# Gamma ray physics at high altitude in the southern hemisphere

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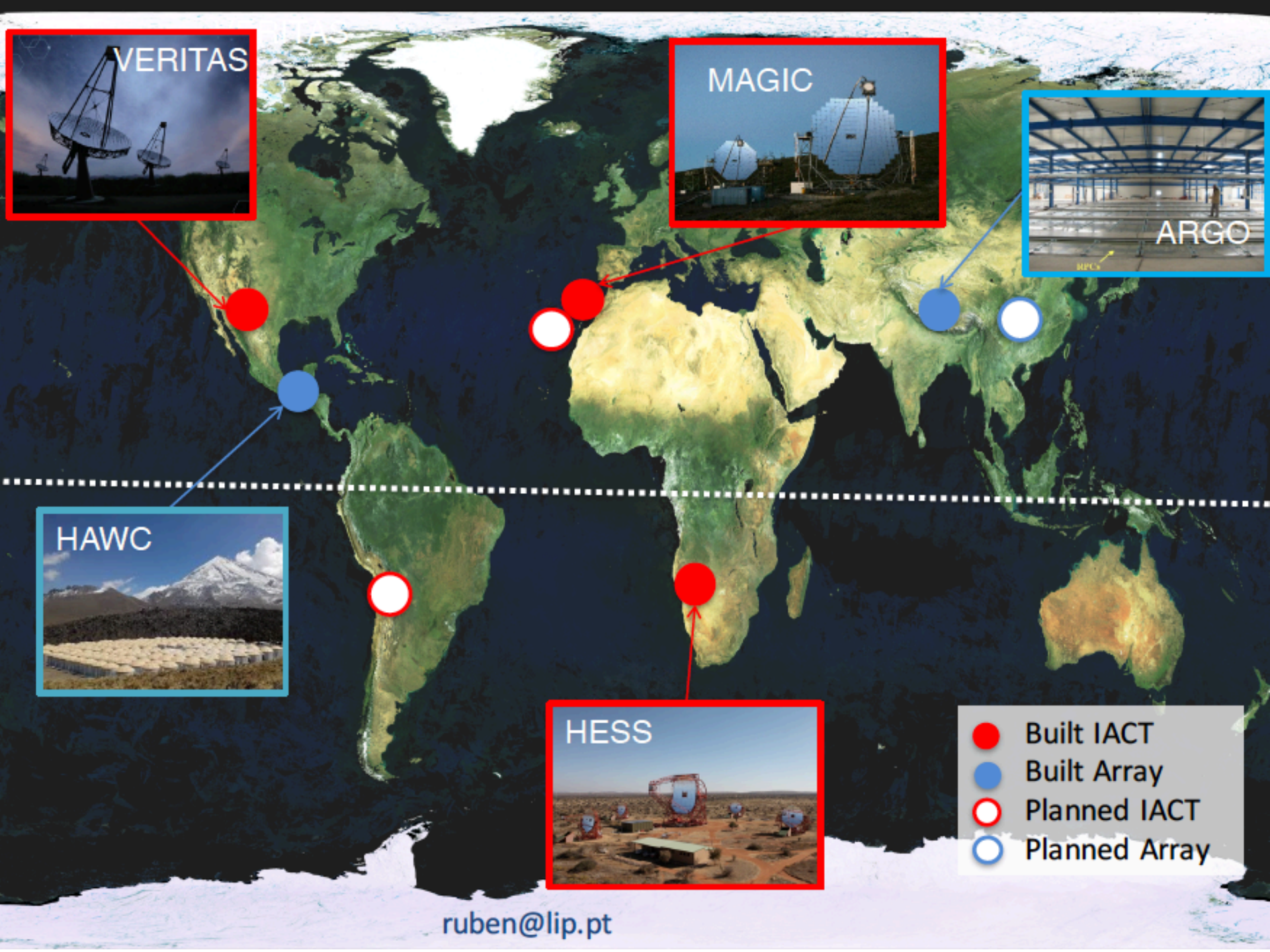
(for the LATTES LIP group)

**Second Lisbon mini-school on Particle and Astroparticle Physics,**
**Sesimbra, 6- 8 February 2017**

LIP


VERITAS
MAGIC
ARGO
HAWC
HESS
Built IACT
Built Array
Planned IACT
Planned Array

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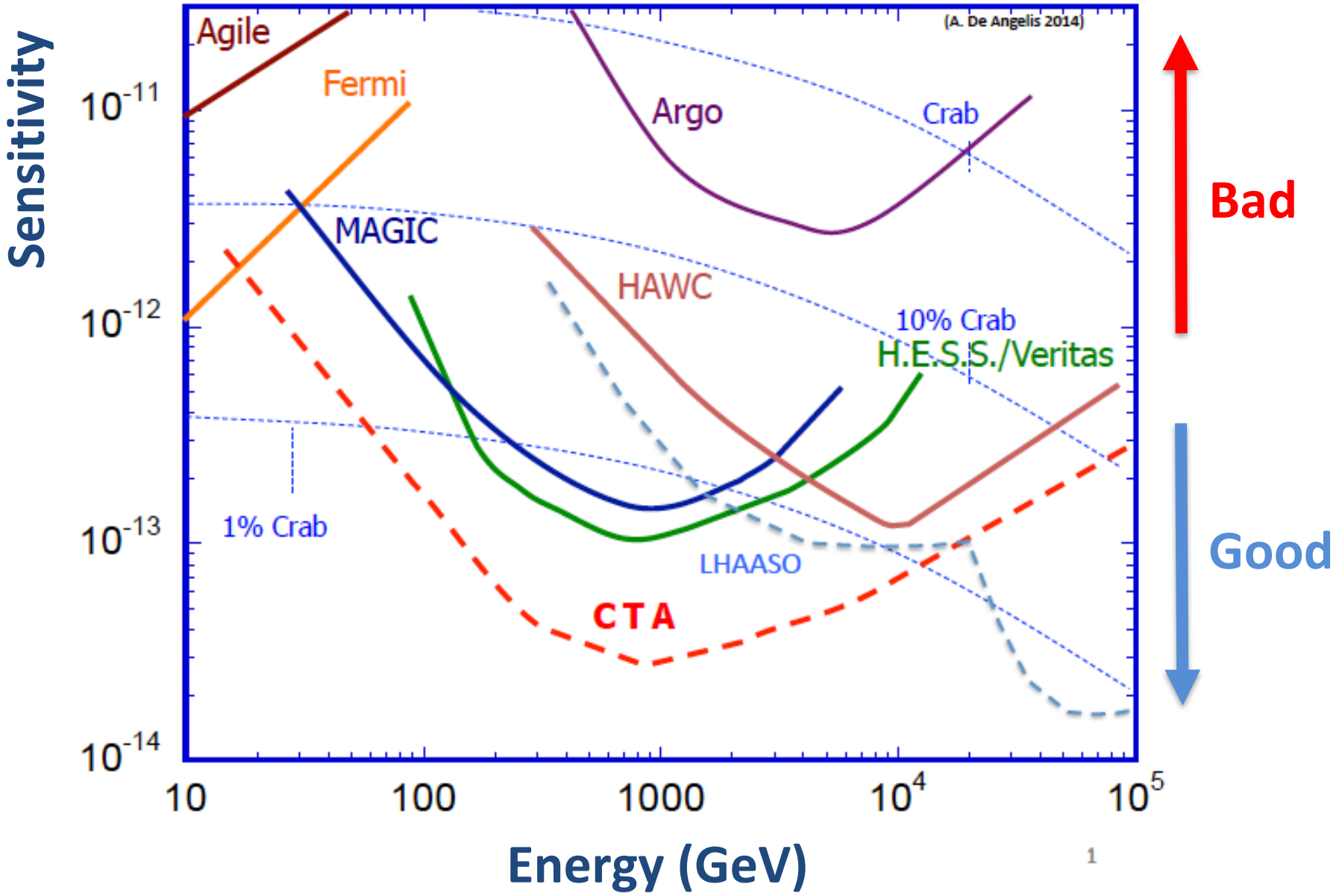
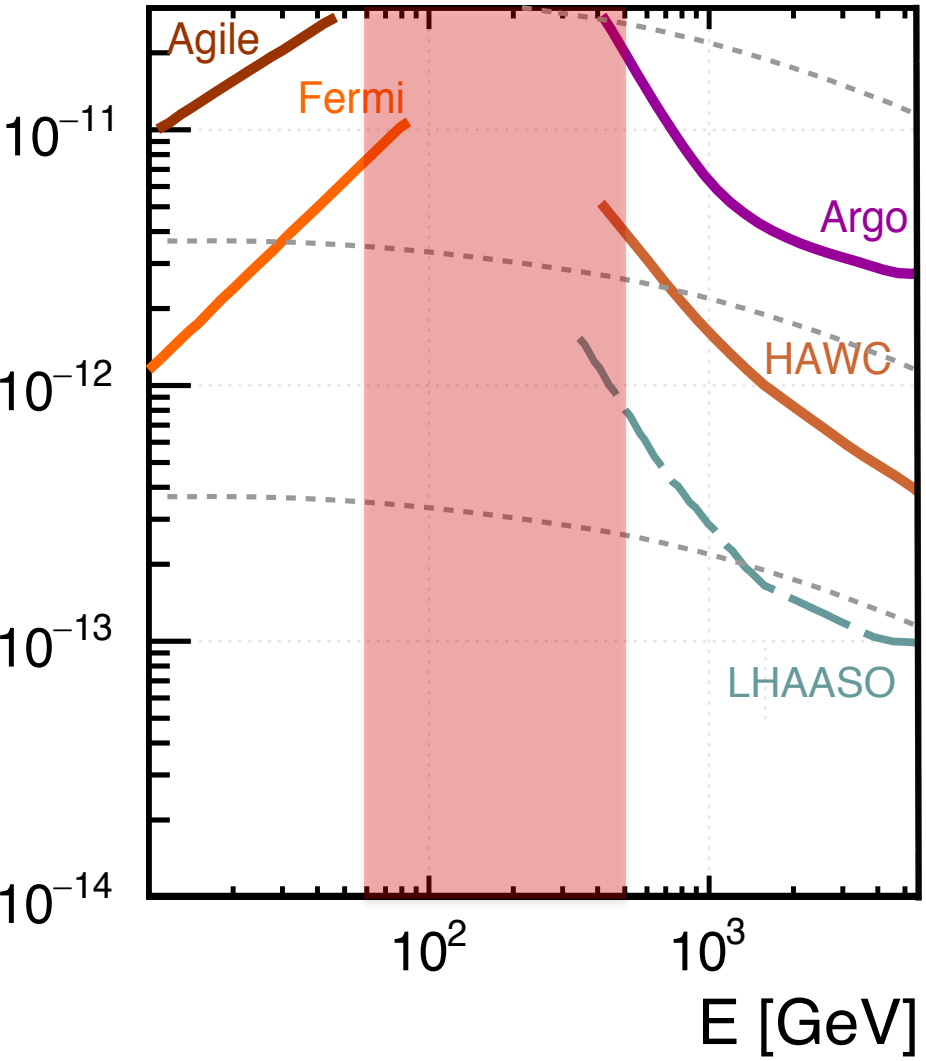
# Sensitivity for gamma detection (present and future)

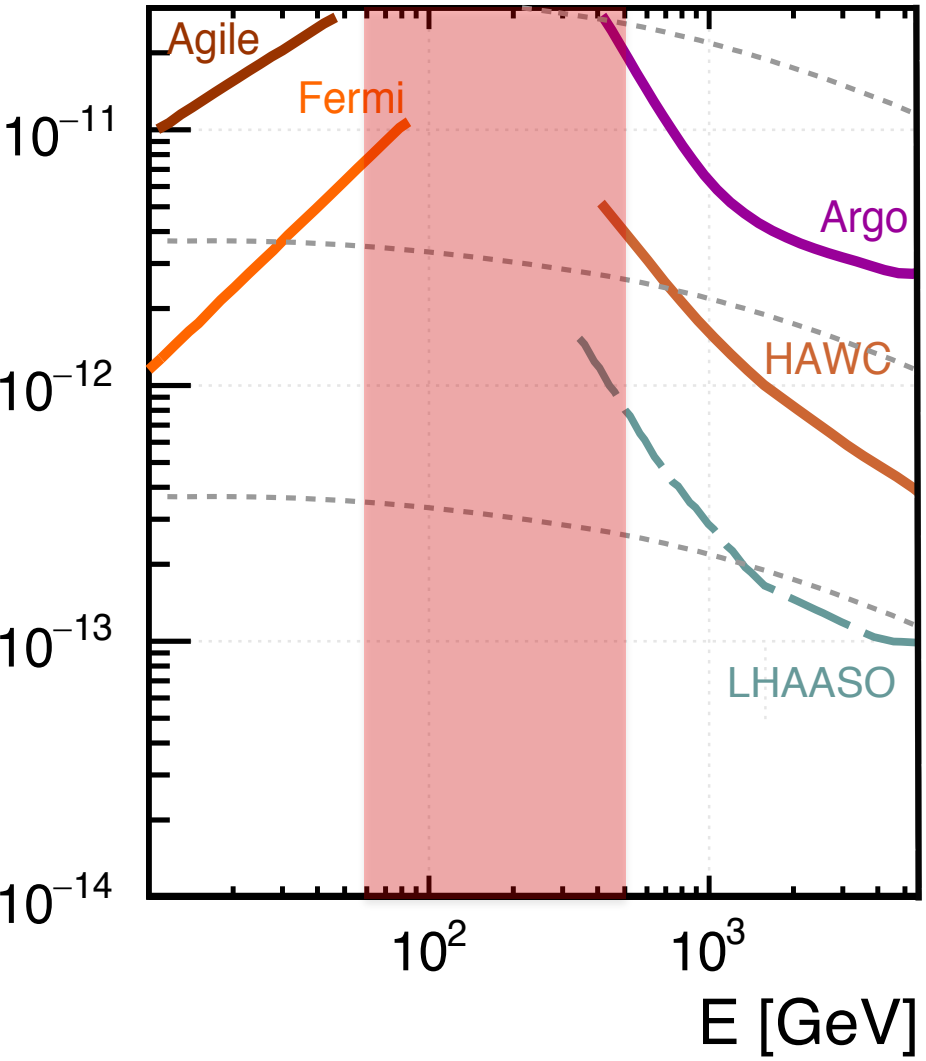


# The challenge…




- A new gamma detector :
  - Large field of view
  - Located in the South Hemisphere (survey the Galactic Center)
  - Low energy threshold
    - Cover the gap between satellite and ground based observations;

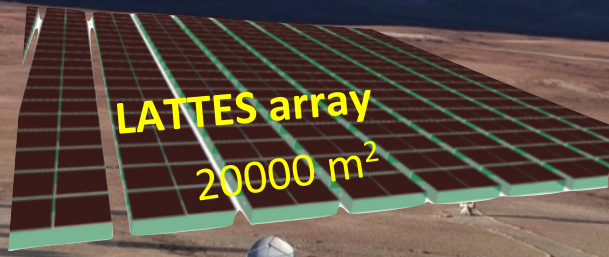
# The challenge




- A new gamma detector :
  - Large field of view
  - Located in the South Hemisphere (survey the Galactic Center)
  - Low energy threshold
    - Cover the gap between satellite and ground based observations;
- How ?
  - If the shower won't come to you, then you must go to the shower
  - Innovate !

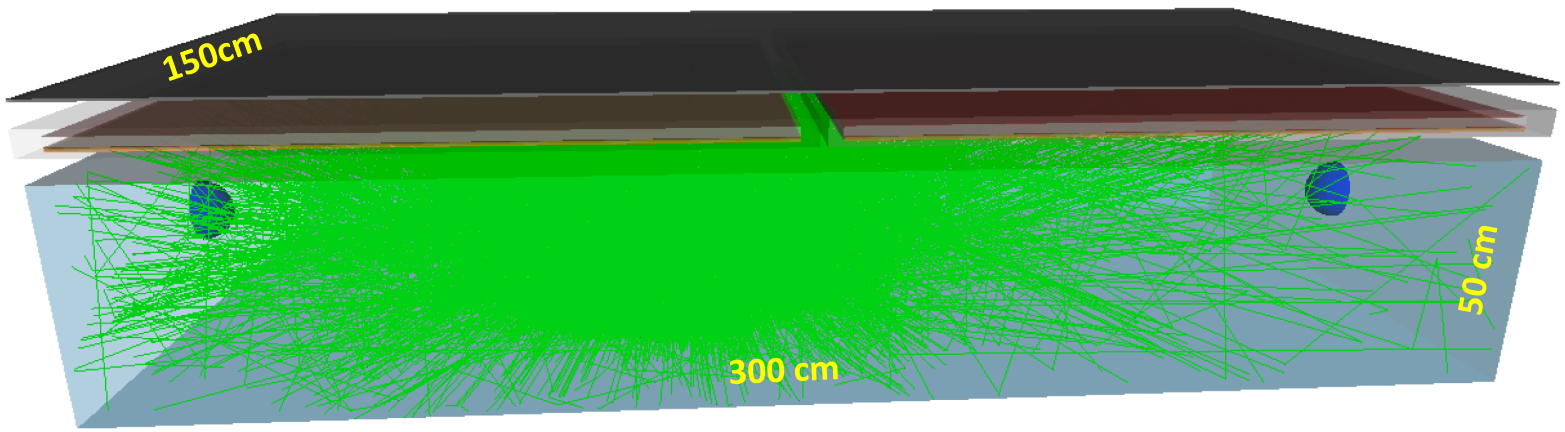
# LATTES @ ALMA site

**Large Array Telescope for Tracking Energetic Sources**


- **Planned site:**
  - **Atacama Large Millimeter Array site**
    - **Chajnantor plateau**
    - **5200 meters altitude in north Chile**
    - **Good position to survey the Galactic Center**

# LATTES station concept




- Thin lead converter plate (**Pb**)
  - Improve shower geometry reconstruction
- Resistive Plate Chambers (**RPC**)
  - Measure charged particles with high spatial and time resolution
- Water Cherenkov Detector **(WCD)**
  - Collect shower secondary photons to improve trigger at low energy

**Next generation detector concept !**

# Design and expected performance of a novel hybrid detector for very-high-energy gamma astrophysics

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**Abstract**

Current detectors for Very-High-Energy $\gamma$-ray astrophysics are either pointing instruments with a small field of view (Cherenkov telescopes), or large field-of-view instruments with relatively large energy thresholds (extensive air shower detectors). In this article we propose a new hybrid extensive air shower detector sensitive in an energy region starting from about 100 GeV, allowing to detect with a $5\sigma$ significance a source as faint as 10% of the Crab Nebula in one year, and able to survey half of the sky. The instrument can detect a source with the luminosity of 25 Crab at $3\sigma$ in 1 minute, making it a very powerful tool to trigger observations of variable sources and to detect transients coupled to gravitational waves and gamma-ray bursts.

*Keywords:* Gamma-ray astronomy, Extensive air shower detectors, Transient sources, Gamma-ray bursts

## 1. Introduction

High energy gamma rays are important probes of extreme, non thermal, events taking place in the universe. Being neutral, they can cover large distances without being deflected by galactic and extragalactic magnetic fields. This feature enables the direct study of their emission sources. The gamma emission is also connected to the acceleration of charged cosmic rays and to the production of cosmic neutrinos. Gamma-rays can also signal the existence of new physics at the fundamental scales, namely by the annihilation or decay of new types of particles, as it is the case for dark matter particles in many models. This motivation, associated to the advances of technology, has promoted a vigorous program of study of high energy gamma rays, with important scientific results (see [1, 2, 3, 4] for a summary of the main achievements).

The detected sources of cosmic gamma-rays above 30 MeV are concentrated around the disk of the Milky Way; in addition there is a set of extragalactic emitters. About 3000 sources emitting above 30 MeV were discovered, mostly by the Large Area Telescope (LAT) detector [5] onboard the *Fermi* satellite, and some 200 of them emit as well above 30 GeV [6] (see Fig. 1) - the region which is labeled the Very High Energy (VHE) region.

Our Galaxy hosts about half of the VHE gamma-ray emitters [7] and most of them are associated to supernova remnants of various classes (shell supernova remnants, pulsar-wind nebulae, etc.). The remaining emitters are extragalactic. The angular resolution of current detectors, which is slightly better than $0.1^\circ$, does not allow to assign the identified extragalactic emitters to any particular region in the host galaxies; however, there is some consensus that the signals detected from the Earth must originate in the proximity of supermassive black holes at the center of the galaxies [8].

Still, many problems remain open, of which we may mention:

- *The origin of cosmic rays* – supernova remnants (SNRs) are accepted to be the sites for the acceleration of protons up to few PeV. However, the mechanism of acceleration of particles to energies of that order is still to be established experimentally. The study of the photon yield from Galactic sources for energies larger than 100 GeV and all the way up to PeV, might solve the problem (see for example [9]). Actually photons, which come from $\pi^0$ decay, correspond to hadronic cascades initiated at energies at least an order of magnitude larger.

- *The propagation of gamma-rays* – tells us about their interaction with the cosmic background radiation and is a

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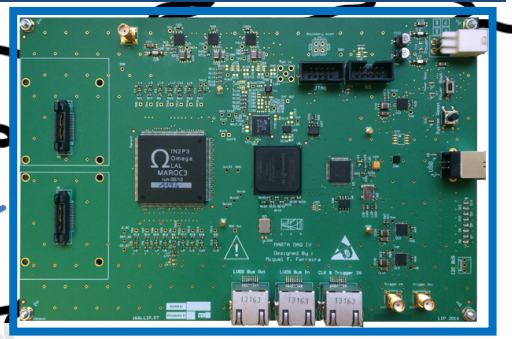
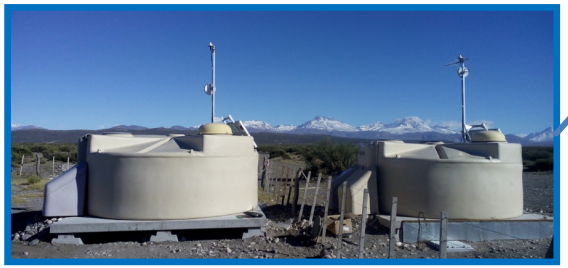
# Ongoing developments and tests on RPCs, electronics and read-out systems



DAQ Engineering prototype

RPC based muon hodoscope for precise studies of the Auger WCD


RPCs in the field @ Auger

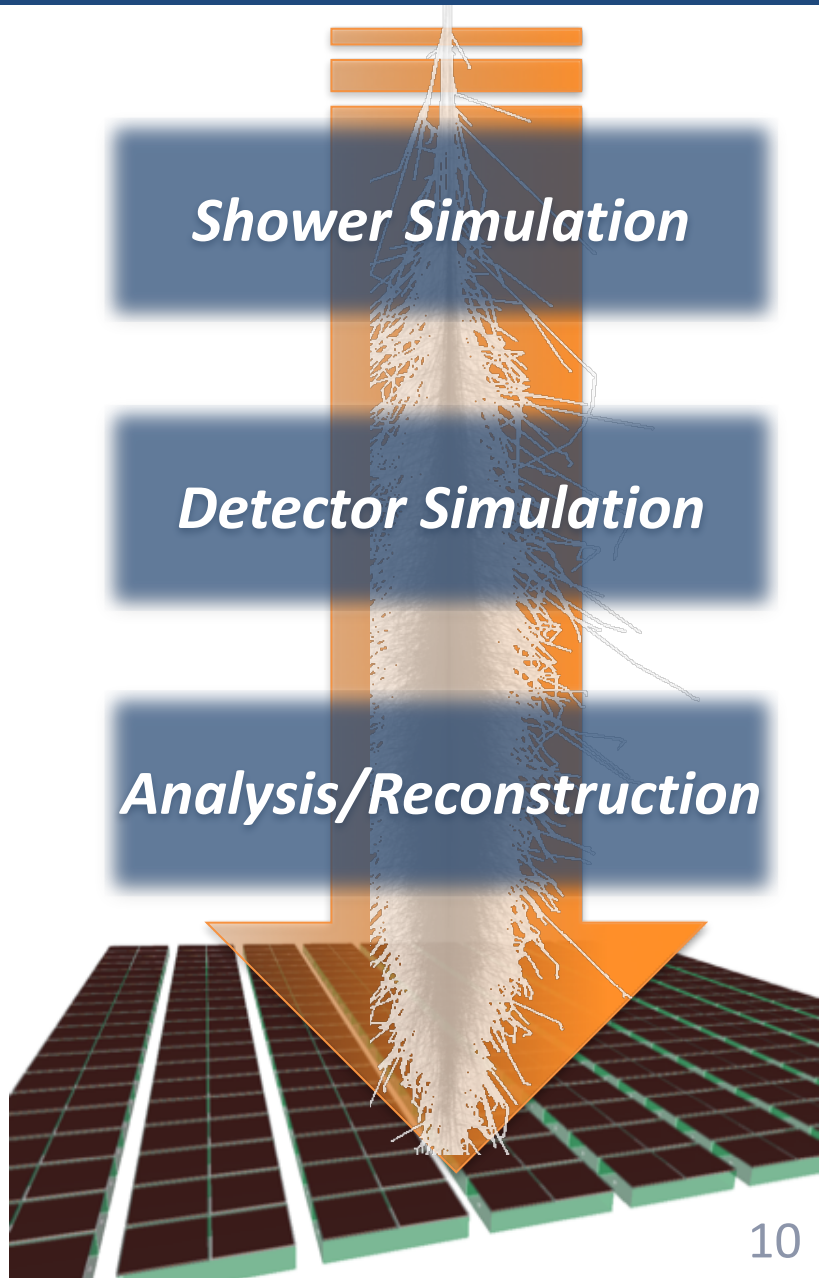


RPC hodoscope

Construction and Assembling

# Analysis tools, detector simulations and performance studies

- Optimization of the detector concept;
- Analysis tools under development;
- New contributions are very welcome.



- LATTES is an ambitious project to develop, prototype and deploy a next-generation high-energy gamma ray detector;
- Perfect place and time to contribute to the development of a new detector;
- Many possible areas of work:
  - Detector related developments, electronics and data acquisition;
  - State-of-the-art detector simulations, development of novel analysis methods;
  - High-energy gamma ray phenomenology;

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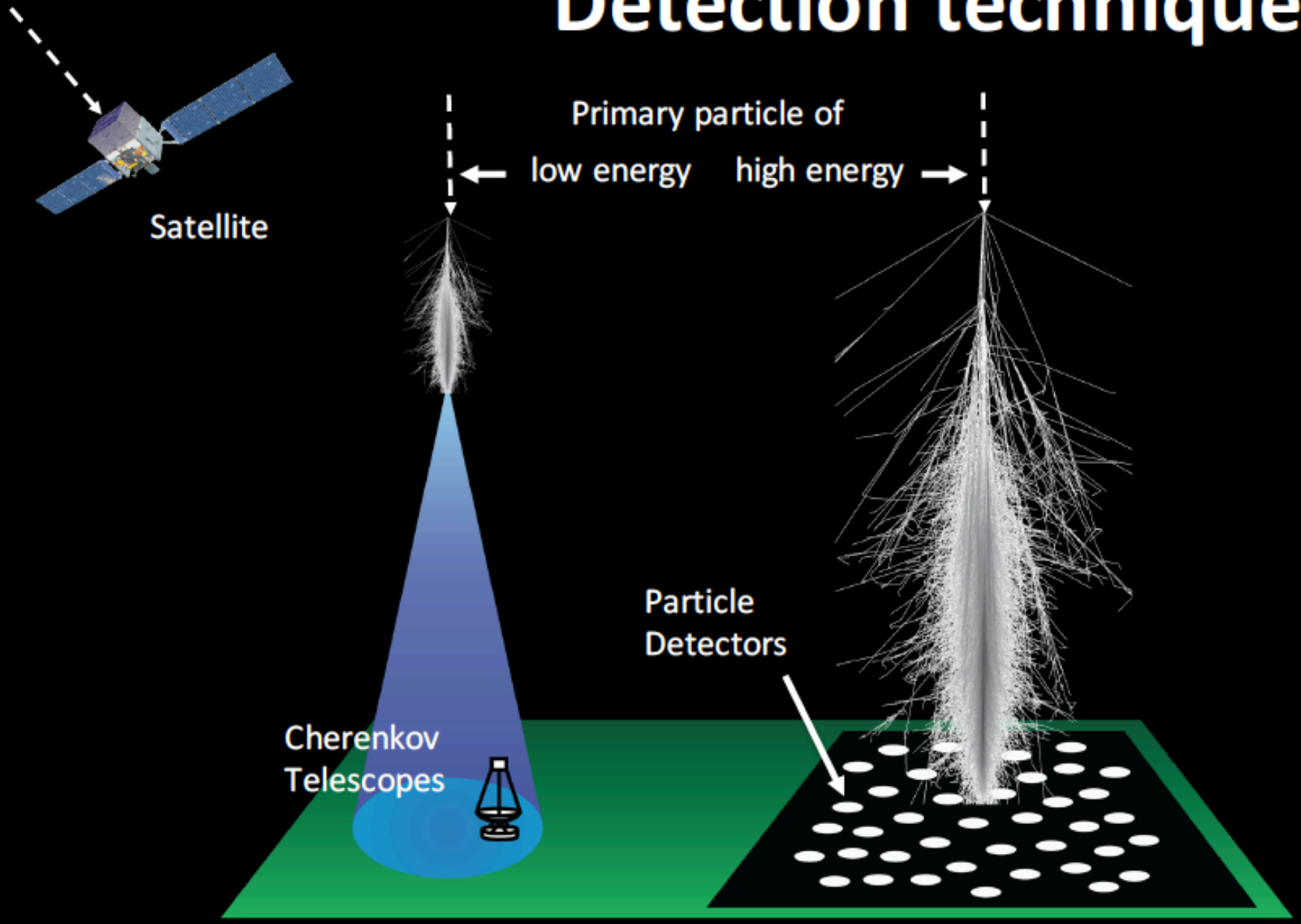
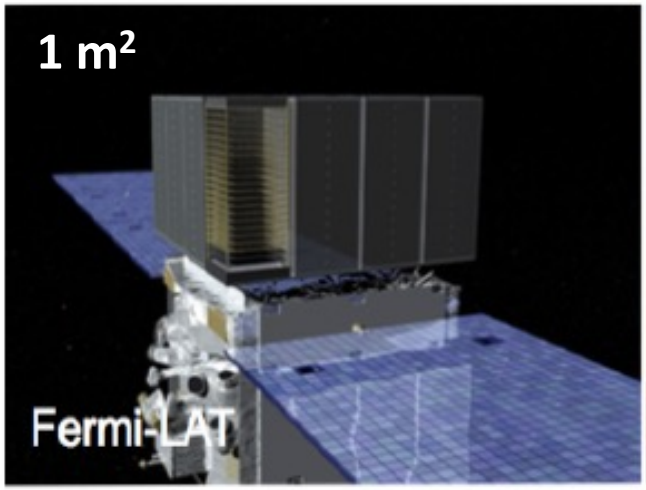
END

# Detection techniques

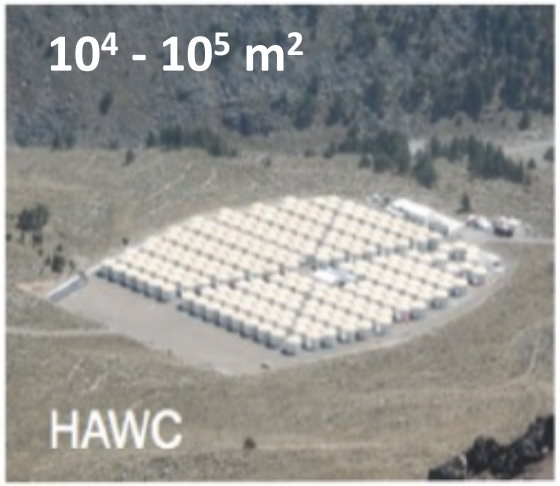



**Arrays at high altitude = large field of view + lower energies**

# (V)HE gamma detectors performance





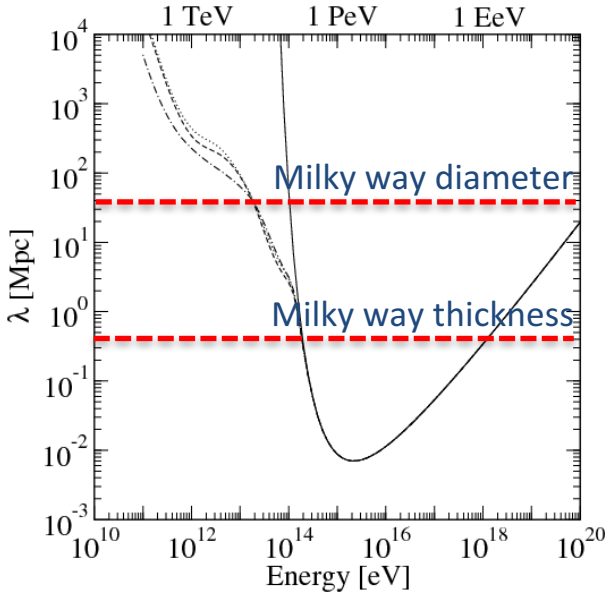


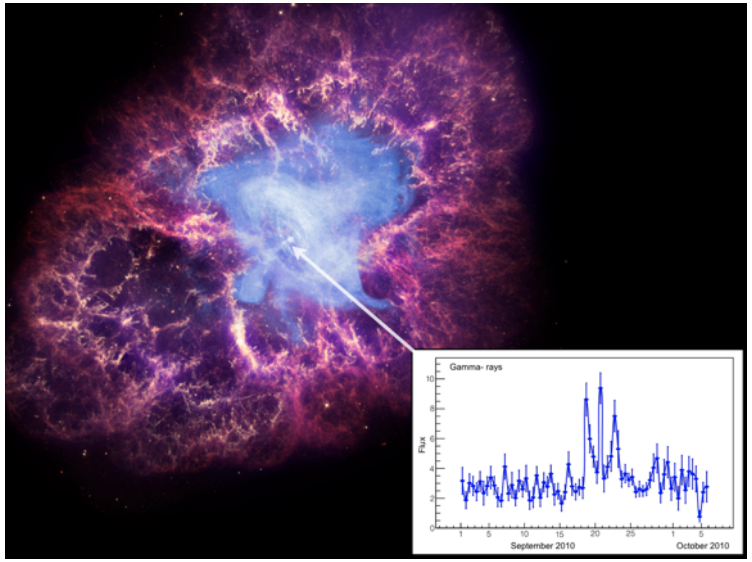

| Quantity | Fermi | IACTs | EAS |
|---|---|---|---|
| Energy range | 20 MeV–200 GeV | 100 GeV–50 TeV | 400 GeV–100 TeV |
| Energy res. | 5-10% | 15-20% | ~ 50% |
| Duty Cycle | 80% | 15% | > 90% |
| FoV | $4\pi/5$ | $5° \times 5°$ | $4\pi/6$ |
| PSF | 0.1° | 0.07° | 0.5° |
| Sensitivity | 1% Crab (1 GeV) | 1% Crab (0.5 TeV) | 0.5 Crab (5 TeV) |

A. De Angelis

# VHE gammas & key science questions

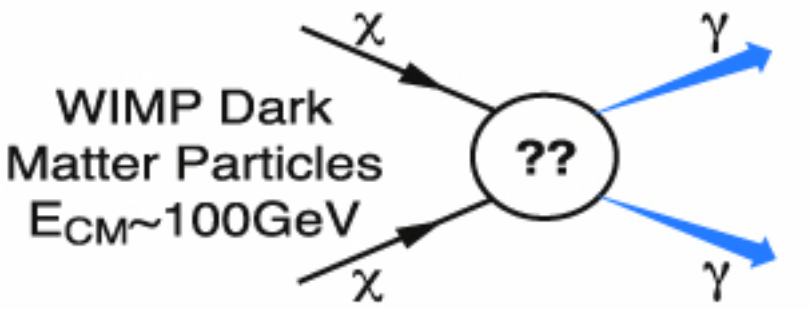
- **The origin of Cosmic rays**
  - PeV gamma rays are expected to be found in our galaxy due to cosmic ray interactions
    - But no detection yet!
      - E < 100 TeV
  - Where/what are the PeVatrons ?
    - Above some PeV, acceleration near supermassive black holes?



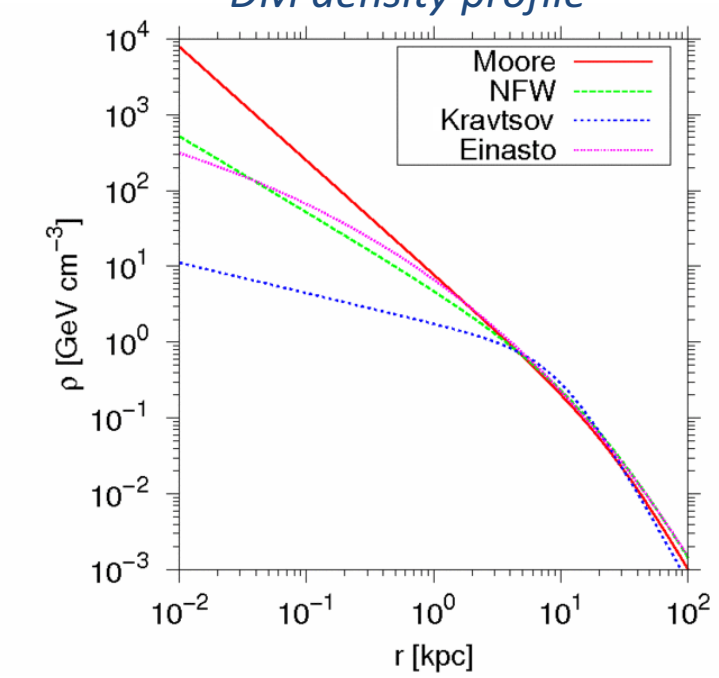



# VHE gammas & key science questions

- **Dark matter annihilations**
  - Many dark matter (DM) candidates are expected to produce gammas in a self-annihilation process
  - Look at the Galactic Center where the density of DM is expected to be higher

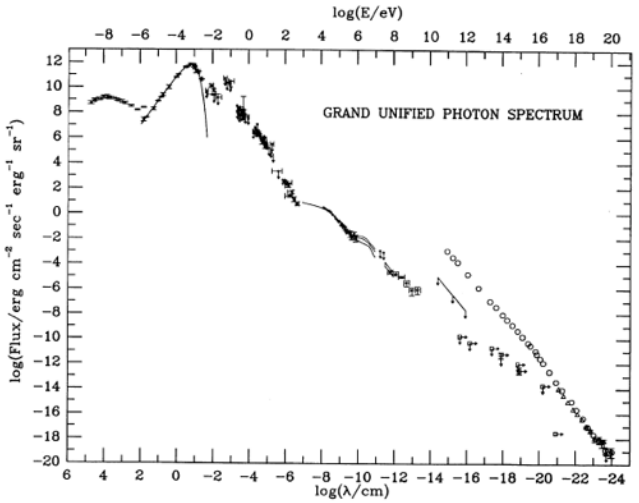



*DM density profile*

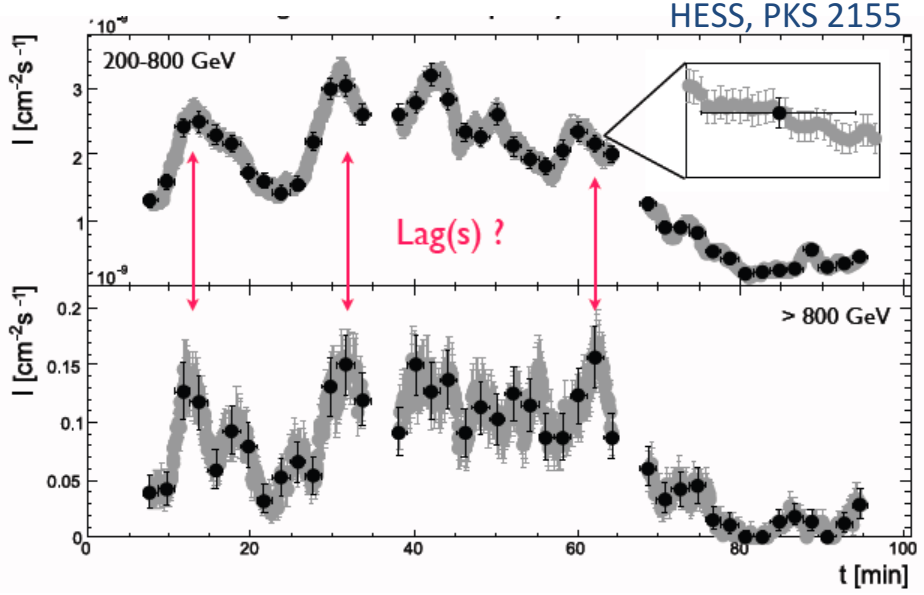


# VHE gammas & key science questions

- **Cosmology**
  - Constraints on intergalactic magnetic and photon radiation fields in the Universe.
  - Tests of Lorentz violation : v(E) ?
    - Fundamental properties of quantum gravity.




HESS, PKS 2155




No claim survived up to now ☹