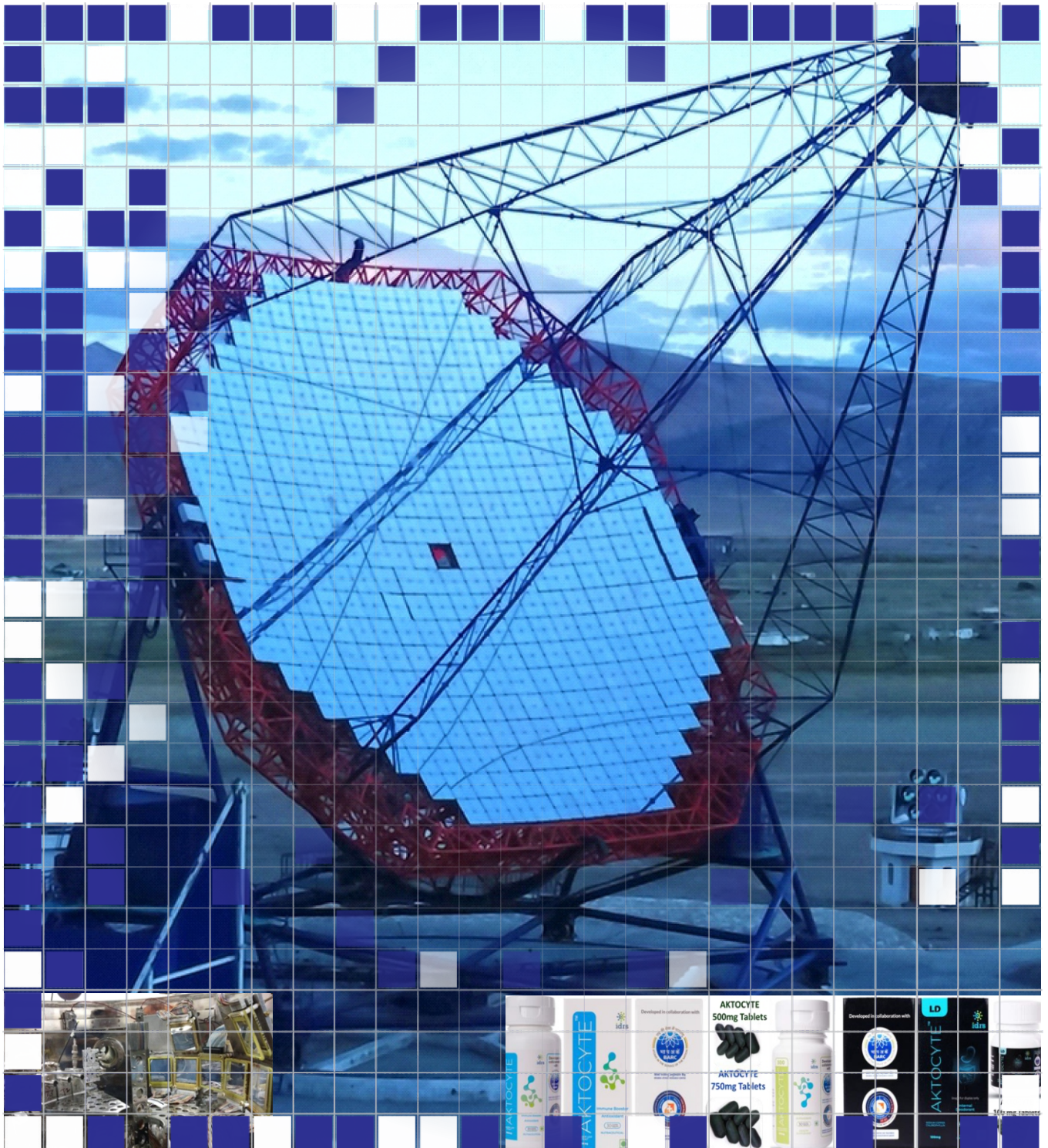


FRONTIERS IN BASIC RESEARCH



FRONTIERS IN BASIC RESEARCH

articulates DAE's vision to strengthen India's scientific, technological, and healthcare frontiers through fundamental research across its premier R&D centres. It lays out a multi-disciplinary roadmap encompassing the domains of physics, chemistry, materials science, biology, and health physics to drive significant progress in atomic energy.

In physics, the initiative focuses on establishing advanced national facilities at MACE in Ladakh for gamma-ray astronomy, high-energy heavy-ion accelerators, and a next-generation radioactive ion beam complex at BARC Vizag. It also prioritizes leadership in quantum technologies through the proposed Centre for Advanced Quantum Computing and the indigenous development of scalable multi-qubit systems for quantum computing and information processing.

In chemistry and materials science, thrust areas include the development of innovative nuclear fuels, molten salt reactor materials, advanced fuel cycle technologies, and high-performance materials for laser and accelerator applications. Some of the other initiatives target indigenous helium recovery and eco-friendly, lead-free radiation shielding materials for both nuclear and medical uses.

The life sciences component highlights novel cancer therapies such as boron and gadolinium neutron capture techniques, radiobiology of charged particles, and the proposed Centre of Excellence in Biophotonics for advanced optical diagnostics and therapeutic innovations. Programmes in health physics focus on next-generation dosimetry, optically stimulated luminescence detectors, space radiation effects, and enhanced radiation monitoring systems. Together, these initiatives reflect DAE's commitment to self-reliance and societal advancement through atomic research.

Physics Research

MACE Detection of Blazar OP 313: The MACE telescope covers an energy range of 30 GeV-5 TeV, while TACTIC operates over 1-20 TeV, complementing MACE by extending coverage to higher energies. On 26 January 2025, MACE detected the blazar OP 313, a member of the rare Flat Spectrum Radio Quasar (FSRQ) subclass; only about ten such sources are known in the Very High Energy (VHE; $E > 30$ GeV) gamma-ray band. FSRQs, among the brightest

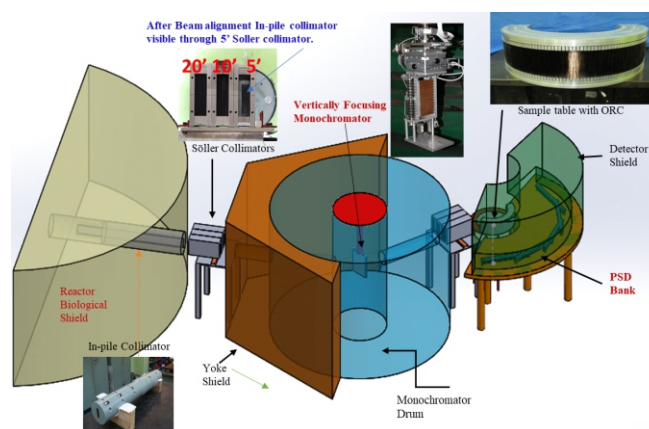
extragalactic objects, are key to probing emission mechanisms underlying Very High Energy gamma rays, whether leptonic or hadronic in origin. Located approximately 8 billion light-years away, OP 313 emitted these photons when the universe was less than half its current age, making it the most distant VHE blazar known and a valuable probe of early cosmic conditions.

Research at NFNBR, Dhruva Reactor: During the past year, NFNBR facilities served about 290 users from across India. Experiments at various beamlines resulted in roughly 145 publications in reputed international journals, with an average impact factor of 4.3. Key highlights are summarized below.

Helical Magnetic Structure at Ni/Gd Interfaces: Studies at the Dhruva reactor using polarized neutron reflectivity (PNR) revealed a twisted magnetic phase at Ni/Gd interfaces due to strong antiferromagnetic coupling between Ni (transition metal) and Gd (rare earth). A 1D spin model confirmed a helical spin structure arising from interfacial intermixing. The observation of this helical phase at room temperature opens new avenues to control magnetic properties for advanced memory storage technologies.

Exotic Magnetic State in $\text{Ca}_3\text{LiRuO}_6$: Investigations using neutron powder diffraction on Powder Diffractometer-I uncovered a canted antiferromagnetic ground state in $\text{Ca}_3\text{LiRuO}_6$. This behavior stems from spin-orbit coupling-induced anisotropic exchange in an orbitally quenched Ru^{5+} system. The results establish $\text{Ca}_3\text{LiRuO}_6$ as an ideal material to study weak ferromagnetism and spin canting driven by spin-orbit and lattice interactions in $4d^3$ oxides.

Upgrades at Dhruva for Probing Local Structure: The High-Momentum Transfer Diffractometer (High-Q) underwent major upgrades, including replacing the



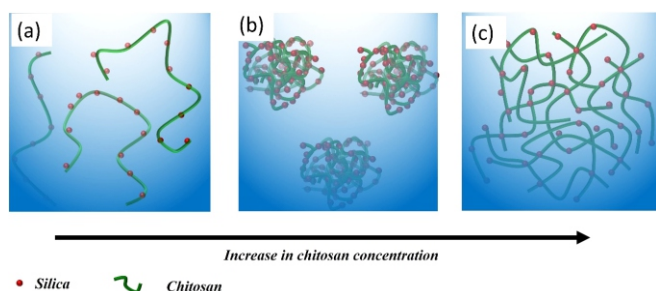
High-momentum Transfer Diffractometer at Dhruva reactor.

in-pile collimator, optimizing beam collimation, upgrading the monochromator, and increasing detector count. These improvements tripled the neutron flux and enhanced resolution threefold. The upgraded instrument now enables faster experiments, partial structure studies through isotopic substitution, high-pressure analyses up to 2 GPa, and time-resolved diffraction, making it a world-class facility for disordered materials research.

Neutron Depth Profiling at APSARA-U: The Neutron Depth Profile (NDP) technique provides quantitative depth concentration profiles up to 5–10 μm with nanometre resolution in solids for selected elements such as He, Li, B, N, and Cl. The NDP system, commissioned at the BT-07 beamline of the APSARA-U reactor, has been used for analyzing B- and Li-containing samples under various reactor power conditions.

Synchrotron-based Research: BARC beamlines at the Indus-1 and Indus-2 synchrotrons operate continuously to support scientific and industrial users. From Sept. '24 to Aug. '25, these facilities catered to approximately 430 users across India, including 20 from industry. The outcome was around 150 peer-reviewed publications and 21 new protein structure depositions in the Protein Data Bank.

AI-Driven Protein Design Pipeline: A generative AI-based protein design pipeline was implemented at BL21 of Indus-2, integrating RFdiffusion, ProteinMPNN, and AlphaFold2. This pipeline combines structure prediction with generative diffusion modelling to design sub-10 kDa protein binders that target pathogen or cancer-associated proteins. Using this approach, mini-protein binders were developed against the SARS-CoV-2 nucleocapsid protein. The crystal structure of one binder, Gpx62, was resolved at 1.8 Å (PDB ID: 9UC5), showing close agreement with the design (RMSD 0.48 Å). Work is ongoing to design binders for cancer surface proteins.



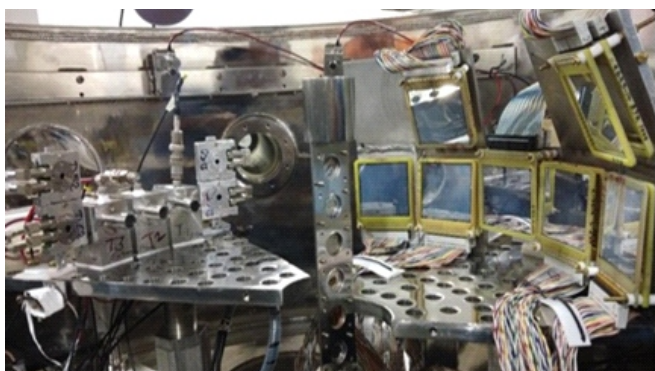
Various intriguing phases of polyelectrolyte-nanoparticles with varying polyelectrolyte concentration, as revealed by SAXS.

Soft Matter Studies via SAXS (BL-18): The Small-Angle X-ray Scattering (SAXS) beamline (BL-18) at Indus-2 enables nanoscale investigations of soft matter, biological systems, and nanomaterials. Recent studies captured electrostatically driven collapse and relaxation of polyelectrolyte-colloid complexes, revealing a multi-step structural transition from intermediate bead-like states to compact domains and stable coacervate-like assemblies. The results elucidate how electrostatic tuning governs the kinetics and morphology of these complexes, guiding researchers in their efforts to design smart drug carriers, adaptive nanocomposites, and bio-responsive materials.

X-ray Absorption of Radioactive Samples (BL-09): A dedicated facility for X-ray Absorption Spectroscopy (XAS) of α - and β -emitting samples has been established at the Scanning EXAFS beamline (BL-09) of Indus-2. Developed through the joint efforts of two scientific groups in BARC, the facility supports both transmission and fluorescence detection modes for dilute and concentrated samples. Custom-designed containment systems ensure sample integrity and maintain radiation exposure below 0.1 mSv h⁻¹ during all handling operations. The setup was validated through Pu L₃-edge XAS measurements on plutonium sulfate, providing Pu–O bond distances consistent with powder XRD data. This facility significantly strengthens synchrotron-based research on actinides and long-lived radioisotopes.

Observation of Scission Proton Emission in Heavy-Ion Fission: Neck rupture in nuclear fission is a turbulent process governed by nuclear viscosity and steep potential gradients, with particle emission near scission offering a sensitive probe of its dynamics. At the BARC–TIFR Pelletron Linac Facility, systematic studies using advanced detection and analysis techniques have examined scission alpha emission, characterized by predominant equatorial emission. For the first time, scission proton emission has also been observed in heavy-ion-induced fission. Unlike alphas, protons show both equatorial and polar emission with nearly equal intensities but an order-of-magnitude lower yield. These observations provide new insights into scission dynamics in heavy nuclei.

Cluster Structure and Reactions of Weakly Bound Light Nuclei: Studies at the BARC–TIFR Pelletron Linac facility, using a large-acceptance silicon strip detector array, explore the cluster structure and reaction mechanisms of weakly bound light nuclei to better understand quantum clustering and stellar nucleosynthesis. Exclusive α – α



Silicon strip detector array at the BARC-TIFR Pelletron Linac Facility.

coincidence measurements from $^9\text{Be} + ^{124}\text{Sn}$ reactions near the Coulomb barrier have distinguished breakup and transfer channels. Reactions with ^{10}B projectiles on ^{159}Tb , ^{197}Au , and ^{209}Bi targets at 54 MeV revealed dominant alpha production, while neutron transfer cross-sections for the $^7\text{Li} + ^{205}\text{Tl}$ system, analyzed with Coupled Reaction Channel calculations, exhibit universal trends linking neutron transfer and fusion processes in weakly bound systems.

High-Transmittance Beam Splitters (HTBSs) for Photoionization Experiments: HTBSs with $\text{TiO}_2/\text{SiO}_2$ multilayer coatings (450–625 nm) were indigenously developed at ATLAD-BTDG for laser-based isotope-selective photoionization studies. Fabricated via confocal RF sputtering on fused silica substrates, these HTBSs exhibit $T > 98\%$ and $R < 2\%$ at 45° incidence. Deployed in Nd:YAG-pumped dye laser systems, they demonstrate excellent optical stability and durability.

Capacitance Gauge for Corrosive Environments: An Inconel 625-based capacitance gauge capable of absolute pressure measurement from 1000 to 1 mbar with ± 0.1 mbar accuracy was developed for highly corrosive environments (HF , CF_4). Long-term HF exposure tests confirm consistent and repeatable performance.



Capacitance Gauge (left) and its pressure measuring & control electronics (right).

Closed-Cycle Refrigerator for Optical Measurements: An indigenous closed-cycle refrigerator (4.2–300 K) was developed for optical and micro-Raman studies, substituting imports. Using this system, negative linear compressibility (NLC) of -20.5 Tpa^{-1} in orthorhombic CuCN was discovered up to 9.8 GPa. Raman and XRD analyses attribute this behavior to structural hinging in its “wine-rack” framework.

Crystal Growth of CsI:Tl for Gamma Spectrometers: Under AIC-BARC incubation, a Bridgman crystal growth facility was established at M/s Ace-ex, Mumbai, in collaboration with the Physics Group, BARC. High-quality 2-inch CsI:Tl crystals were successfully grown, leading to the development of handheld gamma spectrometers. The incubatee has secured GeM contracts to supply detectors to BARC divisions.

RF/DC Electronics for Mass Spectrometers: Compact RF/DC electronics for hydrogen–steam concentration monitoring systems (HSCMS) were developed, enhancing tuning, space efficiency, and EMI/EMC resilience. These systems are poised for deployment in the regular operations of NPCIL facilities at TAPS, RAPS, KGS, MAPS, and NAPS.

Table-Top Proton and Ion Acceleration: At the 200 TW Ti:sapphire laser system, target-normal sheath acceleration (TNSA) of ions was demonstrated via proton and multi-charged $\text{C}^{n+}/\text{Al}^{n+}$ spectra recorded using a Thomson Parabola Spectrometer. Simulations correlate q/m ratios with observed traces. Maximum proton energy reached $\sim 2 \text{ MeV}$ for 1.2 J laser energy, with a detection threshold of $\sim 28 \text{ keV}$.

Molecular Cluster Studies for Energy Applications: Laser-vaporization experiments on transition-metal clusters (Ti, V, Fe, Co, Ni) revealed distinct ammonia activation pathways and N–H bond-cleavage behavior, with Ni clusters showing complete NH_3 dehydrogenation.

Yttrium-oxide clusters (Y_nO_m) were found to promote O_2 activation via charge transfer, providing atomistic insight into catalytic processes relevant to nitrogen, hydrogen, and oxygen chemistry.

Fast-Neutron-Induced Fission of ^{232}Th : At FOTIA, fast-neutron-induced fission of ^{232}Th was studied using CeBr_3 detectors. Measured prompt γ -ray spectra ($> 0.1 \text{ MeV}$) show 40–50% higher total energy than model predictions, and reduced emission below 0.4 MeV relative to ^{252}Cf , ^{238}U , and ^{239}Pu . These results refine fission models and improve γ -heating estimates for Gen-IV systems.

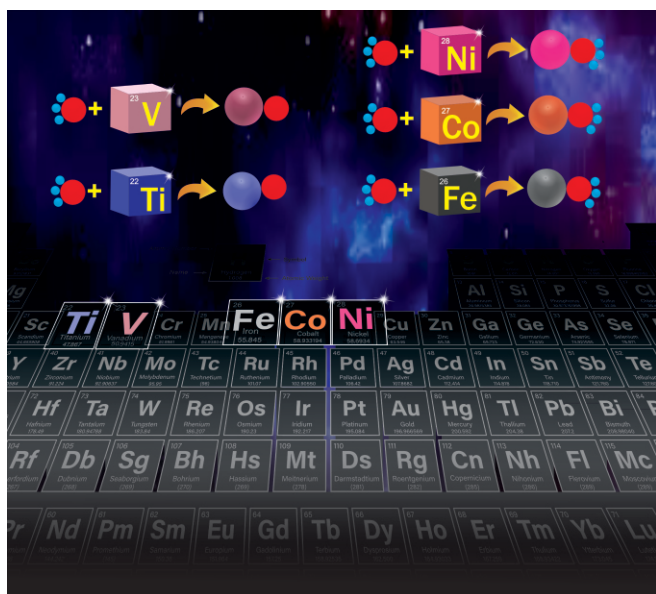


Illustration of ammonia activation pathways & bond cleavage, highlighting Ni clusters' complete NH_3 dehydrogenation. Published as a front cover of ACS' JPC A Vol. 129, No. 37.

Coherent Neutrino–Nucleus Scattering (ICNSE):

The Indian Coherent Neutrino–Nucleus Scattering Experiment (ICNSE) at BARC is being developed to measure CENNS using reactor antineutrinos. Studies indicate strong sensitivity to the weak mixing angle at low energies and to neutrino electromagnetic properties. Simulations further show capability for detecting supernova events within 750 pc and probing shock-revival dynamics via neutrino-flux time evolution.

Chemistry & Material Science

Development of NiMoCrTi-C Alloy for MSBR

Applications: A Ni-based NiMoCrTi-C alloy has been developed as a candidate structural material for molten salt reactors (MSR). Thermo-mechanical processing parameters, including hot deformation and heat treatment, have been optimized to manufacture plates, tubes, and other shapes from as-cast ingots. Using these parameters, large forged ingots have been successfully hot-rolled into thick plates of various dimensions. Additionally, the alloy's compatibility with fluoride salt environments at elevated temperatures was systematically evaluated across varying Mo/Cr and Fe/Cr ratios. Ni-Cr-Mo/Fe alloys such as Hastelloy N, Hastelloy X, Alloy 690, and Alloy 693, when exposed to FLiNaK salt under inert atmospheres, exhibited non-uniform corrosion and selective chromium dealloying. Increased Fe+Cr content and/or higher Cr/Mo ratios were found to enhance the corrosion susceptibility index.

Assessment of RPV Steel Properties:

Microstructural analysis of APURVA, an indigenously developed ultra-thick pressure vessel steel, revealed that ductile fracture occurs through nucleation, growth, and coalescence of micro-voids influenced by inclusions, second phases, and grain boundaries. Studies on quenched-tempered samples from various locations and orientations clarified its failure mechanisms. The ductile-to-brittle transition curve was established. Proton irradiation tests showed that indigenous eastern-grade RPV steel exhibits superior irradiation resistance compared to its imported counterpart.

Threshold Stress for Hydride Reorientation in Pressure Tube Materials:

For Zr-2.5Nb pressure tube materials from 220 and 700 MWe PHWRs, the threshold stress for radial hydride formation (RHF-50%) under both biaxial and uniaxial conditions was found to be 110–130 MPa, independent of stress state. The addition of yttrium (Y) significantly mitigated hydride formation, reducing hydride content by about 7%, even without metallurgical bonding, confirming Y's efficacy as a hydrogen getter.

Pre-oxidised Zr-2.5Nb pressure tubes with steam-formed oxide layers (400°C, 0.5 MPa, 36 h) exhibited parabolic oxidation kinetics in $\text{CO}_2 + 5\% \text{O}_2$, with reduced rates compared to bare specimens. Oxide characterization revealed transformation from tetragonal to monoclinic ZrO_2 over time, the formation of an n-type oxide on pre-oxidised tubes, and preferential oxidation along the β -phase.

Development of Accident Tolerant Claddings:

A Cr sputter coating technique was optimized to deposit 15–25 μm thick, dense, pore-free layers on Zr-4 substrates. The coating process parameters (argon gas pressure, substrate bias, and power) were refined for adhesion and uniformity. The Cr-coated Zr-4 showed excellent oxidation resistance due to a protective Cr_2O_3 layer, remaining intact up to 1200°C.

Advanced Ceramics, Composites, and Carbon

Materials: High-density, isotropic graphite blocks (75 × 100 mm and 200 × 200 × 400 mm^3) were produced using meso-carbon micro-beads (MCMB), achieving densities above 1.85 g/cc and isotropy near 1.05. Properties met ASTM standards. SiC– B_4C reaction-bonded composites exceeded 97% theoretical density via optimized molten-Si infiltration.

Continuous CNT fibers with high conductivity (1.85 MS/m), strain-to-failure (~16%), and modulus (1.4 GPa) were woven into fabrics acting as toxic gas sensors (NO , NH_3 , H_2S) with 50 ppb detection limits and rapid (<30 s) response.



Materials (ingots of varied configuration) for the erection of MSR loops.

Hydrogen Production and Storage Materials: A Mn–Co spinel ($\text{Mn}_{1.5}\text{Co}_{1.5}\text{O}_4$) coating process was developed for High-Temperature Steam Electrolysis (HTSE) interconnects using solution combustion synthesis and electrophoretic deposition, optimized for uniform, adherent, and dense coatings. Oxidation tests confirmed coating stability under HTSE conditions.

A $\text{SiO}_2\text{--Al}_2\text{O}_3\text{--CaO}$ glass sealant was synthesized (100 g batch) for hermetic HTSE sealing, demonstrating compatibility with interconnect and 8YSZ electrolyte at 800°C over 14 thermal cycles. Additionally, 10 L of Cr-doped Fe_2O_3 foam catalyst was produced for sulfuric acid decomposition in the I–S cycle.

Modified Route for Calcium Production: A modified aluminothermic reduction route yielded >99% pure calcium metal directly from CaO, bypassing distillation. Thermodynamic optimization enabled successful 100 g batch production suitable for reactive metal extraction.



Prototype of commercially available NO_x releasing dressing with brand name 'ColoNoX'.

Development of Alloys for Ore Grinding

Applications: U–Ti alloys (0.8–1.7 wt.% Ti) were developed for uranium ore grinding applications. Optimal heat treatment of U–1.5Ti alloy (450°C , 40 min) yielded peak hardness and higher wear resistance due to TiC and U_2Ti precipitates in the alpha-U matrix.

DFU Care with NO_x Releasing Dressing: Diabetes poses India a national health challenge. Among its severe complications, Diabetic Foot Ulcers (DFU) pose a major clinical and socioeconomic burden. Over a third of diabetics face DFU during their lifetime, with infection-driven chronic wounds often leading to amputation. Treatment remains limited to general wound care routines, underscoring the need for specific therapeutic solutions.

Addressing this gap, BARC has developed and patented a novel nitric oxide (NO_x) releasing wound dressing, recently approved by the Central Drugs Standard Control Organization (CDSCO) for clinical use. This innovation, now commercialized by Cologenesis Pvt. Ltd. under the brand name 'ColoNox', marks a breakthrough in targeted wound management for diabetic patients.

Nitric oxide plays a crucial biological role in wound healing through its antimicrobial and anti-inflammatory properties. Diabetic conditions impair endogenous NO production, hindering healing and tissue regeneration. The NO_x releasing dressing counteracts this deficiency by enabling controlled generation and gradual release of therapeutic nitric oxide at the wound site. Its collagen matrix enhances healing by promoting cell migration, relieving pain, and serving as a structural scaffold for new tissues.

Evolved from BARC's research on eco-friendly anti-fouling agents, the technology progressed through extensive laboratory studies, followed by successful clinical trials completed in 2024. With a shelf life of 2.5 years, the product is tailored for India's climatic and healthcare requirements and designed for its affordability and accessibility.

Applied as a two-part system, ColoNox ushers a new era of advanced wound care. It exemplifies India's capability to translate atomic research into socially transformative healthcare advancements, aligning with the vision of "Make in India for the World."

Hybrid granular sequencing batch reactor (hgSBR):

Biogranule-based wastewater treatment technology, developed by BARC, uses compact microbial aggregates called biogranules or bio-beads to efficiently treat domestic and industrial wastewater. Unlike conventional activated sludge systems that

require large land areas and multiple tanks, biogranules function within a single sequencing batch reactor, significantly reducing space and operational costs.

BARC's hybrid granular sequencing batch reactor (hgSBR) systems rely on naturally occurring microorganisms that self-assemble into dense granules capable of simultaneously removing organic matter, ammonium, etc. Biogranules exhibit exceptional settling properties and maintain stable performance across varying temperatures and pollutant concentrations, including heavy metals and antibiotics. The cultivation of bio-beads using indigenous microbes and granular activated carbon enhances granule formation and nutrient removal efficiency, for which BARC received a patent in 2021.

The full-scale demonstration plants treating up to 1500 m³/day have validated the hgSBR process under real conditions. Over 26 installations across India now operate using this technology, supported by technology transfer partnerships. Notably, the UP Jal Nigam deployed hgSBR-based sewage treatment plants during the Maha Kumbh Mela 2025 to maintain sanitation and protect the Ganga river ecosystem.

With effective biological oxygen demand reduction, nutrient removal, lower sludge generation, and smaller land footprint, biogranule systems offer a sustainable and cost-effective alternative to conventional methods. Future research aims to enhance granule stability, identify key structural biopolymers, and extend applications to industrial effluents and emerging contaminants such as pharmaceuticals and metals.

Health Physics - Radiation Safety via development of systems, monitoring & dosimetry

Mobile Gamma Screening System: A shielded, trolley-mounted NaI(Tl)-based detection unit facilitates rapid screening of food items for gamma-emitting radionuclides during radiation emergencies. With a 76 mm × 76 mm detector coupled to a 1K MCA and notebook interface, it achieves minimal detectable activities (MDAs) of 20–100 BqL⁻¹ for I-131, Cs-137, and Co-60, remaining below operational intervention limits.

Portable Whole-Body Contamination Monitor: A compact NaI(Tl) tabletop system enables rapid onsite assessment of internal contamination from high-energy photon emitters. Using a standing geometry and 76 mm × 76 mm detector with 1K MCA, it ensures efficient identification of multiple radionuclides under



The Wet-Oxidizer system for extraction of dissolved inorganic and organic species of C-14 in liquid samples.

elevated background conditions, allowing fast throughput during emergencies.

Compact Wound Contamination Analyzer: This portable, trolley-mounted system measures radionuclide deposition in wounds caused by photon emitter contamination. Equipped with an interlocked shielded chamber, LED-camera alignment, and 51 mm detectors, it achieves MDAs of ~2 Bq for Cs-137/Co-60 and ~1.3 Bq for Am-241 within 5 minutes, ensuring high precision in low-energy assessments.

Semi-Automatic Radiocarbon Combustion Unit: A cost-efficient system designed for high-sensitivity oxidation of biota samples extracts CO₂ containing Carbon-14 and tritiated combustion moisture for OBT estimation, improving sample throughput and combustion reliability.

System for Extraction of Carbon-14 species: The wet oxidizer system achieves 96–98% efficiency in extracting dissolved inorganic and organic carbon species via catalytic conversion to CO₂. Validation through spiked tests confirmed C-14 levels in river samples (DIC: 2.7 mBq/L; DOC: 1.29 mBq/L).

Local Scale Atmospheric Dispersion Model: A Lagrangian puff-based model simulating radionuclide dispersion supports multiple source and receptor grids. It accounts for decay, deposition, and meteorological variability, providing integrated radiological impact assessments for different age groups under both normal and accidental release scenarios.

RDD Aerosol Dynamics Model: A zero-dimensional numerical approach models aerosol evolution post-RDD explosion, incorporating thermal and

microphysical processes like coagulation and condensation. Validated for carbon and cobalt aerosols, the model identifies a dominant respirable fraction, enhancing near-field radiological impact predictions for emergency planning.

Baseline Environmental Surveillance: Environmental Surveillance Laboratories (ESL) conduct baseline radioactivity and meteorological monitoring at nuclear sites (GHAVP, Mahi Banswara, Vizag). ESL units function as regional Emergency Response Centres and engage in public outreach to foster nuclear energy awareness.

Alternate Crisis Management Centre: A remotely operable node outside BARC serves as a backup monitoring hub to the Integrated Centre for Crisis Management, ensuring data continuity, functional redundancy, and resilience against emergencies.

Instrumentation for Radiation Dosimetry: Optically Stimulated Luminescence (OSL) is becoming a widely recognised technique for measuring how much radiation a material has absorbed. It is used in fields such as environmental monitoring, and personal dosimetry. Scientists are continuously working to develop OSL-sensitive materials that more closely mimic human tissue and to build better instruments—called OSL readers—that can measure this light precisely. However, many of the readers available today are built for geological or archaeological dating and tend to be expensive. This has created a strong need for low-cost and compact systems to support radiation monitoring tasks.

Understanding this, BARC has designed a new, highly sensitive laser-based OSL reader that is both portable and affordable. At the heart of this system are two miniature lasers, each about the size of a matchbox, with wavelengths of 473 and 532 nanometers and a power output of 350 milliwatts. These lasers direct light through optical fibers to stimulate the radiation-sensitive sample evenly. A built-in touch-screen computer controls the entire process and ensures stable laser performance during operation.



Front and Back sides of Chest Neutron dosimeter developed in BARC.

The system detects emitted light using a sensitive photon counting module and specialized filters that block unwanted wavelengths, ensuring accurate readings. Extensive tests (evaluated by CW-OSL method followed by comparison with Riso reader) show that this laser-based reader not only matches but nearly doubles the sensitivity of commercial LED-based systems. Its compact design, fast response, and high accuracy make it ideal for radiation dose verification in hospitals and for advanced research in universities.

External Radiation Monitoring - Fresh Insights: BARC oversees the external radiation monitoring of over 250,000 workers in India's medical, nuclear, and industrial sectors using specialized dosimeters. To ensure international accuracy and reliability, it participated in the EURADOS Inter-Comparison Exercises IC2022ph (for photons) and IC2022n (for neutrons), benchmarking its monitoring systems against global standards.

For photon monitoring, BARC deployed $\text{CaSO}_4:\text{Dy}$ -based thermoluminescent dosimeter (TLD) badges. Each badge contains three discs shielded by filters to adjust for energy responses and differentiate radiation types. In IC2022ph, 30 selected badges with uniform sensitivity were exposed to a range of photon energies and doses at an Austrian laboratory. The TLD badges demonstrated reliable performance, precisely measuring personal dose equivalents $H_p(10)$ and $H_p(0.7)$ across multiple scenarios and energies. The badge responses fell well within ISO-14146 acceptance limits, confirming their accuracy, especially at low-dose ranges critical for routine occupational safety.

For neutron monitoring, BARC utilized CR-39 based dosimeters for the IC2022n exercise conducted in France. The neutron dosimeter, designed to withstand environmental challenges, was calibrated using controlled neutron sources. Dosimeters were processed with an advanced in-house Fast Neutron Imaging System, significantly improving track detection and measurement accuracy.

Results from both international inter-comparison exercises validated the efficacy and reliability of India's radiation dosimetry practices. The TLD system proved excellent for routine and low-dose monitoring. Meanwhile, participation in the neutron exercise underscored the advantages of BARC's indigenous imaging system and highlighted the need for continued improvement in detector materials through local development, ensuring robust protection for radiation workers.