What are neutrinos and how are they detected?

Here we discuss how are neutrinos produced, why does INO need a mountain and so on.

Proton, neutron, and electron are tiny particles that make up atoms. The neutrino is also a tiny elementary particle, but it is not part of the atom. Such particles are also found to exist in nature. Neutrino has a very tiny mass, no charge and spin half. It interacts very weakly with other matter particles. So weakly that every second trillions of neutrinos fall on us and pass through our bodies unnoticed.

Neutrinos come from the sun (solar neutrinos) and other stars, cosmic rays that come from beyond the solar system, and from the Big Bang from which our Universe originated. They can also be produced in the lab.

Neutrinos come in three types or “flavours” – electron neutrino, tau neutrino and muon neutrino.

They can change from one flavor to another as they travel. This process is called neutrino oscillation and is an unusual quantum phenomenon.

Neutrino oscillation was established by Sudbury Neutrino Observatory, Canada, and Super-Kamiokande experiment in Japan. They studied Solar neutrinos, atmospheric neutrinos and man-made neutrinos.

The India-based Neutrino Observatory (INO) will study atmospheric neutrinos only. Solar neutrinos have much lower energy than the detector can detect.

Neutrino project: no clearance from villagers

Atmospheric neutrinos are produced from cosmic rays which consist of protons and heavy nuclei. These collide with atmospheric molecules such as Nitrogen to give off pions and muons which further decay to produce neutrinos.

The mountain consists of 1km of solid rock that filters away most of the charged particles from the cosmic rays. The filtered set consist of a part of the incident cosmic ray protons and pions and practically all the neutrinos.

If the detector was placed at the surface of the mountain, it would pick up billions of cosmic ray muons every hour and about 10 neutrino events per day. After placing inside the rock, it would detect only 300 muon events per hour and about 10 neutrino events per day of which 3 will be the desired muon neutrino events.

The ICAl consists of 150 layers of alternating iron slabs and glass detectors called Resistive plate chambers.

The muon neutrino interacts with the iron to produce a muon which is electrically charged. This charge is picked up by sensors in the glass RPCs which set off an electrical pulse, to be measured by the electronics. By piecing together the pulses set off in successive glass plates, the path followed by the muon is tracked. This is used to infer the properties of the neutrino which caused the pulses.

Dimensions

Dimensions of the cavern – The cavern will be 130 m length X 26 m wide X 35 m height. Tunnel will be 7.5 m X 7.5 m cross section. This will be like a 2-inch hole made in a 10 foot wall.

Estimated time to construct the experiment

The detector has three modules. It is estimated to build one module per year, after completing the civil construction which can take up to 3-4 years.

100 years ago, when the electron was discovered, it had no foreseeable uses. Today, a world without electronics cannot be imagined.

Hence basic sciences research is needed to understand the properties of particles before they can be applied.

Properties of the sun

The visible light that reaches us from the sun is emitted from the surface of the sun. The neutrinos which also take close to this time to reach us from the sun, known as solar neutrinos, were produced in the core of the sun. Therefore they give us information about the interior of the sun. Studying these neutrinos can help us understand what goes on in the interior of the sun.

What makes up the universe?

Light coming from distant stars can be studied by astronomers, for example, to detect new planets. Light is the visible part of the electromagnetic spectrum, other parts are used in for example radio astronomy. Likewise, if the properties of neutrinos are understood better, they can be used in astronomy to discover what the universe is made up of.

Probing Early Universe

Neutrinos interact very little with the matter around them, so they travel long distances uninterrupted. Since they take time to cross these distances, they are in effect uninterrupted for very long times. The extragalactic neutrinos we observe may be coming from the distant past. These inviolate messengers can give us a clue about the origin of the universe and the early stages of the infant universe, soon after the Big Bang.

Medical Imaging

Apart from direct future uses of neutrinos, there are technological applications of the detectors that will be used to study them. For instance, X-ray machines, PET scans, MRI scans, etc., all came out of research into particle detectors. Hence the INO detectors may have applications in medical imaging.

Typical fear no. 1:

Radiaoactivity: “Radioactive leak shuts down neutrino study, Scientific American, June 5 2014. This led people to suppose (a) neutrinos can give radiation leaks; (b) Radioactive waste is buried near neutrino facilities.

Fact: The radiation leak was not from the neutrino detector EXO-200, but from a radioactive leak from an underground nuclear waste repository. Currently the experiment is back to operation. Radiation of that kind will drown out and destroy the weak neutrino signal. This only goes to show that underground nuclear waste repository cannot be build anywhere near a neutrino observatory.

Typical fear no. 2:

Natural or manmade: Natural neutrinos are harmless, everyone knows millions of neutrinos pass through us every moment. But artificially produced “collimated” beams of neutrinos generate radiation and can cause diseases.

Fact: Collimated simply means the beams of neutrinos travel in parallel lines. And all that is called radiation, in scientific usage, is not harmful. Even visible light is a form of radiation.

Typical fear no. 3:

Cerenkov Radiation: Some neutrino experiments detect them using the Cerenkov radiation they emit when passing through ice, water or even air. Cerenkov radiation is given off only by radioactive substances.

Fact: Cerenkov radiation, is not ‘radiation’ from nuclear power plants or X ray machines. It is just a tiny spark of electromagnetic radiation, given off by high energy charged particles such as electrons when they pass through water or other liquid. These have nothing to do with radioactive substances. Neutrinos cannot give Cerenkov radiation since they are not charged.

Typical fear no. 4:

Magnet failure: The INO experiment houses the world’s largest magnet which will attract neutrinos. During a power failure, the neutrinos will be emitted out and can cause diseases.

Fact: INO will have the world's largest electromagnet, that is, when the power is switched off, it is no longer a magnet. In addition, unlike most other magnets, the magnetic field is confined inside the magnet. There is hardly any magnetic field OUTSIDE the magnet. You can walk about with a metal watch or any other metal piece just outside and there will be no danger. This is in contrast to magnets in MRIs and such machines which may have permanent magnets inside. Further neutrinos are neutral particles which cannot be attracted by the magnets.

END