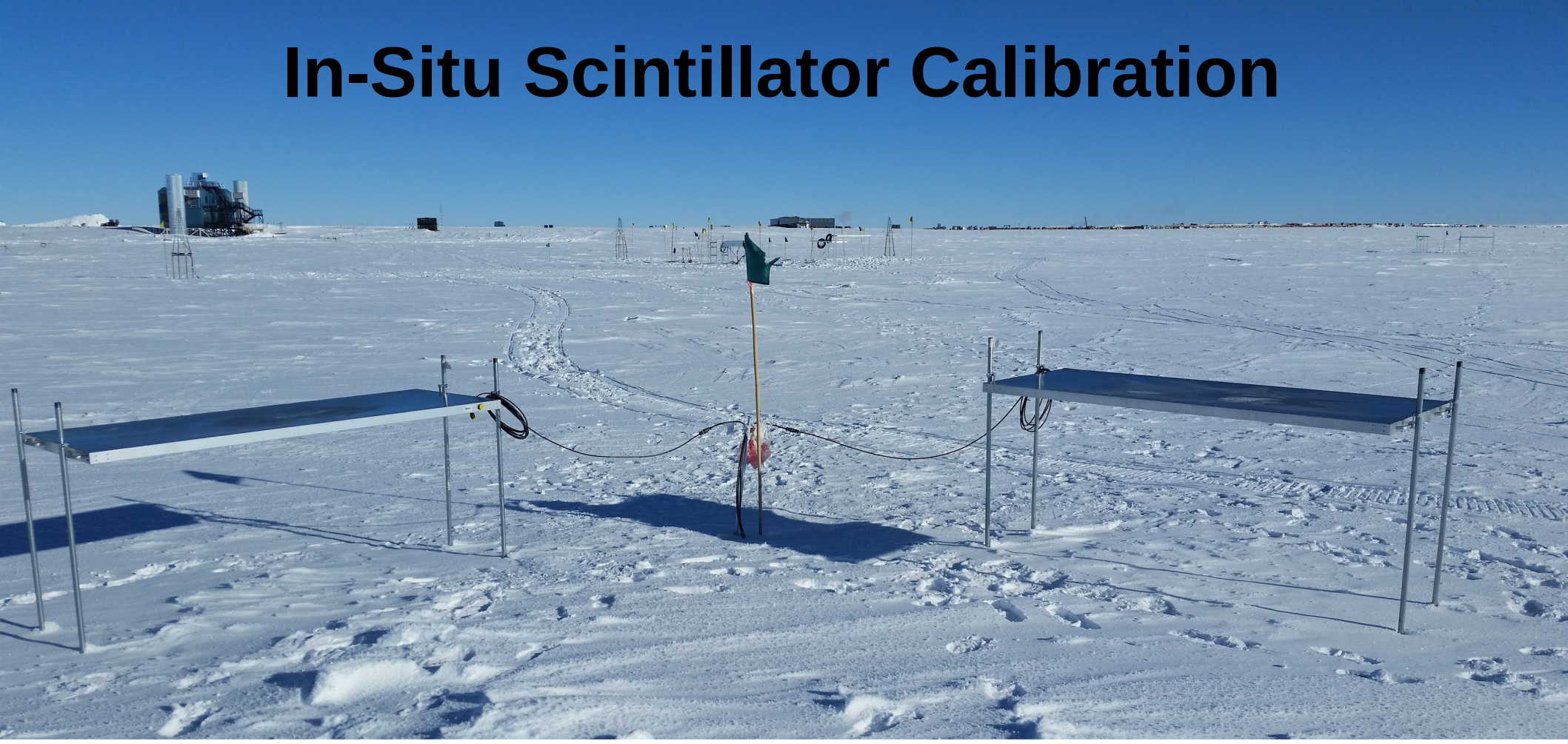
In-Situ Scintillator Calibration



IceCube-Gen2 Calibration Workshop

April 9, 2021

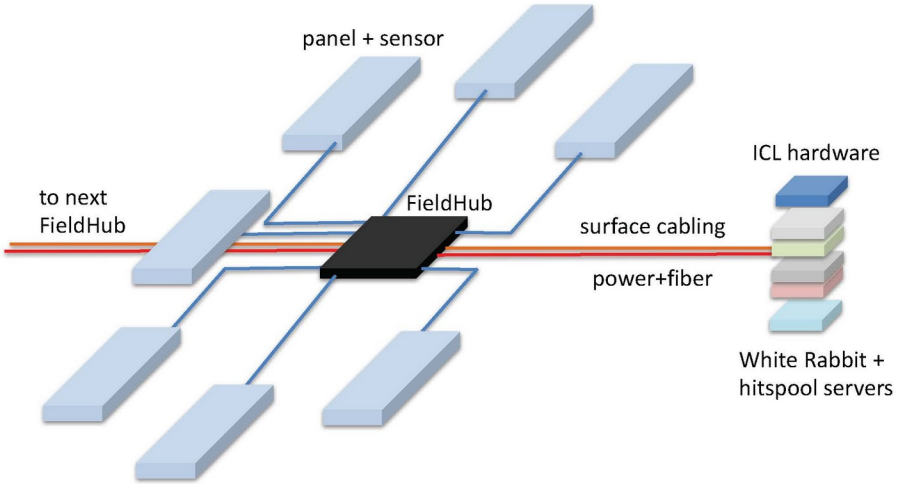
Matt Kauer on behalf of the group

IceCube
South Pole Neutrino Observatory

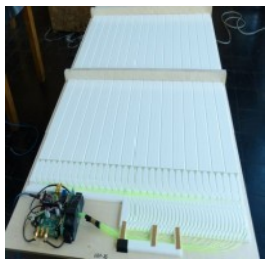
Scintillator Hardware Overview

ICL provides power/comms/clock to FieldHub
- Power via copper
- Comms/clock via fiber

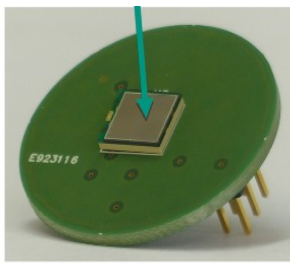
FieldHub provides power/comms/clock to panels
- All via copper



Scint bars
+ WLS fiber

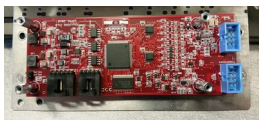


SiPM

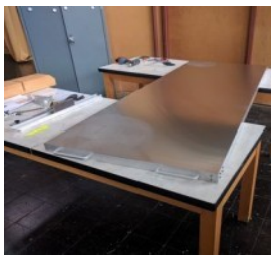


SiPM/fiber
coupling

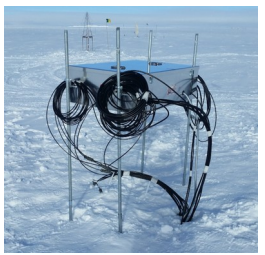
uDAQ



Panel



Field-Hub



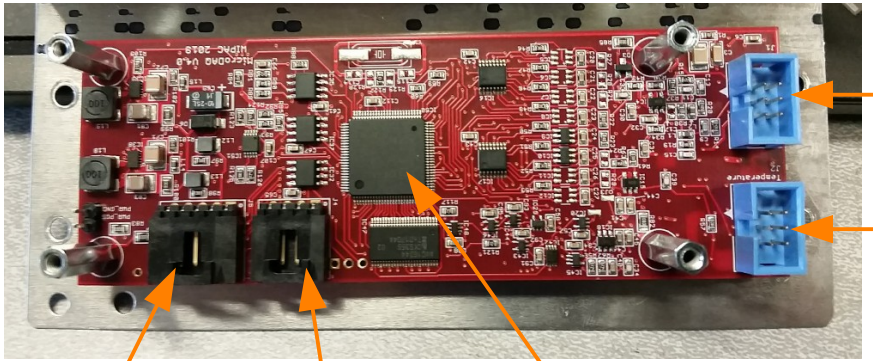
MicroDAQ (uDAQ)

3 gain channels recorded simultaneously
- 1000 VEM dynamic range

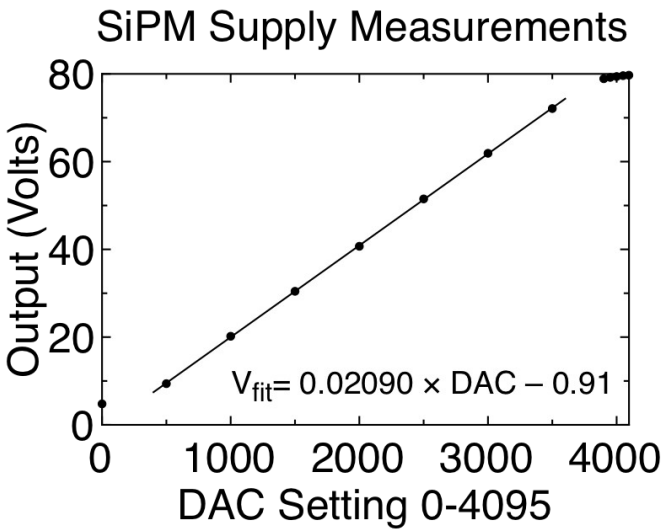
Onboard timestamps
- ~1 ns resolution

Hits sent as chargestamps
- Timestamp
- Charges from 3 gain channels
- CPU trigger flag

1Hz CPU triggers to capture pedestal
Similar to IceCube baseline beacons



Linear mapping of DAQ units to applied SiPM voltage.

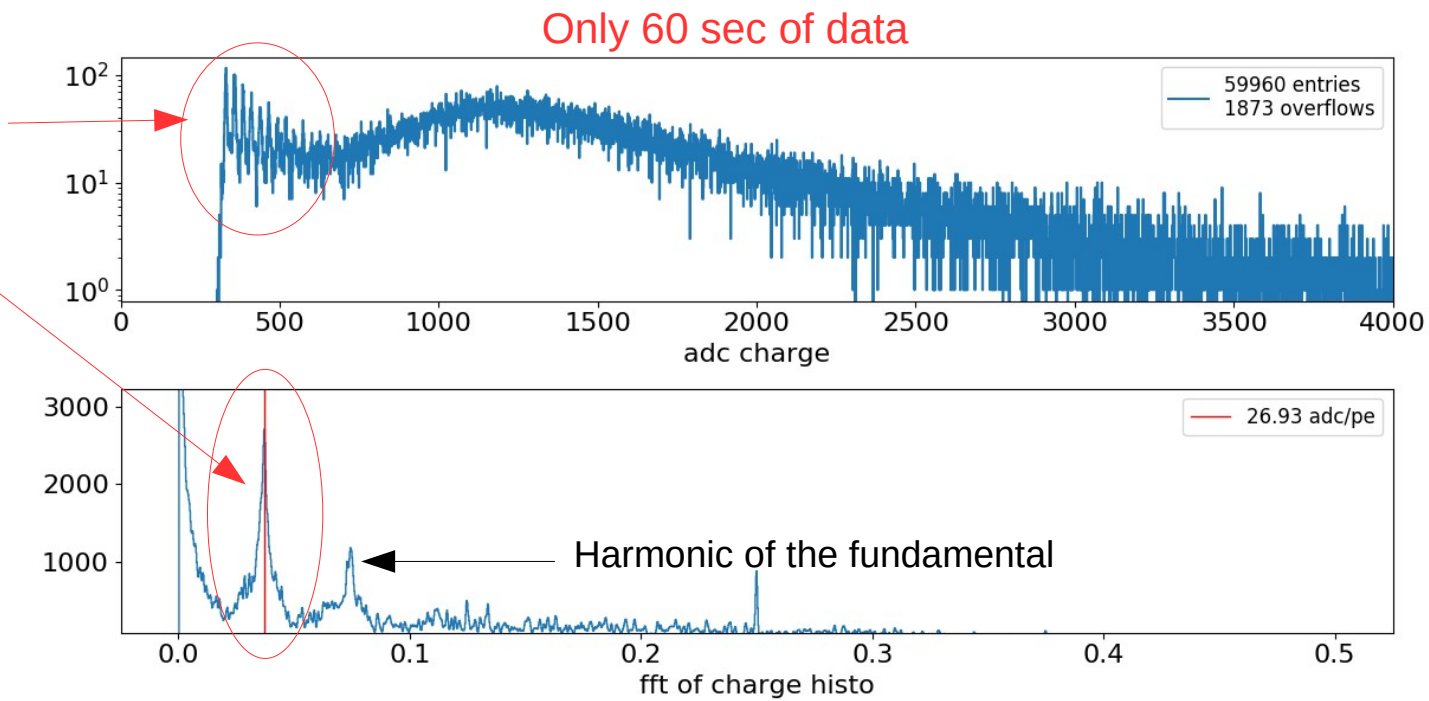


Gain Measurement

Panel thresholds typically 3-5 pe
Evident finger spectrum
Take the FFT to extract the gain
Caveat: Only works for the high gain channel

The pe peaks are a strong sine in freq space.

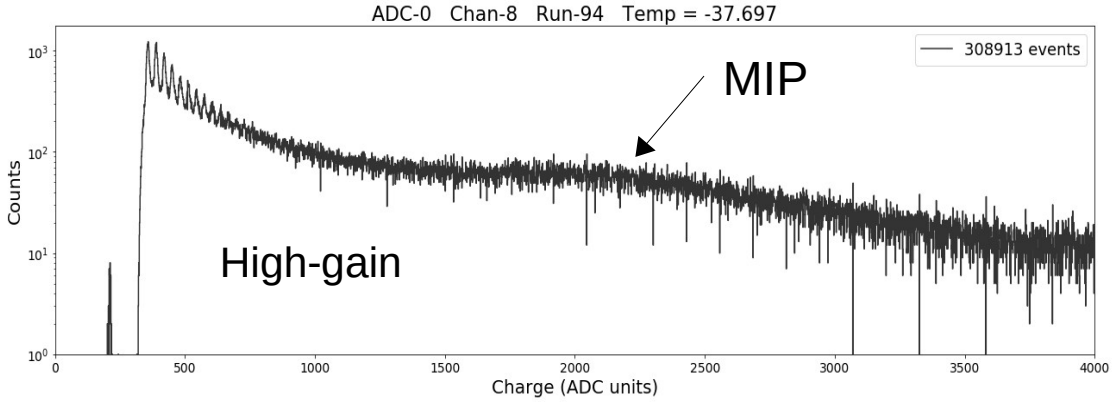
No magic initial conditions, bounds, etc. Just FFT the whole histogram.

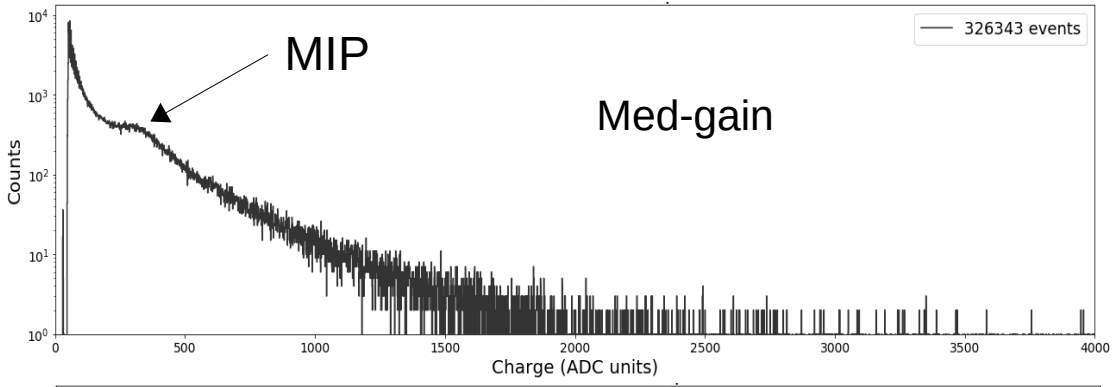


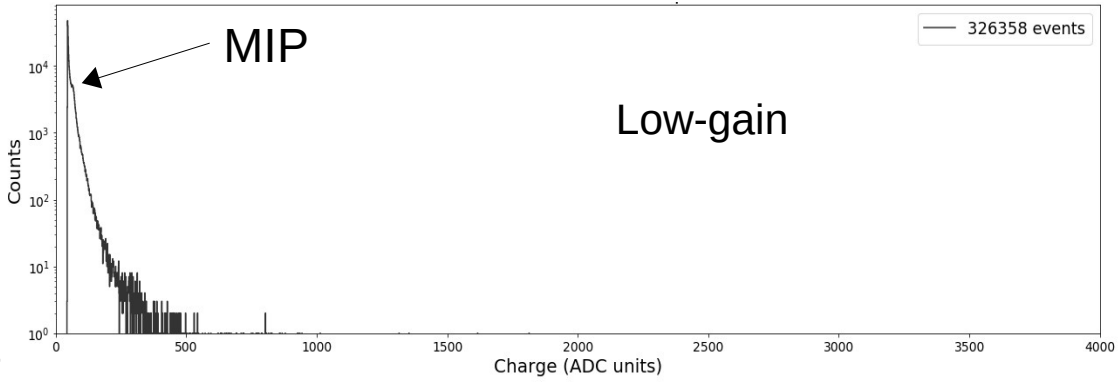
Other Gain Channels

Electronic gains are roughly known

Cross calibrate with the MIP

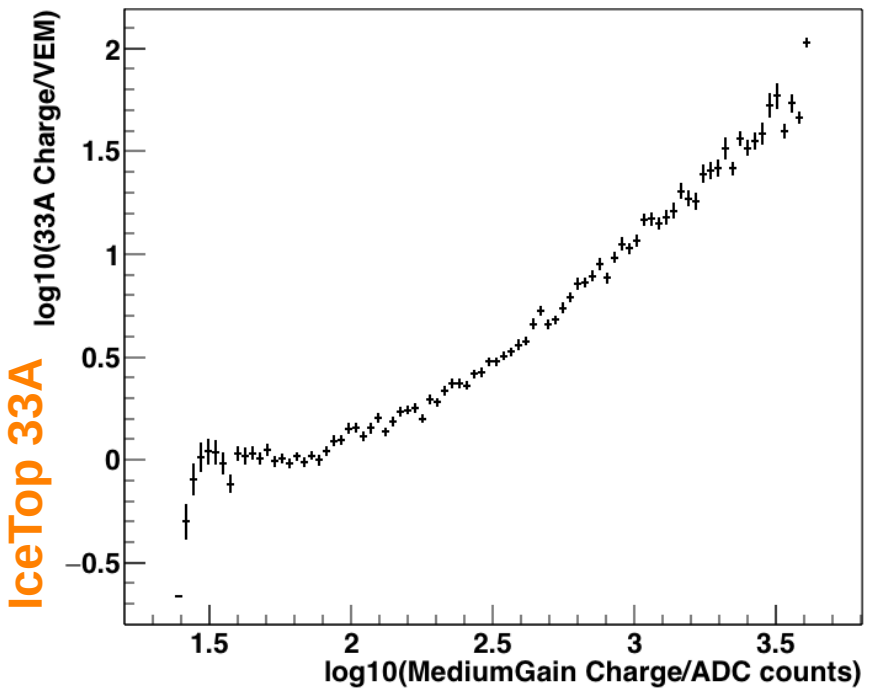




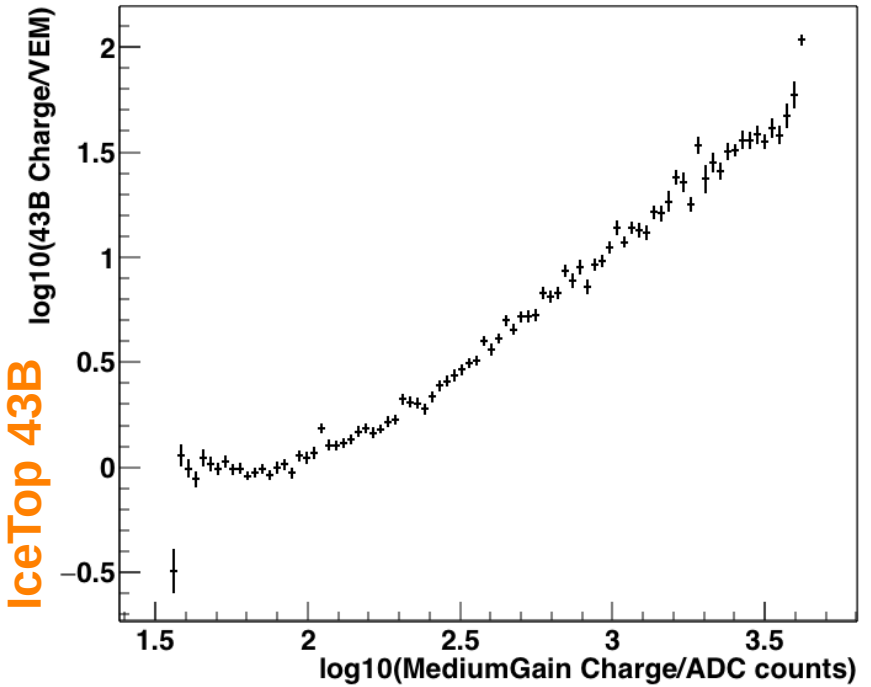


IceTop Coincidence

In the previous layout, two scint panels were directly over IceTop tanks
Serap did a nice coincidence study
Scint medium gain channel saturates ~100 VEM



Scint panel 2

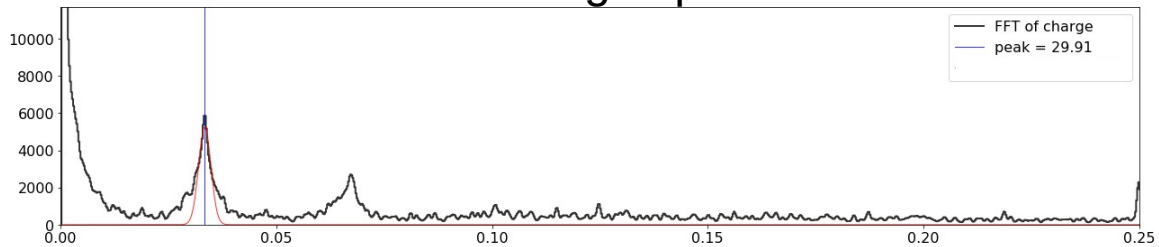


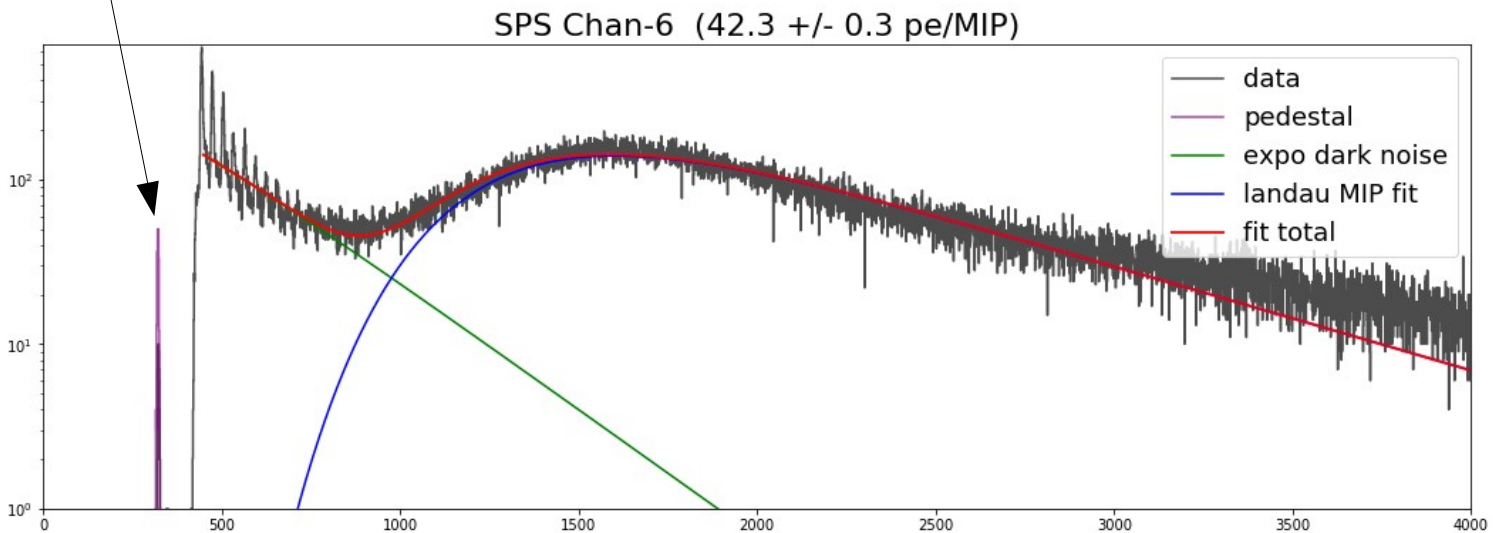
Scint panel 6

MIP Light Yield

- Measure the gain
- Have pedestal from CPU triggers
- Fit the MIP

FFT of the charge spectrum



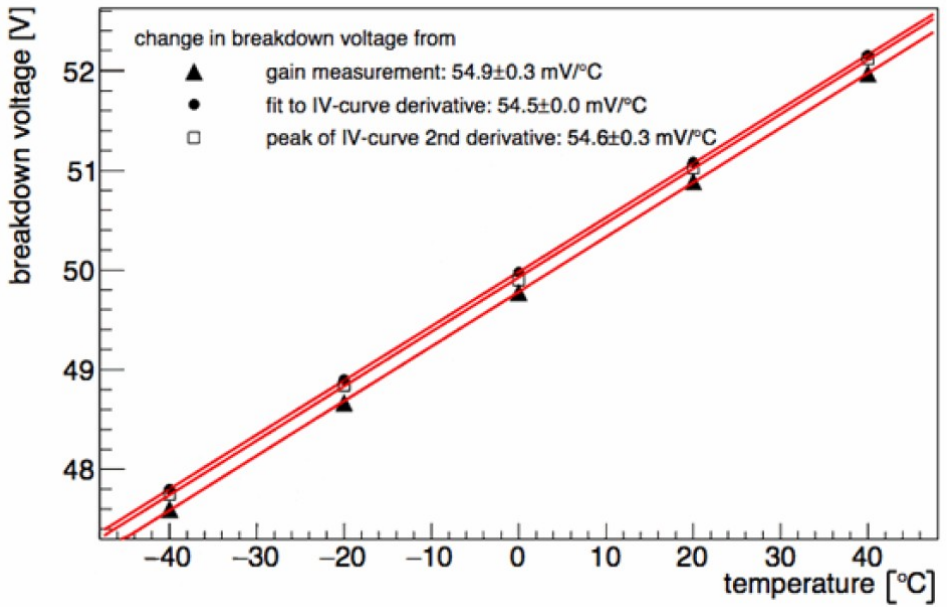


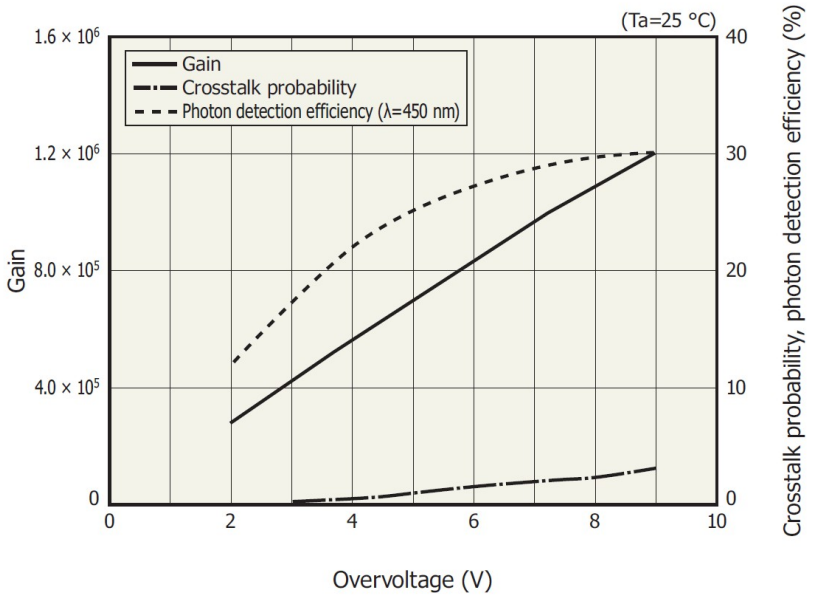
SiPM Temperature Dependence

Ham. S13360 25um

6x6 mm
57600 pixels

- Breakdown voltage linear with temperature (~55 mV / °C)
- Gain linear with overvoltage (~1.3e5 / V)
- Delta-gain ~7.2e3 / °C





SiPM Gain Correction

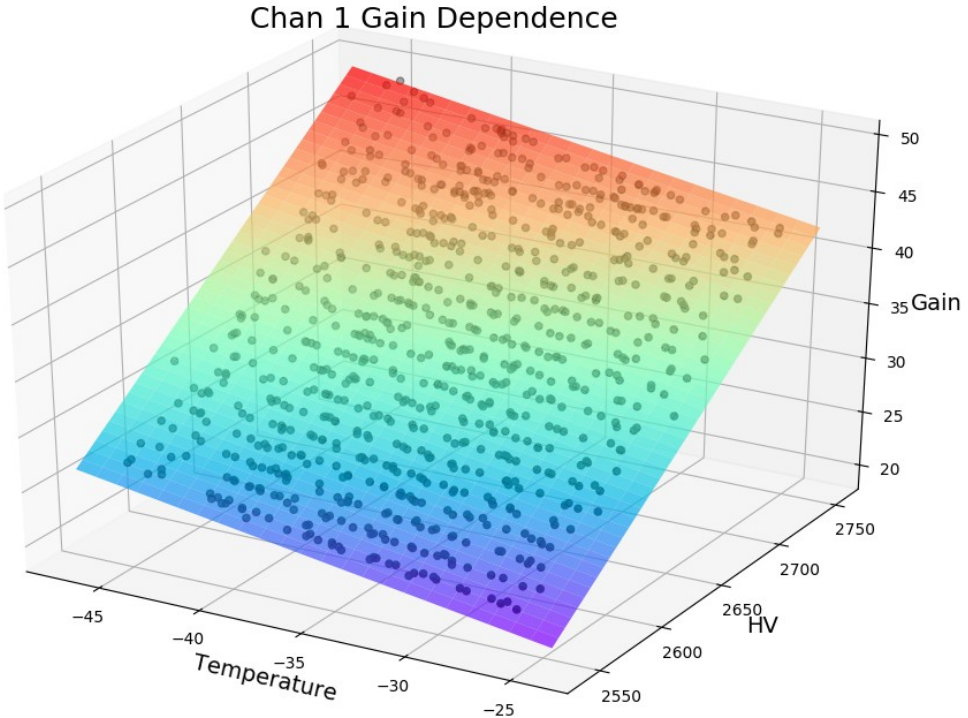
How it was done in the past

Didn’t have time to map out temperature dependence before deployment.

Wait for the South Pole temperature to change ~5 degrees and then take a series of runs at various SiPM voltages.

Each panel has a config file specifying the fit parameters and the target gain.

For each run the uDAQ measures the temperature and sets the SiPM voltage accordingly.



Parameterize with a plane fit

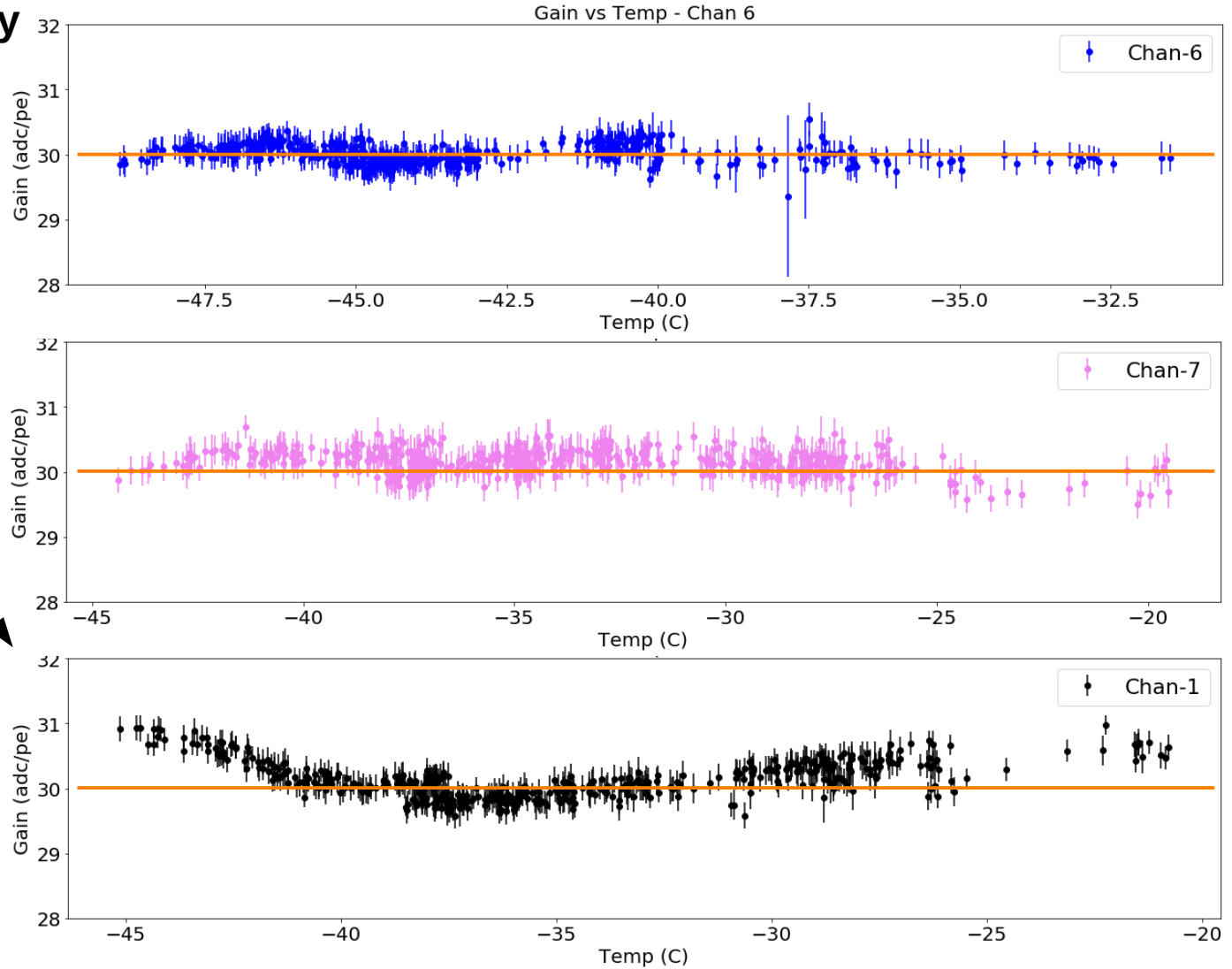
SiPM Gain Correction Stability

Gain set point = 30 adc/pe

Worked well for all panels except for panel #1

Old panels had temperature sensor on the uDAQ board.

New panels have temperature sensor next to SiPM.

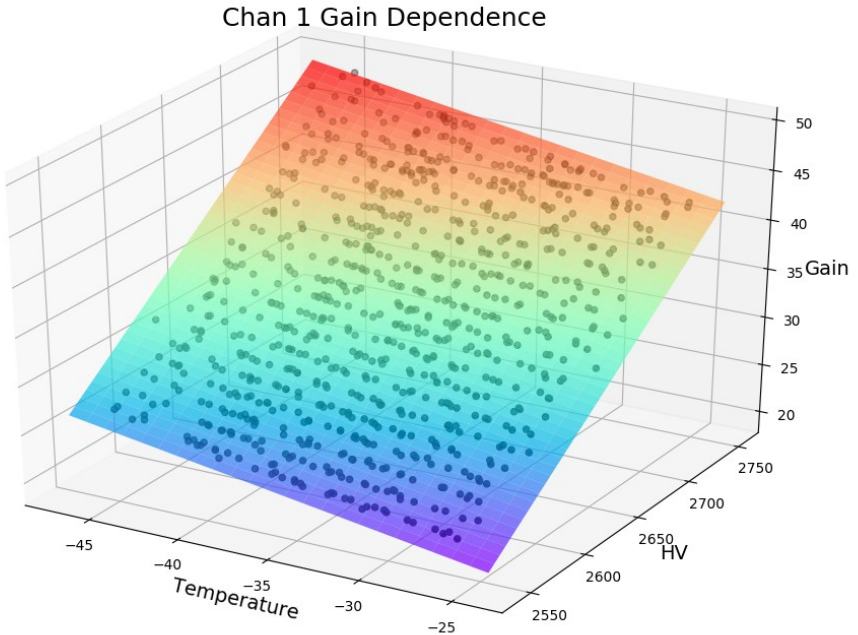


SiPM Gain Mapping

How it should be done in the future

For future deployments the temperature dependence mapping should be done in a controlled environment before shipping to pole.

I think we'd only need to scan 3-4 temperatures and 3-4 HV settings.



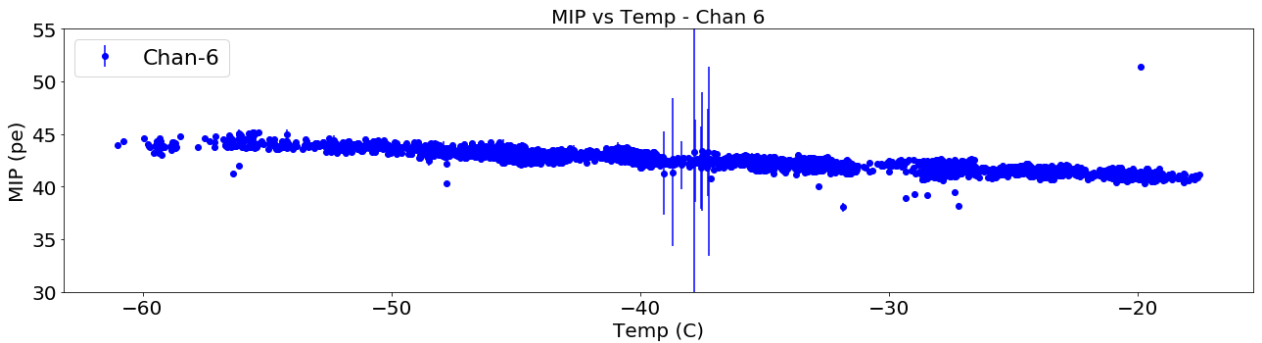
Following the IceCube "domconfig" practice, each scint panel can have a config file holding the gain fit parameters, gain set point, etc.

Panels are electronically identified by the uDAQ microcontroller id.

In-situ Calibration

Monthly IceTop DOMCal like calibrations:

- Scan a few SiPM voltages (20 minutes)
  - Cross check against the current gain mapping
- Scan a few thresholds at the gain set point (20 minutes)
  - Cross check against the current threshold
- Measure the MIP light yield
  - Defines the VEM energy calibration
  - Long term scintillator aging effects
  - Scint light yield has slight temperature dependence (~0.1 pe/°C)

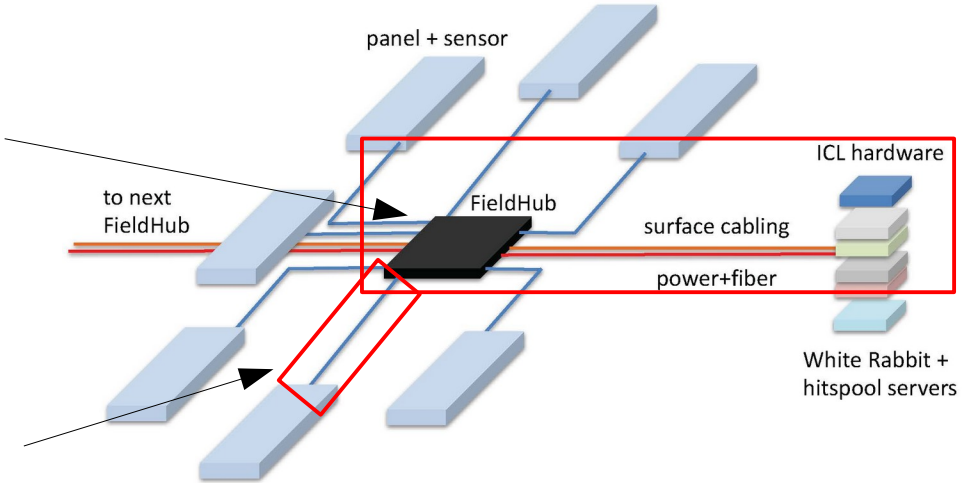


Yearly “run start” operations:

- Gather the monthly ScintCals and produce a new gain mapping

In-situ Time Calibration

White Rabbit has its own version of RAPCal
- WR-LEN in the FieldHub is time corrected



Cable delay between FieldHub and Scint panel currently not measured/corrected.
- We need RAPCal for FieldHub to Scint

Summary

- ★ Each scint panel has a config file identified by the uDAQ microcontroller ID
  - Gain map fit parameters
  - Gain set point
  - Threshold
- ★ Realtime SiPM voltage control to maintain constant gain
  - implement into uDAQ firmware
- 🚫 ScintCal software/script
- 🚫 RAPCal routine