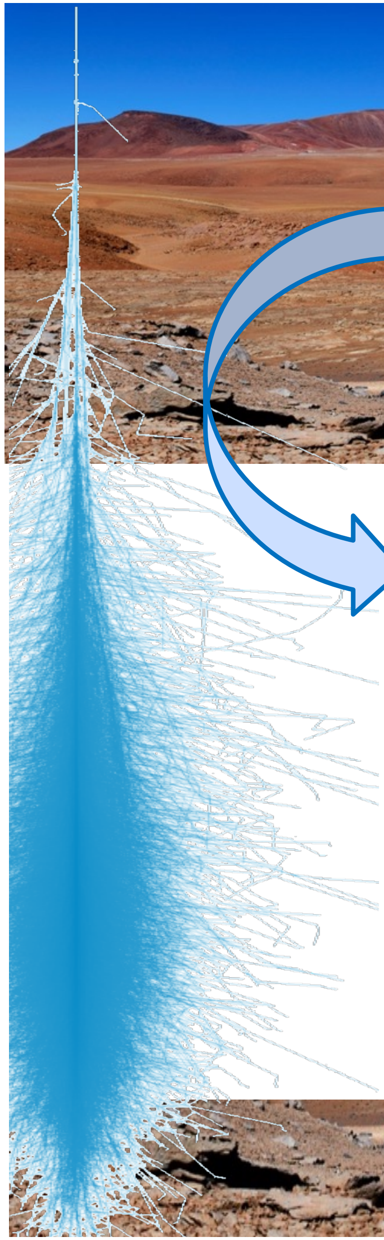


LA✕ES: a proposal for a novel EAS gamma-ray detector concept

Kind Of Name (for a) Detector Of Radiation

Michele Doro

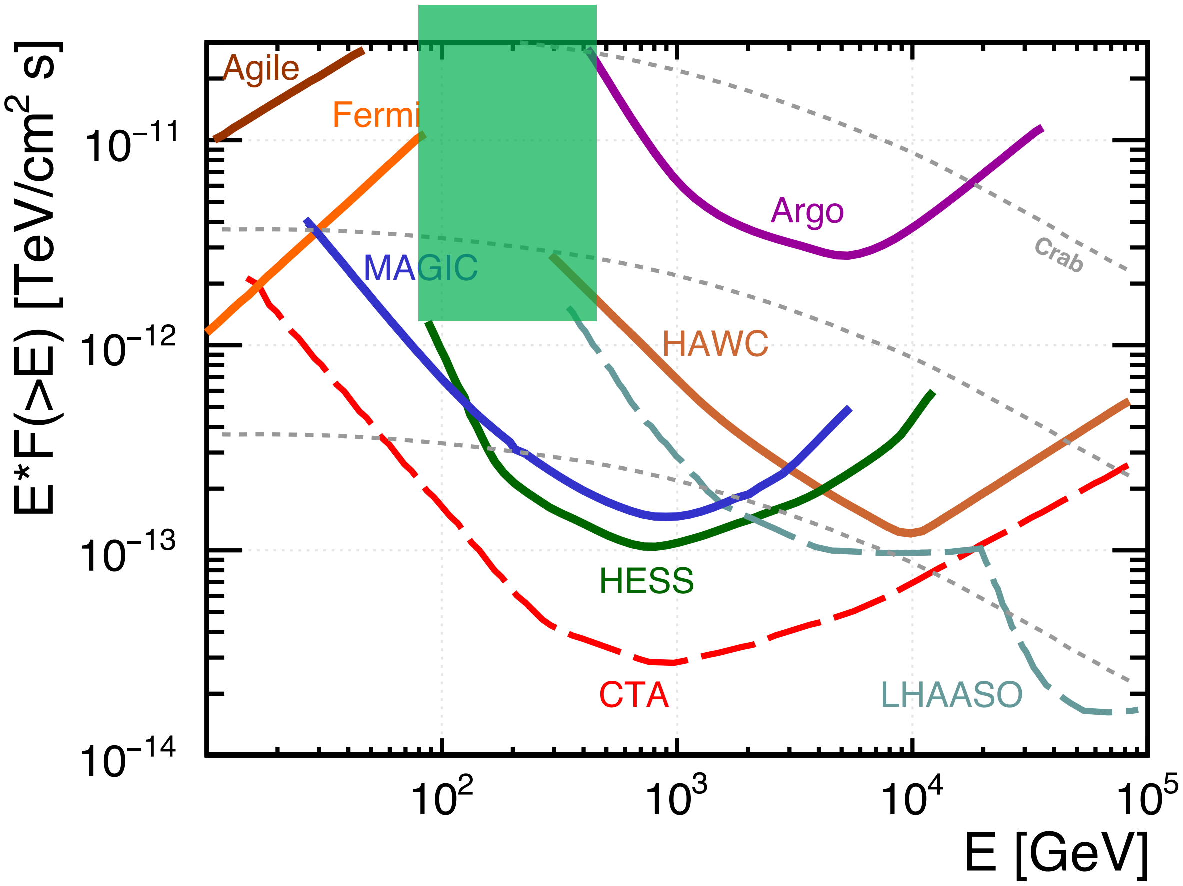
University & INFN Padova (michele.doro@pd.infn.it)

For P. Assis, U. Barres de Almeida, A. Blanco, R. Conceição, A. De Angelis, P. Fonte, L. Lopes, G. Matthiae, M. Pimenta, R. Shellard, B. Tomé

7th Workshop on Air Shower Detection at High Altitude

from 30 November 2016 to 02 December 2016 (Europe/Rome) *Torino*

Motivation



- **Goal:**
  - Fill the gap between 100 GeV and 1 TeV of all-sky gamma-ray instruments
- **Why?**
  - S-hemisphere not convered
  - Create large GeV-TeV leveral arm: Fermi/HERD-CTA-LATTES
  - TeV transients monitoring
  - CTA alert support

Proposers

arXiv.org > astro-ph > arXiv:1607.03051

Astrophysics > Instrumentation and Methods for Astrophysics

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

P. Assis, U. Barres de Almeida, A. Blanco, R. Conceição, B. D'Ettore Piazzoli, A. De Angelis, M. Doro, P. Fonte, L. Lopes, G. Matthiae, M. Pimenta, R. Shellard, B. Tomé

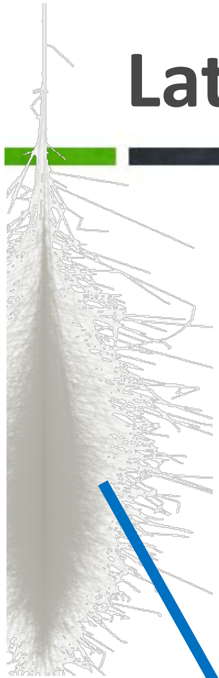
(Submitted on 11 Jul 2016)

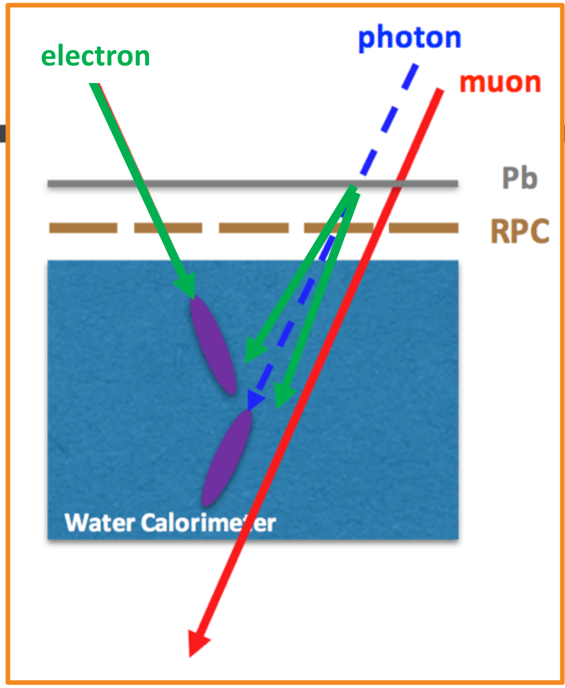
*→ **DISCLAIMER: Only low-energy compact core investigated in this document.***

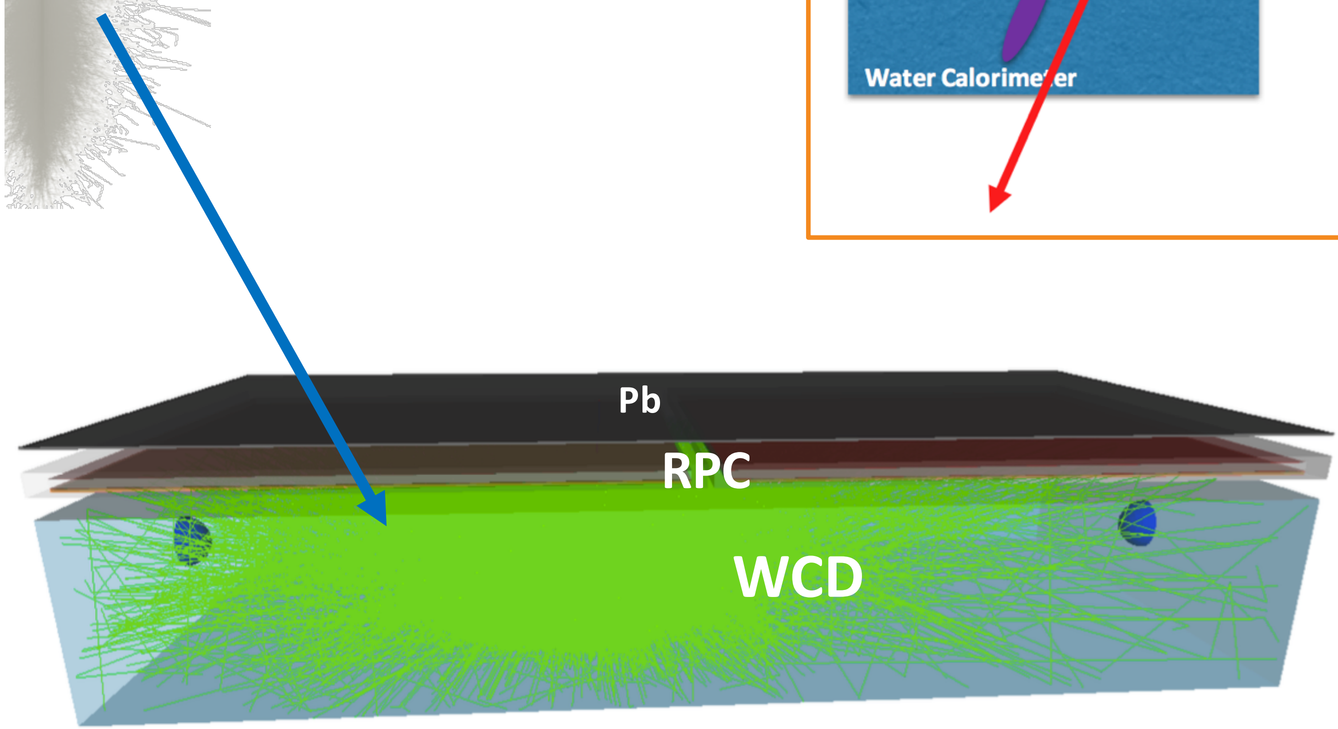
Working toward creating official partnerships and status with funding agencies

Technological idea (still developing)

Lattes unit station



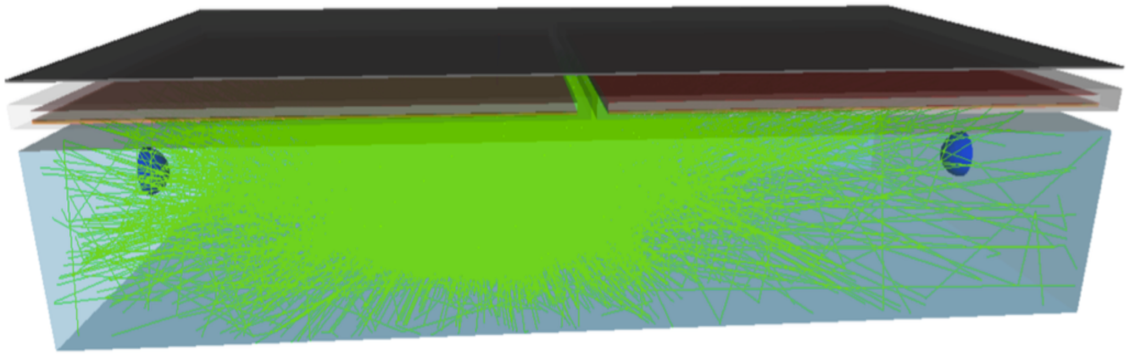




- **1/ Thin lead plate**
  - **To convert** the shower Bremmshtralung GeV **photons**
  - Improve sensitivity + geometric reconstruction
- **2/ Resistive Plates Chamber**
  - Sensitive to charged particles
  - Good **time and spatial resolution**
  - Improve geometric reconstruction:
  - Explore shower **particle patterns at ground**
- **3/ Water Cherenkov Detector**
  - Sensitive to secondary photons and charged particles
  - Measure **energy** flow at ground
  - Improve trigger capability
  - Improve gamma/hadron discrimination

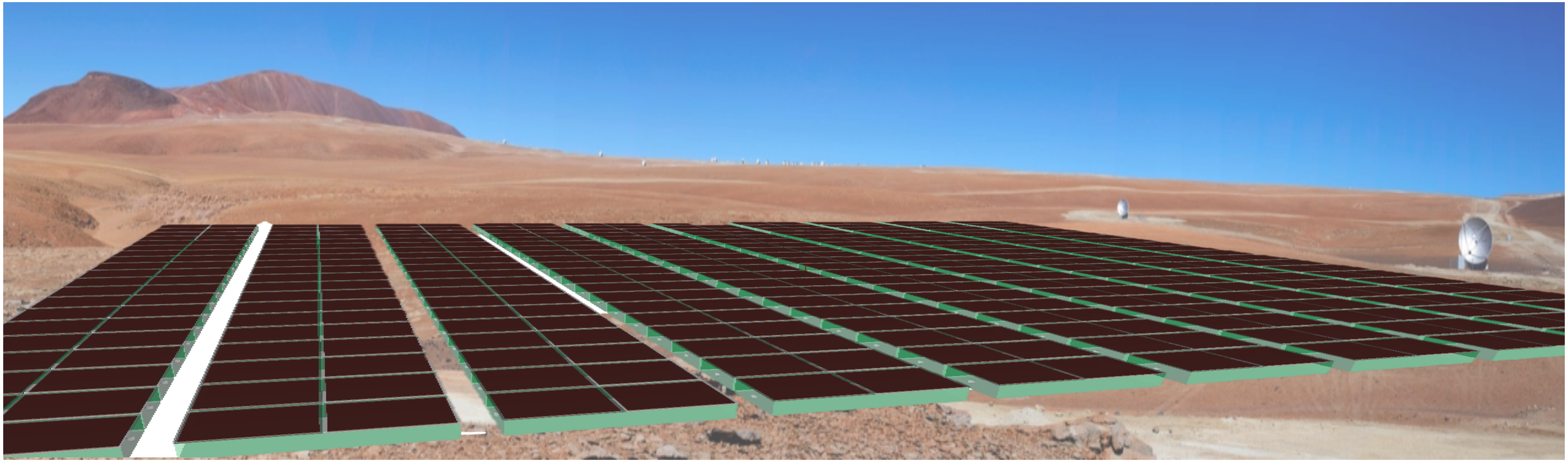
Lattes unit station

- **Thin lead plate (Pb):** 5.6 mm (one radiation lenght)
- **Resistive Plate Chambers (RPC)**
  - 2 RPCs per station. Each RPC with 4x4 readout pads
  - RPC: 100 μm spatial resolution, 50 ps time resolution
- **Water Cherenkov Detector (WCD)**
  - 2 PMTs (diameter: 15 cm)
  - Inner walls covered with white reflective paint



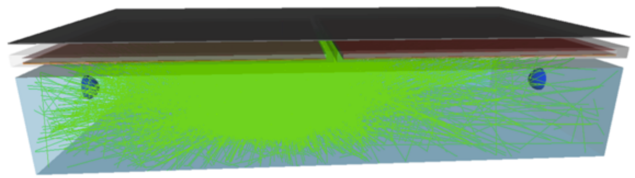
Dimensions: 1.5 m x 3 m x 0.5 m

LATTES concept

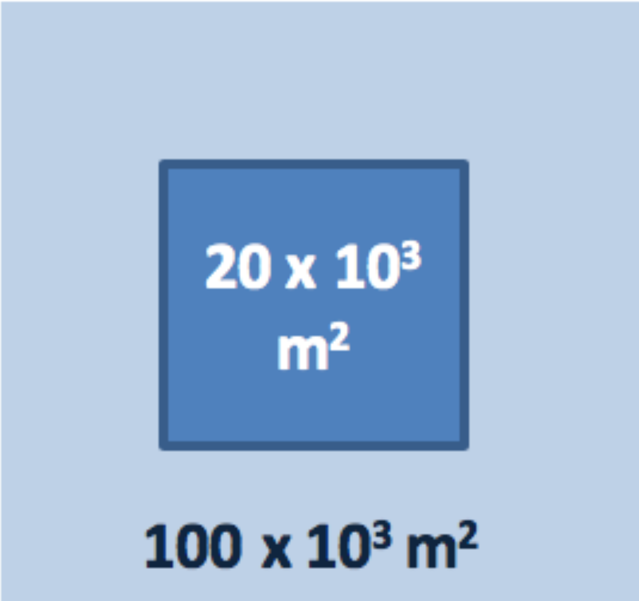


LATTES core array
30 x 60 stations
100 x 100 m^2

LATTES station
1.5 m x 3 m x 0.5 m



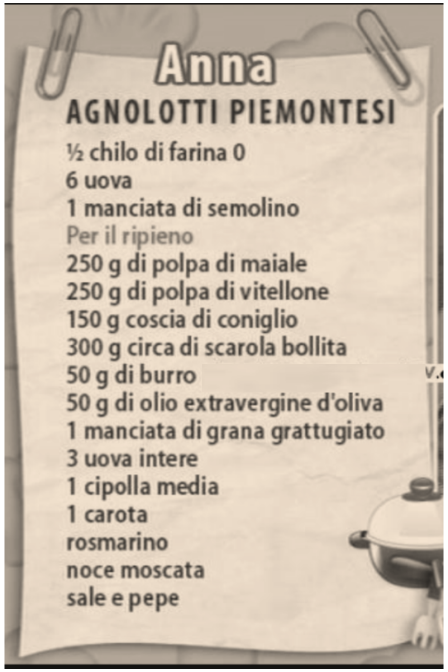
LATTES-TeV extension



Addition of an external corona of sparse detectors to reach higher energies

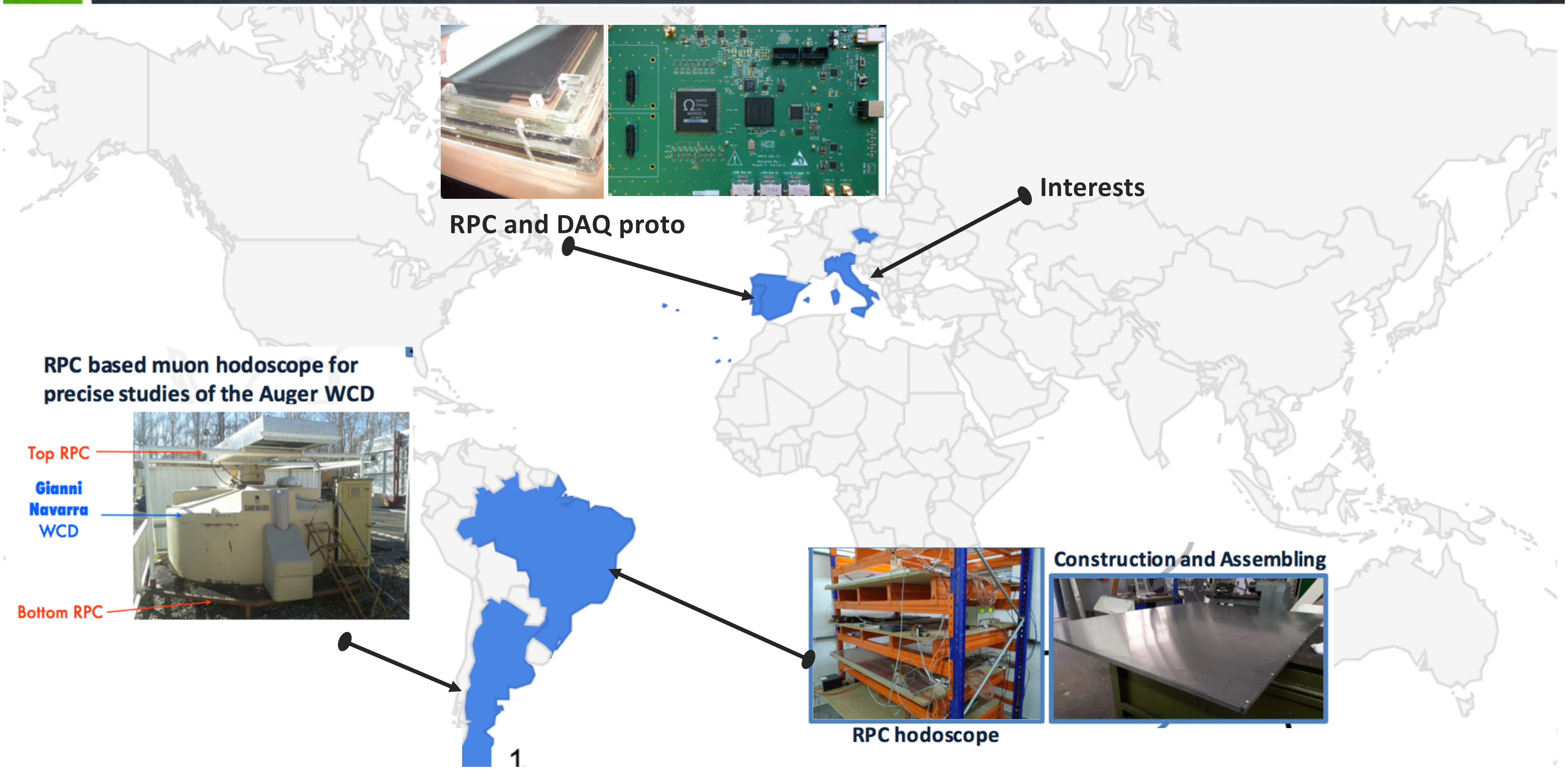
- LATTES-core (2.10^4 m^2) performance addressed in arxiv: 1607:03051
- LATTES-sparse detectors array (10^5 m^2)
  - Add about 500 stations
- On-going simulations to assess performance at high-energies

Design drivers and ingredients



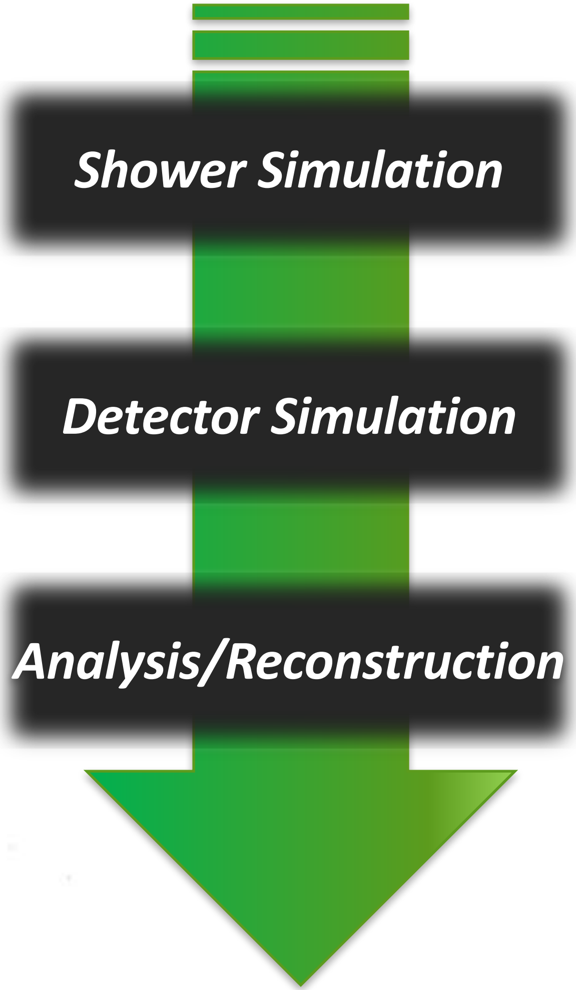
- Compact and small unit to be able to go to very high-altitude (5000+m asl)
  - Hybrid solution required (RPC+WCD)
  - Use of inner reflective layer in the WCD
  - Use of conversion layer on top
- Goal is to go to sub-TeV scale
- G/H separation:
  - Explore time and space distribution at ground (hit pattern & bright islands)
  - Inter-calibration between RPC hits and WCD phes
- Core + sparse array

R&D ongoing


RPC and DAQ proto
Interests
RPC based muon hodoscope for precise studies of the Auger WCD
Top RPC
Gianni Navarra WCD
Bottom RPC
Construction and Assembling
RPC hodoscope

Performance

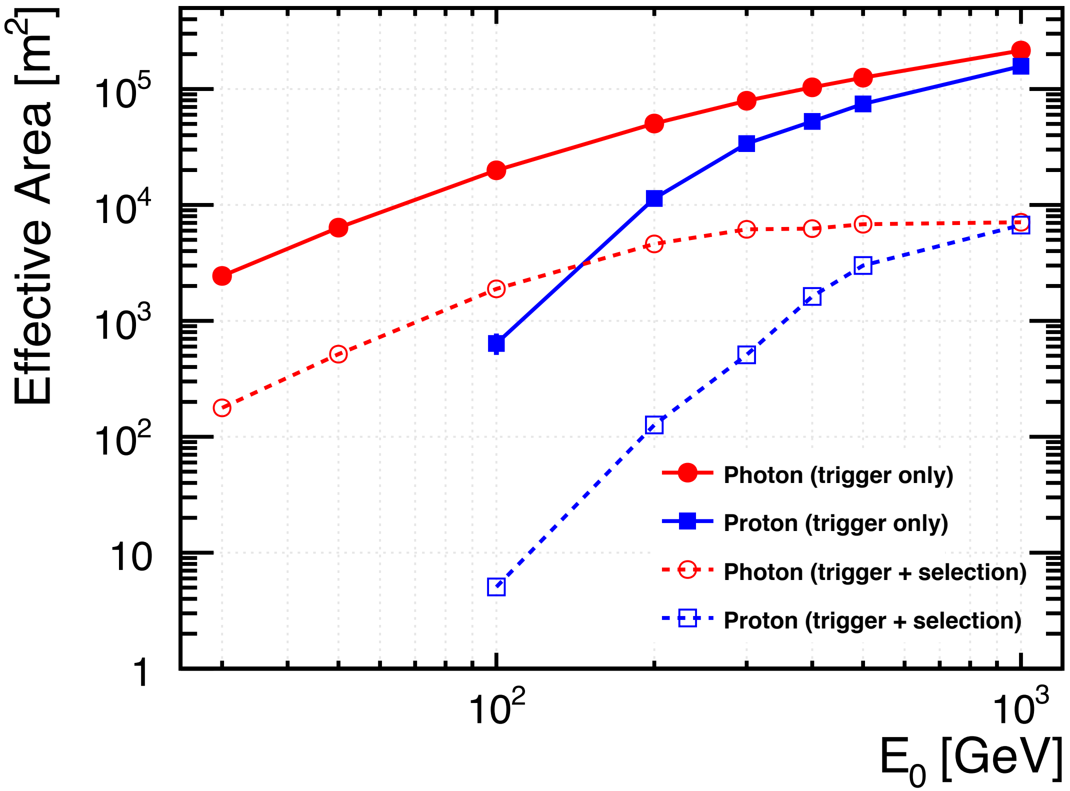
Simulation Framework



Complete **end-to-end simulation** chain to evaluate performance

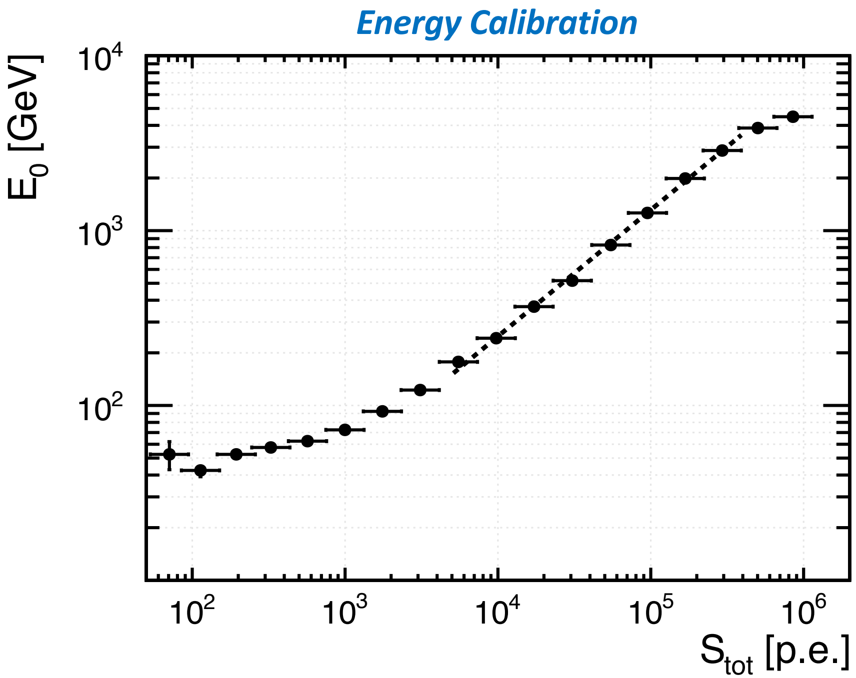
- Showers simulated using **CORSIKA**
- Detector layout and simulation performed by **Geant4**
- **LATTESsim**: Integrated toolkit to study and optimize LATTES performance (**B. Tomè, R. Conceição, LIP, Portugal**)

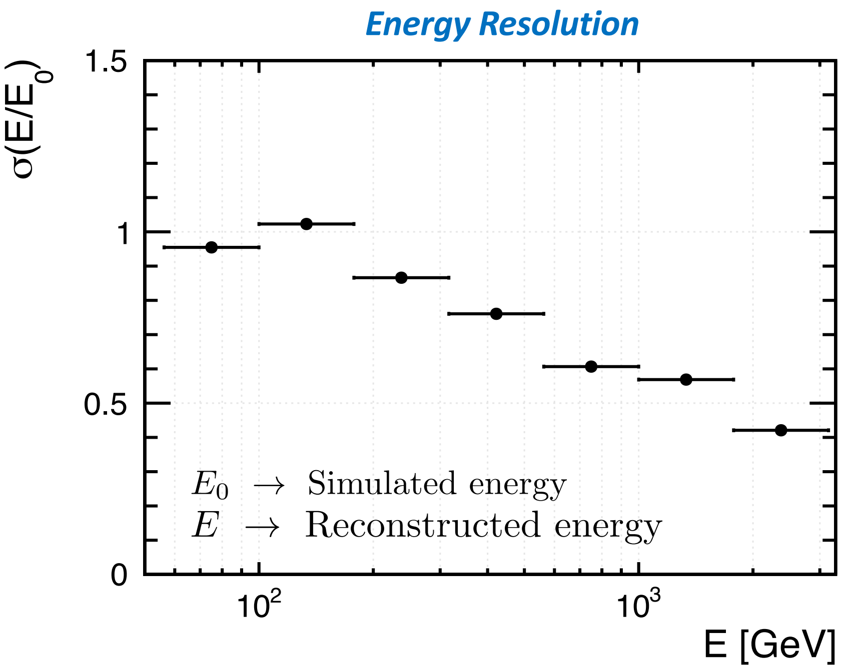
Trigger efficiency



- Use WCD stations to trigger at low energies
  - Trigger condition
    - Station: require more than 5 p.e. in each PMT
    - Event: require 3 triggered stations
  - *Effective Area of 1000 m^2 at 100 GeV! (after quality cuts)*
- Need to discriminate g/h!

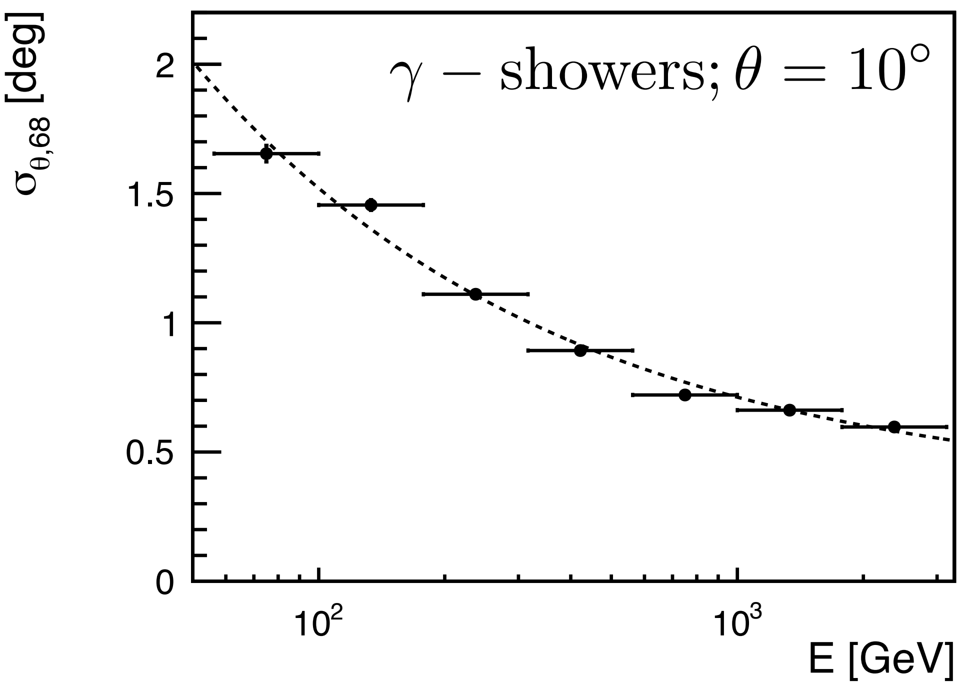
Energy reconstruction





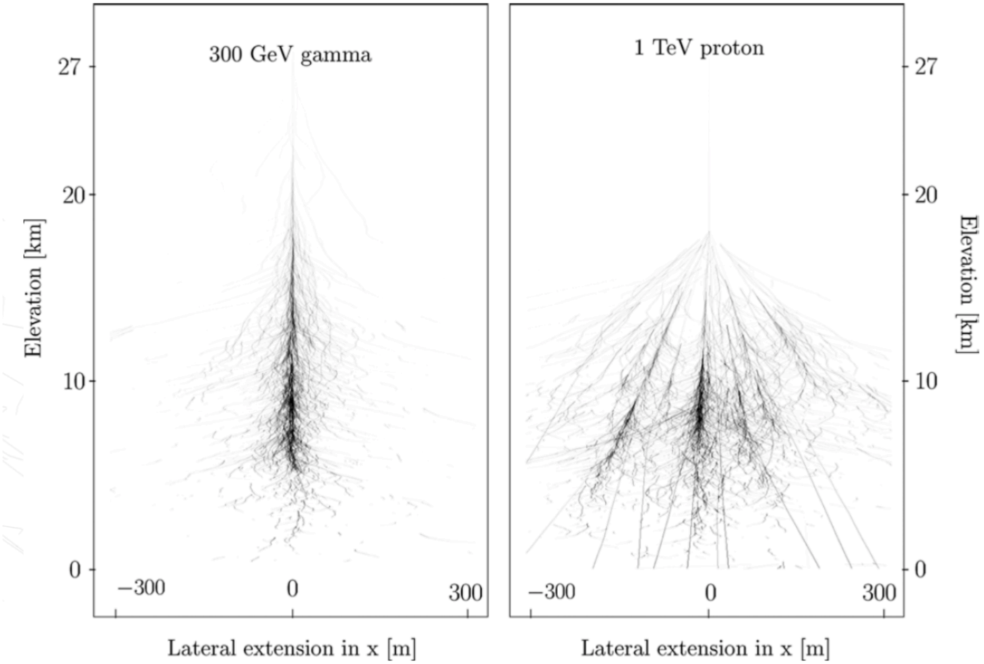
- Use as energy estimator the total signal recorded by WCDs
- Energy resolution below 100% even at 100 GeV
  – Dominated by the shower fluctuations

Geometric reconstruction



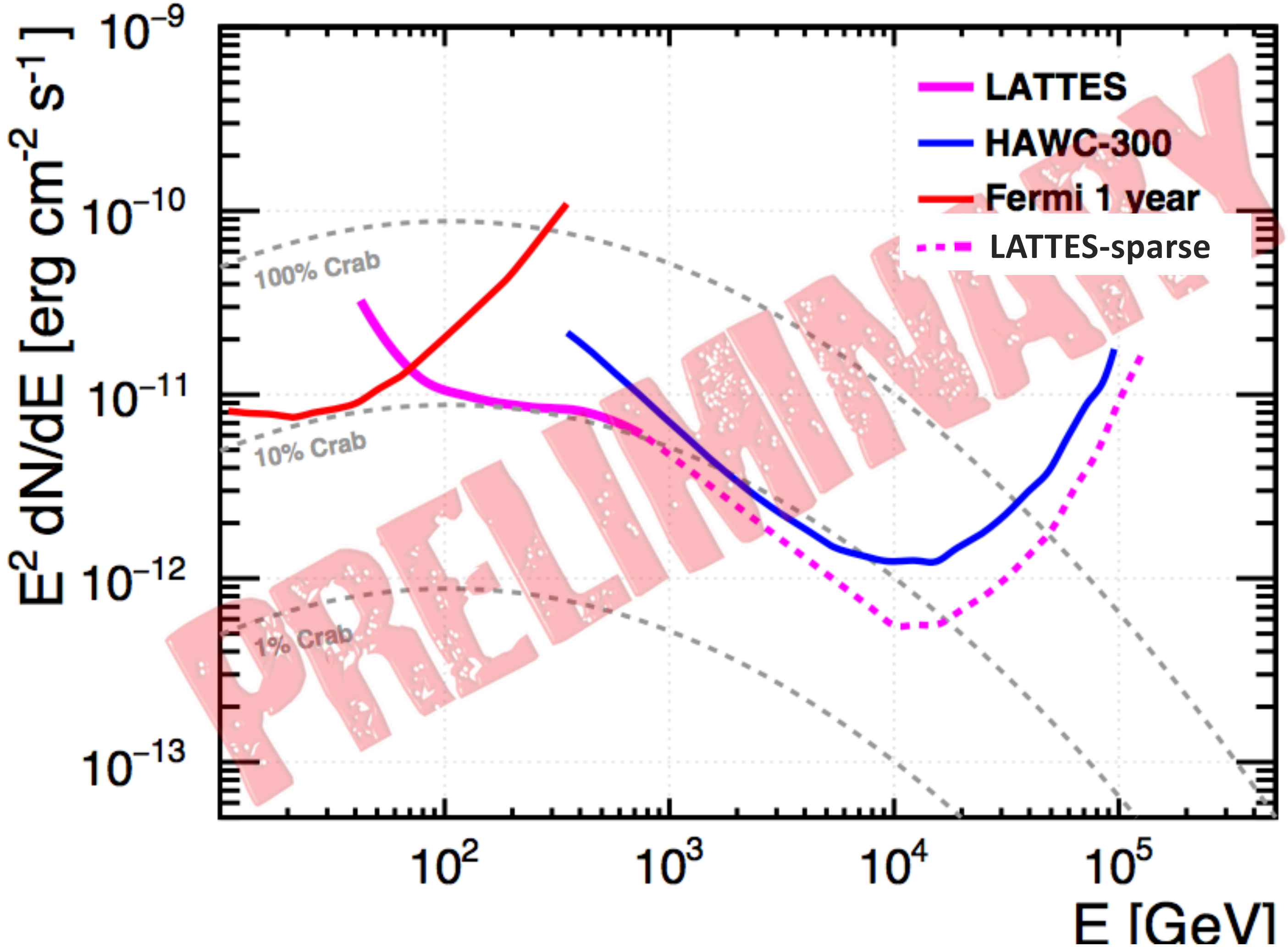
- Shower **geometry reconstruction** done using **RPC hit time**
  - Take advantage of RPCs **high spatial and time resolution**
    - Consider a time resolution of 1 ns
  - Use shower front plane approximation
  - Require more that 10 hits in the RPCs
- – *Angular resolution below 2 deg even for 50 GeV showers*
- – Expected improvements: Account for shower front curvature & Weight each RPC by WCD signal

Gamma/hadron separation



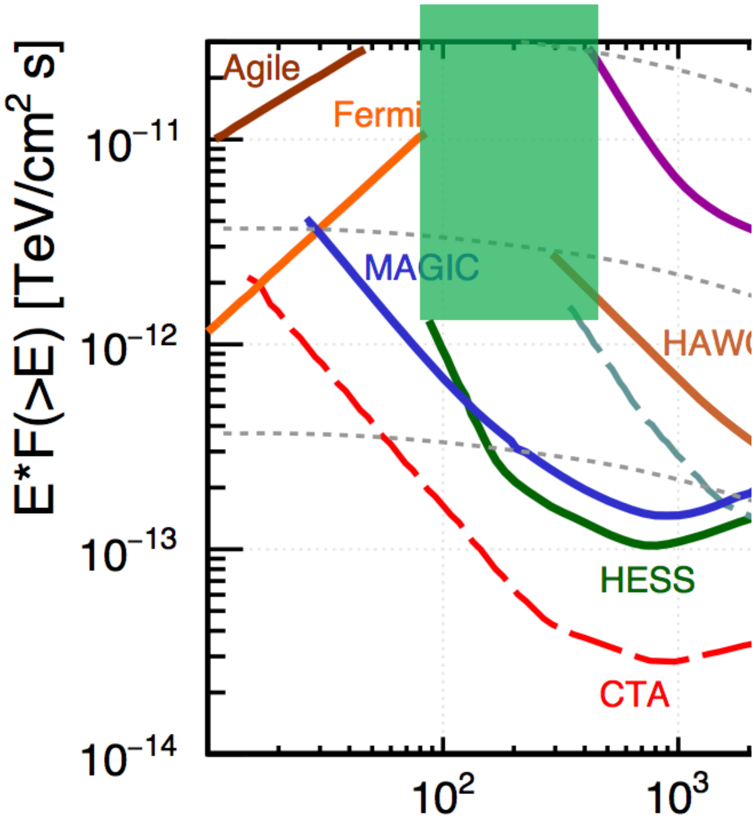
- **Hit pattern at ground**
  - Hits from hadronic showers are more sparse than in gamma induced showers
  - RPC detectors
  - Explored by the ARGO collaboration
- **Search for energetic clusters far from the shower core**
  - Present only in hadronic showers
  - Water Cherenkov Detectors
  - Explored by the HAWC collaboration
- Combine both strategies using an hybrid detector: LATTES

LATTES sensitivity (core+ext)



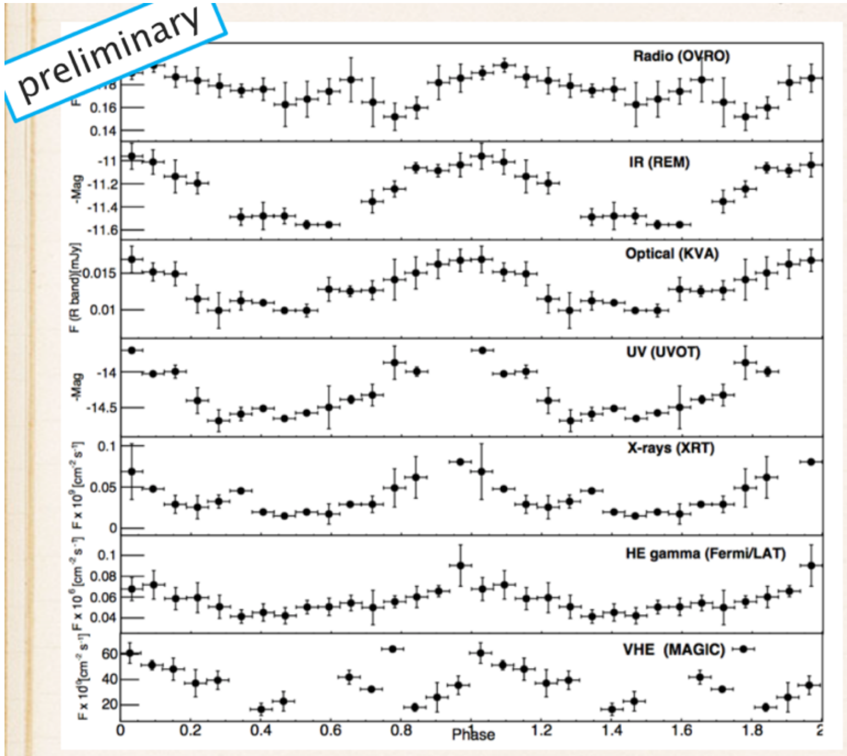
Science

LATTES and IACT



- It is clear that IACTs, and specially CTA will be 10-100x more sensitive than LATTES, however particle detectors have:
  - Larger duty cycle (~10x)
  - Larger FOV (~1000x?)
- There is a **complementarity or ancillarity:**
  - High energy extension to make science
  - Transient monitoring and trigger

1. Long-baseline/slow-monitoring



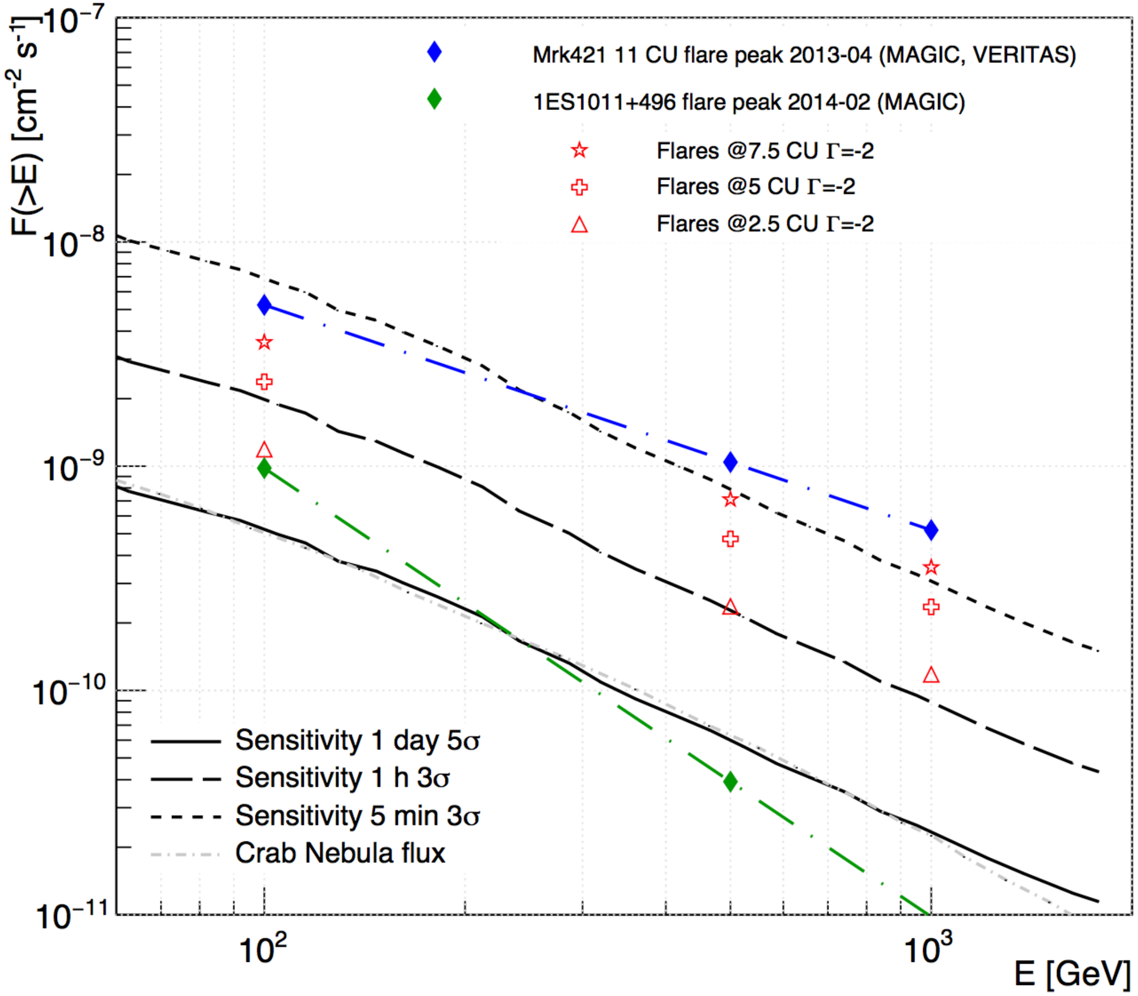
Da Vela+ Proc. Gamma2016

The target of interest for long-baseline are many and for different reasons.

- **Galactic Center** for BH-environment close-by evolution
- **AGN** for acceleration mechanism, dynamics, multi-w campaign, variability ratios
- **Peculiar objects** like the Crab Nebula, the PG1553, all short-term (quasi-) periodic
- …many…

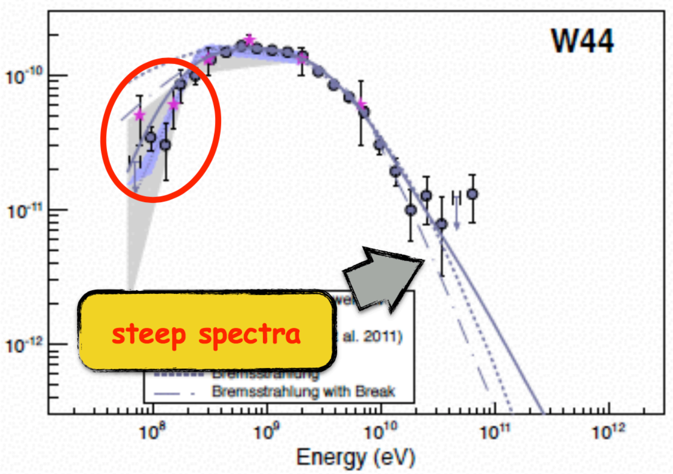
Very important here to be able to provide **spectral evolution**, not only flux evolution

2. Fast monitoring



- Hottest topics:
  - GRBs
  - AGN flares
  - GWs
  - Flash Radio Bursts
  - (Primordial Black Holes evaporation)
- Also as (unique?) TeV-triggers system for CTA in the S-hemisphere

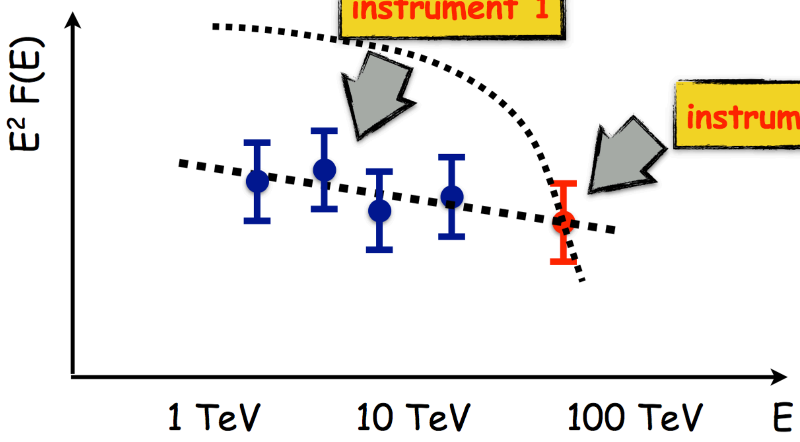
3. Pevatrons (see Gabici's talk at this conference)



Observations Let's assume SNRs do accelerate up to the knee

p-p interactions -> $E^{p}_{max} \sim 1 \text{ PeV} \longrightarrow E^{\gamma}_{max} \sim 100 \text{ TeV}$

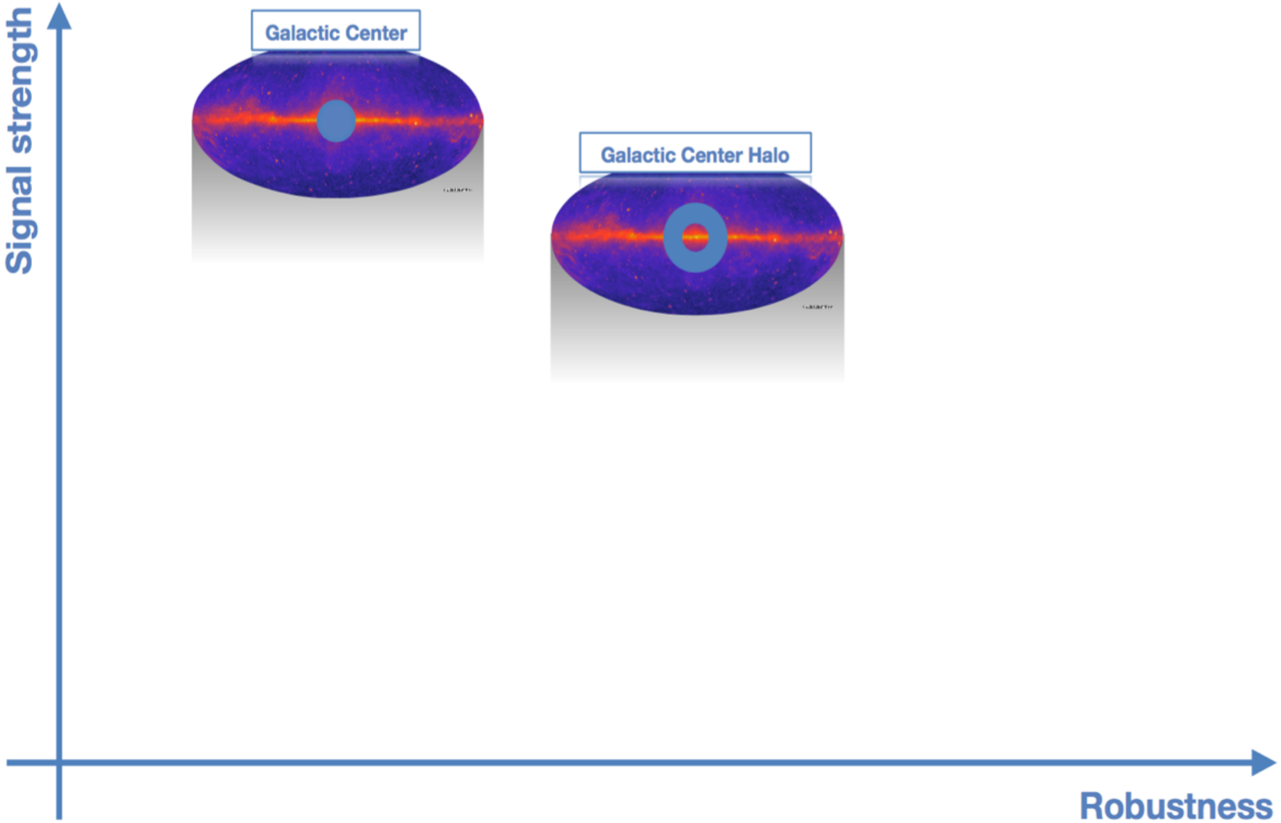
inverse Compton-> suppressed above several tens of TeV (Klein-Nishina effect)



It is not enough to detect something at >>1 TeV

- Hadronic model hopefully probed by sinergy IACT+EAS detectors

4/ Dark Matter



❖ ***Galactic halo and the halo around***
+ Highest *J-factor*
- Strong Astrophysical contamination
- Huge uncertaintiy in core\cusp

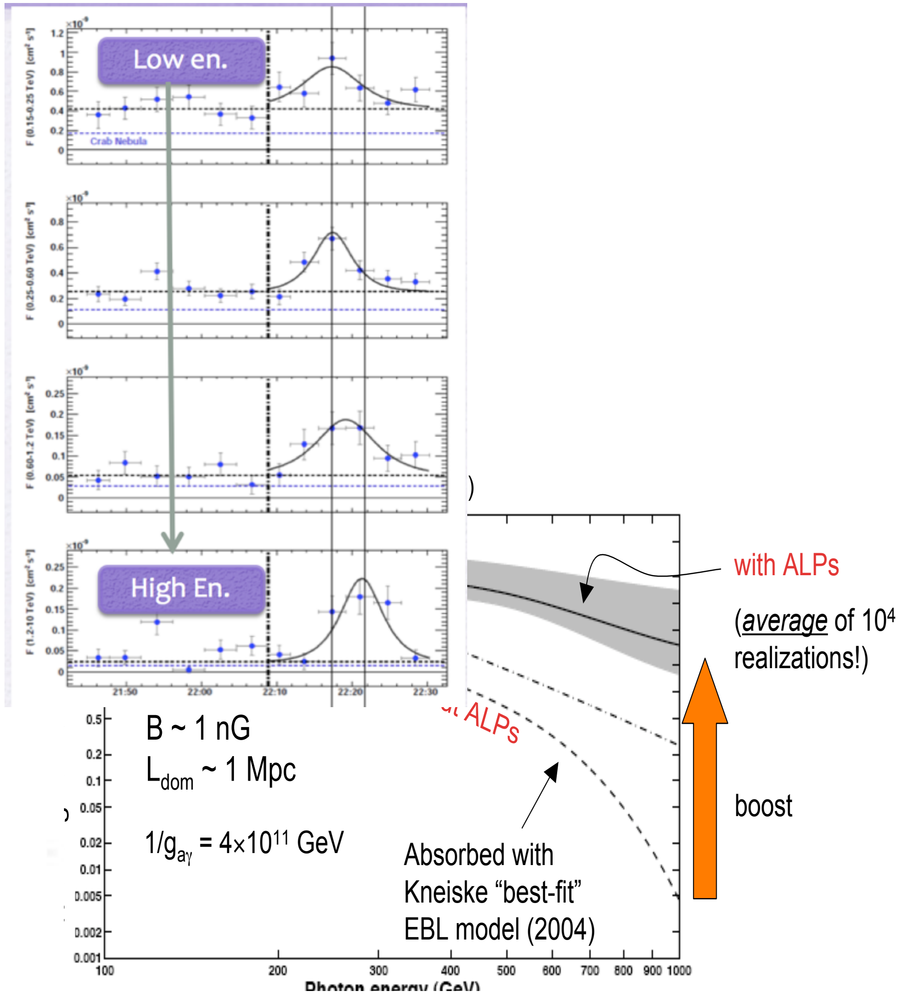
❖ ***Galaxy Clusters***
+ Huge amount of DM but far distance → moderate/low J-factor
– High astropysocal contamination
- Large uncertainties in baryon feedback and substructure contribution

❖ ***Dwarf Galaxies***
+ DM dominated (high M/L ratios) and Free from astroph. bkg
+ Less uncertainties on *J-factors*
- Low J-factor

❖ ***Dark Clumps?***
+ Free from astroph. bkg
+ Nearby and numerous
– How to know where they are?
– Bright enough?

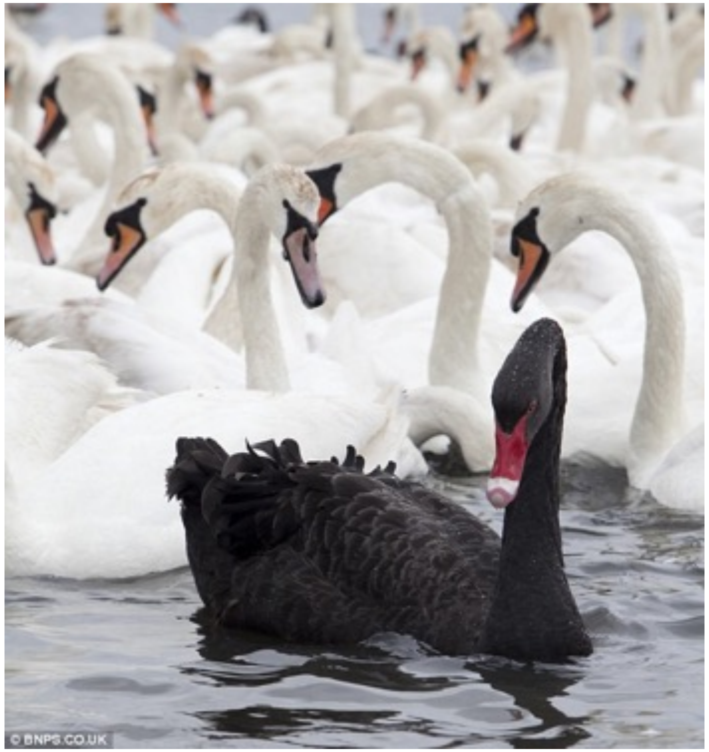
❖ ***DM anisotropies***
+ In principle possible with LATTES although challenging

5. Fundamental Physics



- Besides dark matter, there are two active research fields now:
  - LIV from AGNs (or GRBs)
  - ALP from AGNs
- **LIV**: arrival time delay from g-ray flare versus g-ray energy should disperse
- **ALP**: spectral changes: photon recovery and/or spectral wiggles
- LATTES would suffer from poor energy resolution…is it possible to improve it?

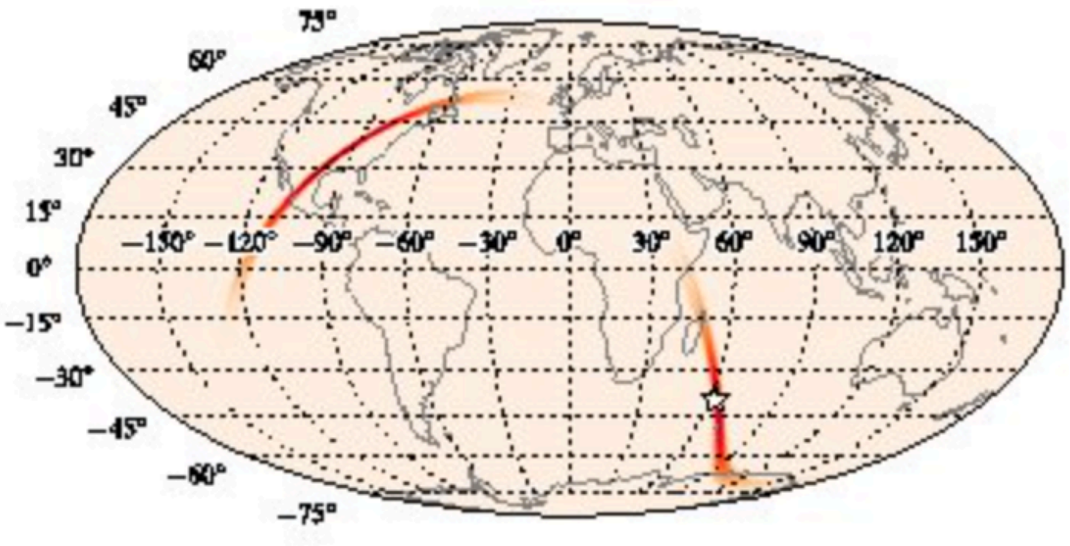
6. Rare Events



See also MD, Ricap 2016

- Magnetic monopoles or Quark matter.
  - Maybe they can provide peculiar signature in the calorimeter?
- Primordial black hole evaporation.
  - Formed in the early Universe, because of the Hawing radiation, those with a specific mass could be evaporating today: Brief bursts of gamma rays (similar to short GRBs)
- Dedicated pipelines needed

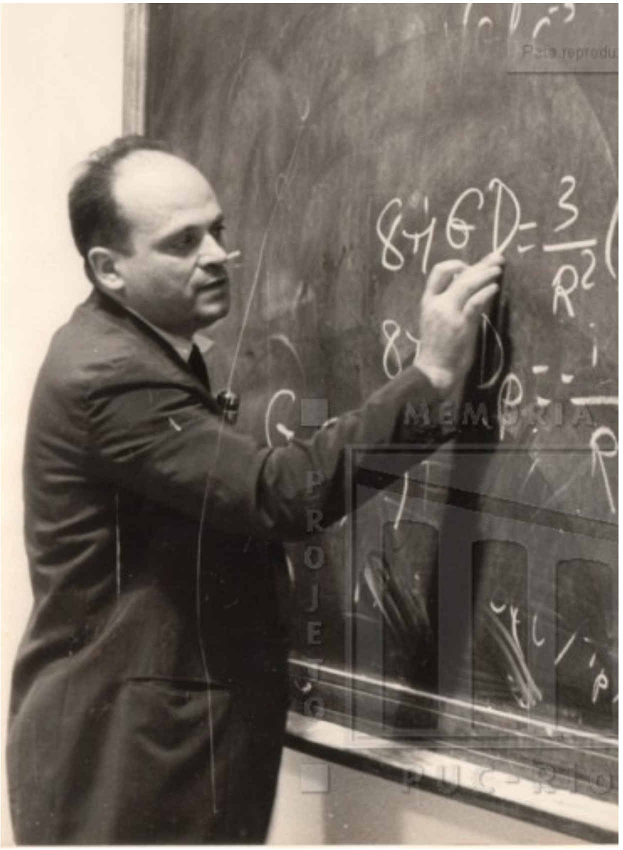
7. Gravitational Waves



- An instrument in the S-hemisphere can address the large uncertainty in the GW position due to large FOV

Conclusions

Summary



César Lattes

- **LATTES: GeV-TeV gamma ray wide field of view instrument in South Hemisphere**
- Complementary project to CTA to survey the center of the galaxy
- Next generation gamma-ray experiment (hybrid)
- Good sensitivity at low energies (100 GeV)
  - Cover the gap between satelitte and ground based measurements
  - Powerful tool to trigger observations of variable source and to detect transients
  - Produce useful spectra