Detector Overview

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

June 18, 2018 – Matt Kauer

WIPAC
Wisconsin IceCube
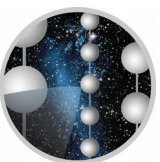Particle Astrophysics Center

Outline

Low level hardware/software centric...
- Where is IceCube and why there
- How was it deployed
- What was deployed
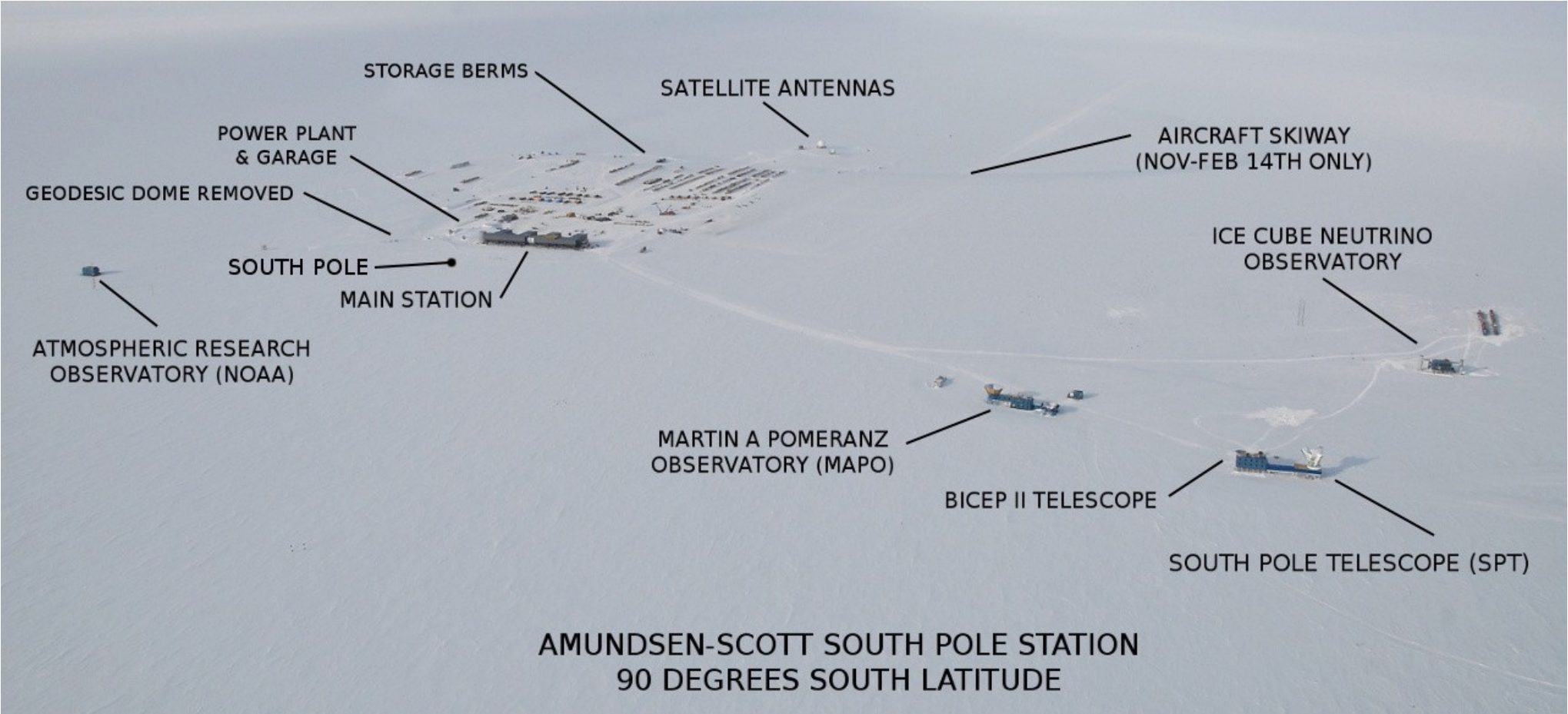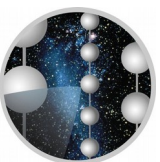- How does it all work...

NASA Website:
"Presently, the Antarctic ice sheet contains 90% of the ice on Earth and would raise sea levels worldwide by over 200 feet were it to melt."
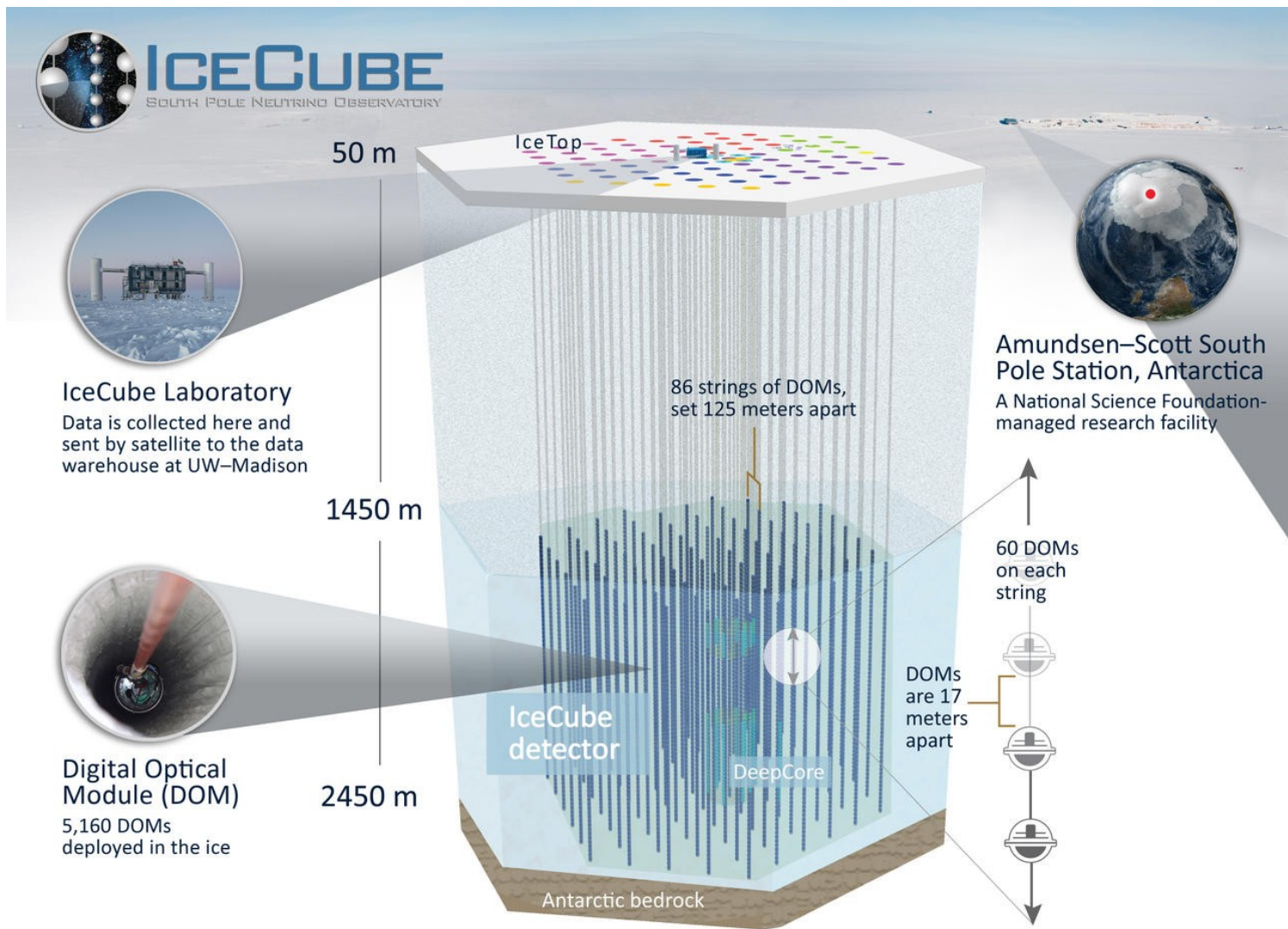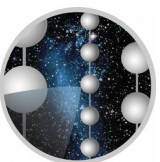
Where?

STORAGE BERMS

SATELLITE ANTENNAS

POWER PLANT & GARAGE

AIRCRAFT SKIWAY (NOV-FEB 14TH ONLY)

GEODESIC DOME REMOVED

ICE CUBE NEUTRINO OBSERVATORY

SOUTH POLE

MAIN STATION

ATMOSPHERIC RESEARCH OBSERVATORY (NOAA)

MARTIN A POMERANZ OBSERVATORY (MAPO)

BICEP II TELESCOPE

SOUTH POLE TELESCOPE (SPT)

AMUNDSEN-SCOTT SOUTH POLE STATION
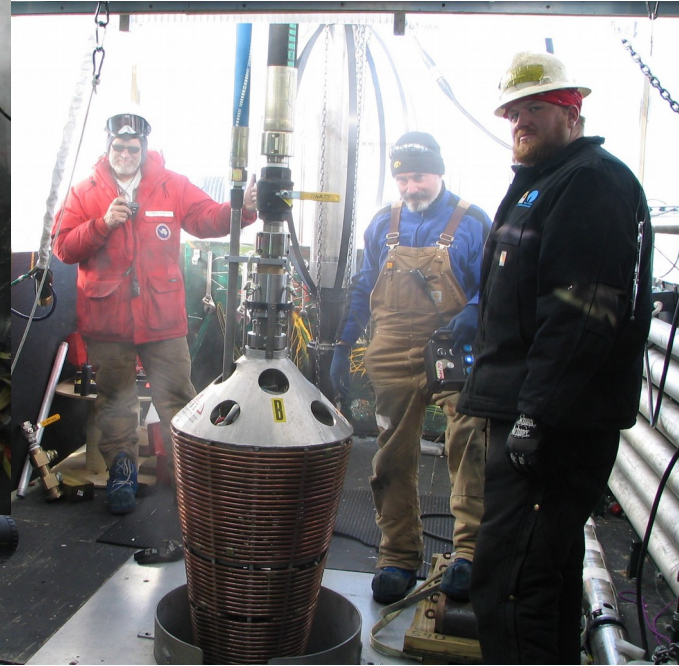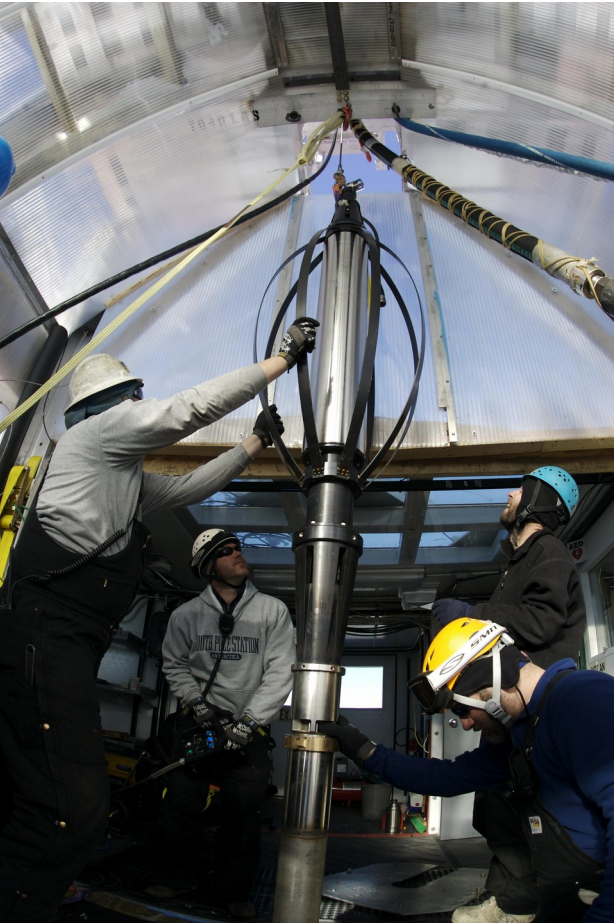90 DEGREES SOUTH LATITUDE

Where?

At the South Pole, why?
- The ice is blue/UV clear
  - great for Cherenkov
- The ice is deep
  - Muon shielding
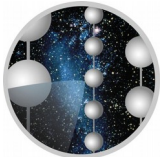- South Pole station is science support driven – it's a science base

ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

IceTop

50 m

IceCube Laboratory
Data is collected here and sent by satellite to the data warehouse at UW–Madison

Amundsen–Scott South Pole Station, Antarctica
A National Science Foundation-managed research facility

86 strings of DOMs, set 125 meters apart

1450 m

60 DOMs on each string

Digital Optical Module (DOM)
5,160 DOMs deployed in the ice

DOMs are 17 meters apart

IceCube detector

DeepCore

2450 m

Antarctic bedrock

How?

Hot Water Drilling
- 60 cm holes
- 2.5 km deep
- ~30 hours per hole

# Enhanced Hot Water Drill

Table 5: EHWD System Characteristics

Specification	Value
Total Power (Thermal + Electrical)	5 (4.7 + 0.3) MW
Maximum Drill Speed	2.2 m/min
Maximum Ream Speed	10 m/min
Water Flow (delivered to main hose)	760 L/min
Water Temperature (delivered to main hose)	88 °C
Water Gauge Pressure (at main pumps)	7600 kPa

Specification	Avg. Value	Peak Value
Total Fuel[a], AN-8	21,000 L	15,000 L
Time to Drill/Ream	30 hr	27 hr
Hole Production Cycle Time[b]	48 hr	32 hr

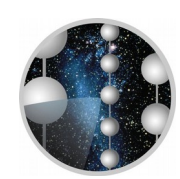Power your house for ~6 months
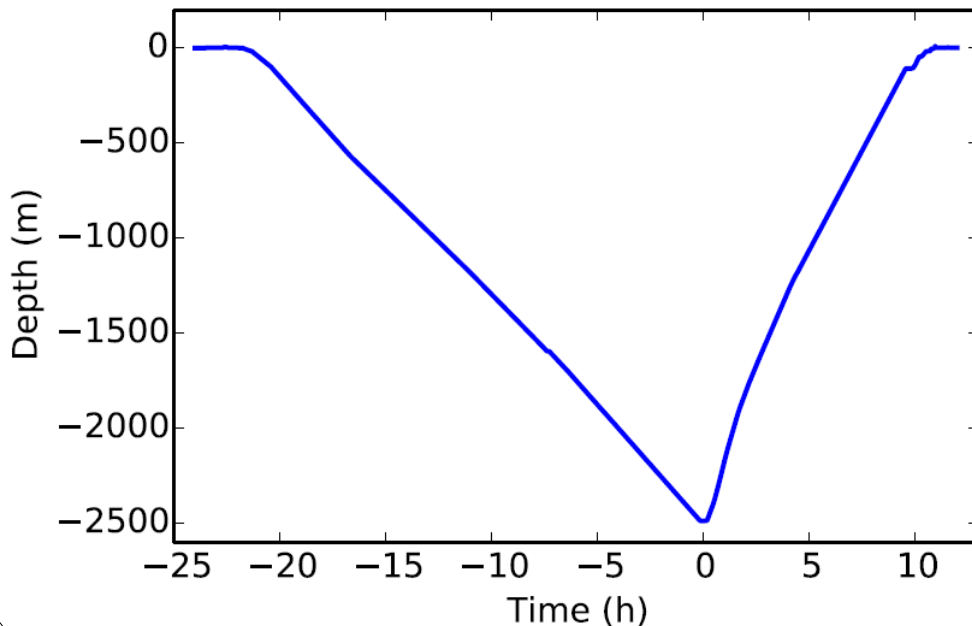
Refuel your car ~500 times
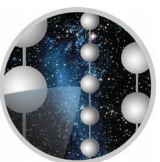
What was deployed?
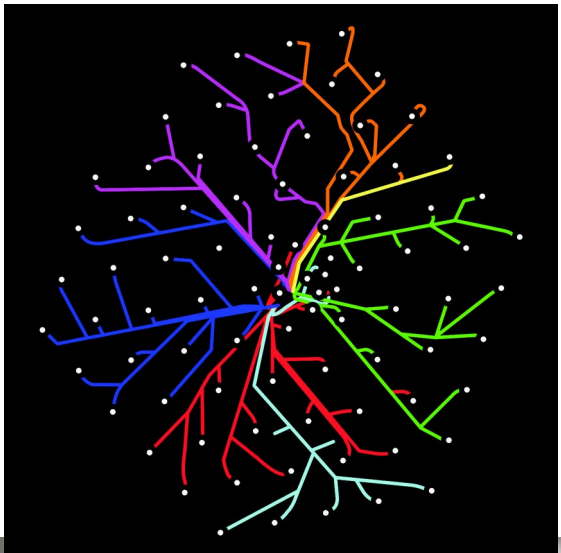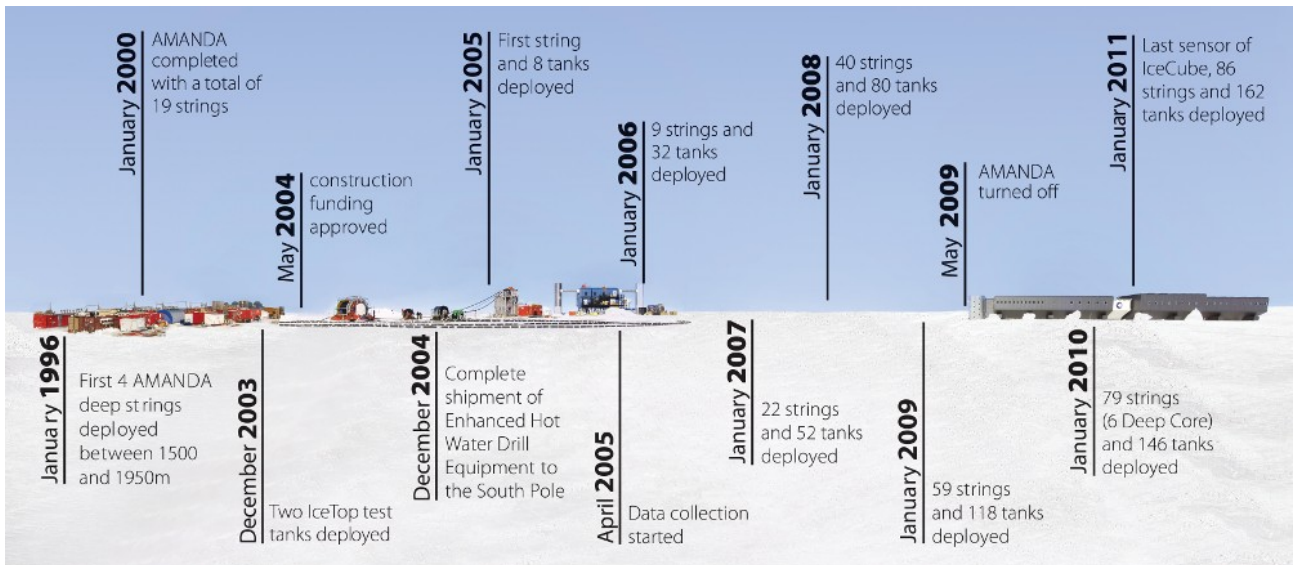
Years: 2004 – 2011
- 5160 DOMs on 86 "strings"
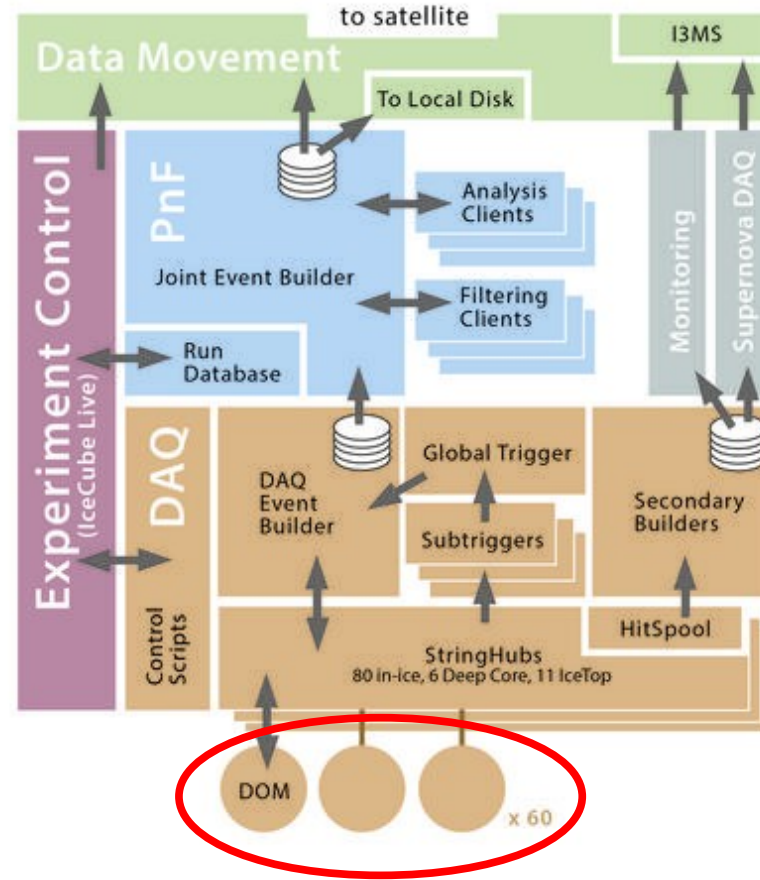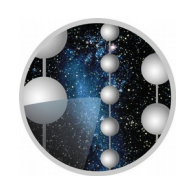- 324 "IceTop" DOMs in 162 tanks
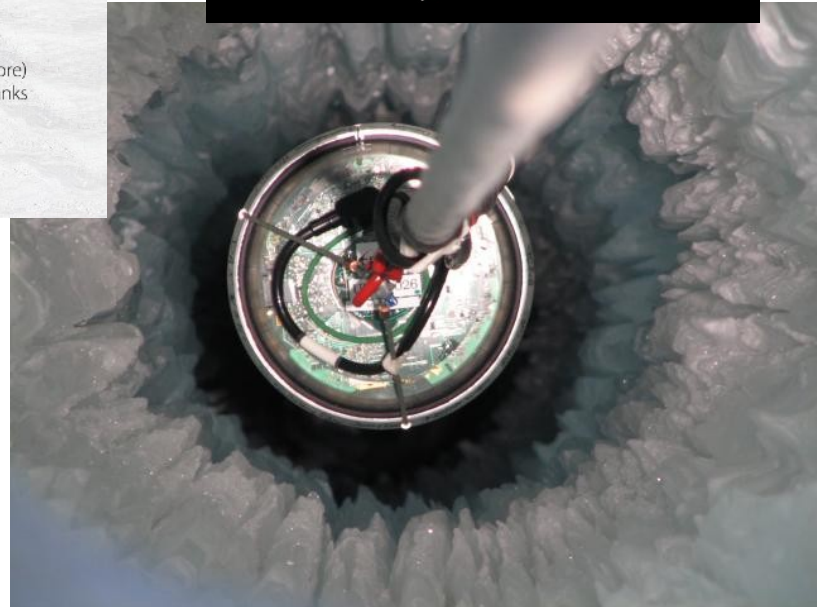
Overview

Data flow…
- The DOMs

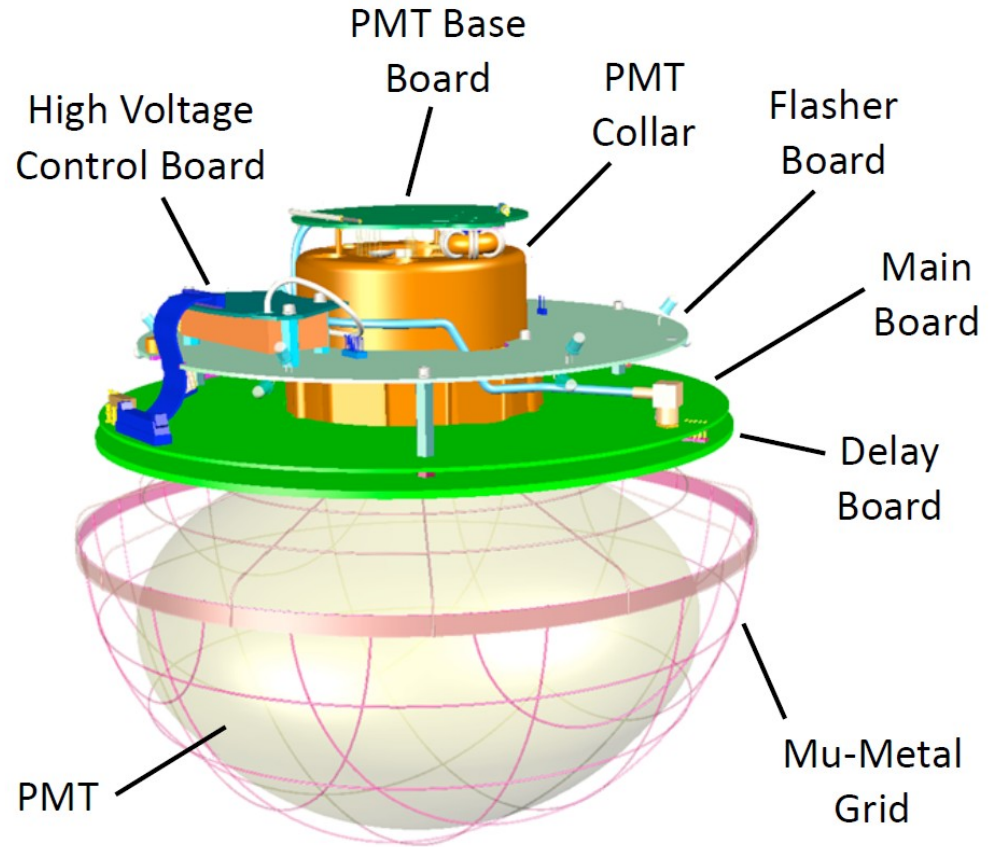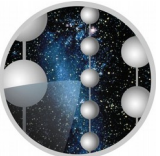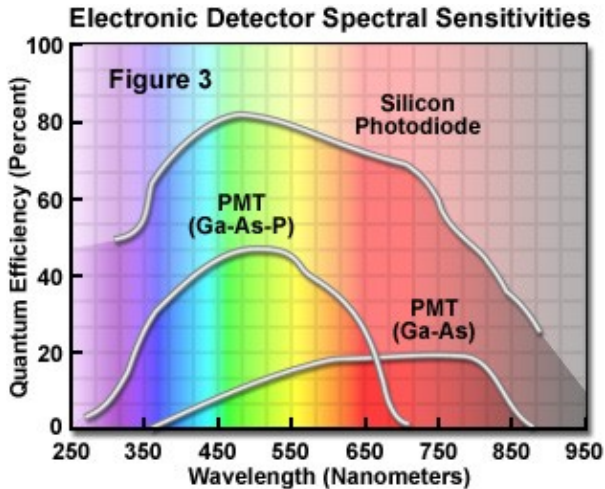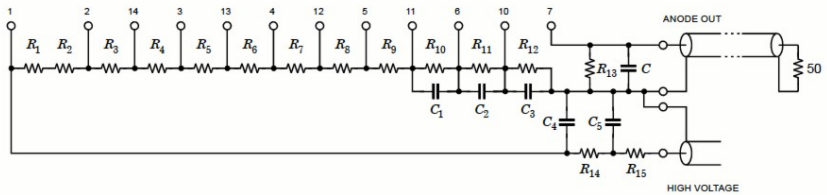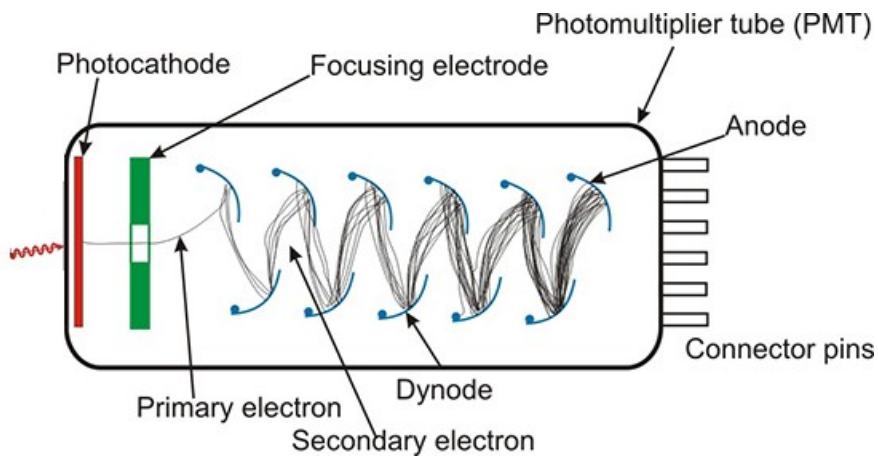# What is a DOM?

An autonomous light detecting unit
- detects light (350-650nm)
- digitizes the waveforms
- timing synchronization
- PMT calibrations
- controls HV and LEDs
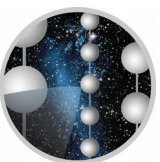- Coincidence with neighbor DOMs

PMT Base Board

PMT Collar

Flasher Board

High Voltage Control Board

Main Board

Delay Board

Mu-Metal Grid

PMT

What is a PMT?

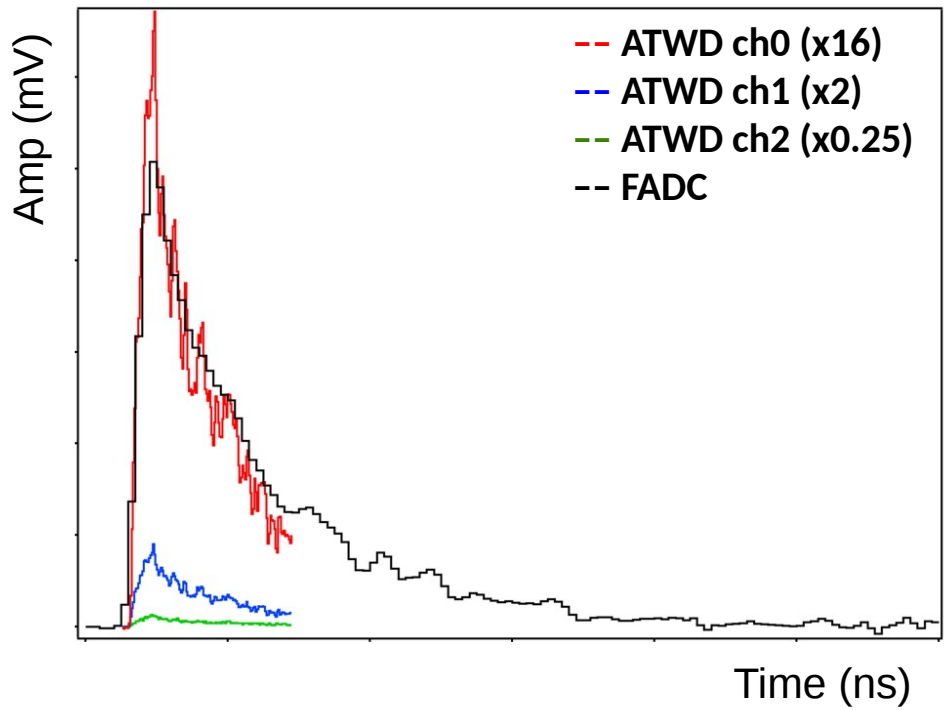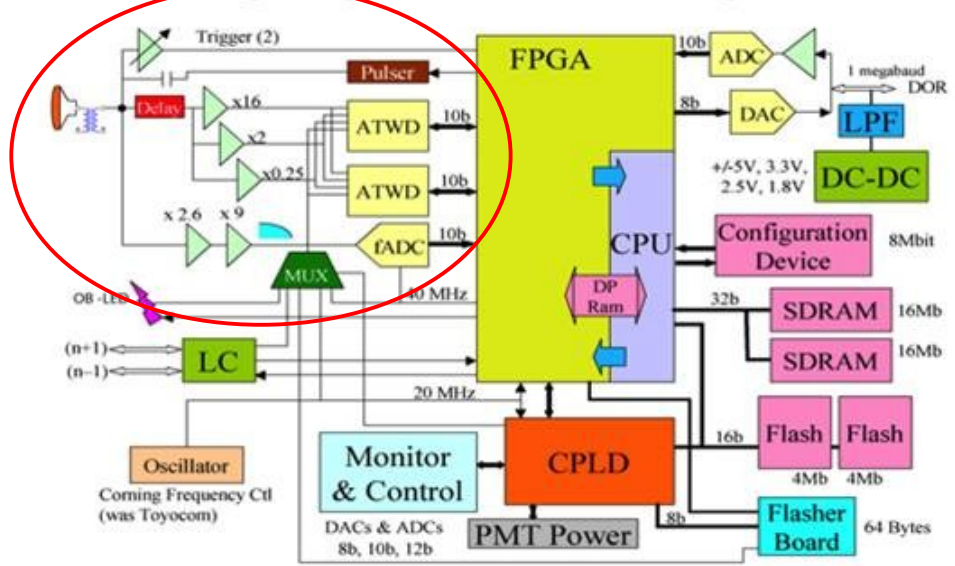Electronic Detector Spectral Sensitivities

Figure 3

- Clever way of converting photons into electrons (since 1934)
- Sensitive between 350-650nm
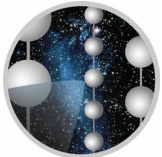- Quantum efficiency 25-45%
- Gain on order 10^7

Digitized Waveforms
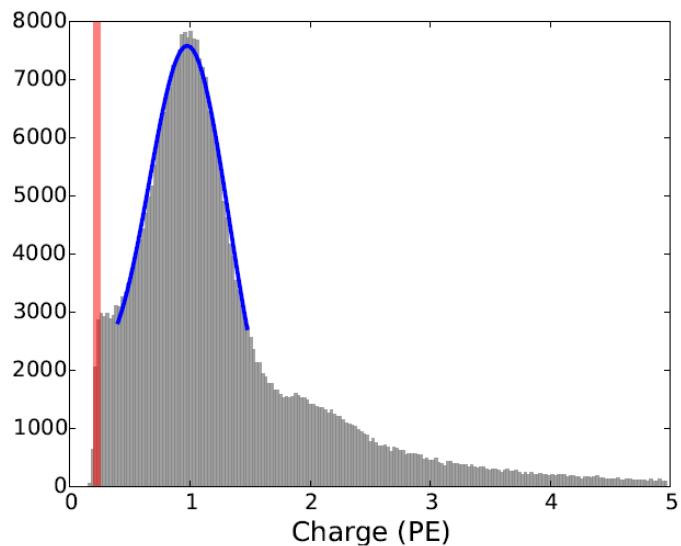

Digital Optical Module Block Diagram

ATWD – 300 MS/sec – 427 ns
FADC – 40 MS/sec – 6.4 us
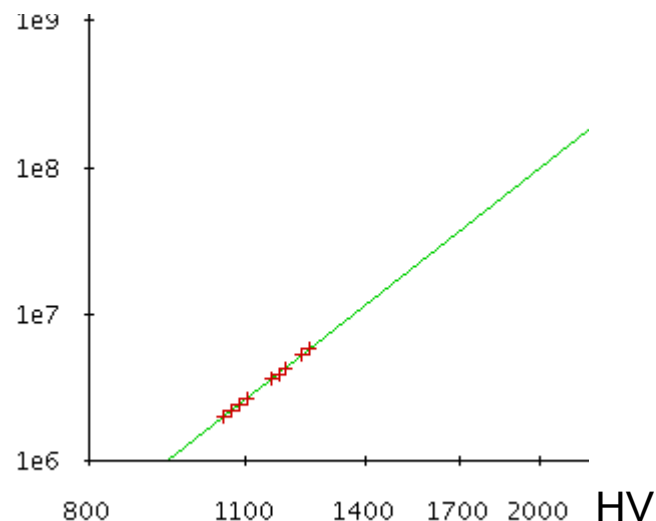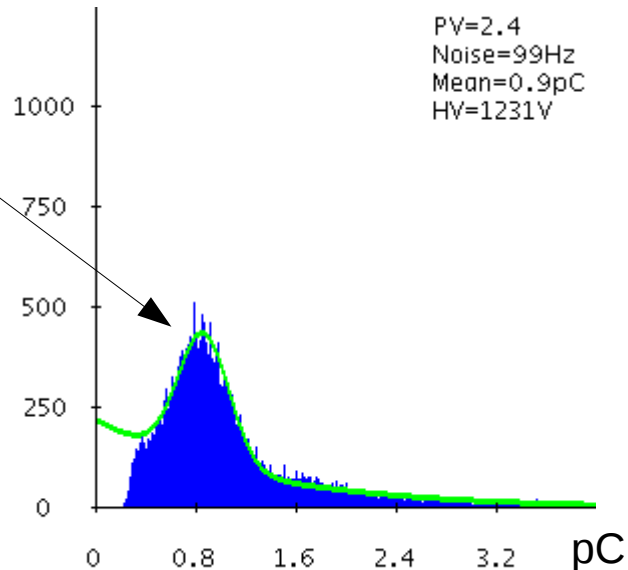
Calibration

- DOMCal
- Flasher board

1 photo-electron

PV=2.4
Noise=99Hz
Mean=0.9pC
HV=1231V

Calibration is done on-board
- ATWD gains
- PMT timing
- PMT gain vs HV

See talk by Dawn Williams!
Tuesday – 11:00am
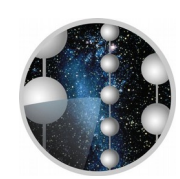
Local Coincidence

If a DOM "triggers" (threshold crossing) but does not see a trigger in the 4 neighbor DOMs
- The waveform is not saved
- Only a timestamp and chargestamp are sent to ICL
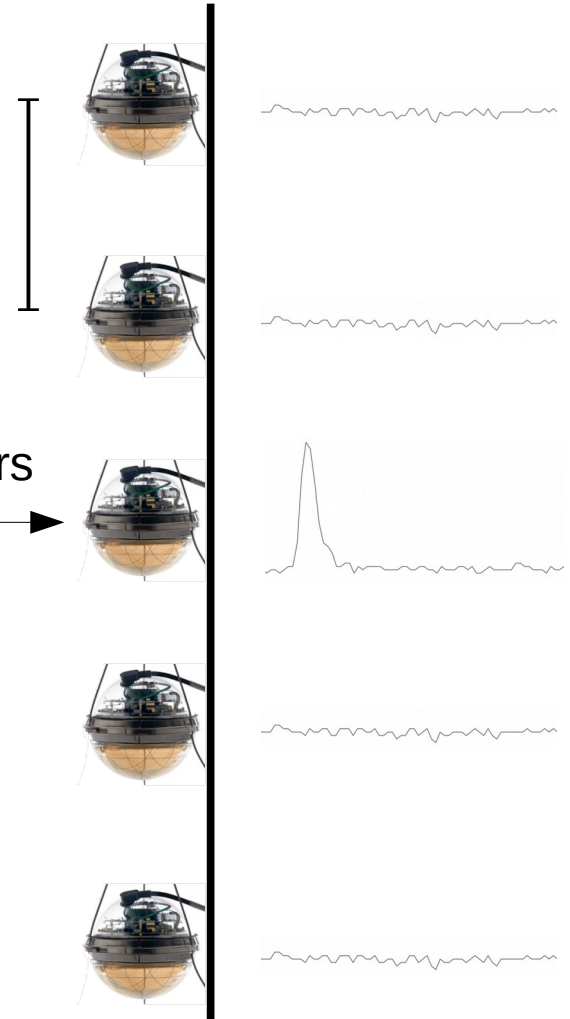- Saves communications bandwidth

17m

DOM checks its neighbors
- 2 up and 2 down
- 1 usec window

We call this Soft Local Coincidence (SLC)
- deceiving nomenclature…
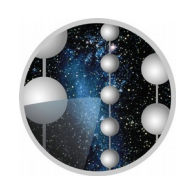
Local Coincidence

If a DOM triggers and sees a trigger in at least 1 neighbor DOM
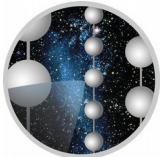- The waveforms are saved
- Waveforms sent to the ICL

DOM checks its neighbors
- 2 up and 2 down
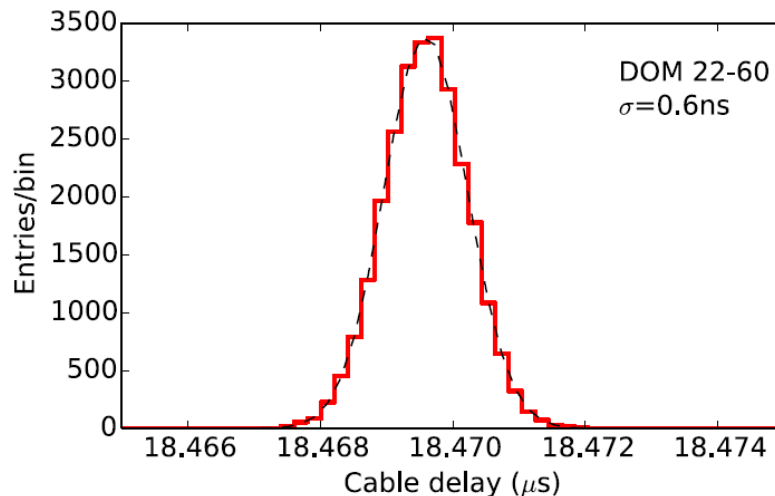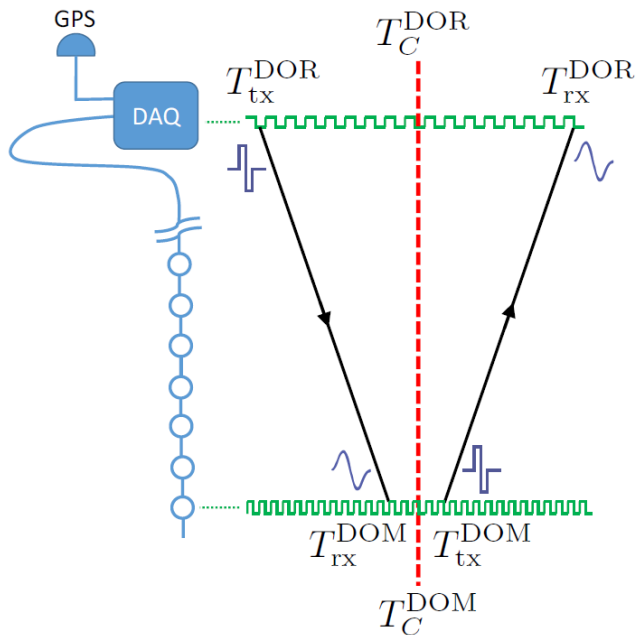- 1 usec window

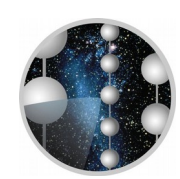We call this Hard Local Coincidence (HLC)

17m
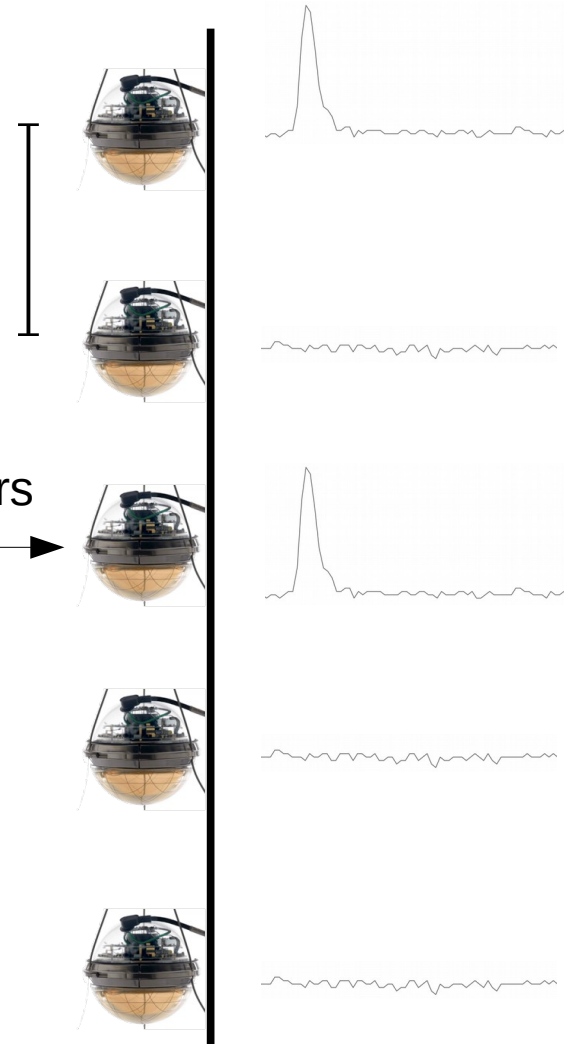
GPS Timing

Primary and secondary GPS units located in the ICL
GPS timing fans out to all "stringHubs" (computers controlling each string of DOMs)
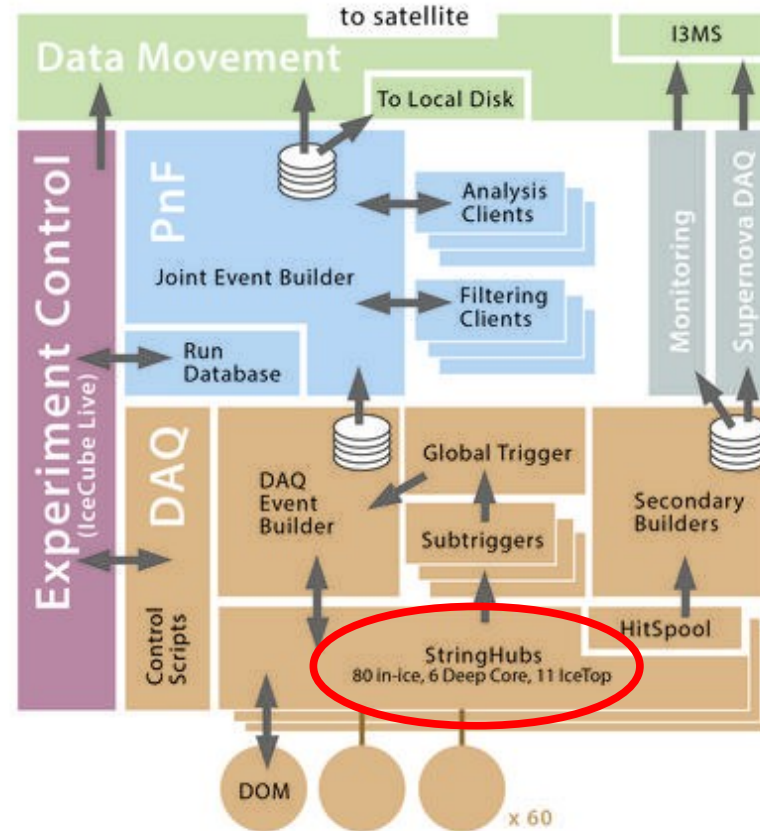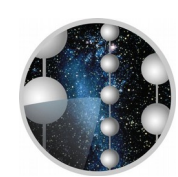Cable delay is measured/corrected for by each DOM
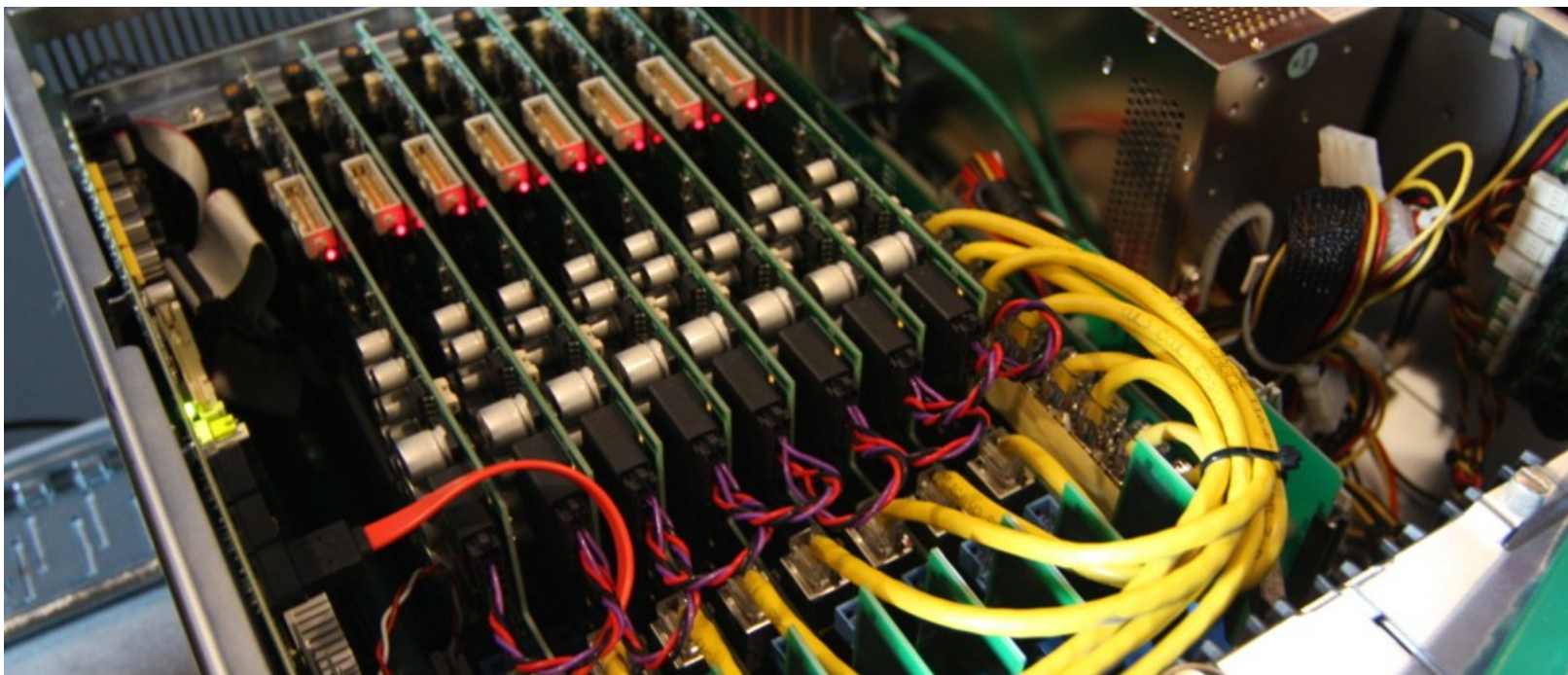
Overview

Data flow…
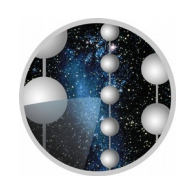- The DOMs
- StringHubs

97 StringHubs

- Each stringHub collects the SLC and HLC hits from its 60 DOMs
- 8 DOR cards each giving power and communications to 8 DOMS
- DSB card fans out the GPS timing to each DOR card
- Data from the string is collected in HitSpool files and buffered in memory
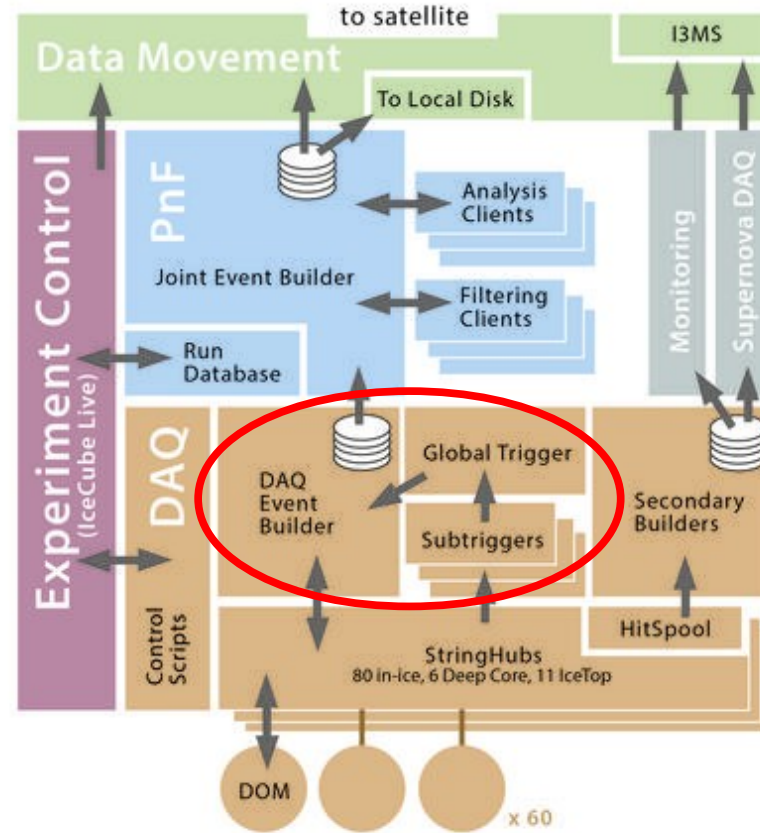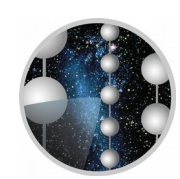
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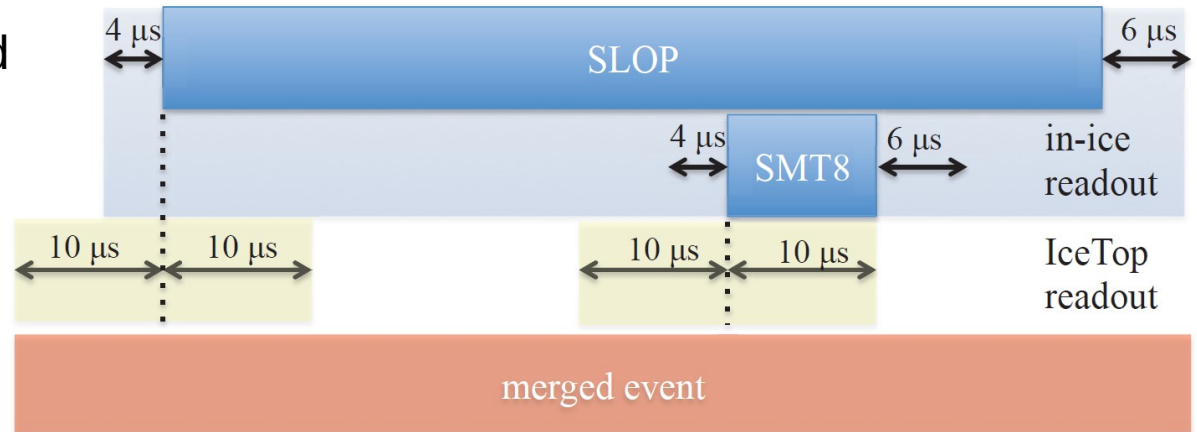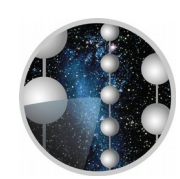- The DOMs
- StringHubs
- DAQ Triggers

DAQ Triggers

- The DAQ sorts through all the HLC hits collected from ALL the stringHubs
- Various algorithms test whether a trigger condition(s) was met
- Merges triggers to form a "Global Trigger"
- The DAQ requests all SLC and HLC hits from stringHubs for the specified time range of the Global Trigger
- Builds the event and sends it to PnF

See talk by John Kelley!
Tuesday at 9:00am

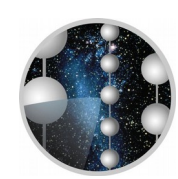| Trigger	DOM set	N HLC hits	Window (μs)	Topology	Rate (Hz)
SMT	in-ice	8	5	—	2100
SMT	DeepCore	3	2.5	—	250
SMT	IceTop	6	5	—	25
Volume	in-ice	4	1	cylinder (r=175m, h=75m)	3700
Volume	IceTop infill	4	0.2	cylinder (r=60m, h=10m)	4
String	in-ice	5	1.5	7 adjacent vertical DOMs	2200

Overview

Data flow…
- The DOMs
- StringHubs
- DAQ Triggers
- PnF
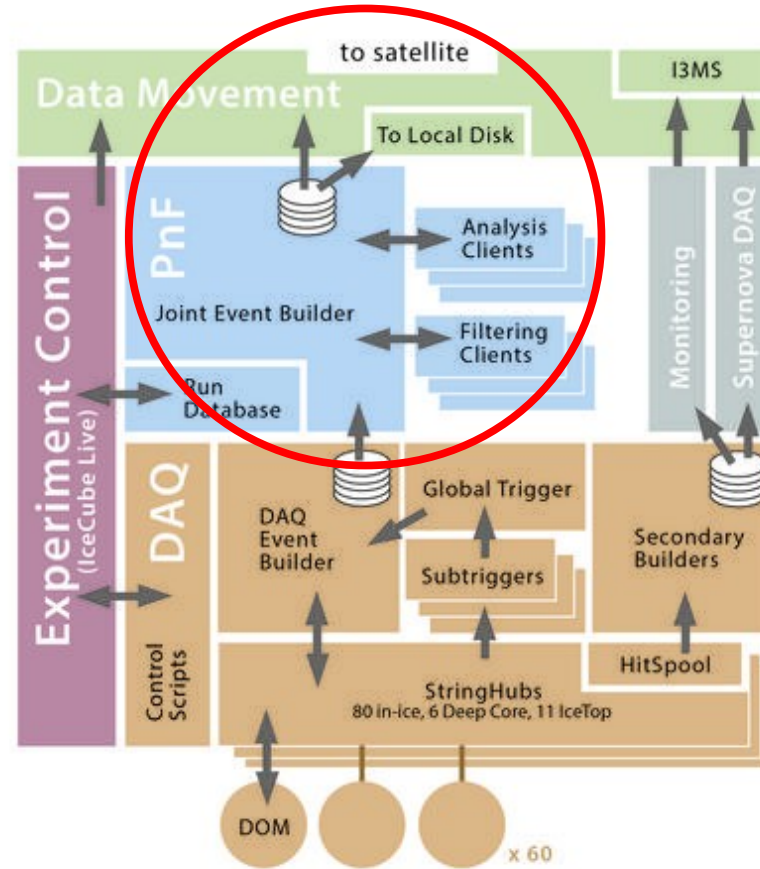
Processing and Filtering

- Applies DOM calibration constants, geometry information, etc.
- Fits the waveforms and encodes them as a few constants
- Track reconstruction
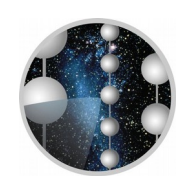- Applies more specific event selection algorithms

IceCube generates ~1 TB/day of raw DAQ triggered data
- These data are archived to disk at the ICL and shipped back every year

PnF filters and compresses those data to ~ 100 GB/day
- Filtered data is sent daily via satellite to the North for "immediate" processing and analysis

See talk by John Kelley!
Tuesday at 9:00am

Summary…

Hopefully I gave an IceCube detector overview? – Questions?
- https://arxiv.org/pdf/1612.05093.pdf