2nd Joint Canada-APCTP Meeting on Nuclear Theory

Report of Contributions

Contribution ID: **1** Type: **not specified**

Tensor force effect on pairing correlations for the Gamow–Teller transition

Wednesday, 10 August 2022 10:00 (40 minutes)

We investigate the tensor force (TF) effect on the Gamow–Teller (GT) transition strength distributions in 42Ca, 46Ti, and 18O, which are known to have strong low-energy GT states,the so-called low-energy super GT (LeSGT) transition, peculiar to nuclei retaining a neutron number N = Z + 2. The TF is explicitly taken into account in the pairing channels of the residual interaction on top of the mean field described by a deformed Woods–Saxon potential. The pairing matrix elements (PMEs) comprising isoscalar and isovector parts,which consistently describe both the ground and the GT excited states, are calculated by a Brückner G-matrix based on the charge-dependent Bonn potential. By switching the TF on and off in the PMEs, we deduce meaningful correlations between the TF and the GT strength distributions. It is found that an attractive TF affects not only the ground state but also plays a crucial role in shifting the main GT peak to the low excitation-energy region leading to the LeSGT.

Primary author: HA, EUN JA (Hanyang University)

Presenter: HA, EUN JA (Hanyang University)

Contribution ID: **2** Type: **not specified**

Comprehensive Analyses of the Neutrino-Process in the Core-collapsing Supernova

Friday, 12 August 2022 10:00 (40 minutes)

We discuss the neutrino flavor change effects due to neutrino self-interaction, shock wave propagation as well as matter effect on the neutrino-process of the core-collapsing supernova (CCSN). For the hydrodynamics, we use two models: a simple thermal bomb model and a specified hydrodynamic model for SN1987A. As a pre-supernova model, we take an updated model adjusted to explain the SN1987A employing recent development of the (n, γ) reaction rates for nuclei near the stability line ($A \sim 100$). As for the neutrino luminosity, we adopt two different models: equivalent neutrino luminosity and non-equivalent luminosity models. The latter is taken from the synthetic analyses of the CCSN simulation data which involved quantitatively the results obtained by various neutrino transport models. Relevant neutrino-induced reaction rates are calculated by a shell model for light nuclei and a quasi-particle random phase approximation model for heavy nuclei. For each model, we present abundances of the light nuclei (^{7}Li, ^{7}Be, ^{11}B and ^{11}C) and heavy nuclei (^{92}Nb, ^{98}Tc, ^{138}La and ^{180}Ta) produced by the neutrino-process. The light nuclei abundances turn out to be sensitive to the Mikheyev-Smirnov-Wolfenstein (MSW) region around O-Ne-Mg region while the heavy nuclei are mainly produced prior to the MSW region. Through the detailed analyses, we find that neutrino self-interaction becomes a key ingredient in addition to the MSW effect for understanding the neutrino-process and the relevant nuclear abundances. The normal mass hierarchy is shown to be more compatible with the meteorite data. Main nuclear reactions for each nucleus will also be discussed in detail.

Primary author: CHEOUN, Myung-Ki

Presenter: CHEOUN, Myung-Ki

Contribution ID: **3** Type: **not specified**

Study of light Sn isotopes through Coulomb excitation and (d,p) transfer experiments

Thursday, 11 August 2022 10:00 (40 minutes)

Shell evolution of Sn isotopes is an active research area in nuclear structure. Recently, Monte Carlo Shell Model calculations predicted shape evolution and active proton core excitations, as explanations for the enhancement of B(E2) values in the light Sn isotopes toward the doubly magic ^{100}Sn, relative to the simple seniority scheme. Several Coulomb excitation experiments were carried out at the HIE-ISOLDE facility, for more precise B(E2) measurements in ^{106,108,110}Sn. Furthermore, (d,p) experiments with the ISOLDE Solenoidal Spectrometer (ISS) to examine the evolution of single-particle states in $^{107,109.111}$Sn are planned. Preliminary results and expected outcomes will be presented.

Primary author: PARK, Joochun (Jason) (Center for Exotic Nuclear Studies, IBS)

Presenter: PARK, Joochun (Jason) (Center for Exotic Nuclear Studies, IBS)

Contribution ID: **4** Type: **not specified**

Shape coexistence in the doubly-odd nuclides: Antimony(Sb) and Iodine(I)

Thursday, 11 August 2022 11:10 (40 minutes)

We present shape coexistence in the odd-odd Sb (Z=51) and I (Z=53) nuclides; spherical and deformed shapes. With a specific focus on the intruder proton (p) and neutron (n) h11/2 orbitals, we show the deformed rotational bands in Sb and I with N = 63 to 67 as discussing systematic features emerged in the neutron-shell space of 50 < N < 82. In addition, we discuss the chiral-like double bands associated with the p[h11/2]n[h11/2] configuration in 120I.

Primary author: MOON, Changbum (Institue for Basic Science)

Presenter: MOON, Changbum (Institue for Basic Science)

Contribution ID: **5** Type: **not specified**

Direct and fusion reactions including weakly-bound and halo nuclei

Tuesday, 9 August 2022 15:50 (40 minutes)

I discuss direct and fusion reactions including weakly-bound and halo nuclei. At first, to this end, I introduce the expended optical potential for direct reaction calculations as elastic scattering, inelastic, and breakup from strand optical model formalism, and emphasize the benefit of extended optical model. Then, I review previous results of direct reactions which include neutron halo systems as ^{11}Li + ^{208}Pb, ^{11}Be+^{64}Zn, ^{11}Be+ ^{120}Sn, ^{11}Be+^{197}Au and proton halo systems as ^{17}F+^{208}Pb. In addition, I also take into account fusion reactions including exotic nuclei in barrier penetration model (BPM) manner. For this calculation, coupled channel approach are employed with folding potential that is considered separation of core and valance part. Finally, I show our results of fusion reactions as ^{11}Li+^{208}Pb and ^{15}C+^{232}Th and look at the contribution of several effects as deformation, valance-neutron and transfer effects.

Primary author: CHOI, Ki-Seok (Korea Aerospace University)

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

Presenter: CHOI, Ki-Seok (Korea Aerospace University)

Contribution ID: **6** Type: **not specified**

The S matrices of elastic alpha-carbon-12 scattering at low energies in effective field theory

Tuesday, 9 August 2022 16:30 (40 minutes)

The elastic alpha-carbon-12 scattering at low energies for $l = 0, 1, 2, 3, 4, 5, 6$ is studied in effective field theory (EFT). We discuss a construction of the S matrices of elastic alpha-carbon-12 scattering in terms of the amplitudes of sub-threshold bound and resonant states of oxygen-16. The parameters appearing in the S matrices are fitted to the phase shift data below the proton-nytrogen-15 breakup threshold energy, and we find that the phase shifts are well described within the theory. We discuss an implication of the result for the application of EFT to the study of nuclear reactions in stellar evolution.

Primary author: ANDO, Shung-Ichi (Sunmoon University)

Presenter: ANDO, Shung-Ichi (Sunmoon University)

Contribution ID: **7** Type: **not specified**

Chiral nuclear force with vector mesons

Thursday, 11 August 2022 14:00 (40 minutes)

We extend chiral perturbation theory to include vector mesons as well as pions and nucleons. By counting the vector meson mass as heavy while treating the associated momentum as light, a consistent scheme can be obtained with a well-defined power counting rule. We find that the extended theory can describe the electric form factors of pions and nucleons far better than the conventional ChPT does, achieving the so-called vector-meson dominance in a systematic way. We then apply the theory to nuclear forces up to next-to-next-to-leading order (N2LO), which in general shows better accuracy, revealing the role of vector mesons in low-energy nuclear dynamics.

Primary author: PARK, Tae-Sun (Institute for Basic Science)

Presenter: PARK, Tae-Sun (Institute for Basic Science)

Contribution ID: **8** Type: **not specified**

Status of RAON and nuclear astrophysics at CENS

Monday, 8 August 2022 11:10 (40 minutes)

The radioactive ion (RI) beam accelerator facility called RAON is under construction in Korea. It will produce RI beams by both the ISOL and In-flight methods. One of the experimental facilities called KoBRA is expected to carry out nuclear astrophysics experiments using both stable beams and RI beams in the early phase of RAON. Experiments using both stable and RI beams of tens of MeV/u are considered for understanding explosive nuclear synthesis in stellar sites such as X-ray bursts and novae. One of the main research objectives of the Center for Exotic Nuclear Studies (CENS), which was launched about 2.5 years ago, is to measure nuclear reactions that are important for understanding thermonuclear reaction processes such as the rp-process and the r-process. Several devices including Si array detectors and active target TPC are being developed. The status of RAON and research activities in nuclear astrophysics by CENS will be presented

Primary author: HAHN, Kevin

Presenter: HAHN, Kevin

Contribution ID: **9** Type: **not specified**

Status of decay spectroscopy at CENS

Monday, 8 August 2022 14:00 (40 minutes)

The Center for exotic nuclear study in the institute of basic science was recently founded to study fundamental questions in astrophysics and nuclear physics through investigations of radioactive atomic nuclei. Many detectors are currently under development/planned which can be applied for the decay spectroscopy study such as Clover HPGe detector array (ASGARD), Co-axial Ge detector array, Si detector array (STARK), LaBr3 detector array (Khala) and conversion electron detector array (SCEPTER). The decay station project has recently started to utilize such detectors at low-energy branches at the new heavy ion accelerator facility RAON. Also, the International collaboration project IDATEN utilizing the LaBr3 detector arrays from Korea(Khala) and the United Kingdom (Fatima) at the RIKEN RIBF BigRIPS facility is underway. CENS contributes an essential role in data acquisition systems, simulations and detector structure. In this presentation, the current status of the detector systems and the possible experimental setup of the decay station will be presented.

Primary author: KIM, Yung Hee (IBS CENS)

Presenter: KIM, Yung Hee (IBS CENS)

Contribution ID: **10** Type: **not specified**

Fractional Skyrmions

Friday, 12 August 2022 11:50 (40 minutes)

We study Skrymion like configurations in the coset space SO(8)/SU(3). \Pi_3(SO(8)/SU(3))=Z_3, hence the Skyrmions have a sort of triality. We establish the existence of the Skyrmions and give some explicit configurations. We speculate as to their physical import.

Primary author: PARANJAPE, Manu (Université de Montréal)

Co-authors: Prof. SEMENOFF, Gordon (UBC); Prof. WILLIAMS, Benedict (UBC)

Presenter: PARANJAPE, Manu (Université de Montréal)

Contribution ID: **21** Type: **not specified**

Constraining neutrinoless double beta decay matrix elements from ab initio nuclear theory

Wednesday, 10 August 2022 11:50 (40 minutes)

As experiments searching for neutrinoless double beta decay are in the planning phase of a next generation with hopes to completely probe the inverted mass hierarchy, the need for reliable nuclear matrix elements, which govern the rate of this decay, is stronger than ever. Since a large discrepancy is found when computing this quantity with different nuclear models, a large unknown still exists on the sensitivity of these experiments to the effective neutrino mass. We tackle this problem from first principle using the valence-space in medium similarity renormalization group ab initio method, which allows to assign rigorous theoretical uncertainties. We present converged results for isotopes of interests for mass number up to A=136 with multiple nuclear interactions obtain from chiral effective field theory. Furthermore, we study correlations with other observables such as the double Gamow-Teller giant resonance in an attempt to betterr constrain our uncertainties.

Primary author: BELLEY, Antoine (TRIUMF/UBC)

Presenter: BELLEY, Antoine (TRIUMF/UBC)

Contribution ID: **23** Type: **not specified**

Gravitational probe to the equations of state at subhadronic level

Monday, 8 August 2022 15:50 (40 minutes)

I will start by introducing a gravitational theory that string theory predicts. It differs from general relativity, and can probe not only the mass but also pressure, hence generically equations of state parameters. For the theory to be consistent with observations, ordinary baryonic matter should be ultra-relativistic, which may be so at subhadronic level. This talk is based on a work with Kang-Sin Choi: *Post-Newtonian Feasibility of the Closed String MasslessSector* (https://arxiv.org/abs/2202.07413) which will soon appear in PRL. The basic question I would like to ask to the experts in the audience is *what is the pressure inside baryons*?

Primary author: PARK, Jeong-Hyuck (Sogang University)

Co-author: Prof. CHOI, Kang-Sin (Ewha Womans University)

Presenter: PARK, Jeong-Hyuck (Sogang University)

Contribution ID: **24** Type: **not specified**

Radiative Capture and Pair Production in p+7Li

Thursday, 11 August 2022 15:50 (40 minutes)

We examine the nuclear reactions 7Li(p,γ)8Be and 7Li(p,e+e-)8Be from an ab initio perspective.

Using the no-core shell model with continuum technique, with chiral nucleon-nucleon and three-nucleon forces as input, we obtain an accurate description of both 8Be bound states and p+7Li scattering states.

We calculate radiative capture reactions in which enough energy is released to produce electron-positron pairs. The distribution of pairs can be compared to recent ATOMKI experiments where an anomaly in the data was used to posit the existence of a new particle.

Primary author: GYSBERS, Peter (TRIUMF / UBC)

Co-author: NAVRATIL, Petr (TRIUMF)

Presenter: GYSBERS, Peter (TRIUMF / UBC)

Contribution ID: **25** Type: **not specified**

Skyrmions and Collective Isospin Dynamics

Friday, 12 August 2022 11:10 (40 minutes)

Skyrmions, the stable soliton solutions in an EFT introduced by Tony Skyrme, have been constructed for many baryon numbers (atomic mass numbers). They have interesting intrinsic shapes and also an intrinsic pion field structure. So a Skyrmion spontaneously breaks translational, rotational and isorotational symmetry. These symmetries are restored through quantization of the collective motion (zero-mode quantization). The resulting quantum states have momentum, spin and isospin and represent nuclei in their ground and excited states. Further states are obtained by including vibrational degrees of freedom. The idea that nuclei have intrinsic shapes and can vibrate, for example as alpha-particle clusters, is well known. The intrinsic pion field structure is less familiar. In this talk I shall explore some evidence for this, by reviewing what is known about correlations between the spin and isospin quantum numbers for quantized Skyrmions up to baryon number 12 (Carbon-12 and its isobars) and comparing with experimental data. It is proposed that the strong spin-orbit coupling in nuclei also arises from the pion field structure, and that beta-decay strengths depend on it too. This latter work is ongoing.

Primary author: MANTON, Nicholas (University of Cambridge)

Presenter: MANTON, Nicholas (University of Cambridge)

Contribution ID: **26** Type: **not specified**

Welcome to TRIUMF

Monday, 8 August 2022 10:00 (40 minutes)

I will present an introduction to TRIUMF with a brief overview of experiments at ARIEL and ISAC facilities covering both the current and the future envisioned programs. I will also discuss the theory program at TRIUMF that relates to the ARIEL experimental program. I highlight several recent experimental results from the nuclear astrophysics, nuclear structure, fundamental symmetries, and the sterile neutrino search.

Primary author: NAVRATIL, Petr (TRIUMF)

Presenter: NAVRATIL, Petr (TRIUMF)

Contribution ID: **27** Type: **not specified**

In-medium similarity renormalization group with resonance and continuum

Tuesday, 9 August 2022 14:40 (40 minutes)

We have developed an ab initio Gamow in-medium similarity renormalization group (IMSRG) method capable of describing resonance and non-resonance continuum properties of weakly-bound and unbound nuclear many-body systems. In this talk, I will discuss how to couple nuclear scattering states and decay channels into the in-medium similarity renormalization (IMSRG) framework by using the complex-energy Berggren basis. This basis treats bound, outgoing Gamow resonant and non-resonant continuum states on an equal footing. Finally, I will present some recent results for nuclei near or beyond dripline, such as limits of atomic nuclei, resonance and halo, calculated by this new ab initio approach with chiral two- and three-nucleon forces.

Primary author: BAISHAN, Hu (TRIUMF)

Presenter: BAISHAN, Hu (TRIUMF)

Contribution ID: **28** Type: **not specified**

Neutron star properties constrained by chiral effective field theory

Monday, 8 August 2022 14:40 (40 minutes)

By employing new energy density functionals, we investigate neutron star properties. The parameters in new energy density functionals are constrained by chiral effective field theory calculations, GW170817, and two nicer analyses using a Bayesian analysis. Nuclear symmetry energy and its slope parameters as well as macroscopic properties of neutron stars such as mass-radius relation, tidal deformabilities, and central densities. Furthermore, we found that the speed of sound needs to exceed the conformal limit when the maximum mass of neutron stars is greater than 2.1 times solar mass.

Primary author: LIM, Yeunhwan

Presenter: LIM, Yeunhwan

Contribution ID: **29** Type: **not specified**

Research on the rare isotope nuclear physics at CENS

Monday, 8 August 2022 11:50 (40 minutes)

Exploring the limits of nuclear existence plays an important role in understanding the particle stability of neutron-rich and proton-rich nuclei. It provides many opportunities to study exotic nuclear structures, nuclear reactions and nuclear astrophysics, and it can be a benchmark for theoretical mass models at the extremely exotic region.

In this talk, the research on the rare isotope nuclear physics at Center for Exotic Nuclear Studies (CENS) will be introduced. The details of the experiments and plans to detector development for nuclear experiments will be also presented. In addition, a search for the determination of neutron driplines for fluorine, neon, and sodium will be presented along with comparisons with nuclear mass and structure models. These results provide new keys to understanding the nuclear stability at extremely neutron-rich conditions.

Primary authors: Dr AHN, Deuk Soon (Center for Exotic Nuclear Studies, IBS); WITH CENS COLLABORATIONS

Presenter: Dr AHN, Deuk Soon (Center for Exotic Nuclear Studies, IBS)

Contribution ID: **30** Type: **not specified**

Structure of neutron-rich neon and magnesium isotopes

Thursday, 11 August 2022 11:50 (40 minutes)

Atomic nuclei have good spin, parity, and third component of the isospin. Yet for many nuclei, symmetry unrestricted mean-field calculations find it advantageous to break rotational invariance and particle number conservation such that the vacuum states accurately reflect the emergent symmetry breaking of intrinsically deformed and superfluid nuclei. Starting from such symmetry-breaking mean-field states in nuclear structure computations has the advantage that less effort needs to be spent in including correlations beyond the mean field; the disadvantage consists in the need to perform symmetry projections. In this talk I will present calculations for even-even neon and magnesium isotopes starting from chiral nucleon-nucleon and three-nucleon forces. I will discuss the restoration of broken rotational symmetry in coupled-cluster calculations, and present results for the rotational structure in these isotopic chains. In particular we predict that neutron-rich 34-Ne is as rotational as 32-Ne and 34-Mg.

Primary author: HAGEN, Gaute

Presenter: HAGEN, Gaute

Contribution ID: **31** Type: **not specified**

Global microscopic description of nucleon-nucleus scattering with quantified uncertainties

Tuesday, 9 August 2022 14:00 (40 minutes)

The nuclear optical potential provides an essential tool for studying nucleon-nucleus elastic scattering and reaction cross sections by incorporating the complexity of many-body correlations into an effective one-body mean field between projectile and target. We develop for the first time a microscopic global nucleon-nucleus optical potential with quantified uncertainties suitable for analyzing nuclear reaction experiments at next-generation rare-isotope beam facilities. We start from the nuclear matter approach, in which the nucleon self-energy in infinite homogeneous matter at varying density and isospin asymmetry is used to construct nucleon-nucleus optical potentials for 1800 nuclei by matching to the isoscalar and isovector densities of the target isotopes by way of the improved local density approximation. This is repeated for five different chiral interactions from which a covariance analysis of the parameters entering in the global optical potential can be used to create a continuous distribution of optical potentials and derived uncertainties.

Primary authors: HOLT, Jeremy (Texas A&M University); Dr WHITEHEAD, Taylor (Michigan State University); LIM, Yeunhwan (Ewha Womans University)

Presenter: HOLT, Jeremy (Texas A&M University)

Contribution ID: **32** Type: **not specified**

Shedding light on neutrinoless double-beta decay nuclear matrix elements

Wednesday, 10 August 2022 11:10 (40 minutes)

The rarest known nuclear process, standard double-beta decay, in which two neutrons in an atomic nucleus turn into protons and two electrons together with two antineutrinos are emitted, has been observed in a dozen nuclei. A neutrinoless mode of the decay, in which only two electrons would be emitted, has been hypothesized but so far not discovered. Observing the neutrinoless mode would however provide unique vistas beyond the standard model of particle physics. It would not only prove that neutrinos are their own antiparticles but also shed light on the unknown absolute mass-scale of them. Nevertheless, observing the decay is extremely difficult, and both planning the experiments and extracting information from the measurements require knowledge on nuclear matrix elements, which are presently not well constrained.

In my talk, I will discuss complementary ways to constrain the nuclear matrix elements by using data on other nuclear observables, especially the standard-model-allowed two-neutrino double-beta decay. I will also discuss the potential of ordinary muon capture to shed light on neutrinoless double-beta decay.

Primary author: JOKINIEMI, Lotta (TRIUMF)

Presenter: JOKINIEMI, Lotta (TRIUMF)

Contribution ID: **33** Type: **not specified**

Nambu-Covariant Many-Body Theory

Thursday, 11 August 2022 14:40 (40 minutes)

In an attempt to tackle systematically the complexity of strongly correlated quantum many-body systems, modern *ab initio* approaches have grown more and more sophisticated, both formally and numerically. One standard strategy consists in combining several pre-existing many-body schemes such as symmetry-breaking mean-field calculations with non-perturbative corrections. In this particular case, the additional formal complexity appears as anomalous propagators and/or anomalous vertices in the diagrammatic.

In this talk, I will show how the introduction of a new tensorial structure enables the reformulation of many-body approximations, such as Self-consistent Green's Functions (SCGFs), in a way that is invariant with respect to any Bogoliubov transformation. As a result, symmetry-breaking extensions of many-body approximations become formally as simple as their symmetric counterpart.

To illustrate the simplifications that occur, I will showcase the set of equations formulating the self-consistent ladder approximation of symmetry-breaking Green's functions at finite temperature, in a general basis. Application of such general expression for a many-body system of interest will then be presented by considering the example of superfluid polarized asymmetric nuclear matter in a plane-wave basis.

Finally, I will revisit the celebrated Thouless'criterion linking the convergence of the series of ladder diagrams at vanishing energy with the stability of the Bardeen-Cooper-Schrieffer (BCS) self-energy for homogeneous matter. Taking advantage of the Nambu-covariant formalism, I will show how Thouless'criterion trivially extends to the case of a complex general Hartree-Fock-Bogoliubov (HFB) self-energy when one considers a general many-body system. Last, as an attempt to make up for the shortcoming of Thouless'criterion, I will introduce a new condition on the stability of the HFB self-energy which is sufficient to ensure the convergence of the series of ladder diagrams at any energy.

Primary author: DRISSI, Mehdi (TRIUMF)

Presenter: DRISSI, Mehdi (TRIUMF)

Contribution ID: **34** Type: **not specified**

Day Chair: Yongseok Oh

Contribution ID: **35** Type: **not specified**

Quantum Monte Carlo calculations of properties of nuclei

Thursday, 11 August 2022 16:30 (40 minutes)

Many progresses have been made in developing nuclear Hamiltonians within the framework of chiral effective field theory. In particular, the develop of chiral interactions that are fully local opened the way of implementing these Hamiltonians in Quantum Monte Carlo calculations. The advantage of using Quantum Monte Carlo methods is that they are not limited to use soft interactions, and calculations dedicated to explore the role of cutoffs can be done.

I will devote this talk to discuss several results for nuclei up to A=16, and addressing several questions regarding the prediction power of these Hamiltonians, and issues related to regulators and cutoffs. I will show nuclear properties including energies, radii, and magnetic moments.

Presenter: GANDOLFI, Stefano