IceTop upgrade with scintillators for IceCube-Gen2

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IceCube Observatory

IceCube is a high-energy neutrino detector covering a cubic-kilometer of Antarctic ice with 86 strings of optical modules. The observatory searches for astrophysical neutrinos to determine the origin and nature of high-energy cosmic-rays. A surface component of IceCube, IceTop, detects cosmic-ray air-showers with 162 ice Cherenkov tanks and constitutes a veto array for the in-ice measurements.

Photo credit: Martin Wolf, IceCube

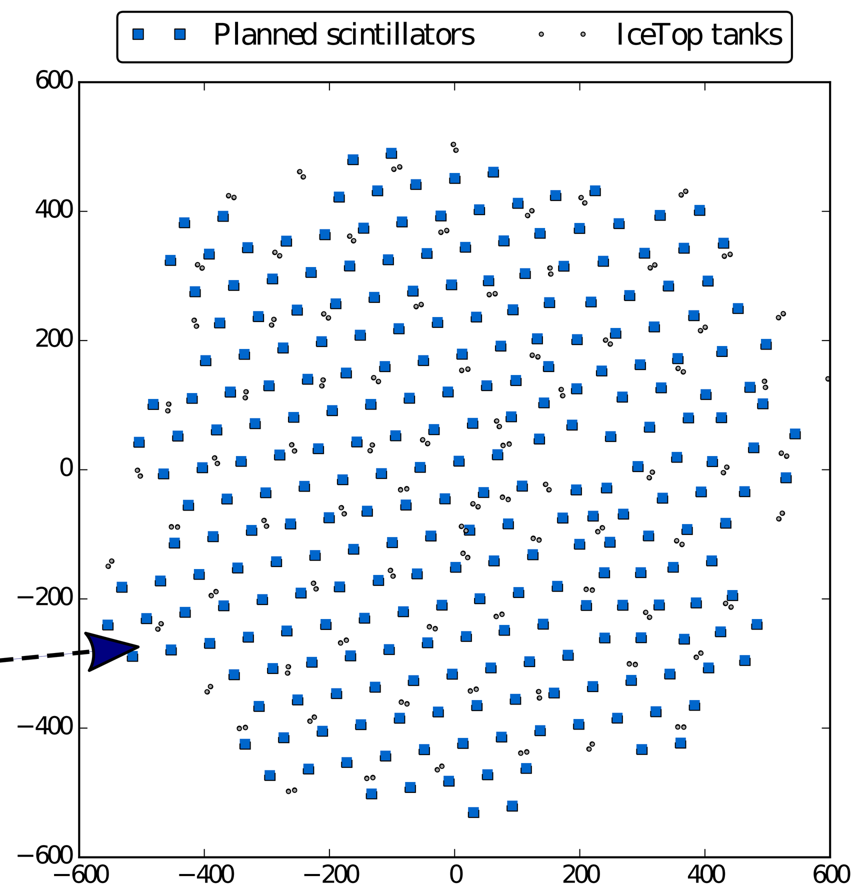

Fig. 1 Planned scintillator array at IceTop

Exceeding the limits of the present observatory can be obtained with a prospective scintillator array. Prototype stations of 7 panels each are currently under construction. One panel consists of 16 scintillator bars, wavelength shifting fibers, and a SiPM, providing an active area of 1.5 m^2. The surface extension will include 259 scintillation panels within IceTop area with 62.5 m spacing.

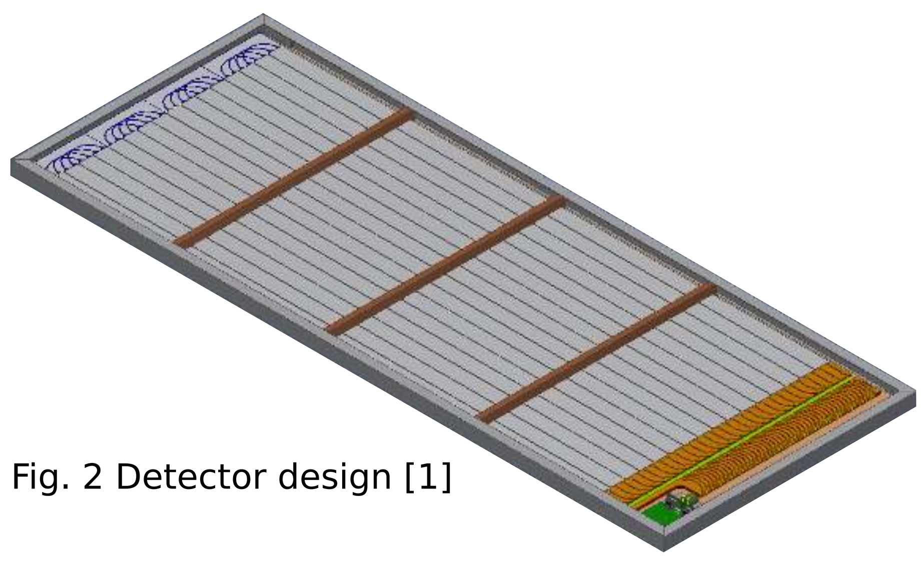

Fig. 2 Detector design [1]

Motivations

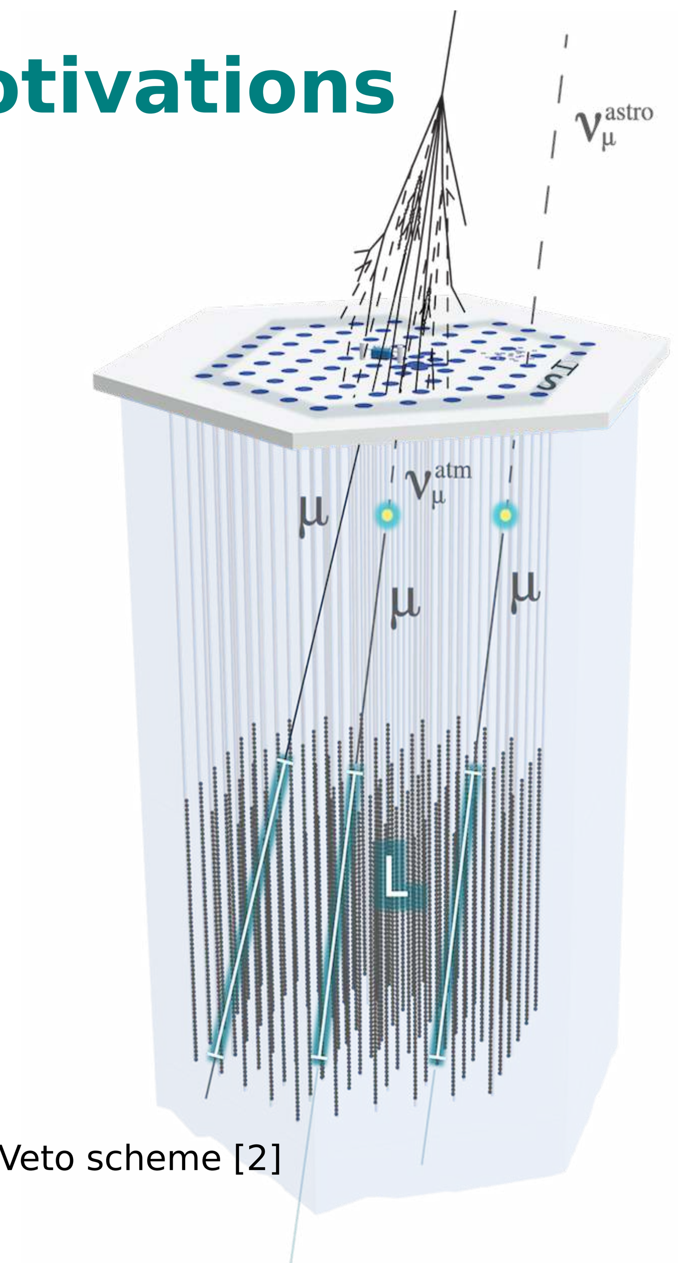

Fig. 3 Veto scheme [2]

One of the challenges of astrophysical neutrino detection is discriminating the signal from the atmospheric background. If an in-ice detection coincides with an air-shower at the surface detector it can be vetoed as a non-cosmogenic event. Scintillator extension will increase veto capabilities and lower the energy threshold.

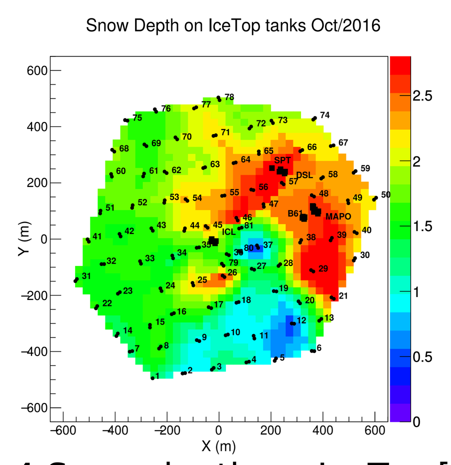

Fig. 4 Snow depth on IceTop [3]

Antarctic environment leads to snow accumulation on the surface detectors. Signal attenuation influences the shower reconstruction and dominates the systematic error in cosmic-ray measurements. The scintillator array will provide a reference signal for IceTop to quantify this attenuation.

Moreover, a study of the presented IceTop extension will contribute to design a future large surface array for the next generation neutrino-detector, **IceCube-Gen2.**

Simulation study

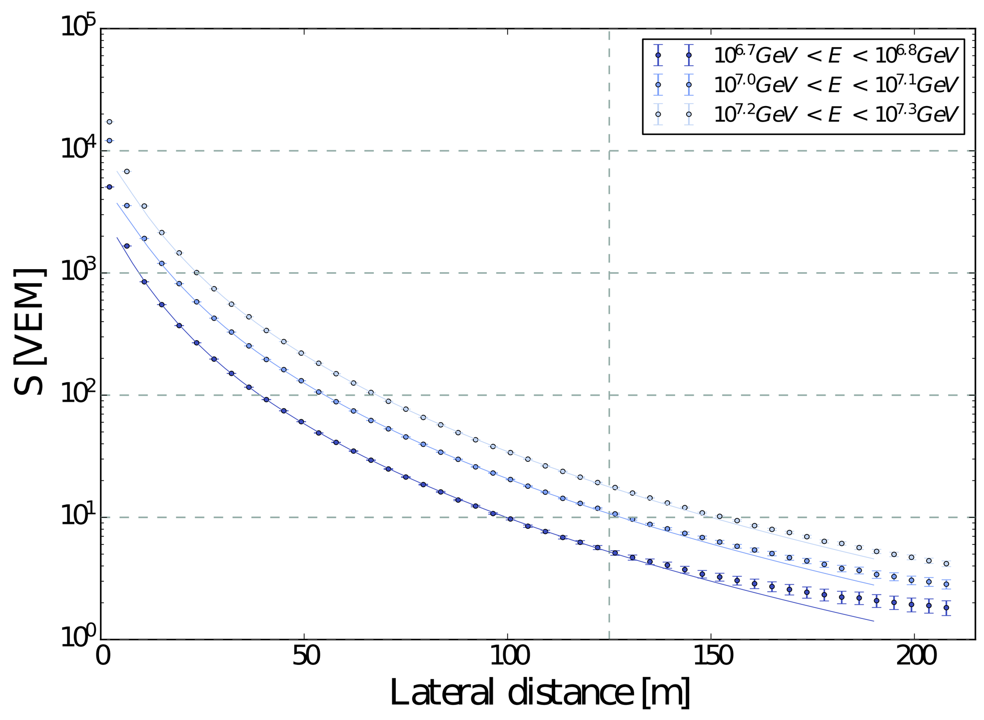

Fig. 5 Averaged lateral distributions for different energy bins

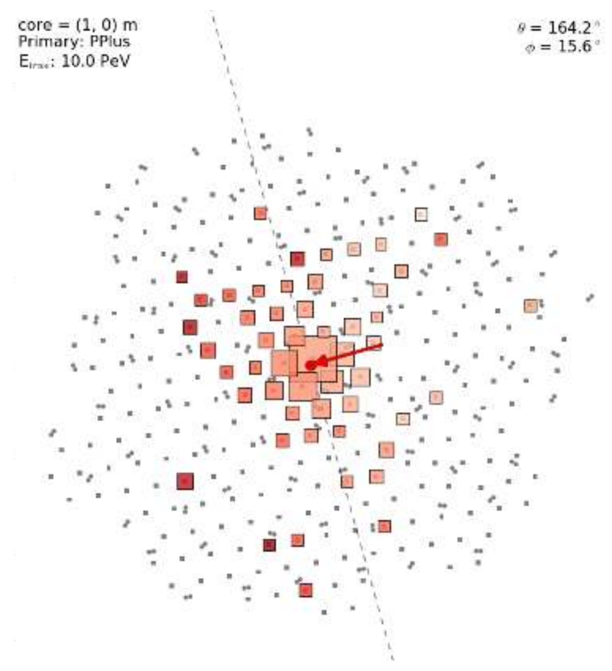

Fig. 6 Example of air-shower footprint

We obtained preliminary generic simulations for the scintillator array using CORSIKA [4] and a simplified model of the deposited energy within IceCube software. Lateral distribution and shower-front studies provide an air-shower parameterization enabling a proper reconstruction. Fit functions, obtained for IceTop tanks, effectively describe the distributions. However, the reconstruction has to be optimized to reduce the influence of the cosmic-ray composition.

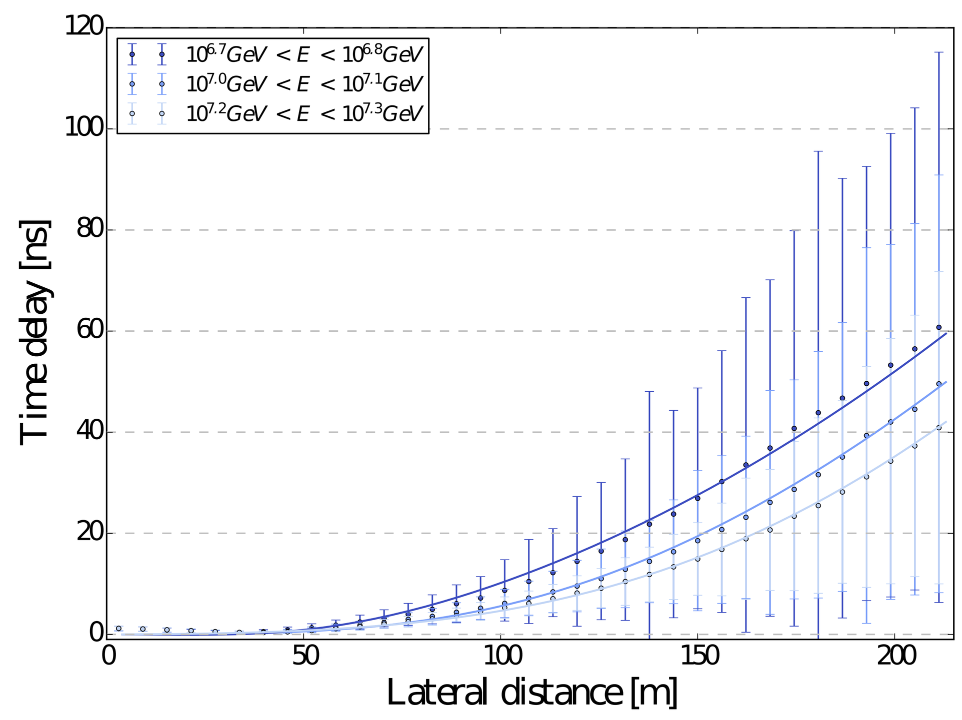

Fig. 7 Shower front for different energy bins

References:
[1] S. Kunwar, [IceCube Collaboration], "The IceTop - Gen2 Scintillator Upgrade", PoS (ICRC2017)
[2] D. Tosi et al., [IceCube Collaboration], "IceTop as Veto for IceCube", PoS (ICRC2015)
[3] D. Tosi, "The IceTop scintillator upgrade", 2016
[4] D. Heck et al., "CORSIKA: a Monte Carlo code to simulate extensive air showers", Forschungszentrum Karlsruhe GmbH (1998)

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