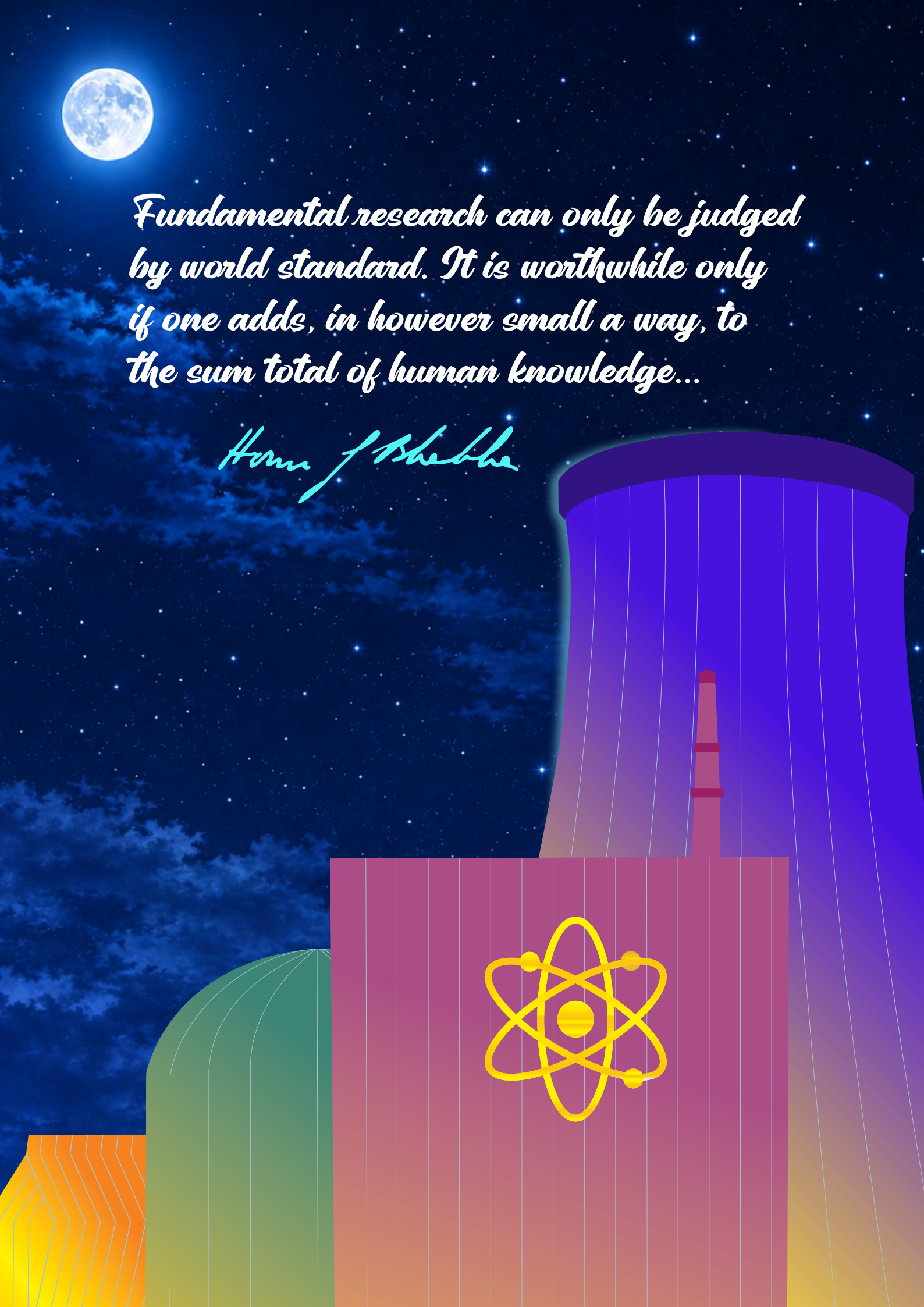

Fundamental research can only be judged
by world standard. It is worthwhile only
if one adds, in however small a way, to
the sum total of human knowledge...
Homi J Bhabha

AATMANIRBHAR

Innovative Advancements in Healthcare, Energy, Materials & Science Accelerators

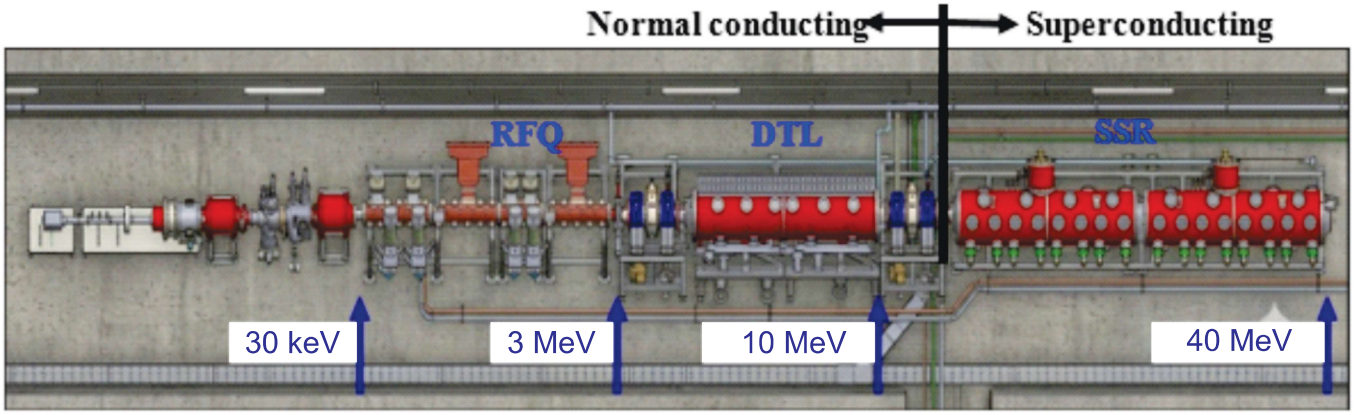
त्वरकों में आत्मनिर्भरता: स्वास्थ्य सेवा, ऊर्जा, विज्ञान और पदार्थ विज्ञान के क्षेत्र में नवाचारी प्रगति

The Amrit Kaal Vision of the Department of Atomic Energy (DAE) envisages the phased development and establishment of a High-Energy (~1 GeV), High-Intensity (>10 mA) Proton Accelerator to support the growing nuclear power programme. The Medium Energy High Intensity Proton Accelerator (MEHIPA) represents the next step towards this goal, aimed at developing and demonstrating superconducting accelerating structures and associated technologies essential for high-intensity proton beams at high energies. The performance of normal-conducting accelerating structures has already been demonstrated through the Low Energy High Intensity Proton Accelerator (LEHIPA), where the proton beam was accelerated to 20 MeV for the first time on August 04, 2023. In parallel, the development of superconducting (SC) cavities and associated technologies has been initiated as part of India's in-kind Contribution to the Proton Improvement Plan (PIP-II) of Fermi National Accelerator Laboratory (FNAL), under the Indian Institutions & Fermilab Collaboration (IIFC). This collaboration has facilitated the establishment of indigenous expertise in SC technologies.

MEHIPA-I, a 40 MeV proton linac planned at BARC Visakhapatnam, builds on the experience gained through LEHIPA and the development of SC technologies under IIFC. Work on establishing the required infrastructure has already commenced. The design of MEHIPA-I's normal-conducting accelerating structures has been adopted from LEHIPA. Key subsystem developments and near-term plans for MEHIPA-I are presented below.

Multi-Cusp Ion Source Development: Compared with conventional solenoidal Electron Cyclotron Resonance (ECR) ion sources, multi-cusp ion sources offer lower ion temperatures and negligible on-axis magnetic fields, resulting in low emittance for high-intensity beams. Further online optimisation of beam emittance can be achieved through the spatial and angular arrangement of magnetic multipoles.

SC Spoke Resonator Cavity: A Single Spoke Resonator (SSR) cavity has been



40 MeV Proton Accelerator: Layout schematic.



SC-Single Spoke Resonator and 7 kW Solid State Power Amplifier systems: Other in-kind contributions of India to FNAL.

indigenously fabricated and delivered to FNAL, where it was successfully used for 17 MeV beam acceleration. The cavity demonstrated the best performance among all cavities. A nearly identical SSR cavity design is envisaged for MEHIPA-I.

High-Power RF Amplifiers: Solid-State Power Amplifiers (SSAs) of 7 kW capacity, developed by BARC, were supplied to FNAL as part of India's in-kind Contribution, and their performance was demonstrated during 17 MeV acceleration. The design has been extrapolated to the 50 kW capacity required for MEHIPA-I. Normal-conducting structures, however, demand much higher power. At LEHIPA, this requirement is met using three 1 MW klystrons. Given the challenges associated with klystron availability, SSAs are being developed as an alternative. The scheme and design of a 350 kW SSPA have already been worked out.

Conduction-Cooled Superconducting Magnets: Alongside SC cavities, multiple superconducting solenoids will be housed within the cryomodule for beam focusing. The design of SC magnets for MEHIPA-I has been adopted from components originally designed and developed under IIFC.

LLRF and RFPI: The in-house-developed EPICS-based Low-Level RF (LLRF) control and RF Protection and Interlock (RFPI) system was successfully demonstrated at the Spoke Test Cryostat (STC) at Fermilab. Building on this experience, an upgraded LLRF and RFPI system is being developed for MEHIPA using BARC PARAS (BARC Particle Accelerator Real-time Automation System), an indigenous software platform. The upgraded system will provide enhanced performance and functionality for real-time RF control, monitoring, and protection.



Multi-cusp ECR Ion Source.



Helium screw compressor installed in BARC.

Development of Indigenous Cryogenic Systems for Superconducting Structures: Most of the cryogenic system for MEHIPA is envisaged to be developed indigenously, including the helium compression system, 2 K refrigerator cold boxes, and cryogenic distribution system. Critical components of these subsystems include helium screw compressors, turbo expanders, and plate-fin heat exchangers. An indigenously developed helium screw compressor has recently been received and installed at BARC for testing.



A 2 kW Cryoplant: Among important in-kind contributions of India to FNAL.