Why INO ?

V. M. Datar

Tata Institute of Fundamental Research

Email: vivek.datar@tifr.res.in

Vigyan Samagam, Nehru Science Centre, Mumbai (8th May 2019)

Prelude…

- Indian scientists working at Kolar Gold Fields discovered atmospheric neutrinos while measuring cosmic muons at various depths (1965)
- Subsequently a proton decay experiment was set up at -2.3km and -2km depths but no p-decay events found. ~ 1990 KGF expt closed down.
- Indian scientists started an initiative in 2000 to re-initiate neutrino research. Resulted in INO project, lab under a mountain (sanctioned by GoI in Jan 2015)
- Studying neutrinos takes us beyond the Standard Model of particle physics!

The INO Collaboration

• INO Collaborating Institutions

Collaborating Institutions:

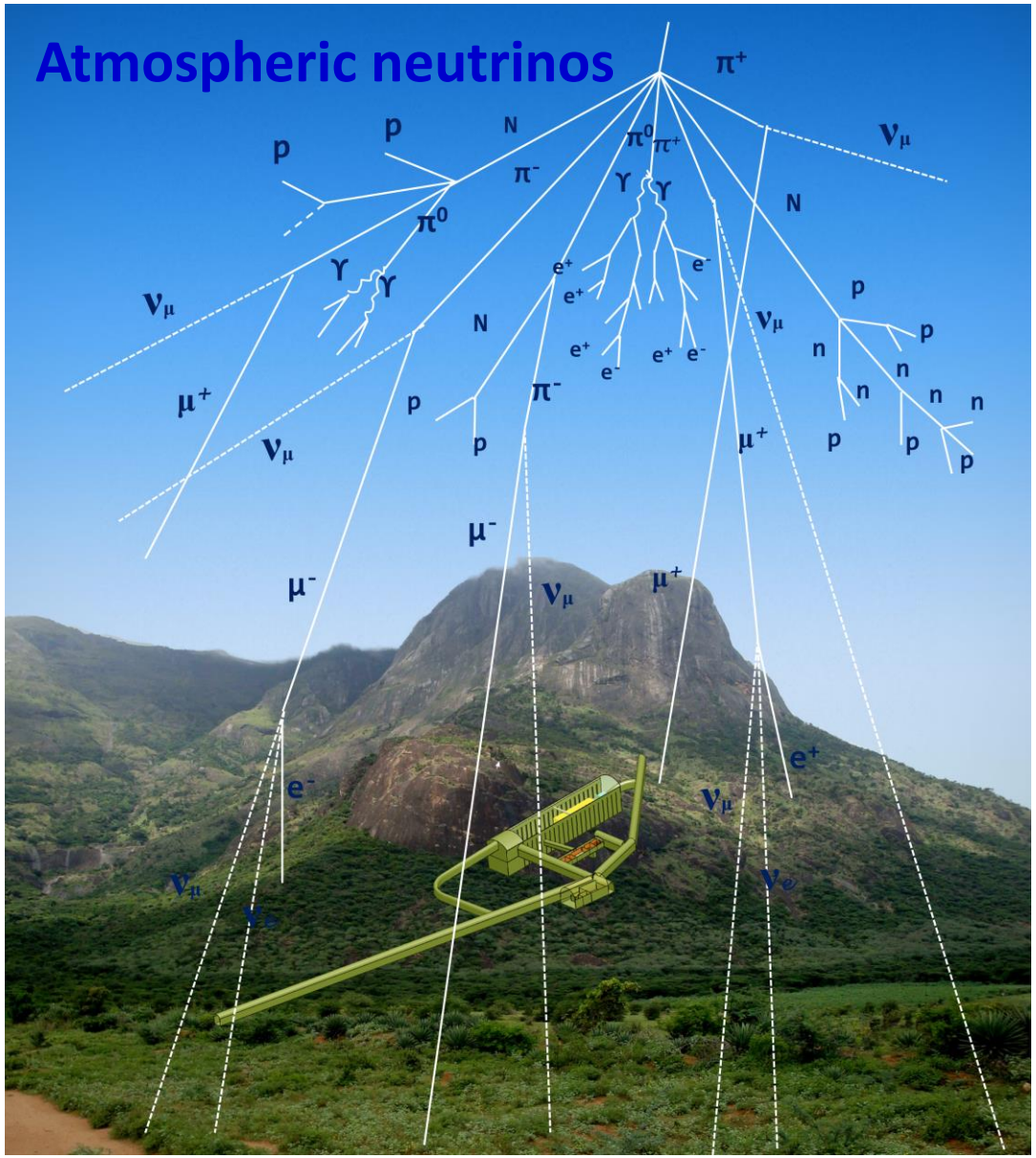
- AMU
- BARC
- BHU
- CU
- DU
- HNBGU
- HPU
- HRI
- IGCAR
- IITB
- IITG
- IITM
- IMSc
- IOP
- JU
- KU
- MU
- NBU
- PRL
- PU
- SINP
- SMIT
- SU
- TIFR
- UoH
- VECC

+IISER (Mohali), American College , Tezpur Univ, CKU (Gulbarga)

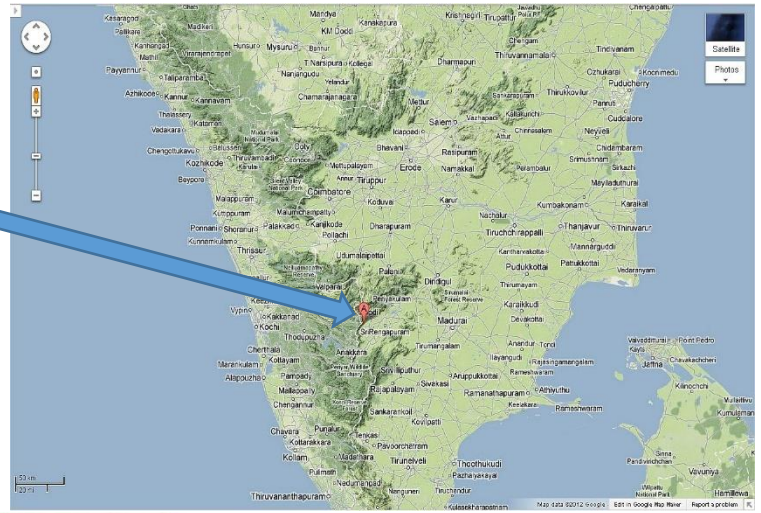
Participants of the INO Collaboration meeting at Madurai Kamaraj University (22-23 March 2018)

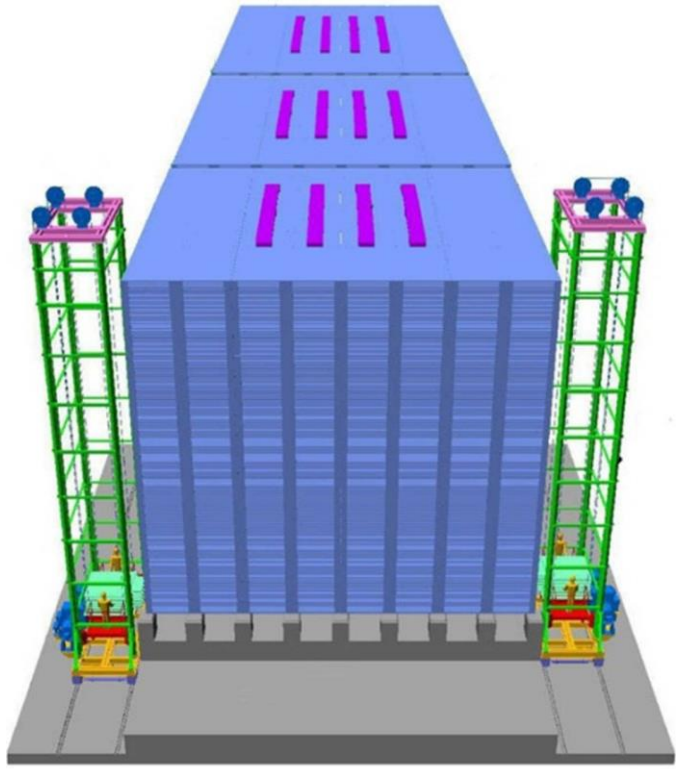
~28 institutions (national labs, Universities, IITs) participating

INO at Pottipuram (Theni)

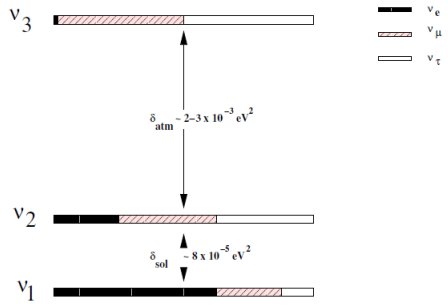


INO site





Mass ordering of ν



Is $m_1, m_2 < m_3$ (NH)
or $m_3 < m_1, m_2$ (IH) ?

Experiments planned at INO

- **Atmospheric neutrinos @ ICAL (**NH/IH, neutrino mixing parameters, DM annih., NSI), anomalous KGF events, Magnetic Monopole search….
- **Neutrinoless Double Beta Decay in ^{124}Sn** using cryogenic bolometric detector – TINTIN (TIFR led collab.)
- **Dark Matter** search using a cryogenic scintillator - DINO (SINP led collab.)
- **Low energy accelerator for nuclear reaction cross sections ~ Gamow energy** of astrophysical interest (IUC-DAEF + Univ., IIT groups): 3 MV Tandetron accelerator + Recoil Mass Separator + gas jet target

Why make a huge magnet?

- **Neutrinos** need matter (iron) to interact and produce **charged particles** ($\mu^{\pm}$ with charge of ± 1)
- These bend in magnetic field in opposite directions

$\Rightarrow$ identification of ν_μ/anti- ν_μ event

Why underground?

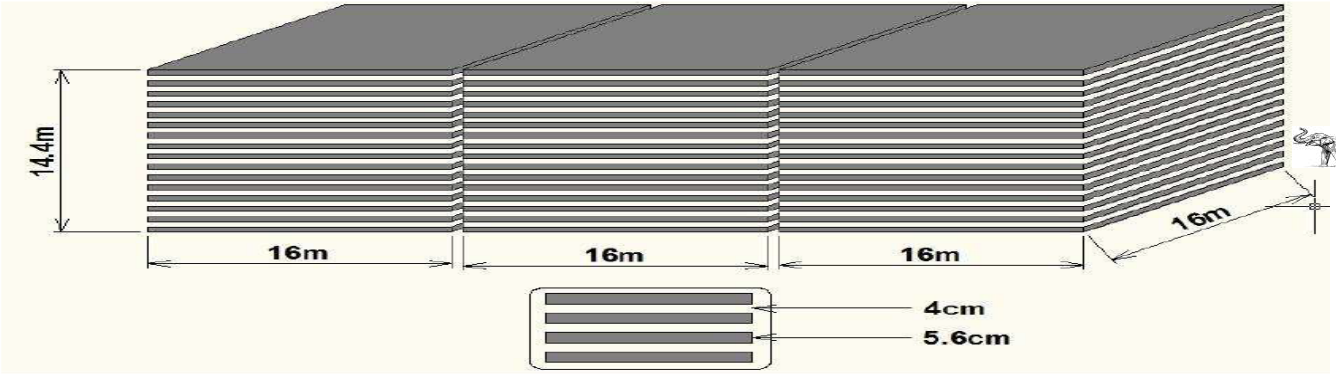
Cosmic muons most important background.

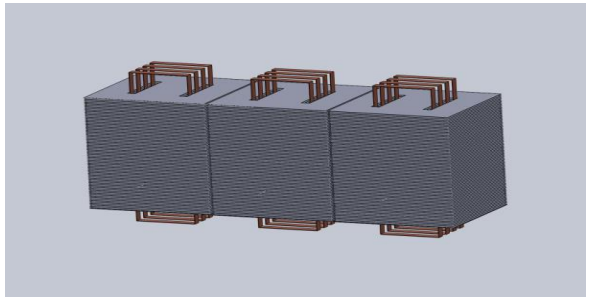
How deep ? 1 km $\Rightarrow$ ~10^6 reduction $\Rightarrow$

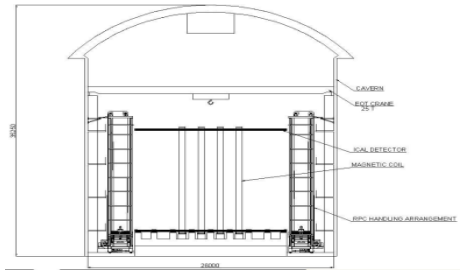
Mines/tunnels

Logistics better at tunnel

Schematic of Iron Calorimeter at INO



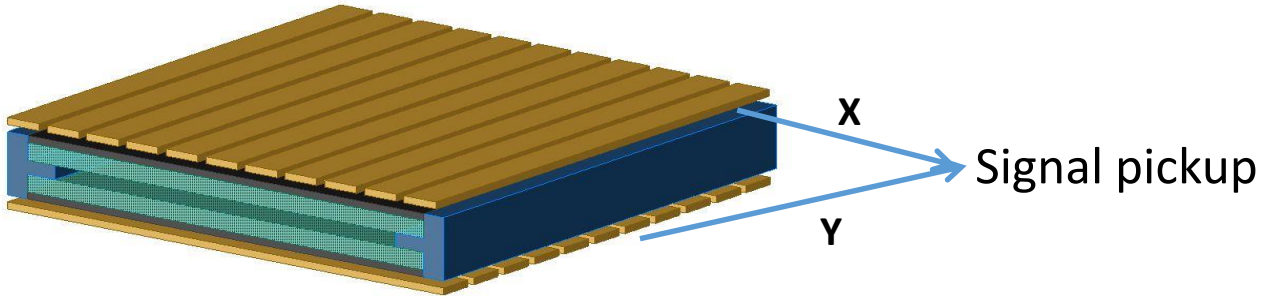


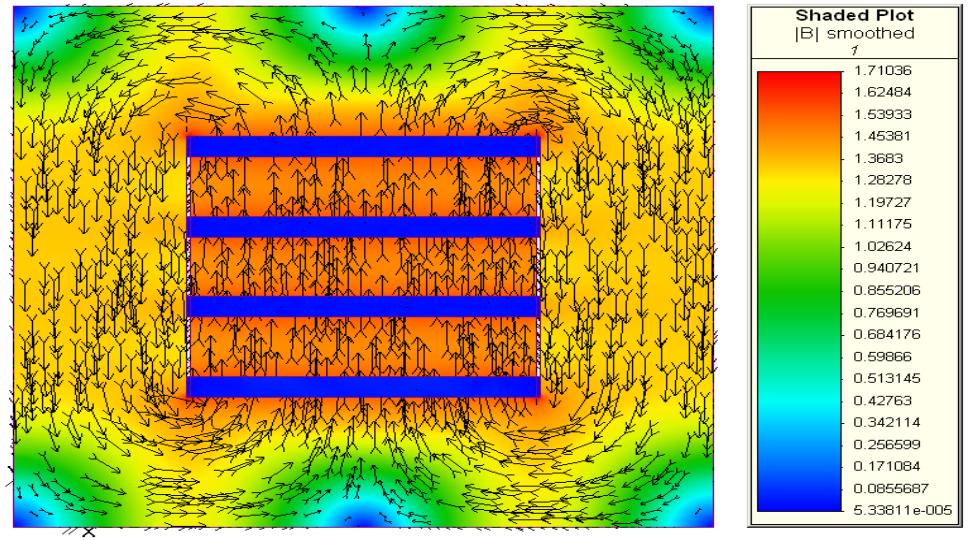


51 kton world's largest electromagnet

17 kton module has 150 layers Fe+RPC

B-field > 1 Tesla (90%)



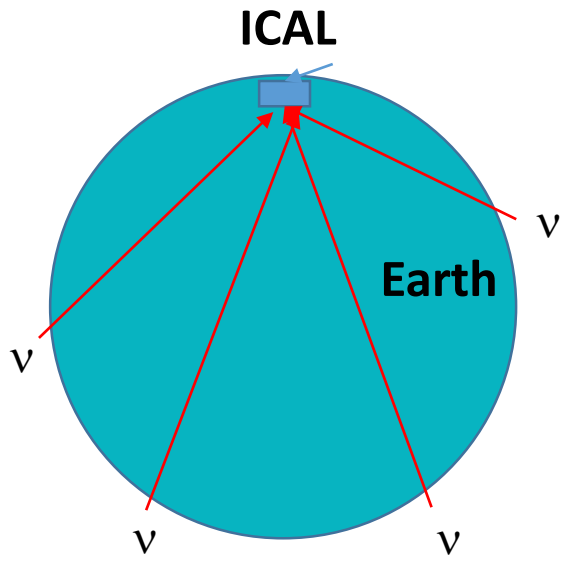


Glass RPC for detecting charged particles

~30,000 RPCs required, ~ 3.8 M channels

Simulated B-field for 60 kA-turns

Iron Calorimeter (ICAL) detector

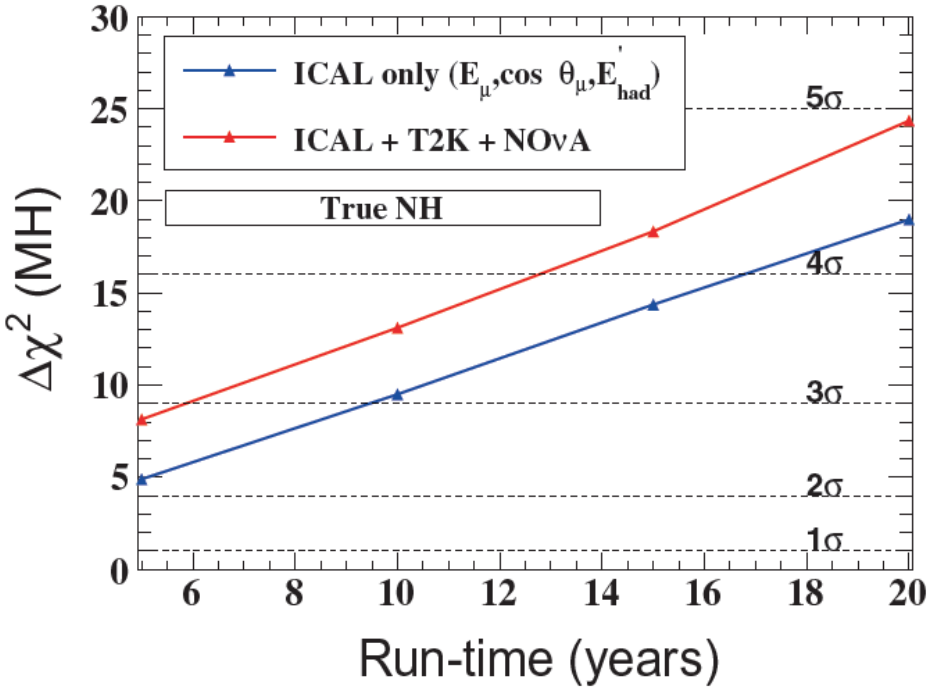


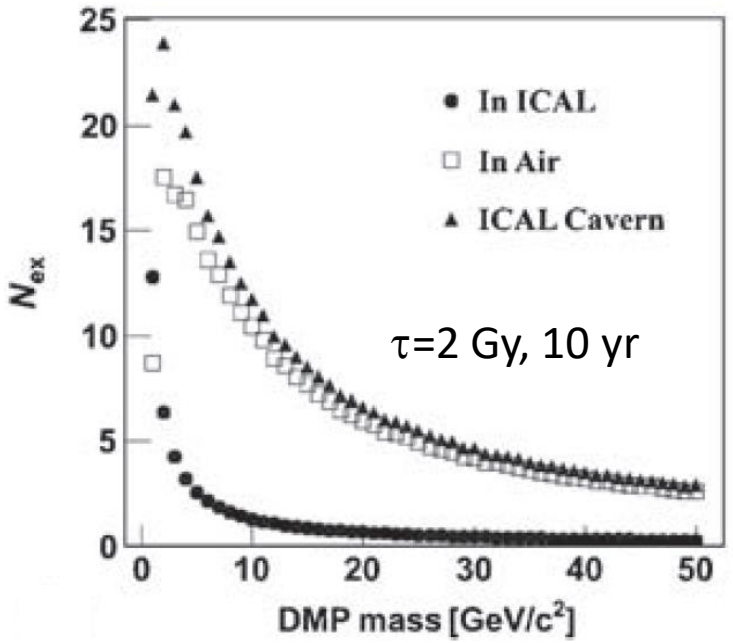
- Atmospheric neutrinos (**free!**): large range of energies (E_ν~1-20 GeV) and matter traversal distances ~ 1 – 13000 kms
- ICAL will identify ν_μ and $\bar{\nu}_\mu$ events via *charged current interaction* $\nu_\mu + n \rightarrow \mu^- + p$, $\bar{\nu}_\mu + p \rightarrow \mu^+ + n$ *and tracking outgoing* μ^- / μ^+
- Matter affects ν_μ and $\bar{\nu}_\mu$ differently and can be used effectively

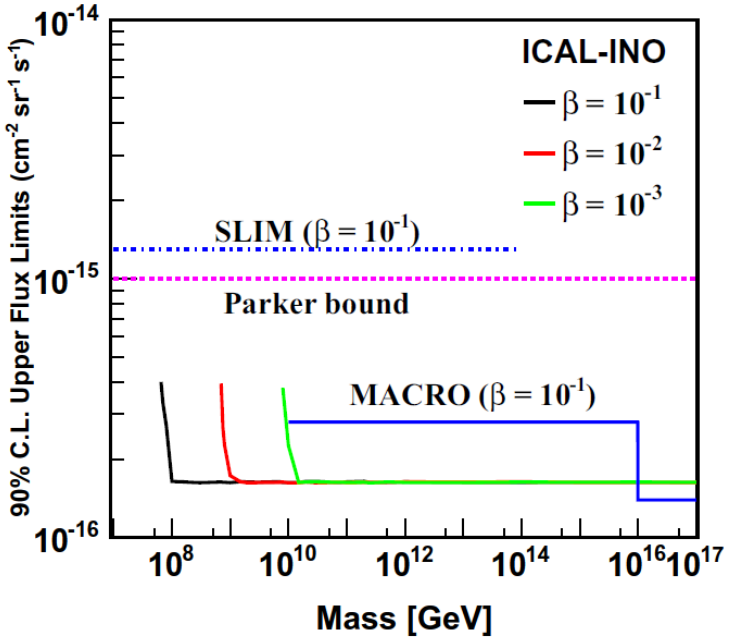
[*White paper on Physics with ICAL : Pramana* ***88****, 79 (2017)*]

Physics with ICAL – some examples

- Neutrino mass ordering, mixing parameters, non-standard interactions, neutrino decay, anomalous KGF events, magnetic monopoles …







The mini-ICAL (85 ton, 4m × 4m × 11 layers of Fe) @ Madurai

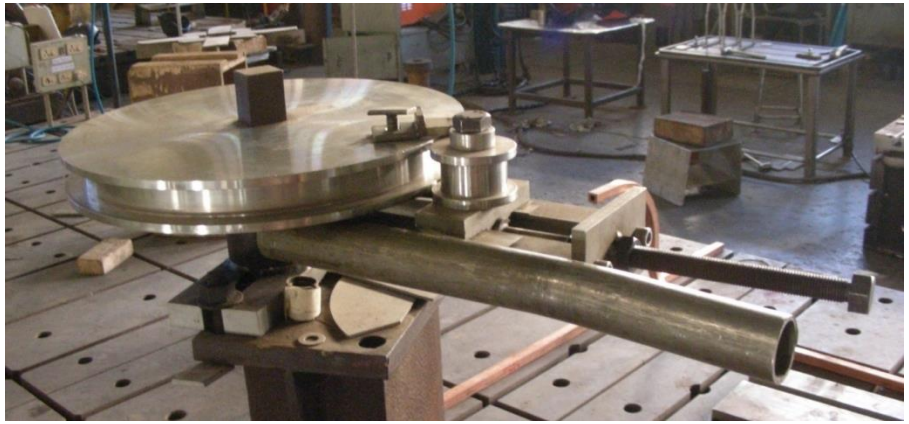
- Performance of Magnet: Measured magnetic field (*using sense coils and Hall probes*) vs 3D FE simulation
- Performance over long period of RPC including DC-DC supply, FE electronics in fringe B-field, EMI, closed loop gas system…..
- Feasibility of Muon Spin Rotation (μSR) for information about B-field complementary to sense loop and Hall probe data
- Measure $\Phi(\mu^+)$, $\Phi(\mu^-)$ at Madurai (near equator) and compare with simulation (by Athar, Honda)
- Prototype cosmic muon veto detector for mini-ICAL

Plate machining Job

Spacers and Pins

Copper Conductor Spool

Magnet Components (Core & Coil) BARC group



Conductor bending machine

Conductor straightening machine

Coil fabrication

mini-ICAL assembly

Pillars for magnet, G10 boards for Cu coils

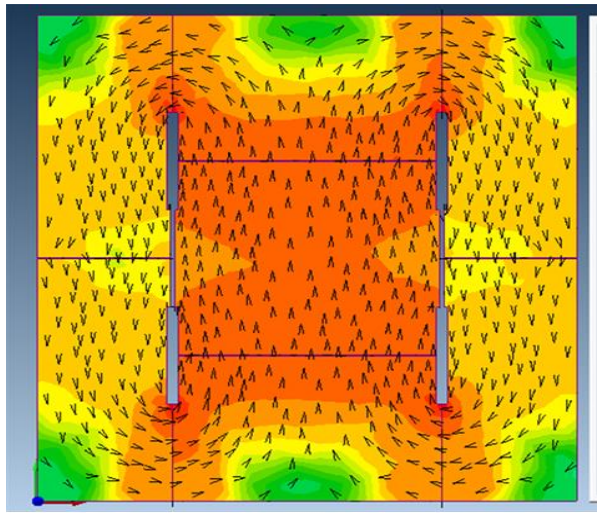
OFHC Cu “U” and “C” sections

Magnet assembly in progress

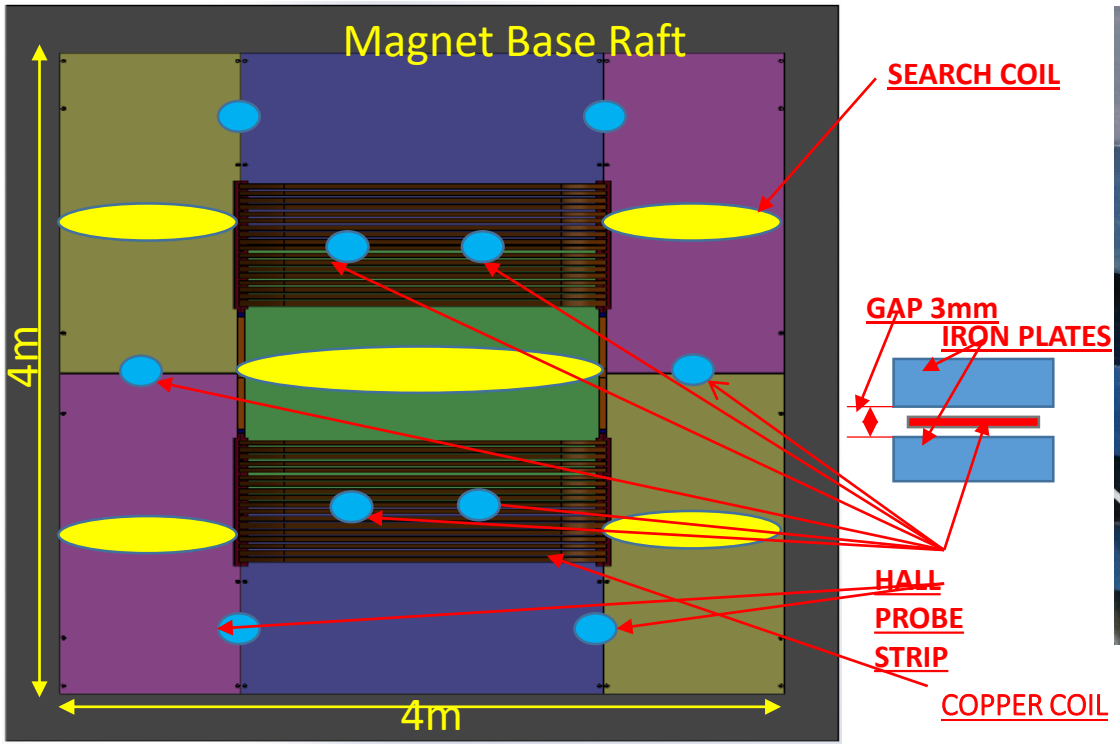
Assembly of iron plates of mini-ICAL magnet

Cu Coil Brazing

Low conductivity water cooling system for magnet & power supply



Field map at 26kAT

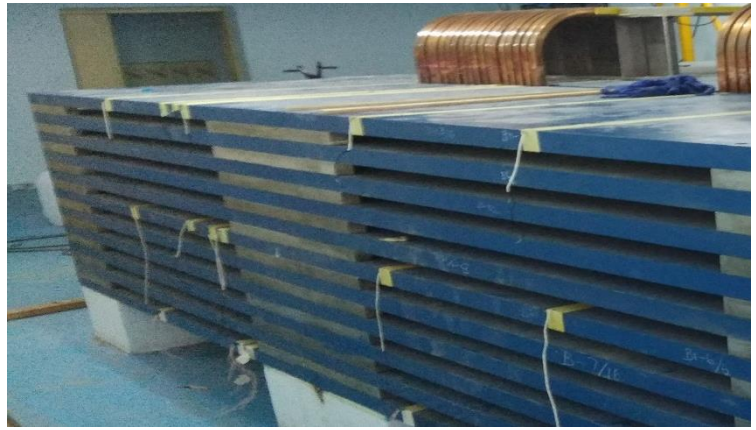


Magnetic measurement system
(1st ,6th , 11th layer)

Hall probe PCB in the gap

Magnet power supply
30V DC, 1200 AMP

Hall probe PCB strip

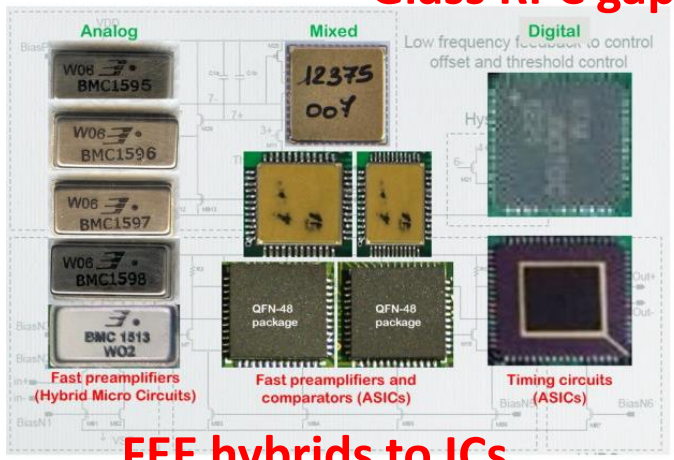


Search coils for flux measurement

RPC re-assembly

Glass RPC gap at St. Gobain

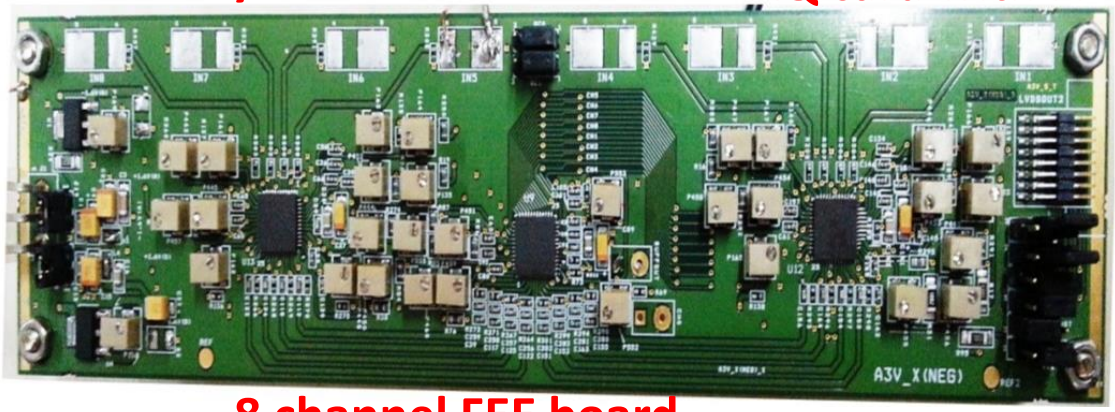
Closed loop gas system



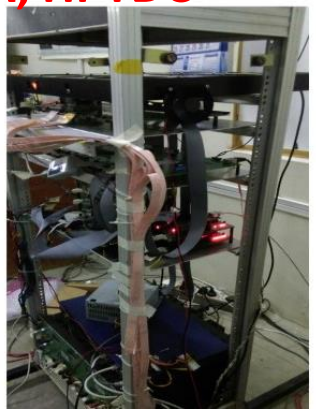
FEE hybrids to ICs

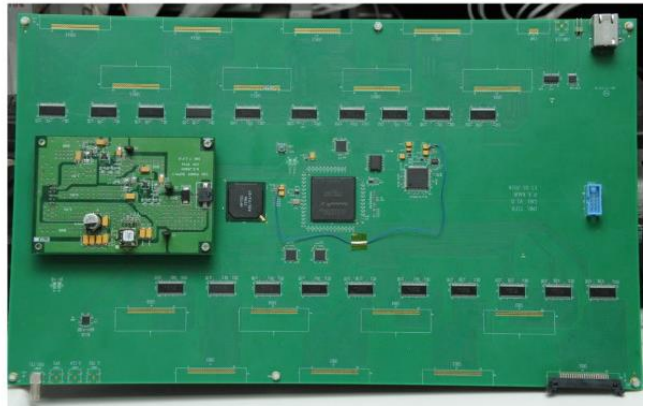
DAQ card with FPGA, HPTDC

±5 kV DC-DC HV card



8 channel FEE board





Trigger and Calibration system

Mini-ICAL team members:

BARC: Sourabh Pathak, Sandip Patel, S. Ajith, N.S. Dalal, S.P. Prabhakar, T.S. Sreenivasan, D.N. Badodkar (DRHR), S.P. Srivastava, K.N. Karn, P.I. Hadagali, P.K. Biswas, Alok Tripathi, Sachin Dolas, Prabhat Singh, Vinay Sharma, Sanjay Patil, Suresh Jaiswar (CDM) , R. Rengan, K. Srinivas (CED), S. Achrekar, N. Ayyagiri, A. Behere, V.B. Chandratre, D. Das, A. Jain, N. Kamble, T. Kasbekar, H. Kolla, A.Manna, S. Mohanan, S. Moitra, P.M. Nair, S. Padmini, M. Punna, S.M. Raut, S. Prafulla, S. Sikder, M. Sukhwani (ED), P.S. Shetty, B. Sivaramakrishna, Mathew Dominic, Shashank Padwal (TSD), special thanks to Dr. Sekhar Basu

SINP: N.K.Mondal

TIFR: B.S. Acharya, Vishal Asgolkar, Rajkumar Bharathi, Apoorva Bhatt*, Santosh Chavan, S. Dasgupta, V.M. Datar, Upendra Gokhale, Darshana Gonji, S.R. Joshi, Suresh Kalmani, Puneet Kaur, A. Lokapure, G. Majumder, Suryanarayan Mondal*, P. Nagaraj, Neha*, Pathaleswar, S. Pethuraj*, K.C. Ravindran, Mandar Saraf, B. Satyanarayana, Ravindra Shinde, Dipankar Sil, Thoi Salam Singh, N. Sivaramakrishnan, Pavan V., L. Umesh, Suresh Upadhya, Piyush Verma, E. Yuvaraj

VECC: S.K. Thakur, A. Bera, A. Ghosh, Noor Mohamed

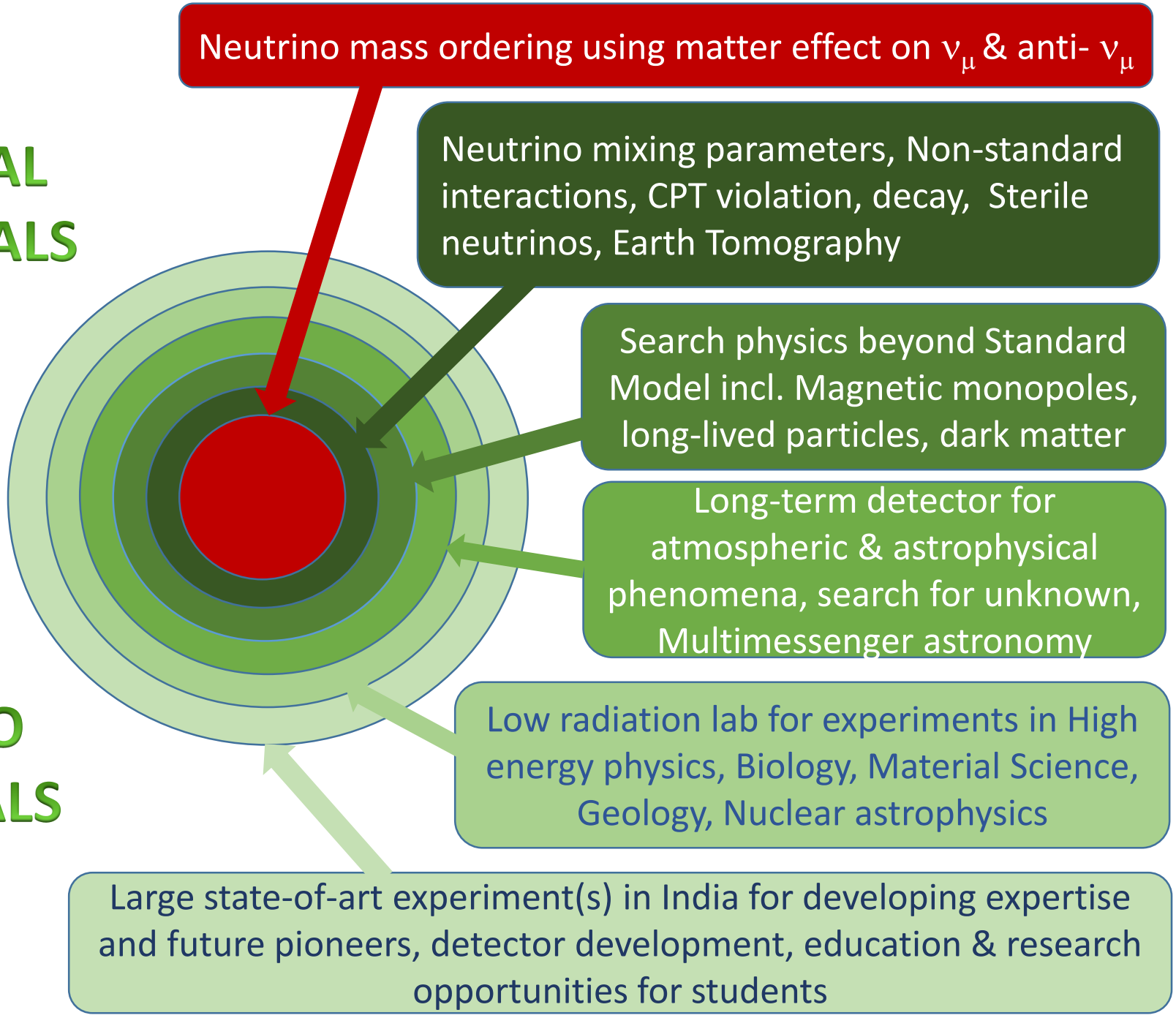
Mini-ICAL Design Safety Review Committee of BARC Safety Council for their suggestions

Essar Steel (steel plates), Green & Green (assembly), St. Gobain (RPC gaps), Ferrite India (Pune), BEC (Bhilai), Entech (B'luru) ….

Mag. Monopole, DM particle decay: Nitali Dash*, VMD

FE 3D EM simulation of ICAL magnet: Shiba Behera^{+}, M.S. Bhatia, VMD

* INO Graduate students $^{+}$ HBNI and NPD-BARC



from Amol Dighe