China's JUNO Experiment to Study Neutrinos

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Why in News?

After years of construction, **China's Jiangmen Underground Neutrino Observatory (JUNO)** is set to begin data collection on **neutrinos**. This cutting-edge particle physics experiment aims to greatly enhance our understanding of the subatomic particles.

What are the Features of JUNO?

- JUNO will observe solar neutrinos for a real-time view of solar processes and study neutrinos from uranium and thorium decay within Earth to gain insights into mantle convection and **tectonic plate movement.**
- Set to **become operational in late 2025**, JUNO will **start ahead of the US Deep Underground Neutrino Experiment (DUNE)**, scheduled **around 2030**.
- **International Collaboration:** JUNO's research team includes scientists from the **US, France, Germany, Italy, Russia, and Taiwan,** demonstrating extensive international cooperation.
- **Future Applications of Neutrino Research:** While direct applications for neutrinos remain distant, researchers speculate about potential communication uses, such as **transmitting long-distance messages through solid matter at near-light speed.**

What are Neutrinos?

- Neutrinos are **subatomic particles** that have **no electric charge**, have a small mass, and **are left-handed (the direction of its spin is opposite to the direction of its motion).**
    - They are the **most abundant massive particles in the universe.** They are produced whenever **atomic nuclei combine (as in the sun)** or **split apart (as in a fission reactor or particle accelerator).**
- The only ways neutrinos interact is through **gravity** and the **weak nuclear force.**
- They can change from one type (**electron-neutrino, muon-neutrino, tau-neutrino**) to another as they travel and interact with other particles, a phenomenon sometimes called **neutrino oscillation.**
- Neutrinos can **carry information across large distances** due to their low interaction rate with matter.
    - They could **potentially be used to transmit information, replacing electromagnetic waves in communication channels.**

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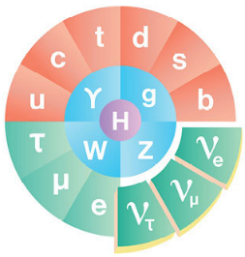
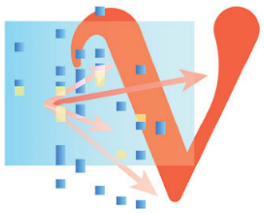


FUNDAMENTAL

Neutrinos are fundamental particles, which means that—like quarks and photons and electrons—they cannot be broken down into any smaller bits.

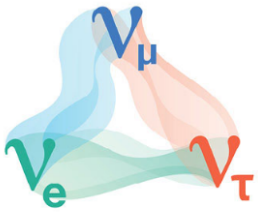
ABUNDANT

Of all particles with mass, neutrinos are the most abundant in nature. They're also some of the least interactive. Roughly a thousand trillion of them pass harmlessly through your body every second.



ELUSIVE

Neutrinos are difficult but not impossible to catch. Scientists have developed many different types of particle detectors to study them.



OSCILLATING

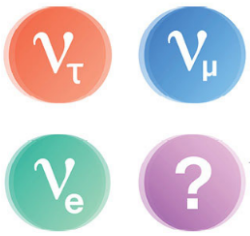
Neutrinos come in three types, called flavors. There are electron neutrinos, muon neutrinos and tau neutrinos. One of the strangest aspects of neutrinos is that they don't pick just one flavor and stick to it. They oscillate between all three.

LIGHTWEIGHT

Neutrinos weigh almost nothing, and they travel close to the speed of light. Neutrino masses are so small that so far no experiment has succeeded in measuring them. The masses of other fundamental particles come from the Higgs field, but neutrinos might get their masses another way.

DIVERSE

Neutrinos are created in many processes in nature. They are produced in the nuclear reactions in the sun, particle decays in the Earth, and the explosions of stars. They are also produced by particle accelerators and in nuclear power plants.



MYSTERIOUS

Neutrinos are mysterious. Experiments seem to hint at the possible existence of a fourth type of neutrino: a sterile neutrino, which would interact even more rarely than the others.

VERY MYSTERIOUS

Scientists also wonder if neutrinos are their own antiparticles. If they are, they could have played a role in the early universe, right after the big bang, when matter came to outnumber antimatter just enough to allow us to exist.

Interested in how the universe works? Read *symmetry*, an online magazine about particle physics and its connections to life and other areas of science. Published by Fermi National Accelerator Laboratory and SLAC National Accelerator Laboratory. symmetrymagazine.org

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Deep Underground Neutrino Experiment (DUNE)

- It will be based in South Dakota, US, situated approximately 1,500 meters underground.
- **Objectives:** To **investigate neutrino oscillations** to understand the **fundamental properties of neutrinos**, including their **mass hierarchy.**
    - Study the **asymmetry between matter and antimatter,** neutrino interactions, and **potential proton decay.**
- **Global Collaboration: Involves scientists from over 30 countries,** including the US, UK, India, Japan, and Brazil, making it one of the **largest international collaborations** in particle physics.
- **Scientific Significance:** Expected to **reveal insights into particle physics** that could impact theories of the universe's evolution.

Indian Neutrino Observatory (INO)

- It is a proposed particle **physics research mega project** with the objective to **study neutrinos in a 1,200-metre deep cave.**
- The project is proposed to be set up at **Pottipuram village in Theni district in Tamil Nadu.**
- The project was initially mooted by the **Institute of Mathematical Sciences** and then by the **Tata Institute of Fundamental Research.**
- As of **October 2024**, the **construction of the INO project is stalled due to opposition** from the **state government and ecologists.**

UPSC Civil Services Examination, Previous Year Question (PYQ)

Q. In the context of modern scientific research, consider the following statements about 'IceCube', a particle detector located at South Pole, which was recently in the news: (2015)

1. It is the world's largest neutrino detector, encompassing a cubic kilometre of ice.
2. It is a powerful telescope to search for dark matter.
3. It is buried deep in the ice.

Which of the statements given above is/are correct?

(a) 1 only

(b) 2 and 3 only

(c) 1 and 3 only

(d) 1, 2 and 3

Ans: (d)