

Key Note Lecture

Historical Prospectives of Insruementations for Nuclear Physics in India

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Invited Talks

PreSPEC – Gamma-spectroscopy on the way towards NUSTAR

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ABSTRACT

In the next years the new international accelerator facility FAIR (Facility for Antiproton and Ion Research [1]), one of the largest research projects worldwide, will be erected at GSI (Helmholtzzentrum für Schwerionenforschung [2]). At FAIR an unprecedented variety of experiments will be carried out to allow new insights into the structure of matter and the evolution of the universe from Big Bang to the present. We will get information on the force acting between the nucleons inside the nucleus, with special emphasis on systems with exotic proton-to-neutron ratios: both proton-rich nuclei and neutron-rich nuclei. In extreme neutron-rich nuclei radical changes in their structure are expected with the possible disappearance of the classical shell gaps and magic numbers and the appearance of new ones. The nuclear structure community is heavily committed to the future NUSTAR (Nuclear Structure, Astrophysics and Reactions [3]) program of in-flight (HISPEC) and decay (DESPEC) γ -ray spectroscopy of highly exotic nuclei produced from the SUPER-FRS (FRagment Separator) [4]. As a pre-cursor of both high-resolution set-ups the PreSPEC project [5] was established, which builds on the very successful RISING (Rare Isotope Spectroscopic Investigation at GSI) campaigns. The PreSPEC project is aimed at nuclear structure and reaction studies using radioactive isotope beams. At the SIS/FRS facility at GSI exotic beams at relativistic energies were employed for Coulomb excitation and secondary fragmentation experiments. High-resolution gamma-ray spectroscopy is the main tool to investigate the shell evolution far off stability, proton-neutron interaction, symmetries and nuclear shapes. Compared to the former RISING set-up an advanced particle (LYCCA) and γ -ray (AGATA) detection system are used. At the future FAIR facility, these tools will be employed by the High-resolution In-flight SPECTroscopy (HISPEC) project. The improvements in the experimental set-ups, together with the opportunities to be opened, are discussed.

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**Multi-Nucleon Transfer and Their Effect on the Reaction Mechanism
Near Coulomb Barrier**

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ABSTRACT

The investigation of multi-nucleon transfer mechanism offers valuable information on the pairing interactions that enhance the transfer of nucleon pairs across heavy ions involved in the reaction. These reactions are also a very useful tool to study exotic nuclei far from the stability line which can be explored with the new generation radioactive beam facility. In this talk I will discuss multi-nucleon transfer reaction mechanisms between heavy ions and their effect on the fusion reaction mechanism around the coulomb barrier energies. Experimental results will be presented with a semi calssical description of muti nucleon transfer reaction calculation. One and two nucleon transfer cross sections reproduced using a quantum mechanical coupled channel calculations will also be discussed.

The Isolde facility and the HIE-Isolde project, recent results

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ABSTRACT

ISOLDE is the CERN facility dedicated to the production of radioactive ion beams for many different experiments in the fields of nuclear and atomic physics, materials science and life sciences. The ISOL method involves in this case the bombardment of a thick target with an intense proton beam, producing high yields of exotic nuclei with half-lives down to the millisecond range. By a clever combination of target and ion source units pure beams of over 1000 different nuclei of 74 elements have been produced and delivered to experiments where properties of the nuclei such as masses, radii, decay modes, structure and shapes are determined. This year ISOLDE celebrates its 50 anniversary of production of radioactive beams offering the largest variety of post-accelerated radioactive beams in the world today.

The HIE ISOLDE upgrade (HIE stands for High Intensity and Energy), intends to improve the experimental capabilities at ISOLDE over a wide front. The main feature is to boost the energy of the beams, going in steps from previous 3 MeV/u via 5.5 MeV/u to finally 10 MeV/u, and to accommodate a roughly fourfold increase in intensity. In 2016 Physics with 5.5 MeV/u for $A/q = 4.5$ was available and six experiments were done with beams from ${}^9\text{Li}$ to ${}^{142}\text{Xe}$ and energies up to 6.8 MeV/u in the case of ${}^9\text{Li}$ were achieved.

In this contribution highlights from ISOLDE and from the HIE-ISOLDE project will be presented.

Isospin ratios of pions - A signature for the equation of state of asymmetric matter?

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ABSTRACT

We use the Isospin Quantum Molecular Dynamics Model (IQMD) [1] to analyse the production of pions and their relation to the nuclear equation of state of symmetric and asymmetric matter. While the relation between pion production and the nuclear equation of state of symmetric matter has been discussed for long time, the discussion on the effect of the nuclear equation of state of asymmetric matter is much younger. A special interest was given to the isospin ratios of pions, since FOPI has measured very high π^-/π^+ ratios in Au+Au energies at rather low energies [2]. Several propositions were given in order to explain that phenomenon, many of them assuming strong influences from the asymmetric equation of state. In our presentation we will analyse the mechanism leading to pion production and its relation to the high density region in order to estimate whether this phenomenon corresponds rather to high density (i.e. eos) or low density (final state) effects.

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Perspectives in Heavy Element Spectroscopy

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ABSTRACT

Superheavy nuclei constitute a key frontier in nuclear structure research. While current theories compete to understand the physics of the heaviest elements, the miniscule cross-sections for their production preclude any substantive experimental touchstone against which the theories may be evaluated. High-spin spectroscopy of deformed $A \sim 250$ nuclei currently offer the best laboratory for any such detailed benchmarking, where deformation and rotation conspire to pull down orbitals from above the next higher neutron and proton spherical superheavy shell gaps into the valence domain. While fusion-evaporation reactions push the high-spin spectroscopy frontier to $Z > 104$, inelastic and transfer reactions are used to push our knowledge of neutron orbitals to $N = 154$. The talk will focus on accessing the highest neutron orbitals with radioactive targets and heavy beams [1,2]. Perspectives on technical developments for the future [3] will be discussed.

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UK Nuclear Data Network: UK research initiatives in industrial nuclear data

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ABSTRACT

This presentation will outline the recent work from the UK Nuclear Data Network (UKNDN). The UKNDN is a new initiative between UK universities, national laboratories, and industry, for the purpose of industrial nuclear data measurements. The talk will focus on three experiments, neutron time-of-flight (nTOF) at CERN, beta-delayed neutron spectroscopy at RIKEN, and total absorption gamma-ray spectroscopy (TAGS). An overview of the SpecTromEter for Fission Fragments (STEFF) will be given and recent results from an experiment to measure fission fragments and gamma-ray multiplicities in U-235 at nTOF. An update of the beta-delayed neutron measurements at the BigRIPS facility (BRIKEN) will be presented, ahead of the first experimental beam time later this year. Finally, recent results of decay experiments from the total absorption gamma-ray spectrometer (TAGS) will also be presented.

Nuclear Structure of ^{76}Ge from Inelastic Neutron Scattering Measurements: Relevance to Neutrinoless Double-Beta Decay

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ABSTRACT

The low-lying, low-spin levels of ^{76}Ge were studied using the inelastic neutron scattering (INS) experiments at the University of Kentucky Accelerator Laboratory (UKAL). Nuclear levels are non-selectively (statistically) populated with the (n,n' γ) reaction. Gamma-ray excitation function measurements were performed at incident neutron energies from 1.6 to 3.7 MeV, and γ -ray angular distributions were measured at neutron energies of 3.0 and 3.5 MeV on GeO_2 sample, enriched to 84% in ^{76}Ge . Lifetimes in the femtosecond region were measured with Doppler-shift attenuation method [1], and multipole mixing ratios were established. No evidence for a number of previously placed levels was found. Below 3.3 MeV, many new levels were identified, and the level scheme was re-evaluated. A comparison of the level characteristics with large-scale shell model calculations yielded excellent agreement. From the measured quantities we evaluated the reduced transition probabilities, which characterize the low-lying levels well, and the level scheme can be used to calculate the nuclear matrix element for the neutrinoless double- β decay experiment [2]. The 2^+ mixed-symmetry state has been identified for the first time and it is supported by microscopic calculations in the shell model. In above-barrier Coulomb excitation measurements by Toh *et al.*[3], band structures were identified in ^{76}Ge with ground-band and \square -band structures based on branching patterns and branching ratios. The $E2$ transition rates measured here support the low-lying band structure. The establishment of the comprehensive level scheme up to near 3 MeV and the observed agreement with shell model calculation, permits confidence in the valence space calculation of the neutrinoless double- β decay of ^{76}Ge [3,4].

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Nuclear Structure Effects on Nuclear Incompressibility

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ABSTRACT

Nuclear Incompressibility is a bulk property of nuclear matter. As such, one expects structure effects to play no role in it. The only direct experimental measurement of this quantity comes from the compression-mode giant resonances—the isoscalar giant monopole resonance (ISGMR) and the isoscalar giant dipole resonance (ISGDR). There have been some experimental results recently suggesting that nuclear structure effects may influence the energy of the isoscalar giant monopole resonance and, hence, the nuclear incompressibility. In this talk we will critically examine those claims and discuss how, and if, nuclear structure effects play a role in nuclear incompressibility.

Fusion in massive stars: Pushing the $^{12}\text{C}+^{12}\text{C}$ cross-section to the limits with the STELLA experiment at IPN Orsay

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ABSTRACT

The $^{12}\text{C}+^{12}\text{C}$ fusion reaction is one of the key reactions governing the evolution of massive stars as well as being critical to the physics underpinning various explosive astrophysical scenarios [1]. Our understanding of the $^{12}\text{C}+^{12}\text{C}$ reaction rate in the Gamow window – the energy range relevant to the different astrophysical scenarios – is presently confused. This is due to the large number of resonances around the Coulomb barrier and persisting down to the lowest energies measured. In usual circumstances, where the fusion cross-section is smooth it can be readily extrapolated from the energy range measured in the laboratory down to the Gamow window but this is not possible for $^{12}\text{C}+^{12}\text{C}$. Moreover, the existing data on this reaction obtained either through detection of evaporated charged particles or detection of gamma rays do not agree. This is a known problem which has been attributed to low-level contamination of targets with e.g. deuterium. In addition, there is considerable disagreement in the theoretical extrapolation of the data down to the Gamow window. Classically, the origin of the resonances has been attributed to molecular states based on a $^{12}\text{C}+^{12}\text{C}$ configuration, while more recently Jiang *et al.* have attributed it to low level density in the compound system [2].

Jiang *et al.* have developed a new experimental approach to study of the $^{12}\text{C}+^{12}\text{C}$ reaction which can circumvent issues related to target contamination [3]. They used the Gammasphere array to detect fusion gamma rays in coincidence with detection of evaporated charged particles using annular silicon strip detectors [3]. This technique has shown considerable promise in essentially removing experimental background from the measurement [3]. However, very long running times and high beam currents are needed to push this technique to the lowest beam energies approaching the Gamow window.

The STELLA experiment has recently been commissioned at IPN Orsay. A intense ^{12}C beam from the Andromede accelerator is incident on thin self-supporting ^{12}C foils. A target rotations system can allow for cooling supporting beam currents in excess of 1 μA . Evaporated charged particles are detected with a dedicated silicon array while gamma rays are detected in coincidence with an array of 30 LaBr_3 detectors [4]. The design and status of STELLA will be presented along with initial results showing good agreement with earlier measurements of the $^{12}\text{C}+^{12}\text{C}$ system.

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Nuclear structure studies at IUAC with heavy-ion beams

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ABSTRACT

At IUAC we have advanced experimental setups to study various features of nuclei at high spin, iso-spin and excitation energy with heavy ions. Heavy ion beams are provided from Pelletron and LINAC particle accelerators. Some of the major experimental facilities for nuclear physics studies are Indian National Gamma Array (INGA), National Array of Neutron Detectors (NAND) and Hybrid Reaction Analyser (HYRA).

INGA has been the main workhorse for nuclear structure studies at IUAC in recent years. It has enabled study of variety of modes of excitation in nuclei and thereby the study of their corresponding underlying structures. Chirality, higher order vibrations, magnetic rotations, termination and emergence of collectivity at very high spins are some of the topics which have been pursued vigorously. Further, we are working on combining HYRA, INGA setups for spectroscopy of heavy nuclei in our forthcoming INGA-HYRA campaign. I shall discuss some of the above mentioned efforts in my talk.

I also wish to acknowledge the great effort by our collaborators from different universities, IITs and research institutions in various experimental campaigns at IUAC.

Fusion Probability in Heavy Mass Region

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ABSTRACT

Presence of fission-like processes (NCNF) in fusion between two massive nuclei, without the formation of a compound nucleus (CN), causes the fusion probability, P_{CN} , to deviate from unity. Extraction of average fusion probability, $\langle P_{\text{CN}} \rangle$, has been attempted using different experimental probes e.g. (a) fission fragment (FF) angular distribution, (b) FF mass and total kinetic energy (TKE) distribution and (c) evaporation residue (ER) excitation function. In our recent systematic analysis of ER excitation functions for 52 reactions [1], $\langle P_{\text{CN}} \rangle$ has been found to be dependent both on the entrance channel parameters and bulk properties of the composite system. This study helps in finding out approximate boundaries from where $\langle P_{\text{CN}} \rangle$ starts to deviate from unity, signifying a transition from statistical to dynamical regime. For the experimental verification of the same, a systematic investigation of the FF angular distribution in pre-actinide nuclei ($Z = 83-88$) has been carried out [2]. The experimental anisotropies and fission cross-sections have been compared with theoretical predictions. Our results, coupled with results from neighbouring systems, show that $\langle P_{\text{CN}} \rangle$, in general, deviates from unity near and below the barrier and the deviation increases as one moves from pre-actinides to actinides.

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Intermediate Mass Fragment Emission in Multiple Neck Snapping in Ca+Sn Reactions

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ABSTRACT

The emission of intermediate mass fragments (IMFs) emitted in peripheral to mid peripheral collisions of ^{48}Ca on $^{112, 124}\text{Sn}$ targets at 45 A MeV has been studied. Kinematic evidence is provided for their dominant origin in a dynamic process, in which a transiently formed neck between projectile and target like fragments snaps quasi simultaneously in 2, 3 or 4 locations. This leads to aligned multi-chance fission-like process. Variations of the isotopic properties of these IMFs with the target A/Z ratio exhibit isoscaling-type behavior indicative of n/p mixing in the neck region. Relative probabilities are also consistent with ground state masses.

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Shape Transition in Pt-Nuclei with Mass $A \sim 190$

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ABSTRACT

The nuclei in mass region $A \sim 190$ are well known for the prolate-oblate shape co-existence/transition phenomena. The shape coexistence phenomena has been observed in nuclei like Hg & Tl of this mass region [1]. The calculations done for Pt nuclei in [2] indicate a smooth shape change from prolate deformed ^{186}Pt to nearly spherical $^{202-204}\text{Pt}$ through the region of triaxially deformed $^{188-198}\text{Pt}$ and slightly oblate ^{200}Pt . In these calculations, a change of shape from prolate to oblate is expected at $A = 188$. In recent high spin spectroscopic investigations, significant amount of reduced prolate collectivity has been observed in ^{188}Pt [3]. The level lifetimes provide valuable information about the nuclear shape and also the shape change with increase in spin along a band. So, to get clear signature of prolate to oblate shape inversion in Pt nuclei near $A = 190$, it is required to perform lifetime measurements. With this objective, the RDM lifetime measurements of high spin states have been done for various even-even Pt isotopes with mass $A \leq 186$ over the years. The results obtained in these measurements are very encouraging and do indicate changing nuclear structure for Pt-isotopes with increasing mass at low spins. A gradual increase in $B(E2)$ values upto 4^+ state and near constant nature thereafter in ^{188}Pt , contrary to the other light neighboring Pt nuclei tends to indicate the volatile nature of deformation in Pt nuclei near $A \sim 190$ which needs further theoretical investigations.

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Physics highlights of Indian National Gamma Array (INGA) Campaign at TIFR and Plan for Super-INGA

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ABSTRACT

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. Information of the properties and the behavior of the nucleus is contained in a cascade of about 20 to 30 gamma-rays emitted within a short time scale (up to few nano-seconds) during the deexcitation of the highly excited states produced in the nuclear reactions. Improvements in high-resolution detector systems involving high purity germanium crystals have continuously expanded the limits of observation and new phenomena have been discovered leading to unexpected insights into the nature of the nucleus. The Indian National Gamma Array (INGA) has contributed significantly in recent years to such studies. INGA is 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 experimental campaign consisting of around 50 experiments was completed recently. Selected results related to the novel excitation modes of atomic nuclei from this array will be presented. Comparison of the measured energy levels and transition strengths with different models that provides interesting insights on various shapes and phases of nuclei will be discussed. Finally, some ideas on the design of Super-INGA will be presented.

Recent Experimental Nuclear Reaction Studies at VECC

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ABSTRACT

In recent years, our group at VECC is actively engaged in different experimental studies to explore the different aspects of nuclear reactions. These studies cover a broad range of topics spanning fusion–fission, quasi fission [1-3], dependence of nuclear level density on the key parameters, such as excitation energy, angular momentum and collectivity [4-6], cluster structure studies in light nuclei [7-8] and transfer reactions for study of structure of nuclei of astrophysical interest [9-10]. An overview of these studies will be presented in this talk.

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Neutron Measurements at BARC, DUBNA and Kentucky facilities

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ABSTRACT

TANGRA facility at Frank Neutron Lab, JINR is a setup for measuring cross-sections and energy distributions of the characteristic gamma-radiation produced in the inelastic neutron scattering processes $A(n, n'\gamma)A^*$. In this regard, a development of an experimental set-up based on the spectrometer "Romashka" consisting of 24 gamma-detectors with NaI (TI) crystals, the neutron generator with an integrated alpha-detector produced by the FSUE Duhov "VNIIA", and fast neutron scintillation spectrometers is ready at Dubna. This facility is unique in terms of its parameters (high gamma-radiation and neutron detection efficiency, low background level through the use of the $(\alpha-n-\gamma)$ -coincidences), for implementation of the planned research. The following positioning of the targets irradiated by the tagged neutron flux is possible, depending on the physical problem: the target is positioned on the tagged neutron beam axis and between two cylindrical assemblies of the detection system "Romashka" (Romashka: consists of 24 NaI(Tl) scintillation detectors, which are arranged in the form of two cylindrical assemblies with 12 detectors in each.); the target is positioned on the tagged neutron beam axis when the axis of the detector assembly arranged in a circle is perpendicular to the tagged neutron beam direction. In addition to the gamma-detectors of the spectrometer "Romashka", neutron counters will be installed in experiments requiring the detection of neutrons. For shielding the gamma- and neutron detectors from direct hit of neutrons a combined neutron collimator will be used. The capture cross section experiments at Indian facilities will be performed by using PURNIMA facility for mono energetic neutrons at 2.45 MeV and FOTIA facility may be used for neutrons up to 5.0 MeV. TIFR Pelletron facility will be used for a higher range of neutron energies for same kind of measurements. The expected outcome of the programme is to get the improved nuclear data with less associated errors.

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How do nuclei rotate ?

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ABSTRACT

The collective model of nuclear coherent quadrupole-quadrupole interaction and rotations gives a specific test for the influence of Coriolis interaction between the even-even core and the unpaired nucleons on the split parity-doublet spectra in nuclei. It provides model estimations for the angular momentum projection K on the intrinsic symmetry axis and the related intrinsic nuclear structure. Based on this result we propose a study of the connection between collective shape characteristic and the intrinsic reflection-asymmetric shell structure of the nucleus. The analysis of the Coriolis interaction with deformed reflection- asymmetric shell- model calculations shows consistency with the results of the model of coherent quadrupole-quadrupole motion.

Role of nuclear shell closure on shape deformation in neutron-rich fission fragments

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ABSTRACT

The shape of the fissioning nucleus evolves in the multidimensional space of relative separation, neck opening, mass asymmetry and deformation of the fragments. Various types of nuclear shape deformation have been observed from the fission fragment spectroscopy studies, which provide crucial information in the understanding of the dynamics of the fission process. Several nuclear models have been put forward to describe the fission fragment mass distribution as well as shape deformation of the fragments.

Nuclear fission process also offers an opportunity to study the interplay of the structure and dynamics in the fission process. Recently, the accelerator-based experiments are performed to populate the high-spin states for studying the mass distribution from the spectroscopy measurements to understand the signature of the reaction mechanism. Fine structure dips have been observed in the fragment mass distribution, corresponding to fragment shell closures at $Z=50$ and $N=82$, indicating the evidence for a new feature of “shape inhibition” of closed shell nuclei at the scission point.

The role of nuclear shell structure as well as importance of shape deformations in the fission fragment mass distribution will be discussed. Some recent investigations on the fission fragment mass measurement using thermal neutrons from reactors will be presented.

Current Perspective of Double Beta Decay

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ABSTRACT

Nuclear Double Beta Decay is one of the most efficient tools to probe the fundamental properties of neutrino as well as weak interaction. Neutrinoless double beta decay is the only experiment at present promising to settle the Majorana/Dirac nature of neutrino and is being pursued by a few groups globally. This experiment is also most sensitive to look for the neutrino mass and establish lepton number violation. However, in the process of extraction of neutrino mass from half life measurement one has to use the nuclear transition matrix elements for the nuclei involved. Studies in different models for nuclear matrix elements calculations will also be presented.

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Sequential breakup of ${}^6\text{Li}$ by ${}^{112}\text{Sn}$

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ABSTRACT

Effects of projectile breakup are known to be manifested in the observation of several interesting phenomena like suppression in complete fusion (CF) cross sections at $E > V_b$, breakup threshold anomaly in the optical potentials obtained from elastic scattering at $E \sim V_b$ and high yield in α particle production at all energies (Ref. [1,2,3] and references therein). To investigate in detail, the breakup reaction mechanisms in a reaction involving a weakly bound projectile, the direct and several sequential breakup cross sections for ${}^6\text{Li} + {}^{112}\text{Sn}$ reaction have been measured at two beam energies, 30 and 22 MeV.

Sequential breakup of ${}^6\text{Li}$ into $\alpha + d$ via its resonant state $1+$ (5.65 MeV) in the continuum has been measured for the first time along with two other dominant resonant states $3+$ (2.18 MeV) and $2+$ (4.31 MeV) at $E_{\text{beam}} = 30$ MeV [4]. At lower beam energy (22 MeV), only the direct breakup of ${}^6\text{Li}$ into $\alpha + d$ was observed. Cross sections for sequential breakup via two transfer channels, (${}^6\text{Li}, {}^5\text{Li}$) and (${}^6\text{Li}, {}^8\text{Be}$), into $\alpha + p$ and $\alpha + \alpha$, respectively have also been measured. These breakup channels proceeding via $1n$ and $1d$ transfer reactions are open at both the energies. The Q-value and relative energy spectra show that $\alpha + p$ breakup proceeds via the same excitations at both the beam energies. However, for the $\alpha + \alpha$ channel, the breakup at $E_{\text{beam}} = 22$ MeV proceeds only through the 0^+ state of ${}^8\text{Be}$ whereas at $E_{\text{beam}} = 30$ MeV it proceeds through both 0^+ and 2^+ states of ${}^8\text{Be}$.

Continuum discretized coupled channels (CDCC) calculations have been performed to understand the resonant breakup cross sections. Excellent agreement between CDCC calculations and experimental $\alpha + d$ breakup cross sections via three resonance states of ${}^6\text{Li}$, using same set of coupling parameters, confirms the observation of sequential breakup via the resonance state of $1+$ along with $2+$ and $3+$ states. A comparison of breakup cross sections at two energies reveals that the cross sections for $\alpha + d$ breakup are more than $\alpha + p$ as well as $\alpha + \alpha$ breakup. All the breakup channels observed in the present measurements produce α as one of the two fragments and contribute to total inclusive α yield. Two additional unmeasured channels, i.e., $\alpha + d$ breakup followed by d capture and $1p$ transfer followed by $\alpha + n$ breakup are expected to have significant contributions in inclusive α . The above results unravel the breakup reaction mechanisms for the present reaction involving a weakly bound projectile and shed light on different breakup channels including a newly found resonant breakup that contribute to inclusive α particle production.

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Neutron emission in fission of $A \sim 200$

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ABSTRACT

It is well recognized that the cumulative fission probability in the heavy-ion induced reaction with excitation energy (E^*) in the range 40 – 60 MeV is not sensitive to the correlated variation of the statistical model (SM) parameters, namely the fission barrier (B_f) and the ratio of the level density parameter at the saddle point to that at the equilibrium deformation (a_f/a_n)[1-2]. The pre-fission neutron multiplicity (ν_{pre}) or the fission chance distribution was found to be sensitive to the above correlated variation in the SM parameters. Simultaneous SM fitting of the experimental fission excitation functions and the ν_{pre} values in $^{12}\text{C}+^{198}\text{Pt}$ results much smaller value of the fission barrier (~ 11 MeV) as compared to that (~ 22 MeV) extracted from the light-ion (p, α) induced fission excitation functions [2-4]. The light-ion induced fission measurement extends up to much lower excitation energy ($E^* \sim 25$ MeV) and thus more sensitive to the fission barrier. The SM calculation with the fission barrier determined from the light-ion data under predicts the measured ν_{pre} data. Significantly large dynamical delay is required if one assumes that the entire excess ν_{pre} as compared to SM prediction is due to dynamical emission [4]. In order to investigate further, we have extracted the fission chance distributions and the ν_{pre} values from the experimental excitation functions in the light-ion induced fission of the neighbouring Po isotopes [5]. The ν_{pre} extracted from the excitation functions corresponds to the pre-saddle emission only and is in excellent agreement with the SM predictions, which accounts for the low-energy light-ion fission data. This implies that the pre-saddle dynamics is not important in this energy range for this mass region. The ν_{pre} determined from the experimental fission excitation functions are much smaller than those extracted from the experimental neutron spectra. This reveals that there is a significant contribution from post-saddle emission to the ν_{pre} determined from the neutron spectra. The saddle point being extremely deformed, the saddle to scission motion in this mass region is expected to be fast and not expected to contribute significantly to the ν_{pre} . This indicates that there is a significant contribution from near scission neutron emission in the ν_{pre} determined from the neutron spectra. Details of the analysis will be discussed.

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Statistical Model of Compound Nucleus Decay: Role of Shell Structure and Collective Motion

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ABSTRACT

The statistical model of compound nucleus decay is the backbone for theoretical understanding of heavy ion induced fusion-fission reactions. The experimental observables in fusion-fission reactions are sensitive to the relative strengths of various decay channels including fission. These strengths in turn depend on the nuclear shell structure. Collective rotation/vibration of a nucleus can also influence the nuclear density of states which will consequently modify the strength of the decay channels. Further, the fission width also gets modified if the spin orientation of the compound nucleus changes.

We shall review the above effects and discuss how they impact different observables in a statistical model calculation

Detector developments for Nuclear Physics experiments at IUAC

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ABSTRACT

Inter University Accelerator Centre (IUAC), New Delhi provides facilities for nuclear physics experiments, focused at energies around Coulomb barrier, using the Pelletron-LINAC accelerator system. The heavy-ion induced fusion and fusion-fission reactions are characterized by performing measurements such as fission mass and angular distributions, fusion cross-section and barrier distributions, multi-nucleon transfer, neutron and charged particle multiplicity, Coulex etc. To execute these experiments, detector systems [1] based on position sensitive and fast timing proportional counters, particle identification telescopes based on gas ionization chambers and gas-silicon detectors, and scintillators for light charged particle and neutron detection have been developed. The detectors are routinely used in experiments involving facilities of mass spectrometers [2], scattering chamber, gamma [3] and neutron array [4] at IUAC. An overview of developments in detector instrumentation at IUAC will be presented.

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Neutron Induced Reaction/Fission Cross Sections on Materials for Nuclear Data Applications

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ABSTRACT

An accurate knowledge of neutron induced reaction/fission cross sections plays a vital role in the design and safe operation of various nuclear systems such as fission power plants, fusion devices, generation IV nuclear reactors and accelerator driven sub critical systems (ADSS). The activation cross sections have direct applications in estimating the radiation levels and decay heat of materials that have been exposed to radiation fields. The International Atomic Energy Agency-Exchange Format (IAEA-EXFOR) database shows that a significant discrepancy as well as wide gap exists in the measured experimental data for large number of neutron induced reactions in the region of fast and thermal energies. [1] In view of this, we are measuring the neutron induced cross sections for materials to measure neutron flux, structural materials and other reactor based materials at different energies using activation and off-line gamma ray technique. The experimentally measured cross sections are being compared with the evaluated nuclear data libraries of ENDF/B-VII.1, JENDL-4.0, TENDL-2010 and also with EXFOR database. The measured cross sections were also estimated theoretically using computer code TALYS over neutron energies from threshold to 20 MeV [2-4]. Some of our recent results will be presented in this talk.

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Structure of Intruder Band in $^{119-129}\text{Xe}$

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ABSTRACT

Xe isotopes in A~130 mass region are known for their variety of structural phenomena, such as, unexpected signature splitting, signature inversion, γ -vibration etc. These phenomena are associated to axially asymmetric shape. The triaxial shape in Xe nuclei are expected to originate due to the availability of prolate driving low- Ω $\pi h_{11/2}$ orbital and oblate driving high- Ω $\nu h_{11/2}$ orbital near Fermi surface. The observed experimental $E(4^+)/E(2^+)$ value (~2.5) also support the γ -soft nature of these nuclei [1]. Interestingly, both proton and neutron alignments have been observed in $\nu h_{11/2}$ band in $^{119-125}\text{Xe}$ and neutron alignment dominates. In ^{129}Xe , proton alignment reported to dominate. It is also supported by TPRM calculations [2], although, there are no significant change in the neutron orbitals. Whether this change in the alignment is occurred at N=75 or 73 is not known. Therefore, it is interesting to understand the status of the neutron and proton alignment in ^{127}Xe , which are not studied well. Hence, in-beam γ -ray spectroscopy of ^{127}Xe was carried out using $^{122}\text{Sn}(^9\text{Be}, 4n\gamma)$ fusion-evaporation reaction at 48 MeV using INGA facility at Inter-University Accelerator Centre, New Delhi. Details of the analysis and results will be discussed during the conference.

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Systematics in Break-up Fusion Reactions at Low Energies

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ABSTRACT

The reaction mechanism of heavy-ion interactions at low projectile energies is still not well understood. Both the fusion as well as break-up fusion of projectile have been observed at these energies. In the break-up fusion, also referred to as the incomplete fusion (ICF), a part of the incident ion fuses with the target nucleus while the remnant moves forward with the same velocity as that of projectile. Several models have been proposed, however, none of them could reproduce the data on ICF process. In order to study the break-up fusion reactions and to study its influence on various entrance channel parameters, several experiments have been carried out using pelletron accelerator facility at the Inter University Accelerator Centre (IUAC), New Delhi. The analysis of data has indicated significant break-up fusion contributions at energies $\approx 4-7$ MeV/nucleon. Important systematic [1,2] for incomplete or breakup fusion reactions have been observed and will be presented.

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Fragmentation analysis of stable and exotic nuclear systems using collective clusterization phenomenon

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ABSTRACT

The dynamical cluster decay model [1-3] based on the collective clusterization approach has been vividly applied to comprehend the dynamics of various mass regions, extended from the light mass [1] to the superheavy regime [2,3]. Within this framework, the decay of various compound nuclei governed through the light particles, intermediate mass, heavy mass and fission fragments etc. is immensely explored. In recent times, the calculations are carried out to understand the dynamics of heavy ion induced reactions, wherein the deformation ($\beta_{\lambda i}$; $\lambda=2, 3, 4$) and orientation (θ_i) effects are duly incorporated. The fragmentation behavior and preformation distribution (yield) of the neutron and loosely bound projectile-induced reactions are also analyzed [1,4] for a variety of hot ($T \neq 0$) and rotating ($\Omega \neq 0$) nuclear systems. The DCM has also been successfully applied to study the quasi-fission (qf) phenomenon [3,5], characterized by the asymmetric mass distribution [3], at incident energies lying across the Coulomb barrier. Furthermore, the role of different Skyrme forces is tested particularly to address sub-barrier fusion anomalies [6].

Beside this, the spontaneous-fission and α -decay paths [7] are explored by introducing the temperature effects in terms of recoil energy of the residual nucleus. The cluster and heavy particle radioactivity around Pb magicity is also explored within the framework of Preformed cluster model (PCM) [8], where the angular momentum and temperature effects remain silent.

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Effect of Alignment and Core Rotation on Shears Mechanism in Mass ~ 140 region

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*Nuclear Physics Division, SINP, 1/AF, Bidhannagar, Kolkata 700064*E-mail: asimananda.goswami@saha.ac.in**ABSTRACT**

Shears mechanism [1], manifested in the observation of both Magnetic and Anti-magnetic rotational bands, has been observed more than a decade ago, and represents a mechanism for the generation of angular momentum in nuclei which are weakly deformed. It leads to rotation-like band structures in the excitation spectra. The experimental signature of this mechanism is the gradual reduction in the reduced transition strength with spin along the bands. In this mode of excitation, the coupling of angular momentum vectors produced by the nucleons is the basic process for generating the total spin of the nuclei.

In mass 140 region several magnetic rotational bands have been observed in a particular nucleus. A few quadrupole bands due to twin shears structures have also been observed in this mass region. These high-spin dipole and quadrupole structures have been populated using fusion evaporation reaction and the de-excitation gamma rays were detected using the Indian National Gamma Array (INGA). The level lifetimes of states have been measured using the Doppler Shift Attenuation Method (DSAM). The role of alignment in producing the multiple magnetic rotational and anti-magnetic rotational bands was investigated in the present work [2-4]. The contribution of core rotation to the total spin, in addition to the angular momentum generated due to shears blades, has also investigated [5]. A sharp change in this contribution was envisaged as a transition from planar to non-planar solution.

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Nuclear Matter and Finite Nuclei Properties Using Finite Range Simple Effective Interaction

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ABSTRACT

The nuclear mean field as a function of momentum and density is the fundamental quantity of crucial importance in the studies related to the field of nuclear research. The importance of momentum dependence of mean field is well established from the studies involving the flow data analysis in heavy-ion (HI) collision at intermediate energies [1 and references therein]. The equation of state (EOS) of nuclear matter (NM) is connected to the behavior of mean field at Fermi momentum. The divergent results on high density behavior of nuclear symmetry energy and neutron (n) and proton (p) effective mass splitting obtained under different model calculations indicates on our poor understanding of EOS of asymmetric nuclear matter (ANM). These diverging trends obtained in connection with the isovector part of the mean field are analyzed using the finite range simple effective interaction (SEI) [2]. The usefulness of any effective model is judged from its prediction in finite nuclei.

The SEI with Gaussian form has been quite successful in the prediction of bulk properties of nuclei, both spherical and deformed, over the nuclear chart [3]. In the recent work [4] the study of the potential energy surface (PES), defined as the Hartree-Fock-Bogoulibov (HFB) energy computed with HFB wave functions constrained to definite values of the axial quadrupole moment, for nuclei ranging from light to very heavy ones have been performed. The results are compared with the predictions of Gogny D1S force set. The calculation of fission dynamics is necessary in order to ascertain the ability of the interaction for its use starting from static properties to dynamical processes in nuclei, which is under way.

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Importance of nucleon in the coupling mechanism to explore the nuclear structure of nearly deformed nuclei

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ABSTRACT

The high-spin states in a nucleus can be generated by a collective rotation either about a principal axis or a tilted axis. The total angular momentum is produced by coupling the neutron and proton angular momentum vectors through specific coupling schemes [1-2]. The magnetic rotation which is built with the coupling of two angular momentum can undergoes band-crossing due to the alignment of a nucleon pair. From the geometry of MR band as given in [3,4,5], the B(M1) value for the states in the crossing region can be calculated assuming that the aligned angular momentum

is quantized. The present Semi Classical (SC) calculation shows good agreement with the experimental observations in mass $A \sim 100$ and $A \sim 200$ regions [6]. Apart from this, it also provides the core contribution, if it is contributing to the generation of total angular momentum. However, in some nuclei a transition from the principal axis to the tilted axis is observed. From the experimental observers such as staggering, B(M1) transition rates etc., it is possible to observe this phase transition. In this work, we are reporting such a phenomenon in the ^{85}Sr nucleus [7].

In some of the nuclei, the multiple and degenerate bands are observed, those can be understood by occupying the nucleon in the different projection (Ω) of Nilsson state. The reduce-transition probabilities of these bands can understood by Tilted axis Cranking (TAC) calculations in which configuration only differ in the occupancy of different (Ω) of a Nilsson state. Few examples will be provided from mass $A=110$ and 130 regions.

The financial support from the Department of Science and Technology (DST), Govt. of India for the INGA project (No. IR/S2/PF-03/2003-I) is gratefully acknowledged. The author also thanks the CSIR, University of Delhi and DAE (Govt. of India) for financial support at various stages. In addition to it, the support provided by the staff of TIFR-BARC Pelletron facility at TIFR is highly appreciated and acknowledged.

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How well do we understand Nuclear Reactions Around the Coulomb Barrier – a few Answers & Questions

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ABSTRACT

The heavy-ion interactions around the Coulomb barrier continue to be a question of wide experimental and theoretical interest for the community due to complex onset of different processes at these energies [1-2]. Several years ago, limitations to fusion for heavy systems were found in extensive research carried out mainly at GSI Germany aiming to explore the possibility of forming super-heavy elements [3]. Lately, it has been observed that the excitation functions at sub-barrier energies drop rapidly due to the influence of (quasi-elastic/multi-nucleon) transfer reactions on fusion with a logarithmic slope much larger than that predicted by tunneling calculations using conventional ion-ion potentials which was taken as a phenomenological signal of the presence of “fusion hindrance”. However, at above-barrier energies, the fusion excitation functions display significant enhancement as compared to the standard fusion-evaporation models which has been attributed to the onset of break-up/incomplete-fusion channels, and the strength of these channels increases with projectile energies [4-5].

In many existing studies [1-5, and the references therein], heavy-ion induced reactions show many facets, reflecting several physical/dynamical situations for different projectile-target combinations, and found to be contradictory in some cases. For better insights into nuclear reactions around the Coulomb barrier, a series of experiments have been performed at LNL, ANL and at IUAC, and our knowledge about the underlying processes has significantly advanced in recent years. Finding of these exciting measurements will be presented in light of the existing studies during the conference. Like the saying goes, “It is better to know some of the questions than all of the answers”, a few outstanding questions related to heavy-ion reactions around the barrier will be discussed.

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Multi-Purpose Accelerator Facility Proposal for Panjab University

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ABSTRACT

A multipurpose accelerator facility proposal is underway with DST, Govt. of India. Details of the proposal and the physics to be undertaken will be discussed.

I-33

High Spin Structure of Highly Neutron Rich Fe and Ni Nuclei in Deformed PHF Model

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ABSTRACT

Tidal Deformability of Neutron and Hyperon Star with Relativistic Mean Field Equations of State

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ABSTRACT

The detection of gravitational waves is a major breakthrough in astrophysics/cosmology which is detected for the first time by advanced Laser Interferometer Gravitational-wave Observatory (aLIGO) detector. Inspiring and coalescing of binary black-hole results in emission of the gravitational waves. We may expect that in a few years the forthcoming aLIGO, VIRGO and KAGRA detectors will also detect gravitational waves emitted by binary neutron star (NSs). This detection will provide a valuable guidance and a better understanding of highly compressed baryonic system. Flanagan and Hinderer [1–3] have recently pointed out that tidal effects are also potentially measurable during the early part of the evolution when the waveform is relatively clean. It is understood that the late inspiral signal may be influenced by tidal interaction between binary stars (NS-NS), which gives the important information about the equation-of-state (EOS). Some recent studies inferred that the tidal effects could be measured using the recent generation of gravitational wave (GW) detectors.

In the present talk, we will systematically present the tidal deformability for neutron and hyperon stars using relativistic mean field (RMF) equations of state (EOSs) [4]. The tidal effect plays an important role during the early part of the evolution of compact binaries. Although, the deformability associated with the EOSs has a small correction, it gives a clean gravitational wave signature in binary inspiral. These are characterized by various love numbers k_l ($l=2, 3, 4$), that depend on the EOS of a star for a given mass and radius. The tidal effect of star could be efficiently measured through advanced LIGO detector from the final stages of inspiraling binary neutron star (BNS) merger.

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Break-up Reaction Mechanism in Interactions with ${}^6,7\text{Li}$

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ABSTRACT

In interactions with weakly bound nuclei such as ${}^6,7\text{Li}$ and ${}^9\text{Be}$, above barrier complete fusion cross sections were found to be suppressed as compared to theoretical predictions. Understanding the mechanism of break-up reaction is crucial to explain the measured the above barrier suppression. Break-up coincidence measurements at sub-barrier energies are performed with ${}^6\text{Li}$ beam on ${}^{58}\text{Ni}$, ${}^{64}\text{Zn}$ targets and compared with previous measurements carried out with ${}^{208}\text{Pb}$ [1]. In interactions of ${}^6\text{Li}$ with these nuclei, break-up is mainly triggered by transfer of nucleons. Among the break-up triggered by transfer channels, neutron stripping from ${}^6\text{Li}$ leading to the α -p break-up pair is the strongest. Deuteron pick-up leading to different resonant states of ${}^8\text{Be}$ (which eventually decays into α - α) is observed only in reactions with ${}^{208}\text{Pb}$. The direct break-up mode with ${}^6\text{Li}$ projectile is found to depend on the mass of the target: break-up occurs via the non-resonant continuum as well as a 3^+ resonant state in reactions with heavy targets, but via only the long-lived 3^+ resonant state in interactions with light mass targets [2].

A modified version of the classical Monte Carlo code PLATYPUS [3] is used for carrying out simulations including an excitation dependent probability of populating unbound projectile-like nucleus states, and the lifetime of resonance and continuum states as function of excitation energy. Previous data on heavy targets have been reanalyzed with these changes and the results were found to be very different [4,5]. Break-up of the projectile-like nuclei can occur via the population of narrow resonant states, such as the 3^+ resonant state in ${}^6\text{Li}$. Due to their long lifetimes, such states only decay into fragments once they have retreated asymptotically from the target-like nucleus. Alternatively prompt break-up — either via population of short-lived resonance or non-resonant states — occurs when the projectile and target are in close proximity. The interaction of the clusters fragments and the target-like nucleus then has an important role in determining the energy and angular correlations of the fragments. The relative strengths of these different mechanisms, and their sensitivity to different targets, will be discussed.

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Investigating the Dynamics of Heavy-Ion Induced Fusion Reactions

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ABSTRACT

Investigation of dynamical effects in heavy-ion induced fusion reactions is an area of intense research. Much progress has been made in this field both on the theoretical and experimental front. In some of the recent experimental studies, it is observed that the light particles spectra from the compound nucleus populated through asymmetric systems could be explained by standard statistical model calculations, whereas the spectra from the symmetric systems could not be explained by these calculations [1,2]. These studies indicated the presence of dynamical effects in fusion leading to non-fusion of higher values of angular momentum and a delay in the fusion process that result in the pre-equilibrium emission of light particles. But most of the existing measurements are inclusive and conclusions are made using one observable only. We have performed the exclusive light particle (α , proton, neutron) evaporation spectra measurements [3] and observed fusion hindrance of higher partial waves and existence of pre-equilibrium processes. Also we have used more sensitive probes like fusion cross-sections and spin distribution measurements for investigating the dynamics of heavy-ion induced fusion reactions for two relatively symmetric systems. The cross-section measurements on comparison with TDHF and CCDEF calculations do not give any indication of the existence of dynamical effects for the symmetric system. However, the comparison of experimental spin distributions with the CCDEF calculations indicate the effect of entrance channel mass asymmetry on fusion dynamics and experimental spin distributions reasonably explained the deviations in the α -particle spectrum for the symmetric system [4]. In this talk I will talk about the anomalous behaviour of the light particle spectra obtained from heavy-ion fusion reaction and later I will highlight the importance of cross-section and spin distribution measurement for the interpretation of the particle spectra.

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Effect of Viscosity on the Fusion-Fission Dynamics Studied by Charged Particle Emission

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ABSTARCT

The study of the dynamics of the fusion-fission at high excitation and angular momentum, provides an excellent testing ground for nuclear any-body theories such as dissipation mechanism and viscosity of nuclear matter as a function of temperature. Time scales in fission process are on of the most important quantities in studying nuclear viscosity. During this time scale, which is called a fission delay time, neutrons, protons and α -particles can be emitted. The Dynamics of fusion-fission is deduced from the multiplicity of light particles which are evaporated after the system has decided to fission and moves towards the scission point [1]. The multiplicity and spectral shapes of the α -particles sensitively depend also on the deformation and angular momentum of the composite system and can provide, of course, additional information such as shielding effects of emitted particles by the two fission fragments in close proximity. In the present work, measured alpha particle multiplicities are used to extract the fission time scales and study the role of viscosity in the heavy-ion-induced fusion-fission reactions.

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Nuclear Structure Studies Close to $N = Z = 50$ Shell Closure

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ABSTRACT

The nuclei approaching the neutron and proton major shell closure at $N = Z = 50$ provide a unique opportunity to study interplay between the single particle and collective degree of freedom and the influence of the valence orbitals on deformation. Theoretical interpretation of band structures observed in the nuclei approaching major shell closures at $N = Z = 50$ have revealed diversity in the deformation-generating mechanisms. The proton particle-hole excitations across major shell gap are energetically possible due to the strong proton-pair correlations and proton-neutron interaction between the spin-orbit partner orbitals. As one approaches $N \approx 54$, the $\nu \frac{11}{2}$ subshell intruder orbital is likely to be occupied. The Neutron Fermi level lie at the bottom in the $\nu \frac{11}{2}$ subshell or the low- $\Omega \nu \frac{11}{2}$ orbitals are accessible at low excitation energies, the shape is driven to prolate deformation. The active intruder orbitals lie near the top in the high- $\Omega \nu g_{7/2}$ orbitals which drives shapes towards oblate deformation. The delicate interplay of strongly shape-driving $\pi g_{7/2}$ and $\nu \frac{11}{2}$ orbitals result in the Υ -soft (triaxial) shapes with modest deformation. Intriguing relevant phenomena such as magnetic rotation and degenerate twin bands have been reported in this mass region. The limited number of valence particles (holes) in the nuclei in this mass region, are able to break the spherical symmetry and induce, albeit small, nuclear deformation. Because the small (prolate) deformation requires high angular velocity to generate collective angular momentum, specific noncollective "aligned" states with the nuclear spin made up completely from single particle angular momentum contributions, are able to compete energetically with the weakly deformed collective structures. In the experiments devoted to study nuclei in the vicinity of the ^{100}Sn , the maximally aligned states have been observed in $^{98,99}\text{Ag}$ and $^{98,102,103}\text{Pd}$ isotopes. In the nuclides in the $A \sim 100$ region, there is existence of isomers due to the presence of low energy states based on the $p_{1/2}$ and $\pi g_{7/2}$ orbitals, with widely different angular momentum where the Υ -decay is slow. The identification of isomers has been a difficult task, considerable effort has been devoted to the study of isomers in $A \sim 100$ nuclides. For the even- Z and odd- A nuclei in this mass region, the presence of nearby $\frac{11}{2}$, $g_{7/2}$, $d_{5/2}$ neutron orbitals usually give rise to different one-quasiparticle band structures, and further rearrangements of neutrons and protons is expected to add richness to the structure. As the neutron $\frac{11}{2}$ and $d_{5/2}$ orbitals with $l = 3$, $j = 1$, and $\pi = 1$, are near the Fermi surface, octupole collectivity will be enhanced in this region. It is worth mentioning that octupole collectivity has been observed in the $Z = 55$ region, where single quasiproton $\frac{11}{2}$, $g_{7/2}$, $d_{5/2}$ bands have been observed at low excitation energy.

Dynamics of Fragmentation in Heavy-Ion Collisions at Intermediate Energies

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ABSTRACT

Nuclear multifragmentation, the breaking of colliding nuclei into various pieces, is one of the interesting processes that occur at intermediate energies. Here, I will discuss some of the aspects of nuclear fragmentation which are studied by us recently. In particular, I will discuss about the peak mass production of various fragments at different beam energies using molecular dynamics approach. Secondly, I will also shed light on the nuclear symmetry energy and how one can exploit multifragmentation to gain insight about nuclear symmetry energy. Our findings reveal that light charged particles production is sensitive to symmetry energy contrary to intermediate mass fragment production which emit from spectator zone. We also found that ratios of relative yields of light charged particles in isotopic-isobaric colliding pairs serve as a good probe compared to bare yields for nuclear symmetry energy.

Evolution of nuclear shapes in the light Radon isotope

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ABSTRACT

Shape coexistence in heavy nuclei poses a strong challenge to state-of-the-art nuclear models, where several competing shape minima are found close to the ground state. A classic region for investigating this phenomenon is in the region around $Z = 82$ and the neutron midshell at $N = 104$. Evidence for shape coexistence has been inferred from α -decay measurements, laser spectroscopy, and in-beam measurements. While the latter allow the pattern of excited states and rotational band structures to be mapped out, a detailed understanding of shape coexistence can only come from measurements of electromagnetic matrix elements. Secondary, radioactive ion beams of ^{202}Rn and ^{204}Rn will be discussed by means of low-energy Coulomb excitation at the REX-ISOLDE in CERN. The results will be discussed in terms of collectivity and the deformation of both nuclei studied is deduced to be weak, as expected from the low-lying level-energy schemes. Comparisons will also be made to state-of-the-art beyond-mean-field model calculations and the magnitude of the transitional quadrupole moments are well reproduced.

Microscopic Study of Spectra and Electromagnetic Transitions in Nuclei

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ABSTRACT

Spectra and electromagnetic properties of nuclei provide insight into the structure of nuclei and this is an active area of research, in theory and experiments worldwide. In this work we review and present theoretical results for the structure of nuclei in various mass regions. We use deformed Hartree-Fock and Angular Momentum Projection model as a versatile tool for the study of spectra and electromagnetic properties [1,2,3] of nuclei. Constrained Hartree-Fock model is used to figure out various excited configurations. Results for nuclei in the $A=80-110$ mass regions and the rare-earth region will be presented. Comparison with recent experimental results of K isomers [4] from RIKEN will be shown.

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Oral Presentations

Breakup Effects on ${}^9\text{Be} + {}^{64}\text{Zn}$ Fusion Reaction at Around Barrier Energies

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ABSTRACT

The fusion reactions induced by weakly bound light projectiles on various targets at around barrier energies are subject of contemporary interest in connection with unambiguous understanding of static and dynamic effects arising because of low binding energy of last nucleon(s) of the projectile on fusion cross section [1-4]. We have studied the fusion excitation function of reaction induced by ${}^9\text{Be}$ on ${}^{64}\text{Zn}$ target at energies in the vicinity of Coulomb barrier within the framework of quantum diffusion model with special emphasis on the role of dominant breakup mechanism ${}^A\text{X}({}^9\text{Be}, {}^8\text{Be}^*){}^{A+1}\text{X}$ on fusion cross section. It is found that when the breakup mechanism is invoked in the analysis the fusion cross section suppresses in near barrier energy region while it remains unchanged at energies much higher than the barrier energy.

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O-2

Pre-compound emission in the system $^{16}\text{O}+^{169}\text{Tm}$: Measurements of isomeric cross-section ratios and Spin distributions

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ABSTRACT

There has been a renewed interest in the study of pre-compound (PCN) emission in heavy ion (HI) induced reactions particularly at low projectile energies where compound nucleus (CN) process dominates [1-3]. In a nuclear reaction, the relative population of isomeric state with respect to the ground state is governed by spin distribution of residual nucleus. The spin distribution is determined by the angular momentum brought in by the projectile and that carried away by the ejectile. The former depends on the projectile and its energy and latter depends on loss of angular momentum during particle emission and types of reaction mechanism. The PCN emission takes place with relatively larger angular momentum carried away by the ejectile than that of CN process. In order to see the angular momentum dependence on PCN process, isomeric cross-section ratios (ICRs) for nuclei populated in the interaction of ^{16}O with target ^{169}Tm at different projectile energies have been measured which is of fundamental interest.

In the present work, both off-beam and in-beam measurements have been carried out at the Inter University Accelerator Centre (IUAC), New Delhi to understand the PCN reactions mechanism. The ICRs for population of isomeric and ground states for reactions $^{169}\text{Tm}(^{16}\text{O},\text{pn})^{183\text{m.g}}\text{Os}$ and $^{169}\text{Tm}(^{16}\text{O},2\text{pn})^{181\text{m.g}}\text{Re}$ have been deduced by off-beam measurements of excitation functions, while in-beam particle-gamma coincidence experiments have been carried out for measurement of the spin distributions (SDs) of reactions $^{169}\text{Tm}(^{16}\text{O},\text{pn})^{183\text{m.g}}\text{Os}$ and $^{169}\text{Tm}(^{16}\text{O},2\text{pn})^{181\text{m.g}}\text{Re}$. Analysis of ICRs of the residues in reactions $^{169}\text{Tm}(^{16}\text{O},\text{pn})^{183\text{m.g}}\text{Os}$ and $^{169}\text{Tm}(^{16}\text{O},2\text{pn})^{181\text{m.g}}\text{Re}$ shows two distinct decay patterns corresponding to PCN and CN processes. Furthermore, SDs is also found to be distinctly different for the PCN and the CN processes. Further details will be presented.

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RMF+BCS Description of $N = 32$ and $N = 34$ Shell Closure

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ABSTRACT

We have employed RMF+BCS (relativistic mean-field plus BCS) approach [1,2] to study $N = 32$ and $N = 34$ shell closure with the help of ground state properties of even-even nuclei. Our present investigations include single particle energies, deformations, separation energies as well as neutron and proton densities etc. Encouraged by the recent experiments showing neutron magicity at $N = 32$ for Ca isotopes [3-5], we have applied RMF theory with delta function pairing along with mass dependency ($1/A$) for full chain of $N = 32$ and $N = 34$ isotones upto drip lines. It is gratifying that our results with mass dependent pairing indeed indicate a shell closure at $N = 32$ in Ca isotopes in agreement of recent experiments and showing ^{52}Ca as a doubly magic candidate.

Moreover, a stronger shell closure at $N = 34$ is also observed in proton deficient ^{48}Si because of reorganization of neutron pf shell moving from Ca to Si isotopes. Taking isospin consideration, we have also studied $Z = 32$ and $Z = 34$ isotopes in a similar manner in which proton single particle structure is more likely to produce shell closure at $Z = 34$ with a doubly magic character for $^{84,116}\text{Se}$. These results are verified with various other popular parameters viz. TMA [6], NL-SH [7], NL3 [8], PK1 [9] and NL3* [10] and fortified by other non-relativistic calculations (HFB) [11]. This study predicts new doubly magic nuclei specially ^{48}Si which is in the same mass region in ^{52}Ca as the recent experiments observed.

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O-4

Study of Fission Time Scale From Particle Multiplicity In $^{16}\text{O}+^{196}\text{Pt}$ Reaction

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ABSTRACT

Exploring the heavy ion induced fusion-fission reactions mechanism has always been of great interest. In order to extract fission time scales, extensive theoretical and experimental efforts have been made. Fission time scales obtained using different probes gives insight of fission reaction mechanism. It has been discern from the earlier studies that the fission decay of excited (hot) nuclei is hindered [1]. Nuclear dissipation [2] is assumed to be responsible for this delay and more light particles are expected to be emitted during the fission process. Evaluation of these light particles such as neutron, proton and alpha deepens the knowledge of fission mechanism.

In the present work, we have measured the particle multiplicities in coincidence with the fission fragments for $^{16}\text{O}+^{196}\text{Pt}$. Energy and direction of charged particles are affected due to the occurrence of coulomb barrier at the exit channel. Deformation dependent particle binding energy plays an important role due to which emission of charged particles is suppressed and neutron is increased [1]. Studying these emitted particles can provide needful information on the dynamical aspects [3] of fusion-fission process.

The charged particles were detected using CsI(Tl) detectors and 2-D spectrum of CsI(Tl) is shown in Fig 1. Particle identification was done using ballistic deficit technique [4]. To obtain fission coincidence spectra, particles were gated with anode of fission detector. Thus the obtained yield was calculated using moving source fitting (MSF) for various sources. To explain the experimentally obtained value of particle multiplicity, fission delay was adjusted accordingly during the theoretical calculations using statistical model code JOANNE2. Thus the total fission time was obtained.

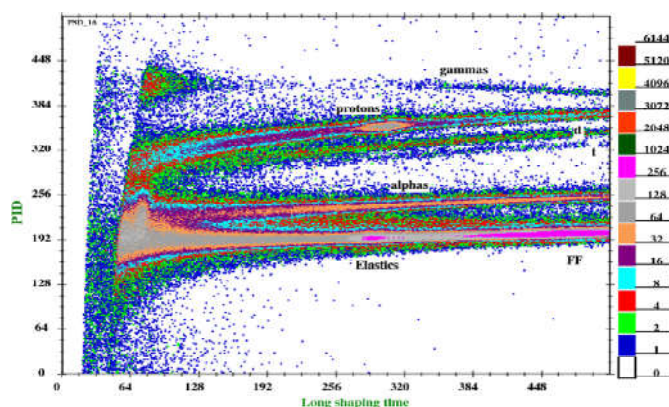


Fig 1-Particle Identification spectrum from CsI(Tl)

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New dipole band structures and their microscopic description in ^{101}Pd

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ABSTRACT

The experimental and theoretical investigations in neutron deficient nuclei approaching the proton and neutron major shell closure at $N=Z=50$ have revealed a variety of band structures resulting from coupling of the valence nucleons in different shape driving orbitals and the core excited configurations. Various new nuclear structure phenomena have been identified, viz., magnetic rotation, antimagnetic rotation, and smooth band termination, wherein the angular momentum is generated through gradual alignment of valence proton hole and neutron particle angular momenta with different initial geometrical compositions. The band structures exhibit different features for dynamic moment of inertia and transition rates. The present work focus on the experimental data for excited states in ^{101}Pd nucleus obtained from $^{75}\text{As}(^{31}\text{P}, 2p3n)$ fusion evaporation reaction at $E_{\text{lab}} = 125$ MeV using the Indian national gamma array (INGA) [1,2] consisting of 21 Compton suppressed clover detectors. In the present work, the previously reported level scheme [3-5] is considerably extended at medium and high spin values. The positive parity quadrupole bands have been found to evolve into dipole bands at high spin states. The positive parity band structures are studied within the framework of projected shell model (PSM) calculations [6] to assign multiquasiparticle configurations. The lower positive band structure originate from projection of one quasiparticle state with $K = 1/2$ and $3/2$ and are signature partner states. After bandcrossing, these bands exhibit different intrinsic bands structures and are labeled bands B1 and B2. Band B1 is dominated by three quasiparticle state with $K = 9/2$ and the band B2 is dominated by three quasiparticle state with $K = 9/2$. The dominance of high-K quasiparticle state indicate that M1 transitions should be dominant mode of decay as observed experimentally. In the cranking model interpretation, the positive parity band structures are found to undergo a transition from principal-axis cranking to tilted-axis cranking after the band crossing.

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O-6

Performance study of glass-based RPC detector with cosmic ray muons

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ABSTRACT

The Resistive Plate Chamber (RPC) is a gaseous detector made up of two parallel electrode plates having high bulk resistivity like glass and bakelite (10^9 – 10^{10} Ω -m); exploits uniform electric field produced by planar parallel electrode plates. RPCs are extensively used in several high energy physics as well as astroparticle physics experiments i.e. RPCs are a part of muon trigger systems of CMS, ATLAS, LHCb experiments and Time Of Flight (TOF) barrel of ALICE at LHC. An RPC detector is preferred over other detectors due to excellent spatial and timing resolution, also due to reduced cost per unit area. In recent years, achievements of position resolution in tens of micron, ps time resolution extended the range of applications in medical imaging i.e. Positron Emission Tomography (PET). In present studies, the glass RPCs are fabricated procuring glass from one of the Indian glass manufacturers (Asahi). The performance studies of RPC based on leakage current, muon detection efficiency and noise rate measurements with varying gas compositions are reported here.

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Experimental signatures of non-compound nuclear processes in near super-heavy nucleus ^{256}Rf through neutron multiplicity measurements

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ABSTRACT

Fair understanding of the reaction dynamics is a prerequisite for synthesis of the super-heavy nuclei [1]. Since, in heavy mass regime, non-compound nuclear processes coexist with compound nuclear processes which introduces further convolution to the reaction dynamics [2]. To disentangle these processes, a number of experimental probes like mass distribution, mass-energy distribution, mass-angle distribution and mass-gated neutron multiplicity measurements have been adopted. For such studies, neutron emission is one of the preferable probes as it helps in measuring time-scales of these processes and in understanding the mechanism of energy dissipation in heavy-ion reactions [3]. With this motivation, we have performed all these measurements for the near super-heavy compound nucleus ^{256}Rf to have its complete study. In present work, we are reporting the results from these measurements for the system $^{48}\text{Ti}+^{208}\text{Pb}$ populating the near super-heavy compound nucleus ^{256}Rf . This experiment has been carried out using National Array of Neutron Detectors (NAND) [4] facility with a pulsed beam of ^{48}Ti ($E_{\text{lab}} = 275$ MeV) from the 15UD Pelletron + LINAC accelerator facility at Inter University Accelerator Centre (IUAC), New Delhi. The presence of non-compound nuclear processes in such a heavy system is evident from the mass, mass-energy and mass-gated neutron multiplicity analysis. It is observed that pre-scission neutron multiplicity increases from value of 1.66 ± 0.07 to 2.23 ± 0.07 as we go from asymmetric to symmetric mass region. This increase is attributed to difference in reaction mechanism and timescale of fusion-fission and quasi-fission processes. Statistical model calculations however are unable to reproduce the experimental multiplicities which indicate that non-equilibrium (transients) processes for the highly fissile compound system together with non-compound nuclear processes possibly play an important role for such heavy systems [5].

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Significance of Non-coplanar Degree-of-freedom for Non-compound Nucleus effects in $^{196}\text{Pt}^*$ at higher excitation energies

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ABSTRACT

Recently, non-coplanar degree-of-freedom ($\Phi \neq 0^0$) is found to be a significant degree-of-freedom in the Dynamical Cluster-decay Model (DCM). The only parameter of the model is the neck-length parameter, which varies smoothly with the temperature of the compound nucleus. In the case of $^{105}\text{Ag}^*$, we found [1] an interesting result that the compound nucleus fusion probability P_{CN} for the coplanar nuclei (degree-of-freedom $\Phi=0^0$) gave an unphysical result for P_{CN} fallen in the class of superheavy nuclei, but on inclusion of Φ this discrepancy gets removed and $^{105}\text{Ag}^*$ went back to the weakly fissioning group of nuclei though the non compound nucleus (nCN) contribution [2] is then further increased. Also, in $^{246}\text{Bk}^*$ [3] at higher energies, $\Phi=0^0$ has shown the nCN contribution which becomes nullified on including Φ and so also is the case with $^{164}\text{Yb}^*$ [4]. Such effects in $^{105}\text{Ag}^*$, $^{164}\text{Yb}^*$ and $^{246}\text{Bk}^*$ has inspired us to include Φ in Pt-isotopes.

For $^{196}\text{Pt}^*$, we have calculated the evaporation residue cross section σ_{ER} and the fusion-fission cross section σ_{ff} , where in the case of $\Phi=0^0$ at higher energies σ_{ff} cross section is shown to contain the nCN contribution [5]. The nCN cross section can be estimated as: $\sigma_{\text{nCN}}^{\text{emp}} = \sigma_{\text{ff}}^{\text{Expt.}} - \sigma_{\text{ff}}^{\text{Cal.}}$. However, when Φ is included, the nCN effect from σ_{ff} also gets reduced to zero. We have calculated evaporation and fission cross sections at only one energy, though data is available at five center-of-mass energies, and large nCN in fission cross section is found at higher two $E_{\text{c.m.}}=195.2$ and 183.7 MeV. Interestingly, at $E_{\text{c.m.}}=195.2$ MeV, with the inclusion of Φ , the nCN contribution, in fission cross section σ_{ff} gets nullified as show in Table I.

Table I

Co-planar degree-of-freedom $=0^0$ [5]							
$E_{\text{c.m.}}$ (MeV)	ℓ_{max} (\hbar)	R_{ER} (fm)	$\sigma_{\text{ER}}^{\text{Cal.}}$ (mb)	$\sigma_{\text{ER}}^{\text{Expt.}}$ (mb)	R_{ff} (fm)	$\sigma_{\text{ff}}^{\text{Cal.}}$ (mb)	$\sigma_{\text{ER}}^{\text{Expt.}}$ (mb)
195.2	125	1.446	260	259	1.5	298	544
Non-coplanar degree-of-freedom $\Phi \neq 0^0$							
195.2	152	1.9035	259	259	1.2556	548	544

Concluding, $^{196}\text{Pt}^*$ is a pure compound nucleus only if the decay products include the non-coplanar configurations. Work is in progress for other isotopes of Pt.

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O-9

States of ^{26}Mg studied via the reaction $^{27}\text{Al}(d,^3\text{He})$

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ABSTRACT

Single nucleon transfer reactions provide us opportunity to extract important spectroscopic information of nuclei like excitation energy, spin, parity, branching ratio and also spectroscopic factor. Spectroscopic factor is a measure of the degree to which a particular state is a pure single particle nature. In the present conference, an experimental study of the single particle structure of the states of ^{26}Mg will be presented. Study of the nucleus ^{26}Mg is very relevant because it is the radioactive β^+ decay product of ^{26}Al . The nucleus ^{26}Al is very important in recent astrophysics research, as it is the first cosmic radioactivity detected through its characteristic gamma rays in the interstellar medium and the detection of ^{26}Al at the present time indicates that nucleosynthesis is currently active in the massive stars within our galaxy [1] as well as its decay may be used as an isotopic chronometer for galaxies [2]. So, it is necessary to understand the formation and destruction of ^{26}Al (leading to ^{26}Mg) in order to understand the evolution of our galaxy. We recently studied the structure of single particle orbitals of the states of ^{26}Al and ^{26}Mg using the reaction $^{27}\text{Al}(d, t) ^{27}\text{Al}(d, ^3\text{He})$, respectively at 25 MeV and have already extracted important structure information for the observed states of ^{26}Al using zero range distorted wave Born approximation calculation [3-8]. We have also investigated the production of low lying T=1 isobaric analog states of ^{26}Al and ^{26}Mg populated through the reactions $^{27}\text{Al}(d, t)$ and $^{27}\text{Al}(d, ^3\text{He})$, respectively [9]. The experiment has been performed at Variable Energy Cyclotron Centre, Kolkata, India, using deuteron beam of 25 MeV on a self- supporting ^{27}Al target ($\approx 90\mu\text{g}/\text{cm}^2$). Here, in the present conference, experimentally extracted information about the single particle structure of the states of ^{26}Mg populated through the reaction $^{27}\text{Al}(d, ^3\text{He})$ at 25 MeV will be presented and the results will also be compared with recent shell model calculation using ab-initio approximations [10].

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Role of shell corrections in doubly magic ^{208}Pb radioactivity within quantum mechanical fragmentation theory

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ABSTRACT

The liquid drop energy (V_{LDM}) along with shell corrections (δU) plays an important role to give the proper understanding of binding energies of atomic nuclei [1]. It is relevant mention here that to study the excited state decay of nuclear systems Gupta and collaborators developed dynamical cluster decay model (DCM) by refitting the binding energies at $T=0$, to get temperature dependent binding energies with shell corrections included, for the same. Also, in literature different types of temperature dependent binding energies formulas are available. In DCM, the temperature dependent binding energies have been included as given by Davidson et al [2,3]. In the process, shell corrections, δU were also calculated along with V_{LDM} to reproduce the available experimental binding energies at $T=0$. It is relevant to mention here that the nuclear shell structure plays main role in the process of cluster radioactivity (CR) as very well explored by the quantum mechanical fragmentation theory (QMFT)-based preformed cluster decay model (PCM) [3], which is the special case of DCM at $T=0$.

Within PCM, Gupta and collaborators also studied the role of deformations or orientations in the decay of number of radioactive nuclei in trans-lead region, specifically, which lead to doubly magic ^{208}Pb daughter nucleus through emission of clusters i.e. ^{14}C , $^{18,20}\text{O}$, ^{22}Ne , ^{23}F , $^{24,26}\text{Ne}$, $^{28,30}\text{Mg}$ and $^{32,34}\text{Si}$ [4], along with many other CR decays. As mentioned earlier, the nuclear shell structure plays an important role in the decay of radioactive nuclei to doubly magic ^{208}Pb through cluster emissions. Within PCM, the QMFT based fragmentation potential consists of liquid drop energy V_{LDM} in addition to shell corrections, coulomb potential, and proximity potential. The shell corrections play a crucial role in the collective clusterization process for the decay of radioactive nuclei. In reference to this, the motivation of present study is to look for the fragmentation potential with and without shell corrections for CR. It will be interesting to explore the extent to which shell corrections play its role in the cluster radioactive decay of nuclei.

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Description of identical superdeformed band using soft rotor formula

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ABSTRACT

The two parameter model defined for even-even nuclei viz. soft rotor formula (SRF) [1] is used for the reliable phenomenological analysis of identical superdeformed bands. The SRF is employed to the identical superdeformed bands of $A \sim 190$ mass region, $\{^{191}\text{Hg}(2), ^{193}\text{Hg}(2)\}$, $\{^{191}\text{Hg}(3), ^{193}\text{Hg}(3)\}$, $\{^{193}\text{Tl}(3), ^{193}\text{Tl}(5)\}$ and middle point identical bands $\{^{193}\text{Tl}(1), ^{193}\text{Tl}(2)\}$. Quantitatively good results of γ ray transitions energies are obtained. The band head moment of inertia is also calculated using the fitting of γ ray transitions energies. The band head moment of inertia obtained in the most of the cases is $\delta^0 / \delta_0 \approx 10^{-2}$, which proves that the SRF is powerful approach in describing the generic rotational property of SD bands.

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Systematic study of deformation effects on fusion cross sections using various proximity potentials

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ABSTRACT

The coupling of different degrees of freedom to the various reaction channels are known to enhance the sub-barrier fusion cross sections by several order of magnitude over the prediction from the one-dimensional barrier penetration model (1DBPM) [1-3]. However, the influence of higher order static deformations on sub-barrier fusion cross sections is yet to be comprehensively understood [4]. We study the role of negative hexadecapole nuclear deformation effect on sub-barrier fusion cross sections using eleven different versions of nuclear potentials. We investigated the effect of deformation as well as orientation of the interacting nuclei on fusion barrier parameters and subsequently on the fusion cross sections. The height and position of the interaction barrier for the reactions induced by spherical projectile (^{16}O) on the deformed targets such as $^{174,176}\text{Yb}$ and $^{182,184,186}\text{W}$ have been estimated. It is found that the nucleus-nucleus potential strongly depends on the value of the deformation parameters and orientation of the target [5]. The experimental fusion cross section of the present reactions are investigated by applying Wong's formula using various parameterizations of the proximity potential as well as an assessment of the results of a multi-dimensional barrier penetration model (BPM). The barrier parameters are orientation dependent, the fusion cross section from the orientation dependent potential were estimated ; thereby a variation of cross sections have seen. The fusion cross sections by Bass 73, Bass 77, Prox 77, Prox 88, Prox 00, Prox 00DP, Denisov DP, and AW 95 potentials are found to be better than the rest in comparison to experimental data.

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In-beam γ -ray Spectroscopy of ^{198}Hg

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ABSTRACT

Mercury isotopes, having two proton hole near $Z=82$ shell closer, are the representative of transitional nuclei in $A\sim 200$ mass region as they exist in between well deformed (prolate) rare-earth nuclei and spherical Pb nuclei. Therefore, the even-even Hg isotopes are good candidate to study various structural phenomena. The experimental energies of 2^+ and 4^+ states were observed with increasing as function of neutron number for $^{192-196}\text{Hg}$ nuclei as expected due to decreasing deformation. But energies of 2^+ and 4^+ states were found decreasing for $^{198,200}\text{Hg}$ nuclei, reason of which was not explained [1]. Such irregularities mostly predicted due to γ -deformation but in this regard more information is needed. Therefore excited states of ^{198}Hg have been investigated via in-beam γ -ray spectroscopy, using $^{197}\text{Au}(^7\text{Li}, \alpha 2n)^{198}\text{Hg}$ breakup fusion reaction [2] at $E_{\text{beam}} = 33$ MeV obtained from the 15UD pelletron accelerator facility of Inter-University Accelerator Centre, New Delhi [3]. Fourteen Compton suppressed clover HPGe detectors of Indian National Gamma Array (INGA) [4] have been used to detect the de-exciting γ -rays. New γ -rays has been placed and spin and parity assignment are made further data analysis is under way. New results will be presented during the conference.

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Study of yrast bands of some neutron-rich Cd isotopes

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ABSTRACT

With the development of large and efficient multi-detector arrays, such as Gammasphere or Eurogam, the detection of prompt gamma-rays emitted from the fission fragments has enabled the study of structure of neutron-rich nuclei near the line of stability [1,2]. The neutron-rich nuclei with $A > 114$ are intermediate between the spherical doubly magic Sn isotopes and the strongly deformed heavy Zr and Mo nuclei. The neutron-rich Cd isotopes with $Z=48$ have been a focus of special interest in nuclear structure studies since they exhibit collective excitations and are located adjacent to the closed $Z=50$ major shell. Very recently, Banerjee et al. [3] reported the yrast band in ^{116}Cd up to spin (16^+) by using prompt gamma-ray spectroscopy of fission fragments produced in the heavy-ion induced fusion-fission reaction. Recently, Luo et al. [4] and Ramayya et al. [5] expanded the high-spin level scheme of ^{118}Cd by analyzing high-statistics triple- and higher- fold coincidence events of prompt fission gamma rays from ^{252}Cf at Gammasphere.

From the overview of theoretical literature, there seems to be no consensus at present about the “vibrational” or “shape-rotational” models in the region of Cd nuclei. Frauendorf, Gu and Sun [6], have presented a non-adiabatic microscopic description of the yrast states in Cd isotopes. The sharp backbendings in the ground state bands in $^{114-122}\text{Cd}$ are similar to those in $^{104-114}\text{Cd}$, so according to Ref. [6], they are caused by the quasi-rotational alignment of a pair of $h_{11/2}$ neutrons. Luo et al. [4] have also discussed the features of neutron-rich Cd nuclei in different models and suggested that different theoretical models may be more appropriate for certain spins, parities or excitation energies and there is no one model that fits all. Motivated by recent experimental data from fission fragments for $^{116,118}\text{Cd}$ isotopes, projected shell model framework [7] is employed to study the yrast spectra, backbending phenomena and electromagnetic quantities in these nuclei. The experimental energy levels are well reproduced by the theoretical results up to spin 8^+ in $^{116,118}\text{Cd}$. The PSM results for the kinematic moment of inertia and square of rotational frequency predict the occurrence of backbending phenomenon around spin 6^+ in $^{116,118}\text{Cd}$. Experimentally, backbending is observed around spin 8^+ in ^{116}Cd and 6^+ in ^{118}Cd . From the analysis of band diagrams, it is found that the backbending may be due to the crossing of ground state band by 2-qp neutron bands. The recent experimental data for $B(E2)$ transition probabilities of 2^+ state [8] in these nuclei is reproduced qualitatively by the calculated results. The experimental value of g-factor for 2^+ state is available only in ^{116}Cd [9]. The calculated value of g-factor is in agreement with the experimental one. Thus, the present theoretical calculations reproduce well the available experimental data on $^{116,118}\text{Cd}$ isotopes and predict the alignment of neutrons in $h_{11/2}$ subshell.

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Experimental Study of the ^7Li -induced Reaction on ^{181}Ta

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ABSTRACT

Study of weakly bound light heavy-ion ($^{6,7,9}\text{Li}$, $^{7,9}\text{Be}$ etc.) induced reactions on medium and heavy targets has been an important tool to understand threshold anomaly around the barrier, breakup fusion, pre-equilibrium processes, quasi-elastic, direct effects [1-6] etc. since several years. In view of this, for the first time, ^7Li -induced reactions on the ^{181}Ta target was explored between 30-45 MeV projectile energy. The ^7Li beam having different energy was allowed to bombard the natural tantalum foils of thicknesses $\sim 3.3 \text{ mg/cm}^2$, which were backed by the aluminum foils of 2 mg/cm^2 thickness. After the end of bombardment (EOB), each Ta-Al combination was assayed by the γ -ray spectrometry using HPGe detector and the GENIE-2K software (Canberra). The cross-sections of the residues: $^{183\text{g+m}}\text{Os}$, ^{183}Ta and $^{180\text{m}}\text{Hf}$, at each projectile energy, were calculated using the activation formula [4].

Measured excitation functions of the residues, $^{183\text{g+m}}\text{Os}$, are depicted in Fig.1 along with the theoretical model calculations obtained from PACE4 and EMPIRE3.2. PACE4 considers only compound nuclear process based on the Hauser-Feshbach (HF) model with Gilbert Cameron level density, while EMPIRE takes care of both compound reaction based on the HF model with enhanced generalized superfluid model (EGSM) level density, and precompound emission of particles based on the exciton model, respectively. It is evident that experimental data agree well with the EMPIRE calculation for both isomeric and ground state of ^{183}Os , which perhaps due to the inclusion of coupled channel calculation for fusion and collective (rotational/vibrational) effect dependencies of the EGSM level density, however, PACE4 mostly underestimates the measured cross sections of ^{183}Os . Although minute, production cross section of ^{183}Ta and $^{183\text{m}}\text{Hf}$ was also observed in the Ta-matrix, which might be the indication towards the breakup/transfer reaction processes occurred in the $^7\text{Li}+^{181}\text{Ta}$ reaction.

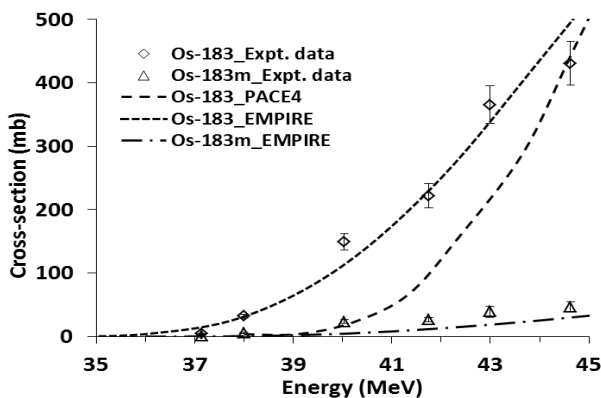


Fig.1 Measured excitation functions of $^{183\text{g+m}}\text{Os}$ compared with the model calculations

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Intermediate Bands Structure of the ^{134}Ba Nucleus

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ABSTRACT

In $A \sim 130$ mass region, the nuclei show many interesting phenomena like shape coexistence, MR bands, chiral bands and spin isomers [1-4]. They are γ -soft in character and have triaxial deformation in the ground state [5]. The ^{134}Ba nucleus has already studied for low-spin states [6,7] and seen to be one of the best candidate for E(5) critical point symmetry [8]. In the previous experimental study, the 10^+ and 5^- isomeric states [6] based on the configurations $(vh_{11/2})_{10^+}$ and $(vs_{1/2} vh_{11/2})_{5^-}$ or $(vd_{3/2} vh_{11/2})_{5^-}$ are also observed. The other isotone of $N=78$ have been already studied for the intermediate and high spin states [9,10]. The ^{136}Ce and ^{138}Nd nuclei exhibit many dipole bands at their high spin states having different shapes and phenomena.

In the present work, the ^{134}Ba nucleus was populated using the reaction $^{124}\text{Sn}(^{13}\text{C}, 3n)^{134}\text{Ba}$ at a beam energy of 48 MeV from the Pelletron accelerator at Tata Institute of Fundamental Research (TIFR), Mumbai. The ^{124}Sn target of thickness 1.5 mg/cm^2 with the Au backing was used. The gamma-rays were detected using the Indian National Gamma Array (INGA) [11]. The clover detectors were arranged at different angles with 3, 3, 1 and 4 clovers are placed at 157° , 140° , 115° and 90° with respect to the beam direction, respectively. In the present study, the level scheme was extended upto a maximum spin of 20. The spin and parity of the levels were assigned using the angular distribution, R_{DCO} and polarization measurements. In the intermediate excitation, three quadrupole bands were observed and the level of the gamma-band was re-confirmed at the low-excitation. The theoretical calculations to understand these bands are in progress.

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Incomplete fusion in $^{19}\text{F}+^{166}\text{Er}$ System @ 4-7A MeV

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ABSTRACT

The breakup [1-8] of a heavy ion at low projectile energies is one of the major subjects of current nuclear studies. The study of heavy ion interactions can provide a great deal of information on the systematic trend of the reactions dynamics. At present energy region of interest, the reaction cross-section is shared predominantly among the complete fusion (CF) and in-complete fusion (ICF) processes. A fraction of the cross-section is also shared by the fission and pre-equilibrium emission. Further, considerable efforts are being employed to synthesize super-heavy element but the presence of various competing channels may add complexity and obstruct the formation of such nuclide. It may be pointed out that, a separation of CF (Complete Fusion) from ICF component is important for the meaningful interpretation of breakup fusion studies. To get a comprehensive knowledge of the role of the Coulomb barrier (C.B.) in the breakup fusion process and in order to see the entrance channel effect[1], viz. (i) the projectile energy, (ii) the mass asymmetry of interacting partners, and (iii) the input angular momenta imparted into the system, the formation of same compound nucleus ^{185}Ir [8] via various target and projectile combination has been taken under consideration. In the present work, the cross-section of the reactions and angular momentum imparted to the $^{19}\text{F}+^{166}\text{Er}$ system at energies near and above the Coulomb barrier have been investigated using PACE4[9] and the modified SUMRULE[10] model. At 15% above of the C.B. a shift ~ 98 MeV in total fusion cross-sections has been observed. The detailed work will be presented during the conference. The author acknowledges the Department of Science and Technology(DST), India to provide financial support via project no. SR/WOS-A/PS-59/2013.

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Collective Vibrations in ^{66}Zn nuclei

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ABSTRACT

In the mass region $A \sim 60-80$, nuclei excited by heavy-ion induced nuclear reactions have revealed a variety of excitation modes, which so far cannot be explained completely in a single theoretical nuclear model. Starting from ^{56}Ni as a closed core, deformation increases with the addition of proton and/or neutron pairs. Describing the collective phenomena for the less deformed Zn isotopes with vibrational modes which for the heavier, more deformed nuclei Se and Kr converts into a rotational description. Even when introducing these physical interpretations, it was clear that these approaches describe only half of the truth because, in detail, one could reproduce the spectra neither with an harmonic vibrator nor with a pure symmetric rotor but had to introduce anharmonicities, triaxial shapes and shape coexistence [1]. As a rule, an orbital of high angular momentum j in the vicinity of Fermi level of nucleus contributes strongly to the configuration of these states [2]. In the mass region of $A \geq 60$ one expects that $1g_{9/2}$ orbital plays a significant role among the degree of freedom excited in the states of high angular momentum. The aim of present investigation is to provide additional information on excited states of ^{66}Zn nucleus in the above discussed scenario.

The excited states in ^{66}Zn are populated through $^{56}\text{Fe}(^{12}\text{C}, 2p)^{66}\text{Zn}$ reaction at beam energy of 62 MeV at BARC-TIFR Pelletron Accelerator facility. The de-exciting γ -rays were detected by the Indian National Gamma Array (INGA), at TIFR consisting of 15 clover detectors using digital data acquisition system based on Pixie-16 modules by XIA LLC [3]. We have done polarisation asymmetry of the gamma rays of this nucleus for the first time and a low-lying negative parity band has been confirmed which is connected to positive parity band via strong interband electric dipole (E1) transitions. These E1 transitions may be attributed to octupole vibrations and/or other reflection asymmetric shapes in this nucleus. TRS [4] calculations has been performed for the nucleus and it predicted an oblate in the ground state which is also consistent with the shape calculations by Moller et al. [5]. Further details of obtained results and shape evolution in this mass region will be presented during the conference.

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A comparative study of different parameterized pocket formulae to calculate fusion barrier characteristics: height and position and cross section

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ABSTRACT

The systematic study of fusion barriers and corresponding fusion cross sections at low incident energies has been of interest in recent years due to the availability of many sophisticated experimental techniques. The above understanding is helpful to explore many nuclear structural effects, cluster-decay phenomena, production of new neutron-rich nuclide and in the synthesis of superheavy elements [1-2].

It is clear from literature, that lot of experimental data is available on fusion barriers and corresponding fusion cross sections since 1970 [1-3]. On the other hand, many theoretical attempts involving different models/theories to calculate fusion barriers and cross sections are also available from time to time [2-3]. Among them some authors follow empirical guidelines to calculate fusion barriers directly whereas, others used detailed theory/model to calculate barrier parameters. Also, several authors parametrized fusion barriers in terms of basic physical quantities like charge number, mass number and mass asymmetry of the colliding partners. All such pocket formulae need to be studied in detail and their outcomes must be properly compared with latest experimental values available so that the best one can be put forward for further fusion barrier calculations.

In this paper we address this problem by employing as many as twelve different parametrized pocket formulae to calculate fusion barrier heights and positions and their outcomes are confronted with available experimental data. All different parametrized pocket formulae are able to reproduce the experimental fusion barrier heights and positions on average within $\pm 10\%$ and $\pm 15\%$, respectively. Our detailed study over 400 reactions reveals that the parametrized pocket formulae based on models such as Bass 1980, Winther 1995, Royer 2001, Prox 2010 and Raj 2014 reproduce the barrier heights nicely as compared to other formulae reported in the literature. Moreover, the results for fusion probabilities are in good agreement with experimental data at above barrier energies.

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Study of the band structure of the neutron-rich odd-odd $^{92,94,96}\text{Rb}$ isotopes using Projected Shell Model

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ABSTRACT

The neutron rich nuclei lying in the mass region $A \sim 100$ are observed to be unique owing to sudden change in their ground state properties. Nuclei in this mass region are situated in a transitional region, between spherical and deformed nuclei, and are characterized by a small quadrupole deformation. Their structure, which is also influenced by the co-existence of deformed and spherical shapes, is complex to study. It is even more complex for studying the odd-odd nuclei due to the presence of large correlations among the valence odd nucleons. Keeping in view the above cited characteristics of nuclei in the $A \sim 100$ mass region, a systematic study of the nuclear structure of some odd-odd $^{92,94,96}\text{Rb}$ nuclei in this mass region is carried out by using a phenomenological approach - Projected Shell Model (PSM). This model has found its success in the past for explaining the ground state properties and near-yrast quasi-particle excitations for both normally deformed and super-deformed nuclei. The yrast spectra of these isotopes are calculated theoretically by using PSM approach and have also been compared with the available experimental data. Being scarcity of the experimental data at higher spins, the present calculations have successfully reproduced the available experimental data of the yrast spectra of these isotopes at low spins (maximum upto spin 10^-). The band diagrams showing the plots of energy $E_k(I)$ versus spin (I) for various bands using PSM for $^{92,94,96}\text{Rb}$ isotopes have also been discussed in the present work. In these band diagrams, the 2-qp configuration that give rise to yrast spectra are based on : $\pi g_{9/2} \otimes \nu h_{11/2}$. The staggering pattern in the transition energies i.e., $E(I) - E(I-1)$ plots has been calculated and compared with the available experimental data. Also, comparisons of the experimentally observed signature inversion in the negative parity yrast levels of $^{92,94,96}\text{Rb}$ with the corresponding results of the Projected Shell Model have been made. According to the interpretation provided by the projected shell model, this signature pattern indicates the presence of a substantial quadrupole shape change occurring with the increase in spin. Further, for the very first time, the electromagnetic transition probabilities i.e., $B(E2)$ and $B(M1)$ for these isotopes have been calculated using PSM approach and due to non-availability of experimental data, the degree of accuracy cannot be commented. These values play an important role in nuclear structure physics and provide information regarding the nature of excitations of nucleons. Moreover, the calculation of these quantities theoretically provides an opportunity for the experimentalists to work for these values for these odd-odd Rb isotopes.

Measurement of lifetimes for high spin states in ^{73}Br

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ABSTRACT

The nuclei in the mass $A=70$ region have been studied extensively during the last decades experimentally as well as theoretically due to occurrence of different structural phenomena such as shape evolution, identical bands, band termination, super deformation etc. [1]. These phenomena are attributed by large change in quadrupole moment of transitional state due to interplay between collective and single particle degree of freedom. Particularly, ^{73}Br nucleus appears to be good candidate for the study of band termination [2]. In order to probe the structure at high spins, lifetime measurements of its yrast and non yrast bands have been carried out using Doppler shift attenuation method. The excited states of the ^{73}Br nucleus have been populated via the $^{50}\text{Cr}(^{28}\text{Si},\alpha\gamma)$ fusion evaporation reaction at an incident beam energy of 90 MeV using the 15-UD Pelletron accelerator at Inter University Accelerator Centre, New Delhi, India. The decaying gamma rays were detected using Indian National Gamma Array (INGA) consisting of 17 clover detectors at various angles. So far, lifetimes of few states of positive and negative-parity bands of ^{73}Br nuclei have been done by Heese et al.,[3] using five Germanium detectors only. However, the present work reports the complementary measurement of lifetimes with high efficiency detector array and up to $33/2^+$ state. The transitional quadrupole moments have been extracted from measured lifetimes. The observed transitional quadrupole moments decreases with spin showing loss of collectivity which is more pronounce for yrast band in this isotope.

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Feeding Intensity Pattern in Complete and Incomplete Fusion Dynamics

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ABSTRACT

The heavy ion (HI) induced reactions has been a topic of special interest at energies above the Coulomb barrier[1-2]. In these HI reactions, the most dominant modes are complete fusion (CF) and incomplete fusion (ICF) process. In ICF process, only a part of projectile fuses with the target nucleus, while remaining part of projectile moves in the forward cone. In the complete fusion (CF) process, the projectile is completely fused with the target nucleus, forming a highly excited composite system, which decays by evaporating low energy nuclear particles. To investigate the CF and ICF dynamics by measurement of spin distribution of ERs using ^{16}O projectile with ^{154}Sm target, an attempt has been made. The present particle- γ coincidence experiment have been performed using 15UD Pelletron Accelerator facility at Inter University Accelerator (IUAC), New Delhi, India. Gamma Detector Array (GDA) coupled with Charged Particle Detector Array (CPDA) experiment setup was used. The experiment for the system $^{16}\text{O} + ^{154}\text{Sm}$ at projectile energy 6.2 MeVA was performed. A self-supporting target of ^{154}Sm (enrichment $\approx 98.69\%$) of thickness $\approx 3.1 \text{ mg/cm}^2$ were prepared by rolling machine. In-beam prompt γ -ray spectra have been recorded in multi-parameter mode employing different gating conditions. The identification of CF and ICF products were carried out by using α -backward and α -forward gated γ -spectra. Spin distribution for several evaporation residues populated through pxn/ α pxn have been measured. The experimentally observed spin distribution for the α pxn channels (fast- α particle emitting associate with ICF) have been found to be distinctly different than that observed for pxn channels (associated with CF). The driving input angular momenta of ICF products have been found to be relatively higher than CF products. Entirely different feeding intensity patterns are observed in fast- α particle emitting channels (ICF) and fusion-evaporation (CF) channels. The fusion-evaporation channels (i.e. pxn) are found to be strongly fed over a broad spin range, while in the case of fast - α particle emitting channels (i.e α pxn) narrow range feeding for only high spin states was observed .

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Poster Presentations

Decay analysis of $^{267}\text{Db}^*$ nucleus formed in $^{249}\text{Bk} + ^{18}\text{O}$ and $^{248}\text{Cm} + ^{19}\text{F}$ reactions

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ABSTRACT

The ^{262}Db nucleus was discovered by Ghiorso et. al. [1] in reaction $^{249}\text{Bk} (^{18}\text{O}, 5n) ^{262}\text{Db}$ with half-life ($T_{1/2}$) of 40 ± 10 sec. In a series of experiments to investigate the chemical properties of Db, the nuclide ^{262}Db was synthesized again employing ^{18}O based reactions. In one of these experiments the production cross-sections of ^{263}Db was measured by Kratz et. al. [2] in 1992 via $4n$ de-excitation channel. Due to highly radioactive nature of ^{249}Bk used in the production of Db, Dressler et. al. [3] suggested $^{248}\text{Cm} (^{19}\text{F}, 5n) ^{262}\text{Db}$ reaction as a possible alternative to understand the dynamics of $Z=105$ superheavy nucleus. In order to address the dynamics of these reactions, the $4n$ and $5n$ cross-sections of $^{267}\text{Db}^*$ nucleus are calculated within the framework of dynamical cluster decay model DCM [4] at comparable excitation energies in the range $E_{\text{CN}}^* = 42-48$ MeV [5]. Due to large difference in the Q - values of the reactions, lower cross-sections of $4n$ and $5n$ channels are reported for $^{248}\text{Cm} + ^{19}\text{F}$ reaction as compared to $^{249}\text{Bk} + ^{18}\text{O}$ [5]. In view of this, higher magnitudes of the neck-length parameters are required to fit the channel cross-sections of $^{249}\text{Bk} + ^{18}\text{O}$ reaction within the same energy range. Also, the $5n$ decay requires higher magnitude of ΔR as compared to $4n$ for both reactions, which seems to suggest that $5n$ decay is more prompt as compare to $4n$.

Further, to understand the behaviour of mass yield distribution, the preformation factor is calculated for $^{249}\text{Bk} + ^{18}\text{O}$ and $^{248}\text{Cm} + ^{19}\text{F}$ reactions using hot-compact and cold-elongated configurations. The hot compact orientations support symmetric fission, whereas asymmetric fission fragmentation is observed for the cold configuration of the fragments for both reactions. In view of synthesis of $^{267}\text{Db}^*$ few possible target-projectile combinations are also predicted.

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Analysis of various emission modes in the ground state decay of ^{240}Pu nucleusKanishka Sharma^{*}, Gudveen Sawhney, Manoj K. Sharma*School of Physics and Materials Science,**Thapar University, Patiala - 147004, India*^{*}E-mail-kanishka.sharma@thapar.edu**ABSTRACT**

Besides α , β and γ emission, cluster decay have been exploited extensively to understand the nuclear structure effects. The present work is associated with the comparative analysis of α - and cluster emission processes governed via ground state decay of ^{240}Pu nucleus. Interesting feature of such a study is that one of the fragments always refers to spherically closed or nearly closed shell nucleus. Note that ^{240}Pu nucleus, being a neutron-rich isotope, lies far away from β -stability line and hence the most probable clusters observed in the decay of ^{240}Pu are found to be highly exotic in nature. Thus, it will be of higher interest to explore the decay path of α - emission along with most probable cluster decay(s), with a way to identify the magic or near magic daughter(s) in the process of exotic emission process. It is well known that the nuclear shapes i.e., the deformations and orientations of nuclei, change the interaction barrier (height, position, curvature, etc.) thereby affecting the dynamics involved. In the present work, we intend to investigate the role of quadrupole (β_2) deformations on the possible fragmentations of ^{240}Pu parent in view of α -, cluster and heavy particle decay modes using the Preformed Cluster Decay Model (PCM) [1, 2]. In PCM, the mass and shape of all possible fragments are treated on equal footing and are found to influence the pre-formation factor P_0 accordingly, which is determined using the mass (or charge) asymmetry coordinate. Whereas the barrier penetrability P in PCM is computed through tunneling along the relative distance coordinate. Note that the half-life depends on P_0 as well as P and hence our PCM calculated half lives $T_{1/2}$ are found to exhibit decent comparison with the available experimental data [3, 4] for both α - as well as cluster decay. The structural aspects in the fragmentation profile of ^{240}Pu become relatively pronounced after the inclusion of deformation effects of decaying fragments.

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Impact of shell corrections on reaction dynamics across the Coulomb barrier

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ABSTRACT

The shell effects play a significant role in the nuclear reaction dynamics because when two nuclei move towards or away from each other, the associated shell structure gets significantly modified. Such effect is investigated for the decay of the nuclear system $^{203,204}\text{Pb}^*$ formed in loosely bound projectiles $^{6,7}\text{Li}$ with a ^{197}Au target within the framework of Dynamical Cluster decay Model (DCM) [1]. In DCM, the total nucleus-nucleus potential comprises of the Coulomb potential, proximity potential, angular momentum dependent potential, and liquid-drop model binding energies with temperature dependent shell corrections of Myers and Swiatecki [2]. In this study, both $^{203,204}\text{Pb}^*$ systems are stable with $Z (= 82)$ as magic number, so it is of interest to study the relative role of shell corrections of decaying fragments across the Coulomb barrier. This study is carried out at different incident energies below and above the Coulomb barrier in reference to data of [3]. Fusion cross-sections for both the systems are calculated with and without the consideration of shell corrections. The deformation effects are included up to quadrupole (β_2) within the optimum orientation approach [4] for the two set of calculations. While switching off the shell corrections, other parameters of the model are kept same. Various observables like the fragmentation potential, preformation probability and the fusion cross-sections etc. are worked out for $^{203,204}\text{Pb}^*$ nuclei. The fragmentation potential and preformation probability is analyzed over a wide range of incident energies for two extreme values of angular momentum. The shell effect influences the magnitude of fragmentation potential as well as the preformation probability, while the structural pattern remains unchanged. In absence of shell corrections, the fusion cross-sections exhibit smaller magnitude. This effect could be of further interest especially for addressing fusion hindrance at sub barrier region. The impact of shell corrections on the reaction dynamics of other target-projectile combinations needs further investigation for better understanding.

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Influence of entrance channel parameters on fusion incompleteness

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ABSTRACT

Nuclear fusion is a process in which two nuclei amalgamates to form a single compound system. The formation of compound system in heavy ion induced reaction consists of two stages namely: capture and fusion [1]. The fate of resulting compound system relies a lot on entrance channel parameters [2]. The pre-requisite condition for the capture of incident projectile by the target nuclei is that energy of the incoming projectile should be large enough to surmount the fusion barrier which is the resultant of three forces viz. Coulomb, nuclear and centrifugal. After capture of projectile by the target nuclei, the dinuclear system will equilibrate its mass distribution and shape while evolving towards a compact mononucleus by the emission of γ -rays, neutrons and/or light charge particles. If the compound nucleus (CN) is heavy or deformed enough then fission process in which the CN split itself into two symmetric nuclei under the influence of excess Coulomb repulsion, competes with the particle evaporation. The evaporation residues (ER) cross section can be given as [3]

$$\sigma_{ER} = \sigma_{cap} P_{CN} W_{sur}$$

where, σ_{cap} is the capture cross section, P_{CN} is the fusion probability. The last term W_{sur} is the probability that CN will survive fission. In this paper we follow the approach prescribed by Sham et al [4] to establish a systematic of P_{CN} using ER excitation function data of heavy ion induced reactions. In order to ensure weak dependence of P_{CN} on excitation energy, we have focused in the energy range of E_{cm} typically $\approx 5\%$ to 35% above the potential barrier.

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Relativistic Mean Field study of Neutron and Hyperon stars

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ABSTRACT

Neutron stars are the valuable laboratories for the study of dense matter. Recent observations about their masses have set a constraint on the neutron star radii. At present, the precise measurement of mass and the radii of neutron stars do not exist. The most accurate measurements concerning the neutron stars are mass determinations from pulsar timing. We now know the precise masses for 35 neutron stars spanning the range from 1.17 to 2.0 M_{\odot} and the radii from 9.9 to 11.2 km [1].

The effect of hyperons resulting in the strong softening of Equation of State (EoS), and the consequent reduction of the maximum mass of neutron stars is more intriguing and difficult to solve because of the recent measurements of unusually high masses of millisecond pulsars PSR J1903+0327 (1.667±0.021 M_{\odot}), PSR J1614-2230 (1.97±0.04 M_{\odot}) and PSR J0348+0432 (2.01±0.04 M_{\odot}) [2]. Current goals to combine the available observations to infer the underlying EoS of dense matter are studied.

We intend to study the impact of hyperon cores on the radius-mass relation for neutron stars and to determine the EoS of dense matter inside the stars by using the promising theoretical model of relativistic mean field (RMF) with different parameterizations. The neutron stars are the excellent emitters of Gravitational waves and occur due to magnetic deformations in newly-born and older isolated radio pulsars [3, 4].

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Structural and decay properties of $Z = 119$ superheavy nuclei

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ABSTRACT

The hunt for searching the limits of mass and charge in nuclear landscape has been a topical issues among nuclear physics community from the last twenty years during which a remarkable experimental progress in the study of structural and decay properties of superheavy nuclides has been achieved. Currently, the shortest life time that still enables the identification of evaporation residue(ER) is about 10 microseconds. The current frontier in superheavy nuclides is at $Z=118$ but the possibility of still heavier superheavies to form an island of stability on the nuclear chart is conceivable. Thus until now SHN with Z less or equal to 118 have been synthesized in the laboratory with no evidence on the production of nuclei with $Z > 118$ obtained so far, except for an attempt [1] to produce $Z = 120$ superheavy nuclei through the $^{244}\text{Pu} + ^{58}\text{Fe}$ reaction.

For the synthesis of superheavy nuclei the two fusion evaporation approaches, namely the cold fusion reaction [2] and hot fusion reaction [3] has proved to be a great success in their synthesis. The former approach has been employed for the production of superheavy elements upto $Z=113$ [4] and latter had been proved to be successful in the production of isotopes of elements upto $Z=118$ [4]. However, our knowledge about various aspects of known nuclei and those beyond the borderline relies substantially or fully on theoretical investigations. Motivated by this fact, we took up $Z=119$ superheavy nuclide and made an attempt to study the structural and decay properties within the state-of-art deformed relativistic mean field framework by employing NL3* effective force. Our theoretical studies about structural and decay aspects of $Z=119$ superheavy nuclei might prove to be quite useful and may serve as a significant input in near future for the experimental people in synthesizing its isotopes.

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Study of complete and incomplete fusion reaction dynamics using ^{13}C non α -cluster structure projectile

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ABSTRACT

The study of complete and incomplete fusion process in heavy-ion reactions around the Coulomb barrier is a topic of current interest, because of its dependence on various entrance channel parameters and lack of appropriate theoretical model [1-3]. To further explore this, the experiment was performed for $^{13}\text{C} + ^{165}\text{Ho}$ system in the energy range of 4-7 MeV/A. Stacked foil activation technique [4] followed by off-line γ -ray spectroscopy has been employed in the present work. The excitation functions of various evaporation residues populated via xn-pxn, α xn-2 α xn channels have been measured and the experimentally measured cross-sections are compared with the theoretical predictions based on statistical model code PACE-4[5]. The PACE-4 code gives only the complete fusion reaction cross-sections and does not take into account the incomplete fusion reaction cross-sections. The experimentally measured cross-sections of the evaporation residues populated via xn and pxn channels were found to be in good agreement with the PACE-4 calculations. However, in the alpha emitting channels, the significant enhancement in the measured cross-sections over PACE-4 calculations is observed, which may be attributed to incomplete fusion process. In the present work, the incomplete fusion fraction has also been deduced and found to increase almost linearly with increasing the incident projectile energy. Morgenstern's mass-asymmetry systematics [6] is also supported by the present results.

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Dependence of incomplete fusion reaction dynamics on entrance channel mass asymmetry

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ABSTRACT

The understanding of low- energy incomplete fusion (ICF) reaction dynamics has been a subject of great concern over the last few decades in nuclear physics due to the lack of proper theoretical aspects [1-2]. Keeping this in consideration the experiment has been performed for $^{16}\text{O}+^{89}\text{Y}$ system at -energies $\approx 4-7$ MeV/nucleon. Forward recoil range distribution of several evaporation residues were measured using recoil catcher technique followed by off-line gamma ray spectroscopy and analyzed in the framework of statistical model code PACE4 [3] based on the concept of equilibrated compound nucleus decay. In addition to complete fusion, measured forward recoil range distributions of these evaporation residues show evidence of certain incomplete fusion (ICF) channels. For better insight into the dynamics of incomplete fusion, present results have been compared with the results obtained in the interactions of ^{16}O with nearby targets to probe the dependence of incomplete fusion on entrance channel mass asymmetry. It has been found that the percentage fraction of incomplete fusion increases linearly with mass asymmetry of interacting partners in the studied mass region as suggested by Morgenstern et al [4]. Also it has been observed that percentage fraction of incomplete fusion increases with the projectile energy.

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Shape Coexistence and bubble structure in Iodine isotopes

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ABSTRACT

The evolution of the shape from the spherical to the axially deformed shapes of Iodine isotopes ($Z=53$, $N=70-80$) have been investigated in the framework of self-consistent Relativistic Hartree-Bogoliubov (RHB) calculations [1]. A nonlinear meson-nucleon coupling model represented by the NL3* [2] parametrization of the relativistic mean-field (RMF) theory has also been used. The bulk and the microscopic properties of these nuclei have been studied. The constraint calculation has been done to obtain potential energy surface (PES). The PES curves clearly shows the shape coexistence behaviour in these isotopes. We have also obtained the neutron, proton and total density of iodine isotopes. We observe the depletion in central density which indicates the bubble structure in iodine isotopes. For which, we have calculated Depletion Fraction (D.F) which clearly states that nuclei posses bubble structure in their intrinsic states. Overall good agreement is found within the different models used and between the calculated and experimental results wherever available.

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RHB Calculations For Superheavy nuclei Z=126

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ABSTRACT

After the prediction of existence of long-lived superheavy nuclei the next magic number for protons ($Z=82$, $N=126$) in superheavy mass regions become very interesting issue. Recent experiments make it possible to reach proton number $Z=118$. Still we cannot reach the predicted centers of the island of stability. In the present work, we have used self-consistent Relativistic Hartree- Bogoliubov (RHB) [1] and non relativistic Skyrme model to discuss the bulk properties of isotopic chain of $Z=126$. In this study the effect of deformation are taken into account which make it different from earlier studies of the shell structure in superheavy nuclei limited to spherical shape. We have obtained the ground state properties such as binding energy, neutron separation energy, quadrupole deformation, potential energy surface. We have also studied spontaneous fission and alpha decay chain of some isotopes of $Z=126$. There is no experimental observation made yet for such a large Z region, therefore comparison made with results of Finite Range Droplet Model[2].

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A study of incomplete fusion reactions at energies above the Coulomb barrier

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ABSTRACT

The observation of incomplete fusion (ICF) reactions at energies $\approx 4-7$ MeV/nucleon, where complete fusion (CF) process is expected to be the sole contributor to the total fusion cross-section has created a resurgent interest in the last couple of years [1]. The fusion of entire projectile is hindered for the partial waves $\ell > \ell_{crit}$ giving way to the ICF. As a consequence, the projectile breaks-up into its constituents to provide the sustainable input angular momentum. One of the fragments fuses with the target nucleus, while remnant flows in forward direction with almost beam velocity. Since the observation of ICF reactions, several theoretical models have been developed and found to be in good agreement with the experimental data at energies ≥ 10 MeV/nucleon to a large extent [2]. However, at low beam energies ($\approx 4-7$ MeV/nucleon), the ICF reactions are not well understood. At present, no theoretical model is available for low energy ICF. In order to understand the reaction dynamics of ICF process at energies $\approx 4-7$ MeV/nucleon and its dependence on various entrance channel parameters, an experiment was performed at the Inter University Accelerator Centre New Delhi, India. In this present work, excitation functions (EFs) of radionuclides populated via CF and/or ICF processes in the interaction of $^{19}\text{F} + ^{169}\text{Tm}$ system have been measured using off-line γ -ray spectroscopy. The analysis of excitation functions has been performed within the framework of statistical model code PACE4 [3]. The incomplete fusion strength function has been deduced and its dependence on various entrance channel parameters has been studied. The present results show a strong dependence on the projectile α -Q value that agrees well with the existing data. To probe the dependence of incomplete fusion on entrance channel mass asymmetry, the present work has been compared with the results obtained in the interaction of ^{12}C , ^{16}O , and ^{19}F with nearby targets available in the literature. It was observed that the mass asymmetry linearly increases for each projectile separately and turns out to be a projectile-dependent mass-asymmetry systematics [2]. Further details will be presented.

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Predictions for matter radii of light neutron rich isotopes using Glauber model

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ABSTRACT

Working within the framework of Glauber model, we have analyzed the interaction cross sections (σ_I) of light neutron rich isotopes (He-Mg) from ^{12}C at 800 MeV and 1.0 GeV per nucleon. The densities of the colliding nuclei are obtained using the Slater determinants consisting of the harmonic oscillator single particle wave functions (SDHO). The parameters of the basic input of the Glauber amplitude, the nucleon-nucleon (NN) scattering amplitude, are fixed from the analysis of σ_I for a stable (N=Z) nucleus, involving phase variation, higher momentum transfer components, and medium modifications (Pauli-blocking) of the NN amplitude. The results clearly demonstrate that the use of SDHO densities along with the in-medium corrected NN amplitude are able to provide satisfactory explanation of the experimental data, and the predicted matter rms radii of the neutron rich isotopes are comparable to those obtained earlier using the relativistic-mean-field (RMF) approach.

On the Determination of Impact Parameter in Coulomb Excitation Experiments by Modified Interaction Radius and Touching Spheres Schemes

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ABSTRACT

Coulomb excitation is the inelastic scattering of projectile due to electromagnetic field of the target or vice versa. It is one of the most important available experimental techniques, used for the determination of some of the nuclear structural observables for exotic nuclei [1]. The beams of these nuclei are commonly being produced at above Coulomb barrier energies. The experiments performed at these energies are termed as intermediate energy Coulomb excitation experiments, which are undoubtedly susceptible to non-Coulomb excitations events. The purity of Coulomb excitation process can only be ascertained by avoiding the interpenetration of interacting nuclei, which can in turn be achieved by keeping the minimum value of impact parameter (b_{min}) of collision above some definite value. The most commonly used schemes for the determination of b_{min} are based either on the idea of the interaction radius as proposed by W W Wilcke et al [2] or on the idea of touching spheres [3-5]. The values of b_{min} obtained by employing the above mentioned schemes are unexpectedly found to be independent of incident beam energy, which is a serious drawback. In addition, the schemes have also been found to be only partially capable of ascertaining the dominance of Coulomb excitation process [6]. Therefore, we have modified the schemes by incorporating appropriate energy dependent term and compared the results with the recently proposed parameterization scheme [7]. The modification leads to a significant improvement in the values of b_{min} obtained by using the modified schemes in comparison to that of the corresponding unmodified counterpart [8].

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**Fast neutron induced fission of even-even Plutonium isotopes, ^{240}Pu and ^{242}Pu
using four dimensional Langevin approach**

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ABSTRACT

Dynamical analysis of energy dissipation in the excited plutonium isotopes, formed during neutron-induced fission reactions was performed using the four dimensional Langevin equations. The mass distribution of fission fragments, neutron multiplicity and fission cross section for plutonium isotopes as a function of incident neutron energies are also obtained. Calculations have been done using Langevin dynamical approach combined with Monte Carlo simulation at different energies of the incident neutron. The energy-dependencies of theoretical results show reasonable agreement with experimental data.

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Level Density of Superheavy Nuclei through Thomas-Fermi Method: Influence of Nuclear Deformation

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ABSTRACT

By using Thomas-Fermi method [1,2] the single particle level density, level density parameter, and nuclear level density have been calculated for some deformed superheavy nuclei. The single particle level density has been obtained for deformed Woods-Saxon potential [3,4]. The effects of nuclear deformation on level density parameter and nuclear level density have been investigated.

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Effect of Surface Diffuseness on Barrier Characteristics

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ABSTRACT

The effective potential of alpha particles and deformed heavy nuclei has been considered as summation of the deformed Woods-Saxon nuclear potential and Coulomb potential. The deformation of surface diffuseness has been included in calculations [1-3]. The effect of deformed surface diffuseness on barrier characteristics has been investigated. The obtained results for some deformed lanthanide and actinide target nuclei showed noticeable effect of deformed surface diffuseness on barrier height and position.

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Gamma Ray Attenuation Studies in Concrete Reinforced with Coconut Shells

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ABSTRACT

Gamma ray absorption studies on wood in general is an area of interest. In Kerala, though coconut tree is a common plantation, a systematic study of gamma ray attenuation in coconut shell has not been reported. In the present study, we have made an attempt to carry out such measurements on coconut shells collected from Trichur district. Coconut shells in to the size of 4cm × 4cm was used in these studies and 662 keV gamma ray counts were measured using 8K channel NaI(Tl) detector. Subsequently we extended these studies by reinforcing concrete with crushed coconut shells, arranged in a layer by layer fashion. Concrete is usually a choice for shielding nuclear radiations. The effect of reinforcing them with coconut shell is also an area of interest. We have carried out absorption studies by using two types of sand also in the concrete mixture. Common sand is not amply available and people use M-sand (Manufactured sand) instead. In the concrete blocks we selectively used common sand and m-sand and its effects on gamma absorption were also investigated. We have estimated both linear and mass attenuation coefficients and the half value layer (HVL) parameter was determined from them. We have noticed an increase in μ/ρ with increase in density of concrete, achieved through the reinforcement.

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Investigation of the Effect of Barium Content on the Structural and Gamma-ray Shielding Properties of Bismuth Borate Glasses

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ABSTRACT

Glasses doped with heavy metal oxides have been proposed to shield the hazardous gamma rays originating from nuclear reactors as alternative to the conventional concretes. In this work, transparent glasses with composition $65\text{Bi}_2\text{O}_3\text{-xBaO-(35-x) B}_2\text{O}_3$ (with $x = 0, 4, 8$ wt %) have been prepared by using melt quenching technique in the laboratory. XRD and FTIR studies have been undertaken to explore the structural properties. The amorphous nature of the prepared samples is confirmed by XRD studies. Structural changes in the system have been explored by FTIR studies. The FTIR results reveal the conversion of $[\text{BO}_3]$ triangular units to $[\text{BO}_4]$ tetrahedral units [1] with the addition of barium oxide along with the creation of non-bridging oxygen in the prepared glass system. Gamma-ray shielding properties have been explored with the help of WinXCom software [2] developed by National Institute Standards and Technology at photon energy 662 keV. Gamma ray shielding properties in terms of mass attenuation coefficient, half value layer, tenth value layer and mean free path have been found to be superior as compared to the ordinary as well as barite concrete [3]. Therefore, it is speculated that our prepared glass samples can serve as better gamma ray shielding materials.

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Gamma Ray Shielding and Structural Properties of $\text{Bi}_2\text{O}_3\text{-B}_2\text{O}_3\text{-Na}_2\text{WO}_4$ Glass System

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ABSTRACT

Gamma ray sources and radioactive materials in several sectors including nuclear power plants, nuclear reactors, nuclear medicine, agriculture and industry can have harmful effects on the humans and it is essential to provide shield against gamma radiations. Gamma radiations are highly penetrating electromagnetic radiations in the environment. The present work is aimed at exploring new glass composition for gamma ray shielding applications. Gamma ray shielding properties of the composition $x \text{ Bi}_2\text{O}_3\text{-}0.6 \text{ B}_2\text{O}_3\text{-(}0.4 - x\text{)Na}_2\text{WO}_4$ where $x=0.1$ to 0.3 (in mole fraction) have been studied by calculating mass attenuation coefficients and half value layer parameters at photon energies 662, 1173 and 1332 keV using XCOM computer software developed by National Institute of Standards and Technology [1]. Higher values of mass attenuation coefficients and lower values of HVL than barite concrete indicate the glass system as better gamma radiation shield [2]. Density, molar volume, XRD and UV-Visible studies have been performed to study the structural properties of the prepared glass system. From the analysis of obtained results, it is reported that density of the prepared glass samples increases with the content of heavy metal oxide Bi_2O_3 . XRD studies confirm the amorphous nature of the glass composition. Decrease in band gap and refractive index values have been obtained from UV-Visible studies which indicates the increase of non-bridging oxygens at higher content of bismuth oxide [3]. It has been concluded that bismuth borate tungstate glasses are better shields for γ -radiations in comparison to the standard nuclear radiation shielding concretes and commercially available glasses.

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Semi empirical model for astrophysical nuclear fusion reactions of $1 \leq Z \leq 15$

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ABSTRACT

The fusion reaction is one of the most important reactions in the stellar evolution. Due to the complicated reaction mechanism of fusion, there is great uncertainty in the reaction rate which limits our understanding of various stellar objects. Low z elements are formed through many fusion reactions such as ${}^4\text{He}+{}^{12}\text{C} \rightarrow {}^{16}\text{O}$, ${}^{12}\text{C}+{}^{12}\text{C} \rightarrow {}^{20}\text{Ne}+{}^4\text{He}$, ${}^{12}\text{C}+{}^{12}\text{C} \rightarrow {}^{23}\text{Na}$, ${}^{12}\text{C}+{}^{12}\text{C} \rightarrow {}^{23}\text{Mg}$, ${}^{16}\text{O}+{}^{16}\text{O} \rightarrow {}^{28}\text{Si}+{}^4\text{He}$, ${}^{12}\text{C} + {}^1\text{H} \rightarrow {}^{13}\text{N}$ and ${}^{13}\text{C}+{}^4\text{He} \rightarrow {}^{16}\text{O}$. A detail study is required on coulomb and nuclear interaction in formation of low Z elements in stars through fusion reactions. For astrophysics, the important energy range extends from 1 MeV to 3 MeV in the center of mass frame, which is only partially covered by experiments. In the present work, we have studied the basic fusion parameters such as barrier heights (V_B), positions (R_B), curvature of the inverted parabola ($\hbar\omega_l$) for fusion barrier, cross section and compound nucleus formation probability (P_{CN}) and fusion process in the low Z element ($1 \leq Z \leq 15$) formation process. For each isotope, we have studied all possible projectile-target combinations. We have also studied the astrophysical $S(E)$ factor for these reactions. Based on this study, we have formulated the semi empirical relations for barrier heights (V_B), positions (R_B), curvature of the inverted parabola and hence for the fusion cross section and astrophysical $S(E)$ factor. The values produced by the present model compared with the experiments and data available in the literature.

Semi empirical formula for exposure buildup factors

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ABSTRACT

The nuclear data of photon buildup factor is an important concept that must be considered in nuclear safety aspects such as radiation shielding and dosimetry. Buildup factor is a coefficient that represents the contribution of collided photons with the target medium. It is defined as the ratio of total intensity to the intensity of un-collided photons. Energy absorption buildup factor is that in which it represents the absorbed or deposited energy in the material/medium. Exposure buildup factor is that in which it represents the energy deposited in the air (exposure). Experiments aimed at obtaining buildup factors are generally not easy. From the literature survey, it is clear that most of the researchers employed GP fitting method [1] to compute the exposure buildup factors. This method requires a number of coefficients which depends on photon energy, mean free path and atomic number. Hence this GP fitting method requires a bulky data. We have established a semi empirical formula for photon exposure buildup factors in the energy region 0.015-15 MeV, atomic number range $1 \leq Z \leq 92$ and for mean free path up to 40 mfp. The results obtained from the present formula are graphically represented. The results produced by the present formulae agree well with the data available in the literature. This semi empirical formula may be extending to any compounds/mixtures/Biological samples. This semi empirical formula finds importance in the calculations of buildup factors of any materials which is required for radiation shielding, nuclear engineering, radiotherapy and nuclear medicine.

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Study of Bubble Structure in $N = 20$ isotones within Relativistic Mean-Field Plus BCS Approach

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ABSTRACT

First experimental evidence for depletion of the central density of protons in ^{34}Si has been recently reported by Mutschler et al. [1] which has opened a testing ground for already developed and successful models and of course new growths for better and consistent understanding of nuclear bubble structure throughout the periodic chart. Theoretically, in past, a strong depletion in the center of the proton density was obtained for ^{46}Ar indicating s and d state inversion [2]. In 2009, Grasso et al. has proposed ^{34}Si as proton bubble candidate and ^{22}O as neutron bubble candidate by applying various theoretical frameworks including shell-model calculations, non-relativistic HF and HFB approaches, relativistic mean field (RMF) and relativistic Hartree-Bogoliubov (RHB) calculations [3].

Guided by various theoretical studies and encouraged with recent first experimental evidence of proton density depletion in ^{34}Si [1], we have applied relativistic mean field plus BCS approach [4,5] for systematic study of bubble structure in magic nuclei with $N = 20$ isotones. Our present investigations include single particle energies, deformations, separation energies as well as neutron and proton densities etc. It is found that proton sd shells ($1d_{5/2}, 2s_{1/2}, 1d_{3/2}$) in $N = 20$ isotones play very important role in the formation of bubble structure. The unoccupied $2s_{1/2}$ state gives rise to bubble since this $2s_{1/2}$ state does not have any centrifugal barrier, therefore for $Z = 8 - 14$ in the isotonic chain radial distributions of such state is found with peak in the interior of the nucleus with corresponding wave functions extending into the surface region. Consequently, in these nuclei with unoccupied s-state the central density found depleted as compared to the nucleus wherein this state is fully occupied. It is important to note here that in these nuclei depletion in proton density for ^{34}Si is found with most significance which is in accord with the recent experiment.

Moving further for higher Z value, $Z = 16$ and $Z = 18$ the $2s_{1/2}$ state remains semi-occupied and contributing partially in the depletion of central density resulting semi-bubble structure for $Z = 16$ and 18. For $Z \geq 20$, $2s_{1/2}$ state get fully occupied and no sign of bubble structures are seen for higher isotones.

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Evaporation residue cross-section measurements for $^{48}\text{Ti}+^{142,150}\text{Nd}$, ^{144}Sm systems using HYRA facility

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ABSTRACT

For understanding the reaction mechanism involving heavy compound nuclei, we have performed measurements of the evaporation residue (ER) cross-sections for the (i) $^{48}\text{Ti}+^{150}\text{Nd}\rightarrow^{198}\text{Pb}$, (ii) $^{48}\text{Ti}+^{142}\text{Nd}\rightarrow^{190}\text{Pb}$ and (iii) $^{48}\text{Ti}+^{144}\text{Sm}\rightarrow^{192}\text{Po}$ systems leading to compound nuclei around $Z_{\text{CN}}=82$ region. Shell effects may favor the survival probability in a fusion-fission reaction. Here, we investigate the effect of proton shell closure $Z_{\text{CN}}=82$, deformation effects through the ER cross-section measurements. It is conjectured that [1] proton shell closure $Z_{\text{CN}}=82$ may lead to enhanced ER production and may help in the synthesis of heavy nuclei. The experiment was carried out using the gas-filled mode of HYbrid Recoil mass Analyzer (HYRA) [2] and ^{48}Ti beam was accelerated using the 15 UD Pelletron+LINAC accelerator facility at IUAC, New Delhi. ER cross-section measurements were carried out using pulsed ^{48}Ti beam with 1 μs pulse separation at laboratory energies ranging from 185-270 MeV (including energy loss from 650 $\mu\text{g}/\text{cm}^2$ carbon window foil and half thickness of target) with an average current of 0.5 pA. Here, ER cross sections from deformed targets ($\beta_2=0.27$) is higher in comparison to the spherical ^{142}Nd ($\beta_2=0.09$) and ^{144}Sm ($\beta_2=0.087$) targets. In order to check the consistency of experimental results with theoretical ones, statistical model (SM) based calculations are performed using the Bohr-Wheeler (BW) formalism [3] for fission width (Γ_f) including shell correction in the level density and the fission barrier. A scaling factor (K_f) for the FRLDM barrier is introduced and treated as an adjustable parameter to the experimental ER cross-sections. Coupled channel calculations were performed to obtain CN spin distributions from the CCFULL code [4] and used as an input in the SM code.

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Fabrication of thin sandwiched $^{142,150}\text{Nd}$ targetsPriya Sharma¹, B.R. Behera¹, Abhilash S.R.², D. Kabiraj² and Heena Duggal¹¹*Department of Physics, Panjab University, Chandigarh-160014, India*²*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, India***ABSTRACT**

The synthesis of heavier elements is one of the prime area of research in experimental and theoretical nuclear physics experiments. Using ^{48}Ti as a projectile, we have planned to carry out the study of ER cross-section and spin distribution of ERs on isotopic $^{142,150}\text{Nd}$ lanthanide targets using HYRA spectrometer [1]. Fabrication of thin self supporting targets is highly difficult. But, due to oxidizing and smearing nature of lanthanides it is very difficult to get a self-supporting very thin target foil (specially for high Z materials). In the trial session, various attempts were made to prepare thin self-supporting Nd targets but all the trials were unsuccessful. So, we have decided to use a very thin backing foil of light Z material to fabricate $^{142,150}\text{Nd}$ targets for the reaction studies. Furthermore, due to the hygroscopic nature of Nd, it quickly reacts with the hot water and form $\text{Nd}(\text{OH})_3$. To avoid the direct contact between Nd layer and water during floating, a very thin coating of carbon (thickness $\sim 10 \mu\text{g}/\text{cm}^2$) was also deposited [2] just after the deposition of Nd layer. Prior to this work, some groups have also reported the preparation of Nd targets, Sugai *et al.* [3] prepared ^{142}Nd targets of thickness $100 \text{ mg}/\text{cm}^2$ by fluorination of rare-earth oxide powders followed by a Ca reduction using RF heating, Greene *et al.* [4] used zirconium as the reducing agent and neodymium targets of thickness 0.5 and $1.2 \text{ mg}/\text{cm}^2$ has been prepared on $500 \mu\text{g}/\text{cm}^2$ carbon backing. In the present work, the fabrication of sandwiched $^{142,150}\text{Nd}$ targets of thickness $\sim 100\text{-}150 \mu\text{g}/\text{cm}^2$ were fabricated between two very thin layers of carbon using thermal evaporation method in diffusion pump based HV chamber which were used for the HYRA spectrometer experiments.

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Fission Dynamics of ^{192,202}Po Nuclei using Neutron Multiplicity and Mass-Distribution as a Probe

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ABSTRACT

The prevalent reaction mechanism for nuclear reactions induced between heavy ions is not only fusion-fission (FF), but a fast, out of equilibrium process called quasi-fission (QF) [1]. For understanding the reaction mechanism of heavy ion induced FF reactions, our aim is to measure neutron multiplicity and mass-energy correlation three systems: (i) $^{48}\text{Ti} + ^{144}\text{Sm} \rightarrow ^{192}\text{Po}$ (ii) $^{48}\text{Ti} + ^{154}\text{Sm} \rightarrow ^{202}\text{Po}$ and (iii) $^{16}\text{O} + ^{186}\text{Os} \rightarrow ^{202}\text{Po}$. For the system $^{18}\text{O} + ^{192}\text{Os} \rightarrow ^{210}\text{Po}$, experimental data exists for neutron multiplicity, evaporation residue (ER) cross-section and fission excitation function [2]. The chosen systems span the neutron deficient ^{192}Po (N=108) to neutron rich ^{210}Po (N=126) nuclei. For systems with heavier projectile, sizable contribution from QF process is expected. Also, ^{144}Sm is nearly spherical ($\beta = 0.088$) and ^{154}Sm is deformed ($\beta = 0.27$) nuclei. We planned to do consistent analysis of Po (N=108 to 126) nuclei to study the role of shell effects in fission dynamics. With this motivation, we have measured pre-scission neutron multiplicities the extracted mass-distribution from two compound nuclei, namely $^{192,202}\text{Po}$ populated by $^{48}\text{Ti} + ^{144,154}\text{Sm}$ systems at 260 and 230 MeV of laboratory energy using National Array of Neutron Detectors (NAND) facility at IUAC, New Delhi. This experiment was performed using 15 UD Pelletron + LINAC facility. Fission fragments were detected by a pair of multi-wire proportional counters (MWPCs) (6.4" × 4.4") kept at fission fragment folding angle of $\pm 60^\circ$. Two silicon PIPS detectors were also placed inside the chamber at $\pm 13.5^\circ$ w.r.t to beam direction for beam monitoring purpose. The neutrons emitted were detected by an array of 100 organic liquid scintillators (BC501A) [3]. The pre- and post-scission components of neutron multiplicities are obtained from the measured neutron energy spectra by using a multiple source least-square fitting procedure, using the Watt expression [4]. Further, statistical model calculations were performed for these systems using Bohr Wheeler as well as Kramer's formalism [5]. The disagreement of the statistical model results with the experimental values even at higher value of dissipation strength (β) may points towards the presence of QF and fast-fission.

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Thin Isotopic ^{144,154}Sm Targets for Nuclear Reaction Studies using NAND Facility

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ABSTRACT

For understanding the dynamics of heavy-fused systems, availability of uniform and high Z targets is an important factor. Fusion reactions at energies near the Coulomb barrier are strongly influenced by the coupling of inter-nucleus distance to nuclear intrinsic degrees of freedom [1]. The deeper understanding of these reactions is possible through the technique of barrier distribution [2]. For carrying out such experiments, good mass-resolution and a very precise measurement of fusion or quasi-elastic excitation function with small energy steps is the main requirement. Due to energy straggling in the target thickness, there is energy loss of beam as well as of the reaction products in the target. This energy loss will alter the energy definition of the incident beam as well as the resolution of the energy spectra of the reaction products. Therefore, for high mass-resolution experiments, thin (150-200 $\mu\text{g}/\text{cm}^2$) isotopically enriched targets with uniform thickness were required. With this motivation, an experiment was planned to study the barrier distribution for ²⁸Si+¹⁵⁴Sm system and the effect of neutron shell closure on the fission of ^{192,202}Po by neutron multiplicity measurements using different isotopes of Sm. This abstract reports the fabrication and characterization techniques of isotopic thin samarium (Sm) targets of 150-200 $\mu\text{g}/\text{cm}^2$ thickness. These targets were prepared in high vacuum (HV) environment by thermal evaporation method on carbon backing of 20-25 $\mu\text{g}/\text{cm}^2$ thickness at Inter University Accelerator Centre (IUAC), New Delhi. Preparation and storage of lanthanide targets is quite challenging task as they are chemically very active [3]. A very thin layer of carbon of thickness 5-10 $\mu\text{g}/\text{cm}^2$ has been evaporated on Sm using electron-gun bombardment technique to prevent it from oxidation. Set of more than twenty ¹⁴⁴Sm and ¹⁵⁴Sm targets each were successfully prepared in the target laboratory of IUAC, New Delhi. Characterization techniques like Rutherford back scattering (RBS), Alpha energy loss technique and Energy dispersive X-ray fluorescence (EDXRF) have been used to access the purity, thickness and elemental composition of targets. Thickness of these targets measured by using different techniques is in well agreement with each other. These targets have been successfully used in three nuclear physics experiments using the National Array of Neutron Detectors (NAND), HYbrid Recoil Mass Analyzer (HYRA) and General Purpose Scattering chamber (GPSC) at IUAC.

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Study of $^{220}\text{Th}^*$ compound system using non-coplanar compact configurations within the dynamical cluster-decay model

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ABSTRACT

Recently, we studied the formation and decay of ^{220}Th compound nucleus (CN) within the Dynamical Cluster-decay Model (DCM) for co-planar nuclei ($\Phi=0^0$), for different reaction channels $^{16}\text{O}+^{204}\text{Pb}$, $^{40}\text{Ar}+^{180}\text{Hf}$, $^{48}\text{Ca}+^{172}\text{Yb}$ and $^{82}\text{Se}+^{138}\text{Ba}$ at near barrier energies [1]. The only parameter of the model, the neck-length parameter R , is used to best fit the experimental data [2-5]. Using DCM we are able to fit the evaporation residue (ER) cross section for 3n and 5n decay channel but there is a non-zero amount of non-compound nucleus component (nCN) in 4n channel. The nCN component could be due to coplanar configuration for nuclei.

In earlier works, the role of non-coplanar degree of freedom Φ for the ^{246}Bk [6], ^{164}Yb [7], and ^{105}Ag [8] systems is studied within the DCM. With Φ included, we found that for ^{246}Bk , formed through $^{11}\text{B}+^{235}\text{U}$, the nCN contribution is reduced to zero, in favor of $^{14}\text{N} + ^{232}\text{Th}$ reaction channel where $\sigma_{\text{nCN}}=0$ for both cases of $\Phi = 0^0$ and $\Phi \neq 0^0$. Similarly, for the case of ^{164}Yb the nCN contribution occurs at two higher energies, which are also reduced nearly to zero with $\Phi \neq 0^0$. An interesting result is seen for ^{105}Ag where inclusion of Φ leads to enhancement of the nCN contribution with improvements in characteristic properties leading to consistent picture with $\Phi \neq 0^0$.

In the present study, we look for the effects of non-coplanar compact configurations ($\Phi \neq 0^0$) for ^{220}Th CN within the DCM. We find that with the inclusion of Φ for $^{48}\text{Ca}+^{172}\text{Yb}$ reaction 3n and 5n channels are fitted but there is large amount of nCN contribution in 4n channel cross section, as compared to $\Phi=0^0$ case. Thus, it seems significant to see the effects of non-coplanar degree of freedom Φ in ^{220}Th . Calculations are in progress.

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Search for nuclear shell structure effects in the evaporation residue cross-sections of $^{48}\text{Ti} + ^{136,140,142}\text{Ce}$ systems

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ABSTRACT

Fusion process between massive nuclei has been extensively investigated so far. It is well known that in reactions involving heavy projectile-target combinations, complete fusion is significantly hindered due to large coulomb repulsion force. The fusion probability rapidly decreases as the charge product $Z_p Z_T$ of the projectile and target nuclei increases. The fusion process depends not only on charge product but also on nuclear structure of interacting nuclei [1]. The enhancement in evaporation residue(ER) cross-sections for the reactions initiated by targets having neutrons equals to magic numbers has been reported earlier [2, 3]. The dependence of fusion on nuclear shell structure of colliding nuclei has been investigated for the three systems $^{48}\text{Ti} + ^{136,140,142}\text{Ce}$. The fusion (evaporation residue and fission) cross-sections were calculated using the statistical model code PACE3 [4]. The target ^{140}Ce has closed neutron shell $N=82$ while the other two isotopic targets $^{136,142}\text{Ce}$ have 78 and 84 neutrons respectively (which are in both sides of the shell closure $N_T = 82$). At beam energies around or above the coulomb barrier, the ER cross-sections would be expected to be larger for the reaction $^{48}\text{Ti} + ^{140}\text{Ce}$ ($N_T=82$) than those for the systems $^{48}\text{Ti} + ^{136,142}\text{Ce}$, but no such enhancement in ER cross-sections was observed from calculations. This deviation from the general trend is not understood at present. Hence, the experimental investigation is needed to search for the dependence of shell closure of target nuclei on fusion process, and also make the relation between fusion and fission clear. The statistical model calculations for the above systems will be presented.

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Light Particle Spectra in Heavy Ion Fusion Reactions

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ABSTRACT

The entrance channel plays an important role in the formation dynamics of the compound nuclei especially at higher l values [1]. According to the Bohr hypothesis, the formation of compound nuclei should be independent of the entrance channel effects. In the present work PACE [2] and CASCADE [3] model calculations have been used to attain the particle spectra of light particles for the systems (i) $^{32}\text{S}+^{48}\text{Ti}\rightarrow^{80}\text{Sr}$ ($\alpha = 0.2$) and (ii) $^{16}\text{O}+^{64}\text{Zn}\rightarrow^{80}\text{Sr}$ ($\alpha = 0.6$) as well as (i) $^{48}\text{Ti}+^{48}\text{Ti}\rightarrow^{96}\text{Ru}$ ($\alpha = 0$) and (ii) $^{27}\text{Al}+^{69}\text{Ga}\rightarrow^{96}\text{Ru}$ ($\alpha = 0.44$). Here α is the mass asymmetry factor given as $\alpha = (A_2 - A_1)/(A_1 + A_2)$, where A_1 and A_2 are the masses of projectile and target respectively. More is the value of α , more is the mass asymmetry. In these systems comparison between a mass symmetric system and a mass asymmetric system, both forming the same compound nuclei has been conducted from energies near the coulomb barrier to 25% above the barrier. Also the excitation function for these systems will be presented using PACE calculations so as to compare the contribution of mass symmetric and mass asymmetric systems forming the same compound nuclei.

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Excited states in ^{100}Pd

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ABSTRACT

The interplay between the single-particle and collective degrees of freedom in $A \sim 100$ mass region is manifested into complex level structures of nuclei. The interpretation of observed level structures has resulted into identification of various nuclear structure phenomena. The relevant intriguing triaxiality based phenomena such as magnetic rotation [1] and degenerate twin bands have been reported in this mass region [2]. The twin degenerate dipole bands with similar energy staggering and electromagnetic strengths have been explained with tilted rotation of the triaxial core along with the valence neutrons and protons aligned along the two extreme axes of the core. Exceptionally long vibrational band has been reported in ^{102}Pd [3], which exhibits sharp increasing trend of $B(E2)$ values with spin and is indicative of angular momentum generation by increasing deformation. Excited states in the even-even ^{100}Pd nucleus ($Z=46$, $N=54$) were populated in the $^{75}\text{As}(^{31}\text{P}, 2p4n)^{100}\text{Pd}$ fusion-evaporation reaction at $E_{\text{lab}} = 125$ MeV. The de-excitations were investigated through in-beam γ ray spectroscopic techniques. The ^{31}P beam was provided by the Pelletron-LINAC facility at TIFR, Mumbai. The ^{75}As target of thickness 2.8 mg/cm² was prepared by vacuum evaporation and rolled onto a 10 mg/cm² thick Pb backing. The recoiling nuclei in the excited states were stopped within the target and the deexciting γ rays were detected using the Indian National Gamma Array (INGA) consisting of 21 Compton suppressed clover detectors. Two and higher fold clover coincidence events were recorded in a fast digital data acquisition system based on Pixie-16 modules of XIALLC [4]. The data sorting routine “Multi pARameter time stamped based COincidence Search program (MARCOS)”, developed at TIFR, sorts the time stamped data to generate E_γ - E_γ matrices and E_γ - E_γ - E_γ cubes compatible with Radware format. For the INGA geometry, the expected value of the DCO ratio is typically ≥ 1.0 for the quadrupole transition and ≤ 0.6 for the dipole transition with gate on the stretched E_2 transition. The earlier reported level scheme of ^{100}Pd [5, 6] based on the $I^\pi = 0^+$ ground state is considerably modified in the present work. New band structures are identified and the level scheme is extended up to excitation energy ~ 17 MeV and angular momentum $I = 26 \hbar$. The placement of new transitions is supported by the observed crossover transitions.

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Study of hindrance effect in fission cross section of $^{242}\text{Cf}^*$ formed via $^{36}\text{S} + ^{206}\text{Pb}$ reaction using Dynamical Cluster-Decay Model

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ABSTRACT

Fission and evaporation residue cross-sections of the compound system $^{242}\text{Cf}^*$, formed via $^{34}\text{S} + ^{208}\text{Pb}$ and $^{36}\text{S} + ^{206}\text{Pb}$ reactions, show that former reaction exhibits a significant hindrance of fusion relative to the later reaction [1]. We have studied the similar hindrance effects around sub-barrier energies in the case of $^{164}\text{Yb}^*$ [2]. This discrepancy is studied on the basis of dynamical cluster-decay model (DCM) of Gupta and Collaborators [3-5]. The only parameter of the model is the neck-length parameter, which varies smoothly with the temperature of the compound nucleus. We have taken the deformation and orientation dependent nuclear proximity potential. The deformations are up to quadrupole deformed (β_2 alone), and only co-planar ($\Phi=0^0$) nuclei, based on hot “compact” orientations are allowed.

We have calculated the evaporation and fission cross sections and our preliminary calculations, only for $^{36}\text{S} + ^{206}\text{Pb}$ reaction at one center-of-mass energy $E_{c.m.}=138.7$ MeV, is presented in Table I, though the data are available at five center-of-mass energies. We have found that there is a contribution of non-compound nucleus (nCN), which gives a measure of the hindrance effect in this reaction.

Table I

$E_{c.m.}$ (MeV)	T (MeV)	E_{cn}^* (MeV)	ℓ_{max} (\hbar)	ΔR_{ff} (fm)	σ_{ff}^{cal} (mb)	σ_{ff}^{Expt} (mb)
138.7	1.035	24.91	140	1.3	442	606.9

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Quasi-elastic scattering studies to understand the fusion dynamics

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ABSTRACT

Understanding the couplings to nuclear intrinsic properties in fusion is important as they influence the barrier height and the formation probability of the compound nuclei [1], which in turn may be related to the synthesis of super heavy elements (SHEs) in heavier systems [2]. In this content, the role of target deformation (static or dynamic) is well established [3], however, relative importance of coupling to the projectile excitation in the presence of significant target coupling is rarely available. As an approach to such study, the ‘‘barrier distribution’’ (BD) derived from quasi-elastic (QE) back-scattering has been studied for the $^{28}\text{Si}+^{154}\text{Sm}$ system. To measure the QE events, a set of hybrid telescope detectors has been fabricated at IUAC, New Delhi [4]. We tried to understand the coupling not only by theoretical means (i.e. through coupled-channels calculation) but also by locating the effect of the coupling in the experimentally observed BD. The implications of the obtained results will be discussed in the heavier systems where deformed actinide targets are utilized for the production of SHEs. Apart from this, the results of our recent QE measurement for $^{48}\text{Ti}+^{232}\text{Th}$ system forming SHE, $^{280}\text{Cn}_{112}$, will be presented. It is observed that the average experimental barrier for the $^{48}\text{Ti}+^{232}\text{Th}$ system is lying on higher energy side of the Bass barrier. This observation is in contrast to that for the $^{70}\text{Zn}+^{208}\text{Pb}$ system [2] forming same compound nucleus where the average experimental barrier is reported as lying on lower energy side of the Bass barrier.

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Analysis of coupling in fusion process through Barrier distribution for the system $^{28}\text{Si} + ^{144}\text{Sm}$

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ABSTRACT

The effect of channel coupling is well known in heavy-ion collisions around the coulomb barrier energies. It has been established that the interplay between the relative motion of two colliding nuclei and their internal degrees of freedom results in a strong enhancement of the sub-barrier fusion cross section [1-6]. A usual way of describing the reaction dynamics in this energy region is the coupled channels (CC) method. The coupling can be described in terms of changes in the potential barrier between interacting bodies, leading to its splitting into several components i.e. distribution of barrier. Distinctive signatures of the nuclear properties can be observed in the barrier distribution (BD) formed due to this coupling and the information about this BD can be extracted from the fusion excitation function [2-3]. It was suggested that channel couplings also affect the scattering process and the same information can also be obtained from quasi-elastic (QE) scattering cross sections at large backward angles [4] and QE-BD [5].

Our plan is to study the nuclear dynamics and the structure effects by performing quasi-elastic experiments at large angles using a 16 O and 28 Si beams on heavy targets. So as a preliminary to our one of the experiment using 28 Si on 144 Sm target, we here study the existing fusion data for the same system through the barrier distribution using CCFULL code [6].

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Gas Electron Multiplier (GEM) Detectors For The Upgrade Of CMS Endcap Muon System At The CERN LHC

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ABSTRACT

The Compact Muon Solenoid (CMS) detector is one of the two general-purpose detectors at the CERN LHC. LHC will provide exceptional high instantaneous and integrated luminosity after second long shutdown. The forward region $|\eta| > 1.5$ of CMS detector will face extremely high particle rates in tens of $\text{kHz}\cdot\text{cm}^2$ and hence it will affect the momentum resolution, efficiency and longevity of the muon detectors. To overcome these issues the CMS-GEM collaboration has proposed to install new large size rate capable Triple Gas Electron Multiplier (GEM) [1] detectors in the forward region of CMS muon system. The first set of triple GEM detectors will be installed in the GE1/1 region ($1.6 < |\eta| < 2.2$) of as part of the Muon Endcap system during the long shutdown 2 (LS2) of the LHC. Towards this goal, full size Triple-GEM detectors R&D has been performed and proto-type detectors have been assembled and tested at the H2 and H4 test beam facilities of CERN-SPS accelerator. The GEM detectors were operated with two gas mixtures: Ar+CO₂ (70/30) and Ar+CO₂+CF₄ (45/15/40). This paper presents a brief review of GEM detectors and their performance studies.

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Systematic of Fission Time Scales Extracted From Particle Multiplicities to Understand Fusion-Fission Dynamics

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ABSTRACT

Exploring and understanding the dynamics of heavy ion induced fusion-fission reactions mechanism has always been of great interest. The role played by nuclear dissipation or viscosity in fission process has been investigated for many reactions using different probes [1-3]. In order to extract fission time scales, extensive theoretical and experimental efforts have been made so far. Fission time scales obtained using different probes give insight of fission reaction mechanism [1]. Nuclear dissipation [2] is considered to be responsible for this delay and more light particles are expected to be emitted during the fission process. The understanding of these excess particles in terms of time scales is a complicated problem. However to elucidate fission mechanism, the total time scale is divided into two major components: Presaddle termed as transient time (τ_{tr}) and post saddle termed as saddle to scission time (τ_{ssc}). In addition to the slowing down of the system and converting some collective energy into internal energy, the two-body viscosity hinders the formation of neck [4].

In the present work, we have made a systematic of alpha, proton and neutron multiplicities reported by various groups for various nuclear reactions. The particle multiplicities reported in coincidence with the fission fragments for variety of systems indicate the fission to be hindered. Charged particles face coulomb barrier at the exit channel whereas neutron being neutral in nature, does not feel coulomb barrier. Deformation dependent particle binding energy plays an important role due to which emission of charged particles is suppressed and neutron is increased. This effect has been already incorporated in standard statistical model code JOANNE2 [1]. Using JOANNE2 and PACE2 code the alpha, proton and neutron multiplicities have been encapsulated from the data available in literature.

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Simultaneous Use of PIXE and PESA Technique to Study the Interaction of Proteins with Metals

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ABSTRACT

The identification and quantification of metals bound to proteins poses an important problem to be solved in structural biology. An absolute measurement of the heavy element concentrations in a dried sample of aqueous protein solution has been combined with the absolute measurement of protein molecular concentration in the same sample. The ratio of these two measurements yields the metal-to-protein compositional stoichiometry. The combination of two Ion Beam Analysis (IBA) techniques, Particle-Induced X-ray Emission (PIXE) and Proton Elastic Scattering Analysis (PESA) allows quantitative assessment of the metal atom to protein ratio in the sample. Application of Particle-Induced X-ray Emission (PIXE) to study the metals bound to proteins has been carried out successfully many times [1, 2]. But with the help of PIXE it is difficult to obtain the exact atomic ratio for the elements of interest because of unknown protein areal density at the point of analysis. To overcome this we use Proton Elastic Scattering Analysis (PESA), which provides the required information on the areal density of the protein molecules on the target. Standardization of the set-up was done by doing quantitative analysis of metal ions per macromolecule for a well-known metalloprotein. The use of PIXE, combined with PESA for areal density determination, turned out to be a very powerful technique in protein analysis, allowing for stoichiometry determinations of very small sample quantities without any further chemical preparation.

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PIXE Analysis of Sassanian Period Pottery Glasses from the Archaeological Site of Tepe Hegmataneh (Iran)

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ABSTRACT

The particle induced x-ray emission (PIXE) method, is a remarkable tool for the scientific investigation of a broad variety of objects of cultural heritage including painted artworks, icons, polychromes, pottery, sculpture, and metal, glass, and stone artifacts. Using PIXE the concentrations of the 23 elements Si, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Br, Rb, Sr, Zr, Sn, and Pb in 11 archaeological pottery glass samples from the 16th season of excavations at Tepe Hegmataneh Iran, were determined. The glasses belong to Sassanian period (224 - 650 A.D.) and the analysis of glass samples has been done in a fully non-destructive way without any sample preparation.

From the viewpoint of chronology, these potsherds belong to an extended period from the Parthian to the modern era. The IBA analyses confirmed the typological division of different pottery glasses through chemical composition that gives us new insights on fabrication techniques of glass matrices and colorants in that period

Electrode Characterization of Resistive Plate Chambers

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ABSTRACT

Resistive Plate Chamber (RPC) is one of the gaseous detectors that are easy to operate and fabricate. These detector works on the principle of ionization of gaseous filled inside two highly resistive plates. These detectors have high count rate, high spatial and good time resolution. RPC also acts as a good tracking device for neutrinos and high energy particles such as cosmic rays, muons etc. Therefore RPC detectors are extensively used in particle/nuclear physics experiments, medical imaging and security devices. So the selection of material for the electrodes of RPC detector is very crucial parameter before the fabrication. High resistivity of electrode is a significant parameter for the efficient working of RPC as it limits the discharge to a smaller region. Electrodes are preferably made up of high resistive material such as glass ($10^{10-13}\Omega\text{cm}$), bakelite ($10^{10-12}\Omega\text{cm}$), and melamine ($10^{9-11}\Omega\text{cm}$). Here we represent the characterization of electrode materials. Elemental composition, surface properties, optical properties and electrical properties of electrode materials are studied. Properties of Glass electrodes are compared with the Bakelite. Glass and Bakelite electrode materials are procured from different vendors i.e. Glass: Asahi, Saint Gobain, Modi and Bakelite: I.E.L, Hylam, Formica, Local Bakelite. Properties of Glass electrode are found to be comparatively better than the Bakelite electrodes. Resistivity of Asahi glass is measured to be 10 times higher than other samples and the surface current of bakelite is found to be better than glass. Asahi glass surface is found to be smoother and better surface uniformity and transmittance is measured to be as high as 95%. Hence after studying the electrode characteristics Asahi glass is used to fabricate the RPC detector ($30\text{cm} \times 30\text{cm}$) and its performance is studied.

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Role of shell effects in the reaction dynamics of low-energy heavy ion collisions forming compound nucleus $^{214}\text{Rn}^*$

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ABSTRACT

Heavy ion fusion reactions around Coulomb barrier are a rich source of information about the properties of compound nucleus (CN) and have been a topic of extensive experimental and theoretical research. The CN resulting from these reactions are sensitive towards the entrance and exit channels aspects such as equilibration in energy, mass, angular momentum and nuclear structure, etc. For the shell correction energies, which are the microscopic component of fission barrier, there is a great surmise that shell closure at $Z=82$ and $N=126$ favours survival probability of CN against fission [1]. In the present work an attempt has been made to understand such aspects within the quantum mechanical fragmentation theory (QMFT), using $^{214}\text{Rn}^*$ compound nucleus formed by ^{16}O projectiles on ^{198}Pt target, at different excitation energies. The study of the decay of CN $^{214}\text{Rn}^*$ has been made within the QMFT-based Dynamical Cluster Decay Model (DCM) [2] in which the CN decays into light particles (LPs) intermediate mass fragments (IMFs), heavy mass fragments, near-symmetric fission (nSF) and symmetric fission (SF) are all treated on same footing as the dynamical collective mass motion of fragments through the potential barrier.

It is relevant to mention here that collective mass motion of the fragments is quantified in terms of preformation probability P_0 which carries the important information about the nuclear structure of the decaying nucleus. Subsequently, penetration probability P of the outgoing fragments across the potential barrier is calculated. These two significant quantities P_0 and P are then used to calculate cross section for the particular decay channel. In DCM, neck length parameter R is the only free parameter which is fitted to calculate evaporation residue (ER) cross sections σ_{ER} and fission cross sections $\sigma_{Fission}$ in the decay of CN $^{214}\text{Rn}^*$, for which the experimental data is available [3]. In the present work we are trying to see the effect of neutron shell closure in the decay process of CN $^{214}\text{Rn}^*$, as it has neutron number $N=128$, which is very near the neutron magic number $N=126$. The calculations for the fragmentation potential and P_0 have been made in the decay of $^{214}\text{Rn}^*$ at the excitation energy $E^* = 49$ MeV. Interestingly, these calculations reveal that among the FF fragments ($A_{CN}/2 \pm 20$), most significant minima exist for ^{86}Kr (and its complimentary fragment ^{128}Sn) or having highest P_0 for these fragments. It is important to note here that both the fragments are magic nuclei having $N=50$ and $Z=50$ for ^{86}Kr and ^{128}Sn , respectively. These preliminary results are quite motivating to study the complete reaction dynamics of $^{214}\text{Rn}^*$ within the DCM.

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Prediction of Superheavy Element $Z = 120$ within RMF+BCS Approach

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ABSTRACT

The synthesis of superheavy nuclei has received remarkable attention in recent years with the advancement of modern accelerators and suitable detectors. In 2010, synthesis of new element 117 with the isotopes $^{293}117$ and $^{294}117$ along with their α -decay chains have been reported by Oganessian et al. [1]. The heaviest element 118 was synthesized with the cross section of about 1 pb in fusion of ^{48}Ca with heaviest available target of ^{249}Cf [2]. Future progress for synthesis of superheavy element $Z > 118$ is going on, especially for the element $Z = 120$. Some predictions have already made by Zagrebaev et al. from different nuclear reactions [3], by A. Sobiczewski for the decay chains of the nuclei $^{298}120$ and $^{299}120$ [4] and by J. J. Li et al. using the framework of RHFB [5].

The existence of superheavy nuclei is controlled mainly by the alpha decay and spontaneous emission. The superheavy nuclei which have small alpha decay half-life compared to spontaneous fission half-life survive and can be detected in the laboratory through alpha decay. Encouraged by the study in the direction to discover element $Z = 120$, we have studied alpha decay half-life and spontaneous half-life of some superheavy elements with $Z = 120$ to make an attempt of prediction for nuclide with $Z = 120$. This kind of theoretical study may provide a very helpful insight to conduct experiments to realize the presence of these nuclei. For our study α -decay half-lives are calculated with the use of a recently proposed simple phenomenological formula [6] for which values of $Q\alpha$ has been calculated using results of Relativistic Mean Field theory (RMF) with TMA parameters, which has been proved already as a successful tool for the study of exotic nuclei throughout the periodic chart [7, 8].

The spontaneous fission half-life T_{SF} is calculated using the phenomenological formula proposed by Ren and Xu taken from Ref. [9]. For our study, we have chosen four isotopes of $Z = 120$ to discuss i.e. $^{292}120$, $^{298}120$, $^{299}120$ and $^{304}120$. These isotopes have been examined by various theoretical methods and likely to be observed experimentally [3-5]. It is seen that T_{SF} are much larger than T_{α} for the first five nuclei in the decay chain of $^{292}120$, and for $^{298}120$. Whereas for other isotopes $^{299}120$ and $^{304}120$, T_{SF} is rather very small. So, it is predicted that $^{292}120$ and $^{298}120$ are the best possible nuclei to be observed in future experiments.

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Competition between compound and non-compound nucleus processes for intermediate mass fragments in the decay of composite system $^{32}\text{S}^*$

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ABSTRACT

In our previous study [1], the decay $^{32}\text{S}^*$ and $^{31}\text{P}^*$ formed through $^{20}\text{Ne} + ^{12}\text{C}$ and $^{19}\text{F} + ^{12}\text{C}$ reactions have been analysed using collective clusterization based Dynamical Cluster Decay Model (DCM) [2]. The target like yield (σ_C) has been calculated for both the reactions at excitation energy $E_{\text{CN}}^* = 60$ MeV. Both the decay processes compound nucleus decay process (CN) i.e. fusion-fission cross section (σ_{ff}) and non compound nucleus decay process (nCN) i.e. deep inelastic orbiting cross section (σ_{DIO}) contribute in total σ_C . In case of $^{32}\text{S}^*$ there is a competition between fusion fission (ff) and deep inelastic orbiting (DIO) processes in total yield σ_C , but for $^{31}\text{P}^*$ there is the contribution from ff process only in the total yield σ_C , as observed in the experimental data also [3]. This study has been further extended to see the role of excitation energy on these two different competing mechanisms in the decay of $^{32}\text{S}^*$. This study revealed that the σ_{ff} becomes almost constant at higher energies, but σ_{DIO} shows prominence as E_{CN}^* increases [4]. Experimentally, the fragments $3 \leq Z \leq 7$ fragments other than target like yield are also observed in the decay of $^{32}\text{S}^*$ formed in $^{20}\text{Ne} + ^{12}\text{C}$ reaction. The motivation behind the present work is to study the emission of another complex fragments or intermediate mass fragments (IMFs) in addition to Carbon i.e. target like, in the decay of $^{32}\text{S}^*$ through collective clusterisation approach via preformation probability P_0 . It will be quite exciting to look into the competing decay modes for these fragments. The experimental analysis observed that in case of Li and Be ff is prominent, but in case of B, C and N the nCN process DIO starts competing with ff. In reference to this observation, we intend to study the competition between CN and nCN processes through P_0 of different IMFs emission within DCM at different excitation energies.

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Collective clusterization approach to study ^{20}Ne induced reactions forming $^{179}\text{Re}^*$ and $^{189}\text{Au}^*$ composite systems at different excitation energies

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ABSTRACT

The nuclear fission, after seven decades of discovery, is still a topic of interest. The innovation of heavy ion accelerator technology further facilitate to investigate the fission process in the hot and rotating compound nuclei formed by different entrance channels over the wide range of mass. The compound nuclei, due to high excitation energy, lead to the emission of light particles ($A \leq 4$, $Z \leq 2$) which is eventually followed by fission of residual nuclei. In addition to fission process of compound nucleus origin, the non-equilibrium processes such as quasi fission, fast fission etc. may have their role in the decay process. The mass distribution of fission fragments is an important feature to explore the reaction dynamics. The broader mass distribution may be signature of non-compound nucleus processes [1].

The decay of $^{164}\text{Yb}^*$, $^{176,182,188,196}\text{Pt}^*$ and $^{200,202}\text{Pb}^*$ compound systems have been explored within the framework of Dynamical Cluster decay Model (DCM) [2, 3]. The decay of $^{179}\text{Re}^*$ formed in $^{20}\text{Ne} + ^{159}\text{Tb}$ reaction and $^{189}\text{Au}^*$ formed in $^{20}\text{Ne} + ^{169}\text{Tm}$ reaction with $E/A=8$ MeV has been explored within DCM [4]. The results show that for both the composite systems (CS) (with mass difference of 10 units) formed in ^{20}Ne induced reactions with same $E/A=8$ MeV and same entrance channel mass asymmetry ($\eta \sim 0.77$), there is large difference in magnitude of evaporation residue (ER) and fission cross-sections comparatively, which is in conformity with the experimental data [5]. Moreover, the same value of calculated neck length parameter (R) for ER and fission cross-section for one reaction works on the whole for the second reaction, which makes an interesting case of study for the reactions with same projectile energy per nucleon and same entrance channel mass asymmetry. In the present work, we have extended the study at higher excitation energies. It is relevant to mention here that these results are similar to the study [6] of fusion cross-section (σ_{fus}) of the reactions having same projectile with same E_{lab} value, where σ_{fus} have been calculated with same value of R . We have explored the nuclear structure effects in the decay of $^{179}\text{Re}^*$ and $^{189}\text{Au}^*$ CS, which permeate through the preformation probability P_0 via the fragmentation potential of different fragments within the collective clusterization process of DCM. The non-compound nucleus process i.e. quasi fission is also observed in both the reactions, which has been evaluated empirically. The study of the role of higher excitation energy and angular momentum on the decay of both CS is in progress.

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Competing reaction mechanisms in complex fragment emission from the decay of $^{43}\text{Sc}^*$ and $^{44}\text{Ti}^*$ composite systems

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ABSTRACT

During the last couple of decades, several experimental studies have been made to unfold the reaction mechanism of complex fragments or intermediate mass fragments (IMFs) emission from the light composite nuclei formed in heavy ion collisions at low bombarding energies ($E \leq 10$ MeV/nucleon). The complex fragment emission is expected to be mainly due to compound nucleus (CN) decay. But several experimental studies show the signature of processes other than of CN origin such as the deep inelastic orbiting (DIO). The IMF emission in case of $^{28}\text{Al}^*$ and $^{31}\text{P}^*$, formed in $^{17}\text{O}+^{11}\text{B}$, $^{18}\text{O}+^{10}\text{B}$, $^{19}\text{F}+^9\text{Be}$ and $^{19}\text{F}+^{12}\text{C}$ reactions, respectively, is explained only on the basis of fusion-fission (FF) process of compound nucleus origin [1]. On the other hand, decay of $^{28}\text{Si}^*$, $^{32}\text{S}^*$, $^{39}\text{K}^*$ and $^{40}\text{Ca}^*$ show enhanced yields near the entrance channel which is an indication of the presence of competing deep inelastic process, in addition to FF process [2]. Also, the study of $^{47}\text{V}^*$ formed in $^{31}\text{P}+^{16}\text{O}$, $^{35}\text{Cl}+^{12}\text{C}$, and $^{23}\text{Na}+^{24}\text{Mg}$ reactions shows the IMF emission from compound nucleus [3], while yet another study for the $^{47}\text{V}^*$ formed in $^{20}\text{Ne}+^{27}\text{Al}$ reactions finds that the IMF emission have contribution from both the competing reaction mechanisms [4].

The decay of composite systems have also been studied successfully within the quantum mechanical fragmentation theory (QMFT)-based dynamical cluster decay model (DCM) [5, 6]. The decay of extremely light mass composite systems $^{20,21,22}\text{Ne}^*$ have been studied within DCM, which show the presence of competition between FF and DIO for emission of IMFs [6]. Therefore, it is evident that there exist some ambiguities to understand the competing reaction mechanisms in the light mass region with $A_{\text{CN}} \sim 20-80$. With this impetus, in the present work, we study the complex fragment emission in the decay of $^{43}\text{Sc}^*$ and $^{44}\text{Ti}^*$ composite systems formed in $^{16}\text{O}+^{27}\text{Al}$ and $^{16}\text{O}+^{28}\text{Si}$ reactions, respectively, within the DCM [6]. The values of FF and DIO cross-sections for different IMFs will be calculated and compared with the available Z-distribution data for the complex fragments [7]. The preliminary results show for the decay of $^{43}\text{Sc}^*$, the asymmetric fission fragments (^6Li , ^{10}B , ^{12}C , ^{13}C and the complementary fragments) are highly preferred compared to symmetric fission fragments ($^{20,21}\text{Ne}$ and $^{22,23}\text{Na}$) whereas in the decay of $^{44}\text{Ti}^*$, the symmetric fission fragment (^{22}Na) strongly competes with asymmetric fission fragments (^6Li , ^8Be , ^{12}C , ^{14}N and the complementary fragments). Moreover, in the decay of $^{43}\text{Sc}^*$, for $Z=5$, ^{10}B is energetically favored and shows maxima in preformation profile while in case of $^{44}\text{Ti}^*$, for $Z=5$, $^{9,10}\text{B}$ have less preformation probability (P_0) compared to neighboring fragments having maxima in P_0 . The result is in consonance/agreement with experimental data for IMFs having $Z=5$. Work is in progress.

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Test of Rigid Triaxiality for even-even *Nd*, *Sm* and *Gd* nuclei

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ABSTRACT

The evidence of rigid triaxiality has been searched for *Nd*, *Sm* and *Gd* nuclei. The relationship of asymmetry parameter γ_0 with the γ -g $B(E2)$ ratios for $(2_{\gamma} \rightarrow 0/2)$, $(2_{\gamma} \rightarrow 2/4)$, $(3_{\gamma} \rightarrow 2/4)$, $(3_{\gamma} \rightarrow 2_g/2_{\gamma})$, $(4_{\gamma} \rightarrow 2/4)$, $(4_{\gamma} \rightarrow 2_g/2_{\gamma})$ is investigated and compared with the results of asymmetric rotor model (ARM), generally termed as Davydov-Filippov (DF) model [1]. These interband $B(E2)$ ratios are derived from experimental E_{γ} , I_{γ} values from the recent Nuclear Data Sheets [2]. On comparing the theoretical predictions with the experiment, the $B(E2; 2_{\gamma} \rightarrow 0/2)$ ratio shows a smooth dependence on γ_0 with average slope similar to that predicted by ARM. However, large deviations are observed for ^{148}Nd , ^{154}Sm and ^{156}Gd . As γ_0 increases more than 20° , the agreement with theoretical values becomes more evident. For $B(E2; 2_{\gamma} \rightarrow 2/4)$ ratio, a poor correlation with γ_0 is observed. *Gd* nuclei show some correspondence with DF model predictions except for ^{158}Gd which lies far higher than the theoretically predicted value. A large variation is seen for *Nd* and *Sm* nuclei. For $B(E2; 3_{\gamma} \rightarrow 2/4)$ ratio, the experimental data falls with increasing γ_0 as predicted theoretically but most of the data points lie above the theoretical curve. For $B(E2; 3_{\gamma} \rightarrow 2_g/2_{\gamma})$ ratio, the experimental data points increase towards a maximum value and then start decreasing. However, the maximum value is smaller than that predicted by DF model. For $B(E2; 4_{\gamma} \rightarrow 2/4)$ ratio, a large variation is observed in the range $\gamma_0=10^\circ-20^\circ$ for the *Nd* and *Gd* nuclei and a weak correspondence with γ_0 is exhibited. The *Sm* nuclei shows a good correlation with γ_0 and the experimental data points lie close to the DF curve except near $\gamma_0=20^\circ$ where a minimum was expected. The $B(E2; 4_{\gamma} \rightarrow 2_g/2_{\gamma})$ ratio shows no correspondence with γ_0 .

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Deformation effect on fusion cross-sections induced by heavy ion reactions.

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ABSTRACT

Applying twelve different versions of nuclear proximity potentials, the influence of static quadrupole and hexadecapole deformation of targets and its orientations with collision axis on the fusion cross section are studied. The height and the position of the interaction barrier for the reactions induced by spherical projectiles ^{16}O and ^{18}O on the deformed targets such as ^{62}Ni and ^{116}Sn have been estimated from the results of the variation of total interaction potential with the internuclear separation; which is then used to find the fusion cross section data with respect to centre of mass energy. It is found that the nucleus-nucleus interaction potential strongly depends on the value of the deformation parameters and the orientation of the target. The experimental fusion cross-section of the reactions $^{16}\text{O} + ^{62}\text{Ni}$, $^{16}\text{O} + ^{116}\text{Sn}$ and $^{18}\text{O} + ^{116}\text{Sn}$ are investigated by applying Wong's formula using various parameterizations of the proximity potential alongwith the results of a multi-dimensional barrier penetration model (BPM) using CCFULL code. The fusion cross-sections so obtained by Prox 10, Prox 88, Prox 00, Prox 00DP, BW 95, CW 76, Ngô 80 and AW 95 potentials are found out to be in better agreement than the rest of the potentials in comparison to the experimental data.

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Systematic study of superdeformed bands of ^{86}Zr nucleus in A~ 80 mass region

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ABSTRACT

A four parameter formula [1-2] and the Power law formula [3] has been applied on the three superdeformed bands (SD-1, SD-3 and SD-4) of ^{86}Zr nucleus in A~80 mass region. We have calculated the transition energies of three bands (SD-1, SD-3 and SD-4) of ^{86}Zr nucleus by using both the models; and the result of which are compared with the experimental data. The variation of kinematic moment of inertia versus rotational frequency has also been studied. In order to check the applicability of these models on the three superdeformed bands (SD-1, SD-3 and SD-4) of ^{86}Zr nucleus in A~80 mass region; the ratio of transition energy over spin has been plotted against spin; and the result of which are compared with experimental data. The calculated results are in good agreement with the available experimental data.

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Efficiency Measurement of Digital MCA based HpGe Gamma Spectroscopy System and Optimization of Detector Performance Parameters

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ABSTRACT

The HpGe (High purity Germanium) gamma detectors are widely used for gamma spectroscopy in neutron activation analysis techniques, environment monitoring, archeological survey etc. The detector calibration measurement were performed for energy range 59.5 keV to 4439.4 keV with standard gamma sources, natural background (^{40}K and ^{208}Tl) gammas and ambient gammas from ^{241}Am - ^4Be neutron source. The efficiency measurement (intrinsic efficiency and absolute efficiency) were performed for the energy range 59.5 keV to 1332.49 keV. Important detector performance parameter like relative efficiency, FWHM, FWTM, peak-to-Compton ratio and gain variation of conversion factor with amplifier gain were also estimated using different method. Optimization results of digital signal processing (DSP) parameters for digital MCA were also presented.

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Magnetic Rotational band in ^{106}In

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ABSTRACT

Magnetic rotational (MR) bands have been identified in several Indium ($Z=49$) nuclei [2-8]. The semiclassical model calculations for $^{111,112,114}\text{In}$ suggest $\pi(g_{9/2})^{-1} \nu(g_{7/2}/d_{5/2}^2 h_{11/2})$ configuration for these bands and predicted $B(M1)$ values of the same order as deduced experimentally [5,6,8]. In the lighter isotopes, $^{108,110}\text{In}$ [3], TAC calculations provide the configuration of the magnetic bands. A $\Delta I=1$ band also reported in ^{106}In [1] up to $18\hbar$ but no information available about the character of this band. This band looks similar to the reported MR band in $^{108,110}\text{In}$ based on excitation energies. In present work, its alignment is calculated and found very similar to the alignment of the MR band in $^{108,110}\text{In}$. Therefore, in order to know the possible configuration and $B(M1)$ semi-classical model calculations has been carried out. Present calculations show that shear angle decreases from $\Theta = 86^\circ$ to 30° when spin changes from $13\hbar$ to $17\hbar$. The calculated $B(M1)$ values are found in the range of $3\mu^2 - 1.4\mu^2$ and it also decreases with increasing spin. These results suggest the MR character of this band. New results will be discussed during the conference.

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Fabrication and Characterization of Iodine Target

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ABSTRACT

In nuclear physics experiment, choice of the target and its fabrication is very important issue. For our in-beam γ -ray spectroscopy and lifetime measurement using $^{127}\text{I} + ^{16}\text{O}$ reaction, a thin Iodine target was required, which was fabricated using high vacuum deposition facility at IUAC, New Delhi. Iodine target is not used generally because it has several limitations. It is very difficult to make a pure iodine target because it is very hygroscopic. Therefore, one has to use the molecular iodine, such as, LiI, KI, PbI_2 or CHI_3 compounds. For our experimental requirements, CHI_3 or KI was most suitable, but CHI_3 has very low melting point. Hence fabrication of a thin target of CHI_3 was difficult. Further it will also de-gas during the experiment due to beam heating. Therefore, thin iodine target was fabricated using KI compound for the present measurement.

A thin layer of KI ($\sim 300 \mu\text{g}/\text{cm}^2$) was deposited on $15 \text{ mg}/\text{cm}^2$ of gold backing. For addition safety of the target, a very thin layer ($\sim 20 \mu\text{g}/\text{cm}^2$) Au capping was used, which will also prevent it from the de-gasing in the vacuum chamber because of continue beam heating.

The thickness of the target has been measured using Rutherford Back Scattering facility at IUAC. The composition as well as the thickness of the target has been verified using XRF facility at Department of Physics, Panjab University, Chandigarh. Results of the measurement will be presented during the conference.

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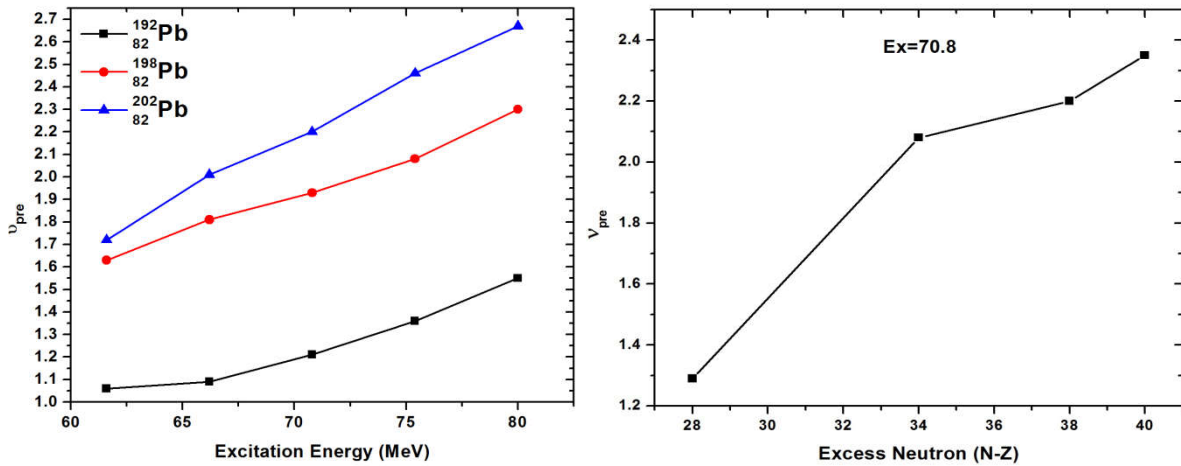
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Calculation of Neutron Multiplicity to investigate the nature of Nuclear Dissipation

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ABSTRACT

It is evident that there exists some dissipation in heavy ion reactions which slows down the fusion-fission processes (1, 2) which leads to increase in pre-scission neutron multiplicity (3-5). Now a days efforts are made to quantify this nuclear dissipation and lot of experiments are carried out to study it's nature by using various observables such as particle multiplicities, fission time delay etc. In this work we are calculating pre-scission neutron multiplicity (v_{pre}) for (^{204}Pb , ^{202}Pb , ^{198}Pb , ^{192}Pb) systems using statistical model code JOANNE2. This code also incorporates the pre-saddle delay (τ_{pre}) and saddle to scission transition time (τ_{ssc}) which constitutes total fission time scale [6]. Enhancement in the fission time scale is of course one of the signatures of nuclear dissipation. τ_{pre} and τ_{ssc} values in the code can be used as free parameter to reproduce experimental values of particle multiplicities. We have used the values of these parameters as reported in the literature [6]. A comparison of calculated v_{pre} for $^{202,198,192}\text{Pb}$ system populating at same excitation energy is shown in Fig.1. The v_{pre} values for higher mass system are higher at particular excitation energy while for a given system it increases with the increasing excitation energy. Calculated v_{pre} is also plotted as a function of excess neutron (N-Z) and is shown in Fig.2. The v_{pre} values are increasing with increasing (N-Z) at fixed excitation energy. The v_{pre} values are showing exactly same trend when plotted as a function of mass number at fixed excitation energy. This shows that the v_{pre} values are depending upon mass number of the compound system as they increase irrespective of entrance channel mass asymmetry.



The calculated v_{pre} may reproduce the experimental pre-scission neutron multiplicity by incorporating fission delay in the statistical model (JOANNE2) and if not then either we have to choose different values of τ_{pre} and τ_{ssc} for our system or some other factors are effecting the dissipation and hence v_{pre} . Proton shell closure may be one of the possible factors in this case.

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Effect of the energy variation on the dissipative evolution of the system in the heavy ion fusion reactions

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ABSTRACT

The studies existing in the literature suggest that the charged particle and neutron spectra for the symmetric systems shows the significant deviations from the statistical model predictions but it is consistent with the statistical model predictions for the asymmetric systems[1-3]. The dynamical model code HICOL [4] was used to explain these deviations, which suggests that for the symmetric systems the angular momentum ℓ contributes in the fusion is less than classical $\ell = \ell_{\max}$, calculated by the statistical model code CASCADE [5]. But in case of asymmetric systems angular momentum predicted by the dynamical model is in agreement with the statistical model prediction. In the earlier studies same compound nucleus was populated at same excitation energy and angular momentum by two different entrance channels (symmetric and asymmetric entrance channels) to match the excitation energy E^* of the populated compound nucleus CN by fixing the projectile energy E_{lab} of the asymmetric systems. So, there was restriction of projectile energy for asymmetric systems with respect to the symmetric systems. Therefore, we have done the theoretical calculations using the HICOL code and calculated the angular momentum for the asymmetric systems at higher energy while for the symmetric systems at lower energy, which is shown in the Fig. 1 and in Fig. 2.

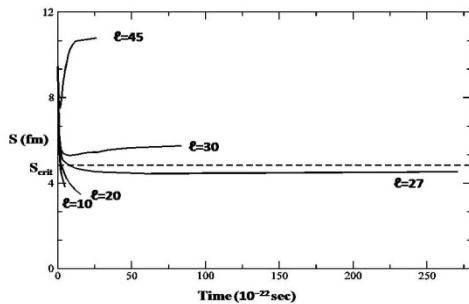


Fig. 1: Calculated evolution of the separation(s) as a function of time for the system $^{12}\text{C}+^{46}\text{Ti}$ at 120 MeV.

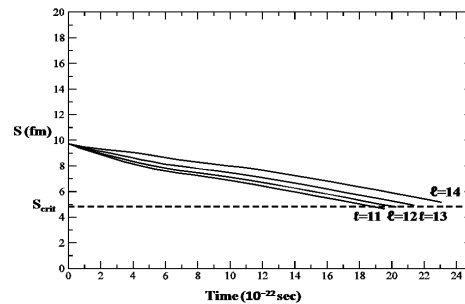


Fig. 2: Calculated evolution of the separation(s) as a function of time for the system $^{31}\text{P}+^{27}\text{Al}$ at 70 MeV.

In the present work ℓ_{\max} calculated by the dynamical model is less than the ℓ_{\max} calculated by the statistical model for the asymmetric systems at higher energy. In case of symmetric systems ℓ_{\max} calculated by the dynamical model and ℓ_{\max} calculated by the statistical model has less difference at lower energy and this difference increases with energy. Therefore, it is necessary to do the particle evaporation spectra measurement at higher energy range for asymmetric systems and at lower energy range for the symmetric systems.

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Shell Model Calculations of $^{126-130}\text{Te}$

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ABSTRACT

The shell model has been very successful in explaining the structure of nuclei close to spherical cores. In this work the shell model calculations has been performed for $^{126-130}\text{Te}$ nuclei using NuShellX@MSU computer code [1]. The valence space includes $0h_{11/2}$; $1f_{7/2}$; $1f_{5/2}$; $2p_{3/2}$; $2p_{1/2}$ orbitals for neutrons, and $0g_{7/2}$; $1d_{5/2}$; $1d_{3/2}$; $2s_{1/2}$; $0h_{11/2}$ orbitals for protons, considering ^{100}Sn as the closed core. The effective interaction sn100, has been used for the present shell model calculations, which is based on renormalized two body the CD-Bonn free nucleon-nucleon potential [2]. The $B(E2)$ values have been calculated for 2^+ , 4^+ and 6^+ states, and compared with the experimental reduced transition probabilities $B(E2)$. In earlier work [3], the $B(E2)$ values predicted by rotational and vibrational models, but with large deviation from experimental data. The present shell model calculations are found in better agreement with experimentally observed data. Details of the calculations and results will be discussed during the work shop.

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Quasi-particle Structure of Doubly-odd $^{92,94}\text{Nb}$ Isotopes

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ABSTRACT

The $A \sim 100$ nuclei are equipped with rich information about the kind of deformation occurring in these nuclei. Nuclei near $A \sim 100$ mass region are situated in a transitional region in between spherical and deformed nuclei and are characterized by a small quadrupole deformation. Their structure, which is also influenced by the co-existence of deformed and spherical shapes, is complex to study. It is even more complex for odd-odd nuclei whose properties at low and moderate angular momentum originate mainly from the odd proton in orbitals situated below the $Z=50$ gap ($g_{9/2}$, $p_{1/2}$, $f_{5/2}$) and odd neutron in the orbitals situated above $N=50$ gap ($g_{9/2}$, $d_{5/2}$, $g_{7/2}$, $h_{11/2}$).

The nuclides with $40 \leq Z \leq 50$ and $N \geq 50$ are of current interest because of the several shape transitions occurring in near $A \sim 100$ mass region. Different types of deformations (e.g. prolate, oblate, triaxial) are observed and can coexist in a same nucleus in accordance with the underlying interplay between orbitals. For nuclei with $Z \geq 40$, the active intruder orbitals lying above the fermi level $g_{9/2}$ dive down in energy and give rise to oblate deformation. On the contrary, the neutron orbitals below the fermi level $h_{11/2}$ subshell (as for $N \sim 60$) derive the shape towards prolate deformation. Thus, the nuclei with $Z \sim 40$ and $N \sim 60$ are good candidates to study the influence of orbitals on the deformation in the mass region $A \sim 100$.

In the present work, the band structure of $^{92,94}\text{Nb}$ has been studied in a microscopic frame work of calculations known as Projected Shell Model (PSM) [1]. The calculated yrast energy levels and the composition of band structure for ^{92}Nb and ^{94}Nb nuclei are presented in this paper.

The basic conclusions drawn from the calculated results are as follows:

1. The low lying experimental yrast states are very well reproduced by PSM calculations.
2. The intrinsic quasiparticle structure of $^{92,94}\text{Nb}$ shows that the yrast levels are arising from the two quasiparticle bands originating from $g_{9/2}$ proton orbital and $g_{9/2}$ neutron orbital.

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Band Structure of Odd-Mass ^{115,117}I Nuclei

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ABSTRACT

The nucleus, as a unique many-body system, possesses a rich variety of quantum-mechanical excitations. The competition and resulting balance between the single particle and collective degrees of freedom are important factors in the determination of the nuclear structure. The single-particle structure that exists for spherical nuclei near closed shells gives way to more collective rotational structure for deformed nuclei that have a large number of valence nucleons outside closed shells. The iodine ($Z = 53$) nuclei lie between the spherical ($Z = 50$) and the well-deformed ($Z = 58$) region and are of considerable interest because of competing shape driving tendencies of the orbitals occupied by the neutrons and the protons. The orbitals available near the Fermi surface of these nuclei are $h_{11/2}$, $g_{9/2}$, $g_{7/2}$, and $d_{5/2}$ for protons and $h_{11/2}$, $g_{7/2}$, $d_{5/2}$, and $d_{3/2}$ for neutrons. Spectroscopic investigations [1] carried out in the odd-A ^{115,117}I nuclei have revealed several bands based upon $\pi g_{7/2}(d_{5/2})$ and $\pi h_{11/2}$ orbitals. These bands are associated with moderately deformed prolate and oblate shapes. In addition, bands based upon particle-hole excitations involving $\pi g_{9/2}$ extruder orbitals, which play a decisive role in the development of collective bands in Sn and Sb nuclei, also persist in the iodine nuclei. High-spin structures in these nuclei are described by abrupt appearance of energetically favoured noncollective oblate states and coexistence of weakly collective and noncollective quasiparticle-aligned configurations. In the present work, PSM [2] calculations for prolate band structures for ^{115,117}I have been analyzed. We have calculated some nuclear structure properties (such as yrast spectra, band diagrams, etc.) corresponding to prolate quadrupole deformation and the experimental data is very well reproduced by the PSM wave function.

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Study of band structure of proton rich doubly odd ^{138}Eu

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ABSTRACT

For the first time Liang et al. [1] have established transitions in the yrast band of doubly odd ^{138}Eu . The band head for this nucleus has been taken as the 8^+ level because they could not observe $9^+ \rightarrow 7^+$ transition. The yrast band was found to be built on the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration. They have also found that the ratios of the reduced transition rates for the yrast band are of the order of $2.5 (\mu_N/eb)^2$. Sometime back, Hecht et al. [2] have reported a new $E=1$ band in ^{138}Eu and extended the yrast band up to spin $I=25^+$. Both these bands have been assigned the same $\pi h_{11/2} \otimes \nu h_{11/2}$ structure. The new bands have been interpreted in the framework of three-dimensional tilted axis cranking model. In order to study the structure of observed bands in ^{138}Eu , projected shell model [3] with axial symmetry has been employed in the present work. However in the model, because of mixing of different bands some degree of nonaxiality creeps into the calculated results. The calculated transition energies of bands have been compared with the available experimental data. The staggering in $E=1$ transitions in the yrast band have been observed from the spin $I=12$, whereas calculated results show staggering from the spin $I=17$. Further, the $E=2$ transitions in the yrast band have been reasonably reproduced up to the spin $I=17$. For the excited side band built on $I=10^+$, the trends in $E=1$ and $E=2$ transition energies have been reasonably reproduced by the present calculations. Besides this, the present calculation predicts that the band head of the yrast band arises from $\pi h_{11/2}[3/2] \otimes \nu h_{11/2}[9/2]$ configuration. As one moves to higher spins multiple bands are seen to contribute to the yrast states.

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Correlations and Fluctuations of Photons at 158 A GeV

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ABSTRACT

In present work, we use the method of scaled factorial moments to analyze pseudorapidity fluctuations in nucleus-nucleus collisions. Scaled factorial moments are used to study short range fluctuations in pseudorapidity distributions of photons. Scaled factorial moments are calculated using horizontal corrected and vertical analysis. The results are compared with simulation analysis using VENUS event generator. The essence of experimental ultra-relativistic heavy ion collision physics is the production and study of strongly interacting matter at extreme energy densities, temperatures and consequent search for equation of state of nuclear matter. For the present analysis, data from the Photon Multiplicity Detector (PMD) is used. The focus of the analysis has been to examine pseudo-rapidity distributions obtained for the γ -like particles in pre-shower photon multiplicity detector. We also attempt to model the fluctuations seen in the data using a simple multi-source model. This allows the extension of scaled factorial moment analysis to bin sizes smaller than those accessible to other experimental techniques. For a sample of 10000 central collisions, moments are calculated using both horizontal and vertical analysis techniques

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Chirality symmetry breaking in triaxial nucleiG. H. Bhat^{1,2}, J. A. Sheikh², S. Sihotra^{3*}, V. Singh³, M. Kaur³, J. Rather³ and D. Mehta³¹*Department of Physics, Govt. Degree College Kulgam, 192231, India*²*Department of Physics, University of Kashmir, Srinagar, 190 006, India*³*Department of Physics, Panjab University Chandigarh, 160014, India*

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ABSTRACT

Chirality of rotating triaxial nuclei is introduced as Spontaneously Broken Symmetry (SBS) of the mean field. This SBS mechanism has played a central role in elucidating the intrinsic structures of quantum many body systems [1]. What all is possible from the experimental analysis of a bound quantum many-body system is a set of energy levels that are labeled by the quantum numbers related to the symmetries preserved by the system. For instance, for the case of atomic nucleus the energy levels are labelled by angular-momentum and parity quantum numbers that are related to the rotational and reflection symmetries. It is through breaking of these symmetries that provides an insight into the excitation modes of the atomic nucleus. The most celebrated model that employs the symmetry breaking mechanism is the Nilsson model. This model breaks the rotational symmetry and has provided invaluable information on the structures of deformed nuclei [2]. The observation of the rotational band structures built on each intrinsic state is a manifestation of the breaking of this symmetry. In recent years, it has also been demonstrated that doublet band structures observed in some odd-odd and odd-mass nuclei may be a manifestation of the breaking of the chiral symmetry in the intrinsic frame of reference [3–10]. The chiral symmetry is possible for nuclei having triaxial shapes with total angular momentum having components along all three mutually perpendicular axis. In odd-odd nuclei, the three angular-momentum vectors that form the chiral geometry are that of core; and of valence-neutron and -proton. The three angular-momentum vectors can either form left- or right-handed system and can be transformed into each other with the chiral symmetry transformation operator, $\hat{T}\hat{R}_y$, where \hat{T} is the time-

reversal operator and \hat{R}_y is the rotation by 180° about y-axis. The chiral dynamical variable so called “handedness” (σ) is not a measurable quantity and what is measurable in the laboratory frame is the set of states of chiral doublet bands which have a well defined value of complementary variable, the chirality (Σ). In the strong chiral symmetry breaking limit with the three angular-momentum vectors perpendicular to each other, σ assumes the values of ± 1 . The left- and right-handed states are well separated and there is no possibility of tunneling between the two states. This results into two degenerate doublet bands in the laboratory frame of reference. For the weak chiral symmetry breaking, the three angular-momentum vectors are not orthogonal which, as a matter of fact, is true in most of the physical situations. The handedness variable then takes the value between +1 and -1 [the value of 0 corresponds to the planar situation]. For this case, the tunneling between the two states takes place and in the laboratory frame this corresponds to the mixing of the two solutions with the result that two bands tend to be non-degenerate. As such, the Multi-Quasiparticle Triaxial Projected Shell Model (TPSM) is reviewed. Selected results are discussed to illustrate the consequences of chirality for energies and transition probabilities. The probability distribution of total angular momentum with respect to body fixed frame is calculated, which display the chiral geometry in a clear way. The $I \rightarrow I$ transitions between the chiral partners are suggested as a new and stringent signature for chirality. The relation to transverse and longitudinal wobbling excitation is well described by TPSM. Further TPSM provides successfully the classification of chiral vibrations as “transverse” and “longitudinal” mode [11]. We would like to express our deep gratitude to S. Frauendorf and R. Palit for their contributions at various stages in the development of the TPSM.

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Application of Power index formula for High spin states in medium mass nuclei

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ABSTRACT

The heavy ion (⁴He, ¹⁶O, ⁴⁰Ca etc.) reaction on medium mass nuclei of rare earths and actinides excite the target nucleus to high spins. At energies below the Coulomb barrier, fairly clean spectra of ground bands are obtained [1]. There are several two to three terms energy expressions used for reproducing the energy spectra for the different nuclei up to given spin. The Single term energy expression $E_I = aI^b$, where 'a' and 'b' are constants, index 'b' being the non integer value, has been proved to be successful for reproducing energies for spin $I^\pi < 12^+$ [2]. Here we extend this work on higher spins to test its validity further.

The parameter 'a', the scaling coefficient, and 'b' the power index are evaluated using the experimental energies from [3]. The systematics of the parameters are studied here with spin I, neutron number N, for high spin up to I=24 for ground band of even Z, even N nuclei. The theoretical calculated energies are compared with experimental energies from [3].

For nuclei, in which the deformation changes by small amounts, the index 'b' is fairly constant. But even below the back banding, if the spectrum changes drastically, the index 'b' also exhibits a sharp change. The parameters evaluated from the Power law show at each spin, clearly indicate the amount of change in the structure of the band.

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Interpretation of Nucleon alignment in the Magnetic Rotational (MR) Band Crossing Phenomenon

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ABSTRACT

In this work, a schematic model was proposed to interpret the nucleon alignment in MR band-crossing. The MR band-crossing occurs due to the alignment of a pair of valence nucleon and the shear blades re-open to build up a new shear band [1]. In the crossing region, there will be some states in which the two valence nucleons are not fully aligned. At these intermediate states, only those angles are possible between the aligned pair which quantized the angular momentum. Due to the above interpretation of MR band-crossing, the B(M1) value can be calculated when the band changes its structure during crossing. Assuming that a shear band, which is built with the coupling of two angular momentum J_v and J_π undergoes band-crossing due to the alignment of a nucleon pair (say j_v^1 and j_v^2) along J_v , which coupled to formed J_v' . The shear blades re-open with the shear blades formed by J_v' and J_π . In the crossing region, the neutron pair is only partially aligned with an angle, ϕ between them (j_v^1 and j_v^2) and the band changes its structure by gradual alignment of the neutron pair. The same formalism can also be used if the band-crossing is brought by the aligning of a proton pair.

From the geometry of MR band as given in [2, 3], the B(M1) value for the states in the crossing region can be calculated as

$$B(M1) = \frac{3}{4\pi} \frac{(2J_v^{eff}+1)^2 (2J_\pi+1)^2}{16J(2J+1)} (g_v^{eff} \quad g_\pi)^2 \sin^2 \theta_{v\pi} \quad [\mu_N^2] \quad \text{and} \quad \cos \theta_{v\pi} = \frac{J(J+1) - J_v^{eff}(J_v^{eff}+1) - J_\pi(J_\pi+1)}{2\sqrt{J_v^{eff}(J_v^{eff}+1)J_\pi(J_\pi+1)}}. \quad \text{The}$$

effective neutron angular momentum, J_v^{eff} is formed by the coupling of J_v and J_v^{12}

i.e $J_v^{eff} = J_v + J_v^{12}$ where $J_v^{12} = \sqrt{(j_v^1)^2 + (j_v^2)^2 + 2j_v^1 j_v^2 \cos \Phi}$. The effective neutron g-factor is given by $g_v^{eff} = (g_v + g_v^{12})$ where, $g_v^{12} = \frac{1}{2}(g_v^1 + g_v^2) + \frac{j_v^1(j_v^1+1) - j_v^2(j_v^2+1)}{2J_v^{12}(J_v^{12}+1)}(g_v^1 - g_v^2)$. The present Semi Classical (SC) calculation shows good agreement with the experimental observations in mass A~100 and A~200 regions [4, 5]. Apart from this, it also provides the core contribution, if it is contributing to the generation of total angular momentum. The examples of MR band with such crossing will be presented in the conference.

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Measurement of cross-section of meta-stable state of ^{116}In

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ABSTRACT

Present work deals with the measurement of cross-sections of the radioisotopes populated in low energy neutroninduced reactions with astrophysical[1-10] point of interest. The cross-section for the $^{115}\text{In}(n,\gamma)^{116\text{m}}\text{In}$ reaction has been measured using the off-line γ -ray spectrometry. To confirm the radioisotope, the life-time of the $^{116\text{m}}\text{In}$ has also been measured. The present work is compared with the data available in the literature and evaluated data ENDF/B-VII.1[11]. The cross-section of the meta-stable state of $^{116}\text{In} = 18.5 \pm 1.5$ b has been reported and it has been observed that the cross section is higher than the evaluated data. The author acknowledges the financial support from the Department of Science and Technology (DST) via project no. SR/WOS-A/PS-59/2013.

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A revisit to the prompt neutron spectrum from the spontaneous fission of ^{252}Cf

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ABSTRACT

The nature of energy distribution of neutrons emitted in the spontaneous fission of ^{252}Cf has been studied. Different formalisms used for describing energy distribution of neutrons from ^{252}Cf in the rest mass frame have been compared. The experimental data is fitted with Maxwell[1], LeCouteur[2] and Watt[3], hypotheses (represented by eqns (1),(2) and (3) respectively) which are generally used for the representation of neutron spectra from ^{252}Cf .

$$\frac{dN}{dE} = \text{const.} \cdot \sqrt{E} T^{3/2} e^{-E/T} \quad (1)$$

$$\frac{dN}{dE} = \text{const.} \cdot \sinh \sqrt{E} e^{-E/T} \quad (2)$$

$$\frac{dN}{dE} = \text{const.} \cdot E^\lambda e^{-E/T} \quad (3)$$

We have considered the Mannhart [4] evaluated experimental data available in the literature, for our study. With temperature as a free parameter, both LeCouteur and Maxwell distribution could explain the experimental data quite satisfactorily. Watt distribution shows considerable deviation as the energy goes higher. It is to be noted that the uncertainty in the experimental data is also large at high energy region. Goodness of fit of these formalisms are compared by Pearson goodness-of-fit statistic by calculating the reduced χ^2 values (χ^2/dof). The Le Couteur prescription gives a better fit (with $T=1.387$ MeV and $\lambda=0.55$) to the experimental data compared to other two prescriptions. However, the Maxwell distribution also explains the experimental data within the acceptable limit (fitted $T = 1.465$ MeV)[5]. We have obtained χ^2/dof as 1.16, 1.66 and 18.49 respectively for Le Couteur, Maxwell-Boltzmann and Watt hypotheses.

Present study reveals that the accurate measurement of neutron energy distribution of ^{252}Cf spontaneous fission source is highly in demand as the available experimental data which have been evaluated are about 30 years old. Overall fit of the data from ^{252}Cf using the same formalism seems to be invalid as the commonly used hypotheses discussed here do not incorporate the scission neutron component[6], which comprises the low energy part of the spectrum. On the availability of more accurate experimental energy distribution, the theoretical formalisms could also be refined.

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Characterization of neutron detectors of NAND array at IUAC

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ABSTRACT

National Array of Neutron Detectors (NAND) is a multi neutron detector array at Inter University Accelerator Centre (IUAC), New Delhi aimed to study the dynamics of heavy ion induced fission and fission like processes around the barrier energies [1]. Important features of heavy ion collisions such as the time scale of fusion-fission process, characteristics of quasi fission and asymmetric fission, neutron-neutron emission correlation, etc. can be studied by measuring energy, emission angle and number of neutrons emitted in a reaction process [2-4]. The array consists of 100 neutron detectors mounted on a geodesic dome structure at a radial distance of 175 cm from the target. The detectors are 5" x 5" organic liquid scintillator BC501A coupled to 5" dia photo multiplier tube (PMT), Hamamatsu 4144. The array consists of a reaction chamber of diameter 100 cm at the centre, made up of stainless steel to mount fission fragment detectors and light charged particles detectors. Time Of Flight (TOF) has been employed for deriving the energy of fast neutrons emitted where start time was taken from a time zero detector or rf signal.

It is of prime importance to perform a detailed characterization of these detectors to quantify time resolution, energy linearity, Pulse Shape Discrimination (PSD), intrinsic efficiency, cross talk probability of the array, etc. prior to use in any Physics experiments. The neutron detectors were tested using standard radioactive sources such as ¹³⁷Cs, ²²Na, ⁶⁰Co, ²⁵²Cf and AmBe. The light output from the detector was calibrated using mono energetic gamma sources. With this calibration factor, the response was found to be linear upto 4.4 MeV incident gamma energy. Also, it has been found that the position of interaction in the scintillation medium has lesser impact on light output produced. The timing studies performed have shown a time resolution less 1 ns for BC501A detectors. PSD was achieved using conventional zero cross method and the figure of merit was found to be better than 1.5 at 120 keVee. The intrinsic efficiency of the neutron detectors which is a function of energy was determined by comparing the measured neutron energy spectrum from ²⁵²Cf source to its theoretical emission spectrum. When the scattered neutron, after depositing a minimum amount of energy, interacts with another detector cell, an event called false coincidence/ cross talk come into picture. Cross talk depends on incident neutron energy, distance between the detectors and detector dimensions. Cross talk probability, which is the ratio of number of cross talk events to number of true coincidences, in one detector from its neighbor detectors was measured to be $\sim 4 \times 10^{-3}$. The details of characterization method adopted, data analysis, etc. will be presented in the conference.

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Barrier distribution for $^{16}\text{O}+^{169}\text{Tm}$ system through quasi-elastic back-scattering

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ABSTRACT

In recent years, there is a great interest in fusion barrier studies due to advances in experimental methods and theoretical interpretations [1-7]. The heavy-ion collisions at energies around the Coulomb barrier are strongly affected by the internal structure of colliding nuclei [1-6]. The coupling between relative motion and internal degrees of freedom of colliding ions (such as static deformations, collective excitations; rotation and/or vibration, nucleon transfer, projectile break-up, etc.) results in a number of distributed barriers in place of a single potential barrier (B_{fus}). It is now well known that a barrier distribution (BD) can be extracted experimentally from the fusion excitation function $\sigma_{\text{fus}}(E)$, using the relation $D_{\text{fus}}=d^2(E\sigma_{\text{fus}})/dE^2$ [3]. The extracted BD can be treated as a fingerprint of the reaction mechanism characterizing the importance of channel couplings because the nature and strengths of the couplings lies in the distribution of barriers. Further, it was suggested that the same information can also be obtained from the cross-section of quasi-elastic scattering (QE) (as the total flux is conserved) measured at large angles using the prescription $D_{\text{qel}}=-d(d\sigma_{\text{qel}}/d\sigma_{\text{R}})/dE$, which gives an alternative representation of fusion BD [5]. In the present work, the QE-measurements have been performed for the system $^{16}\text{O}+^{169}\text{Tm}$, which will be translated to BD. It should be noticed that the doubly closed ^{16}O projectile will behave as an inert, and therefore any effect of the coupling of different degrees of freedom on BD should be pronounced for the target nuclei only.

The experiment has been performed at the IUAC, New Delhi using HYTAR detector system in GPSC [7]. Beam energy was varied in steps of 3 MeV ranging from 17% below barrier to 16% above barrier. Four telescope detectors each at an angle of 173° have been arranged in a symmetrical cone geometry to measure the back-scattered quasi-elastic events. Nine telescopes, six at angles from $+60^\circ$ to $+160^\circ$ with angular separation of 20° and other three telescopes at angles -110° , -122° and -134° , were placed. Two monitor detectors have been placed at $\pm 10^\circ$ for normalization purpose. The QE-excitation functions have been obtained and the experimental BD for the $^{16}\text{O}+^{169}\text{Tm}$ system has been derived. The nuclear potential parameters will be extracted from angular distribution measurements for theoretical calculations. Further, analysis of the data is underway and the details will be presented during the conference.

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**Inhalation dose estimate due to radon and thoron in the dwellings of Kappad,
Kerala**

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ABSTRACT

Major sources of natural back ground radiation received by human beings are cosmic rays and terrestrial radiations. Radon, thoron and their short lived progenies are the main contributors to the terrestrial radiation. The radiation exposure to humans due to these sources occur mainly in three ways 1) external gamma rays 2) inhalation of radon, thoron gases and their progenies, and other radioactive nuclides, 3) ingestion of radioactive materials through food and water. It is well known that about 50% of the natural radiation exposure results from inhalation mode [1], major contributors being radon, thoron and their short lived radioactive decay products. The estimation of the radiation exposure of the public in living rooms requires long term measurements of the potential alpha energy concentration (PAEC) of radon / thoron and progeny nuclides during periods of a few months. Because such measurements are quite difficult to perform, in most cases the radon/ thoron is measured from which the PAEC can be calculated assuming appropriate equilibrium factors for the gases. A sample study in twenty five dwellings in Kappad of the Calicut district, Kerala, India were carried out using twin cup based Solid State Nuclear Track Detectors(SSNTD). The radon and thoron concentration, Potential Alpha Energy Concentration and inhalation doses were calculated. Results for the region show that the radon gas concentration range is within the limit of UNSCEAR East Asian values[2] and the annual effective inhalation dose is less than the action level of 3 mSv/y, recommended by International Commission on Radiological Protection (ICRP)[3].

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Temperature induced shape evolution for rotating Fe⁵⁶ nuclei

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ABSTRACT

The shape of nuclei is very sensitive to increase of its temperature. The shape fluctuation in the nucleus mostly corresponds to the collective degrees of freedom (ϵ and γ). The microscopic calculations taking into account of all these degrees of freedom such as temperature (0.5 MeV to 2.0 MeV), angular momentum ($0\hbar$ to $20\hbar$) and deformations ($\delta = -0.6$ to $+0.6$ in steps of 0.1 for the sector $\gamma = -120^\circ$ to -180°) are used in this study to investigate the role played by shape fluctuations in the Fe⁵⁶ nuclei by using the theoretical framework of the statistical theory of hot rotating nuclei [1-4]. The shape transition parameters such as entropy, kinematic moment of inertia, back-bending phenomenon, spin-cutoff parameter, separation energy for protons and neutrons are discussed and the level density is also extracted using constant entropy.

The free energy is minimized for various deformations, in order to determine the equilibrium state of the deformed nuclei. At low temperature a deformed equilibrium shape nuclei changes to an unstable spherical shape with increase of temperature. The increase of the temperature acts in the direction of decreasing the equilibrium deformation and will eventually lead to the stable spherical shape. This is often referred to as disappearance of shell effects with temperature. It can also be termed as temperature induced shape transition [5]. When the temperature is low, the considered ⁵⁶Fe nucleus is prolate at low angular momentum but the fast rotation makes the prolate configuration unstable. Thus, the shape transition not only depends on temperature it also depends on angular momentum. It is observed that for the temperature $T = 1.0$ MeV, the nucleus ⁵⁶Fe is seen to be prolate for $M = (0 - 2) \hbar$ and when the angular momentum increases $(3 - 15) \hbar$ it becomes oblate shape. For angular momentum above $40\hbar$ it becomes spherical [6]. The results are compared with experimental [7-9] data.

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**Microscopic Study of Positive Parity Yrast States in Neutron-Deficient
^{119,121}Ba Isotopes**

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ABSTRACT

Barium nuclei with atomic number $Z = 56$ represent one of the best examples of an isotopic chain to trace the evolution of nuclear structure with neutron number. The neutron deficient barium isotopes with $120 < A < 130$ have well developed quadrupole deformations ($\beta_2 = 0.2$ to 0.3) and are easily produced in heavy-ion fusion evaporation reactions; these nuclei have therefore been very well studied in gamma ray spectroscopy experiments. J. F. Smith et. al. [1] observed two bands in ¹¹⁹Ba, one negative parity band based on $h_{11/2}$ and one positive parity band based on $(g_{7/2}d_{5/2})$ neutron orbitals. Collective excitations have been identified for the first time in ¹²¹Ba by F. Liden et. al. [2]. Two main rotational bands, both of $\Delta I = 1$ character, have been observed in this nucleus; a positive-parity band based on $5/2^+$ ground state and a negative-parity band based on $5/2^-$ state generated from the $5/2^-$ [532] orbital.

The purpose of the present work is to interpret the positive parity bands observed in ^{119,121}Ba in the framework of Projected Shell Model (PSM) [3]. In the present study, the results are obtained for some of the nuclear structure properties like yrast spectra, band diagrams, and $B(M1)/B(E2)$ ratios and the experimental data is very well reproduced. Previously, PSM has been successfully applied to study the negative parity bands in odd mass ¹¹⁹⁻¹²⁷Ba isotopes [4].

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Investigation of nuclear structure of doubly-odd ^{136}La nucleus

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ABSTRACT

The characteristic nuclear structure properties of doubly-odd ^{136}La nucleus has been calculated within two-body effective interactions incorporated in a self-consistent quantum mechanical approach known as - Projected Shell Model to test the efficacy of the chosen valence space. The Projected Shell Model (PSM) uses a truncated valence space under the assistance of the deformed mean-field solutions so as to make the calculations feasible. This implies that the PSM is a novel and efficient way to bridge the two conventional techniques: the deformed mean-field approximations, which are widely used to study the heavier systems but able to describe the physics only in the intrinsic frame, and the spherical shell model diagonalization method, which is most fundamental but practical only for lighter systems. The PSM calculations are performed to obtain the yrast line of ^{136}La nucleus and also its formation from multi-quasi-particle configurations based on $\pi h_{11/2} \nu h_{11/2}$ band. The yrast line of ^{136}La nucleus is described as interplay among the projected angular momentum multi-quasi-particle states in the region of the Fermi level carrying different intrinsic K-quantum numbers. Further, the back-bending in moment of inertia is reproduced well with the present set of calculations. This anomalous behavior from a regular sequence in the back-bending plot is attributed to band crossing among the multi-quasi-particle bands which lead to modify the intrinsic configuration of the yrast band, thereby, changing the structure of the nucleus. Besides, staggering pattern in transition energies is very well reproduced by the present calculations. The zig-zag pattern of signature splitting in rotational bands of the doubly-odd ^{136}La nucleus shows irregularities at various spin values - known as signature inversion. Further, the reduced transition probabilities (i.e., B(E2) and B(M1) values) have also been calculated for various transitions which provide an opportunity to the experimentalists to look for this data. In conclusion, one can say that the qualitative description of the high-spin band structure of doubly-odd ^{136}La nucleus can be successfully obtained by using the present PSM technique.

**Conditional Entropy and Mutual Information in Pb+Pb Interactions at
158 A GeV**

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ABSTRACT

Many models have been proposed to explain the phenomenon, usually called intermittency [1]. Most of them contain essentially a kind of self- similar cascading process. In this context, self – similar random cascading is the most natural and hopeful mechanism that can reproduce the intermittency phenomena in multiparticle production. Wu Yuanfang and Liu Lianshou [2] developed a method for observing and examining this mechanism of self- similar random cascading, making use of the concepts of conditional entropy and mutual information. In the study we examine the data on photon multiplicity produced in Lead – Lead central collisions at 158 A GeV for the existence of self – similar random cascading using conditional entropy and mutual information variables. The results are compared with Monte Carlo simulation studies using VENUS event generator and GEANT detector simulation software. The experiment is also compared with predictions from Alpha- Model [3, 4]. The studies have concluded that the photon production in central Lead-Lead collisions at 158 A GeV (PMD) data shows evidence of self-similar random cascading mechanism which is amply reproduced by Monte Carlo simulation studies. The statistical sample of data also shows the similar behavior and almost completely accounts for observed conditional entropy signal from experimental and Monte Carlo calculations. The studies therefore conclude that no evidence of fluctuations of dynamical origin in lead-lead central collisions at 158 A GeV is observed.

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Neutrino Energy Reconstruction and CP-phase extraction at DUNE
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ABSTRACT

The neutrino beam in accelerator-based neutrino oscillation experiments is not monochromatic, it's fairly broad band and needs to be reconstructed as it is not known a priori. . The accurate reconstruction of neutrino energy will lead us towards the precise measurements of different neutrino oscillation parameters. In this work we have studied the possible impact of nuclear effects and final state interactions on the reconstruction of neutrino energy at Dune. The current uncertainties on nuclear effects, including FSI is quit large. Here the quasi-elastic kinematics and calorimetric method is used to reconstruct the neutrino energy . The error in reconstruction of neutrino energy is estimated when FSI and nuclear effects are taken into consideration in comparison to the same without FSI. The oscillation physics is looked upon with the reconstructed neutrino energy in both the cases i.e. with and without FSI. The observations are performed with different CP-phases and an accuracy needed to determine the CP-phase is analyzed in each of the case.

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Probing upper limit on Very High Energy Prompt Muon and Neutrino fluxes

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ABSTRACT

We evaluate the parameters of the muon and neutrino spectrum at surface, i.e. the normalisation constant which changes with power index of the all nucleon spectrum γ . We also check the upper limit of the contribution of charm particles to the muon fluxes, and the ratio of muon flux at different zenith angle with respect to vertical flux at the higher energy limit above 1 TeV.

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Contribution of charm particles to the atmospheric prompt muon fluxes at higher energies.

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ABSTRACT

The conventional muon fluxes obtained from the decay of charged pions and kaons till few GeV energies are well studied whereas at higher energies such as 10 GeV along with the conventional muon fluxes needs the inclusion of muon fluxes produced from the leptonic decay of charm particles is also required. This contribution is known as prompt muon fluxes. The estimation of prompt muon fluxes at higher energies is very important. The muon production at higher energies varies with the logarithmic growth of energy. For the evaluation of prompt muon fluxes we have estimated the contribution of leptons from charm particles. Here we have adopted two phenomenological approaches for the charm production: the recombination quark parton model (RQPM) and the quark gluon string model (QGSM) based on non perturbative QCD. Our results of prompt fluxes are compared with the prompt fluxes calculated in different models: TIG, PRS, GGV (based on perturbative QCD). Here the transport equation of muons are calculated by using semi analytical method. Finally the calculated flux is passed through the iron detector and the number of muons cascades is evaluated. These observations will help us to understand the contribution of charm particles at higher energies.

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Octupole correlation in $A \sim 130$ mass region

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ABSTRACT

The nuclei in the mass $A \sim 130$ region are of considerable interest because of the competing shape driving tendencies of the orbitals occupied by the neutrons and protons. These nuclei are known to be soft with respect to the triaxial deformation parameter γ and exhibit various intriguing phenomena. Octupole correlation represents the structural behavior of the atomic nuclei at high spin which can arise when nucleons near the Fermi surface occupy states of opposite parity with orbital and total angular momentum differing by $3\hbar$. A nucleus with Octupole deformation has reflection asymmetric shape. The present work reports the theoretical and experimental evidences of octupole correlation in this mass region for some of the nuclei. Various possible and associated phenomena have been discussed in order to make it more reasonable. We have seen that the maximum octupole coupling occur just above the close shells ($Z, N = 34, 56, 88, 134$). Several theoretical calculations and experiments have suggested the presence of octupole correlation in Ba, Cs and Xe isotopes.

Unequal charge & matter deformations lengths for scattering to (3_1^-) states in even-even nuclei

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ABSTRACT

For direct reactions like inelastic excitations, the dynamics of the interactions are governed by structural parameters of participating nuclei, which determine the coupling to the entrance channel and influence resulting cross sections of all open channels in a system. In a recent study on $^7\text{Li} + ^{120}\text{Sn}$ system, projectile-like fragments were detected in an angular range of 25° - 140° , using six sets of Si-detector telescopes, to measure the cross sections for elastic and inelastic channels at ^7Li beam energies of 28 and 30 MeV, at the BARC-TIFR Pelletron facility. Along with the elastic peak, the target inelastic states corresponding to 2_1^+ quadrupole ($\lambda=2$) and 3_1^- octupole ($\lambda=3$) vibrational states, at 1.17 MeV and 2.40 MeV respectively, were found to be dominant.

Model coupled-channels calculations were performed using FRESKO by coupling 30 major direct reaction channels to the entrance channel, and the results were compared with experimental data for both energies. Simultaneous description of elastic and inelastic scattering has been attempted by using the same set of potential as well as coupling parameters. The inelastic states were treated as collective vibrational states for the spherical ^{120}Sn (g.s. 0^+), approximated by the harmonic oscillator Hamiltonian representing surface oscillations about the mean spherical shape with characteristic deformation lengths. For the ($0^+ \rightarrow 2^+$) transition in ^{120}Sn , measured angular distribution in the forward region, predominantly led by Coulomb interaction, is consistent with the available experimental electric transition probability $B(E2)$ or charge deformation lengths $\beta_2^{\text{C}}R_{\text{C}}$. However, by keeping the charge and matter deformation lengths equal ($\beta_2^{\text{N}}R_{\text{N}} = \beta_2^{\text{C}}R_{\text{C}}$), the backward-angle contribution to the scattering (predominantly led by nuclear interaction) could not be reproduced, i.e., the electric transition probability is unable to explain the data over the complete angular range. Similarly, for the ($0^+ \rightarrow 3^-$) transition, any of the $B(E3)$ values available in literature with $\beta_3^{\text{N}}R_{\text{N}} = \beta_3^{\text{C}}R_{\text{C}}$ could not reproduce the data over the entire range. A much lower value of $\beta_3^{\text{N}}R_{\text{N}} (< \beta_3^{\text{C}}R_{\text{C}})$ was required.

To unravel this inconsistency, the surface oscillations were assumed to be anharmonic, thereby leading to finite static quadrupole moments (reorientating coupling) of the excited states (2_1^+) and (3_1^-). On including a suitable reorientation matrix element ($\beta_{22}^{\text{N}}R_{\text{N}} = \beta_{22}^{\text{C}}R_{\text{C}}$) into the model calculations for the ($0^+ \rightarrow 2_1^+$) transition, the inelastic scattering data could be reproduced using $\beta_2^{\text{N}}R_{\text{N}} = \beta_2^{\text{C}}R_{\text{C}}$, consistent with available $B(E2)$ values, thus indicating anharmonicity for this $\lambda=2$ vibration. This matrix element was also consistent with existing measurement of quadrupole moment for the (2_1^+) state of ^{120}Sn using Coulomb excitation. For the (3_1^-), there is no previous measurement or estimate of static quadrupole moment, and apparently, a large value of reorientation coupling (β_{33}) was required to particularly reproduce the backward angle scattering data in the present measurement, but an optimum representation throughout the angular range is possible only with unequal charge & matter deformations lengths with $\beta_3^{\text{N}}R_{\text{N}} < \beta_3^{\text{C}}R_{\text{C}}$.

Similar results were also deduced from existing scattering data for $\lambda=2,3$ excitations in other vibrational nuclei ^{208}Pb , $^{146,150}\text{Nd}$, for which, measurements of quadrupole moments of excited states were found to exist. On including these static moments into the model calculations for the $\lambda=2$ states, the inelastic scattering data could be reproduced with $\beta_2^{\text{N}}R_{\text{N}} = \beta_2^{\text{C}}R_{\text{C}}$; while for the (3_1^-) states in ^{208}Pb and ^{146}Nd , even after including the static reorientation coupling (β_{33}), nuclear deformation lengths in $^{12}\text{C}, ^{16}\text{O} + ^{208}\text{Pb}$, $^{12}\text{C} + ^{146}\text{Nd}$ systems were not consistent with the available measurements of $B(E3)$ values and had to be kept considerably lower, $\beta_3^{\text{N}}R_{\text{N}} < \beta_3^{\text{C}}R_{\text{C}}$.

Analysis of Fusion Reaction Data Involving Loosely Bound Nuclei

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ABSTRACT

Since last few decades due to the availability of radioactive ion beams the fusion reactions involving loosely bound nuclei attracts more attention and act as a clean probe to investigate the structure of light exotic nuclei. Consequently intensive theoretical and experimental work has already been done in this field. Nevertheless, more work is desirable in the field on theoretical and experimental front. Therefore here we have analyzed the barrier distribution, fusion excitation function and reaction cross section of fusion reactions involving loosely bound nuclei mainly ^{6,7}Li, ^{9,11}Be. Here particularly we have analyzed the breakup effects on fusion through dynamic polarization potential at energies around Coulomb barrier. Hindrance to the reaction cross section has also been investigated. The comparison of calculations and data available will provide a good insight to the readers about the fusion reactions observables and the structure of exotic nuclei.

1p transfer induced breakup in ${}^7\text{Li}+{}^{112}\text{Sn}$ reaction

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ABSTRACT

At above barrier energies, suppression of complete fusion involving weakly bound projectile as compared to the strongly bound projectile is well established. It was proposed that the low breakup threshold of the projectile is the main reason. Along with direct breakup, transfer triggered breakup is also responsible for this suppression. The time scale of different states through which breakup occurs and the location of the breakup, both, are very important quantities in order to understand the complete fusion suppression. If the time scale associated with the breakup states are longer than the collision time scale between the projectile and the target then the breakup associated from that state will not be able to suppress the complete fusion. Similarly, if the breakup occurs prior to reaching the fusion barrier, then only it can suppress the complete fusion. Out of several breakup processes in ${}^7\text{Li}+{}^{112}\text{Sn}$ reaction, here we investigate the mechanisms of 1p transfer induced breakup. By, 1p pickup the ${}^7\text{Li}$ converts into an unbound ${}^8\text{Be}$, which subsequently breaks into two α .

Exclusive measurements of breakup of ${}^7\text{Li}$ by a ${}^{112}\text{Sn}$ target were made at the 14-UD Pelletron-LINAC facility in Mumbai. A self supporting ${}^{112}\text{Sn}$ foil of thickness $\sim 540 \mu\text{g}/\text{cm}^2$ was used as a target. An array of detectors with large angular coverage has been used to measure the two breakup α fragments produced via different excited states of ${}^8\text{Be}$ in coincidence. Five strip telescopes, each consisting of ΔE and E double sided silicon detectors, were placed side by side to cover the angular coverage $\sim 100^\circ$. Along with that, five single telescopes and two monitor detectors were used. Combining the experimental results along with coupled-channels calculations, we study the disintegration cross-section of ${}^8\text{Be}$ into two α particles from different states of ${}^8\text{Be}$ and their effect on complete fusion suppression.

Relative energy and Q-value distribution confirm the observation of breakup of ${}^8\text{Be}$ into two α particles from its 4^+ resonant state for the first time as well as from the well known 0^+ and 2^+ states. Event by event analysis of the data to obtain the difference in energy $|E_1-E_2|$ versus relative energy E_{rel} of two α fragments and also the angular correlation between β vs θ_{12} confirm that disintegration of ${}^8\text{Be}$ into two α particles via its 2^+ and 4^+ states are responsible for complete fusion suppression. Whereas, the dominant breakup of ${}^8\text{Be}$ via its ground state, was found to occur far away after passing by the target, and hence it does not contribute to the suppression of the complete fusion.

Systematic study of next possible magic nucleus beyond $Z=126$

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ABSTRACT

Search for super and hyper heavy nuclei is of current interest in Nuclear Physics. Denisov [1] predicted spherical proton magic numbers at $Z=82, 114, 164, 210, 274, 354$ and spherical neutron magic numbers at $N=126, 184, 228, 308, 406, 524, 644, 772$. Nakada and Sugiura [2] showed evidences on new proton and neutron magic numbers from relatively light to heavy nuclei including nuclei far off the β -stability line, and the possible magicity proposed are $Z=14, 16, 34, 38, 40, 46, 58, 92, 120, 124, 126$ and $N=40, 56, 90, 124, 172, 178, 164, 184$. Recently Ismail et al.[3] have predicted new proton and neutron magic numbers based on the shell and residual pairing correction energies in the framework of Strutinsky's approach as $Z=82, 92, 114, 120, 124, 135, 154, 164, 186, 204, 214, 228, 244, 274$, and $N=100, 126, 148, 164, 184, 210, 228, 258, 308, 320, 338, 346, 406, 524$. Among these nuclei $Z=92, 120, 138, 186, 226, 244$ are expected to be spherical proton magicity. The super and hyper heavy systems are formed either through cold or hot fusion reactions during supernova explosions and such formed fused compound systems are to be treated as hot rotating since the fusion of nuclei itself will generate hot systems. Hence treating it as a thermo dynamical system is appropriate one and so the statistical approach is followed in this work. The statistical code is developed by us and the calculations are performed for a range of even-even nuclei with $Z=114$ to 156 and $N=280$ to 390 . The excitation energy ' E_x ', particle separation energy ' $S_{p(n)}$ ', level density parameter ' a ', and nuclear level density ' ρ ' are calculated at an optimal temperature $T=0.5\text{MeV}$ and spin $J=0\hbar$. Compound nuclear systems formed with more number of nucleons, ie., super and hyper heavy systems are to be stable against S_n than S_{2n} . The neutron magicity on the basis of having higher S_n lies at $N=184, 204, 232, 238, 252$, and 256 . The pronounced gap between $Z\leq 126$ and $Z\geq 128$ in the n° separation energy plot explores the signature for a proton shell closure at $Z=126$. A similar gap is also observed at $Z=138$ and hence the next proton magicity may lie at $Z=138$. And so, this newly predicted proton magic nuclei $Z=138$ is systematically studied in the vicinity of stellar nucleosynthesis. It also shows a pronounced minimum in E_x and higher value of l_{dp} at $N=192$. At $N=152, 192, 220$, and 254 , the S_n is high, and hence the possible neutron magicity for the nucleus $Z=138$, may be at these neutron numbers. But at $N=236$, a small rise in S_n compared to the neighboring isotopes is observed and which resembles the very high nuclear level density. Such an effect is also observed in the E_x energy and l_{dp} plots. Hence the most probable neutron magic number for the hot rotating $Z=138$ may be $N=236$. The deviation of our results from other reports is due to the inclusion of temperature, since this nucleus may be formed during supernova explosions as a hot system, and hence the next magic nuclei beyond $Z=126$ may be $^{374}138$. The structural changes against spin and temperature, and the survival of the system against α -decay and spontaneous fission are also studied for understanding the stability of the system.

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Nuclear Level density for Astrophysical Nuclei: ⁴⁴⁻⁵²TiP.Preetha^{1,*}, S. Santhosh Kumar²¹*Research and Development Center, Bharathiyar University, Coimbatore-606060,
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ABSTRACT

The density of levels provides information about the status of highly excited nuclei and is also a basic quantity in nuclear reaction theory, especially to understand properties of excited nuclei and to describe fission dynamics. Explosive nuclear burning in astrophysical environments produces unstable nuclei, which again can be targets for subsequent reactions. The statistical model approach has been employed in calculations of thermonuclear reaction rates for astrophysical purposes by many researchers [1,2]. A high level density in the compound nucleus at the appropriate excitation energy allows to make use of the statistical model approach for compound nuclear reactions [3,4], which averages over resonances. For large scale astrophysical applications it is necessary to find reliable and computationally feasible methods for level density predictions. Most statistical model calculations use the back-shifted Fermi-gas description [5]. The level density can also provide clues to the applicability of the statistical model which is only correct for a high density of excited states. In this paper we present the level density descriptions[6] of the astrophysically important Ti isotopes, where the shell effects vanishes at high excitation energies. A substantial amount of radioactive elements, primarily, ^{56,57}Ni, and ⁴⁴Ti, are produced when a massive star explodes as a supernova. According to a letter to *Nature* [7], the discovery of gamma ray emission from the decay of ⁴⁴Ti has revealed a new way to search for the remnants of relatively recent supernovae. Recently added isotopic system to the cosmochemical testing tool kit, the titanium isotopes, grasped the attention of world nuclear scientific community because the finding of Zhang et al., [8], that the ratio of ⁵⁰Ti to ⁴⁷Ti is identical in Earth and Moon to within four parts per million. The higher BE/A of ⁵⁰Ti spells out a higher abundance in astronomical as well as geological objects. The most suitable theory for a high density of excited states, the statistical theory, is coded for this study to obtain the particle separation energy, level density, etc. for the Ti isotopes of $44 \leq N < 52$. The level density is calculated using Bethe formula by calculating the energy dependent level density parameter "a", where the single particle energies are obtained through the cranked Nilsson method. The nuclear level density has given rise to the largest uncertainties in the description of nuclear reactions [9,10]. In nuclear reactions the transitions to lower lying states dominate due to the strong energy dependence and hence the present approach will give more accurate results for astrophysical nucleosynthesis calculations.

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Skyrme force GSkI and fusion-fission dynamics of the reaction



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ABSTRACT

The method being successfully used for the synthesis of superheavy elements is that of complete fusion reactions, which are classified as cold fusion and hot fusion reactions. In the present work, our earlier study [1] of evaporation residue cross section in the decay of ${}^{252,254,256}\text{No}^*$ formed in fusion reaction ${}^{48}\text{Ca} + {}^{204,206,208}\text{Pb}$ at energies $E^* = 20-45\text{MeV}$, based on Dynamical Cluster-decay Model (DCM) [1], using the pocket formula for nuclear proximity potential is extended to the use of other nuclear interaction potentials derived from Skyrme energy density functional (SEDF) based on semiclassical extended Thomas Fermi (ETF) approach. We have used GSkI Skyrme force [2] for our calculation and experimental data is taken from [3]. The calculations are done using a single variable parameter, R , the neck length parameter. Interestingly our calculated result by using GSkI Skyrme force is satisfying experimental results as shown in figure 1.

DCM defines the fragments production or CN decay cross section, in terms of ℓ partial waves, as

$$\sigma = \sum_{\ell=0}^{\ell_c} \sigma_{\ell} = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_c} (2\ell + 1) P_{\ell} P; \quad k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}}$$

Where P_0 is pre-formation probability, P is penetrability and here $\mu = mA_1A_2/(A_1+A_2)$ is the reduced mass with m as the nucleon mass.

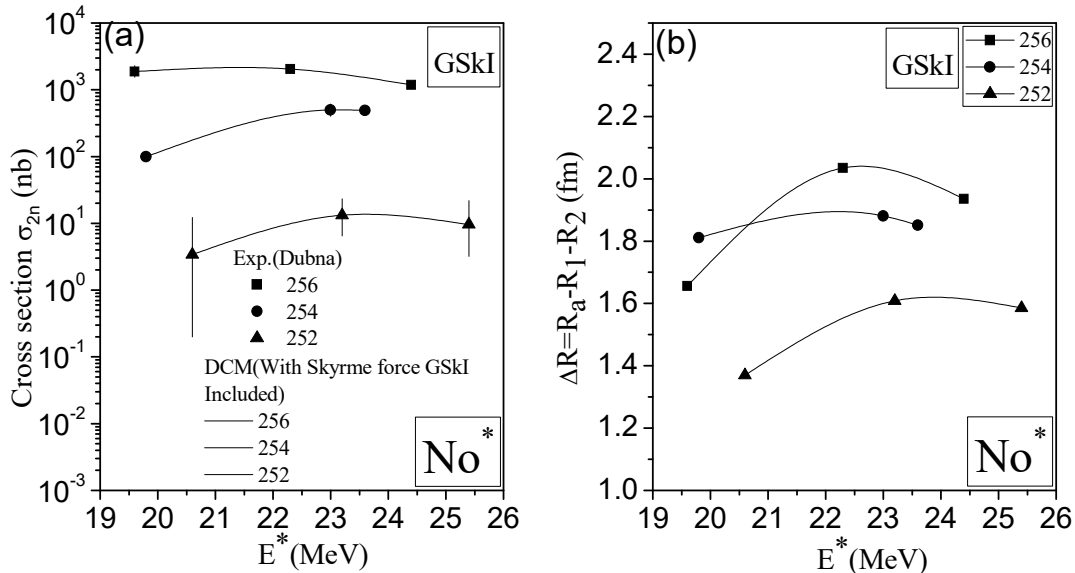


Figure 1: In fig1(a) Comparison of the experimental and DCM(with Skyrme force GSkI included) calculated 2n evaporation residue cross-sections of CN ${}^{252,254,256}\text{No}^*$ as a function of CN excitation energy E^* and in fig1(b) comparison of the best fit neck length parameter ΔR of CN ${}^{252,254,256}\text{No}^*$ as a function of CN excitation energy E^* is shown.

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Systematic dependence of $SFE \cdot B(E2)_{\uparrow}$ and $ROTE \cdot B(E2)_{\uparrow}$ on γ_0 in the framework of Asymmetric Rotor Model

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ABSTRACT

The systematic dependence of $SFE \cdot B(E2)_{\uparrow}$ and $ROTE \cdot B(E2)_{\uparrow}$ on the asymmetric parameter γ_0 is carried out in the $Z = 50-82$, $N = 82-126$ major shell space. The asymmetric parameter γ_0 of Davydov and Fillipov [1] varies from 0 to $\frac{\pi}{3}$ reflect the change in nuclear structure from prolate to triaxial. For the shape transitional isotopes, the product $SFE \cdot B(E2)_{\uparrow}$ shows sudden jump from low negative to large positive values. However, the product $ROTE \cdot B(E2)_{\uparrow}$ decreases as a function of γ_0 for all nuclei approaching towards triaxiality from $Z = 50-82$, $N = 82-126$. In $N < 104$ region, the product $ROTE \cdot B(E2)_{\uparrow}$ increases till the transition point correspond to $\gamma_0 \sim 15^\circ$ for $Dy-Yb$ nuclei and suddenly drops as the nuclei approaching towards triaxiality.

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Astrophysical S-factor and reaction rate of some (p- γ) reactions using relativistic mean field densities

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ABSTRACT

We have been theoretically studied the astrophysically important S-factor of (p, γ) reactions at low energy of some p-nuclei in comparison with available experimental data [1] by using microscopic optical mode potential with the help of Hauser-Feshbach reaction code TALYS [2] using relativistic mean field densities [3]. This is done by folding the density-dependent M3Y (DDM3Y) interaction with relativistic mean field (RMF) spherical densities. Different parameter sets G2, NLSH, NL3* and DD-PC1 are used in the density calculation. The role of different densities on S-factor for various low energy (p, γ) reactions is discussed. Astrophysical reaction rates of these nuclei are also compared with the standard NON-SMOKER results [4].

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Electromagnetic Transition Rates in the Negative-Parity band of ^{85}Sr

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ABSTRACT

The high-spin states in a nucleus can be generated by a collective rotation either about a principal axis or a tilted axis. The total angular momentum is produced by the alignment of neutron and proton angular momentum vectors through specific coupling schemes [1-2]. However, in some nuclei a transition from the principal axis to the tilted axis is observed. From the experimental observers such as staggering, B(M1) transition rates etc., it is possible to observe this phase transition. In this work, we are reporting such a phenomenon in the ^{85}Sr nucleus. In this nucleus, a negative-parity band was investigated through lifetime measurements which was supposed to show the magnetic rotation [3] phenomenon as it was found in the ^{83}Kr nucleus (N = 47 isotone, best example of magnetic rotation in mass 80 region). In the ground state, ^{85}Sr nucleus is nearly spherical ($\beta = 0.15$) having $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, and $0g_{9/2}$ active single-particle orbitals. This nucleus may exhibit principal axis rotation before the neutron alignment and tilted axis rotation after that. The signature of such a transition has been investigated through lifetime measurements of the excited levels of the yrast band. In the ^{85}Sr nucleus, the lifetimes of the states were measured for band 4 (negative-parity) above $I^\pi = 21/2^+$ state [4].

The ^{85}Sr nucleus was investigated for high- spin states via the reaction $^{76}\text{Ge}(^{13}\text{C},4n)^{85}\text{Sr}$ using a ^{13}C beam of 45 MeV from the Pelletron accelerator at Tata Institute of Fundamental Research (TIFR), Mumbai. The ^{76}Ge target of thickness $850 \mu\text{g}/\text{cm}^2$ with $7.06 \text{ mg}/\text{cm}^2$ ^{181}Ta backing was used. Gamma rays were detected using Indian National Gamma Array (INGA) by using 15 Compton suppressed clover detectors at 157° , 140° , 115° , 90° , 65° and 40° with respect to the beam direction. The data were sorted using Multi-pARAMeter time stamped based COincidence Search (MARCOS) and analyzed by DAMM and RADWARE for different matrices to generate gated spectrum. The asymmetric matrices consisting of events at 40° , 140° and 157° detectors along one axis and rest of the detectors on other axis were created using MARCOS, and gate spectra were generated using DAMM and RADWARE for lifetime analysis. The LINESHAPE [5] program was used to calculate the lifetime of different states.

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Investigation of metal concentration in water using PIXE

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ABSTRACT

Availability of clean drinking water is an essential requirement for human health. The Ganga water is being widely used for drinking and irrigation purposes in many cities situated near the bank of the river, which effect the human health. Hence investigation of toxic elements of Ganaga water is very important. PIXE (Particle Induce X-ray Emission) is well known and useful technique for finding out qualitative and quantitative analysis of various samples (taken from environment) and may contains about 30-50 elements together with concentration of about 1ppb. The elemental analysis depends on the inner-shell ionization process and measurement of the X-ray yield of the samples. For the present investigation, samples of Ganga water were collected from Varanasi and Allahabad. Sample for the PIXE measurement were prepared using the technique similar as describe in ref. [1]. Each sample having 200ml of water was added to 10ml of saturated NaDTTC, as a precipitating reagent, to extract metal content in the form of precipitation. The precipitations were collected by using vacuum filtration unit with Nucleopore filter paper of pore size 0.4 μ m and 25mm diameter. The prepared samples were investigated using PIXE facility at Department of Physics, Panjab University, Chandigarh. All measurement were carried out with collimated 2.7 MeV proton beam of 5-9 nA beam current, from the cyclotron facility at Panjab University. The x-ray were measured with and without aluminium absorber of appropriate thickness, using a planar HPGe detector with Be window thickness of 25 μ m having FWHM 180 eV at 5.9 keV. The efficiency and energy calibration was carried out using standard radioactive sources.

The off-line analysis is being carried out using GUPIX software package [2] installed at Department of Physics, Panjab University. Analysis is under way and results will be presented during the conference.

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Behavior of the Strange Sector ΛN and ΛNN Potentials in ${}_{\Lambda}^4\text{H}$ Hypernucleus

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ABSTRACT

Strangeness degree of freedom can be experimentally implanted into a nucleus as the bound states of strange hadrons. The hypernuclei containing one or more quanta of hyperons play an important role to understand the hyperon-nucleon (YN) and hyperon-hyperon (YY) interactions which is otherwise very difficult. The hypernuclear systems as a finite nucleus and also infinite body systems as in hyperon stars provide a unique opportunity to enhance our knowledge about the role of strangeness in a nuclear medium of different densities. Moreover, the study of hypernuclei clarifies many interesting phenomenon related to heavy-ion physics, particle physics, neutron stars and astrophysics. Strangeness degree of freedom when injected to a bound nucleus may induce many dynamical changes to the nuclear structure. Since YN scattering experiments data are scarce and so-far proposed YN interactions have great ambiguities. Therefore, it is imperative to perform hypernuclear structure calculations which provide useful information on YN and YY interactions. Few-body calculations of light hypernuclei are essentially important not only to explore their binding energies but also to know more about the Λ -nuclear interactions, particularly on their spin dependence. Recently, we performed a variational Monte Carlo study of ${}_{\Lambda}^4\text{H}$ and ${}_{\Lambda}^4\text{H}^*$ hypernuclei [1] using two- and three-baryon interactions and a fully correlated wave function (WF). In conjunction with our earlier study of ${}_{\Lambda}^5\text{He}$ [2] and ${}_{\Lambda\Lambda}^6\text{He}$ hypernuclei [3], we investigate the effect of the strange sector potential strengths on the energy breakdown and present a clear understanding of their interplay in ${}_{\Lambda}^4\text{H}$ hypernucleus. For non-strange sector, we used two-body Argonne v_{18} potential along with Urbana IX (UIX) three-body potential. For strange sector, a ΛN two-pion exchange potential with spin and space-exchange component is used and a three-body two-pion exchange interaction with strongly dispersive ΛNN interactions are also included. The best variational wave function (WF) is constructed from pair- and triplet-correlation operators acting on uncorrelated single-particle Slater determinant. The operators in the WF consist of central, spin, isospin, tensor and three-baryon potential components. The WF takes into account all relevant correlations induced by two- and three-body potentials including ΛN space-exchange correlation (SEC) that arises due to space exchange potential

The findings of the investigation suggest that the strengths of the strange sector potentials affect every piece of energy significantly. As these potentials strengths are directly related to the expectation values of operators in Hamiltonian and also to the correlation functions in the WF. Hence, a change in any of the strength of these potentials may leads to appreciable change in the energy breakdown and also in the ground state energy. Thus, in order to present a clear understanding of the role of strange-sector potential strengths and their interplay in ${}_{\Lambda}^4\text{H}$ hypernucleus, there is a need to investigate the effects of these potential strengths on energy breakdown and also on the ground state energy. Also, the present investigation may establish the value of parameters appearing in the two- and three-body potentials in the strange sector.

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