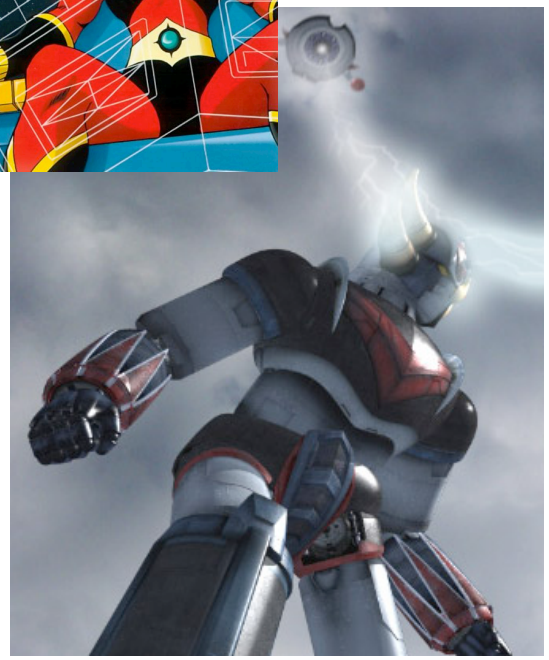
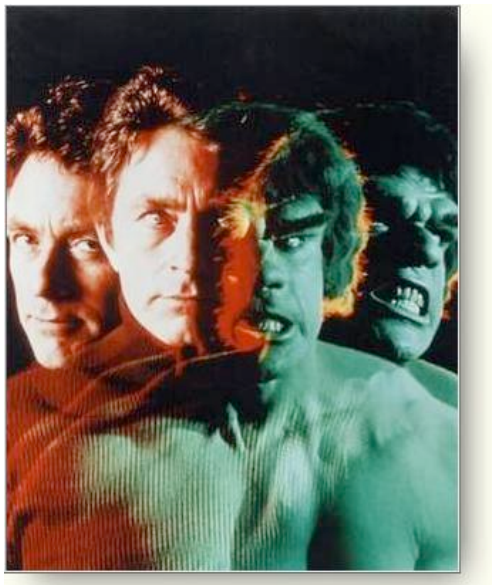
Cosmic Rays & Atmospheric Showers

Villi Scalzotto – MAGIC outreach summer school - 2009

When I was a child…



- Cosmic rays were used by the giant 70/80's robots as weapon! ☺
- Gamma rays were making you green and incredible!



…then I thought it was meaning only…

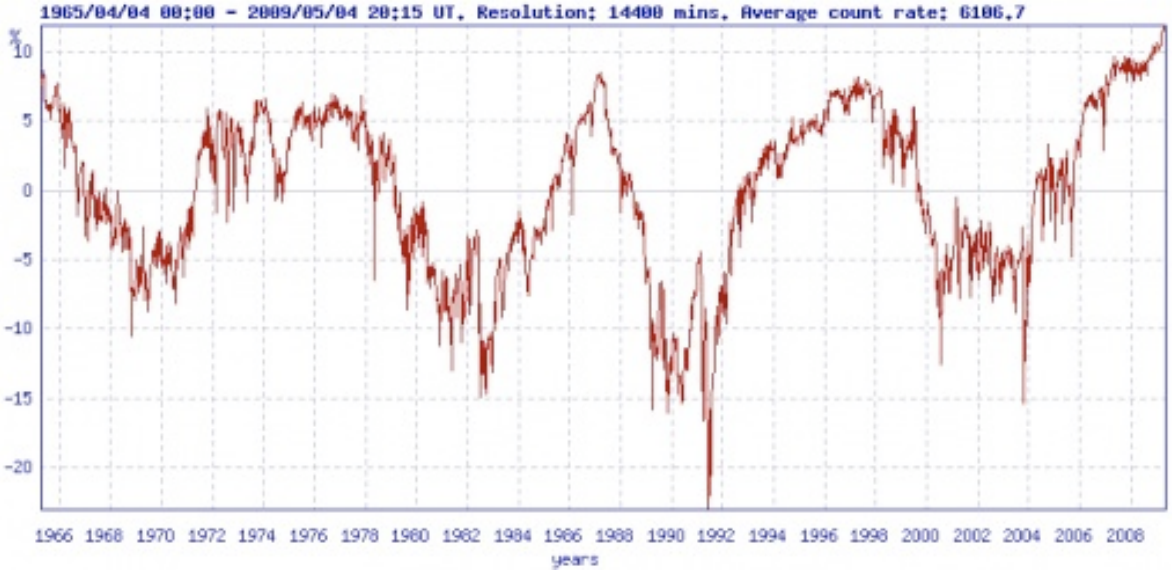
$$Y_l^m(\theta,\varphi) = (-1)^m \left[\frac{2l+1}{4\pi}\frac{(l-m)!}{(l+m)!}\right]^{\frac{1}{2}} P_l^m(\cos\theta)\, e^{im\varphi}$$

Sono normalizzate a 1 sulla sfera unitaria.

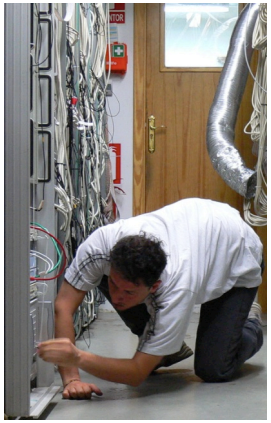
$l = 1,\ldots,\infty;\ -l \le m \le l$

$$Y_l^0 = \sqrt{\frac{2l+1}{4\pi}} P_l(\cos\theta)$$

$$Y_l^l = (-1)^l \left[\frac{2l+1}{4\pi}\frac{(2l)!}{2^{2l}(l!)^2}\right]^{\frac{1}{2}} \sin^l\theta\, e^{il\varphi}$$



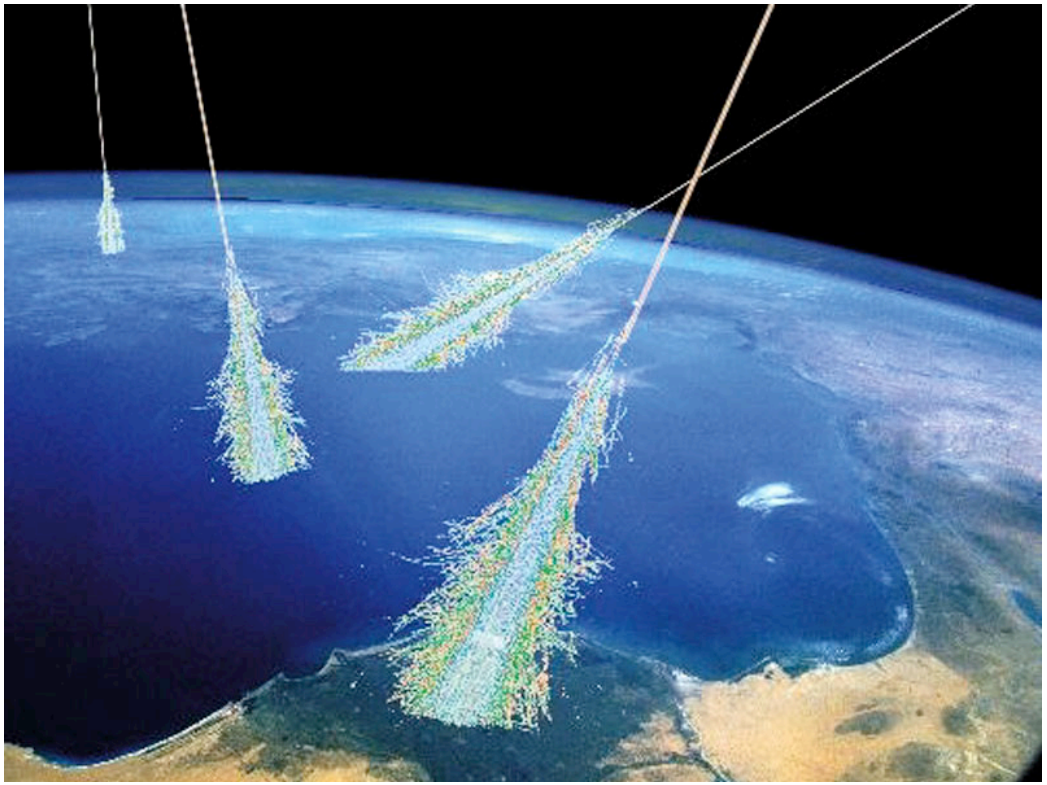
Thanks to MAGIC, it brought also…



+ …like Amaldi and friends!

Have you ever been it by a cosmic ray?

- Have you ever been hit by a beam of high energy particles from above? Surely you have -- it happens all of the time!



Flying on a balloon..

Cosmic rays were discovered in 1912.
At 6o'clock AM of August, 7th from the austriac town of Aussig, a balloon started flying with 3 men. Among them Victor Hess, willing to discover the origin of those misterious particles observed by physicists recently.
The balloon flew up to 5000 meters and Hess realized the radiation was stronger at that altitude..
"My results can be explained by assuming an extremely strong radiation penetrating from the top in our ahmosphere".

Later, Millikan will call this phenomenon COSMIC RADIATION.

The New York Times

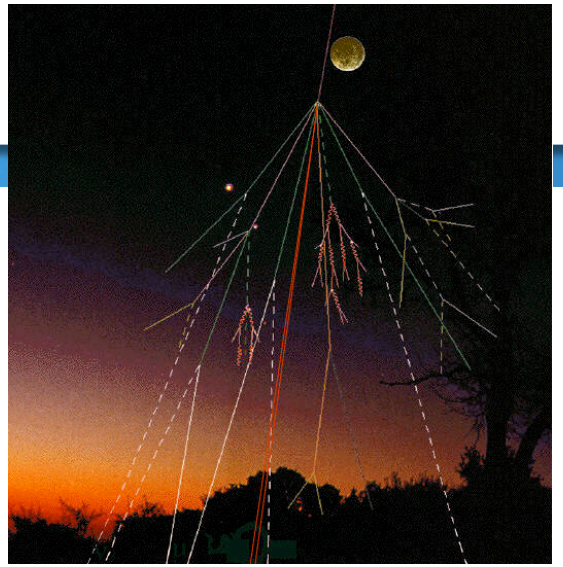
MILLIKAN RETORTS HOTLY TO COMPTON IN COSMIC RAY CLASH

Debate of Rival Theorists Brings Drama to Session of Nation's Scientists.

THEIR DATA AT VARIANCE

New Findings of His Ex-Pupil Lead to Thrust by Millikan at 'Less Cautious' Work.

Cosmic rays



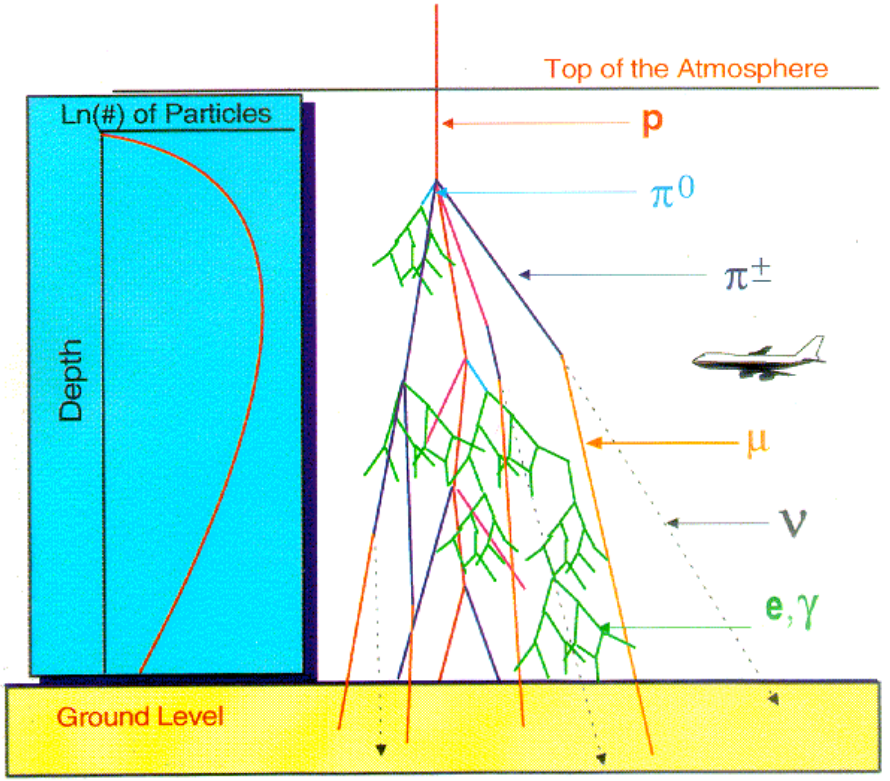
- It is now known that most cosmic rays are atomic nuclei. Most are hydrogen nuclei, some are helium nuclei, and the rest heavier elements.
- The relative abundance changes with cosmic ray energy -- the highest energy cosmic rays tend to be heavier nuclei.
- Although many of the low energy cosmic rays come from our Sun, the origins of the highest energy cosmic rays remains unknown and a topic of much research. Cosmic rays may even be important to Earth's weather -- common lightning may be triggered by passing cosmic rays!

Ground based detectors for cosmics

Telescopes of many different kinds are working in the Earth.
Different tecnhiques.
But for most of them,
the atmosphere itself is part of the detector!!!

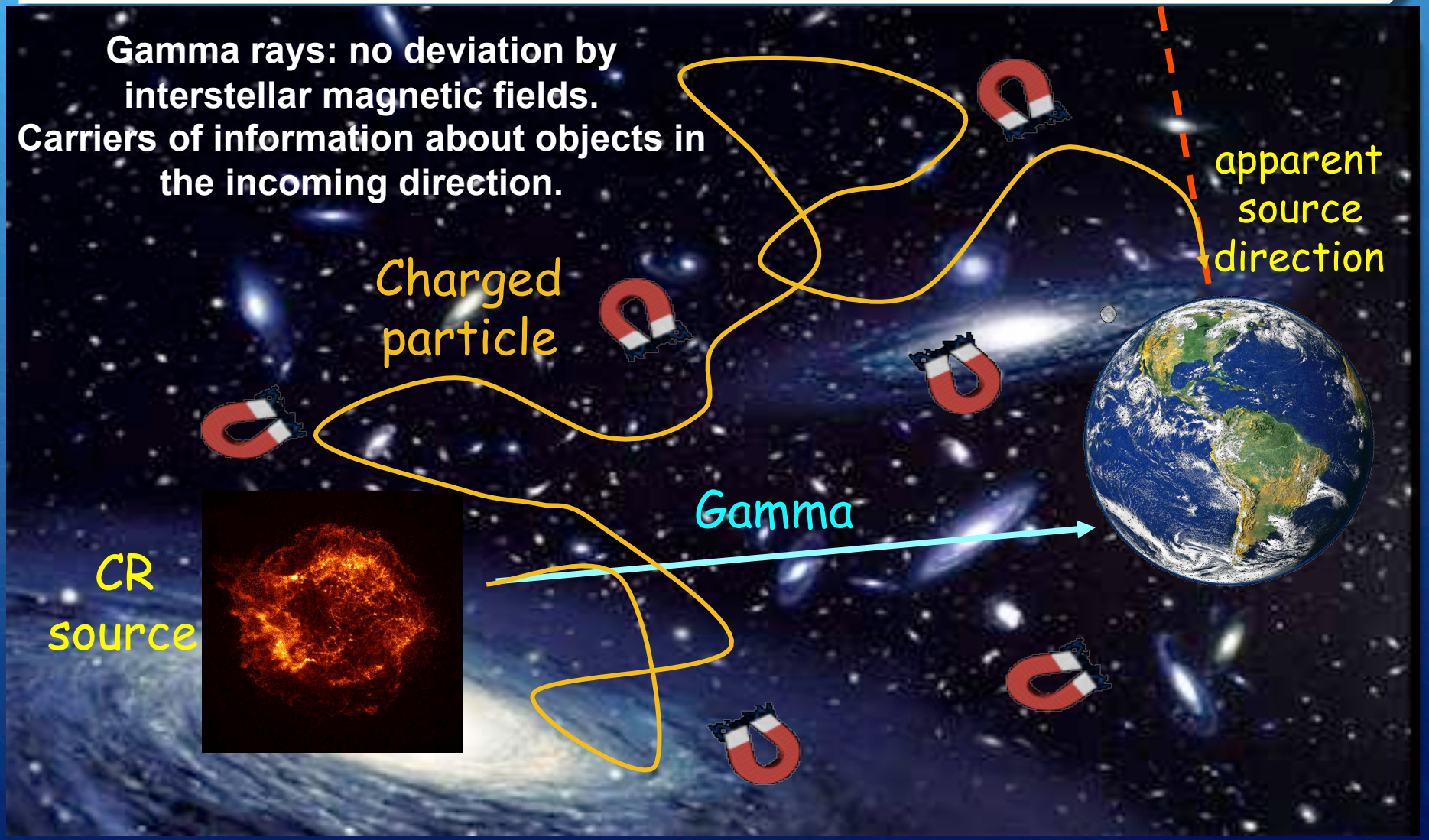
It is quite impossible to detect directly the cosmic rays, because the atmosphere primes a reaction with the primary particle, which develops a cascade of particles.

Among the cosmic rays flux, there is a component of gamma rays…



Extensive Air Showers

Why do we talk about Gamma astronomy?

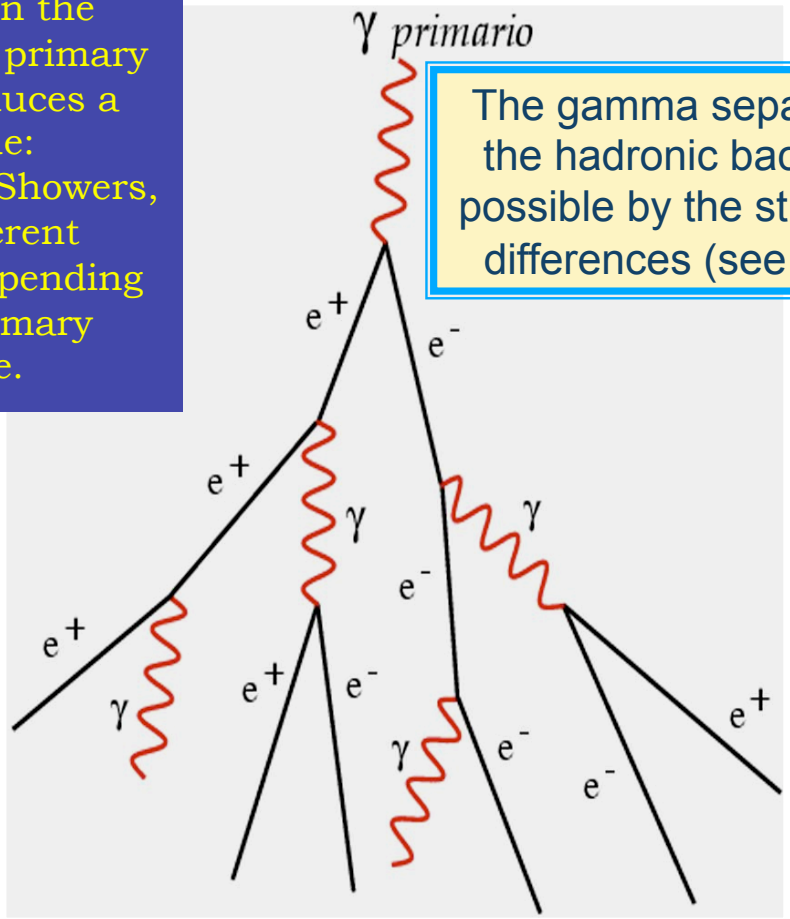


In Gamma Astronomy, the noise is…the cosmic charged radiation!!
Cosmic rays: made up for the 99% of charged particles
(p, H^+, He^{++}, e, ...)

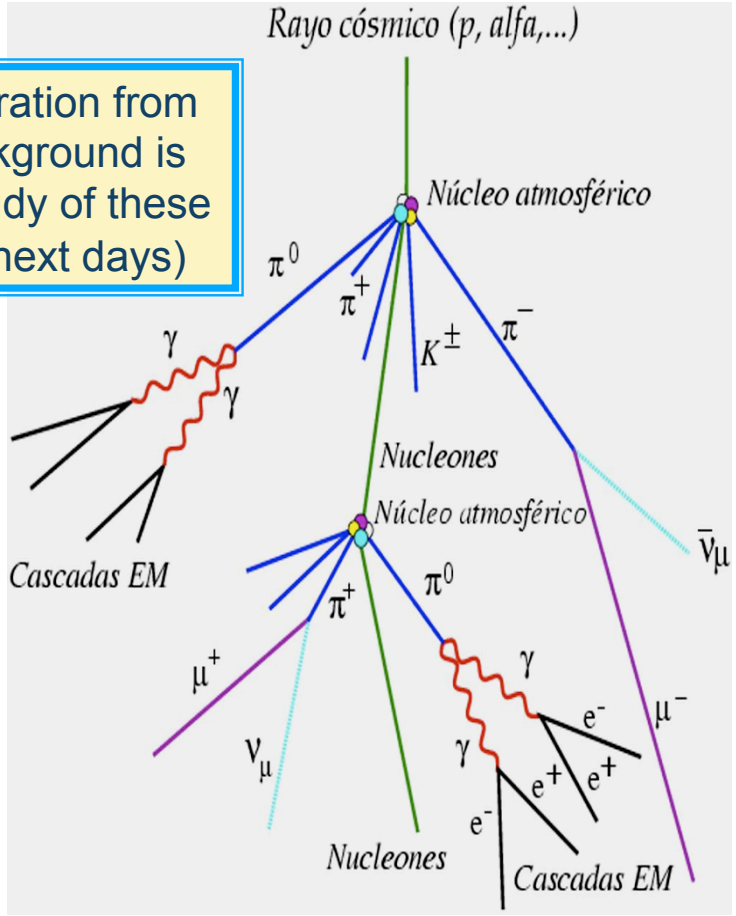
Entering in the atmosphere, primary particle induces a cascade: atmospheric Showers, with different structure depending on the primary nature.

The gamma separation from the hadronic background is possible by the study of these differences (see next days)

Electromagnetic



Hadronic

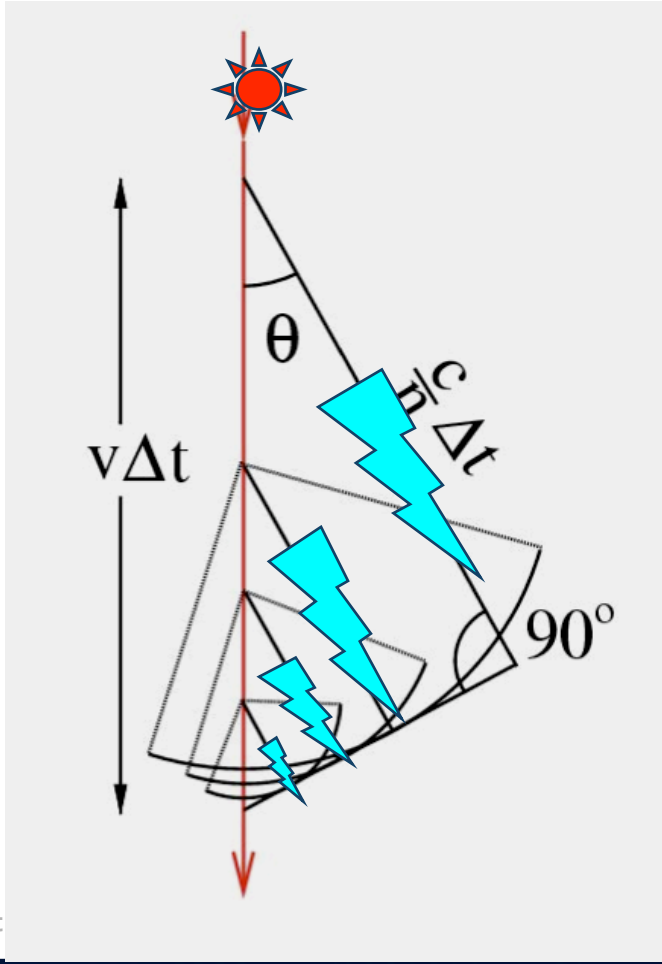


The shower detection

There are different techniques to detect the cosmic induced atmospheric showers. Among them, the IACT technique, looking not directly at the produced particles, but to a particular light emitted by some of them…

The Cherenkov light!

Cherenkov radiation



A charged particle traversing a transparent medium at a velocity higher than that of light in the medium (c/n) emits a radiation, from the reorientation of electric dipoles in the medium induced by the charge (like a sonic boom).

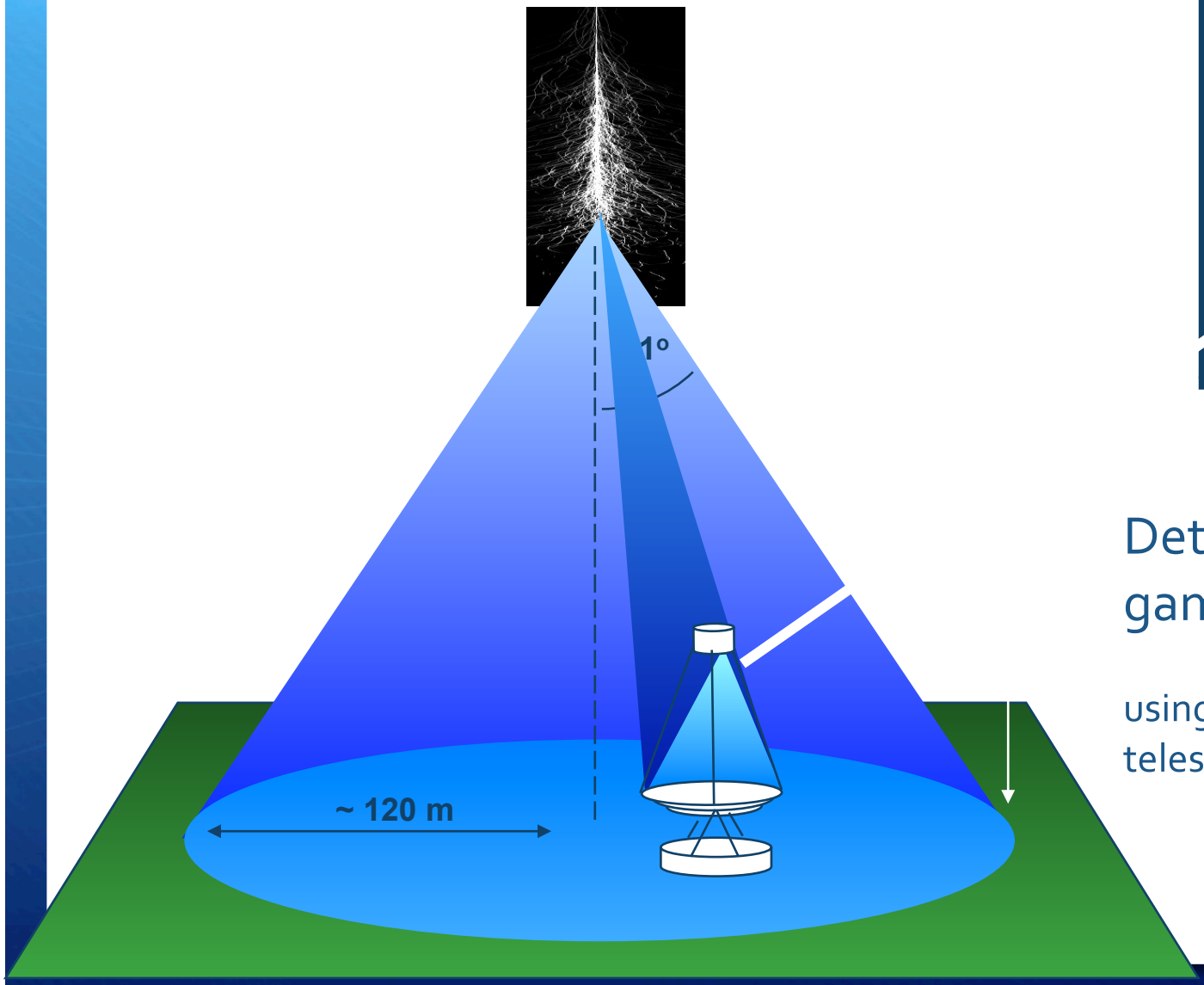
The angle of the emission with respect to the particle direction depends on *n* and β *(v/c)*

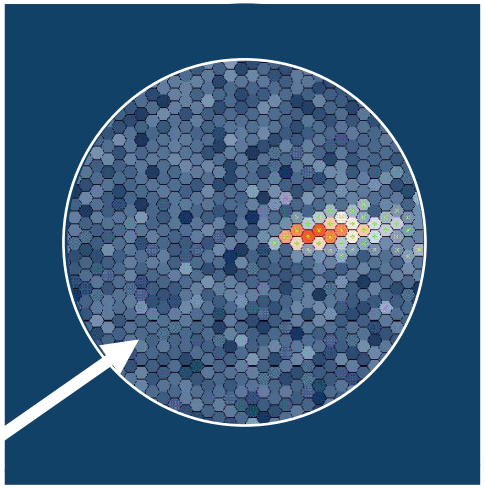
$$\cos\Theta = \frac{1}{\beta n}$$

(θ≈ 1.3 °)

By considering the atmospheric absorption, the peak of Cherenkov photons distribution is around *350 nm*.

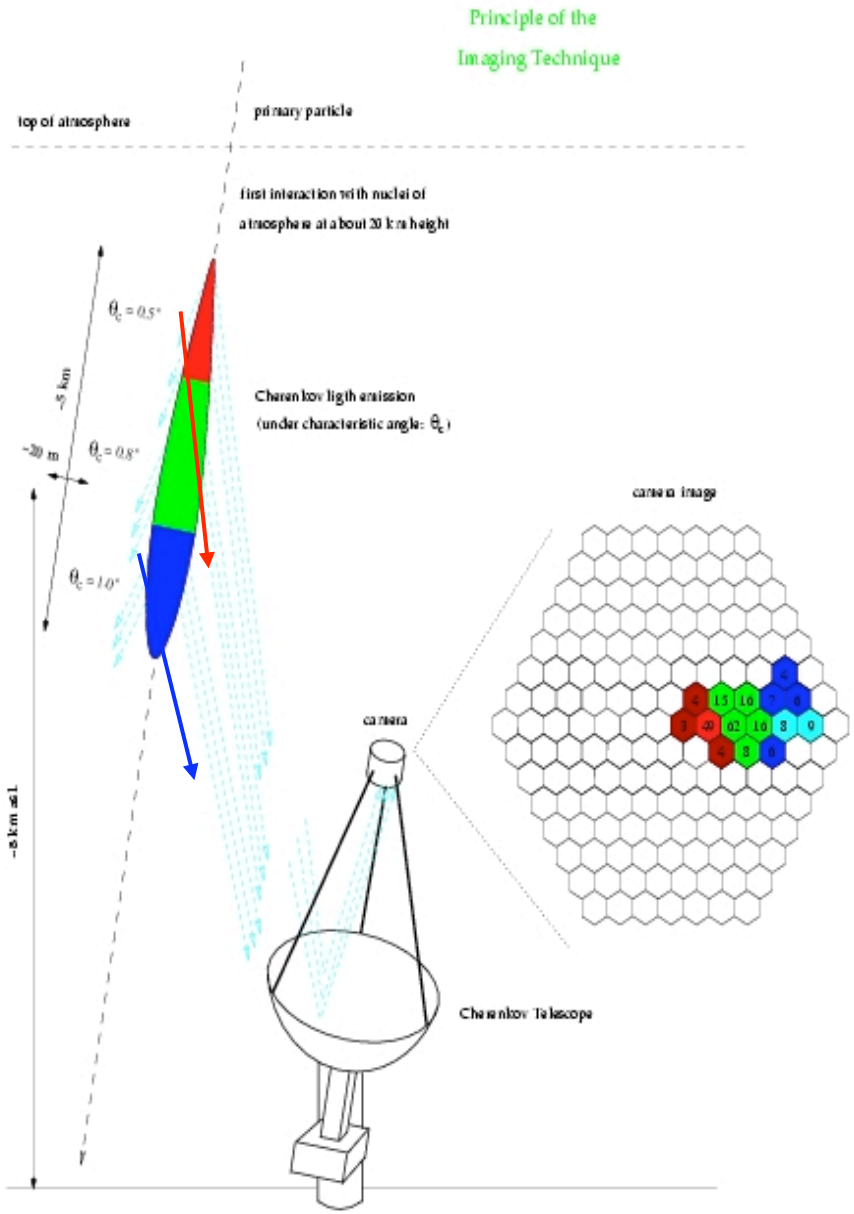
IACT Technique



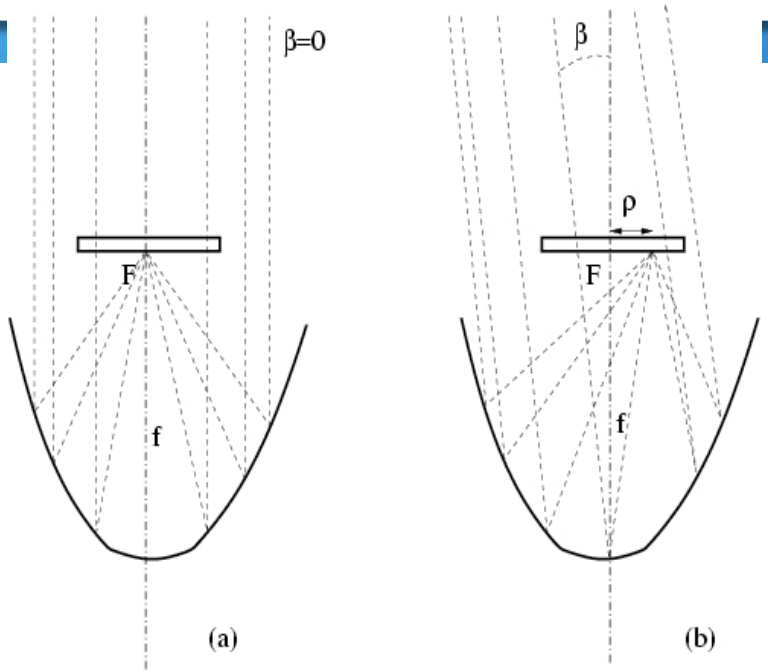


Detection of TeV gamma rays

using Cherenkov telescopes



Altitude of the emission
≈ 8 Km a.s.l.
Extension development
≈ 5 Km.



Closer in the atmosphere

Larger Cherenkov angle

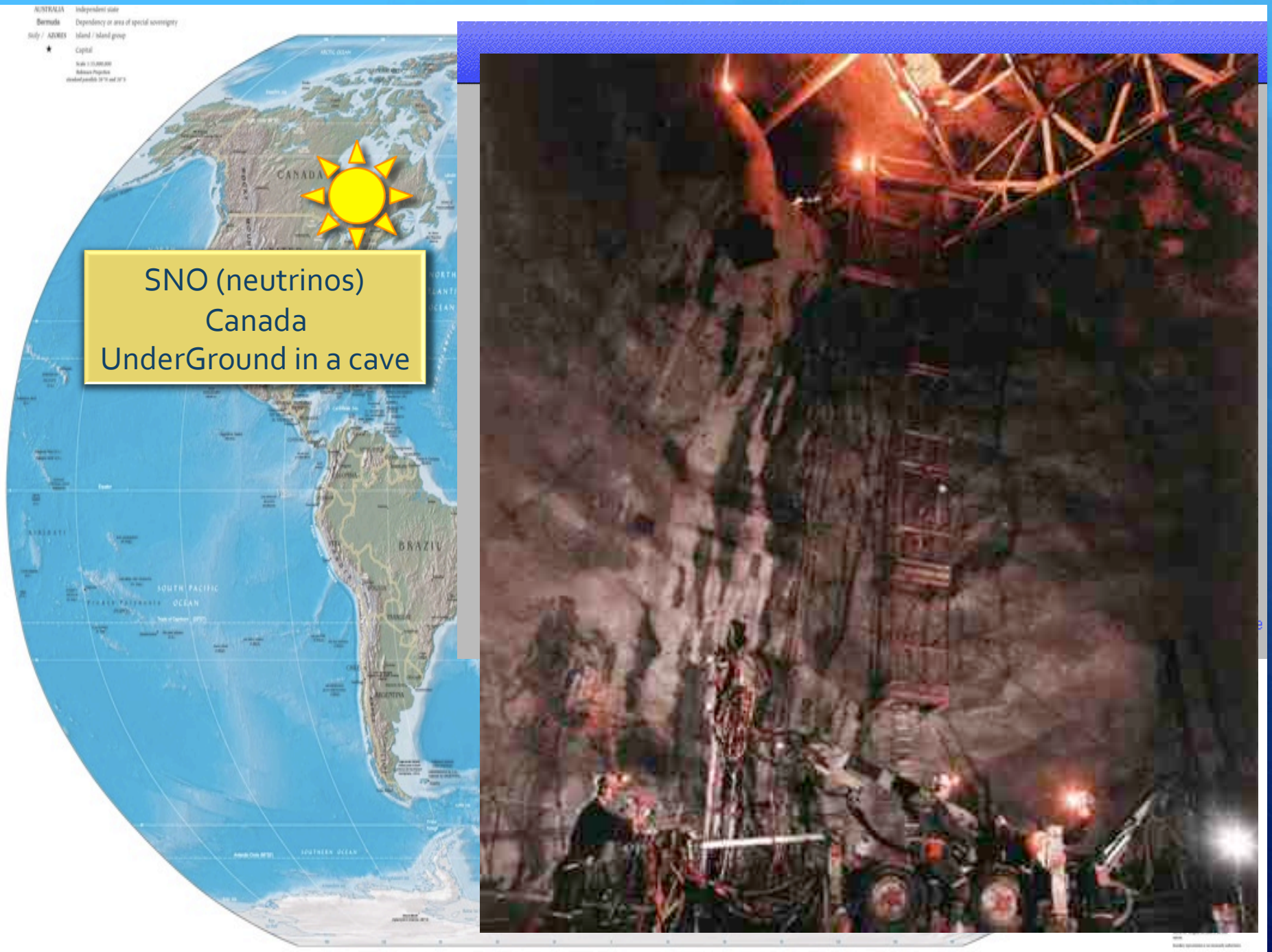
↓

Photons collected far from the camera center

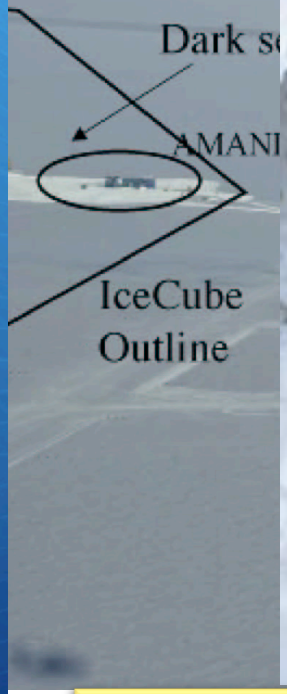
We are not alone…!

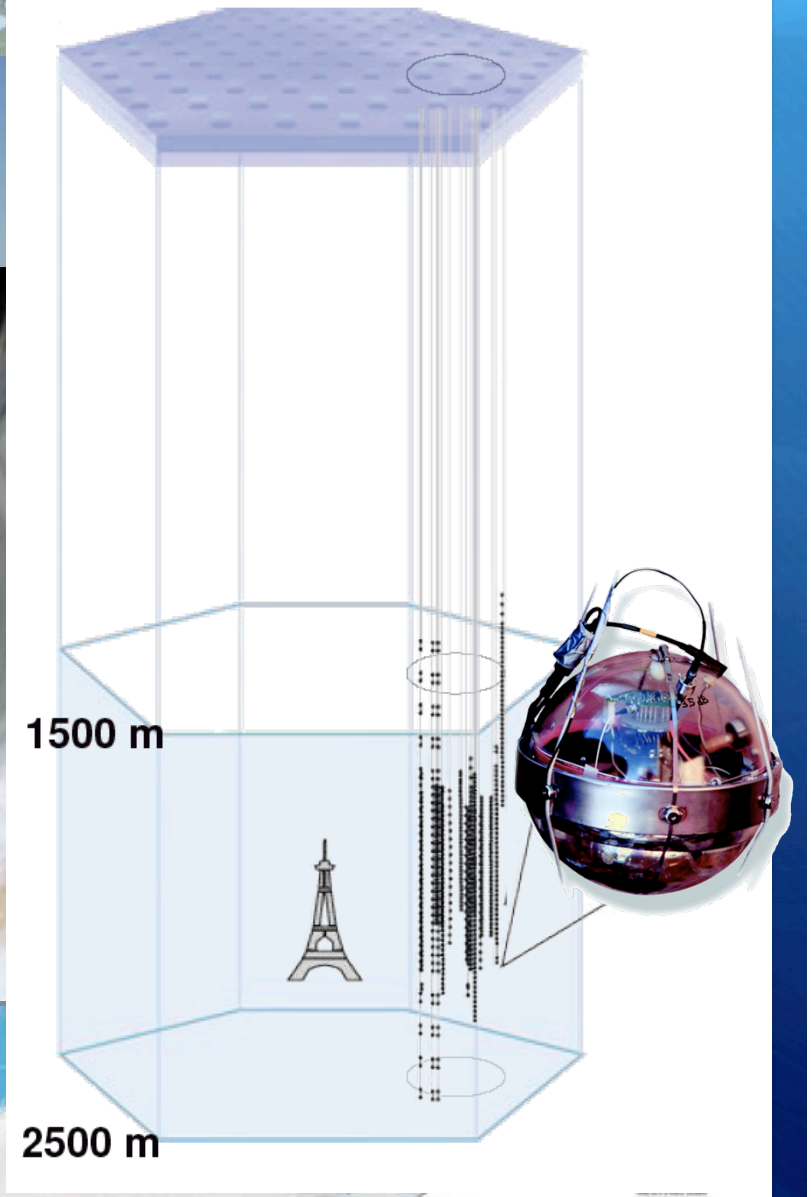
There are many other experiments involved with the **COSMIC RADIATION** (neutrino physics, UHECR physics, particle physics, solar physics, nuclear physics,…)

The common idea is to use the **EARTH** as part of the detector, since these experiments take advantage to it, to compensate often the low incoming flux or the extremely small cross section involved.

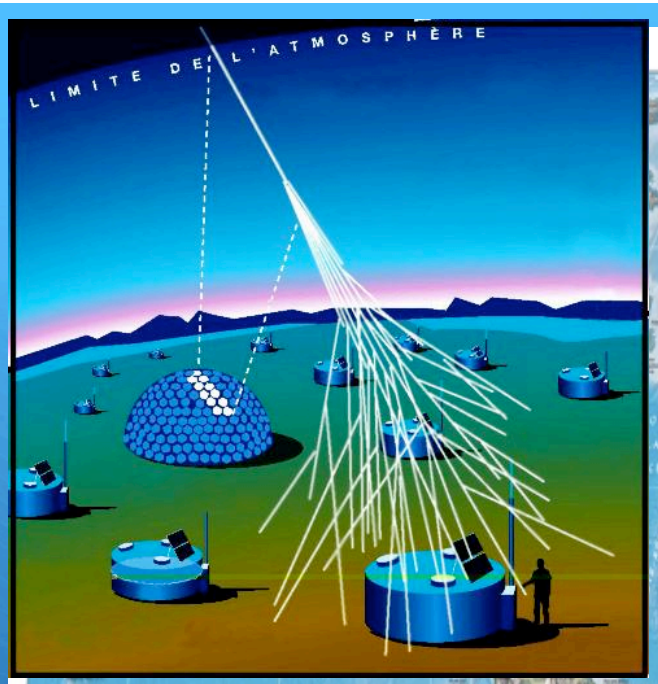

SNO (neutrinos)
Canada
UnderGround in a cave

IceCube at the South Pole



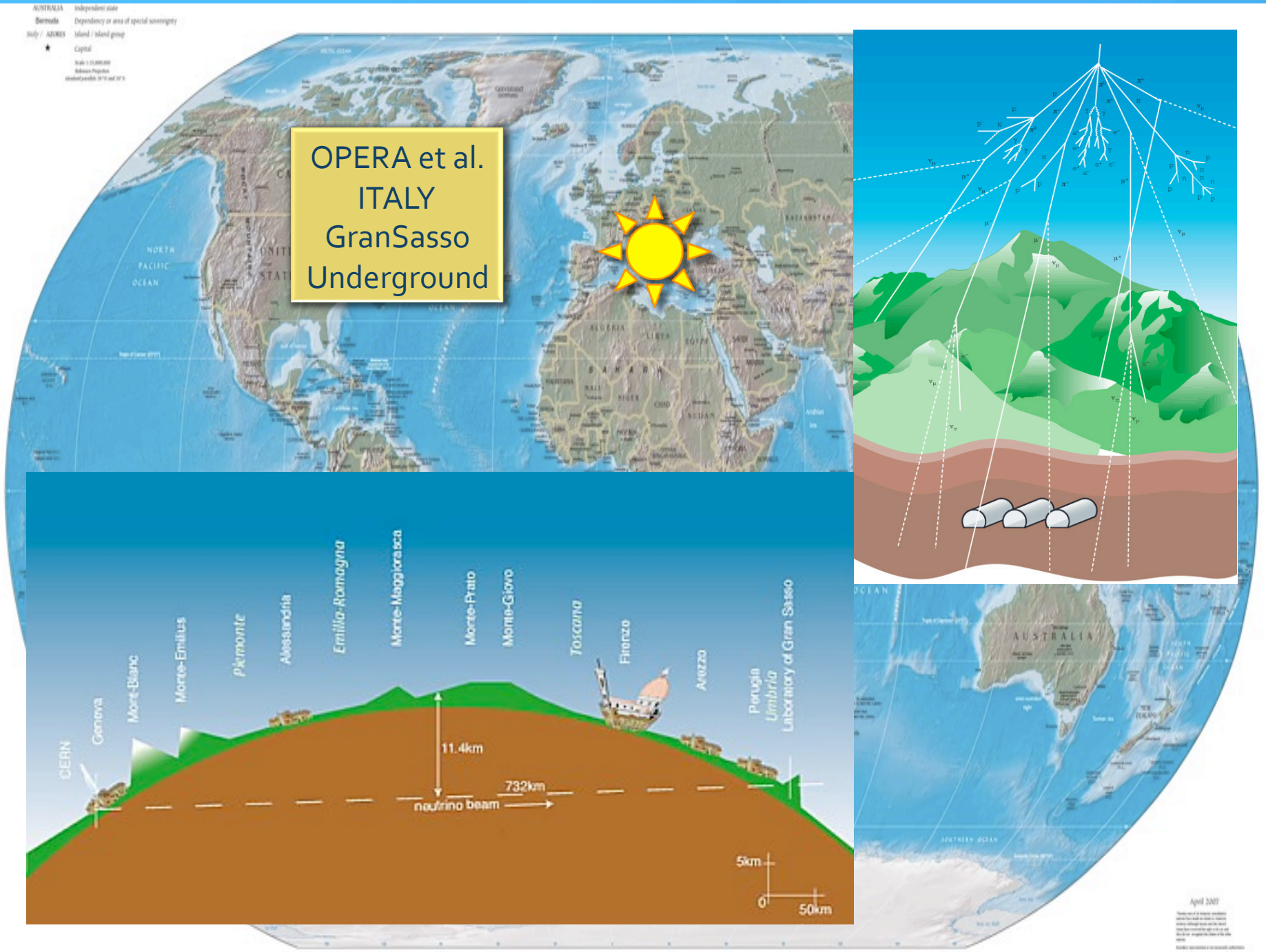


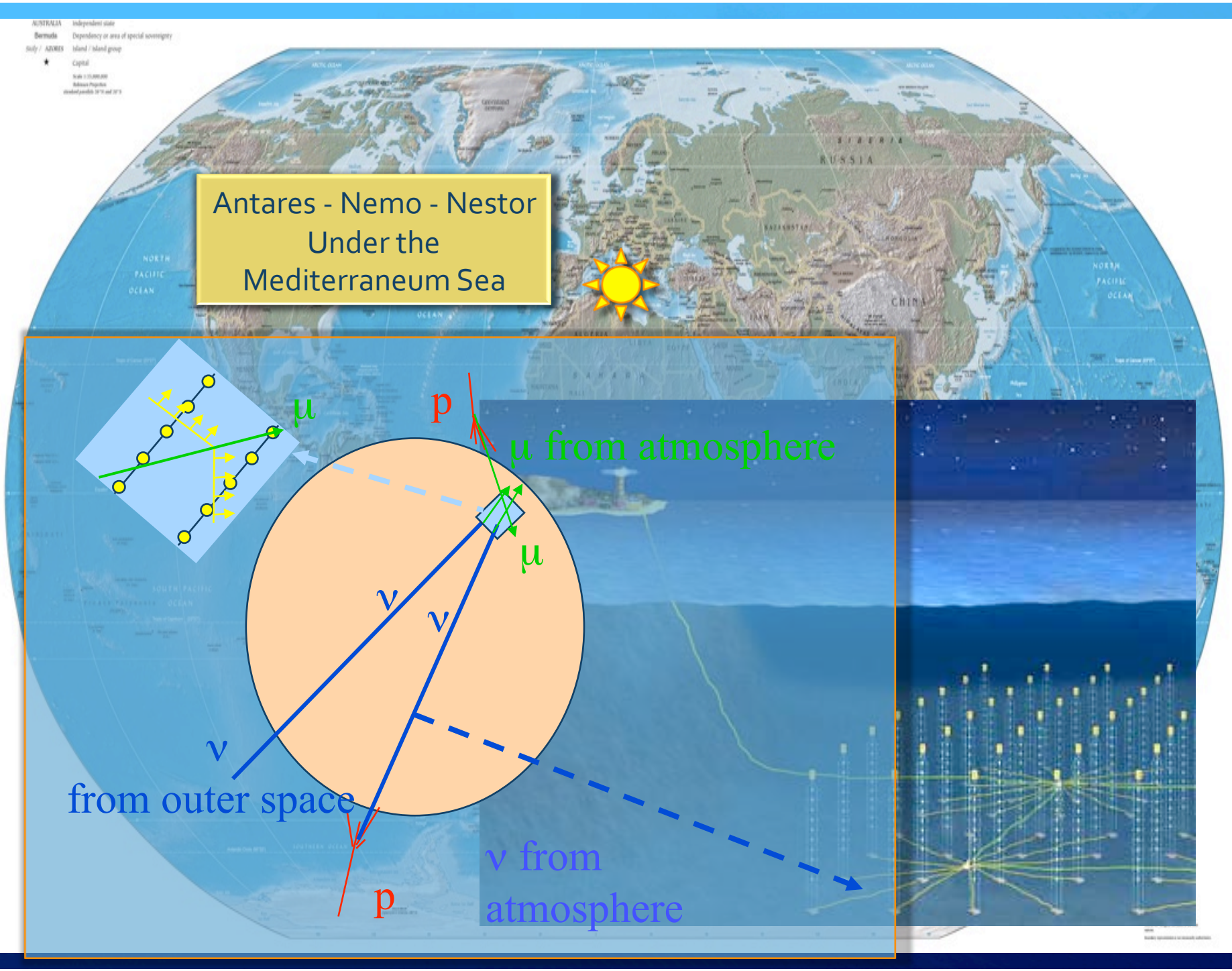
IceCube – Amanda
Antarctica

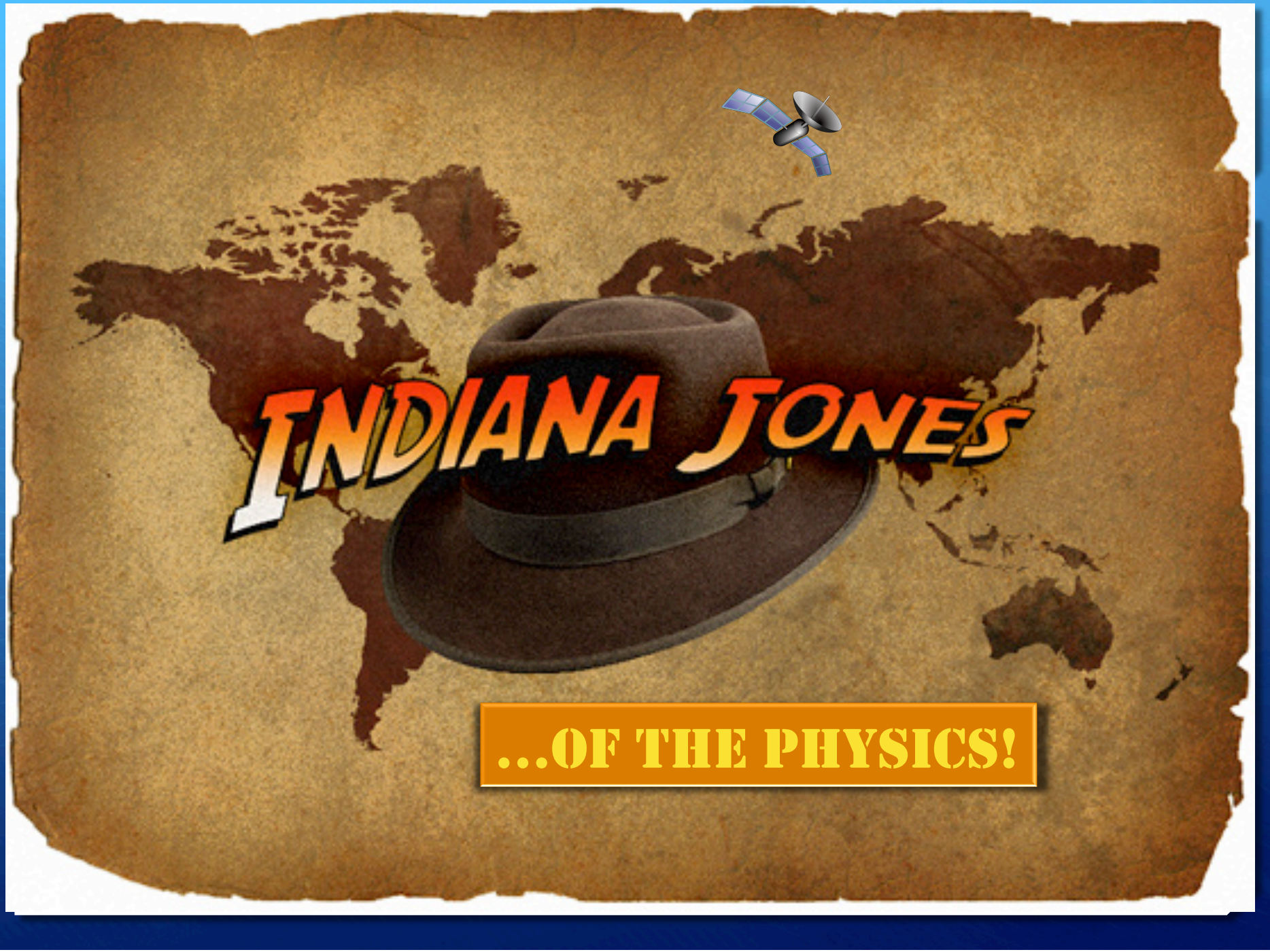


ARGO
Tibet desert

AUGER
Argentina
Pampa – Ande


OPERA et al.
ITALY
GranSasso
Underground
CERN
Ginevra
Mont-Blanc
Monte-Emilius
Piemonte
Alessandria
Emilia-Romagna
Monte-Maggiorasca
Monte-Prato
Monte-Giove
Toscana
Firenze
Arezzo
Perugia
Umbria
Laboratory of Gran Sasso
11.4km
732km
neutrino beam
5km
0
50km
AUSTRALIA


Antares - Nemo - Nestor
Under the
Mediterraneum Sea
μ
p
μ from atmosphere
μ
ν
ν
ν
from outer space
p
ν from
atmosphere


INDIANA JONES
...OF THE PHYSICS!

COFFEE BREAK!