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Book of Abstracts

Contents

26

Fundamental physics with the atomic nuclei I

Presentation type:

27

Fundamental physics with atomic nucleus II

Presentation type:

30

The RIBF Facility: A brief overview for newcomers

Presentation type:

31

Radiation detector, quantum sensing and its medical applications

Presentation type:

32

Radiation detector, quantum sensing and its medical applications II

Presentation type:

36

Direct reaction and r-process nucleothynsesis I

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Presentation type:

38

Partonic structure of hadrons through DIS and physics at the EIC

Presentation type:

Young Scientist Session I / 1

ER cross-section and ER gated spin distribution measurements in the mass region A~190

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Evaporation Residue (ER) cross-sections and ER gated γ-ray fold distributions were measured for the ^{32}S + ^{154}Sm nuclear reaction above the Coulomb barrier at six different beam energies from 148 to 191 MeV. γ-ray multiplicity and spin distributions were extracted from ER-gated fold distributions. The measured ER cross-sections are compared with the results of both the Statistical model calculations and the dynamic model calculations. Statistical model calculations have been performed to generate a range of parameter space for both the barrier height and Kramers' viscosity parameter over which ER cross-section data can be reproduced. The calculations performed by the dinuclear system model reproduce the data considering both complete and incomplete fusion processes. Comparison of the ER cross-sections measured in previous work using very different target-projectile combinations with much less mass asymmetry than the present measurement clearly demonstrates the effect of the entrance channel on ER production cross-section.

In the present case, ^{186}Pt* compound nucleus was popultaed to measure the ER cross-sections. These measurements were carried out using HYbrid Recoil Mass Analyser (HYRA) in gas mode coupled with TIFR 4π spin-spectrometer. ^{32}S pulsed beam from 15 UD Pelletron + LINAC accelerator facility at IUAC(Inter-University Accelerator Facility), New Delhi with an average current of ~ 0.5 - 1 pnA was bombarded on ^{154}Sm target of thickness 118µgm/cm^2 with carbon capping and backing of 25µgm/cm^2 and 10µgm/cm^2 respectively.

Raw fold distributions were ER-gated to remove statistical and non-rotating γ rays contributions. Realistic simulations of TIFR 4π spectrometer, consisting of 32 NaI(Tl) detectors were carried out using Geant4, and fold distribution for different multiplicities were generated i.e. for a given gamma multiplicity M, distribution in fold k. Fold distribution P(k) probability can be given by:
\begin{equation}
P(k) = \sum_{M_{\gamma=0}}^{\infty}R(k,M_{\gamma}) P(M_{\gamma})
\end{equation}
where R(k, M_γ) is the response function, in other words, it is the probability of firing k detectors out of N detectors for M uncorrelated γ rays and P(M_γ) is the probability of multiplicity distribution. Experimental fold data is used to extract multiplicity as well as spin distribution of ^{186}Pt*.

Response function was generated using Geant4 simulations using the exact geometry of the spin-spectrometer. We have convoluted experimental fold data with R(M_γ,k) to get the multiplicity distribution (with error bars). Theoretical calculations along with experimental results will be presented in the school.

Presentation type:

Young Scientist Session I / 4

Investigation of single-particle and collective behavior in K-isotopes

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Nuclei in the neighborhood of doubly closed ^{40}Ca usually exhibit characteristics of spherical single particle excitations [1] and their excitation spectra are well explained by spherical shell model. However, in Nilsson diagram, the low Ω orbitals from pf shell, especially for $1f_{7/2}$ are sharply down sloping for increasing deformation. Therefore, one may expect deformed or superdeformed structures with multi-hole multi-particle configurations in the sd shell nuclei. The observation of super deformed bands in ^{42}Ca [2], ^{40}Ca [3], ^{40}Ar [4, 5], ^{38}Ar [6], ^{36}Ar [7], and ^{35}Cl [8] have generated new interest in this mass region. The observed bands were also explained successfully by shell model calculations. Therefore, this region gives us a unique opportunity to investigate experimentally, the interplay between single-particle and collective degrees of freedom and interpret them theoretically by larger-scale shell model calculations.

^{38}K (N=Z=19) and ^{40}K (Z=19 and N=21) are odd-odd nuclei in this region. ^{38}K and ^{40}K nuclei were previously studied by C.J. van der Poel *et. al.* [9] and P.-A. Soderstrom *et. al.* [10], respectively, through heavy-ion reaction. The level scheme of ^{38}K was extended to 11 MeV, whereas 8 MeV for ^{40}K. The spin and parity of most of the levels were not confirmed / assigned for both nuclei. Lifetime information was also not available for most of the levels. In the present work, we have experimentally investigated the high spin structure of ^{38}K and ^{40}K and interpreted them theoretically through Large Basis Shell Model (LBSM) calculations.

We have performed two heavy-ion experiments at IUAC, New Delhi, to populate ^{38}K and ^{40}K nuclei. We have added 4 new transitions and 2 new levels above the isomer in the existing level scheme of ^{38}K. Our current work identifies 14 new transitions and 6 new levels in ^{40}K. The R_{DCO}, R_{ADO} and linear polarization measurements were carried out to assign / confirm / modify the spin and parity of the levels for both nuclei. In our present work, we have measured the mixing ratio of most the transitions for the first time. LBSM calculations have been performed using the code OXBASH [11] to understand the microscopic origin of each excited state in ^{38}K and ^{40}K. The SDPFMW [12] interaction was used in these calculations. Two-nucleon transfer spectroscopic factor calculations have been carried out for a few levels of interest in these nuclei to understand the spectroscopic co-relation with the levels in the neighboring nuclei (A±2). Evolution of collectivity with angular momentum has also been studied in terms of particle partitions of the levels. Based on the theoretical analysis, we have predicted the presence of a deformed band at the higher excitation energies in ^{38}K.

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Presentation type:

Young Scientist Session I / 49

Development of a cosmic ray calibration method for GAGG(Ce) scintillation detector

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In nuclei, protons and neutrons are not uniformly distributed, but rather form sub-structures called nuclear clusters within the nucleus. This has been known since the discovery of the nucleus by Rutherford, but it has not been explicitly taken into account in the standard picture of nuclei in current nuclear physics. For example, it is not known how the magic number that appears in nuclei is related to the formation of nuclear clusters. On the other hand, without a picture of nuclear clusters, it is difficult to explain even the fundamental decay process, alpha decay.

We have started the ONOKORO project to elucidate the formation mechanism of clusters inside nuclei using the cluster knockout reactions. We are currently developing the TOGAXSI telescope, a detector designed specifically for cluster knockout measurement.
TOGAXSI consists of a GAGG(Ce) scintillation detector as an energy calorimeter and a Si strip detector as a position detector.

In this study, we developed a calibration method for the GAGG scintillator using cosmic rays and evaluated the accuracy of the relative light output and energy calibration among different crystals. The evaluation using the beam showed that a kinetic energy resolution of 0.2% was achieved. This is better than the 1% kinetic energy resolution required to realize the target cluster separation energy resolution of 2 MeV.

On the other hand, the absolute calibration of kinetic energy using cosmic rays could only be determined with an accuracy of about 11%.

This can be due to the difference in the response of the GAGG scintillator to cluster particles and cosmic rays. In future work, we plan to quantitatively evaluate the effects of quenching and the position dependence of the light output.

Presentation type:

Oral presentation

Young Scientist Session I / 3

Moments of inertia of pairing rotation within the BCS model for Sn and Ni isotopes

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The pair condensation in a nucleus can be regarded as the "deformation"of the nucleus in the gauge space due to the pairing correlation, thus creating a rotational degree of freedom. The deformation makes it possible to specify orientation angles. This is analogous to the fact that spatial deformation produces rotational modes in real space.
The energy of rotation in real space is written as $E(I) \approx I(I+1)/2J$, where I is an angular momentum, and J is a moment of inertia. From the analogy with the spatial rotation, we may expect that the energy of rotation in gauge space is described by the ground-state energies of different neutron (proton) numbers as $E(N) \approx (N-N_0)/2J$, and thus the ground states form the rotational spectra. It is called "pairing rotation." Experimental data also support the interpretation of this pairing rotational band.
In this study, we focus on the moment of inertia J of the pair rotation.

In this study, we adopt a pairing model and calculate the pairing rotational bands and their moments of inertia in the BCS approximation. We analyze the properties of neutron pairing correlation for Sn and Ni isotopes.
From our calculation, the energy of pairing rotation is well reproduced by the BCS model. The isotopic trend of moments of inertia calculated with number projection change at 114Sn, 68Ni, and this is because the orbitals that contribute to the pairing correlation change at these isotopes. Furthermore, we will discuss the relation between this change in the moment of inertia and the second-order quantum phase transition with a control parameter N.
We investigate the dependence of moments of inertia on the size of pair condensation.
We will also discuss the properties of the pairing rotational moment of inertia such as the dependence on the size of the pair condensation and the similarity and difference with the inertia for the spatial rotation.

Presentation type:

Young Scientist Session I / 5

High precision calculations of nuclear charge radii using Bayesian neural networks

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Charge radius is one of the most fundamental properties of a nucleus. However, a precise description of the evolution of charge radii along an isotopic chain is highly nontrivial, as reinforced by recent experimental measurements. In this presentation, a Bayesian neural network (BNN) based approach with six inputs including the proton number, mass number, and engineered features associated with the pairing effect, shell effect, isospin effect, and "abnormal" shape staggering effect of ^{181,183,185}Hg, is proposed to accurately describe nuclear charge radii. The new approach is able to well describe the charge radii of atomic nuclei with $A \geq 40$ and $Z \geq 20$. The standard root-mean-square (rms) deviation is 0.014 fm for both the training and validation data. In particular, the predicted charge radii of proton-rich and neutron-rich calcium isotopes are found in wonderful agreement with experimental data. We further demonstrate the reliability of the BNN approach by investigating the variations of the rms deviation with extrapolation distances and mass numbers.

Presentation type:

Young Scientist Session I / 10

Study of $\pi \to \pi\pi$ transition generalized parton distributions and the non-diagonal DVCS

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The generalized parton distributions (GPDs) provide abundant information on the hadron structure such as spin structure and spatial distribution in terms of quark and gluon degrees of freedom and can be accessed through the hard exclusive reactions such as the deeply virtual Compton scattering (DVCS) and deeply virtual meson production. In particular, in the presence of the resonance state of the target nucleon, one can investigate the transition GPDs which may give us information on the dynamics of such transitions. In this work, we study the DVCS process of $\gamma^*\pi \to \gamma\pi\pi$ involving the $\pi \to \pi\pi$ transition GPDs as a spinless example of developing the framework of the transition GPDs. Here we introduce the parameterizations of $\pi \to \pi\pi$ transition GPDs up to the leading twist accuracy and investigate their symmetric properties. We used the soft-pion theorem to show that they are normalized in terms of the usual pion GPDs under the condition that one of the two final state pions is taken to be soft. Also, the hadronic tensor in the DVCS amplitude is calculated in the isospin invariant form so that one can see which GPDs contribute to the physical process such as the Sullivan-type of $eN \to e\gamma\pi\pi N'$ reaction.

Presentation type:

Oral presentation

Young Scientist Session I / 51

Application of quantum computation in predicting the neutron drip line in oxygen isotopic chain

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Atomic nuclei are complex many-body systems composed of nucleons interacting via strong nuclear force. Understanding nuclear properties from the nucleon-nucleon force is one of the main goals of low-energy nuclear physics. Like other quantum many-body problems, the structure of atomic nuclei can be effectively solved using configuration-interaction methods. One such method that is very successful in solving many-body problems of nuclear structure is the nuclear shell model [1, 2, 3]. But, the exponential increase in Hilbert space with increasing nucleon numbers has become a computational challenge for classical computers. Quantum computers are emerging as promising tools for solving many-body problems across the spectrum of physical sciences. These devices are natural quantum systems in which the principles of quantum mechanics, like the superposition principle and entanglement, are embedded.

In the noisy intermediate-scale quantum era [4], variational algorithms have become a standard approach to solving quantum many-body problems. Here, we present variational quantum eigensolver (VQE) [5] results of selected oxygen isotopes within the shell model description. The aim of this work was to locate the neutron drip line of the oxygen chain using unitary coupled cluster (UCC) type ansatze [6] with different microscopic interactions (DJ16 [7], JISP16 [8], and N3LO [8]), in addition to a phenomenological USDB [9] interaction. While initially infeasible to execute on contemporary quantum hardware, the size of the problem was reduced significantly using qubit tapering techniques in conjunction with custom circuit design and optimization. The optimal values of ansatz parameters from classical simulation were taken for the DJ16 interaction, and the tapered circuits were run on IonQ's Aria [10], a trapped-ion quantum computer. After applying gate error mitigation for three isotopes, we reproduced exact ground state energies within a few percent error. The post-processed results from hardware also clearly showed ^{24}O as the drip line nucleus of the oxygen chain. Future improvements in quantum hardware could make it possible to locate drip lines of heavier nuclei.

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Presentation type:

Oral presentation

37

Direct reaction and r-process nucleothynsesis II

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Presentation type:

40

Ab initio calculation I

Presentation type:

33

Radiation detector, quantum sensing and its medical applications III

Presentation type:

28

Fundamental physics with atomic nucleus III

Presentation type:

Young Scientist Session II / 8

Dark matter effect on the neutron star equation of state

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This talk explores the effect of dark matter, captured by the strong gravity and high density of neutron stars, on the equation of state (EoS) of neutron stars. We establish a theoretical framework incorporating dark matter interactions and demonstrate potential modifications in the neutron star EoS. These theoretical modifications allow us to explore potential constraints on the properties of dark matter by comparing them to observational data. In particular, we would like to discuss whether

they can provide unique insights into the characteristics of the dark sector. The presentation concludes with a discussion on future prospects.

Presentation type:

Young Scientist Session II / **56**

Experimental study of halo structure and neutron correlations in 6He nuclei at CRIB via elastic and transfer reaction: p+6He

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The 6He nucleus, as the lightest halo nucleus described well by an alpha particle and two weakly bound neutrons, which can be used as a reference for understanding other complex halo nuclei. In order to investigate the continnum effect of 6He excited state (2+) on elastic scattering and further explore the 6He halo structure and the correlation of two neutrons within 6He, the 6He + p reactions were performed at CNS RI beam separator (CRIB). Two MWDC were used to track the 6He beam, the reaction products of interest were detected by an array of 6 dE-E silicon telescopes covering 10-70 degrees in the lab. system. In this talk, the experiment and preliminary analysis results will be discussed.

Presentation type:

Oral presentation

Young Scientist Session II / **54**

A new method for derivation of the proton distribution radii through charge-changing cross sections for light-mass isotope chains

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We are attempting to derive the proton and neutron distribution radii by simultaneous measurements of the interaction cross sections and the charge-changing cross sections. The relationship between the proton distribution radius and the charge-changing cross section can be intuitively understood through geometric considerations. However, previous studies have revealed that the charge-changing cross section does not simply correspond to the proton distribution radius of the incident nucleus but also depends on the neutron distribution of the incident nucleus. Therefore, in this study, we devised a method to quantitatively evaluate the portion dependent on the neutron distribution and subtract it from the charge-changing cross section to derive the proton distribution radius. Specifically, we measured the charge-changing cross sections at ~ 170A MeV for He, Li, and Be isotopes on several target nuclides. Proton distribution radii of both projectiles and targets are known. As a result, we found that the contribution from the portion of the charge change cross section that depends on the neutron distribution of the incident nucleus is found to be particularly large for the proton target. Utilizing this fact, we will discuss a new method to derive the proton distribution radii.

Presentation type:

Oral presentation

Young Scientist Session II / 7

β-delayed γ-ray Spectroscopy of Neutron-rich Ru Isotopes Below 132Sn

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The beta-delayed gamma-ray spectroscopy of neutron-rich Ru isotopes is investigated at the Radioactive Isotope Beam Factory of RIKEN. The beta-decay schemes of these nuclei are established with the use of prompt-prompt and prompt-delayed gamma-gamma-coincidence measurement by EURICA -ray detection array. The systematic trends of low-lying states and their implications on single-particle orbit and shape evolution far below 132Sn will be discussed.

Presentation type:

Young Scientist Session II / 6

Cooper quartet correlations in infinite symmetric nuclear matter

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In this work, we have studied the quartet correlations in the cold infinite symmetric nuclear matter. The hierarchical structure of in-medium cluster formations has been investigated. We have extended the Bardeen-Cooper-Schrieffer-type variational wave function to the systems also with quartet correlations, and discussed how various physical properties will be modified by the quartet correlations at thermodynamic limit. Our work would be useful for further understanding of exotic matter, and the calculations of different kinds of the equations of states in realistic systems.

Presentation type:

Young Scientist Session II / 9

The equation of state for neutron star using basic relativistic mean-field model

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Neutron stars are known to be one of the densest objects in the universe.
Information on condition in extreme dense matter, which is impossible to measure in the terrestrial experiments, can be obtained through astrophysical observation data.
In particular, the observation results from neutron stars are very useful to constraint the nuclear equation of state (E0S) at high densities.
There are several ways to obtain the EoS in the high-density region.
In our presentation, we use the basic relativistic mean-field model which includes the sigma, omega, and rho mesons, and calculate energy density and pressure of neutron-star matter.
We also study the properties on a neutron star such as a mass-radius relation by solving the TOV equation.

Presentation type:

Young Scientist Session II / 15

Bound and scattering states of the electron wavefunctions calculated with the Dirac equation for $0\nu\beta\beta$

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In some nuclei, a phenomenon called double beta decay, in which two nucleons simultaneously undergo beta decay, is known to occur rarely. In this case, two neutrinos are emitted. Neutrinos may be Majorana particles, which do not distinguish between particles and antiparticles among Fermi particles. In that case, double beta decay without neutrino emission ($0\nu\beta\beta$) may occur. If the half-life of this decay can be measured experimentally and quantities called the phase space factor and nuclear matrix element can be calculated theoretically, the effective neutrino mass can be obtained. In this study, in preparation for the phase space factor calculation, first I calculated the wavefunctions of electrons in the bound state for hydrogen atoms and compared with the exact solution of the Dirac equation, and then calculated the wavefunctions of electrons in the scattering state for several double-beta decaying nuclei including $^{48}\mathrm{Ca}$ and $^{150}\mathrm{Nd}$.

Presentation type:

Young Scientist Session II / 52

Large-scale shell-model study of two-neutrino double beta decay in 82Se

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Double-beta ($\beta\beta$) decay is one of the rarest second-order weak interaction processes with two major decay modes: two-neutrino (2ν) and neutrinoless (0ν). Mayer [1] first introduced the $2\nu\beta\beta$ decay process as a nuclear disintegration with the simultaneous emission of two electrons and two antineutrinos. This process is allowed by lepton number conservation. The study of $2\nu\beta\beta$ decay provides an important test for the standard model and insights into the properties of neutrinos, which are currently a subject of intense research in nuclear and particle physics.

The half-life for the $2\nu\beta\beta$ decay can be given as, $t_{1/2}^{2\nu} = \frac{1}{G^{2\nu} g_A^4 |M_{2\nu}|^2}$. Here, $G^{2\nu}$ denotes the phase-space factor [2]; g_A is the axial-vector coupling strength [3]; $M_{2\nu}$ is the nuclear matrix element (NME) for $2\nu\beta\beta$ decay. There are several candidates for $2\nu\beta\beta$ decay in the nuclear chart, and among them, ^{82}Se is an important candidate for this process. We have performed systematic shell-model calculations for studying the $2\nu\beta\beta$ decay process in ^{82}Se. The jun45 effective interaction [4] is used to calculate the nuclear matrix element (NME) for $2\nu\beta\beta$ decay, having the $0f_{5/2}1p0g_{9/2}$ proton and neutron orbitals. For the calculation of NME, we have calculated 1000 intermediate 1^+ states in ^{82}Br up to the excitation energy of 7.427 MeV. Here, the experimental value for the energy of the lowest 1^+ state in ^{82}Br is taken at 0.075 MeV. Using the shell-model calculated value of NME, we have extracted the half-life of ^{82}Se for $2\nu\beta\beta$ decay as 0.68×10^{20} yr. This value is very close to the average value $0.87^{+0.02}_{-0.01} \times 10^{20}$ yr given in Ref. [5].

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Presentation type:

Oral presentation

44

Equation of state of the nuclear matter

Presentation type:

47

High-precision mass measurements at low ion energies: Penning traps and multi-reflection devices

Presentation type:

41

Ab initio calculation II

Presentation type:

29

Fundamental physics with atomic nuclei IV

Presentation type:

Young Scientist Session III / 48

Measurement of the 11B target thickness by using the elastic scatterings with proton particles of 1.1 - 1.9 MeV energy

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The thickness of the ^{11}B target was determined by using ^{11}B(p,p$_0$) elastic reaction. The proton beams were accelerated up to the energy range from 1.1 - 1.9 MeV by the Pelletron 5SDH-2 accelerator at Hanoi University of Science. The measured ^{11}B target thickness is 65.45 ± 3.78 $\mu g/cm^2$, lower than the value of 74 $\mu g/cm^2$ from the target supplier. This result demonstrates the capability of this method in the target thickness determination.

Keywords: thickness, boron target, proton –nucleus elastic scattering, Pelletron.

Presentation type:

Oral presentation

Young Scientist Session III / 53

High spin spectroscopy of nuclei near A~90

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Nuclei near shell-closed remain a topic of immense interest in nuclear structure research for investigating different aspects of single particle and collective excitation. We have systematically investigated nuclei in the 90-mass region using Indian National Gamma Array (INGA) [1]. The level schemes of most of the isotopes in this region are dominated by single particle excitations, which provide an excellent testing ground for large-scale shell model calculations [2,3,4,5]. Another aspect in this region is observing a dipole band at the intermediate spin for ^{89}Zr, interpreted as a signature of rotation about the longest axis [6]. The odd-odd nuclei in the mass 90 region are equally interesting because both the odd nucleons span the same Z~40, N~50 subshell space, providing a good testing ground to study the role of proton-neutron residual interaction and its influence on both the single-particle as well as collective motion. The odd-odd nucleus ^{90}Nb, with one proton particle and one neutron hole outside the Z = 40 and N = 50 shells, respectively, can provide us valuable information about the particle-hole interaction at low as well as high-spin states. In-beam gamma-ray spectroscopy of ^{90}Nb was studied using fusion-evaporation reaction ^{65}Cu(^{30}Si, 3n2p) at a beam energy of 120 MeV. I will present our experimental results on the ^{90}Nb nucleus and its comparison with the large-scale shell model calculation.

Acknowledgment:
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Presentation type:

Oral presentation

Young Scientist Session III / 58

The Cross-Section Measurement of 16N at Intermediate Energies for ESPRI*

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Density distributions tell us the characteristics of nuclei, such as the nuclear size and nuclear skin structure.
Both proton and neutron density distributions can be acquired by proton elastic scattering at two different intermediate energies such as 200 and 300 MeV/u.
For stable nuclei, proton beam and targets of stable nuclei are used.
Inverse kinematics are used for short-lived nuclei, such as unstable nuclei.
ESPRI (elastic scattering of protons with radioactive ion beams) is the unique way of acquiring nuclear density distributions.
Nuclear isomers, another kind of short-lived nuclei, are planned to be also investigated by inverse kinematics.
Three important devices and techniques are needed to be developped or improved for proton elastic scattering with isomers (ESPRI*):
isomer beam, ESPRI detectors, and isomer tagging detector.
This report shows the brief results of 16N beam production cross-section around 200 and 300 MeV/u, performed at HIMAC (heavy ion medical accelerator in Chiba).

Presentation type:

Oral presentation

Young Scientist Session III / 18

Consistent analyses of nuclear structures and reactions using Gamow Shell Model (GSM)

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The nuclear shell model is a traditional approach for describing and predicting the nuclear properties. It is based on the idea that nucleons occupy shells in the nucleus and interact with each other through a residual two-body interaction. The Gamow shell model (GSM) is an extension of the conventional shell model and uses Gamow-style many-body wavefunctions. GSM is based on Rigged Hilbert space and introduces complex-energy eigenstates. GSM is a quasi–stationary open quantum system extension of the standard configuration interaction approach for well-bound system. GSM explains bound, resonant, and non-resonant states, simultaneously, in unified bases. GSM allows for a unified treatment of nuclear structures and reactions. Calculated results using the GSM will be shown along with the description of the GSM.

Presentation type:

Young Scientist Session III / 20

Calculation of radial moments of charge distribution compared to precision spectroscopy data

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The charge radius is one of the most fundamental quantities concerning nuclear structure. Recent advancements in high-precision spectroscopic measurements utilizing isotope shifts have provided accurate experimental data on the second-order moments of charge distribution, including isotopes in regions of proton and neutron excess. However, there is no precise theoretical calculation that can match these experimental values.
In this study, we conduct an analysis to develop theoretical calculations capable of reproducing the experimental data. Our calculations take into account not only the contribution from proton distribution but also the contribution from neutron distribution in determining the charge distribution of nucleus. By comparing the calculated results with experimental values, we investigate the systematic change among various isotopes. Calculations employing the Fayans type density functionals in the mean field model successfully reproduce the changes in the second-order moments of charge distributions observed in Ca isotopes and other isotopes. However, we know that there are unstable regions where experimental values cannot be reproduced. We will discuss current state of charge radius calculations and the necessity to construct theoretical models beyond the mean field approximation.

Young Scientist Session III / 22

Nuclear data generation by machine learning

Author: Shoto Watanabe[1]

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Nuclear data play an important role in various scientific fields. However, the generation of nuclear data entails enormous human and time costs.
Recently, attempts have been made to solve this problem by using machine learning to generate nuclear data. We aim to generate accurate nuclear data at low cost by combining nuclear reaction models with machine learning.
In this presentation, we will report the results of estimating nuclear data using Gaussian process regression, a form of machine learning, to estimate the optimal values of the parameters of nuclear reaction models at arbitrary energies.

Presentation type:

Young Scientist Session III / 57

Comparison study of transport models, DJBUU and SQMD

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The equation of state (EoS) of dense matter, such as EoS for neutron stars, remains an open question as it has not yet fully been established. To gain insights into the structure of dense stellar objects, we could rely on experimental information provided by heavy ion collisions. These collisions serve as terrestrial experiments that offer valuable data on the EoS. Transport models, in particular, enable us to describe the time evolution of dynamics, and therefore they are well-suited for studying the nature of high baryon number density produced in heavy ion collisions. In this study, we compare the results of simulations using the DJBUU and SQMD transport codes, which are developed based on two different frameworks: Boltzmann-Uheling-Ulenbeck (BUU) and Quantum Molecular Dynamics (QMD). Specifically, we focus on the comparison of the largest primary fragments observed in simulations of the ^{208}Pb+^{40,48}Ca collision scenarios.

Presentation type:

45

Equation of state of nuclear matter II

Presentation type:

42

Ab initio calculation III

Presentation type:

39

Partonic structure of hadrons through DIS and physics at the EIC

Presentation type:

Short presentation for poster contributions / **11**

Performance and Geant4 simulation of the upgraded focal plane polarimeter 2nd-FPP

Author: YUSUKE TANAKA[1]

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We have designed and upgraded the focal plane polarimeter 2nd-FPP to improve the position and angle resolution. Four MWDCs were newly introduced. The experiment with protons of polarization P=0.99 by p-C elastic scattering at 65 MeV was performed at RCNP in order to evaluate the overall performance. The position resolution of about 0.34 mm has been achieved, which is about two orders of magnitude better than that obtained from plastic scintillator information. This better resolution is useful to separate p-C elastic events from p-p scattering events at large angles. The resulting effective analyzing powers at angles larger than 60 degrees are consistent with the design values based on p-C analyzing powers. However, those at small angles are significantly small, and thus we have been developing a Geant4 simulation to evaluate the contribution effect of p-p scattering contribution. In this contribution, the experimental results and the progress of the Geant4 simulation to introduce the polarization effects will be presented.

Presentation type:

Short presentation for poster contributions / **12**

Construction of a renewed 33Mg → 33Al decay diagram

Author: Yamamoto Yosuke[None]

Co-author: S1840 collaboration

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Neutron-rich nuclei near the neutron number 20 are known to exhibit exotic structure, such as shape deformation of their ground states, contrary to a spherical shape expected from the conventional magicity for the neutron shell. The mass region is called the "island of inversion"and a variety of experimental works has been devoted to study it. To unravel the mechanism to generate the "island of inversion", we have systematically studied excited states of neutron-rich Al isotopes by a unique method of the spin-polarized beta-decay spectroscopy, where spins Al levels fed by the beta decay of Mg are experimentally determined without ambiguity. As the first step, we performed an experiment to investigate the level structure of 33Al by using "non-polarized" 33Mg at TRIUMF. In this experiment, the gamma and beta rays were measured by 8 telescopes each consisting of a high-purity germanium detector and a thin plastic scintillator. Based on the analysis of gamma-gamma coincidence and the gamma-ray intensities, we constructed a renewed decay scheme of 33Mg → 33Al. The detailed analysis and results will be presented.

Presentation type:

Short presentation for poster contributions / **13**

Performance evaluation of MWDCs for deuteron-proton scattering measurement

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Understanding nuclear forces is necessary to describe nuclear phenomena, and recently it has become clear that three-nucleon forces, which act between three nucleons, are also essential. We are planning to measure the spin correlation coefficient, one of the spin observables, from deuteron-proton elastic scattering for gathering accurate information on three-nucleon forces.
We use a polarized proton target for the deuteron-proton elastic scattering experiments and the magnetic field generated by an electromagnet for polarization of the target. Since the magnetic field bends the trajectory of scattered particles, we have constructed multi-wire drift chambers, or MWDCs, to track the particle trajectories. The MWDC is a detector with an array of wires that detects passing charged particles by ionization of the gas inside, allowing tracking of particle trajectories.
In this research the detection efficiency and the position resolution of two MWDCs were evaluated using proton-polarized proton elastic scattering at 200 MeV/nucleon, performed with HIMAC in QST. As a result, both MWDCs achieved 99% detection efficiency, and the position resolution of those was 201 ± 2 μm and 227 ± 3 μm, respectively. Based on this result, the evaluation of resolution under the stronger influence of the magnetic field will be discussed in the future.

Presentation type:

Short presentation for poster contributions / 14

Barrier distribution and excitation function measurements of the 51V + 159Tb fusion reaction for estimating the optimal reaction energy for the synthesis of new elements.

Author: Yuya Michimoto[1]

Co-authors: Satoshi Sakaguchi [1]; nSHE Collaboration

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We, the nSHE Research Group, are searching for new elements beyond element 118 (oganesson), i.e. element 119, at RIKEN. The probability of producing superheavy elements by fusion reactions is extremely low. Therefore, it is crucially important to determine the optimal experimental conditions to maximize the production rate, especially by predicting the optimum incident energy that maximizes the cross section. For this purpose, we have been developing a method to estimate the optimal energy based on the experimental data of quasielastic (QE) barrier distributions. In this study, we measured the QE barrier distribution and excitation function of the evaporation-residue cross section for the 51V+159Tb fusion reaction. This reaction system was chosen because 159Tb has a large quadrupole deformation similar to that of 248Cm used in the search for element 119. The comparison of the QE barrier distribution and the excitation function was used to clarify the fusion reaction mechanism involving the deformed nuclei and to improve the accuracy of the method for estimating the optimal incident energy.
In this presentation, We will show the results of the barrier distribution and excitation function measurements for the 51V+159Tb system. The experiments were performed at the RIKEN superconducting heavy-ion linear accelerator facility (SRILAC). The measured data are compared with coupled-channel calculations using the CCFULL code.

Presentation type:

Short presentation for poster contributions / 17

Development of dual-species spin maser of 129Xe and 131Xe toward the EDM measurement

Author: Kohei Tanimoto[None]

Co-authors: Yuichi Ichikawa [1]; Shuhei Tachikawa [1]; Tomoya Sato [2]; Sota Ando [1]; Yusuke Shinohara [1]; Yosuke Yamamoto [1]; Hiroki Nishibata [1]; Shintaro Go [3]; Aiko Takamine [3]; Hideki Ueno [3]; Koichiro Asahi [3]

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We search for the Electric Dipole Moment (EDM) of Xe atoms using a technique of an artificial-feedback nuclear spin maser. In this study, ^{129}Xe and 131Xe are used to deduce the isotope-differential EDM as well as to work as comagnetometry. The isotope-differential EDM is deduced from the difference of the precession frequency between ^{129}Xe and ^{131}Xe under a magnetic field and an electric field. The spin maser sustains the precession of the Xe spins through the optical detection of the precession and the artificial processing of the signals, enabling long-duration measurements of the frequency. The spin maser apparatus has been established and developed at Kyushu University. Because the frequency uncertainty of the spin maser is mainly limited by the instability of the optical systems currently, we are developing the stabilized operation of the lasers. Furthermore, we study the optimization of the fabrication of the cell containing the Xe atoms by evaluating the spin polarization and relaxation of the Xe spins. In this presentation, the current status of the developments of the spin maser and the evaluation of the spin polarization and relaxation of the spins of ^{129}Xe and ^{131}Xe, will be given.

Presentation type:

Short presentation for poster contributions / 21

Pre-bunching and re-bunching systems at RAON for nuclear science experiments

Authors: Donghyun Kwak[None]; Cheolmin Ham[1]; Kyoungho Tshoo[1]; Seok Ho Moon[2]; Junyeong Jeong[2]; Gi Dong Kim[1]; Jangwon Kwon[1]; Garam Hahn[3]; Woojin Song[4]; Hyung Jin Kim[1]; Taeksu Shin[1]; Chung Moses[2]

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Rare Isotope Accelerator complex for ON-line experiments (RAON) is currently under construction in Korea. The low-energy experimental facilities in RAON include the Korea Broad Acceptance Recoil spectrometer and Apparatus (KoBRA) and the Nuclear Data Production System (NDPS). One of the objectives at RAON is to provide rare isotope and stable ion beams with a wide energy range, up to a few hundreds of MeV/nucleon, to the low-energy experimental facilities for diverse nuclear physics experiments and other applications.
In order to ensure accurate particle identification of the produced RI beams in KoBRA, the bunch length of the primary beam at the KoBRA production target should be less than 0.5 ns in standard deviation (σ). Therefore, a re-bunching system has been designed, developed, manufactured, and installed at the RAON site. Additionally, a pre-bunching system has been implemented upstream of the Radio-Frequency Quadrupole (RFQ) of RAON, utilizing a fast chopper and a Double Gap Buncher

(DGB). This system reduces the repetition rate, enabling precise time-of-flight measurements of secondary particles at KoBRA and NDPS.
In this presentation, we will provide information about the pre-bunching and re-bunching systems for nuclear science experiments at the low-energy experimental facilities of RAON.

Presentation type:

Short presentation for poster contributions / 24

Half-life measurement of 107-keV isomeric state in 45Cr

Author: Mei AMITANI[None]

Co-authors: Chihaya Fukushima [1]; Shin'ichiro Michimasa [2]; Daiki Nishimura [3]; Yuki Nakamura [1]

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An isomeric state of 45Cr with an excitation energy of 107 keV is of much interest for its nuclear structure in terms of the isospin symmetry. The mirror nucleus of 45Cr, 45Sc, has an isomeric state. The isomeric state of 45Sc (Jπ = 3/2+, Ex = 12.4 keV, T1/2 = 325.8 ms), has been well investigated. However, the half-life of the isomeric state of 45Cr was not measured. In the previous research, the lower limit of the half-life was only estimated several hundred μs.

We carried out the delayed gamma-ray spectroscopy as part of the SHARAQ13 collaboration of the mass measurement with TOF-Brho method.
A secondary beam consisting of various proton-rich isotopes in the pf-shell region was produced by the fragmentation of a 78Kr primary beam accelerated at 345 MeV/nucleon impinging on a 9Be target with a thickness of 2.2 g/cm^2.
The beam was implanted into an active stopper of two plastic scintillators downstream of the final focal plane(S2) of SHARAQ spectrometer. For the delayed gamma-ray spectroscopy, the active stopper was surrounded by two HPGe detectors located vertically to the beamline.
The energy and timestamp information of gamma rays were recorded by a DAQ system equipped with digital signal processor, operating in a self-trigger mode.
This system enables us to associate the heavy-ion events with and gamma-ray events without any constraints on the time window.

We successfully measured the half-life of the 107-keV isomeric state of 45Cr and deduced the reduced transition strength of the isomeric decay, for the first time. In this presentation, we will discuss the spin and parity of the isomeric state and the isospin symmetry of pf shell in comparison with the theoretical predictions.

Presentation type:

Short presentation for poster contributions / 25

Gamma-ray measurement for isomeric decays in proton-rich pf-shell nuclei at SHARAQ spectrometer

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The mass measurement of proton-rich unstable nuclei in the vicinity of 47Fe has been performed utilizing the TOF-Bρ method with BigRIPS and OEDO-SHARAQ spectrometer at RIBF. In this measurement, the secondary beam included several nuclei with isomeric states in the pf-shell region. The isomer tagging provides us exact particle identification (PID) like a unique fingerprint. Moreover, the isomeric ratio is essential for the precision of the masses of the isotopes with isomeric states. Our porposes are the discovery of new isomers in this region, the determination of unknown lifetimes and energies, and improvement of their precision.
The gamma-ray detection system which consists of two HPGe detectors, two CeBr3 detectors and an active stopper composed of two 10-mm-thick plastic scintillators was installed downstream of the final focal plane (S2) in the air. The active stopper was placed in the center of the detector arranged. The two HPGe detectors were installed perpendicular to the beam direction, while CeBr3 detectors were tilted at a 45-degee angle. A 20-mm-thick aluminum degrader was installed to adjust the stopping range. Additionally, a veto scintillator was placed downstream of the active stopper to eliminate the possibility of nuclides penetrating it. These energy and timestamp information about the gamma-ray signals were recorded using digital signal processers. Currently, the known isomers, such as 38mK, 43mSc, 46mSc, 43mTi, and 46mV, have been analyzed. In this presentation, we will discuss the accuracy of the gamma-ray energies, half-lives and isomeric ratios associated with these isomers.

Presentation type:

Short presentation for poster contributions / **50**

Direct measurement of the cross section for 102Pd(p,g)103Ag reaction in the p-process

Authors: Fulong Liu[1]; Bing Guo[2]; Chuangye He[2]; Hao Chen[2]; Bo Nan[2]

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The study of the p-process is of paramount importance in unraveling the origin of heavy elements in the universe. To describe the entire p-nuclei nucleosynthesis process, a comprehensive reaction network involving over ten thousand nuclear reactions is required, and accurate measurements of some key reaction cross sections are essential for determining reaction rates. 102Pd is one of the more than 30 p-nuclei, and the 102Pd(p,g)103Ag reaction is one of its significant destruction reactions. Experimental studies for the p-nucleus 102Pd indicate that the reaction rate for 102Pd(p,g)103Ag is significantly higher than HF predictions. There are significant discrepancies in the available data on the 102Pd(p,g)103Ag reaction cross section in the low-energy regime relevant to nuclear astrophysics. In light of these discrepancies, a direct measurement was carried out to determine the reaction cross section of 102Pd(p,g)103Ag within the energy range of 1.9-2.8 MeV. The measurement was conducted utilizing the 2*1.7 MV tandem accelerator at China Institute of Atomic Energy (CIAE). The latest cross section data were obtained using offline activation measurement technique based on the low background anti-muon and anti-Compton spectrometer in CIAE.
The latest results have extended the cross section of 102Pd(p,g)103Ag to the lowest energy range of proton down to 1.9 MeV. The newly measured cross section data provide valuable experimental references for the calculation of statistical models, particularly in the low-energy regime of interest in nuclear astrophysics. These results contribute to a better understanding of the p-process and its implications for the nucleosynthesis of heavy elements in the universe.

Presentation type:

Poster presentation

Short presentation for poster contributions / **55**

Development of a mosaic type array formed by Si photodiodes for charged-particle detection in heavy ion collisions

Authors: Jiatai Li[1]; Nobu Imai[2]; Reiko Kojima[None]; Rin Yokoyama[None]; Shin'ichiro Michimasa[3]; Thomas Chillery[None]; Muzuki Shiraishi[4]

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Si detectors are extensively applied in the measurement of charged particles produced in fusion reactions. To achieve a relatively low-cost charged-particle detection with the position sensitivity, we have developed a mosaic-type array based on Si photodiodes (Hamammatsu S13955-01). Its high modularity allows one to modify the geometric configuration of the array according to specific experimental requirements. The array was commissioned using ^{136}Xe + ^{nat}Zn reaction in July 2022 at HIMAC. In this presentation, details of the detector development and experimental results will be presented.

Presentation type:

Oral presentation

Short presentation for poster contributions / **59**

Development of a Radio Frequency Dipole Mass Filter for the Francium Permanent Electric Dipole Moment Search

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Co-authors: Hiroki Nagahama [2]; Keisuke Nakamura [3]; Naoya Ozawa [4]; Motoki Sato [5]; Teruhito Nakashita [2]; Shintaro Nagase ; Daisuke Uehara

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The permanent electric dipole moment (EDM) of elementary particles is a physical quantity that reflects CP symmetry breaking, and is being explored. In particular, it is theoretically suggested that electron EDMs are amplified as atomic EDMs in heavy elements. In this project, we aim to achieve high-precision EDM measurement using francium (Fr) atoms trapped by laser cooling technique. Toward this end, a radio frequency dipole mass filter (RFDMF) was developed for the generation of high-purity Fr ion beams to enhance the number of trapped Fr atoms. The RFDMF is a device that oscillates the beam using an oscillating electric field, and is designed to remove impurity ions lighter than Fr in a short beam transport system with a total length of several tens of cm. The parameters of the oscillating voltage required for the RFDMF to remove impurities were searched for by simulation, and an AC circuit that can apply an oscillating voltage in the range of the parameters obtained from the simulation was created. The performance of the mass filter was evaluated by off-line experiments using stable atom rubidium and Fr generation experiments using the RIKEN AVF cyclotron.

Presentation type:

Oral presentation

Short presentation for poster contributions / **60**

Development of a novel comagnetometer for high-precision measurement of the electron's electric dipole moment using laser-cooled Fr atoms

Author: Shintaro Nagase[None]

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In this presentation, the current status of a comagnetometer which is dedicated to search for the permanent electric dipole moment of the electron (eEDM) using francium atoms is discussed. The designed comagnetometer consists of laser-cooled Rb-87 and Cs-133 atoms trapped simultaneously in an optical lattice in order to observe the effects of Zeeman shift and vector light shift independently. This is expected to increase the measurement precision of the eEDM, consequently allows to search for the CP violation with high precision.

Presentation type:

Poster presentation

Short presentation for poster contributions / **19**

Production of Np isotopes from 238U beam at BigRIPS

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A variety of unstable nuclear beams with atomic numbers (Z) up to 92 can be produced by the projectile fragmentation and in-flight fission from high intensity U beams at RIBF. Recently, it was found that 234–238Np can be created by a proton pickup reaction on 1GeV/nucleon 238U beam. Owing to the recent developments of the high-Z beams at BigRIPS, energy dependence of the proton pickup reaction on 238U can be obtained at RIBF. Thus, we conducted an experiment to determine the energy dependence of the production cross section of 237Np. A test of the production of Np isotopes was performed by using the BigRIPS spectrometer at RIBF in March 2022.
Secondary beams around Z = 90 were produced by a 238U beam with energies of 345 and 250 MeV/nucleon impinging on a 1-mm-thick 9Be production target at F0 in BigRIPS.
The particle identification (PID) of the secondary beam was performed using the TOF-Bρ-ΔE method. To validate the production of the 237Np91+, a two dimensional (2D) Gaussian fitting approach was conducted in accordance with the distribution patterns of neighboring ions of 234U90+,235U90+, and 232Pa89+. It is found that Np isotope can be counted up with contaminated U/Pa isotopes using the 2D Gaussian fitting technique. The production cross sections of 234U, 235U, 236U, 232Pa, and 233Pa as well as Np isotopes were derived.
In this presentation, we will report the analysis status of 345MeV/nucleon.

Presentation type:

43

Ab initio calculation IV

Presentation type:

46

Equation of State of Nuclear Matter III

Presentation type:

34

Radiation detector, quantum sensing and its medical applications III

Presentation type:

35

Radiation detector, quantum sensing and its medical applications IV

Presentation type: