IceACT Monitoring and Data Analysis

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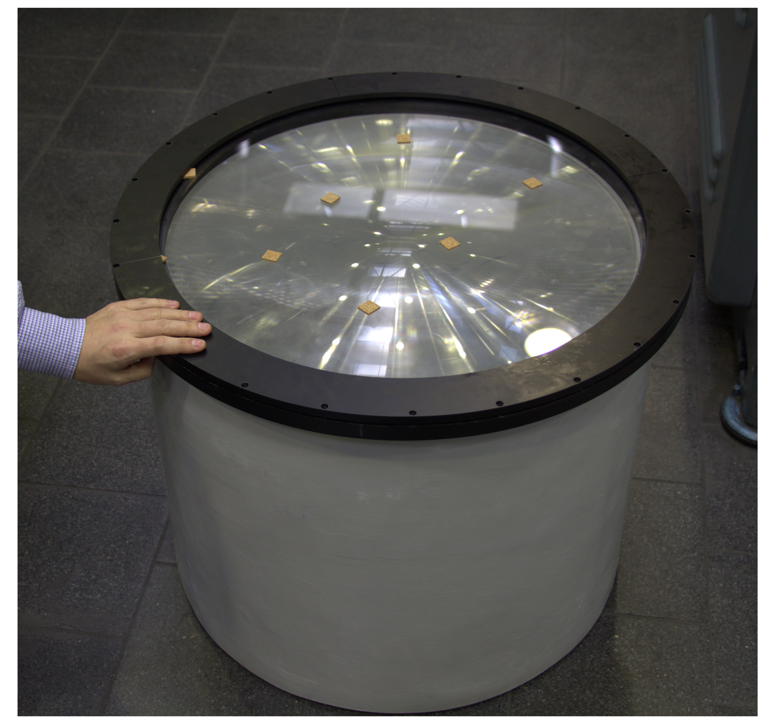
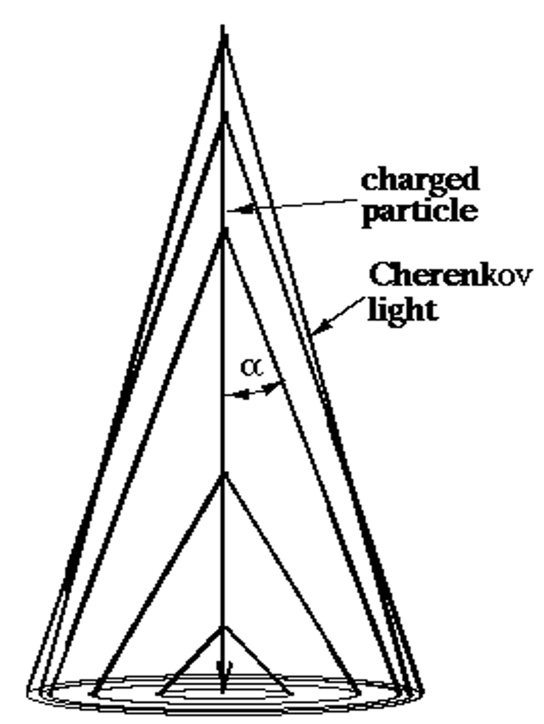
Introduction

The IceCube Neutrino Observatory at the South Pole has opened a new window to our universe by making the first detection of high-energy astrophysical neutrinos. Unlike photons, neutrinos have no charge, and can travel across the universe without being scattered by interstellar magnetic fields. The main background for astrophysical neutrinos are muons and neutrinos produced in the Earth's atmosphere by cosmic-ray air showers. To better identify these background neutrinos, IceCube constructed an imaging air Cherenkov telescope dubbed IceACT. This telescope detects atmospheric muons from the cosmic-ray air showers and can independently calibrate the angular reconstruction of IceCube to provide accurate results in future trials. Once we have demonstrated that such telescopes can be built cheaply and operated efficiently, an array of IceACTs will allow dramatic improvements in IceCube's capability to measure both astrophysical neutrinos and very high energy cosmic rays from our galaxy.



Cherenkov Radiation

The main objectives of IceACT are to detect cosmic-ray muons and to study their composition between iron and proton cosmic ray showers. Since high-energy astrophysical neutrinos travel through cosmic rays towards Earth, they collide with particles in our atmosphere readily charging a fermion particle (i.e. an electron or muon). The fermion then travels faster than the phase velocity of light towards the Earth, and a portion of the particle energy is converted to a faint bluish light, known as Cherenkov radiation, that travels as a wave front traveling at a given angle. This angle is determined by the height of emission of the charged particle and the density of the air; at most the angle is measured to be less than 1.7 degrees. The photons from the Cherenkov radiation interact with other air particles, causing an air shower faster than the local speed of light.



The Structure of IceACT

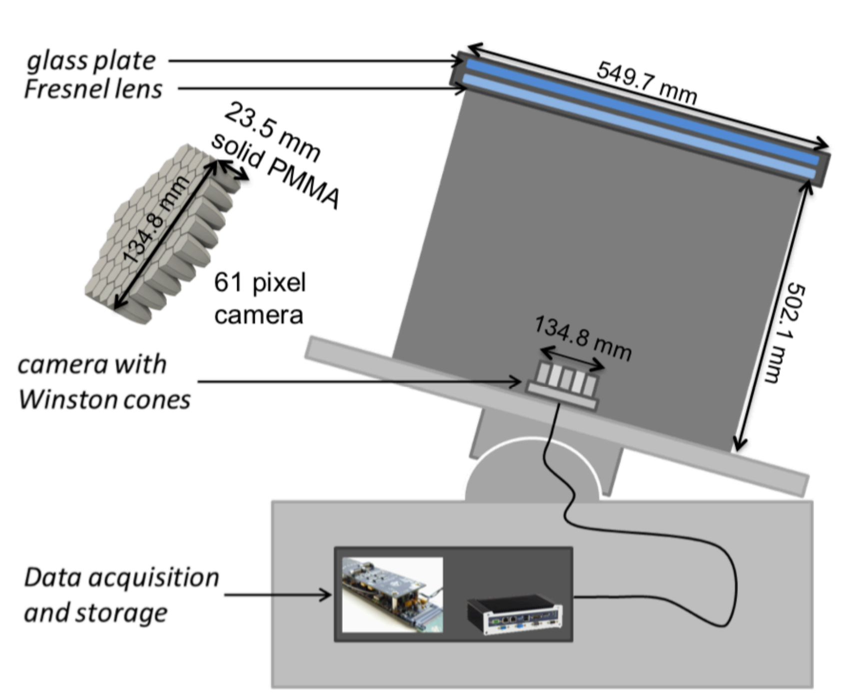


Figure 1: Drawing of the IceAct telescope prototype with a 61 pixel camera. A similar IceAct demonstrator equipped with a 7 pixel camera was deployed at the South Pole on the roof of the counting house of the IceCube neutrino observatory.

The core components of IceACT consists of a Fresnel lens and a 61-pixel SiPM camera with Winston cones, as shown in Fig. 1. The Fresnel lens can capture most of the night sky with a 12 degrees field of view in a single image. 61 specially designed PMMA Winston-Cones positioned in the front of the camera detect these photons. A signal is transmitted to data acquisition where it measures the voltage and trigger rates. These measurements are then compiled to the data storage where we receive this information for analysis.

To prevent snow accumulation on the Fresnel lens, the telescope is enclosed with a carbon cylinder and a glass plate is sealed atop. This prevents moisture accumulating within the telescope which could lead to long-term damage and produce inaccurate results. Likewise, special treatment is required to effectively run IceACT mechanically and electronically due to the low temperatures and drifting snow.

Monitoring IceACT & Analysis

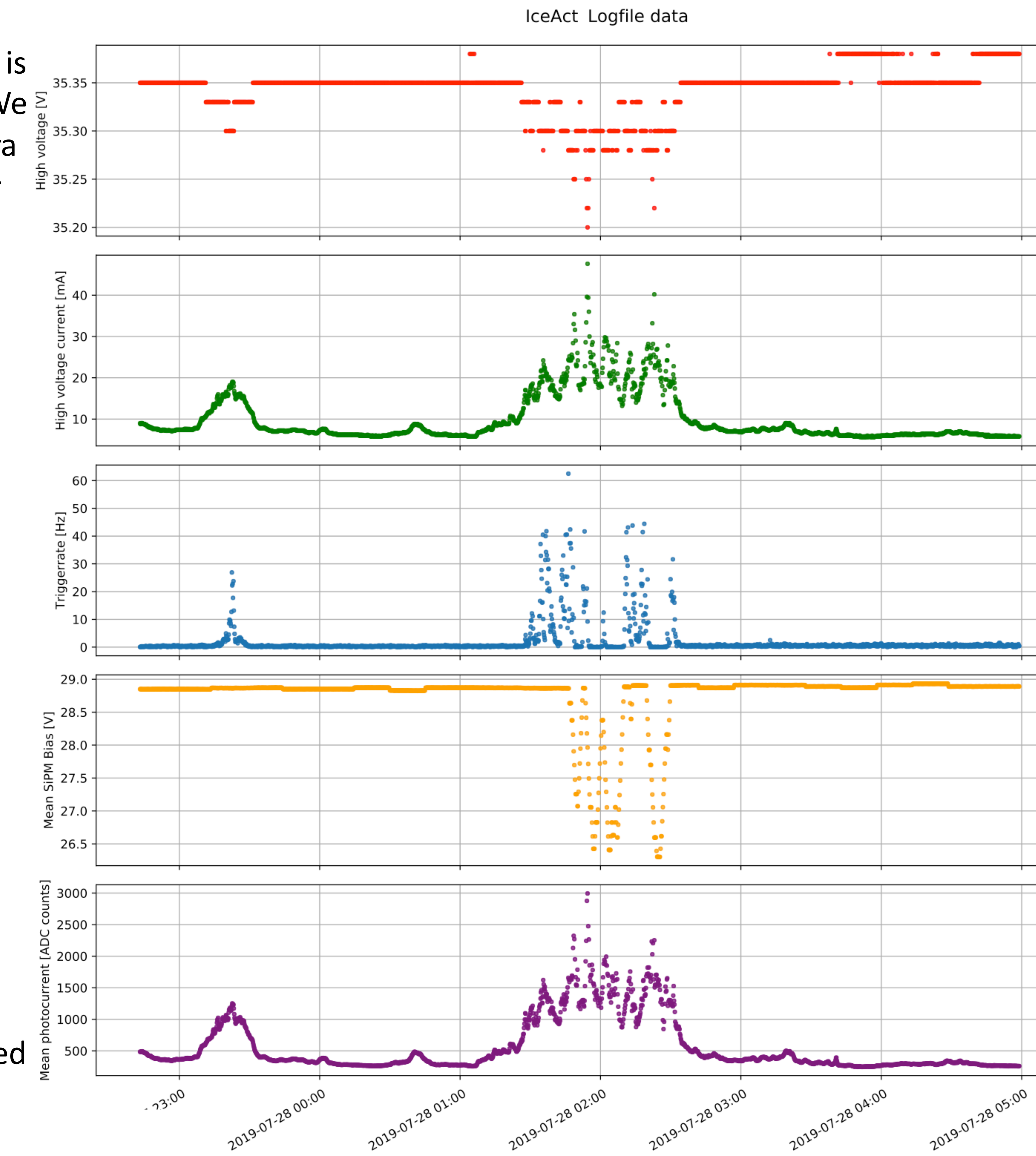
IceACT operated during winter 2019 at the South Pole when it is continuously dark. The logfile data at the right is from a typical 6.5 hour run recorded at the end of July. We use these plots to monitor and deduct any signs of aurora borealis or snow coverage on the lenses, and further our research on cosmic-ray muons.

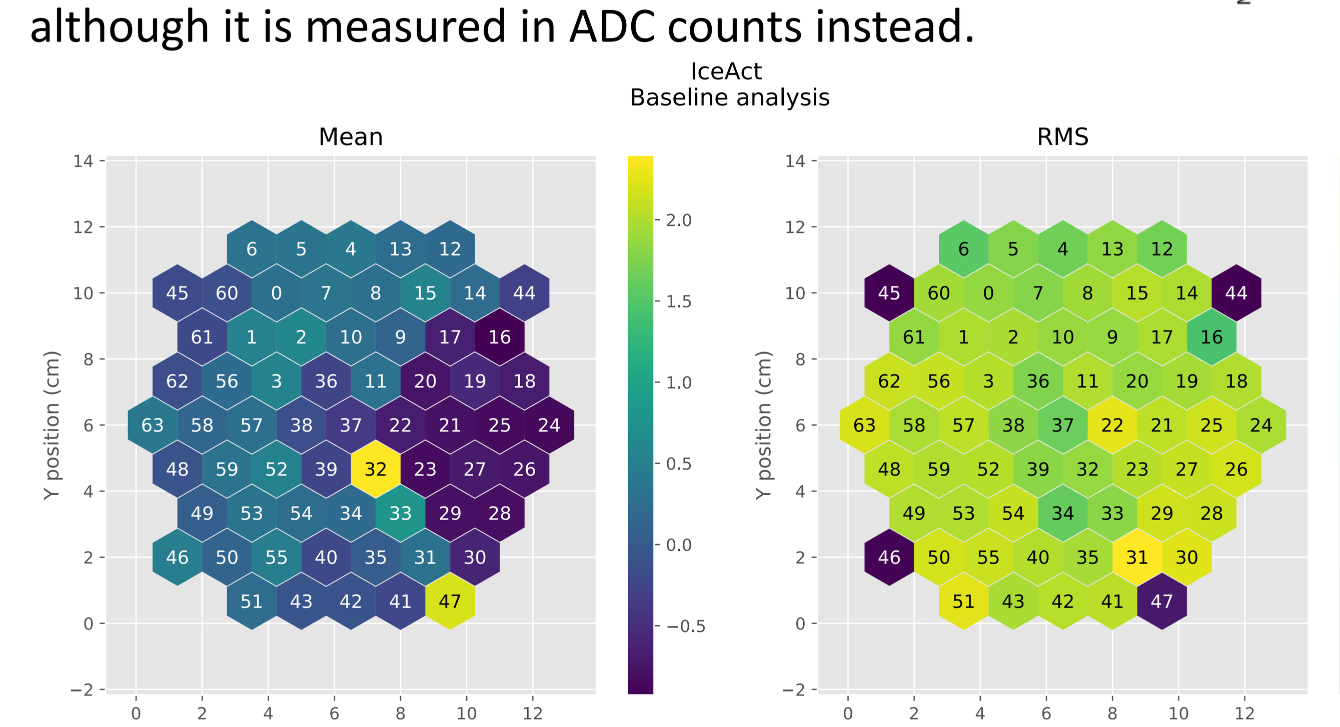
The **high voltage current** determines the energy of photons received with the camera equipped in IceACT. The plot shown in green shows that large abundance of relatively high-energy photons were present between times 1:30 and 2:30.

The **trigger rate** is the amount of times per second that IceACT receives a signal that photons are detected. As shown in the logfile as blue, there are trigger rate peaks when high amount of photons are received such as between times 1:30 and 2:00.

Silicon photomultipliers, or SiPMs, are solid-state detectors that count single photons. The **SiPM bias** controls the detector efficiency and is automatically reduced when the camera receives a lot of light.

Mean photocurrent is highly similar to high voltage current where it calculates the energy of photons received although it is measured in ADC counts instead.

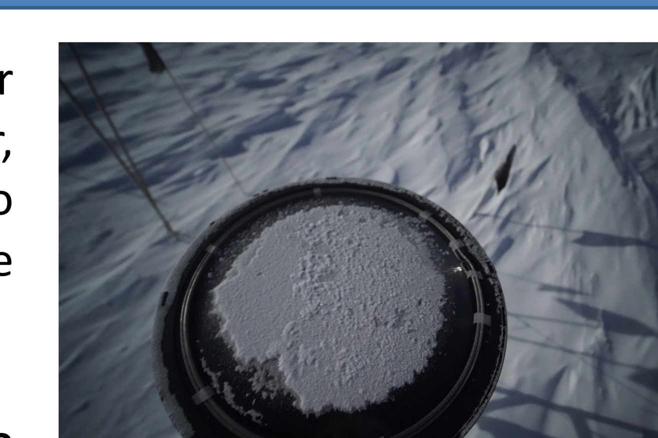




The SiPM camera we use contains a hexagonal structure with 61 pixels each measuring the amplitude of incoming photons. The plot shown at the left is associated with the logfile data above. The mean plot shows that pixel 32 and 47 have larger amplitudes ("hot pixels") than most of the other pixels. On the other hand, the root mean squared (rms) plot shows that there is a high uniform amplitude. Snow accumulation may be accounted for the difference of the two plots as it may have refracted the light through the telescope, providing inaccurate results.

Conclusions

The goal of the IceAct project is to establish an array of small ACTs deployed at the South Pole for neutrino detection, CR composition studies and high energy gamma ray detection. Early this year, a heater was installed on the lens to melt snow and frost. An all-sky-camera was also installed to detect aurorae. The IceACT collaboration will resume observations this summer to validate these improvements and gather further scientific results.



***More than 20 researchers contributed to IceACT from RWTH Aachen University, Marquette University, Friedrich Alexander University Erlangen, Michigan State University, Technical University of Dortmund, University of Canterbury and the University of Wisconsin, Madison.**