A3F-CNS Summer School 2020

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Book of Abstracts

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Young Scientist Session 4 / 1

Formalism of fluid dynamics with spin for Bjorken hydrodynamical background.

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Measurements made recently by the STAR collaboration show that the Lambda hyperons produced in relativistic heavy-ion collisions are subject to global spin polarization with respect to an axis coincident with the axis of rotation of the produced matter. Recently formulated formalism of relativistic hydrodynamics with spin, which is a generalization of the standard hydrodynamics, is a natural tool for describing the evolution of such systems. This approach is based on the conservation laws and the form of the energy-momentum tensor and spin tensor postulated by de Groot, van Leeuwen, and van Weert (GLW). Using Bjorken symmetry we show how this formalism may be used to determine observables describing the polarization of particles measured in the experiment.

Field of your work:

Theoretical nuclear physics

Young Scientist Session 1 / 2

Developed plunger facility for ps lifetimes and g- factor of short lived states at IMP

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A new plunger based facility has been recently developed at Institute of Modern Physics (IMP), Lanzhou. This facility will be used to measure the nuclear level lifetimes in *ns-ps* range and the g-factor, providing deep insight into the study of nuclear wave functions and structure of nucleus. It is based on the plunger technique of Alexander and Bell [1], well known at present for the measurement of lifetimes depending on the Doppler shifts of γ-rays emitted during the reaction [2-4] based on Recoil Distance Method (RDM). The detailed explanation of the above mentioned technique, its application in nuclear gamma spectroscopy and the related data analysis can be found in the refs. [1, 2, 5] . At IMP, the newly designed plunger follows the principle of capacitance measurement measuring the minimum distance in between the two parallel foils, making the capacitance. Minimum the distance measured between the foils allow to measure shorter lifetimes for the decaying state produced during the reaction.
This setup consists of a PI-Q521 motor, capable of moving in the range of 32 *mm* in total with a step accuracy of 2 *nm*. The two foils i.e. target and stopper are mounted on this motor with some special type of structure designed using Inventor 2019 tool. The designed setup is quite small in size and the foils used for making the parallel arrangement are also very thin having thickness ranging from *µg/cm2* to *mg/cm2*, depending on the requirement of study. So, this setup requires high level of expertise and care for handling the motion of motor and the foils stretched with specially designed cones for this purpose. For controlling the motion of motor, LABVIEW based program has been developed which not only controls the motion but also has been upgraded to keep an eye on the variation of capacitance observed due to some mechanical disturbance arising during the experiment. This designed setup has been recently used for an in-beam test experiment to test the

proper working of motor, physical effect on the foils with incident beam, to observe the capacitance fluctuations and the LABVIEW based feedback program to minimize the effects due to mechanical disturbances. During test run, positive results have been observed with some small issues needed to be rectified before performing the other in-beam experiment focusing on lifetimes as well as g-factor measurement. In near future, this newly designed setup will allow us to measure the lifetimes based on RDM technique, and the g-factor of short-lived excited states employing the Time Differential Recoil in Vacuum technique (TDRIV) [6, 7] providing indispensable information for rigorous tests of the nuclear models. There is also plan of using this setup with radioactive ion beams available at IMP, China and Research Center for Nuclear Physics (RCNP), Japan.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 1 / 3

Probing surface α clustering in the ground state of stable heavy nuclei

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George Gamow, about 90 years ago, famously proposed an explanation of α decay phenomena utilizing the quantum tunneling effect of preformed α particles[1]. Since then, α clusters are considered as a prerequisite in heavy nuclei, but the clear experimental evidence of its existence has not been reported until today. Instead, α clustering at the low-density nuclear surface could be one plausible explanation for the origin of preformed α particles[2]. In a recent experiment studying quasi-free α-knockout reactions on tin isotopes - Sn(p, pα), the existence of α particles on the nuclear surface in the ground state of tin isotopes was clarified. The observed reaction cross sections exhibit a monotonous decrease with increasing mass number (A = 112-124), which agrees with the theoretical prediction[3]. This experimental result supports the close correlation between surface α-clustering and neutron-skin thickness in heavy nuclei. This, in turn, calls for a revision of the correlation between the neutron-skin thickness of heavy neutron-rich nuclei, and the density dependence of the symmetry energy in the nuclear equation of state[4], which at present relies on mean-field theories without considering the α- clustering effect. In the presentation, the experimental spectrum for Sn(p, pα) reactions using Grand Raiden[5] and LAS[6] spectrometers at RCNP (Research Center for Nuclear Physics, Osaka University) are shown. We will discuss in details our results and the future experiments using exotic alpha-unstable beams.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 4 / 4

Non-relativistic expansion: A potential bridge to connect the relativistic and non-relativistic density functional theories

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Since the 1970s, the density functional theory (DFT) in both the non-relativistic and relativistic frameworks has achieved great successes in describing and understanding the ground-state and excited-state properties of thousands of nuclei in a microscopic and self-consistent way. However, the connection between these two frameworks remains unclear. The non-relativistic expansion is regarded to be the potential bridge. By working out the analytic expression of the $1/M^4$ order in the conventional similarity renormalization group (SRG) method, the convergence of this method is verified. As a step further, the reconstituted SRG method with a much faster speed of convergence is proposed by using the resummation technique [1]. The origin of the difference between the results obtained with the Foldy-Wouthuysen (FW) transformation and the SRG method is further explored [2]. Inspired by the reconstituted SRG method, the reconstituted FW transformation is developed. Different to the reconstituted SRG method, since only finite steps of unitary transformations are performed, both the single-particle vector and scalar densities can be easily calculated in the reconstituted FW transformations. In addition, the relativistic corrections to the single-particle vector and scalar densities are considered in the reconstituted FW transformations. As a result, the so-called picture-change error is further eliminated [3]. The reconstituted SRG method and FW transformation pave a promising way for the connection between the relativistic and non-relativistic DFTs.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 1 / 5

Studying the exotic decay of ^{70}Kr $\rightarrow$ ^{70}Br

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The β-decay of ^{70}Kr can be used to test the predictions of different theoretical models. First of all, the effects of $T = 0$ pn-pairing can be investigated through the study of the decay rates [1].

Furthermore the theoretical strength distributions of the β-decay of ^{70}Kr show clear differences depending on the shape of the ground state, hence assumptions on the shape of the ground state can be tested [2]. Finally ^{70}Kr might lay on the rp-process path and accordingly its half-life might play a role in rp-process network calculations [3]. Despite its importance, the knowledge on the β-decay of this isotope is rather limited. The half-life is known only with 15% accuracy, and only one γ-transition was identified to date [4,5].

To make the tests of these models possible, we've conducted an experiment at RIKEN-RIBF. The nucleus of interest was produced using a ^{78}Kr primary beam with a kinetic energy of 345 MeV/nucleon and intensity of about 300 pnA. The fragments were separated by BigRIPS using in-flight method, then were stopped in the WAS3ABi active silicon detector [6]. The β-delayed γ-rays were detected by the EURICA cluster array surrounding the implantation station [7].

The experiment significantly increased our knowledge on the structure of the daughter nucleus populated in the β-decay. A precise half-life value, with an uncertainty in the order of 2%, have been derived from time correlations of the β-particles and the decay-curves of the observed γ-transitions. Furthermore, after the identification of several new γ-transitions, a detailed level scheme – including about 20 transitions – have been derived [8]. The experimental approach, as well as the new half-life value and the level scheme, will be presented, along with an insight on the theoretical interpretations of the experimental results.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 4 / 6

Effects of nucleon electric form factors to nuclear binding energy

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It is known that the nuclear interaction is much stronger than the Coulomb interaction, and thus the main contribution to the nuclear properties comes from the nuclear interaction. Nevertheless, the contribution from the Coulomb interaction to the properties is also important, since the Coulomb interaction and the isospin symmetry breaking terms of the nuclear interaction are entangled to each other in some particular nuclear properties, such as the superallowed β decay, the energy difference of the mirror nuclei and its Nolen-Schiffer anomaly, and the isobaric analog states. Although the Coulomb EDFs can be given fully theoretically, the Hartree-Fock-Slater or even Hartree approximation has been widely used.

The Coulomb EDFs are, in principle, written in terms of $\rho_{\rm ch}$, because the Coulomb interaction affects the charge itself instead of the point protons. Nevertheless, the protons and neutrons are assumed to be point particles, i.e., $\rho_{\rm ch} \equiv \rho_p$ is assumed in most of the self-consistent nuclear DFT. In Ref.~[1], for the first time, the finite-size effects of nucleons are implemented to the self-consistent steps of the Skyrme Hartree-Fock calculation. The electric form factors of both protons and neutrons are considered, which corresponds to the leading-order contribution of the finite-size effects. Also, other possible electromagnetic contributions, i.e.,~the vacuum polarization and electromagnetic spin-orbit interaction, are considered in the self-consistent steps. It is found that the neutron finite-size effect and the vacuum polarization are also non-negligible as well as the proton finite-size effect, and the corrections are comparable to the isospin symmetry breaking terms of the nuclear force. The mirror nuclei mass difference between $^{48}\mathrm{Ca}$ and $^{48}\mathrm{Ni}$ is reproduced within $300\,\mathrm{keV}$ accuracy once all the corrections to the Coulomb functional, the GGA, the nucleon finite-size effects, the vacuum polarization, and the electromagnetic spin-orbit term, are considered as well as the isospin symmetry breaking terms.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 3 / 7

Unbound states in ^{16,18,20}C with the R^{3}B setup: the search for the mixed-symmetry 2$^+$ state

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The evolution of the traditional nuclear magic numbers away from the valley of stability is an active field of research. Experimental efforts focus on providing key spectroscopic information that will shed light into the structure of exotic nuclei and understanding the driving mechanism behind the shell evolution.
Recently, $^{\rm A}$N(p,2p)$^{\rm A-1}$C quasi-free scattering reactions were employed at the R3B/LAND setup at GSI to measure the proton component of the 2^+_1 state of ^{16,18,20}C in order to investigate the $\mathrm{Z} = 6$ spin-orbit shell gap towards the neutron dripline. The experimental findings support the notion of a moderate reduction of the proton $1p_{1/2} - 1p_{3/2}$ spin-orbit splitting towards the neutron dripline \cite{ina1,ina2}.

We work upon the model of a two-state mixing of pure proton and pure neutron excitations to describe excited 2^+ states in neutron-rich carbon isotopes \cite{petri, aug}. The coupling of the unperturbed proton and neutron 2^+ states should gives rise to a second 2^+ state of mixed symmetry character expected to be strongly populated in these (p,2p) reactions. This mixed-symmetry 2^+ state should lie at an excitation energy of about 7 MeV, above the neutron separation energy, and thus, likely decay by neutron emission. The goal of this work is to identify this mixed-symmetry 2^+ state. Its observation will add weight to our simple picture of describing the neutron-rich C isotopic chain, giving us great insights into the shell evolution towards the neutron dripline at Z=6.

In this contribution, I will present the current status of the experimental investigation of the structure of unbound states of ^{16}C, ^{18}C and ^{20}C induced via quasi-free scattering $(\mathrm{p}, 2\mathrm{p})$ reactions from ^{17}N, ^{19}N, and ^{21}N, respectively.

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Field of your work:

Experiental nuclear physics

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Nuclear correlation via electron beams 1

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Knockout-reaction with RIB 2

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Knockout-reaction with RIB 3

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Knockout-reaction with RIB 4

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Time-Dependent Microscopic Approaches for Nuclear Dynamics: From Nuclei to Neutron Stars 1

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Time-Dependent Microscopic Approaches for Nuclear Dynamics: From Nuclei to Neutron Stars 2

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Time-Dependent Microscopic Approaches for Nuclear Dynamics: From Nuclei to Neutron Stars 3

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Time-Dependent Microscopic Approaches for Nuclear Dynamics: From Nuclei to Neutron Stars 4

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Nuclear Chemistry of super heavy elements 1

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Nuclear astrophysics at LUNA

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Overview of RIBF

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Opening

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Field of your work:

Young Scientist Session 1 / 30

Position Sensitive Detector Development for use in the Rare Radio-Isotope Ring

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In accelerator physics, particle beams require constant fine tuning for nominal operation. As such, beam monitoring carries great importance. Detectors with position measurement capabilities are required to enact such beam diagnosis whilst causing minimum disruption to the beam quality. A detector of this type is required at the Rare Radio-Isotope Ring at the Radio Isotope Beam Factory (RIBF) in Japan, specifically with a large effective area, to extract position information. This must achieve the positional resolution of the current standard detector to be successful. A Delay Line Electric-field Micro Channel Plate type Detector was chosen for its precision potential while maintaining such a large area. The chosen detector is described along with motivations and improvements that will be made to increase its resolution. In addition, a section considering non-destructive techniques for monitoring the beam are evaluated with regards to their potential use at the RIBF. It is deemed that most are too underdeveloped however the cavity beam position monitor holds exciting potential.

Field of your work:

Experiental nuclear physics

Young Scientist Session 3 / 31

Experimental study of ^{4}n with ^{8}He(p,2p) reaction

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The tetraneutron(^{4}n), has attracted a lot of attention in the last decades. Its existence, whether as bound or resonant states, is of fundamental importance in nuclear physics, serving as a sensitive probe to investigate the nuclear force free from the Coulomb interaction. In case the four constituent neutrons are detected, it will also provide direct information about many-neutron correlations, which are crucial for a deeper understanding of neutron stars. Despite many experimental and theoretical efforts in the past decades, there is still no unambiguous conclusion on its existence or non-existence as a low-lying resonant state [1-6]. No measurements based on four-neutron detection have hitherto been reported.

We carried out new measurement on tetraneutron by using the ^{8}He(p,$2p$)^{7}H{t+^{4}n} reaction in inverse kinematics at RIKEN RIBF facility. Taking advantage of the SAMURAI spectrometer [7], the liquid hydrogen target MINOS, an array of NaI crystals, and a large neutron detector array combining the NeuLAND demonstrator from GSI and the existing NEBULA array, we achieved the kinematically complete measurement of all the reaction products including the four decay neutrons.

The multi-neutron analysis is now in progress, and some preliminary results will be presented.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 1 / 32

Nuclear transmutation of high-radiotoxic nuclide ^{90}Sr via proton- and deuteron-induced reactions in inverse kinematics

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Processing of spent fuel from nuclear power plants is a worldwide problem. The high-level radioactive waste is the product after the reprocessing of spent fuel, which includes minor actinides and fission products of radioactive waste. Especially, ^{90}Sr ($T_{1/2}$ = 28.8 years) is the highest radiotoxic nuclide in the fission products. It is highly desired to develop nuclear transmutation technology using accelerator facilities to reduce these harmful nuclides. The simplest way can be to irradiate a neutron beam on the radioactive waste. However, it is not well known that ^{90}Sr is transmuted into how much and which nuclide in this reaction. Therefore, it is essential to study, in advance, the reaction-cross-sections to each nuclide from ^{90}Sr. From this point of view, the inverse kinematics, i.e. including the ^{90}Sr beam incident on light-particle targets, is an effective method the reaction products can be identified at the forward directions.
To realize this purpose, we have planned the proton- and deuteron-induced reaction-cross-section measurements in inverse kinematics and performed the experiment using the BigRIPS separator [1] and the ZeroDegree spectrometer [1] at the RIKEN Radioactive Isotope Beam Factory. The radioactive ^{90}Sr beam with 104 MeV/u, produced and separated in the BigRIPS, incident on the C, CH_2, and CD_2 targets. The reaction products in the forward directions were transferred to the ZeroDegree and identified using the detectors at the focal plane. The reaction-cross-sections were obtained from the measured yields of each reaction channel. At this time, the contributions from carbon and beam-line materials were subtracted as a background. The obtained reaction-cross-sections were compared to the PHITS calculation [2] and the data with different energy of 185 MeV/u [3].

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Field of your work:

Experiental nuclear physics

Young Scientist Session 4 / 33

Proximity effect of pair correlation in the inner crust of neutron stars

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We study proximity effect of neutron superfluid in the inner crust of neutron stars by solving the Hartree-Fock-Bogoliubov equation in a spherical Wigner-Seitz (WS) cell. Numerical analysis shows that the presence of nuclei affects the pair correlation of neutron superfluid in proximity region, which is characterized by the coherence length measured from the edge of the nuclei. We use the functional SLy4 and density-depend delta interaction as the pairing force, which is designed to reproduce a realistic pairing gap in low-density neutron matter, i.e. Gor'kov's gap at low density limit and Ab-initio gap at $\rho_n \sim 10^{-3}\,\mathrm{fm}^{-3}$, as well as the average neutron gap of $^{120}\mathrm{Sn}$. The length of proximity effect is smaller than the site of WS cell. It reflects short coherence length of dilute neutron superfluid, where the strong-coupling pairing close to the BCS-BEC crossover is realized. At the densities $\rho_{n,\mathrm{ext}} \approx 4 \times 10^{-5}\,\mathrm{fm}^{-3}$ and $\rho_{n,\mathrm{ext}} \approx 4.4 \times 10^{-2}\,\mathrm{fm}^{-3}$, the length of proximity effect is same or longer than the site of WS cell. In this case, external neutron pair density is different from uniform neutron matter.

Field of your work:

Theoretical nuclear physics

Young Scientist Session 4 / 34

Alpha-Cluster Structures above Double Shell Closures from Chiral Effective Field Theory

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α-cluster states above double shell closures are important examples of nuclear α clustering. They include $^{8}\mathrm{Be} = \alpha + \alpha$, $^{20}\mathrm{Ne} = {}^{16}\mathrm{O} + \alpha$, $^{44,52}\mathrm{Ti} = {}^{40,48}\mathrm{Ca} + \alpha$, $^{104}\mathrm{Te} = {}^{100}\mathrm{Sn} + \alpha$, $^{212}\mathrm{Po} = {}^{208}\mathrm{Pb} + \alpha$, etc. Many theoretical and experimental efforts have been made to understand their physical properties.

We develop new cluster models with local potentials to study these α-cluster states in the light of chiral effective field theory (χEFT) [1]. Compared with phenomenological models for nuclear interactions, χEFT is characterized by its intimate connections to quantum chromodynamics through chiral symmetry breaking [2,3]. Also, its EFT framework provides a systematic way to make improvements and estimate theoretical errors. We obtain the local potentials between α clusters and doubly magic core nuclei by doubly folding their realistic density distributions with soft local chiral nucleon-nucleon potentials at next-to-next-to-leading order proposed in Ref. [4]. To simulate the Pauli blocking between alpha clusters and core nuclei, we adopt a modified version of the Wildermuth condition.

Various physical properties of α-cluster states in ^{8}Be, ^{20}Ne, ^{44,52}Ti, and ^{212}Po are studied by our new model. The theoretical results agree well with experimental data and theoretical expectations. We also study ^{104}Te, which has become a hot topic recently [5,6]. We analyze the available experimental data systematically within our model. The results could be helpful references for future experiments.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 2 / 35

Effect of nuclear tensor force on ground-state properties in the rare-earth region within a Skyrme mean-field approach

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Recent years, there are several researches [1-3] studying on the effect of nuclear tensor force in nuclear structure. Few attempts [4-6] have been made to fit the phenomenological Skyrme parameterization with the inclusion of the nuclear tensor term. However, a complete and systematic work to examine the role of nuclear tensor force in the rare-earth region is still lacking. This work aims to examine the effect of nuclear tensor force in the ground-state properties of rare-earth even-even nuclei. This is done within a Skyrme-Hartree-Fock-plus-Bardeen-Cooper-Schrieffer (HF+BCS) framework. The pairing correlations are taken care with the BCS theory. The Skyrme interaction is used to approximate the nucleon-nucleon interaction with various sets of parameterizations. At the moment, this work only considered the parameterization fitted through the perturbative addition of nuclear tensor term. The parameterization considered herein are divided into two sets namely, Set A (SIII and SIII+T) and Set B (SLy5 and SLy5+T) to examine the effect of nuclear tensor force on the ground-state properties. The considered ground-state properties here are binding energy, two-nucleon separation energy, nuclear charge radii and intrinsic charge quadrupole moments. The inclusion of nuclear tensor force has a better agreement with the experimental data but not for all cases. The good agreement between calculated and experimental data are sometimes degraded when taking into account nuclear tensor force. However, the results from this work is still preliminary as one should employ a full refit of all Skyrme parameters such as the TIJ sets [5].

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 3 / 36

Study of the fusion reaction of 6Li + 94,96Zr systems at near-barrier energies

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Investigation of fusion reaction induced by weakly bound nuclei is one of important topics in recent years. Because weakly bound nuclei break up before entering the fusion barrier, the incident flux of the complete fusion reaction channel is reduced. Therefore, the complete fusion cross section occurs suppression phenomenon. In order to study the suppression factor of complete fusion cross section on medium mass target nuclei, the complete and incomplete fusion cross section of 6Li+94,96Zr have been measured by online gamma ray method at the HI-13 Tandem Accelerator of the China Institute of Atomic Energy (CIAE) in Beijing. It is found that the suppression factor of complete fusion of 6Li+96Zr is around 25% [1] which is smaller than that on heavy target nuclei(~40%). In 6Li+94Zr, the angular distribution of gamma rays and angular momentum distribution of compound nuclei will be considered in the experimental results. A systematical behavior of suppression factor of complete fusion on Zr isotopes will be studied.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 4 / 37

Lipkin model analysis with variational quantum eigensolver

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Even though the quantum computing with fault tolerance is still a rather distant target, we are now entering a significant new era in developing quantum technology. In this circumstance, Noisy Intermediate-Scale Quantum Computing (NISQ) is defined by Preskill in 2018[1]. NISQ algorithms try to avoid deep circuits and utilize quantum advantages, which are efficiently preparing quantum states. NISQ devices will be useful for exploring many-body quantum physics and also lead to other useful applications. Variational quantum eigensolver (VQE) was proposed as a first practical algorithm for NISQ and the ground-state molecular energy for He-H$^+$ was calculated [2]. VQE is a hybrid algorithm that uses a variational method and combines quantum and classical computations in order to obtain the minimum eigenvalue of the Hamiltonian H of a given system.

Lipkin model is formulated [3] in order to investigate the validity of varied methods and formalisms proposed for calculating many-body systems. This model is also simple enough to be solved exactly. Therefore, we have adopted this model as a benchmark test for the VQE method. To carry out the

VQE algorithm successfully we need to choose variational trial functions, i.e., ansatze appropriately. We tried out two kinds of ansatze: unitary coupled-cluster (UCC) ansatz [4] and structure learning (SL) ansatz [5]. UCC ansatz is often used for analyzing molecular systems and developed from coupled-cluster theory [6]. SL ansatz is a method for simultaneously optimizing the structure and variational parameters of quantum circuits. The calculations were performed with numerical simulations on a classical computer. Consequently, we obtained consistent results between the exact ground-state energies and the energies with UCC and SL ansatze in the Lipkin model.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 1 / **38**

Proton charge radius measurement

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The proton is one of the essential bricks of matter, alongside with neutron; we know its mass, its charge but not its radius. Before 2010, the proton charge radius was thought to be known by physicists, measurements of the proton charge radius converged to a value of 0.8775±0.051 fm [1] using two different methods: electron scattering and hydrogen spectroscopy. However, in 2010 a German team measured a radius of 0.84087±0.0039 fm with a new experiment based on muonic hydrogen spectroscopy [2]. Since then, many experiments were conducted and obtained results consistent with one of the two previous values. Until now this discrepancy remains a mystery.

At ELPH (Research Center for Electron Photon science), we aim at measuring the proton charge radius using electron scattering. The proton charge radius can be deduced from the charge form factor of the proton obtained from the absolute cross-section measured in a very small 4-vector transferred-momentum range. By sending extremely low-momentum electrons (between 20 and 60 MeV/c) on a polyethylene target, we can realize extremely low transfer-momentum scattering and obtain the proton charge radius with great precision. To prepare the experiment, we simulated the experiment with Geant 4 and calculated the momentum dispersion and the momentum resolution of the spectrometer. These results confirmed that the characteristics of the spectrometer allow us to measure the proton charge radius with the required precision.

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Field of your work:

Experiental nuclear physics

39

Perturbatve refit of Skyrme parametrization with nuclear tensor for fission calculations

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Interest on the impact of nuclear tensor force on nuclear properties has been on the rise in the past decade. Within the Skryme mean-field framework, some new parametrizations have been proposed. Among them are the SLy5+tensor (SLy5+T) [1] and SIII+tensor (SIII+T) [2] in which tensor term was added perturbatively. In another work of Ref. [3], a family of TIJ Skyrme parametrization was introduced whereby all coupling constants entering the energy-density-functional (EDF) were refitted. The impact of nuclear tensor on nuclear properties have also been extensively explored in other studies for e.g. [4, 5] using Skyrme interaction and [6, 7] using the Gogny interaction. On the other hand, the impact of nuclear tensor in fission process is rather limited. To the best of our knowledge, there are two studies by [8] and [9] within the Fayans and Gogny EDF, respectively. We, on the other hand, chose to investigate the impact of nuclear tensor on fission barriers within a Skyrme-Hartree-Fock-plus-BCS framework. Some parametrizations were proposed in which the nuclear tensor component was perturbatively added on top of the SkM* parametrization usually used for fission calculations. A refit of the spin-orbit coefficient was also considered. In this talk, I will share current findings on the performance of these parametrizations on ground-state properties of some plutonium isotopes and fission barriers of ^{240}Pu.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 4 / 40

Pair vibrational excitation modes and pair-field polarizability

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It is known that the nucleus becomes superfluid state when nucleus receives the effects of pair correlation, and this effects is important for experimentally and theoretically understanding the properties of the nucleus. Due to the spontaneous symmetry breaking, the pairing correlation energy

can be expressed by a Mexican hat potential, and the phase mode (a Nambu-Goldstone mode) and the amplitude mode (a Higgs mode) of the pairing fluctuation appear. In the present work, we study the static polarizability of nuclei with respect to various types of pair fields, and its relation to the strength functions of the pair vibrational excitation modes. We define a specific combination of pair operators that is related to the curvature of Mexican hat potential.
We use the Skyrme-Hartree-Fock-Bogoliubov mean-field model and the continuum quasiparticle random phase approximation for ^{120}Sn, in order to describe the response to pair transfer operators and pair density operators. It is found that the convergence of response sum is improved When a Woods-saxon form factor is introduced. We also find that it is necessary to consider the response up to 20MeV including the Giant-Pairing-Vibration(GPV), in order to discuss the static polarizability experimentally.From the relation between the response of pair transfer operators and pair density operators,unmeasurable response of the pair density operators can be evaluated using a simple sum of measurable strength function of pair transfers if we take care of the lowest-lying pairing vibrational states.

Field of your work:

Theoretical nuclear physics

Young Scientist Session 2 / 41

Analysis of (p,pN) reactions with light nuclei in inverse kinematics

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The quenching single-particle strength and its proton-neutron asymmetry dependence is an interesting topic in the last decade. It is well known that results from transfer reactions and nucleon removal do not agree with each other. Recently, the proton-induced nucleon knockout (p, pN) reactions have been applied to rare isotope beams at intermediate energies in inverse kinematics to study the quenching of spectroscopic factors, also known as the reduction factor. Since the reduction factors strongly depend on the reaction model, it is important to investigate the effect of various corrections and uncertainties of the model in used on the results.

In our study, we have analyzed the $(p, 2p)$ and (p, pn) reactions data measured at the R^{3}B/LAND setup at GSI for a wide range of carbon, nitrogen and oxygen isotopes in the incident energy range of 300–450 MeV/u. Cross sections and reduction factors are calculated by the standard partial-wave DWIA method. In this talk, I will discuss our recent work on this subject and its implication for the study of quenching single-particle strength.

Field of your work:

Theoretical nuclear physics

Young Scientist Session 1 / 42

Evaluation of the astrophysical rates of the ^{42}Ti$(p,\gamma)^{43}$V and ^{43}V$(p,\gamma)^{44}$Cr reactions

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In this study we estimated the astrophysical rates of the $^{42}\mathrm{Ti}(p,\gamma)^{43}\mathrm{V}$ and $^{43}\mathrm{V}(p,\gamma)^{44}\mathrm{Cr}$ reactions and their variations due to mass uncertainties of the $^{43}\mathrm{V}$ and $^{44}\mathrm{Cr}$ exotic nuclei in the rp-process. The associated photodisintegration related to the $(p,\gamma)-(\gamma,p)$ equilibrium is also considered. The results show that the photodisintegration-rate variation of the $^{42}\mathrm{Ti}(p,\gamma)^{43}\mathrm{V}$ and $^{43}\mathrm{V}(p,\gamma)^{44}\mathrm{Cr}$ reactions are decreased at higher temperatures. The proton-capture rate variation between those reactions at T_9 = 0.5 is about 35% while it is approximately 60% at T_9 = 2.0. We found that the rate variation less than 20% if the precise mass of 10 keV can be achieved. To reduce the variation of the astrophysical rates, the precise mass measurements using MR-TOF technique at future facility RAON is suggested. Therefore, we also analyzed the resolving power, mass precision, counting rate, timing spread, and the half-life of the exotic isotopes for the MR-TOF technique. It is found that to achieve a mass accuracy of 0.1 ppm at the resolving power 10^5, a counting number of 10^4 is required for the isotopes. In addition, the half-life of the exotic nuclei must be longer than 10 ms for the reflections in the measurements using MR-TOF systems.

Keywords: mass uncertainty, reaction rates, rp-process, MR-TOF technique, exotic isotopes, timing spread, resolving power.

Field of your work:

Astrophysics

Young Scientist Session 3 / 43

Study on the origin of 10B in 6Li+12C reaction at energies around Coulomb barrier

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The weakly bound nuclei with relatively low binding energy and a greater breakup possibility, such as 6Li,7Li, 9Be, will result in complex reaction processes, such as CF (complete fusion), ICF (incomplete fusion), NCBU(non-capture breakup) and transfer processes, etc. The transfer reaction includes stripping and pickup processes. From the above processes, the reactions induced by weakly bound nuclei can produce the same residues. Therefore, different processes cannot be separated by only measuring the characteristic ⊠-rays. The 6Li + 209Bi experiments were performed at the Tandem-XTU accelerator of Legnaro National Laboratory of INFN in Italy. In this experiment, several gamma rays of 10B are observed. There are several possible reactions to form 10B. First of all, 6Li reacts with the 209Bi target, 6Li + 209Bi ⟶10B + 205Tl, which is direct a pickup reaction channel. Besides, 6Li reacts with the 12C foil, it also has two reaction channels, (1) 6Li + 12C ⟶18F ⟶ 10B + 2α, which is fusion-evaporation reaction, (2) 6Li + 12C ⟶10B + 8Be (2α), which is a direct deuteron/alpha pickup reaction, one-step process. It should be noted here that α pickup and deuteron pickup reaction can lead to the same products. All of the above processes can produce the 10B nucleus. It is difficult to give a very clear origin of 10B only on basis of gamma ray analysis. A coincident method of gamma rays with light charged particles can further select the reaction channels.

Field of your work:

Experiental nuclear physics

Young Scientist Session 3 / 44

One-neutron stripping processes to excited states of the 6Li+ 94,96Zr reaction at near-barrier energies

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Direct transfer of neutrons involving stable and radioactive weakly bound projectiles have been investigated in the past few years to contribute to the reaction and scattering mechanisms. At the energy around the Coulomb barrier, the neutron transfer reaction may cause the fission reaction and the enhancement of fusion cross sections to some systems, and the influence of neutron transfer on the fusion reaction can not be ignored. In this study, we adopted online gamma ray method to measure the 1n stripping to respectively product 95,97Zr of 6Li+94,96Zr around the Coulomb barrier. The experiment was performed at the HI-13 Tandem Accelerator of the China Institute of Atomic Energy (CIAE) in Beijing. It is found that the cross sections of 1n stripping of 6Li + 96Zr are smaller than that of complete fusion reaction at energies above the Coulomb barrier, however, at energies around the Coulomb barrier the cross setions of 1n stripping have the same magnitude with that of complete fusion. The transfer process gives a important contribution at energies around the Coulomb barrier. In 6Li + 94Zr, the preliminary results have been obtained. The correction of Gamma ray angular distribution and the determination of energy levels will be considered on basis of the current results. A systematic behavior of 1n stripping on Zr targets can be explored.

Field of your work:

Experiental nuclear physics

Young Scientist Session 3 / 45

Coulomb and Nuclear breakup of 6He

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We performed exclusive measurements of breakup reactions of 6He into 4He+2n on CH2, C, Sn, and Pb targets at 184 MeV/nucleon using the SAMURAI setup at the RI-beam factory (RIBF).
The highest-statistics experiments in these reactions owing to the combination of NeuLAND and NEBULA neutron detector arrays [1, 2] allowed us to study in detail these breakup reactions, the low-lying excited states, and their decays of neutron-halo nucleus 6He. In this presentation, the spectra of the excited state of 6He and the inclusive cross-section for each reaction target will be discussed.
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Field of your work:

Experiental nuclear physics

Young Scientist Session 3 / 46

Study of complete-incomplete fusion mechanisms in ^{7}Li+^{89}Y reaction.

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Fusion mechanism of weakly bound stable (^{6,7}Li and ^{9}Be) and unstable halo (^{11}Li, ^{7,11}Be, and ^{8}B) nuclei is a subject of great interest from the past few years [1,2]. Due to their low breakup threshold, various reaction processes like complete-incomplete fusion (CF-ICF), elastic breakup, and transfer followed by a breakup, appear in the reaction dynamics. Hence, to study the CF-ICF mechanisms and its dependency on entrance channel parameters in ^{7}Li+^{89}Y reaction an experiment was performed at the BARC-TIFR Pelletron facility Mumbai, India, using activation technique within the 2.7–5.7 MeV/nucleon energy range. The γ-spectrometry has been used to identify the residues and residual cross-sections have been measured. A systematic analysis of the complete and incomplete fusion dynamics has been carried out by comparing the measured excitation functions with the equilibrium and pre-equilibrium reaction models in the framework of statistical reaction codes EMPIRE3.2.2 and ALICE19. A strong indication of incomplete fusion has been realized within the energy range considered; hence the strength of incomplete fusion fraction (F_{ICF}) has been deduced. F_{ICF} shows an increasing trend with increasing projectile energy [3]. Further, barrier height and radius parameters extracted from the measured data are in good agreement with the Bass model.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 2 / 47

Glauber model Investigations in probable bubble nuclei.

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A strong depletion of the nuclear central density can have nuclear structure effects leading to the formation of "bubble" nuclei. Nonetheless, probing the density profile of the nuclear interior is, in

general, very challenging. We shall illustrate that the high-energy nucleon-nucleus scattering under the aegis of the Glauber model offers a unique and practical way to quantify the nuclear bubble. The effectiveness of this method is tested on ^{28}Si with harmonic-oscillator densities, before applying it on N = 14 isotones with realistic densities obtained from antisymmetrized molecular dynamics (AMD). I will show that the bubble structure information is imprinted on the nucleon-nucleus elastic scattering differential cross section and relationship between the bubble structure and the nuclear surface profile.

Field of your work:

Theoretical nuclear physics

Young Scientist Session 3 / 48

Does positive Q-value neutron transfer channels influence sub-barrier fusion?

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In heavy-ion induced reactions, sub-barrier fusion plays a crucial role in studying the static and dynamic properties of the nucleus and understanding the astrophysical processes in the steller environment [1]. However, the sub-barrier mechanism is not yet fully explored due to insufficient systematic studies and experimental measurements [2,3]. To unravel the role of positive Q-value neutron transfer channels in sub-barrier fusion enhancement, the fusion cross-sections of 35,37Cl + 130Te systems have been measured from 10 % below to 15% above the barrier using Heavy-Ion Reaction Analyzer at Inter-University Accelerator Centre (IUAC), New Delhi, India. 130Te targets were prepared by employing resistive evaporation techniques [4]. Experimentally measured fusion excitation functions of 35,37Cl + 130Te systems were compared to probe the role of neutron transfer channels in sub-barrier fusion. The comparison particularly interesting because 35Cl + 130Te system has six positive Q-value neutron transfer channels compared to none in 37Cl + 130Te system [5].

In comparison, it has been found that the reduced fusion excitation function of 35Cl + 130Te system shows a significant enhancement over the 37Cl + 130Te system at sub-barrier energies, which suggests the strong influence of positive Q-value of neutron transfer channels in sub-barrier fusion enhancement. Further, the analysis of the excitation functions, including inelastic excitations of interacting nuclei in coupled-channels calculations, indicates the importance of neutron transfer channels in sub-barrier fusion enhancement [6,7]. The experimental findings and detailed analysis of this work will be discussed during the presentation.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 2 / 49

Investigation of low-lying dipole responses in the 'island of inversion'

Authors: Manju .[1]; Jagjit Singh[2]; Shubhchintak .[3]; Rajdeep Chatterjee[1]

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Abstract: The enhancement of the low-lying E1 (electric dipole) strength above the one-nucleon emission threshold is known to be a unique feature of halo nuclei and is often studied via Coulomb breakup reactions. The low-lying E1 strengths has been studied very well both theoretically and experimentally for the lighter nuclei such as 6He, 11Li, 11Be, 15C, and 19C [1]. Due to advancements in the Radioactive-ion beam (RIB) facilities, these studies have been recently extended to the medium-mass nuclei lying in the island of inversion. In view of these recent developments, we have studied the E1 responses for 31Ne, 34Na, and 37Mg using a simple analytic model and finite-range distorted-wave Born approximation theory of the Coulomb dissociation [2]. We will report our recent results for the E1 response of these weakly-bound systems and their scaling phenomenon with parameters such as the binding energy and deformation [2]. Along with this, we will also briefly discuss our new results for speculated moderate halo 29Ne [3].

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 2 / 50

Confining the single particle potential parameters in direct nuclear reactions with radii of nucleon density distributions

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For a nucleus, B, which can be modeled as composed of a core nucleus A and a valence particle x (B = A + x), we derived the relation between the root mean square (rms) radius of the single particle wave function of x in B and the rms radii of nucleon density distributions of B, A and x. This relation allows one to determine the radii parameters of the single particle potentials (SPPs), which are usually not well confined in direct nuclear reaction calculations, with the radii of nucleon density distributions of atomic nuclei, and puts the resulting parameters on a sound physical ground.

Field of your work:

Young Scientist Session 2 / 51

Phenomenological modelling of energy dissipation in near-barrier fusion reactions

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Since the discovery of deep inelastic scattering in 1970s, it has been recognized that energy dissipation plays a crucial role in fusion reactions at energies well above the Coulomb barrier. In order to simulate its effects on the dynamics of relative motion, the Langevin method has successfully been applied to various dissipative nuclear reactions including fusion [1].

Recent experimental studies of multi-nucleon transfer have shown an importance of energy dissipation at slightly above barrier energies [2] and even at sub-barrier energies [3]. Since quantum treatment is required to describe fusion reactions in this energy region, the Langevin method, which is based on the classical equation of motion, is inapplicable. The conventional coupled-channels approach, on the other hand, is based on quantum mechanics [4], but it fails to describe energy dissipation.

To incorporate energy dissipation into the formalism of quantum mechanics, we utilize the bath-oscillator model, which has extensively been employed to study quantum non-equilibrium systems [5]. With a new numerical technique developed by us [6], we carry out a benchmark calculation of dissipative fusion reactions. In the present presentation, we shall describe the details of the model and discuss the role of energy dissipation.

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Field of your work:

Theoretical nuclear physics

Young Scientist Session 3 / 52

Probing for the systematic behavior of incomplete fusion fraction and complete fusion suppression induced by 12,13C on 165Ho target

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Abstract

Fusion reactions induced by Heavy Ions play a role of paramount importance in nuclear physics, as they help the nuclear physicists to study the properties of superheavy nuclei near and away from the stability line. In the reactions involving heavy ion projectiles such as 12C, 13C, 16O, 18O etc., and heavier mass targets at projectile energies below 8 MeV/nucleon, the two most dominant reaction modes are complete fusion (CF) and incomplete fusion (ICF) [1-3]. Study of these fusion reactions has remained the subject of enormous interest for both theoretical and experimental nuclear physicists over the past two decades. Various efforts have been made to comprehend the CF and ICF reaction dynamics since its first observation. However, due to lack of proper theoretical model below 8 MeV/nucleon, which may reproduce the experimentally measured ICF data satisfactorily, the study of CF and ICF is still an interesting area of research work [1-6]. In order to develop a proper theoretical model, the ICF dependence on entrance channel parameters such as projectile energy, mass asymmetry of interacting nuclei, Coulomb effect (ZPZT), projectile Qα-value, target deformation and input angular momentum values needs to be systematically investigated. Keeping the above mentioned aspects into consideration and to have better understanding of CF and ICF, the excitation function of the evaporation residues populated in 12,13C with 165Ho target have been studied. The interesting results have been obtained, which will be discussed during the presentation.

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Field of your work:

Experiental nuclear physics

Young Scientist Session 1 / 53

Performance evaluation of ionization chamber used for particle identification of heavy ion beams

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Ionization chambers are often used as E detectors for particle identification of heavy ion beams in RI beam facilities. The energy resolution of the ionization chamber is relatively high compared with that of solid detectors such as Si semiconductor with the same thickness in units of g/cm^2.

Pfutzner et al. proposed that the high energy resolution of the ionization chamber is caused by the escape of high energy electrons (δ rays) from the sensitive area [1].In our previous study, this effect of the δ-rays escape can be quantitatively reproduced by using the GEANT4 simulation at low atomic number Z [2].However, experimental values of the energy resolution at $Z > 32$ were gradually worse than the GEANT4 simulation.The reason is probably that the charge fluctuation of the incident beams caused by the electron capture and the ionization inside the ionization chamber increase at high Z. In order to evaluate the influence of the charge fluctuation, the energy resolutions of the ionization chamber were measured under several conditions.

The experiment was performed at HIMAC(NIRS).The projectile fragments were produced by a 420-MeV/nucleon ^{132}Xe primary beam in a 370 mg/cm^2 Be target. The fragments with $18 \leq Z \leq 55$ were separated by the secondary beam line(SB2). They were transported to experimental hall, F3, and were passed through plastic scintillators and ionization chambers located at F3.

In this study, we compared the experimental values of the energy resolutions with the Monte Calro simulation of charge fluctuations in the ionization chamber.In this presentation, we will report these results.

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Field of your work:

Instruments

Young Scientist Session 1 / 54

Development of fast-response and high-resolution position detector for high-intensity RI beam

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High-intensity radioactive isotope (RI) beams provide various opportunities to perform important studies of nuclear physics. In the experiment, position detectors have an essential role in the measurement of momentum and emittance, and particle identification. Common technique used for position deduction in conventional detectors such as Delay-line parallel plate avalanche counter (DL-PPAC) and Multi-wire drift chamber (MWDC) is based on time difference between the arrival time of the particle at the detector and the signals at the readout circuit. However, in this method, the plie up of signals is not negligible when the beam intensity is about 10^{6} Hz owing to the signal delay.
We have developed Strip-Readout PPAC (SR-PPAC) for the achievement of almost 100% detection efficiency even for the high-intensity RI beam near 10^6 Hz.
Fast electron pules collected directly from each strip of the cathode and the distribution of induced charge on the electrode are used for the position deduction.
The principle of SR-PPAC and its performance evaluation will be presented in this talk.

Field of your work:

Instruments

55

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