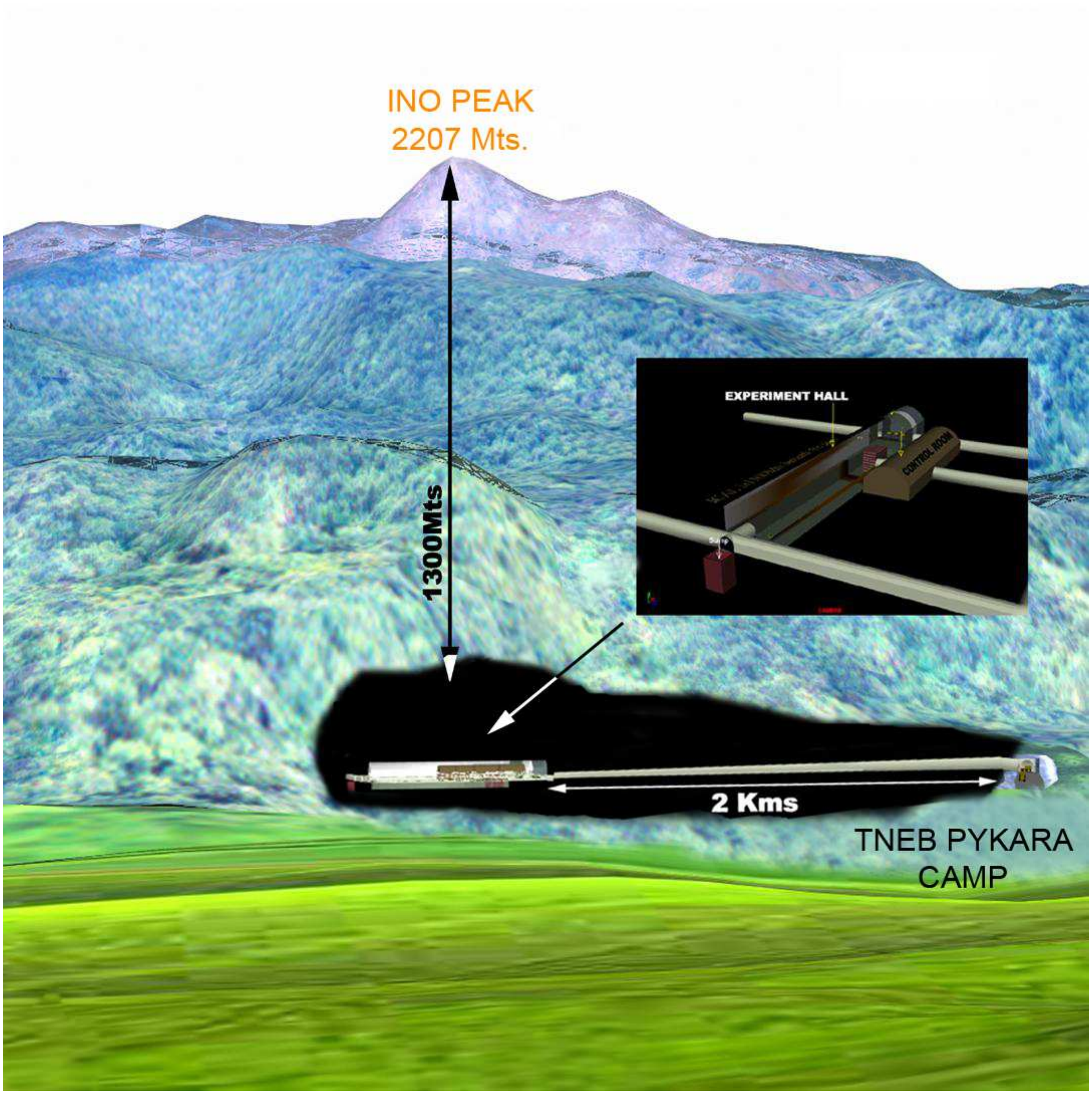
July, 2008

# India-based Neutrino Observatory

# FAQ on INO



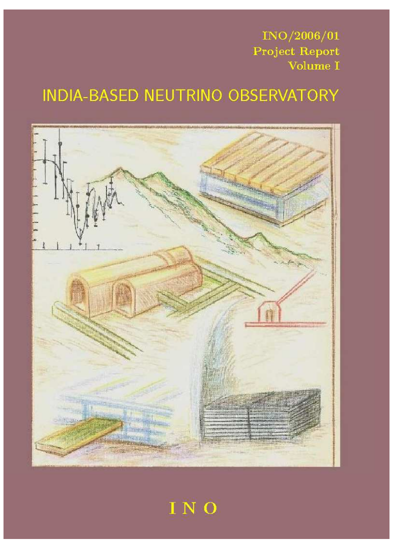
# Frequently Asked Questions on INO

*The India-based Neutrino Observatory (INO) is an effort aimed at building a world-class underground laboratory to study fundamental issues in physics. The primary goal of the laboratory is the study of neutrinos from various natural and laboratory sources. It is envisaged that such an underground facility will develop into a centre for other studies as well, in physics, biology, geology, etc., all of which will make use of the special conditions that exist deep underground. Apart from the scientific goals of INO, the laboratory itself will greatly enhance the development of detector technology and its varied applications.*

## 1 About INO

Several questions have been raised about the nature and goals of INO. Below we list responses to these questions.

- **What is INO?**




The India-based Neutrino Observatory (INO) is a proposed pure-Science underground laboratory. Its primary goal is to study the properties and interactions of weakly interacting, naturally occurring particles called *neutrinos*. The objectives of the study are appended in simple layman's language at the end of this FAQ. There is world-wide interest in this field due to its implications for several diverse and allied fields such as particle physics, cosmology and the origin of the Universe, energy production mechanisms in the Sun and other stars, etc.

Several groups belonging to different Universities and research Institutes in India are part of the collaboration working on the details of INO. The current proposal focusses on neutrino detection with static detectors, to be placed deep underground at a site close to Masinagudi in the Nilgiri mountains of South India. A short account of the physics goals and implications is appended at the end of this FAQ.

- **Where can one find detailed information about INO?**

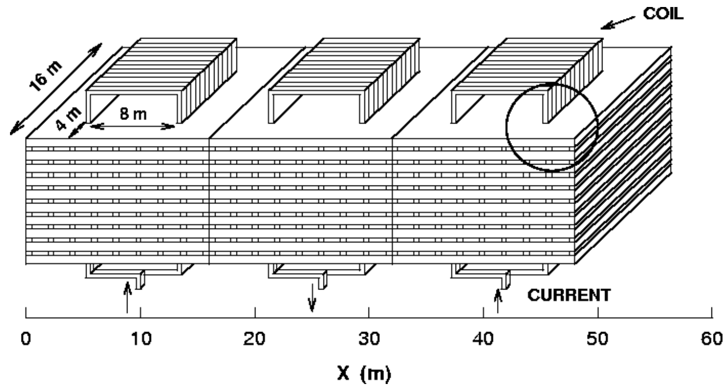
  Many articles, talks and reports about INO are available from the website:

  **URL: http://www.imsc.res.in/∼ino**

  The website provides the current status and is continuously updated. It also contains information for students and non-technical material accessible to the general public.

- **What will be the detector that will be housed at INO?**

  The detector initially housed in the INO underground laboratory will be a magnetised iron calorimeter detector (ICAL). It is a static device without moving parts. Just as a telescope observes the sky through visible light, the ICAL will observe the sky through neutrinos.

  Neutrinos will interact with the iron material of the detector to produce charged particles. The iron layers will be sandwiched with the active detector material that will detect whenever a charged particle passes through it. The ICAL detector will consist of three modules of 16 kton each.

- **What is the status of the proposal?**

  The INO proposal is now under discussion and review at various levels and will be considered for funding during XI five year plan of Government of India. The Government of Tamil Nadu has given an in-principle approval to locate the project at Singara near Masinagudi pending statutory clearances. The project has been given environmental clearance by Ministry of Environment and Forests, Government of India. The process of obtaining other statutory clearances is in progress.

- **What is the time frame for the project from time zero?**

  The first year of the project will be devoted to exploration, finalisation of designs, identifying the contractors, etc. The next two years will involve excavation of the tunnel and laboratory cavern. During the last two years installation of the laboratory equipment and detector construction will begin. The present road map envisages that the first module of the detector, 16 ktons, will start taking data at the end of five years. Immediately after that the subsequent modules will be constructed.

- **What about radioactivity?**

  None of the processes or instruments used underground will generate any radioactivity: the main reason for the underground laboratory is to create an environment free of the radiation that abounds on the Earth's surface. This radiation is due to cosmic rays and to natural radiation of the materials around us. In fact, by going underground, most of the radiation due to cosmic sources is cut down and only natural radioactivity (that always exists in trace amounts in the surrounding rock and laboratory materials) will be remaining. This is low-energy radiation and will not affect the neutrino measurements of interest to ICAL.

- **Will there be hazardous chemicals and gases?**

  No. The main detector contains active detector elements called RPCs which need a mixture of gases circulating. The mixture used in the experiment consists of mainly argon and R134A with small amounts of isobutane. These are used routinely in many laboratory environments around the world and the mixture that will be used will conform to international standards of safety. The project has been cleared by Ministry of Environment and Forests (Expert Committee for big projects), Government of India, with respect to environmental aspects.

# 2 Information about the INO site and other concerns

- **Project location and reasons behind the choice**

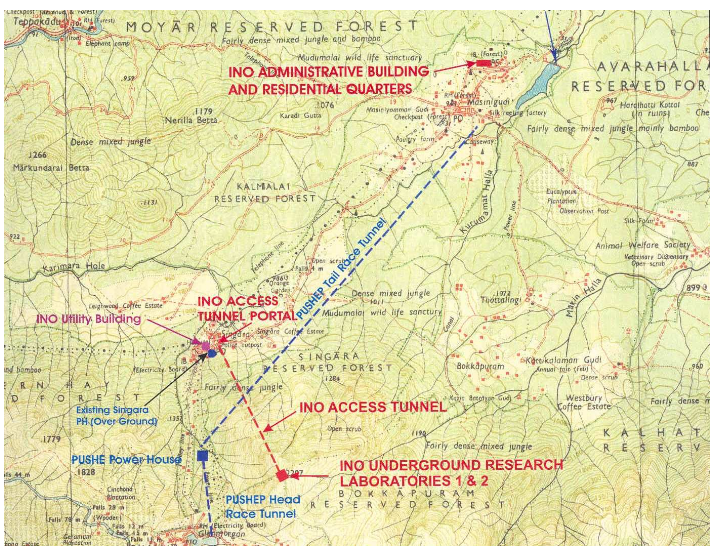
  The proposed project site, at Singara township near Masinagudi in the Nilgiris district of Tamil Nadu, was chosen after detailed survey of several sites in Western Ghats and Himalayas. It comes under the **Manipulation zone of the Nilgiri Biosphere Reserve** and is not located inside the core zone. Expert advice was obtained from geologists and engineers who have studied the area in detail. The main reasons for locating the laboratory at Singara are safety, accessibility, minimal disturbance (during construction stage) to environment. The access tunnel portal will be very close to that of the existing portal of Tamil Nadu Electricity Board's (TNEB) PUSHEP project.

  1. The Nilgiri massif is known to be highly compacted granite which is suitable for tunnelling and locating deep underground caverns. Hence the INO site selection committee preferred this to any location in Himalayas.
  2. The existing underground power station at Singara has provided a wealth of data about the existing conditions for tunnelling. At 1300 meters below the peak, the laboratory cavern will be the deepest in India. Advance information about the rock condition is crucial for stability and safety at such depths. When a laboratory is expected to run for decades underground, the safety and long-term stability of the location is a primary requirement.
  3. The steep northern slopes of Nilgiris provide shortest access, through a horizontal tunnel of length 2100 metres, to the laboratory. In addition, Singara is on the leeward side of the mountain and hence a low rainfall area. This is an important consideration for the experiment which requires low humidity, low moisture conditions.
  4. The project is located in TNEB land which provides all the necessary facilities like land, road access, power and water. The project is surrounded by Coffee estates well away from reserve forest. The tunnel portal (entrance) begins just next to the existing road. Therefore no forest will be cleared. The tunnel starts on the TNEB land, will run underground under a private coffee estate for about 500ms, and will be more than 200ms underground before it reaches the forest boundary.
  5. The site at Singara is easily accessible from major cities like Coimbatore, Mysore and Bangalore. Such factors are important to develop a laboratory with participation from scientists from many parts of India and even abroad.
  6. Other sites surveyed, such as the Rammam Hydel Project in Himalayas and Nellithurai near Mettupalayam, do not match the criteria as well as the one at Singara. Coupled with lack of data for creating such a deep underground cavern is also the fact that the tunnel length is more than 3500 metres. Increase in tunnel length increases the construction time, which is the duration during which maximum disturbance is expected. Lack of access would mean clearing forest land for making roads, putting power lines and water mains in most other sites in western ghats.

7. Many other international laboratories like Kamioka in Japan, Gran Sasso in Italy, Homestake in USA, are also located in wilderness areas. In particular the LNGS underground laboratory in Italy is located in the Gran Sasso National Park.
8. It should be noted that the construction of the hydro electric project which caused disturbance during the construction phase, did not destroy the flora and fauna. INO is a much smaller project compared to the power project in the vicinity.

- **Where is the tunnel portal located?**

The present location of the INO portal is within the TNEB campus in Singara. It is straddled on one side by a coffee estate and the Masinagudi-Singara road on the other side and is at least 500 meters from the nearest forest boundary—namely the Singara Reserve Forest. The portal is well within the Singara township.




The surface facilities at the portal are minimal and include bare necessities like ventilation, cooling and power systems. The laboratory will be serviced along the single access tunnel for all its requirements. The air-blowers situated at the entrance provide fresh air through the tunnel with its outflow being at the portal itself. The present design does not include shafts or vents at any point along the tunnel.

The only opening to the surface is the portal itself which is well within Singara township.

- **Will the project destroy the elephant movement corridors?**

No, since the movement of vehicles on the Singara-Masinagudi road will be greatly restricted and carefully monitored.

There is one critical elephant movement corridor in the vicinity—the Singara-Mavanahalla corridor which cuts through the seven km road between Masinagudi and Singara. The Moyar-Avarahalla corridor segment is located to the north of Masinagudi and is not relevant to the project since the activities of the project are likely to be localised in Singara itself.

The corridor crosses the road about 2 km away from the project site. There will be negligible disturbance during the operation phase. The main disturbance will be during the construction phase when construction material and iron and other materials required for the detector will be brought to the site in trucks. At the end of the construction phase (3-4 years), about 17 ktons of detector material will be moved in a regulated manner over a period of one year. In the next phase (XII Plan) the rest of the detector will be completed. The Environmental Management Plan (EMP) recommends cessation of heavy vehicular movement along the road during the four month period from November–February. During other months, heavy vehicular movement may be restricted to day light hours along the corridor. Furthermore, the number of trips by heavy vehicles may be restricted to about six round trips per day based on the existing traffic pattern along the road. The vehicular movement will be monitored by employing trackers. According to the survey done between October 2007 and January 2008, the traffic density on this road was about 6 vehicles/hour out of which at least one was a heavy vehicle (truck).

- **Will there be any new road construction?**

  No, there will be no new road construction. The existing road from Masinagudi to PUSHEP will connect to INO portal.

- **Will there be any clearing of the Forest?**

  No. As noted before, the portal and its immediate surface facility are the only entities visible on the surface. The tunnel and laboratory will be entirely underground. The location of the portal is next to the road in a clearing surrounded by the coffee estate and village. Therefore no forest land is occupied or cleared.

- **How much rock will be excavated?**

  The total volume of rock to be excavated (all tunnels, laboratories, parking etc) is estimated to be around 2,25,000 cubic meters. Most of this rock debris will be stored in the yard about 200-300ms just across from the portal. Part of this will be used as gravel for the construction of the tunnel road, lining of tunnels and caverns, etc. The rest, about 50%, will be cleared in a systematic manner over a long period of time, so that not more than 6 round trips are made during day-light hours, per day. Caravanning the trucks is an option to further minimise any disturbance. Other ideas to use the debris, including as replacement for construction-sand, in order to further decrease the vehicular movement, are being actively explored. The truck traffic will be regulated using modern, quieter, low-emission trucks.

- **Where will the muck be stored?**

The construction phase requires the removal of the rock excavated from the tunnel and laboratory. The recommended plan is to store the muck (mainly granite) in the existing dumping yard created for the power project which is located near the portal. Hence truck movement is restricted to a small region within the TNEB-owned land.

The existing dumping yard is much bigger than needed for the project since it was created to cater to the power project which is much bigger than the proposed INO project.

The debris from tunnelling does not contain any hazardous waste as confirmed by leachate study conducted by the Environmental Laboratory at Anna University. The excavated material will be stored surrounded on all sides by retaining walls so that there is no seepage of dust and so no contamination of any nearby water bodies.

- **What about vehicular movement and disturbance?**

  During the first 4-5 years, construction material as well as iron for the first module of the detector will be brought in. Subsequently, the remaining two detector modules will be installed. Also, the granite debris that is excavated needs to be taken out; this will take place over a longer period of time. Since the vehicular movement places stress on the Singara-Masinagudi corridor, the heavy traffic on this route will be restricted to not more than 6 round trips during day-light hours per day. More details are in the section about elephant movement corridors.

  When the laboratory is operating it is expected that on the average about 20 personnel will be working inside the laboratory in shifts. As such disturbance due to vehicular movement during this period will be miniscule compared to already-existing traffic on the Masinagudi-Singara road (about 6 vehicles/hour). Furthermore, **if the residential, administrative and work shop facilities are located in Singara itself**, as proposed in the Environmental Management Plan, the addition to the existing traffic is expected to be minimal. The vehicular disturbance can be further minimised by using electric vehicles.

  The major centre of scientific activity, apart from data taking at the underground laboratory itself, will be located at the University of Mysore campus. A decision to reduce or eliminate activities at Masinagudi has been taken and an MOU with the University of Mysore to locate the INO Centre has been put in place.

- **What about the disturbances during construction?**

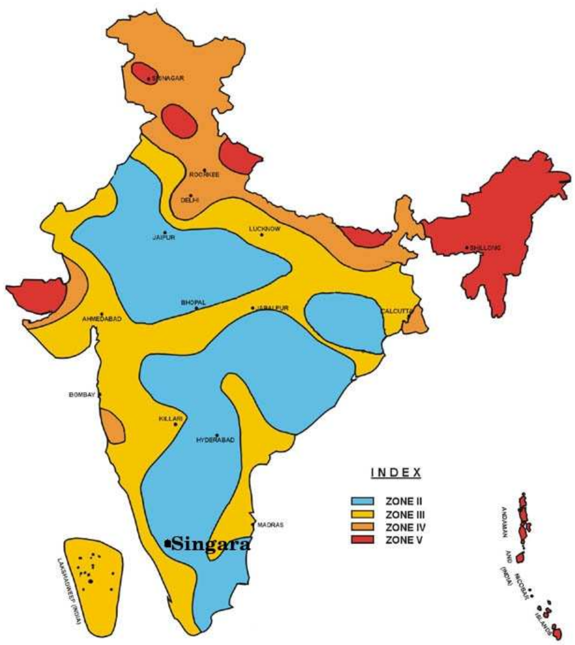
  Muck handling and material movement on the Singara-Masinagudi road have been identified as the major environmental disturbances that need to be carefully managed, as detailed above. In addition, the main source of disturbance, in terms of noise, will be during the initial stages of tunnel boring up to about 200 meters. This will be completed within 2 months using cut and cover technique and no blasting after which noise pollution should subside almost completely. Advanced tunnelling methods may be used to further reduce the noise levels at the initial stages.

During construction the workers will be brought to the construction site. There will be vehicles in the "staging area," which includes a small surface area as well as the area underground. This disturbance will be temporary and will cease after construction ends.

To minimise vehicular pollution and oil spills, only modern and efficient vehicles are proposed to be used. The disturbance during the construction stage will be carefully monitored as laid out in the Environmental Management Plan.

- **What happens when there is an earthquake or rock burst?**

  A tunnel failure or collapse is almost unimaginable especially in the rocks found in the Singara area. This is one of the main reasons to locate the laboratory in the present location. During construction weak structures will be identified and secured using many available reinforcing technologies like rock bolting, shotcreting, etc. The portal, especially, has to be designed to withstand rock falls from outside. The present location indeed is one such where there is unlikely to be rock fall.




  The proposed project location is in seismic zone 2 (unlike the Himalayan sites which are in either zone 4 or zone 5) which is the minimum risk zone in the country according to the zoning map (revised in 2002). Furthermore the deep underground places are often one of the safest locations when an earthquake happens. The occupied areas underground will have a refuge area in the unlikely scenario of an earthquake.

- **How many people are to be located at the site? Will it add to the population pressure at Masinagudi?**

  During the construction phase there will be a work force numbering about 100 or so. During the heavy construction phase the personnel needed includes drilling crews, truck drivers and concrete workers. There will also be design, architectural, and engineering crews along with geologists. The finishing work will require electricians, ventilation engineers, and environmental engineers. The skilled work force is not expected to remain in the project after the construction period. The unskilled labour force is available locally and need not be brought from outside.

  As described in our proposal, the project involves about 100 scientists drawn from several laboratories. Only a small fraction of these, about 20, will spend a substantial part of their time at the underground laboratory. The staff are likely to be housed at the residential quarters in the TNEB housing colony. The main detector R& D will be done at different laboratories in India, including at the University of Mysore, and such people will not be located permanently in Singara.

- **Will INO use up large quantities of water creating a water shortage?**

  No. The requirement (mainly for the staff and for operating the cooling systems) is about 320 kld for running the underground laboratory and about 22 kld for the Guest house, laboratory and administrative set up. This is a small percentage, about 0.0027 percent, of the water available at the Singara diversion weir.

- **What are the benefits to local people from this project?**

  INO is not a commercial activity, it is a basic sciences research project. It cannot employ people on a large scale. However, we do see gainful employment opportunities during construction and operational stage though it is difficult at present to estimate the number.

  1. It is proposed that during the construction stage, unskilled labour force will be employed from the pool available in Singara and Masinagudi.
  2. Local trackers will be employed to provide appropriate warnings about the animal movements in order to monitor vehicular traffic.
  3. During the operating stage, the local people can be employed in maintenance of the INO facilities like the laboratory, Administrative Office, housing and guest house. Drivers for INO vehicles can also be employed from the pool available in Masinagudi.
  4. Training of local students is proposed to provide technical skills required for the project and providing further employment opportunities.
  5. Adopting the local schools in the Panchayat to improve the buildings and laboratories is proposed as part of the INO outreach program.

- **How can INO contribute to preserving the Environment?**

  We plan to develop INO as a model institution combining its scientific goals with preservation of the environment and ecology. INO will implement the findings and recommendations of the EIA (SACCON) and EMP (Care-Earth) to manage the environmental impacts. Tie up with the National Centre for Biological Sciences (NCBS, Bangalore) and the Indian Institute of Science (Bangalore) are possibilities that are being discussed.

# 3 A Neutrino glossary

## 3.1 What are they?

Neutrinos are tiny, neutral, elementary particles which interact with matter via the weak force. The weakness of this force gives neutrinos the property that matter is almost transparent to them. The Sun, and all other stars, produce neutrinos copiously due to nuclear fusion and decay processes within their core. Since they rarely interact, these neutrinos pass through the Sun, and even the Earth, unhindered. There are many other natural sources of neutrinos including exploding stars (supernovae), relic neutrinos (from the birth of the universe), natural radioactivity, and cosmic ray interactions in the atmosphere of the Earth. For example, the Sun produces over two hundred trillion trillion trillion neutrinos every second, and a supernova can release 1000 times more neutrinos than our Sun will produce in its 10-billion year lifetime. Billions of neutrinos stream through our body every second, yet only one or two of the higher energy neutrinos will scatter from you in your lifetime. It is no wonder that they are called "ghostly particles".

The neutrino was proposed by Wolfgang Pauli in 1930; but it took another 26 years for it to be actually detected. In 1956 Reines and Cowan found evidence of neutrino interactions by monitoring a volume of cadmium chloride with scintillating liquid near to a nuclear reactor. Reines was jointly award the Nobel Prize in physics in 1995 in part for this revolutionary work. We now know that not just one but at least three types or flavours of neutrinos and their anti-particles exist in nature. They have a tiny mass whose value is still not known. Moreover, they exhibit a quantum-mechanical phenomenon in which one type of neutrino *oscillates* into another as it propagates in space. This is called neutrino oscillation and this observation has generated immense excitement in the particle physics community.

## 3.2 Why detect them ?

From recent experiments we know that the mass of the neutrino is non vanishing, but we are unsure how large the masses of the three individual neutrino types are relative to each other because of the difficulty in detecting neutrinos. This is important because neutrinos are by far the most numerous of all the particles in the universe (other than photons of light) and so even a tiny mass for the neutrinos can enable them to have an effect on the evolution of the Universe through their gravitational effects. There are other recent astrophysical measurements that provide information on the evolution of the Universe and it is crucial to seek complementary information by direct determinations of the masses of neutrinos and their other properties. In a sense, neutrinos hold the key to several important and fundamental questions on the origin of the Universe and the energy production in stars. We have some partial answers but many details are still awaited from future experiments.

## 3.3 Why should the laboratory be situated underground?

Neutrinos, as mentioned before, are notoriously difficult to detect in a laboratory because of their extremely weak interaction with matter. The background from cosmic rays (which interact much more readily than neutrinos) and natural radioactivity will make it almost impossible to detect them on the surface of the Earth. This is the reason neutrino observatories are located deep inside the Earth's surface. The overburden provided by the Earth matter is transparent to neutrinos whereas most background from cosmic rays is substantially reduced due to their absorption by the Earth; the extent of reduction depends on the depth at which the detector is located.

One of the earliest laboratories created to detect neutrinos underground in the world was located more than 2000 m deep at the Kolar Gold Field (KGF) mines in India. The first atmospheric neutrinos were detected at this laboratory in 1965. This laboratory has been closed due to the closure of the mines. Most underground laboratories around the world are located at a depth of a km or more. There are two types of underground laboratories: either located in a mine or in a road tunnel.

There are now four major laboratories around the world: in Sudbury in Canada, in the Soudan mines in the USA, Kamioka in Japan, and under the Gran Sasso mountains in Italy. The first two are located in mines and house relatively much smaller detectors than the other labs that are accessed by a road tunnel. Several others are planned including INO which is an attempt to recapture the pioneering studies on neutrinos at KGF. The proposed INO is however on a much larger scale (3 modules of 16 kton each as opposed to the 0.34 kton detector that was housed at KGF).

# 4 A vision for INO and the challenge

*INO has been conceived on a scale that no other basic sciences project in India has attempted. The MoU signed by seven institutions, that brought the Neutrino Collaboration Group into existence, is already the first of its kind. It is a testimony to the enthusiasm and collaborative spirit shown by the scientific community in India.* The nuclear and particle physics community in India has listed INO as one of the primary projects in the XIth five year plan.

In the first phase of its operation a magnetised iron calorimeter detector, weighing about 48 ktons, will be used for studying neutrinos produced from cosmic rays in Earth's atmosphere. The aim is to make precision measurements of the parameters related to neutrino oscillations. An exciting possibility is to determine the ordering of the neutrino masses which is not known at present. This is one of the fundamental open questions in neutrino physics and no other detector either existing or planned except perhaps NO$\nu$A may be able to provide an answer in the next 10 years. Because of its ability to distinguish the positively and negatively charged muons, this detector can settle this question.

This detector can also be used as the far-detector of a long-base-line (6000 to 11500 km) neutrino experiment using the neutrino beam from a neutrino factory in Japan, Europe or USA. These are neutrinos that will be produced in a future accelerator facility which are beamed towards the detectors situated in a different part of the Earth. This is envisaged as the second phase of the INO activity, and is a long-term goal (to be implemented after 10-15 years), since neutrino factories are yet to become a reality. However, there is considerable interest in this possibility not only for the rich physics potential but also because the proposed detector at INO will be capable of charge identification, which is crucial for this mode of operation.

INO will have a great impact on the emerging high energy physics scenario in the country. People trained at INO will not only participate here but also have the expertise to contribute to other high energy and nuclear physics projects around the world. Over the long term INO is expected to develop into a world class underground science laboratory straddling many fields like physics, biology, geology and allied engineering fields.

*Members of INO are acutely aware that the laboratory is being located in an environmentally and ecologically sensitive environment. During its normal operation phase, the laboratory is not expected to cause any damage to the environment. All efforts will be made to minimise the disturbance during the construction phase.*

Being part of such a sensitive biosphere reserve will also bestow responsibilities on INO collaboration not only to maintain and but also to improve the conditions where possible. It is the intention of INO members to be active participants in the effort to preserve the Nilgiri Biosphere reserve by active cooperation with existing efforts in the region.

**Contact Information:** For more information, please refer to the web-site address listed in the beginning, or contact

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