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**SPHERE**

**Annual Report**

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# 1 Year 2009

## 1.1 Publications Resulting from the Project 2009

P. Achenbach *et al.* [KAOS-A1 Collaboration],  
Future use of silicon photomultipliers for KAOS at MAMI and  $\bar{P}$ ANDA at FAIR,  
Nucl. Instr. and Meth. in Phys. Res. A 610 (2009) 358-361.

Abstract:

A characterization of scintillating fibres with silicon photomultiplier read-out was performed in view of their possible application in fibre tracking detector systems. Such a concept is being considered for the KAOS spectrometer at the Mainz Microtron MAMI and as a time-of-flight start detector for the hypernuclear physics programme at the  $\bar{P}$ ANDA experiment of the FAIR project. Results on particle detection efficiency and time resolution are discussed. In summary, the silicon devices are very suitable for the detection of the low light yield from scintillating fibres insofar a trigger scheme is found to cope with the noise rate characteristics.

P. Achenbach *et al.* [A1 Collaboration],  
Front-end electronics for the Kaos spectrometer at MAMI,  
IEEE Trans. Nucl. Sci. 56 (2009) 316-319.

Abstract:

A new front-end electronics system has been developed for the electron arm tracking detectors in the Kaos spectrometer at the Mainz microtron MAMI. The signals of multi-anode photomultipliers are collected by 96-channel front-end boards, digitized by double-threshold discriminators and the signal time is picked up by F1 TDC chips. The system was designed to process more than 4,000 channels and to cope with the high electron flux in the spectrometer and the high count rate requirement of the detectors. A subset of 288 channels was installed and successfully used in the 2008 data taking period of the Kaos spectrometer.

M. Agnello *et al.*  
Study of the performance of HPGe detectors operating in very high magnetic fields,  
Nucl. Instr. and Meth. in Phys. Res. A 606 (2009) 560-568.

Abstract:

A new generation of high-resolution hypernuclear  $\gamma$ -spectroscopy experiments using high-purity germanium (HPGe) detectors is presently designed for the FINUDA spectrometer at DAΦNE, the Frascati  $\Phi$ -factory, and for PANDA, the  $p$ - $\bar{p}$  hadron spectrometer at the future FAIR facility. In both spectrometers the HPGe detectors

have to be operated in strong magnetic fields. In this paper we report on a series of measurements performed on a HPGe detector inserted in a magnetic field of intensity up to 2.5 T, the highest ever reached for operations with a HPGe, and with different orientations of the detector's axis with respect to field direction. A significant worsening of the energy resolution was found, but with a moderate loss of the efficiency. The most relevant features of the peak shapes, described by bi-Gaussian functions, are parametrized in terms of field intensity and energy: this allows to correct the spectra measured in magnetic field and to recover the energy resolution almost completely.

M. Agnello *et al.*

Mesonic and Non-Mesonic Weak Decay of Hypernuclei with FINUDA,  
Nucl. Phys. A 827 (2009) 303c-305c.

Abstract:

The FINUDA experiment performed a systematic study of both mesonic and non-mesonic weak decay of *p-shell*  $\Lambda$ -hypernuclei. Recent results on the mesonic decay rates and the non-mesonic decay ratios are illustrated and briefly discussed.

M. Agnello *et al.* [FINUDA Collaboration],

New results on mesonic weak decay of p-shell  $\Lambda$ -hypernuclei,  
Phys. Lett. B 681 (2009) 139-146.

Abstract:

The FINUDA experiment performed a systematic study of the charged mesonic weak decay channel of p-shell  $\Lambda$ -hypernuclei. Negatively charged pion spectra from mesonic decay were measured with magnetic analysis for the first time for  ${}^7_{\Lambda}\text{Li}$ ,  ${}^9_{\Lambda}\text{Be}$ ,  ${}^{11}_{\Lambda}\text{B}$  and  ${}^{15}_{\Lambda}\text{N}$ . The shape of the  $\pi^-$  spectra was interpreted through a comparison with pion distorted wave calculations that take into account the structure of both hypernucleus and daughter nucleus. Branching ratios  $\Gamma_{\pi^-}/\Gamma_{tot}$  were derived from the measured spectra and converted to  $\pi^-$  decay rates  $\Gamma_{\pi^-}$  by means of known or extrapolated total decay widths  $\Gamma_{tot}$  of p-shell  $\Lambda$ -hypernuclei. Based on these measurements, the spin-parity assignment  $1/2^+$  for  ${}^7_{\Lambda}\text{Li}$  and  $5/2^+$  for  ${}^{11}_{\Lambda}\text{B}$  ground-state are confirmed and a spin-parity  $3/2^+$  for  ${}^{15}_{\Lambda}\text{N}$  ground-state is assigned for the first time.

E. Bauer and G. Garbarino,

Exchange terms in the two-nucleon induced non-mesonic weak decay of  $\Lambda$ -hypernuclei,  
Nucl. Phys. A 828 (2009) 29-51.

Abstract:

The contribution of Pauli exchange terms to the two-nucleon induced non-mesonic

weak decay of  ${}_{\Lambda}^{12}\text{C}$  hypernuclei,  $\Lambda\text{NN} \rightarrow \text{nNN}$  ( $\text{N} = \text{n}$  or  $\text{p}$ ), is studied within a nuclear matter formalism implemented in a local density approximation. We have adopted a weak transition potential including the exchange of the complete octets of pseudoscalar and vector mesons as well as a residual strong interaction modeled on the Bonn potential. Among the exchange contributions, only the dominant ones have been evaluated microscopically from the corresponding Goldstone diagrams; a Landau–Migdal model has been adopted for the remaining exchange terms. The introduction of exchange terms turns out to reduce the two-nucleon induced non-mesonic rate by 18% and, jointly with an increase in the one-nucleon induced rate by the same magnitude, reveals to be significant for an accurate determination of the full set of hypernuclear nonmesonic decay widths in theoretical and experimental analyses.

S. Bianchin *et al.* [HypHI Collaboration],  
 The HypHI project: Hypernuclear spectroscopy with stable heavy ion beams and rare isotope beams at GSI and FAIR,  
 Intern. J. of Mod. Phys. E 18 (2009), pp. 2187-2191.

Abstract:

The HypHI collaboration aims to perform a precise hypernuclear spectroscopy with stable heavy ion beams and rare isotope beams at GSI and FAIR in order to study hypernuclei at extreme isospin, especially neutron rich hypernuclei to look insight hyperon-nucleon interactions in the neutron rich medium, and hypernuclear magnetic moments to investigate baryon properties in the nuclei<sup>1,2</sup>. We are currently preparing for the first experiment with  ${}^6\text{Li}$  and  ${}^{12}\text{C}$  beams at 2 A GeV to demonstrate the feasibility of a precise hypernuclear spectroscopy by identifying  ${}_{\Lambda}^3\text{H}$ ,  ${}_{\Lambda}^4\text{H}$  and  ${}_{\Lambda}^5\text{He}$ <sup>2,3</sup>. The first physics experiment on these hypernuclei is planned for 2009. In the present document, an overview of the HypHI project and the details of this first experiment will be discussed.

1. T.R. Saito et al., Letter Of Intent of “Hypernuclei with Stable Heavy Ion Beam and RI-beam Induced Reactions at GSI (HypHI)“. Submitted to GSI PAC EA 30.
2. T.R. Saito et al., Proceedings of The IXth International Conference on Hypernuclear and Strange Particle Physics HYP2006, October 10th-14th 2006, Mainz, Germany, p. 171.
3. T.R. Saito et al, Proposal of the HypHI Phase 0 experiment approved by the G-PAC 34.

D. Cabrera *et al.*  
 Energy-weighted sum rules for mesons in hot and dense matter,  
 Phys. Rev. C 80, 045201 (2009)

Abstract:

We study energy-weighted sum rules of the pion and kaon propagator in nuclear

matter at finite temperature. The sum rules are obtained from matching the Dyson form of the meson propagator with its spectral Lehmann representation at low and high energies. We calculate the sum rules for specific models of the kaon and pion self-energy. The in-medium spectral densities of the  $K$  and  $\bar{K}$  mesons are obtained from a chiral unitary approach in coupled channels that incorporates the  $S$  and  $P$  waves of the kaon-nucleon interaction. The pion self-energy is determined from the  $P$ -wave coupling to particle-hole and  $\Delta$ -hole excitations, modified by short-range correlations. The sum rules for the lower-energy weights are fulfilled satisfactorily and reflect the contributions from the different quasiparticle and collective modes of the meson spectral function. We discuss the sensitivity of the sum rules to the distribution of spectral strength and their usefulness as quality tests of model calculations.

A. Feliciello,  
Strangeness nuclear physics at FINUDA,  
La rivista del Nuovo Cimento 32 (4) (2009) 147-184.

Abstract:

The FINUDA Experiment, installed at DAΦNE, completed its first two data taking campaigns. A selection of the most interesting results is presented.

A. Feliciello,  
Perspectives on the physics of hypernuclei,  
Proc. of 6<sup>th</sup> Japan-Italy Symposium on Heavy-Ion Physics - ASR2008: Perspectives in Nuclear Physics -, Tokai, Japan, November, 11-15, 2008, Eds. S.C. Jeong, H. Miyatake, Y. Utsuno, H. Ikezoe, T. Motobayashi and A. Bracco, (AIP, 29 Melville, New York, 2009) AIP Conference Proceedings Vol. 1120, pp. 114-119 (2009).

Abstract:

The imminent commissioning of the Japan Proton Accelerator Research Complex (J-PARC) and the planned construction of the Facility for Antiproton and Ion Research (FAIR) will offer the opportunity to pursue a systematic program of high-precision and high-statistics studies in the field of hypernuclear physics. This subject will represent as well an important topic in the physics program approved for the upgraded Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (JLab).

A survey of the future experimental initiatives is presented, with particular emphasis on the activities that will be carried out by Italian and Japanese researchers.

E. Friedman,  
Unified approach to nuclear densities from exotic atoms,  
Hyperfine Interactions, 193 (2009) 33-38. [invited talk at EXA08, Sept. 08, Vienna]

Abstract:

Parameters of nuclear density distributions are derived from least-squares fits to strong interaction observables in exotic atoms. Global analyses of antiprotonic and pionic atoms show reasonably good agreement between the two types of probes regarding the average behaviour of root-mean-square radii of the neutron distributions. Apparent conflict regarding the shape of the neutron distribution is attributed to different radial sensitivities of these two probes.

A. Gal,

Overview of  $\bar{K}N$  and  $\bar{K}$ -nucleus dynamics,  
Hyperfine Interactions, 193 (2009) 165-171. [invited talk at EXA08, Sept. 08, Vienna]

Abstract:

The main features of coupled-channel  $\bar{K}N$  dynamics near threshold and its repercussions in few-body  $\bar{K}$ -nuclear systems are briefly reviewed highlighting the  $I = 1/2$   $\bar{K}NN$  system. For heavier nuclei, the extension of mean-field calculations to multi- $\bar{K}$  nuclear quasibound states is discussed focusing on kaon condensation.

A. Gal,

$\pi^-$  decay rates of p-shell hypernuclei revisited,  
Nucl. Phys. A 828 (2009) 72-83.

Abstract:

Explicit expressions for the parity-violating s-wave and the parity-conserving p-wave contributions to  $\pi^-$  weak decay rates of  $\Lambda$  hypernuclei in the 1p shell are given in the weak-coupling limit, to update previous shell-model calculations and to compare with recent  $\pi^-$  spectra and total decay rates measured by the FINUDA Collaboration for  ${}^7_\Lambda\text{Li}$ ,  ${}^9_\Lambda\text{Be}$ ,  ${}^{11}_\Lambda\text{B}$  and  ${}^{15}_\Lambda\text{N}$ . A useful sum rule for the summed strength of  $\Lambda_{1s} \rightarrow p_{1p}$  hypernuclear  $\pi^-$  weak decays is derived. Fair agreement between experiment and calculations is reached, using the primary s-wave amplitude and Cohen-Kurath nuclear wavefunctions. The role of the p-wave amplitude is studied in detail for  ${}^{15}_\Lambda\text{N}$  and found to be secondary. Previous assignments of ground-state spin-parity values  $J^\pi({}^7_\Lambda\text{Li}_{g.s.}) = \frac{1}{2}^+$  and  $J^\pi({}^{11}_\Lambda\text{B}_{g.s.}) = \frac{5}{2}^+$  are confirmed, and a new assignment  $J^\pi({}^{15}_\Lambda\text{N}_{g.s.}) = \frac{3}{2}^+$  is made, based on the substantial suppression calculated here for the  ${}^{15}_\Lambda\text{N} \left(\frac{1}{2}^+\right) \rightarrow \pi^- {}^{15}\text{O}_{g.s.}$  weak decay rate.

A. Gal,

Few-Body Approaches and Problems in Hypernuclei,  
Few-Body Syst. (2009) 45: 105-109 [invited talk at 5th Workshop on Critical Stability of Few-Body Systems, Erice 2008].

Abstract:

It takes two nucleons to bind a  $\Lambda$  hyperon, and perhaps as many as three nucleons to bind two  $\Lambda$  hyperons. Here I review few-body calculations which consider the onset of binding in multi-strange hypernuclei, including  $\Xi$  hyperons once the free-space strong-interaction conversion  $\Xi N \rightarrow \Lambda\Lambda$  becomes Pauli forbidden in  $\Lambda$ -abundant matter. Quasibound states of  $\bar{K}$  mesons in few-nucleon systems are also briefly discussed.

D. Gazda, E. Friedman, A. Gal, J. Mareš,  
Multi- $\bar{K}$  hypernuclei,  
Phys. Rev. C 80, 035205 (2009) [arXiv:0906.5344 [nucl-th]].

Abstract:

Relativistic mean-field calculations of multi- $\bar{K}$  *hypernuclei* are performed by adding  $K^-$  mesons to particle-stable configurations of nucleons,  $\Lambda$  and  $\Xi$  hyperons. For a given hypernuclear core, the calculated  $\bar{K}$  separation energy  $B_{\bar{K}}$  saturates with the number of  $\bar{K}$  mesons for more than roughly 10 mesons, with  $B_{\bar{K}}$  bounded from above by 200 MeV. The associated baryonic densities saturate at values 2–3 times nuclear-matter density within a small region where the  $\bar{K}$ -meson densities peak, similarly to what was found for multi- $\bar{K}$  nuclei. The calculations demonstrate that particle-stable multistrange  $\{N, \Lambda, \Xi\}$  configurations are stable against strong-interaction conversions  $\Lambda \rightarrow N\bar{K}$  and  $\Xi \rightarrow N\bar{K}\bar{K}$ , confirming and strengthening the conclusion that kaon condensation is unlikely to occur in strong-interaction self-bound strange hadronic matter.

Mikhail E. Gusakov, Elena M. Kantor, Pawel Haensel,  
Relativistic entrainment matrix of a superfluid nucleon-hyperon mixture: The zero temperature limit,  
Phys. Rev. C 79, 055806 (2009)

Abstract:

We calculate the relativistic entrainment matrix  $Y_{ik}$  at zero temperature for a nucleon-hyperon mixture composed of neutrons, protons, and  $\Lambda$  and  $\Sigma^-$  hyperons, as well as electrons and muons. This matrix is analogous to the entrainment matrix (also termed mass-density matrix or Andreev-Bashkin matrix) of nonrelativistic theory. It is an important ingredient for modeling the pulsations of massive neutron stars with superfluid nucleon-hyperon cores. The calculation is done in the frame of the relativistic Landau Fermi-liquid theory generalized to the case of superfluid mixtures; the matrix  $Y_{ik}$  is expressed through the Landau parameters of nucleon-hyperon matter. The results are illustrated with a particular example of the  $\sigma - \omega - \rho$  mean-field model with scalar self-interactions. Using this model, we calculate the matrix  $Y_{ik}$  and the Landau parameters. We also analyze the stability of the ground state of nucleon-hyperon matter with respect to small perturbations.



Mikhail E. Gusakov, Elena M. Kantor, Pawel Haensel,  
Relativistic entrainment matrix of a superfluid nucleon-hyperon mixture. II. Effect  
of finite temperatures,  
Phys. Rev. C 80, 015803 (2009)

Abstract:

We calculate the important quantity of superfluid hydrodynamics, the relativistic entrainment matrix for a nucleon-hyperon mixture at *arbitrary* temperature. In the nonrelativistic limit this matrix is also termed the Andreev-Bashkin or mass-density matrix. Our results can be useful for modeling the pulsations of massive neutron stars with superfluid nucleon-hyperon cores and for studies of the kinetic properties of superfluid baryon matter.

O. Majlingová, L. Majling,  
On clusters accompanying weak decay of light hypernuclei,  
Proceedings 16-th Conference of Czech and Slovak Physicists Hradec Králové, Sep-  
tember 8–11, 2008. Editor: J. Kriz, pp. 96–103.

O. Majlingová, L. Majling,  
Delayed clusters accompanying non-mesonic weak decay of the hypernuclei,  
Relativistic Nuclear Physics and Quantum Chromodynamics, (Proceedings of the  
19-th International Baldin Seminar on High Energy Physics Problems, Dubna, Rus-  
sia, September 29 – October 4, 2008.) Editors: A.N. Sissakian, V.V. Burov, A.I.  
Malakhov, S.G. Bondarenko, E.B. Plekhanov, Vol. 1, pp. 315–320.

D. Nakajima *et al.* [HypHI Collaboration],  
Scintillating fiber detectors for the HypHI project at GSI,  
Nucl. Instr. and Meth. in Phys. Res. A 608 (2009) 287-290.

Abstract:

The construction and properties of three sets of two-dimensional scintillating fiber detector arrays for tracking of charged particles used in the HypHI Phase 0 experiment at GSI will be reported in this paper. The position resolutions and the detection efficiency of detectors have been obtained for each layer of detectors by using  ${}^6\text{Li}$  primary beams and particles with  $Z = 1$  produced by fragment reactions of  ${}^{136}\text{Xe}$  projectiles on the hydrogen target. Besides, the response of energy deposition of charged particles in the first detector set placed right behind the target has been studied by using light projectile fragments with  $Z = 1, 2$  and  $3$  produced by  ${}^{58}\text{Ni}$  and  ${}^{12}\text{C}$  beams. Extracted resolutions for energy deposition and position as well as the detection efficiency fulfill the requirements of the HypHI Phase 0 experiment.

J. Pochodzalla,  
Exploring the nuclear potential of antihyperons with antiprotons at  $\bar{\text{P}}\text{ANDA}$ ,  
*Hyperfine Interact* (2009) 194:255–261, DOI 10.1007/s10751-009-0083-9

Abstract:

A schematic Monte Carlo simulation is used to examine the potential of the  $\bar{\text{P}}\text{ANDA}$  experiment to extract information on the interaction of antihyperons in nuclei by exclusive hyperon-antihyperon pair production close to threshold in antiproton nucleus interactions. Due to energy and momentum conservation event-by-event transverse momentum correlations of the produced hyperon and antihyperons contain information on the difference between their potentials. It is demonstrated that for  $\Lambda\bar{\Lambda}$  and  $\Xi\bar{\Xi}$  pairs produced at antiproton momenta of 1.66 GeV/c and 2.9 GeV/c, respectively, the asymmetry is sufficiently sensitive even if the density as well as the momentum dependencies of the potentials are considered.

S. Sánchez Majos *et al.* [KAOS-A1 Collaboration],  
Noise and radiation damage in silicon photomultipliers exposed to electromagnetic and hadronic radiation,  
*Nucl. Instr. and Meth. in Phys. Res. A* 602 (2009) 506-510.

Abstract:

For the electron arm tracking system in the KAOS spectrometer at the Mainz Microtron MAMI a detector based on 2 m long scintillating fibres read out by silicon photomultipliers (SiPM) is planned. Because of the detector's close proximity to the intense electron beam a study of noise and radiation damage in SiPM has been performed. A sample of devices was exposed directly to a 14 MeV electron beam and to a mixed radiation field in the experimental area. First noticeable effects are a large increase in the dark count rate and a severe loss of the gain uniformity.

S. Sánchez Majos, P. Achenbach and J. Pochodzalla,  
Efficiency studies for a tracking detector based on square 1.5 m long scintillating fibers read out by SiPM,  
*Nucl. Instr. and Meth. in Phys. Res. A* 610 (2009) 502-508.

Abstract:

A tracking detector based on 1.5 m long scintillating fibers is being developed for the electron arm of the KAOS spectrometer at the Mainz Microtron MAMI. Measurements on light attenuation, particle detection efficiencies and accidental coincidence rates with a prototype set-up using  $2\times 2\text{ mm}^2$  fibers read out by silicon photomultipliers (SiPM) are presented. The highest efficiency at the lowest accidental coincidence rate was reached for high trigger thresholds at the largest SiPM bias voltages.

The influence of signal attenuation and dispersion on detection efficiencies is discussed. The results are in good agreement with a Monte Carlo model that was used to predict detector characteristics for different fiber geometries.

## 1.2 Conference Presentations 2009

P. Achenbach [A1 Collaboration],  
Installation and commissioning of the KAOS spectrometer at MAMI,  
European Nuclear Physics Conference and Spring Meeting of the German Physical  
Society, Hadronic and Nuclear Physics Division, Bochum, Germany, 16–20 March  
2009.  
[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

Abstract:

At the Institut für Kernphysik in Mainz, Germany, the microtron MAMI has been upgraded to 1.5 GeV electron beam energy and can now be used to study strange hadronic systems. In recent years the compact magnetic spectrometer KAOS was installed in the existing spectrometer facility operated by the A1 collaboration. KAOS is especially suitable for the detection of kaons. Since September 2008 measurements of kaon production on hydrogen have been successfully performed. The identification of  $\Lambda$  and  $\Sigma^0$  hyperons in the missing mass has demonstrated the capability of the extended facility to perform strangeness electro-production spectroscopy. Kaons in the angular range of  $21\text{--}43^\circ$  and momentum range of  $400\text{--}600$  MeV/c were detected with a survival probability of around 10% and identified by their time-of-flight. In 2009, the KAOS spectrometer will cover simultaneously electron scattering angles close to  $0^\circ$  and kaon scattering angles around  $5^\circ$  up to  $15^\circ$  in order to extract dynamical information from the  $K^+$  angular distribution.

P. Achenbach,  
A Roadmap to hypernuclear physics at MAMI and PANDA,  
International Conference on MAMI and Beyond, Schloss Waldthausen, Mainz, Ger-  
many, 30 March – 2 April 2009.  
[<http://www.phmi.uni-mainz.de/3260.php>]

P. Achenbach  
Experimental aspects of hypernuclear physics with electron beams,  
26th Students' Workshop on Electromagnetic Interactions, Bosen (Saar), Germany,  
30 August – 4 September 2009.  
[<http://wwwa1.kph.uni-mainz.de/Bosen/>]

E. Botta,  
Recent results on mesonic and non-mesonic weak decays,  
Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Phy-  
sics, Tokai, Japan, 14-18 September 2009.

[<http://www-conf.kek.jp/hyp2009/program.html>]

E. Botta,  
Hypernuclei,  
EINN09 – 8<sup>th</sup> European Research Conference on Electromagnetic Interactions with Nucleons and Nuclei, Milos Island, Greece 27 September – 2 October 2009.

T. Bressani,  
Summary talk,  
Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009.  
[<http://www-conf.kek.jp/hyp2009/program.html>]

P. Bydžovský,  
Electroproduction of Strangeness,  
SPHERE Kick-off Meeting, Mainz, Germany, 4-5 June, 2009.

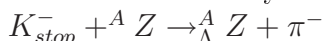
P. Bydžovský,  
Hypernuclear Physics – electroproduction of hypernuclei,  
26th Students' Workshop on Electromagnetic Interactions, Bosen (Saar), Germany, 30 August – 4 September 2009.  
[<http://wwa1.kph.uni-mainz.de/Bosen/>]

S. Bufalino [FINUDA Collaboration],  
Recent results on mesonic weak decays of  $\Lambda$ -hypernuclei with FINUDA,  
European Nuclear Physics Conference, Bochum, Germany, 10-20 March 2009.  
[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

Abstract:

Recent results obtained by analyzing the data collected up to now by the FINUDA spectrometer at the DAFNE complex at INFN-LNF in Frascati (Italy) will be presented, in particular the results on the weak  $\pi^-$ -mesonic decay channel of p-shell  $\Lambda$ -Hypernuclei will be discussed.

The study is related to the spectroscopy of negative pions spectra emitted in the mesonic weak decay of  ${}^5_{\Lambda}\text{He}$ ,  ${}^7_{\Lambda}\text{Li}$ ,  ${}^9_{\Lambda}\text{Be}$ ,  ${}^{11}_{\Lambda}\text{B}$  and  ${}^{15}_{\Lambda}\text{N}$  following the reaction:



Exploiting both the target thinness and the good transparency of the FINUDA apparatus, pion momenta as low as 80 MeV/c have been analyzed with a dedicated version of the FINUDA reconstruction code, allowing to investigate for the first time the very low momentum region of negative pion spectra, populated through

various mesonic decay mechanisms. Many-body and, when present, also two-body mesonic decay channels have been studied and the relative amplitudes,  $\Gamma_{\pi^-}$ -2body and  $\Gamma_{\pi^-}$ -tot, or branching ratios have been measured and will be presented. Comparison with existing experimental data [1] and theoretical predictions [2] will be showed.

[1] S. Kameoka et al., Nucl.Phys. A754 (2005),173. J. Sasao et al., Phys. Lett. B 579 (2004), 258.

[2] T. Motoba and K. Itonaga, Prog. Theor. Phys. Suppl. 117 (1994) 477.

S. Bufalino [FINUDA Collaboration],

Study of non mesonic weak decay of  $\Lambda$ -hypernuclei: recent results from FINUDA experiment,

European Nuclear Physics Conference, Bochum, Germany, 10-20 March 2009.

[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

Abstract:

In free space, a  $\Lambda$  particle decays dominantly as  $\Lambda \rightarrow N\pi$ . In the case of  $\Lambda$  bound in a nucleus, a  $\Lambda$  hypernucleus,  $\Lambda$  is also able to couple with a nucleon as  $\Lambda N \rightarrow nN$  (non-mesonic weak decay, NMWD). The FINUDA experiment is installed at one of the interaction regions of the DAFNE  $\Phi$ -factory in Frascati and it is mostly dedicated to the high resolution spectroscopy of  $\Lambda$  hypernuclei and to the study of their weak decays. The aim of this work is to present the recent experimental results obtained from the study of the NMWD of  ${}^5_{\Lambda}\text{He}$ ,  ${}^7_{\Lambda}\text{Li}$ ,  ${}^9_{\Lambda}\text{Be}$ ,  ${}^{11}_{\Lambda}\text{B}$ ,  ${}^{12}_{\Lambda}\text{C}$ ,  ${}^{13}_{\Lambda}\text{C}$ ,  ${}^{15}_{\Lambda}\text{N}$  and  ${}^{16}_{\Lambda}\text{O}$ . Thanks to the excellent capabilities of the FINUDA detector (measurement of the proton spectra with magnetic analysis and production from very thin targets) the spectra feature a precision and low energy threshold (15 MeV) never reached in previous experiments. The measured spectra are quite different from the ones previously reported [1] as well as from the theoretical predictions [2] ( ${}^5_{\Lambda}\text{He}$  and  ${}^{12}_{\Lambda}\text{C}$ ). Also the contribution of the Final State Interaction and/or two nucleon absorption processes [3] has been evaluated.

[1] S. Okada et al., PLB 597 (2004), 249.

[2] G. Garbarino et al., PRC 69 (2004) 054603.

[3] W.M. Alberico and G. Garbarino, Phys. Rep. 369 (2002), 1.

S. Bufalino,

Mesonic weak decay of  $\Lambda$ -Hypernuclei: a new tool for the spectroscopic study of hypernuclei,

International Conference on Nuclear reactions on Nucleons and Nuclei, Messina, Italy, 5-9 October 2009.

[<http://nucleo.unime.it/conf2009/index.html>]

L. Debenjak, S. Širca, and P. Achenbach [A1 Collaboration],  
Study of transmission and light yield of an  $n=1.07$  silica aerogel,  
European Nuclear Physics Conference and Spring Meeting of the German Physical  
Society, Hadronic and Nuclear Physics Division, Bochum, Germany, 16–20 March  
2009.

[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

Abstract:

The large momentum acceptance of the Kaos spectrometer at the Mainz Microtron MAMI requires the discrimination between kaons and pions for momenta  $\geq 1$  GeV/c. Silica aerogel with refractive index  $n \sim 1.07$  has been chosen as a Čerenkov radiator for pion suppression. The area to be covered by the aerogel ( $H \times W \sim 40 \times 200$  cm<sup>2</sup>) is governed by the focal plane of the magnetic spectrometer.

A prototype detector with two aerogel tiles of  $d = 2$  cm thickness and  $20 \times 10$  cm<sup>2</sup> total area was designed, built and tested. Modifications to the basic geometry of the prototype were tried, e.g. different kinds of polished aluminum faces were used in the interior in order to improve the reflection of photons towards the PMTs.

The behaviour of the prototype has been simulated by using Litrani, a C++/ROOT-based program. Different parameters of the aerogel (absorption and scattering) have been measured and used as input data to the simulation code. The characteristic lengths were of the order of 10 cm in the wavelength range of the produced Čerenkov photons.

During two beam-times in Oct. and Nov. 2008 at MAMI the performance of the prototype was measured with electrons, pions, and protons. The absorption and scattering losses in the aerogel tiles lead to a very low number of detected photons. Detection efficiencies were determined at different threshold settings and particle momenta.

A. Filippi,

Study of two-body non-mesonic decays of light hypernuclei with FINUDA,  
Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009.

[<http://www-conf.kek.jp/hyp2009/program.html>]

E. Friedman,

Many facets of the kaonic atoms 'puzzle',  
in arXiv:1003.2328, p.13. [Abstract of a talk presented at ECT\* Workshop. Oct. 09]

G. Garbarino,

Exchange terms and ground state correlations in non-mesonic weak decay of hypernuclei,

Workshop on Electroweak interactions with nuclei, ECT\*, Trento (Italy), October

26-30, 2009.

D. Gazda *et al.*

Multi- $\bar{K}$ (hyper)nuclei,

ECT\* Workshop on Hadronic Atoms and Kaonic Nuclei, Trento, Italy, 12-16 Oct 2009, arXiv:1003.2328v2 [nucl-ex].

E. Kim *et al.*

The HypHI Phase 0 experiment at GSI,

Korean Physical Society Annual Conference (KPS), Chang-Won, South Korea, October 21st-23rd, 2009.

J. Lukstins,

NIS-GIBS spectrometer for hypernuclear research,

The 10th International Conference on Hypernuclear and Strange Particle Physics, Tokai, Ibaraki, Japan, September 14-18, 2009.

V.K. Magas *et al.*

The in-flight C12 ( $K^-$ ,  $p$ ) reaction at KEK,

International Workshop “Hadronic Atoms and Kaonic Nuclei - solved puzzles, open problems and future challenges in theory and experiment“, ECT\*, Trento, Italy, October 12-16, 2009.

V.K. Magas *et al.*

The ( $K^-$ ,  $p$ ) reaction on  $^{12}\text{C}$  at KEK,

XXXIX International Symposium on Multiparticle Dynamics (ISMD 2009), “Gold Sands“, Gomel Region, Belarus, September 4-9, 2009.

Abstract:

We study the ( $K^-$ ,  $p$ ) reaction on  $^{12}\text{C}$  with a kaon beam of 1 GeV momentum, paying a special attention to the region of emitted protons having kinetic energy above 600 MeV, which was used to claim a deep kaon nucleus optical potential [1]. The experiment looks for fast protons emitted from the absorption of in flight kaons by nuclei, but in coincidence with at least one charged particle in the decay counters sandwiching the target. The analysis of the data is done in [1] assuming that the coincidence requirement does not change the shape of the final spectra. However our detailed calculations show that this assumption doesn't hold, and, thus, the final conclusion of this experiment is doubtful.

We perform Monte Carlo simulation of this reaction. The advantage of our method with respect to Green's function method used in [1] is that it allows to account not



only for quasi-elastic  $K^-p$  scattering, but also for the other processes which contribute to the proton spectra. We investigated the effect of the multi-scatterings and of the  $K^-$  absorptions by one and two nucleons ( $K^-N \rightarrow \pi Y$  and  $K^-NN \rightarrow YN$ ) followed by the decay of the hyperon in  $\pi N$ . We show that all these mechanisms allow us to explain reasonably well the observed spectrum with standard shallow kaon nucleus optical potential, obtained in chiral models.

[1] T. Kishimoto et al., Prog. Theor. Phys. 118, 181 (2007).

L. Majling, O. Majlingová,

Delayed clusters accompanying nonmesonic weak decay of the  $\Lambda$  hypernuclei: a clue to nonleptonic processes,

International Bogolyubov Conference “Problems of Theoretical and Mathematical Physics“ (dedicated to the 100th anniversary of the birth of N.N. Bogolyubov), Dubna, Russia, August 21-27, 2009.

L. Majling, O. Majlingová,

Delayed clusters accompanying non-mesonic weak decay of the hypernuclei,

Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009.

[<http://www-conf.kek.jp/hyp2009/program.html>]

J. Mares,

Kaon condensation and multi-strange matter,

Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009.

[<http://www-conf.kek.jp/hyp2009/program.html>]

Abstract:

We report on dynamical calculations of multi- $\bar{K}$  hypernuclei, which were performed by adding  $\bar{K}$  mesons to particle-stable configurations of nucleons,  $\Lambda$  and  $\Xi$  hyperons. The  $\bar{K}$  separation energy as well as the baryonic densities saturate with the number of antikaons. We demonstrate that the saturation is a robust feature of multi- $\bar{K}$  hypernuclei. Because the  $\bar{K}$  separation energy  $B_{\bar{K}}$  does not exceed 200 MeV, we conclude that kaon condensation is unlikely to occur in finite strong-interaction self-bound  $\{N, \Lambda, \Xi\}$  strange hadronic systems.

D. Nakajima *et al.*

Recent status of the HypHI project for hypernuclear spectroscopy with heavy ion induced reactions,

JPS annual conference, Rikkyo University, Tokyo, Japan, March 27th-30th, 2009.

B. Oezel *et al.*

Das HypHI Projekt an der GSI und an FAIR,  
The XL. Arbeitstreffen “Kernphysik“, Schleching/Obb., February 26th - March 5th,  
2009.

A. Parreño,

Few-body lattice physics,  
19th International IUPAP Conference on Few-Body Problems in Physics, Bonn,  
Germany, 31 August – 5 September 2009.

A. Parreño,

Lattice QCD simulations of baryonic interactions,  
6th International workshop on chiral dynamics, Bern, SWITZERLAND, July 6-10,  
2009.

A. Parreño,

Lattice QCD simulations of baryonic interactions,  
International workshop on effective field theories: from the pion to the upsilon  
(EFT09), Valencia, Spain, February 1-6, 2009.

J. Pochodzalla,

Statistical Decay of Excited  $\Lambda\Lambda$  Hypernuclei,  
Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Phy-  
sics, Tokai, Japan, 14-18 September 2009.  
[<http://www-conf.kek.jp/hyp2009/program.html>]

J. Pochodzalla,

Roadmap for Hypernuclear Physics in Europe,  
NUFRA2009, *Second International Conference on Nuclear Fragmentation - From  
Basic Research to Applications*, September 27 - October 4, 2009, Kemer (Antalya),  
Turkey.  
[<http://fias.uni-frankfurt.de/historical/nufra2009/>]

J. Pochodzalla,

Exploring the potential of antibaryons in nuclei with antiprotons,  
Workshop on “Physics and Upgrade of the J-PARC Hadron Facility“, September  
18th-19th, 2009 at Tokai, Japan.

T.R. Saito *et al.* [HypHI Collaboration],  
Hypernuclear Spectroscopy with Heavy Ion Beams: The HypHI project at GSI and  
towards FAIR,  
Physical Society Annual Conference (DPG), Bochum University Bochum, Germany,  
March 16th-20th, 2009.  
[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

Abstract:

Until recently hypernuclei have been mainly studied via induced reactions of meson- or electron-beams on stable target materials, therefore the isospin of the produced hypernuclei is close to that of the target nucleus. In heavy ion collisions, hyperons are produced in the participant region and can be coalesced in the projectile fragment forming a hypernucleus in the projectile rapidity region. Isospin of the produced hypernucleus is widely distributed due to the nature of fragmentation reactions, therefore, this production method gives an opportunity to study neutron or proton rich hypernuclei. Furthermore, with this method, the produced hypernuclei can be separated and their magnetic moments can be measured for the first time.

The HypHI collaboration aims to perform precise hypernuclear spectroscopy with stable heavy ion beams and rare isotope beams at GSI and FAIR. We are currently preparing for the first experiment (Phase 0) planned in 2009 with  ${}^6\text{Li}$  beams at 2 A GeV impinged on a carbon target to demonstrate the feasibility of the precise hypernuclear spectroscopy by identifying light hypernuclei mainly such as  ${}^3_{\Lambda}\text{H}$ ,  ${}^4_{\Lambda}\text{H}$  and  ${}^5_{\Lambda}\text{He}$ . In the presentation, an overview of the HypHI project and the detail of the Phase 0 experiment will be discussed.

T.R. Saito *et al.*

Unique opportunity of hypernuclear spectroscopy by means of heavy ion collision with the HypHI project at GSI and FAIR,  
Annual NuSTAR Meeting 2009, GSI Darmstadt, Germany, March 23rd-27th, 2009.

T.R. Saito *et al.*

Hypernuclear Spectroscopy with Heavy Ion Beams: The HypHI project at GSI and towards FAIR,  
SPHERE Kick-off Workshop, Mainz University, Mainz, Germany, June 4th, 2009.

T.R. Saito *et al.*

Hypernuclear Spectroscopy with Heavy Ion Beams: The HypHI project at GSI and towards FAIR,  
Korean Physical Society Annual Conference (KPS), Chang-Won, South Korea, October 21st-23rd, 2009.

S. Sánchez Majos, P. Achenbach and J. Pochodzalla [A1 Collaboration],  
Studies on SiPM radiation hardness and low light level detection,  
European Nuclear Physics Conference and Spring Meeting of the German Physical  
Society, Hadronic and Nuclear Physics Division, Bochum, Germany, 16–20 March  
2009.

[<http://bochum09.dpg-tagungen.de/index.html?lang=en>]

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. Low light level detection is challenging for these devices due to their high dark count rate. A relatively large cross-section of  $4\text{ mm}^2$  has been chosen as the optimum value for a minimal particle trajectories disturbance and a maximum detection efficiency. 100% detection efficiencies has been measured with an experimental prototype read out by a SSPM-0606BG4MM-PCB Photonique device at accidental coincidence rates of only a few Hertz. Because of the detectors close proximity to the intense electron beam a study of noise and radiation damage has been performed. SiPM have been irradiated with 14 MeV electron and exposed to mixed radiation in the experimental area. It is shown that the first noticeable damage consists of an increase in the rate of dark pulses and the loss of uniformity in the pixel gains. Realistic amounts of shielding have been tested and found to have only a relatively poor performance. Annealing has been proved to be only partially effective for SiPM recovery.

N.V. Shevchenko,

Isospin mixing  $\bar{K}N - \pi\Sigma$  interaction and  $\bar{K}NN - \pi\Sigma N$  quasi-bound state,  
SPHERE Kick-off Meeting, Mainz, Germany, 4-5 June, 2009.

M. Sotona,

Hypernuclear calculations,

International Conference on MAMI and Beyond, Schloss Waldthausen, Mainz, Germany, 30 March – 2 April 2009.

[<http://www.phmi.uni-mainz.de/3260.php>]

## 2 Year 2010

### 2.1 Publications Resulting from the Project 2010

P. Achenbach [KAOS-A1 Collaboration],  
Strangeness physics with KAOS at MAMI,  
in Proceedings of the XLVII International Winter Meeting on Nuclear Physics, Bor-  
mio, Italy, 26–30 January 2009, Italian Physical Society Conf. Proc. 99 (2010): 1–6.

Abstract:

At the Institut für Kernphysik in Mainz, Germany, the microtron MAMI has been upgraded to 1.5 GeV electron beam energy. The magnetic spectrometer KAOS is now operated by the A1 collaboration to study strangeness electro-production. Its compact design and its capability to detect negative and positive charged particles simultaneously under forward scattering angles complements the existing spectrometers. In 2008 kaon production off a liquid hydrogen target was measured at  $\langle Q^2 \rangle = 0.050 (GeV/c)^2$  and  $0.036 (GeV/c)^2$ . Associated  $\Lambda$  and  $\Sigma^0$  hyperons were identified in the missing mass spectra. Major modifications to the beam-line are under construction and a new electron arm focal-surface detector system was built in order to use KAOS as a double-arm spectrometer under zero degree scattering angle.

P. Achenbach [A1 Collaboration],  
Associated  $\Lambda/\Sigma^0$  electroproduction with the Kaos spectrometer at MAMI,  
EPJ Web of Conferences, Vol. 3 (2010), 19<sup>th</sup> International IUPAP Conference on  
Few-Body Problems in Physics, Bonn, Germany, August 31 - September 5, 2009,  
E. Epelbaum, H.-W. Hammer and U.-G. Meißner (Eds.)  
[<http://www.epj-conferences.org/>]

Abstract:

An instrument of central importance for the strangeness photo- and electroproduction at the 1.5 GeV electron beam of the MAMI accelerator at the Institut für Kernphysik in Mainz, Germany, is the newly installed magnetic spectrometer KAOS that is operated by the A1 collaboration in (e, e'K) reactions on the proton or light nuclei. Its compact design and its capability to detect negative and positive charged particles simultaneously complements the existing spectrometers. The strangeness program performed with KAOS in 2008–9 is addressing some important issues in the field of elementary kaon photo- and electroproduction reactions. Although recent measurements have been performed at Jefferson Lab, there are still a number of open problems in the interpretation of the data and the description of the elementary process using phenomenological models. With the identification of  $\Lambda$  and  $\Sigma^0$  hyperons in the missing mass spectra from kaon production off a liquid hydrogen target it is

demonstrated that the extended facility at MAMI is capable to perform strangeness electroproduction spectroscopy at low momentum transfers  $Q^2 < 0.5 (GeV/c)^2$ . The covered kinematics and systematic uncertainties in the cross-section extraction from the data are discussed.

P. Achenbach *et al.* [KAOS-A1 Collaboration],

First measurements of  $\Lambda$  and  $\Sigma^0$  hyperons in elementary electroproduction at MAMI,

Proceedings of Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009, Nucl. Phys. A 835 (2010) 313-316. [<http://www-conf.kek.jp/hyp2009/program.html>]

Abstract:

Since 2008 the magnetic spectrometer KAOS, dedicated to the detection of charged kaons, is operating at the 1.5 GeV electron beam of MAMI at the Institut für Kernphysik in Mainz, Germany. The strangeness programme performed in 2008–9 is addressing some important issues in the field of elementary kaon photoelectroproduction reactions. The identification of  $\Lambda$  and  $\Sigma^0$  hyperons in the missing mass spectra from kaon production off a liquid hydrogen target demonstrates the capability of the extended facility to perform strangeness electro-production spectroscopy at low momentum transfers  $Q^2 < 0.5 (GeV/c)^2$ . Systematic uncertainties in the cross-section extraction from the data are discussed.

P. Achenbach,

Current Issues in Kaon Photoelectro-Production off the Nucleon,

to appear in the PoS Proceedings of the XLVIII International Winter Meeting on Nuclear Physics, Bormio, Italy, 25–29 January 2010.

Abstract:

The electromagnetic kaon production amplitudes associated to  $\Lambda/\Sigma^0$  hyperons can be described by phenomenological models, most notably by a particular type of effective Lagrangian model, commonly referred to as isobar approach, in which the reaction amplitude is constructed from background and resonance terms using  $s$ -,  $t$ -, or  $u$ -channel exchange diagrammes.

Experimental data on kaon production has been collected at ELSA, SPring8, GRAAL, Tohoku, and Jefferson Lab in the past, the measurements at Jefferson Lab providing the largest kinematic coverage and statistical significance. However, ambiguities inherent in the models, some data inconsistency in the cross-sections taken at different laboratories, and the problem of missing forward angle acceptance of the experimental set-ups hinders a reliable extraction of resonance parameters. Especially the shape discrepancy at a hadronic energy of  $W \approx 1.9$  GeV is problematic, and partial-wave analyses in this energy region have produced various resonance contributions, including  $D_{13}$ ,  $P_{13}$ ,  $D_{11}$ , and  $S_{11}$  states.

Predictions for the hypernuclear photo-production cross-section strongly need a consistent and comprehensive description of the elementary process at forward kaon angles, where the current strong variation of the models is very unsatisfactory.

The situation clearly indicates that more experimental and theoretical work is needed in order to provide a comprehensive understanding of the elementary reaction. A number of new experiments are now addressing these issues, among them the charged kaon electro-production programme with the KAOS spectrometer at the Mainz Microtron MAMI.

In this work predictions of the two prominent phenomenological models, Kaon-Maid and Saclay-Lyon A, are compared for the kinematics at MAMI.

M. Agnello *et al.* [FINUDA Collaboration],

Proton spectra from Non-Mesonic Weak Decay of p-shell  $\Lambda$ -hypernuclei and evidence for the two-nucleon induced process,

Phys. Lett. B 685 (2010) 247-252.

Abstract:

New spectra from the FINUDA experiment of the Non-Mesonic Weak Decay (NMWD) proton kinetic energy for  ${}^9_{\Lambda}\text{Be}$ ,  ${}^{11}_{\Lambda}\text{B}$ ,  ${}^{12}_{\Lambda}\text{C}$ ,  ${}^{13}_{\Lambda}\text{C}$ ,  ${}^{15}_{\Lambda}\text{N}$  and  ${}^{16}_{\Lambda}\text{O}$  are presented and discussed along with the published data on  ${}^5_{\Lambda}\text{He}$  and  ${}^7_{\Lambda}\text{Li}$ .

Exploiting the large mass number range and the low energy threshold (15 MeV) for the proton detection of FINUDA, an evaluation of both Final State Interactions (FSI) and the two-nucleon induced NMWD contributions to the decay process has been done. Based on this evaluation, a linear dependence of FSI on the hypernuclear mass number  $A$  is found and for the two-nucleon stimulated decay rate the experimental value of  $\Gamma_2/\Gamma_p = 0.43 \pm 0.25$  is determined for the first time. A value for the two-nucleon stimulated decay rate to the total decay rate  $\Gamma_2/\Gamma_{\text{NMWD}} = 0.24 \pm 0.10$  is also extracted.

E. Bauer and G. Garbarino,

A Theoretical Determination of  $N_{nn}/N_{np}$  in Hypernuclear Non-Mesonic Weak Decay,

X International Conference on Hypernuclear and Strange Particle Physics (Hyp-X), Tokai, Ibaraki (Japan), September 14-18, 2009, Nucl. Phys. A 835 (2010) 430-433.

Abstract:

The ratio  $N_{nn}/N_{np}$  between the number of neutron-neutron and neutron-proton pairs emitted in the non-mesonic weak decay of  $\Lambda$ -hypernuclei is calculated within a nuclear matter formalism extended to  ${}^{12}_{\Lambda}\text{C}$  via the local density approximation. The single-nucleon emission spectra,  $N_p$  and  $N_n$ , are also evaluated. Our formalism takes care of both ground state correlations (gsc) and final state interactions (FSI). The evaluation of  $N_{nn}/N_{np}$  — which, unlike  $\Gamma_n/\Gamma_p \equiv \Gamma(\Lambda n \rightarrow nn)/\Gamma(\Lambda p \rightarrow np)$ , is an actual observable quantity in non-mesonic decay—is performed within a fully

microscopic model where a proper treatment of FSI, gsc and ground state normalization is considered. All the isospin channels contributing to one- and two-nucleon induced decays are included. Our final result for the coincidence number ratio,  $N_{nn}/N_{np} = 0.374$ , is in agreement with the KEK-E508 datum,  $(N_{nn}/N_{np})^{exp} = 0.40 \pm 0.10$ .

E. Bauer, G. Garbarino, A. Parreño and A. Ramos  
Single and double coincidence nucleon spectra in the weak decay of  $\Lambda$ -hypernuclei,  
Nucl. Phys. A 836 (2010) 199-224.

Abstract:

Single and double coincidence nucleon spectra in the weak decay of  $\Lambda$ -hypernuclei are studied within a nuclear matter formalism extended to finite nuclei via the local density approximation. With respect to previous calculations, the present work adopts a unified microscopic approach for both the one- and two-body induced mechanisms, including the channels  $\Lambda nn \rightarrow nnn$  and  $\Lambda pp \rightarrow npp$  in addition to the mode  $\Lambda np \rightarrow nnp$  already considered in earlier phenomenological studies. The propagation of the final nucleons in the residual nucleus is simulated by an intranuclear cascade code. Through the comparison of our predictions with  $^{12}\text{C}$  KEK nucleon coincidence data obtained with a nucleon kinetic energy threshold of 30 MeV and an opening angle region  $\cos \theta_{NN} \leq -0.7$  we determine  $\Gamma_n/\Gamma_p = 0.66 \pm 0.24$ . We find that the value of  $\Gamma_n/\Gamma_p$  extracted from single nucleon distributions is strongly affected by final state interaction effects. Some discrepancies between measured and calculated proton spectra are also pointed out.

E. Botta *et al.* [FINUDA Collaboration],  
Recent results on mesonic weak decay of  $\Lambda$ -Hypernuclei,  
Proc. of the Sendai International Symposium on Strangeness in Nuclear and Hadronic Systems - SENDAI08, Sendai, Japan, December 15-18, 2008, Eds. K. Maeda, S.N. Nakamura, H. Tamura, O. Hashimoto, (World Scientific Publishing Co. Pte. Ltd., Singapore, 2010) pp. 274-280.

Abstract:

The FINUDA experiment has performed a systematic study of mesonic weak decay of p-shell  $\Lambda$ -hypernuclei. Recent results on the mesonic decay spectra and ratios are illustrated and discussed.

T. Bressani and A. Feliciello,  
HPGe In Magnetic Fields,  
Nucl. Phys. News. Int. Vol. 20, No. 2, (2010) 30.



S. Bufalino *et al.* [FINUDA Collaboration],  
New results on nonmesonic weak decay of  $\Lambda$ -hypernuclei with FINUDA,  
Proc. of the Sendai International Symposium on Strangeness in Nuclear and Hadronic Systems - SENDAI08, Sendai, Japan, December 15-18, 2008, Eds. K. Maeda, S.N. Nakamura, H. Tamura, O. Hashimoto, (World Scientific Publishing Co. Pte. Ltd., Singapore, 2010) pp. 281-286.

Abstract:

The FINUDA experiment has performed a systematic study of the NonMesonic Weak Decay (NMWD) of  $\Lambda$  hypernuclei analyzing all the data collected from 2003 up to 2007. The results of a measurement of the spectra of protons coming from the NMWD of  ${}^5_{\Lambda}\text{He}$ ,  ${}^7_{\Lambda}\text{Li}$ ,  ${}^9_{\Lambda}\text{Be}$ ,  ${}^{11}_{\Lambda}\text{B}$ ,  ${}^{12}_{\Lambda}\text{C}$ ,  ${}^{13}_{\Lambda}\text{C}$ ,  ${}^{15}_{\Lambda}\text{N}$  and  ${}^{16}_{\Lambda}\text{O}$  are the subject of this paper.

A. Gal,

Overview of strangeness nuclear physics,  
in 'Strangeness in Nuclear and Hadronic Systems SENDAI08', Eds. K. Maeda et al. (WS, Singapore, 2010), pp. 9-21.

Abstract:

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

A. Gal,

$\bar{K}$ -nucleus dynamics: from quasibound states to kaon condensation,  
Chinese Phys. Rev. C (in press, 2010). [invited talk at QNP09, Sept. 09. Beijing]

Abstract:

Coupled-channel  $\bar{K}N$  dynamics near threshold and its repercussions in few-body  $\bar{K}$ -nuclear systems are briefly reviewed, highlighting studies of a  $K^-pp$  quasibound state. In heavier nuclei, the extension of mean-field calculations to multi- $\bar{K}$  nuclear and hypernuclear quasibound states is discussed. It is concluded that strangeness in finite self-bound systems is realized through hyperons, with no room for kaon condensation.

G. Garbarino,

Weak decay of hypernuclei: theory review and perspectives,  
X International Conference on Hypernuclear and Strange Particle Physics (Hyp-X), Tokai, Ibaraki (Japan), September 14-18, 2009, Nucl. Phys. A 835 (2010) 144-151.

Abstract:

A theoretical review is presented of hypernuclear weak decay, with special emphasis on the non-mesonic modes. We focus on recent progress which lead to the solution

of long-standing puzzles on the  $\Gamma_n/\Gamma_p$  ratio and on the asymmetry parameter. Perspectives for the future are also indicated.

D. Gazda, E. Friedman, A. Gal, J. Mareš,  
Kaon condensation and multi-strange matter,  
Nucl. Phys. A 835 (2010) 287-294.

Abstract:

We report on dynamical calculations of multi- $\bar{K}$  hypernuclei, which were performed by adding  $\bar{K}$  mesons to particle-stable configurations of nucleons,  $\Lambda$  and  $\Xi$  hyperons. The  $\bar{K}$  separation energy as well as the baryonic densities saturate with the number of antikaons. We demonstrate that the saturation is a robust feature of multi- $\bar{K}$  hypernuclei. Because the  $\bar{K}$  separation energy  $B_{\bar{K}}$  does not exceed 200 MeV, we conclude that kaon condensation is unlikely to occur in finite strong-interaction self-bound  $\{N, \Lambda, \Xi\}$  strange hadronic systems.

O. Hashimoto *et al.* [HKS/HES Collaboration],  
Hypernuclear Spectroscopy at JLab Hall C,  
Nucl. Phys. A 835 (2010) 121-128.

Abstract:

Since the 1st generation experiment, E89-009, which was successfully carried out as a pilot experiment of  $(e, e'K^+)$  hypernuclear spectroscopy at JLab Hall C in 2000, precision hypernuclear spectroscopy by the  $(e, e'K^+)$  reactions made considerable progress. It has evolved to the 2nd generation experiment, E01-011, in which a newly constructed high resolution kaon spectrometer (HKS) was installed and the "Tilt method" was adopted in order to suppress large electromagnetic background and to run with high luminosity. Preliminary high-resolution spectra of  ${}^7_{\Lambda}\text{He}$  and  ${}^{28}_{\Lambda}\text{Al}$  together with that of  ${}^{12}_{\Lambda}\text{B}$  that achieved resolution better than 500 keV(FWHM) were obtained. The third generation experiment, E05-115, has completed data taking with an experimental setup combining a new splitter magnet, high resolution electron spectrometer (HES) and the HKS used in the 2nd generation experiment. The data were accumulated with targets of  ${}^7\text{Li}$ ,  ${}^9\text{Be}$ ,  ${}^{10}\text{B}$ ,  ${}^{12}\text{C}$  and  ${}^{52}\text{Cr}$  as well as with those of  $\text{CH}_2$  and  $\text{H}_2\text{O}$  for calibration. The analysis is under way with particular emphasis of determining precision absolute hypernuclear masses.

In this article, hypernuclear spectroscopy program in the wide mass range at JLab Hall C that has undergone three generation is described.

V.K. Magas *et al.*

Proton emission off nuclei induced by kaons in flight,  
Phys. Rev. C 81, 024609 (2010), 20 pages

Abstract:

We study the  $(K^-, p)$  reaction on nuclei with a 1 GeV/c momentum kaon beam, paying special attention to the region of emitted protons having kinetic energy above 600 MeV, which was used to claim a deeply attractive kaon nucleus optical potential. Our model describes the nuclear reaction in the framework of a local density approach and the calculations are performed following two different procedures: one is based on a many-body method using the Lindhard function and the other is based on a Monte Carlo simulation. The simulation method offers flexibility to account for processes other than kaon quasielastic scattering, such as  $K^-$  absorption by one and two nucleons, producing hyperons, and allows consideration of final-state interactions of the  $K^-$ , the  $p$ , and all other primary and secondary particles on their way out of the nucleus, as well as the weak decay of the produced hyperons into  $\pi N$ . We find a limited sensitivity of the cross section to the strength of the kaon optical potential. We also show a serious drawback in the experimental setup - the requirement for having, together with the energetic proton, at least one charged particle detected in the decay counter surrounding the target - as we find that the shape of the original cross section is appreciably distorted, to the point of invalidating the claims made in the experimental paper on the strength of the kaon nucleus optical.

A. Parreño [NPLQCD Collaboration],

YN and YY interactions from lattice QCD simulations,

10th International Conference on Hypernuclear and Strange Particle Physics

(Hyp-X), Tokai, Ibaraki, JAPAN, 14-18 September 2009. Nucl. Phys. A 835 (2010) 184-191.

Abstract:

One of the main motivations for investing human and economic effort in Lattice QCD calculations of nuclear physics quantities is to explore sectors that cannot be accessed experimentally, or which can be measured with only limited precision. Two lines of research where such kind of calculations may have a clear impact are the study of the evolution of supernova and of the structure and decay of conventional and strange nuclei. Key ingredients for both investigations are the low energy interactions among baryons. Unfortunately, due to the short lifetime of hyperons, the interactions among baryons in the strange sector are only approximately known. The unsatisfactory amount of data coming from scattering experiments produces large uncertainties in the scattering amplitudes. Lattice QCD simulations of baryon-baryon interactions can play a crucial role, and points out as a reliable way to obtain complementary information to what can be obtained from experiments involving baryons in the low energy region.

J. Pochodzalla and A. Sanchez Lorente,

Roadmap for double hypernuclei spectroscopy at PANDA,

EPJ Web of Conferences, Vol. 3 (2010), 19<sup>th</sup> International IUPAP Conference on

Few-Body Problems in Physics, Bonn, Germany, August 31 - September 5, 2009,  
E. Epelbaum, H.-W. Hammer and U.-G. Meißner (Eds.)  
[<http://www.epj-conferences.org/>]

Abstract:

Hypernuclear Physics is currently attracting renewed attention. Thanks to the use of stored  $\bar{p}$  beams, copious production of double  $\Lambda$  hypernuclei is expected at the  $\bar{P}$ anda experiment which will enable high precision  $\gamma$ -spectroscopy of such nuclei for the first time. In the present work we have studied the population of particle stable, excited states in double hypernuclei after the capture of a  $\Xi^-$  within a statistical decay model. In order to check the feasibility of producing and performing  $\gamma$ -spectroscopy of double hypernuclei at  $\bar{P}$ ANDA, an event generator based on these calculations has been implemented in the  $\bar{P}$ ANDA simulation framework PANDAROOT.

J. Pochodzalla, A. Botvina, A. Sanchez Lorente,  
Studies of Hyperons and Antihyperons in Nuclei,  
to appear in the PoS Proceedings of the XLVIII International Winter Meeting on  
Nuclear Physics, Bormio, Italy, 25–29 January 2010.

Abstract:

Stored antiproton beams at the international FAIR facility will provide unique opportunities to study hyperons as well as antihyperons in nuclear systems. Precise  $\gamma$ -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 relativ 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  $\Xi^-$  hyperon. Generally the formation of excited hypernuclear states dominates in this model. For different initial target nuclei which absorb the  $\Xi^-$ , different double hypernuclei nuclei dominate. We also confront the model predictions with the correlated pion spectra measured by the E906 collaboration.

Due to energy and momentum conservation event-by-event transverse momentum correlations of the produced hadrons and antihadrons contain information on the difference between their nuclear potentials. For produced D-meson pairs at 6.7 GeV/c the sensitivity of the transverse momenta correlation will probably be too 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  $\Xi$  and  $\bar{\Xi}$  potentials even if the momentum and density dependence of the the potential are taken into account.

A. Ramos *et al.*

The  $(K^-, p)$  reaction on nuclei with in-flight kaons,  
10th International Conference on Hypernuclear and Strange Particle Physics, 14-18  
September, 2009, Tokai, Ibaraki (Japan). Nucl. Phys. A 835 (2010) 382-385.

Abstract:

We perform a theoretical study of the spectrum of protons with kinetic energies of around 600 MeV, emitted following the interaction of 1 GeV/c kaons with nuclei. A recent experimental analysis of this  $(K^-, p)$  reaction on  $^{12}\text{C}$ , based on the dominant quasielastic process, has suggested a deeply attractive kaon nucleus potential. Our Monte Carlo simulation considers, in addition, the one- and two-nucleon  $K^-$  absorption processes producing hyperons that decay into  $\pi N$  pairs. We find that this kaon in-flight reaction is not well suited to determine the kaon optical potential due, essentially, to the limited sensitivity of the cross section to its strength, and also to unavoidable uncertainties from the coincidence requirement applied in the experiment. A shallow kaon nucleus optical potential obtained in chiral models is perfectly compatible with the observed spectrum

T. R. Saito *et al.* [HypHI Collaboration],

The HypHI Phase 0 experiment,

Proceedings of Hyp X – 10<sup>th</sup> International Conference on Hypernuclear and Strange Particle Physics, Tokai, Japan, 14-18 September 2009, Nucl. Phys. A 835 (2010) 110-116. [<http://www-conf.kek.jp/hyp2009/program.html>]

Abstract:

The HypHI Phase 0 experiment to demonstrate the feasibility of precise hypernuclear spectroscopy with induced reactions of heavy ion beams was performed at GSI in August and October in 2009, with a projectile of  $^6\text{Li}$  at 2 A GeV impinging on carbon graphite target with a thickness of 8 g/cm<sup>2</sup>. The experiment mainly aims to reconstruct events of  $^3_{\Lambda}\text{H}$ ,  $^4_{\Lambda}\text{H}$  and  $^5_{\Lambda}\text{He}$  by observing the  $\pi^-$  decay channel. Details of the HypHI Phase 0 experiment performed in August in 2009 will be discussed.

## 2.2 Conference Presentations 2010

P. Achenbach,

New measurements on the nucleon structure with MAMI,

74th Annual Meeting of the German Physical Society with the Spring Meeting of the Hadronic and Nuclear Physics Division, Bonn, Germany, 15–19 March 2010.

[<http://bonn10.dpg-tagungen.de/index.html>]

Abstract:

The Institut für Kernphysik in Mainz is operating the microtron MAMI producing a high-quality continuous beam of electrons with an endpoint energy of 1.5–1.6 GeV for hadron and nuclear physics.

The spectrometer facility has been used to measure the proton elastic form factors with unprecedented sub-percent precision, being sensitive for the first time to detailed structures in the form factor as currently under debate. Since 2008 the magnetic spectrometer KAOS is used in the facility for kaon spectroscopy addressing some important issues in the field of elementary kaon photoelectro-production.

The Crystal Ball and TAPS set-up was equipped with a frozen-spin polarized target to perform new high-precision, high-statistics measurements of neutral meson production and polarization observables on the nucleon.

At the A4 experimental set-up new measurements of the parity violating asymmetry in elastic electron scattering were performed, leading to an improved determination of the strange quark contributions to the vector form factors of the proton.

To conclude, the electron accelerator MAMI represents a unique research tool for precision measurements with the electroweak probe that is now also covering the strangeness sector.

S. Bleser, P. Achenbach, R. Böhm, J. Pochodzalla and A. Sanchez-Lorente

[PANDA Collaboration],

Performance of silicon-strip-detectors in direct contact with absorbers for the secondary target at PANDA,

74th Annual Meeting of the German Physical Society with the Spring Meeting of the Hadronic and Nuclear Physics Division, Bonn, Germany, 15–19 March 2010.

[<http://bonn10.dpg-tagungen.de/index.html>]

Abstract:

In order to produce and detect double  $\Lambda$ -hypernuclei at the PANDA-detector at GSI, a small secondary sandwich target is foreseen. This will be composed of stacked silicon-strip-detectors and layers of absorber material,  $^9\text{Be}$ ,  $^{10,11}\text{B}$  or  $^{12,13}\text{C}$ .

$\Xi^-$ -baryons escaping the primary  $^{12}\text{C}$ -target are decelerated and the weak decay products will be identified in the secondary target. After assembling a test station, functionality-tests of silicon-strip-detectors in direct contact with absorberlayers

have been performed. The results of these test measurements will be described and the consequences for the operation of the secondary target will be discussed.

J. Mares,  
Nuclear Systems with Strangeness,  
Nordic Winter Meeting on Physics @ FAIR, Björkliden, Sweden, 21-26 March, 2010.

Abstract:

Selected topics in strangeness nuclear physics are reviewed. The discussion involves hyperon-nucleus interactions, few-body systems with hyperons, spectroscopy of Lambda hypernuclei, double- and multi-strangeness baryonic systems. We also briefly report on the study of antikaon-nucleus dynamics in the quest for kaonic nuclei.

T.R. Saito *et al.*  
First results from hypernuclei experiments at GSI,  
Annual NuSTAR Meeting 2010, GSI Darmstadt, Germany, March 1st-5th, 2010.

A. Sanchez-Lorente,  
Hypernuclear physics and TOF,  
XXXII. PANDA Collaboration Meeting, 8-12 March 2010.