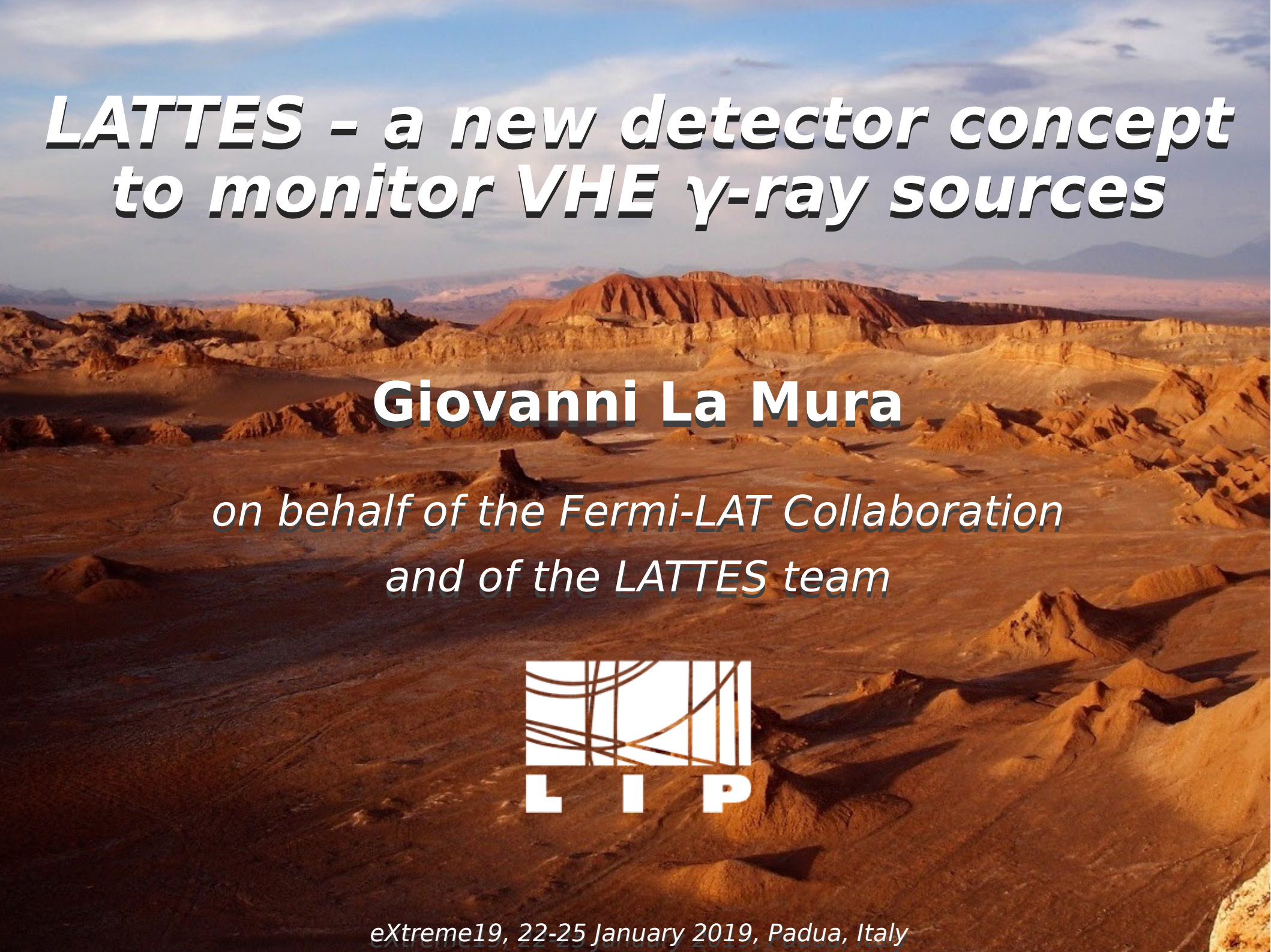


LATTES – a new detector concept to monitor VHE γ-ray sources

Giovanni La Mura

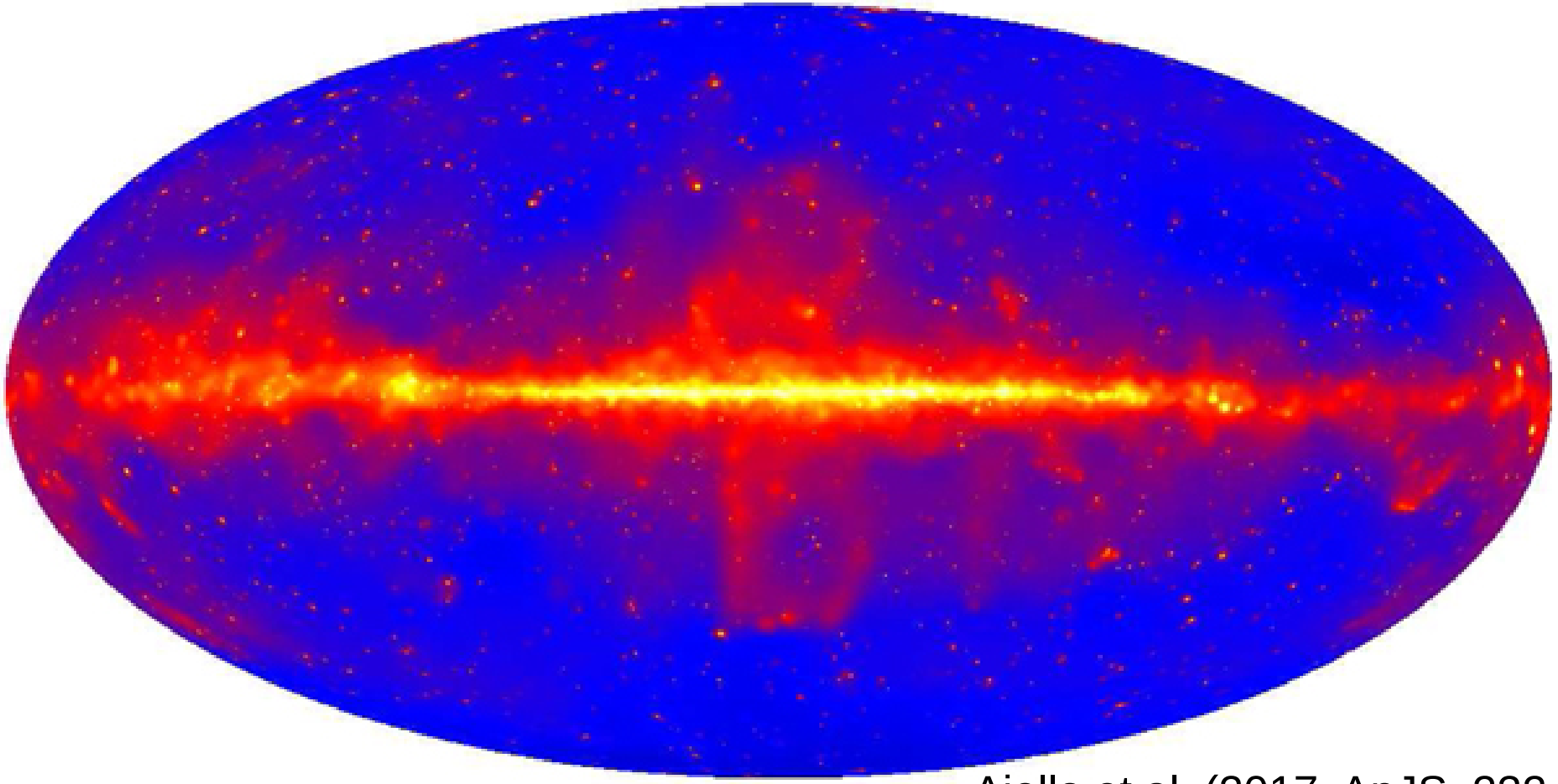
on behalf of the Fermi-LAT Collaboration

and of the LATTES team

LIP

eXtreme19, 22-25 January 2019, Padua, Italy

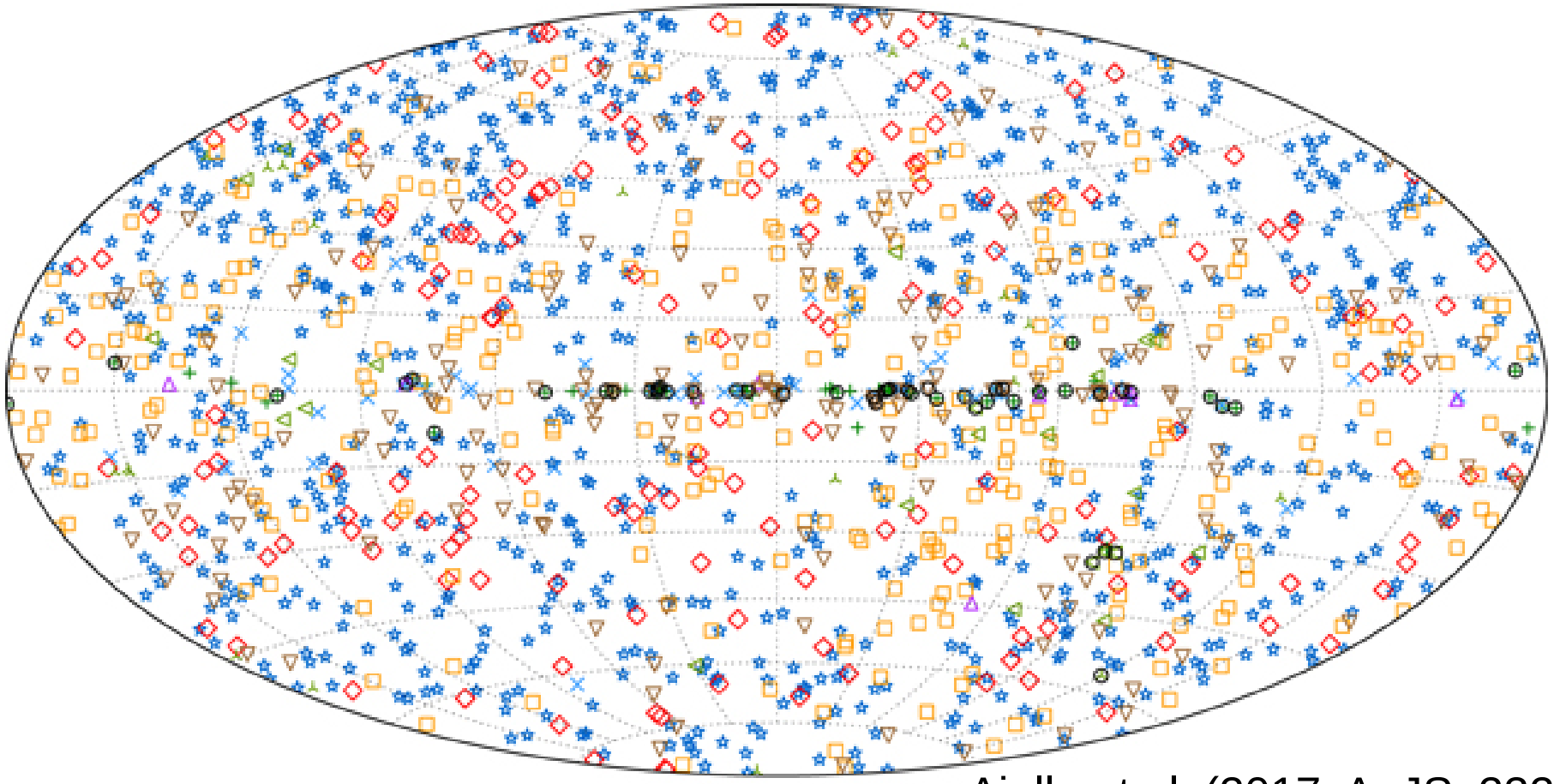
3FHL: the Fermi-LAT VHE sky (10 GeV – 2 TeV)



Ajello et al. (2017, ApJS, 232, 2)

All sky map of VHE gamma-ray emission in 7 years of Fermi-LAT observations, presented in Galactic coordinates and Aitoff projection. Image units are counts and pixel size is $(0.1\ \mathrm{deg})^2$.

3FHL: the Fermi-LAT VHE sky (10 GeV – 2 TeV)

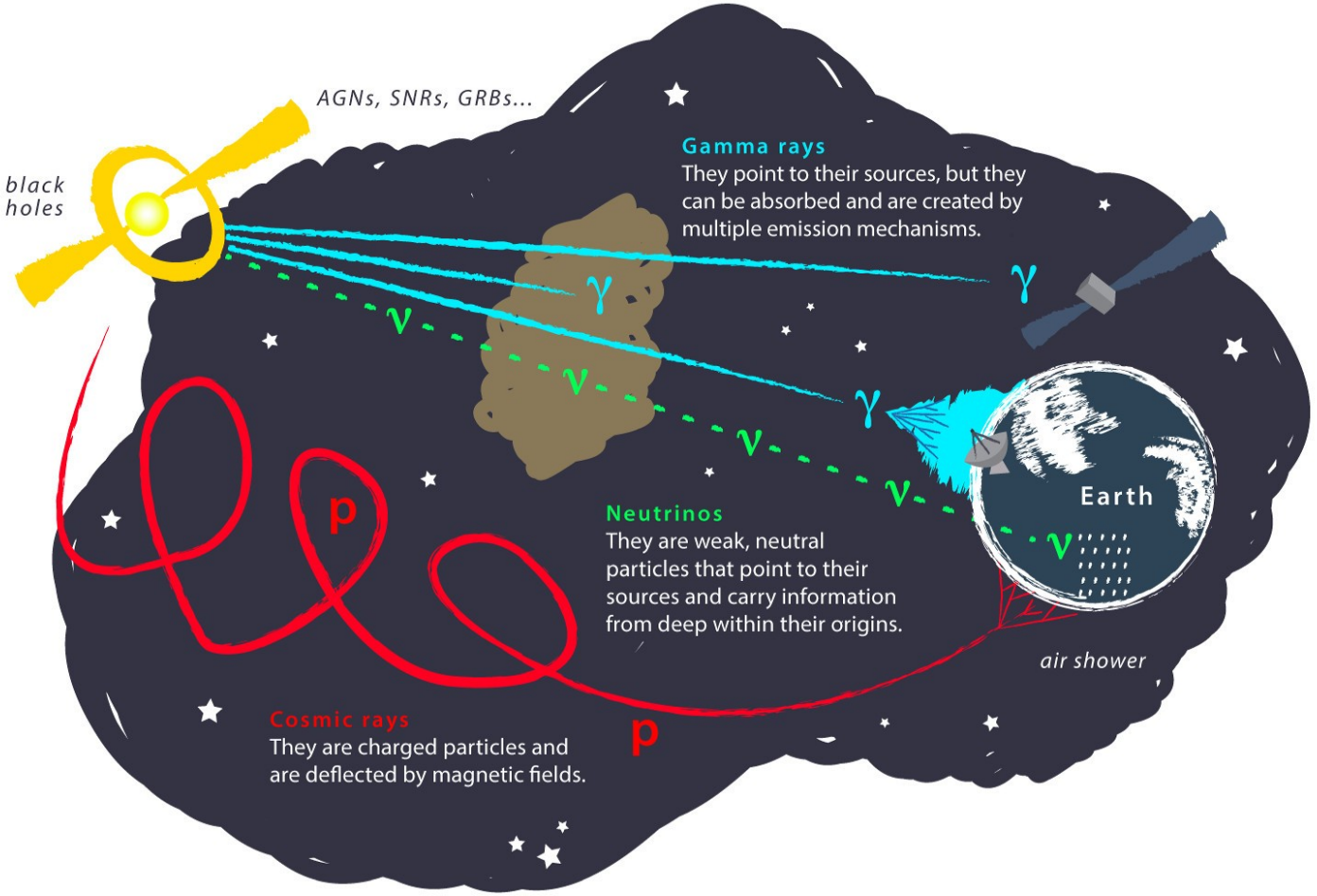


Ajello et al. (2017, ApJS, 232, 2)

+	SNRs and PWNe	★	BL Lacs	□	Unc. Blazars	△	Other GAL	▽	Unassociated
×	Pulsars	◇	FSRQs	⋏	Other EGAL	◁	Unknown	○	Extended

Distribution and classification of the 3FHL Catalogue sources, presented in Galactic coordinates and Aitoff projection. The different classes of blazars are the dominant population and the main sources of extra-galactic photons.

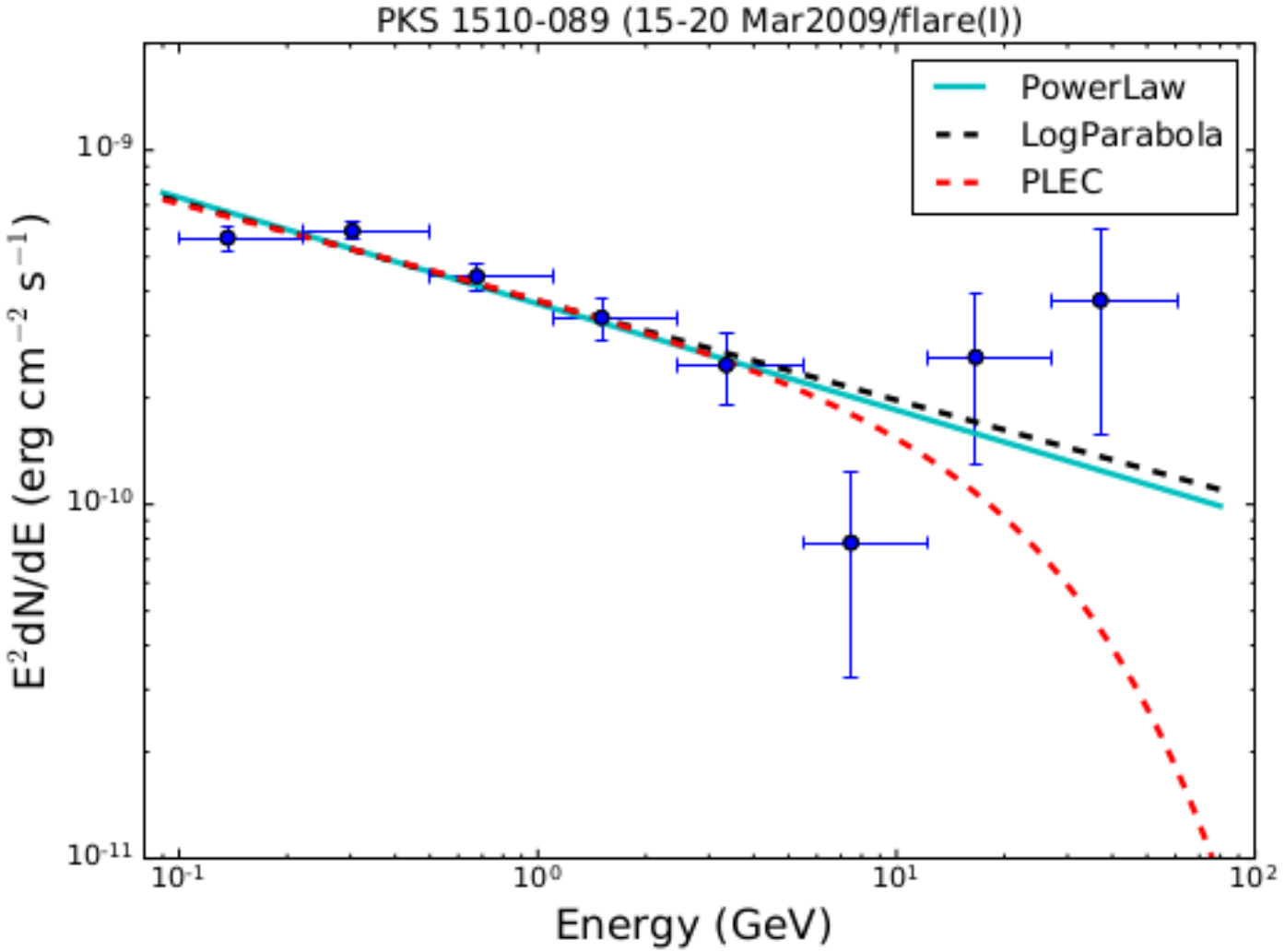
The first (identified) ν source: TXS 0506+056



The first detection of a high energy IceCube neutrino coming from a γ-ray flaring blazar provides important insight in the nature of AGN jets, pointing towards a relevant role played by hadronic mechanisms in the source. Flaring activity is likely involved in the enhancement of such processes.

VHE emission from blazars

When detected at VHE, blazars and other AGNs can exhibit spectral components that add up to the commonly observed IC hump and strongly point towards additional emission mechanisms. Unfortunately, the low statistics of currently available observations makes them hard to model.



PKS 1510-089

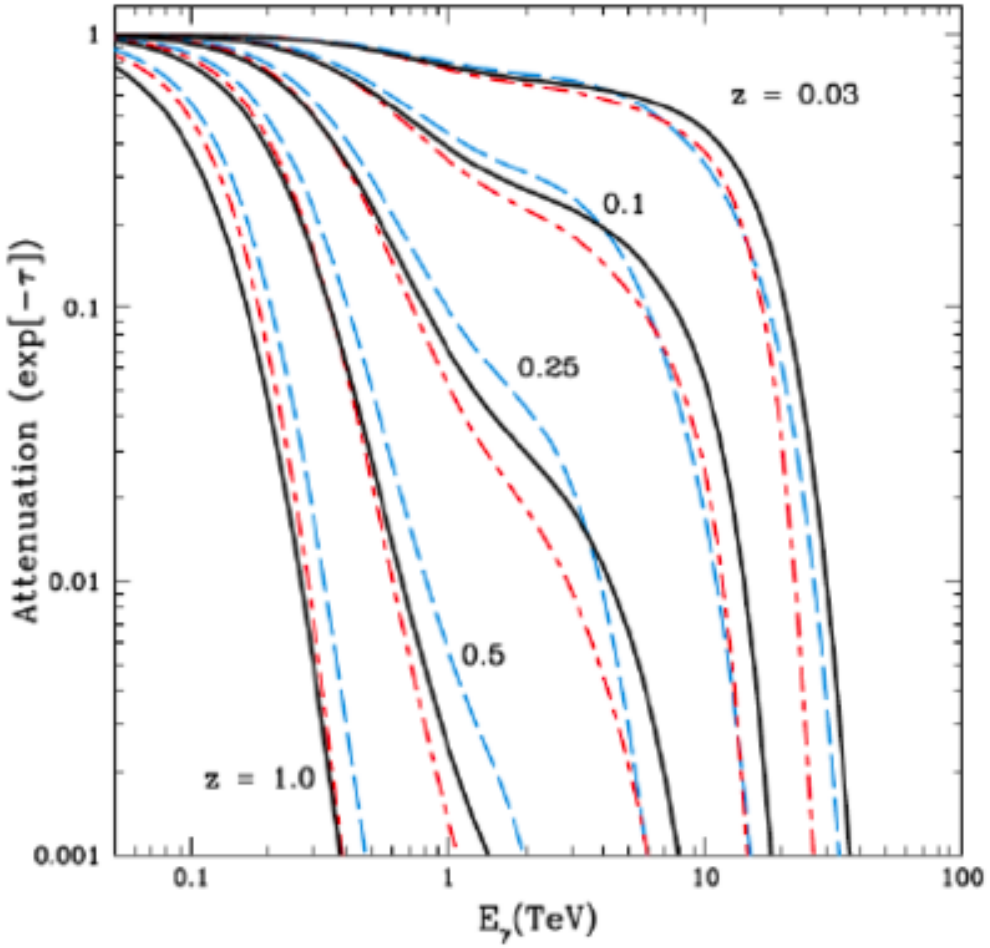
0.1 – 100 GeV SED

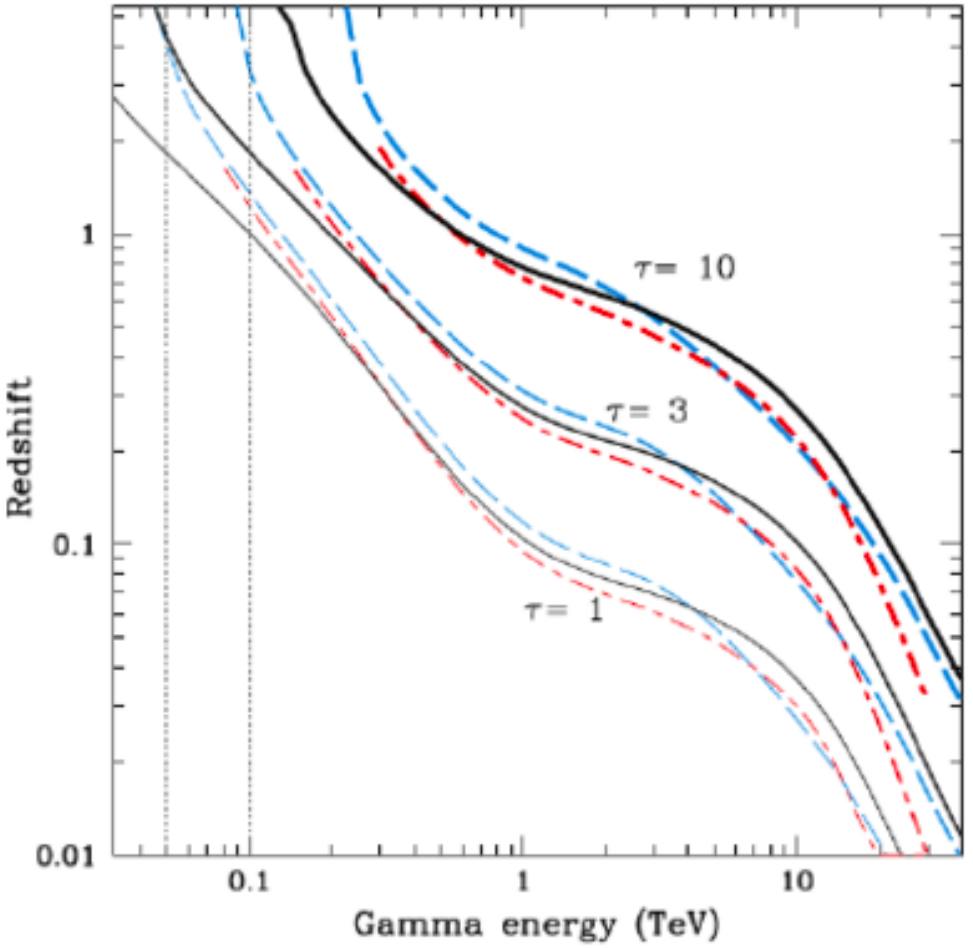
with Fermi-LAT

Prince et al. (2017, ApJ, 844, 62)

γ-ray opacity in VHE emission of high z sources

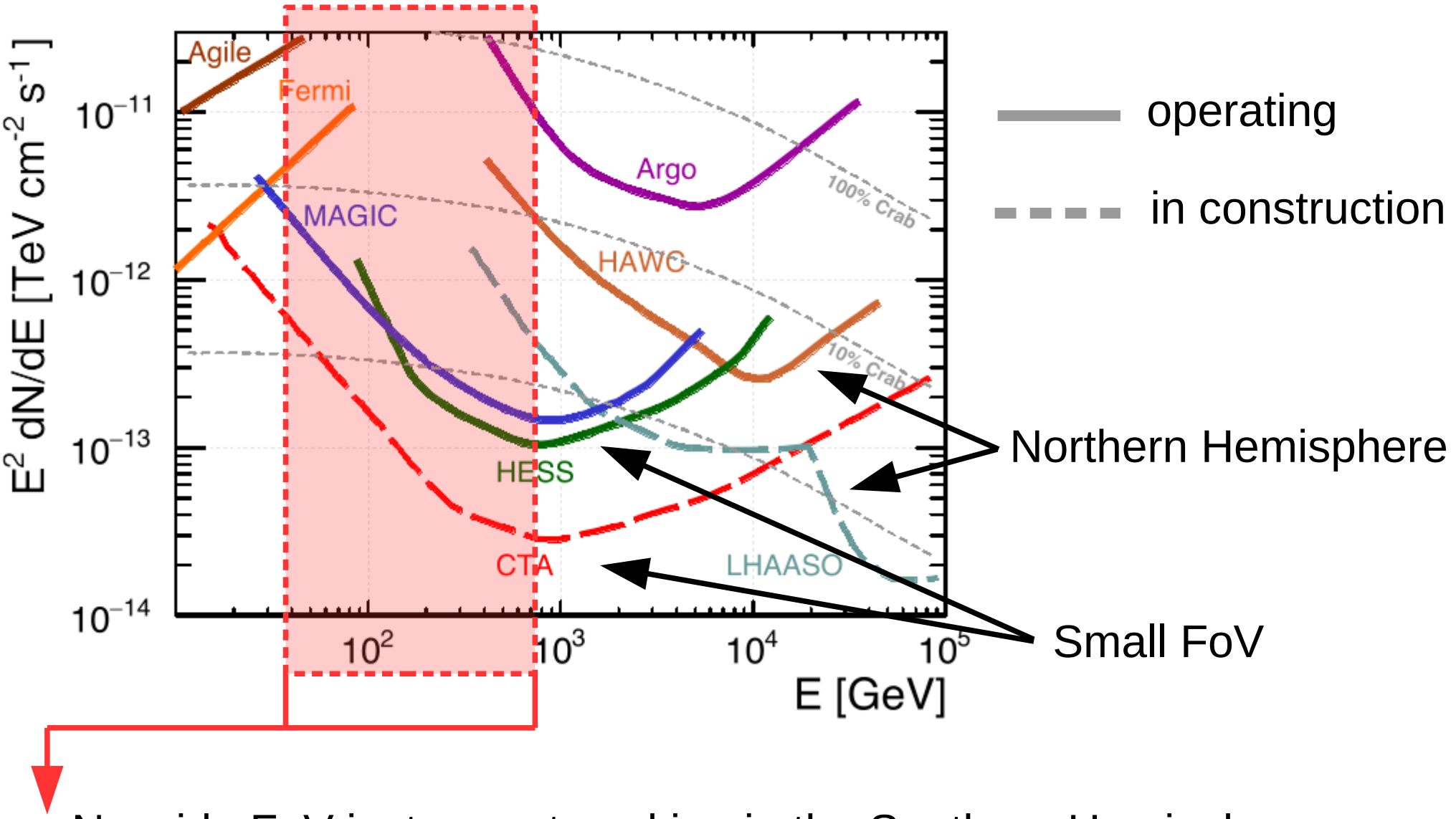
Primack et al. (2011; DOI:10.1063/1.3635825)





In addition to the intrinsic physical properties of the sources, VHE emission from blazars is a powerful beacon that can be used to constrain the opacity of the Universe, due to Extragalactic Background Light, tracing Cosmological parameters and their evolution with *z*.

Gap in the sub-TeV VHE spectral domain



- No wide FoV instrument working in the Southern Hemisphere
- Gap between satellite and ground-based observations

Bridging the gap

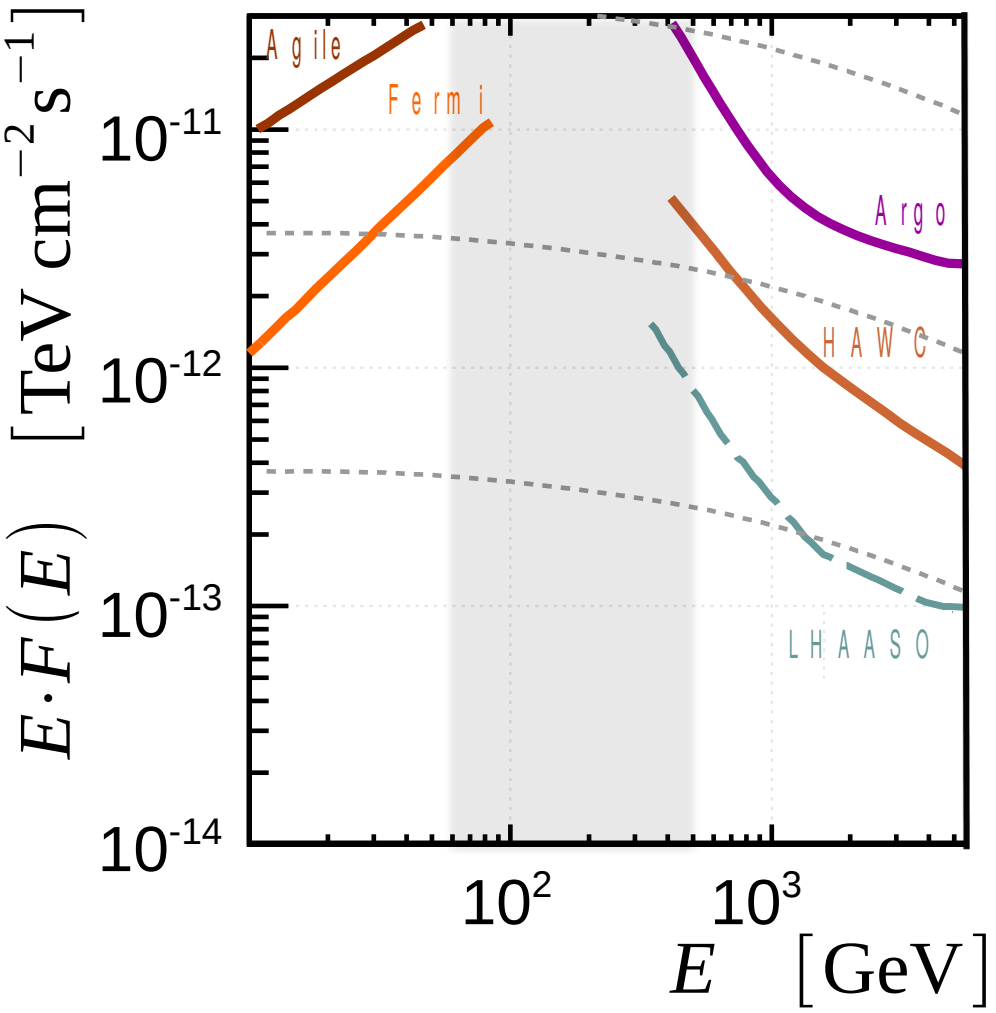
Requirements to fulfil:

- Access the Southern Sky
- Cover a wide FoV (> 2 sr)
- Provide angular + energy resolution
- Sensitivity to sub-Tev domain

Solutions:

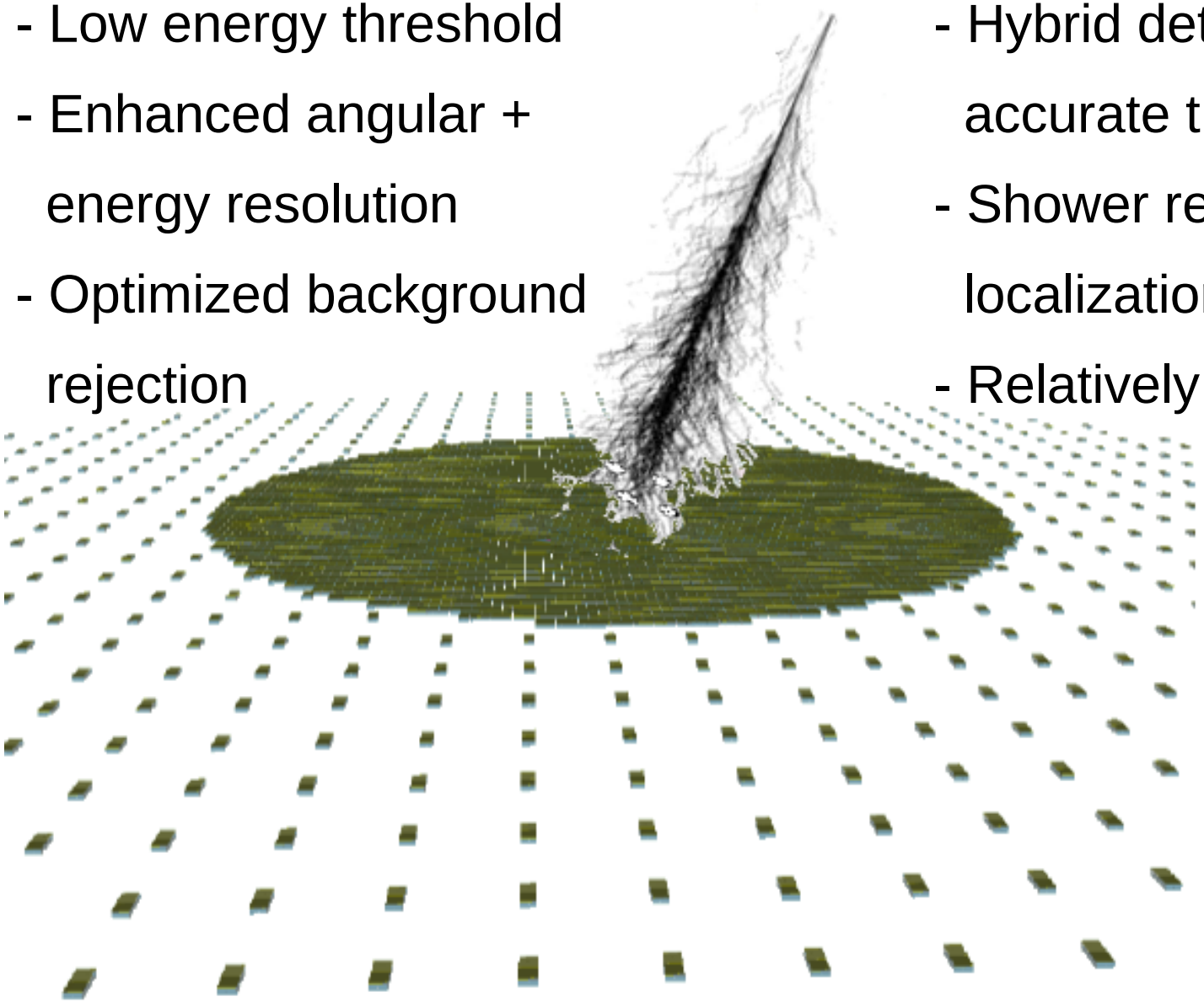
- High-altitude Southern EAS array
- Time resolution better than 2 ns
- Low-energy threshold (10-20 MeV @detector)

LATTES project



Large Area Telescope for Tracking Energetic Sources

- Extensive Air Shower array (EAS)
- Low energy threshold
- Enhanced angular + energy resolution
- Optimized background rejection



Proposal concepts:

- Hybrid detector (provides accurate timing and energies)
- Shower reconstruction (source localization and bkg rejection)
- Relatively low cost (eff. area)

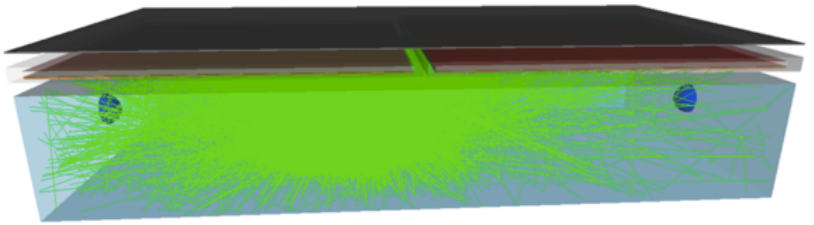
Array core:

20’000 m^2

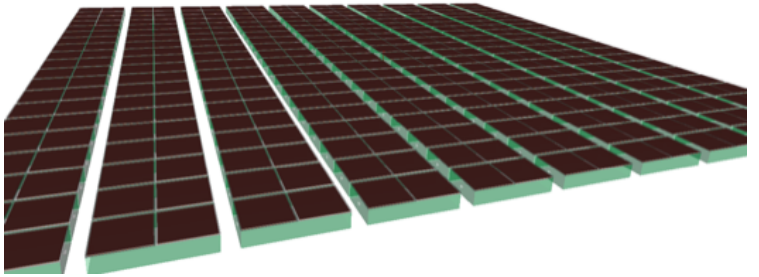
CONCEPT DESIGN

LATTES: a hybrid detector

- Hybrid detector:
  - Thin lead plate
    - To convert the secondary photons
    - Improve geometric reconstruction
  - Resistive Plates Chamber (RPC)
    - Sensitive to charged particles
    - Good time and spatial resolution
    - Improve geometric reconstruction
    - Explore shower particle patterns at ground
  - Water Cherenkov Detector (WCD)
    - Sensitive to secondary photons and charged particles
    - Measure energy flow at ground
    - Improve trigger capability
    - Improve gamma/hadron discrimination



LATTES station
1.5 m x 3 m x 0.5 m



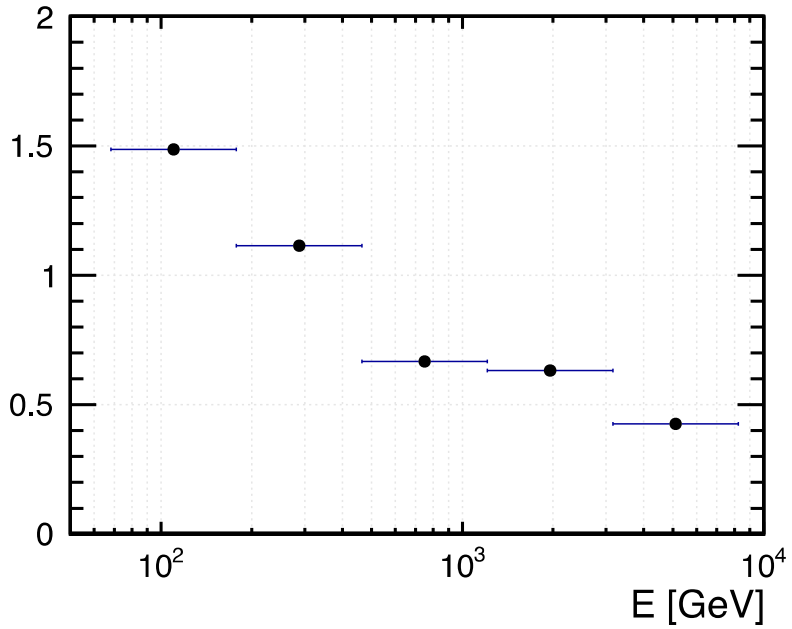
LATTES core array
40 x 90 stations
Circular area R = 80 m
Stations spaced by 0.5 m

LATTES performance evaluation

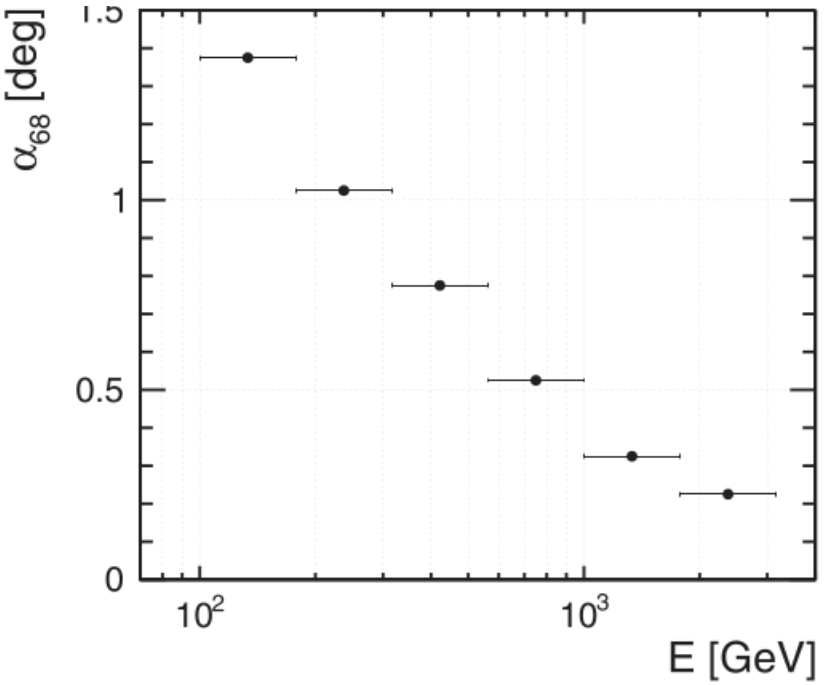
- End-to-end realistic simulation
  - Extensive Air Showers: CORSIKA
  - Detector simulation: Geant4
- Reconstruction
  - First order analyses with little optimization only to demonstrate principle
  - More than 50 000 gamma/proton shower simulated randomly between 10 GeV – 300 TeV
  - Gammas have a fixed zenith angle of 10 degrees
  - Observation level at 5200 m of altitude
  - Each shower is re-sampled 100 times over a big area containing all the array

Energy & Geometry reconstruction

- Shower energy reconstruction
  - Use total signal recorded in WCDs
    - Comparison with HAWC pre-ICRC analysis
  - Lowest energies dominated by shower-to-shower fluctuations

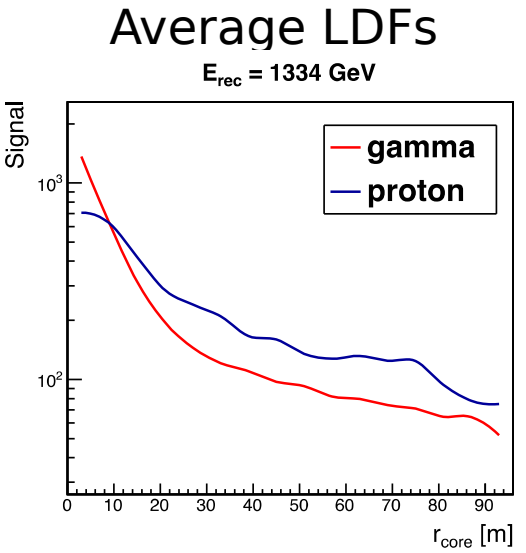


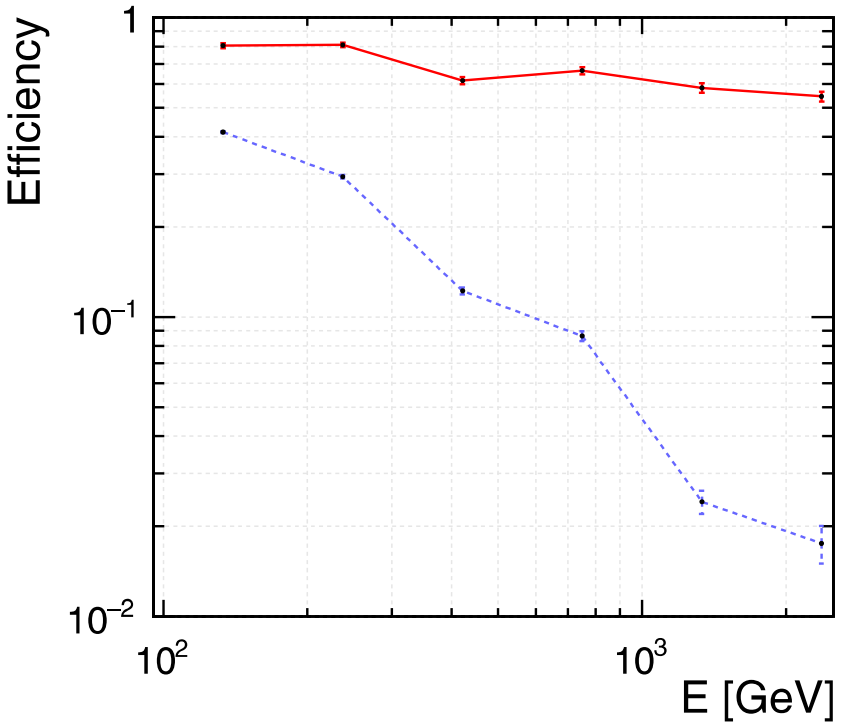
- Shower geometry reconstruction
  - Use RPC hit time
    - Time resolution of 1 ns
  - Geometry obtained using a shower front plane approximation
  - Resolution of about 1° at E =100 GeV



G/H discrimination

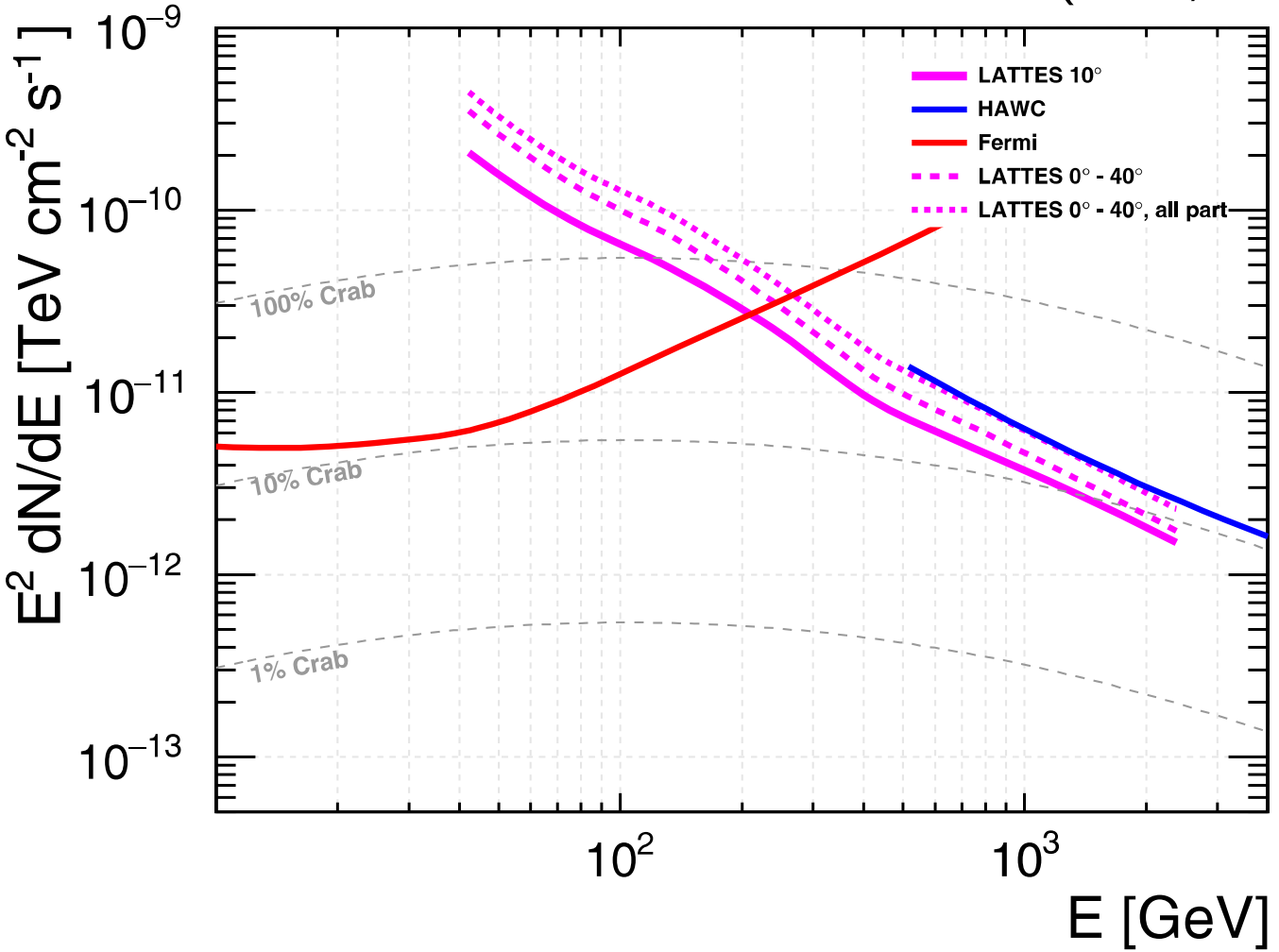
- Gamma/hadron discrimination
  - Currently only using WCD
  - Two variables being used and combined through a Fisher method
    - Stations far away from shower core with signal above a given threshold
    - Shower compactness (explore LDF steepness)
- G/H discr. presents similar results to HAWC
  - No optimization





LATTES sensitivity

Assis et al. (2018, Astropart. Phys., 99, 32)



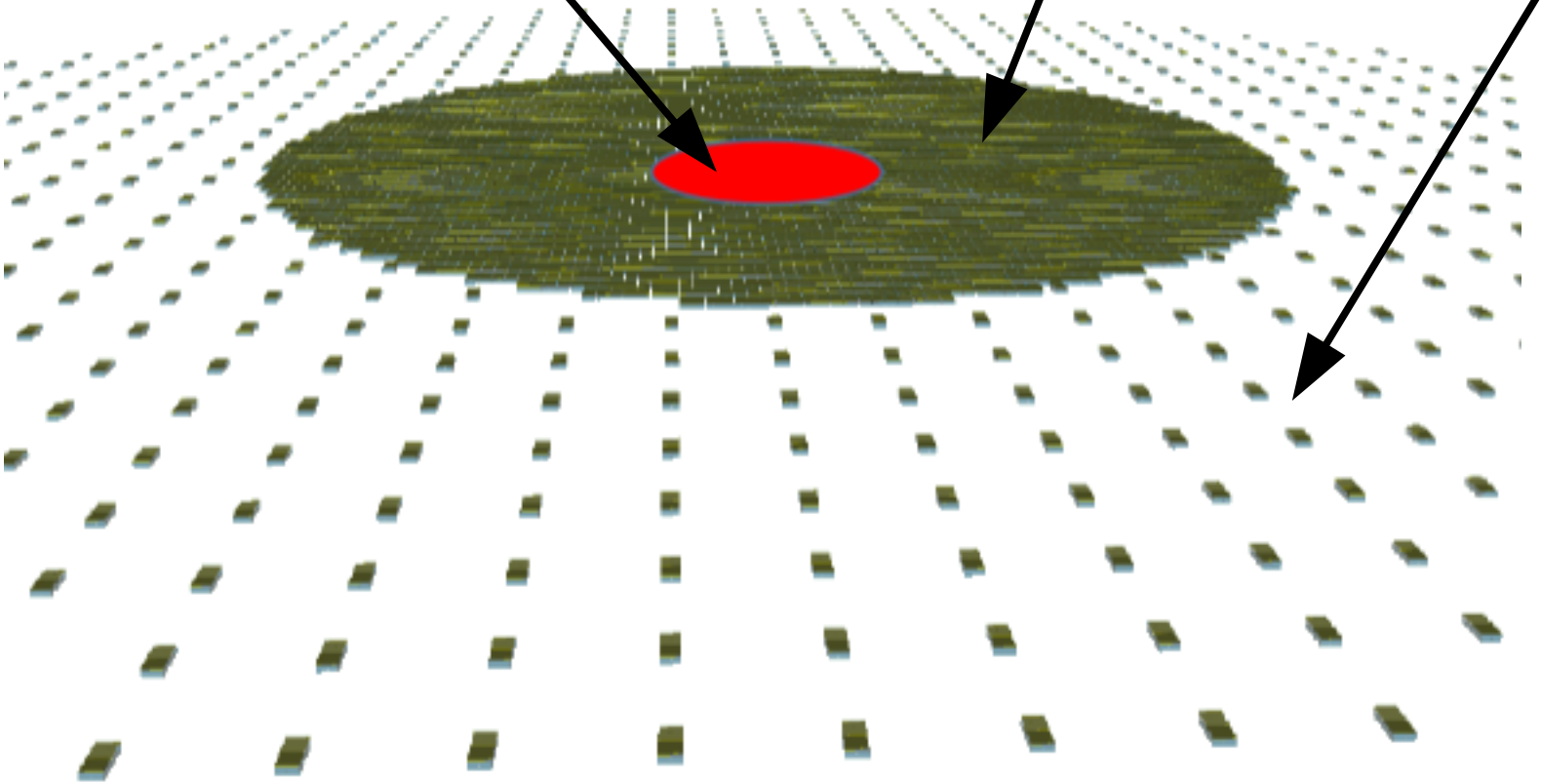
Sens. to steady sources

1 yr of data taking

5σ detection

The LATTES concept design is estimated to extend the VHE monitoring capabilities down to 100 GeV, supporting pointed instruments like CTA.

Investigation of alternatives



Conclusions

- VHE emission is an intriguing property of blazars. It is expected to be a major feature in HSPs and extreme sources, but is also detected in flaring activity of other sources.
- LATTES proposes an innovative detector concept that will enable EAS arrays to explore the VHE spectrum from sub-TeV domain with unprecedented performances.
- The observation of this energy domain is critical in the investigation of blazar jet physics, flares and particle acceleration mechanisms; this spectral window also probes the Universe's opacity to *γ*-rays.
- LATTES provides a solution that overcomes the FoV problems of IACTs and the effective area constraints of satellites; preliminary studies are promising, and there are opportunities of cooperation.

Acknowledgements

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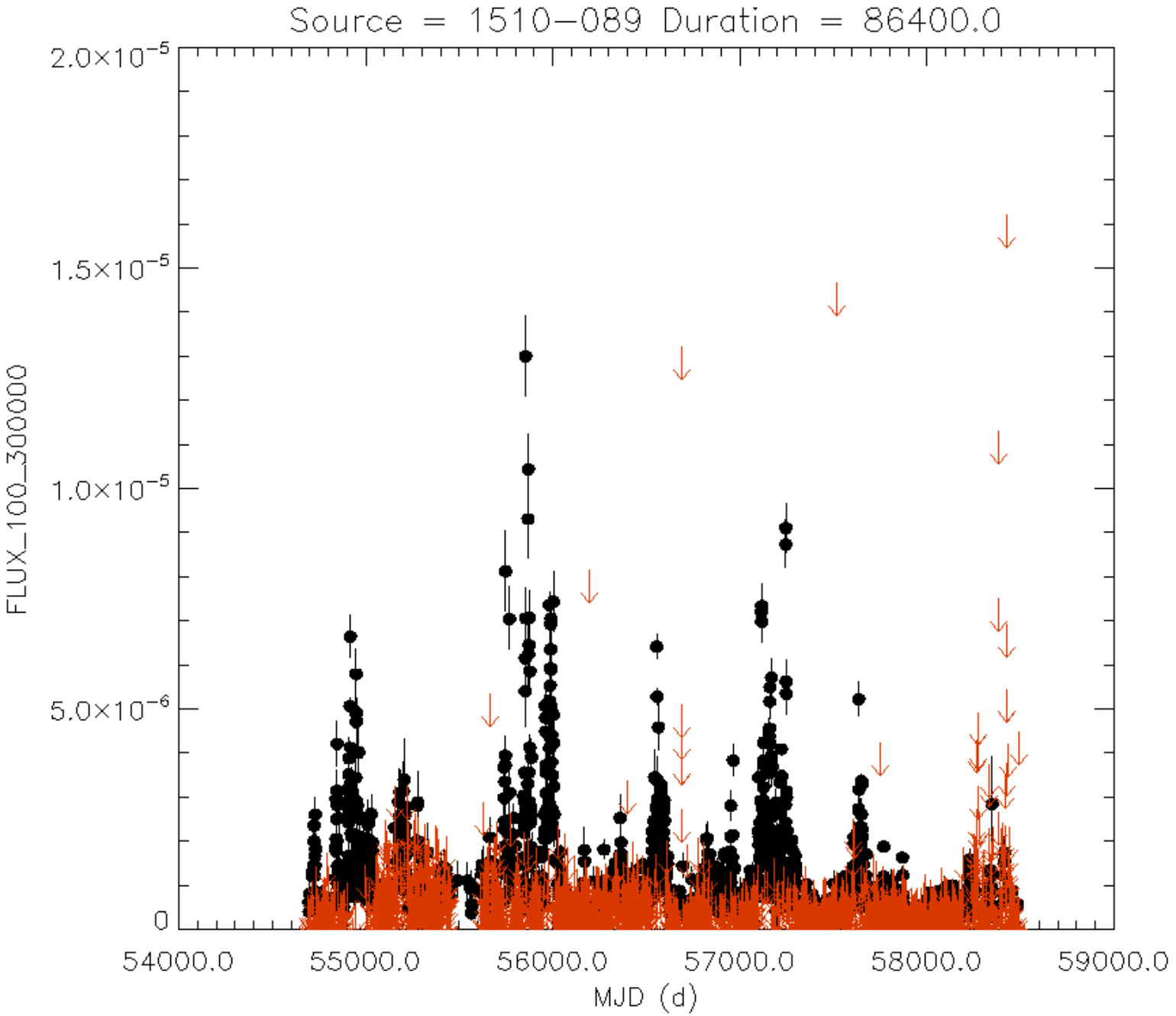
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

REPÚBLICA PORTUGUESA

LIP

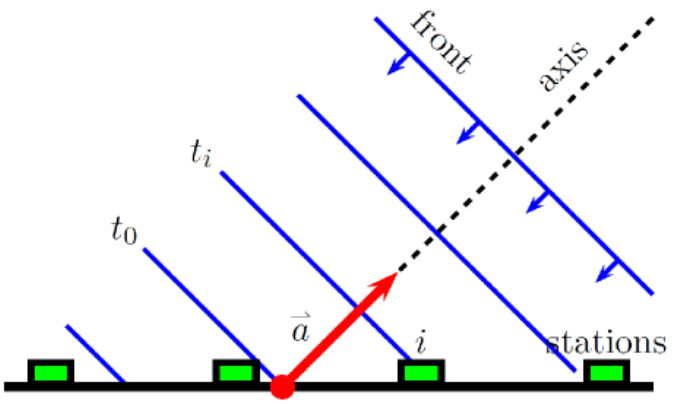
Backup slides

PKS 1510-089, not extreme, but extremely variable...

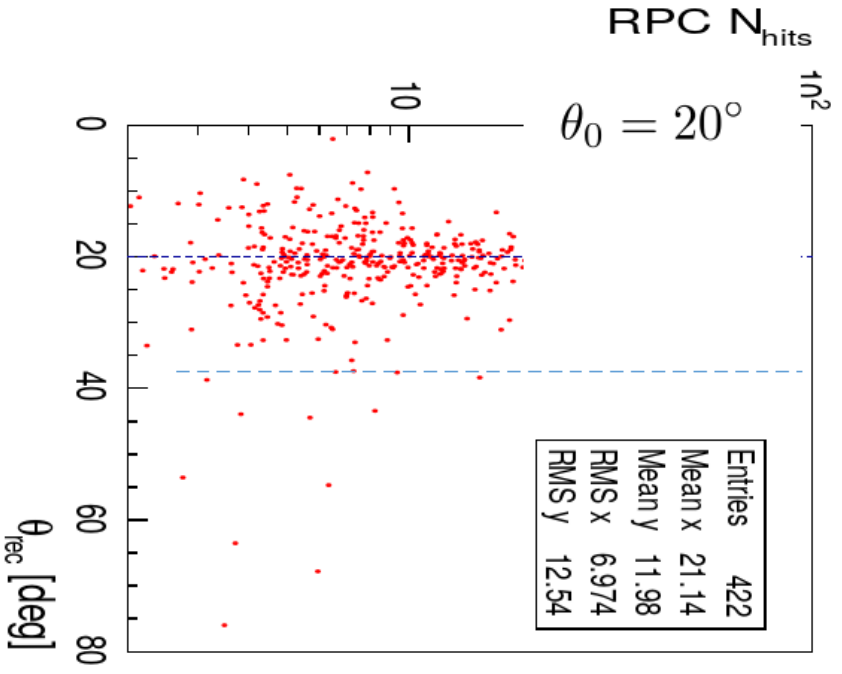


Reconstruction of shower geometry

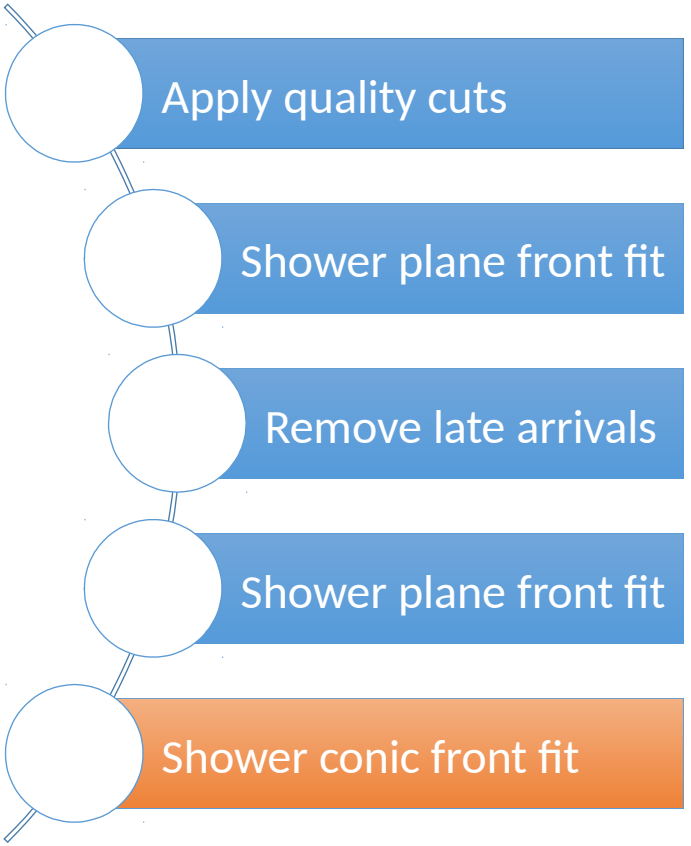
- Use RPC hit time information to reconstruct the shower
  - Take advantage of high spatial and time resolution



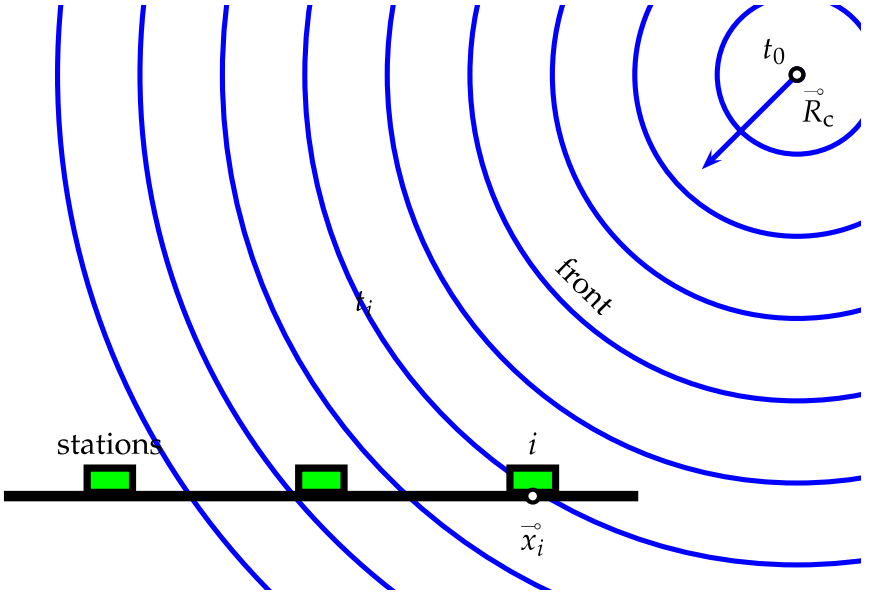
- Shower geometry reconstruction:
  - Use shower front plane approximation
  - Analytical procedure
  - Apply trigger conditions
  - Apply cut on the number of registered hits by the RPCs



Reconstruction of shower geometry



- Use RPC hit time information
  - Fit the shower geometry using a shower conic front model
  - Depends on core position



Cosmic rays and station trigger rate