Giulia Illuminati - ricercatrice INFN

TODAY'S SCHEDULE

Morning:

10:15-12:30 Introductory talks

11:15-11:30 Break

Lunch Break: 12:30-13:30

Afternoon:

13:30-15:30 Data Analysis Exercise

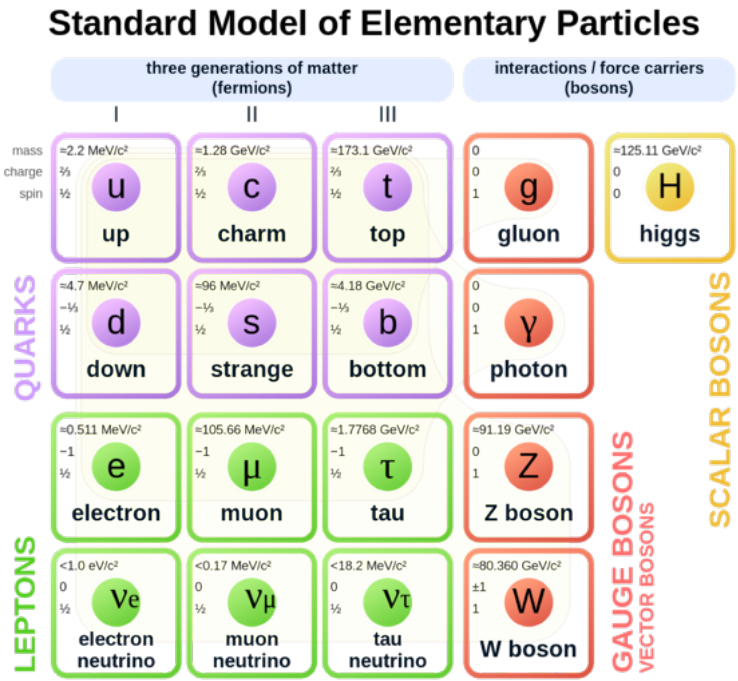
15:30-16:00 Local discussion of results and preparation of videoconference

16:00-16:45 Videoconference - Results comparison

16:45-17:30 Closing

Part I: Neutrinos

Elementary Particles

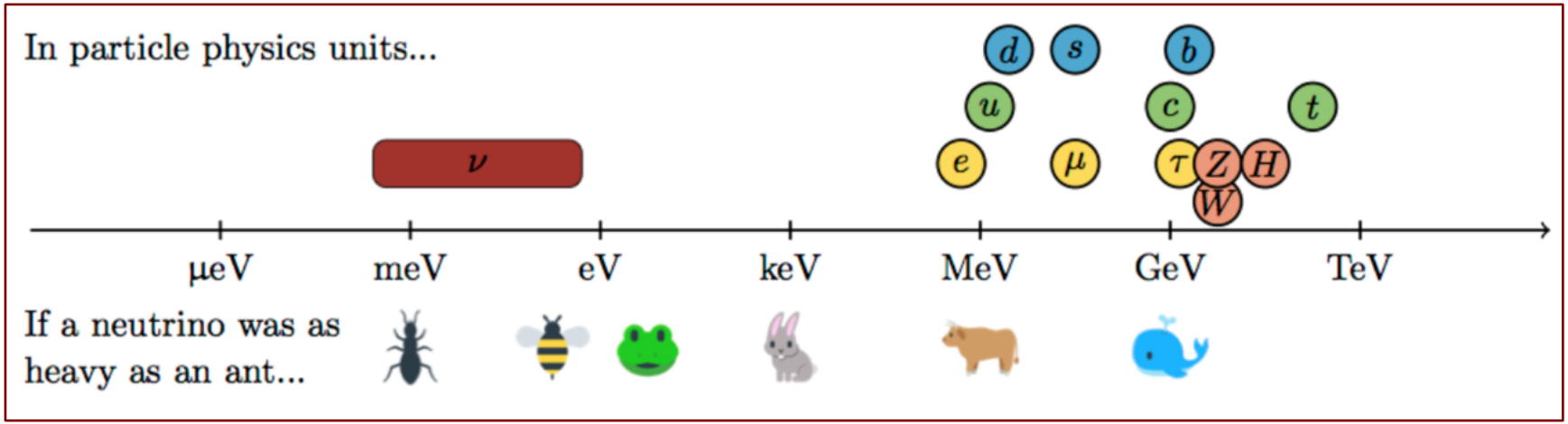


Neutrinos are special: size and mass

Although neutrinos are among the most abundant particles in the Universe, we are only just beginning to understand them…

They are the lightest elementary particles of matter that we know. In fact, they are so light that we don't know their exact mass!!!

For example: if an electron had the mass of a cow, a neutrino would be as light as an ant.



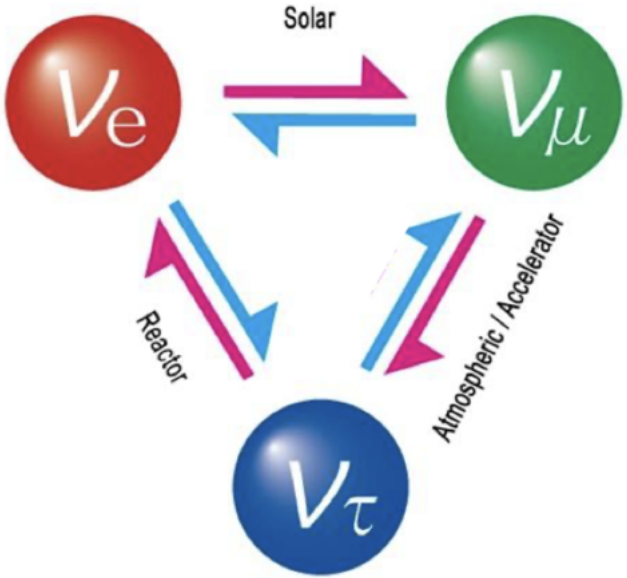
Neutrinos are special: flavors and forces

They are the particles that interact most weakly in the Standard Model, via the weak force.

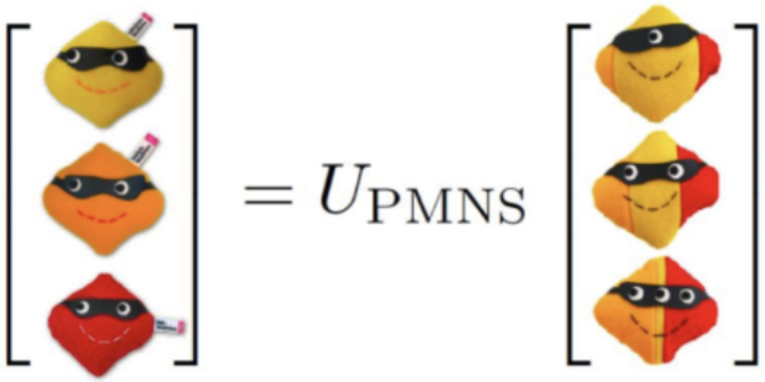
There are three different types of neutrinos, which physicists call flavors.

Credit: Ilaria Del Rosso

Neutrinos can change flavor!



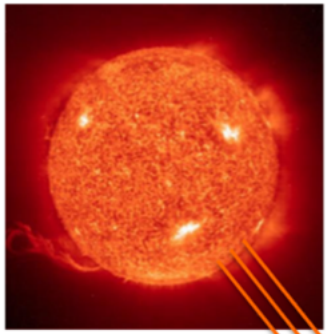
This is called neutrino oscillations!

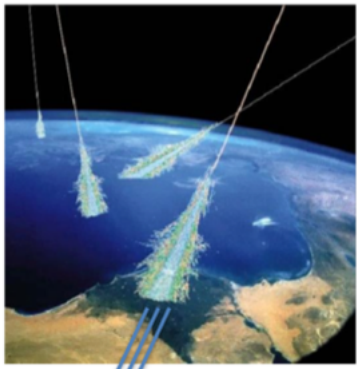


“Neutrinos do not have a single identity”:

Flavor states (v_e, v_μ, v_τ) are superpositions of mass eigenstates, which allows neutrinos to change type while traveling.

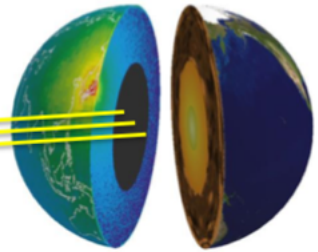
Neutrinos are everywhere





Sun: 5×10^{12}/second

Atmosphere: ~20/second



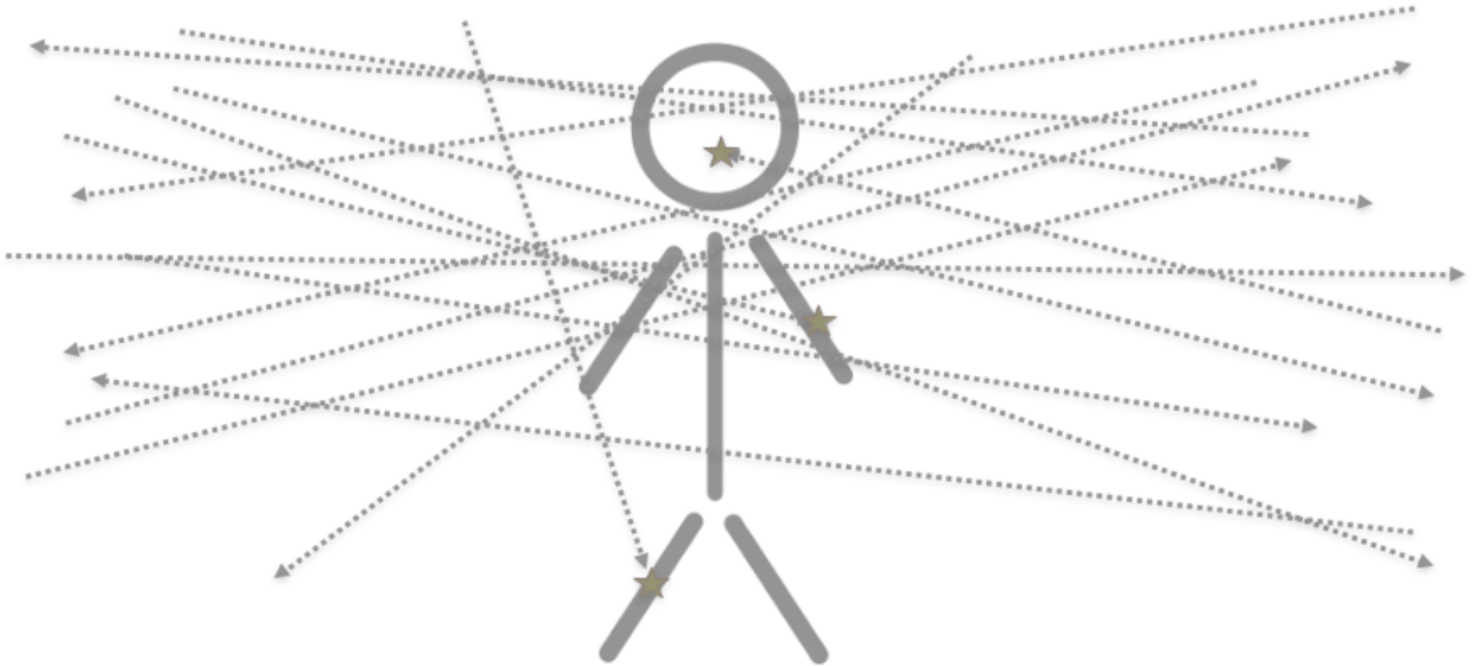
Even bananas emit neutrinos.

For a surface of 10x10 cm²

Earth: ~10^9/second

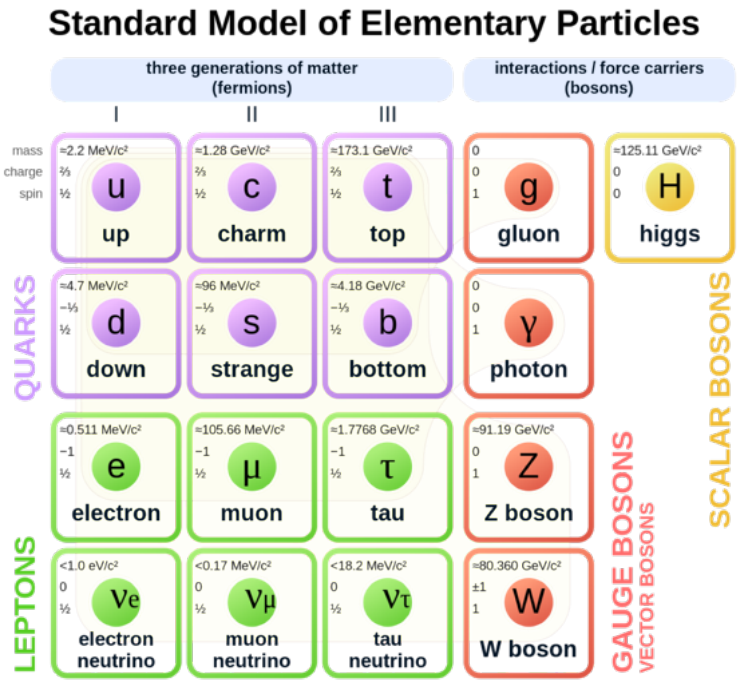
But still...

they barely interact with anything.



Trillions pass through your body every second, yet they leave no trace.

Elementary Particles



Properties of neutrinos:

- Neutral electric charge
- Very small mass
- Three flavors…
- …each associated with a charged particle of the same flavor (e, μ, τ)
- Oscillation among flavors
- Interact very weakly with matter

Can we detect Neutrinos?

How can you detect something that leaves *almost* no trace and barely (weakly) interacts with matter?

That's the challenge for today!

We have to think smarter to detect them.

Why neutrinos?

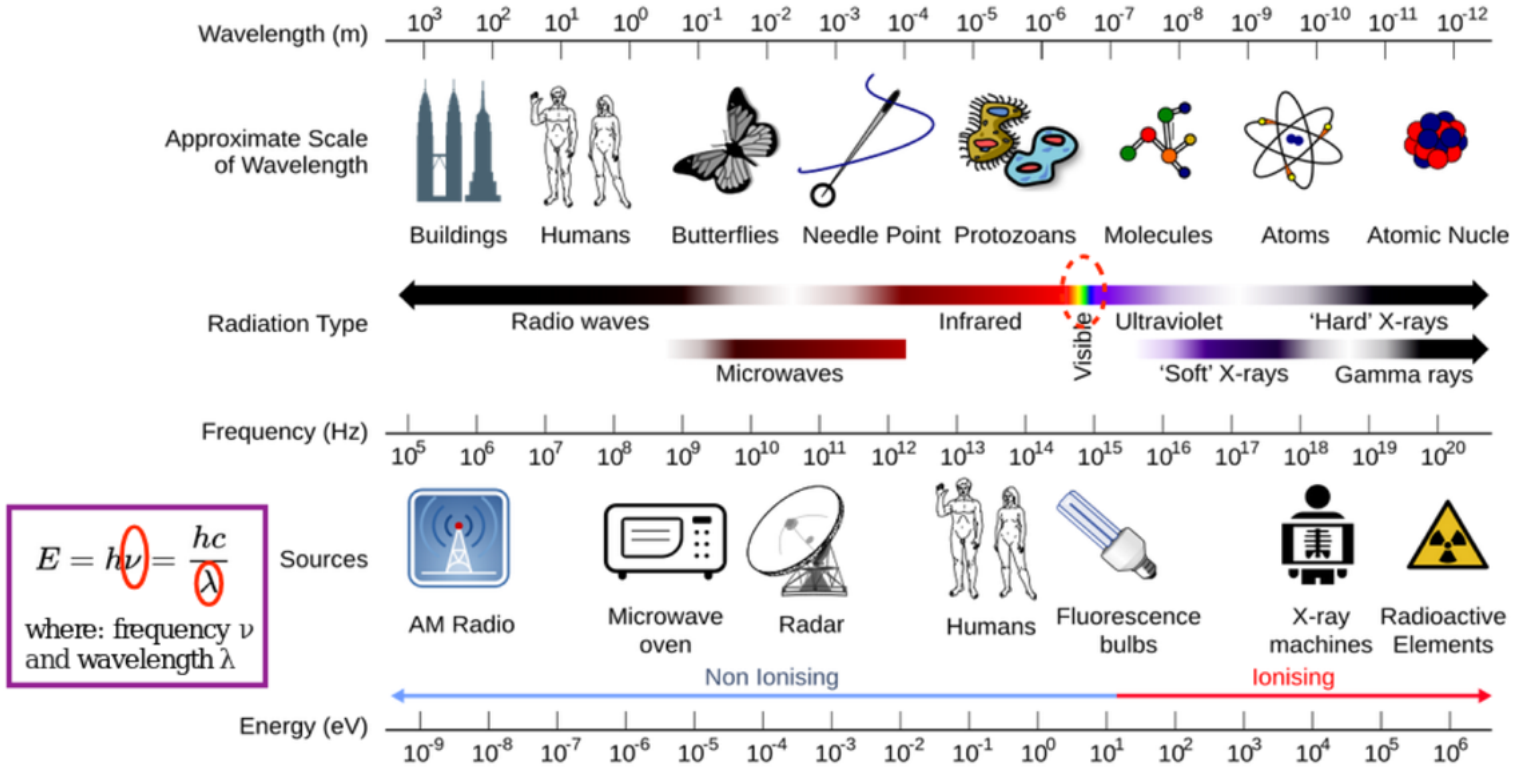
Why are scientists so interested in detecting neutrinos?

Remember: Neutrinos are like ghosts in the Universe… they can pass through almost anything…

Part II: Neutrino Astronomy

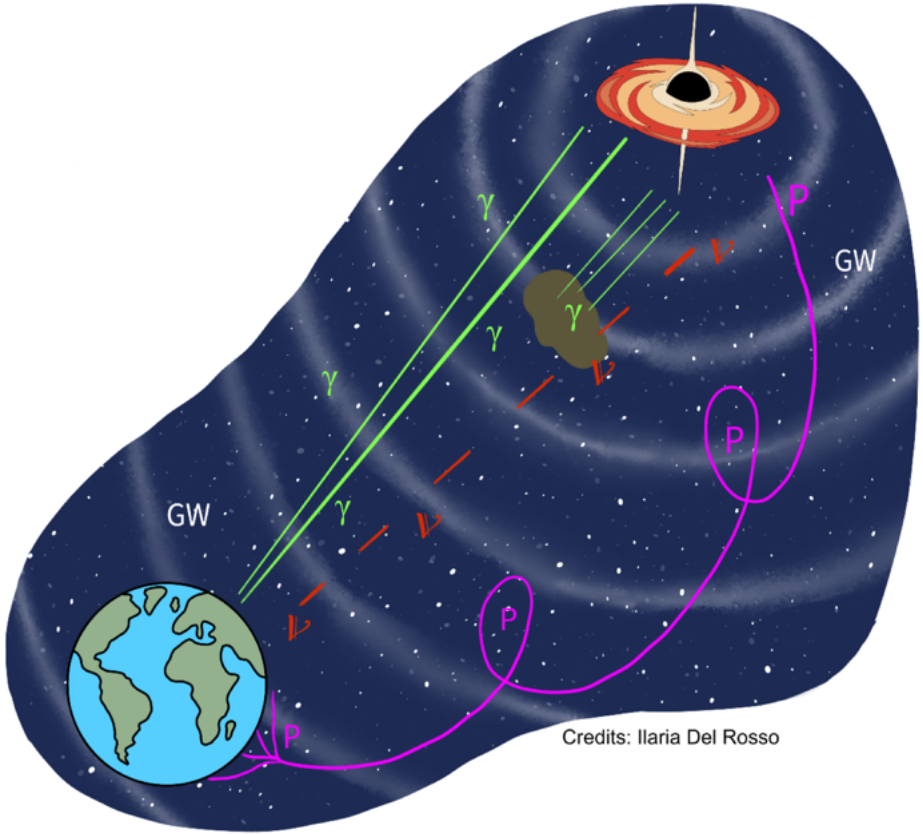
How do we observe the universe?

Energy and Wavelength Ranges



THE UNIVERSE AT DIFFERENT WAVELENGTHS

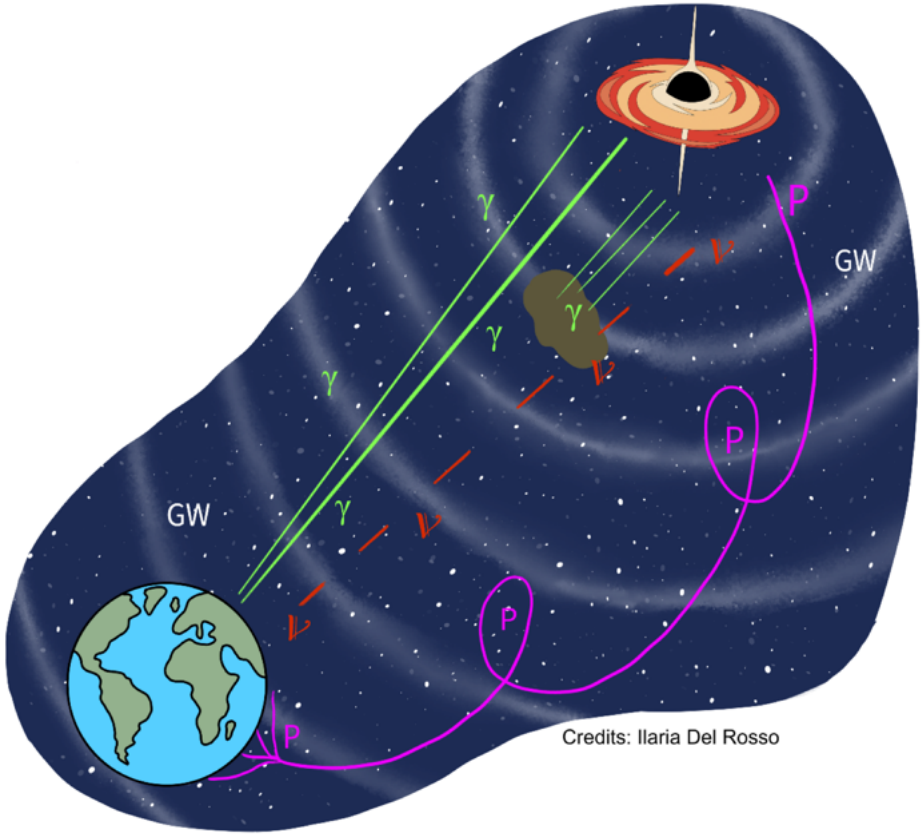
Why neutrinos?



Neutrinos as Cosmic Messengers:

- They travel in **straight lines**
- Practically, they are **not absorbed by the interstellar medium**
- They can **reveal information about processes in astrophysical sources** that light or cosmic rays cannot reveal.

Why neutrinos?



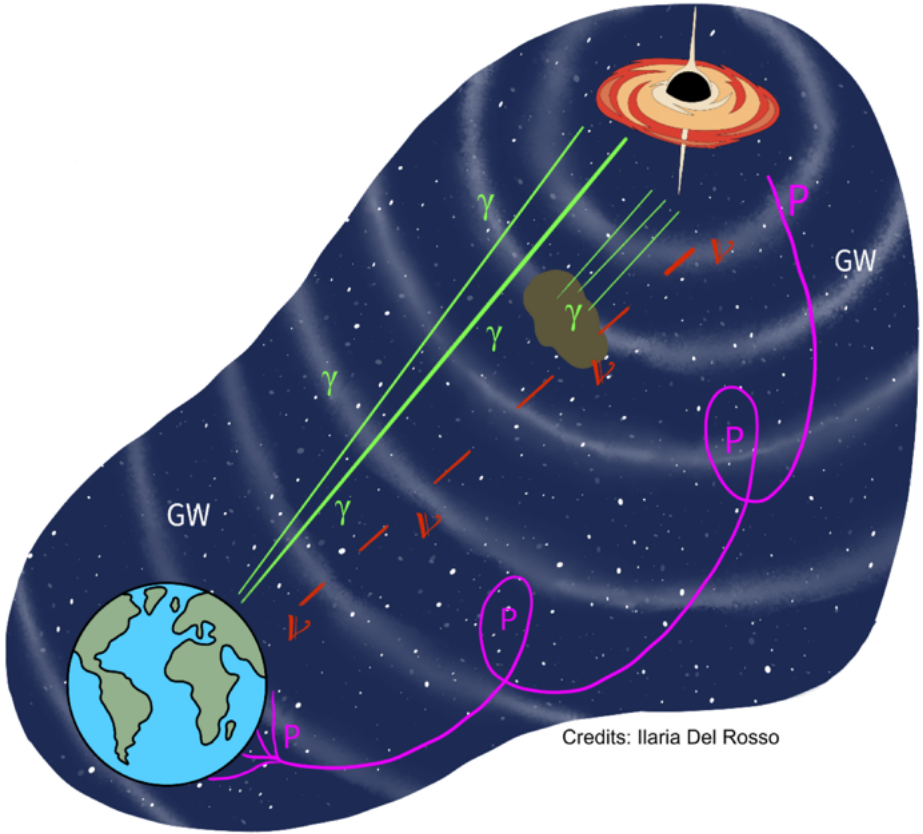
Credits: Ilaria Del Rosso

Neutrinos as Cosmic Messengers:

- They travel in **straight lines**
- Practically, they are **not absorbed by the interstellar medium**
- They can **reveal information about processes in astrophysical sources** that light or cosmic rays cannot reveal.

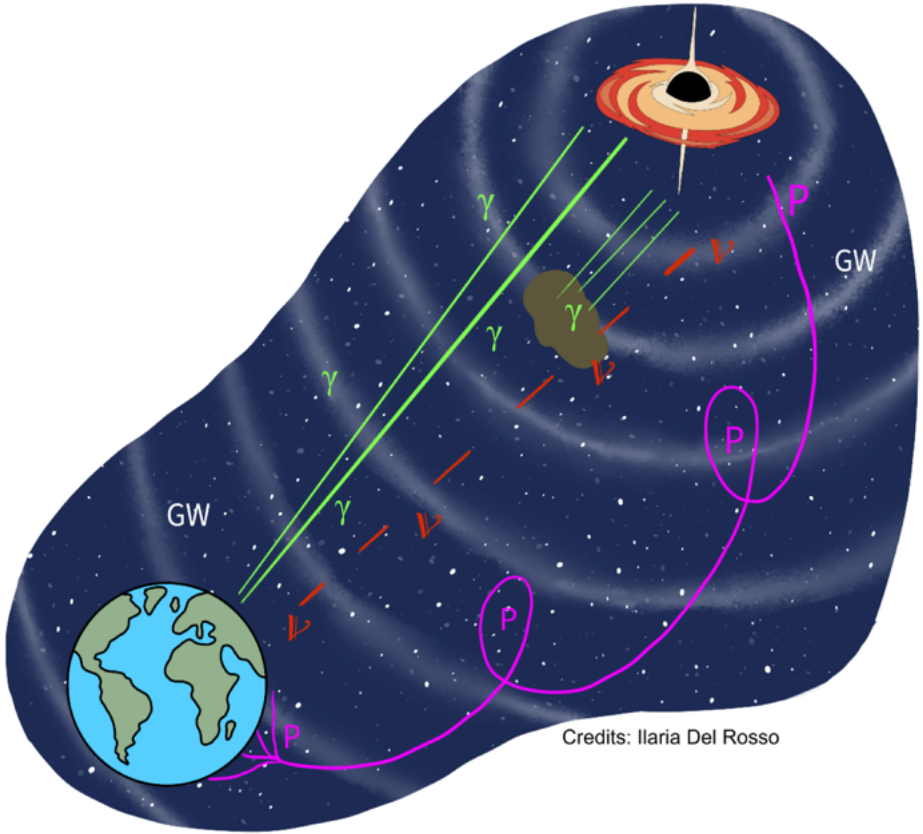
Multi-messenger astronomy: combining different signals to study extreme astrophysical phenomena. Each one brings one piece of the puzzle.

Why neutrinos?



We said that **neutrinos can pass through dense objects** → what is another feature that distinguishes neutrinos from other messengers?

Why neutrinos?



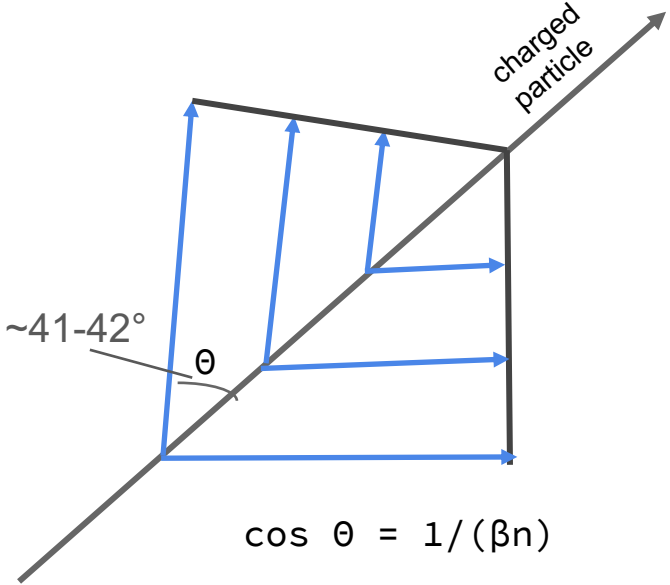
We said that **neutrinos can pass through dense objects** → what is another feature that distinguishes neutrinos from other messengers?

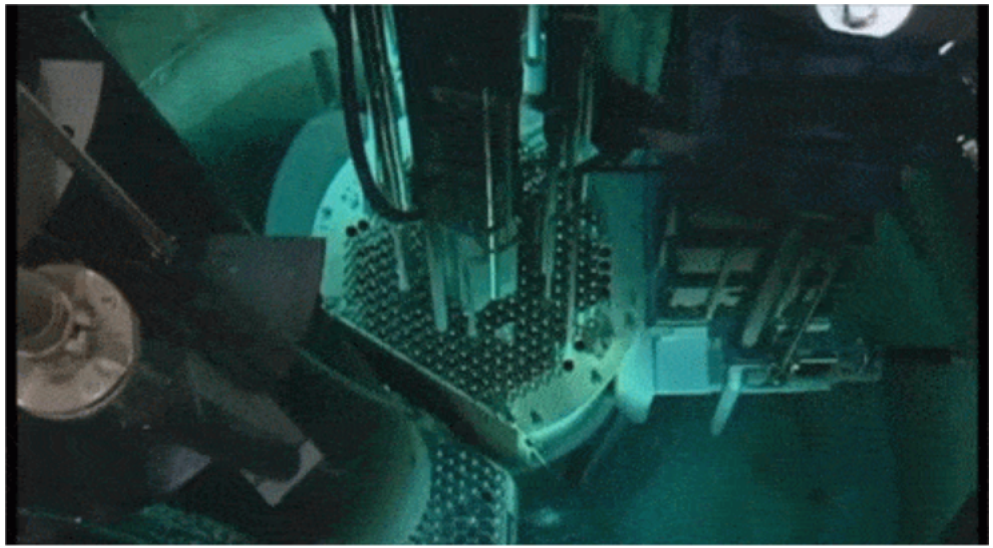
They can pass through the Earth (and the atmosphere)
→ **Every sky location is visible with neutrinos!**

PART III: NEUTRINO DETECTION

THE CHERENKOV EFFECT

A flash of blue light produced when a charged particle travels faster than light in a medium.

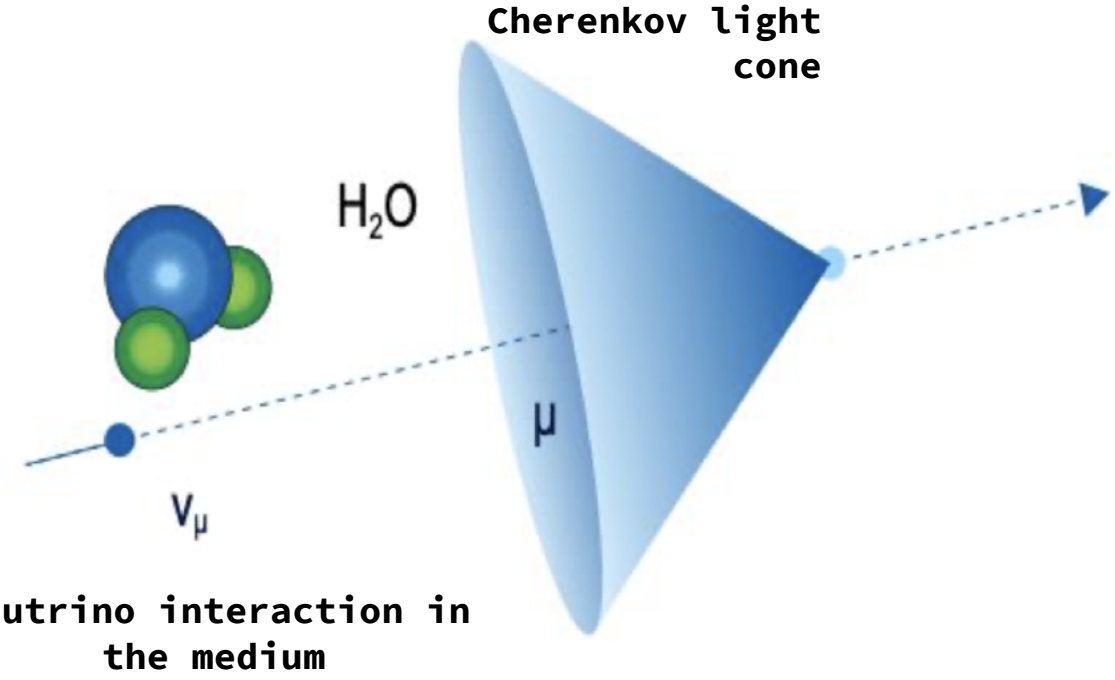




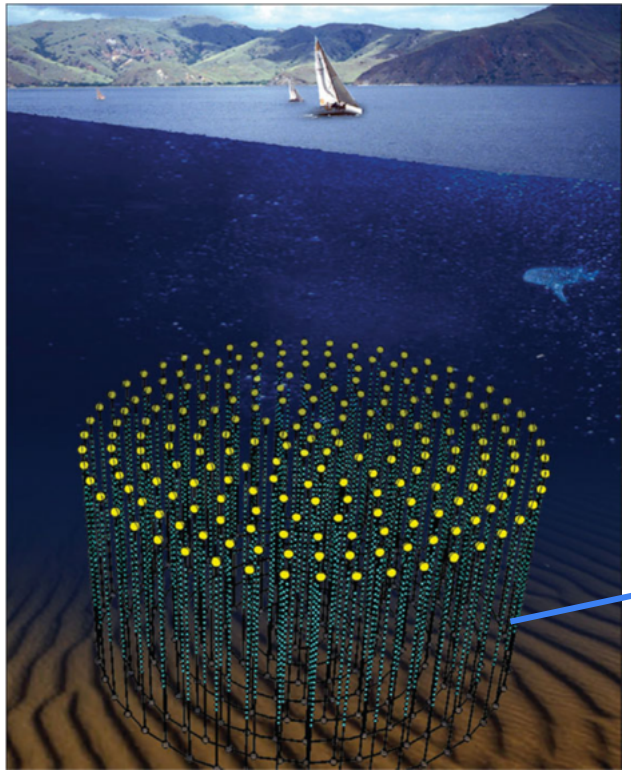
where: **β** = speed of particle/speed of light in vacuum, **n** = refractive index of the medium

Neutrino detection method

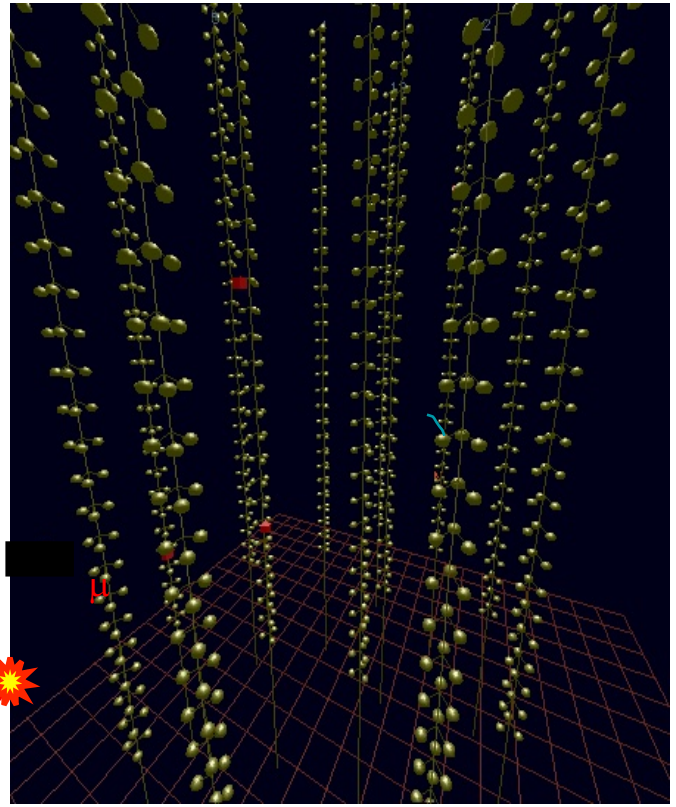
A flash of blue light produced when a charged particle travels faster than light in a medium.



Neutrino detection method



Scientists deploy **large-scale deep-sea** neutrino detectors equipped with **photosensors** to detect neutrino-induced signals

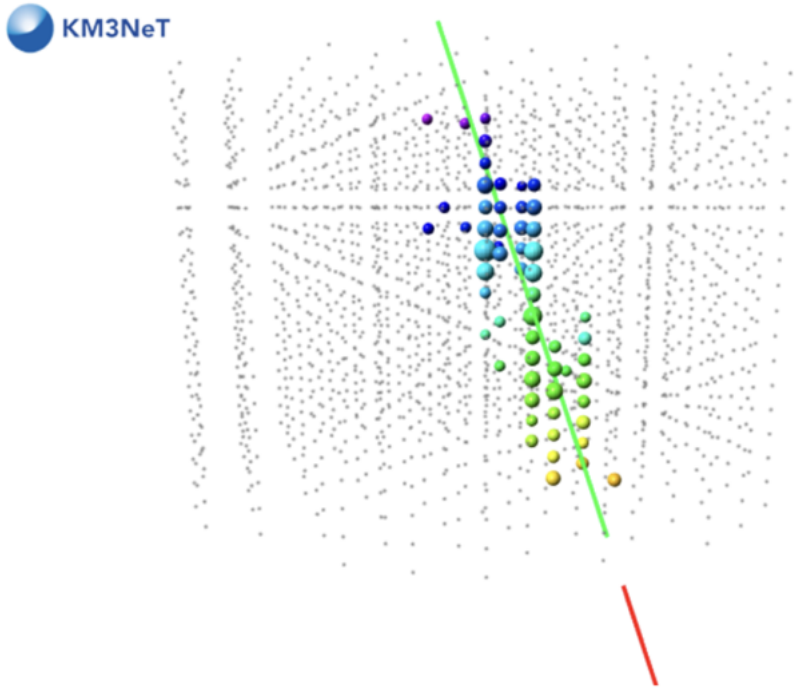


What does a neutrino interaction look like?

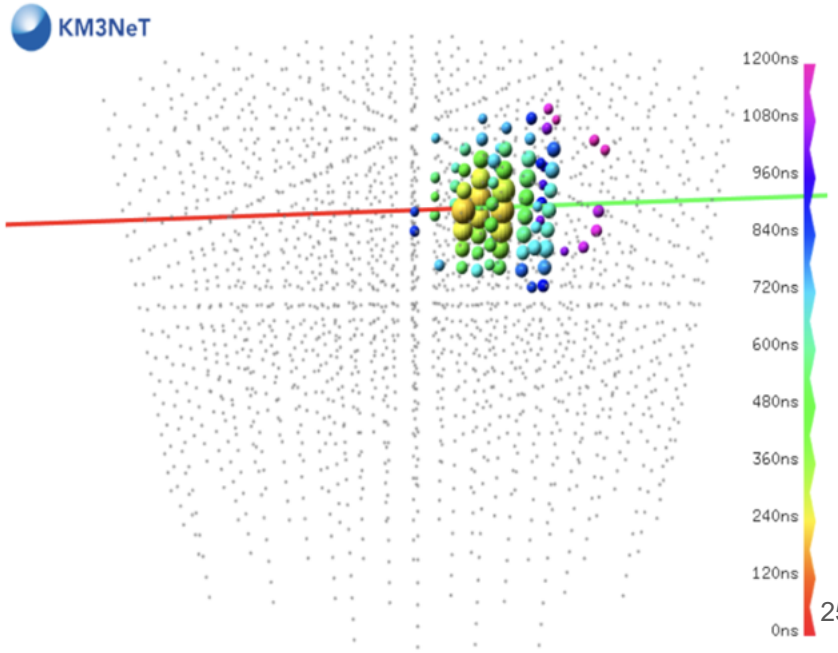
More in next talk!

It depends on which neutrino interacted (ve, νμ, ντ), and which type of interaction it went through

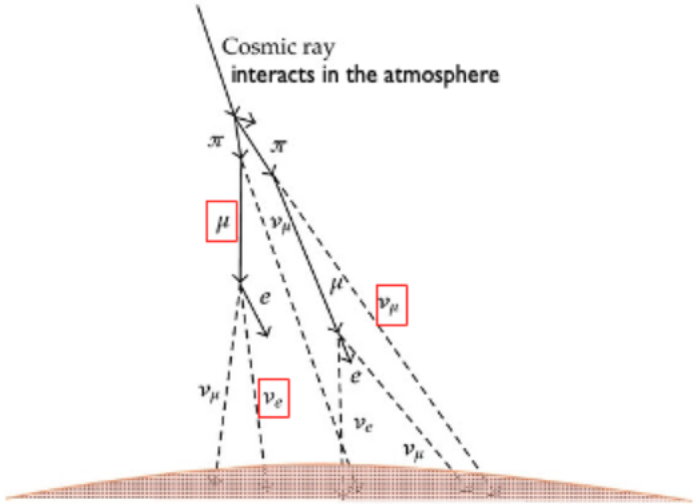
Track

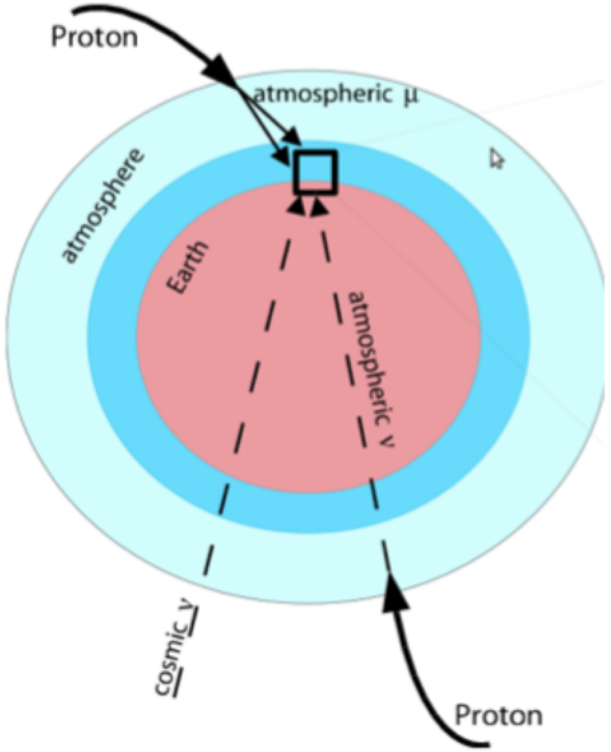


Shower



What is the background for a cosmic neutrino detector?





What is the background for a cosmic neutrino detector?

electron above the Cherenkov threshold →Cherenkov photons

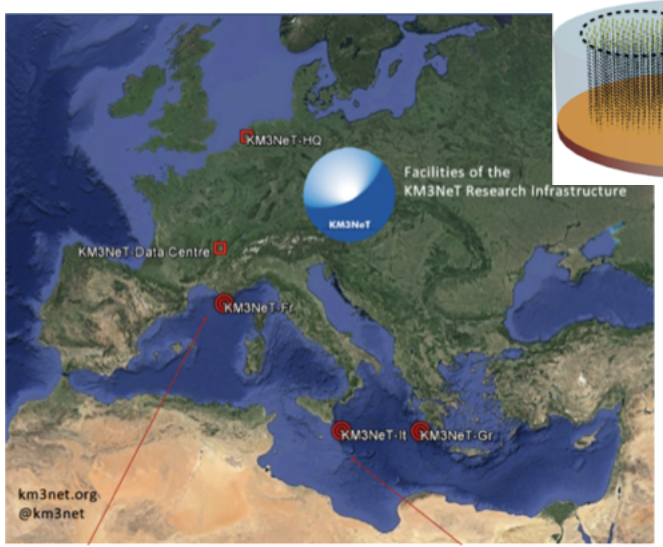
Seawater contains dissolved salts, including **potassium**, and a small fraction of this potassium is radioactive (**potassium-40**), which continuously decays

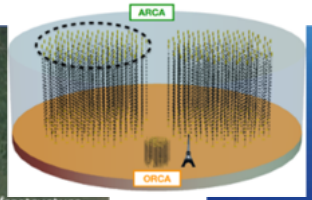
What is the background for a cosmic neutrino detector?

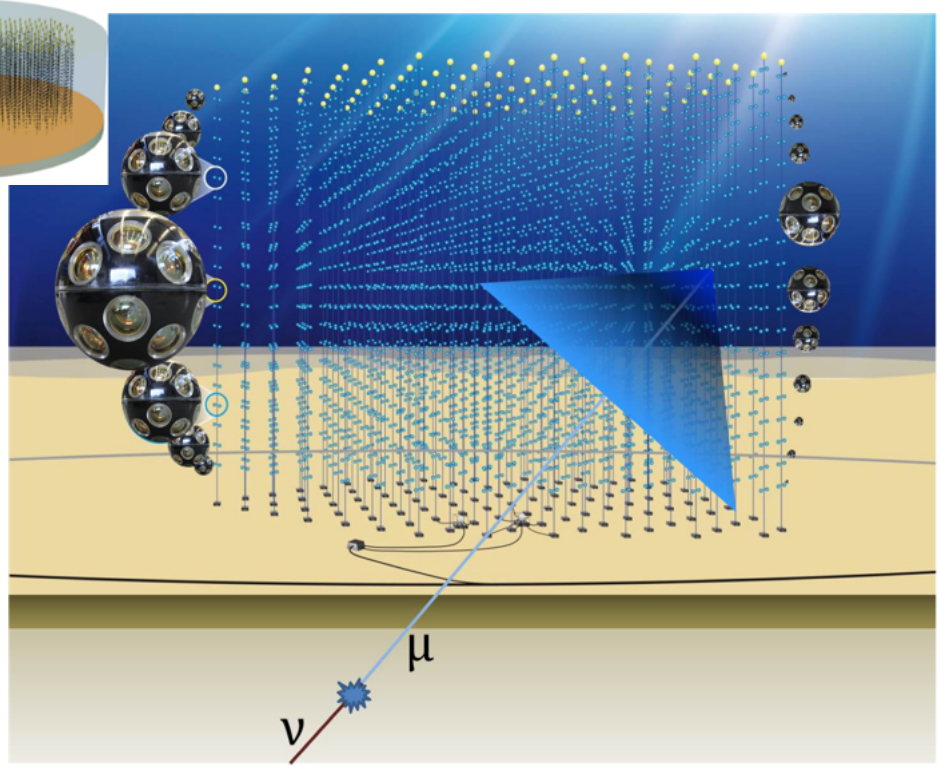
Also organisms living in the sea emit light!

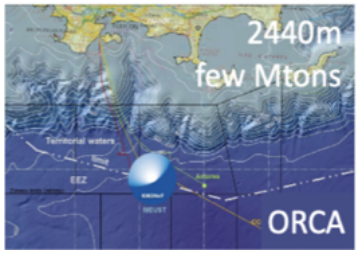
Part IV: The KM3NeT detector

The KM3NeT detectors





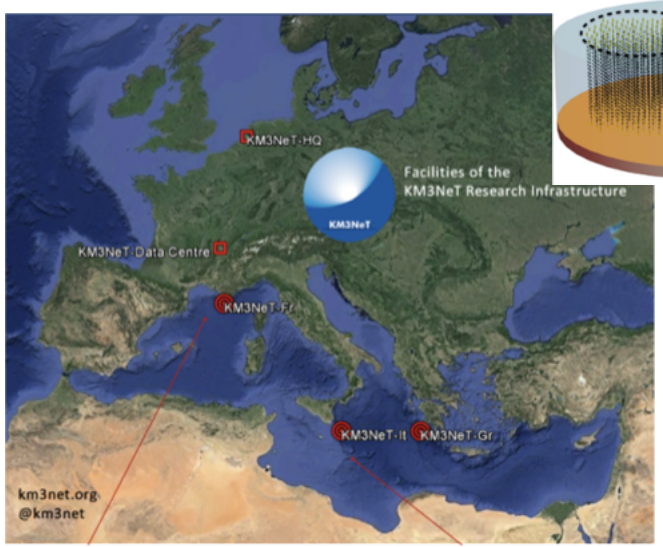


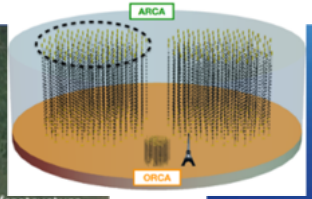


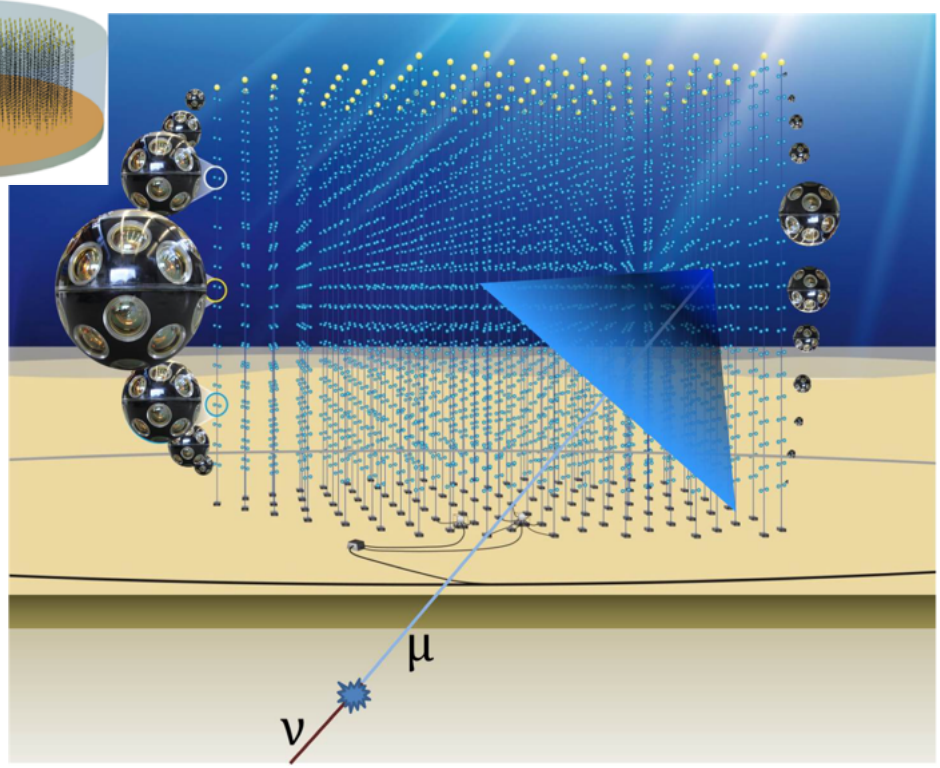
What do “O” and “A” in ARCA and ORCA stand for?

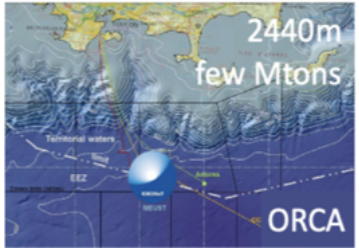
Identical technology for ARCA and ORCA

The KM3NeT detectors







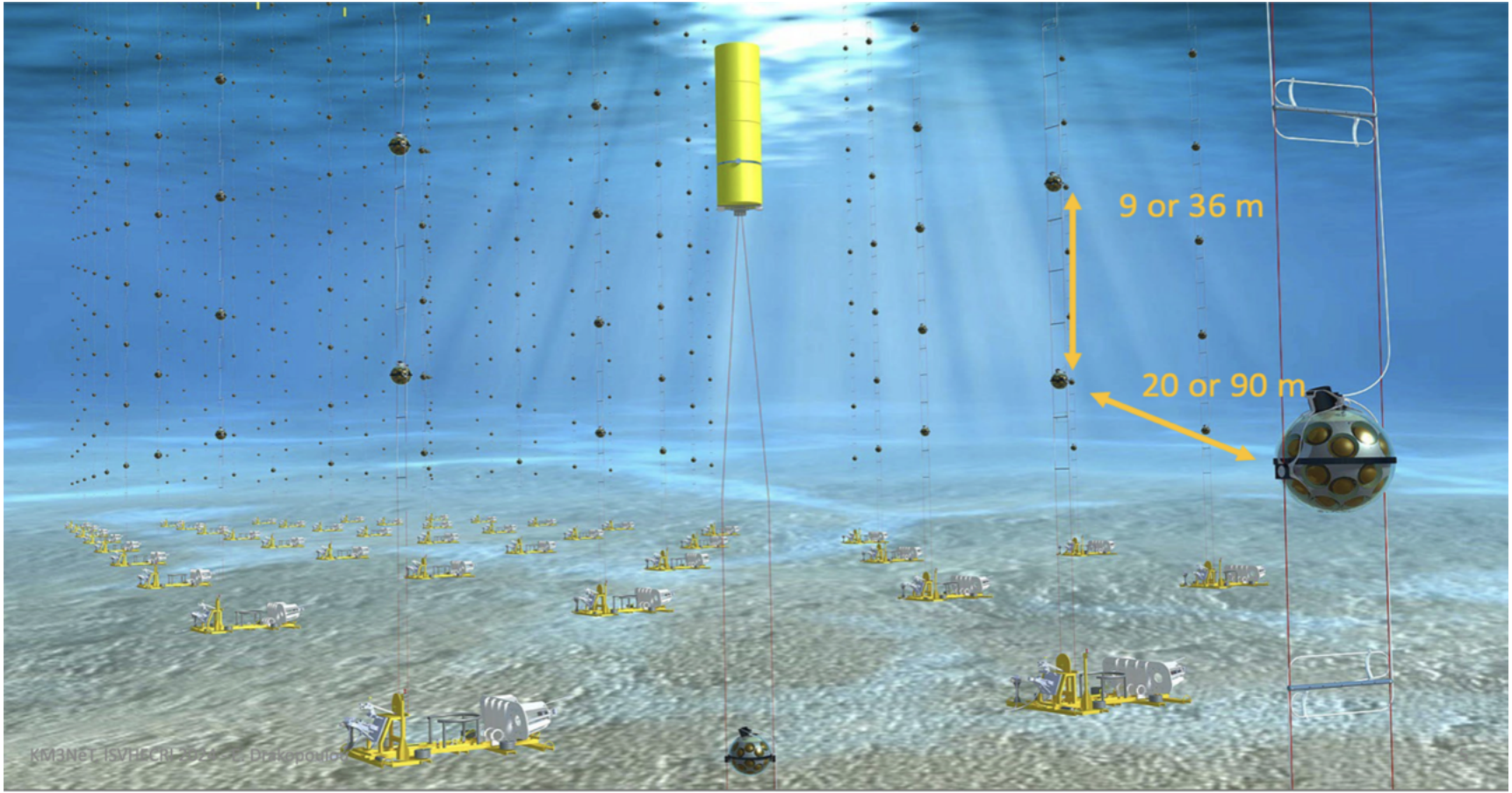


Neutrino Oscillations
Mass Hierarchy

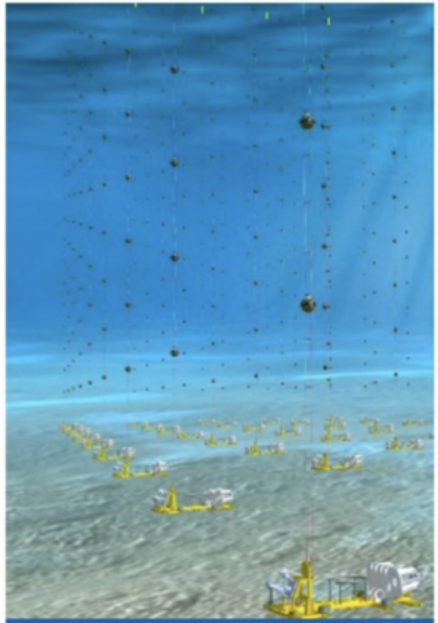
Detection of neutrinos from
astrophysical sources

Identical technology for ARCA and ORCA

The KM3NeT detectors



The KM3NeT optical modules



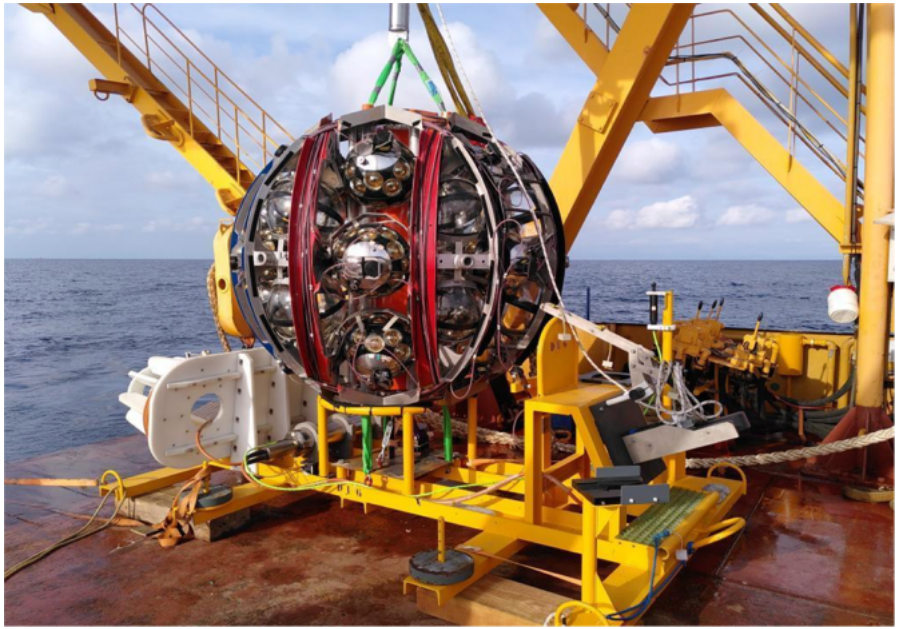
1 building block =
115 lines

1 line =
18 optical modules

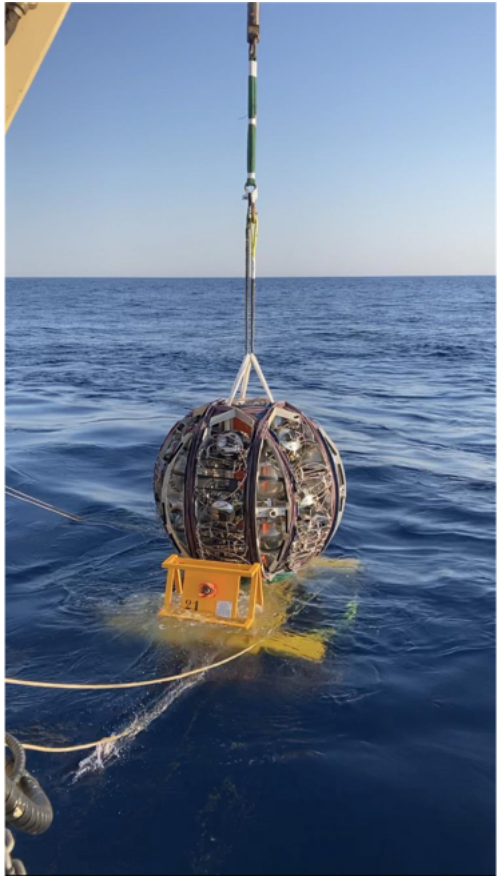
1 optical module =
31 photomultiplier tubes

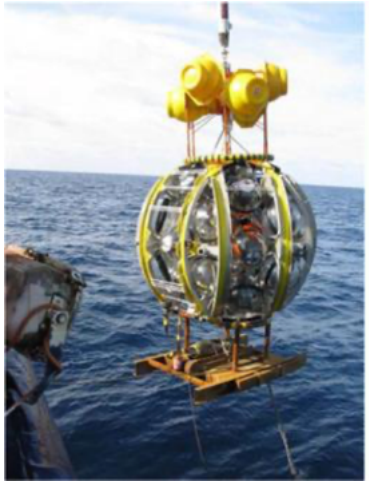
71 unique components
(in solid or liquid phase)

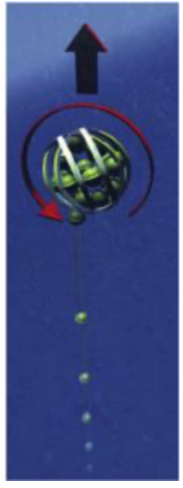
How do we deploy thousands of photosensors on the seabed?



How do we deploy thousands of photosensors on the seabed?



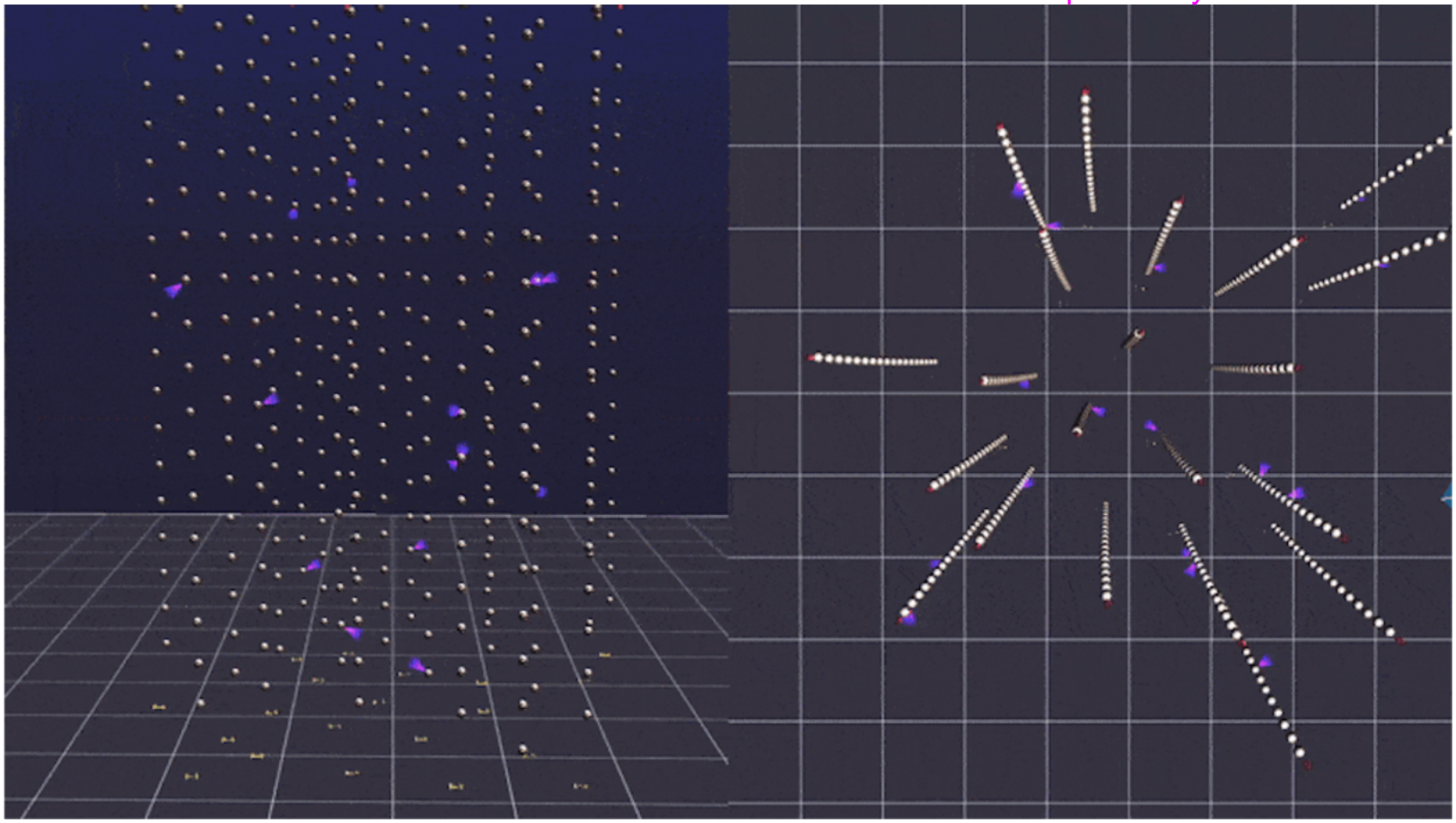




How do we deploy thousands of photosensors on the seabed?

TRACE OF A "REAL NEUTRINO"

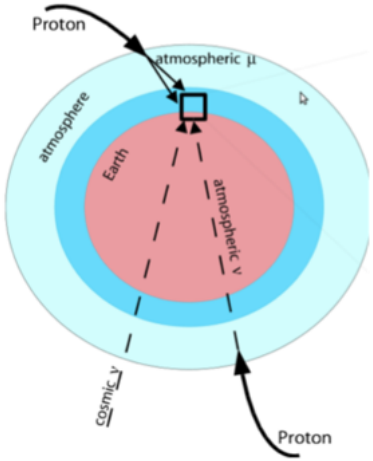
Highest energy neutrino ever observed: 220 PeV (2×10^{17}eV), about 100 times higher in energy than previously observed!!!

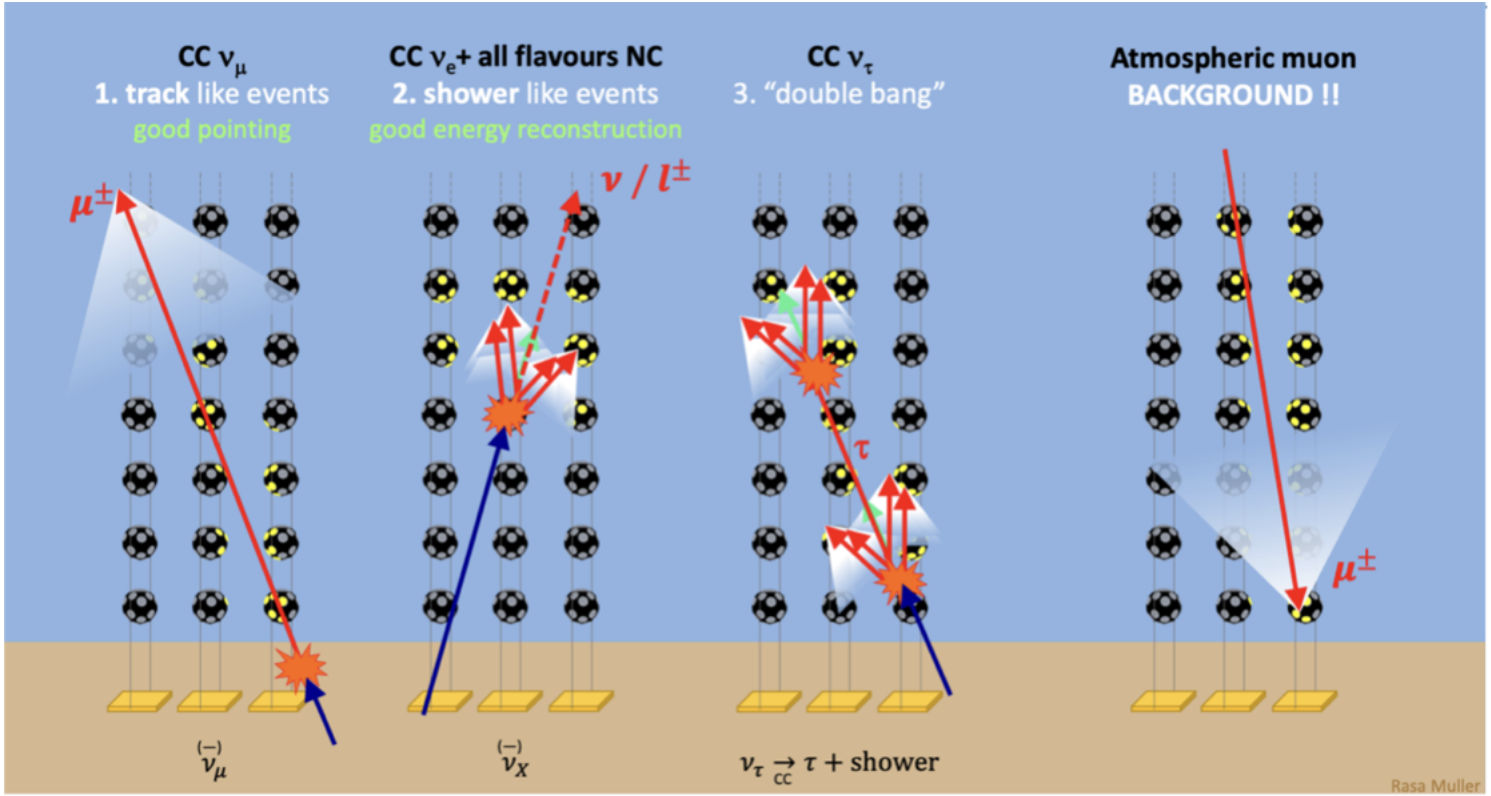


Backup / spares

Elementary Particles

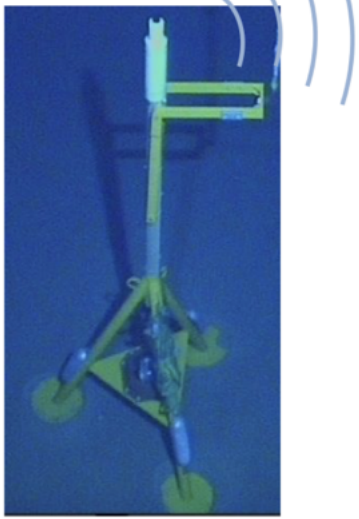
Event signatures

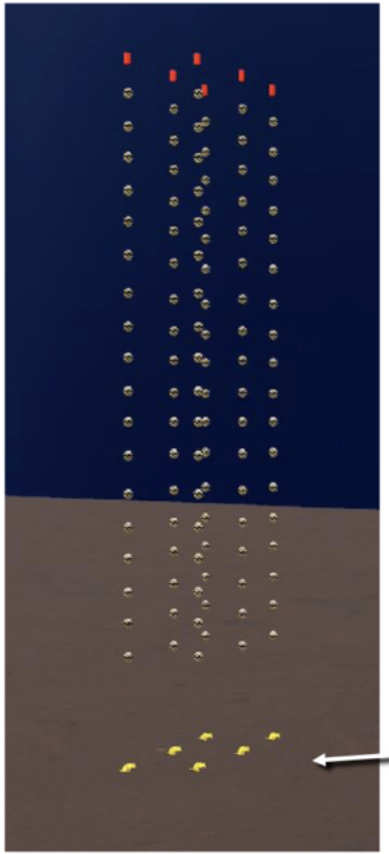




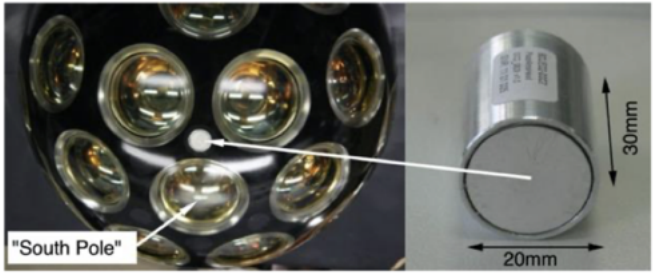
DETECTOR CALIBRATION

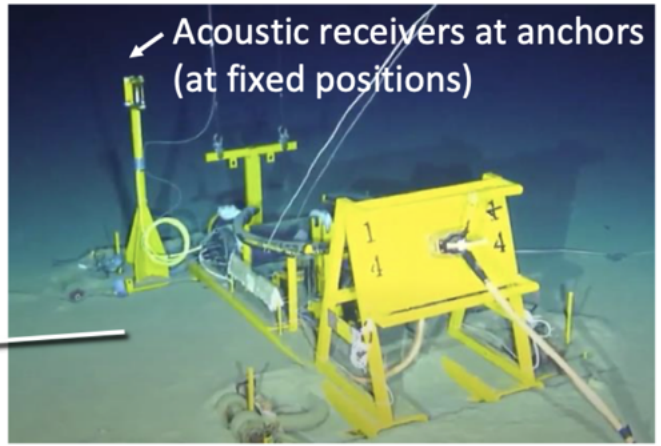
Several acoustic beacons located at fixed positions around detector emit pulse sequences at regular intervals



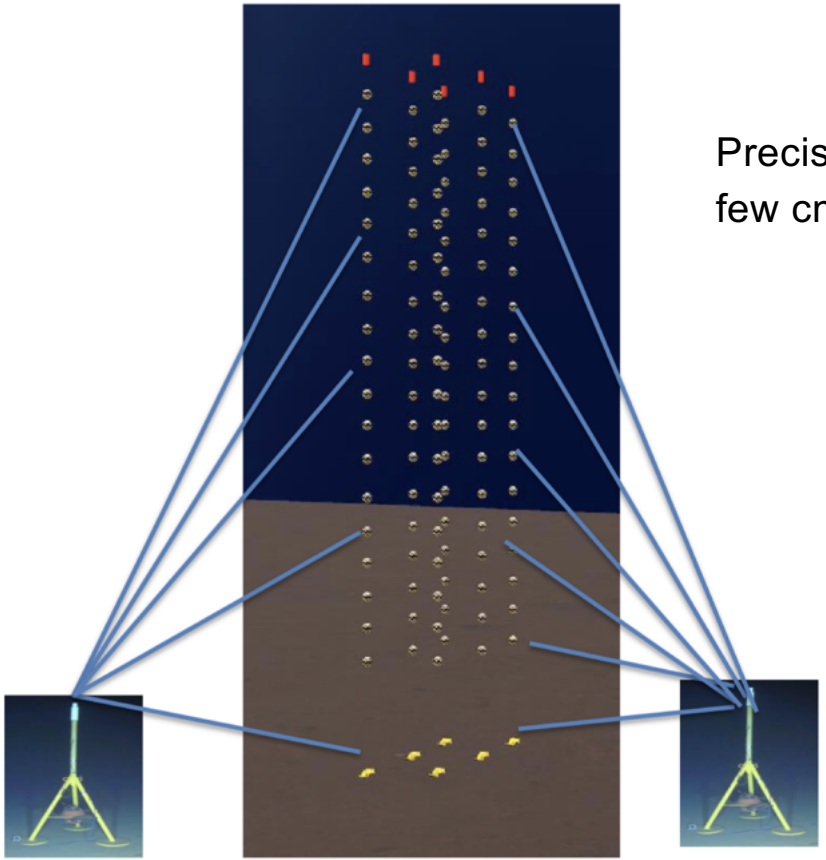


Acoustic receivers in DOMs (swaying in sea currents)





DETECTOR CALIBRATION



Precision of few cm's

Use of dynamic positions, verified by muon calibration