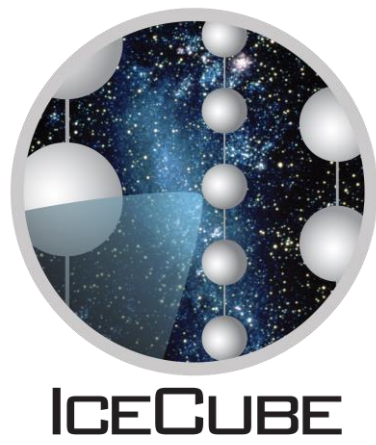




The IceCube Upgrade

and the Sweden Camera

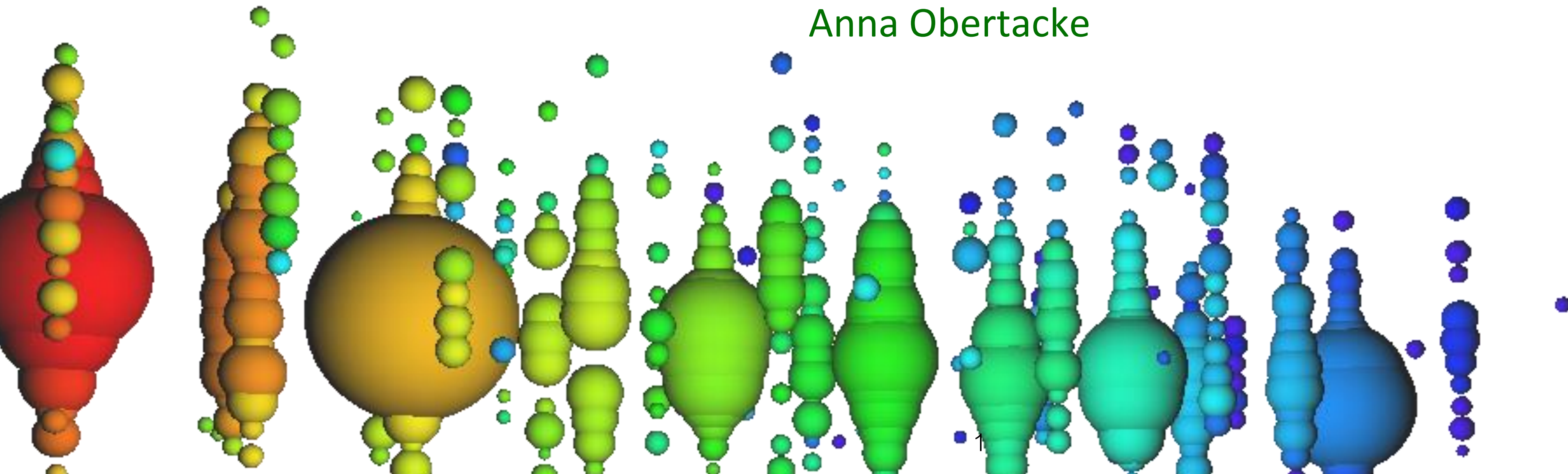
Anna Obertacke



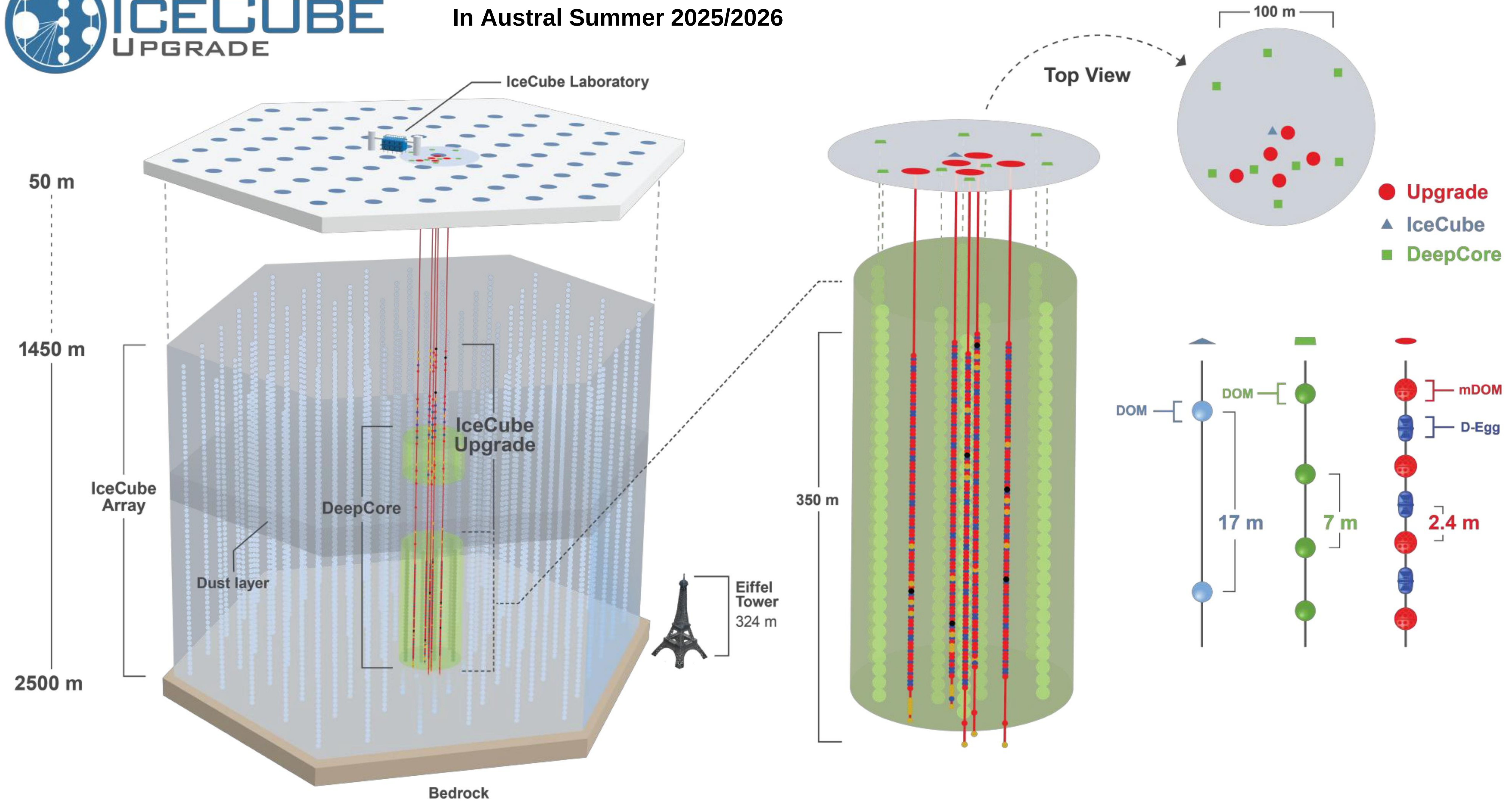
UPPSALA
UNIVERSITET



Stockholm
University



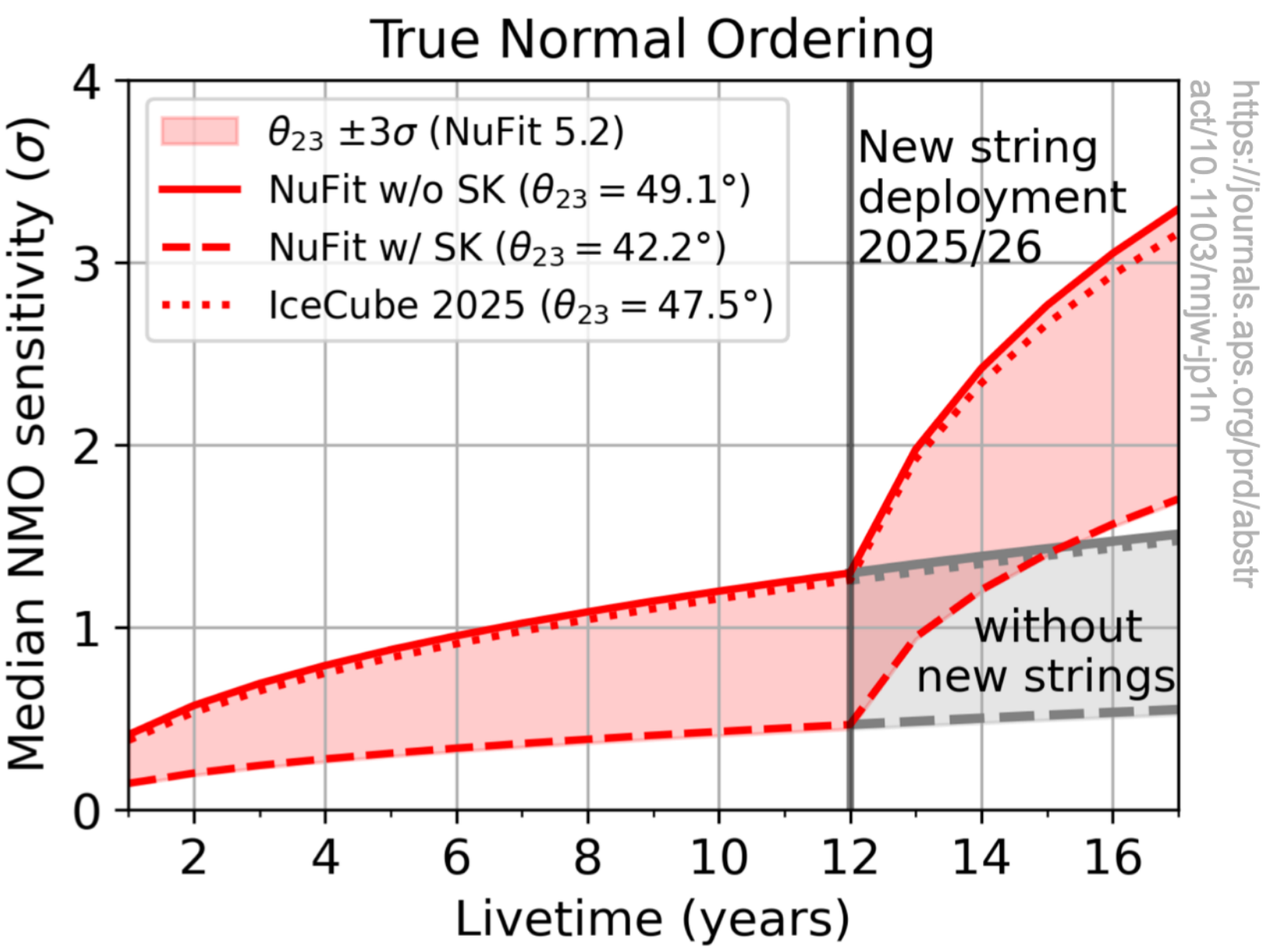
In Austral Summer 2025/2026



Motivation

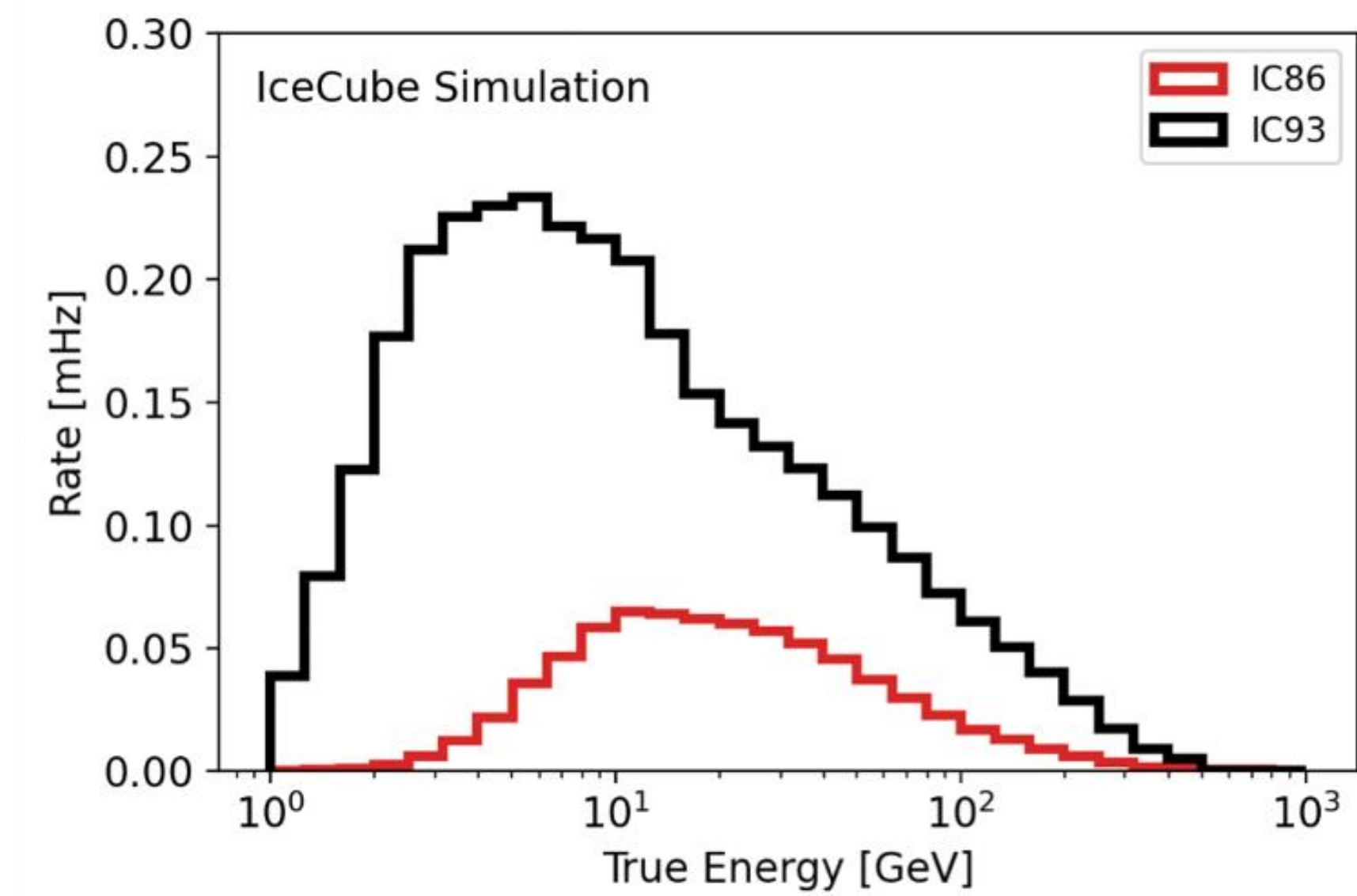
Neutrino oscillation

- neutrino oscillation property measurements best around a few GeV
- current IceCube starts sensitivity around 5 GeV
- infill array can use standard IceCube as veto



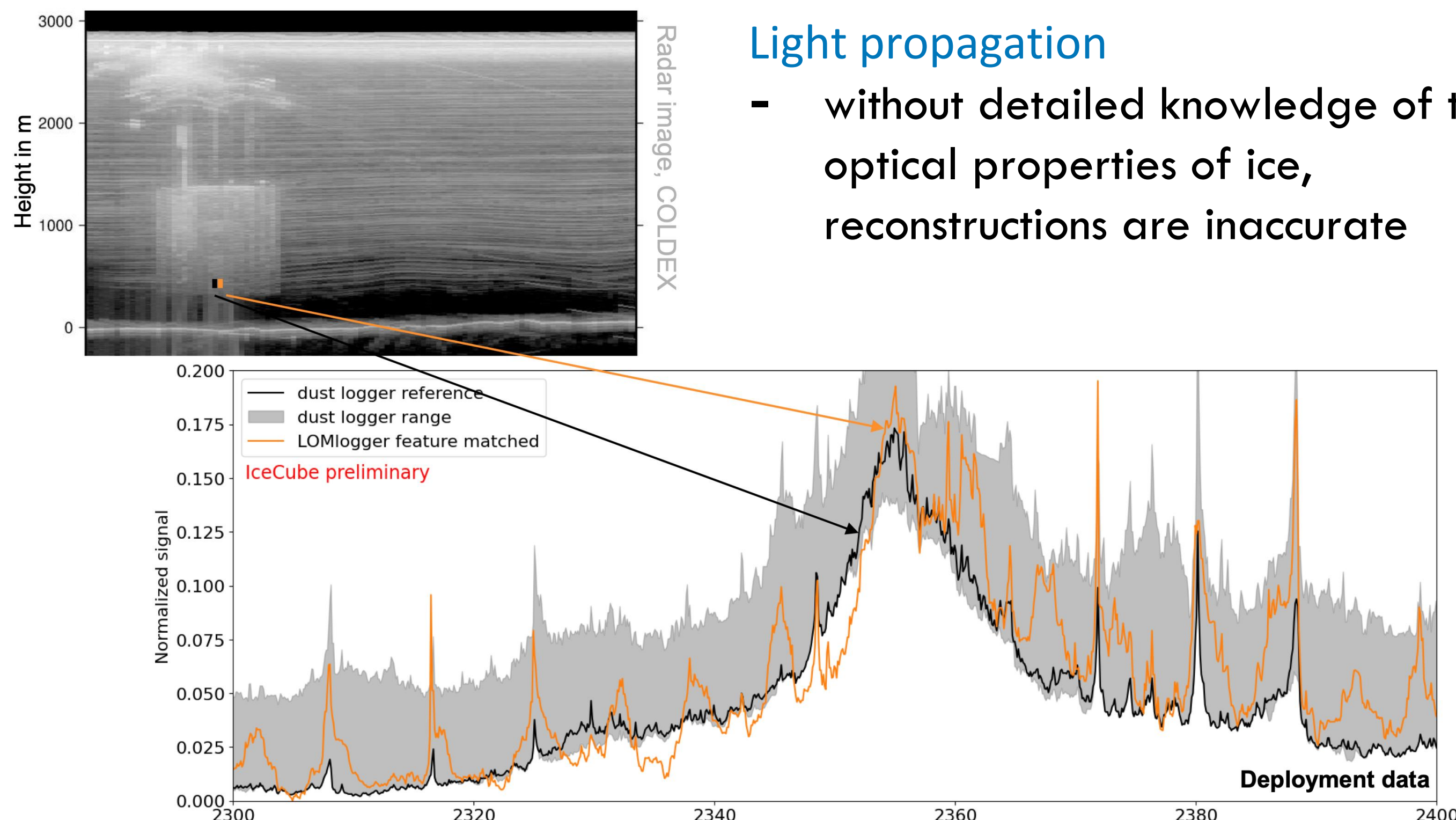
GeV astrophysics

- (Super) Novae
- low energy astrophysical sources



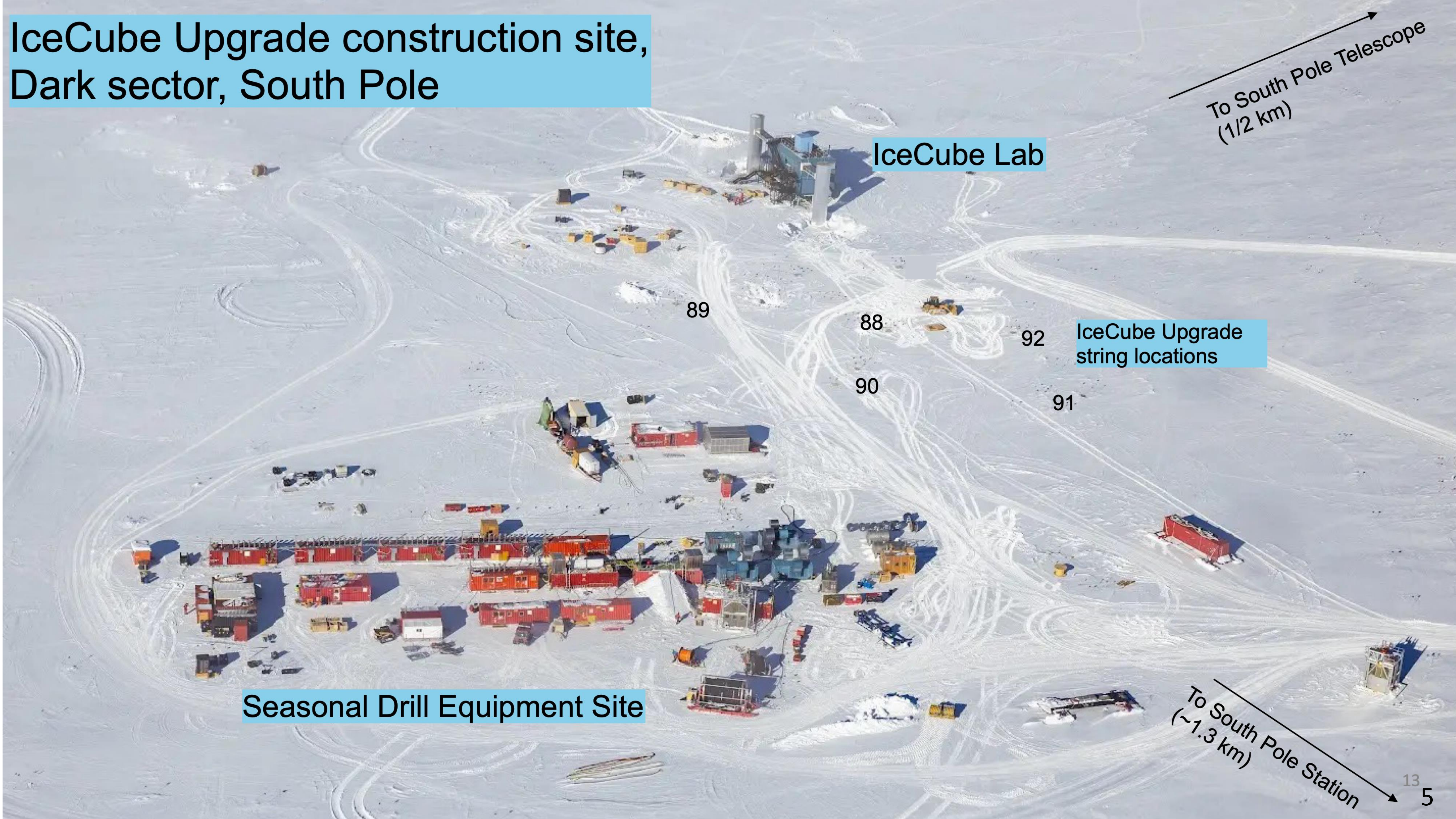
Light propagation

- without detailed knowledge of the optical properties of ice, reconstructions are inaccurate





IceCube Upgrade construction site, Dark sector, South Pole



IceCube Lab

IceCube Upgrade
string locations

Seasonal Drill Equipment Site

To South Pole Telescope
(1/2 km)

To South Pole Station
(~1.3 km)

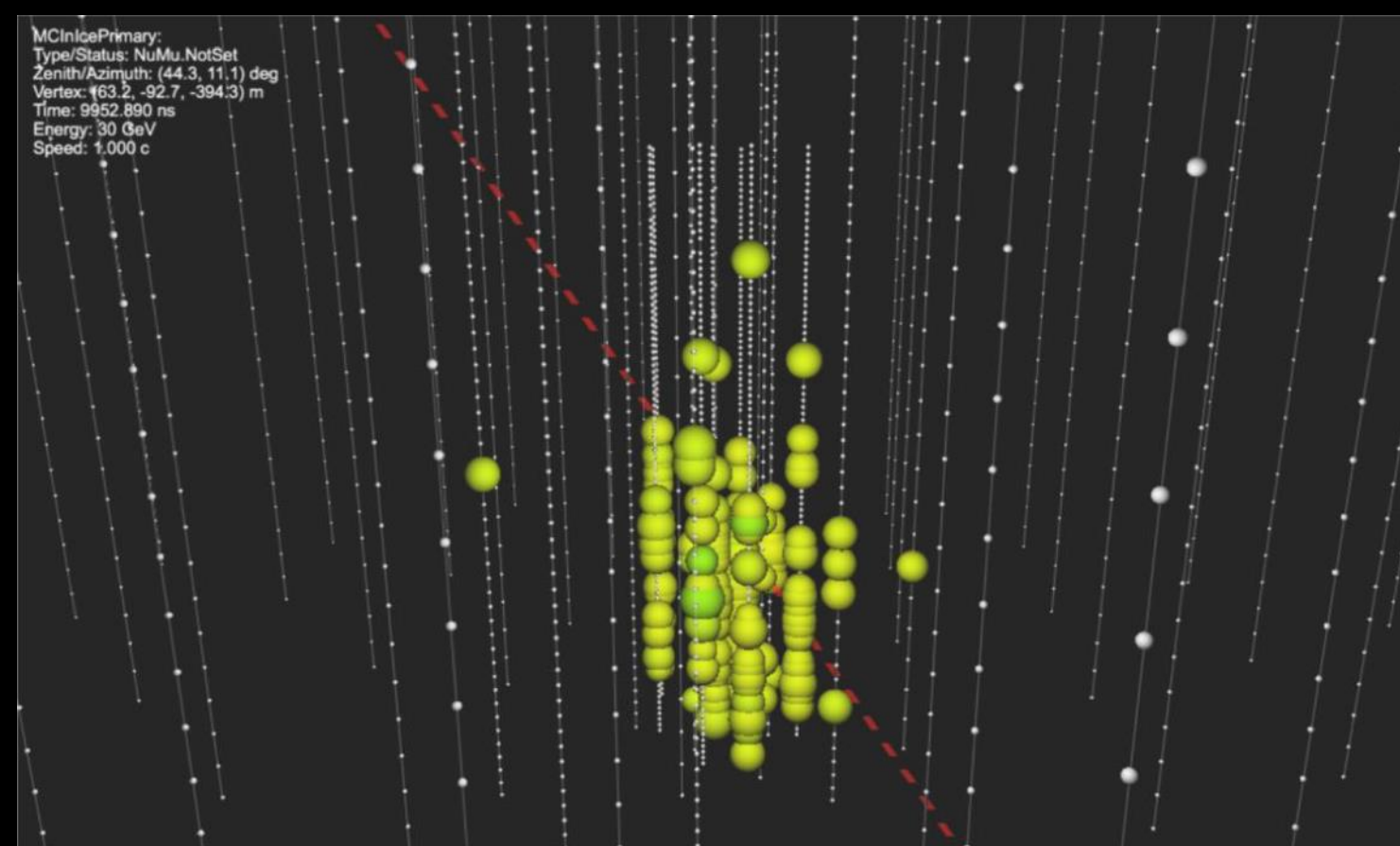
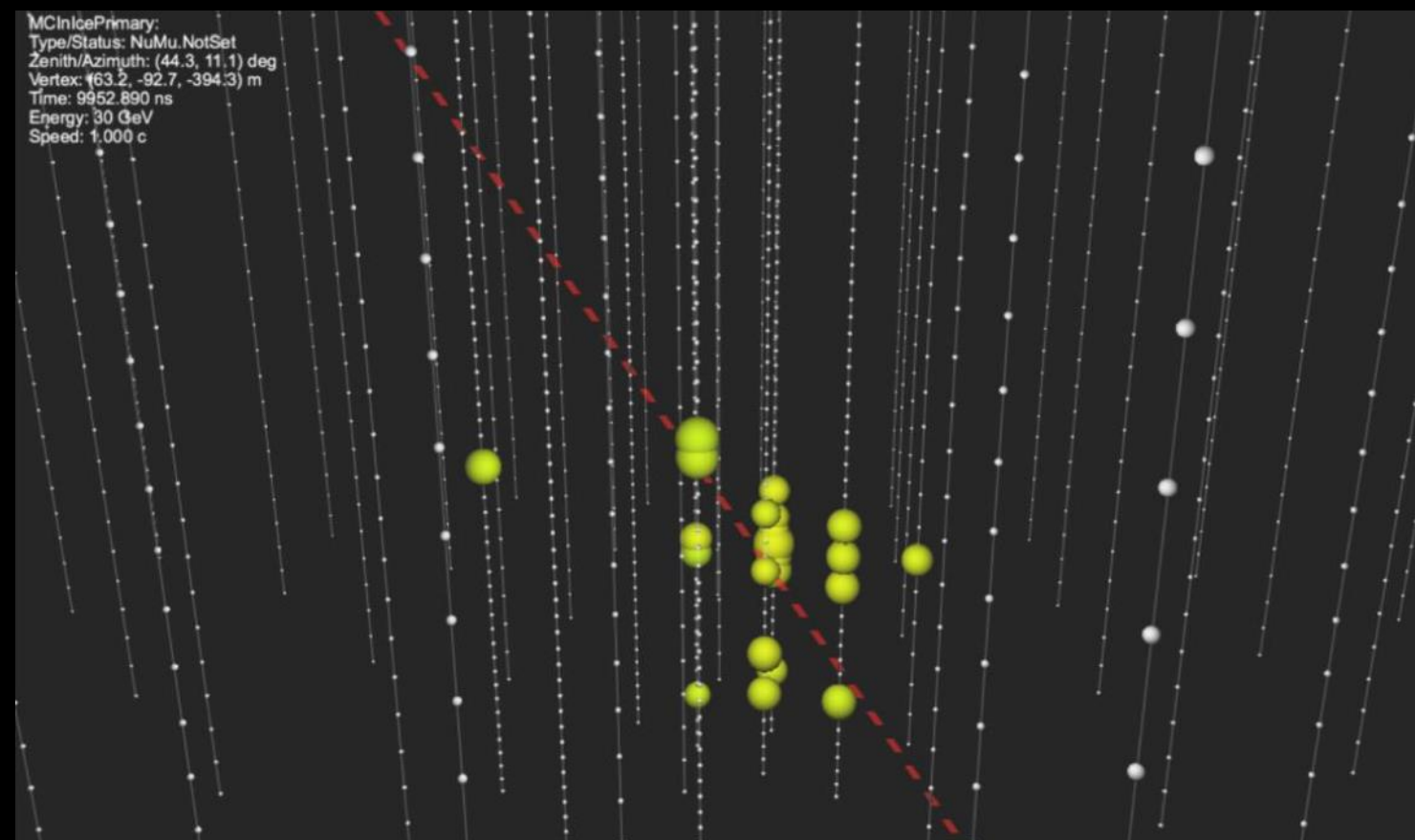




450 mDOM
one of the 2 baseline designs



30 GeV Muon



3x more photo-sensor area

New sensor generation

- large, isotropic sensitivity
- directional information / noise suppression
- integrated calibration systems



450 mDOM
one of the 2 baseline designs



10 WOM 
exploratory design

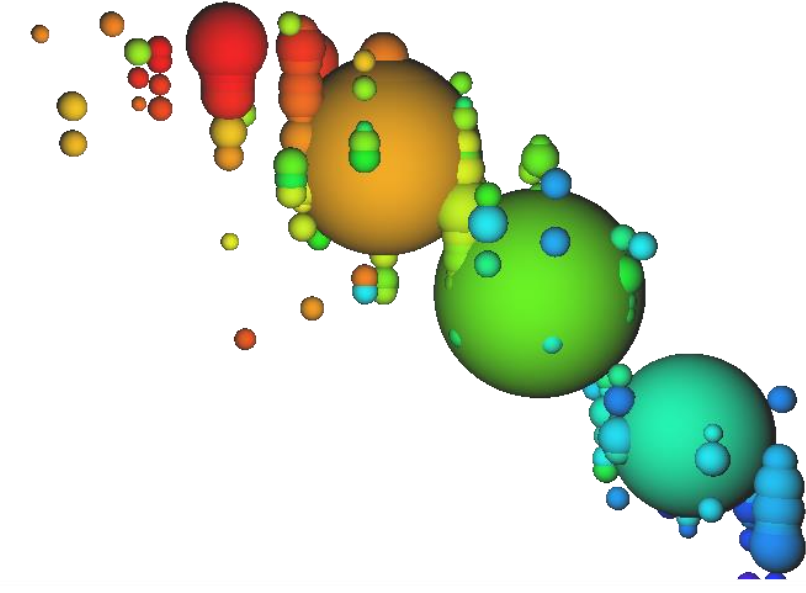
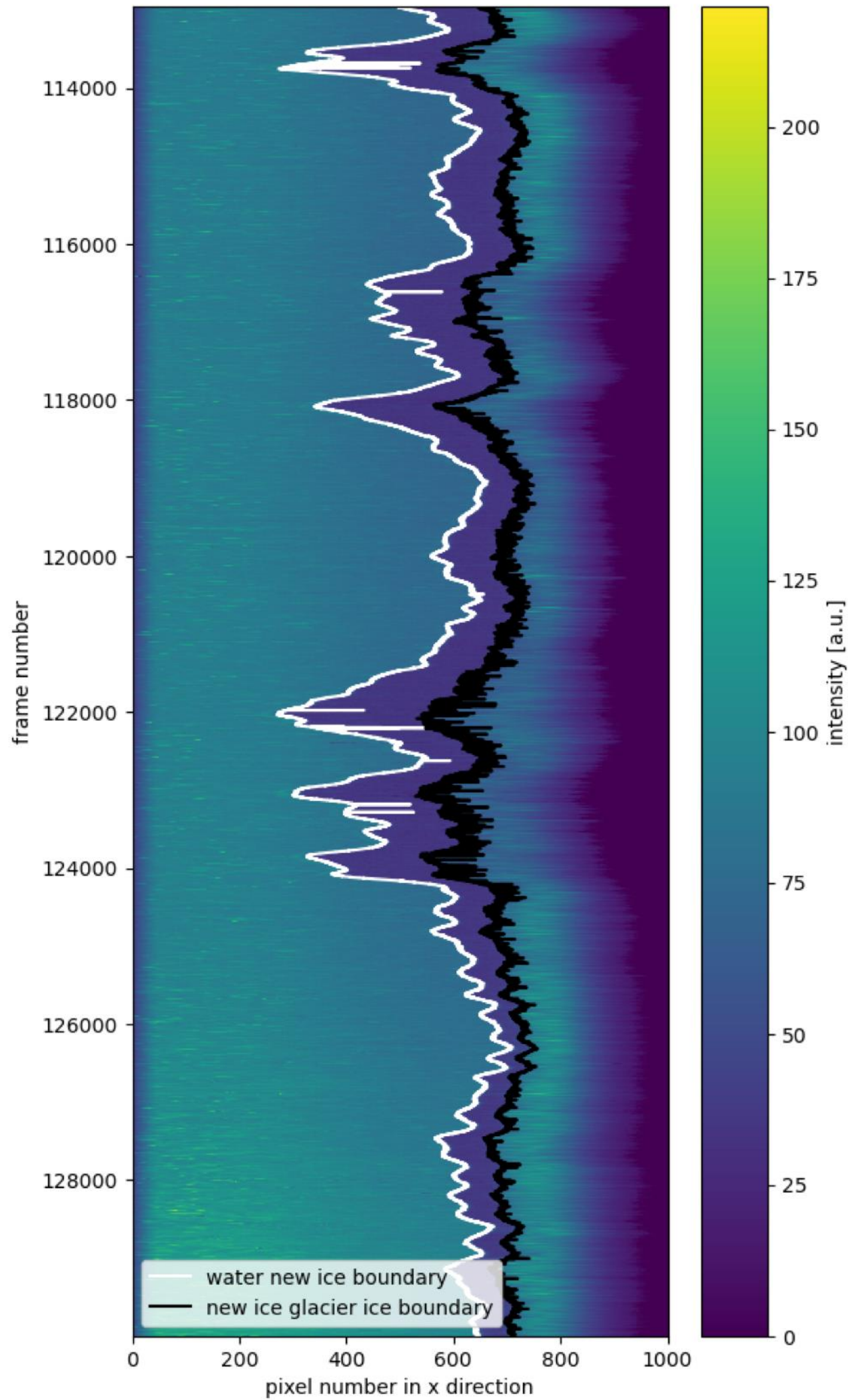
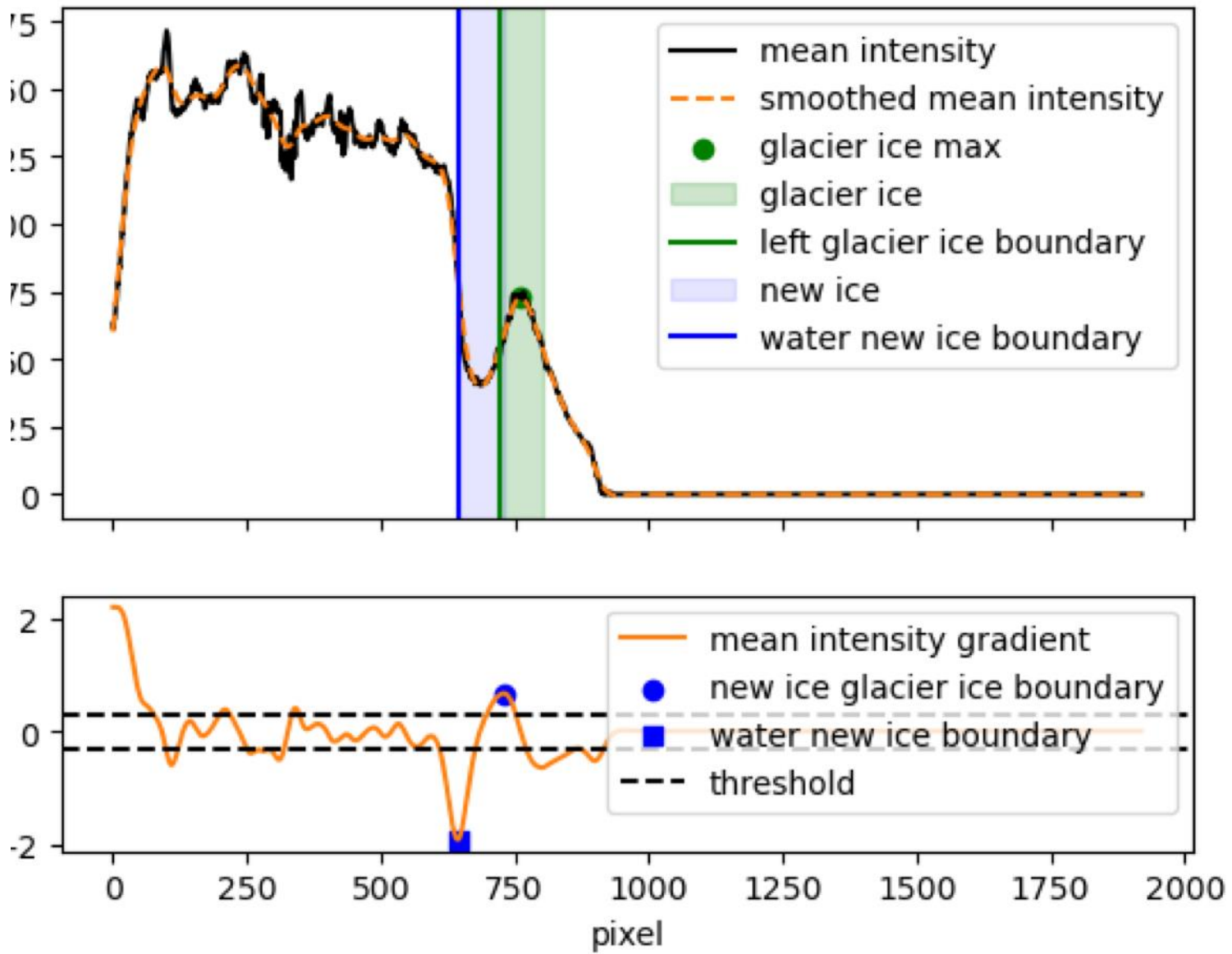
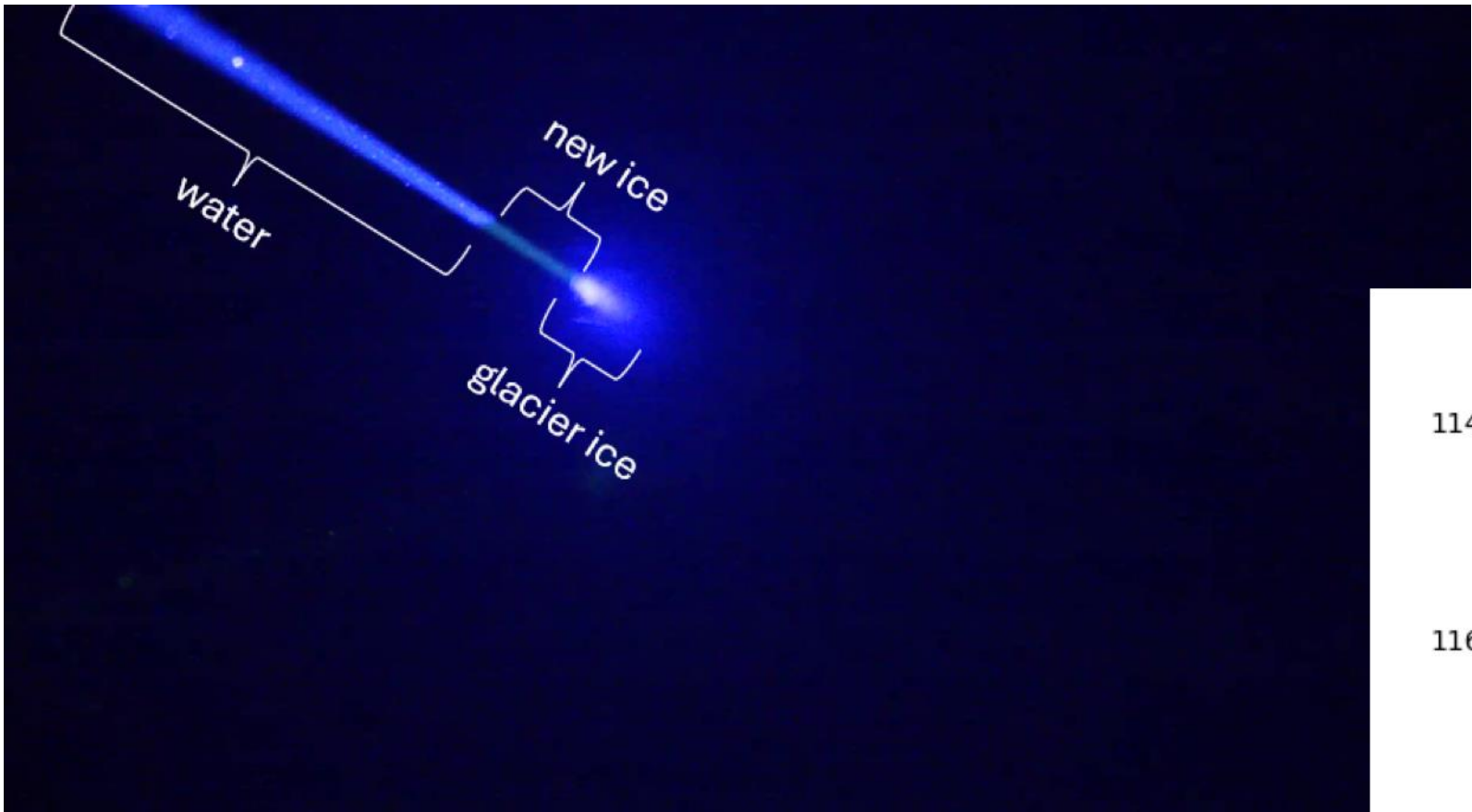
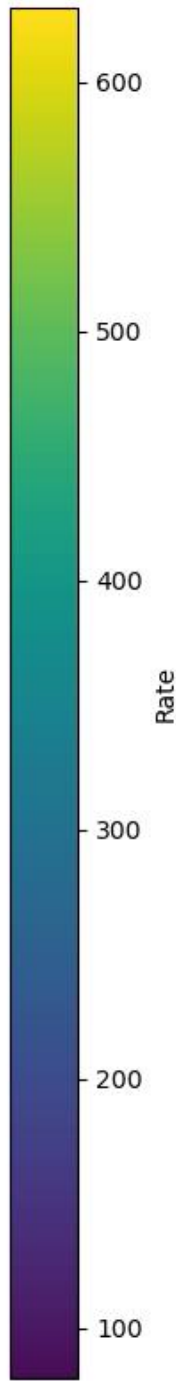
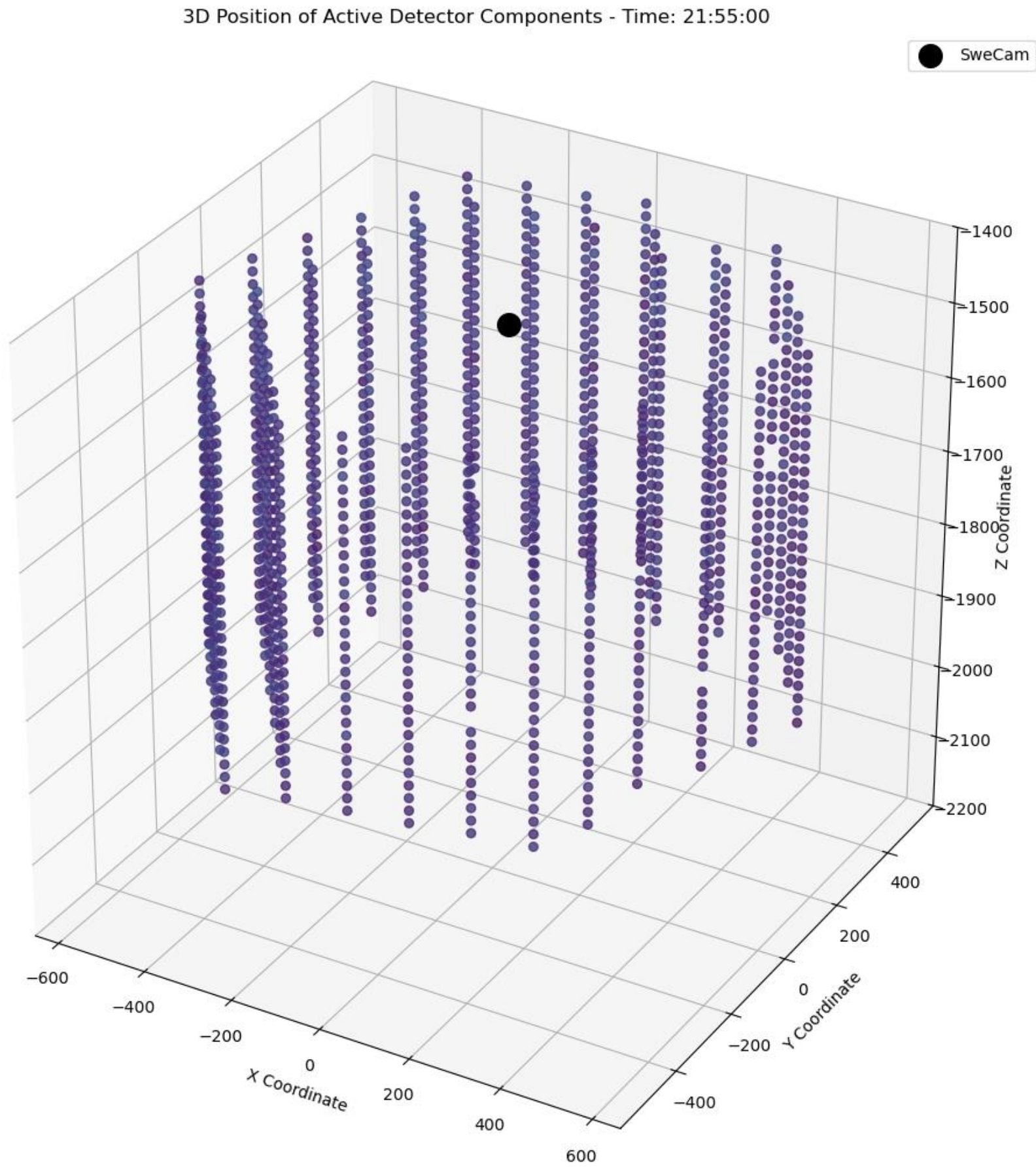


6 Sweden Cameras
calibration devices



Drop operation

- measure stratigraphy

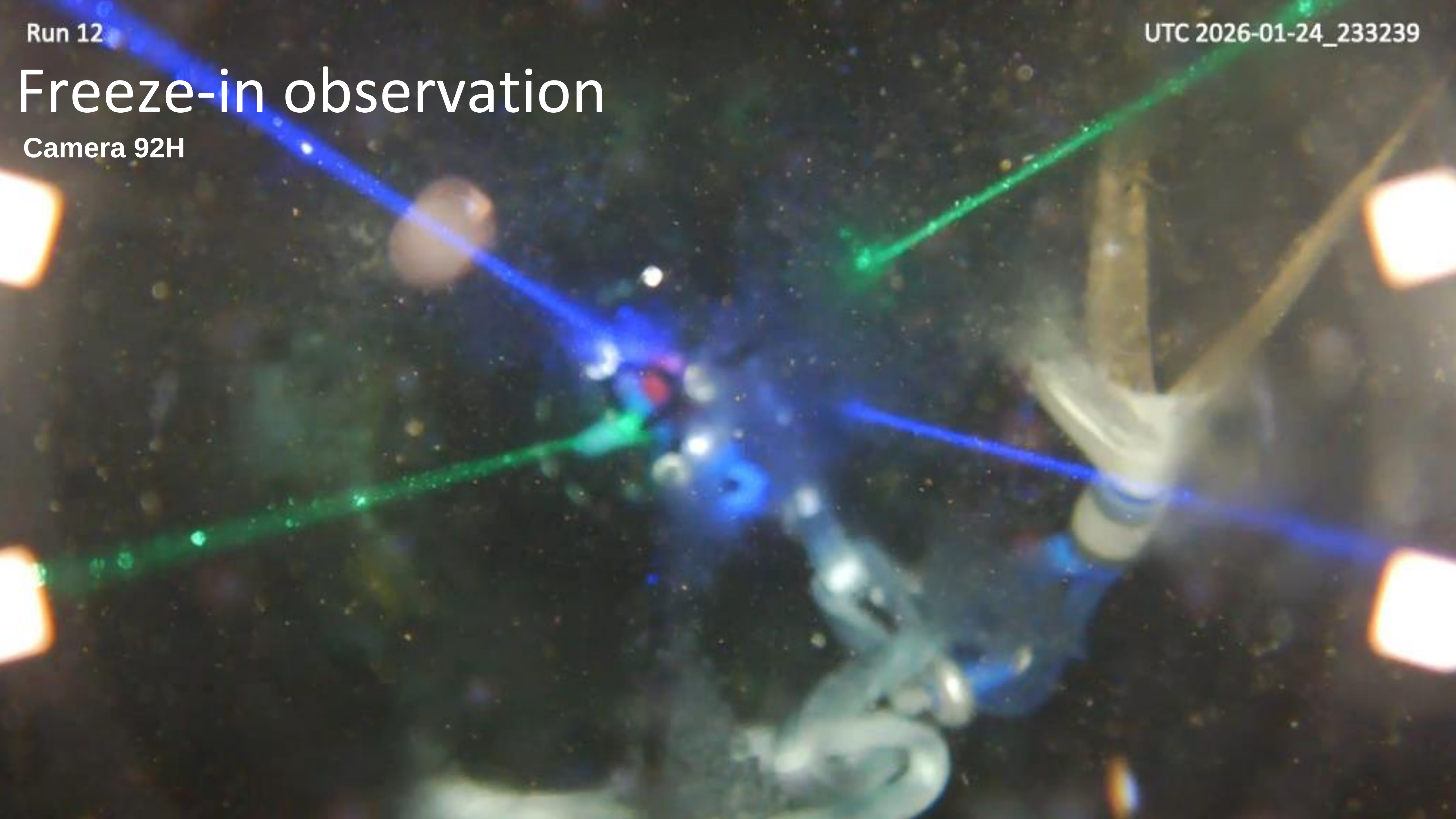


Run 12

UTC 2026-01-24_233239

Freeze-in observation

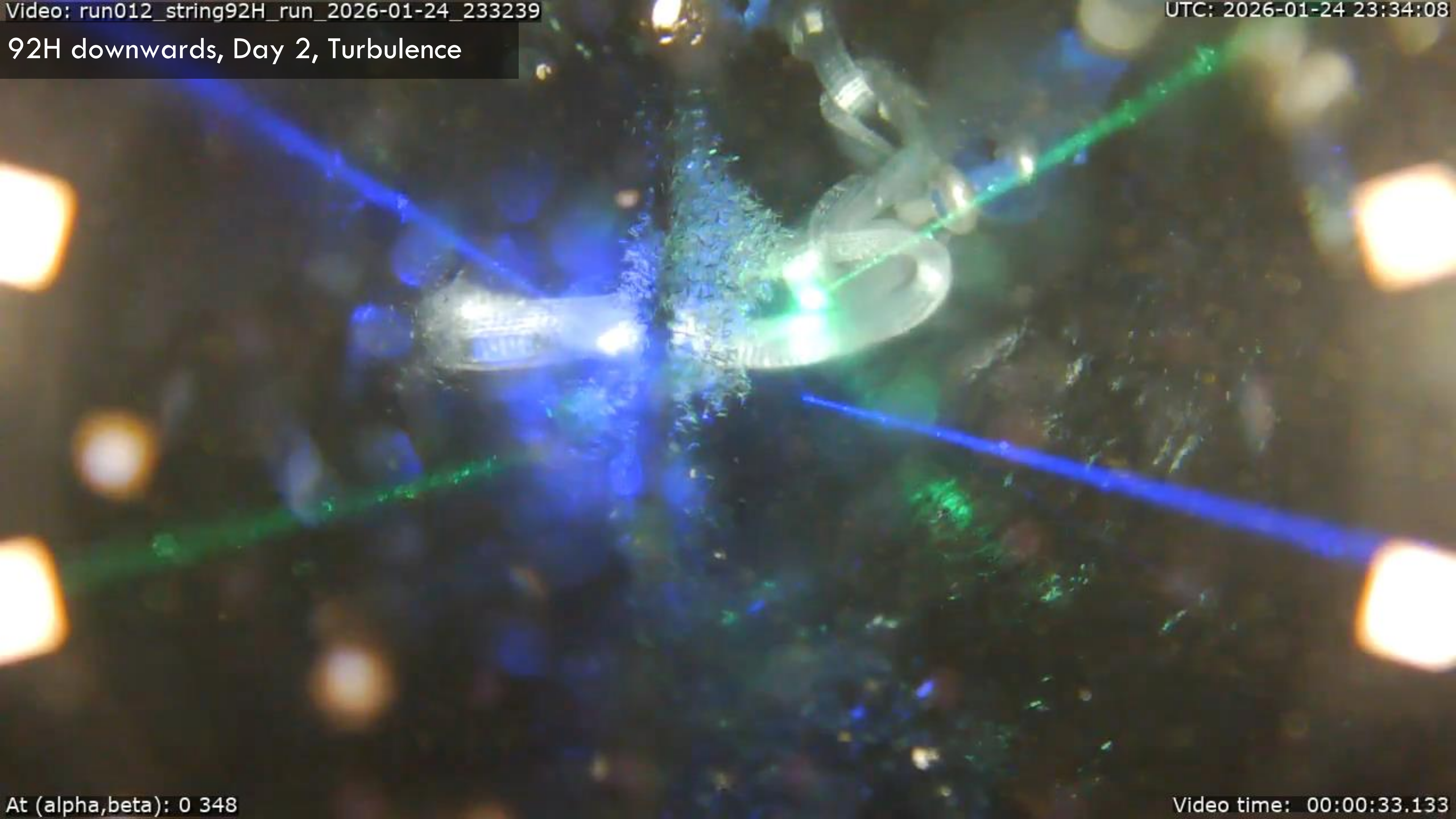
Camera 92H



Video: run012_string92H_run_2026-01-24_233239

UTC: 2026-01-24 23:34:08

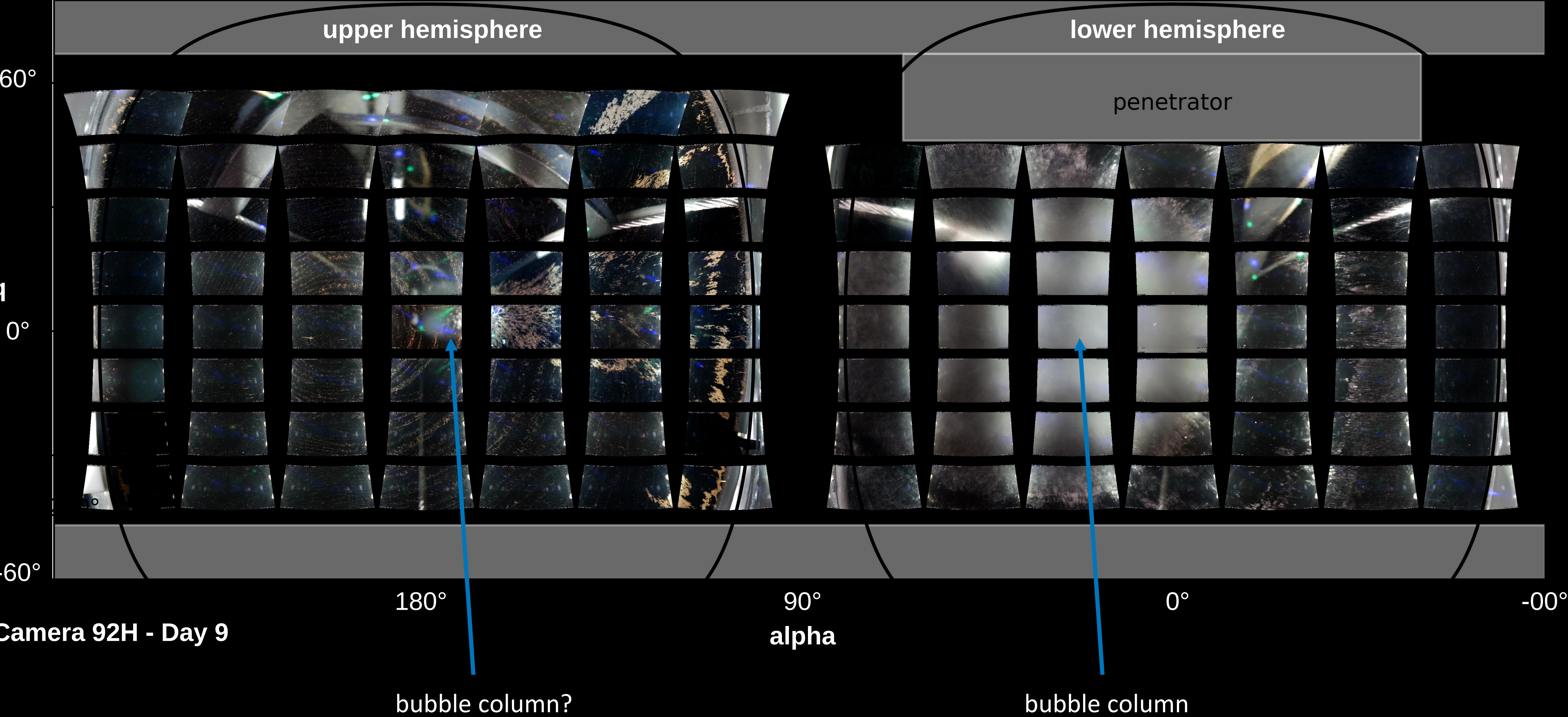
92H downwards, Day 2, Turbulence



At (alpha,beta): 0 348

Video time: 00:00:33.133

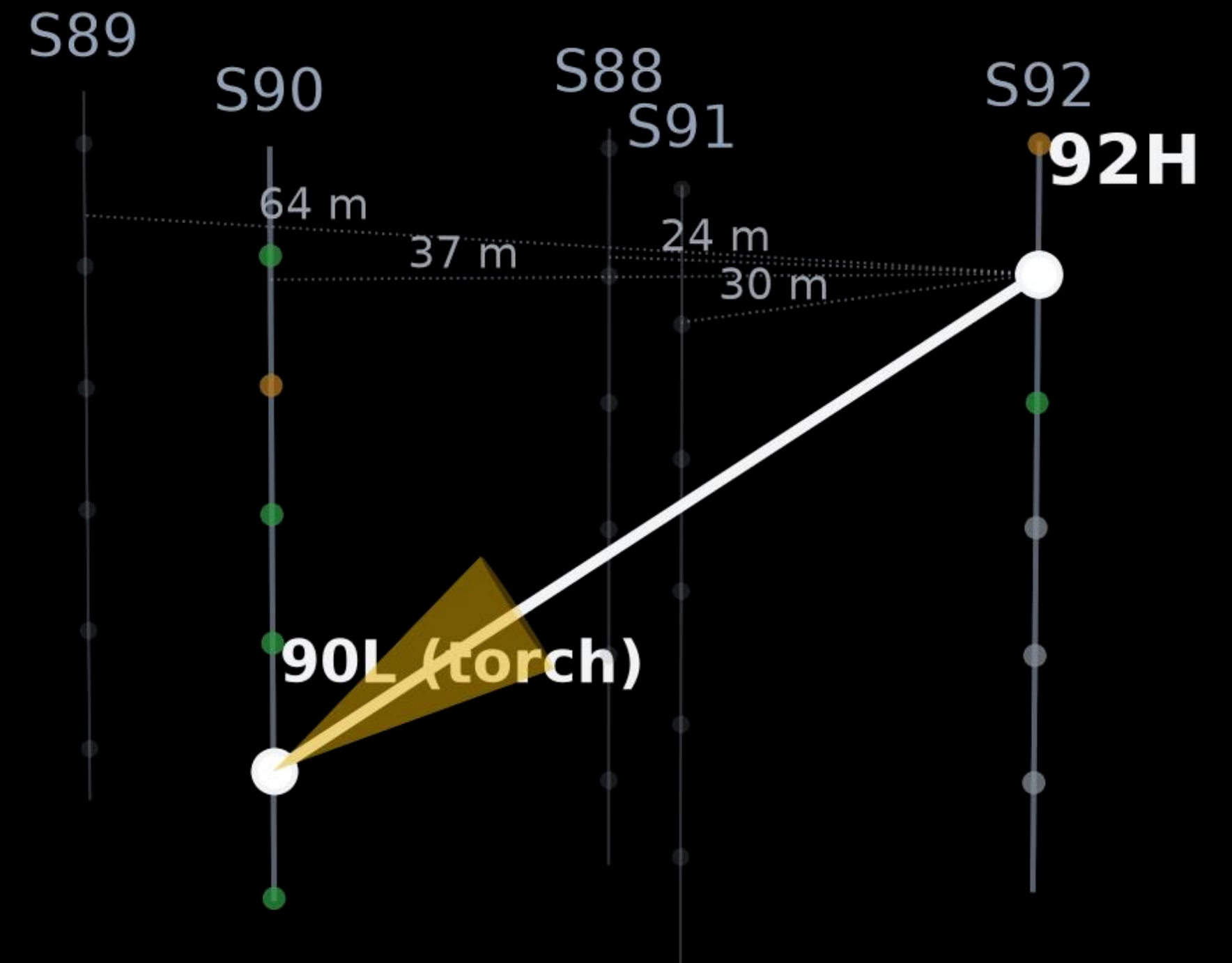
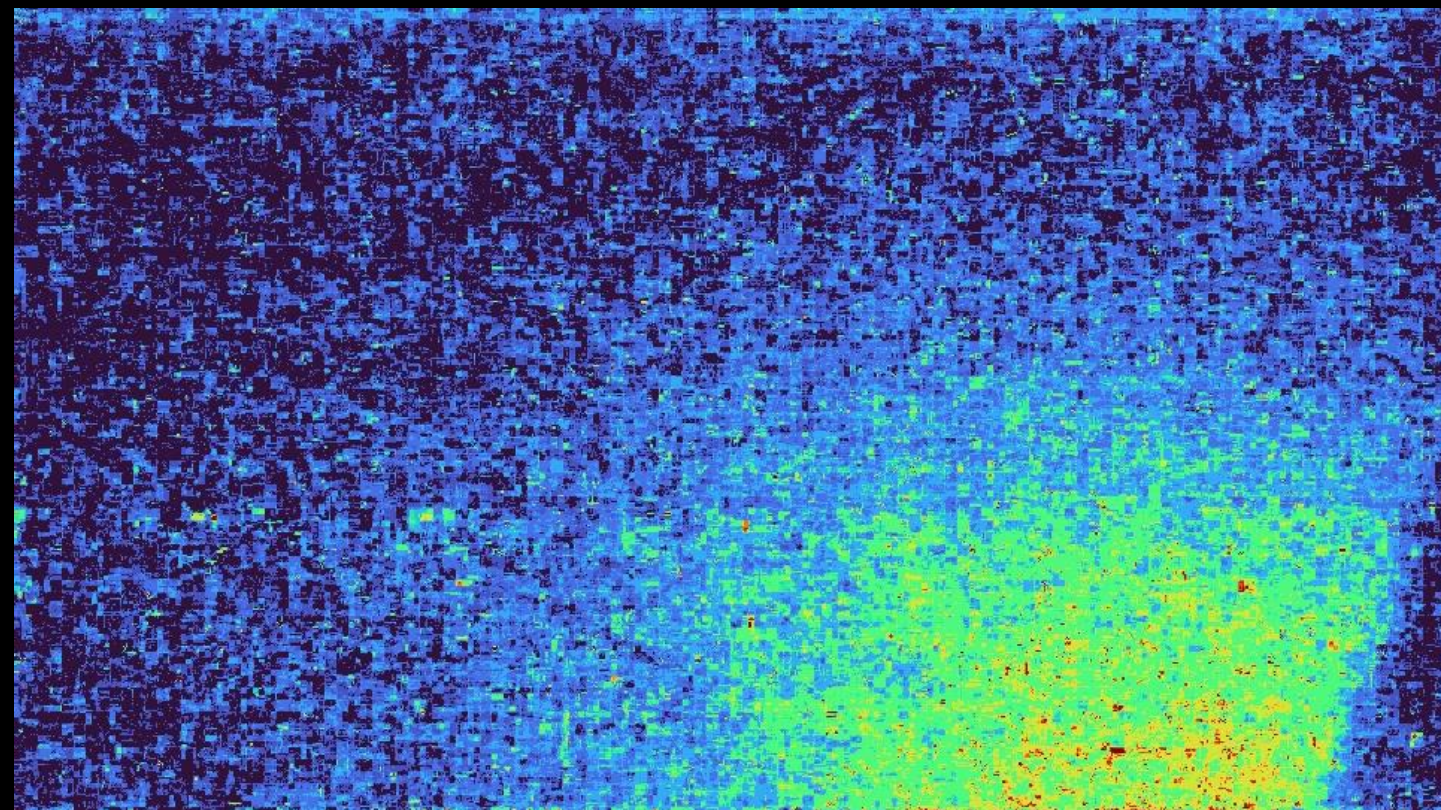
Re-frozen ice's bubble column measurement



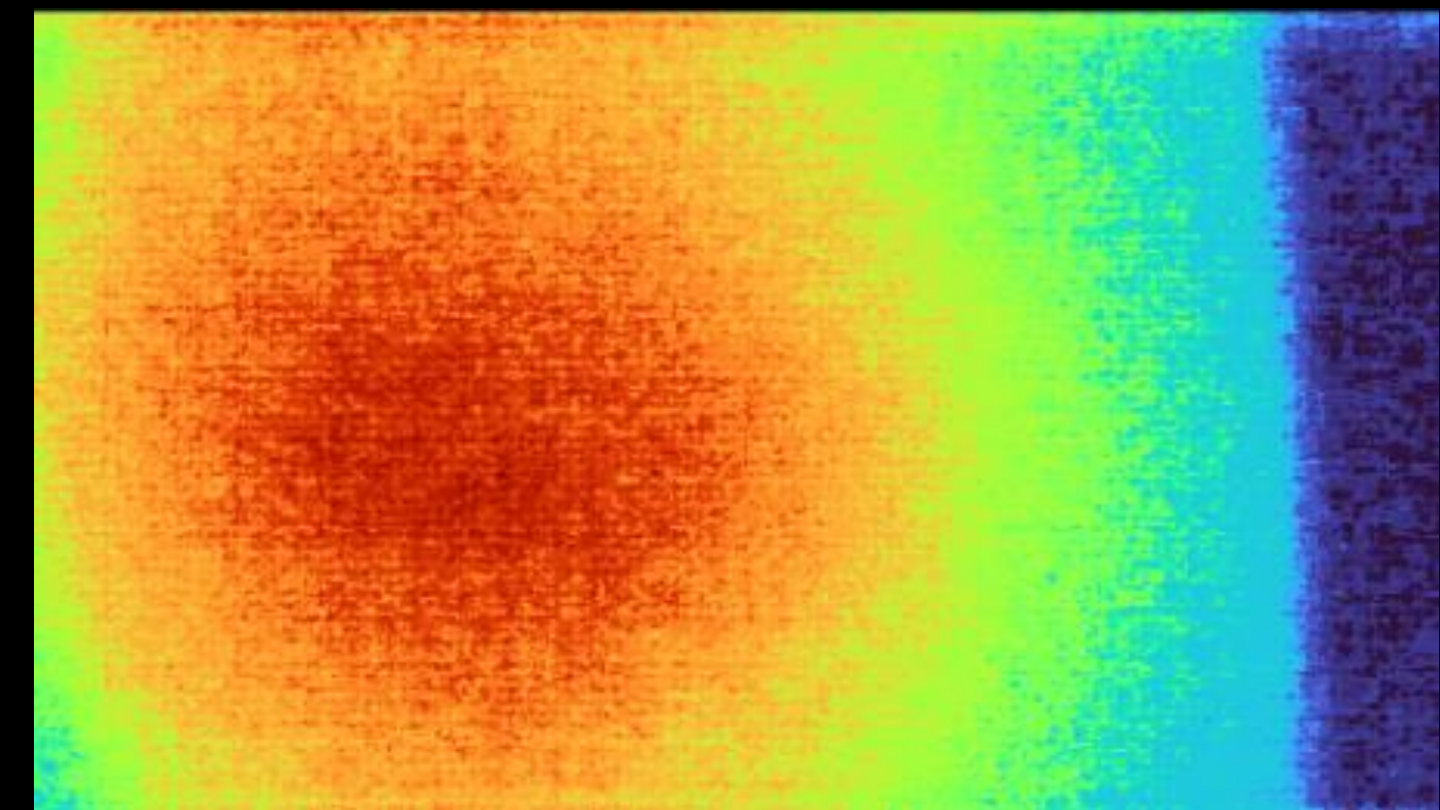
Ongoing: geometry measurement



Camera 90L watching string 88
blue LED of ~10 mW in 20 m distance



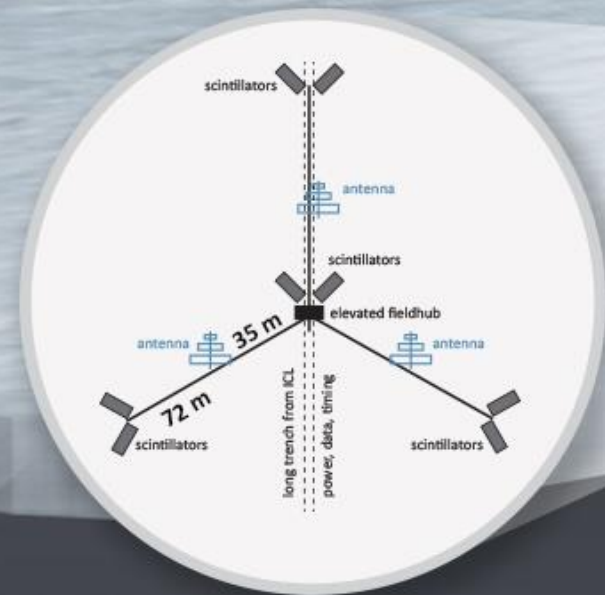
Camera 92H watching string 90L
white light of ~ 5 W in 40 m distance





ICECUBE GEN2

DETECTORS SURFACE • RADIO • OPTICAL



Cosmic Ray Surface Array

An air shower array that sits on top of the optical array

One surface station installed above each optical string



IceCube-Gen2 Optical Module

4x the sensitivity of IceCube's modules

9,600 new optical modules in total to be deployed in the ice



80 modules on each string, spaced 17 meters apart

50 m

1370 m

2780 m

IceCube-Gen2:
120 new strings of optical modules

IceCube:
86 strings of optical modules

DeepCore

Antarctic bedrock

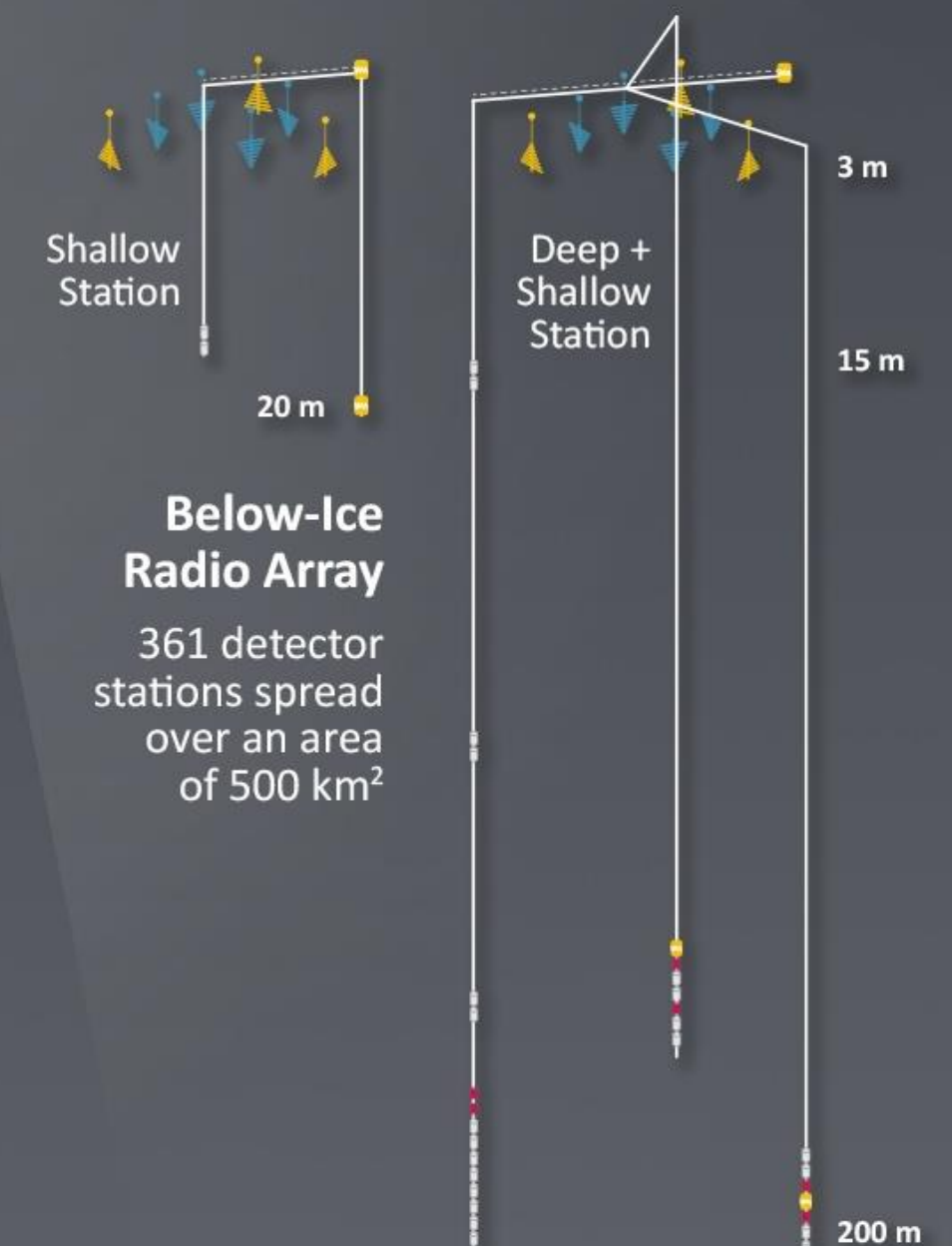
IceCube
(1 km)

IceCube-Gen2
(5 km)



Amundsen-Scott South Pole Station, Antarctica

A National Science Foundation-managed research facility

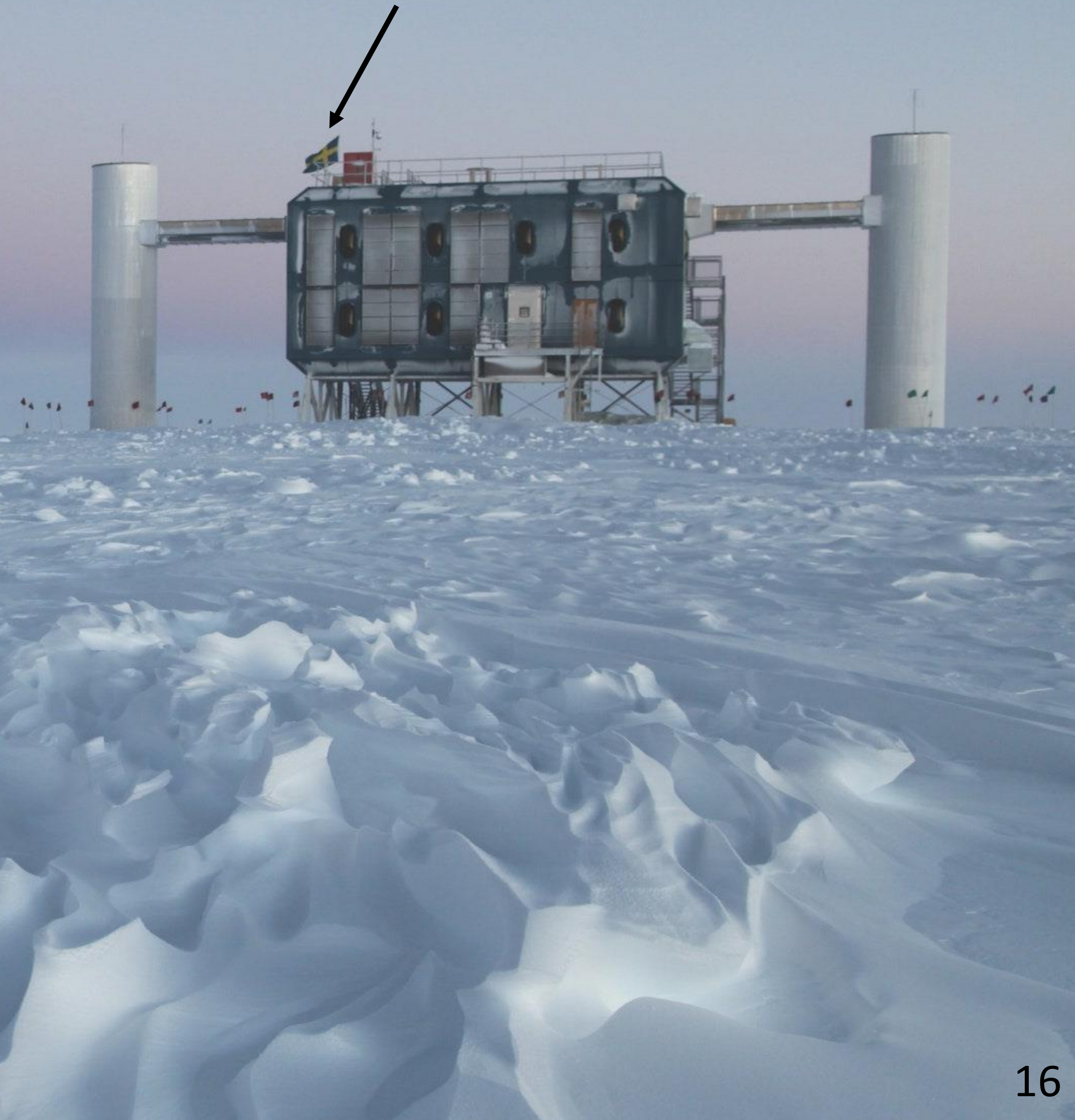


Below-Ice Radio Array

361 detector stations spread over an area of 500 km²

Summary

- successful low-energy extension of IceCube in winter 2025/2026
- first extension of IceCube after 15 years of stable operation
- significant extension of the scope of IceCube
- a lot of new data incoming from the IceCube Upgrade
 - right now: calibration
 - end of year: science
- work on IceCube-Gen2 to push the frontiers of neutrino astrophysics and particle physics



 **AUSTRALIA**
University of Adelaide

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

 **CANADA**
Queen's University
Simon Fraser University
University of Alberta–Edmonton

 **DENMARK**
University of Copenhagen

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

THE ICECUBE COLLABORATION

 **ITALY**
University of Padova

 **JAPAN**
Chiba University

 **NEW ZEALAND**
University of Canterbury

 **REPUBLIC OF KOREA**
Chung-Ang University
Sungkyunkwan University

 **SWEDEN**
Stockholms universitet
Uppsala universitet

 **SWITZERLAND**
Université de Genève

 **TAIWAN**
Academia Sinica

 **UNITED KINGDOM**
University of Oxford

 **UNITED STATES**
Columbia University
Drexel University
Georgia Institute of Technology
Harvard University
Lawrence Berkeley National Lab
Loyola University Chicago
Marquette University

Massachusetts Institute of Technology
Mercer University
Michigan State University
Ohio State University
Pennsylvania State University
South Dakota School of Mines and Technology
Southern University and A&M College
Stony Brook University
University of Alabama
University of Alaska Anchorage
University of California, Berkeley
University of California, Irvine
University of Delaware

University of Kansas
University of Maryland
University of Nevada, Las Vegas
University of Rochester
University of Utah
University of Wisconsin–Madison
University of Wisconsin–River Falls
Yale University

FUNDING AGENCIES

Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen
(FWO-Vlaanderen)

Federal Ministry of Education and Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)

Japan Society for the Promotion of Science (JSPS)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat

The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

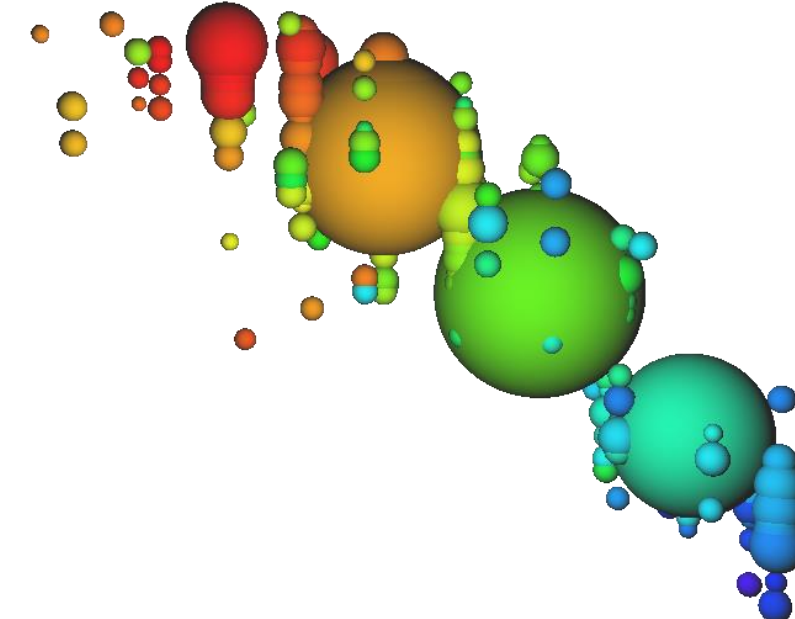


ICECUBE
NEUTRINO OBSERVATORY

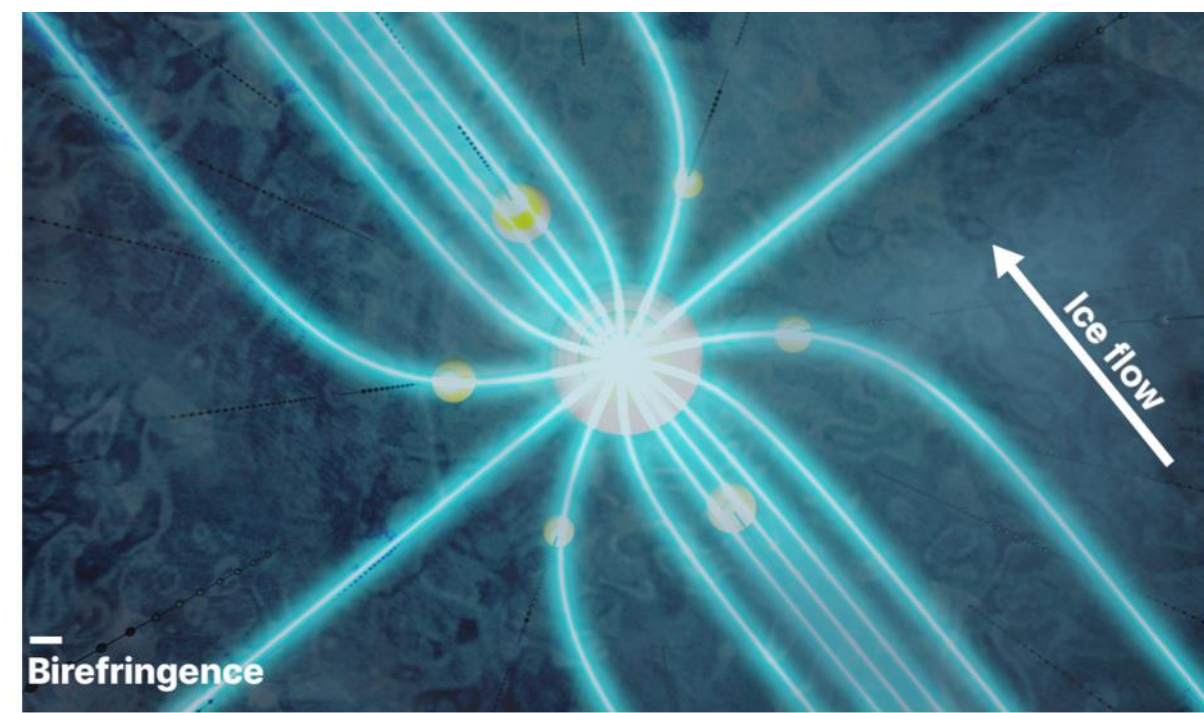
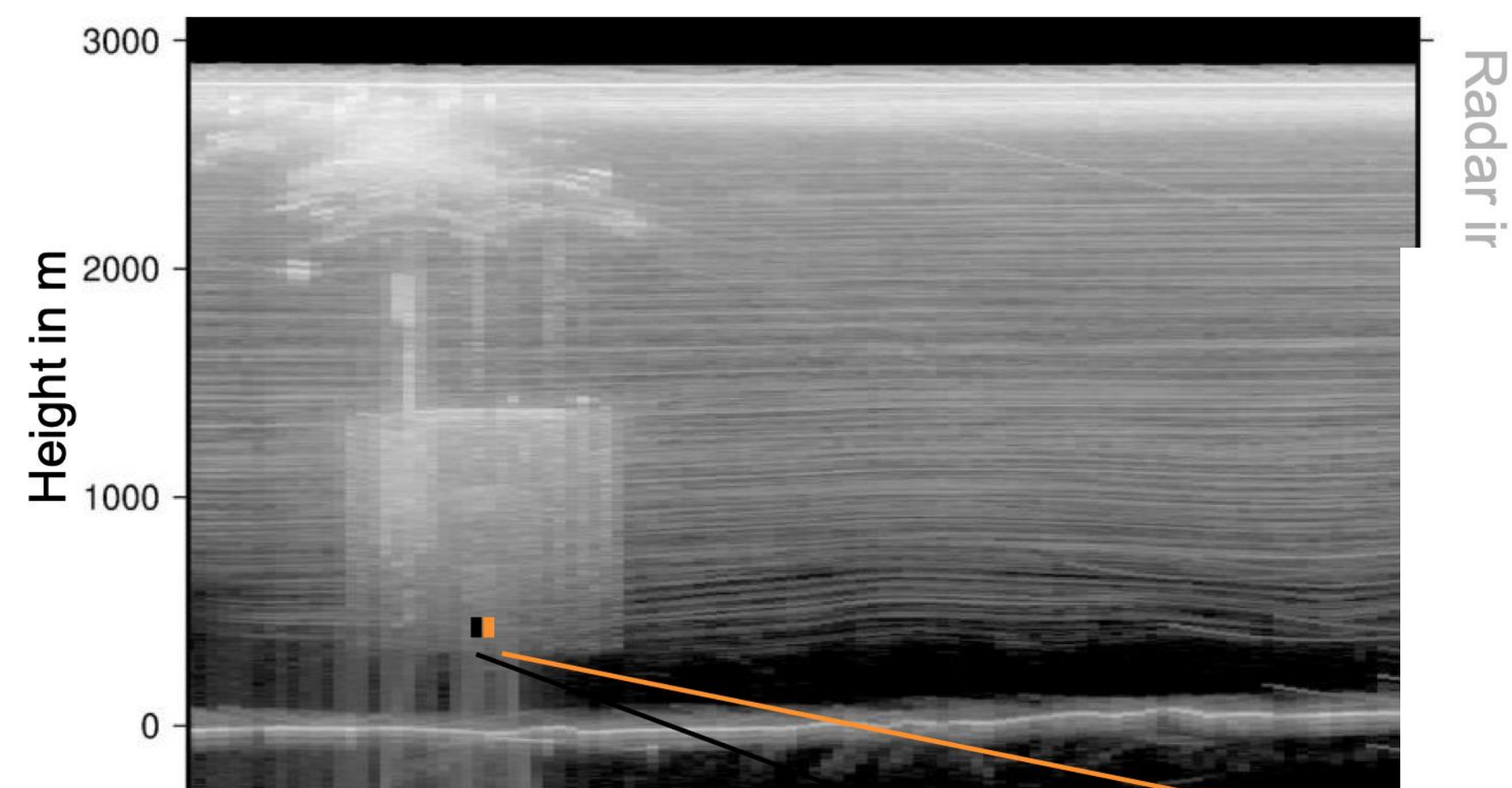
icecube.wisc.edu

Backup

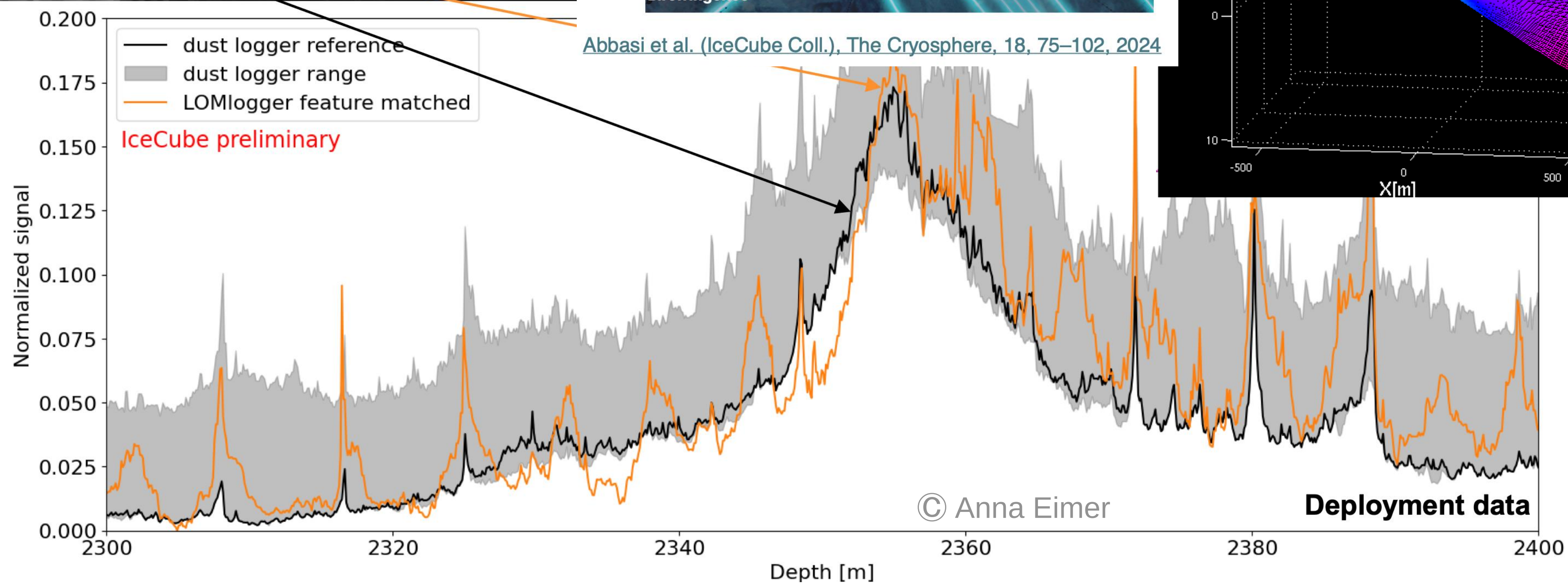
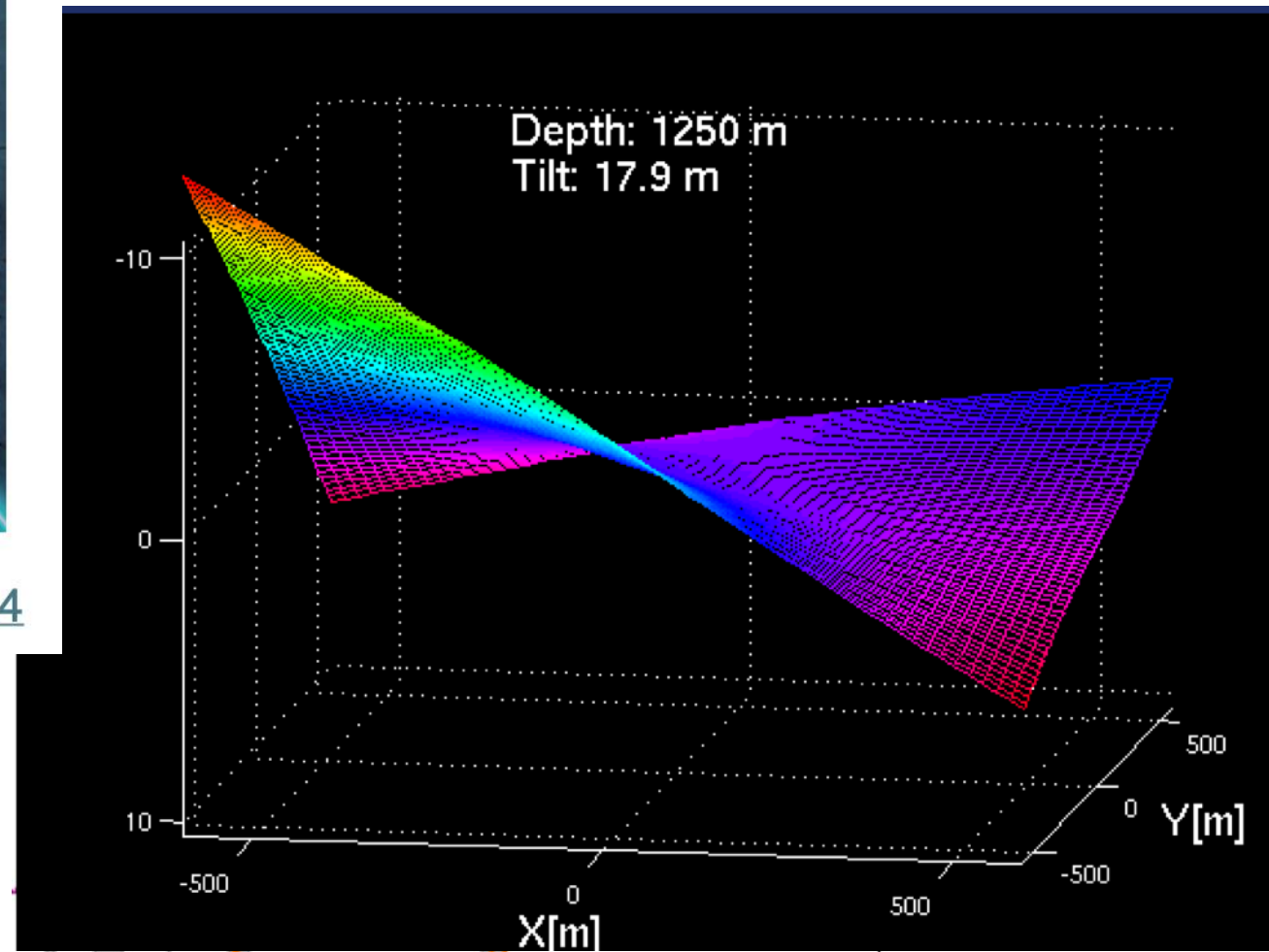
Ice

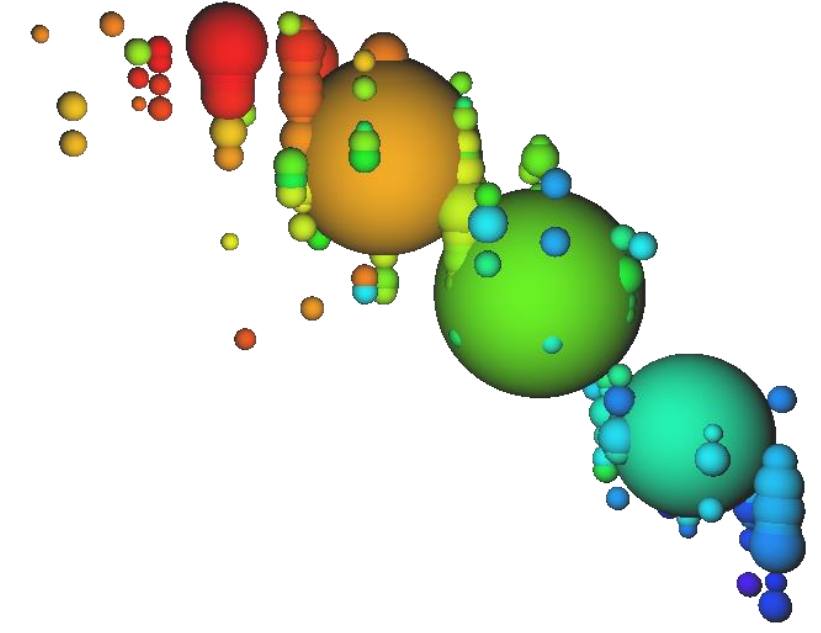


The Antarctic ice is our detector medium!

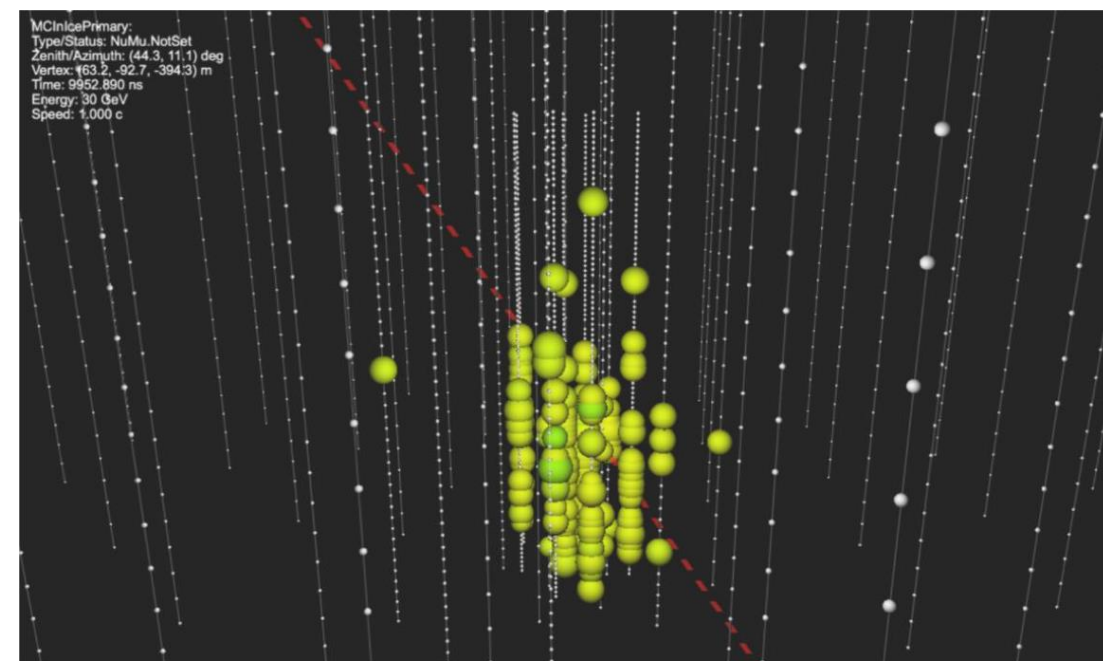
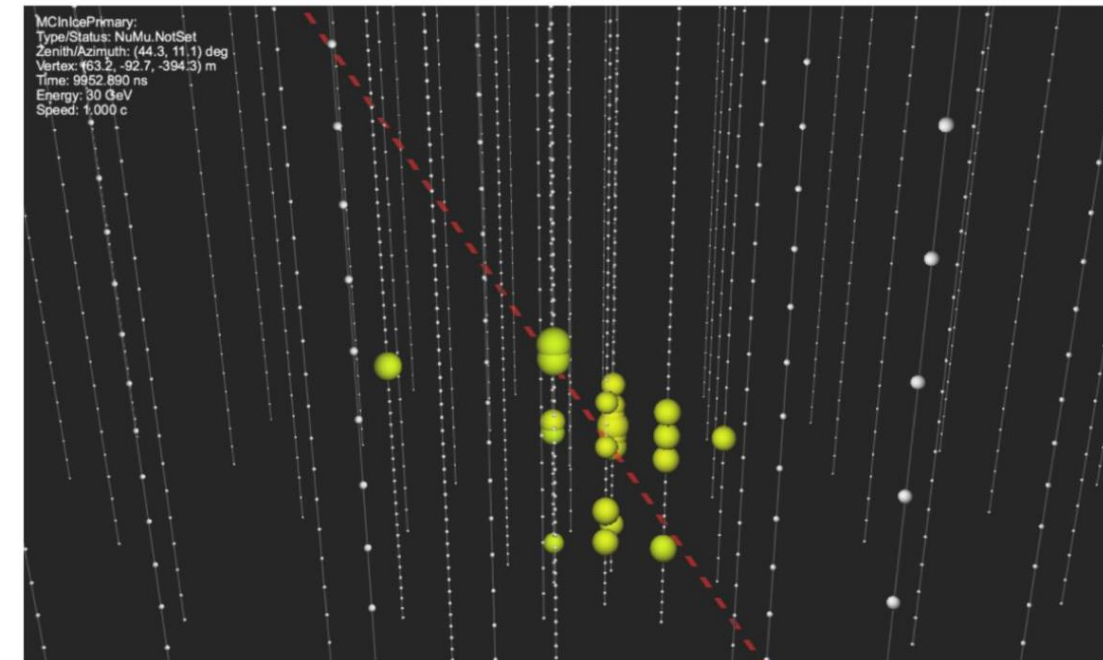


[Abbasi et al. \(IceCube Coll.\), The Cryosphere, 18, 75–102, 2024](#)





30 GeV Muon

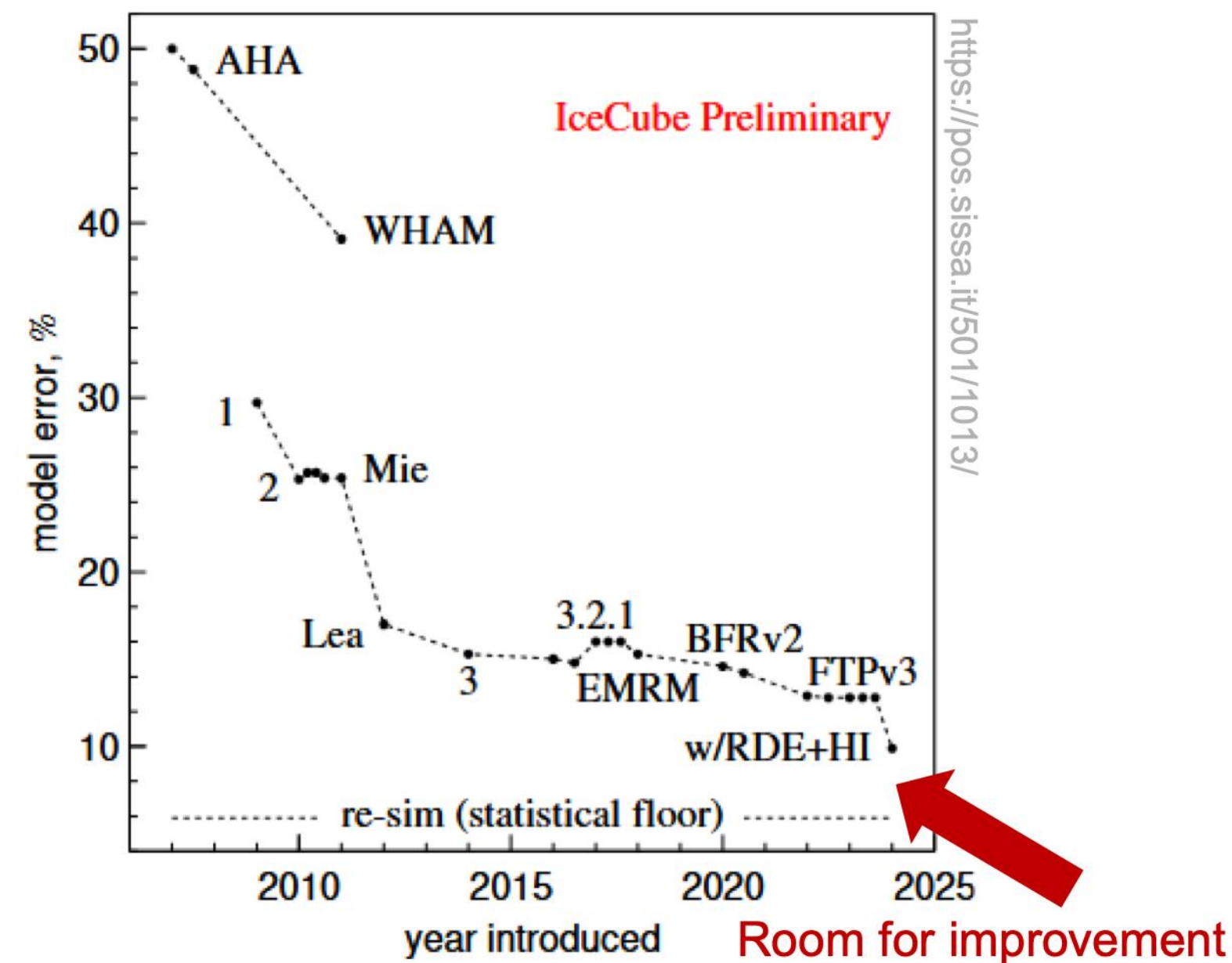


3x more photo-sensor area

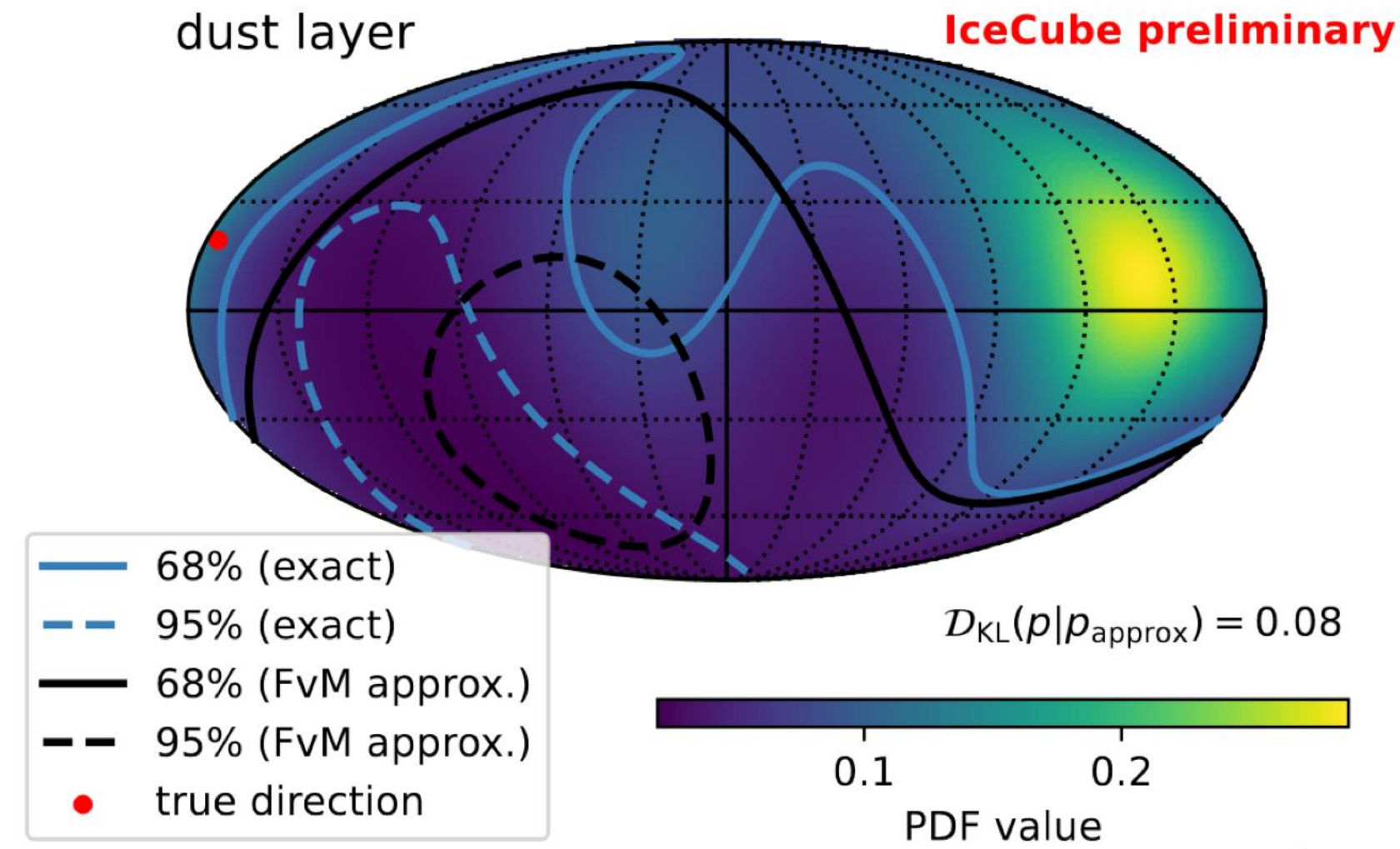
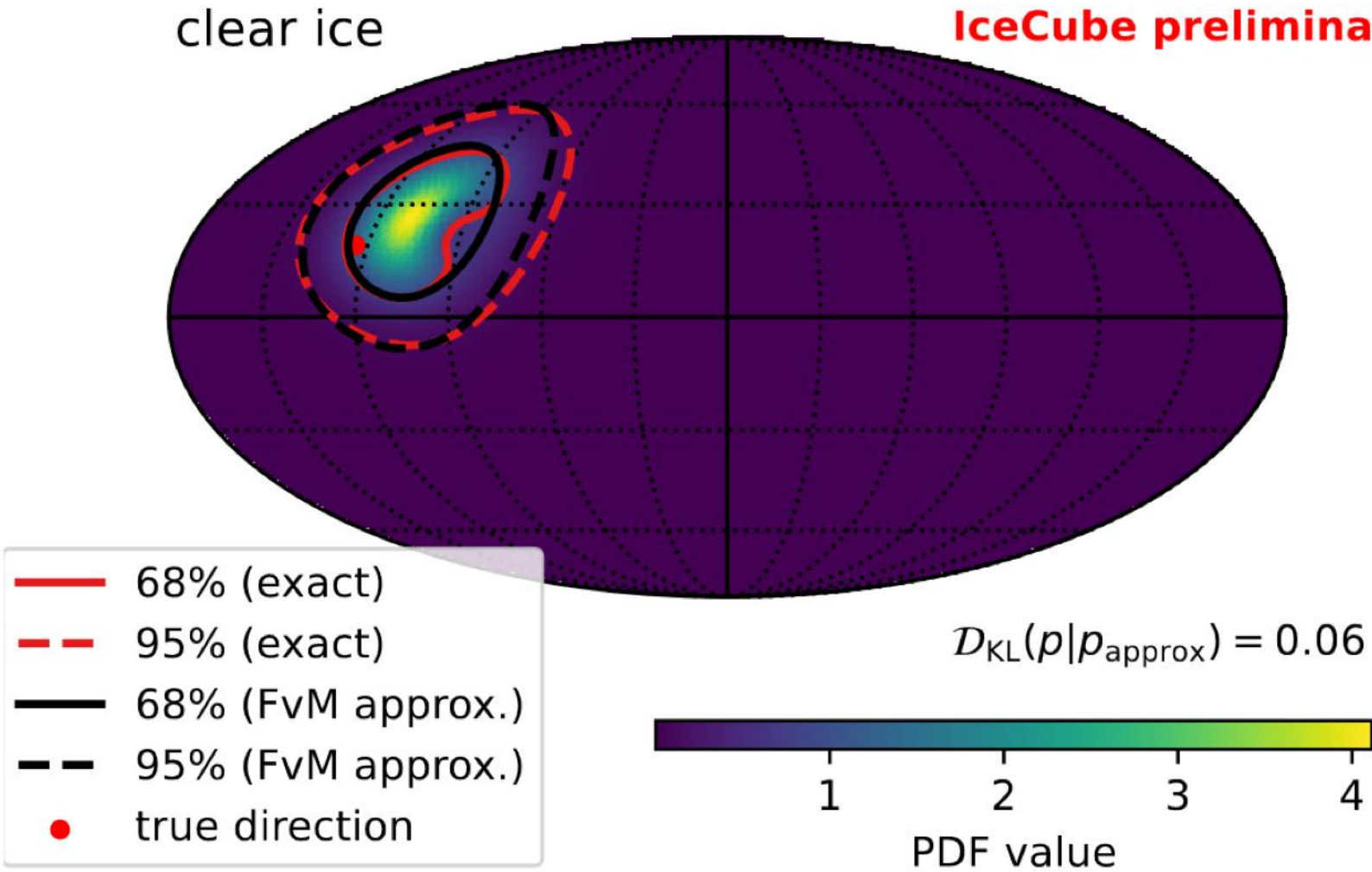
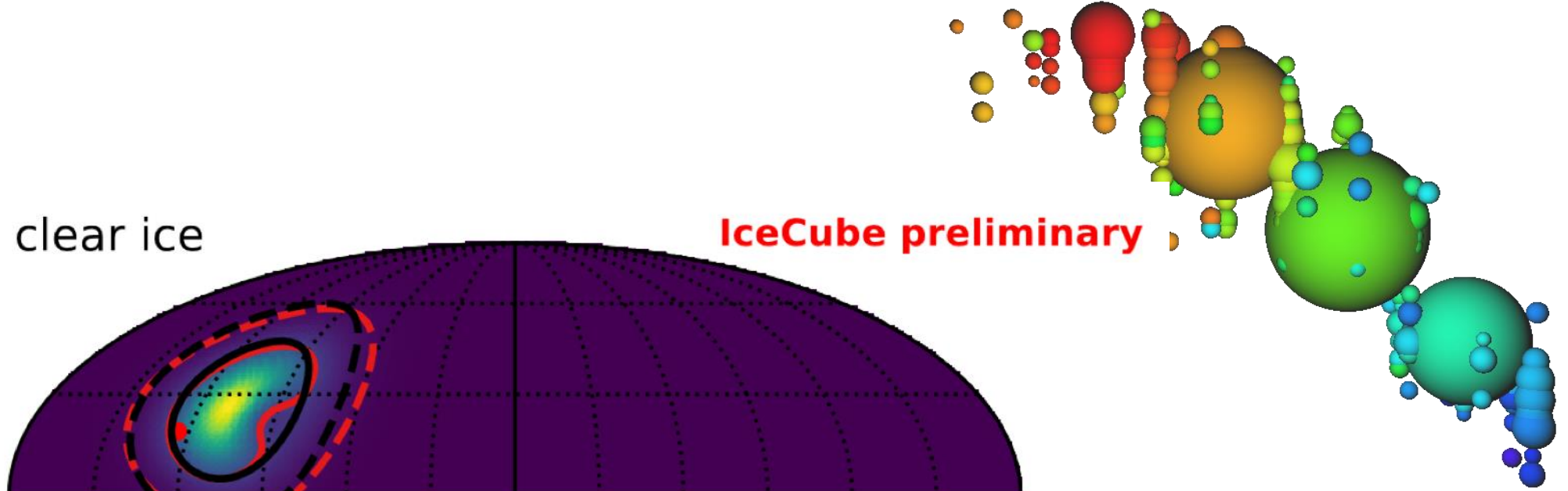
Ice

Light propagation

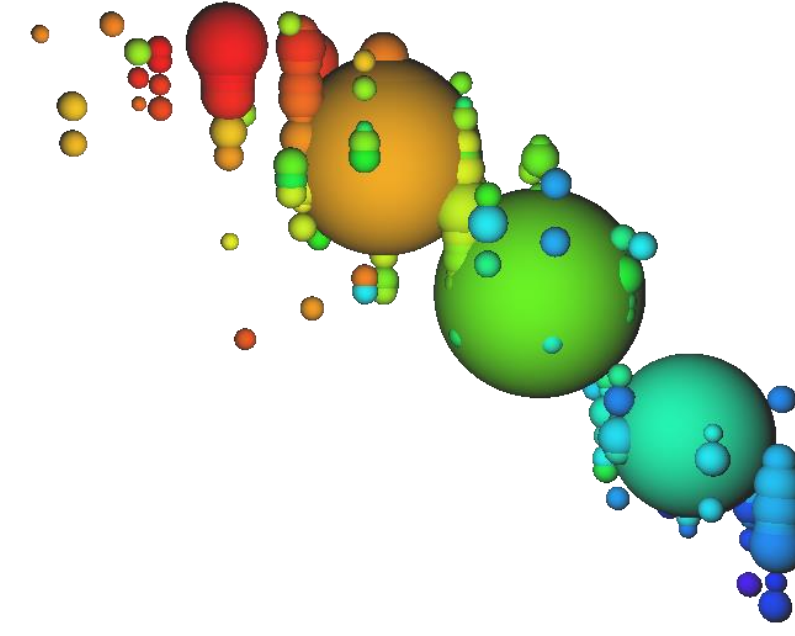
- without detailed knowledge of the optical properties of ice, reconstructions are inaccurate



- there is still room for improvement



Upgrade Baseline Modules



450 mDOM



24 PMT with angular sensitivity in every direction

290 D-Egg



Ellipsoid glass with thin diameter with 2 PMT

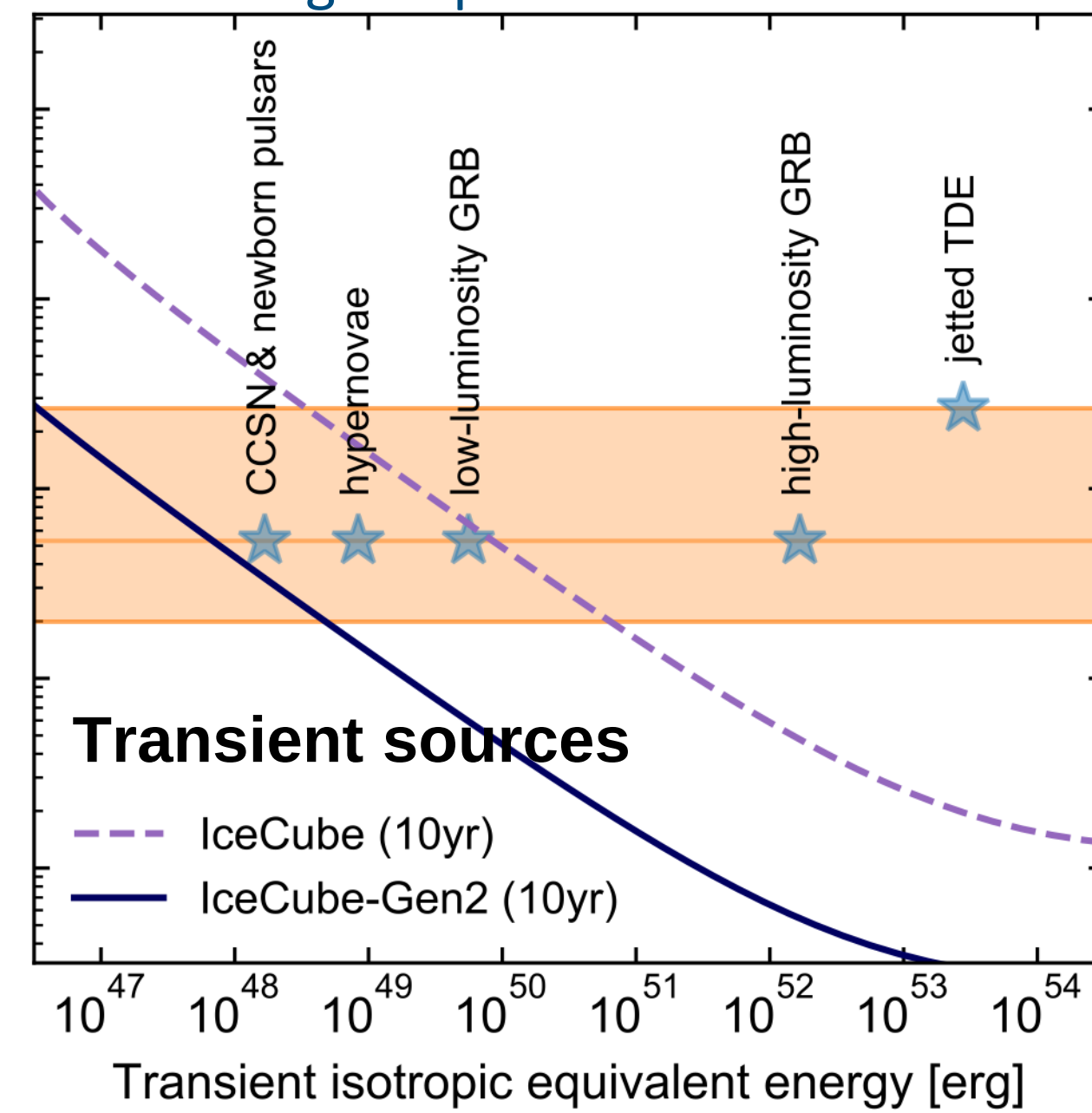
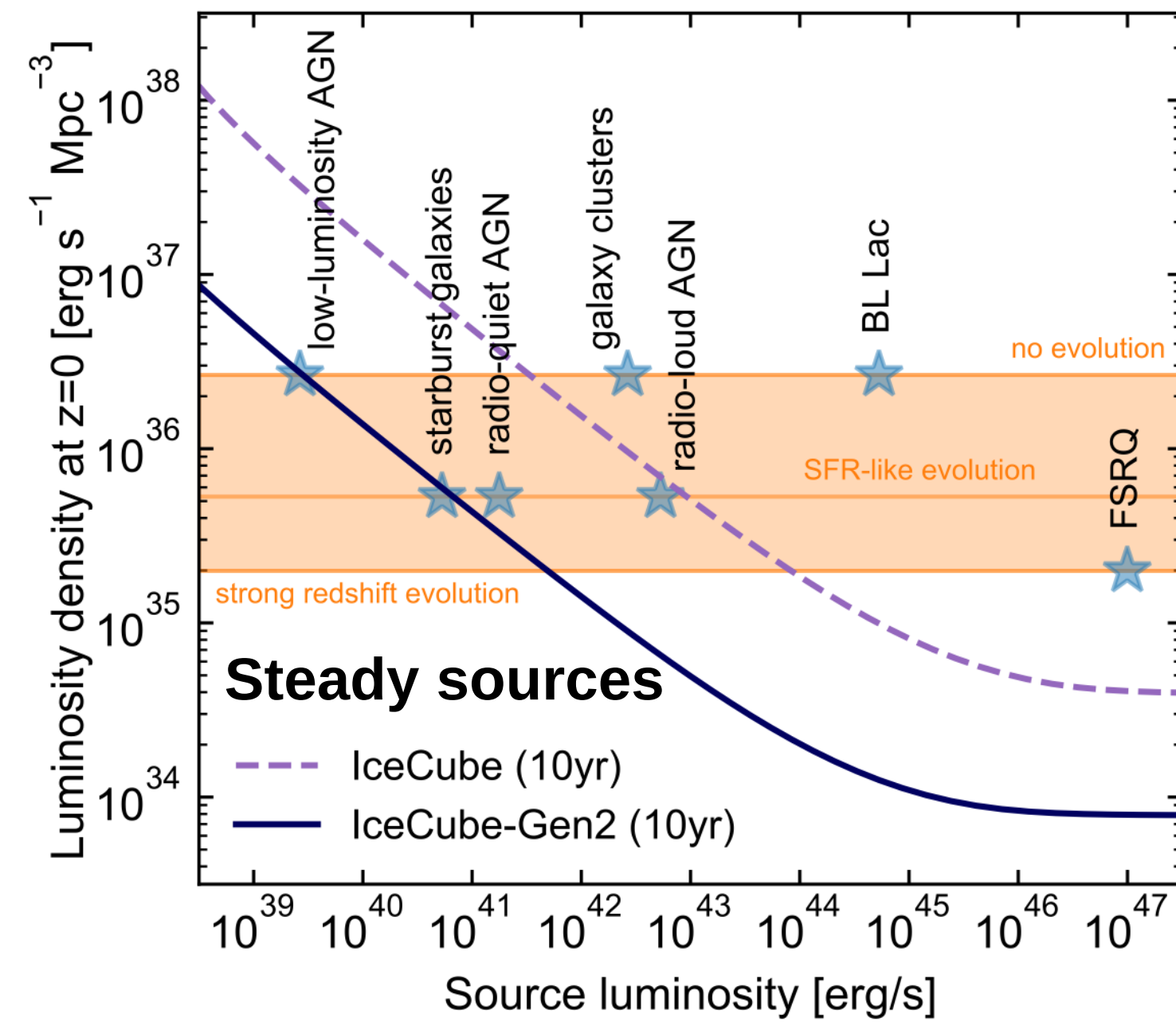


ICECUBE GEN2

Optical array: increasing from 1km^3 to $\sim 8\text{km}^3$



IceCube-Gen2 Technical Design Report



neutron-tagger
of $\sim 10\text{k}$ modules

Video: run012_string92H_run_2026-01-24_233239

UTC: 2026-01-24 23:44:57

92H sideways, Day 2, Turbulence

At (alpha,beta): 108 348

Video time: 00:11:22.400

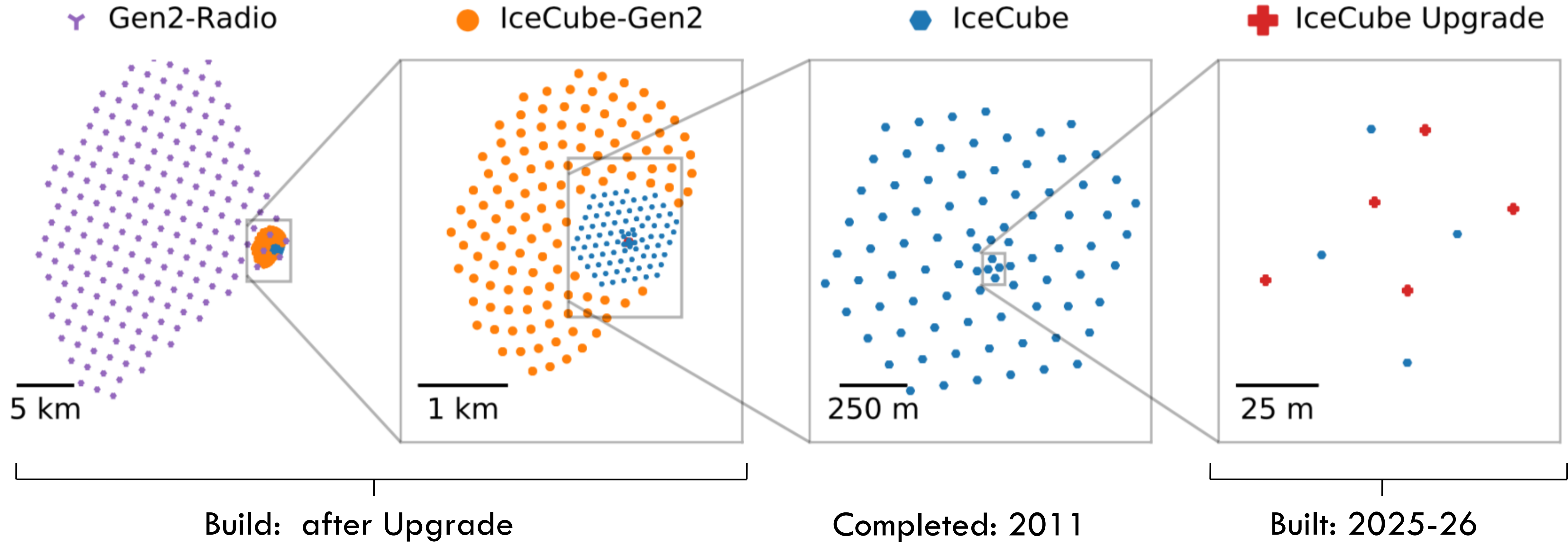
Sweden
Camera
in AMANDA
1998

(P.O. Hulth,
L. Thollander)

<https://www.youtube.com/watch?v=hiJVajBA9TQ&t=548s>



IceCube Present & Future



IceCube-Gen2

Neutrino Astronomy from TeV to EeV

IceCube Upgrade