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DAE-DOE Discovery Science Collaboration

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DAE-BRNS High Energy Physics Symposium

IIT-G, India

Dec 8, 2014

Indian Institutions and Fermilab Collaboration

- High Intensity Superconducting Proton Accelerator for the respective domestic programs
 - Concept of “Total Project Collaboration” on Accelerator
- Intensity Frontier Neutrino Experiments (MINOS, NOvA and LBNF)
 - Develop LBNF-ND physics and Detector Technology



Collaboration

- **Fermilab** has proposed the construction of
 - High Intensity Superconducting Proton Accelerator (HISPA:PIP-II)
 - Long Baseline Neutrino Facility (LBNF)
- DAE laboratories have proposed the construction of
 - Indian Spallation Neutron Source at **RRCAT**, Indore
 - Accelerator for Medical, Energy and Industrial applications at **BARC**
- R&D phase collaboration (2009 →)
 - **HISPA**: Fermilab, BARC, Mumbai, IUAC, New Delhi, RRCAT, Indore and VECC, Kolkata
 - **LBNF**: Fermilab, 15 Indian institutions funded by DAE and DST for Neutrino Collaboration

DOE-DAE Implementing Agreement (2011)

IMPLEMENTING AGREEMENT

BETWEEN

THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA

AND

THE DEPARTMENT OF ATOMIC ENERGY

OF THE REPUBLIC OF INDIA

FOR COOPERATION

IN THE AREA OF ACCELERATOR AND PARTICLE DETECTOR

AND DEVELOPMENT FOR DISCOVERY SCIENCE

दिल्ली में दिनांक 19.07.2011 को अंग्रेजी एवं हिन्दी भाषाओं में, दो-दो प्रतियाँ (दोनों भाषाओं के प्रलेख समान रूप से प्रामाणिक) हस्ताक्षरित।

श्रीकुमार बतौर
भारत गणराज्य के परमाणु ऊर्जा
की ओर से

संयुक्त राज्य अमेरिका के ऊर्जा विभाग की ओर से
विभाग

Discovery Science: The United States' Department of Energy and India's Department of Atomic Energy signed an Implementing Agreement on Discovery Science that provides the framework for **India's participation in the next generation particle accelerator facility at Fermilab. (US State Department Press)**

US-India Strategic Dialogue

SCIENCE & TECHNOLOGY DIALOGUE, WASHINGTON, DC ///

MEET THE CATALYST



June 11, 2012

At the end, the Joint Commission recommended several new directions of cooperation including research in the areas of high energy particle physics and gravitational wave detection under the 'Discovery Science Agreement' between Department of Atomic Energy and U.S. DOE. In Basic and Applied sciences — materials research, computer sciences and neurosciences have been identified as potential areas of future engagement.

Accelerator and Physics Programs Technical Collaboration are No 1 deliverables to the Joint US-India Science Working Group (2012)

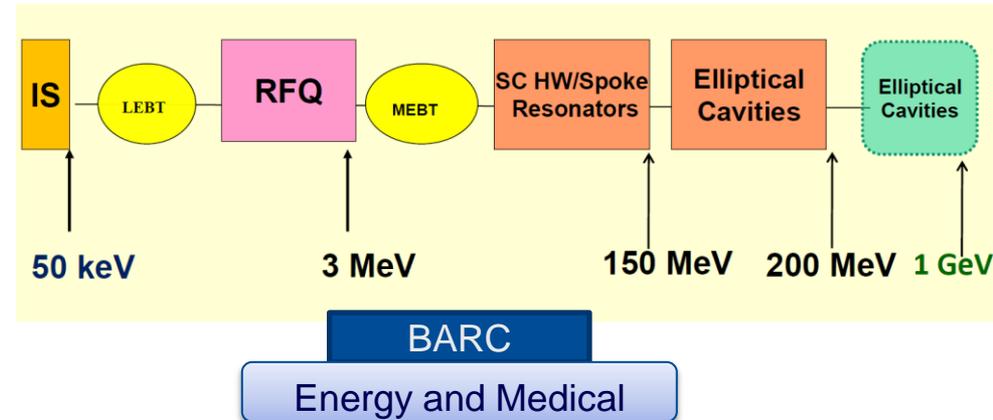
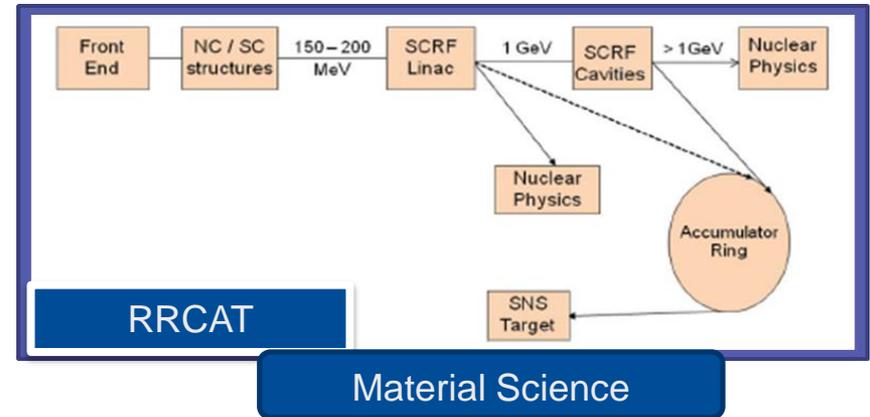
DAE-DOE Agreements for Accelerator and Neutrino

“The President welcomed India’s contribution and cooperation on high-energy physics and accelerator research and development with the U.S. Department of Energy. “ – **The White House, US-India Joint Statement, Sept 2014**

- DAE-DOE Agreement on the joint HISPA construction (Project Annex I).
 - Signed by Secretary, DAE
 - Is awaiting Secretary, DOE signature.
- DAE-DOE Agreement on the joint LBNF construction (Project Annex II)
 - Is going through final approval in GOI.

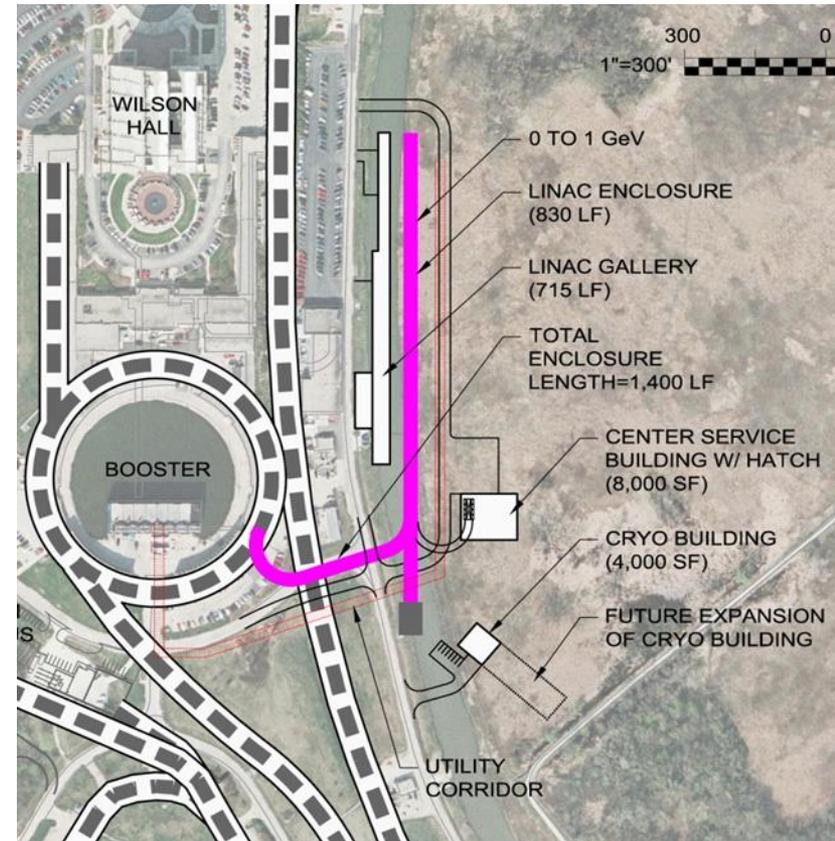
Indian Institutions and Fermilab HISPA Collaboration

- Signed its first institutions level MOU in 2006. Eight addendum MOUs (2007-12)
 - Covering all aspects of SRF linac and Neutrino Collaboration
- Since Jan 2012, Collaboration operates under the DAE-DOE Discovery Science Implementing Agreement to US-India Science and Technology Agreement
 - In the 12th and 13th plan of India

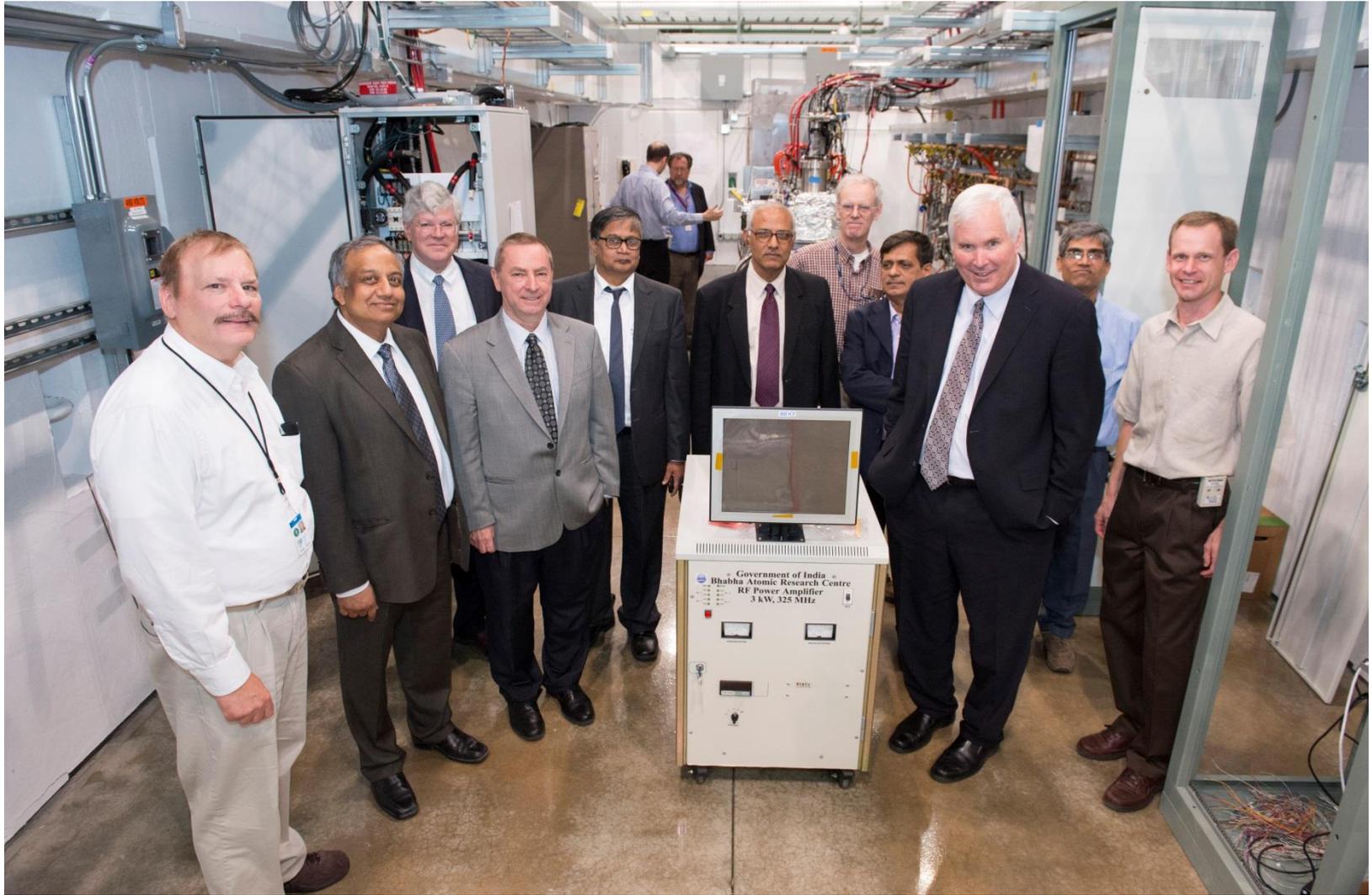


Fermilab: HISPA (aka PIP-II)

- High Intensity Superconducting Proton Accelerator (HISPA) (aka PIP-II) is a ~1 GeV Linac.
 - The design of this machine is similar to the two Indian accelerators.
 - It is design to provide 1.2 MW of beam for LBNF on day one of its operation.
 - It is upgradable.
- PIP-II will be build with significant “In-Kind” contributions of accelerator components from foreign countries.
 - India is a significant collaborator

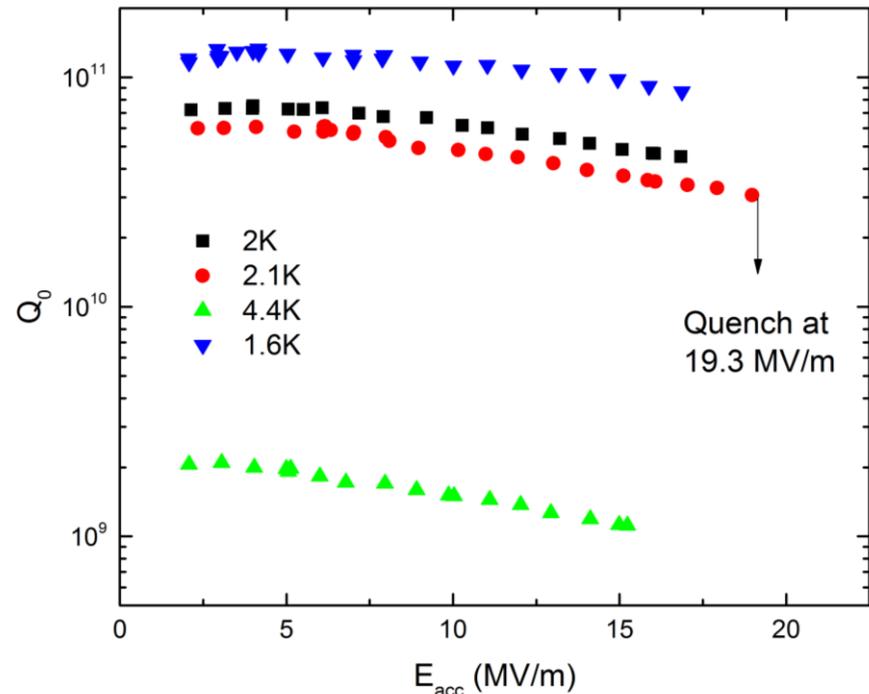


BARC: 325 MHz, 3 kW RF at Fermilab



RRCAT: 650 MHz $\beta=0.9$ 1-cell cavity

- First 650 MHz single-cell niobium cavity fabricated by RRCAT and IUAC was processed and tested at Fermilab during Dec-2013 and January 2014.
- Cavity reached E_{acc} of 19.3 MV/m and Q_o of of 7×10^{10} at 2K. This performance exceeds the design parameters.

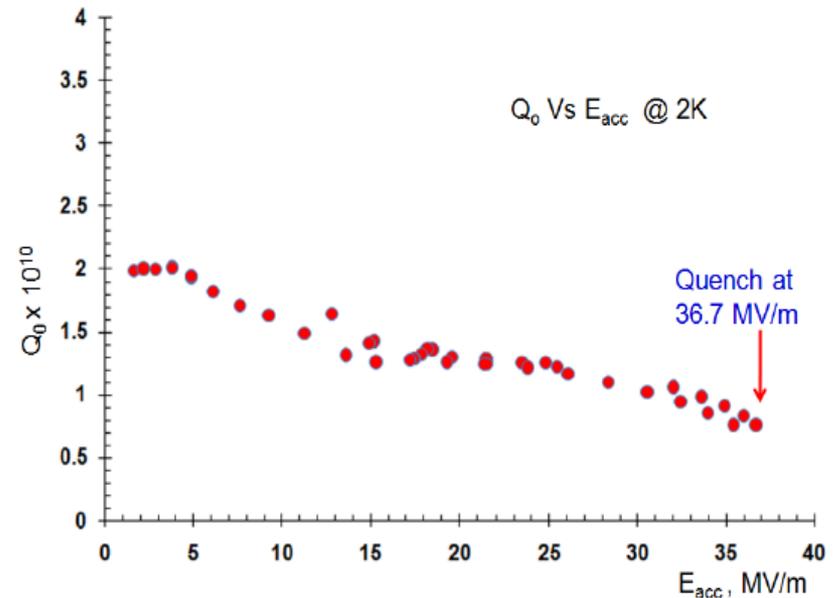


RRCAT: Vertical Test Stand

- A Jointly design and Fabricated Vertical Test facility for RF characterization of SCRF cavities at 2 K has been commissioned.
 - A single-cell 1.3 GHz cavity has been successfully tested using the facility.



Transfer of liquid helium in the VTS cryostat



Testing of single-cell 1.3 GHz SCRF cavity in the VTS facility at RRCAT

IIFC – ν P Collaboration

- Eight Indian Institutions have joined the Fermilab Neutrino Physics Program.
 - MINOS, MINOS+
 - NOvA
 - LBNF
- We are expecting a total of 20-100 Ph.D. students from India under this program.
 - Students jointly supported by DAE-DST and Fermilab.
 - Indian infrastructure is fully supported by DAE-DST with technical support from Fermilab.
- This collaboration is growing
 - Indian Infrastructure Development
 - We continue to include more institutions
 - We are recruiting faculties and postdoctoral fellows.



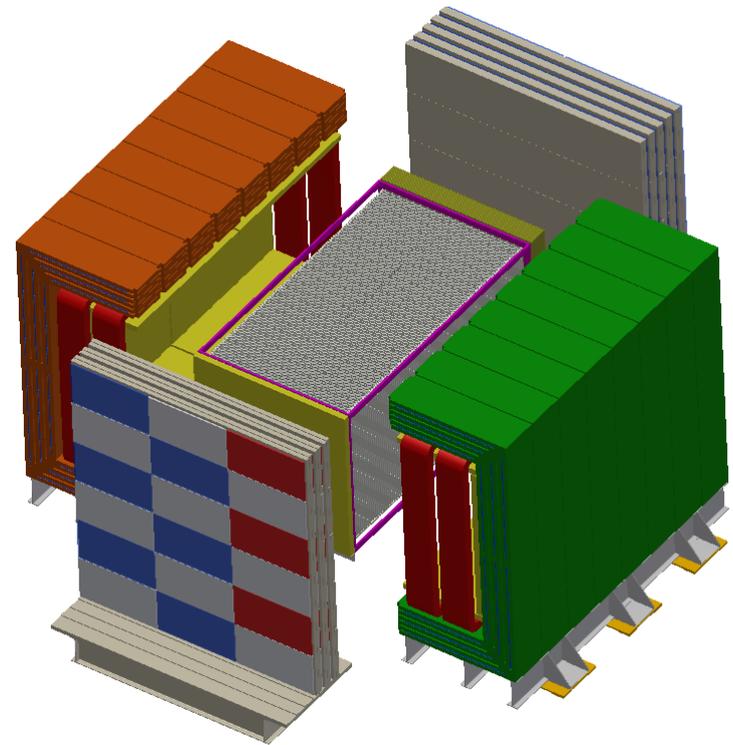
Long Baseline Neutrino Facility

- An accelerator-based long-baseline neutrino experiment, as well as neutrino astrophysics and nucleon decay, with an approximately 40-kton (active mass) modular liquid argon TPC (LAr-TPC) detector located deep underground and a **high-resolution near detector**.
- LBNF will measure with high precision are
 - The oscillations of neutrinos differ from those of anti-neutrinos, testing whether CP symmetry is violated in the leptonic sector.
 - Resolving this neutrino mass hierarchy ambiguity, along with precise measurements of neutrino mixing angles.
 - Near Detector to add many rich program in neutrino scattering physics addressing many non-oscillation topics

IIFC: LBNF-ND Detector

- The details of how the collaboration will develop LBNF-ND is under discussion.
 - **DOE-DAE-DST-Fermilab-India Institutions**
- Major Subsystems with Indian expertise
 - **Straw Tube**
 - **Muon ID**
 - **ECAL**
 - **Magnet**
 - **Instrumentation and DAQ**
- Proposed Schedule
 - **Conceptual Design CY15**
 - **Preliminary Design CY 16**
 - **Final Design and Prototype CY17**
 - **Infrastructure Development CY17-18**
 - **Prototype Construction CY17-18**

Physics utilization of the accelerator (PIP-II) that DAE is helping build at Fermilab.

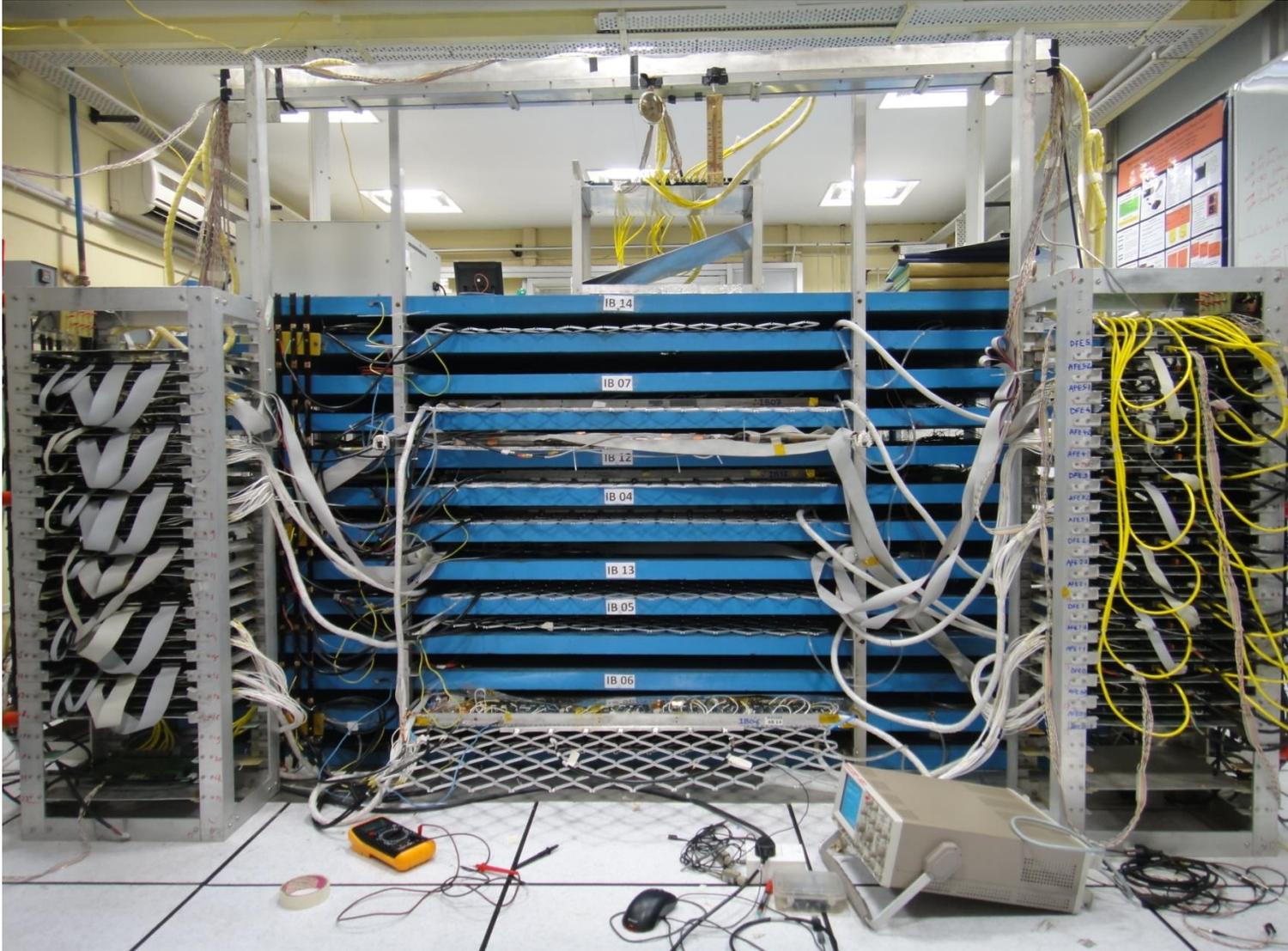


PU: STT Prototype



- **Straw Chamber Received from Dubna operating at PU**
 - **Experience**
- **Purchased 50 Kapton straws for R&D**
- **Establishing infrastructure for fabrication**

VECC: RPC Prototype



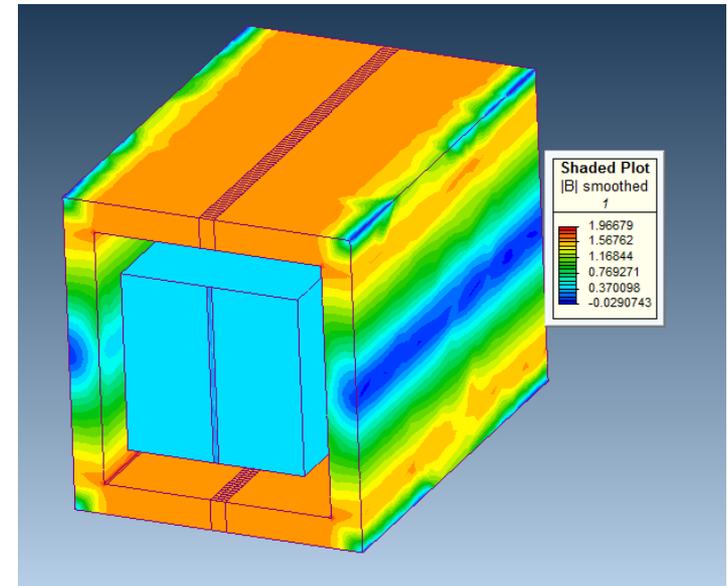
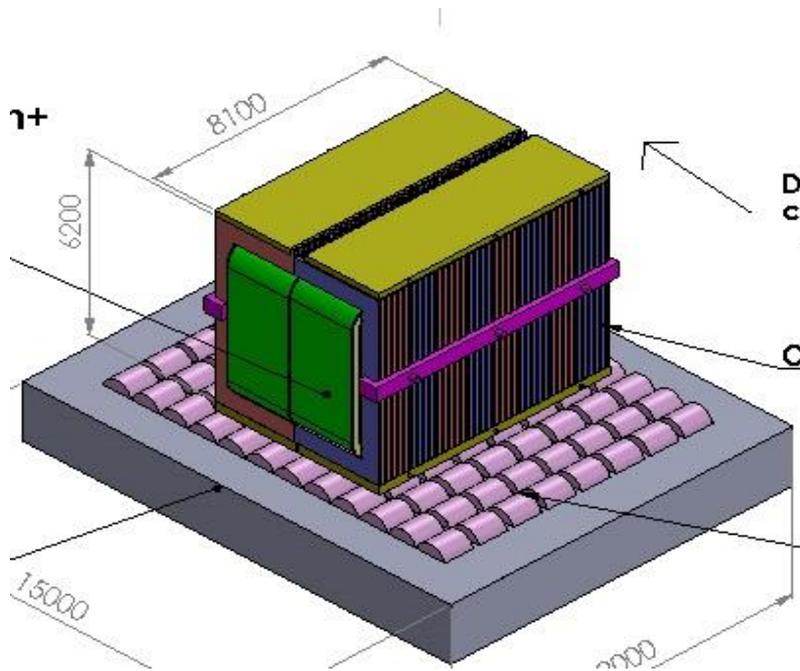
IIT-G: Computing Infrastructure



- Computing for the IIFC-vP collaboration
 - 250 cores High Performance Computing cluster
 - 500 GB RAM
 - 15 TB storage
- LBNF Simulation work of the collaboration
 - LBNF-ND Geant 4 simulation in ART framework.
- Setting infrastructure for the ECAL R&D and construction for LBNF

BARC: LBNF-ND Dipole

- LBNF-ND Tracking detectors and ECAL Modules will reside in 0.4T dipole magnetic field volume with inner dimensions 4.5m*4.5m*8.1m. The magnet needs to support and anchor the detectors



Volumetric Magnet field plot

IIFC: Training the future scientist & Engineers

- We have graduated 3 students with Ph.D.
 - **Sonam, Richa and Amandeep**
- One student was here for one year
- At present we are hosting five students
 - **Pavan Pandey,**
 - **Nitin Yadav,**
 - **Kuldeep Kaur,**
 - **Navaneeth Poonthottathil,**
 - **Siva Prasad**
- Eight new students to work on NOvA
 - **Rijeesh Keloth, Jagjeet Singh, Deepika Grover, Jyoti Tripathi, Daisy Karla, Prabhjot Singh, Sijith Edayath, Biswaranjan Behera**

IIFC: Come Join us

- **IIFC Neutrino Physics Collaboration is jointly funded by DAE and DST. Phase I funding is approved, we are awaiting final agreement to be finalized between DAE and DOE.**
- **We are developing/enhancing the Detector R&D infrastructure at Indian Institutions.**
- **We are looking for people to work in India and beam testing at Fermilab. We have funds for**
 - **Ph.D. Students**
 - **Post Doctoral Fellow**
 - **Assistant Professors**
 - **Junior Scientists**
- **At this conference please see Jim Strait, Raj Gandhi and Bipul Bhuyan if you need addition information.**

Summary

- **DAE/DST-DOE Collaboration for the Indian Institutions participation in the Fermilab based accelerator and physics program has been very successful.**
- **We are established a strong base and now building on its strength to undertake projects to**
 - **Jointly build accelerators at Fermilab and in India**
 - **Jointly build detector R&D infrastructure in India**
 - **Jointly build LBNF Near Detector**