with $B.E. = 42 \pm 3(\text{stat})^{+3}_{-4}(\text{syst})$ MeV and $\Gamma = 100 \pm 7(\text{stat})^{+19}_{-9}(\text{syst})$. Moreover, small spatial size of "K^-pp" is implied, which supports theoretical predictions that a high-density nuclear matter is realized in heavier kaonic nuclei.

In order to expand this successful experimental method to heavier kaonic nuclei, such as $\bar{K}NNN, \bar{K}NNNN, \ldots,$ and detailed study for fundamental properties of the $\bar{K}NN$ state, we are developping a new magnetic spectrometer.
Because an exclusive analysis requires detections of decay particles from the kaonic nuclei as many as possible, the new spectrometer will have larger solid angle of 93%. To realize it, superconducting a sorenoid magnet and some detectors, a cylindrical drift chamber and charged particle/neutron counters, are 3-4 meters long. Detection efficiencies for neutron would be improved at least 1.7 times better than that of the current spectrometer.

Session II / 16

New calculations of the K-pp system

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E15 collaboration at J-PARK reported a clear signal of a KNN quasi-bound state. The width of the state is much larger than theoretical predictions. A series of calculations of the K-pp quasibound state characteristics with different input was performed in order to check, whether it is possible to reach the experimental values.

Session III / 9

Sound velocity, equation of state, and strangeness in neutron star matter

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The speed of sound in the core of neutron stars is a key quantity for providing a characteristic signature of a possible phase transition or the occurance of non-standard degrees of freedom in dense baryonic matter. The first part of this talk presents a status summary of results from a systematic Bayes inference analysis of the equation-of-state based on observational data. In the second part the quest for the appearance of hyperons in neutron stars is examined and discussed, with emphasis on the role of hypernuclear three-body forces in this context.

Session III / 7

Probing hyperons in Neutron Stars using Multimessenger data

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Terrestrial experiments, particularly heavy-ion collision experiments, suggest the appearance of strangeness containing particles, such as hyperons, in dense matter. The ultrahigh density core of Neutron Stars is the ideal environment to search for strange matter. Over the past decade, astrophysical observations of Neutron Stars across multiple wavelengths of the electromagnetic spectrum have improved our understanding of hyperons. However the recent direct detection of gravitational waves from binary Neutron Star mergers opened up a new window to look for signatures of hyperons. In this talk, I will highlight recent works in which combined data from nuclear and hypernuclear physics, heavy-ion physics as well as multimessenger astrophysical data from Neutron Stars provide important insights into the behaviour of hyperons in dense matter.

Session III / 13

Strangeness in binary neutron star mergers and its signature

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The particle content of the interior of neutron stars is still unknown, especially in the case of very massive stars. It is clear that if hyperons or quarks are present, they will affect the dynamics of the merger of two neutron stars. The impact on the observables and even more the prospects for detectability are possibly very interesting, but also uncertain. In this talk, I will illustrate how the presence of quarks or hyperons can impact binary neutron star merger observables, including gravitational wave emission, based on recent simulations in numerical relativity. Moreover, I will show how the determination of the prompt collapse threshold can shade light on the interior particle content, based on the measurement of the nuclear incompressibility at ultrahigh densities.

Session III / 4

Thermal behavior of hyperons in binary neutron star merger remnants

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The coalescence of a binary system of neutron stars represents a natural laboratory to study hot and ultra-dense matter. Under these extreme conditions, exotic species like hyperons may be present. In this work, we present a comprehensive study of hyperons in neutron star mergers, focusing on the thermal impact they have on the Equation of State. The presence of the hyperons in a hot dense matter produces a significant drop of the thermal pressure. This effect consequently leaves a trace in the observables that can be measured. In particular, we identify that hyperonic equations of state produce a characteristic increase of the dominant postmerger gravitational-wave frequency by up to ~ 150 Hz compared to purely nucleonic EoS models. Our findings provide an important analysis tool to finally give an answer to the longstanding question: are hyperons present in ultra dense matter?

Session III / 11

Unveiling Neutron Star Composition and Observables: A Comprehensive Study using Deep Bayesian Neural Networks

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In the emerging field of astrophysics, understanding the intricate nature of neutron stars (NSs) and their equations of state (EoS) remains a challenging task. This talk presents an integrated approach based on deep learning and Bayesian neural networks (BNNs) to unravel the NS composition.

Our research is built upon two key studies. The first exploits BNNs' unique capability to provide prediction uncertainty measures, leveraging them to infer the proton fraction and sound speed within NS interiors, based on their macroscopic properties. A set of simulated observations, including NS radius and tidal deformability, were analysed using BNNs models developed on a dataset of ~25 K nuclear equations of state. These models were obtained through Bayesian inference within a relativistic mean-field framework. The results demonstrated a successful recovery of the NS composition with reasonable uncertainty levels.

The second study introduces a deep learning-based methodology to predict key NS observables from nuclear matter parameters. The neural network model proved to be capable of accurately replicating the inter-correlations between the symmetry energy slope, its curvature, and the tidal deformability arising from a set of physical constraints. The validity of the trained model was established using Bayesian inference, showcasing performance on par with physics-based models at a fraction of the computational cost.

This integrated research provides a comprehensive understanding of the EoS for nuclear matter at densities above the saturation density. It combines the power of deep learning and Bayesian neural networks to analyze NS observables and dense matter equations of state, paving the way for a new era of astrophysical exploration.

Session IV / 10

Λ hypernuclear potentials beyond linear density dependence

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In recent papers [PLB 837 (2023) 137669 and NPA 1039 (2023) 122795] we showed that all measured (1sΛ, 1pΛ) pairs of Λ binding energies in Λ-hypernuclei 12 ≤ A ≤ 208, can be obtained from a Λ-nucleus optical potential with only two adjustable ΛN and ΛN N parameters, associated with leading linear and quadratic terms in the nuclear density. Consequences of suppressing ΛN N interactions between 'core'nucleons and 'excess'neutrons are studied and related predictions are made for (1sΛ, 1pΛ) binding energies in {40,48}^K, obtainable from upcoming {40,48}^Ca(e,e′K+) JLab experiments. We find Λ-nucleus partial potential depths of D(2) Λ = −38.6 ± 0.8 MeV (ΛN) and D(3) Λ = 11.3 ± 1.4 MeV (ΛN N), with a total depth DΛ = −27.3 ± 0.6 MeV at nuclear-matter density ρ0=0.17 fm−3. Extrapolation to higher nuclear densities and possible relevance to the 'hyperon puzzle'in neutron-star matter
are discussed.

Session IV / 29

Kaonic Atom X-ray spectroscopy: the kaon mass puzzle

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Kaonic atoms X-ray spectroscopy is a unique tool to provide experimental data with consequences going from particle and nuclear physics to astrophysics.

30 years ago kaonic atoms were used to measure the charged kaon mass with unprecedented precision. However, there is still a discrepancy of 60 keV between the two most precise measurements, leading to an error of 16 keV on the charged kaon mass with severe consequences for particle physics and all those processes in which kaons are involved, such as the charmonium spectrum.
Combining the excellent quality of the low-energy kaon beam delivered by the DAΦNE collider in Frascati (Italy) with new experimental techniques, as fast and very precise X-ray detectors, we have performed unprecedented measurements of medium and heavy mass kaonic atoms, in the framework of the SIDDHARTA Collaboration, with implication on the charged kaon mass.
I shall introduce the kaon mass puzzle, the first measurement of the kaonic neon, the ongoing measurement of the kaonic lead and their impact on the kaon mass. Finally, I shall discuss future measurements that can lead to the solution of the kaon mass puzzle.

Session IV / 21

The KAMEO proposal: investigating the strong kaon-nucleus interaction through the E2 nuclear resosnance effect in kaonic atoms

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Kaonic atoms are atomic systems in which a negatively charged kaon is captured in the atomic shell, replacing an electron. The capture occurs at a highly excited atomic level, then the kaon starts an electromagnetic cascade to the innermost atomic levels, where the strong kaon-nucleus interaction becomes detectable with X-ray spectroscopy. Kaonic atoms allow the study of strong interaction in the strangeness sector, at low energies. The E2 nuclear resonance occurs when atomic de-excitation energy is closely matched by nuclear excitation energy. It mixes the atomic and nuclear states due to the electrical quadrupole excitation of the nucleus. In the specific, the mixing occurs among $(n, l, 0^+)$ and $(n', l-2, 2^+)$ states. As a consequence, the E2 nuclear resonance produces an attenuation of some of the atomic x-ray lines from resonant versus normal isotope target and, in kaonic atoms, it allows the negatively charged kaon to reach inner levels of the atom not easily accessible through the electromagnetic cascade, because of the nuclear absorption. The investigation of the nuclear E2 resonance effect in kaonic ticklish atoms could provide important information about strong kaon nucleus interaction. The E2 nuclear resonance effect is expected to occur in four kaonic Molybdenum isotopes ($^{94}_{42}$Mo, $^{96}_{42}$Mo, $^{98}_{42}$Mo, and $^{100}_{42}$Mo) with similar energy values. The KAMEO (Kaonic Atoms Measuring Nuclear Resonance Effects Observables) proposal plans to measure this effect in kaonic Mo isotopes at the DAΦNE e^+e^- collider, in Frascati (LNF-INFN). The KAMEO apparatus will equip four solid strip targets of enriched Mo isotope each, exposed to negatively charged kaons produced by DAΦNE. A high-purity germanium detector, placed just behind the target strips, will be used for the x-ray spectroscopy. An additional solid strip target of non-resonant $^{92}_{42}$Mo isotope will be exposed to be used as a reference for standard non-resonant transitions. This experiment would provide a conclusive measurement of the E2 nuclear resonance effects in 4 isotopes of kaonic molybdenum, investigating strong kaon-nucleus properties, at low energies, in heavy kaonic atoms.

Session IV / 18

Towards new intermediate-mass kaonic atoms measurements with novel CdZnTe X-ray detectors at DAFNE

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The SIDDHARTA-2 collaboration at the INFN Laboratories of Frascati aims to reinforce the present knowledge on kaonic atoms by performing several measurements on various targets in parallel with the main K-d experiment.
The recents improvements of CdZnTe detectors in terms of energy resolution, stability and efficiency suggested these devices as ideal tools to measure intermediate-mass kaonic atoms; nevertheless, no literature about the use of CdZnTe detector in a collider was found, requiring preliminary tests to assess their on-beam behavior and response in DAFNE.
Here we present the very promising results of these preliminary tests performed in 2023, as well as the detailed MC simulations developed for the optimization of the experimental setup which is going to be installed on the DAFNE machine in 2024.
We aim to measure, with a few tens of eV precision, energies and widths of several K-Al and K-C transitions both to their lower and upper levels, and the estimations of the achievable results, based on MC simulation, will be reported.

Session IV / 19

Silicon Drift Detectors for high precision kaonic atoms X-ray spectroscopy

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High precision X-ray spectroscopy of kaonic atoms offers the unique opportunity to investigate the strong interaction (QCD) in the low-energy regime, by allowing to directly access the antikaon-nucleus interaction at threshold. In order to do this, a new dedicated technology of Silicon Drift Detectors (SDDs) has been developed by the SIDDHARTA-2 collaboration, with an optimized geometry and a new field configuration, which allows the SDDs to work in the high background environment of the DAFNE collider. The unique features of these SDDs make them ideal for high precision X-ray spectroscopy and kaonic atoms experiments such as SIDDHARTA-2 at LNF-INFN. The contribution will present the working principle, the technical features and the characterization of the SDDs energy response, in preparation for the SIDDHARTA-2 data taking campaign.

Session V / 1

Low-energy K−-nucleus/nuclei interactions with light nuclei with AMADEUS

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The AMADEUS Collaboration conducted research aimed to experimentally investigate the low-energy K− hadronic interactions with light nuclei like hydrogen, helium, and carbon, in order to provide new constraints to the antikaon-nucleon strong interaction studies in the non-perturbative QDC regime. K− nuclear absorption, both at-rest and in-flight, are explored using the unique low-momentum and monochromatic kaon beam from the DAΦNE collider interacting with the KLOE detector components. I shall present an overview of the AMADEUS results.

Session V / 17

Constraining the $\pi\Sigma - \bar{K}N$ models with the $\pi\Sigma$ photoproduction data

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The measurements of $\pi\Sigma$ mass distributions in the $\gamma p \to K^+\pi\Sigma$ photoproduction reaction 1 probe the energy region of the $\Lambda(1405)$ resonance, just below the $\bar{K}N$ threshold, and provide new challenges for the theoretical models of $\pi\Sigma-\bar{K}N$ coupled channels interactions. Adopting the photoproduction model presented in [2, 3] and the chirally motivated Prague model for $\bar{K}N$ interactions [4] we performed a first time attempt on a combined fit of the K^-p low-energy data and the $\pi\Sigma$ photoproduction mass spectra, without fixing the meson-baryon rescattering amplitudes [5]. The achieved description of the photoproduction mass distributions represents a significant improvement when compared with the parameter free predictions made in [3] but remains inferior to a more comprehensive model presented in [6] that employs much larger set of adjustable parameters, some of them purely phenomenological. I will discuss our current results in view of further upgrades being made to the photoproduction kernel.

Session V / 35

E57 Kaonic Deuterium at J-PARC

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Exotic hadronic atoms are a valuable tool to experimentally investigate the strong interaction described by Quantum Chromodynamics (QCD). With kaonic hydrogen/deuterium atoms one can directly measure the interaction at threshold and will be able to extract the antikaon-nucleon scattering lengths at zero energy (no interpolation to zero energy is necessary as in scattering experiments). The antikaon-nucleon interaction close to threshold provides crucial information on the interplay between spontaneous and explicit chiral symmetry breaking in low-energy QCD. Kaonic hydrogen was measured successfully with SIDDHARTA and DEAR at DAFNE (LNF, Italy) and with KpX at KEK (Japan). A measurement of kaonic deuterium is still missing and just now ongoing at DAFNE. A second measurement with different systematic corrections is prepared at J-PARC. The kaonic deuterium data will allow for the first time, together with the already existing kaonic hydrogen data, the determination of the isospin dependent antikaon-nucleon scattering lengths a0 and a1, eagerly awaited by theory.
An overview of the status of the proposed kaonic deuterium measurement at J-PARC will be given.

Session V / 8

Antikaon absorption in nuclear medium and kaonic atoms

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We have developed a microscopic model for the K^-NN absorption in nuclear matter 1. The absorption was described as a meson-exchange process and the primary K^-N interaction strength was derived from the state-of-the-art chiral models. The medium modifications of the K^-N scattering amplitudes due to the Pauli principle were taken into account. The model was applied in calculations of kaonic atoms for the first time [2]. The description of the data significantly improved when the two nucleon absorption was considered. The branching ratios for various K^- absorption channels in ^{12}C+K^- atom were calculated and compared with old bubble chamber data, as well as with the latest data from the AMADEUS collaboration [3]. Next, we considered the hadron (Y, K^-, π) self-energies in the K^-N scattering amplitudes as well as in the K^-NN absorption model. Their effect on the total K^- potential in nuclear matter is currently being explored.

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1 J. Hrtankova, A. Ramos, Phys. Rev. C 101 (2020) 035204.
[2] J. Obertova, E. Friedman, J. Mares, Phys. Rev. C 106 (2022) 065201.
[3] R. Del. Grande et al., Eur. Phys. J. C 79 (2019) 190.

Session V / 27

The kaonic helium measurement with SIDDHARTA-2 at DAFNE accelerator

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The L-series X-rays transitions of the kaonic helium-4 exotic atom were measured by SIDDHARTINO, the reduced configuration of the SIDDHARTA-2 experiment, at the DAΦNE collider of INFN-LNF, with gaseous 4He targets at densities of 1.90 g/l and 0.82 g/l, corresponding to 1.5% and 0.66%, respectively, of the liquid helium-4 density. The two new kaonic helium-4 yields will trigger a renaissance of the cascade calculations for exotic atoms, in particular for the kaonic atoms and a better understanding of the underlying processes and physics. The measurement of the kaonic helium transitions to the 2p level, represents the most precise one for a gaseous target and is expected to contribute to a better understanding of the kaon–nuclei interaction at low energy.

Session VI / 12

Baryon Structure and the QMC model for Nuclear Structure

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We review new insights into baryon structure in relation to the quark model. These insights into baryon structure and its potential for modification in a nuclear medium are then used to motivate the derivation of an energy density functional in the quark meson coupling model. Recent results for nuclear structure obtained in this approach will be presented.

Session VI / 2

Status of hyperon forces in Lattice QCD

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The instability of hyperons against the weak interaction hinders the experimental extraction of baryon-baryon low-energy observables in the strange sector. In this energy regime, a reliable numerical procedure to obtain information of nuclear physics quantities is lattice QCD, a high-demanding numerical approach to solve the complex dynamics of strongly-interacting systems directly from the degrees of freedom of the Standard Model, quarks and gluons. In this talk, I will present the results obtained by the NPLQCD collaboration, constraining the coefficients from the relevant effective field theories of two non-relativistic baryons, as well as the results from a variational calculation using a large set of interpolating operators, for the NN and H-dibaryon channels, at $m_\pi \sim 800$ MeV.

Session VI / 20

The K+ scattering on nucleons and nuclei at DAFNE

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Spontaneous breaking of chiral symmetry in the QCD vacuum is thought to be one of the causes of hadron masses. Many experimental challenges have been made to elucidate the mechanism by precisely measuring the hadron mass in nuclear matter, which is expected to be reduced by the partial restoration of chiral symmetry, known as the nuclear matter effect. To date, however, the mechanism has not been clearly identified.
Because there is no nuclear resonance state near the K+ and nucleon threshold, K+ can penetrate deeply inside the nucleus. Thus, K+ on nucleon and nucleus scattering data might contain information about the interior of the nucleus, specifically, interactions occurring under the conditions of partially restored chiral symmetry.
We are currently preparing a new experimental program with the aim of measuring K+ and nucleon and nucleus scattering to detect evidence of partial restoration of chiral symmetry in nuclear matter. Since low-energy K+ scattering might be sensitive and effective for accessing information inside the nucleus, and furthermore, low-energy K+ scattering data is currently missing, we are proposing to conduct the experiment at the DAFNE facility.
The proposed experiment consists of a Time-Projection Chamber (TPC) as a tracking detector and a Kaon detector to identify the K+ particles. A prototype TPC has been constructed and tested with a positron beam at the Research Center for Electron Photon Science (ELPH), Tohoku University. For the K+ detector, we plan to use almost the same one that is already installed and operational in the SIDDHARTA2 experiment at DAFNE.
During the presentation, we will provide detailed information about the physics motivation, the current state of experiment preparation, and the future prospects of the project.

Session VI / 30

(Hyper)nuclear Pionless Effective Field Theory at next-to-leading order: status and perspectives

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Pionless Effective Field Theory at Leading order proved to be valuable approach in a study of different properties of s-shell Λ- and $\Lambda\Lambda$- hypernuclei. Recently, it was demonstrated that the inclusion of next-to-leading order (NLO) corrections substantially improve predictive power of this theory in a theoretical study of few-body $A \leq 5$ nuclear scattering. In my talk I will review the corresponding nuclear results and show the status of preliminary hypernuclear calculations as well as its future perspectives.

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Deformed charmed hypernuclei

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Charmed Λ_c hypernuclei are investigated in the framework of the deformed Skyrme-Hartree-Fock approach. Their ground-state bulk properties, single-particle energy levels, potential energy curves, as well as the existence limit of charmed hypernuclei are studied, with particular regard to the effects of deformation. $\Lambda_c\ p$ states are found to be strongly bound, in particular in deformed nuclei.

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The history and future of hadronic-molecule/cluster with strangeness

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Mesons are known to behave as virtual particles in nuclei, repeatedly being created and annihilated rapidly so as to form a nuclear potential. In contrast, R. H. Dalitz suggested in the 1960s that the Λ(1405) can be a peculiar ̄KN system, i.e., a nucleon and a ̄K meson molecule-like hadronic cluster. However, there was no clear experimental evidence to strongly support this hypothesis at that time. In 1997, atomic kaonic hydrogen data suggested a strong attraction between kaon and proton, sufficient to form a two-body nuclear bound state. This data triggered a variety of intensive search experiments to confirm the discovery of the kaonic nuclear bound states (A ≥ 2). This is because the existence of a kaonic nuclear state is a natural interpretation of the Λ(1405), to be a molecule-like ̄KN hadronic cluster.
Recently, very clear peak formation below "K−pp"binding threshold (mass ummation of a K− and two protons) was observed in the Λp invariant mass spectrum of the K− + 3He −→ (Λp) + n′ reaction. The most simple interpretation is that the nucleon knockout reaction K−N −→ ̄Kn′ initiates ̄KN N state (charge +1, isospin 1/2 and decay to Λp) formation. In other ords, the peak is the signal

of the simplest kaonic nuclear bound state, "K−pp", a¯K meson behaves as a quasi-on-mass-shell particle and forms its own quantum state together with two nucleons. Very interestingly, a simple form(structure)-factor analysis of the experimental data on the "K−pp"signal suggested that this state may be extremely compact compared to the normal inter-nucleon distance in nuclei. This might lead us to explore physics beyond the normal nuclear saturation density in a quantum equilibrium, via the detailed systematic study on light kaonic nuclei utilizing new ~ 4π spectrometer system under construction. This spectrometer system could be utilized to search for other hadronic-molecule with strangeness such as "φn"two-body bound state, recently predicted by lattice QCD.
In this talk, we'll describe the¯KN interaction study via the x-ray spectroscopy, exploring experiments to identify kaonic nuclear bound states, and the future prospects of the experimental study on molecule-like hadronic cluster with strangeness (¯K and φ), in relation to quark-confinement and in conjecture with the quark-hadron cross over scenario

Session VII / 33

Experimental study of the KbarNNN state and beyond at J-PARC

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Kaonic nuclear states have been one of the hottest topics in hadron physics for these decades. After many experimental efforts, we finally found strong evidence of the KbarNN state in the Λpn final state via in-flight K- reaction on helium-3 in J-PARC E15. We are now constructing an upgraded solenoid spectrometer system to investigate kaonic nuclear systems further. One direction is systematically investigating heavier systems, such as KbarNNN, Kbar-alpha, etc., which would lead to a more solid establishment of the kaonic nuclear states and to study the interplay between the KbarN attraction, the NN repulsion, and other involving effects.

As for the KbarNNN state, we can study it with a quite similar method in E15 by replacing the target with helium-4. We already had a chance to collect data with a helium-4 target as a feasibility test of a lifetime measurement of light hypernuclei (J-PARC T77). In a preliminary analysis, we successfully reconstructed hundreds of Λdn events and observed a structure below the KbarNNN binding threshold in the Λd invariant mass spectrum. The same reaction will be measured in more detail with the new spectrometer as J-PARC E80.

In this contribution, we would like to present the latest results of the Λdn analysis described above and discuss future prospects for a more comprehensive investigation of the heavier kaonic nuclear systems.

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Round Table

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Session VIII / 28

The SIDDHARTA-2 experiment: present status and future perspectives

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SIDDHARTA-2 represents a state-of-the-art experiment designed to perform dedicated measurements of kaonic atoms, which are particular atomic configurations composed of a negatively charged kaon and a nucleus. Investigating these exotic atoms provides an exceptional means to comprehend the strong interactions in the non-perturbative regime involving strangeness. At present, the SIDDHARTA-2 experiment is configured to undertake the challenging task of measuring kaonic deuterium transitions to the ground state, which has not yet been measured due to an expected lower yield and larger width with respect to kaonic hydrogen. To perform this challenging measurement, the collaboration developed a completely new apparatus, involving a large-area X-ray detector system, optimizing the signal and improving the signal-to-background ratio by gaining in solid angle, improving the timing capability, and additionally implementing a charge particle tracking veto systems. A full program of measurements beyond SIDDHARTA-2, i.e. the EXKALIBUR project, was put forward by the collaboration, to fully take advantage of the excellent conditions offered by the DAFNE collider.
An overview of the results obtained with SIDDHARTA-2 in the preparation phase will be presented as well as a short description of future measurements.

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Femtoscopy studies of meson-baryon and baryon-baryon pairs with strangeness

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The two-particle momentum correlation function from high-energy nuclear collisions is beginning to be used to study hadron-hadron interaction. Because this observable is sensitive to the low-energy interaction, it is useful to study the nature of the near-threshold resonances and the underlying mechanism of the interaction. The meson-baryon and baryon-baryon interaction in strangeness sector is the good target of this approach.
In this talk, we first discuss the theoretical and experimental situation of the K^-p correlation function. We see that the coupled-channel source effect gives the important enhancement and the source size dependence of the correlation function is key to investigate the interaction detail from the correlation data.
Next, we discuss the correlation function using the α particle. Because α is the composite particle whose central nuclear density reaches 2 normal nuclear density, it is expected that the correlation function shows the density effect of the interaction. I show the results with the $\Lambda\alpha$ correlation and $\Xi\alpha$ correlation using the effective models and discuss how the detailed ΛN and ΞN interaction can be determined from the measurement.

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The minreview of lower Sigma(1/2-) around 1400 MeV

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In this talk, we will introduce the recent progress of the Sigma(1/2-) state around 1400 MeV. This state is beyond the usual quark model and has been predicted to exist as a pentaquark, compact state, or molecular state. Various experiments have provided evidences for the existence of this state, but it has not been confirmed yet. Therefore, it is crucial to observe this state and determine its nature accurately.

Session VIII / 39

Structure Probing by Holographic Imaging at Nanometer scale with X-ray lasers (SPHINX)

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The SPHINX project aims building femtosecond-exposure X-ray holographic cameras for imaging microscopic samples and their internal parts (in-vivo cell elements, viruses and nanorobotic devices) with nanometer resolution. The proposal is based on a new implementation of phase-contrast holography that overcomes the limitations encountered by the absorption-contrast systems, namely the low energy range, the limited detector granularity and the weak illumination. As a practical solution, a combination of polycapillary lenses, large X-Ray CCD arrays with small pixel size and XFEL sources will allow splitting the beam, focusing, magnification and phase-contrast imaging in the keV range. Unlike absorption-based methods, where angles increase with the energy, the refractive diffraction reduces the diffraction limit together with the characteristic angles, both essential for the resolving power (given the X-ray detector pitch), while also eliminating the shadow effect and giving access to full structure probing. The key parameters are defined by the focusing optics, which consists in a micro semi-lens or a combination of the former with a parabolic monocapillary. The advantage of "non-perfect"optics (diffuse focusing) is their divergence, driven by the single fiber. This allows sending on the same detector area both object and reference beams, condition unreachable with a lens or a mirror.

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Probing hadron-quark phase transition in twin stars using f-modes

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There could be a deconfined quark phase at the ultra-high density core of the neutron stars. The nature of the deconfinement transition is a matter of debate. Whether it exhibits a jump in the thermodynamic variables or represents, a crossover is a question addressed in laboratory experiments and compact star observations. A suitable construction of the hybrid equations of state (EoS) can lead to the existence of twin stars, and their presence can be verified from astrophysical observations. We describe the neutron star matter by a hybrid EoS model mimicking the pasta phase in the mixed phase arising due to consideration of surface tension effects. We then use the hybrid EoS to investigate the properties of the twin stars' fundamental oscillation mode (f-mode). We demonstrated the asteroseismology problem and its difficulty involving f-mode and twin stars. Our investigations suggest that the detection of gravitational waves emanating from the f-modes with the third-generation gravitational wave detectors offers a promising scenario for confirming the existence of the twin stars. We also estimate the various uncertainties associated with the determination of the mode parameters and conclude that these uncertainties make the situation more challenging to identify the nature of the hadron-quark phase transition.

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Conclusions

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From strangeness to wine; the weird but exciting journey of the VOXES spectrometer

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In this a bit off-topic talk, the history of the VOXES spectrometer will be presented, together with its main characteristics and results.
The VOXES spectrometer was intended to be developed for high precision kaonic atoms but then also other possible applications became appealing.
This is the story of how we moved from the VOXES spectrometer for nuclear physics to the MITIQO project to monitor wine's quality

Session V / 3

Lessons from Ξ^- capture events in emulsion

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All five KEK and J-PARC two-body Ξ^- capture events in light emulsion nuclei to single Λ hypernuclei are consistent with Coulomb-assisted $1p_{\Xi^-}$ nuclear states. The underlying Ξ-nuclear potential is strongly attractive
with nuclear-matter depth $V_\Xi \geq 20$ MeV 1, considerably larger than suggested by recent LQCD, femtoscopy and EFT theoretical studies.
We argue that the J-PARC E07 new ^{14}N capture events assigned to $1s_{\Xi^-}$ nuclear states, thereby implying considerably shallower V_Ξ,
have also another interpretation as $1p_{\Xi^0}$ nuclear states [2].

Time permitting, several other Strangeness -2 nuclear systems will be discussed briefly.

1 E. Friedman, A. Gal, Constraints on Ξ^- nuclear interactions from capture events in emulsion, Phys. Lett. B 820, 136555 (2021).

[2] E. Friedman, A. Gal, Has J-PARC E07 observed a Ξ^-_{1s} nuclear state?, Phys. Lett. B 837, 137640 (2022).