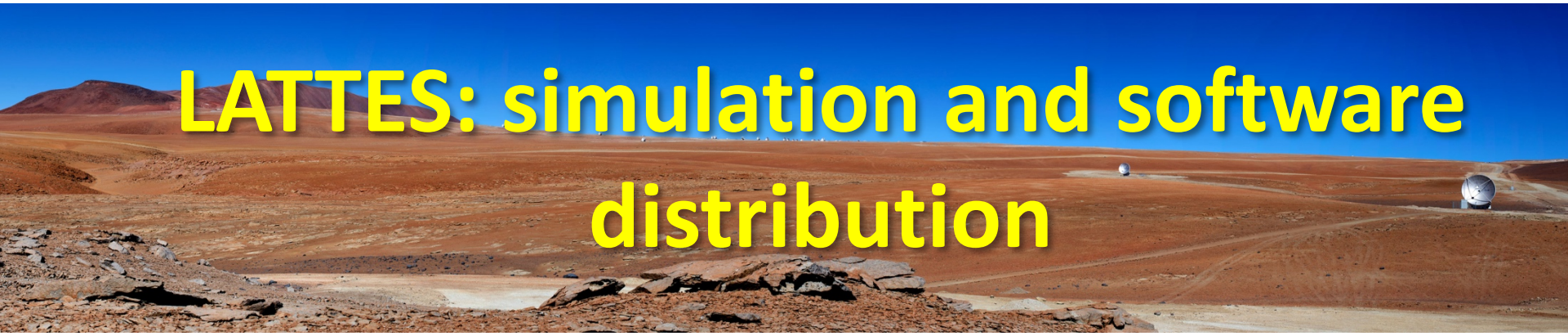


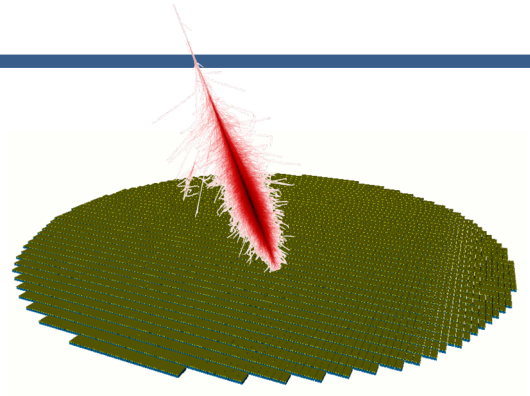
LATTES: simulation and software distribution

Bernardo Tomé, Ruben Conceição

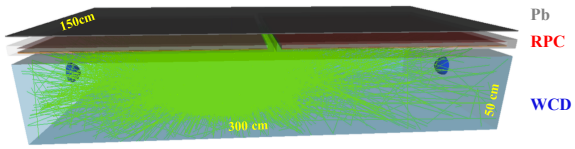
LIP

LATTES: Multivariate Analyses Workshop, 14th September, 2018

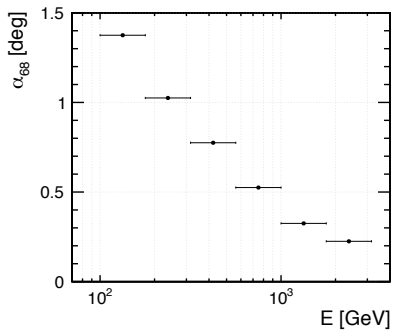
Simulating LATTES performance



Shower simulation
(CORSIKA)

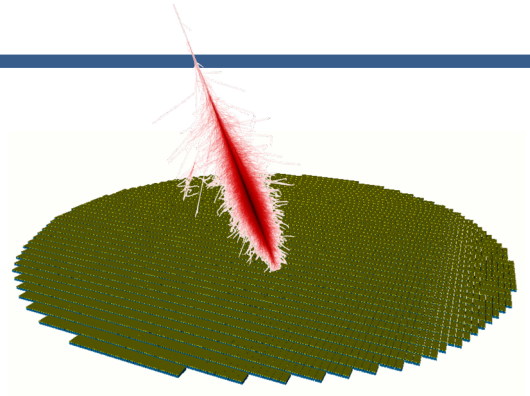


Detector simulation
(LATTESsim)

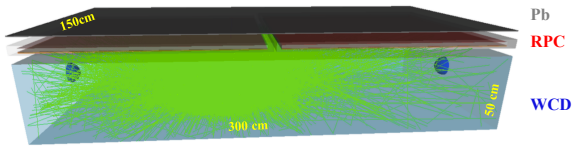


Shower reconstruction
(LATTESrec)

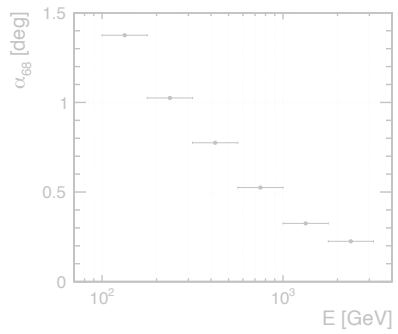
Simulating LATTES performance



Shower simulation
(CORSIKA)

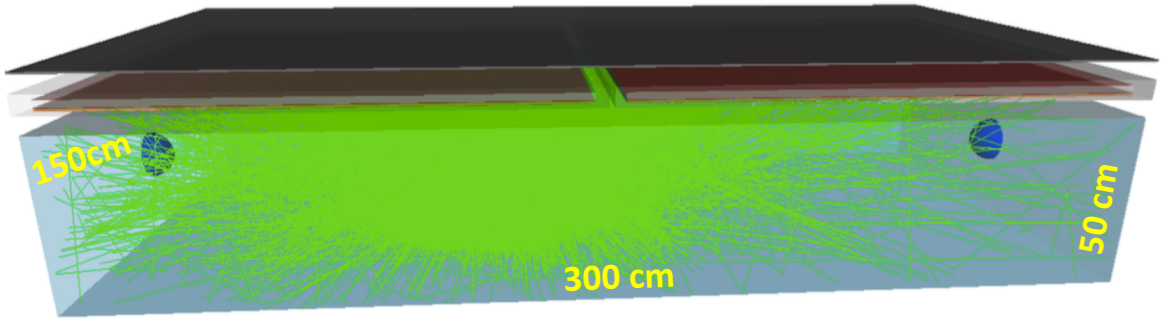


Detector simulation
(Geant4)



Shower reconstruction
(Ruben's talk)

LATTES hybrid detector concept



Pb

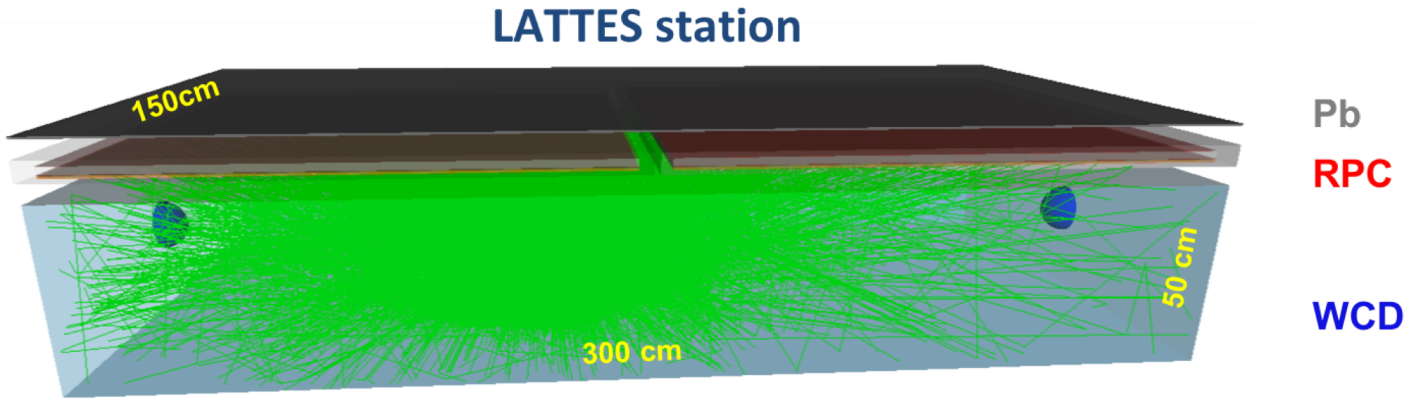
RPC

WCD

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)

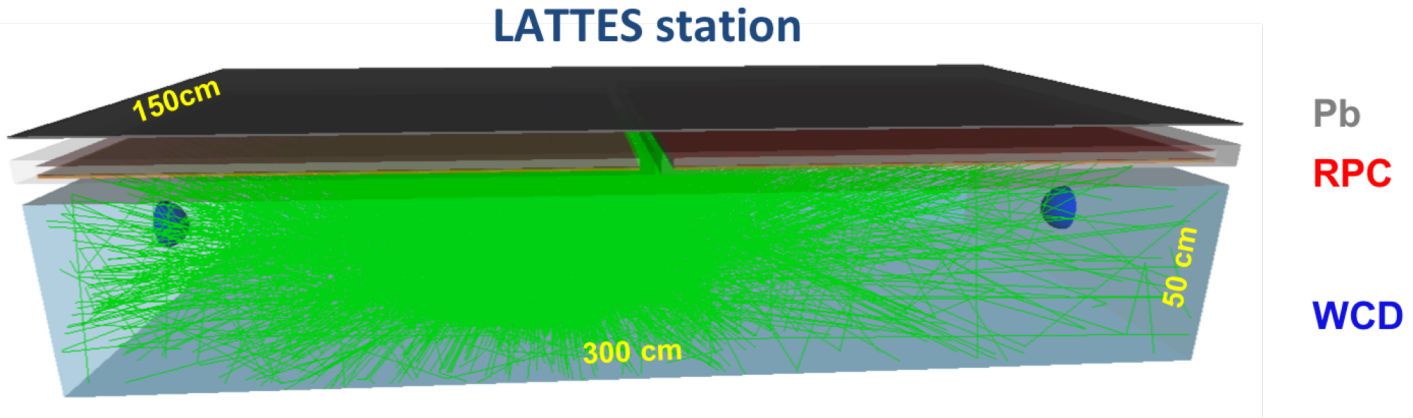
Resistive Plate Chambers (**RPC**)

- 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

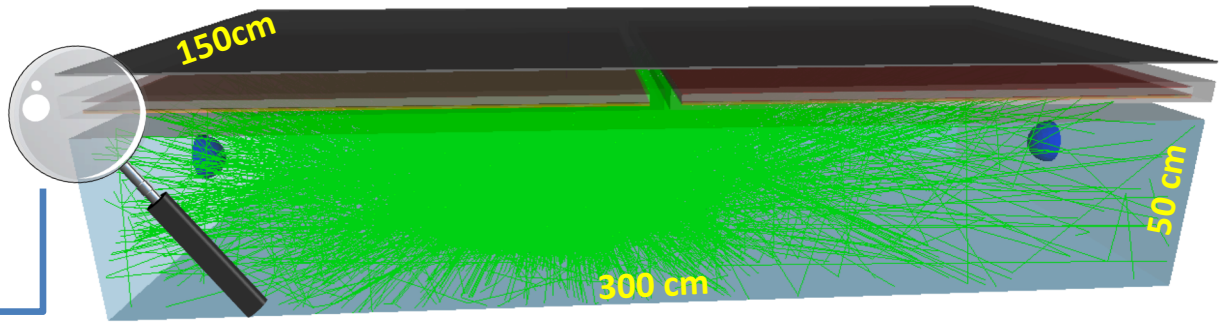
Resistive Plate Chambers (**RPC**)

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

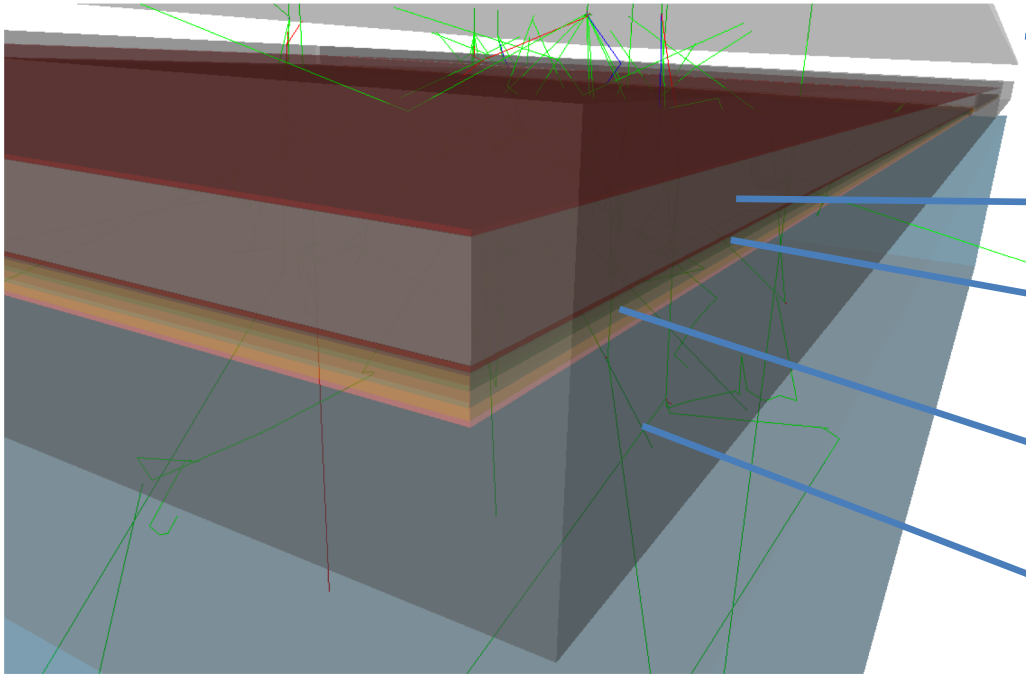
Water Cherenkov Detector (**WCD**)

- 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



Pb converter

Foam

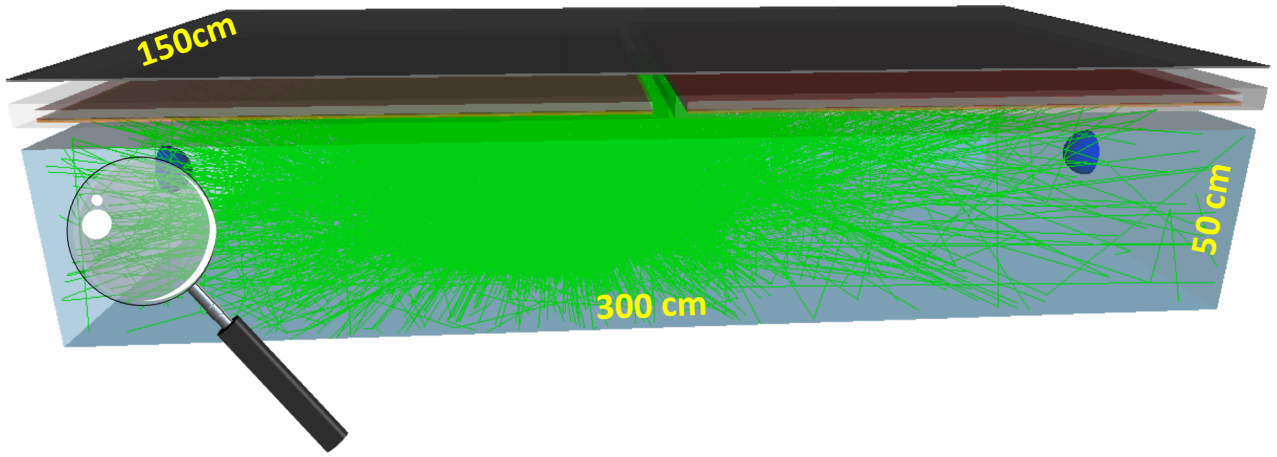
Bakelite PCB with pad readout

Acrylic box with :

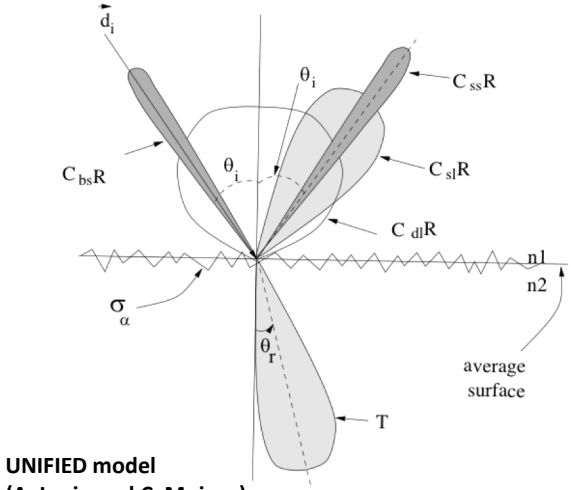
- **glass electrodes and**
- **1 mm gas gaps**

Aluminum housing

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 @ λ = 400 nm
- **PMT**
  - 15 cm diameter
  - $Q.E._{max}$ ~ 30% @ λ = 420 nm
- **Tyvek**
  - Described using the G4 UNIFIED optical model;
  - Specular and diffusive properties;
  - R ~ 95% , for λ > 450 nm

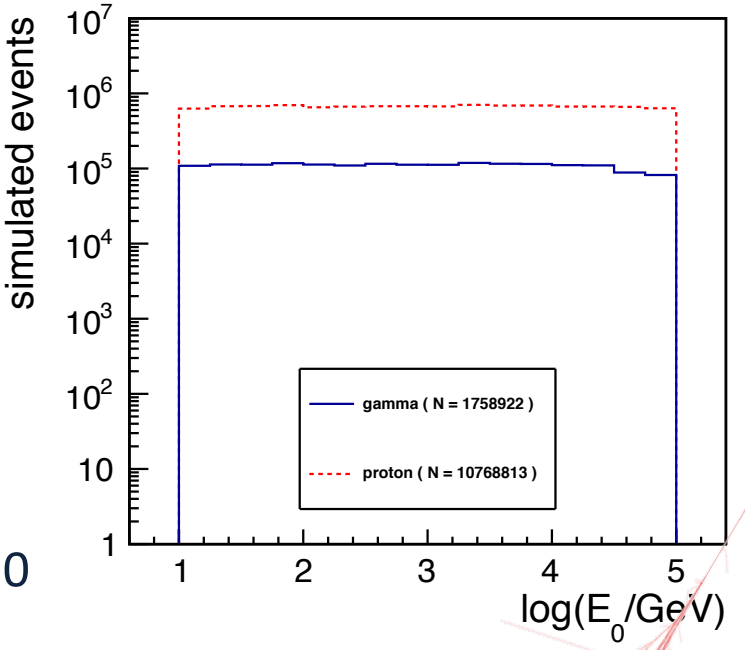


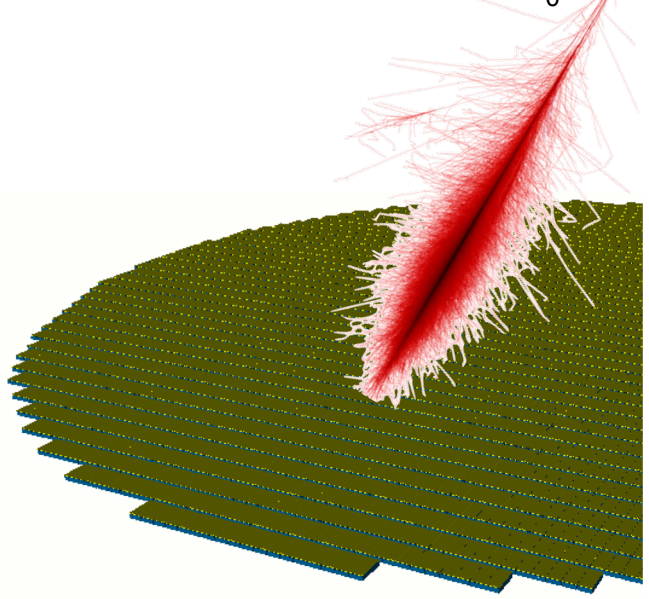
UNIFIED model
(A. Levin and C. Moisan)

- 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.

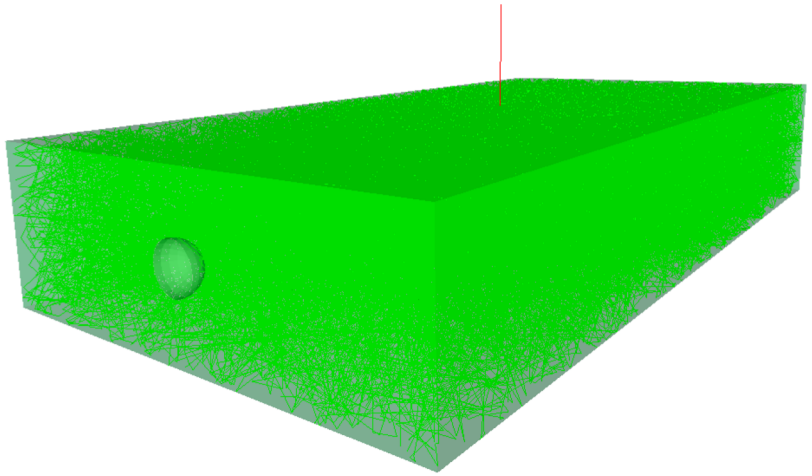
Simulation production

- 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 m^2;
    - Each shower is resampled 100 times over a large area containing all the array.





LATTES fast simulation

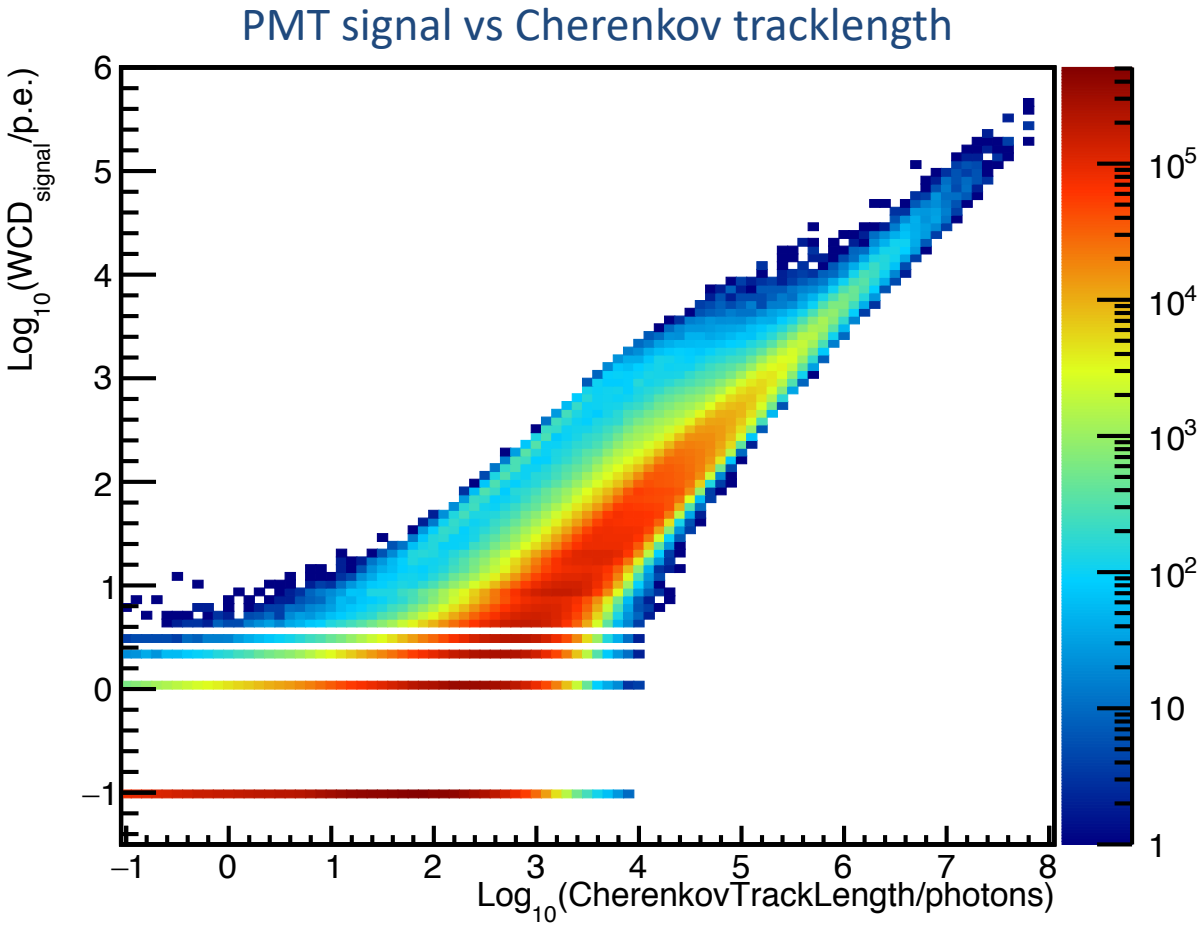


$dN/(dEdL) = 370 * z^2 * \sin^2(\theta_c)\ cm^{-1}\ eV^{-1}$

- 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…

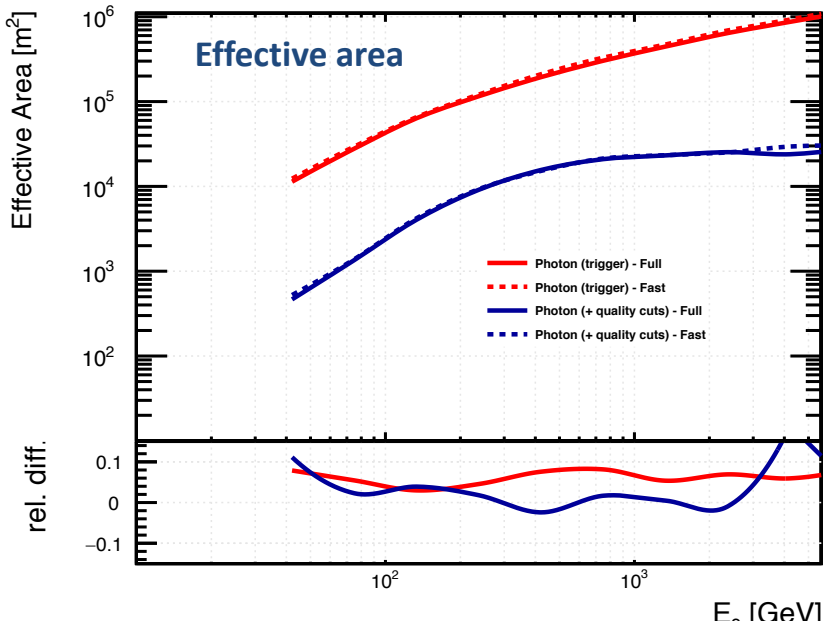
N ~ 8500 Cherenkov photons for a single vertical particle crossing the WCD;
> 10^6 Cherenkov photons may have to be tracked in a single station

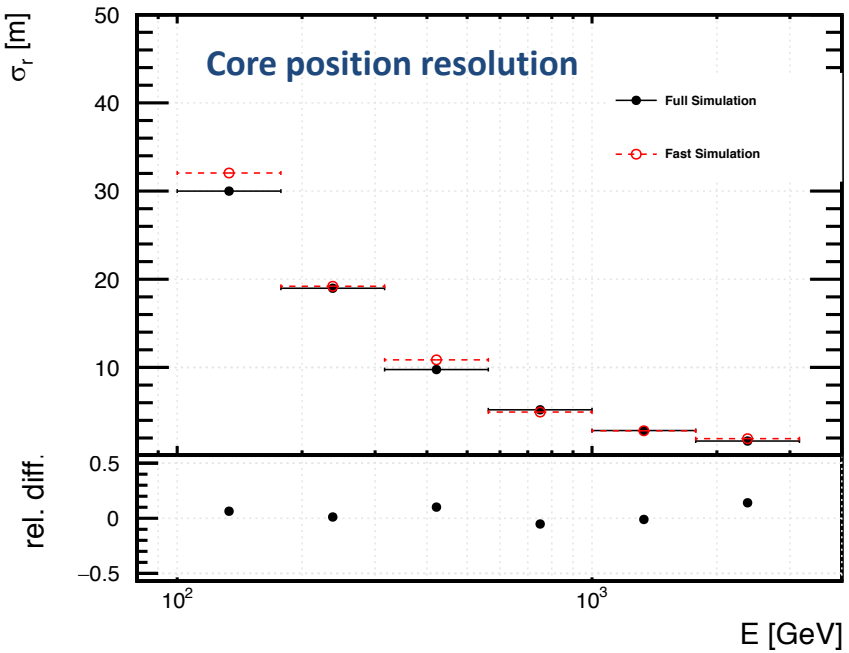
LATTES fast simulation

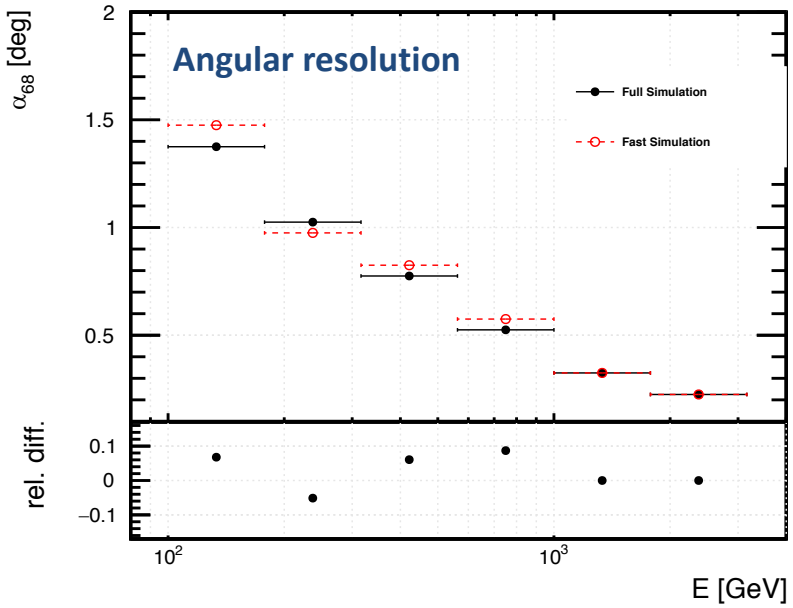


- Parametrize the PMT signal in function of the total emitted Cherenkov light;
- For the RPC's use full simulation.

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

LATTES documentation

LATTESSim v1

Main Page | Namespaces | Classes | Files

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

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

file:///Users/ruben/Desktop/LATTESrec/doxygen/html/classFisherCoef.html#aa2bcb3c7c051

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()

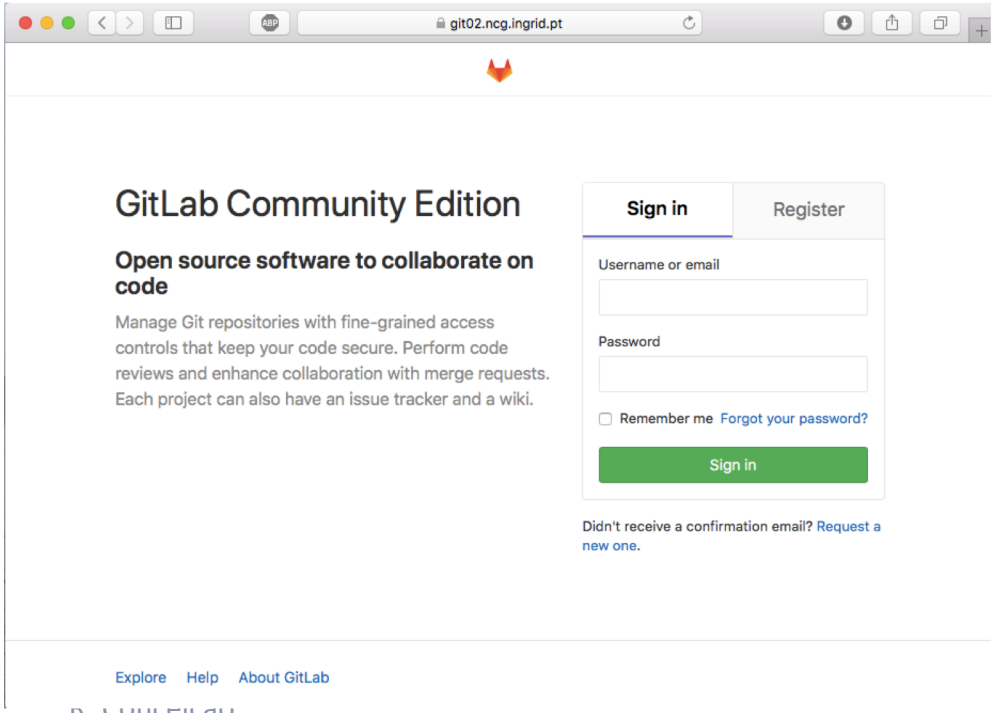
void FisherCoef::SetEnergy (double energy) inline

Definition at line 28 of file FisherCoef.h.

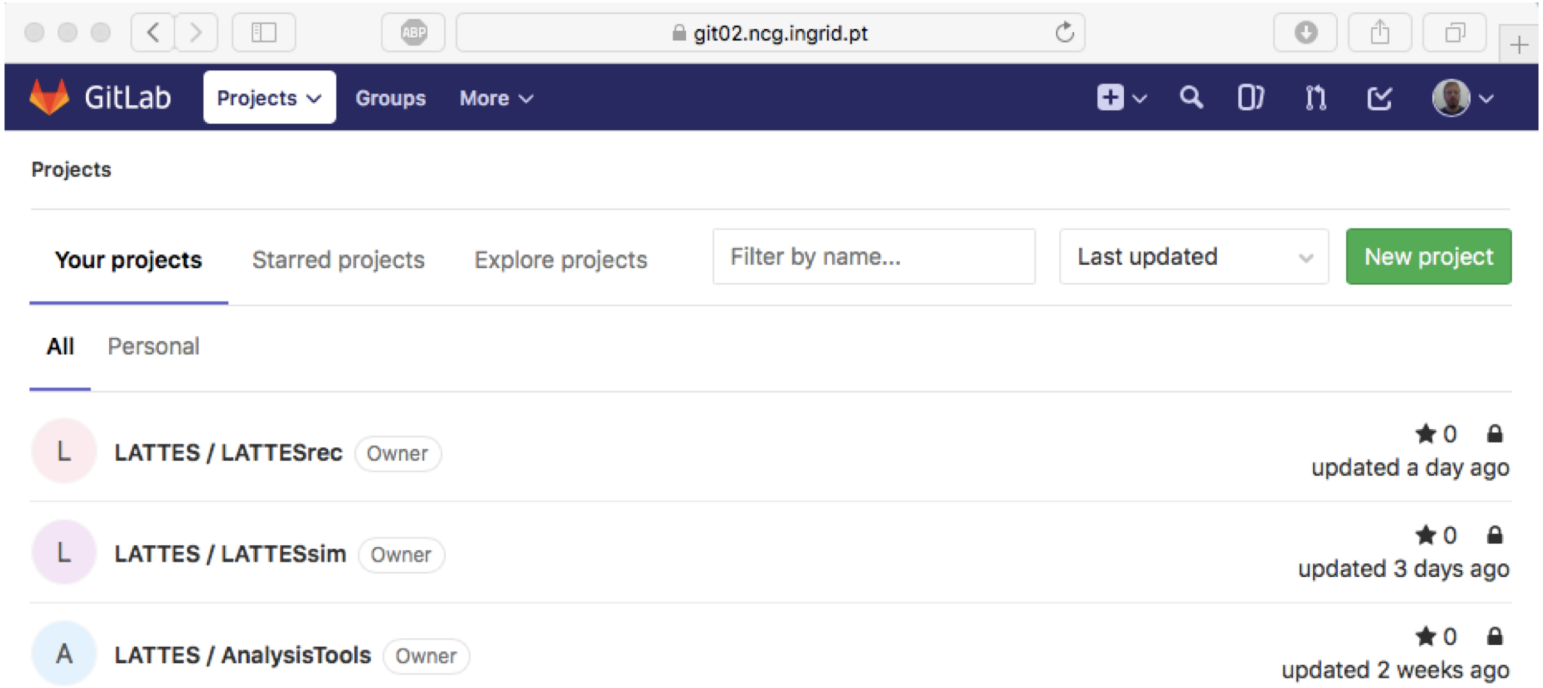
```
28 {fEnergy = energy;}
```

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

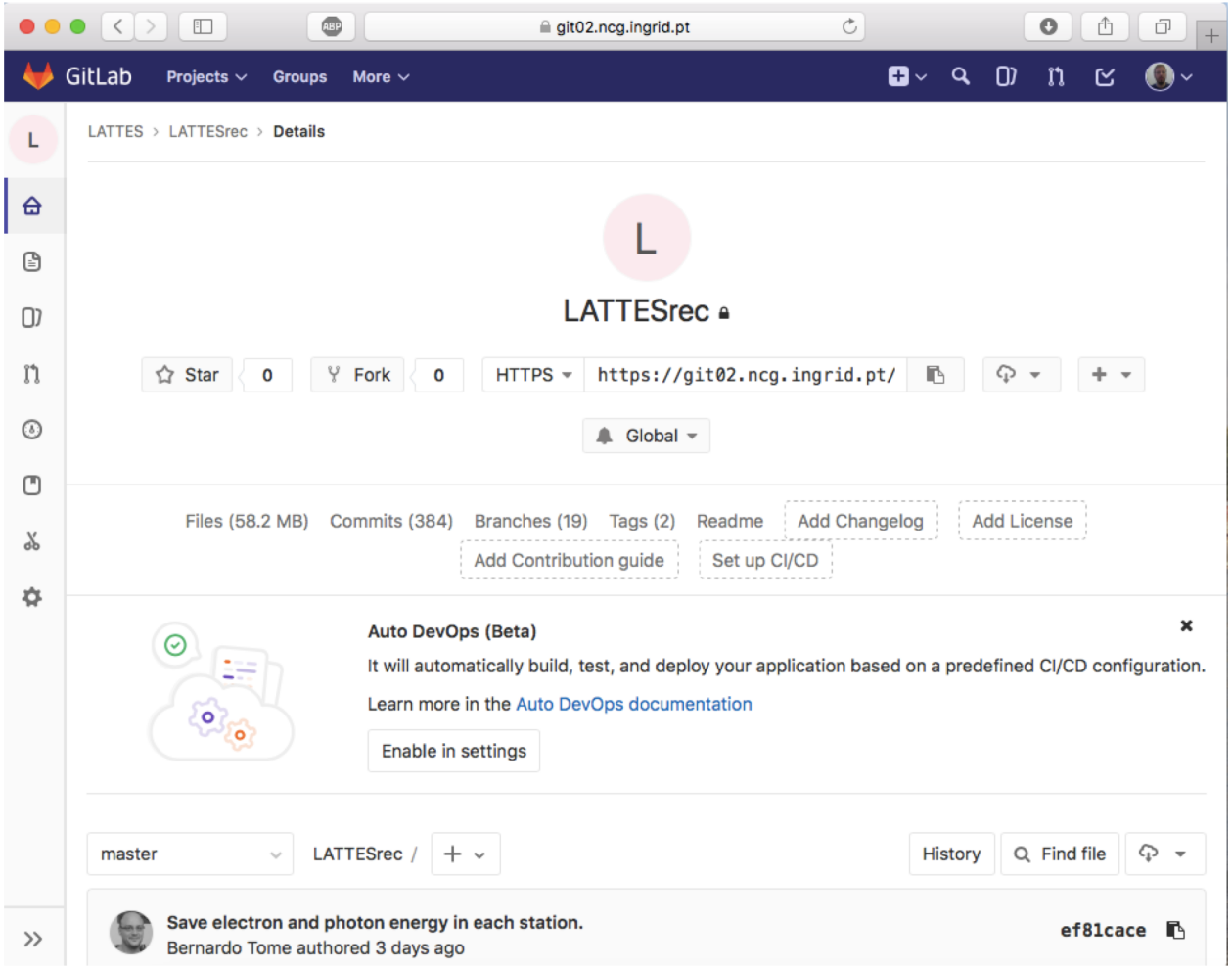


LATTES @ gitlab

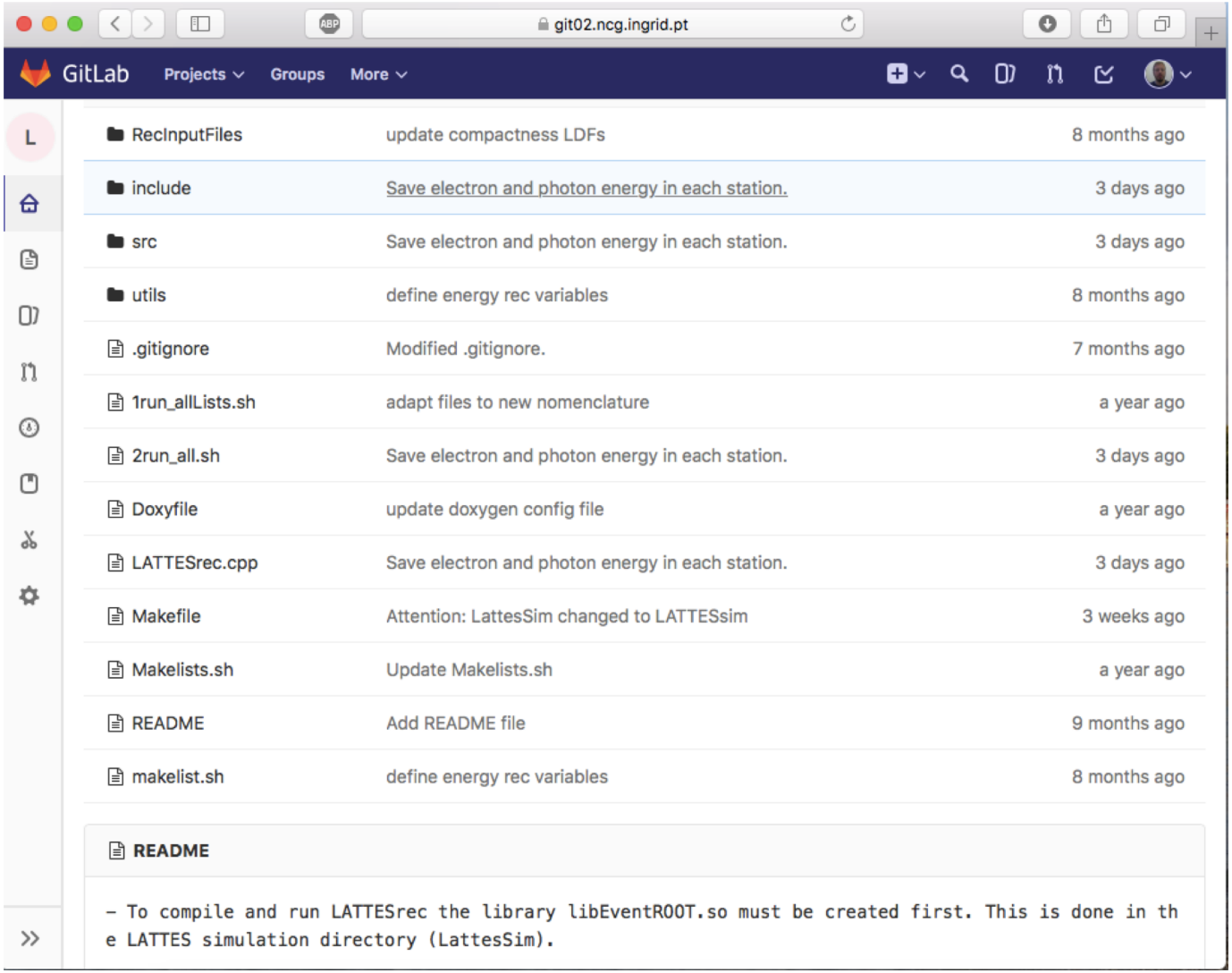


Example: get LATTESrec

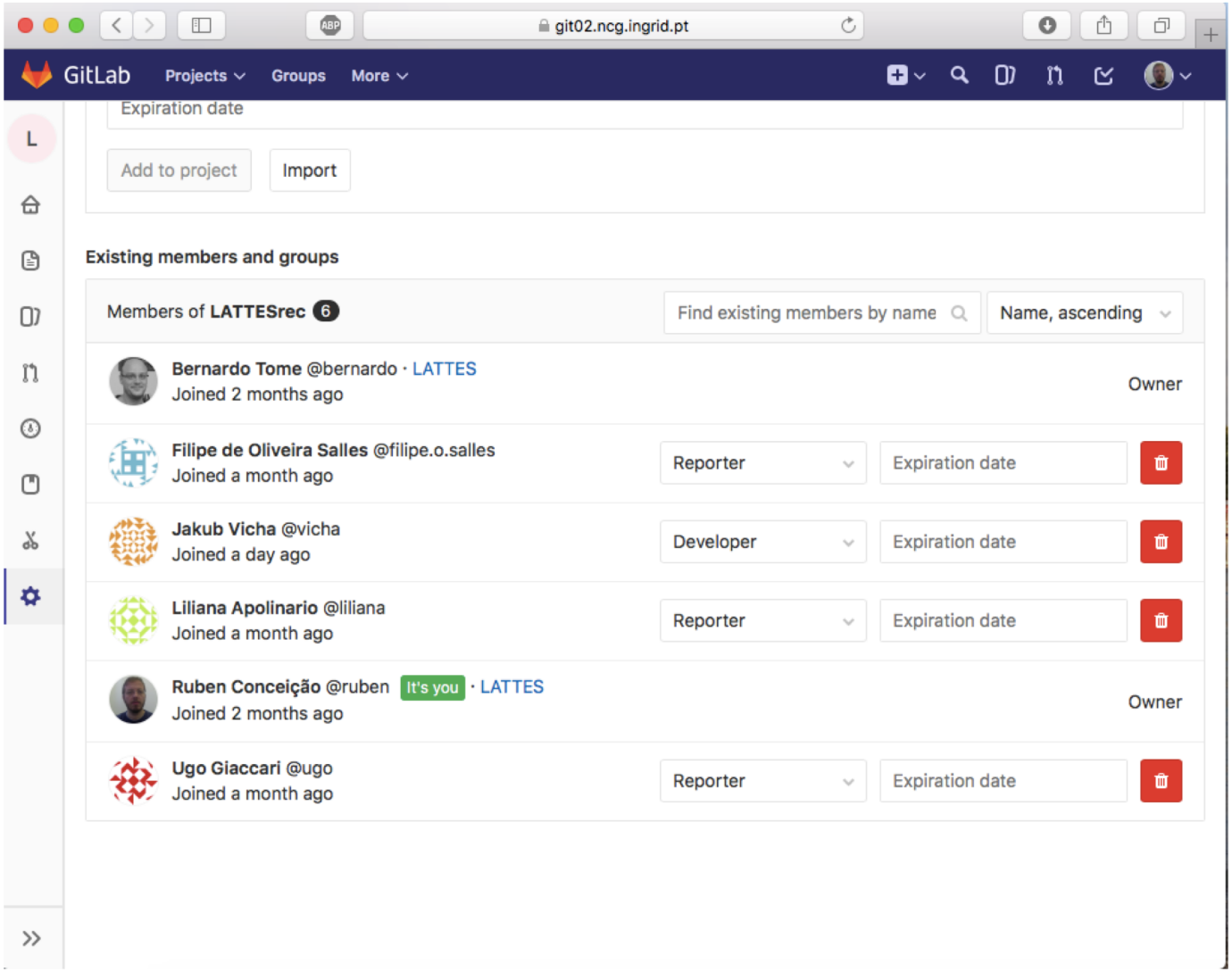
- git clone <https://….>



All info there!



Manage permissions



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

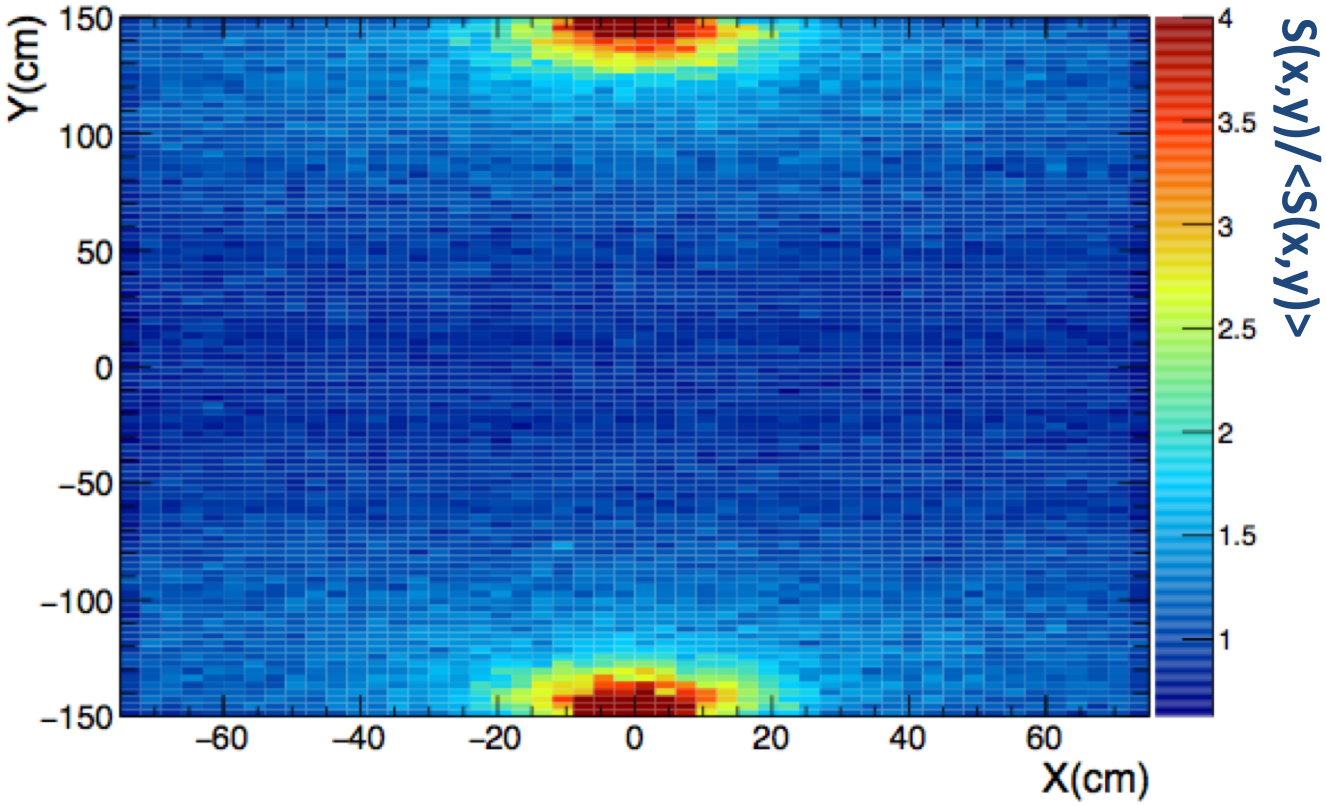
Acknowledgements

REPÚBLICA
PORTUGUESA

TÉCNICO
LISBOA

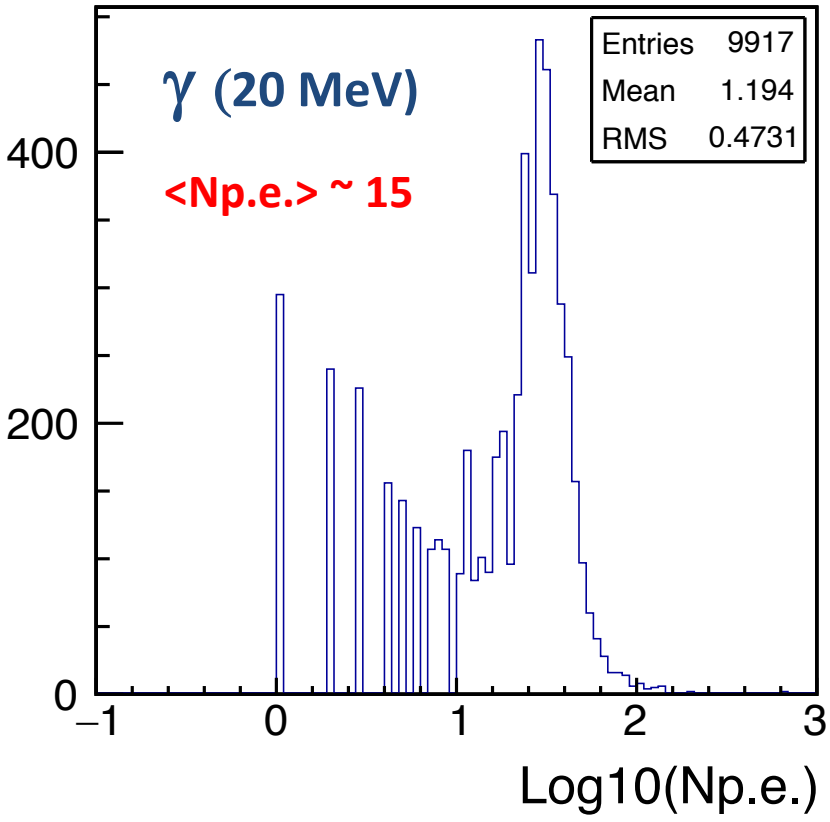
END

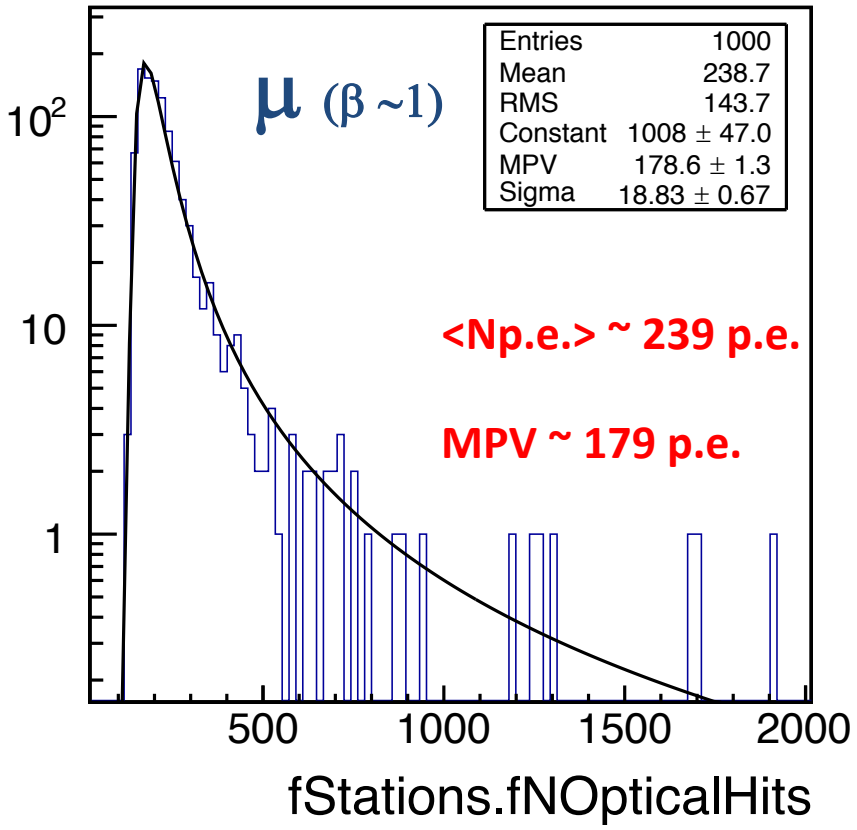
WCD signal uniformity



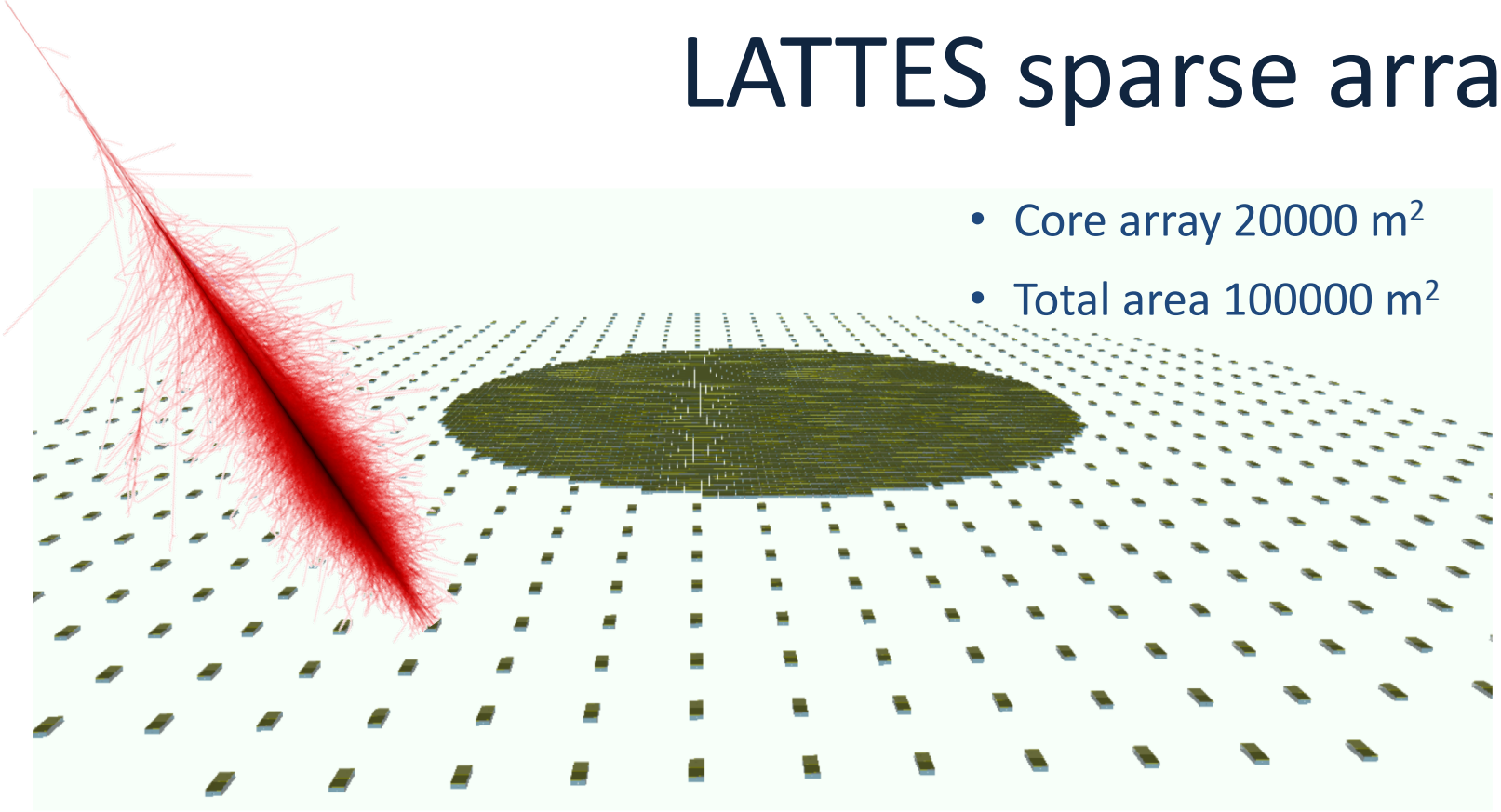
- Good uniformity across the tank area
- PMT spots visible

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 m^2
    - Target lowest energies (E_{min} ~ 100 GeV)
  - Sparse array
    - Area: 100 000 m^2
    - Cover energies up to 100 TeV