IceCube Systems Architecture

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NSF Mid-Term Review
29 April 2024

IceCube
South Pole Neutrino Observatory

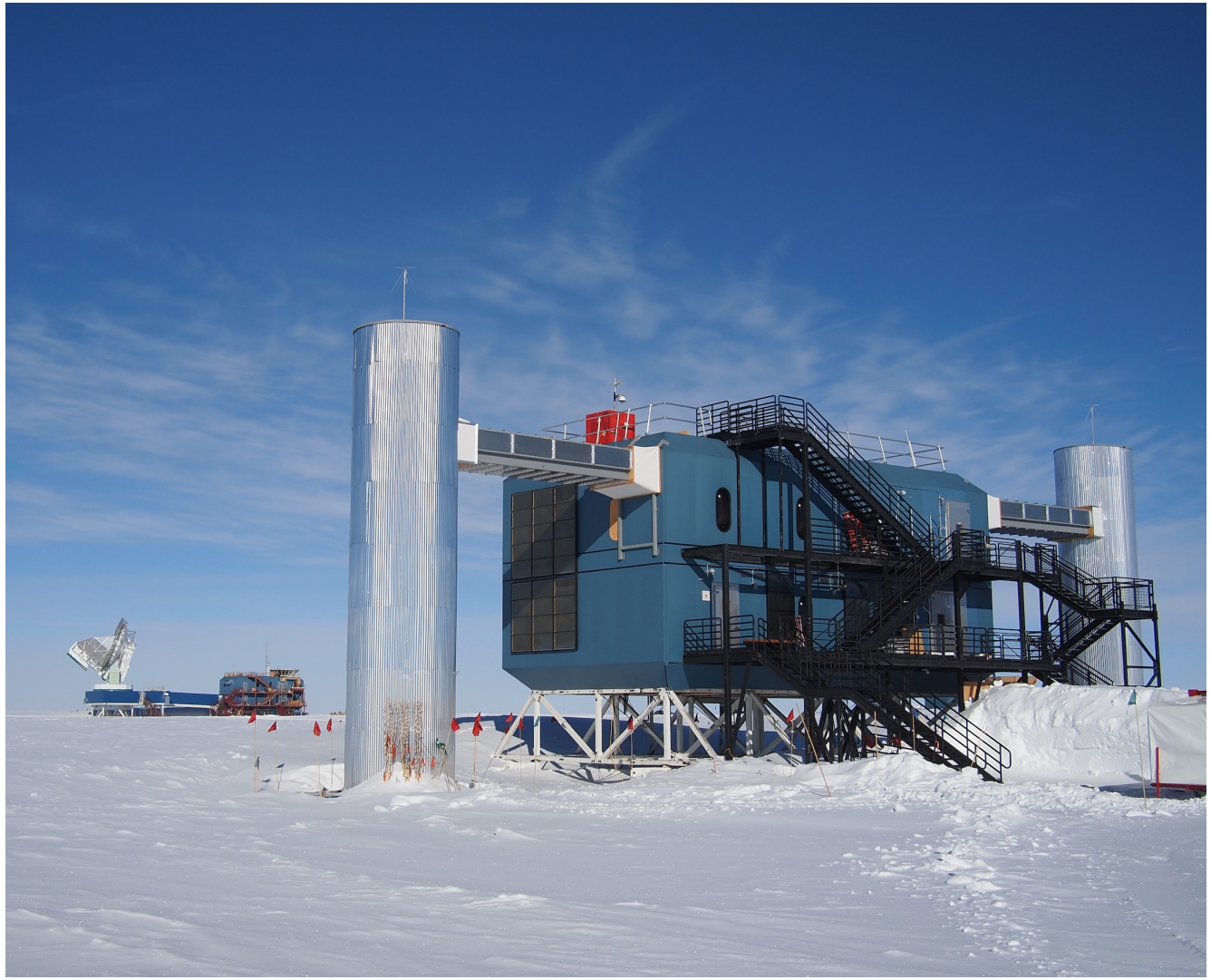
NSF

Presenter Background

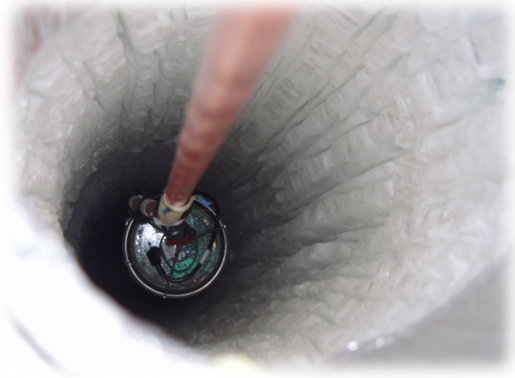
- scientist at UW–Madison
- Director of Operations, 2023–present
- Detector Operations Manager, 2013–2023
- 10 polar deployments
- active in IceCube 2003–2009; 2012–present
- AMANDA / IceCube Ph.D. 2009

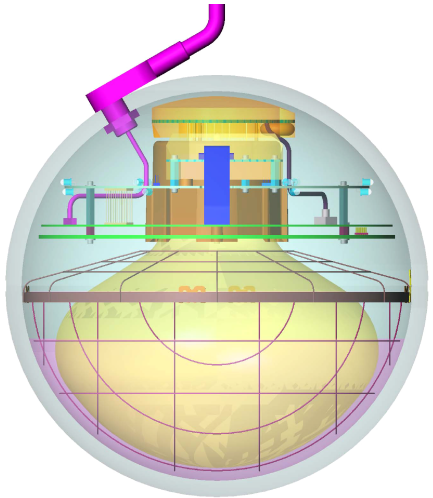
Outline

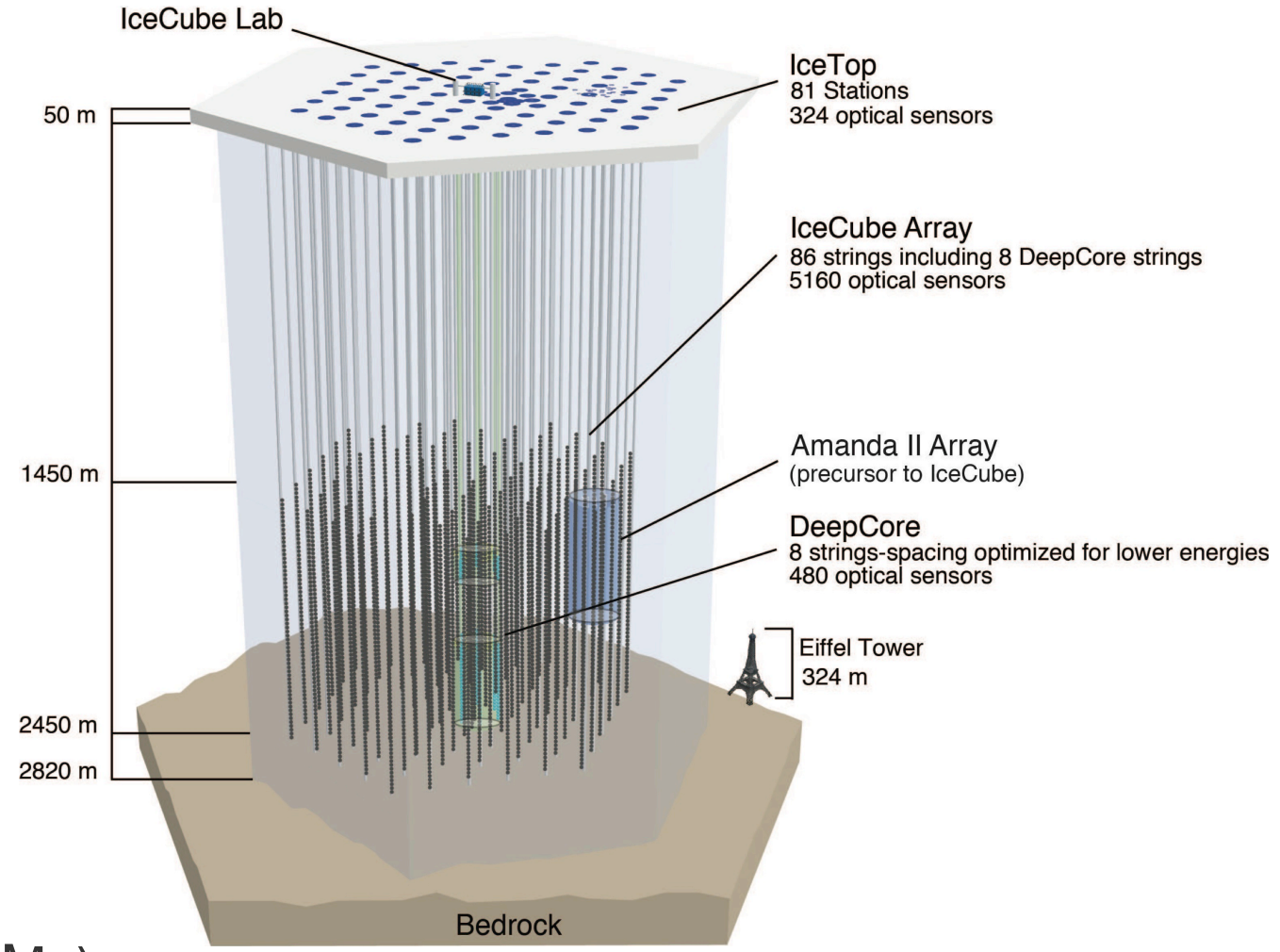
- IceCube detector
- Data flow from the ice to the collaboration
- Triggering and Filtering
- Filtering improvements and Pass 3 reprocessing



The IceCube Detector

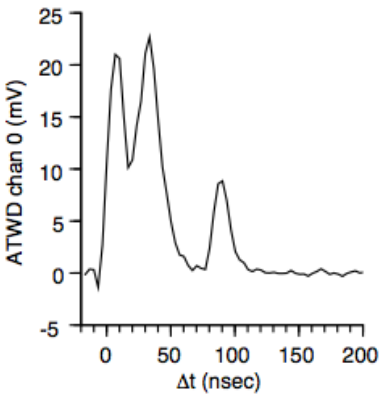






5484 digital optical modules (DOMs)

IceCube Data Flow



South Pole System (SPS)

DOMs

data acquisition

DAQ

trigger

processing & filtering

PnF

filter

JADE

filtered

satellite (TDRSS)

~100 GB/day

raw

~1 TB/day

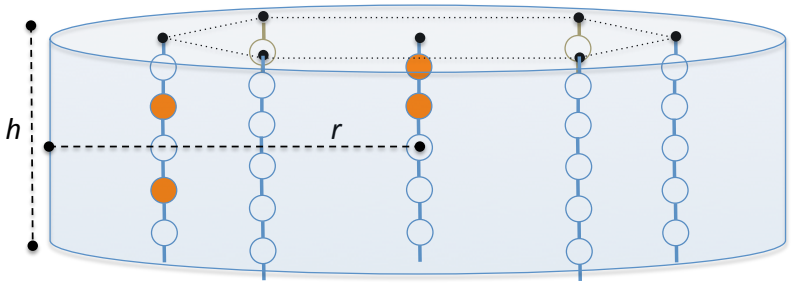
archival disk

data warehouse

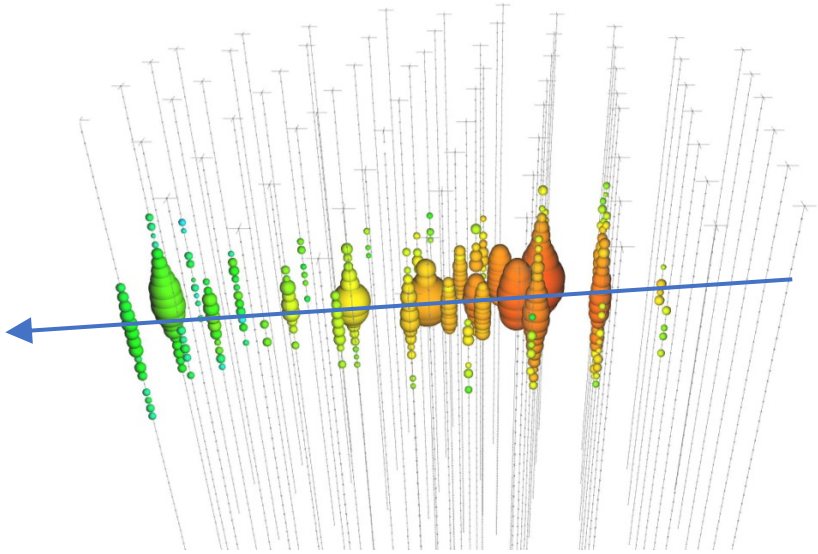
L2, L3 offline processing

"The North"

Triggers and Filters



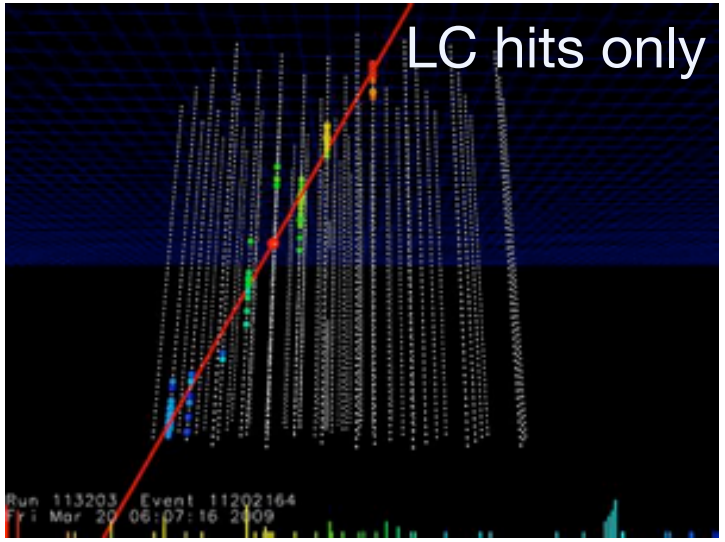
DAQ selects causal patterns of light (hits) from particle interactions

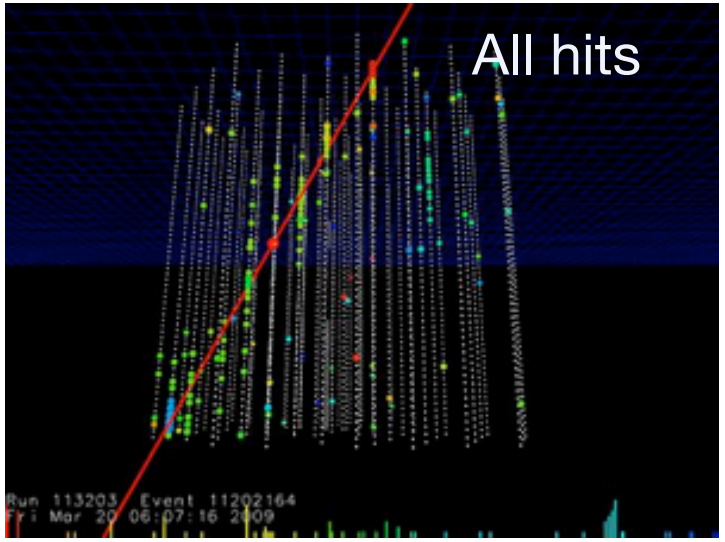


PnF performs fast reconstructions on those events, selects subsets interesting for analysis or real-time followup

Data Acquisition System ”pDAQ”

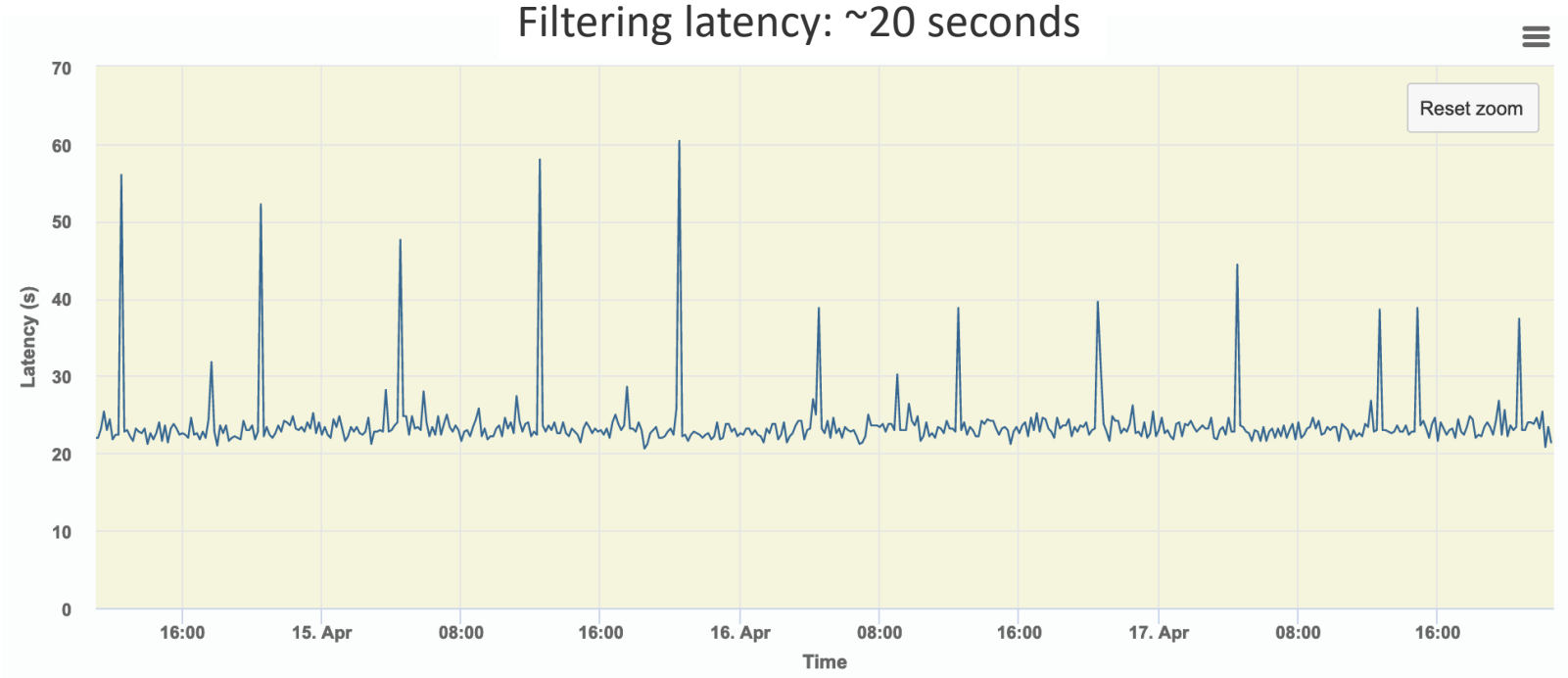
- DAQ forms events by triggering on patterns of light (“hits”)
  - trigger primarily operates on hits with coincidences on neighbor DOMs (“LC”)
- Core triggers are Simple Majority Triggers (SMT)
  - *N* LC hits in a time window
  - all trigger algorithms run in parallel
  - all hits read out and bundled into event
- Untriggered data (“hitspool”) is available for 12.5 days
  - saved on request (automated or manual)
  - gravitational wave follow-up, solar flares, supernova alerts, etc.





Processing and Filtering “PnF”

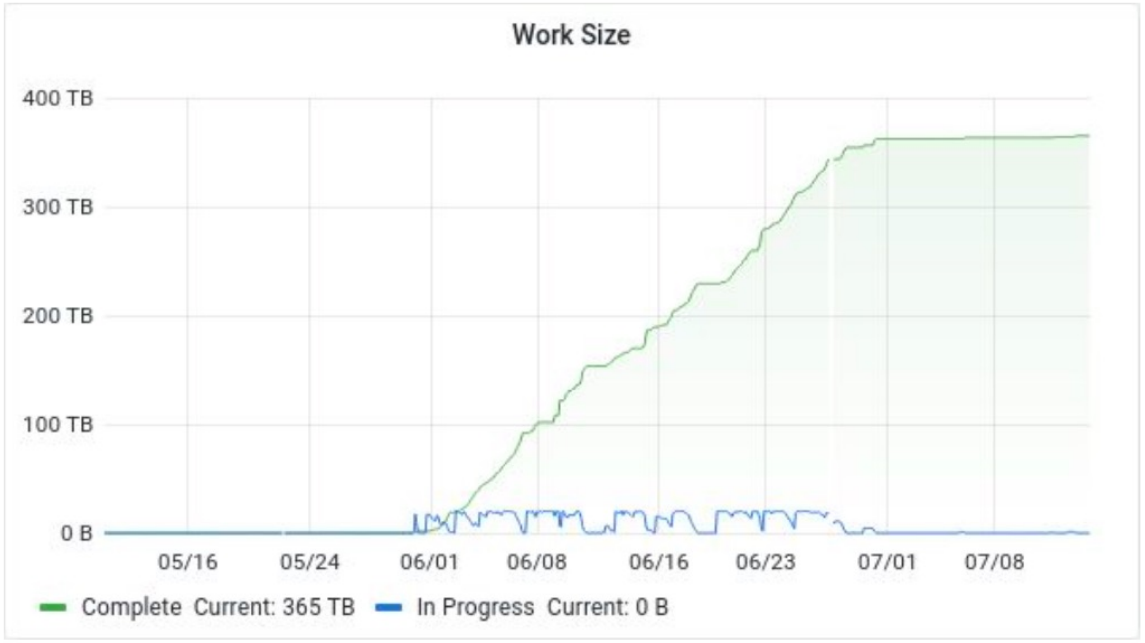
- process all pDAQ events in real time
- apply calibrations, DOM waveform processing, and initial fast reconstructions
- select events for satellite transmission
  - ”L1” data forms the basis of physics analyses
- select astrophysical neutrino event candidates to send to wider astrophysics community



Inside the IceCube Lab (ICL)

- 18 racks
- 97 DOMHubs
  - single-board computers
  - custom DOM readout cards
  - custom clock fanout
  - in-ice: 1 hub/string
- 43 Dell PowerEdge R740 servers
  - 6 data acquisition (DAQ)
  - 17 filtering
  - 2 database
  - 4 data transfer and communications
  - 7 infrastructure
  - 3 miscellaneous (ARA, surface array, IceACT)
  - 4 spares
- GPS receivers + fanouts, network switches, uninterruptible power supplies (UPS), special devices

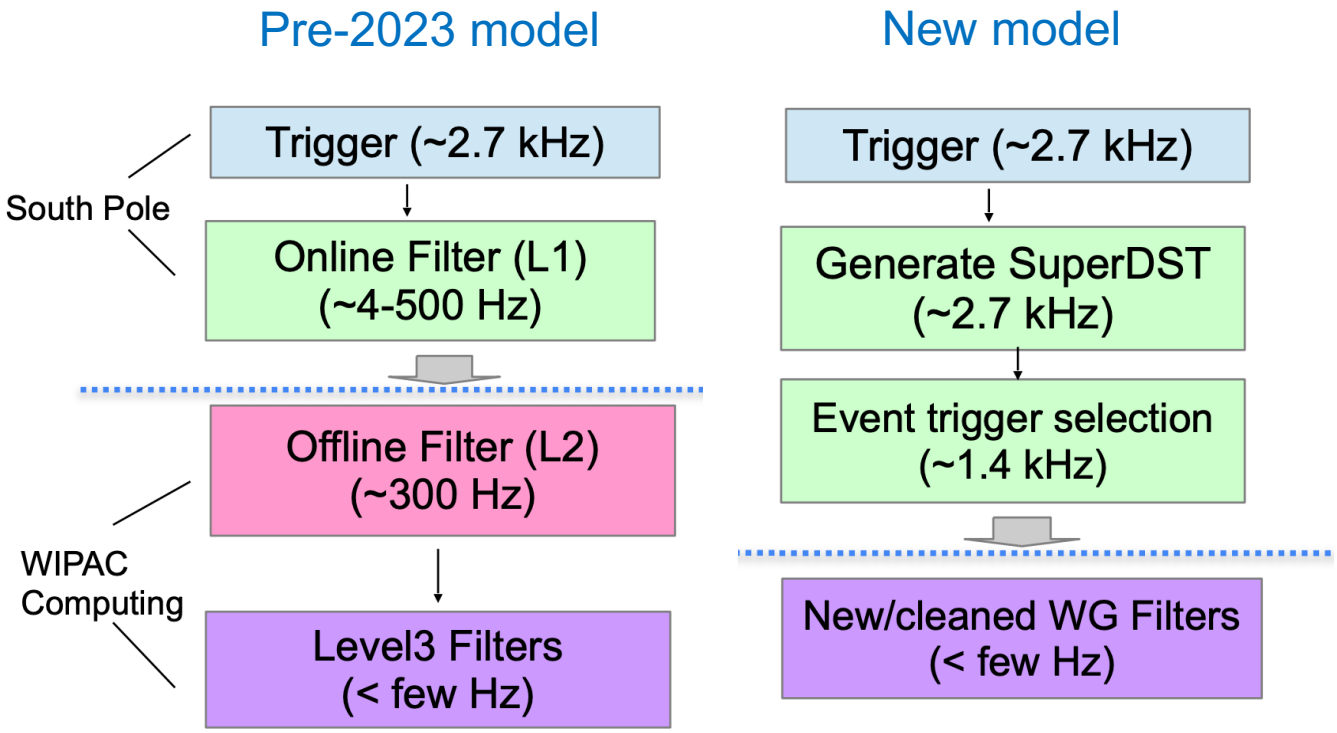
Data Transfer and Management



2022 raw data archival timeline

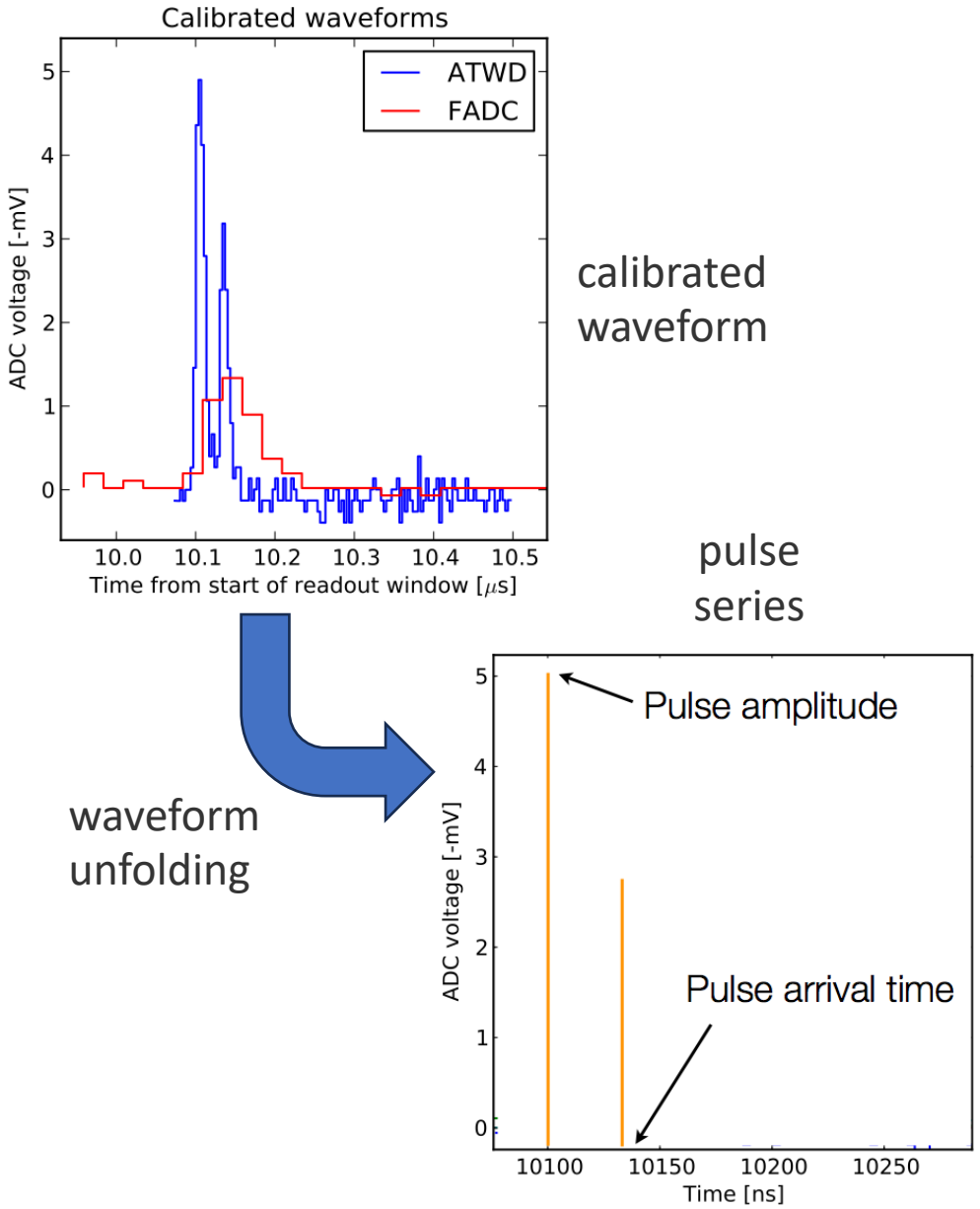
- JADE data transfer software
  - archival of raw data to disk at South Pole (2 copies)
  - handoff of filtered data to ASC for satellite transfer
  - validation of data copies and transfers to the data warehouse
- Data warehouse at WIPAC
  - provides experimental and simulated data to collaboration
  - supports further data processing
  - large distributed filesystem (recently upgraded)
- Local and grid compute resources both provide processing CPUs/GPUs

Streamlined Filtering



- Major effort underway to streamline online and offline processing
- New online processing implemented November 2023
  - before: 20+ separate physics filter streams
  - after: **all** events after SMT12 software retrigger and compression
- New offline working group filters to be deployed at 2024 physics run start
  - employ modern reconstructions
  - remove outdated/unused processing
- Improves efficiency, simplifies processing
  - solid base on which to add the Upgrade

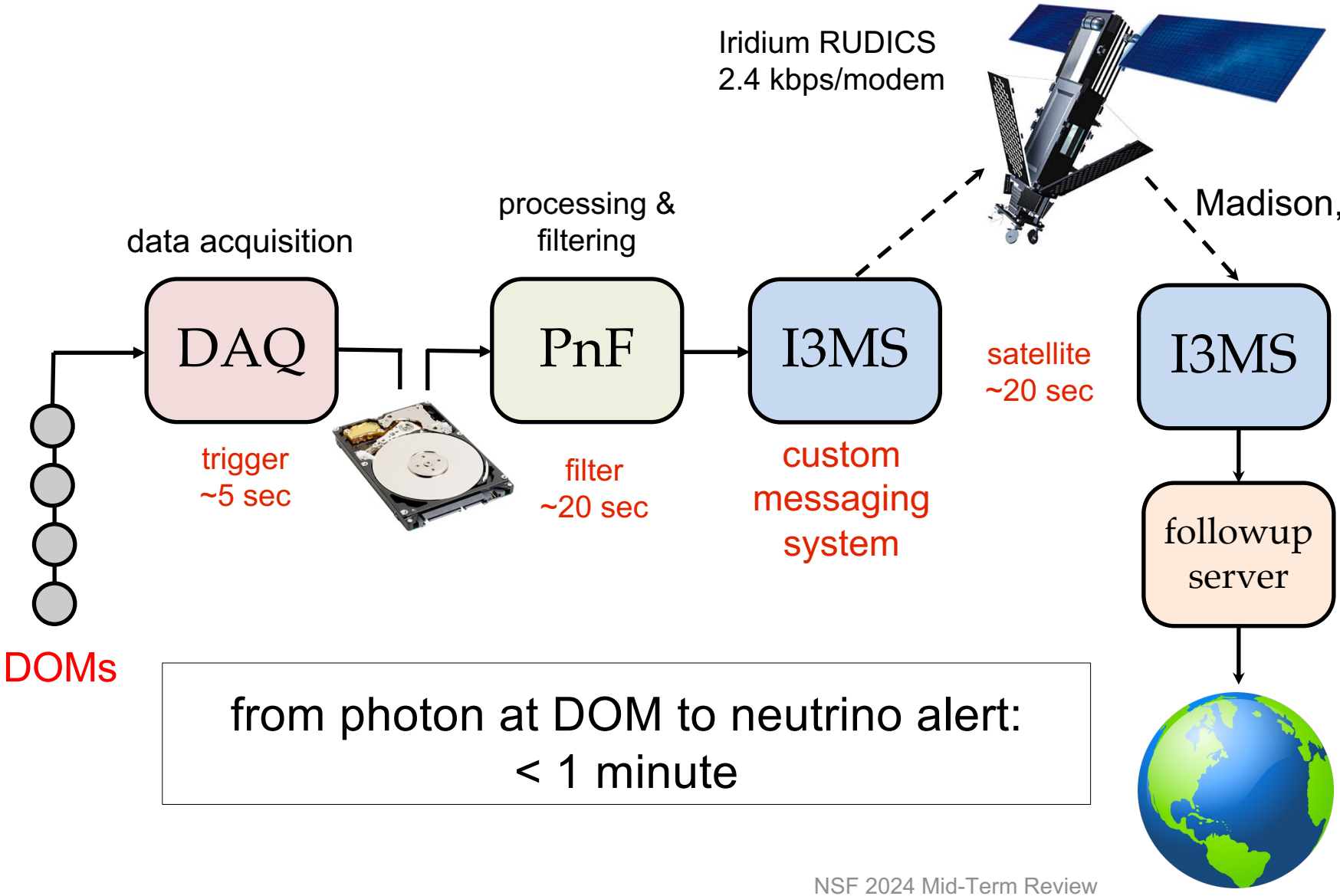
“Pass3” Reprocessing

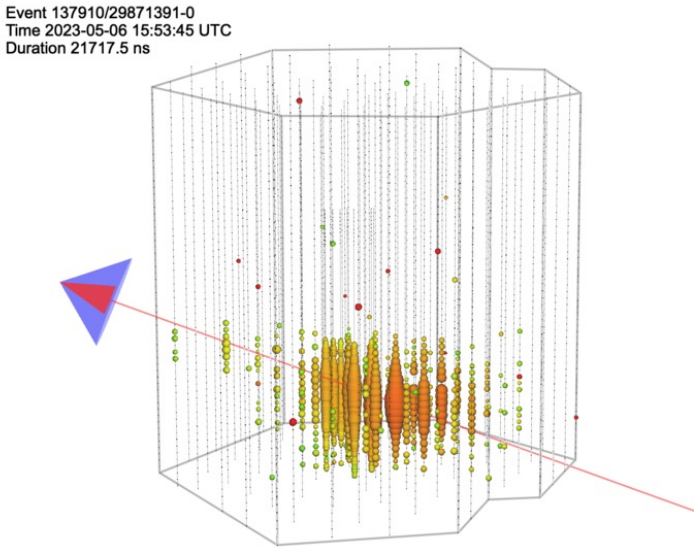


- Improvements to calibration and waveform processing can also be applied to historical data
  - e.g. previous “Pass2” reprocessing
- Raw data to be retrieved from tape archive (NERSC, TACC) and reprocessed
  - significant computing and storage requirements
- Pass3 will homogenize and improve historical data set

Supplementary Material

Real-Time Alert System





"gold" alert event
from 6 May 2023

from photon at DOM to neutrino alert:
< 1 minute