

The IceCube Detector Systems

Current Status and Future Plans

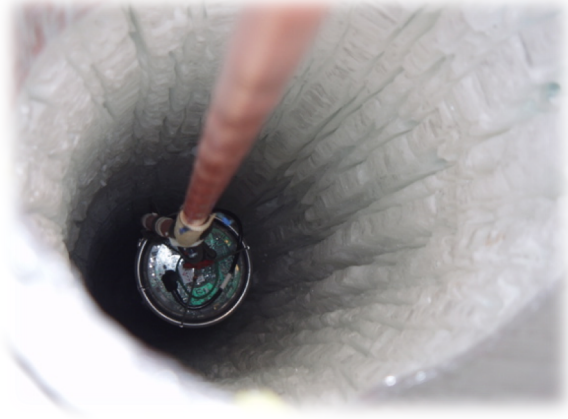


J. Werthebach / NSF

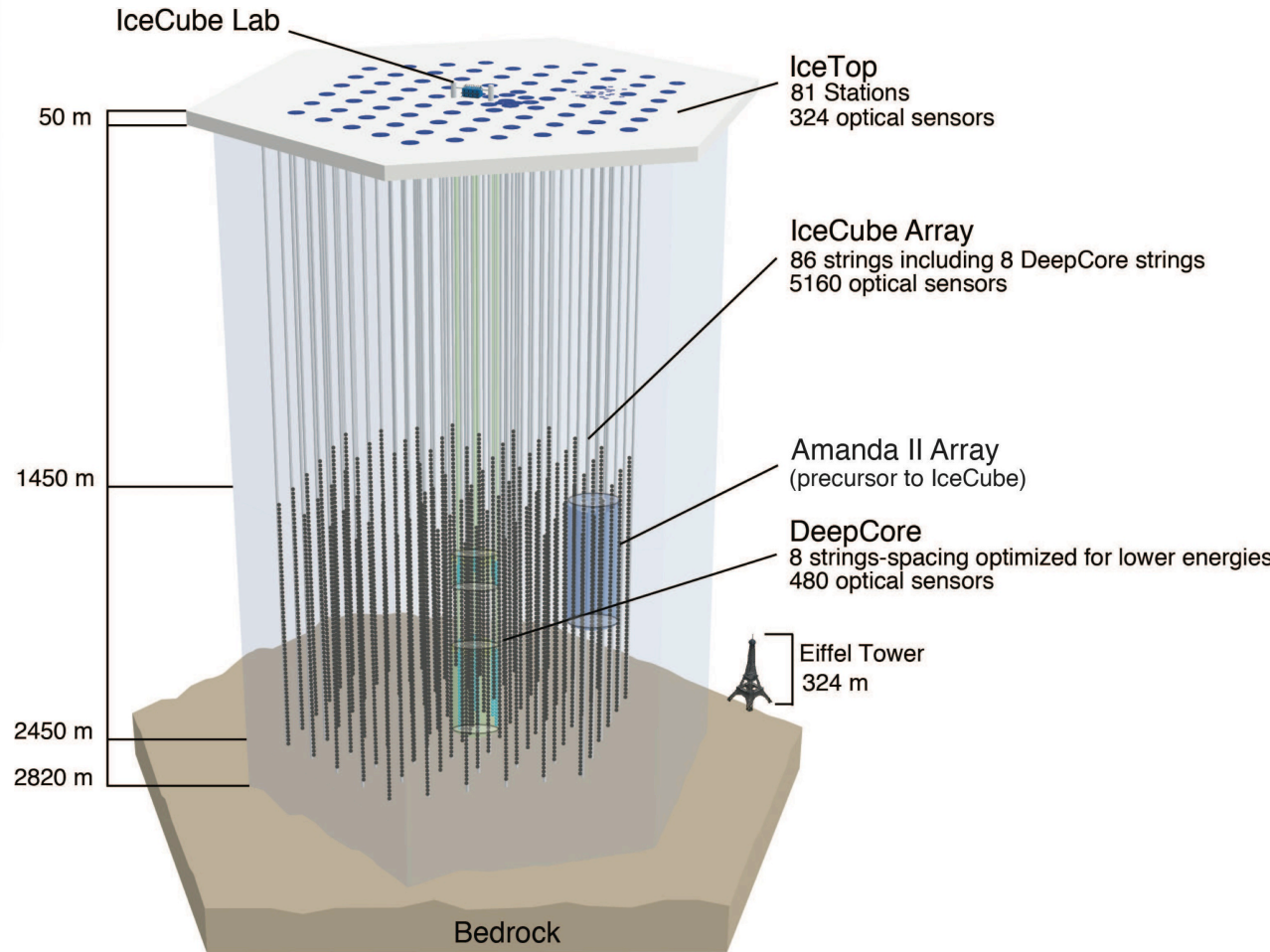
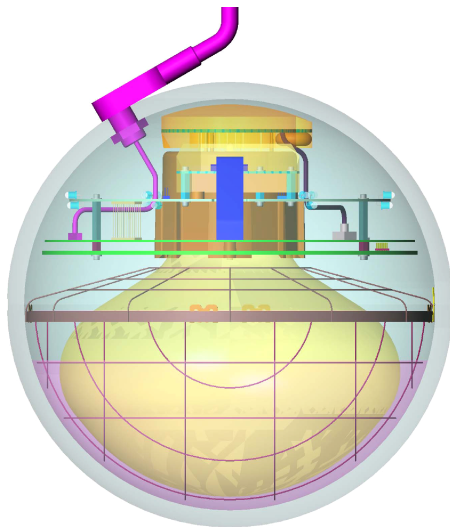
John Kelley for the IceCube Collaboration
Univ. of Wisconsin – Madison
1 November 2018, NNN18, Vancouver

The IceCube Neutrino Observatory

science overview: J. Kiryluk plenary



digital optical module (DOM)



IceCube measures charge vs. time from particle-induced Cherenkov light deposition

Data Acquisition

131654 **RUNNING** 2h 09m
Current run DAQ rate Duration

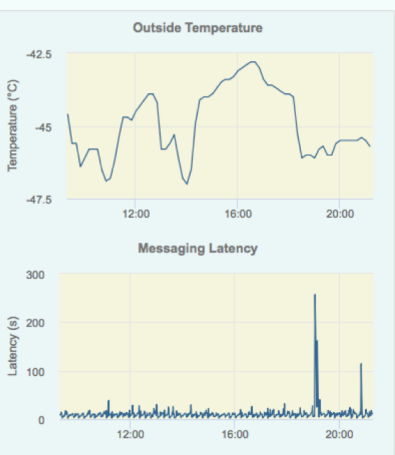
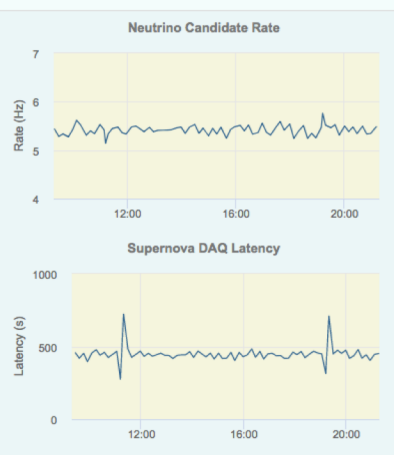
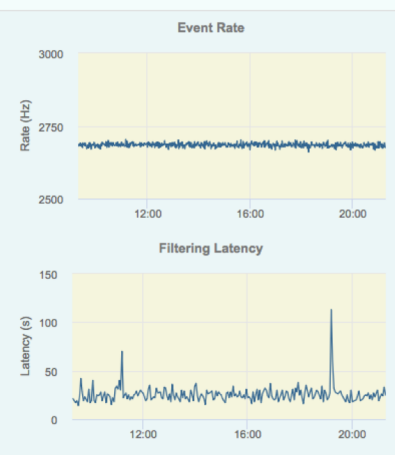
Tyrarena4 20,829,441 dark
DAQ release Event count LID mode

Full Start 5409 / 5409
Transition Active DOMs

sps-IC86-2018-tweak-Grilled-Cheese-V279
Run configuration

Live Alerts

- multirunfail
- runfail
- FPMaster disk usage too high
- PnF file backlog too large
- Too much time betw...DAQ latency messages
- Detector not taking data
- Excessive run failure rate
- I3DAQDispatch is not RUNNING
- I3MS link is not UP
- Lots of LBM overflows
- Modem ttyS1 is unable to connect
- Modem ttyS4 is unable to connect
- Modem ttyS5 is unable to connect
- Modem ttyS6 is unable to connect
- PFDSTWriter is not RUNNING
- PFFiltWriter is not RUNNING
- PFRawWriter is not RUNNING
- PFServer1 is not RUNNING
- PFServer2 is not RUNNING
- PFServer3 is not RUNNING
- PFServer4 is not RUNNING
- PFServer5 is not RUNNING
- PFServer6 is not RUNNING
- PFServer7 is not RUNNING
- PFServer8 is not RUNNING
- PnF latency too high
- PnF rate too low
- PPP link is not UP
- SERIOUS SN alert triggered!
- SNDAQ is not RUNNING
- SNDAQ latency too high
- Throttling messages from noisy service
- Too many *.dat file...local/pdaq/sndaq/tmp
- Too many *sn.tar fil.../mnt/data/pdaq/local
- Too many missing DOMs
- Too much time between...I3MS monitoring msgs
- Too much time between SNDAQ alerts



Components

I3DAQDispatch RUNNING	PFDSTWriter RUNNING
PFFiltWriter RUNNING	PFMoniWriter1 RUNNING
PFMoniWriter2 RUNNING	PFMoniWriter3 RUNNING
PFMoniWriter4 RUNNING	PFOneWriter RUNNING
PFRawWriter RUNNING	PFServer1 RUNNING
PFServer2 RUNNING	PFServer3 RUNNING
PFServer4 RUNNING	PFServer5 RUNNING
PFServer6 RUNNING	PFServer7 RUNNING
PFServer8 RUNNING	sndaq RUNNING
uptimer RUNNING	

Component Alerts

No alerts in past 24h

- PFFiltWriter 2d 5h 58m ago missing events
- I3DAQDispatch 12d 6h 39m ago missing or invalid run summary! waiting for a valid one...
- hubmoni 15d 23h 9m ago ichub29: unexpected number of DOMs
- hubmoni 15d 23h 15m ago lthub07: unexpected number of DOMs
- hubmoni 16d 2h 3m ago lthub08: unexpected number of DOMs
- hubmoni 17d 17h 52m ago ichub35: unexpected number of DOMs
- hubmoni 18d 2h 16m ago ichub29: unexpected number of DOMs
- PFServer server-crash 19d 8h 14m ago
- I3DAQDispatch 20d 10h 13m ago missing or invalid run summary! waiting for a valid one...
- hubmoni 21d 8h 29m ago ichub33: unexpected number of DOMs
- hubmoni 21d 8h 29m ago ichub33: DOM power check failure
- pdaq 22d 3h 7m ago Master Clock is out of agreement with the NTP reference

Recent Log Msgs

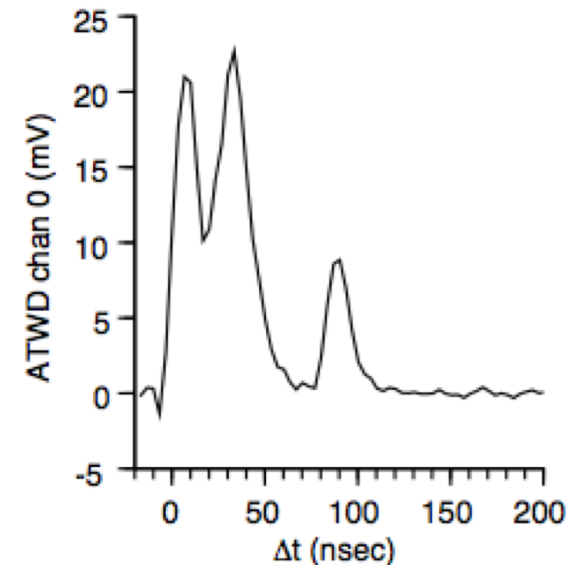
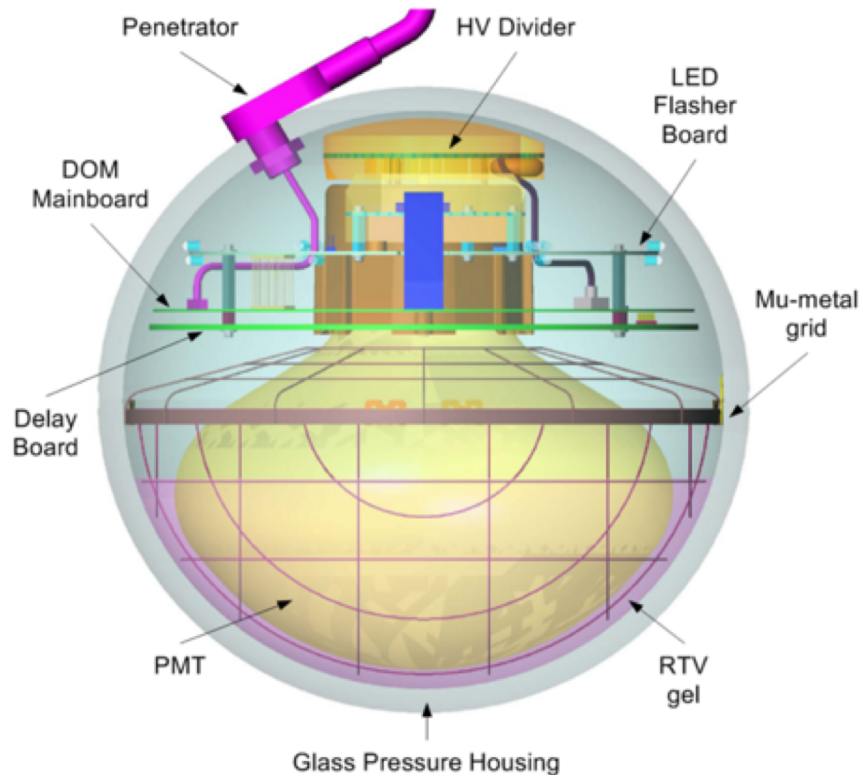
```

2018-10-23 19:09:29 Watchdog reports starved components: stringHub#203->IceTopTrigger icetopHit.RecordsReceived not changing from [16261,
2018-10-23 19:07:33 Using system time for initial event counts (no event times available)
2018-10-23 19:07:15 Starting run 131654...
2018-10-23 19:07:14 Cluster: sps-cluster
2018-10-23 19:07:14 Run configuration: sps-IC86-2018-tweak-Grilled-Cheese-V279
2018-10-23 19:07:14 Version info: Tyrarena4 14222:143282 2018-08-10 20:20:07
2018-10-23 19:06:48 pdaq: STOPPED -> start {'runNumber': 131654, 'subRunNumber': 0, 'runConfig': 'u'sps-IC86-2018-tweak-Grilled-Cheese-V279
2018-10-23 19:06:32 Wrote combined log for run 131653
2018-10-23 19:06:31 Writing combined log for run 131653
2018-10-23 19:06:29 Run terminated SUCCESSFULLY.
2018-10-23 19:06:29 77380228 physics events collected in 28820 seconds (2684.95 Hz)
2018-10-23 19:06:23 pdaq: RUNNING -> stop
2018-10-23 19:05:35 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1956673
2018-10-23 19:05:26 Watchdog reports hanging components: stringHub#84
2018-10-23 19:05:26 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1873574
2018-10-23 19:05:26 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1824024
2018-10-23 19:05:26 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1818865
2018-10-23 19:05:26 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1817186
2018-10-23 19:05:26 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1667354
2018-10-23 13:36:22 Sending Alert 4.82454 (# 57 in run 131653 )
2018-10-23 13:35:18 Sending Alert 5.09722 (# 56 in run 131653 )
2018-10-23 13:33:37 Sending Alert 4.26094 (# 55 in run 131653 )
2018-10-23 13:31:20 Sending Alert 4.80873 (# 54 in run 131653 )
2018-10-23 13:27:18 Sending Alert 4.75233 (# 53 in run 131653 )
2018-10-23 13:25:23 Sending Alert 4.51294 (# 52 in run 131653 )
2018-10-23 13:23:07 Sending Alert 4.66859 (# 51 in run 131653 )
2018-10-23 13:21:23 Sending Alert 4.53064 (# 50 in run 131653 )
2018-10-23 13:19:24 Sending Alert 4.18529 (# 49 in run 131653 )
2018-10-23 13:17:21 Sending Alert 4.29741 (# 48 in run 131653 )
2018-10-23 13:13:18 Sending Alert 4.15197 (# 47 in run 131653 )
2018-10-23 13:11:22 Sending Alert 4.02718 (# 46 in run 131653 )
2018-10-23 13:11:10 Watchdog reports starved components: stringHub#210->IceTopTrigger icetopHit.RecordsReceived not changing from [1597214
2018-10-23 13:10:14 Sending Alert 4.16611 (# 45 in run 131653 )
2018-10-23 13:06:11 Sending Alert 4.44682 (# 44 in run 131653 )
    
```

- computing and networking hardware redundancy
- emphasis on DAQ software stability
- automatic failover + winterover paging: uptime > 99.6%

Digital Optical Module

arxiv.org/0810.4930



10" Hamamatsu R7081-02[MOD]

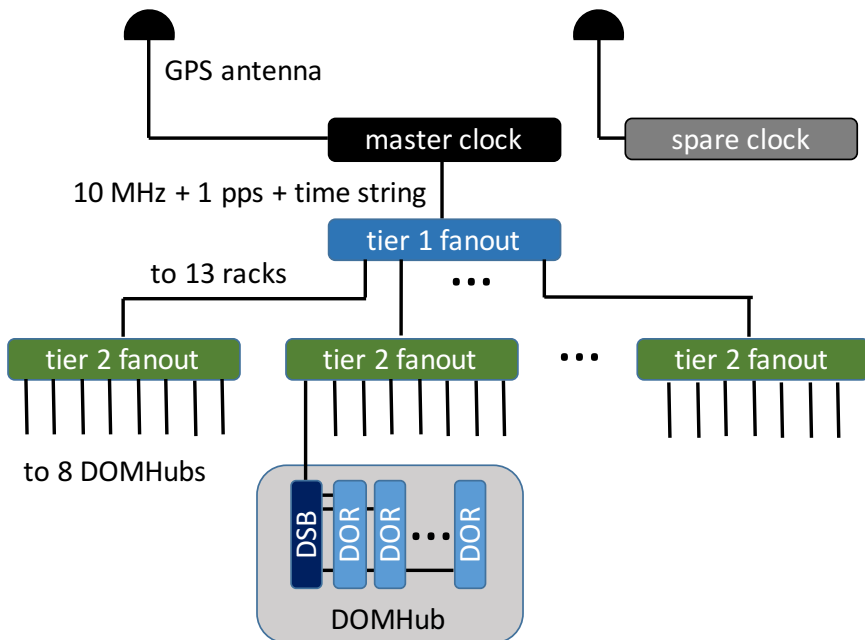
in-DOM digitization @ 300 MSPS
+ longer 40 MSPS trace (6.4 us)

98.5% of deployed modules currently operational

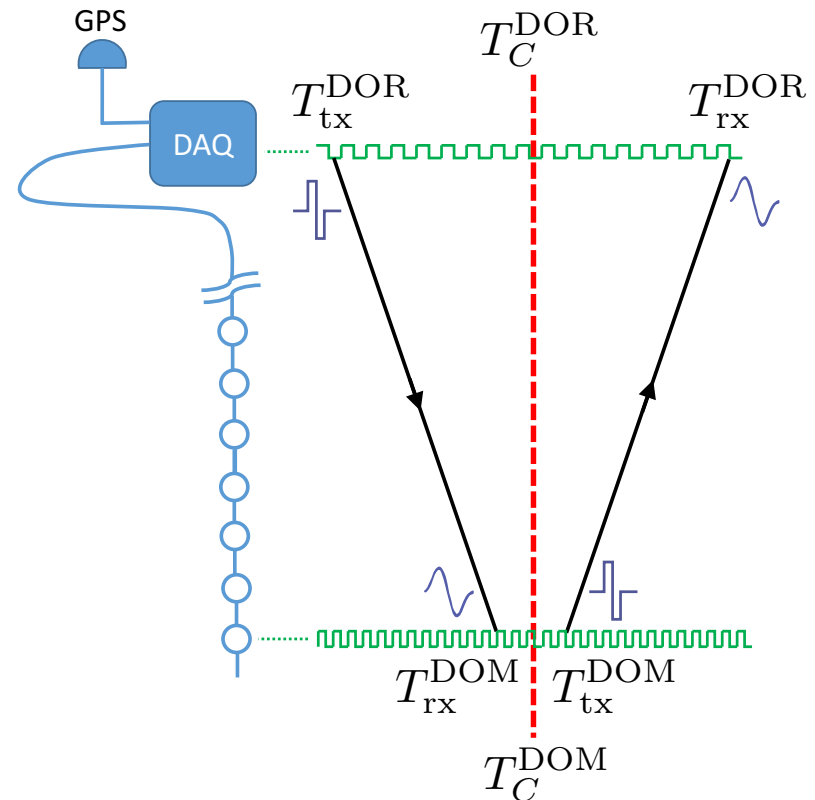
Array Timing

arxiv.org/1612.05093

in the IceCube Lab



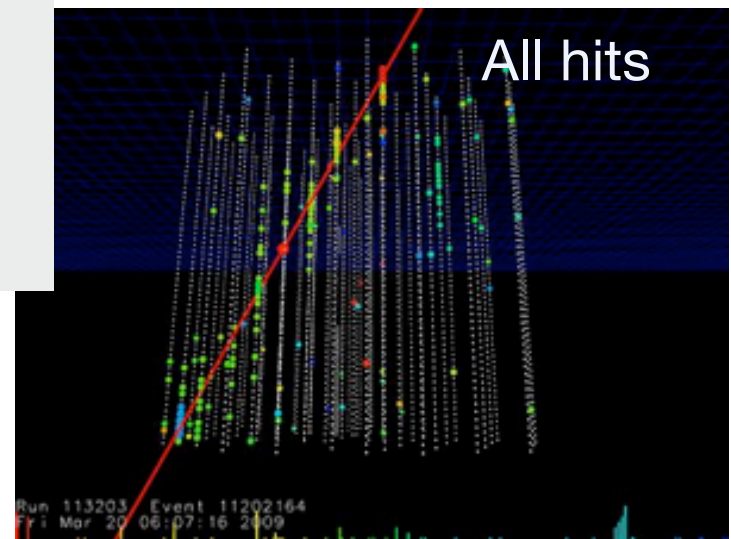
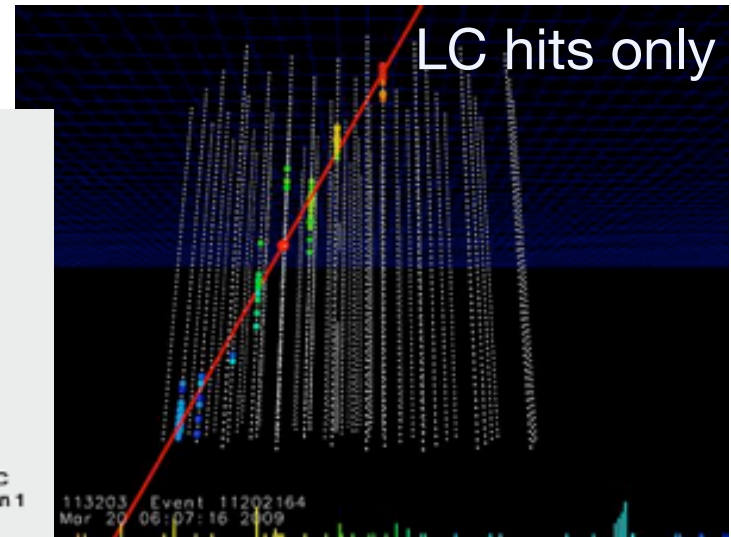
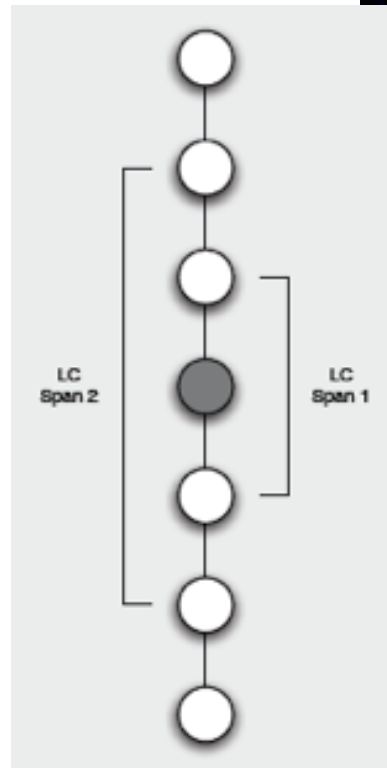
in the ice



- Reciprocal pulsing at 1 Hz (RAPCaI) allows translation of DOM clocks to UTC
- DOM-to-DOM timing spread measured by flashers: 1.7 ns

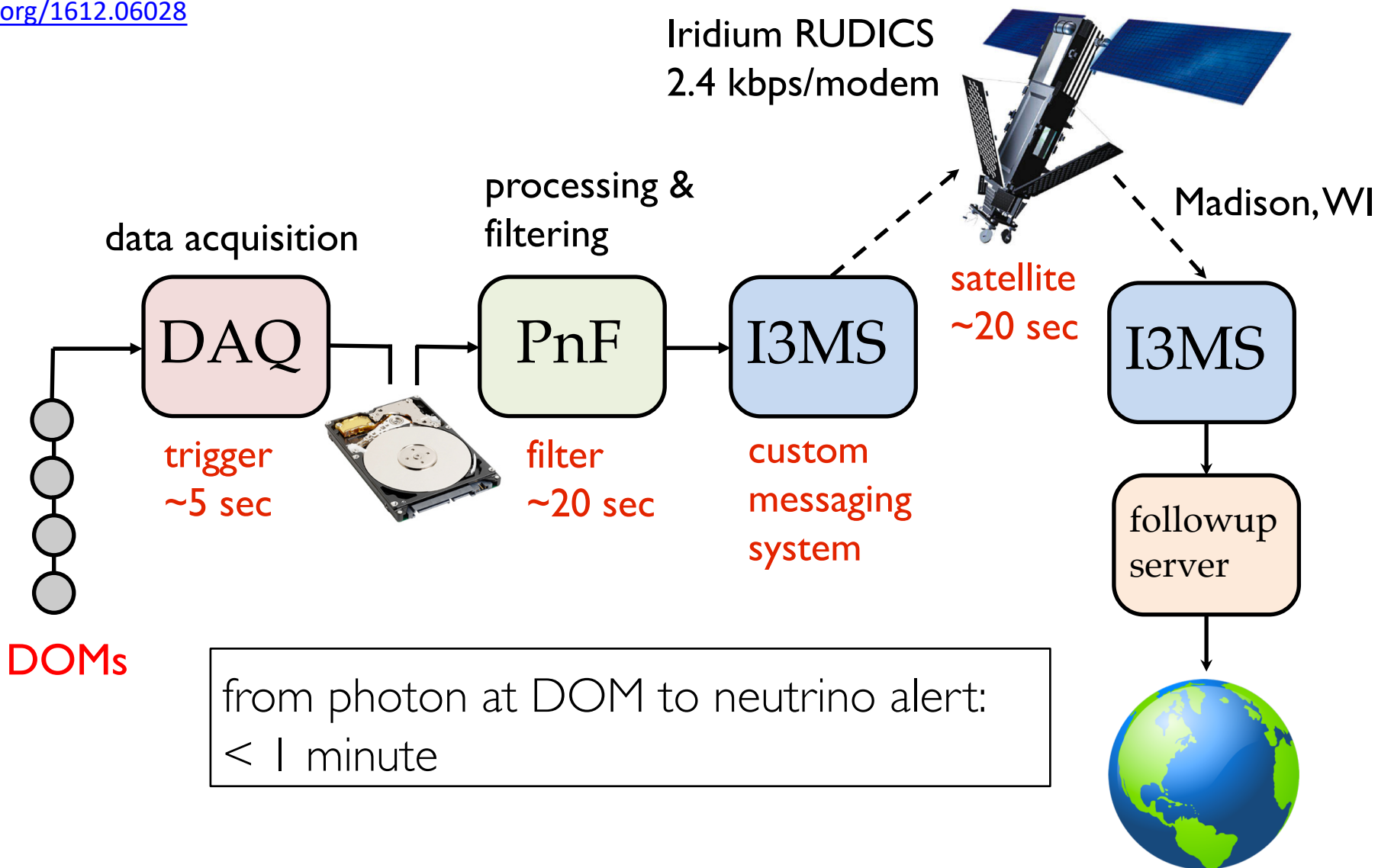
Local Coincidence Data Compression

- Physical connection along in-ice cable
- DOM flags hits that have neighbor hits within $1 \mu\text{s}$
- Only LC hits “HLC” are used in triggering
- Rate (per DOM): reduces 600 Hz darknoise to 5-15 Hz LC
 - non-LC hits highly compressed



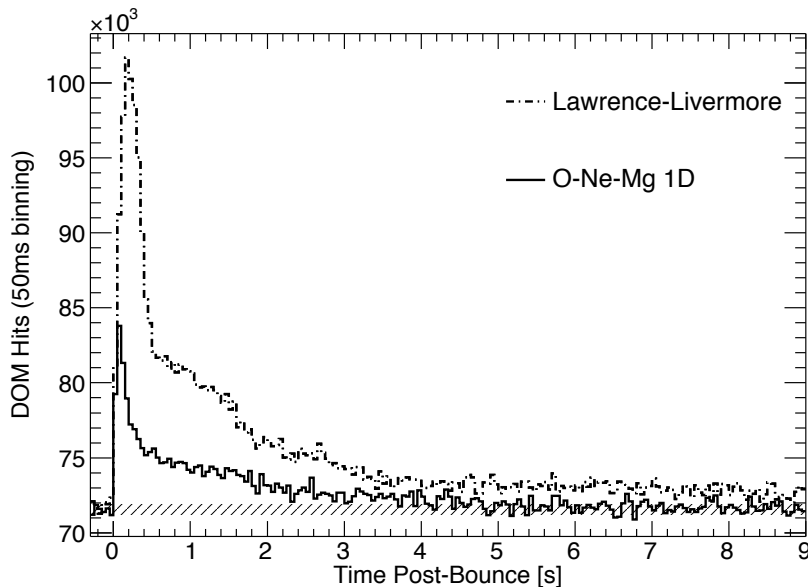
Realtime Alert System

arxiv.org/1612.06028



Supernova Detection

simulated Galactic SN signal
(10 kpc distance)

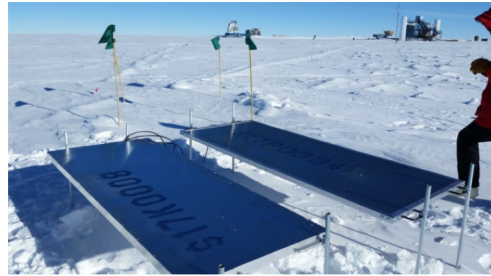


detector noise rate vs. time

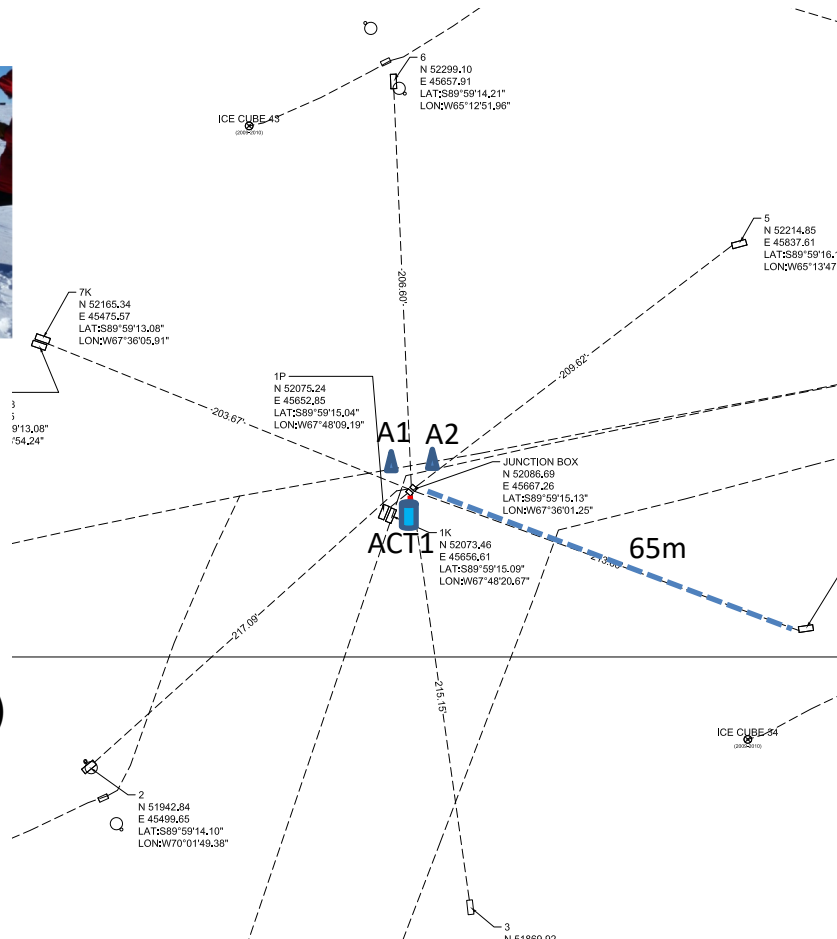
- Detection principle: global DOM noise rate increase from many ~ 10 MeV neutrino interactions
- DOM scaler rates monitored continuously (1.6 ms bins)
- Significant excess in sum reported to SNEWS via alert system

Surface Detector Development

scintillator panels (14)



scintillator FieldHubs



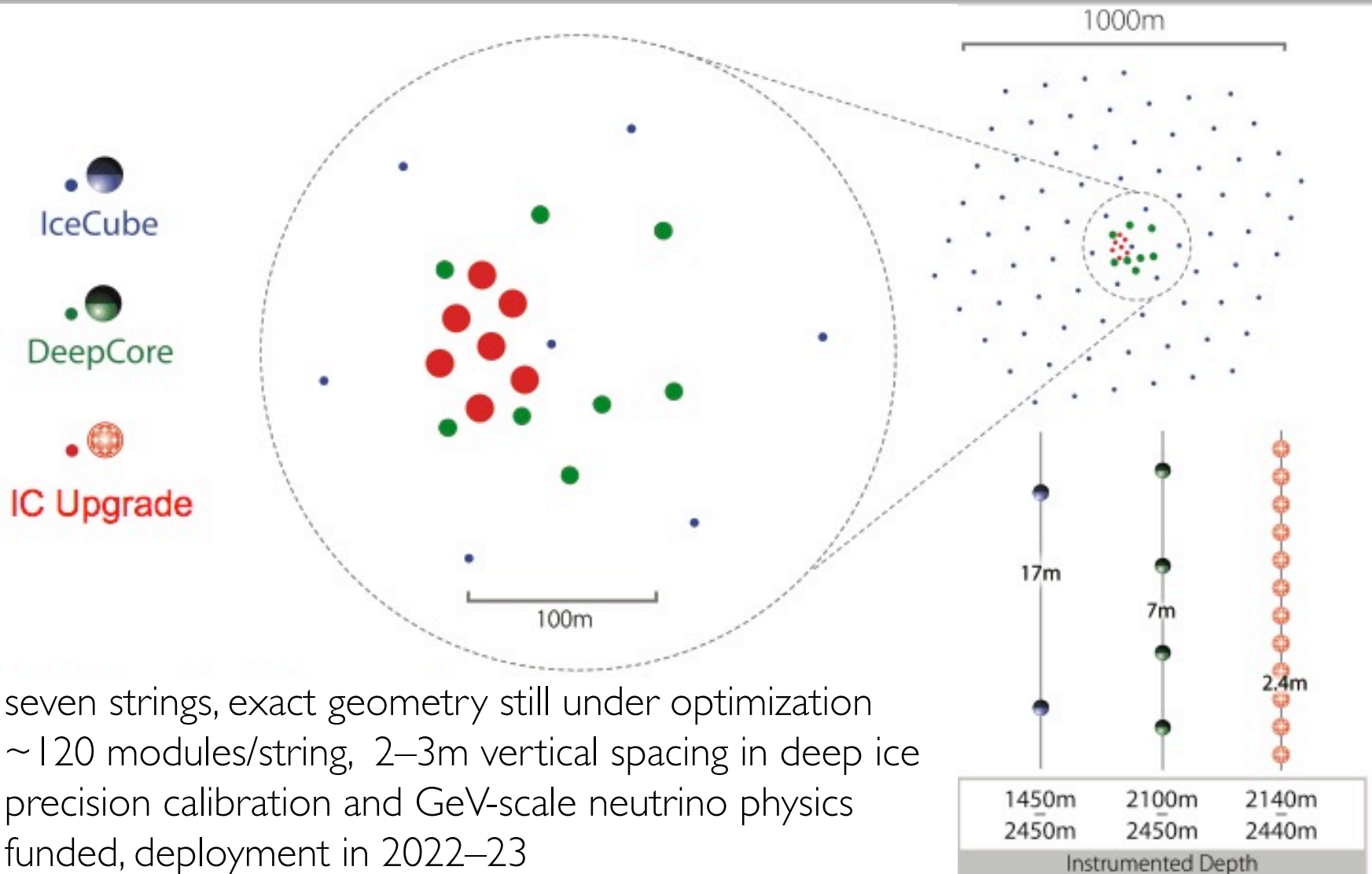
IceACT
air Cherenkov telescope (1)



broadband
radio antennas (2)

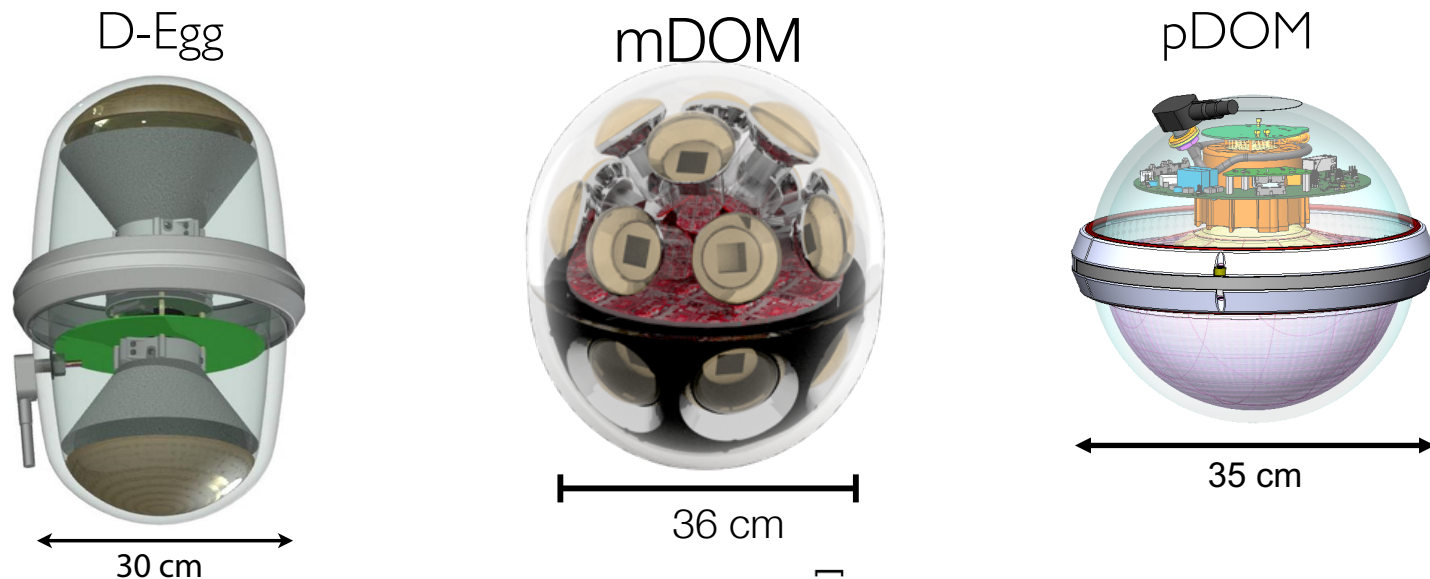


IceCube Upgrade

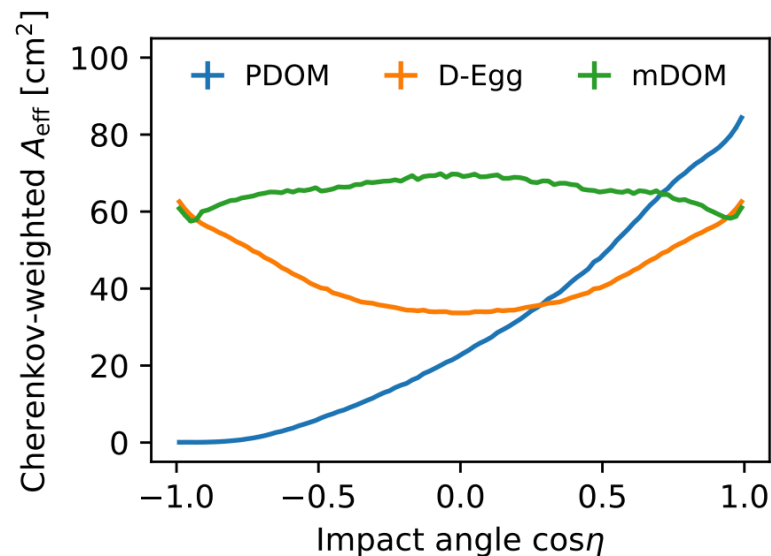


- seven strings, exact geometry still under optimization
- ~120 modules/string, 2–3m vertical spacing in deep ice
- precision calibration and GeV-scale neutrino physics
- funded, deployment in 2022–23

Upgraded DOMs



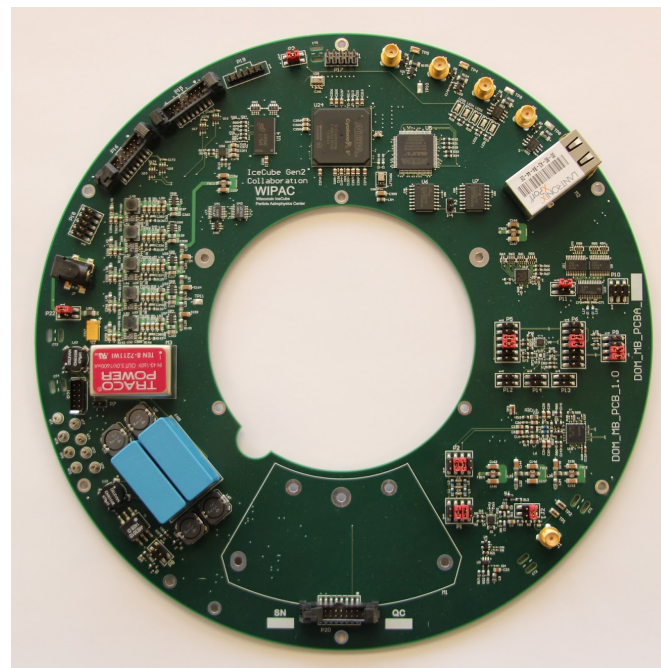
- Modernized signal digitization
- Increased photocathode area and/or wavelength acceptance
- Segmentation of photosensors



pDOM



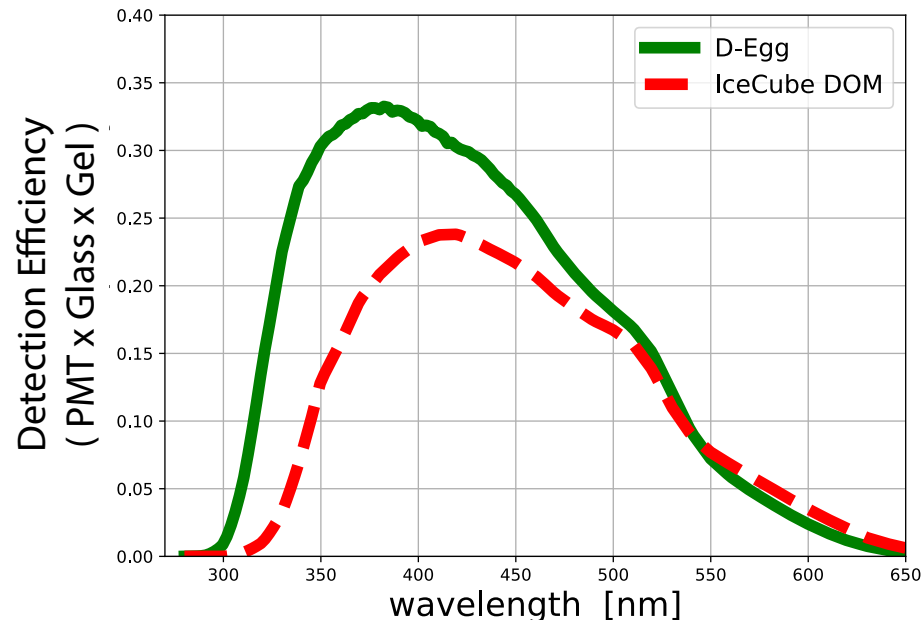
Rev I pDOM mainboard



- Retrofit ~120 spare IceCube DOMs with new electronics
- 250 MSPS continuously-sampling 14-bit ADC
- 2–2.5W power consumption (firmware-dependent)

D-Egg

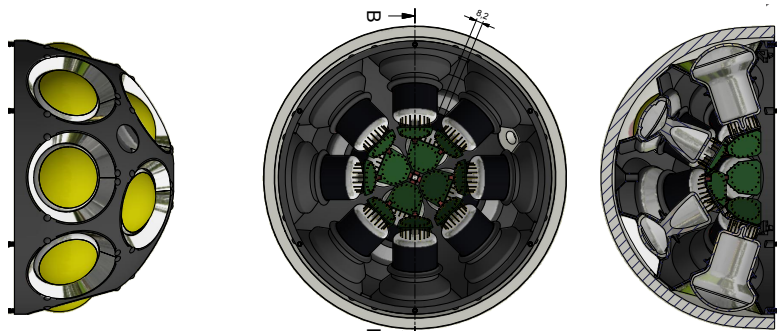
8" HQE Hamamatsu
R5912-100-70



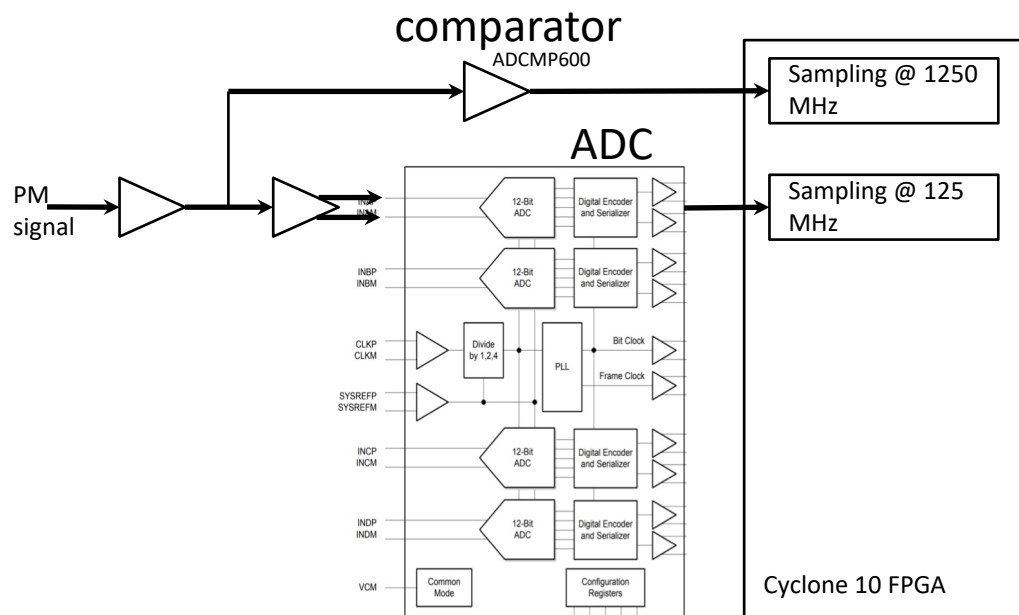
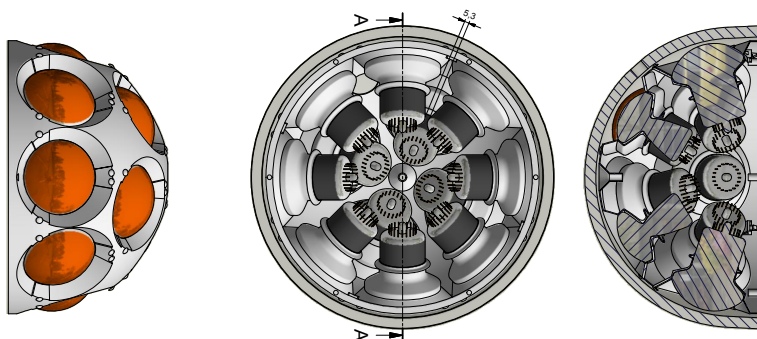
- Improved glass and gel: better UV efficiency
- Redesigned pDOM mainboard with dual ADCs
- Up/down information improves reconstruction

mDOM

Hamamatsu 3"



HZC 3.5"



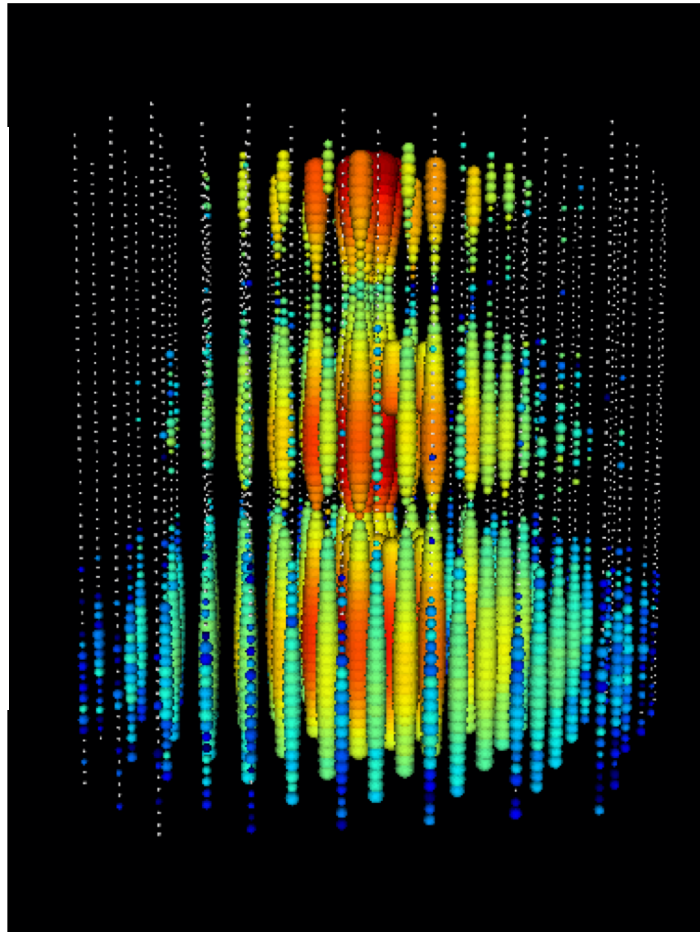
ADC3424 Quad-Channel, 12-bit, 125 MSPS ADC
Ultra-Low Power Consumption: 98 mW / Ch

- 24 PMTs per module with individual HV, waveform readout
- Slower ADCs (100–125 MSPS) for power savings
- Fast comparator provides ns leading edge time

Calibration Devices

simulated 10^{11} photon flashes
from 3 POCAMs

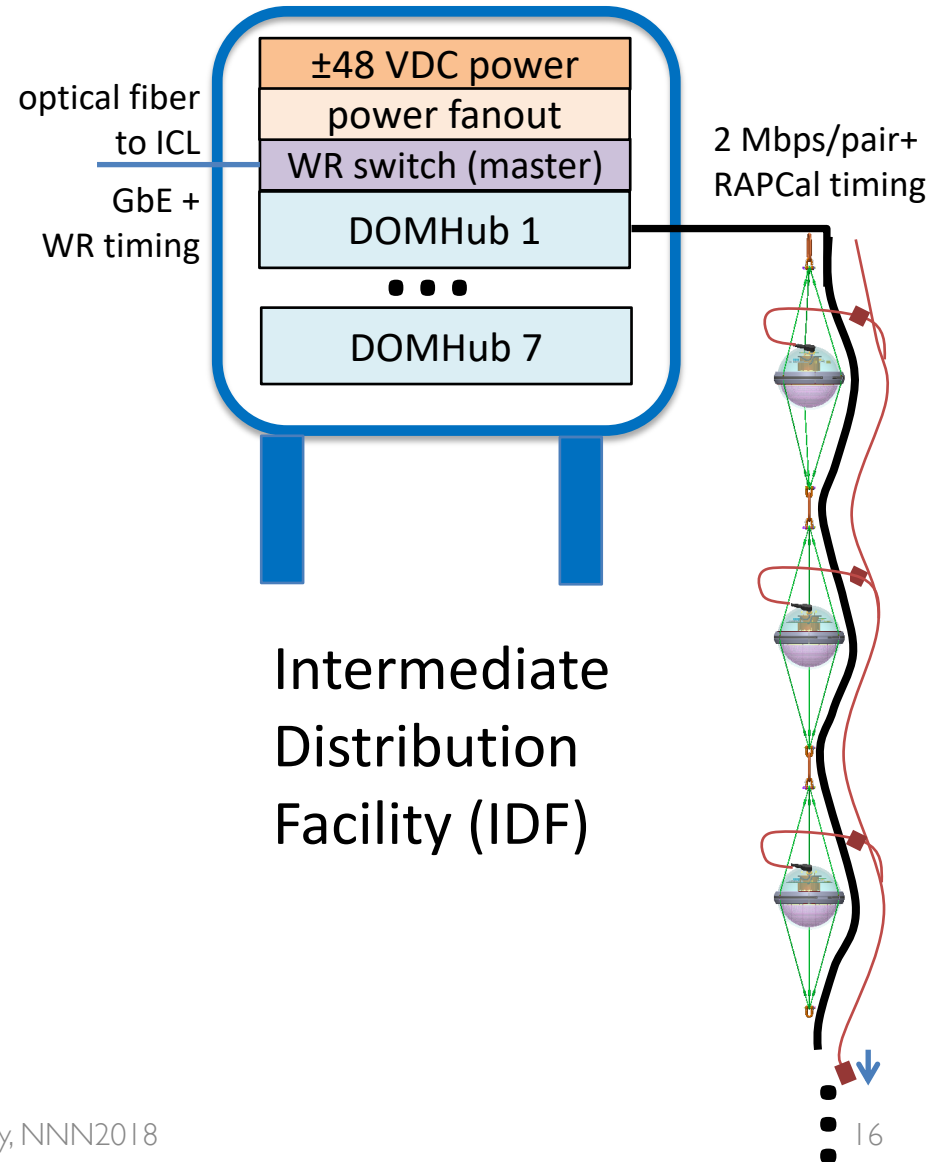
POCAM



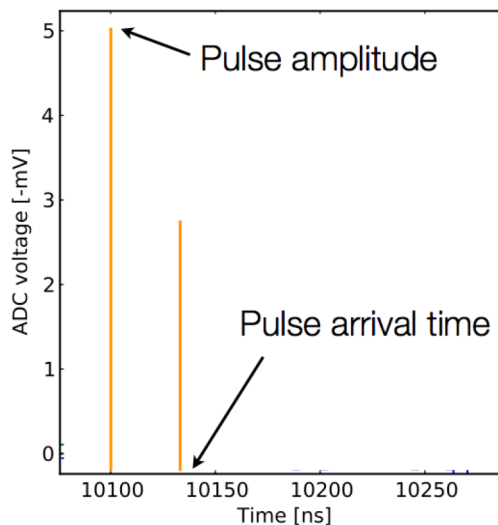
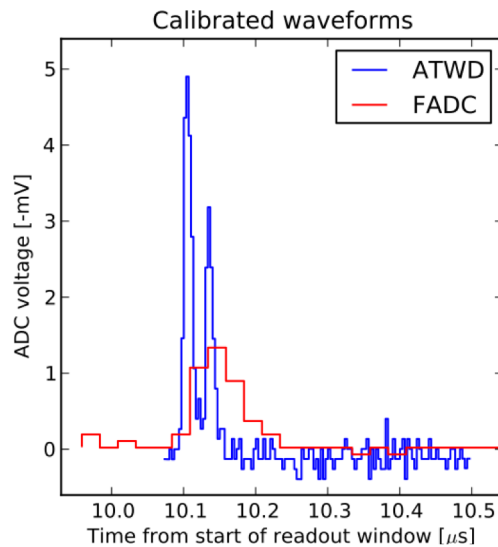
- Precision calibration a major goal of upgrade
 - ice properties, *in situ* module angular acceptance
- Both integrated and standalone devices
 - Precision Optical Calibration Module (POCAM)
 - optical cameras
 - acoustic positioning sensors

Communications / Timing Changes

- Surface clock fanout replaced with White Rabbit
 - scalable to larger arrays
- More devices / wire pair
 - increasing from two to four
- Elimination of local coincidence wiring
 - simpler in-ice cable
 - single-photon data compression required



In-DOM SPE Feature Extraction

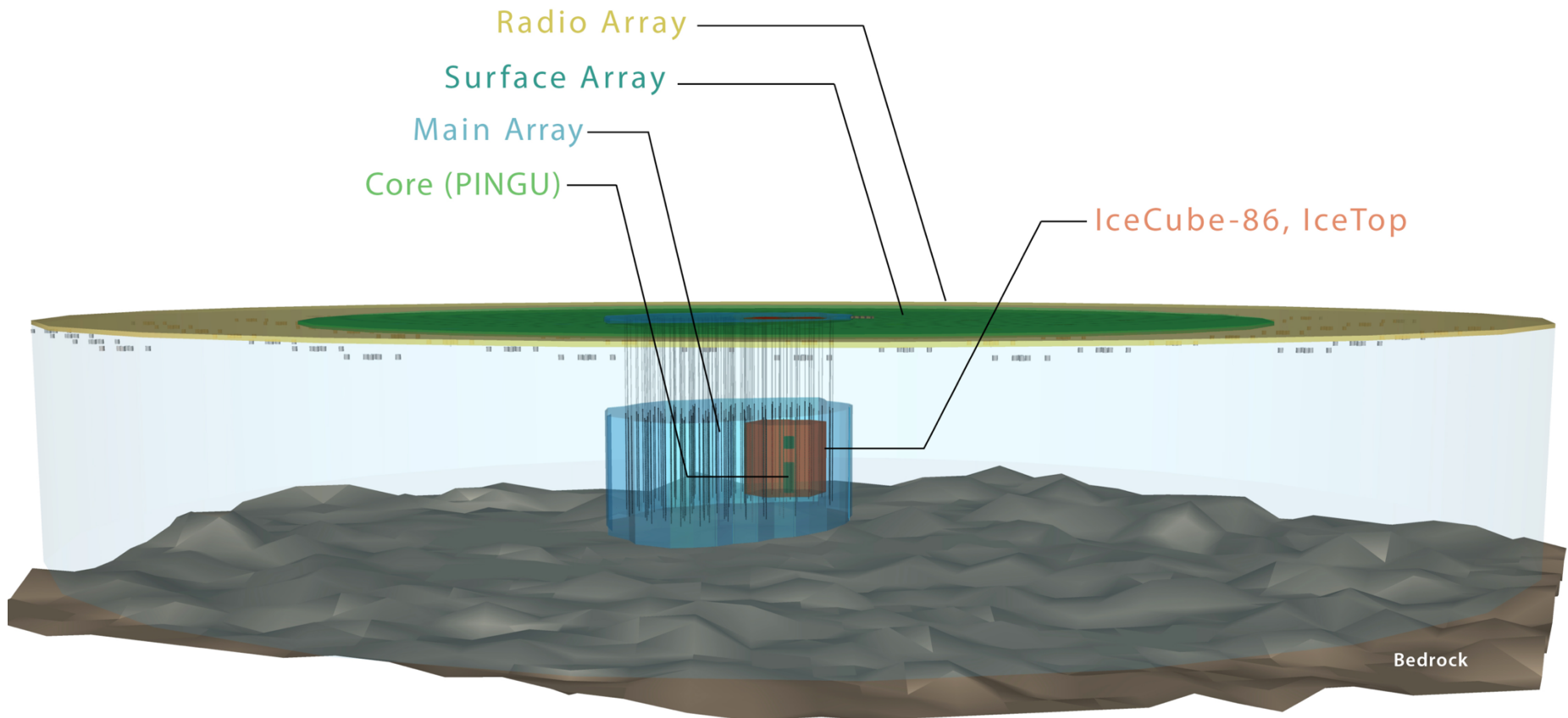


- Standard DOM waveform processing: unfolding using single photoelectron (SPE) template to “pulse series”
- Modifications for DOM firmware in progress
 - single-iteration handles dark noise SPEs
 - ported to fixed-point math
 - complex waveforms handled by other methods
- Most hits compressed from full waveform to (time, amplitude)

IceCube-Gen2 Facility

Multi-component MeV to EeV neutrino detection facility

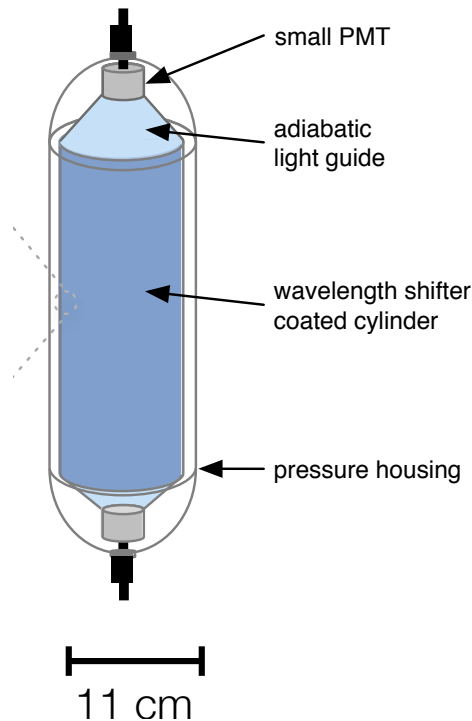
plenary talk by J. Hignight



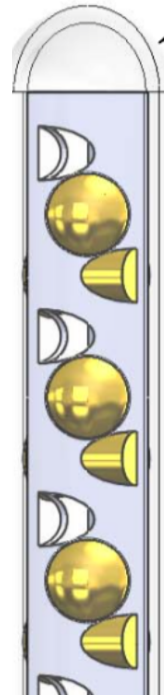
arxiv.org/1412.5106

Additional Module R&D

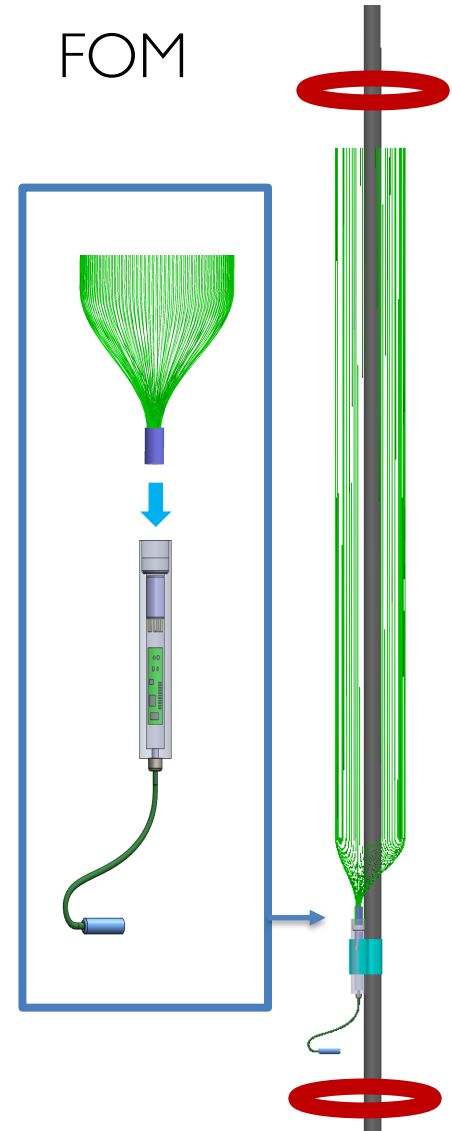
WOM



LOM



FOM




- increase light collection without increasing PMT area
- narrow profile for faster / cheaper drilling
- wavelength shifter for UV acceptance



THE ICECUBE COLLABORATION

 **AUSTRALIA**
University of Adelaide

 **BELGIUM**
Université libre de Bruxelles
Universiteit Gent
Vrije Universiteit Brussel

 **CANADA**
SNOLAB
University of Alberta–Edmonton

 **DENMARK**
University of Copenhagen

 **GERMANY**
Deutsches Elektronen-Synchrotron
ECAP, Universität Erlangen-Nürnberg
Humboldt-Universität zu Berlin
Ruhr-Universität Bochum
RWTH Aachen University
Technische Universität Dortmund
Technische Universität München
Universität Mainz
Universität Wuppertal
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