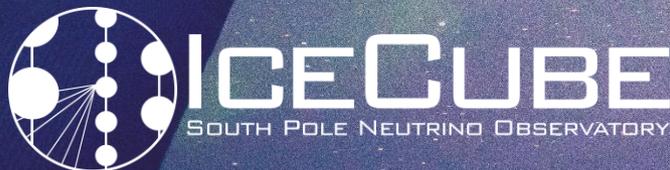


# Calibration

Summer Blot  
DESY

IceCube Management and Operations  
NSF Site Visit March 16, 2020



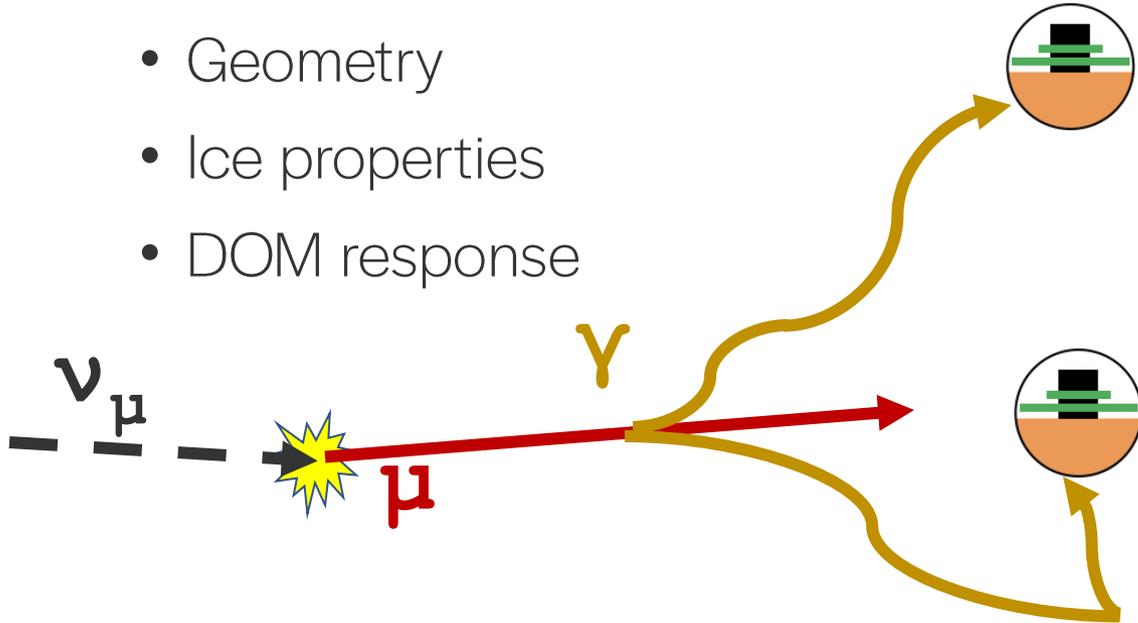
# Outline

- Calibration deliverables
- Tools/Methods
- Organization/interface with other WG
- Recent milestones
- Summary/Outlook



# Calibration deliverables

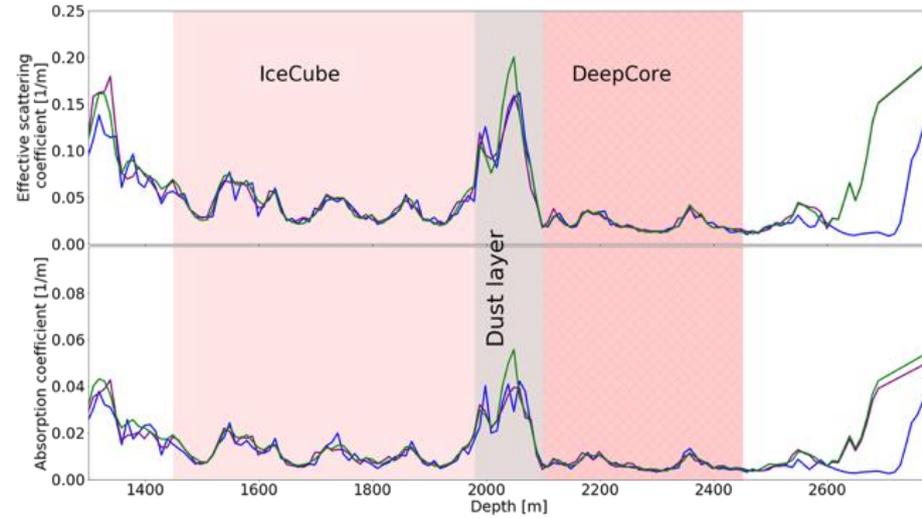
- Geometry
- Ice properties
- DOM response



DOM signal + calib. constants → Charge (p.e.) time (ns)



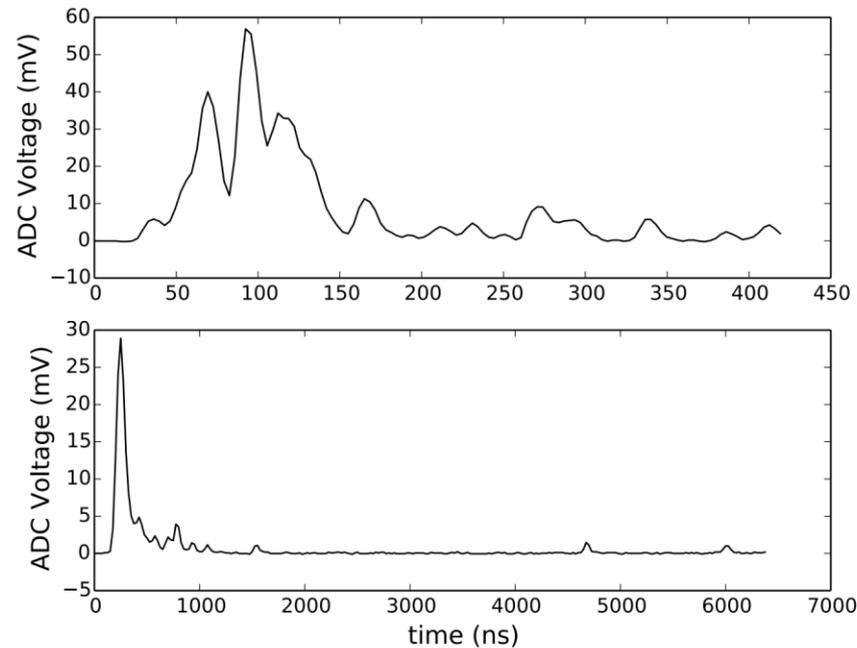
# Ice modelling – photon transport



Scattering

Absorption

## DOM response



300 MSPS  
ATWD (x2)

40 MSPS  
fADC (x1)

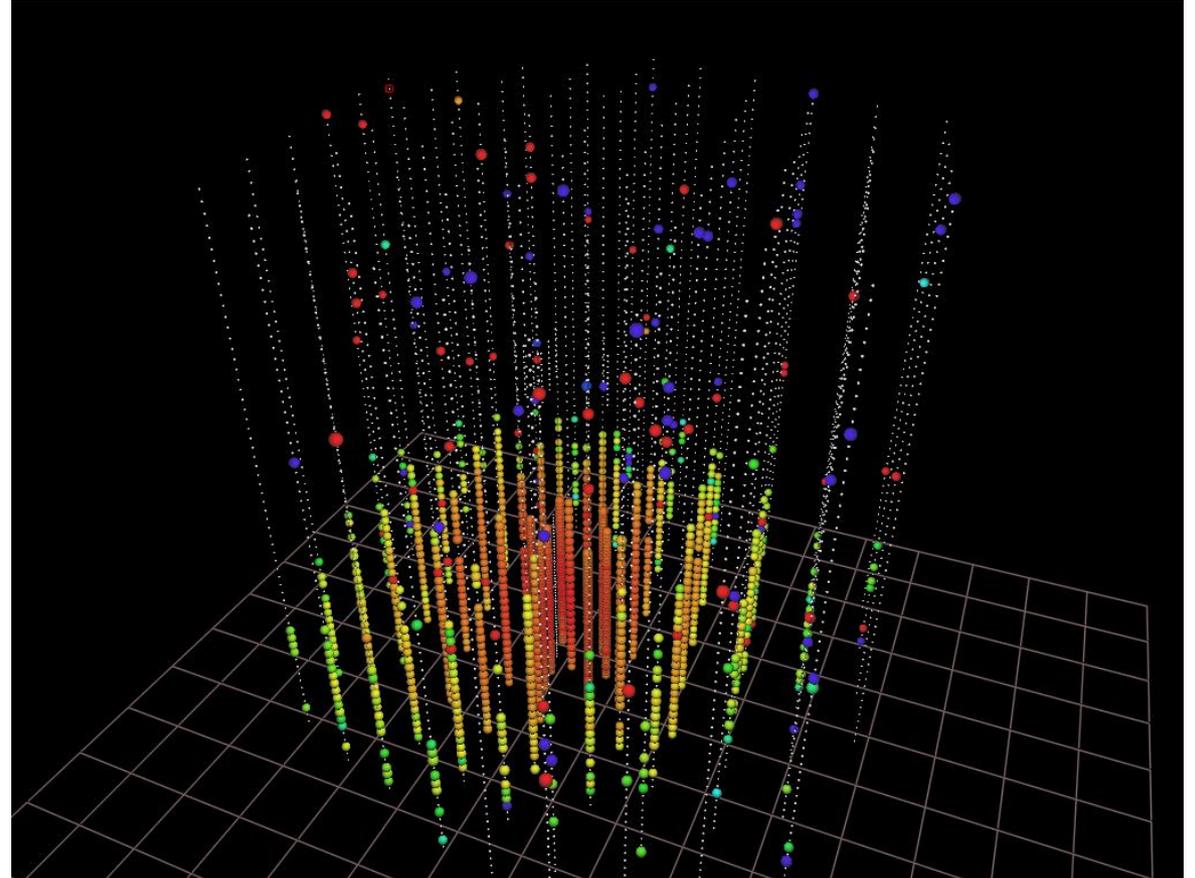


# Calibration tools

- DOMCal: PMT gain, digitizers
- RAPCal: inter-module timing
- Pressure sensors
- 12 LED flashers / DOM
- 2 N<sub>2</sub> pulsed lasers "Standard Candles"
- 2 rotating "Sweden Cameras"
- 8 dust logs from deployment (404 nm retrievable laser)
- 47 Inclinometers
- Minimum ionizing atmospheric muons

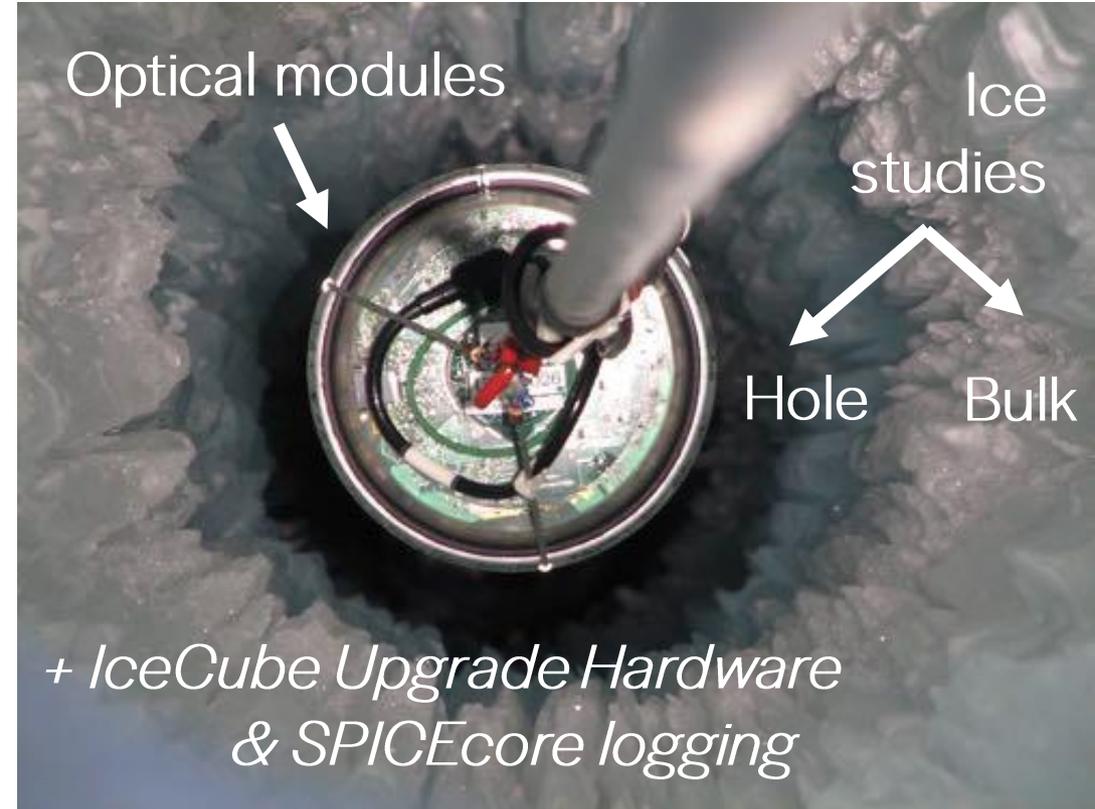
*+ the Moon (not tracked in Calibration WG)*

*Real Flasher event - 2019*



# Organization and key interfaces

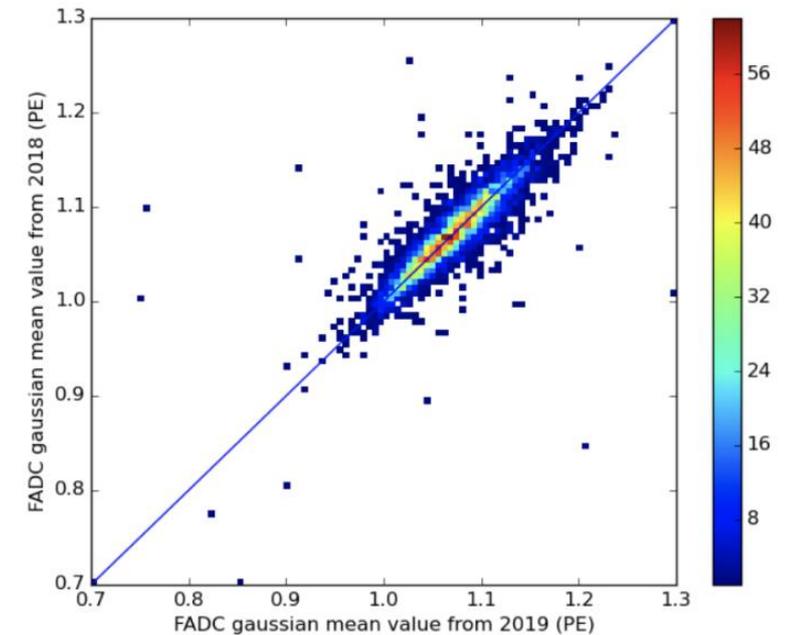
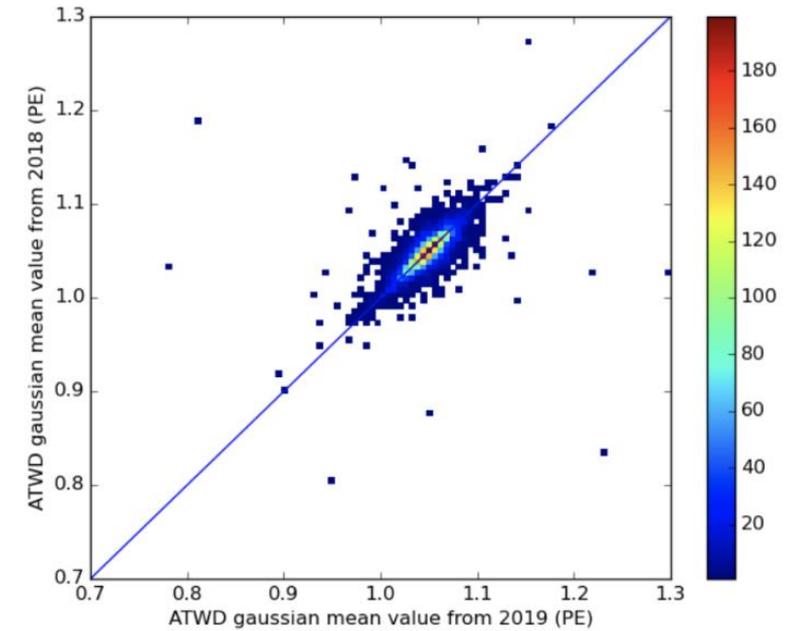
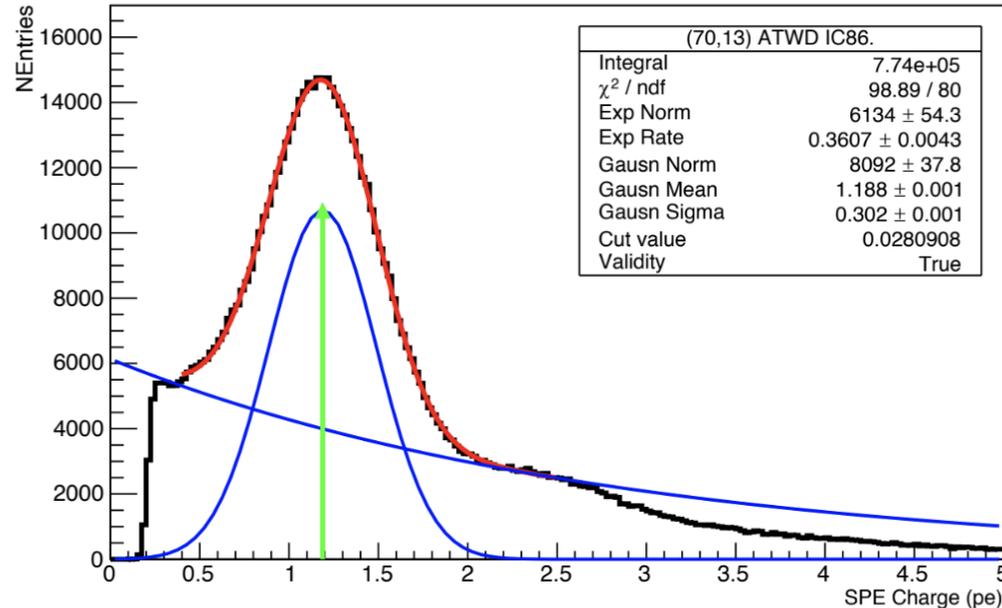
- 2 Calibration Coordinators
  - Summer Blot (DESY) and Allan Hallgren (Uppsala)
- Communication
  - Weekly teleconferences with alternating times
  - Dedicated e-mail list and #slack channels
- DOMcal and flasher runs coordinated through Detector Ops
- New calibrations made available through coordination with Simulation, Software and Reco/Systematics working groups
- **New** - technical analysis "review" process for select analyses, coordinated through ICC



*~7 FTE pledged  
to calibration  
activity  
(US & non-US)*

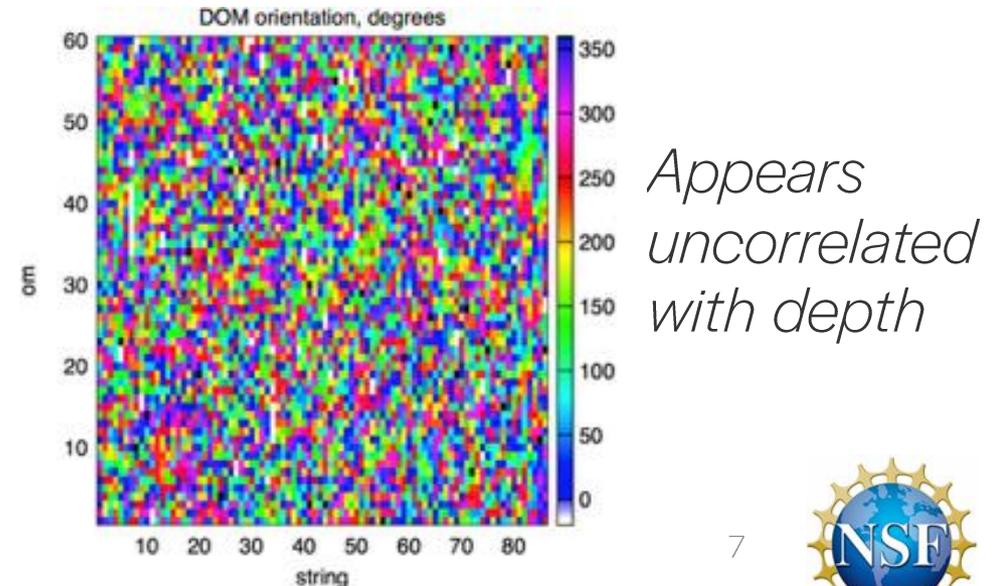
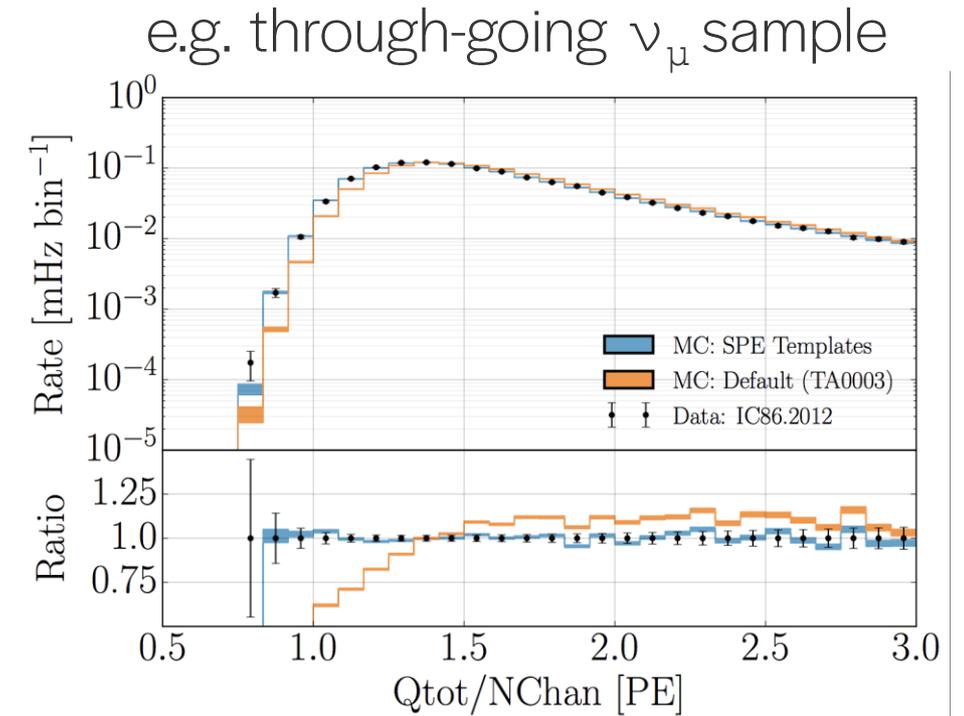
# Bread & Butter Calibrations

- HV v. gain, readout chip calibration (2 ATWD and 1 fADC per DOM)
- Monthly IceTop DOMcal; Yearly in-ice DOMcal
  - Very stable with few year-to-year variations
- Peak SPE charge - corrected to 1 to match simulation



# Recent milestones (I): DOM-wise

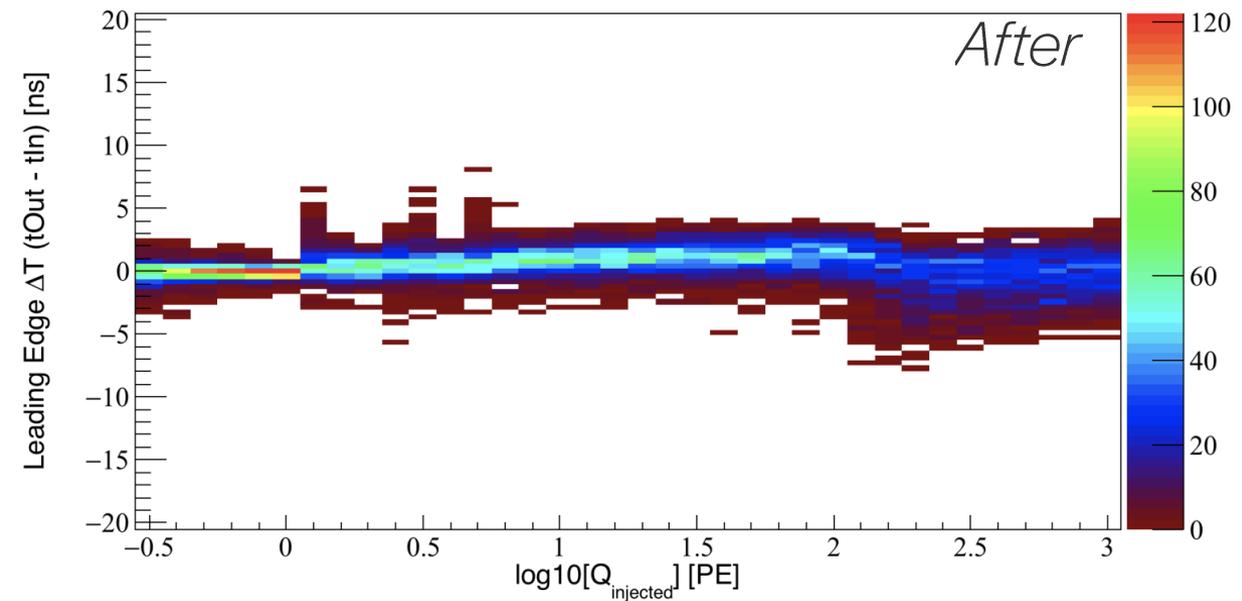
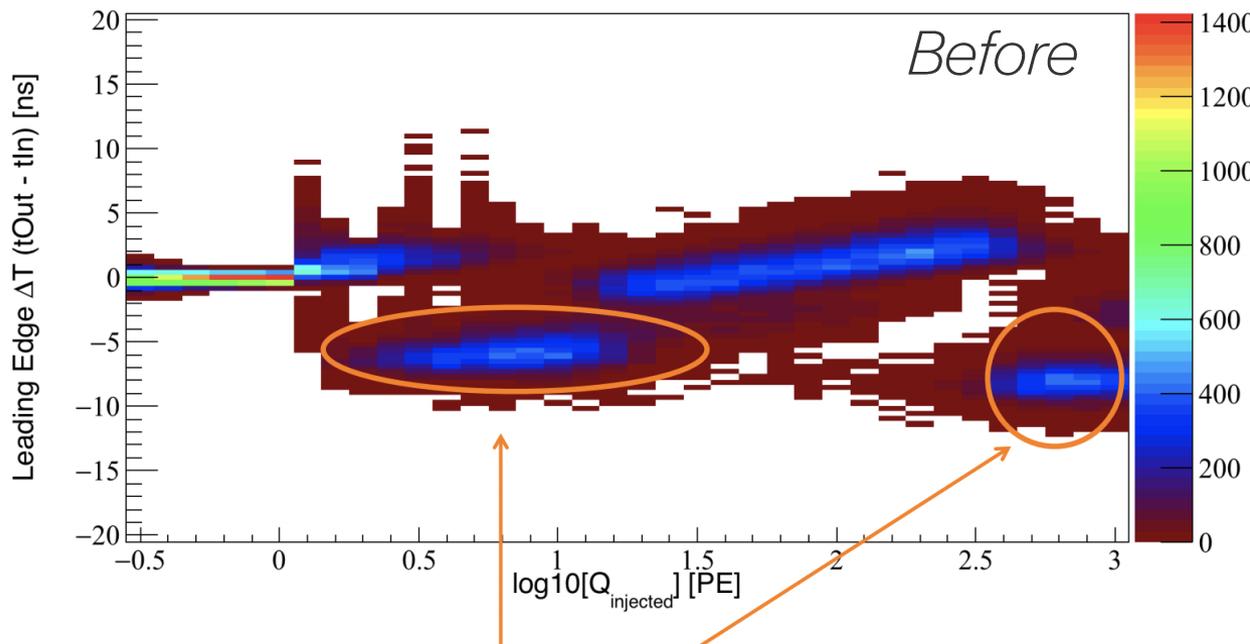
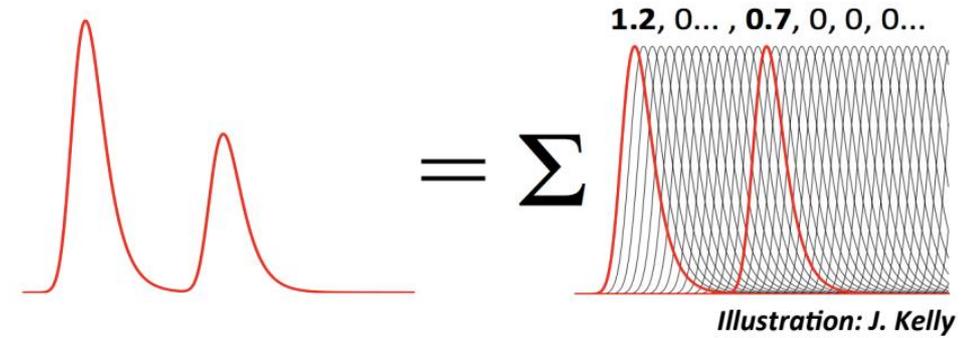
- SPE charge distributions
  - Selection of single PE pulses improved
  - Charge distribution fit for each DOM individually
  - Submitted to JINST, recommended for publication
  - Templates included in next generation physics analyses
  - *IceCube Impact Award* to S. Axani for this work
- Cable positions
  - Required single-LED flashes:  $\sim 2$  TB of data
  - Calibrated cable orientation to  $< 1^\circ$  precision for majority of DOMs
  - Also now know each LED direction *in situ*
  - *Not yet included in major software release*



# Recent milestones (II): bug fix

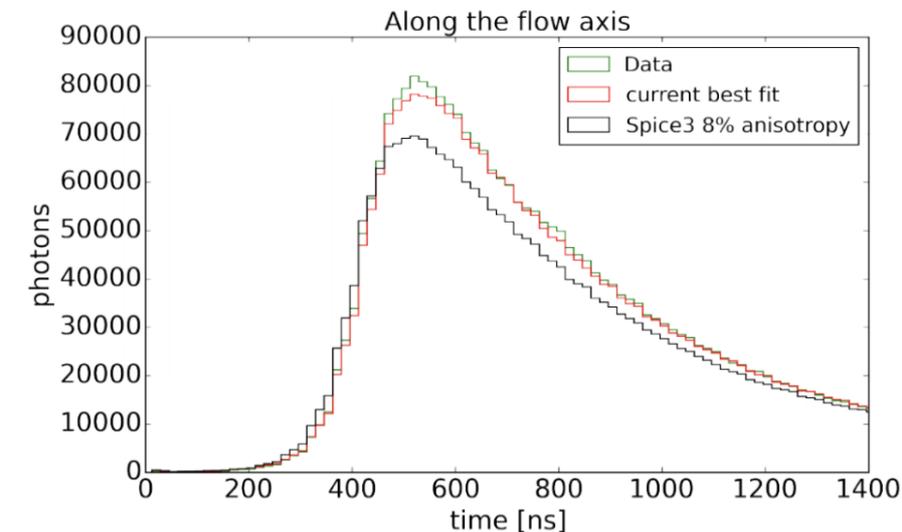
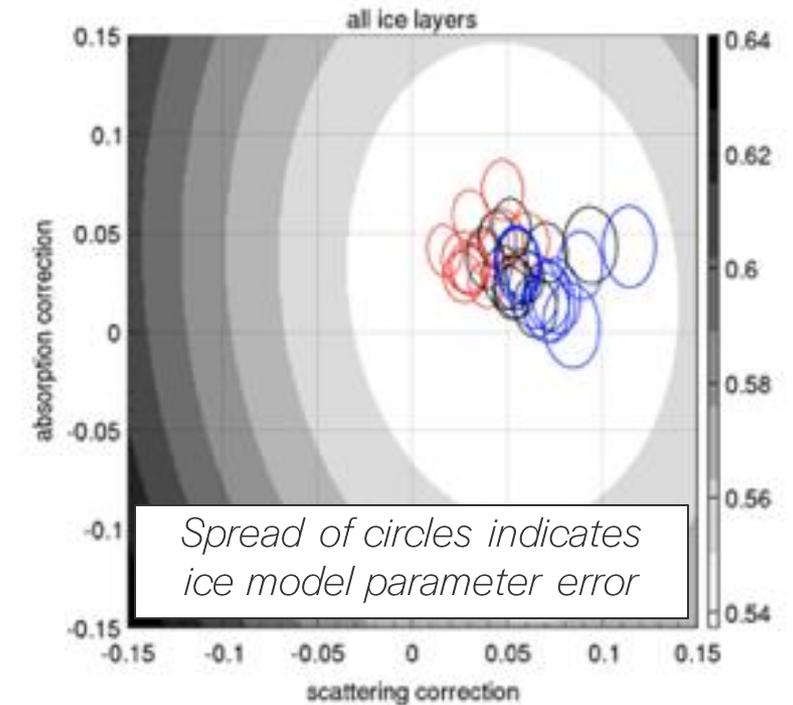
- Waveform unfolding feature

- wavedeform*: known behaviour of "splitting pulses"
  - Sometimes resulted in small, early reconstructed pulses
  - Viable solution found, but minimal impact on reconstructions: *waiting on pass3 to implement*

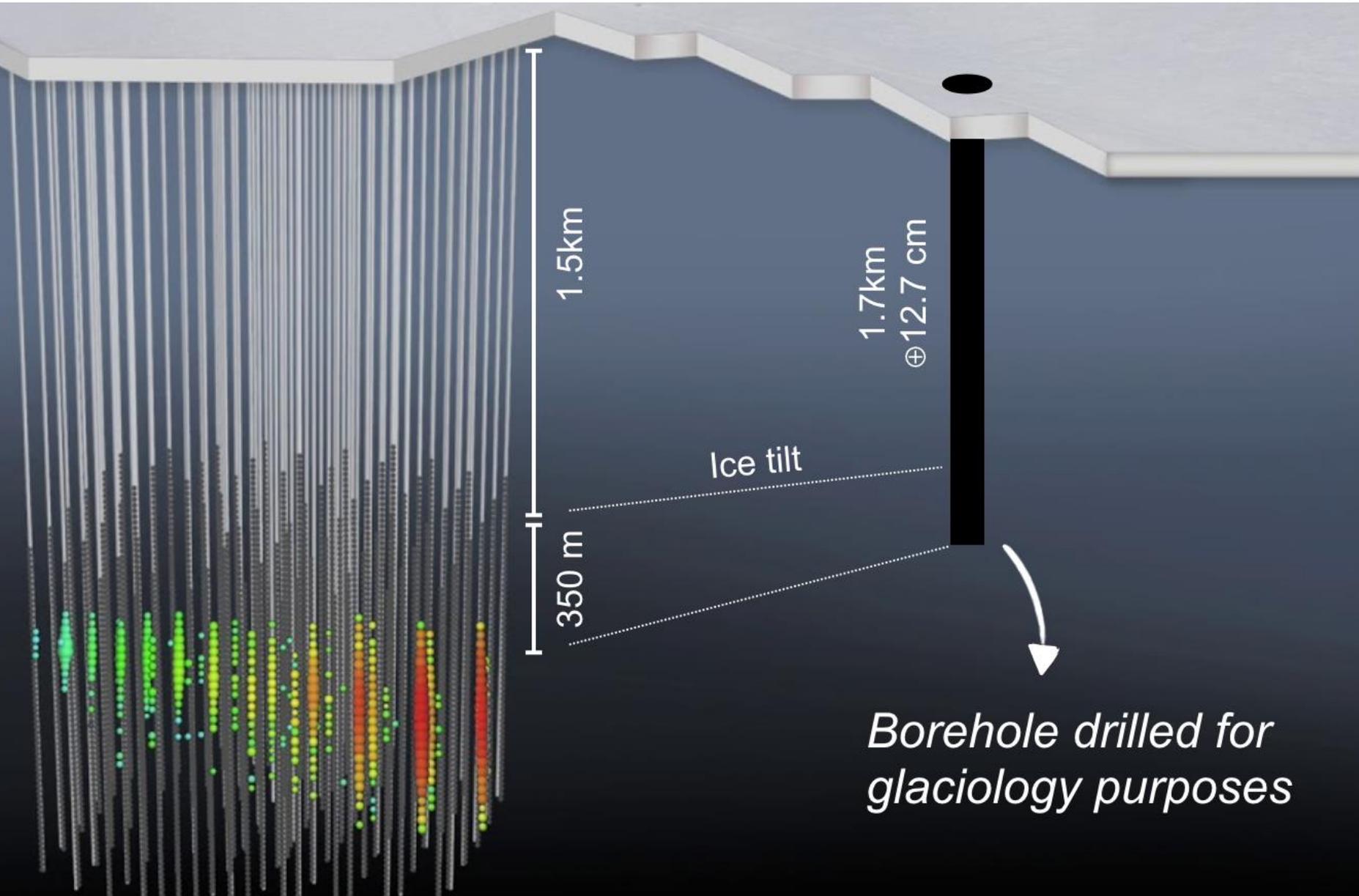


# Recent milestones (III): Ice modeling

- Re-evaluation of bulk ice systematic errors
  - Using single LED data (known LED direction)
  - Reduced systematic errors from 10% --> 5%
  - Model error (measure of remaining data/MC mismatch) at the level of ~10%
- From Calibration to Glaciology
  - Light propagation more efficient along the glacial flow
  - Previously assumed to be due to impurities on ice grain boundaries
  - More likely – birefringence effect of ice polycrystals with preferred (average) orientation
  - Since January 2019: 271k GPU hours
    - ~20% of all NPX GPU usage

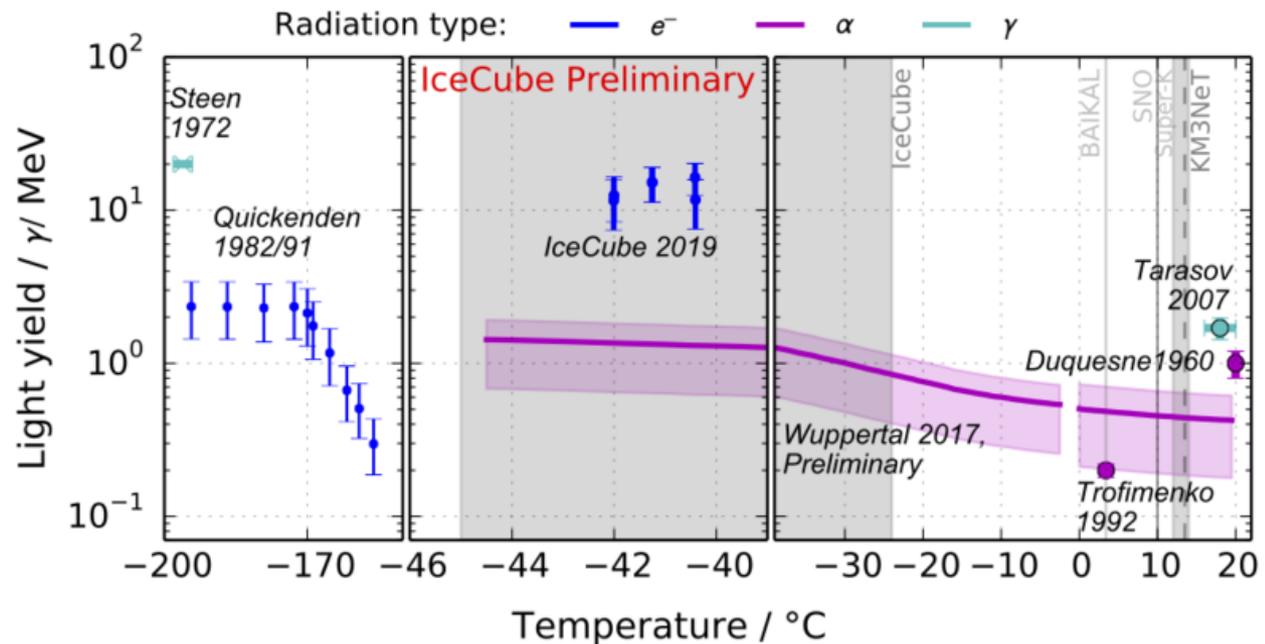


# SPICEcore



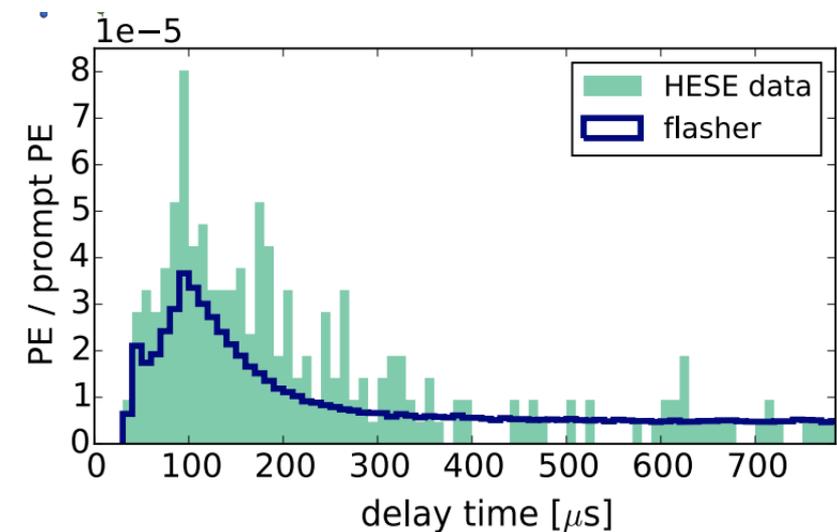
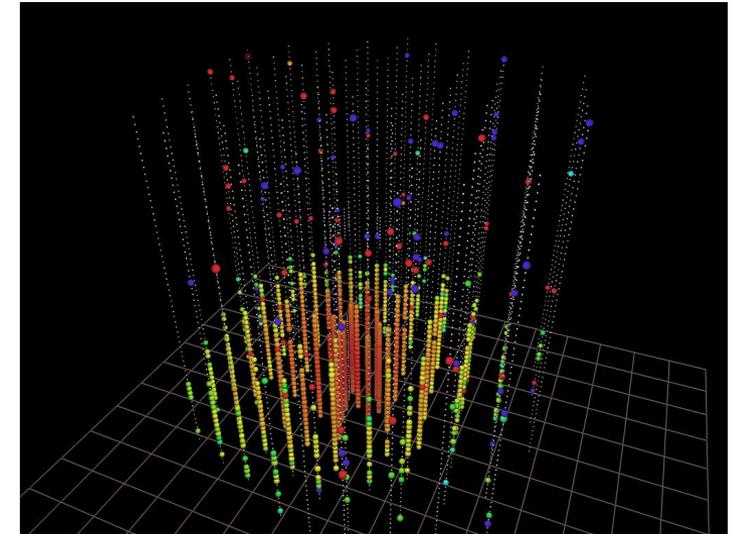
# SPICEcore logging activity

- Luminescence logger: light yield from ice luminescence
- UV logger: scattering and absorption lengths in UV range
- Dust logger: *new* orientation sensor – sensitive to anisotropy through backscattering
- Camera Logger: Field test for Upgrade-like camera system



# Summary & Outlook

- On-going activities:
  - DOM efficiency re-calibration with new SPE templates for latest ice models (requires CORSIKA)
  - Late pulse characterization per-DOM on short (ns) and long (100 $\mu$ s) time scales
- Continue to maximize use of IceCube calibration systems prior to Upgrade deployment
- Upgrade HW reviews
  - Calibration device design/testing
  - Optical module characterization (lab and. *in situ*)
- Continue to encourage/support technical papers and internal notes



Thank you! Questions?

