Book of Abstracts

International Workshop
on
Physics with Recoil Separators
(PRS-26)

July 13-14, 2026

Venue:
Seminar Hall, Main Laboratory Complex
IUAC, New Delhi

Organized by:

Inter-University Accelerator Centre
Aruna Asaf Ali Marg, New Delhi 110067, India

Contents

Programme

International Workshop on Physics with Recoil Separators (PRS-26)

Day 1: Monday, July 13, 2026

Time	Activity / Technical Sessions
08:30 – 09:15	Registration
09:15 – 09:30	**Avinash Chandra Pandey** *(Director, IUAC, New Delhi, India)* **Opening Remarks**
	Session I: Chair - N. Madhavan
09:30 – 10:00	**Subir Nath** *(Nuclear Physics Group, IUAC, New Delhi, India)* **Recoil separators at IUAC: Status and plans**
10:00 – 10:30	**Aradhana Shrivastava** *(Nuclear Physics Division, Bhabha Atomic Research centre, Mumbai, India)* **Role of nuclear structure on reaction dynamics with stable and weakly bound stable nuclei**
10:30 – 11:00	**Dhruba Gupta** *(Department of Physical Sciences, Bose Institute, Kolkata, India)* **Transfer and breakup reactions with ^{7}Be**
11:00 – 11:30	Tea / coffee break
	Session II: Chair - A. M. Vinodkumar
11:30 – 12:00	**Bivash Ranjan Behera** *(Department of Physics, Panjab University, Chandigarh, India)* **Few physics possibilities with the recoil separators at IUAC**
12:00 – 12:30	**Moumita Maiti** *(Department of Physics, Indian Institute of Technology Roorkee, Roorkee, India)* **Exploration of near and sub-barrier fusion phenomena with ^{28,30}Si induced reactions in medium mass targets**
12:30 – 13:00	**E. Prasad** *(Department of Physics, Central University of Kerala, Kasaragod, India)* **Fusion dynamics in reactions forming medium heavy to heavy nuclei: Insights from the evaporation residue studies**
13:00 – 14:15	Lunch break

Time	Activity / Technical Sessions
	Session III: Chair - Aradhana Shrivastava
14:15 – 14:45	**Lorenzo Corradi** **[ONLINE]** *(Laboratori Nazionali di Legnaro, Legnaro, Italy)* **Nucleon-nucleon correlation effects studied in near and sub-barrier transfer reactions**
14:45 – 15:15	**Sophia Heinz** **[ONLINE]** *(GSI Helmholtz Center, Darmstadt, Germany)* **The SHIP velocity filter at GSI: How to catch a single nucleus**
15:15 – 15:45	**H. M. Devaraja** **[ONLINE]** *(Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia)* **In-flight separation and investigation of heavy multinucleon transfer products using the kinematic separator SHELS**
15:45 – 16:15	**Tea / coffee break**
	Session IV: Chair - Bivash Ranjan Behera
16:15 – 16:45	**Jagdish Gehlot** *(Nuclear Physics Group, IUAC, New Delhi, India)* **Investigation of fusion suppression in ^{16}O+^{203,205}Tl systems via ER-gated spin distributions**
16:45 – 17:15	**Gonika** *(Nuclear Physics Group, IUAC, New Delhi, India)* **Investigation of single- and two-nucleon transfer in ^{40}Ca+^{96}Zr and ^{116}Sn+^{60}Ni via coupled reaction channel approach**
17:15 – 17:45	**Chandra Kumar** **[ONLINE]** *(Department of Physics, Institute of Science Tokyo, Japan)* **From fusion barriers to nuclear shapes: Constraining nuclear deformation**
17:45	**Evening snacks**

Day 2: Tuesday, July 14, 2026

Time	Activity / Technical Sessions
	Session V: Chair - Dhruba Gupta
09:30 – 10:00	**Jennifer Pore** **[ONLINE]** *(Nuclear Science Division, LBNL, Berkeley, California, USA)* **Leveraging Recoil Separators for Chemical Studies of Superheavy Elements**
10:00 – 10:30	**Charles M. Folden III** **[ONLINE]** *(Cyclotron Institute, Texas A&M University, Texas, USA)* **Heavy element research with the AGGIE gas-filled separator at Texas A&M University**
10:30 – 11:00	**Fernando Montes** **[ONLINE]** *(FRIB, Michigan State University, East Lansing, Michigan, USA)* **Direct measurements of capture reactions with SECAR at FRIB**
11:00 – 11:30	Tea / coffee break
	Session VI: Chair - Rajesh Pratap Singh
11:30 – 12:00	**G. Mukherjee** *(Physics Group, Variable Energy Cyclotron Centre, Kolkata, India)* **Exploring nuclear structure physics with recoil separators: Why and how**
12:00 – 12:30	**Juha. Uusitalo** **[ONLINE]** *(Department of Physics, JYFL-ACCLAB, University of Jyväskylä, Finland)* **RITU and MARA, three decades of nuclear spectroscopy at JYFL-ACCLAB**
12:30 – 13:00	**A. Isaev** **[ONLINE]** *(Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia)* **Prompt neutron emission from spontaneous fission of superheavy elements using SHELS and GRAND recoil separators**
13:00 – 14:15	Lunch break

Time	Activity / Technical Sessions
	Session VII: Chair - Gopal Mukherjee
14:15 – 14:45	**A. M. Vinodkumar** *(Department of Physics, Calicut University, Calicut, India)* **Sub-barrier fusion enhancement and the role of hexadecapole deformation in the $^{16}O+^{170,172,174,176}Yb$ reactions**
14:45 – 15:15	**Giovanna Montagnoli** **[ONLINE]** *(Department of Physics & Astronomy, University of Padova, Padova, Italy)* **Investigating fusion hindrance in medium-light systems: A pathway to understanding astrophysical processes**
15:15 – 15:45	**Indranil Mazumdar** *(Dept. of Nucl. & Atomic Physics, Tata Institute of Fundamental research, Mumbai, India)* **Probing nuclear collective motion at finite temperature and angular momentum: The fusion-fission Route**
15:45 – 16:15	Tea / coffee break
	Session VIII: Chair - Indranil Mazumdar
16:15 – 16:45	**T. Cap** **[ONLINE]** *(National Centre for Nuclear Research, Warsaw, Poland)* **Probing the fusion probability with gamma-ray multiplicities**
16:45 – 17:15	**Anagha Chakraborty** *(Department of Physics, Visva-Bharati, Santiniketan, India)* **Investigation of nuclear level structure and reaction dynamics using Nd-isotopes**
17:15 – 17:45	**Neeraj Kumar** **[ONLINE]** *(Norwegian Nuclear Research Center, University of Oslo, Oslo, Norway)* **Isotopic mapping of the fission γ-bump: New insights from PARIS@VAMOS**
17:45	Evening snacks

Recoil separators at IUAC: Status and plans

S. Nath

Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India
Email: subir@iuac.res.in

The genesis of recoil separators can be traced back to over a century ago, with the pioneering work of Aston [1] in developing a mass spectrograph to study naturally occurring stable nuclides. These devices [2] utilise electric and magnetic fields to manipulate the trajectories of nuclear reaction products, offering high selectivity for channels of interest and excellent suppression of the primary beam background. Over the last several decades, recoil separators have played crucial roles in investigating both nuclear reaction dynamics and nuclear structure.

Inter-University Accelerator Centre (IUAC) is home to two modern recoil separators: the Heavy Ion Reaction Analyzer (HIRA) [3,4], a recoil mass spectrometer, and the HYbrid Recoil mass Analyzer (HYRA) [5], a dual-stage, dual-mode recoil separator and spectrometer. The first stage of the HYRA, which has been operational for the last fifteen years, is designed for use as a gas-filled separator.

The HIRA has been primarily used for the study of heavy ion-induced fusion dynamics and multi-nucleon transfer reactions for over three decades. It has also been employed to produce ultra-pure low energy secondary (^{7}Be) beam [6,7]. Studies with the HYRA, on the other hand, focused on fusion-fission dynamics in heavy mass region. These two recoil separators have played a pivotal role for the IUAC user community in investigating heavy-ion-induced reaction dynamics [8].

The current focus in the HIRA is to carry out experiments with low energy ^{7}Be beam and to study quasielastic and multi-nucleon transfer reactions in intermediate mass systems. Keeping in mind the availability of a variety of beams from the High Current Injector in near future, there are plans to augment the capabilities of the HYRA. These include commissioning of the complete layout of the second stage, installation of a differential pumping station for window-less beam injection into the separator and upgrading the focal plane detection system. The HYRA coupled with the Indian National Gamma Array (INGA) will open up new possibilities for recoil-tagged γ-spectroscopy.

In this talk, I shall present the current status, discuss some recent results and outline future possibilities with the two recoil separators.

References:

[1] F. W. Aston, Philos. Mag. **38**, 707 (1919).
[2] H. A. Enge, in Treatise on Heavy Ion Science, Ed. D. A. Bromley, Vol 7 (1985).
[3] A. K. Sinha et al., Nucl. Instrum. Methods A **339**, 543 (1994).
[4] S. Nath, Nucl. Instrum. Methods A **576**, 403 (2007).
[5] N. Madhavan et al., Pramana - J. Phys. **75**, 317 (2010).
[6] J. J. Das et al., Nucl. Instrum. Methods B **241**, 953 (2005).
[7] S. Nath *et al.*, Proc. DAE Symp. Nucl. Phys. **69**, 1243 (2025).
[8] S. Muralithar et al., Eur. Phys. J. A **58**, 250 (2022).

Role of nuclear structure on reaction dynamics with stable and weakly bound stable nuclei

A. Shrivastava

Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India
Email: aradhana@barc.gov.in

There is a rich interplay between nuclear structure and reaction dynamics at energies around the Coulomb barrier. This gets reflected in various reaction channels such as fusion, fusion-fission, elastic scattering, inelastic scattering, transfer, breakup reactions etc. The phenomenon of fusion hindrance, observed initially in symmetric systems involving medium-heavy nuclei at deep sub-barrier energies, has inspired current activities related to challenging low cross-section measurements. We have investigated the evolution of the fusion hindrance as a function of increasing mass and charge of relatively light projectiles (both weakly bound and stable) on heavy targets. The influence of shell effects and quasifission in the mass and total kinetic energy distribution in case of pre-actinides is another important area of research. In this talk results from our recent measurements performed at Pelletron LINAC facility will be presented.

Transfer and breakup reactions with ^{7}Be

D. Gupta

Department of Physical Sciences, Bose Institute, EN 80 Sector V, Bidhannagar, Kolkata, 700091, India
Email: dhruba@jcbose.ac.in

Transfer and breakup reactions involving loosely bound stable and unstable nuclei provide crucial insights into nuclear reactions and astrophysics. We carried out experiments on transfer and breakup reactions involving the ^{7}Be nucleus at the HIE-ISOLDE radioactive ion beam facility of CERN. Consequently, we explored the well-known cosmological lithium problem, which delineates a serious anomaly between big-bang nucleosynthesis (BBN) calculations and the observed abundance of ^{7}Li. We also investigated the α-capture reaction ^{12}C(α,γ)^{16}O, known as the “holy grail of nuclear astrophysics”, which determines the C/O abundance ratio in stars and ultimately the evolution of life in the universe. Our measurements of the first exclusive breakup of ^{7}Be on a light-mass target show significant contribution from breakup reactions. The differentiation between prompt and delayed breakup from the data helped in understanding the differences in breakup dynamics or the effects of weak binding on fusion. Such reaction studies involving rare isotope beams are very helpful for a detailed understanding of nuclei and the origin of the elements in the universe.

A few physics possibilities with the recoil separators at IUAC

B. R. Behera

Department of Physics, Panjab University, Chandigarh 160014, India
Email: bivash@pu.ac.in

In the last three decades research has been carried out with the two Recoil Separators at IUAC utilizing Pelletron and Pelletron+LINAC beams. Various experiments, mainly to understand many interesting features of fusion and fusion-fission mechanisms, have been undertaken.

Understanding direct fusion mechanism is still an open problem. Possibility of a few careful measurements may be explored with the existing recoil separator and with the future up-gradation. In addition, few examples of transfer reaction with existing beam species will be discussed in the talk. Interesting possibilities also exist with the light radioactive beams from these separators. Overall I shall discuss a few physics prospects with these two experimental facilities.

Exploration of near and sub-barrier fusion phenomena with ^{28,30}Si induced reactions in medium mass targets

Moumita Maiti

Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, India
Email: moumita.maiti@ph.iitr.ac.in

Heavy-ion fusion reactions near and below the Coulomb barrier have been extensively studied [1] due to their importance in understanding fundamental aspects of quantum tunneling. Enhancement in measured sub-barrier fusion cross sections by a few orders of magnitude over the predictions of the one-dimensional barrier penetration model has been observed in many systems. The reason of this enhancement is predominantly attributed to various internal degrees of freedom of the colliding nuclei, such as deformation, collective vibrations, or positive Q-value neutron transfer (PQNT) channels. Although the influence of inelastic excitations is explained well, the exact role of PQNT channels in sub-barrier fusion remains an unresolved question. To investigate this aspect, we conducted experiments by bombarding pulsed beams of ^{28,30}Si and ^{32}S on enriched targets in the medium mass region at the HYbrid Recoil mass Analyzer (HYRA) and the Heavy Ion Reaction Analyzer (HIRA) facilities at IUAC, New Delhi. The evaporation residues and the target-like recoils were detected using position-sensitive multi-wire proportional counters mounted at the focal plane of the separators. The data were collected using the NIAS-MARS acquisition system and analyzed within the ROOT framework.

Fusion excitation functions (EFs) have been measured for the reactions ^{28}Si+^{158}Gd [2], ^{30}Si+^{156}Gd [3], ^{30}Si+^{140}Ce [4], ^{32}S+^{138}Ba, ^{28}Si+^{130}Te and ^{30}Si+^{128}Te. In addition, quasi-elastic scattering measurements have been performed to extract further information on barrier distributions and reaction dynamics. To examine the reason for the sub-barrier enhancement, coupled-channels calculations have been performed using the CCFULL code. Our analysis shows that the couplings of inelastic excitations alone are insufficient to explain the measured sub-barrier fusion enhancement, whereas the inclusion of $2n$-transfer noticeably improves the agreement between the measured data and theoretical calculations. The quasi-elastic measurements enabled us to determine the barrier distribution, which could be compared with that extracted from fusion EFs. The present studies signify that PQNT channels, along with the coupling of inelastic excitations, provide a significant enhancement. The detailed analyses of the fusion and quasi-elastic scattering data are in progress and are expected to provide further insight into the channel coupling effects governing heavy-ion fusion in the sub-barrier region.

References:

[1] B. B. Back *et al.*, Rev. Mod. Phys. **86**, 317 (2014).
[2] R. Prajapat *et al.*, Phys. Rev. C **107**, 064616 (2023).
[3] R. Prajapat *et al.*, Phys. Rev. C **105**, 064612 (2022).
[4] M. Sagwal *et al.*, Eur. Phys. J. A **60**, 172 (2024).

Fusion dynamics in reactions forming medium heavy to heavy nuclei: Insights from the evaporation residue studies

E. Prasad

Department of Physics, Central University of Kerala, Kasaragod 671325, India
Email: prasadenair@cukerala.ac.in

Nuclear fusion is known to be the mechanism that drives the entire universe, serving as the power source of stars and other explosive stellar environments. In the laboratory, fusion is the most established route to synthesize new, heavy and superheavy elements (SHE). Despite considerable advances in fusion studies, the complex dynamics underlying the fusion process have yet to be fully unravelled. The enhancement of fusion cross sections, particularly at sub-barrier energies, has been a longstanding observation and has been extensively investigated over the past several decades. Though the role of collective excitations of the reactants in enhancing fusion cross sections is fairly well known, the role of transfer channels and other important degrees of freedom are not fully understood. While fusion excitation function is reproduced reasonably well in many cases, the same coupling scheme failed to represent the barrier distribution in many cases. A reduction in fusion cross section has been observed in a few cases at above barrier energies, speculated to be due to dissipative effects. Contrary to the enhancement in fusion cross sections, significant reduction is observed in heavy systems, due to the onset of quasifission process. Fusion measurements in such cases provide valuable information about the fusion probability and survival probability of the compound nucleus against fission, which are crucial in SHE studies.

Measurement of evaporation residue (ER) cross section is inevitable in fusion studies. While ER cross section represents the total fusion cross section in lighter compound nuclei, the sum of fission and ER cross section defines fusion cross section for heavier systems. Recoil mass separators / spectrometers provide the cleanest method for ER cross section measurements. In the present talk, I will be discussing the fusion dynamics of nuclei populated in 140-180 u mass regions, at energies around the Coulomb barrier. Further fission and fusion hindrance observed in the heavy mass region ($A > 200$ u) will also be discussed in the talk.

Nucleon-nucleon correlation effects studied in near and sub-barrier transfer reactions

L. Corradi

Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, Legnaro, I-35020, Italy
Email: corradi@lnl.infn.it

Recently, we studied neutron-neutron [1,2] and proton-proton [3,4] correlation effects in near and sub-barrier transfer reactions, measuring a complete set of observables – mass, nuclear charge, Q-value distributions and cross sections. Comparisons have been made with theoretical models, properly selecting nuclei with superfluid and closed shell structure [5,6].

We also exploited the unique performance of the PRISMA spectrometer coupled to the AGATA gamma array to study a nuclear (alternating current (AC)) Josephson-like effect [7] in the system ^{60}Ni+^{116}Sn [5], directly testing for the first time the possible manifestation of Cooper pair behaviour, observed to date only in condensed matter physics.

In this talk I will present the latest results in the field, outlining the future possibilities offered by employing high resolution magnetic spectrometers and recoil spectrometers.

References:

[1] S. Szilner *et al.*, Phys. Rev. Lett. **133**, 202501 (2024).
[2] J. Diklic *et al.*, Phys. Rev. C. **107**, 014619 (2023).
[3] L. Corradi *et al.*, Phys. Lett. B **834**, 137477 (2022).
[4] T. Mijatovic, Phys. Lett. B **872**, 40085 (2026).
[5] D. Montanari *et al.*, Phys. Rev. Lett. **113**, 052601 (2014).
[6] C. Cook *et al.*, Nature Comm. **14**, 7988 (2023).
[7] G. Potel, F. Barranco, E. Vigezzi, and R. A. Broglia, Phys. Rev. C **103**, L021601 (2021).

The SHIP velocity filter at GSI: How to catch a single nucleus?

Sophia Heinz

GSI Helmholtzzentrum für Schwerionenforschung, GmbH, 64291 Darmstadt, Germany
Email: S.Heinz@gsi.de

For meanwhile 50 years, the Separator for Heavy Ion reaction Products (SHIP) at GSI Helmholtz Center in Darmstadt has been one of the most successful recoil separators for studying heavy and superheavy fusion-evaporation residues. Its combined electric and magnetic fields separate nuclei according to their velocities, allowing SHIP to filter rare reaction products from an overwhelming background of beam particles and unwanted fragments before single-nucleus identification takes place in the detection system. This capability enabled the discovery of six new superheavy elements and many previously unknown isotopes, and SHIP continues to be a key instrument for precision studies of heavy and superheavy nuclei.

In this presentation, I will introduce the operating principles of the SHIP velocity filter, present the detection techniques that make single-nucleus identification possible, and present examples of the physics that can be explored with such a device.

In-flight separation and investigation of heavy multinucleon transfer products using the kinematic separator SHELS

H. M. Devaraja

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, 141980, Russia
Email: devaraja@jinr.ru

Multinucleon transfer (MNT) reactions offer a promising pathway for the production and study of neutron-rich nuclei in the heavy and superheavy element regions [1]. The majority of undiscovered nuclei in these regions are expected to exhibit extremely short half-lives and production cross-sections well below the microbarn range, thus demanding highly efficient separation and detection techniques to enable their identification.

In this context, the applicability of the Separator for Heavy ELement Spectroscopy (SHELS) for MNT studies has been investigated through several collision systems involving Pb and Bi targets [2,3]. The results demonstrate that asymmetric reaction systems can be successfully employed with SHELS to study above-target MNT products. Approximately 40 directly populated α-decaying nuclei have been identified, involving up to an eight-proton transfer from projectile to target, with cross-sections down to the nanobarn level and half-lives as short as a few microseconds.

In this talk, the experimental approach, identification methods, and measured production cross-sections of heavy MNT products will be presented and discussed. The potential of in-flight separators for future investigations of neutron-rich heavy nuclei, particularly with optimized separator settings and high-intensity beams, will also be addressed. In addition, the design of a new kinematic separator, the Separator for Transactinide Research (STAR), to be developed at FLNR, JINR (Dubna), will be introduced [4,5]. This project will be carried out alongside the modernization of the U400 cyclotron (U400R).

References:

[1] S. Heinz and H. M. Devaraja, Eur. Phys. J. A **58**, 114 (2022).
[2] H. M. Devaraja, A. V. Yeremin, M. L. Chelnokov, V. I. Chepigin, S. Heinz, *et al.*, Phys. Lett. B **862**, 139353 (2025).
[3] H. M. Devaraja, A. I. Svirikhin, S. Heinz, A. V. Isaev, I. N. Izosimov, *et al.*, Braz. J. Phys. **56**, 70 (2026).
[4] H. M. Devaraja, A. V. Yeremin, S. Heinz, and A.G. Popeko, Phys. Part. Nucl. Lett. **19**, 693 (2022).
[5] A. V. Yeremin, "Prospects of investigation of multinucleon transfer reactions", in Proceedings of the Programme Advisory Committee for Nuclear Physics, January 30-31, 2020, Dubna, Russia.

Investigation of fusion suppression in ^{16}O+^{203,205}Tl systems via ER-gated spin distributions

Gonika[1], J. Gehlot[1,*], S. Nath[1], I. Mazumdar[2] , T. Varughese[1], Tathagata Banerjee[1,†], A. Shamlath[3], P. V. Laveen[3], M. Shareef[3,‡], P. Jisha[4], P. Sandya Devi[5], G. Naga Jyothi[5,§], Yashraj[1], V. I. Chepigin[6], M. L. Chelnokov[6], A. V. Yeremin[6,¶] , A. M. Vinodkumar[4], and N. Madhavan[1]

[1]*Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India*
[2]*Tata Institute of Fundamental Research, Mumbai 400005, India*
[3]*Department of Physics, Central University of Kerala, Kasaragod 671314, India*
[4]*Department of Physics, University of Calicut, Calicut 673635, India*
[5]*Department of Nuclear Physics, Andhra University, Visakhapatnam 530003, India*
[6]*Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna 141980, Russia*
Email: jagdishgehlot@iuac.res.in

Evaporation residues (ERs), being the clearest signature of compound nucleus (CN) formation, serve as an effective probe for studying fusion dynamics. Their spin distributions provide insight into the angular momenta contributing to the fusion process. Although angular momentum distributions have been studied for several light and medium-mass systems, data for heavy nuclei ($A > 200$) remain limited, where fission and quasifission strongly affect reaction dynamics. Systematic studies of ER cross sections and spin distributions in this mass region would help in investigating the fusion–fission competition, the role of nuclear deformation and shell effects on ER formation, and their survival against fission [1].

In our previous work, ER cross sections were measured for the systems ^{16}O+^{203,205}Tl, where evidence of non-compound nuclear fission (NCNF) was observed in both reactions [2]. A detailed investigation of the partial waves contributing to CN and NCNF processes is therefore of considerable interest. In the present study, we aim to investigate the ER-gated spin distributions for the reactions ^{16}O+^{203,205}Tl.

The experiment was carried out using a pulsed ^{16}O beam, from the 15UD Pelletron at IUAC, New Delhi [3], on ^{203}Tl and ^{205}Tl targets [4]. ERs were separated from the background using the first stage of the HYbrid Recoil mass Analyzer (HYRA) [5] operated in gas-filled mode. The TIFR 4π spin spectrometer [6], with 32 NaI detectors surrounding the target chamber, measured γ-fold distributions from the de-exciting compound nuclei ^{219}Ac and ^{221}Ac. The raw γ-fold spectra were gated with ERs at each E_{lab} to obtain ER-gated γ-fold distributions. ER-gated γ-fold distributions were converted to γ-multiplicity distribution using a detector response matrix generated through a recursive algorithm [7]. The ℓ-distribution was derived from the γ-multiplicity distribution using a generalized relation [8] between the mean γ-multiplicity $\langle M_\gamma \rangle$ and the mean angular momentum $\langle \ell_{\mathrm{CN}} \rangle$, based on the CN decay scheme. Complementary theoretical calculations have been performed using the statistical model code VECSTAT [9]. Model parameters were optimised for the CN ^{221}Ac by reproducing the ER cross-sections for the reactions ^{12}C+ ^{209}Bi (forming the same CN as for the reaction ^{16}O+^{205}Tl), where the NCNF contribution is least expected. Same parameters were used for calculating spin distribution for both the systems, which overpredicted the experimental spin distribution. This depletion of the experimental angular momenta is attributed to the presence of NCNF in these systems.

References:

[1] D. Ackermann *et al.*, Eur. Phys. J. A **20**, 151 (2004).
[2] J. Gehlot *et al.*, Phys. Rev. C **99**, 034615 (2019).
[3] D. Kanjilal *et al.*, Nucl. Instrum. Methods A **328**, 97 (1993).
[4] J. Gehlot *et al.*, J. Radioanal. Nucl. Chem. **305**, 755 (2015).
[5] N. Madhavan *et al.*, Pramana – J. Phys. **75**, 317 (2010).
[6] G. Anil kumar *et al.*, Nucl. Instrum. Methods A **76**, 611 (2009).
[7] A. Maj *et al.*, Nucl. Phys. A **571**, 185 (1994).
[8] A. M. Stefanini *et al.*, Nucl. Phys. A **548**, 453 (1992).
[9] Tathagata Banerjee *et al.*, Phys. Lett. B **776**, 163 (2018).

[*] Presenting author
[†] Present address: Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, 80126 Napoli, Italy
[‡] Present address: Department of Physics, National Institute of Technology, Calicut, India
[§] Present address: Lendi Institute of Engineering and Technology, Vizianagaram
[¶] Deceased

Investigation of single- and two-nucleon transfer in ^{40}Ca+^{96}Zr and ^{116}Sn+^{60}Ni via coupled reaction channel approach

Gonika[1,2,*], Chandra Kumar[1,†], Yashraj[1,2] and S. Nath[1]

[1] *Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India*
[2] *Department of Physics, Panjab University, Chandigarh 160014, India*
Email: gonika@iuac.res.in

Heavy-ion-induced transfer reactions provide a powerful means to explore specific features of nuclear structure and reaction dynamics. Single-nucleon transfer reactions are particularly valuable for examining single-particle characteristics, whereas two-nucleon transfer reactions offer insight into pairing correlations in nuclei [1]. Recently, experimental efforts have focused on investigating the transfer of a Cooper pair responsible for pairing correlations in heavy-ion reactions [2]. In recent years, advances in experimental techniques and computational methods have significantly improved the understanding of multi-nucleon transfer mechanisms in heavy-ion collisions [3]. A microscopic description of one- and two-nucleon transfer reactions has been successful in explaining the experimental data without the need for a normalization factor [4]. However, ambiguities remain in the choice of parameters and in the selection of the states to be coupled within the quantum mechanical framework [5].

In this context, reactions involving closed-shell nuclei are particularly interesting, as they provide favorable conditions for investigating the complex mechanisms of nucleon transfer. Experiments conducted for the systems ^{40}Ca+^{96}Zr and ^{116}Sn+^{60}Ni at energies close to the Coulomb barrier focused on the measurement of angular distributions, transfer probabilities, and γ-transitions associated with single- and two-nucleon transfer [6,7]. Earlier studies using semiclassical models could not adequately describe the transfer channels for these two systems.

In the present work, we have carried out a detailed theoretical investigation of the angular distributions and excitation functions for single- and two-nucleon transfer channels in the ^{40}Ca+^{96}Zr and the ^{116}Sn+^{60}Ni systems using microscopic coupled reaction channel (CRC) calculations with the code FRESCO [8]. Realistic inputs, supported by experimental evidence, have been employed in the CRC calculations to improve the reliability of the results. Our calculations incorporate microscopic double-folding Sẽao Paulo potentials [9] and include all important inelastic and transfer couplings based on observed γ-ray transitions, wherever available. Spectroscopic amplitudes are taken from large-scale shell-model calculations [10]. For two-nucleon transfer, different mechanisms, namely, sequential transfer, microscopic cluster transfer, and extreme cluster transfer have been considered to better describe the experimental data. Our calculations reproduce the experimental data very well, both in shape and magnitude, without the need for any normalization factor. For two-nucleon transfer, the extreme cluster mechanism is found to provide the best description of the data.

Good agreement between the theoretical predictions and the experimental data supports the validity of the adopted reaction model and the chosen nuclear structure inputs. Despite the overall success of the CRC framework for these two systems, certain limitations remain due to uncertainties in the identification of weak γ-transitions, truncations in the shell-model space affecting the spectroscopic amplitudes, and restrictions on coupling to all possible states arising from limited computational resources.

References:

[1] R. A. Broglia and A. Winther, Heavy-Ion Reactions, Addison-Wesley, Reading, MA, (1981).
[2] S. Szilner *et al.*, Phys. Rev. Lett. **133**, 202501 (2024).
[3] F. Cappuzzello et al., Prog. Part. Nucl. Phys. **128**, 103999 (2023); R. M. Pérez-Vidal *et al.*, Eur. Phys. J. A **59**, 114 (2023); H. M. Devaraja *et al.*, Eur. Phys. J. A **56**, 224 (2020); Chandra Kumar and S. Nath, EPJ Web of Conferences **306**, 01043 (2024).
[4] M Cavallaro *et al.*, Phys. Rev. C **88**, 054601 (2013); D. Carbone *et al.*, Phys. Rev. C **95**, 034603 (2017).
[5] Chandra Kumar *et. al.*, Eur. Phys. J. A **59**, 277 (2023).
[6] S. Szilner *et. al.*, Phys. Rev. C **76**, 024604 (2007); L. Corradi *et. al.*, Phys. Rev. C **84**, 034603 (2011); G. Montagnoli *et. al.*, Eur. Phys. J .A **15**, 351 (2002).
[7] L. Corradi, *et al.*, Phys. Lett. B **834**, 137477 (2022); D. Montanari *et al.*, Phys. Rev. Lett. **113**, 052501 (2014); D. Montanari *et al.*, Phys. Rev. C **93**, 054623 (2016).
[8] I. J. Thompson, Comput. Phys. Rep. **7**, 167 (1988); http://www.fresco.org.uk/
[9] L. C. Chamon *et. al.*, Phys. Rev. Lett. **79**, 5218 (1997); Comput. Phys. Commun. **267**, 108061 (2021).
[10] N. Shimizu *et. al.*, Comput. Phys. Commun. **244**, 372 (2019).

*Presenting author
†Present address: Department of Physics, Institute of Science Tokyo, Japan

From fusion barriers to nuclear shapes: Constraining nuclear deformation

Chandra Kumar[*,†], **S. Nath and collaborators**

Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India
Email: dwngn10chandra@gmail.com

Low-energy heavy-ion fusion reactions provide a sensitive probe of nuclear deformation through couplings between the relative motion and the intrinsic degrees of freedom of the interacting nuclei. In the present work, coupled-channels analyses of the fusion and quasielastic scattering excitation functions, together with the corresponding barrier distributions, have been performed for the systems ^{28}Si+^{144}Sm [1], ^{16}O+^{154}Sm [2], ^{36}S+^{140}Ce and ^{16}O+^{140}Ce [3] using a modified version of the CCFULL code. The fusion barrier distributions have been derived from the measured fusion excitation functions using a multi-Gaussian analytical prescription, which significantly reduces the ambiguities associated with the conventional point-difference method.

A combined analysis of fusion and quasielastic observables was carried out for the system ^{28}Si+^{144}Sm to investigate the ground-state deformation parameters of the target nucleus, followed by estimation of optimum uncertainties by a Bayesian technique. The extracted values of β_2 and β_4 remain ambiguous, as the calculated fusion and quasielastic barrier distributions are nearly identical whether ^{28}Si is treated as a rotational (prolate or oblate) or a vibrational nucleus. Moreover, the extracted deformation parameters differ significantly from some values reported in the literature based on quasielastic excitation function analyses.

These observations demonstrate the limitations of constraining deformation parameters using only one system and a restricted set of coupling schemes. To address this problem, we performed a comprehensive study of the ^{16}O+^{154}Sm system by considering various coupling schemes, including, rotational, octupole (3^-) and transfer couplings, and validated the extracted deformation parameters through a simultaneous description of the quasielastic barrier distribution of an independent (^{48}Ca+^{154}Sm) system. Similarly, for ^{140}Ce, the ground-state and dynamic deformation parameters (β_2 and β_3) were extracted independently from analyses of both the ^{16}O+^{140}Ce and ^{36}S+^{140}Ce systems. The resulting parameters were subsequently tested against the more complex ^{28}Si+^{140}Ce system to examine the consistency. For the first time, we demonstrate the consistency and robustness of the extracted ground-state deformation parameters of a nucleus across reactions induced by three distinct projectiles. The consistent reproduction of fusion and quasielastic observables across multiple reaction systems significantly enhances the credibility of the extracted deformation parameters.

References:

[1] Chandra Kumar and S. Nath, Phys. Lett. B **862**, 139319 (2025).
[2] Chandra Kumar and S. Nath, Extraction of ground state deformation parameters of ^{154}Sm via fusion barrier distribution, in Proceedings of The 29th International Nuclear Physics Conference (INPC 2025) (accepted).
[3] Chandra Kumar *et al.* (under review).

[*]Presenting author
[†]Present address: Department of Physics, Institute of Science Tokyo, Japan

Leveraging recoil separators for chemical studies of superheavy elements

Jennifer Pore

Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
Email: jpore@lbl.gov

Studies of superheavy elements (SHE, $Z > 104$) are possible only by producing a single atom at a time in nuclear reactions and then separating it from reaction by-products with recoil separators. Once isolated, unique gas-phase chemical experiments can be performed to determine the elements' fundamental properties and confirm their positions in the Periodic Table. A new program at Lawrence Berkeley National Laboratory now produces and directly identifies SHE molecules, providing the first glimpse of their expected unusual chemistry. The results of recent studies will be discussed. Recent results on the production and identification of actinium (Ac, $Z = 89$) and nobelium (No, $Z = 102$) molecules will be presented. Future directions for unraveling the mysteries of SHE chemistry will be discussed, challenging our current understanding of the Periodic Table.

Heavy element research with the AGGIE gas-filled separator at Texas A&M University

C. M. Folden III

Department of Chemistry, Texas A&M University, College Station, Texas, 77843 USA and Cyclotron Institute, Texas A&M University, College Station, Texas 77843 USA
Email: folden@comp.tamu.edu

In recent years, there have been multiple attempts to discover new elements using fusion-evaporation reactions that have projectiles with atomic numbers greater than 20. These experiments have not produced clear evidence for new element production, so the Heavy Elements Group at Texas A&M University in College Station, Texas, USA is currently studying the so-called "analog reactions" to better understand the factors that influence compound nucleus survival. In a recent study, we measured the excitation functions of the ^{44}Ca+^{154,156,157,160}Gd reactions [1] to understand the role of neutron number on survival, which appears to be a critical factor. Since then, we have commissioned the AGGIE gas-filled separator [2] in order to improve our sensitivity. We recently used it to study the ^{48}Ti+ ^{156,157,158,160}Gd,^{162,163,164}Dy reactions, and that analysis is ongoing. In the future, we will study ^{52}Cr projectiles reacting with similar targets.

Our group also has a vibrant program to conduct "online" chemistry experiments, where AGGIE is used as a pre-separator to remove unwanted reaction products and make ions of interest available for chemical studies. We have developed self-assembled monolayers (organic compounds that form a single molecular layer on an Au surface) as new surfaces for these experiments. We have characterized the surfaces using a variety of techniques, and have used them in an experiment to study the adsorption of Er, Po, and At. We have also used isothermal vacuum chromatography to chemically study nuclides with half-lives less than 1 s [3]. Future experiments will focus on chemistry experiments with short-lived Hg isotopes and ^{254}No.

We are also planning upgrades to improve the sensitivity of future experiments. In 2026, a new commercial ion source will be added to our K150 cyclotron to improve the intensity of medium-mass beams. We are also adding a new refrigeration system to provide liquid He for cryopanels in the K150 cyclotron to improve its vacuum. Finally, we are in the process of increasing the maximum field of the final AGGIE dipole to increase our maximum magnetic rigidity, which will increase the range of possible experiments.

This talk will discuss our most recent results and future plans.

References:

[1] T. A. Werke, C. S. Salas, K. J. Glennon, D. A. Mayorov, E. E. Tereshatov, M. F. Volia, D. M. Wright, and C. M. Folden III, Phys. Rev. C **106**, 054615 (2022).
[2] A. S. Kirkland *et al.*, Nucl. Instrum. Meth. A **1092**, 171801 (2026).
[3] G. Tiebel *et al.*, J. Phys. Chem. C **130**, 3058 (2026).

Direct measurements of capture reactions with SECAR at FRIB

Fernando Montes

Facility for Rare Isotope Beams, Michigan State University, East Lansing, Michigan 48824, USA
Email: montes@frib.msu.edu

Nucleosynthesis in novae, supernovae, and X-ray bursts is driven by nuclear reactions that have largely remained inaccessible to direct experimental study. Recent progress in astronomical observations and in tracing the chemical evolution of the Galaxy has improved our picture of stellar nucleosynthesis, while also raising new questions that can only be resolved through experimental measurements of key reactions on both stable and rare isotopes. SECAR (SEparator for CApture Reactions), operating at the Facility for Rare Isotope Beams (FRIB) at Michigan State University, enables direct measurement of radiative capture reactions on rare isotope beams, separating low-intensity recoil products from intense primary beams. In this talk I will summarize SECAR's design and demonstrated separation performance, and present results from recent capture reaction measurements. I will close with an outlook on the reach SECAR provides for addressing open questions on the origin of the elements.

Exploring nuclear structure physics with recoil separators: Why and how?

Gopal Mukherjee

Physics Group, Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata 700064, India
Email: gopal@vecc.gov.in

Primarily there are two types of complementary physics issues that can be pursued using recoil separators as far as the spectroscopic study is concerned for nuclear structure investigation: the prompt spectroscopy and delayed spectroscopy. In the prompt spectroscopy, the recoil or recoil decay tagging techniques are used to correlate the γ-rays detected at the target site with the residues or its decay (α-particle, electron or γ-ray) detected at the focal plane. In case of delayed spectroscopy, the γ-rays detected at the focal plane are correlated with the residues and/or its decay. In the latter case, the isomeric decays are studied having half-lives of the order of the transit time of the recoils through the separator. In principle, the ideal setup would be to detect both prompt and delayed γ-rays for complete spectroscopy of a nucleus including its isomer decay which is particularly important for heavy nuclei. The combination of HYRA and INGA is ideal for such complete studies. Spectroscopy using recoil separator is not only a powerful technique but is essential to investigate the structure of heavy nuclei above $Z = 82$, the production of which accompanies fission fragments. The fission fragments and the beam-like particles can be effectively separated out to get clean spectrum for the decay of heavy residues at the focal plane even for its low production cross-section. The study of the isomers and their decays in heavy nuclei are important to investigate the high-j single particle orbitals which are important for the stability of the superheavy nuclei. Many of the nuclei which are considered as the "door-way" nuclei to superheavies, are deformed. It has been found, *e.g.*, in ^{254}No, that the rotation survives up to a large angular momentum competing with its fission. The deformation provides extra stability against fission in such nuclei. This can be probed with prompt spectroscopy, gated by recoils which has low production cross section. For recoil decay tagging, one needs to adopt both spatial and temporal correlation. These will be discussed along with a few examples and problems those can be pursued at the focal plane of the HYRA and with the HYRA-INGA combined setup.

RITU and MARA, three decades of nuclear spectroscopy at JYFL-ACCLAB

Juha Uusitalo*

Department of Physics, JYFL-ACCLAB, University of Jyväskylä, Finland and
Department of Physics, Oliver Lodge Laboratory, University of Liverpool, UK
Email: juha.uusitalo@jyu.fi

The Nuclear Spectroscopy Group (NSG) at JYFL-ACCLAB is employing two complementary in-flight separators in their spectroscopic studies. Recoil Ion Transport Unit (RITU) [1] is a gas-filled recoil separator and has been in operation for 30 years. Mass Analyzing Recoil Apparatus (MARA) [2], is a vacuum-mode double focusing mass separator, has been in use for about 10 years. Separators are complementary and allow us to perform spectroscopic studies at and beyond the proton-drip line and in the Very Heavy Element (VHE) region starting from mass $A = 40$ onward. Separators can be occupied with detector setups at the target position and at the focal plane. At the target position, particle array JYtube as well as a Ge-array, JUROGAM, are used. Focal planes consist of gas counters, silicon detectors, and Ge detectors. This allows simultaneous prompt and delayed spectroscopy to be performed. Recoil separators combined with various auxiliary detector arrays has allowed new spectroscopic information to be dug out. In this presentation spectroscopic studies using MARA and RITU recoil separators will be presented.

References:

[1] J. Sarén, J. Uusitalo, M. Leino, and J. Sorri, Nucl. Instr. Meth. Phys. Res. A **654**, 508 (2011).
[2] J. Uusitalo, J. Sarén, J. Partanen, and J. Hilton, Acta Physica Polonica B **50**, 319 (2019).

*For the Nuclear Spectroscopy Group collaboration

Prompt neutron emission from spontaneous fission of superheavy elements using SHELS and GRAND recoil separators*

A. V. Isaev

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, 141980, Russia
Dubna State University, Dubna 141980, Russia and
Institute of Nuclear Physics, Almaty 050032, Kazakhstan
Email: isaev@jinr.ru

Experimental studies of the spontaneous fission of ^{258,260}Sg and ^{260}Rf isotopes were performed using the SHELS velocity filter. For the first time, prompt neutron multiplicities for these superheavy nuclei were measured, yielding average values of 4.9±0.4, 5.03±0.14, and 4.88±0.24, respectively.

The deployment of the SFiNx detection system has successfully opened up a new domain in spontaneous fission studies of superheavy elements. This approach will be extended to the GRAND separator at the SHE Factory to study heavier nuclei.

*This work was supported by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant Nos. BR28712431 and AP26195449).

Sub-barrier fusion enhancement and the role of hexadecapole deformation in the $^{16}O+^{170,172,174,176}Yb$ reactions

A. M. Vinodkumar

Department of Physics, University of Calicut, Malappuram 673635, India
Email: amv@uoc.ac.in

The influence of hexadecapole deformation (β_4) on sub-barrier fusion is a critical area of study, yet currently extracted β_4 values remain model dependent and subject to unresolved systematic uncertainties. To clarify the role of higher-order static deformations and investigate the isotopic dependence of fusion excitation functions, we have extended measurements across the complete $^{16}O+^{170,172,174,176}Yb$ isotopic chain. Evaporation residue (ER) cross sections for the $^{16}O+^{170,172}Yb$ reactions were measured using the Heavy Ion Recoil Analyzer (HIRA) at IUAC, New Delhi, spanning an energy range from 12% below to 35% above the Coulomb barrier. Our results reveal a strong sub-barrier fusion enhancement relative to predictions from the one-dimensional barrier penetration model (1D-BPM). The experimental data were analyzed using coupled-channels and statistical model frameworks. Coupled-channels calculations that incorporate both quadrupole (β_2) and and hexadecapole (β_4) deformations of the target nuclei successfully reproduce the measured fusion excitation functions. Single-Gaussian barrier distribution analysis identifies $^{16}O+^{174}Yb$ as having the largest sub-barrier enhancement in the chain, which is attributed to the midshell character ($N = 104$) of the ^{174}Yb nucleus. The statistical model calculations using a single fission barrier scaling factor($k_f = 1.10$) successfully reproduce ER and fission cross sections simultaneously, effectively ruling out non-compound nuclear fission (NCNF) contributions for these systems. This presentation will detail the role of β_4 across the entire Yb isotopic range. Additionally, we will present a broader systematics of single-Gaussian barrier parameters based on a study of approximately 100 nuclear systems.

Investigating fusion hindrance in medium-light systems: A pathway to understanding astrophysical processes

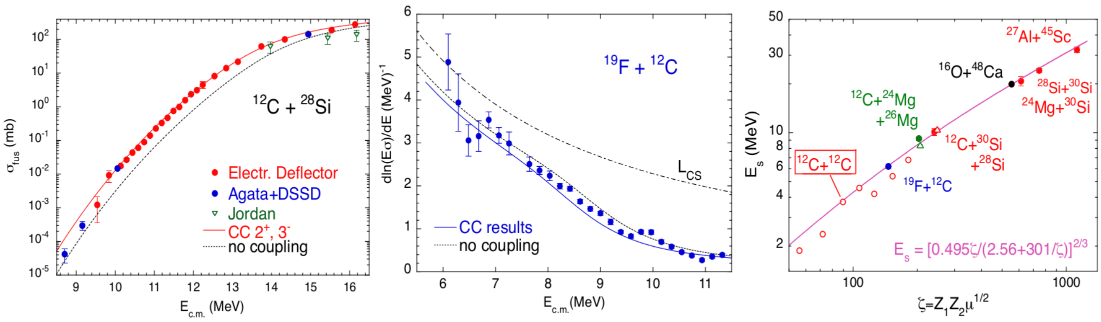
G. Montagnoli

Department of Physics and Astronomy, University of Padua, Padua, I-35020, Italy and INFN, Section of Padua, Padua, I-35020, Italy
Email: montagnoli@pd.infn.it

The physical mechanisms underlying the fusion hindrance phenomenon [1], which may be partly linked to the Pauli exclusion principle [2], have been investigated. Understanding this effect in light systems is important for astrophysics, as it may significantly influence stellar evolution and the nucleosynthesis of heavier elements [3]. However, experimental investigation in light systems with positive Q-values is particularly difficult due to observed S-factor oscillations in several cases.

Slightly heavier systems have been studied to provide a reliable basis for extrapolating to reactions such as ^{12}C+^{12}C and nearby systems. Recent investigations include ^{12}C+$^{28-30}$Si,$^{24-26}$Mg [4] and ^{16}O+^{48}Ca [5], where hindrance has been systematically observed. In the case of ^{12}C+^{28}Si [6], the fusion excitation function was measured down to ∼40 nb at the XTU Tandem accelerator of LNL (see left panel of the figure). This was achieved by detecting evaporated charged particles with DSSSD detectors in coincidence with prompt γ-rays identified by the AGATA spectrometer. Data from the PISOLO electrostatic deflector has provided a useful normalisation for the absolute cross-section scale.

A recent study has been performed for ^{12}C+^{19}F, which has also revealed the hindrance effect, as indicated by the logarithmic derivative of the cross sections reaching the $L_{\rm CS}$ limit (see centre panel). This system has a very large positive fusion Q-value of ∼23 MeV.



The threshold energy for the onset of hindrance across several medium-light systems with positive Q-values is shown in the right panel of the figure. The abscissa is the parameter ζ characterising the system [3] (where μ is the reduced mass). The magenta line is a phenomenological fit of the experimental systematics using the shown function. On the other side, the thresholds for several light systems going from ^{10}B+^{10}B to ^{16}O+^{16}O (open dots, plotted with increasing ζ) are extrapolations from their higher-energy cross sections using the hindrance model [1,3]. They were not included in the fit to the measured data for the slightly heavier systems, which leads to an extrapolation to the light ones, very close to the hindrance model results. In the talk, the experimental evidence will be examined in depth, offering a basis for discussing the conclusions that can be drawn from these measurements.

References:

[1] C. L. Jiang, *et al.*, Phys. Rev. Lett. **89**, 052701 (2002).
[2] C. Simenel *et al.*, Phys. Rev. C **95**, 032601(R) (2015).
[3] C. L. Jiang, *et al.*, Phys. Rev. C **75**, 015803 (2007); Phys. Rev. C **79**, 044601 (2009).
[4] G. Montagnoli and A. M. Stefanini, Eur. Phys. J. A **59**, 138 (2023).
[5] A. M. Stefanini *et al.*, Phys. Rev. C **111**, 064620 (2025).
[6] A. M. Stefanini *et al.*, Phys. Lett. B **872**, 140084 (2026).

Probing nuclear collective motion at finite temperature and angular momentum: The fusion-fission route

Indranil Mazumdar

Tata Institute of Fundamental Research, Colaba 400005, Mumbai, India
Email: indra@tifr.res.in

Studies in heavy-ion induced fusion-fission process has established itself as one of the major branches of low and medium energy nuclear structure and reaction physics. A plethora of dynamical processes manifest through the fusion-fission of two atomic nuclei over a wide range of projectile energy. The process of fission following fusion of two heavy nuclei or survival of the Compound Nucleus (CN) against fission and formation of Evaporation Residues (ER) are deeply connected with various factors like, nuclear shell structure, target-projectile mass asymmetry, projectile energy, angular momentum distribution in the CN etc. Other than studying the dynamical effect associated with fusion and subsequent fission (or survival against fission) of heavy CN, there is also the long-standing desire to understand formation of very heavy or Super Heavy Elements (SHE). In this talk we plan to review the present status of heavy-ion induced fusion-fission processes at energies above the Coulomb Barrier. We would like to touch upon aspects of fission followed by complete and incomplete fusion and processes like fast and quasi-fission. We will be primarily drawing from our measurements carried out at IUAC, New Delhi using the Hybrid Recoil mass Analyser (HYRA) coupled with the TIFR 4π Sum-Spin spectrometer. We will summarise what we have learnt so far and what are the unresolved problems. Detailed analyses using both statistical and dynamical model formalisms will be presented. We will also discuss the very important role of dissipative mechanism or nuclear viscosity in the survival of the CN against fission.

It is worth noting that the Giant Dipole Resonance (GDR) is another fascinating mode of nuclear collective motion. In this talk, we will make an effort to discuss the underlying fundamental aspects of correlated nuclear motion at finite temperature and angular momentum through two different but most prominent collective motions, fission and GDR. We will address the common link of viscosity and how far the collectivity exists, an evergreen question in GDR, but can also be invoked in fission physics.

Probing the fusion probability with gamma-ray multiplicities

Gonika[1], J. Gehlot[1], V. I. Chepigin[2], M. L. Chelnokov[2], T. Varughese[1], Tathagata Banerjee[1,*], A. Jhingan[1], T. Cap[3,†], Y. Jaganathen[3], M. Kowal[3], S. Nath[1], I. Mazumdar[4], N. Madhavan[1], and A. V. Yeremin[2,‡]

[1] *Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India*
[2] *Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna 141980, Russia*
[3] *National Centre for Nuclear Research, Pasteura 7, 02-093 Warsaw, Poland*
[4] *Tata Institute of Fundamental Research, Colaba 400005, Mumbai, India*
Email: tomasz.cap@ncbj.gov.pl

Quasi-fission (QF) is one of the main mechanisms hindering the formation of heavy and superheavy compound nuclei, yet the dependence of the fusion probability $P_{\rm fus}$ on the entrance-channel angular momentum ℓ remains poorly constrained. Different experimental observables sample different – and only partially overlapping – regions of the angular-momentum space: fission and QF fragments are dominated by high partial waves, whereas evaporation residues (EvR) are sensitive to the low-ℓ region that survives both QF and fission. A complete picture of the fusion-QF competition therefore requires combining complementary probes.

This contribution discusses what can be learned about $P_{\rm fus}(\ell)$ from the multiplicity of gamma-rays measured in coincidence with EvR. The comparison of EvR cross sections with statistical-model predictions yields only an average, ℓ-integrated suppression of fusion. The gamma-ray multiplicity distribution, by contrast, gives access to the shape of the EvR spin distribution, and thus to the ℓ-dependence of the fusion hindrance within the partial-wave window feeding the EvR channel. Such measurements can reveal whether the fusion suppression is uniform across partial waves – appearing as a simple scaling of the predicted distribution – or whether it depends on ℓ, in which case it manifests itself as a modification of the distribution's shape.

Such measurements are well suited to recoil separators and associated add-on setups, such as those at the Inter-University Accelerator Centre (IUAC), New Delhi. Particular attention will be given to the ^{19}F+^{197}Au reaction measured at IUAC, where EvR-gated spin-distribution measurements were carried out using the HYbrid Recoil mass Analyzer (HYRA), operated in the gas-filled mode, coupled with the 4π spin spectrometer. The analysis is performed in comparison with statistical-model calculations for the QF-free reference reaction ^{12}C+^{204}Pb, leading to the same compound nucleus ^{216}Ra.

[*] Present address: INFN, Sezione di Napoli, 80126 Napoli, Italy
[†] Presenting author
[‡] Deceased

Investigation of nuclear level structure and reaction dynamics using Nd-isotopes*

Anagha Chakraborty

Department of Physics, Siksha Bhavana, Visva-Bharati, Santiniketan 731235, India
Email: anagha.chakraborty@visva-bharati.ac.in

The well planned research works have been carried out both in the fields of nuclear spectroscopy and nuclear reaction dynamics using different stable Nd-isotopes as the target materials. Several interesting findings have been obtained from such investigations. The research facilities available at IUAC, New Delhi as well as in other places have been effectively used for these investigations. The results obtained from the experiments performed with different experimental setups would be highlighted during the presentation. The proposed plan of research works to be carried out by our group in the very near future would also be discussed.

*Help and support received from all the collaborators in different stages of the works carried out over a long period of time are deeply acknowledged. Financial assistance received from SERB (File No.: CRG/2021/004680) and IUAC (Project Code No.: UFR 71344) is gratefully acknowledged.

Isotopic mapping of the fission γ-bump: New insights from PARIS@VAMOS

N. Kumar[1,*,†], C. Schmitt[1,2], M. Ciemala[2], A. Maj[2], A. Lemasson[3], D. Ramos[3], M. Rejmund[3], et al.

[1] *Institut Pluridisciplinaire Hubert Curien, CNRS/IN2P3-UDS, Strasbourg Cedex 2, 67037, France*
[2] *Institute of Nuclear Physics Polish Academy fo Sciences, Krakow, 31-342, Poland*
[3] *GANIL, CEA/DRF-CNRS/IN2P3, BP 55027, Caen Cedex 5, 14076, France*
Email: neeraj.kumar@fys.uio.no

Nuclear fission produces two highly excited fragments which rapidly fly apart and return to equilibrium through the emission of prompt neutrons and γ-rays. In the Prompt Fission γ Spectrum (PFGS), an excess of γ-ray yield between approximately 3 and 8 MeV, known as the "γ-bump", has been known since the 1980s [1,2] but has remained poorly understood for decades. Its origin, in terms of which fragment emits it and what nuclear structure underlies it, has been the subject of ongoing debate [3,4].

In a recent work, we reported the first isotopically resolved mapping of the fission γ-bump, obtained through an innovative experimental approach at the GANIL facility in France. Fission was induced in inverse kinematics via ^{238}U+^{9}Be at 5.8 MeV/u. The experiment combined, for the first time, two state-of-the-art setups: the heavy-ion spectrometer VAMOS++ [5] and the scintillator array PARIS [6]. The former uniquely identified fission fragments in both mass and charge, while the latter provided access to coincident γ-ray energy and timing. This unique coupling enabled a systematic measurement of the PFGS as a function of the fragment proton number Z and neutron number N across the entire fission-fragment production.

The γ-bump is found to be prominent for heavy fragments with charges around $Z = 50 - 53$. To understand this observation, the experimental findings are compared with calculations using the FIFRELIN Monte Carlo code [7], implementing microscopic nuclear level densities and γ-strength functions within the Quasi-Particle Random Phase Approximation (QRPA). The calculations reproduce the main experimental trends, and a multipolarity decomposition of the theoretical PFGS was also performed. Analysis of the underlying transition densities suggests characteristics similar to those of Pygmy Dipole Resonance (PDR) states [8].

This work thus establishes, for the first time, a direct connection between the fission γ-bump and the Pygmy Dipole Resonance, promoting fission as a novel and complementary tool for studying soft dipole modes across a wide range of neutron-rich nuclei simultaneously.

References:

[1] P. Glaessel *et al.*, Nucl. Phys. A **502**, 315c (1989).
[2] D. Biswas *et al.*, Eur. Phys. J. A **4**, 343 (1999).
[3] H. Makii *et al.*, Phys. Rev. C **100**, 044610 (2019).
[4] A. Francheteau *et al.*, Phys. Rev. C **111**, 034608 (2025).
[5] A. Lemasson, M. Rejmund *et al.*, Nucl. Instrum. Meth. A **1054**, 168407 (2023).
[6] A. Maj *et al.*, Acta Phys. Pol. B **40**, 565 (2009).
[7] O. Litaize *et al.*, Eur. Phys. J. A **51**, 177 (2015).
[8] A. Bracco, E. Lanza, A. Tamii, Prog. Part. Nucl. Phys. **106**, 360 (2019).

*Presenting author
†Present address: Norwegian Nuclear Research Center, University of Oslo, Oslo, Norway