Development of a Scintillation and Radio Hybrid Detector Array at the South Pole
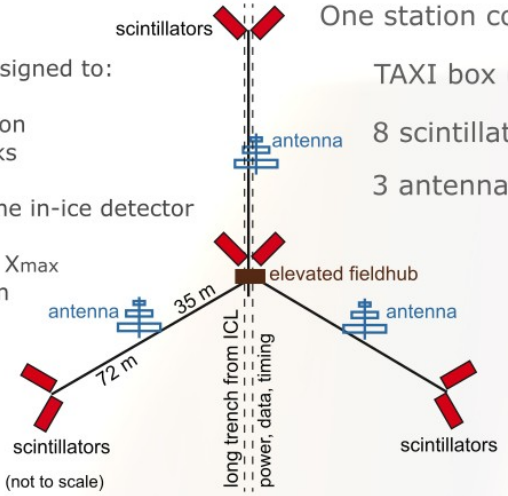
M. Oehler and R. Turcotte-Tardif for the IceCube Collaboration

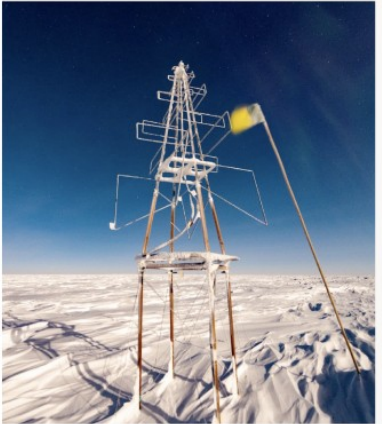# STATION

Enhanced surface array is designed to:

Mitigate snow accumulation effects on the IceTop tanks

Veto the background of the in-ice detector

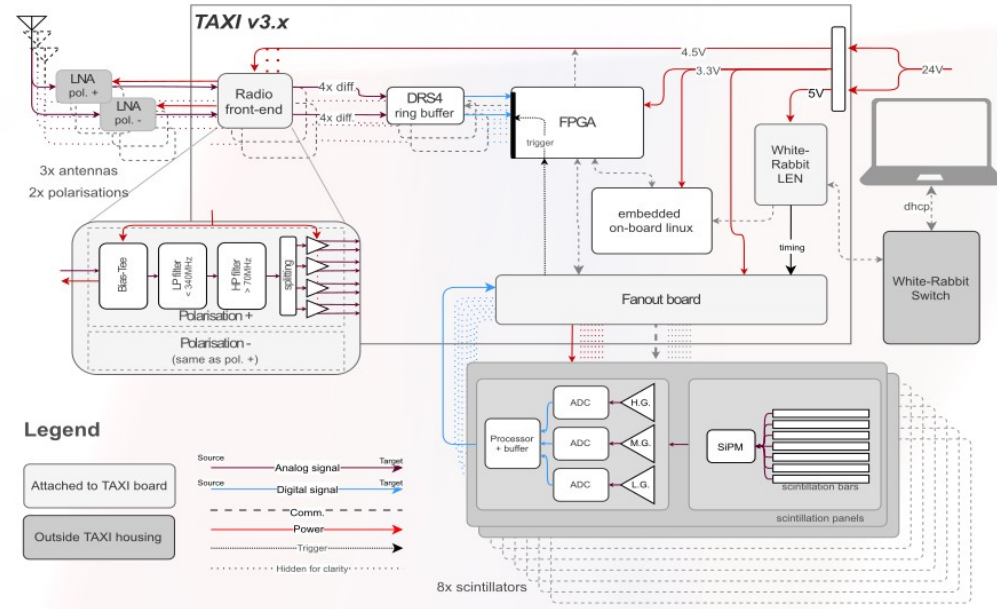Increase the accuracy on X_{max} and energy reconstruction

A prototype station was deployed in January 2020

One station comprises :

TAXI box (in the fieldhub)

8 scintillation detectors

3 antennas

scintillators
antenna
antenna
elevated fieldhub
35 m
72 m
long trench from ICL
power, data, timing
antenna
scintillators
scintillators

(not to scale)

Picture credit: Y. Makino, IceCube/NSF

TAXI v3.x

LNA pol. +
LNA pol. -
Radio front-end
4x diff
4x diff
trigger
DRS4 ring buffer
FPGA
4.5V
3.3V
5V
24V
White-Rabbit LEN
timing
dhcp
White-Rabbit Switch

3x antennas
2x polarisations

Bias-Tee
LP filter < 340 MHz
HP filter > 70 MHz
splitting
Polarisation +
Polarisation −
(same as pol. +)

embedded on-board linux

Fanout board

Processor + buffer
ADC H.G.
ADC M.G.
ADC L.G.
SiPM
scintillation bars
scintillation panels

8x scintillators

Legend

Attached to TAXI board
Outside TAXI housing

Source — Analog signal → Target
Source — Digital signal → Target
- - - - Comm. - - - -
—— Power ——
······ Trigger ······
- · - · - Hidden for clarity

The TAXI board has an embedded Linux operating system running on a microprocessor for processing the signals and provides power, communication and timing for the scintillation detectors

The White Rabbit (WR) system provides nanosecond timing

The DRS4 sampling chip is a 8+1 channel ring buffer chip with 1024 sampling cells each.

Radio signal is digitized by 8-channels, 14 bit ADCs

Possibility of trace lengths of 1024 ns, 2048 ns or 4096 ns

Sampling rate of 1GHz

The radio and scintillator data is sent via a 1 Gb fiber link to the IceCube Lab (ICL) using a WR layer

SCINTILLATOR

Each scintillator panel has a sensitive area of 1.5 m² and weights less than 50 kg

16 extruded plastic scintillation bars with a height of 1 cm polystyrene with a TiO₂ reflective layer

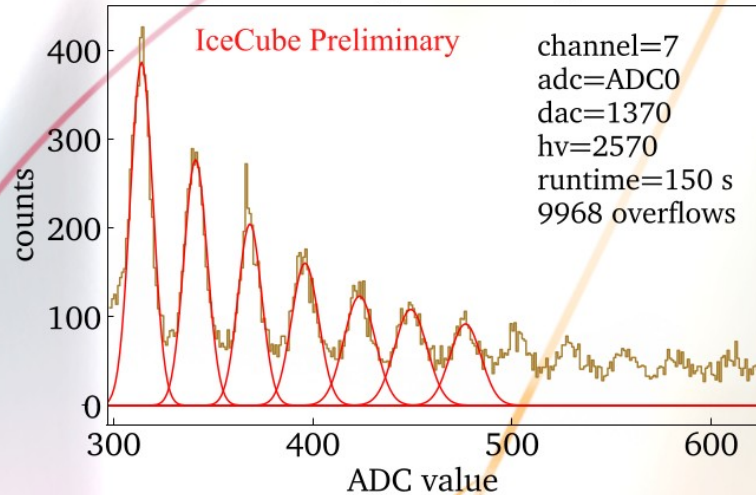Wavelength shifting fibers are routed through the bars and are read out by a SiPM

Scintillator MicroDAQ v4.1 sends data in a digitized format

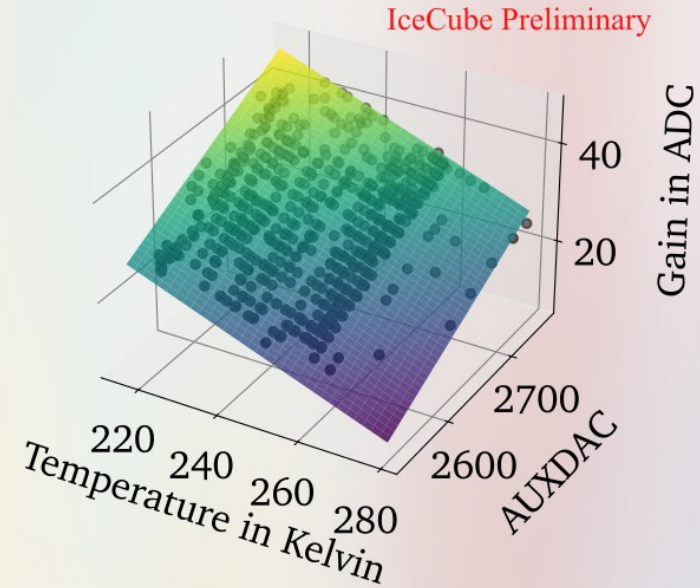SiPM gain depends on temperature

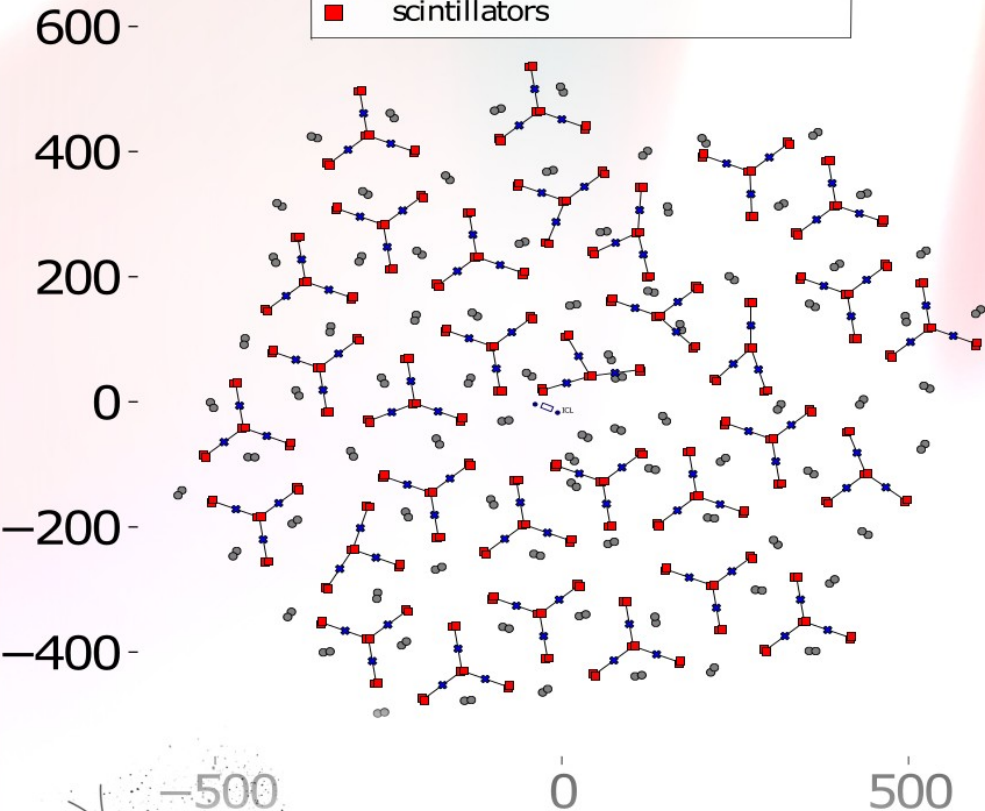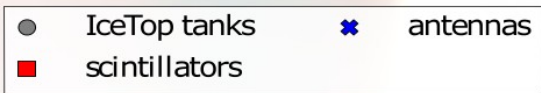Calculated from the distance of the single P.E. peaks in the charge histogram

Voltage can be adjusted as function of the temperature for constant gain

Charge Histogram

IceCube Preliminary

channel=7
adc=ADC0
dac=1370
hv=2570
runtime=150 s
9968 overflows

Channel 7 Gain Dependence

IceCube Preliminary

RADIO

SKALA-2 antennas with dual arms

Pre-processing board:
filtering (70-350 MHz) and amplifying
the signal

Median spectrum of one day
of radio background data

The black line is the galactic noise
based on the Cane model and
convoluted with the electronic chain

The galactic noise is,
as wanted, the noise floor
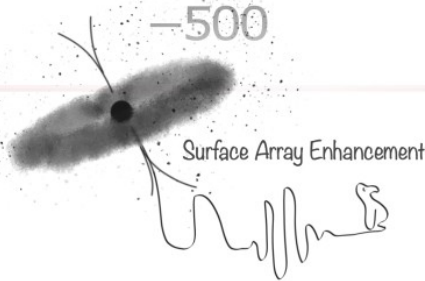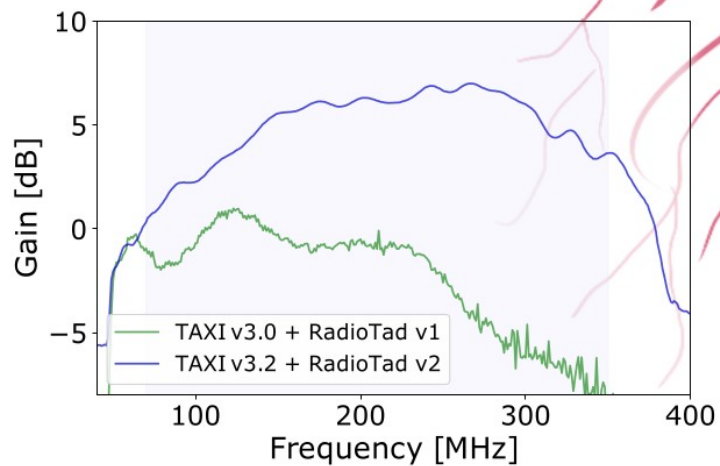of the radio electronics

DEPLOYMENT

Final array : 32 stations by 2026

1 km² of instrumented area

Electronics optimized

The gain for the radio signal is higher and more uniform throughout the band of interest. The deviation between the channels of the radioTads is below 10%

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Surface Array Enhancement

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