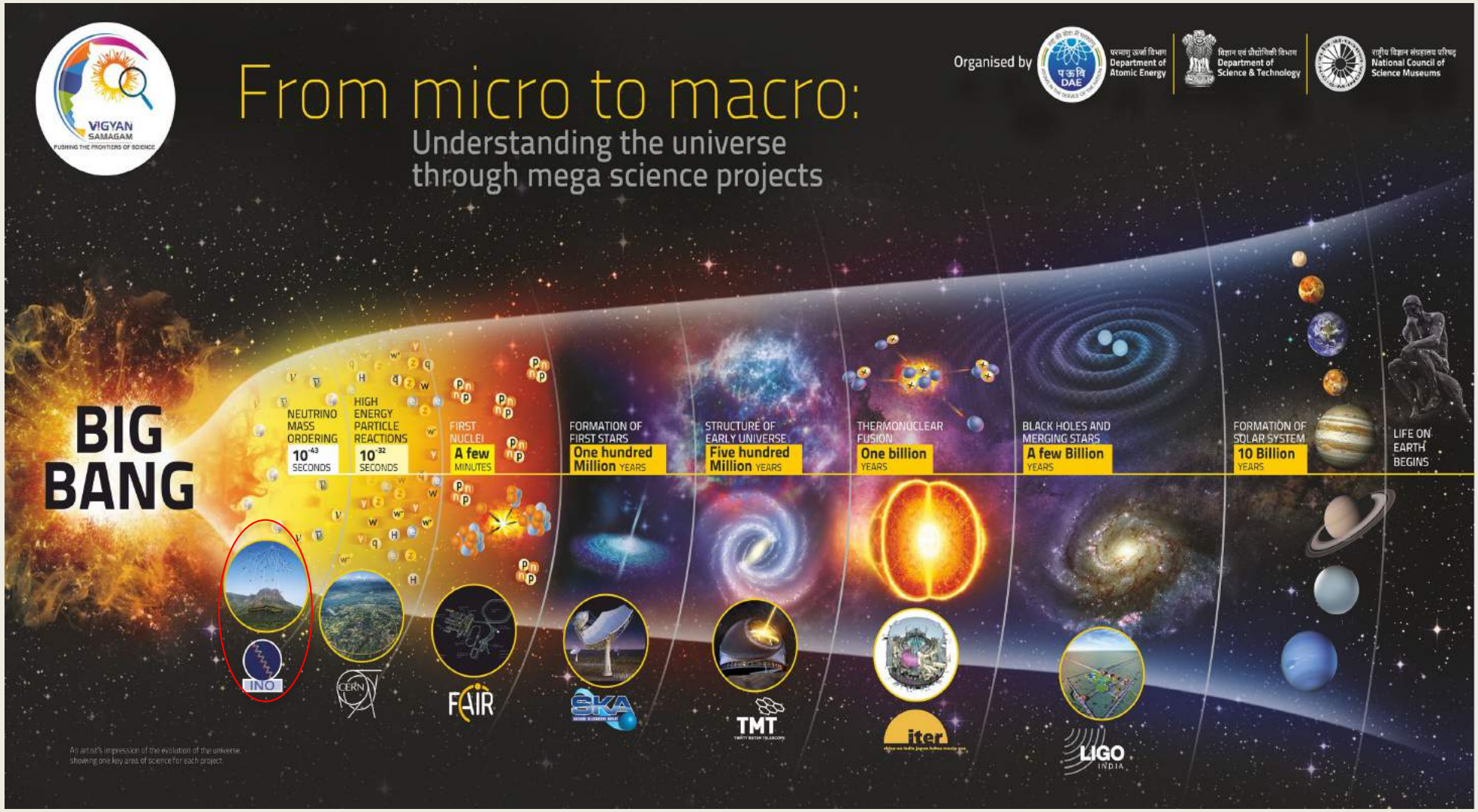
The India-based Neutrino Observatory

The twisted tale of an indigenous mega-science project

Subir Sarkar

Lecture & Discussion with CBS Science Club, Mumbai, 27th December 2020

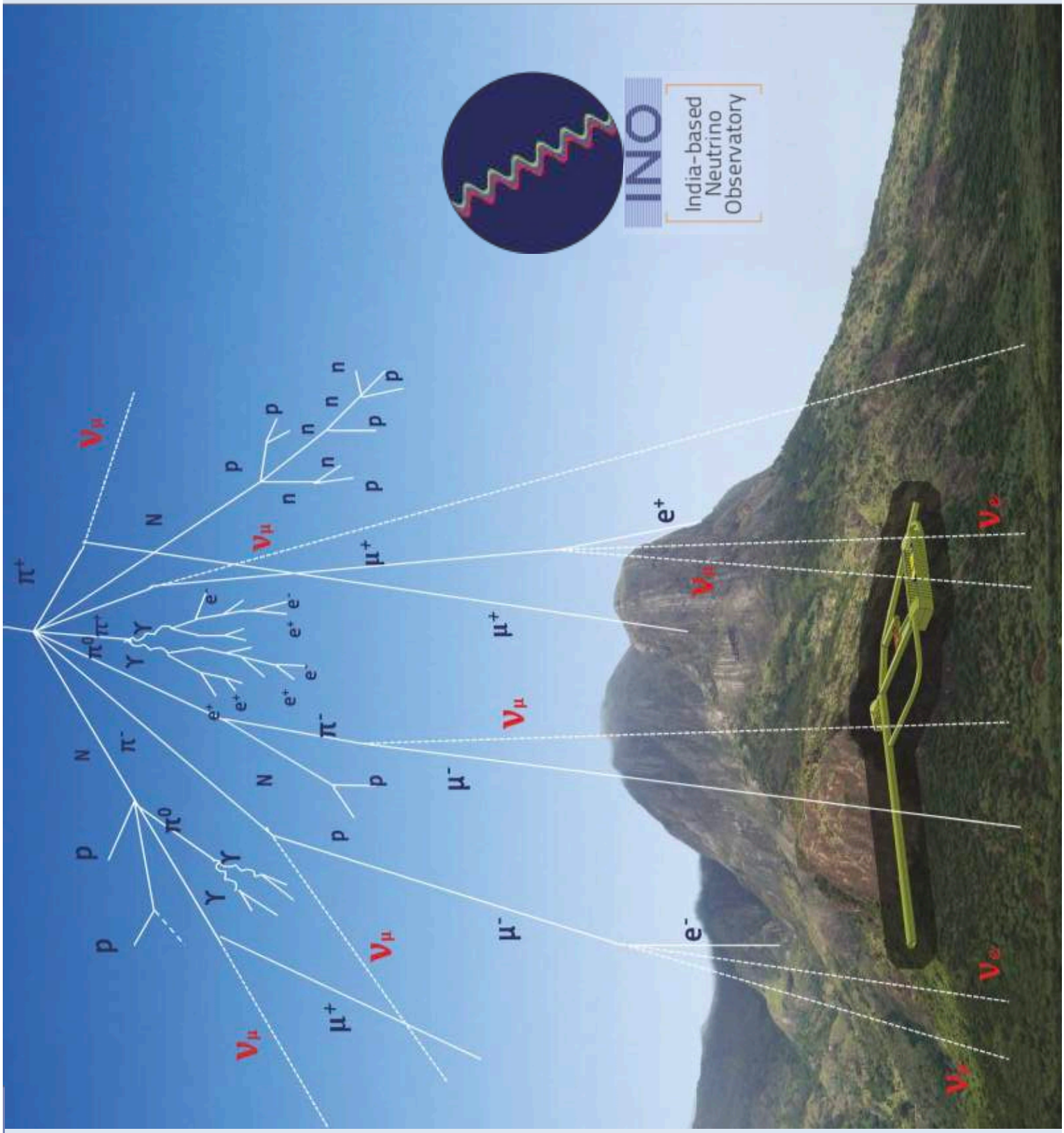
Research in 'pure sciences' is intellectually exciting and the *best* training to meet global challenges … both now and in the future

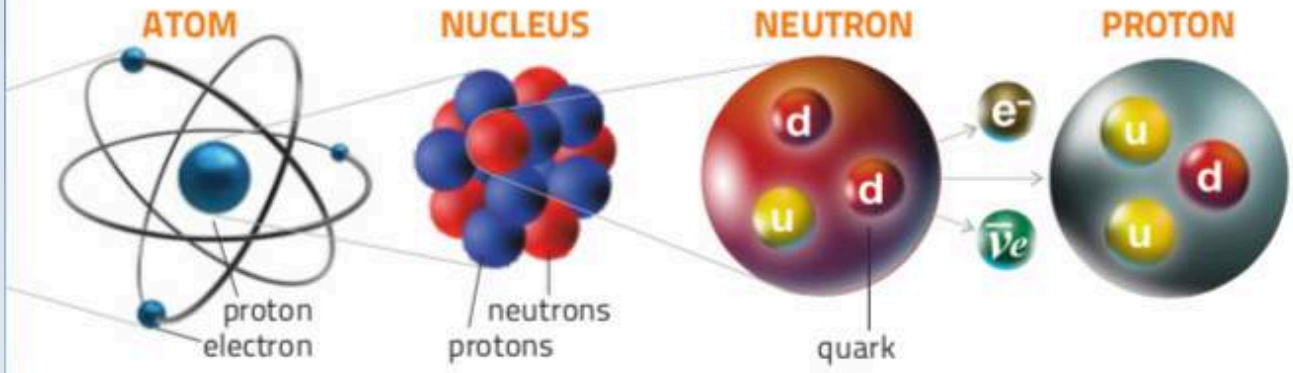


Collaboration leads to mutual understanding among nations and provides the foundation for rewarding partnerships on major international projects

… India naturally wishes to participate in this global arena

https://vigyansamagam.in/assets/documents/Vigyan-Samagam.pdf





Hunting the elusive neutrino

The India-based Neutrino Observatory (INO) project is an ambitious basic science project aimed at studying the properties and interactions of the elusive elementary particle called neutrino. The Government approved the INO project in January 2015. This included the construction of an underground laboratory at Bodi West Hills (BWH) in Theni district, Tamil Nadu, setting up the flagship Iron Calorimeter (ICAL) detector there and the Inter-Institutional Centre for High Energy Physics (IICHEP) in Madurai. IICHEP would be the nodal centre for Research & Development of the associated detector technology and would run the underground laboratory in Theni. The key advantage of constructing a laboratory in a cavern in a mountain accessed by a 2km tunnel, with an all-round rock cover of about 1000m, is that it offers a low cosmic ray background environment (since the cosmic rays and secondary particles produced in their interaction with the upper atmosphere are filtered by the rock cover above the laboratory cavern). This is necessary for specialised experiments making measurements with neutrinos which interact very rarely with the detector material. In particular, ICAL will detect and measure atmospheric neutrinos to study the neutrino properties, including the mass ordering of the three tiny neutrino masses using matter enhanced neutrino oscillations. The ICAL detector can also be used to search for evidence of long-range interactions between neutrinos and matter, dark matter annihilation occurring in the sun, primordial magnetic monopoles and evidence for or against the anomalous events found by the proton decay detector in Kolar Gold Fields. Finally, the underground laboratory will also provide a conducive environment for other experiments. For example, a collaboration led by a TIFR group is working towards search for neutrinoless double beta decay in tin-124 using a cryogenic bolometer. Similarly, a collaboration led by SINP is planning to set up an experiment to search for Dark Matter using a cryogenic scintillator. The initial background studies have begun in a laboratory at -550m level in the Jaduguda mines.

Collaborating Institutes in India

		Aligarh Muslim University Aligarh	American College Madurai	Banaras Hindu University Varanasi
Bhabha Atomic Research Center Mumbai	Central Univ. of Karnataka Gulbarga	Delhi University Delhi	Harish Chandra Research Institute Allahabad	Indian Institute of Science Education & Research Mohali
Indian Institute of Technology Bombay Mumbai	Indian Institute of Technology Bombay Gandhinagar	Indian Institute of Technology Madras Chennai	Institute of Physics Bhubaneswar	Institute of Mathematical Sciences Chennai
Jammu University Jammu	Jawaharlal Nehru University New Delhi	Lucknow University Lucknow	Panjab University Chandigarh	Physical Research Laboratory Ahmedabad
Saha Institute of Nuclear Physics Kolkata	tifr Tata Institute of Fundamental Research, Mumbai	Tezpur University Tezpur	University of Calcutta Kolkata	University of Calicut, Calicut
Univ. of Hyderabad, Hyderabad	Univ. of Kashmir Srinagar	Univ. of Mysore, Mysore	Utkal University Bhubaneswar	Variable Energy Cyclotron Center Kolkata

Technologies developed

Extruded polycarbonate side spacers and spacer buttons for RPCs; 1m x 1m, 2m x 2m Glass Resistive Plate Chambers with resistive graphite coating; front-end electronics; in-house developed boards for Data Acquisition, Trigger Module and Time Calibration. High-permeability low-carbon soft iron steel for ICAL; Layered Electro-Magnet (85 ton mini-ICAL module); induction heating based copper joint brazing technology; inductive proximity sensor based system for continuous gap measurement between two iron plate layers; magnetic measurements system with multiple search coil pickup loops (for magnetic flux) and arrays of Hall probes based measurements (for B-field strength in inter-plate gaps); closed loop chilled water system for cooling current carrying coils in mini-ICAL and associated DC power supply; RPC trolley (8m high) to place and remove 2m x 2m RPC from ICAL.

Indian industries/agencies involved

Consultancy : Tata Consulting Engineers, Mumbai (ICAL magnet DPR); Tamil Nadu Electricity Board, Chennai (INO DPR); Mitcon Consultancy & Engineering Services Ltd, Pune (MoEF & CC clearance); Pro Designa Consultants, Madurai (Civil works approval for IICHEP, INO site civil construction); Walch and Technology Group, Pune (Project Report for RPC manufacture).

RPC glass gaps : St. Gobain (Sriperumbudur); Asahi-India (Taloja); Cybernetic Instruments (Pune).

Closed loop gas system : Alpha Pneumatics (Mumbai); Shriram Automation (Mumbai).

Resistive coating of graphite paint on glass : Kansai-Nerolac (Mumbai).

Paint booth: Green Glory Technologies, Chennai.

RPC trays and pickup panels : Honeycomb International Inc. (Bengaluru); Nexgen Plastics (Mumbai); S. M. Enterprises (Pune); Fibre Reinforced Industry Ltd. (Pune).

Polycarbonate spacers for glass gaps : Ashwin Plastics (Mumbai); Studio CNC (Mumbai).

Low carbon magnetic grade steel plates : Steel Authority of India Ltd. (Bhilai); Essar Steel (Hazira).

Electronics boards of many types : Rangsons (Bengaluru); Dexcel (Bengaluru); PCB Power Circuit Systems India Ltd. (Gandhinagar).

RPC handling equipment, mini-ICAL assembly : Jalaram Industries (Mumbai); P Chandru Machine Tools (Vellore); Green & Green Engineering Solution (Coimbatore).

Magnet Power Reversal switch and gap measurement system - M/S Integrated systems Pvt. Ltd. (Mumbai).

Magnet coil support G-10 material : Autoelectrical & Mechanical works (Mumbai).

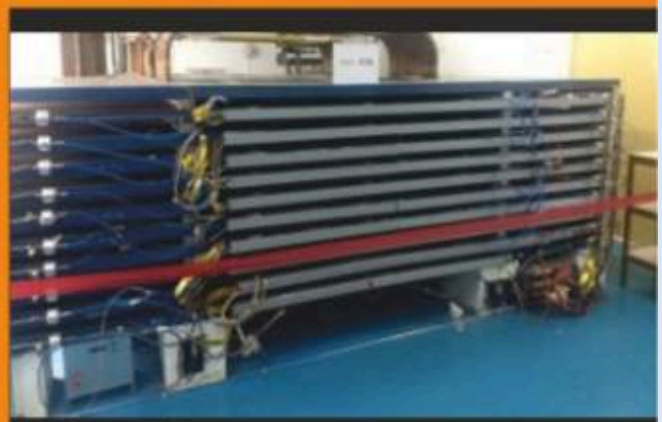
Soft iron plate and SS Spacer-Pin machining : Bhilai Engineering Corporation (Bhilai).

Magnet coil forming and fabrication : Centre for Design & Manufacturing, BARC (Mumbai).

Special Induction based brazing machine : Microtech Industries (Mumbai).

Low conductivity cooling water system: Entech industries (Bengaluru).

Magnetic Measurement Systems : Ferrite India (Pune).



Iron calorimeter (ICAL) prototype

Contact person/Spokesperson

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Project Director, INO, TIFR
Mumbai-400005.
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Email: vivek.datar@tifr.res.in
vivek.datar@gmail.com

Website

www.ino.tifr.res.in

But why do research in *abstract* physical sciences? Should Indian scientists not focus on 'real' problems such as global warming or the world's energy needs or innovation in agriculture, transport, health care, urbanisation, *etc*?


J.C. Bose


C.V. Raman


M.N. Saha


S.N. Bose

- Science seeks to understand the underlying regularities and of the natural world - to find *simple* explanations and make predictions that can be put to experimental test
- Search for broad organisational principles
- Create and develop new conceptual frameworks
- An essential requirement is mathematical consistency … progress is generated by the fruitfulness of ideas

Provides training in both analytic & computational techniques and in …. **how to ask the right questions**


H.J. Bhabha


S. Chandrasekhar


A.K. Raychaudhuri


E.C.G. Sudarshan

India has had a distinguished history of contributions to fundamental science … the work needs to be continued by today's generation

Changes and challenges: Physics in India

December 2011 Physics Today

In the old days we had no money but we had people. Today, we have the money but not the people.

Obaid Siddiqi
Bangalore, India

physicsworld

Special report: India

December 2012

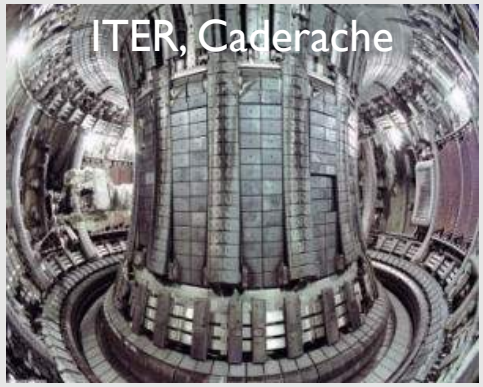
IISER/L S Shashidhara

A new set of institutes are aiming to inspire the next science researchers in India 8

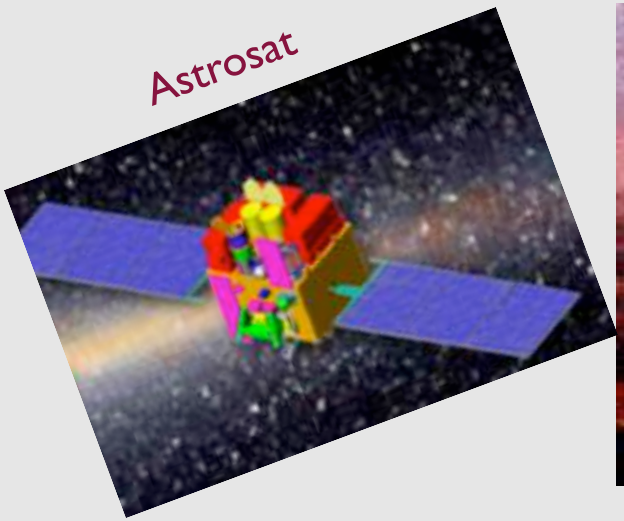
For today's leading physicists in India, money for research is thankfully not in short supply. But as this *Physics World* special report makes clear, what India currently lacks is a critical concentration of highly capable scientists who can really make the country a world leader in research and boost the nation's innovation. This special report shows, however, that India is starting to tap the country's true potential through a series of bold educational initiatives and novel research facilities.

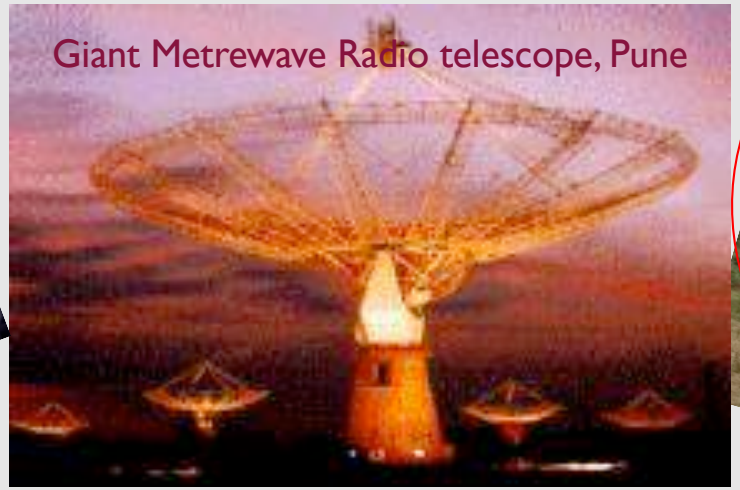
Matin Durrani, Editor of *Physics World*

(Some) International physics projects with Indian involvement



... and Indian projects with international participation





... and many others

India-based Neutrino Observatory

https://en.wikipedia.org/wiki/India-based_Neutrino_Observatory

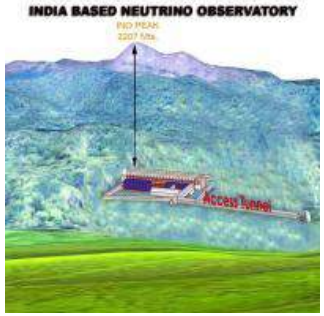
From Wikipedia, the free encyclopedia

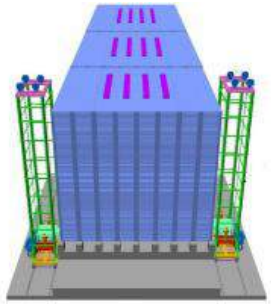
India-based Neutrino Observatory (INO) is a particle physics research project under construction to primarily study atmospheric neutrinos in a 1,300 meters (4,300 ft) deep cave under Ino Peak near Theni, Tamil Nadu, India. This project is notable in that it is anticipated to provide a precise measurement of neutrino mixing parameters. The project is a multi-institute collaboration and one of the biggest experimental particle physics projects undertaken in India.[1][2][3][4]

The project was originally to be completed in 2015 at an estimated cost of ₹ 1,500 crores, has been cleared by the Ministry of Environment (India) for construction in the Bodi West Hills Reserved Forest in the Theni district of Tamil Nadu. Although delayed, the project is underway as of 2015.[5][6]

When completed, the main magnetised iron calorimieter (ICAL) experiment will include the world's largest magnet, four times larger than the 12,500-tonne magnet in the Compact Muon Solenoid detector at CERN in Geneva, Switzerland.[7][8]

Contents [hide]





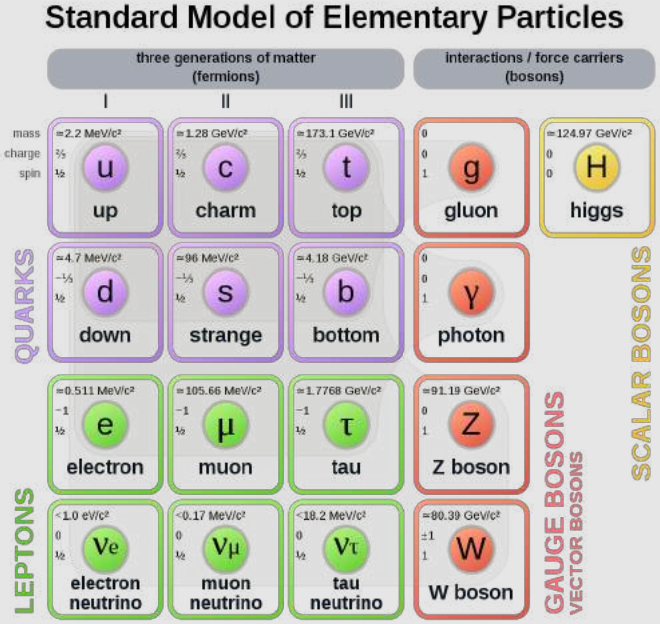
The primary research instrument will consist of a 50,000 ton magnetised iron particle physics calorimeter with glass Resistive Plate Chamber (RPC) technology as the sensor elements.[1]

The ICAL design is mostly based on the monolith experiment that could not go beyond the proposal Stage. The detector was expected to start collecting data in the year 2012. The location of INO has attracted a lot of attention from the neutrino physics community as the distance between INO and CERN is very close to "Magic Baseline" – a distance at which the effect of the CP phase on the measurement of θ_{13} is minimal.[16] The project has been hit by lack of skilled manpower and opposition by environmentalists. In 2008, INO started a graduate training programme leading to PhD Degree in High Energy Physics and Astronomy to deal with the shortage of particle physicists. [17]

The Primary goals of the ICAL are the following: [18]

1. Unambiguous and more precise determination of Neutrino oscillation parameters using atmospheric neutrinos.
2. Study of matter effects through electric charge identification, that may lead to the determination of the unknown sign of one of the mass differences.
3. Study of charge-conjugation and charge parity (CP) violation in the leptonic sector as well as possible charge-conjugation, parity, time-reversal (CPT) violation studies.
4. Study of Kolar events, possible identification of very-high energy neutrinos and multi-muon events.

The ICAL detector consists of 6 centimeters (2.4 in) thick Iron plates as passive material, with RPCs in between as active material.



This is among the *most* exciting topics in physics

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2015 to

Takaaki Kajita
Super-Kamiokande Collaboration
University of Tokyo, Kashiwa, Japan

and

Arthur B. McDonald
Sudbury Neutrino Observatory Collaboration
Queen's University, Kingston, Canada

"for the discovery of neutrino oscillations, which shows that neutrinos have mass"

Metamorphosis in the particle world

The Nobel Prize in Physics 2015 recognises **Takaaki Kajita** in Japan and **Arthur B. McDonald** in Canada, for their key contributions to the experiments which demonstrated that neutrinos change identities. This metamorphosis requires that neutrinos have mass. The discovery has changed our understanding of the innermost workings of matter and can prove crucial to our view of the universe.

Around the turn of the millennium, Takaaki Kajita presented the discovery that neutrinos from the atmosphere switch between two identities on their way to the Super-Kamiokande detector in Japan.

Meanwhile, the research group in Canada led by Arthur B. McDonald could demonstrate that the neutrinos from the Sun were not disappearing on their way to Earth. Instead they were captured with a different identity when arriving to the Sudbury Neutrino Observatory.

A neutrino puzzle that physicists had wrestled with for decades had been resolved. Compared to theoretical calculations of the number of neutrinos, up to two thirds of the neutrinos were missing in measurements performed on Earth. Now, the two experiments discovered that the neutrinos had changed identities.

The discovery led to the far-reaching conclusion that neutrinos, which for a long time were considered massless, must have some mass, however small.

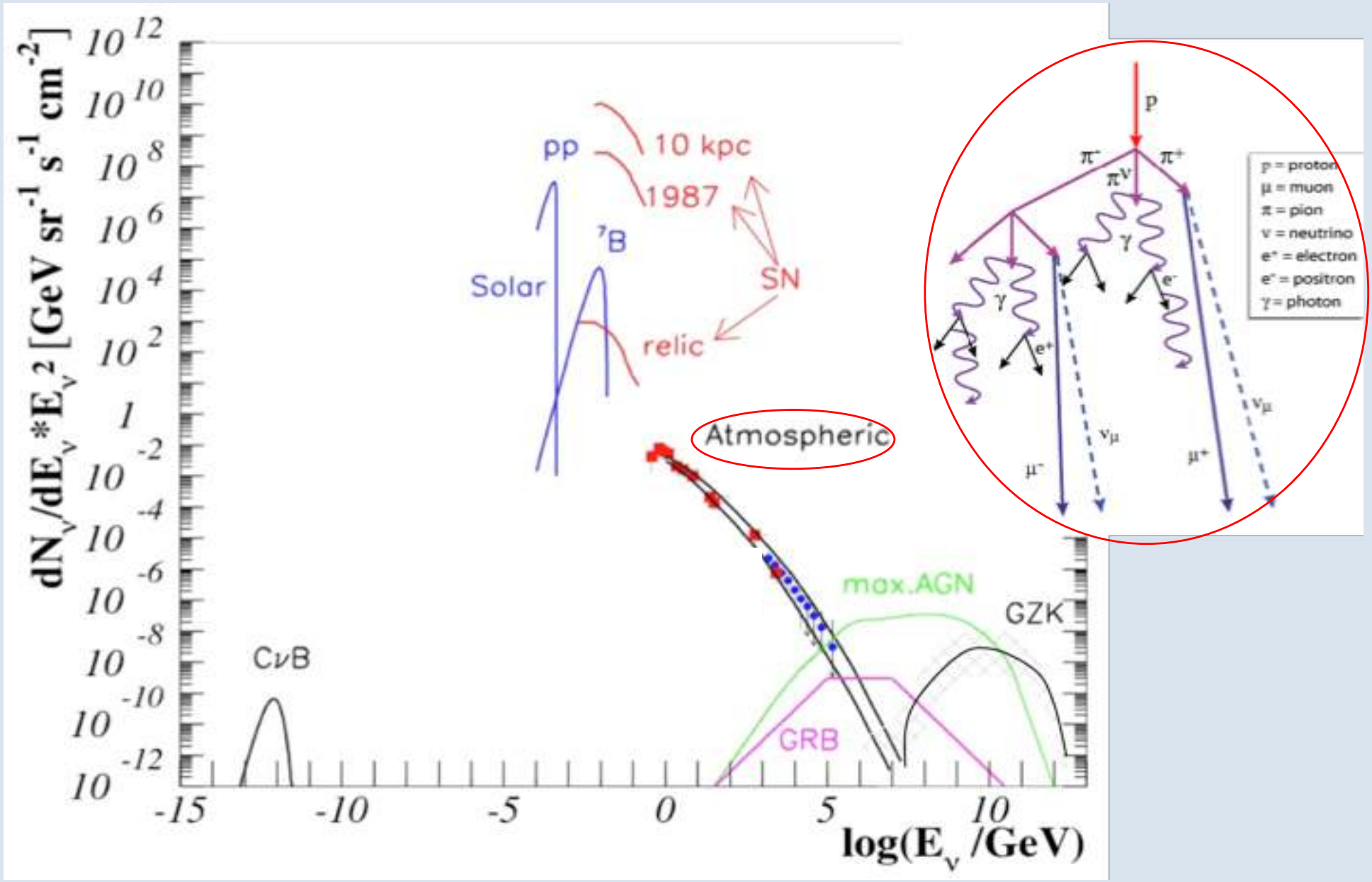
For particle physics this was a historic discovery. Its Standard Model of the innermost workings of matter had been incredibly successful, having resisted all experimental challenges for more than twenty years. However, as it requires neutrinos to be massless, the new observations had clearly showed that the Standard Model cannot be the complete theory of the fundamental constituents of the universe.

The discovery rewarded with this year's Nobel Prize in Physics have yielded crucial insights into the all but hidden world of neutrinos. After photons, the particles of light, neutrinos are the most numerous in the entire cosmos. The Earth is constantly bombarded by them.

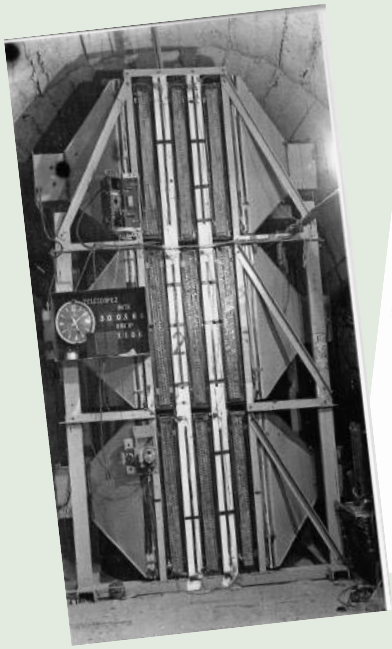
Many neutrinos are created in reactions between cosmic radiation and the Earth's atmosphere. Others are produced in nuclear reactions inside the Sun. Thousands of billions of neutrinos are streaming through our bodies each second. Hardly anything can stop them passing; neutrinos are nature's most elusive elementary particles.

Now the experiments continue and intense activity is underway worldwide in order to capture neutrinos and examine their properties. New discoveries about their deepest secrets are expected to change our current understanding of the history, structure and future fate of the universe.

Detection of naturally generated neutrinos



Discovery of atmospheric neutrinos: 1965



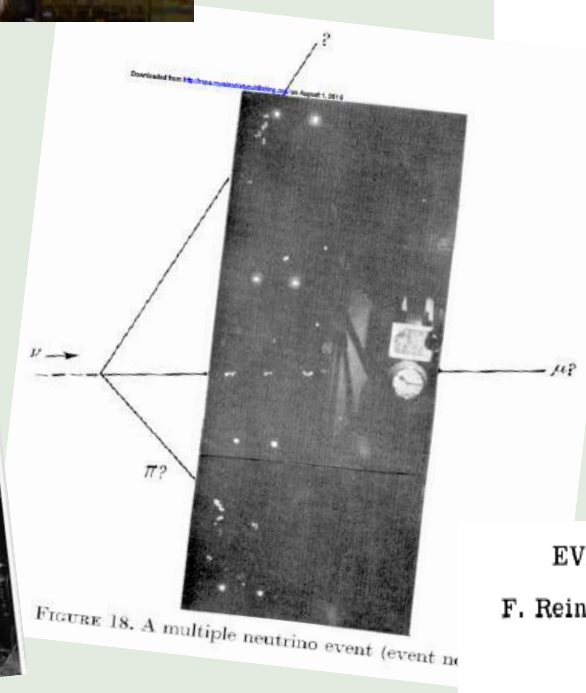


FIGURE 18. A multiple neutrino event (event n

Neutrino detector at the Kolar Gold Fields, India

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

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 - published 15th Aug 1965

EVIDENCE FOR HIGH-ENERGY COSMIC-RAY NEUTRINO INTERACTIONS*

F. Reines, M. F. Crouch, T. L. Jenkins, W. R. Kropp, H. S. Gurr, and G. R. Smith

Case Institute of Technology, Cleveland, Ohio

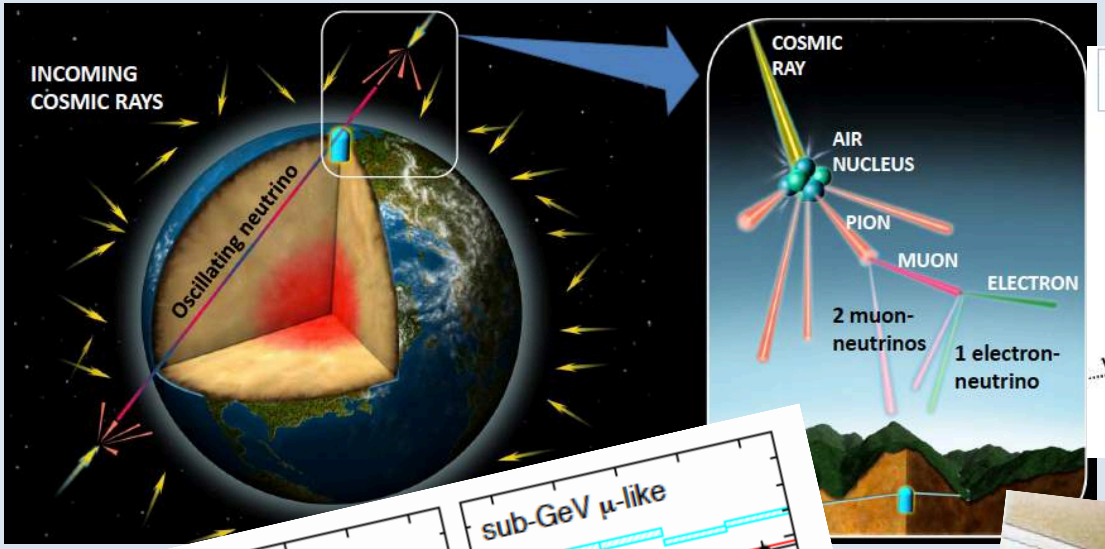
and

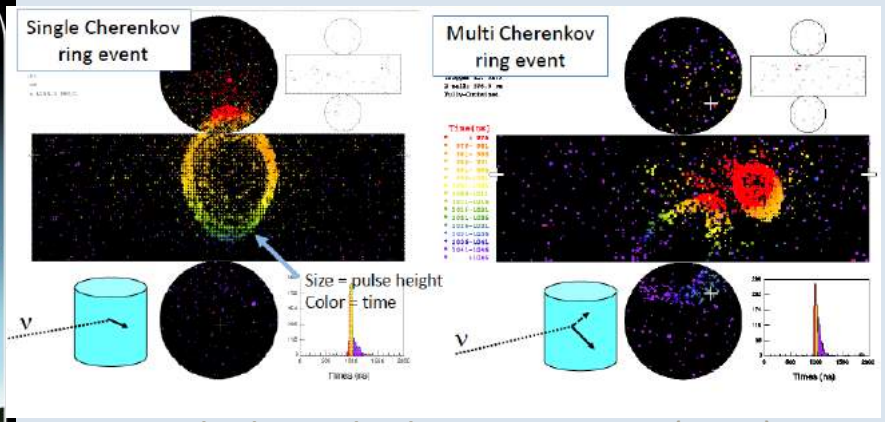
J. P. F. Sellschop and B. Meyer

University of the Witwatersrand, Johannesburg, Republic of South Africa
(Received 26 July 1965)

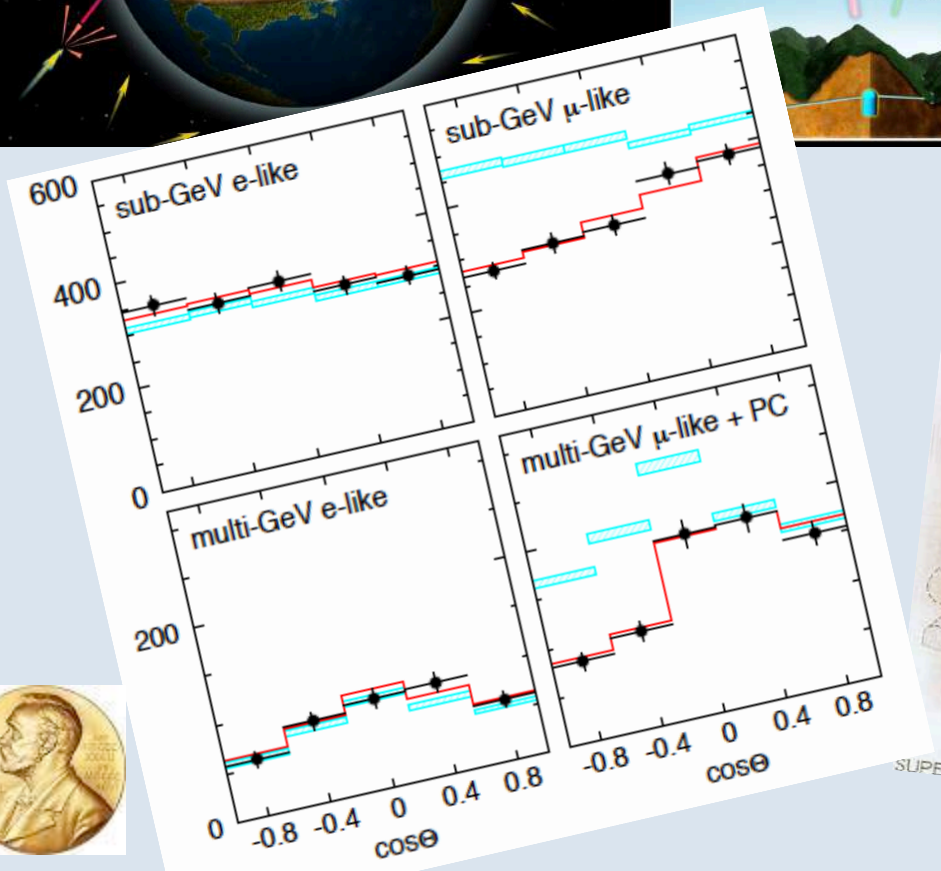
Physical Review Letters 15 (1965) 429 - published 30th Aug 1965

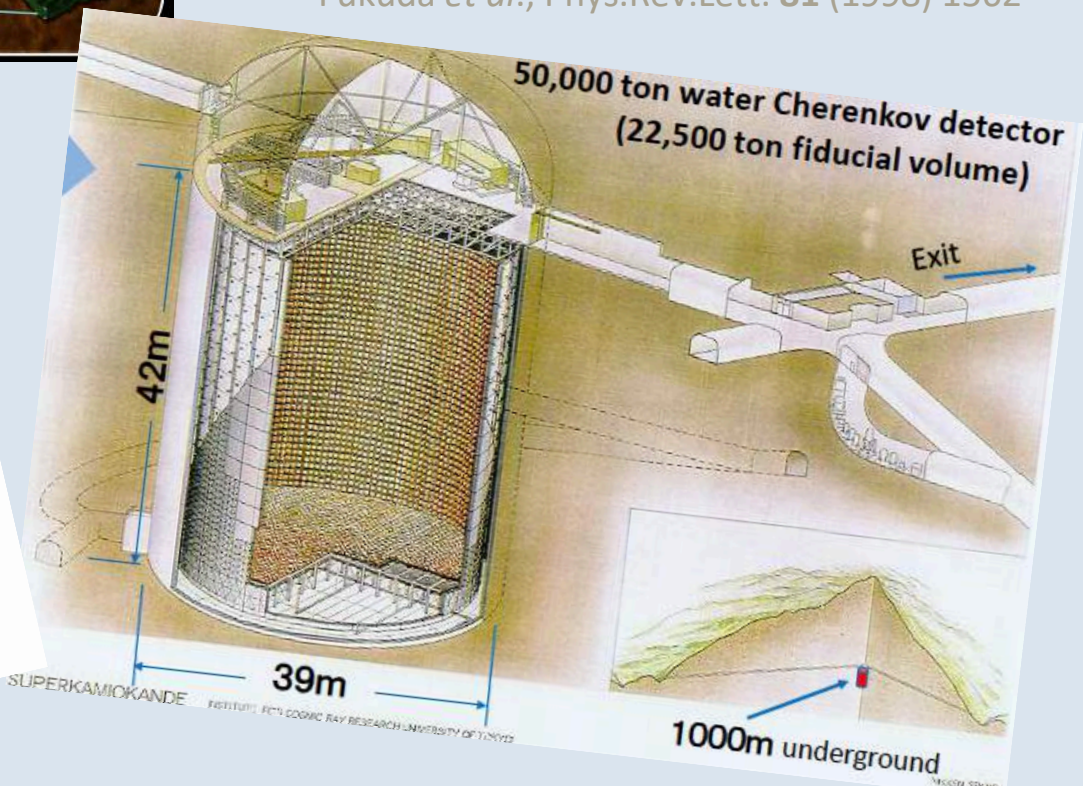
Discovery of atmospheric neutrino oscillations: 1998





Fukuda *et al.*, Phys.Rev.Lett. **81** (1998) 1562





IceCube Neutrino Observatory

IceTop: 1 km^2 surface array (81 'Auger' tanks)

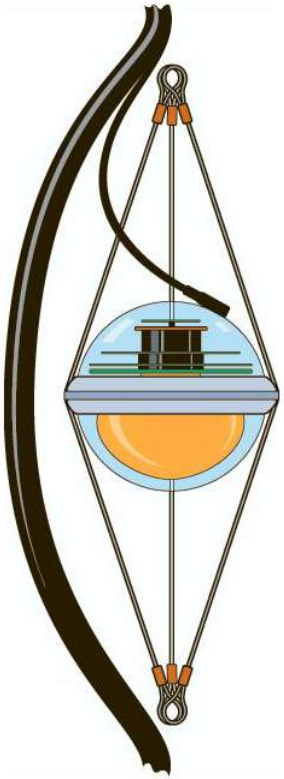
86 strings (125 m between strings)

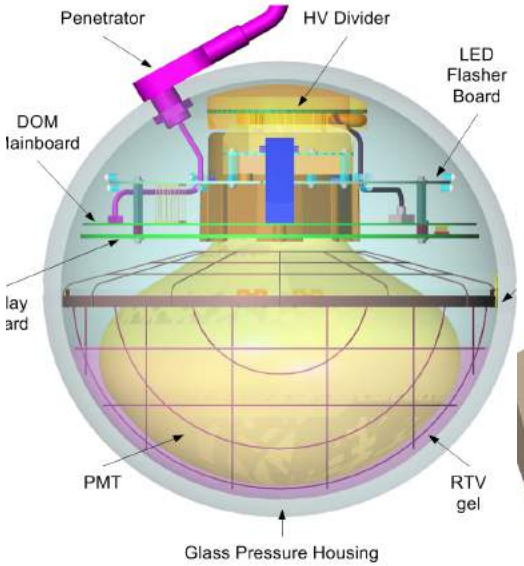
60 Optical Modules per string (17 m apart)

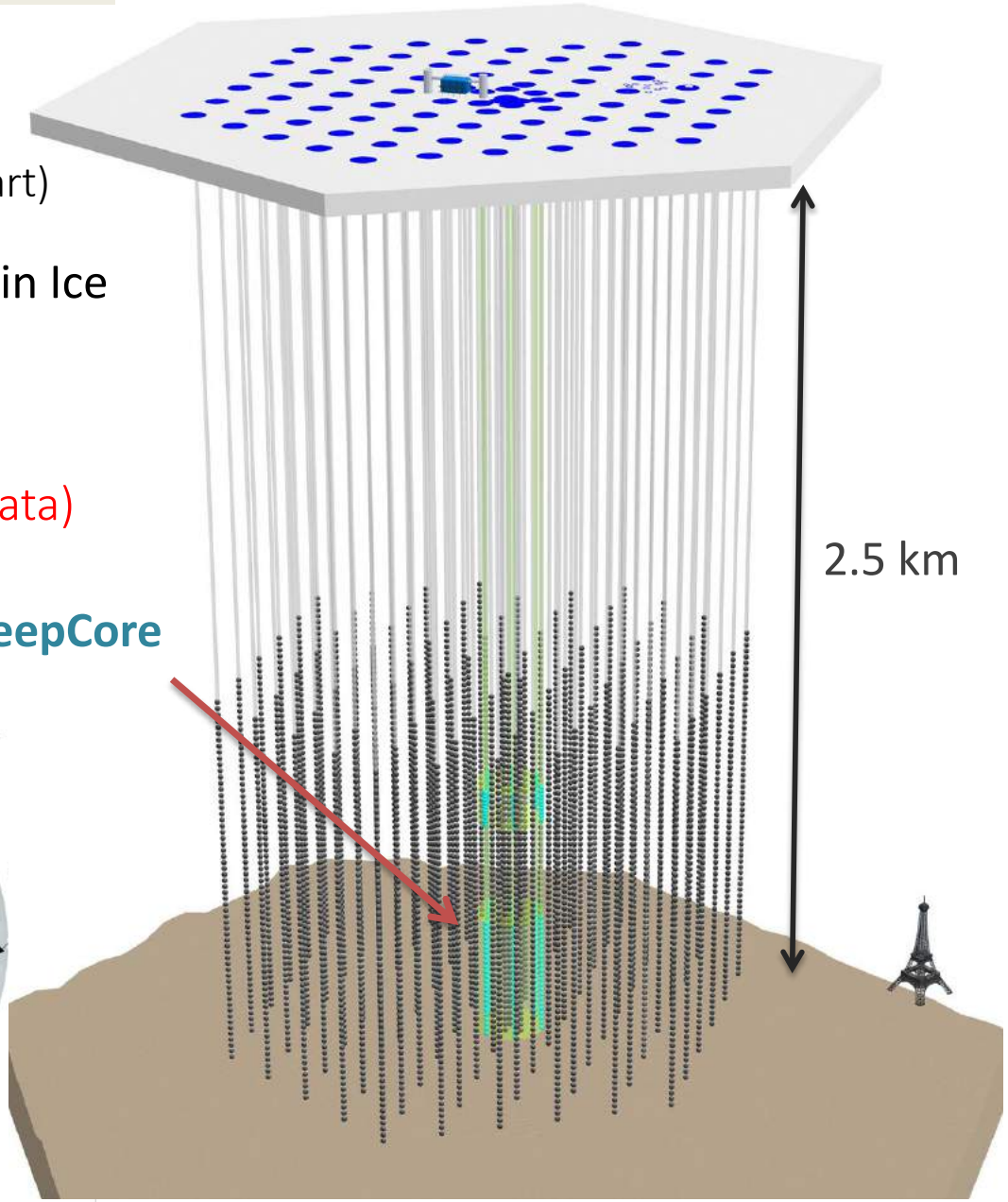
5160 Digital Optical Modules (DOMs) in Ice

1 km^3 ⇒ Gton instrumented volume

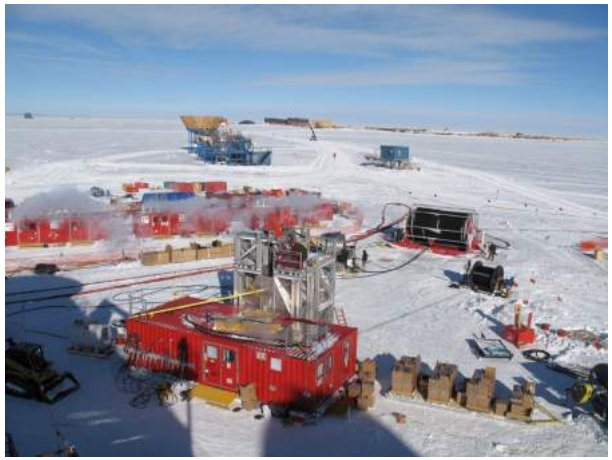
Construction: 2004-11 (now 9+ yrs of data)

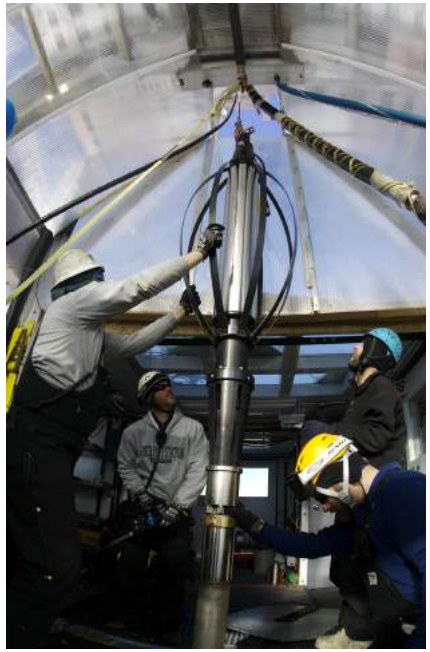


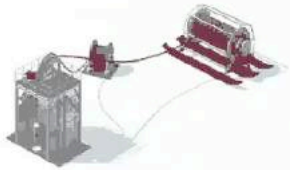




Cost: 279 M$ ⇒ ₹ 20 per ton







High Energy Neutrino Detection Principle

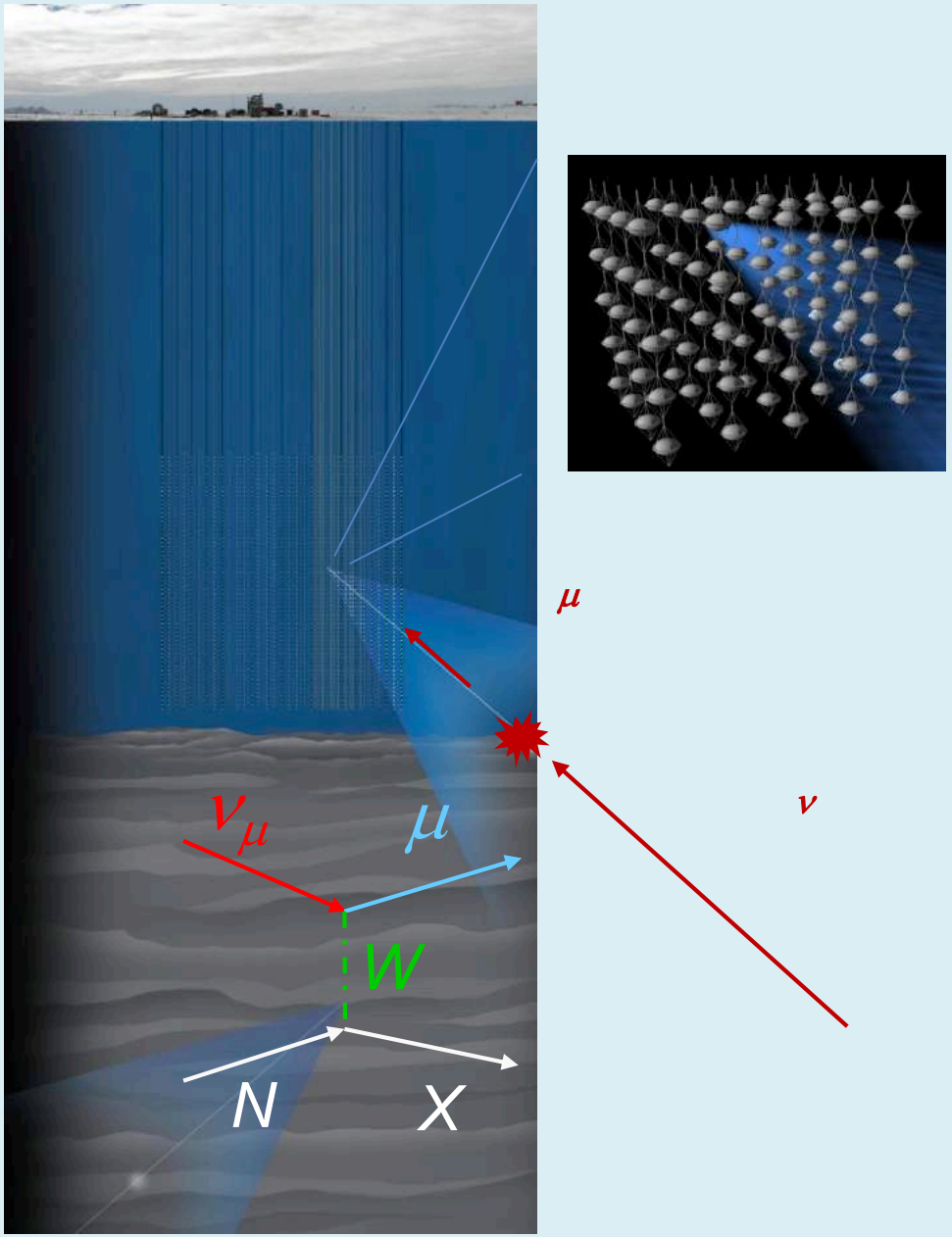
- A ν interacts with a nucleus
  … produces a μ (e or τ)
  and/or a 'cascade'

- A charged particle moving at *superluminal* speed gives rise to Cherenkov radiation (cone $\angle$ 40°)

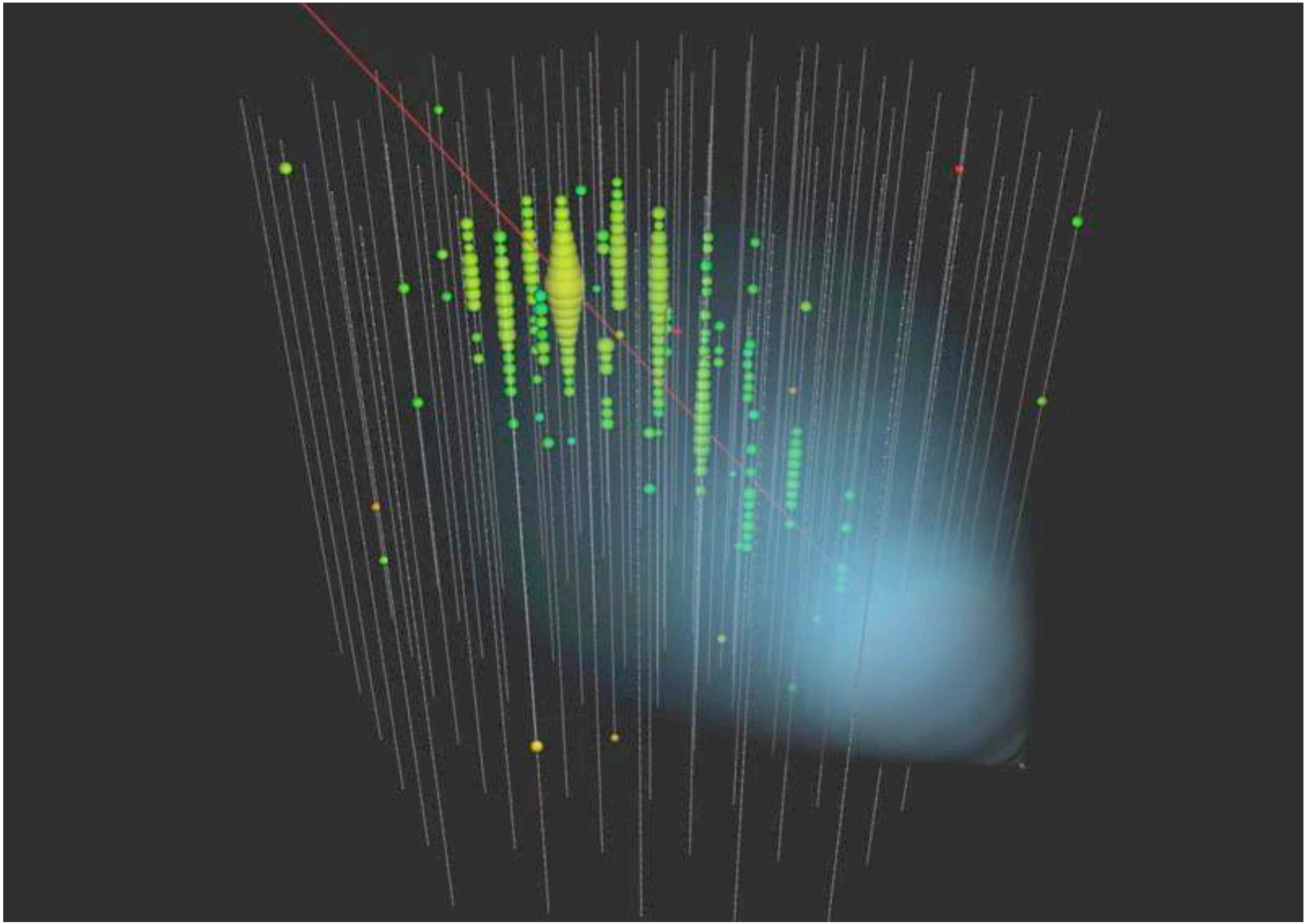
- This radiation is detected by 3D array of optical sensors

Position, time & amplitude of hits allows reconstruction of tracks using likelihood optimisation (machine learning …)

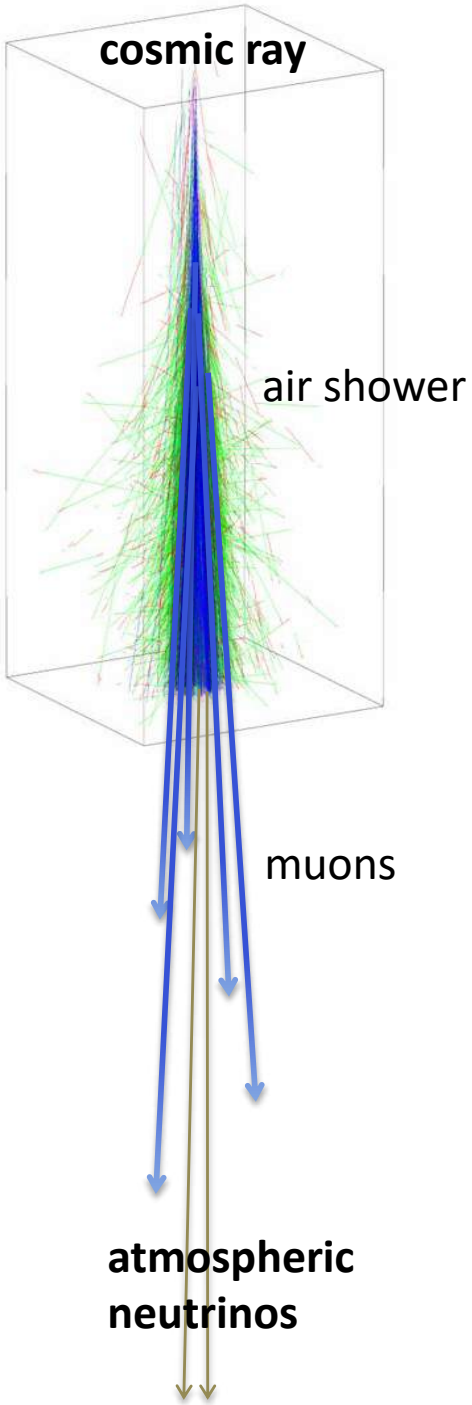
The lepton direction is aligned with the incoming ν ⇝ astronomy!

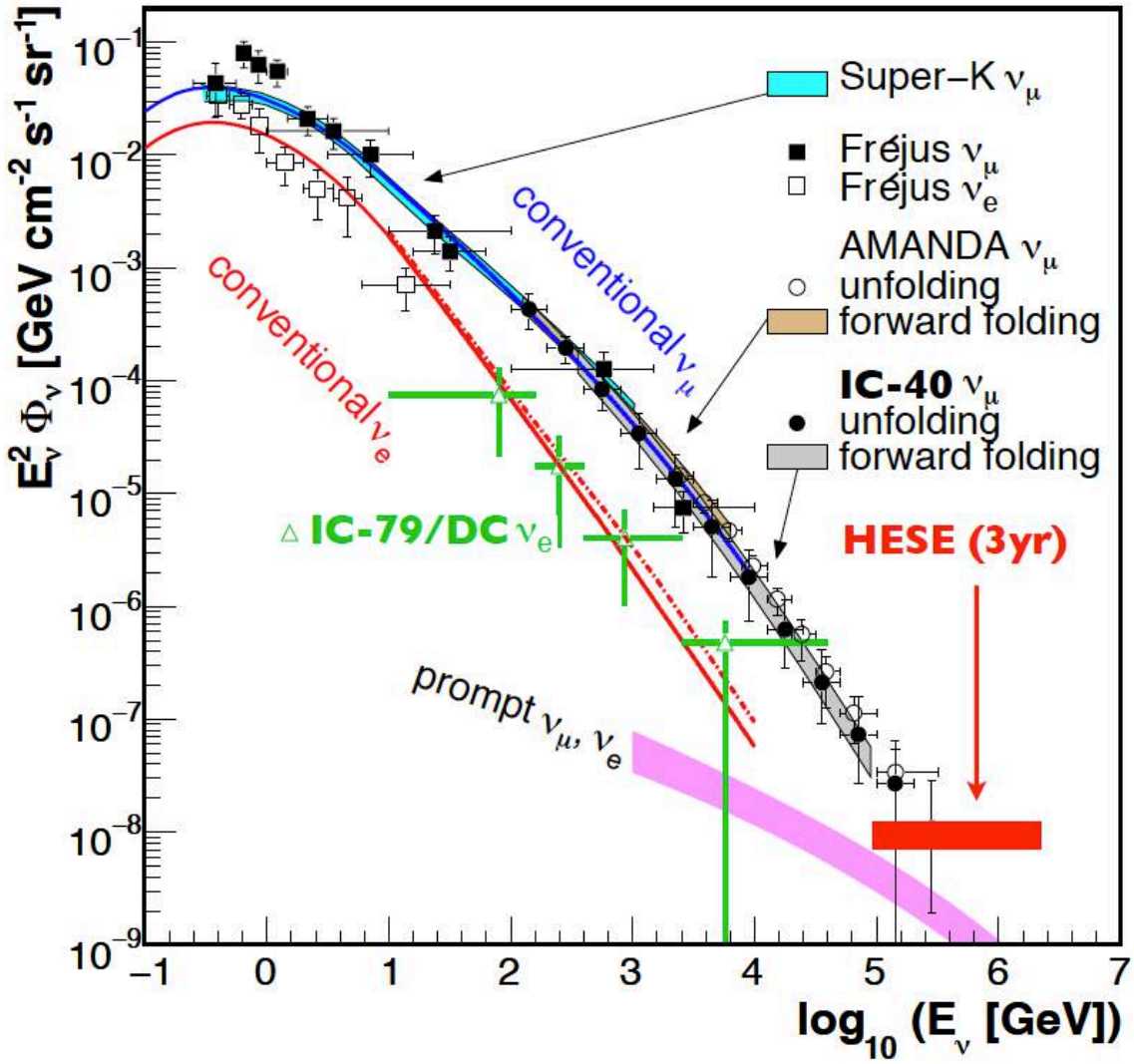


Muon track: time ⇒ colour; number of photons ⇒ energy



Atmospheric Neutrino Spectrum





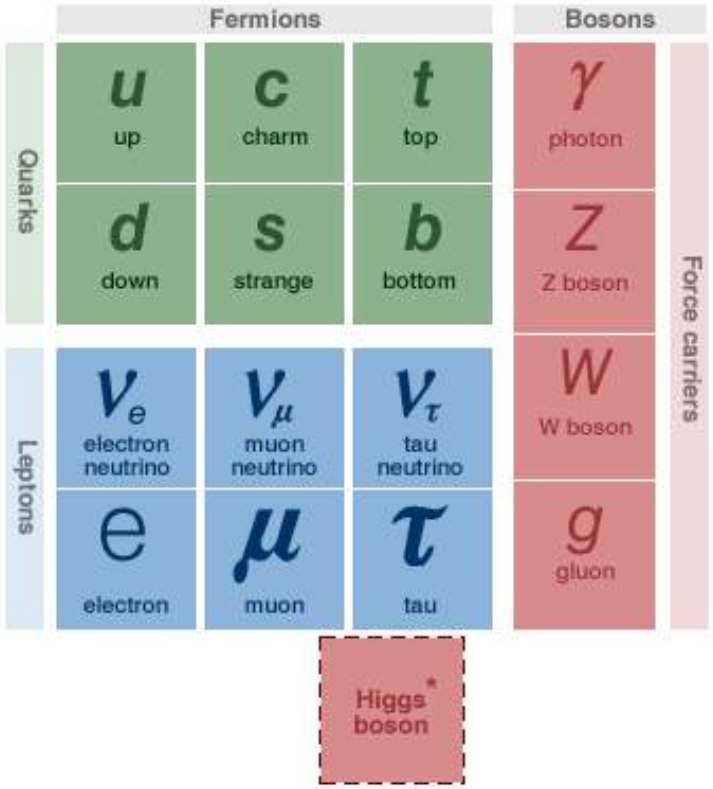
IceCube has measured the atmospheric neutrino flux … in good *agreement* with the expectation from cosmic ray interactions in the atmosphere creating pions and kaons

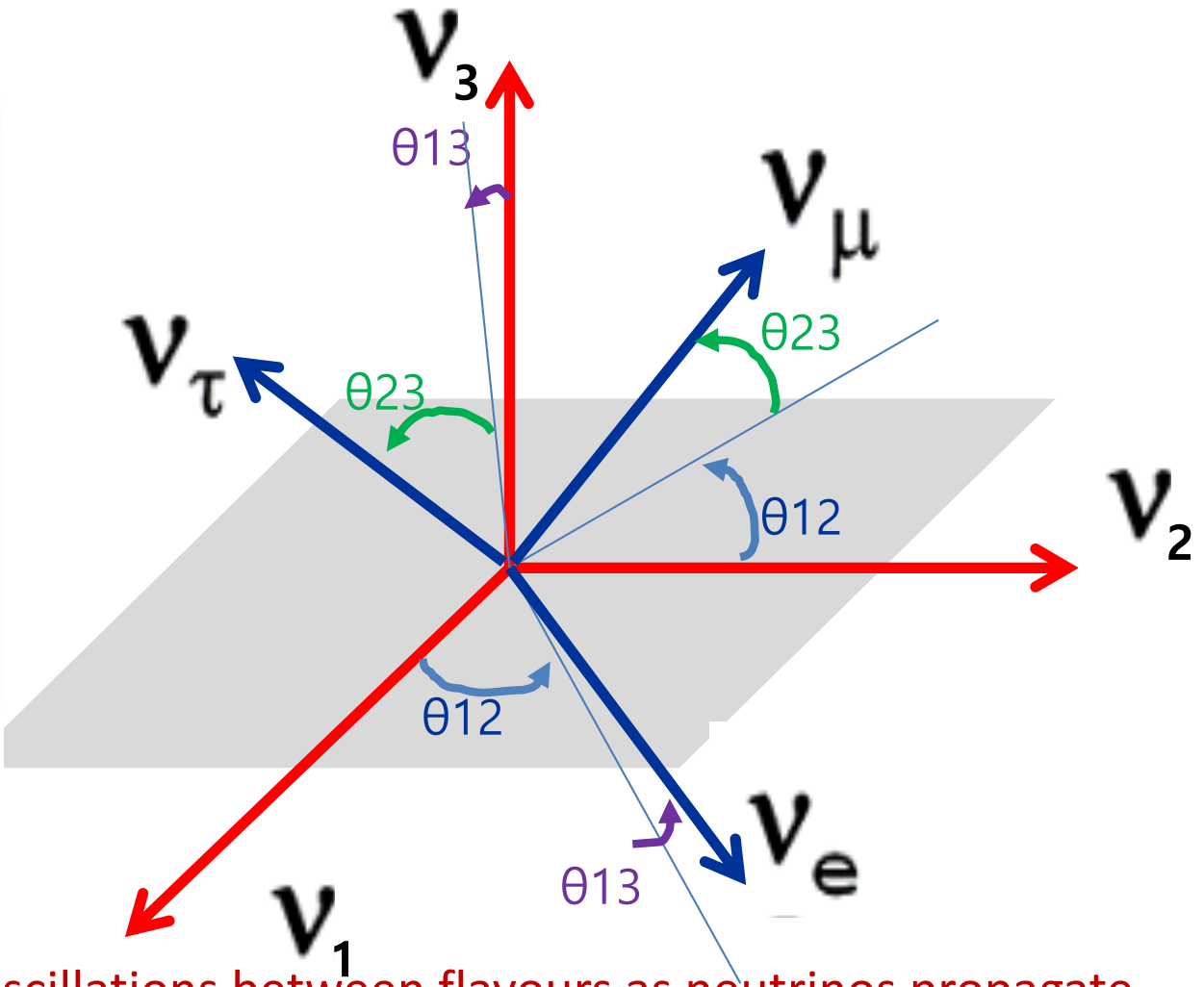
('prompt' flux from charmed meson decays *not* detected)

Neutrino Oscillations

If neutrinos have mass, then the mass eigenstates ≠ weak interaction eigenstates

$$|\nu_\alpha(t)\rangle = U_{\alpha k} e^{-iH_k t}|E_k\rangle, \qquad |\langle E_k|\nu_\alpha(t)\rangle|^2 \neq 1, C$$





→quantum mechanical oscillations between flavours as neutrinos propagate

$$|\nu_\ell\rangle = U|\nu_n\rangle, \quad \text{where} \quad (c_{ij} \equiv \cos\theta_{ij}, \quad s_{ij} \equiv \sin\theta_{ij})$$

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$|<\nu_\beta|\nu_\alpha>|^2 = P(\nu_\alpha \to \nu_\beta)$$

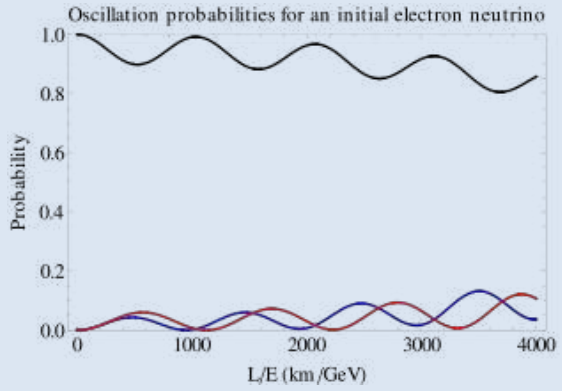
$$\Delta m^2_{21} = m^2_2 - m^2_1 \qquad \Delta m^2_{32} = m^2_3 - m^2_2$$

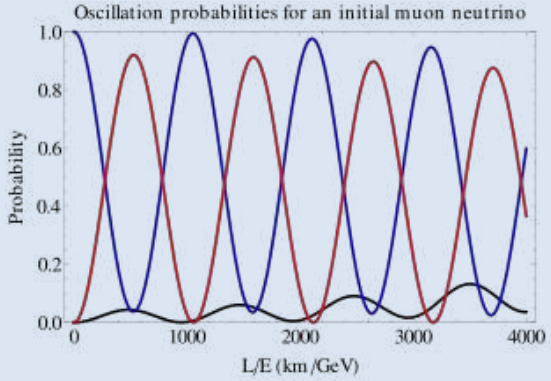
$$P(\nu_\mu \to \nu_\mu) \simeq 1 - 4\cos^2\theta_{13}\sin^2\theta_{23}\left(1 - \cos^2\theta_{13}\sin^2\theta_{23}\right)\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right)$$

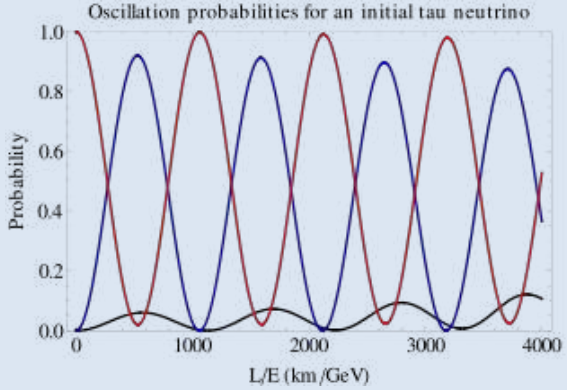
$$P(\nu_\mu \leftrightarrow \nu_\tau) \simeq \sin^2 2\theta_{23}\cos^4\theta_{13}\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right)$$

$$P(\nu_\mu \leftrightarrow \nu_e) \simeq \sin^2\theta_{23}\sin^2 2\theta_{13}\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right)$$

$$P(\nu_e \leftrightarrow \nu_\tau) \simeq \cos^2\theta_{23}\sin^2 2\theta_{13}\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right)$$







$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & c_{23} & s_{23}\\ 0 & -s_{23} & c_{23}\end{pmatrix}\begin{pmatrix}c_{13} & 0 & s_{13}e^{-i\delta_{CP}}\\ 0 & 1 & 0\\ -s_{13}e^{i\delta_{CP}} & 0 & c_{13}\end{pmatrix}\begin{pmatrix}c_{12} & s_{12} & 0\\ -s_{12} & c_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

Global fit – Normal hierarchy

$\Delta m^2_{21} = 7.50^{+0.19}_{-0.17} \times 10^{-5}\text{eV}^2$

$\Delta m^2_{31} = 2.457^{+0.047}_{-0.047} \times 10^{-3}\text{eV}^2$

$\theta_{12} = 33.48^{+0.78}_{-0.75}(^\circ)$

$\theta_{23} = 42.3^{+3.0}_{-1.6}(^\circ)$

$\theta_{13} = 8.50^{+0.20}_{-0.21}(^\circ)$

$\text{sign}(\Delta m^2_{32}) = ?$

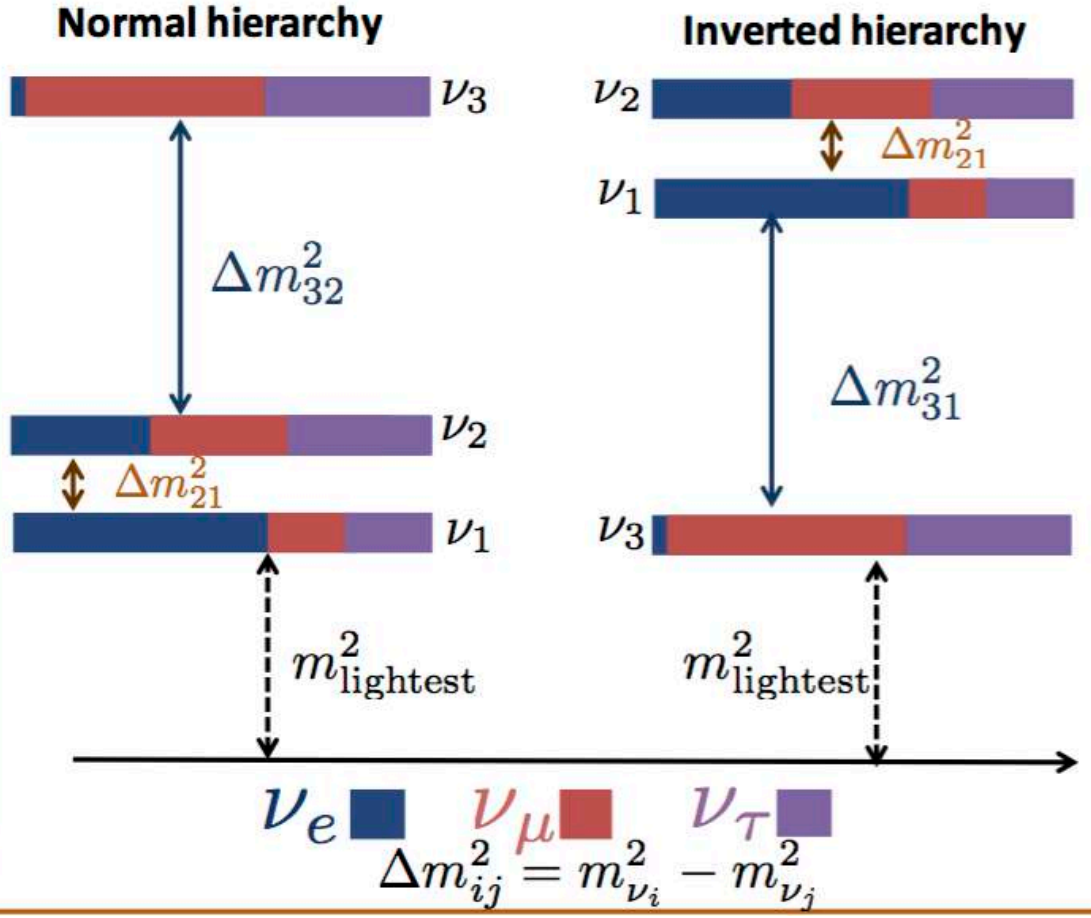
θ_{23} is maximal ?

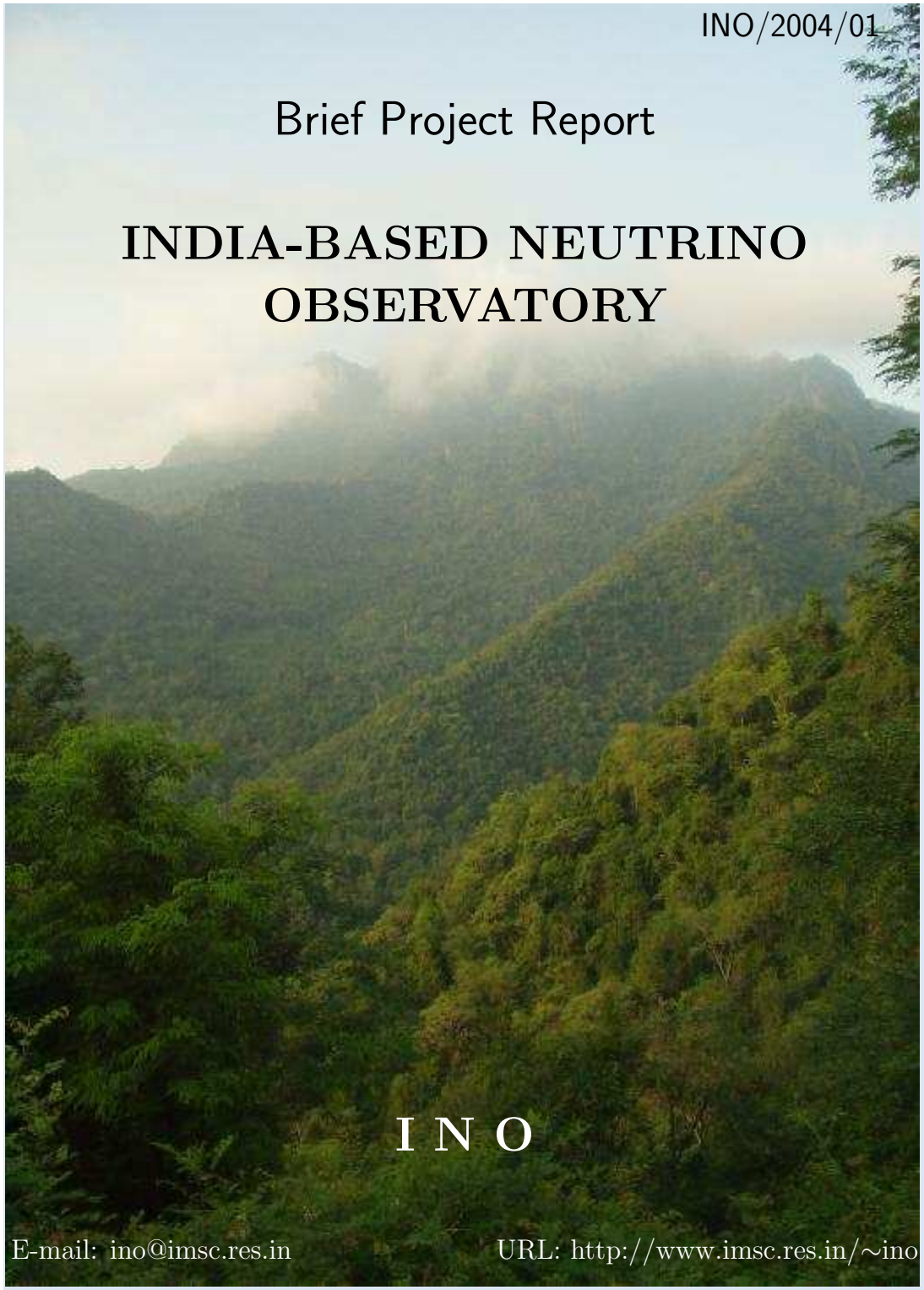
$\delta_{CP} = ?$

$m_{\text{lightest}} = ?$

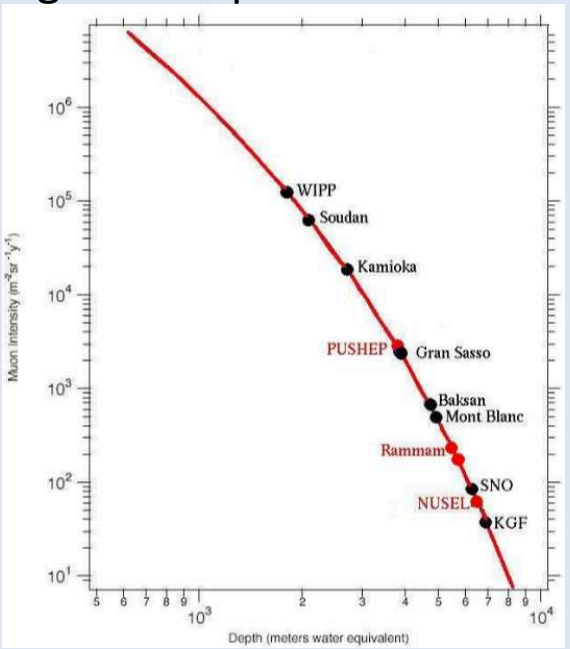
Many open questions

Gonzalez-Garcia *et al.*, arXiv:1512.06856

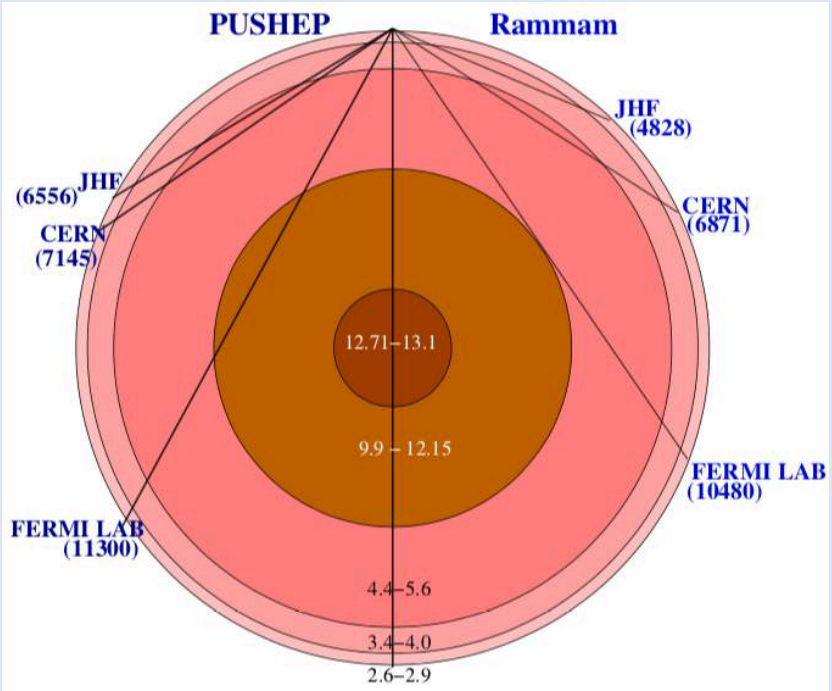




Among the deepest sites worldwide



Possible future long baseline experiments



INO WILL ADDRESS ALL THE ? IN THE NEUTRINO MIXING MATRIX

Pramana – J. Phys. (2017) 88: 79
DOI 10.1007/s12043-017-1373-4

Invited review: Physics potential of the ICAL detector at the India-based Neutrino Observatory (INO)

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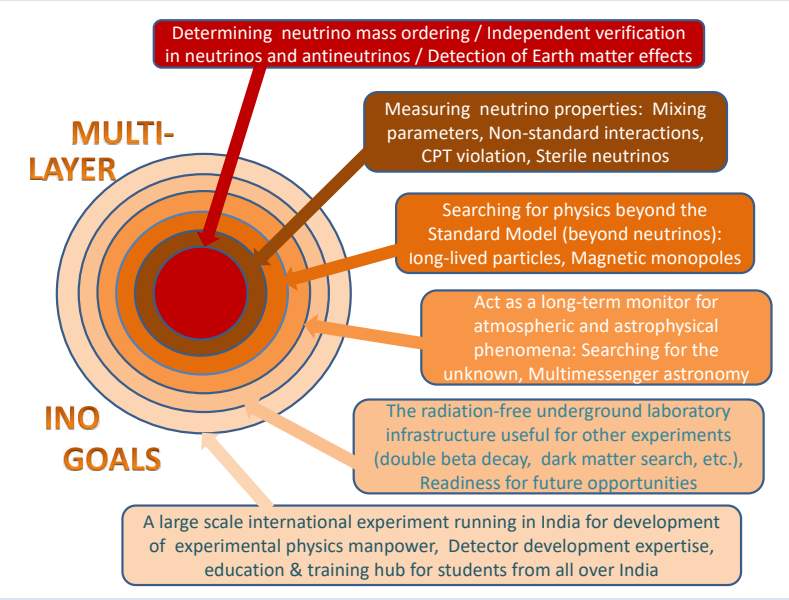
THE ICAL COLLABORATION: http://www.tifr.res.in/~ino

MS received 4 July 2015; revised 3 October 2016; accepted 1 December 2016; published online 26 April 2017

Abstract. The upcoming 50 kt magnetized iron calorimeter (ICAL) detector at the India-based Neutrino Observatory (INO) is designed to study the atmospheric neutrinos and antineutrinos separately over a wide range of energies and path lengths. The primary focus of this experiment is to explore the Earth matter effects by observing the energy and zenith angle dependence of the atmospheric neutrinos in the multi-GeV range. This study will be crucial to address some of the outstanding issues in neutrino oscillation physics, including the fundamental issue of neutrino mass hierarchy. In this document, we present the physics potential of the detector as obtained from realistic detector simulations. We describe the simulation framework, the neutrino interactions in the detector, and the expected response of the detector to particles traversing it. The ICAL detector can determine the energy and direction of the muons to a high precision, and in addition, its sensitivity to multi-GeV hadrons increases its physics reach substantially. Its charge identification capability, and hence its ability to distinguish neutrinos from antineutrinos, makes it an efficient detector for determining the neutrino mass hierarchy. In this report, we outline the analyses carried out for the determination of neutrino mass hierarchy and precision measurements of atmospheric neutrino mixing parameters at ICAL, and give the expected physics reach of the detector with 10 years of runtime. We also explore the potential of ICAL for probing new physics scenarios like CPT violation and the presence of magnetic monopoles.

Keywords. Neutrino physics; atmospheric neutrinos; neutrino experiments; India-based neutrino observatory.



Indian Neutrino Detector: Environmental Costs

I would like to spell out the environmental costs of building the India-based Neutrino Observatory (INO) discussed in the News of the Week story "Indian neutrino detector hits snag on environmental concerns" (P. Bagla, 9 January, p. 197). The first foreseeable impact would be a sizable increase in the human population, furthering habitat destruction. Transporting the estimated 630,000 tons of debris and 147,000 tons of construction material would require about 156,000 truck trips through a vital protected area. INO would require 320,000 liters of water per day, further draining a drought-prone region. The Environmental Impact Assessment (*1*) upon which this project was approved was not based on scientific data and is widely acknowledged as being seriously flawed (*2*).

The international scientific community should be aware that the INO project is not site specific — in theory, a neutrino observatory can be located in any underground site with sufficient rock cover. There was no attempt to find suitable sites in less critical areas. The INO team limited its search to only two sites: Rammam in Darjeeling and Singara in the Nilgiri Biosphere Reserve. Because Rammam is in an area of higher seismic activity, the team selected Singara.

PRIYA DAVIDAR

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A.Desai, P. Davidar, J.P. Puyravaud, G. Srinivasan, N. Mohanraj, T. Thekaekara, "Environmental concerns around the proposed site for the India-based Neutrino Observatory" (NBR Alliance report, 2008); www.nbralliance.org/downloads/environmental- concerns-around-ino-site.pdf.

A DETAILED RESPONSE WAS PROVIDED, REFUTING ALL THE CONCERNS

Response

THE PROPOSED INDIA-BASED NEUTRINO Observatory (INO) (*1*) would be located in Singara, which is 7 to 15 km from the boundary of the Mudumalai Wildlife Sanctuary in the Nilgiri Biosphere Reserve. The INO collaboration is fully committed to protecting the environment and wildlife and will take all possible steps to minimize the impact during the construction of the underground laboratory. During the operation phase, it is expected to have no impact at all.

Regarding population growth, the laboratory will be located deep underground and accessed by a tunnel 2 km in length. Researchers will be located at the main INO research and development center in the city of Mysore, about 100 km away. Except during the construction phase, the number of scientists and engineers manning the laboratory will be kept at a bare minimum (at most 30 people). The present population of Masinagudi village area, in which the project will be housed, is 12,535. INO will not significantly increase this population.

The initial site survey was conducted over a period of 5 years with the assistance of geologists and engineers. The two sites mentioned by Davidar were selected for more serious study. The Singara site was chosen over Rammam on the basis of a geotechnical analysis that considered physics requirements, safety, and long-term stability of the laboratory. About 13 km of tunnels have been constructed over the past decade in the vicinity of the proposed INO site to locate a large underground hydroelectric power station whose access portal is within a few hundred meters of the proposed INO tunnel portal. Due to the proximity of this hydroelectric power station, we do not have to build any new roads, thereby causing minimum damage to the environment.

Regarding transport of material, about 608,000 tons of debris (mainly granite) will be excavated. However, this debris will be stored onsite for a long time. About 35,000 tons of construction material and 51,000 tons of detector material (86,000 tons in all) will be brought into the site over a period of 7 years. The heavy-vehicle traffic required to do so will be no more than six round trips per day over a period of 7 years, which is negligible compared with the existing traffic. The major concern with the transportation of this material is that the access road to the INO site cuts through an elephant corridor. To address this, we plan to restrict the traffic to six round trips a day during daylight hours.

The water requirement is 342,000 liters of water per day, which is 0.2% of the availability at the Singara diversion weir (68,086 million liters of water available per annum). The INO project has been engaged in talks with the local people to clarify these issues, and the local village administration has passed a resolution welcoming the INO project.

The INO project is a pure science laboratory and not an industry. We believe that it is possible to build and run the underground laboratory to explore the working of nature without damaging it. INO is both an opportunity and a challenge to be a model project that combines pure science research with sensitivity to its local ecology and environment.

NABA K. MONDAL

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Reference

1. India-based Neutrino Observatory (www.imsc.res.in/~ino).

Nevertheless environment minister Jairam Ramesh decided *not* to permit construction at Singara … even though the Indian Institute of Sciences ecologist R Sukumar, who had worked in the Nilgiri forests for 20 years, had prepared for him a note on the INO project which stated: "arguments against Singara are, to a very large extent, exaggerated and misplaced".

Indian neutrino lab site rejected

India's particle physicists have lost their battle to build a neutrino laboratory — one of the country's biggest physics projects — under the Nilgiri hills at Singara in the state of Tamil Nadu. The government has upheld conservationists' view that its construction would endanger wildlife in the Nilgiri Biosphere Reserve (NBR), an important tiger and elephant habitat.

The 6.8-billion rupee (US$150 million) India-based Neutrino Observatory (INO) has been mired in environmental controversy since 2006, but physicists were hoping it would be resolved in their favour (see *Nature* 461, 459; 2009). However, on 20 November India's minister of environment and forests, Jairam Ramesh, informed the scientists that they should not proceed at Singara.

Ramesh wrote that he was acting on a "large number of reports" received against the proposed site and the "very weighty reasons" put forward by Rajesh Gopal, head of forestry in his ministry. Ramesh has suggested the project consider instead a site near Suruliyar, also in Tamil Nadu, that does not pose Singara-type problems.

"Everybody in the INO project is disappointed," says project spokesman Naba Mondal, a physicist at the Tata Institute of Fundamental Research in Mumbai. Project scientists had already considered and rejected the potential site at Suruliyar because there were less available data on the characteristics of the rock that would need to be blasted out to create a cavern to host the neutrino detector. "Preparing a new site means a further delay of one year to a project that has already lost four years due to environmental activism," he says.

"A new site means a further delay of one year to a project that has already lost four years."

Conservationists are pleased, however. "We are indeed relieved," says Tarsh Thekaekara, coordinator of the NBR Alliance, the group that spearheaded the campaign against building the neutrino observatory at Singara. The proposed Suruliyar site is also close to the Periyar tiger reserve, although not in a wildlife corridor as the Singara site is.

Thekaekara says that environmentalists near Suruliyar may decide to challenge the new proposal. "We only represent organizations in Nilgiri," he says. "It may happen that some of the members also active in [Suruliyar] will protest if there is a serious threat to nature." Mondal says that work at the new site will start only after all government clearances are in place. ■

K. S. Jayaraman

INO scientists reluctantly accepted the Government's decision and identified a new site in the Bodi Hills in Theni district (where there is no forest) … with the operations centre to be located at Madurai - **this was *granted* environmental clearance in 2010**

THINGS WERE FINALLY LOOKING UP AND THE PROJECT WAS IN FULL SWING BY 2012

Digging deep for neutrinos

Delayed because its original site was on an elephant corridor, work on a giant underground neutrino observatory is now finally getting underway, as **Pallava Bagla** reports

India is embarking on an ambitious project to catch and detect the world's lightest subatomic particle: the neutrino. In an attempt to bag these elusive entities, the country is planning a giant experiment in a subterranean cavern in a site in southern India more than a kilometre beneath the Earth's surface. Called the India-based Neutrino Observatory (INO), it will be India's largest ever single investment towards an experiment in basic science. The Rs18.5bn ($350m) lab is expected to be operational – with the first of three detector modules in place – by 2017. When complete, it will also boast the world's largest magnet, made from some 50000 tonnes of iron, and 30000 particle detectors.

India hopes that the INO will help the country to reclaim its leading position in neutrino research – a field in which it was a pioneer back in the early 1960s. It was then that a team from the Tata Institute of Fundamental Research in Mumbai, led by B V Sreekantan and M G K Menon, famously used a neon flash-tube array in a mine shaft – 2.3 km below ground in the Kolar Gold Fields – to detect for the first time the neutrinos created when cosmic rays smash into the atmosphere. That facility was closed in 1992 when mining at the site started winding down and the experiment became too costly to maintain. "Many of us in the international community grieved over the termination of that line of work," says John Learned, a physicist at the University of Hawaii, Honolulu.

India's Neutrino Observatory

Going underground The India-based Neutrino Observatory, with project spokesperson Naba Mondal pictured left, will be built in a cavern under this mountain in the south-eastern state of Tamil Nadu.

Massive prospects

The INO is certainly an ambitious attempt to recapture past glories. Neutrinos are tiny, neutral particles that travel at the speed of light and interact with matter via the feeble weak force. But so weak is this interaction that trillions of these particles zip right through your body every second without stopping. Detecting neutrinos – whether produced by cosmic rays striking nuclei in the atmosphere or by nuclear fusion in the Sun's core – therefore requires massive detectors to increase the chances of spotting these fleeting particles as they plough their way through the Earth. Neutrino detectors are thus usually located deep underground in locations that allow the rock above to absorb the copious amounts of cosmic rays that would otherwise blanket the signal.

In the case of the INO, the project will involve constructing a large twin-cavern laboratory nestled 1300 m beneath a mountain in the Bodi West Hills – about 110 km from the temple city of Madurai. Connected to the outside world by a 2 km-long tunnel, the lab will initially house a single detector with three modules, known as the Iron Calorimeter (ICAL). Each module will be made from 150 layers of sealed glass plates – containing a mixture of mostly freon and isobutane – sandwiched between layers of iron that form a giant stack 15 m high, 16 m wide and 16 m deep. The idea is that when a neutrino interacts with the iron, it will produce muons and other charged particles that ionize the gas. The resulting avalanche current will then be detected by special electronics channels mounted on the glass.

ICAL has two features that make it different from neutrino detectors of similar size in other nations. One is that it will be able to distinguish between atmospheric neutrinos and antineutrinos because when they interact with the detector material, they produce particles with opposite charges that are bent in different directions by the iron magnet. The other plus point is that ICAL will be able to measure both the energy and direction of these particles. "The INO laboratory will be the world's most massive detector of its kind," says TIFR physicist Naba Mondal, who is the project's spokesperson.

INO researchers intend to use ICAL to study the fact that neutrinos, which come in three types, can change, or "oscillate", from one type to another. However, neutrinos can oscillate only if they have a non-zero mass, and although other experiments around the world have been able to observe neutrino oscillation – and so establish that they have a mass, albeit a very tiny one – physicists do not know which neutrino type is the heaviest and which is the lightest. The ICAL detector, which can distinguish between events produced by neutrinos and those from antineutrinos, will be able to address this issue.

"Neutrino oscillations are not only a new paradigm in physics, but also the first known evidence for physics beyond the Standard Model of particle physics," adds Mondal. In addition to shedding light on the mass of neutrinos, understanding neutrino oscillation could point to why there is so much more matter than antimatter in the universe.

New frontiers

For Indian science, the INO is taking the country into new territory, but it has not all been plain sailing. Researchers had originally expected the project to be complete by 2012 at a cost of just Rs9bn, with the INO built at a different location 500 km away at Singara in the Nilgiri Hills in Tamil Nadu. However, in 2010 the proposed site, which already had housing, power supplies and approach roads in place, was turned down by India's Ministry of Environment and Forests because of the presence of elephants that use the land as a migration corridor and because it had been declared an official tiger reserve in 2008. With the world's largest land mammal having won over the universe's tiniest particle, INO officials were forced to look for a suitable new site that had the right kind of compacted hard rock that can be easily tunnelled through.

Fortunately, the site search proved less tricky second time round thanks in part to the powers of Google Maps. "The process was almost painless," says Bheesette Satyanarayana of the TIFR, who is working on a prototype of the ICAL detector. The new site was eventually given the nod in 2011 by the Indian environment ministry, which has put in place 27 conditions that need to be fulfilled during the construction phase.

One advantage of the new site is that it has few trees, so there will be no loss of forest. "It is imperative to recognize that the study of nature's innermost workings need not be at loggerheads with nature itself," says Mondal. Pre-project work on the new site will start soon and the detectors for the first engineering model of the detector are being readied at the TIFR and at other institutes. "We do not need to make any mid-course correction as a consequence of the delay," claims an optimistic Mondal, who heads what is a collaboration between physicists and engineers at almost 30 different institutes, labs and universities in India.

The ICAL detector is, however, just the first phase of the INO project. In the second phase, researchers will set up detectors in the INO caverns to look for the very rare "neutrinoless double-beta decay" process and for dark-matter particles. An even more ambitious third phase would see the ICAL detector double in size to 100 tonnes to let it be used as a "long baseline" experiment, studying neutrinos beamed by accelerators in Europe or Japan across hundreds of kilometres through the planet.

The INO initiative has received praise from Maury Goodman, a neutrino physicist at the Argonne National Laboratory in Illinois, who calls it "unique and important". "No large dedicated experiment to study atmospheric neutrinos has ever been built," he says, "and the INO design is certainly a better way to study atmospheric neutrinos than has been done before." Goodman is also not too discouraged about the project being behind schedule. "Everything takes time," he says. "Sure, the INO has run into some unexpected delays, but then so does every project."

Teaching the next generation

One important benefit of the India-based Neutrino Observatory is that it has led to the creation of a special, five-year PhD programme to train a new generation of researchers in the art and science of neutrino detection. Launched in 2008 by the INO collaboration and hosted by the Tata Institute of Fundamental Research (TIFR) in Mumbai, the programme teaches students how to build neutrino detectors, how to simulate the tracks the neutrinos leave in the detectors, and how to analyse and interpret the data produced. Some 20 students are currently taking the programme, which leads to a PhD from the Homi Bhabha National Institute in Mumbai.

"This is one of the success stories of the INO project and we hope that [the students] will be part of the INO experimental team when they graduate," says Bheesette Satyanarayana of the TIFR, who is working on a prototype of the INO's Iron Calorimeter detector (see main text). "With almost 30 different institutes, research labs and universities involved in the INO, the project needs a core of experimentally inclined students."

TIFR photographic section

Future pioneers The first five PhD students working on plans for the India-based Neutrino Observatory.

But opposition now came from an environmental group & a local politician

THE HINDU

TAMIL NADU

INO project: Vaiko slams Centre

Shastry V.Mallady

CHENNAI, JANUARY 06, 2015 13:22 IST
UPDATED: JANUARY 07, 2015 01:13 IST

SHARE ARTICLE PRINT A A A

MDMK leader Vaiko

MDMK general secretary Vaiko on Tuesday lambasted the Centre for giving its nod for setting up the India-based Neutrino Observatory (INO) in Theni, but scientists associated with the project allayed all apprehensions about it.

Mr. Vaiko, who was here to participate in a function, charged that "under the guise of development, establishing a laboratory would mean destruction of natural resources." "Let me tell them, Tamil Nadu is neither a place for conducting tests nor are the people here guinea pigs," he said.

Nonetheless, the director and chief spokesperson of the Rs.1,500-crore INO project, Naba K. Mondal, said that he was ready to meet Mr. Vaiko and explain its advantages.

He also appealed to all political parties in Tamil Nadu to extend their support for this multi-institution research project, which would be a big boost for basic science research and advanced studies in particle physics.

"I look forward to meeting Mr. Vaiko and clear all his apprehensions about INO project. We are ready to send him material about what the neutrino observatory is all about. I am sure he will be convinced after reading that," Dr. Mondal told The Hindu over phone on Tuesday.

TAMIL NADU

Environmental group challenges clearance for neutrino project

T. K. Rohit

CHENNAI , APRIL 24, 2018 01:00 IST
UPDATED: APRIL 25, 2018 17:41 IST

SHARE ARTICLE 4 PRINT A A A

Calls for penal action against members of appraisal committee

Poovulagin Nanbargal, an environmental group, has moved the National Green Tribunal's principal bench in New Delhi, challenging the environmental clearance granted to the neutrino observatory project in Theni district.

The appeal also sought direct penal action against members of the Expert Appraisal Committee (Infra-2) for acting beyond their jurisdiction and recommending the project for grant of EC in violation of the EIA notification, 2006. Besides, it sought a departmental inquiry against officers of the Environment Ministry for giving illegal directions to the EAC.

G. Sundarrajan of Poovulagin Nanbargal, who filed the appeal, sought a detailed and comprehensive Environmental Impact Assessment to be conducted by an accredited agency, with "expertise in this specific field looking at the entire project in totality, given that it is the first of its kind in the entire country".

In his petition, Mr. Sundarrajan said the EAC had no statutory power to appraise a project under Item 89(a) of the Schedule to the EIA notification. Hence, the EC is liable to be quashed for want of jurisdiction.

The Marsh of Failures That the India-Based Neutrino Observatory Is Stranded In

Vasudevan Mukunth

THE WIRE
26/Apr/2017

Scientific facts have failed to quell misinformation, an assertion of democratic rights has failed to inspire trust and the EIA has failed as an instrument of legitimisation.

At a meeting organised by the INO collaboration with villagers from Pottipuram, Theni. Credit: INO

Timeline of events

* On 18 October 2010, the Ministry of Environment & Forests approved both environment and forest clearance for setting up the observatory in the Bodi West Hills Reserved Forest in the Theni district of Tamil Nadu.

* As of February 2012, the land was allocated to the INO collaboration by the government of Tamil Nadu and the excavation work was about to start. Naba Mondal, chief spokesperson of INO project and a senior scientist at the Tata Institute of Fundamental Research, Mumbai, told The Hindu that the pre-project work will start in April 2012 and ₹ 66 crores has been sanctioned for the work. The first task will be to have a road connectivity from Rasingapuram to Pottipuram village. The project is expected to be completed in 2015 at an estimated cost of ₹ 1,500 crores.

* On 18 September 2012, Kerala's octogenarian Opposition leader and CPI(M) central committee member V S Achuthanandan expressed anxiety over establishing a neutrino observatory on the Theni-Idukki border between Tamil Nadu and Kerala, citing environmental and radiological issues. Soon the INO collaboration clarified on all the issues raised by him and the responses are on the INO website.

* On 5 January 2015, Union Cabinet headed by Prime Minister Narendra Modi approved to set up the India-based Neutrino Observatory (INO).

Timeline of events (cont.)

* On 20 February 2015, The southern bench of National Green Tribunal ordered notices to the central and state governments on a petition challenging the environmental clearance granted to the India-based Neutrino Observatory project.

* On 26 March 2015, The Madurai bench of the Madras high court restrained the central government from commencing the work on the proposed India-based Neutrino Observatory (INO). The court directed the government to get permission from the Tamil Nadu Pollution Control Board (TNPCB) before commencing the work.

* On 19 March 2018, Ministry of Environment (India) overturned the NGT verdict as a special case. The approval is only conditional and it needs the consent of the Tamil Nadu Pollution Control Board and the National Board for Wildlife. The approval was done under category B of the Schedule to the "Environmental Impact Assessment" (EIA) Notification, 2006. But it should have been ideally been treated as category A as the project lies just 4.9 km from an eco-sensitive national park. Additionally, EIA was done by the Salim Ali Centre for Ornithology and Natural History, which is an "unaccredited agency".

* MDMK general secretary Vaiko began a rally starting 31 March 2018 in the Theni belt to create awareness of 'hazards' due to Neutrino observatory establishment.

Shri Narendra Modi
Honourable Prime Minister of India

22 October 2017

THE SCIENTIFIC COMMUNITY APPEALED TO THE PM

Respected Prime Minister,

We, the undersigned, are Indians comprising a broad cross-section of scientists, engineers, administrators of scientific and educational institutions, and research students - all working in India.

This letter is to draw your attention to the seriousness of the hurdle currently preventing any progress of the prestigious 'India-based Neutrino Observatory' (INO) project for over 2 years, following a court order in March 2015. We request you to take necessary action so that the hurdle is removed as early as possible. The project received final approval from the Union Cabinet chaired by you in January 2015 for its establishment as a multipurpose underground laboratory in Theni district of Tamil Nadu at an estimated cost of Rs 1500 crore. The Tamil Nadu Government has been extremely supportive of the project by giving land in Theni district free of cost, and land for the Inter-Institutional Centre for High Energy Physics (IICHEP) near the City of Madurai at nominal cost. IICHEP will be the nerve-centre of INO, coordinating the work of over 25 institutions in India and also involved in the R&D of detector development as well as student training.

The ICAL particle detector to be housed in INO will be the world's largest electromagnet and particle detector. As Indians, we feel proud that the INO project is entirely indigenous. It has been planned and most of the feasibility studies completed through hard work during the past 15 years by over one hundred scientists, students and engineers working in research institutes and universities spread through the length and breadth of India, who are naturally anxious to see their work bear fruit through timely completion of the project.

From a scientific stand point the project has a golden opportunity to discover one of the most fundamental properties of the most elusive particles in the universe - the neutrino. The property in question is the so-called 'mass-ordering' of the three different species of neutrinos. Such a discovery would be of immense value to the world community of physicists and establish India on the world map of science.

As a spin-off, such a discovery would undoubtedly inspire a good fraction of talented young Indians to pursue fundamental sciences, in which there has been a regrettable decline of interest in recent years in India. Such a decline is unhealthy, because fundamental sciences, apart from being important in their own right, are the backbones of technology. Aside from the prospect of fundamental discovery, the INO project will clearly have a strong impact on science education in the country, as well as development of skills in detector building for Indian students. It would also bring about a healthy interaction between the scientific institutions and the industries in the country, and would inevitably lead to advances in engineering. Projects like INO, carried out in a timely fashion, are thus vitally important for the progress of the nation.

We must also emphasise the INO Graduate Training Program which is quite unique. As many as 39 research students have either already been awarded a PhD under INO (and are receiving further training in various laboratories around the world, while waiting to return to work on INO) or are presently working towards their PhD. Over 50 research papers have already been published by the INO collaboration in reputed international refereed journals.

In addition to the main experiment on neutrino oscillations using the ICAL detector, feasibility studies for 2 other experiments - NDBD (Neutrino-less Double Beta Decay) and DINO (Dark matter at INO) - have also been going on. NDBD will settle the nature of the neutrino, whether it is a 'Majorana' or 'Dirac' fermion and hence is the most fundamental experiment in neutrino physics. DINO seeks to identify the nature of the 'dark matter' which constitutes most of the matter in the Universe. Both these experiments will be under the INO umbrella.

Despite such immense potential benefits of INO to India, there is unfortunately a court order brought about by a group of political and social activists in Tamil Nadu, which has stopped the construction of INO. The consequent delay seriously hurts its purpose because it faces serious competition with other countries as regards the prized discovery (as explained below).

The concern of some politicians and activists that the INO project would cause water pollution, radioactivity and damage to the environment are baseless. First of all neutrinos cause no radioactivity. Being electrically neutral and having no strong nuclear interactions, they are the feeblest and most harmless particles of nature. With or without INO, trillions of neutrinos emitted by the Sun and other sources in the cosmos pass through our body every second, all our life, but cause no harm. The project itself is a benign one which would have little effect on the environment during construction and none during operation. As a 2011 Government report on INO states, "*No forest land is expected to be occupied, since both the tunnels and laboratories are underground*". It might be noted that Japan, Canada and USA have been carrying out neutrino experiments for decades and have had no environmental or radiation concerns.

A Rs 1500 crore project carried out in Theni district will undoubtedly boost the local economy in Tamil Nadu. The flux of national and international visitors to INO will boost education in science & engineering not only in Tamil Nadu but throughout India.

A revival of INO at its present site in TN within the next 2-3 months should be given top priority. This would give a fair chance to India in the race to discover the neutrino mass-ordering since the site in Theni district is ready for the start of tunnelling. If TN does not however take proactive steps promptly, shifting to an alternate site will have to be considered. But this will cause significant further delays, leaving India with little chance of competing with China and other countries. The morale of the INO scientists and students is already very low so the very survival of INO will be doubtful.

The fundamental importance of neutrino physics to be studied at INO may be assessed in part by the fact that the Nobel Prize in physics in 2015 was awarded jointly to Takaaki Kajita (working at the SuperKamiokande Laboratory in Japan) and Arthur McDonald (working at the Sudbury Neutrino Observatory in Canada) for the discovery of neutrino oscillations. Both of them have emphasised in recent statements (McDonald at the Indian Science Congress and on NDTV in January 2016, and Kajita in the Indian Science Congress in January 2017) the importance of INO for the future of particle physics.

The Daya Bay experiment in China and the RENO experiment in South Korea made the landmark discovery of one fundamental neutrino property in 2012. These experiments along with those in Japan and Canada were recently awarded the Breakthrough Prize by high tech firms such as Google and Facebook. These countries as well as USA are moving ahead with bigger and better experiments to study neutrinos. India has a great opportunity to compete with them and even do better in certain aspects.

Of all the methods of determining the neutrino mass-ordering only two are self-contained in that they can arrive at the answer just on the basis of their own experiments without having to use the results of other experiments. One of them is INO of India and the other is JUNO of China. INO has still a good chance of being the first to discover the mass-ordering. But if it is not built in a timely fashion, the Chinese detector will surely steal the show. Here is a chance for India to make a real mark in this field that must not be missed.

But time is of the essence!

Thus for the sake of science, for the sake of the morale of all the Indian scientists, engineers and students who have been working hard for INO for so many years and for the sake of the prestige of India, we earnestly urge you to take all steps necessary to remove the current road-block *as soon as possible* so that the INO project can proceed at full speed at its present site in Tamil Nadu.

Submitted respectfully by**,**

Prof G Rajasekaran (emeritus - IMSc, Chennai) *on behalf of:*

Dr Rathin Adhikari (Jamia Millia Islamia, Delhi)
Dr Sanjib Kumar Agarwalla (IOP, Bhubaneshwar)
Prof Pankaj Agrawal (IOP, Bhubaneshwar)
Prof KG Arun (CMI, Chennai)
Prof Charanjit Aulakh (IISER, Mohali)
Prof Jasjeet Singh Bagla (IISER, Mohali)
Prof Pijushpani Bhattacharjee (SINP, Kolkata)
Prof Utpal Chattopadhyay (IACS, Kolkata)
Dr Baradhwaj Coleppa (IIT, Gandhinagar)
Dr Debottam Das (IOP, Bhubaneswar)
Dr Prasanta Kumar Das (BITS, Goa)
Dr Sudeshna Dasgupta
Dr AseshKrishna Datta (HRI, Allahabad)
Mr Jaydeep Datta (SINP, Kolkata)
Dr Moon Moon Devi (Tezpur University, Tezpur)
Prof Avinash Dhar (ICTS-TIFR, Bangalore)
Prof Shashi Kumar Dhiman (emeritus - HP University, Shimla)
Dr Ng K Francis (Tezpur, University, Tezpur)
Prof Raj Gandhi (HRI, Allahabad)
Prof Rajiv V Gavai (TIFR, Mumbai)
Prof Rohini M Godbole (IISc, Bangalore)
Prof Srubabati Goswami (PRL, Ahmedabad)
Prof Suresh Govindarajan (IIT, Madras)
Mr Abhijit Garai (TIFR, Mumbai)
Dr Partha Ghose (NAS, Delhi)
Dr Kirtiman Ghosh(IOP, Bhubaneshwar)
Prof Rajesh Gopakumar(ICTS, Bangalore)
Dr Debabrata Goswami(IIT, Kanpur)
Prof Atul Gurtu (emeritus - TIFR, Mumbai)
Mr Abhik Jash (SINP, Kolkata)
Prof Bala Iyer (ICTS-TIFR, Bangalore)
Prof Pankaj Jain (IIT, Kanpur)
Prof Anjan S Joshipura (PRL, Ahmedabad)
Prof Kamales Kar (RKMV University, Belur)
Prof Sayan Kar (IIT, Kharagpur)
Dr Rishi Khatri (TIFR, Mumbai)
Prof Govind S Krishnaswami (CMI, Chennai)
Prof Ravindra Kumar (TIFR, Mumbai)
Dr Namit Mahajan (PRL, Ahmedabad)
Prof Swapna Mahapatra (Utkal University, Bhubaneswar)
Prof Karmadeva Maharana (emeritus - Utkal University)
Prof Nayana Majumdar (SINP, Kolkata)
Prof Parthasarathi Majumdar (RKMV University, Belur)
Prof HS Mani (CMI, Chennai)
Prof PT Manoharan (IIT, Madras)
Prof Prakash Mathews (SINP, Kolkata)
Dr Poonam Mehta (JNU, Delhi)
Dr Lakshmi S Mohan
Prof Sunil Mukhi (IISER, Pune)
Mr Dhruv Mulmule (NPD, BARC)
Prof Supratik Mukhopadhyay (SINP, Kolkata)
Prof N Mukunda (emeritus) (IISc, Bangalore)
Prof Palash Baran Pal (SINP, Kolktata)
Prof Mina Ketan Parida (SOA University, Bhubaneshwar)
Prof Apoorva Patel (IISc, Bangalore)
Prof Raj Pillay (TIFR, Mumbai)
Dr Joseph Prabhagar (Loyola College, Chennai)
Mr Rebin Raj (IIT, Madras)
Prof R Rajaraman (emeritus - JNU, Delhi)
Prof Tiruppattur Ramakrishnan FRS (emeritus - BHU, Varanasi)
Prof Ram Ramaswamy (JNU, Delhi)
Prof Raghavan Rangarajan (PRL, Ahmedabad)
Dr Kanishka Rawat (Panjab University, Chandigarh)
Prof Amitava Raychaudhuri (emeritus - Calcutta University)
Prof Saurabh Rindani (PRL, Ahmedabad)
Prof Probir Roy (emeritus - SINP, Kolkata)
Dr Jafar Sadiq (IIT, Madras)
Prof Varun Sahni (IUCAA, Pune)
Dr Deepak Samuel (Central University of Karnataka)
Prof S Uma Sankar (IIT, Bombay)
Dr B Satyanarayana (TIFR, Mumbai)
Prof Ashoke Sen FRS (HRI, Allahabad)
Prof SK Singh (AM University, Aligarh)
Prof Nita Sinha (IMSc, Chennai)
Prof Ajit Srivastava (IOP, Bhubaneshwar)
Prof Sandip Trivedi (TIFR, Mumbai)
Prof PC Vinodkumar (Sardar Patel University, Vallabh Vidyanagar)
Prof Spenta Wadia (emeritus - ICTS-TIFR, Bangalore)
Prof Urjit A Yajnik (IIT, Bombay)

A copy of this letter is also being sent to the Chief Minister of Tamil Nadu.

Finally, MOEFF granted clearance! 26/3/2018

F. No.21-67/2010-IA-III
Government of India
Ministry of Environment, Forest and Climate Change
(IA.III Section)

Indira Paryavaran Bhawan,
Jor Bagh Road, New Delhi - 3

Date: 26th March, 2018

To,

Prof. V.M. Datar,
Project Director INO and Senior Professor, INO Cell,
Tata Institute of Fundamental Research,
1 Homi Bhabha Road, Mumbai-400005
Email: vivek.datar@tifr.res.in

Subject: India-based Neutrino Observatory (INO) at village Pottipuram, Taluk Uthamapalayam, District Theni, Tamil Nadu by M/s Tata Institute of Fundamental Research- Environmental Clearance - reg.

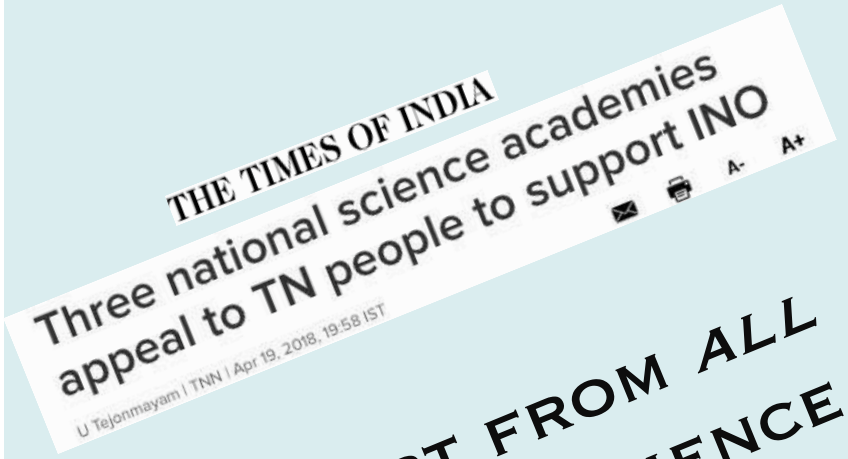
Sir,

This has reference to your online proposal No. IA/TN/NCP/72042/2018 dated 5th January, 2018, submitted to this Ministry for grant of Environmental Clearance (EC) in terms of the provisions of the Environment Impact Assessment (EIA) Notification, 2006 under the Environment (Protection) Act, 1986.

2. The proposal for grant of environmental clearance to the project "India-based Neutrino Observatory (INO) at village Pottipuram, Taluk Uthamapalayam, District Theni, Tamil Nadu promoted by M/s Tata Institute of Fundamental Research, was considered by the Expert Appraisal Committee (Infra-2) in its 27th meeting held on 25th January, 2018 and 28th meeting held on 5th March, 2018. The details of the project, as per the documents submitted by the project proponent, and also as informed during the above meeting, are as under:-

7. The EAC, after detailed deliberations on the proposal and submissions made by the project proponent, recommended the project for grant of environmental clearance to the project. As per recommendations of the EAC, the Ministry of Environment, Forest and Climate Change hereby accords Environmental Clearance to the project Construction of 'India-based Neutrino Observatory (INO)' at village Pottipuram, Taluk Uthamapalayam, District Theni, Tamil Nadu promoted by M/s Tata Institute of Fundamental Research, under the provisions of the EIA Notification, 2006 and amendments/circulars issued thereon, and subject to the specific and general conditions as under:-

http://environmentclearance.nic.in/writereaddata/Form-IA/EC/03262018172042INOECLetter.PDF



THE TIMES OF INDIA

Three national science academies appeal to TN people to support INO

U Tejonmayam | TNN | Apr 19, 2018, 19:58 IST

A- A+

Support from all National Science Academies 19/4/2018

Statement on INO from the three Indian science academies:
The Indian National Science Academy, New Delhi
The National Academy of Sciences, India , Allahabad
Indian Academy of Sciences, Bengaluru

The India-based Neutrino Observatory (INO) is a mega-science research project planned to be undertaken by scientists from more than 25 Indian Central and State Universities and Research Institutes. It is a purely scientific research project of fundamental significance, and one that has been supported and approved by the Government of India.

The Science Academies of India are strongly supportive of the establishment of such an experimental facility for its intrinsic scientific value. In addition to enabling Indian researchers to make a unique contribution to our understanding of several fundamental problems of physics, a major effort on this scale will also contribute significantly to the development of education and research infrastructure in Tamil Nadu. The site selected for INO is in the Bodi West Hills and has been chosen after an extensive nationwide site survey. All environmental regulations will be adhered to and no residents will have to be relocated.

The INO will help us learn more about neutrinos which are elementary particles that have no charge and almost no mass and therefore do not affect anything they pass through. They are naturally produced in the atmosphere of the Earth and are present around us at all times, causing no damage. The INO experiment is a pure science experiment that will lead to the creation of a new Inter-Institutional Educational and Research Centre for High Energy Physics at Madurai. These benefits are not just for the short term: the INO is one of a set of major experiments that can consolidate our position as a leading scientific nation.

The Science Academies hereby appeal to people of the district, state, and country to support this educational and research project wholeheartedly. A successful INO experiment will be a major technological and scientific national achievement.

Scientists come forward in support of neutrino project in Tamil Nadu

B Sivakumar | Updated: Apr 19, 2018, 14:47 IST

THE TIMES OF INDIA

The proposed INO site in Theni

CHENNAI: A group of senior scientists, including Nobel laureates and Padma awardees, have said India-based Neutrino Observatory (INO) proposed to come up in Theni district in south Tamil Nadu is absolutely safe and would not affect either the environment or the water table.

The appeal comes in the wake of protests by local residents, activists and political parties after the Union ministry of environment and forests gave its nod for the project recently. Incidentally, MDMK chief Vaiko is on a padayatra against setting up of the lab in Theni.

The appeal drafted by Chennai-based Institute of Mathematical Sciences (IMSc) professors emeriti G Baskaran and T R Govindarajan said the observatory was initiated two decades ago by Indian high energy physics groups. “The motivation was purely academic and not commercial. It is part of Indian scientific community’s sincere ongoing attempt at a deeper understanding of nature,” said the draft.

According to the scientists, the lab will have a telescope, built under a hill, to detect billions of neutrinos that are passing through us continuously without any effect. “It is similar to the optical telescopes we have at Kodaikanal and Kavalur as well as the radio telescope in Ooty. It will bring fame to India through scientific contributions,” they said.

But not all agree …

g sekar
G – 981 days ago

OK scientists, keep the scientific issues with you, what the people of TN will get out of it, what about the employment potential, will the scientific community assure guaranteed 100% reservation for TN natives at least in staff level jobs and a min.50% reservation for TN natives in officer and scientific jobs. are you going to put the project here and give employment opportunities to people from other states.why should we TN people take the risk .

REPLY SHOW RESPONSES 3 4 FLAG

marvan
marvan – Pavvam – 981 days ago

INO at bodi is aimed at destabilizing Mullai Periyar dam. This crooked design is crystal clear. INO just get out of TN.

REPLY SHOW RESPONSES 1 1 FLAG

marvan
marvan – Pavvam – 981 days ago

Why dump this project in TN. We simply don"t want this project, we don"t have sufficient water. Period.

REPLY SHOW RESPONSES 1 0 FLAG

Sivaraman Ramakrishnan
Sivaraman Ramakrishnan – 981 days ago

In whose payroll do they exist

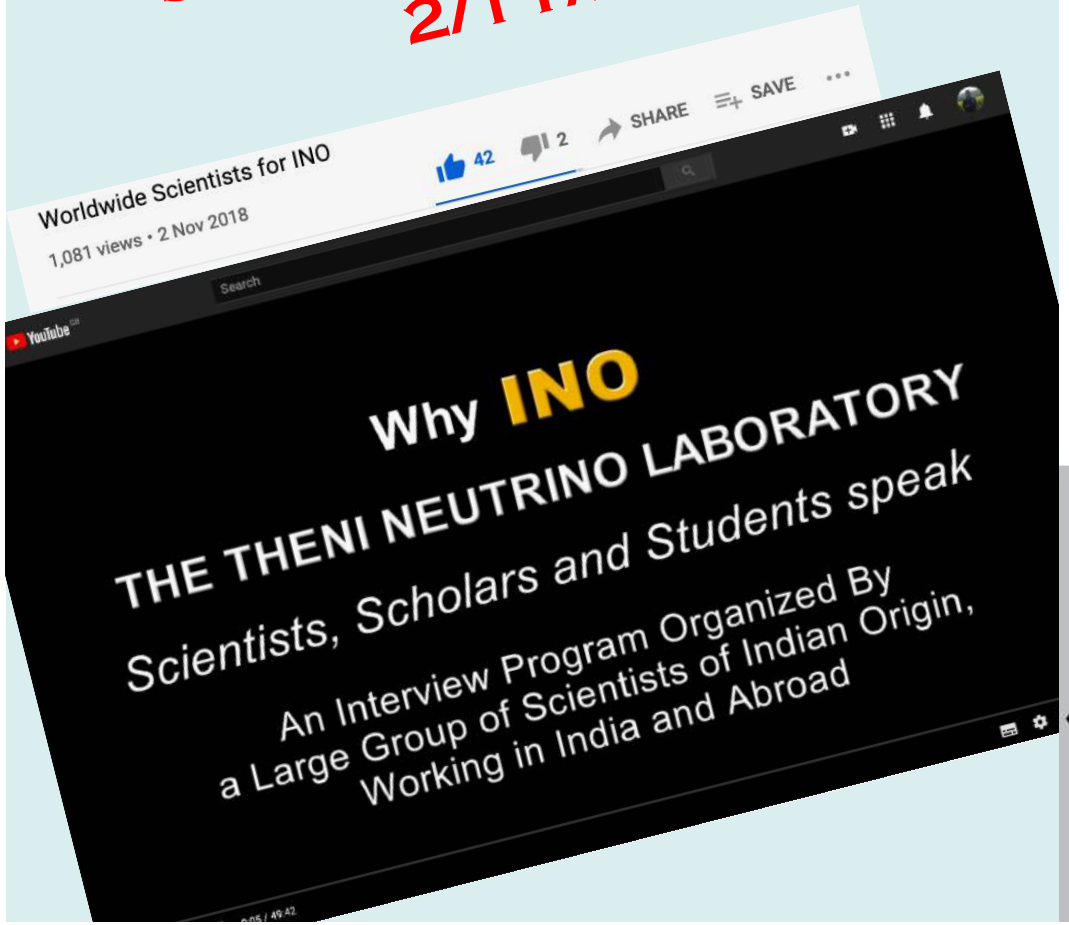
REPLY 1 1 FLAG

uma sankar
uma sankar – Madurai – 961 days ago

This is one of the safest projects. I do not how politicians were able to easily manipulate people for their own gains. People please awake. Dont miss this project and deny the good opportunity for our future students.

REPLY 0 0 FLAG

Even though INO is Backed by National and International Scientific community 2/11/2018



THE TIMES OF INDIA

4 November 2018

Nobel laureates back INO, dispel myths on social media

"Neutrinos pass through everything (including humans). No doubt, these detectors will not cause harm
Takaaki Kajita | NOBEL LAUREATE

"Mega projects like INO will benefit the local community. INO could bring the same benefits as CERN did to Geneva
Rohini Godbole | THEORETICAL PHYSICIST

"Explosions during construction will last less than a second. Under the hill, vibrations won't be felt even at the tunnel entrance
Balachandran | ...OLOGIST

U.Tejonmayam@timesgroup.com

TESTING TIMES: A file photo of INO project director Vivek M Datar with the prototype of the neutrino detector; (below) the project site in Theni district

Hours after the National Green Tribunal said the India-based Neutrino Observatory (INO) in Theni would not take off without approval from the National Board for Wildlife, scientists including two Nobel Laureates took to social media to dispel myths and fears about the project.

In a video posted on YouTube on Friday, Nobel Laureates said INO will help solve unanswered questions about the evolution of the universe. The detector to be housed under the Bodhi West Hills in Theni will be similar to the one built in one of the world's most protected regions in Antarctica, indicating its safety, they said.

Professors Takaaki Kajita and Arthur McDonald, who won the Nobel Prize for proving that neutrinos have mass, were part of the video, along with five other scientists and a geologist. "The INO is a telescope similar to the instrument used to study stars. The detector is placed underground, as it is a favourable location to observe the otherwise difficult to detect neutrinos. We would like to know through INO, the ordering of the neutrino mass. This is something the Indian scientific community can contribute to the world," said McDonald.

Professor Francis Halzen, principal investigator, IceCube Neutrino in Antarctica, emphasized it was because neutrinos are harmless that they are being researched in the South Pole where the sensors are placed under thick sheets of ice.

The hour-long video addressed various concerns about the project including its safety, environmental impact, benefits to the local people, industries and the scientific community. Allaying fears, Kajita said, "There is no doubt these detectors will not cause any hazard." He said that since neutrinos can pass through detectors without being traced, a large instrument, like the Super-Kamiokande built 1km under Mount Ikeno, Japan, is required.

On the impact of explosives to be used to construct the tunnel for the observatory, V Balachandran, a retired deputy director general of Geological Survey of India, said vibrations of each blast, which may last less than a second, will be felt up to a maximum of 500m. "It will not have any impact on the Mullaiperiyar or Idukki dam, which already have tunnels beneath them for power projects. Since this observatory will be underground, people can continue to use the land above," he explained.

Highlighting that neutrino research is not new to India, Ramanath Cowsik, astrophysicist at Washington University, said this kind of research was initiated in the 1950s in the Kolar Gold Fields. "It'll create numerous jobs in engineering, electronics and computer science and Theni will attract national and international attention," he said.

"With INO, we hope the Indian science community will be able to provide a basic understanding of the properties of neutrinos
Arthur McDonald | NOBEL LAUREATE

INO Nus Letter

May 2019

Option 1: Optimistically, we hope that the Supreme Court will decide in favour of MoEF (in the appeal against the decision of NGT filed by an activist group which is pursuing legal opposition to stop INO at Theni). This will ensure that the environmental clearance already given will be valid. Then what?

Again, optimistically, we hope that the TN state forwards a favourable opinion to the Wildlife Board and we get **clearance from National Board of Wildlife Board** too. Furthermore, based on the above clearance and another pending for civil construction at the site, the **TNPCB will grant permission to establish the INO project** at Theni. This will result in **vacating the pending case** at the High Court Bench in Madurai filed by the politician Mr. Vaiko (V. Gopalaswamy).

Thus there are many things that should fall in place in a short time even after the extension mentioned above is sought and given. It is not impossible if the TN state government, after elections, firmly stands behind the INO project.

https://www.newindianexpress.com/states/tamil-nadu/2020/oct/24/india-will-lose-edge-over-rivals-if-neutrino-project-in-tn-delayed-by-another-year-scientists-2214646.html

India will lose edge over rivals if neutrino project in TN delayed by another year: Scientists

24 October 2020

"After a year, other competitors will be ahead of us and there is no second prize for discovery in science," said Sandip Trivedi, noted theoretical physicist and former director of TIFR

The India-based Neutrino Observatory (INO), an underground laboratory proposed in the Bodi Hills of Theni district in Tamil Nadu, has been a non-starter for years. If there is a delay of another year, scientists say the country would lose its edge over competitors.

China has begun construction of an Underground Neutrino Observatory (JUNO) near the city of Jiangmen in Guangdong province. The construction is likely to be completed by 2022. Similarly, other neutrino experiments, such as Hyper-Kamiokande (Hyper-K) in Japan and the Deep Underground Neutrino Experiment (DUNE) in the USA, are also under construction. Although the INO project had similar timelines, it got stuck due to difficulties in getting approvals both at the central and state level.

Trivedi said India still has an edge over others. "The detector technology which TIFR and related institutes built is unique in the world. It's a great experiment. We have a unique way to do the experiment with proven ideas that no one in the world can match." He also rued the fact that scientists failed to convince the public and explain effectively the importance of the project. "It's a shocking failure."

Issues for discussion

- What went wrong?
- What can be done now?
- What lessons can be drawn for the future?
- Is public outreach the sole responsibility of the experts?
  What role should a (free and critical) media play?
- The role of basic education to ensure *participatory* democracy
  (especially when dealing with complex scientific questions)

How will this affect India's status on the international stage?