

IceCube South Pole Neutrino Observatory

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1. Introduction

The IceCube Neutrino Observatory is the largest neutrino detector in the world and is located on the continent of Antarctica. The detector takes advantage of the ice at the South Pole to form a detector comprising of photomultipliers on strings that are lowered into holes that have been drilled into the ice. Once the strings have been lowered to as far down as 3km into the ice, water is poured back into the hole and allowed to freeze around the detectors, which are known as Digital Optical Modules (or DOM) and these contain the photomultipliers [3]. Instead of using a standard scintillator material, the IceCube detector takes advantage of the properties of ice.

2. Digital Optical Modules

The digital optical modules that make up the detector array at IceCube are approximately the size of a basketball, and they are designed to detect the particle showers created by neutrinos interacting with the surrounding ice. When a high energy neutrino interacts with the ice, it can generate a measureable signal by pair-production, Bremsstrahlung, or photonuclear interactions. Inside of the glass pressure housing is sophisticated electronics and a photomultiplier designed to read these signals. Each DOM runs autonomously from all other DOMs, and receives power from the surface. Because of stringent fuel requirements, and the fact that all fuel must be flown in, each DOM must be able to run on 5 watts of power [4]. The DOMs are designed to withstand the pressures of the ice and temperatures as low as -55 C [4]. The DOMs are equip with LED lights that are used to measure the scattering properties of the ice surrounding them so that calibrations can be made for measuring the Cherenkov light emitted by charged particles interacting with the ice [2]. The DOMs use field-programmable gate arrays (FPGAs) for the data acquisition and digitization when the discriminator trigger fires for an event.

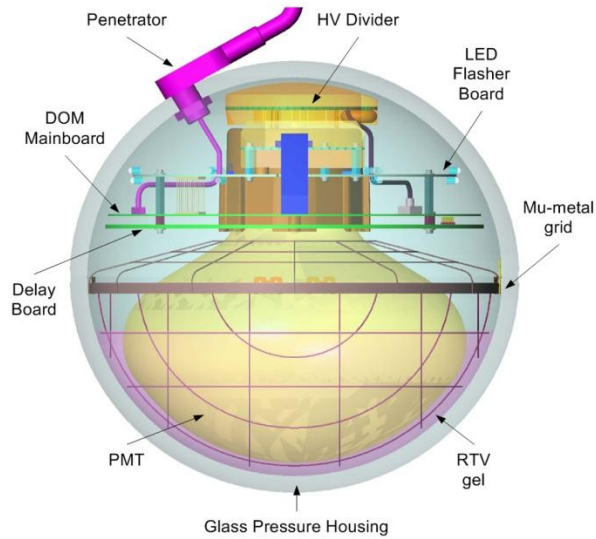


FIGURE 1. A schematic for a Digital Optical Module (DOM) [2].

A Common triggering setup for the DOMs is to acquire data when 8 locally situated DOMs fire within 5 microseconds of one another [4]. In order to achieve the necessary accuracy for detecting events, the photomultiplier tubes have a timing resolution of less than 5 nanoseconds [3]. In order to cut out on extraneous noise sources the entire photomultiplier tube is surrounded in a μ -metal grid, as seen in figure 1 [3]. The μ -metal is effective at shielding against static and low-frequency magnetic fields, such as the earth's magnetic field. Overall, there are 5,964 DOMs operating in the IceCube observatory [2].

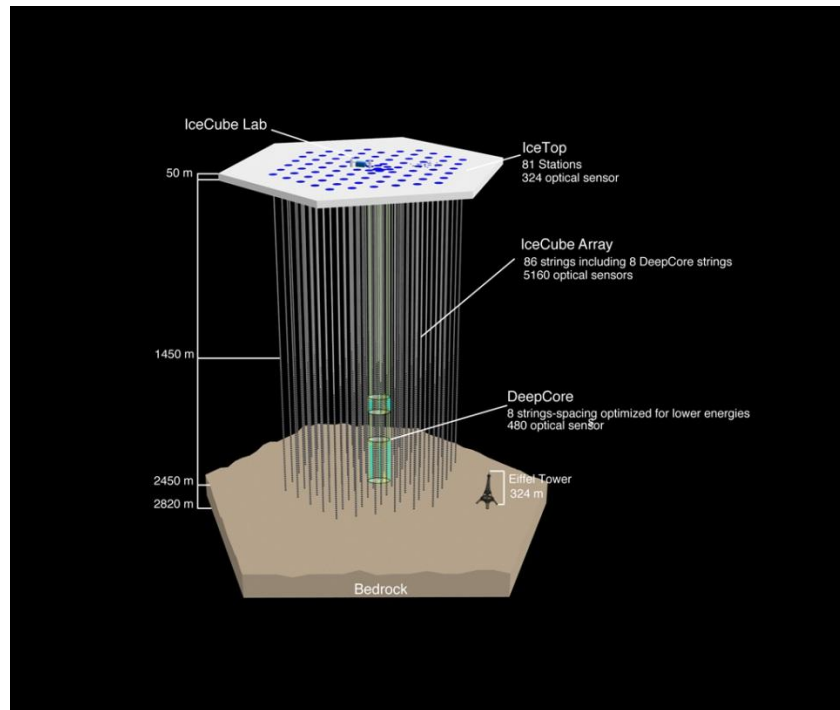


FIGURE 2. A layout of the IceCube Neutrino Observatory [2].

3. The IceCube Array

The IceCube array is now comprised of 3 layers of detection that serve separate purposes, but still work in conjunction with one another.

IceTop is a layer of DOMs that are placed in ice-filled tanks above the surface of the Antarctic ice shelf, see figure 2. This upper layer of IceCube is designed to detect cosmic rays with an upper limit on energy of about 300 TeV [4]. The IceTop array is also used as a coincidence module for incoming events: it can be configured to reject high energy events in IceCube in order to probe lower energies, or it can be configured to screen out low energy events and look for muon-free showers from photons in the PeV energy range [4].

The middle of IceCube is the IceCube Array, see figure 2. Comprised of 5,160 DOMs dispersed on 86 strings, the IceCube Array forms the bulk of the neutrino observatory. The DOMs used in this layer and IceTop are the same, with a lower limit on energy of 100 GeV [4]. The Array's goal is to detect neutrinos from galactic supernova explosions, gamma ray bursts, and the background neutrino flux from the big bang [2].

The newly installed lowest component of the IceCube array is the IceCube Deep Core, see figure 2. The DOMs used in the Deep Core setup are more efficient and sensitive than the rest of the DOMs in IceCube, and have a lower limit of about 10 GeV [1]. The Deep Core also has a higher density of the DOMs than any other layer of IceCube [1]. The Deep Core DOMs use a different triggering protocol than the middle array, they are designed to acquire data when the Deep Core DOMs fire within 2.5 microseconds of one another. Because of the low energies sensitivity in the Deep Core, IceCube will be able to detect atmospheric neutrino oscillations [1]. Another one of the goals of the Deep Core setup is to detect weakly interacting massive particles (WIMPs) that could be dark matter passing through the array [1].

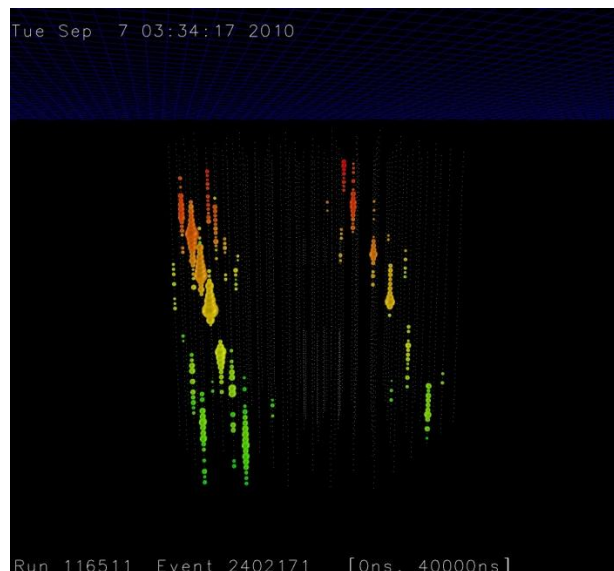


FIGURE 3. Two downgoing events in the IceCube array [2].

4. Conclusion

With the three layers of IceCube, it has the potential to see neutrinos with energies between $10^{10} - 10^{21} \text{ eV}$ that create showers in the ice, such as the tracks in figure 3. IceCube has the ability to detect the oscillation of flavors in solar neutrinos, neutrinos from varying sources, such as gamma ray bursts and supernova, and it has the potential to detect WIMPs, a dark matter candidate. In order to further the ability of the science community to sift through the data produced by IceCube, the event data from IceCube is made publicly accessible after the main analysis is completed [2].

REFERENCES

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