Neutrino Astronomy
Fishing for Neutrinos

Sofoklis A. Sotiriou
Ellinogermaniki Agogi

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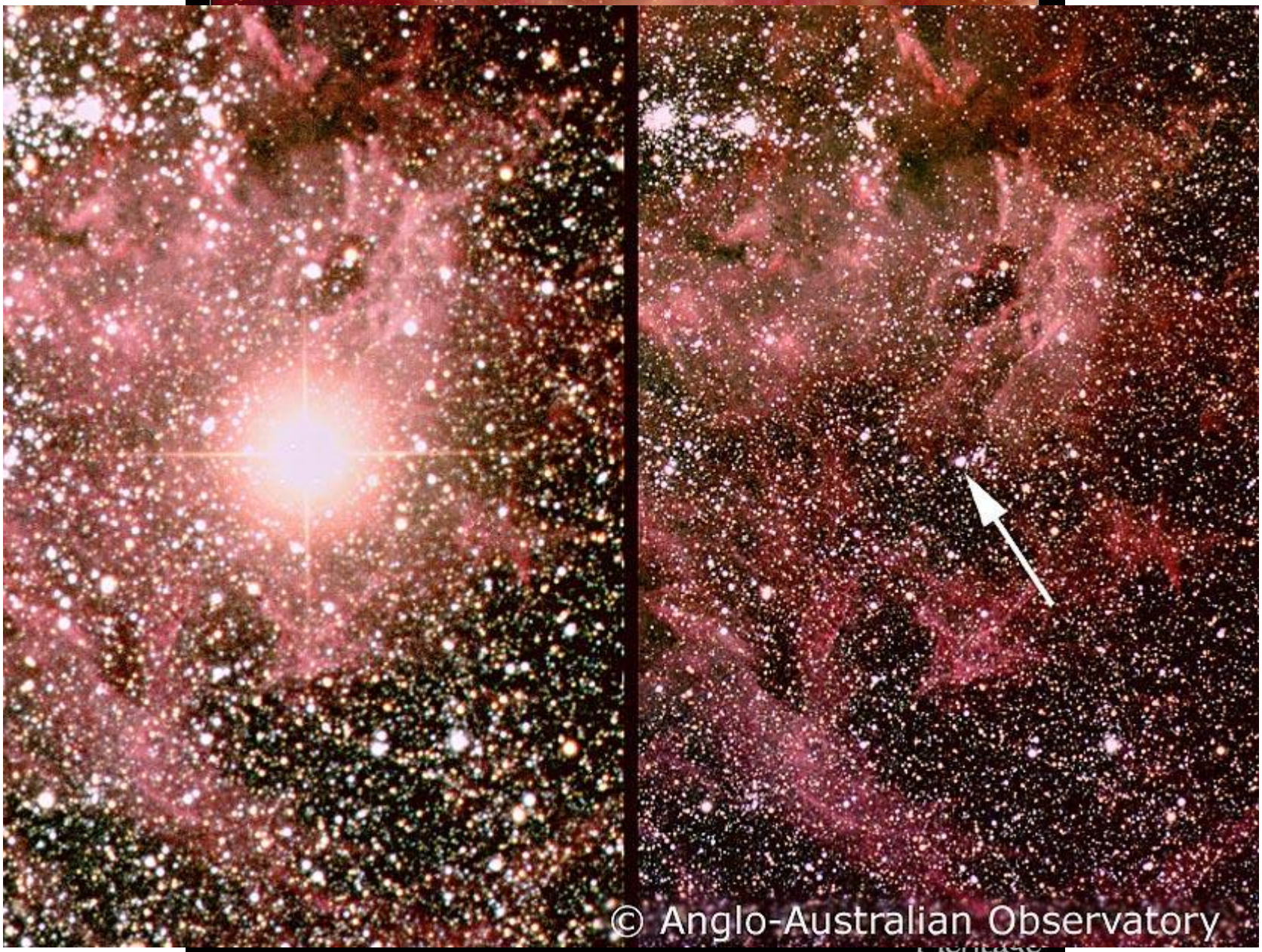
Supernova 1987A
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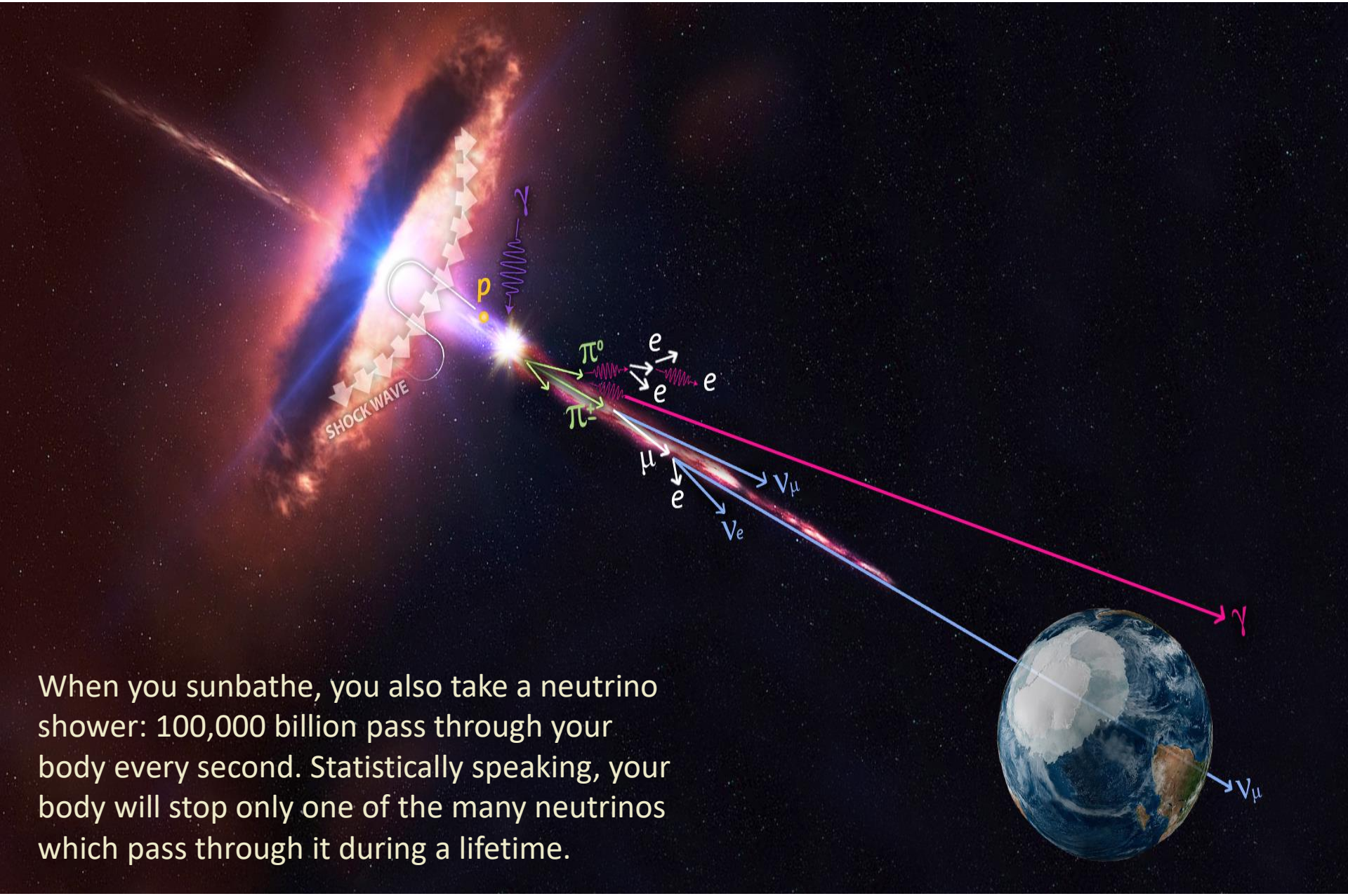
Question 1

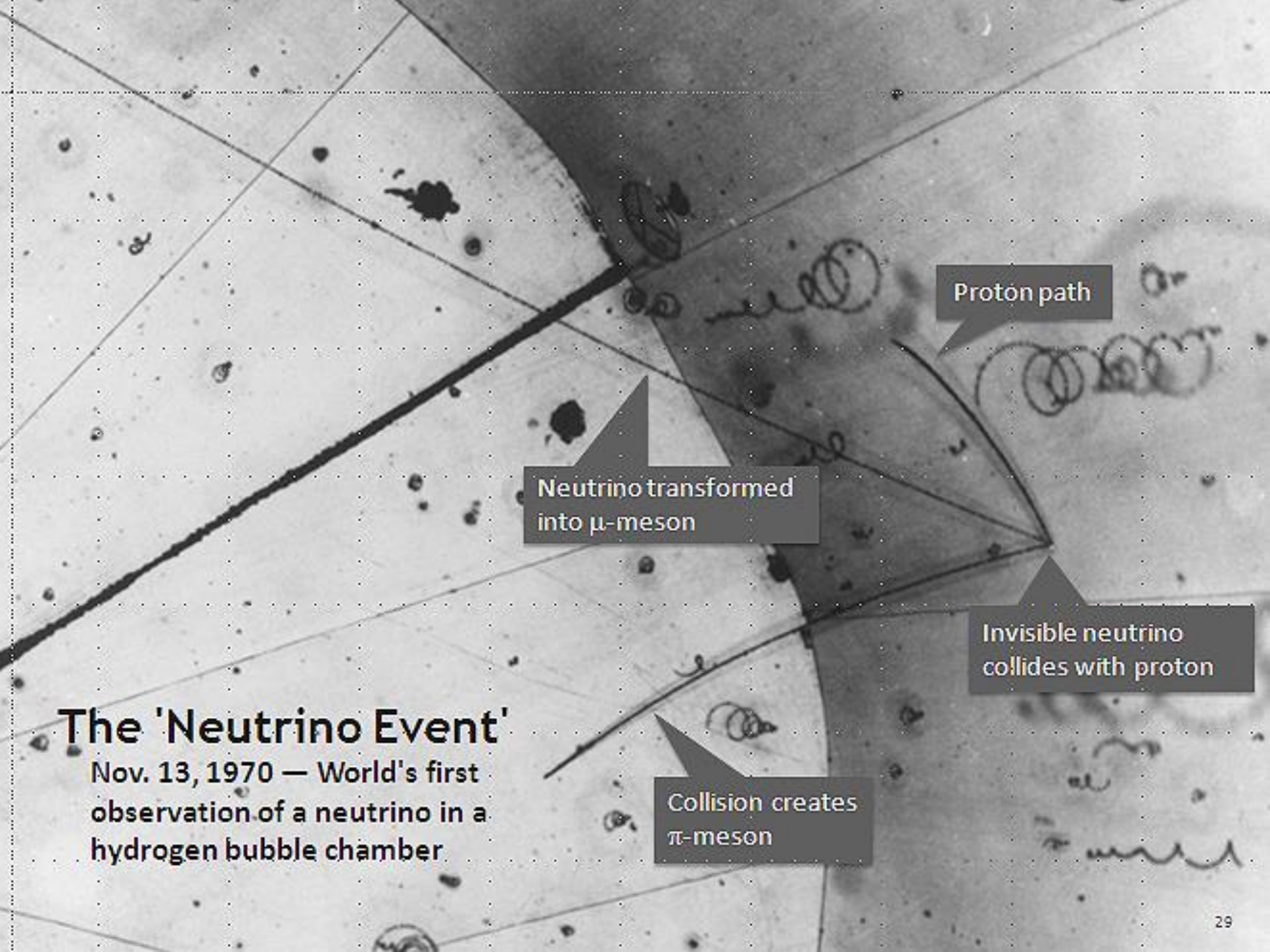
The birth of Neutrino Astronomy

SN 1987A was a type II supernova in the Large Magellanic Cloud, a dwarf galaxy satellite of the Milky Way. It occurred approximately 51.4 kiloparsecs (168,000 light-years) from Earth and was the closest observed supernova since Kepler's Supernova. 1987A's light reached Earth on February 23, 1987, and as the earliest supernova discovered that year, was labeled "1987A". Its brightness peaked in May, with an apparent magnitude of about 3. Approximately two hours before the visible light from SN 1987A reached Earth, a burst of neutrinos was observed. This was likely due to neutrino emission, which occurs simultaneously with core collapse, but before visible light was emitted. Visible light is transmitted only after the shock wave reaches the stellar surface. At 07:35 UT, Kamiokande II detected 12 antineutrinos; IMB, 8 antineutrinos; and Baksan, 5 antineutrinos; in a burst lasting less than 13 seconds

10^{58} neutrinos were produced with average energy of 10-15MeV.



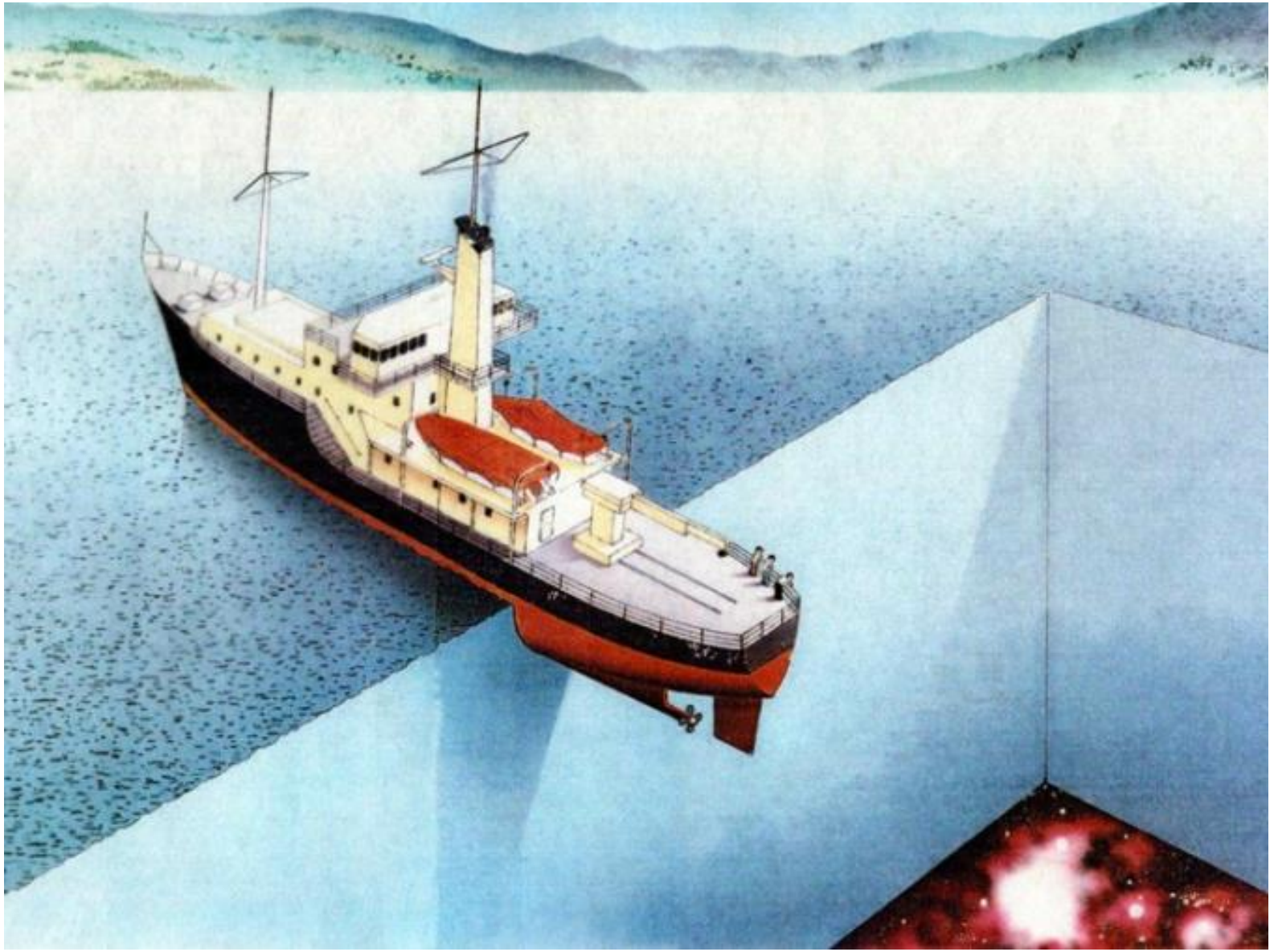
When you sunbathe, you also take a neutrino shower: 100,000 billion pass through your body every second. Statistically speaking, your body will stop only one of the many neutrinos which pass through it during a lifetime.



The 'Neutrino Event'

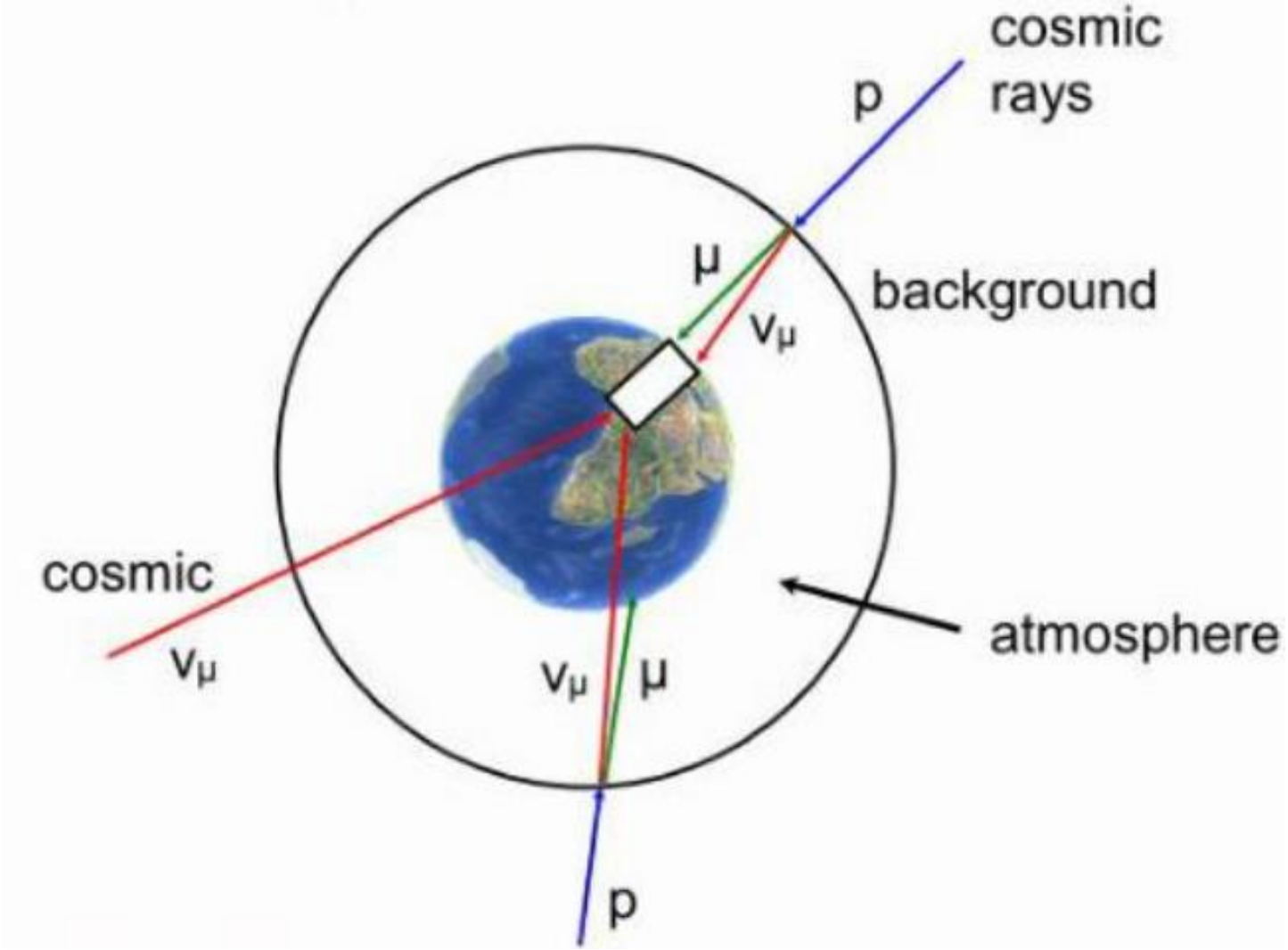
Nov. 13, 1970 — World's first observation of a neutrino in a hydrogen bubble chamber

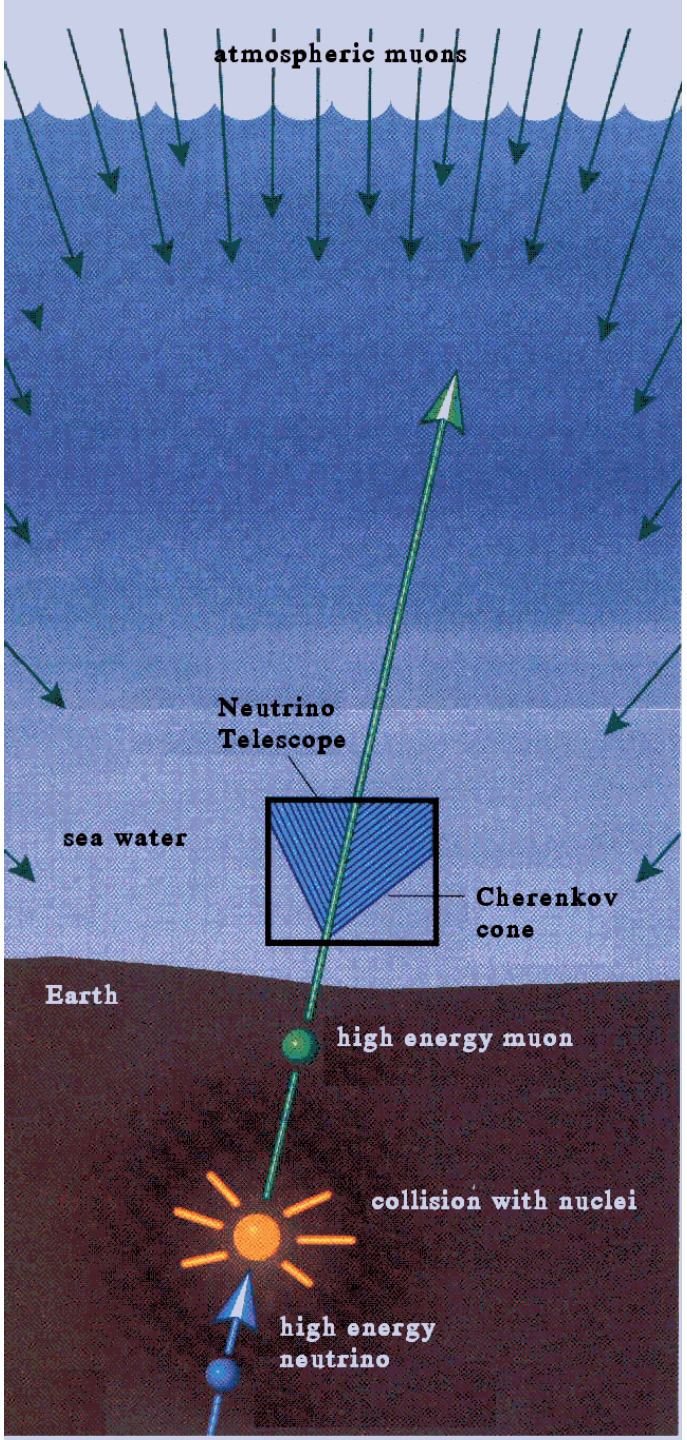
Question 2



Question 2

Signal and Noise




atmospheric muons
Neutrino
Telescope
sea water
Cherenkov
cone
Earth
high energy muon
collision with nuclei
high energy
neutrino

Question 3

Neutrinos Detection

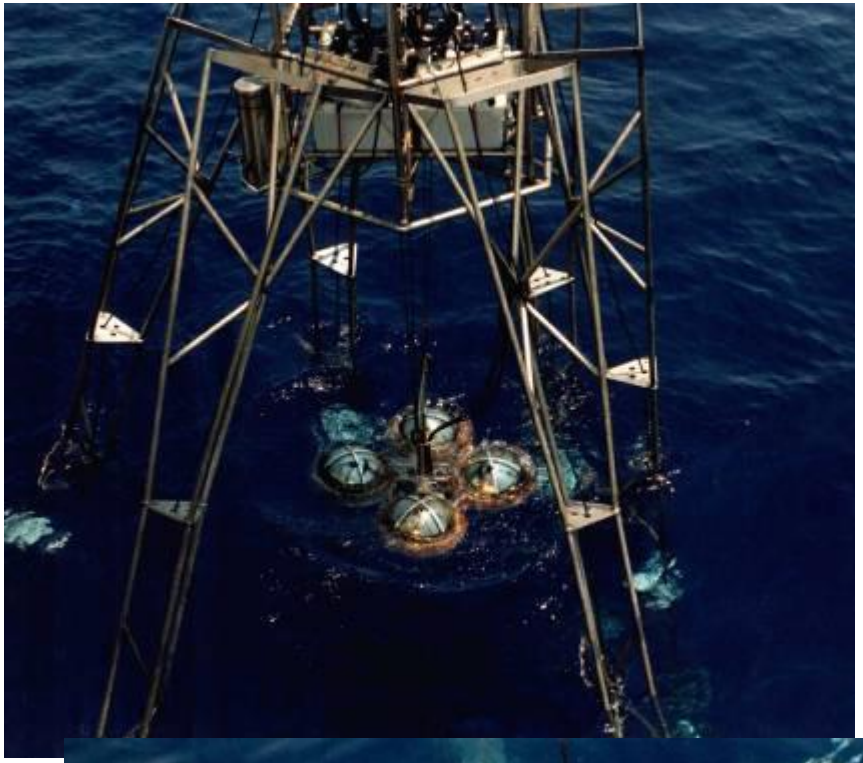
The detection of high-energy muon neutrinos exploits three properties:

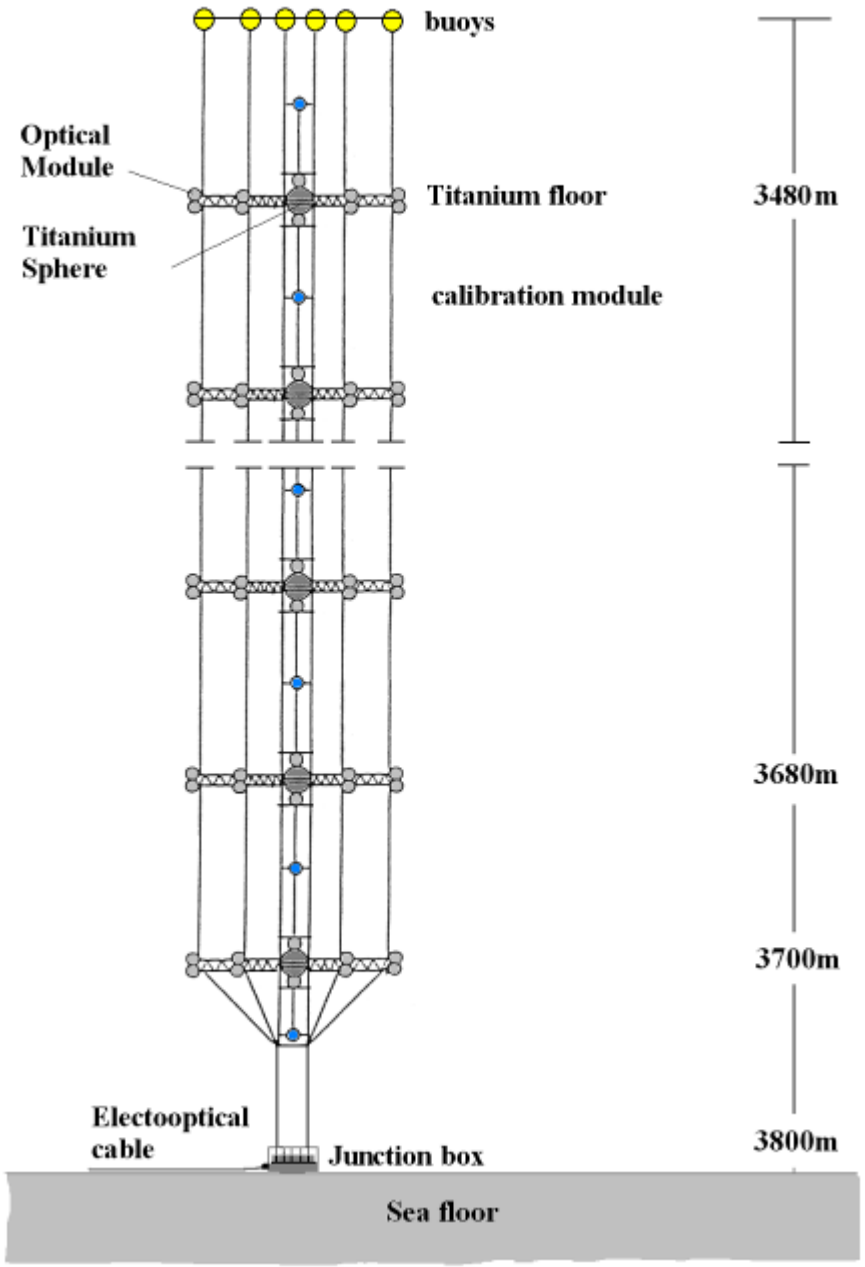
i) The **directional correlation of the muon and parent neutrino** trajectories to within 0.3◦ for Ev > 10 TeV.

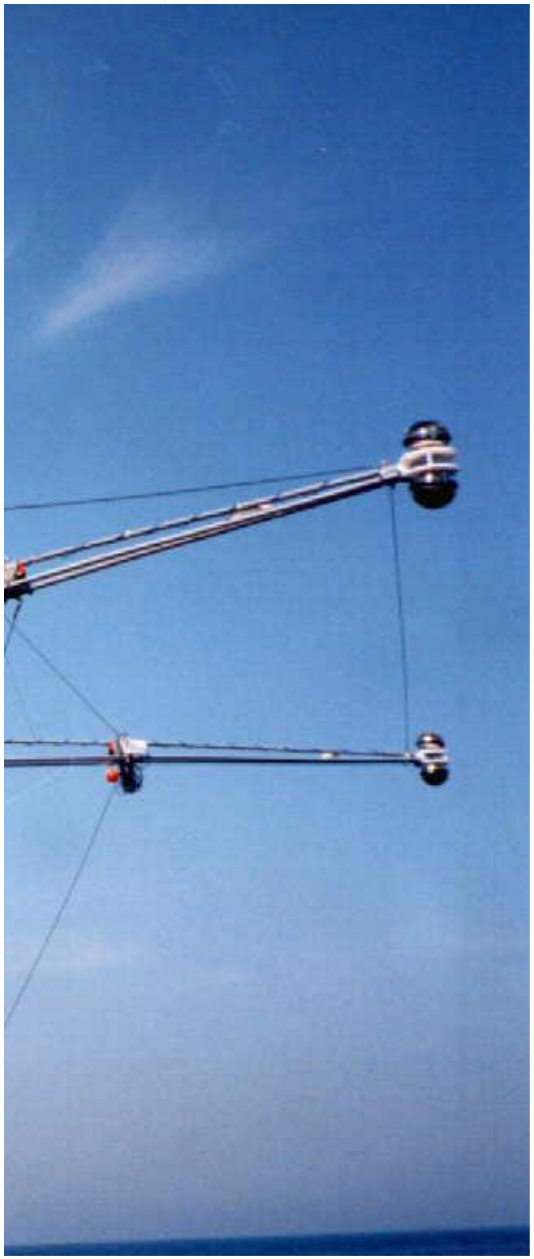
ii) The **unique upward-going directional signature of muons** from cosmic neutrino interactions with respect to the vastly higher muon background from cosmic ray collisions in the atmosphere. Upward-going muons can only originate from local neutrino interactions: the earth filters out all other particles.

iii) The **long range of muons in water and rock over the neutrino energy range of interest**. Upward-going muons may be generated far from the instrumented volume and still be detected.

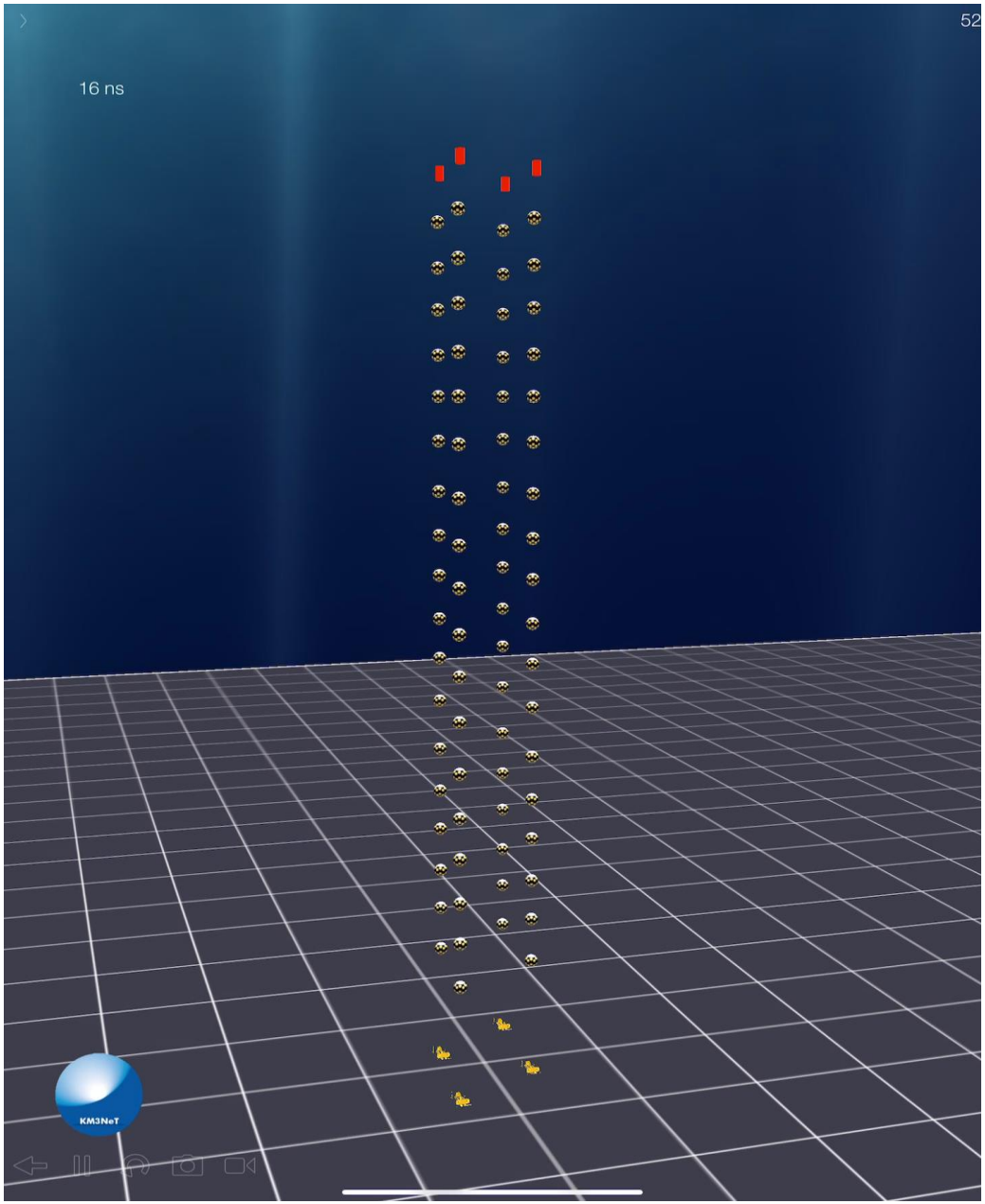
Accurate reconstruction of the trajectory of a neutrino-induced muon relies on tracking over many tens of meters and measurement of the arrival time of the UV-blue component of the Cerenkov wave front to nanosecond accuracy on photomultiplier tubes whose positions must be known to better than 20 cm.




buoys
Optical Module
Titanium Sphere
Titanium floor
calibration module
3480m
3680m
3700m
3800m
Electooptical cable
Junction box
Sea floor

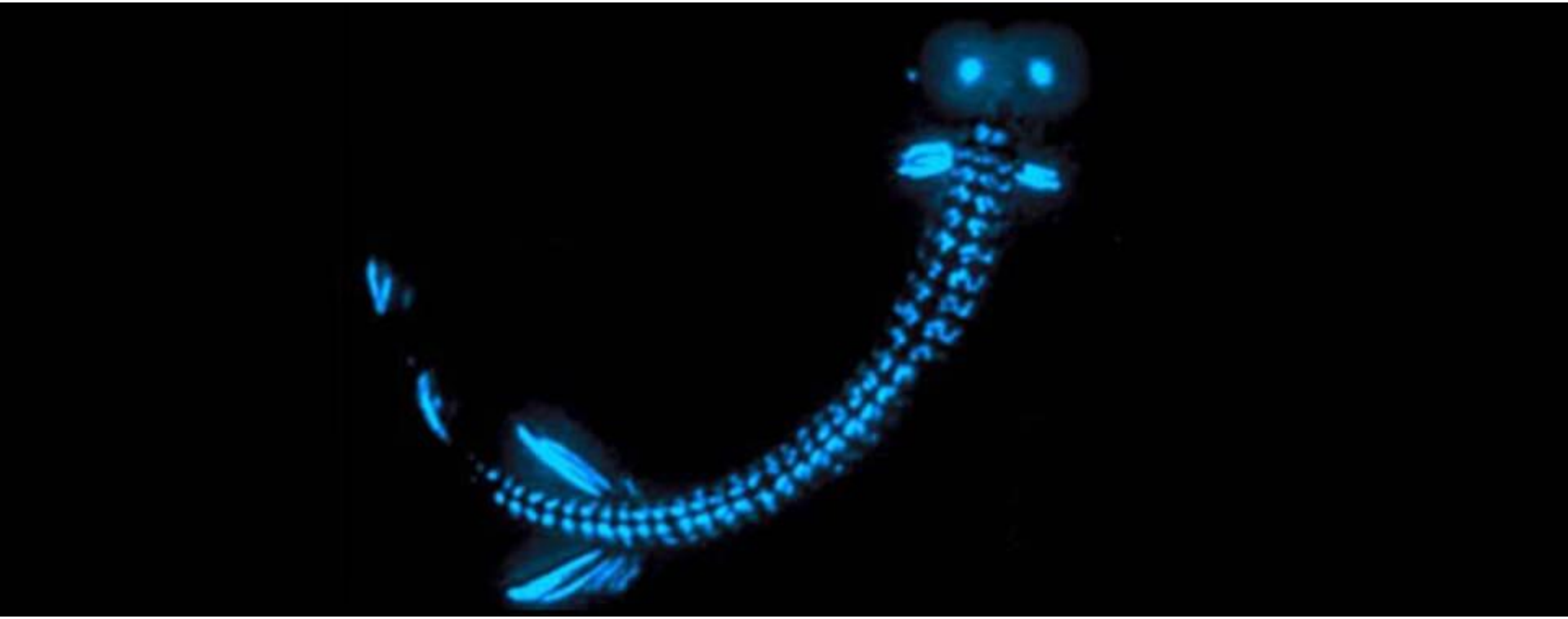


ORCA4 first events

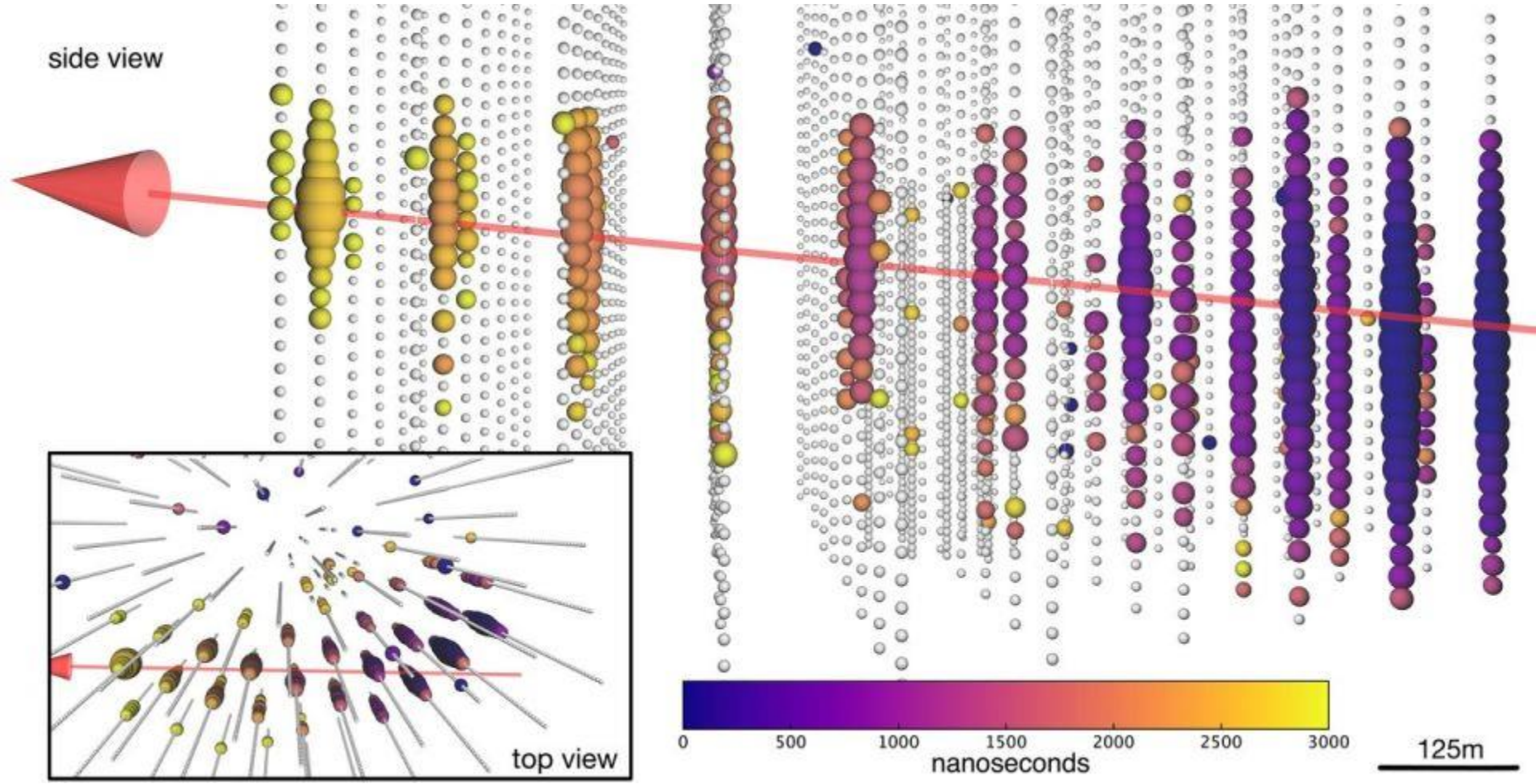


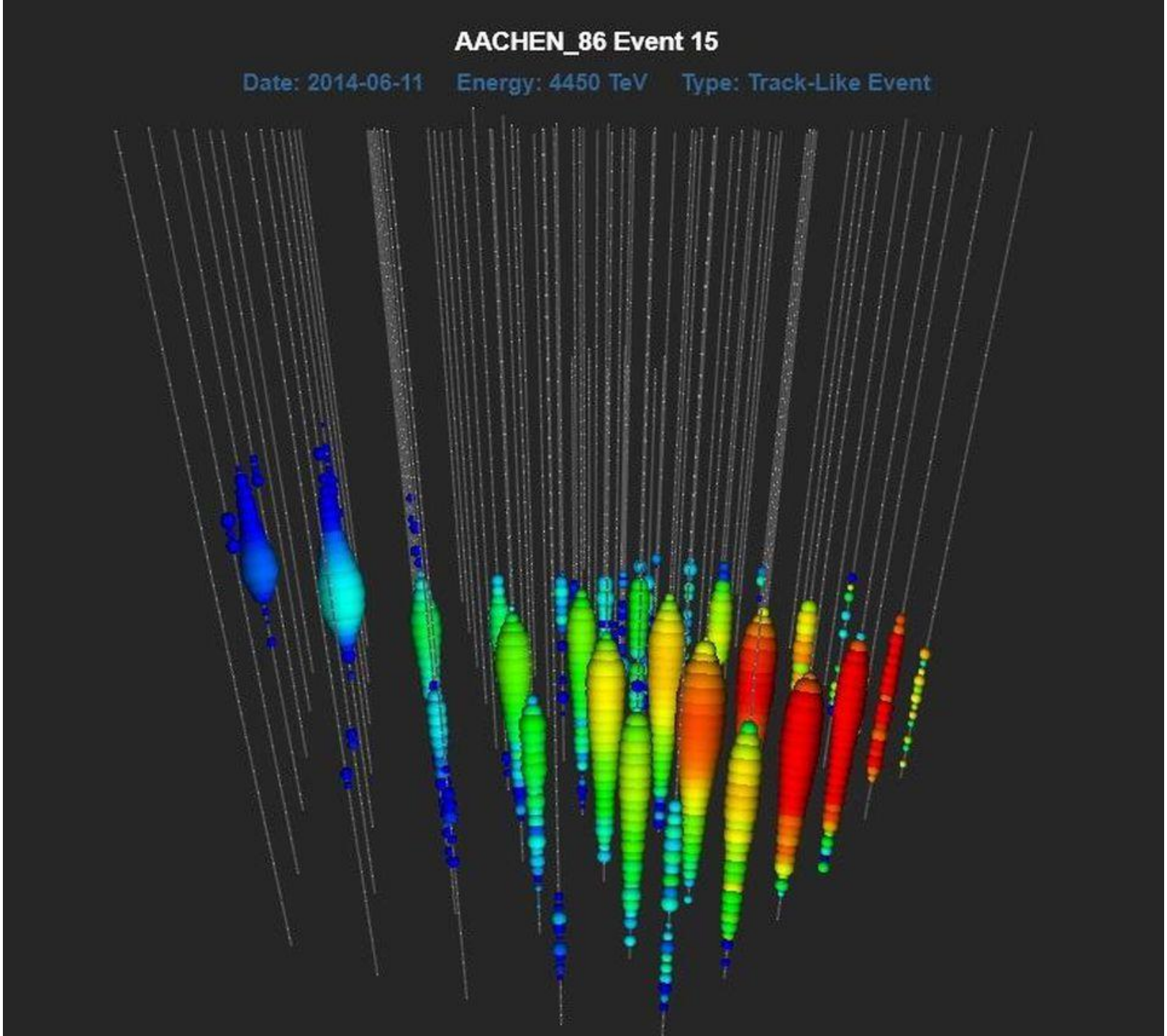
Question 3

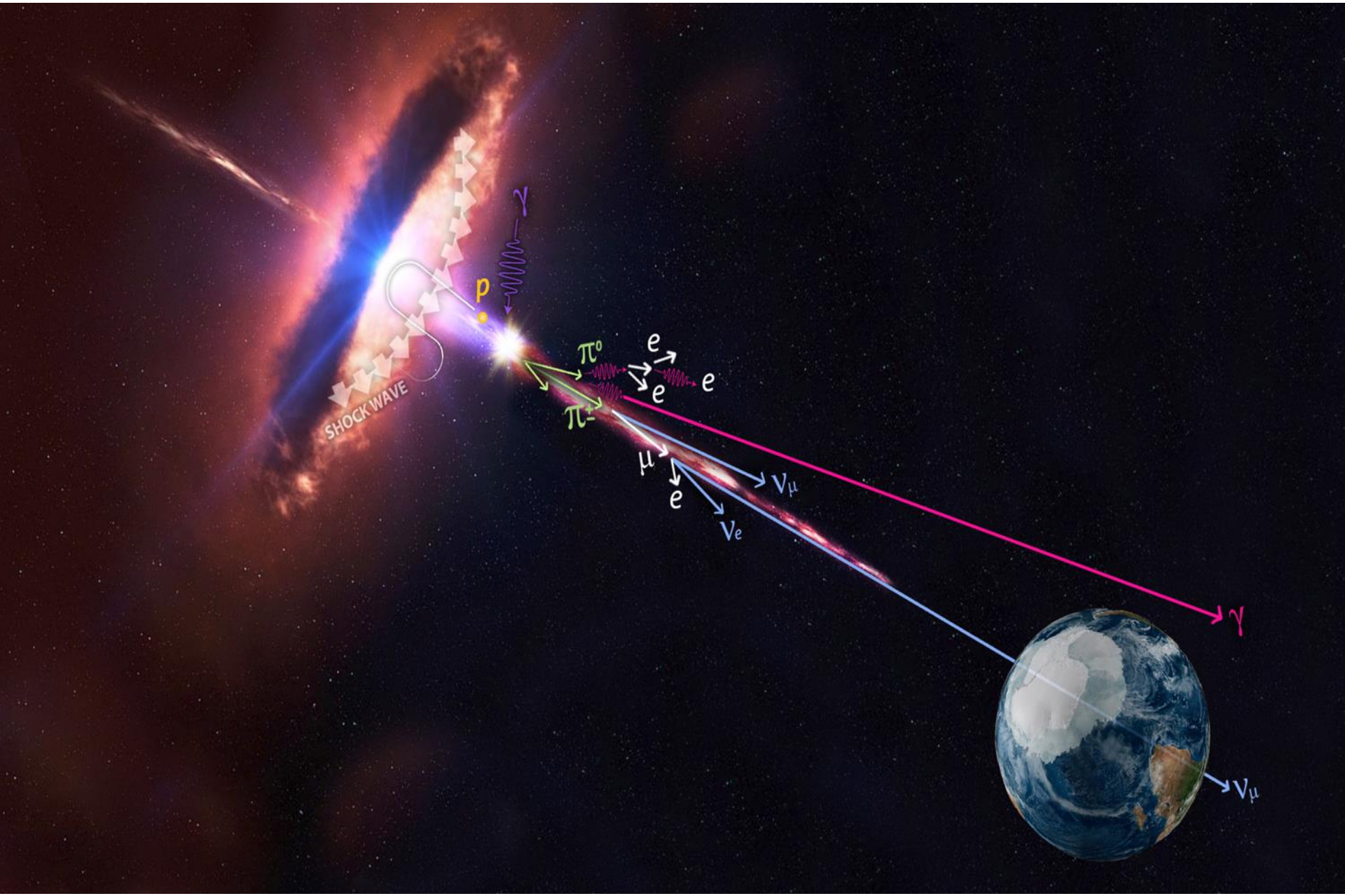
What is bioluminescence?



The background light from bioluminescence potentially affects both the angular resolution and the reconstruction efficiency.


side view
top view
0
500
1000
1500
2000
2500
3000
nanoseconds
125m


AACHEN_86 Event 15
Date: 2014-06-11
Energy: 4450 TeV
Type: Track-Like Event


γ
p
SHOCK WAVE
π⁰
e
e
e
π⁻
μ
e
νμ
νe
γ
νμ

Neutrino emission from a flaring blazar

- On September 22, 2017, the IceCube Neutrino Observatory detected a high energy muon neutrino, dubbed **IceCube-170922A**. The neutrino carried an energy of ~290 tera–electronvolts (TeV); for comparison, the Large Hadron Collider can generate a maximum energy of 13 TeV. Within one minute of the neutrino detection, IceCube sent an automated alert to astronomers around the world with coordinates to search for a possible source.
- A search of this region in the sky, 1.33 degrees across, yielded only one likely source: TXS 0506+056.

Thank you!

sotiriou@ea.gr