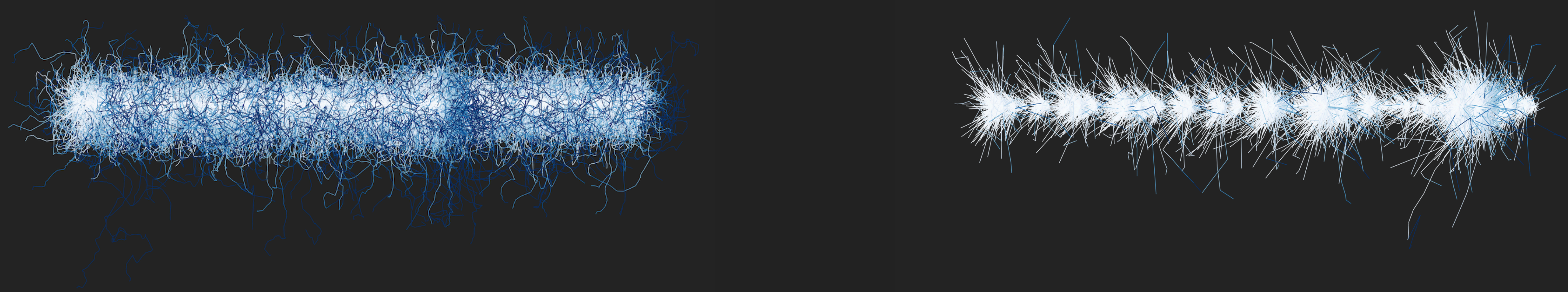
PLEνM



UK HEP Forum, 24-25 September 2019

HIGH ENERGY NEUTRINO ASTRONOMY: THE NEED OF A PLANETARY SCALE EFFORT

(Disclaimer: this is NOT a review talk)

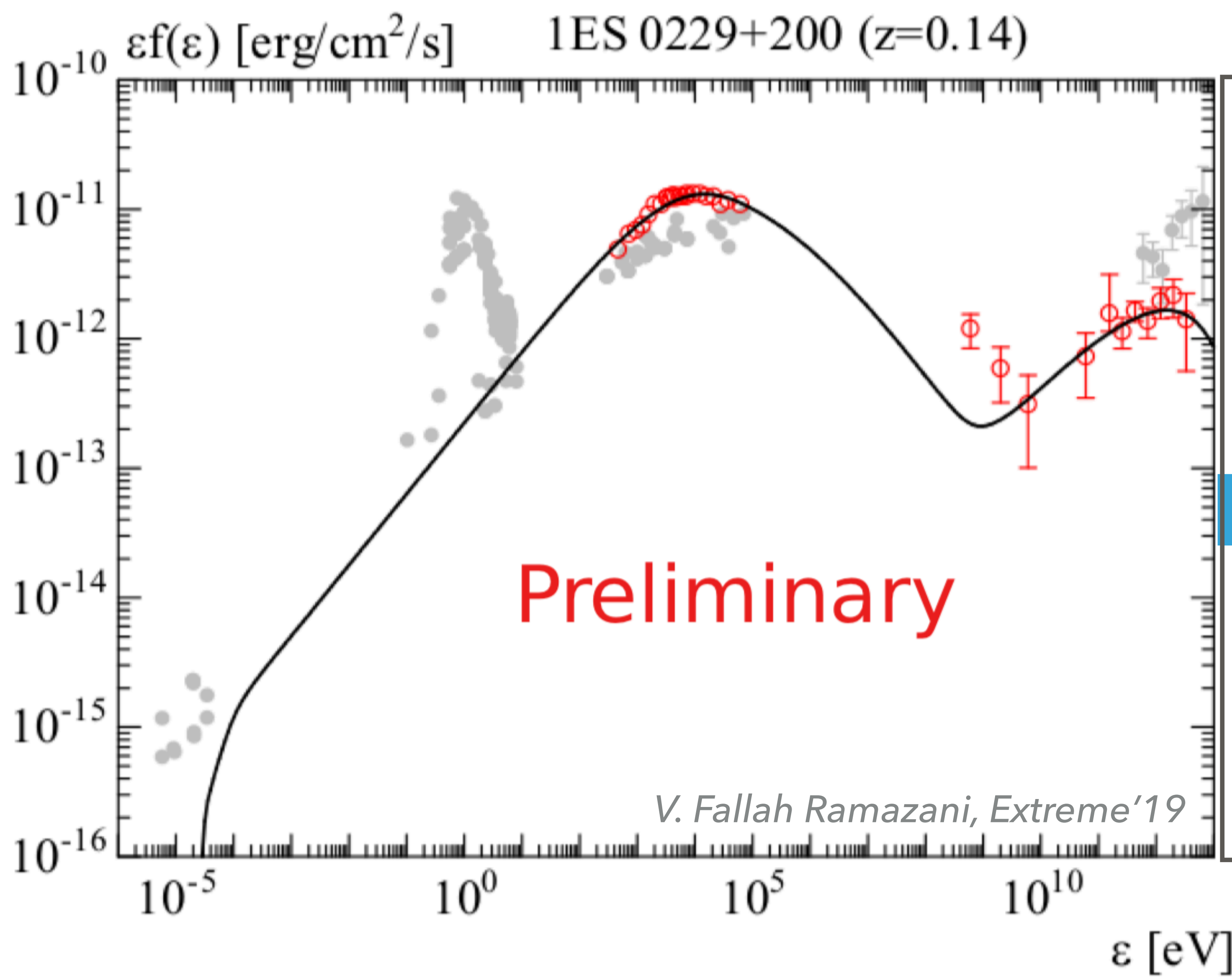
Elisa Resconi

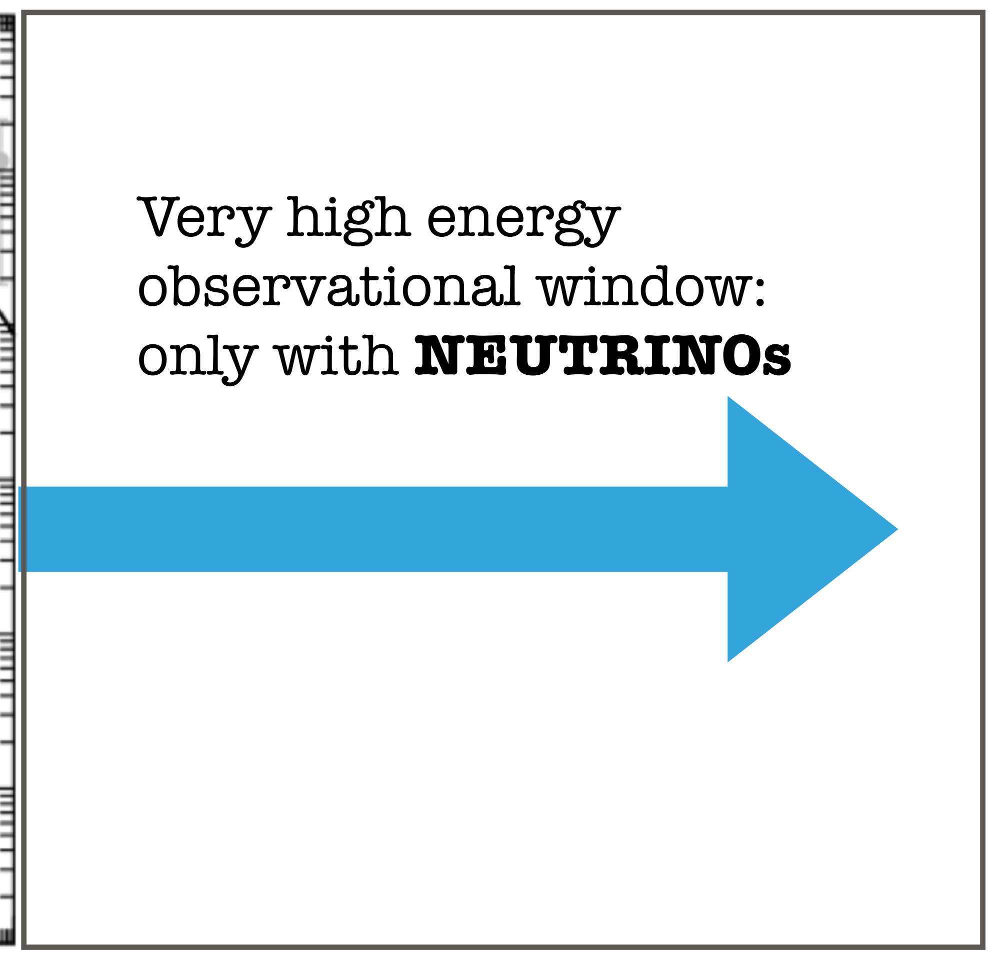
Experimental Physics with Cosmic Particles (ECP-TUM)

Image: K. Krings (TUM)

WHY NEUTRINOS FOR ASTRONOMY?

The universe is <u>not transparent</u> to photons >50-100TeV but it is transparent to neutrinos. [@10TeV < 90% gamma-ray photons from sources at z~0.1][1]



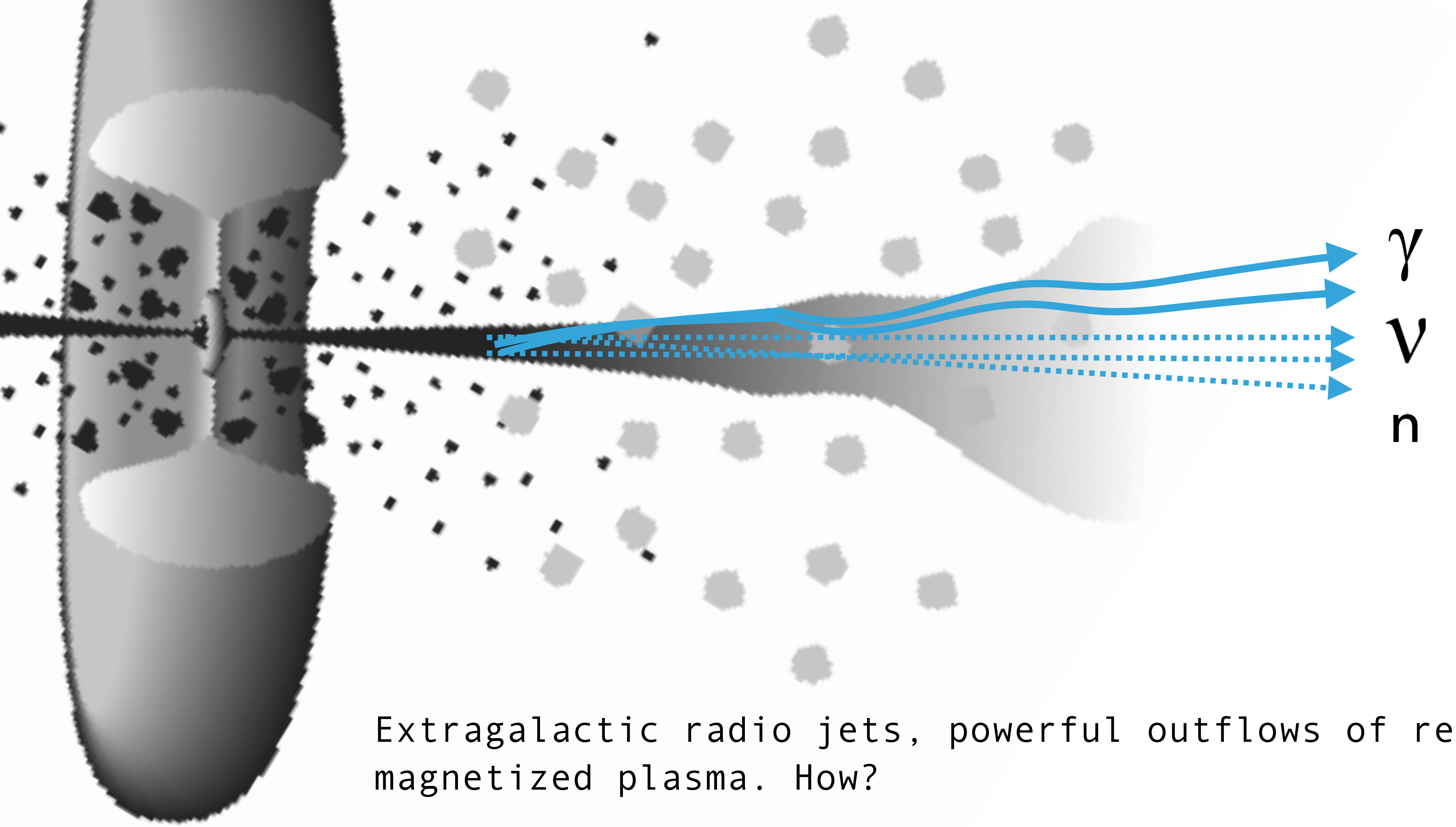


[1] Dominguez, A. et al. Extragalactic background light inferred from AEGIS galaxy-SED-typefractions. MNRAS (2011)

WHY NEUTRINOS FOR PHYSICS?

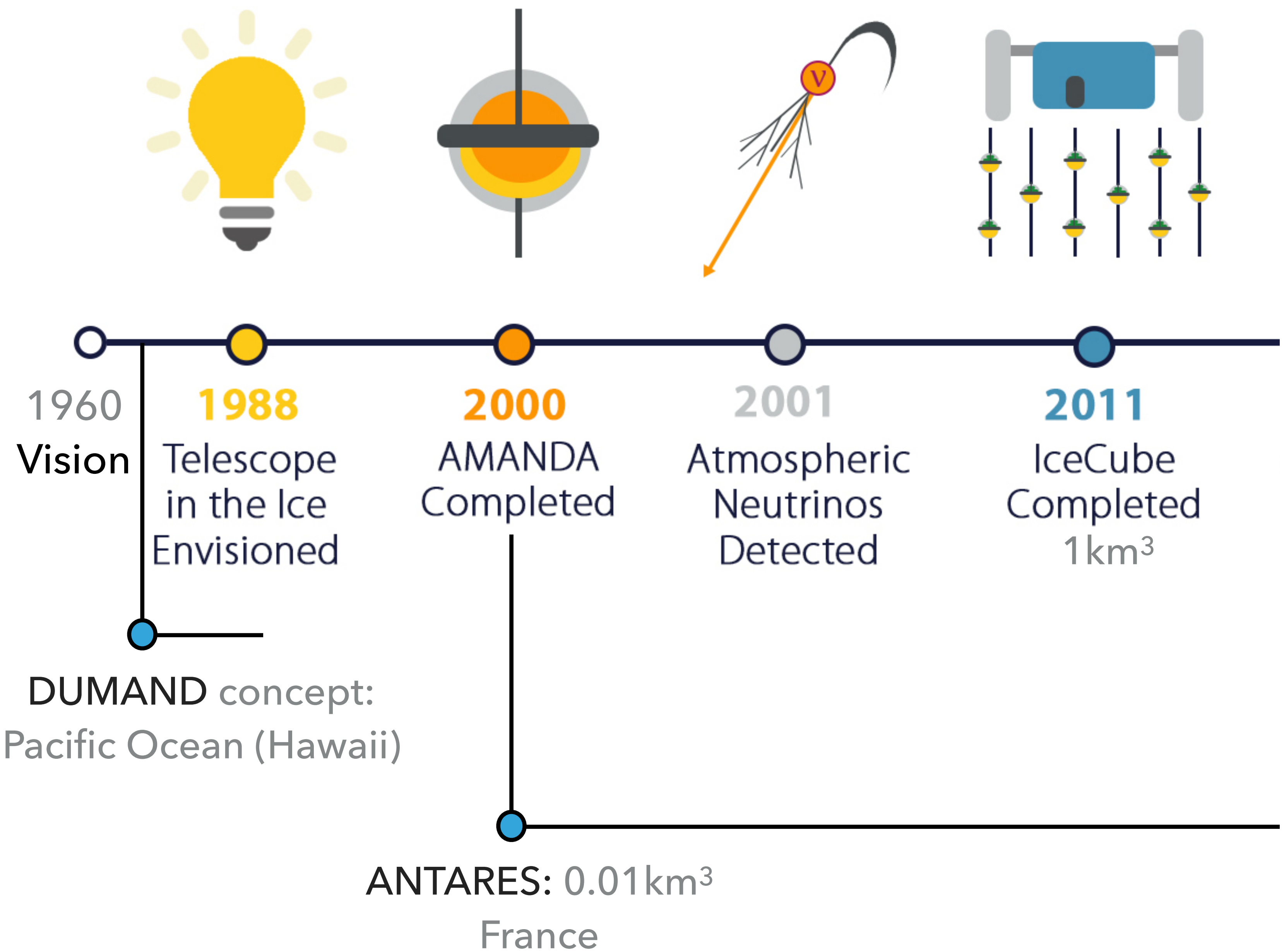
How do cosmic accelerators work?

Relativistic jets accelerate charged particles up to 10^{18} or even 10^{20}eV. How?

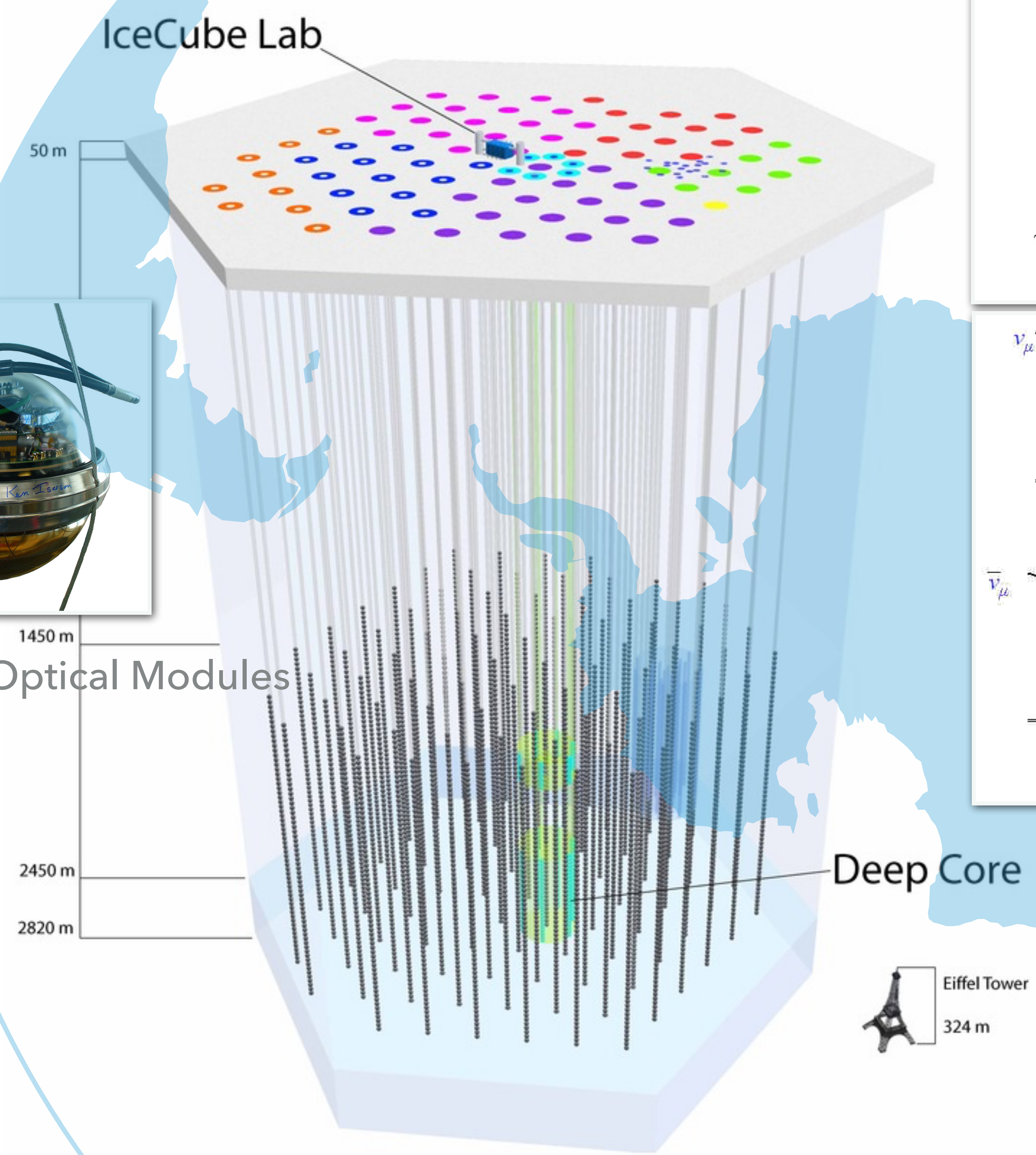


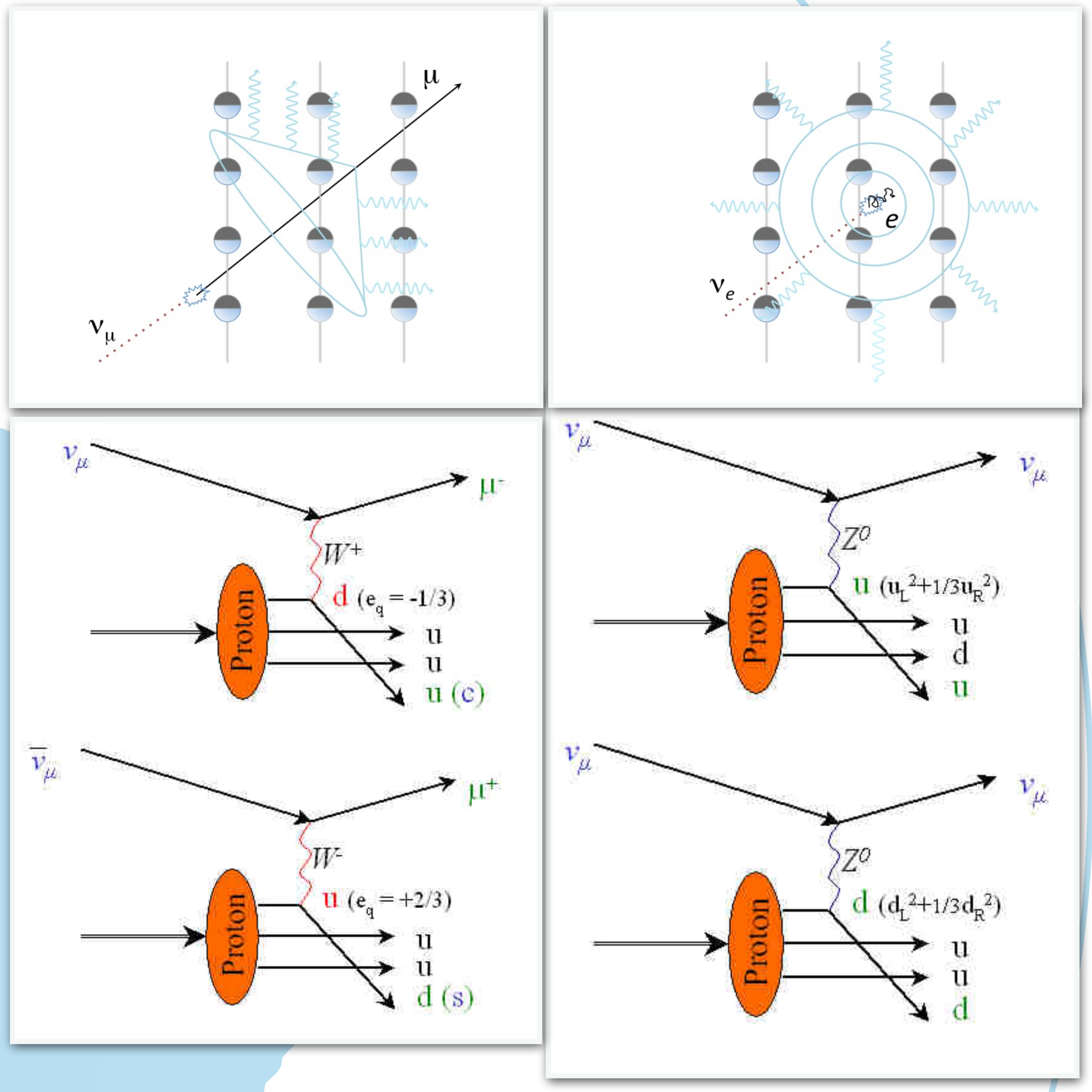
Extragalactic radio jets, powerful outflows of relativistic magnetized plasma. How?

Milestones in Neutrino Astronomy

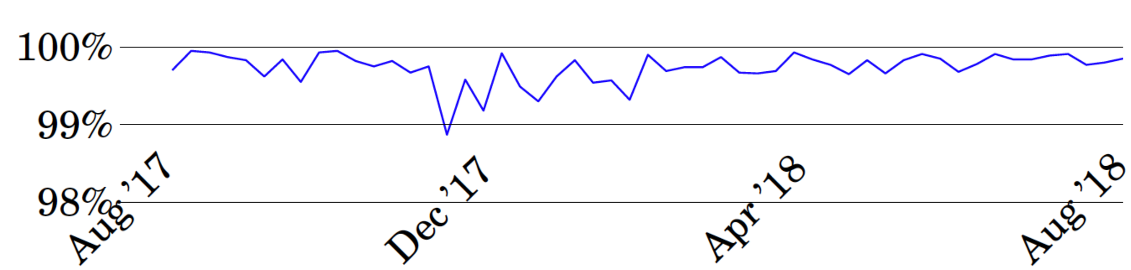


THE ICECUBE NEUTRINO OBSERVATORY



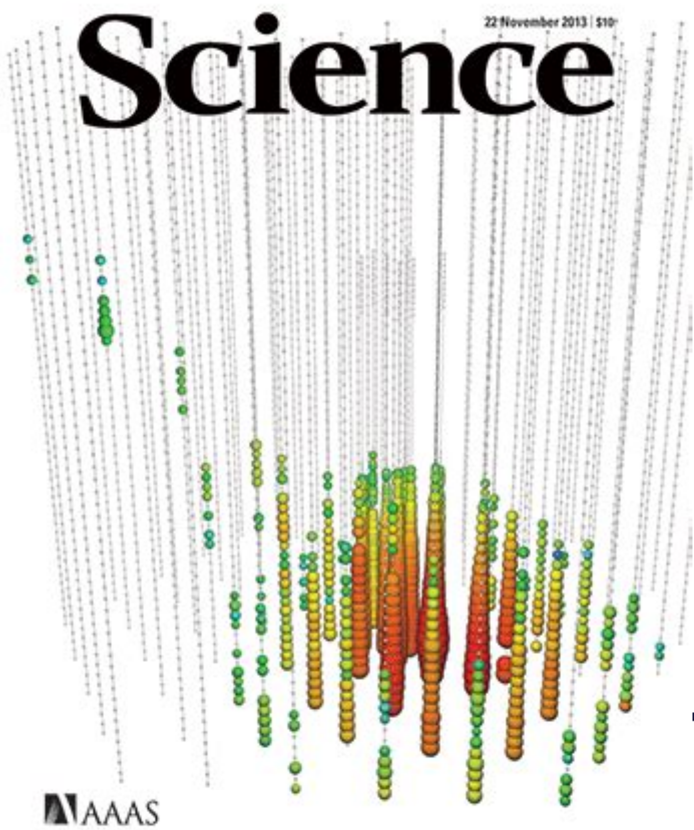


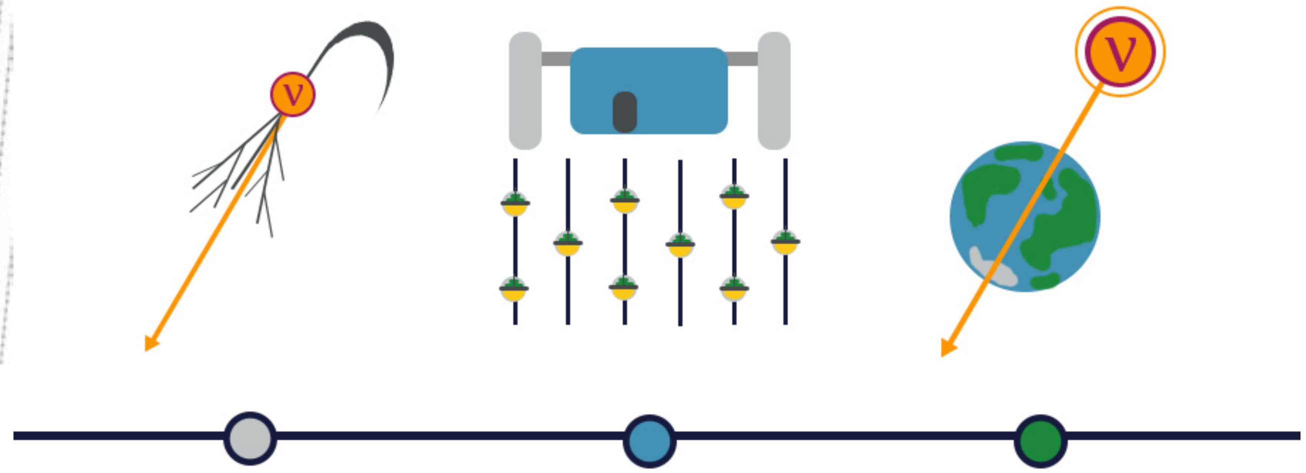
Uptime



99.85%

Milestones in Neutrino Astronomy





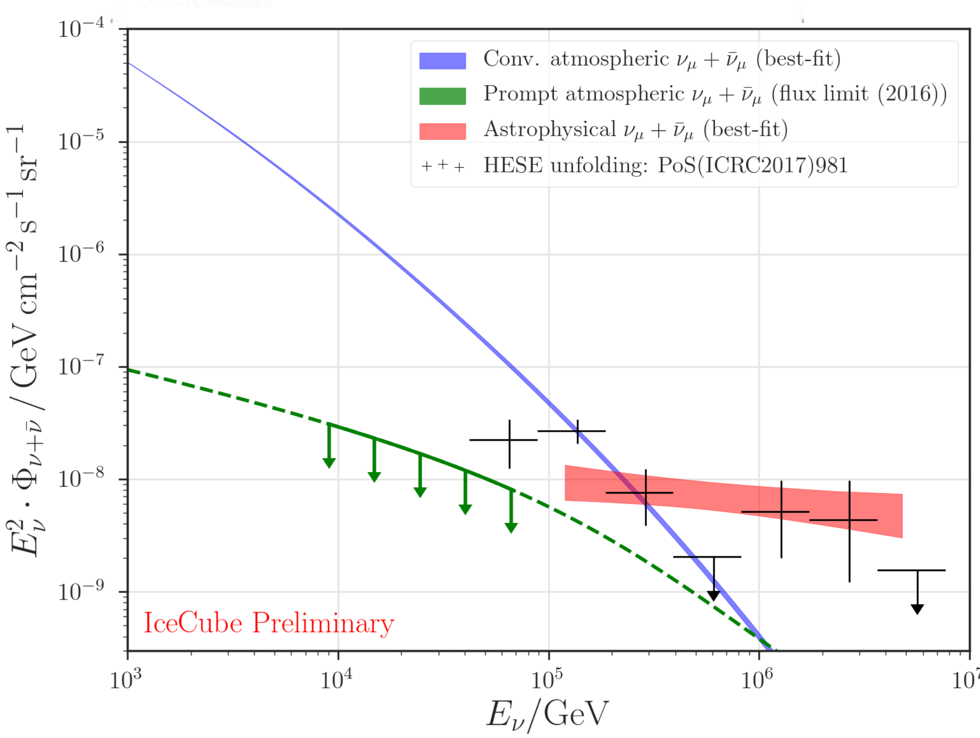
19

2001
ospheric
utrinos
etected

2011
IceCube
Completed
1km^3

2013
Astrophysical
Neutrinos
Discovered

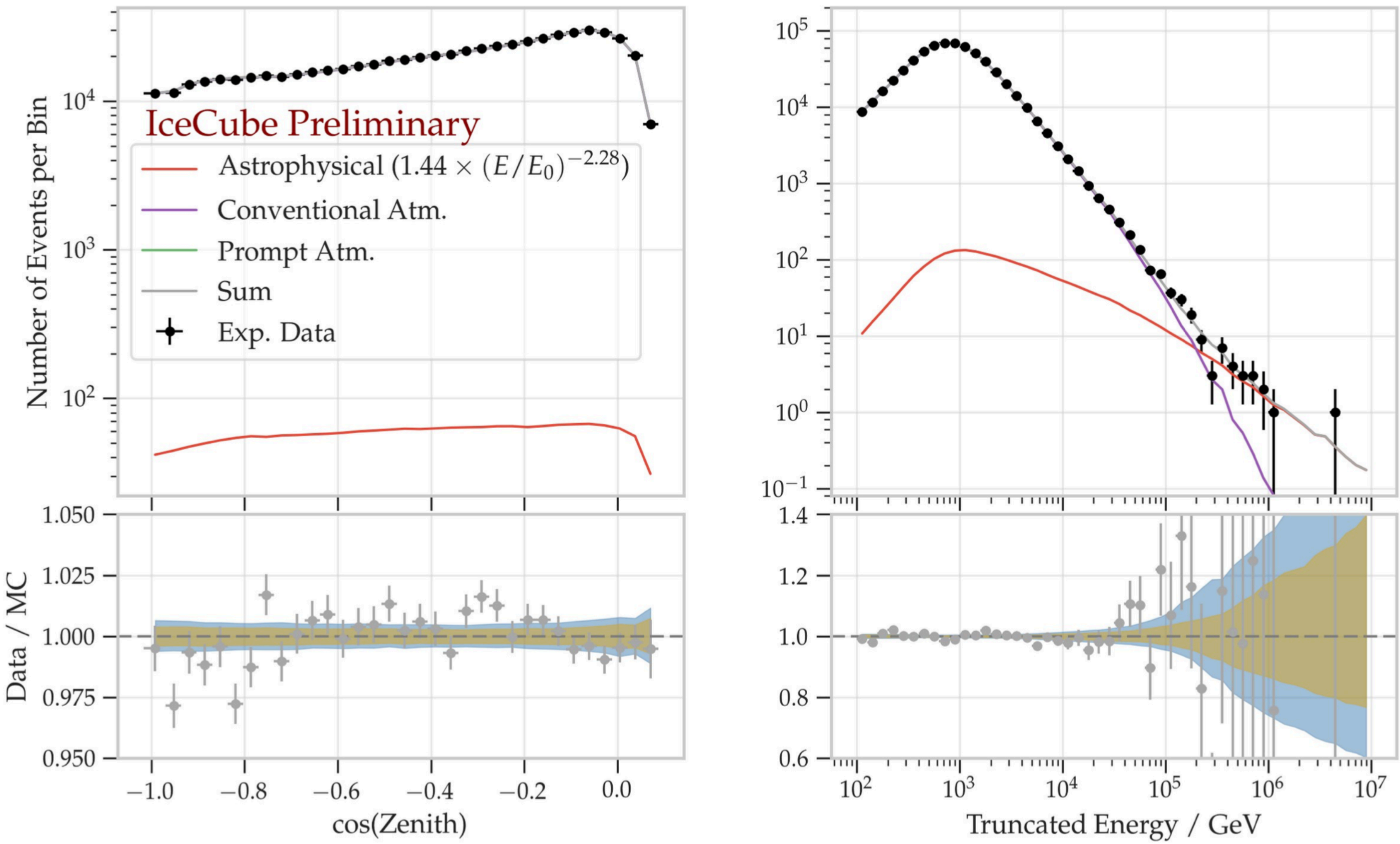
IceCube discovery of *diffuse* astrophysics neutrinos



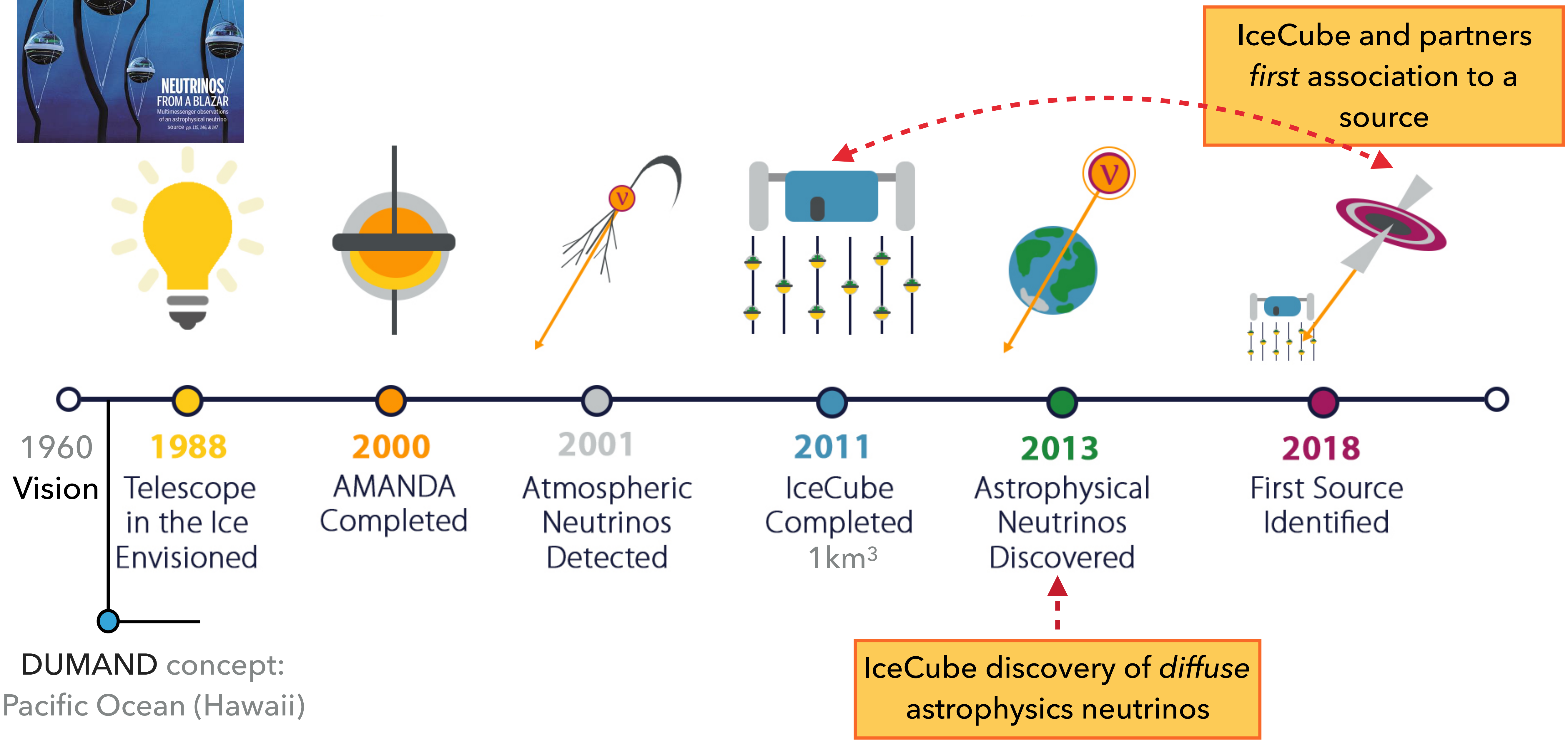
Milestones in Neutrino Astronomy

IceCube discovery of *diffuse* astrophysics neutrinos

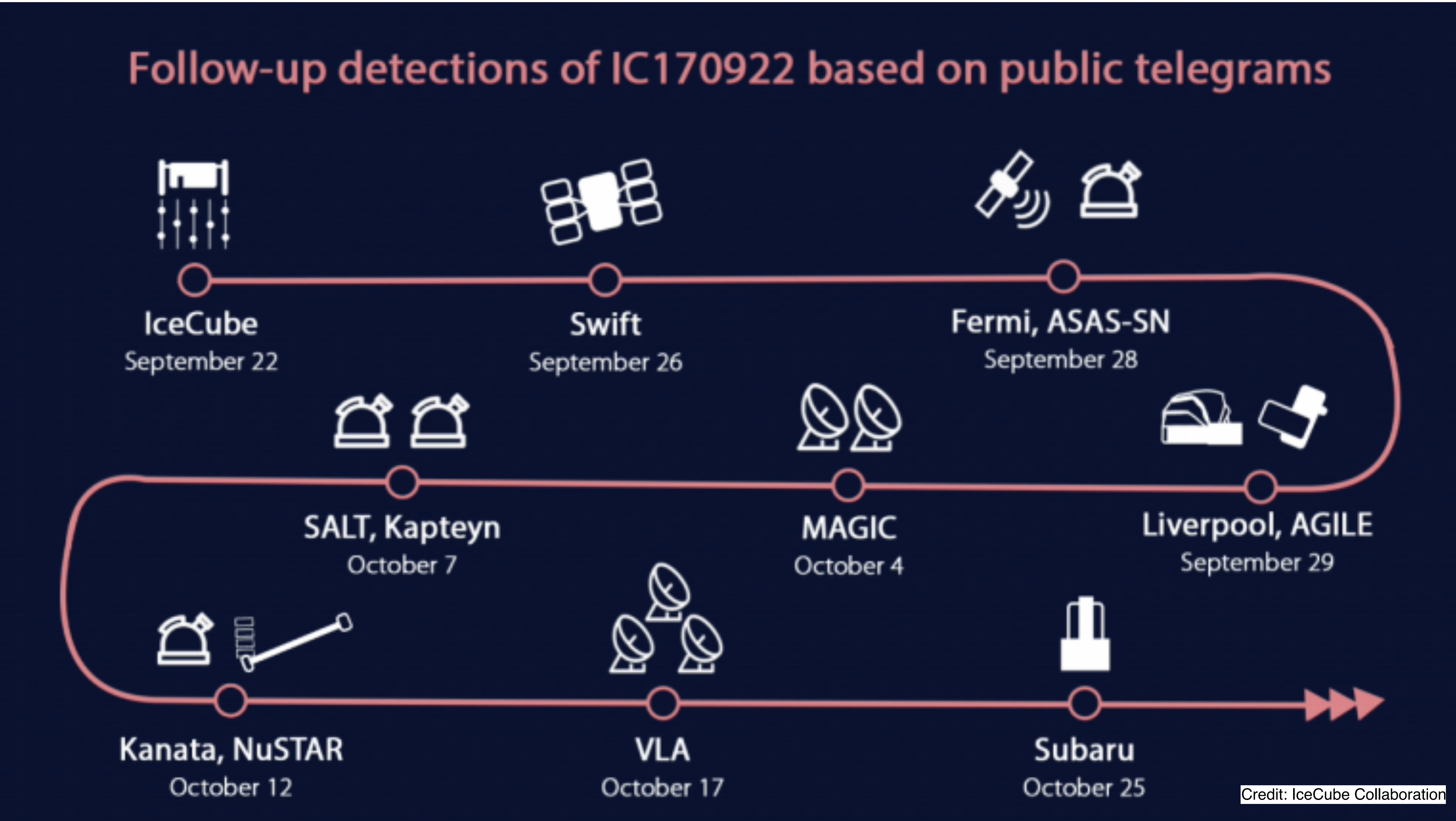
Jöran Stettner, PAHEN'19



Milestones in Neutrino Astronomy

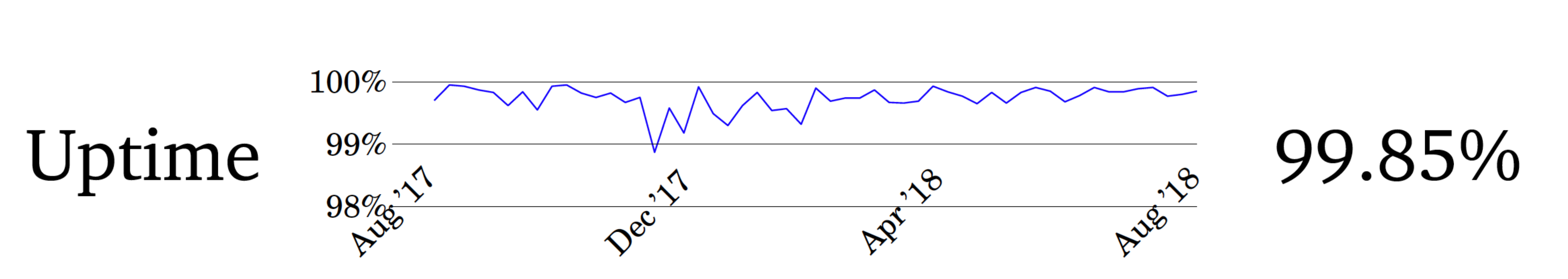


More than twenty instruments reacted to the neutrino alert



For the first high energy neutrino source: *8 years* of exposure from 1km³ Neutrino Telescope -IceCube- under *ideal* detector conditions.

Martin Wolf (TUM)



What do we need in order to open the cosmic neutrino sky to more *routine* observations?

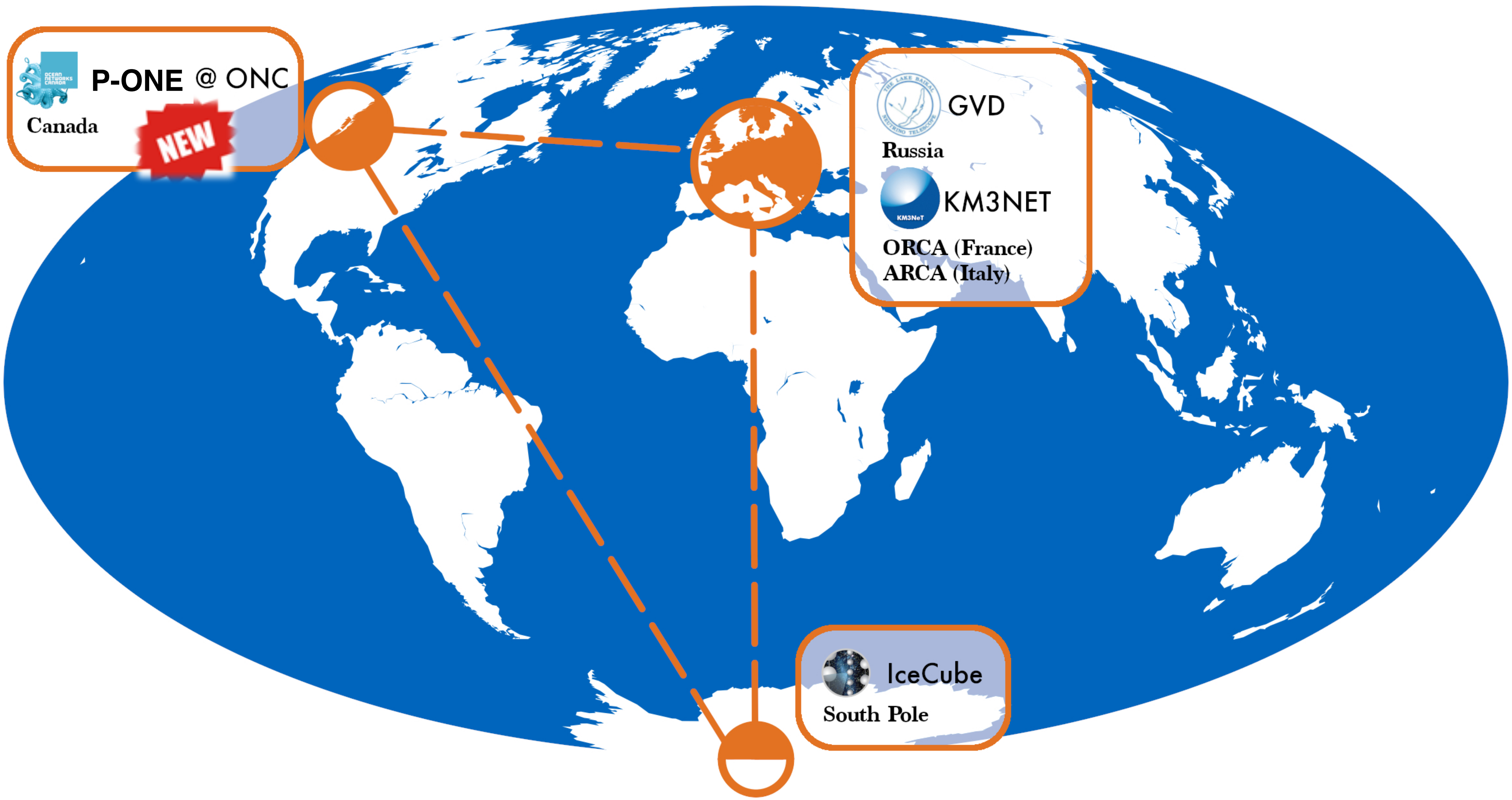
Martin Wolf (TUM)

What do we need in order to open the cosmic neutrino sky to more *routine* observations?

More / larger OBSERVERS

Martin Wolf (TUM)

PLEνM*

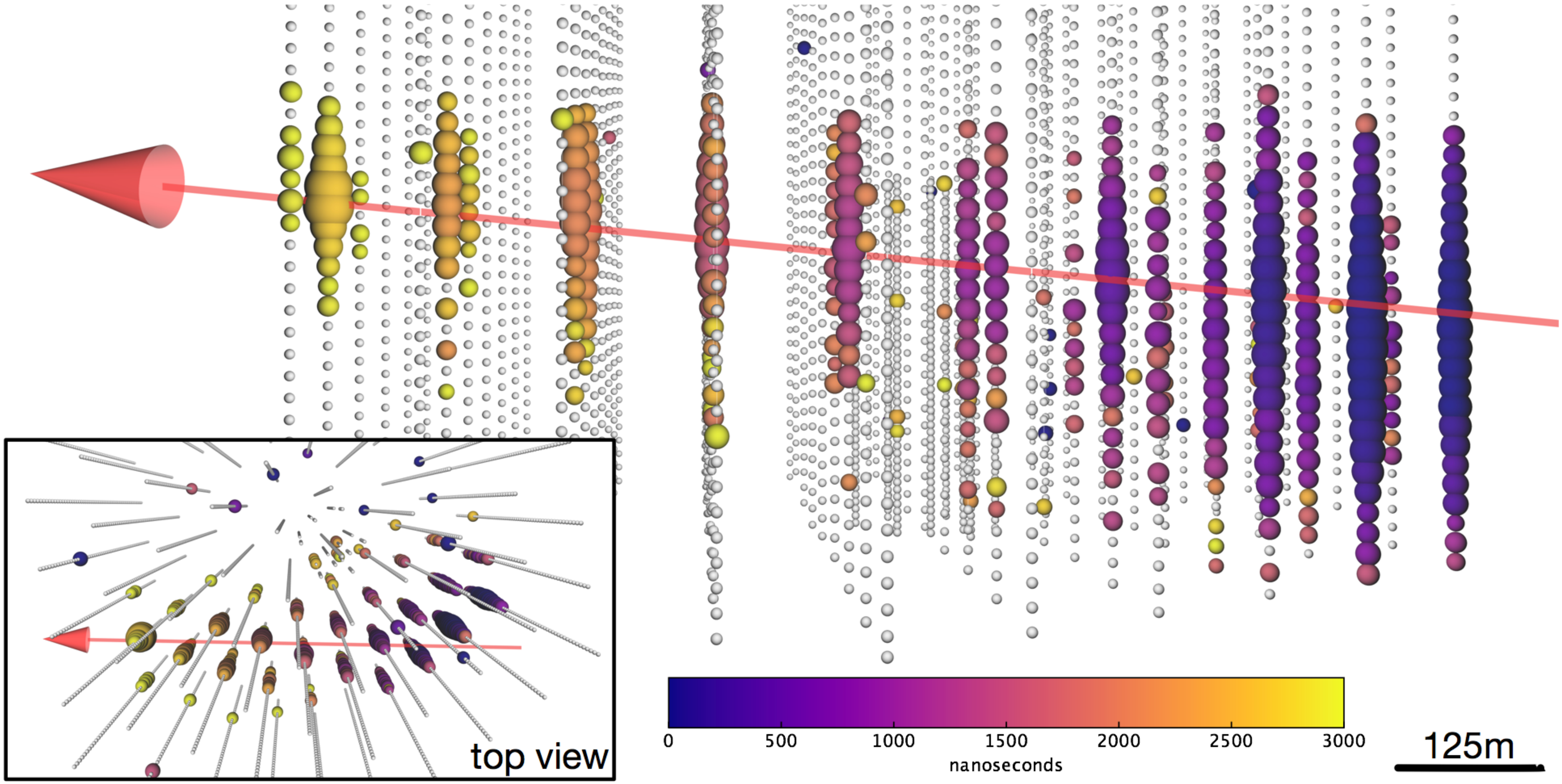


*Planetary neutrino monitoring system

Image: A. Turcati (TUM)

THE AFTERMATH OF TXS 0506+056

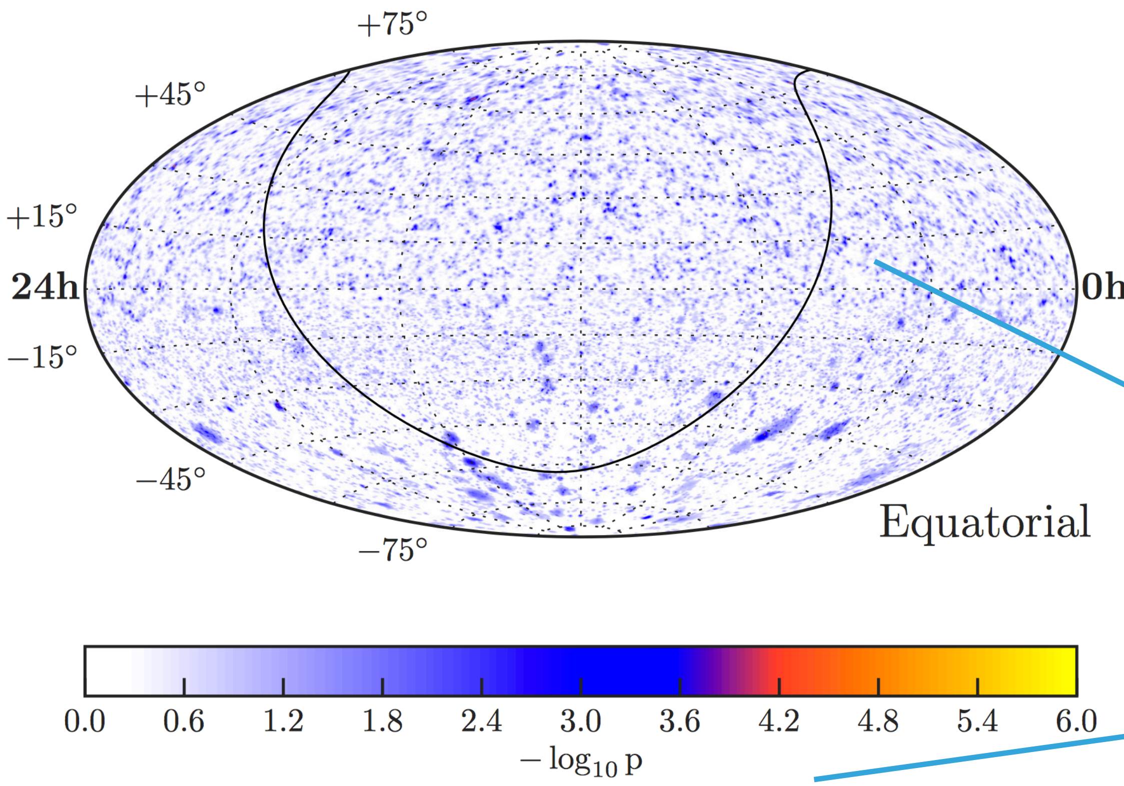
1) ICECUBE-170922A: HORIZONTAL ALERT [~290 TEV, DEC ~5.72 DEG]



"Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A", The IceCube, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S, INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool telescope, Subaru, Swift/NuSTAR, VERITAS, and VLA/17B-403 teams. *Science* 361, 2018

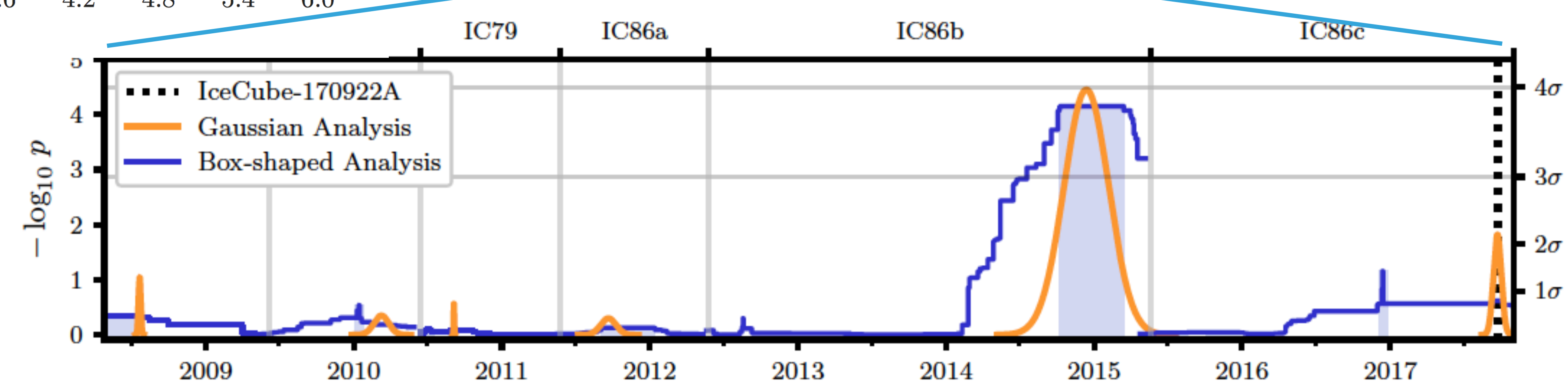
THE AFTERMATH OF TXS 0506+056

2) THE ICECUBE NEUTRINO FLARE: HARD SPECTRUM



Neutrino energy information: included in the definition of the likelihood [$E^{-\gamma}$]

$\gamma = 2.1 \pm 0.2$

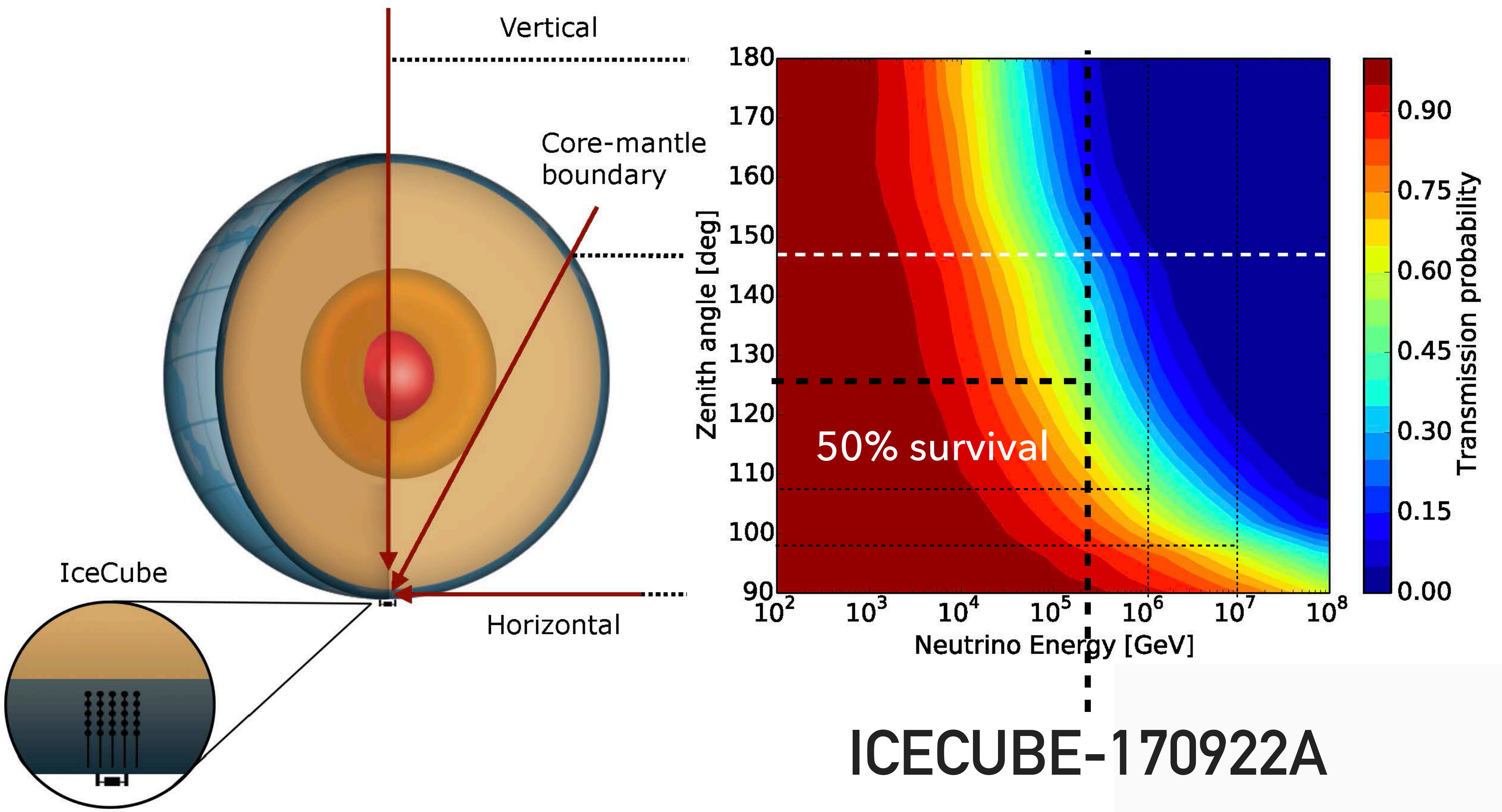


"Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert", IceCube Collaboration: M.G. Aartsen et al. *Science* 361, 147-151 (2018).

THE AFTERMATH OF TXS 0506+056: WHY AT THE HORIZON?

AT HIGH ENERGY THE EARTH IS OPAQUE TO NEUTRINOS

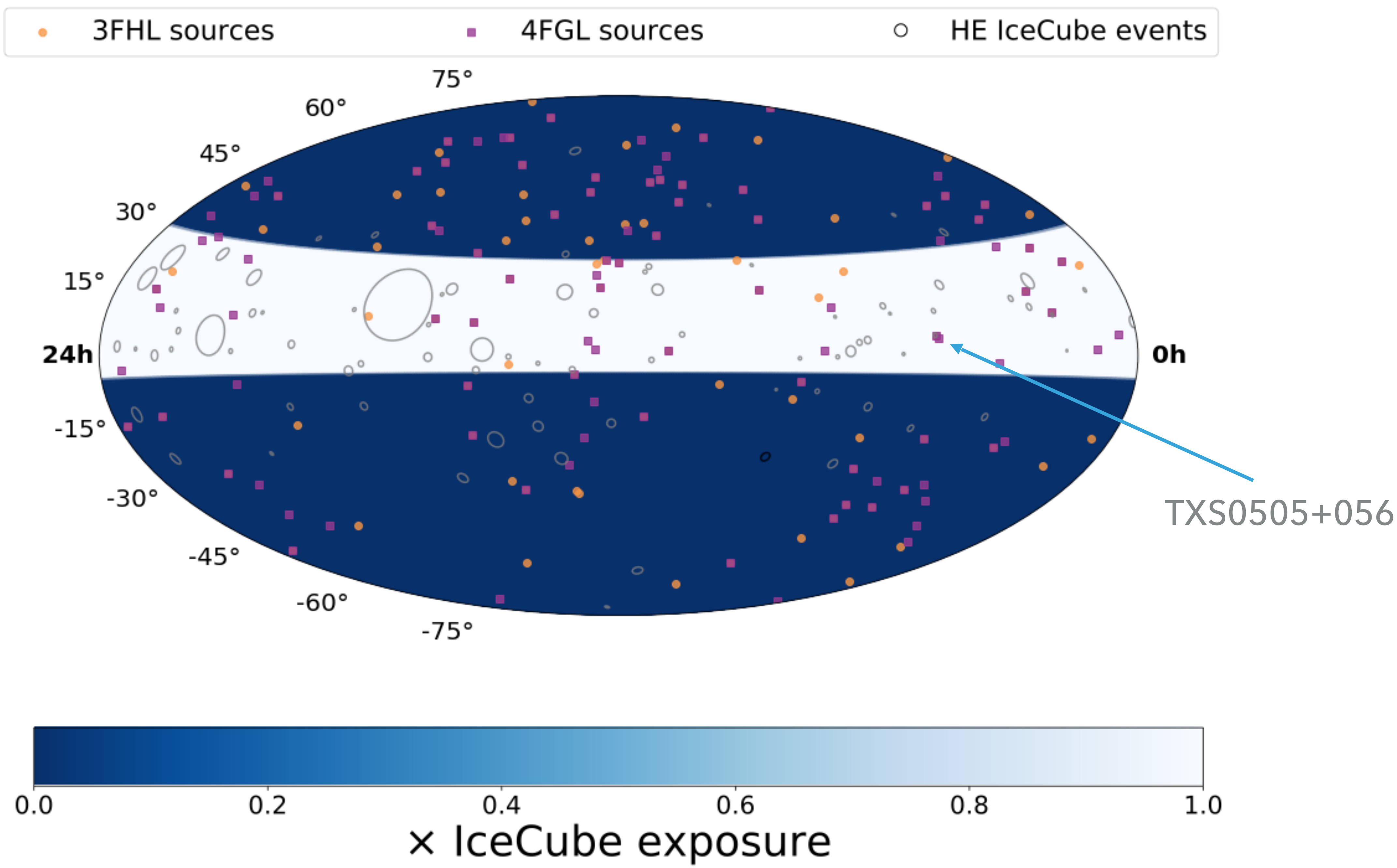
➡ THE FIELD OF VIEW OF NTs (>50TeV): THE HORIZON



IceCube Collaboration, "Measurement of the multi-TeV neutrino cross section with IceCube using Earth absorption," *Nature 551 (2017) 596-600.*

ICECUBE FIELD OF VIEW AT HIGH ENERGIES (>50TEV)

ABOUT 1/3 OF THE SKY COVERED

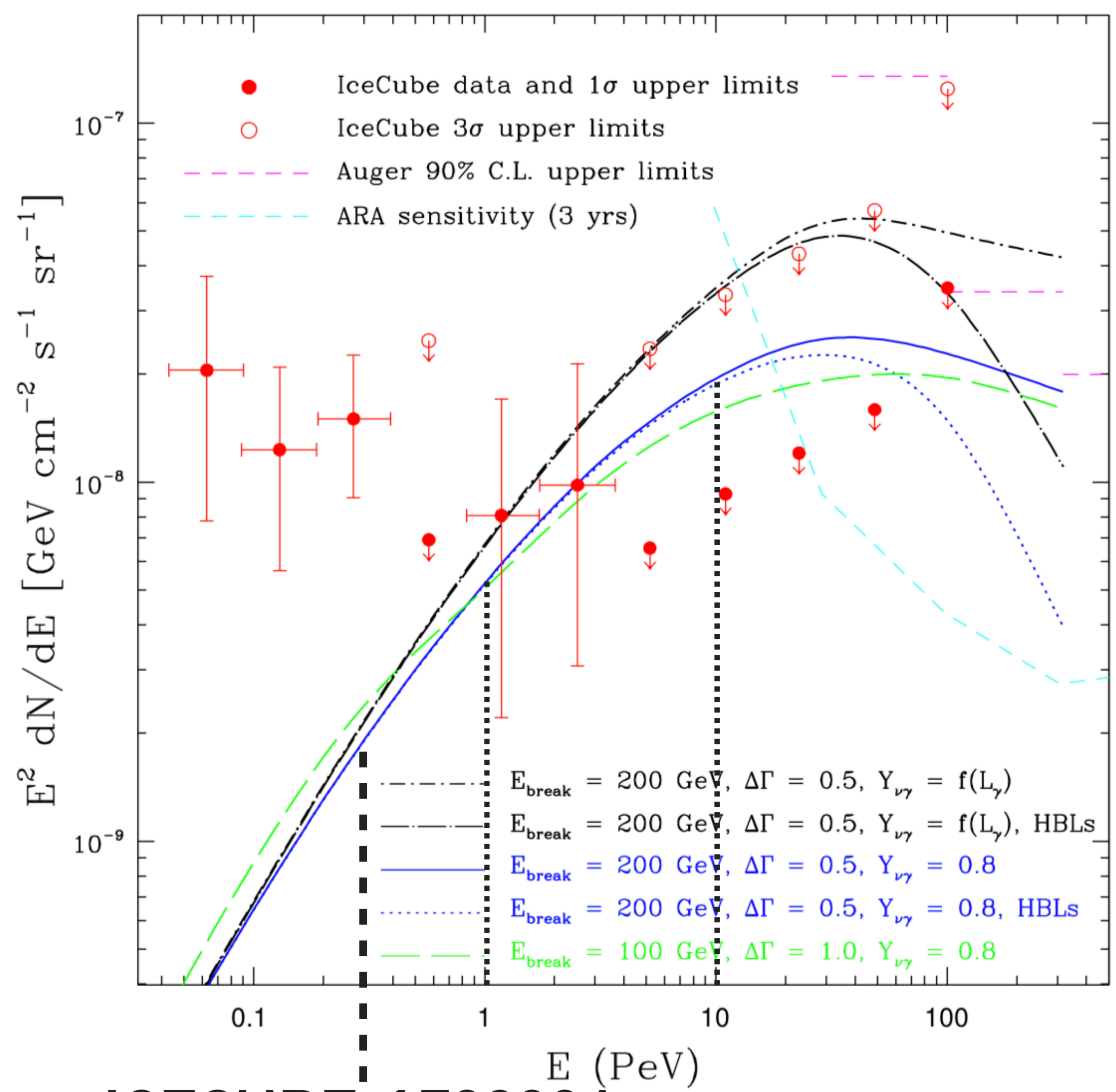


M. Huber (TUM)

THE AFTERMATH OF TXS 0506+056: IS A BLAZAR

TXS0506+056 IS AN INTERMEDIATE BLAZAR, NOT A BL-LAC *

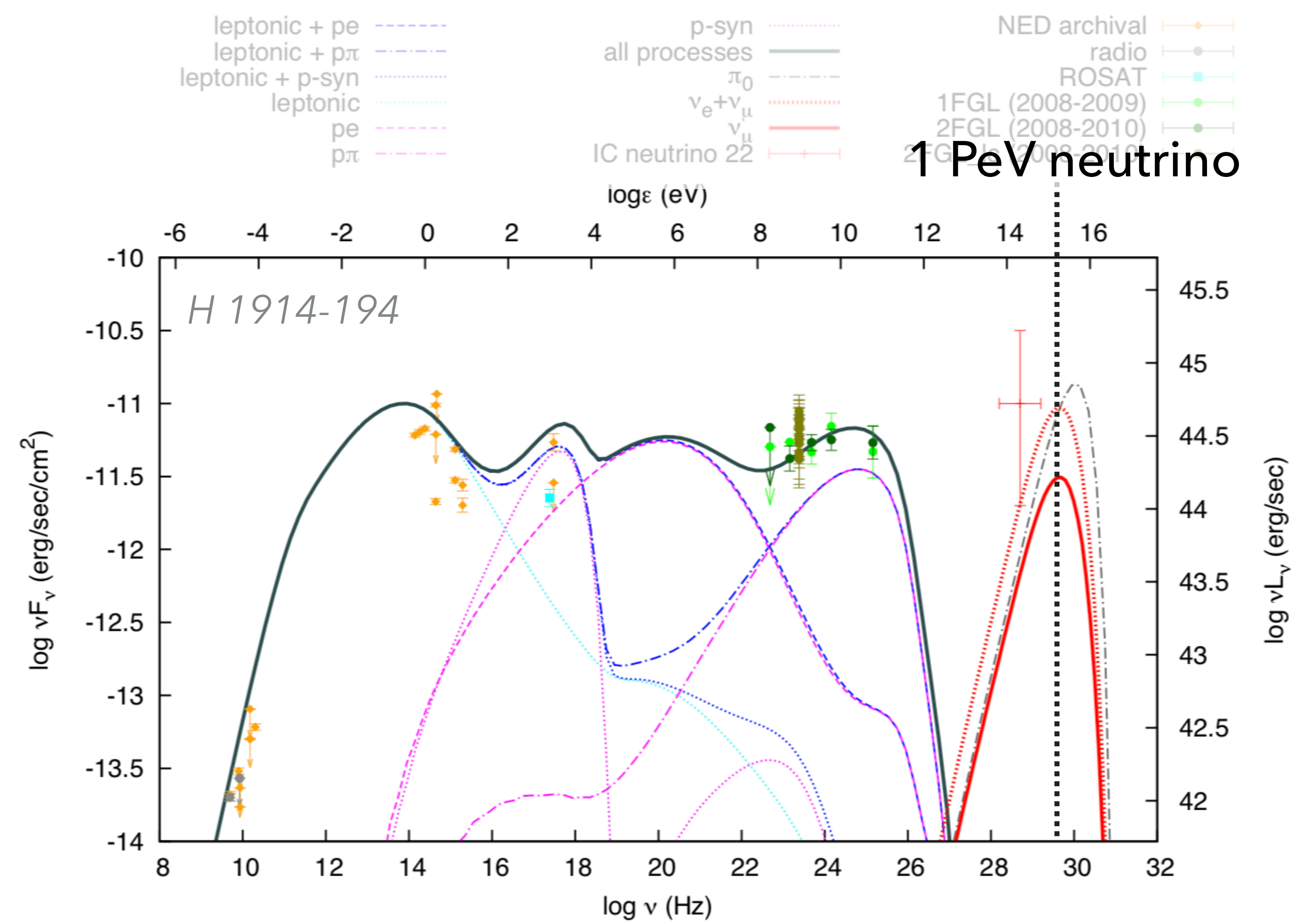
➡ EXPECTED NEUTRINOS FROM BLAZARS AT HIGH ENERGY



ICECUBE-170922A

P. Padovani, M. Petropoulou, P. Giommi, E. R., MNRAS(2015)

* P. Padovani et al., MNRAS (2019)

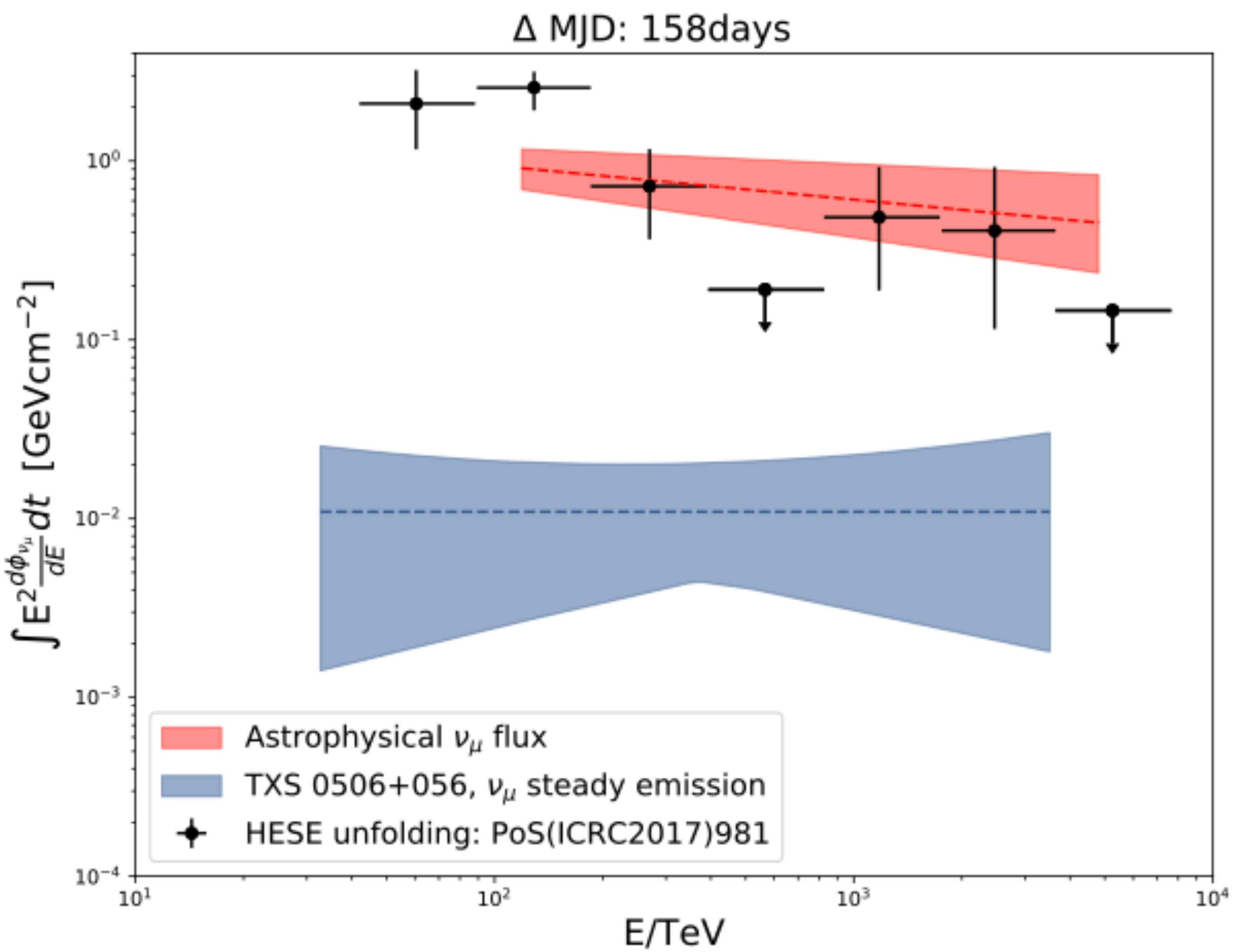


M. Petropoulou, S. Dimitrakoudis, P. Padovani, A. Mastichiadis, E. R. MNRAS(2015)

THE AFTERMATH OF TXS 0506+056: IS A BLAZAR

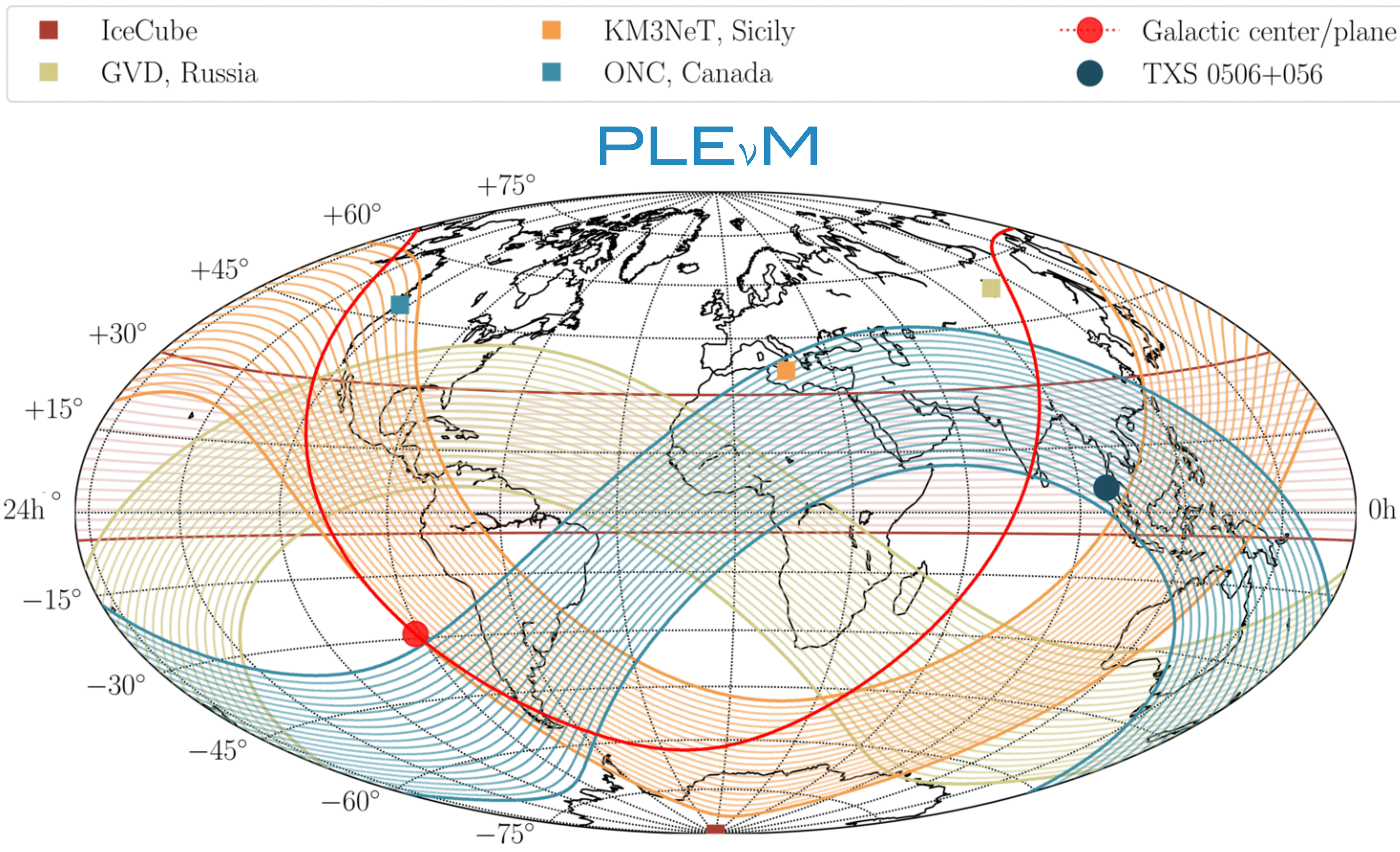
TXS0506+056 NEUTRINO CONTRIBUTION TO THE DIFFUSE: SMALL

➡ MUCH MORE TO DISCOVER OUT THERE!!



M. Huber (TUM)

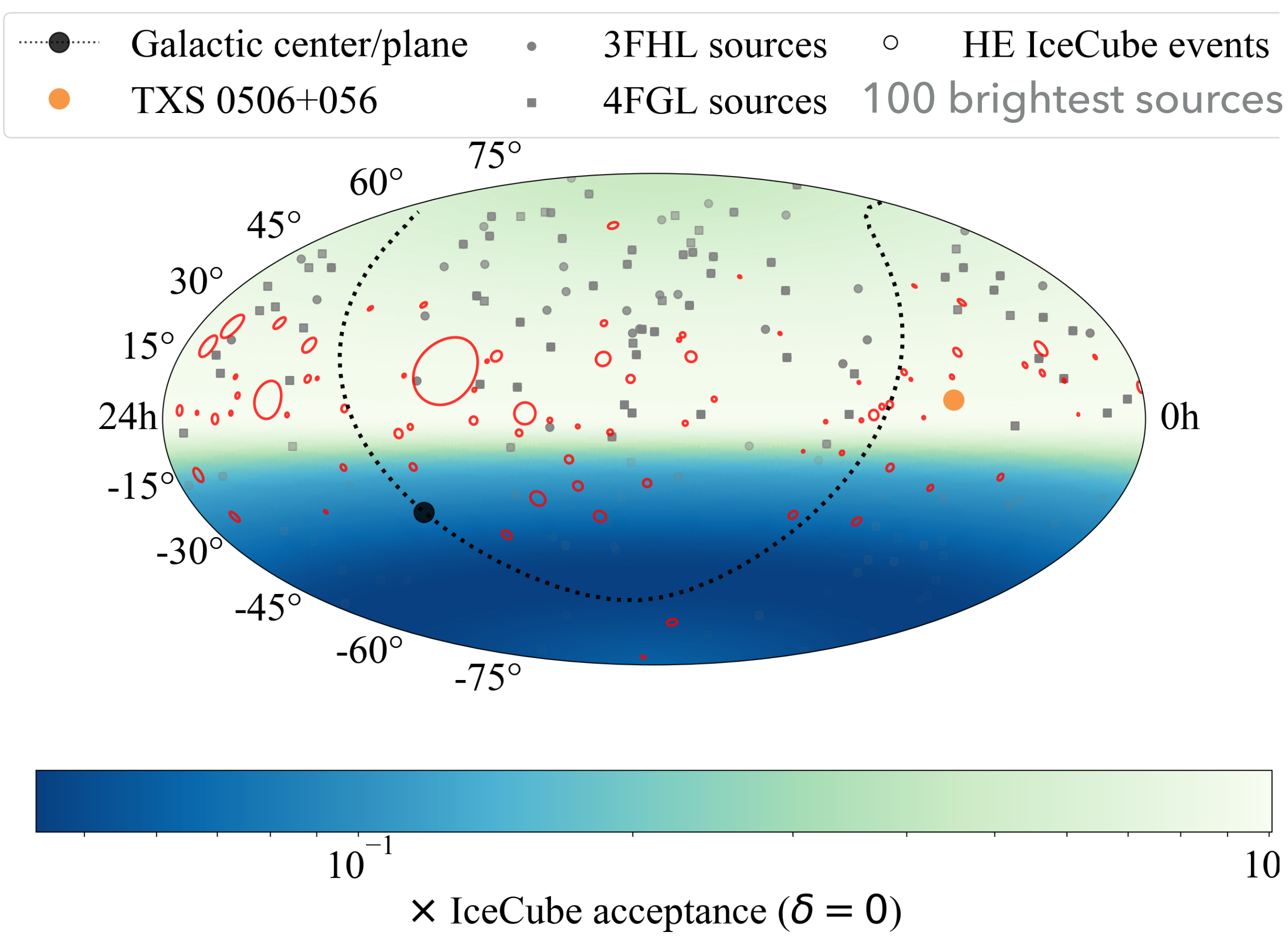
THE FRONTIER: A PLANETARY NEUTRINO MONITORING SYSTEM



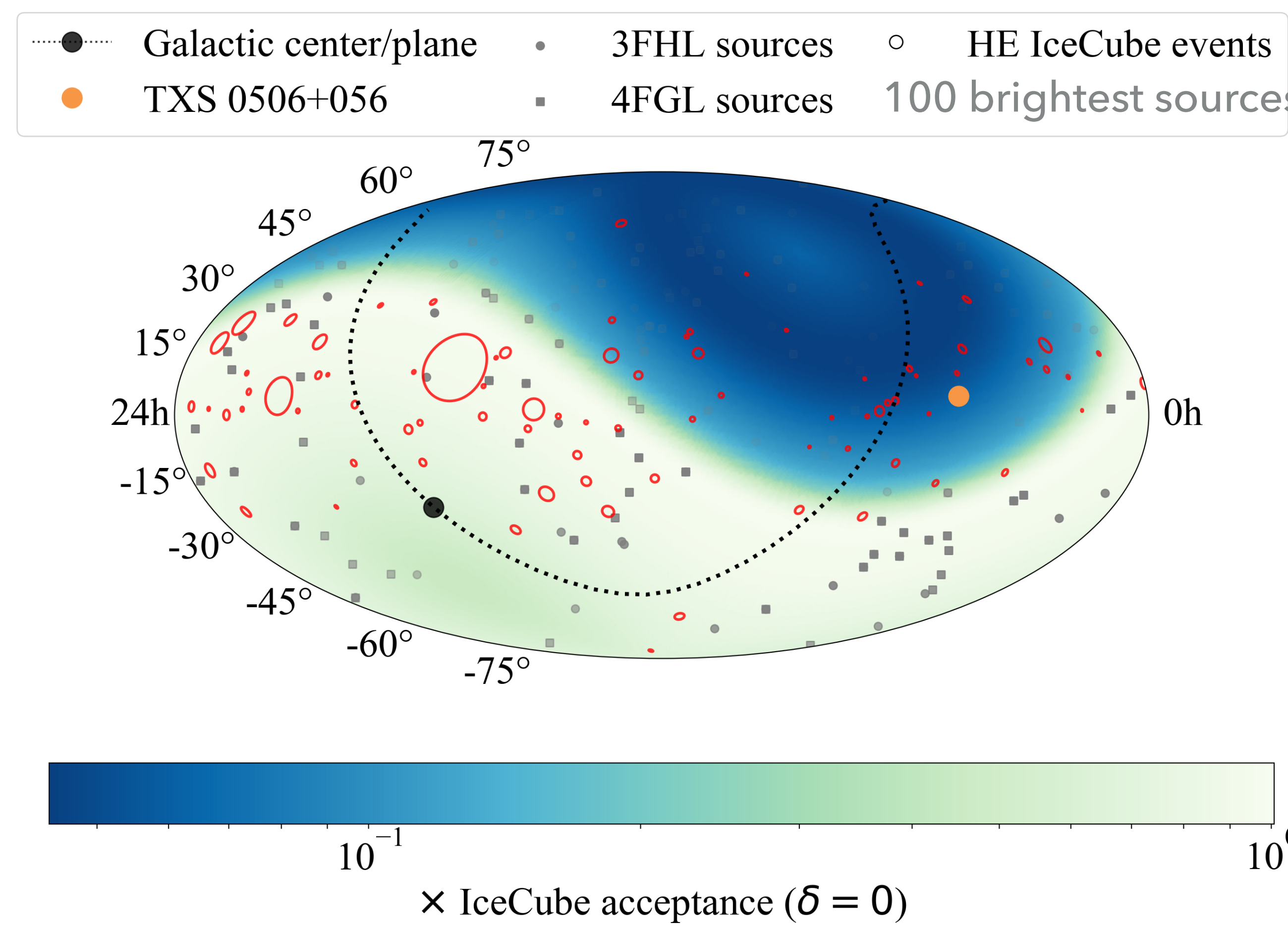
M. Huber (TUM)

ASSUME ONE ICECUBE @ BAIKAL, @ CAPO PASSERO, @ OCEAN NETWORKS CANADA

PLEνM



$$\text{IceCube acceptance} \equiv \int_0^\infty A_{\text{eff}}(\delta, E) \cdot E^{-\gamma} dE$$



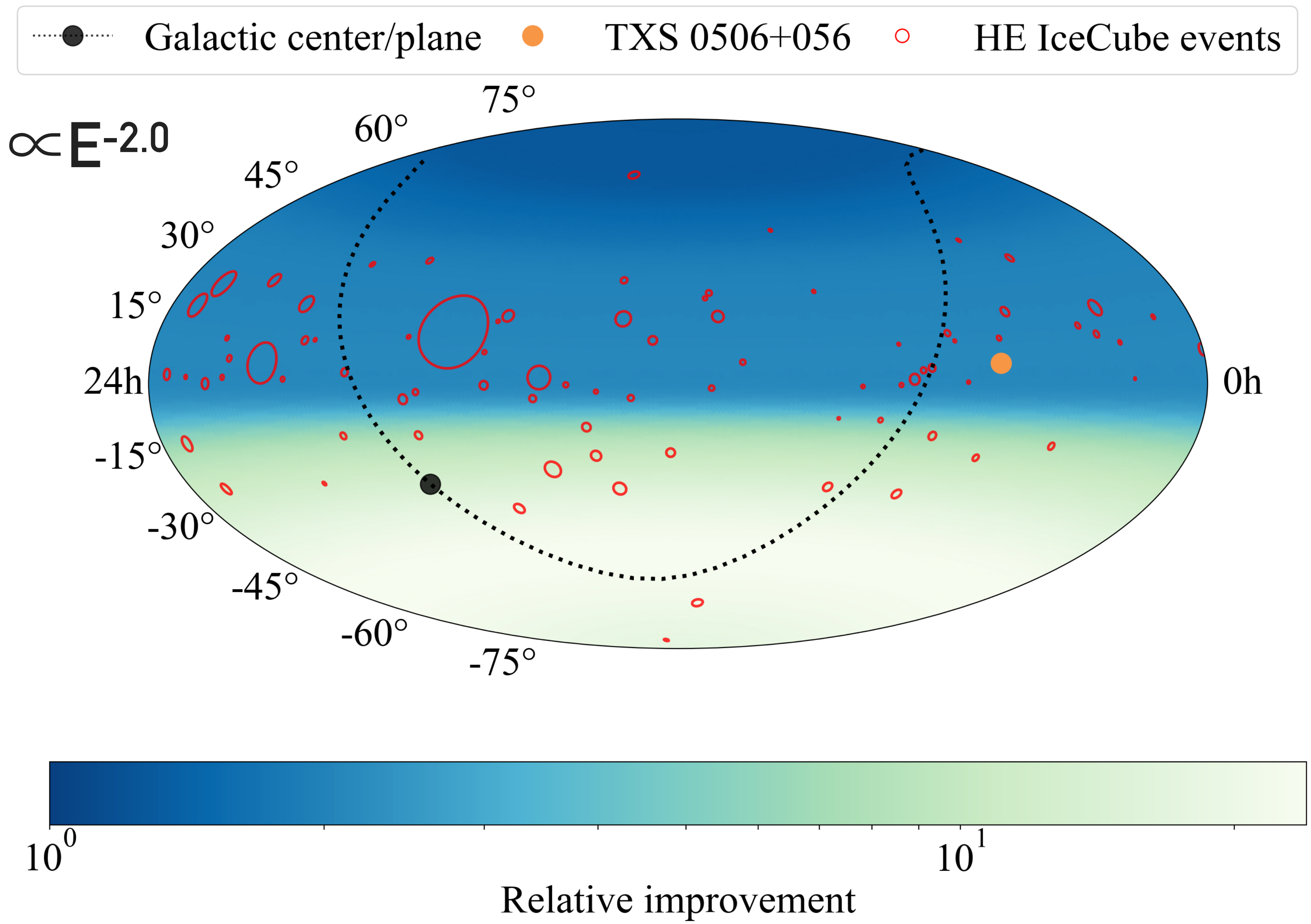
IceCube acceptance at the GVD location

on going study by M. Huber (TUM)

PLEνM

ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

➡ RELATIVE IMPROVEMENT VS ICECUBE ALL SKY



on going study by M. Huber (TUM)

PLEνM

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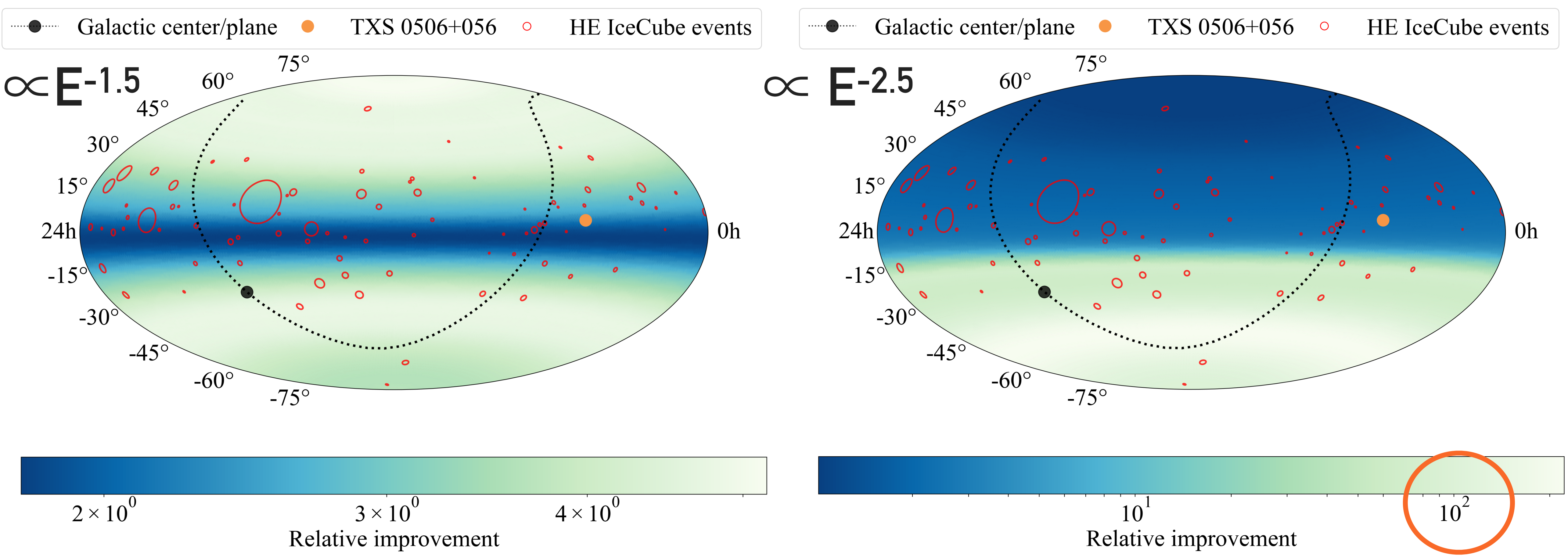
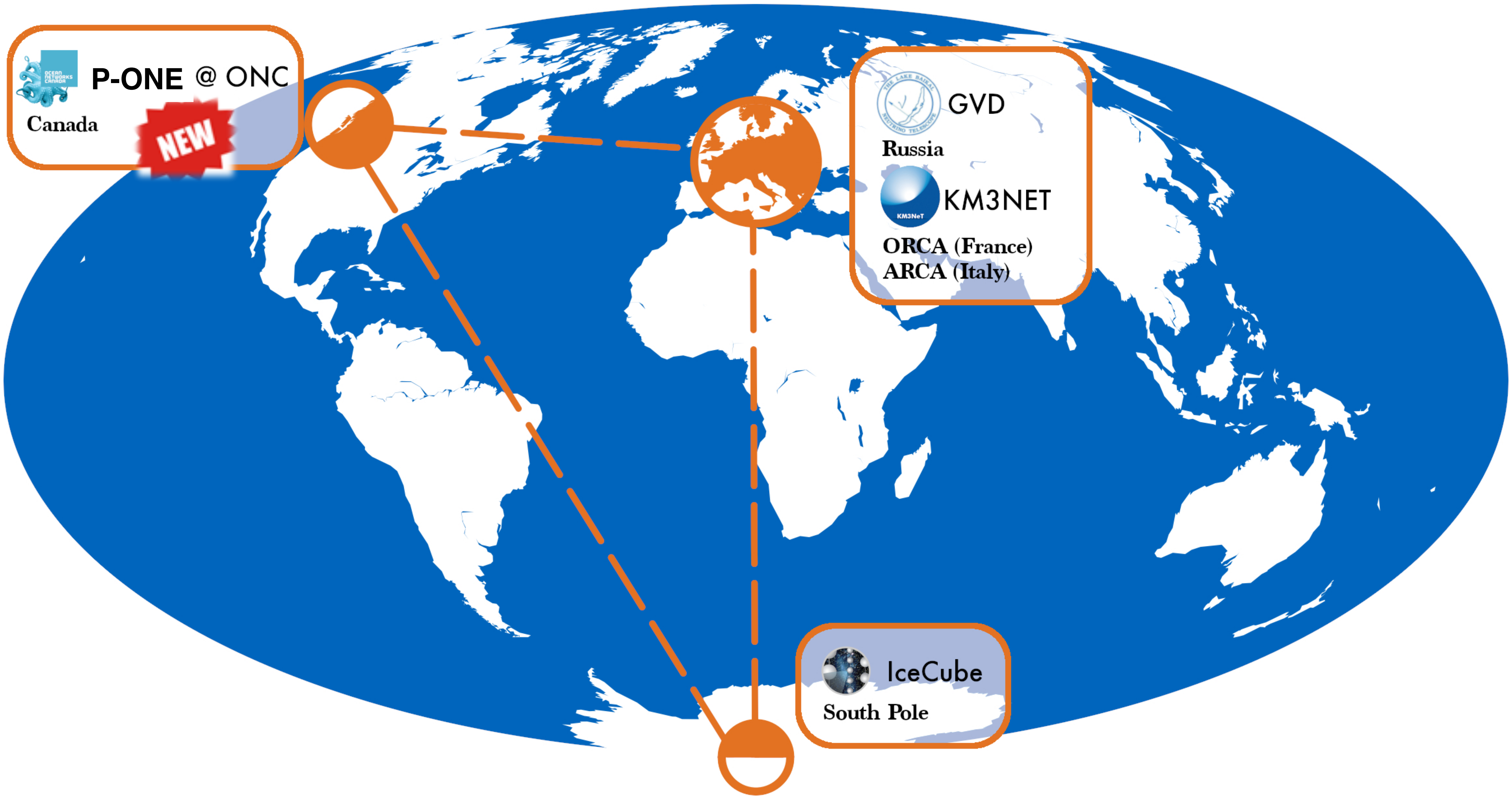


on going study by M. Huber (TUM)

PLEνM*



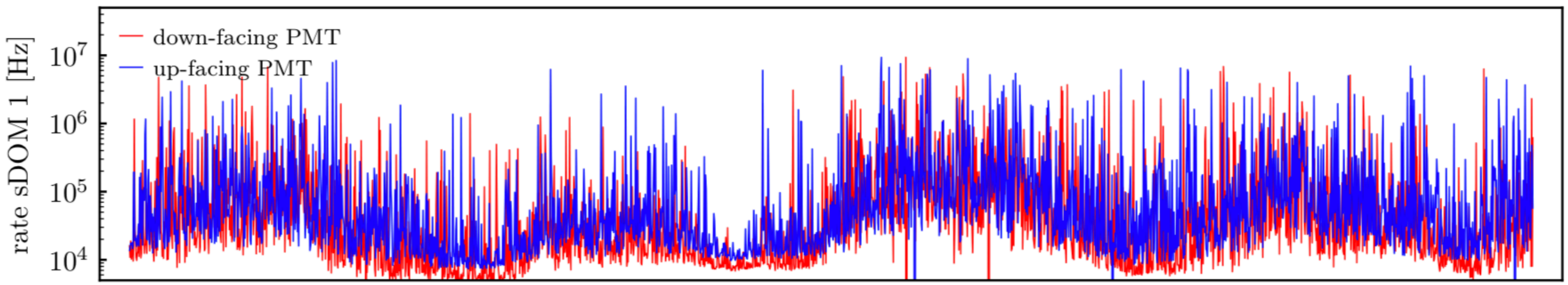
* … *in a plenum, there are no empty places.*
(Bertrand Russell)

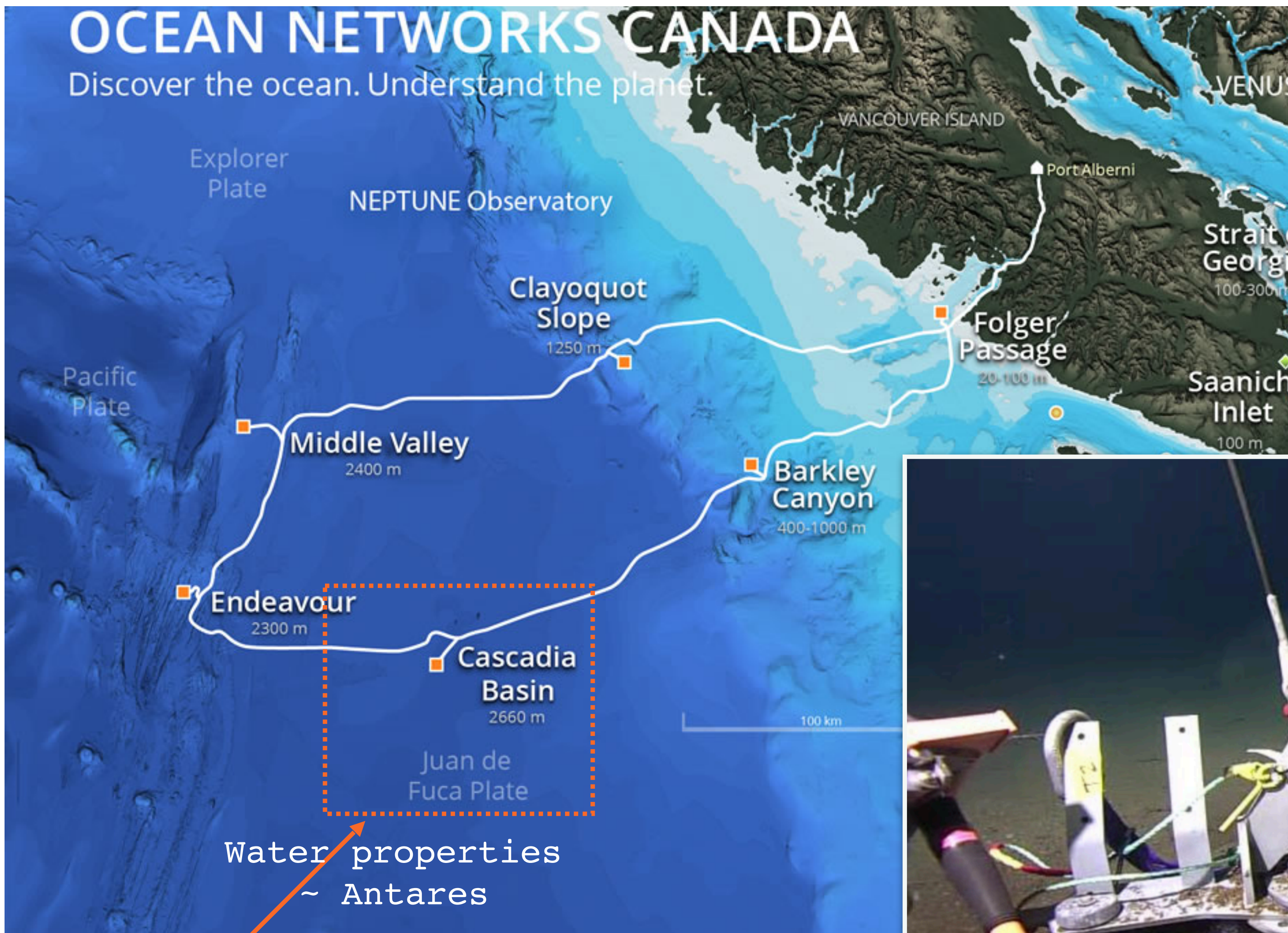
NEW! PACIFIC OCEAN NEUTRINO EXPERIMENT (P-ONE)

ONC (U. VICTORIA), U. OF ALBERTA, QUEEN'S U., TU MUNICH

STRAW PATHFINDER DEPLOYED IN 2018, DATA TAKEN ON-GOING

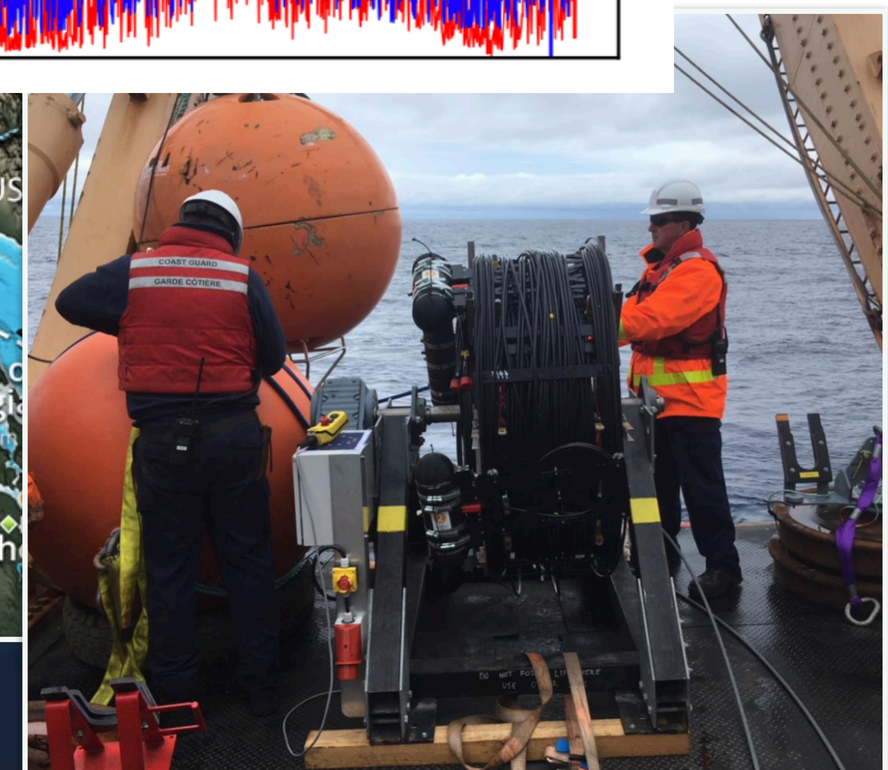
M. Boemer et al., 'STRAW (STRings for Absorption length in Water): pathfinder for a neutrino telescope in the deep Pacific Ocean', JINST(2019), https://arxiv.org/abs/1810.13265

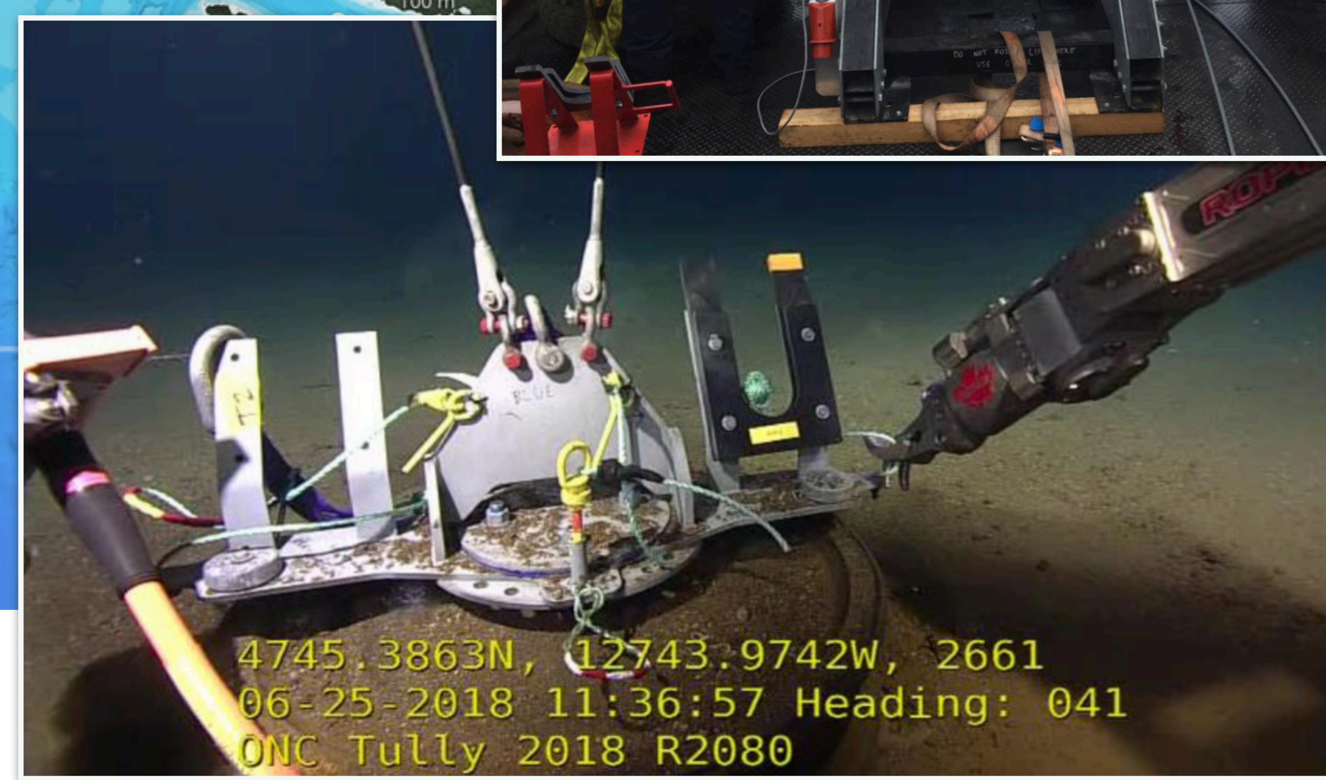




Water properties
~ Antares

Huge volume available and (partly) cabled

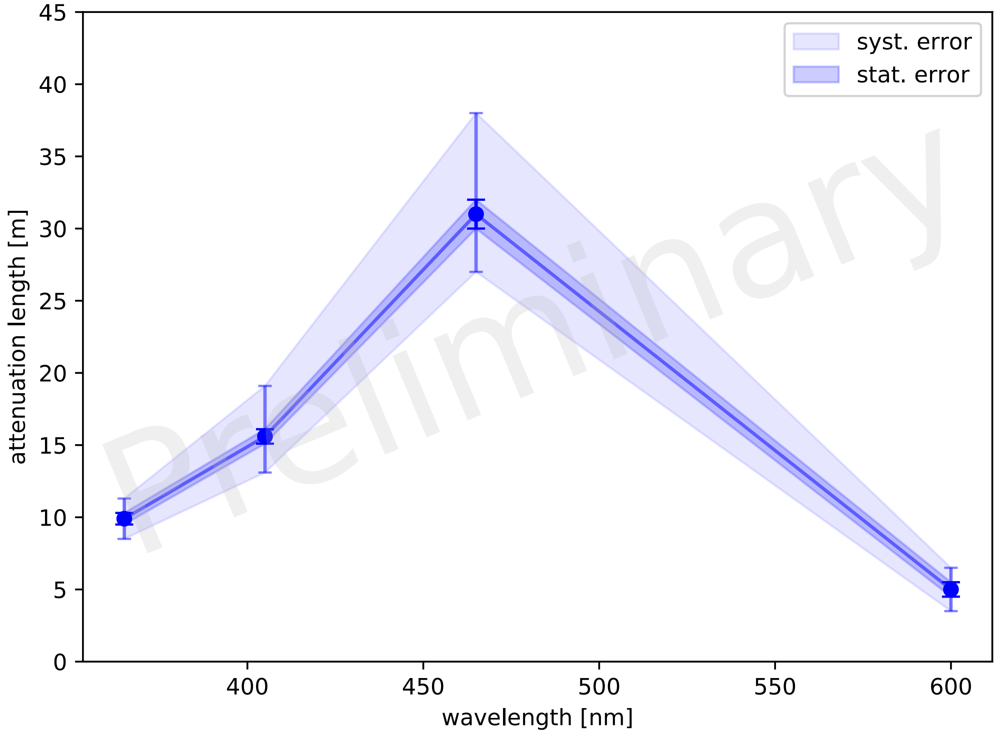




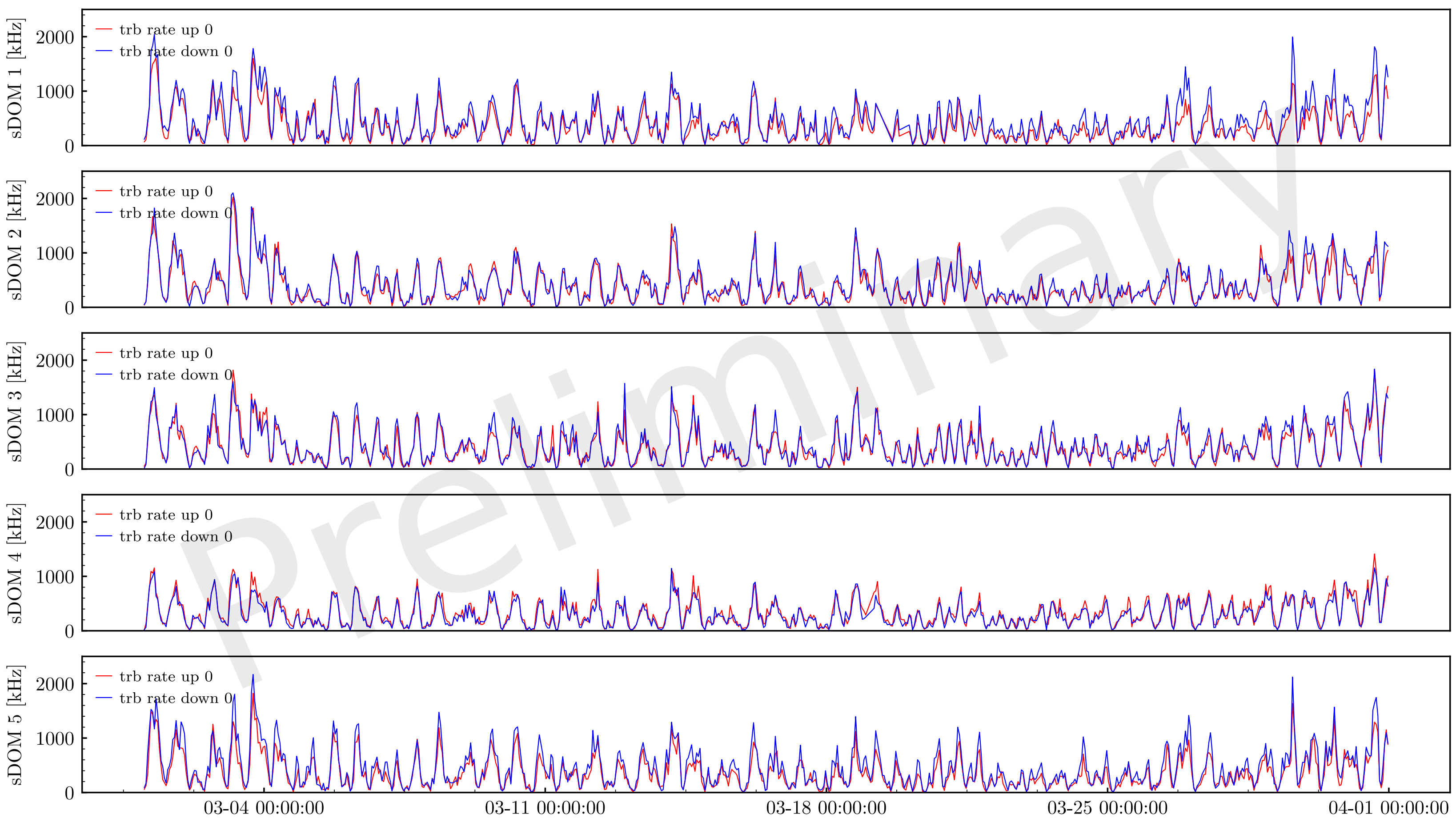
PACIFIC OCEAN NEUTRINO EXPERIMENT (P-ONE)

STRAW PATHFINDER: PRELIMINARY RESULTS

Result No.1: Attenuation length



Results No.2: Bioluminescence modulated as the ocean's tides

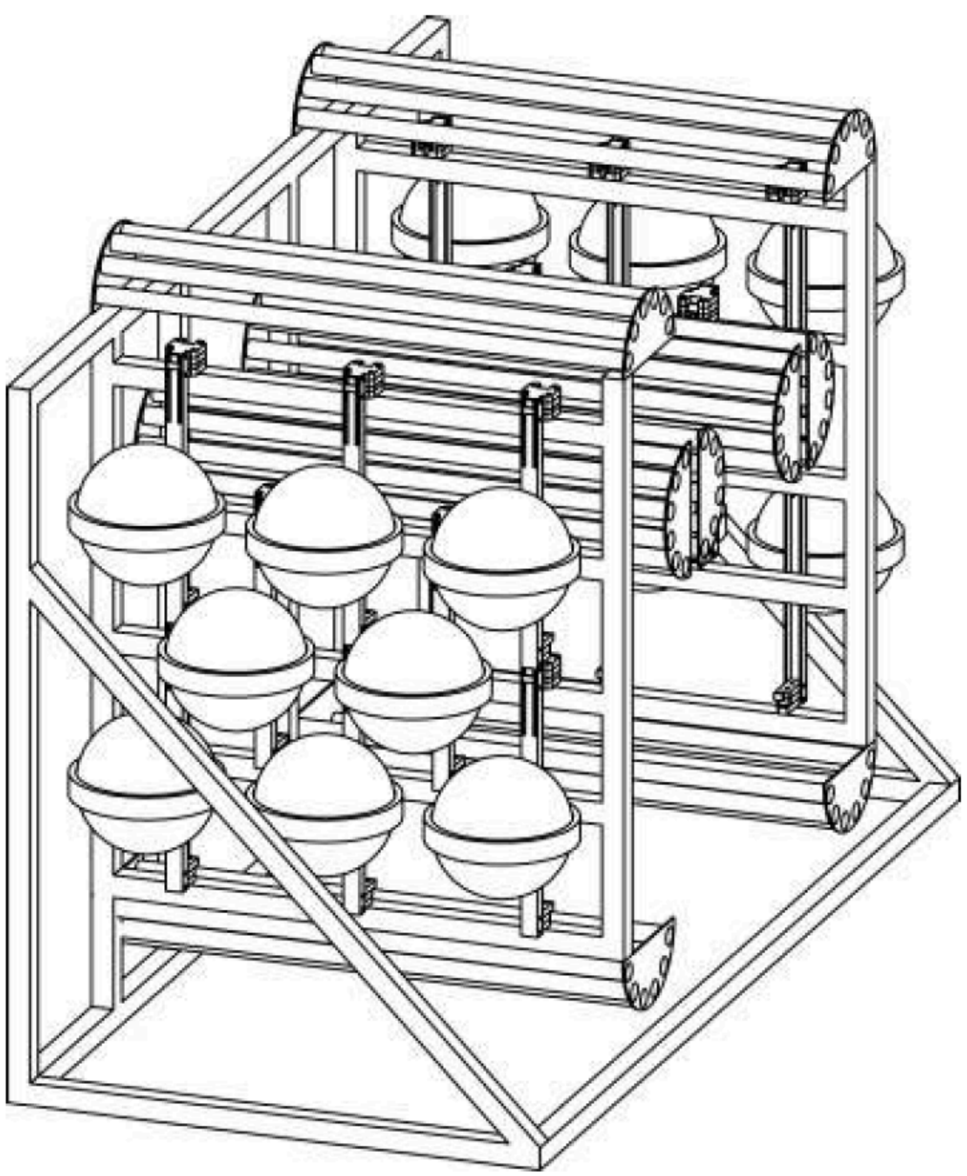


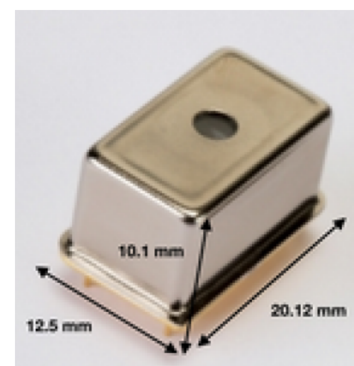
work in progress ….

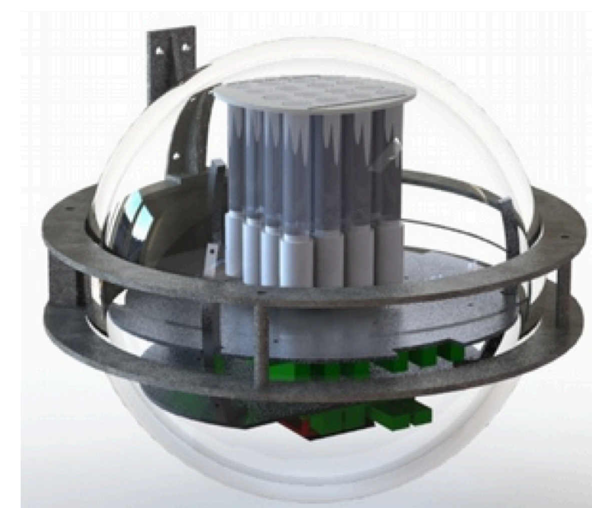
PACIFIC OCEAN NEUTRINO EXPERIMENT (P-ONE)

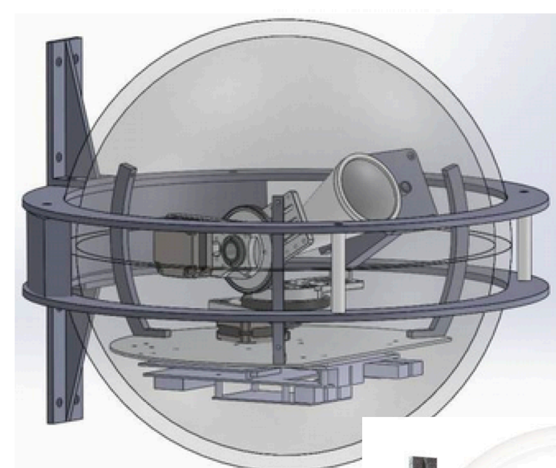
STRAW-B PATHFINDER II: DEPLOYMENT IN 2020

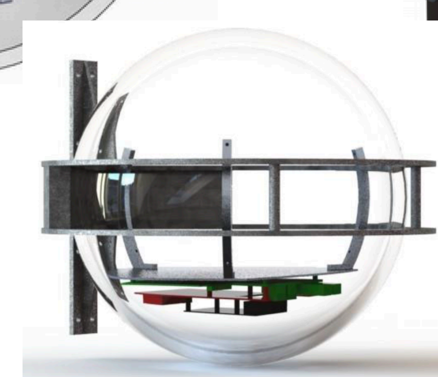
Test longer mooring (500m) and specialised devices.
Complete qualification of the deep site.

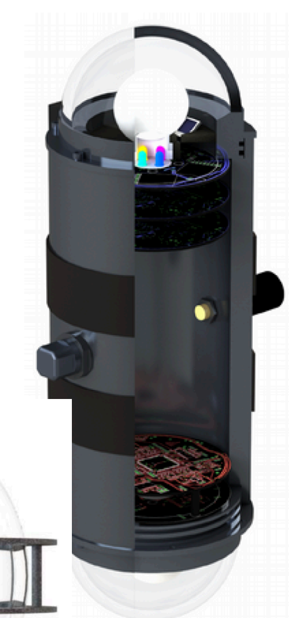


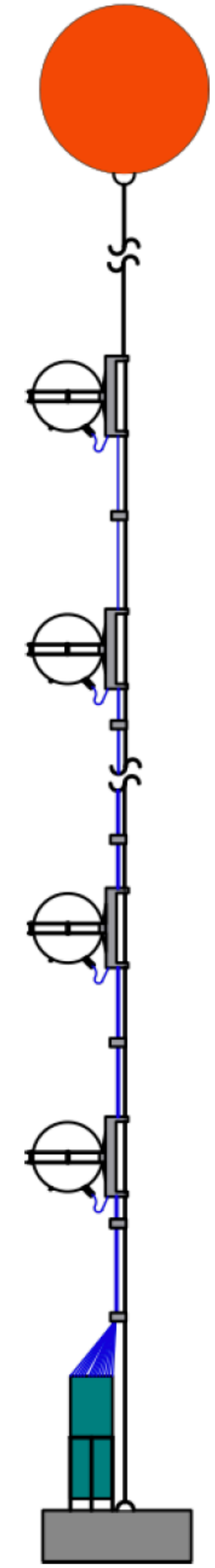






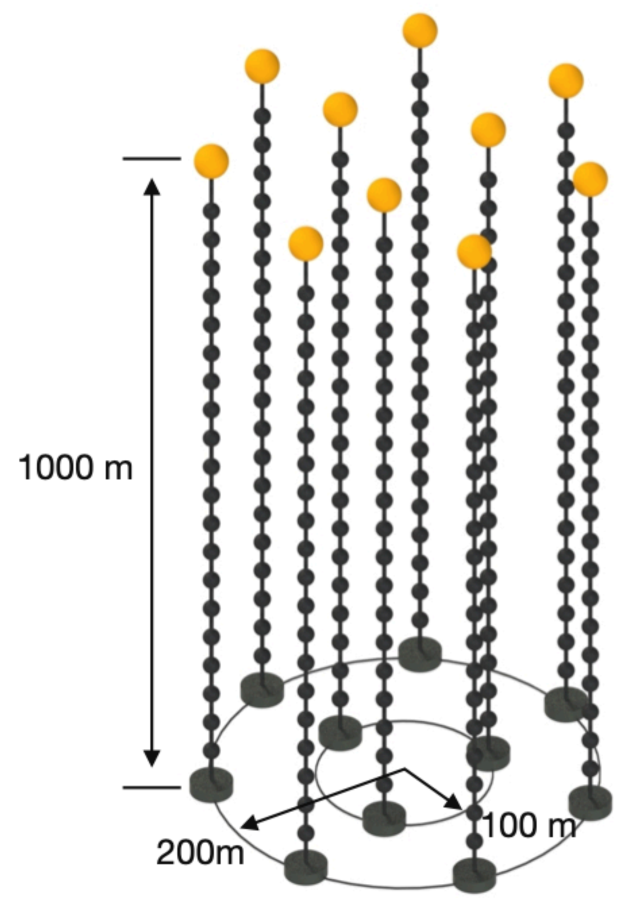






PACIFIC OCEAN NEUTRINO EXPLORER (P-ONE)

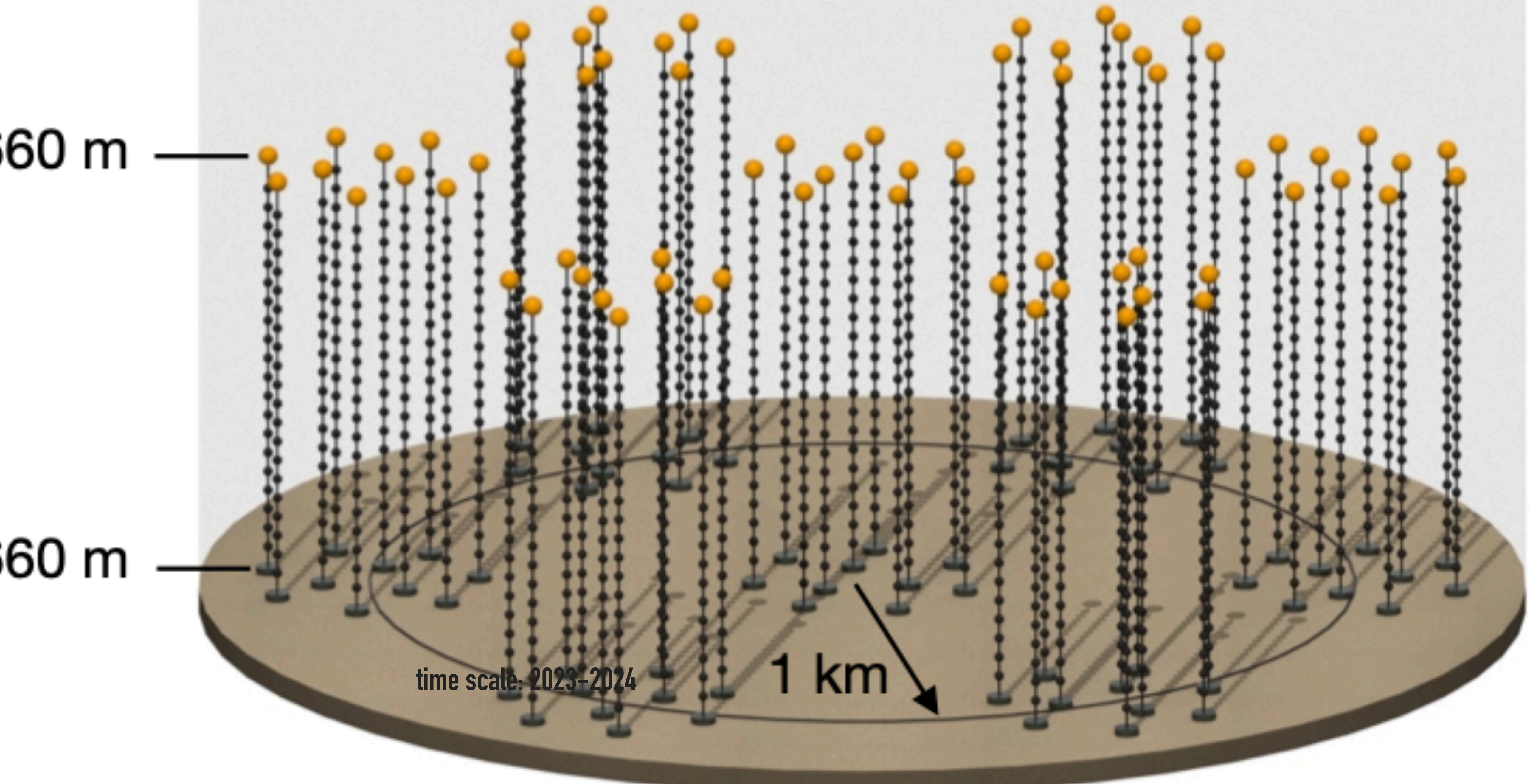
PROPOSAL FOR FIRST 10 STRINGS BUNDLE IN PREPARATION



time scale: 2023-2024

PACIFIC OCEAN NEUTRINO EXPERIMENT (P-ONE)

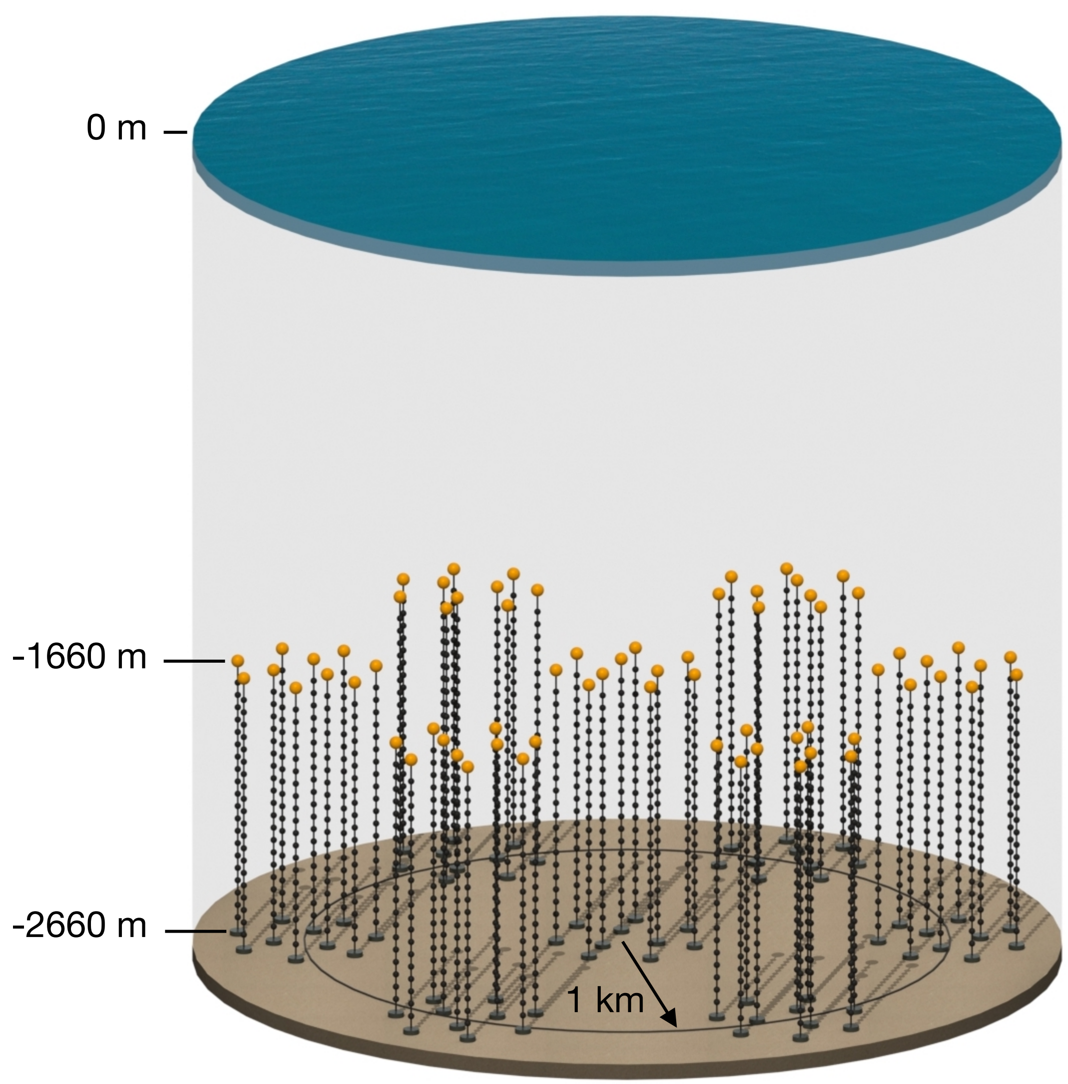
➡ IN CONCEPTUAL DESIGN



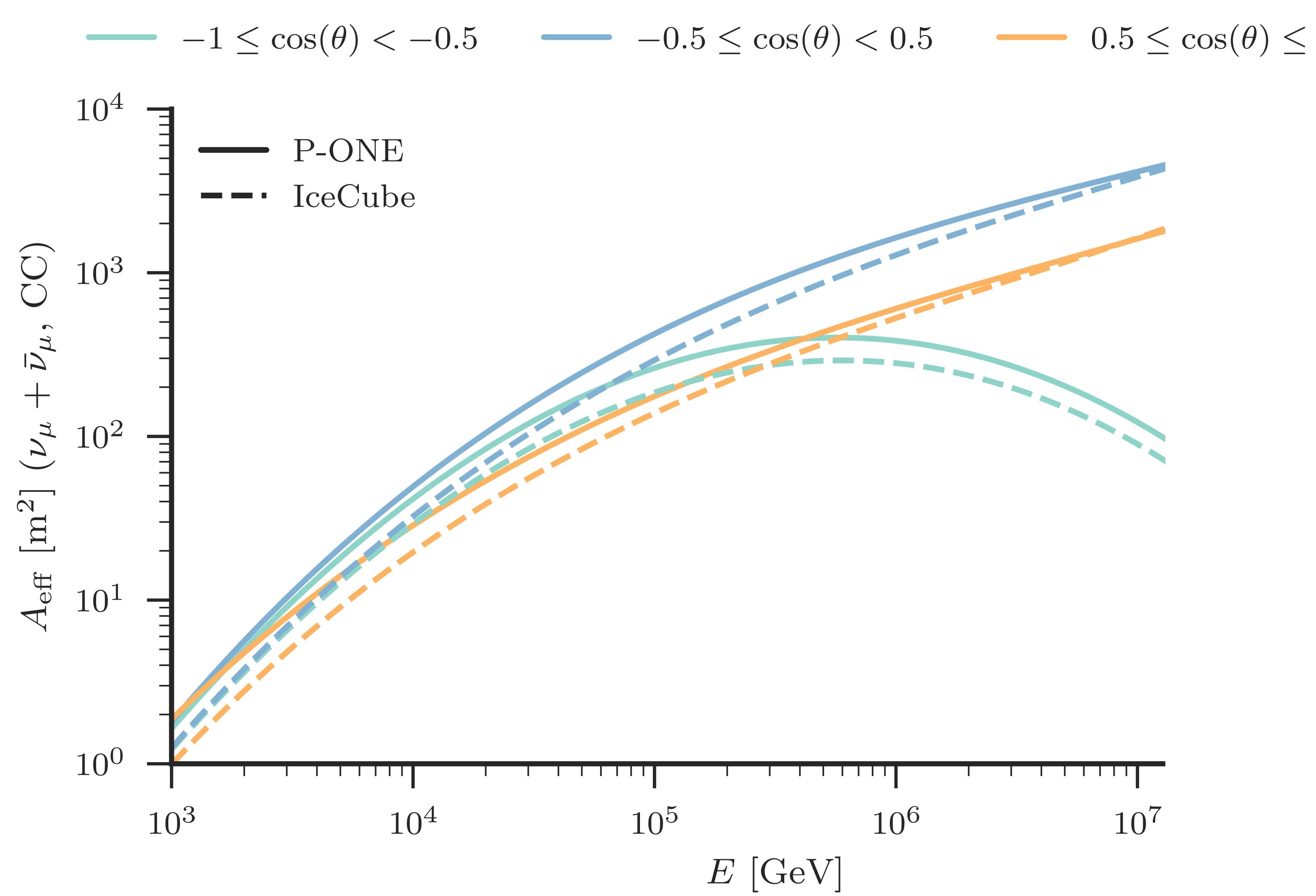
PACIFIC OCEAN NEUTRINO EXPERIMENT (P-ONE)

➡ IN CONCEPTUAL DESIGN

P-ONE AS OPTIMISED TELESCOPE FOR HE TRACKS: ~2 X ICECUBE

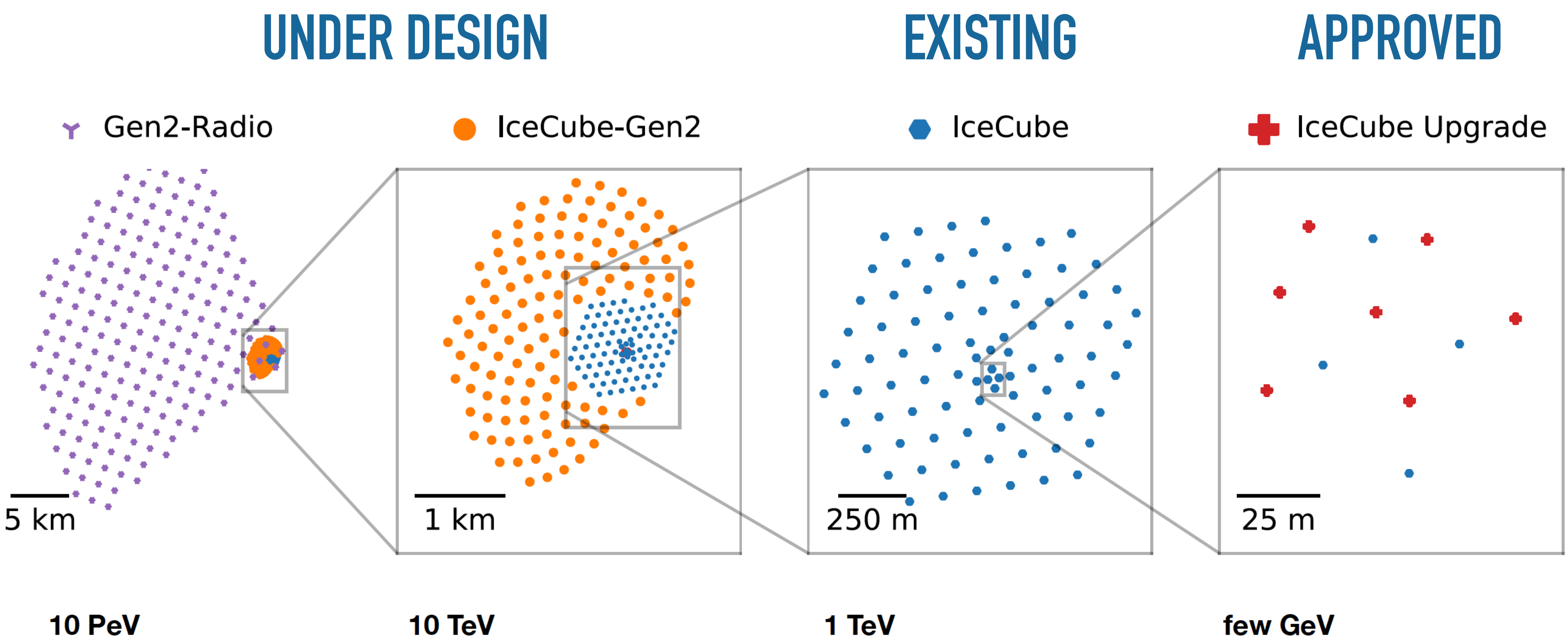


time scale: 2026–2028



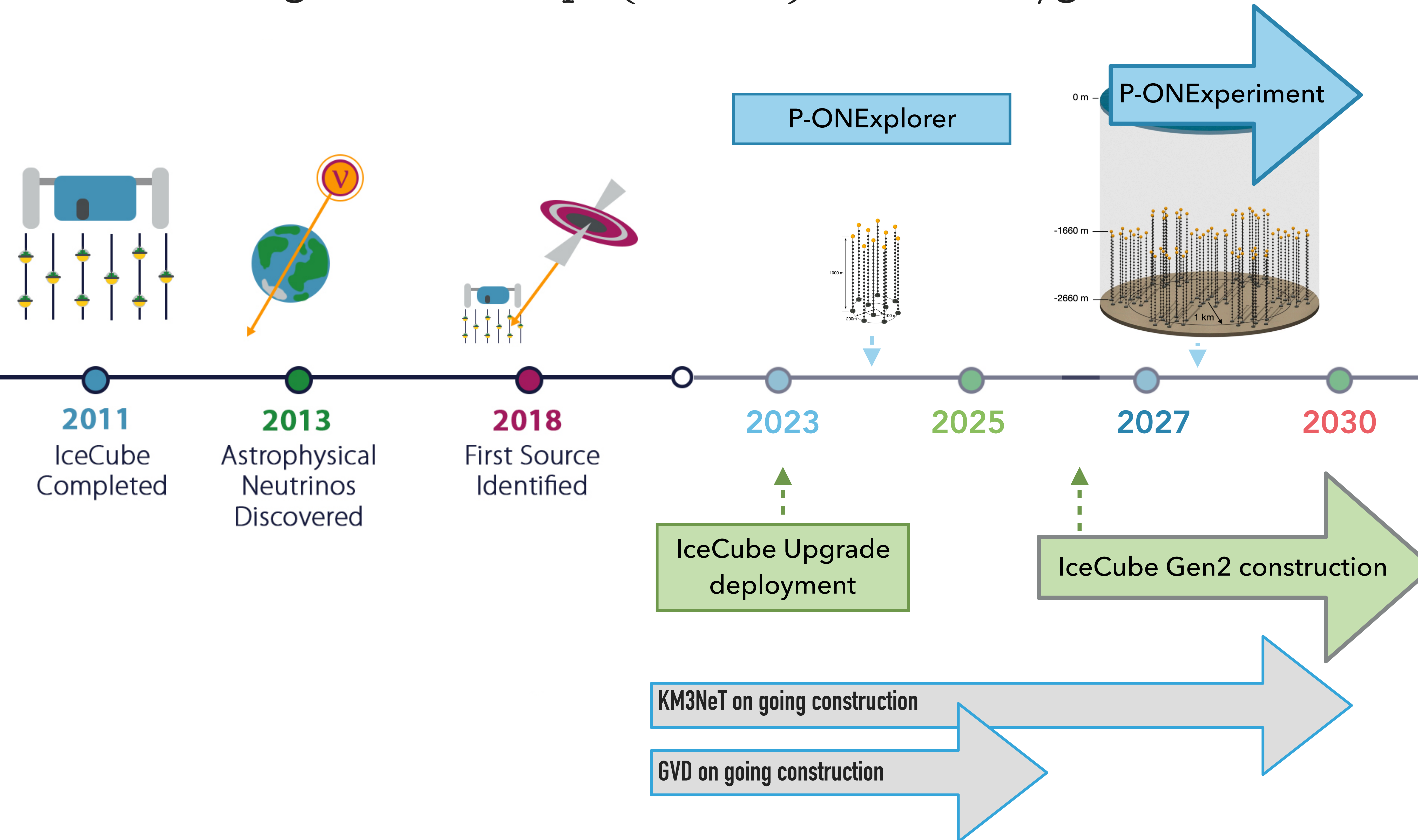
ON THE ICECUBE SIDE: UPGRADE AND GEN2

➡ ICECUBE AS MULTIPURPOSE EXPERIMENT



What do the next 10 years have in store?

from the single site telescope (IceCube) to the multi/global network



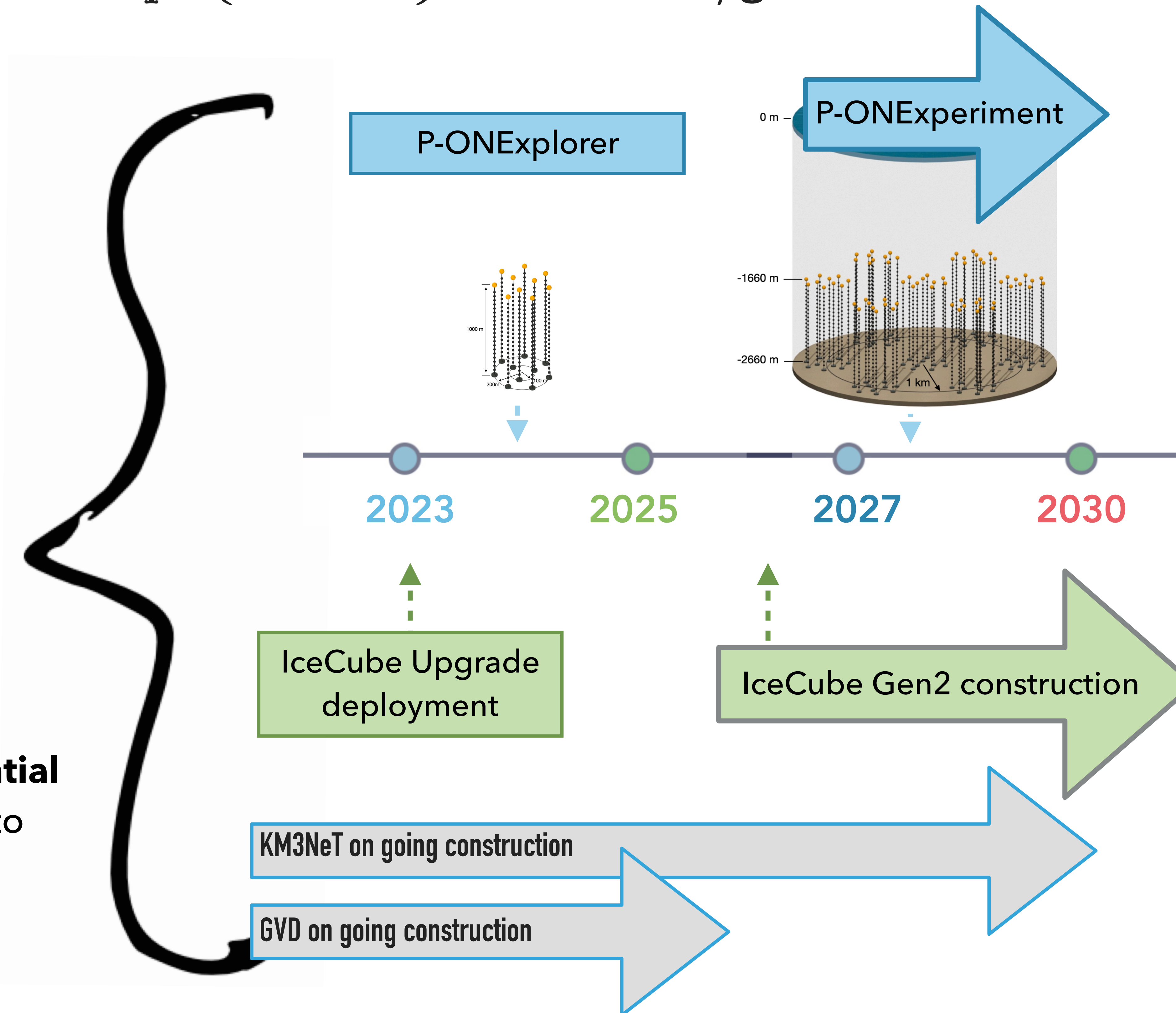
What do the next 10 years have in store?

from the single site telescope (IceCube) to the multi/global network

PLEνM

- share hardware developments
- share software packages
- cross-calibration
- combined analyses
- on line sky monitor for astrophysical alerts

Boost of the **discovery potential** for cosmic accelerators up to factor 100!



OUTLOOK

IceCube has pioneered the exploration of the universe with high-energy neutrinos as intergalactic probes.

The first association between neutrinos and an extragalactic source (TXS0506+056) in 2018. Aftermath:

- Blazars are viable HE neutrino sources and so far the only;
- Neutrino signal from blazars most probably 100 TeV - 100 PeV, most interesting region to explore;
- Neutrino absorption in the Earth significant effect, field of view at the horizon.

Need of more and larger neutrino telescopes around the planet Earth to cover the sky and boost the discovery potential.

Example: With 3 IceCubes in the North overall improvement by a factor of 10-100, strong synergy.

New collaboration established with Ocean Network Canada for a possible neutrino telescope named Pacific Ocean Neutrino Experiment (P-ONE) in the Pacific ocean: new insights into deep sea operations.

A path forward for IceCube Gen2 guaranteed.

WHAT DO THE NEXT 10 YEARS HAVE IN STORE?

The next ten years will mark the emergence of multi-messenger astronomy through numerous discoveries at the highest energies including:

-> macro and microscopic physics of particle acceleration in the vicinity of the black holes

-> magnetic fields and their amplification

-> interaction of the accelerated particles producing the energetic photons and neutrinos

To achieve the golden era of multi messenger astronomy and explore the universe in neutrinos it is necessary to

1) open the observation window to the whole sky with a coordinated effort among KM3NeT & GVD & IceCube & P-ONE = PLEvM

2) achieve energy flux sensitivity in the range of 10^{-12} TeVcm^{-2}s^{-1} through the optimisation of the neutrino telescopes (e.g. P-ONE) and broad band observatories (e.g. IceCube-Gen2)

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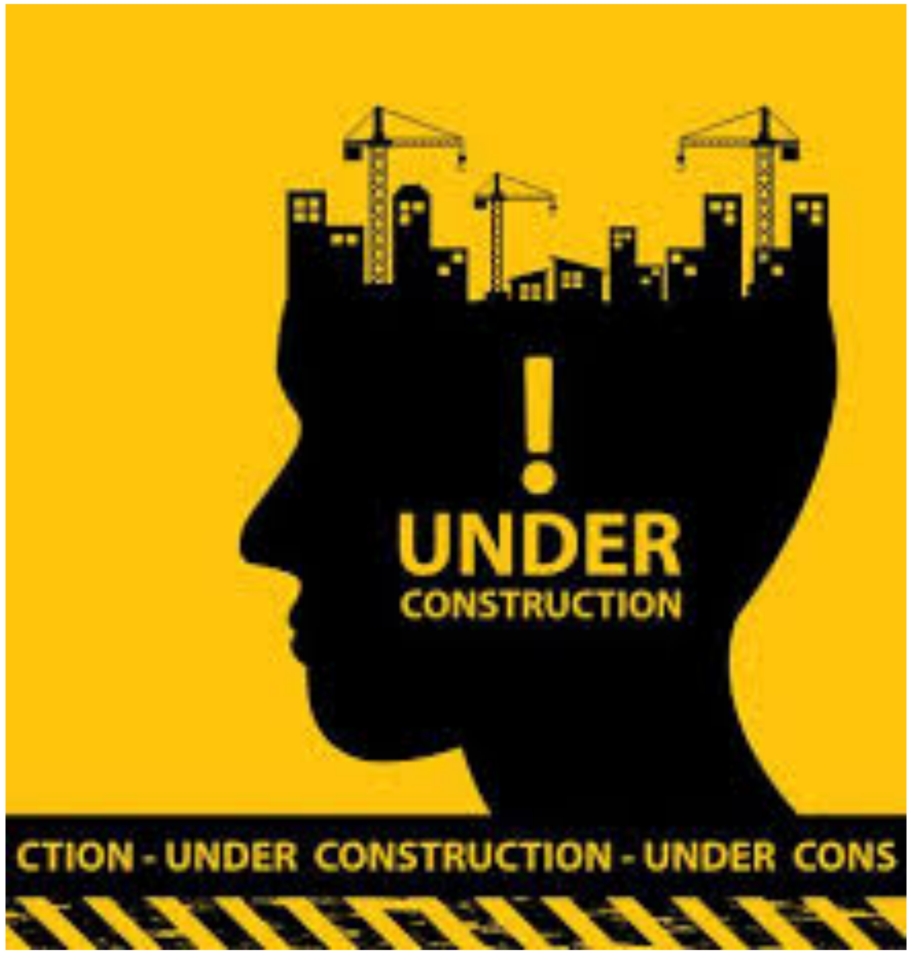
2) achieve energy flux sensitivity in the range of 10^{-12} TeVcm^{-2}s^{-1} through the optimisation of the neutrino telescopes (e.g. P-ONE) and broad band observatories (e.g. IceCube-Gen2)

In addition, the neutrino telescopes also allow to search for the products of dark matter as well as to research the signatures of exotic particles but this would require another talk.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CONSTRUCTION
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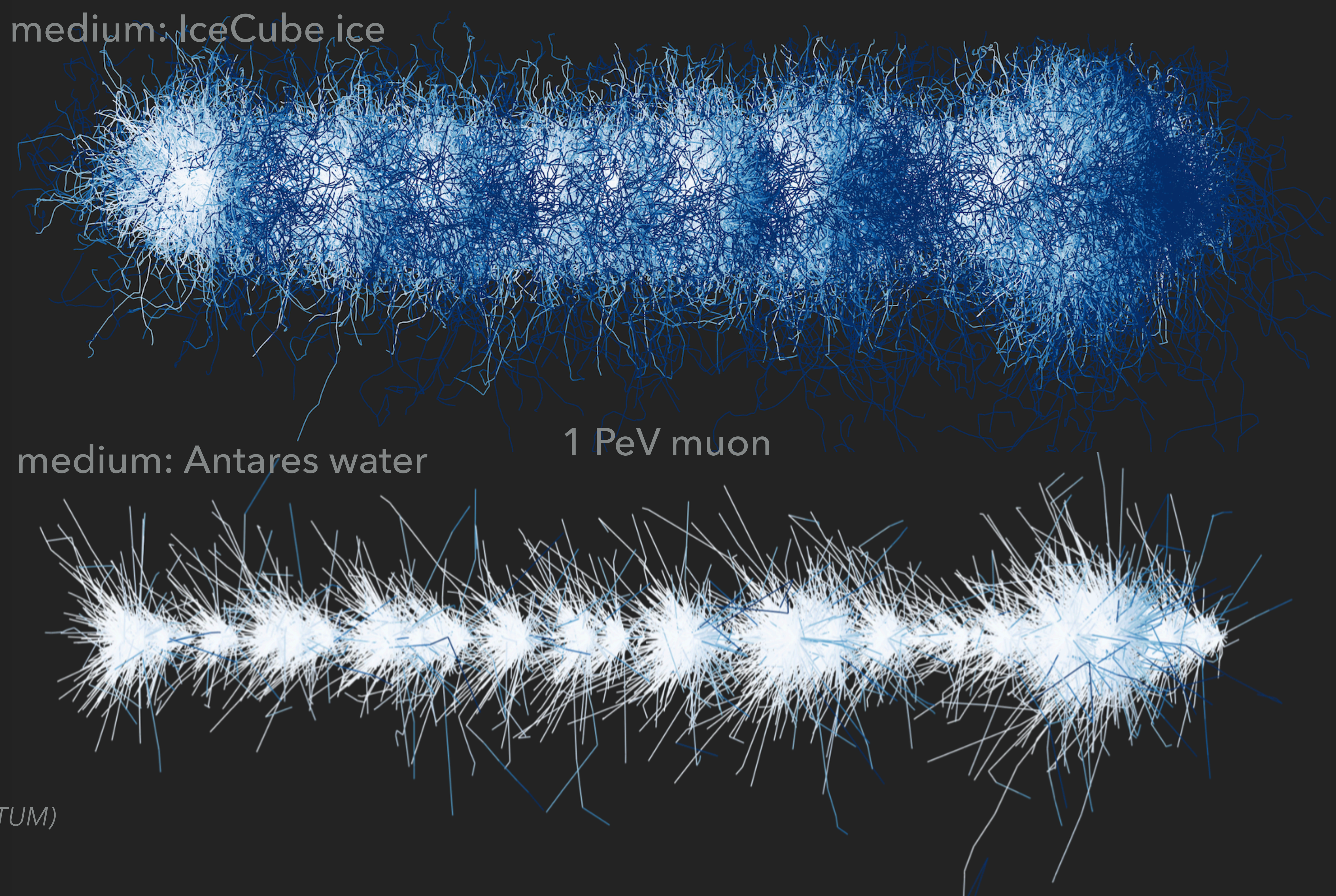
NEW ENTRY ON THE NEUTRINO MAP - PLENUM@ONC

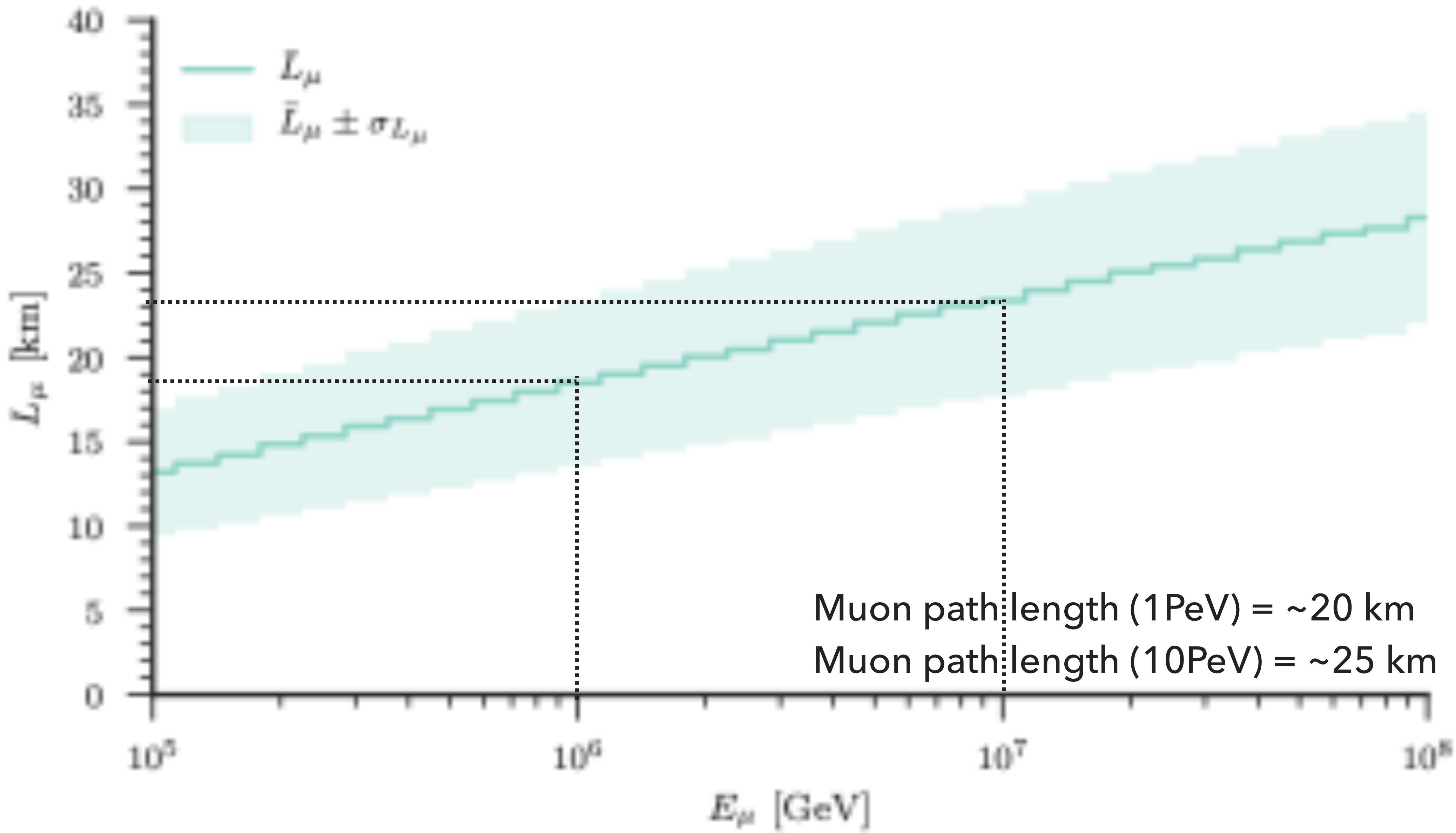
BRAINSTORMING AROUND A SEGMENTED DETECTOR FOR HE HORIZONTAL TRACKS



K. Krings (TUM)

NEUTRINO INTERACTION CHANNEL - MUON TRACKS

➡ ~1KM: SHORT FOR HIGH ENERGY MUONs



K. Krings (TUM)

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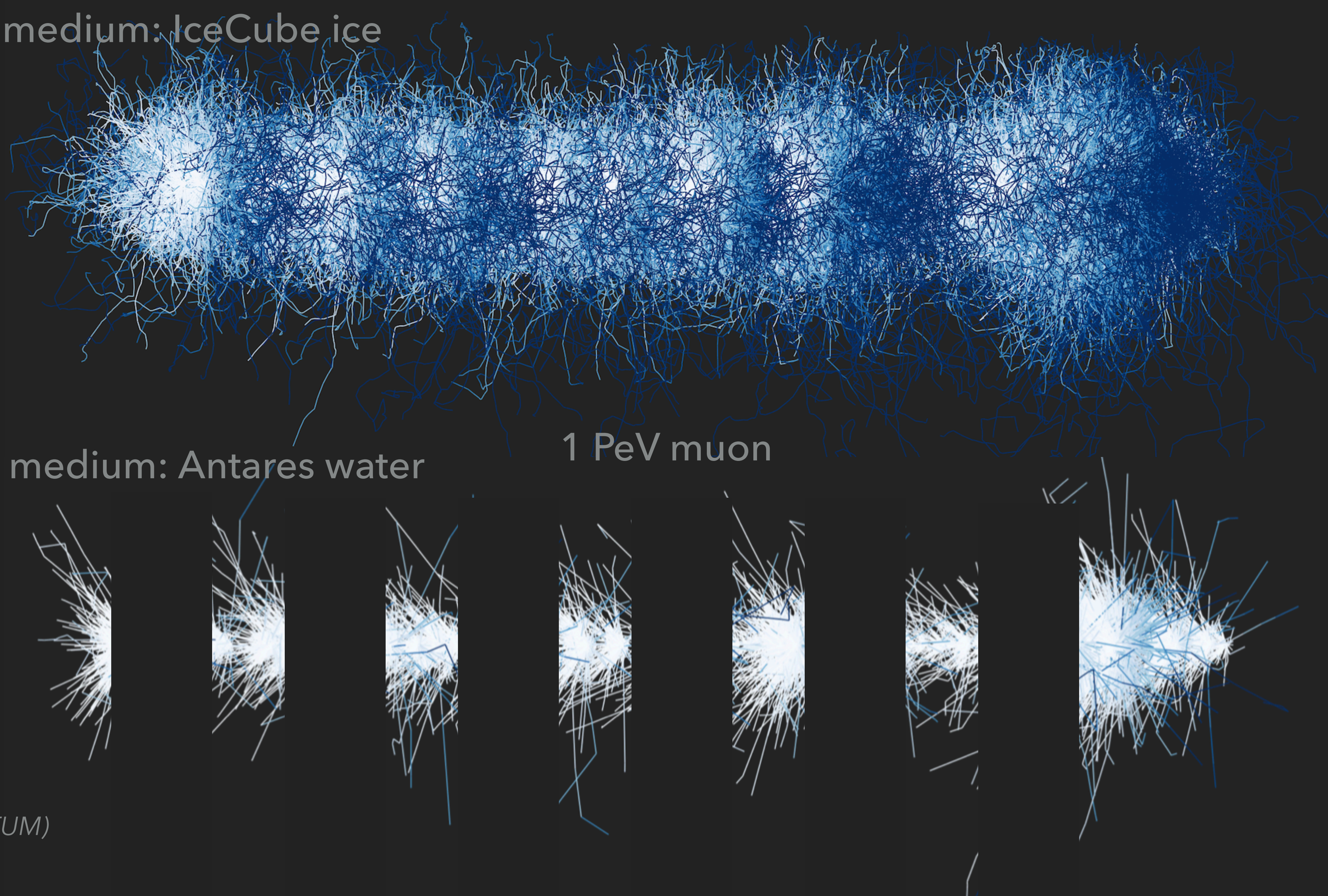
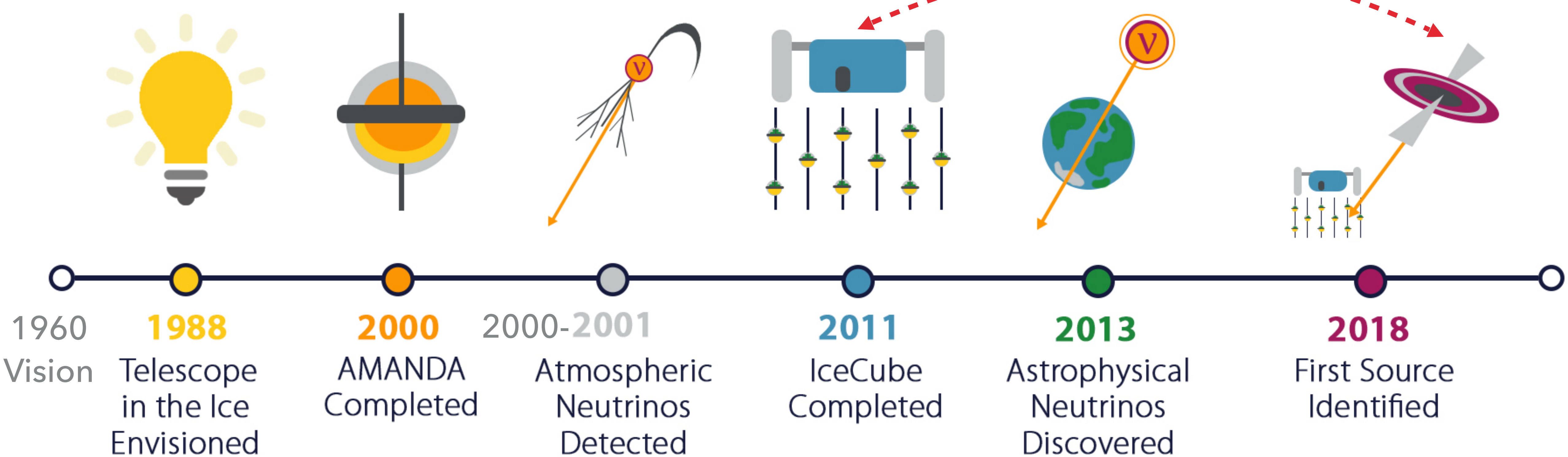


K. Krings (TUM)

A History of Neutrino Astronomy in Antarctica

IceCube and MM partners *first* association to a source

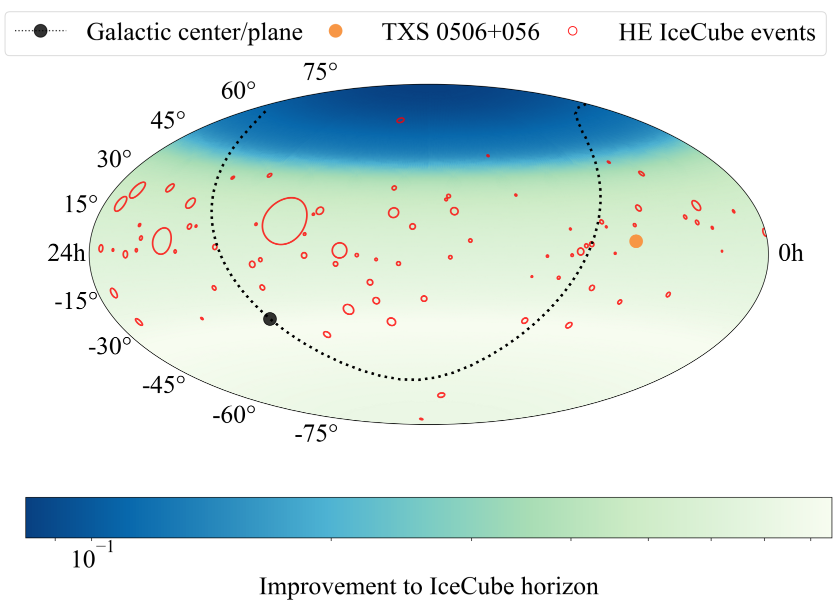


IceCube discovery of *diffuse* astrophysics neutrinos

PLEνM

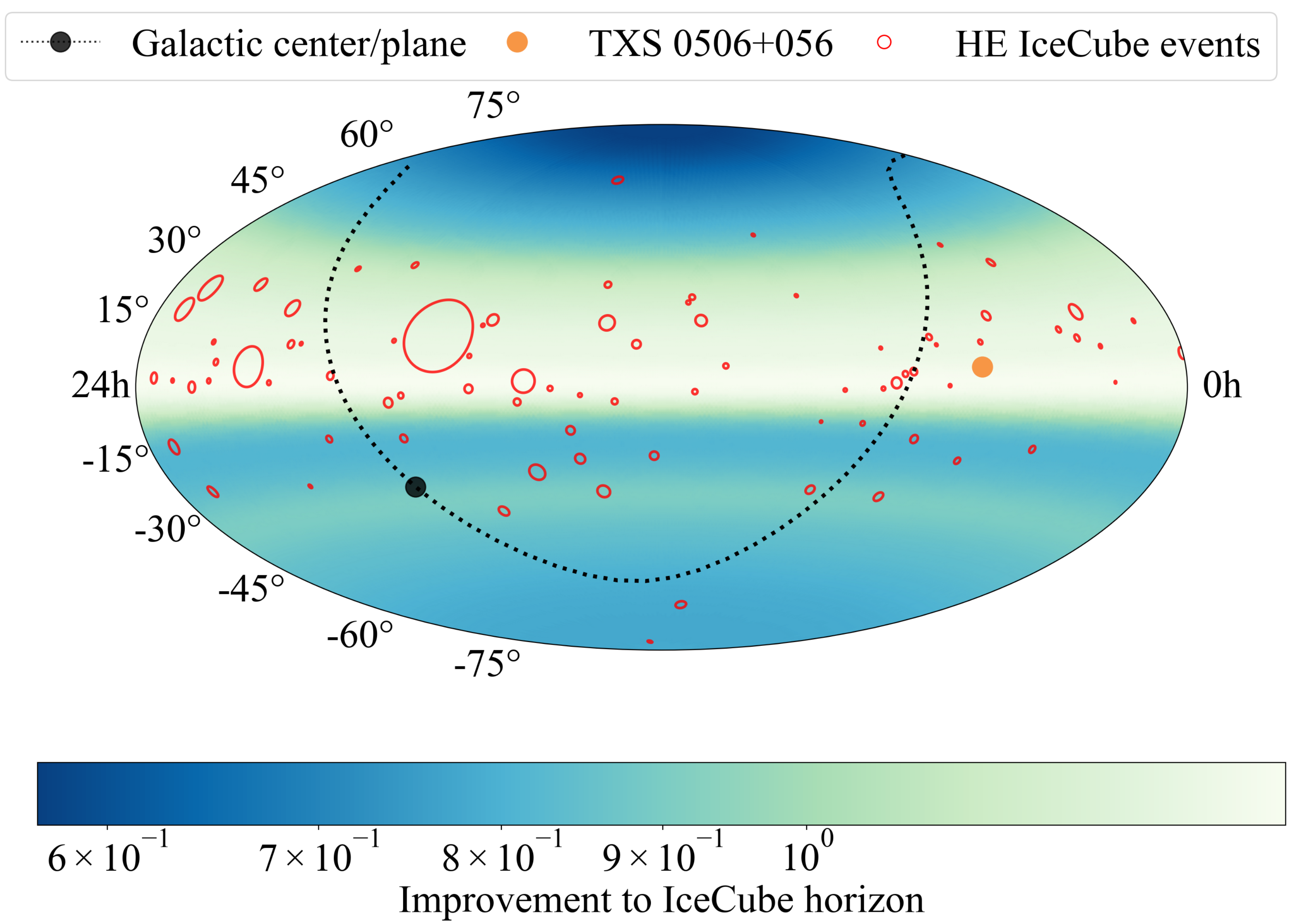
ICECUBE & BAIKAL (OR ANOTHER SINGLE SITE IN THE NORTH)

➡ RELATIVE IMPROVEMENT VS ICECUBE HORIZON BEST SENSITIVITY



GVD only

GVD+IceCube / IceCube horizon



on going study by M. Huber (TUM)

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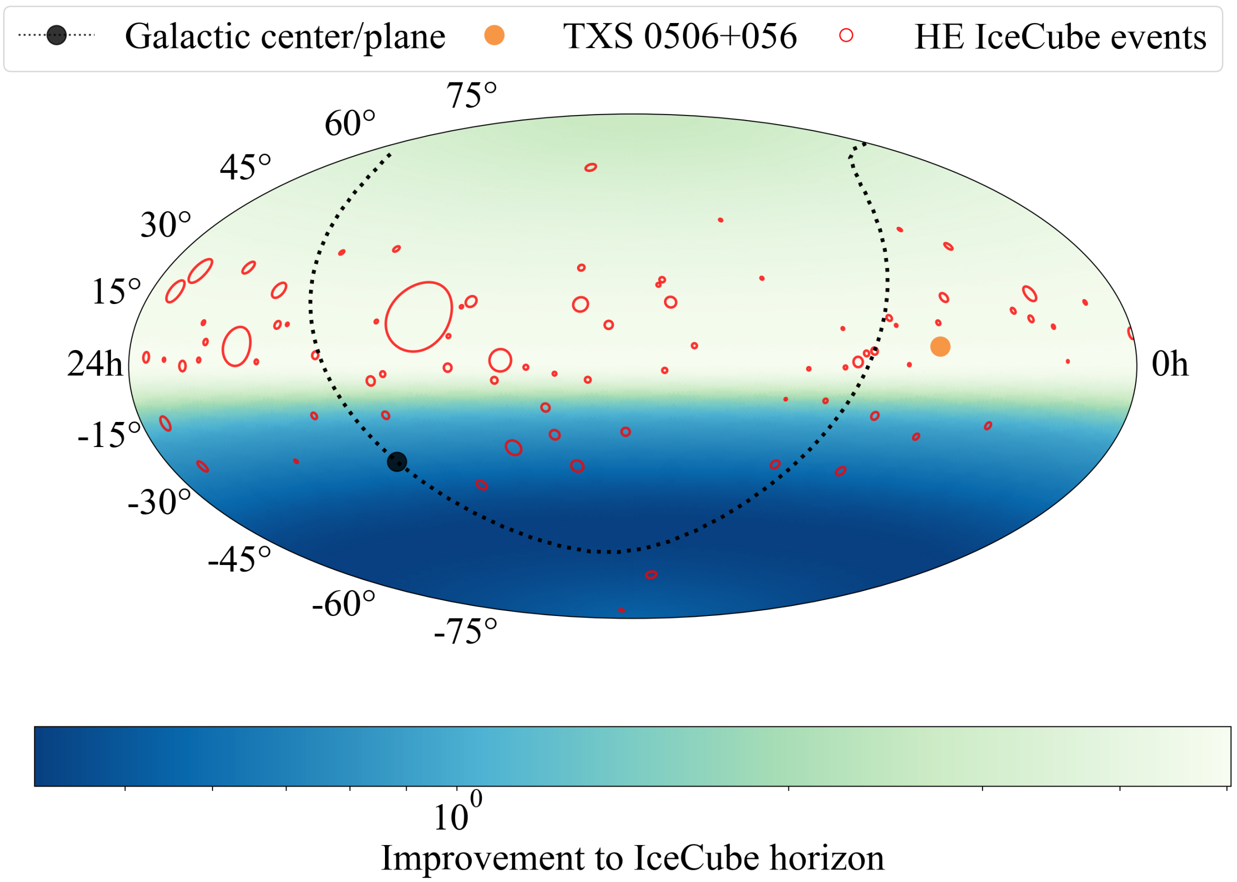
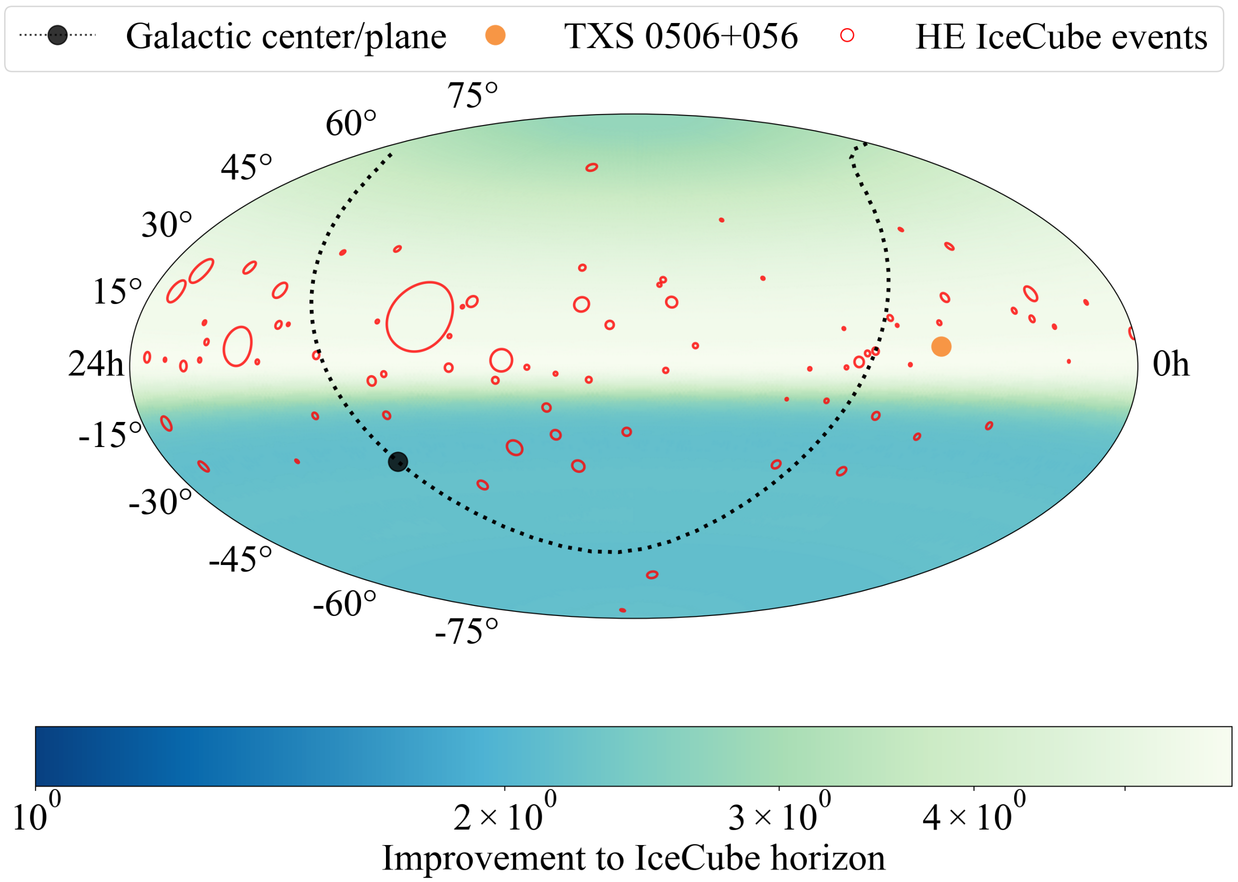
➡ RELATIVE IMPROVEMENT VS ICECUBE HORIZON BEST SENSITIVITY

IceCube vs Gen2



IceCube vs Gen2+GVD+KM3NeT+ONC



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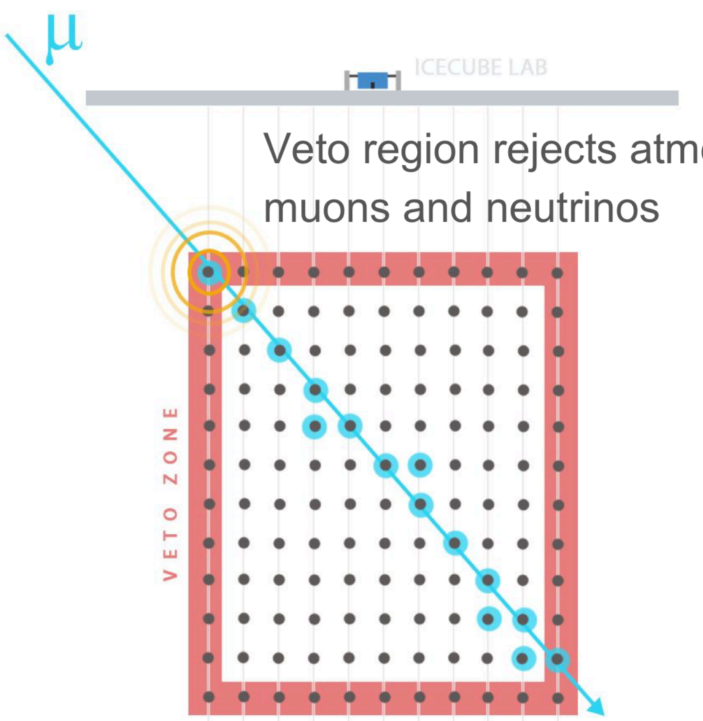
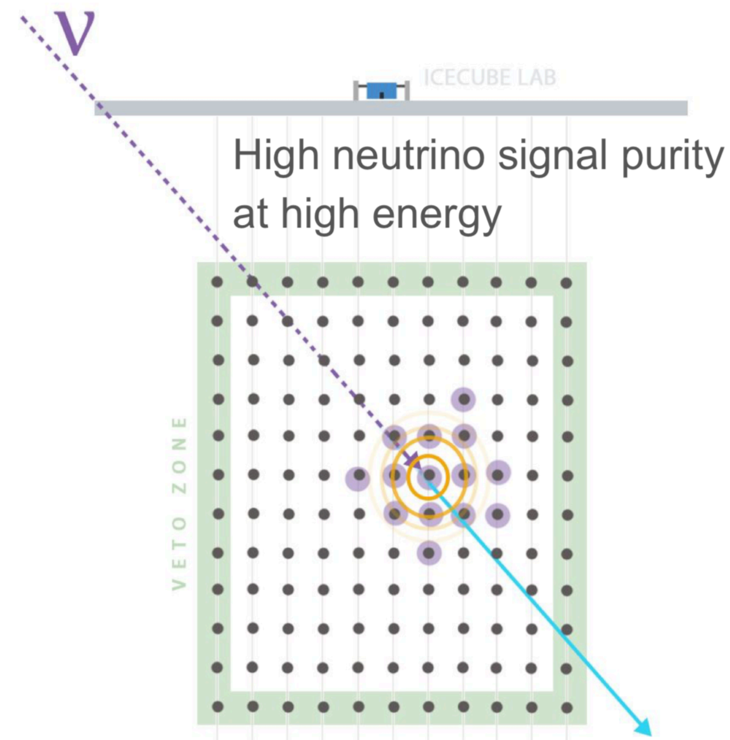
Starting Events



Veto region rejects atmospheric muons and neutrinos



High neutrino signal purity at high energy

1960 Vision

1988 Telescope in the Ice Envisioned

2000 AMANDA Completed

2001 Atmospheric Neutrinos Detected

2011 IceCube Completed 1km³

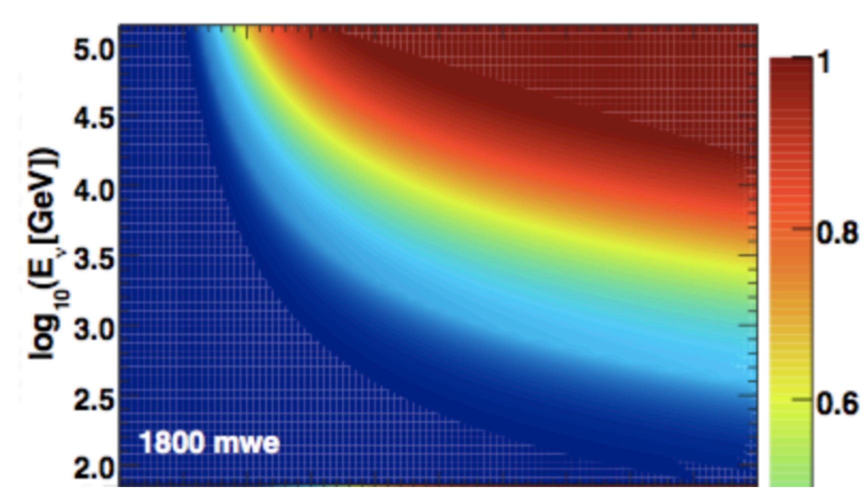
2013 Astrophysical Neutrinos Discovered

DUMAND concept: Pacific Ocean (Hawaii)

ANTARES: 0.01km³ France

Design of atmospheric neutrino veto @ MPIK

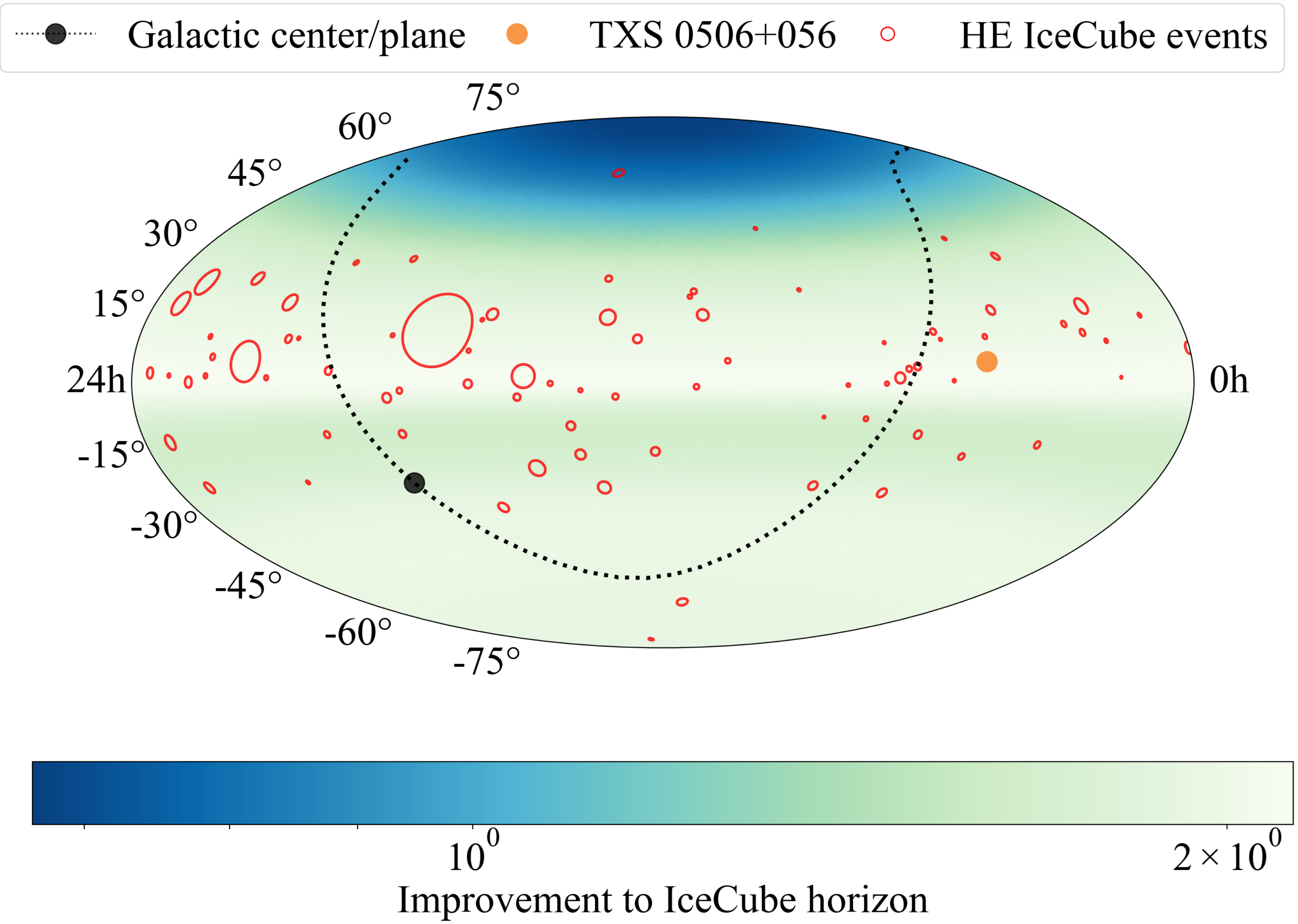
S. Schonert, T. K. Gaisser, E.R., O. Schulz, *Vetoing atmospheric neutrinos in a high energy neutrino telescope.* Phys.Rev. D79 (2009) 043009



PLEνM

ICECUBE & BAIKAL & CAPO PASSERO & OCEAN NETWORK CANADA

➡ RELATIVE IMPROVEMENT VS ICECUBE HORIZON BEST SENSITIVITY



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