LATTES: a new gamma-ray detector concept for South America

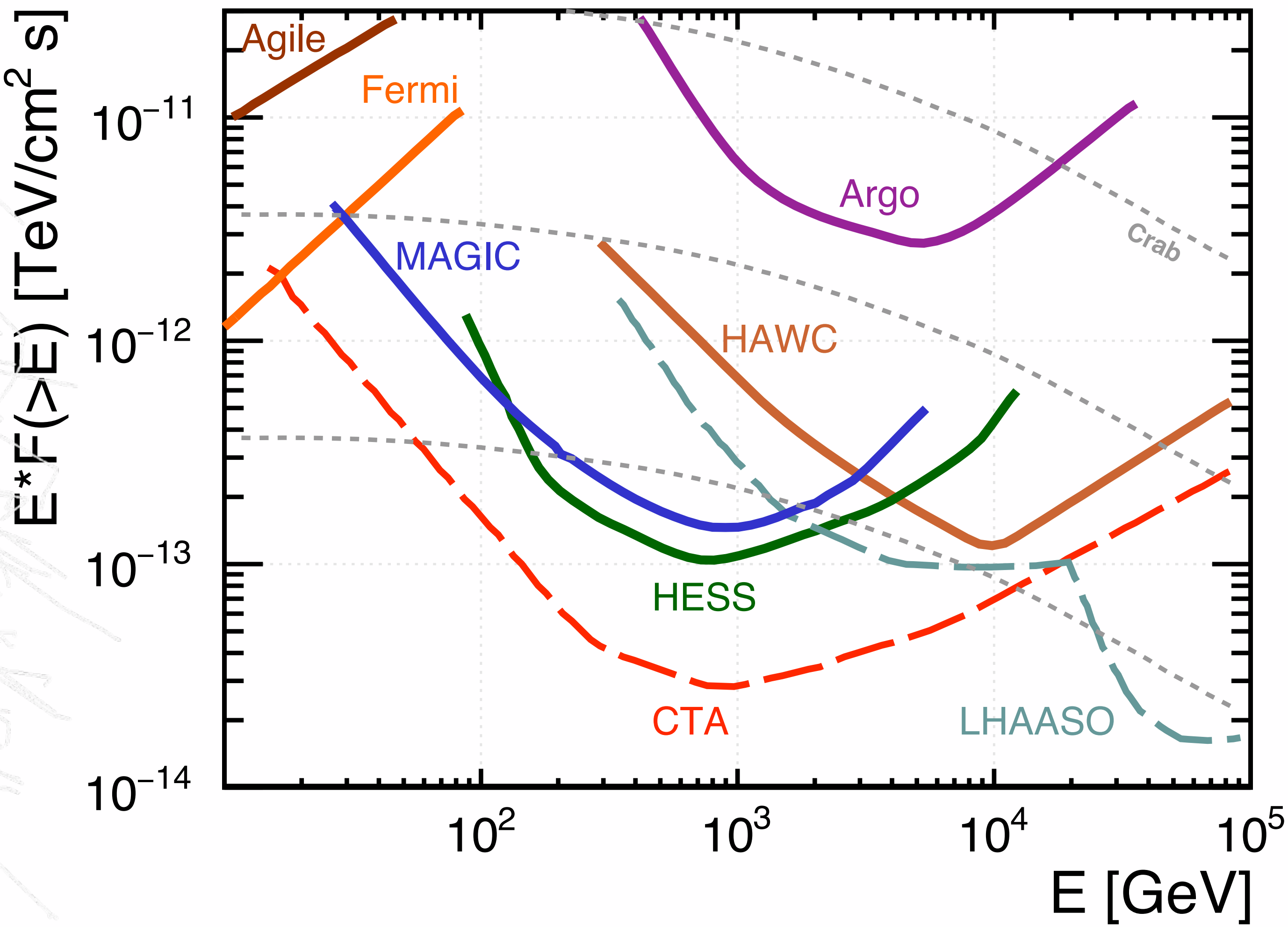
Ruben Conceição

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

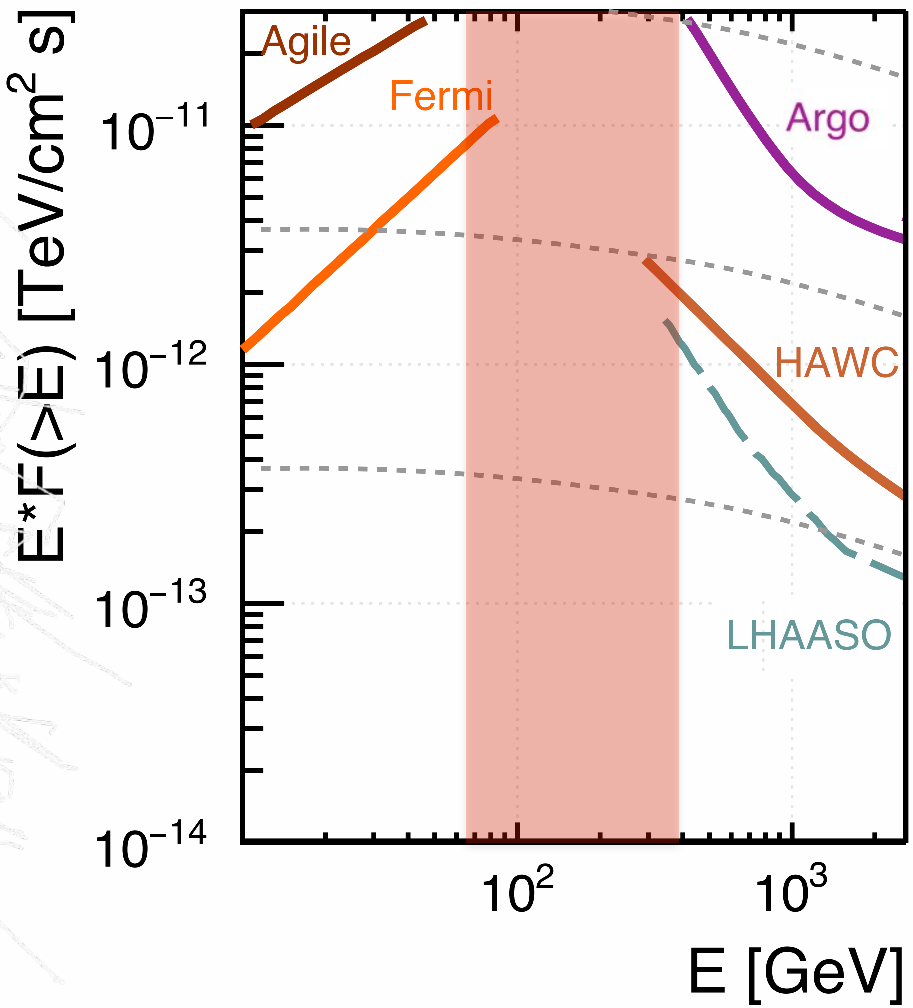
LIP

RICAP, Rome, June 23rd 2016

Current experimental status

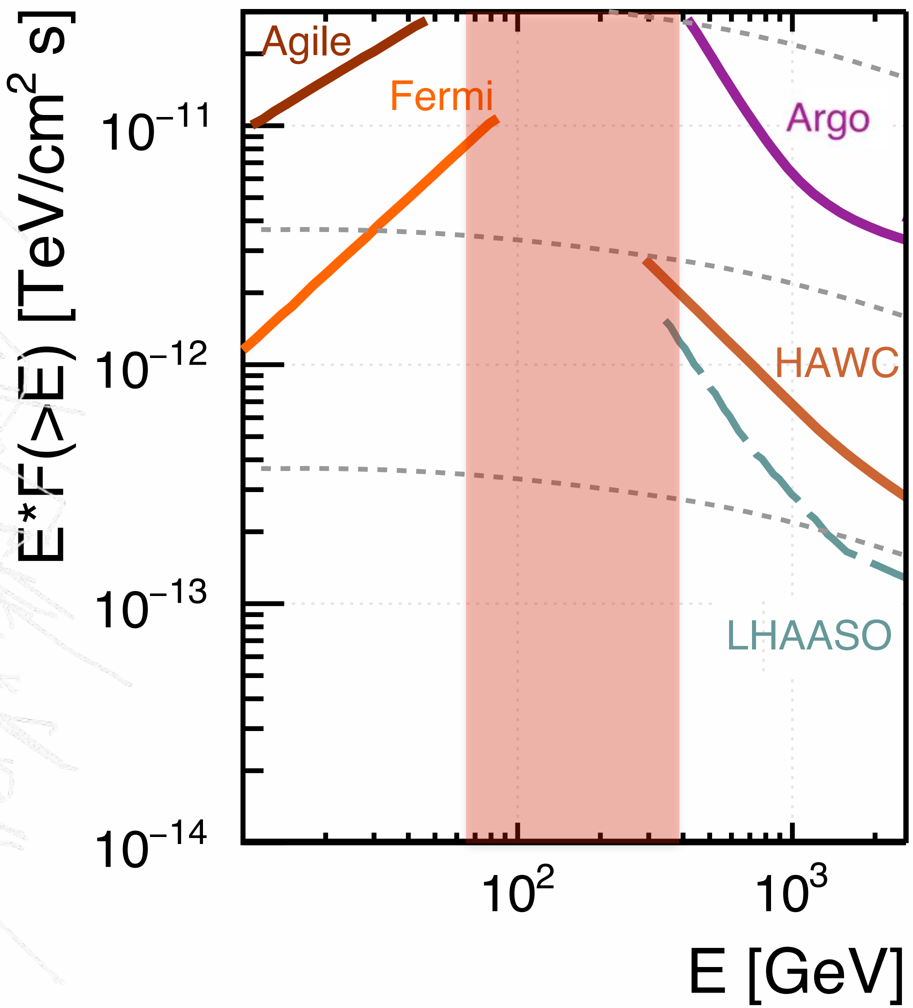


Current Situation



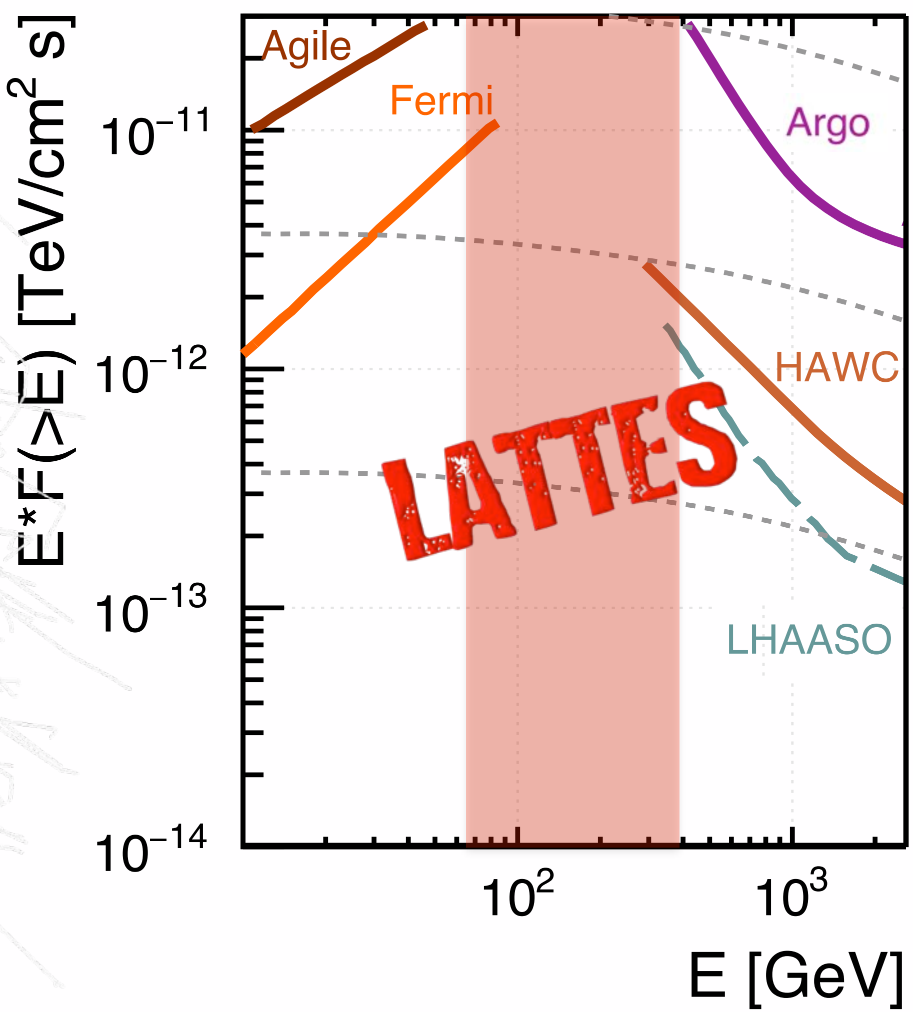
- No wide FoV experiment to:
  - Survey the Galactic Center (GC)
  - Explore the energy region of 100 GeV

Requirements



- Build an EAS array experiment:
  - Located in the South Hemisphere
  - Low energy threshold:
    - High altitude
    - Next generation detector concept

Solution



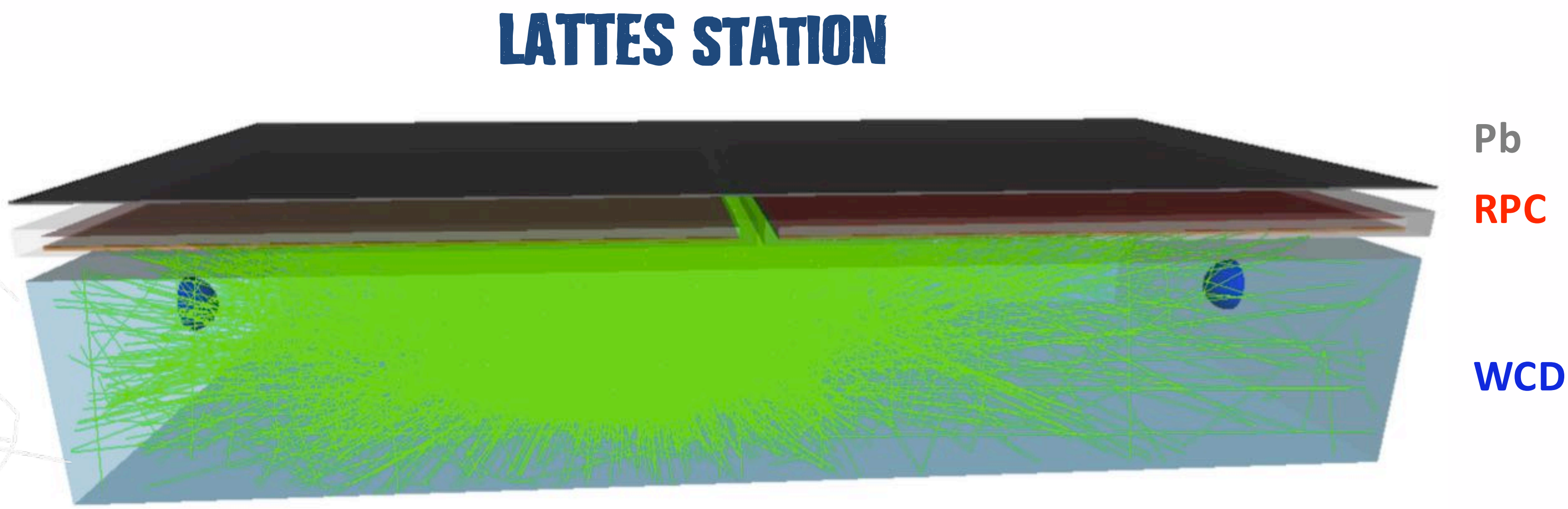
- Build an EAS array experiment:
  - Located in the South Hemisphere ✓
  - Low energy threshold:
    - High altitude ✓
    - Next generation detector concept ✓

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**

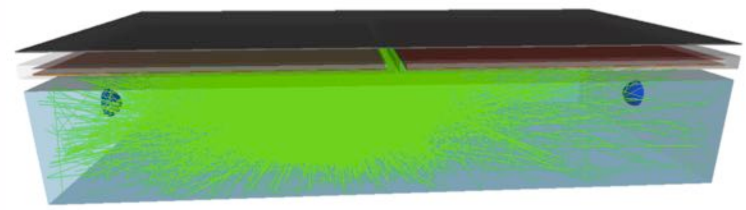
LATTES concept



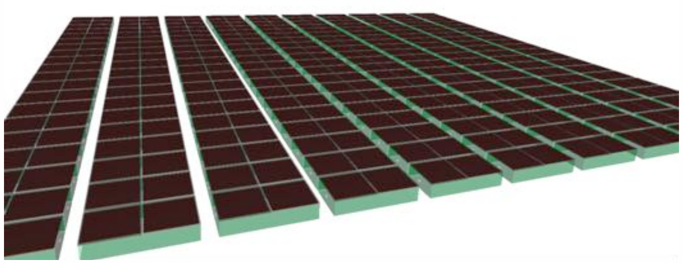
- Thin lead plate (**Pb**)
  - 5.6 mm (one radiation lenght)
- Resistive Plate Chambers (**RPC**)
  - 2 RPCs per station
  - Each RPC with 4x4 readout pads
- Water Cherenkov Detector (**WCD**)
  - 2 PMTs (diameter: 15 cm)
  - Dimensions: 1.5 m x 3 m x 0.5 m

LATTES concept

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



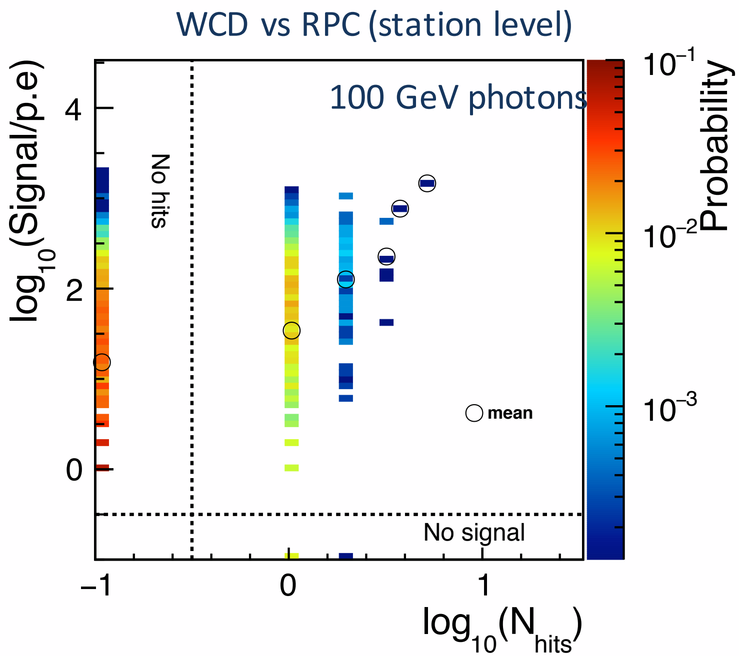
LATTES station
1.5 m x 3 m x 0.5 m

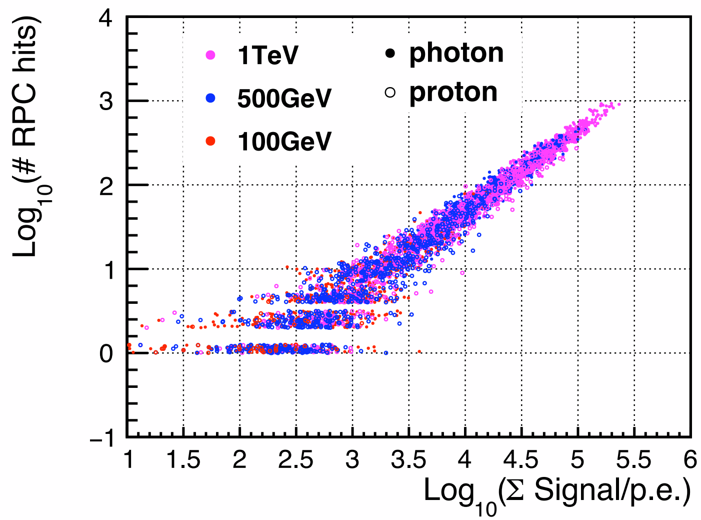


LATTES core array
30 x 60 stations
100 x 100 m^2

LATTES: complementary

- Combined detection:
  - Lower the **energy threshold**
    - Improve the trigger conditions (WCD)
  - Enable detector **inter-calibrations**
    - Energy calibration can be used to control detector systematic uncertainties
    - Check Monte Carlo simulations performance
  - Enhance **gamma/hadron discrimination**
    - Explore shower characteristics
    - Access to Argo/HAWC discrimination techniques

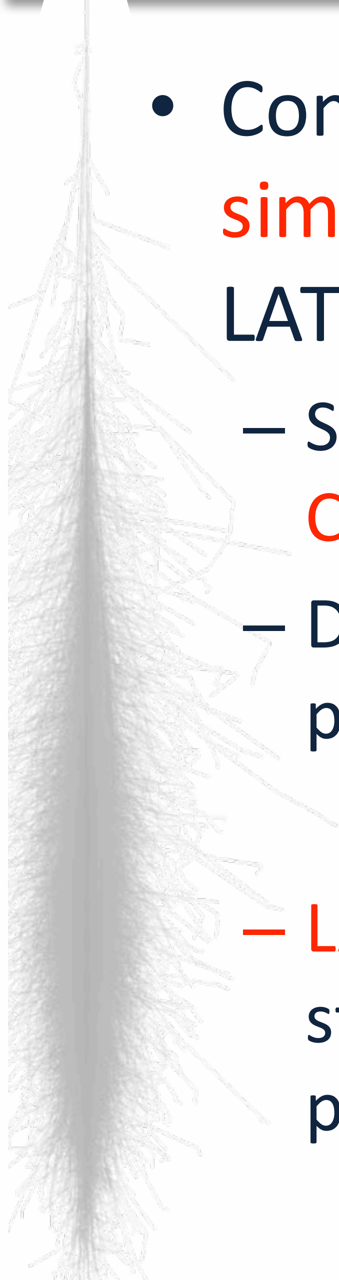




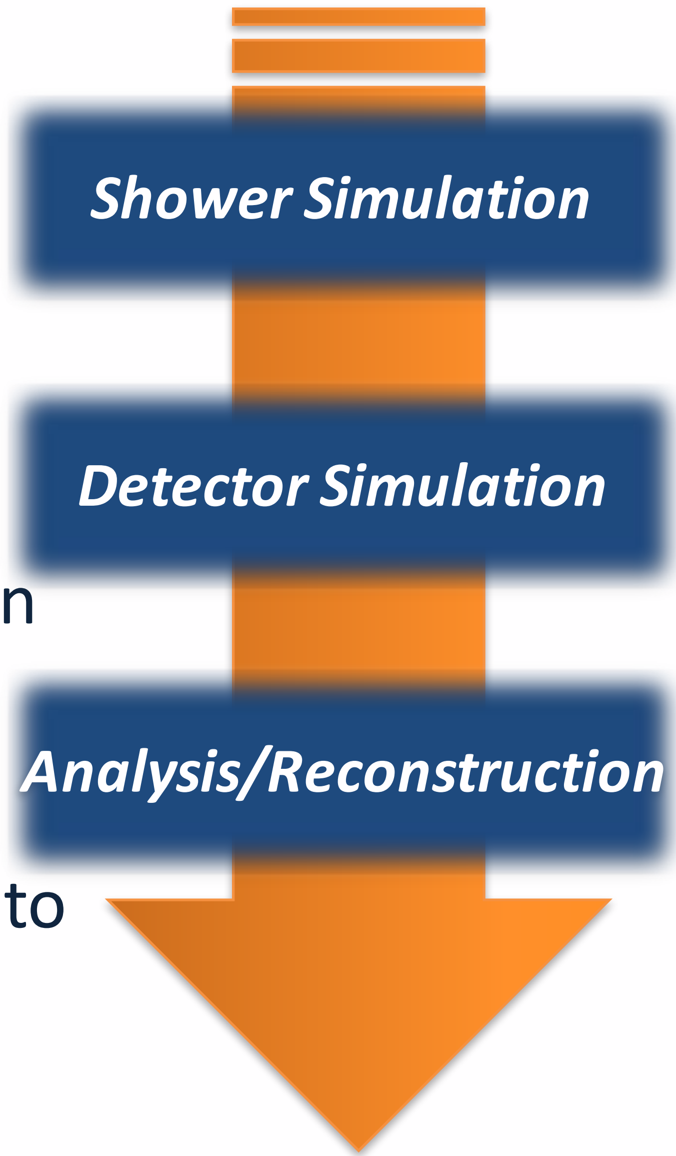
- **LATTES perfomance:**
  - Trigger efficiency
  - Energy Reconstruction
  - Geometric Reconstruction
  - Gamma-hadron discrimination

- LATTES sensitivity

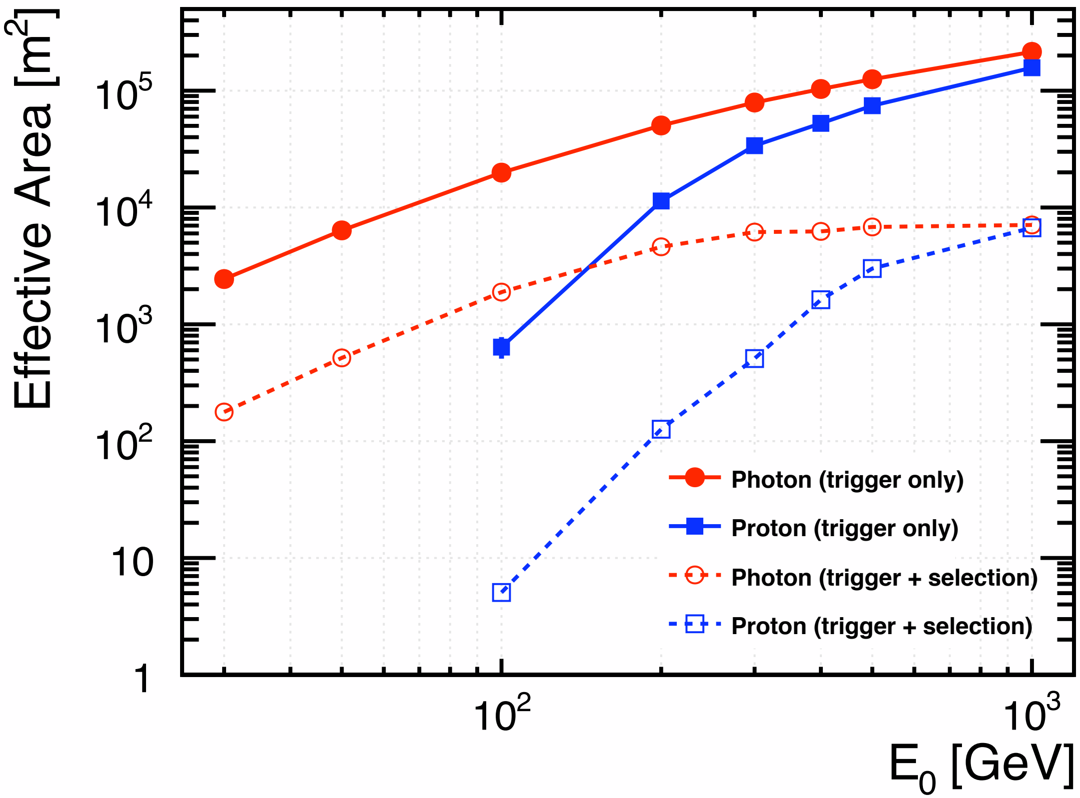
Simulation Framework



- Complete end-to-end simulation chain to evaluate LATTES performance
  - Showers simulated using CORSIKA
  - Detector layout and simulation performed by Geant4
  - LATTESsim: Integrated toolkit to study and optimize LATTES performance



Trigger efficiency

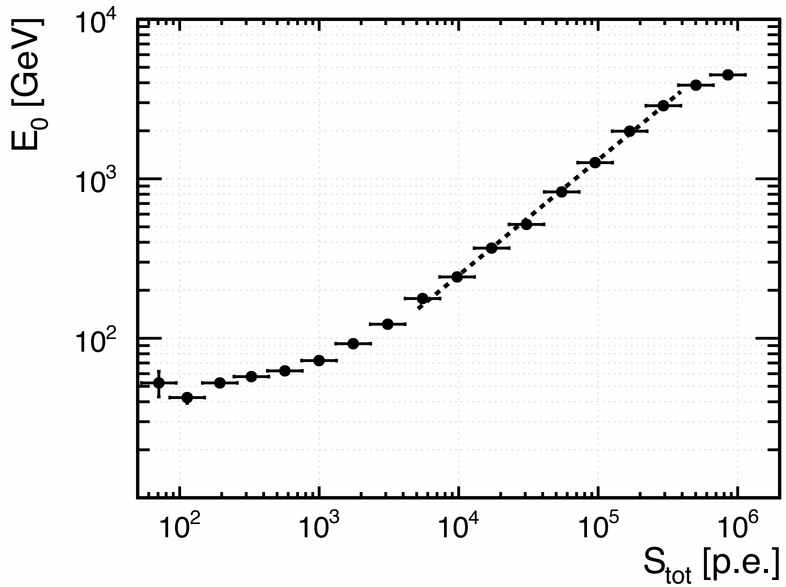


- Use WCD stations to trigger at low energies
  - Trigger condition
    - Station: require more than 5 p.e. in each PMT
    - Event: require 3 triggered stations
  - *Effective Area of 1000 m^2 at 100 GeV! (after quality cuts)*

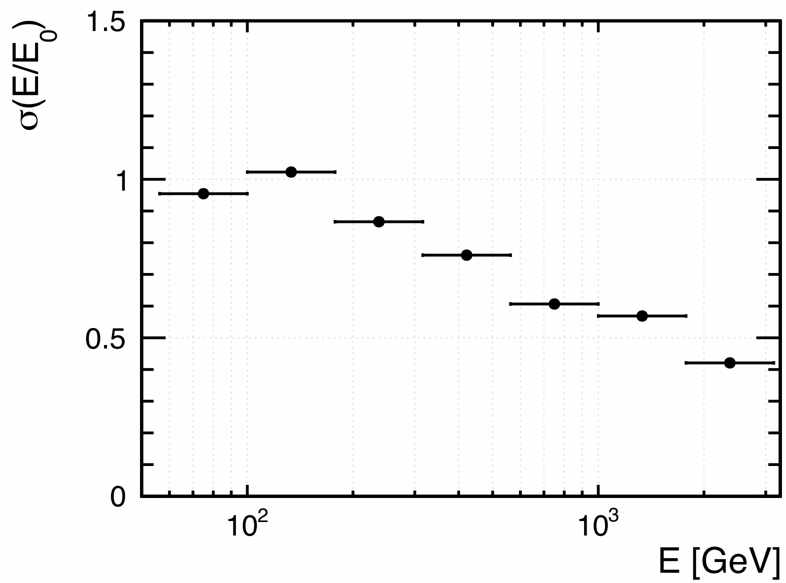
Energy reconstruction

$E_0 \rightarrow$ Simulated energy
$E \rightarrow$ Reconstructed energy

Energy Calibration



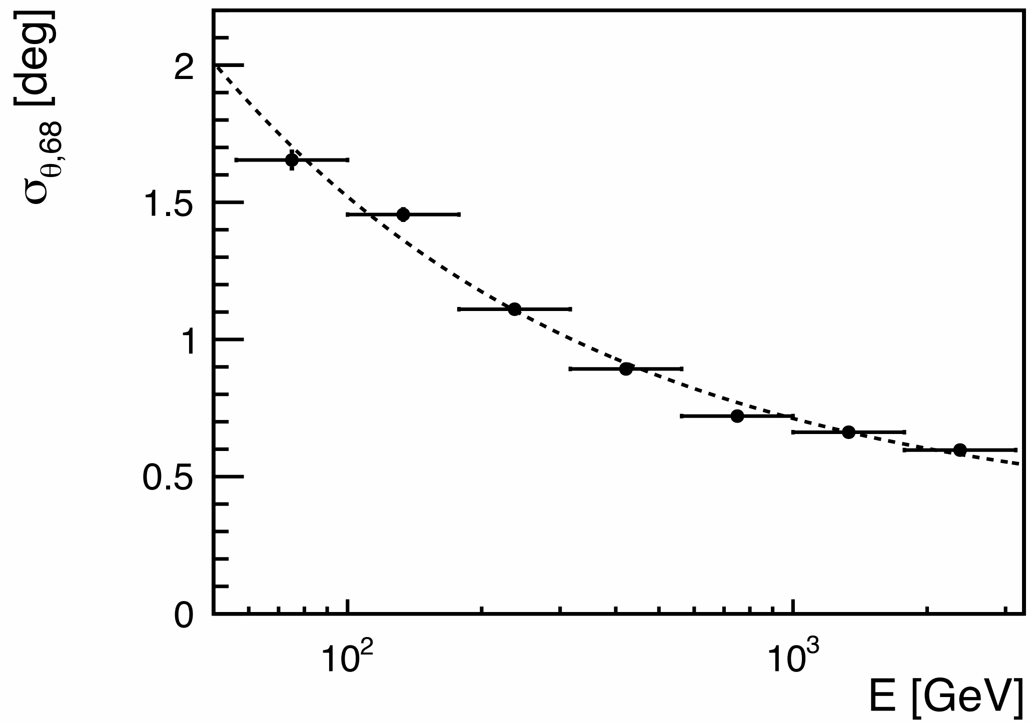
Energy Resolution



- 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

$\gamma - \text{showers}; \theta = 10^\circ$



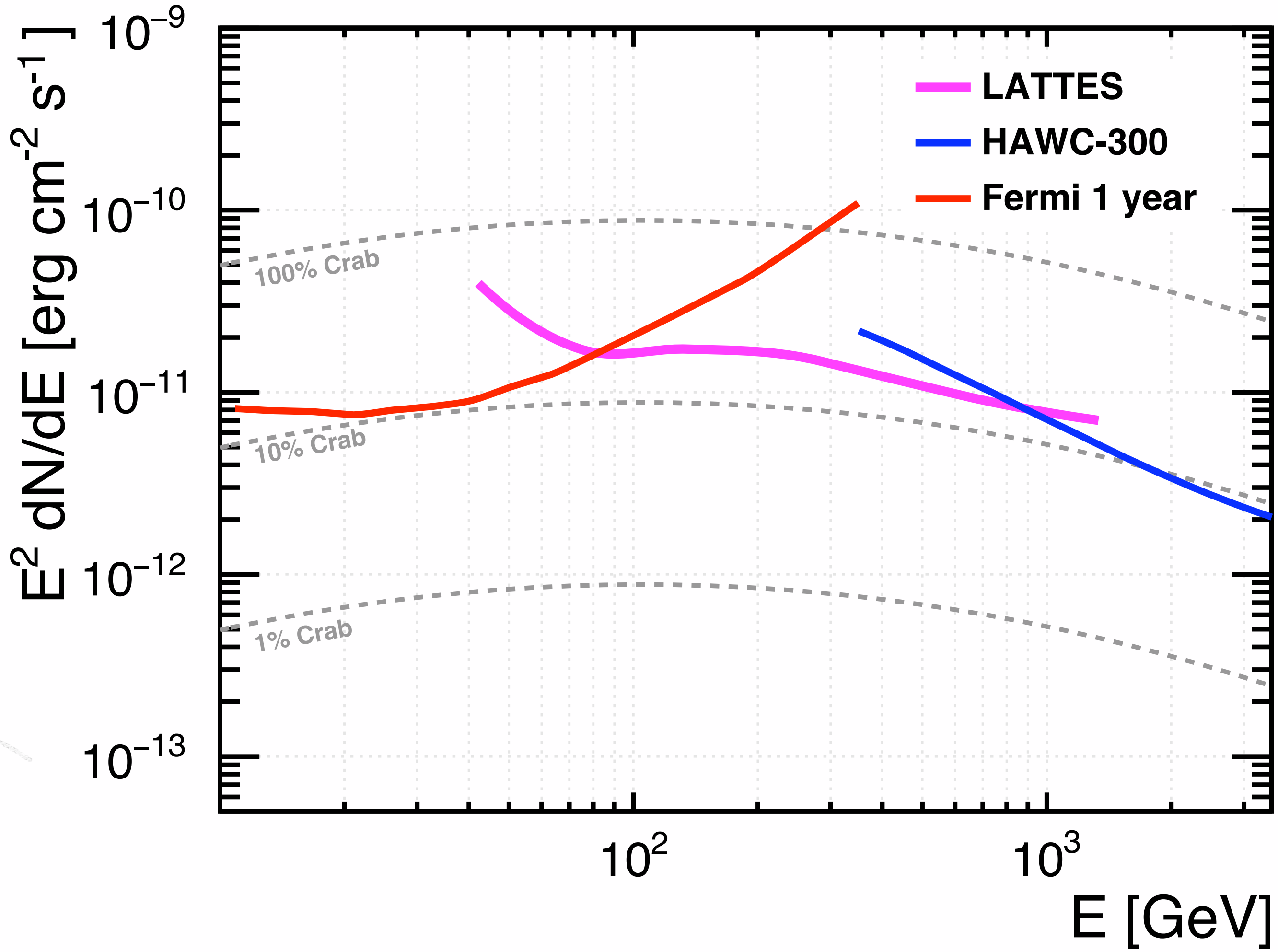
- Shower **geometry reconstruction** done using **RPC hit time**
  - Take advantage of RPCs **high spatial and time resolution**
    - Consider a time resolution of 1 ns
  - Use shower front plane approximation
  - Require more that 10 hits in the RPCs

– *Angular resolution below 2 deg even for 50 GeV showers*

- LATTES performance:
  - Trigger efficiency ✓
  - Energy Reconstruction ✓
  - Geometric Reconstruction ✓
  - Gamma-hadron discrimination 

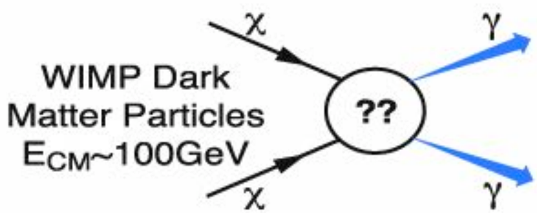
    - For now use a conservative approach:
      - Below 300 GeV don't consider any discrimination
      - Above 300 GeV use HAWC discrimination curve
- **LATTES sensitivity**

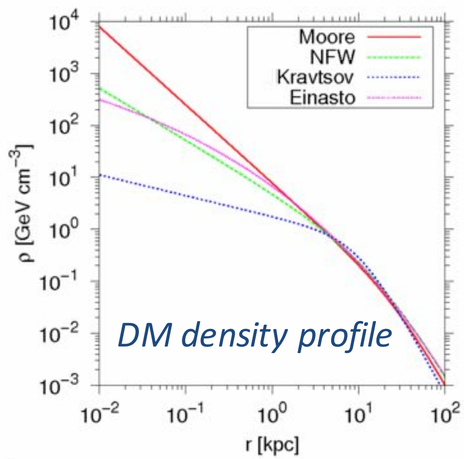
LATTES sensitivity

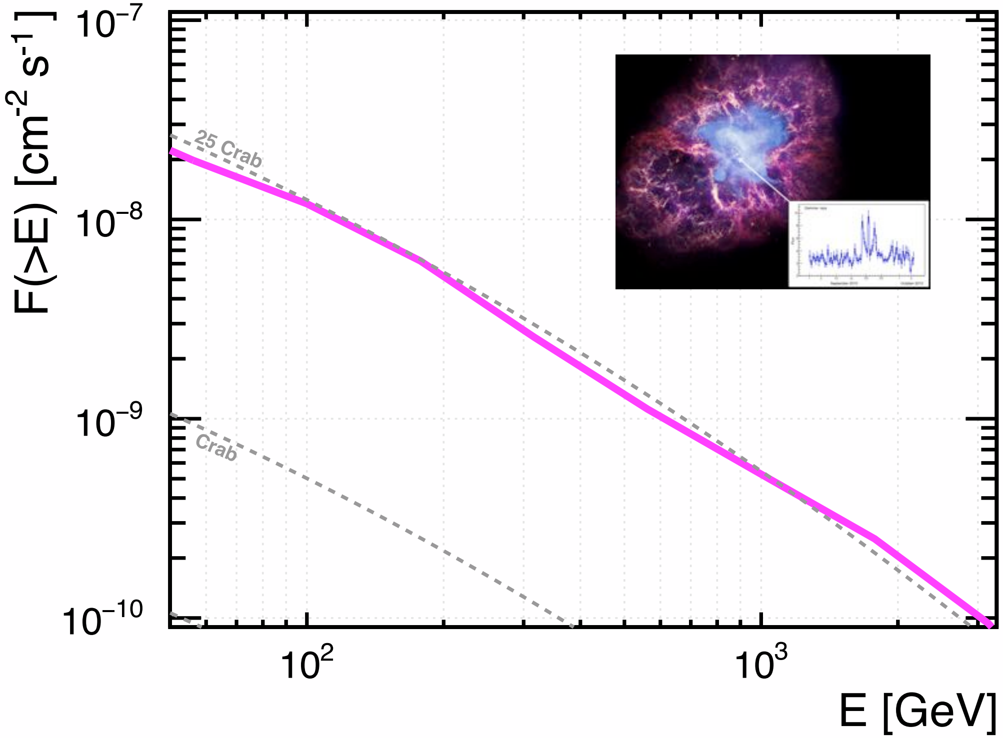


Differential sensitivity to steady sources in one year

LATTES physics opportunities

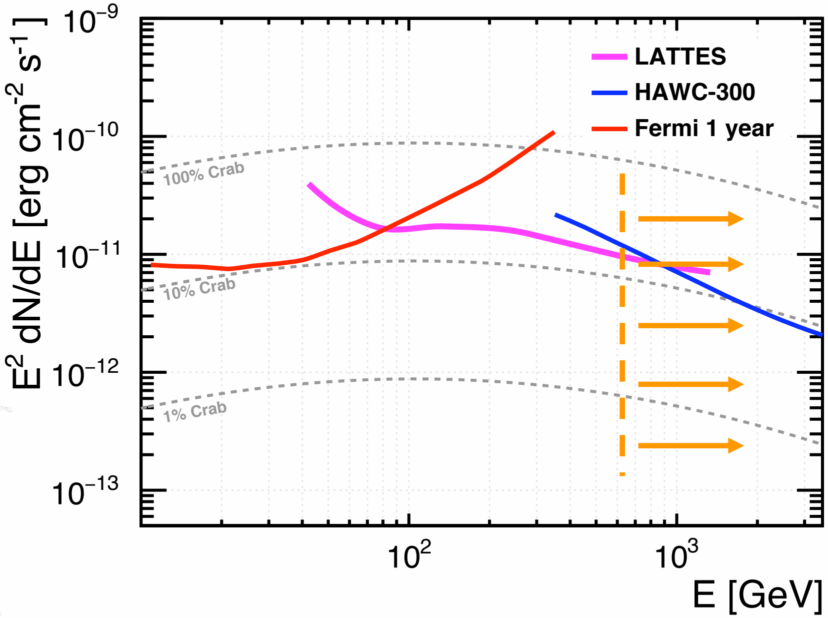


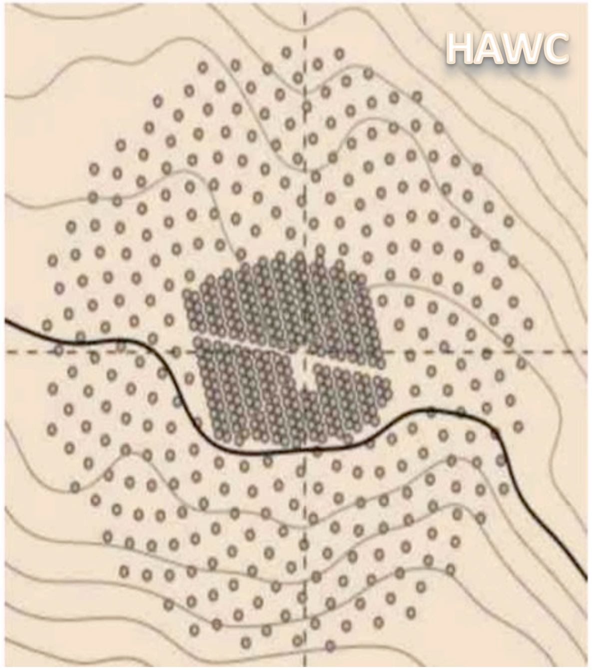




- Many interesting scientific goals:
  - Dark matter searches at the center of the galaxy
  - Study transient phenomena
    - LATTES can detect a 25 Crab source at 3 sigma in 1 minute

LATTES at higher energies





- The sensitivity scales with the array area
- It could be extended to reach higher energies with an external corona of sparse detectors

Summary

- LATTES: gamma ray wide field of view experiment at South America
  - 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

Acknowledgments

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

COMPETE
PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE

QREN
QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL
PORTUGAL 2007.2013

UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

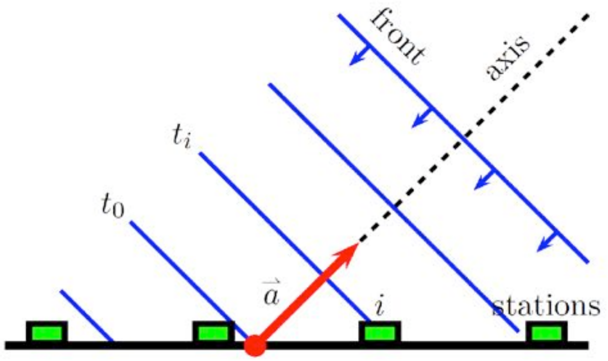
LIP

TÉCNICO LISBOA

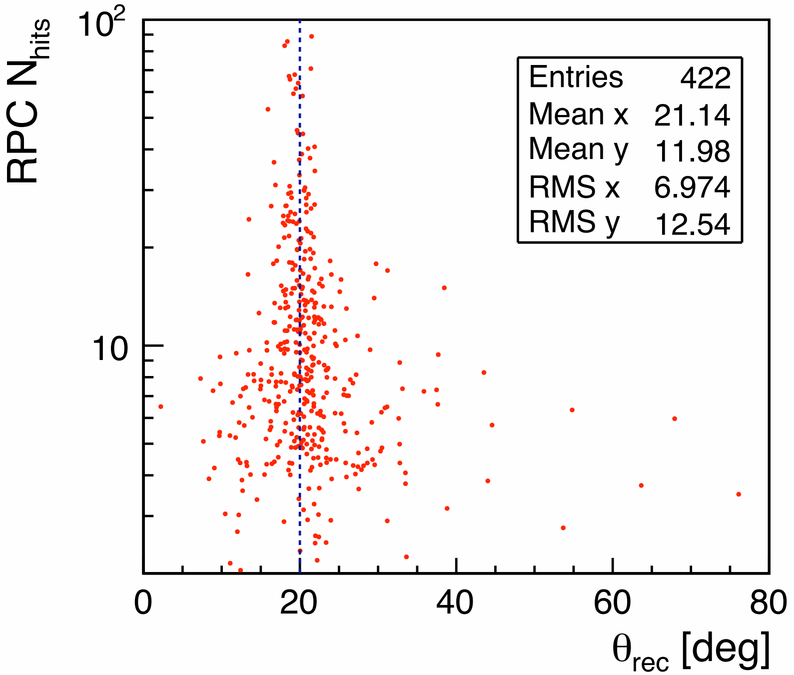
BACKUP SLIDES

Reconstruction of shower geometry

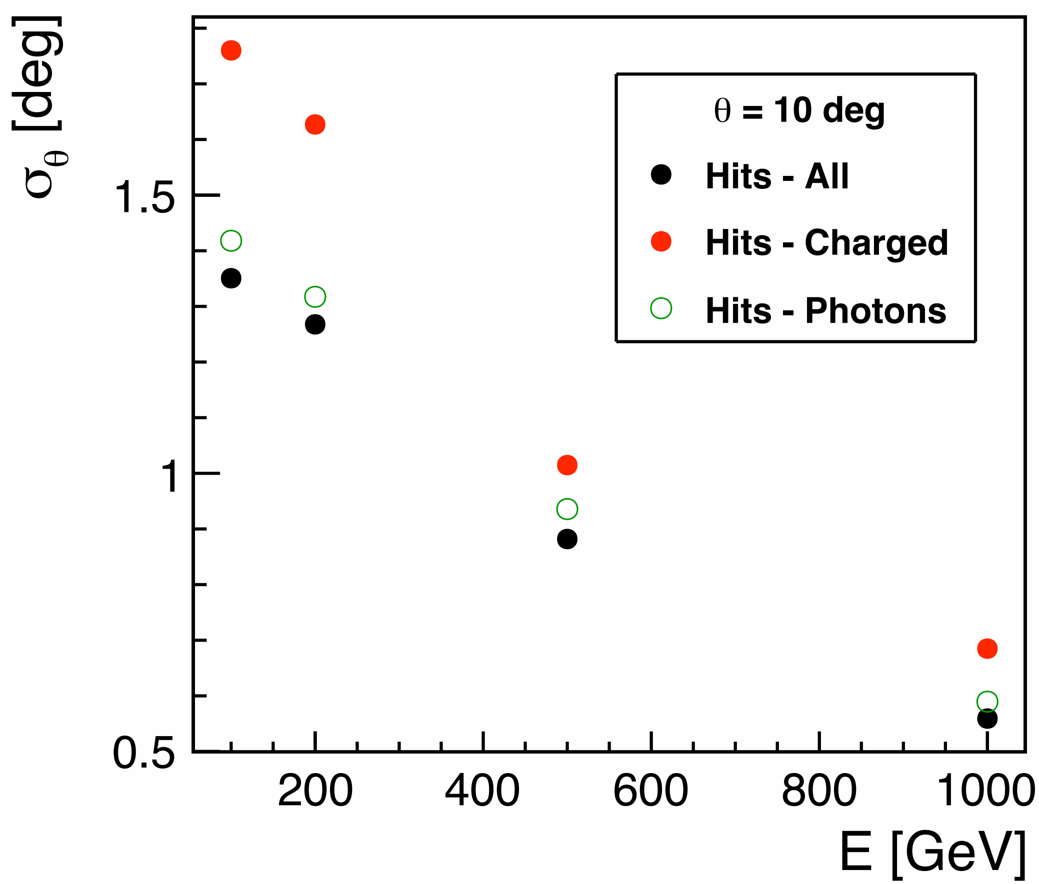
- **Use RPC hit time** information to reconstruct the shower
  - Take advantage of **high spatial and time resolution**



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

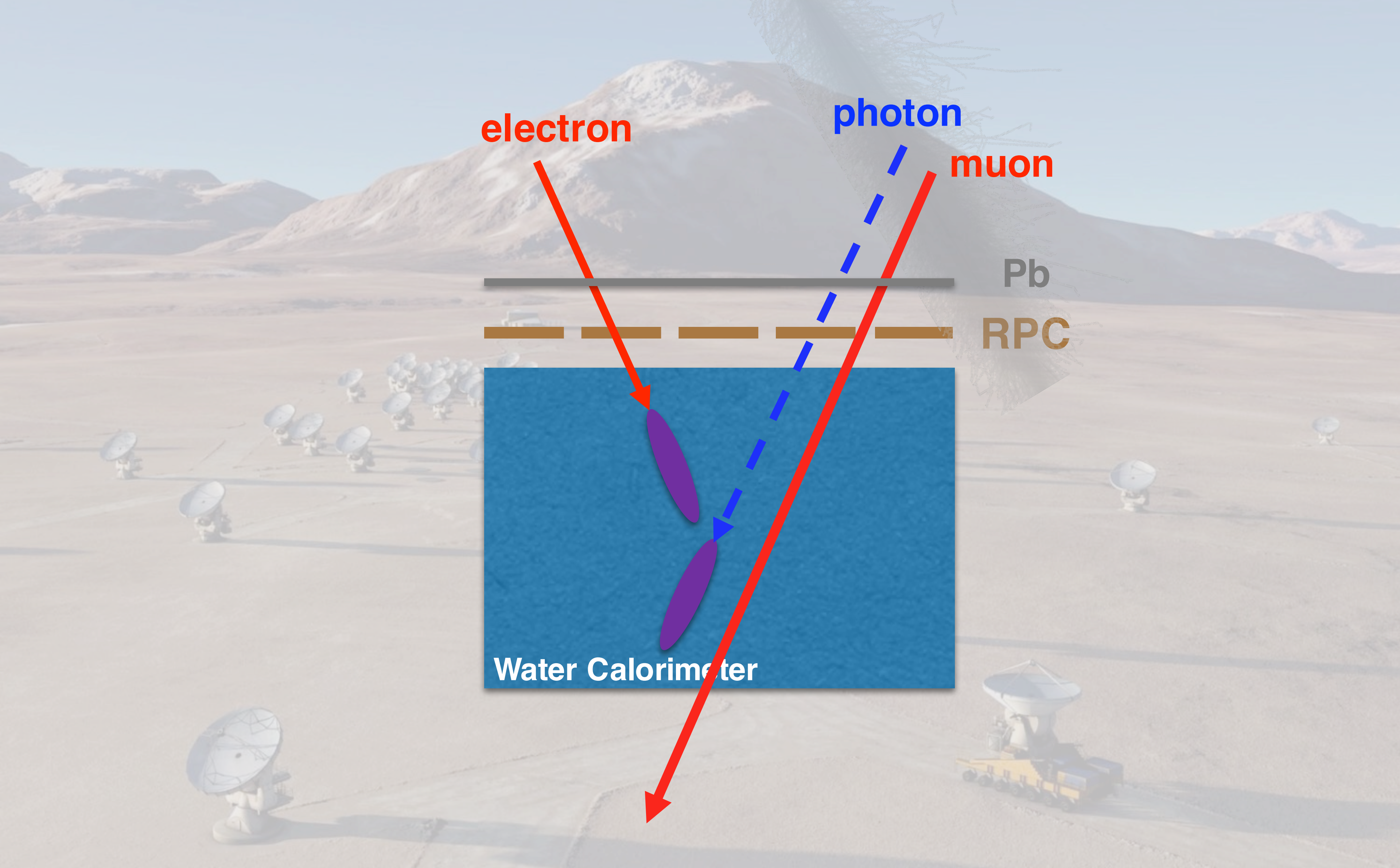


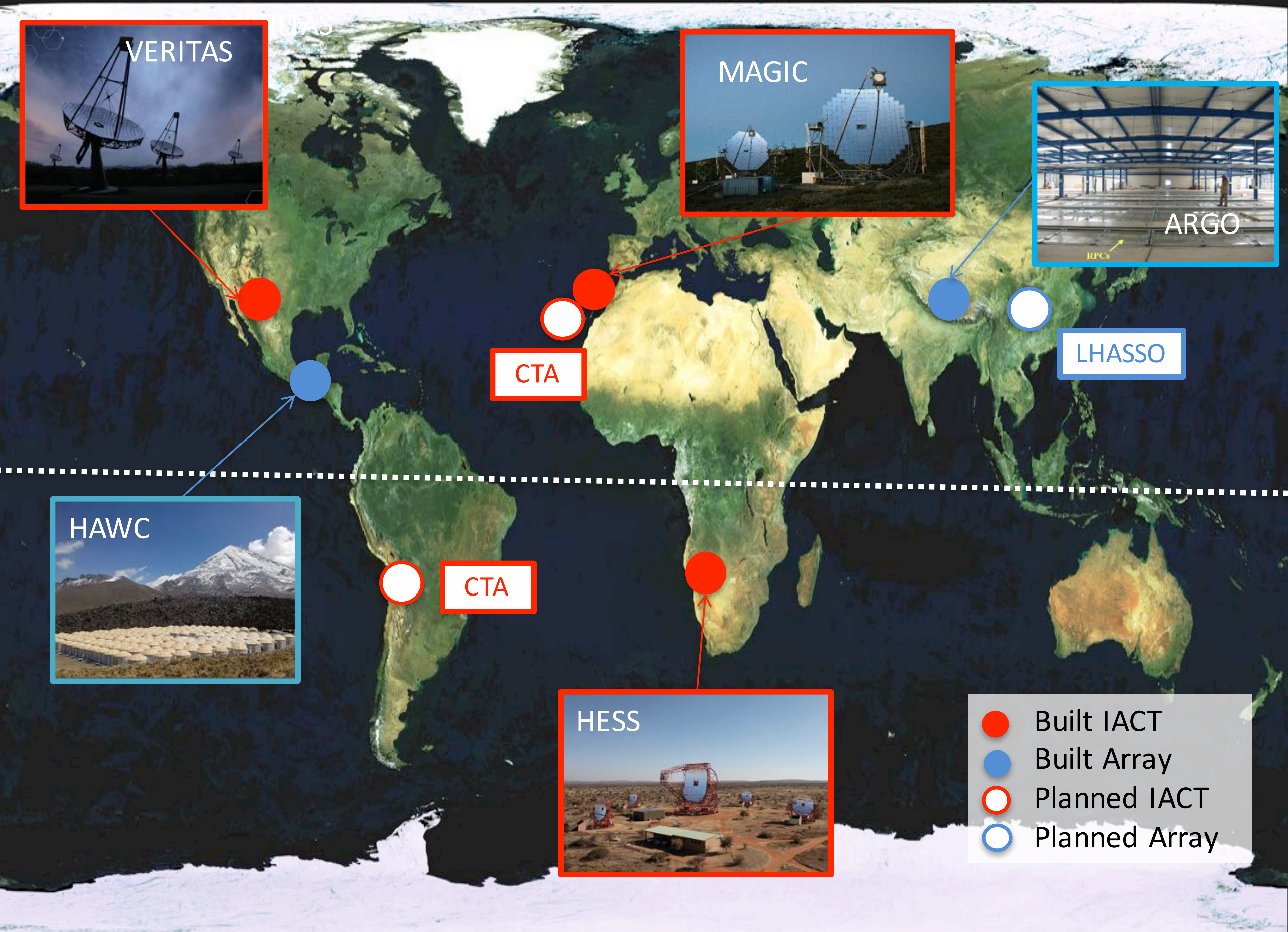
Contributions to the geometric reconstruction

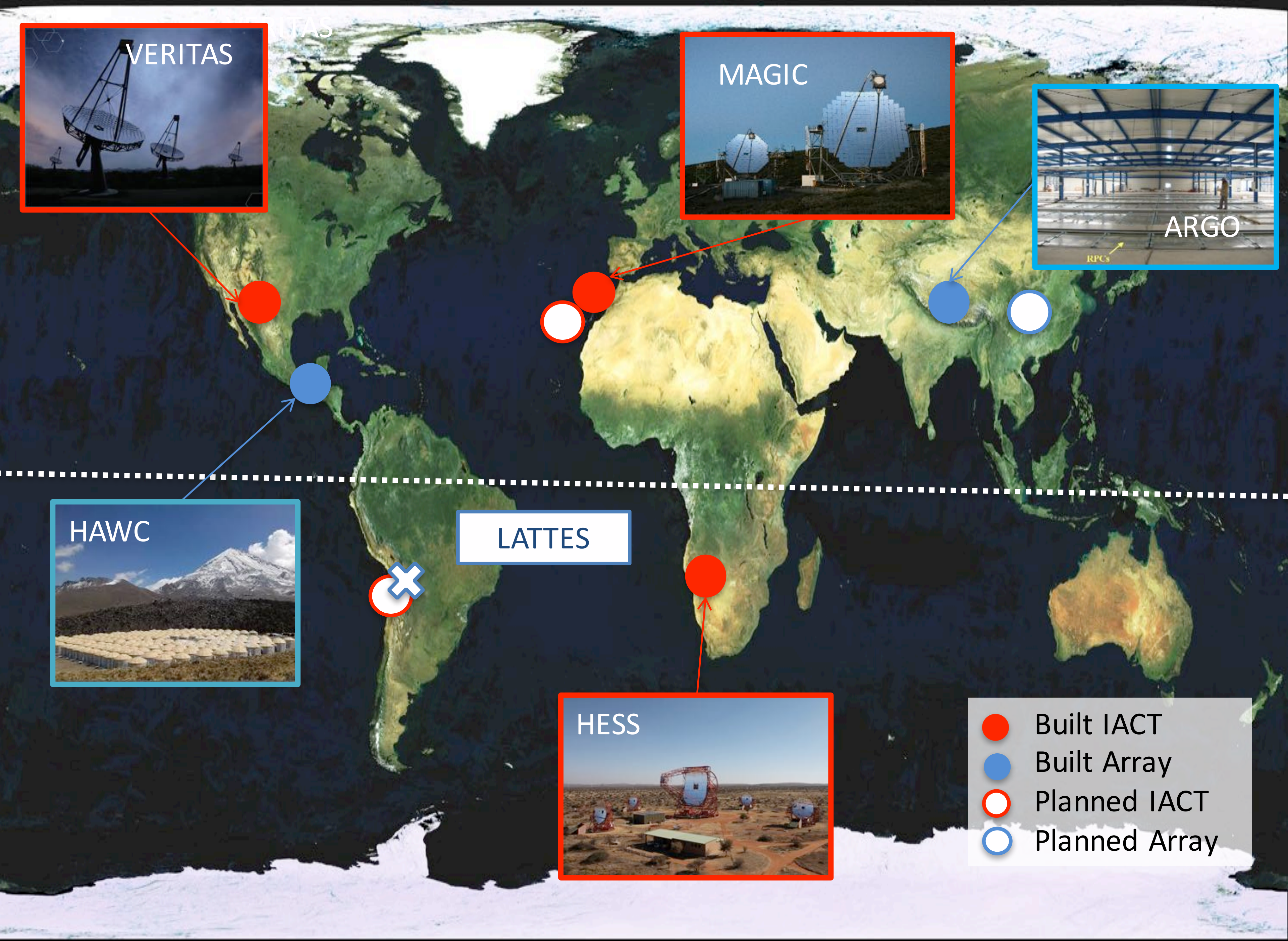


- **Photons** retain a **higher correlation** with the **shower geometry** than charged particles
- Could we measure photons with the RPC instead?

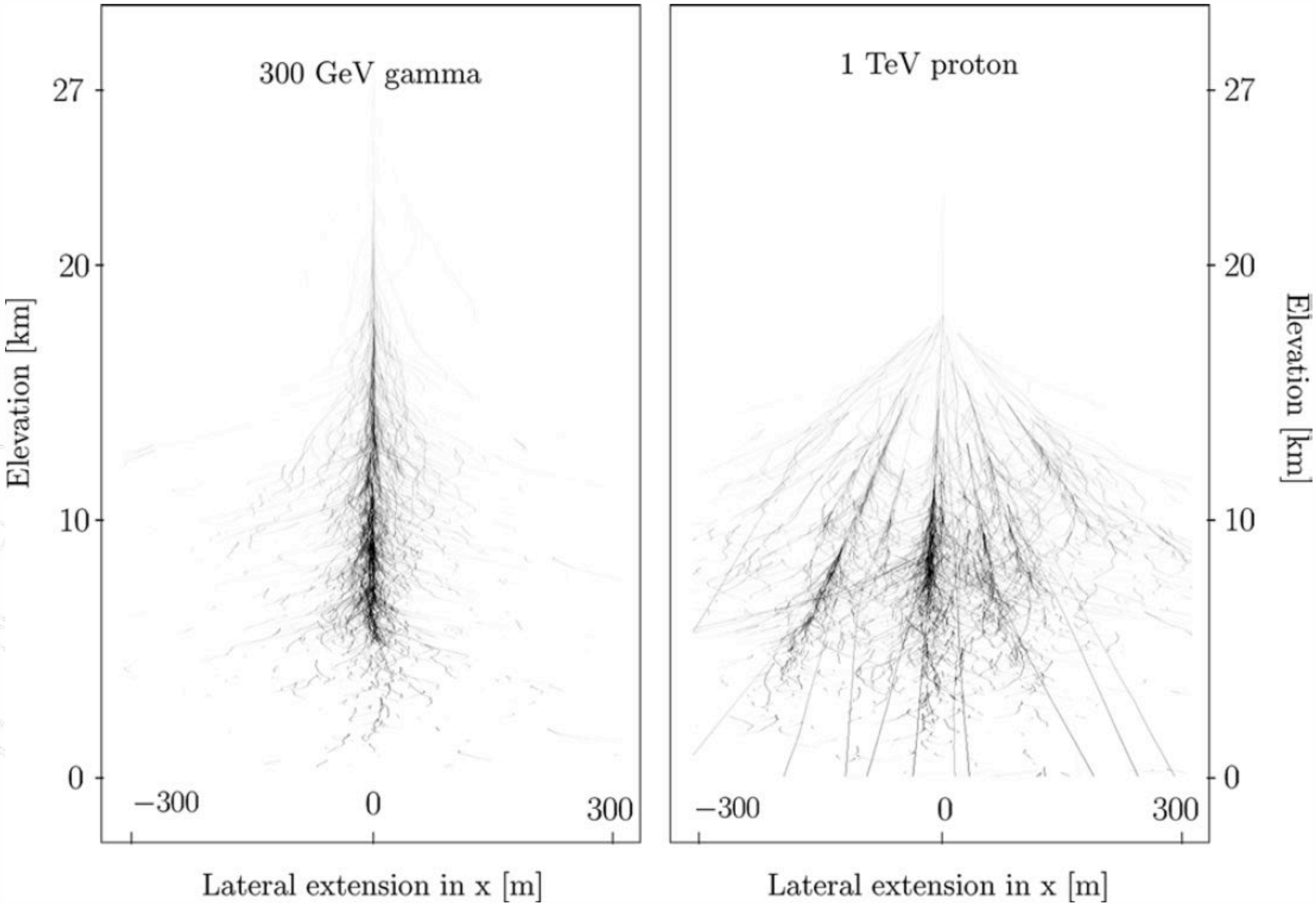
LATTES station baseline concept




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

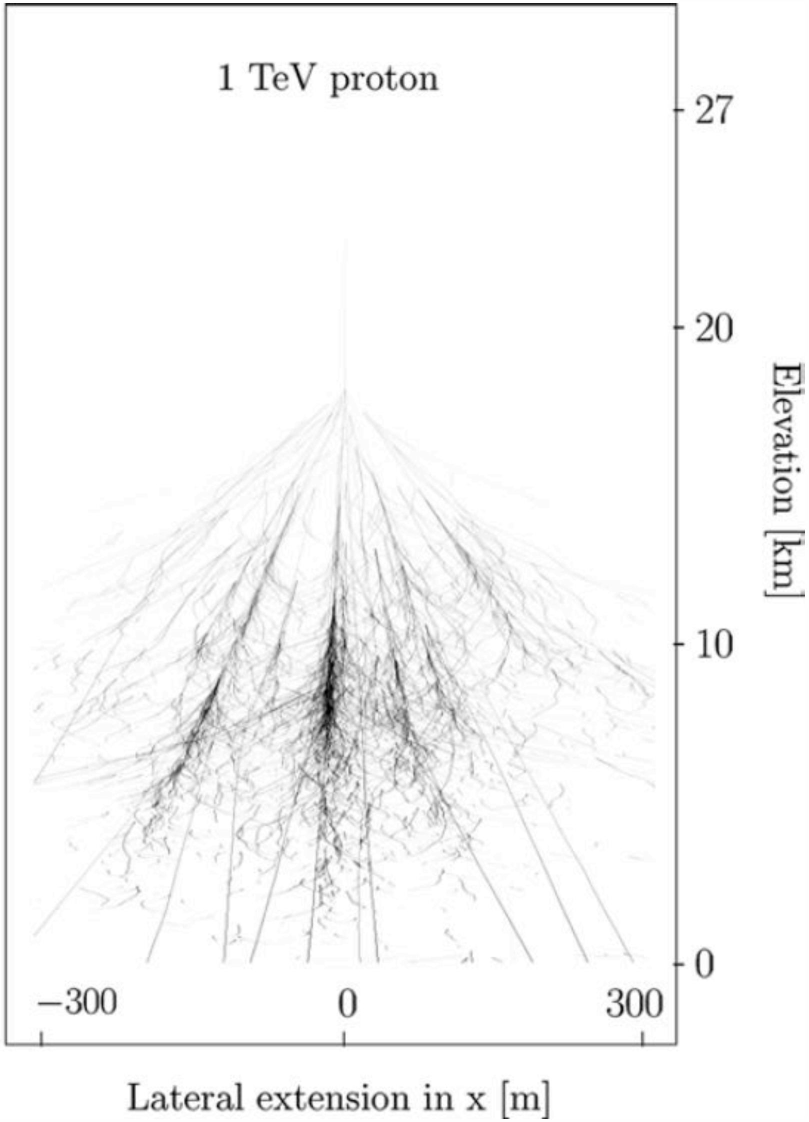

VERITAS
MAGIC
ARGO
HAWC
LATTES
HESS
Built IACT
Built Array
Planned IACT
Planned Array

Strategies for primary discrimination



Explore differences in shower development

Strategies for primary discrimination

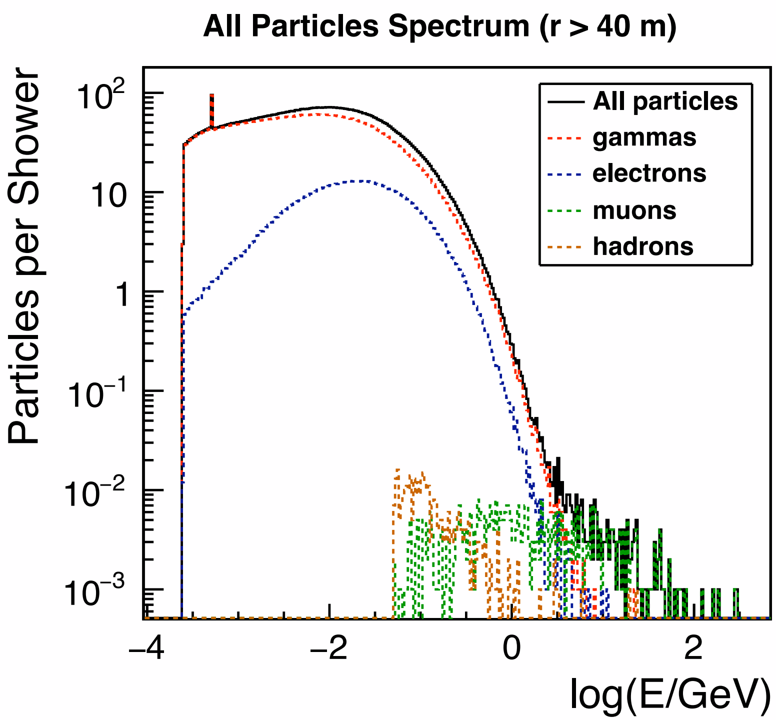


- **Hit pattern at ground**
  - Hits from hadronic showers are more sparse than in gamma induced showers
  - RPC detectors
  - Explored by the ARGO collaboration
- **Search for energetic clusters far from the shower core**
  - Present only in hadronic showers
  - Water Cherenkov Detectors
  - Explored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

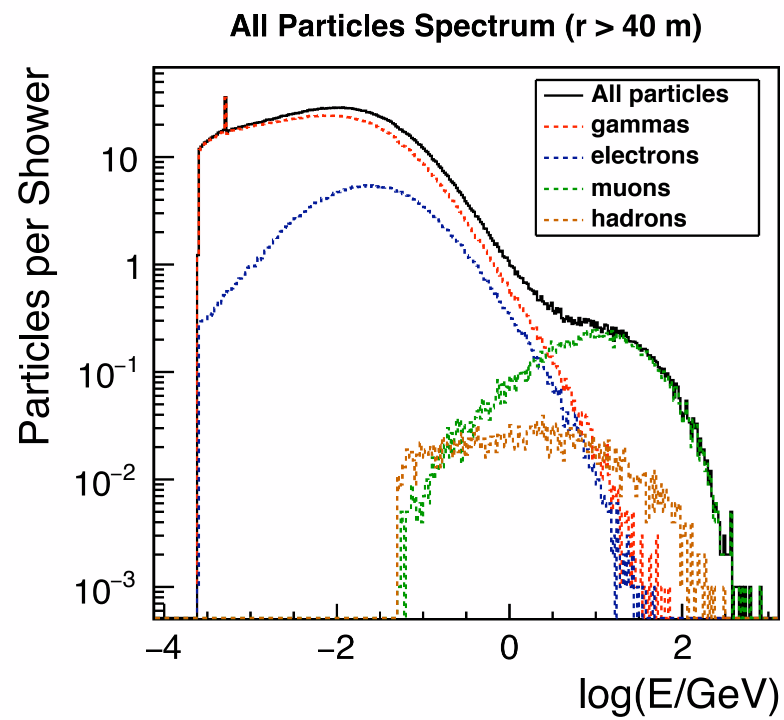
Exploring the WCD

5 TeV

Gamma showers

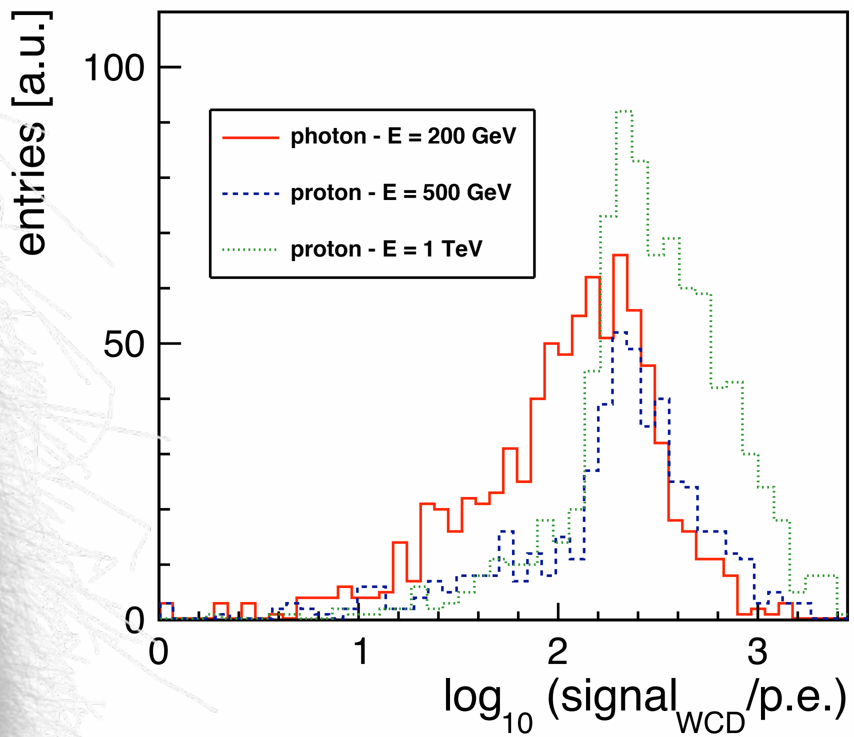


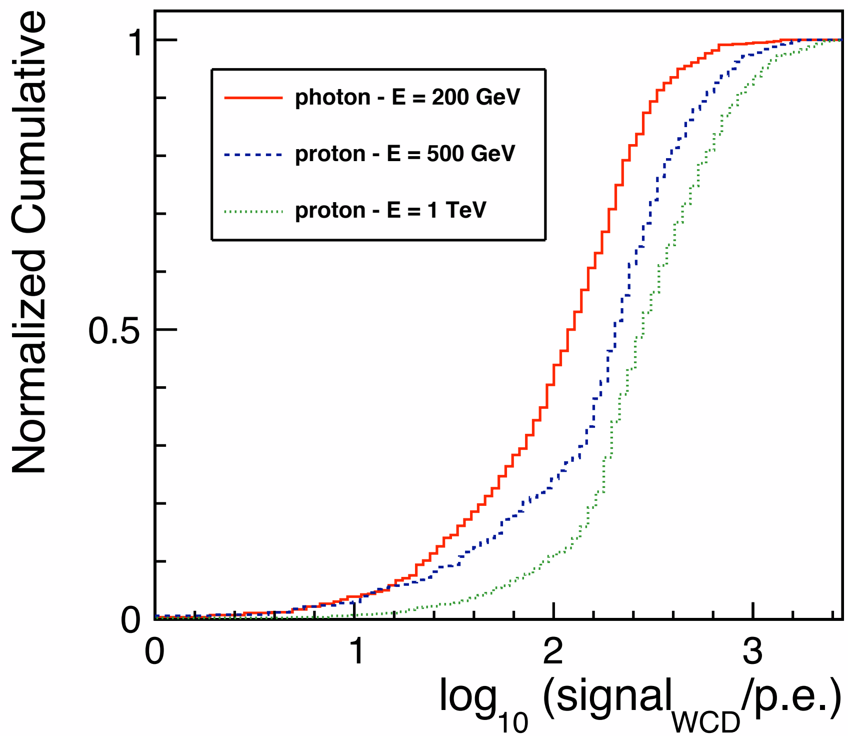
Proton showers



- What should we look for?
  - Look for energetic clusters far from the shower core
  - Above 40 m

LATTES hottest station





- Signal of **the hottest WCD station**
  - **above 40 m** from the shower core
  - with **only one hit in the RPC**

LATTES integrated sensitivity

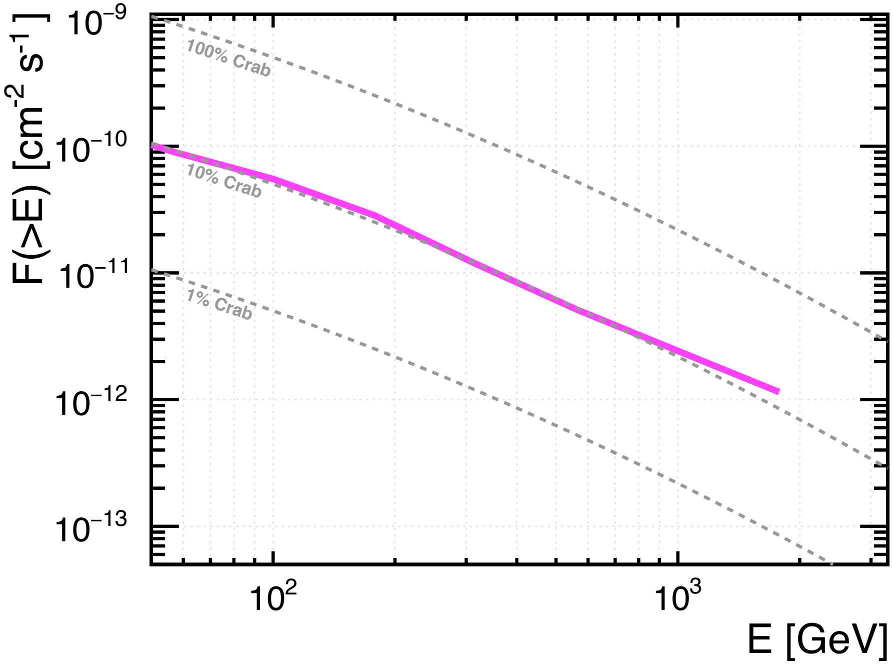
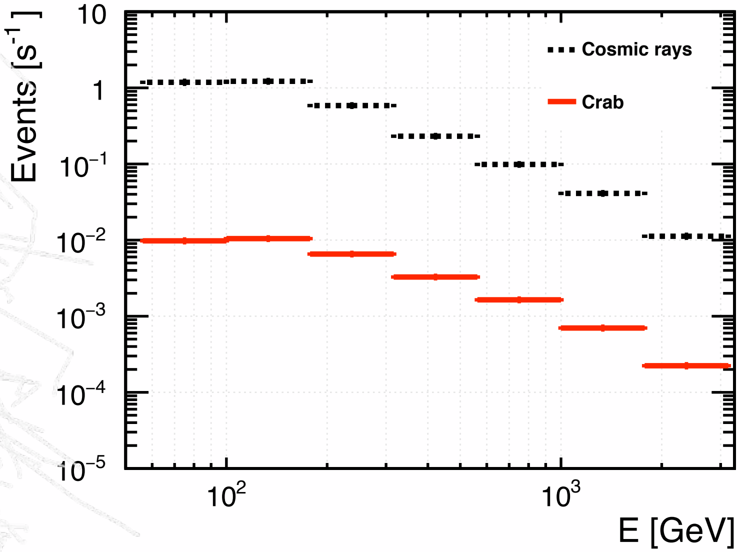
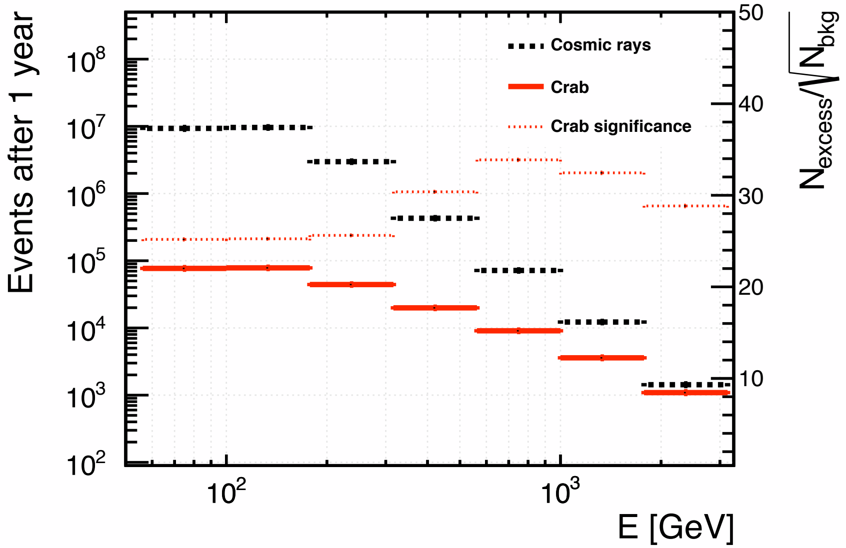


Figure 10: Integral sensitivity, defined as the flux of a source above a given energy for which $N_{\text{excess}}/\sqrt{N_{\text{bkg}}} = 5$ after 1 year; it is assumed that the SED is proportional to the SED of Crab Nebula. For comparison, fractions of the integral Crab Nebula spectrum are plotted with the thin, dashed, gray lines.

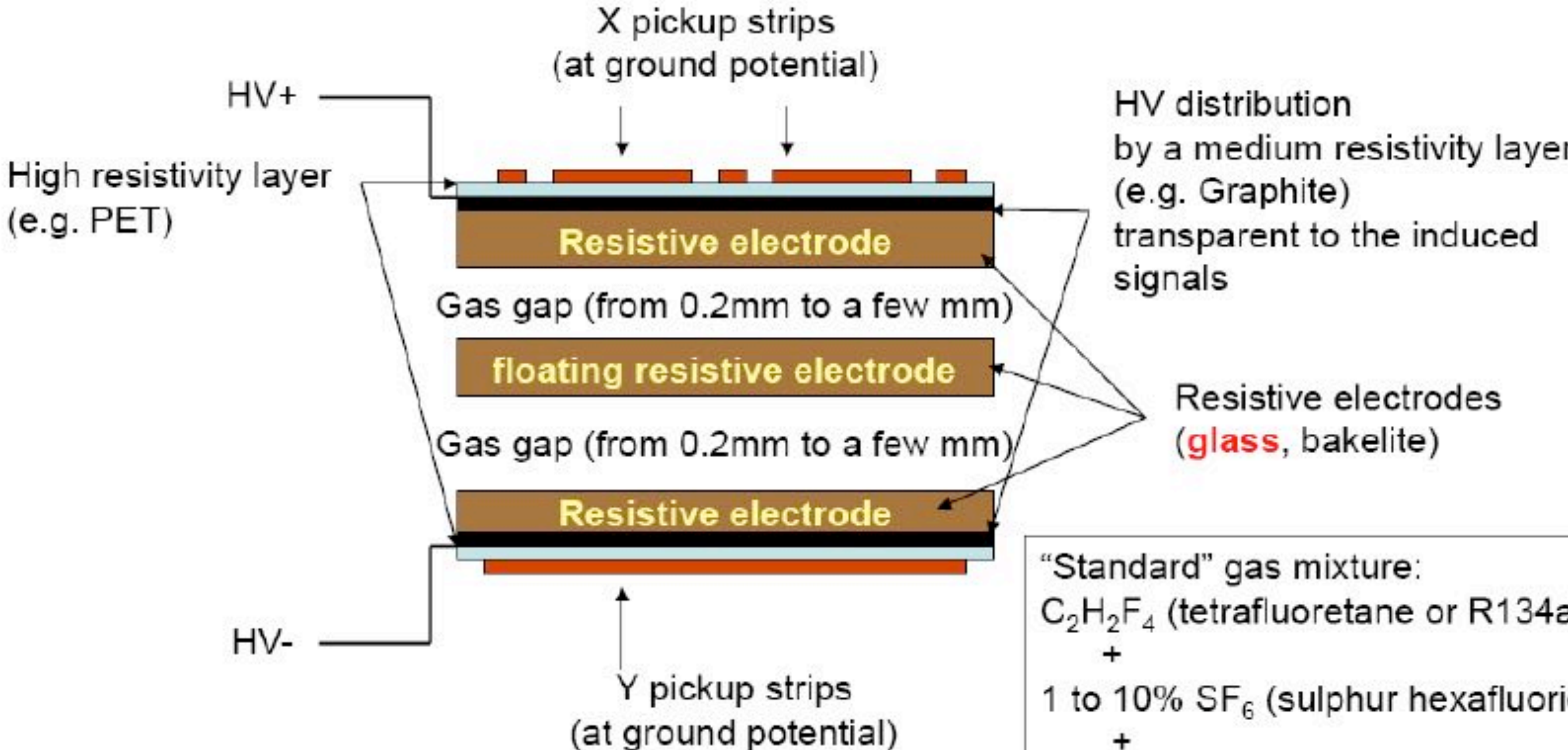
LATTES expect events from Crab





RPCs – basic structure

Many variations allowed



"Standard" gas mixture:
$C_2H_2F_4$ (tetrafluoretane or R134a)
+
1 to 10% SF_6 (sulphur hexafluoride)
+
0 to 5% C_4H_{10} (isobutane)

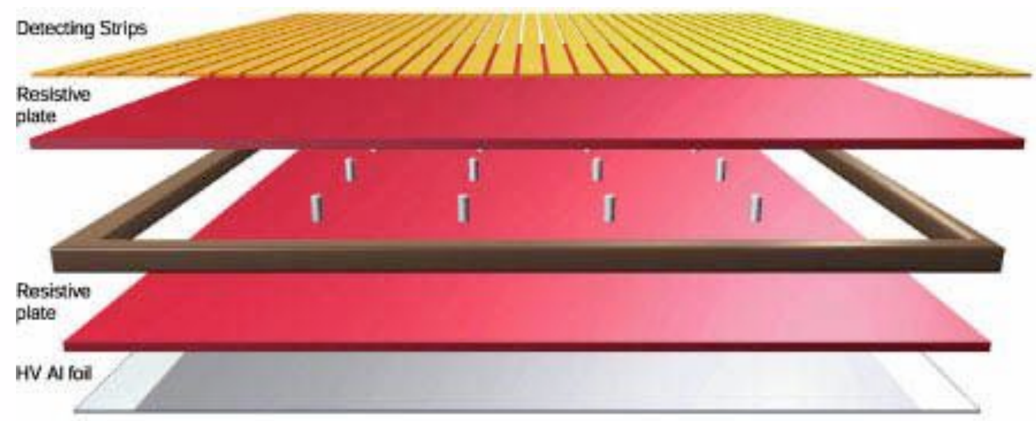
The current is limited by the resistive electrodes: no sparks by construction

Þ very safe detector, although limited to low particle rates (~2kHz/cm^2)

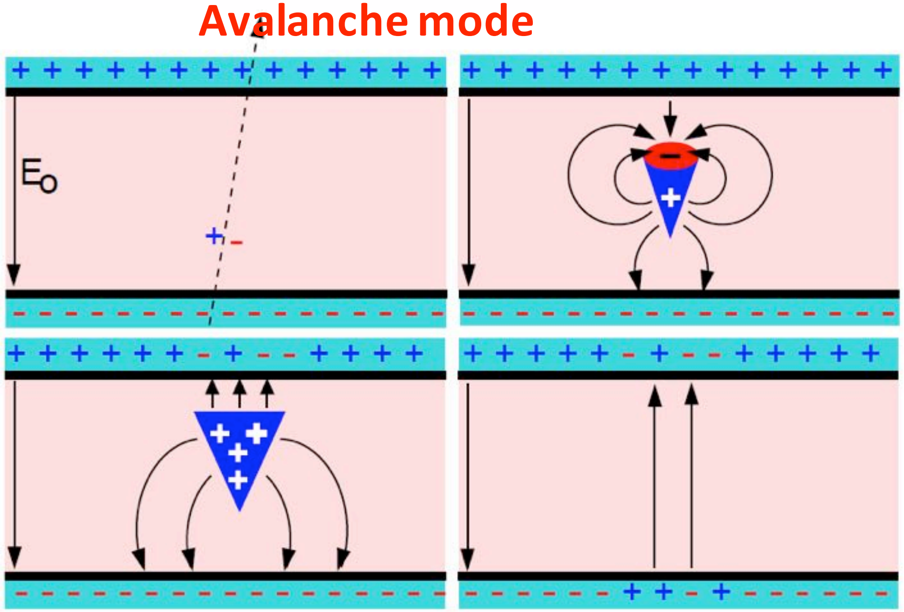
Þ excellent efficiency (99%), time (~50 ps) and position resolution (~100μm)

RPCs Resistive Plate Chamber

- Gaseous detector
- Planar geometry
- uniform electrical field imposed.
- High resistive plates in between the electrodes limit the avalanche current.
- Signal is picked up by the induction of the avalanche in the readout pads.



Avalanche mode



Streamer mode