[RIBF ULIC mini-WS] Structure of neutron-rich matter revealed by beta decay

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Book of Abstracts

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Beyond mean field approach for beta decay

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We study beta decay by using beyond mean field model so called Subtracted second RPA model including 2-particle-2hole configurations on top of 1p-1h configuration. We study also the effect of tensor correlations in beta decay process.

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Large-scale shell model study of β^--decay properties of $\mathbf{N = 126, 125}$ nuclei along the r-process path

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The rapid neutron capture process (r-process) is the most important mechanism for the synthesis of about half of the elements heavier than iron. It occurs in an environment with relatively high temperatures and high neutron densities. The abundances of the elements created by the r-process strongly depend on several nuclear inputs like masses, neutron capture rates, β-decay rates, and β-delayed neutron emission probabilities at the waiting point nuclei. Among them, the β-decay process is crucial in the r-process. In this work, we have investigated various nuclear β-decay properties of $N = 126, 125$ isotones with proton numbers $Z = 52 - 79$ within the framework of the nuclear shell model. This comprehensive analysis considered both Gamow-Teller (GT) and first-forbidden (FF) transitions to evaluate β-decay rates. We have found that including FF transitions in addition to GT transitions is essential, as they significantly impact the total β-decay half-lives near $Z = 82$. Additionally, we systematically analyzed the GT strength distributions as a function of proton number. We have observed that the GT strengths at low excitation energies are rather strong on the proton deficient side due to the increasing number of proton holes in the proton $0h_{11/2}$ orbit, which accelerates GT decay. This investigation aims to provide detailed information on β-decay properties around $A \approx 195$ to understand the distribution of the third r-process abundance peak.

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Nuclear spectroscopy of the nuclei in the vicinity of $N = 126$ at KISS

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The study of the β-decay half-lives and massees of waiting-point nuclei with $N = 126$ is crucial to understand the explosive astrophysical environment for the formation of the third peak in the observed solar abundance pattern, which is produced by a rapid neutron capture process (r-process). However, the half-life and mass measurements of the waiting-point nuclei remain impracticable due to the difficulty in the production of the nuclei. Therefore, accurate theoretical predictions for the half-lives and masses are required for investigations of astrophysical environments. It is essential to perform nuclear spectroscopy for investigating β-decay schemes including spin-parity values, nuclear wave-functions and interactions, and nuclear masses in this heavy region for more precise predictions.

For the nuclear spectroscopy, we developed KEK Isotope Separation System (KISS). The nuclei in the vicinity of $N = 126$ are produced by multi-nucleon transfer reactions (MNT) of ^{136}Xe beam (10.75 MeV/A) impinging upon a ^{198}Pt target. Thanks to newly developed doughnut-shaped gas cell, the extraction yields of the reaction products increased by more than one order of magnitude. This system enabled us to successfully perform bg-decay spectroscopy, in-gas-cell laser ionization spectroscopy, and mass measurements by using MRTOF-MS. To promote these nuclear spectroscopy, we started KISS-1.5/2 project to upgrade the KISS facility to provide more exotic RI beam.

In the presentation, we will report the present status of KISS, experimental results of nuclear spectroscopy in the heavy region, and future plan.

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Recent progress and attempts to describe beta decay based on nuclear DFT

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Perspectives for next beta-decay and delayed-neutron data table

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TBA

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Introduction: Challenges to nuclear theory of beta decay

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I will discuss the roles of nuclear structure on the beta decay in the framework of DFT.

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[online] Sensitivity studies of the r-process rare-earth peak abundances to nuclear masses and beta-decay half-lives

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The sensitivities of the r-process rare-earth peak abundances to nuclear masses and beta-decay half-lives have been studied in different astrophysical scenarios. The most impactful nuclei are identified by varying nuclear masses and beta-decay half-lives, respectively. The impacts of nuclear mass as well as β-decay rate of an individual nucleus on the r-process rare-earth peak abundances are analyzed. The role of fission is discussed in details. This work provides recommended targets for future researches and thus helps to increase the understanding of rare-earth peak formation mechanism and the efficacy of the rare-earth peak as an r -process site diagnostic.

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Test of segmented plastic implantation detector with RI beam at RIBF

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The segmented plastic scintillation detector GARi was tested with RI beam in the focal plain F11 of the RIBF accelerator complex. Implantation-decay correlation was obtained based on the reconstructed ion and beta positions on GARi. Known half-lifes in neutron-rich Ar region were used to validate the implantation-decay correlation. Additionally, several new half-lives in this region were measured for the first time.

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Decay spectroscopy results from EURICA and future perspective of IDATEN

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In this talk, the some experimental results from the previous decay spectroscopy carried out at RIBF, EURICA (EUROBALL-RIKEN Cluster Array), will be introduced. These results are mostly from the neutron-rich isotope beyond the doubly-magic ^{132}Sn nucleus, which are important for the r-process nucleosynthesis scenario. New nuclear structure observables will be presented with the theoretical predictions.

In addition, a newly initiated international collaboration, IDATEN (International Detector Assembly for fast-Timing measurements of Exotic Nuclei) will be also introduced. The IDATEN is the world-largest fast-timing γ-ray detection system comprised of 82 $LaBr_3$(Ce) detectors for decay spectroscopy and a commissioning experiment was recently carried out at RIBF. Preliminary results from this experiment will be presented and the future perspective will be given in this talk.

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[online] Why beta delayed neutrons matter⋯

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Discovered by Roberts et al. beta delayed neutrons are very relevant in reactor control, nuclear astrophysics and nuclear structure. Beta delayed neutron emission is a process that become more a more dominant as we move far away from stability, so its study is crucial for understanding the nuclear structure of very exotic neutron rich nuclei. In this talk, I will present how it is possible to infer nuclear shapes from Pn and T1/2 measurements and why it is relevant to combine neutron spectroscopic measurements with total absorption studies.

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[online] Recent progress in studying β-delayed neutron emission

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β-delayed neutron emission is a common and dominating decay process for most of the neutron-rich nuclei far from the stability line. Experimental investigations on β-delayed neutrons are of great significance in a large variety of fields, including nuclear physics, astrophysics, and industrial applications. First, it is a sensitive probe to the β-decay feedings above neutron separation energy, which is related to the nuclear structures of parent and daughter nuclei. Second, the decay process itself carries fundamental information on how neutron unbound states are formed in β decay. Owing to its importance, rapid progress has been made in measuring β-delayed neutron emission, either inclusive or exclusive, at many different radioactive ion-beam facilities in the last decade. In this contribution, I will present a few highlights of our recent experimental effort in studying β-delayed neutrons in a range of nuclei with mass numbers $A = 24 \sim 132$. The experimental findings were compared with various theoretical models, gaining valuable insights into the shell evolution in exotic nuclei as well as the statistical/nonstatistical natures of β-delayed neutron emission in medium-heavy and heavy isotopes.

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Shape Coexistence and Shape Evolution in Neutron-Rich Nuclei Studied by Beta Decay

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We have been systematically studying shape coexistence and shape evolution in neutron-rich nuclei. These are one of the important subjects to understand appearance of variety of nuclear structure as increase of neutron and proton numbers. We have studied change of nuclear structure by the β decay in wide isospin region such as neutron-rich Mg and Al isotopes close to 'Island of Inversion (IoI)'and neutron-rich A ~ 140 nuclei, which are located in the northeast region of the doubly-magic nucleus on the nuclear chart.
In the former case, experiments have been performed by using spin-polarized beam at TRIUMF with effectiveness to unambiguously assign the spins and parities of the states in daughter nucleus by measuring the β-decay spatial asymmetry of the spin-polarized isotope. We have been systematically studying shape coexistence and shell evolution of neutron-rich nuclei in and around the N = 20 IoI.
In the latter case, the experiment was performed as one in EURICA campaign at BigRIPS in RIKEN. Nuclear structure gradually changes from spherical (single-particle like) shape in nuclei close to the doubly-magic 132Sn to deformed (collective like) shape for nuclei located in transitional region with increasing neutron and proton number. Additionally, octupole correlation can be observed in nuclei around 144Ba (Z=56 and N=88). Namely, we a variety of structure, such as prolate deformation and vibrational states (octupole band, beta band, and gamma band) can be observed in low-lying states. In this workshop, I will talk mainly results of EURICA experiment about nuclear structure of $^{141-144}$Xe nuclei by the beta decay of $^{141-144}$I as well as results of TRIUMF experiments.

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Can nuclear physics solve the "missing gold problem" in the evolution of Galaxy?

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Understanding neutron-rich unstable nuclei is crucial for investigating the r-process nucleosynthesis. In particular, the β decay of the $N = 126$ isotones is decisive for the production of the third peak, including gold and platinum. In this talk, based on nucleosynthesis uncertainty calculations, I will discuss the possibility of addressing the "missing gold problem" in the galactic chemical evolution study by improving the β-decay half-live of $N = 126$ nuclei.

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RI experiment for the r-process

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RI experiment for the r-process

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Summary and discussion

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Summary and discussion

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Beta-decay in heavy neutron-rich nuclei

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Beta-decay in heavy neutron-rich nuclei

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Research opportunities of heavy neutron-rich nuclei with DTAS at RIBF: TATAKI-Pro

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Exploring the heavy neutron-rich region around and beyond $N = 126$ is one of the major aims of nuclear facilities worldwide. The foremost reason is understanding the nucleosynthesis of the heaviest elements existing in nature, formed only by the rapid neutron-capture process. At the third waiting point, the only observable measured systematically up to date —some β half-lives near stability— reveals the largest discrepancies among the models used to calculate nuclear inputs for r-process simulations. Measuring observables better suited to obtain detailed structural information in nuclei with few tens of neutron above $N = 126$ or protons below $Z = 82$, is key to obtain higher-quality calculated nuclear inputs getting far away from stability, in the inaccessible regions of the r-process reaction path. In this talk, the potential of the TATAKI-Pro setup at RIBF, consisting of the WAS3ABi active stopper and the Decay Total Absorption Spectrometer DTAS, will be discussed. The main advantage of the latter is the possibility to use it simultaneously as a calorimeter to measure β-strength functions, and as a segmented γ array to measure key structural properties such as isomeric states, nuclear lifetimes, decay schemes, and, in combination with WAS3ABi, Meitner-Ellis electrons.

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Half-life and beta-delayed neutron emission measurements of $N \sim 126$ neutron-rich nuclei by BRIKEN at RIBF

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The neutron-rich $N \sim 126$ region is important to r-process calculations, but difficult to be accessed by experiments. This region is unique for its strong competition between allowed and first-forbidden transitions, which complicates half-life predictions. Besides, the abundances of the third r-process peak elements and actinides are sensitive to half-lives of $N = 126$ isotones. Measurements of more exotic nuclei are essential to benchmark theoretical models commonly used in r-process calculations. We will present results from the BRIKEN experiment, which is the first attempt to investigate $N \sim 126$ nuclei at RIBF. Particle identification was confirmed by the BigRIPS separator and a silicon energy-loss telescope. Charged-particle decay and neutron emission were measured by the WAS3ABi beta-counting system and the BRIKEN neutron counter. Half-lives and beta-delayed neutron emission probabilities (P_n) of $N \sim 126$ exotic isotopes were determined. Several of which were first measurements. Preliminary results of Z
$leqq$79 isotopes will be discussed.

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[online] Experimental Beta-Decay Half-Lives and Beta-Delayed Neutron Emission Probabilities in Medium-Mass Nuclei ($A \sim 110$)

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beta-delayed neutrons