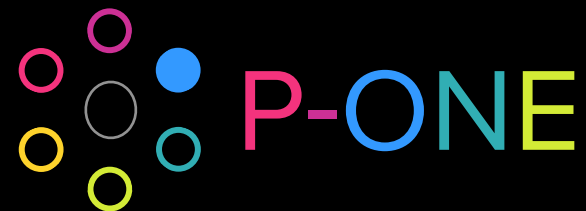


Pacific Ocean Neutrino Experiment



Elisa Resconi
Technical University of Munich
Bormio - 30.01.2025



Pacific Ocean Neutrino Experiment



*Everything you've ever imagined doing with
neutrinos (and why it's worth doing)*

Elisa Resconi

Technical University of Munich

Bormio - 30.01.2025



Neutrino missions

1. Understand neutrino properties
2. Probe cosmic neutrino factories
3. Discover new physics using cosmic neutrinos

Neutrino missions

IceCube Neutrino Observatory

1. Understand neutrino properties
2. Probe cosmic neutrino factories
3. Discover new physics using cosmic neutrinos

Neutrino missions

IceCube Neutrino Observatory

1. Understand neutrino properties

P-ONE aspiration

2. Probe cosmic neutrino factories

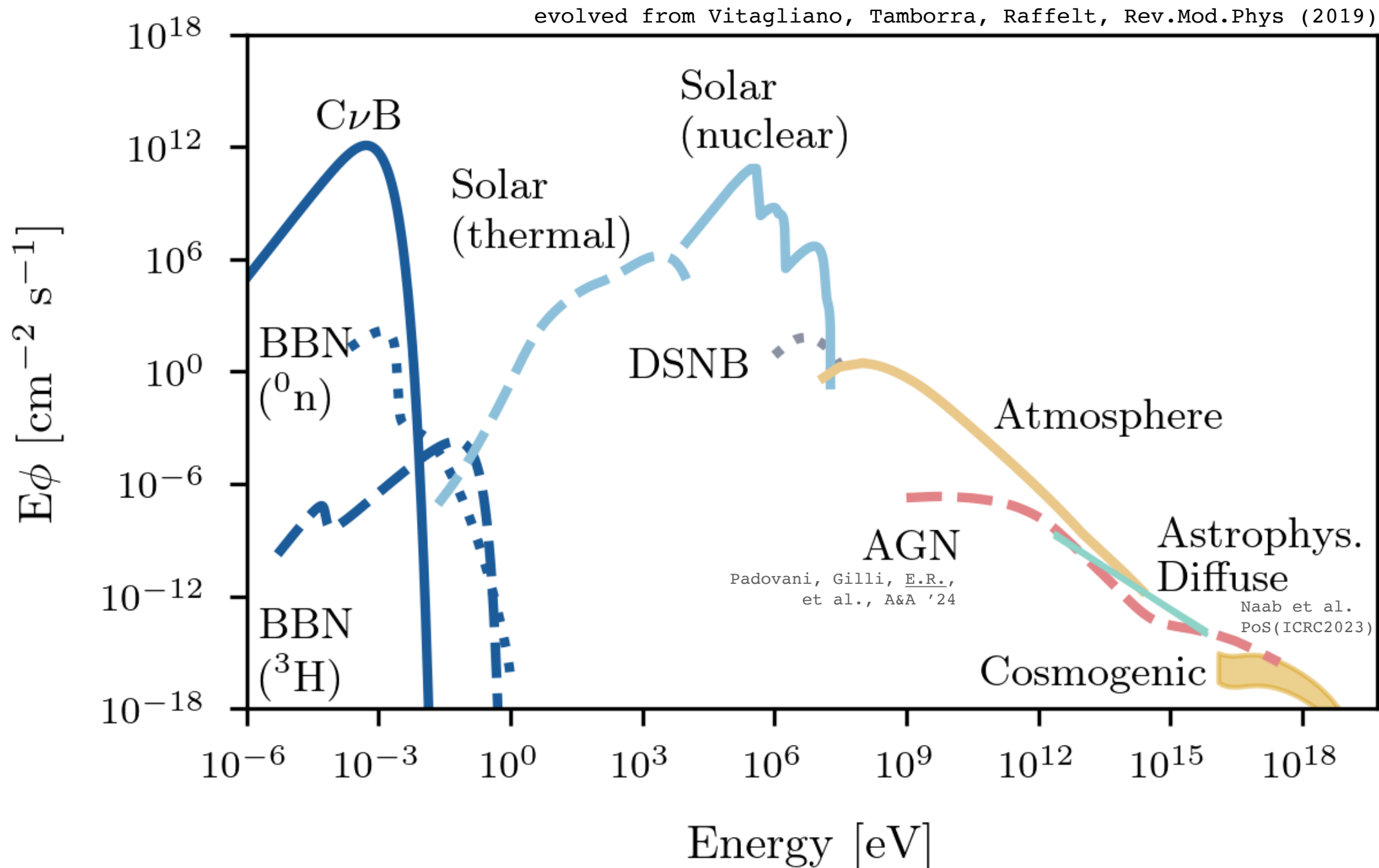
3. Discover new physics using cosmic neutrinos

in R&D phase

Neutrino Sources

Neutrino Sources: natural ones

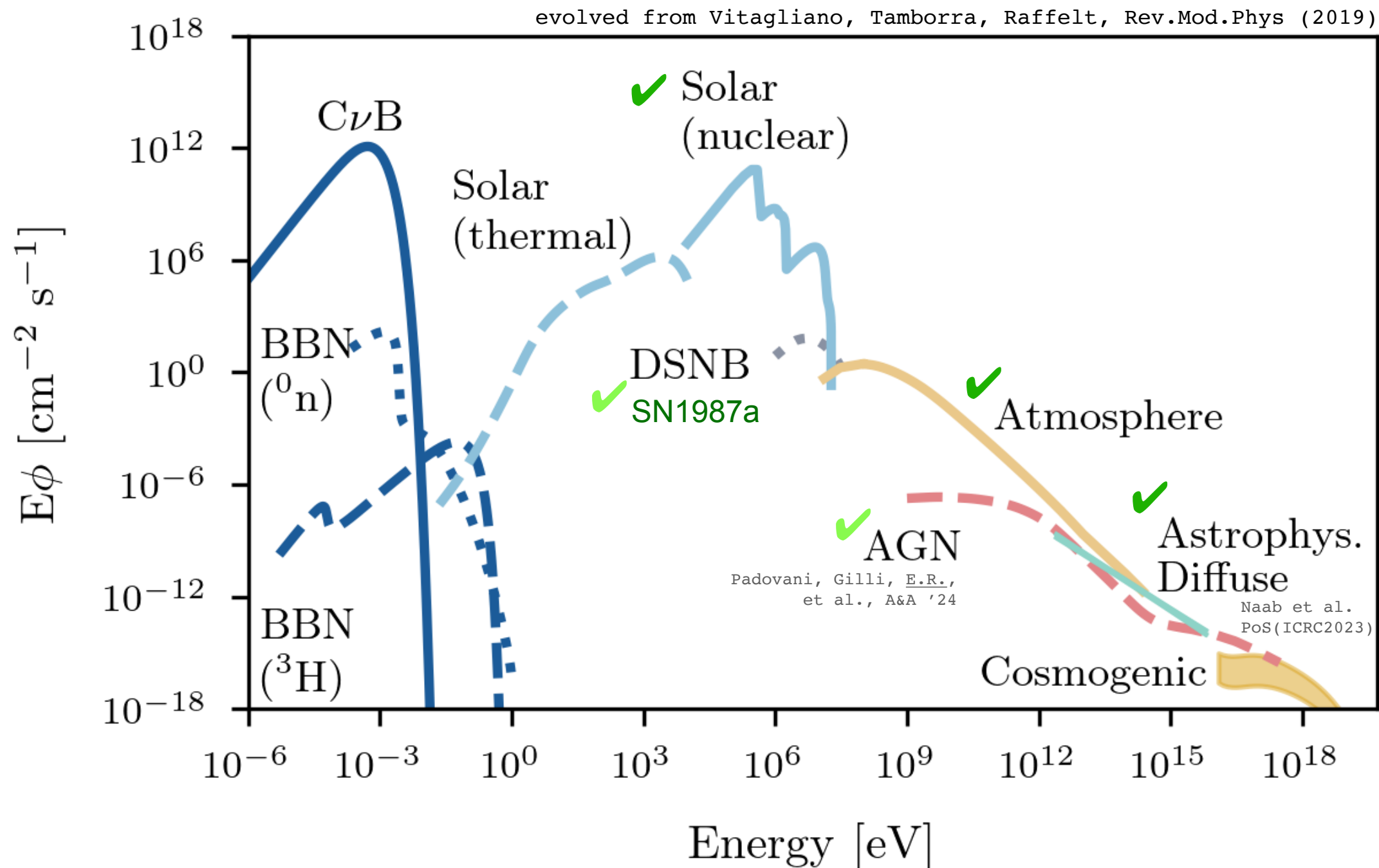
Grand Unified Neutrino Spectrum (GUNS) at Earth integrated over directions and flavors



Neutrino Sources: natural ones

Grand Unified Neutrino Spectrum (GUNS) at Earth integrated over directions and flavors

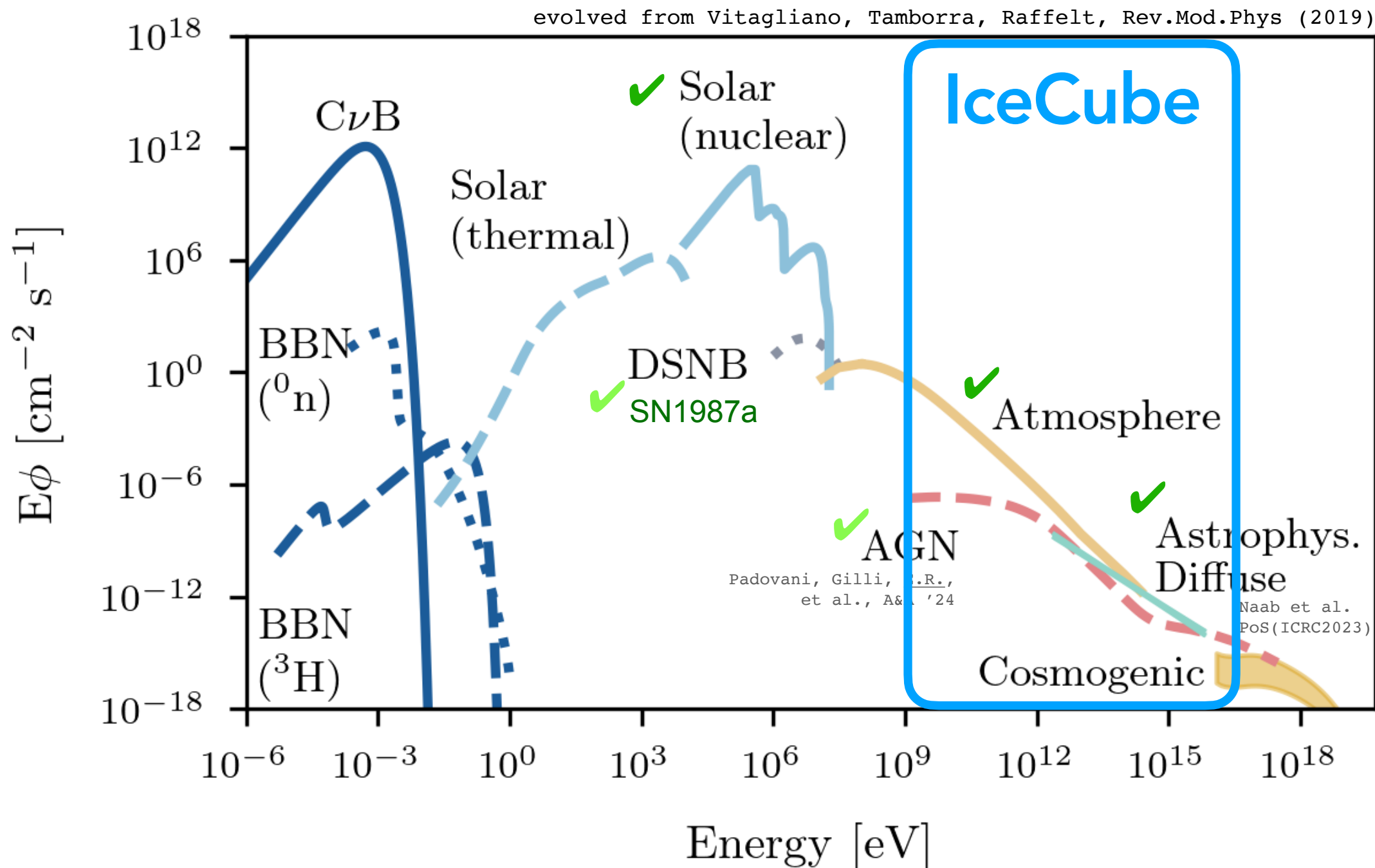
✓ Detected ✓ Associated



Neutrino Sources: natural ones

Grand Unified Neutrino Spectrum (GUNS) at Earth integrated over directions and flavors

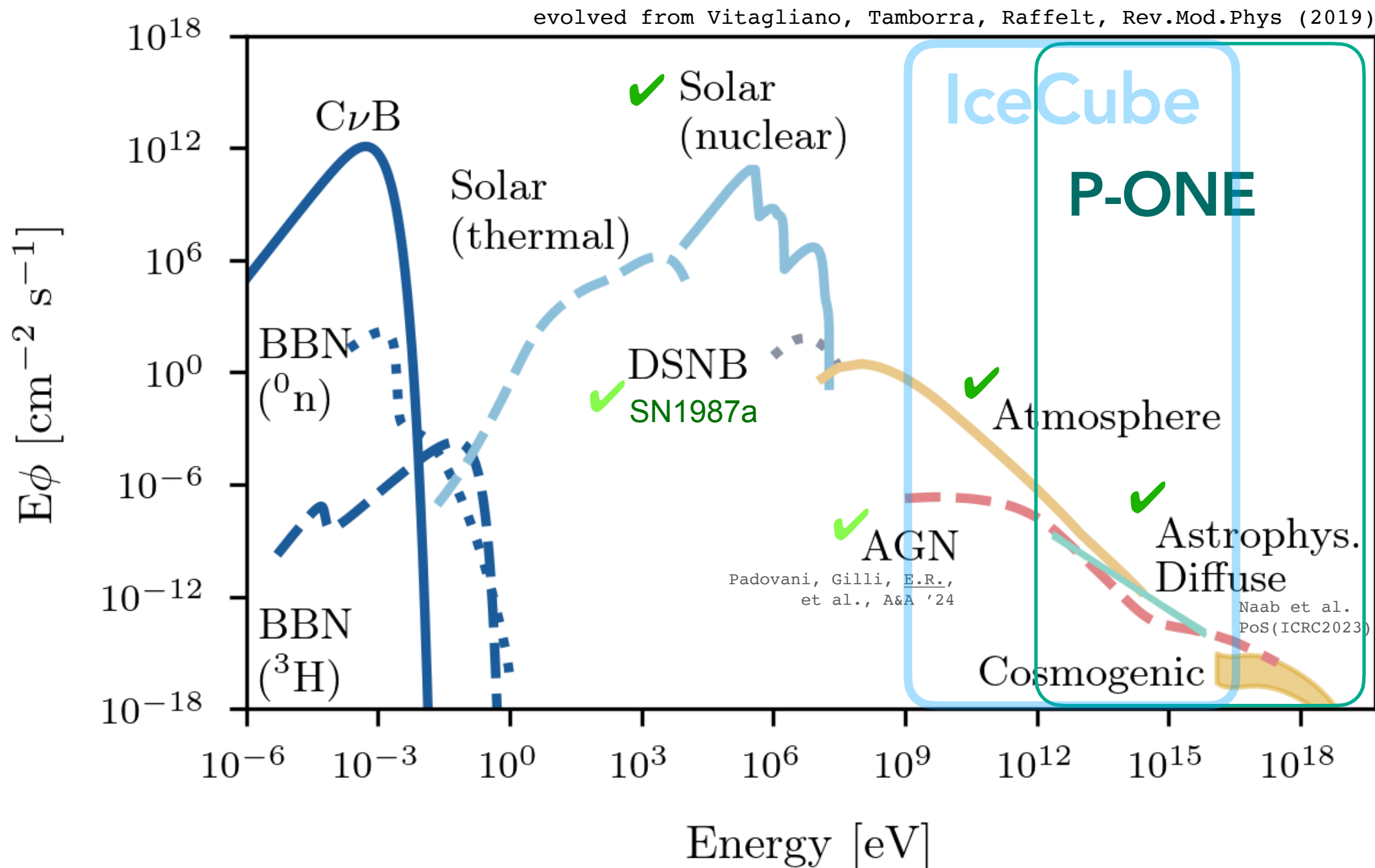
✓ Detected ✓ Associated



Neutrino Sources: natural ones

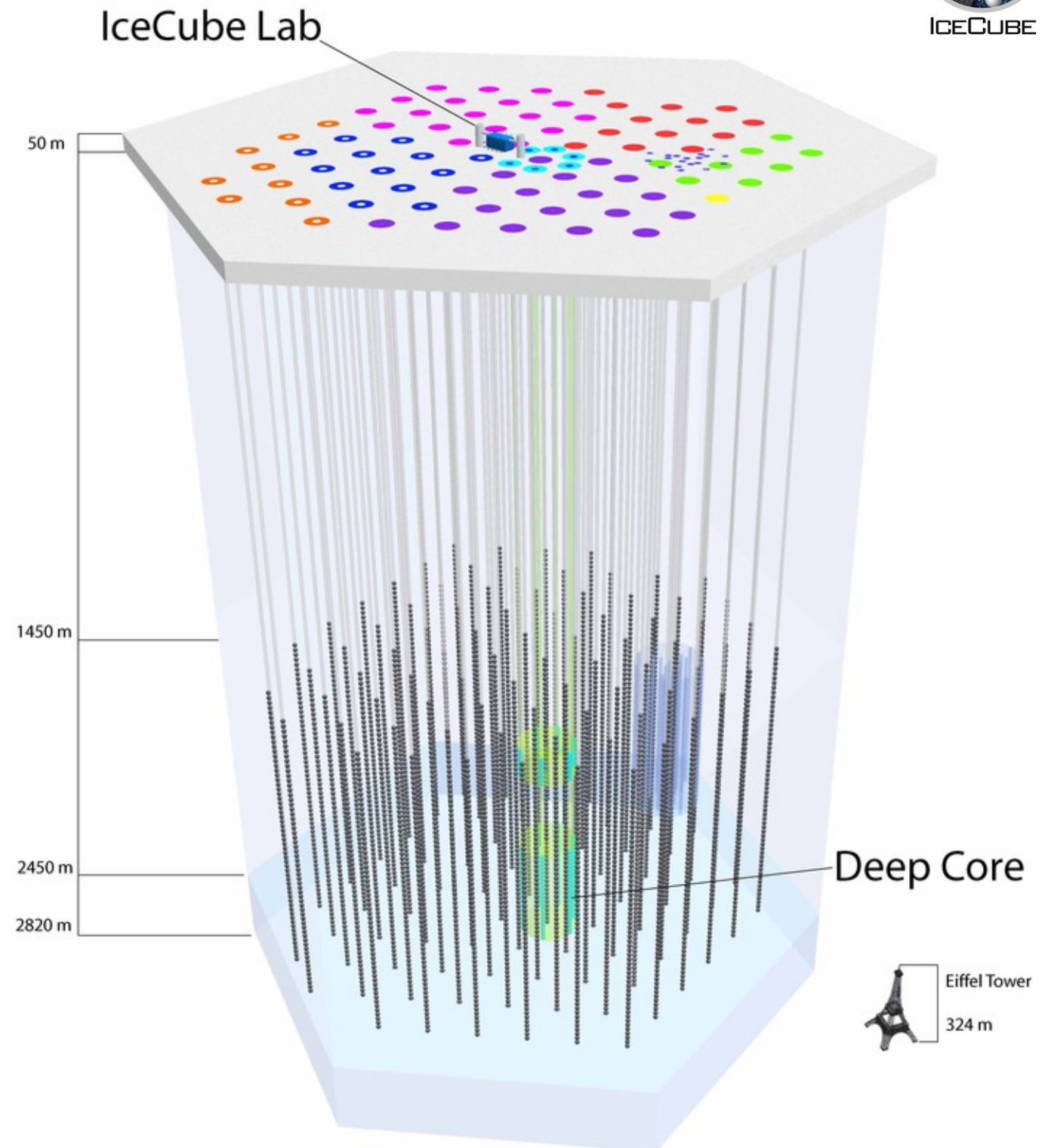
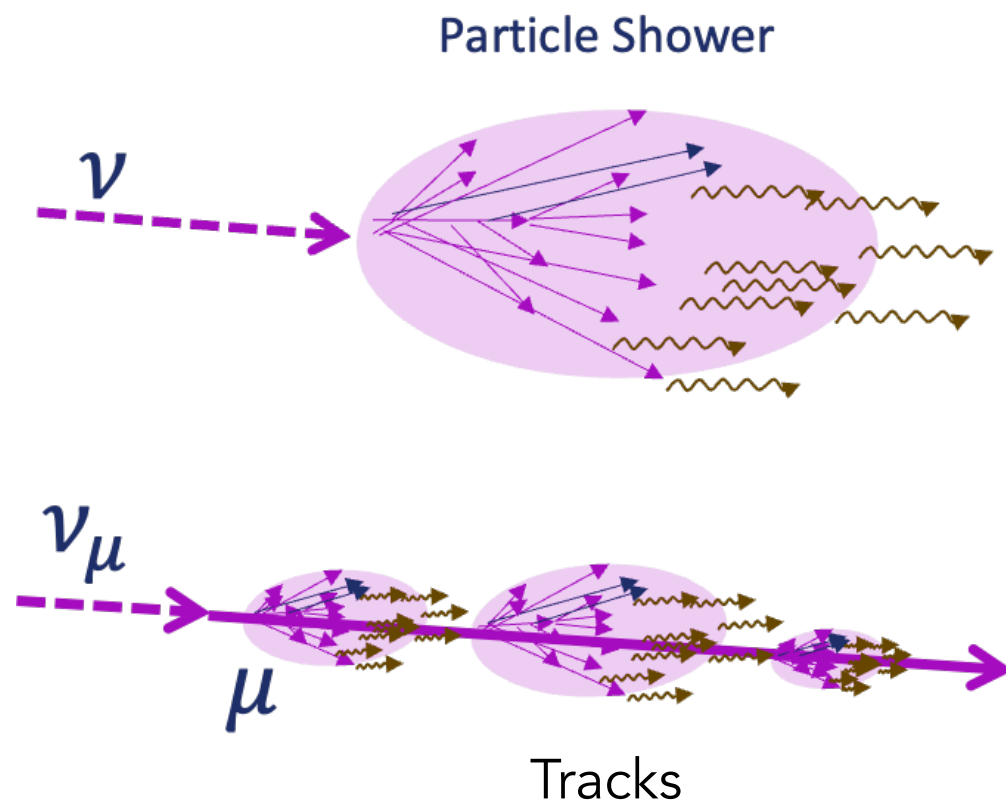
Grand Unified Neutrino Spectrum (GUNS) at Earth integrated over directions and flavors

✓ Detected ✓ Associated



IceCube Neutrino Observatory

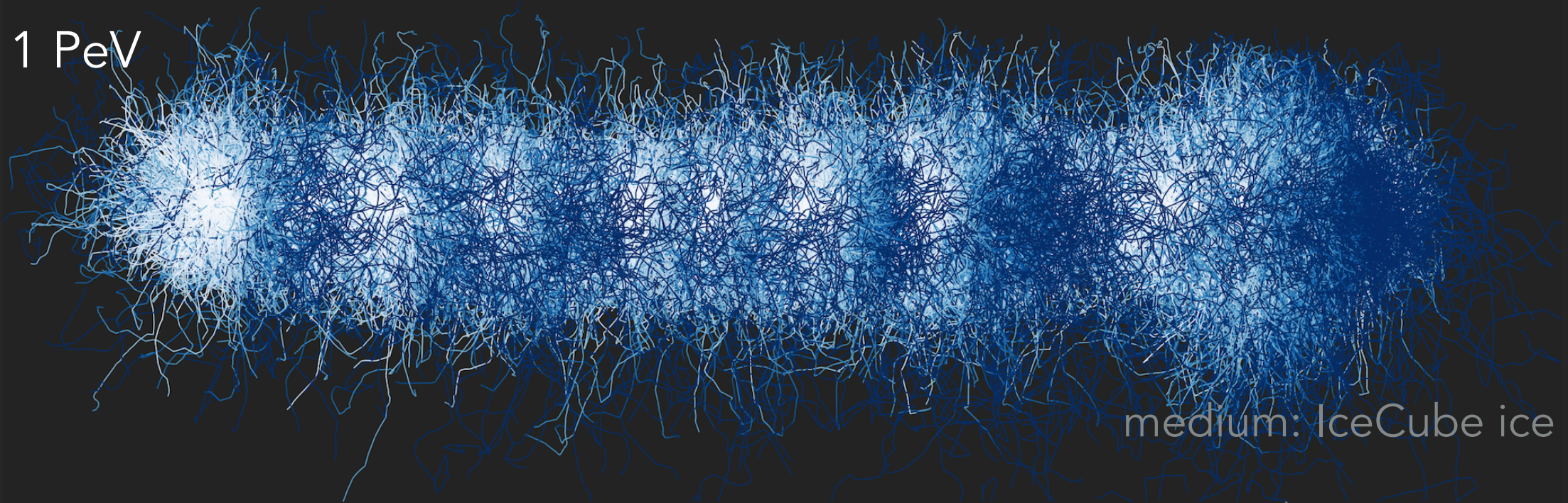
Two topological channels



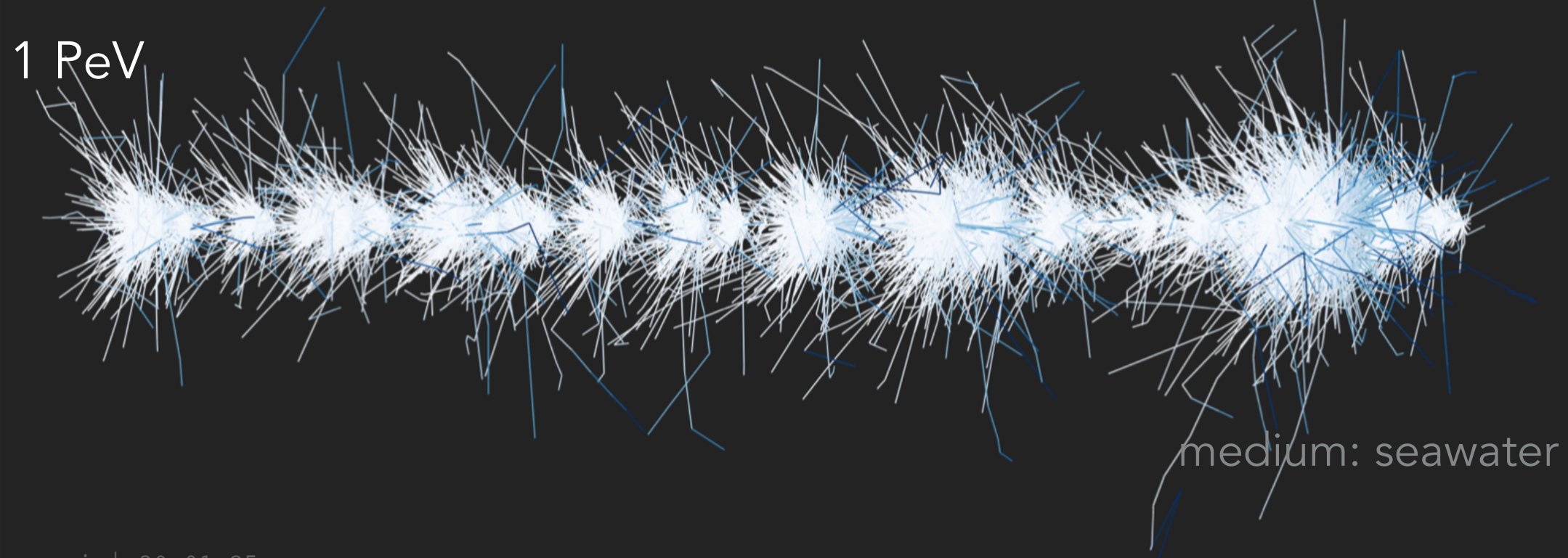
Measuring high energy muons

Driven by photosensors areas, timing, medium

1 PeV



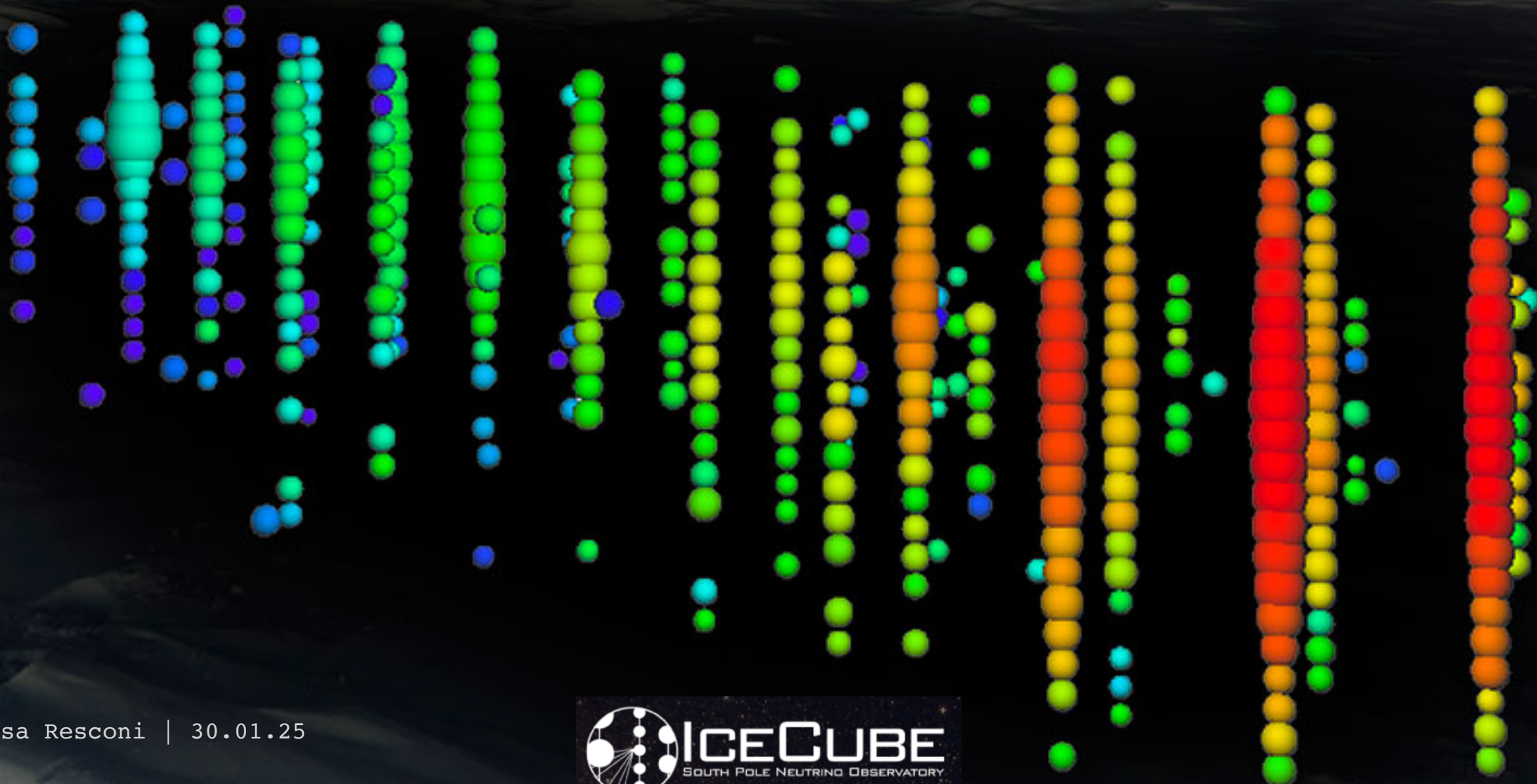
1 PeV



Cosmic Neutrinos



Fortune favours the brave



Cosmic Neutrinos

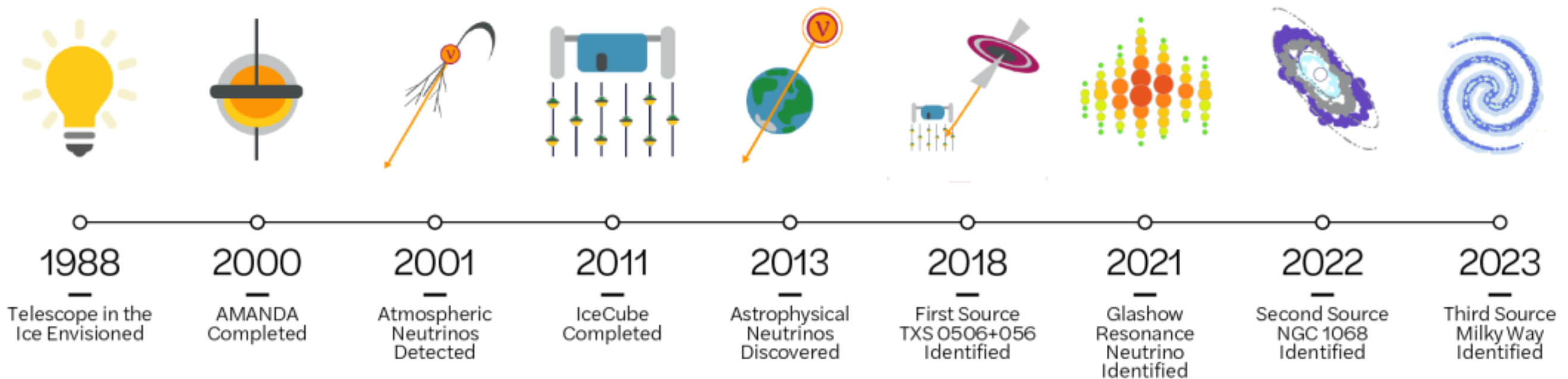
IceCube milestones

Event Rates in IceCube:

For every 1 Cosmic Neutrino,

$\sim 10^9$ Atmospheric Muons

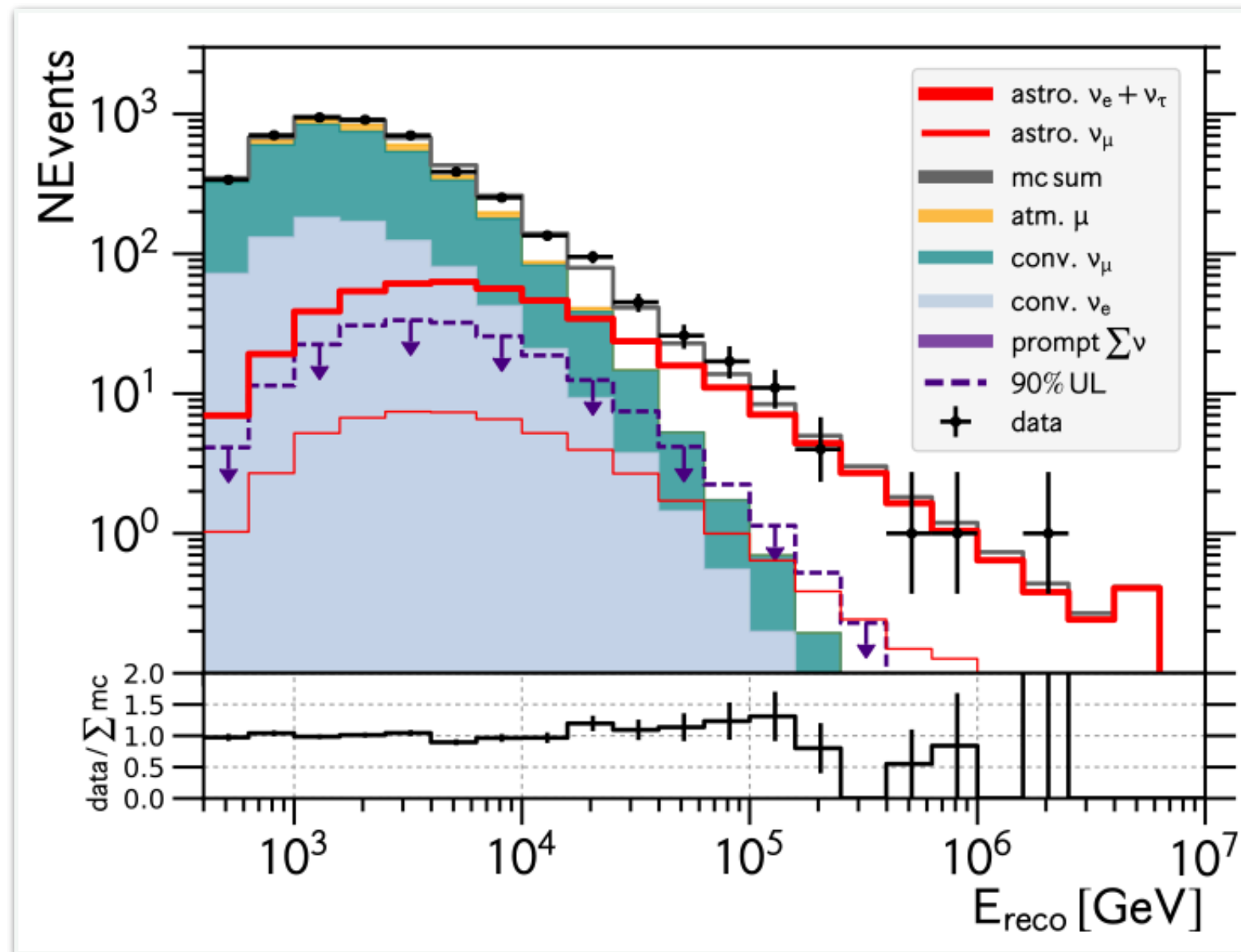
$\sim 10^3$ Atmospheric Neutrinos



The cosmic neutrino diffuse signal

The IceCube Coll., *PRL* '20
 The IceCube Coll., *Nature* '21
 The IceCube Coll., *ApJ* '22
 The IceCube Coll., *PRD* '24

9.9 σ excess



Record events:

- 8.7 PeV track-like event
- 6.4 PeV shower-like
- 7 high-energy double peaked

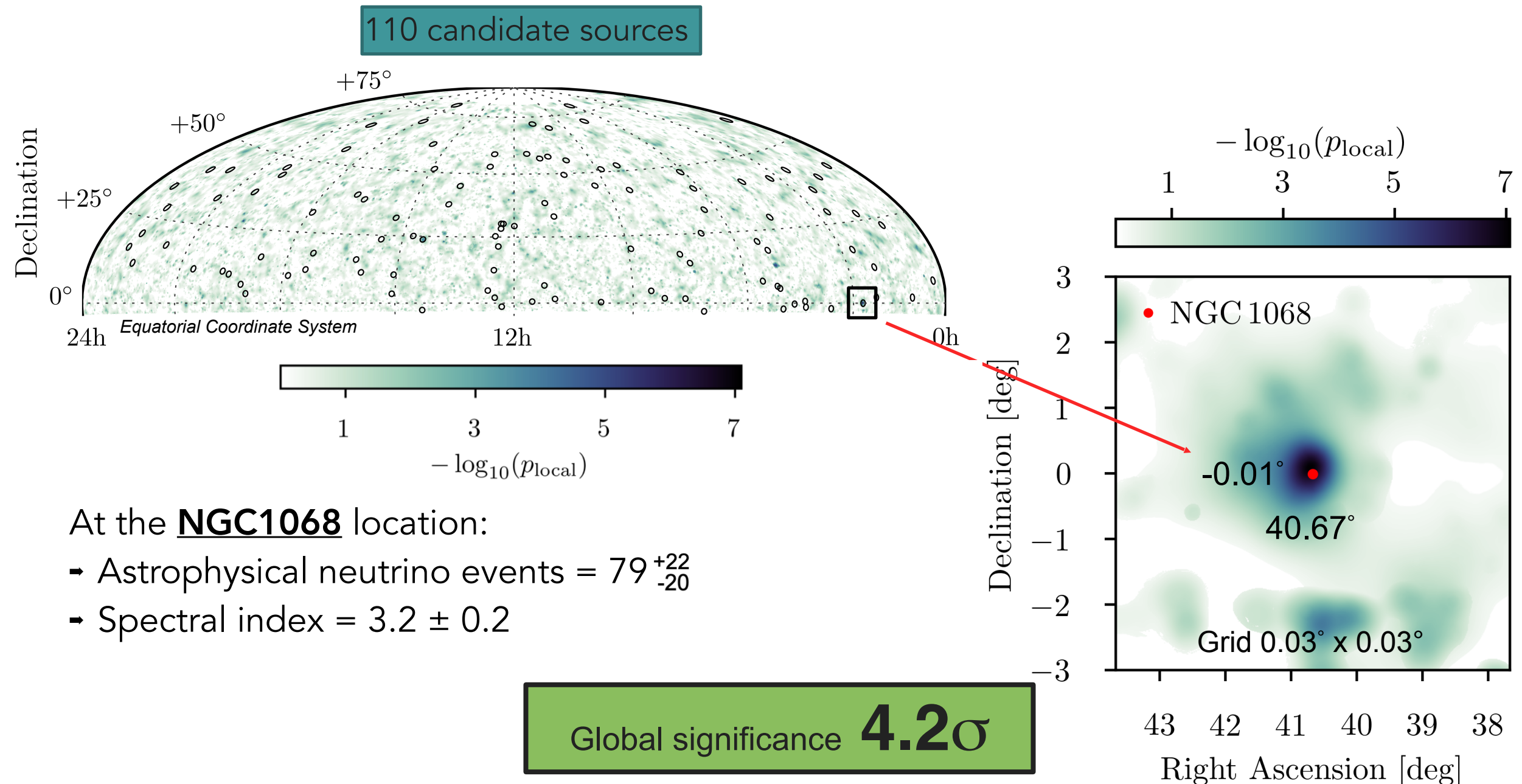
First evidences for source association

IceCube first association: **TXS 0506+056** - alert event (~ 290 TeV) and neutrino flare (2015-2016)

The IceCube Coll. and others, *Science* 361 (2018)

The IceCube Coll., *Science* 361 (2018)

The IceCube Coll., *Science* 378 (2022)



NGC 1068 ($D_L = 10.1 \pm 1.8$ Mpc)

Neutrinos from an obscured super massive black hole

P. Padovani, E.R., et al., *Nature Astronomy* '24

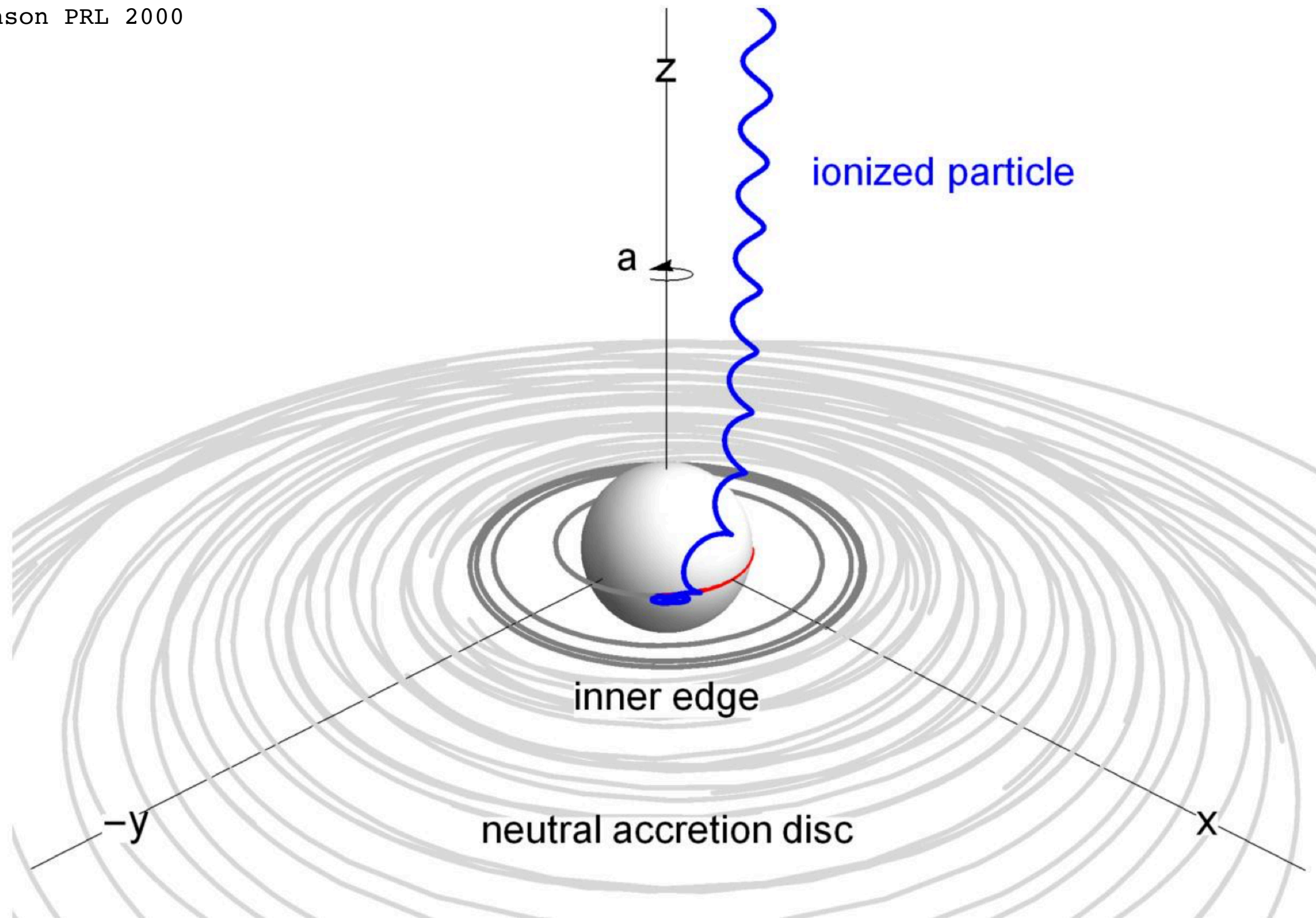
p-p & p- γ
 $E_p \sim 100$ TeV

target γ ~ X-ray domain
(Corona component)

Super Massive Black Hole as accelerator?

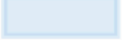
E. Boldt and P. Ghosh, MNRAS '99

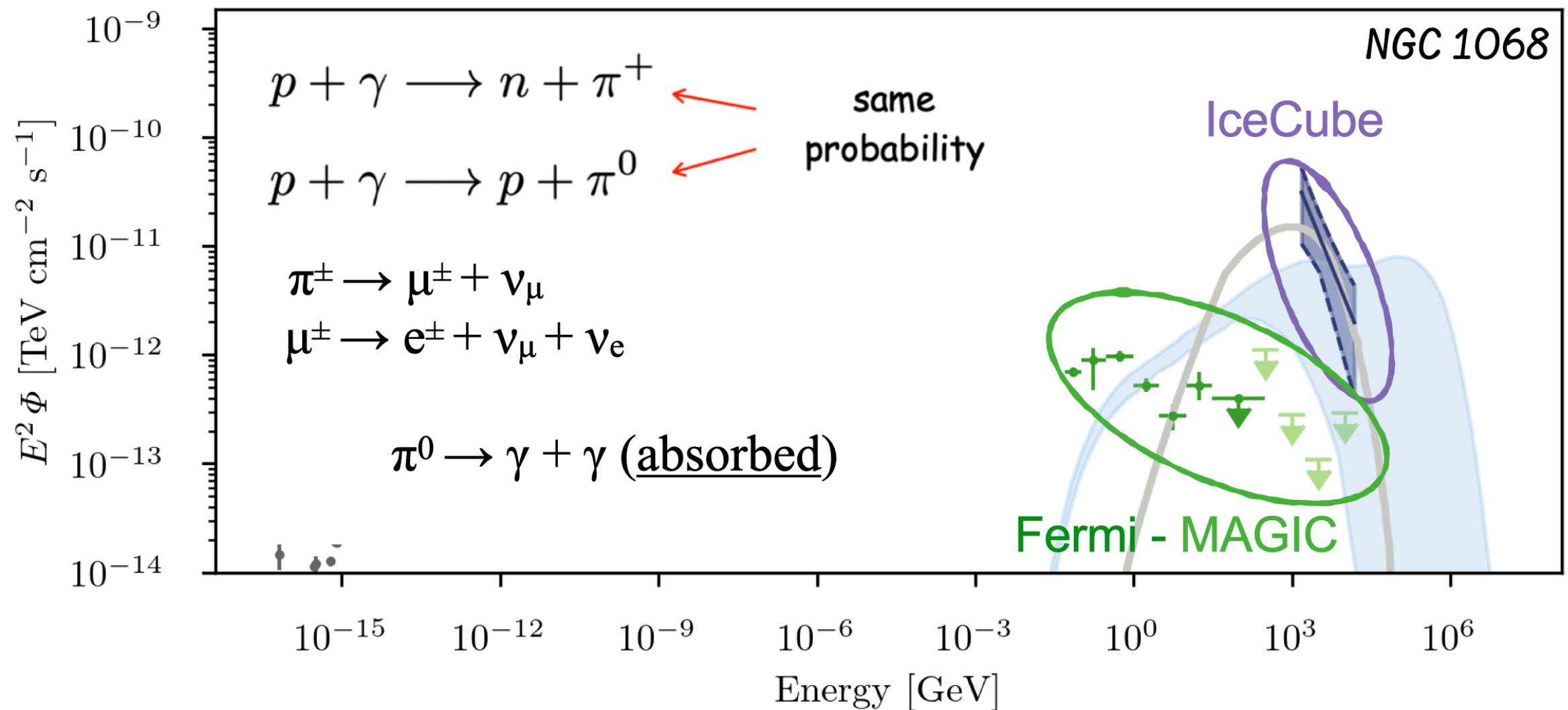
A. Levinson PRL 2000



NGC1068 is not a Gamma Ray Source

The IceCube Coll., *Science* '22

- | | | |
|--------------------------|---|---|
| |  IceCube (this work) |  Electromagnetic observations (26) |
| Y. Inoue et al., ApJL'20 |  Theoretical ν model (44,45) |  0.1 to 100 GeV gamma-rays (41,42) |
| K. Murase et al., PRL'20 |  Theoretical ν model (46) |  > 200 GeV gamma-rays (43) |



Are there similar sources?

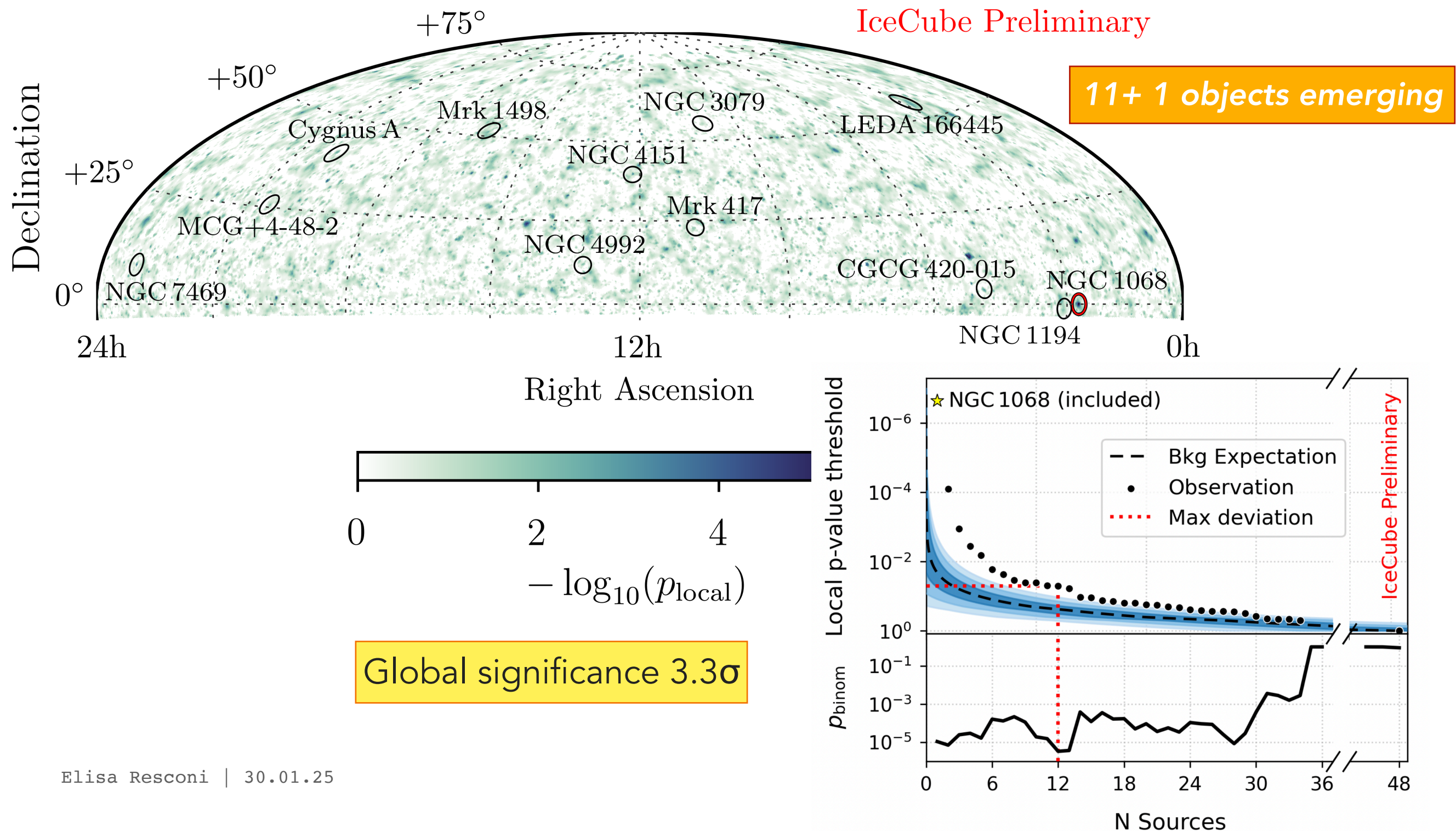
👉 new IceCube results

PRELIMINARY

What about other similar AGN as NGC1068?

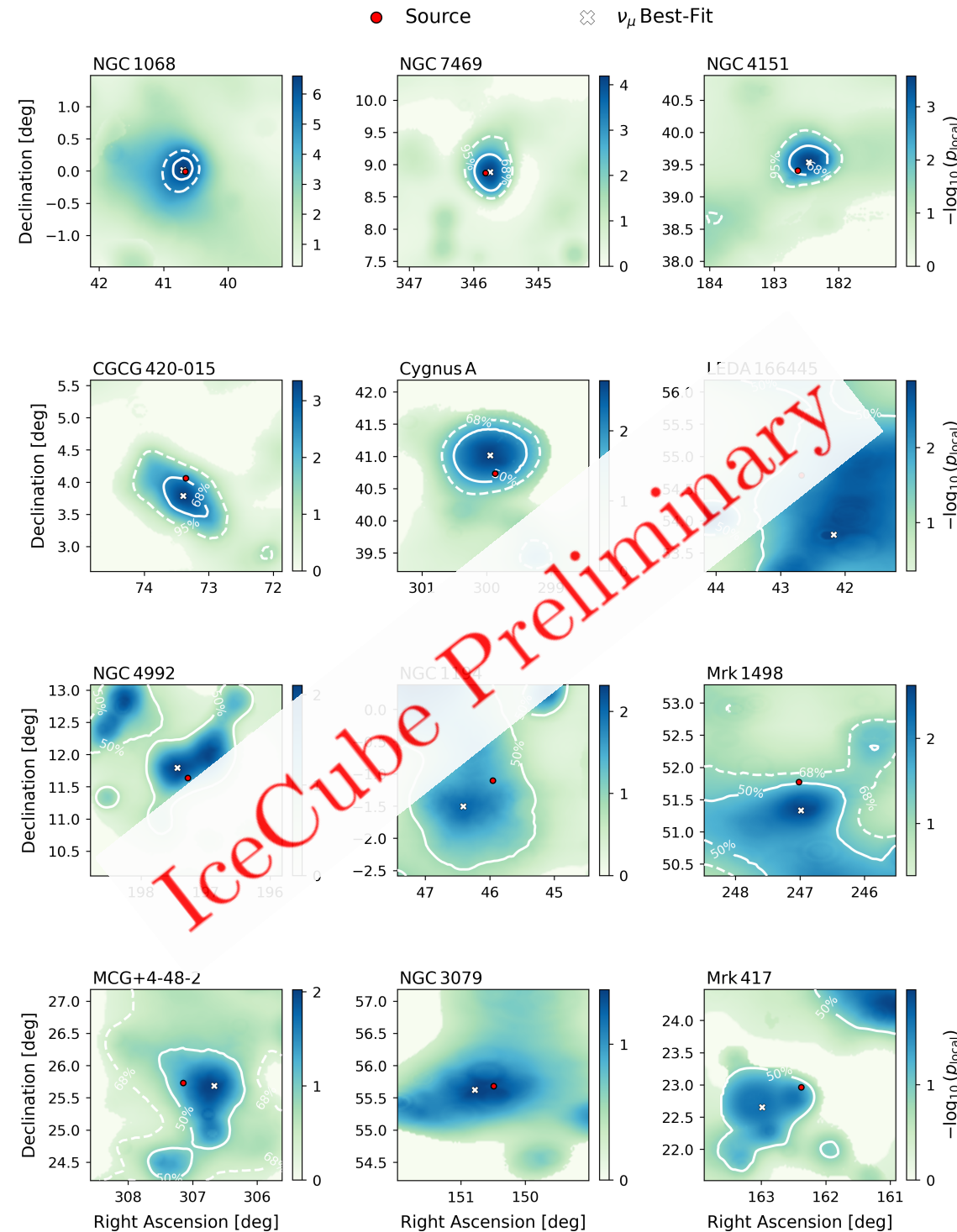
Selected a new list of 47 X-ray bright AGN

C. Bellenghi, E. Manao, T. Kontrimas, M. Ha Minh, E.R., M. Wolf (TUM) & the IceCube Coll., in preparation



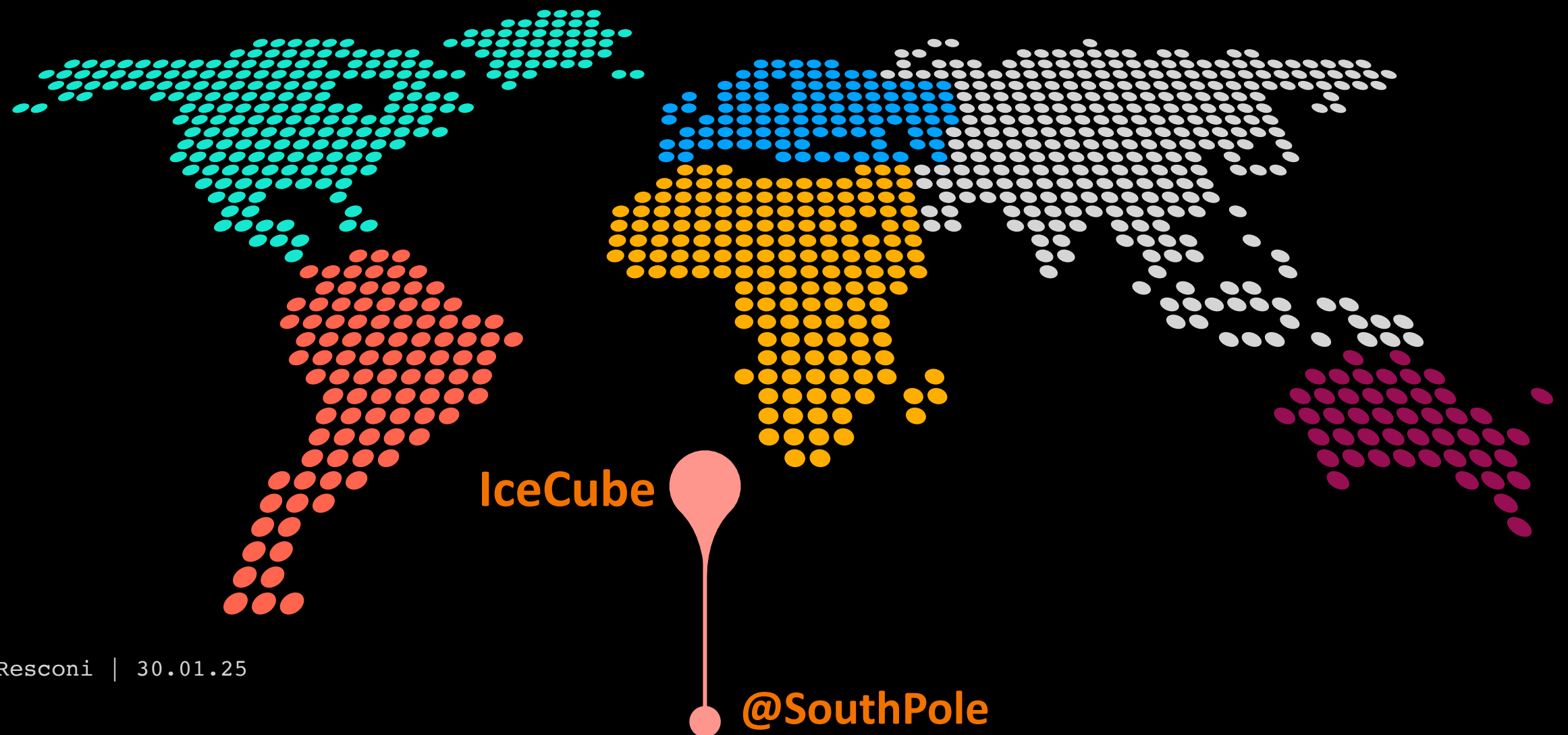
Emerging of a population of HE neutrino sources?

C. Bellenghi, E. Manao, T. Kontrimas, M. Ha Minh, E.R., M. Wolf (TUM) & the IceCube Coll., in preparation



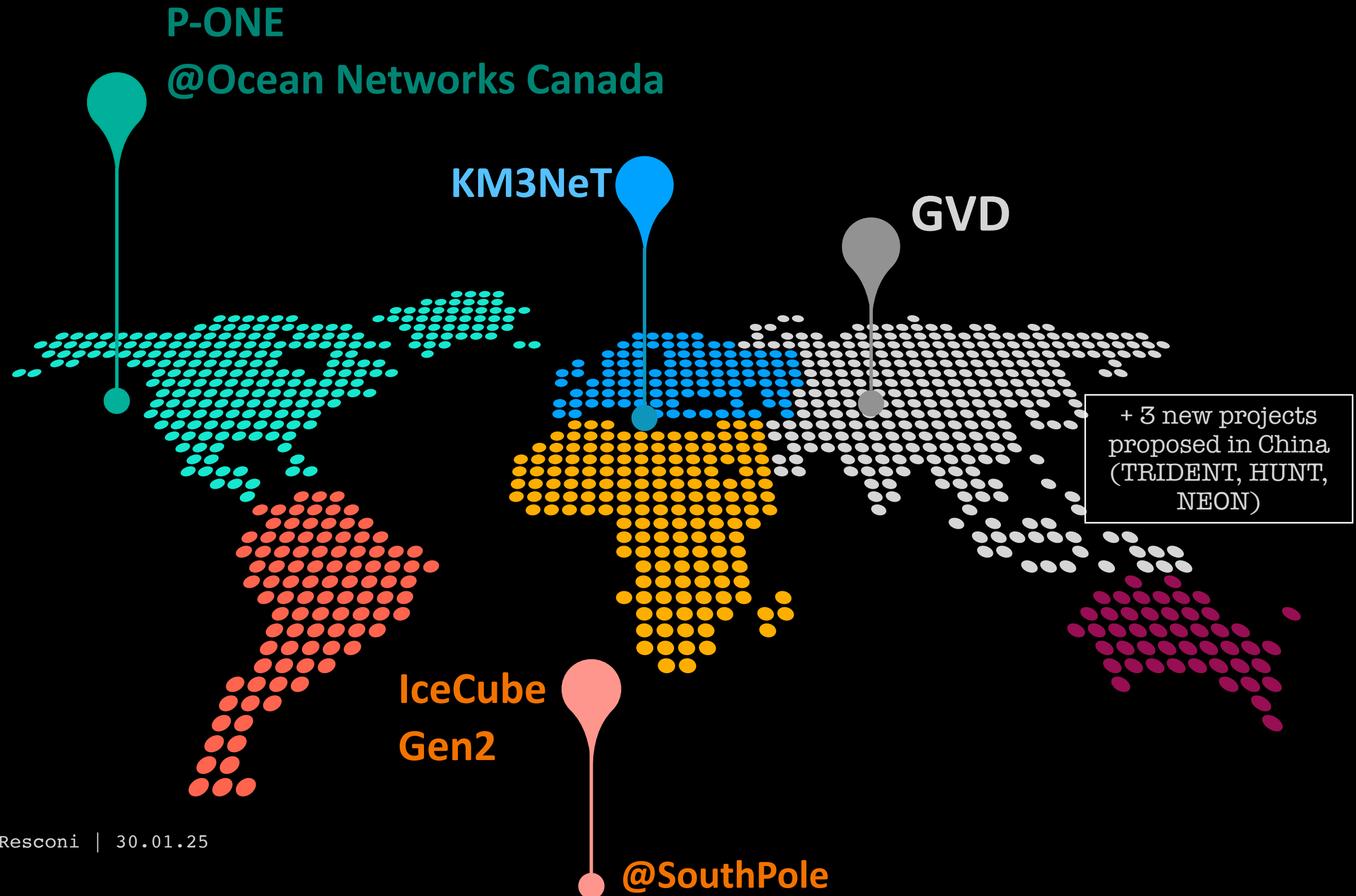
11+ 1 objects emerging

Neutrino experiments sensitive to cosmic fluxes

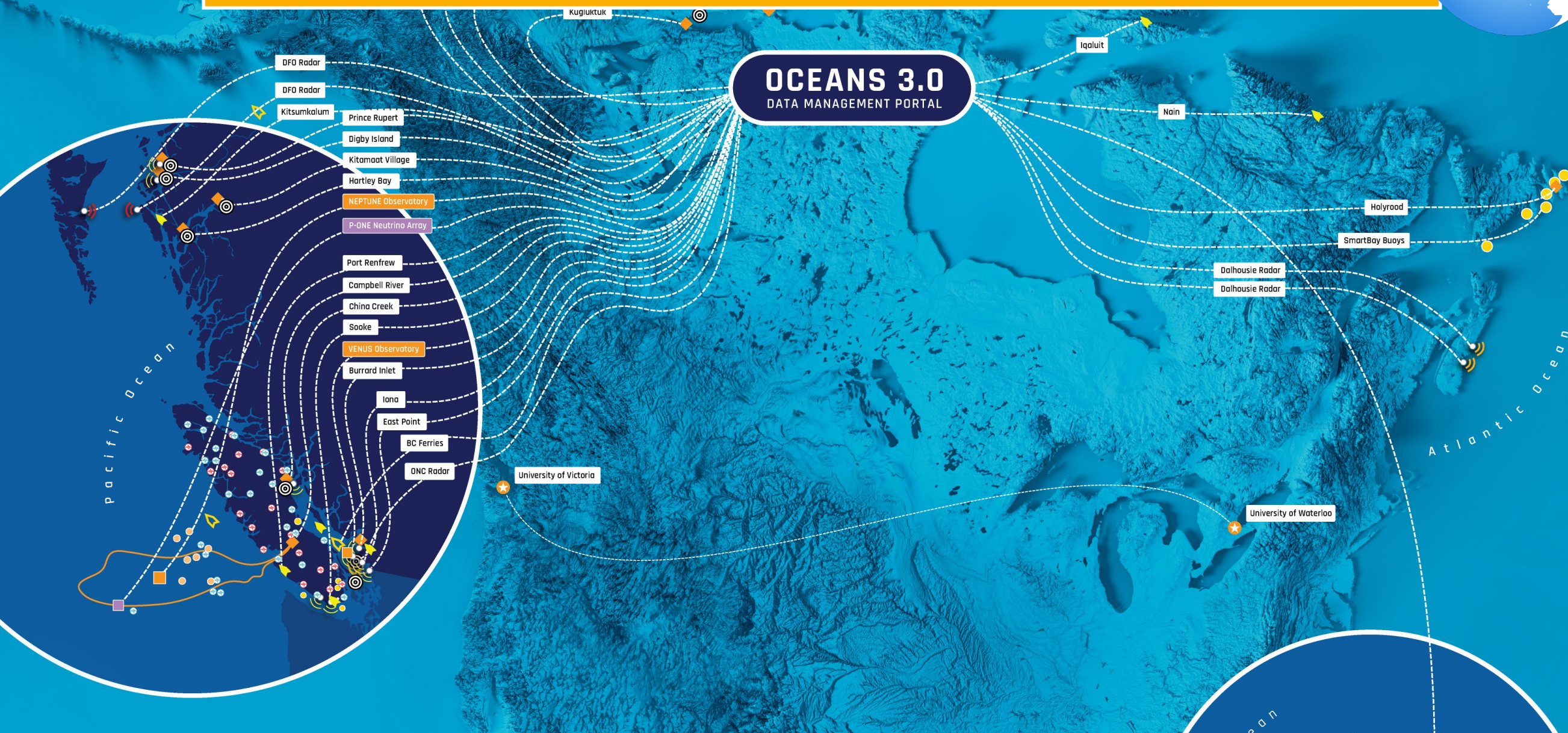


We need multiple LV neutrino experiments

L. Schumacher et al., PLEnuM, <https://github.com/PLEnuM-group/Plenum>

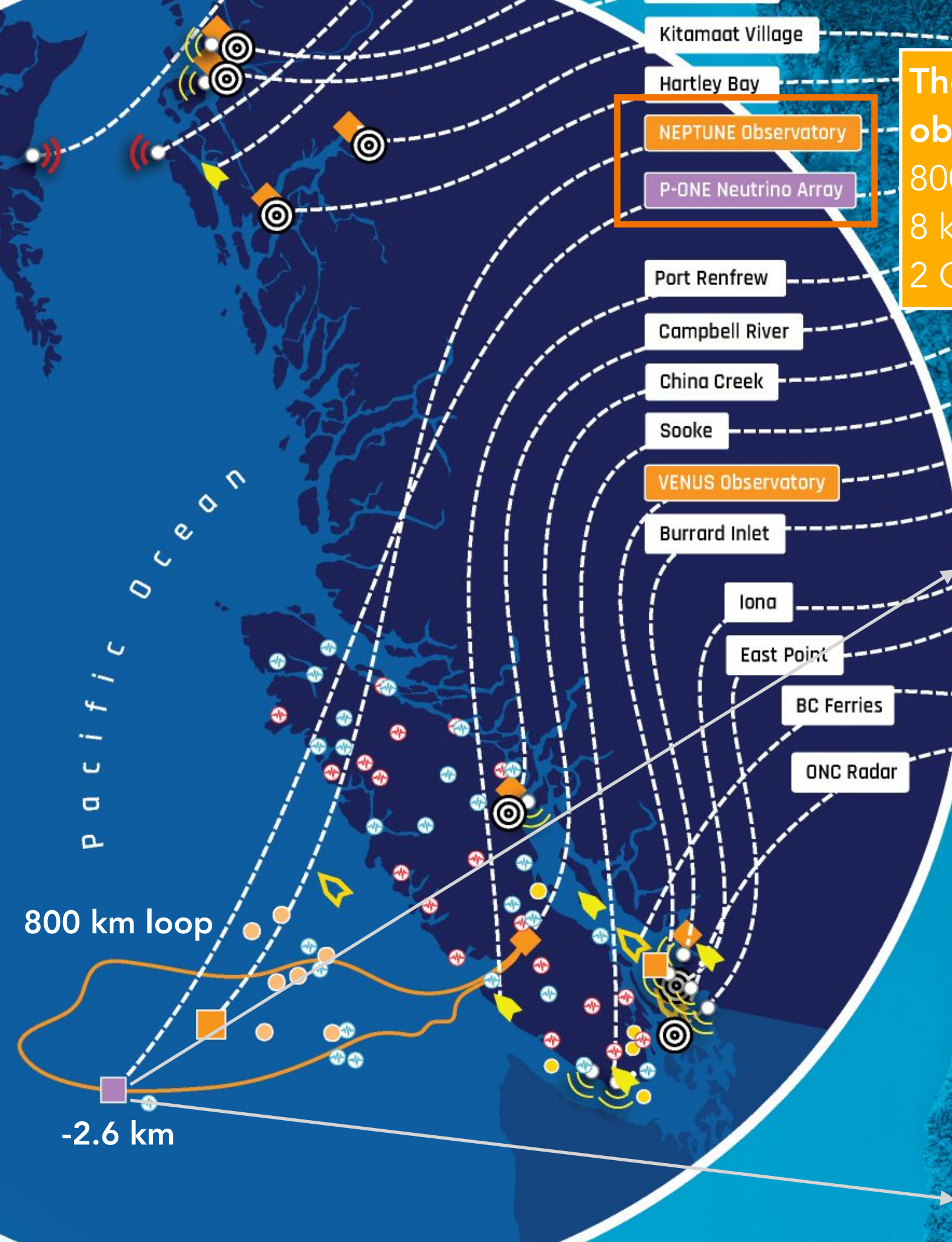


The Pacific Ocean Neutrino Experiment @ Ocean Networks Canada

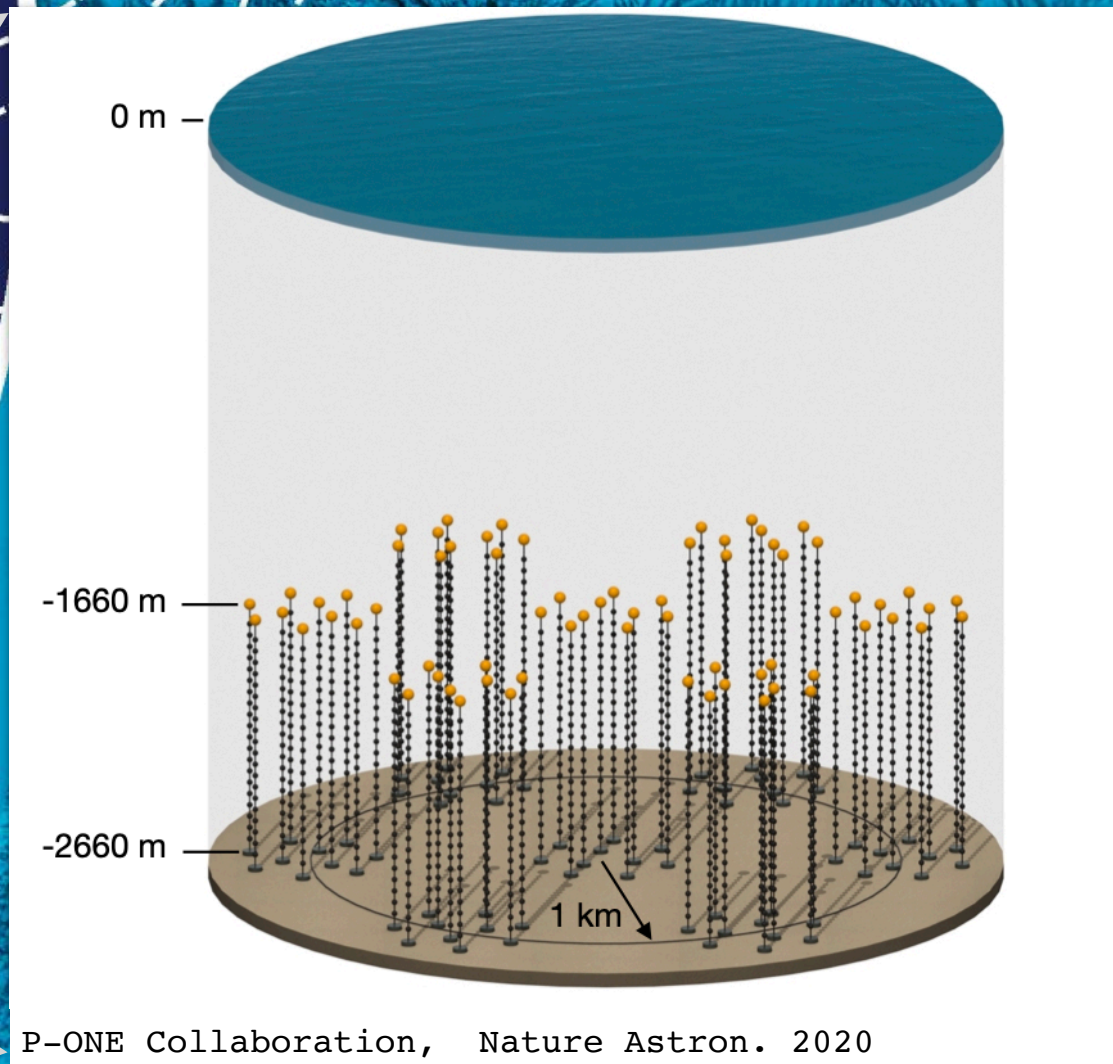


DATA SOURCES

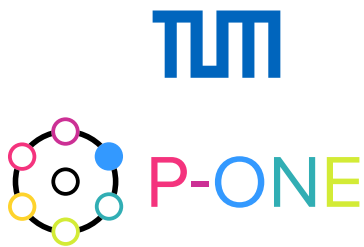
- | | | |
|---|---------------------------------|--|
| Major Observatory | Neutrino Array | Mobile Asset |
| Coastal Community Observatory | Community Fishers Mobile Assets | AIS Receiver |
| Coastal Observatory | Subsea Fibre Optic Cable | RADAR |
| Geo-Seismic Sensor (ONC) | Mooring/Buoy | RADAR (Department of Fisheries and Oceans) |
| Geo-Seismic Sensor (Natural Resources Canada & ONC) | Data Center | RADAR (Dalhousie University) |



The world's largest undersea, real-time observatory network -
800 km loop of fibre-optic cables,
8 kW x 6 nodes,
2 Gbit

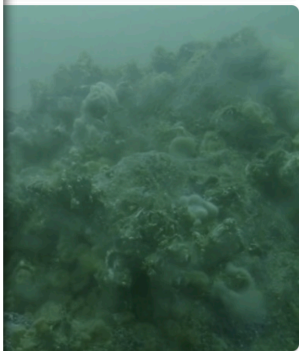
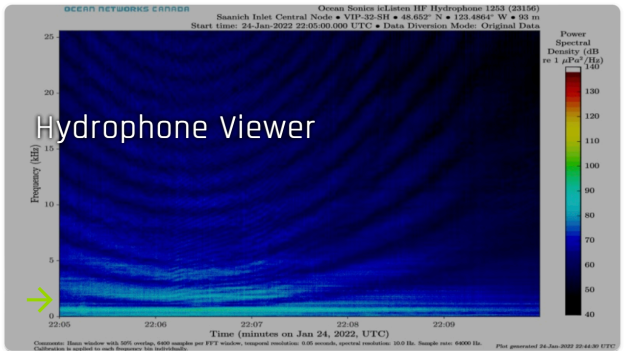
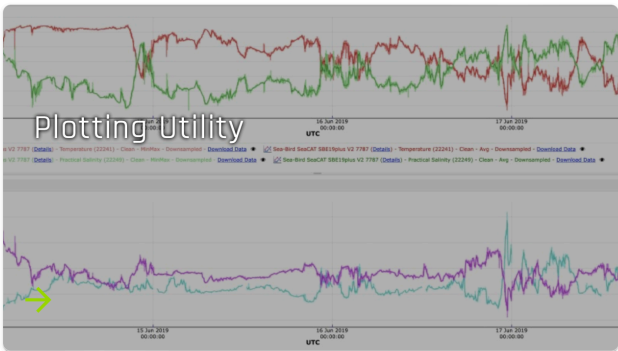


Ocean Networks Canada (ONC)



Oceans 3.0 Data Portal

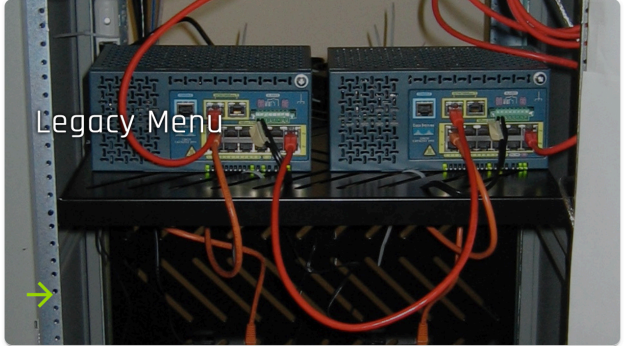
Visualize data from cabled observatories, mobile platforms and autonomous instruments.



```
import json
import requests

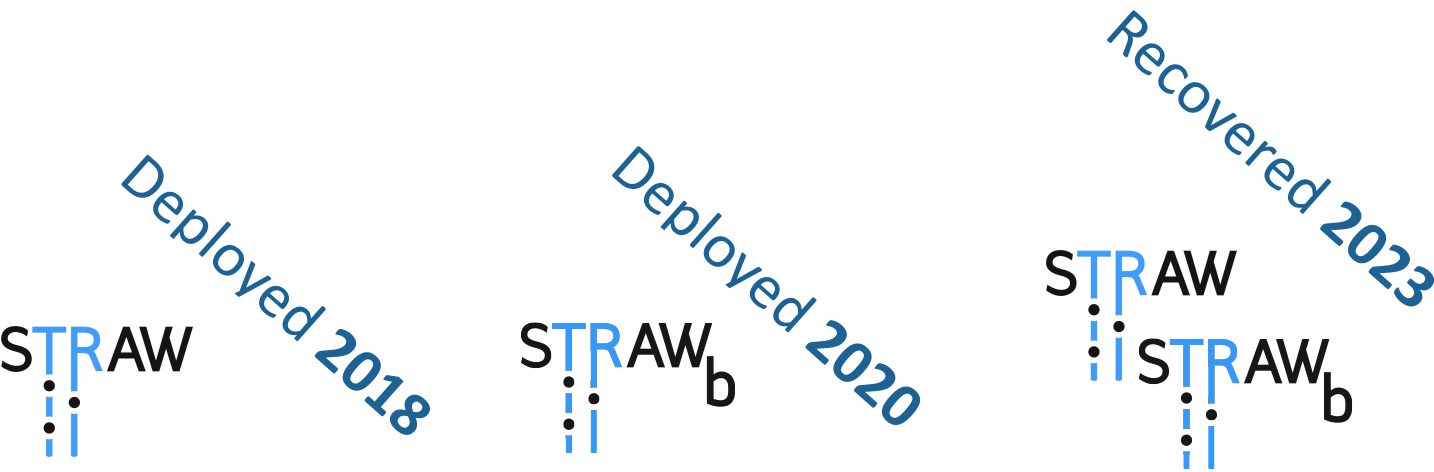
def get_device_category_codes(parameters):
    url = 'https://data.oceannetworks.ca/api/deviceCategories'
    params = {'method': 'get', **parameters}
    response = requests.get(url, params=params)
    device_category_codes = json.loads(str(response.content, 'utf-8'))
    [print('{} : {}'.format(deviceCategory.get('deviceCategoryCode'),
                           deviceCategory.get('deviceCategoryName')) for deviceCategory in deviceCategories)]
    else:
        if response.status_code == 400:
            error = json.loads(str(response.content, 'utf-8'))
            print(error)
        else:
            print('Error {} - {}'.format(response.status_code, response.reason))

if __name__ == '__main__':
    with open('glob.glob('/x/x/x/myocean2.token.csv')[0], 'r') as file:
        token = file.read().strip('\n')
        user_params = {'token': token, 'propertyCode': 'salinity'}
        get_device_category_codes(user_params)
```

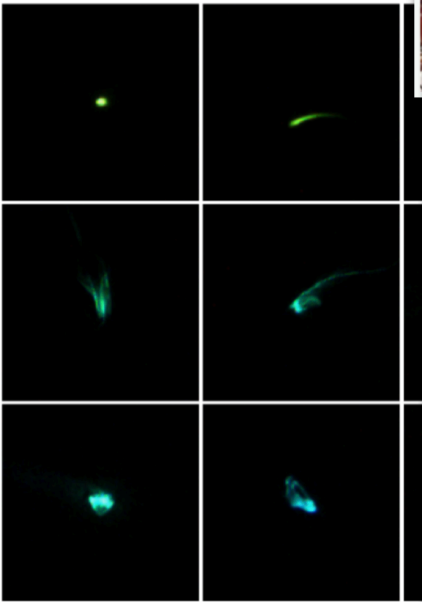


<https://data.oceannetworks.ca/home>

The Pacific Ocean Neutrino Experiment (P-ONE): pathfinders



1st pathfinder 2nd pathfinder Papers in preparation



Jinst PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: November 20, 2018
ACCEPTED: January 28, 2019
PUBLISHED: February 13, 2019

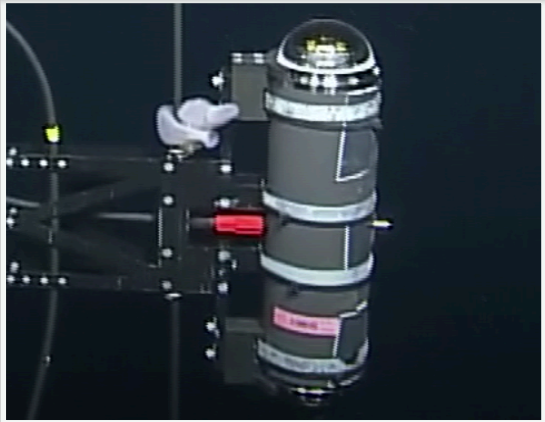
**STRAW (STRings for Absorption length in Water):
pathfinder for a neutrino telescope in the deep Pacific
Ocean**

Jinst PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: October 26, 2023
REVISED: February 7, 2024
ACCEPTED: March 16, 2024
PUBLISHED: May 28, 2024

The Pacific Ocean Neutrino Experiment

The Pacific Ocean Neutrino Experiment is a new initiative towards constructing a multi-cubic-kilometre neutrino telescope to expand our observable window of the Universe to the highest energies, and will be installed within the deep Pacific Ocean underwater infrastructure of Ocean Networks Canada.



Jinst PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: October 26, 2023
REVISED: February 7, 2024
ACCEPTED: March 16, 2024
PUBLISHED: May 28, 2024

**STRAW-b (STRings for Absorption length in Water-b): the
second pathfinder mission for the Pacific Ocean Neutrino
Experiment**

K. Holzappel^{a,*}, C. Spannfellner^a, O. Aghaei^b, A. Baron^b, J. Bedard^b, M. Böhmer^a, J. Bosma^b, N. Deis^b, C. Fink^a, A. Gärtner^c, R. Gernhäuser^a, F. Henningsen^d, R. Hotte^b, R. Jenkyns^b, M. Karl^a, Na. Khera^a, Ni. Khera^a, I. Kulin^b, A. Lam^b, T. Lavallee^b, K. Leismüller^a, L. Papp^a, B. Pirenne^b, E. Price^b, T. Qiu^b, I.C. Rea^e, E. Resconi^a, A. Round^b, C. Rott^{b,i}, A. Ruskey^b, L. Ruohan^a, K. Sasaki^b, M. Tradewell^b, M. Traxler^f, D. Vivolo^{g,k}, S. Wagner^b, E.L. Winter^a and M. Wolf^a

^aDepartment of Physics, Technical University of Munich, James-Frank-Straße 1, Munich, Germany
^bOcean Networks Canada, University of Victoria, 2474 Arbutus Road, Victoria, British Columbia, Canada
^cDepartment of Physics, University of Alberta, 4-181 CCIS, Edmonton, Alberta, Canada
^dDepartment of Physics, Simon Fraser University, 8888 University Drive, Burnaby, Canada
^eCenter for Advancing Electronics Dresden, Technische Universität Dresden, Helmholtzstraße 18, Dresden, Germany
^fDepartment of Physics, Technical University Kaiserslautern, Erwin-Schrodinger-Strasse 46, Kaiserslautern, Germany
^gNational Institute of Nuclear Physics, Complesso universitario di Monte Sant'Angelo, Strada Comunale Cinthia, Napoli, Italy

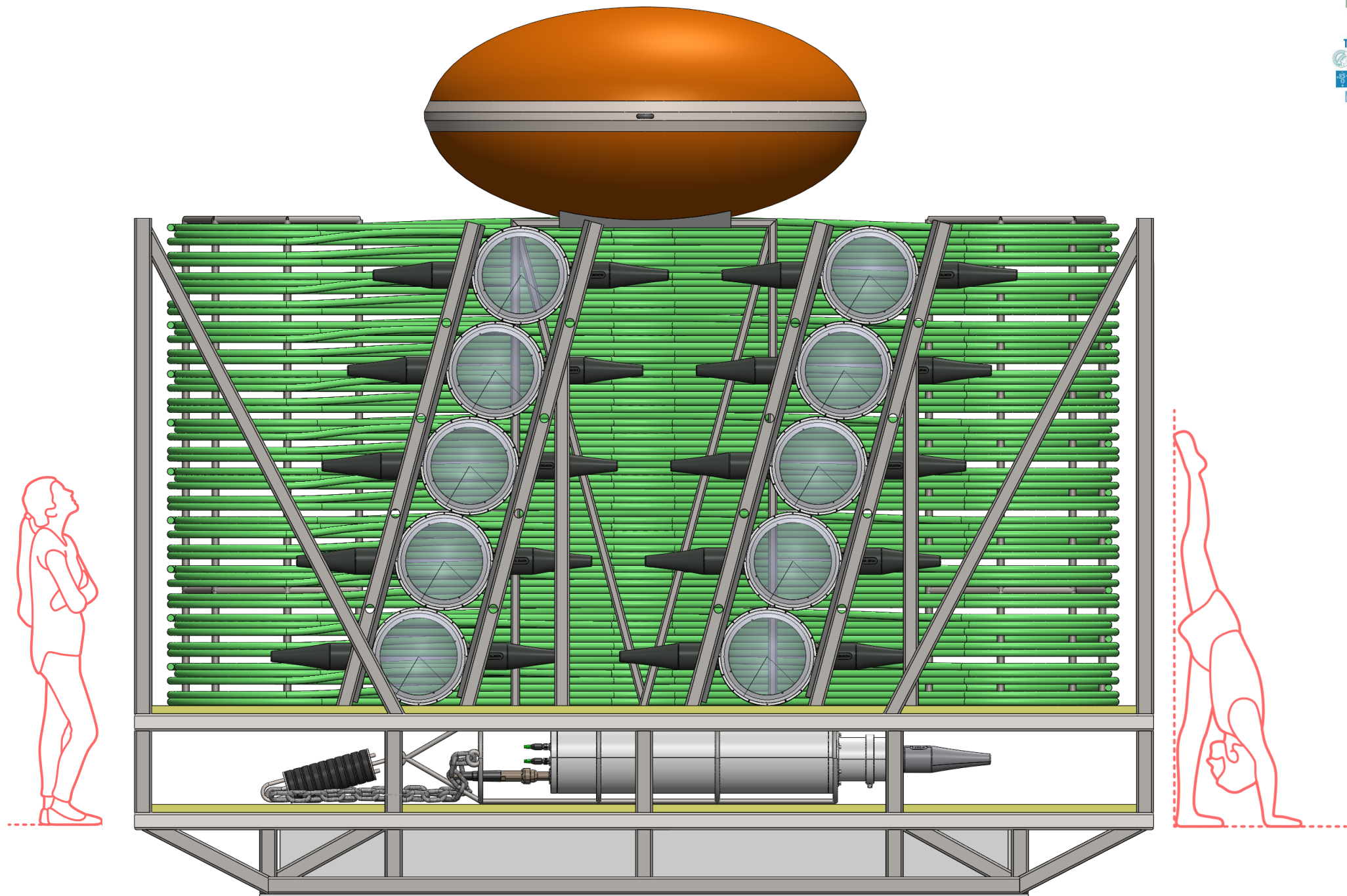
in R&D

The Pacific Ocean Neutrino Experiment (P-ONE)

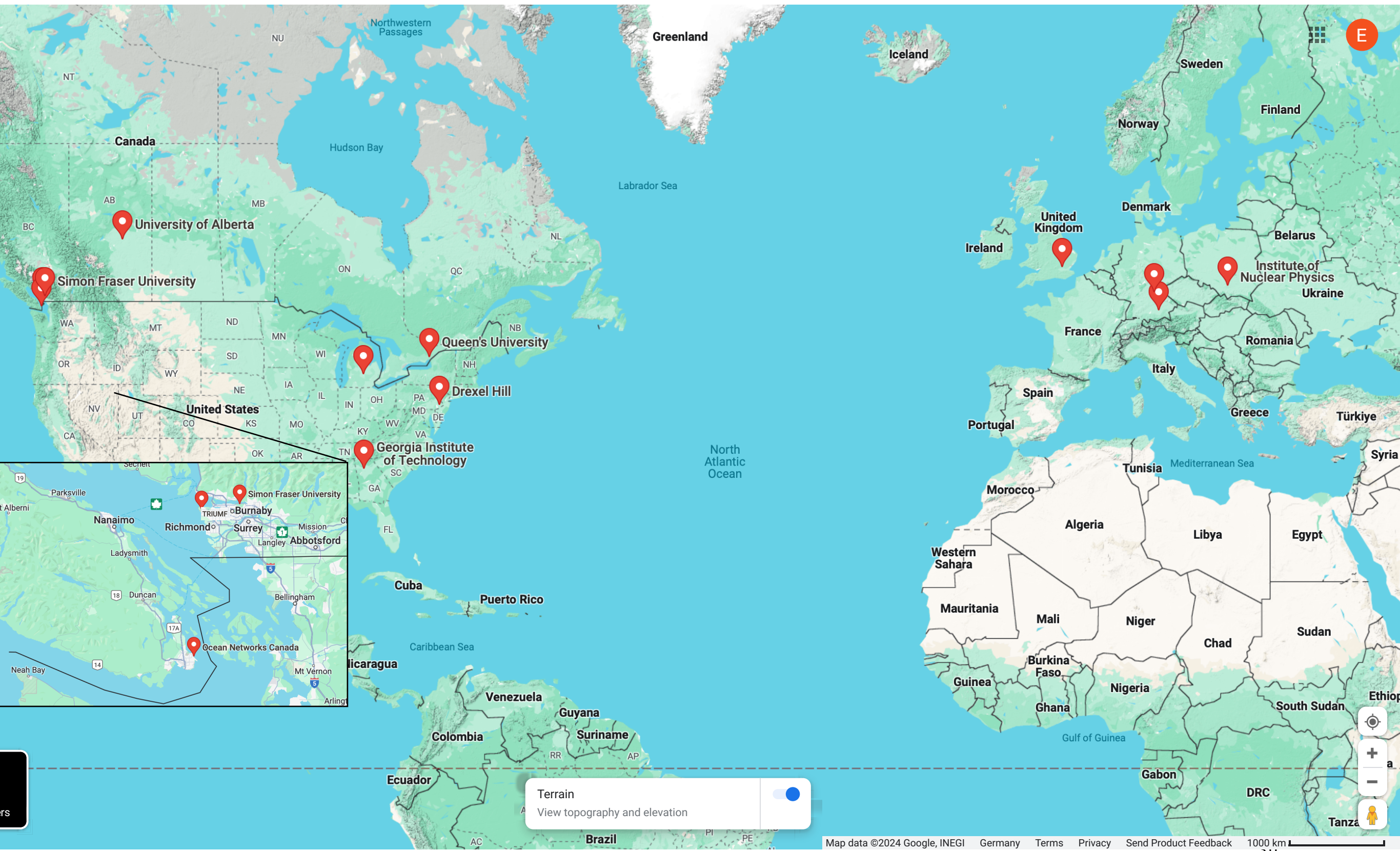
The Element: A 1 km Tall Instrumented Line Compactly Designed to Fit in a Transport Container

P-ONE Coll., *Nature Astron.* '20

C. Spannfellner et al., PoS ICRC23



P-ONE System: Oceanography and Neutrino Experiments

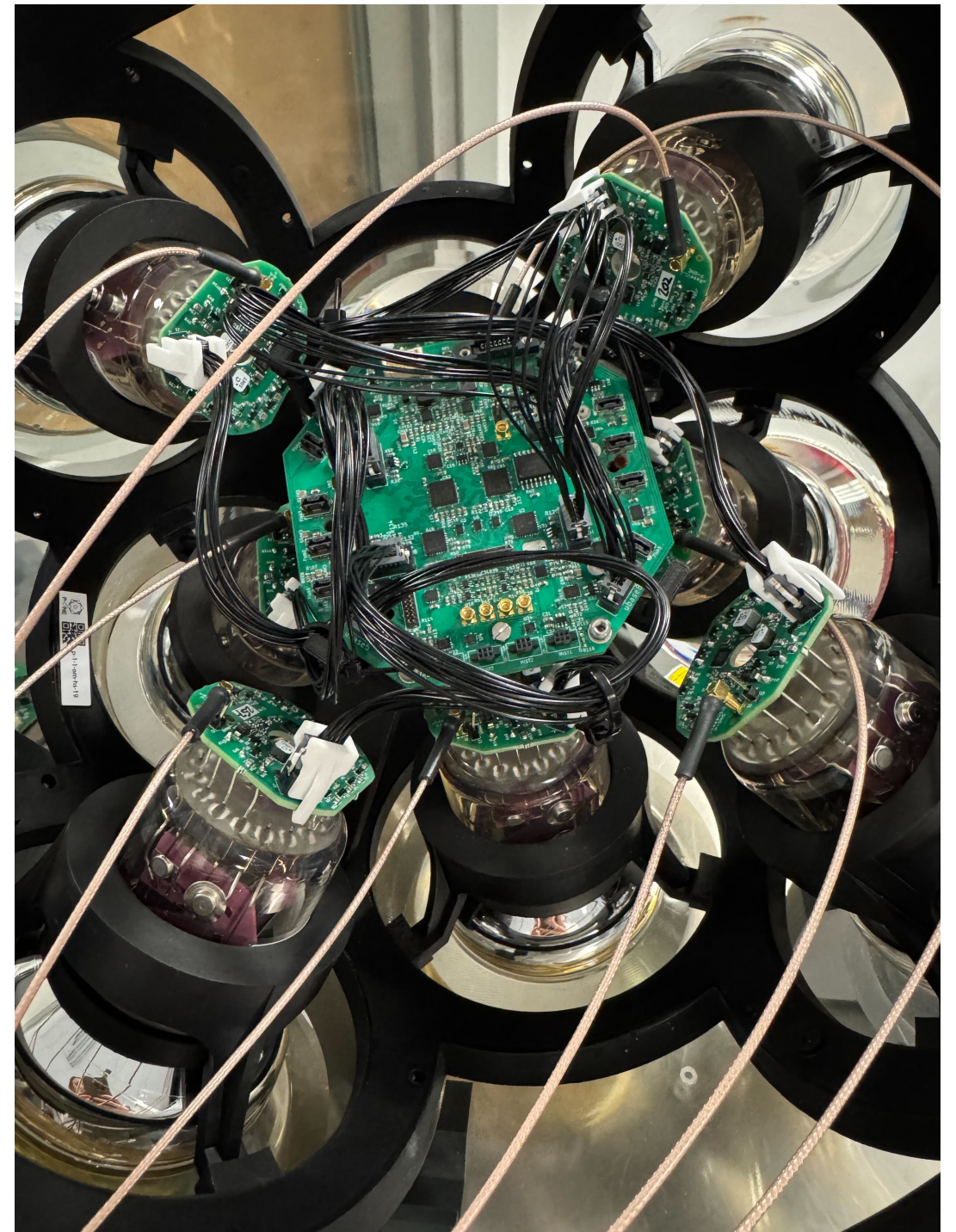




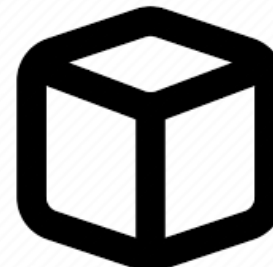
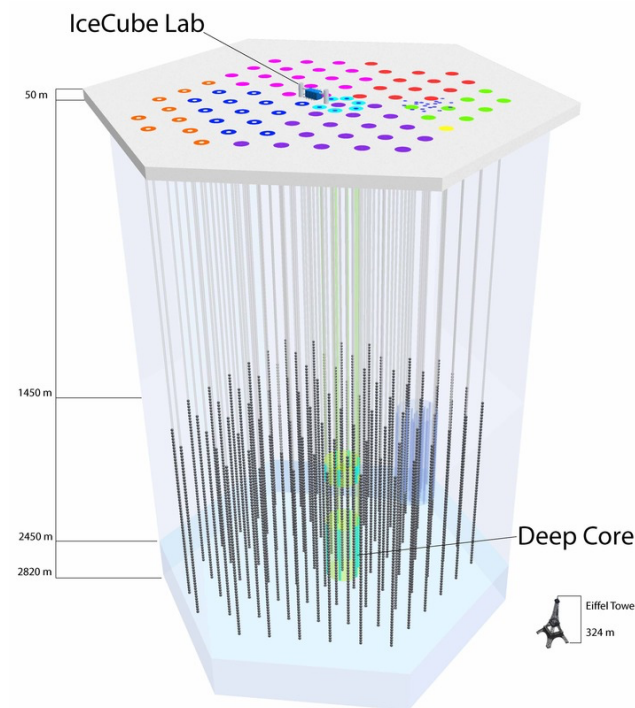
P-ONE line: first complete prototype in advanced stage

Design parameters:

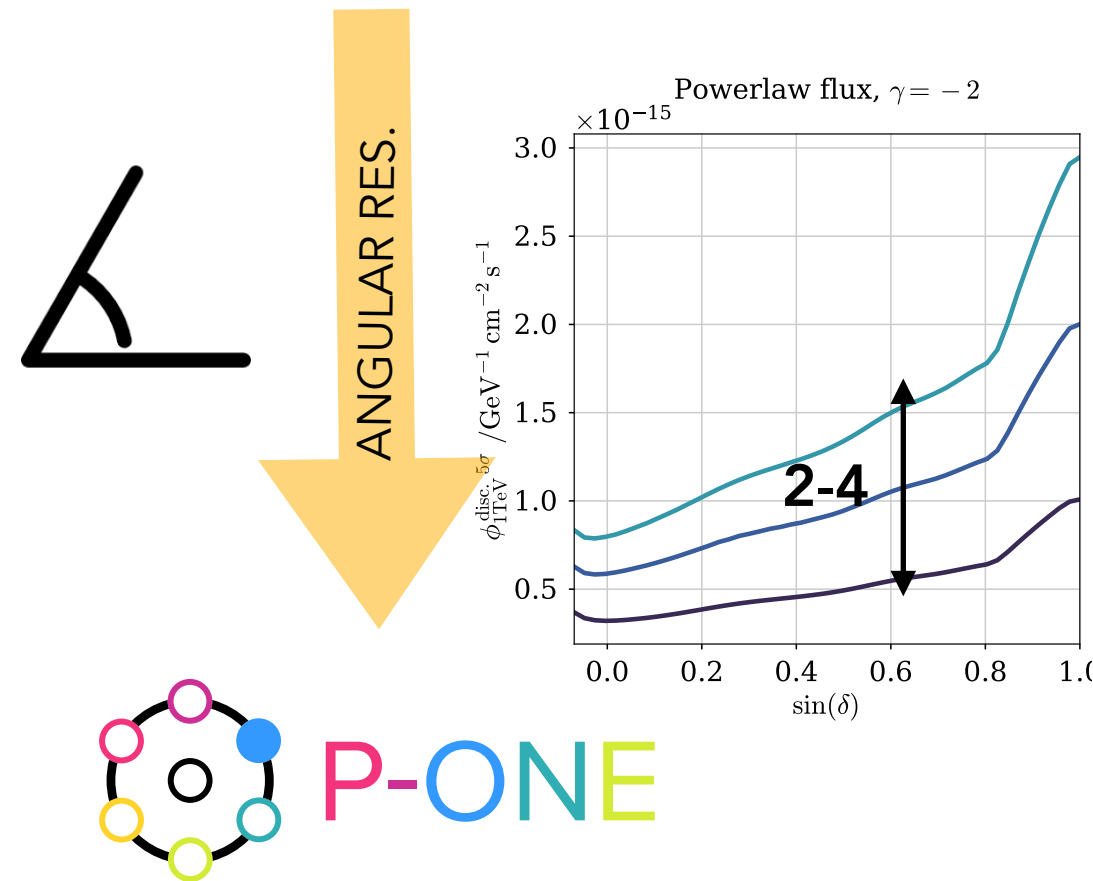
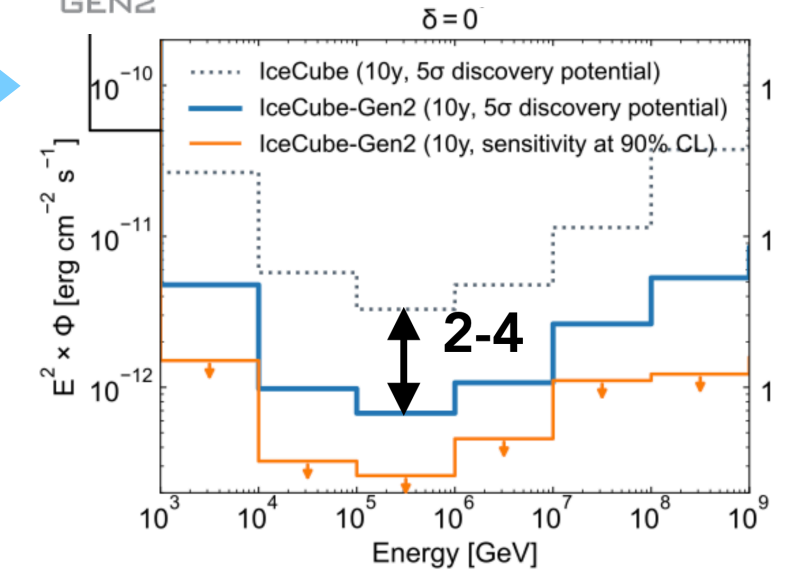
- Integrated System
- Advanced Waterproofing
- Precision Data
- Environmental Monitoring
- Scalability



P-ONE as *next generation neutrino experiment*



VOLUME



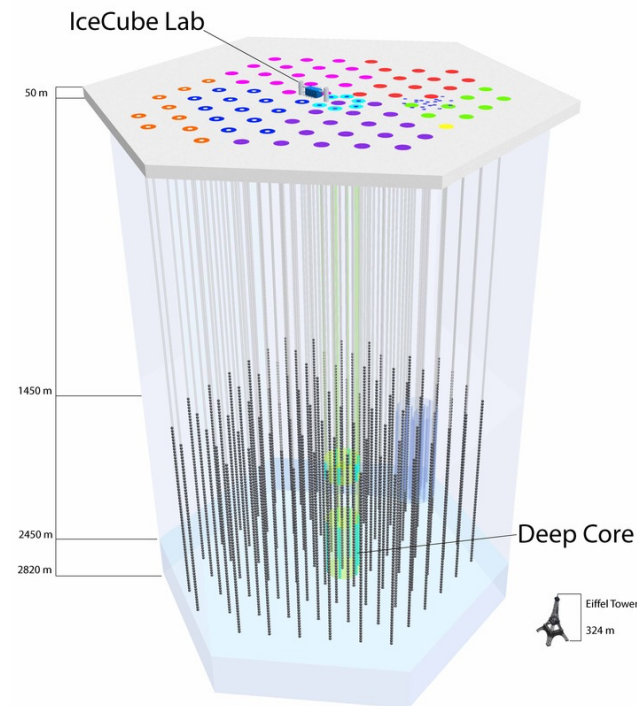
Challenges for Implementation:

- IceCube: Impacted by ice scattering
- KM3NeT: Uses PMTs and Time-over-Threshold (ToT) technology

P-ONE as *next generation neutrino experiment*

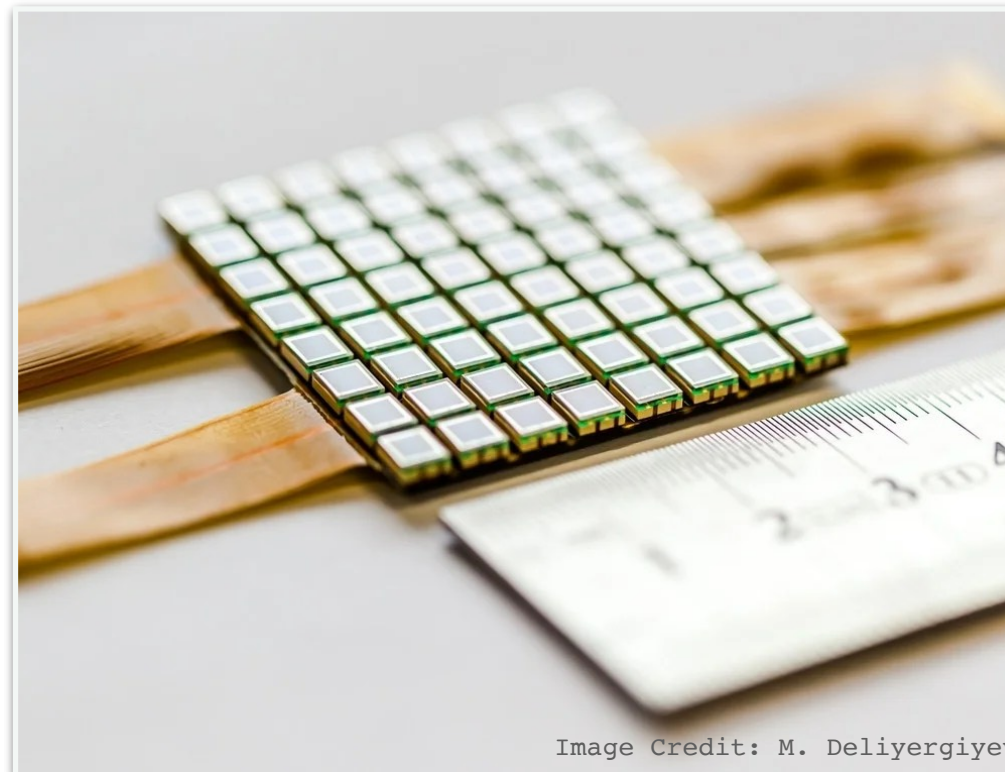
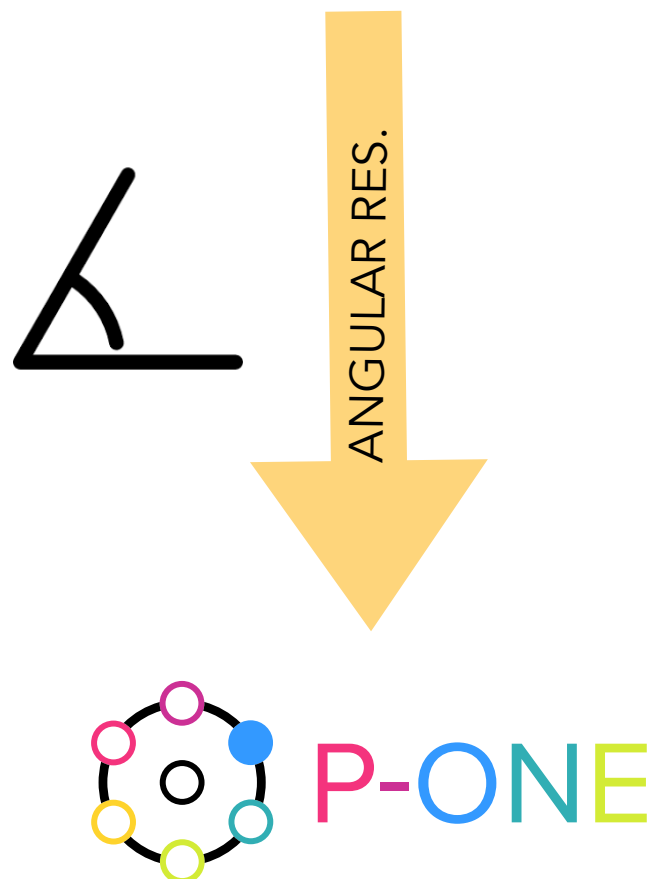
Gain through boost of **Angular Resolution**

Gain through boost of **Timing**



TTS ~ 1.5 - 1.7 nsec

NEW TECHNOLOGY REQUIRED



R&D on SiPMTs for large area, extreme conditions and **sub-ns**

Image Credit: M. Deliyergiyev

In conclusion

- **IceCube discovered** astrophysical neutrinos and (first) sources.
- To understand the physics at play in cosmic sites and validate IceCube findings, we need **more and better experiments/telescopes**.
- **P-ONE's ambitious R&D program** started.
- The **first complete P-ONE prototype** line will be tested in **2025**.
- **Next Steps:** Deployment of **3-5 similar or improved lines** to demonstrate system capabilities and scalability.
- **Mission Goals:**
P-ONE aims to continue and extend the **IceCube success story** while keeping design and deployment **realistic and achievable**.
- **Wish Us, Good Luck!** 🎯

It takes a village

TUM/ECP, SFB1258, Cluster ORIGINS, IceCube, P-ONE

