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From the fog of cloud chambers to the secrets of neutrinos: how physics unlocks the invisible

In the early 20th century, the first visual representations of atomic particles appeared as ghosts in cloud chambers, true “photographs” of electrons and muons crossing space. However, these first detectors had a limitation: they were unable to identify neutral particles, such as neutrinos, which pass through matter almost without interacting, as undetectable spectra.

Over time, technology evolved and researchers discovered indirect ways to record these cosmic messengers. Grand facilities such as Super-Kamiokande in Japan and IceCube, immersed in the ice of Antarctica, began to “observe” neutrinos by tracking the bluish light (Cherenkov radiation) resulting from collisions of these unusual particles with atoms in water or ice.

Currently, the new phase of detectors such as SBND (Short-Baseline Near Detector) and DUNE (Deep Underground Neutrino Experiment) employs liquid argon and high-accuracy three-dimensional detection systems, revealing neutrinos with unprecedented detail. These experiments not only help us unravel enigmas such as neutrino oscillations and the possibility of the existence of even more elusive versions (the “sterile neutrinos”), but can also provide information about one of the greatest mysteries of the universe: why is the cosmos composed of matter rather than antimatter?

In this study, we present an analysis of the existing literature on the advances that neutrino research is driving in new technologies and how preparations are going for future generations of neutrino detection equipment.

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