

High Energy Physics in India

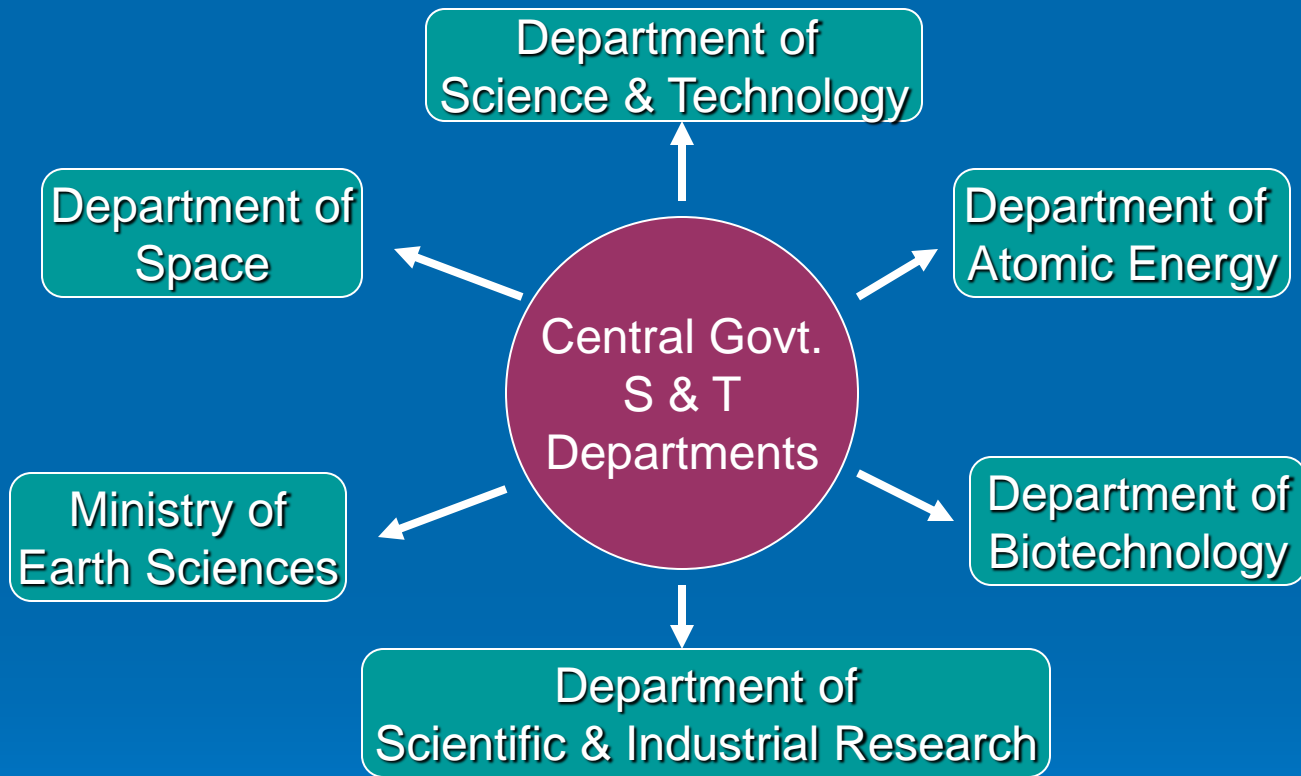
Naba K Mondal

Tata Institute of Fundamental Research

Mumbai, India

The background of the slide is a solid blue color. In the lower half, there are several decorative elements consisting of concentric circles, resembling ripples in water or a stylized atomic structure. These circles are centered at various points and vary in size and opacity, creating a subtle pattern.

Science Funding in India



Funding for High Energy Physics Research In India

➤ *Main Funding Agencies:*

- *Department of Science & Technology, Govt. of India (DST)*
 - *Main funding agency for Universities and institutes under DST. It is also the nodal agency to coordinate international agreement for cooperation in science research with other countries.*
- *Department of Atomic Energy, Govt. of India (DAE)*
 - *Main funding agency for autonomous institutes under DAE like TIFR, SINP, VECC etc.*

High Energy Physics In India

➤ *Early experiments:*

- *Cosmic ray studies using Cloud Chambers & Emulsion at Sandakphu near Darjeeling during 30s & 40s.*
- *Kolar Gold Fields (KGF) underground Facility.*
- *KGF Air Shower Array.*
- *Ooty Cloud Chamber & Air Shower Array.*
- *Cosmic ray Observatory at Gulmarg.*

➤ *Ongoing Experiments:*

- *Ooty GRAPES Air Shower Array.*
- *TACTIC (TeV Atmospheric Cherenkov Telescope with Imaging Camera) at Mt. Abu.*
- *HAGER Gamma Ray array at Hanle.*

➤ *Upcoming Facilities:*

- *High Energy Gamma Ray Observatory at Hanle (MACE project).*
- *India-Based Neutrino Observatory near Madurai in Tamil Nadu.*
- *LIGO-India.*

Participation in International Experiments

➤ *Early Experiments:*

- *Analysis of emulsion and bubble chamber data during 60s & 70s.*
- *L3 experiment in LEP at CERN*
- *DZERO experiment at Fermilab*
- *Belle Experiment at KEK Laboratory*

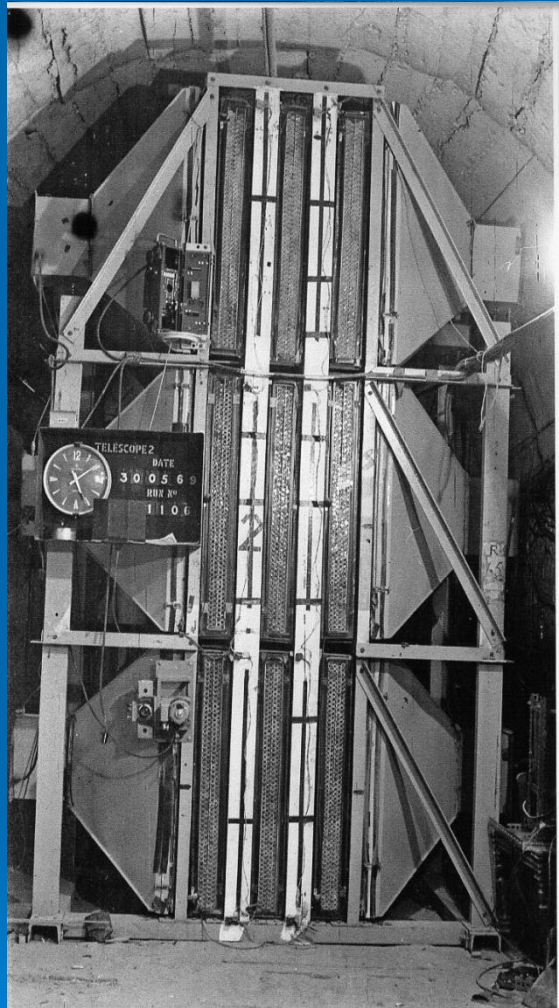
➤ *Current Experiments:*

- *CMS experiment in LHC at CERN*
- *Belle-II in Super KEKB*
- *Neutrino program in Fermilab*

➤ *Future possibilities:*

- *ILC*
- *LBNF*

Atmospheric neutrino detection at KGF in 1965



**Atmospheric neutrino detector
at Kolar Gold Field – 1965**

DETECTION OF MUONS PRODUCED BY COSMIC RAY NEUTRINO DEEP UNDERGROUND

C. V. ACHAR, M. G. K. MENON, V. S. NARASIMHAM, P. V. RAMANA MURTHY
and B. V. SREEKANTAN,

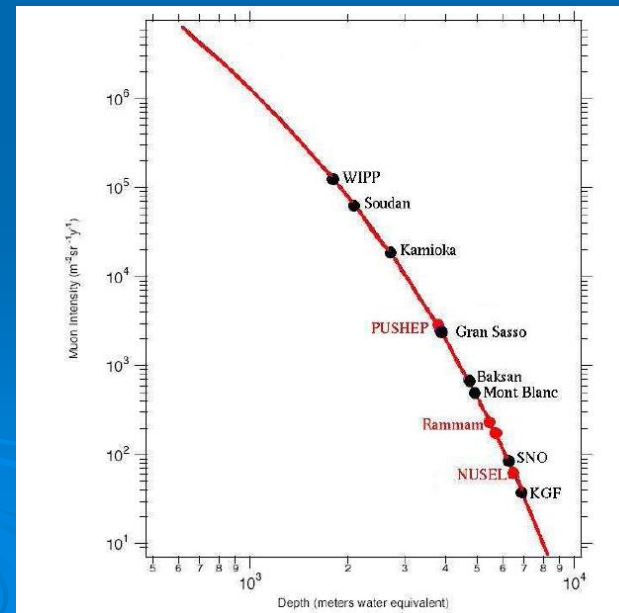
Tata Institute of Fundamental Research, Colaba, Bombay

K. HINOTANI and S. MIYAKE,
Osaka City University, Osaka, Japan

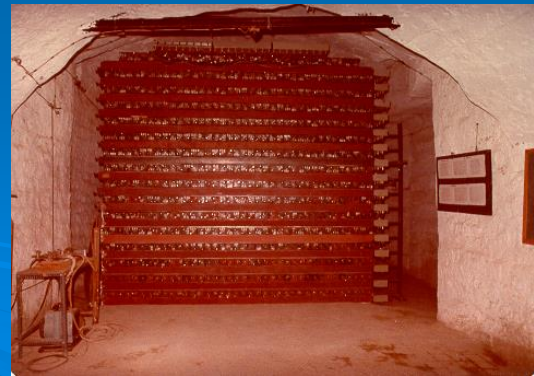
D. R. CREED, J. L. OSBORNE, J. B. M. PATTISON and A. W. WOLFENDALE
University of Durham, Durham, U.K.

Received 12 July 1965

Physics Letters 18, (1965) 196, dated 15th Aug 1965



KGF Phase I Nucleon Decay Detector



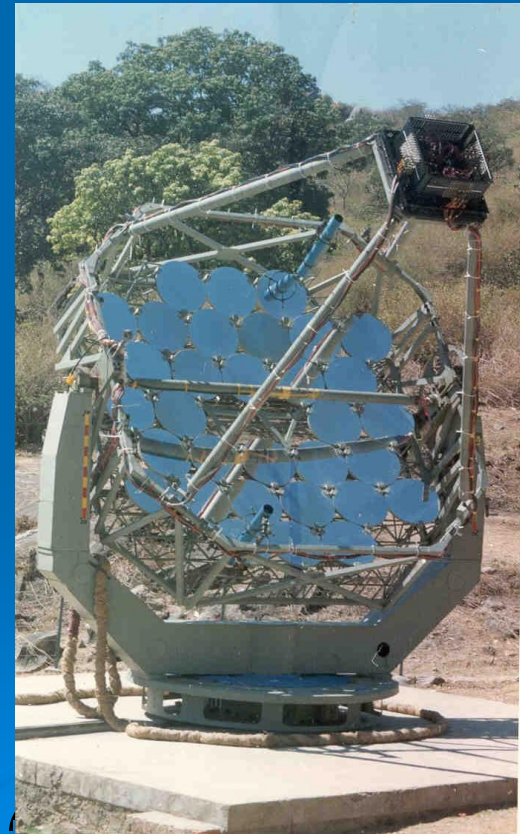
KGF Phase-II Nucleon decay Experiment



TeV Astronomy Programme at Mt. Abu

➤ *TACTIC (TeV Atmospheric Cherenkov Telescope with Imaging Camera).*

- *Location: Mt.Abu, Western India (24.6 N, 72.7 E, 1300m asl)*
- *Trigger threshold : ~1.5 TeV*
- *Light collector area : 9.5 sq. m*
- *Pixel size: 0.31 degrees*
- *Number of pixels: 349*
- *Sensitivity for Crab Nebula
5 sigma in 25 h*

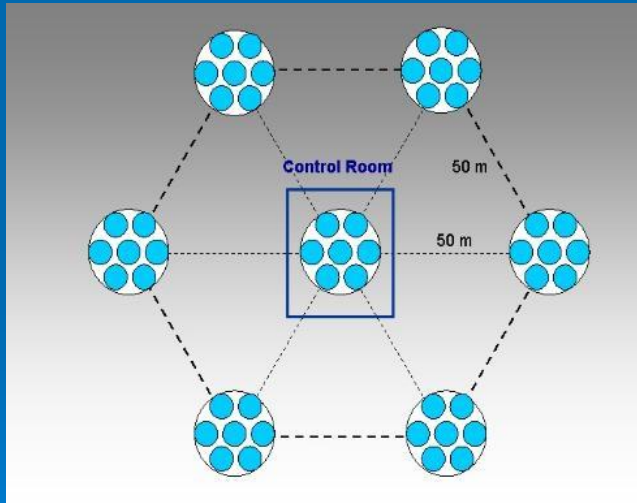


HAGAR Array at Hanle

Latitude: $32^{\circ} 46' 46''$ N

Longitude : $78^{\circ} 57' 51''$ E

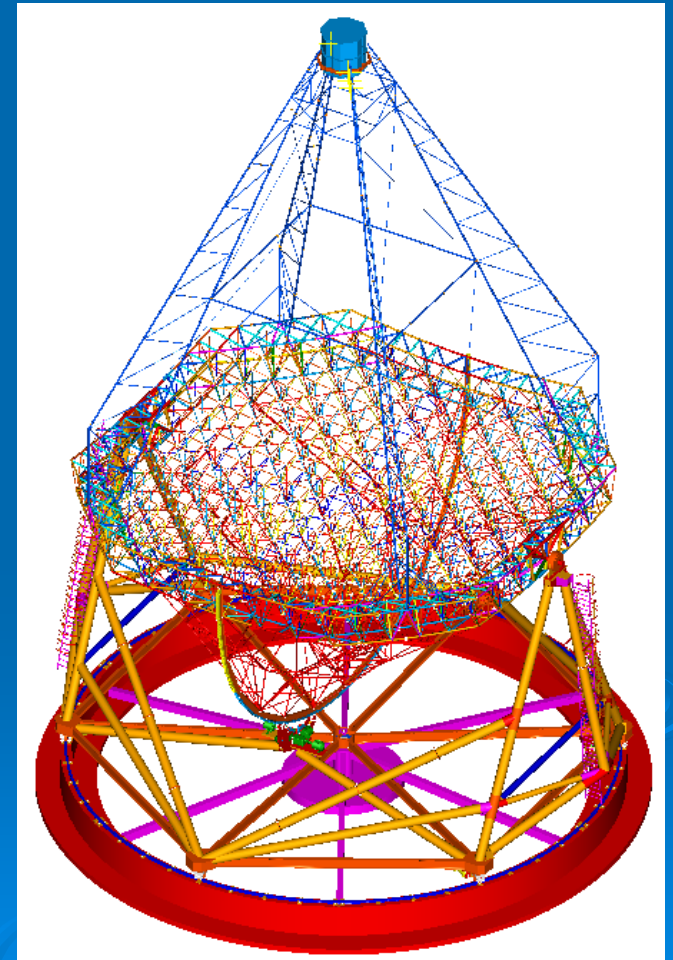
Altitude : 4300 m



**All 7 telescopes are commissioned.
Array is operational since Oct. 2008**

MACE Gamma-Ray Telescope

- *MACE (Major Atmospheric Cherenkov Experiment).*
- *Location: Hanle, North India.*
- *(32.8 N, 78.9E, 4200m asl).*
- *Trigger threshold : ~20 GeV.*
- *Light collector : 356 sq.m.*
- *Pixel size : 0.1 d.*
- *Number of pixels : 1408.*
- *Cost : 10m USD . (fully funded).*
- *Status: Installation at Hanle started.*



GRAPES Air Shower Array at Ooty

➤ Objectives:

- Origin, acceleration & propagation of UHE ($> 10^{14}$ eV) particles in the galaxy & beyond through the study of the “knee” in energy spectrum and the nuclear composition.
- Production and acceleration of highest energy particles in cosmic rays through the study of diffuse > 100 TeV γ rays flux.
- Astronomy at multi-TeV using γ rays from neutron stars and other compact objects.
- Sun the closest astrophysical source and accelerator of energetic particles and its effects on the earth.



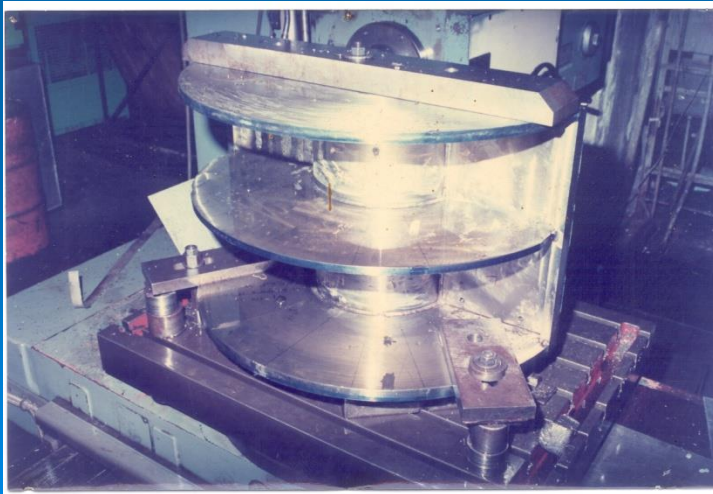
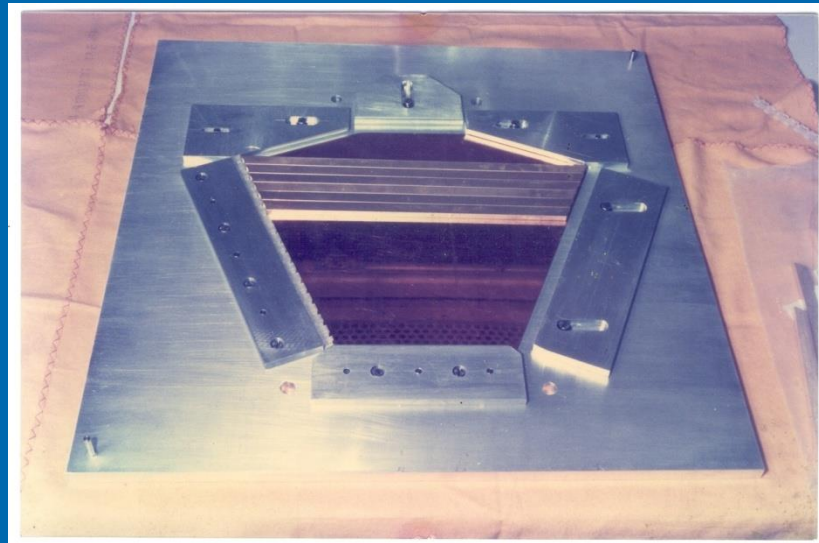
Obs. Height : 2.2 km.

400 (1 m²) Plastic detectors.

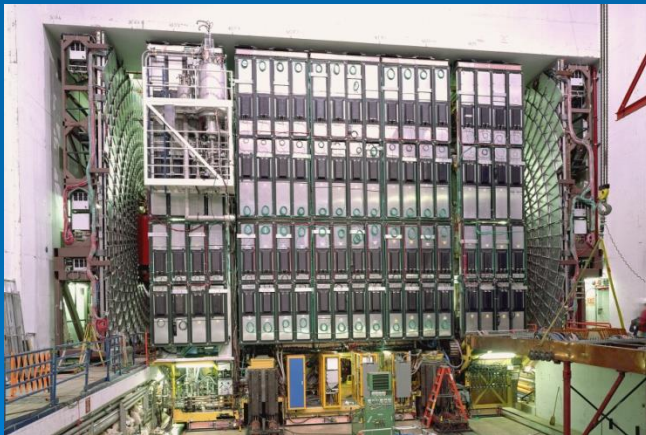
3712 Proportional counters.

**Plans to expand the array
& muon detector in near future.**

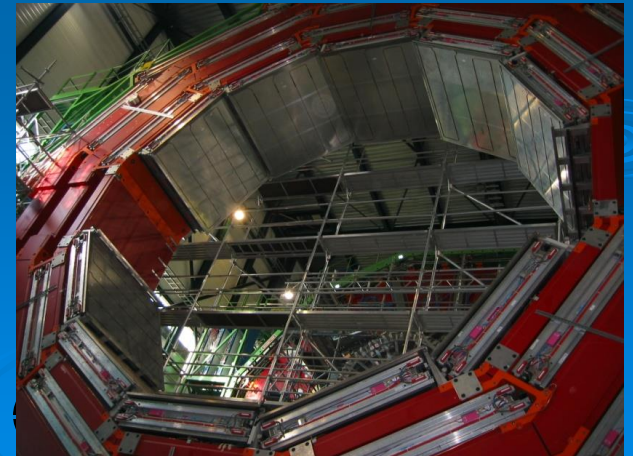
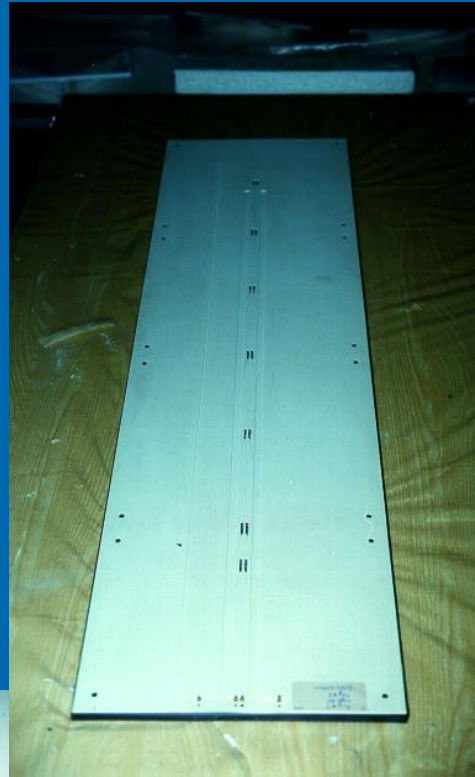
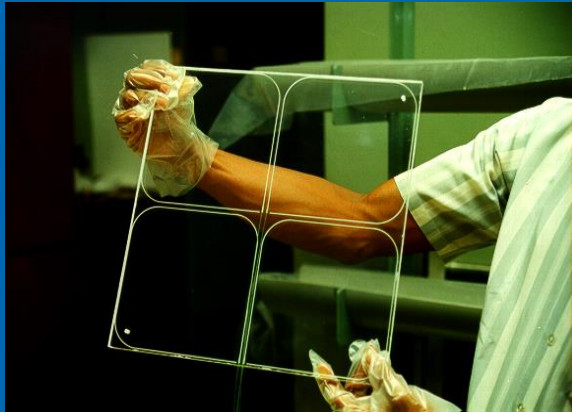
L3 Experiment at CERN



DØ Detector Fabrication



CMS Outer Hadron Calorimeter



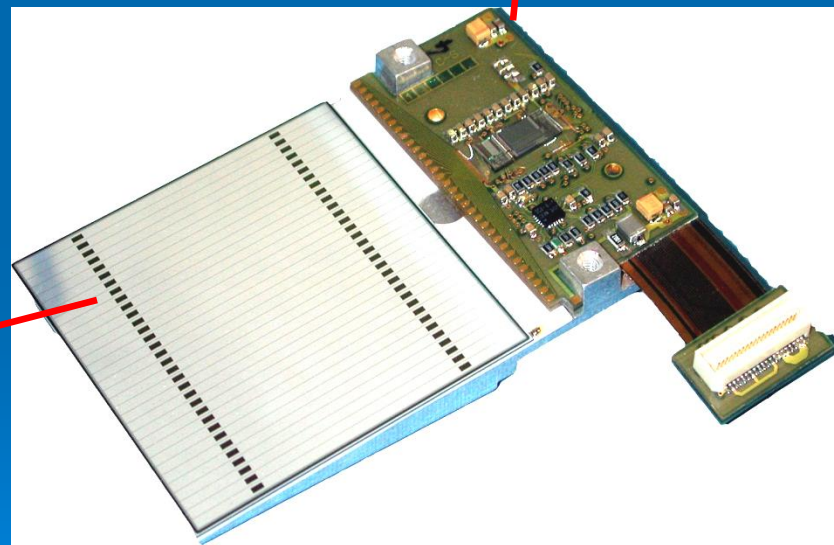
Silicon Preshower Detector for CMS

Preshower silicon strip detector being used for π^0/γ rejection in the ECAL, CMS

- *Strips of 1.80 mm width with a pitch of 1.9 mm*
- *Area - 63mm x 63mm*

First time, Silicon Strip Detector is made in India

Rad-hard front end electronics (made at CERN)



RPCs for CMS upgrade

India's contribution to RE4 upgrade of CMS : installation of the fourth disk (\pm)

50 of 200, Resistive Plate Chambers (RE4/2) & 200 Cu cooling system for all the RPCs



**RE4 negative
Successfully Commissioned
in May 2014**



**RE4 positive
Successfully Commissioned
in Feb 2014**

INO Project

- **Construction of an underground laboratory & surface facilities near Madurai, Tamil Nadu.**
 - Construction of a massive 50 kton detector (ICAL) for neutrino physics.
- **Setting up INO Centre at Madurai to act as hub for all INO related activities (Inter-Institutional Centre for High Energy Physics).**
 - Base station for INO physicists & Engineers.
 - Development of various particle detectors.
 - INO Graduate School for Human Resource Development.
 - Industry Interface.
 - INO visitors from India & Abroad.
- **Possible Future experiments**
 - Neutrinoless double beta decay (R & D started)
 - Ton scale dark matter detector

INO Collaboration

Ahmedabad: Physical Research Laboratory

Aligarh: Aligarh Muslim University

Allahabad: HRI

Bhubaneswar: I OP, Utkal University

Calicut : University of Calicut

Chandigarh: Panjab University

Chennai : IITM, IMSc

Delhi : Delhi University

Kolkata : SINP, CU, VECC

Lucknow : Lucknow University

Madurai : American College

Mumbai : BARC, IITB, TIFR

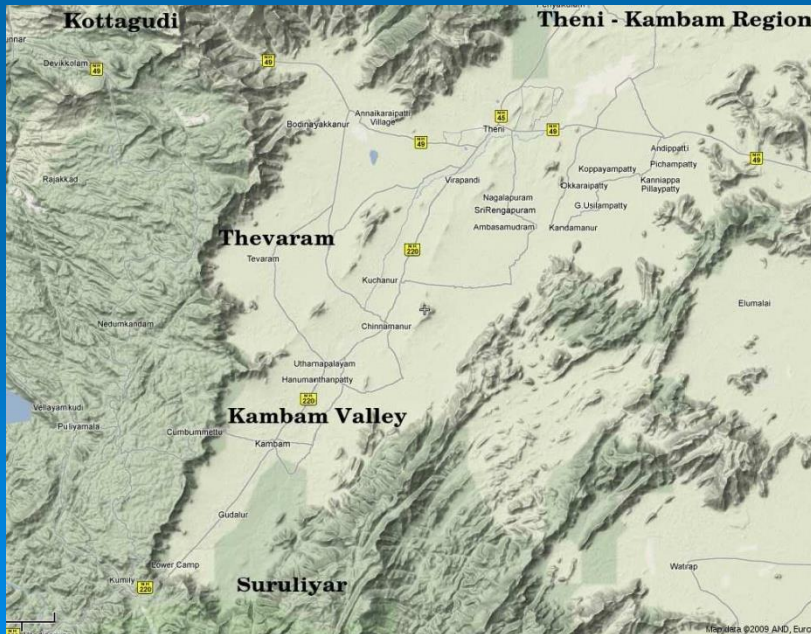
Mysore : University of Mysore

Srinagar : University of Kashmir

Varanasi : Banaras Hindu University



INO site : Bodi West Hills

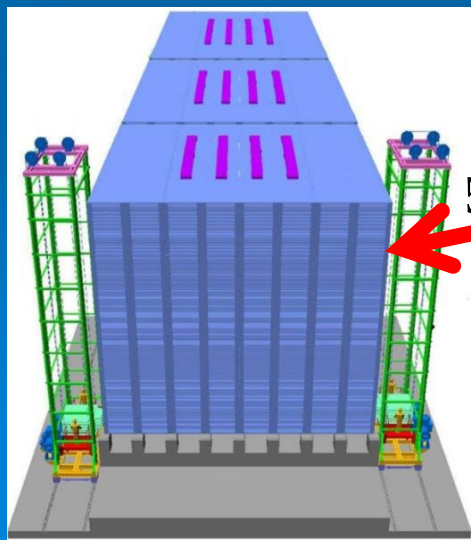
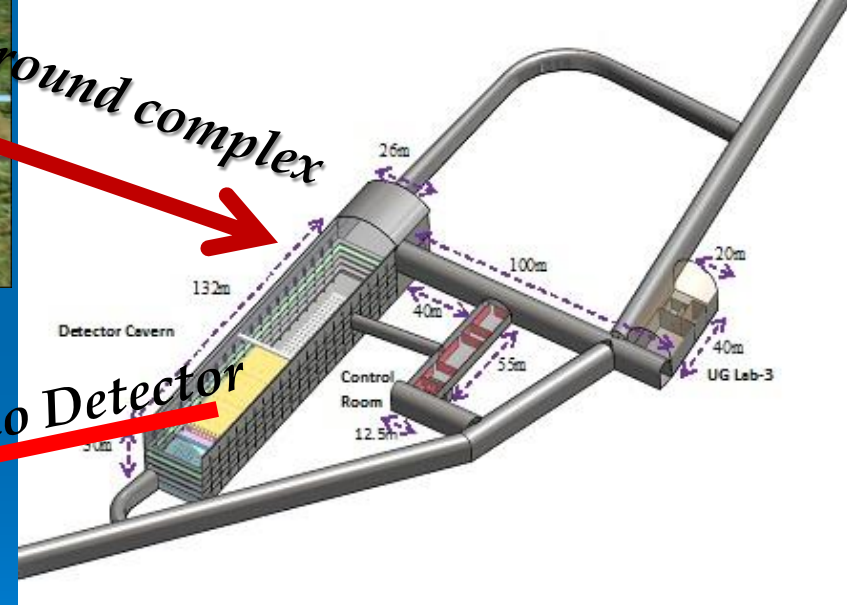
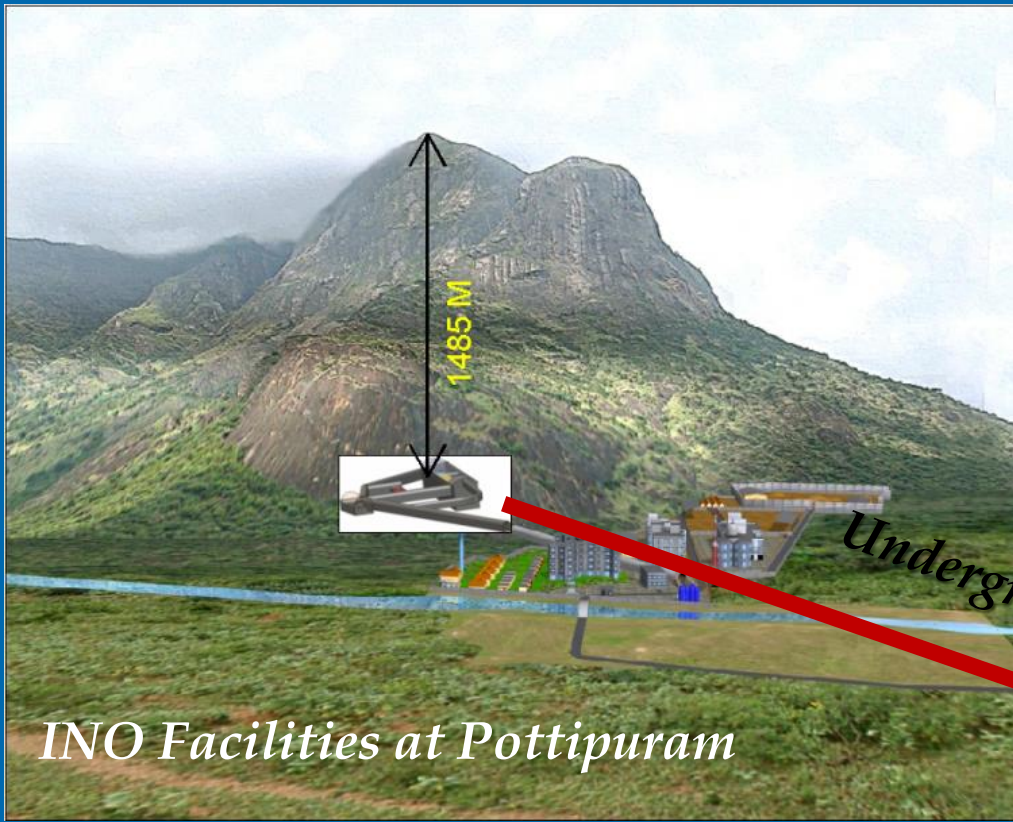


Contact us:

- $9^{\circ} 58' N, 77^{\circ} 16' E$
- Pottipuram Village
- Theni District
- Tamil Nadu State

ICAL: The physics goals

- *Reconfirm neutrino oscillation using neutrinos and anti-neutrinos separately.*
- *Improved precision of atmospheric oscillation parameters.*
- *Determine neutrino mass hierarchy using matter effects via charge discrimination.*
- *Measure the deviation of 2-3 mixing angle from its maximal value and its octant.*
- *Test bed for various new physics like NSI, CPT violation, long range forces.*
- *Detect Ultra High Energy Neutrinos, Cosmic Muons.*
- *Indirect searches of DM.*



Status of activities at INO Site



Site for Inter-Institutional Centre for High Energy Physics (IICHEP)



➤ **To be located on a 13 Ha land very close to the Madurai Kamraj University in the city of Madurai.**

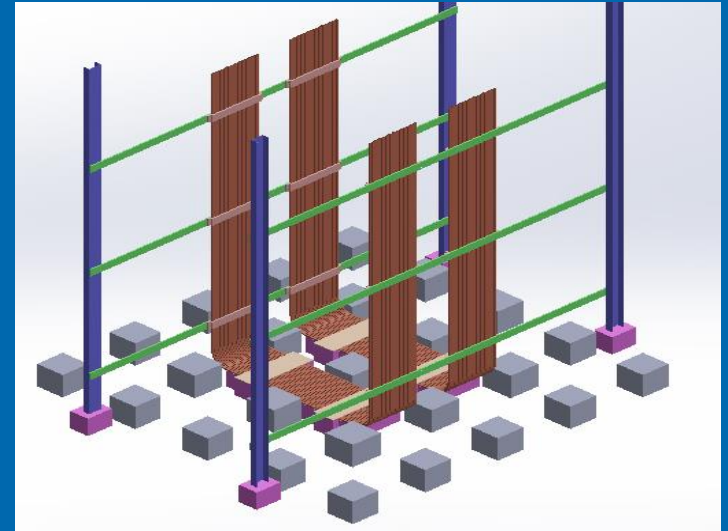
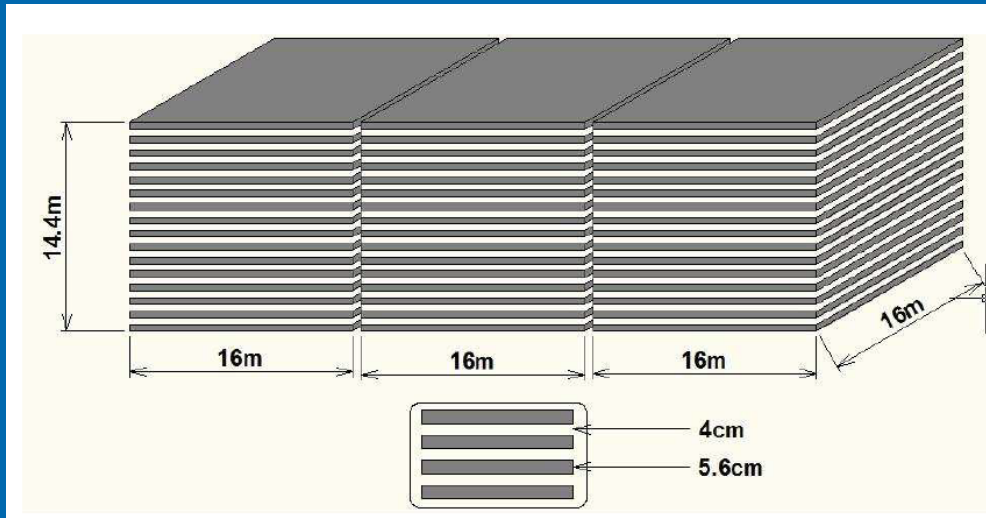
➤ **Will act as the nodal centre for all INO activities.**

➤ **Will have a major detector development laboratory.**

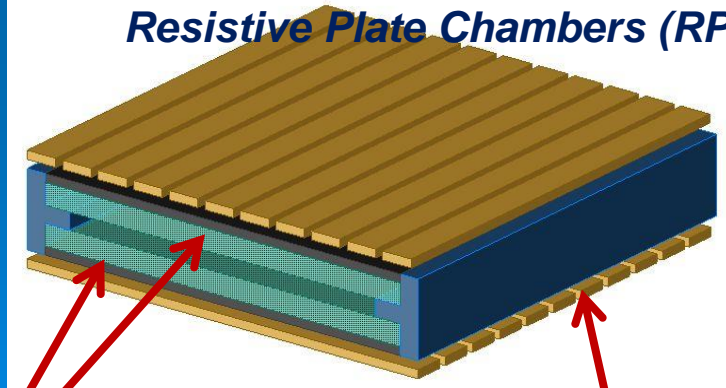
➤ **INO Graduate Training program will move to IICHEP when ready.**



INO-ICAL Detector

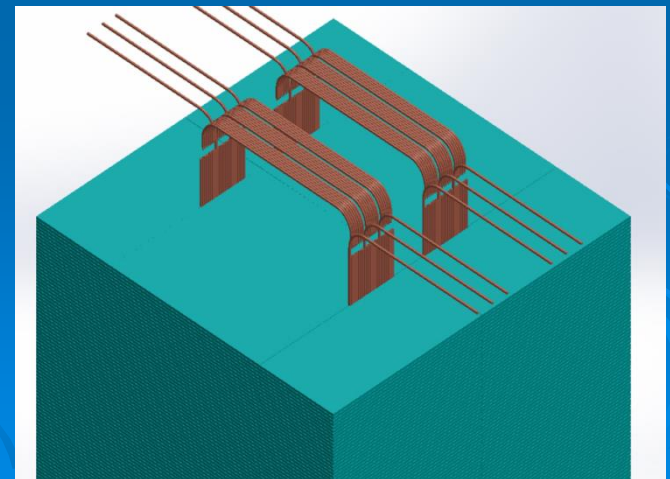


Resistive Plate Chambers (RPC)



Glass plates

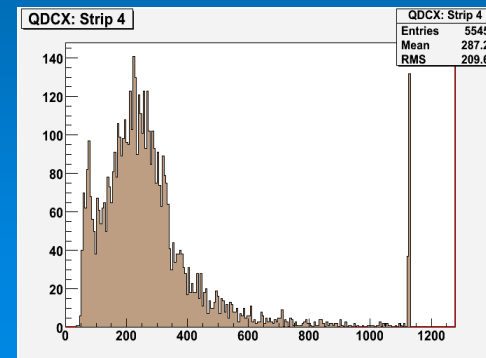
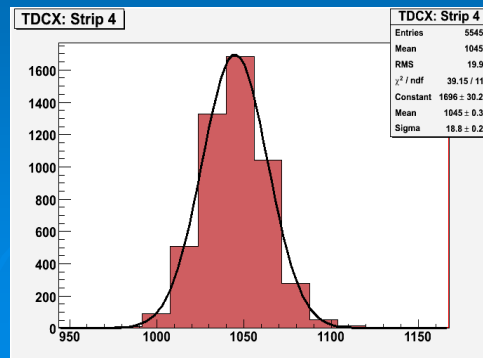
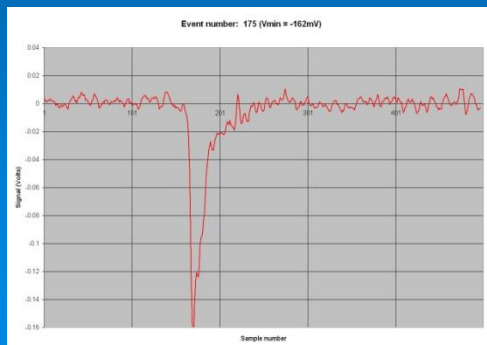
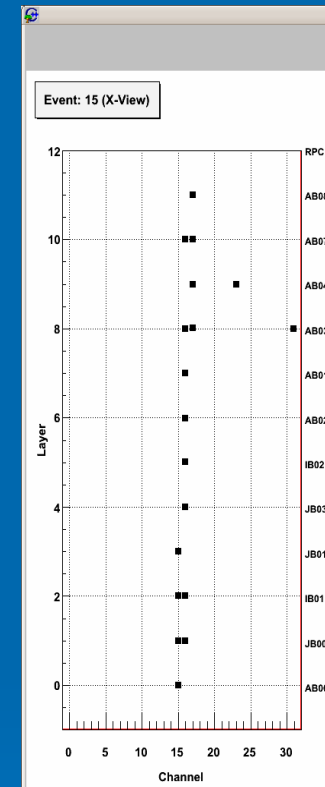
Pickup strips



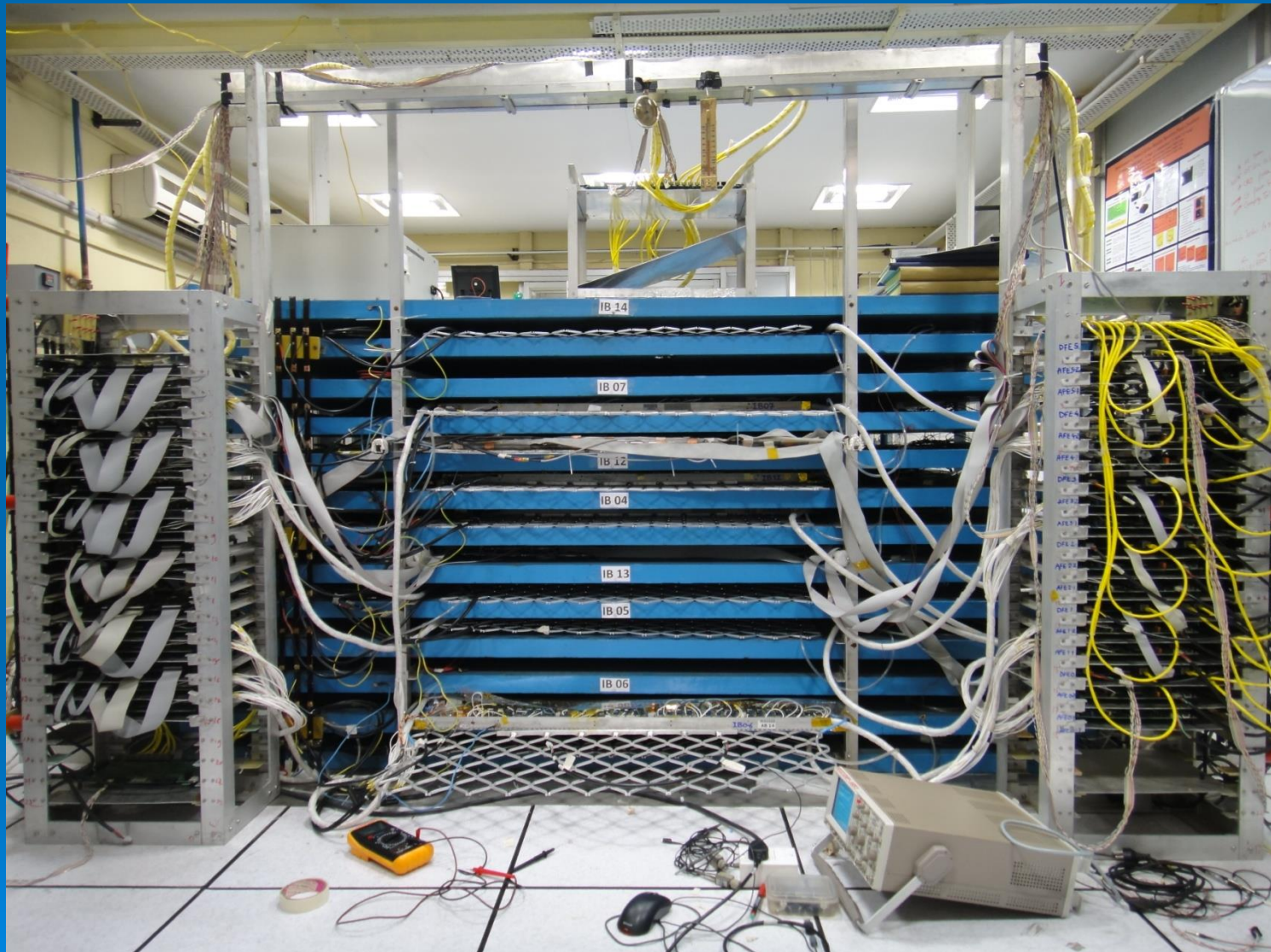
Development of Glass RPC



Prototype RPC Stack tracking Muons



Prototype Magnet with RPC layers



Human Resource Development & Training

INO Training School:

- *We have already started INO graduate training program from August 2008.*
- *Affiliated to HBNI.*
- *At present INO students are being trained for one year at TIFR, Mumbai in both experimental techniques and theory.*
- *Being attached to Ph.D. guides at various collaborating institutions for a Ph. D. degree after completion of coursework.*



INO Outreach Activities

Oriented towards :

General public, environmentalists, administrators, students, teachers and media



Concluding remarks

- *India has a strong presence in High Energy Physics research using both cosmic rays and accelerators.*
- *Two Indian funding agencies DAE & DST are now acting synergistically to raise India's research capabilities in several frontline areas of research including High Energy & Astroparticle Physics. Several small & large projects are at various stages of approval.*
- *Because of the collaborative nature of these projects, it allows us to develop networking of research and higher education with institutions in the country and abroad. Such networking are encouraged by our funding agencies.*
- *We should look for synergies in various projects, operational or under consideration in different regions of the world and if possible should find ways for common R & Ds for various sub areas connected to these projects.*

***Thank You for
your attention***

