INPC 2013

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FIRENZE, ITALY 2-7 JUNE 2013

Book of Abstracts

09 – Hadrons in Nuclei

Foreword

In the present booklet we have collected the one-page abstracts of all contributions (invited, oral and poster) accepted at the INPC2013 Conference in the topic

Hadrons in Nuclei

The submitted abstracts have been divided into the various topics of the Conference following mostly the indication given by the authors. In few cases, where the subject was on the borderline of two scientific areas or it appeared misplaced, the abstracts have been moved to the booklet of the more appropriate topic.

The abstracts are numbered and arranged alphabetically according to the name of the first author. In the parallel and poster sessions of the Conference, each contribution will be identified by the number of the corresponding abstract.

We wish you a pleasant and stimulating Conference.

The Organizing Committee

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HN 001.	Experimental results on antiproton–nuclei annihilation cross section at very low energies *H. Aghai-Khozani, D. Barna, M. Corradini, R. Hayano, M. Hori, T. Kobayashi, M.Leali, E. Lodi-Rizzini, V. Mascagna, M. Prest, A. Soter, K. Todoroki, E.Vallazza, L.Venturelli, N. Zurlo* Contact email: *valerio.mascagna@ing.unibs.it*
HN 002.	Study of the Λ(1116) interaction in cold nuclear matter *O. Arnold* Contact email: *oliver.arnold@mytum.de*
HN 003.	Photoproduction of Λ from the deuteron near the threshold *B. Beckford, P. Bydžovský, A. Chiba, D. Doi, T. Fujii, Y. Fujii, K. Futatsukawa, T. Gogami, O. Hashimoto, Y.C. Han, K. Hirose, S. Hirose, R. Honda, K. Hosomi, T. Ishikawa, H. Kanda, M. Kaneta, Y. Kaneko, S. Kato, D. Kawama, C. Kimura, S. Kiyokawa, T. Koike, K. Maeda, K. Makabe, M. Matsubara, K. Miwa, S. Nagao, S. N. Nakamura, A. Okuyama, K. Shirotori, K. Sugihara, K. Suzuki, T. Tamae, H. Tamura, K. Tsukada, K. Yagi, F. Yamamoto, T. O. Yamamotoi, H. Yamazaki, and Y. Yonemoto* Contact email: *brian@lambda.phys.tohoku.ac.jp*
HN 004.	Neutral Kaons in Cold Nuclear Matter *J. Berger-Chen* Contact email: *jia-chii.chen@tum.de*
HN 005.	Neutron-rich Λ-Hypernuclei study with the FINUDA experiment *E. Botta* Contact email: *botta@to.infn.it*
HN 006.	Unveiling the strangeness secrets: low-energy kaon-nucleon/nuclei interaction studies at DAΦNE *Catalina Curceanu* Contact email: *Catalina.Curceanu@lnf.infn.it*
HN 007.	Angular Distribution of ρ meson in the (γ,ρ) Reaction *Swapan Das* Contact email: *swapand@barc.gov.in*

HN 008.	ϱ meson Nucleus Optical Potential in the GeV Region *Swapan Das* Contact email: *swapand@barc.gov.in*
HN 009.	Search of strange multi-baryons in the hadronic decays of ϒ(nS) *F. De Mori, A. Filippi, S. Marcello* Contact email: *demori@to.infn.it*
HN 010.	Light nuclei and hyper-nuclei from lattice QCD *W. Detmold* Contact email: *wdetmold@mit.edu*
HN 011.	New approach to investigation of nuclei *E. G. Drukarev, M. G. Ryskin, V. A. Sadovnikova* Contact email: *drukarev@thd.pnpi.spb.ru*
HN 012.	The role of two-nucleon mechanisms in pion photoproduction on nuclei in the region of high momentum transfer *M.Egorov, A. Fix* Contact email: *egorovphysl@mail.ru*
HN 013.	Spectroscopy of η′ Mesic Nuclei via Semi-Exclusive Measurement at FAIR *H. Fujioka, K. Itahashi, S. Friedrich, H. Geissel, R. S. Hayano, S. Hirenzaki, S. Itoh, D. Jido, V. Metag, H. Nagahiro, M. Nanova, T. Nishi, K. Okochi, H. Outa, K. Suzuki, T. Suzuki, Y. K. Tanaka, and H. Weick* Contact email: *fujioka@scphys.kyoto-u.ac.jp*
HN 014.	Dynamics of multi-Λ hypernuclei in antiproton-induced reactions *T. Gaitanos, A.B. Larionov, H. Lenske, U. Mose* Contact email: *Theodoros.Gaitanos@theo.physik.uni-giessen.de*
HN 015.	Neutron-rich hypernuclei beyond ${}_{\Lambda}^{6}H$ *A.Gal, D.J. Millener* Contact email: *avragal@savion.huji.ac.il*
HN 016.	High-Resolution Hypernuclear Spectroscopy at JLab Hall A. Results and perspectives *Franco Garibaldi* Contact email*: franco.garibaldi@iss.infn.it*
HN 017.	$\pi - {}^{4}He$ interactions in the Δ resonance energy region *I. Gnesi* Contact email: *gnesi@to.infn.it*

HN 018.	A search for the K^-pp bound state in the ^{3}He(*inflight*-K^-,n) reaction at J-PARC *T. Hashimoto* Contact email: *hashimoto@nucl.phys.s.u-tokyo.ac.jp*
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HN 020.	Excited states with Λ hyperon in p orbit in $^{25}_{\Lambda}Mg$ *M. Isaka, M. Kimura, A. Dote and A. Ohnishi* Contact email: *isaka@nucl.sci.hokudai.ac.jp*
HN 021.	Feasibility Study of Pionic Atom Spectroscopy with Unstable Nuclei *K. Itahashi, H. Fujioka, R.S. Hayano, T. Nishi, K. Okochi, Y.K. Tanaka, Y.N. Watanabe* Contact email: *itahashi@riken.jp*
HN 022.	RIKEN's activity at J-PARC Hadron Hall *M. Iwasaki* Contact email: *masa@riken.jp*
HN 023.	Nonmesonic weak decay of light hypernuclei within soft $\pi + K$ meson-exchange model *Franjo Krmpotić* Contact email: *krmpotic@fisica.unlp.edu.ar*
HN 024.	Search for the η-mesic ^{4}He with WASA-at-COSY *W. Krzemien, P. Moskal, J. Smyrski and M. Skurzok* Contact email: *wojciech.krzemien@if.uj.edu.pl*
HN 025.	Manifestation of multibaryons in hadronic collisions at intermediate energies *V.I. Kukulin, M.N. Platonova* Contact email: *kukulin@nucl-th.sinp.msu.ru*
HN 026.	Spectroscopy of the Hadronic Atoms: K-N Strong Interaction Effects *A.S. Kvasikova, T.A. Florko and D.E. Sukharev* Contact email: *quantkva@mail.ru*
HN 027.	Hypernucleus production in heavy ion collision - a theoretical analysis *A.LeFèvre, Y. Leifels, C. Hartnack, J.Aichelin* Contact e-mail: *aichelin@subatech.in2p3.fr*

HN 028.	Hadronization in Nuclei – Recent Multidimensional Results from HERMES *Inti Lehmann* Contact email*: inti.lehmann@fair-center.eu*
HN 029.	Antiproton-Nucleus Interactions and Meson Production on Complex Nuclei *H. Lenske, S. Lourenço, S. Wycech* Contact email: *horst.lenskephysik.uni-giessen.de*
HN 030.	Shape evolution of Ne isotopes and Ne hypernuclei: The interplay of pairing and tensor interactions *A.Li, E. Hiyama, X.-R. Zhou, H.Sagawa* Contact email: *liang@xmu.edu.cn*
HN 031.	First measurement of low momentum dielectrons radiated off cold nuclear matter *Manuel Lorenz* Contact email: *m.lorenz@gsi.de*
HN 032.	Charmonium photoproduction in coherent and incoherent heavy ion collisions at the LHC *M.V.T. Machado* Contact email: *magnus@if.ufrgs.br*
HN 033.	Measurements of the ^{2}H($\vec{p}$, n) breakup reaction at 170MeV for the study of the three-nucleon force effects *Y. Maeda, T. Saito, H. Miyasako, T. Uesaka, S. Ota, S. Kawase, T. Kikuchi, H. Tokieda, T.Kawabata, K. Yako, T. Wakasa, S. Sakaguchi, R. Chen, H. Sakaguchi, T. Shima, T. Suzuki, A. Tamii* Contact email: *yukie@cc.miyazaki-u.ac.jp*
HN 034.	Calculations of $\overline{K}$ nuclear quasi-bound states using chiral $\overline{K}$N amplitudes *J. Mareš, N. Barnea, A. Cieplý, E. Friedman, A. Gal, D. Gazda* Contact email: *mares@ujf.cas.cz*
HN 035.	Microscopic Investigation of the Structure Characteristics and Wave functions of the Five-Body Hypernucleus H_{λ}^{5} *Lia Leon Margolin* Contact email: *lmargolin@mmm.edu*
HN 036.	J-PARC Experiment (E07) to Study Double Hypernuclei *K. Nakazawa* Contact email: *nakazawa@gifu-u.ac.jp*

HN 037.	Determination of the η′-nucleus optical potential *Mariana Nanova* Contact email: *Mariana.nanova@exp2.physik.uni-giessen.se*
HN 038.	The first precision measurement of deeply bound pionic states in ^{121}Sn *T. Nishi , G.P.A. Berg, M. Dozono, H. Fujioka, N. Fukuda, T. Furuno, H. Geissel, R.S. Hayano, N. Inabe, K. Itahashi, S. Itoh, D. Kameda, T. Kubo, H. Matsubara, S. Michimasa, K. Miki, H. Miya, Y. Murakami, M. Nakamura, N. Nakatsuka, S. Noji, K. Okochi, S. Ota, H. Suzuki, K. Suzuki, M. Takaki, H. Takeda, Y.K. Tanaka, K. Todoroki, K. Tsukada, T. Uesaka, Y.N. Watanabe, H. Weick, H. Yamada, and K. Yoshida* Contact email: *nishi@nucl.phys.s.u-tokyo.ac.jp*
HN 039.	New interpretation of the ABC effect in the basic double-pionic fusion reaction *M.N. Platonova, V.I. Kukulin* Contact email: *platonova@nucl-th.sinp.msu.ru*
HN 040.	Search for H-dibaryon at J-PARC with a Large Acceptance TPC *H. Sako, J. K. Ahn, S. H. Kim, S. J. Kim, S. Y. Kim, A. Ni, J. Y. Park, S. Y. Ryu, S. H. Hwang, S. Hasegawa, R. Honda, Y. Ichikawa, K. Imai, S. Sato, K. Shirotori, S. Sugimura, H. Fujioka, M. Niiyama, R. Kiuchi, Tanida. Ieiri, K. Ozawa, H. Takahashi, T. Takahashi, K. Nakazawa, M. Sumihara, B. Bassalleck* Contact email: *hiroyuki.sako@j-parc.jp*
HN 041.	Spectroscopy of the Pionic Atoms: Energy Shifts and Widths and π-N Strong Interaction Effects *A.N. Shakhman and I.N. Serga* Contact email: *quantsha@mail.ru*
HN 042.	The yield of kaonic hydrogen X-rays in SIDDHARTA experiment *H. Shi, M. Bazzi, G. Beer, C. Berucci, L. Bombelli, A.M. Bragadireanu , M. Cargnelli, A. Clozza, C. Curceanu, A. d'Uffizi, C. Fiorini, F. Ghio, C. Guaraldo, R. S. Hayano, M. Iliescu, T. Ishiwatari, M. Iwasaki, P. Kienle, P. Levi Sandri, V. Lucherini, J. Marton, S. Okada, D. Pietreanu, K. Piscicchia, M. Poli Lener, T. Ponta, R. Quaglia, A. Romero Vidal, E. Sbardella, A. Scordo, D.L. Sirghi, F. Sirghi, H. Tatsuno, A. Tudorache, V. Tudorache, O. Vazquez Doce, E. Widmann, B. Wünschek, J. Zmeskal* Contact email: *shx@nucl.phys.s.u-tokyo.ac.jp*
HN 043.	Search for ^{4}He-η bound states in $dd \to (^4\text{He-}\eta)_{bs} \to {}^3\text{He}p\pi^-$ and $dd \to (^4\text{He-}\eta)_{bs} \to {}^3\text{He}n\pi^0$ reactions with the WASA-at-COSY facility. *M. Skurzok, W. Krzemien, P. Moskal* Contact email: *mskurzok@gmail.com*

HN 044.	Study on $^{6}_{\Lambda}H$ hypernucleus by the (π^{-};K^{+}) reaction at J-PARC *H. Sugimura, M. Agnello, J. K. Ahn, S. Ajimura, Y. Akazawa, N. Amano, K. Aoki, H. C. Bhang, M. Endo, P. Evtoukhovitch, A. Feliciello, H. Fujioka, T. Fukuda, S. Hasegawa, S. Hayakawa, R. Honda, K. Hosomi, S. H. Hwang, Y. Ichikawa, Y. Igarashi, K. Imai, N. Ishibashi, R. Iwasaki, C. W. Joo, R. Kiuchi, J. K. Lee, J. Y. Lee, K. Matsuda, Y. Matsumoto, K. Matsuoka, K. Miwa, Y. Mizoi, M. Moritsu, T. Nagae, S. Nagamiya, M. Nakagawa, M. Naruki, H. Noumi, R. Ota, B. J. Roy, P. K. Saha, A. Sakaguchi, H. Sako, C. Samanta, V. Samoilov, Y. Sasaki, S. Sato, M. Sekimoto, Y. Shimizu, T. Shiozaki, K. Shirotori, T. Soyama, T. Takahashi, T. N. Takahashi, H. Tamura, K. Tanabe, T. Tanaka, K. Tanida, A. O. Tokiyasu, Z. Tsamalaidze, M. Ukai, T. O. Yamamoto, Y. Yamamoto, S. B. Yang, K. Yoshida* Contact email: *sugimura@scphys.kyoto-u.ac.jp*
HN 045.	Formation of strange dibaryon X(2265) in p^{+} p → K^{+} + X reaction at T_{P} = 2.5 and 2.85 GeV *K. Suzuki, P. Kienle, M. Maggiora, T. Yamazaki* Contact email: *ken.suzuki@oeaw.ac.at*
HN 046.	Missing Mass Spectroscopy of η′ Mesic Nuclei with (p, d) Reaction at GSI *Y. K. Tanaka, K. Itahashi, H. Fujioka, S. Friedrich, H. Geissel, R. S. Hayano, S. Hirenzaki, S. Itoh, D. Jido, V. Metag, H. Nagahiro, M. Nanova, T. Nishi, K. Okochi, H. Outa, K. Suzuki, T. Suzuki, Y. N. Watanabe, and H. Weick* Contact email: *tanaka@nucl.phys.s.u-tokyo.ac.jp*
HN 047.	Beam diagnostics for measurements of antiproton annihilation cross sections at ultra-low energy *K. Todoroki, H. Aghai-Khozani, D. Barna, M. Corradini, M. Hori, R. Hayano, T. Kobayashi, M. Leali, E. Lodi-Rizzini, V. Mascagna, M. Prest, A. Soter, E. Vallazza, L. Venturelli, and N. Zurlo* Contact email: *todoroki@nucl.phys.s.u-tokyo.ac.jp*
HN 048.	Six-body calculations for hyperhydrogen $^{6}_{\Lambda}H$ *Sh. Tsiklauri* Contact email: *stsiklauri@bmcc.cuny.edu*
HN 049.	p d→^{3}He η reaction beyond threshold energies *N. J. Upadhyay, B. K. Jain* Contact email: *upadhyay@nscl.msu.edu*
HN 050.	Structure of low-lying spectrum of cluster αnΛ system *B.Vlahovic, V.M. Suslov, I. Filikhin* Contact email: *vlahovic@nccu.edu*

HN 051.	Charmonium-Nucleus Bound States *A.Yokota, E. Hiyama, M. Oka* Contact email: *yokota.a.aa@m.titech.ac.jp*

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Experimental results on antiproton–nuclei annihilation cross section at very low energies

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Investigating the antiproton cross section on nuclei at low energies (1 eV – 1 MeV) is of great interest for fundamental cosmology and nuclear physics as well.

The process is of great relevance for the models which try to explain the matter/antimatter asymmetry in the universe assuming the existence of the so-called "island" where antinucleon-nucleon annihilations occur in the border region [1]. For the nuclear physics point of view, the annihilation process is considered a useful tool to evaluate the neutron/proton ratio probing the external region of the nucleus. Moreover, the cross section measured at LEAR in the 80s–90s showed an unexpected behaviour for energies below 1 MeV. The results showed a saturation with the atomic mass number against the $A^{2/3}$ trend which is known for higher energies.

The ASACUSA collaboration at CERN measured 5.3 MeV antiproton in-flight annihilation cross section on different nuclei whose results demonstrated to be consistent with the black-disk model with the Coulomb correction [2]. So far, experimental limits prevented the data acquisition for energies below 1 MeV. In 2012 the 100 keV region has been investigated for the first time [3].

We present here the results of the experiment.

[1] A. G. Cohen, A. de Rujula and S. L. Glashow, The Astrophys. Journ. 495 (1998), 539;
[2] A. Bianconi et al., Phys. Lett. B 704, (2011) 461;
[3] H. Aghai-Khozani et al., Eur. Phys. J. Plus (2012) 127: 125.

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Study of the $\Lambda(1116)$ interaction in cold nuclear matter

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The stiffness of nuclear matter in the interior of neutron stars is still an open question. The appearance of Λ(1116)-hyperons inside the star might lead to a soft equation of state due to the attractive Λ-hyperon potential. With the recent finding and precise measurement of a two solar mass neutron star, new constraints are available to examine this hypothesis. An important parameter which enters some theoretical models underlying nuclear equations of state is the strength of the hyperon potential.
To determine the value of the in-medium Λ interaction strength in cold nuclear matter at ground state density, we interpret the HADES results on Λ production in proton-niobium collisions at a beam kinetic energy of 3.5 GeV. The comparison with different transport models allows us to extract the interaction strength. In this context we discuss the influence of various parameters entering the transport model (such as production and scattering cross-sections) with help of the GiBUU code.

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Photoproduction of Λ from the deuteron near the threshold

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The electromagnetic production of strange meson and baryons continues to be a growing topic in more recent years due in part to the continual increase of beam energy at accelerator facilities. It is well known that production of strangeness on nucleons provides details about hadronic structures including form factors. With the limited available data for the neutral channel our efforts were placed there. In this report we present results on cross sections for Λ in the $\gamma d \rightarrow \Lambda X$ reaction measured at the Research Center for Electron Photon Science (ELPH) at tagged photon energies between $0.8 \leq E_\gamma \leq 1.1$ GeV. The experiment was successfully performed using the Neutral Kaon Spectometer (NKS2+) where the produced Λ was measured by exploiting the $p\pi^-$ decay channel. Momentum and angular distributions in the laboratory frame were measured in addition to the integrated cross sections for forward Λ scattering angles. From integrated measurements of Λ from γd, total cross sections of $\gamma d \rightarrow K^0 \Lambda p$ were estimated. Results were compared to theoretical calculations, where the Saclay-Lyon A (SLA) [1] and Regge-Plus-Resonance (RPR-2007) model [2] calculations compared favorably to the data.

[1] T. Mizutani, C. Fayard, G. H. Lamot, and B. Saghai. Phys Rev. C 58,75 (1998).
[2] P. Vancraeyveld et.al. Nucl. Phys. A 897,42 (2013).

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Neutral Kaons in Cold Nuclear Matter

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Since the recent discovery of a massive neutron star of 1.97 solar masses [1] the discussion about a possible existence of a condensed kaon matter inside the neutron star has been revived [2,3]. Kaons not only influence the nuclear EOS [1,2], but also play an important role for the cooling process of a neutron star [4]. Thus a better understanding of the kaon nucleon/nucleus interaction is urgently requested. For example, characteristics of the interaction such as the KN potential and the KN scattering in medium still need further investigation.

By studying proton and pion induced reactions a potential strength of $U_{KN}(\rho_0) \approx +20$ MeV was extracted from comparisons of kaon momentum distributions with transport calculations [6,7]. In contrast a potential of $U_{KN}(\rho_0) \approx +40$ MeV was deduced from a heavy ion experiment, thus providing a puzzle about the exact strength of the KN potential [5]. One of the possible reasons is the unsufficient knowledge of in-medium KN scattering. In order to pin down the respective cross section more high quality data are needed.

In this contribution we present high statistics K^0_S data from p+p and p+^{93}Nb collisions at $E_{kin} = 3.5$ GeV obtained with the HADES detector at GSI. The p+p data serve as the reference for the proton+nucleus data. Good statistics in both data sets allow differential analysis in p_t-y and angular distributions in momentum bins. As in-medium effects, such as the KN potential and the KN scattering cross sections, will be extracted from p+^{93}Nb analysis with the help of transport models, a good description of the p+p data by the models is required. Therefore, production cross sections of single reactions (e. g. $p + p \to Y + \Delta^{++} + K^0$, $p + p \to Y + p + \pi^+ + K^0$) are needed as a constraint for the transport models. Results of the ongoing investigation will be presented in the contribution.

[1] P.B. Demorest et al., Nature 467, 10811083 (2010);
[2] K. Masuda et al., arXiv:1205.3621[nucl-th] (2012);
[3] K. Kim et al., Phys. Rev. C 84, 035810 (2011);
[4] S. Kubis et al., Nucl. Phys. A, 720 189-206 (2003);
[5] G. Agakishiev et al., Phys. Rev. C 82, 044907 (2010);
[6] M. Büscher et al., Eur. Phys. J. A 22, 301-317 (2004);
[7] M.L. Benabderrahmane et al., PRL 102, 182501 (2009).

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Neutron-rich Λ-Hypernuclei study with the FINUDA experiment

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Λ-hypernuclei are long lived systems in which the Λ hyperon acts as constituent nucleon. The strangeness degree of freedom of the hyperon makes the Pauli exclusion principle ineffective on it and allows the Λ to populate sharp single particle shell model states down to the Λ(1s) ground state.

In Λ-hypernuclei, then, a strong contribution to the total binding energy is added by the Λ, with the possibility of producing bound systems containing unstable core nuclei (glue-like rôle of the Λ). Λ-hypernuclei are thus suitable tools for investigating neutron-rich (proton-rich) systems, even beyond the neutron (proton) drip line.

The study of neutron-rich Λ-hypernuclei is one the main topics of the scientific program of the FINUDA experiment which has completed its operation at DAΦNE, the INFN-LNF (e^+, e^-) collider working at the Φ(1020) center of mass energy. FINUDA has performed an extensive search for bound neutron-rich Λ-hypernuclear states. In the first data taking (2003-2004), ${}^{6}_{\Lambda}$H, ${}^{7}_{\Lambda}$H and ${}^{12}_{\Lambda}$Be have been investigated by looking at the π^+ from the double charge exchange (K^-_{stop}, π^+) production reaction; upper limits for the production rates have been reported [1]: $R_{\pi^+}({}^{6}_{\Lambda}\mathrm{H}) < (2.5 \pm 0.4_{\mathrm{stat}}{}^{+0.4}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$, $R_{\pi^+}({}^{7}_{\Lambda}\mathrm{H}) < (4.5 \pm 0.9_{\mathrm{stat}}{}^{+0.4}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$ and $R_{\pi^+}({}^{12}_{\Lambda}\mathrm{Be}) < (2.0 \pm 0.4_{\mathrm{stat}}{}^{+0.3}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$.

In the second data taking (2006-2007) a ∼5 times larger statistics has been collected and a new analysis technique has been applied for the search of bound ${}^{6}_{\Lambda}$H and ${}^{9}_{\Lambda}$He, based on the coincidence between a π^+ from the (K^-_{stop}, π^+) production reaction and a π^- from the two body mesonic weak decay of the hypernucleus to $\pi^- +^6 He_{g.s.}$. With this method the existence of ${}^{6}_{\Lambda}$H as a bound state has been assessed, based on 3 clearly identified events, with a binding energy B_Λ=(4.0±1.1) MeV, with respect to ^{5}H+Λ; and a production rate $R_{\pi^+}({}^{6}_{\Lambda}\mathrm{H})$= (5.9±4.0)·$10^{-6}$/$K^-_{stop}$ [2,3] has been evaluated. Indications on the structure of the ${}^{6}_{\Lambda}$H energy levels have been obtained from a systematic difference among the ${}^{6}_{\Lambda}$H mass evaluated from production and decay reactions.

The same method has been applied to the search for bound ${}^{9}_{\Lambda}$He, which is interesting since it could be a neutron-halo Hypernucleus. No event was found and an upper limit for its production, $R_{\pi^+}({}^{9}_{\Lambda}\mathrm{He})$¡(5.0±4.1) ·$10^{-6}$/$K^-_{stop}$, was deduced [4].

In the presentation a review of all observed neutron-rich Λ-hypernuclei will be given, with particular emphasis on the FINUDA results and on their discussion.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Unveiling the strangeness secrets:

low-energy kaon-nucleon/nuclei interaction studies at DAΦNE

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The low-energy QCD in the strangeness sector is still lacking fundamental experimental results in order to arrive to a breakthrough in its understanding. Part of this information is provided by the low-energy kaon-nucleon/nuclei interaction studies, both as kaonic atoms and nuclear processes.

Combining the excellent quality kaon beam of the DAΦNE collider with new experimental techniques, as fast and very precise X ray detectors like the Silicon Drift Detectors and almost full acceptance detector of charged and neutral particles as KLOE, we have performed unprecedented measurements in the framework of SIDDHARTA and AMADEUS Collaborations.

The kaonic atoms, as kaonic hydrogen and kaonic deuterium, provide the isospin dependent kaon-nucleon scattering lengths from the measurement of X rays emitted in the de-excitation process to the fundamental 1s level of the excited formed atom. The most precise kaonic hydrogen measurement was performed by the SIDDHARTA collaboration, which realized, as well, the first exploratory measurement for kaonic deuterium ever. Additional important measurements of more complex systems, as kaonic helium 3 and kaonic helium 4 were as well done (the kaonic helium 3 was measured for the first time as well). Presently, a major upgrade of the setup, SIDDHARTA-2 is ready to perform in the near future a precise measurement of kaonic deuterium and other exotic atoms.

The kaon – nuclei interactions are being measured by the AMADEUS collaboration for kaon momenta smaller than 100 MeV/c by using the KLOE detector implemented in the central region with a dedicated setup. Preliminary results for the interaction of negatively charged kaons with various type of nuclei will be shown, including an analyses of the mysterious Λ(1405). Future plans will be discussed.

DAΦNE, with SIDDHARTA, SIDDHARTA-2 and AMADEUS, represents an opportunity which is unique in the world to, finally, unlock the secrets of the QCD in the strangeness sector, with important consequences going from particle and nuclear physics to astrophysics.

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Angular Distribution of ρ meson in the (γ,ρ) Reaction

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We calculate the angular distribution of the ρ meson produced in the (γ,ρ) reaction on ^{12}C nucleus. This meson is probed by the dielectron emission at Jefferson Laboratory [1] for its momentum range: k_ρ(GeV/c) = 0.8-3.0. Since the kinetic energy of the ρ meson is much higher than its potential energy, we approximate the propagation this meson by the eikonal form [2]:

$$G_\rho(\mathbf{r}'-\mathbf{r}) = \delta(\mathbf{b}'-\mathbf{b})\theta(z'-z)\, exp\,[i\, \mathbf{k}_\rho.(\mathbf{r}'-\mathbf{r})]\, D_\rho, \qquad (1)$$

where D_ρ is given by

$$D_\rho = -\frac{i}{2k_\rho}\exp\left[\frac{i}{2k_\rho}\int_z^{z'} dz''\{\tilde{G}_{0\rho}^{-1}(m) - 2E_\rho V_{O\rho}(b,z'')\}\right] \qquad (2)$$

with $\tilde{G}_{0\rho}^{-1}(m) = m^2 - m_\rho^2 + i m_\rho \Gamma_\rho(m)$. The symbols carry their usual meanings. $V_{O\rho}$ is the ρ meson nucleus optical potential which can be obtained by folding the elementary ρ meson nucleon t-matrix with the nuclear density distribution [2].

We plot in figure 1 the calculated angular distribution of the ρ meson. This figure shows that the ρ meson of momentum 0.8 to 3.0 GeV/c is emitted distinctly in the forward direction.

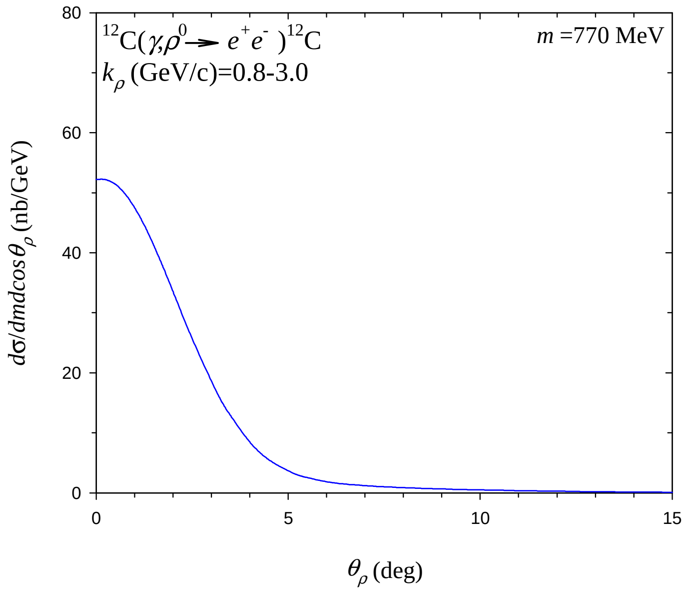

Figure 1: *Angular distribution of the ρ meson for its momentum k_ρ(GeV/c)=0.8-3.0.*

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ρ meson Nucleus Optical Potential in the GeV Region

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We calculate the momentum dependent ρ meson nucleus optical potential $V_{O\rho}(\mathbf{r})$ which can modify the hadronic parameters of the ρ meson in the nucleus. This potential can be obtained by folding the elementary ρ meson nucleon t-matrix with the nuclear density distribution [1], i.e.,

$$V_{O\rho}(\mathbf{r}) = -\frac{1}{2} v_\rho [i + \alpha_{\rho N}] \sigma_t^{\rho N} n_A(\mathbf{r}), \quad (1)$$

where v_ρ is the velocity of the ρ meson. $\alpha_{\rho N}$ is the ratio of the real to imaginary part of the ρ meson nucleon scattering amplitude $f_{\rho N}$. $\sigma_t^{\rho N}$ is the corresponding total cross section. In the GeV region, these quantities can be extracted from the elementary ρ meson photoproduction ($\gamma N \to \rho N$) data [2]. In fact, the vector meson dominance model relates the reaction amplitude $f_{\gamma N \to \rho N}$ to $f_{\rho N}$ [2]. $n_A(\mathbf{r})$ appearing in the above equation represents the nuclear density distribution, obtained from the electron nucleus scattering data [3].

We evaluate the real and imaginary parts of the ρ meson optical potential for $n_A(0) \approx 0.17$ fm^{-3} in the ρ meson ^{12}C cm system. In figure below, we show them for the ρ meson momentum k_ρ lying between 0.8 to 3 GeV/c.

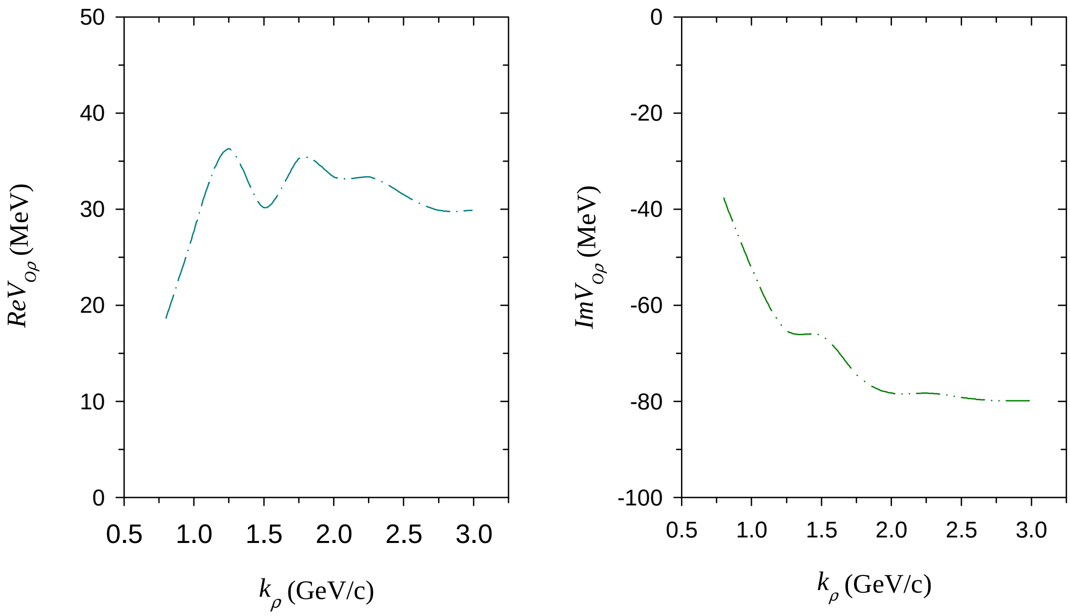

Figure 1: *Variation of the ρ meson optical potential with its momentum.*

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Search of strange multi-baryons in the hadronic decays of Υ(nS)

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The baryonic production in the hadronic decays of Υ(nS) has been found enhanced of about a factor of two relative to the continuum hadronization by CLEO [1] and previous experiments due to the dominant decay of $\Upsilon(1S)$ to ggg and ggγ (B.R. 80%).
Measurements of antideuteron production in Υ(nS, n=1, 2,3,4) resonance decays and in the nearby continuum had been performed by ARGUS [2] and CLEO [3]. In this case the experimental data seem to favor a coalescence mechanisms for this production.
These results encourage to search [4] for slightly more complex baryons in the hadronic decay of Υ, like Λ(1405) or possible strange multi-baryonic clusters (as K^-NN) whose existence is still debated.
The B factories represent an environment completely different from those in which these searches have been carried out up to now [5] and the observation of a signature of these states could cast new light on the understanding of strange nuclear matter. The possibility of such a search will be presented in this talk.

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Light nuclei and hyper-nuclei from lattice QCD

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Theoretical nuclear physics is undergoing a transition, in which the long promised connection to the underlying Standard Model is beginning to be explored quantitatively using the lattice field theory methods. Growth in the available computational resources and significant advances in algorithms have made it possible to study light nuclei and hyper-nuclei directly from QCD for the first time [1], albeit at quark masses heavier than those in nature. In addition, the low-energy nucleon-nucleon scattering phase shifts have also been extracted from lattice QCD calculations [2], paving the way for the investigation of more complex systems. I will summarize the calculational approach, present recent results of ongoing studies, and outline the impact and future directions of these calculations.

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NEW APPROACH TO INVESTIGATION OF NUCLEI

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It is well known that the standard approach to description of nucleon in nuclear matter, based on the conception of interaction between the point-like nucleons faces many problems connected with the short distances. On the other hand the strong interactions are known to become increasingly simple at short distances due to the asymptotic freedom of the Quantum Chromodynamics (QCD). It is tempting to use this feature of the QCD in building the nuclear forces. Our approach is based on extension of the QCD sum rules (SR) method in vacuum [1] to the systems with finite density of the baryon quantum number. It is based on the dispersion relations for the function, describing the space-time propagation of the system which carries the quantum numbers of the hadron. Due to the asymptotic freedom of the QCD it became possible to connect the strong interactions at the distances of the order of the confinement radius with those at much smaller distances, where the interactions are determined by the QCD condensates. Thus we expect that the parameters of the nucleon in nuclear matter can be expressed in terms of the in-medium values of the QCD condensates.

The generalization of the SR method for the case of the nucleon in nuclear matter which was started in [2]was not straightforward. One of the main problems was the choice of the variables which enabled to separate the singularities connected with the in-medium nucleon from those connected with the medium itself. Dependence of the Dirac effective mass m^* and the vector self energy Σ_v on the QCD condensates of the lowest dimension $d = 3$ (the vector and scalar ones) was found. The vector condensate was calculated, it is proportional to the nuclear density ρ. The linear part of the scalar condensate (shown to be the most important part close to the saturation density) was presented in terms of the pion-nucleon σ-term which can be expressed in terms of the amplitude of elastic πN scattering. The SR approach provided reasonable values for m^* and Σ_v at the phenomenological value of the saturation density.

These results were not altered by inclusion of the higher condensates which were calculated in framework of relativistic quark models of the nucleon. The four-quark condensates beyond the gas approximation provided the three-nucleon forces in a natural way. Thus we calculated the nucleon self-energies and traced their density dependence. Turning to the meson-exchange picture of the nucleon interaction, in SR approach the exchange by strongly correlated quark systems (mesons) is expressed in terms of weakly correlated quark systems (radiative corrections were included) with the same quantum numbers.

The approach proved itself to be a consistent tool for solving various problems of nuclear physics-see [3], where the work of several groups is reviewed. Among these problems are those which are difficult or unaccessible for the standard methods. For example, the SR approach enabled to investigate internal structure of the nucleon, providing some features of the EMC effect.We show that the nonlinear contributions to the scalar condensate $\kappa(\rho)$ are provided by the pion cloud. Its simplified inclusion signals on a possible saturation mechanism. The rigorous treatment leads to a self-consistent scenario. The pion propagator, renormalized by the interactions in the matter depends on the nucleon effective mass m^*, and thus the condensate κ depends on $m^*(\rho)$. On the other hand, the SR approach enables to calculate the dependence $m^*(\kappa)$. Hence, solution of the self-consistent equations provide the dependencies $m^*(\rho)$ and $\kappa(\rho)$. Inclusion of the hyperons enables to trace the phase transitions of the matter. Note that the approach can be applied also for investigation of the systems with a finite density of strange baryons.

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The role of two-nucleon mechanisms in pion photoproduction on nuclei in the region of high momentum transfer.

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The contribution of two-nucleon mechanisms into quasi-free photoproduction of pions on p-shell nuclei is studied. In addition to the single-nucleon knockout A(γ,πN)B the channels with two free nucleons in the final state A(γ,πNN)B′ are considered. The simple spectator [1] model is shown to be unable to provide reliable description of the reaction in the kinematical region corresponding to high momentum transferrred to the residual nucleus [2]. Within this model the interaction between the final particles is ignored (or is taken into account as a mere absorption of the produced pions). As a result there is a strong mismatch between the large initial nucleon momentum needed to produce the pion in this region and the average available momentum in the target nucleus. Inclusion of interaction in the fianl state provides an efficient mechanism to compensate this momentum mismatch through the collision between the final particles. As a consequence inclusion of mechanisms where two nucleons are actively involved into reaction leads to a strong enhancement of the pion production rate in the high momentum transfer region. As the most important two-nucleon mechanisms appearing in the reaction A(γ,πNN)B′ we considered rescattering between the knocked-out nucleons, as well as pion rescattering and double pion photoproduction with the subsequent absorption of one of the pions on the second nucleon.

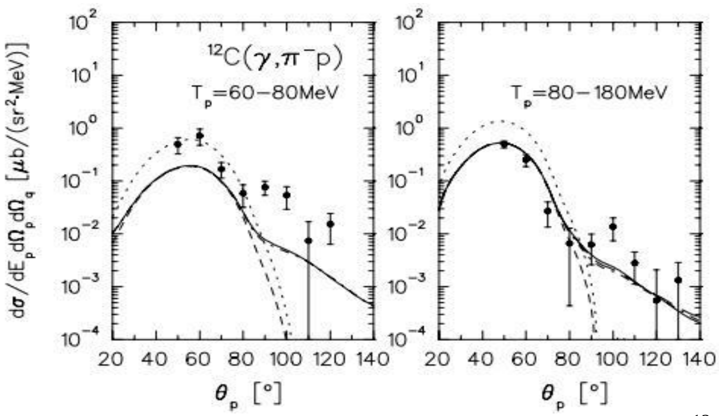

Figure 1: *Differential cross section for quasifree pion photoproduction on ^{12}C. Data from Ref. [3]. The dotted, dashed and the solid lines correspond to the spectator model, inclusion of the final particle absorption and to full calculation where two nucleon mechanisms are taken into account. The dash-dotted line is obtained if only interaction between the knocked-out nucleons is added to the spectator model.*

Among the considered mechanisms, the role of NN interaction is shown to be the most significant (dash-dotted curve in Fig.1). Its inclusion provides sizable improvement of the model and leads to much better agreement with the existing data [3].

The work has been done with financial support of “Dynasty” foundation.

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Spectroscopy of η' Mesic Nuclei via Semi-Exclusive Measurement at FAIR

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The peculiarly large mass of an η' meson is theoretically attributed to the interplay between chiral symmetry breaking and axial anomaly [1]. Accordingly, at finite density, where chiral symmetry is partially restored, the η' mass may be reduced. For example, the Nambu–Jona-Lasinio model suggests that the mass reduction at the normal nuclear density amounts to $150\,\mathrm{MeV/c^2}$ [2]. This indicates that the interaction between an η' meson and a nucleus is attractive, and that an η'-nucleus bound state may exist. While there is no experimental information on the strength of the interaction nor the existence of the bound state, a small absorption width of η' at the normal nuclear density (15–$25\,\mathrm{MeV}$) is reported by CBELSA/TAPS [3]. The suggested narrow absorption width stimulates an experimental study of η' mesic nuclei.

As a first step, we plan to carry out a missing-mass spectroscopy experiment at GSI, by using the (p,d) reaction on ^{12}C target [4] in the near future. We will adopt an *inclusive* measurement, where we detect the ejectile deuteron by the fragment separator FRS as a spectrometer. While the background mainly from quasi-free multi-pion production processes ($p + N \to d + \pi$'s) dominates, the observation of an excited state η' mesic nuclei near the η' production threshold may be realistic, according to the theoretical calculation [5] and the background evaluation.

As a possible extension, we are investigating a feasibility to carry out a *semi-exclusive* measurement with an additional proton tagging from the decay of η' mesic nuclei, such as $\eta' N \to \pi N$, $\eta' N \to \eta N$, $\eta' NN \to NN$. Such a coincidence measurement will be enabled with the fragment separator SuperFRS at FAIR, which is under construction, since the region between the pre-separator and the main separator is wide enough to install the proton-tagging counter as well as the carbon target. The counter will be located at a a backward angle, in order to suppress the influence of the multi-pion production processes as much as possible.

In this contribution, the concept of the experiment with SuperFRS/FAIR, as well as the R&D status of the proton-tagging counter system, will be discussed.

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Dynamics of multi-Λ hypernuclei in antiproton-induced reactions

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The knowledge of hyperon-nucleon and hyperon-hyperon interactions is essential for a deeper understanding of baryonic matter as found, e.g., in nuclear astrophysics. Strangeness dynamics is still a widely debated theoretical and experimental topic of current research. Reactions induced by heavy-ions and (anti)hadron beams on nuclear targets offer a promising opportunity to explore the still little known strangeness sector of the equation of state at ordinary nuclear densities and beyond. In such reactions, which will be experimentally studied at the forthcoming FAIR and J-PARC facilities, we investigate the formation and propagation of strangeness particles with the associate production of multi-strange hypernuclei using a dynamical transport model (Giessen Boltzmann-Uehling- Uhlenbeck, GiBUU) [1] extended by a statistical approach (Statistical Multifragmentation Model, SMM) [2] of fragment formation. First theoretical predictions on a quantitative level on spectra and inclusive cross sections of double-Λ hypernuclei have been already reported in Ref. [3]. Recently, in-medium dependences of the elementary hyperon-nucleon channels have been studied [4], by solving the in-medium Bethe-Salpeter equation. A strong density dependence of the hyperon-nucleon cross sections was found, particularly, at low energies. Note that for the formation of hypernuclei slow-moving hyperons are necessary [3]. It is therefore of particular interest to study the in-medium effects, arising from the elementary channels as well as from the hyperon-nucleon (and also kaon-nucleon) mean-fields, in reaction dynamics. In this contribution we discuss in detail these in-medium dependences on the production of strangeness and hypernuclei in reactions induced by antiproton beams.

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Neutron-rich hypernuclei beyond ${}^{6}_{\Lambda}$H

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Recent experimental evidence presented by the FINUDA Collaboration for a particle-stable ${}^{6}_{\Lambda}$H [1] has stirred renewed interest in charting the limits of particle-stable neutron-rich Λ hypernuclei, particularly when the nuclear core is unbound. Ongoing few-body calculations of ${}^{6}_{\Lambda}$H have been reported in HYP2012 [2], and a (π^-, K^+) experiment on ^{6}Li and ^{9}Be targets is underway at J-PARC [3].

We have studied theoretically within a shell-model approach several neutron-rich Λ hypernuclei in the nuclear p shell that may be formed in (π^-, K^+) or in (K^-, π^+) reactions on stable nuclear targets. The relevant hypernuclear shell-model matrix elements are taken from a theoretically-inspired successful fit [4] of γ-ray transitions in p-shell Λ hypernuclei [5] which includes also $\Lambda N \leftrightarrow \Sigma N$ coupling. Predictions will be given for the binding energies of ${}^{9}_{\Lambda}$He, ${}^{10}_{\Lambda}$Li, ${}^{12}_{\Lambda}$Be, ${}^{14}_{\Lambda}$B. None of the large effects conjectured by Akaishi and Yamazaki [6] to arise from $\Lambda N \leftrightarrow \Sigma N$ coupling is borne out by these detailed realistic shell-model calculations. This is evident from the relatively modest $\Lambda N \leftrightarrow \Sigma N$ component of the total beyond-mean-field contribution to the Λ hypernuclear g.s. binding-energy, marked $\Delta B_{\Lambda}^{\rm g.s.}$ in Table 1. A detailed exposition will be given during the presentation.

Table 1: Beyond mean field $\Delta B_{\Lambda}^{\rm g.s.}$ shell-model contributions (in keV) to g.s. of neutron-rich hypernuclei

target ^{A}Z	n–rich ${}^{A}_{\Lambda}(Z-2)$	less $2n$ ${}^{(A-2)}_{\Lambda}(Z-2)$	$\Lambda-\Sigma$ last $2n$	$\Lambda-\Sigma$ total	induced $l_N \cdot s_N$	$\Delta B_{\Lambda}^{\rm g.s.}$ total
^{6}Li	${}^{6}_{\Lambda}$H(0^+)	${}^{4}_{\Lambda}$H(0^+)	101	101	176	278
^{9}Be	${}^{9}_{\Lambda}$He($\frac{1}{2}^+$)	${}^{7}_{\Lambda}$He($\frac{1}{2}^+$)	152	253	619	879
^{10}B	${}^{10}_{\Lambda}$Li(1^-)	${}^{8}_{\Lambda}$Li(1^-)	115	275	595	1022
^{12}C	${}^{12}_{\Lambda}$Be(0^-)	${}^{10}_{\Lambda}$Be(1^-)	123	158	554	748
^{14}N	${}^{14}_{\Lambda}$B(1^-)	${}^{12}_{\Lambda}$B(1^-)	152	255	458	785

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

High-Resolution Hypernuclear Spectroscopy at JLab Hall A. Results and perspectives

Franco Garibaldi (INFN Roma1), on behalf of the Jlab Hall A hypernuclear collaboration

Hypernuclear spectroscopy via electromagnetic induced reactions is a valuable and powerful way to study hypernuclei, hadronic systems with non-zero strangeness content, providing an alternative to the hadron induced reactions mainly studied so far. Electron-induced hypernuclear spectroscopy has been studied in Hall A at Jefferson Lab [1] on three nuclei, ^{12}C, ^{16}O, and ^{9}Be with unprecedented resolution and with an improved particle identification system, using a RICH detector, in order to unambiguously identify kaons, thus allowing the measurement of high-quality, almost background-free, hypernuclear spectra. Two superconducting septum magnets were added to the existing apparatus in order to permit particle detection at very forward angle providing a reasonable counting rate. These studies have provided the first quantitative information on core-excited states in hypernuclei. In the case of oxygen, a waterfall target has been employed allowing for the simultaneous measurement of hypernuclear production on oxygen and of elementary kaon-Λ electro-production on protons: a crucial measurement to disentangle the contribution of the elementary reaction from the measured hypernuclear production cross section, yielding direct access to the nucleus-hypernucleus transition structure. A Λ binding energy value for $^{16}_{\Lambda}$N calibrated against the elementary (e, e′K^{+}) reaction on hydrogen, has been obtained. Final results for ^{12}C, ^{16}O, ^{9}Be will be presented [1-3]. Results of Hall C experiments will be presented in another talk in this Conference. Since it is essential for further theoretical study of hypernuclei to collect enough information about L production on nucleons and about excitation spectra of a wide variety of Λ hypernuclei, a continuation of the successful hypernuclear program at JLab is very desirable. For these reasons Hall A and Hall C Jefferson Lab hypernuclear collaborations decided to merge and propose a new layout for the 12 GeV Jefferson Lab era that has the advantages of both the experimental setups. In fact the new experimental design not only widens and deepens the physics range but also dramatically improves production yield and efficiency allowing to study both mass spectroscopy on a wide range of nuclei (from few body to ^{208}Pb) and pion decay spectroscopy at the same time [4]. Figs.1, 2 show the results obtained for ^{12}C and ^{16}O. Fig. 3 shows the new layout.

Fig.1 $^{12}_{\Lambda}$B excitation-energy spectrum

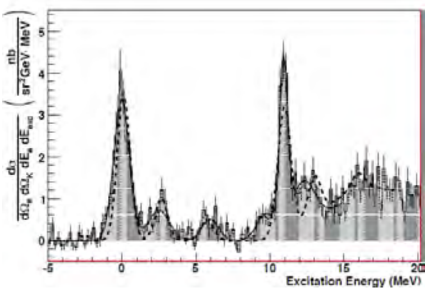


Fig.2 $^{16}_{\Lambda}$N binding-energy spectrum

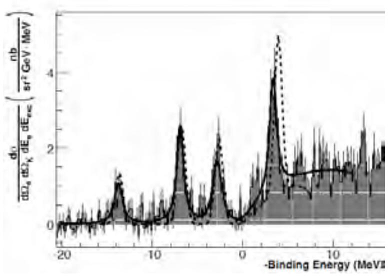
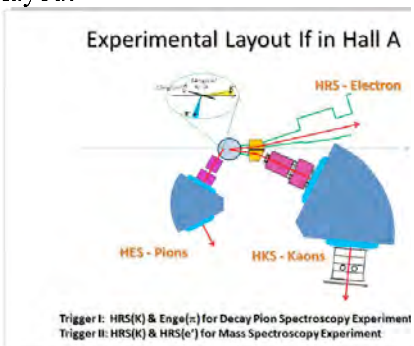


Fig 3 The new experimental layout



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2. M. Iodice et al., Phys. Rev. Lett. 99, 052501 (2007).
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$\pi - {}^4$He interactions in the Δ resonance energy region

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PAINUC experiment obtained the first experimental evidence for the presence of a radiative interaction channel in π^4He interaction: $\pi^{\pm 4}$He$\rightarrow$ $\pi^{\pm 4}$Heγ. The main physical feature of the channel is the good agreement of the γs energy distributions with the radiation distributions of a Planck blackbody at T$\sim$16 MeV. Besides, the first experimental observation of the excitation of the Δ^- resonance, below the threshold energy for pion production, has been obtained. The resonant invariant mass of the π^-n system has been measured at M$_{\pi n}$ =(1157 $\pm$ 14) MeV/c^2 with a width Γ =(38$\pm$ 2) MeV/c^2, thus shifted with respect to the free nucleon Δ values. The resonance has been found to be formed at high three-momentum transfer and at low Q^2, suggesting that its excitation involves more than one nucleon.
The positive pion absorption reaction (π^+ ^{4}He $\rightarrow$ 3pn) in the Δ resonance energy region shows strong angular correlations and weak Final and Initial State Interactions (FSI/ISI) among final state nucleons, for all the different two-nucleons and three-nucleons systems. On the basis of model-independent kinematical arguments the branching ratio of pion absorption on systems of three or four nucleons has been evaluated to be $\sim$14%; even if signatures of pd absorption are observed, where the slow proton is just a spectator, interesting signatures of pure 3-4 nucleon absorption are also present, supporting the hypothesis of the excitation of a nuclear collective resonance.

According to the experimental findings, the physical features of the π induced collective resonance have been extracted, according to a two parameters semi-empirical model, by fitting data from a collection of resonant πA elastic scattering cross sections. The contributions to the total binding energy per each additional nucleon has been found to be E$_B$ >50 MeV, being 7 times more than the binding energy per nucleon in ^{4}He; the interaction strength with the surrounding nuclear medium seems to steeply fall within a range of 1 fm [1].

The direct measurement of the muon neutrino mass is also being studied at PAINUC since the most accessible channel for its direct study is the pion decay. A high precision simulation has been performed, studying the limits on m_ν imposed by π/μ momentum resolutions and masses. The required resolution for resolving a 1 keV/c^2 neutrino is 1 meV/c: this value can be reached in a near future. The poor pion mass resolution, at present 350 eV, heavily constrains the accessible m_ν sector above 419 keV/c^2. Finally, from a set of $\pi^\pm$ decays, collected at PAINUC, new upper limits of the muon (anti)neutrinos have been extracted.

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A search for the K^-pp bound state in the ^{3}He(*inflight*-K^-,n) reaction at J-PARC

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Kaonic nuclei are extremely valuable systems to understand the $\bar{K}$N interaction and the possible nuclear shrinkage caused by $\bar{K}$ meson. Especially, the simplest kaonic nuclear state, K^-pp, is recently attracting great interest in both experimental and theoretical fields. Many theoretical calculations have been progressed for the K^-pp system, resulting in various binding energy and width predictions. Experimentally, however, only a small amount of information is available, which is not sufficient to discriminate between a variety of conflicting interpretations.

In this situation, we are carrying out an experimental search of the K^-pp bound state at J-PARC K1.8BR beam-line [1]. The most important key of our experiment is the inflight (K^-,n) reaction at 1 GeV/c. At this reaction, neutron backgrounds from non-mesonic two-nucleon absorptions or hyperon decays are expected to be substantially suppressed and kinematically separated. In addition, by using a liquid ^{3}He target and a large acceptance detector surrounding it, we can detect decay particles from "K^-pp" to fully reconstruct the reaction kinematics. For this purpose, we have constructed a new spectrometer system (fig. 1) [2], which has a quite unique feature of having large-acceptance high-resolution neutron detector system in the forward direction. A cylindrical detector system (CDS) is also developed for the detection of decay particles from the liquid ^{3}He target.

A commissioning of the brand-new beam line and the spectrometer system has been completed. Figure 2 is a semi-inclusive (requiring 1 charged track in CDS) neutron $1/\beta$ spectrum of the ^{3}He(K^-, n) reaction obtained in the engineering run in June, 2012. The clear gap between the γ-ray peak and the broad neutron distribution shows a well suppressed background. Both the missing-mass resolution of this reaction and the invariant-mass resolution for the "K^-pp" $\rightarrow \Lambda p$ decay mode were revealed to be $\sim$10 MeV/c^2 as designed. Further engineering run with a forward proton detection system for the "K^-pn" study was carried out in January, 2013. In the first-stage physics run planned in March, 2013, a neutron spectrum of more than 50 times statistics will be accumulated, which will enable us a coincidence study with the decay particles detected in the CDS.

In this contribution, an overview of the experiment and a preliminary result of the first-stage physics run will be presented.

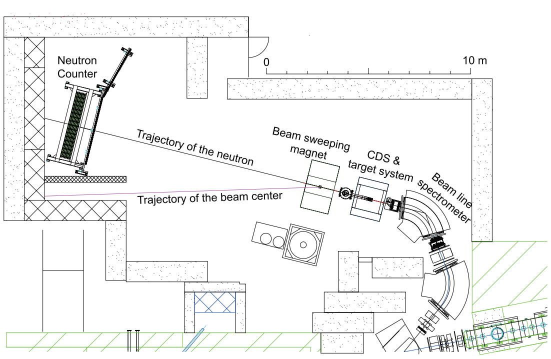

Figure 1: J-PARC K1.8BR spectrometer [2].

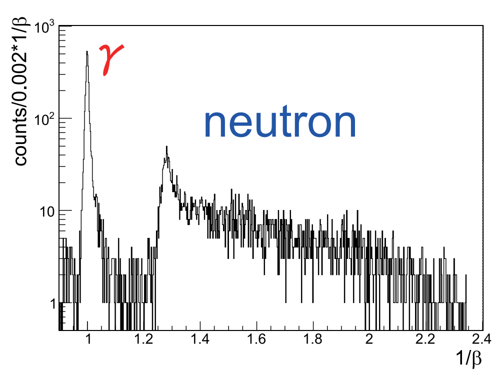

Figure 2: Semi-inclusive neutron $1/\beta$ spectrum [2].

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Structure of Be hyper isotopes

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In this talk, we will discuss the low-lying structure of Be hyper isotopes by using Antisymmetrized Molecular Dynamics (AMD). One of the unique and interesting aspects of hypernuclei is the structure change caused by hyperon. Through the interaction with surrounding nucleons, a hyperon in the atomic nucleus can affect and modify nuclear clustering and deformation. Especially the structure changes of Be hyper-isotopes are of interest, since the Be isotopes have characteristic cluster structure with 2α clustering.

In the ground states of Be isotopes, it is well known that an α + α clustering is affected by extra neutrons and the clustering and deformation are changed depending on the number of neutron. Indeed, such exotic structure appears as an abnormal parity of the ground state in ^{11}Be [1]. The observed spin parity of the ground state is $1/2^+$, while ^{11}Be with the seven neutrons should have $1/2^-$ state as the ground state. By adding a Λ hyperon to them, the drastic structure changes are expected because a Λ hyperon can affect and modify the clustering and deformation of nuclei. In the other Be isotopes, the different kinds of structure changes are also expected by Λ hyperon. For example, it is interesting to reveal the excitation spectra of $^{10}{}_{\Lambda}$Be, because the resonance state of ^{9}Be will be bound by the glue like role of Λ hyperon and it will be observed by the JLab experiments.

To study such phenomena, we have applied an extended version of Antisymmetrized Molecular Dynamics for hypernuclei (HyperAMD [2]) to Be hyper isotopes. By using the YNG and Gogny D1S as the effective ΛN and NN interactions, we have investigated the low-lying spectra and electro-magnetic transition rates of Be hyper-isotopes systematically without any assumption on the clustering. It is found that the abnormal parity of the ^{11}Be ground state is reverted by Λ hyperon and $^{12}{}_{\Lambda}$Be has the normal shell order as shown in Figure 1. In this talk, we will discuss the changes of the clustering by Λ hyperon and its effects to the excitation spectra for several Be hyper isotopes as well as $^{12}{}_{\Lambda}$Be.

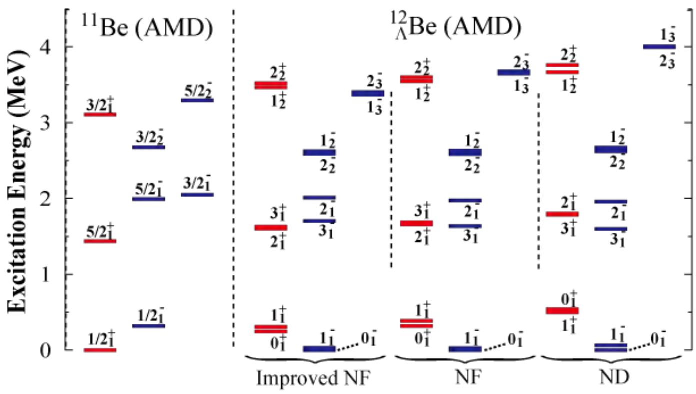

Figure 1: *Calculated excitation spectra of ^{11}Be and $^{12}{}_{\Lambda}$Be.*

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[2] M. Isaka, M. Kimura, A. Dote, and A. Ohnishi, Phys. Rev. C **83**, 044323 (2011).

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Excited states with Λ hyperon in *p* orbit in $^{25}_{\Lambda}$Mg

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In this talk, we will discuss the level structure of the excited states with a Λ hyperon in p orbit in triaxially deformed hypernucleus $^{25}_{\Lambda}$Mg by using the Antisymmetrized Molecular Dynamics (AMD). Forthcoming experiments at J-PARC will reveal the spectroscopy of *sd*-shell Λ hypernuclei that have various kind of deformation. ^{24}Mg is a largely deformed nucleus in *sd*-shell region and is one of the candidates for triaxially deformed nuclei, because of the existence of the $K^{\pi} = 2^{+}$ side band build on the 2^{+}_{2} state at small excitation energy.

In triaxially deformed nuclei, the response to the addition of a Λ particle will be different from those of axial symmetric nuclei [1]. Especially, the level structure of the excited states with the Λ hyperon in p orbit will be quite different from that of the axially symmetric deformed nuclei such as $^{9}_{\Lambda}$Be where the Λ hyperon in p orbit will generate two kinds of p states [2, 3]. Since the p orbit of the Λ hyperon in nuclei has anisotropy along with three directions, the binding energy of the Λ hyperon in each p orbit is different from each other in triaxial deformed hypernuclei. Therefore, it is expected that the excited states with Λ hyperon in p orbit will split into three states corresponding to the axis of deformation in triaxial deformed $^{25}_{\Lambda}$Mg.

To study such phenomena, we have applied an extended version of the AMD for hypernuclei (HyperAMD [4]) to $^{25}_{\Lambda}$Mg. The AMD model is a microscopic model describing low-lying structure without any assumption on symmetry of nuclei. It is found that the Λ hyperon in p orbit generates three different states in $^{25}_{\Lambda}$Mg as shown in Figure 1. In this talk, we will show the excitation spectra of $^{25}_{\Lambda}$Mg, and discuss the structure of these three states compared with the axial symmetric hypernucleus $^{9}_{\Lambda}$Be.

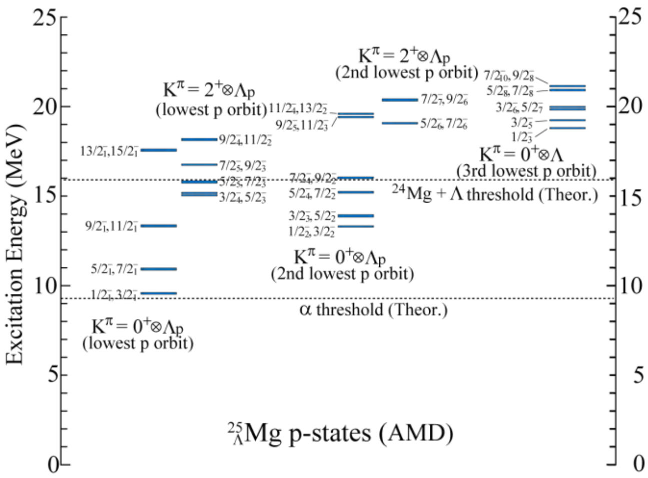

Figure 1: *Calculated excitation spectra of $^{25}_{\Lambda}$Mg with Λ hyperon in p orbit.*

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Feasibility Study of Pionic Atom Spectroscopy with Unstable Nuclei

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We will present our most recent results in the feasibility study toward deeply bound pionic atom spectroscopy with unstable nuclei [1]. We set our goal to an experiment in the RI beam factory (RIBF) of RIKEN using an inverse-kinematics reactions $d(\mathrm{HI}, {}^3\mathrm{He})$, where HI denotes unstable nuclei, with a moderate spectral resolution of 700 keV (FWHM) and with a realistic data accumulation rate of $> 10^3$/day at the first stage of the experiment. The assumed secondary beam intensity is 10^8/second.

Precision spectroscopy of deeply bound pionic atoms has been providing stringent constraints on the physics of low energy region of QCD [2,3]. One of the most important achievements is the first quantitative evaluation of the chiral condensate $<\bar{q}q>_{0.6\rho_0}$ at the nuclear density of 0.6 ρ_0 where ρ_0 denotes the nuclear saturation density. Presently we are conducting a series of experiments at RIBF to make a systematic high precision spectroscopy of pionic atoms with stable nuclei [4] aiming at unprecedented resolution of < 300 keV (FWHM) in order to improve the $<\bar{q}q>_{0.6\rho_0}$ precision by reducing the experimental ambiguities.

Proceeding further to the spectroscopy of deeply bound pionic atoms with unstable nuclei, we have a chance for the first time to achieve information on the density dependence of the chiral condensate, which will place an indispensable milestone for understanding the whole picture of spontaneous breaking of chiral symmetry [5].

For the spectroscopy of pionic atoms with unstable nuclei, we need to employ reactions with a so-called inverse kinematics $d(\mathrm{HI}, {}^3\mathrm{He})$. We measure the Q value of the reaction to deduce the mass of the reaction products, pionic atoms. We need to detect emission angle and momentum of the recoil ${}^3\mathrm{He}$ with the kinetic energy of about 60 MeV. This very low momentum requires delicate design of the experiment. The reaction vertices must be determined precisely otherwise the energy loss of the low-momentum ${}^3\mathrm{He}$ will deteriorate the spectral resolution miserably.

We have elaborately examined experimental feasibility in cases of solid, liquid, and gaseous targets and came to conclude that the experimental feasibility will remain only in a deuterium gaseous target in a TPC (time projection chamber) used as an active target. A set of silicon detectors will be placed to detect the full energy of ${}^3\mathrm{He}$.

Based on above considerations, we will present the detailed simulation results in terms of the spectral resolution and the yield of the pionic atom formation with unstable nuclei.

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RIKEN's activity at J-PARC Hadron Hall

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J-PARC has been founded to accommodate wide range of scientific fields utilizing high intensity proton accelerator research complex, as a joint project between KEK (High energy accelerator research organization) and JAEA (Japan atomic energy agency). One of the research objective of J-PARC is the fundamental physics using slow-extracted 30 GeV proton beam to the Hadron Hall bombarding on the fixed nuclear target, and delivering variety of secondary particles, such as $\pi^{\pm}$, $K^{\pm}$, K^0 and $\overline{p}$. The intensity of the proton beam is $\sim$ 20 kW at present, and it is keep improving towards its design value of few 100 kW.

RIKEN's research groups have been committed several research programs at K1.8BR kaon beam line and High-p primary proton beam line of J-PARC Hadron Hall. In both cases, we are focused on the study of meson property change in nuclear medium. The K1.8BR spectrometer system is equipped with large neutron counter system in the forward angle. Using this unique feature, we are running E15 experiment for deeply bound kaonic nuclear state search using ^{3}He$(K^-, n) < K^-pp >$ reaction, and preparing E31 for the study of $\Lambda(1405)$ using d$(K^-, n)\Lambda(1405)$ reaction. We are also preparing several experiments using $\overline{p}$ beam at K1.8BR by upgrading our experimental apparatus. At High-p line, we are preparing E16 for the study of in-medium mass shift of ϕ mesons in nuclei via the invariant-mass spectroscopy of e^+e^--pair using $A(p, e^+e^-)X$ reaction. Very recently, the construction budget of High-p line had been approved, and will be constructed within two years. On the other hand, the size of the J-PARC Hadron Hall is still quite limited compared to the facility scale. Therefore, cooperating with KEK Hadron group and Hadron Hall users association (HUA), we established our design proposal how to extend the Hadron Hall to fulfill next generation experimental programs as shown in the figure.

In this paper, we will describe some of the results of our present experiments, and overview the Hadron Hall extension plan.

Figure 1: *Schematic figure of the J-PARC Hadron Hall extension plan.*

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Nonmesonic weak decay of light hypernuclei within soft $\pi + K$ meson-exchange model

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Studies of exotic nuclei, such as those possessing large isospin, or including hadrons with nonstandard flavor quantum numbers(strangeness, charm or bottom) are of continuous interest. Particularly interesting is the hypernucleus, that is formed when a hyperon, specifically a Λ-hyperon with strangeness $\mathsf{S} = -1$, replaces one of the nucleons. Since this strange baryon is stable against strong and electromagnetic decays, and as it does not suffer from Pauli blocking by other nucleons it can live long enough in the nuclear environment to become bound. The composed system acquires different properties from that of the original one, such as the occurrence of the nonmesonic weak decay (NMWD): $\Lambda N \to nN$ with $N = p, n$, which is the main decay channel for medium and heavy hypernuclei. This process takes place only within nuclear environment, and is the unique opportunity that nature offers us to inquire about strangeness-flipping baryon-baryon interaction.

Kinetic energy and coincidence spectra in NMWD of light hypernuclei have been evaluated in a systematic way for the first time, adopting as theoretical framework the independent particle shell model and three different one-meson-exchange transition potential. We have considered only one-nucleon induced processes, neglecting entirely the events induced by two-nucleon emission, as well as the effects of the final state interactions. The comparison with data strongly suggests that the $\pi + K$ meson-exchange model with soft monopole form factors could be a good starting point for describing the dynamics responsible for the decays of ${}^{4}_{\Lambda}\mathrm{He}$, and ${}^{5}_{\Lambda}\mathrm{He}$ hypernuclei. The importance of the recoil effect in defining the shape of spectra in light hypernuclei is highlighted.

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Search for the η-mesic ^{4}He with WASA-at-COSY

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An exclusive measurement of the excitation function for the $dd \rightarrow {}^3\mathrm{He}p\pi^-$ reaction was performed at the Cooler Synchrotron COSY-Jülich with the WASA-at-COSY detection system. The data were taken during a slow acceleration of the beam from 2.185 GeV/c to 2.400 GeV/c crossing the kinematic threshold for the η production in the $dd \rightarrow {}^4\mathrm{He}\,\eta$ reaction at 2.336 GeV/c. The corresponding excess energy with respect to the $^4\mathrm{He} - \eta$ system varied from -51.4 MeV to 22 MeV. No signal of the $^4\mathrm{He} - \eta$ bound state was observed in the excitation function. An upper limit for the cross-section for the bound state formation and decay in the process $dd \rightarrow ({}^4\mathrm{He} - \eta)_{bound} \rightarrow {}^3\mathrm{He}p\pi^-$, was determined on the 90 % confidence level. In November 2010 a new data set was collected. The status of the research will be presented.

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Manifestation of multibaryons in hadronic collisions at intermediate energies

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Although the exotic dibaryons, mainly with signatures $I(J^P) = 0(3^+)$ and $1(2^+)$, in the form of six-quark bags have been predicted still long ago (see, e.g., [1]) and have been often used to explain different hadronic phenomena accompanied with high momentum transfer and also the EMC effect, their experimental status has been rather unclear up to recent years. However in last few years the WASA-at-COSY collaboration reported [2,3] about a quite reliable discovery of a dibaryonic resonance D^* with a signature $I(J^P) = 0(3^+)$, having the mass $M_{D^*} \simeq 2.37$ GeV and the total width $\Gamma_{D^*} \simeq 70$ MeV. It is very important that the basic parameters of this isoscalar resonance and also the another, isovector dibaryon with $I(J^P) = 1(2^+)$ (found in the phase-shift analyses of $NN \to NN$, $\pi d \to \pi d$ and $\pi d \to NN$ processes) were in a full coincidence with those predicted by Dyson and Xuong [1] still in 1964. This agreement provides some additional confirmation for existence of such dibaryon resonances.

On the other hand, we developed [4] more than a decade ago a model for fundamental nuclear force at intermediate and short distances, in which an intermediate dibaryon production plays a crucial role in a consistent explanation of both strong intermediate-range attraction and short-range repulsion in the NN system [4,5]. The above mechanism has very numerous implications in hadronic collisions, e.g., to explain the high yield of cumulative particles or to treat the production of subthreshold hadrons (mesons, antiprotons, etc.). It should be stressed that in all such treatments we employ the same di- and multibaryon model which has been used to describe the fundamental nuclear force and fit the empirical NN phase shifts [5].

The main focus in the present review talk is on the consistent treatment of cumulative and subthreshold production phenomena at intermediate energies. In particular, we will show that the basic scale parameter which governs the momentum distribution of the secondary high-momentum nucleons emitted in the backward hemisphere can be deduced straightforwardly from the NN-potential form factor which has been fitted to the NN scattering. Another nice consequence of the dibaryon model is a new quantitative interpretation of the ABC puzzle discovered more than 50 years ago and had no consistent theoretical explanation up to now (see the dedicated talk at this conference). There are many other interesting implications of the dibaryon concept for the basic nuclear force, like an enhanced dilepton emission in heavy-ion collisions at $E \sim 1$ GeV/u [6]. In the talk we discuss some of these intriguing implications and their experimental confirmations.

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Spectroscopy of the Hadronic Atoms: K-N Strong Interaction Effects

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Ab initio approach to description of the kaonic atoms spectra with précised accounting for the relativistic, radiative, nuclear, strong kaon-nucleon interaction effects on the basis of the Klein-Gordon-Fock equation and relativistic QED perturbation theory [1] is presented. For low orbits there are the important effects due to the strong K-N interaction. The energy shift is connected with a length of the hadron-nuclear scattering. It is carried out calculating energy parameters of X-ray transitions group in the kaonic atoms of hydrogen, helium, W, Pb U and other, including estimating the values of strong kaon-nuclear interaction energy levels shifts and widths, defining corrections due to an electron screening, vacuum polarization etc to transition energies. The potential includes SCF ab initio potential, the electric and polarization potentials of a nucleus (the Gauss models for a nuclear charge distribution) [1]. The Lamb shift polarization part is treated in the Uhling-Serber approximation and the self-energy part – within the Green function method.

The calculated X-ray spectrum for kaonic He and estimate of 2p level shift due to the strong K-N interaction 1.57 eV are in the reasonable agreement with experimental data (cited shift 1.9eV) by Okada et al (2008; E570; KEK 12GeV, RIKEN Nishina Centre, JAPAN) and differ (about order) of other experimental data by Wiegand-Pehl (1971), Batty et al (1979), Baird et al (1983) [2]. There are also presented data on the shifts and widths of low-lying + Rydberg transitions in some heavy kaonic atoms. As example, in table 1 we present our data on the energy shifts, induced by strong K-N interaction in the kaonic atoms: W, Pb,U. The comparsion with avalable experimental and alternative theoretical results is carried out.

Table 1: *Calculated (C) and measured (M) shifts ΔE (keV), induced by strong K-N interaction: a – theory Batty etal; b – our theory (data from* [1,2] *and refs, therein)*

Reference	*M*	*C-a*	*C-b*
W, 8-7	0.079 0.052	-0.003	0.038
W, 7-6	-0.353 -0.250	-0.967	-0.294
Pb, 8-7	0.072 0.047	-0.023	0.046
U, 8-7	0.12 0.032 -0.405 -0.213	-0.189	-0.205

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Hypernucleus production in heavy ion collision - a theoretical analysis

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Hyper nuclei are not only a laboratory to study the interaction among strange and non strange baryons [1] but can be as well a very useful tool to study the space time evolution of heavy ion reactions . Therefore recently the first attempts have been made to produce hypernuclei in heavy ion reactions[2, 3]. If this method could be established not only hypernuclei can be produced in numbers but their multiplicity and momentum space distribution provides also valuable information on the time evolution of heavy ion reactions. The reason is that the Λ which is formed in these collisions has to find fellow nucleons to form a hyper nucleus and therefore the production yield depends on the phase space distribution (and not only the momentum distribution) of the nucleons around the Λ. As for normal multifragmentation [4] there will be two formation processes. Hypernuclei can be formed by coalescence type processes from participant matter. This will be the dominant process at midrapidity and will create light hypernuclei. Around projectile and target rapidity for hyper nucleus formation the Λ has to be absorbed in the preformed target/projecile fragments [4]. There also heavier hypernuclei may be created. Because the Λ is produced by participant nucleons the hypernucleus production in the target/projectile region will provide information about the interaction between spectators and participants and therefore about the space time evolution of the system. Such a space time information is necessary to clarify the mechanism of multi fragmentation at these energies, which is still not understood.

To study hyper nuclei we use for the time evolution of the heavy ion reaction the Quantum Molecular Dynamics program which propagates nucleons from the initial separation of projectil and target to the particles which are observed in the detectors. To identify fragments and especially hyper nuclei we have improved our standard approach, SACA [5] , based on the Simulated Annealing (SACA) procedure which has successfully described fragment formation and even details like the bimodality of the fragment production from 50 AMeV up to 1 AGeV [6]. These improvement include the use of the Λ-N interaction, of quantum corrections and the symmetry energy for the identification of hypernuclei.

We present the model in detail, show first comparisons with the recently measured hyper nuclei at GSI and draw conclusions about the production mechanism.

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Hadronization in Nuclei – Recent Multidimensional Results from HERMES

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A method to investigate the process of quark fragmentation and hadronization is to measure hadron yields when scattering off nuclei of various sizes. As the path length of hadronization is comparable to the size of a nucleus one can study the length/time dependence of hadronization. This is because hadron yields depend on whether hadronization occurs inside or outside nuclear matter.

Hadron multiplicities in semi-inclusive deep-inelastic scattering were measured on neon, krypton and xenon targets relative to deuterium at an electron-beam energy of 27.6 GeV at HERMES. These ratios were determined as a function of the virtual-photon energy ν, its virtuality Q^2, the fractional hadron energy z and the transverse hadron momentum p_t with respect to the virtual-photon direction [1]. Recently, dependences were analysed separately for positively and negatively charged pions and kaons as well as protons and antiprotons in a two-dimensional representation [2]. The latter results will help to constrain mechanisms and models of hadronization much more decisively than by the use of integrated results as traditionally done.

A few features particular to the two-dimensional representation will be highlighted in this contribution. For example, at lower values of ν positive kaons do not show the typical rise of the multiplicity ratio with ν when $z > 0.4$. In addition, protons were found to behave very differently from the other hadrons.

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Antiproton-Nucleus Interactions and Meson Production on Complex Nuclei

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Interactions of antiprotons with nuclei and the coherent production of mesons in antiproton annihilation on a nucleus are investigated in a fully microscopic approach. Initial and final state interactions are accounted for by newly derived optical potentials. Interactions of antiprotons are described by a meson and baryon exchange model, accounting for the strong coupling to the annihilation channels [1,2]. Meson-nucleus interactions over large ranges of incident energies are obtained by including high-lying resonances, much beyond the level followed by previous approaches. State-of-the-art HFB nuclear structure input is used for nuclear density distributions [3]. A fully quantum mechanical description of the reaction process is obtained on the basis of an extended eikonal approach. Elastic scattering in the initial antiproton and final meson-nucleus channels is well reproduced as far as data are available. The production vertex contains contributions from t- and u-channel baryon exchange processes and s-channel production by $N\bar{N}$ annihilation into intermediate resonances. The same types of diagrams are contributing to the dispersive parts of the antinucleon-nucleon and antinucleon-nucleus optical potentials. Results of exploratory studies on differential mass distributions and total cross sections for pion and kaon production in antiproton-nucleus annihilation reactions are presented. We pay special attention on the energy region to be investigates by PANDA@FAIR.

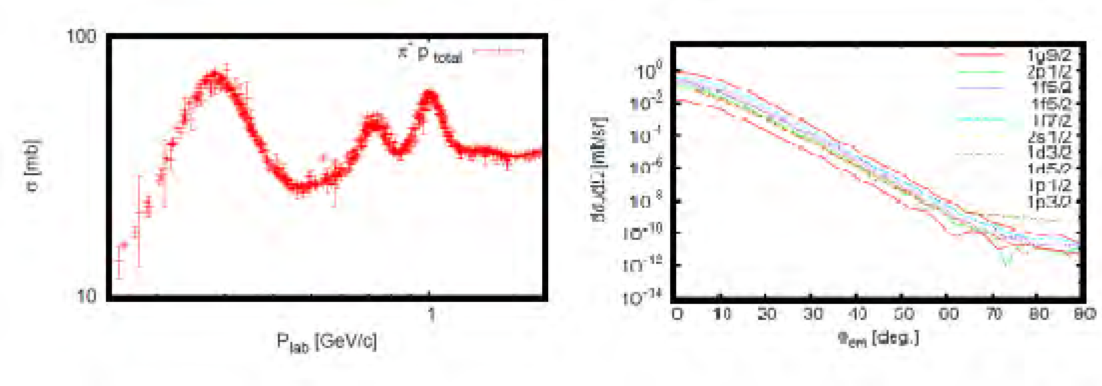

Figure 1: *Pion-nucleon total cross sections (left) and angular distributions for two-pion production on a Ni-isotope at T_{lab}=800 MeV.*

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Shape evolution of Ne isotopes and Ne hypernuclei: The interplay of pairing and tensor interactions

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We study tensor and pairing effects on the quadruple deformation of neon isotopes based on a deformed Skyrme-Hartree-Fock model with BCS approximation for the pairing channel. We extend the Skyrme-Hartree-Fock formalism for the description of single- and double-lambda hypernuclei adopting two different hyperon-nucleon interactions. It is found that the interplay of pairing and tensor interactions is crucial to derive the deformations in several neon isotopes. Especially, the shapes of ^{26,30}Ne are studied in details in comparisons with experimentally observed shapes. Furthermore the deformations of the hypernuclei are compared with the corresponding neon isotopic cores in the presence of tensor force. We find the same shapes with somewhat smaller deformations for single Λ-hypernuclei compared with their core deformations. It is also pointed out that the latest version of hyperon interaction, the ESC08b model, having a deeper Λ potential makes smaller deformations for hypernuclei than those of another NSC97f model.

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First measurement of low momentum dielectrons radiated off cold nuclear matter.

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The High Acceptance DiElectron Spectrometer HADES is installed at the Helmholtzzentrum für Schwerionenforschung (GSI) accelerator facility in Darmstadt. It investigates dielectron emission and strangeness production in the 1-3 AGeV regime. A recent experiment series focusses on medium-modifications of light vector mesons in cold nuclear matter. In two runs, p+p and p+Nb reactions were investigated at 3.5 GeV beam energy; about $9 \cdot 10^9$ events have been registered. In contrast to other experiments the high acceptance of the HADES allows for a detailed analysis of electron pairs with a low momenta relative to nuclear matter, where modifications of the spectral functions of vector mesons are predicted to be most prominent. Comparing these low momentum electron pairs to the reference measurement in the elementary p+p reaction, we find in fact a strong modification of the spectral distribution in the whole vector meson region and will discuss these results [1].

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Charmonium photoproduction in coherent and incoherent heavy ion collisions at the LHC

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In this contribution we report the predictions for the photoproduction of the vector mesons Psi(1S) and Psi(2S) in both coherent and incoherent ultrarelativistic heavy ion collisions collisions at the Large Hadron Collider energies using the color dipole approach and the Color Glass Condensate (CGC) formalism. In particular, we present our predictions for the first run of the LHC for PbPb collisions at 2.76 TeV concerning the rapidity dependence distributions at forward and backward regions. These results are presented in figure below including the coherent and incoherent contributions and compare them to the ALICE experiment. Predictions are done for the Psi(2S) photoproduction, which has not been properly addressed in literature and can be measured in the current LHC experiments.

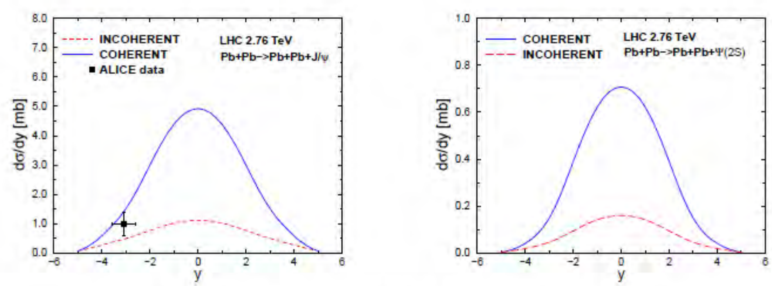

Figure 2: Rapidity distribution of J/ψ (left) and Ψ' (right) production.

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Measurements of the ^{2}H($\vec{p}, n$) breakup reaction at 170MeV for the study of the three-nucleon force effects

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Recently the effects of three-nucleon force (3NF) are regarded as important not only in the few-body nuclear physics but also in the study of the nuclear structure or the astrophysics. Precise study of 3NF has been actively performed by using the nucleon-deuteron (Nd) scattering states. The differential cross sections of the elastic Nd scattering at the energy below 150 MeV can be well reproduced by adding 3NF in the Faddeev calculation based on modern nucleon-nucleon (NN) interactions [1-2]. On the other hand, the differential cross sections of Nd elastic and inelastic scatterings at 250 MeV show large discrepancies between the data and the Faddeev calculations with 3NF [3-4], which indicates the presence of the missing features of the three nucleon system at this energy region. And this large discrepancy between the data and the theory was also shown in the ^{2}H($\vec{p}, p$)pn inclusive breakup reaction at $E_p =$ 250 MeV [5]. For the systematic study about the energy dependence of this large discrepancies, we measured the differential cross sections and the vector analyzing power A_y for the ^{2}H($\vec{p}, n$) inclusive breakup reaction at 170 MeV.

The experiment was carried out at RCNP. The polarized proton beam of 170MeV was injected to the deuterated polyethylene (CD_2) target and scattered neutrons were detected by using the neutron detector NPOL3. The energy of a detected neutron was deduce by TOF method.

The data was compared with the results of the Faddeev calculations with and without the 3NF [6-7]. Concerning about the differential cross sections, we can see large discrepancies between the data and the calculations in the low neutron energy regions, which is similar to the results of the ^{2}H($\vec{p}, p$) inclusive breakup reaction at 250 MeV.

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Calculations of $\bar{K}$ nuclear quasi-bound states using chiral $\bar{K}N$ amplitudes

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We review our latest calculations of K^- quasi-bound states in few- and many-body nuclear systems using subthreshold energy dependent chiral $\bar{K}N$ amplitudes [1,2].

We performed calculations of three-body $\bar{K}NN$ and four-body $\bar{K}NNN$ and $\bar{K}\bar{K}NN$ nuclear clusters in the hyperspherical basis, with interactions practically identical to those used in ref. [3]. Results of previous K^-pp calculations were reproduced and and upper bound was placed on the binding energy of a K^-d quasibound state. In view of the low K^-pp binding energy $B(K^-pp) \approx 16$ MeV and relatively large $\bar{K}N \to \pi Y$ mesonic width $\Gamma(K^-pp) \approx 40$ MeV, it might be difficult to identify the K^-pp quasi-bound state unambiguously in ongoing experiments. A self-consistent handling of the energy dependence of the subthreshold $\bar{K}N$ amplitude was found to restrain binding of the four-body $\bar{K}$ nuclear clusters. We found relatively modest binding, about 30 MeV in both, with mesonic widths ranging from 30 MeV for $\bar{K}NNN$ to about 80 MeV for the lowest $\bar{K}\bar{K}NN$ quasi-bound state. However, the binding energies of K^- nuclear clusters could be enhanced by dispersive contributions. Our recent fits to kaonic atoms [4,5] suggest that $\Delta B_{\rm disp} \sim \Delta\Gamma_{\rm nonmesonic}$, and the binding energies could reach values $B(K^-pp) \sim 25$ MeV and $B(\bar{K}NNN,\ \bar{K}\bar{K}NN) \sim 50$ MeV.

For many-body K^- nuclear systems with densities close to nuclear matter density, the energy dependence of the chiral in-medium $\bar{K}N$ scattering amplitudes controls the self-consistent evaluation of the corresponding K^- optical potentials. We considered two in-medium versions of the scattering amplitudes: a version which takes into account only Pauli blocking in the intermediate states, and a version which adds self-consistently hadron self-energies [2,4]. The $\bar{K}N$ amplitudes were constructed using the in-medium coupled-channel model [6] that reproduces all available low energy $\bar{K}N$ observables, including the latest $1s$ level shift and width in the K^- hydrogen atom from the SIDDHARTA experiment [7]. While the two in-medium versions of the $\bar{K}N$ scattering amplitudes yield considerably different potential depths ReV_K at threshold, they give similar depths in the self-consistent calculations with the subthreshold extrapolation, -Re$V_K \sim 80 - 120$ MeV. The mesonic widths of low-lying K^- states are substantially reduced in the self-consistent calculations, thus reflecting the proximity of the $\pi\Sigma$ threshold. On the contrary, the widths of higher excited K^- states are quite large even if only the pion conversion modes on a single nucleon are considered. After including 2 body $K^-NN \to YN$ nonmesonic modes, the total decay widths Γ_K are comparable or even larger than the corresponding binding energies B_K for *all* K^- nuclear quasi-bound states, exceeding considerably the level spacing. Our conclusions should discourage attempts to search for isolated peaks corresponding to K^- nuclear quasi-bound states in many-body nuclear systems.

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Microscopic Investigation of the Structure Characteristics and Wave functions of the Five-Body Hypernucleus H_{λ}^{5}

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Parentage Scheme of Summarization to the N-body symmetrized basis construction [1] necessary for the description of the structural characteristics and decay reactions of the hypernuclear and nuclear systems with arbitrary amount of particles is applied to solve five-body problem in hypernuclear physics. Five particle hypernucleus H_{λ}^{5} as a system of four nucleons and one hyperon is investigated with the use of the Hyperspherical Function Method in the momentum representation. The dependence of the structure characteristics and wave functions on the types of nucleon-nucleon ad hyperon-nucleon interaction potentials is studied. Mean Square $\alpha - \lambda$ distance and binding energies are obtained.

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J-PARC Experiment (E07) to Study Double Hypernuclei

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Double-Λ hypernuclei give us information about the Λ-Λ interaction which is valuable for unified understanding of Baryon-Baryon interaction in SU(3)-flavor symmetry. Nuclear physics with double strangeness also guides us to multi-strangeness systems such as “strange matter” and is closely related to the H-dibaryon. However experimental knowledge is very limited so far.

In the previous experiment E373 at KEK, we have succeeded to detect nearly one thousand events with Ξ^- hyperon capture at rest in nuclear emulsion, where Ξ^- hyperons were produced via quasi-free ‘*p*’(K^-, K^+)Ξ^- reaction on diamond target. Among them, production and decay topology of double- Λ hypernucleus has been shown in 7 events. As for uniquely identified *Nagara* event ($_{\Lambda\Lambda}{}^{6}$He), although it was published in PRL [1], the binding energy ($B_{\Lambda\Lambda}$) and the interaction energy ($\Delta B_{\Lambda\Lambda}$) of two Lambda hyperons should be revised due to the change of the mass of Ξ^- hyperon by 0.4 MeV in Particle Data (2008). The modified $B_{\Lambda\Lambda}$ and the $\Delta B_{\Lambda\Lambda}$ using a new knowlege of *Nagara* event are summarised in elsewhere[2] with other three events of *Mikage*, *Demachi-yanag*i and *Hida* event under the check of the consistency of the $\Delta B_{\Lambda\Lambda}$ with that of *Nagara* event.

The comming experiment, E07 at J-PARC, is expected to give us about 10^2 and 10^3 double-Λ hypernuclei with a “*new hybrid method*” and “*overall scanning method*”, respectively. We probably succeed to detect nuclear species with two Λ hyperons other than *Nagara* event by such amount of double-Λ hypernuclear events.

As for “*new hybrid method*”, we have developed a system for full-automated track following by the success of precise position alignment (~1 μm) for emulsion plate by plate which size is 35 x 35 cm^2. By using Ge-detector set around the emulsion, we will mesure X-ray of level energy for Ξ^- hyperon capture in Ξ atom without any ambiguity, because the capture event are located in the emulsion. In “*overall scanning*” of the emulsion, we will search for double-Λ hyper nuclear events independent on the information by electrical detectors (counters, chambers and so on). It is expected that non-tagged event for Ξ^- hyperon capture can be in the emulsion about ten or more times than that followed with the above “*new hybrid method*” due to limited acceptane of electric detectors. To carry out “*overall scanning*” in a few years, we develp very fast scanning system with CMOS Camera (800 Hz) and new lens barrel (piezo actuator). The system gives us ~ 200 times’ faster speed than that of the previous E373 experiment.

Although the beam expeosure for the E07 experiments, above introduced systems will start to work on the E373 emulsion from this march, then some new events of double-Λ hypernuclei can be detected in the coming spring. In our contribution, we will discuss physics given by the E07 experiment with developed apparatues, first, and report production of double-Λ hypernuclei, if it is possible.

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Determination of the η'-nucleus optical potential*

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Experimental approaches for determination of the η'-nucleus potential are presented. As discussed in [1] the transparency ratio measurements provide information on the inelastic cross section and in-medium width of η' and thereby on the imaginary part of the η'-nucleus potential. The relatively narrow in-medium width of about 20 MeV of the η'-meson makes it a promising candidate for a mesic state only bound by the strong interaction [2]. Therefore, it is very important to learn more about the real part of the η'-nucleus optical potential. The momentum distribution and the excitation function show some sensitivity to in-medium modifications and could provide information on the sign and depth of the potential. Data taken in 2009 at CB/TAPS@ELSA on a carbon target have been analysed and compared to model calculations [3] assuming different scenarios for the real part of the potential, related directly to the in-medium mass modification of the meson. The preliminary results are consistent with an only weakly attractive η'-nucleus potential and do not favour theoretical predictions claiming potential depth of -100 to -200 MeV.

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The first precision measurement of deeply bound pionic states in ^{121}Sn

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We report our recent experiment of the pionic ^{121}Sn atom using missing-mass spectroscopy of the ^{122}Sn(d,^{3}He) reaction near the $^{-}$ emission threshold. While a detailed analysis is on-going, preliminary spectra already show distinct structures in bound region. The experiment serves as a pilot experiment for systematic study of deeply bound pionic atoms at the RIKEN RI beam factory (RIBF).

Recent studies revealed that the chiral condensate at the normal nuclear density can be deduced by precision spectroscopy of pions captured in deep states (such as $1s$ or $2p$) of heavy atoms, which are called deeply bound ponic atoms[1, 2]. So far the $1s$ pionic states in ^{205}Pb and ^{115,119,123}Sn have been discovered at GSI [3-5]. The deduced chiral order parameter was compared with that of the vacuum, which was deduced from the pionic hydrogen, and partial chiral restoration was suggested. However, the evaluation still had large systematic and statistical errors. To reduce the systematic errors from ambiguity of the nuclei, we are planning the pionic Atom Factory (piAF) project, in which the deeply bound pionic atoms of isotopes and isotones will be produced.

As a pilot experiment for the project, we performed a precision spectroscopy of the ^{122}Sn(d,^{3}He) reaction. In the experiment, we succeeded in the first observation of the pionic states in $1s$ and some other orbits of ^{121}Sn and the angular dependence of the pionic-atom formation cross section owing to the large angular acceptance of the BigRIPS spectrometer [6]. The resolution was at least as good as in the previous experiment. At the same time, the data-taking time was reduced dramatically, which is essential for the systematic spectroscopy. These results revealed the encouraging potential capability of the RIBF facility for systematic high-precision spectroscopy of deeply-bound pionic atoms.

Now we are working to decompose the spectrum to each state and extract the chiral order parameter. The current status of the analysis, including new results about the angular dependence of the pionic-atom formation cross section for each state, will be reported.

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New interpretation of the ABC effect in the basic double-pionic fusion reaction

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The ABC effect first observed by Abashian, Booth and Crowe [1] more than 50 years ago stands for a pronounced near-threshold enhancement in the $\pi\pi$ invariant mass spectrum of the double-pionic fusion reactions, such as $pn \to d + \pi\pi$, $pd \to {}^3\mathrm{He} + \pi\pi$, etc. Numerous theoretical and experimental studies undertaken since the discovery of the ABC effect shed light on its basic features, such as its scalar-isoscalar nature. However the effect has not received a reliable and commonly accepted theoretical explanation up to now.

The interest in the ABC effect has increased again quite recently, after publication of the results of the first exclusive and kinematically complete experiments for the basic 2π-fusion reaction $pn \to d + \pi^0\pi^0$ in the ABC region ($T_p = 1.0$–1.4 GeV) done by WASA-at-COSY collaboration [2]. The comparison of the new experimental data with theoretical predictions has demonstrated clearly that the conventional model for this reaction which included the $\Delta\Delta$ and the Roper resonance excitations via t-channel meson exchange cannot reproduce the observed energy and angular distributions. At the same time, the new exclusive measurements revealed a generation of the dibaryon resonance D_{03} in the pn collision, with quantum numbers $I(J^P) = 0(3^+)$, the mass $m_{D_{03}} \simeq 2.37$ GeV and the narrow width $\Gamma_{D_{03}} \simeq 70$ MeV. Such a resonance state has been predicted already in 1964 by Dyson and Xuong [3] and since then studied in numerous works, both theoretical and experimental, but never reached such a level of evidence before. Furthermore, from the exclusive experiments [2], the direct interrelation between the production of the D_{03} resonance and the ABC effect was clearly established.

We investigated the basic 2π-fusion reaction in the ABC region within a framework of a new model [4] involving the D_{03}-dibaryon production and its subsequent decay via two interfering channels: $D_{03} \to d + \sigma \to d + \pi^0\pi^0$ and $D_{03} \to D_{12} + \pi^0 \to d + \pi^0\pi^0$. Here the D_{12} is the isovector dibaryon with quantum numbers $I(J^P) = 1(2^+)$, the mass $m_{D_{12}} \simeq 2.15$ GeV and the width $\Gamma_{D_{12}} \simeq 110$ MeV, which was also predicted in [3] and then found in the phase-shift analyses of NN and πd elastic scattering and $\pi d \to NN$ reaction [5]. We shall demonstrate in the talk that the constructive interference of the above two decay channels of the D_{03} resonance gives a strong near-threshold enhancement in the $\pi\pi$ invariant mass spectrum, i.e. the ABC effect. Herewith, the σ-meson emission from the D_{03} dibaryon plays a crucial role in reproducing the shape and position of the ABC enhancement and is tightly connected to the idea of chiral symmetry restoration in dense and excited hadronic systems, such as the D_{03} state. In particular, the σ-meson parameters found by us are in a general agreement with models which predict the chiral symmetry restoration at high excitation energy and/or high density of matter, and they are essentially less than those accepted for the free σ meson. So, this result might be considered as an indication of the partial chiral symmetry restoration in pn, pd, etc., collisions at intermediate energies.

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Search for H-dibaryon at J-PARC with a Large Acceptance TPC

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H-dibaryon was proposed as a most stable 6-quark state hadron more than 30 years ago [1]. Since then, many experiments extensively searched for it in various reactions and decay channels, but have never discovered it. Recent lattice QCD calculations [2,3] show H-dibaryon as bound or resonant states close to the ΛΛ threshold. In E224 [4] and E522 [5] experiments at KEK, peaks in ΛΛ invariant mass spectra near the threshold were observed in (K^-, K^+) reactions, which might indicate H-dibaryon, but the statistics was not significant enough.

Therefore, we proposed an experiment at J-PARC (E42) to search for H-dibaryon. The experiment will measure decay products of ΛΛ, $\Lambda\pi^-p$ in (K^-, K^+) reaction where Λ decays into π^-p. We design a large acceptance spectrometer based on a Time Projection Chamber (TPC) under Helmholz dipole magnetic field of 1T. The TPC contains a Cu target inside to cover large acceptance. In order to operate at high K^- beam rate of 10^6 Hz, we adopt GEM (Gas Electron Multiplier) and gating grid wires to suppress positive-ion feedback leading to drift field distortion. We expect to measure 11 K ΛΛ events in the invariant mass resolution of ~1.5 MeV/c^2 at the ΞN threshold. The spectrometer has been under R&D, aiming at completion in 2014.

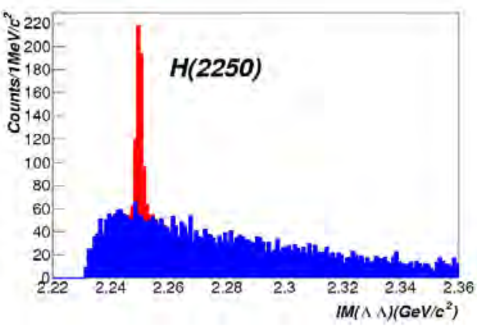

Figure 1: *Simulated ΛΛ invariant mass spectrum at E42. The production cross section is assumed to be 1.0 μb/Sr and H-dibaryon mass width is assumed to be zero.*

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Spectroscopy of the Pionic Atoms: Energy Shifts and Widths and π-N Strong Interaction Effects

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The work is devoted to calculation of spectra of the pionic atoms and some heavy ions within ab initio relativistic many-body perturbation theory with account of the relativistic, nuclear, radiative effects [1]. One of the main purposes is establishment a quantitative link between quality of the nucleus structure modeling and accuracy of calculating spectral properties. The wave functions are found from the Klein-Gordon-Fock (pionic atom) or Dirac (usual heavy ion) equations. The potential includes the SCF ab initio potential, electric and polarization potentials of a nucleus (the RMF and Gauss models for a charge distribution in a nucleus are used). Data on the energy levels for some superheavy Li-like ions and shifts and widths for the low-orbit and Rydberg transitions in pionic atoms (H, He, Cs, Tl, Pb,U) are presented. The received data are compared with available theoretical and experimental data [2,3]. The strong pion-N interaction corrections to energies are estimated. It is considered an advanced approach to redefinition of the pion-nucleon phenomenological optical model potential parameters and increasing an accuracy of the hadronic transitions energies definition.

In table 1 the data on the transition energies in some pionic atoms (from. Refs. [2,3]): the measured values form the Berkley, CERN and Virginia laboratories, the theoretical values for the $2p-1s$, $3d-2p$, $4f-3d$, $5g-4f$ pionic transitions (E^N_{th1} - values from the Klein-Gordon-Fock equation with the pion-nucleus potential [2]; E_{KGF}- values from the Klein-Gordon-Fock equation with the finite size nucleus potential (our data), E^N_{th2} - values from the Klein-Gordon-Fock equation with the generalized pion-nucleus potential: our data).

Table 1. Transition energies (keV) in the spectra of some pionic atoms

Element	E_{EXP}			E_{th}		
	Berkley	CERN	Virginia	E_{KGF}	E^N_{th1}	E^N_{th2}
			Transition *4f-3d*			
Cs^{133}	560.5±1.1	562.0±1.5		553.330	561.47	562.12
			Transition *5g-4f*			
Tl^{204}		561.67±0.25		556.562	560.93	561.63
Pb^{207}		575.56±0.25		570.614	575.21	575.78
U^{238}	731.4±1.1	732.0±0.4	730.88±0.75	724.317	729.80	730.52

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The yield of kaonic hydrogen X-rays in SIDDHARTA experiment

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In the SIDDHARTA experiment at the DAΦNE e^+e collider, we measured the K-series X-rays of kaonic hydrogen atoms with significant improvements over the past experiments[1][2]. Moreover, we also performed the first ever deuterium target study searching for kaonic deuterium X-rays.

Based on the data from the measurements of both hydrogen and deuterium targets, we determined a new set of values for the strong interaction energy-level shift and width of the $1s$ atomic state of kaonic hydrogen, published in 2011[3]. The Kp scattering length at threshold derived directly from this new set of shift and width is consistent with those extrapolated from the low-energy Kp scattering data. The new results from SIDDHARTA also provide vital constraints on the QCD chiral SU(3) theory for the low-energy $\bar{K}N$ interaction[4].

In addition to the shift and width of the $1s$ state of kaonic hydrogen, we further determined preliminarily the yield of X-rays per stopped kaon for K_α and all the K-series X-rays of kaonic hydrogen atom. In this talk, I will present the details of the combined analysis of the kaonic hydrogen and deuterium spectra, from which the yield of kaonic hydrogen X-rays is determined. The yield of K-series X-rays will improve the understanding of the atomic cascade of kaonic hydrogen atom, especially the width of its $2p$ state which cannot be measured directly.
Meanwhile, a preliminary upper limit for the yield of kaonic deuterium K_α X-rays as another conclusion from the combined analysis will also be presented.

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Search for ^{4}He-η bound states in $dd \rightarrow (^4\text{He-}\eta)_{bs} \rightarrow {}^3\text{He}p\pi^-$ and $dd \rightarrow (^4\text{He-}\eta)_{bs} \rightarrow {}^3\text{He}n\pi^0$ reactions with the WASA-at-COSY facility.

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The existence of η-mesic nuclei in which the η meson is bound in a nucleus by means of the strong interaction was postulated already in 1986 [1] but it has not been yet confirmed experimentally. The discovery of this new kind of an exotic nuclear matter would be very important as it might allow for a better understanding of the η meson structure and its interaction with nucleons [2,3]. The search for η-mesic helium (^{4}He-η) is carried out with high statistics and high acceptance with the WASA detector, installed at the cooler synchrotron COSY of the Research Center Jülich [4].
The search is conducted via the measurement of the excitation function for selected decay channels of the ^{4}He-η system. The kinematics of the reaction is schematically presented in Fig. 1.

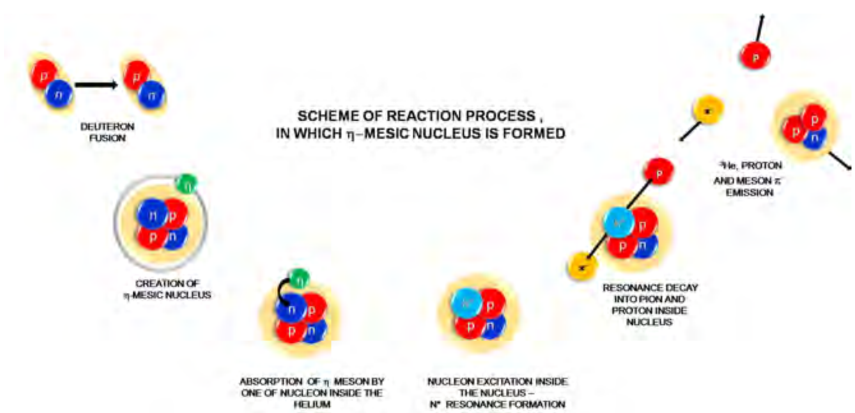

Figure 1: *Reaction process of the* (^{4}*He*-η)$_{bs}$ *production and decay.*

The deuteron beam - deuteron target collision leads to the creation of the ^{4}He nucleus bound with the η meson via strong interaction. The η meson can be absorbed by one of the nucleons inside helium and may propagate in the nucleus via consecutive excitation of nucleons to the $\text{N}^*(1525)$ state until the resonance decays into the pion-proton pair outgoing from the nucleus [5]. The relative angle between p and π^- is equal to 180° in the N^* reference frame and it is smeared by about 30° in the center-of-mass frame due to the Fermi motion of the nucleons inside the helium nucleus.

In the experiment, performed in November 2010, two reactions $dd \rightarrow (^4\text{He-}\eta)_{bs} \rightarrow {}^3\text{He}p\pi^-$ and $dd \rightarrow (^4\text{He-}\eta)_{bs} \rightarrow {}^3\text{He}n\pi^0$ were measured with a beam momentum ramped from 2.127GeV/c to 2.422GeV/c. The poster will include description of the experimental method and status of the analysis.

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Study on $^{6}_{\Lambda}$H hypernucleus by the (π^-, K^+) reaction at J-PARC

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One of the frontier topics in the strangeness nuclear physics is the study of neutron-rich Λ hypernuclei[1]. It is expected that the glue like role of the Λ hyperon is critical in nuclei beyond the neutron-drip line. The knowledge of the behavior of hyperons in a neutron-excess environment will significantly affect our understanding of neutron stars, because adding hyperons softens the Equation of State of matter at the core[2].

Motivated by these issues, we aimed to produce $^{6}_{\Lambda}$H hypernucleus because the hypernucleus has the largest neutron to proton ratio. The study would provide new information on the hypernuclear physics and the neutron star structures. Recently, the FINUDA collaboration reported observation of 3 candidate events for the production of the $^{6}_{\Lambda}$H hypernucleus[3]. The FINUDA result was suggesting a bound state of the $^{6}_{\Lambda}$H hypernucleus and was encouraging for us.

We carried out the $^{6}_{\Lambda}$H production experiment by the (π^-, K^+) double charge-exchange reaction on a ^{6}Li target at the pion beam momentum of 1.2GeV/c. Moreover, in order to calibrate the scale of the mass or Λ binding energy of the hypernucleus, we measured the ^{12}C$(\pi^+, K^+)^{12}_{\Lambda}C, p(\pi^-, K^+)\Sigma^-$ and p$(\pi^+, K^+)\Sigma^+$ reactions. In our experiment during December 2012 to January 2013 at the K1.8 beamline, Hadron Hall, J-PARC, the data have been collected for an integrated beam intensity of 1.65×10^{12} pions. The results of the $^{6}_{\Lambda}$H production experiment will be presented and discussed in this conference.

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Formation of strange dibaryon X(2265) in $p + p \to K^+ + X$ reaction at T$_p$ = 2.5 and 2.85 GeV

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The so-called $X(2265)$ resonance state has been observed [1] in an exclusive data set of $pp \to p\Lambda K^+$ at $T_p = 2.85$ GeV of DISTO data with a mass of 2267 MeV/c^2 and a width 118 MeV. The $X(2265)$ state has a baryon number 2 and a strangeness -1 and it is possibly a candidate of the $(\bar{K}NN)_{S=0,I=1/2}$ kaonic nuclear system, often called K^-pp. We studied [2] the energy dependence of the production rate of the $X(2265)$ in the DISTO $pp \to p\Lambda K^+$ data at $T_p = 2.5$ and 2.85 GeV. If the $X(2265)$ is produced in a similar mechanism as a hyperon production in the $pp \to p\Lambda K^+$ then the $X(2265)$ at $T_p = 2.5$ GeV would be produced as much as 33% of the $T_p = 2.85$ GeV case. However, if the $\Lambda(1405)$ plays an important role as a door way to the high density kaonic nuclear systems [3], then the production of the $X(2265)$ would be strongly suppressed at 2.5 GeV as the beam energy is too close to the production threshold of the $\Lambda(1405)$ and therefore $\Lambda(1405)$ is merely produced at that energy. We found in the 2.5 GeV data no clear sign of a formation of the $X(2265)$. This fits to the latter scenario, supporting that the $X(2265)$ resonance is the long-searched K^-pp system.

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Missing Mass Spectroscopy of η' Mesic Nuclei with (p, d) Reaction at GSI

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An η' meson has a peculiarly large mass, which is theoretically understood as the $U_A(1)$ axial anomaly effect. Since the strength of this effect for the η' mass is considered to be related to the chiral condensate [1], the η' mass may be reduced in nuclear medium, where the chiral symmetry is partially restored. According to the Nambu-Jona-Lasinio model calculation, the mass of η' at normal nuclear density is reduced by about 150 MeV/c^2 [2, 3]. Such large mass reduction implies a strong attractive potential between η' and a nucleus. Thus, η' meson-nucleus bound states (η' mesic nuclei) may exist.

As for the decay width, the CBELSA/TAPS collaboration deduced that the absorption width of the η' meson at the nuclear saturation density is around 15 - 25 MeV at the average η' momentum of 1050 MeV/c [4]. This suggests that the decay width of η' mesic nuclei could be small as well, and they may be observed as narrow peaks experimentally.

We are planning a missing-mass spectroscopy of η' mesic nuclei with the ^{12}C$(p, d)\eta'\otimes^{11}$C reaction at GSI [5]. A 2.5 GeV proton beam of the Heavy Ion Synchrotron (SIS) will be injected to a ^{12}C target. Then, to obtain the missing mass of the reaction, the momentum of the ejectile deuterons will be analyzed by the Fragment Separator (FRS) as a spectrometer. In this inclusive measurement, a signal-to-noise ratio is expected to be very small due to background processes dominated by quasi-free multi-pion production ($p+N \rightarrow d+\pi$'s). This can be overcome by a high-statistics measurement using an intense proton beam ($\sim 10^{10}$ /spill) and a thick production target (~ 4 g/cm^2). With this condition, if the mass reduction in the medium is around 150 MeV as predicted by the NJL model and the decay width is as small as 20 MeV, peak structures may be observed even in the inclusive spectrum [5].

In this contribution, we will describe the plan of this experiment, and report the feasibility study for several mass reductions and decay widths in the medium. Moreover, the status of the preparation for the first pilot experiment expected in 2013 - 2014 will be presented.

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Beam diagnostics for measurements of antiproton annihilation cross sections at ultra-low energy

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The ASACUSA collaboration of CERN measured the antiproton-nucleus annihilation cross sections with targets of Mylar, Ni, Sn, and Pt at 5.3 MeV of kinetic energy. Their values were consistent with a prediction from a modified black-disk model, which meant antiprotons were so strongly absorbed by nuclei that elementary processes of quarks inside antiprotons and nuclei could not be observed explicitly[1]. Recently we have extended the measurements down to 130 keV, where no experimental data existed and a clear deviation from the black-disk model was expected to be observed[2,3]. The knowledge of the cross section at the very low energy was also important to understand the annihilation process between matter and antimatter which should be occurred at the nucleosynthesis time[2].

The low-energy antiprotons were produced by using the Antiproton Decelerator (AD) and a radio-frequency quadrupole decelerator. As the AD provided a 200-ns-long pulsed beam containing 10^7 antiprotons, the instantaneous flux arriving at the experiment was too high to resolve individual annihilations. This made it difficult to distinguish the signals of annihilation events occurring on the target from backgrounds caused by spurious annihilations in the surrounding apparatus. A beam profile monitor and electrostatic quadrupole triplet were therefore developed to ensure that the antiprotons were precisely tuned to the 8-cm-diameter experimental target. The monitor placed at the position of the target was a secondary electron emission detector with an active area of 40×40 mm^2 and a spacial resolution of 4 mm[4]. The electrostatic triplet had a 10-cm-diameter aperture which was large enough to avoid the 5-cm-diameter antiproton beam from striking the electrodes and causing background annihilations. A beam chopper consisting of two parallel electrode plates was also developed to reduce the pulse length of the antiproton beam to 100 ns. This allowed the antiproton annihilations to be better separated in time from the background. These new instruments are presented, and their performance in connection with the preliminary experimental results are discussed.

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Six-body calculations for hyperhydrogen ${}^{6}_{\lambda}H$

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In this work we show results for six body heavy hyperhydrogen ${}^{6}_{\lambda}H$ using the symmetrized hyperspherical harmonics basis. We consider a nucleon system interacting through the Volkov potential and a Hyperon nucleon system through the Nijmegen potential [1]. Our calculation for binding B(${}^{6}_{\lambda}H$ energy, respect $\lambda + {}^{5}H$ is -3.91 Mev which is in good agreement with experimental result [2] and with earlier calculations [3], but is smaller than prediction of [4]. Our results indicates that $\lambda N \to \Sigma N$ conversion is ineffective for p state -neutrons in ${}^{6}_{\lambda}H$.

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p d $\rightarrow$ ^{3}He η reaction beyond threshold energies

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Experimental data on p d $\rightarrow$ ^{3}He η reaction near threshold energies show an unusual rise in the cross section and nearly an isotropic angular distribution. These aspects have been understood in the two-step model including the final state interaction between ^{3}He and η [1]. At higher energies the two-step model predicts cross sections which peak in backward direction of the eta meson. This is in total variance with the observed cross sections which peak near to the forward directions. As a first step in the direction of understanding these data, we present in this contribution calculated angular distributions (shown in Fig. 1) using the elementary reaction, p p $\rightarrow$ p p η as a step for eta production in the nucleus. Other aspects which will affect the calculated cross sections are the FSI and the choice of the bound state wave functions. At present we have ignored these aspects, and have taken wave functions generated by the Paris N-N potential [2]. The η-production vertex is described in the Boson-Exchange Model (BEM). In the description of the elementary reaction, in the literature, both π and ρ-exchanges have been used. However, the magnitude of the ρ contribution depends on whether one uses $\gamma_5\sigma_{\mu\nu}$ or $\gamma_5\sigma_\mu$ coupling. The contribution of the former is very small. Also the recently reported polarization data [3] disfavors the ρ-exchange. Therefore, in the present contribution we have included only one pion-exchange in the BEM. Results presented in Fig. 1 are for different beam energies well above the threshold. Distributions peak in the forward hemisphere, though a second peak can also be seen in the backward hemisphere. Magnitude of cross section increases with the beam energy. Further study of small magnitude of cross sections is in progress.

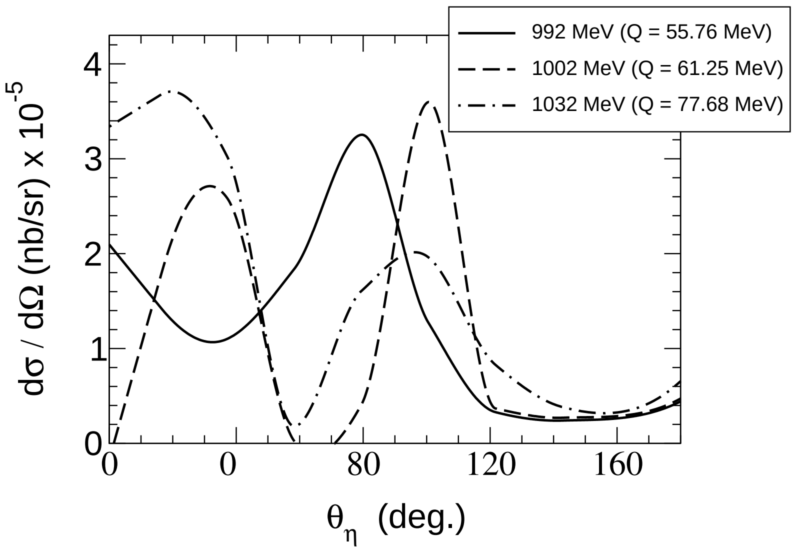

Figure 1: *Angular distribution of η as a function of angles for different beam energies well above threshold. Corresponding excitation energy, $Q(=\sqrt{s}$ - $M_{^3\mathrm{He}}$ - $M_\eta)$ is also shown.*

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Structure of low-lying spectrum of cluster $\alpha n\Lambda$ system

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We study structure of energy spectrum of hypothetic ${}^{6}_{\Lambda}$He hyprnuclei using a $\alpha + n + \Lambda$ cluster model. The spin doublet $(1^-,2^-)$ of ${}^{6}_{\Lambda}$He is interesting for the testing purpose of the theoretical hyperon-nucleon interaction models [1-3]. The binding energy of the 1^- state (singlet $n\Lambda$ spin state) of ${}^{6}_{\Lambda}$He has been evaluated in [1] (-0.17 MeV). Theoretical considerations for the 2^- state (triplet $n\Lambda$ spin state) have been done by Motoba et al. in [2] and Hiyama et al. in [3]. An indirect prediction for the 2^- state has been given in [4]. In the present work, our cluster approach is based on the configuration-space Faddeev equations for a system of three non-identical particles. The analytical continuation method in a coupling constant is applied for calculation of resonance parameters. The αn interaction is constructed to reproduce the results of R-matrix analysis for αn-scattering data [5]. An $\alpha\Lambda$ potential was proposed in [6]. For the $n\Lambda$ interaction the s-wave potential [7] simulating model NSC97f was used. We calculated energies of the low-lying 1^-, 2^-, 2^+, 0^- states. Our predictions for the $(1^-,2^-)$ energy gap agree with those obtained in other calculations. Structure of the ${}^{6}_{\Lambda}$He low-lying spectrum is presented in Fig. 1. Comparing the ^{6}He and ${}^{6}_{\Lambda}$He spectra one can consider the 0^- state to be a genue hypernuclear state.

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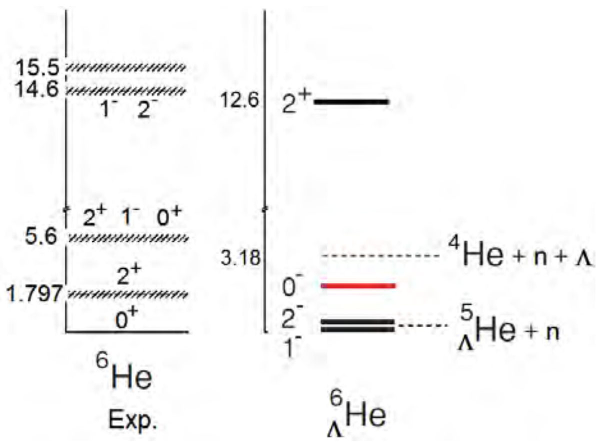

Figure 1: *Spectra of the ^{6}He (experimental data are from [8]) and ${}^{6}_{\Lambda}$H.*

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Charmonium-Nucleus Bound States

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It was conjectured [1] that the charmonium ($c\bar{c}$) forms bound states in nuclear medium since the charmonium-nucleon interaction dominated by the QCD color van der Waals interaction is weak but attractive. Recent lattice QCD calculation [2] also suggests that the $c\bar{c}-$nucleon scattering lengths correspond to weak attractive interactions.

In this study [3], we give a precise calculation of the $(c\bar{c}) - NN$ three body bound states and $J/\psi-^4$He bound states by using phenomenological potential model via the Gaussian Expansion Method [4] which was developed by Kyushu Univ. group. We adopt the Gaussian potentials for the $\eta_c - N$ and $J/\psi - N$ interactions. The relations between the scattering lengths a and the $(c\bar{c}) - NN$ binding energies are given for both $\eta_c - NN$ and $J/\psi - NN$ cases. Our calculations show that scattering lengths $a \leq -0.95$ fm are needed to form $\eta_c - NN$ and $J/\psi - NN$ bound states. We also calculate $J/\psi-^4$He binding energy and obtain the condition, $a \leq -0.24$ fm, for a bound state. The values of the scattering lengths found in the lattice QCD calculation [2], $a \sim -0.35$ fm, seem to be too small to form $\eta_c - NN$ or $J/\psi - NN$ bound states. In contrast, we find that $J/\psi-^4$He will form a bound state (B.E. ~ 0.5 MeV) with the scattering length from the lattice QCD (see Fig. 1). It is found that the results are not sensitive to the choice of the Gaussian form or its range of the potential.

Thus, we conclude that the charmonium ($c\bar{c}$) will form bound states with nuclei of $A \geq 4$, supposing that the lattice QCD evaluation of the charmonium-nucleon scattering length is reliable.

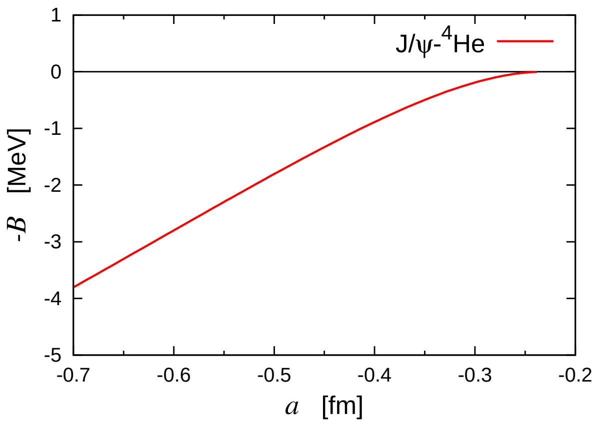

Figure 1: Relation between the binding energy B of $J/\psi-^4$He and the $J/\psi - N$ scattering length a. A bound state is formed when $a \leq -0.24$ fm.

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