Nuclear Power Plant’s Eerie Glow Spotted 150 Miles Away

Description

In a groundbreaking achievement, a subterranean tank of exceptionally pure water, encased beneath several kilometers of rock in Ontario, Canada, registered an ephemeral flash as a scarcely detectable particle traversed its molecular structure. This marked the inaugural occasion on which water was employed to discern an antineutrino, emanating from a nuclear reactor located over 240 kilometers (150 miles) away.

The remarkable findings, elucidated in a 2023 study, herald a new era for neutrino investigations and the development of monitoring technologies utilizing cost-effective, readily available, and inherently safe materials.

Neutrinos, among the universe's most prolific particles, exhibit intriguing properties that offer profound insights into the cosmos. However, their almost negligible mass, lack of charge, and minimal interactions with other particles render them elusive—consequently, these particles have earned the moniker "ghost particles."

Antineutrinos serve as the antiparticle counterparts to neutrinos. Unlike other particle-antiparticle pairs, which possess opposite charges—consider the negatively charged electron and its positively charged counterpart, the positron—the distinction between neutrinos and antineutrinos is evidenced solely by their interactions during decay processes.

Fermions and bosons
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Particles in the Standard Model of physics have antiparticle equivalents. (ScienceAlert)

Electron antineutrinos are products of nuclear beta decay—an inherently radioactive process wherein a neutron transmutes into a proton, electron, and antineutrino. In this interaction, an antineutrino can subsequently engage with a proton, resulting in the generation of a positron and another neutron, a phenomenon referred to as inverse beta decay.

Detection of this decay typically necessitates large tanks filled with liquid scintillators, outfitted with photomultiplier tubes designed to capture the faint illumination produced by Cherenkov radiation—analogous to a sonic boom but in the realm of light. Despite their prolific generation in nuclear reactors, antineutrinos are low in energy, complicating the detection process.

The SNO+ laboratory, situated over 2 kilometers (1.24 miles) underground, offers an environment remarkably shielded from cosmic interference, enabling the acquisition of exceptionally high-resolution signals. In the calibration phase of 2018, the lab's 780-tonne tank, originally filled with ultrapure water, identified evidence of inverse beta decay after analyzing 190 days of collected data.

This discovery indicates that water-based detectors could potentially serve as instruments for monitoring nuclear reactor power outputs and enhances our comprehension of neutrinos and antineutrinos—two entities that, due to their illusive nature, remain poorly understood.

As physicist Logan Lebanowski from the SNO+ collaboration has remarked, “The ability to utilize pure water

for the detection of antineutrinos from reactors at such substantial distances is profoundly intriguing." This research was subsequently published in *Physical Review Letters*.

An earlier version of this article was published in April 2023.

Vocabulary List:

1. **Subterranean** /ˌsʌb.təˈreɪ.ni.ən/ (adjective): Existing occurring or done under the earth's surface.
2. **Ephemeral** /ɪˈfɛm.ər.əl/ (adjective): Lasting for a very short time.
3. **Elucidated** /ɪˈluː.sɪ.deɪ.tɪd/ (verb): Made (something) clear; explained.
4. **Transmutes** /trænzˈmjuːts/ (verb): Changes in form nature or substance.
5. **Cherenkov** /ˈʧɛr.ɛn.kɒf/ (adjective): Relating to the radiation produced when a charged particle moves through a medium faster than the speed of light in that medium.
6. **Illusive** /ɪˈluː.sɪv/ (adjective): Deceptive; based on illusion; tending to mislead.

Comprehension Questions

Multiple Choice

1. Where was the subterranean tank of exceptionally pure water located for the groundbreaking achievement described?

Option: Ontario, Canada
Option: California, USA
Option: Paris, France
Option: Sydney, Australia

2. What marked the inaugural occasion in the detection of an antineutrino described in the text?

Option: A flash in the water tank
Option: A seismic event
Option: A solar flare
Option: A chemical reaction

3. What does the term "ghost particles" refer to in the context of neutrinos?

Option: Their almost negligible mass
Option: Their lack of charge
Option: Their minimal interactions with other particles

Option: All of the above

4. What is the antiparticle counterpart to a neutrino?

Option: Antineutrino
Option: Electron
Option: Positron
Option: Photon

5. Which laboratory is mentioned in the text as being situated over 2 kilometers underground?

Option: SNO+ laboratory
Option: CERN
Option: NASA Jet Propulsion Laboratory
Option: Harvard-Smithsonian Center for Astrophysics

6. What process results in the generation of a positron and another neutron when an antineutrino engages with a proton?

Option: Inverse beta decay
Option: Alpha decay
Option: Fission
Option: Gamma decay

True-False

7. Neutrinos and antineutrinos possess opposite charges.

8. Detection of antineutrinos typically requires large tanks filled with liquid helium.

9. The SNO+ laboratory identified evidence of inverse beta decay in its 780-tonne tank after analyzing 100 days of collected data.

10. Antineutrinos have high energy levels making their detection process straightforward.

11. Photomultiplier tubes are used to capture Cherenkov radiation in the detection of decay processes.

12. Pure water was found to be ineffective in detecting antineutrinos from nuclear reactors according to the text.

Gap-Fill

14. The lab's 780-tonne tank identified evidence of inverse beta decay after analyzing _____ days of collected data.

15. Neutrinos and antineutrinos are entities that remain poorly understood due to their _____ nature.

16. Logan Lebanowski is a physicist from the SNO+ collaboration group who remarked on the intriguing ability to detect antineutrinos using pure water at _____ distances.

17. This groundbreaking achievement in neutrino detection occurred in a subterranean tank of exceptionally pure water beneath several kilometers of _____ in Ontario, Canada.

18. The ability to monitor nuclear reactor power outputs using water-based detectors enhances our understanding of _____.

Answer

Multiple Choice: 1. Ontario, Canada 2. A flash in the water tank 3. All of the above 4. Antineutrino 5. SNO+ laboratory 6. Inverse beta decay
True-False: 7. False 8. False 9. False 10. False 11. True 12. False
Gap-Fill: 14. 190 15. illusive 16. substantial 17. rock 18. neutrinos and antineutrinos

CATEGORY

1. Health - LEVEL6

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