INTERNATIONAL WORKSHOP
ON QUANTUM MANY-BODY PROBLEMS
IN PARTICLE, NUCLEAR, AND ATOMIC PHYSICS
March 8 – 11, 2017

DUY TAN UNIVERSITY
K7/25 Quang Trung, Danang City, Vietnam
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Topics

- *Lattice QCD*
- *Physics of cold atoms*
- *Nuclei physics*
- *Astrophysics*
- *Related subjects*

PROGRAM

Workshop

Wednesday, March 8, 2017

8:00 – 9:00	Registration
9:00 – 9:30	Opening addresses

Section chair: Tetsuo Hatsuda

9:30 – 10:30	**Hideki Hamagaki**, *Topics on Heavy Ion Collisions*
10:30 – 11:00	Coffee break
11:00 – 12:00	**Gordon Baym**, *New States of Quantum Matter*
12:00 – 14:00	Lunch

Section chair: Hideki Hamagaki

14:00 – 15:00	**Emiko Hiyama**, *Recent Progress of Nuclear Physics with Strangeness*
15:00 – 15:30	**Gyorgy Wolf**, *Phase Diagram in the Vector Meson Extended PQM Model*
15:30 – 16:00	Workshop's photos and Coffee break
16:00 – 16:30	**Hajime Togashi**, *Nuclear Equation of State with the Variational Method and the Effect of Lambda Hyperons in Supernova*
16:30 – 17:00	**Takayuki Oyamada**, *Three-Body Gaussian Expansion Method Calculations for He Atom*

17:00 – 17:30 **Luu Anh Tuyen**, *Nuclear Spectroscopy for the Study of Material Structure: Positron Annihilation and X-ray Diffraction*

Thursday, March 9, 2017

Section chair: Gordon Baym

8:30 – 9:30 **Toshiyuki Azuma**, *Atomic Physics Related with Resonance State of e+e-e- (Ps-) and the Lamb-Shift of Highly-Charged Uranium Ion*

9:30 – 10:30 **Pascal Naidon**, *From the Yukawa to the Efimov Attraction*

10:30 – 11:00 Coffee break

11:00 – 12:00 **Le Van Hoang,** *Dynamic Chemical Imaging with Ultra-Short Laser Pulses Using High-Order Harmonic Generation*

12:00 – 14:00 Lunch

Section chair: Toshiyuki Azuma

14:00 – 15:00 **Takashi Inoue**, *Strange Nuclear Physics from QCD on Lattice*

15:00 – 16:00 **Nguyen Quang Hung**, *Nuclear Theory Group at Duy Tan University*

16:00 – 16:30 Coffee break

16:30 – 17:00 **Vu Tran Dinh Duy**, *Extracting Dynamic Molecular Structural Information From Low-Energy Laser-Induced Electron Diffraction Spectra*

17:00 – 17:30 **Le Xuan Chung,** *In-beam Gamma-ray Spectroscopy of* ^{68}*Fe*

18:00 – 20:00 Gala Dinner

Friday, March 10, 2017

Section chair: Nguyen Dinh Dang

8:30 – 9:30 **Shigehiro Natagaki,** *Massive Star Explosions*

9:30 – 10:30 **Hoang Ngoc Long,** *The 3-3-1 Models and New Physics*

10:30 – 11:00 Coffee break

11:00 – 12:00 **Pham Ngoc Diep,** *Millimetre/Submillimetre Astronomy Studies in Hanoi*

12:00 – 14:00 Lunch

Section chair: Nguyen Quang Hung

14:00 – 15:00 **Vuong Huu Tan,** *Fundamental Research Based on Neutron Beam at Dalat Nuclear Research Reactor*

15:00 – 15:30 **Shin Watanabe,** *Dynamic and Static Core Excitation Effects on Deformed Halo Nuclei*

15:30 – 16:00	Coffee break
16:00 – 16:30	**Le Thi Quynh Huong,** *Microscopic Description of Average Level Spacing in Even-Even Nuclei*
16:30 – 17:00	**Paramasivan Arumugam,** *Microscopic Non-adiabatic Rotation Particle Coupling for Proton Emitters with γ deformation*
17:00 – 17:30	**Le Tan Phuc,** *Disappearance of Bubbles in Hot* ^{28,34}*Si Nuclei*
17:30 – 18:00	Closing addresses

PROGRAM

Mini-Workshop

Wednesday, March 8, 2017

Section chair: Tran Hoai Nam

9:30 – 10:00	**Nguyen Kien Cuong**, *Computational System Code for Core and Fuel Management of the Dalat Nuclear Research Reactor using LEU Fuel*
10:00 – 10:30	**Do Quang Binh**, *A Hybrid Method for Multi-Objective Optimization of Nuclear Reactor Fuel Reloading Patterns*
10:30 – 11:00	Coffee break
11:00 – 11:30	**Pham Nhu Viet Ha**, *Rare Earth Element Effect on Core Physics of a Sodium-Cooled Fast Reactor for TRU Transmutation*
11:30 – 12:00	**Hoang Anh Tuan Kiet**, *Mesoscale Model and Application to Nuclear Fuels*
12:00 – 14:00	Lunch

Section chair: Do Quang Binh

14:00 – 14:30	**Tran Hoai Nam**, *New Design of VVER-1000 Fuel Assembly using Burnable Poison Particles*
14:30 – 15:00	**Nguyen Minh Tuan**, *Rossi-α Parameter Measurement of Dalat Nuclear Reactor by Analysis of Cross Power Spectral Density Obtained from 2 Ion Chambers*
15:00 – 15:30	Coffee break

15:30 – 16:00	**Le Ngoc Thiem**, *Characterization of a Neutron Calibration Field with $^{241}Am - Be$ Source using Bonner Sphere Spectrometers*
16:00 – 16:30	**Duong Thanh Tung**, *Uncertainty Quantification of Relap5/Mod3.3 for Interfacial Shear Stress During Small Break LOCA*
16:30 – 17:00	**Tran Viet Phu**, *Fuel Loading Pattern Optimization for VVER Nuclear Reactors*

ABSTRACT

Workshop

Microscopic Non-Adiabatic Rotation Particle Coupling for Proton Emitters with γ Deformation

Swati Modi[1], M. Patial[1], P. Arumugam[1], E. Maglione[2], and L.S. Ferreira[3]

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A proper formalism to study the proton emitters with γ deformation leads to an accurate identification of the triaxiality in exotic nuclei where the experimental data are scarce. We have developed such a non-adiabatic approach to study the structure and decay properties of proton emitters with the rotation particle coupling treated microscopically. In this approach the core energies are coupled to the quasiparticle states to obtain the matrix elements of the particle-rotor system. This approach for calculating the wavefunctions of the odd-A nuclei, is numerically intensive and reduces to the conventional particle-rotor model [1,2] under the assumption of a constant moment of inertia. The proton decay proceeds through Nilsson resonance of the unbound proton of the odd-A nucleus, generated by the Coulomb and centrifugal barrier [3]. The decay width is calculated from the overlap of parent and the daughter wave functions. We have studied the proton emitters ^{109}I and ^{147,147m}Tm with triaxial degree of freedom. It reveals that the triaxial shapes are not much important in 109I but quite crucial in the case of ^{147,147m}Tm. The ground and proton decaying

states of ^{109}I [4] are not yet assigned reliably. With our calculations for the decay width of ^{109}I we are able to unambiguously assign the decaying state's spin and parity as $3/2^{+}$. In the case of ^{147,147m}Tm, we infer that the proton emission study is a precise tool to ascertain triaxility in such an exotic nucleus.

[1] P. Arumugam, L.S. Ferreira, and E. Maglione, Phys. Lett. B **680**, 443 (2009); Phys. Rev. C **78**, 041305(R) (2008).

[2] M. Patial, P. Arumugam, A.K. Jain, E. Maglione, and L.S. Ferreira, Phys. Lett. B **718**, 979 (2013).

[3] E. Maglione, L.S. Ferreira, and R.J. Liotta, Phys. Rev. C **59**, R589 (1999); L. S. Ferreira and E. Maglione, Phys. Rev. Lett. **86**, 1721 (2001).

[4] M. Petri, et al., Phys. Rev. C **76**, 054301 (2007); E. S. Paul, *et al.*, Phys. Rev. C **51**, 78 (1995); C.H. Yu, *et al.*, Phys. Rev. C **59**, R1834 (1999).

Atomic Physics Related with Resonant State of e+e-e- (Ps-) and the Lamb-Shift of Highly-Charged Uranium Ion

Toshiyuki AZUMA

AMO Physics Laboratory, RIKEN, Japan

Two recent experimental activities by our group, a shape resonance observed by photodetachment of negative positronium ion (Ps-) at KEK, Japan and resonant excitation of uranium ions at GSI, Germany will be introduced.

When an electron binds to its anti-matter counterpart, the positron, it forms the exotic atom positronium (Ps). Ps can further bind to another electron to form the positronium negative ion, Ps- (e-e+e-). This system provides an excellent testing ground for the three-body problem in quantum mechanics. We have succeeded in laser spectroscopy study of Ps-, and a strong shape resonance of 1Po symmetry has been observed near the Ps (n=2) formation threshold.

The x-ray spectroscopy with high-Z ions uniquely provides the opportunity to prove the effects of relativity, higher-order quantum electrodynamics (QED), and the structure of nuclei. So far the spectroscopic study of high-Z few-electron ions is only available by measuring the energy of x-rays emitted after collisional excitation. We recently observed of the resonant fluorescence from highly charged uranium ions. Using the resonant coherent excitation (RCE) technique by an electric field inside a thin silicon crystal, the 2s-2p3/2 transition in about 200 MeV/u Li-like U89+ ions was excited at 4.5keV with a resonance width of 4.4eV. The result demonstrated that the RCE can be applied to resonant fluorescence spectroscopy of high-Z ions up to uranium with high efficiency and resolution.

New States of Quantum Matter

Gordon Baym
Department of Physics, University of Illinois, Urbana IL 61901, USA

In recent years physicists have created new states of quantum matter – from quark-gluon plasmas in ultrarelativistic heavy ion collisions to Bose and Fermi superfluids in ultracold trapped atomic clouds. Although these systems differ in energy scales by some 20 orders of magnitude, they share many questions of physics in common. This talk will review these new states and touch upon intriguing connections between the two areas.

In-Beam Gamma-ray Spectroscopy of ^{68}Fe

L.X. Chung[1], B.D. Linh[1], A. Gillibert[2], P. Doornenbal[3], A. Obertelli[2,3], F. Nowacki[4], G. Authelet[2], H. Baba[3], D. Calvet[2], F. Chateau[2], A. Corsi[2], A. Delbart[2], J.-M. Gheller[2], T. Isobe[3], V. Lapoux[2], M. Matsushita[5], S. Momiyama[3,6], T. Motobayashi[3], M. Niikura[6], H. Otsu[3], C. Peron[2], A. Peyaud[2], E.C. Pollacco[2], J.-Y. Rousse[2], H. Sakurai[3,6], C. Santamaria[2,3], M. Sasano[3], Y. Shiga[3,7], S. Takeuchi[3], R. Taniuchi[3,6], T. Uesaka[3], H. Wang[3], K. Yoneda[3], F. Browne[8], Zs. Dombradi[9], S. Franchoo[10], F. Giacoppo[11], A. Gottardo[10], K. Hadynska-Klek[11], N.T. Khai[1], Z. Korkulu[9], S. Koyama[3,6], Y. Kubota[3,5], C. Louchart[12], J. Lee[13], M. Lettmann[12], R. Lozeva[4], K. Matsui[3,6], T. Miyazaki[3,6], S. Nishimura[3], L. Olivier[10], S. Ota[5], Z. Patel[14], N. Pietralla[12], E. Sahin[11], C. Shand[14], P.-A. Soderstrom[3], G.L. Stefan[10], D. Steppenbeck[5], T. Sumikama[15], D. Suzuki[10], N.D. Ton[1], Zs. Vajta[9], V. Werner[12], J. Wu[3,16], and Z. Xu[13]

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The in-beam gamma-ray spectroscopy of ^{67}Fe and ^{68}Fe from hydrogen-induced neutron and proton knockout and inelastic scattering at 250 MeV/nucleon is reported. The experiment was performed at the Radioactive-Isotope Beam Factory of RIKEN with a setup composed of the MINOS target-tracker and the DALI2 NaI scintillator array. New transitions were observed and level schemes are proposed.

Millimetre/Submillimetre Studies in Hanoi

Pham Ngoc Diep
Vietnam National Satellite Center, 18 Hoang Quoc Viet, Hanoi, Vietnam

The observation of molecular emission at millimetre and submillimetre wavelengths gives access to the study of stars having a large and cool circumstellar envelope as well as of the gas reservoirs of galaxies, in particular remote galaxies with redshift in the 2 to 5 range at the epoch of maximum star formation rate. The observation of the continuum emission underneath the molecular excitation lines provides important information on the dust content. Using Plateau de Bure and archival ALMA observations, we have been able to reconstruct in space, under simplifying hypotheses such as of invariance by rotation about an axis, both the morphology and the kinematics of such sources. Examples will illustrate these studies, including Asymptotic Giant Branch stars, protostars and gravitationally lensed high redshift galaxies.

Extracting Dynamic Molecular Structural Information from Low-Energy Laser-Induced Electron Diffraction Spectra

Dinh-Duy T. Vu, Ngoc-Loan T. Phan, Van-Hoang Le
Department of Physics, Ho Chi Minh city University of Pedagogy,
280 An Duong Vuong Street, District 5, Ho Chi Minh city, Vietnam

Thanks to the recently developed quantitative rescattering theory, it is possible to separate the laser-free cross section, which contains desired structural information of target molecules, from laser-induced electron diffraction spectra (LIED). Inspired by the extraction experiment using mid-infrared laser of Blaga *et al*. [Nature **483**, 7388 (2012)], we aim at developing this method so that it is applicable on more common near-infrared laser sources. Due to the limits of kinetic energy electron can gain in near-infrared laser field; we develop a theoretical model to describe low-energy electron collision based on Multiple scattering (MS) theory. As an alternative to the previously used Independent atoms model (IAM), MS is proven to be superior to IAM in reproducing low-energy cross section. Therefore, our modified fitting procedure using MS can extract information from collision cross section of less than 50eV, where IAM is unable to operate. Our method is then demonstrated in a specific case of retrieving CO_2^+ bond length from available 800 nm-laser LIED experiment data. From these data, we retrieve the image at 1.7fs after ionization, shorter than the period 4-6fs in Blaga's experiment.

Topics on Heavy Ion Collisions

Hideki Hamagaki
Institute for Innovative Science and Technology,
Nagasaki Institute of Applied Science, Japan

Studies of hot QCD matter have made significant progress since RHIC has started operation in 2000. Many interesting features of the hot QCD matter have been revealed. In 2010, LHC has joined the alliance, and deeper investigations became feasible. Great surprise is that QCD matter behaves as near-ideal liquid, which seems to be true in the wide range of collision energies spanning from RHIC to LHC. Recently, debate on the conditions to be a fluid has been going on quite actively, after possible signatures of the hydro-dynamical behavior was found out in p+Pb collisions at LHC seveal years ago. In this talk, recent achievements in the QCD matter studies with heavy ion collisions at RHIC and LHC will be briefly reviewed, with emphasis on the hydro-dynamical behaviors in large and small systems. Probing the QCD matter using heavy flavors and single photons will also be covered. Experimental plans in the near future will be briefly mentioned, if time allows it.

Recent Progress of Nuclear Physics with Strangeness

Emiko Hiyama

Strangeness Nuclear Physics Laboratory, RIKEN Nishina Center, Japan

Major goals of nuclear physics with strangeness are to understand baryon-baryon interaction and to study the structure of multi-strangeness systems. Especially, baryon-baryon interaction is fundamental and important for the study of nuclear physics. For this purpose, they are planning to produce many nuclei with strangeness and to study the structure of these systems, During these five years, we have many observed data at J-PARC , JLab etc which are related these purpose. One of the most impacting data is that some neutron-rich hypernuclei ,nnΛ, ${}^{7}_{\Lambda}$He (^{6}He+Λ) have been observed. These observation are important to study for ΛN-ΣN coupling. In this talk, I will give an overview about present status and future perspective in hypernuclear physics.

Dynamic Chemical Imaging with Ultra-Short Laser Pulses Using High-Order Harmonic Generation

Van-Hoang Le

Department of Physics, Ho Chi Minh City University of Pedagogy,

280 An Duong Vuong Street, District 5, Ho Chi Minh City, Vietnam

High-order harmonic generation is a non-linear optical effect that occurs when intense ultra-short laser pulses interact with molecules in gas phase. One can measure not only high-order harmonics but also laser-induced electron diffraction spectra. Both are rich in molecular structure information, which opens a new way of imaging molecules and chemical processes. We review some recent progresses in dynamic chemical imaging and report some results of our research in this direction.

Nuclear Theory Group at Duy Tan University

Nguyen Quang Hung
Institute of Research and Development, Duy Tan University, Danang city, Vietnam

Nuclear theory group of Duy Tan University was established about 1 year ago with 3 members and many external collaborators. This talk will give an overview on the past, present, and future research topics of our group.

Microscopic Description of Average Level Spacing in Even-Even Nuclei

Le Thi Quynh Huong[1], Nguyen Quang Hung[2], and Le Tan Phuc[2]
[1)] *University of Khanh Hoa, Nha Trang city, Vietnam*
[2)] *Institute of Research and Development, Duy Tan University, Danang city, Vietnam*

A microscopic theoretical approach to the average level spacing at the neutron binding energy in even-even nuclei is proposed. The approach is derived based on the Bardeen-Cooper-Schrieffer (BCS) theory at finite temperature and projection *M* of the total angular momentum *J,* which is often used to describe the superfluid properties of hot rotating nuclei. The exact relation of the *J*-dependent total level density to the *M*-dependent state densities, based on which the average level spacing is calculated, was employed. The numerical calculations carried out for several even-even nuclei have shown that in order to reproduce the experimental average level spacing, the *M*-dependent pairing gaps as well as the exact relation of the *J*-dependent total level density formula should be simultaneously used.

Strange Nuclear Physics from QCD on Lattice

Takashi Inoue
Nihon University, College of Bioresource Sciences, Kanagawa, Japan

Hyperon forces are interesting in many aspects. First, they are in the company of nuclear force but not revealed yet due to shortage of experimental data. It is necessary to pin down hyperon forces in order to understand force between baryons including nuclear force.

Second, they are essential for physics of neutron star. Equation of state of dense baryonic matter depends on fraction of hyperons strongly. Recent discovery of heavy neutron star indicate a hard equation of state which is difficult to explain in matter with hyperons. This is one of most challenging puzzle in modern physics.

The 3-3-1 Models and New Physics

Hoang Ngoc Long
Institute of Physics, Vietnam Academy Science and Technology, Hanoi, Vietnam

In this talk, I will review status of the 3-3-1 models and their specific phenomena concerning the beyond Standard Model

Massive Star Explosions

Shigehiro Nagataki
Astrophysical Big Bang Laboratory, RIKEN, Japan

I would like to introduce activities of our laboratory, Astrophysical Big Bang Lab. We are studying Massive Star Explosions such as core-collapse supernovae and gamma-ray bursts. I would like to present the current status of our understanding on the massive star explosions.

From the Yukawa to the Efimov Attraction

Pascal Naidon
Quantum Hadron Physics Laboratory, RIKEN Nishina Center, RIKEN, Japan

The Yukawa attraction (screened $1/r$ interaction) is known to arise between two particles exchanging bosons, such as nucleons exchanging mesons. On the other hand, at the three-body level, the Efimov attraction ($1/r^2$ three-body interaction) can emerge from resonant two-body interactions, leading to the existence of the famous Efimov three-body bound states.

In this talk, I will look into how the mediated interaction between two particles immersed in a Bose-Einstein condensate can go from a Yukawa attraction to an Efimov attraction, as the strength of the particle-boson interaction is increased. This has implications on the many-body physics of Bose polarons, which are currently being realised in ultra-cold mixtures of atoms.

3-body Gaussian Expansion Method Calculations for the He Atom

Takayuki Oyamada[1], Emiko Hiyama[2], and Masanori Tachikawa[3]

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[2)] *RIKEN Nishina Center, RIKEN, Japan*

[3)] *Graduate School of Nanobioscience, Yokohama City University, Yokohama, Japan*

Nuclear physics or Elementary particle physics and Quantum chemistry are independently developed in each academic field. The aim of the present study is to create an interdisciplinary academic field by the collaborations among nuclear physics, elementary particle physics, and quantum chemistry. The ultimate goal of the present study is the unified understanding of the multiple-hierarchic quantum many-body problems in the nature. Toward the above aim and goal, we are making a contribution for the further development of **Gaussian Expansion Method** (GEM) [1], which is one of the most accurate *ab initio* method to solve the many-body Schrodinger equation. As an example of application of GEM in this study, we developed GEM code for two or three-body Coulombic systems. In GEM calculations, all the rearrangement channels of Jacobian coordinate are used to take full account of the correlation between the particles. In the nuclear or elementary particle physics, three y-type Jacobian coordinates are generally used for three-body systems since the mass of constituent particles are in the same order of magnitude. On the other hand, in the study of atoms, two Jacobian coordinates (T-type and V-type) are sufficient to describe the electron-electron correlation and the electron-nucleus correlation since the mass of nucleus is more than 10^3 times heavier than the mass of electrons.

One of the advantages of GEM is that the accurate eigenvalues and eigenvectors for the excited states as well as for the ground state are simultaneously obtained by the diagonalization of the generalized matrix-eigenvalue problems. The energy differences between the ground and the excited states are directly comparable to reliable experimental value (e.g. NIST Atomic Spectra Database). For the S states arising from 1s1ns1 electronic configuration of the He atom, the excellent agreement with spectroscopic experiments are confirmed up to n=6, where n is the main quantum number.

For any stationary states of Coulombic many-body systems, the virial theorem $2T+V=0$ holds, where T is the total kinetic energy and V the total potential energy. Therefore, we also analyzed the energy-component of the total energy $E(=T+V)$ to check the reliability of our GEM calculations. We also evaluated (i) the radial electron density distribution $D(r_1)$, (ii) the electron-electron pair distribution function $f(r_{12})$, (iii) the collision probability between the electron-nucleus $\langle\delta_{en}\rangle$ and the electron-electron $\langle\delta_{ee}\rangle$ and (iv) the expectation values of $\langle r^k\rangle$ ($k=-2,-1,+1,+2$), where r is the interparticle distance. The present GEM calculations are in excellent agreement with other accurate calculations using the explicitly correlated wavefunctions.

The development of accurate *ab initio* method to solve the many-body Schrodinger equation is also important to clarify the mechanism of pair annihilation between particle and antiparticle and to clarify the reason why antiparticles are very few in the present nature. Therefore, the further development of GEM is indispensable for the proper understanding of nature including the multiple-hierarchy problems.

[1] E. Hiyama, Y. Kino, and M. Kamimura, Prog. Part. Nucl. Phys. **51**, 223, (2003).

Disappearance of bubbles in hot $^{28,34}Si$ nuclei

Le Tan Phuc[1], Nguyen Quang Hung[1], and Nguyen Dinh Dang[2]
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[2)] Quantum Hadron Physics Laboratory, RIKEN Nishina Center, RIKEN, Japan

Depletion of the central nucleon density in the interior of atomic nucleus is known as the bubble structure. This interesting feature, which is caused by very small occupancy of the $s_{1/2}$ orbitals having radial distribution peaked in the interior of the nucleus, has been studied within several theoretical approaches such as shell model and nonrelativistic and relativistic microscopic mean-field approaches in many decades. Very recently, the very small occupancy of $s_{1/2}$ orbital in ^{34}Si at zero temperature (T = 0), which is the signature of bubble structure, has been for the first time detected experimentally via the one-proton removal reaction [1].

At finite temperature ($T \neq 0$), it is well known that occupancies of the nuclear orbitals, which are unoccupied at $T = 0$, increase with increasing T, leading to the reduction of the central-density depletion and consequently to the reduction of the bubble structure. The latter is expected to completely disappear when T is high enough. This talk will discuss the disappearance of bubbles in hot $^{28,34}Si$ nuclei using the microscopic Skyrme Hartree-Fock plus BCS and Exact Pairing at fininte temperature.

[1] A. Mutschler *et al.*, Nature Physics **13**, 152 (2017).

Fundamental Research Based on Neutron Beam at Dalat Nuclear Research Reactor

Vuong Huu Tan[1], Pham Dinh Khang[2], Nguyen Nhi Dien[3], Nguyen Xuan Hai[3], Nguyen Ngoc Anh[3], Pham Ngoc Son[3], Tran Tuan Anh[3], and Nguyen Quang Hung[4]
[1)] Vietnam Atomic Energy Society, Hanoi, Vietnam
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[4)] Institute of Research and Development, Duy Tan University, Danang city, Vietnam

Dalat Nuclear Research Reactor (DNRR), which was reconstructed and upgraded from the 250 kW TRIGA Mark-II reactor and loaded with the Soviet WWR-M2 fuel assemblies, has nominal power of 500 kW and is the biggest neutron source in Vietnam at present. The external beams of neutron originated from the reactor core can be extracted from three radial and one tangential beam ports. The latter are equipped by various compositions of neutron filters to produce quasi-monoenergetic neutron beams of 0.0253, 2, 24, 54, 59, 133, and 148 keV. The beams are appropriate for performing experiments to study nuclear reactions, neutron cross-section and nuclear level scheme, whereas transmission and PGNAA method were applied on channel 2^{nd} and 4^{th} to measure total neutron cross-section and capture neutron cross-section, respectively. Besides, a gamma–gamma coincidence spectrometer was placed on channel 3^{rd} to measure two-step-gamma cascades through (n,γ) reaction. Experimental data then could be used for adjusting or complement nuclear data library, as well as constructing nuclear level scheme and calculating nuclear parameters.

Nuclear Equation of State with the Variational Method and the Effect of Lambda Hyperons in Supernova Cores

Hajime Togashi
Strangeness Nuclear Physics Laboratory, RIKEN Nishina Center, RIKEN, Japan

We study the characteristics of a new nuclear equation of state (EOS) for core-collapse supernovae, which is obtained by the variational many-body theory with realistic nuclear forces (AV18 + UIX). The study is based on the cluster variational method for uniform matter and the Thomas-Fermi method for non-uniform matter. The obtained thermodynamic quantities for various temperatures, proton fractions, and densities are reasonable, as compared with those in the Shen EOS. It is also found that, in simplified numerical simulations of core-collapse supernovae, the stellar core created after the bounce with the present EOS is more compact than that with the Shen EOS. This result implies that the variational EOS is softer than the Shen EOS.

In this presentation, we will report on the properties of our EOS in detail, and its applications to (proto) neutron stars and numerical simulations of spherical adiabatic core-collapse supernovae.

Furthermore, as an extension of the above supernova EOS, we will discuss the effects of Lambda hyperon mixing in neutron stars and supernova cores by constructing the EOS for dense nuclear matter containing Lambda hyperons.

Dynamic and static core excitation effects on deformed halo nuclei

Shin Watanabe[1], Kazuyuki Ogata[2], and Takuma Matsumoto[3]
[1)] RIKEN Nishina center, RIKEN, Japan
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Nuclei in the vicinity of the neutron-drip line have exotic properties never seen in stable nuclei. One of the most dramatic changes is so called "halo" discovered by Tanihata *et al* [1]. They performed systematic measurements of interaction cross sections (σ_I) and found a prominent enhancement of ^{11}Li. This result surely triggered further studies on unstable nuclei as well as halos. After the discovery of a halo structure of ^{11}Li, σ_I and total reaction cross sections (σ_R) have been further measured to find new halo nuclei [2]. For example, it was established that ^{11}Be, ^{15}C, and ^{19}C are one-neutron halo nuclei, and ^{6}He, ^{14}Be, and ^{22}C are two-neutron halo nuclei with Borromean structures. Nowadays, the measurements reach the *pf*-shell region: the vicinity of the neutron-drip line for Ne and Mg isotopes. ^{31}Ne and ^{37}Mg are considered to be *p*-wave one-neutron halo nuclei [3,4]. These nuclei are strongly affected by the "island of inversion" and their core nuclei (^{30}Ne and ^{36}Mg) are expected to be largely deformed [4,5]. This kind of halo, which is composed of a deformed core and neutron(s), is called "deformed halo" and shows new phenomena.

In deformed halo nuclei, each core nucleus easily gets excited because of its strong deformation, i.e., "core excitation". From the structural points of view, the core excitation leads to admixture of angular momenta of a valence neutron (*static core excitation*). From the reaction points of view, deformed halo nuclei easily break up during scattering induced not only by the excitation of relative motion between neutron and a core but also by the core excitation itself (*dynamic core excitation*). On the other hand, so far, most nuclear reaction theories often neglected the core excitation effects for simplicity, and possible core-exciting processes are missing. It is necessary to take into account both static and dynamic core excitation effects explicitly for further investigation of halo nuclei.

In this talk, we focus on several one-neuron nuclei such as ^{11}Be, ^{15}C, ^{19}C, ^{31}Ne, and ^{37}Mg. The structural part is constructed with the particle plus rotor model (PRM) and then reaction part is solved by the distorted wave Born approximation method (DWBA) [6]. This framework allows us to explicitly investigate static and dynamic core excitation effects, respectively. We will discuss the differences between the spectroscopic factor of structural calculations and that deduced from reaction calculations.

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Nuclear Spectroscopy for the Study of Material Structure: Positron Annihilation and X-ray Diffraction.

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In this work, nuclear spectroscopies such as positron annihilation, X-ray diffraction have been used for the study of the nano-sized structure, framework and crystalline materials. Results related to structural characteristics of multiwall-carbon nanotube, zeolite, PbI2 will be presented. Moreover, influences of the synthetic and physical conditions to the material structure will be also discussed.

Phase diagram in the vector meson extended PQM model

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In the framework of an SU(3) (axial)vector meson extended linear sigma model with additional constituent quarks and Polyakov loops, we investigate the chiral phase transition. The parameters of the Lagrangian are set at zero temperature and we use a hybrid approach where in the effective potential the constituent quarks are treated at one-loop level and all the mesons at tree-level. We have four order parameters, two scalar condensates and two Polyakov loop variables and their temperature and baryochemical potential dependence are determined from the corresponding field equations. We investigate the thermodynamics of the system, and at zero chemical potential we compare our results with lattice calculations. We study, furthermore, the changes of the tree-level scalar meson masses in the hot and dense medium.

ABSTRACT

Mini-Workshop

A Hybrid Method for Multi-Objective Optimization of Nuclear Reactor Fuel Reloading Patterns

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This paper presents a new genetic algorithm in conjunction with the weighted sum method for multi-objective optimization of fuel loading patterns that maximize the effective multiplication factor k_{eff} and minimize the power peaking factor while satisfying operational and safety constraints for nuclear reactors. The proposed genetic algorithm consists of two types of genetic operators: one working on binary chromosomes and the other working on integer chromosomes. The new hybrid method automatically searches for weighting factors of the weighting function and the optimal fuel loading patterns. The most suitable weighting factors and the optimal fuel loading patterns are found simultaneously in the search process. Illustrative calculations are implemented for the Da Lat research reactor. Global reactor calculations were performed by a 3-D finite difference multi-group diffusion theory code CITATION, and group constants for use in CITATION were generated by using WIMSD-5B. Results from illustrative calculations show that the proposed GA can successfully search for both a set of approximate optimal loading patterns and the best weighting factors.

Computational System Code for Core and Fuel Management of the Dalat Nuclear Research Reactor using LEU fuel

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After carrying out full core conversion on 2012, the system code to serve for core and fuel management of the Dalat Nuclear Research Reactor (DNRR) using low enriched Uranium (LEU) fuel have been established. The system code has been validated before approval as official tool in neutronics calculation management for the DNRR. Neutronics characteristics parameters following operation time of the DNRR have been obtained by using the system code including fuel burn-up and beryllium poisoning. To validation the system code, measured data during start-up for full core conversion of the DNRR were used as reference for comparing with calculation data from the system code. So neutronics analysis different critical fresh LEU core loading configurations were carried out. The maximum discrepancy of calculation results and experimental data in reactor parameters is about 10% as some parameters like neutron flux, reactivity, etc. This means that the system code is completely met requirements in operation management and design new experiments on the DNRR.

Rare Earth Element Effect on Core Physics of a Sodium-Cooled Fast Reactor for TRU Transmutation

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The Korea Atomic Energy Research Institute (KAERI) has developed an advanced sodium-cooled fast reactor (SFR) concept for transuranics (TRU) transmutation with an electricity output of 600 MWe (called the KALIMER-600 TRU burner). The core design philosophy is highly based on passive safety mechanisms for meeting the Generation-IV technology goals. In this design, the metal fuel has been adopted to enhance its inherent passive safety characteristics. The charged fuel in a ternary metal alloy (U-TRU-Zr) consists of self-recycled TRU and TRU recovered from the spent nuclear fuels of current light water reactors through a pyro-metallurgical process, which is assumed to carry over 5% of the inventory of rare earth (RE) elements. It has been recognized that an additional amount of RE in the fuel would decrease the material attractiveness of the charged fuel with respect to proliferation resistance and physical protection (PR&PP). However, this may raise concerns because most of the reactor physics parameters will tend to negatively affect the passive safety features encoded in the original core concept. Therefore, this study investigates the impact of the RE recovery fraction on the core physics performance and important safety parameters such as Doppler coefficients

and sodium void reactivity. The results are expected to help provide guidance regarding the development of limiting conditions for RE contents to recycling technology flow sheet developers and ternary metal fuel developers, and to provide insight into optimizing the core passive safety characteristics under accident conditions should a significant amount of RE be needed to enhance PR&PP.

Mesoscale Model and Application to Nuclear Fuels

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This talk presents the mesoscale modeling which aims at describing the evolution of microstructure under in-pile or iron irradiation such as the evolution of the populations of point defects, defect clusters and fission gas atoms and bubbles. In particular, the talk will focus on the Kinetic Monte Carlo simulation and Rate theory and their specific applications to nuclear fuels as UO_2.

New Design of VVER-1000 Fuel Assembly using Burnable Poison Particles

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New design of VVER-1000 fuel assembly using Gd_2O_3 spherical particles as burnable poison for controlling excess reactivity and pin power peaking factor has been investigated. The motivation is that the use of Gd_2O_3 in form of micro-particles would increase the thermal conductivity of the Gd_2O_3 bearing fuel pellet which is one of the desirable characteristics for designing future high burnup fuel. Neutronics calculations have been conducted for the fuel assembly with the Gd_2O_3 particles distributed randomly using the Monte Carlo neutron transport MVP code. The results show that the Gd_2O_3 particles with the diameter of 60 µm could control the reactivity similarly to the homogeneous distribution of Gd_2O_3 with the same total amount. The power densities at the fuel rods with Gd_2O_3 particles increase by about 11%, leading to the decrease of the power peak and a slightly flatter power distribution. The power peak appears at the periphery fuel pins at the beginning of burnup which decreases slightly by 0.9%. Investigation has been performed to reduce the pin power peaking factor by increasing the number of Gd_2O_3-dispersed fuel rods and optimizing the particle diameter. The results show that by using 18 Gd_2O_3-dispersed fuel rods (instead of 12 Gd_2O_3-bearing fuel rods) with the same total amount of Gd_2O_3 and the particle diameter of 150 µm, similar reactivity curve can be obtained as the reference one while the pin power peaking factor at the beginning of burnup is decreased by about 5%.

Fuel Loading Pattern Optimization for VVER Nuclear Reactors

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A study on fuel loading pattern optimization of a VVER reactor has been conducted. A core physics simulator has been developed based on a multi-group diffusion theory which could handle the triangular meshes for the use in the problem of fuel loading optimization of VVER reactors. Several optimization methods such as Simulated Annealing (SA), Tabu Search (TS) and a combination of them have been investigated and implemented in coupling with the core simulator. Calculations have been performed for optimizing the fuel loading pattern of a VVER-1000 core based on a benchmark core model and compared with the reference core. Comparison among the optimization methods shows that a combination of SA+TS is more effective. In the future works, further advanced methods are being investigated for the problem of fuel loading pattern optimization.

Characterization of a Neutron Calibration Field with ^{241}Am − Be Source using Bonner Sphere Spectrometers

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This paper presents the characterization of a neutron calibration field of a ^{241}Am−Be source using Bonner sphere spectrometers. The characterization of the neutron field in terms of neutron ambient dose equivalent (nDE) rates and neutron flux spectra was performed using generalized-fit and semi-empirical fit methods together with an unfolding technique using the MAXED code. Monte Carlo simulations using MCNP5 and the measurements using a neutron survey meter Aloka TPS-451C have also been conducted to qualify the characterization process. Comparison of the neutron fluxes and the nDE rates obtained from the various methods shows that the components of the neutron fluxes are in good agreement with a discrepancy of about 2%. The discrepancy of the direct nDE rates obtained from different methods is within 3%. This good agreement among the methods indicates the reliability of the neutron calibration field characterization process for practical calibration of neutron measuring devices. The results also suggest that the calibration should be conducted at a distance less than 200 cm to ensure the contribution of the scattered component in the reading of the device less than that of the direct component by 40%.

Rossi-α Parameter Measurement of Dalat Nuclear Reactor by Analysis of Cross Power Spectral Density Obtained from 2 Ion Chambers

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Measurement and analysis of reactor power fluctuations from the compensated ion chambers (CIC) placed in the reactor are a powerful method in experimental study of nuclear reactor. This method allows us to determine the important kinetic parameters such as Rossi-α parameter (prompt neutron decay constant), reactivity, square module of reactor transfer function, effective delayed neutron fractions and neutron generation time, etc. .

In this report, the authors present basis on theory, system of equipment used to measure power spectral density (PSD) and cross power spectral density (CPSD) of signals obtained from 2 KHK-56 ion chambers placed in the Dalat nuclear reactor. By fitting of the theoretical curves with the measured curves, Rossi-α parameter was determined.

Uncertainty Quantification of Relap5/Mod3.3 for Interfacial Shear Stress During Small Break LOCA

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The Best-Estimate Plus Uncertainty (BEPU) is applied as Deterministic Approach for safety analysis of Nuclear Power Plant using the system analysis code. The system analysis code such as Relap5/Mod3.3 is required to be able to simulate the thermal-hydraulic behavior of nuclear reactor in some accident scenarios. Relap5/Mod3.3 is developed based on two-fluid models and 6 conservation equations for each phase which challenge for mathematical modeling such as one-demensional equation, time-dependent equation, multidimensional effects or complicated geometry. Thus, it is necessary to verify the applicability of a system analysis code that is abble to predict accurately the two-phase flow such as interfacial shear between two phases; liquid and gases. It is also important to know the prediction uncertainty due to the constitutive relation in order to close the two-fluid model equation. Therefore, the experimental data is used to compare with simulation results.

In this work, the UPTF-TRAM simulated the counter-current flow in Loop-seal Clearing between vapor and liquid in Loop-seal clearing during Small-Break LOCA is used to verify the applicability of Relap5/Mod3.3. Moreover, the uncertainty of simulation results is also investigated using the statistical method or BEPU using SUSA program which is developed by GRS. The results show that the multiplier of interfacial shear stress

between exprimental data and calculated by Relap5/Mod3.3 model has Normal distribution and the uncertainty of prediction by computer code is estimated by these multipliers.

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