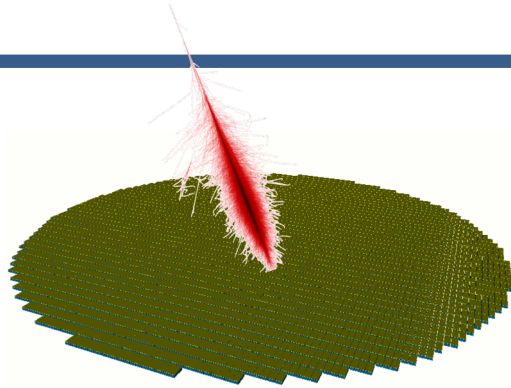


LATTES: simulation and software distribution

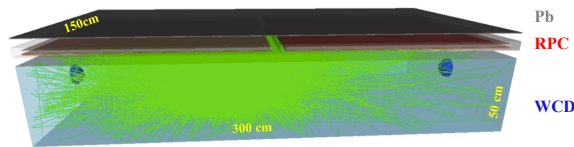
Bernardo Tomé, Ruben Conceição



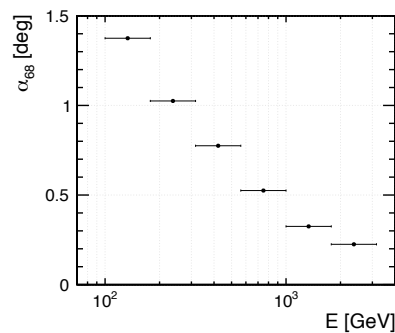
Simulating LATTES performance



Shower simulation
(CORSIKA)

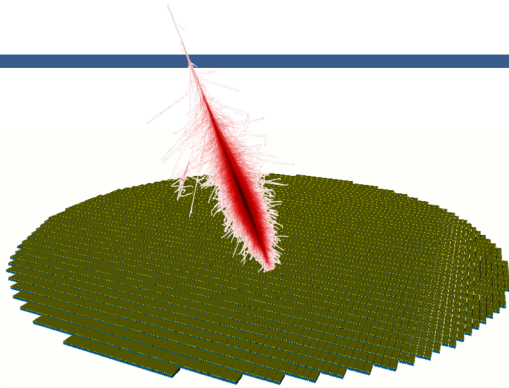


Detector simulation
(LATTESsim)

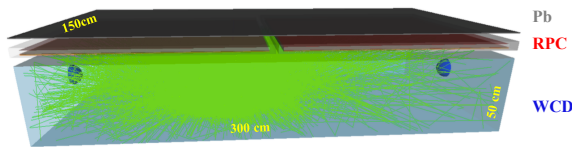


Shower reconstruction
(LATTESrec)

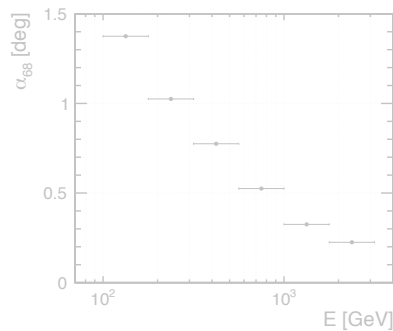
Simulating LATTES performance



Shower simulation
(CORSIKA)

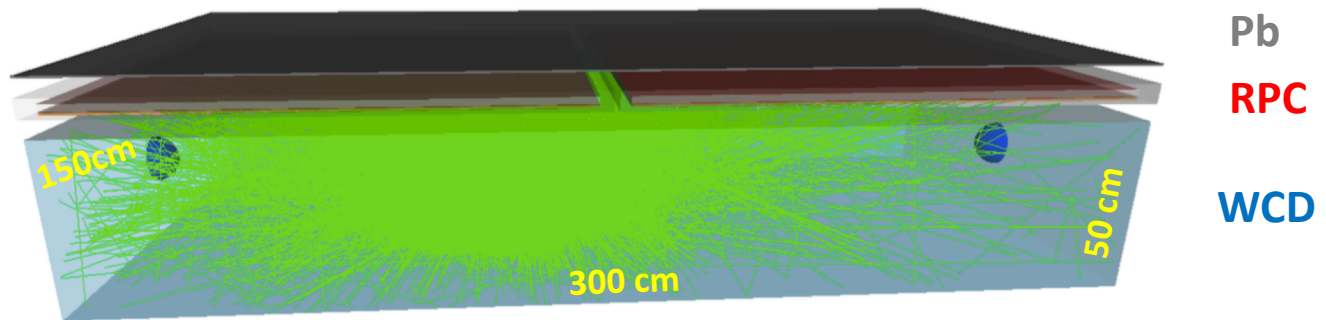


Detector simulation
(Geant4)



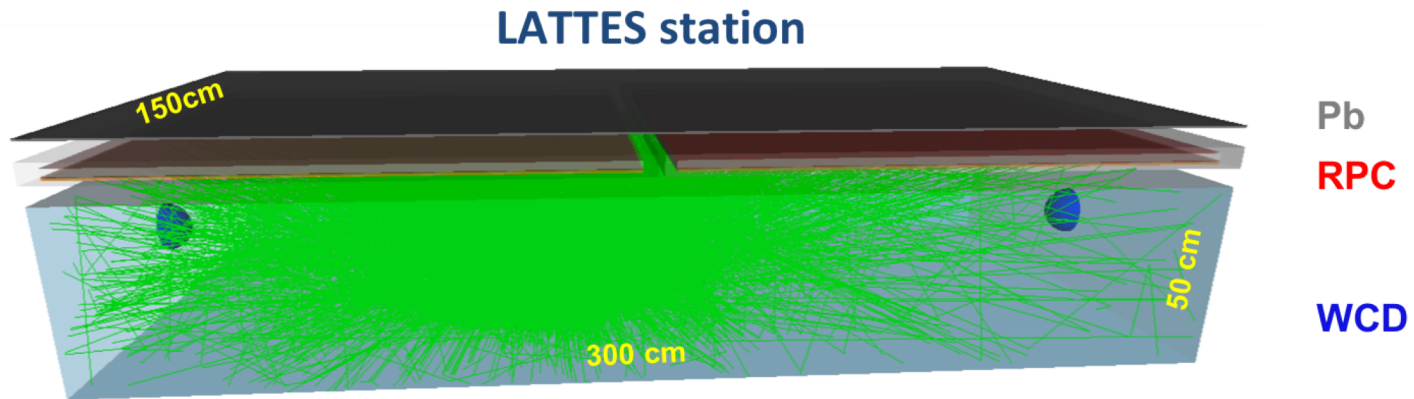
Shower reconstruction
(Ruben's talk)

LATTES hybrid detector concept



RPCs : time and spatial resolution
WCDs: e.m. energy, g/h discrimination
and trigger

LATTES hybrid concept baseline design



Thin lead plate (Pb)

- 5.6 mm (one radiation length)

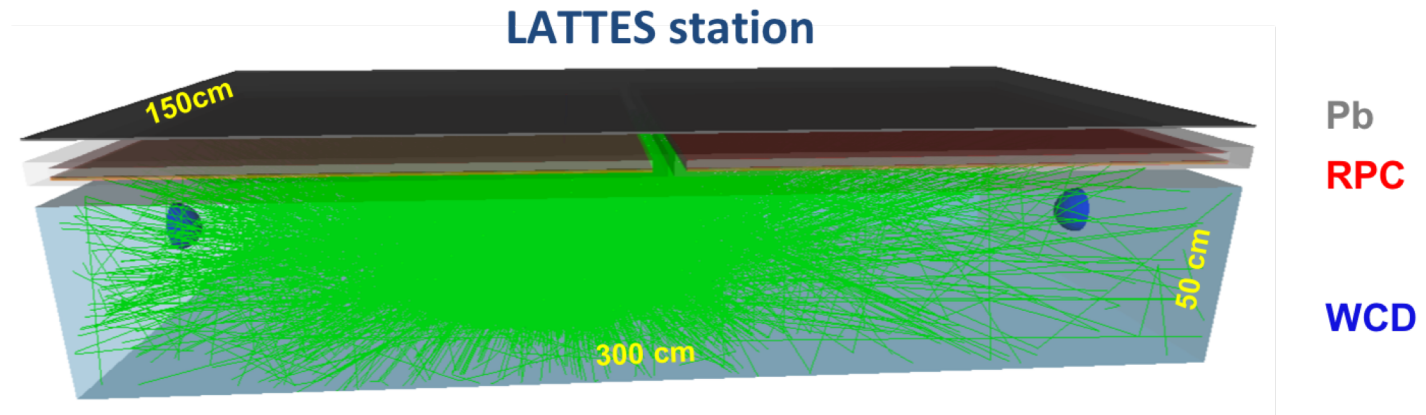
Resistive Plate Chambers (RPC)

- 2 RPCs per station
- Each RPC with 4x4 readout pads

Water Cherenkov Detector (WCD)

- 2 PMTs; 15 cm diameter
- inner walls covered with white diffusing Tyvek

LATTES hybrid concept



Thin lead plate (Pb)

- Convert the shower photons;
- Improve angular reconstruction

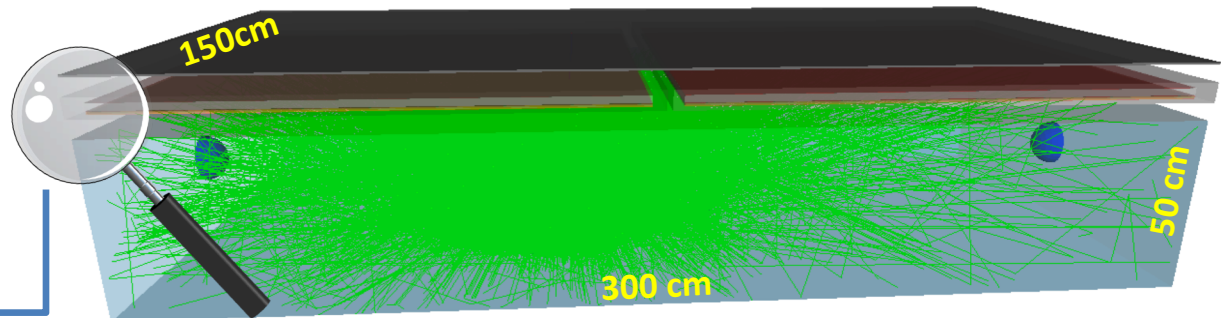
Resistive Plate Chambers (RPC)

- Sensitive to charged particles
- Very good time (1 ns) and spatial resolution (tens of cm)
- Improve geometric reconstruction
- Explore shower particle patterns at ground

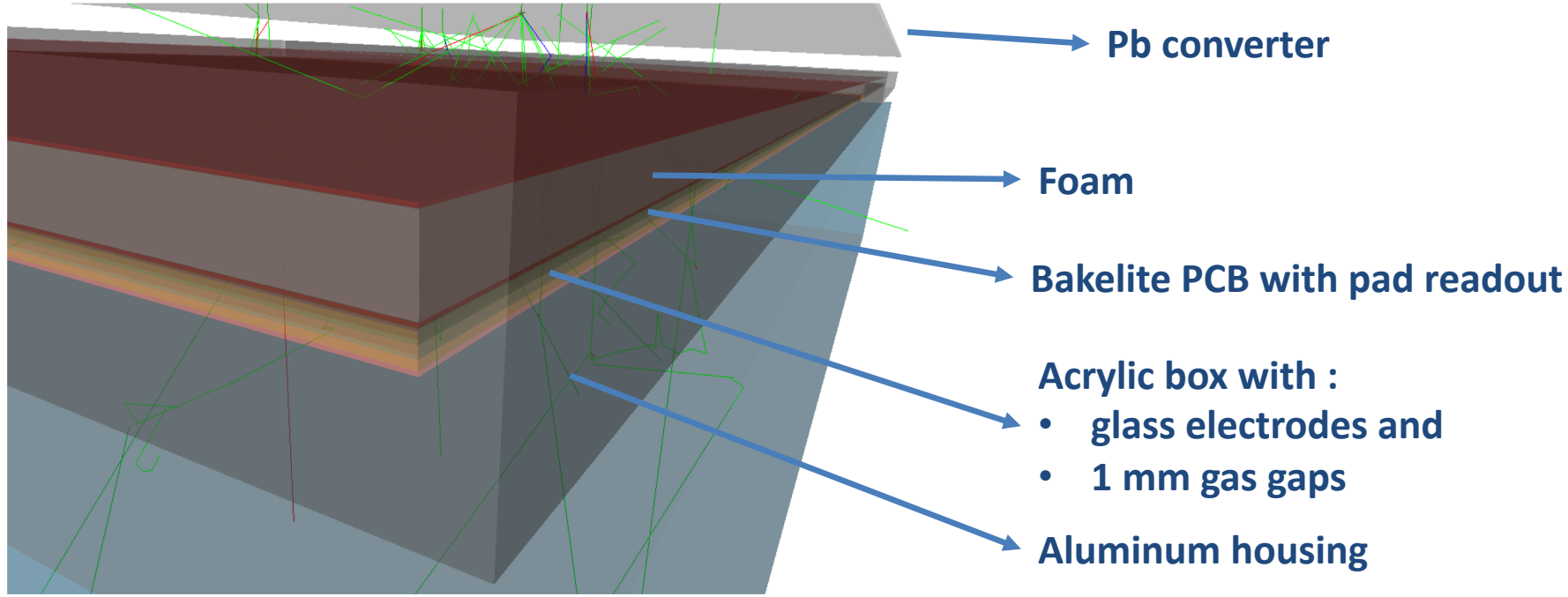
Water Cherenkov Detector (WCD)

- Sensitive to shower photons and charged particles
- Measure energy flow at ground
- Improve trigger capability
- Improve gamma/hadron discrimination

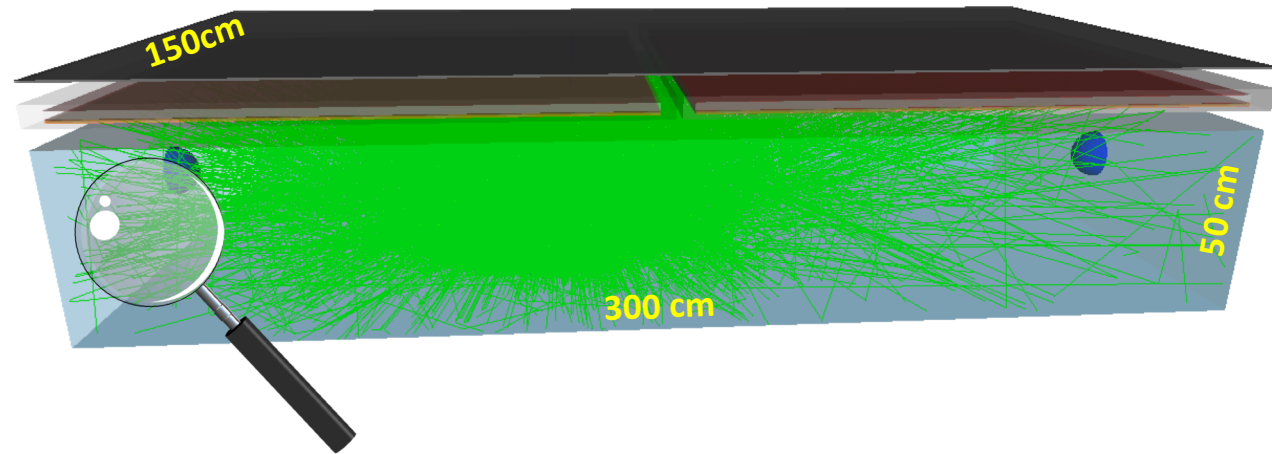
LATTES station in Geant4



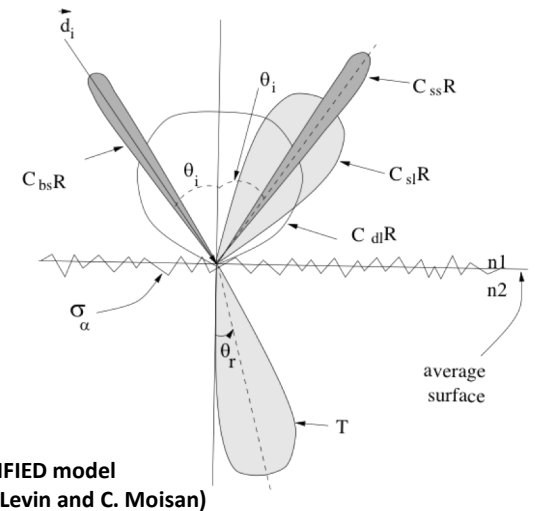
Detailed RPC structure



LATTES station in Geant4



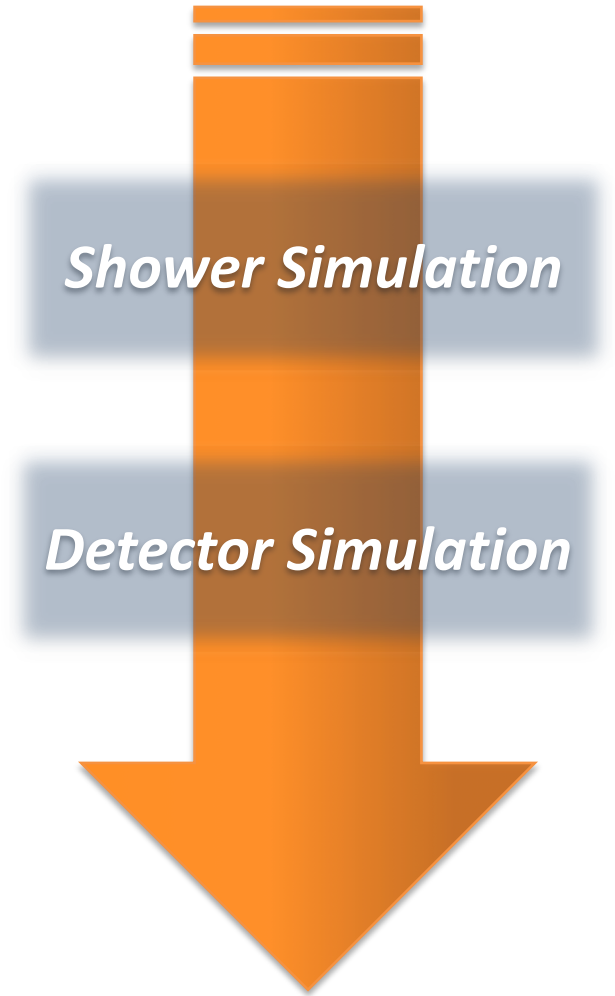
- Explore **Geant4 capabilities** to simulate **optical photon propagation**;
- λ dependence of all relevant processes and materials
- **Water**
 - Attenuation length ~ 80 m @ $\lambda = 400$ nm
- **PMT**
 - 15 cm diameter
 - $Q.E._{max} \sim 30\%$ @ $\lambda = 420$ nm
- **Tyvek**
 - Described using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



- Detector simulation output

- **ROOT tree structure** :

- Shower simulation parameters;
 - Detector configuration parameters;
 - Info at particle level;
 - PMT signal vs time;
 - RPC hits (position,time,...) for each pad.



Simulation production

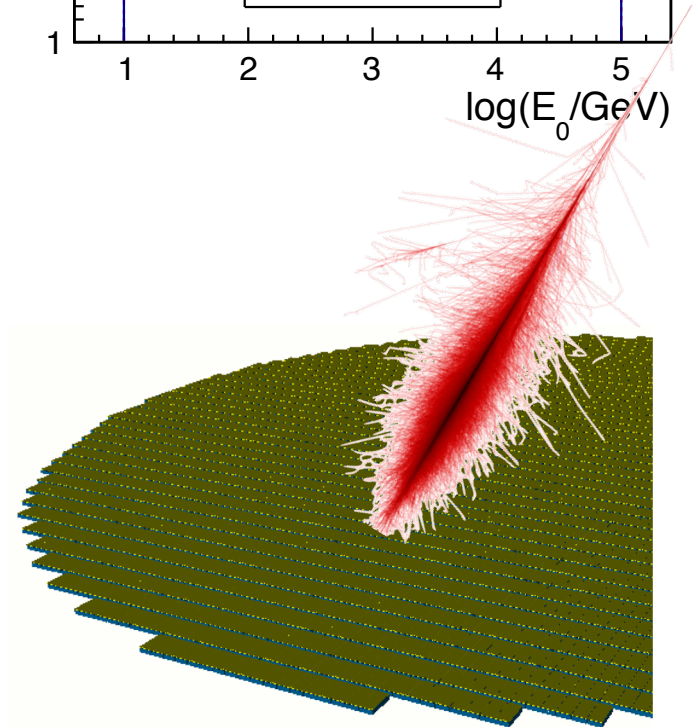
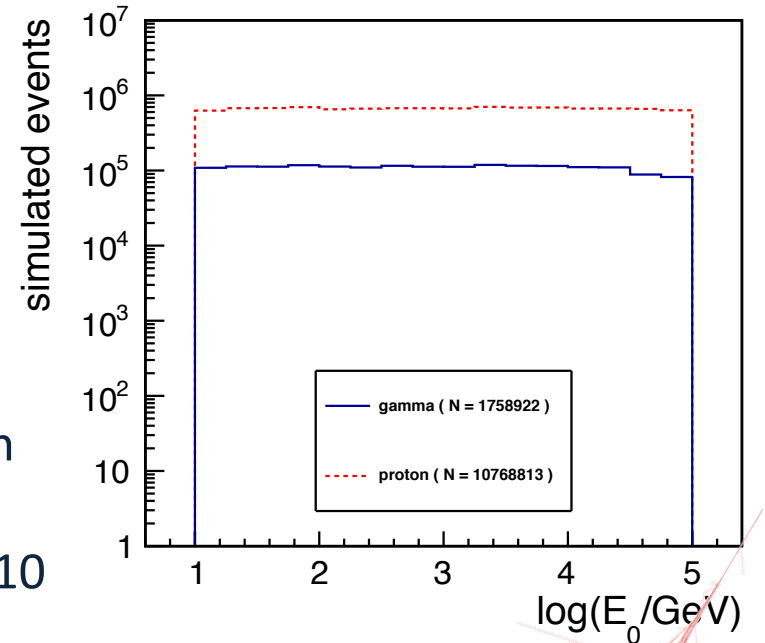
- End-to-end realistic simulation

- Extensive Air Showers: **CORSIKA**

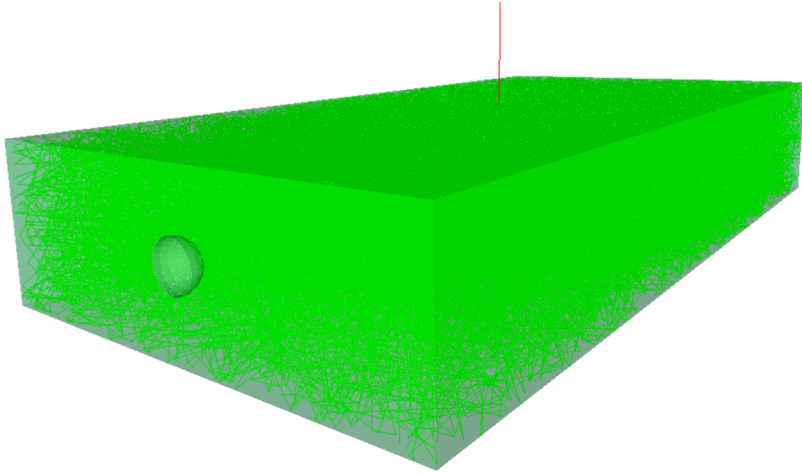
- v7.6400 with Fluka2011.2c;
- More than **50 000 gamma/proton** showers simulated randomly between 10 GeV – 300 TeV;
- Gammas have a fixed zenith angle of 10 degrees;
- Observation level at **5200 m of altitude**

- Detector simulation: **Geant4**

- Version 10.1.3;
- Core array 20 000 m²;
- Each shower is resampled 100 times over a large area containing all the array.



LATTES fast simulation

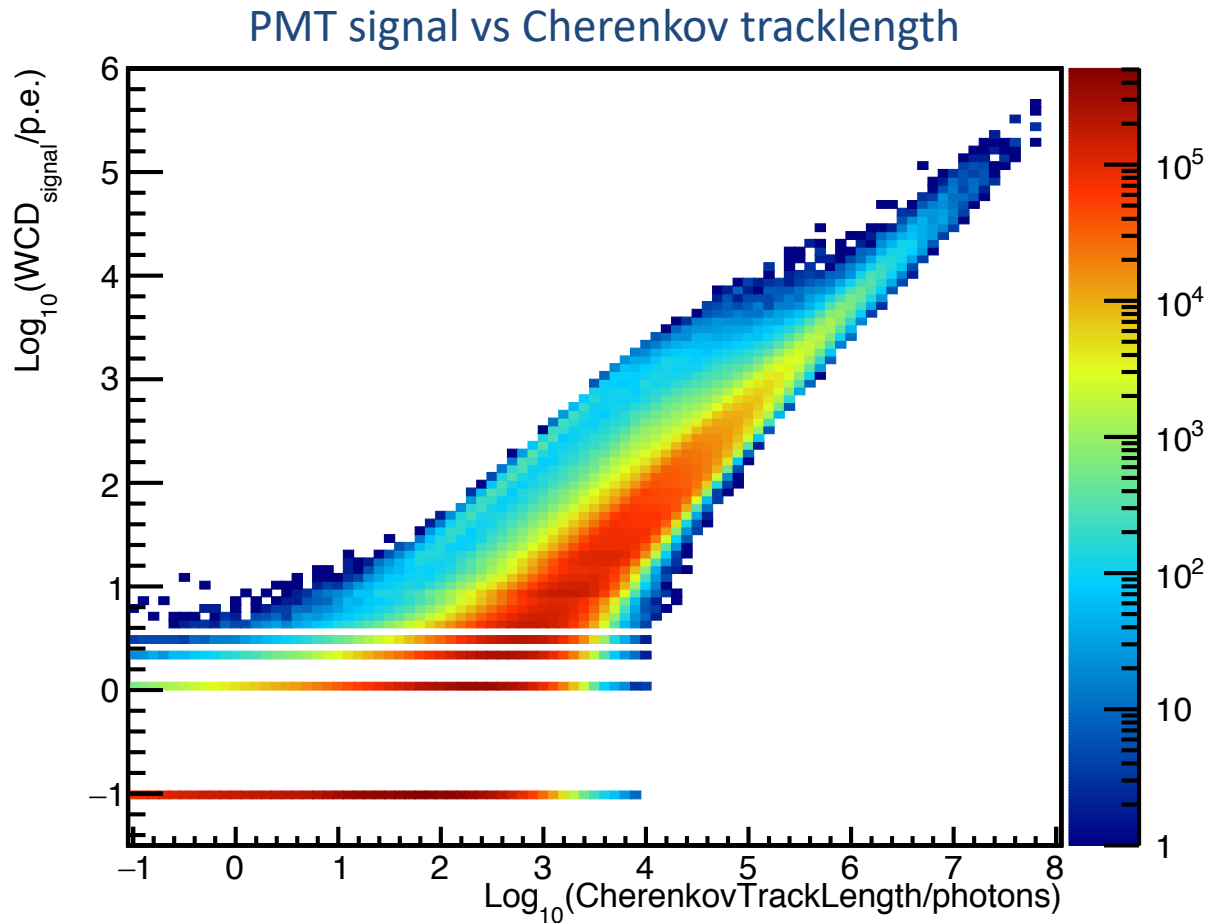


$$dN/(dEdL) = 370 * z^2 * \sin^2(\theta_c) \text{ cm}^{-1} \text{ eV}^{-1}$$

- Full simulation requires the tracking of a large number of Cherenkov photons;
- Large simulation sets for performance and optimization studies;
- Simulation of the sparse array...

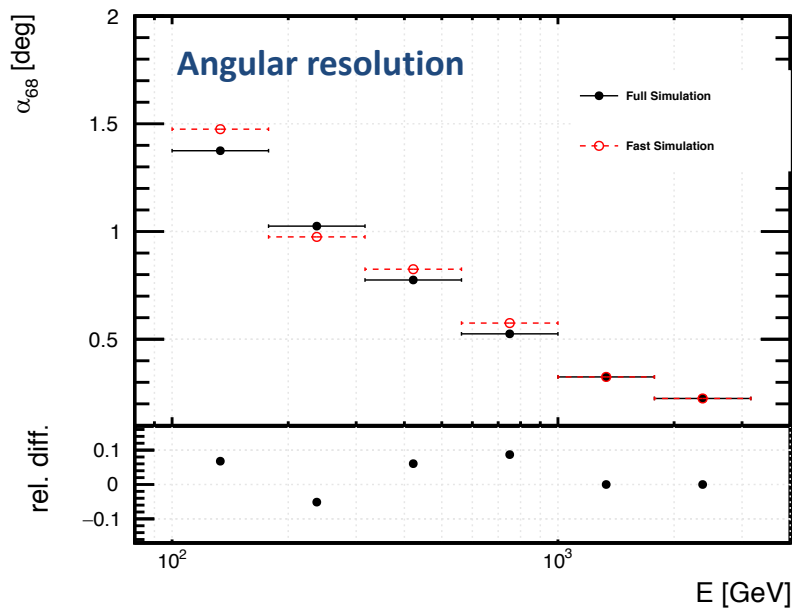
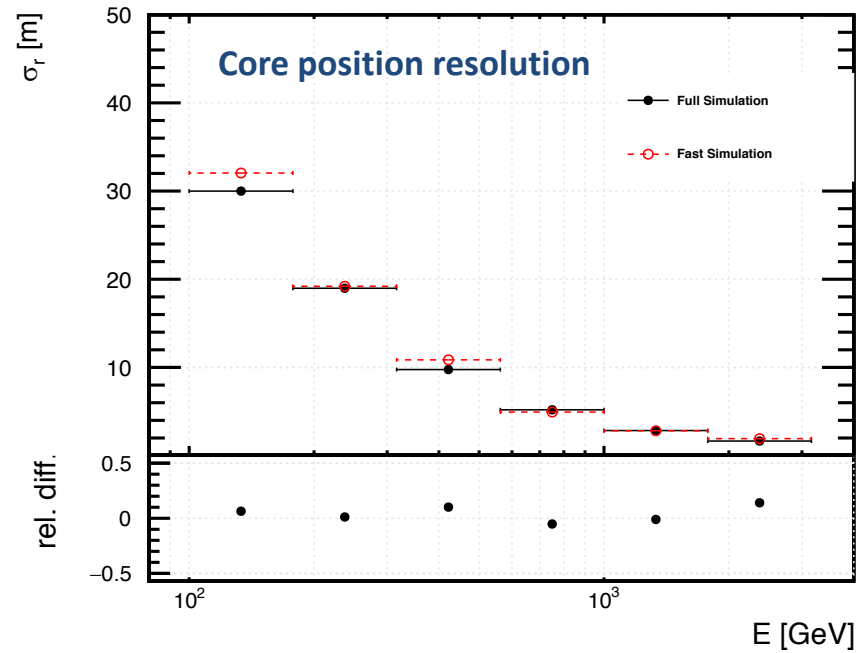
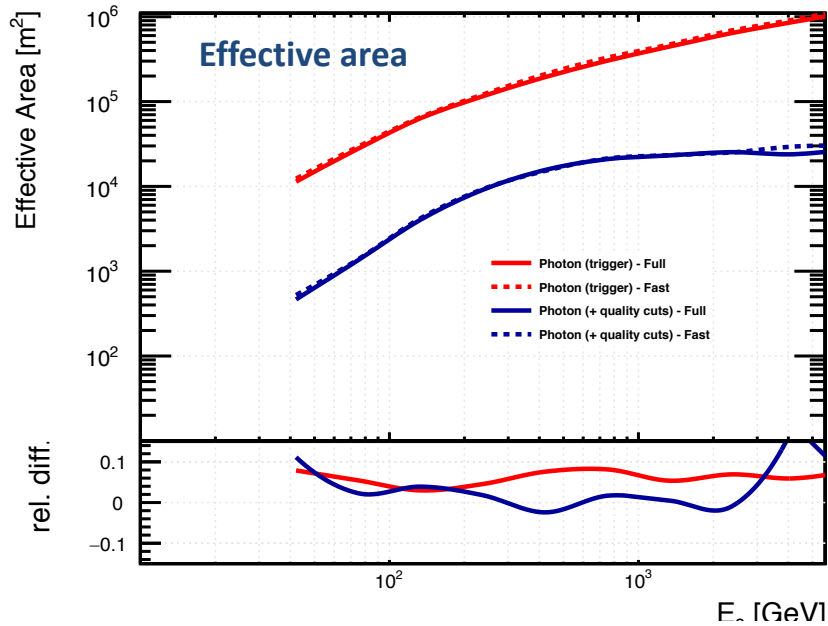
N ~ 8500 Cherenkov photons for a single vertical particle crossing the WCD;
> 10⁶ Cherenkov photons may have to be tracked in a single station

LATTES fast simulation



- Parametrize the PMT signal in function of the total emitted Cherenkov light;
- For the RPC's use full simulation.

Fastsim validation



- Agreement with full simulation at the level of **10%**;
- Further improvements ongoing;

Shower reconstruction

- Detector simulation output
 - Format is a ROOT tree
 - Methods to access specific simulated shower parameters
 - WCD signal
 - RPC hits
 - Detector configuration and parameters
 - Shower simulation parameters
- Reconstruction tool
 - Several modules to reconstruct the shower
 - Geometry
 - Energy
 - Gamma/hadron discrimination
- Lightweight and easy to re-process for higher level analysis

LATTES software

- LATTES software has been tested and is currently running at:
 - Our laptops ;-)
[MACOS]
 - Lisbon cluster [SL6]
 - Prague cluster [SL6]
 - Rio de Janeiro interactive machines (CBPF) [Ubuntu16]
- The codes are relatively modular and documentation can be obtained via Doxygen
 - Just run: *doxygen Doxyfile*

LATTES documentation



file:///Users/ruben/Desktop/LattesSim/doxygen/html/index.html

LATTESim v1

Main Page Namespaces ▾ Classes ▾ Files ▾

LATTESim Documentation

Generated by [doxygen](#) 1.8.13



file:///Users/ruben/Desktop/LATTESrec/doxygen/html/index.html

LATTESrec v1

Main Page Classes ▾ Files ▾

LATTESrec Documentation

Generated by [doxygen](#) 1.8.13

LATTES documentation

LATTESSim v1

Main Page	Namespaces ▾	Classes ▾	Files ▾	
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Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

▾ N corsika	
C Longi	
C Particle	
C SubBlock	
▾ N utl	
C CORSIKAEvent	
C CORSIKAREader	
C Particle	
C CORSIKAEventROOT	
C EventROOT	
C HitROOT	
C PadROOT	
C PMTROOT	
C PrimaryVertex	
C RPCROOT	
C StationROOT	

LATTESrec v1

Main Page	Classes ▾	Files ▾	
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Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

C AxisRec	
C Compactness	
C CoreRec	
C DoubleWithError	
C EbinInput	
C FisherCoef	
C FitParameters	
C GeomRecPar	
C LDFFitParameters	
C Tree	

LATTES documentation

LATTESrec v1



◆ GetFisherVarNames()

std::vector<string> FisherCoef::GetFisherVarNames () const inline

Definition at line 24 of file **FisherCoef.h**.

```
24 | {return fVarNames;}
```

◆ HasFisher()

const bool FisherCoef::HasFisher () const inline

Definition at line 27 of file **FisherCoef.h**.

```
27 | {return fHasFisher;}
```

◆ PrintFisherCoefficients()

void FisherCoef::PrintFisherCoefficients () const

Definition at line 32 of file **FisherCoefs.cc**.

References **fVarNames**, and **fWeights**.

Referenced by **PerformShowerRec()**.

```
33 | {  
34 |     for (unsigned int i = 0; i < fVarNames.size(); ++i)  
35 |         cout << "i: " << i << " --> " << fVarNames[i].c_str() <<  
36 |             " = " << fWeights[i] << endl;  
37 | }
```

◆ SetEnergy()

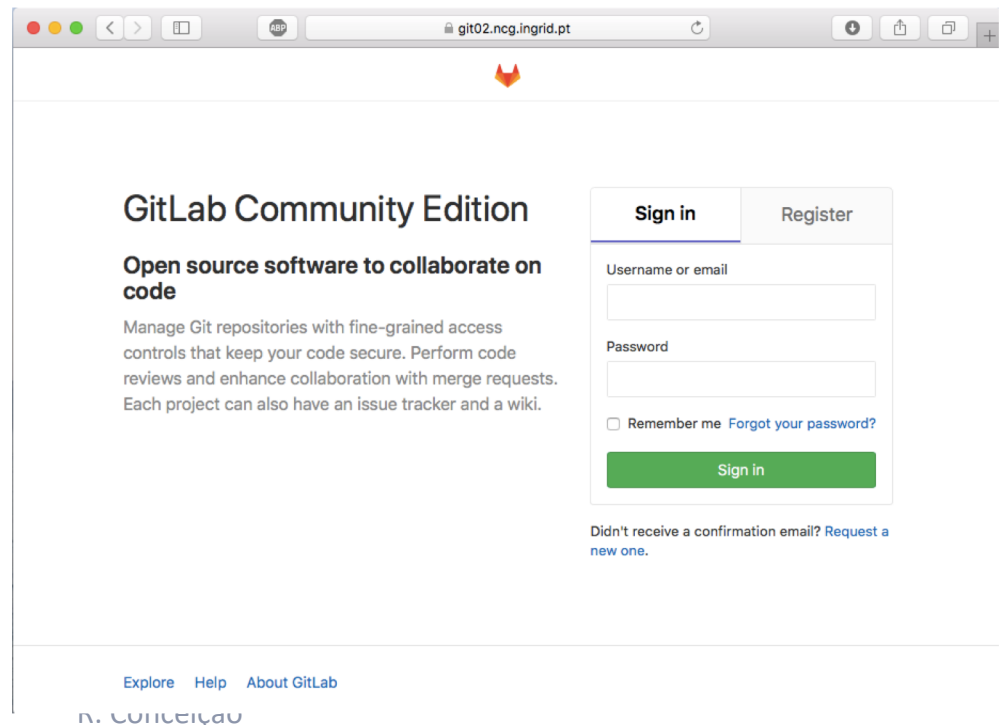
void FisherCoef::SetEnergy (double energy) inline

Definition at line 28 of file **FisherCoef.h**.

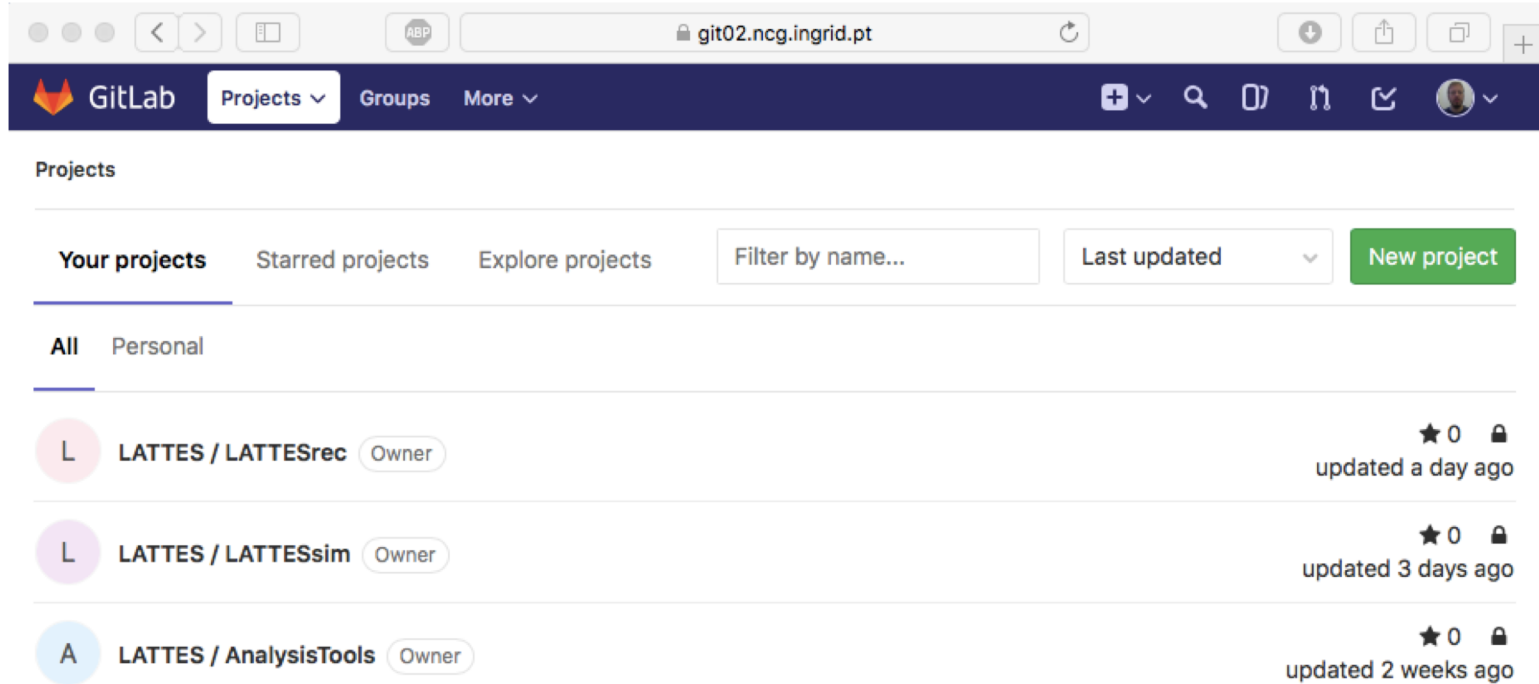
```
28 | {fEnergy = energy;}
```

LATTES SW distribution

- If you want to install LATTES SW register at:
 - git02.ncg.ingrid.pt
 - Then send us (bernardo@lip.pt, ruben@lip.pt) your username so that we can give you permissions



LATTES @ gitlab

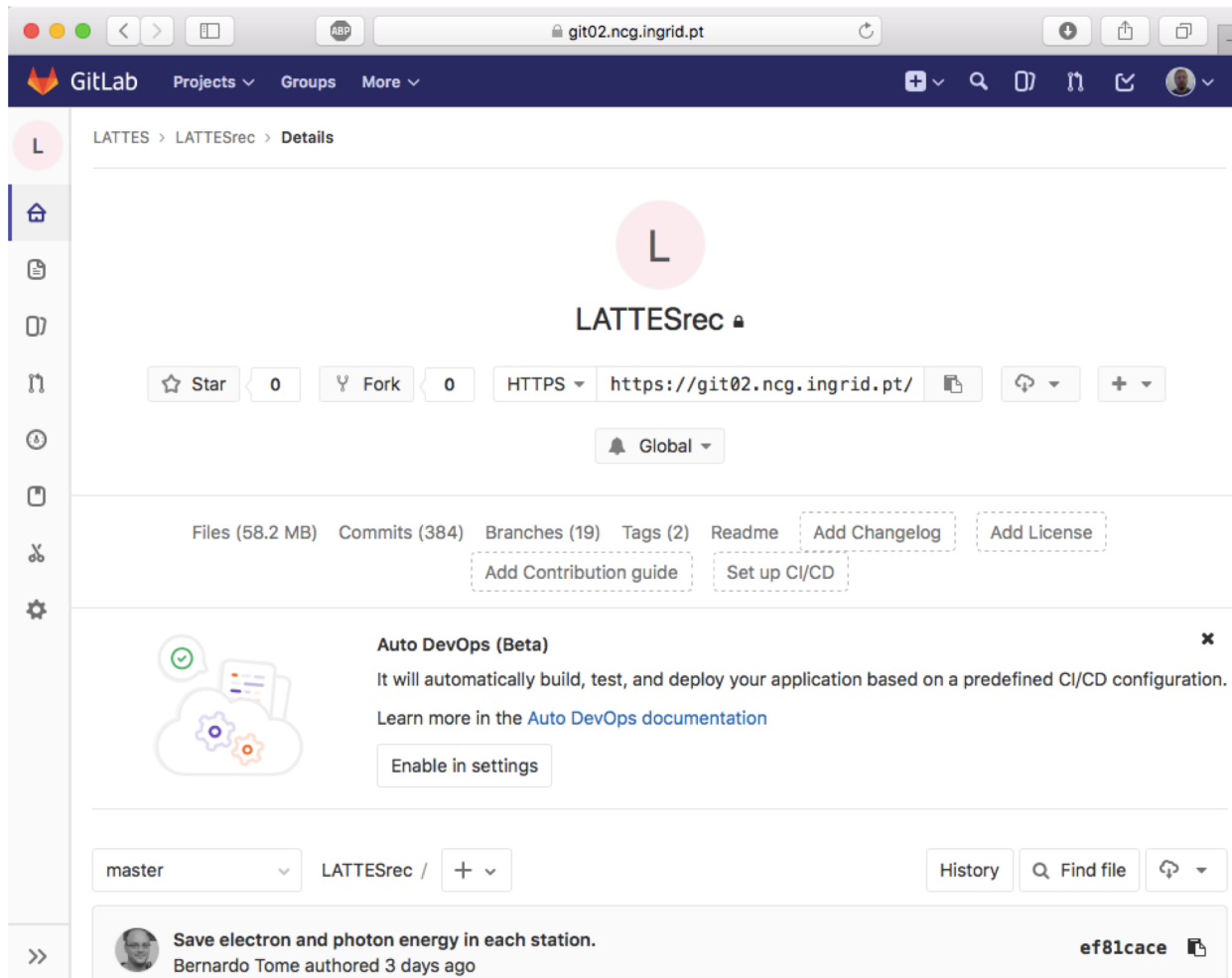


The screenshot shows the GitLab web interface. The browser address bar displays 'git02.ncg.ingrid.pt'. The navigation bar includes the GitLab logo, 'Projects' (selected), 'Groups', and 'More'. The main content area is titled 'Projects' and features tabs for 'Your projects', 'Starred projects', and 'Explore projects'. A search box labeled 'Filter by name...' and a dropdown menu for 'Last updated' are present, along with a green 'New project' button. Below these are filters for 'All' and 'Personal'. The project list includes:

- L** LATTES / LATTESrec (Owner) 0 stars, updated a day ago
- L** LATTES / LATTESsim (Owner) 0 stars, updated 3 days ago
- A** LATTES / AnalysisTools (Owner) 0 stars, updated 2 weeks ago

Example: get LATTESrec

- `git clone <https://....>`



All info there!

The screenshot shows a web browser window displaying a GitLab repository page. The browser's address bar shows the URL `git02.ncg.ingrid.pt`. The GitLab interface includes a navigation sidebar on the left with icons for home, search, and other repository actions. The main content area displays a list of files and folders with their commit messages and timestamps. The 'include' folder is highlighted in blue. Below the file list, a snippet of the README file is visible, containing instructions for compiling and running the LATTESrec simulation.

File/Folder	Commit Message	Timestamp
RecInputFiles	update compactness LDFs	8 months ago
include	Save electron and photon energy in each station.	3 days ago
src	Save electron and photon energy in each station.	3 days ago
utils	define energy rec variables	8 months ago
.gitignore	Modified .gitignore.	7 months ago
1run_allLists.sh	adapt files to new nomenclature	a year ago
2run_all.sh	Save electron and photon energy in each station.	3 days ago
Doxyfile	update doxygen config file	a year ago
LATTESrec.cpp	Save electron and photon energy in each station.	3 days ago
Makefile	Attention: LattesSim changed to LATTESsim	3 weeks ago
Makelists.sh	Update Makelists.sh	a year ago
README	Add README file	9 months ago
makelist.sh	define energy rec variables	8 months ago

README

```
- To compile and run LATTESrec the library libEventROOT.so must be created first. This is done in the LATTES simulation directory (LattesSim).
```

Manage permissions

Expiration date

Add to project Import

Existing members and groups

Members of **LATTEsrec** 6 Name, ascending

	Bernardo Tome @bernardo · LATTES Joined 2 months ago			Owner
	Filipe de Oliveira Salles @filipe.o.salles Joined a month ago	Reporter	Expiration date	
	Jakub Vicha @vicha Joined a day ago	Developer	Expiration date	
	Liliana Apolinario @liliana Joined a month ago	Reporter	Expiration date	
	Ruben Conceição @ruben It's you · LATTES Joined 2 months ago			Owner
	Ugo Giaccari @ugo Joined a month ago	Reporter	Expiration date	

Summary

- Modular end-to-end simulation framework
 - From showers to high-level analysis
- Realistic and detailed description of the LATTES concept using Geant4 - LATTESsim
 - Optimization studies
 - Test different designs
- Reconstruction algorithms integrated in a single module – LATTESrec
 - Allows high-level analysis
- LATTESsim and LATTESrec available in gitlab repositories + doxygen documentation

Acknowledgements



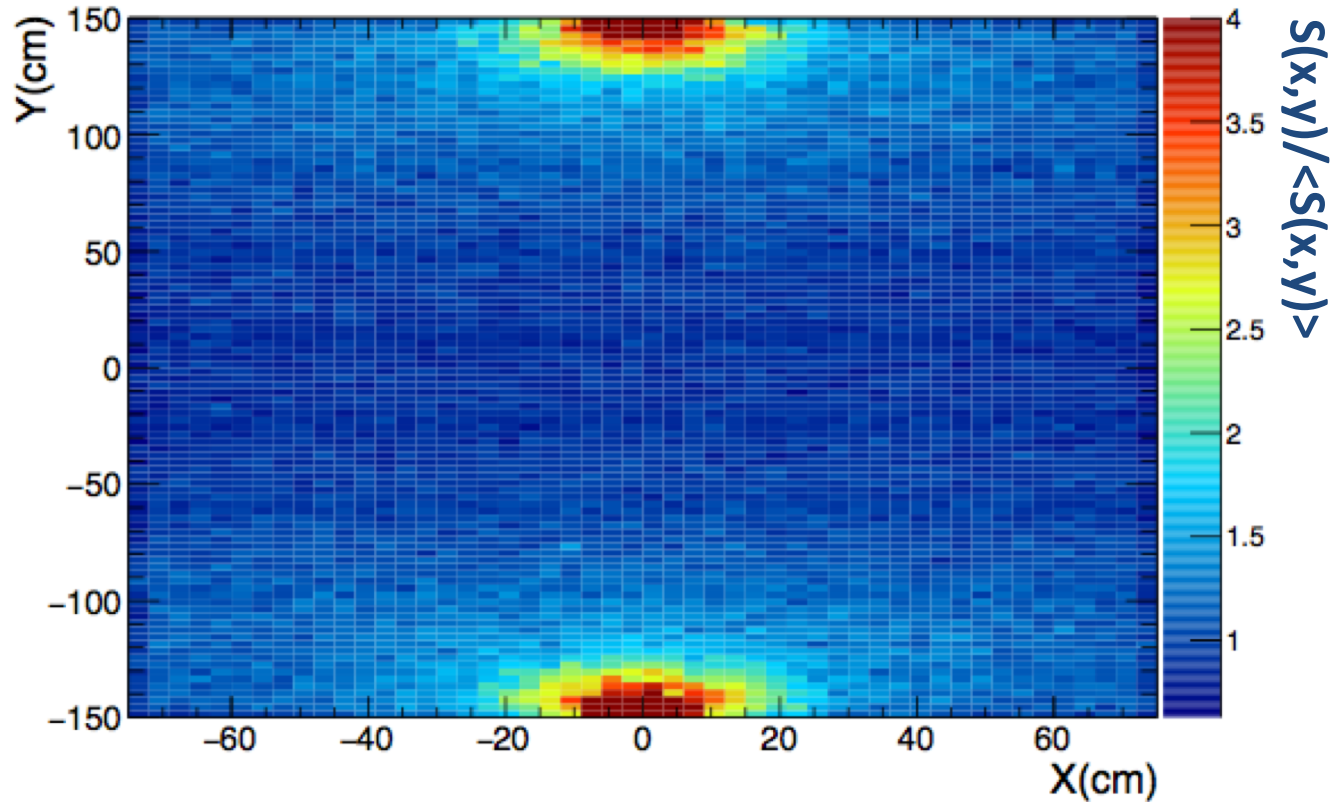
REPÚBLICA
PORTUGUESA



TÉCNICO
LISBOA

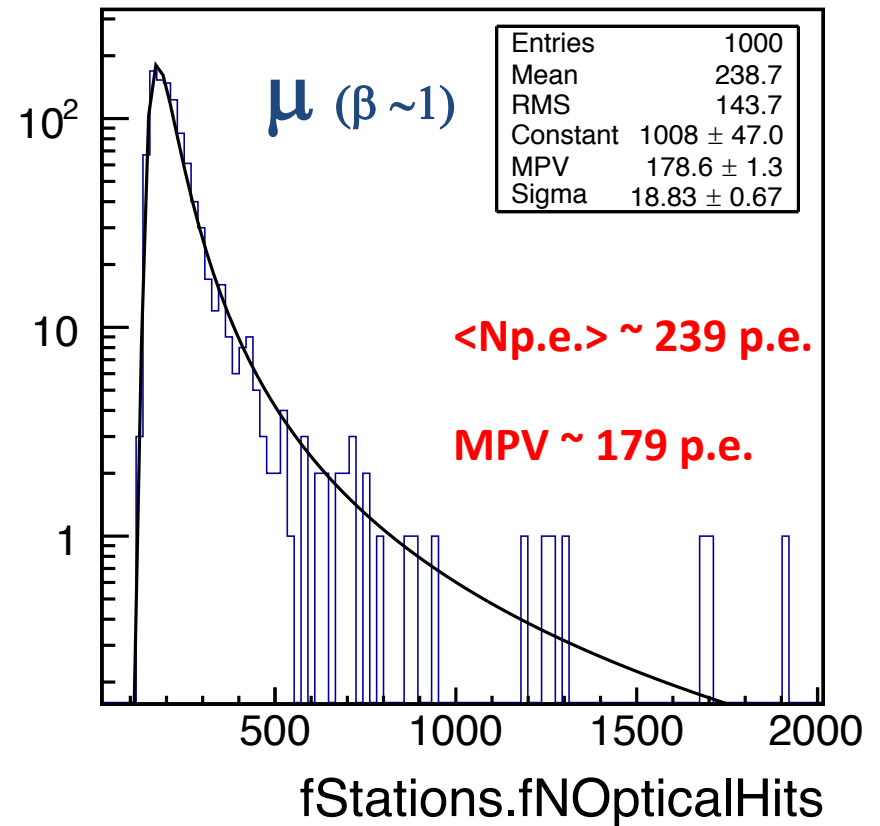
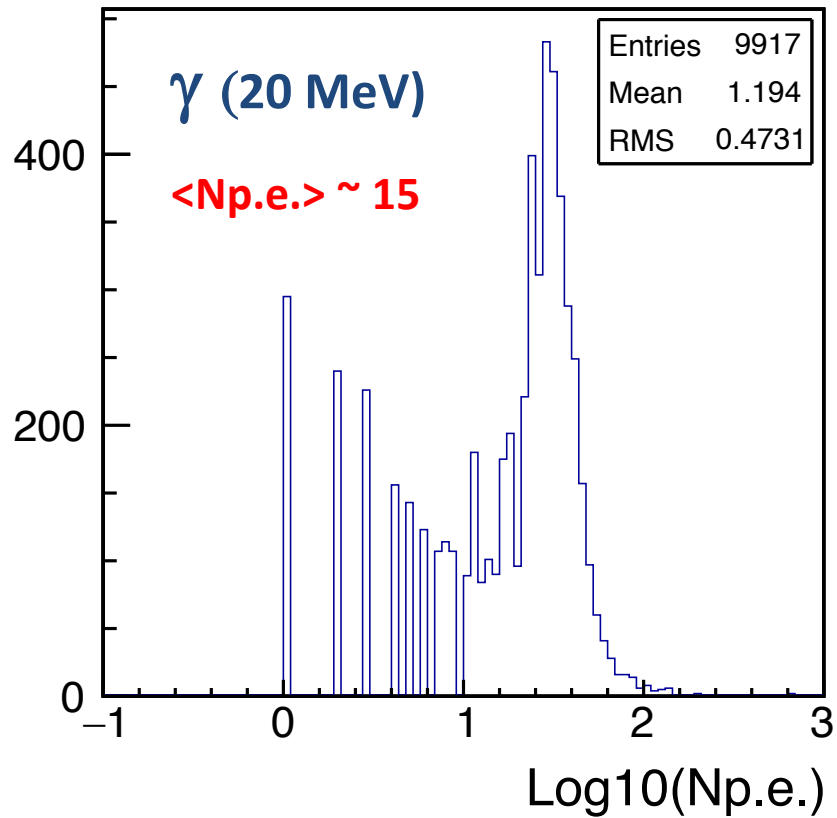
END

WCD signal uniformity

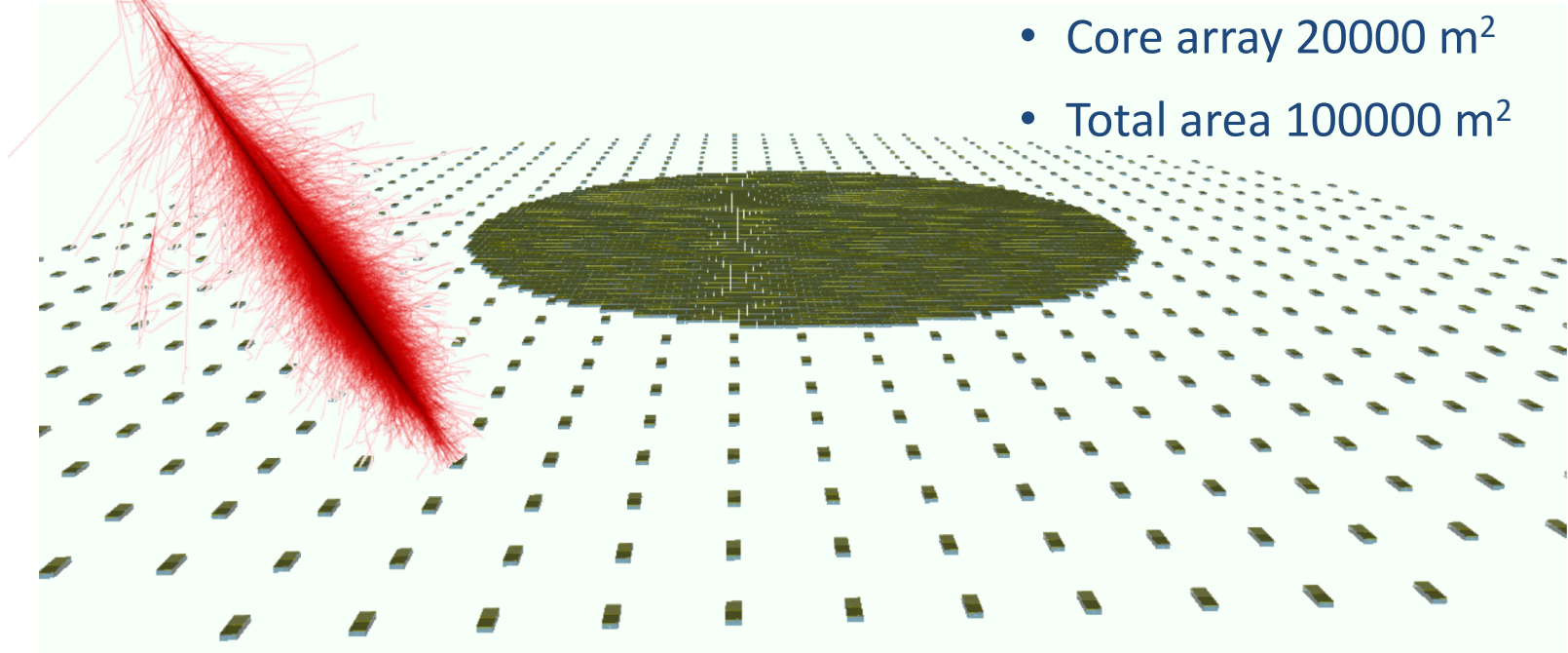


- Good uniformity across the tank area
- PMT spots visible

Single station signal



LATTES sparse array



- Extend LATTES sensitivity to higher energies (~ 100 TeV);
- Improve sensitivity at low energies (veto hadron showers outside the core array);
- Layout to be optimized...
- Simulations ongoing using the fastsim.

LATTES

Large Array Telescope for Tracking Energetic Sources

- ❖ Joint Brazil/Italy/Portugal initiative
- ❖ Czech group joined recently
- ❖ Possible sites:
 - ❖ Atacama Large Millimeter Array site - Chajnantor plateau (5200 m)
 - ❖ North of Argentina (~ 5000 m)
 - ❖ ...
- ❖ LATTES array baseline
 - ❖ Compact core array
 - ❖ Area: 20 000 m²
 - ❖ Target lowest energies ($E_{\min} \sim 100$ GeV)
 - ❖ Sparse array
 - ❖ Area: 100 000 m²
 - ❖ Cover energies up to 100 TeV

