The Scintillator Upgrade of IceTop

Performance of the Surface Array

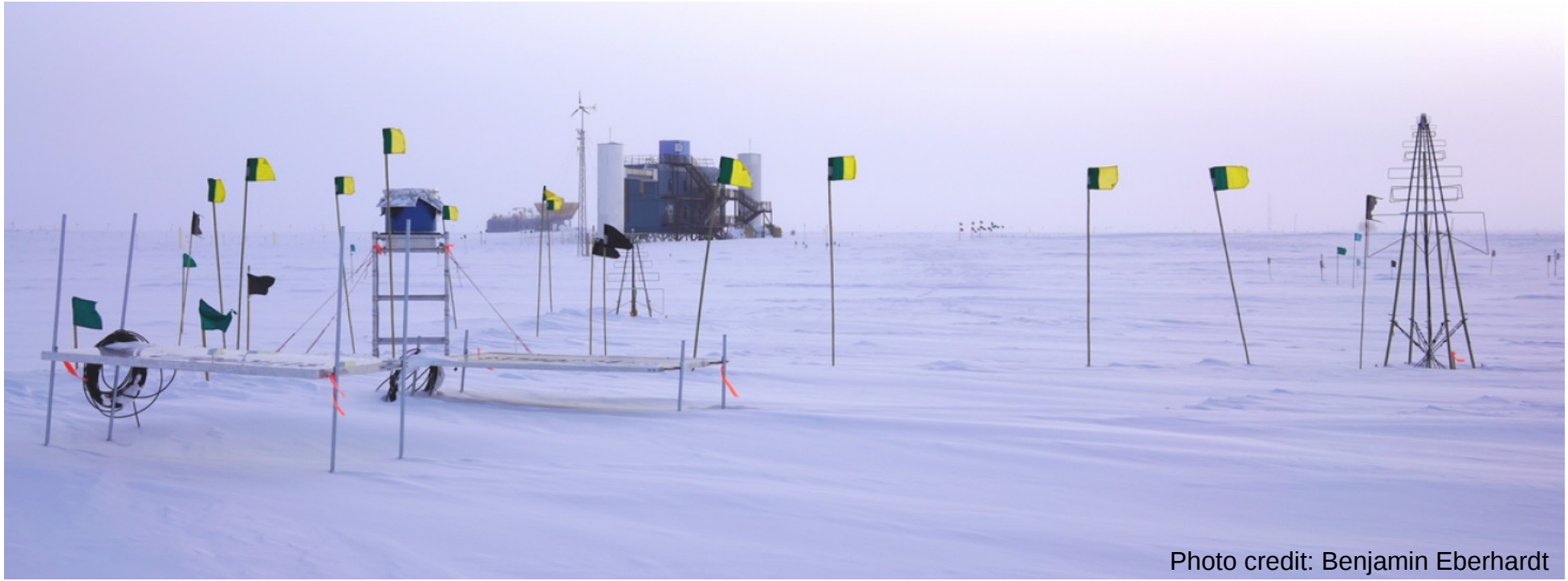


Photo credit: Benjamin Eberhardt

ICRC 2019 – July 26
Madison, Wisconsin, USA
Matt Kauer – for the IceCube Collaboration

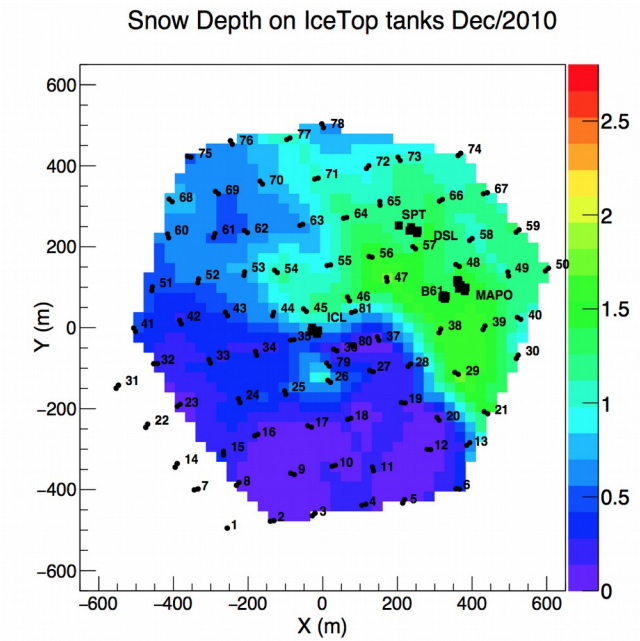
IceCube
South Pole Neutrino Observatory

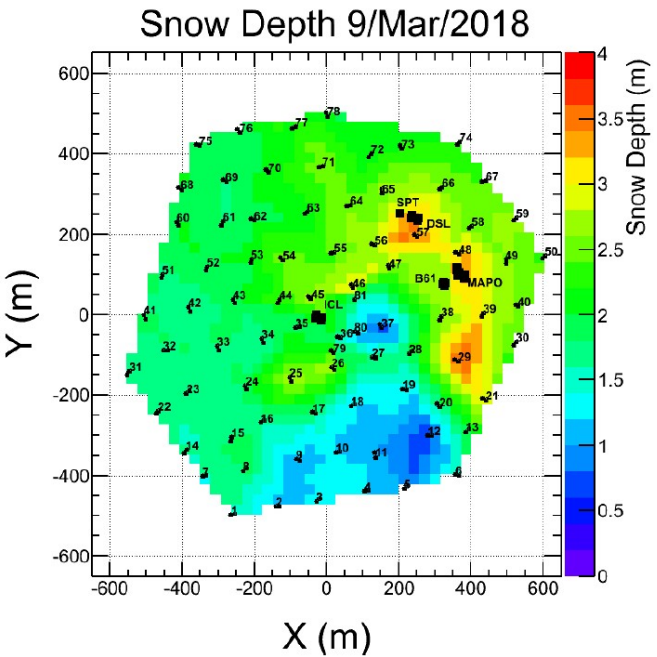
Outline

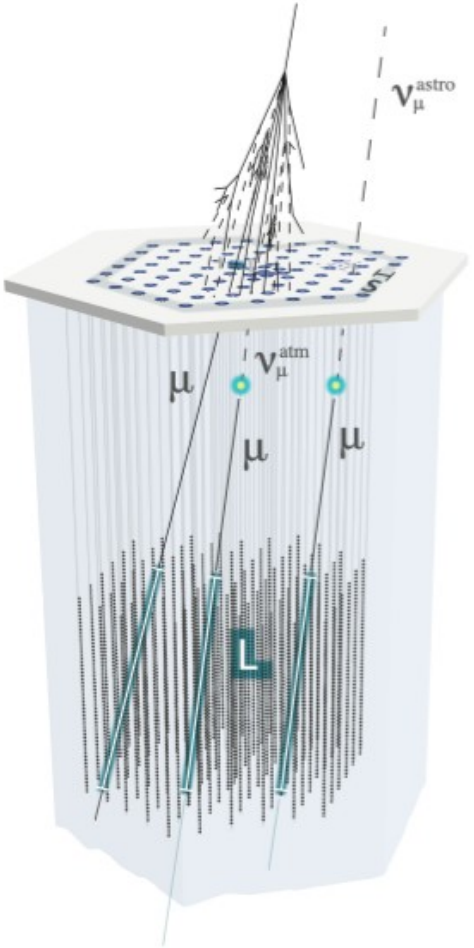
- Motivation
- Scintillator panel design, DAQ, and Surface Field Hub
- Characterization, Temperature Compensation, and Stability
- Optical Simulations
- Prototype Deployment
- Array performance
- Simulations
- Summary

Motivation

- IceTop is accumulating about 20cm of snow a year and the energy threshold is increasing
- We need a cost effective and robust IceTop upgrade to push the energy threshold back down and do more cosmic ray physics
- Also a proof of design of the infrastructure in development for the IceCube Upgrade



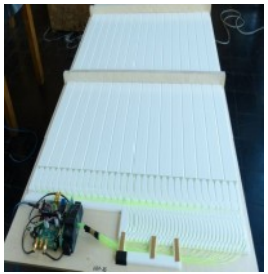


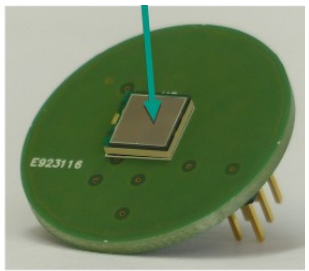


See D. Tosi's talk up next...

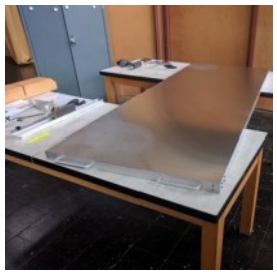
Scintillator Panel Design

- 16 scintillator bars extruded by FNAL, 1cm x 5cm x 1.875m (area = 1.5 m^2)
- 16 Kuraray Y11(300) wavelength shifting fibers looped through 2.5mm holes in the scintillator
- 32 fiber ends read out by 6x6 mm^2 Hamamatsu 13360-6025PE (25um pitch)
- On-board electronics (voltage control, temperature sensor readout, data transfer)





On-board Electronics



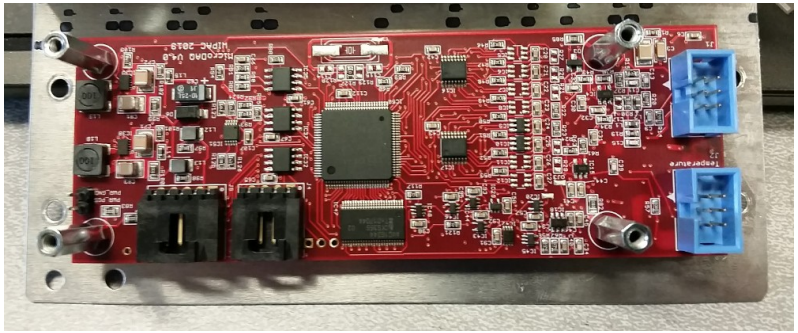
Surface Field Hub

The DAQs

Two different DAQ concepts tested

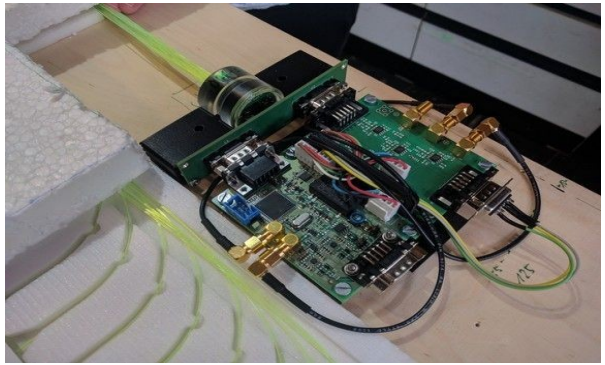
microDAQ

- 3 gain channels operating simultaneously
- Waveforms are charge integrated and charge plus timestamp digitally transferred to the surface field hub
- SiPM gain is temperature compensated via bias voltage control from the microDAQ firmware



Analog Readout Module

- 2 selectable gain channels
- Waveforms transferred analog to the surface field hub (SFH)
- Timestamps provided by the SFH
- SiPM gain is temperature compensated via bias voltage in SFH firmware

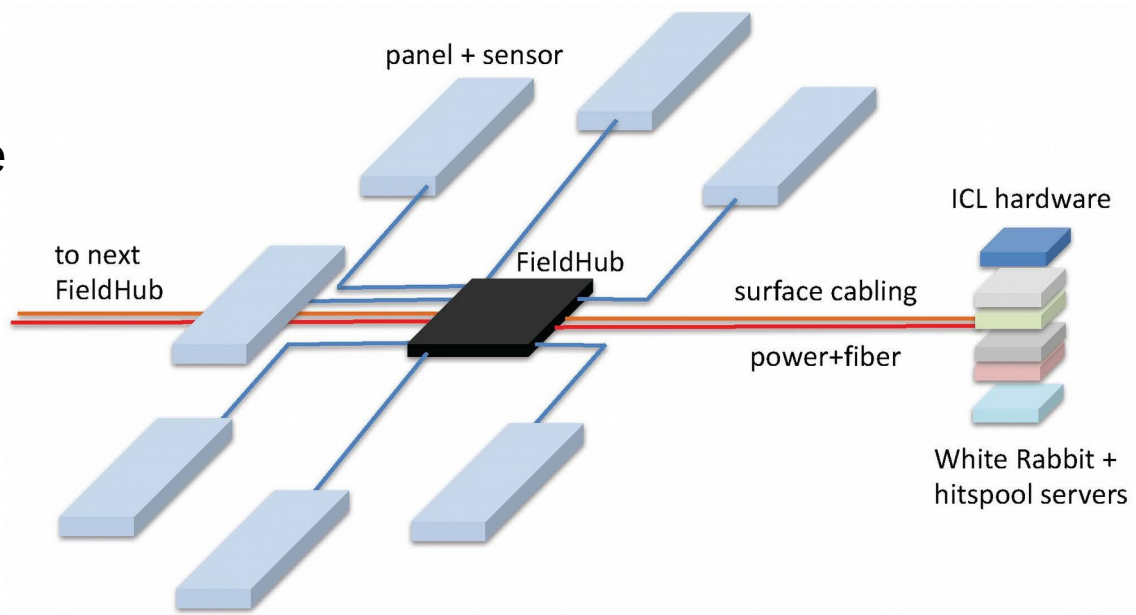


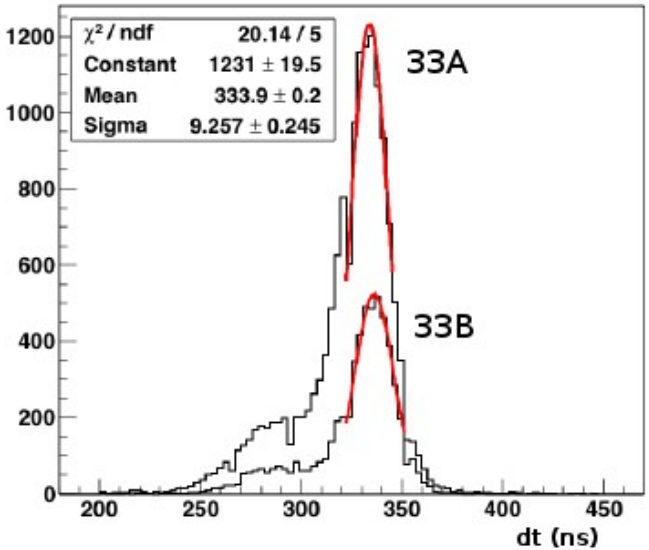
Hybrid-DAQ in development for the IceTop Upgrade

- Combine the best attributes of both...

Surface Field Hubs

Proof of concept for the IceCube Upgrade
- Timing and Coms via WR-LEN fiber
- Power via copper



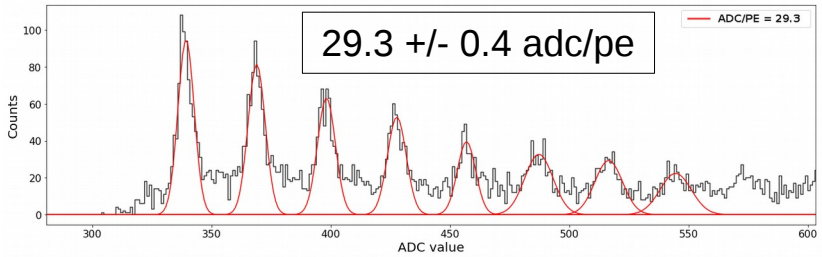


- Timing transferred via copper from the SFH to the scint panel
- Coincident events with IceTop are ~330ns offset due to 70m of copper cable delay between the SFH and the scint.

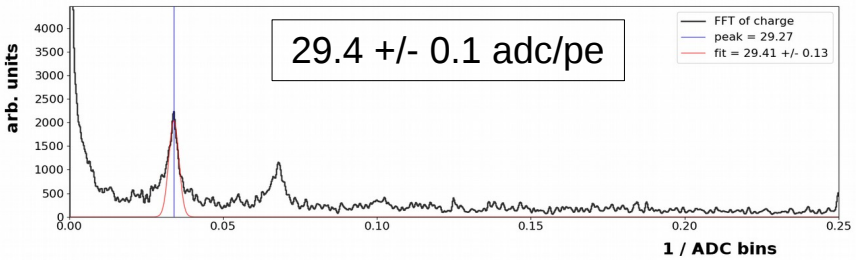
Characterization

Measure the gain and light yield of the scint panels in-situ

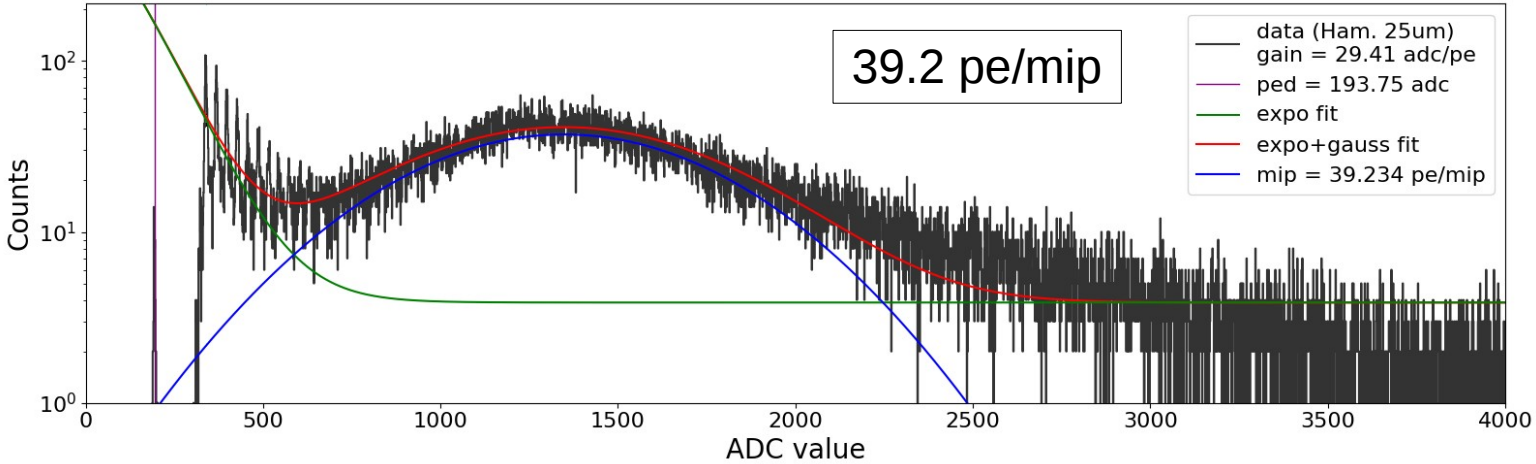
Measure the gain using PE peak separation from Gaussian fits



Much quicker and more robust method is to take the FFT of the finger spectrum

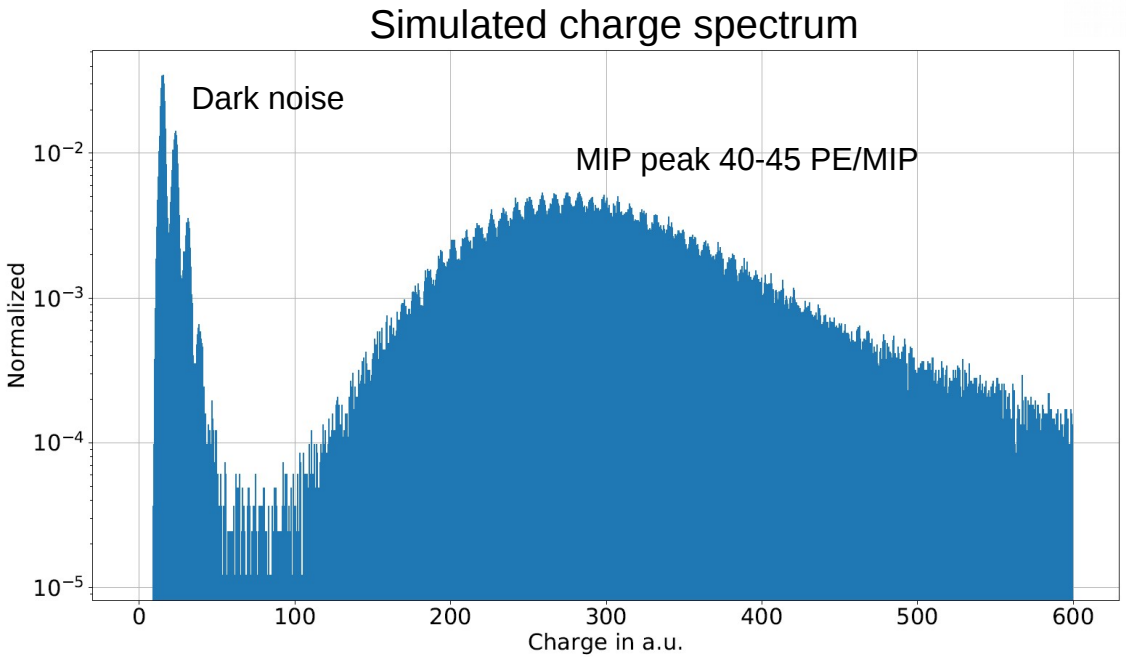


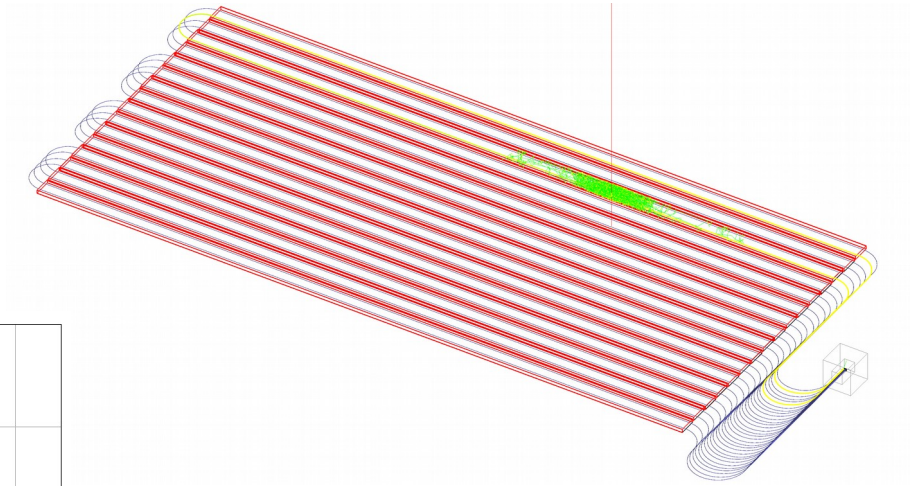
Measure the light yield from the scint panel by fitting the minimally ionizing particle (MIP) peak

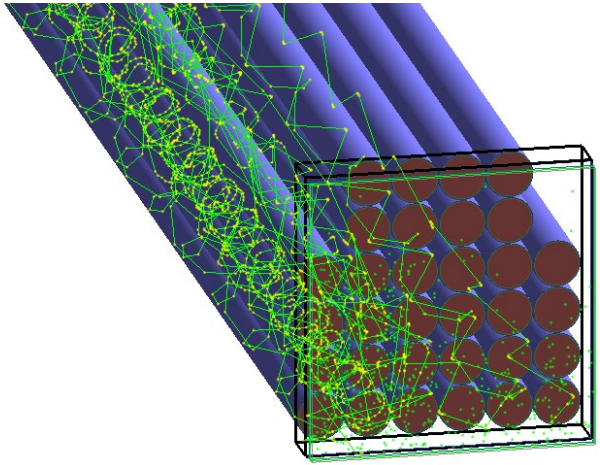


Optical Simulations

- Exhaustive Geant4.10 optical simulations return 40-45 PE/MIP
- Consistent with measurements

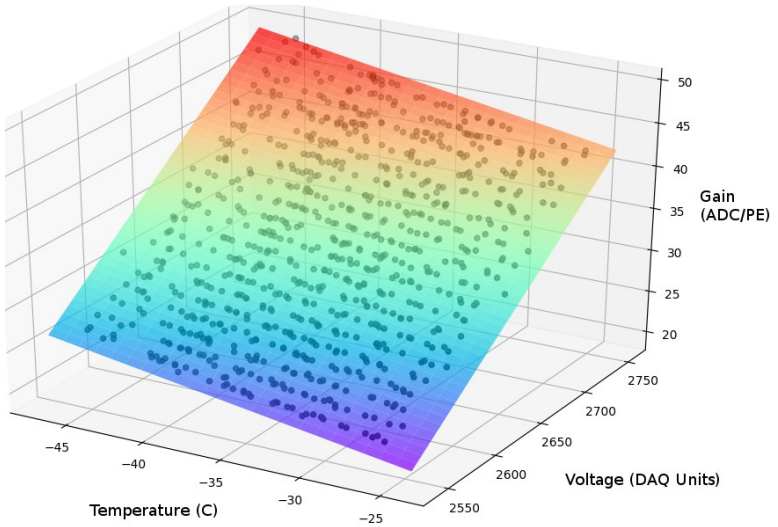


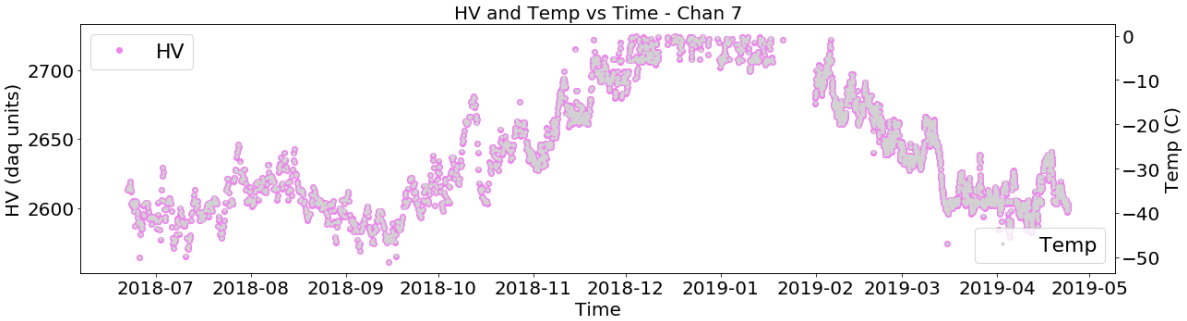


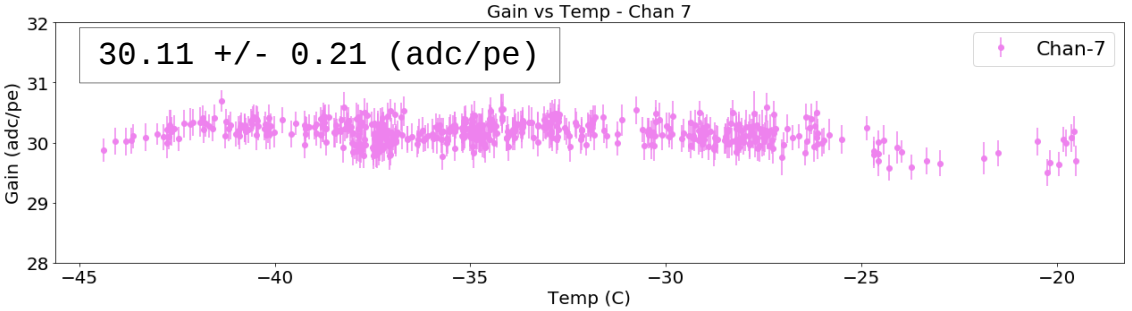


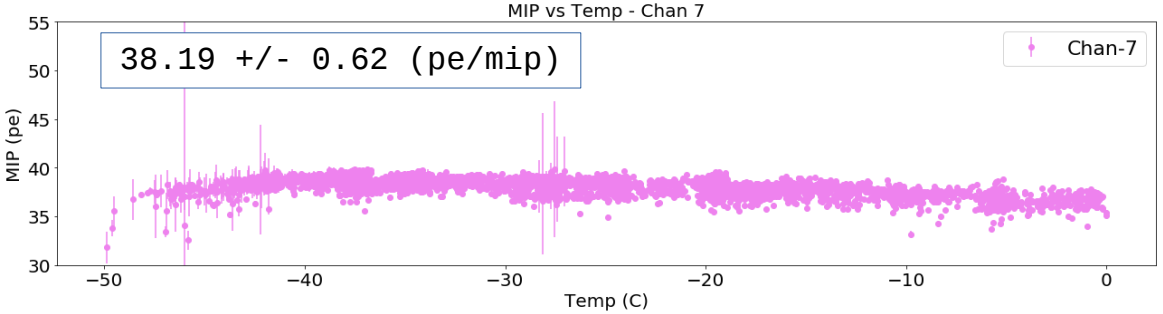
See A. Leszczynska and M. Plum's poster (PS1-190)
Great Hall, 4th floor, after this session

Temperature Compensation and Stability





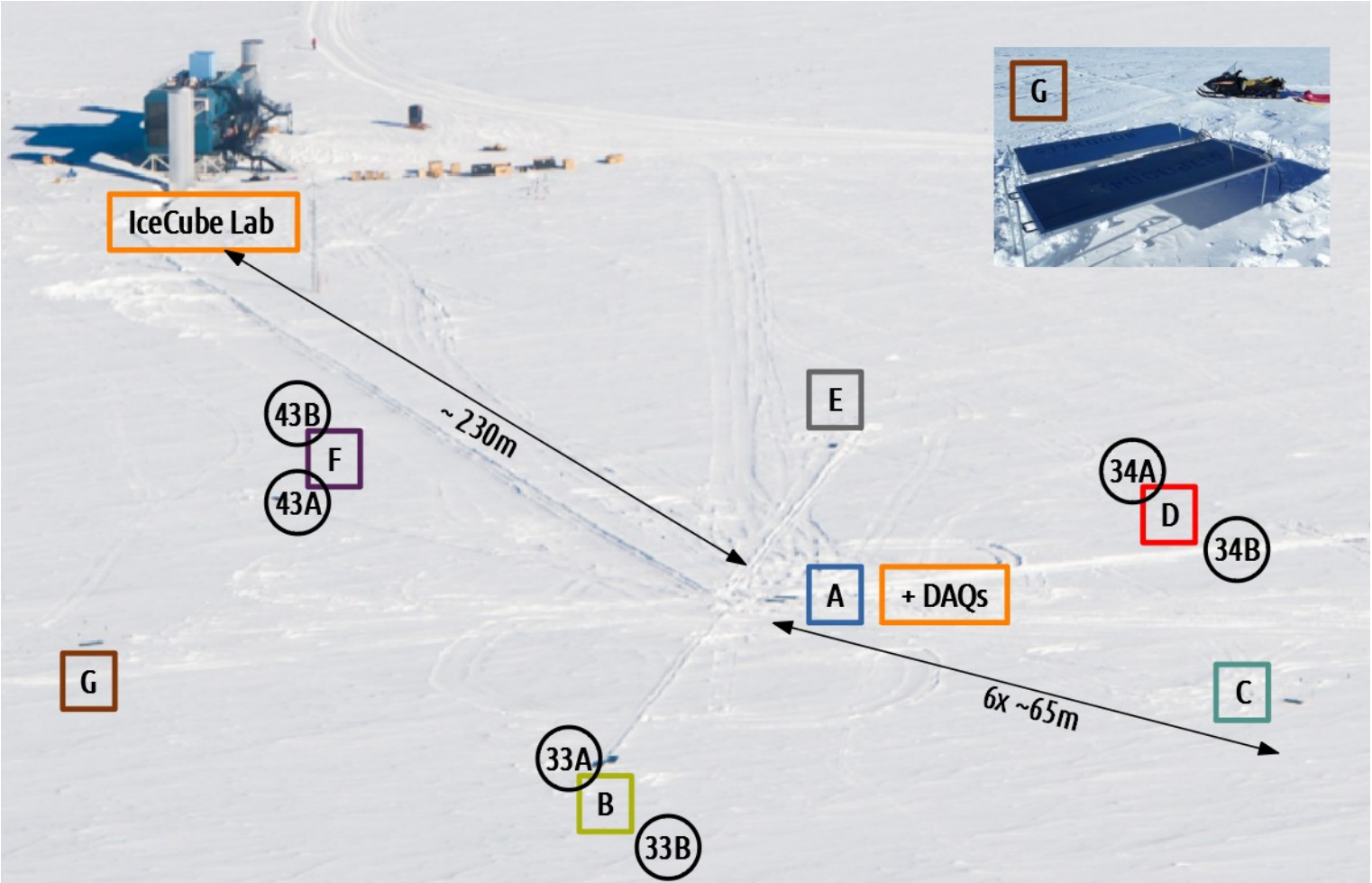




- Fit the temp-volt-gain plane
- Use the fit constants for the temp compensation
- Currently set to a gain of 30 ADC/PE to optimize the dynamic range of the DAQ

Prototype Deployment

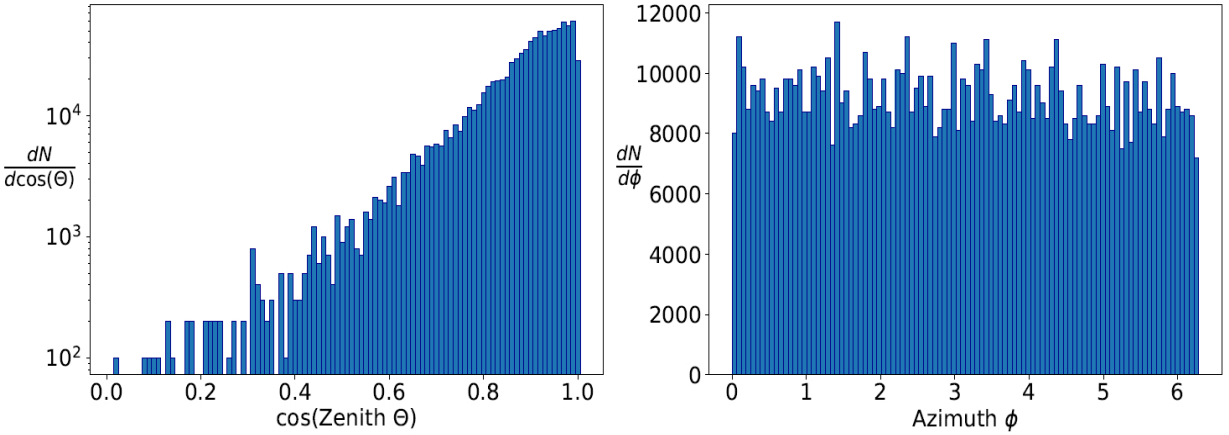
- Deployed Jan 2018
- 3 scint pairs over/near IceTop stations
- Surface field hubs at the center of the array

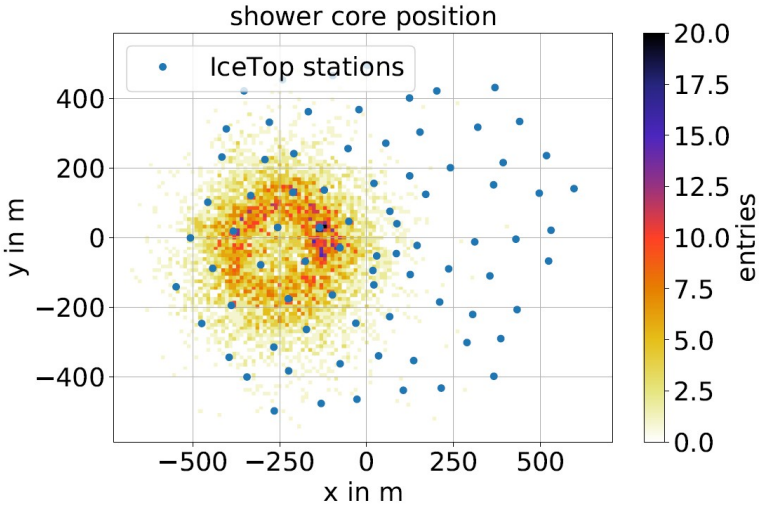


Prototype Array Performance

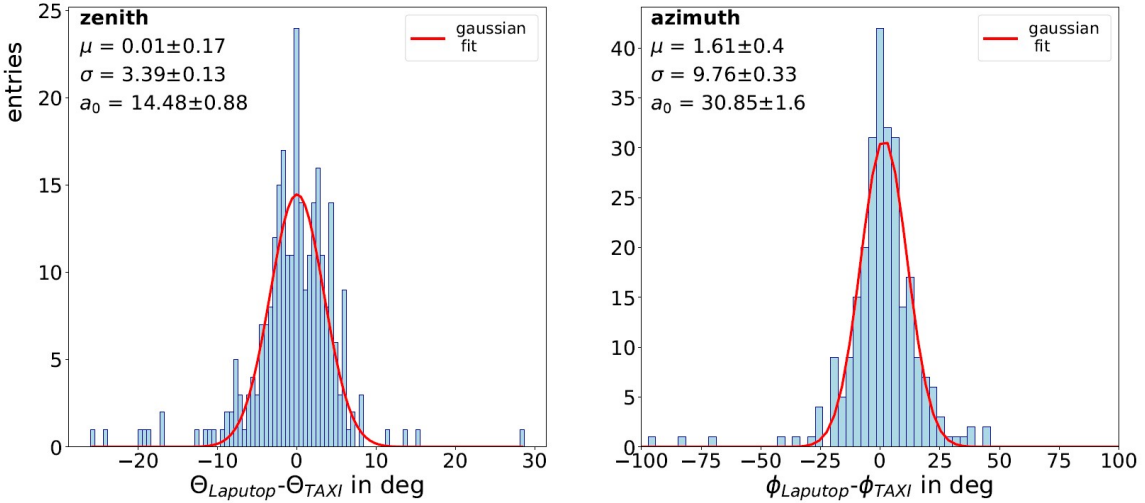
- Reconstructed showers coincident with IceTop
- Resolution limited by small size of the Scint array

Scintillator Array Shower Reconstructions





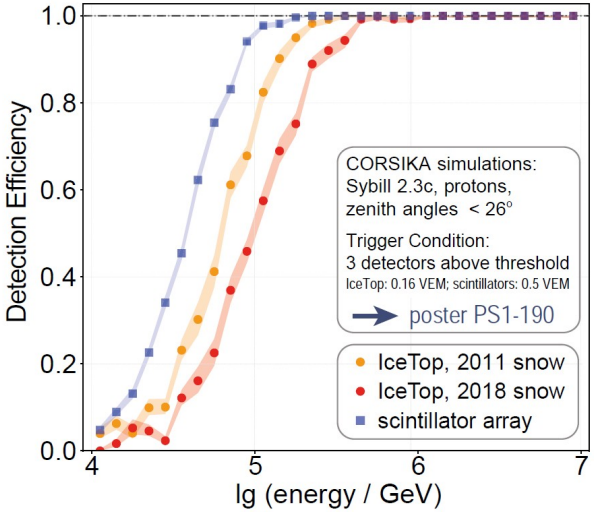
Compared to IceTop Reconstructions

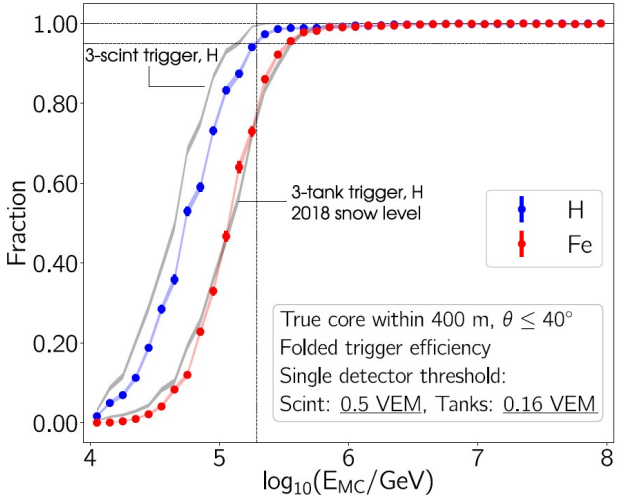


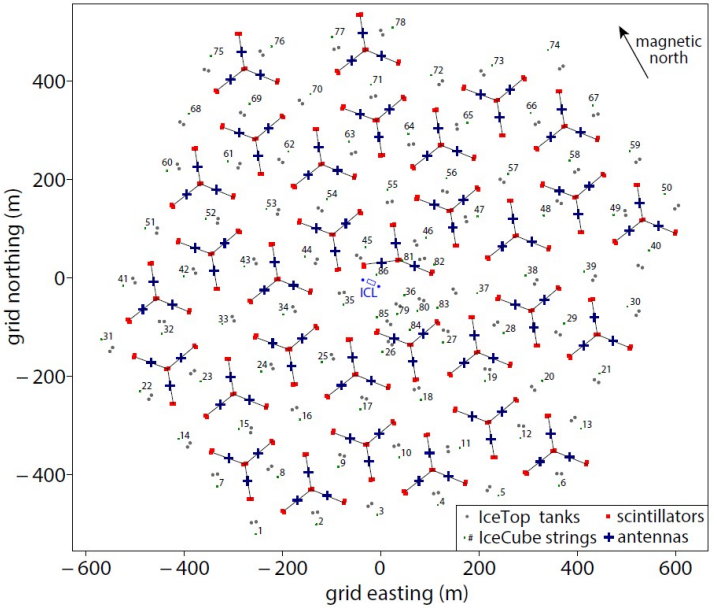
Scintillator Upgrade Simulations

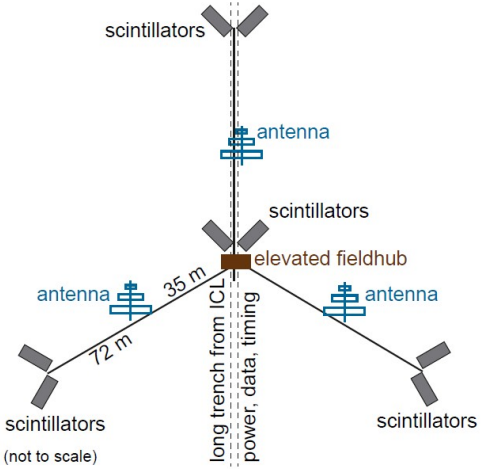
- IceTop Upgrade plans for 32 stations with 8 scintillator panels at each station
- Iron induced shower threshold ~250 TeV
- Proton induced shower threshold ~200 TeV

Threshold Improvement





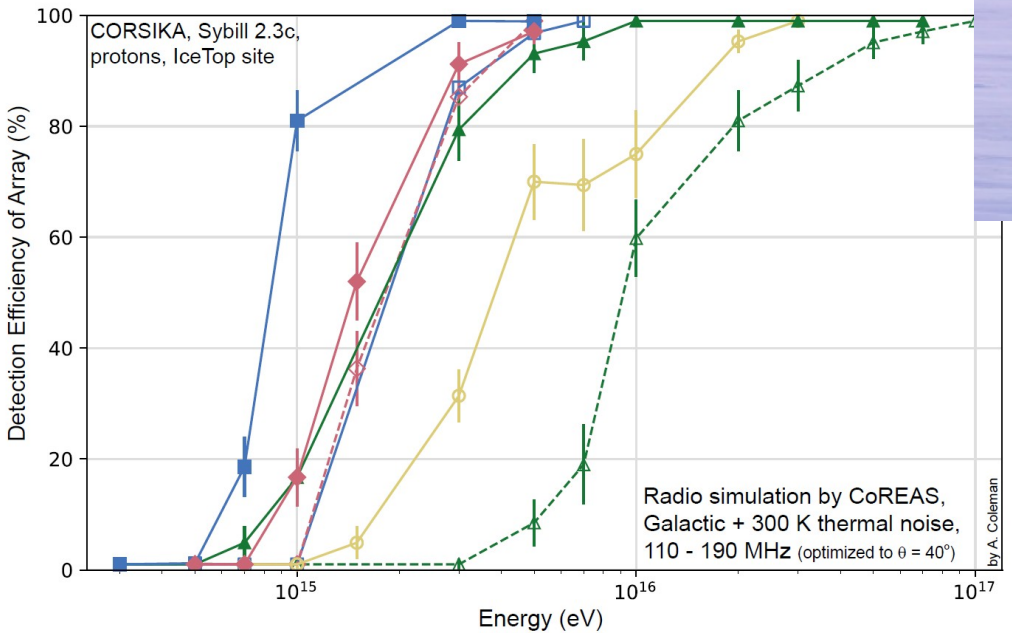


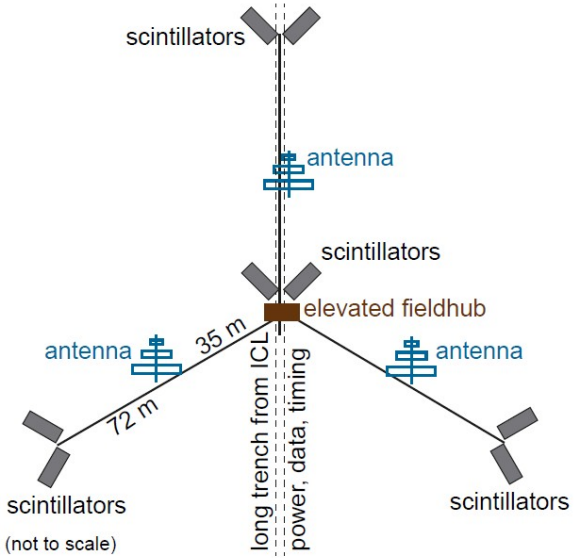


See A. Leszczynska and M. Plum's poster (PS1-190)
Great Hall, 4th floor, after this session

Radio Extension

- IceTop Upgrade plans for 32 stations with 3 antennas at each station
- 3 scint to trigger radio
- Energy range 0.2 PeV – 1.0 EeV





See F.G. Schroeder's poster (PS1-210)
Great Hall, 4th floor, after this session
And M. Renschler's poster (PS3-207)
Great Hall, 4th floor, Tuesday afternoon

Summary

- Two successful prototype arrays operating since 2018
- Scintillator arrays are well characterized and stable
- Successful proof of design of the surface field hub towards the IceCube Upgrade
- Shower reconstructions are consistent with IceTop
- IceTop Upgrade simulations demonstrate significant improvements for cosmic ray science
- Refurbished prototype station to be deployed January 2020

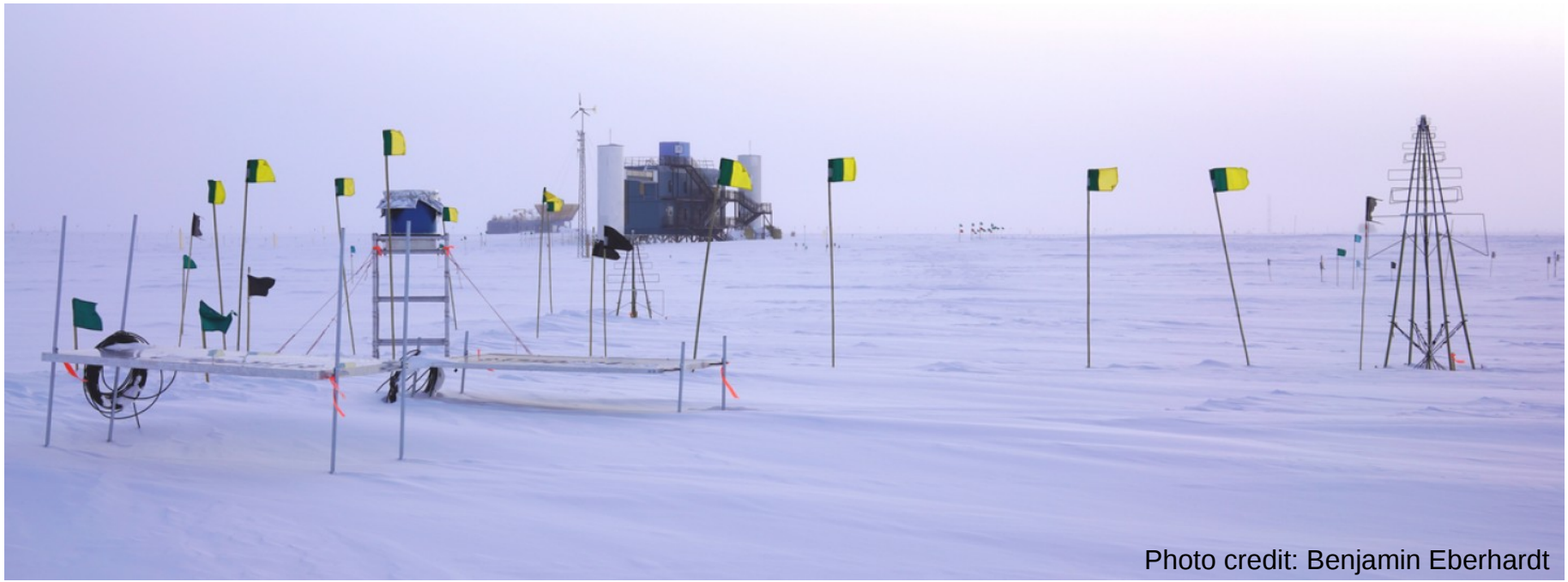


Photo credit: Benjamin Eberhardt