



# **IIHE-ULB Activities**

**COSPA meeting 2021**

**J. A. Aguilar on behalf of the IIHE astro-particle group**

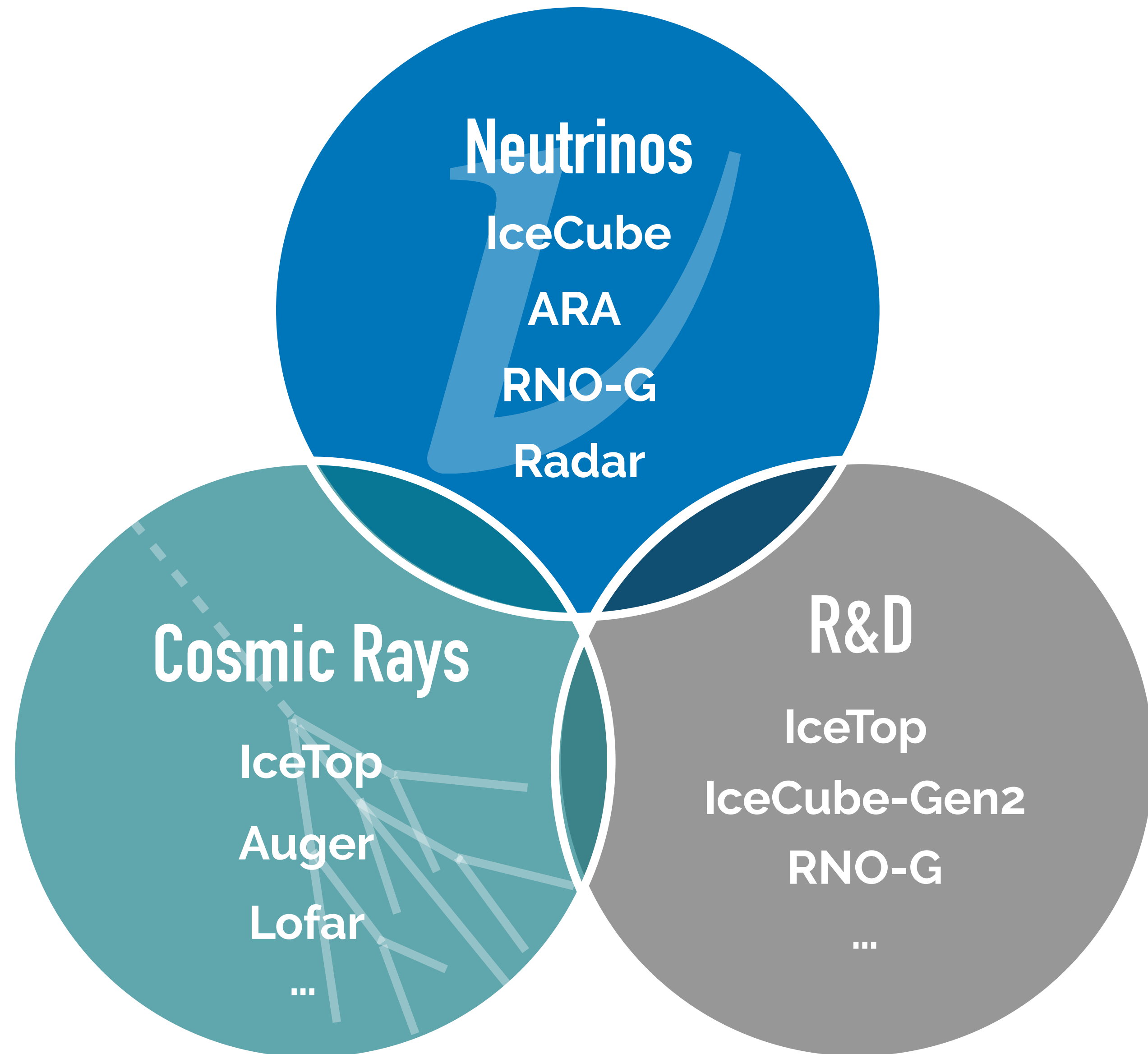
*Some*

**IIHE-ULB Activities**

**COSPA meeting 2021**

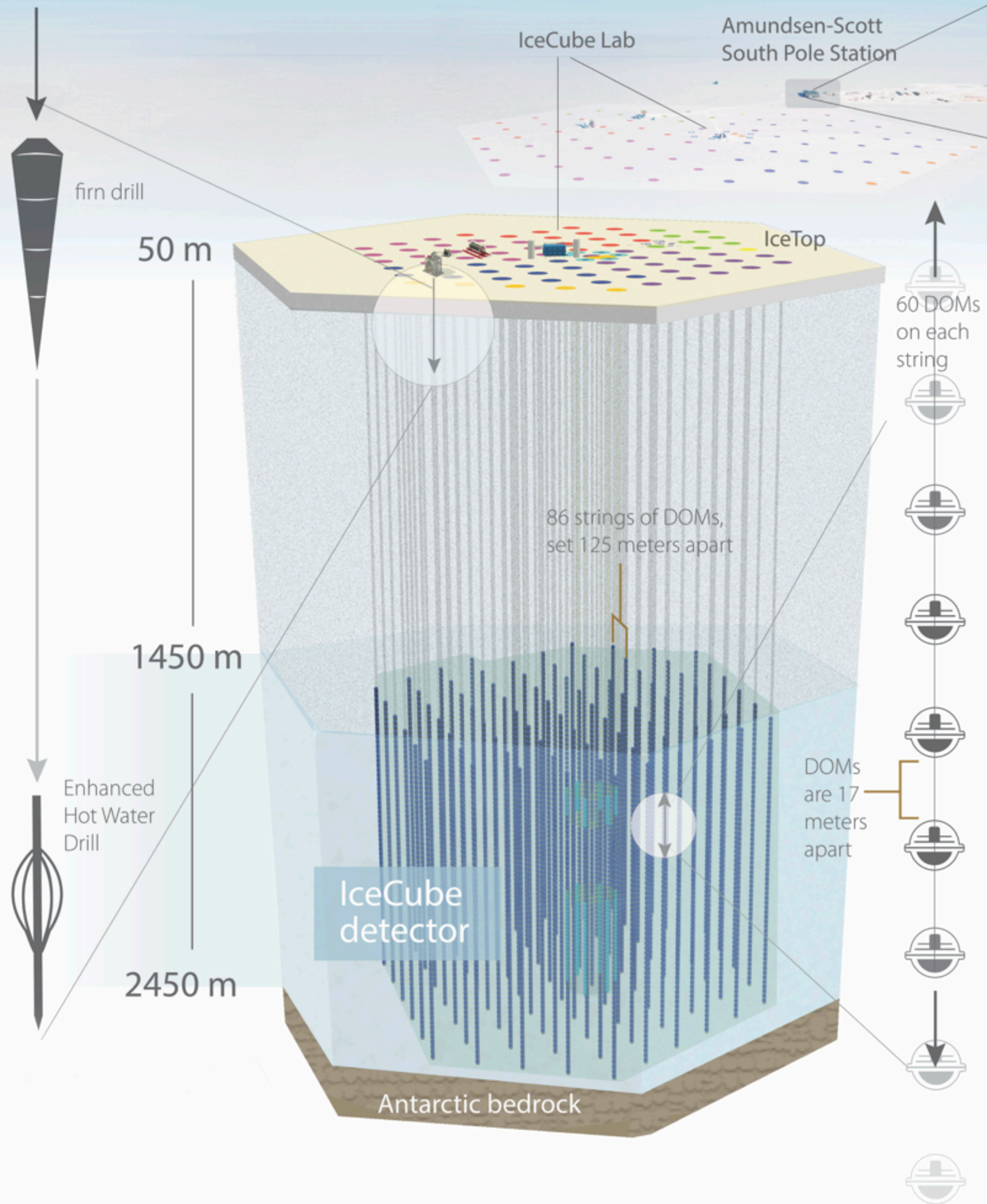
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# Multimessenger Astronomy @ IHE

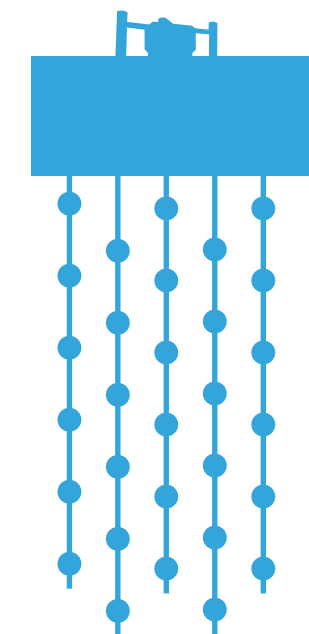


- This talk:
  - Neutrinos: Optical neutrino detections (IceCube, Gen2)
  - R&D: SiPMs
- For Auger see Ioana's slides
- For the radio part (RNO-G, ARA, Lobar, Radar) see Nick's talk.

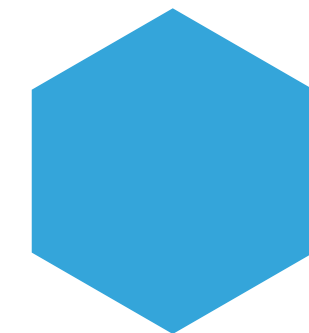
# IceCube Neutrino Observatory



**5,160** Digital Optical Modules (DOMs)



**86** string with 60 DOMs each  
**6** denser strings called **DeepCore**



**1 km<sup>2</sup>** surface array with 324 DOMs: **IceTop**



**Completion in December 2010**

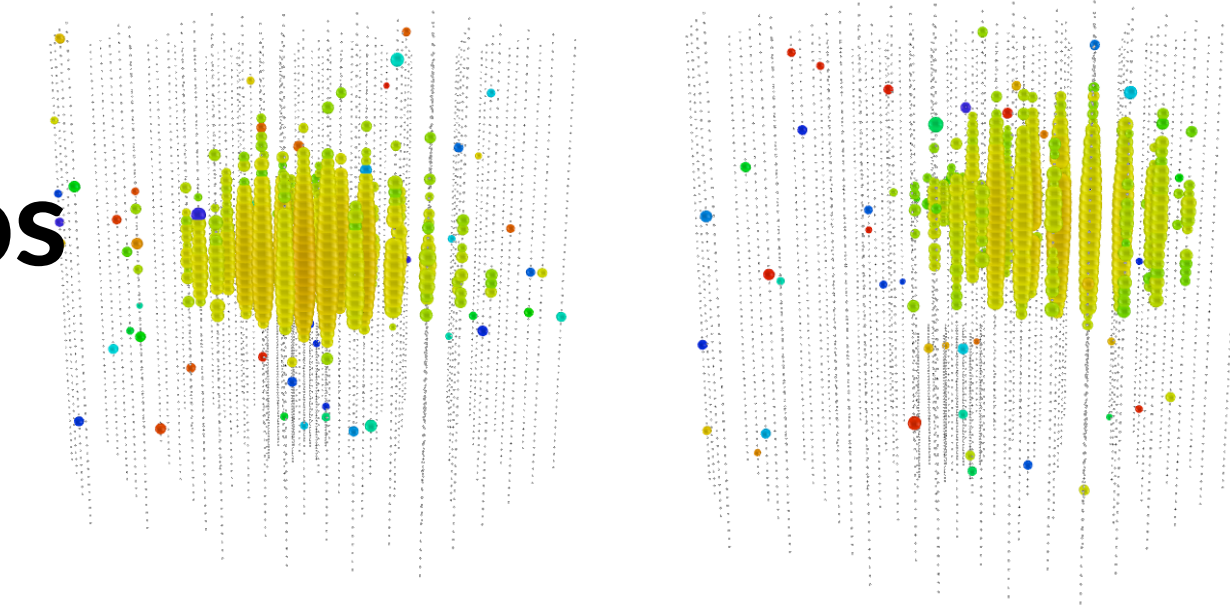


# IceCube 10

## A Decade of Discoveries

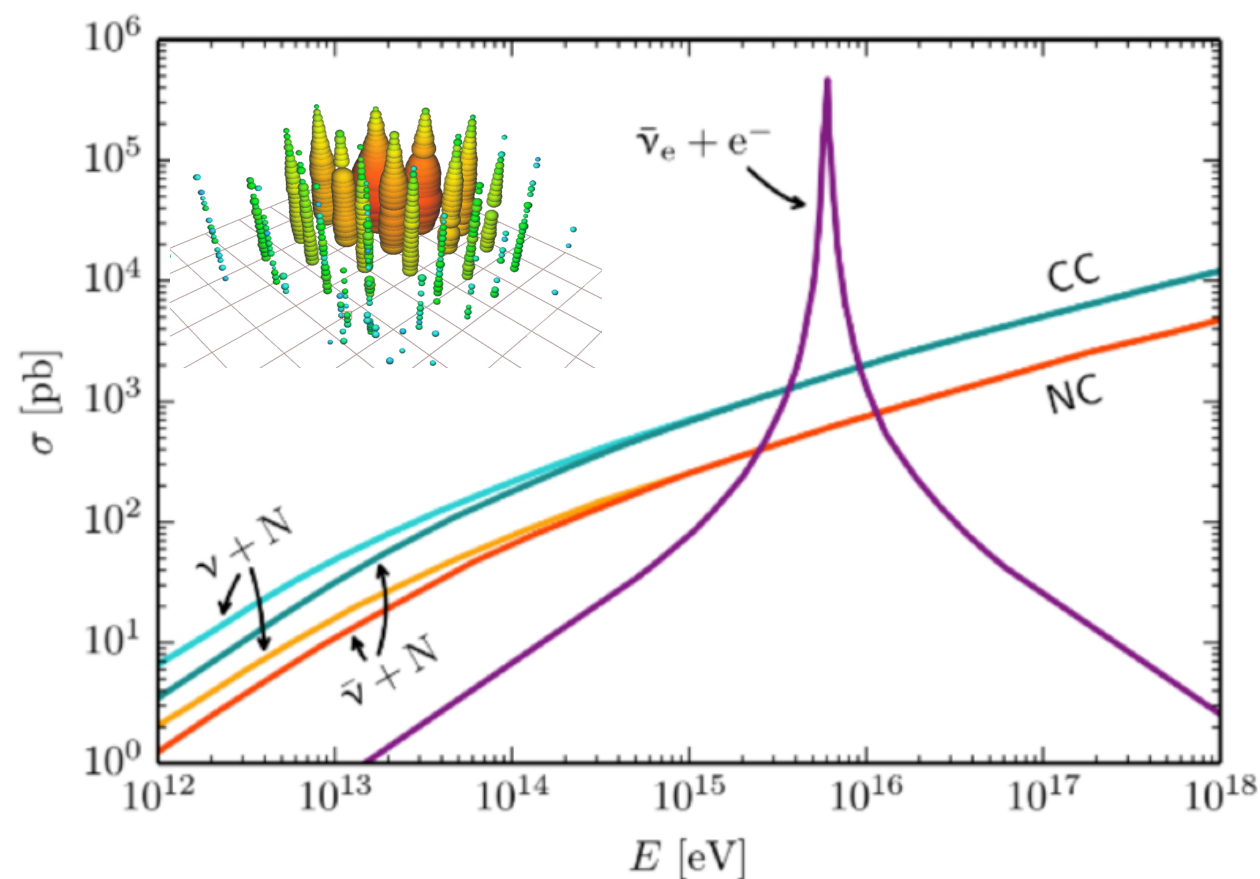
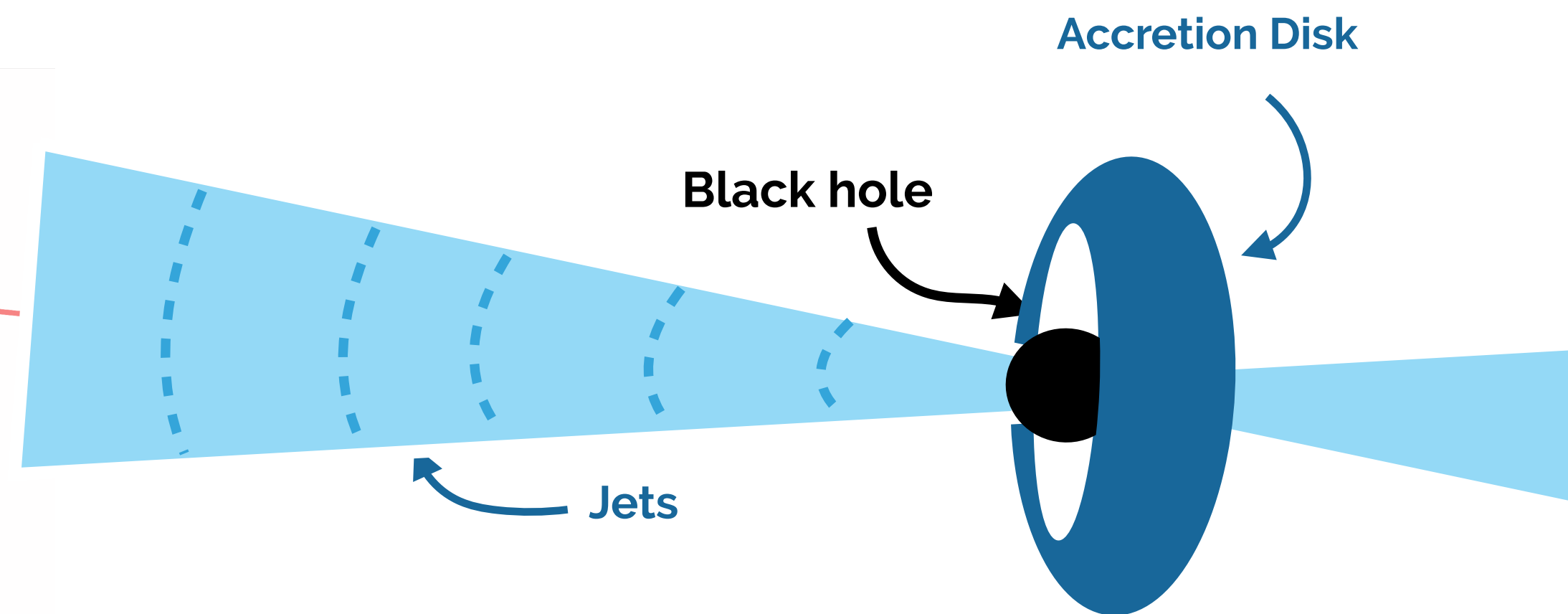
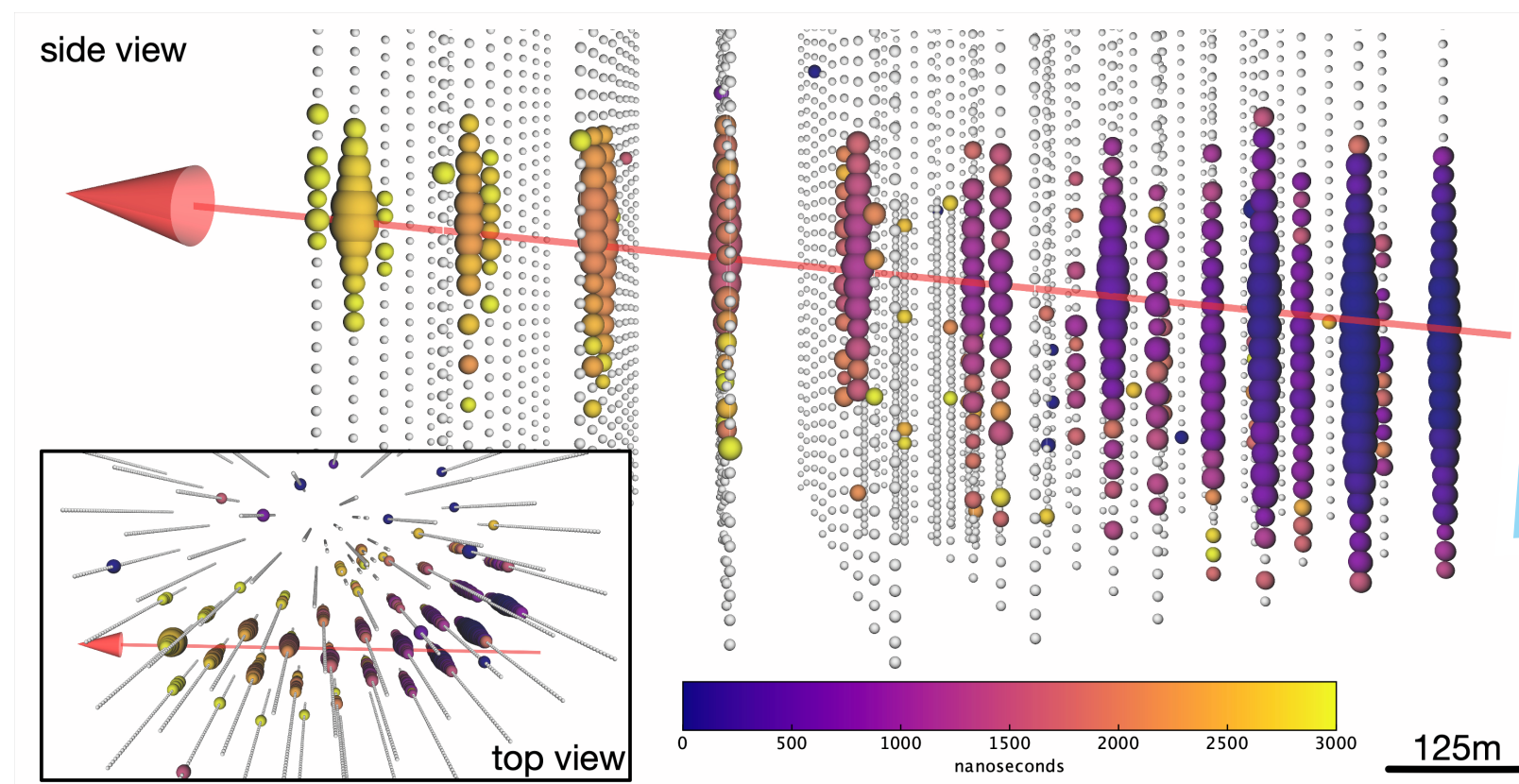
### 2013 Astrophysical Neutrinos

Detection of the first flux of astrophysical neutrinos



### 2017 TXS 0506+056

Coincidence of a neutrino event with a flare of gamma-rays from a Blazar

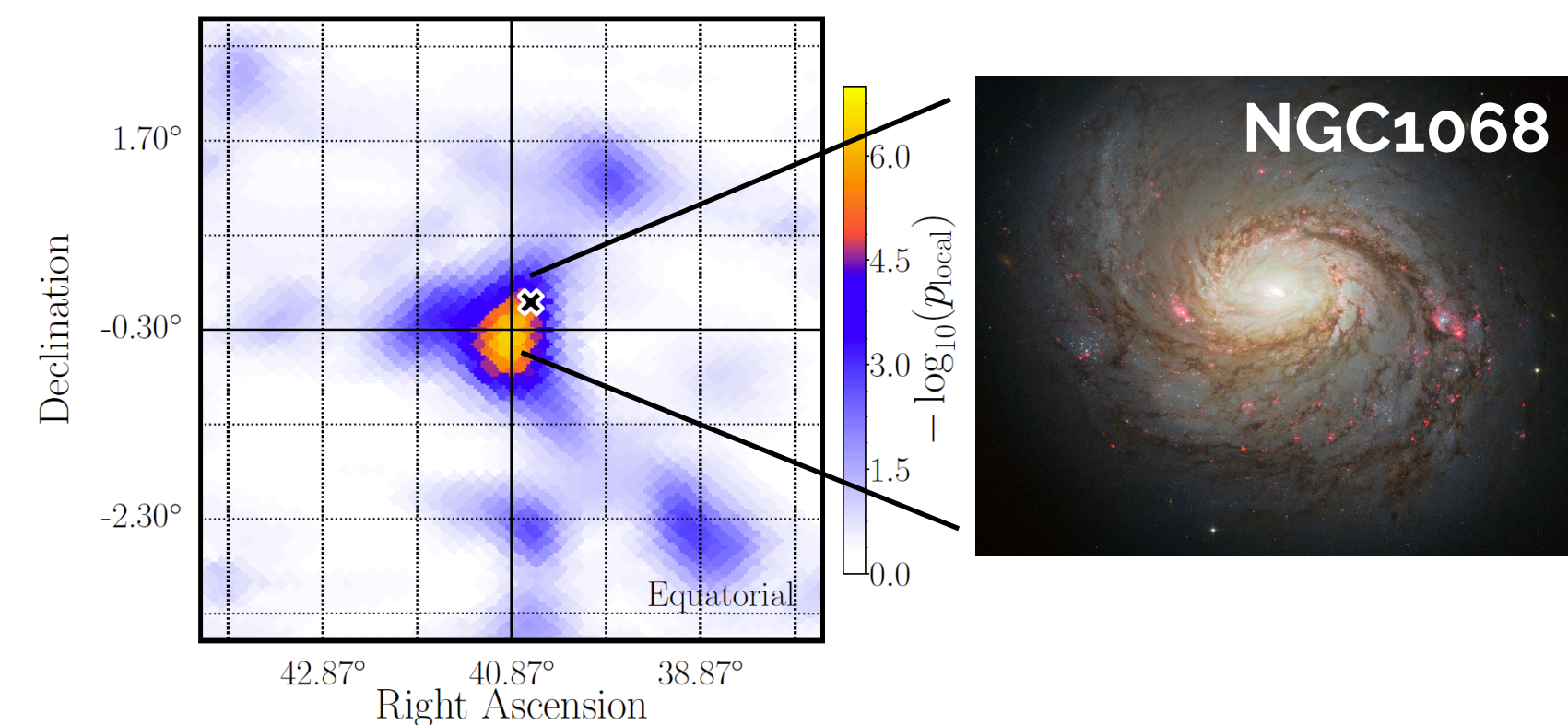


### 2021 Glashow Resonance Event

Observation of neutrino event at the Glashow energies (first  $\bar{\nu}_e$ )

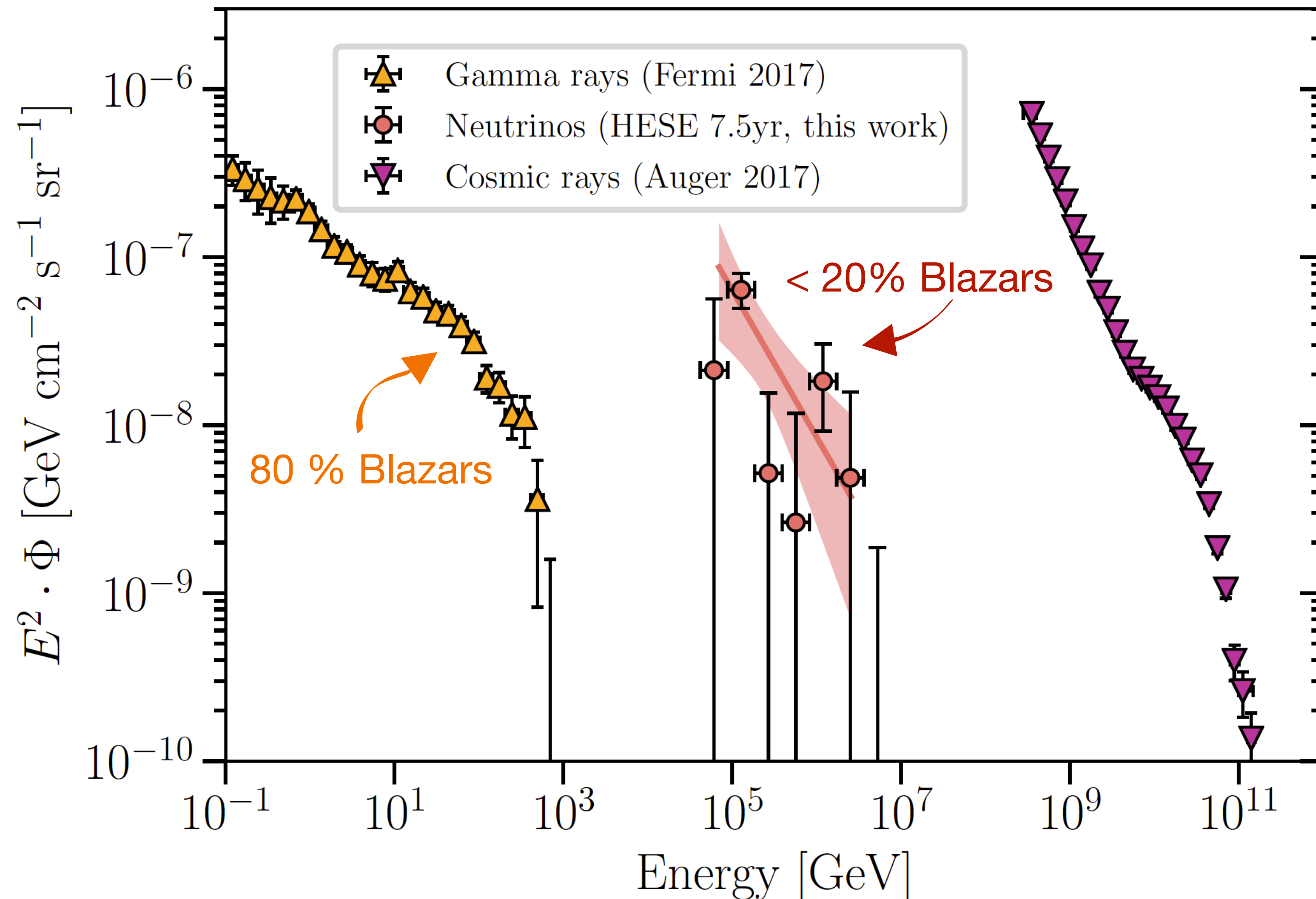
### 2021 M77

First hint of a point source in 10 years of data ( $2.9\sigma$ ). Improved point source analysis on the way



# Astrophysical Neutrinos

## State-of-art

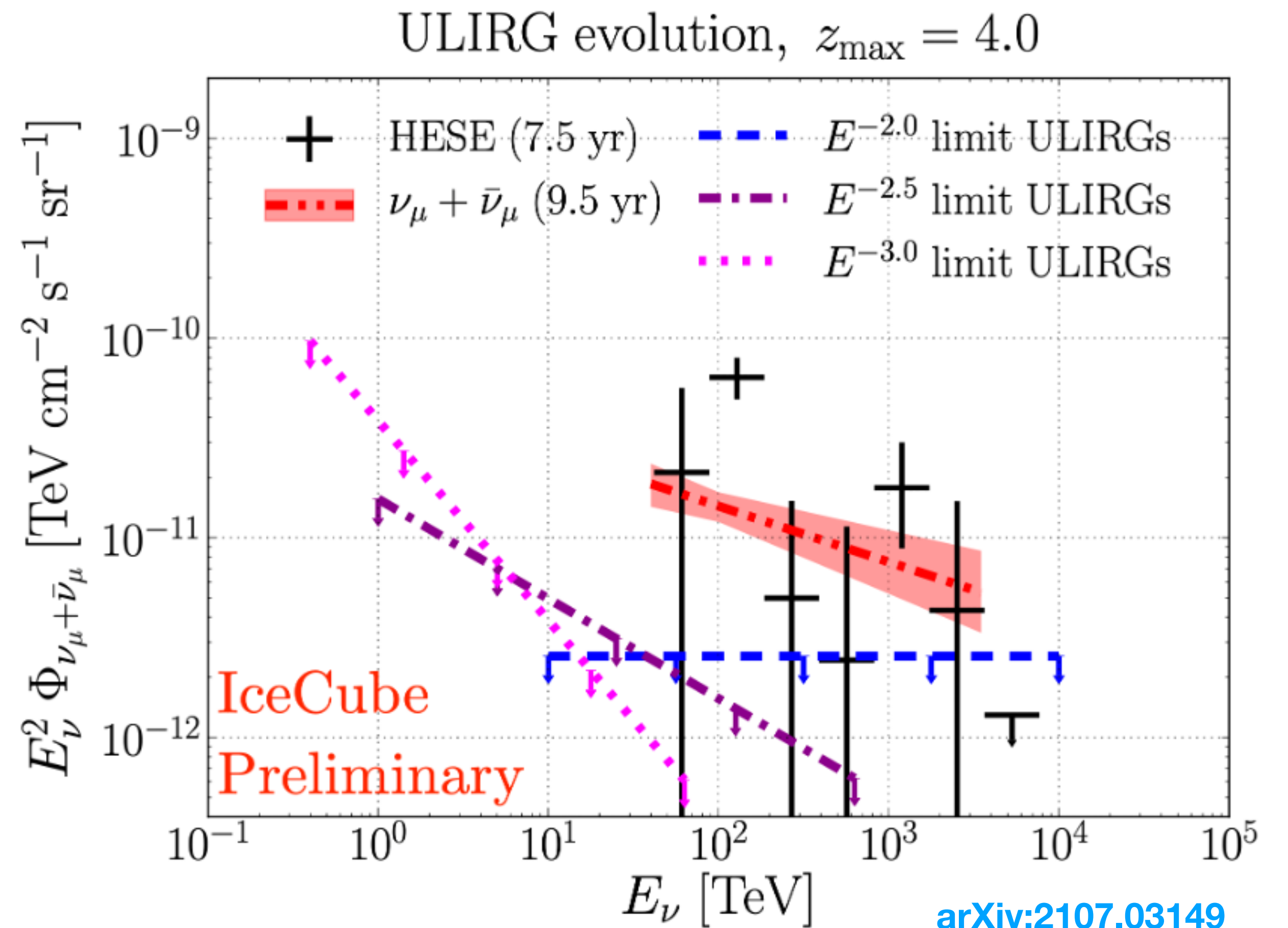


- Spectral index of astro. flux:  
 $\gamma = 2.3 - 2.9$   
depends on analysis / energy range
- Similar energies among messengers ... but also evidence for different origin!
- Gamma-obscured sources?

# Astrophysical Neutrinos @ IHE

## Search for High-Energy Neutrinos from Ultra-Luminous Infrared Galaxies

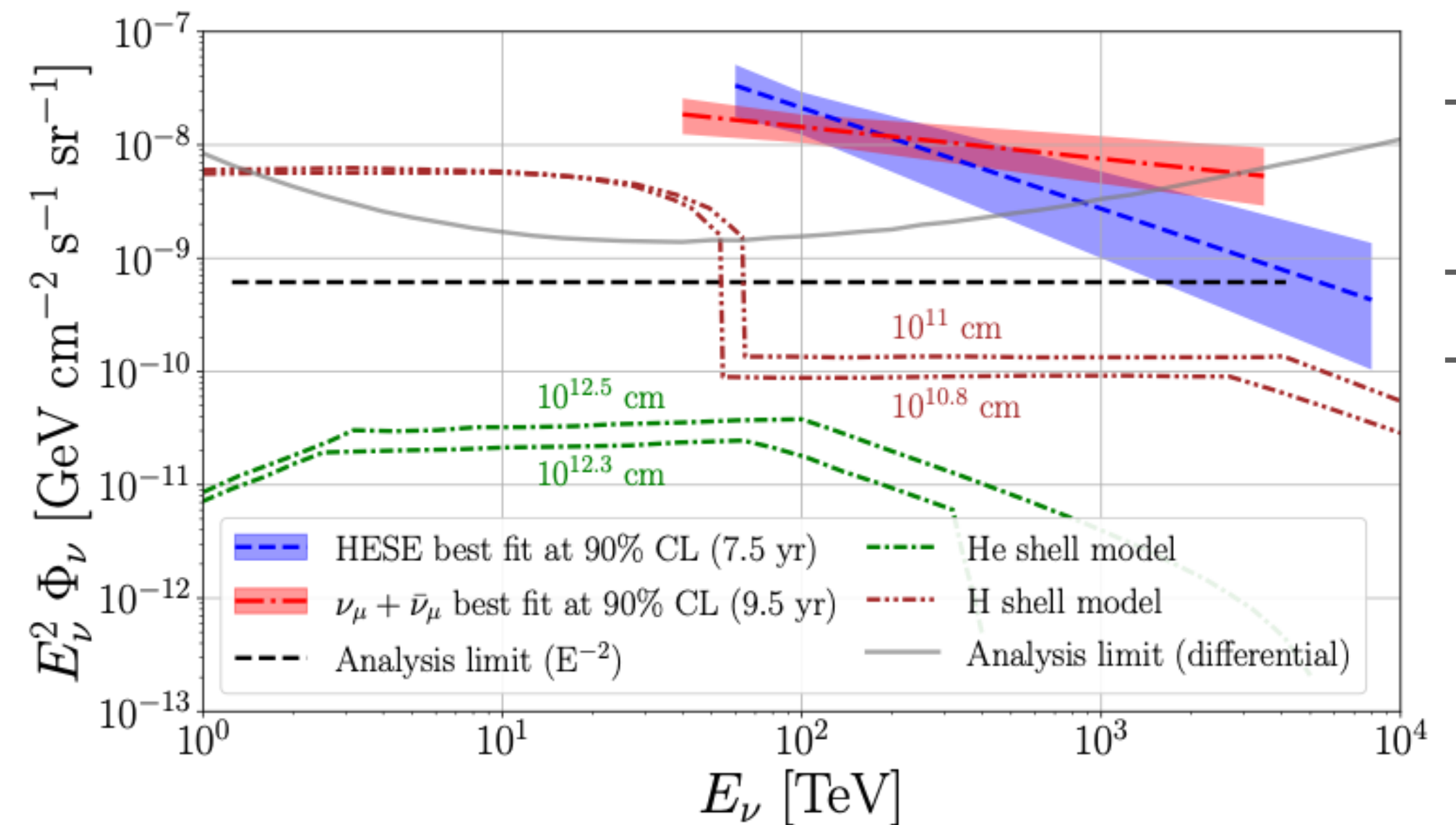
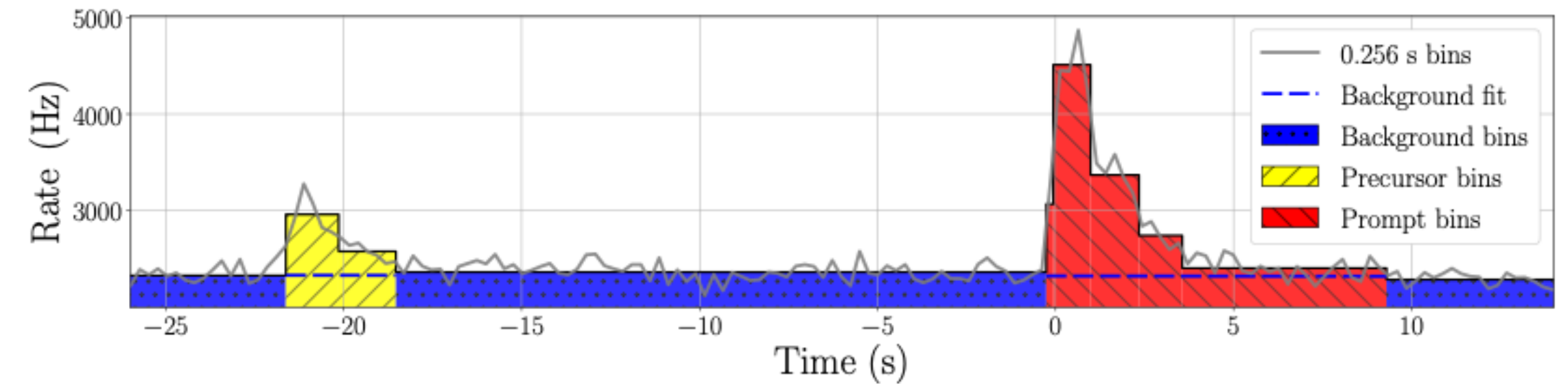
- **ULIRGs:**  $L_{IR} \geq 10^{12} L_{\odot}$  (8 – 1000  $\mu\text{m}$ )
  - Powered by starburst/AGN
  - Candidate neutrino sources
- **Stacking** analysis
  - 75 local ULIRGs ( $z \leq 0.13$ )
  - 7.5 years of data
- **No neutrinos** found
  - Set upper limits
  - Constrained diffuse contribution of ULIRGs
  - Constrained model predictions



# Astrophysical Neutrinos @ IHE

## Neutrinos from gamma-ray burst precursors

- Transient events offer a unique discovery opportunity.
- Analysed light curves of 2684 bursts from Fermi-GBM
  - 10% shows signs of precursor emission
  - New temporal features identified!
  - Published in PRD: [arXiv:2004.03246](https://arxiv.org/abs/2004.03246)
- Performed 2 searches with IceCube to look for coincident neutrinos
  - No significant coincidences observed
  - Able to limit model predictions!

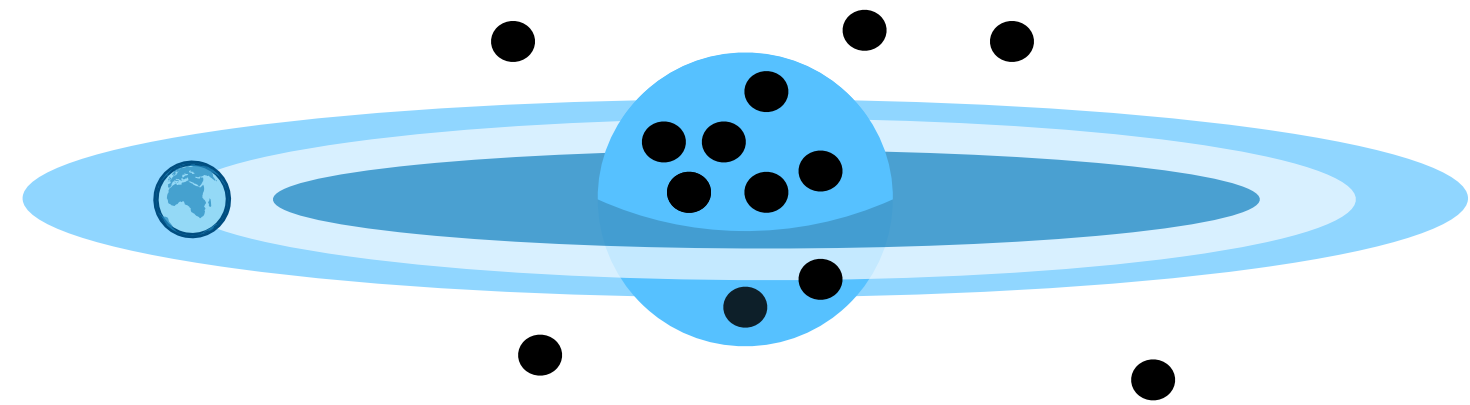


Paper in preparation



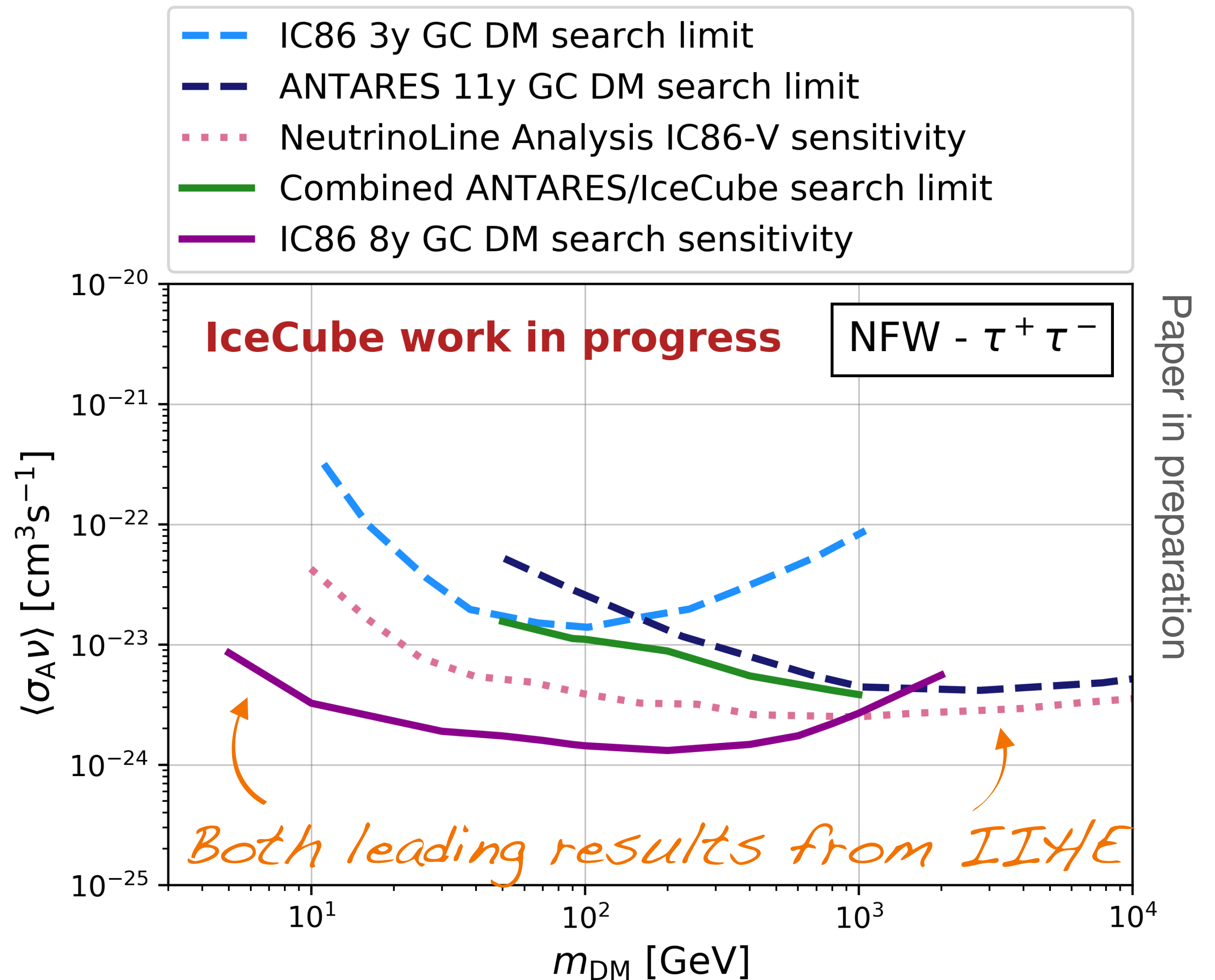
# Particle Physics @ IHE

## Dark Matter Searches



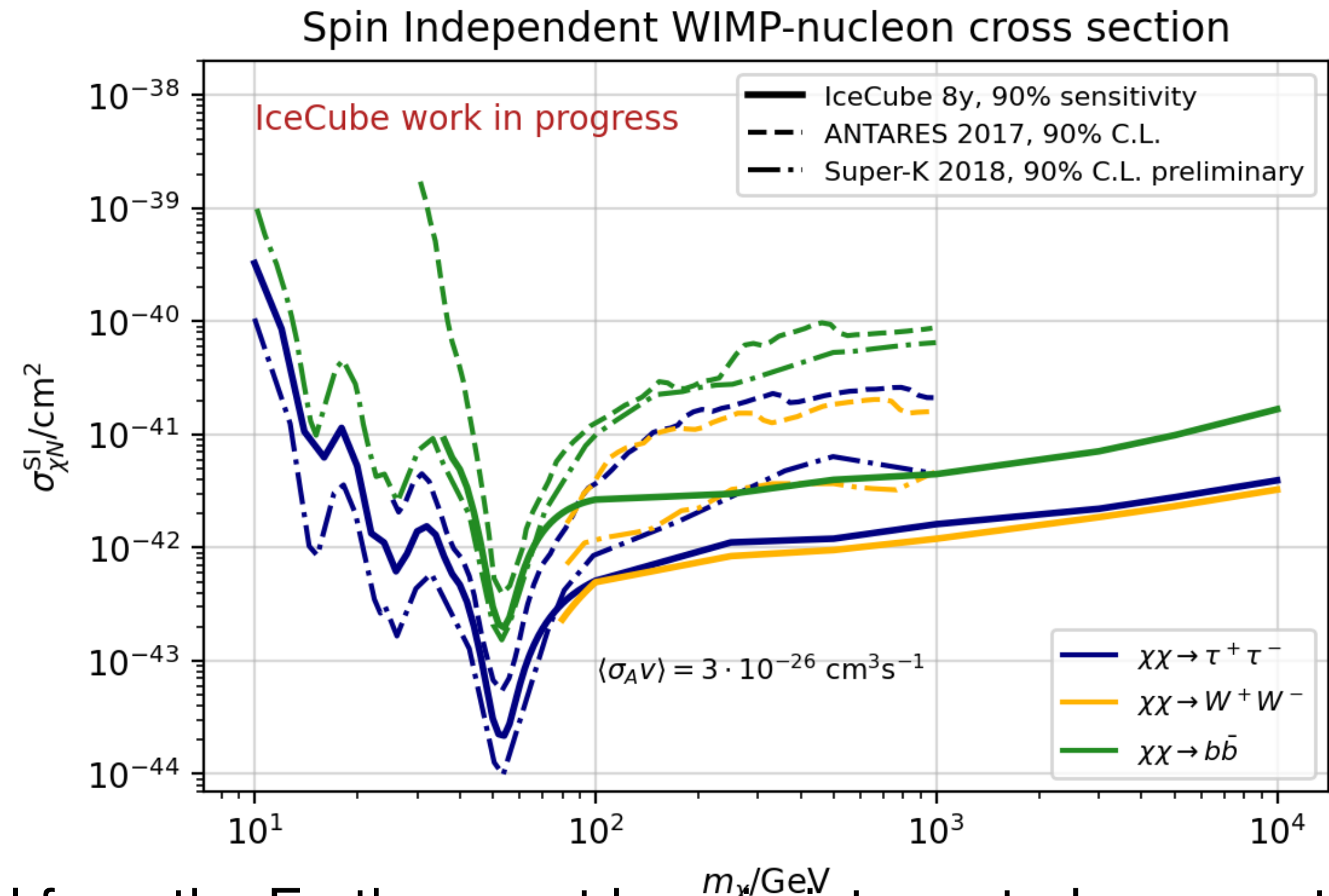
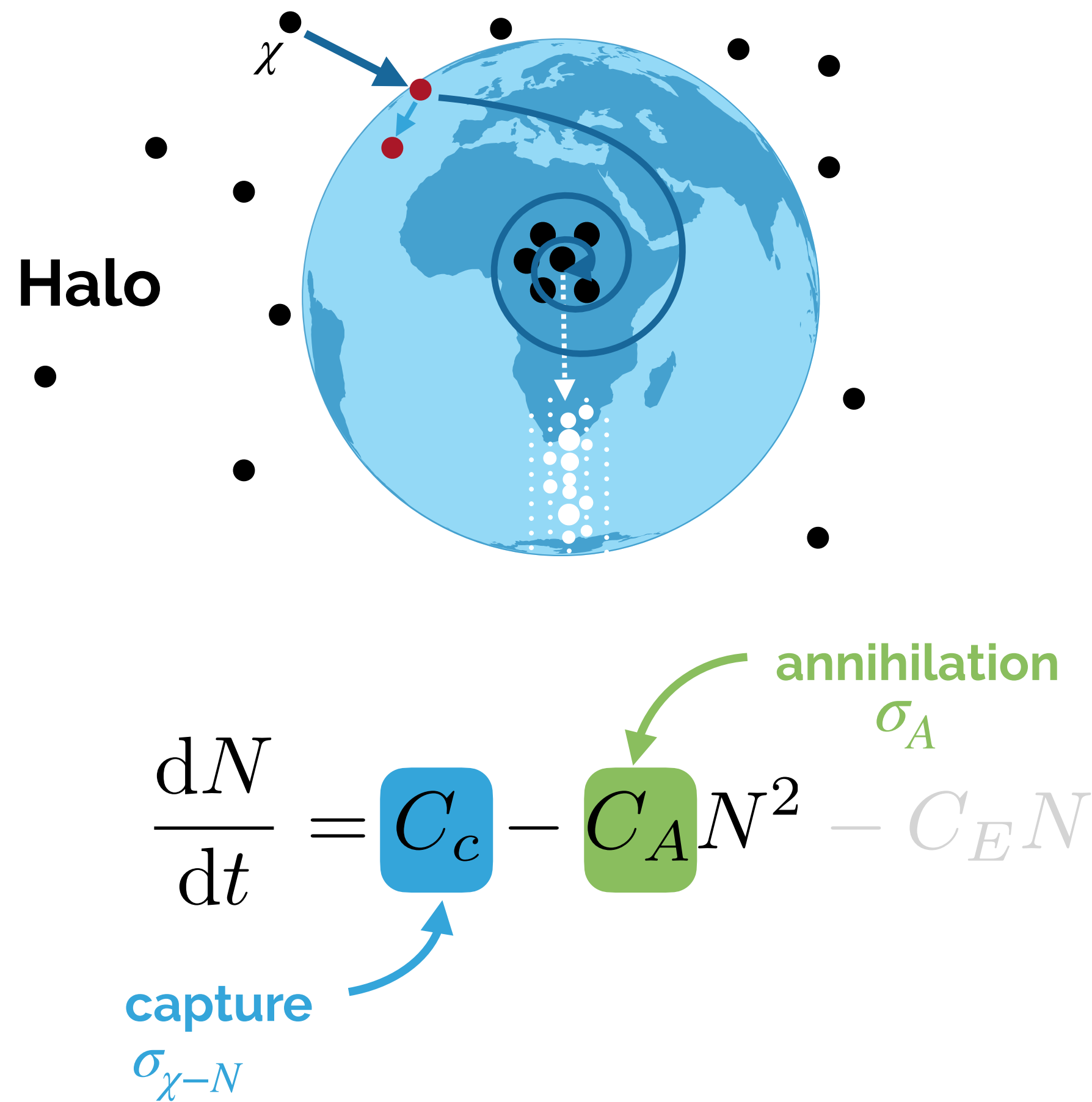
- Use neutrinos to search for annihilation/decay signatures of Dark Matter
  - Combined analysis with ANTARES using published data. [PhysRevD.102.082002]
- Performed 2 additional analyses:
  1. First analysis using energy and the neutrino spectra (Neutrino Lines) with the Service de Theory.
  2. Extending towards lower masses with Deep Core.

*Best limits in neutrino channel in the whole mass range.*



# Particle Physics @ IHE

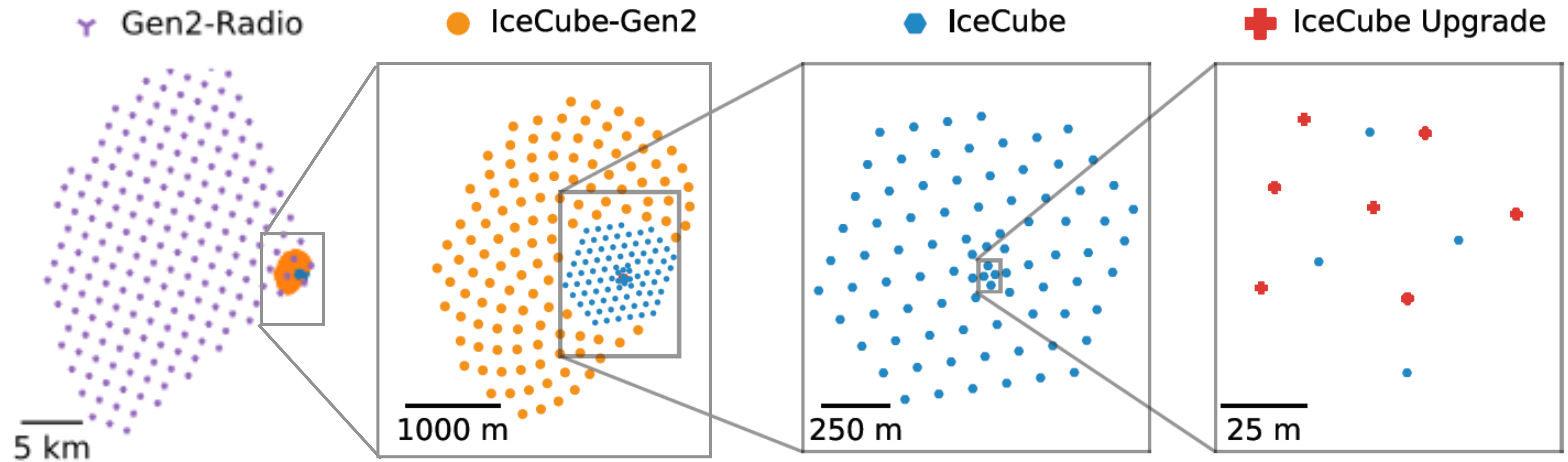
## Dark Matter from the Center of the Earth



- Signal from the Earth cannot be mis-interpreted as an astrophysical source.
- We can relate the  $\sigma_A$  and  $\sigma_{\chi-N}$
- IceCube has the best sensitivity above 100 GeV
- Analysis recently unblinded (no results public yet).

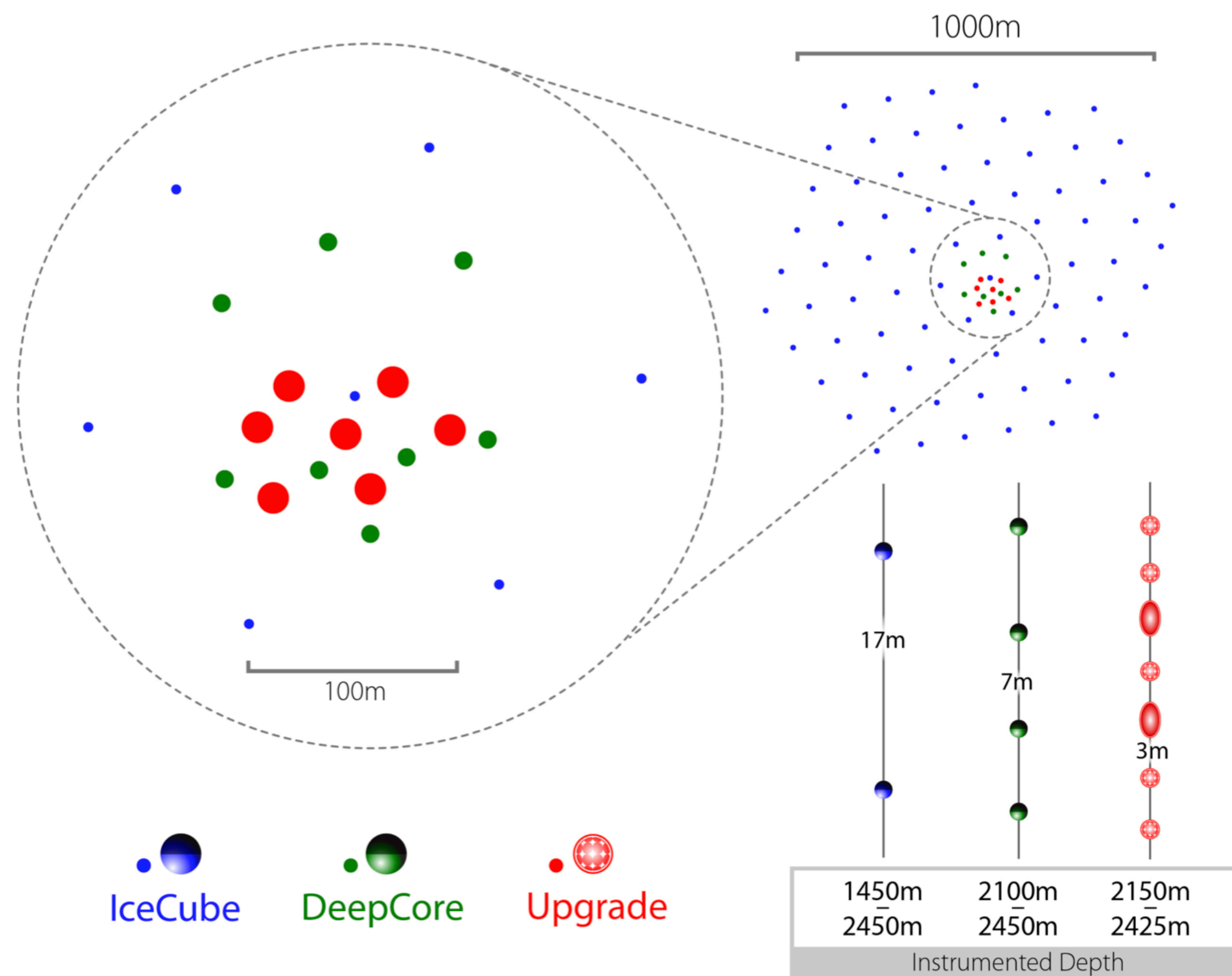
# Future Extensions

a.k.a IceCube Gen2 Phase I



# IceCube-Upgrade

## IceCube-Gen2 Phase I

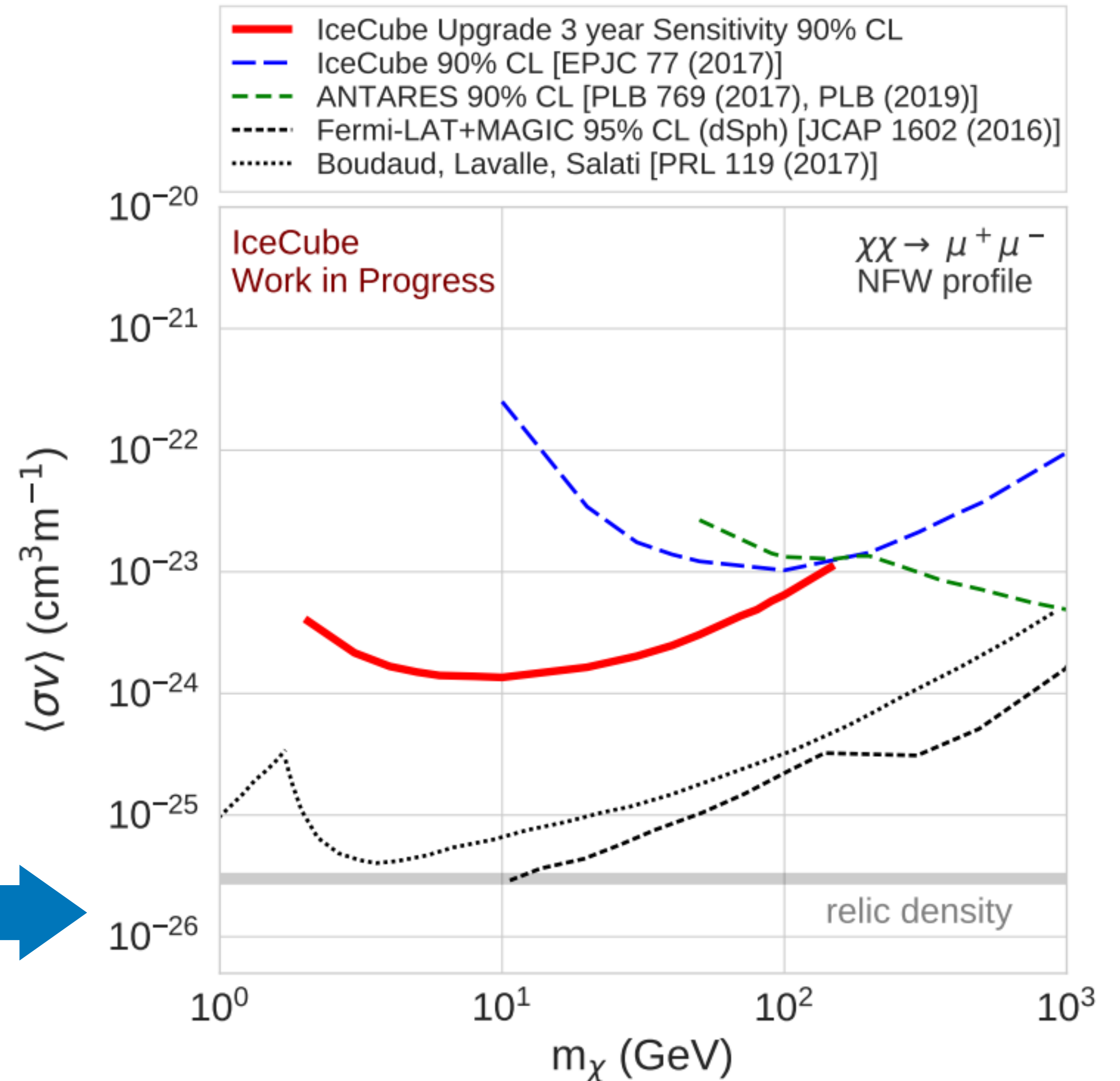
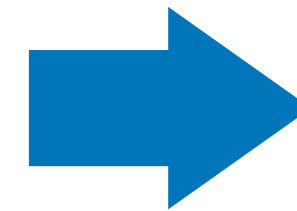


- Improved calibration of ice, reduced systematic uncertainties
- Improved angular and energy reconstructions.
- Precision measurement of atmospheric neutrino oscillations.
- Construction scheduled for 2022, delayed because COVID-19, rescheduling undergoing (1-2 years)

# IceCube-Upgrade

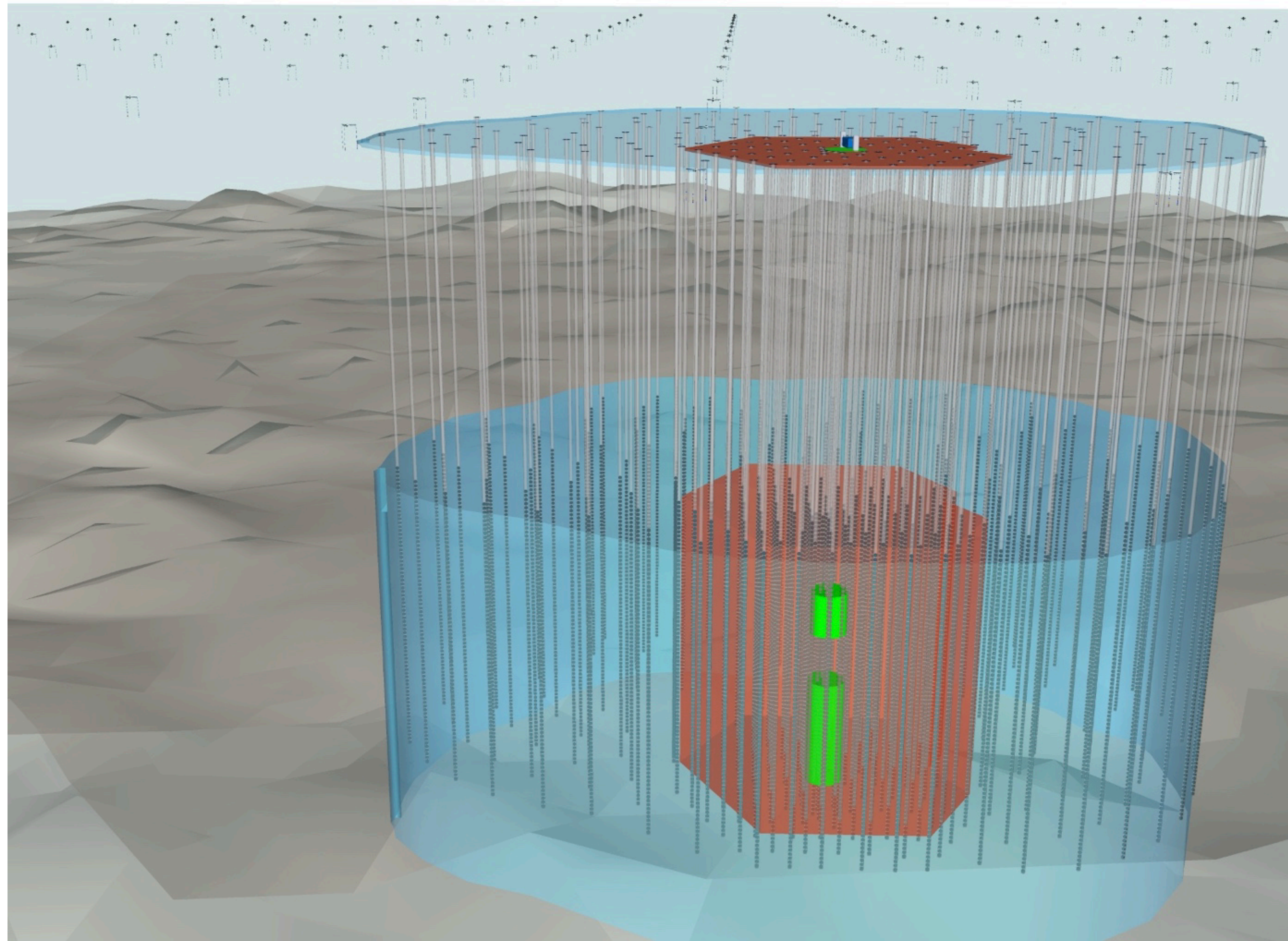
## Science Case

- Unprecedented sensitivity to atmospheric neutrino mixing parameters and neutrino mass ordering
- Detailed calibration of ice properties.
- Expanding beyond the TeV-WIMP paradigm.
- Preliminary studies for DM made at the IIHE [PoS (ICRC2019) 506]



# IceCube-Gen2

- Three new elements, leveraging complimentary technologies, to achieve sensitivity to MeV-EeV neutrinos:
  - Enlarge deep optical array
  - Surface Array extension
  - Shallow Radio Array

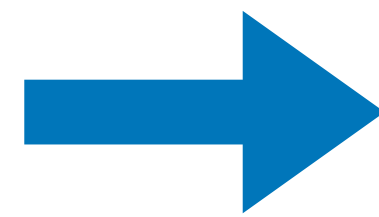


# IceCube-Gen2

## Science

- 5x improvement in effective area
- 2x improvement in angular resolution

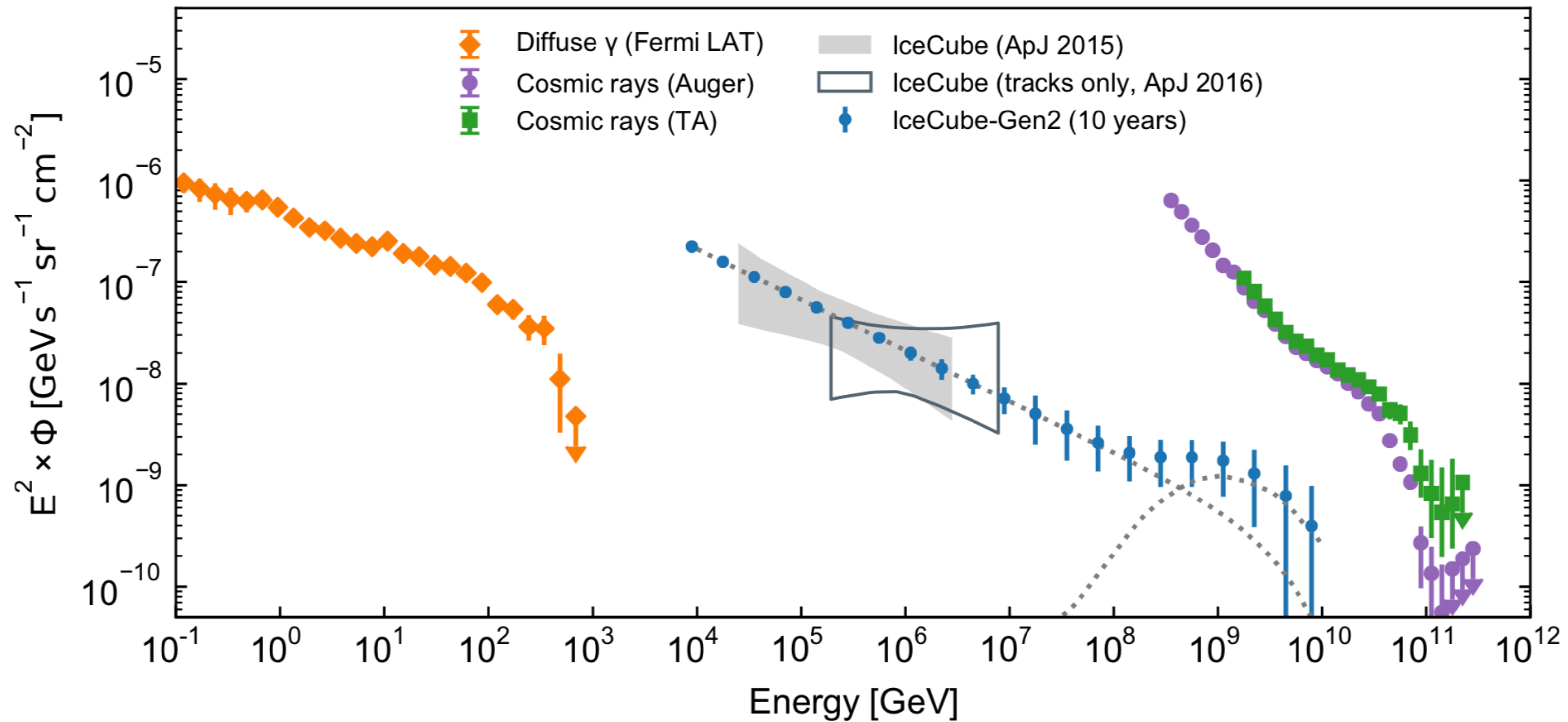
## Multimessenger spectroscopy



*Is there a change in the spectrum?*

*Is there a cut-off?*

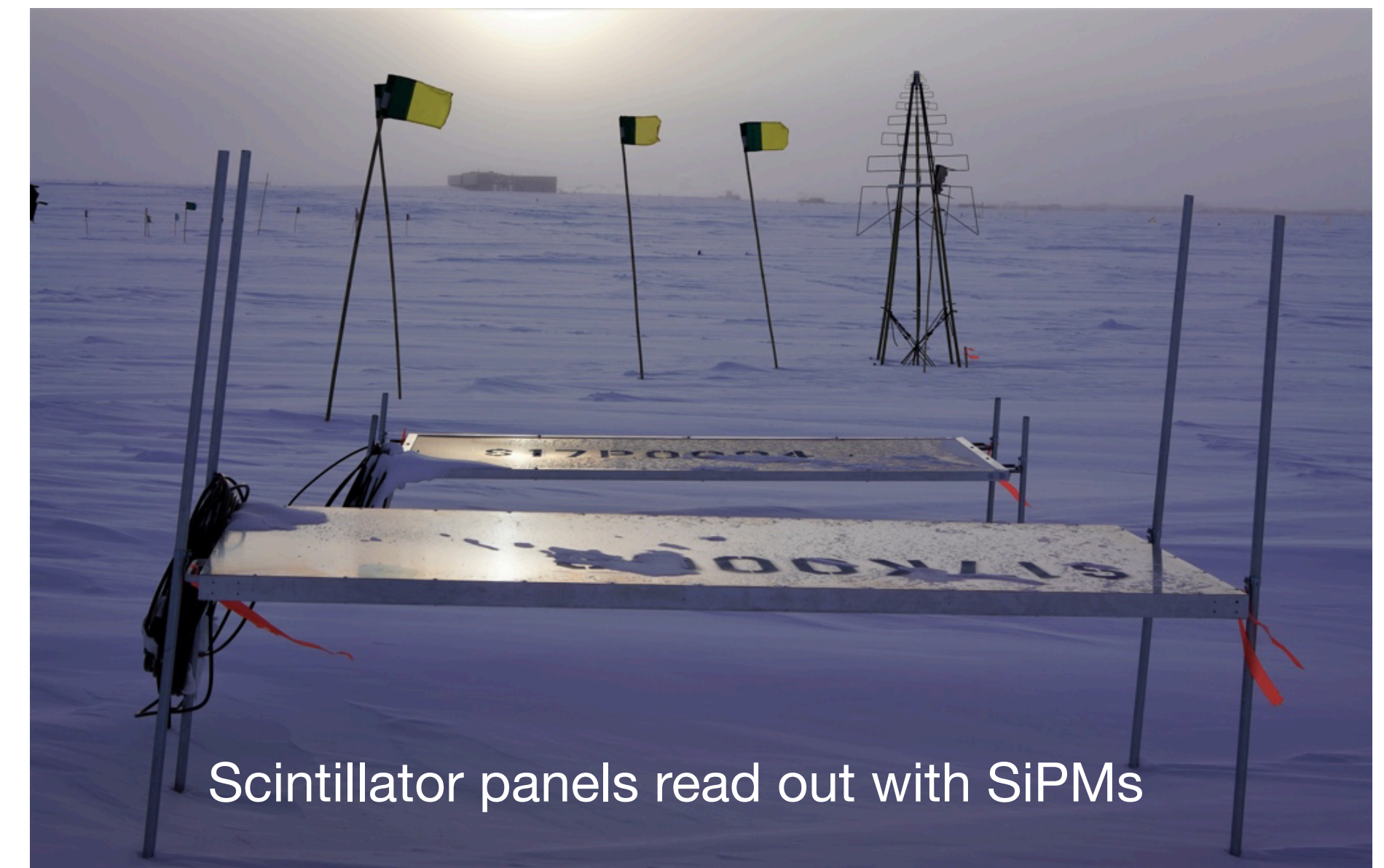
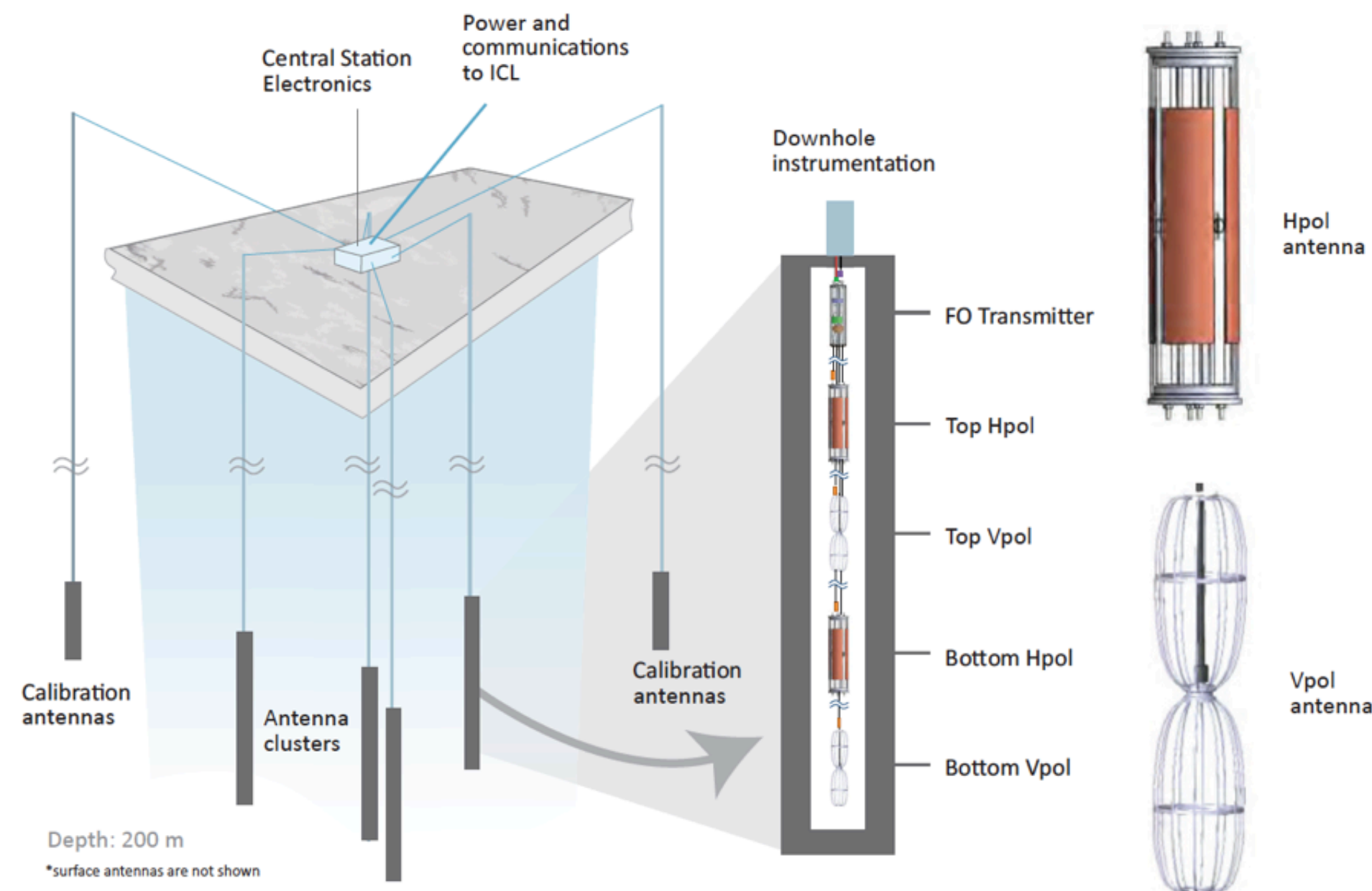
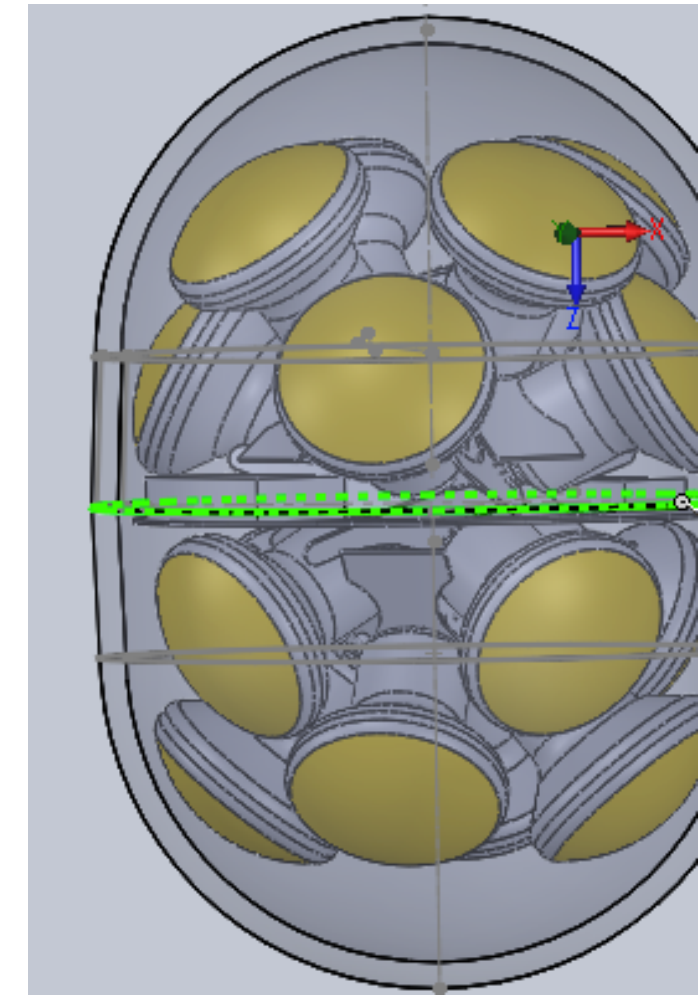
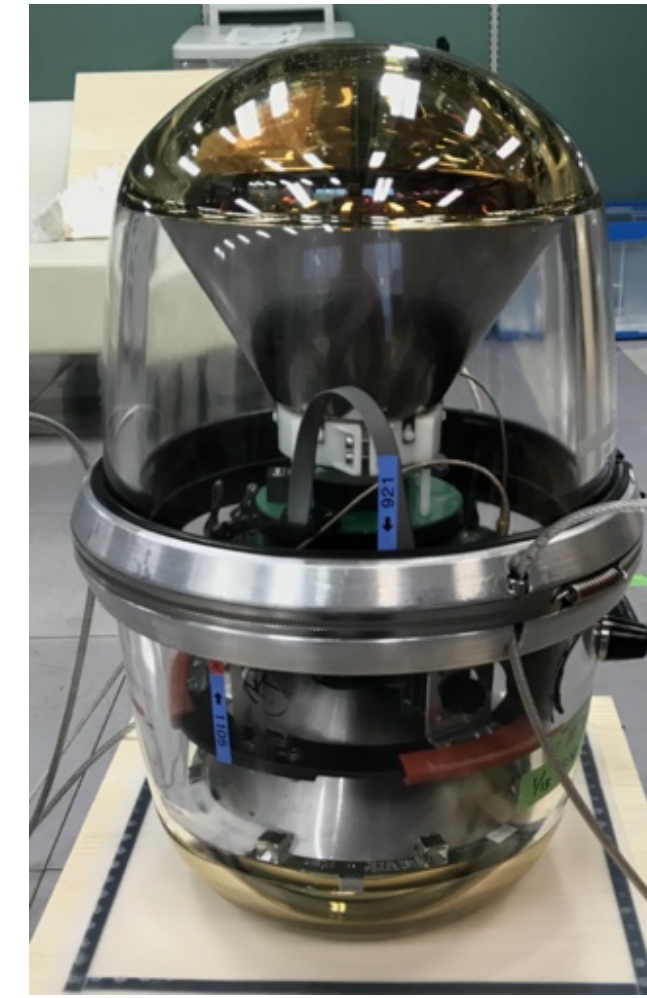
*Are there cosmogenic neutrinos there?*



# IceCube-Gen2

## Instrumentation

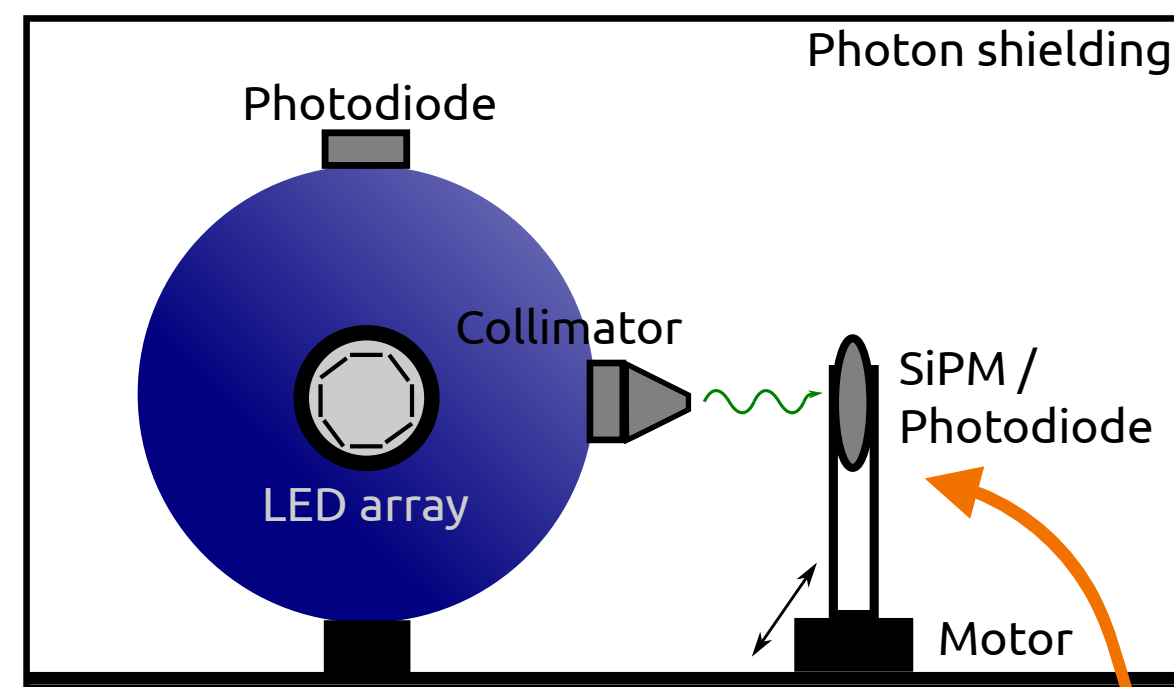
Pixelated optical modules, surface technology, radio technology, ...





# IceCube-Gen2 @ IIHE

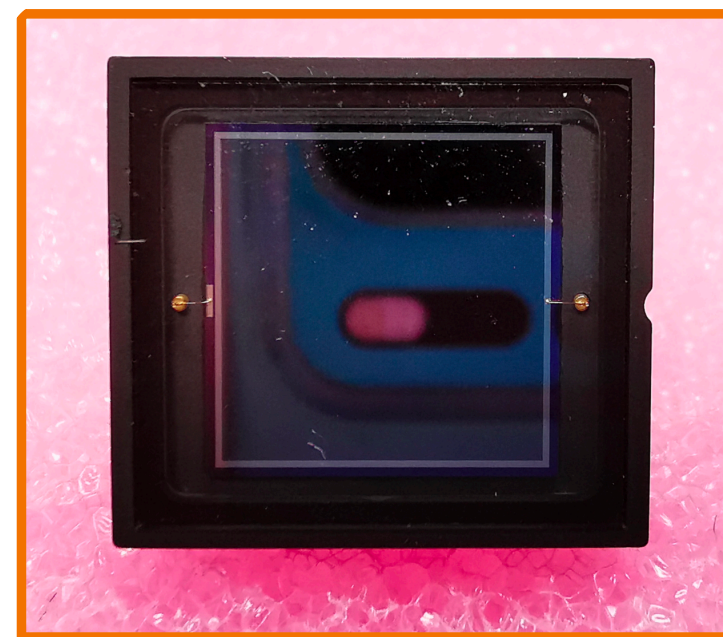
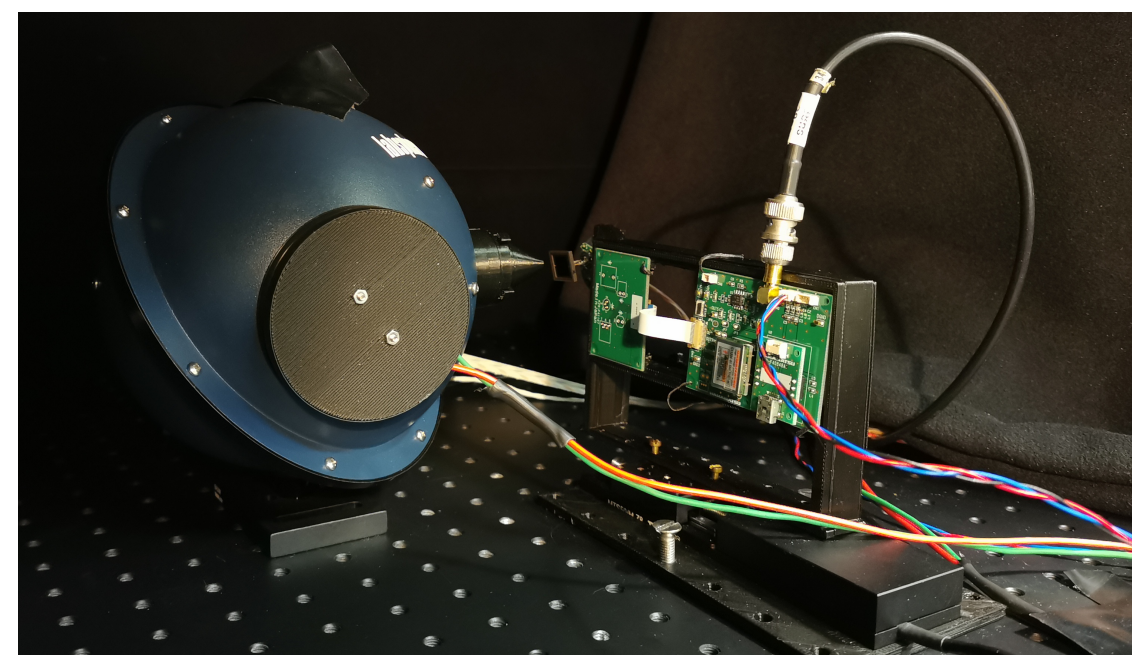
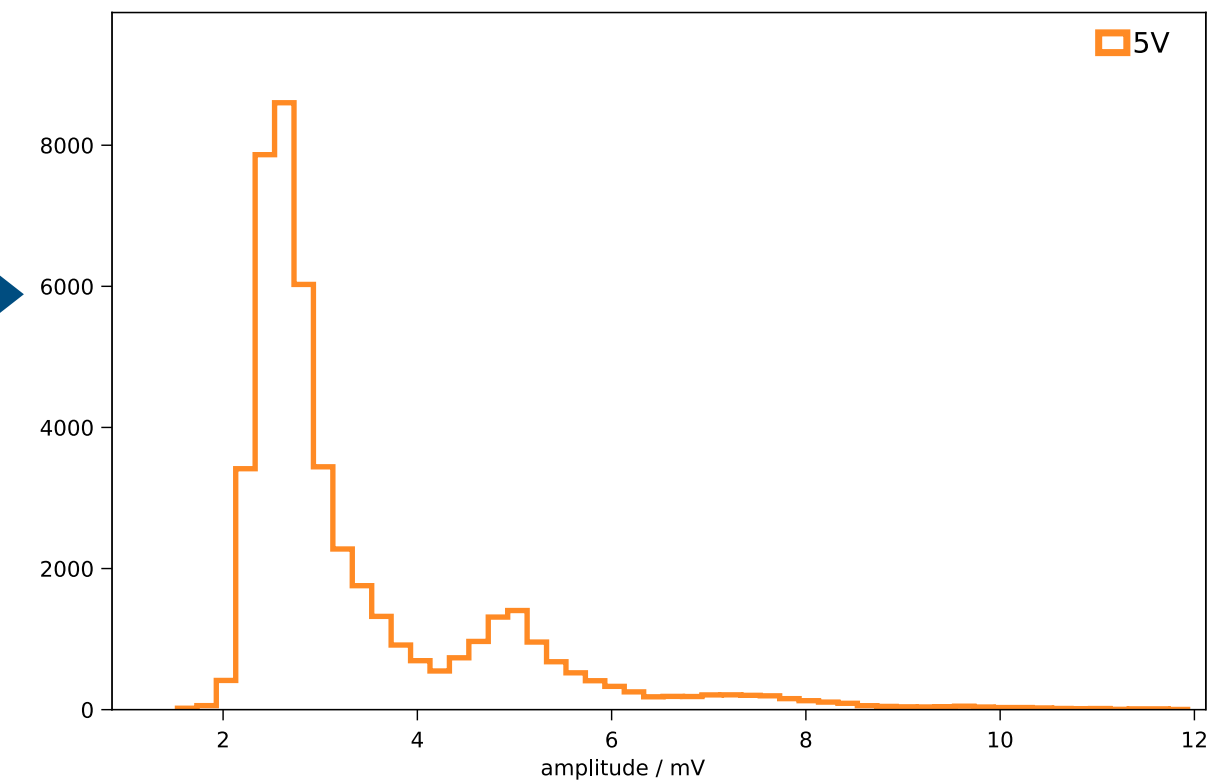
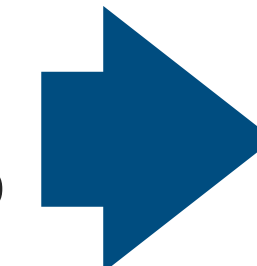
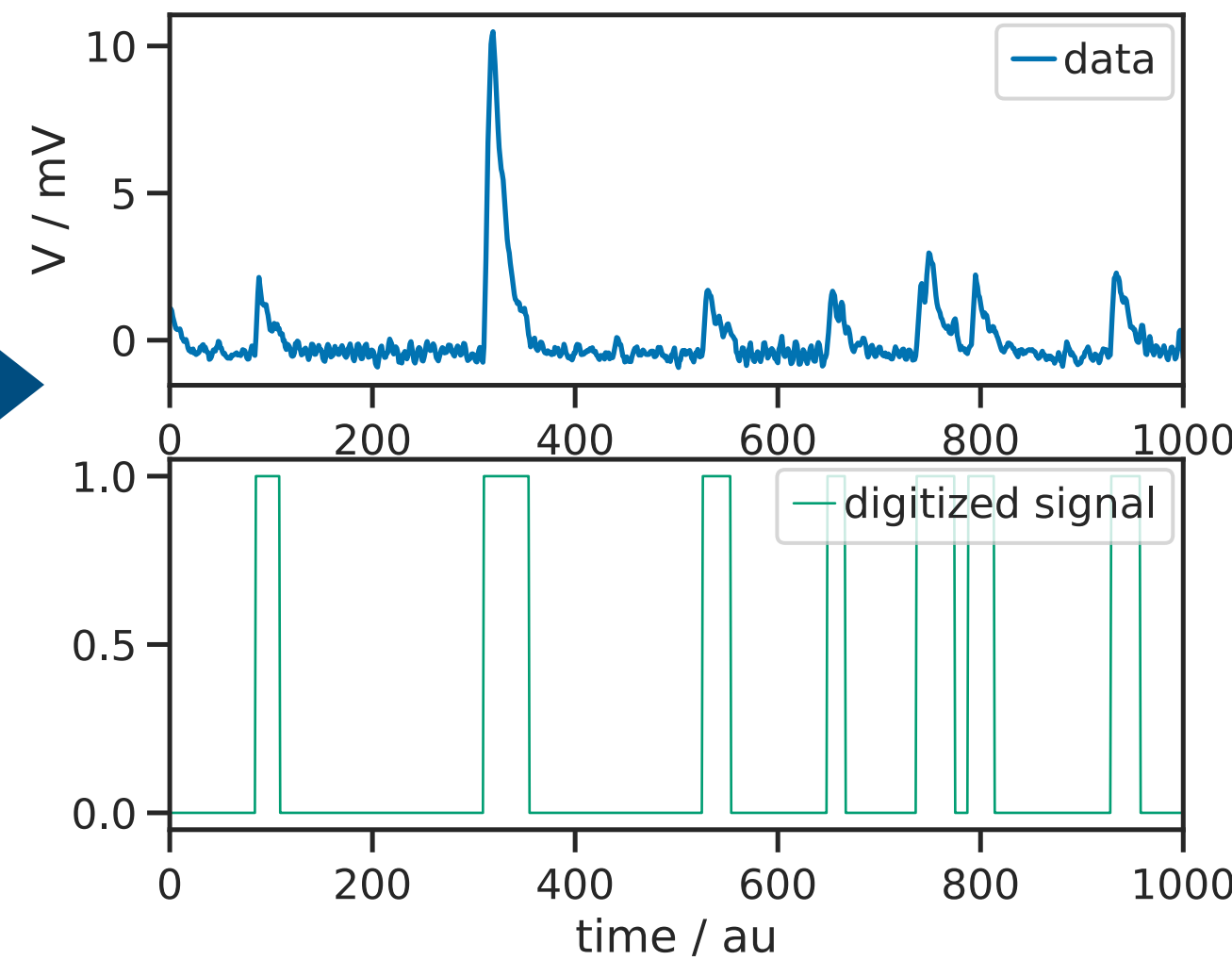
## Calibration and Characterization of SiPMs



Signal Extraction



from raw traces



- Characterize the breakdown voltage, gain, resolution and noise.
- Measure the Photo Detection Efficiency.
- Future: Climate Chamber to estimate the properties at different temperatures.
- Applications to other experiments: Proton therapy, etc.

# Conclusions

- IceCube just had its 10 years birthday!
- We witnessed several important results in this past decade, and the IHE was very much involved but...
- ...we need a bigger detector!
- IceCube-Gen2 is designed and optimized to harvest the enormous scientific opportunities.



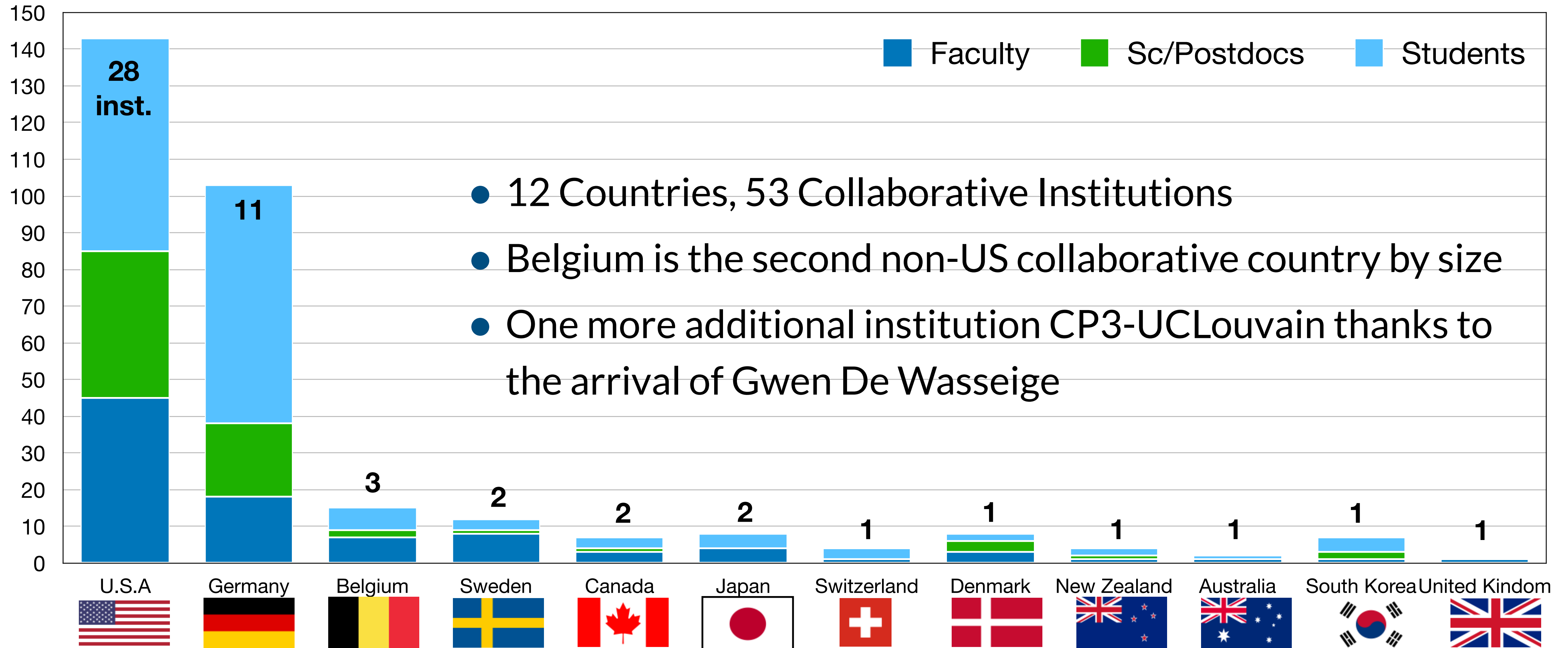
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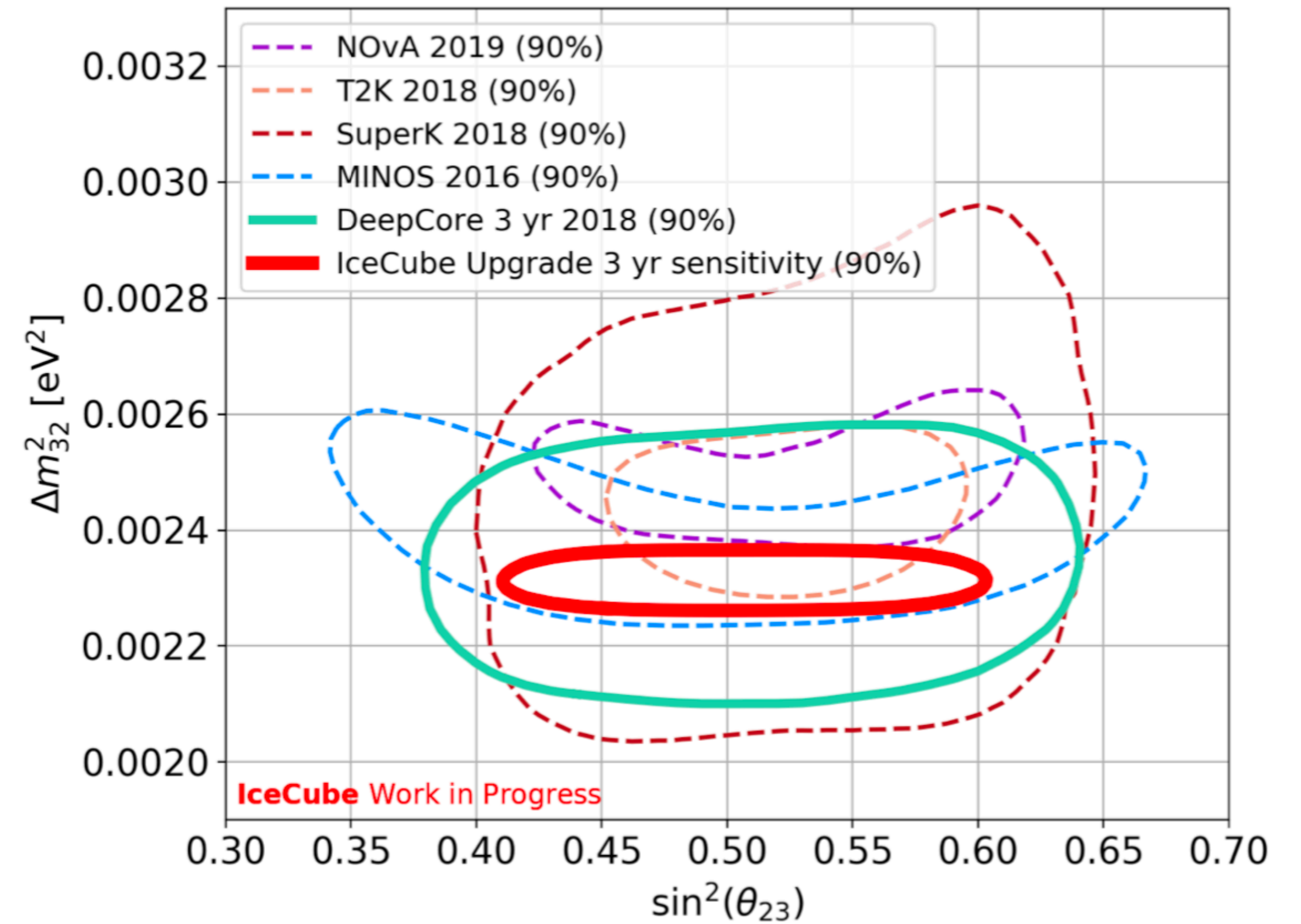
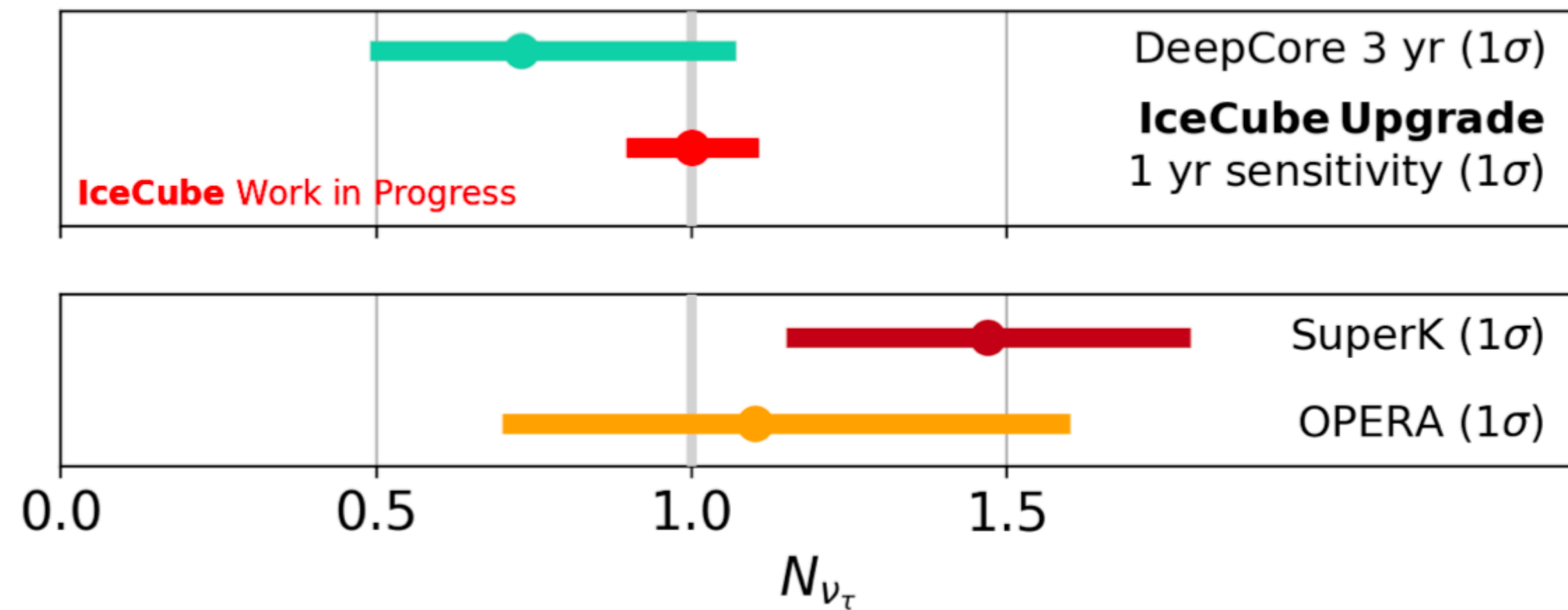
# Backups

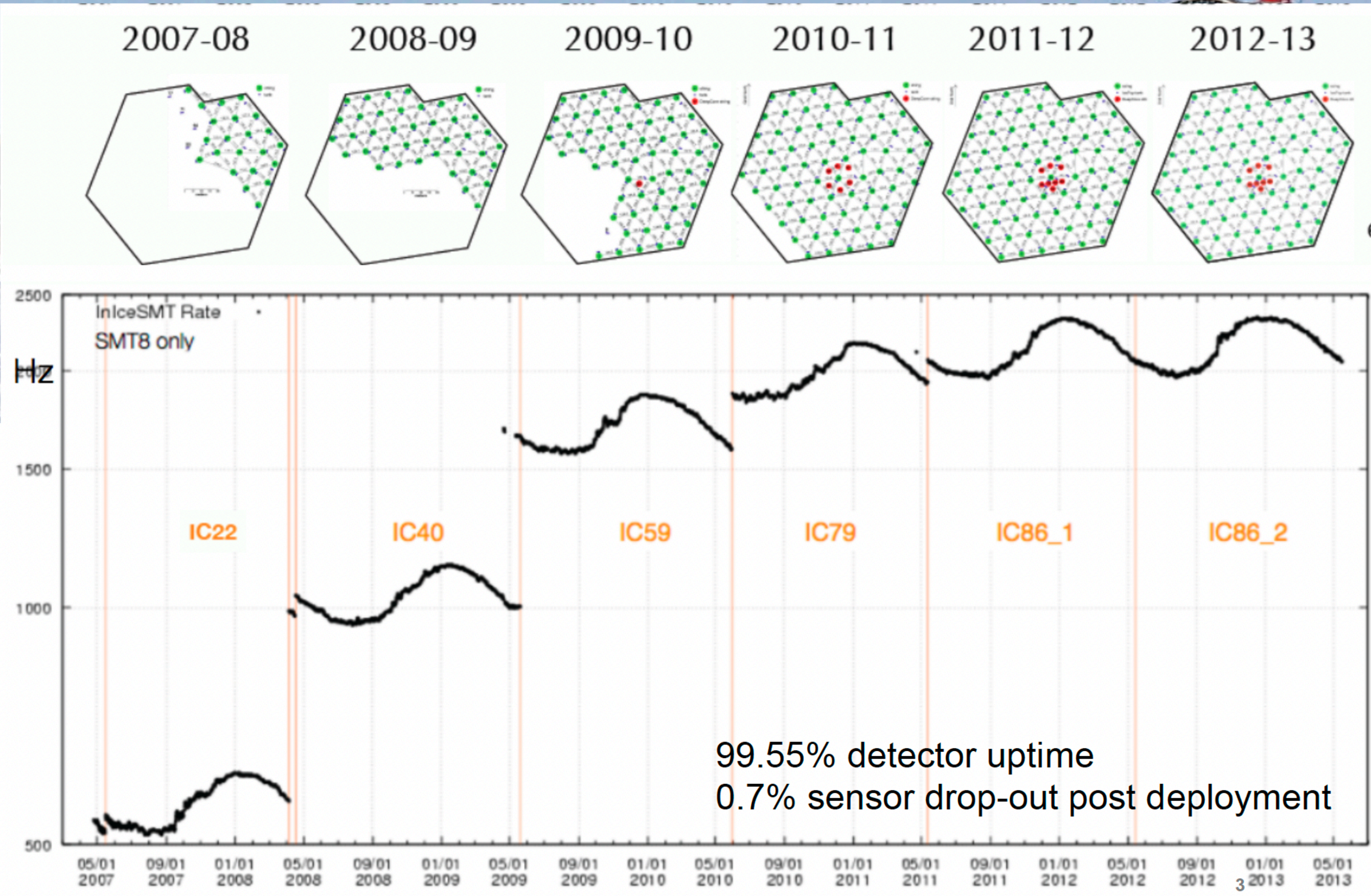
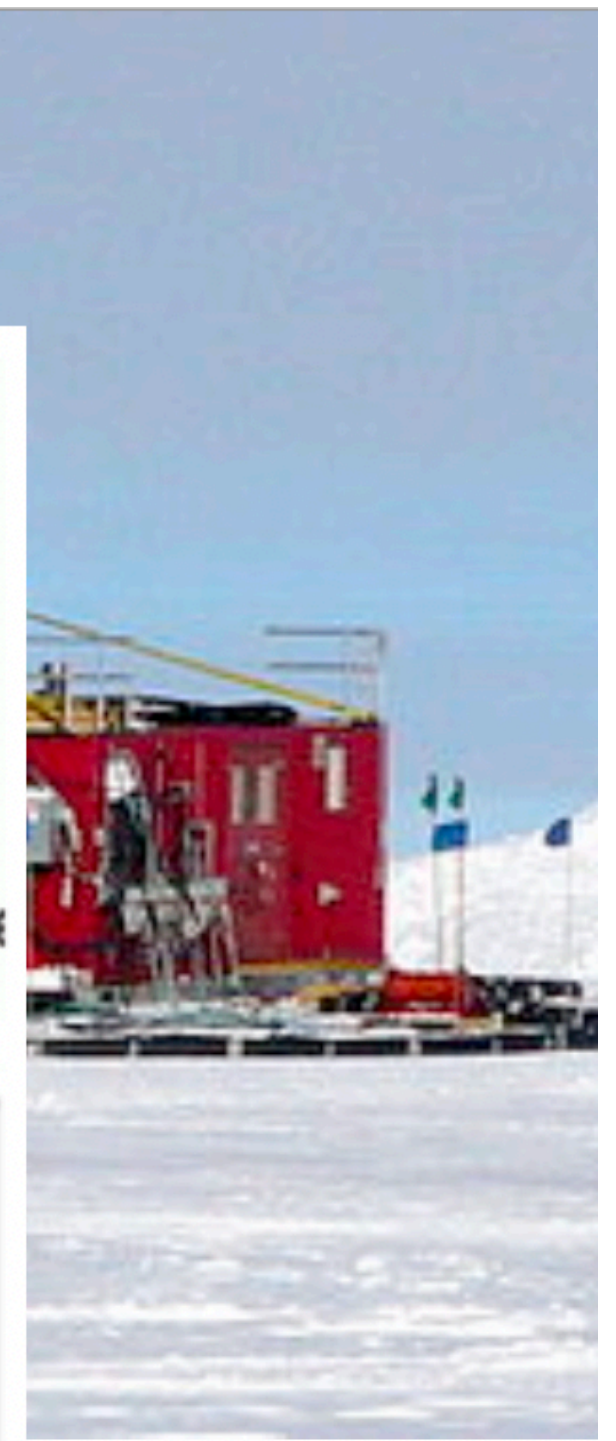
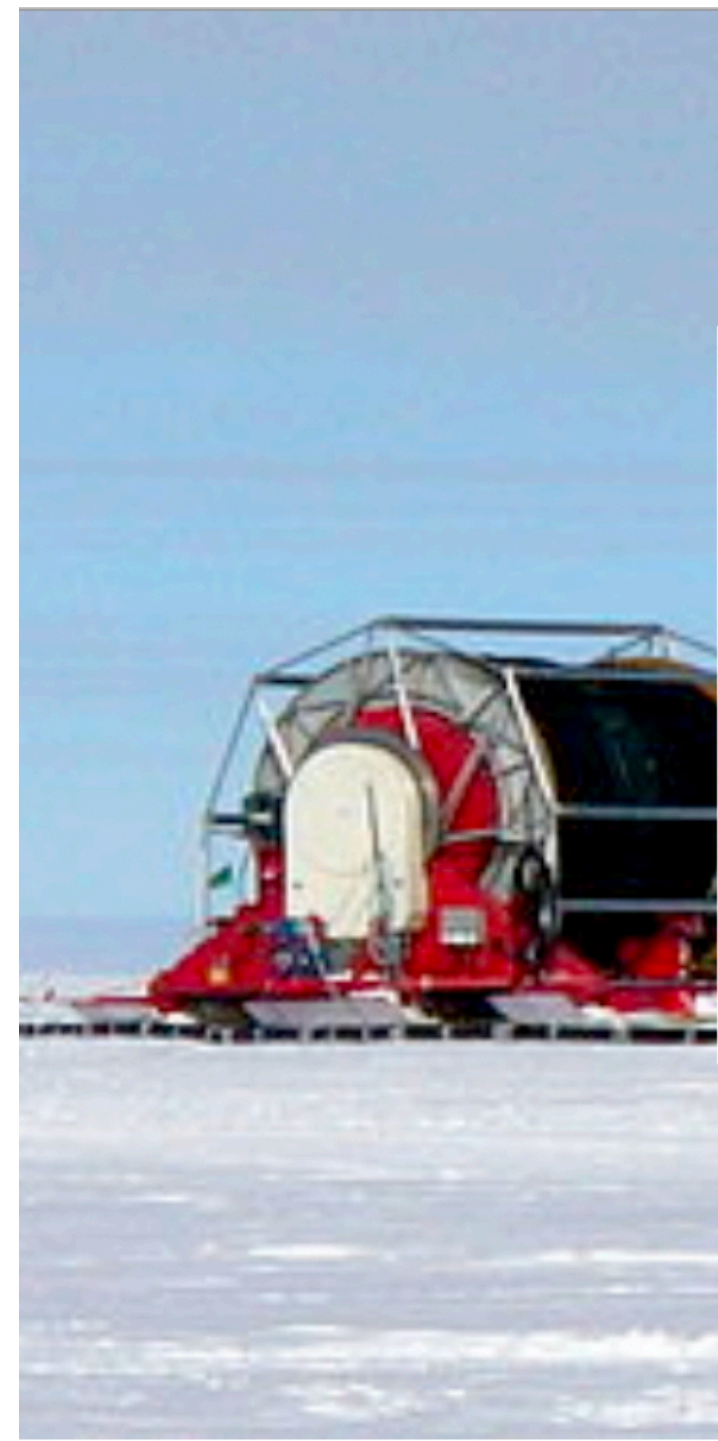
# Belgium in IceCube



- 12 Countries, 53 Collaborative Institutions
- Belgium is the second non-US collaborative country by size
- One more additional institution CP3-UCLouvain thanks to the arrival of Gwen De Wasseige

# IceCube-Upgrade





## IceCube Installation



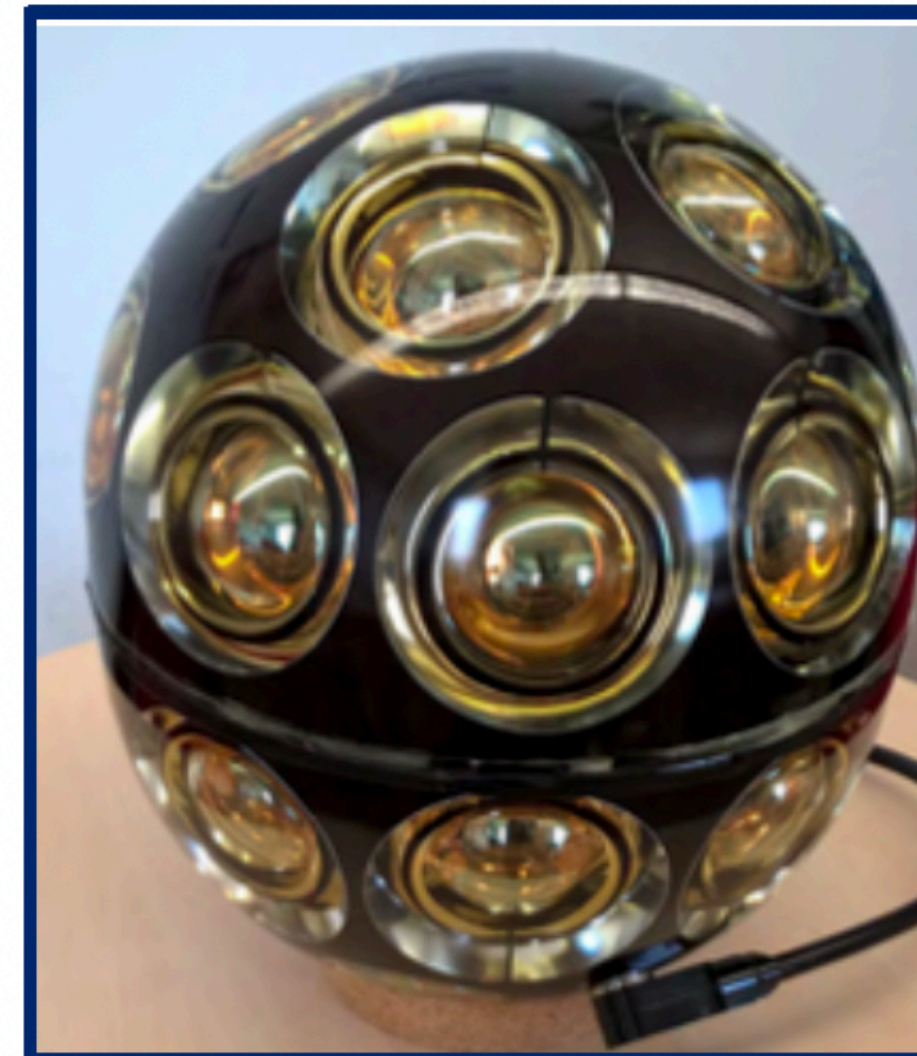
Operating sensors in the ice since 2006, with no evidence for aging

## New surface technology



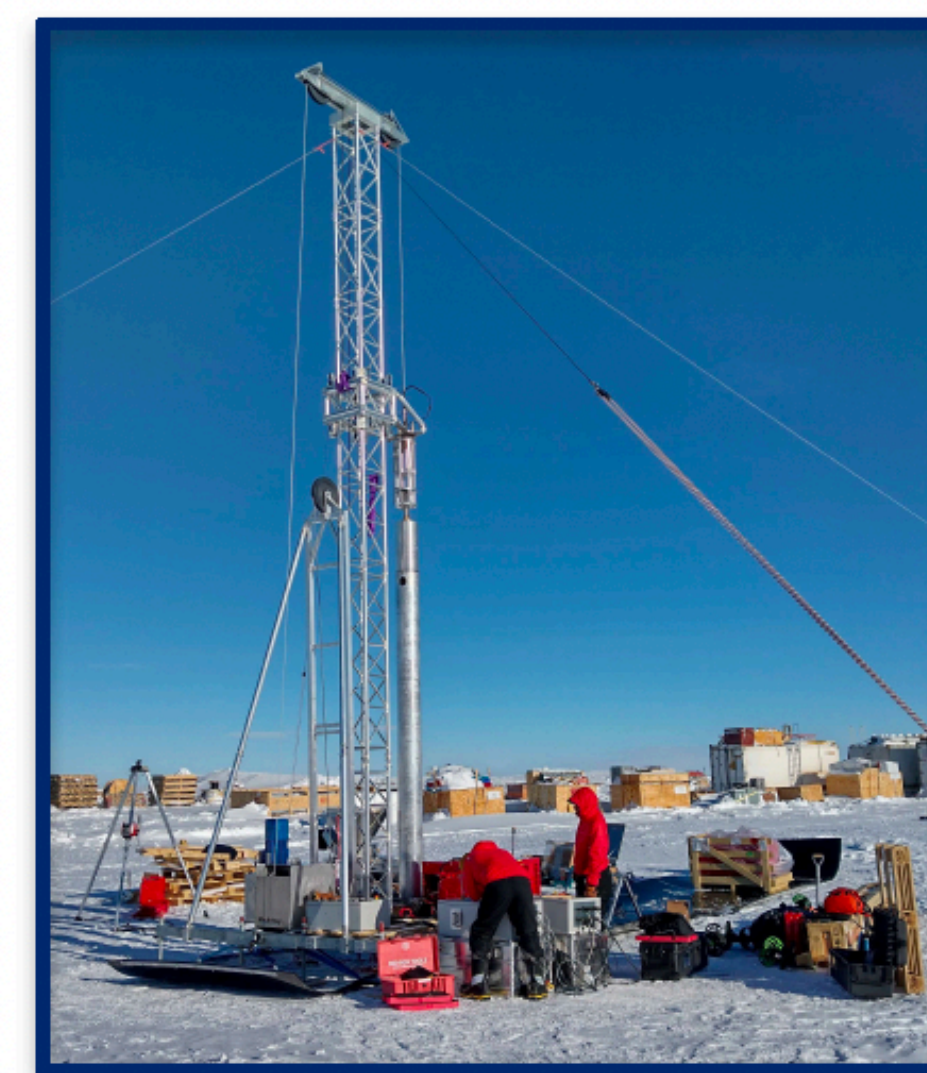
Scintillator / radio station deployed at South Pole (2019) (PoS ID 314)

## IceCube Upgrade / Gen2 Phase 1



Deployment of next generation sensors (see next slide)

## Radio-Tests in Greenland



Radio technology deployed in Greenland (2021, see S. Wissel et al., [PoS ID 001](#))



ICECUBE  
GEN2



# IceCube-Gen2 Plan

## Simplified Plan

○ Major field activity / Deployment

