# T 33: Cosmic Rays VI

Time: Tuesday 16:00–18:15 Location: Th

T 33.1 Tue 16:00 Th

**The hybrid detector stations of the IceCube surface array enhancement** — •Thomas Huber for the IceCube-Collaboration — Institut für Astroteilchenphysik (IAP), Karlsruher Institut für Technologie (KIT)

The IceCube Collaboration foresees to upgrade IceTop, the present surface array, with scintillation detectors augmented by radio antennas. As one of several goals the detectors will be used to measure and mitigate the effects of snow accumulation on the IceTop tanks: The increasing energy threshold and efficiency loss are nowadays the sources of the largest systematic uncertainties in shower reconstruction and mass composition analysis. In addition, the enhancement will provide useful experience for the development of next generation (IceCube-Gen2) neutrino detectors.
A full prototype hybrid station was installed near the center of the IceTop array. The station features custom-designed DAQ electronics and consists of three radio antennas, sensitive in the MHz region and eight scintillation detectors, each having an active area of 1.5 $m^2$ plastic scintillators, coupled via wavelength-shifting fiber and read out by a Silicon Photomultiplier (SiPM).
In this talk the DAQ and detector R&D decisions, the calibration methods and the performance are reviewed and results from more than three years of operation of the hybrid station are shown. Several thousand air-shower events have been measured in coincidence with IceTop. In addition, the future plans for instrumenting the whole IceTop surface with scintillation detectors and radio antennas will be presented.

T 33.2 Tue 16:15 Th

**Studying the Energy-Dependent Cosmic-Ray Moon and Sun Shadow with IceCube Data.** — •Johan Wulff, Frederik Tenholt, and Julia Tjus for the IceCube-Collaboration — Ruhr-Universität Bochum

Measuring the temporal variation of the Cosmic-Ray Sun shadow has proven to be a useful tool for assessing solar magnetic field models.

By comparing seven years of IceCube data with the Solar Cycle and magnetic field models, the relationship between the solar activity and the strength of the Cosmic-Ray Sun shadow was investigated in a recent publication (Aartsen et al, accepted for Publication in PRD). Furthermore, two different models of the coronal magnetic field were tested by modelling cosmic-ray propagation in the solar magnetic field and comparing the predicted Sun shadow to the measured one.

In this work, an event-based energy reconstruction was introduced in the analysis of the 7-year data set. This allows for an investigation of the energy dependence of both shadows. Furhtermore, magnetic field effects of the Sun shadow can be investigated at different energies and an energy-dependent pointing can be studied with the Cosmic-Ray Moon shadow.

In this talk, various approaches at an event-based energy reconstruction using machine-learning techniques will be discussed with respect to their performance on the IceCube Cosmic-Ray Moon and Sun shadow data.

T 33.3 Tue 16:30 Th

**Simulation study of the IceCube-Gen2 Surface Array** — •Mark Weyrauch, Agnieszka Leszczynska, Frank Schröder, and Andreas Haungs for the IceCube-Collaboration — Karlsruhe Institute of Technology (KIT), Institute for Astroparticle Physics (IAP), Karlsruhe, Germany

The IceCube Neutrino Observatory at the South Pole consists of an in-ice array and a surface array, IceTop. IceTop is comprised of 162 ice-Cherenkov tanks distributed over 1 $km^2$ and is currently getting enhanced by scintillator panels and radio antennas.

IceCube-Gen2 is a planned extension of the IceCube detector, which will increase its science capabilities in many aspects. IceTop has proven to be a very valuable component of IceCube, providing among others measurements of the cosmic-ray (CR) spectrum and mass composition as well as the discrimination of CR induced background for the in-ice array. Consequently, IceCube-Gen2 will feature a surface array, too. The IceCube-Gen2 surface array will also consist of scintillator panels and radio antennas distributed over an array of $\sim 8\,km^2$, extending the range of CR measurements towards higher energies and improving veto as well as multi-messenger capabilities of the observatory. In order to quantify the science capabilities, a first simulation study of the IceCube-Gen2 surface array has been performed. In this talk I will present the results of this study.

T 33.4 Tue 16:45 Th

**Low-Energy Cosmic Ray Composition Spectra with IceCube and IceTop in Synergy** — •Julian Saffer for the IceCube-Collaboration — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology (KIT)

IceTop is the surface component of the IceCube South Pole Neutrino Observatory and dedicated to the indirect detection of cosmic rays (CRs). The recent implementation of a new trigger that only requires 2 of IceTop's 6 central infill stations hit by a CR-induced shower allowed to reduce the primary energy threshold for the detection of low-energy CRs from 1.6 PeV to 250 TeV. This lead to a narrowing of the gap between direct and indirect CR measurements and coverage of the entire 'knee' region of the spectrum. [M. G. Aartsen et al. (IceCube Collaboration) Phys. Rev. D 102, 122001]

This talk presents the concept and performance of this new filter/trigger combination as well as reconstruction results for shower position, zenith angle and primary energy from Monte Carlo simulations and experimental data. Additionally, plans towards an enhancement of the machine learning techniques used for the determination of direction, primary energy and mass-composition of CRs are discussed. This will include the combination of the surface signals with the corresponding tracks of high-energetic muons within the deep in-ice detector.

T 33.5 Tue 17:00 Th

**Muon studies with the IceTop surface array** — •Donghwa Kang for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie

IceTop is the surface component of the IceCube Neutrino Observatory at the geographical South Pole. It is designed to measure the air showers of cosmic rays in the energy range from PeV up to EeV. In general, it is reasonable to assume that the muon signal becomes significant for a large distance from the shower axis, since they are overwhelmed by the signal from electromagnetic components close to the shower axis. Considering the charge signal distribution, the a muon parameter was defined and reconstructed, which is the sum of the charge signals divided by the total number of tanks and the area of the tanks at a fixed distance from the shower axis. In this talk the estimated muon parameter based on the charge distribution will be presented and its use for energy determination and composition reconstruction of primary cosmic rays discussed.

T 33.6 Tue 17:15 Th

**Studies and comparison of charge signals measured by IceTop** — •Sally-Ann Browne for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT)

IceTop is the surface array of the IceCube Neutrino Observatory and one of its missions is the detection of air showers initiated by cosmic rays. IceTop consists of 81 stations with two ice-Cherenkov tanks, each, which can be operated in either 'Hard Local Coincidence' (HLC) mode or 'Soft Local Coincidence' (SLC) mode. In HLC mode, signals are read out only if two neighboring tanks are triggered simultaneously. In SLC mode, the signal is recorded when one single tank is triggered. The latter becomes more likely with increasing distance to the air shower core. Thus, most SLC signals occur in the region where the muon component dominates the air shower. Therefore, by studying SLC signals one can obtain relevant information about the muon content and thereby also about the primary particle of detected air showers. In this talk, I will illustrate the characteristics of SLC signals and explain some challenges of studying them. In addition, I will give examples of ongoing studies in which Monte-Carlo-simulated SLC signals are being compared with real data from IceTop.

T 33.7 Tue 17:30 Th

**Design and Calibration of the Surface Radio Antennas of the Prototype Station for the planned IceTop Enhancement** — •Roxanne Turcotte for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT)

The IceTop array, located at the surface of the IceCube Neutrino Observatory, is currently used as a veto for the in-ice neutrino detection as well as a cosmic-ray detector. Over the years, snow accumulated on the IceTop detector which has reduced the sensitivity and resolution. In order to improve the detector, an enhancement of IceTop is planned in the next few years which consists of an array of scintillator panels and radio antennas. Upgrading IceTop with surface radio antennas will improve the measurement accuracy and the field-of-view for the detection of cosmic rays. This in turn will lead to a better resolution of the energy and the depth of shower maximum ($X_{max}$) in the second knee region of the cosmic-ray energy spectrum. Radio measurements combined with particle measurements will also enable a better estimation for the mass of the cosmic ray. In January 2020, a prototype station comprising three antennas and eight scintillators was deployed at the South Pole. In this talk, I will focus on the functioning of the radio hardware of this station: the mechanical installation, the electronic chain and its calibration. I will also give a small overview about the performance of the improved final hardware for the planned full-scale deployment.

T 33.8 Tue 17:45 Th

**First radio measurements of cosmic air showers with the prototype station of the IceCube surface enhancement** — •Hrvoje Dujmovic for the IceCube-Collaboration — Institut für Astroteilchenphysik, Karlsruher Institut für Technologie (KIT)

IceTop, the surface array of the IceCube Neutrino Observatory, currently consists of 162 ice-Cherenkov tanks distributed over an area of $1\,\mathrm{km}^2$. IceTop is used for cosmic-ray air shower detection and as a veto for the in-ice neutrino detector. The science case of IceTop will be greatly improved by complementing the existing detectors with an array of radio antennas and scintillator panels. The IceTop enhancement array will cover the same footprint as IceTop and will consist of 32 stations. One such station, consisting of 3 radio antennas and 8 scintillator panels, was deployed in January 2020.

In this talk, we will present the results from the radio measurements with the prototype station. We will introduce the event selection and basic reconstruction of the first identified air shower events, as well as compare the data to the predictions from Monte Carlo simulations.

The results obtained from the prototype station will help us to better understand the full capabilities and physics potential of IceCube's surface enhancement.

T 33.9 Tue 18:00 Th

**Development of a scintillation and radio hybrid detector station at the South Pole** — •Marie Oehler — KIT, Karlsruhe, Germany

The IceCube Observatory is a cubic-kilometer neutrino detector installed in the ice at the geographic South Pole. To increase the efficiency of detecting astrophysical neutrinos the upgrade IceCube-Gen2 is under development. To also boost the sensitivity of the surface array, IceTop, an enhancement consisting of a hybrid scintillation-detector and radio-antenna array is planned.

An optimized prototype station, consisting of eight scintillation detectors and three radio antennas, was deployed in January 2020. Both, scintillation detectors and radio antennas, are read out by a central hybrid data acquisition system (DAQ), researched, developed and built by a cooperation of DESY, UW-Madison and KIT. The scintillation detectors transfer digitized integrated signals to the DAQ to minimize the amount of transmitted data and trigger the radio antennas. The radio waveforms are transferred as analog signals to the central DAQ and are digitized and read out, when triggered by the scintillation detectors. In this contribution the enhanced prototype station and its DAQ will be presented and first measurement results will be shown.