KM3NeT

CAMK PAN annual meeting
05.02.2026

Fantastic neutrinos and how to find them

Piotr Kalaczyński

Work supported by:

Nicolaus Copernicus Astronomical Center
Polish Academy of Sciences

ASTROCENT
Particle Astrophysics Science and Technology Centre
International Research Agenda

AGH
AGH University of Krakow

WFIIS AGH

CEAI
Center of Excellence in Artificial Intelligence

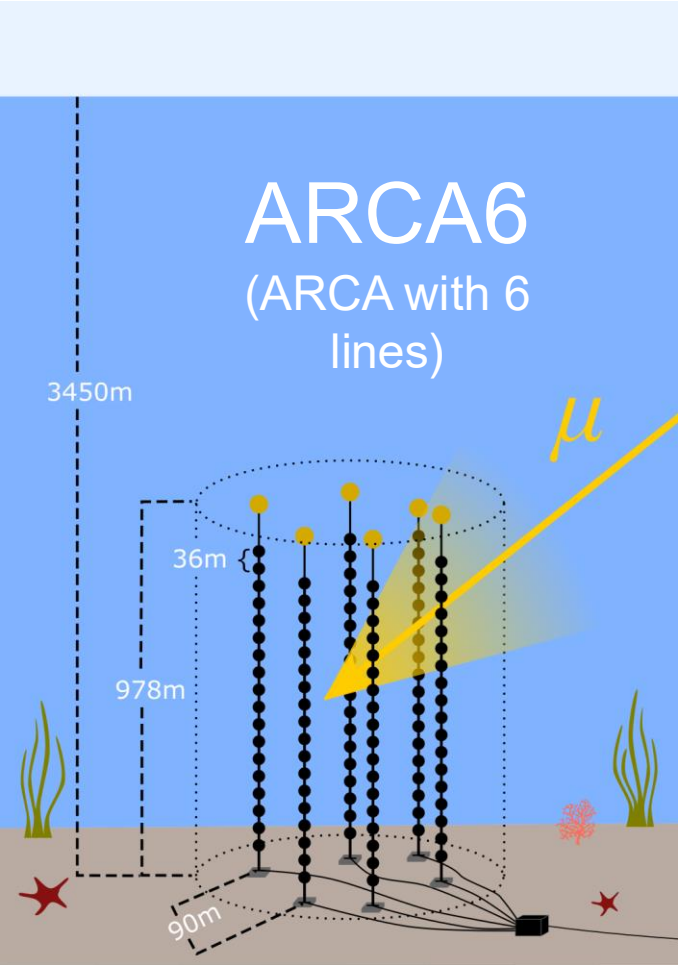
European Funds
Smart Growth

Republic of Poland

FNP
Foundation for Polish Science

European Union
European Regional Development Fund

KM3NeT detectors: brief summary

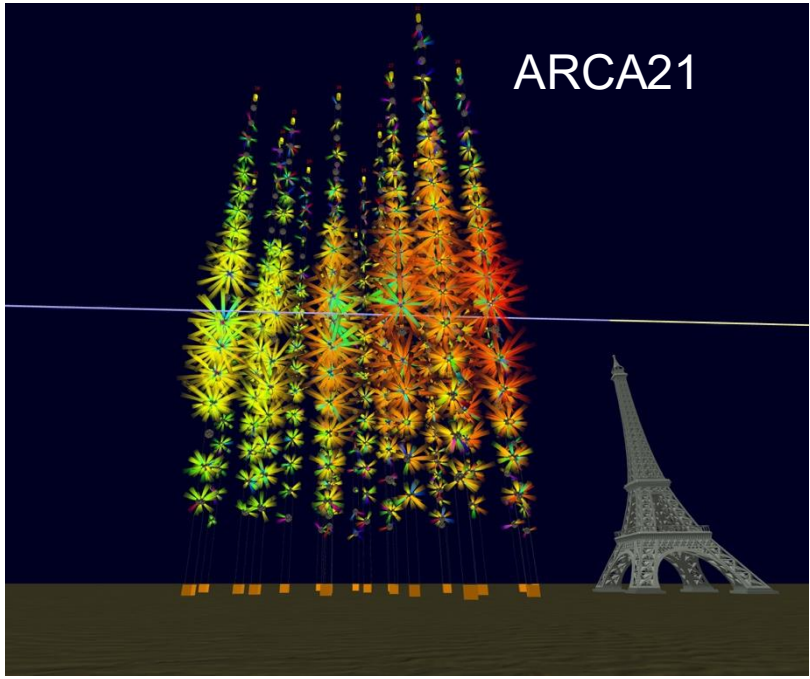


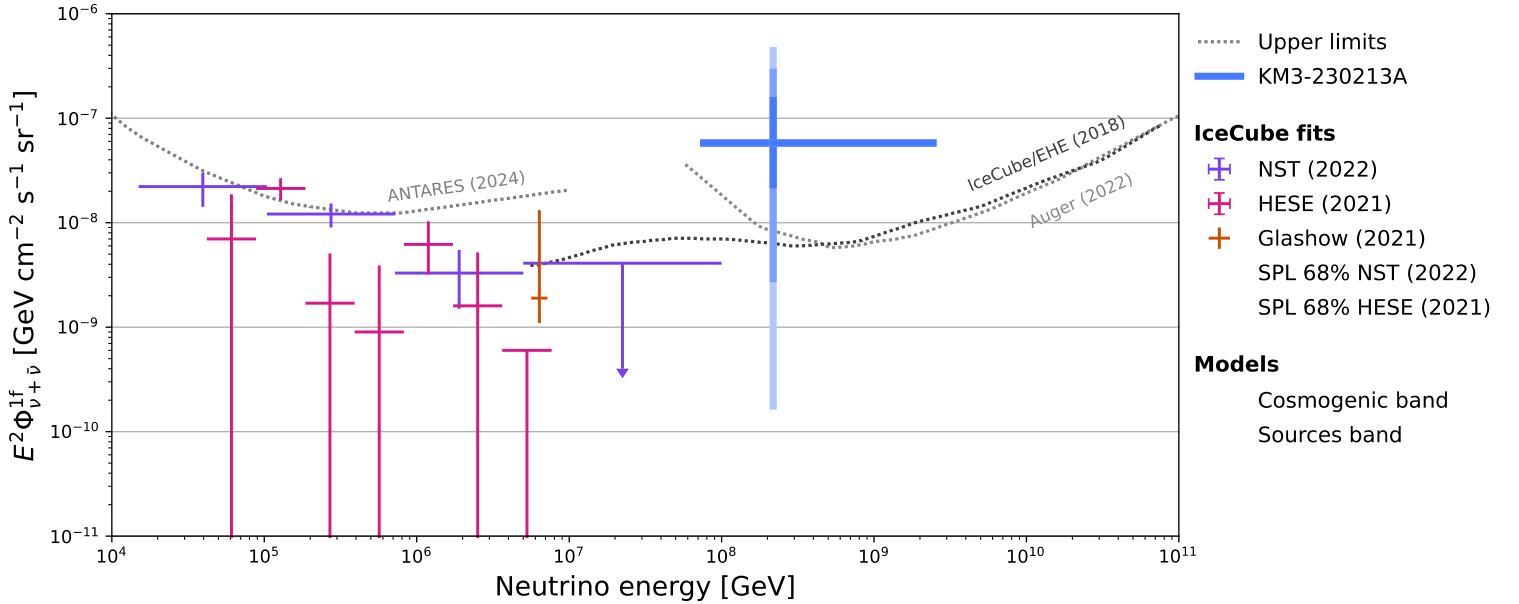
Detector	ARCA	ORCA
Depth	3.5 km	2.45 km
Volume	1 km^3 (1Gton)	0.007 km^3 (7Mton)
# lines	45 / 226	33 / 108
Topic	Astroparticle RCA*	Oscillation RCA*
Goal	ν_{astro}	m_ν hierarchy

*RCA : Research with Cosmics in the Abyss

In case you missed the paper and media coverage

We've observed the most energetic ν ever!





How do we increase the statistics?

We want more UHE neutrinos! → **Instrument even bigger volume**

… but how?

multi-km^3 water Cherenkov telescopes very expensive, biggest planned: $7.5\ \mathrm{km}^3$

TRIDENT 海铃计划

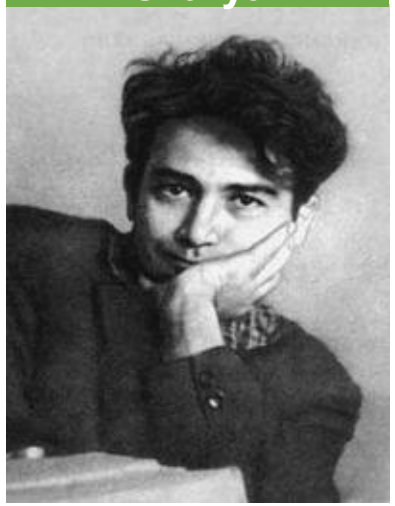
(TRIDENT)

The problem: light range ~ few 100m

The solution: sound range ~ few km

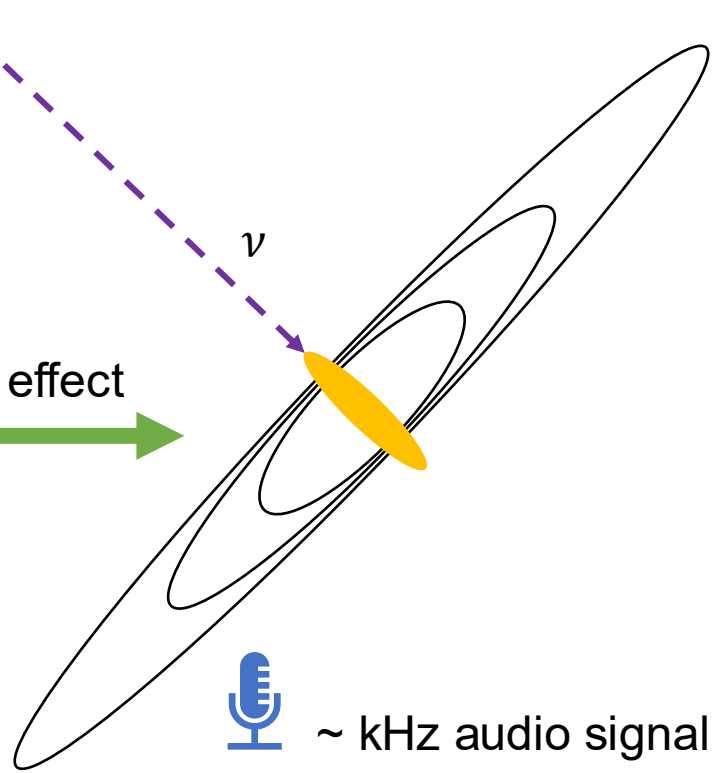
But how do we „hear" a neutrino? →

Gurgen A. Askaryan



source: https://en.wikipedia.org/wiki/Gurgen_Askaryan#/media/File:G_Askaryan.jpg

→ thermoacoustic effect →



~ kHz audio signal

Towards an acoustic neutrino telescope

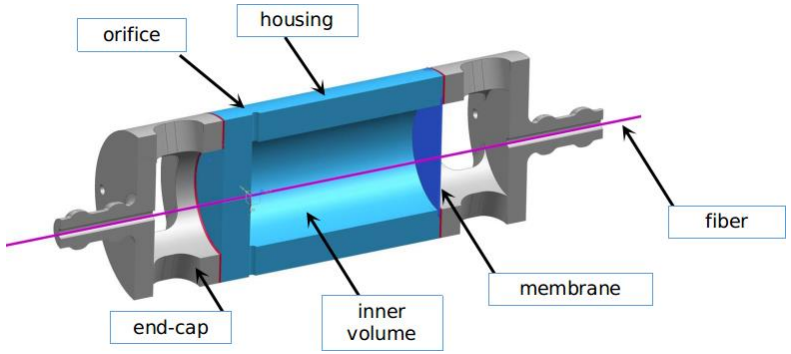
Hardware

Hydrophones:

- Piezoelectric (already installed)
- Membrane (already installed)
- Optic fibre + membrane (pathfinder with 4x40 hydrophones funded by NIOZ!)

oceansonics.com

doi.org/10.1051/epjconf/201921602007

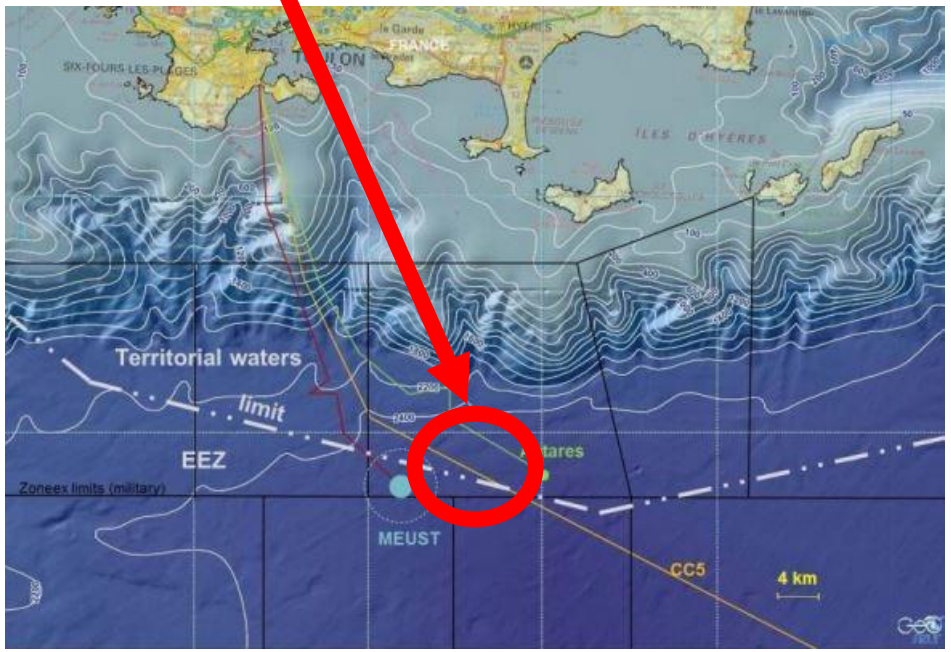


doi.org/10.1016/j.astropartphys.2025.103109

Site

KM3NeT-Fr:

- near Toulon
- depth: 2450m
- Use extensive calibration data from KM3NeT/ORCA



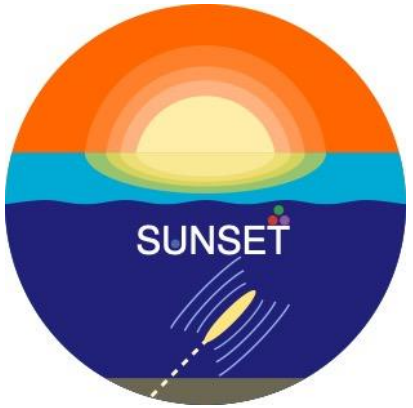
Software

- There once was a MATLAB code from The ACoRNE Collaboration (and it is not available anymore …)
- well … and there's nothing else
- that's where we step in!

Simulation studies

More funding …

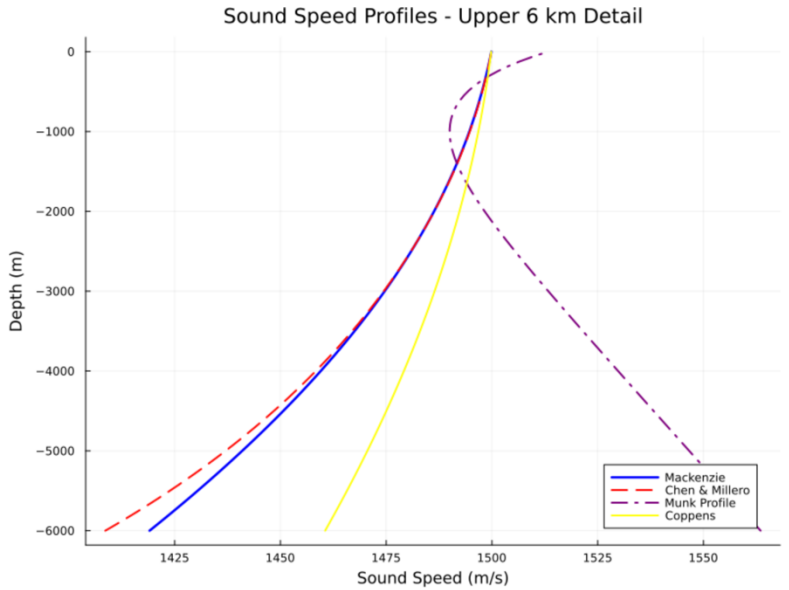
Some preliminary simulation results

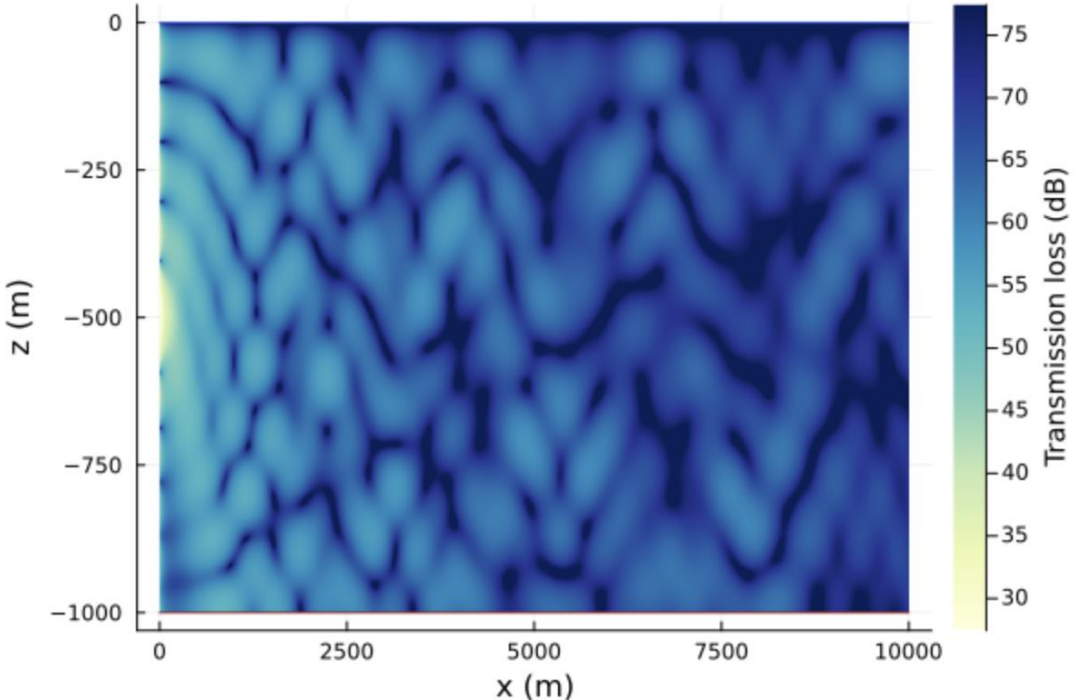


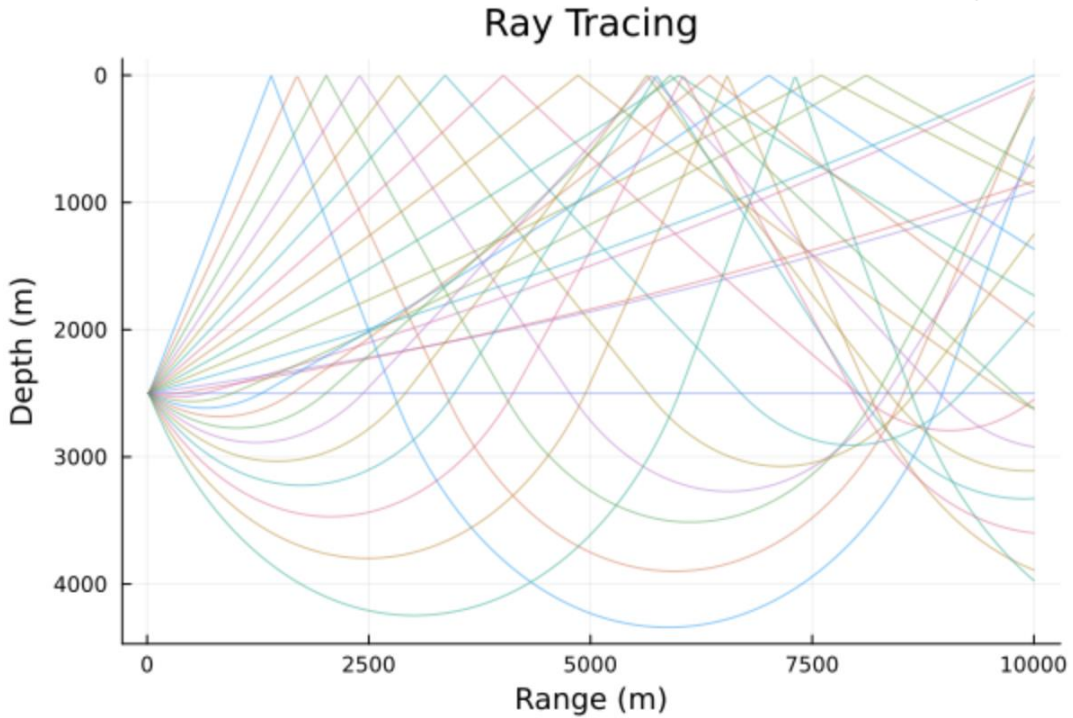
SUNSET.jl:

(**S**imulation of **U**nderwater **N**eutrino-induced **S**ound **E**mission and **T**ransport)

- Acoustic simulation code in pure Julia
- For:
  - Acoustic position calibration
  - Simulation of acoustic signals of UHE ν events
  - Approaches: both ray tracing & wave treatment

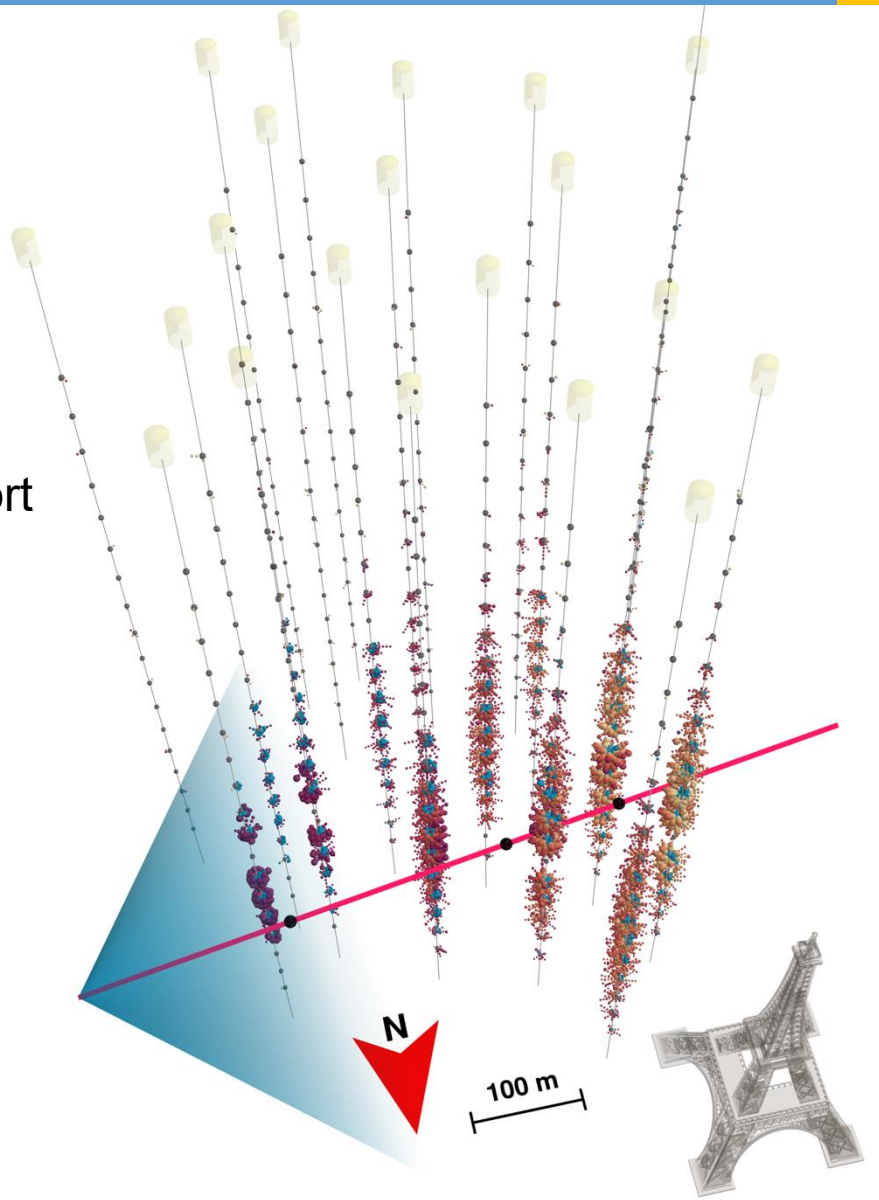






Summary:

- KM3NeT keeps growing & collecting data
- Already competitive in astronomy (and beyond)
- New acoustic hardware on the way
- SUNSET.jl already able to model sound generation and transport
- Stay tuned for more exciting results! ☺



Thank you for your attention!

European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund

Backup

KM3NeT

nature

NEWS | 21 June 2024

‘Fantastic’ particle could be most energetic neutrino ever detected

The ultra-high-energy neutrino was spotted by deep-sea detectors and could point to a massive cosmic event.

By Davide Castelvecchi

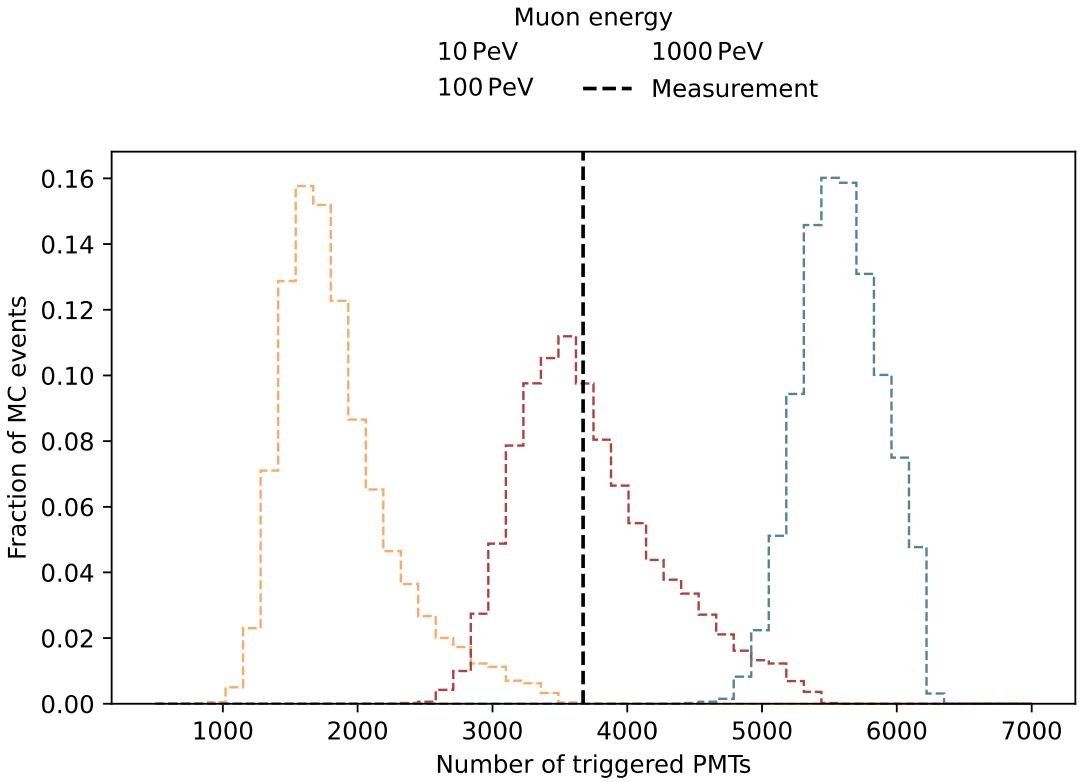
An observatory still under construction at the bottom of the Mediterranean Sea has spotted what could be the most energetic neutrino ever detected. Such ultra-high-energy neutrinos – tiny subatomic particles that travel at nearly the speed of light – have been known to exist for only a decade or so, and are thought to be messengers from some of the Universe’s most

Paper to be published in Nature on

12 February

stay tuned …

KM3-230213A briefly summarized



Online attention

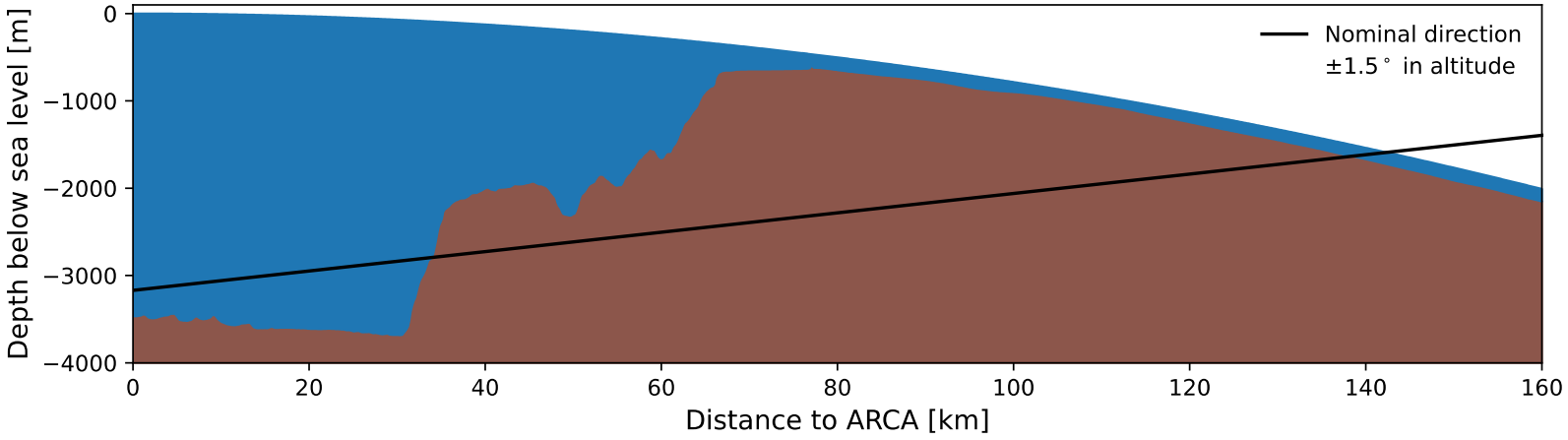
- 318 tweeters
- 248 news outlets
- 10 Wikipedia page
- 46 Mendeley
- 20 blogs
- 2 Redditors
- 5 Facebook pages
- 11 Video uploaders

Reco energies:

$$E_\mu = \left(120\ ^{+110}_{-60}\right)\ \text{PeV}$$
$$\mathrm{E}_\nu = \left(220\ ^{+570}_{-110}\right)\ \text{PeV}$$

Origin:

- galactic [1] x
- blazar [2] ?
- cosmogenic [3] ?
- BH merger [4] ?
- …



Geometry:

104 km of rock
38 km of water

309 km w. e. in total

link to the paper

link to the data

Polish KM3NeT team: current status

Nicolaus Copernicus Astronomical Center
Polish Academy of Sciences

AGH University of Krakow

AstroCeNT
Particle Astrophysics Science and Technology Centre
International Research Agenda

- me ☺
- Mariusz Suchenek

WFiIS AGH

WFiIS:

- Artur Ukleja
- Tomasz Szumlak
- Agnieszka Obłąkowska-Mucha
- Mateusz Goncerz (post-doc)
- Saliha Bashir (post-doc)
- Kalyani Mehta (PhD student)
- Paweł Lewicki (PhD student)
- Zofia Stateczna(MSc student)
- Daniel Rakus (BSc student)

CEAI
Center of Excellence in Artificial Intelligence

- me ☺

Grants:

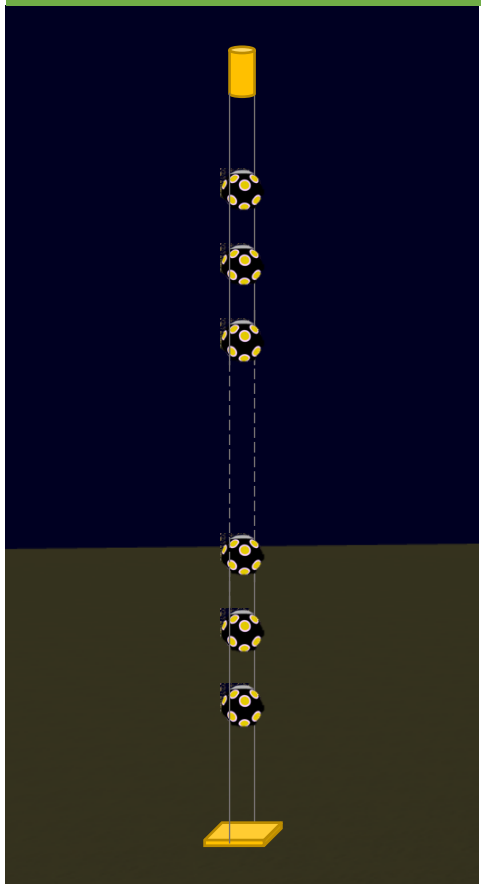
Under evaluation: OPUS (NCN)
Next planned: MNiSW grant

Detector design summary

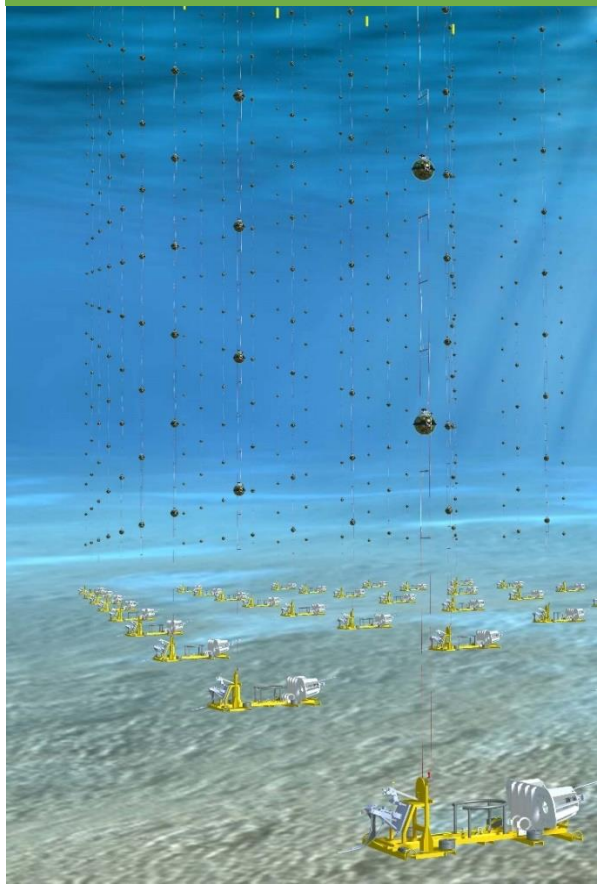
DOM:
71 unique components

1 DOM:
31 PMTs

1 string (DU):
18 DOMs



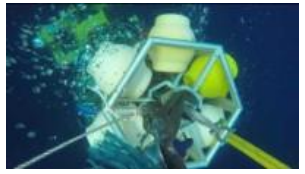
1 building block:
115 DUs



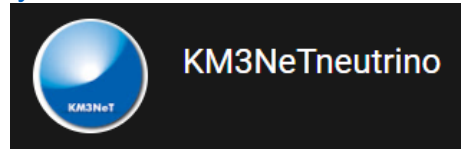
[DOM production:(@Nikhef)]

[Preparation for deployment:]

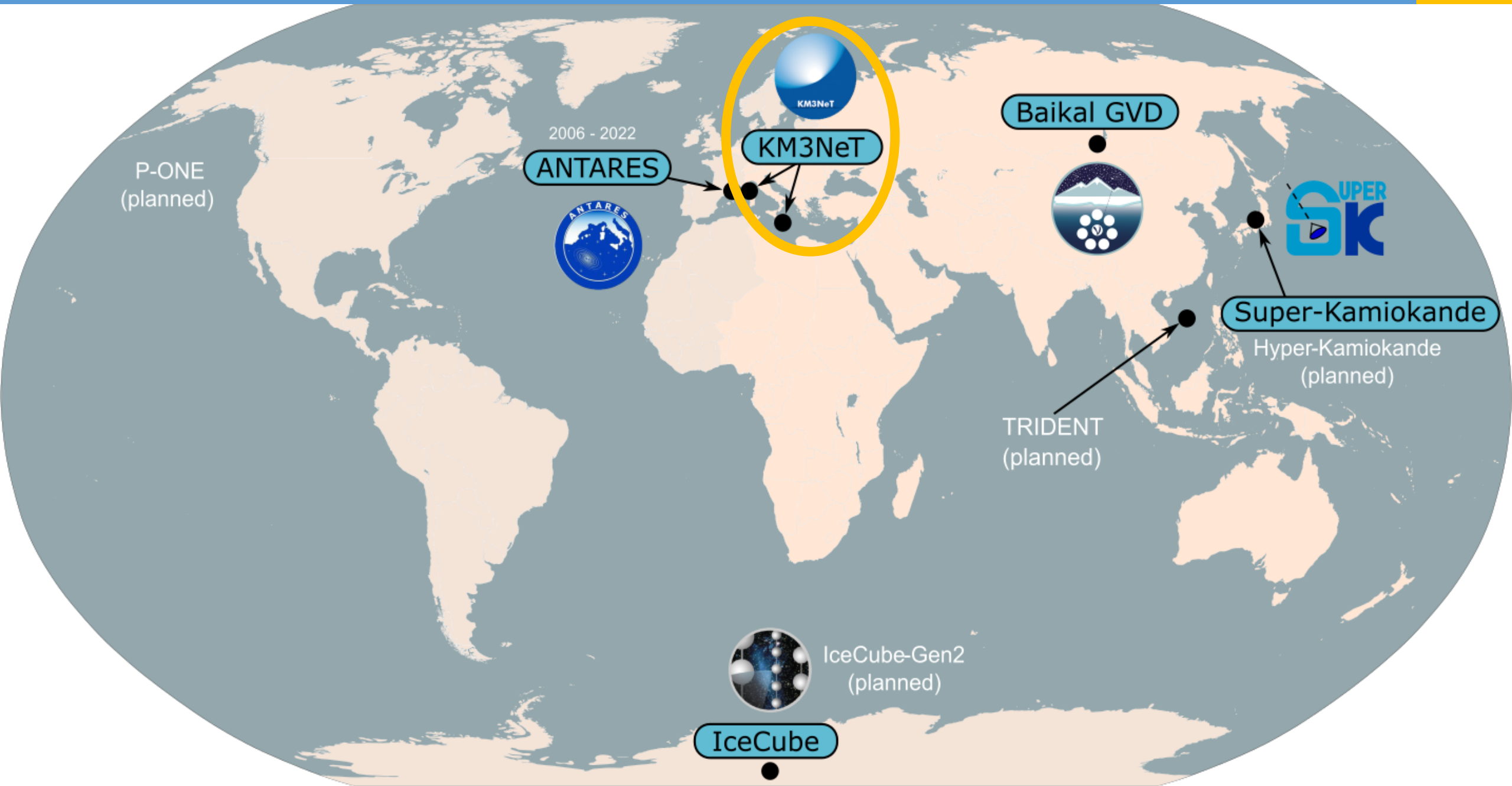
[String deployment:]



More at:
youtube.com/KM3NeTneutrino



Water Cherenkov ν telescopes



Digital Optical Module (DOM)

acrylic glass sphere with:

- 31 3” PMTs,
- readout electronics,
- pressure gauge,
- acoustic sensonrs,
- ...

2022 JINST 17 P0703

JATIS 7(1), 016001 (2021)

Photomultiplier Tube (PMT)

converts light into electric signal

JINST13 (2018) P05035

DOM arrangement

Detection Unit (DU):

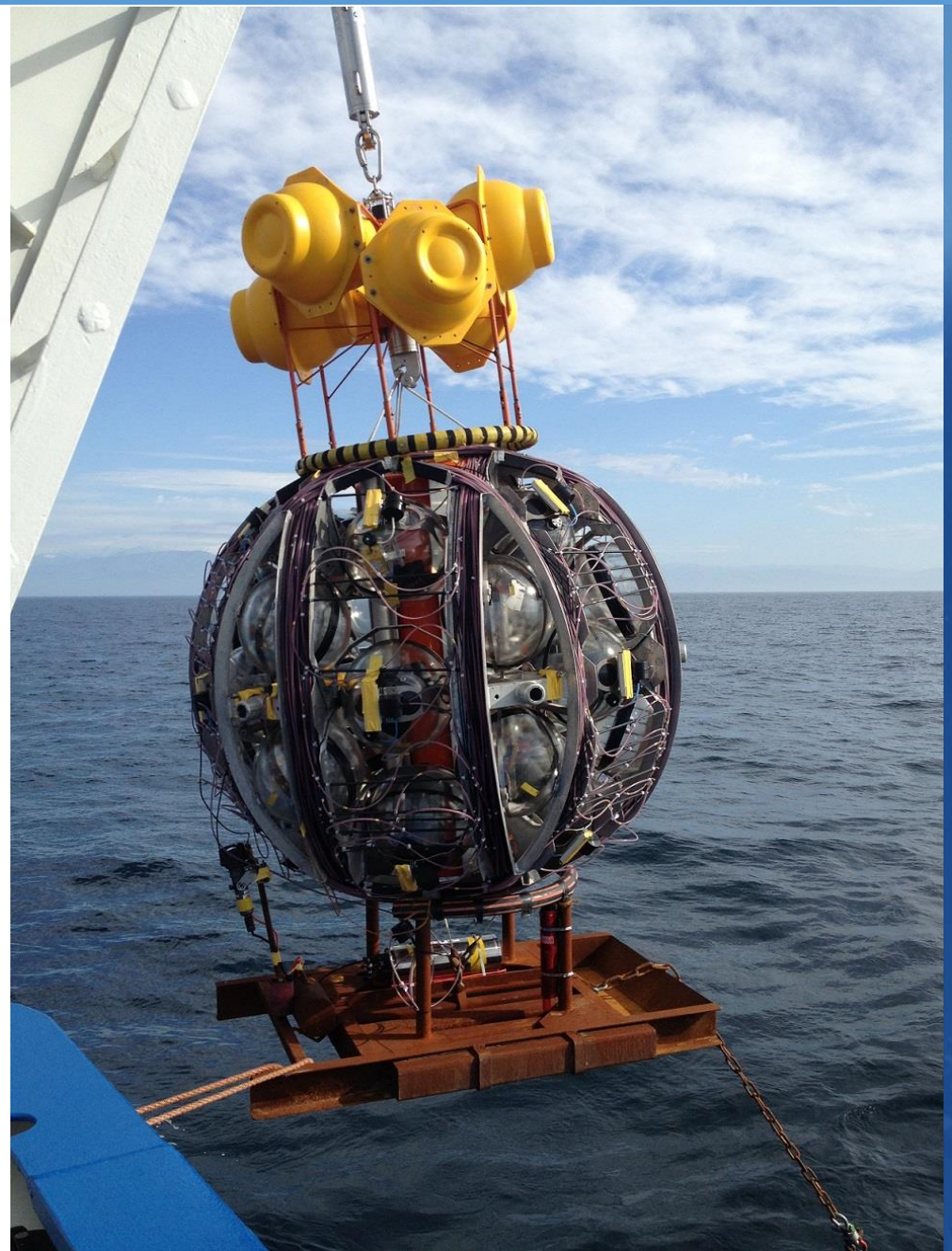
vertical **string** with 18 DOMs

Eur. Phys. J. C 76 (2016) 76:54

Naming:

ORCA6 ↔ ORCA with 6 strings
ARCA2 ↔ ARCA with 2 strings
etc.

2020 JINST 15 P11027



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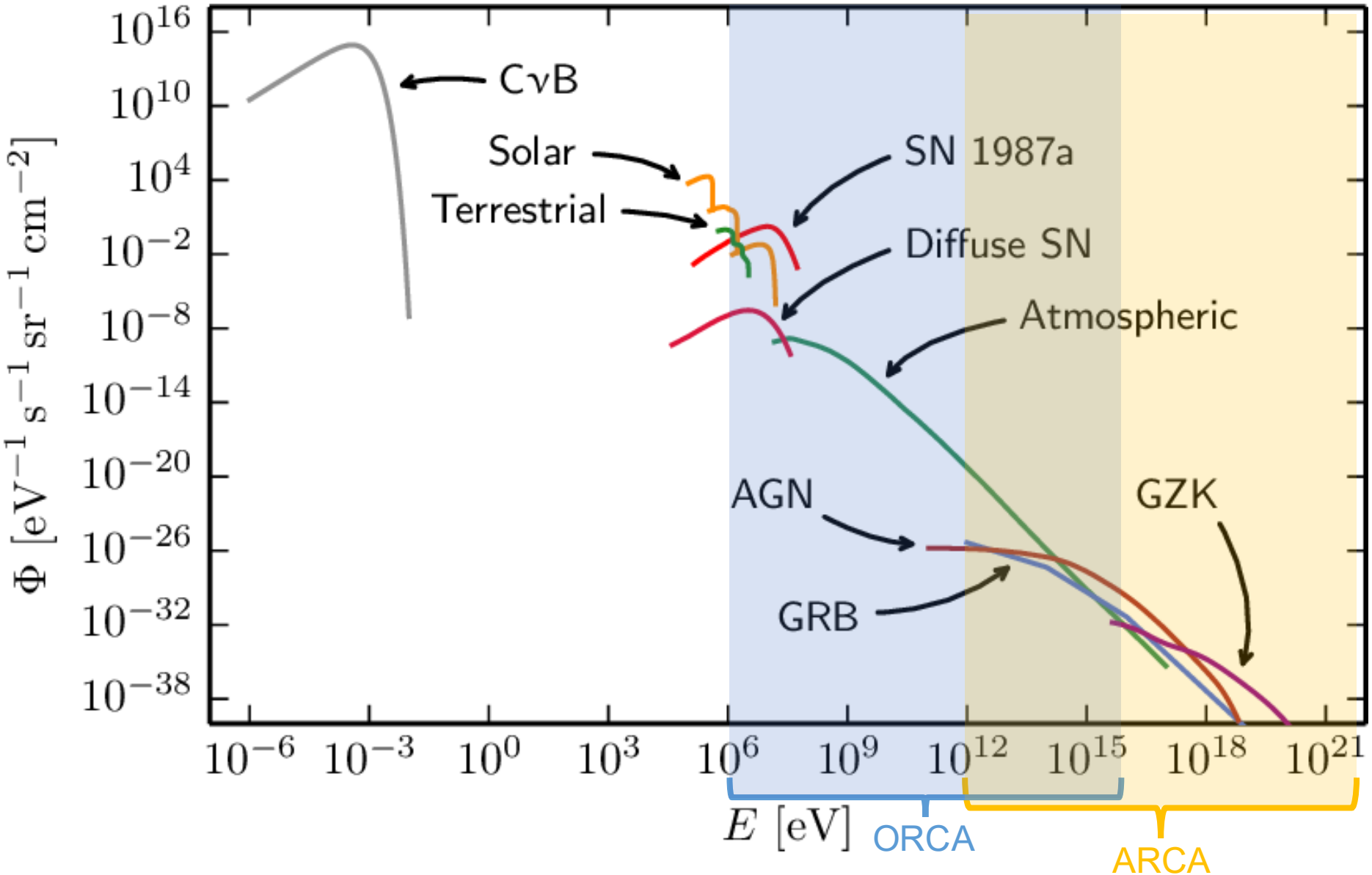
2020 JINST 15 P11027

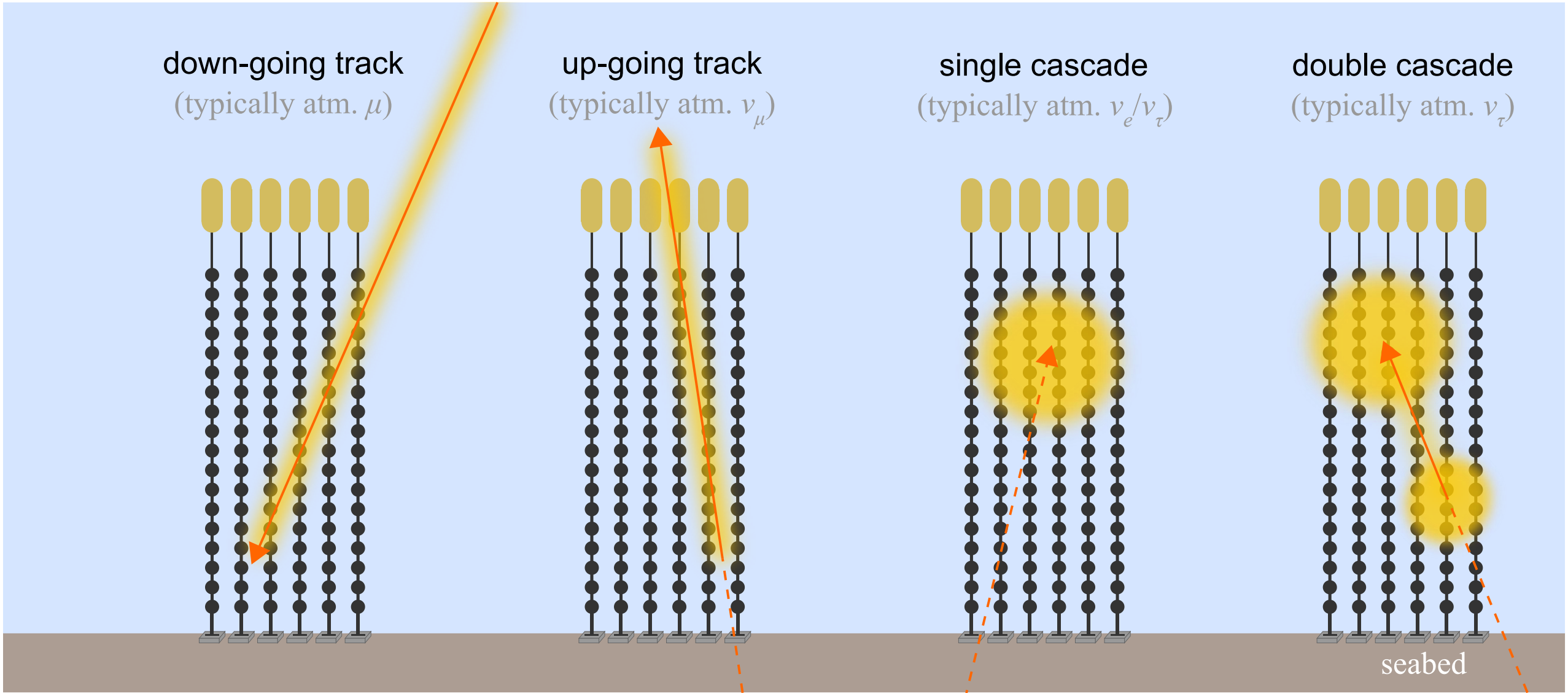
Neutrino sources



L. Mohrmann, Characterizing cosmic neutrino sources – a measurement of the energy spectrum and flavor composition of the cosmic neutrino flux observed with the IceCube Neutrino Observatory, Humboldt U., Berlin (2015)

Event topologies

Examples of basic event topologies:

Classes based on combinations of:

- Direction
- Shape