MESON2023

Thursday, 22 June 2023 - Tuesday, 27 June 2023

Auditorium Maximum

Book of Abstracts

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Opening

Plenary session / 206

Quarkonium at Belle II

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Belle II offers unique possibilities for the discovery and interpretation of exotic multiquark states to probe the fundamentals of QCD. This talk presents recent results on searches for the hidden bottom transition between $\Upsilon(10750)$ and χ_{bJ}, and measurements of the energy dependence of the $e^+e^- \to B^{(*)}\bar{B}^{(*)}$ cross section.

Collaboration:

Belle II

Plenary session / 201

Exotic states from LHCb

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The Large Hadron Collider beauty (LHCb) collaboration has made significant strides in the study of exotic states of matter. These states, which include particles composed of more than three quarks or with non-quark constituents, challenge our understanding of the strong force and the nature of hadrons. In this talk, we present the latest experimental results from LHCb on exotic states, including studies of charmonium sector and heavy-flavor baryons. We will also discuss the implications of these findings for our understanding of QCD and prospects of upcoming data taking periods.

Collaboration:

LHCb

Plenary session / 167

Exotic meson spectroscopy from lattice QCD

Author: Marc Wagner[1]

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I discuss the basic principle as well as typical problems, when computing masses of exotic mesons with lattice QCD. I also present selected recent lattice QCD results for exotic mesons. I focus on systems composed of two heavy anti-bottom quarks and two lighter quarks.

Collaboration:

Plenary session / 187

Exploring Meson Photoproduction with the GlueX Experiment

Author: Matthew Shepherd[1]

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An outstanding puzzle in our study of strong interactions is understanding how the spectrum of mesons arises from Quantum Chromodynamics. There is a growing body of evidence that QCD generates mesons and baryons beyond quark-antiquark and three-quark configurations. In addition, theoretical calculations of the spectrum of mesons predict states with gluonic degrees of freedom that arise from the gluon-gluon interaction in QCD. A key objective of the GlueX experiment is search for these hybrid mesons in the light quark sector. Results concerning production of conventional mesons with linearly-polarized photons will presented. These measurements allow one to learn about photoproduction mechanisms of conventional hadrons, knowledge that can be leveraged in the search for hybrid mesons. The current status of and future plans for the light hybrid meson search program at GlueX will be presented. In addition, the GlueX results on production of charmonium will be presented. These results provide constraints on interpretation of pentaquark candidates in the heavy quark sector and suggest the need for additional investigations in photoproduction.

Collaboration:

GlueX

Plenary session / 204

Recent results on spectroscopy of XYZ states from BESIII

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Exotic hadrons beyond the simple quark model are allowed for and predicted within quantum chromodynamics. They offer laboratories to study the strong interaction. Experimental searches are performed since decades, however, most of them were not conclusive yet. Since the beginning of the millenium, a new era has begun with the discovery of the so-called charmonium-like (exotic) XYZ states. With the observation of tetraquark candidates, the BESIII experiment has discovered manifestly exotic states in the meson sector. We give a selected overview on recent results on XYZ states as obtained with the BESIII experiment at BEPCII in Beijing, China. Especially, we report evidence for a new state $Y(4710) \to K_s^0 K_s^0 J/\psi$ and the first observation of three vector charmonium-like states in an open charm decay that we find consistent with $Y(4230)$, $Y(4500)$ and $Y(4660)$

Collaboration:

BESIII

Plenary session / 149

Revealing the origin of mass through studies of hadron spectra and structure

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The Higgs boson is responsible for just 1% of the visible mass in the Universe. Obviously, therefore, Nature has another, very effective way of generating mass. In working toward identifying the mechanism, contemporary strong interaction theory has arrived at a body of fundamental predictions, *viz.* the emergence of a nonzero gluon mass-scale, a process-independent effective charge, and dressed-quarks with constituent-like masses. These three phenomena - the pillars of emergent hadron mass (EHM) - explain the origin of the vast bulk of visible mass in the Universe. Their expressions in hadron observables are manifold. This presentation will highlight some of the measurements that have been and can be made in order to validate the paradigm, stressing the role of EHM in building the meson spectrum; producing the leading-twist pion distribution amplitude; shaping pion and nucleon parton distribution functions - valence, glue and sea, including the antisymmetry of antimatter; and moulding hadron charge and mass distributions.

Collaboration:

Plenary session / 212

Hadron spectroscopy on the Lattice

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I illustrate recent progress in hadron spectroscopy from Lattice QCD. The scope of this presentation will be studies making use of finite-volume methods to determine hadronic scattering amplitudes. I will focus in particular on recent calculations for mesons and baryons whose properties posed a challenge for traditional quark-model calculations.

Collaboration:

Parallel session B1 / 156

Review of physics program at J-PET

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The Jagiellonian Positron Emission Tomograph (J-PET) is a multipurpose detector for tests of discrete symmetries and quantum entanglement of photons originating from the decay of positronium atoms. The research is performed by measurement of angular correlations in the annihilations of the lightest leptonic bound system. The J-PET detector is the only device which enables determination of polarization of photons from positronium annihilation together with estimation of positronuium spin axis on the event-by-event basis. The novelty of the system is based on a usage of plastic scintillators as active detection material and trigger-less data acquisition system. The aim of two independent detection setups currently in use together with different annihilation chambers is to improve limits on C, CP and CPT symmetries and to search for the entanglement of photons originating from electron-positron annihilation. In the talk experimental techniques and new results of tests in the decays of positronium in a whole available phase-space at J-PET are presented.

Collaboration:

J-PET

Parallel session A1 / 121

Compositeness of T_{cc} and $X(3872)$ with decay and coupled-channel effects

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The compositeness is useful to quantitatively characterize the internal structure of states whether it is composite dominant (molecular dominant) or not. There have been many studies to analyze the internal structure of the exotic hadrons with the compositeness, in particular, for weakly bound states [1,2]. It is known that the near-threshold states are dominated by the molecular structure in the limit of the vanishing binding energy [3]. However, the decay and coupled-channel effects modify the compositeness as shown in Ref. [1], and therefore the composite nature of the near-threshold states with finite binding might be affected by these contributions.

In this study, we focus on the compositeness of weakly bound states with the effective field theory. At first, to consider the nature of shallow bound states, we introduce a simple model with the coupling of the single-channel scattering to the bare state. The compositeness of the typical and shallow bound states is studied by varying the model parameter. In contrast to the naive expectation for shallow bound states, we demonstrate that a non-composite state can always be realized even with the small binding energy. At the same time, however, it is shown that a fine tuning is necessary to obtain the non-composite weakly bound state. In other words, the probability to find a model with the composite dominant state becomes larger with the decrease of the binding energy in accordance with the low-energy universality.

For the application to the exotic hadrons, we then discuss the modification of the compositeness by the decay and coupled-channel effects. We quantitatively show that these contributions suppress the compositeness, because of the increase of the fraction of other components. Finally, as the examples of the near-threshold exotic hadrons, the structure of T_{cc} and $X(3872)$ is studied by evaluating the compositeness. We find the importance of the coupled-channel and decay contributions for the structure of T_{cc} and $X(3872)$, respectively. Details of this study can be found in Ref. [4].

[1] Y. Kamiya and T. Hyodo, PTEP 2017, 023D02 (2017)
[2] T. Kinugawa and T. Hyodo, Phys. Rev. C 106, 015205 (2022)
[3] T. Hyodo, Phys. Rev. C 90, 055208 (2014)
[4] T. Kinugawa and T. Hyodo, arXiv:2303.07038 [hep-ph]

Collaboration:

Parallel session A1 / 142

Mechanisms of production of exotic $X(3872)$ in proton-proton collisions and its structure

Author: Antoni Szczurek[1]

Co-author: Wolfgang Schafer [1]

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We calculate the total cross section and transverse momentum distributions for the production of the enigmatic $\chi_{c1}(3872)$ (or X(3872)) (see [1]) assuming different scenarios: $c\bar{c}$ state and $D^{0*}\bar{D}^0 + D^0\bar{D}^{0*}$ molecule. The derivative of the $c\bar{c}$ wave function needed in the first scenario is taken from a potential $c\bar{c}$ model calculations. Compared to earlier calculations of molecular state we include not only single parton scattering (SPS) but also double parton scattering (DPS) contributions. The latter one seems to give smaller contribution than the SPS one. The upper limit for the DPS production of $\chi_{c1}(3872)$ is much below the CMS data. We compare results of our calculations with existing experimental data of CMS, ATLAS and LHCb collaborations. Reasonable cross sections can be obtained in either $c\bar{c}$ or molecular $D\bar{D}^*$ scenarios for $X(3872)$, provided one takes into account both directly produced $D^0, \bar{D}^0$, as well as $D^0, \bar{D}^0$ from the decay of D^*. However, arguments related to the lifetime of D^* suggest that the latter component is not active. With these reservations, also a hybrid scenario is not excluded.

[1] A. Cisek, W. Sch\"afer and A. Szczurek, Structure and production mechanism of the enigmatic $X(3872)$ in high-energy hadronic reactions', Eur. Phys. Jour. {\bf C882}, (2022) 1062.

Collaboration:

Parallel session B1 / 161

Dilepton production in the proton-proton reaction at 4.5 GeV with the HADES spectrometer

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The High Acceptance DiElectron Spectrometer (HADES) is a fixed target experiment at GSI, Darmstadt, Germany, with large geometrical acceptance and high efficiency, dedicated to the studies of heavy-ions, proton and pion induced reactions. In February 2022, proton-proton reactions at 4.5 GeV beam kinetic energy were measured and e^+e^- data was collected. The data allows to study the specific channels that produced dileptons, as baryonic resonance Dalitz decays ($\Delta/N^* \to pe^+e^-$) and vector meson decays ($\rho/\omega/\phi \to e^+e^-$). The measurement will also serve as a reference for in-medium effects observed in heavy-ion collisions at CBM and STAR Beam Energy Scan energies.

In this contribution, the strategy for the identification of correlated electron-positron pairs and the rejection of combinatorial background will be discussed. The signal to background ratio in the vector meson region is larger than 10 and ω and ϕ peaks are clearly visible. In addition, e^+e^- pairs are reconstructed in the high invariant mass region ($M_{e^+e^-} > 1020$ MeV/c^2).

Collaboration:

HADES

Parallel session A1 / 144

Light front approach to axial meson photon transition form factors: probing the structure of $\chi_{c1}(3872)$

Author: Wolfgang Schafer[1]

Co-authors: Antoni Szczurek [1]; Izabela Babiarz [1]

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We propose to study the structure of the enigmatic $\chi_{c1}(3872)$ axial vector meson through its $\gamma_L^*\gamma \to \chi_{c1}(3872)$ transition form factor.
We use our recently derived light-front wave function representation of the form factor for the lowest $c\bar{c}$ Fock-state. We found that the reduced width of the state is well within the current experimental bound recently published by the Belle collaboration. This strongly suggests a crucial role of the $c\bar{c}$ Fock-state in the photon-induced production.
Our predictions for the Q^2 dependence can be tested by future single tagged e^+e^- experiments, giving further insights into the short-distance structure of this meson.

The talk is based on
I.Babiarz, R.Pasechnik, W.Schafer and A.Szczurek,
Light-front approach to axial-vector quarkonium $\gamma^*\gamma^*$ form factors,
JHEP 09 (2022), 170
and
I.Babiarz, R.Pasechnik, W.Schafer and A.Szczurek,
Probing the structure of $\chi_{c1}(3872)$ with photon transition form factors,
[arXiv:2303.09175 [hep-ph]].

Collaboration:

Parallel session B1 / 95

Light meson decays at BESIII

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The world's largest sample of J/ψ events accumulated at the BESIII detector offers a unique opportunity to investigate η and η' physics via two-body J/ψ radiative or hadronic decays. In recent years the BESIII experiment has made significant progresses in η/η' decays. A selection of recent highlights in light meson spectroscopy at BESIII are reviewed in this report, including the observation of $\eta' \to \pi^+\pi^-\mu^+\mu^-$, observation of the cusp effect in $\eta' \to \pi^0\pi^0\eta$, search for CP-violation in $\eta' \to \pi^+\pi^- e^+e^-$, as well as the precision Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$.

Collaboration:

BESIII

Parallel session A1 / 128

Derivative expansions of hadronic potentials coupled to quarks for X(3872)

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

We consider, in this talk, the channel coupling between the inter-quark and inter-hadron potentials. We then derive the effective potential of hadrons by eliminating the quark channel in the Feshbach method[1]. In the case of the Yukawa type transition potential, we obtain the effective potential of hadrons,
\begin{align}
V(\mathbf{r},\mathbf{r'},E)
&= \frac{g_0^2}{E-E_0}\frac{e^{-\mu r}}{r}\frac{e^{-\mu r'}}{r'}, \tag{1}
\end{align}
where g_0 is the coupling constant of the channel transition between quarks and hadrons, E_0 is the energy of the bound state of the quark degrees of freedom. We show that the effective potential has non-locality and depends on the energy E[2].

There are two methods of converting non-local potentials into local ones[3]. A formal derivative expansion decomposes directly a non-local potential in terms of the derivatives of the local potential. In the HAL QCD method, one derives the local potential from the wave function $\psi_{k_{\rm pot}}(r)$ at a momentum $k_{\rm pot} = \sqrt{2mE_{\rm pot}}$ which is obtained by the non-local potential.In the case of potential (1), we obtain at leading order,
\begin{align}
V^{\rm{{formal}}}(r,{E}) &= \frac{4\pi g_0^2}{\mu^2(E-E_0)}\frac{e^{-\mu r}}{r}. \tag{2}
\end{align}
\begin{align}
V^\mathrm{{HAL}}(r,E_\mathrm{pot}) &= E_\mathrm{pot}+\frac{-k_\mathrm{pot}^2\sin(k_\mathrm{pot} r+\delta)-\mu^2\sin\delta e^{-\mu r}}{2m(\sin(k_\mathrm{pot} r+\delta)-\sin\delta e^{-\mu r})}.\tag{3}
\end{align}

Finally, we take $c\bar{c}$ as the quark channel and $D\bar{D}^*$ as the hadron channel to apply this study to $X(3872)$[4]. We construct the effective local $D\bar{D}^*$ potentials which reproduce the observed mass of $X(3872)$. By evaluating these local potentials numerically, we discuss the quantitative difference of local potentials in two methods. To study the effect of the local approximations in observables, we calculate the phase shifts from local potentials in comparison with the exact phase shift from the original non-local potential. In addition, we show that the phase shift is sensitive to the choice of $E_{\rm pot}$ in the HAL QCD method for the system with a weakly bound state such as X(3872).

[1] H. Feshbach, Ann. Phys. **5**, 357 (1958); ibid., **19**, 287 (1962).
[2]I.Terashima and T.Hyodo, EPJ Web Conf. **271**, 10004 (2022).
[3] S.Aoki and K.Yazaki, PTEP **2022**, no.3, 033B04 (2022).
[4] A.Hosaka, T.Iijima, K.Miyabayashi, Y.Sakai, and S.Yasui, PTEP **2016** (2016).

Collaboration:

Parallel session B1 / 111

Physics Beyond the Standard Model with NA62

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The NA62 experiment at CERN took data in 2016–2018 with the main goal of measuring the $K^+ \to \pi^+\nu\bar{\nu}$ decay. The NA62 dataset is also exploited to search for light feebly interacting particles produced in kaon decays. Searches for $K^+ \to e^+N$, $K^+ \to \mu^+N$ and $K^+ \to \mu^+\nu X$ decays, where N and X are massive invisible particles, are performed by NA62. The N particle is assumed to be a heavy neutral lepton, and the results are expressed as upper limits of $O(10^{-8})$ of the neutrino mixing parameter $|U_{\mu 4}|^2$. The X particle is considered a scalar or vector hidden sector mediator decaying to an invisible final state. Upper limits of the decay branching fraction for X masses in the range 10–370 MeV/c^2 are reported. An improved upper limit of 1.0×10^{-6} is established at 90% CL on the $K^+ \to \mu^+\nu\nu\nu$ branching fraction.
Dedicated trigger lines were employed to collect di-lepton final states, which allowed establishing stringent upper limits on the rates lepton flavor and lepton number violating kaon decays. Upper limits on the rates of several K^+ decays violating lepton flavour and lepton number conservation, obtained by analysing this dataset, are presented.
The NA62 experiment can be run as a "beam-dump experiment" by removing the Kaon production target and moving the upstream collimators into a "closed" position. More than 10^{17} protons on target have been collected in this way during a week-long data-taking campaign in 2021. New results from analysis of this data, with a particular emphasis on Dark Photon and Axion-like particle Models, are reported.

Collaboration:

NA62

Parallel session A2 / 138

Molecular-type pentaquarks from coupled channel dynamics with strangeness S=-2

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The existence of the nucleonic pentaquark resonances $P_c(4312)$, $P_c(4380)$, $P_c(4440)$ and $P_c(4457)$, established by the LHCb collaboration, has been one of the major discoveries in hadron physics in the latest years. This has been followed by the discovery of pentaquarks with one unit of strangeness,

$P_{cs}(4338)$ and $P_{cs}(4457)$. Most of these states can be understood as hadronic molecules, namely bound states of a sufficiently attractive meson-baryon interaction.

In our recent work [1] we revisit the procedure of the unitarized coupled-channel hidden gauge formalism, which has been a very successful approach in explaining other exotic hadrons in the charm and hidden charm sectors. Employing realistic regularization parameters, we predict double strangeness pentaquarks of molecular nature [1]. The first one, $\Xi(4493)$, is a $J^P = 1/2^-$ resonance generated from the interaction of pseudoscalar mesons with baryons, which couples most strongly to the $\bar{D}\Omega_c$ and $\bar{D}_s\Xi_c'$ channels and can be most likely observed via its decay to $\eta_c\Xi$ states, for instance in decay processes of bottomed baryons, such as $\Xi_b \to \Xi\ \eta_c\ \phi$ and $\Omega_b \to \Xi\ \eta_c\ \bar{K}$. The other one, $\Xi(4633)$, is a spin-degenerate resonance which can have $J^P = 1/2^-$ or $J^P = 3/2^-$ and is obtained from the interaction of vector mesons with baryons. It couples dominantly to the $\bar{D}^*\Omega_c$ and $\bar{D}_s^*\Xi_c'$ channels and it should be looked for in invariant mass spectra of $J/\Psi\ \Xi$ pairs which could be produced in the decays $\Xi_b \to \Xi\ J/\Psi\ \phi$ and $\Omega_b \to \Xi\ J/\Psi\ \bar{K}$.

These molecular-type pentaquarks are dynamically generated in a very specific and unique way, via a strong non-diagonal attraction between the two heaviest meson-baryon channels [1].
This effect was overlooked before because the very mild attraction in the diagonal interaction of the heaviest meson-baryon state was neglected, hence effectively preventing the coupled-channel mechanism to take effect.

We hope that our work would stimulate experiments looking for these type of pentaquarks, the discovery of which would enrich the family of their already observed $S = 0$ and $S = -1$ pentaquark partners.

[1] J. A. Marse-Valera, V. K. Magas and A. Ramos, Phys. Rev. Lett. 130 (2023) no.9, 9.

Collaboration:

Parallel session B2 / 132

Recent studies of e+e− annihilation into hadrons at low energies via ISR at $BABAR$

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The measurement of exclusivee^+e^- to hadrons processes is a significant part of the physics program of $BABAR$ experiment, aimed to improve the calculation of the hadronic contribution to the muon g−2 and to study the intermediate dynamics of the processes. We present the most recent studies performed on the full data set of about 470 fb^{-1} collected at the PEP-II e^+e^- collider at a center-of-mass energy of about 10.6 GeV.
In particular, we report the results on $e^+e^- \to \pi^+\pi^-\pi^0$. From the fit to the measured 3π mass spectrum we determine the products $\Gamma(V \to e^+e^-)$
$calB(V \to 3\pi)$ for the ω and ϕ resonances and for
$calB(\rho \to 3\pi)$. The latter isospin-breaking decay is observed with 6σ significance. The measured $e^+e^- \to \pi^+\pi^-\pi^0$ cross section is used to calculate the leading-order hadronic contribution to the muon magnetic anomaly from this exclusive final state with improved accuracy.
We show also new results on the study of $e^+e^- \to 2K3\pi$ processes, in an energy range from production threshold up to about 4 GeV. For each process, the cross section is measured as a function of the invariant mass of the hadronic final state. The production of several intermediate final states is also measured, allowing for the search for new decay modes of recently discovered resonances.

Collaboration:

BABAR

Parallel session B2 / 175

A dispersive estimate of $a_0(980)$ contribution to hadronic light-by-light scattering in g-2

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A dispersive implementation of the $a_0(980)$ resonance to (g-2) requires the knowledge of the double-virtual S-wave $\gamma^*\gamma^* \to \pi\eta, KK$ amplitudes. To obtain these amplitudes we used a modified coupled-channel Muskhelishvili–Omnès formalism, with the input from the left-hand cuts and the hadronic Omnès function. The latter we obtained using a data-driven N/D method in which the fits were performed to the different sets of experimental data involving $\pi\eta$ and KK final states.

Collaboration:

Parallel session A2 / 103

Properties of the Tcc(3875) and its heavy-quark spin partner in nuclear matter

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We discuss the modification of the properties of the tetraquark-like $T_{cc}^+(3875)$ in dense nuclear matter. We consider the T_{cc}^+ in vacuum as a purely molecular isoscalar ($D^0 D^{*+}/D^+ D^{*0}$) bound state in $S-$wave, generated from a heavy-quark symmetry leading-order interaction between the charmed mesons. We compute the D and D^* spectral functions embeded in a nuclear medium and use them to determine the corresponding T_{cc}^+ self energy and spectral function. We find important modifications of the DD^* scattering amplitude and of the pole position of the T_{cc}^+ exotic state already for $\rho_0/2$, with ρ_0 the normal nuclear density. We also discuss the dependence of these results on the DD^* molecular component in the T_{cc}^+ wave-function. Finally, we perform a similar analysis for the isoscalar $J^P = 1^+$ heavy-quark spin symmetry partner of the T_{cc}^+ (T_{cc}^{*+})
by considering the $D^{*0}D^{*+}$ scattering $T-$matrix.

Collaboration:

Parallel session A2 / 181

The $T_{c\bar{s}}(2900)$ as a threshold effect from the interaction of the D^*K^*, $D_s^*\rho$ channels

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We look at the mass distribution of the $D_s^+\pi^-$ in the $B^0 \to \bar{D}^0 D_s^+\pi^-$ decay, where a peak has been observed in the region of the $D_s^*\rho$, D^*K^* thresholds. By creating these two channels together with a $\bar{D}^0$ in B^0 decay and letting them interact as coupled channels, we obtain a structure around their thresholds, short of producing a bound state, which leads to a peak in the $D_s^+\pi^-$ mass distribution in the $B^0 \to \bar{D}^0 D_s^+\pi^-$ decay. We conclude that the interaction between the D^*K^* and $D_s^*\rho$ is essential to produce the cusp structure that we associate to the recently seen $T_{c\bar{s}}(2900)$, and that its experimental width is mainly due to the decay width of the ρ meson. The peak obtained together with a smooth background reproduces fairly well the experimental mass distribution observed in the $B_0 \to \bar{D}^0 D_s^+\pi^-$ decay.

Collaboration:

Parallel session B2 / 104

Signatures for tetraquark mixing from experimental partial widths of the two light-meson nonets

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Tetraquark mixing model has been proposed recently as a possible structure for the two nonets in the $J^P = 0^+$ channel, the light nonet composed of $a_0(980)$, $K_0^*(700)$, $f_0(500)$, $f_0(980)$, and the heavy nonet of $a_0(1450)$, $K_0^*(1430)$, $f_0(1370)$, $f_0(1500)$. Two tetraquark types are introduced in this model, and their mixtures that diagonalize the color-spin interaction are realized by the two nonets. Among various signatures, we report in this talk that the experimental partial decay widths collected from Particle Data Group (PDG) support this mixing model clearly. Specifically, we demonstrate that the coupling strengths of the light nonet to two pseudoscalar mesons estimated from the experimental partial widths are consistently larger than those of the heavy nonet. This feature agrees qualitatively well with the predictions from the tetraquark mixing model and, therefore, provides supporting evidence for the tetraquark mixing.

Reference: Hungchong Kim and K. S. Kim,"Tetraquark mixing supported by the partial decay widths of two light-meson nonets", Eur. Phys. J. C 82, no.12, 1113 (2022)

Collaboration:

Parallel session A2 / 141

The $Y(4230)$ as a D_1D molecule

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We investigate the nature of the $Y(4230)$ in a simultaneous fit of the $DD^*\pi$, $J/\psi\pi\pi$ and $h_c\pi\pi$ cross-sections and invariant mass spectra of the subsystems. We show to what extend a single $D_1 D$ bound state can explain the non-trivial asymmetric lineshape observed in these channels. At the same time we study if the $Z_c(3900)$ observed in the $J/\psi\pi$ invariant mass distribution can be understood as a $D^* D$ molecule or is a simple re-scattering effect.

Collaboration:

Parallel session B2 / 150

Dynamical generation of axial-vector mesons

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We present recent results on the dynamical generation of the a_1, h_1, and b_1 axial-vector mesons. We demonstrate the emergence of the a_1 and h_1 mesons from the $\pi\rho$ scattering process, based on the coupled-channel formalism with the $\pi\rho$ and $K\bar{K}^*$ ($\bar{K}K^*$) channels. This is achieved by constructing kernel amplitudes using the effective Lagrangian and computing the coupled integral equation for $\pi\rho$ scattering. By performing the partial-wave expansion, we explicitly show that the $a_1(1260)$ meson arises as a $K\bar{K}^*$ molecular state, generated only by including the $K\bar{K}^*$ ($\bar{K}K^*$) channel. The pole position of the a_1 meson is determined to be at $\sqrt{s_R} = (1170.7 - i173.0)$ MeV. We also investigate four different h_1 mesons by coupling additional channels such as $\eta\omega$ and $\eta\phi$, and find that $h_1(1415)$ is strongly coupled to the $K\bar{K}^*$ and $\eta\phi$ channels, indicating its significant strange quark content. Additionally, we report a novel observation that the b_1 meson has a two-pole structure that arises from $\pi\omega$ scattering, with the interference of these two-pole resonances resulting in the appearance of $b_1(1235)$.

Collaboration:

Parallel session B2 / 106

Helicity flip transitions and the t-dependence of exclusive photo-production of rho meson

Authors: Anna Cisek[1]; Antoni Szczurek[2]; Wolfgang Schäfer[2]

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We calculate the differential cross section dσ/dt for the diffractive photoproduction process γp⟶ρp and compare to recent data extracted by the CMS collaboration. Our model is based on two-gluon exchange in the nonperturbative domain. We take into account both helicity conserving and often neglected helicity-flip amplitudes in the γ⟶V transition, which can contribute at finite t. The shape of the differential cross section as well as the role of helicity flip processes is strongly related to the

dependence of the unintegrated gluon distribution on transverse momenta in the nonperturbative region. Results for different unintegrated gluon distribution will be shown. The presentation will be based on paper published recently [1].

[1] A. Cisek, W. Schäfer, A. Szczurek, „Exclusive production of rho meson in gamma-proton collisions: dσ/dt and the role of the helicity flip process"; Phys. Lett. B836 (2023) 137595.

Collaboration:

Parallel session A2 / 98

Observation of e+e- to chi_c1 at BESIII

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In electron-positron annihilation, the process of $e^+e^- \to \chi_{c1}$ can occur via the production of two virtual photons or through neutral current, therefore being suppressed with respect to the normal annihilation process via one virtual photon. Using a dedicated scan sample around the χ_{c1} mass, the direct production of χ_{c1} has been established for the first time in experiments. This provides a new approach for the study of the internal nature of hadrons.

Collaboration:

BESIII

Plenary session / 197

(Exotic) mesons with functional methods

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I will highlight recent progress in the applications of functional methods, in particular the combination of Dyson-Schwinger and Bethe-Salpeter equations, to meson structure and dynamics. This includes calculations of light and heavy four-quark states and their mixing with ordinary mesons, studies of light-front dynamics using contour deformations in the complex momentum plane, and progress towards ab-initio calculations of meson properties.

Collaboration:

Plenary session / 203

Probing Gluon Dynamics with High Energy Photons

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High energy nuclear collisions produce ultra-Lorentz contracted electromagnetic fields which manifest as high energy photons.
The photons from the electromagnetic fields of one nucleus can fluctuates into a $q\bar{q}$ and interacts with the target through a Pomeron - a two gluon state at lowest order. Such photonuclear processes have been known for decades as a probe of the gluon distribution within nucleons and nuclei. Nevertheless, the Pomeron remains a poorly understood object of fundamental importance in high energy scattering processes. Similarly, gluons are proving to play a central role in carrying the (e.g. spin) quantum number of the nucleon - yet pinning down the gluonic contributions to nucleon quantum numbers remains challenging.

This talk will discuss novel approaches for investigating gluonic structures within the nucleus via photonuclear collisions. First, the recent discovery of the polarized Breit-Wheeler process in heavy-ion collisions has provided an entirely new experimental handle for investigating the spin states of the Pomeron. I will discuss the signatures of a Tensor Pomeron in photonuclear collisions at RHIC, LHC, and the future Electron Ion Collider.
Secondly, I will discuss a novel proposal for using photonuclear interactions to investigate the carrier of the Baryon quantum number within nucleons and nuclei. While the 'conventional' picture attributes 1/3 Baryon number to each valence quark, there exist strong motivation from QCD to consider that the Baryon number may be carried by the 'gluon junction' within nuclear systems. Photonuclear interactions provide a unique way to investigate the nature of the object(s) carrying the Baryon quantum number.

Collaboration:

STAR

Plenary session / 107

Recent Highlights on Meson Spectroscopy at BESIII

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Despite mesons being one of the longest known type of particles, there are still many open questions. Besides well understood states that can be clearly attributed to meson nonets, there are many candidates which could have an exotic nature instead. Such exotic particles e.g. glueballs, hybrids and tetraquarks can be especially studied in clean, gluon-rich environments.
The BESIII experiment, which is in operation at the BEPCII electron-positron collider in Beijing since 2009, has collected world leading high statistic data samples in the charmonium region. This allows to study rare reactions that are considered to be suppressed. This offers unique possibilities to study exotic QCD states in the charmonium sector, but also the light meson spectrum which can be accessed via charmonium decays. Especially radiative J/ψ decays offer a gluon-rich environment in which gluebells and hybrid states can be expected. Since these states are often hard to identify and disentangle, partial wave analysis are needed to determine the different contributions.
The talk will discuss the results of recent studies carried out by the BESIII experiment and their implications. Special focus will put on the used amplitude analysis techniques.

Collaboration:

BESIII

Plenary session / 202

Meson Molecules

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Over the past two decades, numerous new hadrons have been observed in the charmonium and bottomonium energy regions. Many of these states reside near meson-antimeson thresholds and therefore can be considered as potential candidates for meson molecules. In this talk, I will discuss how to decipher the nature of such states from experimental line shapes and lattice QCD simulations. An overview of the effective-field-theory approach for analysing the near-threshold states will be presented. Some applications, e.g., to the recently discovered doubly charm Tcc(3875)+ state will be discussed.

Collaboration:

Plenary session / 139

Recent High Precision Measurement of the Neutral Pion Lifetime and the PrimEx Experimental Program at Jefferson Lab

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The neutral pion is the lightest two-quarks strongly interacting particle in Nature. As such, the properties of π0 decay are especially sensitive to the underlying fundamental symmetries of quantum chromodynamics (QCD). In particular, the π0 →γγ decay width is primarily defined by the braking effects of axial and chiral symmetries (chiral anomaly) in QCD. Theoretical activities in this domain over the last years resulted in small corrections to the anomaly with a percent level accuracy for the π0→γγ decay width. The PrimEx collaboration at Jefferson Laboratory has developed and performed two new experiments to measure the π0 →γγ decay width with high precision using the Primakoff effect. The combined result from two experiments: Γ(π0→γγ) = 7.802±0.052(stat.) ±0.105(syst.) eV was recently published in the Science journal. With its 1.50% total uncertainty it represents the most accurate measurement of this fundamental quantity to date. The results of these experiments together with the experimental method will be presented and discussed in this talk.

Collaboration:

PrimEx at Jefferson Lab

Plenary session / 159

Prospects for XYZ studies at future facilities

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The next generation of electron-hadron facilities has the potential for significantly improving our understanding of exotic hadrons. The XYZ states have not been seen in photon-induced reactions so far. Their observation in such processes would provide an independent confirmation of their existence and offer new insights into their internal structure. I will discuss what are the opportunities for spectroscopy at the newly planned facilities.

Collaboration:

Plenary session / 190

Light-Front Hamiltonian Approach to Hadrons

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Light-front quantization of a Hamiltonian derived from quantum field theory has a long history. The introduction of Basis Light-Front Quantization (BLFQ) has led to the development of Hamiltonians and numerical methods for solving both relativistic bound state and scattering applications in models linked to QCD. For QCD applications in limited Fock spaces, one assumes a form of confinement based on light-front holography along with an additional longitudinal confinement. In applications limited to valence quarks, an effective one-gluon exchange interaction in light front gauge is employed. Recent applications include expanding Fock spaces beyond valence fermions to include the dynamical gauge degrees of freedom. Since the light-front wave functions are interpreted as appropriate to a low-resolution scale, calculated observables such as parton distribution functions (PDFs) can be QCD-evolved to higher scales for comparison with experiments. I will survey comparisons between theory and experiment from recent applications to mesons and baryons and discuss prospects for future developments.

Collaboration:

Plenary session / 211

FAIR Facility

T.B.A.

Parallel session C3 / 179

Second-order pion-nucleus potential for scattering and photoproduction

Authors: Viacheslav Tsaran[1]; Marc Vanderhaeghen[1]

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Coherent pion photoproduction on nuclei is an efficient tool for studying nucleon density and determining neutron skin thickness. However, a reliable description of pion scattering and other medium effects is needed for these purposes. We build a universal model describing both pion scattering and photoproduction on spin-zero nuclei within the same framework. We develop second-order momentum space scattering and photoproduction potentials based on the Delta(1232) effective self-energy modification and nucleon two-body correlation functions. The model's parameters are determined by fitting pion-carbon scattering data and are shown to be universal. We demonstrate the importance of the charge and spin exchange corrections for nuclear pion photoproduction.

Collaboration:

Parallel session B3 / 114

Decays of the tensor glueball in a chiral approach

Authors: Arthur Vereijken[1]; Francesco Giacosa[1]; Milena Piotrowska[1]; Shahriyar Jafarzade[None]

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Glueballs remain an experimentally undiscovered prediction of QCD. Lattice QCD predicts a spectrum of glueballs, with the tensor ($J^{PC} = 2^{++}$) glueball being the second lightest, behind the scalar glueball. From an effective field theory based on spontaneous and explicit chiral symmetry breaking, we compute branching ratios of the tensor glueball into various meson decay channels. We find the tensor glueball to primarily decay into 2 vector mesons, dominated by $\rho\rho$ and K^*K^*. These results are compared to experimental data of decay rates of spin 2 mesons. Based on this comparison we make statements on the eligibility of these mesons as potential tensor glueball candidates.

Collaboration:

Parallel session A3 / 153

Quark mass dependence on D_{s0}^* resonance

Authors: Fernando Gil Domínguez[1]; Raquel Molina Peralta[1]

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We study the light and heavy quark mass dependence of the low-lying charmed mesons in the framework of one-loop HHχPT. The low energy constants are determined by analyzing the available lattice data from different LQCD simulations. Model selection tools are implemented to determine the relevant parameters as required by data with a higher precision.
By fitting energy levels we extract results for the D_{s0}^* quark mass dependence.

Collaboration:

Parallel session C3 / 173

The phi meson in nuclear matter from theory and experimental data

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

Collaboration:

Parallel session B3 / 194

Exotic meson candidates in COMPASS

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The COMPASS experiment at the SPS-enjected M2 beam line at CERN is a major player in the field of light-meson spectroscopy. The two-stage spectrometer provided a good acceptance and covered a wide kinematic range for charged and neutral particles, allowing to access a wide range of final states. Operating with liquid hydrogen as well as heavier nuclear targets and a negative hadron beam at 190 GeV/c, the diffractively produced excited states π_J, a_J and K_J can be accessed.

The talk will be focused on the signal of the lightest hybrid candidate with spin-exotic quantum numbers $J^{PC} = 1^{-+}$ measured at COMPASS and final states in which we can observe it such as $\pi^-\pi^+\pi^-$, $\eta^{(\prime)}\pi^-$, $\omega\pi^-\pi^0$, $\pi^-\pi^+\pi^-\eta$. In addition, we highlight our new results of the $K^-\pi^+\pi^-$ final state.

Collaboration:

COMPASS

Parallel session A3 / 130

Far-forward production of D-mesons and neutrinos from their semileptonic decays at the LHC

Authors: Antoni Szczurek[1]; Rafał Maciuła[1]

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We discuss production of far-forward D mesons/antimesons and neutrinos/antineutrinos from their semileptonic decays in proton-proton collisions at the LHC energies. We include the gluon-gluon fusion $gg \to c\bar{c}$, the intrinsic charm (IC) $gc \to gc$ as well as the recombination $gq \to Dc$ partonic mechanisms. The calculations are performed within the k_T-factorization approach and the hybrid model using different unintegrated parton distribution functions (uPDFs) for gluons from the literature, as well as within the collinear factorization approach. We compare our results to the LHCb data for forward D^0-meson production at $\sqrt{s} = 13$ TeV for different rapidity bins in the interval $2 < y < 4.5$. The IC and recombination model give negligible contributions at the LHCb kinematics. Both the mechanisms start to be crucial at larger rapidities and dominate over the standard charm production mechanisms. At high energies there are so far no experiments probing this region. We present uncertainty bands for the both mechanisms. Somewhat reduced uncertainty bands will be available soon from fixed-target charm meson production experiments in pA-collisions. We present also energy distributions for forward electron, muon and tau neutrinos to be measured at the LHC by the currently operating FASERν experiment, as well as by future experiments like FASERν2 or FLArE, proposed very recently by the Forward Physics Facility project.

Contributions of different mechanisms are shown separately. For all kinds of neutrinos (electron, muon, tau) the subleading contributions, i.e. the IC and/or the recombination, dominate over light meson (pion, kaon) and the standard charm production contribution driven by fusion of gluons for neutrino energies $E_\nu > 300$ GeV. For electron and muon neutrinos both the mechanisms lead to a similar production rates and their separation seems rather impossible. On the other hand, for $\nu_\tau + \bar{\nu}_\tau$ neutrino flux the recombination is reduced further making the measurement of the IC contribution very attractive.

[1] R. Maciuła and A. Szczurek, "Far-forward production of charm mesons and neutrinos at forward physics facilities at the LHC and the intrinsic charm in the proton", Phys.Rev.D 107, no.3, 034002 (2023).

Collaboration:

Parallel session C3 / 119

Scattering of glueballs with J=0,2

Author: Enrico Trotti[1]

Co-authors: Alessandro Pilloni [2]; Francesco Giacosa [1]; Shahriyar Jafarzade

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The scalar and the tensor glueballs ($J^{PC} = 0^{++}$ and 2^{++}) are, according to lattice results, the two lightest particle in the Yang-Mills sector of QCD. We study the scattering of two scalar and two tensor glueballs starting from the well known dilaton potential, that depends on a single dimentionful parameter, denoted as Λ_G. Upon a proper choice of the unitarization scheme, we find that, from the scattering of two scalar glueballs, a bound state, called glueballonium, can form if Λ_G is small enough (namely, the smaller Λ_G, the larger the attraction). Additionally, we use these scattering results to estimate the correction of the interactions to the pressure of a glueball gas, that describes the YM thermodynamics in the confined phase.

Collaboration:

Parallel session A3 / 93

Analytic continuation of the relativistic three-particle scattering amplitudes

Author: Sebastian Dawid[1]

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Many hadronic resonances, including the most intriguing ones (Roper, $\pi_1(1600)$, or $T_{cc}^{+}(3872)$), decay into three or more particles. In principle, one can determine their properties from the multi-body version of the Luscher finite-volume scattering formalism. However, one of the obstacles in specifying their masses from Lattice QCD is the lack of developed three-body amplitude analysis techniques that would allow one to translate a finite-volume output into physically meaningful quantities. In particular, an amplitude obtained from the Lattice QCD calculation must be analytically continued to the complex energy plane, where resonances exist as pole singularities.

In the talk, I will explore the relativistic scattering of three identical scalar bosons interacting via pair-wise interactions. I will describe a general prescription for solving and analytically continuing integral equations describing the three-body process. As an illustration, I will use these techniques to analyze a system governed by a single scattering length leading to a bound state in a two-body sub-channel. I will present the resulting three-body scattering amplitudes for complex energies in the physical and unphysical Riemann sheets. In particular, I will discuss the emergence of three-particle bound states in the system under study that agrees with previous work utilizing relativistic finite-volume formalism. Finally, I will also comment on the obtained numerical evidence of the breakdown of the two-body finite-volume formalism in the vicinity of left-hand cuts.

Collaboration:

Parallel session B3 / 195

Progress in the Partial-Wave Analysis Methods at COMPASS

Authors: Florian Kaspar[1]; Julien Beckers[1]

Co-author: Jakob Knollmüller [1]

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COMPASS aims at extracting the excitation spectrum of light and strange mesons in diffractive scattering. Resonances are identified through partial wave analysis, which inherently relies on analysis models. Besides statistical uncertainties, systematic effects connected to the analysis methods are a key challenge. We will discuss some sources of systematics connected to $\pi^-\pi^-\pi^+$ and $K_s^0K^-$ final states and present methods of their remedies. We have developed a new approach using a-priori knowledge of signal continuity over adjacent final-state-mass bins to stably fit a large pool of partial-waves to our data, allowing a clean identification of very small signals in our large data sets. For two-body final states such as $K_s^0K^-$, mathematical ambiguities in the partial-wave decomposition, result in different combinations of amplitude values to describe the same intensity distribution. We will discuss these ambiguities and present solutions to resolve or at least reduce the number of solutions. Resolving these issues will allow complementary analyses of the a_J-like resonance sector in these two final states.

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Part of the work was done in collaboration with J. Knollmüller

Collaboration:

COMPASS

Parallel session B3 / 198

Mathematical Ambiguities in Partial Wave Analysis

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Mathematical ambiguities in partial wave analysis cause unavoidable problems in interpreting data from scattering experiments. These ambiguities appear as distinct sets of partial waves which can describe the same experimental data. In principle, these ambiguities may be resolved by leveraging knowledge about the physics of the process of interest, or by enforcing additional constraints. We will describe the resolution of mathematical ambiguities in the analysis of the photoproduction of spinless meson resonances, such as eta-pi photoproduction at GlueX. We will present some simulations, fits to toy data, and discuss statistical effects which might alter the treatment of ambiguities in real data.

Collaboration:

Parallel session B4 / 105

Phenomenology of the lightest hybrid meson nonet

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The state pi1(1600) has exotic quantum numbers 1^-+ and is rightfully treated as a hybrid (quark-antiquark-gluon) candidate. Recently, the eta1(1855) has been experimentally discovered. It is then natural to expect that a whole nonet of hybrid states must exist: besides the two states above, a kaonic hybrid and a light eta1 hybrid should exist as well. Predictions and postdictions for the strong (PLB.B 834 (2022) 137478) and radiative (2302.07687) decays of hybrids are outlined. This may be useful for the future search of the yet undiscovered light isoscalar and kaonic hybrid states. The production of the in J/Psi decays is also discussed.

Collaboration:

Parallel session A4 / 146

A coupled-channel system with anomalous thresholds and unitarity

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A first non-perturbative and unitary treatment of multichannel systems with anomalous thresholds based on realistic potentials is presented. We consider the isospin one-half example system, with $D\,\pi, D\,\eta, D_s\bar{K}, D^*\pi, D^*\eta, D^*\bar{K}$ coupled channels in the $J^P = 1^-$ partial wave, chosen such that various phenomena that come with the opening of an anomalous threshold can be illustrated in a step-wise procedure by a suitable variation of up, down and strange quark masses. We use a set of low-energy constants in the chiral Lagrangian that were adjusted to a large set of lattice QCD results. At the physical point the D^* meson decays into the $D\,\pi$ channel and an anomalous threshold develops in the $D^*\pi \leftrightarrow D^*\eta$ reaction. The six phase shifts and inelasticity parameters are presented for various choices of the pion mass. For a pion mass of 150 MeV there are no anomalous thresholds encountered. The small change from 150 MeV to 145 MeV pion mass causes a dramatic impact of the anomalous threshold on the phase shifts showing that our results are highly relevant for the extrapolation of lattice QCD calculations towards the physical pion mass.

Collaboration:

Parallel session C4 / 183

Measurement of KbarN scattering below the KbarN mass threshold

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We measured \pi\Sigma invariant mass spectra below and above the KbarN mass threshold in the K-d -> N\pi\Sigma in order to study the KbarN interaction and the Lambda(1405) resonance. For this purpose, a negatively-charged kaon (K^-) beam of 1 GeV/c was irradiated on a deuterium target at the K1.8BR beam line in the J-PARC Hadron Experimental Facility. In the experiment, a nucleon (N: neutron or proton) knocked out from a deuteron (d) by an incident K- was detected at a very forward angle, and four different final states of \pi^+\Sigma^-, \pi^-\Sigma^+, \pi^0\Sigma^0, and \pi^-\Sigma^0 were identefied by measuring the charged particles emitted around the target.

This reaction can be described by the two step process: (i) K-"N_1"->KbarN and (ii) Kbar"N_2"->\pi\Sigma, where "N_1" and "N_2" are nucleons bound in the deuteron. Since the nucleon emitted at the forward angle carries away most of the collision energy in (i), the center-of-mass energy in (ii) can be lower, even below the KbarN mass threshold. Around the KbarN mass region, one expects that the S-wave Kbar"N_2"->\pi\Sigma scattering is dominant. In order to separate the I=0 and 1 amplitudes in (ii), we demonstrate that an isospin relation of the cross sections between the four final \pi\Sigma states is satisfied as \pi^0\Sigma^0 = [\pi^+\Sigma^- + \pi^-\Sigma+ - \pi^-\Sigma^0]/2. By reproducing the \pi\Sigma spectra of the I=0 channel, we deduced the S-wave scattering amplitude of KbarN->KbarN as well as KbarN->\pi\Sigma in I=0 in the framework of the KbarN-\pi\Sigma coupled channel. We find a resonance pole at 1417.7^+6.0_-7.4(fitting error)^+1.1_-1.0(systematic error) -i[26.9^+6.0_-7.9(fitting error)^+1.7_-2.0(systematic error)] MeV.

Collaboration:

J-PARC E31

Parallel session B4 / 102

Pion absorption from the lowest atomic orbital in ^{2}H, ^{3}H and ^{3}He

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The $\pi^- + {}^2\mathrm{H} \rightarrow n + n$, $\pi^- + {}^3\mathrm{H} \rightarrow n + n + n$, $\pi^- + {}^3\mathrm{He} \rightarrow n + d$ and $\pi^- + {}^3\mathrm{He} \rightarrow p + n + n$ capture reactions from the lowest atomic orbitals are studied under full inclusion of final state interactions. Our results are obtained with the single-nucleon and two-nucleon transition operators derived at leading order in chiral effective field theory. The initial and final three-nucleon states are calculated with the chiral nucleon-nucleon SMS potential up to N^{4}LO$^+$ augmented by the consistently regularized chiral N^{2}LO three-nucleon potential. We found that absorption rates depend strongly on the nuclear pion absorption operator used, and its two-body parts change the rates by a few orders of magnitude. The final state interactions between nucleons generated by the two-nucleon forces are also important, while the three-nucleon interaction plays a visible role only in the $\pi^- + {}^3\mathrm{He} \rightarrow n + d$ reaction. Our absorption rate for the $\pi^- + {}^2\mathrm{H} \rightarrow n + n$ process is in good agreement with the experimental data from the hadronic ground-state broadening in pionic deuterium. The capture rates on ^{3}He are also generally consistent with the spectroscopic data within error bars, though our central values are found to be systematically below the data. We show that for the three-body breakup processes the dominant contributions to the absorption rates arise from the quasi-free scattering and final-state interaction kinematical configurations.

Collaboration:

Parallel session A4 / 89

Revealing violations of macrorealism in flavor oscillations: Leggett-Garg inequalities and no-signaling-in-time conditions

Authors: Fabrizio Illuminati[1]; Kyrylo Simonov[2]; Luca Smaldone[3]; Luciano Petruzziello[1]; Massimo Blasone[1]

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We consider two necessary and sufficient conditions for macrorealism recently appeared in the literature, known as no-signaling-in-time and arrow-of-time conditions, respectively, and study them in the context of flavor transitions, within both the plane wave description and the wave packet approach. We then compare the outcome of the above investigation with the implication of various formulations of Leggett-Garg inequalities. In particular, we show that the fulfillment of the addressed conditions for macrorealism in flavor oscillations implies the fulfillment of Leggett-Garg inequalities, whereas the converse is not true. Finally, in the framework of wave packet approach, we

also prove that, for distances longer than the coherence length, the no-signaling-in-time condition is always violated whilst Leggett-Garg inequalities are not.

Collaboration:

Parallel session C4 / 115

Kaonic Atoms at the DAΦNE collider beyond SIDDHARTA-2: future perspectives

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Kaonic atoms are exotic atoms formed when a negatively charged kaon (K^-), stopped in a target, is captured by the atomic system, replacing the electron in a highly excited level. The captured K^- starts an electromagnetic cascade down to the more internal levels of the atom. Approaching the innermost levels of the exotic atom, the kaon-nucleons strong interaction produces an energy shift and width of the atomic levels. These energy shifts and widths are measured by the SIDDHARTA collaboration with dedicated high-precision x-ray spectroscopy and a comparison with the purely electromagnetic values calculated with the QED. The x-ray spectroscopy on kaonic atoms provide a direct measure of the effects of the strong kaon-nucleons interaction at low energies, thus being a fundamental data source for the development of theoretical models. These models are used to derive: Kaon-Nucleon (KN) interaction at threshold, KNN interaction at threshold, Nuclear density distributions, Possible existence of kaon condensates, Kaon mass, Kaonic atoms cascade models and E2 nuclear resonance effects. Except for some selected recent measurements at DAFNE and JPARC, the whole knowledge on kaonic atoms dates back to 1970s - 1980s. Many of these old measurements were affected by big uncertaintes and hard incompatibilities. Moreover, many kaonic atoms measurements are not yet performed. The SIDDHARTA collaboration is planning a new series of measurements beyond the SIDDHARTA-2 experiment as for example the revisiting K^- mass, first measurement of unmeasured kaonic atoms, nuclear resonance effects in kaonic atoms and so on. Purposes, perspectives of these measurements, together with the description of setups and technologies implied, will be reviewed.

Collaboration:

SIDDHARTA-2

Parallel session B4 / 152

Studying the production mechanisms of light meson resonances in two-pion photoproduction: A Regge Approach

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Hadron photoproduction is an essential experimental tool that gives important information on the spectroscopic and structural nature of hadrons. At large photon energies and low invariant mass of the $\pi\pi$ subsystem, the differential cross section is dominated by the prominent $\rho(770)$ resonance. At forward angles, the production of the ρ is mostly diffractive, and exhibits a hierachy of partial waves which may be interpreted as the result of approximate s-channel helicity conservation (SCHC). Regge formalism captures these reaction properties in terms of the Pomeron exchange. In this talk, we present a theoretical model of two-pion photoproduction which encodes the prominent ρ resonance and the expected leading background contribution coming from the so-called "Deck" or "Drell-Soding" mechanism. After fitting this model to a subset of moments, we compare our predictions for the angular moments with the CLAS data. We observe the apparent breakdown of SCHC at larger four momentum transfers, and extract the t- dependence of the Regge amplitude residue function for subdominant exchanges.

Collaboration:

JPAC

Parallel session A4 / 91

$B \to K^{(*)}\nu\bar{\nu}$ in covariant confined quark model

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We study the $B \to K^{(*)}\nu\bar{\nu}$ decays within the Standard Model (SM) by using the relevant transition form factors obtained from the covariant confined quark model (CCQM) developed by us. The $B \to K$ and $B \to K^*$ transition form factors are calculated in the full kinematic q^2 range. The branching fractions are then calculated. It is shown that our results are in an agreement with those obtained in other theoretical approaches. Currently, the Babar and Belle collaborations provide us by the upper limits at 90\% confidence limit. The obtained bounds are roughly an order of magnitude larger than the SM predictions. This should stimulate experimental collaborations to set up experiments that allow one to obtain more accurate branching values, which is quite achievable on the updated LHCb and Belle machines. If the discrepancies between theory and experiment are confirmed, this will open up opportunities for constructing models with new particles and interactions leading to an extension of the SM.

Collaboration:

Parallel session C4 / 136

Analysis of $\Xi(1620)$ resonance with chiral unitary approach

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While various theoretical studies have been performed for the excited $\Xi(1620)$ state, its nature was not well understood due to the lack of experimental data. Recently, new experimental results on $\Xi(1620)$ were reported.In 2019, Belle collaboration observed the invariant mass distribution of the

$\pi\Xi$ system in the $\Xi_c \to \pi\pi\Xi$ decay [1].By fitting the invariant mass spectrum with the Breit-Wigner distribution, the mass and decay width of the $\Xi(1620)$ were obtained as $M_R = 1610$ MeV and $\Gamma_R = 30$ MeV, respectively. In 2021, ALICE collaboration determined the scattering length of $K^-\Lambda$ with femtoscopy in Pb-Pb collisions [2]. Because the $\Xi(1620)$ resonance locates near the $K^-\Lambda$ threshold, the ALICE result of the $K^-\Lambda$ scattering length constrains the property of the $\Xi(1620)$ resonance.Given the detailed experimental results are obtained, it is desired to perform detailed theoretical analysis of $\Xi(1620)$ based on the newly observed data.

In this talk, we study $\Xi(1620)$ as a dynamically generated resonance in the coupled-channel meson-baryon scattering amplitude using the the chiral unitary approach. In the previous study [3], the mass and width of $\Xi(1620)$ were predicted to be $M_R = 1607$ MeV and $\Gamma_R = 280$ MeV, with the natural values of the subtraction constants. Because the width is broader than the value reported by Belle, it is required to improve the model of $\Xi(1620)$.By adjusting the subtraction constants of the $\pi\Xi$ and $\bar{K}\Lambda$ channels, we successfully reproduce the mass and width of $\Xi(1620)$ by Belle. We, however, find that the threshold effect shifts the resonance peak of $\Xi(1620)$ from the simple Breit-Wigner distribution.We conclude that the cation must be paid to determine the resonance pole near the threshold [4].

Next, we construct a model by taking into account the $K^-\Lambda$ scattering length by ALICE.We show that the $K^-\Lambda$ scattering length can be reproduced by tuning the subtraction constants of the $\pi\Xi$ and $\bar{K}\Lambda$ channels. In this case, the pole of $\Xi(1620)$ in the scattering amplitude does not appear in the physically relevant Riemann sheet which is directly connected to the physical scattering on the real energy axis. We discuss the property of the near-threshold pole of the scattering amplitude in relation with the complex scattering length.

Finally, we search for the model which reproduces both the $K^-\Lambda$ scattering length by ALICE and the $\pi\Sigma$ spectrum by Belle within the experimental uncertainties. By analyzing the properties of the constructed model, we aim to find out the nature of the $\Xi(1620)$ resonance.

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Collaboration:

Parallel session B4 / 126

Near-threshold hadron scattering using effective field theory

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In this work, we study the general properties of the scattering amplitude with the channel couplings using the effective field theory. Recently, exotic hadrons have drawn intensive attention. Internal structure of these hadrons is related to the scattering lengths and effective range. When an exotic hadron locates near the threshold with channel couplings, we must consider the threshold effect. Based on this observation, the Flatte amplitude [1,2] has been often used to determine the scattering length and effective range [3]. In more general frameworks, how are the expressions of those?

As one of the general frameworks, we consider the effective field theory(EFT) [4]. The scattering amplitude from EFT satisfies the optical theorem which is derived from the conservation of probability. We find, however, the Flatte amplitude does not satisfy the optical theorem. In order to verify the validity of the Flatte results, we compare the scattering length and the effective range in the Flatte amplitude with those in the EFT amplitude. As a result, we find that the scattering length and the effective range in the Flatte amplitude are different from those in the EFT amplitude.

We also discuss the determination of parameters of the scattering amplitude from the slopes of the cross section around the threshold. It is known that three parameters in the Flatte amplitude reduce to two independent combinations near the threshold [2]. In contrast, the near-threshold behavior of the EFT amplitude depends on three parameters independently. From this feature, we can determine the EFT parameters uniquely, from the slopes of the cross section. Finally, we present an alternative representation of the EFT scattering amplitude up to first order of the momentum,which can be expressed by the complex scattering length and one real parameter.

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Collaboration:

Parallel session A4 / 143

η_c production within light-cone approach in pp and $e^- A$ collisions

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The charmonium state η_c is the heavy pseudoscalar meson ($J^{PC} = 0^{-+}$) lied under $D\bar{D}$ threshold. We will review the proton-proton and $e^- A$ reactions, where η_c can be produced through the two virtual gluons or one virtual photon.
The main ingredient in our light-cone approach is the space-like transition form factor with dependence on two virtualities of the fused particles.
The idea is to construct the form factor on the basis of the wave function of the $c\bar{c}$ state. The radial part of the wave function can be found by solving the Schrödinger equation then "translation" to the light-cone variable is performed using the Terentev prescription.
I will present the effects of the so-obtained form factors in the context of proton-proton collisions by taking into account the proper color factors and coupling constant for the off-shell gluon-gluon transition to the pseudoscalar meson. We have compared our results to LHCb data for the prompt production of η_c at 7 TeV, 8 TeV and 13 TeV c.m. energies.
Future facilities such as EIC or LHeC give the opportunity to probe the form factor dependence on the virtuality in $e^- A$ collisions. I will present results for the photon Q^2-dependence within the equivalent photon approximation.

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Collaboration:

Parallel session C4 / 134

The FAIR Phase-0 Hyperon Program at HADES

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Hyperons are a unique probe to study the non-perturbative aspects of the strong interaction. At HADES they are produced in proton or pion induced reactions at a few GeV. The detector has recently been extended with a forward detector featuring straw tube trackers developed for the PANDA experiment and a time of flight detector, extending the acceptance for hyperon channels at forward angles. The main objectives of the HADES hyperon program are electromagnetic decays of hyperons and double strangeness production.
The upgrade of the HADES detector plus its capability to tag electron-positron pairs makes up an ideal combination to study electromagnetic decays of hyperons. First measurements at HADES on both virtual and real photon decays, $Y^* \to Ye^+e^-$ and $Y^* \to Y\gamma$, respectively, will significantly impact our understanding of meson effects on the electromagnetic structure of strange resonances. In addition the Dalitz decay will provide valuable information about electromagnetic transition form factors of hyperon resonances.
Very little is known about the production of hyperons with masses larger than the Σ^0 hyperon or hyperons with double strangeness at HADES energies. These measurements can provide important references for future heavy-ion experiments planned at FAIR which explore the high net-baryon density region of the QCD phase diagram. Especially the measurement of double Λ hyperon production can make $\Lambda - \Lambda$ correlation studies possible which will constrain the hyperon-hyperon interaction playing a key role in $\Lambda - \Lambda$ double hyper nuclei, neutron star core studies and the Ξ^- production mechanism.
These possibilities and selected results on hyperon production from proton induced reactions together with the prospects of a pion beam experiment will be presented.

Collaboration:

HADES

Parallel session B4 / 210

A Dalitz-Plot Analysis of the $\omega \to 3\pi$ Decay

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The GlueX Experiment in Hall D at Jefferson Laboratory has accumulated high-statistics samples of photoproduction data off the proton in recent years. Since the light vector mesons ρ, ω and ϕ have the same J^{PC} quantum numbers as the incident photon, these mesons are copiously produced in photoproduction and therefore, make GlueX an ideal place to study their production and decay properties. Such studies provide valuable insight into their structure and internal dynamics. Several prominent meson resonances are known to have a dominant three-pion decay mode. At low energies, the light meson decays $\eta \to 3\pi$ and $\phi \to 3\pi$ have been extensively studied and experimental results of their Dalitz-plot distributions are satisfactorily explained by theoretical approaches. In particular, within the dispersive models, the description of the Dalitz plot for vector-to-pseudoscalar decays has shown good agreement with experimental results for the $\phi \to 3\pi$ decay but cannot accurately describe the data for $\omega \to 3\pi$. For the latter, given that the nominal $\rho\pi$ threshold is above the mass of the ω, the distribution of events in the Dalitz plot is rather smooth and, therefore, it can be efficiently parametrized in the experimental analyses by a low-order polynomial in the Dalitz-plot variables.

The coefficient α of the leading term in the Dalitz-plot polynomial expansion is consistent with the dominance of the ρ-meson contribution, even though it lies outside the kinematical boundary. In this talk, I will present preliminary results of a high-statistics $\omega \to 3\pi$ Dalitz-plot analysis from GlueX. The available statistics exceeds the number of events in a recent BESIII analysis by more than an order of magnitude and allows us to also substantially reduce the uncertainty of the next-to-leading order Dalitz-plot parameters.

Collaboration:

The GlueX Collaboration

Parallel session C4 / 163

Production and decays of hyperons in p+p reactions measured with HADES

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Within the framework of the quark model, hyperon states are composed of "u" (up) and "d" (down) "s" (strange) quarks. However, there are also competing models describing excited hyperons as dynamically generated by meson- baryon interactions. Prominent examples are Λ(1520) [1] and Λ(1405) [2]. In order to discriminate between models, it is helpful to measure hadronic decays, e.g. Λ(1520) ⟶ Σ+(1385) ⊠- , Λ(1520) ⟶ Kp, Λ(1405) ⟶ Σ ⊠

In this presentation, a study of the inclusive production and decays of Σ+ (1385) ⟶ Λ⊠+ and Λ (1520) ⟶ Λ⊠+⊠- hyperons produced in proton-proton reactions at beam energies of 3.5 and 4.5 GeV with HADES detector at FAIR will be presented [3]. Particular attention will be put on application of machine learning methods for Λ identification in HADES, specifically utilizing multilayer perceptron neural networks, and the so-called Classification Without Labels method. The preliminary analysis results from 4.5 GeV data will be presented and compared to the results from the former experiment at 3.5 GeV.

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Collaboration:

HADES

Plenary session / 133

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

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The discoveries of the pentaquark states and XYZ mesons in the charmed quark sector initiated a new epoch in hadron physics, where the existence of exotic multi-quark states beyond the conventional three and two quark systems has been unambiguously realised. Similar structure may be evidenced in the light, uds sector in meson photoproduction, where access to a low momentum exchange and forward meson production angles is crucial to study such phenomena. The BGOOD photoproduction experiment is uniquely designed to explore this kinematic region, being comprised of a central calorimeter complemented by a magnetic spectrometer in forward directions.

Highlighted results indicate a peak-like structure in the $\gamma n \rightarrow K^0\Sigma^0$ cross section at a centre-of-mass energy of 2 GeV consistent with a meson-baryon interaction model which predicted the charmed P_C states. The same $K^*\Sigma$ molecular nature of this proposed $N^*(2030)$ is also supported in a measurement of $\gamma p \rightarrow K^+\Lambda(1405) \rightarrow K^+\pi^0\Sigma^0$, where it is predicted to drive a triangle singularity mechanism. In the non-strange sector, coherent meson photoproduction off the deuteron enables access to proposed dibaryon states, including the recently discovered $d^*(2380)$. Data will be presented which support experimental claims of higher mass isoscalar and isovector dibaryons.

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Collaboration:

BGOOD

Plenary session / 160

Overview of hadron photoproduction experiments in SPring-8 LEPS2 project

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At SPring-8 LEPS2 beamline, a linearly polarized photon beam is available in the tagged energy range of 1.3–2.4 GeV. The first stage of LEPS2 project was carried out using an experimental setup with a large acceptance calorimeter, called BGOegg, which had the world's best resolution in the energy range around 1 GeV. So far, we have intensively studied for the origin of hadron mass via η' meson photoproduction inside a nucleus, where the spontaneous breaking of chiral symmetry is expected to be partially restored. A summary of our analyses will be shown including a direct spectral measurement of in-medium η' mass and a search for η' mesic nuclei. In addition, an on-going experiment with an upgraded setup will be discussed as a second-stage study for the in-medium η' mass.

Other physics subjects with the use of the BGOegg calorimeter will be also overviewed, containing the investigation of high mass and high spin baryon resonances via photoproduction of π^0, η, ω, and η' mesons from a liquid hydrogen target. Recently, we have succeeded in observing the photoproduction of a f_0(980) meson decaying into $\pi^0\pi^0$, for the first time. The measured differential cross sections and photon beam asymmetries provide useful information about the f_0(980) structure, which may be an exotic non-$q\bar{q}$ state.

In parallel to the second-stage experiment with the BGOegg calorimeter, we now operate a different experimental setup with a 4π charged-particle spectrometer installed inside a large volume solenoidal magnet. Recent status and future prospect will be given for a variety of subjects in the LEPS2 project.

Collaboration:

SPring-8 LEPS2

Plenary session / 124

Meson effects on the QCD phase transition at physical and unphysical quark masses

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We summarise recent theoretical results on the QCD phase diagram and the properties of hadrons at finite temperature and chemical potential based on a combination of lattice QCD and Dyson-Schwinger equations. We discuss the silver blaze property of mesons with different quantum numbers along the zero-T-finite-mu-axis and assess the influence of meson and baryon fluctuations on the location of the critical end point. We furthermore investigate the influence of mesonic long range fluctuations on the order of the phase transition in the limit of vanishing up/down quark masses, varying the strange quark mass from zero to infinity. We find a second order phase transition for the whole left hand boundary of the Columbia plot in contrast to expectations based on the Pisarski/Wilczek.

Collaboration:

Plenary session / 135

(Axial-)Vector Mesons in Nuclear Matter

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We present recent results on the in-medium spectral function of the rho(770) vector meson and the a1(1260) axial-vector meson in nuclear matter, as well as on the resulting thermal dilepton rate. As an effective description of the thermodynamics and the phase structure of nuclear matter we use a chiral baryon-meson model, taking into account the effects of fluctuations from scalar mesons, nucleons, and vector mesons within the Functional Renormalization Group (FRG) approach. Our results show strong modifications of the spectral functions in particular near the chiral critical endpoint which suggest an enhanced dilepton yield at lower energies. Such an enhancement is also found in GiBUU transport simulations for C+C at 1A GeV when including effects of chiral symmetry restoration in the kinetic equations for baryon propagation. Our results may therefore well be of relevance for electromagnetic rates in heavy-ion collisions and help to identify phase transitions and the critical endpoint.

Collaboration:

Plenary session / 165

Studies of Time-like Electromagnetic Structure of Baryons with HADES

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The High Acceptance Di-Electron Spectrometer (HADES) [1], installed at GSI Helmholtzzentrum in Darmstadt, was designed for spectroscopy of positron-electron pairs in heavy-ion reactions in the SIS-18 energy range (1-2 GeV/nucleon). HADES results on e+e- production in proton-nucleus and nucleus-nucleus systems at various energies reveal a strong enhancement of the e+e- yield with respect to a nucleon-nucleon reference. Such observations point to a significant contribution from baryon resonance decays (R⟶ Ne+e-) and a strong modification of the in-medium rho spectral function driven by the coupling of the rho to baryon-resonance hole states. To study this effect a precise measurement of the electromagnetic baryon-resonance transition form factors (eTFF) in the time-like region is needed.
The elementary collisions, especially those with pion beams, offer a great opportunity to study eTFF in a direct way. The HADES collaboration has started these investigations with measurement of the Delta(1232) Dalitz decay in pp collisions [2]. In the next step, combined measurements of hadronic and dielectron final states have been performed in p-N reactions using polyethylene and carbon targets [3].
Two-pion channels have been included into the multichannel Partial Wave Analysis (PWA) developed by the Bonn-Gatchina group [3]. As a result cross sections for \Delta\pi. N\rho, N\sigma isobar contributions have been extracted. In particular the off-shell rho meson contribution has been obtained providing \rho-N couplings for N*(1520) and N*(1535) and extraction of the mass dependence of the effective time-like eTFF [4]. Studies of angular distributions of emitted electrons have delivered information on hadronic spin density matrix elements (the helicity structure of baryon eTFF) [5].

The results of the HADES collaboration obtained with proton and pion beams will be presented, with emphasis on the connection with the HADES results on the emissivity of baryonic matter measured in heavy ion collisions [6]. The eTFF will be compared to various versions of the Vector Dominance Model, to quark-constituent model [7] and Lagrangian microscopic calculations [5]. Prospects for HADES measurements at SIS-18 in the near future within the FAIR-Phase0 program will also be discussed.

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Collaboration:

HADES

Plenary session / 129

The hadron experimental facility extension at J-PARC

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The J-PARC Hadron Experimental Facility was constructed with an aim to explore the origin and evolution of matter in the universe through the experiments with intense particle beams. In the past decade, many results on particle and nuclear physics have been obtained at the present facility. To expand the physics programs to unexplored regions never achieved, the extension project of the Hadron Experimental Facility has been extensively discussed. We will discuss the physics of the extension of the Hadron Experimental Facility for resolving the issues in the fields of the strangeness nuclear physics, hadron physics, and flavor physics.

Collaboration:

Taskforce on the extension of the J-PARC Hadron Experimental Facility

Plenary session / 191

Meson nucleus bound states studied with high-resolution missing-mass spectroscopy

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Meson-nucleus bound states, such as mesic atoms and nuclei, are important topics in hadron physics as they provide valuable information on the properties of hadrons at finite nuclear density. For example, deeply-bound pionic atoms have been intensively studied with missing-mass spectroscopy of the (d,3He) reaction and have led to the experimental evaluation of partial restoration of chiral symmetry at finite matter density. Recently, eta'-mesic nuclei are also attracting both theoretical and experimental interests due to their relation to axial U(1) anomaly and chiral symmetry breaking in QCD. Various experiments have been performed including the recent WASA-FRS experiment, which combines the large acceptance WASA detector system with the high-resolution forward spectrometer FRS at GSI. In this talk, we introduce general motivations for these studies of meson-nucleus bound states and present current status of the experiments performed with high-resolution missing-mass spectroscopy.

Collaboration:

Plenary session / 164

Overview on hadronization of quarks in proton-proton and e+e- collisions

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The so-called hadronization is a non-perturbative QCD phenomenon corresponding to the formation of colourless hadrons from coloured quark constituents. The hadron formation in point-like e^+e^- collisions is described via the Lund string fragmentation, according to which the $q\bar{q}$ pair production in the scattering is followed by a shower of light partons produced via multiple color-string breaking, which produce color singlets in the final states. The probability to obtain a hadron of a given species carrying a certain momentum fraction of the original quark is quantified by the fragmentation functions. They are assumed universal and usually constrained from e^+e^- and e^-p collisions, and they succesfully describe the production of mesons in e^+e^- and pp collisions at the colliders. However, recent measurements of pp collision data from the LHC showed a surprising relative enhancement of baryon production compared to mesons, and model predictions based on Lund string fragmentation do not describe the data. In this talk, an overview of the most recent experimental results of hadron production cross section in pp collisions at the LHC compared with $e+e-$ results will be provided. A comparison with novel theoretical models implementing hadronization mechanisms different from the Lund string fragmentation will be also discussed.

Collaboration:

Parallel session A5 / 196

Measurement of the photoproduction cross section for $\gamma p \to \phi\pi^+\pi^- p$ and search for the $Y(2175)$ at GlueX

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The $Y(2175)$, recently renamed to $\phi(2170)$, is one of the rare exotic candidates connected to strangeonium instead of the heavier charmonium-like and bottomonium-like exotic states. Originally observed in initial-state radiation by the BaBar experiment in 2006,it could be a strange partner of the famous charmonium-like exotic vector state $Y(4260)$. Various interpretations exist in the literature, such as conventional strangeonium, tetraquark or hybrid state. Meanwhile, it has been seen in different experiments and decay channels. The available experimental information obtained only from e^+e^- collider experiments is, however, not sufficient to confirm or disprove any of the proposed interpretations. Information about the production of this state in other processes is required. Using intense photon beams is especially well suited to study strangeonium-like states because of the strong coupling of the photon to $s\bar{s}$. In this talk, we report on our measurement of the production cross section of the reaction $\gamma + p \to \phi\pi^+\pi^- + p$ and the search performed for $Y(2175) \to \phi\pi^+\pi^-$ with the GlueX experiment.

Collaboration:

GlueX

Parallel session C5 / 109

Accessing the strong interaction between Λ baryons and kaons with femtoscopy at LHC

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The interaction between Λ baryons and kaons/antikaons is a crucial ingredient for low energies effective models aiming at describing the strangeness $S = 0$ (ΛK) and $S = -2$ (ΛK) sector of the meson-baryon interaction.
Of particular interest is the ΛK interaction, where the presence of the \XRes close to the threshold should play a significant role. The $\pi\Xi$ decay channel of the $\Xi(1620)$ resonance has been recently observed by the Belle collaboration, providing the first experimental values for its mass and width. However, no measurements are available for the ΛK channel. Delivering high-precision data on the ΛK system can help to shed light into the nature of the $\Xi(1620)$ state and its formation. Experimental data on ΛK, and as well on ΛK, are currently rather scarce, leading to large uncertainties and tensions between the available theoretical predictions. Recently, measurements of two-particle correlations in small colliding systems such as pp collisions at the LHC provided a significant improvement in the knowledge of several hadron-hadron interactions, in particular when strange baryons and mesons are involved.
In this talk, we present ΛK^+ and ΛK^- femtoscopic correlations measured by ALICE in pp collisions at $\sqrt{s} = 13$ TeV, obtained with a high-multiplicity trigger. The measurements indicate a repulsive interaction for ΛK^+ pairs and an attractive interaction for ΛK^-. In particular, we will show the first experimental evidence of the $\Xi(1620)$ decaying into ΛK^- pairs and discuss the effect of the $\Xi(1620)$ state on the ΛK interaction.

Collaboration:

ALICE

Parallel session C5 / 137

Correlation Function constraints on S=-2 meson-baryon interaction from UChPT.

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As it is well known, for heavier hadrons, there is no possibility of performing scattering experiments due to technical limitations related to the extremely short life time of these particles. Instead, Lattice QCD (LQCD) simulations have played a key role in understanding the dynamics of heavy sectors, being more precise. A successful reproduction of the lattice data is regarded as a strong evidence that the Effective Field Theory EFT employed to such an end can describe reality in the energy regime considered. This leads one to see LQCD as a benchmark scheme to discriminate among theoretical models developed from EFTs in use. However, due to the lack of experimental data in these sectors, the theoretical models have been limited to describe the current hadron spectroscopy or to predict new states (exotic or not) that can be seen in different decay processes.

In contrast, the promising Femptoscopy Techinique in High-Energy Nuclear Collisions offers a direct connection to experimental observables, from which the corresponding scattering parameters can be extracted. The reason lies in the fact that, in high-energy heavy-ion collisions and high-multiplicity events of pp, pA and AA collisions, the hadron production yields are well described by the statistical models, thereby leaving the correlations between outgoing particles relying upon the final state interactions.

In this theoretical study, for the first time, an experimental Correlation Function (CF) has been employed to extract unprecedented information about the Low Energy Constants (LECs) present in EFTs. In particular, the K-Lambda pair CF have been used to constrain the LECs present in our theoretical Model based on the Effective Chiral Lagrangian expanded up to next-to-leading order [1]. More precisely, theoretical CF has been calculated and adjusted to the ALICE data thereby providing novel information of the S=-2 meson-baryon scattering at low energies as well as its intrinsic dynamics that allows the generation of resonances and bound states, from which the molecular nature of Xi(1620) and Xi(1690) can be discussed.

[1] A. Feijoo, V. Valcarce and V. K.Magas, arXiv:2303.01323 [hep-ph].

Collaboration:

Parallel session A5 / 116

Towards a common particle-emitting source in small systems for mesons and baryons with ALICE

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The ALICE Collaboration recently published a plethora of results obtained from femtoscopic measurements, studying the interaction between many exotic combinations of particles, most notably p–Ω. In general these studies depend on a precise understanding of the particle-emitting source, which is constructed employing the resonance source model (RSM). In the RSM, deviations from a Gaussian source caused by the short-lived resonances are modeled via a Monte Carlo (MC) procedure. The MC procedure is employed to access the convolution of the Gaussian source with the exponential decay functions of the resonances, while taking into account the decay kinematics. For two-particle correlations between baryons (p–p and p–Λ) the RSM was already validated with great success. The goal of this work is to ascertain whether the RSM can also be applied to constrain the source in the mesonic sector, for example in the case of same charge π–π (or K^+–p), for which by far the largest contribution from resonances is expected. A differential study of the spatial extension of the source function as a function of transverse mass (m_T) and multiplicity is presented. The results are based on minimum-bias and high-multiplicity pp collisions at $\sqrt{s} = 13\,\mathrm{TeV}$ recorded with the ALICE detector. An m_T scaling behaviour of the source is observed and found to be compatible with previous results in the bayronic sector. This measurement gives confidence for a common source for mesons and baryons in small systems, allowing to employ the RSM to constrain the source for meson–baryon and meson–meson.

Collaboration:

ALICE

Parallel session C5 / 122

A study of K^-d and K^+d interactions via femtoscopy technique

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The strong interaction between charged kaon and deuteron has previously been studied by scattering cross section measurements. However, due to the complexity of the system, some questions remain open at both experimental and theoretical levels. For example, the scattering lengths of the strong interaction of K^-d and K^+d have never been measured. Moreover, currently available theoretical calculations of this scattering parameter for K^-d are largely based on input from kaonic hydrogen measurements. In the case of the scattering length of K^+d, there are no theoretical predictions published so far.

In this talk, the first measurements of the scattering lengths of K^+d and K^-d particle pairs are presented. The values of the scattering parameters are obtained using a femtoscopy technique, which is excellent for studying interactions between two particles with low relative momenta.

Collaboration:

ALICE

Parallel session A5 / 123

Two-particle angular correlations of identified particles in pp collisions at s√ = 13 TeV with ALICE

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The angular correlations between two particles in ΔyΔφ produced in high-energy collisions provide a wealth of information about the hadronization mechanisms and the evolution properties of the created system. This is achieved by a detailed study of the various physical phenomena that influence the structure and shape of the correlation functions. These phenomena, such as Bose-Einstein correlations, conservation laws, resonance decays, mini-jets, and others, generate correlation functions with characteristic properties, each with its own shape and dependence on pT and/or multiplicity.

Results of the angular correlation analysis in pp collisions at √s = 7 TeV showed anticorrelation for pairs of baryons with the same sign in the ΔηΔφ space in contrast to the theoretical predictions generated by the PYTHIA and EPOS models. To investigate this behavior and distinguish different physical contributions, it is useful to analyze the results at different multiplicities. In this work, the correlation function with different normalization method is used to study the combinations of the identified particles charges (i.e., π±, K± and p(¯p)) in pp collisions at √s = 13 TeV in four multiplicity classes.

Collaboration:

Parallel session C5 / 171

Femtoscopy of p – Λ system obtained in heavy-ion collision in the HADES experiment

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Over the past decades, the properties of hyperons in dense matter have been widely concerned about in connection with hypernuclei and the hyperon component in neutron stars. Hyperons are supposed to possibly exist within the inner layer of neutron stars whose structure depends strongly on the equation of state (EOS) of nuclear matter at supersaturation densities. The appearance of hyperons in the core softens the EOS, resulting in neutron stars having masses lower than 2M, where M is the sun's mass. In contrast, soft EOS typically predicts small radii, which cannot support large neutron star masses. The conflict is called the" hyperon puzzle in neutron stars." In order

to understand the hyperon-nucleon interactions experimentally, the two-body system is taken into consideration. Femtoscopy, the technique of two-particle correlations in momentum space, is one method for exploring such phenomena and has proven to be a powerful tool for determining parameters of strong interaction and lifetimes in heavy ion physics. It allows for the measurement of the collision-generated system's spacetime features, which has a lifespan of 10^{-23} seconds and a lifetime of femtometers (10^{-15} m).
The analysis uses the HADES detectors, one of several experiments at the GSI Helmholtz Center for Heavy-Ion Research in Darmstadt, Germany. Experiments data include Ag-Ag heavy-ion collision at EKin at 1.58 AGeV. In order to study more about strong interactions, particles with strange quarks are perfect for this study, i,e. Λ, K0s etc. The particles containing strangeness are produced very rarely in heavy-ion collisions at typical HADES energies.
The Lambdas are reconstructed through the decay channel Λ ⟶ π − + p, with a branching ratio of 64%. The invariant mass range of the lambda candidates is 1115 MeV/c2 . Pions and protons (i.e., lambda daughters) are selected using their specific energy loss. Mainly, using so-called off-vertex-decay or V0 topology, the secondary vertex is reconstructed. The p − Λ correlation function is measured for HADES for the first time in a heavy-ion collision and will be presented. It is also found that the strong interaction induces a prominent peak in the correlation function and provides more sensitive source size measurements than pp correlations under some circumstances.

Collaboration:

HADES

Parallel session A5 / 148

Insight into the light-flavour particle production mechanism from studies of the transverse spherocity dependence in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC

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The ALICE experiment at LHC has unique capabilities for the identification of light-flavour particles. Recent observations by ALICE of heavy-ion-like features such as enhanced strangeness production and long-range azimuthal correlation in high-multiplicity pp collisions pave the way to rethink particle production in small collision systems. Event shape observables like transverse spherocity are sensitive to isotropic and jetty topologies, which are useful tools to distinguish the pp collisions dominated by soft or hard physics. The interplay between multiplicity and transverse spherocity on light-flavour particle production can be understood by comparing the results obtained by selecting multiplicity and/or transverse spherocity. This contribution presents recent results on light-flavour particle production (π, K, p, ϕ, K^{*0}, K^0_s, Λ, Ξ) at midrapidity obtained by the ALICE experiment in pp collisions at $\sqrt{s}$ = 13 TeV as a function of event multiplicities and transverse spherocity. The results are even obtained by going to the most extreme selections such as the highest 0-1$\%$ in multiplicity and the highest 0-10$\%$ in transverse spherocity. The results include the transverse momentum spectra, yields, $\langle p_{\rm T} \rangle$ and their ratio to the yields of long-lived particles. These measurements will be compared with the Monte Carlo (MC) predictions obtained from models such as PYTHIA8, EPOS and Herwig7.

Collaboration:

ALICE

Public Lecture / 193

The dawn of high energy neutrino astronomy

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Current knowledge of the Universe is based on information carried by electromagnetic radiation, gravitational waves, neutrinos, and cosmic rays. For over a century, scientists have observed cosmic rays, but the understanding of their place of production is limited. As a product of cosmic ray interaction, neutrinos can shed light on the extreme part of the Universe. IceCube Neutrino Observatory has been leading neutrino astronomy research over the last ten years and is the only observatory with the exposure to detect high-energy neutrinos beyond Earth*s atmosphere. This presentation will highlight the IceCube observations, including new recent results. Despite the exiting times, with IceCube operating alone and limited by the South Pole location and cubic-km scale, the neutrino astronomy efforts have yet to advance the field past infancy. It is clear that more observatories and larger telescopes, ultimately linked via a global network, are needed to advance fundamental discoveries in astro and particle physics. In this direction, a new opportunity has emerged over the last years to construct a new large volume neutrino telescope, the Pacific Ocean Neutrino Experiment (P-ONE), which will be based on the first time, within an existing oceanographic infrastructure. I will summarize how we have established a scientific relationship with Ocean Networks Canada to pioneer their global network as a testbed infrastructure and identified the optimal location and prepared the ground for first case deployment.

Collaboration:

IceCube

Plenary session / 113

Theoretical status of antikaon-nucleon interactions

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In this talk, we discuss the recent theoretical studies of the strong interaction between an antikaon ($\bar{K}$) and a nucleon (N) [1,2]. The isospin $I = 0$ channel is of particular interest, as it exhibits an attractive interaction that can generate a quasi-bound state known as the $\Lambda(1405)$ resonance, located below the $\bar{K}N$ threshold. This suggests that the $\bar{K}N$ interaction may also produce quasi-bound states of kaonic nuclei [1]. Furthermore, the quasi-bound picture of the $\Lambda(1405)$ is related to the discussion of hadronic molecules in hadron spectroscopy.

Theoretical description of the $\Lambda(1405)$ in the coupled-channel meson-baryon scattering is developed with chiral SU(3) dynamics [2]. Based on the next-to-leading order (NLO) chiral SU(3) dynamics combined with the precise measurement of kaonic hydrogen by SIDDHARTA, it is shown that there are two resonances between the $\pi\Sigma$ and $\bar{K}N$ thresholds, $\Lambda(1405)$ and $\Lambda(1380)$. We review the current status of the theoretical studies of chiral SU(3) dynamics, including the recently performed NNLO analysis [3].

Femtoscopic study of the two-particle momentum correlation functions in high-energy collisions has become a new method to extract the hadron-hadron interactions. We present the study on the two-particle correlation function of a K^-p pair in high-energy collisions within the $\bar{K}N$-$\pi\Sigma$-$\pi\Lambda$ coupled-channels framework, which accurately account for all relevant effects, including the

Coulomb potential and the threshold energy difference between $K^- p$ and $\bar{K}^0 n$ [4]. Realistic $\bar{K}N$-$\pi\Sigma$-$\pi\Lambda$ potential based on NLO chiral SU(3) dynamics is used. We discuss the resulting $K^- p$ correlation functions in comparison with the recent measurements by the ALICE collaboration under various collision conditions [4].

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Collaboration:

Plenary session / 199

Towards many body nuclear interaction studies at the LHC

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The residual strong interaction for two-body hadron systems has successfully been studied
with an innovative technique at the LHC by the ALICE collaboration in recent years.
Correlation in momentum space measured in pp and p-Pb collisions at the LHC energies for several hadron pairs involving strange hadrons have been employed to test the strong interaction with unprecedented precision. Lattice calculations could be tested and effective field theory results partially challenged.
This kind of studies was possible even for hadron pairs containing charm quarks.

The new direction of such studies is now pointing to three-body systems, with the aim of providing an innovative tool to study the genuine three body interaction for several triplets. Such interactions are currently completely unconstrained if strange quarks are considered.
In this talk I will discuss the state of the art of such studies at the LHC, demonstrating that three baryon systems can be precisely measured at the LHC and that light nuclei can be exploited for such studies as well.
I will show that an exciting new path is laid in front of us to investigate many body nuclear forces with innovative methods.

Collaboration:

ALICE

Plenary session / 155

Studies of hypernuclei with the WASA-FRS setup, nuclear emulsions and machine learning

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Studies of hypernuclei, subatomic bound systems with at least one hyperon, have been contributing for understanding the fundamental baryonic interactions as well as the nature of dense nuclear matters. Hypernuclei can also reveal nature of ordinary sub-atomic nuclei by using a hyperon as a prove or/and an impurity in nuclei. Hypernuclei have already been studied for almost seven decades in reactions involving cosmic rays and with meson- and electron-beams. In recent years, hypernuclear studies can also be performed by using energetic heavy ion beams, and some of these experiments have revealed unexpected results on three-body hypernuclear states, i.e., shorter lifetime [1-7] and larger binding energy [8] of the lightest hypernucleus, the hypertriton, than what was formerly determined and the unprecedented bound state with a Lambda hyperon with two neutrons [9]. These results have initiated several ongoing experimental programs all over the world to study these three-body hypernuclear states precisely. We are studying those light hypernuclear states by employing different approaches from the other experiments. We employ heavy ion beams on fixed nuclear targets with the WASA detector and the Fragment separator FRS at GSI (the WASA-FRS project) in Germany for measuring their lifetime precisely [10]. The experiment was already performed in the first quarter of 2022, and the data analyses are in progress. We also analyze the entire volume of the nuclear emulsion irradiated by kaon beams in the J-PARC E07 experiment [11, 12, 13] in order to measure their binding energies at the world best precision [10]. We have already uniquely identified events associated with the production and decays of the hypertriton, and the binding energy of the hypertriton is to be determined. We also search events of other single-strangeness hypernuclei and double-strangeness hypernuclei in the E07 emulsion to understand the nature of Lambda-nucleon, Lambda-Lambda and Xi-nucleon interactions. We are using Machine Learning techniques for all our projects with heavy ion beams and nuclear emulsions [10]. These projects will be extended at FAIR in Germany, HIAF in China and J-PARC in Japan.

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Collaboration:

WASA-FRS, Super-FRS Experiment

Plenary session / 127

Knowledge on doubly-strange hypernuclei and experimental prospect

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The interaction energy between Lambda; hyperons and the presence or absence of Xi; hypernuclei (is Xi; hyperons bound to the nuclei?), which can be obtained from doubly-strange hypernuclei, are

essential information for a unified understanding of baryons under SU(3)_{*f*} symmetry. Especially in recent years, they are also valuable information for understanding the existence of neutron stars. Over the past 40 years, doubly-strange hypernucleus search experiments have been conducted in Japan using nuclear emulsion, and 47 samples of doubly-strange hypernuclei have been detected. From the double-Lambda; hypernuclei, we know that the Lambda;-Lambda; interaction between two Lambda; hyperons is weakly attractive and that the binding energy of two Lambda; hyperons by the nucleus seems to depend linearly on the nuclear mass number. In addition, the Xi; hypernucleus does indeed exist, the attraction between Xi; hyperon and nucleon works, and the level structure of the ¹⁵_{Xi;}C hypernucleus can now be inferred. Efforts are being made to further explore the entire emulsion volume to dramatically improve the number of the samples of doubly-strange hypernuclei.

Collaboration:

KEK-E176, E373, J-PARC E07, and Emulsion-ML

Plenary session / 157

Kaonic atoms measurements performed by SIDDHARTA-2 collaboration: results and expectations.

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Today, the most important experimental information missing in the field of the low-energy antikaon-nucleon interactions is the experimental determination of the hadronic energy shift and width of kaonic deuterium measurement that will be performed by the new SIDDHARTA-2 experiment, which just finished the installation in DAFNE and is ready to start a new data taking campaign.
The precise measurement of the shift and width of the 1s level to the purely electromagnetic calculated values, generated by the presence of the strong interaction, through the measurement of the X-ray transitions to this level, in kaonic hydrogen, already performed by the SIDDHARTA collaboration and in kaonic deuterium, underway by SIDDHARTA-2 experiment, will allow the first precise experimental extraction of the isospin dependent antikaon-nucleon scattering lengths, fundamental quantities in understanding low-energy QCD in strangeness sector.
The experimental challenge of the kaonic deuterium measurement is the exceedingly small x-rays yield, the even larger width (compared to kaonic hydrogen), and the difficulty to perform x-rays spectroscopy with weak signals in the high radiation environment of DAFNE.
It is, therefore, crucial to develop a new large-area X-rays detector system, to optimize the signal and to control or improve the signal-to-background ratio by gaining in solid angle, increasing the timing capability, and as well implementing additional charge particle tracking veto systems.
An overview of the results obtained with SIDDHARTA-2 in the preparation phase will be presented as well as a description of the apparatus.

Collaboration:

SIDDHARTA-2

Plenary session / 154

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.

Collaboration:

Plenary session / 88

Strangeness in Neutron Stars

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Understanding the dynamics of hadrons with strangeness has received a lot attention over the past decades in connection with the study of exotic atoms, the analysis of strangeness production and propagation in particle and nuclear research facilities, and the investigation of the possible strange phases in the interior of neutron stars.

In this talk I will review the dynamics of strange mesons and baryons with nucleons and nuclear matter, as presented in Ref. [1], paying a special attention to their presence in the inner core of neutron stars and the consequences for the structure and evolution of these compact stars.

[1] Laura Tolos and Laura Fabbietti, Prog. Part. Nucl. Phys. 112 (2020) 103770

Collaboration:

Plenary session / 151

KLong Facility

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A lot of progress has recently been made in a field of hadron spectroscopy. Intense photon beams complemented by high-resolution hermetic 4pi detectors, supplied with linearly or circularly polarised photons, polarised nuclear targets and ability to detect recoil nucleon polarisation improved our knowledge on excited nucleon states considerably. Most of the progress has been achieved in N*and Delta* areas. A poorly established field of particles with strangeness (hyperons and strange mesons) had little to no benefit from this progress.

The new Compact Photon Source (CPS) technologies will underpin a major new capability - the production of intense, strange-quark containing hadronic beams in low background regime. The CPS beam intensities will reach up to five orders of magnitude beyond that currently achievable, opening up a wealth of new hadron and nuclear physics perspectives for the future experimental programme. These beams of neutral Kaon mesons (KL) will be the basis of the new K-Long facility (KLF), which will elucidate the strange quark sector of hadron physics with unprecedented precision.

The KLF project aims to discover many new particles in the strange quark sector, elucidate the interaction of strange-quark containing baryons (hyperons) with nucleons and, through the unprecedented Kaon flux of 1 billion Kaons per day enable searches for rare KL decays at new limits. Alongside the hadron physics impact KLF canl deliver key data for fundamental astrophysics including a deeper understanding of neutron star composition and of the early universe during the transition from deconfined plasma to hadrons through the strange epoch.

As well as direct measurement in YN and YNN scattering reactions, many body hyperon forces can be constrained at KLF (at lower nuclear momenta) by accurate hypernuclear information. The energy levels of hypernuclei can be used to constrain models of the (established) hyperon nucleon interaction with various models of three-body (YNN) forces.

In a talk, I will review the current status of the project, major development in the main hardware systems, e.g. Compact Photon Source, Be-Target, Flux Monitor…as well as theoretical development related to the project.

Collaboration:

KLF

Parallel session A6 / 117

N(1520) electromagnetic transition form factors

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The electromagnetic transition form factors of the nucleon provide important information on the internal structure of hadrons. A model-independent dispersive calculation of the Electromagnetic form factors $N^*(1520) \to N$ at low energies will be presented. Taking pion rescattering into consideration, we derived dispersive relations for the $N^*(1520) \to N$ TFFs that relate space-like and time-like regions from the first principles. Based on the space-like data from JLab, we make predictions for TFFs in the time-like region and our predictions can be tested in future experiments (e.g.HADES).

Collaboration:

Parallel session B6 / 101

Xi nuclear constraints from recent Xi^- capture events in emulsion

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All five KEK and J-PARC two-body $\Xi^- + {}^A\mathrm{Z} \to$ twin-Λ capture events in light emulsion nuclei 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 2 assigned to $1s_{\Xi^-}$ nuclear states, thereby implying considerably shallower V_Ξ, have also another interpretation as $1p_{\Xi^0}$ nuclear states [3].

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Collaboration:

Parallel session A6 / 125

\Lambda hyperon in covariant quark model

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Main modes of Λ hyperon was investigated by nonlocal covariant confined quark model. The short-distance effects are induced by five topologies of external and internal weak W± exchange, while long-distance effects are saturated by an inclusion of the so-called pole diagrams with intermediate $1/2^+$ and $1/2^-$ baryon resonances. The contributions from $1/2^+$ resonances are calculated straightforwardly by account for nucleon and Σ baryons whereas the contributions from $1/2^-$ resonances are calculated by using the well-known soft-pion theorem in the current-algebra approach. It allows one to express the parity-violating Swave amplitude in terms of parity-conserving matrix elements. It is known that short-distance effects induced by internal topologies are not suppressed in comparison with external W-exchange diagram and must be included for description of data. Here, in the case of Λ decays we found that the contribution of external and internal W-exchange diagrams is sizably suppressed, e.g., by one order of magnitude in comparison with data, which are known with quite good accuracy. Pole diagrams play the major role to get consistency with experiment.

Collaboration:

Parallel session B6 / 158

Hypernuclear halos

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The phenomenon of neutron halos was discovered in light-mass nuclei at the limit of nuclear existence. Historically, ^{11}Li was the first halo nucleus discovered from interaction cross section measurements by Tanihata et al. Understood as a universal feature of bound baryonic systems, halos are also predicted in hypernuclei, while no direct experimental evidence has been obtained so far. The lightest predicted hypernuclear halo is the hypertriton, $^{3}_{\Lambda}$H, where predictions for its matter radius vary between 4–10 fm, depending on the binding-energy.

The HYDRA (HYpernuclei Decay at R3B Apparatus) physics program within the R^{3}B collaboration will focus on studying the decay spectroscopy of hypernuclei produced from heavy-ion collisions at GSI/FAIR. The program aims at measuring with high resolution the in-flight pionic decay of light- and medium-mass hypernuclei. To achieve that, a pion tracker is conceived as a time projection chamber (TPC) inside the GLAD magnet of the R3B setup. The first experiment of HYDRA, foreseen in 2025, aims at the matter radius of $^{3}_{\Lambda}$H from the measurement of its interaction cross section (ICS). Due to the low production cross section of hypernuclei and their very short lifetime, a direct measurement of their ICS is difficult. To overcome that, a new experimental method has been developed, adapting the ICS measurement to hypernuclei which will allow to make a conclusion on the halo or non-halo character of $^{3}_{\Lambda}$H. The method and its sensitivity to the ICS, investigated with detailed realistic simulations of the experimental conditions will be presented.

Collaboration:

R3B

Parallel session A6 / 108

The reaction $\pi N \to \omega N$ in a dynamical coupled-channel approach

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This talk is on a refined investigation on light flavor meson-baryon scatterings, using a dynamical coupled-channel approach, i.e. the Jülich-Bonn model. The previous channel space of πN, $\pi\Delta$, σN, ρN, ηN, $K\Lambda$ and $K\Sigma$ is extended by adding the ωN final state. The spectra of N^* and Δ resonances are extracted, based on the result of a global fit to a worldwide collection of data, in the energy region from the πN threshold to center-of-mass energy $z = 2.3$ GeV (approximately 300 parameters against 9000 data points). A negative value of the ωN elastic spin-averaged scattering length has been extracted.

Collaboration:

Parallel session B6 / 180

Electroproduction of hypernuclei

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Electroproduction of hypernuclei is an object of interest since information on properties of the bound system of nucleons and a hyperon gives important insight onto the structure of nuclear matter and provides a stringent test of the hyperon-nucleon interactions. We will present a technique (distorted-wave impulse approximation) of computing the cross sections in electroproduction of Lambda-hypernuclei discussing various components of the amplitude, such as the radial integrals, the elementary amplitude, and the nucleus-hypernucleus structure. Particularly, we will show effects in the cross sections from the kaon distortion, proton Fermi motion and description of the nucleus structure (one-body density matrix elements).

Collaboration:

Parallel session A6 / 188

Forward to finite volume pion-pion scattering

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We study the effect of a finite volume for pion-pion scattering over energy levels and physical observables such as the phase-shift or pion mass. The method to determine the energy levels is done using a finite set of cubic harmonics, which expands our Bether-Salpeter equation (BSE) over a set of irreducible groups of rotations from the octahedral group, giving us a forward classification of energy levels, independently of whether we are including u- and t-loops. On the other hand, the study of finite corrections of pion mass and phase-shift is already done, looking at dependence with the size of the box (L). We expect that our results will help optimize the process of determining the energy levels and phase-shifting with higher accuracy, including multiple loops.

Collaboration:

Parallel session B6 / 174

Model selection in electromagnetic production of kaons

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New models for photo- and electroproduction of kaons on the proton were constructed utilizing new experimental data from LEPS, GRAAL, and particularly CLAS collaborations. The higher spin nucleon (spin-3/2 and spin-5/2) and hyperon (spin-3/2) resonances were included using a consistent formalism and they were found to play an important role in the data description. In these analyses, we paid close attention to model predictions of the cross section at small kaon angles which are vital for accurate calculations of the hypernucleus-production cross section. In order to account for the unitarity corrections at the tree level, we introduced energy-dependent widths of nucleon resonances, which affect the choice of hadron form factors and the values of their cutoff parameters extracted in the fitting procedure.

In order to be able to describe the $K^+\Lambda$ electroproduction, we implemented a new shape of electromagnetic form factors. Moreover, we revealed that for a reliable description of $K^+\Lambda$ electroproduction at small Q^2 within our models it is necessary to take into account the longitudinal couplings of virtual photons to nucleon resonances.

Once all the ingredients of the model were well prepared, we faced the problem of selecting the appropriate set of resonances. Since a plain χ^2 minimization, which we used in our previous studies, could not prevent us from overfitting the data, i.e. introducing more parameters (and thus resonances) than were needed for data description, we opted for a regularization method, the least absolute shrinkage selection operator, and information criteria for avoiding this issue and choosing the best fit. In the analysis of new CLAS $K^+\Sigma^-$ data, we were then able to arrive at a very economical model including only the most needed resonances. Similarly, in our very recent study of the role of hyperon resonances in the $K^+\Lambda$ channel, we made use of ridge regression to reduce some of the couplings and arrived at much more robust model.

Collaboration:

Parallel session A7 / 178

The Role of Mesons in Light-by-Light Scattering at Low Transverse Momentum

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Light-by-Light scattering involves the interaction of two strong electromagnetic fields, resulting in the emission of two photons. The phenomenon was first observed experimentally in 2017 1, using photon measurements in ultraperipheral lead-lead collisions (UPC). Applying the Equivalent Photon Approximation model gives results which describe differential and total cross sections presented by ATLAS and CMS Collaborations [3]. They have detected photons in midrapidity for $p_t > 2.5$ (ATLAS) and $p_t > 2$ GeV (CMS).

In the next few years, the ALICE 3 experiment [4] is going to measure photons in forward calorimeter (FoCal) [5], in the transverse momentum range p_t = 1 - 50 MeV and 100 - 5000 MeV, which have not been investigated so far. Moving to a lower range of p_t imposes a consideration of low-energy meson resonances which decay into two-photon channel. The first contribution from η, η' mesons in UPC was studied in [6]. Research in the low p_t area allows to verify the importance of pion. Furthermore, experimental possibilities to investigate the VDM-Regge mechanism [7] will be discussed. The role of the vertical background in light-by-light scattering measurements will also be shown.

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Collaboration:

Parallel session B7 / 176

Studies of pi-12C reactions at 0.7 GeV/c with the HADES spectrometer

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At incident momenta below 2 GeV/c pion nucleus scattering is an ideal tool to study
properties of baryonic resonances in the nuclear medium. Previous measurements were mostly focused on the Δ(1232) resonance region and performed mostly with positive pions. In this energy range [1,2] pion absorption or scattering, including charge exchange reactions have been extensively studied. At higher energies, in the so-called second resonance region, where N* resonances dominate (N(1440), N(1520), N(1535),…) the data base is very scarce. Such information is however needed in the context of dense hadronic matter studies as a benchmark for the description of heavy-ion reactions at a few GeV/A, where pion-nucleus dynamics plays a crucial role. More generally, measurements of pion-induced spallation reactions and investigations of pion and proton differential spectra is very important for validation and further development of transport and hadronic cascade models. Especially the cascade models are used in the GEANT4 tool for various applications.
In this talk I will focus on the analysis of the π−+12C data collected with the HADES (High Acceptance Dielectron Spectrometer) [3], using the GSI pion beam at an incident pion momentum of 0.7 GeV/c. Pion and proton differential spectra measured in various exit channel topologies (inclusive, pπ−, pπ+, pp, π+π−,…, ππpp) are compared to predictions of the INCL++ cascade [4] and of transport models (SMASH [5,6], rQMD-RMF [7], GIBUU [8]). The results allow to test selectively the capacity of such models to describe the various mechanisms (quasi-eleastic scattering, multipion production, rescatterings and pion absoprtion). The sensitivity of the data measured in the quasi-elastic channel to short range correlations is also investigated.

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Collaboration:

HADES

Parallel session B7 / 147

Systematics of strange hadron yields from heavy-ion collisions at few GeV

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Basing on the available published yields of strange hadrons emitted from heavy-ion collisions at beam kinetic energies within 0.6A - 3A GeV we propose the parametrizations of yields of $K^{\pm}$, K^0_s, ϕ mesons and $\Lambda + \Sigma^0$ hyperons as function of available energy and mean number of participants, $A_{\rm part}$. As different sources estimate $A_{\rm part}$ using three different models, we performed the Glauber Monte Carlo calculaions for all the systems 1. We found that the α exponent of yield dependency on $A_{\rm part}$ appears not to change with beam energy and provide its found value.

After positive comparisons of our parametrizations with the experimental data, we provide the predictions of strangeness yields for some currently analysed and planned experiments. The predictions cover: Ag+Ag at beam kinetic energies of 1.23A and 1.58A GeV (HADES), Au+Au at 0.6A and 0.8A GeV (HADES), Au+Au at 2.91A GeV (STAR) and Au+Au at 2A, 4A and 6A GeV (CBM). For the Ag+Ag data we also compare our results with the predictions of public versions of RQMD.RMF, SMASH and UrQMD transport models.

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Collaboration:

Parallel session A7 / 92

Laser spectroscopy of metastable pionic helium atoms at Paul Scherrer Institute

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Metastable pionic helium is a three-body exotic atom composed of a helium nucleus, electron, and negatively-charged pion occupying a highly-excited state with a principal and orbital angular momentum quantum numbers of n≈l-1≈17 [1-4]. The atom has a τ=7 ns lifetime. We used the 590 MeV ring cyclotron facility of PSI to synthesize π4He+ and irradiate the atoms with 800 ps-long resonant laser pulses of frequency ν=183760 GHz that induced a pionic transition (n,l)=(17,16)⟶(17,15) [1,2]. This laser transition triggered an electromagnetic cascade that resulted in the pion being absorbed into the helium nucleus [1-3]. The nucleus immediately underwent fission and the neutron, proton, and deuteron fragments were detected by an array of 140 plastic scintillation counters surrounding the target. This constitutes the first laser excitation and spectroscopy of an atom containing a meson. By further improving the precision of the transition frequencies and comparing them with the results of three-body QED calculations [2,4], the pion mass may be determined to a high precision, as has been done for the case of metastable antiprotonic helium [5,6].

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Collaboration:

ASACUSA and PiHe

Parallel session A7 / 120

MUonE experiment

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The anomalous magnetic moment of muon has been a long standing issue in the field of particle physics. The recent results by Fermilab have pointed to a possible discrepancy of 4.2 sigma with respect to the Standard Model prediction.
Although the future measurements will undoubtedly strengthen this result, the large uncertainty of the prediction, caused by its non-perturbative contributions, remains an issue.
The MUonE experiment is designed to provide an independent, precise measurement of such contribution, originating in the hadronic vacuum polarization, by employing a series of tracking stations, each with a low-Z target, to accurately determine the shape of differential cross-section of an elastic ue->ue scattering.
It is expected to increase the result's significance to at least 7 sigma, thus solidifying the discovery. The design of the detector allows also for searches of displaced vertices from New Physics phenomena.

Collaboration:

MUonE

Parallel session B7 / 118

Neutral meson production in AgAg@1.58 A GeV

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Relativistic nucleus–nucleus collisions offer a unique possibility for studying nuclear matter under the influence of high temperature and pressure. During the collision a system of interacting nucleons, resonances, and mesons, called hadronic fireball, is created.\par
The Dielectron Spectrometer HADES operated at the SIS18 synchrotron of FAIR/GSI Darmstadt recently provided new intriguing results on production of electron pairs and strangeness from nucleus-nucleus collisions, as well as from reference elementary reactions, in energy region of $1-2$~A~GeV. At 2019 it was complemented by a new electromagnetic calorimeter based on lead-glass modules, which allows to measure production of the π^0 and η mesons via their two-photon decay. In this energy range, π^0 and η mesons are the most abundantly produced mesons carrying information from the hadronic fireball. In addition, the knowledge of the neutral meson production is a mandatory prerequisite for the interpretation of dielectron data and at the same time almost no respective data are presently available for this energy range.\par
Recent result on π^0 production in Ag + Ag collisions at 1.58~A~GeV with 14×10^9 collected events will be presented . The yields, transverse mass and rapidity distributions will be shown and compared with existing data from other experiments as well as with transport model calculations.

Collaboration:

HADES

Parallel session B7 / 172

Photon-photon correlations in Ag+Ag √ collisions at SNN = 2.55 GeV

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The study of femtoscopic correlations of photon pairs emitted from heavy-ion collisions can serve as an unique probe of the source's spacetime evolution and properties. In contrast to commonly used charged particles, photons are not subject to strong, nor electromagnetic interactions, having relatively long mean free path. These properties imply no to minimal distortion of the carried information, from the point of their creation up to the detection in the experiment. Consequently, it is plausible to investigate source features, which are not only based on the information available after thermal freeze-out, but also include previous stages of expansion, without meaningful distortions caused by surrounding particles. Unfortunately, photon detection is not a trivial problem, requiring a dedicated approach. Moreover, the photon yield is mainly dominated by π^0 meson decays. Therefore one has to distinguish between femtoscopic signal from direct photons and decay photons (originating from f.eg. π^0 or η decays) emitted at later stages of collision.

As a part of FAIR/GSI scientific complex, the HADES experiment specializes in detecting light vector mesons form of dielectron ($e^{\pm}$) channels created in heavy system collisions at energies of several (1-2) A GeV. With use of detectors included in the spectrometer (among others electromagnetic calorimeters, capable of detecting neutral particles), combined with specially created software, a dedicated framework and reconstruction algorithm, the photon sample was obtained.

We present the first preliminary results from experimental data of Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV, measured with HADES at the GSI-SIS18.

Collaboration:

HADES

Parallel session A7 / 209

Dark Matter and rare decay searches of the ortho-Positronium with the J-PET detector

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The J-PET is a high-acceptance multi-purpose detector optimized for the detection of photons from positron-electron annihilation and can be used in a broad scope of interdisciplinary investigation. The Positronium system, a bound state of an electron and a positron, is suitable for testing the predictions of quantum electrodynamics (QED). In particular, the Ps triple state, the ortho-Positronium (o-Ps), which mainly decays to three photons, is a well-suited system to perform searches of new

physics.
We propose to study the lifetime of the o-Ps state in search of a new type of matter, the so-called Alice or Mirror Matter (MM), a suitable candidate for Dark Matter. By performing a high-precision measurement of the o-Ps lifetime, the accuracy of the present QED calculations can be tested. A discrepancy with the expectation from theory could indicate the presence of Physics Beyond the SM, i.e. a signal for MM. Furthermore, profiting from the triggerless acquisition mode of the J-PET detector, we will search for decays of the o-Ps into 4γ and 5γ, the former C-violating decay and the latter never observed. The large acceptance and high angular resolution of the J-PET detector will push the present limits in these forbidden and rare decays.

Collaboration:

J-PET

Plenary session / 90

J/psi and XYZP photo production

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I will discuss the recent results from JLab on J/\psi photo production and prospects and exceptions for exotic charmonia at future photon-/lepton- machines

Collaboration:

JPAC

Plenary session / 140

The JLab 12 GeV Program: Results and Future Perspectives

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The CEBAF accelerator complex at Jefferson Laboratory has been delivering precise electron beams with energies up to 12 GeV for several years now. I will review the results to date, with an emphasis on meson spectroscopy and dynamics, and provide an outlook for measurements from approved experiments that will run in the next several years.

Collaboration:

Plenary session / 207

Hadronic contribution to the muon g-2 with emphasis on photon-photon fusion processes

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This talk will present a brief status review of the anomalous magnetic of the muon (g-2), highlighting the recent progress in experiments, lattice QCD simulations, and Standard Model theories to understand the hadronic contribution to the muon g-2, namely the hadronic vacuum polarization (HVP) and hadronic light-by-light scattering (HLbL). Both are the major sources of theoretical uncertainty in the Standard Model prediction. We will present the recent efforts to obtain a reliable error estimate to meet the accuracy of the forthcoming experiments, particularly, for the studies of HLbL. As the subprocess of HLbL, the photon-photon fusion processes need to be carefully investigated to confront the experimental data and achieve data-driven prediction. We will discuss the studies of photon-photon fusion processes to single pseudo scalar mesons, production processes of two pions or pseudo scalar mesons, as well as recent work on three pion production processes. Finally, we will provide an outlook in this field.

Collaboration:

Plenary session / 112

Search for a Dark Photon with the PADME experiment

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In spite of the variety of attempts to create dark matter at accelerators, up-to-now, none of the conducted experiments has produced any evidence.
This elusiveness of dark-matter has then triggered innovative and open-minded approaches spanning a wide range of energies with high-sensitivity detectors 1.
In this scenario is inserted the Positron Annihilation into Dark Matter Experiment (PADME) ongoing at the Laboratori Nazionali di Frascati of INFN. PADME is searching a Dark Photon signal 2 by studying the missing-mass spectrum of single photon final states resulting from positron annihilation events on the electrons of a fix target. Actually, the PADME approach allows to look for any new particle produced in $e^+ e^-$ collisions through a virtual off-shell photon such as long lived Axion-Like-Particles (ALPs), proto-phobic X bosons, Dark Higgs …
After the detector commissioning and the beam-line optimization, PADME collaboration collected in 2020 about 5×10^{12} positrons on target at 430 MeV. These data have been used to evaluate the cross-section of the process $e^+ e^- \to \gamma\gamma(\gamma)$ at $\sqrt{s}$=20 MeV with a precision of 5% [3].
PADME has also the unique opportunity to confirm/disprove the particle nature of the X17 anomaly observed in the ATOMKI nuclear physics experiments studying de-excitation of some light nuclei [4].
The PADME 2022 data taking has been precisely conducted with this scope. About 1010 positrons have been stopped on the target for each of the 47 beam energy values in the range 262 - 298 MeV. This precise energy scan is intended to study the reaction $e^+ e^- \to X17 \to e^+ e^-$.
The talk will give an overview of the scientific program of the experiment and of the data analyses ongoing.

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Collaboration:

PADME

Plenary session / 110

Precision measurements with Kaon decays at CERN

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The NA62 experiment at CERN collected the world's largest dataset of charged kaon decays in 2016-2018, leading to the first measurement of the branching ratio of the ultra-rare $K^+ \to \pi^+\nu\bar{\nu}$ decay, based on 20 candidates. In this talk the NA62 experiment reports recent results from analyses of $K^+ \to \pi^0 e^+\nu\gamma$, $K^+ \to \pi^+\mu^+\mu^-$ and $K^+ \to \pi^+\gamma\gamma$ decays, using a data sample recorded in 2017–2018. The radiative kaon decay $K^+ \to \pi^0 e^+\nu\gamma$ (Ke3g) is studied with a data sample of O(100k) Ke3g candidates with sub-percent background contaminations. Preliminary results with the most precise measurements of the Ke3g branching ratios and T-asymmetry are presented. The $K^+ \to \pi^+\mu^+\mu^-$ sample comprises about 27k signal events with negligible background contamination, and the presented analysis results include the most precise determination of the branching ratio and the form factor. The $K^+ \to \pi^+\gamma\gamma$ sample contains about 4k signal events with 10% background contamination, and the analysis improves the precision of the branching ratio measurement by a factor of 3 with respect to the previous measurements.
Preliminary results of the $K^\pm \to \pi^0\pi^0\mu^\pm\nu$ (K00mu4) decay first observation and analysis based on the NA48/2 data collected in 2003-2004 are also presented.

Collaboration:

NA62, NA48/2

Plenary session / 166

Hadron Physics results at KLOE-2

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KLOE and KLOE-2 data are the largest dataset ever collected at an electron-positron collider operating at the ϕ resonance peak (almost 8 fb^{-1}).
The data corresponds to the production of about 24 billion of ϕ mesons, namely 8 billion pairs of neutral K mesons and 300 million η mesons.
A wide hadron physics program, investigating rare meson decays, $\gamma\gamma$ interaction, and dark forces, is being carried out by the KLOE-2 Collaboration.

The η decay into $\pi^0\gamma\gamma$ is a test bench for various models and effective theories, like VMD (Vector Meson Dominance) or ChPT (Chiral Perturbation Theory, which predict branching ratio (BR) far from the experimental value. KLOE-2, with its highly pure η sample produced
in $\phi \to \eta\gamma$ process, performed a new precise measurement of this BR.

KLOE-2 is currently probing a complementary model to the U boson or "dark photon", where the dark force mediator is a hypothetical leptophobic B boson that could show up in the $\phi \to \eta B \to \eta\pi^0\gamma\,, \eta \to \gamma\gamma$ channel. The preliminary upper limit on the dark $\alpha_{\rm B}$ coupling constant will be shown.

The High Energy Tagger detectors of KLOE-2 open the possibility to investigate π^0 production from $\gamma\gamma$ scattering by
tagging final-state leptons from $e^+e^- \to \gamma^*\gamma^* e^+e^- \to \pi^0 e^+e^-$ in coincidence with the π^0 in the barrel calorimeter. The preliminary measurement of the $\gamma^*\gamma^* \to \pi^0$ counting obtained by using single tagged events will be reported.

Moreover, the search for the double suppressed $\phi \to \eta\,\pi^+\pi^-$ and the conversion $\phi \to \eta\,\mu^+\mu^-$ decays are being performed at KLOE-2 with both $\eta \to \gamma\gamma$ and $\eta \to 3\pi^0$. Clear signals are seen for the first time.

Finally, preliminary and promising results on the ω cross-section measurement in the $e^+e^- \to \pi^+\pi^-\pi^0\gamma_{\rm ISR}$ channel using the Initial State Radiation (ISR) method will be also presented.

Collaboration:

KLOE-2

Plenary session / 208

Closing