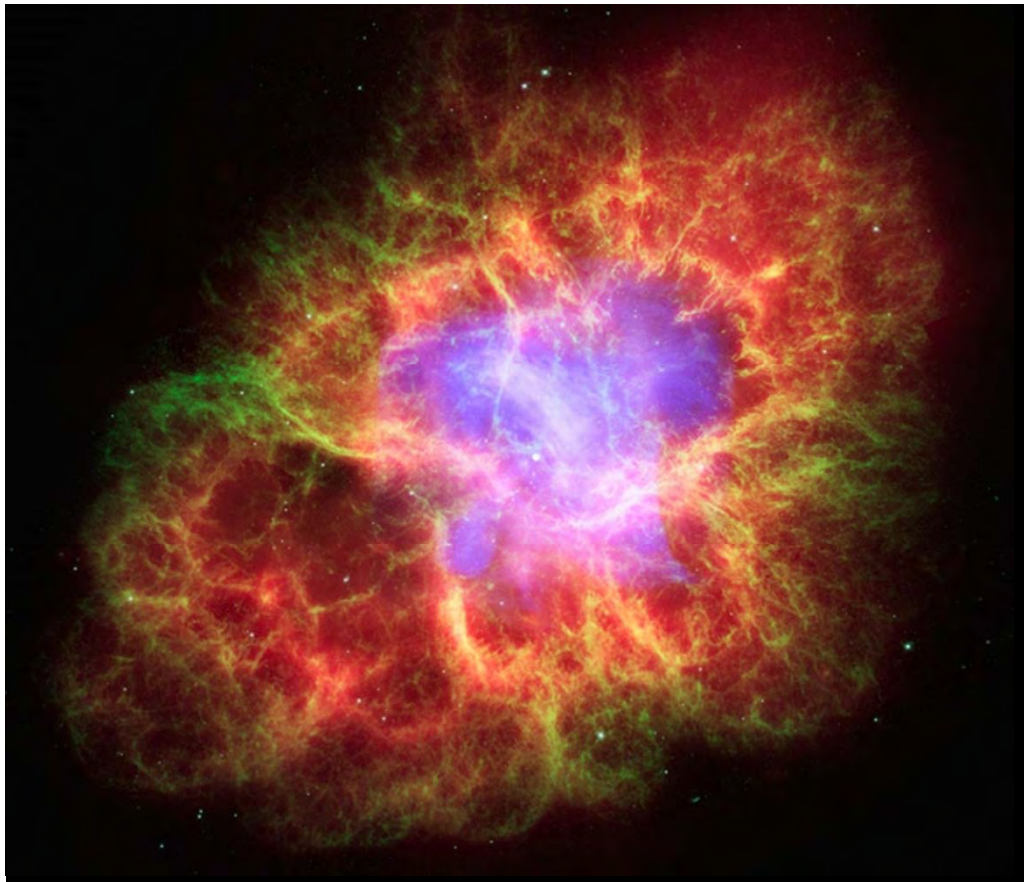
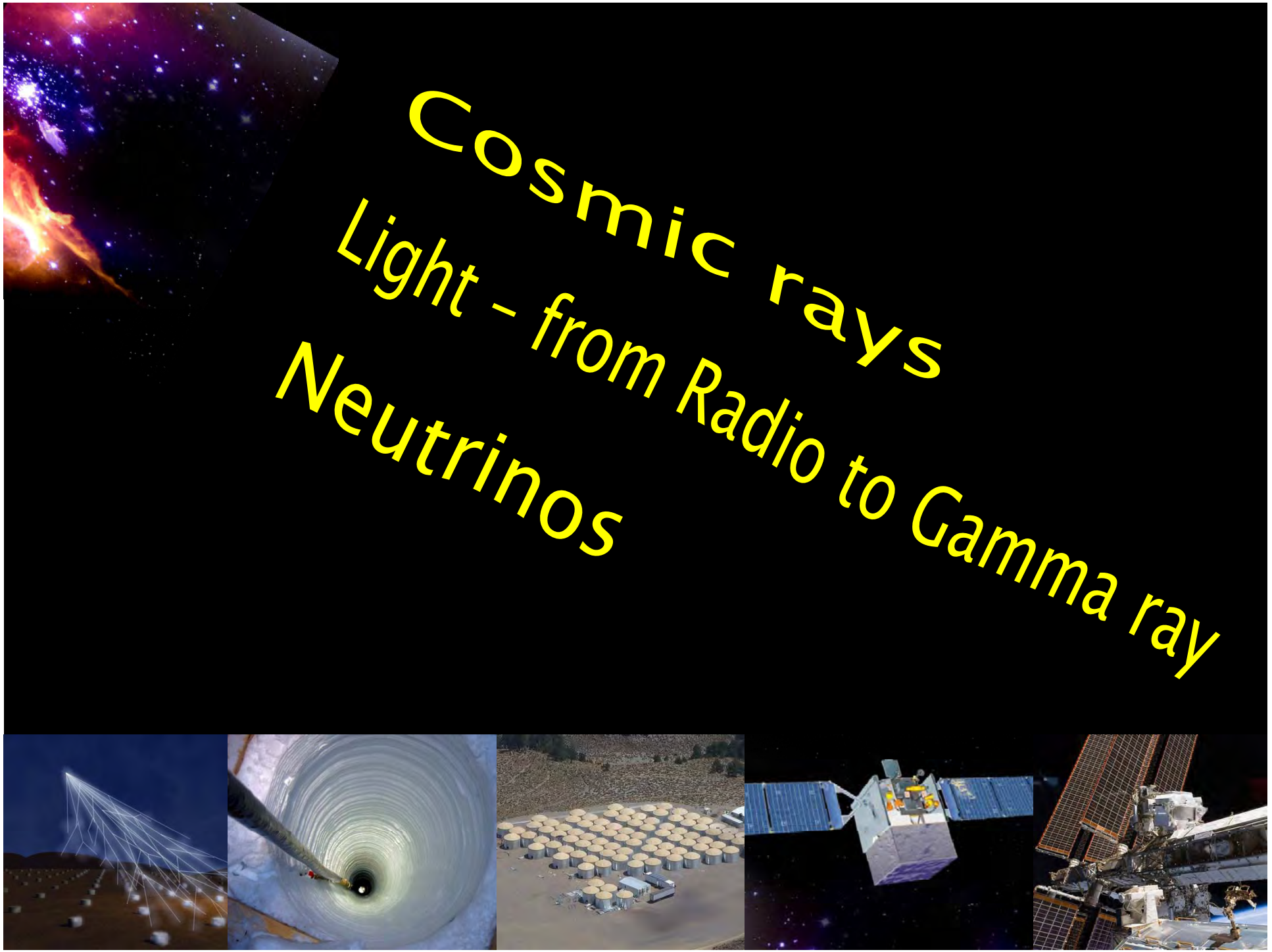


Messengers from the high-energy universe

Jenni Adams
University of Canterbury, N.Z.
Visitor at NBIA

Nyt fra Niels Bohr International Academy Kurs 2013

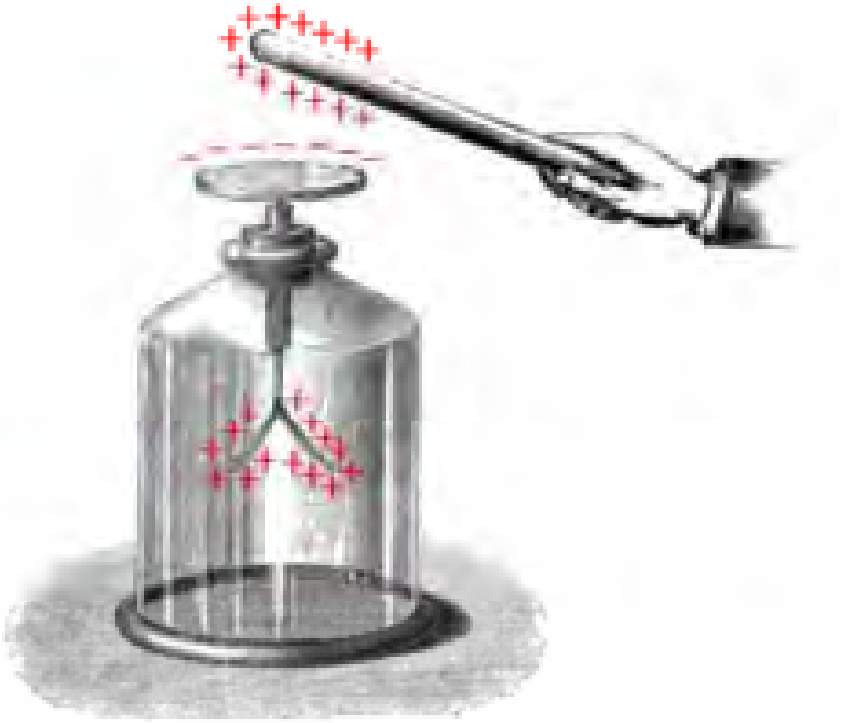

Cosmic rays
Light – from Radio to Gamma ray
Neutrinos

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

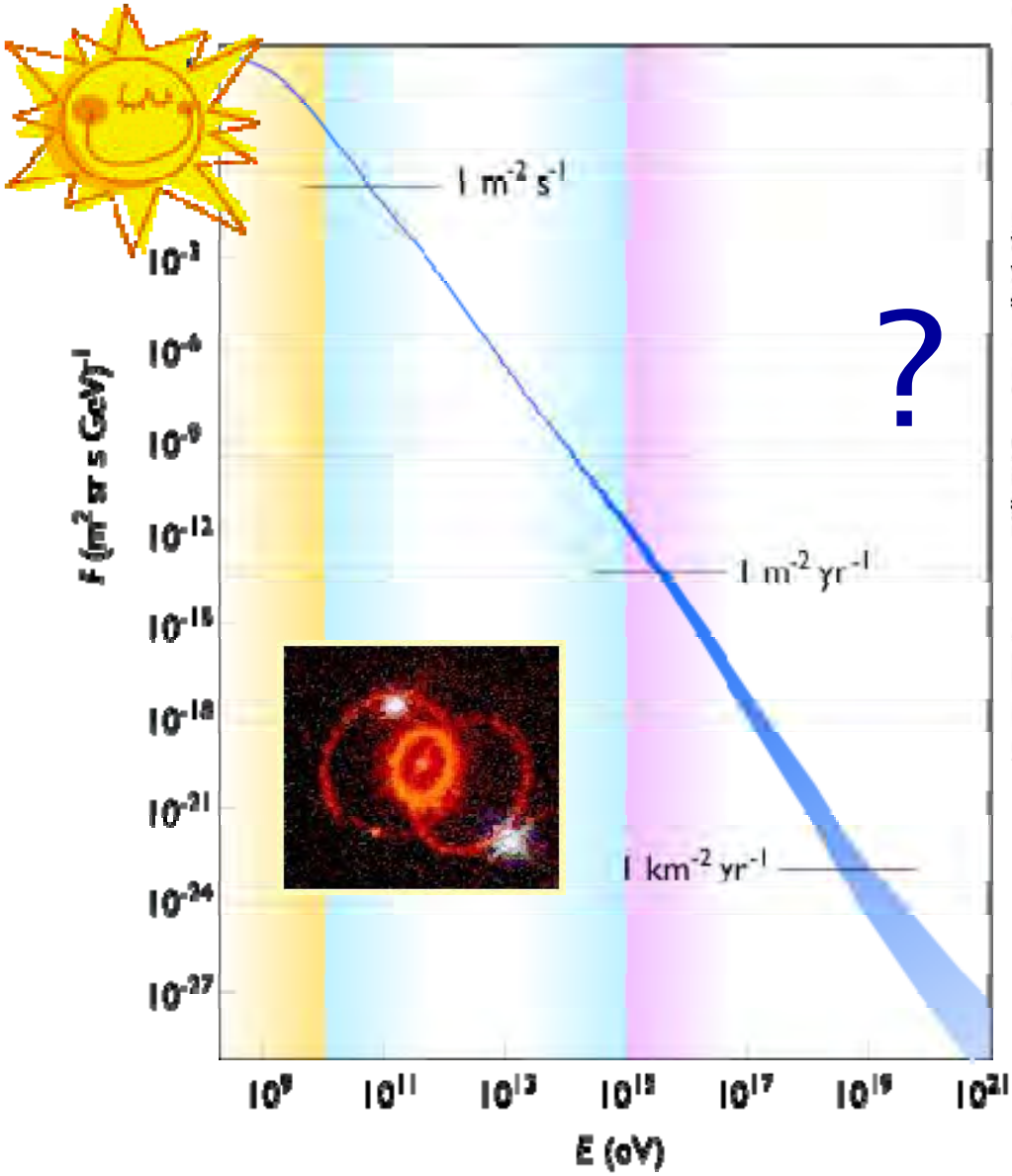
100 years since Victor Hess's discovery

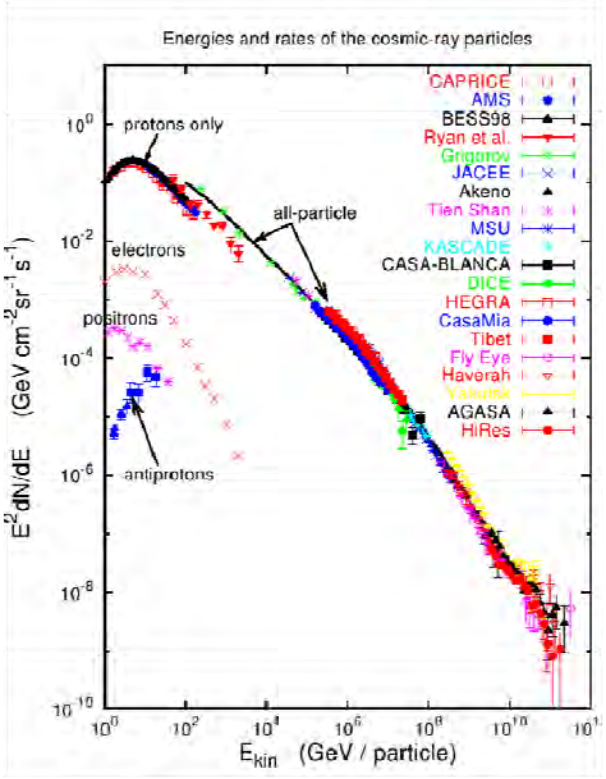
"The results of present observations are more reliably explained assuming that an highly penetrating radiation enters our atmosphere from the top, and then produces in the lower layers part of the ionization observed in closed detectors."

Hess (1913) published article

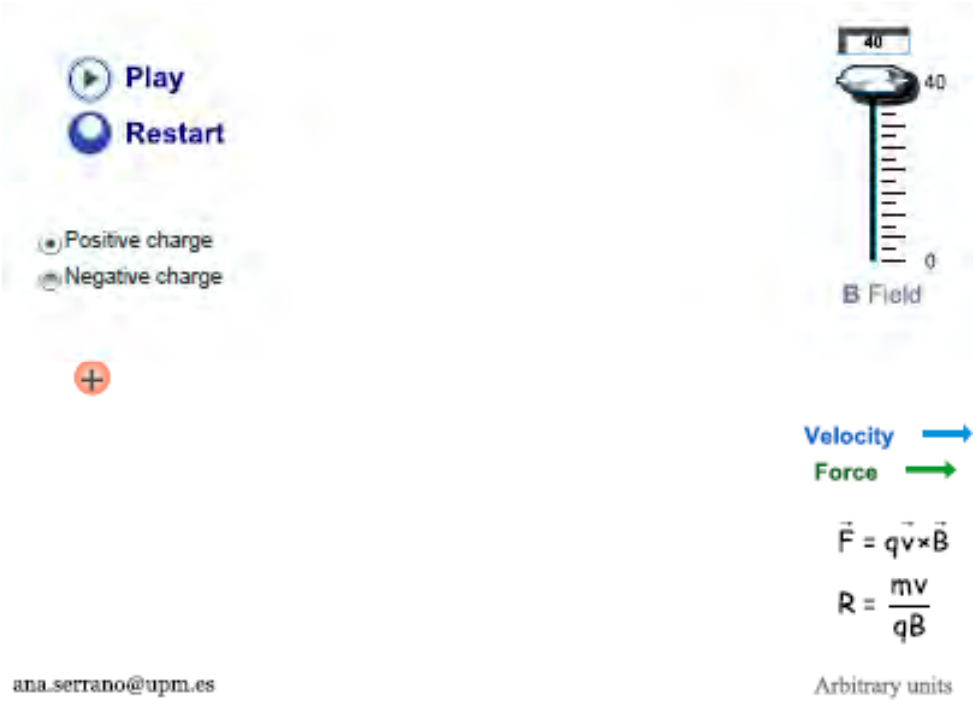
Cosmic Rays

Spectrum and possible sources...





Cosmic Rays
Influenced by magnetic fields

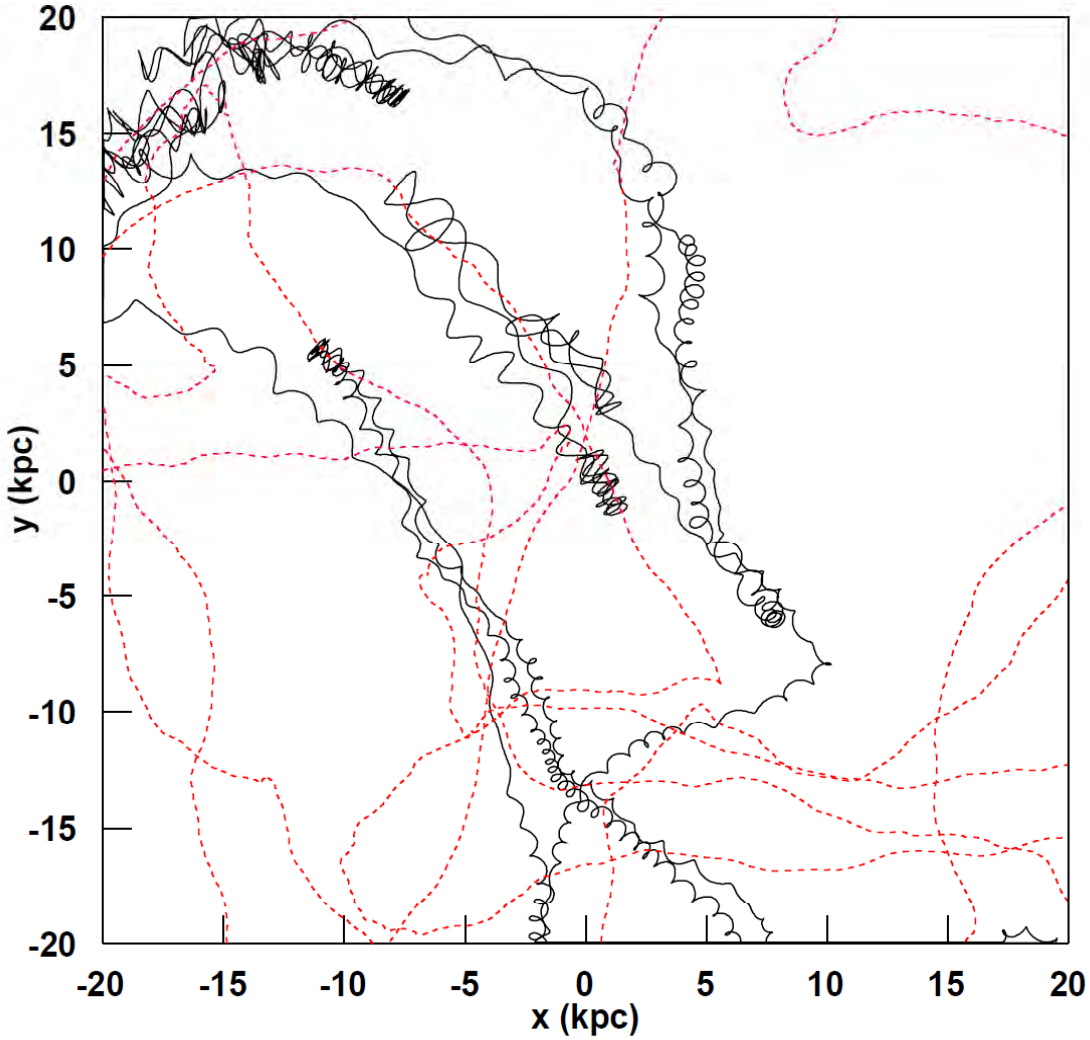


Cosmic Rays

Influenced by magnetic fields, luckily for us

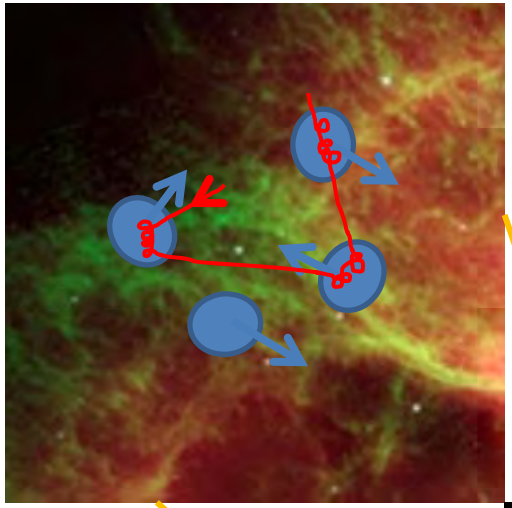
Cosmic Rays

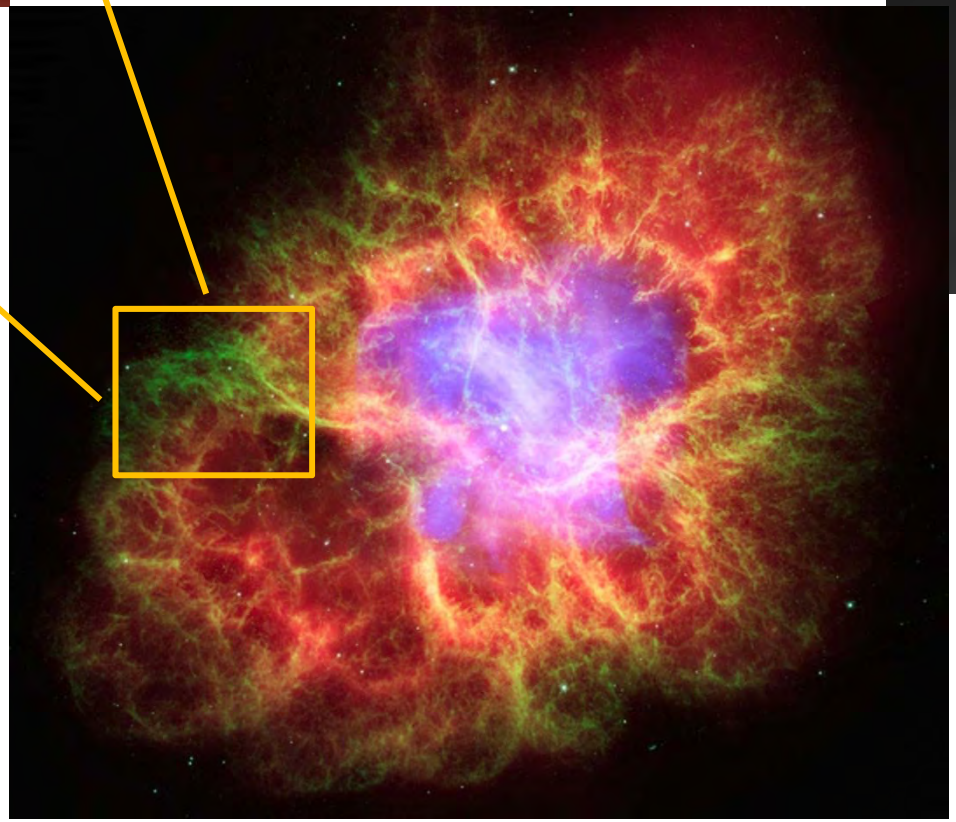
Influenced by magnetic fields, unluckily for cosmic ray astronomy

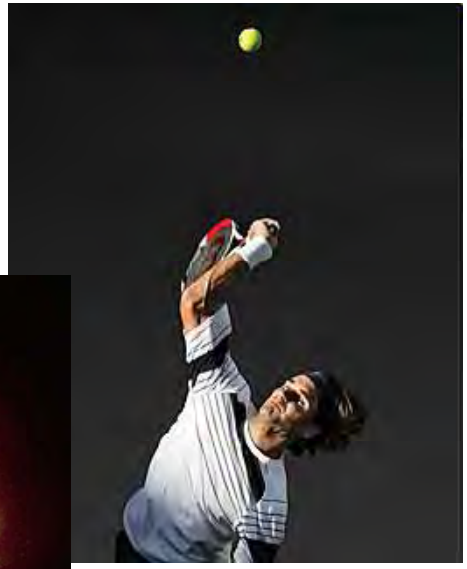


Cosmic Rays

How are they accelerated?

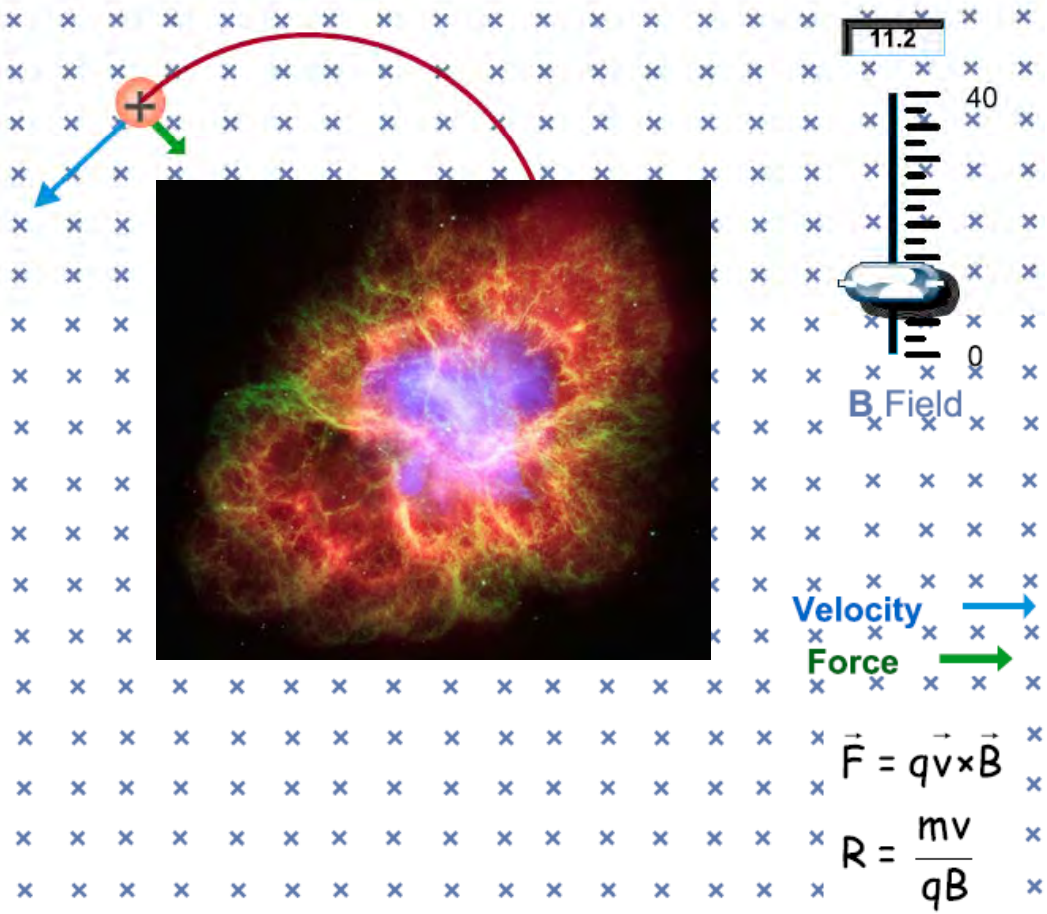






Cosmic Rays

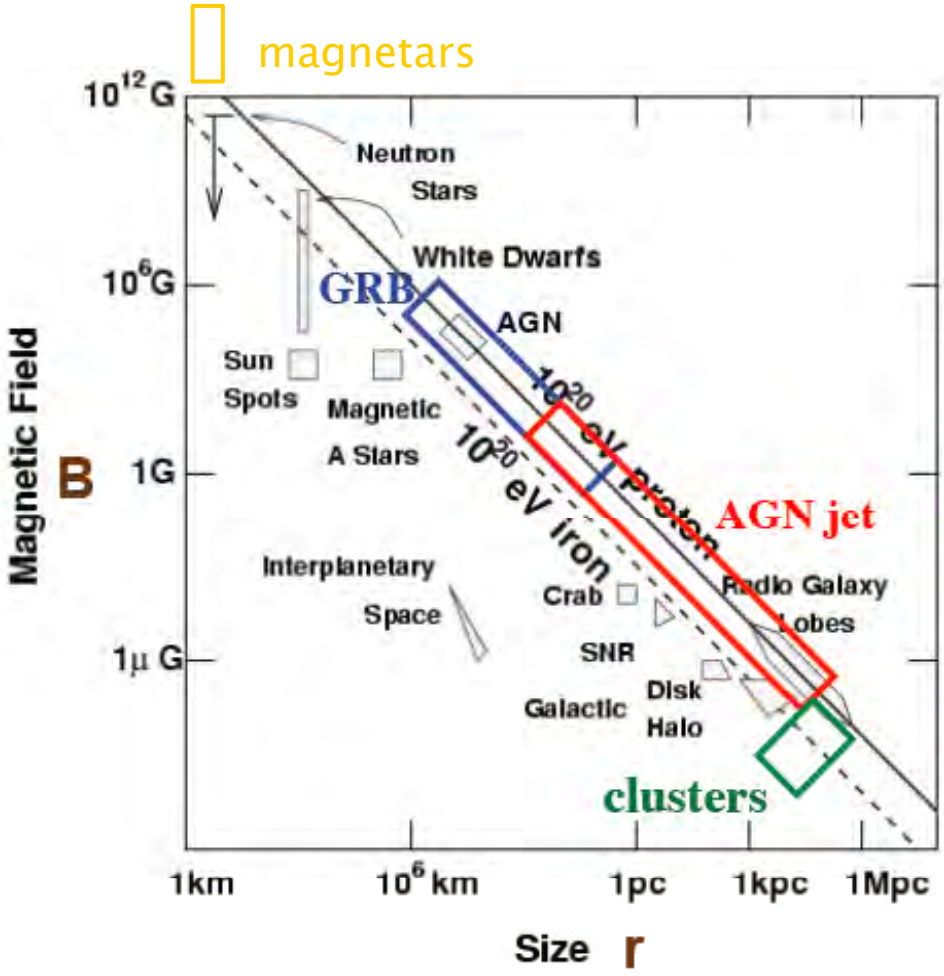
Where could they be accelerated?



$E_{max} \sim \beta ZBR$

Cosmic Rays

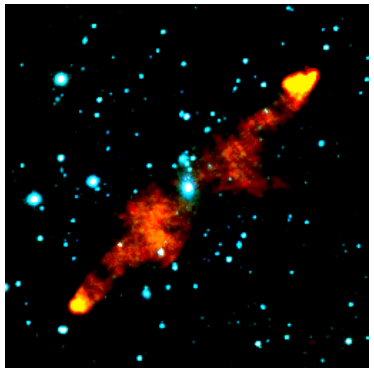
Where could they be accelerated?



$E_{max} \sim \beta ZBR$

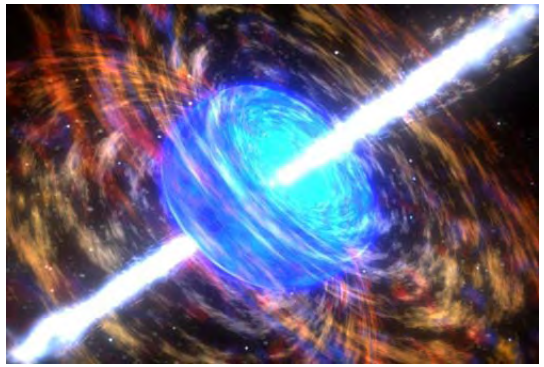
Cosmic Rays

From the Universe's most extreme objects



AGNs
The most massive black holes

Magnetars
The strongest magnetic fields



GRBs
The brightest explosions

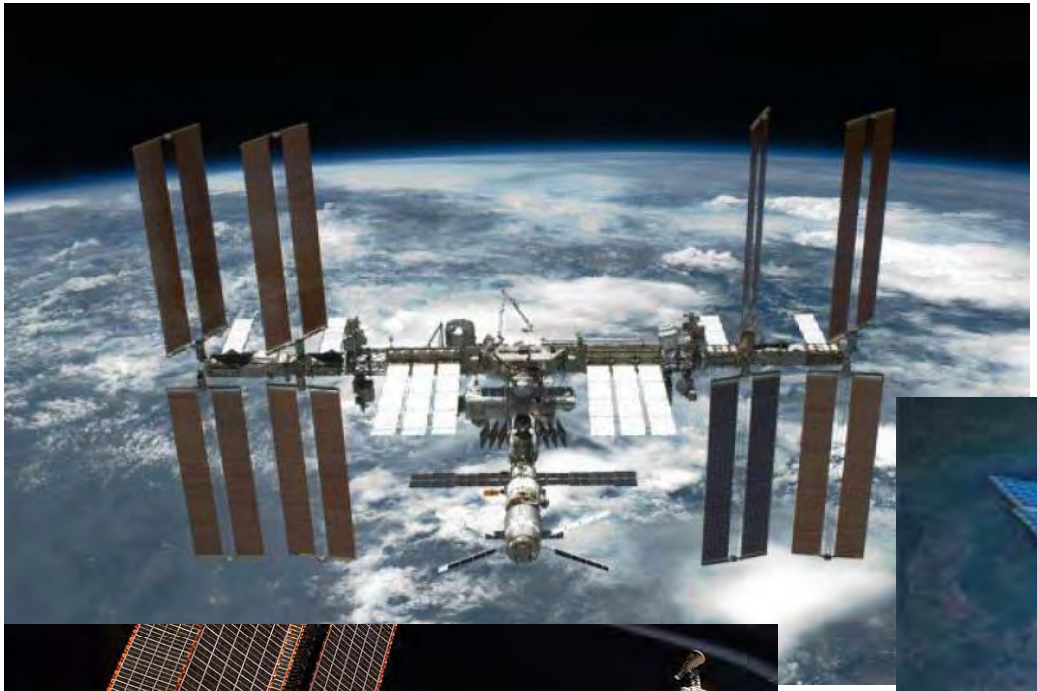
Galaxy Clusters
The largest gravitationally bound objects

Cosmic Rays

How do we detect them?

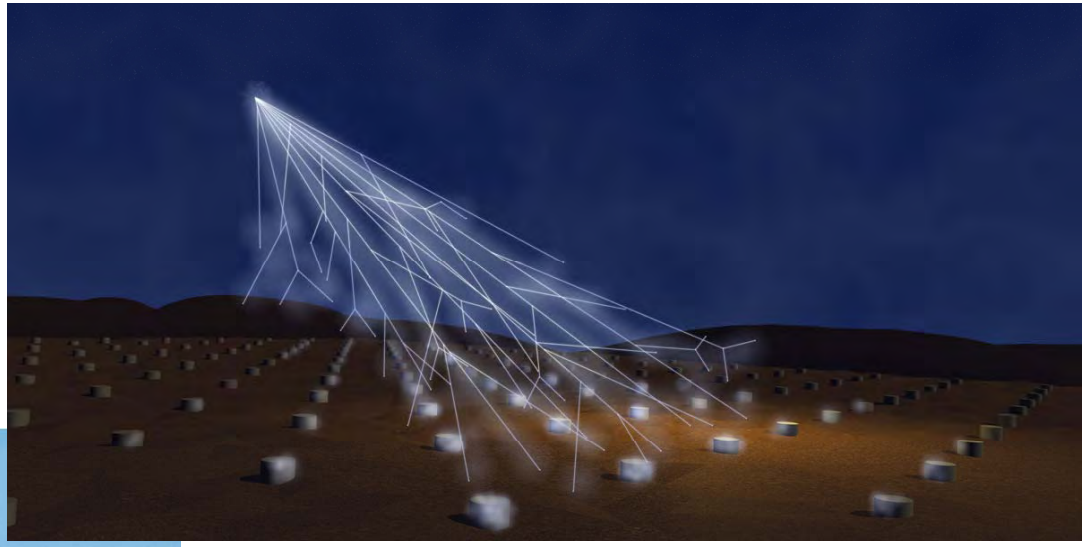
Cosmic Rays

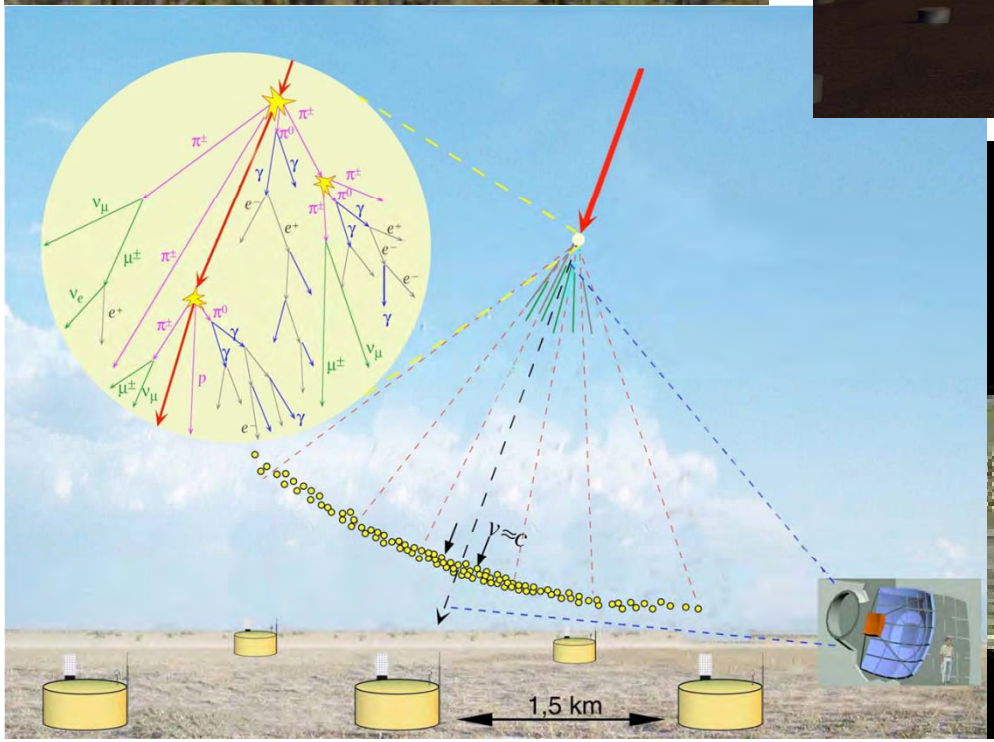
How do we detect them?

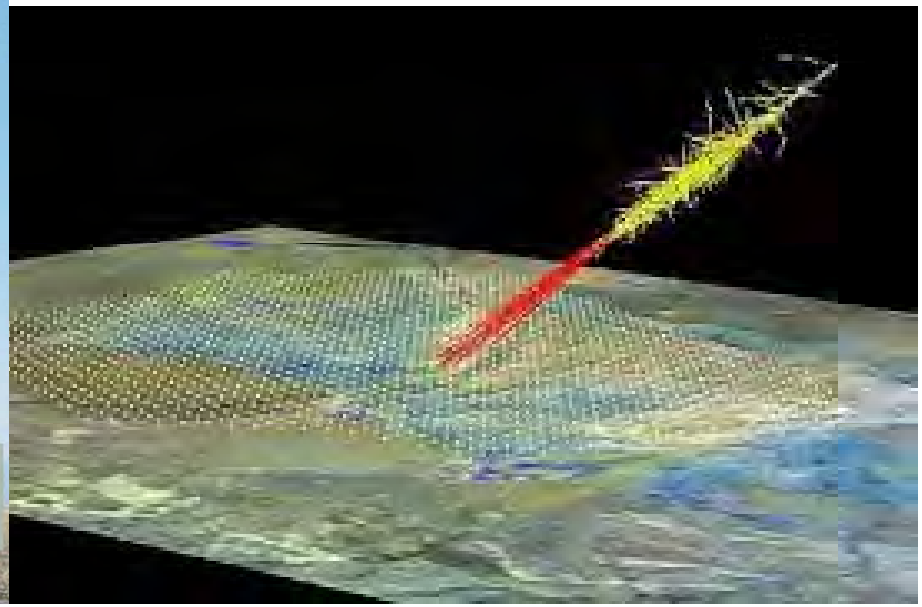


Cosmic Rays

Pierre Auger Observatory

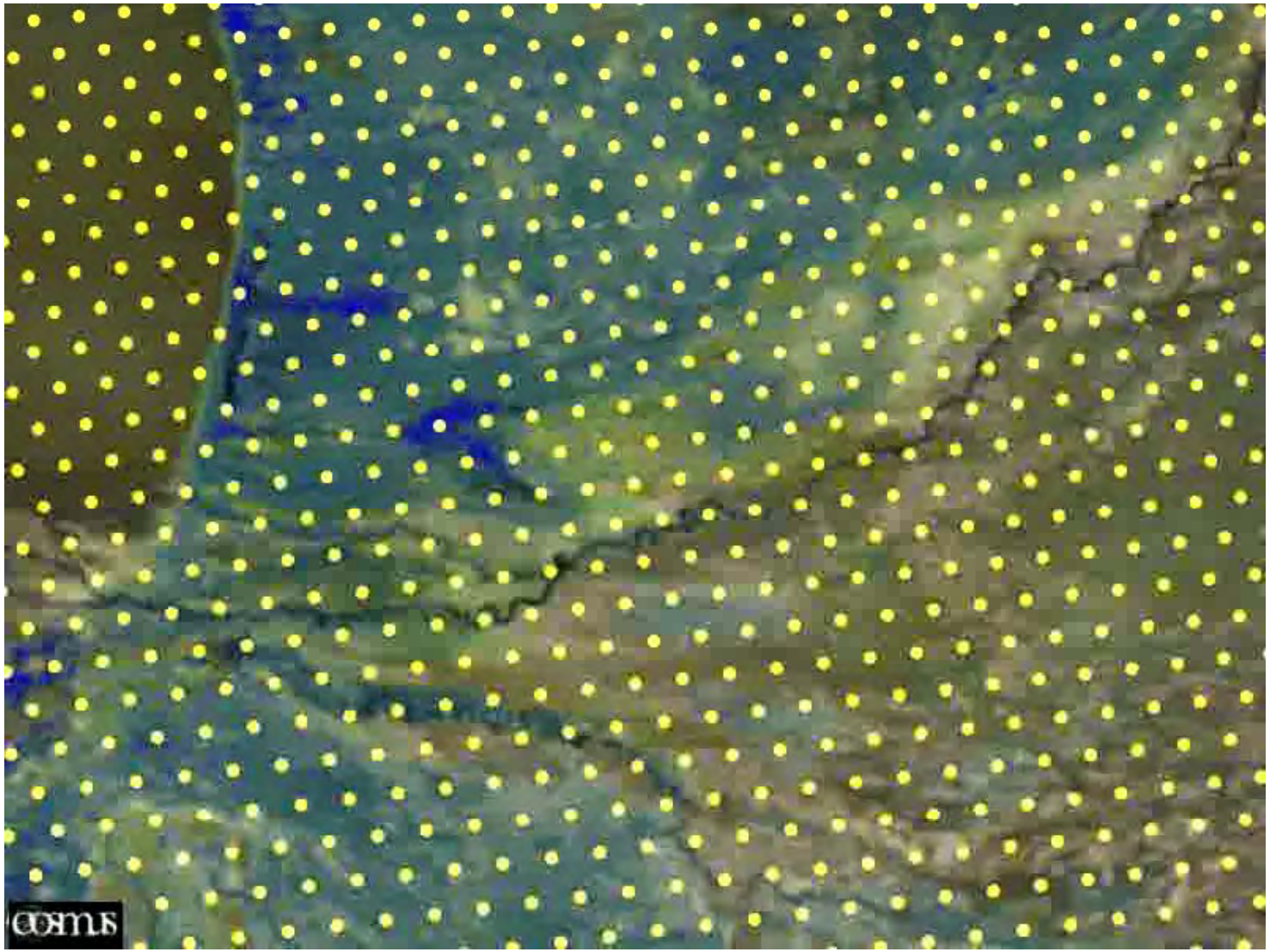






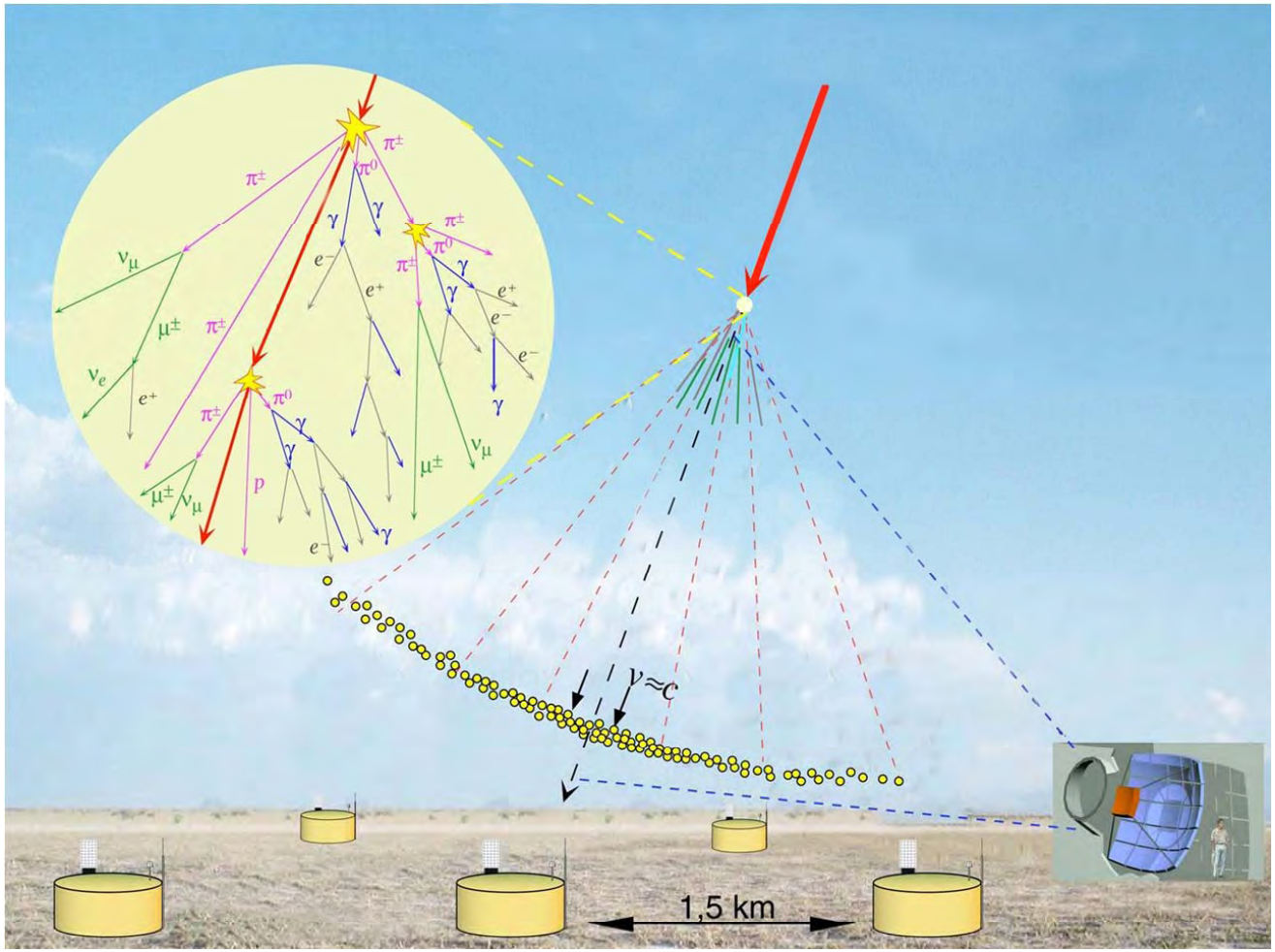
Cosmic Rays

How do we detect them?



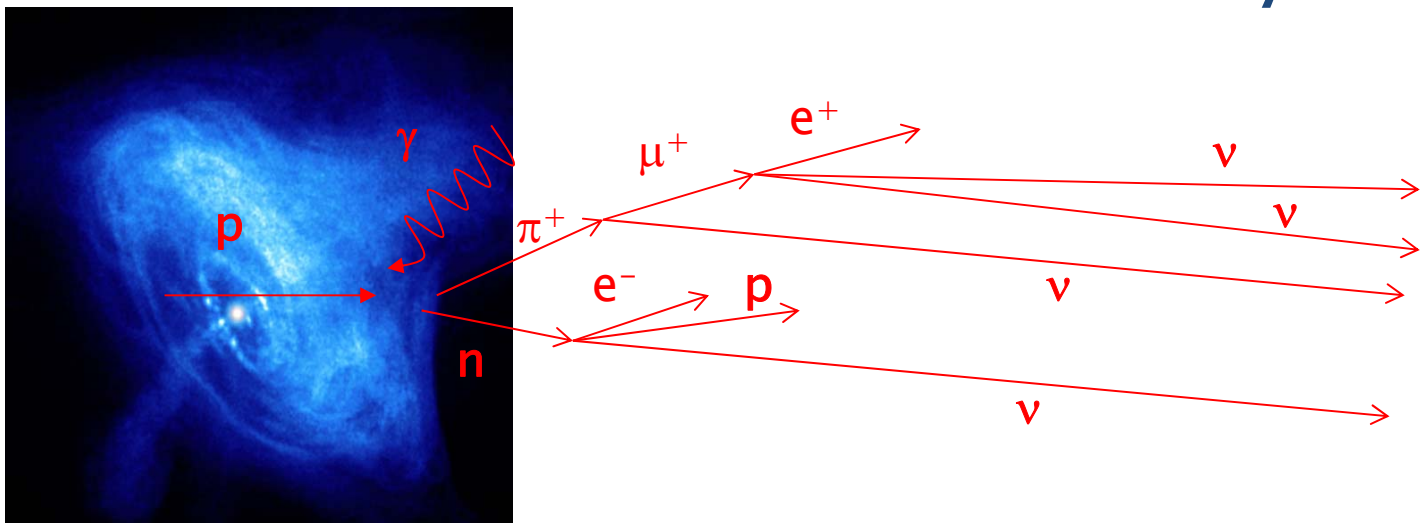
Neutrinos and Gamma Rays

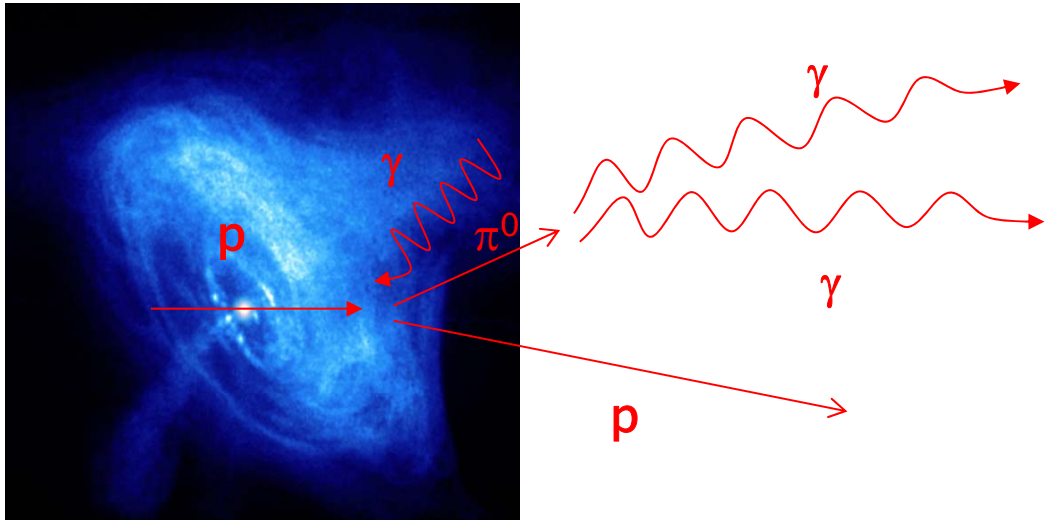
From cosmic ray interactions



Neutrinos and Gamma Rays

From cosmic ray interactions





Messenger Comparison

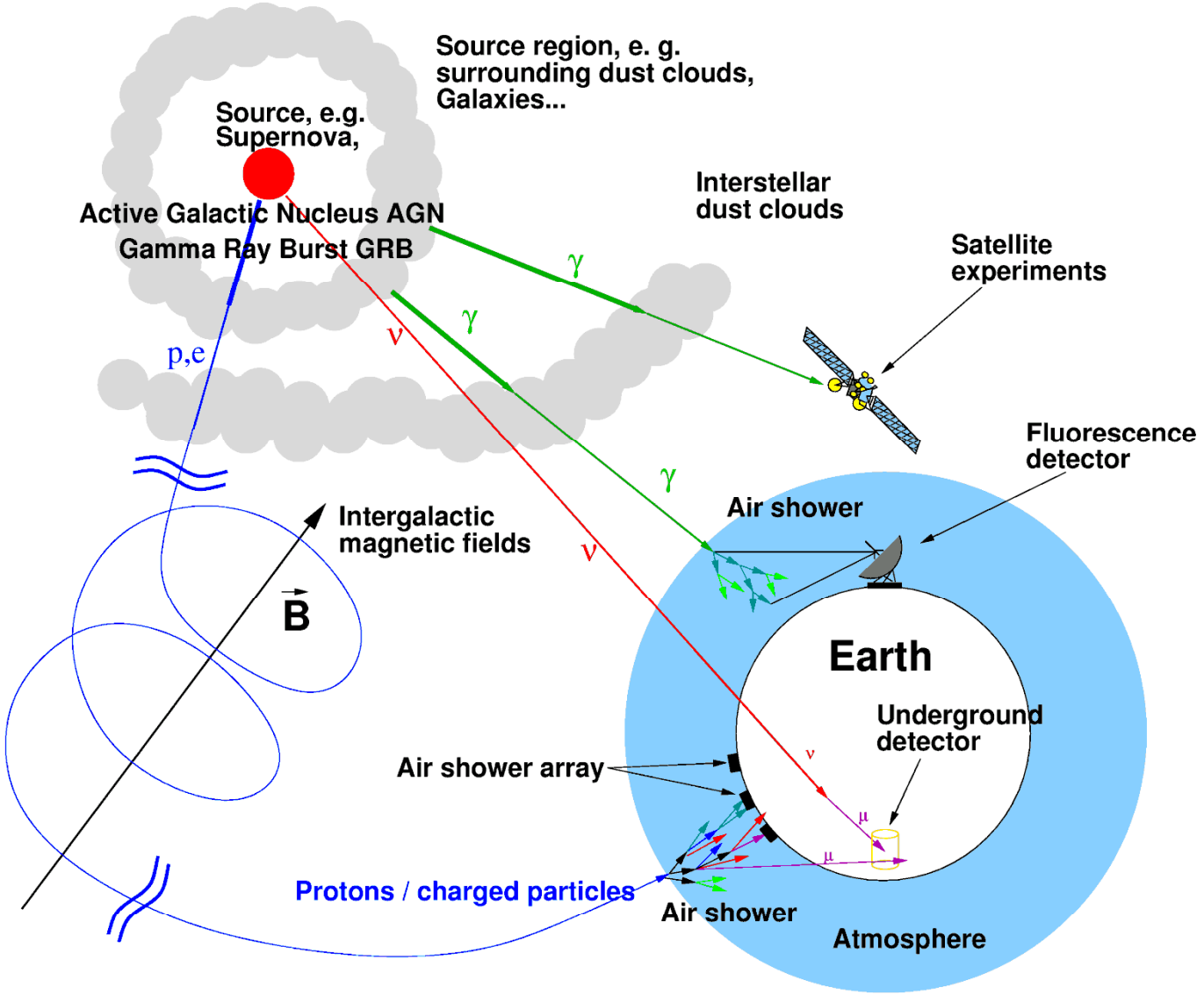
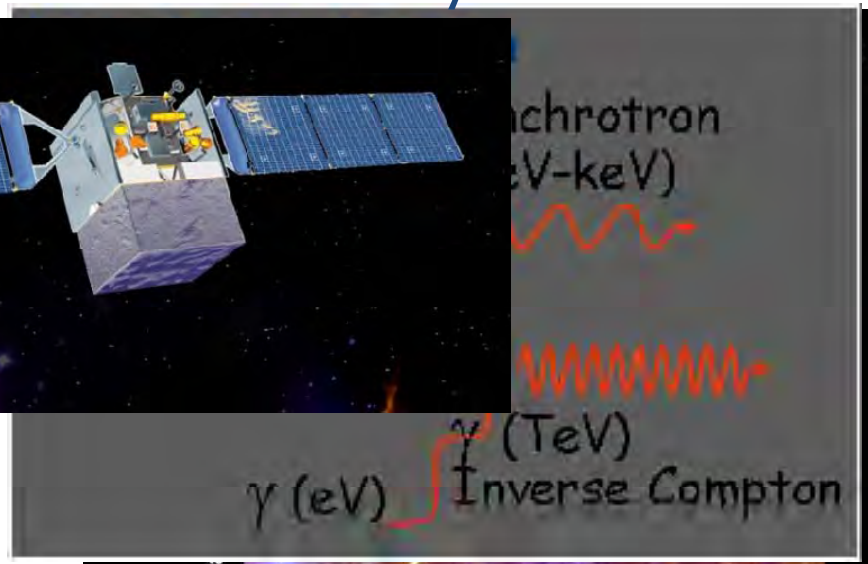
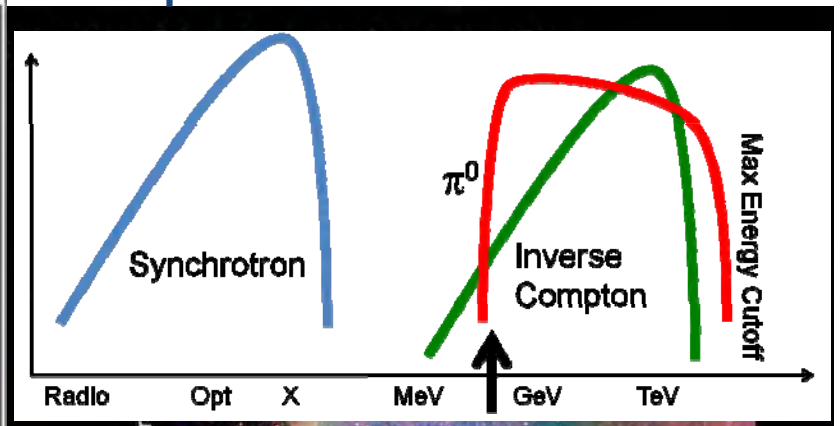


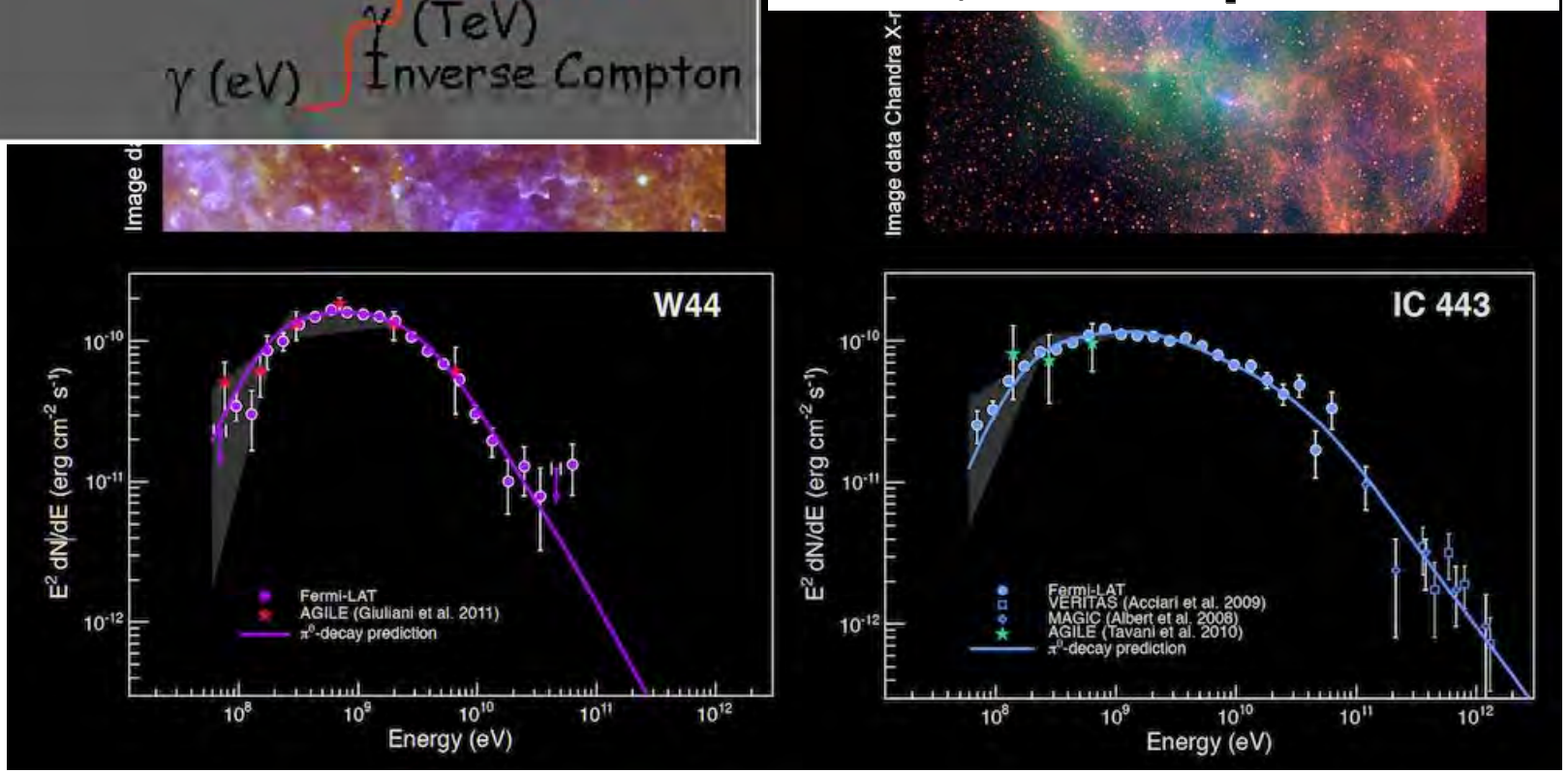
Figure: Wolfgang Wagner, PhD thesis

Cosmic Rays

Fermi – Gamma Ray verification of supernova remnant source







Messenger Comparison

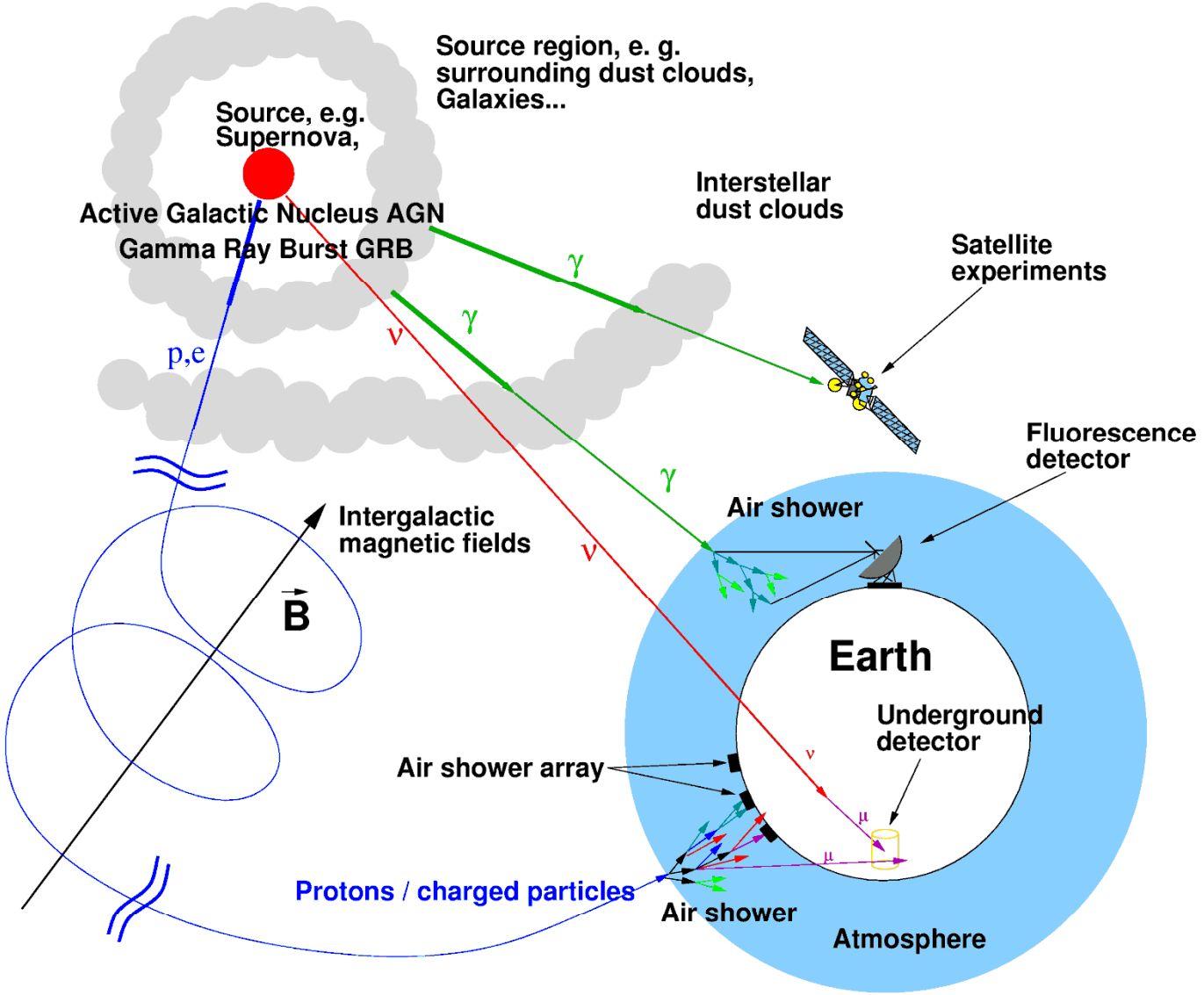
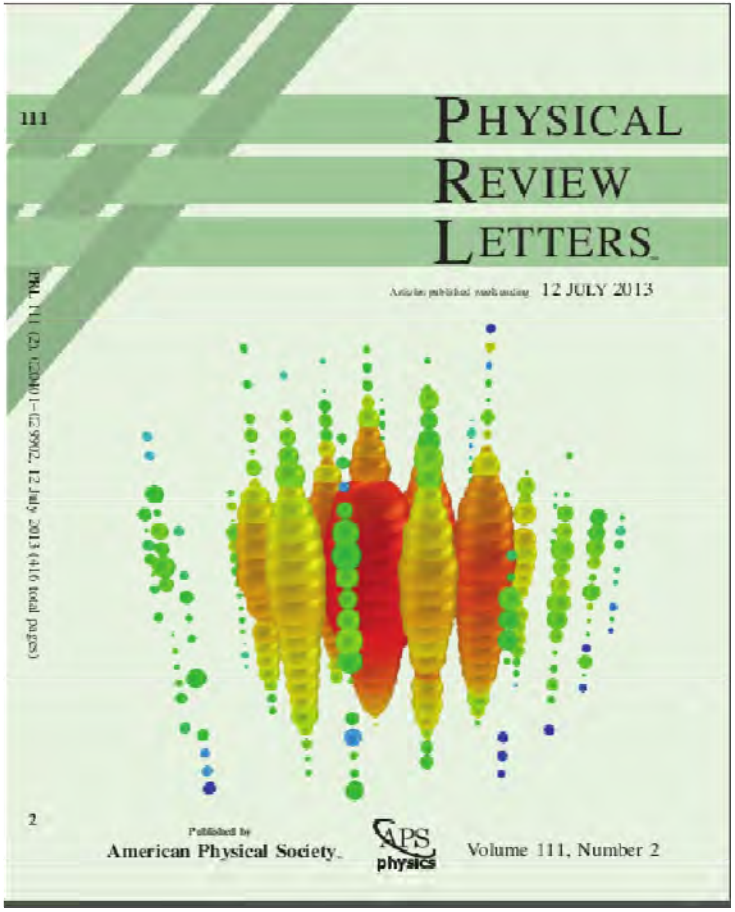
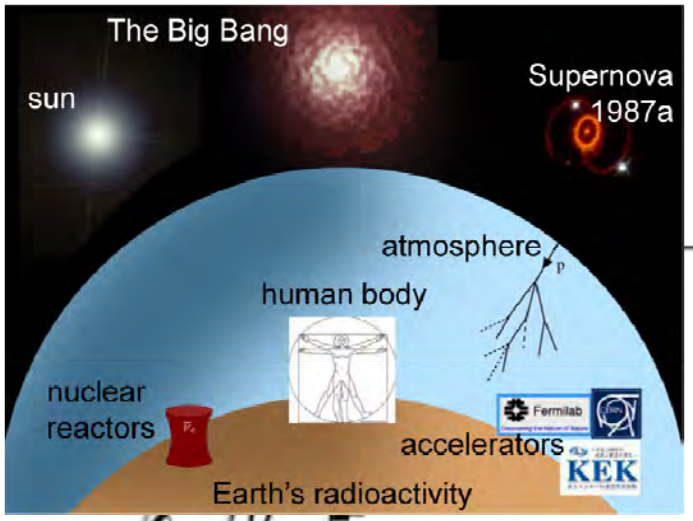


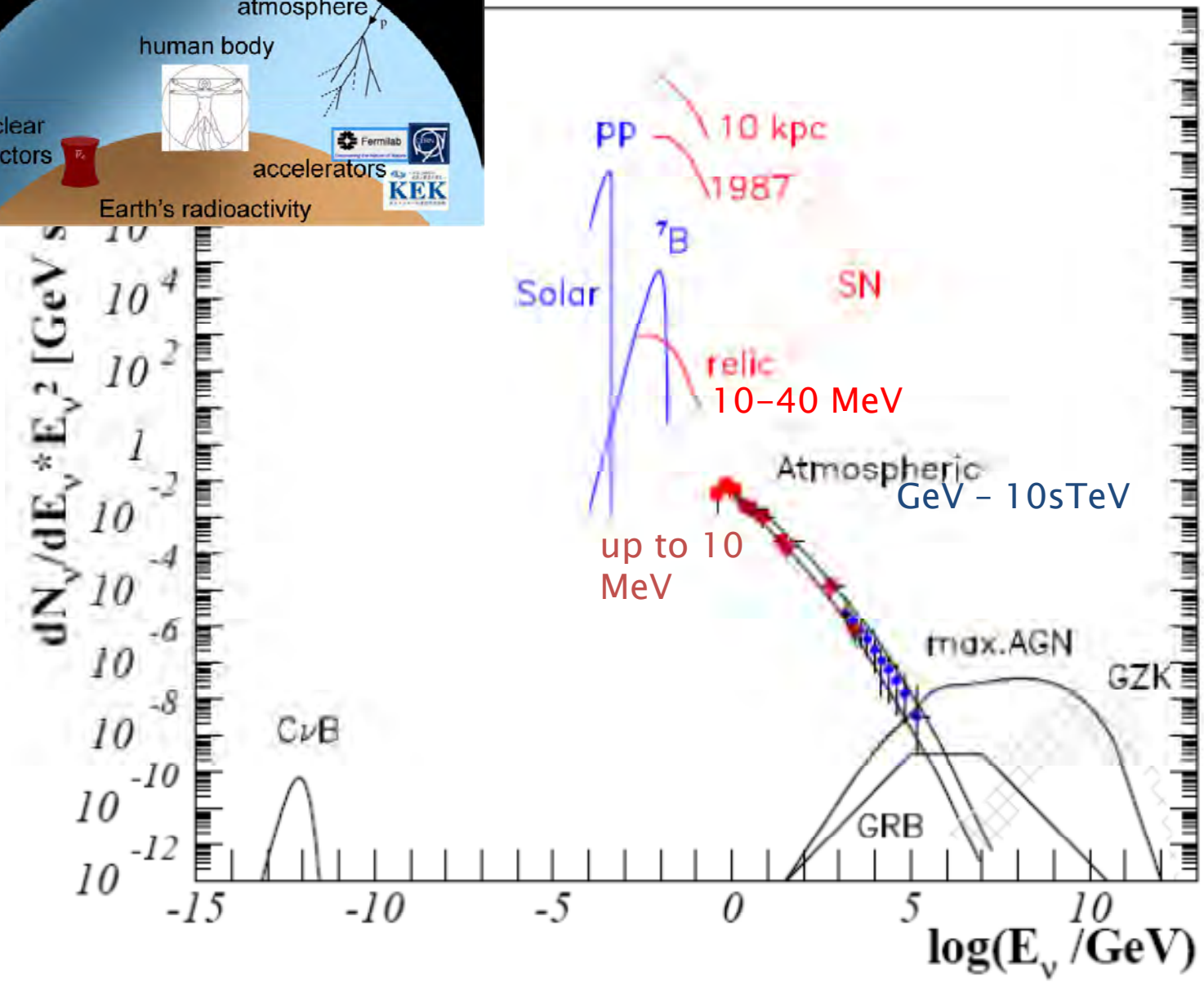
Figure: Wolfgang Wagner, PhD thesis

Astrophysical neutrinos



Neutrino sources





J. Becker
Phys. Rep.
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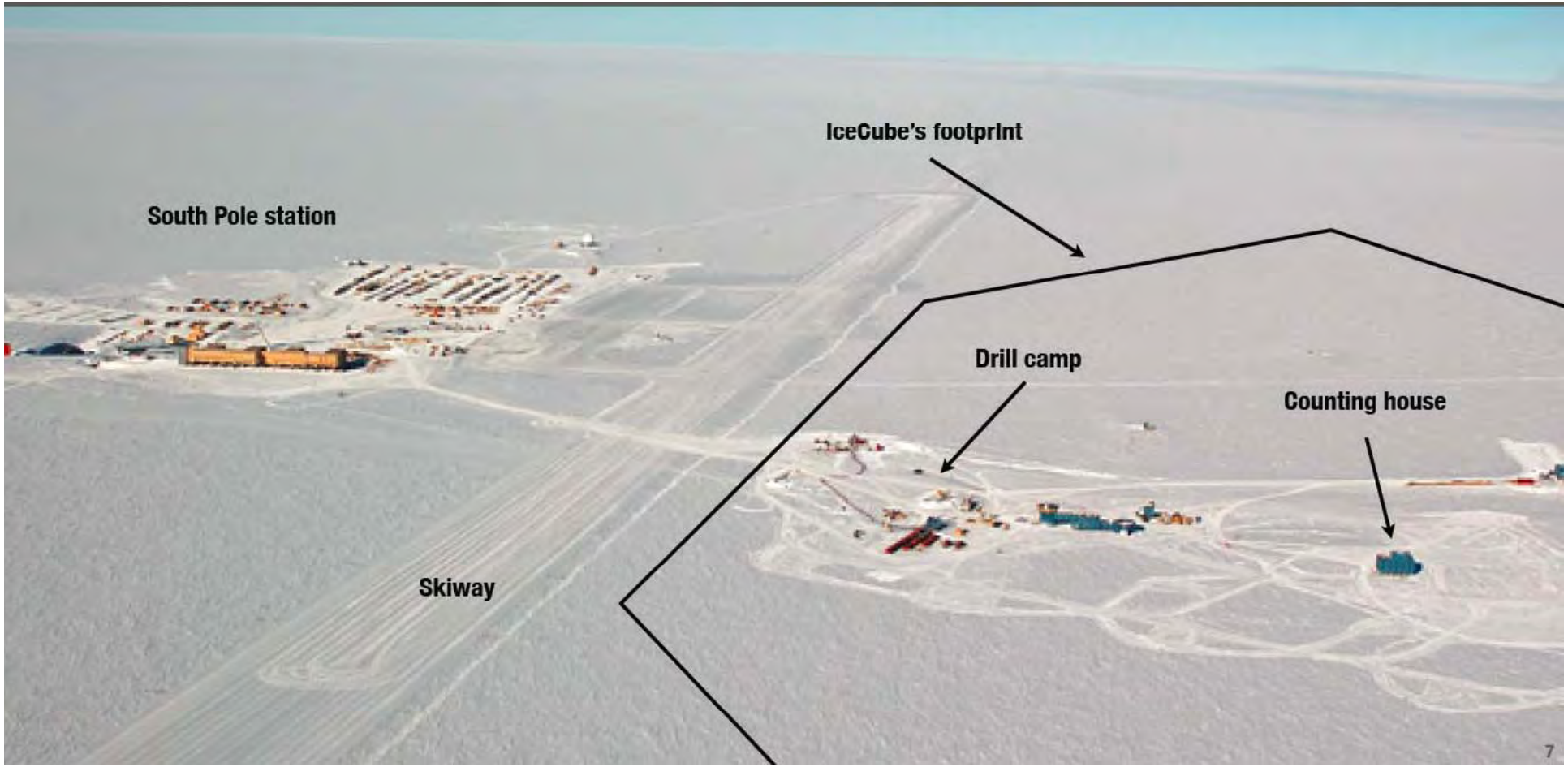
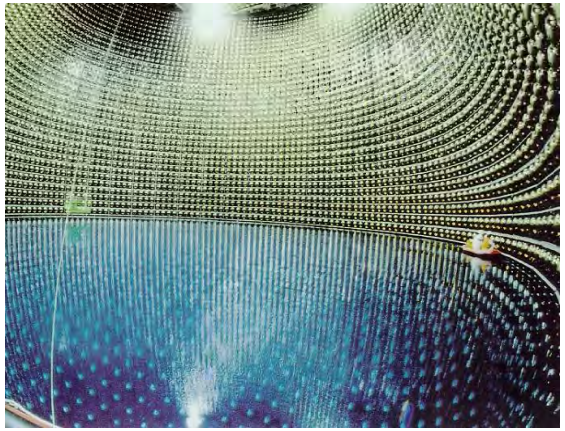
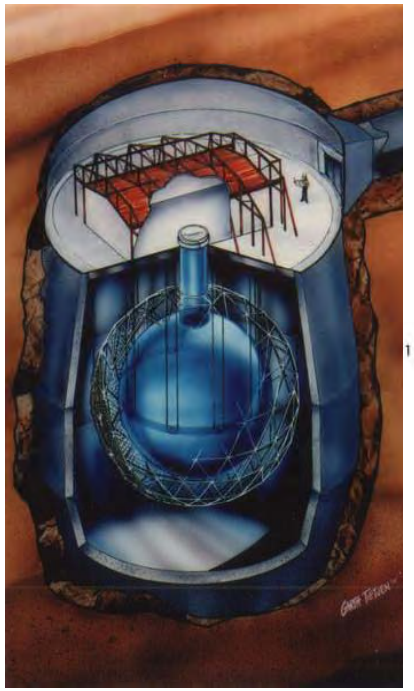
IceCube Neutrino Observatory



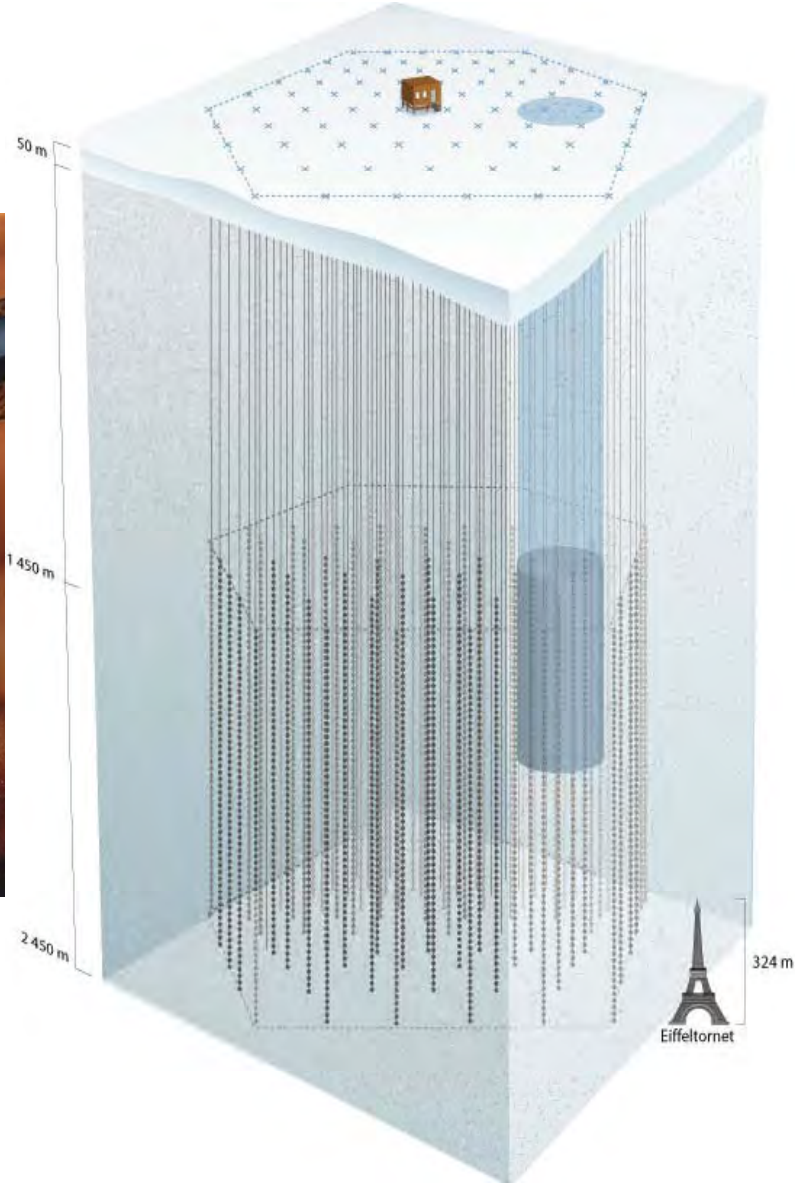
IceCube is a LARGE neutrino detector...



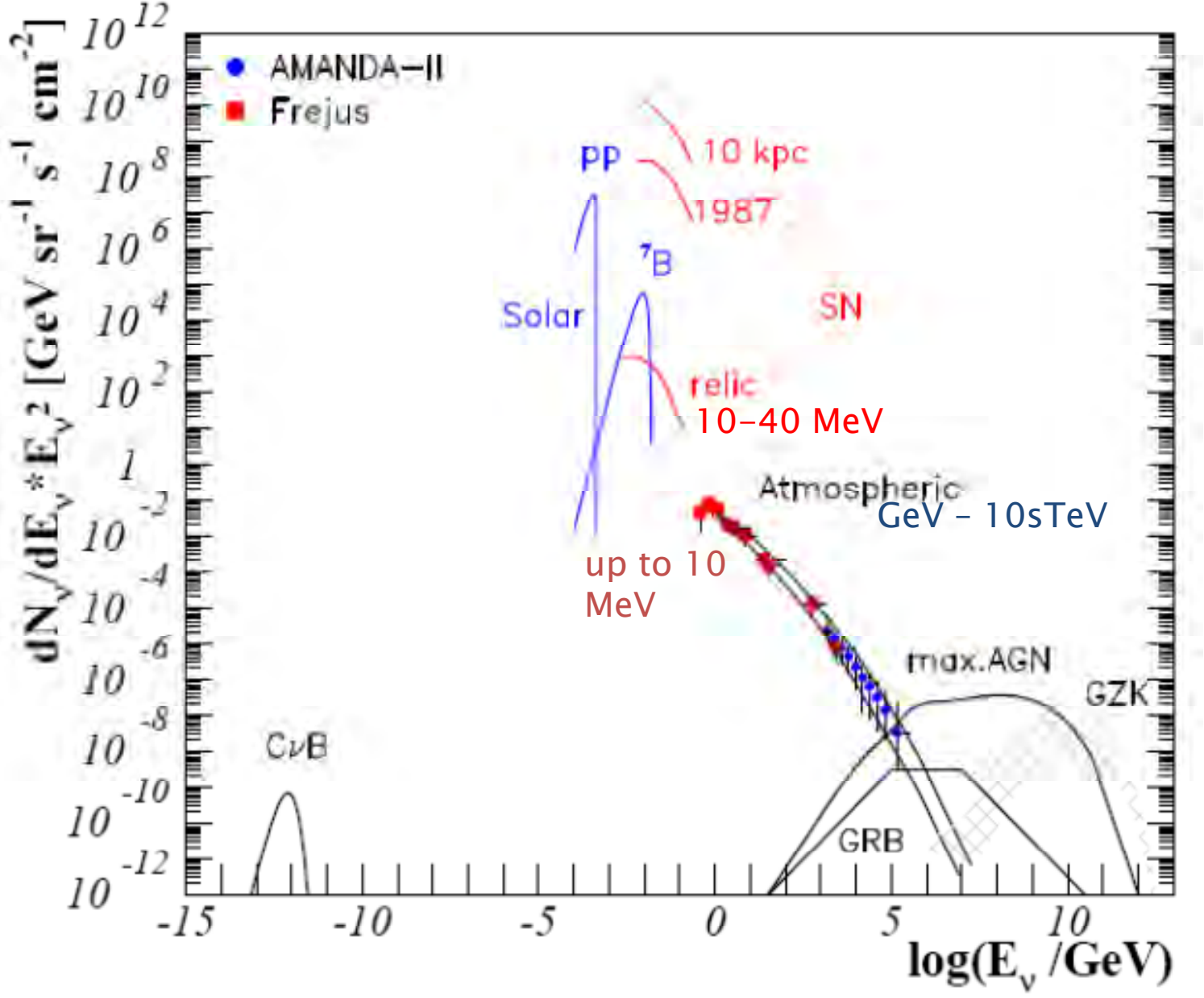
Super Kamiokande



SNO



Neutrino sources



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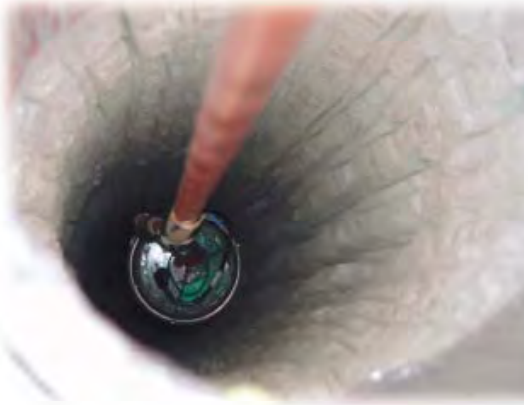
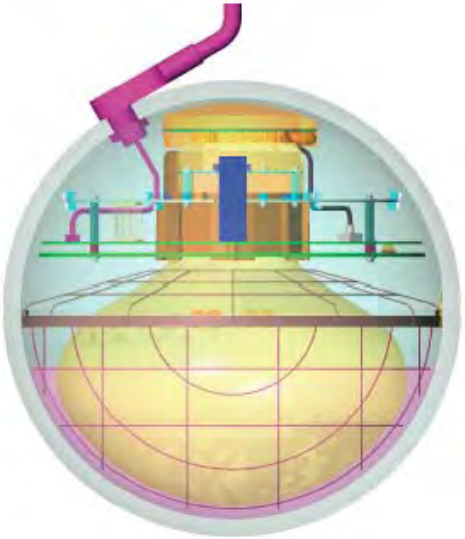
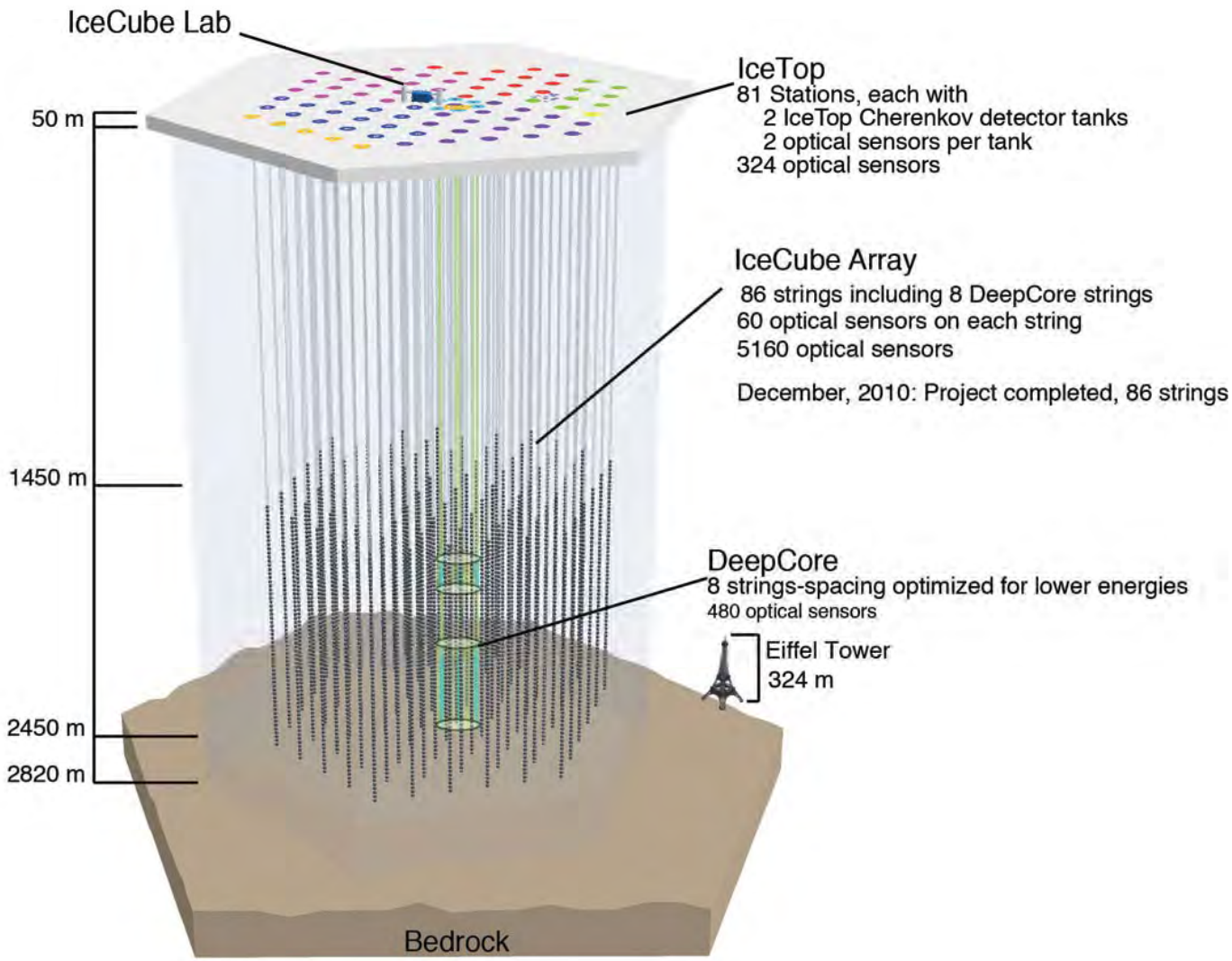
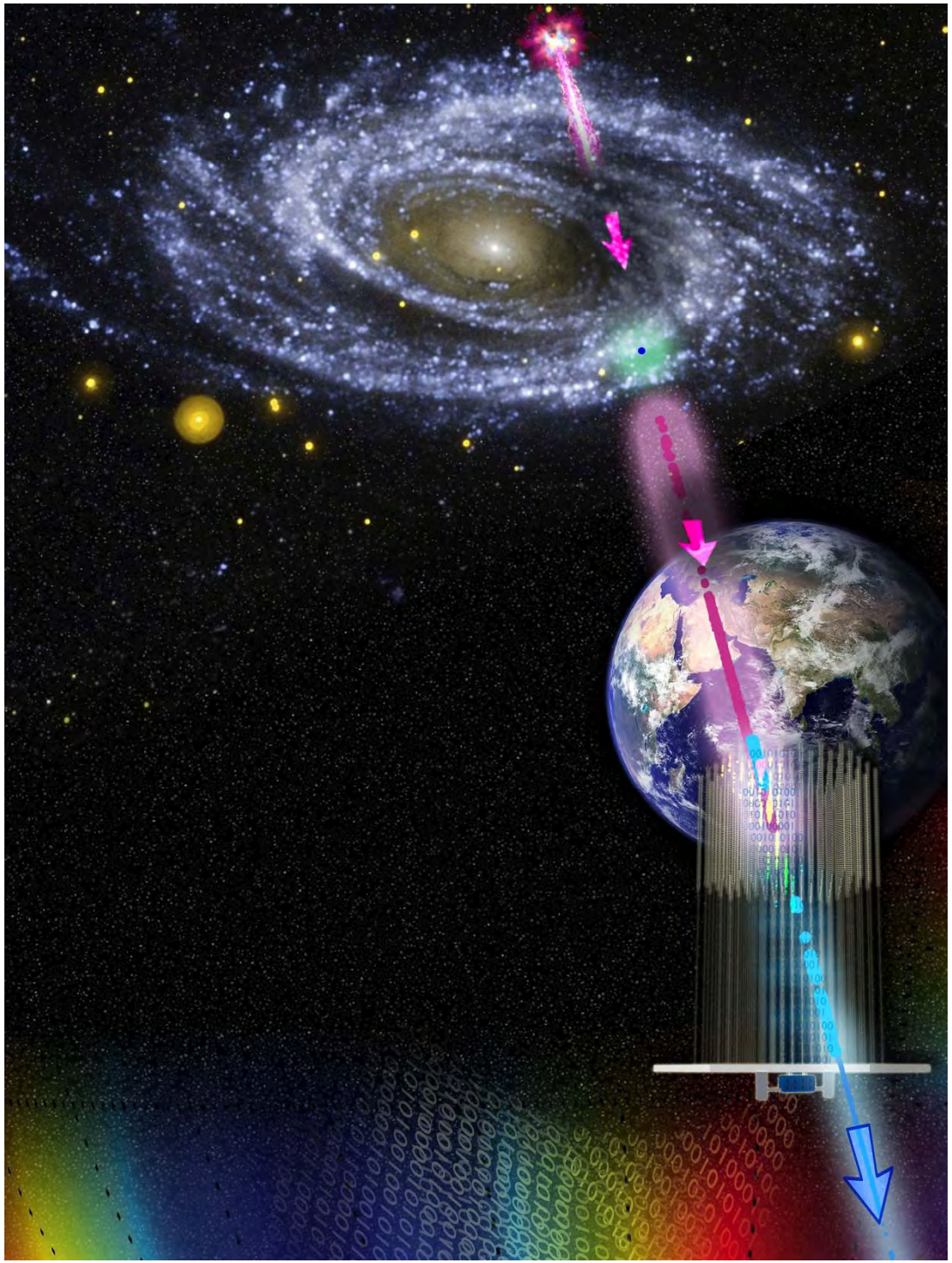
IceCube detector

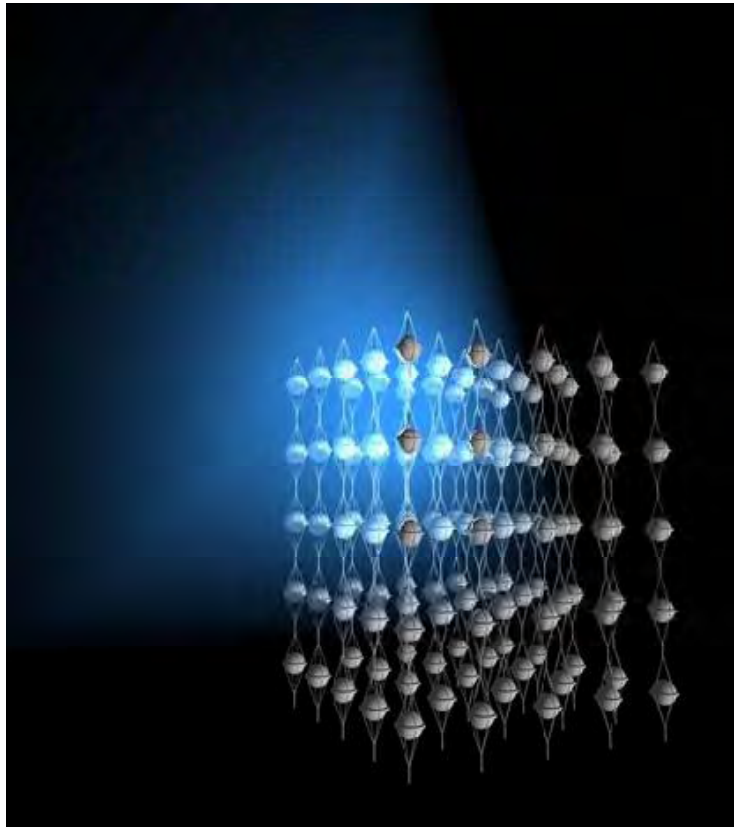




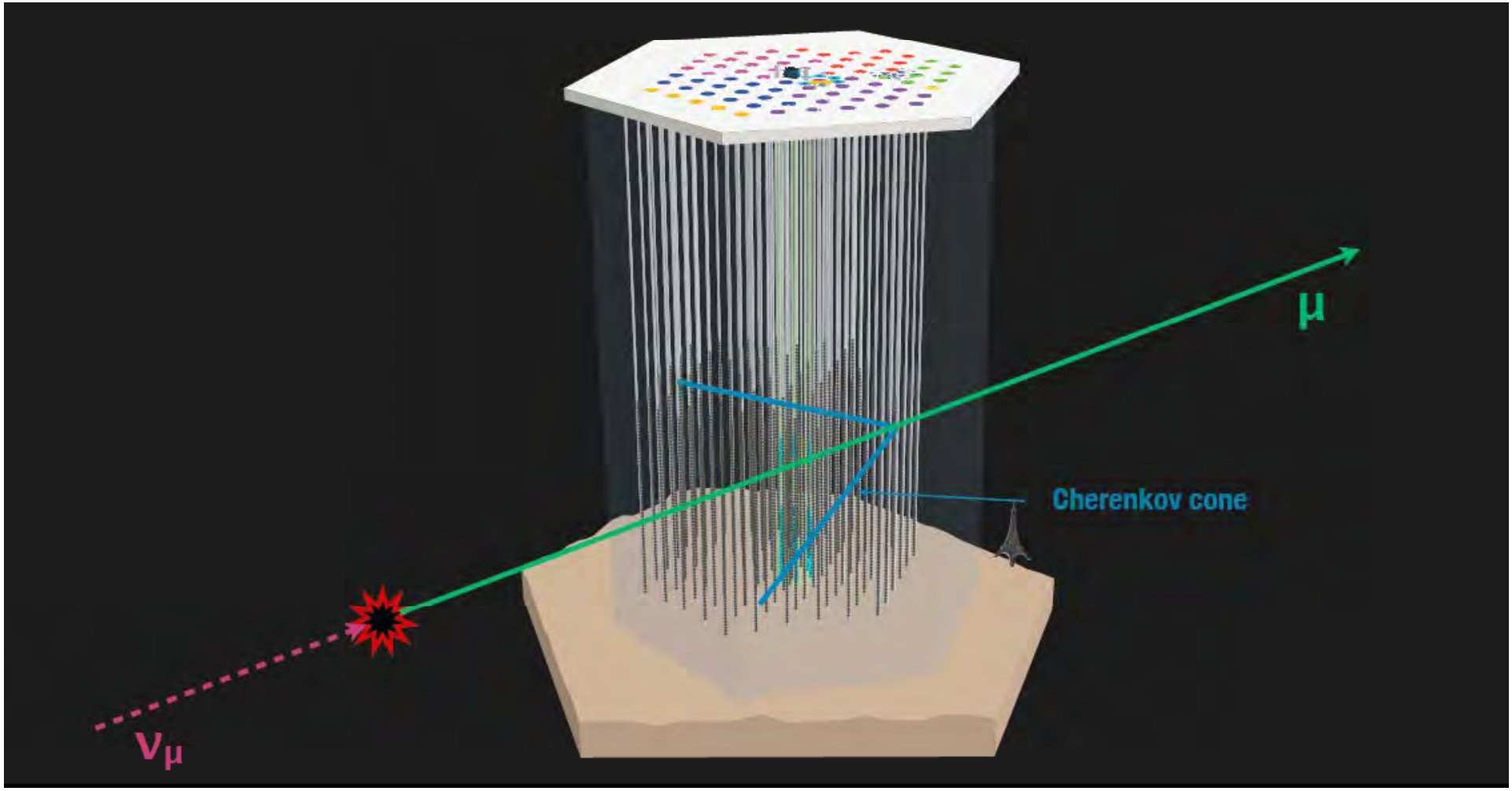


Detection Principle



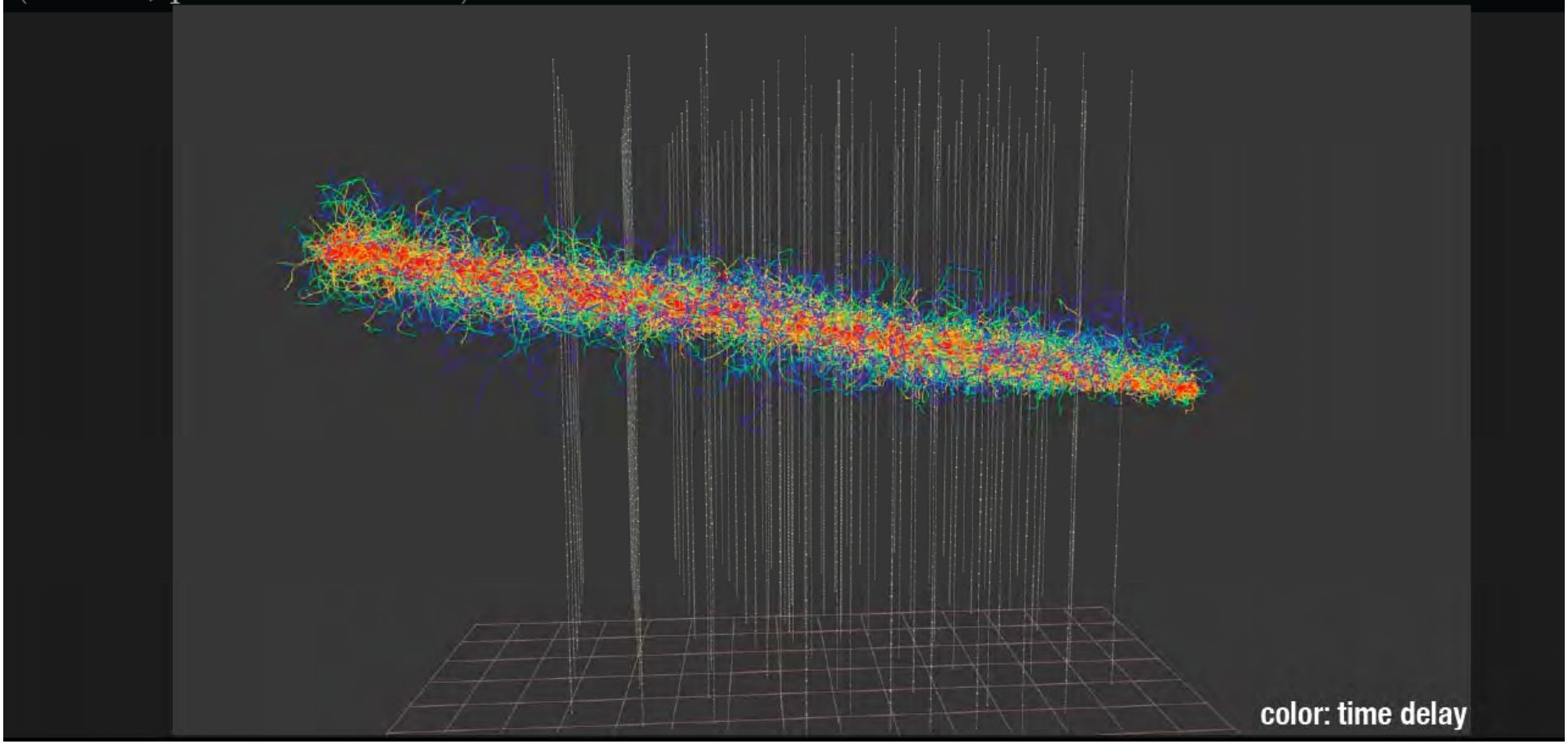


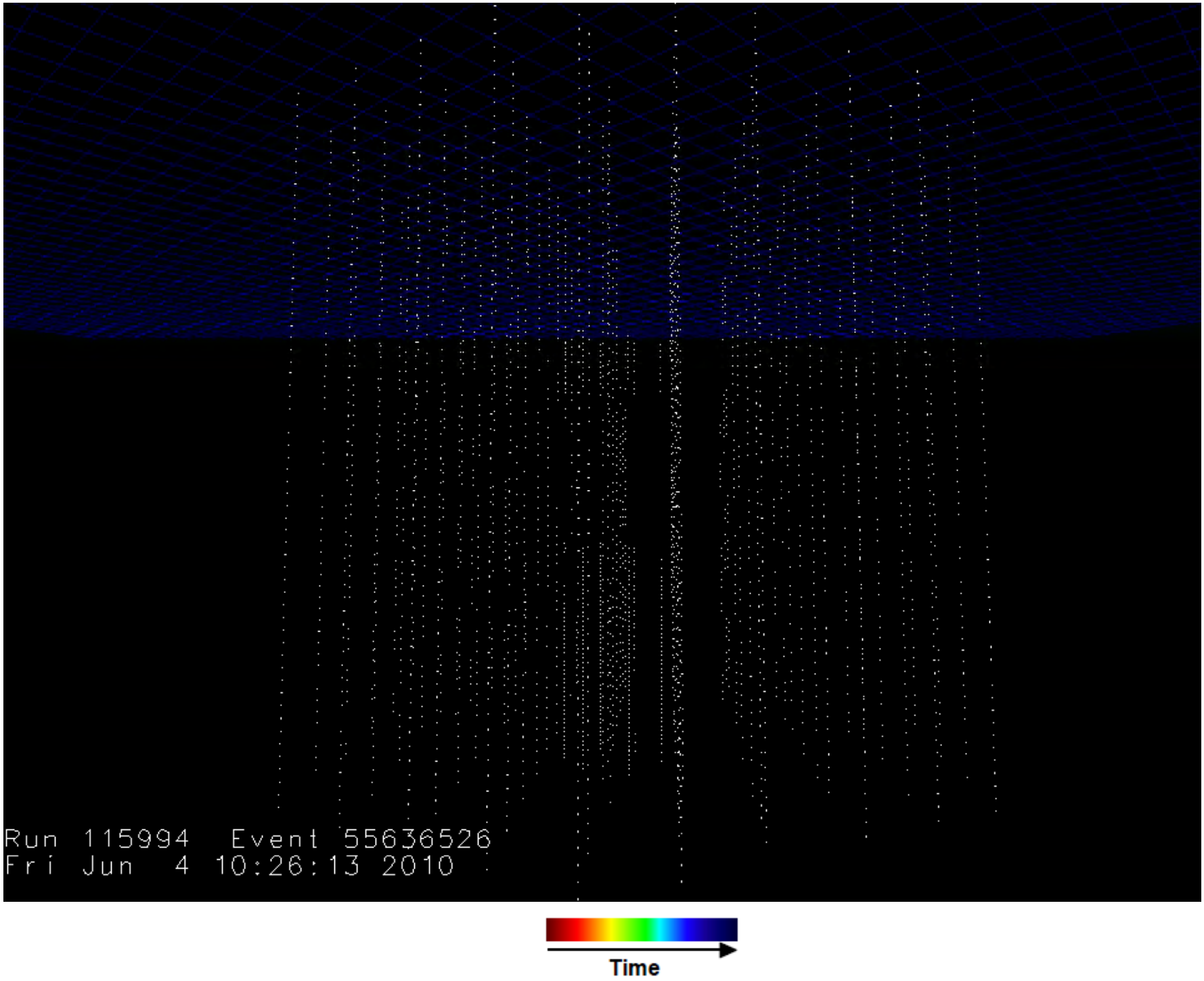
Detection Principle



The IceCube Neutrino Observatory

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

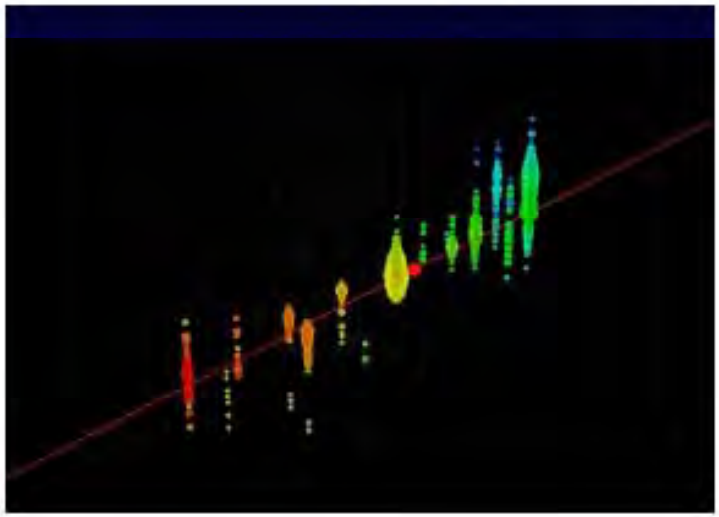



Run 115994 Event 55636526
Fri Jun 4 10:26:13 2010
Time

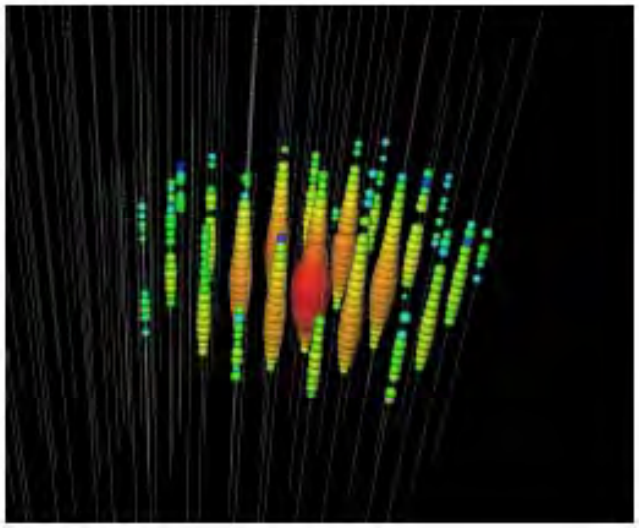
Neutrinos

IceCube – two event signatures

Neutrino creates long range particle

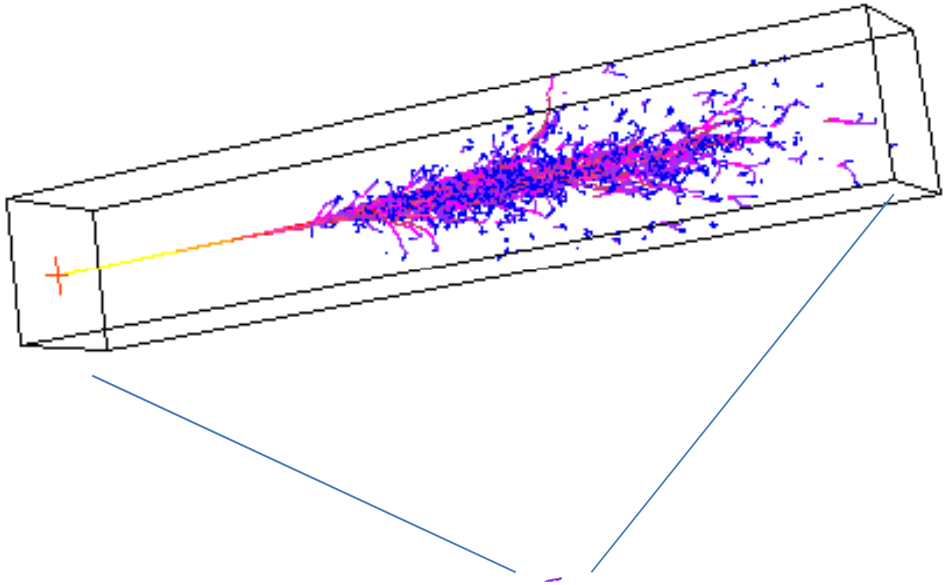


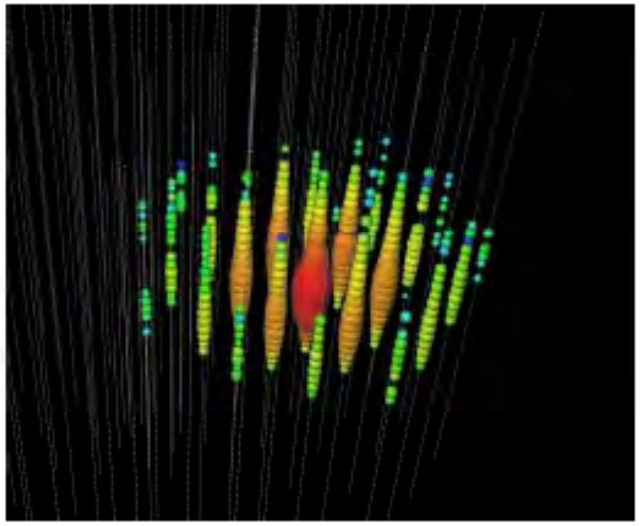
Neutrino creates short range particle which initiates a shower



Neutrino

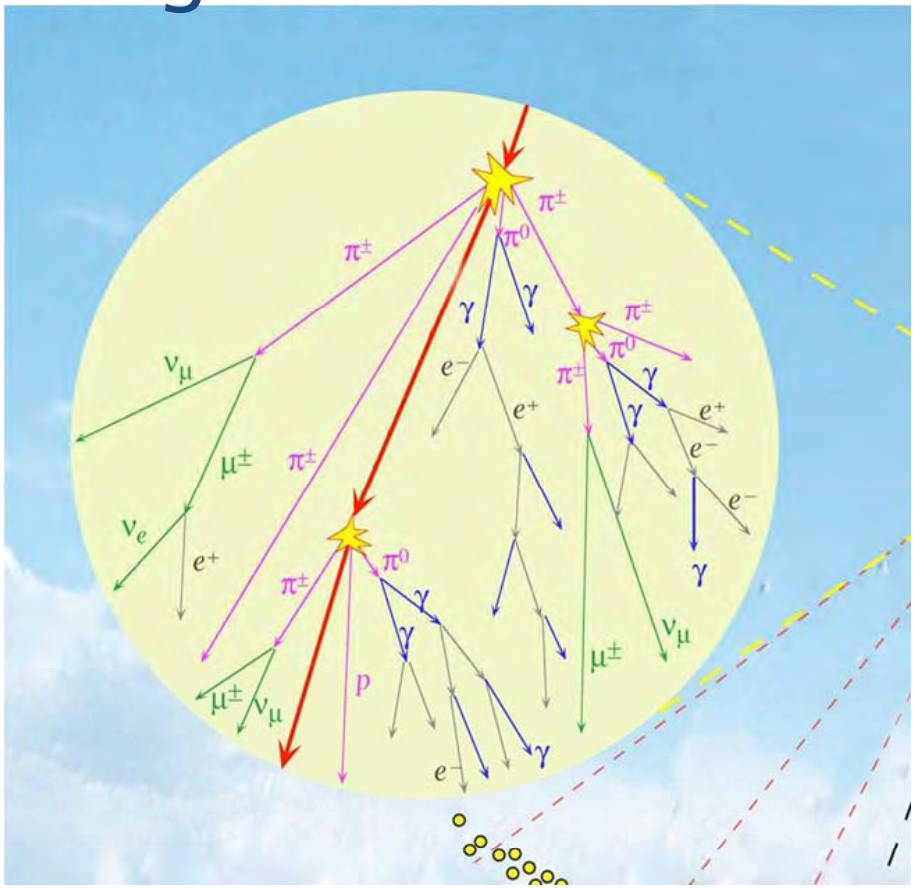
Cascade event signature

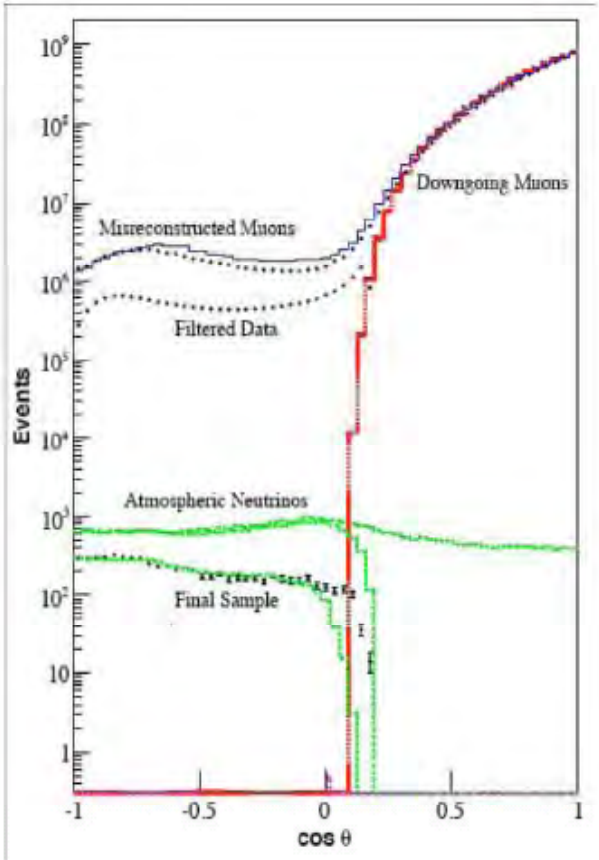




IceCube

Background from cosmic ray air showers





Muon rate:

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

Requires 10^6 background rejection

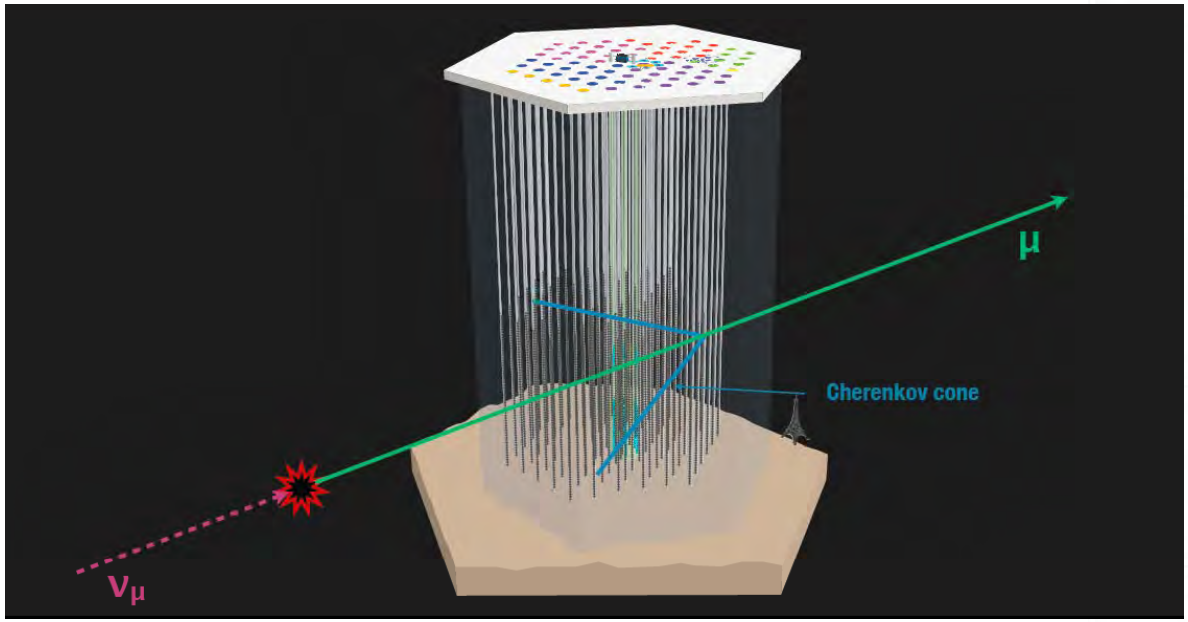
rinos in the data
rbial needle in a
haystack task

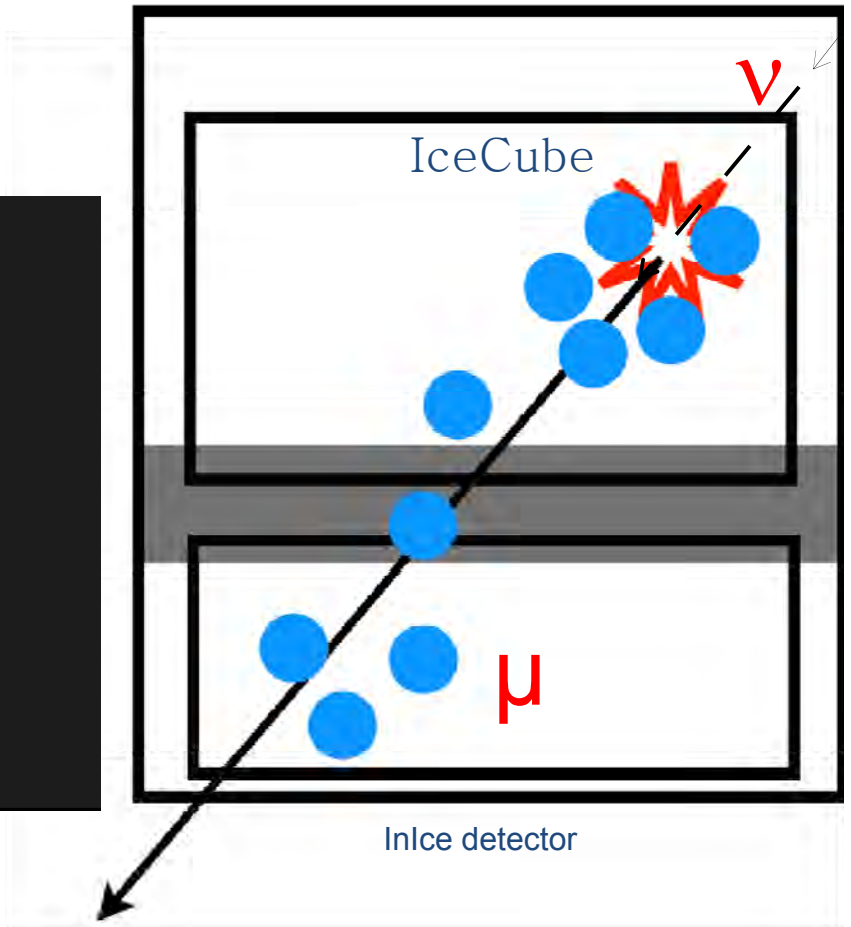
Hunts Needle in a Haystack

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

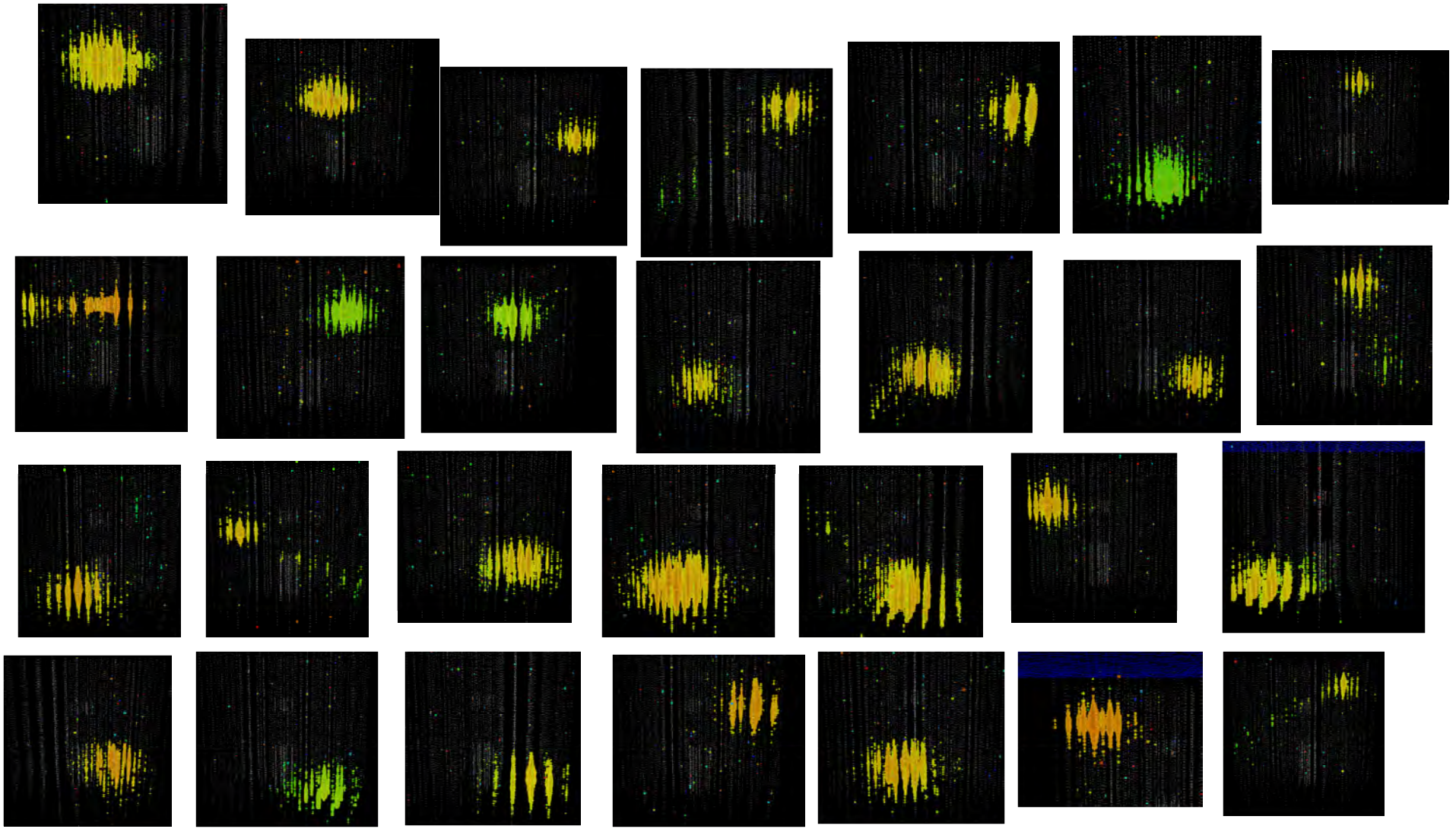
Background rejection
– upward tracks
–use outer parts of the detector as a veto





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