Book of Abstracts

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Contents

CAGRA Project at RCNP, Osaka University

We have started a CAGRA (Clover Array Gamma-ray spectrometer at RCNP/RIBF for Advanced research) project at RCNP, Osaka Univeristy. This project constructs a Compton-suppressed Germanium clover array (CAGRA) by an international collaboration (U.S.-Japan-China-Italy, …). It consists of 16 Ge Clover detectors with BGO Compton shields. and a digital data acquisition system employing GRETINA digitizers is used, which enables high-rate data taking. At RCNP cylclotron facility, there are various experimental capabilities such as high-resolution spectrometer, Grand Raiden, low-energy RI beam facility, EN beam line, and the DC muon beam facility, MuSIC. By combining the CAGRA with these devices, many physics opportunities will be provided. So far, CAGRA campaign experiments at EN beam line and Grand Raiden were successfully performed. It is also planned to bring the CAGRA array to RIBF for further experimental studies using unstable nuclear beams. In this talk, an overview of the CAGRA project and recent experimental results in the studies of mass 40 region obtained from the CAGRA experiment ar RCNP will be presented.

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Isomers, Twin Bands, and Yrast Traps in Odd-Odd Nuclides

Content The study of the odd-odd nuclei near magic shell closures is indispensable for understanding the interplay between the single particle motion of two non-identical valence nucleons and the collective motion, but it is challenging for both experiment and theory. Even in the simple system where only a single proton and a neutron outside an even-even core, a complex residual interaction spreads the lowest multiplets into a group of closed spaced states, giving rise to long-lived isomers. In this talk, the detailed level schemes based on the proton-neutron configurations in doubly odd iodine nuclei, with three valence protons outside the proton magic 50 tin core, are presented. On the basis of both in-beam and out-of-beam γ-ray spectroscopy, as focusing on the systematics of the collective bands built on the coupled proton $h_{11/2}$ and neutron $h_{11/2}$ orbitals, we study various distinctive features over $60 < N < 80$, such as; isomers, twin bands, and non-collective high-spin oblate states. Finally, we outline the future measurements for the very neutron-rich odd-odd iodines beyond $N = 82$.

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The K600 + GAMKA array for studying the Pygmy Dipole Resonance

A project to increase the γ-ray detection efficiency of the iThemba LABS setup was recently funded by the South African National Research Foundation (NRF). This project will result in the installation of the γ-ray detector array GAMKA (Gamma-ray AsyMmetric spectrometer for the Knowledge of Africa), composed of 16 HPGe clover detectors and 23 large volume LaBr3:Ce, which can be coupled to the K600 spectrometer and silicon detector arrays for γ-particle coincidence measurements. This unique setup will allow for a new generation of experiments with a much increased efficiency for detecting γ decay compared to arrays currently available worldwide.
The scientific research program for the K600+GAMKA project covers experiments from nuclear structure to nuclear astrophysics. Among these the study of the Pygmy Dipole Resonance (PDR) [1,2,3], the low energy part of the electric dipole strength, in deformed nuclei is of particular interest. Several theoretical and experimental studies have been performed on deformed nuclei to investigate the response of the Giant Dipole Resonance (GDR) while only a few were focused on the PDR [4,5].
An (α,α′γ) experiment was performed at iThemba LABS, South Africa, in October 2016 for the deformed 154Sm nucleus. The scattered particles were detected by the K600 magnetic spectrometer in the zero-degree configuration, while the subsequent γ decay was measured by the BaGeL (Ball of Germanium and LaBr detectors) array. A larger systematic data set is needed to address some of the questions on the role of the deformation on P The coupling of the K600 spectrometer with the GAMKA array will be crucial to extend the study of the PDR in other prolate and oblate nuclei. In this talk, I will report on the status and future of this project. I will also discuss preliminary results on 154Sm aimed at studying the PDR in deformed nuclei.

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Presenter(s): PELLEGRI Luna

Transfer Reactions with CAGRA at OEDO

Transfer reactions are powerful tools in nuclear physics to study the shell structure of atomic nuclei. With the rise of radioactive beam facilities such studies have been applied to a variety of unstable nuclei. However, there are still limitations in available beam intensities which are hindering studies on unstable isotopes in key areas of the nuclear chart. At RIBF at Riken the desired beams can be produced with the necessary intensities and the OEDO beamline, which went into operation in June 2017, aims to degrade the high beam energy down to velocities well suitable for transfer reactions while keeping the beam spot size reasonably small. That opens a plenty of new possibilities for missing mass studies.

A collaboration of CNS, RCNP and RNC is developing a Silicon setup for the detection of light recoiling particles (protons). A first experiment with stable beam has been successfully performed and the setup is now being optimized for experiments at OEDO.

In some physics cases, especially if the level density is too dense to separate populated levels via missing mass only, an additional gamma-ray detection is mandatory. CAGRA is with its high energy resolution and reasonably large efficiency an ideal candidate for completing the Silicon proton detection setup.

Presented will be an overview of the performance of the setup, potential first physics cases at the RIBF and the envisioned coupling to CAGRA.

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Probing the fine structure of giant resonances with Grand Raiden + $LaBr_3$ gamma-ray detectors

Detailed studies of the Giant Resonance (GR) decay mechanism can reveal how an ordered particle-hole excitation dissolves into increasingly complex states that eventually results in a compound nucleus characterized by disordered motion. Observations of the *γ*-decay associated with the IVGDR fine structure can provide unique information on the GR damping mechanisms, different from those obtained from nucleon decay observations. Although the branching ratio for *γ*-decay is small (10^{-2} - 10^{-4}) of the total decay width), the electromagnetic nature of the transitions provides simple, unambiguous information on the processes involved. In particular, the value of the γ ground state decay width or the presence of fine structure revealed by the *γ*'s, are necessary to validate theoretical frameworks. A pilot experiment will be conducted at Grand Raiden by probing the IVGDR of ^{90}Zr with the ^{90}Zr (p, p'*γ*) reaction at zero-degrees. The small branching ratio of the *γ*'s (10^{-2}) requires a large detection efficiency, which will be achieved with an array of eight large-volume LaBr3 scintillators. A new detector support frame is being developed at RCNP and is expected to be built by the end of 2017. The commissioning experiment is expected to test the feasibility of the approach, and open up the possibility to measure *γ* decay from a variety of giant resonances, such as ISGQR and GTGR, uncovering the mechanism of fine structure in these giant resonances.

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In-beam gamma-ray spectroscopy of ^{43}S via one-neutron knockout reaction

The erosion of the neutron magic number 28 and the onset of collective behavior have been observed south of ^{48}Ca in the nuclear chart. Especially the ground-state deformation, the shape coexistence, and the high-K isomerism in ^{44}S have been discussed both experimentally and theoretically. In this region these phenomena related to the deformation of the nucleus are thought to originate from the interplay of quenching the N = 28 shell gap and quadrupole excitations across Z = 14, 16 sub-shell and N = 28 shell gaps. The proton configuration of the 44S ground state was investigated previously but neutron occupation of this nucleus remains unknown prior to this study. To clarify the reduction of the N = 28 shell gap and the role of the neutron configuration to the deformation in ^{44}S, an in-beam gamma-ray spectroscopic study focused on the one-neutron knockout reaction from ^{44}S was performed.

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

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

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Low-frequency quadrupole vibrations induced by pairing fluctuation around ^{40}Mg studied by quasiparticle RPA calculation with Skyrme energy density functional

We have constructed a new computer code for quasiparticle RPA (QRPA) calculation. By using up-to-date Skyrme energy density functional, we can perform predictive investigations into vibrational excitations of rotating unstable nuclei. The matrix QRPA equation is diagonalized by the canonical basis of the Hartree-Fock-Bogoliubov states that break the spatial axial symmetry and the time-reversal symmetry. The Fourier-series expansion method is used to reduce the computational effort.

With this code, we discuss low-frequency quadrupole vibrations of weakly-bound nuclei around 40Mg. These nuclei have quadrupole deformation due to the broken magic number N=28. We emphasize that the coupling to the fluctuation of quadrupole pairing field generates the K=0 mode of quadrupole vibration. Eventually, this mode has strong sensitivity to the collective rotation. The microscopic structure will be clarified.

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Nuclear structure studies in Italy: AGATA, Galileo and perspectives for the SPES Facility

There is a very long tradition of studying nuclear structure and reactions at the Legnaro National Laboratories (LNL) of the Italian Institute of Nuclear Physics. The wide expertise acquired in building and running large germanium arrays has made the laboratories one of the most advanced research centers in gamma-ray spectroscopy. The 'gamma group' has been deeply involved in all the national and international developments of the last 20 years and is currently one of the major contributors to the AGATA project, the first (together with its American counterpart GRETINA) gamma-detector array based on gamma-ray tracking. The physics campaign of the AGATA detector array has been very fruitful, some selected results will be presented. At present the advancements of the AGATA project, in particular in the electronics, are been exploited for the GALILEO setup that this year will finish its first physics campaign. Some preliminary results of the campaign will be shown.

This line of research is expected to be strongly boosted by the coming into operation of the SPES radioactive ion beam project, currently under construction at LNL. The facility is based on the ISOL method with an UCx Direct Target able to sustain a power of 10 kW. The primary proton beam is provided by a high current Cyclotron accelerator with energy of 35-70 MeV and a beam current of up to 0.75 mA. New instrumentation is required for operation with unstable beams and needs to be implemented coherently with the relevant milestones of the facility. Non-reaccelerated beams will be used for beta decay studies aided by the state of the art setup planned to this purpose. Re-accelerated beams, making use of direct reactions, will exploit magnetic spectrometers coupled to gamma array. For the operation with the first re-accelerated beams the AGATA tracking array will be installed again at Legnaro in conjunction with a variety of ancillary detectors. Some examples of possible setups and physics opportunities will be discussed.

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Presenter(s): RECCHIA Francesco

Measurement of gamma rays from the giant resonance of C-12 and O-16

We measured γ-rays from giant resonances of ^{16}O and ^{12}C using 392 MeV proton beam, magnetic spectrometer "Grand Raiden" and an array of NaI(Tl) γ-ray counters at RCNP (Osaka). The γ-ray emission probability is derived with ∼10% accuracy. The γ-ray emission mechanism is discussed and the measurement has been compared with the hadronic deacy model calculation. The application of the measurement to the detection of mu-type and tau-type neutrinos from supernova explosion at the large water and liquid scintillator detectors.

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Presenter(s): SAKUDA Makoto

Studies on the reaction mechanism of ^{9}Be

Weakly bound nuclei usually behave differently with stable bound nuclei in the induced fusion reaction, because of the low break up threshold. It is assumed theoretically that the complete fusion cross section with weakly bound projectiles will be suppressed due to the high break up probabilities. However, this has not been verified systematically due to the lack of the experimental data. We measured precise complete fusion, incomplete fusion, as well as the one neutron transfer cross sections for the 9Be + 89Y, 181Tl, 187Re, and 169Tm systems, at energies near the Coulomb barrier. Complete fusion suppression of the order of 30% was found, at the energy range slightly above the Coulomb barrier. This suppression is found in relation to predictions of coupled-channels calculations that do not include the breakup channel. At the same time, we also found that the transfer cross sections for the systems investigated are very similar and are much larger than the corresponding fusion cross sections at subbarrier energies, whereas fusion predominates at energies above the barrier. These experimental data supplement the bases for studying the reaction mechanism induced by weakly bound nuclei systematically.

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Xi^{-} atom X-ray Spectroscopy with Hyperball-X (J-PARC E07)

The strong interaction between nucleons has been studied well with extensive data. On the other hand, experimental data on that of hyperon such as Λ and Ξ and nucleon are still very limited. Especially, not much is known for Ξ-N interaction involving two strange quarks. One way to obtain such information is through measurement of X rays from Ξ− atom, in particular, by measuring energy shift of the atomic levels which can be precisely calculated based purely on electromagnetic interaction. From the shift, information on Ξ-N potential and interaction can be extracted.

In 2016 and 2017, we performed Ξ− atomic X-ray spectroscopy using a hybrid emulsion method at J-PARC. In this experiment (J-PARC E07), Ξ−s are produced in a diamond target following the p(K−,K+)Ξ− reaction and traverse the emulsion stacks located downstream. Some of them stop there and are captured by composite atoms of the emulsion such as Ag and Br. The Ξ− atoms formed are at highly excited states and decay to lower levels by X-ray emission before absorbed by nuclei via strong interaction. We measured these X rays with Ge detector array, Hyperball-X. The X ray transitions of interest are (n,l)=(8,7)→(7,6) in Ag and (7,6) →(6,5) in Br with the transition energy of 370.5 keV and 315.5 keV, respectively. The theoretical predictions of energy shift for these transitions are from 200 eV to 500 eV.

Hyperball-X consists of six Ge detectors of clover and single crystal type. Each Ge detector is surrounded by BGO suppresser. To determine the energy shift precisely, high precision energy calibration with less than 50 eV uncertainty is necessary. LSO scintillators had been employed as a trigger-able source for in-beam calibration with gamma-beta coincidence method between the Ge detectors and the scintillators. In addition, two 22Na sources are placed near the target. Two 511-keV γ rays emitted back to back are detected by two Ge detectors. Two γ rays, 201 keV and 307 keV, from the LSO and 511 keV from 22Na are used as calibration peaks.

I will introduce the J-PARC E07 experiment and the report performance of our calibration method for the Hyperball-X system.

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Presenter(s): FUJITA Manami

Measurements of gamma rays from the giant resonances of ^{12}C and comparison with the hadronic decay model calculations.

Experiment (E398) was carried out at RCNP, Osaka University to measure the energy and emission probabilities of γ-rays from giant resonances of ^{12}C using 392-MeV proton beam, high-resolution magnetic spectrometer “Grand Raiden" and an array of NaI(Tl) scintillators.

γ-ray emission probability from the giant resonances ^{12}C has been measured as the function of excitation energy. We will present the hadronic decay model calculations for the transition probability (via various decay channels- n, p, d, t and α) from the giant resonance states(Ex) to the excited states of daughter nuclei. Combining this information with gamma transitions in daughter nuclei (TOI), we can directly compare the calculations with our measured γ-ray emission probability and can have a good insight into the decay mechanisms of the giant resonances.

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Presenter(s): REEN Mandeep

Study of shape coexistence and shape evolution by using RI beam combined with CAGRA and RCNP tracking Ge detector

Study of shape evolution as a function of spin and isospin, as well as shape coexistence is one of the most important subjects to understand the competition between single-particle-like and collective-like modes in various deformed nuclear systems. To investigate shape evolution as an increase of spin, we have searched isomers which are caused by large shape difference.

Experiments were performed by using low-energy (around 10 MeV/u) RI beam induced fusion reaction at RCNP secondary beam line (EN beam line) combined with γ-ray detector array, such as CAGRA and so on. Low-energy RI beam induced fusion reaction enables to extend the limit of mass region to observe high-spin states which it is difficult to populate by using stable beam and stable target. Even if very small beam intensity of around 105 pps, high-S/N measurement has been carried out by event-by-event analysis which can select events correlating RI beam.

As next step, we have a plan to develop high-spin isomer beam at EN beam line combined with γ-ray detector array to search for exotic nuclear structure. RCNP tracking Ge detector will effectively work with its high efficiency for correction of Doppler shift in the experiment based on the in-beam γ-ray spectroscopy.

In my talk, I will present some results of our CAGRA experiment with the low-energy ^{17}N RI beam induced fusion reaction at EN beam line and future experimental plan at RCNP.

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Preliminary result of CAGRA E455 experiment

In this contribution we will present some preliminary results of CAGRA E455 experiment which was performed in CAGRA 2016 campaign to search for confident evidence of triaxiality in A=190 region. The nuclei of interest were populated by using ^{7}Li+^{186}W reaction with bean energy of 38 and 45 MeV. A CsI(Tl) scintillator detector array which consists of 127 detectors has been constructed for reaction channel selection. The charged particle identification was made based on the digital pulse shape analysis using GRETINA digitizer. The experimental results include the first high-spin level scheme for 189Os, new structure based on the long-lived 8^{+} isomer for ^{186}Re and extended high-spin states for 188,189Ir.

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Presenter(s): FANG Yongde

Importance of the in-situ gain shift calibration for the γ-ray counter in X(p,p’,γ) experiment

RCNP E398 measured γ-ray emission probability from giant resonance of 12C and 16O. The data taking took 2 weeks. We observed the gain shift during the experiment due to the scattered protons and neutrons. We tracked the gain shift of each γ-ray counter using the radioactive source and in-situ γ-rays from 12C and 16O. In my presentation, I will explain the details of in-situ calibrations and the efficiency estimation using GEANT4(2.1,4.4,6.9,15.1MeV), which was critical in obtaining the γ-ray emission probability.

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Complementary measurements at HIE-ISOLDE and GAMKA

The HIE-ISOLDE-GAMKA synergy focus at complementing existing Coulomb-excitation proposals at HIE-ISOLDE (CERN) and provide final crucial measurements by exploiting the various angular positions of the detectors in angular-distribution measurements (e.g., nuclear lifetimes and mixing ratios). The combination of diagonal matrix elements of higher-lying states determined at HIE-ISOLDE together with transitional matrix extracted by different experimental probes at iThemba LABS will shed light on how nuclei readily change shape with a small amount of energy, a phenomenon occurring only in nuclei and called shape coexistence. Results from experiments done at HIE-ISOLDE and iThemba LABS will be presented together with details concerning the new GAMKA array at iThemba LABS

Primary author(s): MASANGO Senamile (University of the Western Cape)
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Non-destructive elemental analysis of a carbonaceous chondrite with Muon beam

So far, we have carried out the Muonic X-ray analysis of extraterrestrial materials at J-PARC MUSE and teh RCNP MuSIC. We report on the recent progress of Muonic X-ray analysis and/or future prospect.

An analysis of characteristic X-rays from muonic atoms, in which a muon is captured, has attracted attention because both a muon beam and a muon-induced characteristic X-ray have high transmission abilities. So far, we have carried out the Muonic X-ray analysis of extraterrestrial materials at J-PARC MUSE and RCNP MuSIC (Terada et al. Sci.Rep. 2014). At the conference, we will report on the recent progress of Muonic X-ray analysis of carbonaceous chondrite and/or future prospect.

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Investigation of chemical environmental effect in muon capture processes by measuring cascade muonic X-ray

Muonic atom is an atomic system that has one negatively charged muon instead of an atomic electron. Due to a large mass of a muon, the atomic muon orbit is very close to a nucleus. However, chemical environmental effect has been known in formation process of muonic atom. In fact, muon capture probability of each atom and initial quantum level of captured muon are changed by the molecular structure. Our group has been studying on chemical environmental effect in muon capture processes. Recently, we performed quantitative discussion for the effect in muon capture process by lone pair electrons in carbon mono-oxide (J. Radioanal. Nucl. Chem., 303, 1277-1281(2015)). At the presentation, we will report the latest result of muon capture process for iron complexes performed at RCNP-MusSIC and show the future experimental plan using CAGRA system.

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Test experiment of a tracking detector at the NewSUBARU

We have been developing a tracking detector at RCNP. In order to perform the operation confirmation of our detector system, in the end of June 2017, we carried out a test experiment of a tracking detector at the NewSUBARU BL1 beamline where laser Compton gamma-ray beam of energy around 1 to 40 MeV is avaliable. We irradiated collimated gamma-ray beam to a Ge crystal, and taken waveform data were analyzed using the signal decomposition program. From analysis results, the measured width of the reconstructed gamma-ray interaction point distribution determined the position resolution. I would like to introduce analysis results of this test experiment.

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Summary of the CAGRA+GR campaign experiments

CAGRA+GR campaign experiments were performed at RCNP from October to December in 2016. The CAGRA was placed at the target position of the high-resolution spectrometer, Grand Raiden (GR), for coincidence measurements of a particle spectrometer and a gamma-ray detector array. The aims of the experiments were to investigate the nature of the pygmy dipole resonances, isovector spin-flip responses of nuclei for astrophysical neutrino-nucleus inelastic-scattering, gamma-transitions in the super-deformed band-head, and excitation of high-spin states via light-ion reactions. In this talk, we will summarize technical problems and their solutions in the preparation of the campaign and the beam time in order to share information for future CAGRA experiments.

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The Proton and Neutron Quadrupole Collectivity in ^{32}Si

This study aims to investigate the properties of quadrupole collectivity of protons and neutrons in ^{32}Si nucleus by (d, d') reaction in inverse kinematics technique. Collectivity is an essential characteristic in nuclear structure as well as nuclear deformation. The quadrupole collectivity as an index of proton and neutron collectivity can be deduced from the differential cross section of the (d, d') reaction to the first 2+ states. By combining with the known B(E2) value, which represents the proton quadrupole collectivity, the quadrupole collectivities of proton and neutron parameters is determined separately. The (d, d') reaction was performed at the EN course (RCNP). The unstable 32Si beam produced at the EN beam line at the average energy of 18.5 AMeV bombarded a solid deuterium target. The reaction channels were identified by measuring de-excitation γ-rays using the Clover Ge detector array CAGRA, in coincidence with scattered ^{32}Si identified by ΔE-E method using silicon telescope. The angular distribution of 32Si is extracted by PPACs located upstream and downstream of the target. A distorted-wave Born approximation (DWBA) calculation is carried out to compare with experimental results. The presentation will give the details of this study.

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Nuclear fission and structure studies using ^{254}Es

We are planning nuclear fission and structure studies at the JAEA tandem facility using the rarest radioactive target material ^{254}Es (T1/2 =276 days), produced at the High Flux Isotope Reactor of ORNL and will specially delivered to JAEA. The purpose of fission measurement is to elucidate a long-standing question observed in the region of neutron-rich fermium isotopes, i.e. the dramatic transition from a standard mass-asymmetric fission (e.g. ^{256}Fm) to the sharp symmetric fission (e.g. ^{258}Fm). A novel experimental technique using multinucleon transfer (MNT) reactions [1], developed by the JAEA group, will be utilized. Structure of nuclei around ^{258}Fm will be investigated by in-beam gamma-ray spectroscopy, where excited states of these nuclei will be populated also with MNT reactions. Several other experiments using the ^{254}Es target are under discussion.

Reference [1] R. Léguillon et al., Phys. Lett. B, Physics Letters B, 761, (2016) 125.

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Particle rotor model with chiral basis: purity of chiral geometry and a role of planar component

An interplay between collective and single particle degree of freedom is one of the key aspects of nuclear structure studies. Nuclear chirality is a consequence of such coupling of collective rotations to that of angular momenta of valence nucleons resulting in doubling of states or so called chiral doublets as pointed out first by Fraeundorf and Meng in 1998. When a collective rotation is generated from a triaxial body with irrotational-like moment of inertia, its energy is minimized by aligning its angular momentum along the intermediate principle axis with the largest moment of inertia. On the other hand, angular momentum of a particle-like and hole-like valence nucleon aligns, respectively, along the short and long axis to minimize the energy. This physical picture/geometry can be investigated quantitatively by a particle rotor model, which, in fact, has been used numerous times over the last two decades for the investigation of nuclear chiral rotation.

In 2004, a theoretical limit of a particle rotor model was proposed where a triaxial rotor with irrotational moment of inertia and gamma deformation parameter (γ) of 90 degree is coupled to a particle and hole [1]. The core has a triaxial shape, but collective rotation is yet symmetric around the intermediate axis which is taken as a quantization. Numerical diagonalization of the Hamiltonian exhibited a few pair of degenerate energy eigen states. In addition, a special symmetry of the Hamiltonian resulted an additional good quantum number and electromagnetic selection rules.

In this contribution, a new chiral basis is proposed [2] which takes the above mentioned model one step further by introducing respective projection axis for the rotor, the valence particle, and the valence hole. The proposed basis states are then naturally separated into right-handed, lefthanded, and planar states, i.e., one can explicitly extract amplitudes of these states in numerically obtained wave functions. Furthermore, a particle rotor model calculation by
exploiting the newly proposed chiral basis with some truncation will be reported [3]. The results show that (1) the numerical results of Ref [1] is reproduced, (2) the side-band structure has no planar components and thus purely chiral, and (3) amplitudes of the planar basis states lower the energy of otherwise degenerate main band at lower spin.

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The ultrafast dE-ToF single crystal diamond detector

The state-of-art PID detectors such as ultrafast dE-ToF single crystal (sc) diamond detector with an excellent energy and time resolution together with an advanced gamma-ray array will allow us to access highly excited states of exotic nuclei which were hitherto not possible. Our recent studies of the single crystal CVD diamond as a high-resolution timing detector for the high-intensity beam detection applications show encouraging results. The best timing resolution of about 12 ps (σ) was obtained for the single crystal with and without preamplifier in the combination with a polycrystalline CVD diamond detector taking into account the position dependence correction in this polycrystalline. Comparisons of results for timing resolution obtained with different preamplifiers are presented.

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Energy-degraded beam line at RIBF, OEDO

For the missing mass spectroscopy via transfer reactions with the RIBs, the beam energy of a few tens of MeV/nucleon is desired. Even for the Coulomb excitation, the lower beam energy is preferred to avoid the atomic background. A simple way to get the low-energy RI beam is to slow down from the fast one. However, the emittance of the energy-degraded beam deteriorates due to the multiple scattering. In particular, the large beam spot size of the energy-degraded beam is problematic. To address this issue, the energy-degraded beam line named OEDO, which consists of the two superconducting quadrupole magnets and a RF deflector, has been constructed. The beam spot size will become smaller by rotating the beam emittance to the time axis. The commissioning experiment has been successfully performed to prove the princilple. Two physics experiments are scheduled this autumn by using OEDO. In this talk, a preliminary result of the commissioning experiment will be presented.

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Shapes of medium-mass nuclei studied by Monte Carlo shell model calculations

The nuclear shape is one of the fundamental properties of nuclear structure and related to nuclear shell structure and other properties. Monte Carlo shell model can describe nuclear intrinsic shapes as well as other properties such as energies, electromagnetic moments and transitions. We performed Monte Carlo shell model calculations for nuclei around Ni (Z=28) and Sm (Z=62) isotopes. Nuclei in Ni region are calculated with the fine-tuned effective interaction in the model space composed of pf shell and 0g9/2, 1d5/2 orbits and the results agree with the experimental data well.

Calculations of heavier nuclei in Sm region are more challenging and need large model space in order to describe deformation. Shape coexistence and shape evolution in these regions are discussed by using "T-plot", a method to visualize the information of nuclear intrinsic shape of the states calculated by Monte Carlo shell model. The mechanism of these change of the shape is explained with the concept of shell evolution.

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Present status of the KISS project.

KISS project aims at finding an astrophysical condition for synthesizing r-process heavy elements, which form the third peak in the solar abundance pattern. This is an experimental challenge in nuclear physics to measure ground/isomer state properties of unknown nuclei around the region of N=126 isotones.

So far we have constructed and developed new type of mass separation system, KISS (KEK Isotope Separation System) and performed measurements of lifetimes and hyperfine structures of some platinum, iridium, and osmium neutron-rich radioactive isotopes by applying multi-nucleon transfer reactions and in-gas laser ionization and spectroscopy methods.

In this report, I will present some physics results, present KISS performance, and future's research plan.

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Mass dependence of the octupole correlation investigated with the constrained 3D Hartree-Fock plus BCS model

Spontaneously symmetry breaking (SSB) is the one of most important keywords to describe modern physics. In nuclear physics, the rotational symmetry of nucleus is spontaneously breaking induced by the coupling among individual particle motions and the corrective motion, which was pioneered by Bohr and Mottelson [1]. The breaking of nucleon number also appears due to the pairing correlation, which is understood as the deformation in the gauge space.

Furthermore, the interplay between the spatial deformation and the pair deformation, plays important roles in nuclear structure. The "deformation" is a fundamental element to determine microscopic properties of nuclei. To investigate the universality of the "deformation" in nuclear system, we perform a systematic, non-empirical, and unrestricted mean-field calculations. The systematic study of the ground state has been studied for even-even 1,002 nuclei in which 28 octupole-deformed nuclei are found, with the Skyrme Hartree-Fock plus BCS (HF+BCS) model represented in the 3D Cartesian coordinate space [2].

The quadrupole and octupole deformed nuclei appear in the mass region with characteristic neutron and proton numbers which are consistent with previous studies. In our results, there appear only pear shape (beta_30) in the octupole deformed nuclei, although our model space can describe any deformation.

To investigate the mass dependence of the octupole correlation, ^{144}Ba and ^{220}Rn are chosen, and we investigate the potential energy surfaces as functions of the octupole deformations (beta_3m; m = 0; 1; 2; 3). ^{220}Rn has also local minima in the beta_31 and beta_32 potential energy surfaces [3].

Second, because the interplay between the spatial deformation and the pairing correlation, plays important roles in nuclear structure, then the relation between octupole-deformation and the pair correlation is studied by changing the pairing strength.

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The AGATA campaign at GANIL

The Advanced GAmma Tracking Array is installed at GANIL since 2015. The AGATA overall campaign has been organized in sub-campaigns in which AGATA is coupled to several major ancillary devices. Until this year, it was coupled to the VAMOS large acceptance spectrometer to perform the spectroscopy of neutron rich nuclei populated in deep inelastic reactions and heavy-ion induced fission.

In 2018, the goal is to couple AGATA to the NEDA neutron array and the DIAMANT charged particle detector to investigate various aspects of the structure of neutron deficient nuclei like isospin symmetry breaking or the octupole degree of freedom in the xenon region. AGATA will stay at GANIL until at least 2019 and other possibilities are also considered for the future of AGATA at GANIL like the use of VAMOS in a gas filled mode to study heavy nuclei or neutron deficient isotopes, and the coupling with MUGAST, a charged particle array particularly suited for transfer reactions.

In this talk, the AGATA array will be very briefly presented. Some preliminary results from the first (VAMOS in vacuum mode) campaign will be shown and the future campaigns will be discussed.

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Physics highlights of Indian National Gamma Array (INGA) campaign at TIFR and the plan for its upgrade

Investigation of the response of the atomic nucleus to varying rotational stress gives rise to diverse phenomena related with symmetries of the nuclear structure and correlations among nucleons. The Indian National Gamma Array (INGA) campaigns at the three accelerator facilities within India have contributed significantly in recent years to such studies. During 2010 to 2014, INGA was set up at TIFR-BARC accelerator facility at Mumbai, as a part of a collaboration between BARC, IUAC, SINP, TIFR, UGC-CSR-KC, VECC and different Universities. The array is designed for 24 Compton suppressed clover detectors providing around 5% photo-peak efficiency. In the last campaign at TIFR, a digital data acquisition system with 96 channels has been implemented for this Compton suppressed clover array. Conventional systems with analog shaping has been replaced by digital system that provides higher throughput, better energy resolution and better stability for the multi-detector Compton suppressed clover array. A successful experimantal campaign consisting of around 50 experiments was completed. Selected results related to the novel excitation modes of atomic nuclei from this array will be presented. Finally, we will discuss the plan to augment the INGA program by strengthening the gamma detection facilities at each of the three accelerator centers within India.

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Presenter(s): Rudrajyoti Palit

Status of ELIGANT-GN instrument for gamma above neutron threshold experiments at ELI-NP

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) is the laboratory dedicated to nuclear physics research with a very brilliant gamma-beam system (GBS). ELI-NP GBS is an evolution from HIGS and NewSubaru. The idea of acquiring the quasi-monochromatic, pencil-like and highly polarized γ beam at ELI-NP is to use the inverse scattering of laser photons on relativistic electrons (LCS).

Wide range of experiments is planned at the ELI-NP: study of electromagnetic responses of atomic nuclei, photo-neutron reaction cross-section measurements, charged particle emission in photoreactions or photo-fission studies. This talk focuses on the possibility to measure the high-energy gamma rays and fast neutrons within the ELIGANT (Gamma Above Neutron Threshold) part of the project using the ELIGANT-GN array being under development. In particular, the GDR decay (γ and neutron) of 208Pb would be discussed which is planned as a Day1 experiment. Similar attempts are being done using protons as complementary probe within CAGRA+GR campaign in RCNP Osaka.

The ELIGANT-GN array will constitute of LaBr3:Ce and CeBr3 detectors for the gamma detection as well as liquid scintillators and 6Li glass for fast neutron detection. The both types of bromide detectors are treated as almost the same type, but two neutron detectors have very different properties and purpose. While liquid scintillators are best suited for the neutrons of energies above 1 MeV, the 6Li glass is the most efficient for the lower neutron energies.

The status of the setup development will be presented as well as examples of test measurements and simulations.

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Presenter(s): M. Krzysiek

Spectroscopy of low lying states of ^{50}Ar

The rearrange of shell closures for exotic isotopes, and in particular for neutron rich nuclei is a topic of high interest in the field of nuclear physics nowadays. Experimental evidence of the existence of a sub-shell closure at N=32 has been reported for ^{52}Ca, ^{54}Ti and ^{56}Cr. For the case of ^{50}Ar (Z=18), a recent measurement of the energy of the 2+ state suggests the presence of the sub-shell closure at N=32. A candidate for the 4+ state was also reported, although with low statistics. In order to obtain a clearer insight on the structure of 50Ar and the sub-shell closure at N=32, deeper studies of low lying states of ^{50}Ar, in particular a more precise measurement of the 4+ state, are desirable.

Low lying states of ^{50}Ar were measured at RIKEN within the third SEASTAR campaign. A beam of 70Zn accelerated at 345 MeV/u collided with a 9Be target. The isotopes produced by the fragmentation of the beam were separated and identified using the BigRIPS spectrometer. Secondary reactions took place in the 150 mm long liquid hydrogen target of MINOS. The DALI2+ detector array, consisting of 226 NaI detectors, was used to measure gamma rays emitted by the secondary reaction products. The outgoing particle identification was performed by using the SAMURAI magnetic spectrometer. From this experiment ^{50}Ar was produced by several reaction mechanism, such as (p,p') and (p,2p) allowing to study the low lying excited states. In this work the ongoing data analysis of the spectroscopy of low lying states of ^{50}Ar will be presented.

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Presenter(s): Wilmar Rodríguez

Detector system for the measurement of gamma decay from giant resonances using LaBr3 detectors and Grand Raiden

Measurement of giant resonances is powerful in studying nuclear structure. We plan to measure the gamma decay from isovector giant dipole resonance (IVGDR) in ^{90}Zr via (p,p’) reaction using at the Ring Cyclotron facility of the Research Center for Nuclear Physics (RCNP). The measurement of the gamma-branching ratio allows us to get the information on the nuclear fine structure in detail. Since the gamma-branching ratio is expected to be very small (of the order of 10^{-2}), an efficient gamma detection system is needed. The experimental set up is the combination of Grand Raiden with large-volume scintillators. As a first step of the technical development, I checked the detector characterization and simulated by geant4. In this presentation, I plan to report on the results and the optimized detector setup.

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Development of a new scintillation detector based spectrometer at the RIBF

Research on reactions and structure of exotic isotopes has been invigorated by the development of Radioactive Ion Beams. At the same time, the use of such exotic beams has imposed new demands on the gamma-ray detection systems: As experiments are usually performed in inverse kinematics at velocities around 0.5c, the gamma-rays emitted by the projectiles are heavily affected by the Doppler-shift. A proper Doppler correction requires a good angular resolution which translates to a high detector granularity. Additionally, the focus in more exotic isotopes implies very low cross sections and gamma-ray yields, which makes high efficiency of utmost importance. Finally, the need to discriminate between the background and the events coming from the desired reaction, make good timing properties also of importance for gamma-ray arrays.

At RIBF, the DALI2 array provides a high detection efficiency, but only modest angular and energy resolutions. Nonetheless, gamma transitions from direct reactions, such as Coulomb excitation, proton and alpha inelastic scattering, and nucleon transfer reactions have been successfully studied. In order to extended the research opportunities at RIBF, an upgrade of the DALI2 array based on the newly developed GAGG:Ce is being considered. In this talk, the general properties of GAGG:Ce crystals, which make it a suitable candidate for an improved gamma-ray array, will be discussed. Experimental results obtained using prototype crystals readout by standard Photomultiplier Tubes, as well as by Avalanche Photo-diodes and Silicon Photomultipliers will be presented. Finally, the possible geometries of an array based on GAGG:Ce crystals will be evaluated based on Geant4 simulations.

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In-beam γ-ray spectroscopy of ^{54}Ca

The tensor-force component of the nucleon-nucleon interaction is mediated through π+ρ meson exchange. This is a driving force of shell evolution [Otsuka, 2001], further repudiating the concept of immutable single particle energies (SPEs). A drastic display of this phenomenon can be found in the N=34 calcium isotope, which, a decade after its initial prediction [Otsuka, 2005], was shown to have a doubly magic character [Steppenbeck, 2013]. Moreover, the N>32 calcium isotopes are expected to be influenced by the monopole repulsion of the three-body interaction induced by the Fujita-Miyazawa force [Otsuka, 2010]. The detailed experimental study of ^{54}Ca is, therefore, an excellent opportunity to probe the tensor and three-body forces.

Spectroscopy of the N=34 calcium isotope was conducted as during the third SEASTAR campaign. Neutron-rich nuclei were produced from the fragmentation of a ^{70}Zn primary beam on a 9Be target. Nuclei with 18<Z<24 and 31<N<41 were transported through and identified with BigRIPS to the LH2 target of MINOS, which was situated upstream of the SAMURAI spectrometer. A myriad of reaction channels were employed to populate excited states in ^{54}Ca. Preliminary results of the detailed spectroscopy of ^{54}Ca shall be presented and discussed in terms of the reaction channels used for population of excited states.

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Overview of in-beam gamma-ray spectroscopy at the RIBF

At the Radioactive Isotope Beam Factory in-beam gamma-ray spectroscopy experiments take advantage of the wide range of radioactive ion beams produced by projectile fragmentation. Isotopes of interest are separated by the BigRIPS fragment separator and guided to a secondary reaction target. Reaction residues are identified either in the ZeroDegree spectrometer or with the SAMURAI setup. Gamma rays emitted at the reaction target are detected with high efficiency in the DALI2 NaI(Tl) array.

The physics program includes a wide range of topics in nuclear structure addressing collective and single-particle structure of nuclei far away from stability.

In this talk I will give an overview of recent results on proton- and neutron-rich nuclei and discuss future experimental campaigns at the RIBF.

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