The 9th Japan-China Joint Nuclear Physics Symposium
(JCNP 2015)

November 7-12, 2015
Osaka, Japan

Abstracts
Sunday, Nov. 8  Opening session (8:50-10:30)
Chairperson: Kichiji Hatanaka (RCNP), Guoqing Xiao (IMP)

[8:50-9:00]
Welcome Address
Presenter: Takashi Nakano (RCNP)

Opening Address
Presenter: Yanlin Ye (Peking University)

[9:00-9:30]
Ever Growing Tradition of China-Japan Cooperation on Nuclear Physics
Presenter: Masayasu Ishihara (RIKEN)

International collaboration is vital for enhancing productivity of scientific activities, and is particularly so for the fields of Big Science such as nuclear physics, where harmonic organization of the best intelligence and expertise over the world is demanded so as to fully exploit the rare opportunities provided by a limited number of leading edge facilities available. Bearing such spirits in mind contemporary China-Japan Cooperation on nuclear and accelerator physics has been pursued intensively for the last few decades. The cooperation effectively started in 1990 when the 1st Joint Symposium on Accelerator Science was held in Atami. Ever since, the collaboration between the two countries has been developing steadily on both nuclear physics and accelerator science. Nowadays a wide variety of cooperative programs are active on the sites of daily research activities on experimental and theoretical nuclear physics.

In pursuing such collaboration one rather seeks for long-term merits which would gradually build up over a time span extending towards prosperity in far future. To accomplish such a long-term endeavor, one often needs to be patient by consistently making ceaseless efforts. Thus successful programs have often demanded commitment of such leaders as are genuinely equipped with the spirits of bilateral respect and reliance and with a clear perspective about for what/how the eventual goals should/could be realized.

Indeed, by tracing our history of the China-Japan collaboration, we readily find several individuals/institutions, who are/were determined to take initiatives to open up an innovative program and to exercise strong leaderships to successfully accomplish it. In
this talk I shall try to pick up and illustrate some examples of those respectable individuals/institutions so as to properly acknowledge their contributions and also to learn a lesson about how the productive cooperation can be established.

[9:30-10:00]

**Mass Measurement of Short-lived Nuclei at HIRFL-CSR**

*Presenter: Meng Wang (Institute of Modern Physics)*

Six campaigns of mass measurements for short-lived nuclei have been conducted at HIRFL-CSR (Cooler Storage Ring) in Lanzhou. The radioactive nuclei were produced by projectile fragmentation and injected into the experimental storage ring CSRe, which was set as an isochronous mass spectrometry (IMS). Revolution times of the ions stored in the CSRe were measured, and from which masses of 78Kr, 58Ni, 86Kr, 112Sn and 36Ar fragments have been determined with a relative uncertainty of about $10^{-6}$-$10^{-7}$.

In the latest experiment the IMS with two time-of-flight detectors have been realized. In this way the velocity of each stored ion can be measured in addition to its revolution time, thus the resolving power of the IMS could be significantly improved. Some of the experimental results will be presented and their impacts on nucleosynthesis in the rp process and nuclear structure will discussed.

[10:00-10:30]

**SHE research at RIKEN/GARIS**

*Presenter: Kosuke Morita (Kyushu University/RIKEN)*

A cold heavy-ion fusion reactions have been used for producing nuclei of the heaviest elements at RIKEN with use of a gas-filled type recoil ion separator GARIS. The heaviest nuclei which we studied were an isotope of the 113th element, 278113, produced in the 209Bi(70Zn, n) reaction [1-3]. Unambiguous identification of an atomic number and an atomic mass-number of the isotope based on the genetic correlation was done.

Before performing the experiment on element 113, we have done a series of experiment to confirm the experimental results performed at GSI on the atomic numbers 108 (Hs) [4], 110 (Ds) [5], 111 (Rg) [6], and 112 (Cn) [7,8] by using 58Fe, 64Ni, and 70Zn beams on to 208Pb, and 209Bi targets. The results provide firm confirmation to the results obtained at GSI. Some of new spectroscopic information on the nuclei were obtained also. Study of an actinide based hot fusion reaction are also started. The
reaction in study is $^{248}\text{Cm} + 48\text{Ca}$. Similar decay chains to the ones previously observed at FLNR/GFRS and at GSI/SHIP were observed in two different beam energies. The corresponding excitation energies of the compound nucleus $^{296}\text{Lv}$ were $37.5 \pm 1.5$ MeV and $41.5 \pm 1.5$ MeV. We plan to measure one more point at higher excitation energy to obtain an excitation function of the reaction. A $^{50}\text{Ti}$ beam is now in development by MIVOC method [9] for the future study of the $^{248}\text{Cm} + 50\text{Ti} \rightarrow 298\text{I}^{18*}$ reaction.

References:
[1] K. Morita et al., J. Phys. Soc. Jpn. 73 (2004) 2593.
[2] K. Morita et al., J. Phys. Soc. Jpn. 76 (2007) 045001.
[3] K. Morita et al., J. Phys. Soc. Jpn. 81 (2012) 103201.
[4] N. Sato et al., J. Phys. Soc. Jpn. 80 (2011) 094201.
[5] K. Morita et al., Eur. Phys. J. A21 (2004) 257.
[6] K. Morita et al., J. Phys. Soc. Jpn. 73 (2004) 1738.
[7] K. Morita et al., J. Phys. Soc. Jpn. 76 (2007) 043201.
[8] T. Sumita et al., J. Phys. Soc. Jpn. 82 (2013) 024202.
[9] J. Rube rt , J. Piot , Z. Asfari , B.JP. Gall , J. Ä rje et al., Nucl. Instr. Meth. Phys. Res., 2012 , B 276 , 33-37
[11:00-11:30]
**Recent Advances in Covariant Chiral Perturbation Theory: from Static Properties to Scattering Processes**
*Presenter:* Lisheng Geng (Beihang University)

[11:30-12:00]
**The nucleon-pair approximation of the shell model**
*Presenter:* Yiyuan Cheng (Shanghai Jiaotong University/RCNP)

The nucleon-pair approximation (NPA) is an efficient truncation scheme of the gigantic shell model space. Building blocks of the NPA model space are nucleon pairs with given spins. The key technique of calculating the Hamiltonian matrix elements between the NPA basis is the Wick theorem for coupled fermion clusters [1], and the general framework of the NPA was proposed in Ref. [2] and refined in Refs. [3,4]. The nucleon-pair approximation leads to simple pictures in physics, as the dimension of nucleon-pair subspace is always small. Recently, we study semi-magic $N=82$ isotones and Sn isotopes [5], and find most low-lying states of these nuclei are well represented by very simple nucleon-pair configurations. In particular, the yrast parity-positive (parity-negative) states above the seniority-two spin-maximum parity-positive (parity-negative) state (denoted as $J^p$) can be well approximated by breaking $S$ pairs of the $J^p$ state. From another perspective, the NPA with isospin symmetry [6] provides an appropriate framework to study proton-neutron pairing in the low-lying states of $N=Z$ nuclei. Interestingly, it is found low-lying states of $N=Z$ nuclei can be well described by both the isoscalar pair approximation and the isovector pair approximation.

References:
[1] J. Q. Chen, Nucl. Phys. A 563, 218 (1993).
[2] J. Q. Chen, Nucl. Phys. A 626, 686 (1997).
[3] Y. M. Zhao, N. Yoshinaga, S. Yamaji, J. Q. Chen, and A. Arima, Phys. Rev. C 62, 014304 (2000).
[4] Y. M. Zhao and A. Arima, Phys. Rep. 545, 1 (2014).
[5] Y. Y. Cheng, Y. M. Zhao and A. Arima, to be published.
[6] G. J. Fu, Y. Lei, Y. M. Zhao, S. Pittel, and A. Arima, Phys. Rev. C 87, 044310 (2013).

[12:00-12:30]

**Study of Nuclear Responses with Grand Raiden Spectrometer**

*Presenter:* Atsushi Tamii (RCNP)

I will pickup recent experimental studies with the high-resolution spectrometer Grand Raiden of the nuclear spin-isospin responses and the nuclear equation of state.
Sunday, Nov. 8  Session 3 (14:00-15:30)
Chairperson: Kosuke Morita (Kyushu University/RIKEN)

[14:00-14:30]
**CAGRA project and gamma-ray spectroscopy at RCNP**
*Presenter:* Eiji Ideguchi (RCNP)

CAGRA project is now on-going at RCNP cyclotron facility. Based on the U.S.-Japan-China collaboration, this project has constructed a Compton suppressed Germanium clover array (CAGRA) consisted of 16 Ge Clover detectors with BGO anti-Compton shields. It will provide many physics opportunities and strongly enhance the scientific output from the experimental program at RCNP. Three experimental sites are foreseen: at the EN beam line, where beams of rare isotopes are available; the Grand Raiden Spectrometer, where high-precision coincidence experiments utilizing light-ion reactions can be performed; and the muon beam facility (MuSIC) at RCNP. A wide variety of important scientific questions will be addressed, such as the detailed nature of pygmy dipole and Gamow-Teller resonances, the shell-evolution across the chart of nuclei, searches for superdeformed states, as well as astrophysical applications. Recently, CAGRA campaign experiments were successfully performed at RCNP EN beam line. An overview of EN CAGRA campaign and future prospect of CAGRA project will be presented.

[14:30-15:00]
**Spectroscopic study on the intruder states in $^{12}$Be via $^{11}$Be (d,p)**
*Presenter:* Jianling Lou (Peking University)

The s-wave spectroscopic factors (SF) of the 01+( ground state ), 02+( isomeric state ) of $^{12}$Be were extracted from the differential cross sections of $^{11}$Be( d, p )$^{12}$Be transfer reaction using a 27 MeV/nucleon $^{11}$Be beam at Research Center of Nuclear Physics, Osaka University, Japan. The ground state and isomeric state were clearly identified from other low-lying excited states by the coincident measurements. SFs were primarily determined to be $0.14\pm0.04$ and $0.24 \pm 0.08$ for 01+ and 02+, respectively. The experimental results were compared to the oxbash calculations in the psd model space with the newly constructed shell-model Hamiltonian, which includes $(2-3)$ excitations and reproduce well the ground state energies, drip lines, energy levels, electric
properties, and spin properties of psd-shell nuclei. The differential cross sections of 11Be + p, 11Be + d elastic scattering were also measured at the same experiment to obtain the reliable optical potential parameters of the entrance channel 11Be + d and the proton percent in CD2 target by comparing these two elastic scattering data sets. The X-CDCC method, including the core-excitation of 11Be was employed to describe the angular distributions of the break-up reactions to 10Be + n continuums of the 11Be on protons and deuterons, and the results indicated that the core-excitations could not be ignored in the description of the break-up data.

[15:00-15:30]

**Two-proton emission from proton-rich nuclei** -\textsuperscript{22}Mg and \textsuperscript{23}Al

*Presenter: Deqing Fang (Shanghai Institute of Applied Physics)*

The decay of proton-rich nuclei, especially the two-proton (2\(p\)) radioactivity, is an interesting process that may be observed in nuclei beyond or close to the proton dripline. One and two-proton emission from \textsuperscript{23}Al and \textsuperscript{22}Mg have been measured experimentally by the nuclear reaction method and also the beta-delayed decay method. The energy spectrum for one proton emission and the half-life for beta-decay were obtained. From the spectrum of relative momentum and open angle between two protons, we observed strong component of \(^2\)He-like cluster emission from high excitation energy states of \textsuperscript{22}Mg. While for \textsuperscript{23}Al, sequential proton decay is dominate.
Sunday, Nov. 8  Session 4 (16:00-17:30)
Chairperson: Furong Xu (Peking University)

[16:00-16:30]
**Container picture for cluster structures of 12C**
*Presenter:* Bo Zhou (Nanjing University/Hokkaido University)

A container picture is proposed for understanding cluster dynamics where the clusters
make nonlocalized motion characterized by the size parameter in the THSR
(Tohsaki-Horiuchi-Schuck- Röpke) wave function. Quite recently, we studied some
cluster states of 12C using an extended 2+ THSR wave function. Some resonance
cluster states and 2 correlation problems in 12C are discussed in the container picture.

[16:30-17:00]
**Alpha inelastic scattering and cluster structures in 24Mg**
*Presenter:* Takahiro Kawabata (Kyoto University)

Alpha particle clustering is an important concept in nuclear physics. The most famous
α cluster state is the 0\(^+_2\) state in 12C which locates at an excitation energy higher than the
3α-decay threshold by 0.39 MeV. This 0\(^+_2\) state is theoretically described by introducing
a novel concept of the nuclear structure, *i.e.*, this state has a dilute-gas-like structure
where three α clusters are weakly interacting and are condensed into the lowest s-orbit.
The next natural question addressed is whether such α condensed states exist in heavier
self-conjugate 4n nuclei.

Such α condensed states are theoretically predicted up to \(n = 10\). The energy of the \(n\alpha\) condensed state from the \(n\alpha\)-decay threshold increases with \(n\) due to the short-range
nature of the attractive force between α clusters and the long-range nature of the
Coulomb repulsion, and the \(n\alpha\) condensed state becomes unstable beyond \(n = 10\).

A recent theoretical work proposed a new conformation of the α condensed state
where α clusters are condensed into the lowest s-orbit around a core nucleus. Attractive
potential for α clusters provided by the core nucleus stabilizes the α condensed state
around the core nucleus even in heavier nuclei. Thus, such α condensed states around
core nuclei are expected to appear at lower excitation energies than the corresponding
cluster-decay threshold energies.
In our previous work, it was demonstrated that spatially well-developed cluster states in light nuclei, whose spins and parities are the same as in the ground state, are strongly excited by isoscalar monopole transitions. The alpha inelastic scattering at intermediate energies and at forward angles is one of the most useful probes to measure the isoscalar monopole strengths because its reaction mechanism is simple. It has a selectivity for isoscalar natural-parity transitions and there is a good linear relation between the reaction cross sections and the relevant nuclear transition matrix elements.

Recently, we performed a high-resolution measurement of alpha inelastic scattering from $^{24}\text{Mg}$ to search for the alpha condensed states with the configuration of $6\alpha$ or $2\alpha+^{16}\text{O}$. In the present talk, we will present the experimental details and results on the cluster structures in $^{24}\text{Mg}$.

[17:00-17:30]

**Monopole transitions in light unstable nuclei**

*Presenter: Makoto Ito (Kansai University)*

In light unstable nuclei, many kinds of molecular structures are discussed from the viewpoint of the clustering phenomena. In particular, much attention has been concentrated on Be isotopes, and various chemical-bonding-like structures appear in these isotopes on the basis of the $^8\text{Be}=\alpha+\alpha$ structure. For example, the molecular orbit (MO) structures, such as $\alpha+\alpha+N+N...$, appear in the low-lying states, while the atomic (AO) structures, corresponding to the binary $^x\text{He}+^y\text{He}$ configurations, are expected to realize in the highly-excited resonances. The picture of the chemical-bonding structures are extended to the C, O, and Ne isotopes in recent studies.

In this report, we will discuss the monopole transition of light unstable nuclei in connection to the chemical-bonding structures. The monopole transition is considered to be an important tool to identify the cluster degrees of freedom. We employ the Generalized Two-center ClusterModel (GTCM), which is possible to describe the formation of the MO and AO structures in general two-center systems.

We will show the feature of the isoscalar and isovector monopole-transitions in the $^{12}\text{Be}$ nucleus. The former transition mainly excites the $\alpha-\alpha$ relative excitation, while the latter transition strongly responds to the excitation of the excess neutrons. We will demonstrate that the excitation degrees of freedom can be identified by combing the isoscalar and isovector transitions.
The GTCM calculations are also applied to the mirror systems of $^{10}\text{Be}^{-10}\text{C}$, and their mirror symmetry is investigated. We have found that the Coulomb shift is clearly suppressed in the cluster states. Moreover, we have confirmed that a prominent breaking of the mirror symmetry occurs in the monopole transition. We will discuss the important and interesting aspects in the analysis of the mirror systems.
Monday, Nov. 9  Session 5 (9:00-10:30)
Chairperson: Hiroyoshi Sakurai (University of Tokyo/RIKEN)

[9:00-9:30]
**Introduction on the New Project HIAF**
*Presenter: Guoqing Xiao (Institute of Modern Physics)*

[9:30-10:00]
**Current Status of J-PARC**
*Presenter: Naohito Saito (KEK)*

[10:00-10:30]
**Toward high precision nuclear spectroscopy at SLOWRI, RIKEN RIBF**
*Presenter: Michiharu Wada (KEK)*

In modern nuclear physics, high precision measurements of the ground state properties of all available nuclei are in high demand. For such measurements, ion traps and low-energy, low-emittance beams have played important roles, providing accurate atomic masses, nuclear spins and moments, nuclear charge radii and so on. However, such RI beams have been obtained for only a limited number of elements and relatively long-lived nuclei.

A newly constructed facility, SLOWRI at RIKEN RIBF, will be able to provide high-purity, low-energy or trapped radioactive nuclei of almost all elements, including short-lived nuclei. SLOWRI consists of two gas catcher devices: one is the RFC gas cell for universal ion beams using an rf-carpet ion guide and the other is the PALIS gas cell for parasitic RI beams using resonant re-ionization in the gas cell. Thus obtained RI beams will be transported to the SLOWRI experimental area where such experimental devices as a collinear fast beam apparatus, a multi-reflection time-of-flight mass spectrograph, and decay spectrometers are under preparation.

In order to emphasize the low-energy nuclear physics research activity using SLOWRI and KISS (KEK Isotope Separator System), an international collaboration group, SSRI-pns (stopped and slow RI beams for precise nuclear spectroscopy), has recently been organized. Within a few years, these facilities will be ready for users from universities and international laboratories, and comprehensive precision measurements
of nuclear properties will be performed.
Monday, Nov. 9  Session 6 (11:00-12:30)
Chairperson: Chengjian Lin (China Institute of Atomic Energy)

[11:00-11:30]
**Status of the deuteron stripping reaction theories**
*Presenter:* Danyang Pang (Beihang University)

For more than 60 years deuteron stripping reactions have been one of the main tools to extract spectroscopic information, such as spectroscopic factors and asymptotic normalization coefficients, that are important for nuclear structure, nuclear astrophysics, and applied physics. In this talk we examine the main features of the theories for such a reaction, starting from the plane-wave Born approximation developed in early 50’s of the last century to the Faddeev method which is still under development. Problems of nonlocality and inconsistency in the nucleon potentials and their effects on the transfer reaction cross sections will also be discussed.

[11:30-12:00]
**Microscopic reaction theory for many-body nuclear reactions**
*Presenter:* Kosho Minomo (RCNP)

Microscopic description of many-body nuclear reactions is the fundamental subject in nuclear physics. Based on multiple scattering theory, elastic scattering, which is one of most basic processes, is described by multistep processes with a nucleon-nucleon effective interaction. In practice, a g-matrix interaction is used as effective interactions. We aim for fully microscopic understanding of many-body nuclear reactions with the nucleon-nucleon effective interactions.

In this talk, I introduce a new microscopic reaction theory starting from two- and three-nucleon forces based on chiral effective field theory (Ch-EFT). We first construct a g-matrix with the nuclear forces based on Ch-EFT using Brueckner-Hartree-Fock Theory, in which the three-nucleon force effects are represented through the density dependence of the g-matrix. Then, the folding model and microscopic coupled-channels method with the g-matrix are applied to nucleon-nucleus and nucleus-nucleus scattering at intermediate incident energies. This new microscopic reaction theory well describes the elastic and inelastic cross sections with no ad-hoc parameters. Furthermore, I show an application of the microscopic reaction theory to knockout and breakup reactions.
Isovectoror Reorientation of Deuteron in the Field of Heavy Target

Presenter: Zhigang Xiao (Tsinghua University)

The difference of nuclear force experienced by the proton and the neutron, known as isovector potential, is relevant to the reaction dynamics induced by exotic nuclei and to the evolution process and static properties of neutron star. Represented in the density dependence of the nuclear symmetry energy, it has been extensively discussed in the past decade. Some effective probes have been identified to probe the symmetry energy and some convergent constraints have been achieved near the saturation density. In this talk, I will describe the reorientation effect of deuteron attributed to isovector interaction in the nuclear field of heavy target nuclei within the framework of the ImQMD transport model. The isovector force forms a torque acting on the proton and the neutron and modifies the orientation of the incident deuteron. This effect, in addition to the Coulomb polarization effect first reported by Oppenheimer and Lawrence in 1930s, shows clean and sensitive dependence on the symmetry energy varying with density. The experimental accessibility of this observable is demonstrated.
Monday, Nov. 9  Session 7 (14:00-15:40)
Chairperson: Hidetoshi Akimune (Konan University)

[14:00-14:30]
Commissioning of the rare-RI ring at RIKEN RI Beam Factory
Presenter: Yoshitaka Yamaguchi (RIKEN)

A commissioning run using a $^{78}$Kr beam was performed in June 2015 and basic performances of rare-RI ring (R3) were verified. We succeeded in injecting a particle, which was randomly produced from a DC beam from cyclotrons, into the R3 individually with a fast kicker system, and in extracting the particle from the R3 1 ms after the injection. We measured TOF of the $^{78}$Kr particles between the entrance and the exit of the R3 to check the isochronism. Through the first-order adjustment with trim-coils fixed on the dipole magnets of the R3, the isochronism on the 10-ppm order was achieved for the momentum spread of $\pm0.2\%$. Higher-order adjustment employed in future will lead us to the isochronism on the order of ppm. In addition, we confirmed that a resonance-type Schottky pick-up successfully acquired the frequency information of one particle in a storage mode. In this conference, the technical aspects of the R3 and some results of the beam commissioning will be presented.

[14:30-14:50]
Direct mass measurements of $^{58}$Ni projectile fragments at CSRe
Presenter: Xinliang Yan (Institute of Modern Physics)

Isochronous mass spectrometry (IMS) is a storage ring based technique for accurate mass measure- ments of short-lived nuclei. Masses of nuclides with half-lives as short as a few ten microseconds and production rates as tiny as a few ions per day can be addressed. In this contribution we describe experimental results obtained at the Experimental Cooler-Storage Ring (CSRe) at the Institute of Modern Physics in Lanzhou, China. The IMS was applied to the neutron-deficient $^{58}$Ni fragments. Masses of series of $Tz = -3/2$ short-lived neutron-deficient nuclides including $^{41}$Ti, $^{45}$Cr, $^{49}$Fe and $^{53}$Ni were measured with a typical uncertainty of 30 keV. The impact of the new $^{45}$Cr masses on the modeling of rp-processes in X-ray bursts will be discussed.
MRTOF mass measurements at GARIS-II: Toward SHE identification via mass spectroscopy

Presenter: Peter Schury (University of Tsukuba)

In recent years multi-reflection time-of-flight mass spectrographs (MRTOF-MS), first proposed by Wollnik more than 20 years ago [1], have begun to make an impact in nuclear physics as isobar separators [2,3] and for use in precision mass measurements [4-6]. We hope to be able to use the MRTOF-MS to eventually change from a paradigm of identifying transactinide isotopes by α-decay chain to one of identification by mass determination. Doing so will reduce uncertainty in identification, especially in the region of hot-fusion where α-decay chains terminate in spontaneous fission before reaching well-known nuclei, which has bottlenecked acceptance by IUPAC of super heavy elements (SHE) with Z=113, 115, 117 and beyond [7].

The MRTOF-MS is the ideal tool for such a paradigm shift, being well-suited for low-yield, heavy, and short-lived nuclei. It achieves mass resolving powers $R_m > 100,000$ with flight times shorter than 10 ns for even the heaviest nuclei [8]. Additionally, it is a true spectrograph – as opposed to a spectrometer – making it capable of mass determinations with, in principle, as few as one detected ion. Owing to its spectrographic nature, the MRTOF-MS is able to simultaneously measure several species with high-precision. This capability has until now been limited to storage rings. As we have demonstrated [5,8], the MRTOF-MS allows for a considerably less complex data analysis than that used for storage rings.

As the first step toward mass spectrographic identification of SHE, we have installed a gas cell connected to an MRTOF-MS after the gas-filled recoil ion separator GARIS-II [9]. The system is described in some detail elsewhere [10]. We have used this system to initially perform mass measurements with fusion-evaporation reaction products lighter than Uranium, the masses of some of which have not previously been directly measured. In these measurements we demonstrated the ability of the MRTOF-MS to precisely determine the masses of several isotopes simultaneously and to do so in some cases with less than 10 detected ions. This provides the first steps towards a paradigm shift in which SHE will eventually be identified by mass spectroscopy rather than decay spectroscopy – an absolute necessity if the “island of stability” is to be identified.

References:
Alpha-decay of the neutron-deficient isotopes $^{215-217}$U

Presenter: Zaiguo Gan (Institute of Modern Physics)

The isotopes $^{216}$U and $^{215}$U were produced in the reaction $^{40}$Ar+$^{180}$W. At the beam energy of 187.2 MeV, six correlated $\alpha$-decay chains were assigned to the $^{216}$U. Four of them were attributed to the decay of $^{216}$U from the ground state and the others were assigned to the decay of $^{216}$U from an isomeric state. The $\alpha$-particle energies and half-lives were determined to be $8.384(30)$ MeV and $4.72(1.57)(+4.72)$ ms for the ground state of $^{216}$U and $10.582(30)$ MeV and $0.74(-0.29)(+1.34)$ ms for the isomeric state. The production cross section for $^{216}$U was measured to be about 300 pb. At the beam energy of 205.5 MeV, two decay chains of $^{215}$U were identified. The obtained $\alpha$-particle energy and half-life for $^{215}$U are $8.428(30)$ MeV and $0.73(-0.29)(+1.33)$ ms, respectively. The cross section for $^{215}$U at the beam energy of 205.5 MeV was determined to be about 50 pb. The measured
$\alpha$-particle energies of the two new isotopes fit well into the systematic of neutron-deficient uranium isotopes and they are also consistent with the systematic regularities observed in the $\alpha$ decay of neutron-deficient Rn isotopes through Pa isotopes (shown in fig.1). Fig.1. $\alpha$-particle energies of ground state to ground state transitions for neutron-deficient Rn, Fr, Ra, Ac, Th, Pa and U isotopes. Open squares refer to literature values. The red solid squares refer to the values of 216U and 215U measured in this work. Although one $\alpha$-particle energy if 8.005(20) MeV for the $\alpha$ decay of 217U has been reported in reference and this value has been plotted in this figure, it may not be the $\alpha$-particle energy of the ground state to ground state transition for 217U, due to its significant deviation from this systematic regularities. However, this assumption need to be confirmed by further experiments.

References:
L. Ma et al., Phys. Rev. C 91, 051302 (2015).
Z.Y. Zhang et al., Nucl. Instrum. Methods B 317, 315,(2013).
J.A. Heredia et al., Eur. Phys. J. A 46, 337 (2010). Y.B. Qian, Z.Z. Ren, D.D. Ni, Phys. Rev. C 83, 044317(2011).
Monday, Nov. 9  Session 8 (16:10-17:10)

Chairperson: Xiaohong Zhou (Institute of Modern Physics)

[16:10-16:40]

Recent activities in the time-dependent density-functional theory

Presenter: Takashi Nakatsukasa (University of Tsukuba)

In the study of strongly correlated many-particle systems, a fundamental challenge is to find basic properties of a variety of elementary modes of excitation, and to identify the degrees of freedom that are suitable for describing the collective phenomena. This leads to deep insights into the basic concepts of quantum many-body physics.

The energy density functional (EDF) models for nuclei are currently a leading theory for describing properties of heavy nuclei. A single EDF is capable of quantitative description of almost all the nuclei, including infinite nuclear matter. The concept is very similar to the density functional theory (DFT) in electronic systems, utilized in atomic, molecular, and solid state physics. Major conceptual difference is that, for the isolated finite nucleus, the nuclear EDF models are designed to reproduce the intrinsic ground state. Namely, the self-consistent solution produces a density distribution which spontaneously violates symmetries of the system, such as translational, rotational, and gauge symmetries. Nevertheless, these features can be rigorously treated in the DFT theorems for “wave-packet” states.

An extension of the DFT to the time-dependent DFT (TDDFT) provides a feasible description of many-body dynamics, which contains information on excited states in addition to the ground state. According to the spontaneous violation of the symmetry, the nuclear EDF has advantages and disadvantages which I want to clarify in this talk. I also present selected recent results of the TDDFT activities (mainly in Japan) and future perspectives.

[16:40-17:10]

Direct effect of tensor force by (p,d) reaction

Presenter: Satoru Terashima (Beihang University)

The tensor forces are the major components of the nucleon-nucleon interactions that provide the attractive forces in atomic nuclei. The tensor forces are essential in theoretical calculations to reproduce the binding energies of deuteron and alpha
particles. Despite the importance, there are few experimental signatures for tensor forces until now. Recently we started to search for experimental signatures of tensor forces via highly momentum miss-matched neutron transfer (p,d) reaction on 16O using 200 MeV proton beam at RCNP and GSI. These measurements will cover high momentum transfer up to and beyond 2 fm-1 where the effect of the tensor forces is expected to be dominant. We found a strong energy dependence of the ratio of differential cross sections of the excited 5/2+ state and the ground 1/2− states in 15O, which is a possible signature of tensor forces. Extensive study on the scattering-angle dependence to understand/exclude effect of the reaction mechanism is ongoing. Further study of tensor effect at high momentum transfer region by measuring correlated nucleons via the (p,dp) and (p,dn) reactions has been proposed and approved at RCNP. Detailed study of such correlated nucleons with high momentum beyond the Fermi momentum is expected to provide a clear signature of the tensor force. New experiment using inverse kinematics via the (p,d) reaction is also planned at future RI-beam facilities. In this meeting, we would like to report our recent measurements and future plans, and discuss possible strategies for the experimental studies of tensor forces.
Tuesday, Nov. 10  Session 9 (9:00-10:30)
Chairperson: Tomohiro Uesaka (RIKEN)

[9:00-9:30]
Study of charge symmetry breaking via the gamma-ray spectroscopy of hypernuclei
Presenter: Mifuyu Ukai (KEK)

Charge symmetry breaking effect in level structures of A=4 hypernuclei ($^4\Lambda\text{H}, ^4\Lambda\text{He}$) were experimentally reported since 1970’s. When a $\Lambda$ coupled to the mirror nuclei of $^3\text{H}$ and $^3\text{He}$ ground states($1/2^-$) hypernuclear levels split into the spin-doublet states($1^+, 0^+$). Energy difference of $0^+$ states were measured by emulsion experiments to be 350 keV and that of splitting energies of the doublet were measured by gamma-ray spectroscopy using NaI counters to be 280 keV. These energy differences were already excluded of the mass difference of core nuclei. Such large differences for both $0^+$ and $1^+$ were not theoretically explained. However, the statistics of the gamma-ray data of $^4\Lambda\text{He}(1^+ \rightarrow 0^+)$ to be 1.15 ± 0.04 MeV seems not enough.

In 2015 April, gamma-ray spectroscopy of $^4\Lambda\text{He}$ via the $^4\text{He}(K^-,\pi^-)$ reaction was performed at J-PARC Hadron Experimentaly Facility (J-PARC E13). The gamma-ray energy were measured by a germanium detector array, Hyperball-J. We successfully observed and assigned the $^4\Lambda\text{He}(1^+ \rightarrow 0^+)$ transition to be 1.406 MeV. Therefore, the previous result of 1.15 MeV was denied.

Combining previous data and our new result, the energy difference of $1^+$ was obtained to be almost zero (0.03 ± 0.05 MeV). The fact implies that the charge symmetry breaking effect in $\Lambda\text{N}$ interaction is spin dependent. In this paper, we will present over view of the J-PARC E13 experiment and the results.

[9:30-10:00]
Structure of neutron-rich L hypernucleus, $^7\Lambda\text{He}$
Presenter: Emiko Hiyama (RIKEN)

In 2013, a neutron rich $\Lambda$ hypernucleus, $^7\Lambda\text{He}$ was observed via the $(e,e'K^+)$ reaction and an observed $\Lambda$ separation energy of $B_\Lambda = 5.68 \pm 0.03 \pm 0.25$ MeV was reported [1]. This hypernucleus is interesting from the following three points: (1) We can get information about charge-symmetry-breaking (CSB) components in the $\Lambda\text{N}$ interaction.
It is considered that the most reliable evidence for CSB appears in the $\Lambda$-separation energies ($B_\Lambda$) of the $A = 4$ hypernuclei with $T = 1/2$ ($^4_\Lambda$H and $^4_\Lambda$He). Then, the CSB effects are attributed to the separation-energy difference $\Delta_{\text{CSB}} = B_\Lambda(^4_\Lambda\text{He}) - B_\Lambda(^4_\Lambda\text{H})$, the experimental values of which are 0.35±0.06 MeV and 0.24±0.06 MeV for the ground ($0^+$) and excited ($1^+$) states, respectively. It is also likely that CSB contribution affects to the binding energy of $^7_\Lambda$He and the experimental research at JLab on the $^7_\Lambda$He was motivated by this question. (2) Using this glue-like role of $\Lambda$ particle, we have another question ‘Is there a possibility to have other new hypernuclear states in $^7_\Lambda$He?’ To answer this question, it is necessary to look at the energy spectra of $^6$He core nucleus before studying $^7_\Lambda$He. The observed data of $^6$He [2] reported 0$^+_1$ round state as a bound state and the 2$^+_1$ resonant state with $E_x = 1.797$ MeV, $\Gamma = 0.113$ MeV. To search the second 2$^+$ state, some experiments were performed. For example, the charge-exchange reaction, $^6$Li($t,^3$He)$^6$He, was studied to explore the excited states above the first 2$^+$ state [3]. However, clear evidence of the second 2$^+$ state was not obtained. In 2012, in Ref. [4], the transfer reaction experiment $p(^8$He,$t)^6$He shows an indication of the second 2$^+$ state of $^6$He as a resonant state at $E_x = 2.6 \pm 0.3$ ($\Gamma = 1.6 \pm 0.4$) MeV. When a $\Lambda$ particle is added to such a resonant state, due to a glue-like role of $\Lambda$ particle, it is likely to result in narrower resonant states of $3/2^+_2$ and $5/2^+_2$ of $^7_\Lambda$He. The prediction of energies of second $3/2^+$ and $5/2^+$ states and decay widths would encourage further experimental investigation of $^7_\Lambda$He at JLab. (3) This observation stimulated us to study neutron-rich $\Lambda$ hypernuclei because in light nuclei near the neutron drip line, interesting phenomena concerning neutron halos have been observed. When a $\Lambda$ particle is added to such nuclei, it is expected that the resultant hypernuclei will become more stable against neutron decays due to the attraction of $\Lambda N$ interaction and the fact that there is no Pauli exclusion effect between nucleons and a $\Lambda$ particle. This phenomenon is one of the ‘glue-like’ roles of $\Lambda$ particle.

In the symposium, I will report the above three issues within the framework of $\alpha + \Lambda + n + n$ four-body problem.

References:
[1] S. N. Nakamura et al., Phys. Rev. Lett. 110, 012502 (2013).
[2] D. R. Tilley et al., Nucl Phys. A 708, 3 (2002).
[3] T. Nakamura et al., Phys. Lett. B 493, 209 (2000).
[4] X. Mougeot et al., Phys. Lett. B 718, 441 (2012).
[10:00-10:30]

**Many-body calculations with realistic and phenomenological nuclear forces**

_Presenter:_ Furong Xu (Peking University)
Tuesday, Nov. 10  Session 10 (11:00-12:30)
Chairperson: Zhongzhou Ren (Nanjing University)

[11:00-11:30]
**Breakup Reaction of $^8$B**

*Presenter:* Wang Jiansong (Institute of Modern Physics)

$^8$B is a candidate of proton halo nuclei due to the very small separation energy of the last proton. Many experimental and theoretical efforts are done for $^8$B. In this talk, some recently experimental results of direct breakup reaction of $^8$B will be shown. The longitudinal momentum distributions of $^7$Be fragments in the breakup of $^8$B on a carbon target have been measured at 36 MeV/u. The longitudinal momentum distributions of $^7$Be fragments from both the stripping and the diffraction mechanisms have been distinguished by coincidence measurements and the results are consistent with the noneikonal calculations and CDCC calculations. The full widths at half maximum of the longitudinal momentum distributions are $124 \pm 17$ and $92 \pm 7$ MeV/c for the stripping and diffraction components, respectively. The comparison with the different model calculations is discussed. It indicates that separating the different reaction mechanisms experimentally is crucial to benchmark nuclear reaction theories.

[11:30-12:00]
**Experimental study of multi-nucleon transfer reactions of $^{136}$Xe + $^{198}$Pt for KISS project**

*Presenter:* Yutaka Watanabe (KEK)

Multinucleon transfer (MNT) reaction between two heavy ions at energies around the Coulomb barrier is considered as a promising candidate to produce and investigate exotic nuclei. Especially in the region of neutron-rich nuclei around the neutron magic number of 126, which is difficult to access by other production methods, the MNT reaction is expected to provide a means to efficiently produce them. The nuclear region of the neutron magic number of 126 has been attracting an astrophysical interest because the waiting point nuclei on the r-process path, which are considered as progenitors of the peak at the mass number of 195 in the solar r-abundance distribution, are located there.
We have constructed the KEK Isotope Separation System (KISS) at RIKEN RIBF facility to produce, separate and measure the nuclear properties of the neutron-rich nuclei around the neutron magic number of 126, which will be produced by the MNT reaction. KISS consists of an argon gas cell based laser ion source and an isotope separation on-line (ISOL), to produce pure low-energy beams of neutron-rich isotopes around $N = 126$ and to study their beta-decay properties.

We adopted the reaction system of $^{136}\text{Xe} + ^{198}\text{Pt}$, which is considered to be one of the best candidates to efficiently produce the nuclei of interest. In order to investigate the feasibility of the nuclear production of the system, we have studied the collisions between $^{136}\text{Xe}$ and $^{198}\text{Pt}$ at the laboratory energy of 8 MeV/A by using the large acceptance magnetic spectrometer VAMOS++ at GANIL. In this presentation, we will show the isotopic distributions of projectile-like fragments (PLFs) detected by the spectrometer and isotopic distributions of target-like fragments (TLFs) deduced from the detected PLFs. We will discuss about the production of $N = 126$ TLFs. We will also introduce the KISS project and its present status.

[12:00-12:30]

Effects of three-nucleon force and the experimental study via the few-nucleon systems

Presenter: Yukie Maeda (Miyazaki University)

Recently the three-nucleon force effects (3NF) are considered to play an important role not only in the few-nucleon systems but also in the heavier systems like neutron-rich nuclei and neutron stars. The main component of 3NF is considered to be a 2 pion-exchange between three nucleons with a Delta isobar excitation as an intermediate state. And now there are several 3NF models which have additional components. It is important to study the detail of 3NF from the ab-initio study via the three-nucleon bound states or scattering states. In these studies, the nucleon-deuteron reactions have been playing an essential roles because they can provide various observables like spin- or energy- dependencies and they allowed us to discuss about the detail features of 3NF from the comparisons between Faddeev calculations and highly precise data. One of the remarkable studies is that the differential cross sections of the proton-deuteron elastic scattering are well reproduced by the introduction of 2 pion-exchange type 3NF at the intermediate energy regions. On the other hand, there are many observables which can
not be explained by the Faddeev calculations including the 3NF, for instance, some spin observables and cross sections at higher than 200 MeV/A. These results indicate the lack of some components in modern 3NF models. To investigate the origin of these disagreements, proton-deuteron breakup reactions in some kinematical configurations and the elastic reactions in the higher energy regions have been measured recently. The results of the comparisons between these data and the theoretical calculations will be shown in this talk.
Tuesday, Nov. 10   Session 11 (14:00-15:30)
Chairperson: Kimiko Sekiguchi (Tohoku University)

[14:00-14:30]
Research programs at RIKEN RIBF
Presenter: Hideki Ueno (RIKEN)

In the RIKEN RIBF facility, a large variety of heavy-ion beams are delivered at the energies $E/A \leq 135$ MeV and $230-345$ MeV to the low- and high-energy beam ports, respectively, under the scheme of the cascade acceleration utilizing the four ring cyclotrons, at most, and one of the three injectors. At the high-energy ports, high current radioactive-isotope (RI) beams are produced and isotope-separated with the superconducting in-flight RI separator BigRIPS. They are transported to three spectrometers, ZD, SAMURAI, and SHARAQ, having different functions. Furthermore, Rare RI Ring, a new isochronous storage ring for nuclear-mass measurements, and SLOWRI, a gas-catcher RF-ion guide system for slow the delivery of RI beams, has been/will be equipped with BigRIPS. For Rare RI Ring, the first beam commissioning experiment has been successfully conducted soon after the construction. Making use of these experimental key devices, BigRIPS-based experiments have so far been performed since 2007. Among them, for instance, a series of - spectroscopy, the EURICA (Euroball RIKEN Cluster Array) project, has been unfolded since 2011, and invariant mass spectroscopy of extremely far unstable nuclei utilizing SAMURAI has started since 2012. In spring 2014, in-beam -ray spectroscopy was conducted in combination with the active liquid hydrogen target system MINOS that enables vertex position reconstruction. At the low-energy beam ports, SCRIT for e-RI scattering studies and GARIS-II for SHE researches have been installed. Their R&D studies for regular measurements are in progress. The previous RI separator RIPS is also available. In the talk, recent results and future plans of the RIBF facility will be presented.

[14:30-15:00]
Laser driven plasma collider for nuclear studies
Presenter: Changbo Fu (Shanghai Jiaotong University)

A mini version of nuclear collider was realized for the first time by using laser-induced plasma. We studied the Deuteron-Deuteron (DD) nuclear reactions by using head-on
collision plasma currents with lasers of 1 ns pulse width and $2000 \text{J}$ total laser energy. The experimental results show that this mini version plasma collider can produce much higher low energy flux than the traditional accelerators. And also, due to the head-on collision, the nuclei’s center-of-mass energy is doubled, and therefore can significantly enhance the reaction products, which is especially important for reactions in sub-coulomb barrier energy ranges. We observed up to $7.6 \times 10^5$ DD neutron products in the experiments, which was much larger than that of the non-collision cases. The possibilities of using this plasma version collider to study low energy nuclear reactions will be discussed.

[15:00-15:20]
**Present status of the RCNP cyclotron facility and future prospects of cyclotron applications**
*Presenter:* Mitsuhiro Fukuda (RCNP)

[15:20-15:40]
**Preparation of Tc-99m and PET nuclides for nuclear medicine**
*Presenter:* Naruto Takahashi (Osaka University)

The use of radioisotopes such as Tc-99m or F-18 is essential for the diagnosis of cancer today. Single photon emission tomography (SPECT) using Tc-99m in particular is used widely in the world. In addition, the positron emission nuclide including F-18 is prepared by rhinoceros black for the positron emission tomography (PET) use a lot. We produced the SPECT and PET nuclides using the AVF cyclotron of the Research Center of Nuclear Physics (RCNP), Osaka University and performed the separation, the refinement and the mark to a drug. Furthermore, we performed the animal experiment using them and observed the accumulation to cancer of the mark drug. The radioisotope which I used was prepared by $^{100}\text{Mo}(p,\alpha)n^{99}\text{Tc}$, $^{124}\text{Te}(p,n)^{124}\text{I}$ reaction. The K-course and the F-course for the RI production are established in the RCNP and use it properly by a purpose of use each. The k-course has the device which can irradiate a solid sample, and distance of 70m is automatically conveyed to the solid target through a pneumatic tube to the RI laboratory after having irradiated it under a vacuum or atmospheric pressure. The sample during the irradiation is water-cooled from the back and prevents low melting elemental evaporation. On the other hand, the irradiation
equipment installed in the F-course can produce a large quantity of RI. It jets water cooling from the target back and the cooling He from the front to prevent fusion, the evaporation of the irradiation sample by the increase of the beam current. The RI manufactured from these devices was refined with the chemical separation from a target in the RI laboratory. The radioisotopes were extracted to organic solvents after the dissolving targets into alkali or acid solution. Further the radioisotopes were reversely extracted into aqua and prepared the labeled compounds. Or the targets were heated up in electric furnaces, and an objective low boiling point compounds were sublimated, and supplemented cooling trap solution. These labeled compounds were injected into a rat and performed SPECT and PET photography.
[16:10-16:40]

**10 years of the shell evolution by nuclear forces and beyond**

*Presenter*: Takaharu Otsuka (University of Tokyo)

The tensor-force-driven shell evolution has been proposed in December, 2005. There have been many notable developments in experimental (e.g. observation of N=34 magic number) and theoretical sides, and I will overview it with an introduction of basic concepts. In 2010, the shell evolution due to the Fujita-Miyazawa three-nucleon force was proposed, and I shall review it as well. In recent years, the group in Tokyo has developed a new theory of effective interaction for multi-shell configurations, which are essential to exotic nuclei but cannot be treated in conventional theories. I will present some highlights from this new work. At the end, I will introduce Type II Shell Evolution in connection to shape coexistence phenomena, for instance in 68Ni and 186Pb. This leads us to a picture of Dual Quantum Liquid, which may be related further to the spontaneous fission and the island of stability.

[16:40-17:10]

**Neutron-proton asymmetry dependence of spectroscopic factors**

*Presenter*: Jenny Lee (University of Hong Kong)

Spectroscopic factors are fundamental quantities in nuclear physics. They have been extensively used in understanding the single particle properties and nucleon correlations in nuclei. The inconsistent spectroscopic factors obtained in transfer [1] and knockout reaction measurements [2] pose an intriguing question about the reaction mechanisms as well as the nature of nucleon correlations in nuclei with extreme isospin asymmetry. To solve the long-standing puzzle and establish reliable probes for extracting spectroscopic factors, we performed one-nucleon knockout reaction measurements of 30Ne at 250 MeV/u at RIKEN [3] and 14O at 60 MeV/u at RCNP [4] respectively for examining the knockout reaction mechanisms in details. In addition, we recently completed the (p,d) transfer measurements of 34,46Ar at 70 MeV/u at NSCL [5] for investigating the energy dependence in the reaction mechanism.
In this talk, the setup of these experiments, preliminary results and physics conclusions will be discussed.

References:
[1] J. Lee et al., Phys. Rev. Lett. 104, 112701 (2010), Phys. Rev. C 83, 014606 (2011).
[2] A. Gade et al., Phys. Rev. C77, 044306 (2008) and reference therein.
[3] J. Lee et al., paper in preparation
[4] Y. Sun, J. Lee et al., paper in preparation
[5] NSCL E09084, spokesperson: J. Lee; Ph.D. Thesis: Juan Manfredi (MSU)

17:10-17:40

**Weakly bound and unbound nuclei**

*Presenter:* Takashi Nakamura (Tokyo Institute of Technology)

We discuss characteristic features of weakly bound and barely unbound nuclei near the neutron drip line. Weakly bound nuclei often exhibit neutron halo structure, while barely unbound nuclei may show novel few-body resonances. Such nuclei lying at the extreme of the nuclear chart have recently attracted much attention. I will show recent experimental studies performed at RIBF at RIKEN, where nuclear and Coulomb breakup reactions have primarily been used. In particular, I will show results on unbound oxygen isotopes, which have been recent focuses, as keys to understand three nucleon forces, shell evolution, and continuum effects near the nuclear bound limit. I will also discuss neutron halo nuclei, and other cases of unbound nuclei to clarify the characteristic features of weakly bound and unbound nuclei.
Nuclear symmetry energy - from nucleus to neutron star

Presenter: Betty Tsang (Michigan State University)

The symmetry energy term in the nuclear equation of state affects many aspects of nuclear physics and astrophysics, from the structure of exotic nuclei to properties of neutron stars. A decade ago, Brown showed that realistic parameterizations of the Skyrme interactions that fit the binding energy differences between $^{100}$Sn and $^{132}$Sn nuclei yield very different symmetry term in the nuclear equation of state and predict a wide range of the skin radii of $^{208}$Pb. Substantial progress has been achieved in recent years in constraining the density dependence of nuclear symmetry energy at and below the saturation density with a wide range of experiments. In the talk, I will review current experimental constraints on the symmetry energy. I will discuss the implications of recent observations of massive neutron masses and radius on nuclear equation of state. I will give an up-to-date experimental effort by the US-Japan SpiRIT collaboration effort in the ongoing quest to determine the symmetry energy dependence in regions above the saturation density including exploration of three neutron force and the effective nucleon masses.

Three-body force effect on the properties of asymmetric nuclear matter

Presenter: Wei Zuo (Institute of Modern Physics)

We report our microscopic investigation on the single-particle properties and the EOS of isospin asymmetric nuclear matter within the framework of the Brueckner theory extended to include a microscopic three-body force. We pay special attention to the discussion of the three-body force effect and the comparison of our results with the predictions by other ab initio approaches. Three-body force is shown to be necessary for reproducing the empirical saturation properties of symmetric nuclear matter within nonrelativistic microscopic frameworks, and also for extending the hole-line expansion to a wide density range. The three-body force effect on nuclear symmetry energy is repulsive, and it leads to a significant stiffening of the density dependence of symmetry
energy at supra-saturation densities. Within the Brueckner approach, the three-body force affects the nucleon s.p. potentials primarily via its rearrangement contribution which is strongly repulsive and momentum-dependent at high densities and high momenta. Both the rearrangement contribution induced by the three-body force and the effect of ground state correlations are crucial for predicting reliably the single-particle properties within the Brueckner framework.

[10:00-10:30]

**Status of $Kpp$ search experiments**

*Presenter:* Tomofumi Nagae (Kyoto University)

Kaonic nuclei are a new type of hadron many-body system with strangeness degrees of freedom, if existed. It is a bound system of meson and baryons instead of baryon many-body systems such as hypernuclei. Among them, so-called "$Kpp$" system which is composed of a $K^-$ and two protons is in strong focus as the simplest case. There is a possibility that the system has a large binding energy of $> 60$ MeV which could reach a high nuclear density close to twice the normal nuclear matter density. Thus, the experimental confirmation of the existence of kaonic nuclei or "$Kpp$" is an urgent task in this field.

A lot of experimental searches are recently carried out or on-going in various facilities in the world. In SPring-8/LEPS, a search for the "$Kpp$" was carried out in the $\gamma + d \rightarrow K^+ \pi^- + X$ reaction at $E_\gamma = 1.5-2.4$ GeV. Because of a large background from $K^+ \Lambda(1520)$ and $K^+ \pi^- \pi^+ \Lambda$ processes, they were only able to put the upper limits of the production cross section of the order of 10-20% of typical hyperon production cross sections, when the decay width is assumed to be $\Gamma = 100$ MeV.

HADES collaboration has reported their partial wave analysis result on the reaction of $p(3.5 \text{ GeV}) + p \rightarrow p K^+ \Lambda$ to search for the "$Kpp$". They also put the upper limit for the "$Kpp$" production cross section of about 4 $\mu$b, while the $\Lambda(1405)$ production cross section at this energy is about 100 $\mu$b.

At J-PARC, there are two experiments, E15 and E27, on the "$Kpp$" search. The E15 collaboration just reported a semi-inclusive spectrum of the $^3\text{He}(K,n)$ reaction at 1 GeV/c with a preliminary data. They estimated the upper limit of the "$Kpp$" production cross section to be 100–270 $\mu$b/sr in the case of $\Gamma = 100$ MeV, which is about 5% of the
quasi-elastic $K N$ cross section. In E27 experiment, the "$Kpp$" search was carried out in the $d(\pi^+,K^+)$ reaction at 1.69 GeV/c. In order to enhance the signal to background ratio, high-momentum proton ($\geq 250$ MeV/c) coincidence in the large scattering angles was requested. Such proton coincidence probability showed a large bump structure centered at around 2.27 GeV/c$^2$ for the "$Kpp$" mass, in addition to the rather sharp structure of $\Sigma N \rightarrow \Lambda N$ cusp and conversion process near 2.13 GeV/c$^2$. With two-proton coincidence condition, the decay modes of the "$Kpp$" into $\Lambda p$, $\Sigma^0 p$, and $\pi Y p$ were separated in the missing energy. From the mass distribution obtained for the $\Sigma^0 p$ decay mode, the mass and width of the "$Kpp$" were obtained to be $2275^{+17}_{-18} (\text{stat})^{+21}_{-30} (\text{syst})$ MeV/c$^2$ and $162^{+87}_{-45} (\text{stat})^{+66}_{-76} (\text{syst})$ MeV, respectively. It corresponds to the binding energy of $95^{+18}_{-17} (\text{stat})^{+30}_{-21} (\text{syst})$ MeV.

In this talk, the above experimental data and their implications will be discussed.
Wednesday, Nov. 11  Session 14 (11:00-12:00)

Chairperson: Yuhu Zhang (Institute of Modern Physics)

[11:00-11:30]

**Nuclear astrophysics experiment at China Jinping underground Laboratory**

**Presenter:** Xiaodong Tang (Institute of Modern Physics)

China Jinping underground Lab (CJPL) is currently the deepest underground lab in the world, with an overburden of 6720 m.w.e. In addition to its existing dark matter experiments, a new research project, “The underground experimental study of the key problems in nuclear astrophysics”, has been initiated in 2015 by the JUNA collaboration. The goal of the project is to take the advantage of the ultralow background in CJPL, the first underground high current accelerator based on an ECR source and highly sensitive detection systems to study directly the crucial nuclear reactions within their relevant stellar energy range. In my talk, the research plan and status of this project will be reported. This project is funded jointly by NSFC, CAS and CNNC.

[11:30-12:00]

**Experimental challenges: study of r-process nucleosynthesis at RIBF**

**Presenter:** Shunji Nishimura (RIKEN)

Nuclear decay properties, such as β-decay half-lives (T1/2), delayed neutron emission probabilities (Pn), and level schemes, provide the first signatures of nuclear shell evolution and deformation far from the stability. These parameters are also extremely important to understand the rapid neutron-capture process (r process), which is responsible for synthesis of the half of elements heavier than irons in the universe.

New generation radioactive isotope factory (RIBF) has started to study on the decay properties of nuclei with extreme neutron-to-proton ratio. The decay properties of hundreds of exotic nuclei have been surveyed using the high efficiency βγ spectrometer EURICA, which comprise of double-sided silicon strip detectors (WAS3ABi) and twelve Euroball cluster germanium detectors (EURICA). In this paper, the highlight of the EURICA [1,2,3] will be presented together with a new project BRIKEN, which is dedicated for measurement of Pn-values.

[1] H. Watanabe et al., Phys. Rev. Lett. 111, 152501 (2013).
[2] J. Taprogge et al., Phys. Rev. Lett. 112, 132501 (2014).
[3] G. Lorusso et al., Phys. Rev. Lett. 114, 192501 (2015).
Wednesday, Nov. 11  Session 15 (13:30-15:00)
Chairperson: Yugang Ma (Shanghai Institute of Applied Physics)

[13:30-14:00]
**Exotic Nuclear Structures and Dynamics in HFB Theory**
*Presenter: Juncheng Pei (Peking University)*

[14:00-14:30]
**Experimental study of the neutron-rich nuclei around $^{68}\text{Ni}$**
*Presenter: Bing Ding (Institute of Modern Physics)*

The doubly magic character of $^{68}\text{Ni}$ has been established from experimental data, such as the relatively high excitation energy of the first 2+ state (2033 keV) and low B(E2, 2+ ->0+) reduced transition probability. The N = 40 subshell closure in this nucleus was attributed mainly to the strong attractive spin-flip interaction between the proton f7/2 and neutron f5/2 orbitals.

On the other hand, the N = 40 subshell closure is very fragile and gets reduced (or even disappeared) when coupling of nucleon particles and/or holes to the 68Ni core [1]; a satisfactory description of nuclear structure is still lacking in this mass region [2]. The first SEASTAR experiment was carried out last year at RIEKN in Japan to complete the experimental data and then for a further understanding of the property of the N = 40 subshell closure in these neutron-rich nuclei below $^{68}\text{Ni}$. The experimental data for the V and Mn isotopes, namely $^{58-63}\text{V}$ and $^{63-66}\text{Mn}$ are under analyzing in IMP; the preliminary results will be presented.

References:
[1] W. F. Mueller et al., Phys. Rev. Lett. 83 3613 (1999).
[2] S. Zhu et al., Phys. Rev. C 85 034336 (2012).

[14:30-15:00]
**SUNFLOWER --- In-beam gamma-ray spectroscopy at RIBF**
*Presenter: He Wang (RIKEN)*

In-beam gamma-ray spectroscopy is one of the major tools to study the structure of very exotic nuclei. The RIKEN Radioactive Isotope Beam Factory provides intense secondary beams in a wide range of unstable nuclei. For in-beam gamma-ray
spectroscopy, exotic beams produced by the BigRIPS fragment separator are incident on a secondary target. The reaction residues are analyzed by the ZeroDegree spectrometer. The gamma rays are detected by the DALI2 spectrometer. An overview of recent experiments performed at RIBF employing the in-beam gamma-ray spectroscopy will be presented.
Wednesday, Nov. 11  Closing session (15:30-17:10)
Chairperson: Hiroshi Toki (RCNP)

[15:30-16:00]

**Probing fundamental symmetry using antimatter**

*Presenter:* Ryugo Hayano (University of Tokyo)

At CERN’s antiproton decelerator (AD), experiments to study possible violation of the CPT symmetry are being carried out. They are 1) microwave and laser spectroscopy of antihydrogen (antiproton-positron bound state) 2) antiproton-proton magnetic moment comparison, and 3) laser spectroscopy of antiprotonic helium atoms (antiproton+electron+helium nucleus bound state). The progress made since 2000 when the AD started its operation, and future prospects using a new facility under construction called ELENA (Extremely low energy antiproton ring) will be discussed.

[16:00-16:30]

**Production cross sections for super heavy and neutron-rich nuclei**

*Presenter:* Fengshou Zhang

The current situation of producing super heavy and neutron-rich nuclei is reviewed. The recent results concerning the production cross sections for Z=119 and 120 in hot fusion reactions are shown. The production cross sections for neutron-rich nuclei in transfer reactions are predicted.

[16:30-17:00]

**Nuclear structure studies at Beihang University**

*Presenter:* Isao Tanihata (RCNP/ Beihang University)

Experimental nuclear physics group at Beihang university is working on several nuclear structure and it’s dynamic problems. Here I report the selected recent studies in the group that include a) 12C+12C elastic scattering to study the repulsive three-body interactions, b) Effect of tensor interactions in nuclei, c) and charge-exchange reactions of neutron rich C isotopes. Some development of new types of detectors will also be covered.
[17:00-17:10]

Closing address

Presenter: Guoqing Xiao (Institute of Modern Physics)