LATTES Reconstruction

Analyses opportunities

Ruben Conceição

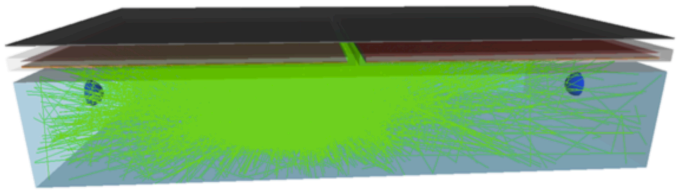
P. Abreu, A. Bueno, J. Cordeiro, A. Guillén, L. J. Herrera, J. Jesus, S. Marques, M. Pimenta, F. Salles, M. Serra, B. Tomé, A. Torcato, J. Vicha

And you?!....

LIP

Towards LATTES reconstruction

- Reconstruction
  - First order analyses with little optimization only to demonstrate principle



- Performance and sensitivity

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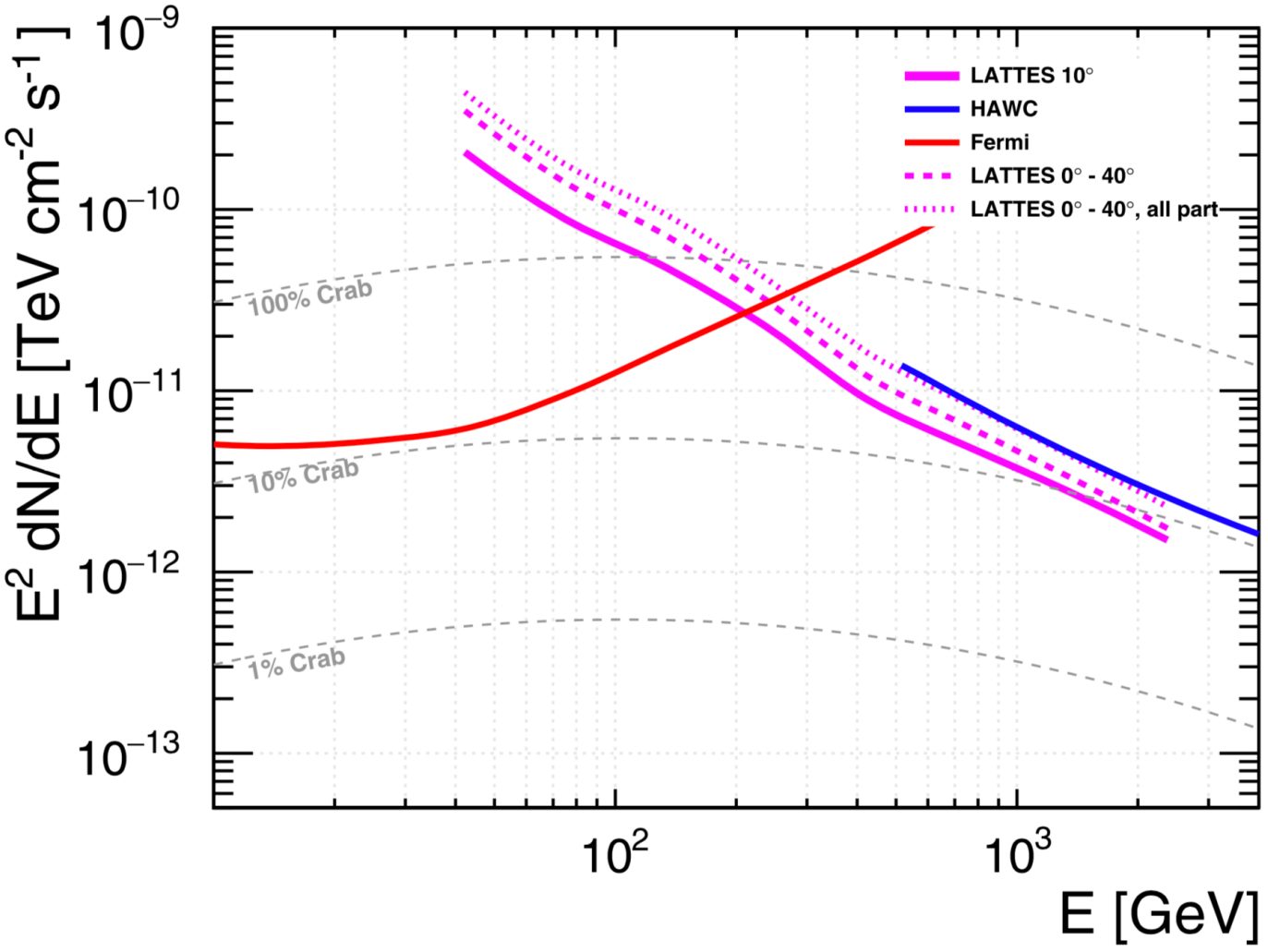
Design and expected performance of a novel hybrid detector for very-high-energy gamma-ray astrophysics

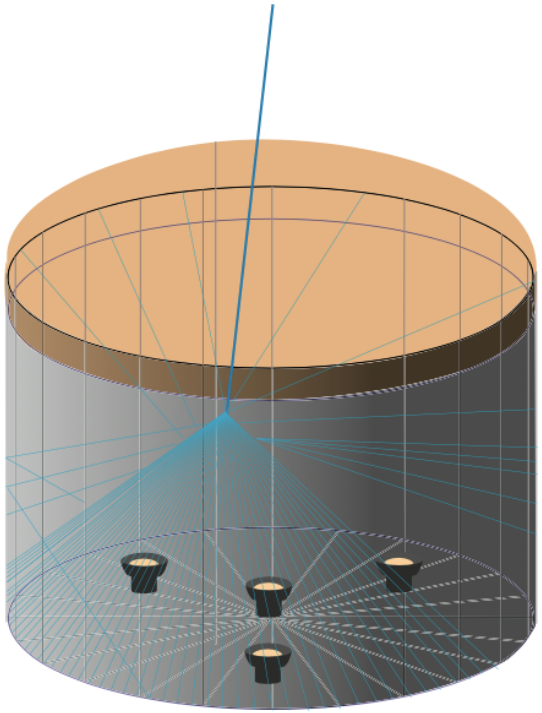
P. Assis[a,b], U. Barres de Almeida[c], A. Blanco[d], R. Conceição[a,b,*], B. D'Ettorre Piazzoli[e], A. De Angelis[f,g,b,a], M. Doro[h,f], P. Fonte[d], L. Lopes[d], G. Matthiae[i], M. Pimenta[b,a], R. Shellard[c], B. Tomé[a,b]

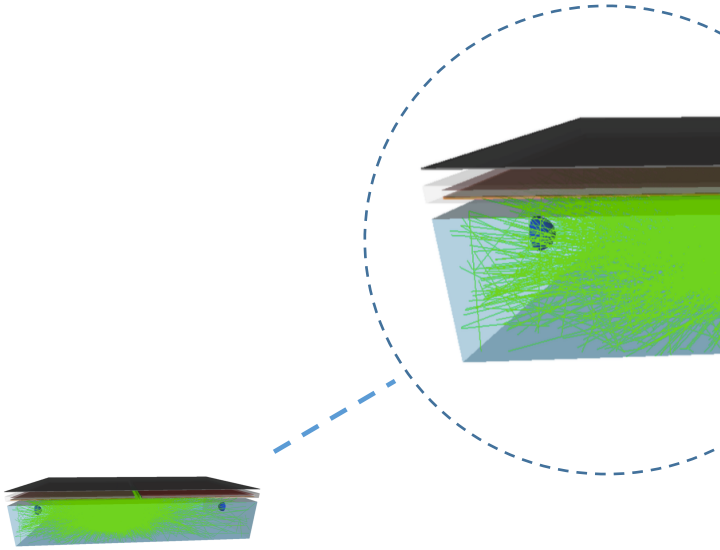
Sensitivity to steady sources



Can we improve LATTES reconstruction?

Station: HAWC vs LATTES





HAWC
(present detector)

LATTES
(next generation)

A hybrid detector with lots of potential…

What we have learned so far…

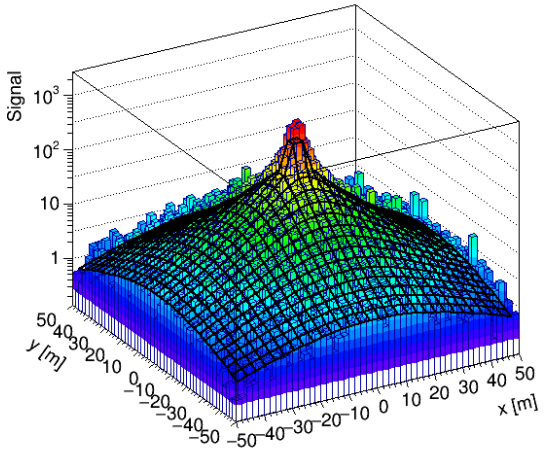
- Core reconstruction
- Energy reconstruction
- Geometry reconstruction
- Gamma/hadron discrimination
- Sensitivity and angular dependency
- Sparse Array

Shower Core Position Reconstruction

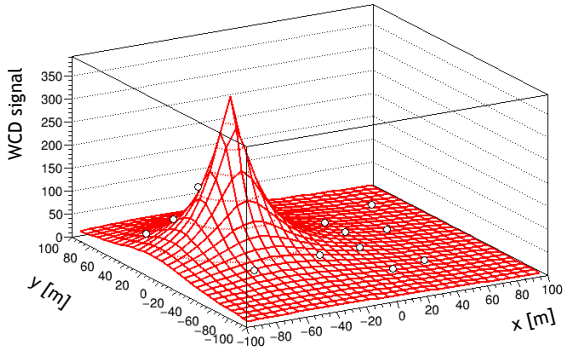
Shower core reconstruction

- Use the WCD signal
- Barycenter
  - Initial guess
  - 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
    - Nearly no evolution with energy
  - Use this form to find the maximum, i.e. the shower core

Average LDF



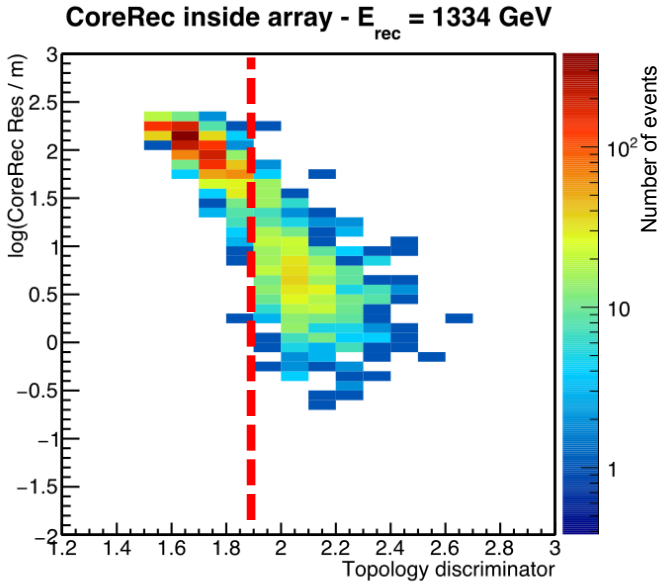
Single event

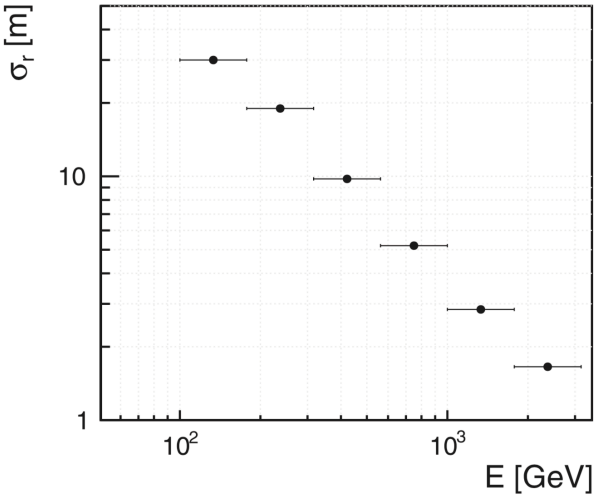


$$S_i = S(A, \vec{x}, \vec{x}_i) = A\left(\frac{1}{2\pi\sigma^2} e^{-|\vec{x}_i - \vec{x}|^2/2\sigma^2} + \frac{N}{(0.5 + |\vec{x}_i - \vec{x}|/R_m)^3}\right)$$

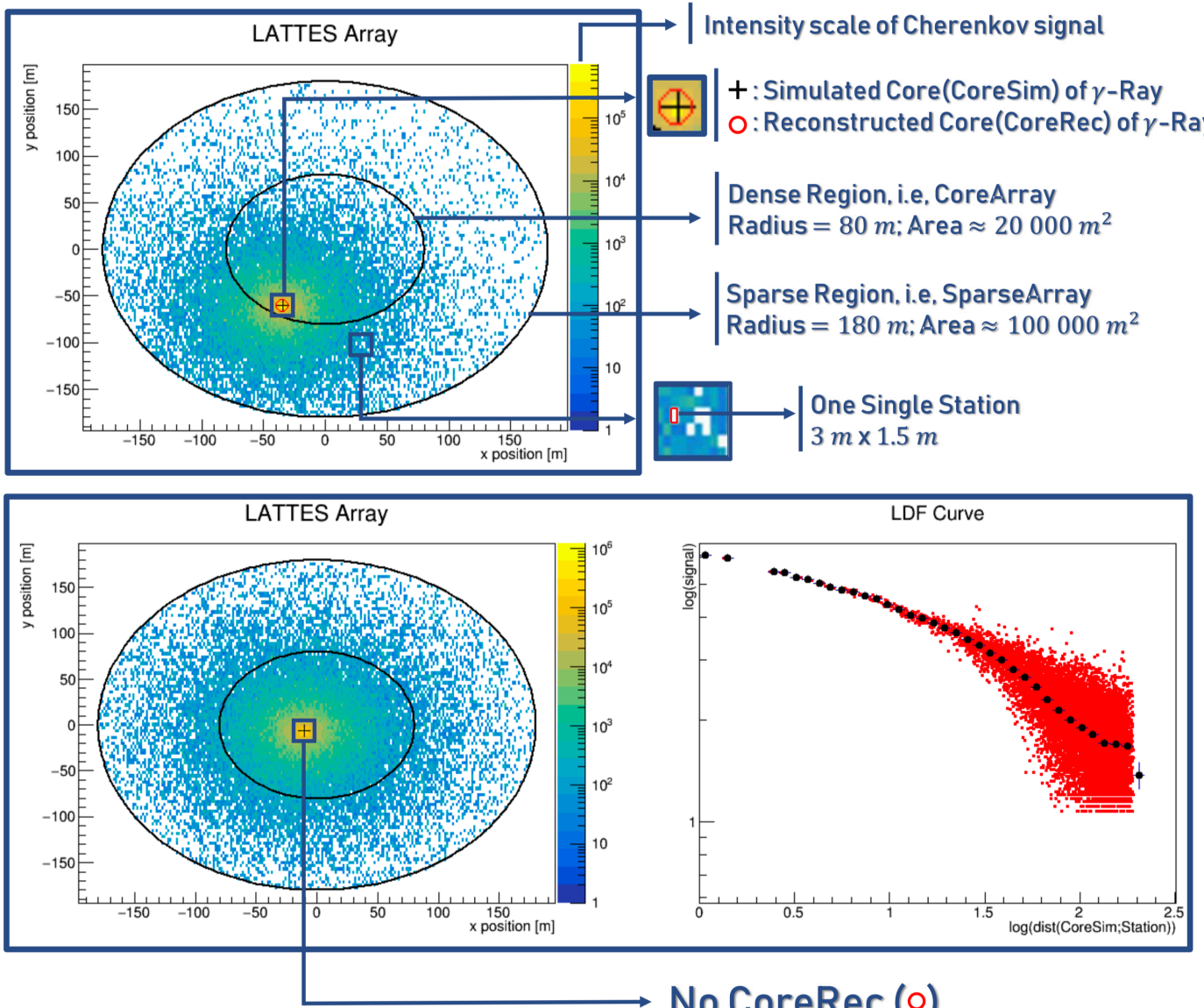
Shower core reconstruction

- Test whether the shower is inside/outside the array
  - Explore LDF topology
  - Is maximum observed inside of array?
  - Currently exploring the quality of the fit
  - Fixed cut for all energies
- Resolution better than 10 meters for showers above 300 GeV

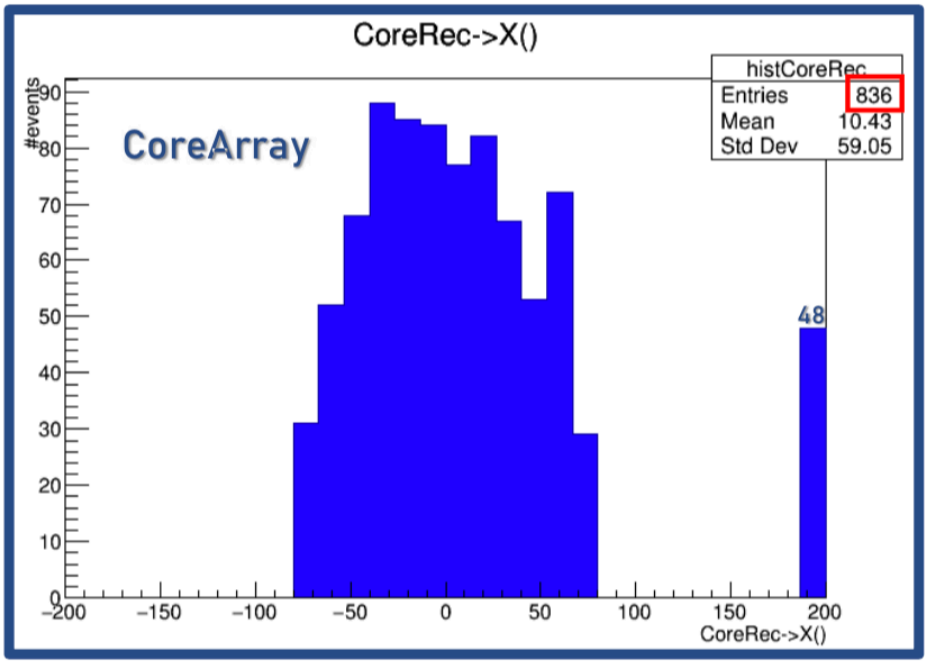




Core Rec of high-energy events



How many events?

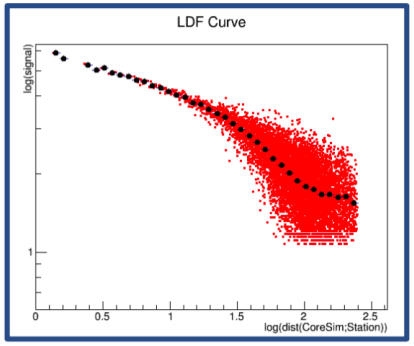


- For events above 5 TeV about 5 % of the events do not get a reconstructed core

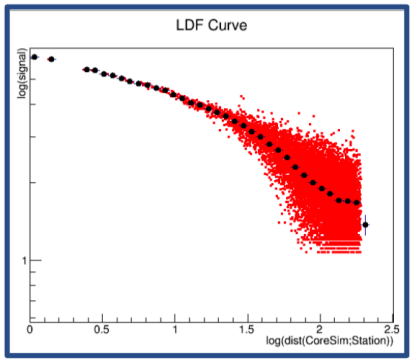
Probable cause…

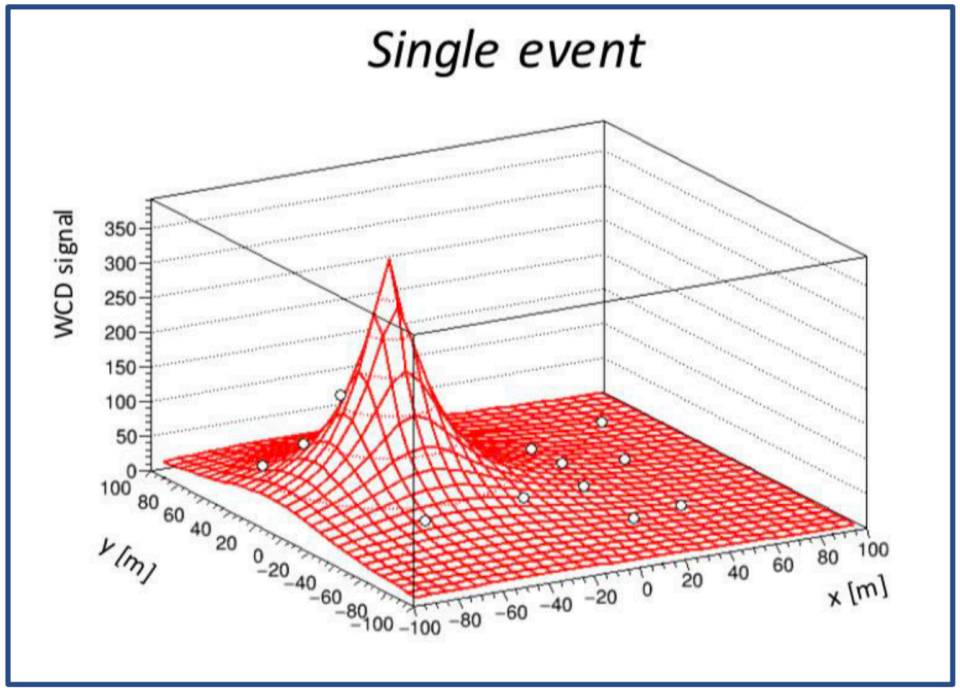
André Torcato
Melissa Serra

Fit OK



Fit Fail





- Average LDF needs to account for some WCD leakage in the core

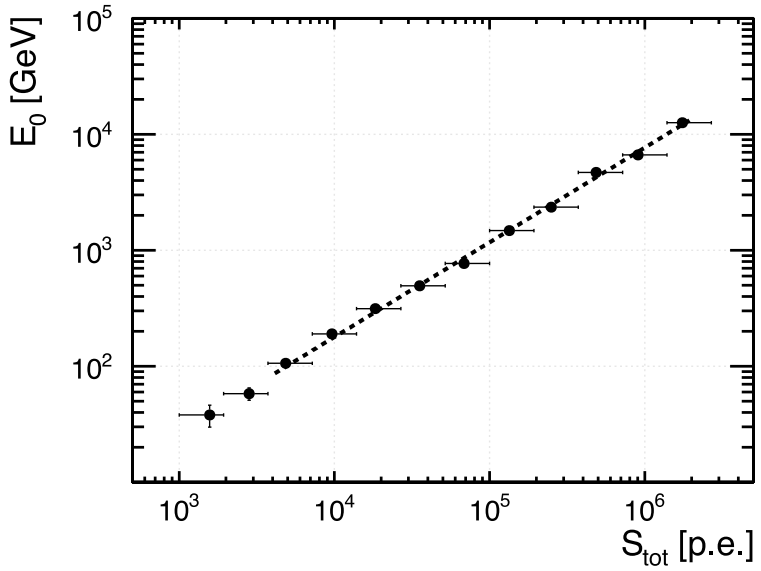
Shower Energy Reconstruction

Energy reconstruction

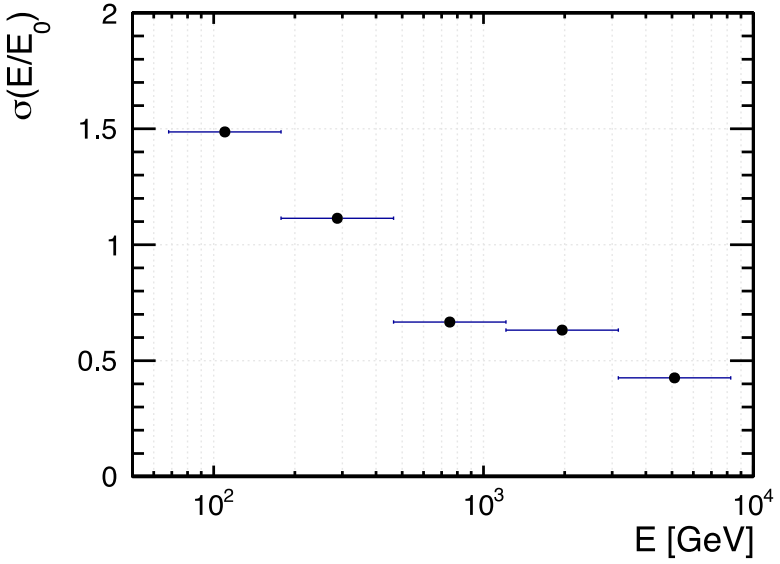
$E_0 \rightarrow$ Simulated energy

$E \rightarrow$ Reconstructed energy

Energy Calibration



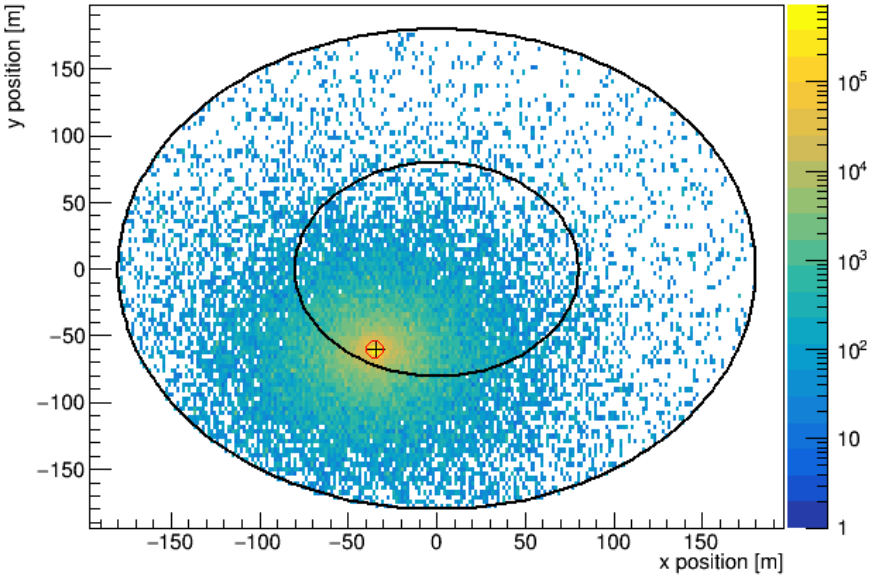
Energy Resolution

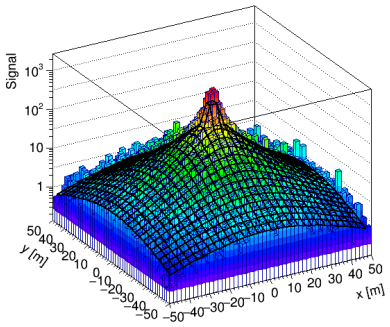


- Use as energy estimator the total signal recorded by WCDs
  - Use only shower cores reconstructed inside array
- Energy resolution at low energy dominated by shower fluctuations

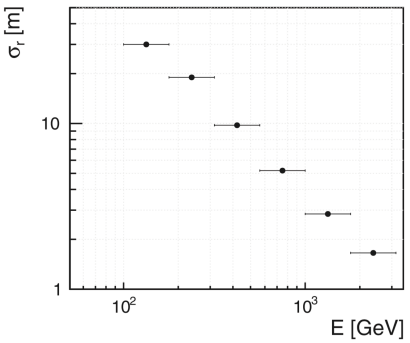
Towards a more sophisticated energy reconstruction

Pedro Abreu





Average LDF



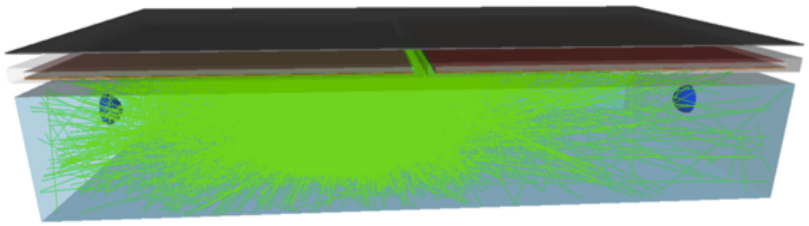
Core resolution

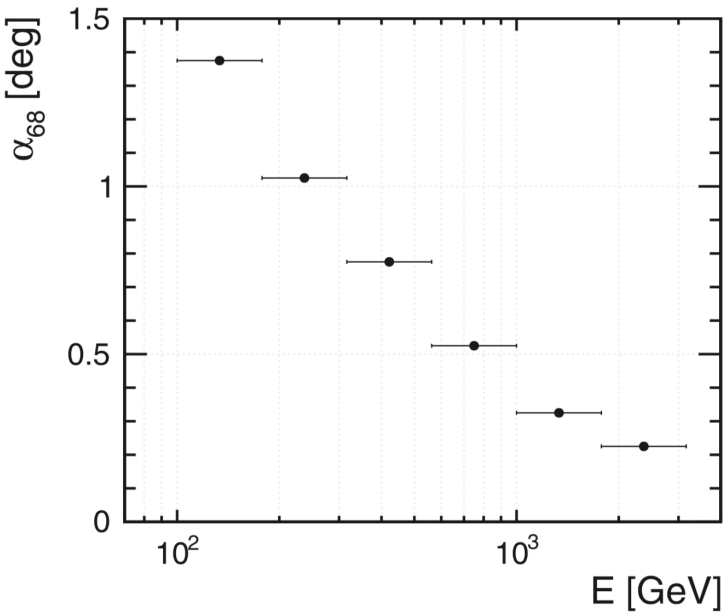
- Combine the core position with an average LDF to estimate the amount of energy outside of the array

Shower Geometry Reconstruction

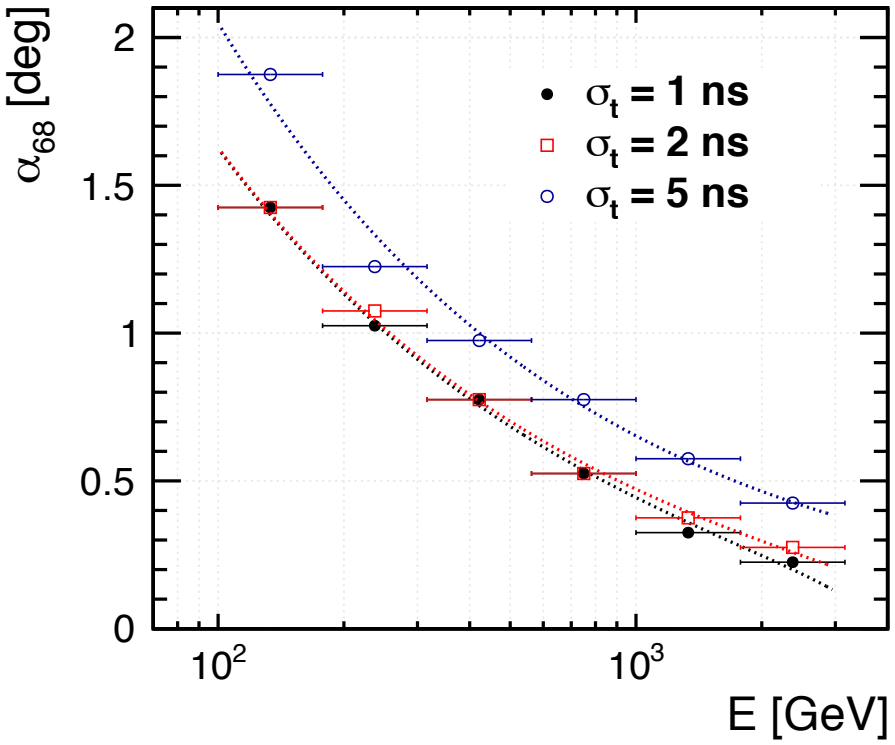
Shower geometry reconstruction

- Use RPC hit time information
  - Take advantage of high spatial and time resolution
  - Used time resolution of 1 ns
  - Obtain shower geometry using a conic shower front model



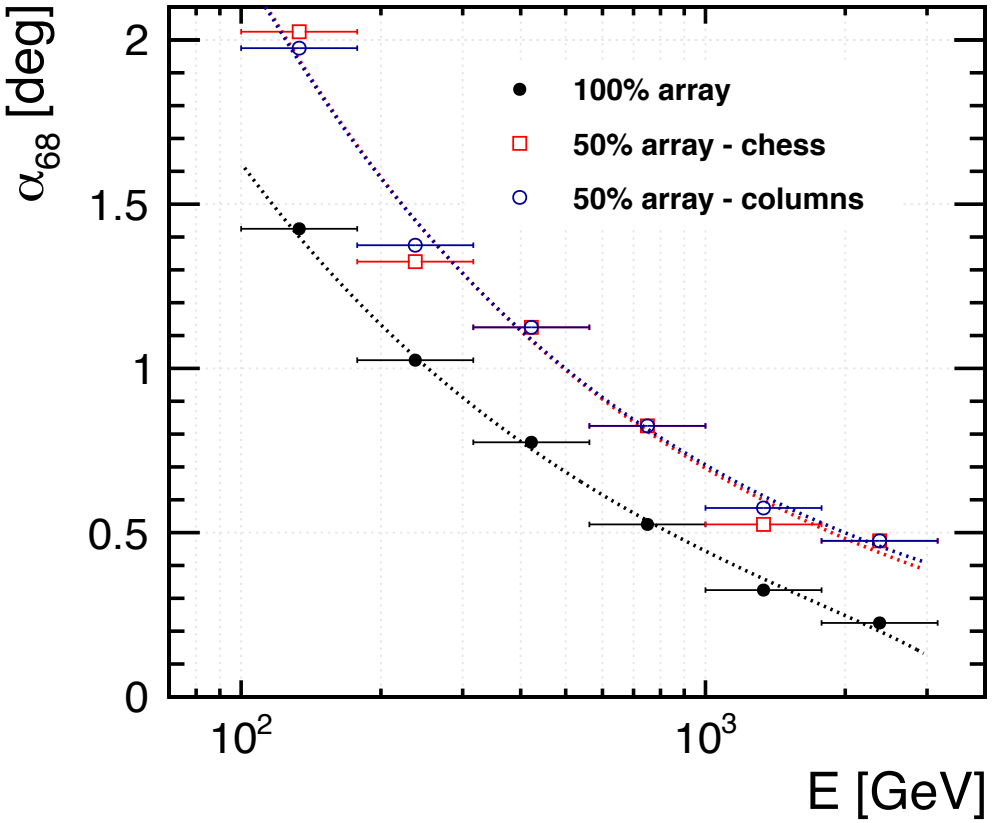


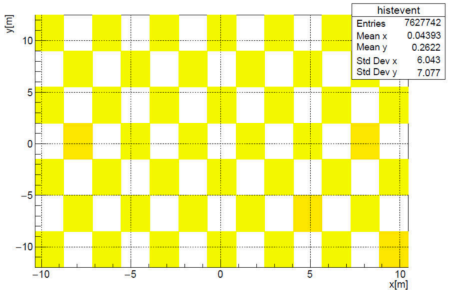
Geom Rec: RPC time resolution



- Need of a time resolution of 1-2 ns to obtain a good geometry reconstruction

Geom Rec: array configuration

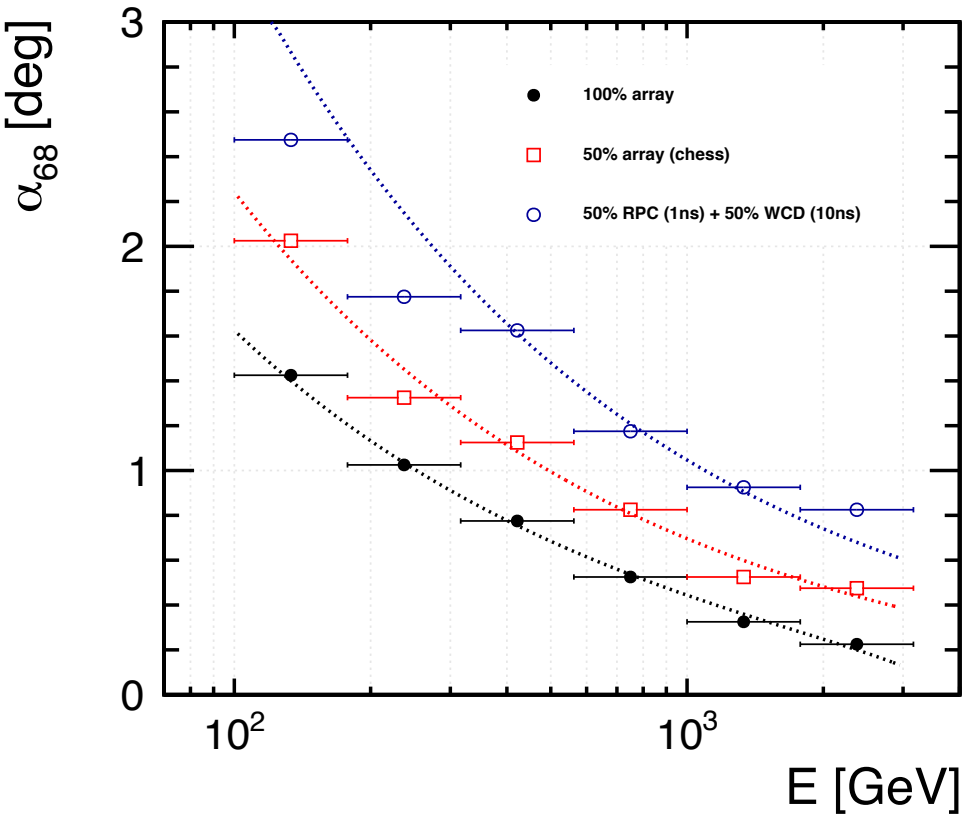




- It seems important to have RPCs on all stations

Geom Rec: RPC + WCD

José Jesus, ...

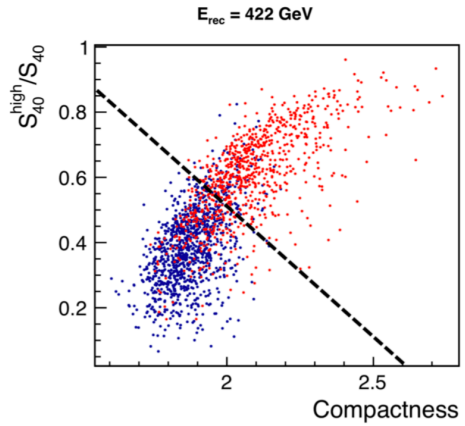


- Next steps: use only first hit in pad (trade-off between higher correlation with shower front and event statistics)

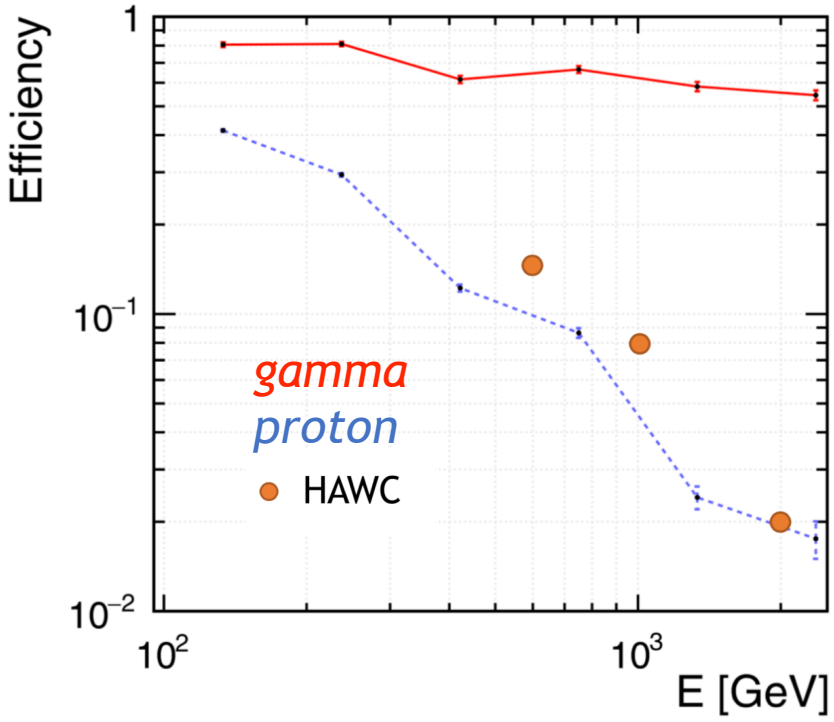
Gamma/hadron Discrimination

LATTES g/h discrimination

Using only the WCD



Compactness = LDF steepness
S40 = Signal outside 40 m

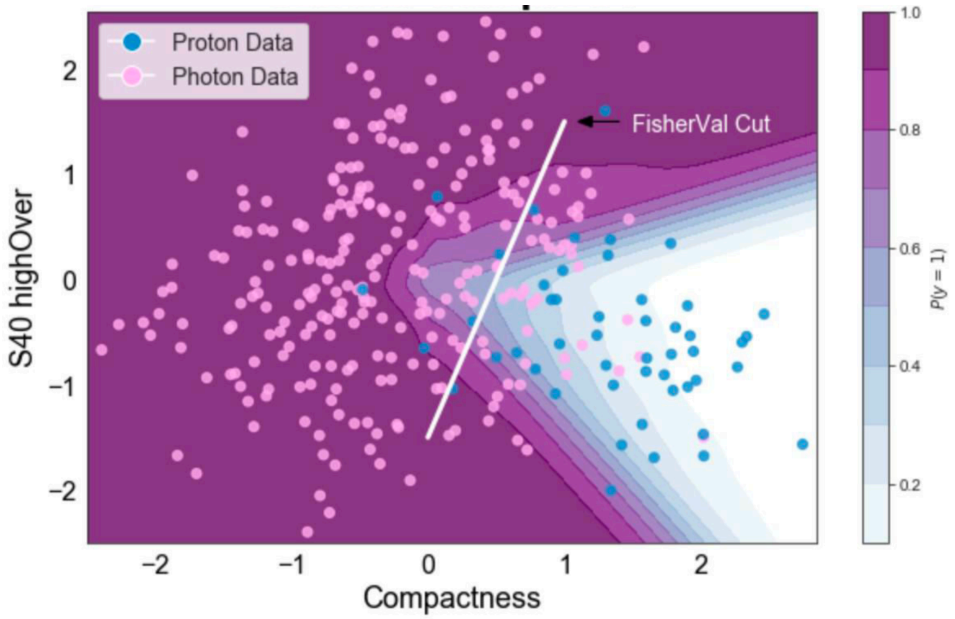


Although not optimized the gamma/hadron discrimination results are already very encouraging

G/H discrimination and ANN

Sara Marques, …

- Linear Discriminante (Fisher) allows a good separation
- Simple artificial neural networs can improve g/h discrimination
- Keras + Scikit-learn + ANN with 5 layers
- More simulation statistics necessary to apply parametric cuts
- Test at lower energies…



G/H discrimination: next step

Antonio Bueno et al...

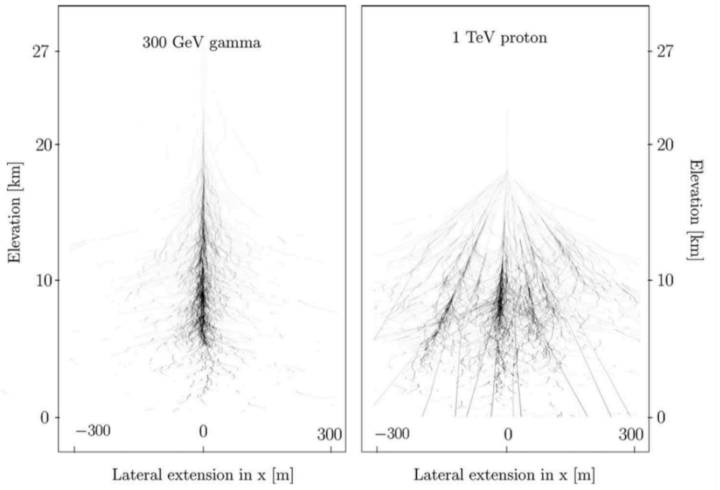
LATTES: Multivariate Analyses Workshop

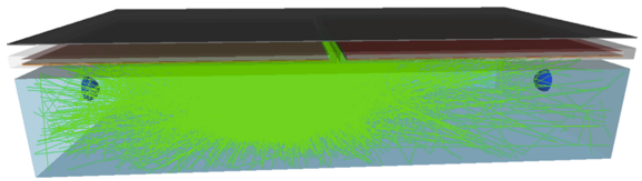
Friday 14 Sep 2018, 09:00 → 18:30 Europe/Madrid

Seminario de Física Teórica, Edificio Mecenas, University of Granada

ugr Universidad de Granada

- Use shower patterns at ground to distinguish between gamma and hadron induced showers
- Meeting at Granada
  - Use pattern recognition ANN
  - Master thesis to be opened in Granada

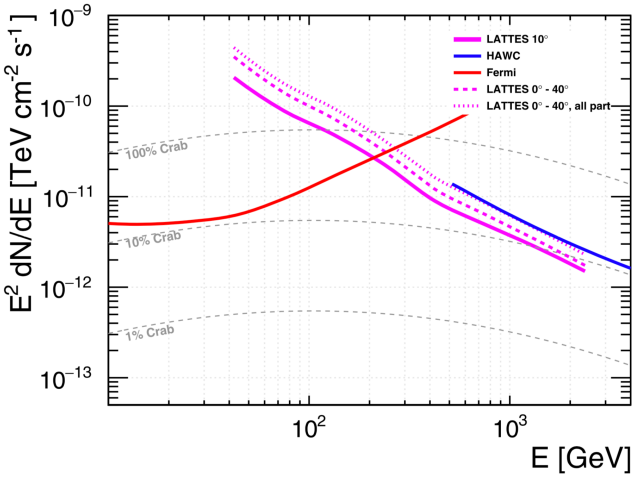


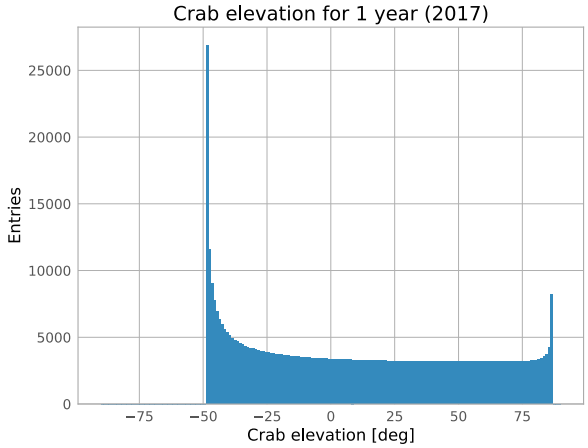


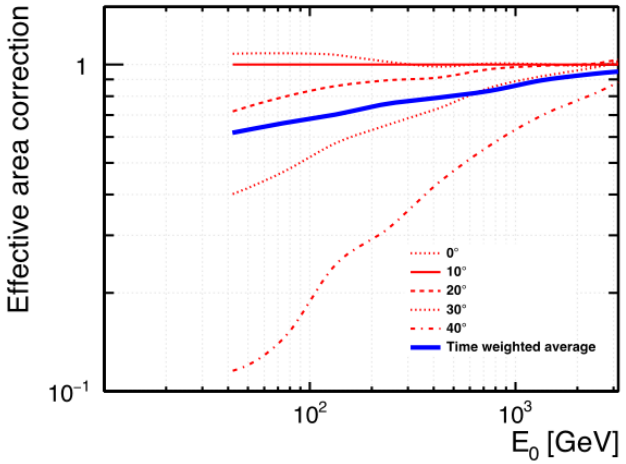
Reconstruction of showers at different zenith angles

Sensitivity to steady sources

- *Dashed line*: Crab transit as seen by HAWC
  - Degradation of effective area with zenith angle estimated from electromagnetic energy at ground



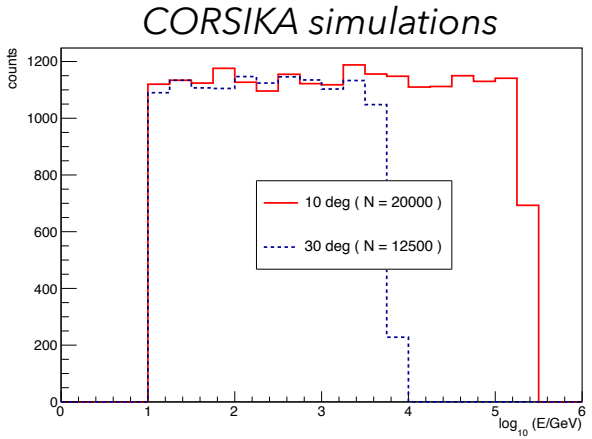


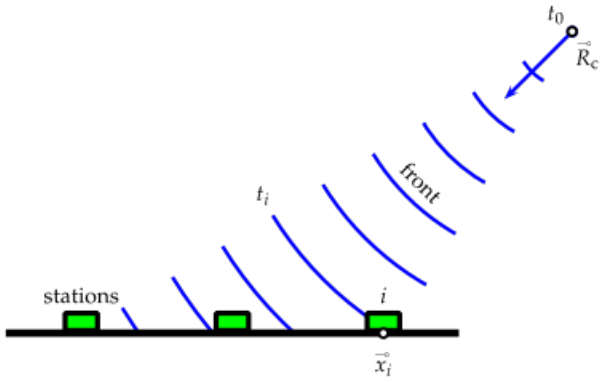


Shower rec at higher zenith angles

Filipe Salles

- Simulate 30 degree showers
- Use LATTESrec standard tools to make precise assessment of reconstruction
- Refine analyses to higher time dispersal + less hits at ground

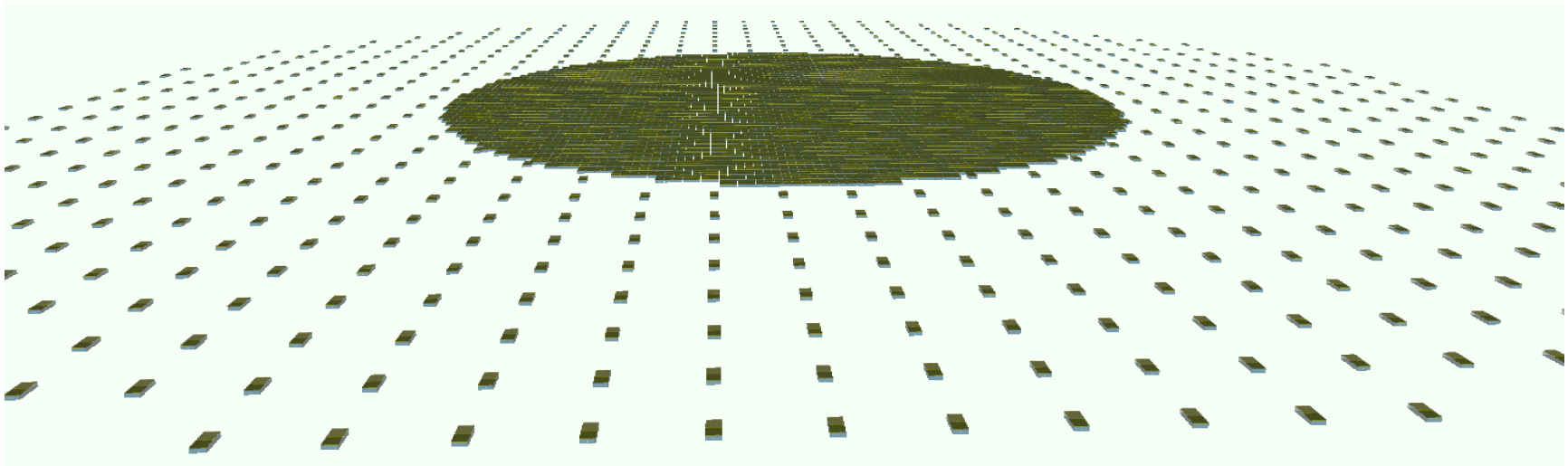




Sparse Array

Sparse Array

- Use a sparser array (100 000 m2)
  - Collect more events at higher energies
  - Remove high energy events that fall outside of the core array

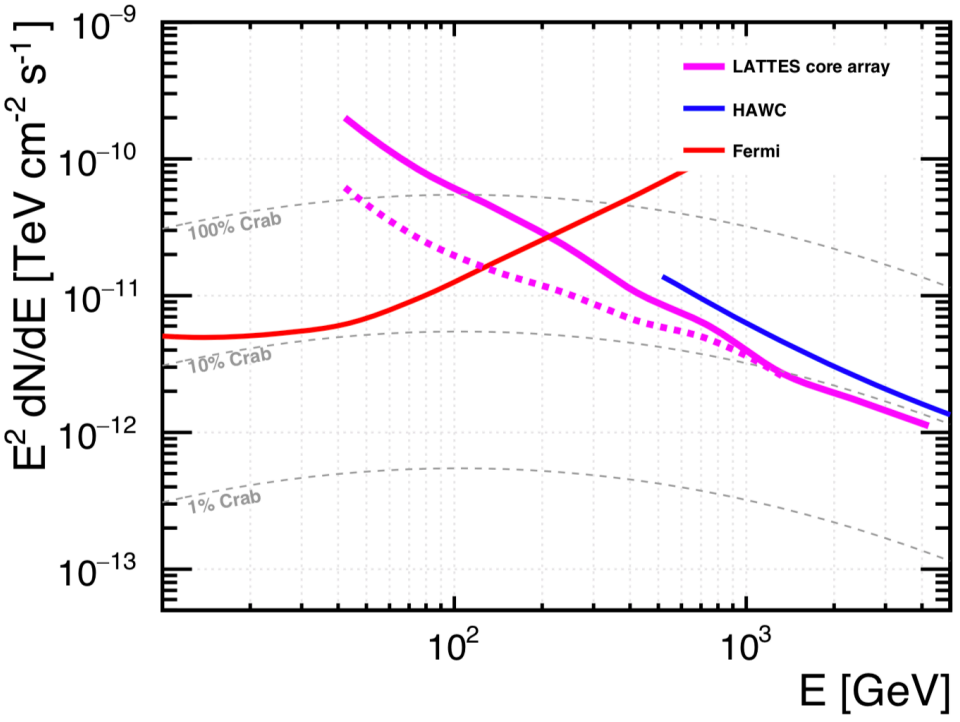


Sparse Array impact at low energies

Bernardo, Ruben, …

- Sparse array simulation completed
- Fast simulation
- Inconclusive results
  - CORSIKA vs LATTESrec simulation currently in progress

Vetoing showers that fall outside the array

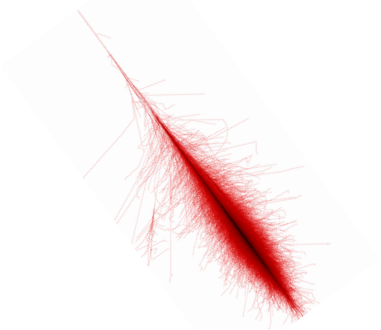


Summary

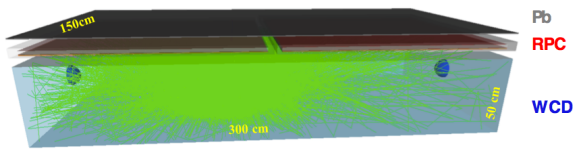
LATTES reconstruction

can still be considerably improved

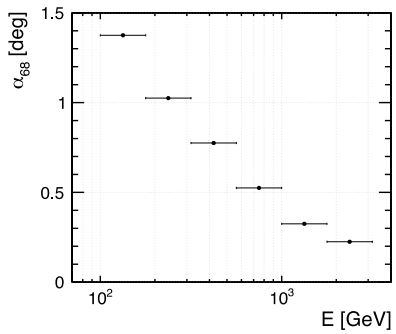
And the limit is your imagination ;-)



Shower simulation
(CORSIKA)



Detector simulation
(Geant4)



Shower reconstruction
(LATTESrec)

Acknowledgements

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MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

REPÚBLICA PORTUGUESA

LIP

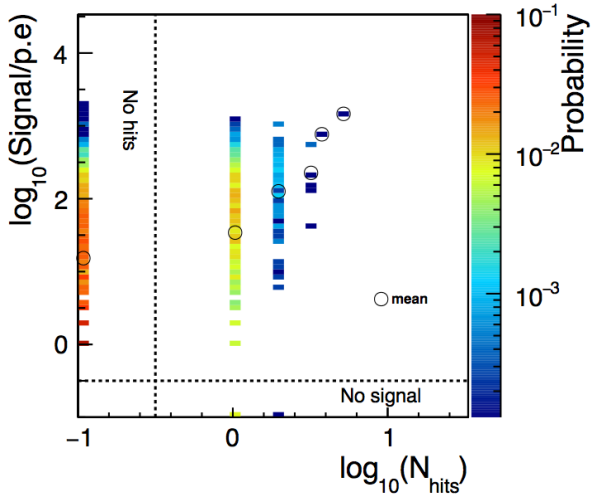
TÉCNICO LISBOA

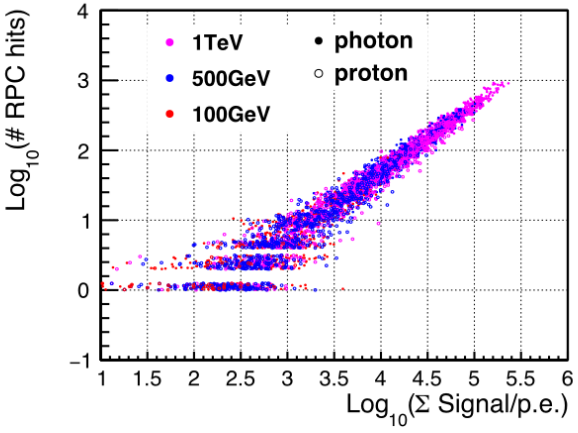
Backup slides

LATTES: a 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

WCD vs RPC (station level)

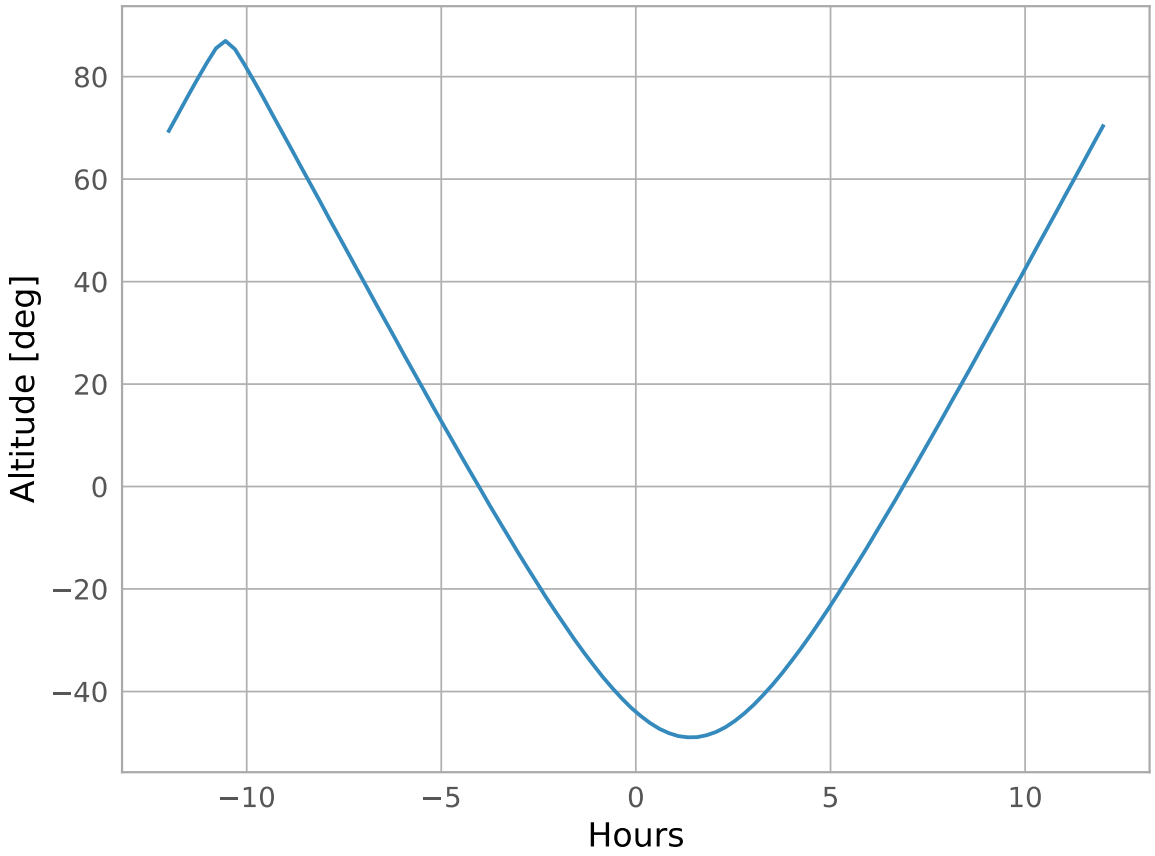




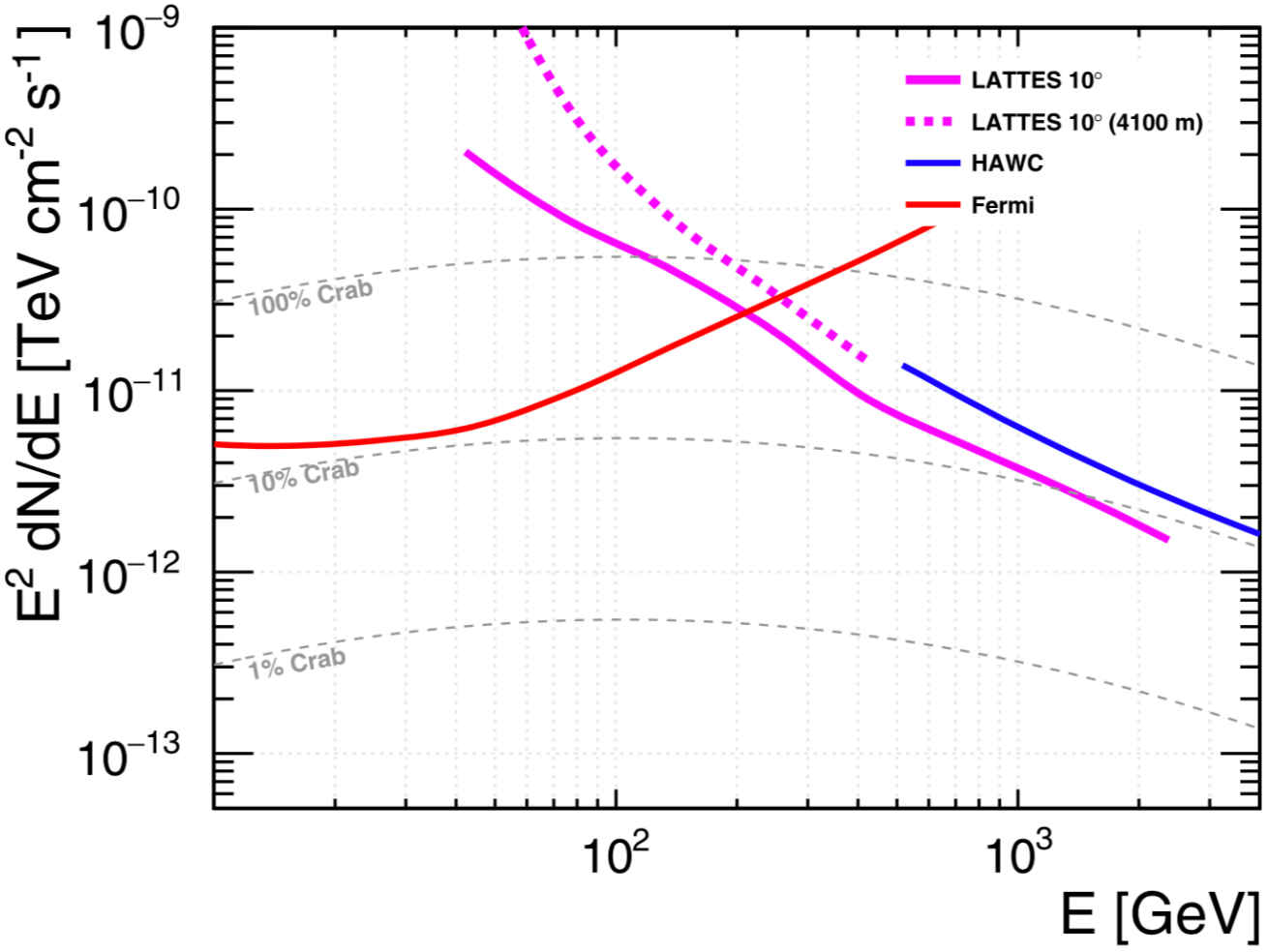
Complementarity

Inter-calibration

Crab



Impact of altitude



Reconstruction efficiency