SPHERE Annual Report
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P. Achenbach et al.
Particle tracking in kaon electroproduction with cathode-charge sampling in multi-wire proportional chambers

Abstract:
Wire chambers are routinely operated as tracking detectors in magnetic spectrometers at high-intensity continuous electron beams. Especially in experiments studying reactions with small cross-sections the reaction yield is limited by the background rate in the chambers. One way to determine the track of a charged particle through a multi-wire proportional chamber (MWPC) is the measurement of the charge distribution induced on its cathodes. In practical applications of this read-out method, the algorithm to relate the measured charge distribution to the avalanche position is an important factor for the achievable position resolution and for the track reconstruction efficiency. An algorithm was developed for operating two large-sized MWPCs in a strong background environment with multiple-particle tracks. Resulting efficiencies were determined as a function of the electron beam current and on the signal amplitudes. Because of the different energy-losses of pions, kaons, and protons in the momentum range of the spectrometer the efficiencies depend also on the particle species.

P. Achenbach et al.
A Large-Scale FPGA-Based Trigger and Dead-Time Free DAQ System for the KAOS Spectrometer at MAMI

Abstract:
The Kaos spectrometer is maintained by the A1 collaboration at the Mainz Microtron MAMI with a focus on the study of (e,e'K$^+$) coincidence reactions. For its electron-arm two vertical planes of fiber arrays, each comprising approximately 10 000 fibers, are operated close to zero degree scattering angle and in close proximity to the electron beam. A nearly dead-time free DAQ system to acquire timing and tracking information has been installed for this spectrometer arm. The signals of 144 multi-anode photomultipliers are collected by 96-channel front-end boards, digitized by double-threshold discriminators and the signal time is picked up by state-of-the-art F1 time-to-digital converter chips. In order to minimize background rates a sophisticated trigger logic was

implemented in newly developed VUPROM modules. The trigger performs noise suppression, signal cluster finding, particle tracking, and coincidence timing, and can be expanded for kinematical matching (e'K$^+$) coincidences. The full system was designed to process more than 4 000 read-out channels and to cope with the high electron flux in the spectrometer and the high count rate requirement of the detectors. It was successfully in-beam tested at MAMI in 2009.

P. Achenbach et al.
A Tracking Fiber Detector based on Silicon Photomultipliers for the Kaos Spectrometer

Abstract:
A tracking detector based on two meters long scintillating fibers read out by silicon photomultipliers (SiPM) is being developed for the KAOS spectrometer at the Mainz Microtron MAMI. Results from a prototype setup using 2 mm square fibers and large area SiPM readout are presented. The detection efficiency of such a combination was measured to be between 83 and 100% depending on the threshold on the SiPM amplitude. A Monte Carlo simulation based on a physical model was employed in order to extract the photon detection efficiency of the SiPM devices.

P. Achenbach et al.
Detector developments for the hypernuclear programme at PANDA

Abstract:
The technical design of the PANDA experiment at the future FAIR facility next to GSI is progressing. At the proposed anti-proton storage ring the spectroscopy of double Λ hypernuclei is one of the four main topics which will be addressed by the Collaboration. The hypernuclear experiments require (i) a dedicated internal target, (ii) an active secondary target of alternating silicon and absorber material layers, (iii) high purity germanium (HPGe) detectors, and (iv) a good particle identification system for low momentum kaons. All systems need to operate in the presence of a high magnetic field and a large hadronic background. The status of the detector developments for this programme is summarized.

P. Achenbach et al.
Exclusive electroproduction of K$^+\Lambda$ and K$^+\Sigma^0$ final states at Q^2 = 0.036 (GeV/c)^2

Abstract:
Cross section measurements of the exclusive p(e,e'K$^+$)Λ,Σ^0 electroproduction reactions have been performed at the Mainz Microtron MAMI in the A1 spectrometer facility using for the first time the KAOS spectrometer for kaon detection. These processes were studied in a kinematical region not covered by any previous experiment. The nucleon was probed in its third resonance region at invariant energies of W = 1750 MeV with a low virtual photon four-momentum, Q^2= 0.036 (GeV/c)^2. The MAMI data indicate a smooth transition in Q^2 from photoproduction to electroproduction cross sections. Comparison with predictions of effective Lagrangian models reveal that strong longitudinal couplings to the resonances are not present in the process.

M. Agnello et al.

An improved determination of the two–nucleon induced non mesonic weak decay of Λ hypernuclei

Abstract:

The decay of Λ-hypernuclei without π emission, known as Non Mesonic Weak Decay (NMWD), gives an effective tool to investigate $\Delta S=1$ four-baryon interactions. It was theoretically suggested that the two-nucleon induced mechanism could play a substantial role in reproducing the observed NMWD decay rates and nucleon spectra, but at present no direct evidence of such a mechanism has been obtained. The FINUDA experiment, exploiting the possibility to detect both charged and neutral particles coming from the hypernucleus decay, has allowed us to deduce the relative weight of the two nucleon induced decay rate to the total NMWD rate. The value of $\Gamma_{2N}/\Gamma_{NMWD}$ = $0.24\pm0.03_{stat}{}^{+0.03sys}_{-0.02sys}$ has been deduced, with an error reduced by a factor more than two compared with the previous assessment.

M. Agnello et al.
Direct experimental evidence of the weak $\Lambda np \rightarrow nnp$ hypernucleus decay

Abstract:

A direct experimental evidence of the occurrence of the weak reaction $\Lambda np \rightarrow nnp$ in nuclei has been obtained by the FINUDA experiment. Three events have been found that can be attributed to $^7_\Lambda$Li and $^9_\Lambda$Be two nucleon-induced non mesonic weak decays. The kinematic analysis of such events is presented here.

E. Bauer and G. Garbarino
Microscopic Approach to Nucleon Spectra in Hypernuclear Non–Mesonic Weak Decay

Abstract:

A consistent microscopic diagrammatic approach is applied for the first time to the calculation of the nucleon emission spectra in the non-mesonic weak decay of Λ-hypernuclei. We adopt a nuclear matter formalism extended to finite nuclei via the local density approximation, a one-meson exchange weak transition potential and a Bonn nucleon-nucleon strong potential. Ground state correlations and final state interactions, at second order in the nucleon-nucleon interaction, are introduced on the same footing for all the isospin channels of one- and two-nucleon induced decays. Single and double-coincidence nucleon spectra are predicted for $^{12}_\Lambda$C and compared with recent KEK and FINUDA data. The key role played by quantum interference terms allows us to improve the predictions obtained with intranuclear cascade codes. Discrepancies with data remain for proton emission.

A. Cieply et al.
Constraints on the threshold K^- nuclear potential from FINUDA $^AZ(K^-_{stop}, \pi^-)^A_\Lambda Z$ spectra

Abstract:

$1s_\Lambda$ hypernuclear formation rates in stopped K^- reactions on several p-shell targets are derived from hypernuclear formation spectra measured recently by the FINUDA Collaboration and are compared with calculated $1s_\Lambda$ formation rates based on a chirally motivated coupled channel model. The calculated rates are about 15% of the derived rates, and in contrast with previous calculations depend depend weakly on the depth of the threshold K^- nuclear potential. The A dependence of the calculated $1s_\Lambda$ rates is in fair agreement with that of the derived $1s_\Lambda$ rates, showing a slight preference for a deep density dependent potential, Re $V_{K^-}(\rho_0) \sim -(150–200)$ MeV, over a shallow potential, Re $V_{K^-}(\rho_0) \sim -50$ MeV. These new features originate from a substantial energy and density dependence found for the in-medium subthreshold $K^- n \to \pi^- \Lambda$ branching ratio that enters the hypernuclear formation rate calculations.

A. Cieply et al.
Chirally motivated K^- nuclear potentials

arXiv:1102.4515v3   [nucl-th]   1 May 2011

Abstract:

In-medium subthreshold $\overline{K}N$ scattering amplitudes calculated within a chirally motivated meson-baryon coupled-channel model are used self consistently to confront K^- atom data across the periodic table. Substantially deeper K^- nuclear potentials are obtained compared to approaches based on threshold amplitudes. When $\overline{K}NN$ contributions are incorporated, a very deep K^- nuclear potential results, Re $V_{K^-}(\omega_K = m_K, \rho = \rho_0) \sim -175$ MeV at nuclear matter density, in agreement with density dependent potentials obtained in purely phenomenological fits to the data. Self consistent dynamical calculations of K^--nuclear quasibound states are reported and discussed.

FINUDA Collaboration
Hypernuclear spectroscopy with K^- at rest on ^{7}Li, ^{9}Be, ^{13}C and ^{16}O

Abstract:

The FINUDA experiment collected data to study the production of hypernuclei on different nuclear targets. The hypernucleus formation occurred through the strangeness-exchange reaction $K^-_{stop} + {}^A Z \to {}^A_\Lambda Z + \pi^-$. From the analysis of the momentum of the emerging π^-, binding energies and formation probabilities of $^7_\Lambda$Li, $^9_\Lambda$Be, $^{13}_\Lambda$C and $^{16}_\Lambda$O have been measured and are here presented. The behavior of the formation probability as a function of the atomic mass number A is also discussed.

FINUDA Collaboration
Study of some two-body non-mesonic decays of $^4_\Lambda$He and $^5_\Lambda$He

arXiv:1010.5616v2   [nucl-ex]   5 Apr 2011

Abstract:

The Non-Mesonic (NM) decay of $^4_\Lambda$He and $^5_\Lambda$He in two-body channels has been studied with the FINUDA apparatus. Two-body NM decays of hypernuclei are rare and the existing observations and theoretical calculations are scarce and dated. The $^4_\Lambda$He $\to d + d, p + t$ decay channels simultaneously observed by FINUDA on several nuclei are compared: the *pt* channel is dominant.

The decay yields for the two decay channels are assessed for the first time: they are $(1.37 \pm 0.37) \times 10^{-5}/K^-_{stop}$ and $(7.2 \pm 2.7) \times 10^{-5}/K^-_{stop}$, respectively. Due to the capability of FINUDA of identifying $^5_\Lambda$He hypernuclei, a few $^5_\Lambda$He $\rightarrow d + t$ decay events have also been observed. The branching ratio for this decay channel has been measured for the first time: $(3.0 \pm 2.3) \times 10^{-3}$.

A. Gal
Meson Assisted Strange Dibaryons

Submitted to Gerry Brown's 85th birthday Festschrift
arXiv:1011.6322v2   [nucl-th]   1 Dec 2010

Abstract:
The state of the art in dibaryons with strangeness is reviewed, including the K$^-$pp dibaryon which signals the onset of $\overline{K}$-nuclear binding. A new type of strange dibaryons is highlighted, where the primary binding mechanism is provided by strong p-wave pion interactions, as demonstrated by a quasibound (I=3/2, $J^P=2^+$) πYN dibaryon calculation.

A. Gal
Strangeness nuclear physics – 2010

Journal reference: Prog.Theor.Phys.Suppl.186:270-281,2010
arXiv:1008.3510v2   [nucl-th]   23 Dec 2010

Abstract:
Selected topics in Strangeness Nuclear Physics are reviewed: Λ-hypernuclear spectroscopy and structure, multistrangeness, and $\overline{K}$ mesons in nuclei.

A. Gal and D.J. Millener
Comment on "Five-Body Cluster Structure of the Double-Λ Hypernucleus $^{11}_{\Lambda\Lambda}$Be"

arXiv:1011.0181v3   [nucl-th]   21 Apr 2011

Abstract:
Hiyama et al. [Phys. Rev. Lett. 104, 212502 (2010)] have recently reported on a pioneering five-body $\alpha\alpha n\Lambda\Lambda$ cluster-model (CM) calculation of $^{11}_{\Lambda\Lambda}$Be in order to confront a possible interpretation of the KEK-E373 HIDA event [Nucl. Phys. A 835, 207 (2010)]. Unfortunately, a six-body $\alpha\alpha nn\Lambda\Lambda$ calculation of $^{12}_{\Lambda\Lambda}$Be to confront another possible interpretation is beyond reach at present. Using experimental B_Λ values with small corrections based on recently determined ΛN spin-dependent interaction parameters [Nucl. Phys. A 835, 11 (2010)], we obtain binding-energy shell-model (SM) estimates for both $^{11,12}_{\Lambda\Lambda}$Be, concluding that neither $^{11}_{\Lambda\Lambda}$Be nor $^{12}_{\Lambda\Lambda}$Be provide satisfactory interpretation of the HIDA event. The shell model approach is tested by reproducing $B_{\Lambda\Lambda}^{exp.}(^{13}_{\Lambda\Lambda}$Be).

A. Gal and D.J. Millener
Shell-model predictions for $\Lambda\Lambda$ hypernuclei

Journal reference: Phys. Lett. B 701 (2011) 342-345
arXiv:1104.3429v2   [nucl-th]   30 May 2011

Abstract:
It is shown how the recent shell-model determination of ΛN spin dependent interaction terms in Λ hypernuclei allows for a reliable deduction of $\Lambda\Lambda$ separation energies in $\Lambda\Lambda$ hypernuclei across the nuclear p shell. Comparison is made with the available data, highlighting $^{11}_{\Lambda\Lambda}$Be and $^{12}_{\Lambda\Lambda}$Be which have been suggested as possible candidates for the KEK-E373 Hida event.

A. Gal and H. Garcilazo
Coupled channel Faddeev calculations of a $\bar{K}N\pi$ quasibound state

Abstract:
The $\bar{K}N\pi$ system is studied using separable interactions fitted to data available on the s-wave $\bar{K}N$-πY subsystem and the p-wave πN, πY, $\pi\pi$ and $\pi\bar{K}$ subsystems. Three-body $\bar{K}N\pi$–$\pi Y\pi$ coupled channel Faddeev equations with relativistic kinematics are solved in search for poles in the complex energy plane. A $\bar{K}N\pi$ quasibound pole with quantum numbers $I(J^P) = 1(3/2^-)$ is found near and below the $\bar{K}N\pi$ threshold, its precise location depending sensitively on the poorly known shape of the p-wave πY interaction. This $\bar{K}N\pi$ quasibound state suggests the existence of a $D_{13}\Sigma$ resonance with width about 60 MeV near threshold (M ≈ 1570 MeV), excluding meson absorption contributions.

C.E. Jimenez-Tejero et al.
Open charm meson in nuclear matter at finite temperature beyond the zero range approximation

Abstract:
The properties of open charm mesons, D, $\bar{D}$, D_s and $\bar{D}_s$ in nuclear matter at finite temperature are studied within a self-consistent coupled-channel approach. The interaction of the low lying pseudoscalar mesons with the ground state baryons in the charm sector is derived from at-channel vector-exchange model. The in-medium scattering amplitudes are obtained by solving the Lippmann-Schwinger equation at finite temperature including Pauli blocking effects, as well as D, $\bar{D}$, D_s and $\bar{D}_s$ self-energies taking their mutual influence into account. We find that the in-medium properties of the D meson are affected by the D_s-meson self-energy through the intermediate D_sY loops coupled to DN states. Similarly, dressing the $\bar{D}$ meson in the $\bar{D}Y$ loops has an influence over the properties of the $\bar{D}_s$ meson.

A. Krejcirik et al.
Λ-hypernuclear production in (K^-_{stop}, π) reactions reexamined

Abstract:
Distorted wave impulse approximation calculations of Λ-hypernuclear production rates in stopped K^- reactions on several p-shell targets used recently in experiments by the FINUDA Collaboration are reported. Chirally motivated $K^- + N \rightarrow \pi + \Lambda$ in-medium transition amplitudes are employed and the sensitivity of the calculated rates to the initial K^--atomic wave functions and final pion distorted

waves is studied. The calculated rates are compared with measured rates, wherever available, confirming earlier observations that (i) the calculated rates are generally lower than the measured rates, and (ii) the deeper the K$^-$ -nuclear potential, the worse is the discrepancy. The A dependence of the calculated $1s_\Lambda$ production rates is discussed for the first time, providing a useful tool in resolving the issue of depth of the K$^-$ -nuclear potential near threshold.

V.K. Magas et al.
Experimental status of deeply bound kaonic states in nuclei

Abstract:
We review recent claims of the existence of deeply bound kaonic states in nuclei. Also we study in details the (K$^-$,p) reaction on ^{12}C with 1 GeV/c momentum kaon beam, based on which a deep kaon nucleus optical potential was claimed in [1]. In our Monte Carlo simulation of this reaction we include not only the quasi-elastic K$^-$ p scattering, as in [1], but also K$^-$ absorption by one and two nucleons followed by the decay of the hyperon in πN, which can also produce strength in the region of interest. The final state interactions in terms of multiple scattering of the K$^-$, p and all other primary particles on their way out of the nucleus is also considered. We will show that all these additional mechanisms allow us to explain the observed spectrum with a "standard" shallow kaon nucleus optical potential obtained in chiral models.
[1] T. Kishimoto et al., Prog. Theor. Phys. 118, 181 (2007).

V.K. Magas et al.
Latest results for the antikaon-nucleon optical potential

Abstract:
The key question of this letter is whether the K$^-$ -nucleus optical potential is deep, as it is prefered by the phenomenological fits to kaonic atoms data, or shallow, as it comes out from unitary chiral model calculations. The current experimental situation is reviewed.

J. Pochodzalla
Hypernuclei – the next decade

Abstract:
We are at the verge of a new impact from hypernuclear experiments planned or already operative at various laboratories all over the world. The complementary of these different experimental approaches to hypernuclei provides a wide basis for a comprehensive understanding of strange hadrons in cold hadronic matter. High precision studies of light Λ hypernuclei, spectroscopy of

double $\Lambda\Lambda$ nuclei and the properties of antihyperons in nuclei are examples for the outstanding challenges for hypernuclei research in the next decade.

J. Pochodzalla et al.
Studies of Hyperons and Antihyperons in Nuclei

Abstract:
Stored antiproton beams at the international FAIR facility will provide unique opportunities to study hyperons as well as antihyperons in nuclear systems. Precise γ-spectroscopy of multi-strange hypernuclei will serve as a laboratory for the hyperon-hyperon interaction. Exclusive hadron-antihadron pair production close to threshold can measure the potential of a antihadron relative to that of the coincident hadrons.
In the present work we explore the production of excited states in double hypernuclei following the micro-canonical break-up of an initially excited double hypernucleus which is created by the absorption and conversion of a stopped Ξ^- hyperon. Generally the formation of excited hypernuclear states relative to ground states dominates in this model. For different initial target nuclei which absorb the Ξ^-, different double hypernuclei nuclei dominate. We also compare the model predictions with the correlated pion spectra measured by the E906 collaboration.
In antiproton nucleus reactions the event-by-event transverse momentum correlations of hadron-antihadron pairs produced close to threshold contain information on the difference between the nuclear potential of the hadron and the associated antihadron. For produced D-meson pairs at 6.7 GeV/c the sensitivity of the transverse momenta correlation will probably be to small to deduce differences between the potentials for D^+ and D^- mesons. However, for $\Xi\bar{\Xi}$ pairs produced at 2.9 GeV/c the asymmetry is sufficiently sensitive to predicted differences between the Ξ and $\bar{\Xi}$ potentials even if the momentum and density dependence of the the potential are taken into account.

A. Sanchez Lorente et al.
Production of excited double hypernuclei via Fermi breakup of excited strange systems

Abstract:
Precise spectroscopy of multi-strange hypernuclei provides a unique chance to explore the hyperon-hyperon interaction. In the present work we explore the production of excited states in double hypernuclei following the micro-canonical break-up of an initially excited double hypernucleus which is created by the absorption and conversion of a stopped Ξ^- hyperon. Rather independent on the spectrum of possible excited states in the produced double hypernuclei the formation of excited states dominates in our model. For different initial target nuclei which absorb the Ξ^-, different double hypernuclei nuclei dominate. Thus the ability to assign the various observable γ-transitions in a unique way to a specific double hypernuclei by exploring various light targets as proposed by the Panda collaboration seems possible. We also confront our predictions with the correlated pion spectra measured by the E906 collaboration.

L. Tolos et al.

$\overline{K}^*$ meson in nuclear matter

Abstract:
The properties of the $\overline{K}^*$ meson in dense matter are studied using a unitary approach in coupled channels within the framework of the local hidden gauge formalism. We obtain the $\overline{K}^*$ spectral function in the nuclear medium and we found that the $\overline{K}^*$ develops an in-medium width up to five times bigger than in free space. We also estimate the transparency ratio of the $\gamma A \rightarrow K^+ K^{*-} A'$ reaction, which we propose as a feasible experimental scenario to detect in-medium modifications of the $\overline{K}^*$ meson.

L. Tolos et al.

Heavy meson production in hot dense matter

Abstract:
The properties of charmed mesons in dense matter are studied using a unitary coupled-channel approach in the nuclear medium which takes into account Pauli-blocking effects and meson self-energies in a self-consistent manner. We obtain the open-charm meson spectral functions in this dense nuclear environment, and discuss their implications on hidden charm and charm scalar resonances and on the formation of D-mesic nuclei at FAIR energies.

L. Tolos et al.

Heavy mesons in dense matter

Abstract:
Charmed mesons in dense matter are studied within a unitary coupled-channel approach which takes into account Pauli-blocking effects and meson self-energies in a self-consistent manner. We obtain the open-charm meson spectral functions in this dense medium, and discuss their implications on hidden charm and charm scalar resonances and on the formation of D-mesic nuclei.