DREB2018 – 10th International Conference on Direct Reactions with Exotic Beams

Report of Contributions

Contribution ID: **0** Type: **Oral contribution**

Spectroscopy of 63,65,67Mn: Strong Coupling in the N=40 Island of Inversion and Improved Constraints for Urca Cooling in the Accreted Neutron Star Crust

Excited states in 63;65;67Mn were studied via in-beam gamma-ray spectroscopy following the knockout reaction from 68Fe. Similar level schemes, consisting of the 11/2-, 9/2-, 7/2- and 5/2- g.s. level sequence, connected by I $\longrightarrow$ I − 1 transitions, were established, the first time for 65;67Mn. Their level structures show features consistent with strongly-coupled rotational bands with K = 5/2. State-of-the-art shell-model calculations with the modified LNPS effective interaction reproduce the

observed levels remarkably well and suggest 4p−4h neutron and 1p−1h proton configurations for all the states. The data on the low-lying excited states of 53-67Mn provide a textbook example of nuclear structure evolution from weak coupling through decoupling to strong coupling along a single isotopic chain. Our results enhance Urca neutrino cooling from e−capture/beta−decay cycles in the accreted neutron star crust associated with A = 63 nuclei and experimentally rule-out significant cooling from A = 65, 67. This improves constraints that can be made on past surface nuclear burning on accreting neutron stars with observed quiescent cooling light curves.

Primary author: Prof. LIU, zhong (IMP,CAS)

Co-author: Mr XIAOYU, Liu (IMP, CAS)

Presenter: Prof. LIU, zhong (IMP,CAS)

Contribution ID: **1** Type: **Poster Contribution**

STRUCTURE OF β-DECAY STRENGTH FUNCTION Sβ(E) IN HALO NUCLEI

The strength function Sβ(E) governs [1,2] the nuclear energy distribution of elementary charge-exchange excitations and their combinations like proton particle (πp)–neutron hole (νh) coupled into a momentum Iπ : [πp ⊗ νh]Iπ and neutron particle (νp)–proton hole (πh) coupled into a momentum Iπ : [νp ⊗ πh)]Iπ. The strength function of Fermi-type β-transitions takes into account excitations [πp ⊗ νh]0+ or [νp ⊗ πh]0+. Since isospin is a quite good quantum number, the strength of the Fermi-type transitions is concentrated in the region of the isobar-analogue resonance (IAR). The strength function for β-transitions of the Gamow–Teller (GT) type describes excitations [πp ⊗ νh]1+ or [νp ⊗ πh]1+. At excitation energies E smaller than Qβ (total β-decay energy), Sβ(E) determines the characters of the β-decay. For higher excitation energies that cannot be reached with the β-decay, Sβ(E) determines the charge exchange nuclear reaction cross sections, which depend on the nuclear matrix elements of the β-decay type. From the macroscopic point of view, the resonances in the GT β-decay strength function Sβ(E) are connected with the oscillation of the spin–isospin density without change in the shape of the nucleus [1,3].
When the nuclear parent state has the two-neutron Borromean halo structure, than IAR and configuration states (CSs) can simultaneously have nn, np Borromean halo components in their wave functions [4]. After M1 γ-decay of IAR with np Borromean halo structure or GT β- - decay of parent nuclei with nn Borromean halo structure, the states with np halo structure of tango type may be populated [5-7].
In this work the structure of resonances in the GT β-decay strength function Sβ(E) for halo nuclei is discussed. It is shown that when the parent nucleus has nn Borromean halo structure, then after GT β- -decay of parent state or after M1 γ-decay of IAR the states with np tango halo structure or mixed np tango + nn Borromean halo structure can be populated. Or, in other words, resonances in the GT β-decay strength function Sβ(E) of halo nuclei, may have np tango halo structure or mixed np tango + nn Borromean halo structure. Structure of Sβ(E) may be studied both in experiments on M1 γ-decay of (or on) IAR and in experiments on Sβ(E) measurements in charge exchenge nuclear reactions or in β-decay [1,2]. Since the operators of GT β-decay and M1 γ-decay have no spatial components, GT β-transitions and M1 γ-transitions between states with similar spatial shapes are favoured. Data of 6He (Borromean nn halo) ground state (g.s., Iπ=0+) GT β-decay and M1 gamma decay of its IAR (Borromean np halo, resonans in 6Li, E=3.56 MeV, Iπ=0+) were analysed. The enhancement of the M1 gamma transition from the IAR to the ground state of the 6Li nucleus (Iπ=1+) complies the presence of an np tango halo in 6Li g.s.

1.Yu.V. Naumov, A.A. Bykov, I.N. Izosimov, Sov.J.Part.Nucl., 14, 175 (1983)

2.I.N. Izosimov, V.G. Kalinnikov, A.A. Solnyshkin, Physics of Particles and Nuclei, 42, 1804 (2011). DOI: 10.1134/S1063779611060049

3.I.N. Izosimov, A.A. Solnyshkin, J.H. Khushvaktov, Yu.A. Vaganov, Joint Institute for Nuclear Research Preprint E6-2017-29, Dubna (2017)

4.I.N. Izosimov, Procceedings of the International Symposium on Exotic Nuclei (EXON2012), Vladivostok, Russia, 2012 (World Scientific, 2013), p.129.

5.I.N. Izosimov, AIP Conference Proceedings, 1681, 030006 (2015).

6.I.N. Izosimov, EPJ Web of Conferences, 107, 09003 (2016)

7.I.N. Izosimov, Phys. of At. Nucl., 80, 867 (2017). DOI:10.1134/S1063778817050118

Primary author: Prof. IZOSIMOV, Igor (Joint Institute for Nuclear Research)

Presenter: Prof. IZOSIMOV, Igor (Joint Institute for Nuclear Research)

Contribution ID: **2** Type: **Poster Contribution**

Ab initio translationally invariant nonlocal one-body densities

Nonlocal nuclear density is derived from the no-core shell model (NCSM) one-body densities by generalizing the local density operator to a nonlocal form. The translational invariance is generated by exactly removing the spurious center of mass (COM) component from the NCSM eigenstates expanded in the harmonic oscillator (HO) basis. The ground state local and nonlocal density of ^{4,6,8}He, ^{12}C and ^{16}O are calculated to display the effects of COM removal on predicted nuclear structure. This enables the ab initio NCSM nuclear structure to be used in intermediate energy nuclear reactions. We include the nonlocal density in calculations of optical potentials and show more accurate theoretical predictions for the differential cross sections of proton scattering off of stable and exotic light nuclei.

Primary author: Mr GENNARI, Michael (TRIUMF)

Co-authors: Dr CALCI, Angelo (TRIUMF); Dr VORABBI, Matteo (TRIUMF); Dr NAVRATIL, Petr (TRIUMF)

Presenter: Mr GENNARI, Michael (TRIUMF)

Contribution ID: **3** Type: **Poster Contribution**

Study of three-body force via 12C + 12C scattering at 100A MeV

The angular distribution of 12C + 12C scattering at an incident energy of 100A MeV has been measured. The elastic and inelastic scatterings in 12C to the excitation energies of up to ~15 MeV were measured simultaneously for the first time with the high-resolution Grand Raiden spectrometer at the Research Center for Nuclear Physics (RCNP). The angular distributions of the elastic scattering to the ground state and inelastic scattering to the 4.44MeV excited state were precisely obtained in the angular range of 1.0–7.5 degrees with a step of 0.1 degree. Additionally, the angular distribution was obtained for the sum of the cross sections for excitation energies above the 4.44MeV state up to 11MeV. Those combined data provide a means to study the effects of channel coupling on the elastic cross section. The observed angular distributions are compared with theoretical calculations based on three double-folding models with complex G-matrix interactions, the CEG07b, MPa, and ESC models. The importance of three-body repulsive forces included in the CEG07b and MPa models is discussed.

Primary authors: Dr ZHANG, Gaolong (Beihang University); Dr TANIHATA, Isao (Beihang University); Dr FURUMOTO, Takenori (Yokohama National University); Dr QU, Weiwei (Soochow University)

Presenter: Dr ZHANG, Gaolong (Beihang University)

Contribution ID: **4** Type: **Oral contribution**

Investigating neutron-proton pairing in sd-shell nuclei via (p,3He) and (3He,p) transfer reactions

Monday, June 4, 2018 3:15 PM (18 minutes)

Pairing correlations, influencing almost every feature of ground and low-lying states in nuclei, lie at the heart of nuclear physics. Understanding the mechanism of neutron-proton (np) pairing in N=Z nuclei has been a long-sought goal in nuclear structure since the early sixties. Despite large efforts in both theoretical and experimental studies, the fundamental nature and the interplay between T=0 and T=1 pairs are still the subject of debate. Cross section measurement of np-pair transfer is considered as a sensitive probe for the insight into T=0 and T=1 np pairing collectivity and its mechanism [1-3].

We therefore carried out systematic np-transfer measurements spanning N=Z sd-shell nuclei using (p,3He) and (3He,p) reactions at RCNP Osaka University. In particular, we study the cross-section ratio of the lowest 0+ and 1+ states as an observable to quantify the interplay between T=0 (isoscalar) and T=1 (isovector) pairing strengths. The experimental results are compared to second-order distorted-wave Born approximation calculations with proton-neutron amplitudes obtained in the shell-model formalism using the universal sd-shell interaction B. Our results suggest underestimation of the nonneglible isoscalar pairing strength in the shell-model descriptions at the expense of the isovector channel. In this talk, we will present this work [4].

References:

[1] R. A. Broglia, O. Hansen and C. Riedel, Adv. Nucl. Phys. Vol 6, 287 (1973).
[2] D.R. Bes et al., Phys. Rep. Vol 34C, 1 (1977).
[3] P. Van Isacker et al., Phys. Rev. Lett. 94, 162502 (2005).
[4] Y. Ayyad, J. Lee et al., Phys. Rev. C 96, 021303(R) (2017).

Primary author: Dr LEE, Jenny (The University of Hong Kong)

Presenter: Dr LEE, Jenny (The University of Hong Kong)

Session Classification: Session 4

Contribution ID: **5** Type: **Oral contribution**

Microscopic optical potential for proton elastic scattering off light exotic nuclei

Tuesday, June 5, 2018 2:18 PM (18 minutes)

A microscopic optical potential for intermediate energies is derived using ab initio translationally invariant nonlocal one-body nuclear densities computed within the no-core shell model approach utilizing two- and three-nucleon chiral interactions. The optical potential is obtained at first-order within the spectator expansion of the non-relativistic multiple scattering theory by adopting the impulse approximation. The nuclear density and the nucleon-nucleon t matrix are the two basic ingredients underlying the computation of the optical potential and are both obtained using the same chiral interaction, that represents the only input of our calculations. The ground state local and nonlocal densities of several unstable nuclei are calculated and applied to optical potential construction. The differential cross sections and the analyzing powers for the elastic proton scattering off these nuclei are then calculated for different values of the incident proton energy. The model is first tested on 4He, 12C, and 16O, and then is used to compute and compare the results for the scattering observables with the existing experimental data for 6He and 8He halo nuclei. Finally, predictions for the same observables will be also presented for proton elastic scattering off other unstable nuclei like 10Be, 10C, 14C, and 14O.

Primary author: Dr VORABBI, Matteo (TRIUMF Canada's particle accelerator centre)

Co-authors: Mr GENNARI, Michael (TRIUMF); Dr PETR, Navratil (TRIUMF)

Presenter: Dr VORABBI, Matteo (TRIUMF Canada's particle accelerator centre)

Session Classification: Session 7

Contribution ID: **6** Type: **Oral contribution**

Shape coexistence of neutron-rich ^{69,71,73}Co isotopes

Monday, June 4, 2018 11:03 AM (18 minutes)

Observation of high 2^+ excitation energy in ^{68}Ni (Z = 28, N = 40) had drawn a clear signature of double magic character in this nucleus [1]. And while ^{68}Ni can be described as spherical isotope, 2^+ excitation energy of ^{66}Fe drops significantly [2], indicating deformed shape of ^{66}Fe. ^{67}Co isotope is in between ^{68}Ni and ^{66}Fe nuclei and found to share coexistence of both spherical and deformed structures in low-lying excited states [3]. This effect can be described as superposition of a proton $f_{7/2}$ hole coupled to neighbouring spherical even-even nickel isotope and a prolate proton-intruder state coupled to the ^{66}Fe isotope [4]. Discovery of shape coexistence in ^{67}Co rose an interesting question about further shape evolution in Co nuclei, namely ^{69,71,73}Co and shell transformation from N = 40 to N = 50.
In-beam gamma experiment was performed at Radioactive Isotope Beam Factory, RIKEN Nishina centre, Japan. Secondary beam of ^{70,72,74}Ni and ^{72}Co isotopes at energy of 260 MeV/μ bombarded liquid hydrogen target (MINOS) to produce ^{69,71,73}Co nuclei via (p, 2p) and (p, pn) reactions. DALI2 NaI(Tl) detector array was used to measure γ-rays. Energy levels were studied using γ-γ coincidence technique. Systematics of excited states of cobalt isotopes was compared with Lenzi-Nowacki-Poves-Sieja (LNPS) model [5] of nuclear interaction using fpgd model space. Experimental results of ^{69,71}Co spectrums show that isotopes share shape coexistence, as spherical structure coexists with deformed band. In case of ^{73}Co nucleus, due to the lack of statistics only spherical band is confirmed.
In this talk the evolution of shell structure in ^{69,71,73}Co isotopes will be discussed together with physics behind the shape coexistence in neutron-rich Co nuclei.

References.

1. R. Broda, B. Fornal, W. Krolas, and T. Pawkat, Phys. Rev. Lett. 74, 868 (1995);
2. S. Lunardi, S. M. Lenzi, F. Della Vedova, Phys. Rev. C, 76, 034303 (2007);
3. F. Recchia et al., Phys. Rev. C 85, 064305 (2012);
4. D. Pauwels et al., Phys. Rev. C 78, 041307(R) 2008;
5. S. M. Lenzi, et. al., Phys. Rev. C 82, 054301 (2010).

Primary authors: Dr LEE, Jenny (The University of Hong Kong); Mr LOKOTKO, Taras (The University of Hong Kong)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr POVES, Alfredo (Departmento de Fiica Teorica and IFT-UAM/CSIC, Universidad Aut´onoma de Madrid); Dr NOWACKI, Frédéric (Institut de Recherches Subatomiques (IN2P3-ULP) F 67037 Strasbourg Cedex 2, France); Dr DOORNENBAL, Pieter (RIKEN); Dr LEBLOND, Sylvain (Laboratoire de Physique Corpusculaire de Caen (LPC Caen))

Presenter: Mr LOKOTKO, Taras (The University of Hong Kong)

Session Classification: Session 2

Contribution ID: **7** Type: **Oral contribution**

LINKING NUCLEAR REACTIONS AND NUCLEAR STRUCTURE ON THE WAY TO THE DRIP LINES

Tuesday, June 5, 2018 2:00 PM (18 minutes)

The dispersive optical model (DOM), originally conceived by Claude
Mahaux [1], provides a unified description of both elastic nucleon scattering and structure information related to single-particle properties below the Fermi energy [2]. Extensions of this framework have introduced a fully non-local implementation for 40-Ca [3,4]. For the first time properties below the Fermi energy like the charge density and the presence of high-momentum nucleons can be included in the DOM description while elastic cross section data can be represented as accurately as in the local DOM implementation. Application of the non-local DOM to 48-Ca incorporates the effect of the 8 additional neutrons and allows for an excellent description of elastic scattering data of both protons and neutrons [5]. The corresponding neutron distribution constrained by all available data generates a prediction for the neutron skin of 0.249 +/- 0.023 fm for this nucleus [5] which is larger than most mean-field and available ab initio results.

We report on the most recent developments including a non-local DOM analysis for 208-Pb, an extension to heavier Ca isotopes, an analysis of the energy density in comparison with ab initio nuclear matter calculations, applications to (d,p) and (p,d) transfer reactions with DOM ingredients, and a reanalysis of (e,e'p) data to determine if experimental data can constrain the magnitude of absolute spectroscopic factors.

[1] C.Mahaux and R.Sartor, Adv.Nucl. Phys. 20, 1 (1991).

[2] W.H.Dickhoff, R.J.Charity, and M.H.Mahzoon, J. Phys. G: Nucl. Part. Phys. 44, 033001 (2017).

[3] M.H.Mahzoon et al., Phys. Rev. Lett. 112, 162503 (2014).

[4] H.Dussan et al., Phys. Rev. C 90, 061603(R) (2014).

[5] M.H.Mahzoon et al., Phys. Rev. Lett. 119, 222503 (2017).

Primary author: Prof. DICKHOFF, Willem (Department of Physics, Washington University in St. Louis)

Presenter: Prof. DICKHOFF, Willem (Department of Physics, Washington University in St. Louis)

Session Classification: Session 7

Contribution ID: **8** Type: **Oral contribution**

A POSSIBLE NUCLEAR SOLUTION TO THE 18F DEFICIENCY IN NOVAE

Tuesday, June 5, 2018 4:18 PM (18 minutes)

A POSSIBLE NUCLEAR SOLUTION TO THE 18F DEFICIENCY IN NOVAE

M. La Cognata1, R. G. Pizzone1, J. José2,3, M. Hernanz3,4, S. Cherubini1,5, M. Gulino1,6, G. G. Rapisarda1,5, and C. Spitaleri1,5

1 INFN - Laboratori Nazionali del Sud, Catania, Italy
2 Departament de Física, EEBE, Universitat Politècnica de Catalunya, E-08019 Barcelona, Spain
3 Institut d'Estudis Espacials de Catalunya, E-08034 Barcelona, Spain
4 Institut de Ciencies de l'Espai (ICE-CSIC). Campus UAB. c/ Can Magrans s/n, E-08193 Bellaterra, Spain
5 Dipartimento di Fisica e Astronomia, Università degli Studi di Catania, Catania, Italy
6 Facoltà di Ingegneria ed Architettura, Kore University, Viale delle Olimpiadi, 1, I-94100 Enna, Italy

Crucial information on nova nucleosynthesis can be potentially inferred from γ-ray signals powered by 18F decay [1]. Therefore, the reaction network producing and destroying this radioactive isotope has been extensively studied in the last years. Among those reactions, the 18F(p,α)15O cross-section has been measured by means of several dedicated experiments, both using direct and indirect methods. The presence of interfering resonances in the energy region of astrophysical interest has been reported by many authors including the recent applications of the Trojan Horse Method (THM). The THM is an indirect method using direct reactions to populate 19Ne states of astrophysical importance, with no suppression by the Coulomb and centrifugal barriers. In this work, we evaluate what changes are introduced by the Trojan Horse data [2-4] in the 18F(p,α)15O astrophysical factor recommended in a recent R-matrix analysis, accounting for existing direct and indirect measurements [5]. We will particularly focus on the role of the THM experiment, since it allowed us to cover the 0-1 MeV energy range with experimental data, with no need of extrapolation and with unprecedented accuracy. Then, the updated reaction rate is calculated and parameterized and implications of the new results on nova nucleosynthesis are thoroughly discussed. In particular, while no change on the dynamical properties of the explosion is found due to the revised reaction rate, important differences in the chemical composition of the ejected matter is observed, with a net reduction in the mean 18F content by a factor of 2 and a corresponding increase in the detectability distance [4].

[1] J. José, Stellar Explosions: Hydrodynamics and Nucleosynthesis (Boca Raton, FL, London: CRC/Taylor and Francis, 2016)
[2] R. G. Pizzone et al., Eur. Phys. J. A, 52 (2016) 24
[3] S. Cherubini et al., Physical Review C, 92 (2015) 015805
[4] M. La Cognata et al., The Astrophysical Journal, 846 (2017) 65
[5] D. W. Bardayan et al. 2015, Phys. Lett. B, 751, (2015) 311

Primary author: Dr LA COGNATA, marco (infn-lns)

Presenter: Dr LA COGNATA, marco (infn-lns)

Session Classification: Session 8

Contribution ID: **9** Type: **Oral contribution**

Reaction mechanisms of 17F+58Ni at energies around the Coulomb barrier

Thursday, June 7, 2018 5:12 PM (18 minutes)

With the radioactive ion beam 17F provided by CRIB (Center for Nuclear Study Radioactive Ion Beam separator), the reactions on the proton-shell closed 58Ni target were measured at four energies around the Coulomb barrier: 46.0, 49.8, 57.9 and 65.1 MeV. A specially designed detector array, which consists of ionization chambers and silicon detectors, was used to identify the heavy and light reaction products simultaneously. The angular distributions of the quasi-elastic scattering and inclusive breakup were obtained. The quasi-elastic data were analyzed with the framework of the optical model to deduce the total reaction cross section. The breakup angular distribution can be reproduced reasonably by the continuum-discretized coupled-channels (CDCC) and IAV (Ichimura, Austern, Vincent) model calculations, hence the cross sections of breakup reactions can be derived. Meanwhile, the fusion cross section can be determined by measuring the fusion-evaporation proton and alpha. The resulting fusion excitation function shows an enhancement at energies below the Coulomb barrier, and some suppression above the barrier.

Primary author: Dr YANG, Lei (Center for nulcear study, the University of Tokyo)

Presenter: Dr YANG, Lei (Center for nulcear study, the University of Tokyo)

Session Classification: Session 14

Contribution ID: **10** Type: **Oral contribution**

Corrections to the eikonal description of elastic scattering and breakup of halo nuclei

Tuesday, June 5, 2018 3:12 PM (18 minutes)

In the mid-80s, the development of Radioactive-Ion Beam (RIB) has enabled the study of nuclei away from stability. Indeed, these very short-lived nuclei cannot be studied through usual spectroscopic techniques but information about their structure can be deduced from reaction measurements. To conduct a precise analysis, an accurate reaction model coupled to a realistic description of the nuclei are required. The eikonal model provides reliable results at high enough energies, i.e. above 60A MeV, while having a short computational time. Since facilities, such as HIE-ISOLDE at CERN and ReA12 at MSU, aim to accelerate RIBs up to 10A MeV, extending the range of validity of the eikonal model to these energies would be of great interest. In this work, we study two corrections to the eikonal model in the framework of elastic scattering and breakup reactions of halo nuclei. These corrections improve the treatment of the Coulomb and nuclear interactions during the collision. The first is based on a semi-classical approach [1,2] while the second combines the partial-wave expansion and the eikonal model [3]. Considering the case of the one-neutron halo projectile 11Be impinging on a 12C target at 10A MeV, we show that both corrections lead to elastic scattering cross sections in excellent agreement with full CDCC calculations. The extension of these corrections to breakup observables seems, however, less successful. By showing the success and limitations of these corrections, we pinpoint more precisely the flaws of the eikonal approximation at low energy. This will hopefully pave the way towards a more efficient correction to the eikonal model at such energies.

[1] C. E. Aguiar, F. Zardi, and A. Vitturi, Phys. Rev. C 56, 1511 (1997).
[2] C. Hebborn and P. Capel, Phys. Rev. C 96, 054607 (2017).
[3] J. M. Brooke, J. S. Al-Khalili, and J. A. Tostevin, Phys. Rev. C 59, 1560 (1999).

Primary author: Ms HEBBORN, Chloë (Université libre de Bruxelles)

Co-author: Prof. CAPEL, Pierre (Johannes Gutenberg-Universität Mainz)

Presenter: Ms HEBBORN, Chloë (Université libre de Bruxelles)

Session Classification: Session 7

Contribution ID: **11** Type: **Oral contribution**

Constraints on the Symmetry Energy from Neutron-Removal Cross Sections

Tuesday, June 5, 2018 10:12 AM (18 minutes)

An experimentally constrained equation-of-state (EoS) of neutron-rich matter is one of the fundamental goals in nuclear physics that has not been reached yet.The asymmetry term of the EoS is usually expressed by the symmetry energy, with its parameters representing its value J and slope L at saturation density. To date, in particular the parameter L is still poorly known. One method to bring insight into this open issue is to relate nuclear observables as theoretically predicted using well-calibrated energy-density functionals (EDF) with the corresponding L-value. The challenge is to find observables that are sensitive to L and experimentally accessible. Two appropriate candidates, \textit{i.e.}, the neutron-skin thickness Δr_{np} and the ground-state dipole polarizabillity α_D have been identified in recent years. The accurate experimental determination of these observables, however, remains as a challenging task in particular for neutron-rich nuclei.

Several publications by Roca-Maza \textit{et al.} demonstrate the feasibility of this method on the basis of a large set of EDF. The reachable constraint on L naturally scales with the experimental uncertainty of the measured observable while the model-dependence, \textit{i.e.}, the scatter of theory points sets a hard limit that is in the order of ± 10 MeV [1]. The latest analysis [2] limits the symmetry-energy slope parameter to 20-66 MeV by comparing available data for α_D with calculations in the random-phase approximation.

Following the idea described above we have recently proposed a new method to constrain L that might allow to reach the theoretical limit, namely, the measurement of neutron-removal cross sections $\sigma_{\Delta N}$ of neutron-rich nuclei [3]. In our fist systematical study we show the sensitivity of $\sigma_{\Delta N}$ to Δr_{np} and L for the Sn isotopic chain using a parameter-free eikonal reaction-theory and modified versions of the DD2 interaction where L is systematically varied. We conclude that L can be potentially constrained down to $\pm$ 10 MeV, given that both the measured and calculated cross-section are known to a 2\,\% accuracy.
Being aware that this seems to be an ambitious goal, both aspects, \textit{i.e.}, the status and perspectives of the reaction theory as well as the requirements of the experiments proposed to be performed at R^3B will be discussed to show that this goal is definitely not out of reach.

References:

[1] X. Roca-Maza, M. Centelles, X. Vi{\~n}as, and M. Warda, Phys. Rev. Lett. \textbf{106}, 252501 (2011)

[2] X. Roca-Maza, X. {Vi{\~n}as}, M. Centelles, B.K. Agrawal, G. Col{\'o}, N. {Paar}, J. {Piekarewicz}, and D. Vretenar, Phys. Rev. C \textbf{92}, 064304, (2015)

[3] T. Aumann, C.A. Bertulani, F. Schindler, and S. Typel, Phys. Rev. Lett. \textbf{119}, 262501 (2017)

Summary

Primary authors: Prof. BERTULANI, Carlos (Department of Physics and Astronomy, Texas A&M University-Commerce, USA, Technische Universität Darmstadt, Germany); Dr SCHINDLER, Fabia (Technische Universität Darmstadt, Germany); Dr TYPEL, Stefan (Technische Universität Darmstadt, Germany, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany); Prof. AUMANN, Thomas (Technische Universität Darmstadt, Germany, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany)

Presenter: Prof. AUMANN, Thomas (Technische Universität Darmstadt, Germany, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany)

Session Classification: Session 5

Contribution ID: **13** Type: **Oral contribution**

Interplay of charge-clustering and weak binding in direct reactions of 8Li

Wednesday, June 6, 2018 11:21 AM (18 minutes)

A critical problem affecting studies and uses of light weakly-bound nuclei is the suppression of above-barrier complete fusion (e.g. [1]). The cause of suppression is uncertain, particularly for exotic neutron-rich radioactive nuclei. The suppression is thought to be related to their low thresholds for breakup into charged clusters. The observation of fusion suppression in the neutron-rich radioactive nucleus 8Li [2] is therefore puzzling: breakup into 7Li+n has the lowest breakup threshold, and cannot contribute to fusion suppression as 7Li retains all the projectile charge, while breakup into charged particles has a much higher threshold. Studies of breakup in reactions of 6,7Li and 9Be show that transfer into unbound states of neighbouring nuclei ("transfer triggered breakup") forms a significant portion of the total breakup yield [3,4], but no such study has yet been performed for neutron-rich radioactive weakly bound nuclei.

Here we present the full characteristics of 8Li direct reactions in collisions with 209Bi, which were investigated at energies slightly above the coulomb barrier using the SOLEROO radioactive beam capability at the Australian National University. Through measuring coincidences and correlations between charged fragments, we show for the first time the diversity of breakup modes for the neutron rich radioactive isotope 8Li, and that the breakup occurs too slowly (> few 10^-21 s) to result in suppression via the commonly assumed mechanisms.

Our work conclusively demonstrates that the almost universally assumed mechanism for complete fusion suppression –fast charged-cluster breakup –is not correct in reactions of 8Li, and provides evidence that it is clustering in the ground-state that is the crucial factor in fusion suppression. This work identifies a new mechanism for fusion suppression that must be investigated, and motivates further studies of fusion suppression in neutron rich nuclei.

[1] M. Dasgupta, D. J. Hinde, R. D. Butt, R. M. Anjos, A. Berriman, N. Carlin, P. R. S. Gomes, C. R. Morton, J. O. Newton, A. Szanto de Toledo, and K. Hagino, Physical Review Letters 82, 1395 (1999).
[2] E. F. Aguilera, E. Martinez-Quiroz, P. Rosales, J. J. Kolata, P. A. Deyoung, G. F. Peaslee, P. Mears, C. Guess, F. D. Becchetti, J. H. Lupton, and Y. Chen, Physical Review C 80, 044605 (2009).
[3] D. H. Luong, M. Dasgupta, D. J. Hinde, R. du Rietz, R. Rafiei, C. J. Lin, M. Evers, and A. Diaz-Torres, Physical Review C 88, 34609 (2013).
[4] R. Rafiei, R. du Rietz, D. H. Luong, D. J. Hinde, M. Dasgupta, M. Evers, and A. Diaz-torres, Physical Review C 81, 024601 (2010).

Primary author: Dr COOK, Kaitlin J. (Australian National University)

Co-authors: Mr SWINTON-BLAND, Benjamin M.A. (Australian National University); Dr SIMENEL, Cedric (Australian National University); Ms SENGUPTA, Chandrima (Australian National University); Prof. HINDE, David J. (Australian National University); Dr SIMPSON, Edward C. (Australian National University); Dr WILLIAMS, Elizabeth (Australian National University); Dr CARTER, Ian P. (Australian National University); Ms VO-PHUOC, Kirsten (Australian National University); Ms BEZZINA, Lauren T. (Australian National University); Prof. DASGUPTA, Mahananda (Australian National University); Dr KALKAL, Sunil (Thapar University)

Presenter: Dr COOK, Kaitlin J. (Australian National University)

Session Classification: Session 10

Contribution ID: **14** Type: **Oral contribution**

From Nuclei to Neutron Stars with a Microscopic Approach

Tuesday, June 5, 2018 4:00 PM (18 minutes)

Neutron-rich systems are associated with a variety of important and still open questions such as: the location of neutron drip lines, the thickness of neutron skins, and the structure of neutron stars. Common to these diverse situations is the equation of state (EoS) of neutron-rich matter, namely the energy per particle in isospin-asymmetric matter as a function of density (and other thermodynamic quantities as appropriate, such as temperature). In the presence of different neutron and proton concentrations, the symmetry energy emerges as an important component of the EoS and plays an outstanding role in the physics of neutron-rich systems.

Our predictions of the EoS are based on microscopic high-precision nuclear interactions derived from chiral Effective Field Theory (EFT) [1]. In recent years, chiral EFT has evolved into the authoritative approach to construct nuclear two- and many-body forces in a systematic manner [1, 2].
We apply the microscopic EoS of symmetric nuclear matter and the ones of pure neutron matter as derived in Ref. [3]. The derivation is based on high-precision chiral nucleon-nucleon potentials at next-to-next-to-next-to-leading order (N3LO) of chiral perturbation theory [1, 4]. The leading three-nucleon force, which is treated as an effective density-dependent force [5], is included.

It is well known that the available information on neutron radii and neutron skins is scarce and carry considerable uncertainty. Although future experiments are anticipated which should provide reliable information on the weak charge density in 208Pb and 48Ca, the identification of other "observables"whose knowledge may give complementary information on neutron skins would be most welcome. An issue of current interest is whether information on the neutron skin can be obtained through the knowledge of proton radii alone, specifically those of mirror nuclei. In particular, the difference between the charge radii of mirror nuclei in relation to the slope of the symmetry energy, and, in turn, to the neutron skin, was nvestigated in Ref. [6]. Although phenomenological analyses are a useful exploratory tool to gain some preliminary insight into sensitivities and interdependences among nuclear properties, only through microscopic predictions can we understand a result in terms of the physical input. We will explore, from the microscopic point of view in contrast to the phenomenological one, the relation between the neutron skin of a nucleus, on the one hand, and the difference between the proton radii of the mirror pair with the same mass, on the other.

Moving on to a dramatically different scale, it is remarkable that the relation between the mass and the radius of neutron stars is uniquely determined by the EoS together with their self-gravity. In fact, these compact systems are intriguing testing grounds for nuclear physics. Most recently, the detection by LIGO of gravitational waves from two neutron stars spiraling inward and merging has generated even more interest and excitement around these exotic systems. In fact, the LIGO/Virgo [7] detection of gravitational waves originating from the neutron star merger GW170817 has provided new and more stringent constraints on the maximum radius of a 1.4 M⊠ neutron star, based on the tidal deformabilities of the colliding stars [8]. We will present and discuss predictions of neutron star masses and radii based, as far as possible, on state-of-the-art nuclear forces. The focal point is the radius of a star with mass equal to 1.4 M⊠ (the most probable mass of a neutron star), which we wish to predict with appropriate quantification of the theoretical error.

[1] R. Machleidt and D.R. Entem, Physics Report 503, 1 (2011).

[2] E. Epelbaum, H.-W. Hammer, and U.-G. Meissner, Rev. Mod. Phys. 81, 1773 (2009).

[3] F. Sammarruca, L. Coraggio, J.W. Holt, N. Itaco, R. Machleidt, and L.E. Marcucci, Phys. Rev. C 91, 054311 (2015).

[4] D.R. Entem and R. Machleidt, Phys. Rev. C 68, 041001 (2003).
[5] J.W. Holt, N. Kaiser, and W. Weise, Phys. Rev. C 79, 054331 (2009);
[6] B.A. Brown, Phys. Rev. Lett. 119, 122502 (2017).
[7] B.P. Abbott et al. [LIGO Scientific and Virgo Collaborations], Phys. Rev. Lett. 119, 161101 (2017).
[8] Eemeli Annala, Tyler Gorda, Aleksi Kurkela, and Aleksi Vuorinen, arXiv:1711.02644 [astro-ph.HE]; and references therein.

Primary author: Prof. SAMMARRUCA, Francesca (University of Idaho)

Presenter: Prof. SAMMARRUCA, Francesca (University of Idaho)

Session Classification: Session 8

Contribution ID: **15** Type: **Oral contribution**

Linking structure and dynamics in (p,pN) reactions induced by Borromean nuclei

Friday, June 8, 2018 2:06 PM (18 minutes)

One-nucleon removal (p,pN) reactions in inverse kinematics, performed at intermediate energies to increase the mean free path of the proton inside the nucleus, can provide quite clean spectroscopic information on exotic nuclei. The Transfer to the Continuum framework, originally developed for the case of two-body projectiles [1], has been recently extended to describe (p,pN) reactions induced by Borromean (core+N+N) nuclei [2]. In this method, the relative energy distribution of the residual unbound two-body subsystem, which is assumed to retain information on the structure of the initial three-body projectile, is computed by evaluating the transition amplitude for different neutron-core final states in the continuum. These transition amplitudes depend on the overlaps between the original three-body ground-state wave function and the two-body continuum states populated in the reaction, thus ensuring a consistent description of the incident and final nuclei.

We applied the method to the 11Li(p,pn)10Li reaction at 280 MeV/u, obtaining a very good agreement with GSI data [3]. In order to describe the 14Be(p,pn)13Be reaction, in which gamma coincidences from the decay of 12Be provide additional information [4], the effect of core excitations has been incorporated in the structure description. Preliminary results show the sensitivity of the cross sections to the structure input. Other cases of interest include 8He(p,pn)7He, 17Ne(p,2p)16F, or 22C(p,pn)21C.

[1] A. M. Moro, PRC 92 (2015) 044605.
[2] M. Gómez-Ramos, J. Casal, and A. M. Moro, PLB 772 (2017) 115.
[3] Y. Aksyutina et al., PLB 666 (2008) 430.
[4] Y. Kondo et al., PLB 690 (2010) 245.

Primary authors: Prof. MORO, Antonio M. (Universidad de Sevilla); Dr CASAL, Jesús (ECT*); Mr GÓMEZ-RAMOS, Mario (Universidad de Sevilla)

Presenter: Dr CASAL, Jesús (ECT*)

Session Classification: Session 17

Contribution ID: **16** Type: **Oral contribution**

In-beam gamma-ray spectroscopy near the proton drip line: 25Si and 26P

Tuesday, June 5, 2018 9:36 AM (18 minutes)

The structure of neutron-deficient nuclei plays a vital role in nucleosynthesis via the rp process. Near the proton drip line, the Q values of (p,g) reactions are low and the reaction rates are dominated by single resonances and direct capture. We present here studies of 25Si and 26P produced through one-neutron knockout and charge exchange at the National Superconducting Cyclotron Laboratory at Michigan State University. Energy levels and branching ratios in 25Si and 26P were measured using in-beam gamma-ray spectroscopy with the high-efficiency CsI(Na) array CAESAR and the high-resolution segmented Ge array SeGA. The results are compared with the mirror nuclei to show a significant Thomas-Ehrman shift in this region. Shell-model calculations using the USDB-CDPN interaction with a downward shift of the single-particle energy for the 1S1/2 proton orbital to reproduce the observed Thomas-Ehrman shift are discussed and used with the experimentally measured resonances to calculate the (p,g) reaction rates.

Primary authors: BROWN, Alex (Michigan State University / National Superconducting Cyclotron Laboratory); GADE, Alexandra (Michigan State University / National Superconducting Cyclotron Laboratory); LONGFELLOW, Brenden (Michigan State University / National Superconducting Cyclotron Laboratory); RICHTER, Werner (University of the Western Cape / iThemba LABS)

Co-authors: ELMAN, Brandon (Michigan State University / National Superconducting Cyclotron Laboratory); BAZIN, Daniel (National Superconducting Cyclotron Laboratory); WEISSHAAR, Dirk (National Superconducting Cyclotron Laboratory); LUNDERBERG, Eric (Michigan State University / National Superconducting Cyclotron Laboratory); BOWRY, Michael (National Superconducting Cyclotron Laboratory); BENDER, Peter (National Superconducting Cyclotron Laboratory); WILLIAMS, Scott (National Superconducting Cyclotron Laboratory)

Presenter: LONGFELLOW, Brenden (Michigan State University / National Superconducting Cyclotron Laboratory)

Session Classification: Session 5

Contribution ID: **17** Type: **Oral contribution**

Microscopic description of global optical potential toward unstable nucleus

Tuesday, June 5, 2018 2:36 PM (18 minutes)

The optical model potential has an aspect of useful tool to analyze the nuclear reaction data of the non-elastic scattering. Therefore, the construction of the optical model potential is developed. Nowadays, the microscopic description based on the realistic nucleon-nucleon interaction is advanced to construct the optical model potential. The microscopic optical potential is success to describe not only the elastic scattering but also inelastic scattering and transfer reaction and so on.
In this talk, we will introduce the microscopic global optical potential for the nucleon-nucleus systems. The microscopic global optical potential is based on the single-folding model with the complex G-matrix interaction. The microscopic global optical potential is designed for the nucleon-nucleus systems including the unstable nucleus at E = 50-400 MeV.

Primary author: Dr FURUMOTO, Takenori (Yokohama National University)

Co-authors: Dr TSUBAKIHARA, Kosuke (Tokyo Institute of Technology); Dr EBATA, Shuichiro (Tokyo Institute of Technology); Dr HORIUCHI, Wataru (Hokkaido University)

Presenter: Dr FURUMOTO, Takenori (Yokohama National University)

Session Classification: Session 7

Contribution ID: **18** Type: **Poster Contribution**

Fragmentation of carbon on elemental targets at 400 A MeV

The total charge-changing reaction cross-sections and the partial cross-sections of projectile fragments(PFs) production for the fragmentation of 12C on C, Al, Cu, Pb and CH2 targets at the highest energy of 400 A MeV are investigated. It is found that the total charge-changing cross-sections and the partial cross-sections of PFs production for the fragmentation are independent of the beam energy, and increase with increase of mass of target for the same beam energy. The total charge-changing reaction cross section is the same as the prediction of Bradt-Peters semi-empirical formula, PHITS and NUCFRG2 models. The partial cross section of PFs production increases with the increase of the mass of target, and it is the same as the prediction of NUCFRG2 model. The average scattering angle of beam particle is less than the mean emission angle of PF, and the width of scattering angle distribution of beam particle is less than that of emission angle distribution of PF. The mean emission angle of PF increases with the mass of target for the same beam energy and charge of PF.

Primary author: Prof. ZHANG, Dong-Hai (Institute of Modern Physics, Shanxi Normal University)

Co-authors: Dr LI, Jun-Sheng (Institute of Modern Physics, Shanxi Normal University); Dr KODAIRA, Satoshi (Radiation Measurement Research Section, National Institute of Radiological Sciences)

Presenter: Prof. ZHANG, Dong-Hai (Institute of Modern Physics, Shanxi Normal University)

Contribution ID: **19** Type: **Oral contribution**

a new measurement of the intruder configuration in 12Be

Tuesday, June 5, 2018 11:18 AM (18 minutes)

A new 11Be(d,p)12Be transfer reaction experiment was carried out in inverse kinematics at 26.9 MeV/nucleon, with special efforts devoted to the determination of the deuteron target thickness and of the required optical potentials from the present elastic scattering data. In addition, a direct measurement of the cross section for the 02+ state was realized by applying an isomer-tagging technique. The s-wave spectroscopic factors of 0.20(0.04) and 0.41(0.11) were extracted for the 01+ and 02+ states, respectively, in 12Be. Using these spectroscopic factors, together with the previously reported results for the p-wave components, the single-particle component intensities in the bound 0+ states of 12Be were deduced, allowing a direct comparison with the theoretical predictions. It is evidenced that the ground-state configuration of 12Be is dominated by the d-wave intruder, exhibiting a dramatic evolution of the intruding mechanism from 11Be to 12Be, with a persistence of the N = 8 magic number broken.

Primary authors: Dr LOU, Jianling (Peking University); Dr CHEN, Jie (Argonne lab)

Presenter: Dr LOU, Jianling (Peking University)

Session Classification: Session 6

Contribution ID: **20** Type: **Oral contribution**

Manifestation of α-clustering in 10Be via α-knockout reaction

Wednesday, June 6, 2018 9:54 AM (18 minutes)

Despite the remarkable successes obtained by the cluster models, the physical observables that are directly related to the cluster degree of freedom is not available until very recent studies of α-transfer reactions and α-knockout reactions. We introduce the microscopic structure models into the theoretical frameworks for α-knock out reactions to probe the α-clustering in 10Be nucleus. In this work, we integrate the THSR wave function and the distorted wave impulse approximation (DWIA) framework, and make calculation for the 10Be(p,pα)6He reaction at 250MeV. We predict the triple differential cross sections (TDX). We further construct artificial states with extreme shell-model like or gas like states for the target nucleus 10Be, and find the strong dependence of the TDX on the α-clustering structure. With this new framework, we may directly relate the microscopic description of α-clustering structure to the reaction observables in the (p,pα) knockout reaction, and provide sensitive manifestation of α-clustering in the 10Be nucleus. We are further extending this framework to the α-knockout reaction for the 12Be nucleus.

Primary author: Dr LYU, Mengjiao (RCNP, Osaka University)

Co-authors: Mr YOSHIDA, Kazuki (research center for nuclear physics); Prof. OGATA, Kazuyuki (RCNP, Osaka University); Prof. KANADA-EN'YO, Yoshiko (Kyoto University)

Presenter: Dr LYU, Mengjiao (RCNP, Osaka University)

Session Classification: Session 9

Contribution ID: **21** Type: **Oral contribution**

Study of N=34 sub-shell closure in 54Ca from knock-out reaction

Wednesday, June 6, 2018 9:36 AM (18 minutes)

The structure of neutron-rich Ca isotopes have attracted interest from both experimental and theoretical side for a decade. The N=32 sub-shell gap is found to be well established from the measured 2+ energy in 52Ca[1]. Recently, with the availability of intense radioactive beam, the N=34 sub-shell closure was also found experimentally in 54Ca[2]. To quantitatively study the nature of N=34 sub-shell closure, the spectroscopic factor of 54Ca(p,pn) reaction is a useful index. Besides, the 53Ca nucleus, located in between 52Ca and 54Ca, its single-particle properties of low-lying states are of importance to the study of structures for very neutron-rich Ca isotopes above 54Ca and shell evolution towards the potential sub-shell closure nucleus 60Ca. We therefore performed 54Ca(p,pn) experiment at the RIBF facility of the RIKEN Nishina Center.

In this experiment, proton induced neutron knock-out cross sections from 54Ca ground state to individual final states of 53Ca have been investigated. The in-beam gamma-ray spectroscopy technique has been employed to tag the final states in 53Ca. The exclusive cross section as well as the residues momentum distribution to individual final states have been measured. The spectroscopic factors deduced from the experimental knock-out cross sections and momentum distribution of the residues to individual final state will be compared to the reaction theory for quantitative structure study. In this report, the experimental setup as well as the preliminary result of data analysis will be presented.

[1] A. Gade et al., Phys. Rev. C 74,021302 (R) (2006)
[2] D. Steppenbeck et al., Nature, 502, 207-210, (2013)

Primary authors: Dr LEE, Jenny (The University of Hong Kong); Mr CHEN, Sidong (Peking University)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr DOORNENBAL, Pieter (RIKEN)

Presenter: Mr CHEN, Sidong (Peking University)

Session Classification: Session 9

Contribution ID: **22** Type: **Poster Contribution**

Maris polarization of neutron-rich nuclei

I will discuss the Maris polarization effect and its application in quasi-free reactions to assess information on the structure of exotic nuclei. The uncertainties in the calculations of triple differential cross sections and of analyzing powers due the choices of various nucleon-nucleon interactions the optical potentials and limitations of the method are the main focus. Theoretical calculations explore a large number of choices for the nucleon-nucleon (NN) interactions and the optical potential for nucleon-nucleus scattering and implies that polarization variables in (p,2p) reactions in inverse kinematics can be an effective probe of single-particle structure of nuclei in radioactive-beam facilities.

Primary author: Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce)

Co-authors: Dr SHUBHCHINTAK, Shubhchintak (Texas A&M University-Commerce); Prof. AUMANN, Thomas (Technische Universitaet Darmstadt)

Presenter: Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce)

Contribution ID: **23** Type: **Oral contribution**

Assessing the foundation of the Trojan Horse Method

Wednesday, June 6, 2018 9:00 AM (18 minutes)

I will discuss the foundation of the Trojan Horse Method (THM) within the Inclusive Non-Elastic Breakup (INEB) theory. This work demonstrates that the direct part of the INEB cross section, which is of two-step character, becomes, in the DWBA limit of the three-body theory with appropriate approximations and redefinitions, similar in structure to the one-step THM cross section. I will also discuss the connection of the THM to the Surrogate Method (SM), which is a genuine two-step process.

Primary author: Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce)

Co-authors: Prof. HUSSEIN, Mahir (University of Sao Paulo); Dr TYPEL, Stefan (TU-Darmstadt)

Presenter: Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce)

Session Classification: Session 9

Contribution ID: **24** Type: **Poster Contribution**

Constraining bound state potentials of A≈80 nuclei with (d,p) measurements

The empirical spectroscopic properties of unstable nuclei are important input to understanding nucleosynthesis in stars and their explosions, as well as constraining models of nuclear structure. In particular, the spectroscopic factor is a key ingredient in calculating direct-semi-direct neutron capture on weakly bound nuclei, as well as informing the single-particle character of excitations. However, deducing spectroscopic factors is highly sensitive to the shape of the bound state potential; in peripheral reactions spectroscopic factors can vary by factors of 2-4 for reasonable potential parameters. In nuclei away from stability, especially on the neutron-rich side, the validity of bound state parameters common for stable nuclei is unknown, especially for less bound configurations. Mukhamedzhanov and Nunes [1] have proposed measuring the same reaction at two very different energies to constrain the bound-state potential parameters. At low energies, a peripheral reaction constrains the external contribution, the nuclear asymptotic normalization coefficient (ANC). At higher energies, the ANC would not be constrained, yet the reaction would still be sensitive to the unknown bound state parameters. Because, the spectroscopic factor is a property of the many-body wave function of the final bound state populated in the (d,p) reaction, it should be independent of the reaction energy. Therefore, the spectroscopic factor is determined by the value (with uncertainties) consistent with measurements at both reaction energies. We have recently demonstrated the validity of this approach by measuring the (d,p) reaction with 35 MeV/u 86Kr beams at the National Superconducting Cyclotron Laboratory (NSCL) with the Oak Ridge Rutgers University Barrel Array (ORRUBA) and SIlicon Detector Array (SIDAR); the results were compared with previous measurements of the reaction with 86Kr targets and 11 MeV d beams [2]. More recently, we measured at NSCL the (d,p) reaction with 45 MeV/u 84Se beams, which would be combined with the previous study [3] at 4.5 MeV/u. The present talk would summarize the results from the 86Kr measurements, including the deduced bound state parameters for the 87Kr ground state, and present preliminary results from the 84Se beam measurements.

This work is supported in part by the National Science Foundation and U.S. Department of Energy.

[1] A.M. Mukhamedzhanov and F.M. Nunes, Phys. Rev. C 72, 017602 (2005)
[2] K. Haravu et al., Phys. Rev C 1,938 (1970)
[3] J.S. Thomas et al., Phys. Rev C 76, 044302 (2007)

Primary author: Mr WALTER, David (Rutgers University)

Co-authors: Prof. NUNES, Filomena (Michigan State University); Prof. CIZEWSKI, Jolie (Rutgers University); Dr PAIN, Steven (Oak Ridge National Laboratory)

Presenter: Prof. CIZEWSKI, Jolie (Rutgers University)

Contribution ID: **26** Type: **Oral contribution**

Study of spectroscopic factors at N=29 using isobaric analog resonances in inverse kinematics

Thursday, June 7, 2018 11:00 AM (18 minutes)

A measurement was recently performed at the National Superconducting Cyclotron Laboratory on resonant proton scattering of 46Ar in inverse kinematics in the region of isobaric analog states of 47Ar. The experiment was performed using a re-accelerated 46Ar radioactive beam at 4.6 MeV/u from the ReA3 linac after production via the projectile fragmentation of a 48Ca primary beam from the Coupled Cyclotron Facility. This beam was injected into the Active Target Time Projection Chamber where the reaction took place on an isobutane target and the scattered protons were detected. Four candidate resonances were observed, two of which corresponding to the isobaric analogs of 47Ar ground and first excited states. Spectroscopic factors were deduced from the strength of these resonances and compared to values in the literature. This novel experimental method to extract spectroscopic information from proton elastic scattering on radioactive nuclei will be presented, as well as the analysis methods used to extract results from the data.

Primary author: Dr BAZIN, Daniel (Michigan State University)

Co-authors: Dr GILLIBERT, Alain (CEA IRFU); Prof. BROWN, Alex (NSCL); Dr PEREZ-LOUREIRO, David (NSCL); Dr POLLACCO, Emmanuel (CEA IRFU); Mr SAMMUT, Jason (NSCL); Mr BARNEY, John (NSCL); Dr YURKON, John (NSCL); Dr BRADT, Joshua (NSCL); Mr MANFREDI, Juan (NSCL); Mr ESTEE, Justin (NSCL); Ms CARPENTER, Lisa (NSCL); Dr CORTESI, Marco (NSCL); Prof. KUCHERA, Michelle (Davidson University); Mr WATWOOD, Nathan (NSCL); Dr MORFOUACE, Pierre (GANIL); Dr BECEIRO-NOVO, Saul (NSCL); Mr SWEANY, Sean (NSCL); Mr ROST, Stefan (NSCL); Prof. DATTA, Ushasi (Saha Institute); Prof. LYNCH, William (NSCL); Prof. MITTIG, Wolfgang (NSCL); Dr AYYAD, Yassid (LBNL)

Presenter: Dr BAZIN, Daniel (Michigan State University)

Session Classification: Session 12

Contribution ID: **27** Type: **Poster Contribution**

Study of the deuteron scattering on 7Li nuclei

N. Burtebayev1, Maulen Nassurlla1,2, Zh.K. Kerimkulov1, D.T. Burtebayeva1, E.S. Mukhamedzhanov1, Marzhan Nassurlla1,2, T. Suzuki3, S.B. Sakuta4

1 Institute of Nuclear Physics, Almaty, Kazakhstan
2 Al-Farabi Kazakh National University, Almaty, Kazakhstan
3 Saitama University, Saitama, Japan
4 National Research Center "Kurchatov Institute", Moscow, Russia

New data of the differential cross section of the elastic and inelastic scattering of deuterons has been measured at energies 14.5 MeV on the isochronous cyclotron U-150M (Institute of Nuclear Physics, Almaty). The differential cross sections of the scattering were obtained for the ground state and the following excited states of the 7Li: 1/2- (0.478 MeV), 7/2- (4.68 MeV) in the angular range 180 - 1400 in laboratory system. The angular distribution showed the diffraction structure of the elastically and inelastically scattered deuterons.
The optimal values of the potential parameters were established for the system "d + 7Li" as a function of the energy from the joint analysis of the literature data at the energy range 7 - 25 MeV [1-4] within the framework of the optical model. Previously, the analysis of scattering process was performed at energies 14.7 MeV [3] and 25 MeV [4], while at energy 14.7 MeV [3] the experimental data were obtained at the forward hemisphere.
The analysis of differential cross sections of elastic and inelastic scattering of deuterons on 7Li at energy 14.5 MeV were performed within the framework of the coupled channel method for the negative parity levels that constitute the rotational band on the ground state of the nucleus using the FRESCO program. The value of the quadrupole deformation parameter β2 determined from the analysis of the inelastic scattering and is in agreement with the values established from the analysis of the scattering data for deuterons [4].

References:

1. S. N. Abramovich, B. Ja. Guzhovskij, B. M. Dzuba et al., J. Izv. Ross. Akad. Nauk, Ser. Fiz. 40, 842 (1976).
2. H. G. Bingham, A. R. Zander, K.W. Kemper et al., Nucl. Phys. A 173, 265 (1971).
3. S. Matsuki, S. Yamashita, K. Fukunaga et al., J. Phys. Soc. Jpn. 26, 1344 (1969).
4. Burtebayev. N., Burtebayeva. J.T., Duisebayev A. et al. Acta Phys. Pol. B. 46, 1037(2015).

Primary author: Mr NASSURLLA, Maulen (Institute of Nuclear Physics, Kazakhstan, Almaty;Al-Farabi Kazakh National University, Almaty, Kazakhstan)

Co-authors: Ms BURTEBAYEVA, Djumazia (Institute of Nuclear Physics, Kazakhstan, Almaty); Dr MUKHAMEDZHANOV, Erzhan (Institute of Nuclear Physics, Kazakhstan, Almaty); Dr NASSURLLA, Marzhan (Institute of Nuclear Physics, Kazakhstan, Almaty; Al-Farabi Kazakh National University, Almaty, Kazakhstan); Prof. BURTEBAYEV, Nassurlla (Institute of Nuclear Physics, Kazakhstan, Almaty); Prof. SAKUTA, Stanislav (National Research Center "Kurchatov Institute", Moscow, Russia); Prof. SUZUKI, Takeshi (Saitama University, Saitama, Japan); Dr KERIMKULOV, Zhambul (Institute of Nuclear Physics, Kazakhstan, Almaty)

Presenter: Mr NASSURLLA, Maulen (Institute of Nuclear Physics, Kazakhstan, Almaty;Al-Farabi Kazakh National University, Almaty, Kazakhstan)

Contribution ID: **28** Type: **Poster Contribution**

Coulomb shift in two-center mirror nuclei

The so-called alpha cluster structure appears in the excited states of light nuclear system, and the structures have been extensively investigated in the N=Z systems. Furthermore, the alpha cluster structures are also discussed in neutron-excess (N>Z) systems extensively.

In the present report, we focus on the mirror systems, which are obtained by replacing neutrons to protons in neutron-excess system, and demonstrate that the Coulomb shift of the mirror systems is a new probe to catch the sign of the clustering phenomena. Here we discuss the Coulomb shift of the mirror systems, such as (18O = alpha + 14C) - (18Ne = alpha + 14O).

The interaction potential of alpha and the residual nucleus is derived from the double folding (DF) model with the effective nucleon-nucleon interaction of the density-dependent Michigan 3-range Yukawa. The validity of the DF potential is checked by applying it to the alpha + 14C elastic scattering. The scattering calculation with the DF potential nicely reproduces the observed differential cross sections.

The energy level of these mirror systems are calculated from the orthogonality condition model (OCM), in which the functional space allowed by the Pauli's exclusion principle is exactly constructed. Here we have constructed the Pauli's allowed space by employing the mathematical technique of the SU(3) group representation in nuclei. The resonant 0+ levels and their decay width are identified by imposing the absorbing boundary condition. Above the alpha decay threshold, two resonant 0+ states are obtained, which seem to be consistent to the recent observations of the alpha + 14C elastic scattering and the multi-nucleon transfer reaction.

We have evaluated the energy shift of the 0+ states in the mirror systems of 18O - 18Ne, which arises from the difference of the Coulomb interaction. The OCM calculation predicts that the Coulomb shift for the resonant 0+ states is prominently reduced in comparison to the shift for the low-lying bound states. This reduction of the Coulomb shift for the resonant 0+ state is induced by the development of the alpha clustering. Therefore this result strongly suggests that the Coulomb shift is new probe to identify the cluster degrees of freedom.

In this report, we will discuss the relation of the reduction of the Coulomb shift and the development of the cluster degrees of freedom in detail.

Primary author: Mr NAKAO, Makoto (Kansai university)

Co-authors: Mr UMEHARA, Hajime (Department of Physics, Osaka University); Dr ITO, Makoto (Department of Pure and Applied Physics, Kansai University); Dr EBATA, Shuichiro (Faculty of Science, Hokkaido University)

Presenter: Mr NAKAO, Makoto (Kansai university)

Contribution ID: **29** Type: **Oral contribution**

X-ray bursts: Indirect measurement of the astrophysical 23Al(p,γ) reaction

Tuesday, June 5, 2018 4:36 PM (18 minutes)

X-ray bursts are the most frequent stellar explosions to occur throughout the cosmos and as such, represent key research environments for the field of nuclear astrophysics. These cataclysmic binary systems are known to exhibit distinctive light curves, which have now been observed with unprecedented sensitivity, that provide a detailed reflection of the underlying nuclear physics processes involved. Consequently, an accurate understanding of the observed light curves may hold the key to the unraveling of the burst mechanism, as well as the companion neutron star properties.

Recently, an in-depth study of the dependence of X-ray burst models on nuclear reaction rates has highlighted the 23Al(p,γ)24Si as being of particular significance in determining the shape of the X-ray burst light curve [1]. A direct investigation of this reaction is presently unfeasible due to the current low intensities of radioactive 23Al beams. As such, an innovative indirect approach is required.

In this talk, I will present the first ever study of the 23Ne(d,p)24Ne transfer reaction, which was recently performed at the ISAC-II facility at TRIUMF using a radioactive beam of 23Ne. Here, the high-granularity TIGRESS γ-ray array was used in conjunction with the SHARC silicon detection system to extract spectroscopic information on excited states in 24Ne. These states represent key isobaric analogs of resonances in 24Si and therefore, by measuring their spectroscopic strengths and employing mirror symmetry, it is possible to indirectly determine the 23Al(p,γ) stellar reaction rate. Such investigations have been extremely successful in recent years in constraining astrophysical reactions that lie outside the reach of direct measurements [2,3].

[1] R.H. Cyburt et al., Astrophys. J. 830, 55 (2016).
[2] V. Margerin, G. Lotay et al., Phys. Rev. Lett. 115, 062701 (2015).
[3] S.D. Pain et al., Phys. Rev. Lett. 114, 212501 (2015).

Primary authors: Dr LOTAY, Gavin (University of Surrey); Dr MOUKADDAM, Mohamad (University of Surrey)

Co-authors: Dr GARNSWORTHY, Adam (TRIUMF); Mr IHSAN KILIC, Ali (Guelph); Ms MATHEWS, Anita (Waterloo/TRIUMF); Mr GREAVES, Beau (Guelph); Mr LUNA, Benjamin (Tennesse Tech); Dr OLAIZOLA, Bruno (TRIUMF); Mr JONES, Calum (University of Surrey/TRIUMF); Mr LEVY, Daniel (TRIUMF); Prof. MUECHER, Dennis (Guelph); Mr HYMERS, Devin (Guelph); Mr CHAENY, Donald (Tennesse Tech); Ms KASANDA, Eva (Guelph); Ms GHAZI MORADI, Farnaz (Guelph); Mr ALI, Fuad (Guelph, Canada / Sulaimani, Kurdistan, Iraq); Dr HACKMAN, Greg (TRIUMF); Ms PATEL, Hiral (Waterloo/TRIUMF); Dr HENDERSON, Jack (TRIUMF); Dr SMALLCOMBE, James (TRIUMF); Mr BEREAN, Jonah (TRIUMF/UBC); Mr WHITMORE, Kenneth (TRIUMF/SFU); Ms ATTAR, Leyla (Guelph); Mr WILLIAMS, Matthew (TRIUMF/University of York); Dr BOWRY, Michael (TRIUMF); Mr SPENCER, Michael (Surrey/TRIUMF); Prof. RAJABALI, Mustafa (Tennesee Tech); Dr ORR, Nigel (LPCCaen); Ms BERNIER, Nikita (TRIUMF); Dr CABALLERO-FOLCH, Roger (TRIUMF); Mr HALLAM, Samuel (University of Surrey); Dr BHATTACHARJEE, Soumendu Sekhar (TRIUMF); Dr GILLESPIE, Stephen (TRIUMF); Prof. DRAKE, Tom (Toronto); Prof. CATFORD, Wilton (University of Surrey); Ms SAITO, Yukiya (TRIUMF/UBC)

Presenter: Dr MOUKADDAM, Mohamad (University of Surrey)

Session Classification: Session 8

Contribution ID: **30** Type: **Oral contribution**

Transfer reactions induced with 56Ni: np pairing and N=28 shell closure

Monday, June 4, 2018 3:33 PM (18 minutes)

An efficient way to explore the nuclear structure is the effective use of transfer reactions. Two different physical aspects are being investigated with the use of transfer reactions on 56Ni, which is a N=Z unstable doubly magic nucleus.

(i)To probe the gap of N=28, we study the spectroscopy of the N=29 and N=27 isotones by the (d,t), (p,d) and (d,p) one nucleon transfer reactions on 56Ni (N=28 isotone) and extract information on the single-particle configuration around the Fermi surface.

(ii)To study the np pairing in the self-conjugate nucleus 56Ni, we have measured the two-nucleon transfer reactions 56Ni(p, 3He)54Co [1] and 56Ni(d,α)54Co. In the (p,3He) reaction, the ratio of the population of the T=0 and T=1 states indicates a predominance of T=1 pairing [1]. The selectivity of the (d,α) reaction enables the investigation of the T=0 channel with better precision.

During spring 2014 the experiment aiming to these studies took place at GANIL-Caen, France. The radioactive beam of 56Ni at 30MeV/u was produced by fragmentation of 58Ni and purification. Measurements were performed in inverse kinematics on CH2 and CD2 targets. The experiment included a 4π coverage for the study of the charged projectiles with the MUST2 and TIARA detectors, while 4 clovers of EXOGAM were also used for γ-particle coincidences in order to identify the populated state of the residue. The analysis of the 56Ni(d,t)55Ni and 56Ni(d,p)57Ni reactions yield the differential cross-section for transfer reaction to the ground state and the excited states of 55Ni and 57Ni giving information about the shell closure and depicting the Fermi surface of 56Ni. I will present the angular distribution and compare with the results for the (p,dγ), (d,tγ) and (d,pγ) reactions, as well as with DWBA calculations. The results for the transfer reaction 56Ni(d,α)54Co will be also presented, completing the information about the strength of the isoscalar np pairing in the closure of the fp shell.

[1]Benjamin Le Crom, Thesis: "Etude de l'appariement neutron-proton dans les noyaux instables N=Z par réactions de transfert."Physique Nucléaire Expérimentale [nucl-ex]. Université Paris-Saclay, 2016.

Primary author: Ms GEORGIADOU, Anastasia (Institut de Physique Nucléaire d'Orsay (IPN))

Co-authors: CORSI, A. (DRF/IRFU/DPhN//LENA); GILLIBERT, A. (DRF/IRFU/DPhN//LENA); MATTA, A. (LPC Caen); BASTIN, B. (GANIL); FERNANDEZ, B. (Universidade de Santiago de Compostela, E-15782 Santiago de Compostela, Spain); LE CROM, B. (IPN); KAMALOU, C. (GANIL); SUZUKI, D. (IPN); CLEMENT, E. (GANIL); POLLACCO, E. (DRF/IRFU/DPhN//LENA); DELAUNAY, F. (LPC Caen); FLAVIGNY, F. (IPN); HAMMACHE, F. (IPN); ROTARU, F. (Horia Hulubei National Institute of Physics and Nuclear Engineering, Măgurele, Romania); DEFRANCE, G. (GANIL); VERDE, G. (Laboratori Nazionali del Sud, Instituto Nazionale di Fisica Nucleare, Catania, Italy); STEFAN, I. (IPN); GIBELIN, J. (LPC Caen); GUILLOT, J. (IPN); PANCIN, J. (GANIL); PEREIRA, J. (Universidade de Santiago de Compostela, E-15782 Santiago de Compostela, Spain); SCARPACI, J.-A. (Centre de Sciences Nucléaires et Sciences de la Matière, Université Paris-Sud –CNRS/IN2P3, 91406 Orsay, France); THOMAS, J.-C. (GANIL); ACHOURI, L. (LPC Caen); PERROT, L. (IPN); ASSIÉ, M. (IPN); FISICHELLA, M. (Laboratori Nazionali del Sud, Instituto Nazionale di Fisica Nucleare, Catania, Italy); MARQUES, M. (LPC

Caen); STANOIU, M. (Horia Hulubei National Institute of Physics and Nuclear Engineering, Măgurele, Romania); VANDEBROUCK, M. (DRF/IRFU/DPhN//LENA); DELATTRE, M.-C. (IPN); DE SÉRÉVILLE, N. (IPN); ORR, N. (LPC Caen); SORLIN, O. (GANIL); MORFOUACE, P. (GANIL); DESHAYES, Q. (LPC Caen); BORCEA, R. (Horia Hulubei National Institute of Physics and Nuclear Engineering, Măgurele, Romania); FRANCHOO, S. (IPN); LEBLOND, S. (LPC Caen); ROGER, T. (GANIL); LAPOUX, V. (DRF/IRFU/DPhN//LENA); CATFORD, W. (Department of Physics, University of Surrey, United Kingdom); BLUMENFELD, Y. (IPN)

Presenter: Ms GEORGIADOU, Anastasia (Institut de Physique Nucléaire d'Orsay (IPN))

Session Classification: Session 4

Contribution ID: **31** Type: **Oral contribution**

Nuclear structure study for the neutron-rich cadmium nuclei beyond 132Sn

Tuesday, June 5, 2018 11:36 AM (18 minutes)

Nuclear structure study for exotic nuclei far away the stability is one of major topics in today' s nuclear physics research. In particular, the neutron-rich nuclei beyond 132Sn provide a pivot region to explore the exotic nuclear structure because 132Sn is doubly magic and locates far away the stability. In this region, two phenomena in nuclear structure have attracted much attention in recent years: the persistence of N=82 shell gap in the nuclei locating at the south of 132Sn and neutron dominance nature in the 2+ excitation in Te and Sn beyond N=82.

To address these two questions, neutron-rich cadmium isotopes are critical. For N=82 shell gap, mass measurement and spectroscopic studies show contradictory results for 130Cd (Z=48,N=82). While a reduced N=82 shell gap is deduced from the mass measurements on 130,131Cd, spectroscopic study suggests a good N=82 shell closure because the first 2+ state 130Cd is comparable to other N=82 isotones. For the neutron dominance nature, the first 2+ state in 132Cd (Z=48,N=84) is essential to investigate on the role of neutron in low-lying excitation in more neutron-rich system.

Aiming at investigating the exotic nuclear structure beyond 132Sn, we have measured reduced transition possibility B(E2) for the semi-magic nucleus 130Cd and 2+ state in 132Cd at the RI Beam Factory. Coulomb excitation at around 160MeV/u was applied to obtain the B(E2) value in 130Cd and the two-proton removal reaction was used to produce the 2+ state in 132Cd. Gamma rays emitted from the excited states were measured via the DALI2 spectrometer. In the presentation, the newly obtained BE2 value and 2+ state for 130Cd and 132Cd, respectively, will be discussed and experimental details will be given.

Primary author: Dr WANG, He (RIKEN Nishina Center)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr JUNGCLAUS, Andrea (Instituto de Estructura de la Materia - CSIC); Dr RICCARDO, Avigo (INFN); Dr BAUER, Christopher (TU Darmstadt); Dr SANTAMARIA, Clementine (NSCL, MSU); Dr STEPPENBECK, David (RIKEN Nishina Center); Dr IDEGUCHI, Eiji (RCNP, Osaka University); Dr OTSU, Hideaki (RIKEN Nishina Center); Dr BABA, Hidetada (RIKEN); Dr SAKURAI, Hiroyoshi (RIKEN Nishina Center for Accelerator-Based Science); LIU, Hongna (CEA Saclay); Dr LEE, Jenny (The University of Hong Kong); Mr WU, Jin (RIKEN); Dr YONEDA, Ken-ichiro (RIKEN Nishina Center); Dr MATSUSHITA, Masafumi (Center for Nuclear Study, University of Tokyo); Dr NIIKURA, Megumi (Department of Physics, the University of Tokyo); Dr AOI, Nori (RCNP, Osaka Univ.); Dr DOORNENBAL, Pieter (RIKEN); Dr SÖDERSTRÖM, Pär-Anders (RIKEN Nishina Center); Mr TANIUCHI, Ryo (Department of Physics, Graduate School of Science, The University of Tokyo); MOMIYAMA, Satoru (Department of Physics, University of Tokyo); Dr TAKEUCHI, Satoshi (Tokyo Institute of Technology); Dr NISHIMURA, Shunji (RIKEN Nishina Center); Dr ISOBE, Tadaaki (RIKEN); Dr YAMAMOTO, Tetsuya (RCNP); Dr MOTOBAYASHI, Tohru (RIKEN Nishina Center); Dr SUMIKAMA, Toshiyuki (RIKEN Nishina Center); Mr XU, Zhengyu (University of Tokyo); Dr ELEKES, Zoltan (MTA ATOMKI); Dr DOMBRADI, Zsolt (MTA ATOMKI); Mr VAJTA, Zsolt (MTA Atomki)

Presenter: Dr WANG, He (RIKEN Nishina Center)

Session Classification: Session 6

Contribution ID: **32** Type: **Oral contribution**

Mirror energy differences and neutron skin

Thursday, June 7, 2018 4:00 PM (18 minutes)

Isospin symmetry is one of the basic concepts in nuclear physics. One of its consequences is that the level scheme of mirror nuclei, i.e. nuclei with the same number of nucleons but interchanged number of protons and neutrons should be identical. The Coulomb excitation breaks this degeneracy to some extent. It is also known that at the strong interaction level, the symmetry is also broken and manifested in the difference in mass of protons and neutrons and in the nucleon-nucleon scattering phase shifts.
New developments in the study of the mirror energy differences in the sd shell suggest that these observables can give information on the nuclear skin as a function of excitation energy. The calculations are performed in the shell model framework using state-of-the-art charge-dependent nucleon-nucleon potentials.
In the presentation some new data together with the calculations will be shown and discussed.

Primary author: Prof. LENZI, Silvia M. (University of Padova and INFN)

Presenter: Prof. LENZI, Silvia M. (University of Padova and INFN)

Session Classification: Session 14

Contribution ID: **33** Type: **Oral contribution**

Study of multi-neutron system with (p,2p) reaction

Tetraneutron has been drawing the attention of nuclear physicists around the globe for decades. But no firm conclusion on its properties has been drawn despite many experimental and theoretical efforts. The multi-neutron systems, whether existing as bound or low-lying resonances, are of fundamental importance in nuclear physics. They provide the possibility to investigate "purely" the nuclear forces which is free from Coulomb interaction, and serve as the most stringent test of our knowledge of the nuclear force. The properties of the tetraneutron are also essentially important for our understanding of neutron-rich nuclear matter, neutron star, and the evolution of the universe.
We have carried out new measurements on the four-neutron system populated in the decay of 7H in 2017/July at RIBF, aiming to pin down the low-lying states of tetraneutron and to study the multi-neutron correlation. 7H was produced in the (p,2p) reaction on 8He with the vertex-tracking liquid hydrogen target MINOS. The recoil protons were tracked by the TPC of MINOS and then recorded by NaI scintillator array. The charged fragments were analyzed by the SAMURAI spectrometer, and the decay neutrons are detected by a combined setup of NEBULA and NeuLAND. A presentation of the preliminary data analysis, which is in progress, will be given.

Primary author: Dr YANG, Zaihong (RIKEN)

Presenter: Dr YANG, Zaihong (RIKEN)

Contribution ID: **34** Type: **Oral contribution**

Elastic scattering measurement for the 10Be+natPb reaction at above the Coulomb barrier energy

Wednesday, June 6, 2018 11:03 AM (18 minutes)

Recently, elastic scattering has been of great interest to study the information on the exotic structure and reaction mechanism of the weakly bound nuclei. In the last few years, some of the experimental and theoretical works have appeared for proton as well as neutron-rich nuclei at above and near barrier energies [1-3]. Interesting features have been discovered in the study of the elastic scattering induced by light radioactive ion beams. Strong Coulomb rainbow (Coulomb-nuclear interference peak) suppressions are found for neutron halo nuclei such as 11Be,11Li and 6He elastic scattering from heavy targets at energy near the Coulomb barrier. However, elastic scattering with proton halo nuclei does not reveal Coulomb rainbow suppressions showing small break-up coupling effects on elastic scattering at an energy about three times the Coulomb barrier. Under this scenario, a systematic study on elastic scattering at well above the Coulomb barrier energy is required to unfold the new observations in the reactions with near drip-line nuclei [4, 5]. In this context, we have measured elastic scattering at three times of the Coulomb barrier energy using 10Be projectile beam at Institute of Modern Physics, Lanzhou. The secondary beams of radioactive isotopes were produced by the fragmentation of (60 MeV/nucleon) 16O primary beam on a 3000 μm Be target and separated by Radioactive Ion Beam Line in Lanzhou (RIBLL). The scattered particles were detected by four sets of ΔE-E detector telescopes. A Monte Carlo simulation is performed to evaluate the absolute differential cross sections. Continuum Discretized Coupled Channels method will be followed to disentangle the Coulomb and Nuclear breakup coupling effects on the suppression of Coulomb Rainbow. The detailed observations made from the measured elastic scattering data along with the theoretical calculations using FRESCO will be presented in the conference.

Keywords: Elastic scattering, halo nuclei, Coulomb and Nuclear breakup coupling

References

[1]J. J. Kolata et al., Eur. Phys. J. A 52, 123 (2016).
[2]Y. Y. Yang, J. S. Wang, Q. wang et al., Nucl. Instrum. Methods Phys. Res. Sect. A 701, 1 (2013).
[3]A. G´omez Camacho et al., Nucl. Phys. A 833, 156 (2010).
[4]Y. Y. Yang, X. Liu, D. Y. Pang et al., Phys.Rev. C 94, 034614 (2016).
[5]Y. Y. Yang, J. S. Wang, Q. wang et al., Phys.Rev. C 90, 014606 (2014).

Primary author: Dr PATEL, D. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China)

Co-authors: Prof. SAXENA, Alok (Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai-400085, India); Prof. NAYAK, B.K. (Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai-400085, India); Ms DUAN, F. F. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr YU, G.M. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr MA, J. B. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Prof. WANG, J. S. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr MA, P. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr HU, Q. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr JIN, S. L. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Prof. MUKHERJEE, S. (Department of Physics, Faculty of Science, The M.S. University of Baroda, Vadodara 390 002, India); Dr MA, W.H. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr LIU, X. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr YANG, Y. Y. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr YU, Y.C. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr GUPTA, Y.K. (Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai-400085, India); BAI, Z. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China); Dr GAO, Z.H. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China)

Presenter: Dr PATEL, D. (Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, 730000, China)

Session Classification: Session 10

Contribution ID: **35** Type: **Poster Contribution**

cluster structure in 18O

Alpha particle clustering is an important concept in nuclear physics, and it has been used over the years to explain certain features in nuclei, especially for the study of light N = Z nuclei. It proved to be far more difficult to study clustering phenomena in non-self-conjugate N != Z nuclei because of the addition degrees of freedom from the extra nucleons. However, the extra nucleons may have important and special contribute to the formation of exotic, molecular-type structures, which provide an opportunity to understand the interplay between cluster and nucleon degrees of freedom. 18O is the prime example of a non-self-conjugate nucleus for which clustering is known to play an important role.
A new experiment has been carried out at CIAE in 2017 to investigate the cluster structures of 18O through the multi-nucleon transfer reaction 9Be(13C,14C+alpha)alpha at 13C beam energy of 65MeV. In this experiment, coincidence detection of the 14C and alpha breakup fragments from 18O was done by six sets of silicon detector telescopes. Owing to the extremely large positive reaction Q-value, the interested reaction channel has been identified clearly. Through the missing mass method and invariant mass method, excited states of 18O from 7MeV to ~20MeV were observed. At present, further analysis has been applying to such states to extract the spin and then to search the monopole transition in 18O.

Primary author: Dr YANG, Biao (Peking University)

Presenter: Dr YANG, Biao (Peking University)

Contribution ID: **36** Type: **Oral contribution**

Pairing collectivity in the ground state of Borromean nuclei and unbound 2n-systems: 22C and 26O

Thursday, June 7, 2018 9:54 AM (18 minutes)

In recent years, there has been rapidly increasing interest in the study of the Borromean nuclei sitting right on the top of neutron driplines and two-neutron decays of unbound systems beyond the neutron dripline. These systems demands a three-body description with proper treatment of continuum, the conventional shell-model assumptions being insufficient. Very recently a high precision measurement of interaction cross-section for 22C was made on a carbon target at 235 MeV/nucleon [1] and also the unbound nucleus 26O has been investigated, using invariant-mass spectroscopy [2] at RIKEN Radioactive Isotope Beam Factory. These high precision measurements, are the motivation for selecting these systems for the present study. We have studied the pairing collectivity in the ground state of Borromean nuclei 22C and in the 2n- unbound system 26O. For this study we have used our recently implemented 3 - body (core+n+n) structure model for ground and continuum states of the Borromean nuclei [3, 4].

We will present the ground state properties of 22C and 26O systems and transitions to the continuum that might be of help in disentangling the still poorly known low-energy resonances and predicting new resonances of these nuclei. We compare our findings with the more recent experimental works and the scarce theoretical work that has been done in the recent past on these systems.

The neutron single-particle unbound spdf- continuum states of the 21C and 25O system are calculated in a simple shell model picture for different continuum energy cut-off's of 5, 10 and 15 MeV by using a Dirac delta normalization and are checked with a more refined phase-shift analysis. The sensitivity of the (core+n) potential has been explored for the emergence of different dominant configurations in the ground state of 22C and 26O. After fixing convergence with the continuum energy cuts and bining size, a reasonable energy cut of 5 MeV and bin size of 0.1 MeV is used for present study. These (core+n) continuum wavefunctions are used to construct the two-particle 22C and 26O states by proper angular momentum couplings and taking contribution
from different configurations. We have explored the role of different pairing interactions such as density independent (DI) contact-delta pairing interaction and density dependent (DD) contact-delta pairing interaction in the structure of these systems. We have shown how the ground state displays a collective nature, taking contribution from many different oscillating continuum states that coherently sum up to give an exponentially decaying bound wavefunction in 22C and an oscillating unbound wavefunction in case of 26O.

[1] Y. Togano et al., Phys. Lett. B761, 412-418 (2016).
[2] Y. Kondo et al., Phys. Rev. Lett. 116, 102503 (2016).
[3] L.Fortunato, R.Chatterjee, Jagjit Singh and A.Vitturi, Phys. Rev. 90, 064301 (2014).
[4] Jagjit Singh, L.Fortunato, A.Vitturi and R.Chatterjee, Eur. Phys. J. A 52 209 (2016).

Primary author: Dr SINGH, JAGJIT (Nuclear Reaction Data Center, Faculty of Science, Hokkaido University, Sapporo 060-0810, Japan)

Co-authors: Prof. VITTURI, Andrea (Dipartimento di Fisica e Astronomia "G.Galilei", and INFN-Sezione di Padova, via Marzolo 8, I-35131 Padova, Italy); Dr FORTUNATO, Lorenzo (Dipartimento di Fisica e Astronomia "G.Galilei", and INFN-Sezione di Padova, via Marzolo 8, I-35131 Padova, Italy); Dr HORIUCHI, Wataru (Department of Physics, Hokkaido University, Sapporo 060-0810, Japan)

Presenter: Dr SINGH, JAGJIT (Nuclear Reaction Data Center, Faculty of Science, Hokkaido University, Sapporo 060-0810, Japan)

Session Classification: Session 11

Contribution ID: **37** Type: **Poster Contribution**

Theoretical Study of Heavy-ion Charge Exchange Reaction at Intermediate Energies With Eikonal Model

Heavy-ion charge exchange reactions at intermediate energies have drawn much attention because they have great advantages for determination of spin-isospin strength with better resolution and selectivity than that with nucleon probes such as (p,n) reaction. Such reactions could be used to extract values of GT strengh which is important for electron capture and beta-decay rates, and electron capture results in the deleptonization of the Steller environment. With the development of new facilities, accelerators, and detectors, there are more and more experimental studies of heavy-ion charge exchange reactions. However, in spite of the advantages of heavy-ion charge exchange reaction at intermediate energies, the reaction mechanisms for heavy ion induced charge exchange reactions are more complicated than that for (p,n) or (n,p) reactions. Now, based on Eikonal approximation, a newly developed theoretical instrument could give some results, and the results have been compared with that predicated by FOLD which has been developed based on DWBA.

Primary author: Ms LI, Jingjing (Peking University)

Presenter: Ms LI, Jingjing (Peking University)

Contribution ID: **38** Type: **Oral contribution**

Pygmy dipole states in deformed nuclei

Thursday, June 7, 2018 4:18 PM (18 minutes)

In the last years special attention has been devoted to the study of the dipole strength at low excitation energy in neutron-rich nuclei, the so called Pygmy Dipole Resonance (PDR). This mode carries few per cent of the isovector EWSR, and it is present in many stable and unstable isotopes with a consistent neutron excess.
It is possible to study these low lying dipole states by using an isoscalar probe in addition to the conventional isovector one due to the fact that their transition densities show a strong mixing of their isoscalar and isovector components. Indeed, the combined use of real and virtual phonons and experiments employing (α,α γ) as well as (17O, 17O'γ), for the investigation of the PDR states has unveiled a new feature of these states. Namely, the peak of these low-lying dipole states can be separated in two parts: the part lying at low energy is excited by both the isoscalar and isovector interactions while the high energy part is populated only by the electromagnetic probes.
Recently, the interest has moved on deformed nuclei. In these nuclei the Giant Dipole Resonance (GDR) peak is separated in two parts. Each of them corresponds, in the hydro-dynamical model, to an out-of-phase oscillation of neutron against pro- tons along the symmetry and its perpendicular axes. These modes are characterized by two quantum number K = 0− and K = 1− that give rise to two separated bands in the laboratory frame. If it is true that the pygmy states are generated by the out-of-phase oscillation of the neutron excess against a proton plus neutron core, then the same mechanism producing the splitting of the GDR should be valid also for the low lying dipole states. Therefore one should expect as well to observe a separation of the pygmy dipole peak in two bumps.
Calculations done within a simple macroscopic model show that the transition densities of the low lying dipole states have the same typical behaviour of the non- deformed nuclei namely a strong isoscalar-isovector mixing at the nuclear surface. These results are corroborated by some microscopic calculations performed by using a relativistic Hartee-Bogoliubov mean field plus a relativistic quasi-particle random phase approximation.
Therefore a suitable way to investigate the pygmy states in deformed prolate nuclei is through the use of isoscalar probes. Measurement of the pygmy dipole states excitations along an isotope chain with increasing deformation may enlighten and give new perspectives about these novel excitation modes.

Primary author: Dr LANZA, Edoardo G. (INFN - Sezione di Catania)

Presenter: Dr LANZA, Edoardo G. (INFN - Sezione di Catania)

Session Classification: Session 14

Contribution ID: **39** Type: **Oral contribution**

Halo-induced large enhancement of soft dipole excitation of 11Li observed via proton inelastic scattering

Friday, June 8, 2018 1:30 PM (18 minutes)

Proton inelastic scattering off a neutron halo nucleus, 11Li, has been studied in inverse kinematics at the IRIS facility at TRIUMF. The aim was to establish a soft dipole resonance and to obtain its dipole strength. Using a high quality 66 MeV 11Li beam, a strongly populated excited state in 11Li was observed at Ex=0.80 ± 0.02 MeV with a width of Γ = 1.15 ± 0.06 MeV. A DWBA (distorted-wave Born approximation) analysis of the measured differential cross section with isoscalar macroscopic form factors leads us to conclude that this observed state is excited in an electric dipole (E1) transition. Under the assumption of isoscalar E1 transitions, the strength is evaluated to be extremely large amounting to 30~296 Weisskopf units, exhausting 2.2%~21% of the isoscalar E1 energy-weighted sum rule (EWSR) value. The large observed strength originates from the halo and is consistent with the simple di-neutron model of 11Li halo.

Primary author: Dr TANAKA, Junki (TU Darmstadt)

Co-authors: DIAZ VARELA, Alejandra (University of Guelph); SANETULAEV, Alisher (Saint Mary's University); DAVIDS, Barry (TRIUMF); BURBADGE, Christina (University of Guelph); PADILLA RODAL, Elizabeth (TRIUMF/UNAM); HACKMAN, Greg (TRIUMF); BIDAMAN, Harris (University of Guelph); TANIHATA, Isao (IRCNPC/RCNP); HENDERSON, Jack (TRIUMF); RANDHAWA, Jaspreet singh (Saint Mary's University / TRIUMF); SMITH, Jenna K (TRIUMF); LIGHTHALL, Jon (TRIUMF); EVEN, Julia (KVI-CART); RITUPARNA, Kanungo (Saint Mary's University / TRIUMF); LEACH, Kyle G. (TRIUMF); ALCORTA, Martin (TRIUMF); KEEFE, Matthew (Saint Mary's University); HARAKEH, Mushin N. (KVI-CART); AOI, Nori (RCNP); WORKMAN, Orry (Saint Mary's University); RUOTSALAINEN, Panu (TRIUMF); KRÜCKEN, Reiner (TRIUMF); KAUR, Satbir (Saint Mary's University / Dalhousie University); ISHIMOTO, Shigeru (KEK); CRUZ, Steffen (TRIUMF)

Presenter: Dr TANAKA, Junki (TU Darmstadt)

Session Classification: Session 17

Contribution ID: **40** Type: **Oral contribution**

Benchmarking reaction theories for nucleon knockout reactions

Wednesday, June 6, 2018 9:18 AM (18 minutes)

Recently, proton-induced nucleon knockout reactions, (p,pN), have been utilized for the nucleon spectroscopy of nuclei, for unstable nuclei in the inverse kinematics in particular. In this study the benchmarking of the three reaction theories for describing the (p,pN) reaction has been done. The momentum distributions calculated with the distorted wave impulse approximation (DWIA) and the transfer-to-the-continuum model (TC) for the 15C(p,pn)14C reaction at 420 MeV/u have been compared with the already published results of the Faddeev/AGS (FAGS) method. The same inputs are adopted to three reaction calculations as much as possible.
As a result, a very good agreement has been found between DWIA, TC and FAGS. Within the DWIA framework, the energy dependence of the distorting potentials, which is difficult to be taken into account in the TC and FAGS frameworks, is found to affect in a modest way on the shape and magnitude of the momentum distributions. However, it is found that the inclusion of relativistic corrections increases the knockout cross section by about 30%, which shows the importance of that treatment for deducing the spectroscopic information from the (p, pN) cross sections.

Primary author: Mr YOSHIDA, Kazuki (RCNP, Osaka University)

Co-authors: Prof. MORO, Antonio (Universidad de Sevilla); Prof. OGATA, Kazuyuki (RCNP, Osaka University); Mr GÓMEZ RAMOS, Mario (Universidad de Sevilla)

Presenter: Mr YOSHIDA, Kazuki (RCNP, Osaka University)

Session Classification: Session 9

Contribution ID: **41** Type: **Oral contribution**

RI-beam-induced charge-exchange reaction studies combined with gamma-ray spectroscopy

Tuesday, June 5, 2018 9:54 AM (18 minutes)

Charge-exchange reactions at intermediate beam energies have been a powerful tool for studying spin-isospin responses of nuclei. They become even more powerful when rare isotope beams are utilized or when combined with gamma-ray spectroscopy, as they gain new spin-isospin selectivities that are not possible with conventional reaction probes, or allow for pinning down specific excitations with precise energy determination. They are useful in particular for studying giant resonances and a variety of other astrophysical phenomena such as stellar electron captures. In this presentation, I will discuss some of these instances including our recent results on rare-isotope-beam-induced charge-exchange reactions including (12N,12C), (10Be,10B), and (t,3He) experiments performed at RIBF/RIKEN and NSCL/MSU.

Primary author: Dr NOJI, Shumpei (NSCL/MSU)

Presenter: Dr NOJI, Shumpei (NSCL/MSU)

Session Classification: Session 5

Contribution ID: **42** Type: **Poster Contribution**

Investigation on alpha clustering via knockout reaction

The alpha clustering has been one of the main interest in nuclear physics. In order to probe the alpha clustering through reaction observables, the proton-induced alpha knockout reaction, (p,p alpha), is considered in this study. The purpose of this work is to reveal how the alpha cluster amplitude is probed through the (p,p alpha) reactions.
Within the distorted wave impulse approximation (DWIA) framework, We have newly introduced the "masking function" which defines the probed region of the alpha cluster amplitude through the (p,p alpha) reactions. It has been clearly shown by means of the masking function that the alpha knockout reaction probes the alpha cluster in the nuclear surface, which will be the direct measure of well-developed alpha cluster states. A simplified form of the masking function is also introduced and the incident energy dependence of the masking effect is investigated.
As a conclusion, alpha knockout reaction can be the probe for the alpha cluster amplitude in the nuclear surface owing to the masking effect originated from the absorption of distorting potentials, and is a suitable method to investigate how alpha cluster states are spatially developed.

Primary author: Mr YOSHIDA, Kazuki (RCNP, Osaka University)

Co-authors: Prof. OGATA, Kazuyuki (RCNP, Osaka University); Prof. KANADA-EN'YO, Yoshiko (Kyoto University)

Presenter: Mr YOSHIDA, Kazuki (RCNP, Osaka University)

Contribution ID: **43** Type: **Oral contribution**

Experimental study of the single-particle strength in 22F and 11Be using transfer reactions

A single-nucleon transfer reaction is a powerful experimental tool to probe the energies of shell-model orbitals and to study the changes in the energies of these orbitals away from the stable nuclei. In this light, 21F (d,p) 22F and 12B(d,3He)11Be measurements were carried out at the Argonne National Laboratory ATLAS In-Flight Facility. The HELIcal Orbit Spectrometer (HELIOS) was used to analyze outgoing protons and 3He particles.
Neutron configurations of the low-lying states in 22F have been determined using the neutron adding (d, p) reaction on a radioactive beam of 21F at 10A MeV. Five previously observed states in 22F were populated, showing a 0d5/2 or 1s1/2 neutron coupled to the 21F ground state. A large amount of strength with a configuration of 0d3/2 neutron coupled to 21F ground state was also observed. Spectroscopic factors and strengths determined from a DWBA analysis using a reasonable normalization, are reasonably well reproduced by shell-model calculations using the USDA/USDB interactions while calculation using USD interaction underestimates the 0d3/2 single particle energy. This reinforces the need to increase 0d3/2 single-particle energy in the USD interaction in order to reproduce the Z = 8 drip line. Estimates of the N = 14 shell gap and a lower limit of the N = 16 shell gap could also be deduced in 22F. Diagonal (0d5/2)2 two-body matrix elements were obtained using Pandya transformation and the particle-hole excitation energies from the present work. Furthermore, the monopole component of the (0d5/2)2 two body interaction was deduced and comparison was made with previous work.
The proton-removal reaction on a radioactive beam of 12B at 12A MeV has been carried out to determine the 0p-orbital strength in 11Be, a one-neutron-halo nucleus. Considering the very pure p-wave ground state of 12B, the 12B(d,3He) 11Be reaction is a highly selective for the p-wave strength. This strength is inverted with respect to the sd-shell strength predicted by the conventional independent particle model. Resulting spectroscopic factors and strengths determined using a DWBA analysis will be discussed.

Primary author: Dr CHEN, jie (Argonne national laboratory)

Co-authors: Dr ROGERS, Andy (University of Massachusetts Lowell); Dr KAY, Ben (Argonne National Laboratory); Dr BACK, Birger (Argonne National Laboratory,); Dr HOFFMAN, Calem (Argonne National Laboratory); Dr BARDAYAN, Dan (University of Notre Dame); Mr MCNEEL, Daniel (University of Connecticut); Dr GORELOV, Dimitry (University of Winnipeg,Argonne National Laboratory); Dr BLANKSTEIN, Drew (University of Notre Dame); Mr ZANG, Hongliang (Peking University); Dr WINKLEBAUER, Jack (Argonne National Laboratory, Los Alamos National Lab); Dr ALLEN, Jacob (University of Notre Dame); Dr SETHI, Jasmine (University of Maryland,Argonne National Laboratory); Dr LAI, Jianping (Argonne National Laboratory); Dr WU, Jin (Argonne National Laboratory); Dr SCHIFFER, John (Argonne National Laboratory); Dr AURANEN, Kalle (Argonne National Laboratory); Mr QIANG, Liu (Peking University); Dr AVILA, Melina (Argonne National Laboratory); Dr COPP, Patrick (University of Massachusetts Lowell); Dr O'MALLEY, Patrick (University of Notre Dame); Dr TALWAR, Rashi (Argonne National Laboratory,); Dr DANIEL, Santiago (Argonne National Labrotary); Dr KUVIN, Sean (University of Connecticut,Argonne National Laboratory,); Prof. AHN, Tan (University of Notre Dame); Dr GAMMA, Wilson (Louisiana State University,Argonne National Laboratory,)

Presenter: Dr CHEN, jie (Argonne national laboratory)

Contribution ID: **44** Type: **Oral contribution**

Spectroscopic Factors in the Islands of Inversion à la Nilsson *

Tuesday, June 5, 2018 9:00 AM (18 minutes)

Guided by the formalism developed for studies of single-nucleon transfer reactions in deformed nuclei [1], we have analyzed spectroscopic factors data in the Islands of Inversion at N=8 and 20, in the rotational strong-coupling limit.

Based on the fact that intruder deformed configurations dominate the low-lying structure of nuclei within the Islands of Inversion, the Nilsson formalism provides an intuitive and simple approach to obtain important structure information from direct reactions, and a complementary view to shell model calculations.

We will present results for 10,11,12Be and 32,33Mg [2,3], showing good agreement with the experimental data, and discuss some predictions for other regions.

- This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract no DE-AC02-05CH11231.

[1] B. Elbek and P. Tjom, Advances in Nucl. Phys. Vol 3, 259 (1969).
[2] A. O. Macchiavelli, et al. Phys. Rev. C97, 011302 (R) (2018).
[3] A. O. Macchiavelli, et al. Phys. Rev. C96, 054302 (2018).

Primary authors: MACCHIAVELLI, Augusto (Lawrence Berkeley National Laboratory); CRAWFORD, Heather (Lawrence Berkeley National Laboratory); FALLON, Paul (Lawrence Berkeley Laboratory)

Co-authors: RICHARD, Andrea (Ohio University); CAMPBELL, Chris (Lawrence Berkeley National Laboratory); LEE, I-Yang (Lawrence Berkeley National Laboratory); SALATHE, Marco (Lawrence Berkeley National Laboratory); CROMAZ, Mario (Lawrence Berkeley National Laboratory); JONES, Michael (Lawrence Berkeley National Laboratory); CLARK, Roderick (Lawrence Berkeley National Laboratory)

Presenter: MACCHIAVELLI, Augusto (Lawrence Berkeley National Laboratory)

Session Classification: Session 5

Contribution ID: **45** Type: **Poster Contribution**

A Particle-Rotor Model Description of 29F *

Recent results from RIKEN/RIBF on the low-lying level structure of 29F, and state of the art Shell Model calculations using the SDPF-M effective interaction [1], suggest the extension of the N=20 Island of Inversion to the Z=9 Fluorine isotopes.

In this work we discuss the low-lying excitation spectrum of 29F in terms of a collective picture [2], with a level structure corresponding to the rotation-aligned coupling limit of the Particle Rotor Model (PRM) [3].

The Coriolis coupling effects on the proton d5/2 Nilsson multiplet give rise to a (favored) decoupled band, with its 5/2+ bandhead naturally emerging as the ground state. The first excited state corresponds to the anti-aligned 1/2+ configuration at an energy that depends directly on the core E(2+).
We find a consistent solution at a deformation of ε ~ 0.17, corresponding to an excitation energy of the 2+ in 28O at ~2.4 MeV, in line with the conclusions reached in Ref. [1].

PRM predictions for some spectroscopic observables will also be presented and discussed in the context of a Coulomb Excitation experiment approved at RIKEN [4]. If similar energetics and coupling conditions persist, a πd5/2 x νf7/2 double-decoupled structure in 30F is predicted with a 6- ground state.

- This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract no DE-AC02-05CH11231.

[1] P. Doornenbal, et al., Phys. Rev. C95, 041301(R) (2017).
[2] A. O. Macchiavelli, et al., Phys. Lett. B775, 160 (2017).
[3] F. S. Stephens, Rev. Mod. Physics , 47, 43 (1975).
[4] H. L. Crawford, et al., RIBF164 proposal (2017).

Primary authors: MACCHIAVELLI, Augusto (Lawrence Berkeley National Laboratory); CRAWFORD, Heather (Lawrence Berkeley National Laboratory); FALLON, Paul (Lawrence Berkeley Laboratory)

Co-authors: CAMPBELL, Chris (Lawrence Berkeley National Laboratory); LEE, I-Yang (Lawrence Berkeley National Laboratory); SALATHE, Marco (Lawrence Berkeley National Laboratory); CROMAZ, Mario (Lawrence Berkeley National Laboratory); JONES, Michael (Lawrence Berkeley National Laboratory); CLARK, Roderick (Lawrence Berkeley National Laboratory)

Presenter: FALLON, Paul (Lawrence Berkeley Laboratory)

Contribution ID: **46** Type: **Oral contribution**

Single-particle structure of ^{93,94,95}Sr nuclei

Monday, June 4, 2018 11:21 AM (18 minutes)

The level structure of neutron rich ^{93,94,95}Sr were studied via the \dtsr{94,95,96}, one neutron pickup reactions at TRIUMF. Excited states were populated when ^{94,95,96}Sr beams of 5.5 AMeV bombarded a 0.5 mg/cm^2 CD_2 target. The de-exciting γ-rays and outgoing charged particles were detected by using the TIGRESS and SHARC arrays, respectively. The level scheme was contructed by using both E_x vs E_γ and E_γ vs E_γ matrices. Three excited states were observed in ^{93}Sr and ^{95}Sr, respectively. A total of ten excited states were observed in ^{94}Sr of which four states were newly identified in the present experiment. Angular distribution measurements suggest spin and parity assignments for the 1880 (0^+), 2294 (0^+) and 2415 (3^+) keV levels and constrain the other five levels 2615, 2705, 2921, 3077 and 3175 keV in ^{94}Sr. In this work no γ-ray transitions were observed from the 1880 and 2294 keV levels directly to the ground state. This is consistent with spin and parity assignments of the 1880 and 2294 keV levels as 0^+. The spectroscopic factors were calculated by fitting DWBA calculations to experimental angular distribution data and taking into consideration γ-decay branching ratios. Shell model calculations were carried out to understand the present experimental observations by using updated interaction and appropriate truncation schemes. The calculation was performed by using an updated NuShellX code and $glek$ interaction. The single-particle energies of the interaction were adjusted in such a way that the calculated and experimentally observed energy levels were in good agreement in the $N \sim 56$ and $Z \sim 38$ region. In the present calculations the valence $[1d_{5/2}]$, $[2s_{1/2}]$, $[1d_{3/2}]$ and $[0g_{7/2}]$ orbitals were included for neutrons outside the $N = 50$ inert core. The proton degrees of freedom were varied systematically so that the effect of the proton valence space on the calculated levels could be studied. The calculated energy levels and spectroscopic factors that were predicted are in reasonable agreement with the experimental findings. This suggests that the low-energy states are predominantly neutron configurations with minor contributions from excitations between the proton $[1p_{3/2}]$ and $[1p_{1/2}]$ orbitals.

Primary author: Dr SOUMENDU SEKHAR BHATTACHARJEE, Soumendu (Post Doctoral Fellow at TIGRESS)

Co-authors: GARNSWORTHY, A. B. (TRIUMF, Vancouver, BC V6T 2A3, Canada); CHEESEMAN, A. (TRIUMF, Vancouver, BC V6T 2A3, Canada); CHESTER, A. (TRIUMF, Vancouver, BC V6T 2A3, Canada); KNAPTON, A. (Department of Physics, University of Surrey, Guildford, Surrey, GU2 7XH, United Kingdom); MATTA, A. (LPC, ENSICAEN, CNRS/IN2P3, UNICAEN, Normandie Universit\'{e}, 14050 Caen cedex, France); SANETULLAEV, A. (TRIUMF, Vancouver, BC V6T 2A3, Canada); DIGET, C. Aa. (Department of Physics, University of York, York, YO10 5DD, United Kingdom); ANDREOIU, C. (Department of Chemistry, Simon Fraser University, Burnaby, BC V5A 1S6, Canada); SVENSSON, C. E. (Department of Physics, University of Guelph, Guelph, ON, N1G 2W1, Canada); BANCROFT, C. S. (Department of Physics, Central Michigan University, Mt Pleasant, MI 48859, USA); UNSWORTH, C. (TRIUMF, Vancouver, BC V6T 2A3, Canada); MILLER, D. (TRIUMF, Vancouver, BC V6T 2A3, Canada); CROSS, D. S. (Department of Chemistry, Simon Fraser University, Burnaby, BC V5A 1S6, Canada); AMES, F. (TRIUMF, Vancouver, BC V6T 2A3, Canada); HACKMAN, G. (TRIUMF, Vancouver, BC V6T 2A3, Canada); LASSEN, J. (TRIUMF, Vancouver, BC V6T 2A3, Canada); KUHN, K. (Department of Physics, Colorado School of Mines, Golden, CO 80401, USA); WIMMER, K. (Department of Physics, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan); MARCHETTO, M. (TRIUMF, Vancouver, BC V6T 2A3, Canada); MOUKADDAM, M. (TRIUMF, Vancouver, BC V6T 2A3, Canada); ORR, N. A. (LPC, ENSICAEN, CNRS/IN2P3, UNICAEN, Normandie Universit\'{e}, 14050 Caen cedex, France); SACHMPAZIDI, N. (Department of Physics, Central Michigan University, Mt Pleasant, MI 48859, USA); TERPSTRA, N. (Department of Physics, Central Michigan University, Mt Pleasant, MI 48859, USA); BENDER, P. C. (TRIUMF, Vancouver, BC V6T 2A3, Canada); VOSS, P. (Department of Chemistry, Simon Fraser University, Burnaby, BC V5A 1S6, Canada); BRAID, R. (Department of Physics, Colorado School of Mines, Golden, CO 80401, USA); KANUNGO, R. (Department of Astronomy and Physics, Saint Mary' s University, Halifax, NS B3H 3C2, Canada); KR\"{U}CKEN, R. (TRIUMF, Vancouver, BC V6T 2A3, Canada); LAXDAL, R. (TRIUMF, Vancouver, BC V6T 2A3, Canada); CRUZ, S. (TRIUMF, Vancouver, BC V6T 2A3, Canada); BRUHN, T. (TRIUMF, Vancouver, BC V6T 2A3, Canada); DRAKE, T. (Department of Physics, University of Toronto, Toronto, ON M5S 1A7, Canada); KORTEN, W. (IRFU, CEA, Universit\'{e} Paris-Saclay, F-91191 Gif-sur-Yvette, France); CATFORD, W. N. (Department of Physics, University of Surrey, Guildford, Surrey, GU2 7XH, United Kingdom)

Presenter: Dr SOUMENDU SEKHAR BHATTACHARJEE, Soumendu (Post Doctoral Fellow at TIGRESS)

Session Classification: Session 2

Contribution ID: **47** Type: **Oral contribution**

Study of the unbound nuclei 27O and 28O using proton removal reactions

Thursday, June 7, 2018 10:12 AM (18 minutes)

The sudden change of the neutron dripline from 24O (N=16) to 31F (N=22), called oxygen anomaly, is one of the exotic phenomena. Recent theoretical studies suggest importance of three nucleon forces on the binding energies of the oxygen isotopes, especially for N>16, while available experimental data are limited because the measurement requires production of extremely neutron rich nuclei.
The region of the oxygen anomaly is also interesting in terms of the shell evolution. It is well known that the shell closure of the N=20 nuclei disappears in the island of inversion. Recent in-beam gamma-ray spectroscopy suggests that the N=20 shell gap is quenched at 29F. The experimental study of 28O is strongly desired to clarify the shell evolution along N=20 isotonic chain down to Z=8.

The SAMURAI21 collaboration studied 27O and 28O with SAMURAI spectrometer at RIKEN-RIBF. These unbound nuclei are produced by two- and one-proton removal reaction on a liquid hydrogen target from 29Ne and 29F, respectively. Decay products, 24O and neutrons, are detected in coincidence to reconstruct the invariant mass of the 27O and 28O. The experimental results will be discussed in the presentation.

Primary author: Dr KONDO, Yosuke (Tokyo Institute of Technology)

Presenter: Dr KONDO, Yosuke (Tokyo Institute of Technology)

Session Classification: Session 11

Contribution ID: **48** Type: **Poster Contribution**

Elastic scattering measurement for the proton dripline nucleus 9C at above the Coulomb barrier energy

The proton dripline nucleus 9C, with a small two-proton separation energy of 1.43 MeV, can be considered as a two-proton halo candidate. Special attention has been recently devoted to the experimental and theoretical studies of the exotic nature of 9C [1-4]. Elastic scattering angular distributions of proton drip-line isotones 9C impinging on lead target have been measured for the first time at energies around three times of Coulomb barriers. The experiment was performed at the National Laboratory of Heavy Ion Research of the Institute of Modern Physics, Lanzhou, China. The secondary beams of radioactive isotopes were produced by the fragmentation of the 12C primary beam on a 9Be target with a thickness of 2652 m using Heavy Ion Research Facility of Lanzhou (HIRFL). The secondary, 7Be, 8B and 9C beams were separated by their magnetic rigidity and delivered by the Radioactive Ion Beam Line in Lanzhou (RIBLL). The elastic scattering events were detected using two sets of ΔE-E silicon telescopes, which consisted of a double-sided silicon strip detector (DSSD, 48 strips in 1 mm width each including a 0.1mm interval) with a thickness of 150 μm and a large surface silicon detector (SD) with a thickness of 1500 μm. The obtained elastic scattering cross sections have been normalized with the Rutherford cross sections and the resultant angular distributions have been reproduced reasonably well by the optical model calculations with the systematic nucleus-nucleus potential. In the present work, it has been observed that proton-rich nuclei 9C and 8B, do not show reduction in the elastic scattering cross sections in comparison to that of neutron rich nuclei at the present bombarding energy of measurement. Similar observation also has been made in previous experimental results for proton halo nucleus 8B, showing tiny influence from the breakup coupling [5]. This fact could be interpreted as due to the valence protons in these nuclei where the Coulomb and centrifugal barriers (if any) counteract the breakup coupling effects and the result is the absence of the Coulomb rainbow suppression for proton-rich nuclei such as 9C and 8B, in contrast to the cases of neutron-rich nuclei. Further, to elucidate the breakup coupling effects on the elastic scattering of 9C, Continuum Discretized Coupled Channels (CDCC) calculations have been performed and results have been compared with those of 8B. In the present calculations, 9C is assumed to have 8B+p and 7Be+2p configurations. The results from these two different configurations are consistent and reproduce the experimental data within the error bars, suggesting that the elastic scattering data are not sensitive to the assumed cluster structure of 9C.

References:

[1] B. Blank et al., Nucl. Phys. A 624, 242 (1997).
[2] J. Enders et al., Phys. Rev. C 67, 064301 (2003).
[3] R. E. Warner et al., Phys. Rev. C 69, 024612 (2004).
[4] T. Fukui et al., Phys. Rev. C 86, 022801 (2012)(R).
[5] Y.Y.Yang et al., Phys. Rev. C 87, 044613 (2013).

Primary author: Dr YANG, Yanyun (Institute of Modern Physics, CAS, China)

Co-authors: Mrs DUAN, Fangfang (Institute of Modern Physics, CAS, China); Prof. WANG, Jiansong (Institute of Modern Physics, CAS, China); Dr PATEL, PATEL DIPIKABEN BALDEVBHAI (Institute of Modern Physics, CAS, China); Mr MA, Peng (Institute of Modern Physics, CAS, China); Dr LIU, Xingquan (Institute of Modern Physics, CAS, China); Mr GAO, Zhihao (Institute of Modern Physics, CAS, China)

Presenter: Dr YANG, Yanyun (Institute of Modern Physics, CAS, China)

Contribution ID: **49** Type: **Poster Contribution**

S-matrix analysis of pairing correlation effects on low-energy s-wave scattering in neutron-rich nuclei

Effects of pairing correlation on s-wave scattering in superfluid nuclei are discussed. In the s-wave, single-particle potential resonance cannot be formed due to no potential barrier, whereas quasi-particle resonance can be formed by the pairing correlation. The quasi-particle resonance is a novel resonance in superfluid nuclei which is predicted by the Hartree-Fock-Bogoliubov (HFB) theory.
In recent progress of the SAMURAI experiments in RIKEN, characteristic s-wave peaks are observed in invariant mass spectroscopy of 21C. We anticipate that the s-wave peaks can be the s-wave quasi-particle resonance.
We analyze in detail how the low-lying s-wave quasi-particle resonance is governed by the pairing correlation in neutron drip-line nuclei. Solving the HFB equation in coordinate space with the scattering boundary condition, we calculate the phase shift, the elastic cross section, and the S-matrix. We find that the pairing correlation influence strongly the phase shift and the elastic cross section, in addition, four poles of S-matrix emerge by the pairing correlation. As a numerical example, we consider the 20C+n(s1/2) system to discuss the low-lying s-wave quasiparticle resonance.
In this presentation, we explain, using the S-matrix analysis, how the s-wave resonance caused by the pairing correlation (the s-wave quasi-particle resonance) emerge in neutron drip-line nuclei.

Primary author: Dr KOBAYASHI, Yoshihiko (Faculty of Arts and Science, Kyushu University)

Co-author: Prof. MATSUO, Masayuki (Department of Physics, Niigata University)

Presenter: Dr KOBAYASHI, Yoshihiko (Faculty of Arts and Science, Kyushu University)

Contribution ID: **50** Type: **Poster Contribution**

Recent advances and current status of chiral nuclear forces

During the past two decades, chiral effective field theory has evolved into a powerful tool to derive nuclear two- and many-body forces in a systematic and model-independent way. Nowadays, most ab initio calculations of nuclear structure and reactions (including, in particular, exotic nuclei) are conducted with chiral forces. Therefore, it is of interest to have an overview of the status in the field. Thus, after providing some background, I will summarize the state of the art in the construction of high-quality chiral two-nucleon forces. Furthermore, I will also elaborate on the derivation and application of chiral three-nucleon forces, indispensible for any meaningful microscopic calculation.

Primary author: MACHLEIDT, Ruprecht (University of Idaho)

Presenter: MACHLEIDT, Ruprecht (University of Idaho)

Contribution ID: **51** Type: **Poster Contribution**

The neutron magic number 28 and the structure in neutron-rich nuclei

The magic number 28 appears in the pf shell because of the spin-orbit interaction. However, in some $N \approx 28$ neutron-rich nuclei, the neutron magic number 28 disappears. This leads to the quadrupole deformation of the ground state, the reduction of the excited energies and so on. In what region of the nuclear chart, does the magic number disappear? This is one of the interesting problems. In particular, in $N = 26$ isotones which have less neutrons than closed nuclei, does the effect appear in the low-lying energy spectra? Then, we apply the antisymmetrized molecular dynamics (AMD) combined with the generator coordinate method (GCM), and study the structure of $N = 26$ isotones.

As a result, we found that 44Ar and 40Si have triaxially deformed shape, and 42S has prolate-deformed shape at the ground states. In addition, we found that several 2^+ states appear at low energies in these nuclei. It suggests that they are unstable against the deformation parameter γ.

Furthermore, we found that the rotational bands appear on the low-lying excited 0^+ states in 44Ar and 40Si. In these bands, 44Ar has prolate-deformed shape and 40Si has oblate-deformed shape. As a result of the analysis of the single particles, we found that around 40% of last neutrons occupy the p orbits in the oblate-deformed states of 40Si.
It suggests the reduction of the energy gap in the neutron magic number 28.

Primary author: SUZUKI, Yoshiki (Hokkaido Univ.)

Co-author: Dr KIMURA, Masaaki (Hokkaido University)

Presenter: SUZUKI, Yoshiki (Hokkaido Univ.)

Contribution ID: **52** Type: **Poster Contribution**

Decay mode of the linear-chain states in C isotopes

Recent years have seen many important experimental studies for the linear-chain states (linearly aligned 3α particles) in 14C and 16C.
These new data motivated us to perform an analysis and to summarize the calculated and observed properties of the linear-chain bands in carbone isotopes.
In this presentation, the linear-chain states of 14C and 16C and their decay modes are theoretically investigated by using the antisymmetrized molecular dynamics. It is found that the positive-parity linear-chain states have the molecular orbit configuration and primary decay to the 10,12Be(2+ 1) as well as to the 12Be(g.s.) by the α particle emission.
Moreover, we show that they also have 6He decay widths.
Their α and 6He reduced widths are sufficiently large to be distinguished from other non-cluster states.

Primary author: Mr BABA, Tomoyuki (Hokkaido University)

Co-author: Dr KIMURA, Masaaki (Hokkaido University)

Presenter: Mr BABA, Tomoyuki (Hokkaido University)

Contribution ID: **53** Type: **Poster Contribution**

Effect of Tensor Force on Proton Shell Evolution in the "SouthWest" of 132Sn: Low-Lying -emitting Isomers in 123,125Ag

The beta-delayed gamma-ray spectroscopy of 123,125Pd are investigated at the Radioactive Isotope Beam Factory of the RIKEN Nishina Center. Neutron-rich nuclei 123,125Pd are produced by in-flight fission of the 238U beam at 345 MeV/nucleon. The 1/2− low-lying beta-emitting isomers in 123,125Ag and gamma transitions feeding into the isomers are constructed for the first time and the results are compared to large-scale shell-model calculations using the state-of-the-art EPQQM effective interaction. The effects of the monopole interaction on the proton shell evolution in the "southwest"of 132Sn are discussed in terms of Vmu interaction.

Primary author: Dr LI, Zhihuan (Peking University)

Presenter: Dr LI, Zhihuan (Peking University)

Contribution ID: **54** Type: **Poster Contribution**

Examination of the adiabatic approximation for (d,p) reactions

Deuteron-induced one-neutron transfer reactions have been used to extract single-particle properties of nuclei, and the adiabatic (AD) approximation is often used to simply treat the deuteron breakup states.
We examine the validity of the AD approximation for describing the breakup process in the (d,p) reaction systematically.
We calculate the (d,p) cross sections with the continuum-discretized coupled-channels method (CDCC) for 128 reaction systems and compare the results with those obtained by the CDCC calculation with the AD approximation.

Primary author: CHAZONO, Yoshiki (Research Center for Nuclear Physics, Osaka University)

Co-authors: Mr YOSHIDA, Kazuki (research center for nuclear physics); Prof. OGATA, Kazuyuki (RCNP, Osaka University)

Presenter: CHAZONO, Yoshiki (Research Center for Nuclear Physics, Osaka University)

Contribution ID: **55** Type: **Oral contribution**

Probing the pn correlation in nuclei via the (p,pd) reaction

Deuteron is the only binding system which consists of two nucleons (a proton and a neutron) in free space.
Recently, theoretical calculation with density functional theory (DFT) suggests that the "deuteron-like" pn pair exists in nuclei.
We propose the (p,pd) reaction to probe the pn pair, and discuss how the (p,pd) cross section reflects the pn pair inside the target nucleus.
We calculate the cross section employing the transition density calculated with DFT. The results are compared with those obtained with assuming a deuteron "cluster" a priori.

Primary author: CHAZONO, Yoshiki (Research Center for Nuclear Physics, Osaka University)

Co-authors: Mr YOSHIDA, Kazuki (research center for nuclear physics); Prof. OGATA, Kazuyuki (RCNP, Osaka University); Dr YOSHIDA, Kenichi (Kyoto University)

Presenter: CHAZONO, Yoshiki (Research Center for Nuclear Physics, Osaka University)

Session Classification: Session 4

Contribution ID: **56** Type: **Oral contribution**

Production of neutron-rich nuclei via two-proton knockout reaction with deuterium target

Thursday, June 7, 2018 11:18 AM (18 minutes)

Production of neutron-rich nuclei through one-nucleon knockout (p,2p) reactions has been successfully demonstrated with the MINOS at RIBF. In future RIBF experiments, a method to remove more than one protons with a reasonable rate will be required for production of more neutron-rich nuclei. At present there is no consensus on what is the best reaction for two-proton removal. In this presentation, a performance of the (d, 3pn) reaction with the MINOS as a candidate of the two-proton knockout driver in future RIBF experiments is discussed. The experiment was carried out using the SAMURAI spectrometer. A secondary cocktail beam including 58Ti was produced with projectile fragmentation reactions of a primary 70Zn beam at 345 MeV/u impinging on a beryllium target. The liquid hydrogen and deuterium with thicknesses of 1.1 g/cm2 and 2.6 g/cm2, respectively, were used as the secondary targets. The cross sections were derived by counting the numbers of particles before and after the target, considering an effective beam intensity. The secondary beam and fragments were identified event by event using the ΔE–TOF–Bρ method. It was found that cross section for two-proton removal with a deuteron target is larger by a factor of ~3 than that with a proton target. This fact may imply possible advantages of a deuteron target to produce neutron-rich nuclei via two-proton knockout.

Primary author: Ms MIWA, Midori (Department of Physics, Toho University)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr WANG, He (RIKEN Nishina Center); Dr OTSU, Hideaki (RIKEN Nishina Center); Dr DOORNENBAL, Pieter (RIKEN); Dr UESAKA, Tomohiro (RIKEN Nishina Center); Dr KUBOTA, Yuki (RIKEN Nishina Center)

Presenter: Ms MIWA, Midori (Department of Physics, Toho University)

Session Classification: Session 12

Contribution ID: **57** Type: **Poster Contribution**

Microscopic optical potentials for nucleus-nucleus scattering based on the Glauber model

Recently, study on unstable nuclei near the neutron dripline has been attracted by the development of radioactive ion-beam experiments. The optical potential between a projectile and a target is a basic ingredient to describe the elastic scattering. In the neutron-rich region, it is difficult to determine the phenomenological optical potential due to restrictions on experimental data. Therefore, we need to construct the optical potential microscopically.

The g-matrix folding model has been widely used as a reliable method to obtain the microscopic optical potential. In the previous works, we proposed a double-single folding (DSF) model for 3He and 4He scattering, in which the optical potential between 3,4He and a target is constructed by folding the projectile density with a microscopic nucleon-target optical potential. The DSF model well reproduces the experimental data without any adjustable parameter. However, the same approach does not work well for the case of unstable nuclei, since the DSF model neglects projectile-excitation effects that are important for reactions involving weakly-binding nuclei. The continuum-discretized coupled-channels method (CDCC) can provide the framework to circumvent this shortcoming.

In our research, we propose a method to construct a microscopic optical potential including projectile-excitation effects by combining the DSF model with the Glauber model. In this conference, we will report properties of the obtained potential, and discuss applicability to reactions involving unstable nuclei.

Primary author: Mr OGAWA, Shoya (Kyushu university)

Co-authors: Dr TOYOKAWA, Masakazu (Kyushu University); Mr HORINOUCHI, Ryo (Kyushu University); Dr MATSUMOTO, Takuma (Kyushu University)

Presenter: Mr OGAWA, Shoya (Kyushu university)

Contribution ID: **58** Type: **Oral contribution**

Evidence of enhanced 3alpha radius probed by nuclear reactions

In light nuclear systems, it is well known that cluster structures appear in excited states. One of characteristic properties in the cluster structures is a prominent extension of the nuclear radius. Typical examples are the Hoyle 02+ state and its rotational excited state, 22+, in 12C, which are considered to have the developed 3alpha cluster structure. The matter radii of these 3alpha states are expected to be enhanced by about 60% in comparison to the radius of the ground state but the direct measurement of the radius of the 3alpha state is completely impossible.

In the present study, we focus on the 3alpha rotational state, 22+, and demonstrate that the evidence of the enhanced radius in the 22+ state can be clearly identified in the differential cross section of the alpha + 12C inelastic scattering. We perform the microscopic coupled-channel (MCC) calculation for the alpha + 12C inelastic scattering. The differential cross sections for the elastic and inelastic scattering are calculated at the incident energy of E/A= 96.5 MeV. The MCC calculations for the alpha scatterings nicely reproduce the differential cross sections of the various exit channels.

From the MCC calculation, we have found that the angular distribution of 22+ is prominently shrunk in comparison to the 21+ distribution. This shrinkage structure can be attributed to the enhanced matter radius in the 22+ state. In the present report, we will discuss the relation of the matter radius and the differential cross section in the 3alpha final channel. Furthermore, we will report the application of our analysis to the hyper nucleus production, such as 13C(K-,pi-)13LambdaC.

Primary author: Dr ITO, Makoto (Department of Pure and Applied Physics, Kansai University)

Co-authors: Mr NAKAO, Makoto (Kansai university); Prof. YAMADA, Taiichi (Laboratory of Physics, Kanto Gakuin University); FUNAKI, Yasuro (Beihang University)

Presenter: Dr ITO, Makoto (Department of Pure and Applied Physics, Kansai University)

Contribution ID: **59** Type: **Oral contribution**

Total cross sections of reactions 6,8He+28Si, 9,11Li+28Si and role of neutron rearrangement

Monday, June 4, 2018 4:09 PM (18 minutes)

It is well known that neutron rearrangement may play an important role in nuclear reactions. The aim of this work is the investigation of the reactions with light nuclei having different external neutron shells. A series of experiments on measurement of total cross sections for reactions 4,6,8He + Si and 6,7,9,11Li + Si in the beam energy range 5–50 AMeV was performed at Flerov Laboratory of Nuclear Reactions (FLNR), Joint Institute for Nuclear Research (JINR). The interesting results were the unusual enhancements of total cross sections for 9,11Li + Si reactions as compared with 6,7Li + Si reactions and 6,8He + Si reactions as compared with 4He + Si reaction. The microscopic approach based on the numeric solution of the time-dependent Schrödinger equation [1] for the external neutrons of weakly bound projectile nuclei combined with the optical model is used for description of the observed effects [2]. These are explained by the rearrangement of external neutrons and thus the increase of neutron probability density in the region between the two nuclei depending on the collision energy. The calculated cross sections are in agreement with the experimental data on the total reaction cross sections for the studied nuclei.

References

[1] V. V. Samarin. Description of nucleon-transfer and fusion reactions within time-dependent approaches and coupled-channel method. Phys. At. Nucl. 78 128 (2017).
[2] Yu. E. Penionzhkevich, Yu. G. Sobolev, V. V. Samarin, and M. A. Naumenko. Peculiarities in total cross sections of reactions with weakly bound nuclei 6He, 9Li. Phys. At. Nucl. 80 928 (2017).

Primary author: Prof. SAMARIN, Viacheslav (Joint Institute for Nuclear Research)

Co-authors: Mr NAUMENKO, Mikhail (Joint Institute for Nuclear Research); Prof. PENIONZHKEVICH, Yuri (Joint Institute for Nuclear Research)

Presenter: Prof. SAMARIN, Viacheslav (Joint Institute for Nuclear Research)

Session Classification: Session 4

Contribution ID: **60** Type: **Poster Contribution**

Peculiarities of interaction of weakly bound lithium nuclei (A=6–11) at low energies: Elastic scattering and Total reaction cross sections

The review presents the latest experimental data on the total reaction cross sections and angular distributions of differential cross sections for elastic scattering of light weakly bound lithium nuclei 6–9,11Li [1].
A review of papers on the interaction of weakly bound (cluster and exotic) 6-9Li and 11Li nuclei published so far and their analysis shows that there are no experimental data on total reaction cross sections (TRC, σR) and it is necessary to measure it for Li-isotopes at energies from the Coulomb barrier Bc=(3–4) MeV up to (10–40) MeV/nucleon on 28Si, 27Al, 9Be, and 12C nuclei.
For the interacting systems (8,9Li+28Si), there are only two points with a large energy error (about ±10 MeV/nucleon) in Ref. [2] (Warner et al.): for (8Li+28Si)- reaction at 34 and 50 MeV/nucleon, and for reaction (9Li+28Si)- at 37 and 50 MeV/nucleon.
The new data on TRC for reactions (8,9Li+28Si) in the energy range (5–30) MeV/nucleon with their analysis are presented in [3]. In the TRC energy dependence of (9Li+28Si) reaction, a "bump", i.e., a local increase in the cross section in the energy interval (10–30) MeV/nucleon, was first observed. Therefore, this dependence requires further theoretical analysis and experimental study.
In Ref. [2] in the energy range from 25 to 52.5 MeV/nucleon there were only three points for TRC for the system (11Li+28Si) at energies of 29.9, 42.5 and 52.5 MeV/nucleon. The points have large errors both in energy (up to ±7 MeV/nucleon) and in the values of the cross section (±100 mb). In the work of Villari [4] one point at an energy of 25.5 with an error in the TRC value of ±386 mb was obtained. Li Chen [5] presents six points at energies from 25 to 41 MeV/nucleon, however, he does not give errors in cross sections and energy.
Therefore, the measurements of TRC (8,9,11Li+28Si), presented in [5, 3] and planned for 2018 in the previously unexplored energy interval, will fill the gap in the available literature data.
Large TRC values detected in the σR(E) dependence, as well as their rapid increase in a short energy interval in the low-energy region, can lead to a release of a large amount of energy, which is interesting in terms of search for new energy sources of the future.
The obtained new data (the existence of an anomalous increase in the TRC) in a narrow energy range (10-30) MeV/nucleon in the (6He, 9Li)+28Si reactions at barrier energies will enable scientists to explain important questions of nucleosynthesis (nuclear astrophysics).
One of the most important features explaining why light elements are abundant in the universe is the increase in the interaction cross sections in the sub-barrier energy region in nuclear reactions with weakly bound nuclei. This effect is especially strongly manifested for light cluster nuclei 6,9,11Li and nuclei with a neutron halo 6,8He and 11Li. The main channels of interaction of such nuclei are transfer, breakup and complete- fusion reactions.
Such peculiarities of interactions manifested in an increase in the cross section for the transfer of clusters and for complete-fusion reactions near the Coulomb barrier are typical of many weakly bound nuclei.
In the future, this will enable us to predict the trend in the change in the excitation function σR(E) in the interaction of a light weakly bound nucleus with the same target nucleus, in order to obtain the TRC energy dependence at barrier energies. In particular, scientists are very interested in the TRC behavior for such reactions as (11Li+2H), (11Li+9Be) and others at energies near (above and below) the Coulomb barrier.

1. Kuterbekov K.A. et.al. // Chinese Journal of Physics. –2017. –V. 55. –P. 2523-2539. https://doi.org/10.1016/j.cjph.2017.

2. Warner R.E. et al. // Phys.Rev.C. –1996. –V. 54. –P. 1700.

3. Kabyshev A.M. et al. // J.Phys.G: Nuclear and Particle Physics. –2018. –V. 45. –P. 025103. https://doi.org/10.1088/1361-6471/45/2/025103.

4. Villari A.C.C. et al. // Phys.Lett.B.–1991. –V. 268.–P. 345.
5. Li Chen et al. // High Energy Physics and Nuclear Physics. –2007. –V. 31, No. 12.–P. 1102.

Primary authors: Mr AZHIBEKOV, Aidos (L.N. Gumilyov Eurasian National University); Dr MUKHAMBETZHAN, Aisulu (Korkyt-Ata Kyzylorda State University); Dr KABYSHEV, Asset (L.N. Gumilyov Eurasian National University); Dr SADYKOV, Bakhtiyar (Institute of Nuclear Physics); Prof. KUTERBEKOV, Kairat (L.N.Gumilyov Eurasian National University)

Presenter: Prof. KUTERBEKOV, Kairat (L.N.Gumilyov Eurasian National University)

Contribution ID: **61** Type: **Poster Contribution**

A new scattering chamber for conducting precision experiments on the heavy-ion reaction cross sections at the accelerator DC-60 (Astana, Kazakhstan) at low energies

Within the framework of the long-term program of cooperation between JINR, ENU and Institute of Nuclear Physics (INP), joint experiments connected with the peculiarities of the interaction of lithium nuclei (6-9,11Li) at energies near the Coulomb barrier will be conducted on the U-400M cyclotron of G.N. Flerov Nuclear Reaction Laboratory (FLNR JINR) and on the DC-60 accelerator (Astana) of the INP. To obtain new experimental information on the properties of weakly bound (cluster and exotic) lithium nuclei (the entire chain of lithium isotopes) and their manifestation in interaction with other nuclei, the features of the angular distributions of elastic and inelastic scattering cross sections, the energy dependences of the total reaction cross sections (σR(E) and cross sections of individual dominant reaction channels; the corresponding reaction mechanisms in the previously unexplored region of energy will be studied.
Experiments in Astana (Kazakhstan) are supposed to be carried out at the DC-60 using a new scattering chamber and corresponding detector systems and nuclear electronics, which was manufactured at the FLNR JINR. The new dispersion chamber for the DC-60 is a completely new modern installation, which includes a new electronic system for collecting and processing experimental information FASTER.
Control experiments using the new camera will be conducted on beams 6,9,11Li at the FLNR JINR and on 7Li nuclei –on the DC-60. These nuclei (6,7,9Li) have a weakly bound cluster structure, and the 11Li nucleus is an exotic nucleus with a very low binding energy (Ebind = 0.3 MeV). In such experiments, we are expected to detect the features of their manifestation in nuclear reactions near the Coulomb barrier: subbarrier fusion, an increase in the cross section for cluster transfer reactions, features in the angular distributions of elastic and inelastic scattering, and features in σR(E. The obtained information is of great importance for fundamental nuclear physics and in other fields of science, for example, for describing the scenario of nucleosynthesis in astrophysics.

Primary authors: Mr AZHIBEKOV, Aidos (L. N. Gumilyov National University); Dr KABYSHEV, Asset (L. N. Gumilyov National University); Prof. KUTERBEKOV, Kairat (L.N.Gumilyov Eurasian National University); Mr MENDIBAYEV, Kairat (L. N. Gumilyov National University); Dr LUKYANOV, Sergey (G. N. Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research); Prof. PENIONZHKEVICH, Yuri (G. N. Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research)

Co-authors: Dr MUKHAMBETZHAN, Aisulu (Korkyt-Ata Kyzylorda State University); Dr SADYKOV, Bakhtiyar (Institute of Nuclear Physics); Prof. KENZHIN, Ergazy (Institute of Nuclear Physics); Mr IVANOV, Igor (Institute of Nuclear Physics); Mr KOLOBERDIN, Mikhail (Institute of Nuclear Physics); Mrs ALINA, Rita (L. N. Gumilyov National University); Dr MASLOV, Vladimir (G. N. Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research); Mr ORDA, Yernar (L. N. Gumilyov National Universit); Dr SOBOLEV, Yuri (G. N. Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research)

Presenter: Prof. KUTERBEKOV, Kairat (L.N.Gumilyov Eurasian National University)

Contribution ID: **62** Type: **Oral contribution**

Robustness of the N=34 shell closure: First spectroscopy of 52Ar

Tuesday, June 5, 2018 11:54 AM (18 minutes)

It is now well known that the magic numbers are not universal across the nuclear landscape and that new shell closures may emerge in nuclei far from stability. In particular, a new subshell closure at N=34 has been reported in 54Ca. While the systematics of the E(2+) of the Ti isotopes does not show any evidence for the existence of the N=34 subshell closure, the significant 2+ excitation energy in 54Ca was a sign of its doubly magic character. For 52Ar, no spectroscopic information has been measured, however, its E(2+) was predicted to be the highest among Ar isotopes with N > 20, suggesting a robust N=34 shell gap. The spectroscopy of 52Ar thus offers a unique chance to explore the robustness of the N = 34 subshell closure and pin down the mechanism at the origin of its emergence.

The measurement of 52Ar was performed at RIBF at RIKEN using the spectrometers of BigRIPS and SAMURAI. The low-lying states of 52Ar were populated via 53K(p, 2p) and 54Ca(p, 3p) reactions at ~240 MeV/u. The selectivity of the (p, 2p) and (p, 3p) channels is used to build the level scheme of 52Ar. The challenge posed by the low secondary beam intensity was tackled by the combination the MINOS device with a 150-mm thick liquid hydrogen target and the recent upgraded high efficiency DALI2+ gamma detector array. In the presentation, we will report on the first in-beam gamma spectroscopy of low-lying states of 52Ar, and discuss the robustness of the N=34 shell closure in light of shell model and ab initio calculations.

Primary author: Dr LIU, Hongna (CEA, Saclay)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr CALVET, Denis (CEA Saclay); Dr BROWNE, Frank (RIKEN Nishina Center); Dr BABA, Hidetada (RIKEN); Dr DOORNENBAL, Pieter (RIKEN Nishina Center); Dr SUN, Yelei (CEA Saclay)

Presenter: Dr LIU, Hongna (CEA, Saclay)

Session Classification: Session 6

Contribution ID: **63** Type: **Oral contribution**

Status report of Beijing Radioactive Ion-beam Facility (BRIF)

The Beijing Radioactive Ion-beam Facility (BRIF) is a large-scale scientific infrastructure, which was commissioned as the national first RIB facility based on the Isotope Separator On Line (ISOL) technique in October, 2016. BRIF is comprised of a high-intensity proton cyclotron, thick-target and ion source system, isotope separator on line and the HI-13 tandem as the post accelerator. The radioactive nuclides are produced by intense proton beam of 100 MeV bombarding a thick-target, the reaction products diffusing out of the target are ionized by an ion source, and separated by the online mass separator.
In this talk, the recent progress on the development of 20-25Na ISOL beams is reported, together with the preliminary results from a trial measurement of the exotic decay of 20Na.

Primary author: Prof. WANG, Youbao (China Institute of Atomic Energy)

Presenter: Prof. WANG, Youbao (China Institute of Atomic Energy)

Session Classification: Session 12

Contribution ID: **64** Type: **Oral contribution**

In-beam gamma-ray spectroscopy of 51K and 53K

Friday, June 8, 2018 11:39 AM (18 minutes)

One of the major focus of modern nuclear physics is to explore which part of the nuclear interaction gives rise to significant shell modifications. Recently, the evolution of the 2s1/2+ and 1d3/2+ single-particle states in odd-A K isotopes attract particular interests. The energy gap between these two states decrease continuously when neutrons fill f7/2 orbit. Inversion of the ordering of the 2s1/2 and 1d3/2 orbits has been observed in 47K (N=28) and 49K(N=30). As the neutrons continue filling the orbits beyond the N = 28 shell, reinversion was observed for the first time in 51K using laser spectroscopy. Such reinversion is consistent with the shell model calculations using different effective interactions and was revealed to be mainly driven by the central term of the monopole interaction. However, different interactions predict very different energy gaps between 2s1/2 and 1d3/2 in 51K. In addition, the shell model calculation and the recently available ab initio calculation also predict the reversion in 53K but also with very different energy gaps. The experimental spectroscopy of the excited states in 51K and 53K are thus crucial to benchmark the shell model and ab initio calculations and improve our understanding on the shell evolution mechanisms.

The in-beam gamma-ray spectroscopy measurement of 51K and 53K was carried out at RIBF at RIKEN, as part of the third campaign of the SEASTAR program. The low-lying states of 51K and 53K were populated via 52Ca(p, 2p) and 54Ca(p, 2p), respectively. In the presentation, I will report on the energy level scheme of 51,53K, exclusive cross sections and the individual parallel momentum distributions.

Primary author: Dr SUN, Yelei (CEA Saclay)

Presenter: Dr SUN, Yelei (CEA Saclay)

Session Classification: Session 16

Contribution ID: **65** Type: **Oral contribution**

Structure Beyond the Dripline in the Boron Isotopes: from 18B to 21B

As part of the first phase program of experiments utilizing the SAMURAI spectrometer and NEBULA neutron array, we have undertaken invariant mass spectroscopy of 18,19,20,21B using the complementary probes of neutron and proton knockout. After a brief introduction to the experimental setup and analysis techniques, the results for 18,19B are discussed where, in addition to substantially improving our knowledge of the known threshold states in both systems, evidence for new levels has been found. Finally, the first observations of 20,21B are presented.

Primary authors: Dr MARQUÉS, F. M. (Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France); Dr GIBELIN, Julien (Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France); Dr ORR, Nigel (Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France); Dr LEBLOND, Sylvain (Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France)

Presenter: Dr GIBELIN, Julien (Normandie Univ, ENSICAEN, UNICAEN, CNRS/IN2P3, LPC Caen, 14000 Caen, France)

Contribution ID: **66** Type: **Oral contribution**

Breakup reactions of one-neutron halo nucleus 31Ne

Monday, June 4, 2018 1:30 PM (18 minutes)

It is well known that N=20 shell gap disappears in the "island of inversion" and thus strong deformation appears.
The one-neutron halo nucleus 31Ne, located in the island of inversion, has attracted much attention because it is the first example of a deformation-driven halo nucleus.
Recent experimental studies on 31Ne revealed that it has low separation energy Sn=0.15(+0.16)(-0.10)MeV, and ground-state spin and parity 3/2-.
These experimental results are consistent with a picture of deformed halo structure.
However the deformation has not measured directly yet.

We have performed an invariant-mass spectroscopy of 31Ne in the nuclear breakup reaction with a carbon target at ~230 MeV/u, aiming at observing its rotational band.
Additionally we also carried out a Coulomb breakup measurement with a lead target at ~230 MeV/u, in order to investigate its ground state properties.
These experiments have been done using SAMURAI spectrometer at RIBF, RIKEN.
The experimental results will be discussed in the presentation.

Primary author: Mr TOMAI, Takato (Tokyo Institute of Technology, Department of physics)

Presenter: Mr TOMAI, Takato (Tokyo Institute of Technology, Department of physics)

Session Classification: Session 3

Contribution ID: **67** Type: **Oral contribution**

Analysis of isospin dependence of ”quenching factors” for (p,pn) and (p,2p) reactions via the Transfer to the Continuum formalism

Friday, June 8, 2018 10:45 AM (18 minutes)

Nucleon removal (p,pn) and (p,2p) reactions at intermediate energies have gained renewed attention in recent years as a tool to extract information from exotic nuclei, thanks to the availability of exotic beams with which to perform these reactions in inverse kinematics. The information obtained from these experiments is complementary to that obtained from nucleon removal experiments with heavier targets (knockout), but is expected to be sensitive to deeper portions of the wave function of the removed nucleon.

Recently, two sets of (p,pn) and (p,2p) data on oxygen and nitrogen isotopes have been obtained by the R3B collaboration [1,2] and have been analysed in terms of the eikonal DWIA [1] and Faddeev/AGS [2] formalisms. Both analyses obtain a reduction in the spectroscopic strength but predict a different magnitude for this reduction and different isospin dependence. Also, it must be noted that the analysis of [1] was restricted to five selected oxygen isotopes, which were deemed to be more suitably described by the Independent Particle Model (IPM).

In this contribution we present a joint analysis of both sets of data, including all measured isotopes, using a common reaction framework, the recently developed Transfer to the Continuum [3] formalism, with consistent potentials and structure inputs. Our analysis shows an almost constant reduction factor with a very small, nearly absent, isospin dependence. This result is in accord with recent transfer experiments [4], but at odds with the marked asymmetry obtained from the systematic analysis of nucleon knockout reactions at intermediate energies [5]. The effect of the distorting potentials on these results is explored by using two different sets of potentials. It is found that the small asymmetry is maintained with both sets even if the reduction factors for the specific reactions may be significantly different.

[1] L. Atar et al, Phys. Rev. Lett. 120, 052501 (2018)
[2] P. Díaz-Fernández et al, To be published in Phys. Rev. C
[3] A.M. Moro, Phys. Rev. C 92, 044605 (2015)
[4] F. Flavigny et al, Phys. Rev. Lett. 110, 122503 (2013)
[5] J. A. Tostevin and A. Gade, Phys. Rev. C 90, 057602 (2014)

Primary authors: Dr MORO, Antonio M. (Universidad de Sevilla); Mr GÓMEZ RAMOS, Mario (Universidad de Sevilla)

Presenter: Mr GÓMEZ RAMOS, Mario (Universidad de Sevilla)

Session Classification: Session 16

Contribution ID: **68** Type: **Oral contribution**

Effect of two-particle two-hole excitations in target nuclei on inelastic differential cross sections

Friday, June 8, 2018 9:54 AM (18 minutes)

A basic picture of nuclear excited states can be described by one-particle one-hole (1p1h) excitation. Experimental data of inelastic scatterings of nucleon-nucleus reaction are reasonably reproduced theoretically in this picture. However, it is known that higher-order configurations are important for a better understanding of the excited states. This may apply to the inelastic scattering. However, the relation between higher-order configuration and inelastic scattering is still not clear. To clarify the relation between higher-order configuration and inelastic scattering, we consider two-particle two-hole (2p2h) excitation of target nuclei and pay attention to the angular differential cross sections. The 2p2h stats of target nuclei are calculated by Second RPA, and the reaction process is calculated by DWBA. As reaction channels, inelastic scattering and (p,n) reaction are chosen. Our approach reproduces experimental data reasonably. However, it turned out that the diffraction patterns of the angular differential cross section considering 2p2h excitation were not significantly different from those considering 1p1h excitation although the absolute values were smaller than 1p1h calculation if the same nucleon-nucleon force is used for 1p1h and 2p2h calculations. This indicates that the effect of 2p2h contribution cannot be seen in the inelastic channels. We discuss it in more detail from the nuclear structural point of view.

Primary author: Dr MINATO, Futoshi (Japan Atomic Energy Agency)

Co-author: Dr FUKUI, Tokuro (INFN, Napoli)

Presenter: Dr MINATO, Futoshi (Japan Atomic Energy Agency)

Session Classification: Session 15

Contribution ID: **69** Type: **Poster Contribution**

Quasi-free (p, 2p) reactions with 200-MeV protons on 112,124Sn

Single-particle structure and nucleon-nucleon correlations are a few topics of the R3B (Reactions with Relativistic Radioactive Beams) research program to be carried out at FAIR. CALIFA (CALorimeter for In-Flight detection of gamma rays and high-energy charged pArticles) is one of the detector systems of R3B. Components of the CALIFA Barrel are currently being assembled and tested. At the Bronowice Cyclotron Center in Krakow, a beam of 200-MeV protons was used to induce quasi-free (p, 2p) reactions on various targets such as 12C, 16O, 112Sn, 124Sn, and 208Pb. Light charged fragments and gamma rays were detected with several CALIFA Barrel detector modules consisting of CsI(Tl) crystals. Preliminary results from reactions on the 112Sn and 124Sn targets will be presented, with emphasis on the differences in reaction cross sections to the ground and excited states of the residual isotopes.

Primary author: Dr PARK, Joochun (Lund University)

Co-authors: Mr KNYAZEV, Alexander (Lund University); Prof. CEDERKÄLL, Joakim (Lund University); Prof. GOLUBEV, Pavel (Lund University)

Presenter: Dr PARK, Joochun (Lund University)

Contribution ID: **70** Type: **Poster Contribution**

GRIT: A four π silicon array dedicated to direct reactions

Direct reactions are a powerful experimental tool to investigate nuclear structure. Single nucleon transfer is thus an excellent way to probe single particle states and to study shell model evolutions far from the stability valley.
The new generation of facilities (RIKEN, FAIR, FRIB, Spiral2) will produce fission fragment beams and direct reactions will populate residues with a high density of states. Particle detection only will not be sufficient to disentangle the states. This is why particle-gamma coincidence measurements are highly needed.
The GRIT (Granularity Resolution Identification Transparency) international project is aiming at developing a four π Silicon array to be coupled with the new generation of gamma arrays, like AGATA and PARIS. Constraints on compactness and transparency to gamma make it very challenging. In particular, new techniques based on pulse shape analysis (PSA) have been implemented in order to identify the light particles. Digital electronics is being developed by the collaboration in order to fit these requirements.
In this talk, I will introduce the project aims and show the detectors and electronics designs. I will also present the first in-beam results for the trapezoidal highly segmented Silicon detector of GRIT coupled with the first version of the front-end electronics. The effect of capacitance on the discrimination of light particle will be presented. Also, results from radiation damage effect with protons and 7Li particles will be shown.

Primary authors: Dr GRASSI, Laura (IPNO); Dr ASSIE, Marlene (IPNO)

Co-authors: Dr GOASDUFF, Alain (INFN-LNL); Dr GEORGIADOU, Anastasia (IPNO); Dr LE CROM, Benjamin (University of Edinburgh); Dr GENOLINI, Bernard (IPNO); Dr MENGONI, Daniele (INFN-LNL); Dr BEAUMEL, Didier (IPN Orsay / RIKEN Nishina center); Dr BRETON, Dominique (LAL); Dr RAULY, Emmanuel (IPNO); Dr HAMMACHE, Faïrouz (IPNO); Dr FLAVIGNY, Freddy (IPNO); Dr GUILLOT, Jacques (IPNO); Dr DORMARD, Jean-Jacques (IPNO); Dr MAALMI DI BELLO, Jihane (LAL); Dr CHABOT, Marin (IPNO); Dr DE SÉRÉVILLE, Nicolas (IPNO); Dr CAPRA, Stefano (University of Milano - INFN Sez. of Milano); Dr ID-BARKACH, Tijani (IPNO); Dr BLUMENFELD, Yorick (IPNO)

Presenter: Dr GRASSI, Laura (IPNO)

Contribution ID: **71** Type: **Oral contribution**

Spectroscopy of the 67,68Fe isotopes by direct reactions on a LH2 target

68Ni and neighbor nuclei have been extensively studied since, in the nuclear shell-model, a sizeable effect was expected for the addition of the ⊠f7/2 proton shell closure Z=28 and the vf5/2 neutron subshell closure N=40. While the energy of the first 2+ state for Ni isotopes reaches a maximum for 68Ni, the evolution of the two neutron separation energy S2n is not significant of a major shell effect. Moreover, the 2+ energy of the neighboring 64,66Fe is quite small with indications of a prolate deformation while only two protons are removed from the spherical 68Ni.
While the first SEASTAR campaign at RIBF was focused on the study of 78Ni, data was also taken around 68Fe, which gave the opportunity to study the spectroscopy of the neutron rich Mn, Fe and Co isotopes subject to pairing and neutron-proton interactions. 67,68Fe in the vicinity of 68Ni have been studied with the help of nucleon removal reactions, mainly (p,2p) and (p,pn) in inverse kinematics with radioactive beams. In addition, the inelastic scattering channel (p,p') was also used to provide different selectivity of the final states. In-beam gamma measurement was performed with the DALI2 spectrometer surrounding the MINOS set-up, consisting in a 10 cm long LH2 target and a TPC for detection of charged particles and reconstruction of the reaction vertex in the target.
New transitions were observed with a tentative assignment of a new intruder band in 68Fe. They will be compared to shell model and Hartree-Fock-Bogoliubov calculations, consistent with a sizeable quadrupolar deformation.

Primary authors: Dr GILLIBERT, ALAIN (CEA/IRFU/SPhN); Dr OBERTELLI, Alexandre (TU Darmstadt); LINH, B.D. (INST Ha Noi); Dr CHUNG, X.L. (INST Ha Noi)

Presenter: Dr GILLIBERT, ALAIN (CEA/IRFU/SPhN)

Contribution ID: **72** Type: **Poster Contribution**

Study of astrophysical α + 22Ne reaction using alpha transfer in inverse kinematics with TIARA and MDM spectrometer

In core He burning and C-shell burning of massive stars, the 22Ne(α,n)25Mg reaction is considered to be a dominant neutron source for the weak s process. The reaction also largely contributes to the neutron production for the main s process in asymptotic giant branch (AGB) stars. While a variety of experimental attempts to determine the rate for this reaction at the Gamow window corresponding to s process temperatures have been made either through direct or indirect measurements, uncertainties of some resonance strengths in 26Mg, particularly about two resonances (Ex ~ 11.17 and 11.32 MeV) above neutron separation energy (Sn =11.09 MeV), have remained a long-standing problem. To address this problem, we performed an experiment using the 6Li(22Ne,26Mg)d α-transfer reaction in inverse kinematics at K150 cyclotron of Texas A&M University. A 6LiF target was bombarded with a 7 MeV/u 22Ne beam. Deuterons, γ-rays, and recoil Mg ions were detected in coincidence using a large Si detector array (TIARA), HPGe clover detectors, and an MDM spectrometer backed by an ionization chamber, respectively, to precisely obtain the 26Mg excitation spectrum. Results about the resonances obtained from the experiment will be presented.

Primary author: Dr OTA, Shuya (Texas A&M University)

Co-authors: Dr MATTA, Adrien (CNRS); Mr MAGANA, Cordero (Texas A&M University); Mr HUNT, Curtis (Texas A&M University); Mr BENNETT, Eames (Texas A&M University); Dr LOTAY, Gavin (University of Surrey); Prof. CHRISTIAN, Gregory (Texas A&M University); Prof. ROGACHEV, Grigory (Texas A&M University); Mrs JAYATISSA, Heshani (Texas A&M University); Mr HOOKER, Josh (Texas A&M University); Mr MUZEK, Mateo (Texas A&M University); Dr MOUHKADDAM, Mohamed (University of Surrey); Mr WILKINSON, Ryan (University of Surrey); Dr ANTTI, Saastamoinen (Texas A&M University); Mr HALLAM, Samuel (University of Surrey); Mr UPADHYAYULA, Sriteja (Texas A&M University); Mrs DEDE, Stefania (Texas A&M University); Prof. CATFORD, Wilton (University of Surrey)

Presenter: Dr OTA, Shuya (Texas A&M University)

Contribution ID: **73** Type: **Oral contribution**

Investigating excitation and nucleon correlation in 8He using reactions with a solid hydrogen target

Monday, June 4, 2018 3:51 PM (18 minutes)

The nucleus 8He is the most neutron-rich nucleus known. Its structure, consisting of a 4He core surrounded by four neutrons makes it an ideal case to study phenomena in highly neutron-proton asymmetric systems and neutron correlations at the nuclear surface.
The effects of the valence neutrons were investigated experimentally using proton elastic and inelastic scattering of 8He at the IRIS facility at ISAC-II at TRIUMF at 8.25 A MeV. The two-neutron transfer from 8He was also measured to gain insight into pairing of the valence neutrons.
The presentation will give an overview of the IRIS reaction spectroscopy facility. It utilizes the novel solid H2 target in combination with a low-pressure ionization chamber to identify the incoming beam particles, and two Delta E-E telescopes to measure the reaction products.
Results of the data analysis will be presented featuring excited states in 8He from inelastic scattering. The elastic scattering cross section will be discussed in comparison to semi-microscopic optical potential calculations. A preliminary comparison of the cross sections for the population of the ground and first excited state in 6He from two-neutron transfer will be discussed as well.

Primary author: HOLL, Matthias (Saint Mary's University / TRIUMF)

Co-authors: DIAZ VARELA, Alejandra (University of Guelph); KILIC, Ali Ihsan (University of Guelph); LENNARZ, Annika (TRIUMF); PSALTIS, Athanasios (McMaster University); DAVIDS, Barry (TRIUMF); CONNOLLY, Devin (TRIUMF); HACKMAN, Greg (TRIUMF); HENDERSON, Jack (TRIUMF); MEASURES, James (TRIUMF / University of Surrey); SMALLCOMBE, James (TRIUMF); SINGH RANDHAWA, Jaspreet (Saint Mary's University); LIANG, Johnson (McMaster University); ALCORTA, Martin (TRIUMF); WILLIAMS, Matt (TRIUMF / University of York); PAETKAU, Owen (TRIUMF); KRÜCKEN, Reiner (TRIUMF); KANUNGO, Ritu (Saint Mary's University / TRIUMF); ISHIMOTO, Shigeru (KEK); MITTIG, Wolfgang (NSCL / Michigan State University)

Presenter: HOLL, Matthias (Saint Mary's University / TRIUMF)

Session Classification: Session 4

Contribution ID: **74** Type: **Oral contribution**

Study of Charge-Exchange Reactions for constraining Stellar Electron-Capture Rates

Thursday, June 7, 2018 11:36 AM (18 minutes)

Charge-exchange (CE) reactions at intermediary energies serve as a direct method for the extraction of the Gamow-Teller (GT) transition strengths, which are of importance for the estimation of weak-reaction rates for a variety of astrophysical phenomena such as core-collapse supernovae (CCSN) and the crustal heating of neutron
stars. In particular, CE reactions in the β^+ direction, like $(t, ^3\mathrm{He})$ and $(d, ^2\mathrm{He})$, are essential to determine the electron-capture (EC) rates that play a significant role in the above-mentioned scenarios.\\
Recently, a $^{88}\mathrm{Sr}(t, ^3\mathrm{He} + \gamma)^{88}\mathrm{Rb}$ experiment was performed at NSCL using the S800 spectrometer in coincidence with the gamma-ray detector array GRETINA. Experimental results provide a constrain of the EC rates on neutron-rich nuclei, around the $N = 50$ line, which
are of importance for understanding the late stages of CCSN.\\
In the future, $(d, ^2\mathrm{He})$ experiments in inverse kinematics will open up the opportunity to investigate CE reactions of far-from-stability nuclei. The AT-TPC, a detector based on time
projection chamber, provides a unique technique for achieving such experiments. Simulation results show a very good reconstruction of the $(d, ^2\mathrm{He})$ kinematics and
also indicate that this technique might be feasible for upcoming experiments.\\
Results of the data analysis and perspectives for $(d, ^2\mathrm{He})$ experiments will be discussed.

Primary authors: Dr ZAMORA, J. C. (National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, USA); Prof. ZEGERS, R.G.T. (National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, USA)

Co-author: FOR THE E15112 COLLABORATION, . (National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, USA)

Presenter: Dr ZAMORA, J. C. (National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, USA)

Session Classification: Session 12

Contribution ID: **75** Type: **Oral contribution**

Exotic light nuclei from ab initio theory

Friday, June 8, 2018 9:00 AM (18 minutes)

One of the recently developed approaches capable of describing both bound and scattering states in light nuclei simultaneously is the No-Core Shell Model with Continuum (NCSMC). I will present recent NCSMC calculations of weakly bound states and resonances of exotic halo nuclei 6He and 11Be. I will also discuss the 11Be mirror 11N, an unbound 10C+p system, and highlight the role of chiral NN and 3N interactions in the description of the 10C(p,p) scattering measured recently at TRIUMF. Finally, I will discuss our new calculations of the structure of the unbound 9He nucleus as well as our ongoing calculations of the 11C(p,p) scattering and 11C(p,gamma)12N capture.

Primary author: Dr NAVRATIL, Petr (TRIUMF)

Co-authors: Dr HUPIN, Guillaume (IN2P3/CNRS Orsay); Dr VORABBI, Matteo (TRIUMF); Dr QUAGLIONI, Sofia (LLNL)

Presenter: Dr NAVRATIL, Petr (TRIUMF)

Session Classification: Session 15

Contribution ID: **76** Type: **Oral contribution**

First Spectroscopy of 40Mg

Monday, June 4, 2018 1:48 PM (18 minutes)

The study of nuclei far from stability is one of the most active and challenging areas of nuclear structure physics. One of the most exotic neutron-rich nuclei currently accessible to experiment is 40Mg [1], which lies at the intersection of the nucleon magic number N=28 and the dripline, and is expected to have a large prolate deformation similar to that observed in the neighboring lighter isotopes 32-38Mg [2]. In addition, the occupation of the weakly bound p3/2 state may lead to the appearance of an extended neutron halo[3]. Thus 40Mg offers an exciting possibility and a rare opportunity to investigate the coupling of weakly bound valence particles to a deformed core, and the influence of near threshold effects on collective rotational motion.

We will discuss the results of an experiment carried out at RIBF RIKEN to study low-lying states in 40Mg produced by a 1-proton removal reaction from a ~240 MeV/u 41Al secondary beam. 40Mg and other final products were separated and identified using the Zero Degree Spectrometer, and prompt gamma rays detected using the DALI2 array. The observed excitation spectrum is shown to reveal unexpected properties as compared to both neighboring (more bound) Mg isotopes and theoretical model predictions.

This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract no DE-AC02-05CH11231.

[1] H. L. Crawford et al., Phys. Rev. C 89, 041303(R) (2014).
[2] P. Doornenbal et al., Phys. Rev. Lett. 111, 212502 (2013).
[3] F. Nowacki and A. Poves, Phys. Rev. C 79, 014310 (2009).

Primary authors: CRAWFORD, Heather (Lawrence Berkeley National Laboratory); Dr FALLON, Paul (Lawrence Berkeley Laboratory)

Presenter: CRAWFORD, Heather (Lawrence Berkeley National Laboratory)

Session Classification: Session 3

Contribution ID: **77** Type: **Poster Contribution**

TINA - a New Silicon Tracker for Transfer Reactions

Transfer reactions are powerful tools to study the structure of atomic nuclei. The recently commissioned OEDO beamline of CNS and RIKEN can provide beams with the necessary intensities at low energies (10-20 MeV/u) offering experimental access to regions of the nuclear chart which were hitherto not accessible for transfer studies.

To utilize OEDO for transfer reactions, a detector array called TINA has been built and successfully used in two experiments. TINA is a joint project of CNS, RCNP Osaka and RIKEN Nishina Center. It is designed for the position and energy measurements of the recoiling light particles (protons) from transfer reactions in inverse kinematics.

The first version consists of six deltaE - E telescopes, each consisting of YY1-type silicon strip and CsI detectors. It has been used at Kyushu University Tandem Accelerator and at the OEDO facility. An excellent performance has been achieved in identifying light reaction products and in obtaining kinematics information with both stable and energy-degraded radioactive beams.

TINA is also compact enough to be coupled with 4-Pi gamma-ray detector arrays. An upgrade is ongoing that implements highly granular DSSD detectors to improve the angular resolution. The upgraded TINA will be well-suited for future transfer studies at OEDO and can compete with other world-leading devices.

A general overview, some first results about the performance and a short outlook on future perspectives will be presented.

Primary author: Dr SCHROCK, Philipp (CNS, University of Tokyo)

Presenter: Dr SCHROCK, Philipp (CNS, University of Tokyo)

Contribution ID: **78** Type: **Poster Contribution**

Spectroscopy of Neutron-Rich Al Isotopes at the Border of the Island of Inversion

Neutron-rich Al isotopes (Z=13) lie at the transition point between the classical shell gap N=20 and the Island of Inversion (IoI). Extended spectroscopy of the isotopes 32-35Al was performed at NSCL. Each isotope has been produced via several reaction mechanisms (proton and neutron knockout, fragmentation, charge changing, inelastic scattering) which are sensitive either to the proton or neutron single-particle-like states or to collective states. The reaction products, i.e. fragments and prompt gamma-rays, were detected with the S800 Spectrograph and GRETINA, respectively.

Gamma-gamma coincidence analyses were performed and existing level schemes were updated. The N=20 nucleus 33Al was produced via one- and two-proton and one-neutron knockout. A comparison of the cross sections for the populated states shows clearly states belonging either to the proton or neutron shells. The analysis of the parallel momentum distribution from one-neutron knockout offers complementary information to reported one-proton knockout data.

The preliminary results will be presented and compared to state-of-the-art shell model calculations.

Primary author: Dr SCHROCK, Philipp (CNS, University of Tokyo)

Presenter: Dr SCHROCK, Philipp (CNS, University of Tokyo)

Contribution ID: **79** Type: **Oral contribution**

Borromean Feshbach resonance in 11Li studied via 11Li(p,p')

Friday, June 8, 2018 1:48 PM (18 minutes)

We analyzed the 11Li(p,p') reaction at 6 MeV/nucleon by using a microscopic continuum-discretized coupled-channels method, in which 11Li is described by a 9Li + n + n three-body model. In this analysis, we found a dipole resonance of 11Li, and the resonance can be interpreted as a bound state in the 10Li + n system, that is , a Feshbach resonance in the 9Li + n + n system. For 11Li, the 10Li + n threshold is open above 9Li + n + n one, which reflects a distinctive property of the Borromean system. Thus we refer to this resonance as a Borromean Feshbach resonance. The calculated cross sections by taking into account the resonance and nonresonant continuum reproduce the experimental data recently observed. In this conference, we will show the results and discuss properties of the Borromean Feshbach resonance.

Primary author: Dr MATSUMOTO, Takuma (Kyushu University)

Co-authors: Dr TANAKA, Junki (TU Darmstadt); Prof. OGATA, Kazuyuki (RCNP, Osaka University)

Presenter: Dr MATSUMOTO, Takuma (Kyushu University)

Session Classification: Session 17

Contribution ID: **80** Type: **Poster Contribution**

Search for the 1/2_2 intruder bandhead in 35P

Nuclei in the N=20 island of inversion, located around the neutron-rich 32Mg isotope, have ground-states dominated by deformed and collective configurations arising from neutron-pair excitations across the shell gap (See Ref. [1] for a recent review). Particle-hole sd-pf cross-shell intruder configurations have also been observed in the low-lying level scheme of heavier N = 20 even-even nuclei. However, the expected 1/2_2 intruder bandhead has not yet been identified in the odd-even nucleus 35P. Previous attempts to identify this state suffered from a large background in the region of interest arising from contaminants in the target [2].

We will report on a recent measurement using the 36S(d, 3He)35P reaction in inverse kinematics with the Helical Orbit Spectrometer (HELIOS) at ATLAS/ANL [3]. Thanks to the unique capabilities of HELIOS, enhanced with a recoil detector setup, it is possible to perform the reaction in nearly background free conditions.

An analysis of the reconstructed 3He spectrum in HELIOS did not show a peak that could be associated with the 1/2_2 intruder state. We have not observed any candidate state in the region of interest with an intensity greater than 5% of the ground-state. This in turn can be used to set a limit to the amount of 2p2h excitations in the 36S ground state wavefunction. These results provide an additional constraint to state-of-the-art theoretical descriptions to further understand the evolution of shell structure in the region.

[1] O. Sorlin and M. Porquet, Prog. Part. Nucl. Phys. 61, 602 (2008).
[2] C. E. Thorn, J. W. Olness, E. K. Warburton, and S. Raman, Phys. Rev. C 30, 1442 (1984).
[3] A. H. Wuosmaa et al., Nucl. Inst. Meth. 580, 1290 (2007).

Primary author: Dr SALATHE, Marco (Lawrence Berkeley National Laboratory)

Co-author: COLLABORATION, ANL1637 (ATLAS/HELIOS)

Presenter: Dr SALATHE, Marco (Lawrence Berkeley National Laboratory)

Contribution ID: **81** Type: **Poster Contribution**

Modeling and simulation of data from radioactive waste processing

Achieving efficient radioactive waste management is only possible in the presence of international cooperation, based on the principles established by the Joint Convention on the Safety of Spent Fuel Management and on the Safe Management of Radioactive Waste and the security recommendations of the International Agency's for Atomic Energy (IAAE) on the safe management of spent fuel and radioactive waste.
In order to maintain a high level of security of radioactive waste and environment, radioactive waste packages must meet a number of acceptance criteria. The National Commission for Nuclear Activities Control (CNCAN) introduced through the "Fundamental Norms for the Safe Management of Radioactive Waste" the IAAE principles in Romania. In our country, the body empowered to promote, develop and monitor nuclear activities for exclusively peaceful purposes and to coordinate at national level the process of radioactive waste management, including its final disposal, and the decommissioning of nuclear installations is Nuclear Agency and for Radioactive Waste (ANDR). Romania is among the pioneers of the international nuclear domain, the peaceful applications of nuclear energy being the subject of research activities since the 1950s. Decommissioning of nuclear installations refers to the progressive elimination of risks through a series of decontamination and decommissioning actions which must be achieved according to a Integrated Plan for the Decontamination, Decommissioning and Radioactive Waste Management.
The paper presents a non-linear regression model for assessing the evolution of the radioactivity of the waste arising from the decommissioning of a nuclear reactor based on a statistical analysis of the data obtained from the processing of radioactive waste. Such a model allows the Monte-Carlo simulation method (or other real-time amplification methods) of the variation in the emission of radioactive substances. The phenomenon studied can be defined by the introduction of control coefficients and the use of records and documents elaborated during the decommissioning of a nuclear reactor.

Primary author: Dr BOLDEA BALASA, Afrodita Liliana (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Măgurele,Bucharest, România, University of Craiova, Craiova, Romania)

Co-author: Prof. STEFANESCU, Mariana Florentina (University POLITEHNICA of Bucharest, Romania)

Presenter: Dr BOLDEA BALASA, Afrodita Liliana (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Măgurele,Bucharest, România, University of Craiova, Craiova, Romania)

Contribution ID: **82** Type: **Oral contribution**

Direct Measurement of Resonances in ⁷Be(α,γ)¹¹C With DRAGON

Tuesday, June 5, 2018 4:54 PM (18 minutes)

Nucleosynthesis of the p-nuclei is one of the remaining unsolved puzzles in nuclear astrophysics. One possible mechanism for production of p-nuclei is the νp-process, which is thought to occur in the ejecta of core-collapse supernovae. A recent study found that the p-p chain breakout reaction ⁷Be(alpha;,gamma;)¹¹C significantly influences nuclear flow in the νp-process. However, the ⁷Be(alpha;,gamma;)</e
reaction rate is poorly known over the temperature range of interest (T=1.5–3 GK). In this temperature range, the astrophysical reaction rate is dominated by resonant capture to states in ¹¹C within the Gamow window, three of which have unknown resonance strengths. A new direct measurement of ⁷Be(alpha;,gamma;)¹¹C was performed at TRIUMF's DRAGON recoil separator in order to measure the strengths and energies of these resonances. Experimental methods and preliminary results will be discussed.

Primary authors: Mr PSALTIS, Athanasios (McMaster University); Dr CONNOLLY, Devin (TRIUMF)

Co-authors: Prof. CHEN, Alan (McMaster University); Dr LENNARZ, Annika (TRIUMF); Dr DAVIDS, Barry (TRIUMF); Dr RUIZ, Chris (TRIUMF, University of Victoria); Dr HUTCHEON, Dave A. (TRIUMF); Mr TENKILA, Gaurav (University of British Columbia); Ms GILARDY, Gwenaelle (University of Notre Dame); Mr LIANG, Johnson (McMaster University); Mr KARPESKY, Jonathan (Colorado School of Mines); Mr LOVELY, Matthew (Colorado School of Mines); Mr WILLIAMS, Matthew (University of York, TRIUMF); Dr ESKER, Nicholas (TRIUMF); Mr GIRI, Rekam (Ohio University); Mr PANERU, Som (Ohio University); Prof. GREIFE, Uwe (Colorado School of Mines); Mr HUANG, William (University of Northern British Columbia)

Presenter: Dr CONNOLLY, Devin (TRIUMF)

Session Classification: Session 8

Contribution ID: **83** Type: **Poster Contribution**

Effect of shell correction on the dynamics of 203Pb* nucleus within collective clusterization approach

During the collision of heavy ions, their associated shell structure gets significantly modified, leaving corresponding impact on the dynamics of decaying clusters/fragments. Clustering of nucleons play a significant role in the decay analysis of excited compound systems formed via heavy ion reactions. For an overall understanding of the nuclear dynamics, a collective clusterization model is developed for addressing excited-state decay and is termed as dynamical cluster-decay model (DCM) [1]. In this model, all possible decay fragments are taken into account, where the yield of each set of binary fragment gets influenced by the relative yield of rest of the combinations. In the present work, the application of DCM is exercised to 6Li+197Au -> 203Pb* reaction, with a specific reference to the relevance of shell corrections. In context of recent experimental data [2], fusion-evaporation cross sections of this reaction are fitted using the optimized neck length with and without inclusion of shell corrections, for a wide range of incident energies spread across the Coulomb barrier. It is observed that the shell corrections affect the fusion-evaporation cross sections significantly and as expected the use of shell correction becomes indispensable at below barrier region. The removal of shell correction energy lowers the fusion-evaporation cross sections as compared to the one which are calculated with the inclusion of shell correction energy. In other words, 6Li+197Au reaction hinders to fuse when the shell correction is not included in the dynamics. However, to make an overall understanding of the effect of shell correction energy on the reaction dynamics, we have explored this effect for a variety of nuclear reactions forming the compound nuclei in the mass region 100 to 200. In this mass region, the shell correction energy have positive or negative impact on the fusion-evaporation cross-sections which depends upon the type of fragments minimized and their associated shell correction energy that are different for the decay of different compound nuclei.

REFERENCES

1. R. K. Gupta, Clusters in Nuclei, Lecture Notes in Physics 818, 223 (2010).
2. C. S. Palshetkar et. al., Phys. Rev. C 89, 024607 (2014).

Primary author: Ms VIRK, Navjot Kaur (Thapar Institute of Engineering and Technology, Patiala-147004, Punjab, INDIA)

Co-authors: Prof. SHARMA, Manoj Kumar (Thapar Institute of Engineering and Technology, Patiala-147004, Punjab, INDIA); Dr KUMAR, Raj (Thapar Institute of Engineering and Technology, Patiala-147004, Punjab, INDIA)

Presenter: Dr KUMAR, Raj (Thapar Institute of Engineering and Technology, Patiala-147004, Punjab, INDIA)

Contribution ID: **84** Type: **Oral contribution**

Shell structure of 43S studied by one-neutron knockout reaction

Monday, June 4, 2018 2:06 PM (18 minutes)

South of 48Ca in the nuclear chart, the erosion of the neutron magic number 28 and the onset of collective behavior have been observed.
Especially the ground-state deformation, the shape coexistence, and the high-K isomerism in 44S have been discussed both experimentally and theoretically.
In this region these phenomena related to the deformation of the nucleus are thought to originate from the interplay of quenching the N = 28 shell gap and quadrupole excitations across Z = 14, 16 sub-shell and N = 28 shell gaps.
The proton configuration of the 44S ground state was investigated previously but the neutron occupation remains unknown prior to this study.
To clarify the reduction of the N = 28 shell gap and the role of the neutron configuration to the deformation in 44S, an in-beam gamma-ray spectroscopic study focused on the one-neutron knockout reaction from 44S was performed.
One-neutron knockout reaction can selectively produce neutron-hole states and is sensitive to the neutron occupation of the ground state of the projectile nucleus.
Also the parallel momentum distribution of the reaction residue is related to the orbital angular momentum of the knocked out neutron, which is helpful to assign the spin-parity to each final state of reaction residue.

The experiment was performed at the NSCL.
A 100-MeV/u secondary beam of 44S was produced by fragmentation of a 48Ca primary beam on a Be production target.
The secondary beam impinged on a secondary beryllium target inducing the one-neutron knockout-reaction.
Prompt gamma-rays from excited states in 43S emitted at the target were detected by the GRETINA tracking array.
The one-neutron knockout residues were identified in the S800 spectrograph which also measures the momenta and angles of ejectiles.
In order to deduce the level scheme above the isomeric state at 320 keV in 43S and population to this state for the deduction of the neutron configuration in the fp shell, the IsoTagger which consists of 32 CsI scintillators was placed downstream at the end of the beam line.

The level scheme of 43S deduced via the in-beam gamma-ray spectroscopy of this experiment will be presented combining the analysis on momentum distributions produced by the one-neutron knockout reaction. There also will be the comparison with shell model calculations.

Primary author: MOMIYAMA, Satoru (Department of Physics, University of Tokyo)

Co-authors: Dr GADE, Alexandra (NSCL); Mr ELMAN, Brandon (NSCL); Dr BAZIN, Daniel (Michigan State University); Dr WEISSHAAR, Dirk W (NSCL/MSU); Dr LUNDERBERG, Eric (NSCL); Dr BELARGE, Joe (NSCL); Dr WIMMER, Kathrin (The University of Tokyo); Dr KEMPER, Kirby W (Florida State Universy); Dr NIIKURA, Megumi (Department of Physics, the University of Tokyo); Mr KITAMURA, Noritaka (Center for Nuclear Study, University of Tokyo); Dr BENDER, Peter (NSCL); Dr SCHROCK, Philipp (CNS, University of Tokyo); Dr OTA, Shinsuke (Center for Nuclear Study, University of Tokyo)

Presenter: MOMIYAMA, Satoru (Department of Physics, University of Tokyo)

Session Classification: Session 3

Contribution ID: **85** Type: **Poster Contribution**

Progress of PANDORA Project

The PANDORA (Particle Analyzer Neutron Detector Of Real-time Acquisition) system is a neutron detector based on plastic scintillator coupled to digital readout.[1] This system is designed for study of unstable nuclei by (p,n) reaction using inverse kinematics. As it is well known, the detection of low energy neutrons is difficult due to the gamma events background. A new type of scintillation material provides different response to neutrons and gamma rays, so we can select neutron events by analyzing the pulse shape. This pulse shape analyses can be done by a digital data acquisition (DAQ) system so that the gamma background can be greatly suppressed.

Comparing to ref. 1, newer version scintillators with better neutron-gamma discrimination performance are applied. In addition, the DAQ software was modified to suit our configuration and some bugs were fixed. The system was commissioned in a 6He(p,n)6Li reaction experiment and the system shows a good performance on neutron-gamma separation.

In this poster, we will show some results of the neutron-gamma separation and some preliminary results of our (p,n) reaction experiment.

Reference:
[1] L. Stuhl et al., Nucl. Instr. Meth. A 866, 164 (2017).

Primary author: Mr GAO, JIAN (RIKEN)

Co-authors: Prof. TAKADA, Eiichi (NIRS); Dr BABA, Hidetada (RIKEN); Dr ZENIHIRO, Juzo (RIKEN Nishina Center); Prof. YAKO, Kentaro (CNS); Dr STUHL, László (CNS); Prof. SASANO, Masaki (RIKEN); Dr UESAKA, Tomohiro (RIKEN Nishina Center); Dr PANIN, Valerii (RIKEN, Spin-isospin laboratory); Dr KUBOTA, Yuki (RIKEN Nishina Center); Dr YANG, Zaihong (RIKEN); Dr KORKULU, Zeren (ATOMKI)

Presenter: Mr GAO, JIAN (RIKEN)

Contribution ID: **86** Type: **Oral contribution**

Search for T=5 isobaric analog states in 48Ca

Thursday, June 7, 2018 3:12 PM (18 minutes)

Particle-hole excitations near closed shells carry information on single-particle energies and on two-body interactions. The particle-hole excitations near the doubly magic nuclei are of special interest. Information on the charge-changing particle-hole excitations (T= 5 negative parity states) in ^{48} Ca is not available. We performed an experiment to establish the level scheme of the low-lying negative parity T= 5 states in ^{48} Ca. Excitation functions for the ^{1} H (^{47} K, p) ^{47} K (gs) and ^{1} H (^{47} K, p) ^{47} K (3/2^{+}) reactions in the cm energy range from 1 MeV to 4.5 MeV were measured. The T= 5 states are expected to show up in the p+ ^{47} K excitation function as narrow resonances. This experiment was performed at NSCL using the ReA3 beam of ^{47} K at energy of 4.6 MeV/u. ANASEN, set in active target mode, was used for this experiment. Experimental results from this experiment will be presented.

Primary author: UPADHYAYULA, Sriteja (Cyclotron Institute - Texas A&M University)

Co-authors: HOOD, Ashley (Louisiana State University); Prof. DEIBEL, Catherine (Louisiana State University); Mr HUNT, Curtis Hunt (Texas A&M University - Physics and Astronomy); Dr SANTIAGO-GONZALEZ, Daniel (Louisiana State University); Prof. ROGACHEV, Grigory (Cyclotron Institute - Texas A&M University); Prof. BLACKMON, Jeffrey (Louisiana State University); Dr LIGHTHALL, Jon (Louisiana State University); Mr HOOKER, Joshua (Texas A&M University - Cyclotron Institute); BROWNE, Justin (NSCL, Michigan State University); ANASTASIOU, Maria (Florida State University); RIJAL, Nabin (Florida State University); Dr BEDOOR, Shadi (Cyclotron Institute - Texas A&M University); Dr AHN, Sunghoon (Cyclotron Institute - Texas A&M University); ONG, Wei Jia (NSCL, Michigan State University); Dr KOSHCHIY, Yevgen (Cyclotron Institute - Texas A&M University)

Presenter: UPADHYAYULA, Sriteja (Cyclotron Institute - Texas A&M University)

Session Classification: Session 13

Contribution ID: **87** Type: **Oral contribution**

In-beam gamma-ray spectroscopy of F and Ne isotopes near the island of inversion

It is known that neutron magic number N=20 disappears in the region of Z=10~12. Study of nuclei in this region, called "island of inversion" is important for understanding the evolution of shell structure in neutron-rich region. Neutron-rich F and Ne isotopes are located at the south boundary of the island of inversion. Due to the difficulty in production of these extremely neutron-rich nuclei, available experimental data are not sufficient.

We performed in-beam gamma-ray spectroscopy of the neutron-rich 29F,
28-30Ne generated by inelastic scattering and single-nucleon removal reactions on a liquid hydrogen target at the RIKEN RI Beam Factory. 29F, 29,30Ne secondary beams were generated by projectile fragmentation of a 48Ca primary beam on a beryllium target at a beam energy of 345 MeV/u. High statistical data was obtained by using MINOS, which consists of 15 cm thick liquid-hydrogen target and recoil-proton tracking detector. Outgoing particles were identified by SAMURAI spectrometer. The de-excitation gamma rays were measured with the NaI(Tl) scintillator array DALI2 arranged to surround the target.

We studied high-lying excited states and gamma-gamma coincidences for decay from the populated nuclei. In case of nucleon-removal reactions of 29,30Ne, partial cross sections have also been investigated. In this presentation, we discuss the nuclear structure of these nuclei based on the experimental results.

Primary author: Mr YASUDA, Masahiro (Tokyo Tech)

Presenter: Mr YASUDA, Masahiro (Tokyo Tech)

Session Classification: Session 16

Contribution ID: **88** Type: **Poster Contribution**

Nucleosynthesis by the neutrinos in the supernova explosion

We present recent results of the the neutrino-process in the supernova explosion. In particular, we discuss the neutrino-nucleus reactions by the QRPA formalism. Sensitivity of the reaction on the nucleosynthesis is studied in detail. Also the MSW effects of the neutrino propagation are to be presented for discussions. Finally, other exotic effets on the neutrino propagation, like the neutrino self interaction, will be also discussed with numerical results of the related elements abundances in this talk.

Primary author: Prof. CHEOUN, Myung-Ki (Soongsil University)

Co-authors: Dr HA, Eunja (Soongsil Univ.); Ms KO, Heamin (Soongsil Univ.); Prof. KAJINO, Taka (NAOJ, University of Tokyo)

Presenter: Prof. CHEOUN, Myung-Ki (Soongsil University)

Contribution ID: **89** Type: **Poster Contribution**

Shape fluctuations in transitional nuclei

Some nuclei in the transitional region exhibit shape coexistence and shape fluctuations (for example γ-soft) in low-lying energy spectra. To treat such shape fluctuations, quadrupole collective Hamiltonian approach based on energy density functionals (EDF) has often been employed [1]. However, in that approach, the collective inertial functions in the Hamiltonian is derived by the so-called cranking approximation, which neglects dynamical effects. Our goal is to construct the quadrupole collective Hamiltonian, especially to derive the collective inertial functions by the local quasiparticle random phase approximation (QRPA) that correctly includes dynamical effects [2]. Toward this goal, we have first developed an efficient computational framework to perform QRPA on β–γ deformation space based on Skyrme EDF with the finite amplitude method (FAM) that efficiently computes strength functions for multipole modes [3]. We have obtained the strength functions of isoscalar quadrupole modes of triaxial superfluid nuclei ^{110}Ru and ^{190}Pt within a reasonable computational cost [4]. Then, as a next step, we estimate collective inertial functions in the quadrupole collective Hamiltonian. To do this, we apply our Skyrme-QRPA to local Skyrme-QRPA on each $\beta - \gamma$ deformation to estimate collective inertial functions, rotational mass (moment of inertia) and vibrational mass. We find a significant enhancement of the inertial functions from those by the cranking approximation. This is due to dynamical effects derived from local QRPA calculations.

In this contribution, we will show strength functions of isoscalar quadrupole modes of selected triaxial superfluid nuclei. Then, we will discuss the property of mass inertial functions derived from the present local Skyrme-QRPA calculation for the case of a transitional nucleus ^{106}Pd.

[1] T. Niksic et al., Phys. Rev. C79, 034303 (2009); J. P. Delaroche et al., Phys. Rev. C81, 014303 (2010)
[2] N. Hinohara, K. Sato, T. Nakatsukasa, M. Matsuo, and K. Matsuyanagi, Phys. Rev. C82, 064313 (2010).
[3] T. Nakatsukasa, T. Inakura, and K. Yabana, Phys.Rev.C76, 024318 (2007).
[4] K. Washiyama and T. Nakatsukasa, Phys. Rev. C96, 041304(R) (2017).

Primary author: Dr WASHIYAMA, Kouhei (Center for Computational Sciences, University of Tsukuba)

Co-author: Prof. NAKATSUKASA, Takashi (Center for Computational Sciences, University of Tsukuba)

Presenter: Dr WASHIYAMA, Kouhei (Center for Computational Sciences, University of Tsukuba)

Contribution ID: **90** Type: **Oral contribution**

Elastic scattering of 6He from polarized proton at 200 A MeV

Monday, June 4, 2018 10:45 AM (18 minutes)

Spin-dependent interactions play essential roles in nuclear structure and reactions. One of the best known examples is the spin asymmetry found in nucleon elastic scattering, which is a direct manifestation of the spin-orbit interaction. Since the spin-orbit interaction is expected to work in the surface region, it is natural to expect that such interaction could be strongly modified by the characteristic surface structure of neutron-skin or -halo nuclei.
At RIKEN RIBF, we have measured the proton elastic scattering from 6He at 200 A MeV utilizing a spin-polarized proton target specially developed for the RI-beam experiments. Recoil protons were detected with ESPRI Recoil Proton Spectrometer. Scattered particles were analyzed by the SAMURAI spectrometer.
The differential cross sections have been obtained in the highest momentum transfer region among the existing measurement, where the cross sections are dominated by the contribution of an alpha core. The data will be shown and compared with theoretical calculations assuming different radii of the core distribution. Preliminary results of the vector analyzing power will also be presented.

Primary author: Dr SAKAGUCHI, Satoshi (Dept. of Physics, Kyushu University)

Presenter: Dr SAKAGUCHI, Satoshi (Dept. of Physics, Kyushu University)

Session Classification: Session 2

Contribution ID: **91** Type: **Poster Contribution**

Microscopic optical potential obtained from energy-density-functional approach for nucleon-nucleus elastic scattering

Nucleon-nucleus (NA) optical potentials are microscopically generated from a fully self-consistent framework of the particle-vibration coupling (PVC), in which the nucleon-nucleon (NN) effective interaction of the Skyrme type is consistently used to describe the Hartree-Fock (HF) mean-field, the small amplitude collective motions of the target, and the particle-collective states coupling. For the first time, a systematic calculation of low-energy NA elastic scattering off a series of doubly closed-shell nuclei is carried out without ad hoc adjusted parameters. Angular distributions obtained using the present optical potentials are in good agreement with the experimental data. This will be a major step forward in the applications of the Skyrme energy-density-functional theory to build up the global microscopic optical potentials, which are expected to be a powerful tool for the study of unstable (exotic) nuclei at low incident nucleon energies.

Primary author: Mr TRAN VIET NHAN, Hao (Department of Physics and Astronomy, Texas A&M University-Commerce, Commerce, TX 75429, USA)

Co-authors: Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce); Mr NGUYEN HOANG, Tung (VNUHCM-University of Science, 227 Nguyen Van Cu Street, District 5, Ho Chi Minh city, Viet Nam)

Presenter: Mr NGUYEN HOANG, Tung (VNUHCM-University of Science, 227 Nguyen Van Cu Street, District 5, Ho Chi Minh city, Viet Nam)

Contribution ID: **92** Type: **Oral contribution**

Study of neutron-neutron correlation in Borromean nucleus 11Li via the quasi-free (p,pn) reaction

Friday, June 8, 2018 2:24 PM (18 minutes)

Dineutron correlation is one of the phenomena expected to appear in neutron drip-line nuclei. It has been studied using different approaches, such as the transfer reaction and the break up reaction. However, currently available data seem to be insufficient to study the neutron-neutron correlation in terms of (i) the decomposition of high-angular-momentum components, (ii) the extraction of a core excitation, (iii) and the effect of final state interactions (FSIs)[1]. In the present study, (i) the MINOS[2] was used for higher luminosity, (ii) γ rays were detected to tag the core excitation, (iii) and the quasi-free (p,pn) reaction was employed to minimize the FSI. In order to determine the neutron momentum distribution, the kinematically complete measurement was performed. The opening angle between the two neutrons was reconstructed from the measured momentum vectors of all the particles involved in the reaction.
The experiment was carried out by using the SAMURAI spectrometer[3] combined with the liquid hydrogen target system MINOS. Momentum vectors of a knocked-out neutron and a recoil proton were respectively determined by the neutron detector WINDS and a recoil proton detector setup, developed for this project. Decay neutrons and heavy fragments were momentum analyzed by the neutron detector NEBULA and the SAMURAI spectrometer, respectively.
The results on 11Li will be presented in this talk.

References
[1] Y. Kikuchi et al., Phys. Rev. C 87, 034606 (2013).
[2] A. Obertelli et al., Eur. Phys. Jour. A 50, 8 (2014).
[3] T. Kobayashi et al., Nucl. Instr. Meth. B 317, 294(2013).

Primary author: Dr KUBOTA, Yuki (RIKEN Nishina Center)

Presenter: Dr KUBOTA, Yuki (RIKEN Nishina Center)

Session Classification: Session 17

Contribution ID: **93** Type: **Poster Contribution**

Microscopic analysis of elastic scattering based on chiral g matrix

We investigated the effects of three-nucleon force (3NF) from chiral effective field theory on nucleon-nucleus (NA) and nucleus-nucleus (AA) elastic scattering by using g-matrix folding model. To clarify the 3NF effects accurately, we constructed new g-matrix, so called chiral g matrix, from chiral two-nucleon force and 3NF by using Bruckner-Hartree-Fock method and localized the g matrix in order to apply g-matrix folding model. In this conference, we will show the microscopic analysis with chiral g matrix reproduces the experimental data without introducing any adjustable parameter.

Primary author: Dr TOYOKAWA, Masakazu (Kyushu University)

Co-authors: Prof. YAHIRO, Masanobu (Kyushu University); Dr KOHNO, Michio (RCNP, Osaka University); Dr MATSUMOTO, Takuma (Kyushu University)

Presenter: Dr MATSUMOTO, Takuma (Kyushu University)

Contribution ID: **94** Type: **Oral contribution**

Coupled-channels analyses for ^{9,11}Li + ^{208}Pb fusion reactions with multi-neutron transfer couplings

Wednesday, June 6, 2018 10:45 AM (18 minutes)

We discuss the role of two-neutron transfer processes in the fusion reaction of the ^{9,11}Li + ^{208}Pb systems.
We first analyze the ^{9}Li + ^{208}Pb reaction by taking into account the coupling to the ^{7}Li + ^{210}Pb channel. To this end, we assume that two neutrons are directly transferred to a single effective channel in ^{210}Pb and solve the coupled-channels equations with \textcolor[rgb]{0.98,0.00,0.00}{the} two channels. By adjusting the coupling strength and the effective Q-value, we successfully reproduce the experimental fusion cross sections for this system. We then analyze the ^{11}Li + ^{208}Pb reaction in a similar manner, that is, by taking into account three effective channels with ^{11}Li + ^{208}Pb, ^{9}Li + ^{210}Pb, and ^{7}Li + ^{212}Pb partitions. In order to take into account the halo structure of the ^{11}Li nucleus, we construct the potential between ^{11}Li and ^{208}Pb with a double folding procedure, while we employ a Wood-Saxon type potential with the global Aky\"uz-Winther parameters for the other channels.
Our calculation indicates that the multiple two-neutron transfer process plays a crucial role in the ^{11}Li + ^{208}Pb fusion reaction at energies around the Coulomb barrier.

Primary author: Dr KI-SEOK, Choi (Department of phyiscs, Soongsil Univ.)

Co-authors: Prof. MYUNG-KI, Cheoun (Department of physics, Soongsil Univ.); Prof. K.S., Kim (Korea Aerospace University); Dr HAGINO, Kouichi (Department of Physics, Tohoku University); Prof. W.Y., So (Kangwon National University)

Presenter: Dr KI-SEOK, Choi (Department of phyiscs, Soongsil Univ.)

Session Classification: Session 10

Contribution ID: **95** Type: **Oral contribution**

Probing three-nucleon-force effects via knockout reactions

Friday, June 8, 2018 9:18 AM (18 minutes)

Understanding of the roles of three-nucleon forces (3NFs) in nuclear few- and many-body systems is one of the fundamental subjects in nuclear physics. Recently, 3NFs are constructed with chiral effective field theory in which two-, three-, and many-nucleon forces are treated consistently and systematically. The chiral 3NF effects have been analyzed in few-body systems and nuclear matter, and the binding energies of light nuclei and the saturation property in symmetric nuclear matter were well reproduced. Furthermore, it was found that the chiral 3NF effects improve the agreement between theoretical and measured cross sections for nucleus-nucleus elastic scattering.
In this talk, we propose to use proton knockout reactions (p,2p) at intermediats and high energies, which can be regarded as a two-proton quasielastic scattering, as a new probe into chiral 3NF effects on reaction observables. In a many-body system, 3NF effects can be represented by the density-dependence of nucleon-nucleon effective interaction. Proton knockout reactions from a deeply bound orbit should be suitable for probing 3NF effects since such reactions occur mainly in the internal region of the target nucleus in which the density is high. We clarify the roles of chiral 3NF for knockout reactions based on the distorted-wave impulse approximation with a nucleon-nucleon g-matrix interaction including the 3NF effects. The chiral 3NF effects significantly change the peak height of the triple differential cross section of (p,2p) reactions.

Primary author: Dr MINOMO, Kosho (Research Center for Nuclear Physics, Osaka University)

Co-authors: Mr YOSHIDA, Kazuki (research center for nuclear physics); Prof. OGATA, Kazuyuki (RCNP, Osaka University); Dr KOHNO, Michio (Research Center for Nuclear Physics, Osaka University)

Presenter: Dr MINOMO, Kosho (Research Center for Nuclear Physics, Osaka University)

Session Classification: Session 15

Contribution ID: **96** Type: **Poster Contribution**

Isoscalar monopole and dipole transitions as a probe for cluster states in 24Mg

In this contribution, we will show that isoscalar monopole and dipole transitions are a good probe for cluster states in 24Mg. The cluster states having significant influence on He- and Carbon-burning processes such as 12C+12C and 4He+20Ne are expected in 24Mg according to Ikeda diagram. However, their existences are still ambiguous due to experimental and theoretical difficulties. In this decade, it was suggested that cluster states can be strongly populated by isoscalar monopole and dipole transitions. This means that unknown cluster states can be accessible by isoscalar monopole and dipole transitions. Therefore, we will present antisymmetrized molecular dynamics calculation results for 24Mg and reveal that relation between isoscalar monopole and dipole transition strengths and cluster states of 24Mg. Furthermore, we discuss the p-, 4He- and 12C-decay widths of the excited states.

Primary author: Dr CHIBA, Yohei (Hokkaido University)

Co-author: Dr KIMURA, Masaaki (Hokkaido University)

Presenter: Dr CHIBA, Yohei (Hokkaido University)

Contribution ID: **97** Type: **Poster Contribution**

Neutron-proton Pairing Correlations and Deformation for N = Z Nuclei in sd, pf, gd-shell by the deformed BCS and HFB approach

We investigated neutron-proton pairing correlations effects on the shell evolution of ground state energies by the deformation for $N = Z$ nuclei in sd, pf, dg-shell. We started from a simple shell-filling model constructed by a deformed Woods-Saxon potential with β_2 deformation, and included pairing correlations in the residual interaction, which give rise to smearing of the Fermi surface revealing interesting evolution of the Fermi energy along the shell evolution. In this work, like-pairing and unlike-pairing correlations decomposed as isoscalar $T = 1$ and isovector $T = 0$ components

are explicitly taken into account. Finally, we estimate ground state energies comprising the mean field energy, the pairing energy and the self-energy due to the pairing correlations, in terms of the deformation.

Primary author: Dr HA, Eunja (Soongsil University)

Co-authors: Prof. SAGAWA, Hiroyuki (RIKEN, Aizu University); Prof. CHEOUN, Myung-Ki (Soongsil University)

Presenter: Dr HA, Eunja (Soongsil University)

Contribution ID: **98** Type: **Oral contribution**

Complete Glauber calculations for high-energy inelastic processes

Friday, June 8, 2018 9:36 AM (18 minutes)

The Glauber theory is a powerful and widely used method to describe
high energy nuclear collisions. Since the complete evaluation
of the so-called Glauber amplitude is much involved,
approximate treatment has often been made.
In this contribution, we present our recent developments
of the Glauber model calculations for
nuclear inelastic processes. The Monte Carlo and the factorization methods are employed in order
to evaluate the Glauber amplitude which involves a multi-dimensional integral.
The power of the complete Glauber calculations is demonstrated
by showing some examples:
The total reaction cross sections of 22C [1],
and the inelastic cross sections involving deformed nuclei [2].

[1] T. Nagahisa and W. Horiuchi, in preparation.

[2] S. Hatakeyama and W. Horiuchi, in preparation.

Primary author: Dr HORIUCHI, Wataru (Hokkaido University)

Co-authors: Mr HATAKEYAMA, Shinya (Hokkaido University); Mr NAGAHISA, Taku (Hokkaido University)

Presenter: Dr HORIUCHI, Wataru (Hokkaido University)

Session Classification: Session 15

Contribution ID: **99** Type: **Poster Contribution**

Two novel determinations of nuclear density, temperature, symmetry energy

Nuclear symmetry energy, temperature and density at the time of the intermediate mass fragment formation are determined using two novel methods, i.e., a self-consistent method and a chemical potential method.

(1) In a self-consistent manner, the yields of primary hot fragments are experimentally reconstructed for multifragmentation events in the reaction system ^64Zn + ^112Sn at 40 MeV/nucleon. Using the reconstructed hot isotope yields and an improved method, based on the modified Fisher model, symmetry energy values relative to the apparent temperature, a_sym/T, are extracted. The extracted values are compared with those of the anti-symmetrized molecular dynamics (AMD) simulations, extracted in the same way as that for the experiment, with the Gogny interaction with three different density-dependent symmetry energy terms. a_sym/T values change according to the density-dependent symmetry energy terms used. Using this relation, the density of the fragmenting system is extracted first. Then symmetry energy and apparent temperature are determined in a self consistent manner in the AMD model simulations. Comparing the calculated a_sym/T values and those of the experimental values from the reconstructed yields, \rho /\rho_0 = 0.65 \pm 0.02 , a_sym = 23.1 \pm 0.6 MeV and T= 5.0 \pm 0.4 MeV are evaluated for the fragmenting system experimentally observed in the reaction studied.

(2) In the chemical potential method, ratios of differential chemical potential values relative to the temperature, (\mu_n-\mu_p)/T, extracted from isotope yields of thirteen reaction systems at 40 MeV/nucleon are compared to those of a quantum statistical model to determine the temperature and symmetry energy values of the fragmenting system. The experimental (\mu_n-\mu_p)/T values are extracted based on the Modified Fisher Model. Using the density value of \rho/\rho_0=0.56 from the previous analysis, the temperature and symmetry energy values of T=4.6 \pm 0.4 MeV and a_sym=23.6 \pm 2.1 MeV are extracted in a frame work of a quantum statistical model. These values agree well with those of the previous work, in which a self-consistent method is utilized with AMD simulations.

Primary author: Dr LIU, Xingquan (IMPCAS)

Co-authors: Prof. WANG, Jiansong (IMPCAS); Prof. WADA, Ryoichi (IMPCAS); Dr YANG, Yanyun (Institute of Modern Physics, CAS, China)

Presenter: Dr LIU, Xingquan (IMPCAS)

Contribution ID: **100** Type: **Oral contribution**

Single-particle states and collective modes: results from magnetic moment measurement of 75mCu

Monday, June 4, 2018 11:39 AM (18 minutes)

The atomic nuclei have dual features, the single-particle shell nature and collective modes, which are competing with each other to express the actual nuclear structure. Here we demonstrate the precision analysis of this competition by focusing on the magnetic moment of an isomeric state of a neutron-rich nucleus 75Cu, where an intriguing shell evolution has been reported.
The experimental magnetic moment measurement was carried out at RIBF, taking advantage of a spin-aligned RI beam obtained in a two-step projectile fragmentation scheme. The 75Cu beam with spin alignment reaching 30% was produced by one-proton removal from a secondary beam of 76Zn. The magnetic moment was determined by means of TDPAD method.
In this presentation, the production of spin alignment in the two-step fragmentation scheme will be introduced and the experimental results will be presented. Discussion on the above competition at the neutron-rich Ci isotopes, analyzed with the Monte-Carlo shell model calculation, will also be given.

Primary author: Dr ICHIKAWA, Yuichi (RIKEN Nishina Center)

Presenter: Dr ICHIKAWA, Yuichi (RIKEN Nishina Center)

Session Classification: Session 2

Contribution ID: **101** Type: **Oral contribution**

Persistence of nuclear shell closures far from stability: in-beam γ spectroscopy of 79Cu after proton knockout

Friday, June 8, 2018 11:21 AM (18 minutes)

The shell model remains one of the main building blocks of nuclear structure. Its robustness is well proven for nuclei close to stability, where it successfully explains the occurence of magic numbers. However, these magic numbers are not universal throughout the nuclear chart and their evolution away from stability, observed experimentally over the last decades, has generated much interest. To probe the possible erosion of the Z=28 shell gap in 78Ni, in-beam γ-ray spectroscopy of 79Cu was performed at the Radioactive Isotope Beam Factory of Riken in Japan. The incoming isotopes were identified in the Bigrips spectrometer. The knockout reaction from the selected 80Zn beam at 270 MeV/n took place in the Minos liquid-hydrogen target, surrounded by a TPC for proton tracking. The outgoing nuclei were identified in the Zerodegree spectrometer. The Dali2 scintillator array was installed around Minos for gamma-ray detection. We built the first level scheme of 79Cu up to 4.6 MeV of excitation energy, at the limit of gamma-ray spectroscopy. The results were compared to Monte-Carlo shell-model calculations and show that the 79Cu nucleus can be described in terms of a valence proton outside a 78Ni core, providing indirect evidence of the magic character of the latter. Cross sections were extracted and compared to recent DWIA calculations, from which we find more fragmentation of the single-particle strengths than expected.
New data was also obtained on the 83Ga and 85Ga isotopes beyond N=50, which is presently under analysis and includes a fresh level scheme for 83Ga.

Primary author: FRANCHOO, Serge (IPN Orsay)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Dr FLAVIGNY, Freddy (IPN Orsay); Dr OLIVIER, Louis (IPN Orsay); Dr NIIKURA, Megumi (University of Tokyo); Dr DOORNENBAL, Pieter (RIKEN); Prof. OTSUKA, Takaharu (University of Tokyo); Dr TSUNODA, Yusuke (University of Tokyo)

Presenter: FRANCHOO, Serge (IPN Orsay)

Session Classification: Session 16

Contribution ID: **102** Type: **Oral contribution**

Study of spin-isospin responses of light nuclei near and along the drip line with PANDORA

Thursday, June 7, 2018 9:18 AM (18 minutes)

The charge-exchange (p,n) reactions at intermediate beam energies and small angles, can selectively excite Gamow-Teller (GT) states up to high excitation energies in the final nucleus. Therefore, (p,n) reactions in inverse kinematics applying the missing mass reconstruction[1,2] provide the best and efficient tool to study the B(GT) strengths values of unstable isotopes in a wide excitation energy region, without Q-value limitation.
An experimental program aiming to study the spin-isospin responses of light nuclei along the drip line was started at RIKEN RIBF. A measurement [3], SAMURAI-30, with 5 days of beam time was approved to investigate 8He, 11Li and 14Be nuclei. In a pilot measurement of the mentioned experiment at HIMAC facility in Chiba, we studied the Gamow-Teller transitions of 6He in inverse kinematical (p,n) reactions at 123 MeV/nucleon incident energy using polyethylene target. Our new neutron detector, PANDORA [4], with digital readout was also commissioned.
In this talk, details of experiment and the results of B(GT) strengths distribution of 6He will be reported as well as a brief overview of the whole program will be presented.

[1] M. Sasano et al., Phys. Rev. Lett. 107, 202501 (2011).
[2] M. Sasano et al., Phys. Rev. C 86, 034324 (2012).
[3] L. Stuhl et al., RIKEN Accelerator Progress Report 48, 54 (2015).
[4] L. Stuhl et al., Nucl. Instr. Meth. A 866, 164 (2017).

Primary author: Dr STUHL, Laszlo (Center for Nuclear Study, University of Tokyo)

Co-authors: Dr TAKADA, Eiichi (NIRS); Dr BABA, Hidetada (RIKEN); Mr GAO, JIAN (RIKEN); Dr ZENIHIRO, Juzo (RIKEN Nishina Center); Prof. YAKO, Kentaro (CNS, University of Tokyo); Dr SASANO, Masaki (RIKEN Nishina Center); Dr UESAKA, Tomohiro (RIKEN Nishina Center); Dr PANIN, Valerii (RIKEN, Spin-isospin laboratory); Dr KUBOTA, Yuki (RIKEN Nishina Center); Dr YANG, Zaihong (RIKEN); Dr KORKULU, Zeren (ATOMKI)

Presenter: Dr STUHL, Laszlo (Center for Nuclear Study, University of Tokyo)

Session Classification: Session 11

Contribution ID: **103** Type: **Oral contribution**

E1 responses of neutron-rich Ca isotopes 50Ca and 52Ca

Thursday, June 7, 2018 4:36 PM (18 minutes)

The density dependence of the symmetry energy is one of the keys for understanding the bulk properties of neutron-rich nuclei and astrophysical events, such as supernovae and neutron stars.

Recent theoretical works show that the E1 response of nuclei is well correlated to the density dependence of the symmetry energy close to the saturation density. The dipole polarizability, the inversely energy weighted sum of E1 strength, is pointed out as less model-dependent observable to constrain the density dependence of the symmetry energy. In addition, it is indicated that the low-energy E1 strength up to 10 MeV in 52Ca is well correlated to the density dependence of the symmetry energy. To constrain the symmetry energy with these correlations, the E1 response of 50Ca and 52Ca have been measured by using the relativistic Coulomb excitation.

The experiment was performed using the SAMURAI spectrometer at RIKEN RIBF. The 50Ca and 52Ca beams were impinged on Pb and C targets. The outgoing charged particles and neutrons were measured by SAMURAI spectrometer and the neutron detectors NEBULA and the NeuLAND demonstrator, respectively. The de-excitation gamma-ray from the reaction residue was measured by the gamma-ray detector CATANA.

In this talk, we will report the results obtained for the bound excited states and one-neutron decay channel of 52Ca.

Primary author: Dr TOGANO, Yasuhiro (Tokyo Institute of Technology)

Presenter: Dr TOGANO, Yasuhiro (Tokyo Institute of Technology)

Session Classification: Session 14

Contribution ID: **104** Type: **Oral contribution**

Elastic scattering Investigation of proton-rich 8B and 10C projectiles

Proton-rich nuclei have received less attention from both theory and experiments when compared to neutron-rich nuclei since proton-halo structure is relatively less pronounced as compared to those of neutron-halos [1,2]. The proton-halo configuration for 8B has already been established by the strong dynamic effects observed in elastic, breakup and fusion measurements [3,4,5]. However, the influence of the breakup in the elastic and fusion is not well established yet. The role of the breakup channel in the elastic for the 8B+208Pb system was recently calculated [7]. This work showed that the elastic cross sections at forward angles are damped and at backward angles are enhanced by the breakup channel also indicating that the Coulomb-nuclear interference on the breakup channel is relevant in such system. Another interesting light proton-rich nucleus to be investigated is 10C. This nucleus has a four-body cluster configuration p+p+a+a. It is the only nucleus supposed to have a Brunnian (super-borromean) structure where four rings interconnected are associated to the four body interactions [6]. These facts motivated us to perform two new measurements for the elastic scattering of 8B+208Pb and 10C+208Pb at energy close to the barrier at Cyclotron Institute of the Texas A&M University. In this work we will present the status of the analysis of these measurements. The preliminary results for elastic scattering experiments performed in April and November 2017 at TAMU with 8B and 10C radioactive ion beams on 208Pb target will be present.

[1] J. J. Kolata, V. Guimarães, E. F. Aguilera, Eur.Phys.J. A 52, 123 (2016).
[2] I. Tanihata, H. Savajols, R. Kanungo, Prog. Part. Nucl. Phys. 68, 215 (2013).
[3] V. Guimarães, J. Kolata, et al., Phys. Rev. Lett. 84, 1862 (2000).
[4] E. F. Aguilera, et al., Phys. Rev. C 79, 021601 (2009).
[5] E. F. Aguilera, et al., Phys. Rev. Lett. 107, 092701 (2011).
[6] N. Curtis et al., Journal of Physics: Conf. Series 111 012022 (2008).
[7] J. Rangel, J. Lubian, L. F. Canto and P. R. S. Gomes. Phys. Rev. C 93, 054610 (2016).

Primary authors: Dr SINHA, Mandira (Bose Institute, Kolkata, India); Dr LINARES, Roberto (Universidade Federal Fluminense, Niteroi, Brazil); Dr GUIMARAES, Valdir (Universidade de São Paulo - São Paulo - Brazil)

Co-authors: Dr SAASTOMIENNE, Antti (Texas A&M University, Texas, USA); Dr ROEDER, Brian T. (Texas A&M University, Texas, USA); Mr HUNT, Curtis (Texas A&M University, Texas, USA); Dr AGUILERA, Eli F. (5) Instituto Nacional de Investigaciones Nucleares - Mexico); Dr KOSHCHIY, Evgeniy (Texas A&M University, Texas, USA); Dr ROGACHEV, Grigory V. (Texas A&M University, Texas, USA); Ms JAYATISSA, Heshani (Texas A&M University, Texas, USA); Mr HOOKER, Joosh (Texas A&M University, Texas, USA); Dr PIRES, Kelly C. C. (Universidade de São Paulo, São Paulo, Brazil); Dr JESUS, Lubian (Universidade Federal Fluminense - Niteroi - Brazil); Dr ASSUNCAO, Marlete (Universidade Federal de São Paulo, Diadema, Brazil); Dr LUKYANOV, Sergei (Joint Institute for Nuclear Research, Dubna, Russia); Mr UPADHYAYULA, Sriteja (Texas A&M University, Texas, USA); Dr AHN, Tony (Texas A&M University, Texas, USA); Dr JOBOLEV, Yuri (Joint Institute for Nuclear Research, Dubna, Russia); Prof. PENIONZKEVICH, Yuri (Joint Institute for Nuclear Research, Dubna, Russia)

Presenter: Dr GUIMARAES, Valdir (Universidade de São Paulo - São Paulo - Brazil)

Contribution ID: **105** Type: **Oral contribution**

Study of 19Ne using the 15O + alpha experiment

Tuesday, June 5, 2018 5:12 PM (18 minutes)

Classical novae are one of the most energetic stellar events in the Universe. In this site, intense γ-rays due to the beta decay of 18F produced are emitted by the HCNO cycle. The amount of 18F is determined by two destructive channels 18F(p,α)15O and 18F(p,γ)19Ne[1]. The reaction rates of the two destructive channels affect to the novae calculation model[2,3]. For this reason, many experiments and theoretical works have been reported on the resonances of 19Ne near and above the proton threshold, which can contribute to the reaction rate. However, many relevant parameters are still not measured.[4,5] We performed alpha elastic scattering experiment with the radioactive 15O beam for investigating the resonance parameters near the proton threshold using the thick target method at CRIB of the Center for Nuclear Study. The excitation function of 19Ne was obtained between Ex=3.53 MeV and Ex=11.13 MeV. The experimental details and results on the structure of 19Ne will be presented.

[1] M. Hernanz et al., Astrophys. J. 526, L97 (1999).
[2] S. Utku et al., Phys. Rev. C 58, 1354(E) (1998).
[3] A. Coc et al.,Astron. Astrophys. 357, 561(2000).
[4] A. St. J. Murphy et al., Phys. Rev. C 79, 058801 (2009).
[5] A. M. Laird et al., Phys. Rev. Lett. 110, 032502 (2013).

Primary author: Ms KIM, Dahee (Department of Physics, Ewha Womans University, Seoul, Korea)

Co-authors: Prof. CHEN, A. A. (Department of Physics and Astronomy, McMaster University, Hamilton, Canada); Dr KIM, A. (Department of Physics, Ewha Womans University, Seoul, Korea); Dr KAHL, D. (School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom); Ms LEE, E. J. (Department of Physics, SungKyunKwan University, Suwon, Korea); Ms LEE, E. K. (CUP, Institute of Basic Science, Daejeon, Korea); Ms KIM, G. W. (Department of Physics, Ewha Womans University, Seoul, Korea); Prof. YAMAGUCHI, H. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Mr LEE, J. H. (Department of Physics, SungKyunKwan University, Suwon, Korea); Dr MOON, J. Y. (RISP, Institute of Basic Science, Daejeon, Korea); Mr ABE, K. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Prof. CHAE, K. Y. (Department of Physics, SungKyunKwan University, Suwon, Korea); Prof. HAHN, Kevin Insik (Department of Science Education, Ewha Womans University, Seoul, Korea); Mr GWAK, M. S. (Department of Physics, SungKyunKwan University, Suwon, Korea); Prof. IMAI, N. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Mr KITAMURA, N. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Dr BELIUSKINA, O. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Prof. CHOI, S. H. (Department of Physics and Astronomy, Seoul National University, Seoul, Korea); Mr HAE, S. H. (Department of Physics and Astronomy, Seoul National University, Seoul, Korea); Dr HAYAKAWA, S. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Prof. KUBONO, S. (RIKEN, Nishina Center, Wako, Japan); Ms CHA, S. M. (Department of Physics, SungKyunKwan University, Suwon, Korea); Prof. HONG, S. W. (Department of Physics, SungKyunKwan University, Suwon, Korea); Ms PARK, S. Y. (Department of Physics, Ewha Womans University, Seoul, Korea); Dr PANIN, V. (RIKEN, Nishina Center, Wako, Japan); Mr SAKAGUCHI, Y. (Center for Nuclear Study, University of Tokyo, Wako, Japan); Dr WAKABAYASHI, Y. (RIKEN, Nishina Center, Wako, Japan)

Presenter: Ms KIM, Dahee (Department of Physics, Ewha Womans University, Seoul, Korea)

Session Classification: Session 8

Contribution ID: **106** Type: **Oral contribution**

Inclusive Quasifree Scattering Cross Sections from Medium-Mass Neutron-Rich Nuclei

Friday, June 8, 2018 11:03 AM (18 minutes)

Direct nucleon removal has become a tool of choice to study structure and reactions in exotic nuclei [1,2,3]. Despite the pervasiveness of this method, theoretical approaches to describe these reactions remain incomplete. To remedy this, part of the community has focused on experiments with pure proton targets at intermediate energies where the quasifree scattering paradigm may be invoked and the reaction mechanism simplified [3,4]. However, to date, little data exists for exotic nuclei.
At the Radioactive Isotope Beam Factory, we have measured 77 single proton and neutron removal inclusive cross sections from neutron-rich exotic nuclei from Cr (Z=24) to Tc (Z=43). Obtained on a 10 cm thick liquid hydrogen target [5] at ~250 MeV/U, consistent with quasifree scattering, these results provide a systematic exploration of direct reaction cross sections with isospin and across the N=50 shell closure. The evolution of the cross sections with mass and separation energy will be presented, and the results compared to state-of-the-art Intranuclear Cascade Model and Distorted Wave Eikonal calculations.

[1] T. Wakasa, K. Ogata, T. Noro, Proton-induced knockout reactions with polarized and unpolarized beams, Progress in Particle and Nuclear Physics 96, 32 (2017).
[2] V. Panin et al, Exclusive measurements of quasi-free proton scattering reactions in inverse and complete kinematics, Physics Letters B 753, 204 (2016).
[3] T. Aumann, C. A. Bertulani, J. Ryckebusch, Quasifree (p,2p) and (p,pn) reactions with unstable nuclei, Phys. Rev. C 88, 06461010 (2013).
[4] A. Obertelli and T. Uesaka, Hydrogen targets for exotic-nuclei studies developed over the past 10 years. Eur. Phys. J. A 47: 105 (2011).
[5] A. Obertelli et al, MINOS: A vertex tracker coupled to a thick liquid-hydrogen target for in-beam spectroscopy of exotic nuclei. Eur. Phys. J. A 50: 8 (2014).

Primary author: Ms PAUL, Nancy (CEA Saclay)

Co-authors: Dr OBERTELLI, Alexandre (TU Darmstadt); Prof. CARLOS BERTULANI, Carlos (Texas A&M University-Commerce); Dr SANTAMARIA, Clementine (NSCL, MSU); RODRIGUEZ SANCHEZ, Jose-Luis (GSI, CEA); Dr DOORNENBAL, Pieter (RIKEN)

Presenter: Ms PAUL, Nancy (CEA Saclay)

Session Classification: Session 16

Contribution ID: **107** Type: **Oral contribution**

Study of breakup channels for the 6He+64Zn reaction at energies around the Coulomb barrier.

Thursday, June 7, 2018 4:54 PM (18 minutes)

Reactions induced by neutron halo nuclei have been intensively studied in the last years. The neutron halo structure can affect the dynamic of reactions at energies around the Coulomb barrier producing a significant reduction of the elastic scattering cross section with respect to the Rutherford prediction. This effect can be associated with couplings to breakup channels, since the continuum of such nuclei is close to the ground state. The breakup channel can be split into two parts; the elastic breakup and non-elastic breakup.

The halo nucleus 6He is composed by an alpha core and two weakly bound neutron (S=0.97 MeV). These two neutrons have a large probability to be far away from the alpha core, producing the so-called nuclear halo.
New experimental elastic cross sections for the reaction 6He+64Zn at energies around the Coulomb barrier have been measured and compared with CRC and CDCC calculations. CDCC calculations are based on the elastic breakup of the projectile, while the CRC calculations consider the transfer of one/two-neutron to the bound and unbound states of the target, which is part of the non-elastic breakup. To compute the total non-elastic breakup, the formalism reported in [Phys. Rev. C 95, 044605 (2017)] has been performed. The results show the angular and energy distributions of the breakup fragment coming from 6He+64Zn reaction are well reproduced by the one/two-neutron transfer mechanism, indicating the importance of the non-elastic breakup.

Primary author: Dr FERNÁNDEZ-GARCÍA, Juan Pablo (University of Seville)

Presenter: Dr FERNÁNDEZ-GARCÍA, Juan Pablo (University of Seville)

Session Classification: Session 14

Contribution ID: **108** Type: **Poster Contribution**

Proton- and deuteron-induced reactions on 107Pd and 93Zr at 20 - 30 MeV/u

Nuclear transmutation of long-lived fission products (LLFPs), which are produced in nuclear reactors, is one of the candidate techniques for the reduction and/or reuse of LLFPs. To design optimum pathways of the transmutation process, several nuclear reactions have been studied by using LLFPs as secondary beams. In this study, we report on the proton- and deuteron-induced reactions on 107Pd and 93Zr at 20 - 30 MeV/u.

The experiment was performed at RIKEN RIBF. The degraded RI beams at 20 - 30 MeV/u were produced by a newly developed beam line, OEDO. To induce the reactions, the high-pressure cooled gas targets (H2 and D2) were used. Reaction residues were analyzed by the SHARAQ spectrometer.

In this talk, we will present the details of the experiments and the obtained results.

This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

Primary author: Dr DOZONO, Masanori (Center for Nuclear Study, the University of Tokyo)

Co-authors: COLLABORATION, For ImPACT-RIBF (dummy); Dr OTSU, Hideaki (RIKEN Nishina Center); Mr IRIBE, Kotaro (Department of Physics, Kyushu University); Dr IMAI, Nobuaki (CNS, Univ. of Tokyo); Dr MICHIMASA, Shin'ichiro (CNS, Univ. of Tokyo); Dr OTA, Shinsuke (Center for Nuclear Study, University of Tokyo); Prof. SHIMOURA, Susumu (CNS, University of Tokyo); Dr SUMIKAMA, Toshiyuki (RIKEN Nishina Center); Mr CHIGA, nobuyuki (japan)

Presenter: Dr DOZONO, Masanori (Center for Nuclear Study, the University of Tokyo)

Contribution ID: **109** Type: **Oral contribution**

Evidence for Z=6 subshell closure in neutron-rich carbon isotopes

Tuesday, June 5, 2018 11:00 AM (18 minutes)

The nuclear magic numbers, as we know in stable nuclei, consist of two different series of numbers. The first series – 2, 8, 20 – is attributed to the harmonic oscillator potential, while the second one – 28, 50, 82, and 126 – is due to the spin-orbit (SO) interactions. The spin-orbit interactions are known to be significant and responsible for the large (spin-orbit) splitting of the single-particle states in heavy nuclei. These splittings, however, are expected to diminish in light nuclei due to low orbital angular momenta. This general expectation is supported by the fact that there is an apparent lack of fingerprints for a 'magic number' (subshell closure) at 6 or 14 [1], which might have arisen from the widening 1p1/2-1p3/2 and 1d3/2-1d5/2 gaps, respectively, in the stable nuclei. A possible subshell closure at N=6 has been suggested both theoretically [2] and experimentally [3] in the very neutron-rich 8He isotope. For Z=6 and 14, possible subshell closures have been suggested [4] in the semi-magic 14C and 34Si.

In this talk, we will present experimental evidence for a prevalent subshell closure at proton number Z=6 in the neutron-rich carbon isotopes. We investigated (i) the point proton density distribution radii, combining our recent data for Be, B and C isotopes measured at RCNP, Osaka University and GSI, Darmstadt, with the available data from Ref. [5]; (ii) the atomic masses [6]; and (iii) the electromagnetic transition strengths [7] for a wide range of isotopes. Our systematic analysis revealed marked regularities which support a prominent proton 'magic number' Z=6 in 13-20C.

[1] M. G. Mayer, Nobel Lectures in Physics, 20 - 37 (1963).
[2] T. Otsuka et al., Phys. Rev. Lett. 87, 082502 (2001).
[3] F. Skaza et al., Phys. Rev. C 73, 044301 (2006).
[4] I. Angeli and K. P. Marinova, J. Phys. G: Nucl. Part. Phys. 42, 055108 (2015).
[5] I. Angeli and K. P. Marinova, At. Data Nucl. Data Tables 99, 69 -95 (2013).
[6] M. Wang et al., Chinese Phys. C 41, 030003 (2017).
[7] B. Pritychenko et al., At. Data Nucl. Data Tables 107, 1 - 139 (2016).

Primary author: Dr ONG, Hooi Jin (RCNP, Osaka University)

Co-authors: Dr TRAN, D.T. (RCNP, Osaka University); Dr HAGEN, G. (ORNL); Dr MORRIS, T.D. et al. (ORNL)

Presenter: Dr ONG, Hooi Jin (RCNP, Osaka University)

Session Classification: Session 6

Contribution ID: **110** Type: **Oral contribution**

From ab initio structure predictions to reaction calculations via effective field theory

Tuesday, June 5, 2018 2:54 PM (18 minutes)

Halo nuclei exhibit an uncommon nuclear structure with a larger matter radius compared to stable nuclei [1]. This large size is qualitatively understood as due to the loose binding of one or two valence neutrons, which have then a high probability of presence at a large distance from the other nucleons. They thus form a sort of halo around the compact core of the nucleus. The best known examples are 11Be, with a one-neutron halo, and 11Li, with a two-neutron halo. Due to their short lifetime, these nuclei are mostly studied through reactions like breakup [2]. In order to extract valuable structure information from measured cross sections, a precise model of the reaction coupled to a reliable description of the projectile is needed. Many such models have been developed (see Ref. [3] for a recent review). However, they mostly rely on a simple two- or three-body description of the nucleus. Recently, some of these exotic nuclei have become accessible to ab initio calculations [4]. Unfortunately, such A-body descriptions are too computationally demanding to be directly included within existing reaction models. In the present work, we use the outputs of an ab initio calculations of 11Be as inputs to the description
of that nucleus within a reliable breakup model [5]. That description is inspired by an effective field theory treatment of 11Be [6] (see Ref. [7] for a recent review). Our calculations of the breakup of 11Be on Pb and C at about 70AMeV are in very good agreement with experimental measurements [2]. These excellent results prove the feasibility of incorporating results from ab initio calculations in reaction theory in this way. More importantly, they confirm the results for important aspects of 11Be obtained by the calculations of Calci et al. [4], hence improving our understanding of the nuclear structure far from stability.

References

[1] I. Tanihata J. Phys. G 22 157 (1996)
[2] N. Fukuda et al. Phys. Rev. C 70 054606 (2004)
[3] D. Baye and P. Capel Clusters in Nuclei, Vol. 2 vol 848 ed Beck C (2012, Springer, Heidelberg)
[4] A. Calci, P. Navratil, R. Roth, J. Dohet-Eraly, S. Quaglioni and G. Hupin Phys. Rev. Lett. 117 242501 (2016)
[5] D. Baye, P. Capel and G. Goldstein Phys. Rev. Lett. 95 082502 (2005)
[6] C. Bertulani, H.-W. Hammer and U. van Kolck Nucl. Phys. A 712 37-58 (2002)
[7] H.-W. Hammer, C. Ji and D. R. Phillips J. Phys. G 44 103002 (2017)

Primary author: Prof. CAPEL, Pierre (Johannes Gutenberg Universität Mainz)

Co-authors: Prof. PHILLIPS, Daniel (Ohio University); Prof. HAMMER, Hans-Werner (Technische Universität Darmstadt)

Presenter: Prof. CAPEL, Pierre (Johannes Gutenberg Universität Mainz)

Session Classification: Session 7

Contribution ID: **111** Type: **Oral contribution**

Structure and reactions of N=7 isotones: the role of core degrees of freedom

The explicit consideration of core degrees of freedom is crucial in order to obtain an accurate description of the structure and reactions of light exotic nuclei. In particular, it is important to consider the role of ground state correlations, respecting the Pauli principle, and including at the same time the continuum in the calculations (1). This is possible in the framework of Nuclear Field Theory, taking the coupling of valence particles and core vibrations in a consistent way. I will present calculations of the spectrum and of direct reactions on N=7 isotones, going from the halo nuclei 10Li and 11Be to the more bound systems 12B and 13C.

(1) F. Barranco, G. Potel, R.A. Broglia and E. Vigezzi, Phys. Rev. Lett. 119 (2017) 082501

Primary author: Dr VIGEZZI, Enrico (INFN Milano)

Presenter: Dr VIGEZZI, Enrico (INFN Milano)

Session Classification: Session 6

Contribution ID: **112** Type: **Poster Contribution**

Estimation of α-decay branching and T1/2 of even-even alpha emitters using systematics of r0 parameters

The spin–independent part of Preston's equations [1] of alpha-decay radioactivity is used to calculate nuclear radius parameter (r0) of various even–even alpha emitters. In this approach, the r0 parameter is determined by defining the calculated transition probability for an alpha transition from parent's ground state to daughter's ground state (0+ to 0+) to be equal to the experimental transition rate. [2]. It is observed that, the variation of r0 parameters shows a regular behavior with parent neutron numbers i.e. the value of r0 parameters for each nuclide lies on fairly smooth curves with exception at major and minor shell closures [2, 3]. A similar kind of pattern has also been observed for alpha reduced widths [4-6]. In present work the above said regular behavior of r0 parameters is utilized to calculate α-decay half-lives and branching of an observed alpha transition in various even-even nuclides namely 110Te, 110Xe, 166W, 186Pt, 178Hg, 186Pb, 250Fm and 252No. In order to calculate α-decay branching and half-lives, we used Evaluated Nuclear Structure Data File (ENSDF) analysis program namely ALPHAD [7] and for these calculations r0 parameter is obtained from systematics of neighboring nuclides. On the basis of present study, we also attempted to predict best possible half-lives and α-branching among group of experimentally measured values. These predicted values could be useful for future experimental investigations.

Primary author: Dr KUMAR, Sushil (Department of Physics, Akal University Talwandi Sabo, Punjab (India)-151302)

Co-authors: Prof. JAIN, A.K. (Department of Physics, Indian Institute of Technology, Roorkee 247667, India); Dr SINGH, Balraj (Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada L8S 4M1); Dr SINGH, Sukhjeet (Department of Physics, Akal University, Talwandi Sabo-151302, India)

Presenter: Dr KUMAR, Sushil (Department of Physics, Akal University Talwandi Sabo, Punjab (India)-151302)

Contribution ID: **113** Type: **Oral contribution**

Multinucleon transfer and double charge-exchange reactions

Monday, June 4, 2018 2:24 PM (18 minutes)

There is a renewed interest in single and double charge-exchange reactions due to its connection with the Fermi and Gamow-Teller transitions and double beta decay. It has given origin to different campaigns mainly at RCNP and RIKEN in Japan and at the LNS-INFN Catania in Italy. This last one is focused on the connection of double charge-exchange and the neutrinoless double-beta decay which would help to constrain the possibility of neutrinos to be Majorana particles and eventually the measurement of the mass of the neutrinos.

At the bombarding energies used at the LNS-INFN, different combinations of multinucleon transfer contributes to the final double charge cross section. These contributions are not present in the correspondent beta decay. However, this fact can be of help to further constrain the wavefunction of the nuclei involved since they can also be studied in terms of one and two nucleon transfer cross section which will be measured in the same experiment.

In this contribution, we will evaluate the total cross section for the double charge-exchange reactions 116Cd(20Ne,20O)116Sn and 40Ca(18Ne,18O)40Ar at 15 MeV/nucleon in order to compare with the preliminary experimental data. The double charge exchange will be evaluated as two sequential single charge-exchange processes in 2nd order DWBA. Multinucleon transfer will be added coherently. We will evaluate the possibility of obtaining a full description of the absolute cross section and non-orthogonality terms involved in the 3rd and 4th order DWBA calculations corresponding to the multinucleon transfer processes.

Primary author: Dr LAY VALERA, José Antonio (Universidad de Sevilla)

Presenter: Dr LAY VALERA, José Antonio (Universidad de Sevilla)

Session Classification: Session 3

Contribution ID: **114**   Type: **Oral contribution**

Measurement of ^{77,79}Se(d,p) reactions in inverse kinematics at OEDO

Thursday, June 7, 2018 11:54 AM (18 minutes)

A new beam line named OEDO which can degrade the beam energy and squeeze the spatial distribution was installed at RIBF. As the first campaign of the experiments, ^{77,79}Se(d,p)^{X}Se reactions were measured as a surrogate of the ^{79}Se$(n,\gamma)^{80}$Se* reaction for the nuclear mutation of the radioactive waste of ^{79}Se. The γ transition probabilities from the unbound states of ^{78,80}Se were determined by directly measuring the outgoing particles instead of detecting the γ rays. In this talk, we will explain the experimental setup and the preliminary result on the (n,γ) cross sections.

Primary author: Dr IMAI, Nobuaki (CNS, Univ. of Tokyo)

Co-authors: Mr SUZUKI, Daisuke (Department of Physics, University of Tokyo); Dr WIMMER, Kathrin (The University of Tokyo); Dr DOZONO, Masanori (Center for Nuclear Study, the University of Tokyo); Dr SCHROCK, Philipp (CNS, University of Tokyo); Dr MICHIMASA, Shin'ichiro (CNS, Univ. of Tokyo); Dr OTA, Shinsuke (Center for Nuclear Study, University of Tokyo); Prof. SHIMOURA, Susumu (CNS, University of Tokyo); Dr SUMIKAMA, Toshiyuki (RIKEN Nishina Center)

Presenter: Dr IMAI, Nobuaki (CNS, Univ. of Tokyo)

Session Classification: Session 12

Contribution ID: **115** Type: **Oral contribution**

Structure of 9C via proton elastic scattering

Thursday, June 7, 2018 2:18 PM (18 minutes)

The structure of ^{9}C was studied using ^{8}B+p resonance scattering with the newly commissioned Texas Active Target (TexAT) detector system. Recent theoretical developments allow for robust predictions of level structure of light nuclei, including continuum effects, starting from nucleon-nucleon and three-nucleon interactions [1, 2, 3]. High quality experimental data are necessary to benchmark these predictions. Experimental data on ^{9}C is limited - only two excited states in ^{9}C have been observed. The goal of this work was two-fold. First, the ^{8}B+p resonance scattering was used as the first commissioning experiment for the active target detector system TexAT. This reaction was chosen because the experimental data on ^{8}B+p elastic scattering excitation function at low energy are available [4]. The second goal was to search for positive parity states in ^{9}C (non are known). For that we extended the ^{8}B+p elastic scattering excitation function to higher excitation energy, improved statistics and quality of the existing low energy data, measured angular distribution, and also searched for the ^{8}B(p,2p) reaction channel. Preliminary results of this run will be discussed. [1] N. Mihel, W. Nazarewiz, M. Ploszajzak, and J. Okolowiz, PRC 67, 054311 (2003). [2] A. Volya and V. Zelevinsky, PRL 94, 052501 (2005). [3] S. Baroni, P. Navratil, S. Quaglioni, PRC 87, 034326 (2013). [4] G. Rogachev, et al., PRC 75, 014603 (2007).

Primary author: Mr HOOKER, Joshua (Texas A&M University - Cyclotron Institute)

Co-authors: Dr SAASTAMOINEN, Antti (Texas A&M University - Cyclotron Institute); Dr ROEDER, Brian (Texas A&M University - Cyclotron Institute); Mr HUNT, Curtis Hunt (Texas A&M University - Physics and Astronomy); Ms JAYATISSA, Dangallage Heshani (Texas A&M University); Dr POLLACCO, Emanuel (CEA/DSM/DAPNIA/SPhN, Saclay); Dr UBERSEDER, Ethan (Texas A&M University - Cyclotron University); Dr KOSHCHIY, Evgeniy (Texas A&M University - Cyclotron); Dr ROGACHEV, Grigory (Texas A&M University - Cyclotron Institute); UPADHYAYULA, Sriteja (Cyclotron Institute - Texas A&M University); Dr AHN, Sunghoon (Texas A&M University - Cyclotron Institute)

Presenter: Mr HOOKER, Joshua (Texas A&M University - Cyclotron Institute)

Session Classification: Session 13

Contribution ID: **116** Type: **Poster Contribution**

Complexities in 3QP Coriolis Mixing Calculations

In present paper, we explored various complexities involved in three-quasiparticle (3QP) Coriolis mixing calculations [1]. The major issues involved in these calculations are:
a)The parallel and anti-parallel coupling of projections of angular momenta of three valence particles on nuclear symmetry axis leads to four different band-heads and hence four different rotational bands for a given 3QP configuration [2]. Thus, even for a small number of 3QP configurations, the basis space of interacting bands become large and hence enhance the complexity of calculations.
b)Since experimental data for 3QP bands is still scarce so that the band-head energies of most the important bands taking part in the Coriolis mixing are not known.
c)The sign of the Newby shift, one of the important input parameter used in 3QP calculations, is still an open problem.
In order to resolve above said complexities involved in 3QP Coriolis mixing calculations we used empirical version Three-Quasiparticle plus Rotor Model [1]. In these calculations we only considered 3QP bands containing low- orbitals and hence leads to a relatively small basis space. The band-head energies of various interacting bands are estimated using known properties of the involved one-quasiparticle (1QP) configuration from the neighboring odd-A nuclei [3]. The Newby shifted energies are estimated using approach of Sood and Ray [4] for odd-odd nuclei. In present study, we successfully explained the experimentally observed staggering pattern in some 3QP bands based on low- orbitals using axially symmetric Three-Quasiparticle plus Rotor Model.

Primary author: Dr SINGH, Sukhjeet (Department of Physics, Akal University, Talwandi Sabo-151302, India)

Co-author: Dr KUMAR, Sushil (Department of Physics, Akal University, Talwandi Sabo-151302, India)

Presenter: Dr KUMAR, Sushil (Department of Physics, Akal University, Talwandi Sabo-151302, India)

Contribution ID: **117** Type: **Poster Contribution**

Beta-delayed proton emission of the drip-line nucleus 73Rb

Nuclei near the neutron and proton drip lines play a key role in our understanding of astrophysics, weak-interaction physics, and nuclear structure. Weakly-bound or proton-unbound nuclei at the rp-process waiting points, such as the unbound Tz = −1/2 nucleus 73Rb, are critical for constraining calculations and observations of type I x-ray bursts. For instance, the rp process is greatly slowed near 72Kr (N = Z) due to its relatively long β-decay half-life and inhibited proton capture. This waiting point, however, may be bypassed by sequential 2p-capture through 73Rb - a reaction which is sensitive to the 73Rb proton separation energy [1]. The recent discovery of the relatively long-lived 72Rb nuclear "sandbank" highlights the interplay of the Coulomb interaction and structure effects that can arise at the proton drip line, particularly in the region of 73Rb [2]. To probe the extent by which 73Rb is proton unbound we have performed an implant-decay experiment designed to measure β-delayed protons from states in 73Rb fed through the decay of 73Sr (t1/2 ~ 30 ms). The experiment was carried out at NSCL where a newly available 92Mo primary beam was used to access neutron-deficient nuclei with Z>36 (krypton), producing 73Sr as well as other nearby neutron-deficient isotopes of interest. Short-lived nuclei were transported to the Beta-Counting Station (BCS) where they were identified and implanted in a silicon DSSD surrounded by the Segmented Germanium Array (SeGA). The secondary beam was purified with the RF Fragment Separator which reduced the total implantation rate to ~10 pps, thereby enabling the successful detection and correlation of β-delayed proton groups from 73Rb. Details of the experimental setup and new decay results, as well as the potential impact on the 72Kr rp-process waiting point will be presented.

- This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Award No. DE-FG02-94ER40848 (UML) and DE-AC02-06CH11357 (ANL); the National Nuclear Security Administration through the Nuclear Science and Security Consortium under Award Number(s) DE-NA0003180 and/or DE-NA0000979; and the National Science Foundation under Contract No. PHY-1102511.

Primary authors: Prof. ROGERS, Andrew (Department of Physics and Applied Physics, University of Massachusetts Lowell); Dr MORSE, Christopher (Department of Physics and Applied Physics, University of Massachusetts Lowell)

Co-authors: Dr DOMBOS, Alexander (National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University); Prof. LISTER, Christopher (Department of Physics and Applied Physics, University of Massachusetts Lowell); SOLTESZ, Douglas (Institute of Nuclear and Particle Physics, Department of Physics and Astronomy); DOUCET, Emery (Department of Physics and Applied Physics, University of Massachusetts Lowell); Prof. SCHATZ, Hendrick (National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University); Dr CLARK, Jason (Argonne National Laboratory); CHILDERS, Katherine (National Superconducting Cyclotron Laboratory and Department of Chemistry, Michigan State University); Dr SCHMIDT, Konrad (National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University); BRANDENBURG, Kristyn (Institute of Nuclear and Particle Physics, Department of Physics and Astronomy); Prof. BENDER, Peter (Department of Physics and Applied Physics, University of Massachusetts Lowell); LEWIS, Rebecca (National Superconducting Cyclotron Laboratory and Department of Chemistry, Michigan State University); Prof. LIDDICK, Sean

(National Superconducting Cyclotron Laboratory and Department of Chemistry, Michigan State University); Dr JIN, ShiLun (National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University); SUBEDI, Shiv Kumar (Institute of Nuclear and Particle Physics, Department of Physics and Astronomy); Prof. MEISEL, Zachary (Institute of Nuclear and Particle Physics, Department of Physics and Astronomy)

Presenter: Prof. ROGERS, Andrew (Department of Physics and Applied Physics, University of Massachusetts Lowell)

Contribution ID: **118** Type: **Poster Contribution**

Constraining the ^{30}P(p,γ)^{31}S Reaction Rate, via a Measurement of the ^{32}S(p,d)^{31}S* Reaction

Accurate modeling of classical nova nucleosynthesis is fundamentally dependent on the thermonuclear reaction rates of the nuclei involved. In particular it has been shown that the ^{30}P(p,γ)^{31}S reaction rate is the largest source of uncertainty in the final abundance of nuclei created in a classical nova, involving an ONe white dwarf. The calculation of the ^{30}P(p,γ)^{31}S reaction rate, at nova temperatures, requires knowledge of the spin and parity assignments and partial widths of the levels in ^{31}S just above the proton threshold. To obtain the relevant nuclear data, a measurement of the ^{32}S(p,d)^{31}S* reaction has been performed at the Texas A&M Cyclotron Institue using a proton beam from the K150 cyclotron and a target consisting of ZnS deposited on a thin carbon backing. The newly commisioned, high-efficiency, particle-gamma array, Hyperion, was used in a configuration with 12 HPGe clover detectors and a dE-E telescope of segmented annular silicon detectors downstream of the target position for the detection of direct reaction products. In addition, a single silicon detector was placed upstream of the target for the detection of decay protons. Initial results from the experiment will be presented.
\\\\
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physic under contracts DE-FG02-96ER40983 (UTK), DE-AC05-00OR22725 (ORNL), DE-NA-0003780 (Notre Dame), DE-AC52-07NA27344 (LLNL), and DE-FG03-93ER40773 (TAMU), with additional support from The Welch Foundation, The National Science Foundation under PHY-1430152 (JINA-CEE), and the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory.

Primary authors: CHIPPS, K.A. (Oak Ridge National Laboratory); HUGHES, R.O. (Lawerence Livermore National Laboratory); BURCHER, Sean (University of Tennessee Knoxville)

Co-authors: SAASTAMOINEN, A. (Texas A&M University); SIMON, A. (University of Notre Dame); REINGOLD, C. (University of Notre Dame); CLARK, H. (Texas A&M University); JAYATISSA, H. (Texas A&M University); BURKE, J. (Lawerence Livermore National Laboratory); HOOKER, J. (Texas A&M University); CIZEWSKI, J.A. (Rutgers University); ALLMOND, J.M. (Oak Ridge National Laboratory); SCHMIDT, K. (Joint Institute for Nuclear Astophysics - Center for the Evolution of the Elements); JONES, K.L. (University of Tennessee Knoxville); COOPER, N. (University of Notre Dame); AHN, S. (Texas A&M University); OTA, S. (Texas A&M University); UPADHYAYULA, S. (Texas A&M University); PAIN, S.D. (Oak Ridge National Laboratory)

Presenter: BURCHER, Sean (University of Tennessee Knoxville)

Contribution ID: **119** Type: **Oral contribution**

Study of the A=9 T=3/2 isobaric quartet through R-Matrix analysis of resonance scattering of analogue states.

Thursday, June 7, 2018 2:36 PM (18 minutes)

Studies of the structure of neutron rich nuclei are important for exploring shell evolution and the development of theoretical models. While transfer reactions are currently the primary method of studying neutron rich nuclei it is suggested that study of isobaric analogue states through resonance proton scattering could be used as well [1]. We've performed a benchmark study of the A=9, T=3/2 isobaric quartet, populating T=3/2 states in 9Be using 8Li+p resonance scattering. R-matrix analysis combined with the optical model has been applied for analysis of the 8Li+p excitation function to extract the parameters of the isobaric analog states in 9Be. We compare the results of this experiment to the available data on 9Be T=3/2 states and on the other members of the A=9, T=3/2 isobaric quartet - 9Li [2] and 9C [3]. We show that proton resonance scattering can be a useful complimentary tool for spectroscopy studies of neutron rich nuclei with radioactive beams, provided that robust procedure can be established to fix the parameters of the optical model potentials. The radioactive beam of 8Li was delivered by RESOLUT facility at the John D. Fox superconducting linear accelerator facility at Florida State University and also by MARS facility at the Cyclotron Institute at Texas A&M University. The 8Li+p excitation function was measured using modified thick target approach and also with active target detector - Texas Active Target (TexAT), as part of TexAT's commissioning run.

[1] V. Z. Goldberg, AIP Conference Proceeding 455 319 (1998)
[2] A.H. Wuosmaa, et al., Phys. Rev. Lett. 94 082502 (2005)
[3] G. V. Rogachev et al., Phys. Rev. C 75 014603 (2007)

Primary author: Mr HUNT, Curtis (Texas A&M University - Physics and Astronomy)

Co-authors: Prof. (University of Notre Dame - Department of Physics); Dr KUCHERA, Anthony (Florida State University -Department of Physics; Davidson); Prof. ROGACHEV, Grigory (Texas A&M University - Physics and Astronomy); Ms JAYATISSA, H. (Texas A&M University - Department of Physics and Astronomy); Prof. WIEDENHOVER, Ingo (Florida State University - Department of Physics); Mr HOOKER, J. (Texas A&M University - Department of Physics and Astronomy); Dr BABY, L. T. (Florida State University - Department of Physics); Dr AHN, S. (Texas A&M University - Cyclotron Institute); Dr ALMARAZ-CALDERON, Sergio (Florida State University - Department of Physics); Mr UPADHYAYULA, T. (Texas A&M University - Department of Physics and Astronomy); Dr GOLDBERG, Vladilen (Texas A&M University - Cyclotron Institute); Prof. TAN, Wanpeng (University of Notre Dame - Department of Physics); Dr KOSHCHIY, Y. (Texas A&M University - Cyclotron Institute)

Presenter: Mr HUNT, Curtis (Texas A&M University - Physics and Astronomy)

Session Classification: Session 13

Contribution ID: **121** Type: **Poster Contribution**

Neutron-rich nuclei produced at zero degrees in damped collisions

Deep-inelastic processes between complex nuclei were first observed in the 1960s, and in the 1970s the importance of such reaction mechanism was recognized and theoretical concepts were developed. Characteristic features of deep-inelastic collisions include: formation of a dinuclear system which rotates almost rigidly, nucleons exchange governed by N/Z equilibrium, evaporation of nucleons or/and light clusters followed by the separation into a quasi-projectile (QP) and quasi-target(QT).
It has been long known that QP obtained from short interaction time has minimum exchange of nucleons and they are generally observed around the grazing angle where a maximum in the angular distribution of the QP. On the other side QP obtained from long interaction times can be observed at all the angles, with their kinetic energy decreasing further they are deviated from grazing angle. A second maximum can be expected at forward angles for QP obtained from more nucleons exchanged as illustrated in Wilczynski plot [2]. Until now, measurements close to 0° have not been performed due to the difficult experimental measurement.
An experiment have been performed in GANIL, France, where was studied the deep-inelastic reactions induced by a beam of 18O at 8.6 MeV/A on a 238U target. The quasi-projectiles emitted at an angle ≤1° were selected and separated using LISE spectrometer. The identification was performed using a dE-E silicon telescope. The double differential reaction cross-section was obtained for stable and neutron rich isotopes around the 18O beam. The momentum distribution obtained for the neutron-rich nuclei will be shown together with the prediction of two different deep-inelastic models: DIT [1] and NNCLE [2].

[1] L. Tassan-Got, C. Stephan Nucl. Phys. A524, 121 (1991).
[2] A.V. Karpov and V.V. Saiko, Phys. Rev. C 96, 024618 (2017).

Primary author: Dr STEFAN, Gheorghe Iulian (IPN Orsay)

Presenter: Dr STEFAN, Gheorghe Iulian (IPN Orsay)

Contribution ID: **122** Type: **Poster Contribution**

TI-STAR: A new silicon tracker for direct reaction studies at ARIEL

The future ARIEL facility, under development at TIRUMF, Vancouver, BC, will produce radioactive ion beams from photofission with unprecedented purities and intensities in the mass A=100 region. The first stage of ARIEL is the $4.24M CANadian Rare Isotope Facility with Electron Beam Ion Source (CANREB), which will go online in 2019.

Within an international collaboration of the University of Guelph (Canada), TRIUMF (BC, Canada), Colorado School of Mines (USA) and the Technical University of Munich (Germany), we have designed a new auxiliary charged particle detector, to be coupled to the high-granularity TIGRESS array of HPGe detectors at TRIUMF. The new TI-STAR (TIGRESS Silicon Tracker ARray) is optimized for direct nuclear reaction studies with heavy, exotic beams at ARIEL. TI-STAR will host an extended gas target, filled with a pure 1H, 2H, 3He or 4He gas at 1 bar. For the first time, ultrathin silicon detectors (20um) will be used to track the interaction vertex event-by-event with over 4000 channels of silicon strip detectors, processed by SKIROC ASICs. The new approach of TI-STAR offers a number of benefits over active targets (rate capabilities, less background reactions, better missing mass resolution for heavy beams etc.) and will allow to couple the tracker to an array of HPGe detectors.

TI-STAR will offer a gain of up to two orders of magnitude in luminosity for direct nuclear reaction studies at ISOL facilities in comparison to experiments with loaded foils. We will discuss the opportunity to measure neutron-capture cross sections via the "Oslo" method following one-neutron transfer to key nuclei along the r-process path in the A=130 region. Thanks to the vertex reconstruction in TI-STAR, the Doppler correction of TIGRESS spectra is significantly enhanced specially at high gamma ray energies, allowing to measure momentum transfers and spectroscopic factors in the region of high level densities, like at threshold energies for critical reactions along the rp process in the A=60 region.

Using the Skyrme Hartree-Fock method it has been shown that the measurement of the energy dependence of direct nuclear reaction cross sections is a sensitive measure for the radial wavefunctions of the outermost orbitals in neutron-rich nuclei. We will discuss how TI-STAR will give access to systematic measurements of neutron halos in medium-heavy and heavy nuclei. This will allow to inspect the importance of the characteristic behavior of weakly bound orbitals with low angular momentum for a more consistent description of nuclear shell evolution. Another goal of TI-STAR is the direct measure of (alpha, p) and (p, alpha) cross sections, constraining thermonuclear reaction rates. Here, TI-STAR offers the possibility to measure the temperature dependence of S-factors in a single measurement. TI-STAR also will allow new access to the neutron-rich region north-east of 208Pb for the study of shell evolution and fission barrier heights, critical for our understanding of r-process fission re-cycling.

This presentation will concentrate on the new physics opportunities accessible through TI-STAR at ARIEL. We also will present the technical and electronics design of TI-STAR and will discuss the results from detailed GEANT4 simulations.

Primary author: Ms ATAR, Leyla (University of Guelph)

Co-authors: KILIC, Ali (University of Guelph); SVENSSON, Carl (University of Guelph); BERNER, Christian (TU Munich); Dr MUECHER, Dennis (Technical University Munich); HYMERS, Devin (University of Guelph); SARAZIN, Fred (Colorado School of Mines); Dr HACKMAN, Greg (TRIUMF); POLLACCO, Lolly (CEA Saclay); BOEHMER, Michael (TU Munich); GARRETT, Paul (University of Guelph); HEN-

DERSON, Robert (TRIUMF); OPENSHAW, Robert (TRIUMF); GERNHAEUSER, Roman (TU Munich); ROCKMAN, Tomer (University of Guelph); BILDSTEIN, Vinzenz (University of Guelph)

Presenter: Ms ATAR, Leyla (University of Guelph)

Contribution ID: **123** Type: **Poster Contribution**

Optical Potentials of Exotic Nuclear Systems Studied by Transfer Reactions

Since the optical model was first applied to describe nuclear scattering and absorptions of neutron on a variety of target nuclei, it has been extensively utilized with great success for the last seven decades and is now considered as one of the most fundamental reaction models in nuclear physics. In general, optical model potentials (OMPs) are extracted by fitting the angular distribution of elastic scattering. However, at energies close to and below the barrier, the distributions become flat and not enough information can be extracted. For reactions induced by unstable nuclei, the situation becomes even dire due to limitations of the intensity and/or the phase-space qualities of radioactive ion beams (RIBs). In view of this fact, a transfer reaction method was proposed to study the OMPs of halo systems by the utilization of a stable beam, which can yield fairly precise results. With this novel method, the energy dependence of the OMPs of 6He+64Zn and 209Bi have been investigated intensively, by measuring the single proton transfer reactions 63Cu(7Li,6He)64Zn and 208Pb(7Li,6He)209Bi at the HI-13 tandem accelerator at CIAE (China Institute of Atomic Energy). For the case of 6He+209Bi, an abnormal behavior was observed in the imaginary potential: it increases first with energy decreasing below the barrier and then falls quickly down to 0. It is the first time the threshold of the imaginary potential has been determined in an exotic nuclear system. Moreover, the experimental results indicate that the dispersion relation is not applicable for this system, which may be a common phenomenon for exotic nuclear systems. Some possible explanations for such a peculiar behavior are discussed, but further study is still desired for the underlying physics.

Primary authors: Prof. LIN, Chengjian (China Institute of Atomic Energy); Dr JIA, Huiming (China Institute of Atomic Energy); Dr YANG, Lei (China Institute of Atomic Energy)

Presenters: Prof. LIN, Chengjian (China Institute of Atomic Energy); Dr JIA, Huiming (China Institute of Atomic Energy); Dr YANG, Lei (China Institute of Atomic Energy)

Contribution ID: **124** Type: **Oral contribution**

Studying clustering in O-14 and Be-7 nuclei using resonant scattering and Coulomb excitation

Thursday, June 7, 2018 2:54 PM (18 minutes)

Clustering in light nuclei is a prominent feature that manifests itself through various physical observables, which serve as a guide and constraint for nuclear theory. More precise data on these observables, especially for unstable nuclei, are needed to better constrain nuclear theory and thus give us a more fundamental understanding of what causes nuclei to cluster. In order to obtain more data on cluster states in light nuclei, we performed an experiment using resonant alpha scattering with a C-10 radioactive beam to search for cluster states in the proton-rich nucleus O-14 where the structure and properties of levels above the alpha threshold are not well known. Scattering cross sections for the C-10 + alpha resonant scattering were measured with the Prototype Active-Target Time-Projection Chamber. Preliminary results for the analysis of this experiment will be presented. A second experiment using Coulomb excitation with a radioactive beam of Be-7 will be presented. The electromagnetic transition strength to the first excited state was measured and the current results will be compared to various ab-initio nuclear model predictions. These predictions show that clustering and thus the inclusion of continuum states is important for reproducing several electromagnetic observables.

Primary author: AHN, Tan (University of Notre Dame)

Co-authors: SIMON, Anna (University of Note Dame); BARDAYAN, Dan (University of Notre Dame); Dr BAZIN, Daniel (Michigan State University); LONG, Jacob (University of Notre Dame); BRADT, Joshua (NSCL, Michigan State University); CARPENTER, Lisa (NSCL, Michigan State University); HALL, Matthew (University of Notre Dame); BRODEUR, Maxime (University of Notre Dame); HENDERSON, Samuel (University of Notre Dame); BECEIRO, Saul (NSCL, Michigan State University); AGUILAR, Sebastian (University of Notre Dame); TAN, Wanpeng (University of Notre Dame); MITTIG, Wolfgang (NSCL, Michigan State University); AYYAD, Yassid (Lawrence Berkeley National Lab)

Presenter: AHN, Tan (University of Notre Dame)

Session Classification: Session 13

Contribution ID: **125** Type: **Poster Contribution**

Investigation of 198,200Hg isotopes

The observation of a large permanent electric dipole moment (EDM) would represent a clear signal of CP violation from new physics outside the Standard Model. The 199Hg isotope currently provides the most stringent limit on an atomic EDM, which is converted to a limit on the nuclear EDM via a calculation of the Schiff moment, requiring knowledge of the nuclear structure of 199Hg. Ideal information to further develop and constrain the 199Hg Schiff moment nuclear structure theoretical models would be the E3 and E1 strength distributions to the ground state, and E2 transitions amongst excited states. The high level density of 199Hg makes those determinations extremely challenging, however similar information can be obtained from exploring surrounding even-even Hg isotopes. One of the most direct ways of measuring the E3 and E2 matrix elements is through inelastic hadron scattering, and single-nucleon transfer reactions on targets of even-even isotopes of Hg can yield important information on the single-particle nature of 199Hg.

As part of a campaign to study the Hg isotopes, a number of experiments have been performed using the Q3D spectrograph at the Maier-Leibnitz Laboratory, with 22 MeV deuteron beams impinging on enriched Hg32S targets. The first set are inelastic deuteron scattering experiments, 198Hg(d,d')198Hg and 200Hg(d,d')200Hg. Deformation parameters were extracted through coupled-channel calculations with global optical-model potential (OMP) parameter sets for 200Hg. The second set of experiments were single-nucleon transfer reactions, 198Hg(d,p)199Hg and 200Hg(d,t)199Hg, with spin-parity assignments and spectroscopic factors extracted through distorted-wave Born approximation calculations with global OMP sets. Highlights of the results for the four experiments will be presented.

Primary author: DIAZ VARELA, Alejandra (University of Guelph)

Co-authors: RADICH, A.J. (University of Guelph); LAFFOLEY, A.T. (University of Guelph); MACLEAN, A.T. (University of Guelph); HADINIA, B. (University of Guelph); JIMEDDORJ, B. (University of Guelph); REBEIRO, B. (University of the Western Cape); BURBADGE, C. (University of Guelph); SVENSSON, C.E. (University of Guelph); JAMIESON, D.S. (University of Guelph); RAND, E.T. (University of Guelph); BALL, G.C. (TRIUMF); WIRTH, H.-F. (Ludwig-Maximilians-Universitat Munchen); LEACH, K.G. (Colorado School of Mines); GARRETT, P.E. (University of Guelph); HERTENBERGER, R. (Ludwig-Maximilians-Universitat Munchen); TRIAMBAK, S. (University of the Western Cape); FAESTERMANN, T. (Technische Universitat Munchen); BILDSTEIN, V. (University of Guelph)

Presenter: DIAZ VARELA, Alejandra (University of Guelph)

Contribution ID: **126** Type: **Poster Contribution**

Study of the Molecular States in Oxygen 20

It is well established that clustering is an essential aspect of nuclear many-body system. In neutron-rich domains, the valence neutrons in nuclei can exist in molecular orbitals, their role is similar to that of electrons in covalent bonds in atomic molecules, which help to stabilize the unstable multi-cluster states. The AMD plus GCM calculation found that the valence neutrons give richer structures for 20O. It suggests that the second 0+ band is a mixture of the 12C+4He+4n and 14C+6He cluster structures, and the third 0+ band and the 0- band have prominent 16C+4He cluster structure, and these two bands are regarded to be parity doublet bands.

Our group has performed an inelastic breakup experiment with a 30MeV/A 20O beam off a plastic target in Lanzhou to study the cluster states in 20O above 16C+α breakup threshold. With both the invariant mass and missing mass methods, we have detected the breakup fragments and the recoiled protons to reconstruct the two interest rotational bands. Thanks to the excellent energy calibration results and particle identification, 7 excited states of Oxygen 20 from this spectrum are in excellent agreement with those published in Bohlen's work. Besides, a new excited state is proposed to exist in Oxygen 20 with excitation energy of 17.16MeV, which decays predominantly in the way of cluster emission rather than neutron emission. And this state has not been observed by previous experiments.

Primary authors: Mr LIU, Yang (Peking University, China); Prof. YE, Yanlin (Peking University)

Presenter: Mr LIU, Yang (Peking University, China)

Contribution ID: **127** Type: **Oral contribution**

Dynamics of 11Be on a gold target at energies around the Coulomb barrier

The study of exotic nuclei has become a central focus of nuclear structure research. The advent of intense secondary beams has allowed for the production and detailed study of the most extreme nuclear systems. The discovery of halo nuclei and the coupling of these weakly bound systems to the continuum have brought renewed interest in the modelling of nuclear reactions. Reaction studies of these weakly bound systems at energies close to the Coulomb barrier are of great interest due to the interplay between the reaction process and the structure of the projectile. In elastic scattering at low energies the nucleus has time to adapt during the collision, giving rise to unique polarization effects. The Coulomb interaction dominates the reaction process with heavy targets. The low binding energy and the strong dipolar polarization contribute to a significant enhancement of the breakup cross section, even below the Coulomb barrier [1].

Together with the deuteron, 11Be is the first and the most studied one-neutron halo nucleus with the particular feature that its first excited state (Ex=320 keV, J⊠= ½-) is also a halo state and presents a strong dipolar coupling to the ground state (J⊠= ½+). In this conference, I will present new experimental data for the elastic, inelastic and breakup channels of the 11Be + 197Au reaction at incident energies around and below the Coulomb barrier, with the elastic and inelastic channels separated for the first time in this energy range [2]. The experiment was performed at TRIUMF, using the HPGe detector array TIGRESS in coincidence with Silicon detectors for the identification of the Be fragments. State-of-the-art CDCC calculations including core excitations are able to explain all the scattering distributions simultaneously, and clearly support the latest dB(E1)/dE distribution measured at RIKEN (Fukuda et al [3]). The present study settles the question about the dB(E1)/dE to the continuum of the 11Be and demonstrates that the reaction mechanism is sensitive to subtle structure features, such as core deformation in a halo nucleus. The energy distribution of the breakup fragments for different angular intervals has also been deduced and compared with the different models and kinematic scenarios [4].

[1] J. P. Fernández-García et al., PRL 110, 142701 (2013)
[2] V. Pesudo et al., PRL118, 152502 (2017)
[3] N. Fukuda et al., PRC 70, 054606 (2004)
[4] V. Pesudo et al., in preparation

Primary author: Prof. G. BORGE, Maria Jose (Instituto de Estructura de la Materia, CSIC)

Co-authors: Dr MORO, A. M. (University of Seville); Dr PESUDO, Vicente (CIEMAT)

Presenter: Prof. G. BORGE, Maria Jose (Instituto de Estructura de la Materia, CSIC)

Contribution ID: **128** Type: **Oral contribution**

One-neutron Knockout from Proton-rich Carbon Isotopes

The structure of proton-rich Carbon isotopes has been investigated using one-neutron knockout reactions on a ^9Be-target at 1670\,AMeV. The knockout cross section and corresponding momentum distribution of the residue have been measured for the reactions ^9Be(^{12}C,^{11}C)X, ^9Be(^{11}C,^{10}C)X and ^9Be(^{10}C,^{9}C)X. The experimental cross sections were compared to theoretical predictions of shell-model calculations. The quenching factor of the spectroscopic factor has been obtained.

Primary author: Mr SCHLEMME, Steffen (TU Darmstadt / GSI)

Co-authors: WEICK, Helmut (GSI); Prof. ENDERS, Joachim (TU Darmstadt); NOCIFORO, Steffen (GSI)

Presenter: Mr SCHLEMME, Steffen (TU Darmstadt / GSI)

Contribution ID: **129** Type: **Oral contribution**

Direct reaction mechanisms and fusion hindrance of light, weakly-bound nuclides

Wednesday, June 6, 2018 11:39 AM (18 minutes)

Near-barrier collisions involving light, weakly-bound nuclei exhibit a diverse range of reaction phenomenon, including direct breakup, nucleon transfer, and fusion. The interplay of these different mechanisms is of great interest, since fusion reactions of 6,7,8Li, 9Be and 10,11B have been found to be significantly suppressed, by up to 35% [see 1 and refs. therein]. The root cause of this suppression is believed to be direct reaction processes, which cause disintegration of the projectile into clusters. If only part of the projectile is then captured (incomplete fusion), then complete fusion will be reduced. A strong correlation between the lowest energy direct breakup threshold QBU and the degree of fusion suppression [1], suggests that direct breakup into intrinsic clusters (e.g., 6He=α+2n, 7Li=α+t) is the culprit. The reality is more subtle: transfer reactions can also trigger projectile disintegration [2,3], and in some cases transfer dominates over direct breakup.

Here we consider stochastic classical dynamical models (SCDMs), which can treat both direct and transfer-triggered breakup simultaneously, and make predictions for above-barrier reaction outcomes [4,5]. SCDMs follow the classical trajectory of the projectile and target R(t), which is stochastically sampled to determine a location of breakup given some assumed probability function PBU(R) [4,5,6]. The resulting breakup fragments are then propagated in the field of the target-like nucleus, until they fuse or escape. By constraining PBU(R) using sub-barrier breakup, above-barrier reaction outcomes can be predicted.

The development of SCDMs has also clarified the crucial role that nuclear structure plays. Since the formation of a compound nucleus takes just 10-21 seconds, if breakup is to suppress fusion, it must occur promptly: narrow resonance states will not decay fast enough [3]. Understanding the mechanisms for prompt breakup requires careful analysis of the measured energy and angle correlations of the fragments, but suggests that (a) prompt breakup following direct excitation (e.g., 7Li to α+t) occurs quickly [6], whereas (b) prompt breakup following transfer to broad resonances is delayed, and cannot explain the observed fusion [5,7].

We discuss this key topic in near-barrier reactions via reactions of 7Li, where both direct and transfer-induced are strong, and consider whether the phenomenon is likely to persist in light exotic systems such as 6He, 7Be, and 8B.

[1] Wang et al., Phys. Rev. C 90, 034612 (2014).
[2] Shrivastava et al., Phys. Letts. B, 633, 463 (2006).
[3] Luong et al., Phys. Letts. B 695, 105 (2013)
[4] Diaz Torres et al., Phys. Rev. Letts. 98, 152701 (2007)
[5] Simpson et al., Phys. Rev. C 93, 024695 (2016)
[6] Kalkal et al., Phys. Rev. C 93, 044605 (2016)
[7] Cook et al., Phys. Rev. C 93, 064604 (2016)

Primary author: Dr SIMPSON, Edward (Australian National University)

Co-authors: Prof. HINDE, David (Australian National University); Dr COOK, Kaitlin (Australian National University); Prof. DASGUPTA, Mahananda (Australian National University); Dr KALKAL, Sunil (Thapar Institute of Engineering and Technology)

Presenter: Dr SIMPSON, Edward (Australian National University)

Session Classification: Session 10

Contribution ID: **130** Type: **Oral contribution**

Study of 19C using single-neutron knockout

Thursday, June 7, 2018 9:36 AM (18 minutes)

The evolution of shell structure toward the driplines is a subject of importance in nuclear physics. For a half decade the p-sd-shell nuclei have been a useful tool for expanding our understanding of shell evolution. 19C is one of those nuclei, well known as the s-wave halo ground state. While the low-lying excited states with 3/2+ and 5/2+ were identified by experimental studies, there exists an argument of bound nature of 5/2+1. From a theoretical point of view, shell model calculations with different interactions show discrepancy in location and ordering of levels.

We investigated the neutron-unbound states of 19C using the one-neutron knockout reaction with SAMURAI spectrometer at RIBF, RIKEN. The 20C beam impinged on a carbon target to produce 19C. The decay products, 18C and a neutron, were detected using SAMURAI and NEBULA neutron array.

In this talk, the observation of populated states and the discussion in the context of shell-model calculations will be reported.

Primary author: Dr HWANG, Jongwon (Center for Nuclear Study, University of Tokyo)

Presenter: Dr HWANG, Jongwon (Center for Nuclear Study, University of Tokyo)

Session Classification: Session 11

Contribution ID: **131** Type: **Poster Contribution**

Study on performance of the OEDO beamline

OEDO (Optimized Energy Degrading Optics for RI beam) is the renovation project of the SHARAQ beamline at RIBF-RIKEN to accommodate a RI beam of with a few tens of MeV/u by energy degrading method. The highly exotic beams with such an energy, which still have been uncharted territory for the existing RI beam facilities, are expected to be achievable by the OEDO beamline. The beamline was designed to produce a well-focused beam of small momentum dispersion from secondary beams separated by BigRIPS with the help of the angle-tunable energy degrader and the RF deflector.

The commissioning experiment of the OEDO beamline as a part of the ImPACT program for nuclear transmutation of long-lived fission products (LLFPs) was carried out after the completion of construction in last year. The 79Se and 107Pd beams at 35 MeV/u (30 MeV/u for 107Pd) were produced from the 180-MeV/u beams. The beamline elements were carefully optimized to obtain a beam of high quality.

In this talk, the evaluation results of the performance of the OEDO beamline together with responses on the beamline elements will be reported.

Primary authors: Dr HWANG, Jongwon (Center for Nuclear Study, University of Tokyo); Dr MICHIMASA, Shin'ichiro (CNS, Univ. of Tokyo)

Presenter: Dr HWANG, Jongwon (Center for Nuclear Study, University of Tokyo)

Contribution ID: **132** Type: **Poster Contribution**

Production of isomer beam around 52Fe nucleus via projectile fragmentation

Nuclear reaction in extreme condition is one of the attractive topics from the point of view of not only the nuclear structure and reaction but also the nucleosynthesis. Although the electron capture rate in supernova explosion is estimated from the charge exchange reaction with the ground state, the charge exchange reaction with the high-excitation energy state may provide the rate in the similar circumstance with the supernova explosion. Fusion reactions with superdeformed nuclei may provide us the high spin limit.

In some nuclei, there are long-lived states with high spins, so called isomers. The 12+ state in 52Fe is a typical high-spin isomer with the lifetime of 46 second. The production of such an isomer beam provides us the opportunities to challenge the reactions with high-temperature and high-spin state. Presently the reported isomer ratio of 52Fe(12+) is below 1% while the isomer ratio of 10% is required for charge exchange reactions. In this study we are aiming at the production of high-isomer-ratio beams by changing the transfer momentum and incident angle.

Experiment (program number H362) was performed at HIMAC in Chiba. The ratios of isomeric states in the beams are measured by using projectile fragmentation from 58Ni and 82Kr, changing momentum transfer, incident angle and incident nucleus.The incident energy was 350 MeV/u, which is similar to the typical incident energy at RIBF. The beam particles implanted the active stopper of plastic scintillator and two germanium detectors were placed beside the stopper in order to measure the gamma rays from the decay of isomeric states. The decay gamma ray from isomer of 52Fe was clearly observed and typical isomer ratio is more than 10 %.

In this talk, we report the detail of experiment and its result, and discuss the isomer production via fragmentation reactions.

Primary author: Mr KAWATA, Keita (Center for Nuclear Study, University of Tokyo)

Co-authors: Prof. SAKAI, Hideyuki (RNC); Dr NISHIBATA, Hiroki (RIKEN Nishina Center); Dr ZENIHIRO, Juzo (RIKEN Nishina Center); YAKO, Kentaro (CNS, University of Tokyo); Dr STUHL, Laszlo (Center for Nuclear Study, University of Tokyo); Dr DOZONO, Masanori (Center for Nuclear Study, the University of Tokyo); Dr IMAI, Nobuaki (CNS, Univ. of Tokyo); Mr KITAMURA, Noritaka (Center for Nuclear Study, University of Tokyo); Ms TSUNODA, Rieko (Center for Nuclear Study,University of Tokyo); Mr YOKOYAMA, Rin (CNS, the University of Tokyo); Dr MICHIMASA, Shin'ichiro (CNS, Univ. of Tokyo); Dr OTA, Shinsuke (Center for Nuclear Study, University of Tokyo); Mr MASUOKA, Shoichiro (Center for Nuclear Study,University of Tokyo); Mr HARADA, Tomoya (Toho univ.); Dr NINGTAO, Zhang (Center for Nuclear Study,University of Tokyo); Dr IWAMOTO, chihiro (Research Center for Nuclear Physics (RCNP), Osaka University,Center for Nuclear Study,University of Tokyo)

Presenter: Mr KAWATA, Keita (Center for Nuclear Study, University of Tokyo)

Contribution ID: **133** Type: **Poster Contribution**

Valence particle/hole-core couplings in neutron-rich, exotic nuclei

The couplings between single-particle/hole degrees of freedom and collective and non-collective excitations are of primary importance in nuclear physics, as they are responsible for many phenomena observed in atomic nuclei, from the damping of giant resonances, to the quenching of spectroscopic factors and the anharmonicity of vibrational spectra [1].
While such properties have been investigated in the past in a limited number of stable nuclei, it is still under discussion whether neutron rich, exotic nuclei display similar features and how couplings with core excitations are influenced by the proton-to-neutron ratio and shell evolution.
To answer these questions, we present recent experimental results in the medium-heavy mass regions around the doubly-magic, neutron-rich ^{48}Ca and ^{132}Sn nuclei. In particular, we discuss new spectroscopic information on the ^{47}Ca, ^{49}Ca, ^{133}Sb and ^{131}Sn isotopes, obtained in different experimental campaigns, at ILL (France) and LNL (Italy), by using large γ-ray setups based on HpGe Detectors.
Experimental results will be interpreted by a new microscopic theoretical model, the Hybrid Configuration Mixing Model [2-3], specifically designed to describe the structure of nuclear systems with one valence particle/hole outside a core. The model includes couplings between valence nucleons and core excitations in a self-consistent way, by means of Hartree-Fock (HF) and Random Phase Approximation (RPA) calculations using the Skyrme effective interaction and it accounts for both collective phonons and non-collective configurations.
The agreement between experimental and theoretical energies, electromagnetic transition probabilities and spectroscopic factors will be outlined, especially in the case of ^{133}Sb and ^{49}Ca, showing the relevance of the new approach, as compared to traditional shell model calculations with a frozen core. Recent improvements of the model and possible future experimental developments with radioactive beams will be discussed.

[1] A. Bohr and B. M. Mottelson, Nuclear Structure. Volume II: Nuclear Deformations (W. A. Benjamin, New York, 1980).
[2] G. Colò et al., Phys. Rev. C 95, 034303 (2017).
[3] G. Bocchi et al., Phys. Lett. B 760, 273 (2016).

Primary author: Dr BOTTONI, Simone (University of Milano and INFN)

Co-authors: Prof. BRACCO, Angela (University of Milano and INFN); Prof. FORNAL, Bogdan (IFJ PAN Krakow); Dr MILLION, Bènèdicte (INFN Milano); Dr UR, Calin A. (ELI-NP); Dr MICHELAGNOLI, Caterina (ILL Grenoble); Dr CRESPI, Fabio C. L. (University of Milano and INFN); Prof. COLÒ, Gianluca (University of Milano and INFN); Dr BENZONI, Giovanna (INFN Milano); Dr JENTSCHEL, Michael (ILL Grenoble); Dr CIEPLICKA-ORYŃCZA, Natalia (IFJ PAN Krakow); Dr MUTTI, Paolo (ILL Grenoble); Prof. BORTIGNON, Pierfrancesco (University of Milano and INFN); Prof. LEONI, Silvia (University of Milano and INFN); Dr SOLDNER, Torsten (ILL Grenoble); Dr KÖSTER, Ulli (ILL Grenoble); Prof. URBAN, Waldemar (University of Warsaw); Dr NIU, Yifei (ELI-NP); Dr ISKRA, Łukasz (IFJ PAN Krakow)

Presenter: Dr BOTTONI, Simone (University of Milano and INFN)

Contribution ID: **134** Type: **Poster Contribution**

Nuclear collective excitation within finite-amplitude method

Giant resonances provide us important information on nuclear collective properties. For the nuclear density functional theory (DFT), the giant resonance will determine the coupling constants that are not very well constrained from the ground-state properties. In order to assess the giant resonances in a wide region of the nuclear chart, an efficient technique to compute the giant-resonance energy is necessary for constraining the coupling constants in the nuclear energy density functional.
The quasiparticle random-phase approximation (QRPA) is a standard theory for describing various kinds of small-amplitude collective modes including giant resonances based on the nuclear DFT. The widely used technique for the QRPA problem is, however, based on the matrix diagonalization, and is too demanding to perform repeatedly in medium and heavy systems as the dimension of the two-quasiparticle space become large.
The finite-amplitude method (FAM) technique for the linear-response theory [1] allows us to derive efficient solutions for the QRPA problem within the nuclear DFT. In this presentation, I will show the technique for evaluating the QRPA sum rules using the contour integration of the FAM response function in the complex-energy plane [2]. From the ratio of the sum rule, the giant-resonance peak energy can be evaluated. Typical examples of the giant-resonance energies of doubly magic systems are discussed. Among the sum rules of different energy moments, the energy-weighted and inverse-energy-weighted sum rule are the most important ones. I will extend the Thouless theorem for the energy-weighted sum rule in the case of the generalized nuclear DFT. The Thouless theorem has been conventionally derived from the expectation value of the double commutator of the Hamiltonian, but such a Hamiltonian operator does not exist in the case of the nuclear DFT. I will derive the theorem without using the double commutator of the Hamiltonian, and show the extended version of the theorem for the nuclear DFT [3].

[1] T. Nakatsukasa, T. Inakura, and K. Yabana, Phys. Rev. C 76, 024318 (2007).
[2] N. Hinohara, M. Kortelainen, W. Nazarewicz, and E. Olsen, Phys. Rev. C 91, 044323 (2015).
[3] N. Hinohara, in preparation.

Primary author: Dr HINOHARA, Nobuo (Center for Computational Sciences, University of Tsukuba)

Presenter: Dr HINOHARA, Nobuo (Center for Computational Sciences, University of Tsukuba)

Contribution ID: **135** Type: **Poster Contribution**

Cooled BGO array detector for experiments at JUNA

Jinping Underground lab for Nuclear Astrophysics (JUNA) is designed to directly measure the cross-sections of crucial reactions during the evolution of hydrostatic stars. The extremely low cross-sections of radiative capture reactions within their relevant Gamow peaks require a gamma detector with high detection efficiency. For this reason, we have constructed a 4π BGO array detector composed of eight crystals with a length of 250 mm and a radial thickness of 63 mm. In order to improve the energy resolution of the BGO array detector, all the crystals are cooled to -20 degrees Celsius. An energy resolution <11% is observed for the 661 keV gamma ray.

Primary author: Dr SU, Jun (China Institute of Atomic Energy)

Presenter: Dr SU, Jun (China Institute of Atomic Energy)

Contribution ID: **136** Type: **Poster Contribution**

Development of the gaseous Xe scintillation detector for the particle identification of high intensity and heavy RI beams

For the experiments of unstable nuclei, the cocktail RI beams produced by the fragmentation of HI beams are often used. It is necessary to identify the RI beam event by event RIBF can provide the high intense RI beam, but we cannot fully utilize it due to the radiation damages of the existing detectors for the particle identification. To get enough data efficiently in a limited time, we need new detectors which have a good radiation hardness, a fast timing response, and a good energy and timing resolution.
For this purpose, we have developed a new detector employing the scintillation of the gaseous Xe. Since Xe gas is known to have a small work function,a high energy resolution is expected. However, the scintillation properties of the gaseous Xe from high-energy and –intensity HI particles not fully understood so far.
In order to evaluate the performance of the gaseous Xe scintillation detector, we tested it with a primary beam of 132Xe 290Mev/u and a secondary beam of A/Z ~2.28 at 300MeV/u produced by 132Xe 400MeV/u at Heavy Ion Medical Accelerator in Chiba in Nov.2017. I will report the result of this experiment in this conference.

Primary authors: Dr SAKAGUCHI, Harutaka (Research center for Nuclear Physics); Dr ZENIHIRO, Juzo (RIKEN Nishina Center); TERASHIMA, Satoru (RIKEN Nishina Center); Mr HARADA, Tomoya (Toho univ.); Dr MATSUDA, Yohei (Cyclotron and Radioisotope Center, Tohoku University)

Co-authors: Mr KAWATA, Keita (University of Tokyo(CNS)); Mr KASAMATSU, Koki (Cyclotron and Radioisotope Center, Tohoku University); Dr DOZONO, Masanori (Center for Nuclear Study, the University of Tokyo); Dr OTA, Shinsuke (Center for Nuclear Study, University of Tokyo); Mr ISHIDA, Shunya (Cyclotron and Radioisotope Center, Tohoku university)

Presenter: Mr HARADA, Tomoya (Toho univ.)

Contribution ID: **137** Type: **Oral contribution**

Three-body correlations in direct reactions: Example of 6Be populated in (p, n) reaction

Tuesday, June 5, 2018 9:18 AM (18 minutes)

The nuclear driplines are defined by instability with respect to particle emission, and therefore the entire spectra of the systems beyond the driplines are continuous. The first emission threshold in the light even systems is often, due to pairing interaction, the threshold for two-neutron or two-proton emission, and therefore one has to deal with three-body continuum. Such continuum provides rich information about nuclear structure of ground state and continuum excitations, which is, however, often tightly intertwined with contributions of reaction mechanism. The way to extract this information is to explore the world of various correlations in fragment motions and to look for methods to disentangle contributions of a reaction mechanisms.

The 47 AMeV 6Li beam was produced by the cyclotron U-400M and injected into ACCULINNA facility [1]. The 6Be continuum states were populated in the charge-exchange reaction 1H(6Li,6Be)n collecting very high statistics data (~5x10^6 events) on the three-body alpha+p+p coincidences. The first results of the experiment studying the α+p+p correlations in decays of the 6Be states populated in the (p, n) charge-exchange reaction were published in Ref. [2]. The paper was focused on the proof that the observed 6Be excitation spectrum above ~3 MeV is dominated by the novel phenomenon –isovector breed of the soft dipole mode "built"on the 6Li ground state (g.s.). The correlations in the decay of 6Be states with excitation energy below ~3 MeV, where the data are dominated by the contributions of the known and well-understood 0+ and 2+ states of 6Be, are presented.

A general quantum-mechanical formal issue and important practical task of data interpretation is the extraction of the most complete quantum-mechanical information from the accessible observables. Important but very rare case when extraction of the complete quantum-mechanical information from data is possible is elastic scattering: from angular distributions one can, in principle, extract set of phase shifts which contains all possible information about this process. For the majority of other classes of experimental data, extraction of complete quantum-mechanical information is not possible. For certain classes of reactions the most complete quantum-mechanical information which can be extracted is contained in the density matrix. Because of internal symmetries the density matrix could provide very compact form of data representation depending just on very few parameters.

We demonstrate that basing on the known level scheme it is possible to extract the maximal possible quantum mechanical information about reaction mechanism (e.g. the density-matrix parameters) from the three-body correlations. It is demonstrated how the high-statistics few-body correlation data can be used to extract detailed information on the reaction mechanism. The suggested method of analysis allows for identification of such fine effects like the ratio of the populated states, interference between them and alignment of the states with J>1/2 for other nuclei, and it may be regarded as a general tool for different tasks on radioactive beams.

[1] A. M. Rodin, S. I. Sidorchuk, S. V. Stepantsov, G. M. Ter-Akopian, A. S. Fomichev, R. Wolski, V. B. Galinskiy, G. N. Ivanov, I. B. Ivanova, V. A. Gorshkov, A. Y. Lavrentev, and Y. T. Oganessian, Nuclear Instruments and Methods in Physics Research A 391, 228 (1997)
[2] A. Fomichev, V. Chudoba, I. Egorova, S. Ershov, M. Golovkov, A. Gorshkov, V. Gorshkov, L. Grigorenko, G. Kaminski, S. Krupko, I. Mukha, Y. Parfenova, S. Sidorchuk, R. Slepnev, L. Standylo, S. Stepantsov, G. Ter-Akopian, R. Wolski, and M. Zhukov, Physics Letters B 708, 6 (2012)

Primary author: Dr CHUDOBA FOR ACCULINNA COLLABORATION, Vratislav (JINR Dubna, Russia && Silesian University in Opava, Czech Republic)

Presenter: Dr CHUDOBA FOR ACCULINNA COLLABORATION, Vratislav (JINR Dubna, Russia && Silesian University in Opava, Czech Republic)

Session Classification: Session 5

Contribution ID: **138** Type: **Oral contribution**

Exploring the most neutron-rich isotopes of carbon and nitrogen

Thursday, June 7, 2018 9:00 AM (18 minutes)

Exploring and understanding the structure of nuclei far from stability is one of the central themes of present day nuclear physics, as evidenced by this workshop. In this presentation, work investigating the structure of the most neutron-rich isotopes of carbon and nitrogen employing high-energy nucleon removal (or "knockout") will be discussed. These nuclei are of particular interest as they encompass the N=14 and 16 sub-shell closures and lie below doubly magic 22,24O.
Following a brief résumé of the motivation for this work and the tools employed, the results obtained for the unbound system 21C will be presented together with the prospects for probing the continuum states of 22C, including the search for the first 2+ state. The first observation of 24N will also be presented together with evidence for the existence of 25N as a resonance.

Primary author: ORR, Nigel (LPC-Caen)

Co-authors: Dr GIBELIN, Julien (LPC Caen, ENSICAEN, Université de Caen, CNRS/IN2P3, Caen, France); G, Maruques (LPC-Caen); DESHAYES, Q (LPC-Caen); LEBLOND, S (LPC-Caen)

Presenter: ORR, Nigel (LPC-Caen)

Session Classification: Session 11

Contribution ID: **139** Type: **Oral contribution**

Resonance scattering with exotic beams - past, present and future

Thursday, June 7, 2018 2:00 PM (18 minutes)

Experiments employing resonance scattering reactions with radioactive beams have been performed since mid-90s, and originally they were primarily
targeting structure of light weakly bound or unbound proton rich nuclei [1]. Strong scientific potential of resonance reactions as an experimental tool
has been immediately recognized for physics of exotic proton rich nuclei. Unlike for stable nuclei, for weakly bound or unbound nuclei resonance reactions provide access to states with small or zero excitation energy. Typically low level density at small excitation energies allow for detailed and often unambiguous analysis. These features, combined with application of thick target inverse kinematics approach that allowed high efficiency and excellent energy resolution with relatively simple experimental setup, made resonance scattering experiments popular. Many successful experiments have been performed, including those in which ground states of exotic nuclei were observed for the first time (10N is the latest example [2]). More recently resonance reactions have been applied to study clustering phenomena in neutron and proton rich nuclei [3, 4] and also the structure of neutron rich nuclei through isobaric analog states [5]. Significant improvements of experimental techniques, such as active target systems, open up new exciting opportunities. The goal of this talk is to provide a brief highlight of the most interesting past results, overview the current directions and discuss the outlook and future perspectives.

References
[1] L. Axelsson, et al., Phys. Rev. C, 54, R1511 (1996).
[2] J. Hooker, et al., Phys. Lett. B, 769, 62 (2017).
[3] C. Fu, et al., Phys. Rev. C, 77, 064314 (2008).
[4] D. Suzuki, et al., Phys. Rev. C, 87, 054301 (2013).
[5] E. Uberseder, et al., Phys. Lett. B, 754, 323 (2016).

Summary

Primary author: Prof. ROGACHEV, Grigory (Texas A&M University)

Presenter: Prof. ROGACHEV, Grigory (Texas A&M University)

Session Classification: Session 13

Contribution ID: **140** Type: **not specified**

Welcome speech

Monday, June 4, 2018 9:00 AM (5 minutes)

Presenter: Prof. OGATA, Kazuyuki

Session Classification: Session 1

Contribution ID: **141** Type: **not specified**

Welcome speech

Monday, June 4, 2018 9:05 AM (5 minutes)

Presenter: Prof. YAMADA, Kotaro (Tokyo Institute of Technology)

Session Classification: Session 1

Contribution ID: **142** Type: **not specified**

Keynote talk 1

Monday, June 4, 2018 9:10 AM (30 minutes)

Presenter: Dr OBERTELLI, Alexandre

Session Classification: Session 1

Contribution ID: **143** Type: **not specified**

Keynote talk 2

Monday, June 4, 2018 9:40 AM (30 minutes)

Presenter: Dr MORO, A. M.

Session Classification: Session 1

Contribution ID: **144** Type: **Oral contribution**

Concluding remark

Friday, June 8, 2018 3:15 PM (30 minutes)

Presenter: Dr TANIHATA, Isao

Session Classification: Session 18

Contribution ID: **145** Type: **Oral contribution**

Prize and Closing

Friday, June 8, 2018 3:45 PM (30 minutes)

Presenters: Prof. NAKAMURA, Takashi (Tokyo Institute of Technology); Dr KONDO, Yosuke

Session Classification: Session 18