

# IceCube Systems Architecture

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NSF Mid-Term Review  
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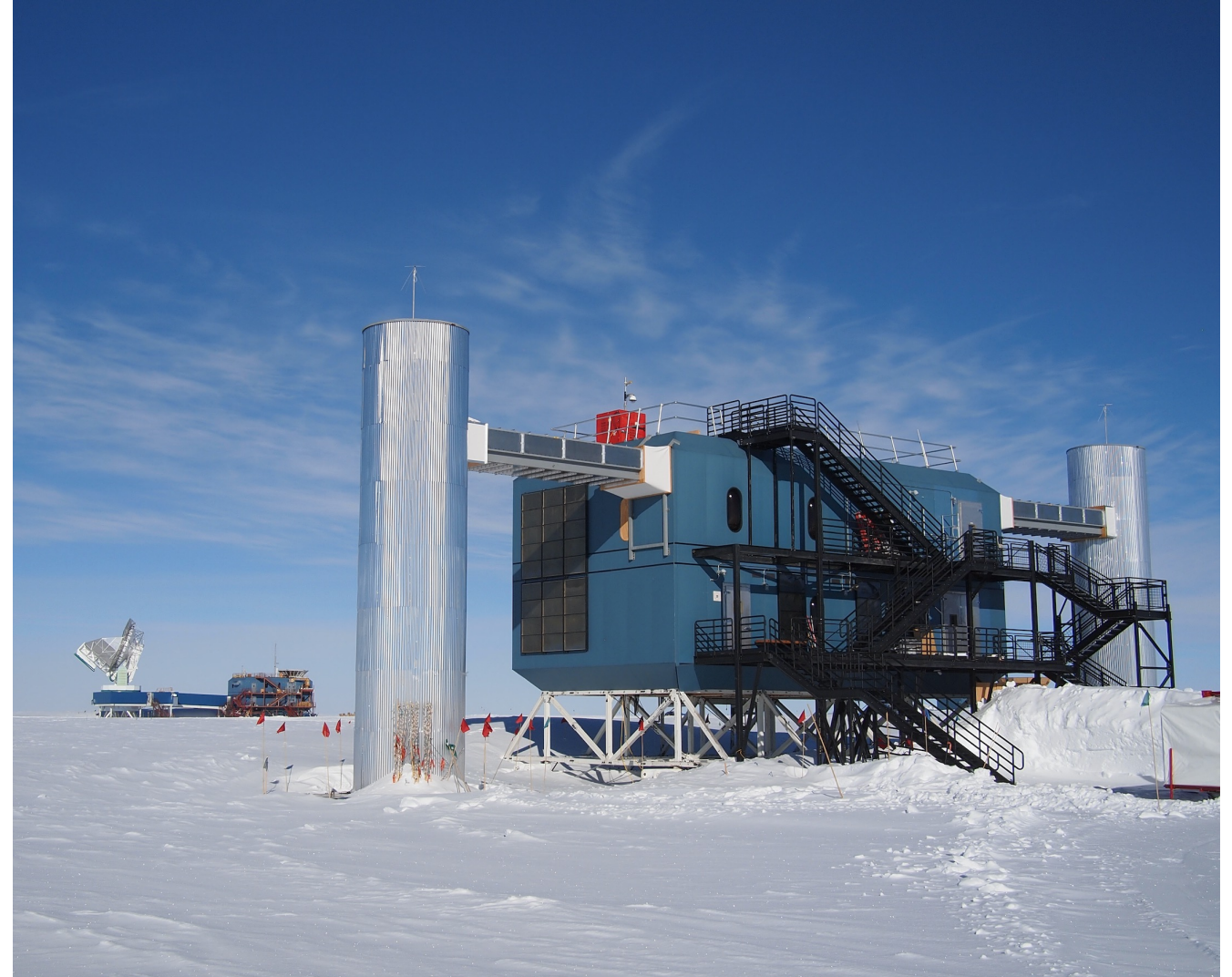
# Presenter Background

- 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

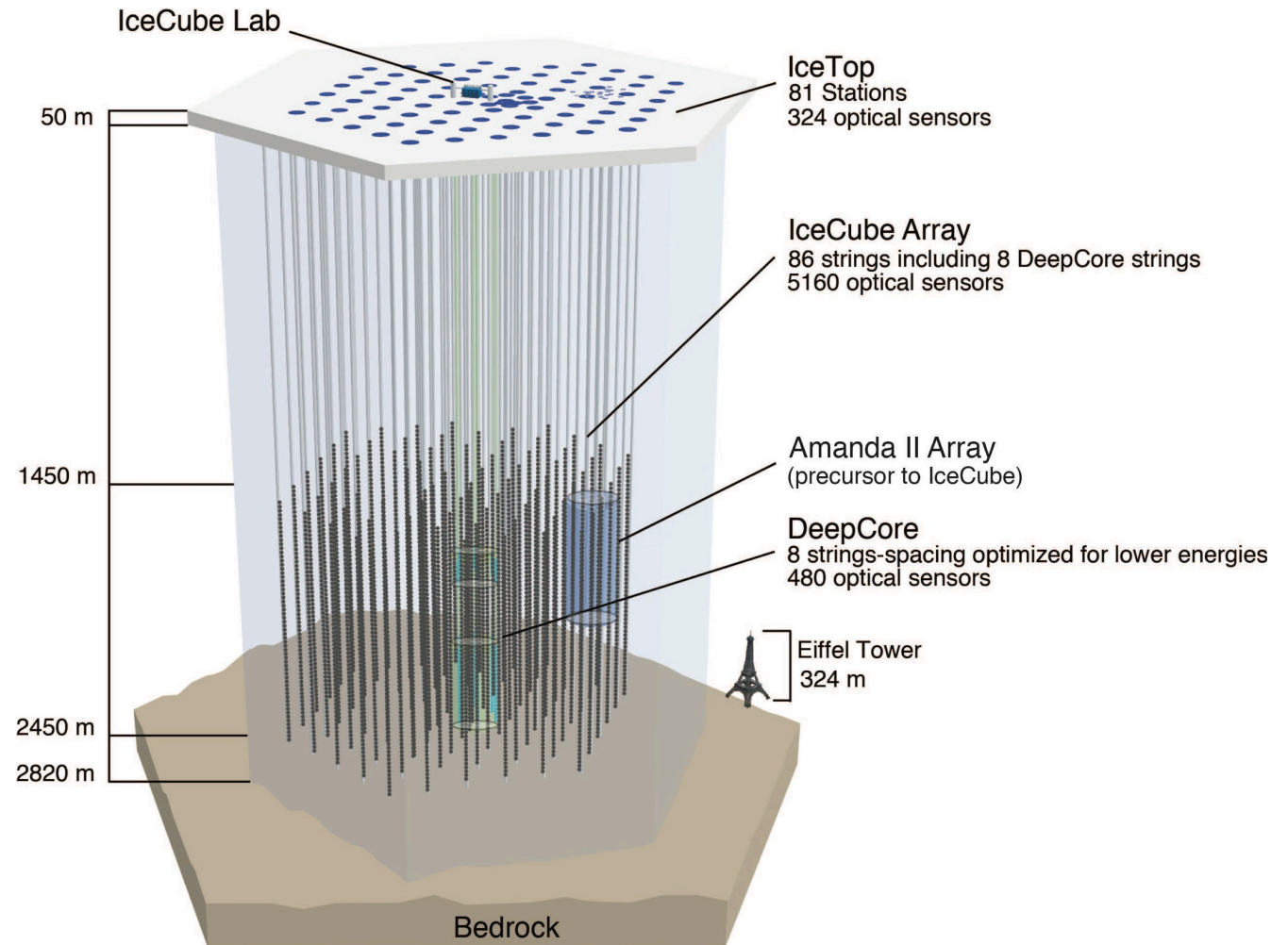
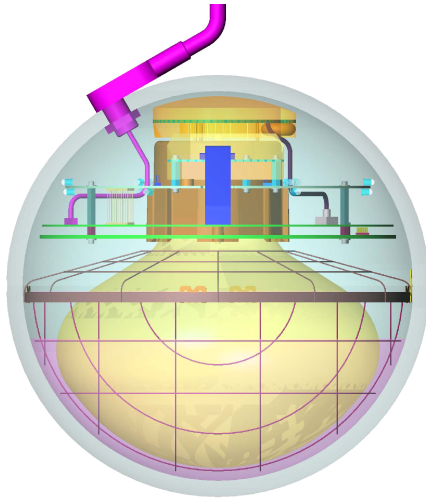
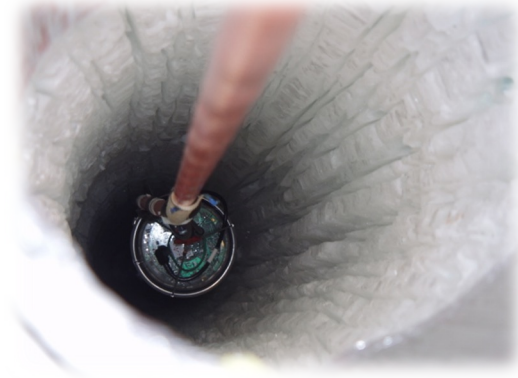
- IceCube detector
- Data flow from the ice to the collaboration
- Triggering and Filtering
- Filtering improvements and Pass 3 reprocessing



The IceCube Laboratory (ICL; 2013 photo)

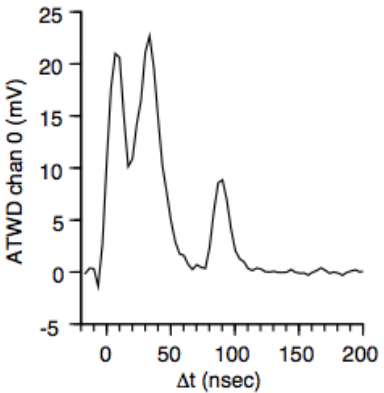
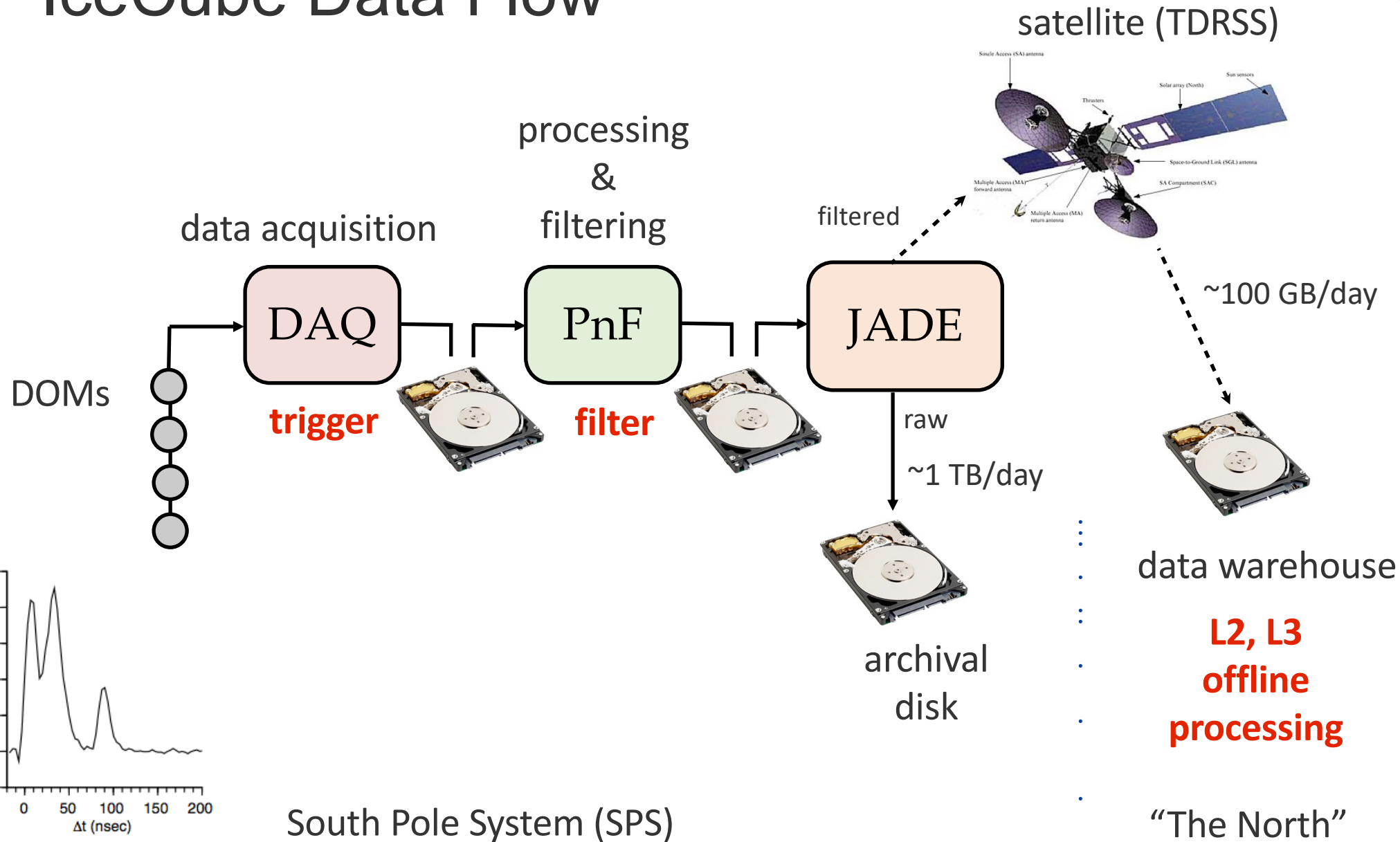


# The IceCube Detector

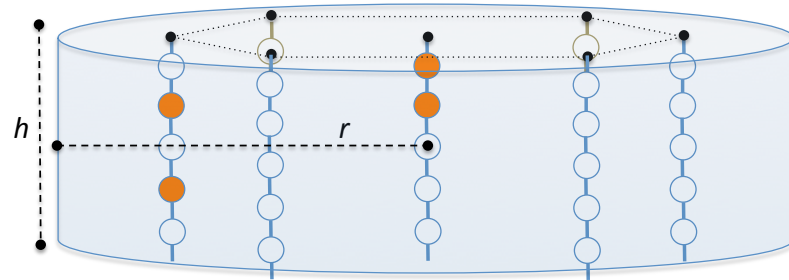


5484 digital optical modules (DOMs)

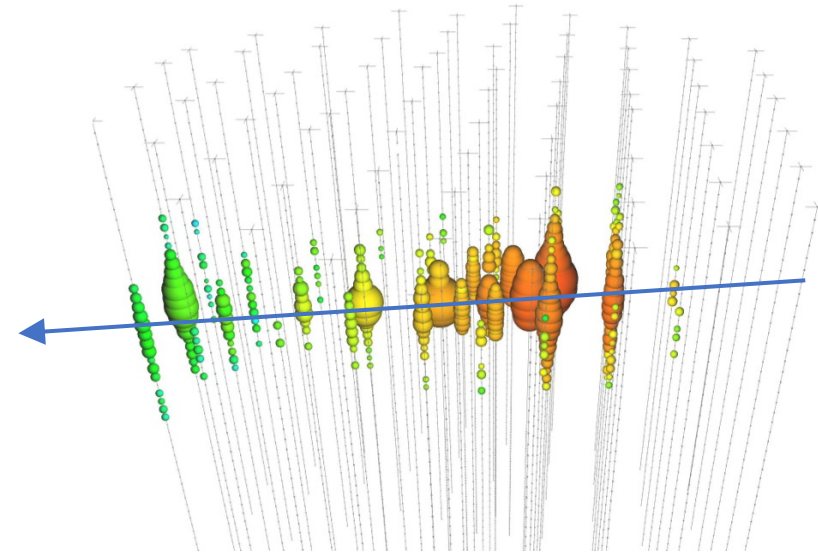
# IceCube Data Flow



# Triggers and Filters



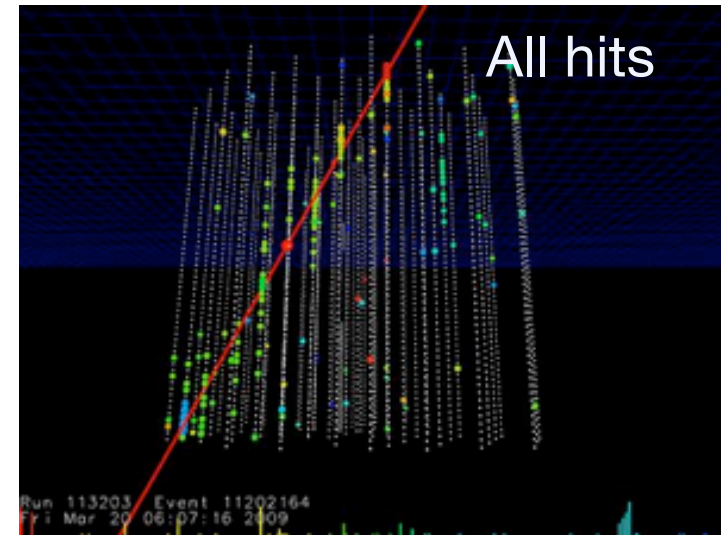
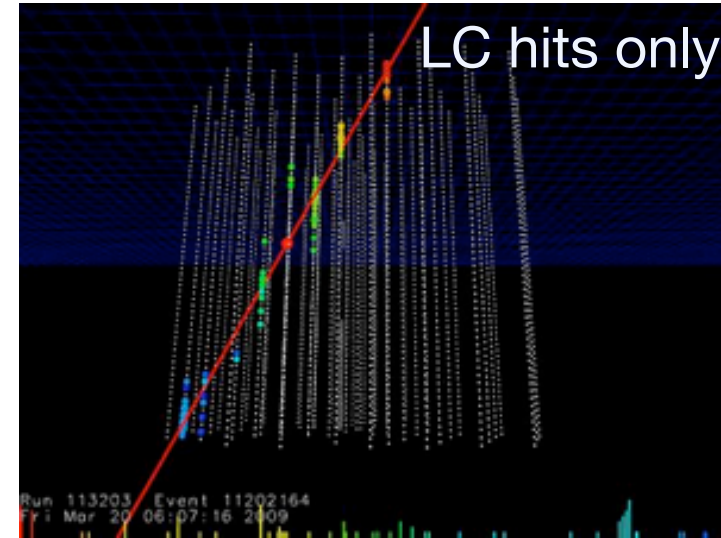
DAQ selects causal patterns of light (hits) from particle interactions



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

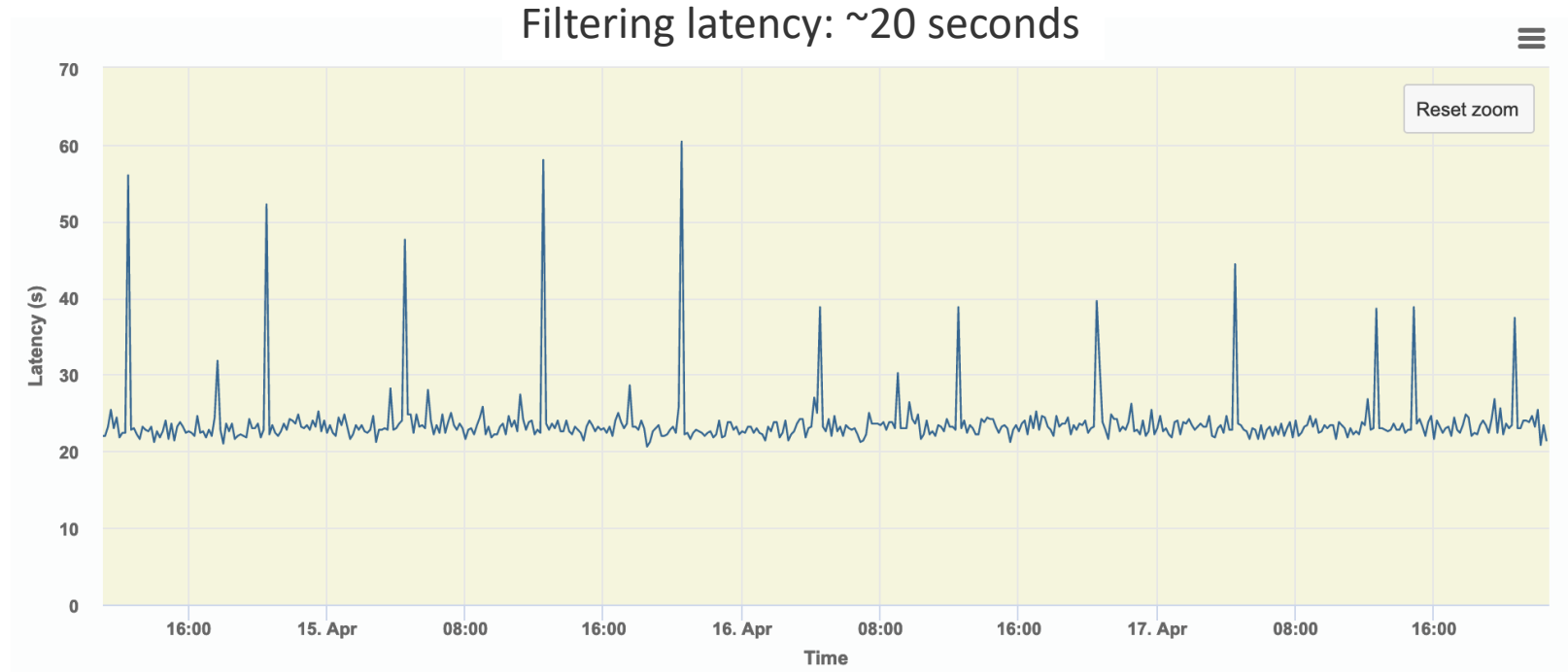
# Data Acquisition System "pDAQ"

- 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



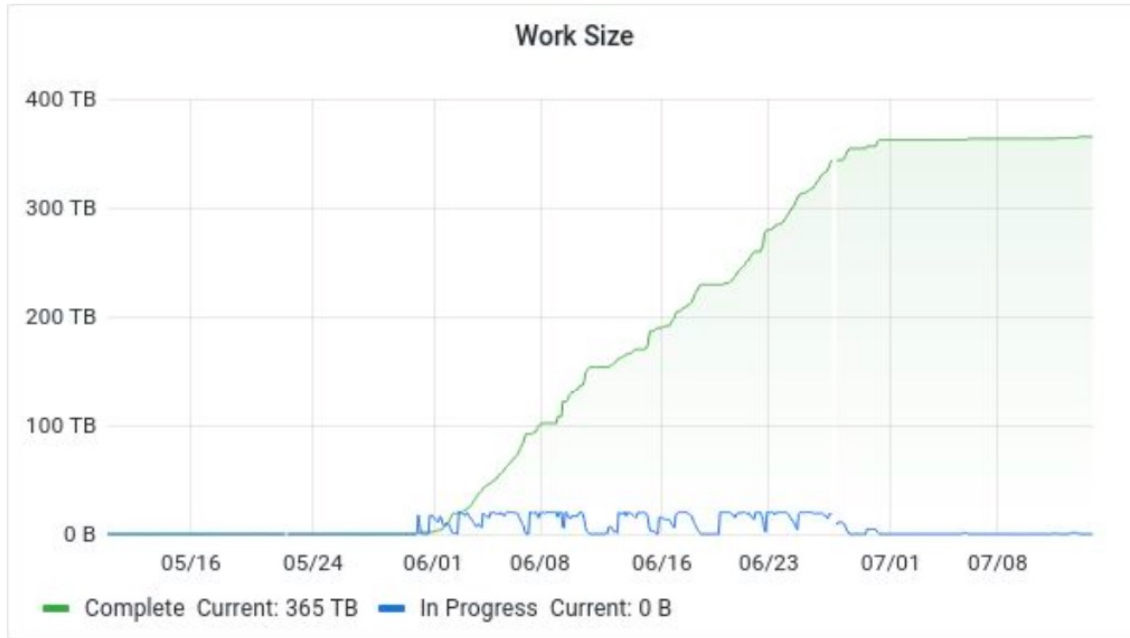


# Inside the IceCube Lab (ICL)



- 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

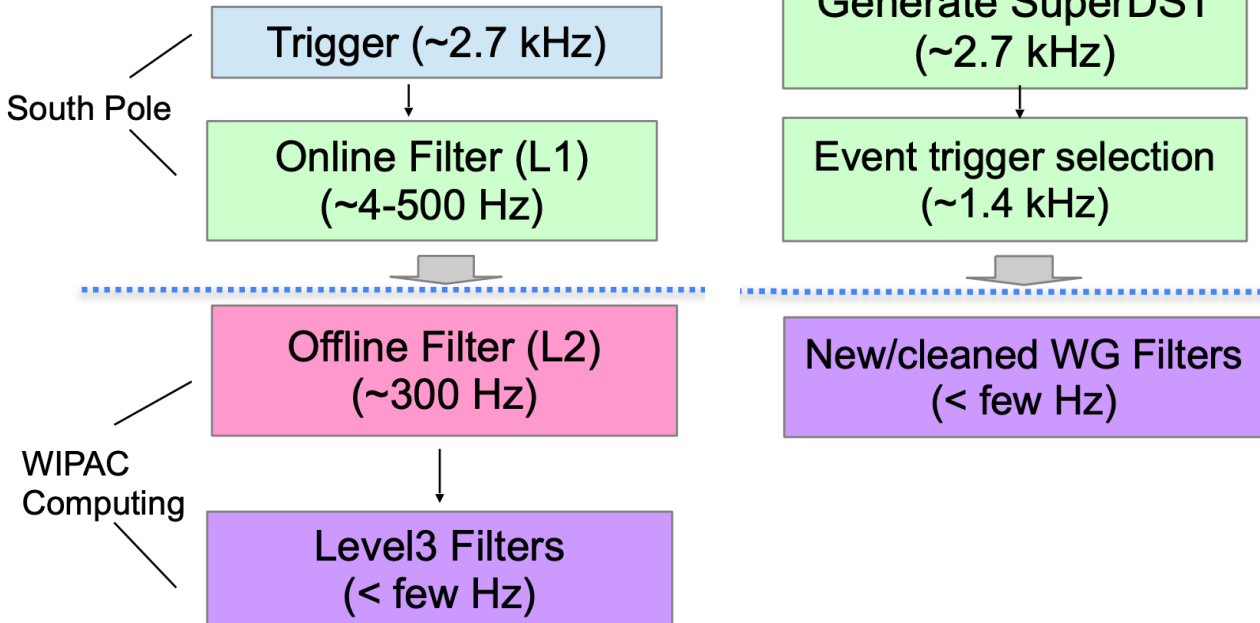
- JADE data transfer software
  - archival of raw data to disk at South Pole (2 copies)
  - handoff of filtered data to ASC for satellite transfer
  - validation of data copies and transfers to the data warehouse
  
- Data warehouse at WIPAC
  - provides experimental and simulated data to collaboration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



# Streamlined Filtering

## Pre-2023 model

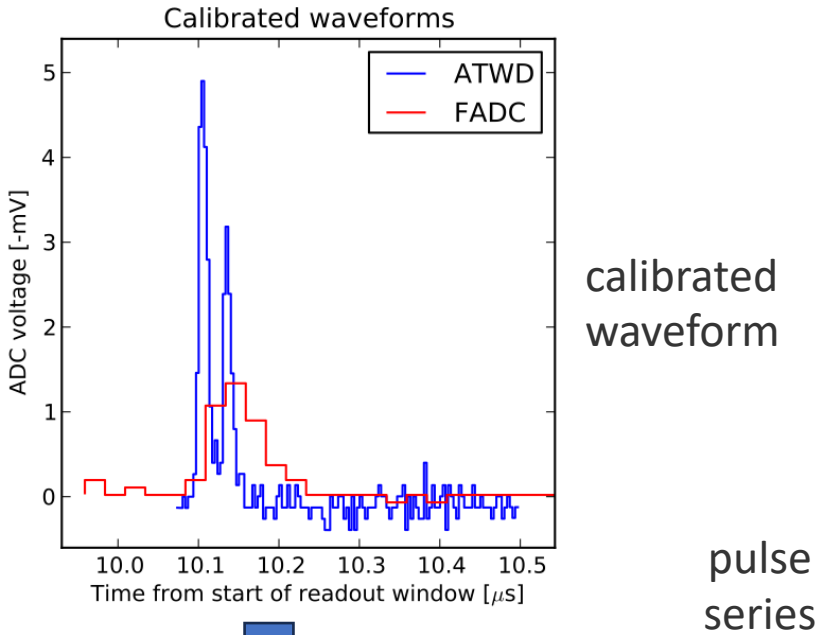
## New model



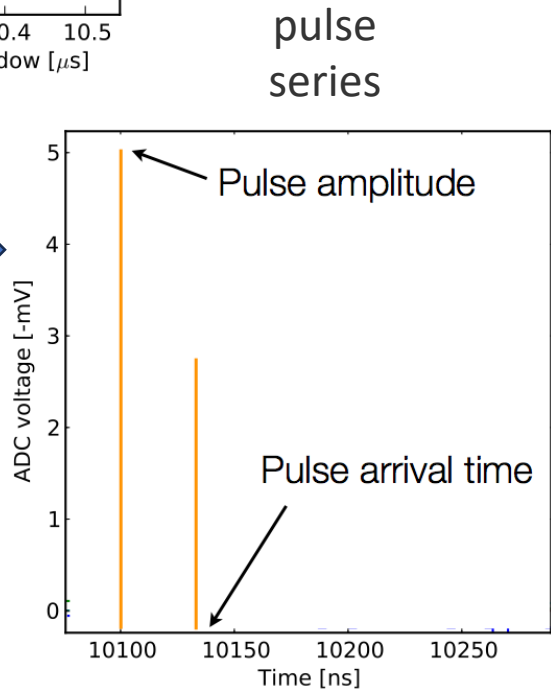
see also talks by Kauer, Riedel, Díaz Vélez, and Blaufuss

- 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
  - archival not changed (all events saved in raw and superDST format)
- 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



waveform unfolding

- Improvements to calibration and waveform processing can also be applied to historical data
  - e.g. previous “Pass2” reprocessing
  - “Pass3” will apply streamlined data processing from IC86-2023/24 to all historical data
- Raw data to be retrieved from tape archive (NERSC, TACC) and reprocessed
  - significant computing and storage requirements to process all historical data
- Pass3 will homogenize and improve historical data set



# Supplementary Material

# Real-Time Alert System

