IceCube Neutrino Observatory

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The IceCube Neutrino Observatory is a massive detector spread throughout a cubic kilometer of ice in Antarctica [2]. Its goal is to detect neutrinos: neutrally charged subatomic particles formed in nuclear reactions, such as ones in stars, nuclear power plants, and supernovae [6]. By detecting neutrinos, IceCube allows researchers to learn more about our universe. For instance, an increase of neutrinos indicates the occurrence of a supernova before it becomes visible, allowing time for scientists to correctly position their telescopes [6]. A recent neutrino detection by IceCube, known as the 170922A event, was the first time the exact source of a neutrino was able to be confirmed [5]. Because of an automated alert system, scientists all around the world were alerted to the event within a minute of its occurrence, allowing one observatory to pinpoint the origin of the neutrino to a blazar, a stream of plasma originating from a supermassive black hole [5]. Data taken from IceCube was also used to further research in black matter and magnetic monopoles, with the IceCube Collaboration publishing a report on these topics just two years after construction of IceCube was completed [4].

Beginning in 2004, the construction of the IceCube Neutrino Observatory was spread over seven years, with it finally being completed in January of 2011 [1]. Construction took place over the southern hemisphere's summers, with teams melting shafts of ice in order to lower digital optical modules into them before the shafts refroze [1][5]. 86 shafts were drilled total, with IceCube containing 60 digital optical modules, each roughly the size of a basketball and protected from the ice's pressure by borosilicate glass [1][5]. The modules detect an effect called Cherenkov radiation, which is produced when a particle travels faster than the local speed of light, or how fast light travels in the given material [5][7][8]. The local speed of light in ice is about 25% slower than its speed in a vacuum, slow enough that neutrinos are able to travel faster than light [5]. Cherenkov radiation produces a blue glow which can be measured to determine where the neutrino came from and how much energy it originally had [5][8]. IceCube's sensors are between 1,450 and 2,450 meters deep in order for the pressure to be great enough to squeeze out air bubbles that would otherwise scatter the Cherenkov radiation [3][5]. IceCube is able to use the light pattern emitted by the neutrino to determine what type of neutrino was detected, with the three known types of neutrinos - electron, muon, and tau - each producing unique light signatures [8].

Despite its incredible contributions as is, there are plans to further expand IceCube's capabilities. Upgrades are currently being developed for a future version of IceCube called IceCube-Gen2 [1][7]. These upgrades would increase IceCube's sensitivity enough to get data on lower-energy neutrinos which it currently cannot detect, helping researchers determine how neutrinos' mass correlates to their type (neutrino mass ordering) [7]. Insights gained during the original IceCube construction will allow light detectors in future additions to be twice as far apart, drastically reducing costs of any upgrades [1]. According to the IceCube website, "[b]y roughly doubling the instrumentation already deployed, the telescope will achieve a tenfold increase in volume to about 10 cubic kilometers, aiming at an order of magnitude increase in neutrino detection rates," [1]. In addition to enhancing its detection, "sharper resolution achieved through the upgrade can be retroactively applied to data already acquired and stored during the first decade of IceCube's operation," meaning that upgrades would benefit both past and future data [1]. IceCube's contributions have and will continue to increase scientists' understanding of our universe.

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