LATTES: shower reconstruction and expected performances

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on behalf of the LATTES team

LIP

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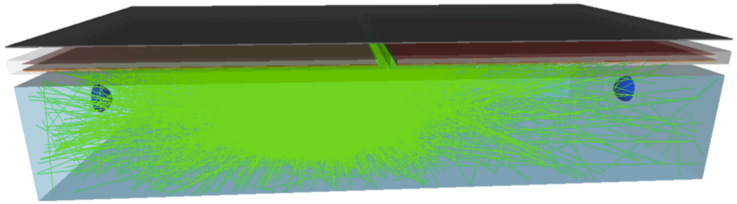
LATTES expected performance

- Trigger and effective area
- Energy reconstruction
- Core reconstruction
- Geometry reconstruction
- Gamma/hadron discrimination (previous talk)

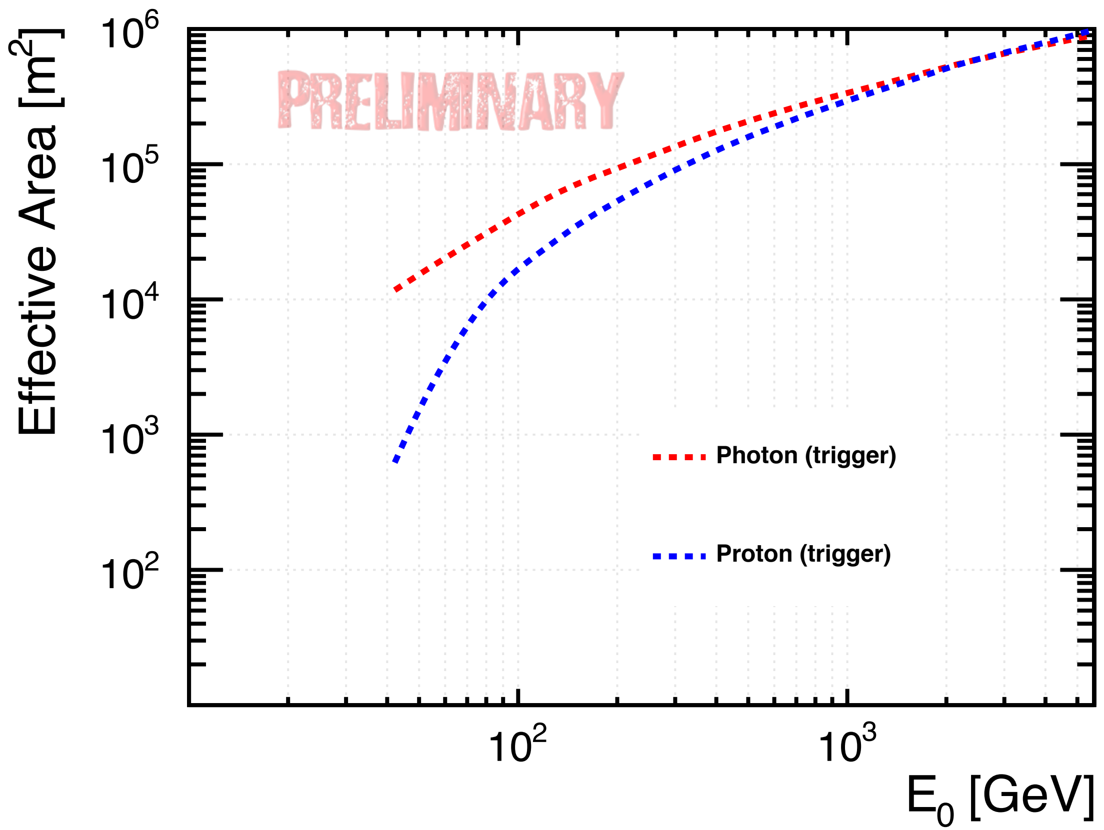
- Sensitivity to steady sources

Simulation framework

- **CORSIKA**
  - 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
- **LATTESsim**
  - Each shower is resampled 100 times over a big area containing all the array
  - Array has an area of 20 000 m^2
  - LATTES baseline detector concept
- **LATTESrec**
  - Shower reconstruction



Trigger efficiency

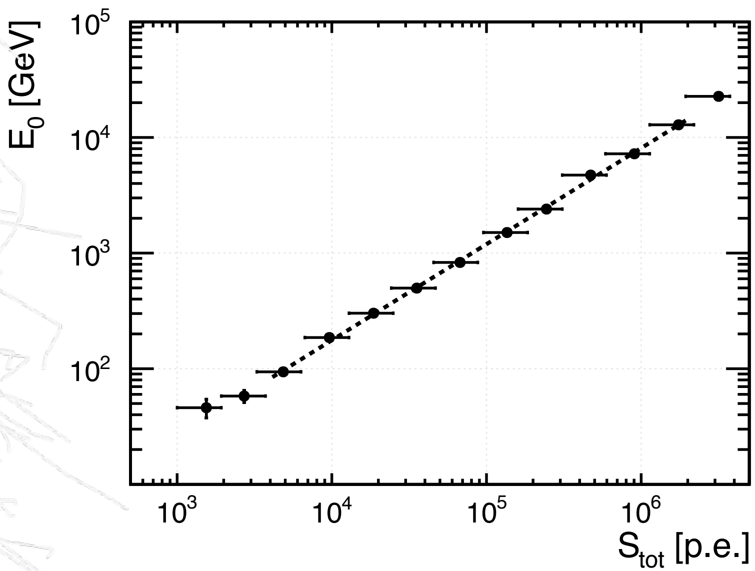


- Use WCD stations to trigger at low energies
  - Trigger condition
    - Station: require more than 5 p.e. in each PMT
    - Event: require 3 triggered stations

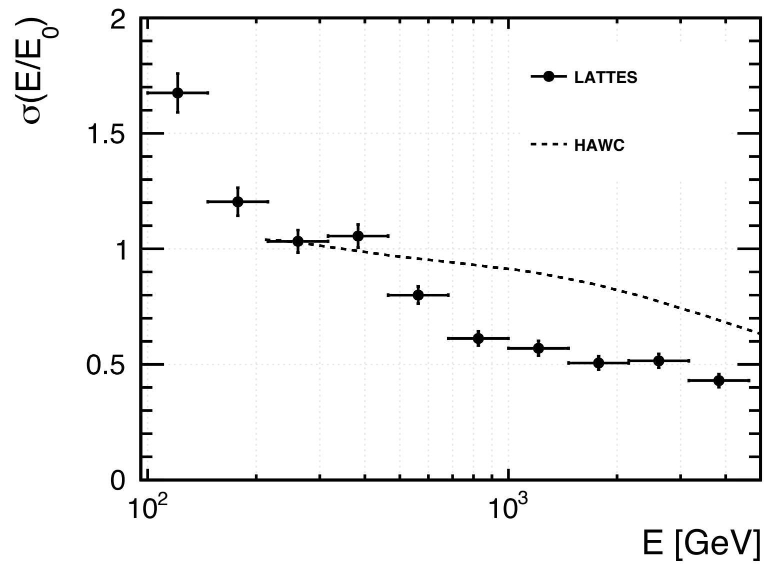
Energy reconstruction

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

Energy Calibration



Energy Resolution

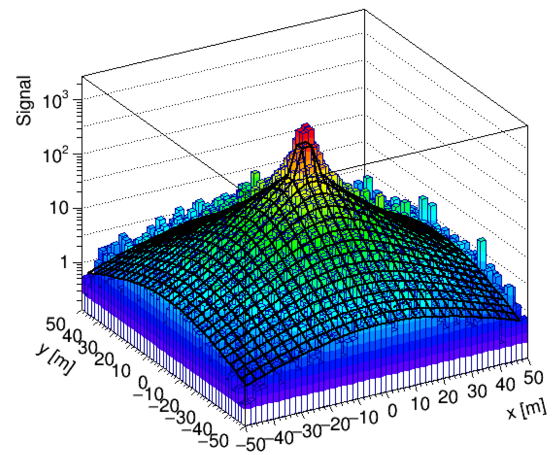


- Use as energy estimator the total signal recorded by WCDs
- Energy resolution below 100 GeV dominated by shower fluctuations

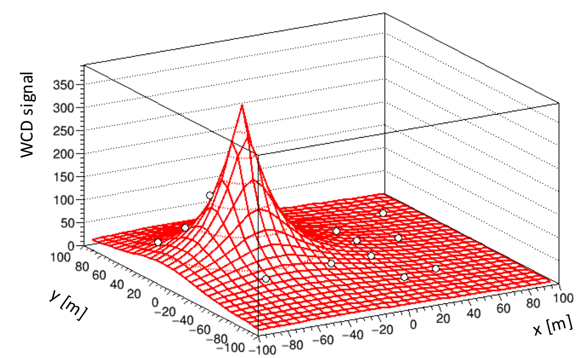
Shower core reconstruction

- Barycenter
  - First approach
  - Use WCD signal
  - Works but the core is always reconstructed inside the array
- Fit the WCD LDF
  - Fit photon average LDF to fix the shape
    - Function inspired in HAWC
  - Use this form to find the maximum, i.e. the shower core

Average LDF



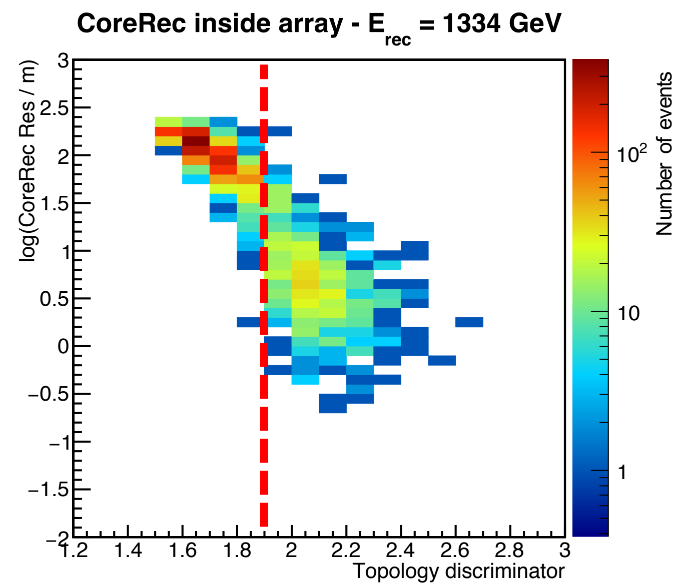
Single event

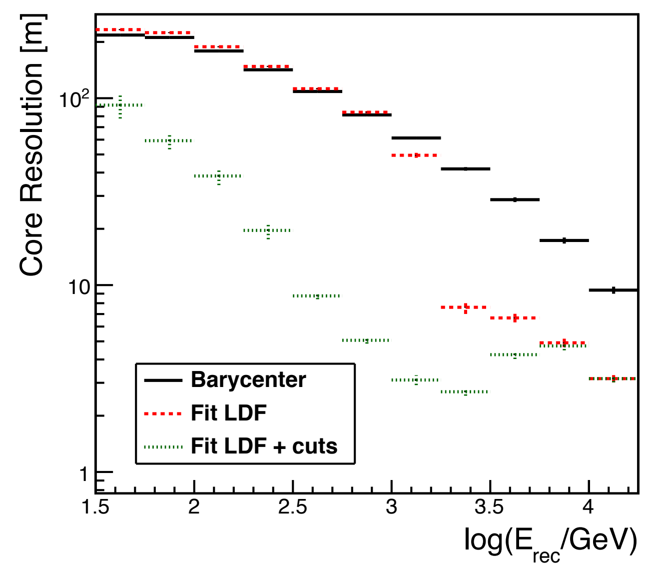


$$S_i = S(A, \vec{x}, \vec{x}_i) = A\left(\frac{1}{2\pi\sigma^2} e^{-|\vec{x}_i - \vec{x}|^2/2\sigma^2} + \frac{N}{(0.5 + |\vec{x}_i - \vec{x}|/R_m)^3}\right)$$

Shower core reconstruction

- Fit the WCD LDF
  - Test whether the shower is inside/outside the array (topology)
  - Quality of the fit connected with the quality of the core reconstruction
  - Resolution better than 10 meters for showers above 300 GeV



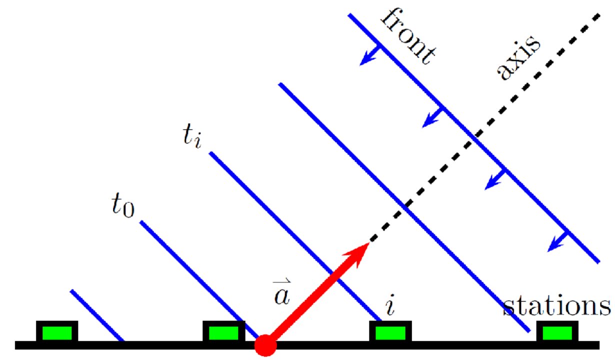


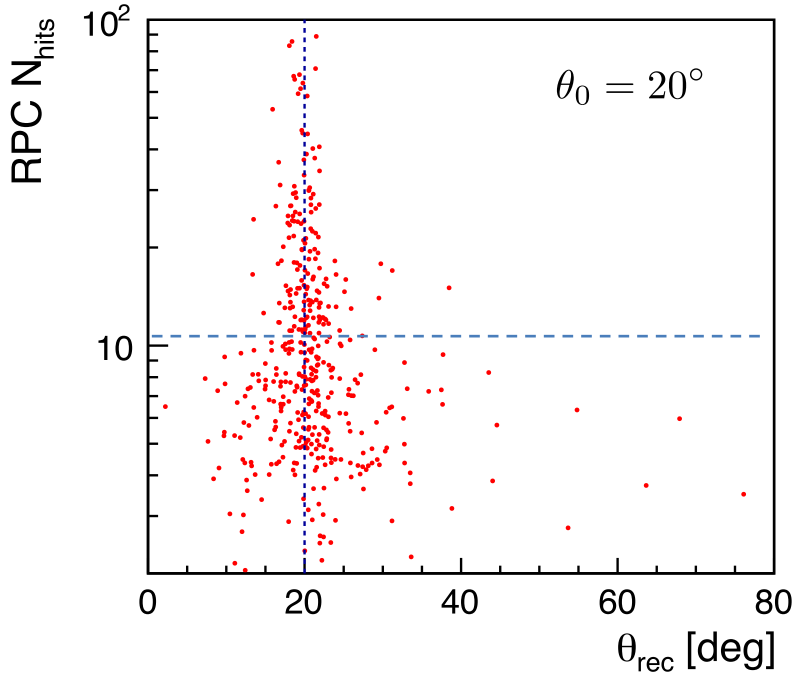
- Disclaimer:
  - g/h discrimination is not yet taking advantage of this improvement

Reconstruction of shower geometry

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

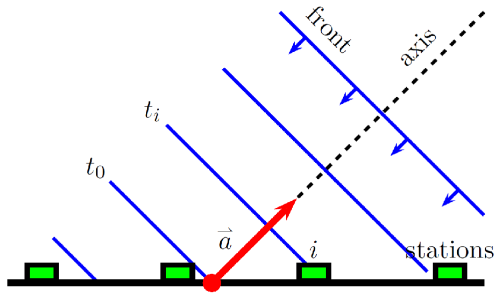
- Shower geometry reconstruction:
  - Use shower front plane approximation
  - Analytical procedure
  - Apply trigger conditions
  - Apply cut on the number of registered hits by the RPCs

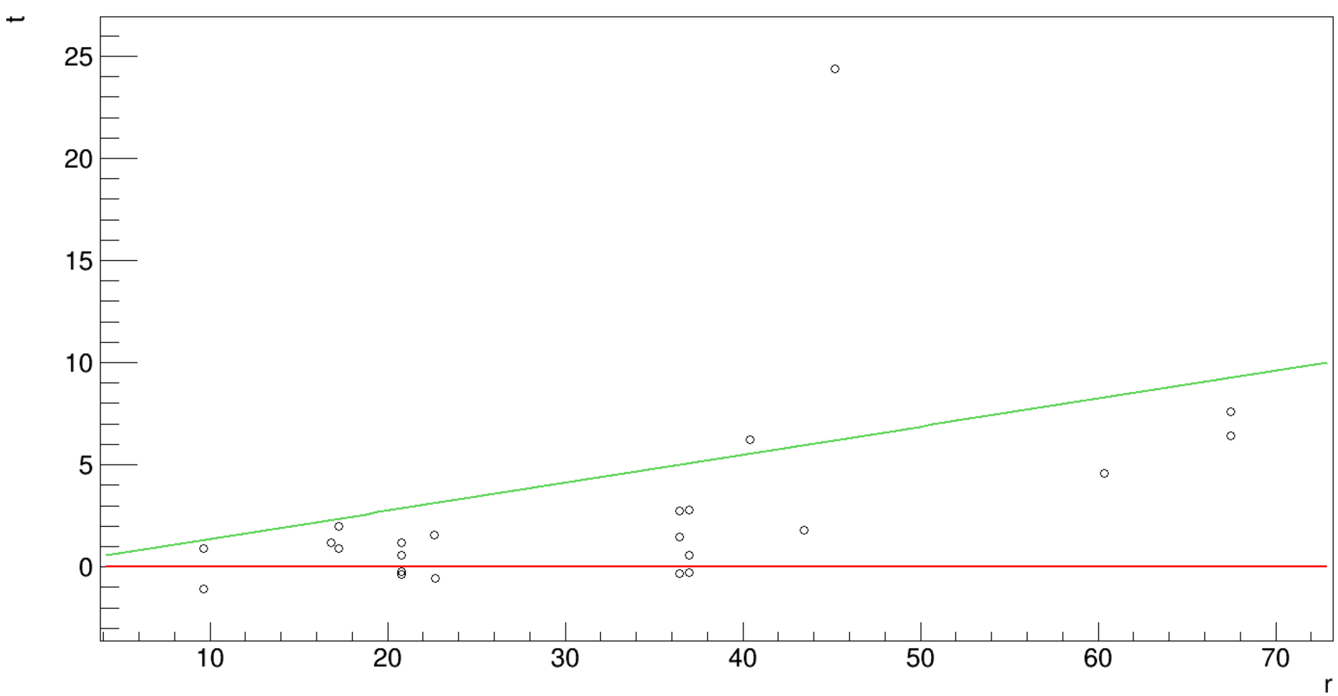




Reconstruction of shower geometry

- Remove late hits
  - Low energy electrons that lost correlation with shower front





$\theta_{rec} = 2.4°$

$\theta_0 = 0°$

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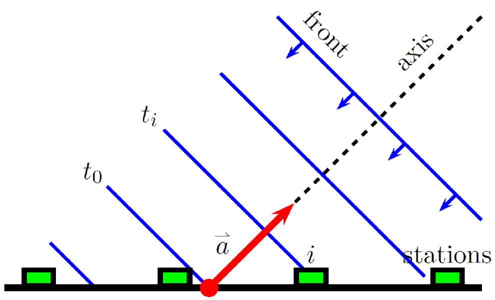

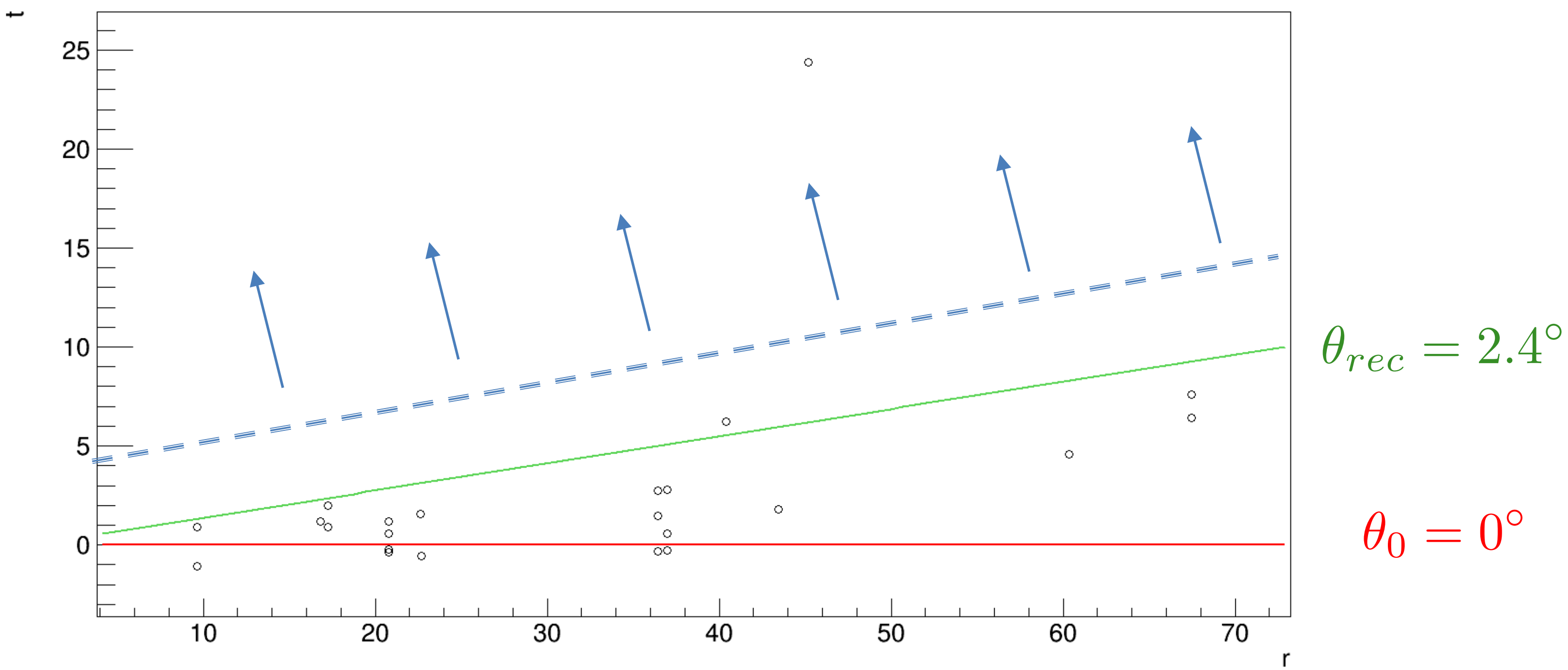

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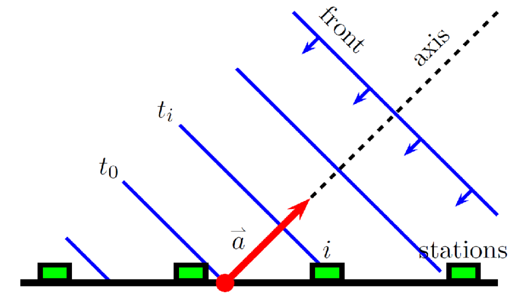
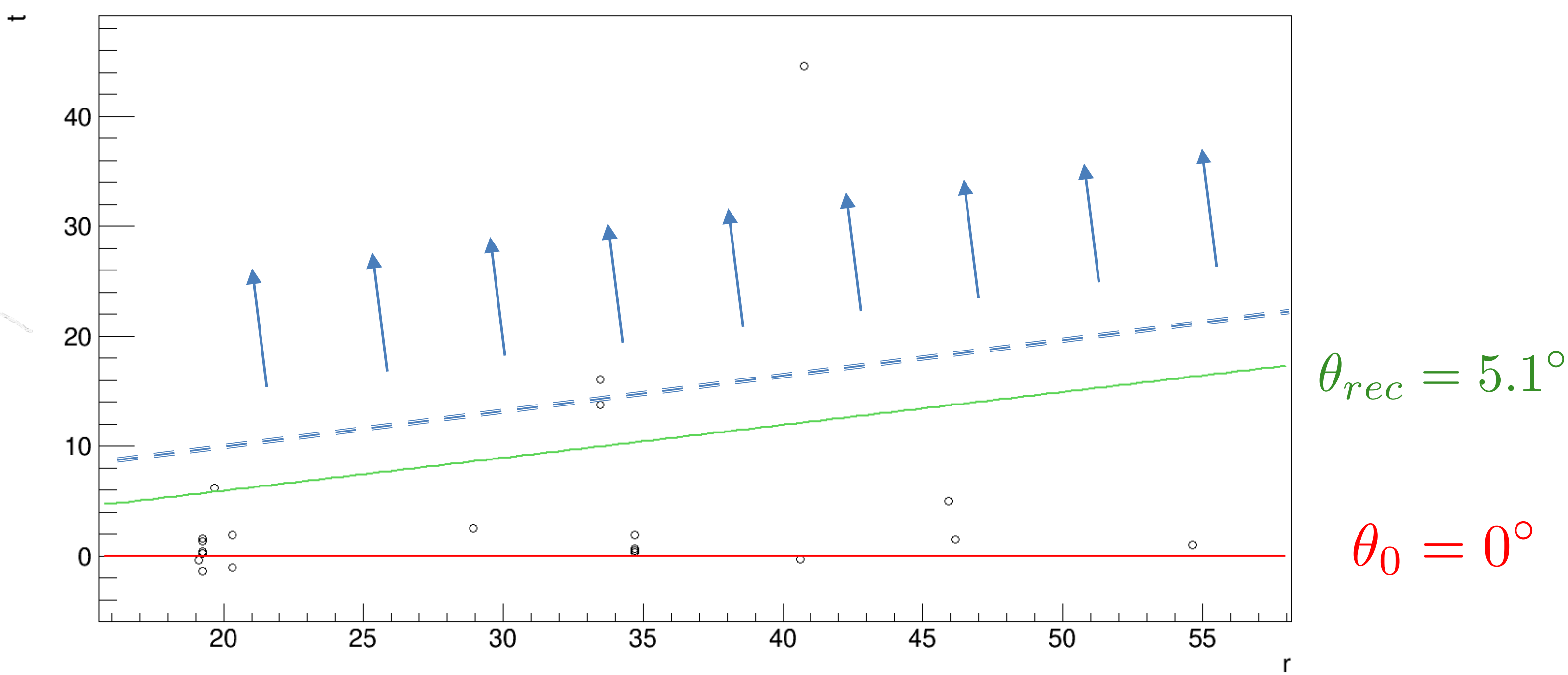
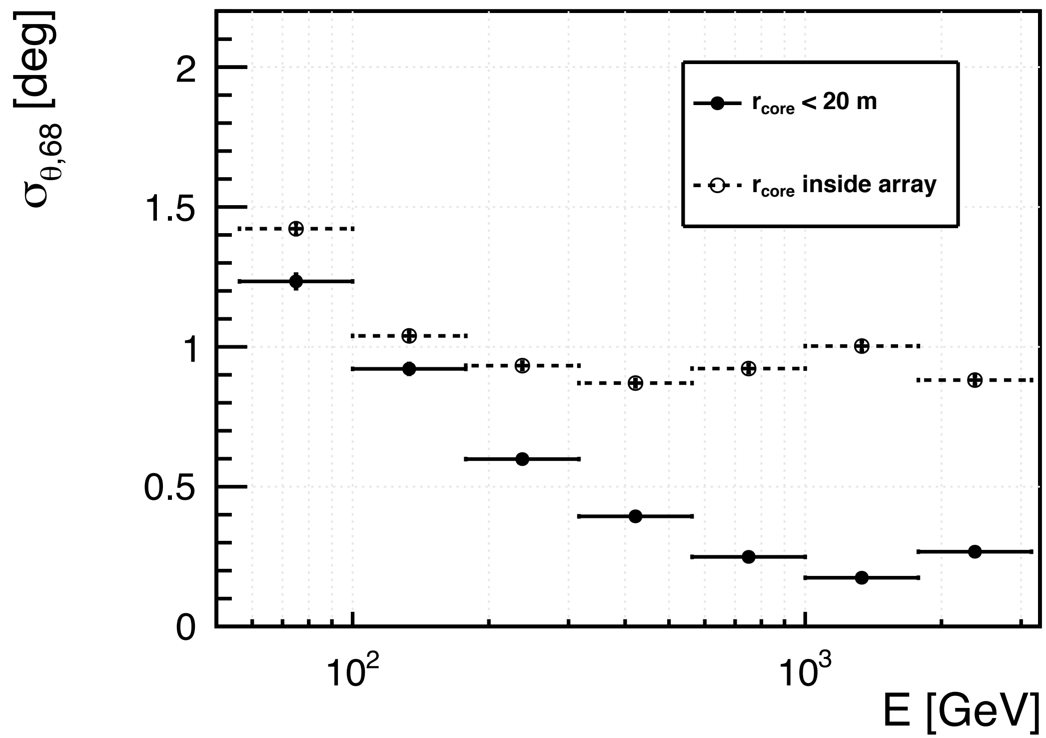




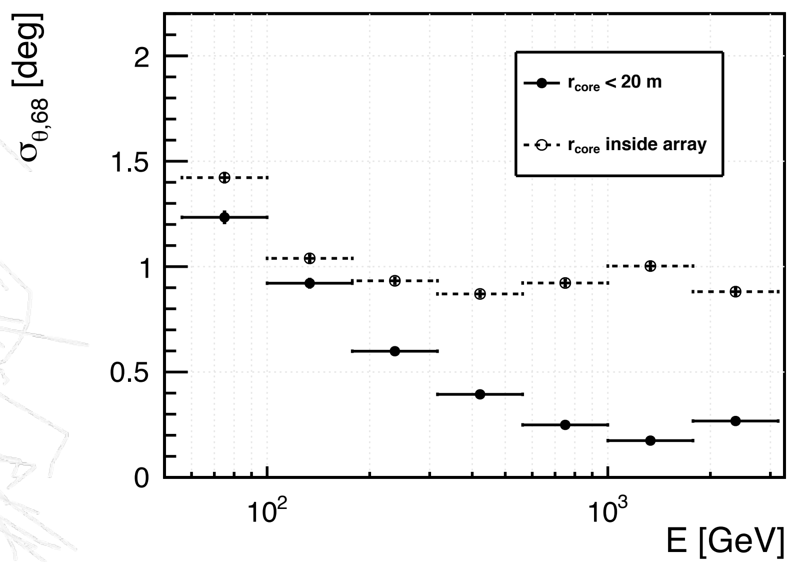
Geometric reconstruction

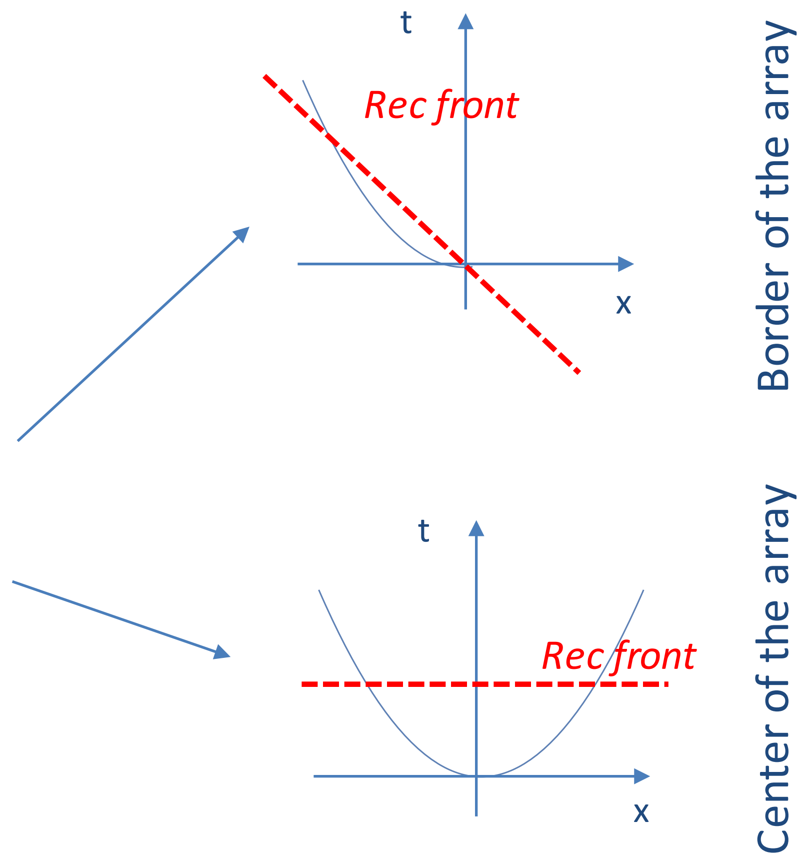
$$\gamma - \text{showers}; \theta = 10^\circ$$



- Shower geometry reconstruction done using RPC hit time (RPC time resolution of 1 ns)
  - *Angular resolution of about 1 deg even for 100 GeV showers*

Improving the geometry reconstruction





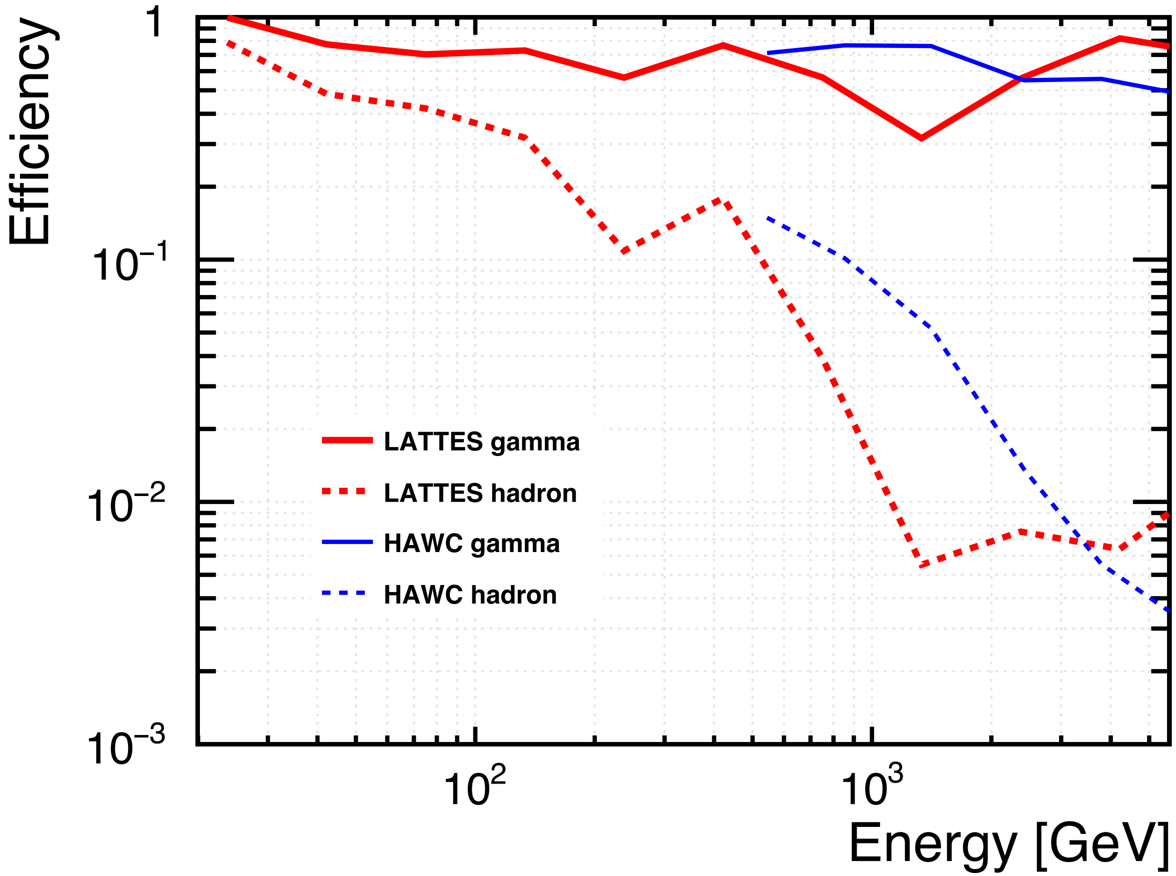
Solution: implement a conic fit instead of fitting a plane

(yet to be done)

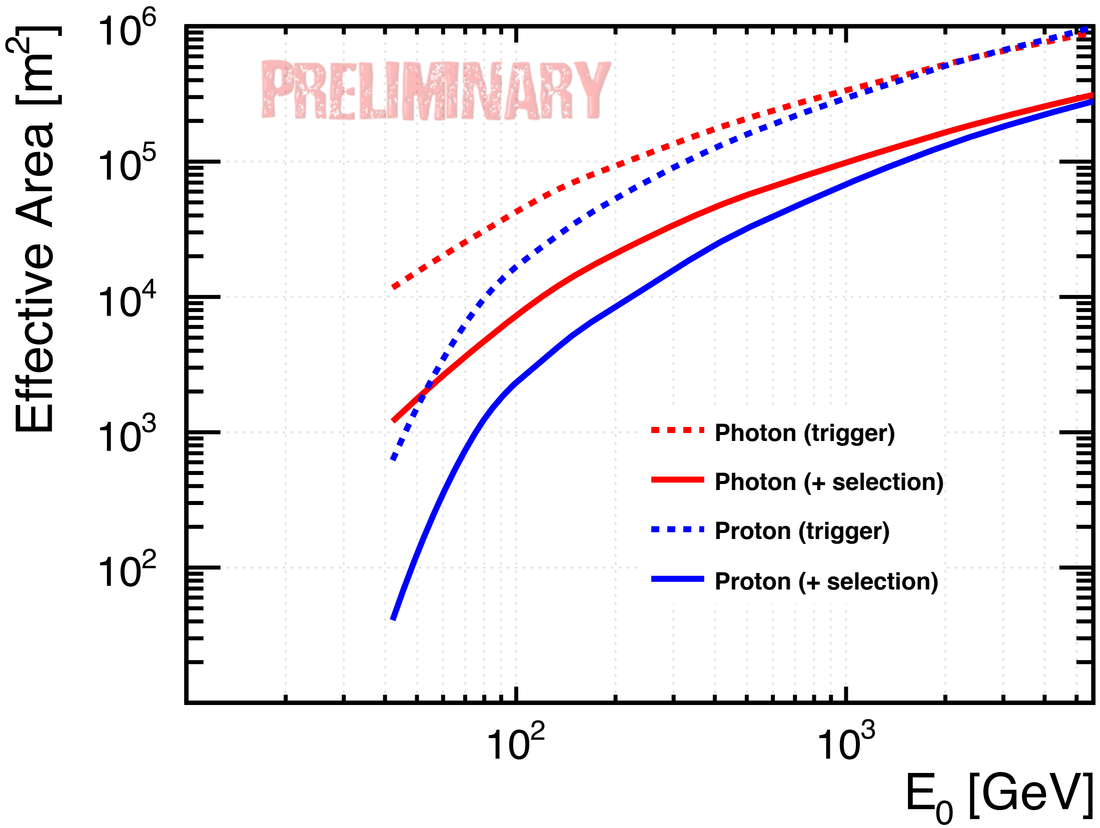
$$\chi^2 = \sum(c \cdot (T_n - T_0) - X_n \cdot l - Y_n \cdot m - R_n \cdot \alpha)^2$$

LATTES g/h discrimination

(discussed in the previous talk)



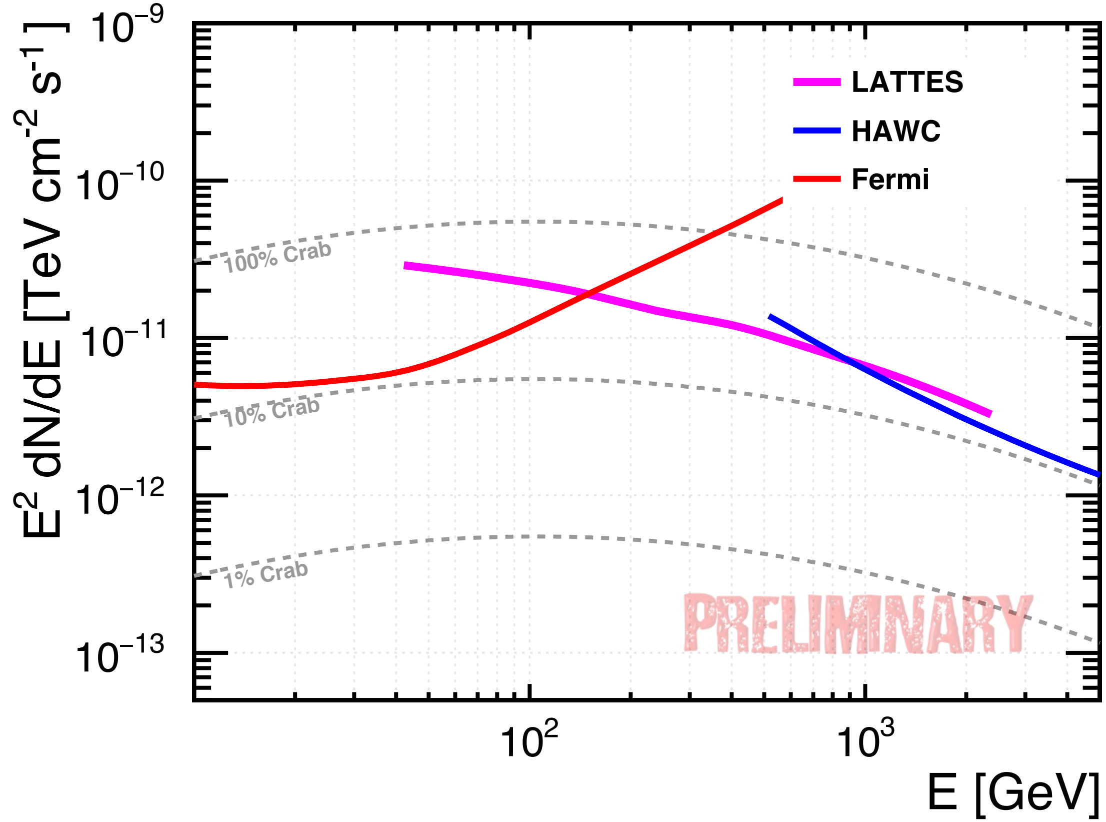
LATTES effective Area



After quality cuts we remain with an effective area of nearly 10 000 m^2 at 100 GeV

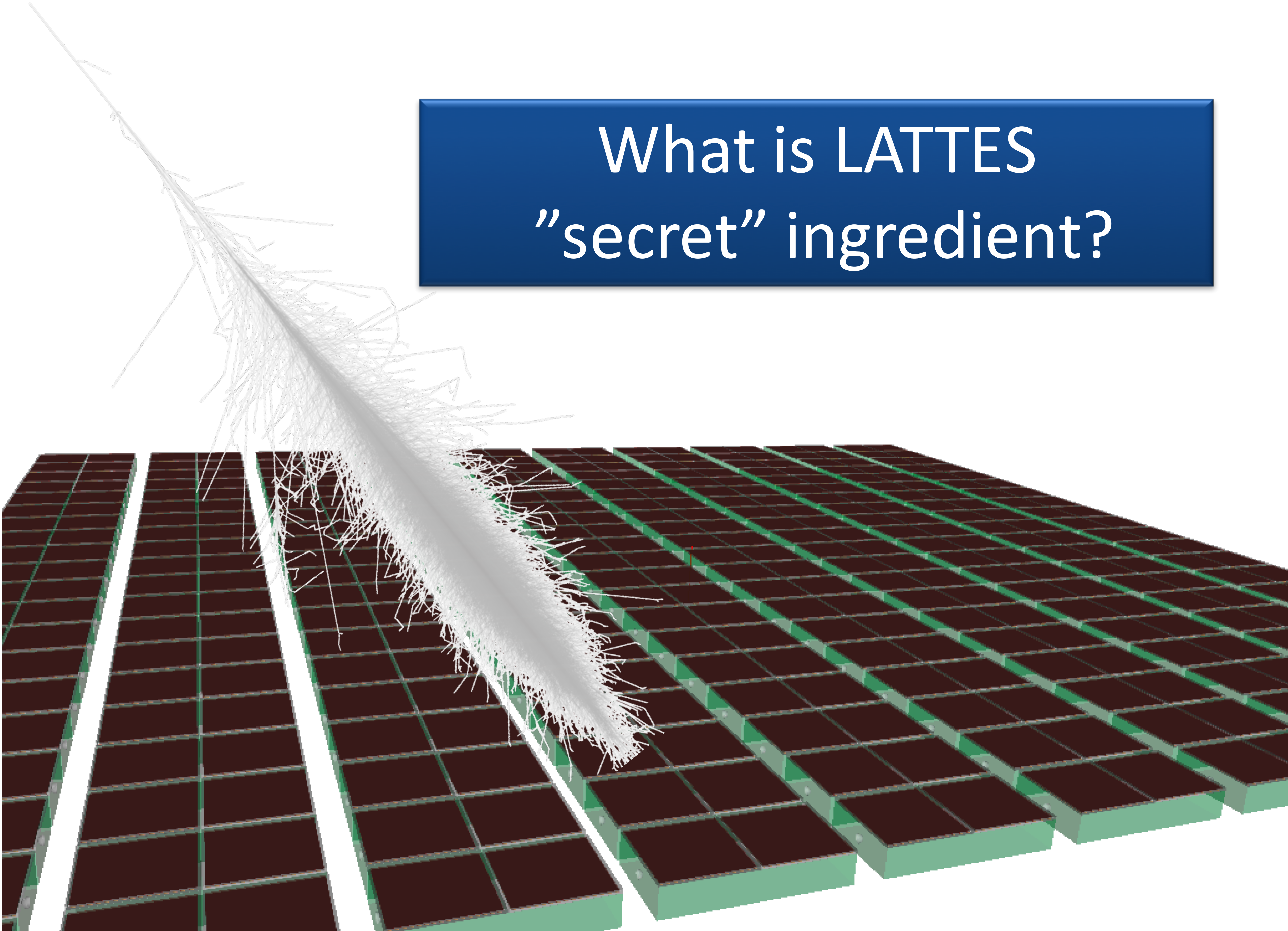
(lower energy to be explored with dedicated high statistics simulations)

LATTES Sensitivity

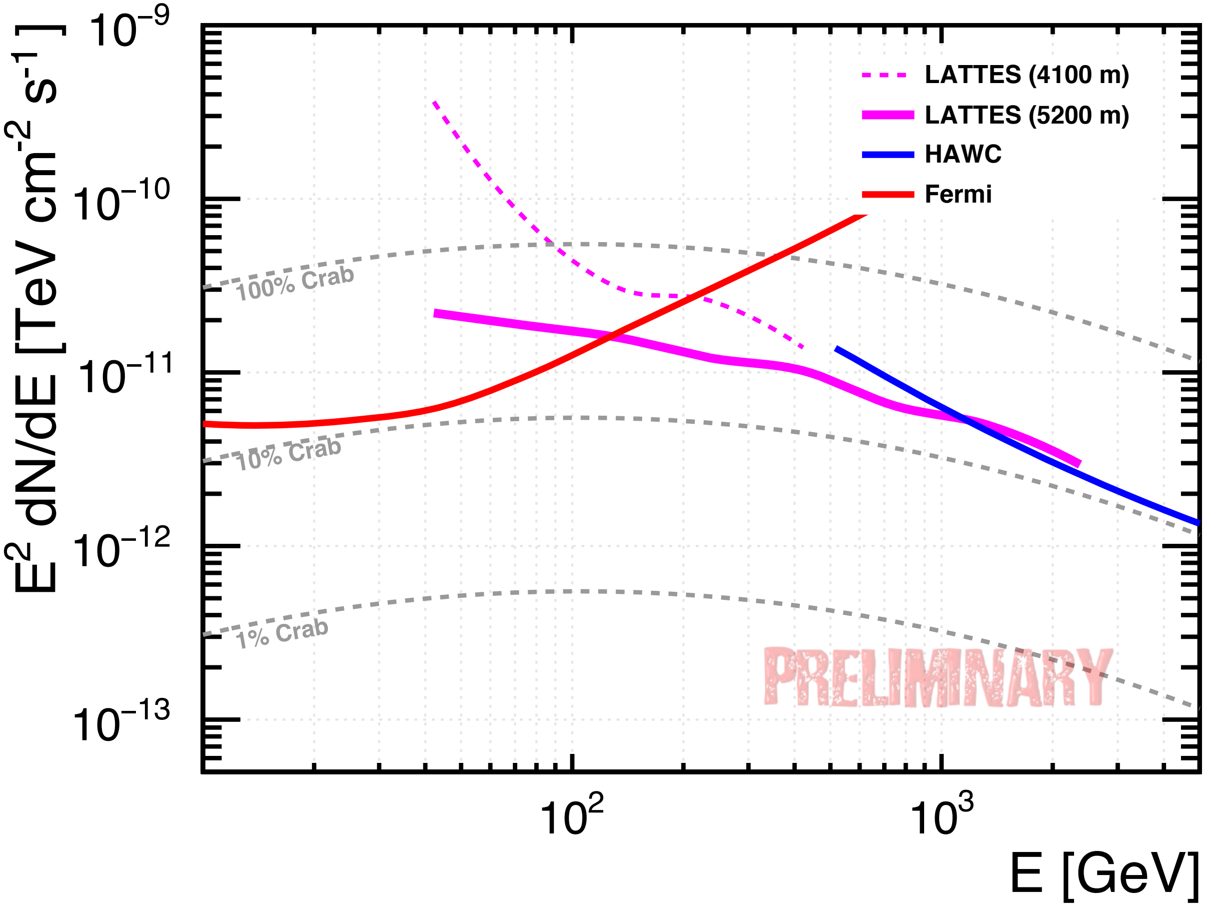


LATTES sensitivity to steady source in one year of operation

What is LATTES ”secret” ingredient?



Observation Altitude

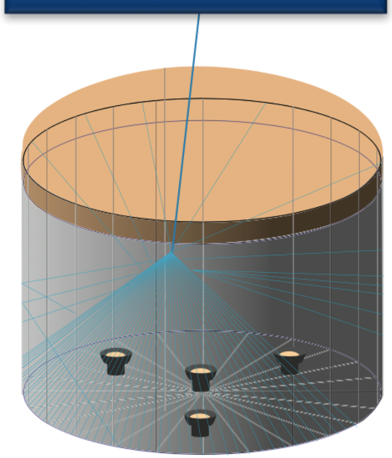


The ability to reach the lowest energies depends on the altitude but also on the detector concept

LATTES: complementarity

ARGO

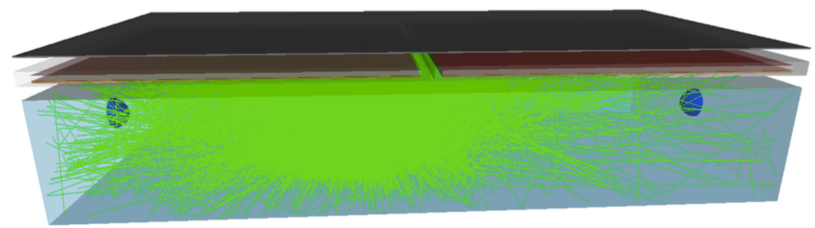
HAWC



LATTES

(hybrid detector)

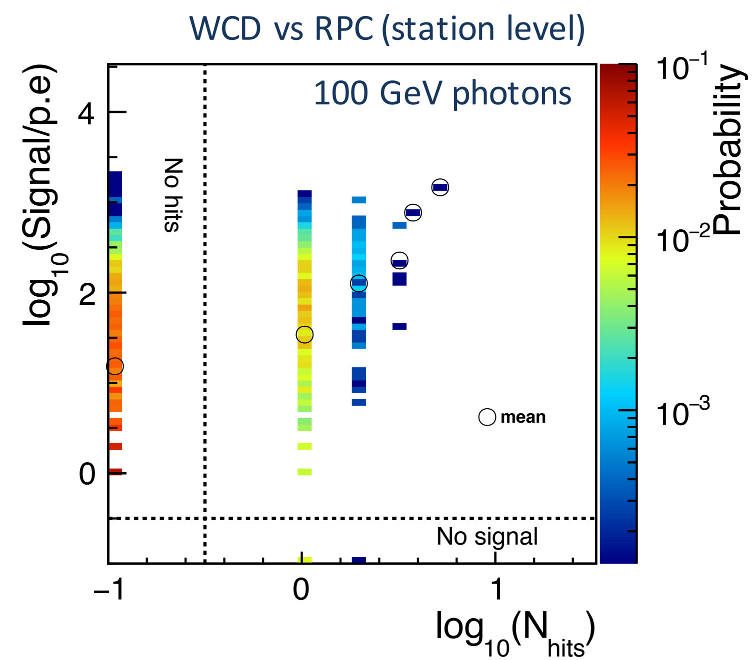
RPC => Spatial and time resolution
(ability to reconstruct the shower geometry)

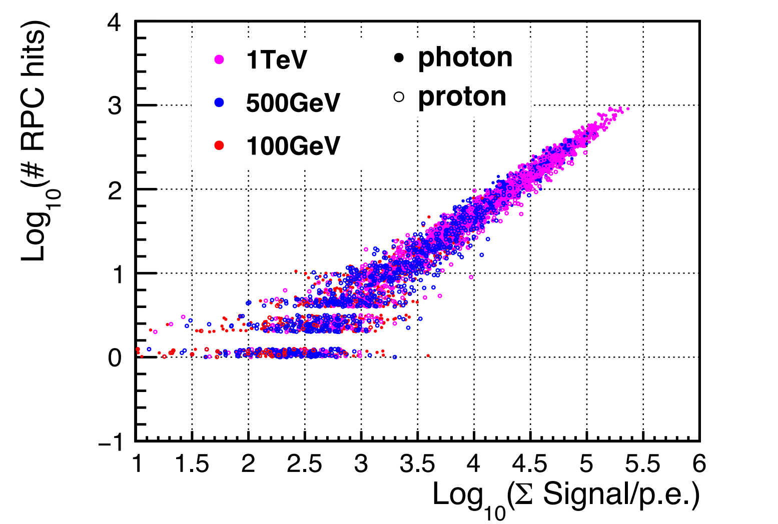


WCD => Calorimetry
(ability to trigger at low energies)

LATTES: complementarity

- 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 combined Argo/HAWC discrimination techniques





Summary

- LATTES performance assessed using a realistic simulation
- Results with “first order” analysis demonstrate that LATTES can cover the energy gap between satellite and ground array gamma-ray experiments
- Several improvements to the analysis have been identified
  - LATTES concept is still far from being fully explored

Acknowlegments

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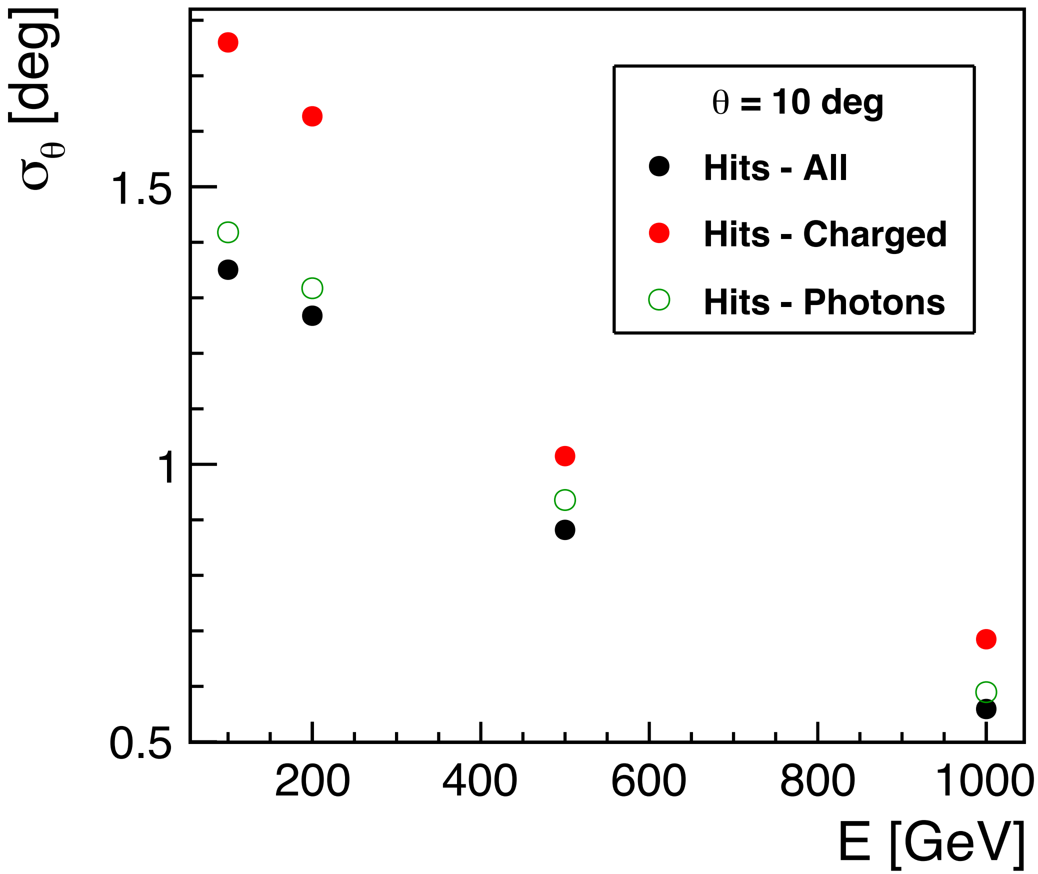
LIP

TÉCNICO LISBOA

BACKUP SLIDES

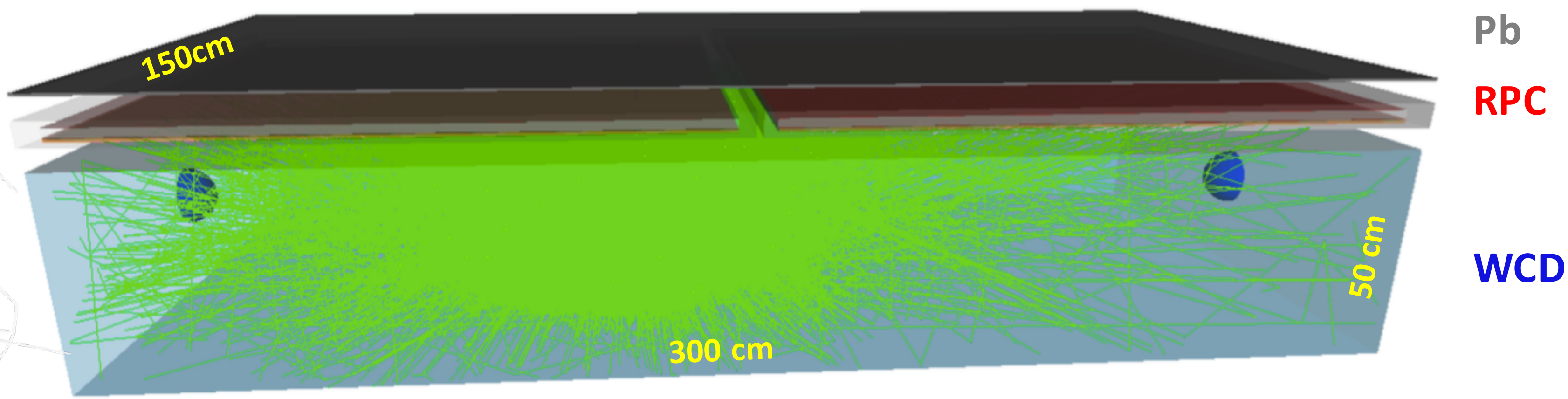
Contributions to the geometric reconstruction



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

LATTES concept

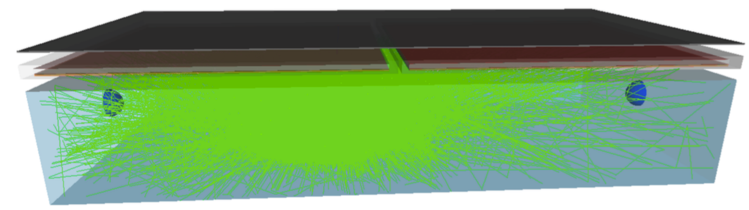
LATTES STATION



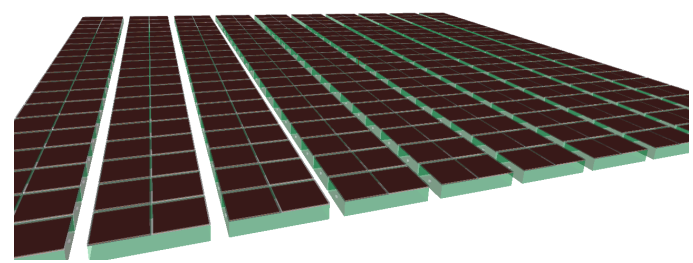
– Thin lead plate (Pb)
  - 5.6 mm (one radiation lenght)
– Resistive Plate Chambers (**RPC**)
  - 2 RPCs per station
  - Each RPC with 4x4 readout pads
– Water Cherenkov Detector (**WCD**)
  - 2 PMTs (diameter: 15 cm)
  - Inner walls covered with white diffusing paint

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
90 x 40 stations
140 x 140 m^2

LATTES: complementary

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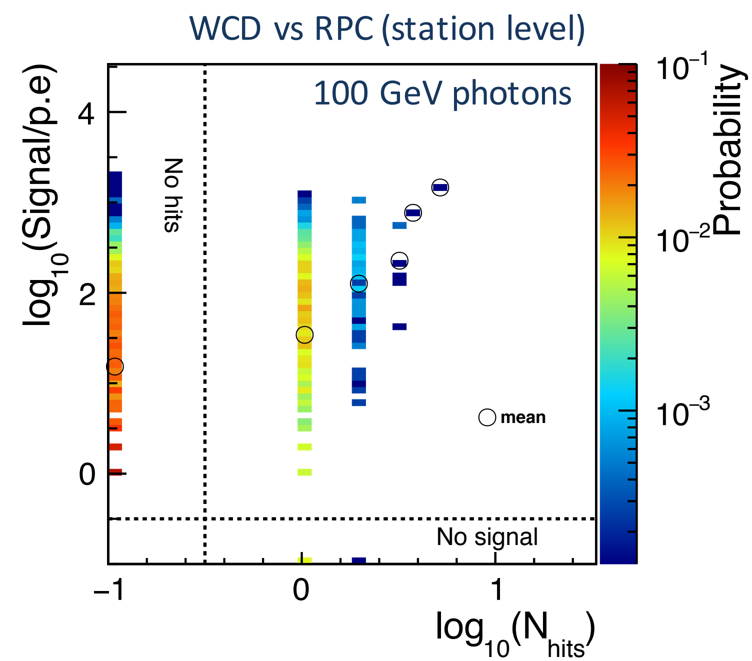
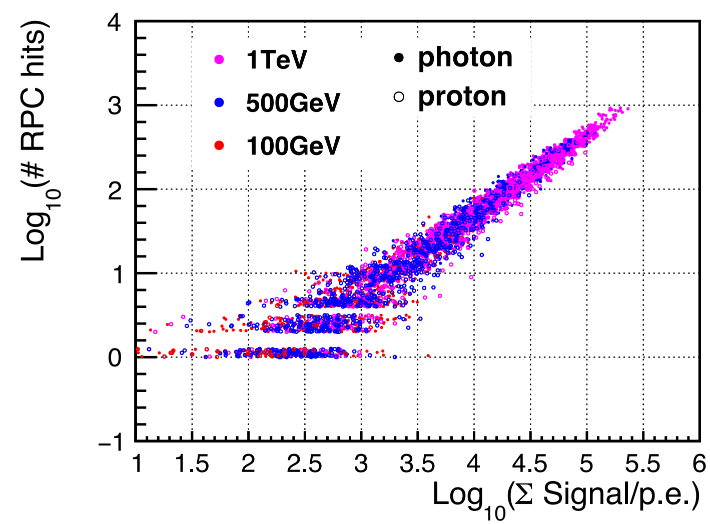
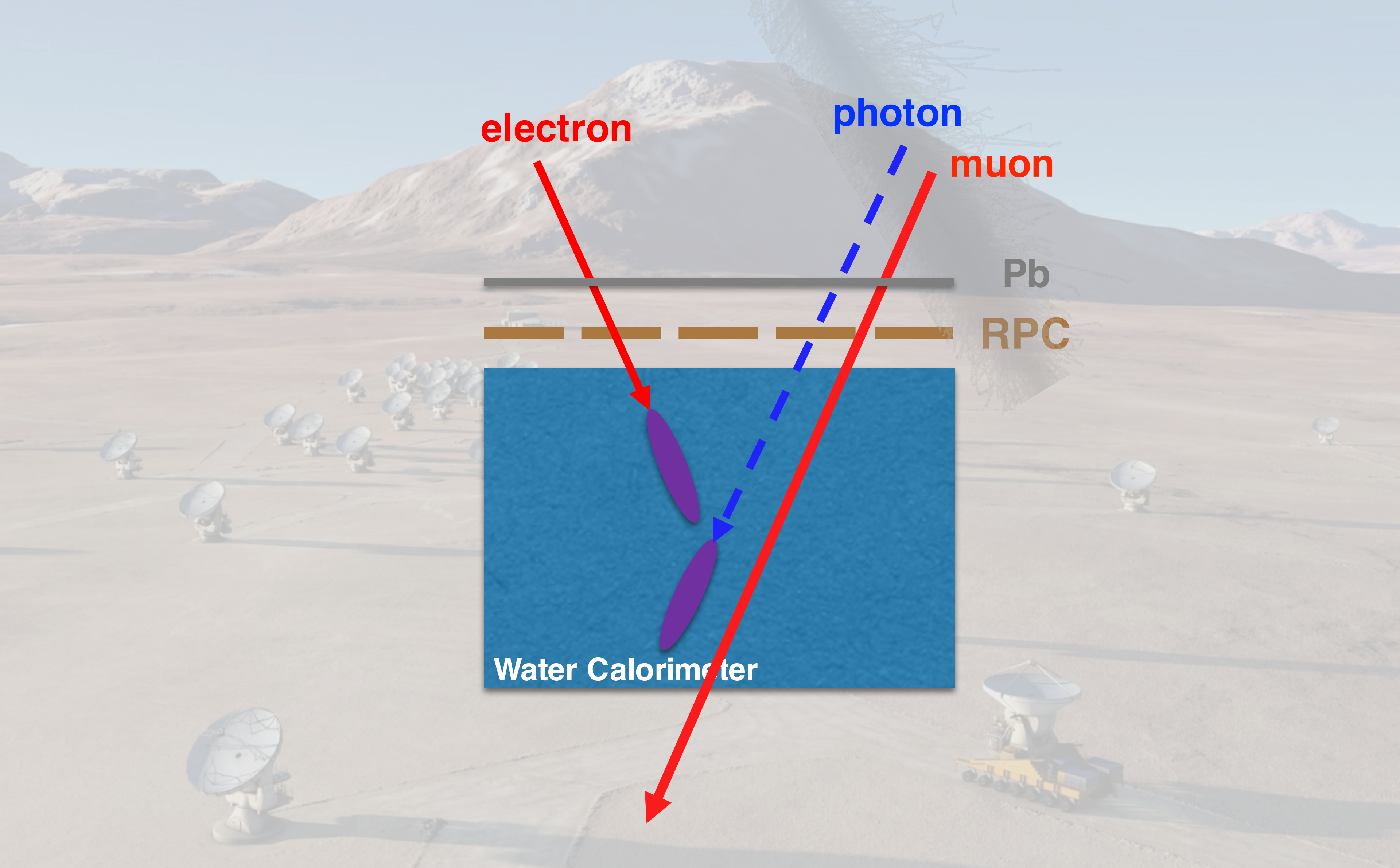




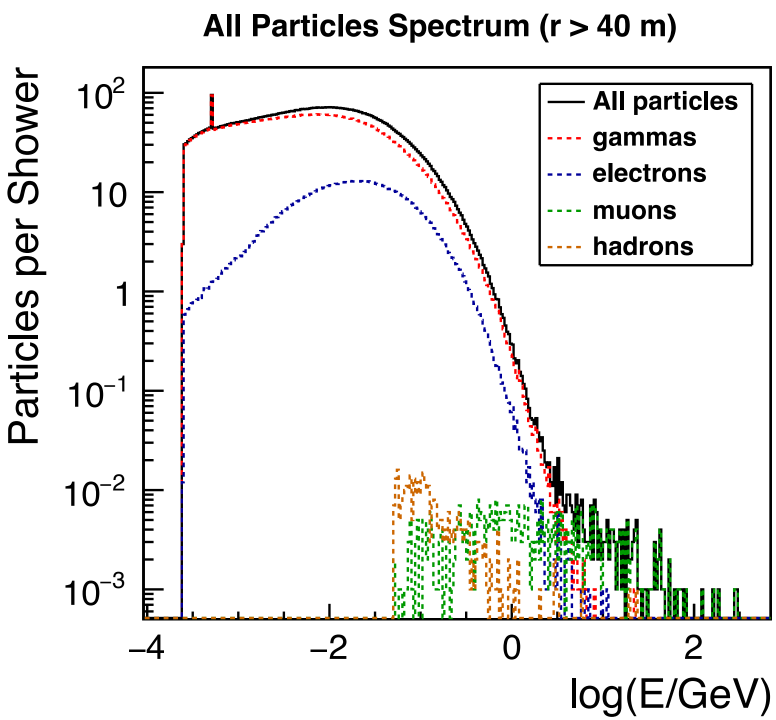
LATTES station baseline concept



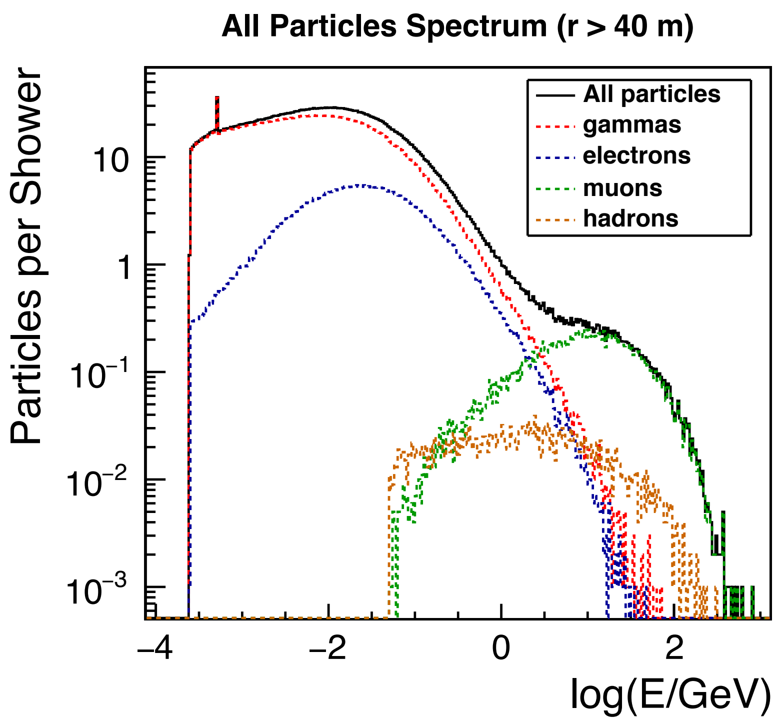
Exploring the WCD

5 TeV

Gamma showers

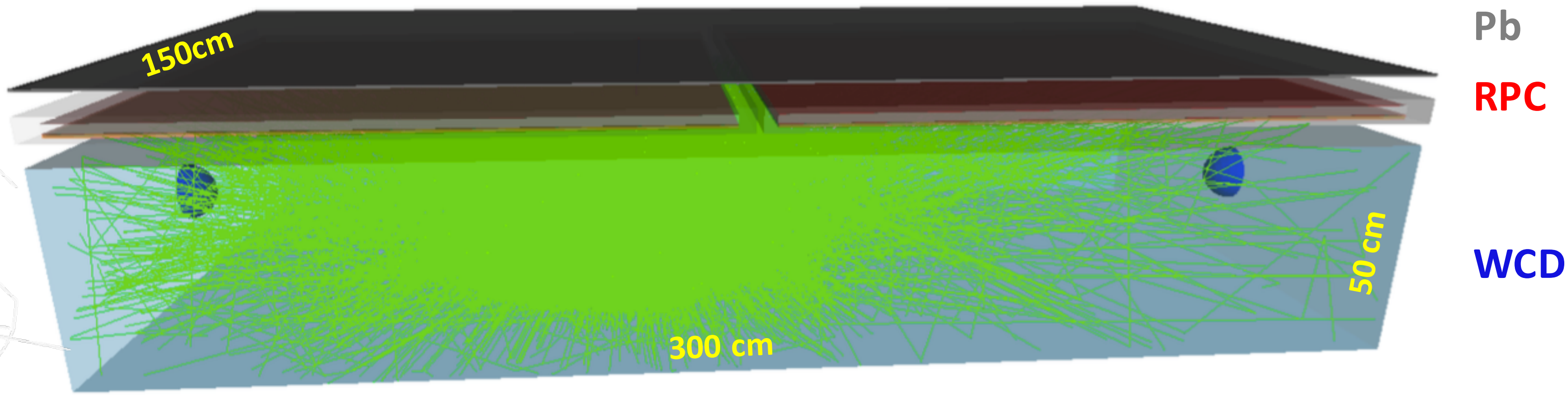


Proton showers



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

LATTES STATION



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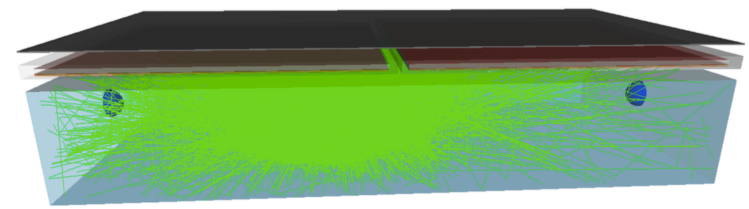

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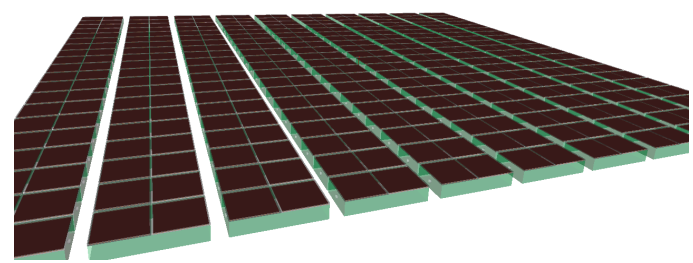
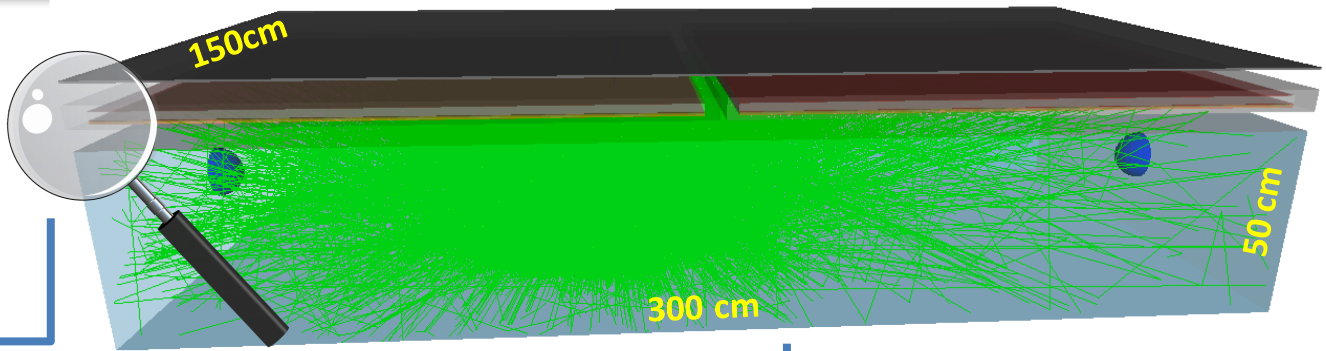


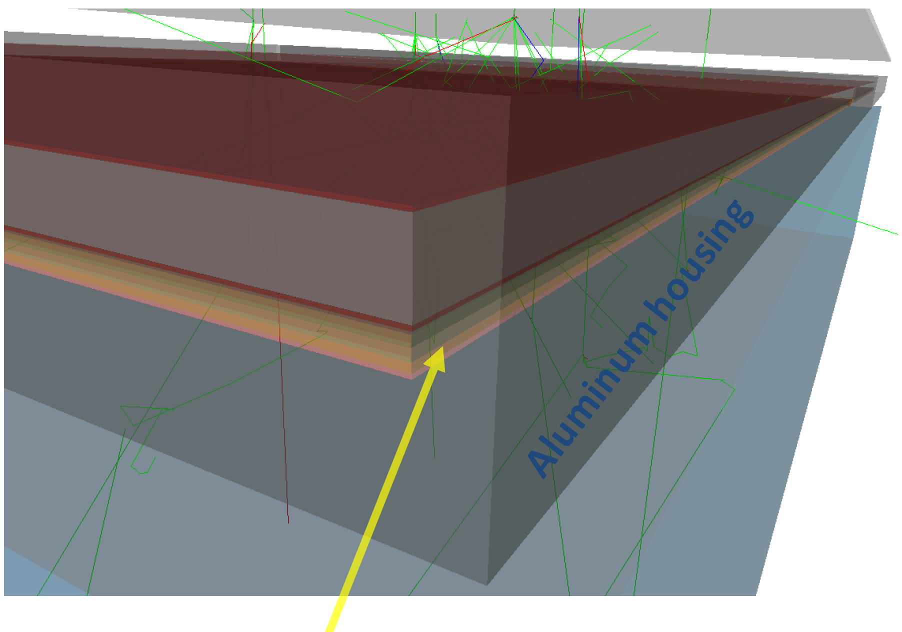
LATTES core array
30 x 60 stations
100 x 100 m^2

LATTES station in Geant4

- **Realistic description**



Detailed RPC structure



Acrylic box with glass electrodes and 1 mm gas gaps

- **Explore Geant4 capabilities to simulate optical photon propagation;**
- λ dependence of all relevant processes/materials taken into account;
- **Water**
  - Attenuation length ~ 80 m @ λ = 400 nm
- **PMT**
  - Q.E.$_{max}$ ~ 30% @ λ = 420 nm
- **Tyvek**
  - Described using the G4 UNIFIED optical model;
  - Specular and diffusive properties;
  - R ~ 95%, for λ > 450 nm