VECC NEWSLETTER

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ACCELERATOR

OPERATIONAL ACTIVITIES OF K130 ROOM TEMPERATURE CYCLOTRON

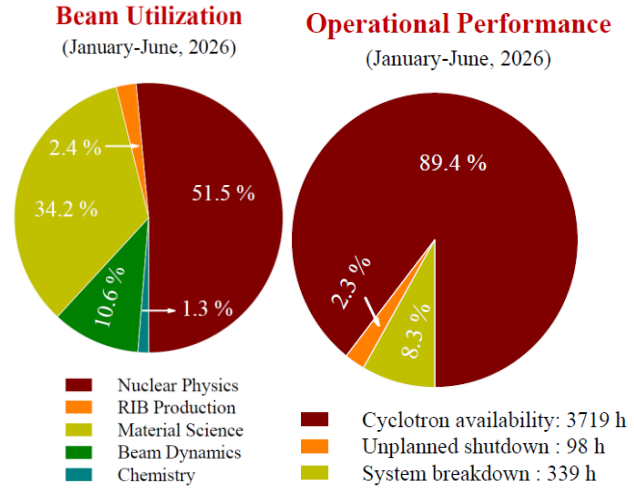
Throughout the year, the K130 variable energy cyclotron serves as a reliable source of accelerated particle beams for a broad spectrum of scientific investigations. Its operational capabilities include the production and delivery of proton, alpha-particle, deuteron and heavy-ion beams at different energies. The facility supports diverse research activities, encompassing nuclear physics, radiation effects on materials, material science, isotope production and other experimental programmes, thereby contributing significantly to ongoing scientific research. During the period from January to June 2026, the K130 cyclotron remained actively engaged in meeting the beam requirements of the user community, with extensive utilization of proton and alpha beams. In parallel with routine cyclotron operations, various maintenance works, system upgradation initiatives and beam dynamics study were undertaken to improve the reliability, operational efficiency and overall performance of the facility. Preliminary trials of AI-based algorithms were conducted for autonomous beam tuning and experimental data acquisition during low-energy alpha beam operation. The characterization of the main magnet hysteresis was carried out to improve understanding of its magnetic behavior. In addition, the existing fire alarm system was also upgraded through the installation of new detectors in the RTC control room, vault and PIT areas. A steering magnet in Channel #1 was installed for beam correction, alignment and transport efficiency for RTC-based RIB beam development experiments at the ISOL facility.

The K130 cyclotron successfully delivered alpha beams at the energies specified in Table 1. In accordance with the user requirements, the beam current on target was maintained at approximately 40 nA to 400 nA in Channel #1, 1 nA to 8 nA in Channel #2 and 500 pA to 5 nA in Channel #3. Furthermore, proton beams at the energies listed in Table 1 were successfully provided, with beam currents on target ranging from approximately 20 nA to 4.2 µA in Channel #1, 2 nA to 5 nA in Channel #2 and 1 nA to 4 nA in Channel #3, while a beam current of approximately 450 nA was achieved in Channel #4.

Table 1

Projectile	Beam Energy (MeV)
Proton	6.5-14.5
Alpha	26-50

Experimentalists from VECC, IGCAR, BHU, UGC-CSR, RCD/BARC, Visva-Bharati University and other institutes, have extensively utilized the facility. The beam utilization chart of the K130 cyclotron (3037 hours) and its overall performance during this period are shown below.



For further details, please contact Dr. Animesh Goswami (animesh@vecc.gov.in), Head, Cyclotron Operation Section/ APG.

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K500 SUPERCONDUCTING CYCLOTRON (SCC)

The K500 Superconducting Cyclotron (SCC) at the Variable Energy Cyclotron Centre (VECC) is currently delivering a range of heavy-ion beams for user experiments. During the period from January 2026 to June 2026, the facility primarily provided ^{40}Ar ion beams with energies ranging from 190 to 314 MeV, ^{84}Kr ion beams with energies ranging from 577 MeV to 611 MeV, ^{20}Ne ion beams with energies ranging from 107 MeV to 172 MeV, ^{16}O ion beams with energies ranging from 120 MeV to 141 MeV with the cyclotron operating in the second harmonic mode. These beams were utilized for various experiments of nuclear physics like Quasi fission reaction, study of Alpha cluster state through decay particles, study of fragment emission from $^{16}O^{3+}$, ^{9}Be reaction channel and study of fragment emission mechanism in $^{16}O^{3+}$ on ^{112,116,120,124}Sn reaction.

In addition to fundamental nuclear physics studies, a dedicated experiment was conducted using 577 MeV $^{84}Kr^{14+}$ beam towards the development of a national Single-Event Effects (SEE) testing facility, compliant with MIL and ASTM standards. A newly designed scattering chamber dedicated to this type of experiments was installed and used this time, which reduced target switch over time significantly. Later this experiment was continued with 198 MeV $^{40}Ar^{6+}$ beam achieving a uniform flux of approximately 10^3 ions/cm^2/s and a total fluence of ~10^6 ions/cm^2 achieved. Moreover, characterisation of Cerium doped Yttrium Aluminium Garnet (YAG-Ce) scintillator was also carried out. Radiation dose mapping experiment was carried out by Health Physics unit of VECC at various location of external beam line.

OPERATIONAL ACTIVITIES OF MEDICAL CYCLOTRON FACILITY AT CHAKGARIA

The Medical Cyclotron-30 (MC-30) is an advanced accelerator facility supporting medical radioisotope production and research activities. It operates with a fixed magnetic field of 0.9 T and RF frequency of 65.5 MHz, using two RF cavities to accelerate H^- ions and deliver proton beams at different energies. The facility has five beam lines: one for ^{18}F-FDG production, two for SPECT radioisotopes, and two for research. The research lines support studies on radiation effects in nuclear structural materials and window materials for Lead-Bismuth target assemblies, contributing to improved material performance, target development and operational safety.

Period: 1st January 2026 to 30th June 2026:

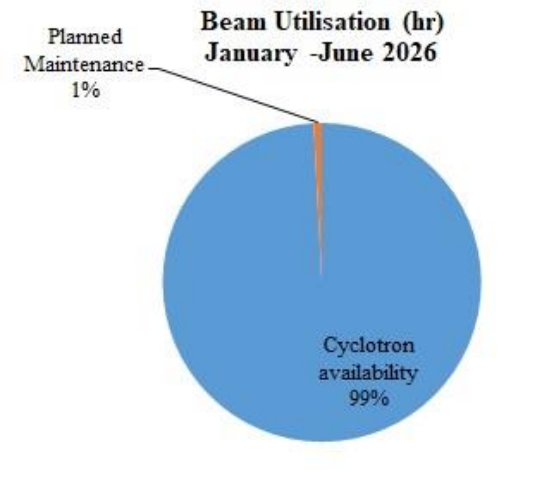
The MC-30 has demonstrated consistent and dependable performance in routine ^{18}F-FDG production for PET imaging. During 108 production days, an 18 MeV proton beam with an average current of about 34 µA was delivered for approximately 90 minutes per day. The facility achieved nearly 104 Ci of ^{18}F-FDG, with around 136 hours of Beam on Time and a cumulative integrated current of about 4415 µA-h. Operations included brief maintenance-related interruptions involving the liquid target, HOT cells, RF system and stripper. Overall, the facility maintained stable operation and effectively met the regular ^{18}F-FDG production requirement.

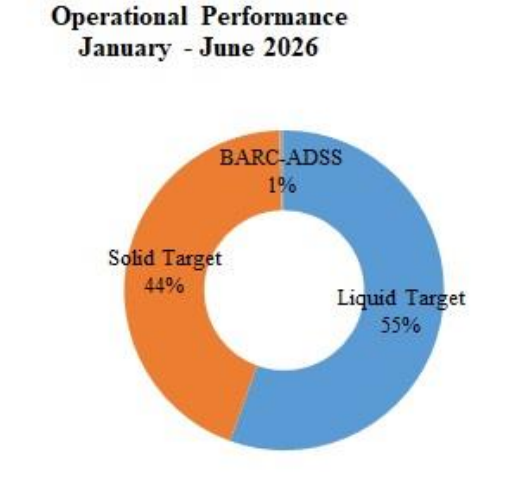
The MC-30 successfully provided a 29.8 MeV proton beam to the solid target line for ^{68}Ge production. The beamline was operated for nine days, with approximately 37 hours of Beam on Time (B.O.T.) and a cumulative integrated current of about 3500 µA-h. This operation demonstrated stable beam delivery for solid-target radioisotope production.

In addition to routine production activities, the MC-30 was successfully operated for accelerator-based

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research through the ADSS beamline. A 30 MeV proton beam was transported to the beam dump at a steady current of 50 μA, with about 70% beam transmission. The operation demonstrated the capability of the facility to deliver stable, high-





current proton beams for experimental research.

For further details, please contact Shri. Aditya Mandal (aditya@vecc.gov.in), Head, Medical Cyclotron Facility Section/ ATG

COMMISSIONING OF HEAVY ION BEAM LINE AND ACCELERATION UP TO 1 MEV/U

The radioactive ion beam (RIB) facility at VECC is built around the K130 variable energy cyclotron as the driver accelerator. It is a technology demonstration facility for the ANURIB (Applied and Nuclear research with Rare Isotope Beams) project. The RIB facility with post-accelerators has been set up in one of the available experiment caves and an adjacent annex building. Ion beams produced in an ECR ion-source are mass separated in a magnetic separator and thereafter accelerated in a series of linac modules starting with a radio frequency quadrupole linac. Low energy ion beams with $A/q \leq 14$ from the separator are accelerated in a four-rod-type RFQ linac to about 100 keV/u. This is followed by three modules of heavy-ion Linacs (L1, L2, L3) accelerating the beam further to around 415 keV/u. Another two linac modules (L4, L5) would further accelerate beam to energy of 1 MeV/u. Apart from these, re-bunchers RB1 to RB5 have been installed. The operating frequency for cavities RFQ, L1, L2, RB1, RB2 is 37.8 MHz while others are 75.6 MHz cavities. Successful acceleration of Nitrogen beam has been achieved through eleven RF cavities, which needs to be phase matched and powered to achieve desired accelerating voltages. Almost 90% of the components installed at RIB facility have been indigeniously developed including the Solid State Amplifiers. Fig 1 shows the schematic layout of the RIB facility. Beam energy of 415 keV/u accelerated by L3 and 715 keV/u accelerated by L4 have been corroborated using Si detector shown in Fig 2.

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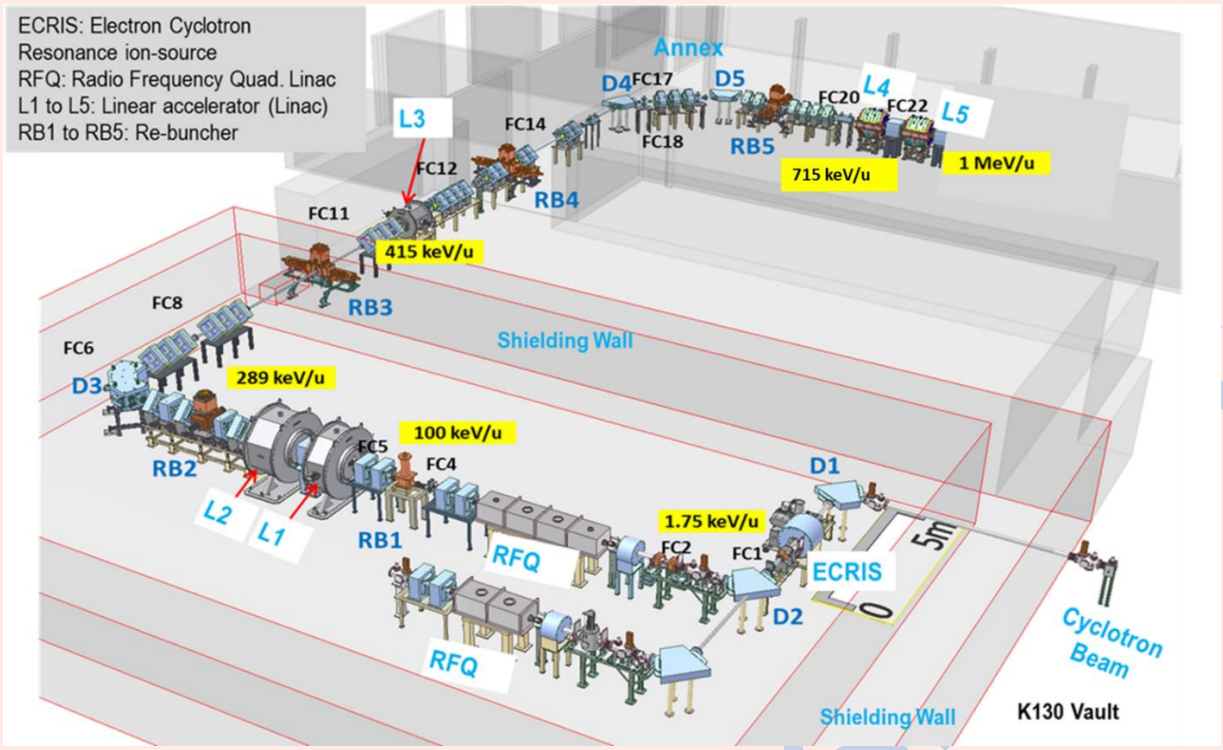


Figure 1. Schematic Layout of RIB post accelerator facility

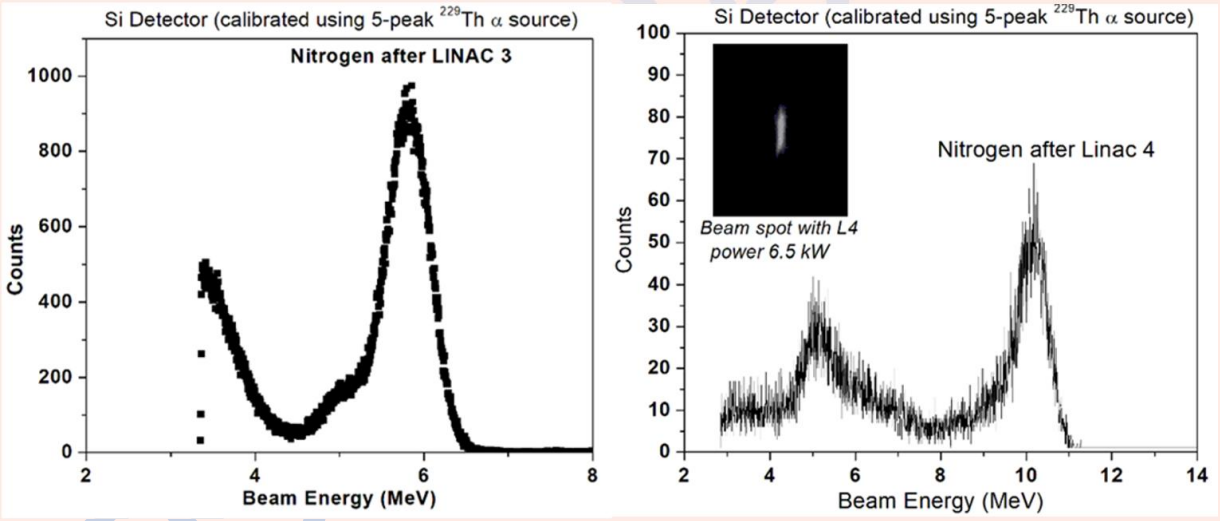


Figure 2. Energy measurement of L3 and L4 Nitrogen beam using Si detector

The L4 beam with cavity energized to required 6.5 KW, has been first transported through L5 without any RF power acting as drift space to the silicon detector for measuring the energy of the nitrogen beam accelerated by L4 tuned to optimum power and phase. During the beam trials, the 715 keV/u beam accelerated in L4 was further accelerated in the L5 energised to calculated rf power of 5.5 kW. The intermediate quadrupole magnets were tuned to values corresponding to the beam energy of 1 MeV/u. The beam current for the nitrogen beam accelerated through L5 measured in a Faraday Cup placed at the end of beam line was 20 nA. Using energy attenuation method through thin aluminium foils, the beam energy was first corroborated to be > 920 keV/u through a 8.9 micron foil and subsequently through a foil of thickness 10.4 micron to be 1.04 MeV/u while the RF power and phase of the L5 was fine tuned.

DIGITAL ALARM ANNUNCIATOR SYSTEM FOR THE K-130 AND K-500 CYCLOTRON

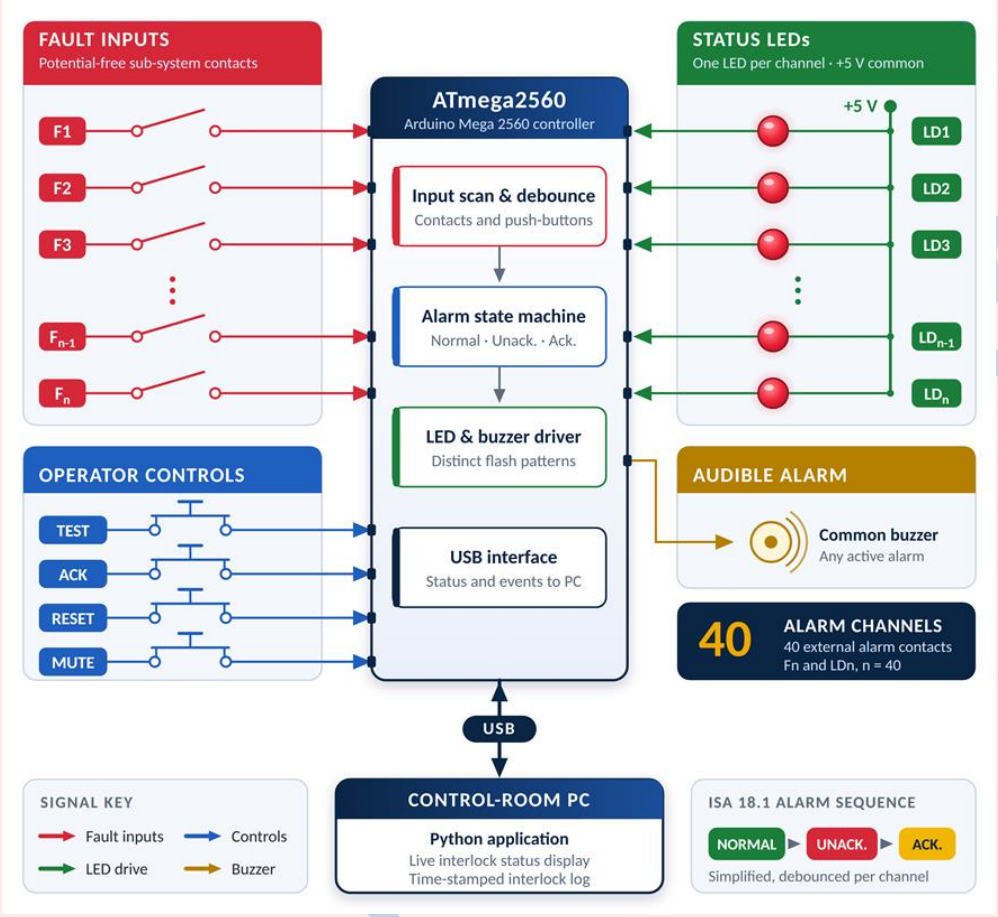


Figure 1: Functional schematic of the alarm annunciator interface board: fault inputs, operator controls, status LEDs, buzzer and the USB link to the control-room PC.

The interlock status in the Room Temperature Cyclotron (RTC) & Super Conducting Cyclotron (SCC) control room was shown on a commercial analog alarm annunciator through LED-based panel with a buzzer that signals each interlock as it is activated. This system has several limitations as outlined below.

- It cannot record when an interlock was activated or cleared.
- Lighting the LED status display needs a significant amount of power.
- It is neither expandable nor reconfigurable for more number of channels.

Therefore, a new digital alarm annunciator is designed, developed and commissioned for RTC & SCC cyclotron. It is modular and reconfigurable, and it records the sequencing and history of interlocks with time stamps. The digital alarm annunciator implements 40 alarm channels on a microcontroller. The operators work through three global controls, Test, Acknowledge and Reset, and read status from 40 individual LED indicators plus the buzzer. Figure 1 shows how the interface board is connected to the alarm contacts, controls, LEDs and buzzer to the controller. The communication with the control-room PC is done over USB.

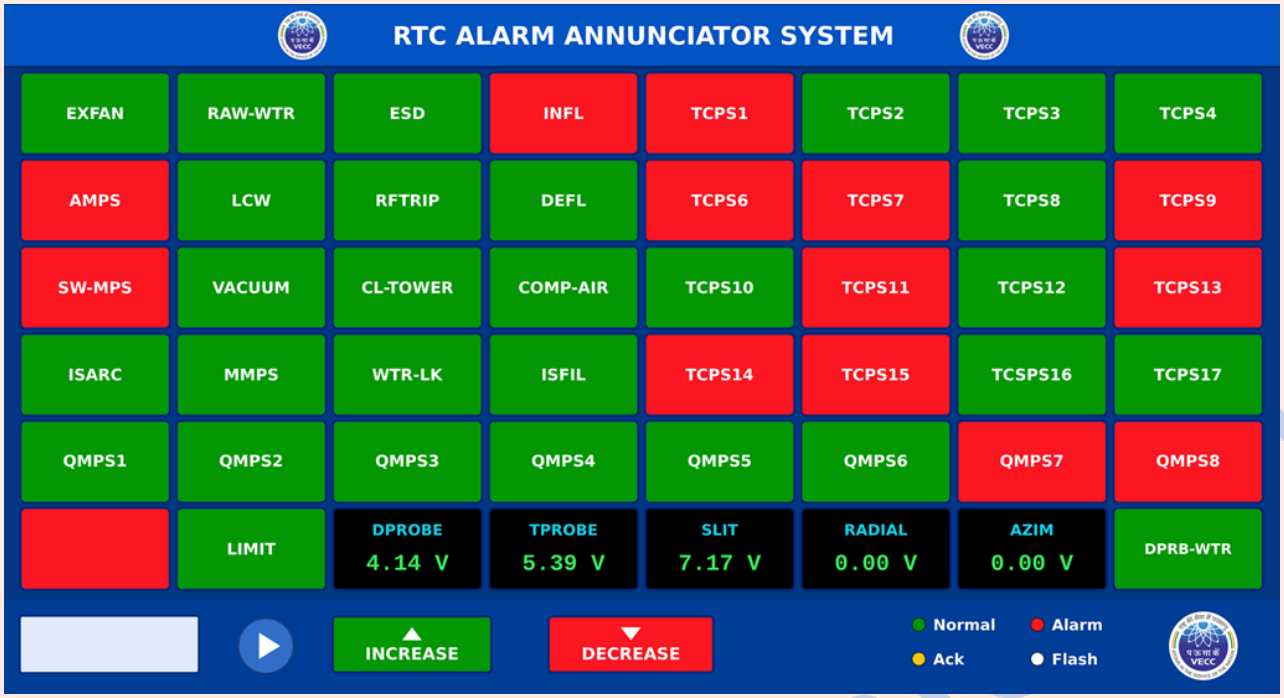


Figure 2: The RTC Alarm Annunciator System, showing colour-coded Normal and Alarm tiles

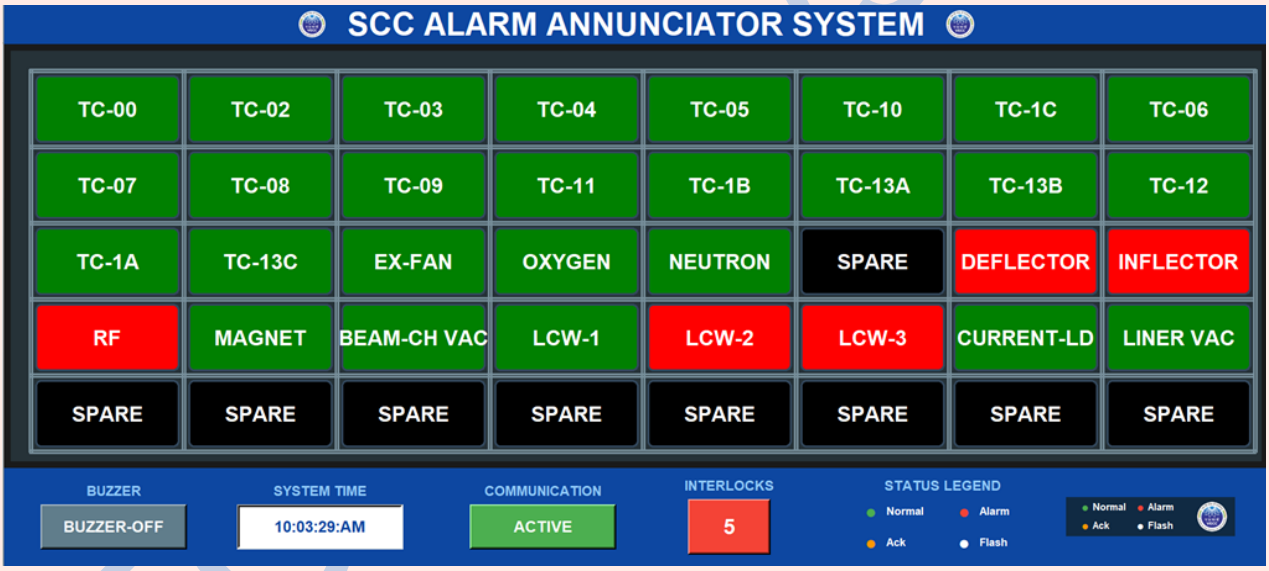


Figure 3: The SCC Alarm Annunciator System, showing colour-coded Normal and Alarm tiles.

The interlock status is also shown on a graphical interface developed in Python and running on the control-room PC as shown in Figure 2 and Figure 3. A red tile on screen marks an interlock that has failed or is in the OFF state, matching the lit LED on the panel. Logging takes place when an alarm has been activated and the Acknowledge button is pressed, so the record captures each alarm the operator has acknowledged. The analog alarm annunciator has been completely replaced by the indigenously developed digital annunciator. All alarm contacts are connected to it, and it is in regular operation at the RTC & SCC cyclotron, where its performance has been found to be excellent.

PHYSICS

How Light Can Dark Matter Be? Neutron Stars May Hold the Answer

Dark matter is one of the biggest unresolved puzzles in modern physics. We know from its gravitational influence that it makes up most of the matter in the Universe, yet we still do not know what dark matter is made of. One of the most fundamental unknowns is the mass of the dark matter particle, which can vary enormously among different theoretical candidates.

Neutron stars may provide a natural laboratory to address this question. These extremely dense objects can contain dark matter along with ordinary nuclear matter. If enough dark matter is present, its properties can leave an imprint on observable quantities such as the star's mass, radius, and tidal deformability. This raises an interesting question: Can neutron-star observations tell us how light a dark matter particle is allowed to be?

Dark Matter Inside a Neutron Star

In our study, we consider neutron stars containing self-interacting fermionic dark matter. The ordinary nuclear matter and dark matter are treated as two separate fluids that communicate only through gravity. The interaction among the dark matter particles is assumed to be repulsive and mediated by a massive vector particle.

We systematically vary the dark matter particle mass m_χ, its interaction strength Y_ξ, and the amount of dark matter present at the centre of the star i.e., ratio of central energy density of dark matter to hadron ϵ_{DM}/ϵ_H. For each combination, we calculate the resulting mass-radius relation and other observable stellar properties. The interesting behaviour appears when the dark matter particle becomes light.

Light Dark Matter Leaves a Strong Signature

From Fig. 1 we can see that for relatively small m_χ, dark matter can dramatically alter the structure of the star. Some of the resulting configurations have unusually large radii or maximum masses and are difficult to reconcile with present neutron-star observations.

As the dark matter particle mass increases, these extreme effects gradually disappear. The predicted stellar properties become much more compatible with observations. This sensitivity is particularly strong at the lower end of the dark matter mass range. Small changes in m_χ can produce substantial changes in the maximum mass, radius, and tidal deformability of the star. This makes the light-dark-matter region especially interesting from an observational point of view.

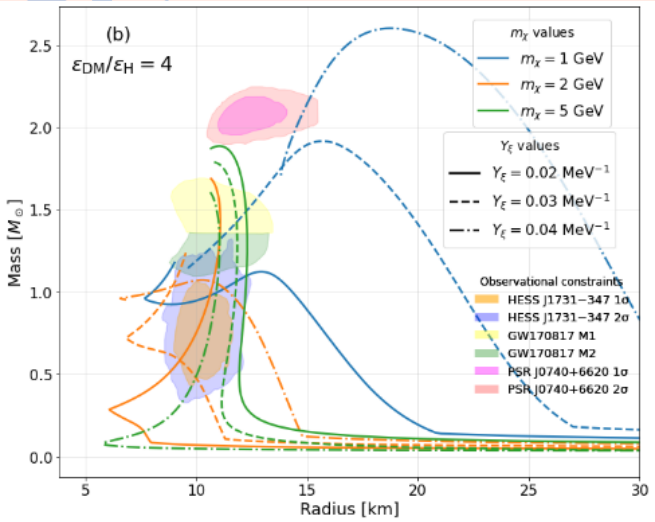


Figure. 1: Mass- Radius relations showing the effect of different dark matter particle masses and interaction strengths

Finding a Lower Mass Limit

Fig. 2 further illustrates this behaviour clearly. At low m_χ, M_{max} varies strongly with both m_χ and Y_ξ whereas at larger m_χ the variation becomes progressively weaker and approaches a saturation regime. This shows that neutron-star properties are particularly sensitive to the DM particle mass in the low-m_χ region..

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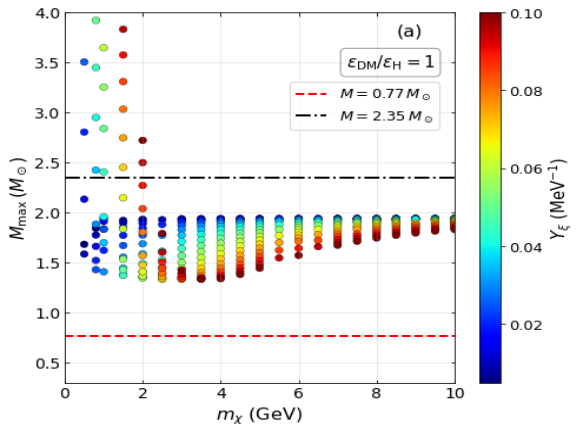


Figure. 2: Maximum mass in (m_χ, Y_ξ)

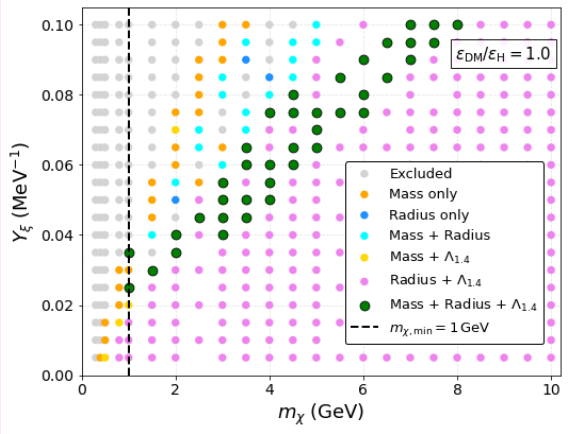


Figure. 3: Observationally allowed and excluded regions of the dark matter parameter space. The observations increasingly disfavour the low- m_χ region.

It is also evident from the Fig. 3 that within the model and parameter range considered in our study, the combined observations point toward a characteristic lower mass scale of approximately $m_\chi \gtrsim 1-2$ GeV.

This is the central outcome of the work: neutron-star observations can provide an astrophysical lower bound on the mass of self-interacting fermionic dark matter within the adopted model.

Neutron Stars as Dark Matter Laboratories

The result highlights a different role for neutron stars in the search for dark matter. Instead of detecting a dark matter particle directly, we can use the response of an entire star to infer which particle properties are compatible with observations.

Future improvements in neutron-star mass and radius measurements, together with more precise gravitational-wave observations, could further narrow the allowed region. In this way, neutron stars may provide a complementary astrophysical window into one of the most fundamental unknowns of dark matter—the mass of the particle itself.

For further details, please contact Gargi Chaudhuri, TNPG (gargi@vecc.gov.in)

COMPREHENSIVE EVIDENCE OF X(5) CRITICAL POINT SYMMETRY IN NUCLEAR MANY BODY SYSTEMS

The atomic nuclei provides a unique platform for the study of quantum shape phase transition in a finite self-bound many body system. Unlike the infinite classical systems, where phase transitions are sharply defined, nuclei exhibit gradual structural evolution driven by changes in nucleon number and shell occupancy. The emergence of collective motion and critical point symmetry in a strongly interacting finite systems can be accessed through intermediate structural properties of the nucleus at the transition point.

One such, among few, critical point symmetry is known as X(5) symmetry representing the critical point of the quantum phase transition from a spherical vibrator [U(5) symmetry] to symmetric axially deformed [SU(3) symmetry] nuclear shape. The experimental signature for existence of this symmetry is primarily manifested with the observation of five excited rotational band structures

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developed on five close lying 0^+ states, including the ground state (0_1^+) of the nucleus. The N = 90 ^{152}Sm is long predicted as a candidate for displaying X(5) symmetry from the observation and characterization of first two 0^+ bands in this nucleus. At VECC, using alpha beam from K 130 cyclotron and a setup with twelve Clover HPGe detectors, the first comprehensive evidence of X(5) symmetry has been found with the observation of multiple excited 0^+ structures and their characterization in this transitional nucleus.

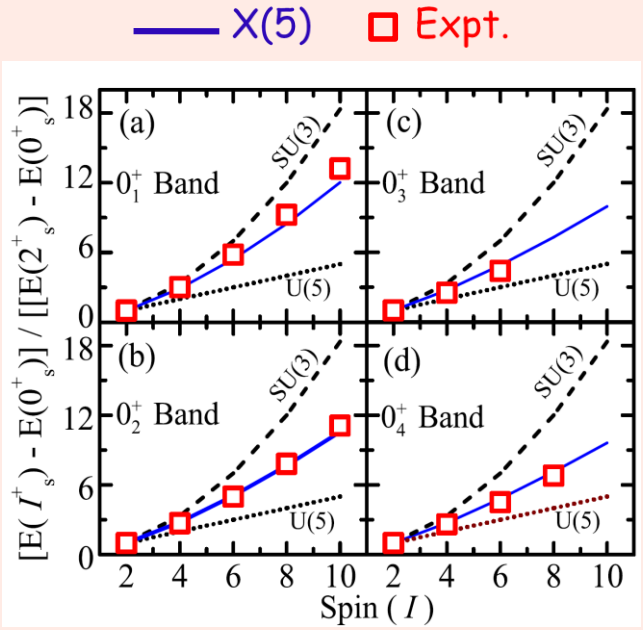


Figure 1: Comparison of experimental energy ratios (red squares) with those obtained from the X(5) model calculations (solid blue lines). The limiting values corresponding to the axial rotor SU(3) and spherical vibrator U(5). symmetries are indicated by black short-dashed and dotted lines, respectively.

Certain energy ratios evaluated for these band structures, observed in a nuclear system exhibiting. X(5) symmetry, is an important fingerprint. Such ratios, evaluated for ^{152}Sm, follows the conclusive evidence of X(5) symmetry lying between the vibrational and axially deformed shapes, as shown in the adjacent figures. The results have been published in Phys. Lett. B 879 (2026) 140662

For further details, please contact Tumpa Bhattacharjee, NLSS (btumpa@vecc.gov.in)

TECHNOLOGY DEVELOPMENT

A 32-Channel Front-End Built for Precision DSSD Readout

A 32-channel front-end electronics module for double-sided silicon strip detectors (DSSD) has been developed using indigenously designed VECC-005 (nCSA) and VECC-006 (pCSA) charge-sensitive amplifier ASICs. The module integrates a leakage current compensation (LCC) circuit to suppress leakage-current-induced noise, enabling low-noise operation at longer shaping times. Figure 1 shows the developed ASICs, and assembled module.

Validation of the module with Si strip detectors and Am-241 and Th-232 alpha sources

The module was tested with ^{241}Am & ^{229}Th alpha source and DSSD detector. The energy resolution of all 32 channels was measured with and without LCC circuit. Figure 2 illustrates the comparison which clearly indicates that the importance of inclusion of LCC circuit before CSA in such a low noise application with DSSD detectors.

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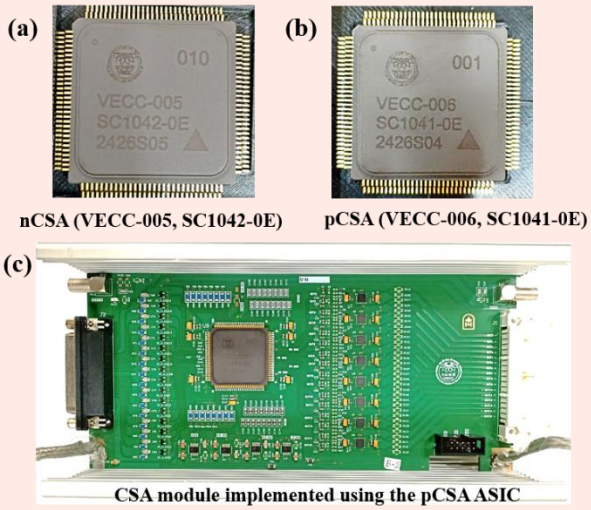


Figure 1: (a) nCSA ASIC (VECC-005, SC1042-0E). (b) pCSA ASIC (VECC-006, SC1041-0E). (c) CSA module implemented using the pCSA ASIC.

In-beam Characterization

The performance of the modules has been evaluated through rigorous in-beam testing using alpha ion beams with energies ranging from 30 to 50 MeV. The analysed results are presented in Figure 3.

The measured non-linearity was found to be less than 1%, demonstrating excellent linear response over the investigated energy range. In addition, the obtained energy resolution was found to be satisfactory for the intended application.

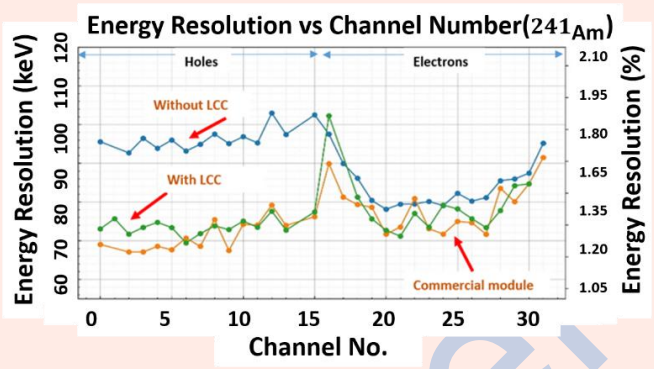


Figure 2: Comparison of Energy resolution with ^{241}Am source

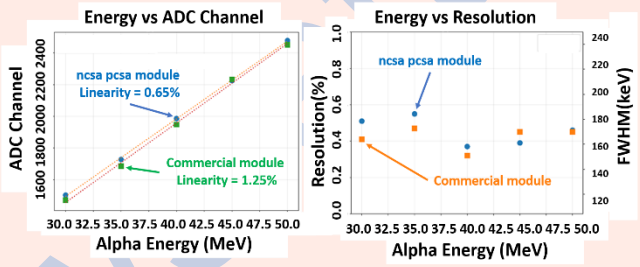


Figure 3: Measured linearity and energy resolution

For further details, please contact Manish Kumar Jha (mjha@vecc.gov.in), EC&ADS, C&I Group, VECC

A Dedicated Single Event Effects Test Chamber Takes Shape

A dedicated Single Event Effects (SEE) test chamber has been designed and fabricated for the radiation-reliability qualification of electronic components and devices intended for space missions and other radiation-intensive applications utilizing accelerated ion beams from K-500 superconducting cyclotron at VECC. The chamber houses an integrated experimental assembly comprising gold (Au) and rhodium (Rh) scattering targets for tuning the ion flux and penetration depth through Rutherford scattering, a PIPS detector assembly for beam-flux measurement and monitoring, and a dedicated mounting arrangement for the Device-Under- Test (DUT). This configuration enables controlled irradiation of electronic devices under well-defined radiation conditions.

These include a motorized linear-drive mechanism for automated target positioning, front-end detector readout electronics, and a dedicated data acquisition system (DAQ) for beam monitoring and experimental data collection. Together, these systems provide the essential infrastructure for systematic evaluation and characterization of Single Event Effects in accordance with relevant

internationally followed MIL and ASTM standards.

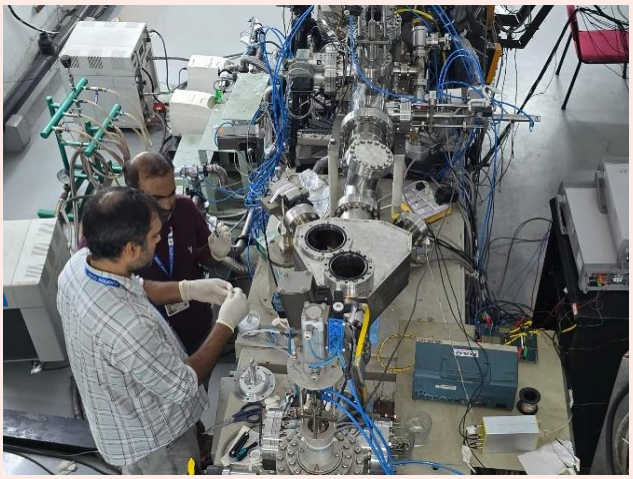


Figure 1: Installed Chamber in beamline (Channel-1)



Figure 2: Static target

(For further details, please contact Dr. Tapas Samanta (tsamanta@vecc.gov.in), C&I Group, VECC)

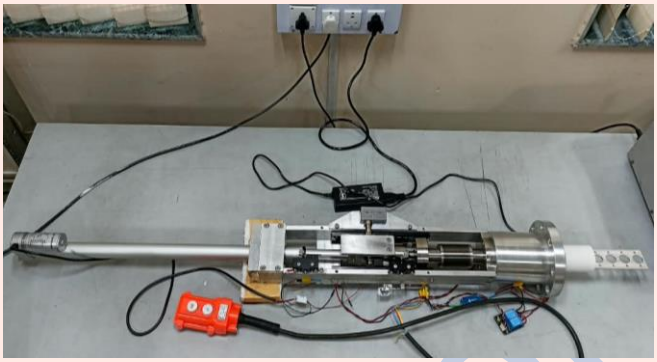


Figure 3: Target ladder drive system, and associated control and measurement

The facility provides access to heavy-ion beams covering a Linear Energy Transfer (LET) range of approximately 4-40 MeV·cm²/mg, with ion penetration depths ranging from 25 µm to more than 100 µm in silicon targets. Ne, Ar and Kr ion beams at energies of 5-8 MeV/u are currently available for irradiation experiments. In addition, irradiation capability using Xe ions at 5 MeV/u is being established, with the objective of extending the achievable LET to approximately 60 MeV·cm²/mg.

These capabilities will enable comprehensive characterization of radiation-induced effects, failure mechanisms and the radiation tolerance of advanced electronic components, supporting their reliability assessment and qualification for space and other radiation-intensive applications.

FACILITIES

TRANSFORMER AND MAGNET COIL WINDING FACILITY REPORT

The PE&MCD Section had regularly facilitated in the production of transformers, inductors and magnet coils for various sections of the Centre over several years. These include design, development as well as assisting in winding facilities of various coils for diverse applications, mostly at VECC. The facility continues to develop several types of coil systems for power supplies and magnets and for power line frequency and high frequency applications.

During January to June 2026, the facility was put to use for producing 7 1-ϕ transformers, and 9 inductors. Transformer production, during the said period, amounted to 1592.70 VA while total production of inductors constituted a total stored

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energy of 6.07 J. Figure 1 gives the production summary since 2024.

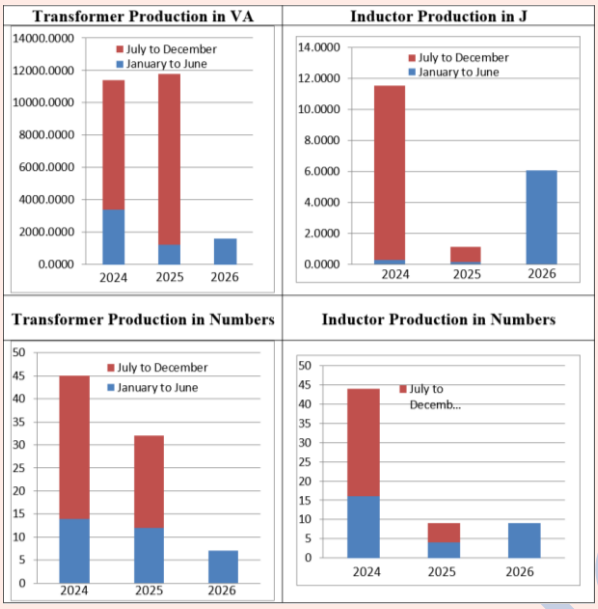


Figure 1: Production from January, 2024 to June, 2026

For further details, please contact Dr. Anirban De (ade@vecc.gov.in), Head, PE&MCDS/PED/ATG

AWARDS & HONOURS

AWARD FOR RESEARCH PAPER IN 3RD TECHNICAL HINDI SYMPOSIUM

The Third Technical Hindi Symposium (Takniki Hindi Sangoshthi) "Abhyuday-3" was organised on 5th-6th January 2026 at IIT Indore with the active collaboration of CSIR-NIScPR, New Delhi, along with the IIT Indore and IIT Jodhpur, to promote the use of Technical Hindi and expand the outreach of science and technology to the wider section of society. The two-day symposium witnessed research study outcomes on recent innovations and development in science and technology, and their societal interface. A total of 26 research papers were accepted after peer review and compiled in the publication.



Dr. Anuraag Misra from Variable Energy Cyclotron Centre was awarded 2nd Prize for his research paper

"स्वदेशी 2.0: वैश्विक संकटों से आत्मनिर्भर भारत की ओर" .

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newsletter@vecc.gov.in
Variable Energy Cyclotron Centre
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