LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
*partículas e tecnologia*

# [ LIP **Summer Projects 2018** ]

## Cosmic Rays, Neutrinos, Dark Matter

# Astroparticle Physics

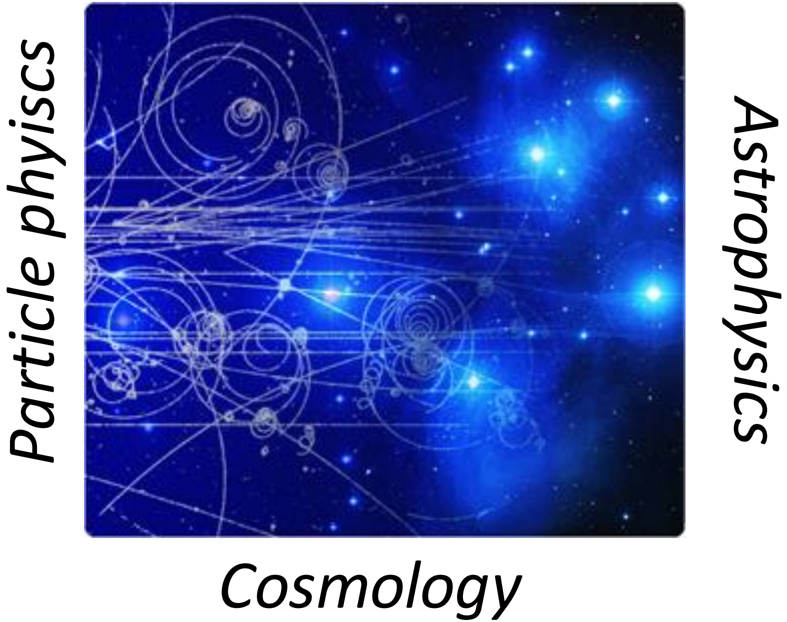
Understand the dynamics of our Universe through the radiation/particles collected at Earth

Perform fundamental particle physics tests otherwise not possible to be achieved with current technology

Example:

- The neutrino oscillations were found analyzing the neutrinos coming from the Sun

Astroparticle Physics



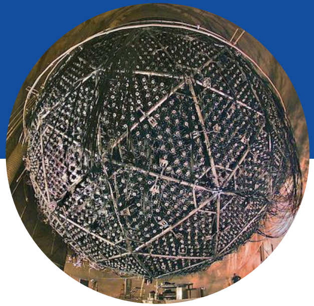
LIP Groups (Lisbon)

# Astroparticle Physics

AMS

LATTES

Pierre Auger Observatory



SNO+

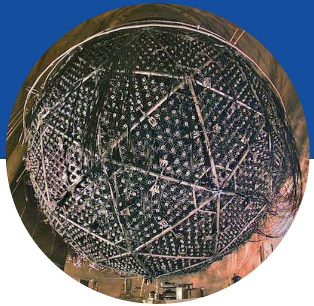
## LIP Groups (Lisbon)

# Astroparticle Physics

Anti-matter

Gamma-rays

Ultra High Energy Cosmic Rays



Neutrino physics

*a.s.l. = above sea level*

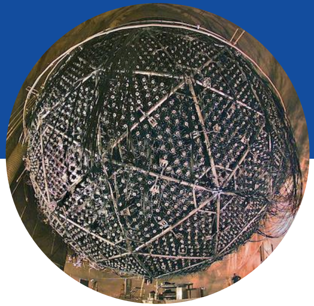
## LIP Groups (Lisbon)

# Astroparticle Physics

400 km a.s.l.

5.2 km a.s.l.

1.4 km a.s.l.



-2 km a.s.l.

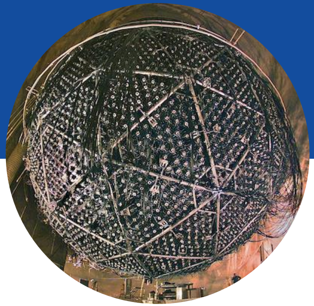
## LIP Groups (Lisbon)

# Astroparticle Physics

Space

Mountain

Pampa



Mine

MeV = $10^6$ eV
GeV = $10^9$ eV
TeV = $10^{12}$ eV
EeV = $10^{18}$ eV

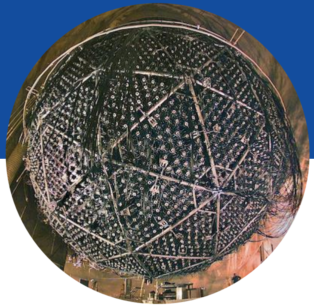
# LIP Groups (Lisbon)

# Astroparticle Physics

GeV

TeV

EeV



MeV

# LIP’s summer internship projects in Astroparticle Physics

Number of projects to be presented:

- AMS: 1
- LATTES: 1
- Auger: 5
- SNO+: 3
- Muon tomography: 1

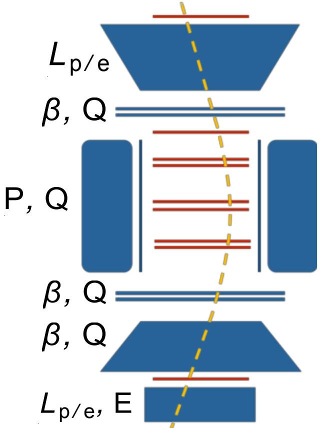
# Alpha Magnetic Spectrometer (AMS)

# The Alpha Magnetic Spectrometer

**The Alpha Magnetic Spectrometer (AMS-02)** is a state-of-the-art cosmic-ray detector designed to operate as an external module on the International Space Station (ISS).

Installed on the ISS in May of 2011, its main objective is the **search for antimatter and dark matter**.

AMS has collected more than **115,000,000,000 events** up to this day, at a rate of about 45 million events per day. It will continue in space for the duration of ISS' lifetime.



# Projects (AMS)

- **Solar Modulation of Cosmic Rays**
  - Explore the simulation of this phenomenon using a package name SOLARPRO which solves the **cosmic ray transport equations** using **a 2D stochastic approach**

**Contacts:**
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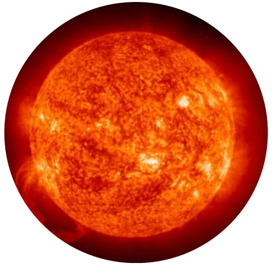
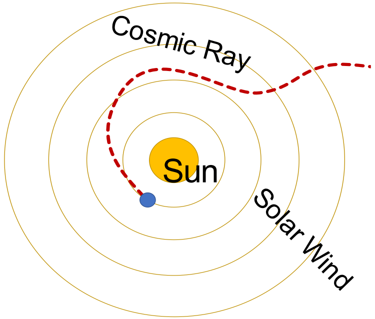
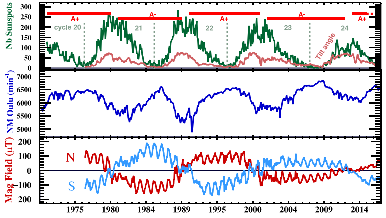


## Solar Wind

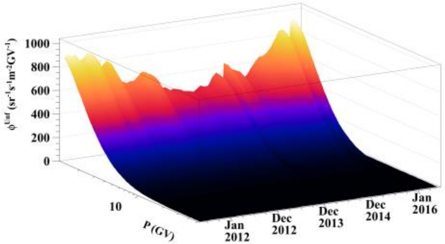
## Solar Modulation




### Solar Activity



### Time Variability of cosmic ray flux



# Large Array Telescope for Tracking Energetic Sources (LATTES)

# LATTES

Next generation gamma-ray experiment

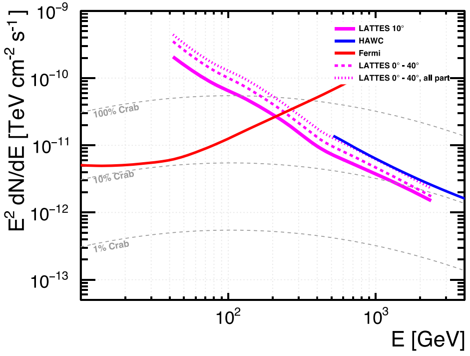
Lower energy threshold to cover gap between satellite and ground measurements

Location: South America at an altitude of about 5200 m

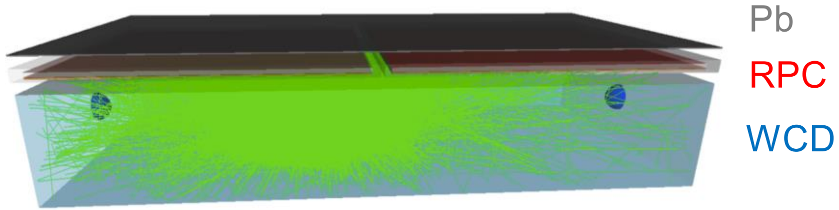
Wide-field of view experiment able to monitor the center of our galaxy

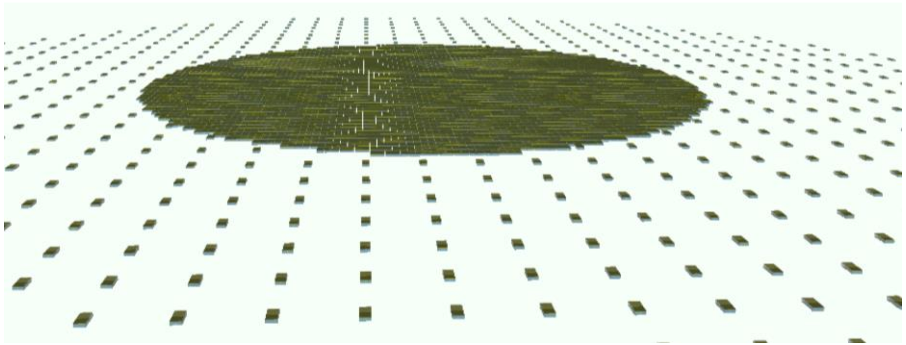
Important for multi-messenger searches

Indirect dark matter searches



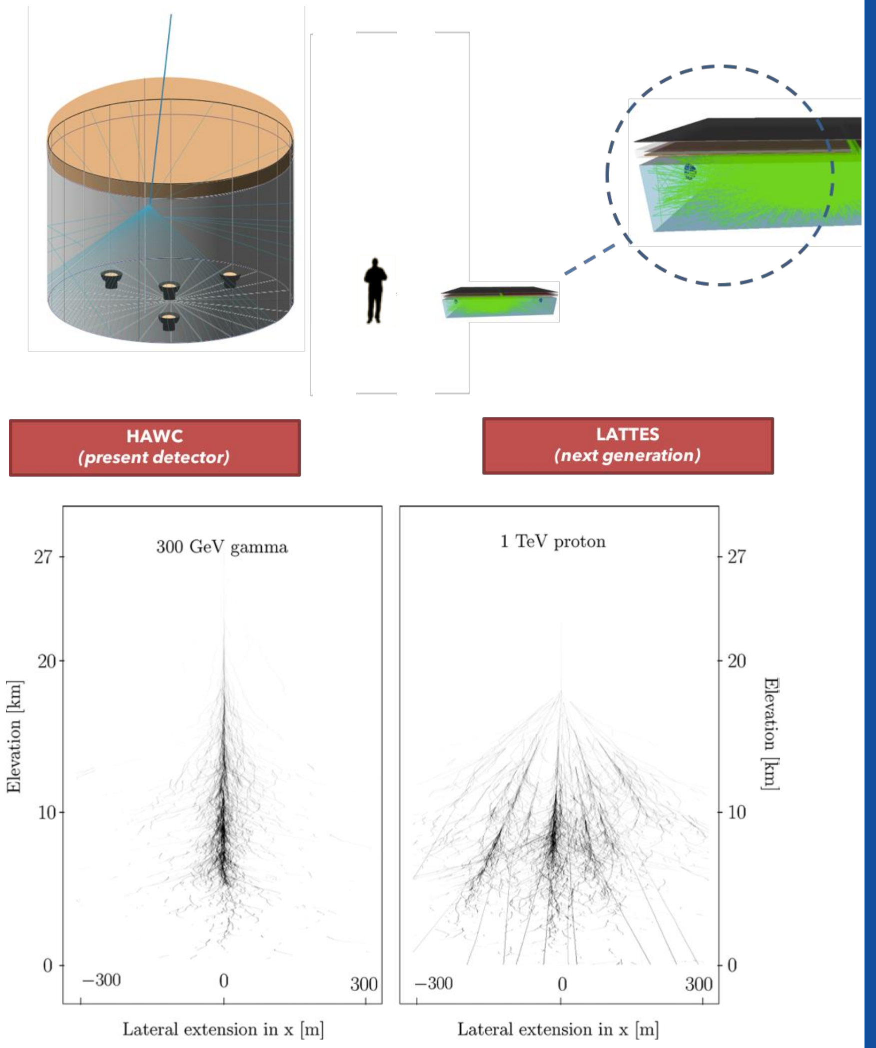

Collaboration



# Projects (LATTES)

- **Gamma/Hadron discrimination**
  - Combine WCD and RPC measurements to distinguish gammas (signal) from protons (background)
  - Use Multivariate analysis: Artificial Neural Networks, Boosted Decision Trees…




**Contacts:**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Mário Pimenta (pimenta@lip.pt)
Bernardo Tomé (bernardo@lip.pt)

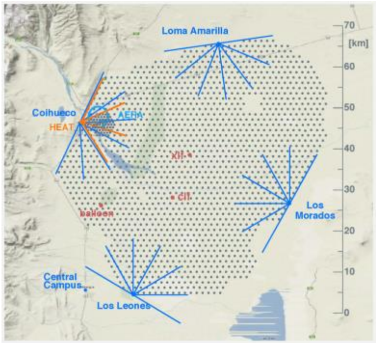
# Pierre Auger Observatory

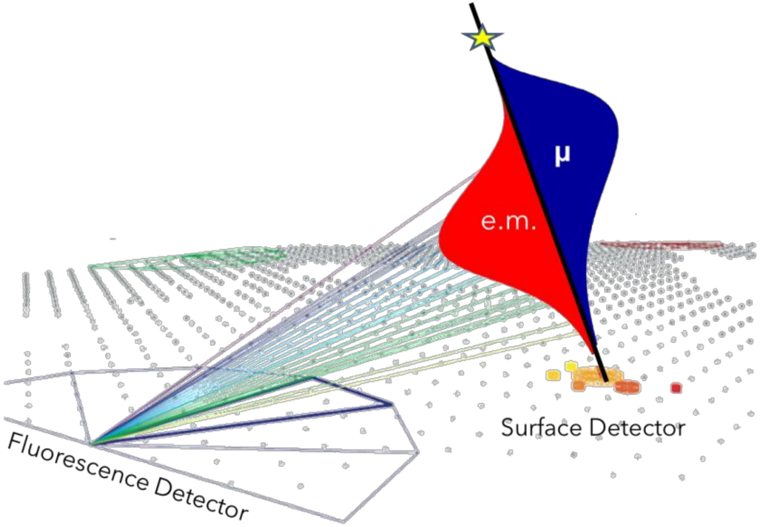
# Pierre Auger Observatory

Located in the Pampa Amarilla, it is the largest observatory in the world dedicated to the study of Ultra High Energy Cosmic Rays (UHECRs)

The main array is composed by more that 1600 water Cherenkov detectors which are overlooked by 4 Fluorescence Detectors

The study of UHECRs allows not only to understand the nature and acceleration mechanisms of the most energetic known particles but also can be used to probe hadronic interaction above LHC energies



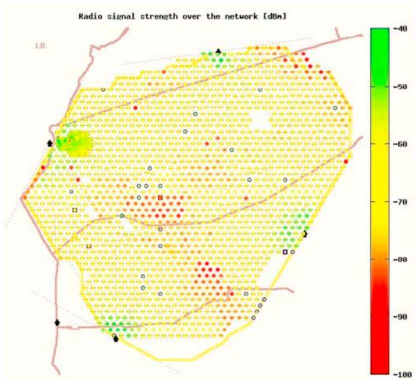



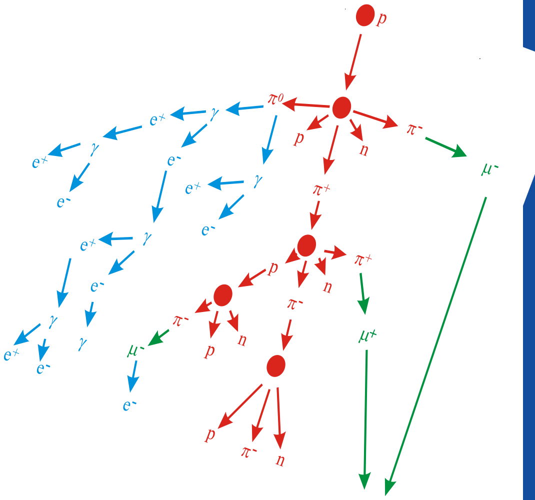
# Projects (Auger)

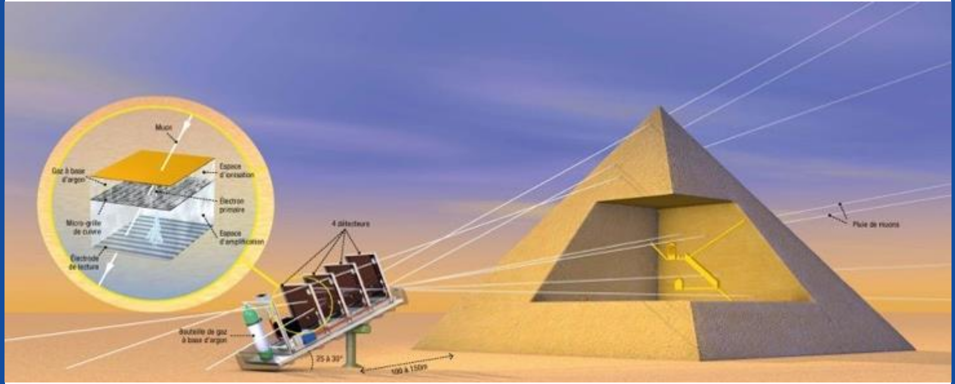
- **Measure EAS muon content** (LC,SA)
  - Create analysis to extract muon number in EAS from Auger Data
- **Performance of Surface Detector** (BT,PA)
  - Long term performance studies to better understand the SD array
- **Muon tomography** (LC,SA)
  - Produce and analyze muon tomography images
  - Project outside from Auger scope

**Contacts:**

PA = Pedro Assis (pedjor@lip.pt)
SA = Sofia Andringa (sofia@lip.pt)
LC = Lorenzo Cazon (cazon@lip.pt)
BT = Bernardo Tomé (bernardo@lip.pt)



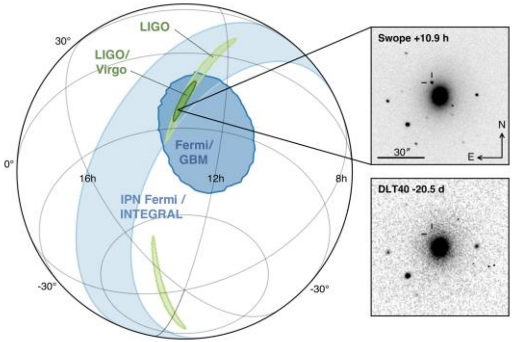


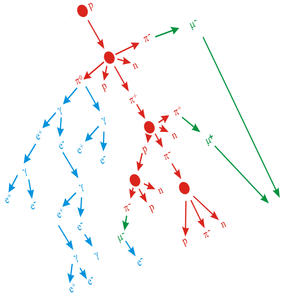
# Projects (Auger)

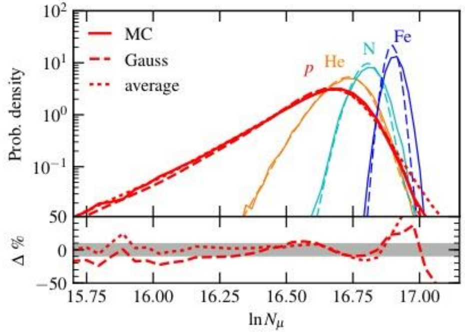
- **Multi-messenger searches** (SA,LC)
  - Search for photon events connected to gravitational waves
- **Hadronic interactions** (LC,RC,FR)
  - Investigate relation of hadron spectrum of first interaction with muon distributions at ground
- **LRC event display** (RC,FR)
  - Create tools to visualize Auger events

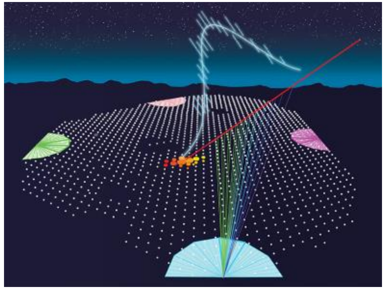
**Contacts:**

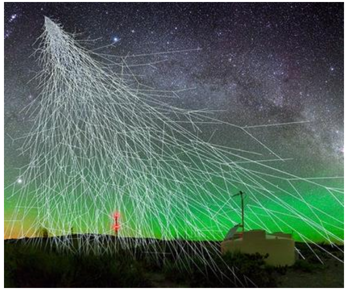
SA = Sofia Andringa (sofia@lip.pt)
LC = Lorenzo Cazon (cazon@lip.pt)
RC = Ruben Conceição (ruben@lip.pt)
FR = Felix Riehn (friehn@lip.pt)



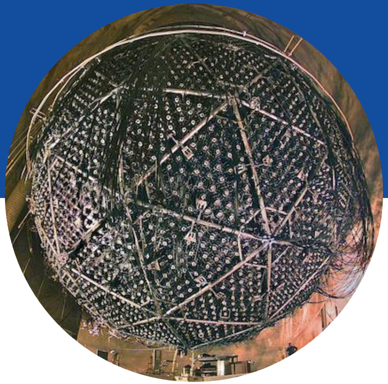







# Sudbury Neutrino Observatory (SNO+)



# The SNO+ experiment

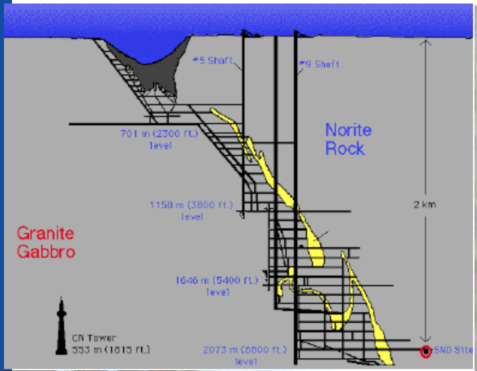
**Detector and signals in a nutshell**

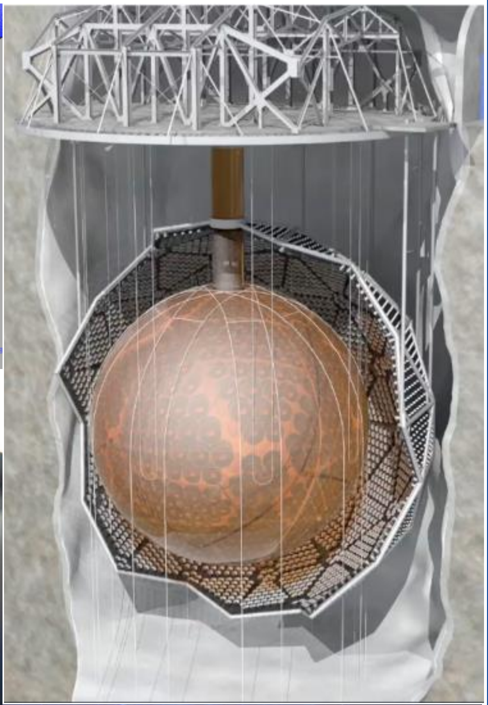
A sphere of 10 000 sensitive devices (photo-multipliers) able to record light from the interaction between the detector media and particles coming from the space (e.g. cosmic ray muons, dark matter) or produced inside the detector (radio-active interaction).

Located 2 km underground in a Canadian mine (clean class 2000 laboratory).

Taking data with the detector filled with water since May 2017.

Will replace the water with liquid scintillator and introduce a radio-active isotope ($^{130}Te$) to hunt for a **measurement of the neutrino mass**.



# Projects (SNO+)

- **Coincidence events tagging** (SA,VL)
  - search for these events in the data
  - identify methods to separate the signal
- **Search for Dark Matter** (GP,FB)
  - study of Dark Matter masses/energy
  - analysis of the particle signature
- **Cosmic rays muons reconstruction** (FB,GP)
  - identification of the muon direction
  - detector performance study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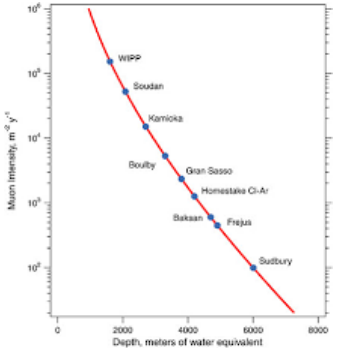
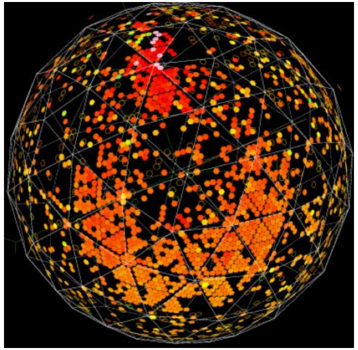
SA = Sofia Andringa (sofia@lip.pt)

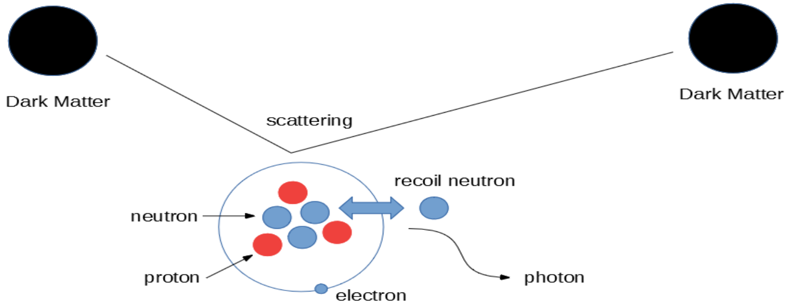
VL = Valentina Lozza (vlozza@lip.pt)

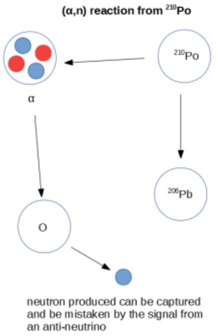
GP = Gersende Prior (gersende@lip.pt)

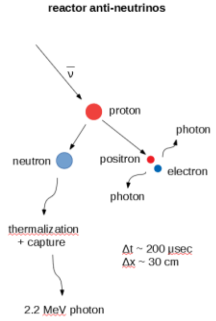
FB = Fernando Barão (barao@lip.pt)



# Time for Questions with Experts!!

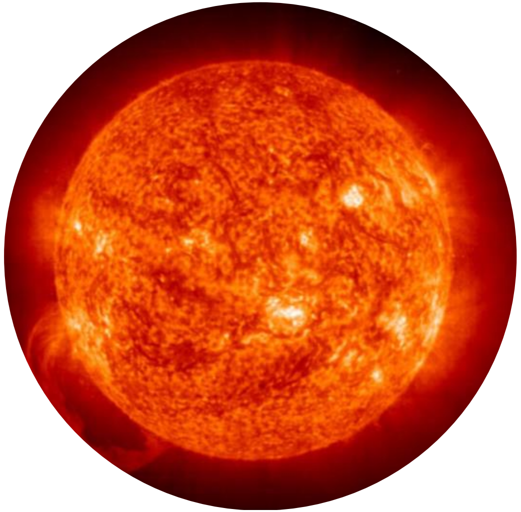
# Backup Slides

# The Alpha Magnetic Spectrometer

The Sun emits a continuous stream of highly conductive plasma (**Solar Wind**) that permeates the entire Solar system, transporting **Solar magnetic field** lines with it.

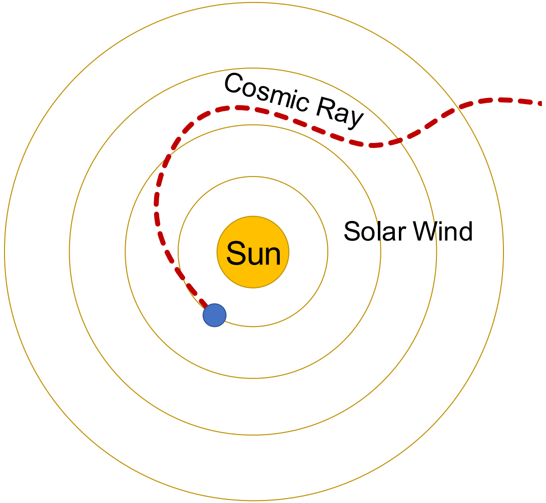
The Solar magnetic field changes the direction and energy of cosmic-rays inside the Solar system, creating an effect known as Solar modulation. Cosmic-ray flux is especially sensitive to this effect on the low energy range, up to 30 GV.

The goal of this work is to explore the simulation of this phenomenon using a package named SOLARPROP which solves the **cosmic ray transport equations** using a **2D stochastic approach**.



## Solar Wind

## Solar Modulation

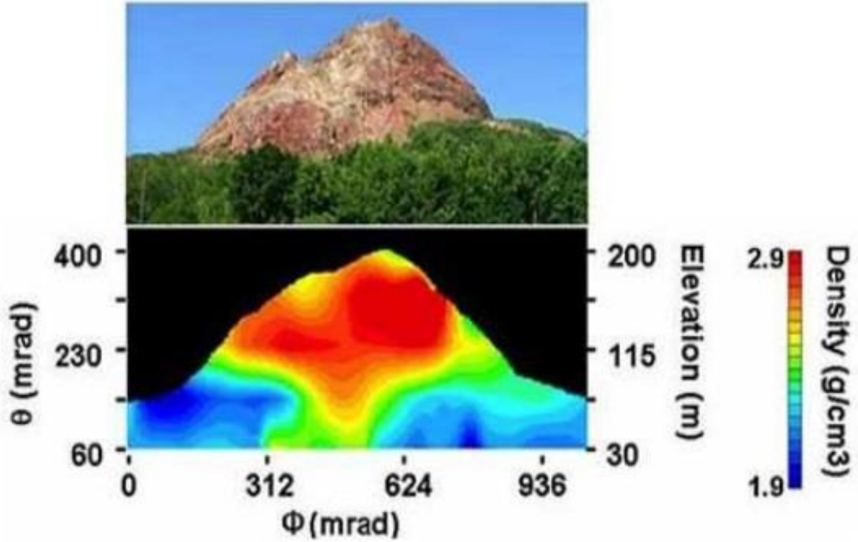


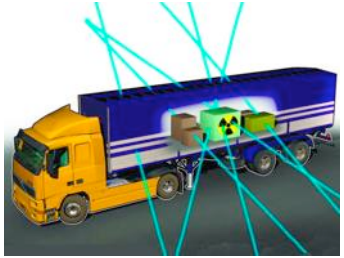
# Muon Tomography

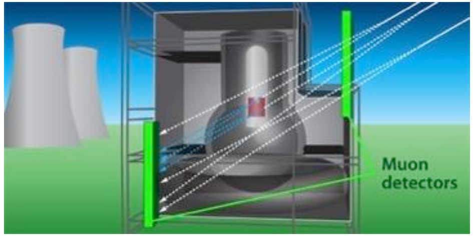
Cosmic ray muons are deeply penetrating particles. Muon telescopes can form images of the interior of **mines, vulcanos, builidings, and even the nuclear reactors and cargo containers**

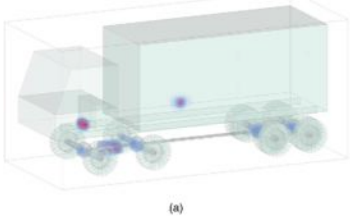
**Producing and analysing muon tomographic images.**

Contact: Lorenzo Cazon (cazon@lip.pt)
Sofia Andringa (sofia@lip.pt)

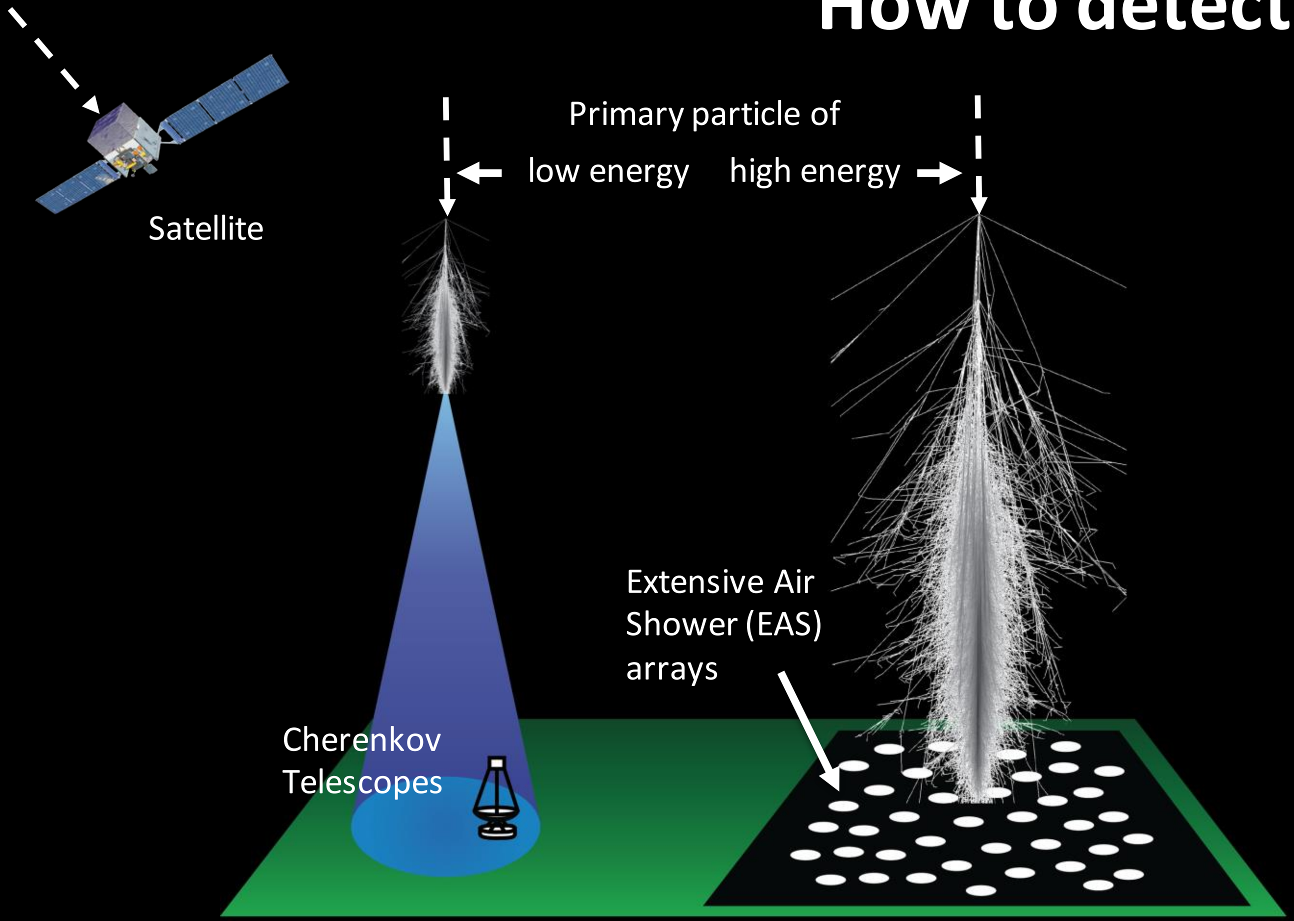





# How to detect?




Arrays at high-altitude = large field of view + large duty cycle + low energy

# Spanning a magnitude of scales