Glashow Event FAQ

## What is a neutrino? Why do we use them to study the universe?

Neutrinos are invisible, nearly massless fundamental particles. Every second, trillions of them zip harmlessly through our bodies at close to the speed of light. While neutrinos are incredibly common—they are the most abundant particle in the universe behind photons—they are incredibly difficult to detect, earning them the moniker “ghost particles.” In fact, a light-year of lead would only stop half of the neutrinos produced by the sun.

But collaborators working on the IceCube experiment are most interested in a specific subset called *astrophysical neutrinos*. These neutrinos have extremely high energies, and researchers suspect that they are produced and accelerated by some of the most cataclysmic phenomena in the universe: hypernovas, neutron star mergers, fast radio bursts, and more.

Importantly, researchers can learn about these phenomena by studying the neutrinos that they create. Astrophysical neutrinos can travel through outer space for billions of light-years, carrying with them important information about their sources. And unlike charged particles and photons, neutrinos aren’t deflected by intervening magnetic fields or easily scattered off matter, so they are capable of traveling over great distances on a perfectly straight path. Neutrinos are the ultimate cosmic messengers.

## What is an antineutrino? How is it different from a neutrino?

An antineutrino is a common subatomic particle, the antimatter version of a neutrino. Like the neutrino, an antineutrino has no electric charge. Usually, the only way to experimentally distinguish an antineutrino from a neutrino is by studying what happens when it collides with an atom: An electron neutrino always produces an electron among the collision products while an electron antineutrino always produces the antimatter version of an electron, a positron. Electrons and positrons carry electric charge and can be distinguished in a magnetic field because, when moving, their trajectories bend in opposite directions. The Glashow resonance, which can only be detected when an electron antineutrino with a very precise energy collides with an atomic electron, is a second way to identify an electron antineutrino.

## Where did the antineutrino that created the Glashow event come from?

We haven't been able to associate this antineutrino with any known source. The angular uncertainty in the localization of the event, even using the track information, is large enough that it’s not possible to make a clear astrophysical association. We do know that it is from outside of the Milky Way galaxy in the direction of the supergalactic plane.

## What is the W– boson?

In Sheldon Glashow’s 1960 paper, he predicted that an antineutrino could interact with an electron to produce an as yet undiscovered particle—an intermediate vector boson—through a process known as resonance. This charged weak intermediate boson is the carrier of the weak force, which is the force responsible for radioactivity and other processes where particles change identities. Its role is analogous to what photons do for the electromagnetic force and what gluons do for the strong force. The W and Z bosons’ eventual discovery in 1983 was celebrated with the [1984 Nobel Prize in Physics](https://www.nobelprize.org/prizes/physics/1984/summary/).

In typical neutrino interactions, a “virtual” W/Z boson is produced, which means it cannot be detected even in principle. However, in the case of the Glashow resonance, a real W– boson was produced. While charged, it’s lifetime is incredibly short, so we were only able to detect it through its decay products.

## What does this result mean for nonscientists?

The result helps us better understand the universe on a number of levels. For one, it is yet another step toward a more complete knowledge of powerful cosmic accelerators, in which we learn more about their sizes and magnetic fields. We have theories about cosmic accelerators, but we need experimental data to truly understand what is going on.

In addition, the Glashow resonance event provides a rare opportunity for IceCube to distinguish neutrinos and antineutrinos, which it normally cannot do, and hence refine our understanding of the astrophysical neutrino flux.

## How does IceCube work?

IceCube is an unconventional telescope made up of 5,160 light sensors, called digital optical modules (DOMs), interspersed in a cubic kilometer of crystal-clear ice a mile below the surface at the South Pole. It is able to detect the presence of neutrinos thanks to a phenomenon called “Cherenkov radiation.”

In the rare event that a neutrino runs into an atomic nucleus, it produces a charged particle. When this interaction takes place in a medium where light is slowed down (like water or ice), the charged particle travels faster than the speed of light in that medium and emits photons of Cherenkov radiation, which are detectable by IceCube’s DOMs. An IceCube “event” is recorded when multiple neighboring DOMs detect photons within 0.000005 seconds of each other. By studying an event, IceCube scientists can determine the energy and incoming direction of the original particle.