




Messengers from the high-energy universe

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Visitor at NBIA

Nyt fra Niels Bohr International Academy Kurs 2013

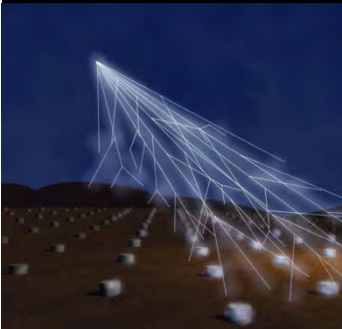






Cosmic rays
Light – from Radio to Gamma ray
Neutrinos

The diagram shows a spectrum of cosmic rays. The x-axis represents energy, with labels for Radio, Microwave, Infrared, Visible, Ultraviolet, X-ray, and Gamma ray. The y-axis represents flux. The spectrum shows a peak in the radio and microwave regions, followed by a dip, then a rise through the infrared and visible regions, a sharp peak in the ultraviolet region, and a gradual decline through the X-ray and gamma ray regions. A vertical line is drawn at the ultraviolet region, and a horizontal line is drawn at the X-ray region, intersecting at a point labeled 'Neutrinos'.



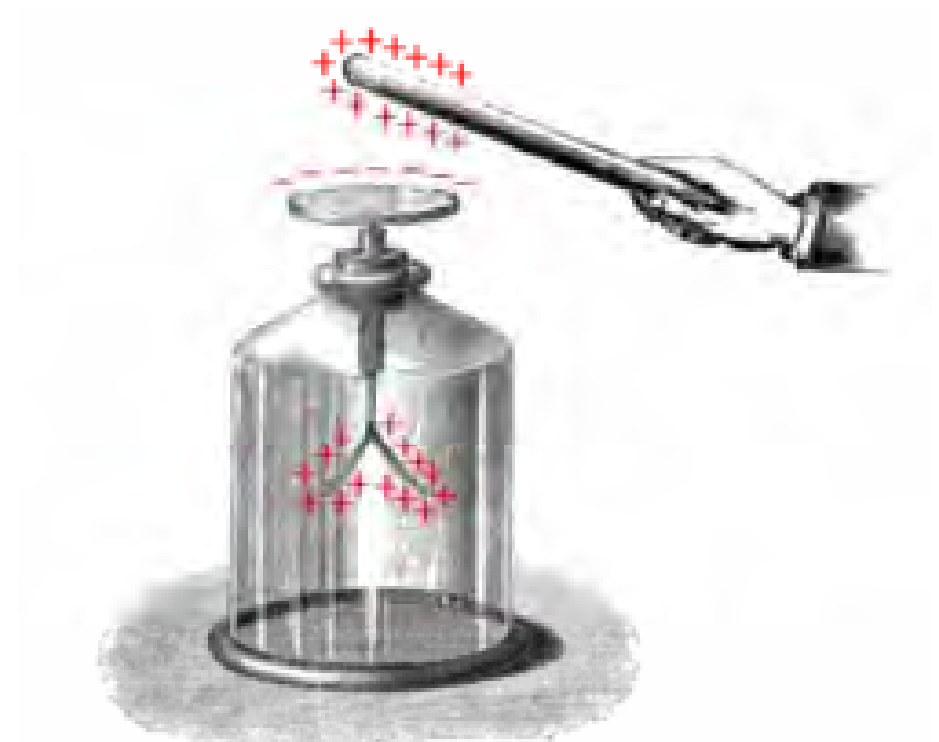
Cosmic Rays

100 years since Victor Hess's discovery



Cosmic Rays

Puzzling physicists for over 200 years



Cosmic Rays

100 years since Victor Hess's discovery



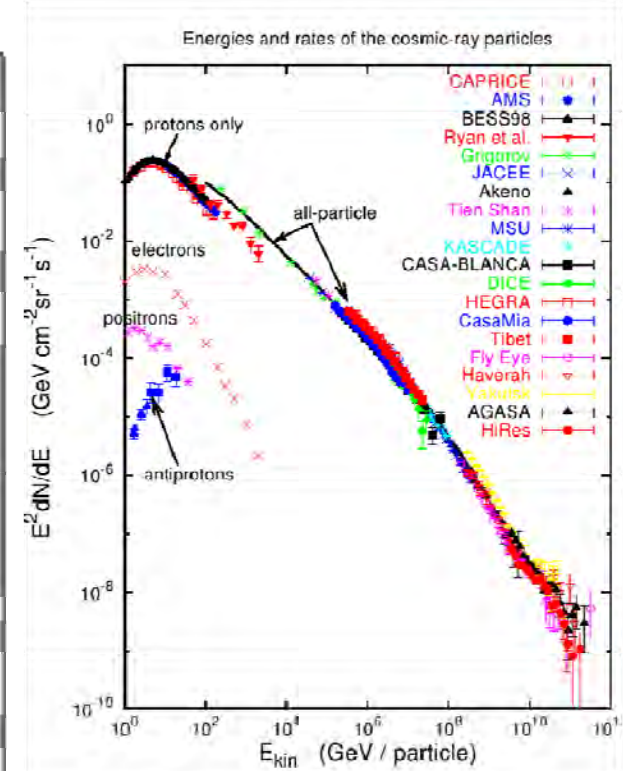
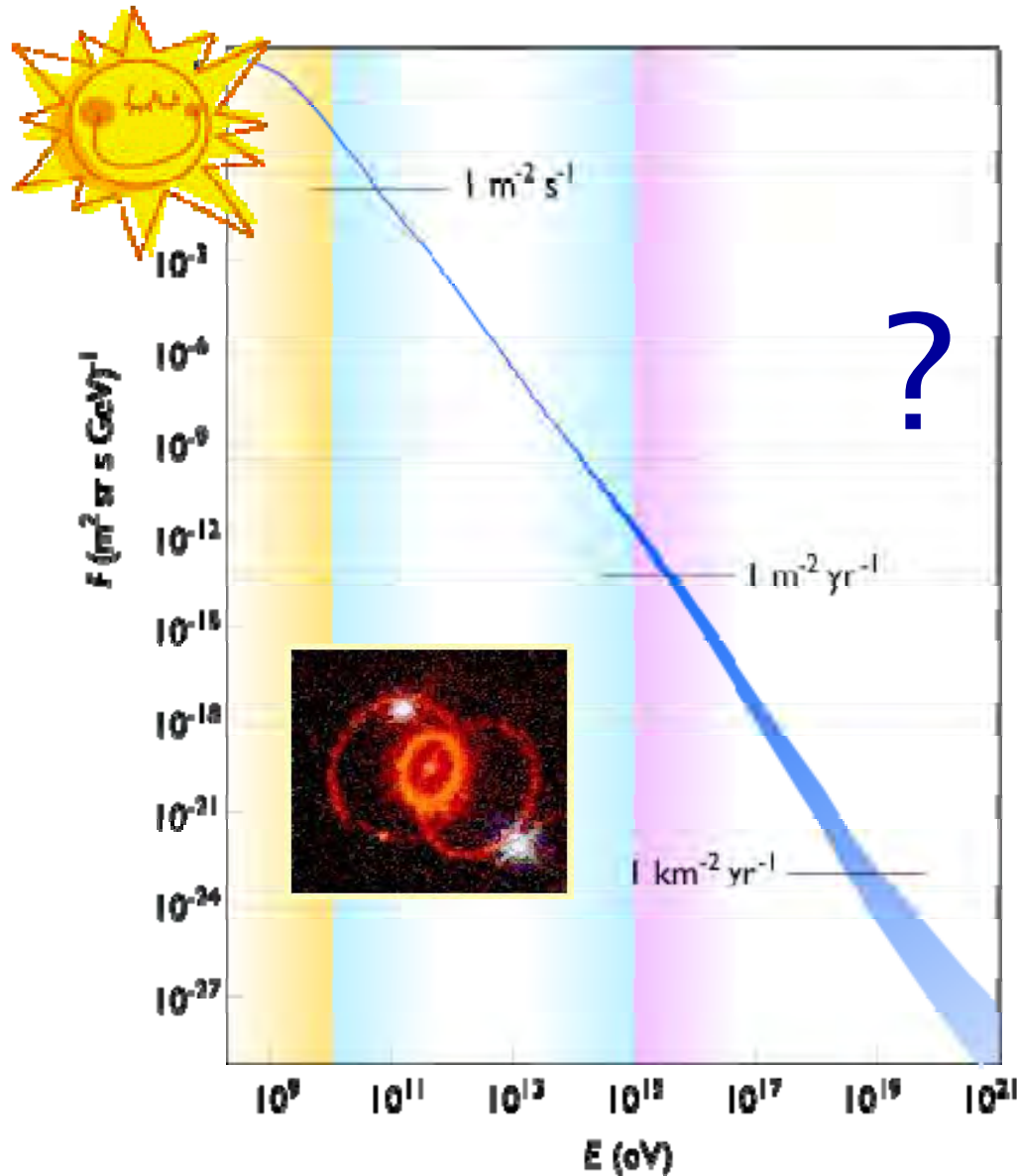
Cosmic Rays

100 years since Victor Hess's discovery

"The results of present observations are more reliably explained assuming that an highly penetrating radiation enters our atmosphere from the top, and then produces in the lower layers part of the ionization observed in closed detectors."

Hess (1913) published article

Cosmic Rays Spectrum and possible sources...



Cosmic Rays Influenced by magnetic fields



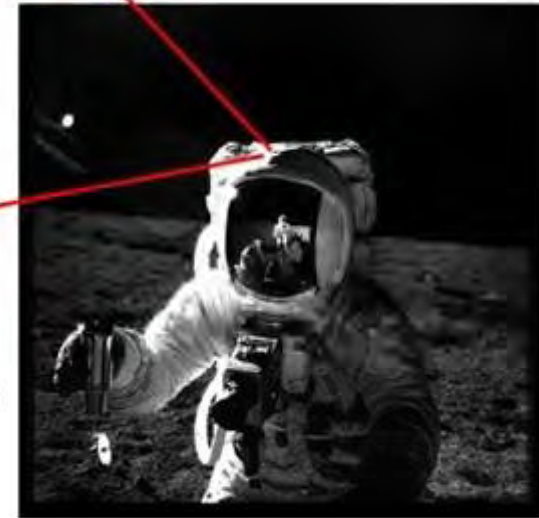
The image shows a simulation interface with the following elements:

- Controls:** "Play" (play button icon) and "Restart" (refresh button icon).
- Charge Selection:** Radio buttons for "Positive charge" (selected) and "Negative charge".
- Charge Indicator:** A red circle with a white plus sign (+).
- Magnetic Field Control:** A vertical slider labeled "B Field" with a value of 40. The slider has a scale from 0 to 40.
- Legend:** "Velocity" represented by a blue arrow and "Force" represented by a green arrow.
- Equations:**
$$\vec{F} = q\vec{v} \times \vec{B}$$
$$R = \frac{mv}{qB}$$
- Units:** "Arbitrary units" at the bottom.

ana.serrano@upm.es

Cosmic Rays

Influenced by magnetic fields, luckily for us

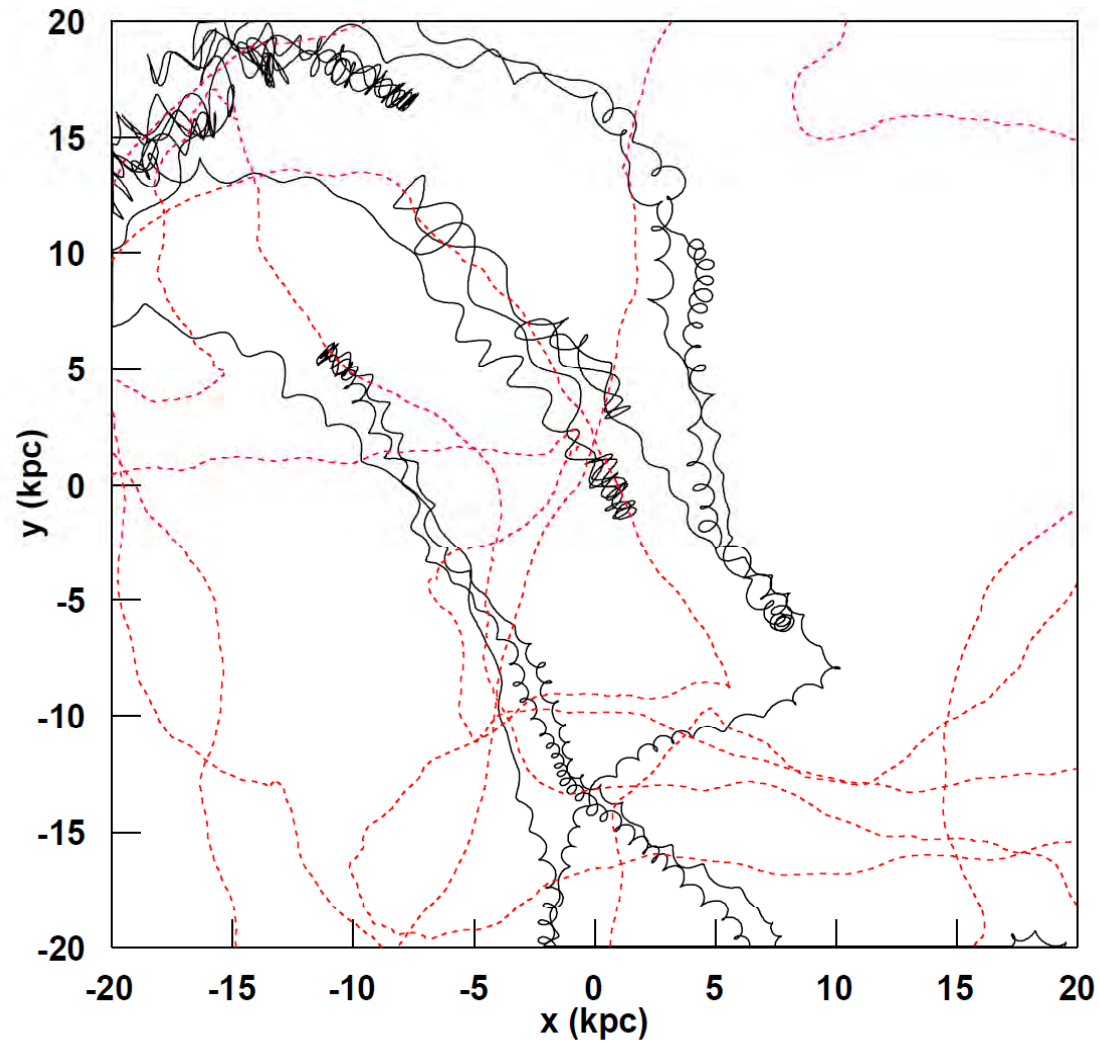


Astroparticle Physics [5A1312]



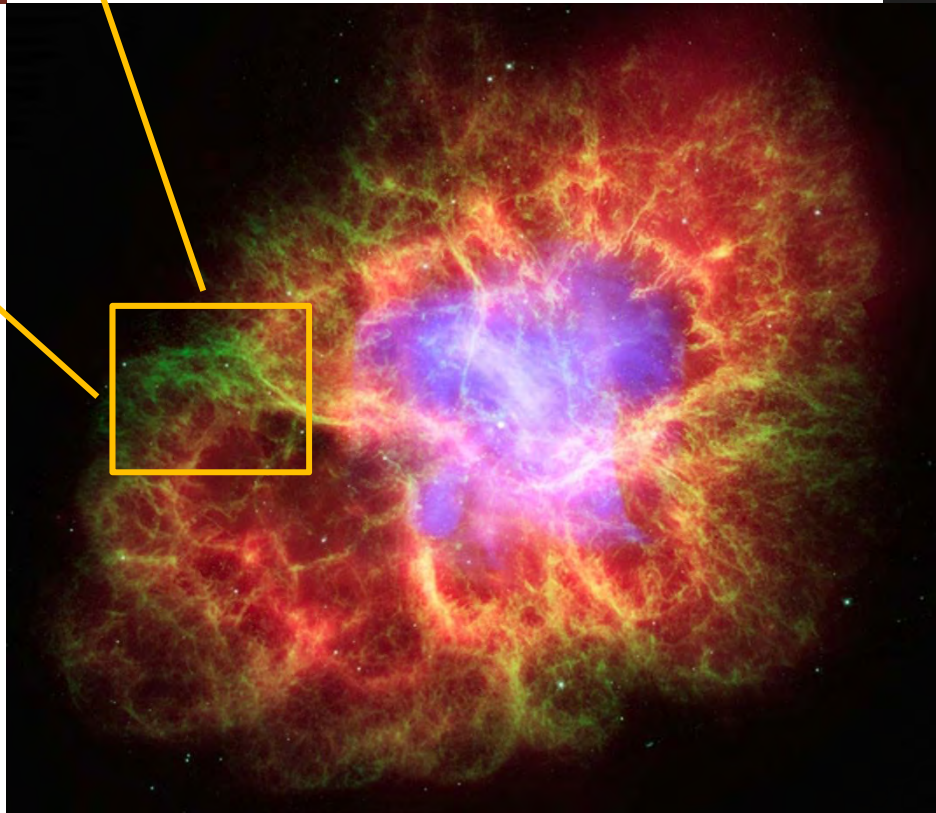
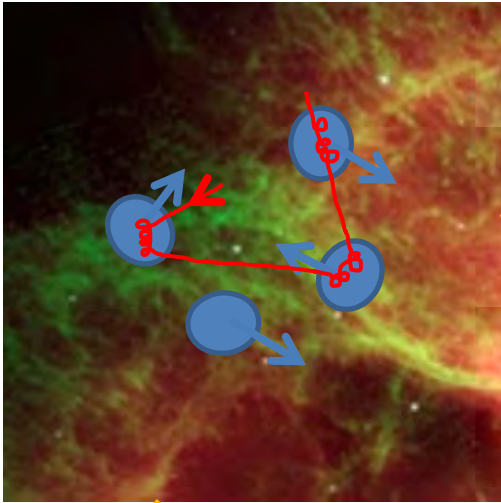
Cosmic Rays

Influenced by magnetic fields, unluckily for cosmic ray astronomy



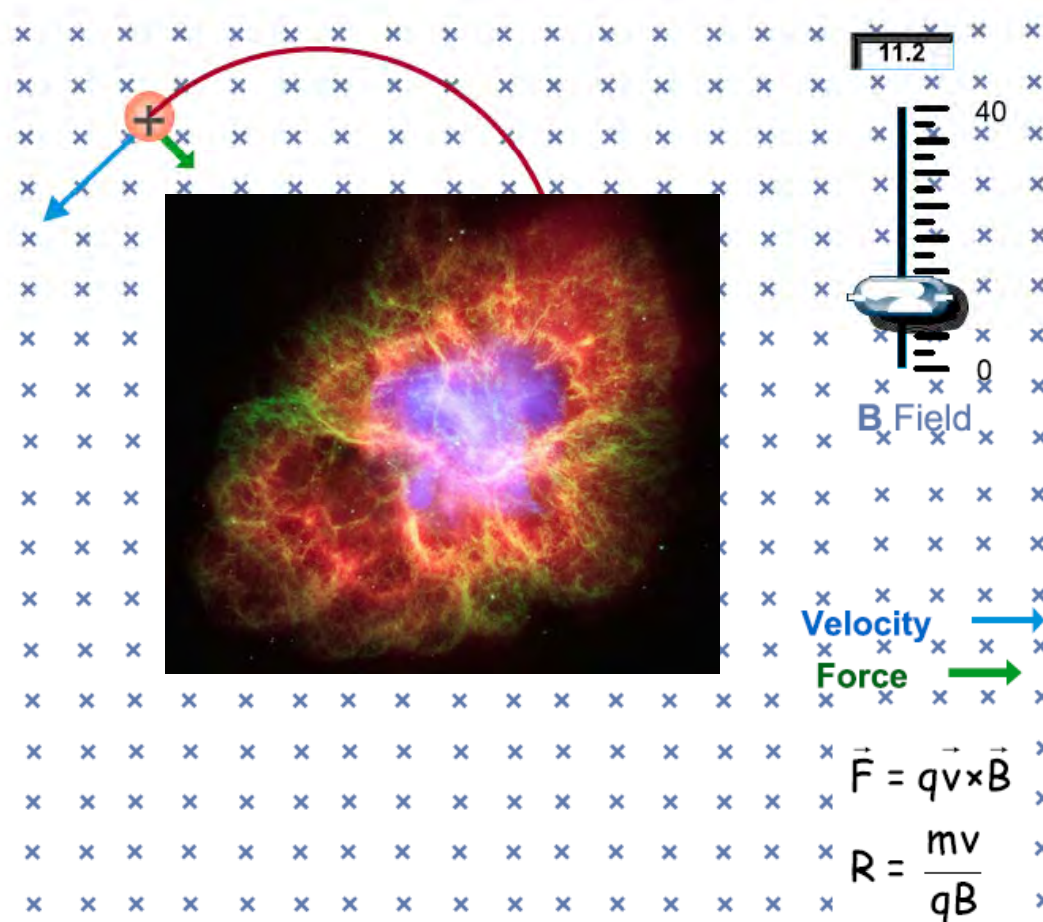
Cosmic Rays

How are they accelerated?



Cosmic Rays

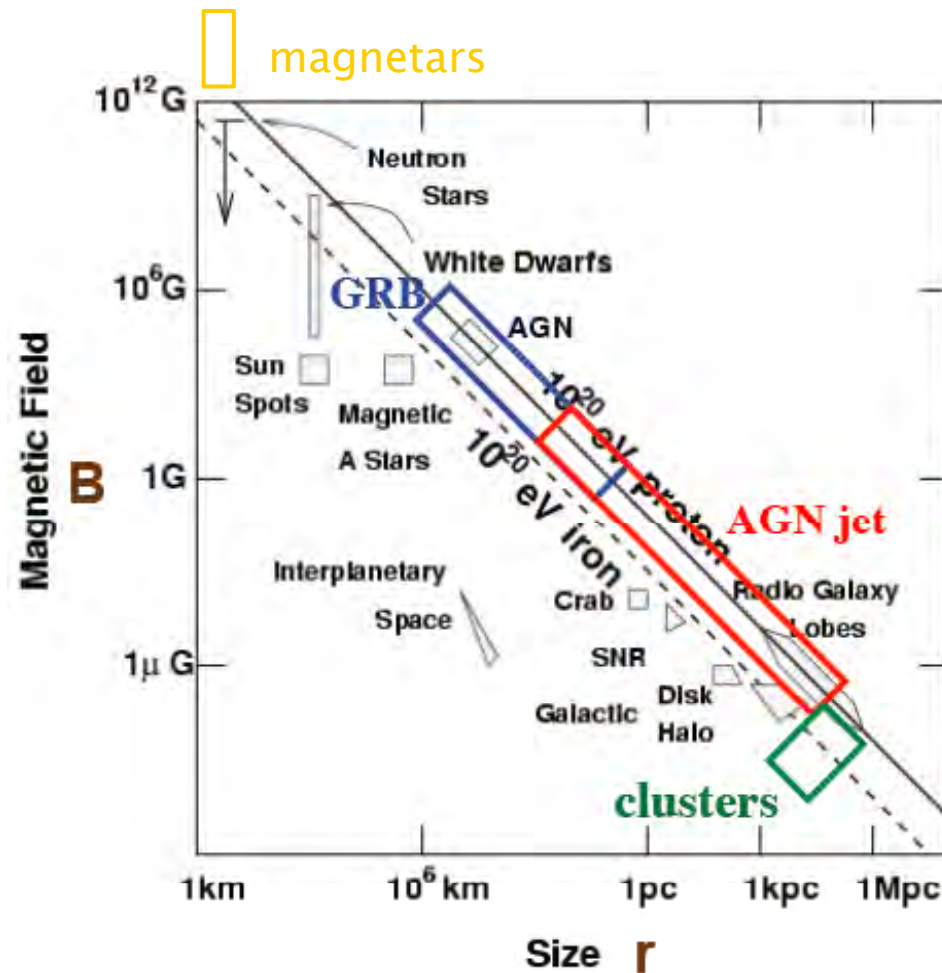
Where could they be accelerated?



$$E_{\max} \sim \beta ZBR$$

Cosmic Rays

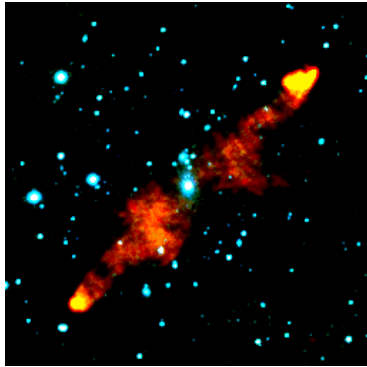
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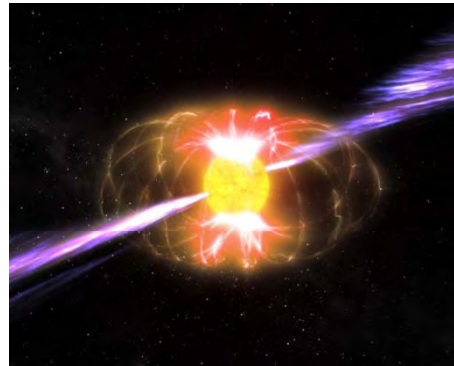
$$E_{\max} \sim \beta ZBR$$

Cosmic Rays

From the Universe's most extreme objects



AGNs
The most massive black holes



Magnetars
The strongest magnetic fields



GRBs
The brightest explosions



Galaxy Clusters
The largest gravitationally bound objects

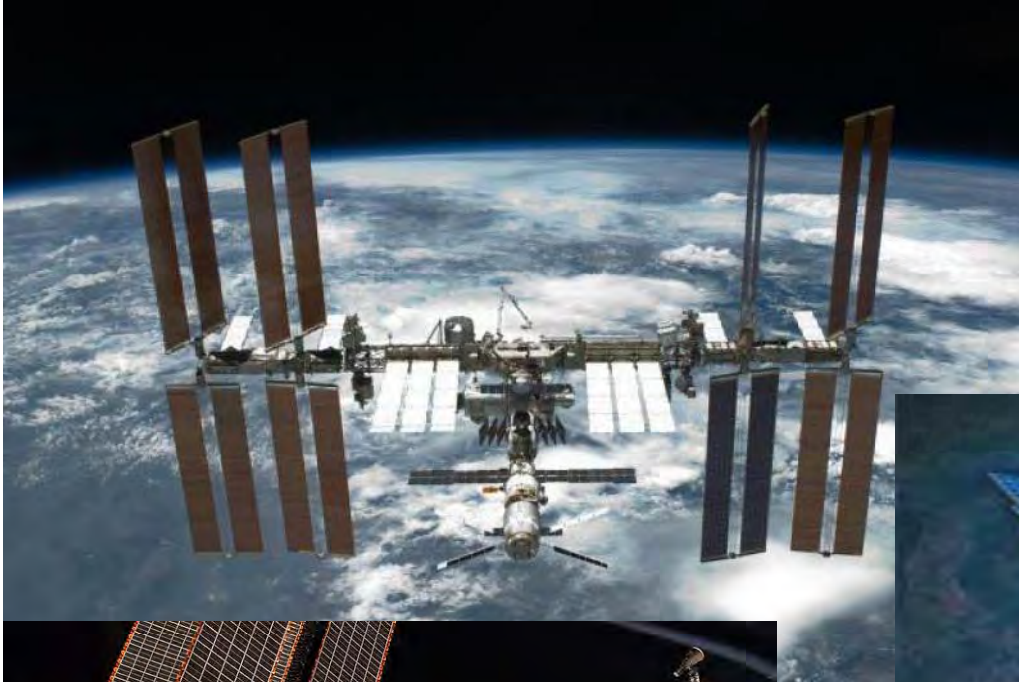
Cosmic Rays

How do we detect them?



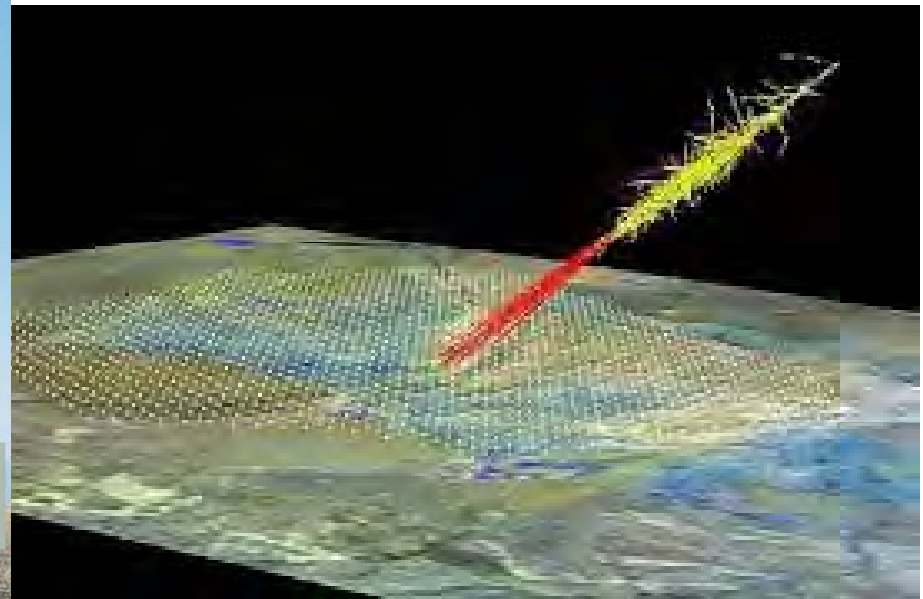
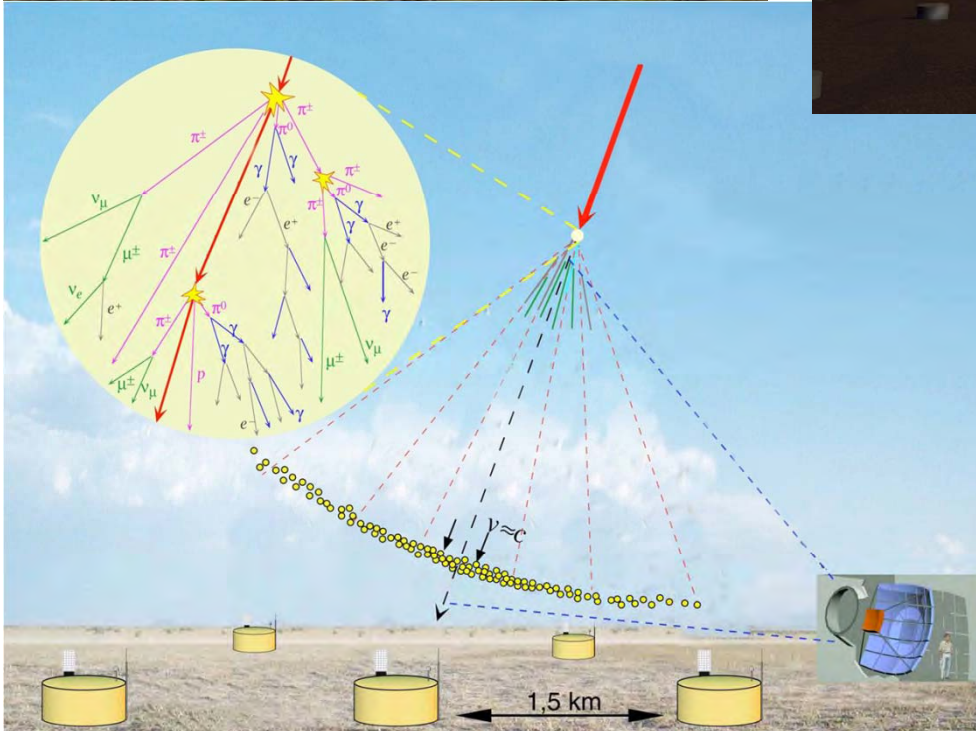
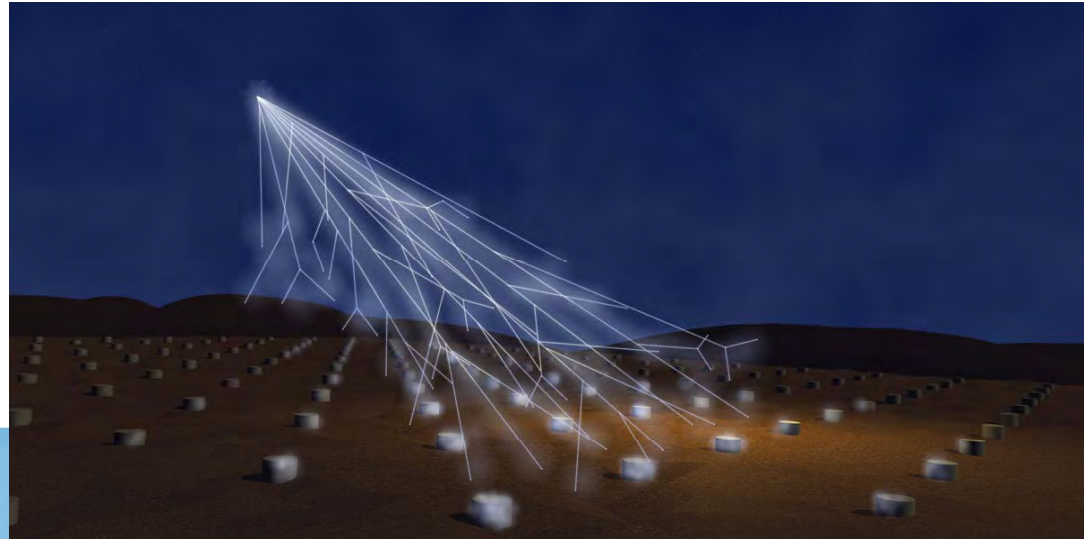
Cosmic Rays

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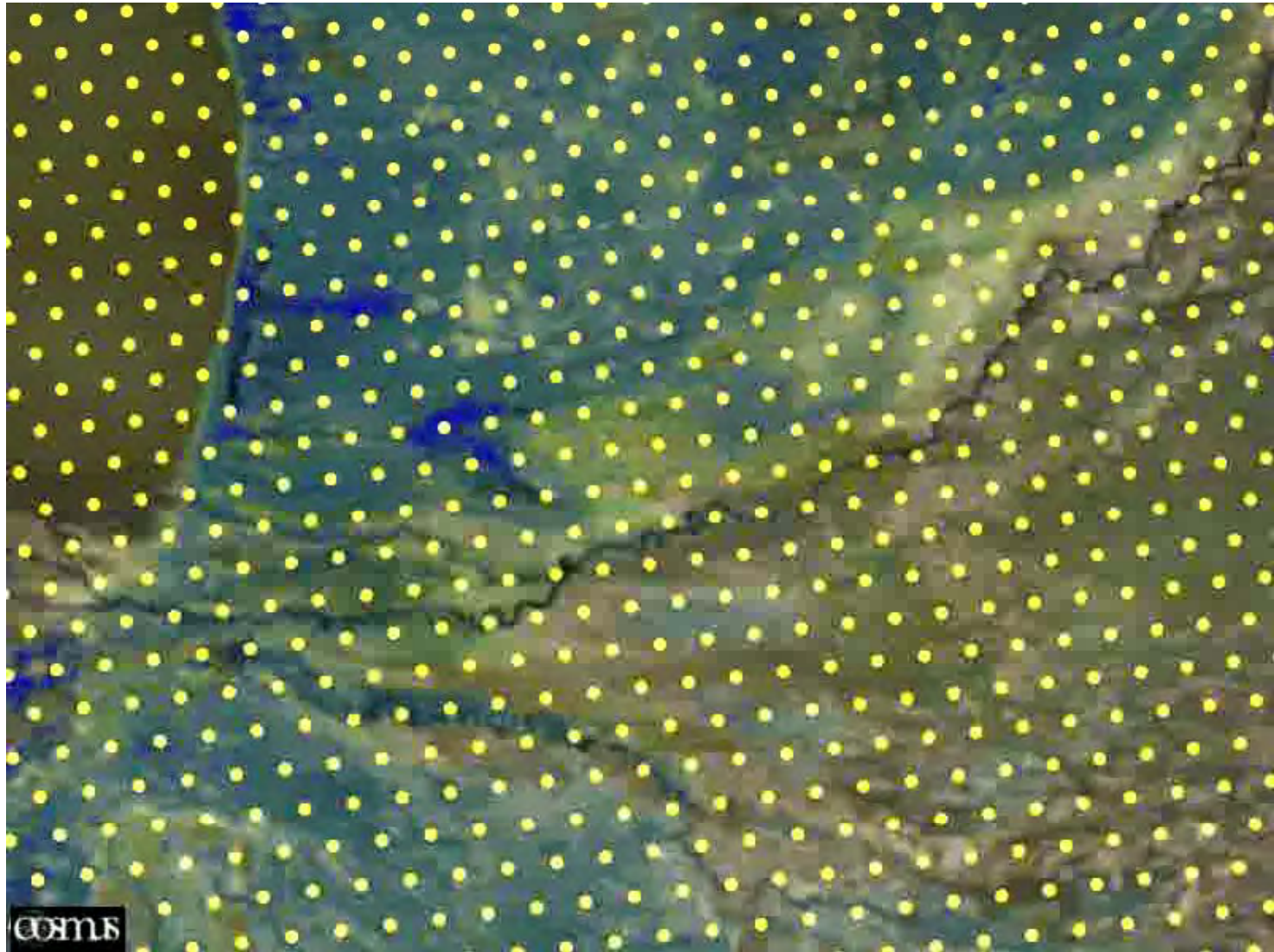
Cosmic Rays

Pierre Auger Observatory



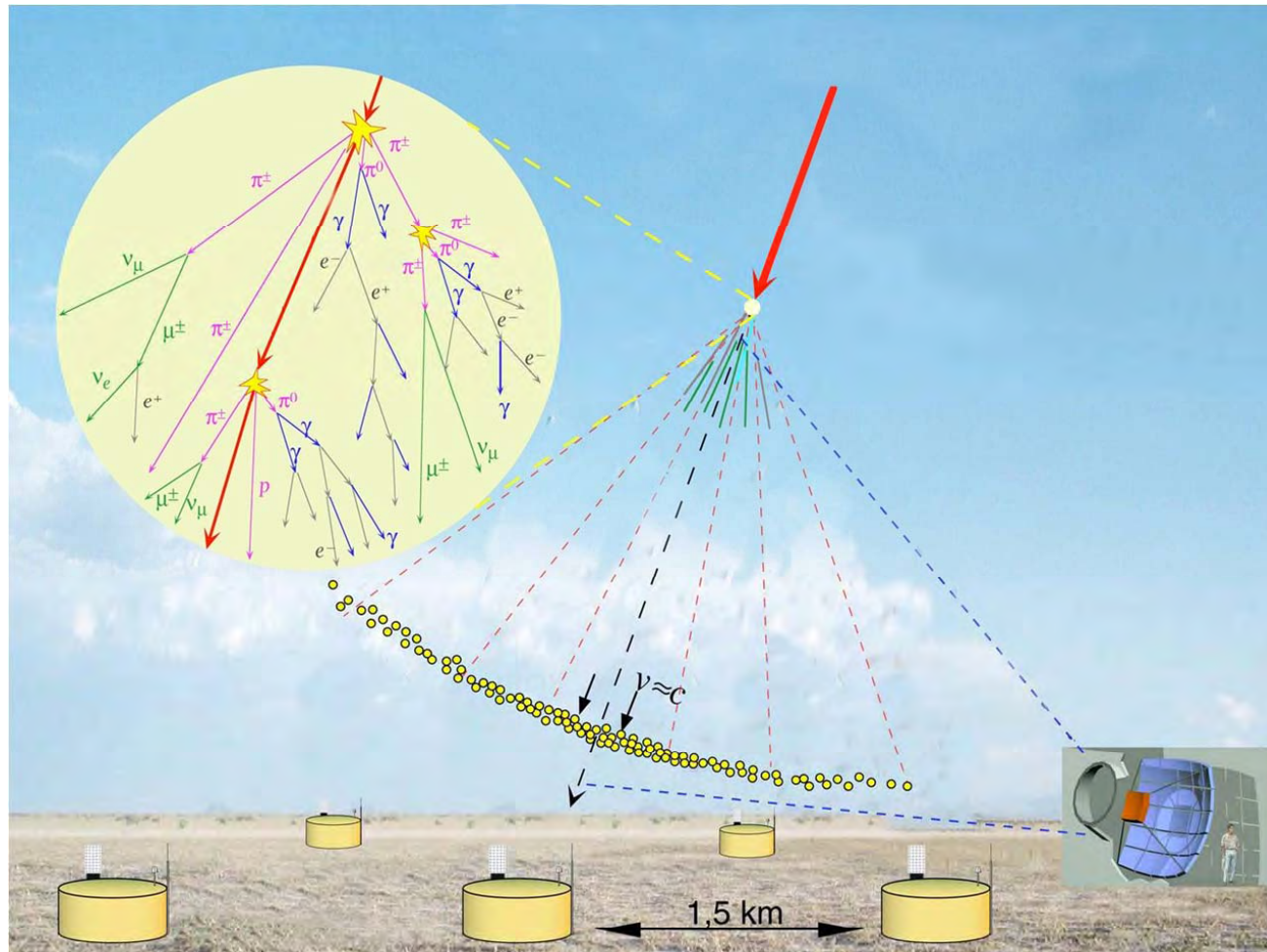
Cosmic Rays

How do we detect them?



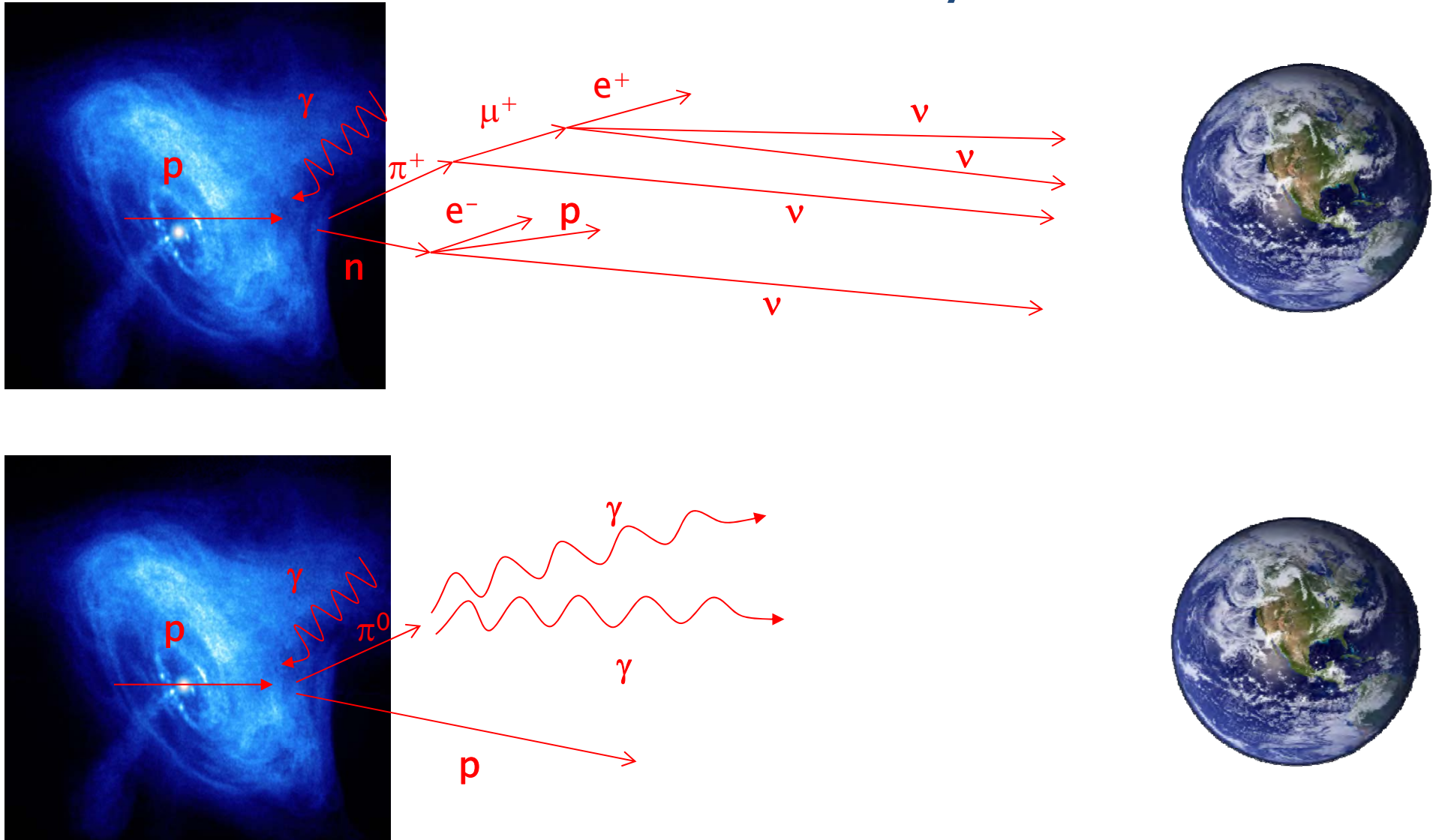
Neutrinos and Gamma Rays

From cosmic ray interactions



Neutrinos and Gamma Rays

From cosmic ray interactions



Messenger Comparison

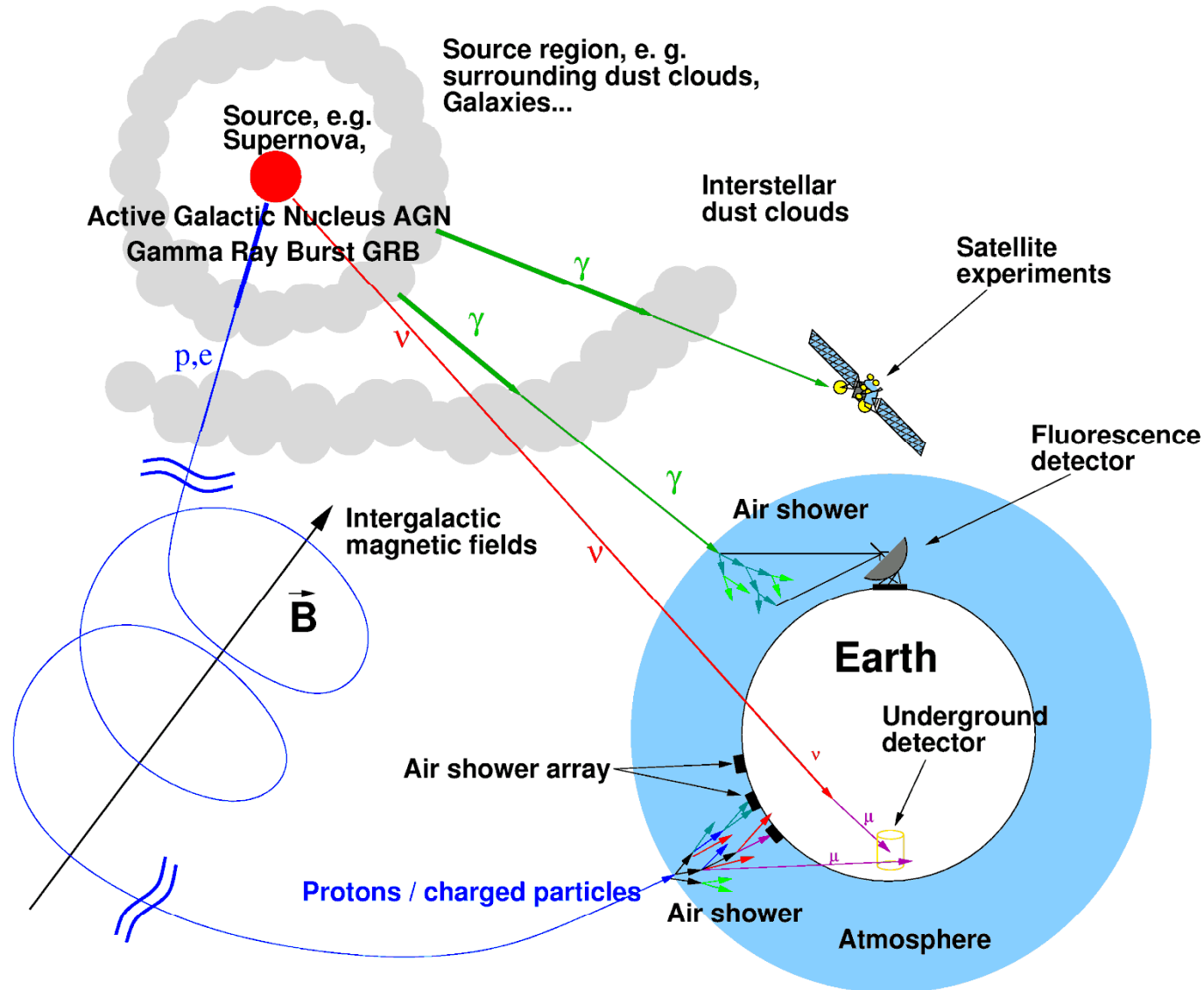
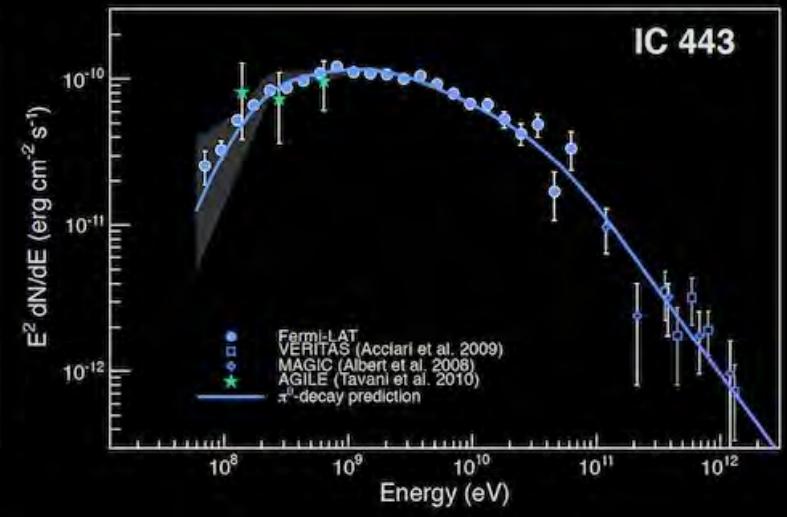
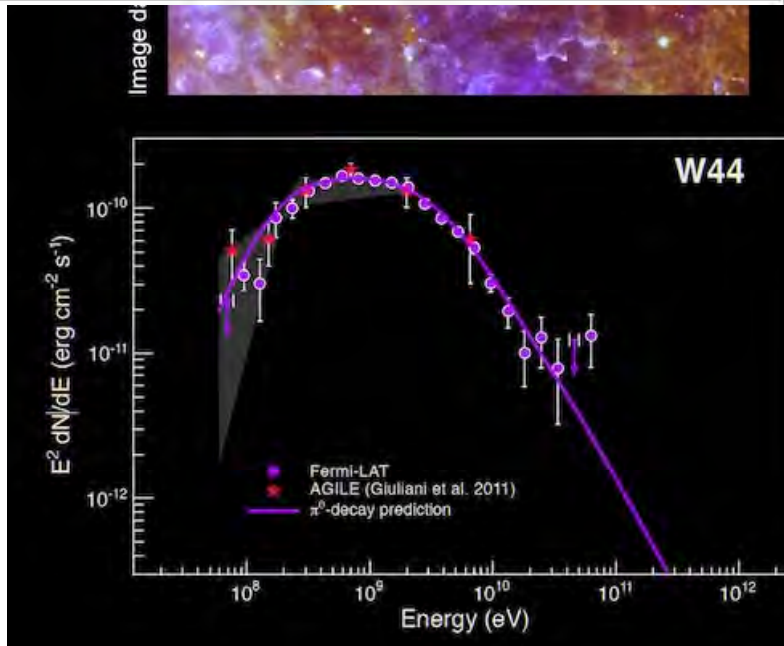
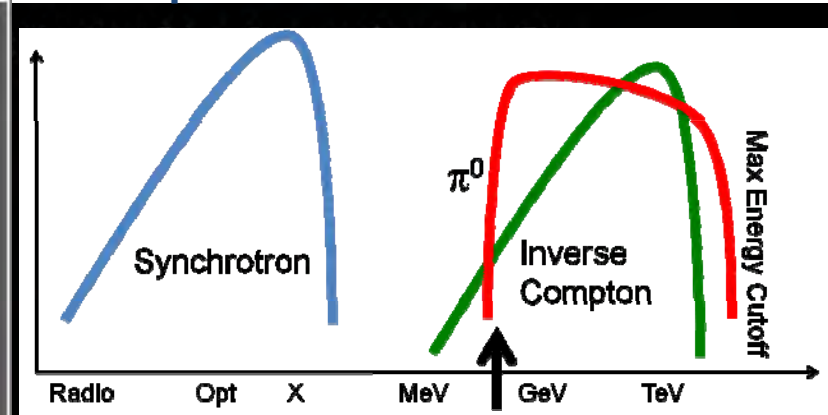
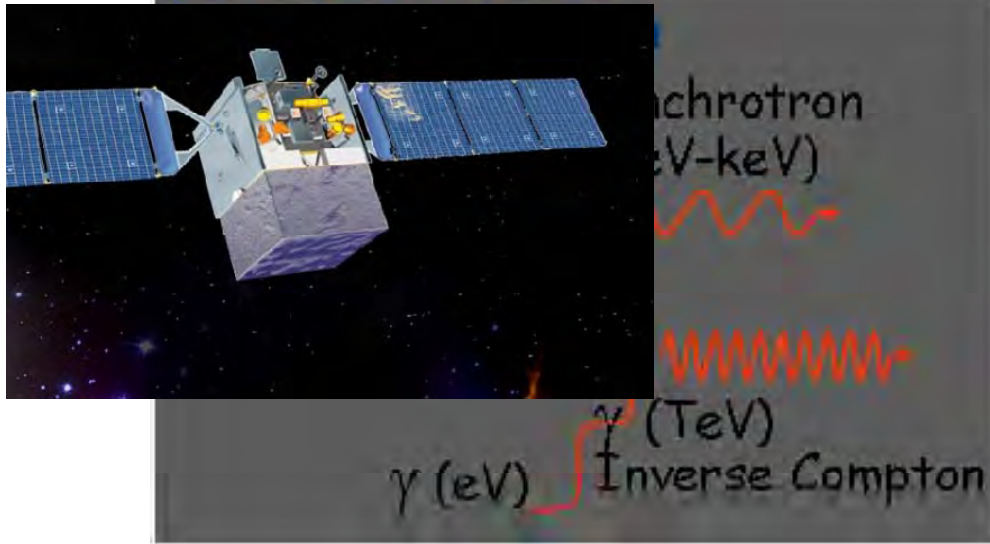


Figure: Wolfgang Wagner, PhD thesis

Cosmic Rays

Fermi – Gamma Ray verification of supernova remnant source



Messenger Comparison

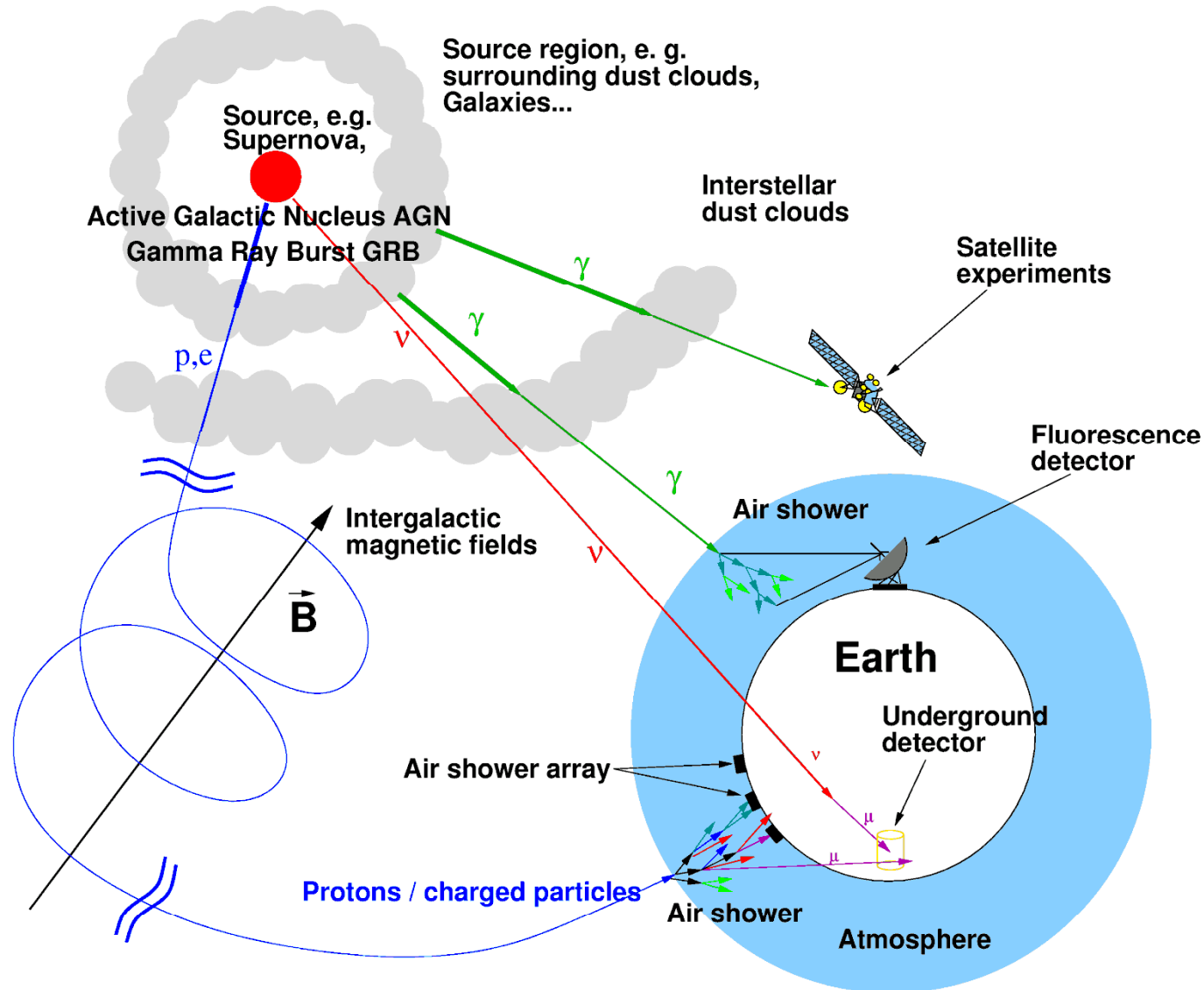
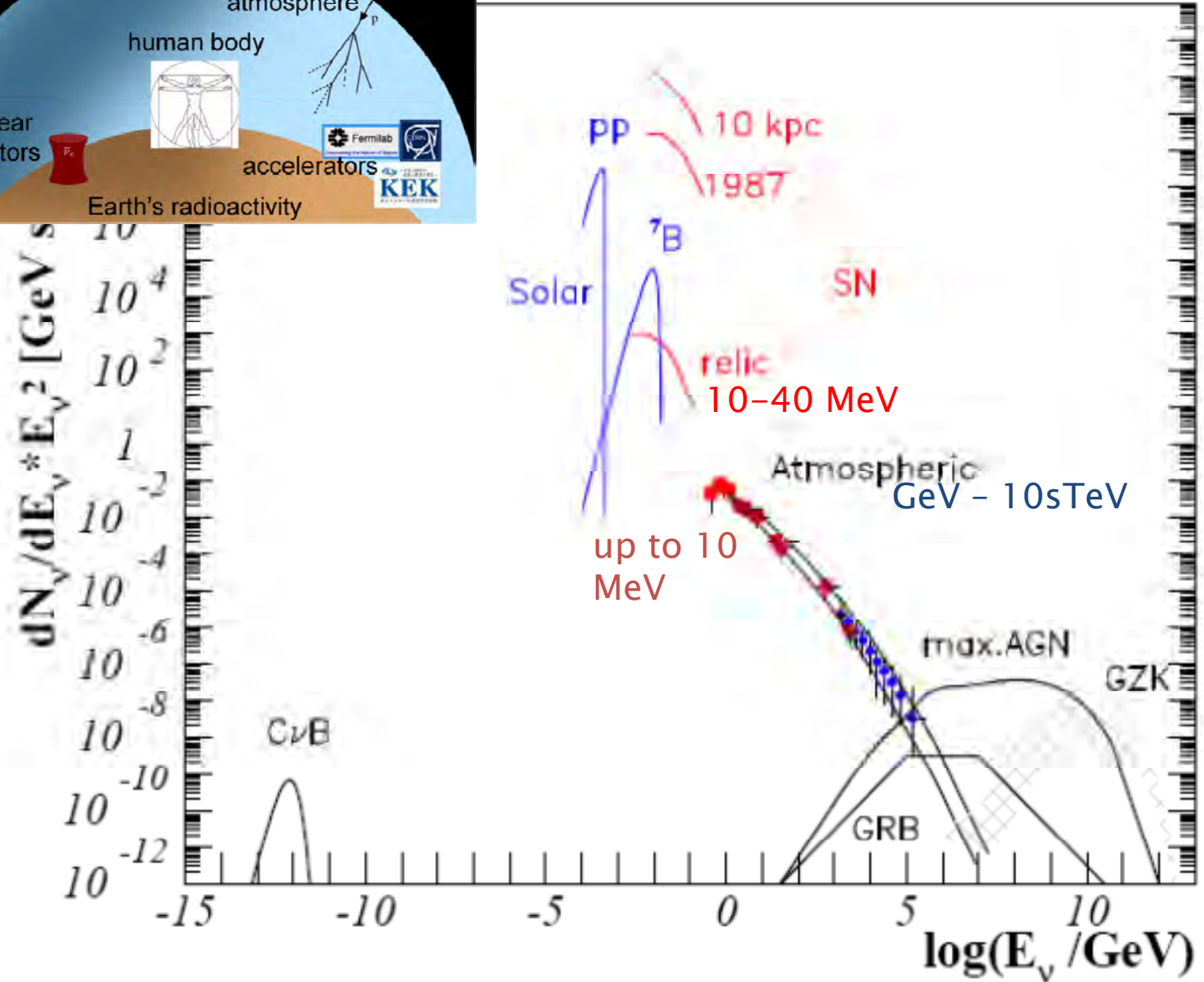
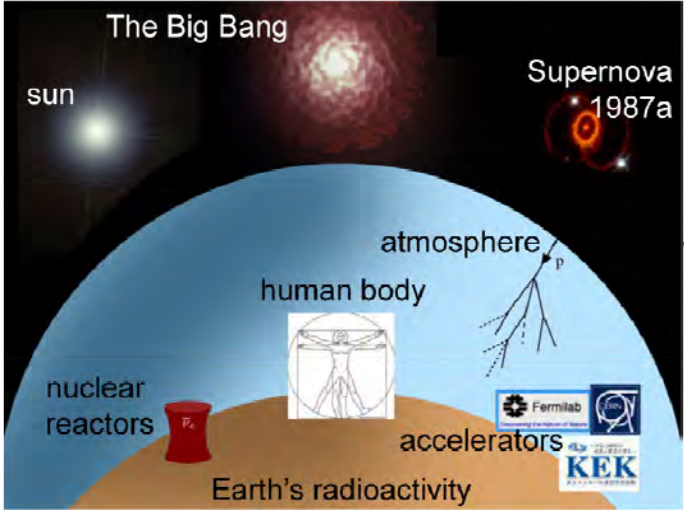


Figure: Wolfgang Wagner, PhD thesis

Astrophysical neutrinos

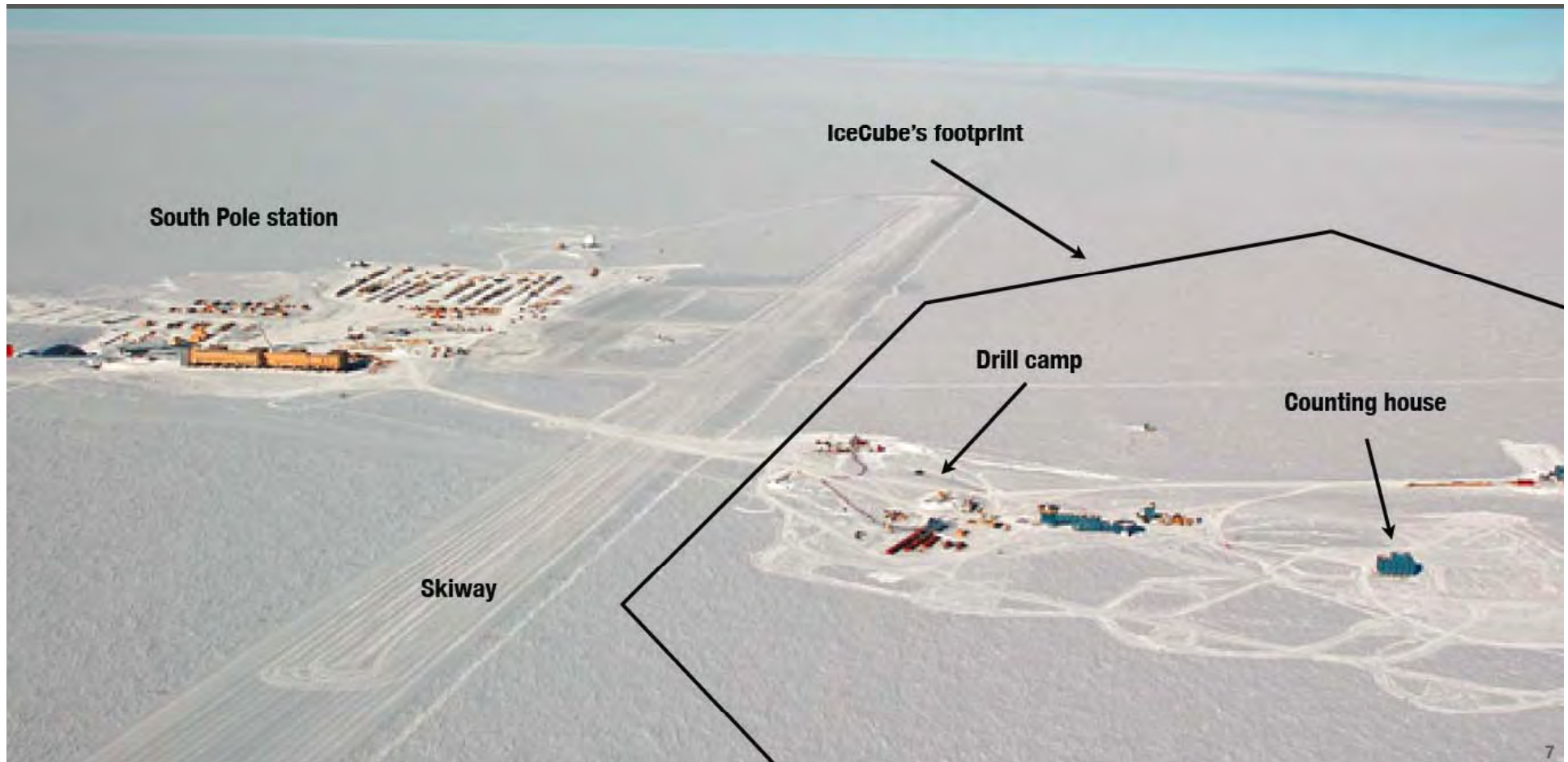


Neutrino sources

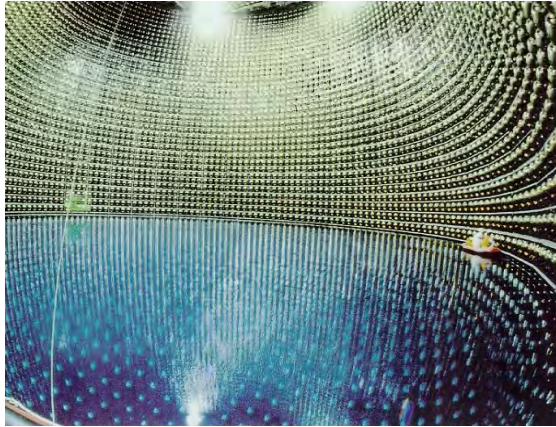


J. Becker
 Phys. Rep.
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IceCube Neutrino Observatory



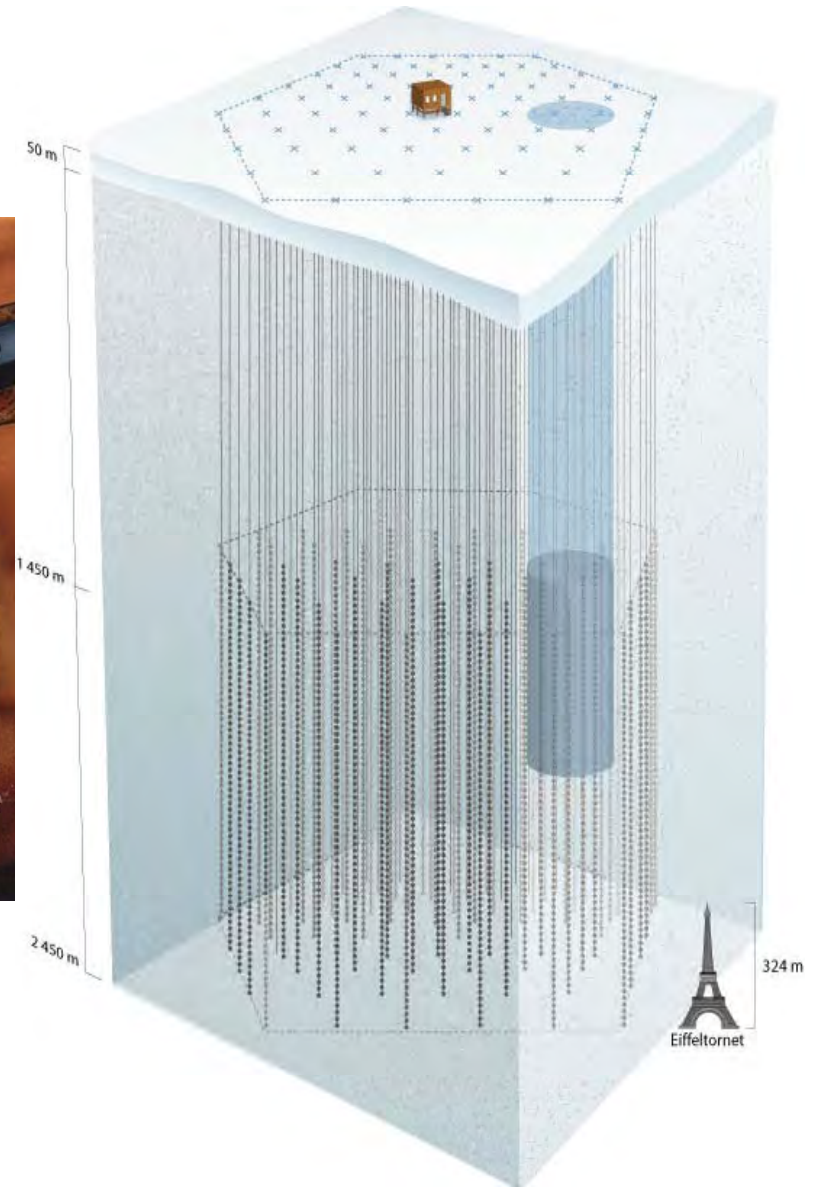
IceCube is a LARGE neutrino detector...



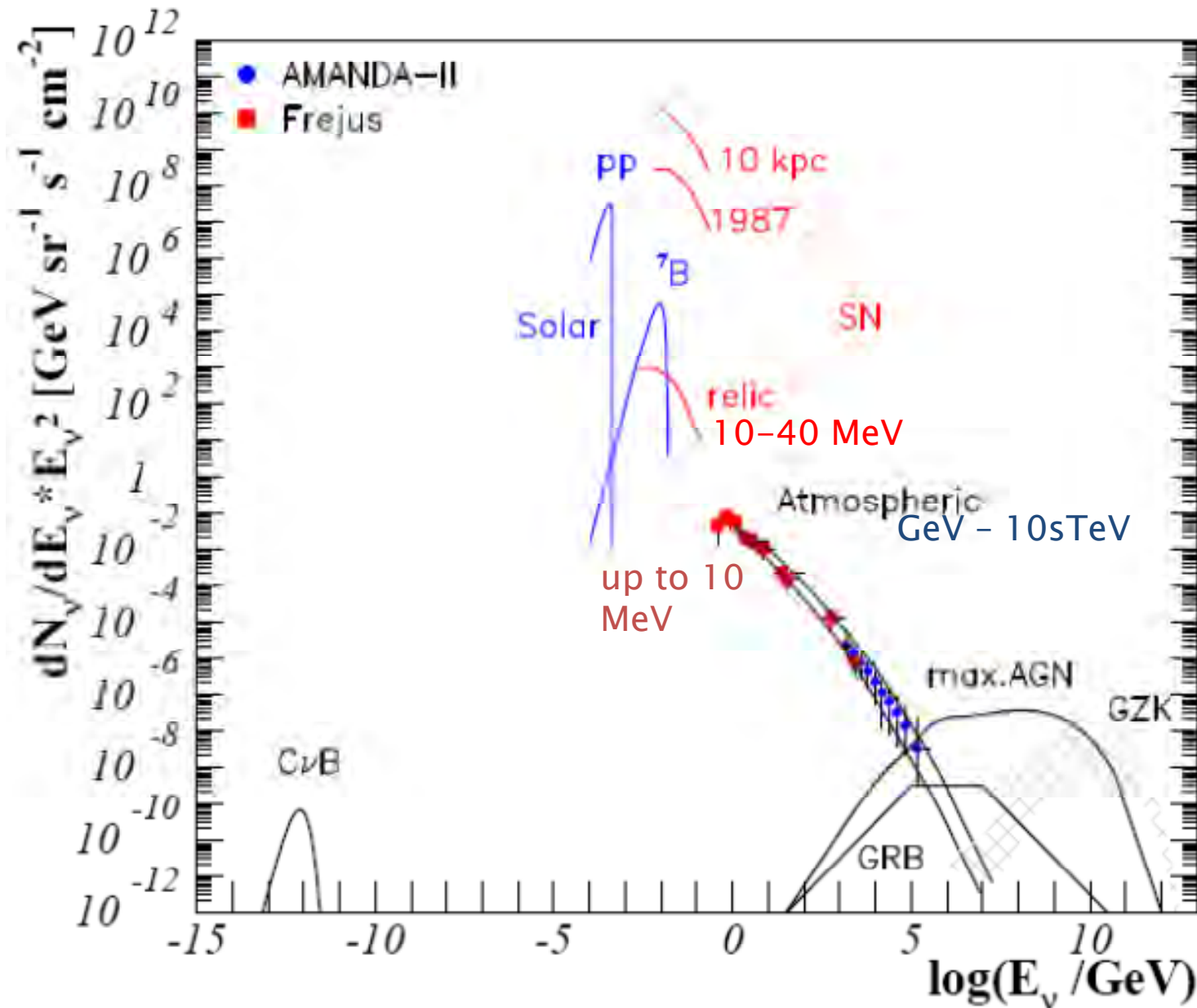
Super Kamiokande



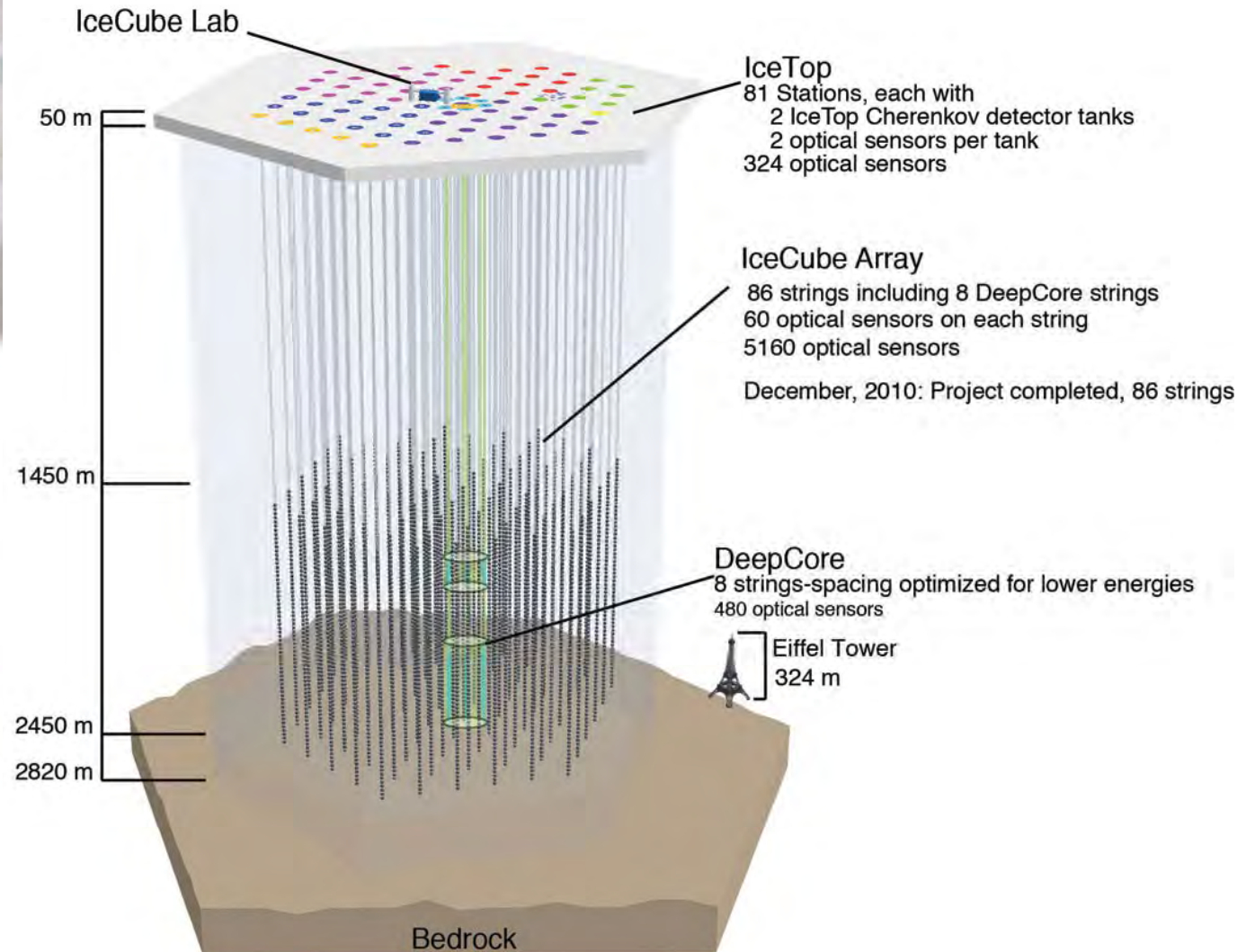
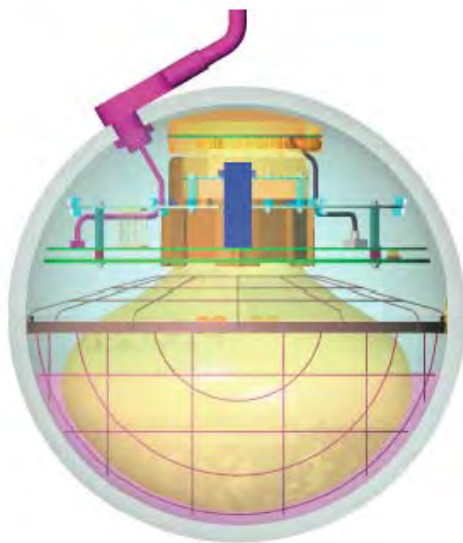
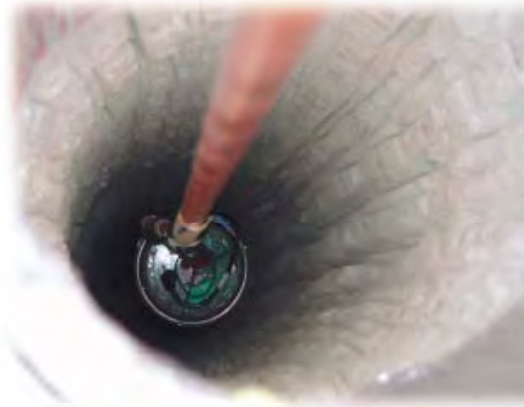
SNO



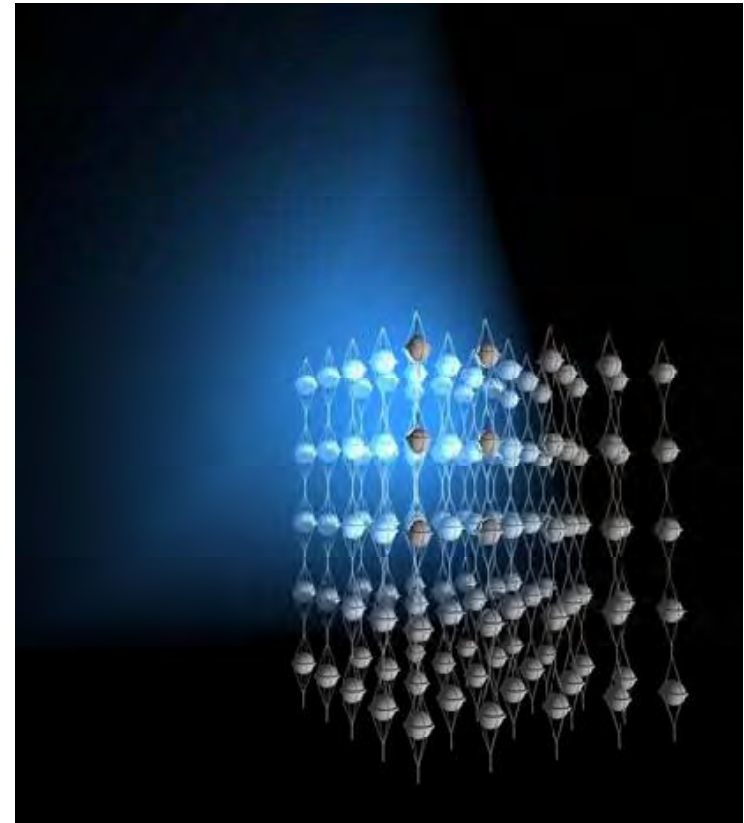
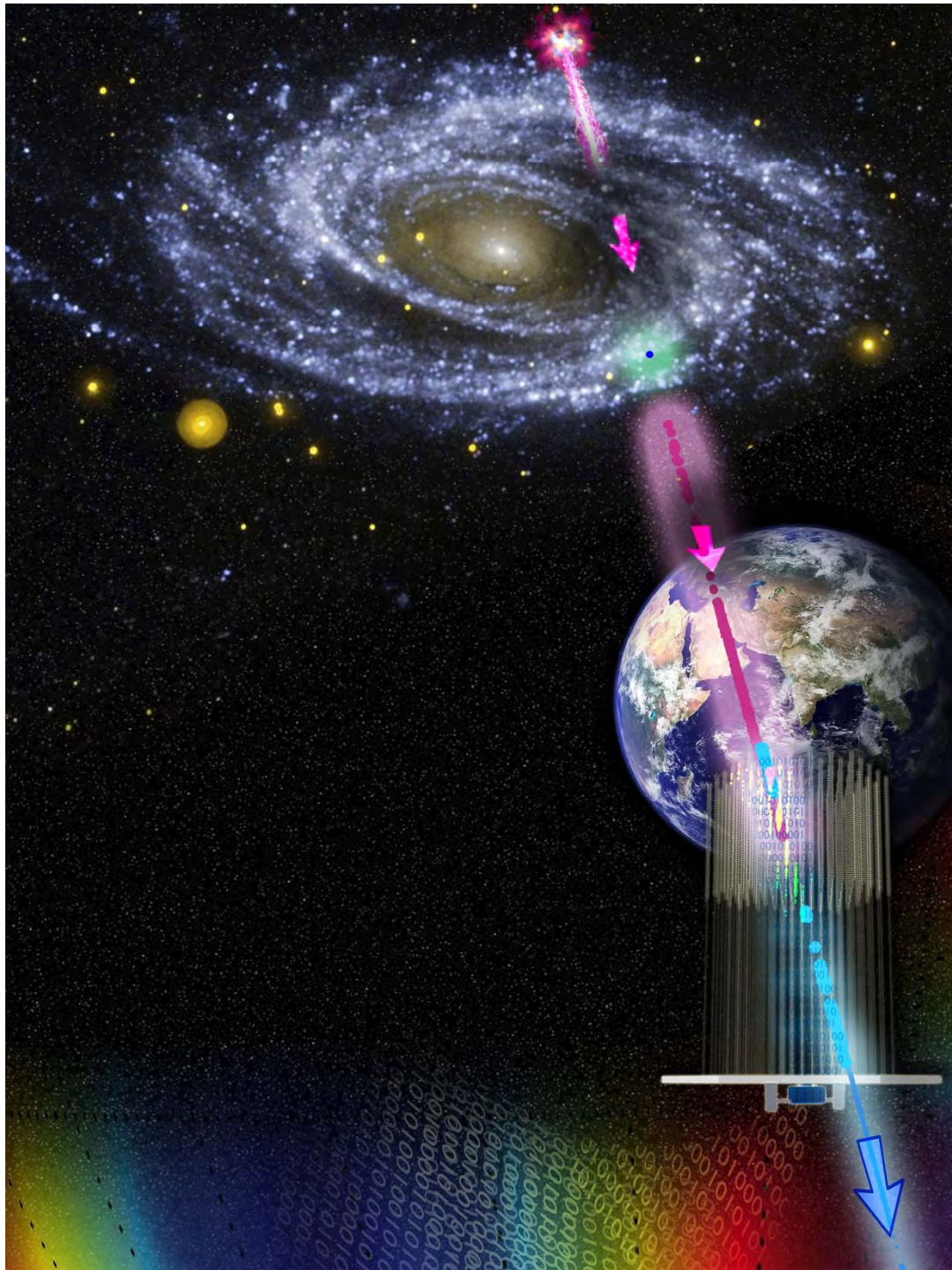
Neutrino sources



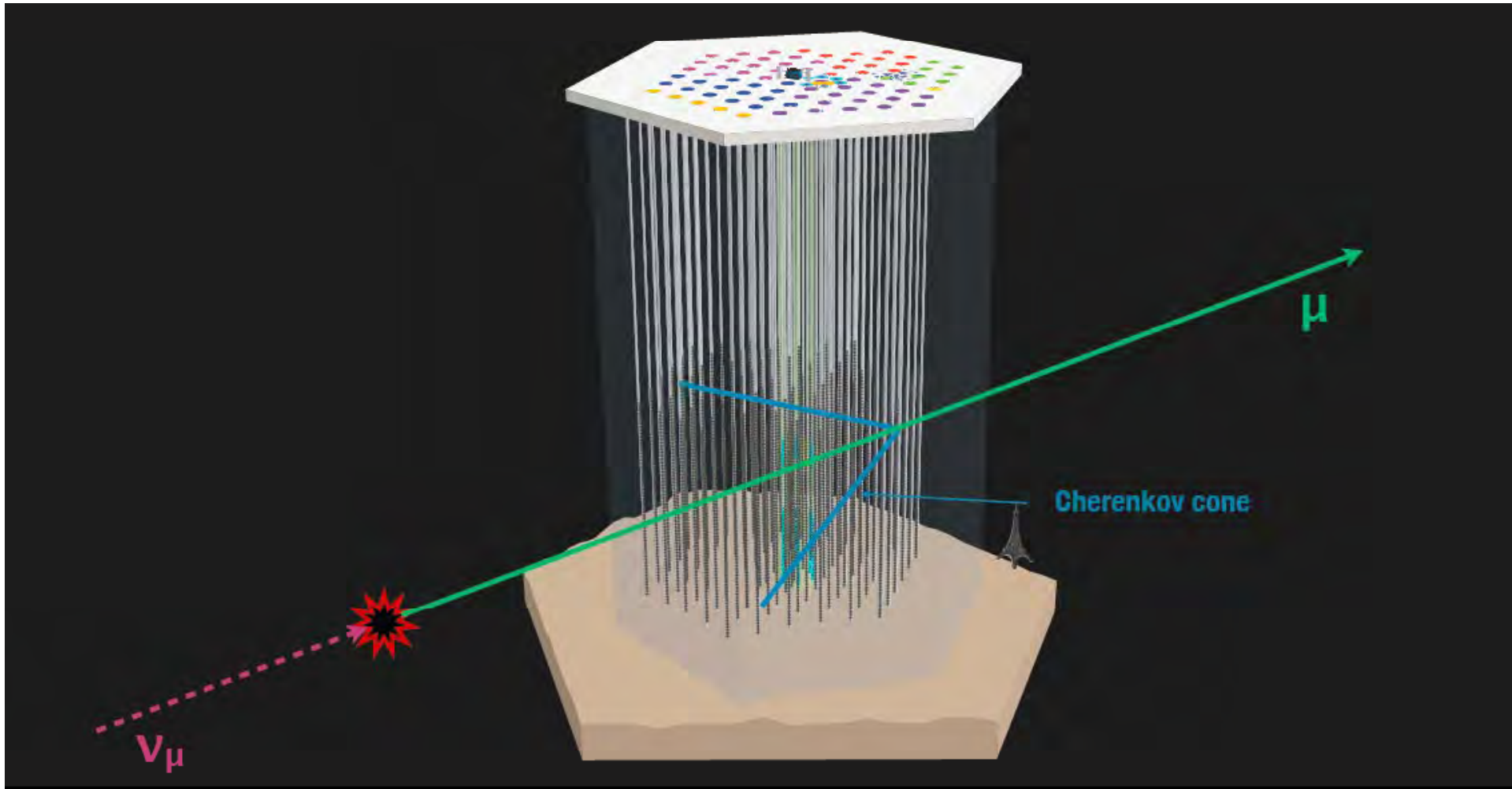
IceCube detector



Detection Principle

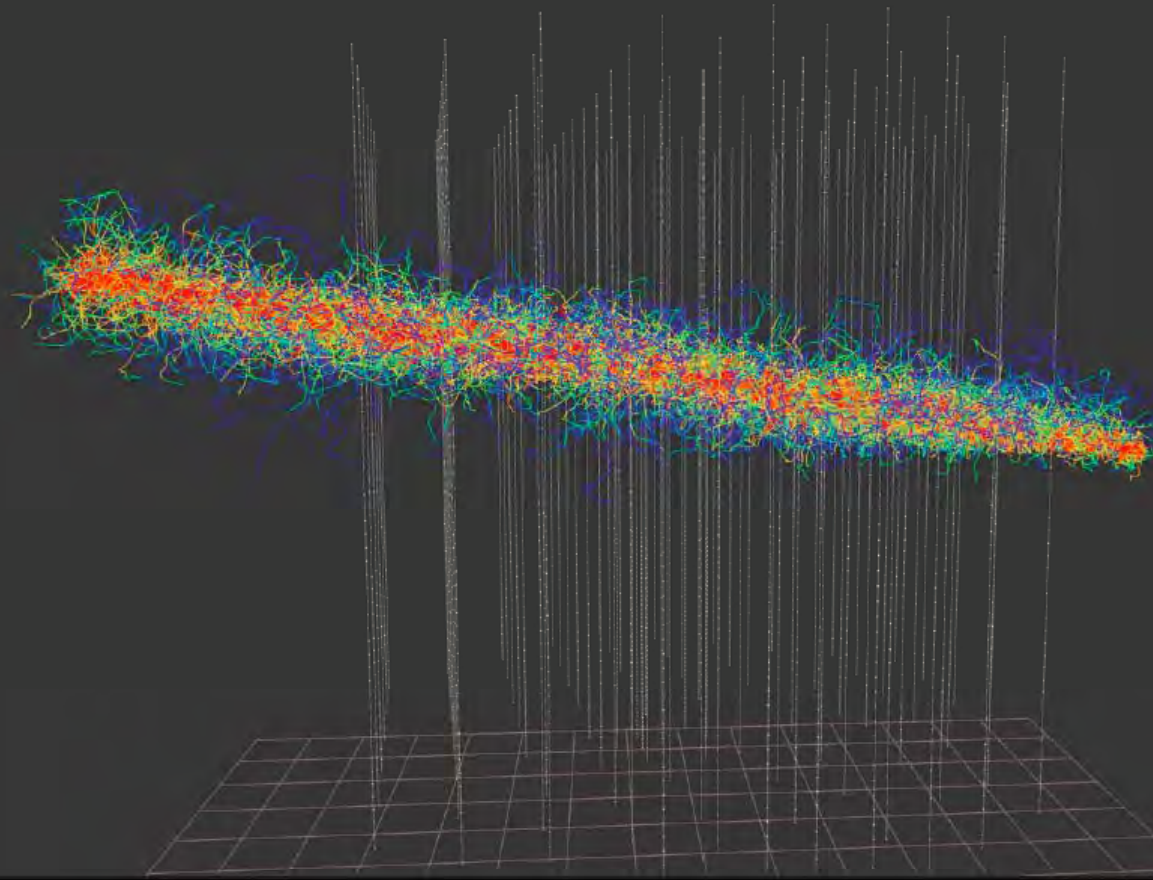


Detection Principle

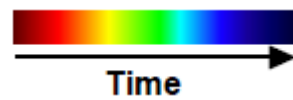
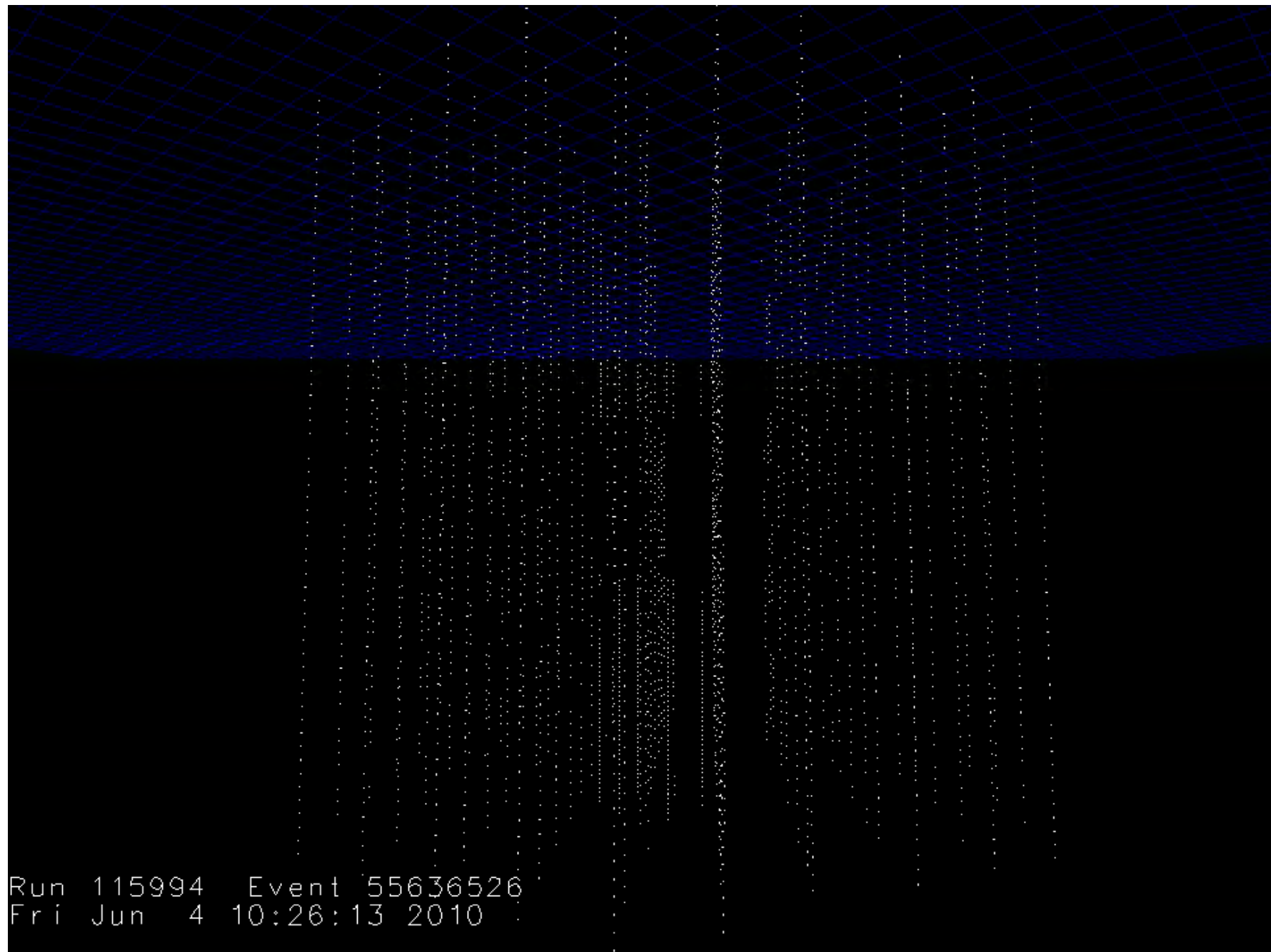


The IceCube Neutrino Observatory

Neutrinos are detected by looking for Cherenkov radiation from secondary particles (muons, particle showers)



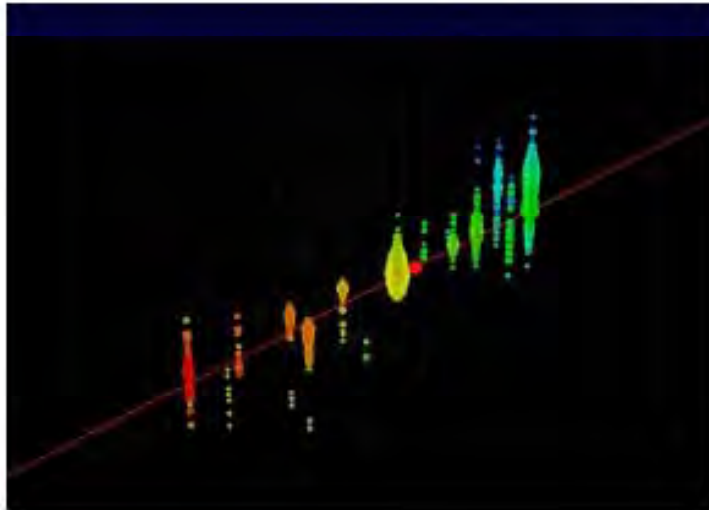
color: time delay



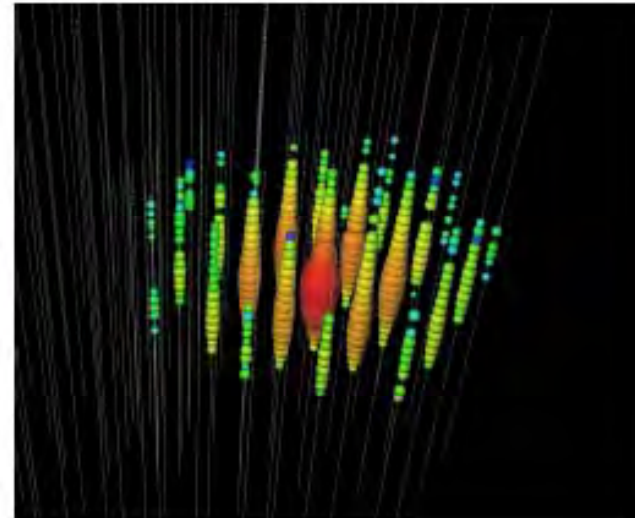
Neutrinos

IceCube – two event signatures

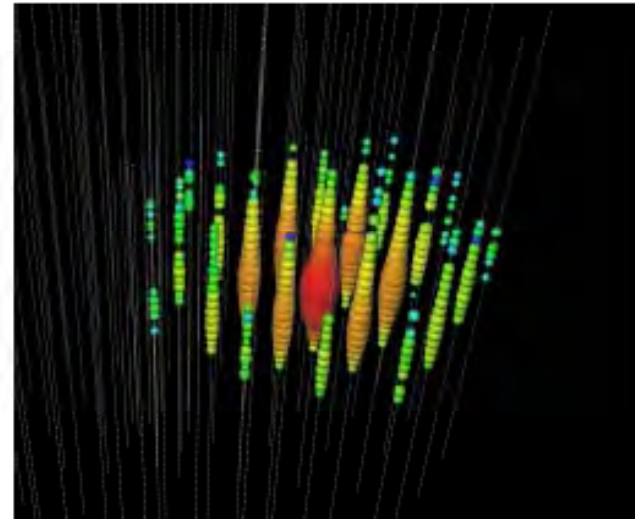
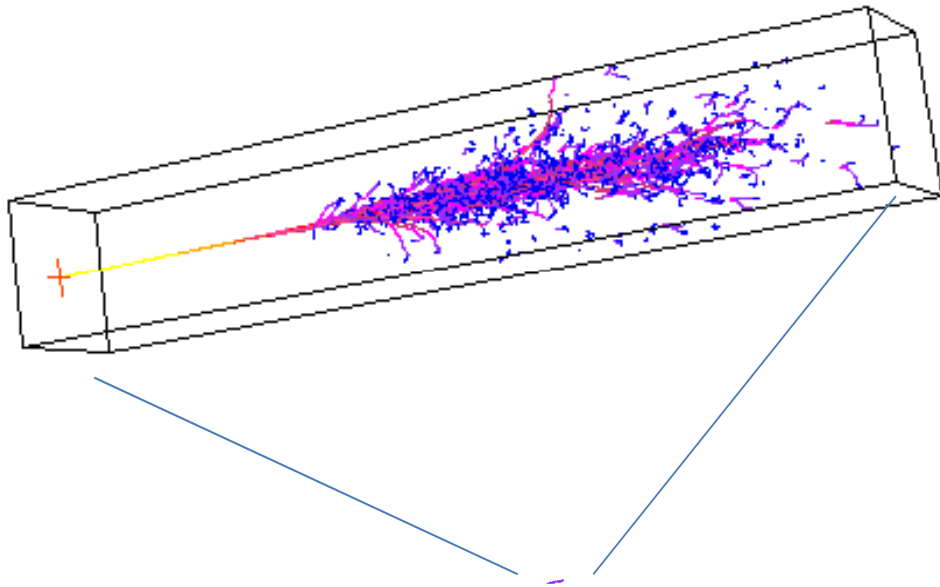
Neutrino creates long range particle



Neutrino creates short range particle which initiates a shower

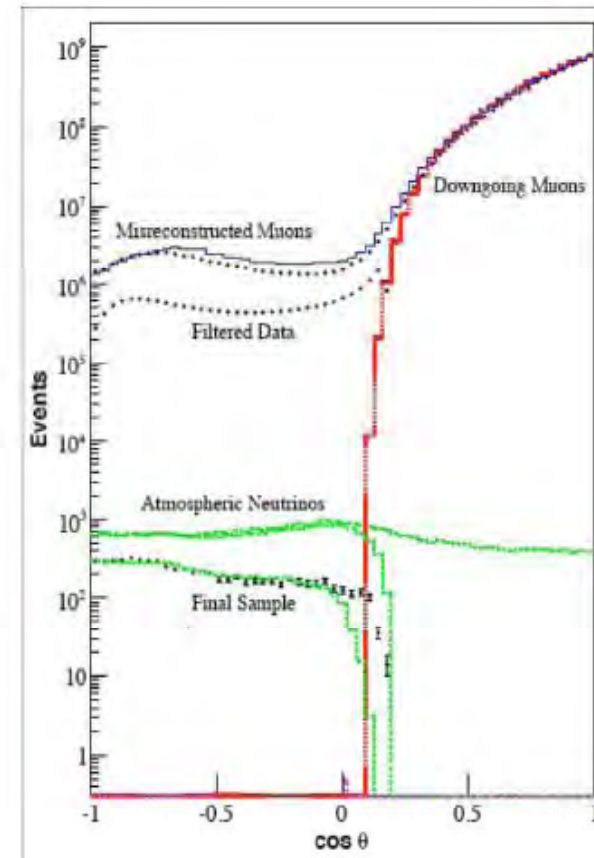
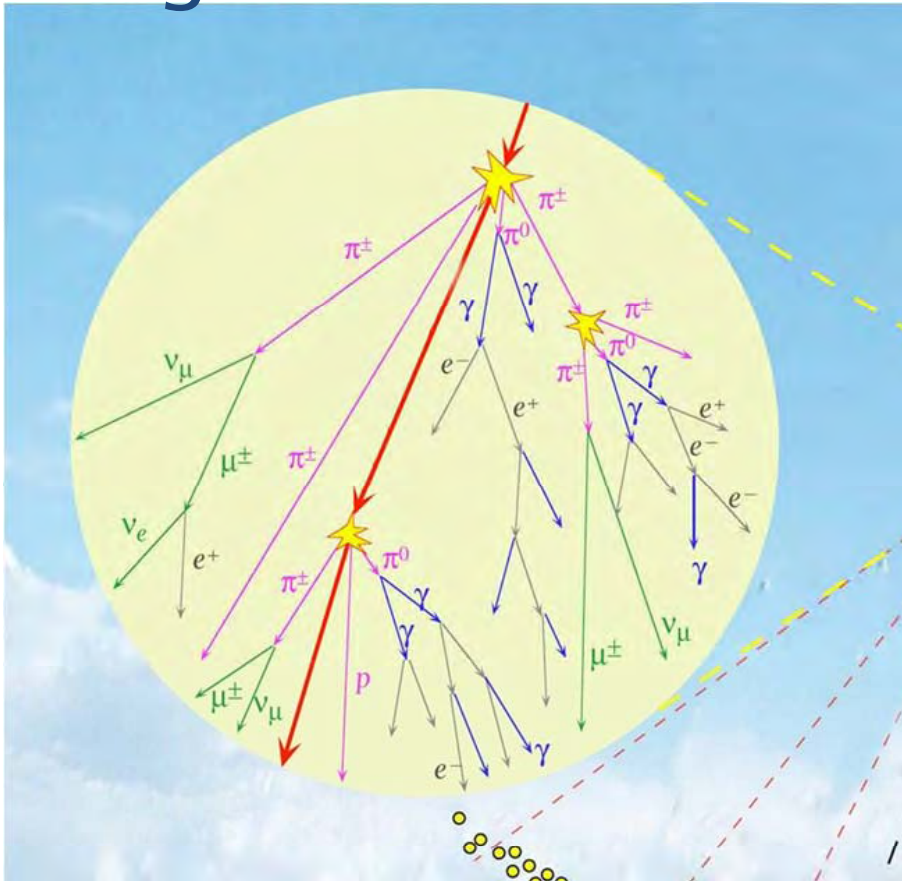


Neutrino Cascade event signature



IceCube

Background from cosmic ray air showers



Muon rate:

In ice: 2800 /second – compared to 1 neutrino/10 minutes

Requires 10^6 background rejection



Moran in the data
comparial needle in a
haystack task

Hunts Needle in a Haystack

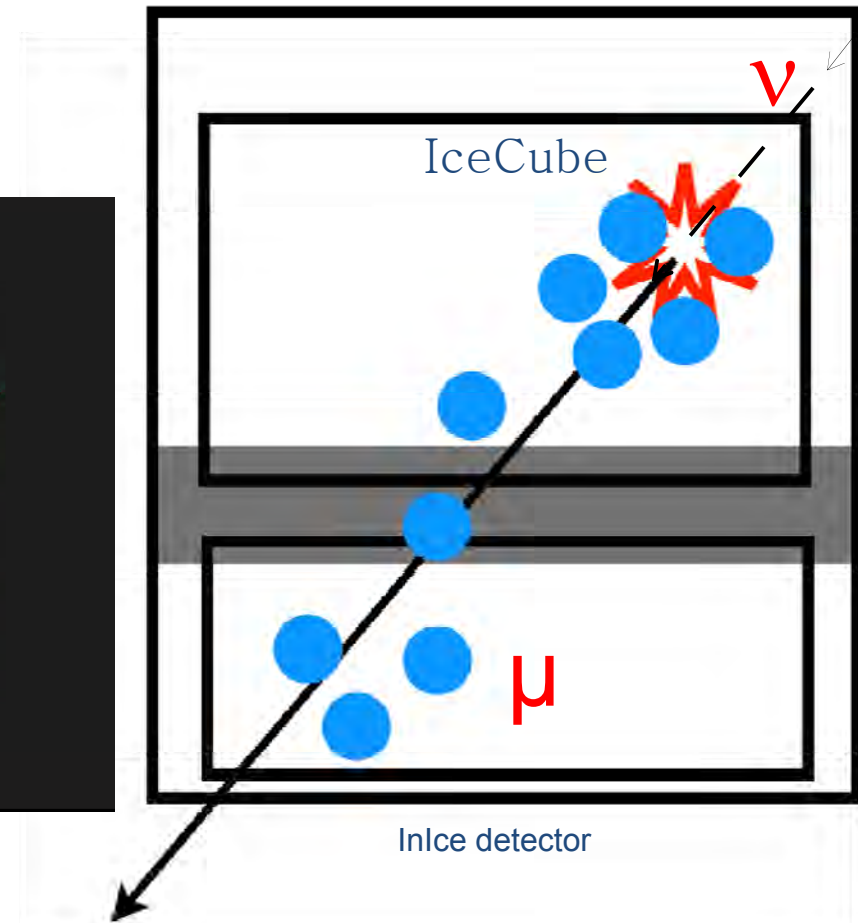
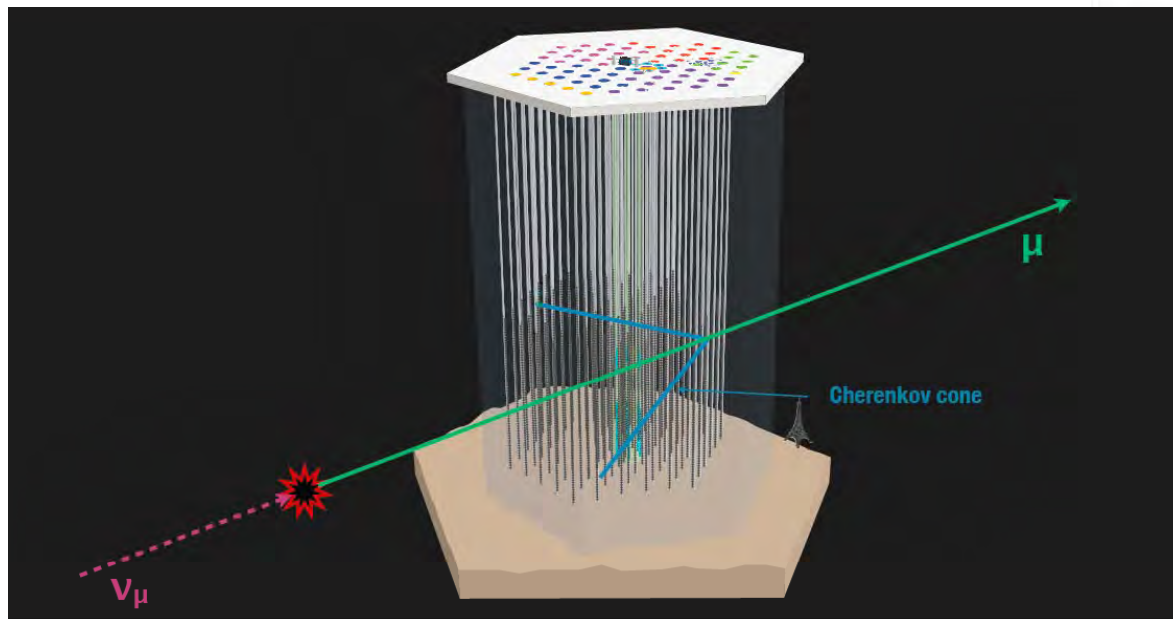
HOW LONG does it take to find a needle in a haystack? Jim Moran, Washington, D. C., publicity man, recently dropped a needle into a convenient pile of hay, hopped in after it, and began an intensive search for (a) some publicity and (b) the needle. Having found the former, Moran abandoned the needle hunt.

IceCube

Background rejection

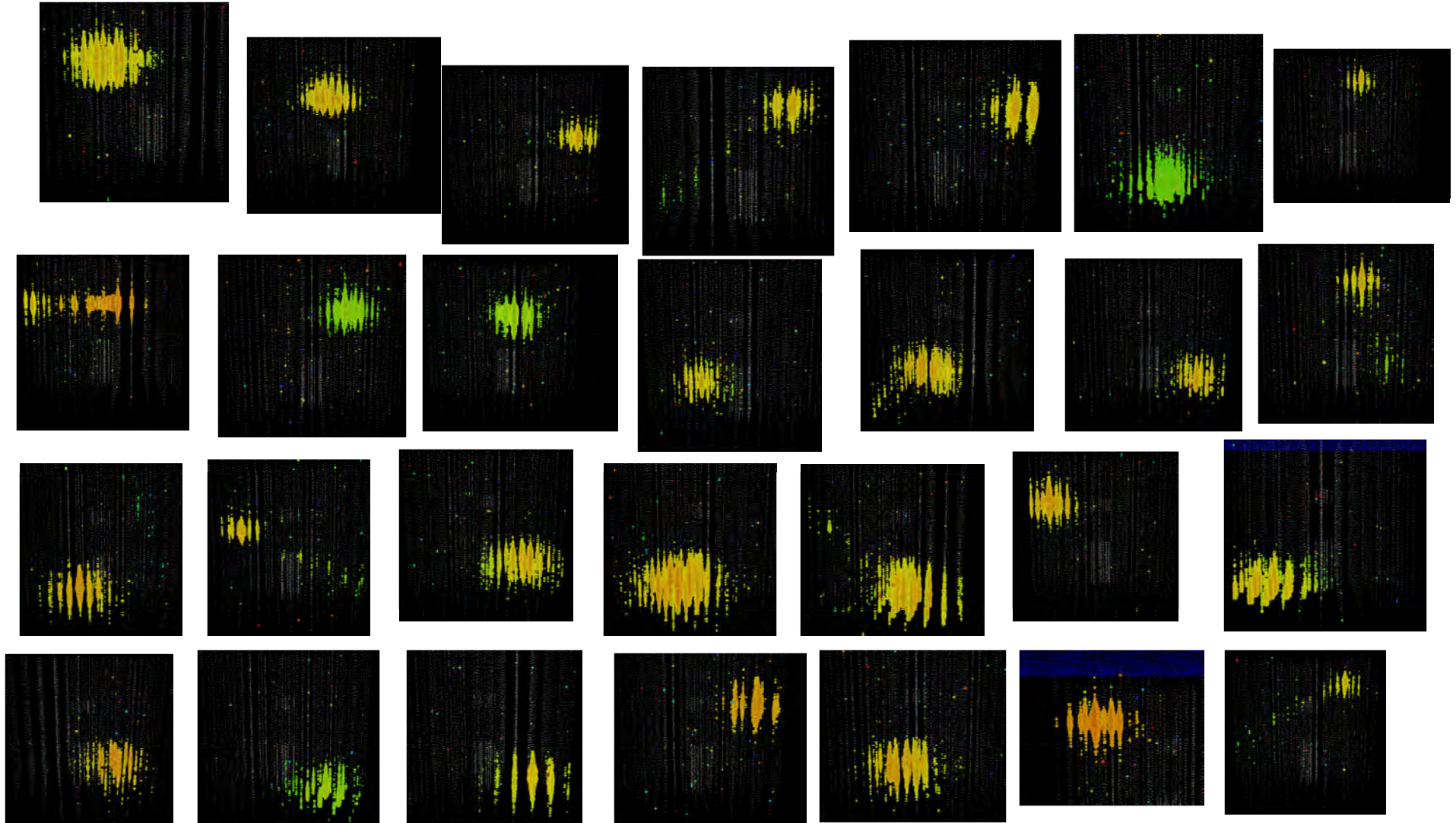
- upward tracks

- use outer parts of the detector as a veto



Two year IceCube Search

28 high-energy neutrinos found





Summary

- Cosmic rays, gamma rays and neutrinos offer a view into the high-energy universe
 - A range of detectors used to observe them
- It is still a mystery where the highest energy cosmic rays come from
- Through the detection of astrophysical neutrinos we might be soon able to solve this mystery

