LATTES

Southern Wide-field Gamma-ray Observatory

Ruben Conceição

LIP

TÉCNICO LISBOA

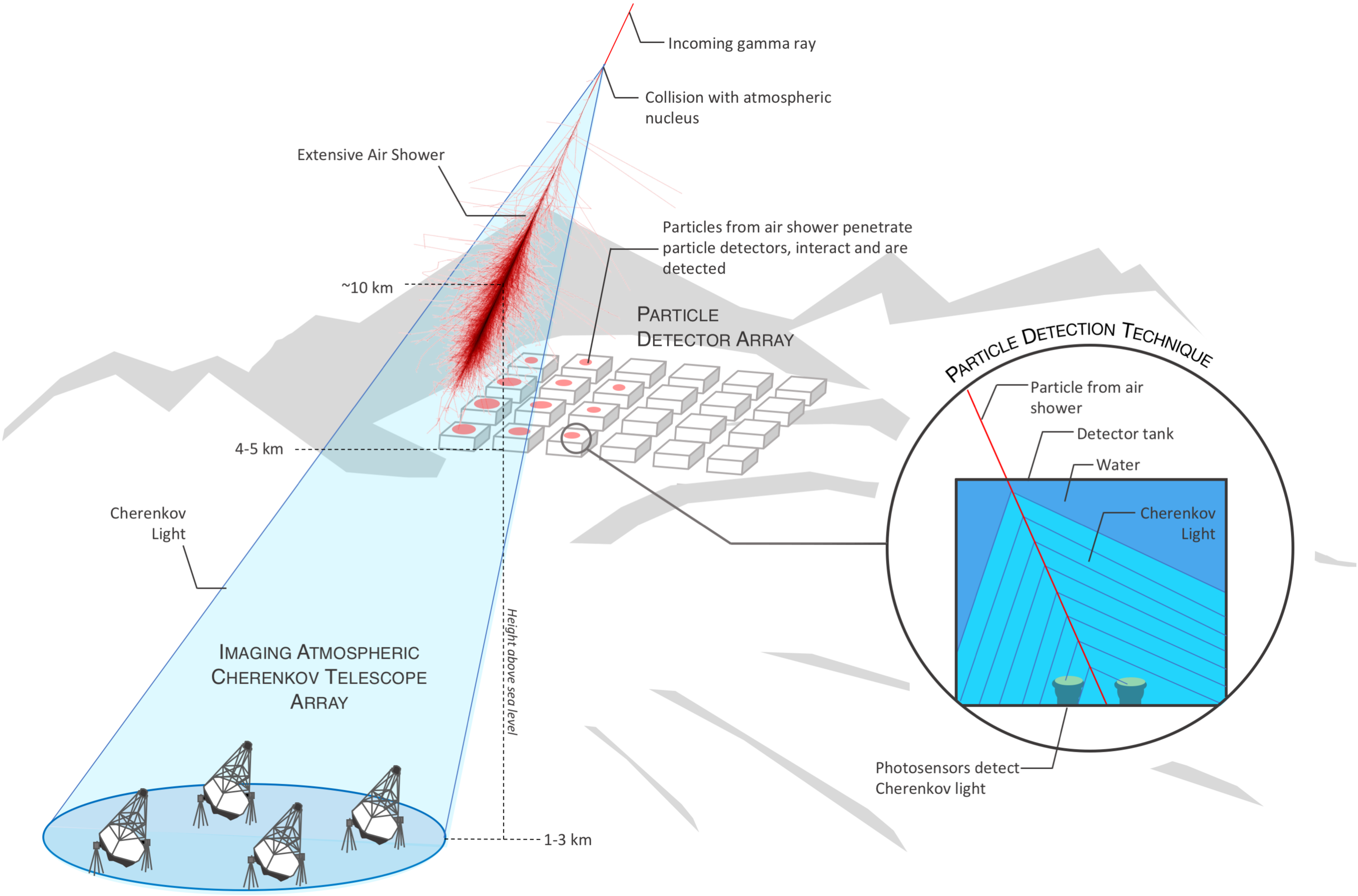
Jornadas LIP, Braga, February 15th 2020

(Very) high-energy gamma-rays

- Photons **extremely energetic**
  - From a few GeV to 100 TeV
    - Point to production source
    - Travel long distances
- Probes for the **most violent processes** known in the Universe
  - Supernovae; Active Galaxy Nuclei; Pulsars; …
- Allows to perform strong **tests to fundamental physics**
  - Dark matter indirect searches; Lorentz invariance; Quantum gravity; …

VERITAS
MAGIC
ARGO
RPC's
LHASSO
CTA
HAWC
CTA
HESS
Built IACT
Built Array
Planned IACT
In construction Array

High-energy gamma-ray detection techniques




LHASSO
Built IACT
Built Array
Planned IACT
In construction Array

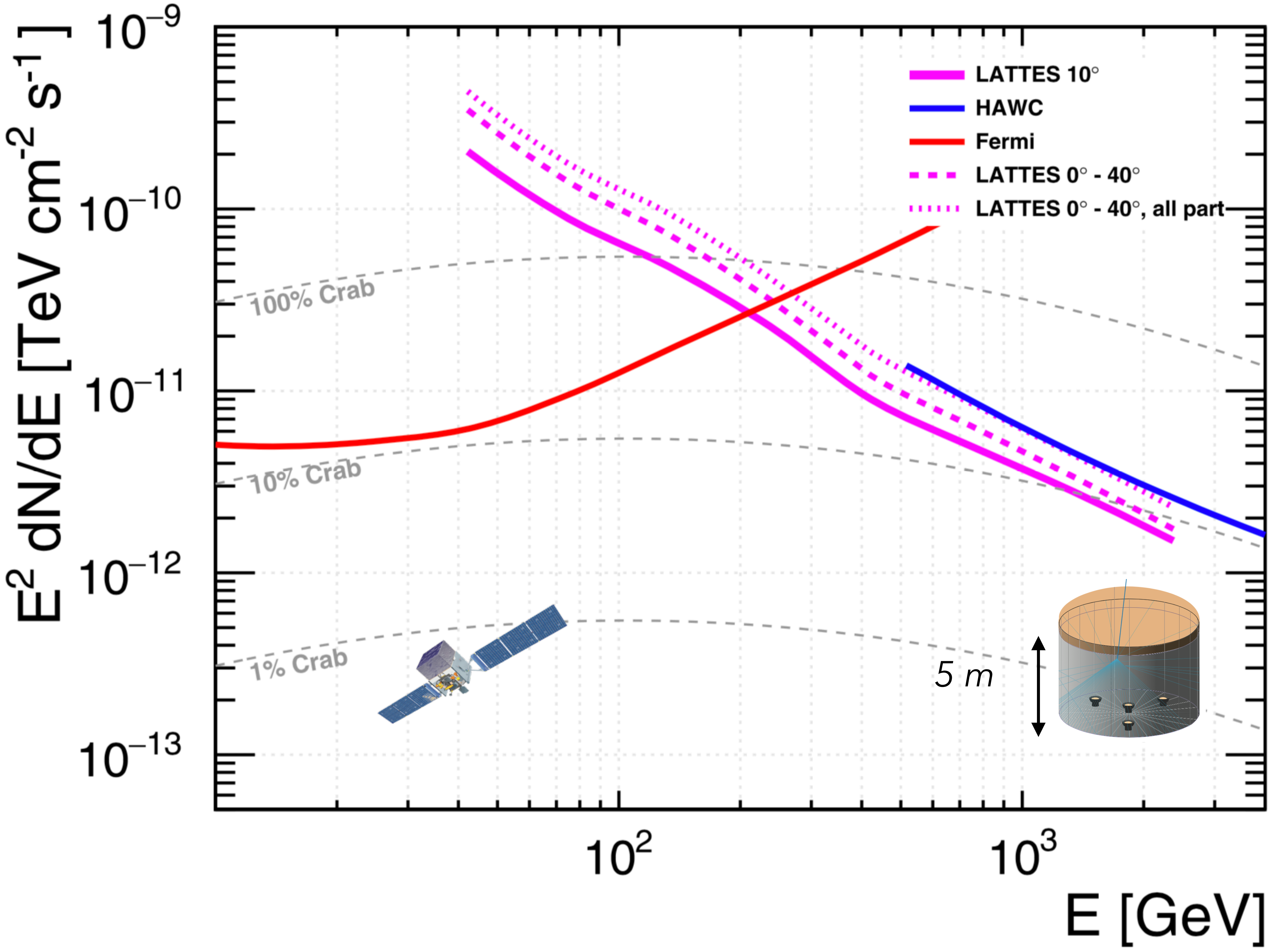

LHASSO
Built Array
In construction Array

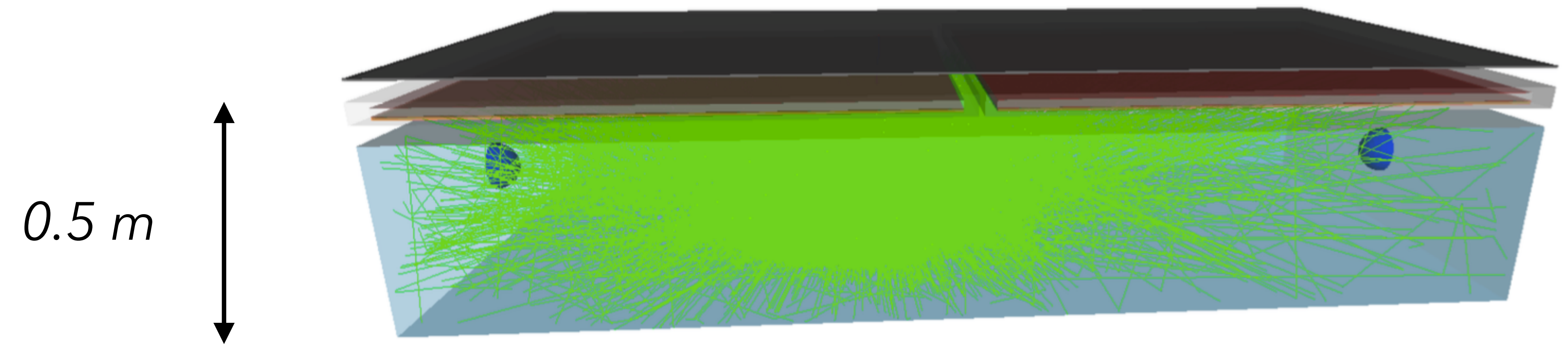
Complementary to the powerful Cherenkov Telescope Array project

LATTES

- Design of a **hybrid detector** able to cover the sensitivity gap between satellite and ground-base experiments
  - Water Cherenkov Detector
  - Resistive Plate Chamber
- Collaboration between Brazil, Czech Republic, Italy, Portugal
- https://www.lip.pt/experiments/lattes

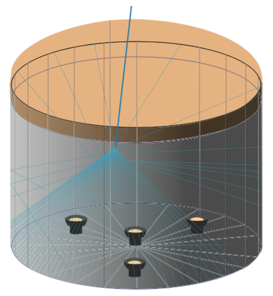
Astroparticle physics 99 (2018) 34-42



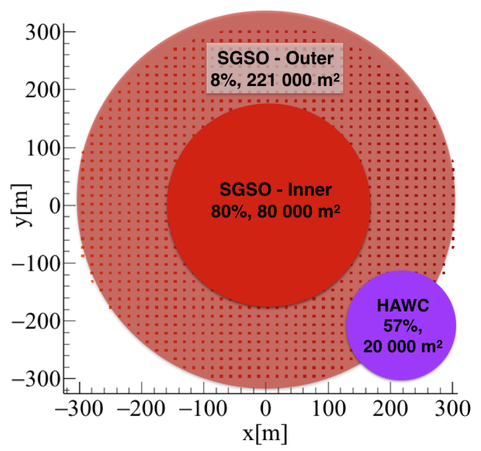


More projects in the world besides LATTES

HAWC

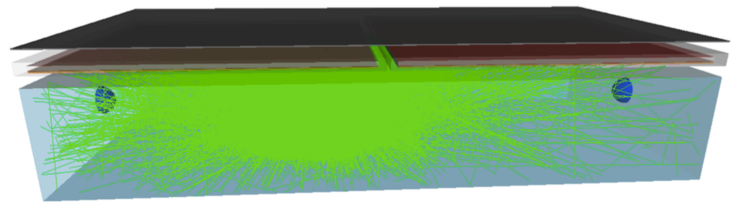


SGSO

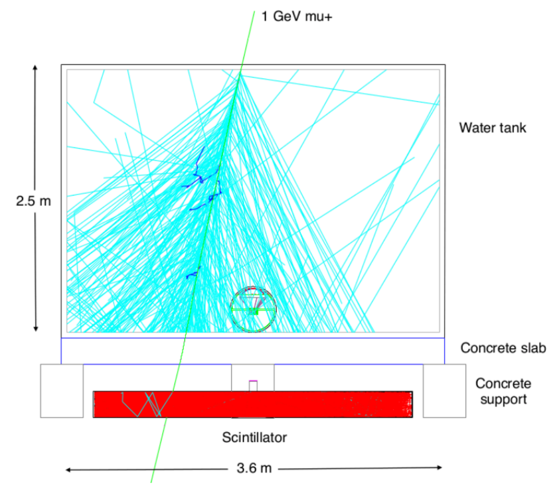


STACEX

LATTES

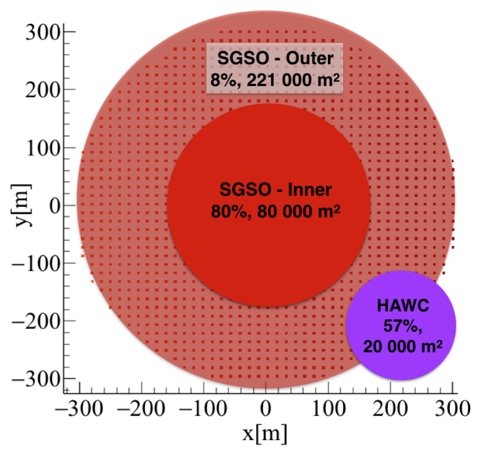


ALTO

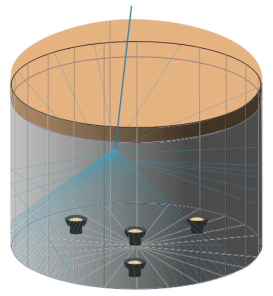


Towards convergence

SGSO



HAWC



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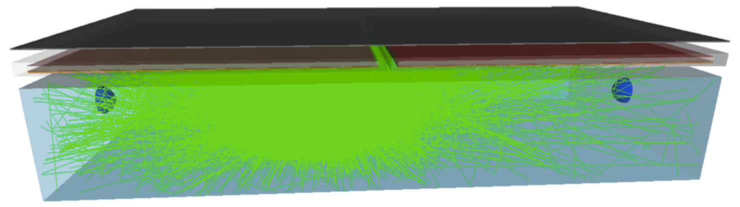

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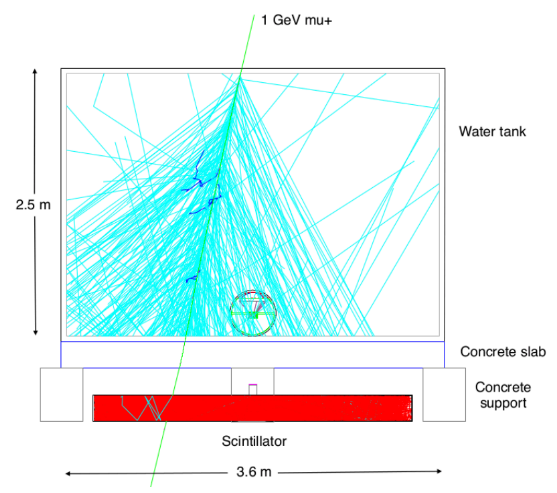


Wide field-of-view gamma-ray observatory in the Southern hemisphere

20-22 May 2019
LIP
Europe/Lisbon timezone

- Overview
- Timetable
- Contribution List
- Registration
- Participant List
- Venue & Travel Information
- Workshop Dinner
- Accommodation

Contact
- ruben@lip.pt
- bernardo@lip.pt

This meeting aims to be a further step towards the construction of one wide Field-of-View Gamma Ray Observatory in the Southern Hemisphere able to cover the energy range of 100 GeV to 100 TeV.

It follows the meeting held in Heidelberg last October. Both the scientific case and the different proposed designs will be reviewed and discussed.

Starts 20 May 2019, 13:00
Ends 22 May 2019, 15:00
Europe/Lisbon

LIP
Lisbon, Portugal

Bernardo Tomé
Fabian Schussler
Harm Schoorlemmer
Michele Doro
Ruben Lopez-Coto
Rúben Conceição

There are no materials yet.

Registration
You are registered for this event.
See details

Meeting in Lisbon on May 2019

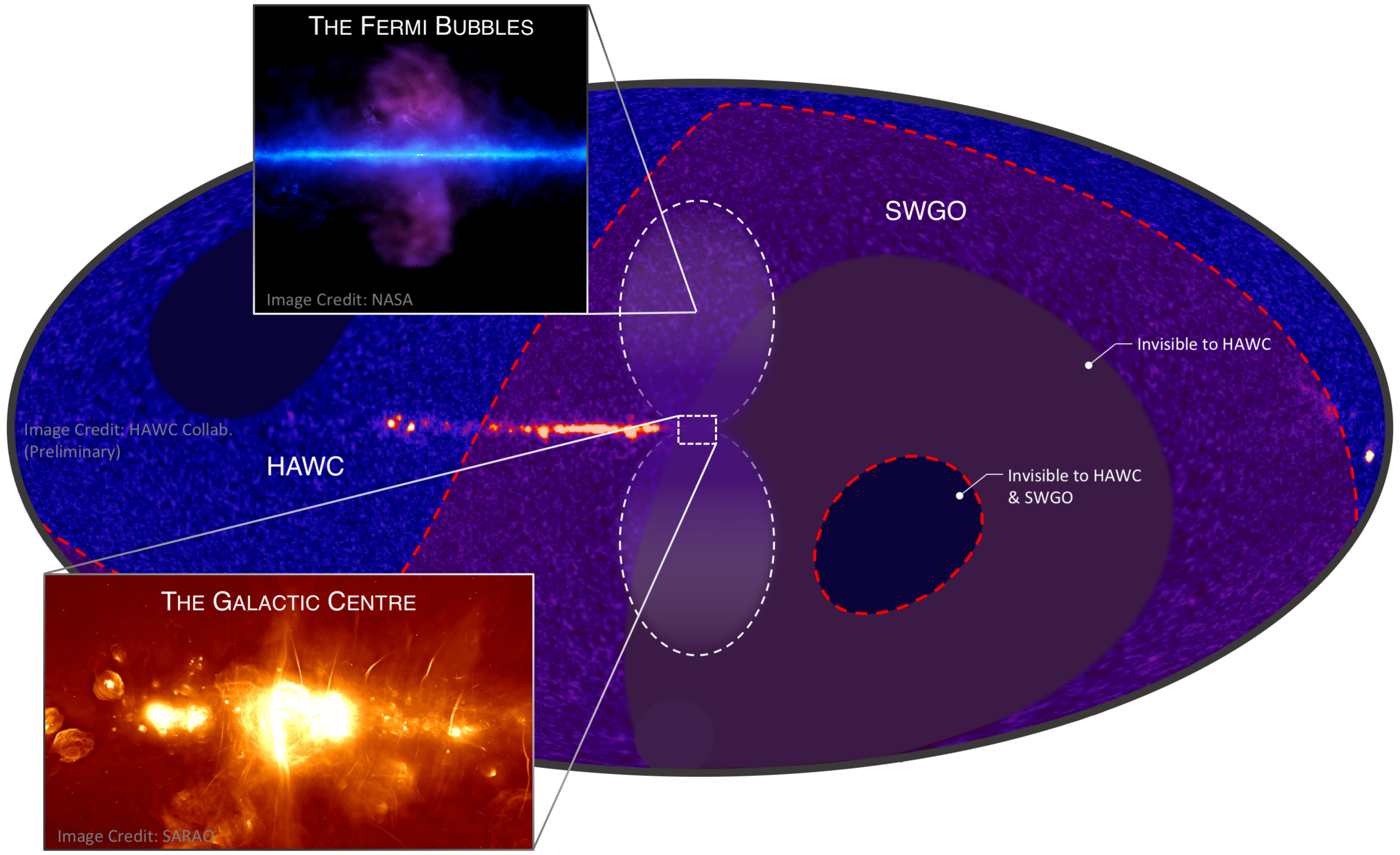
www.lip.pt/GammaRaySouthernObservatory

SWGO collaboration

3-year R&D project to design and plan the next generation wide field-of-view gamma-ray able to survey and monitor the Southern sky

- **S**outhern **W**ide-field **G**amma-ray **O**bservatory
  - Formed at *July 1st 2019*
  - 10 Countries
  - 44 institutes
  - More than 100 scientists

The scientific goal



swgo.org

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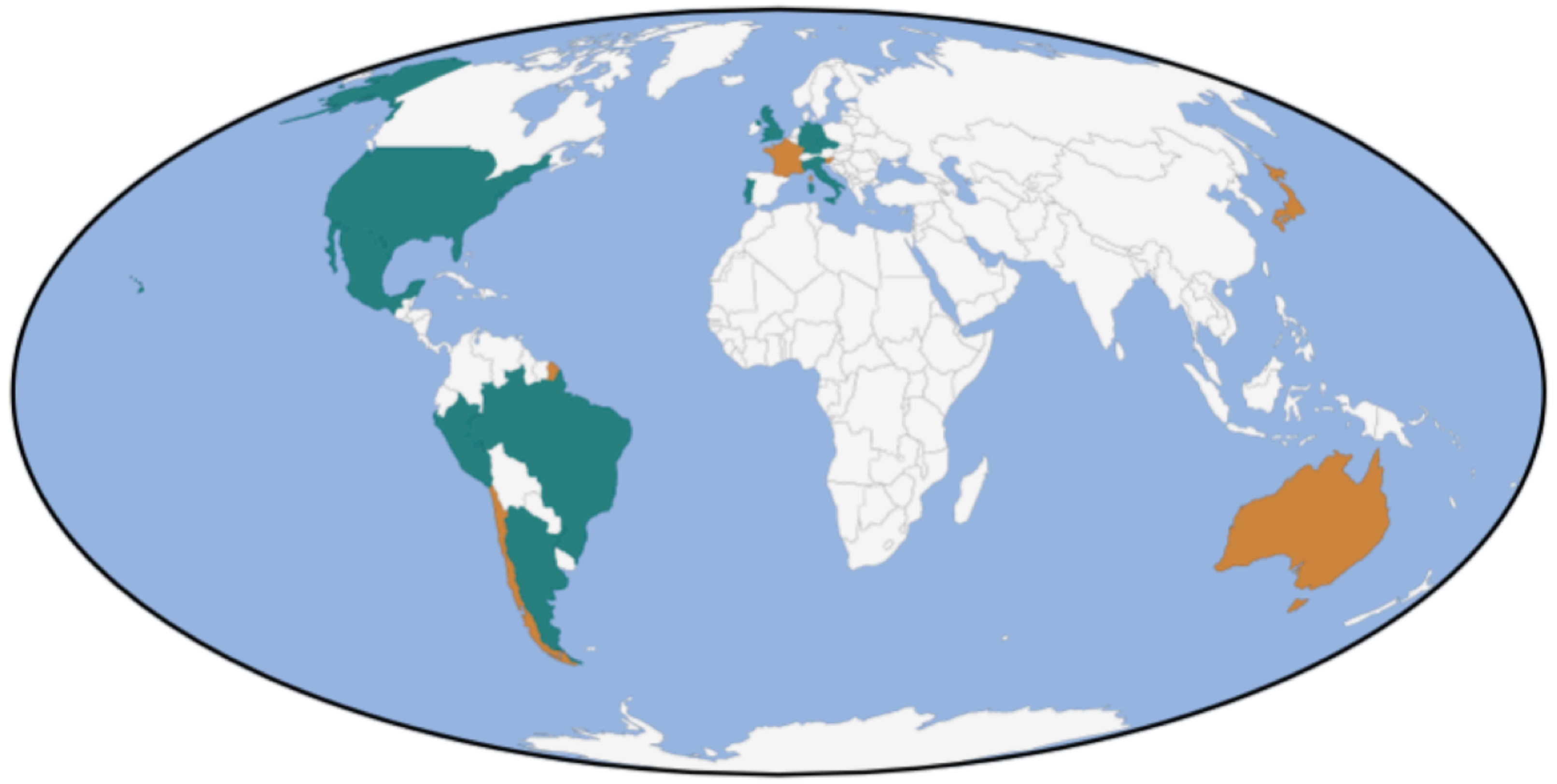
3-year R&D project to design and plan the next generation wide field-of-view gamma-ray able to survey and monitor the Southern sky



Countries in SWGO

Institutes

Argentina*, Brazil, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, United Kingdom, United States*

Supporting scientists

Australia, Chile, France, Japan, Slovenia

**also supporting scientists*

- The collaboration is organized in five major working groups:

Science

Site selection

Simulation and Analysis

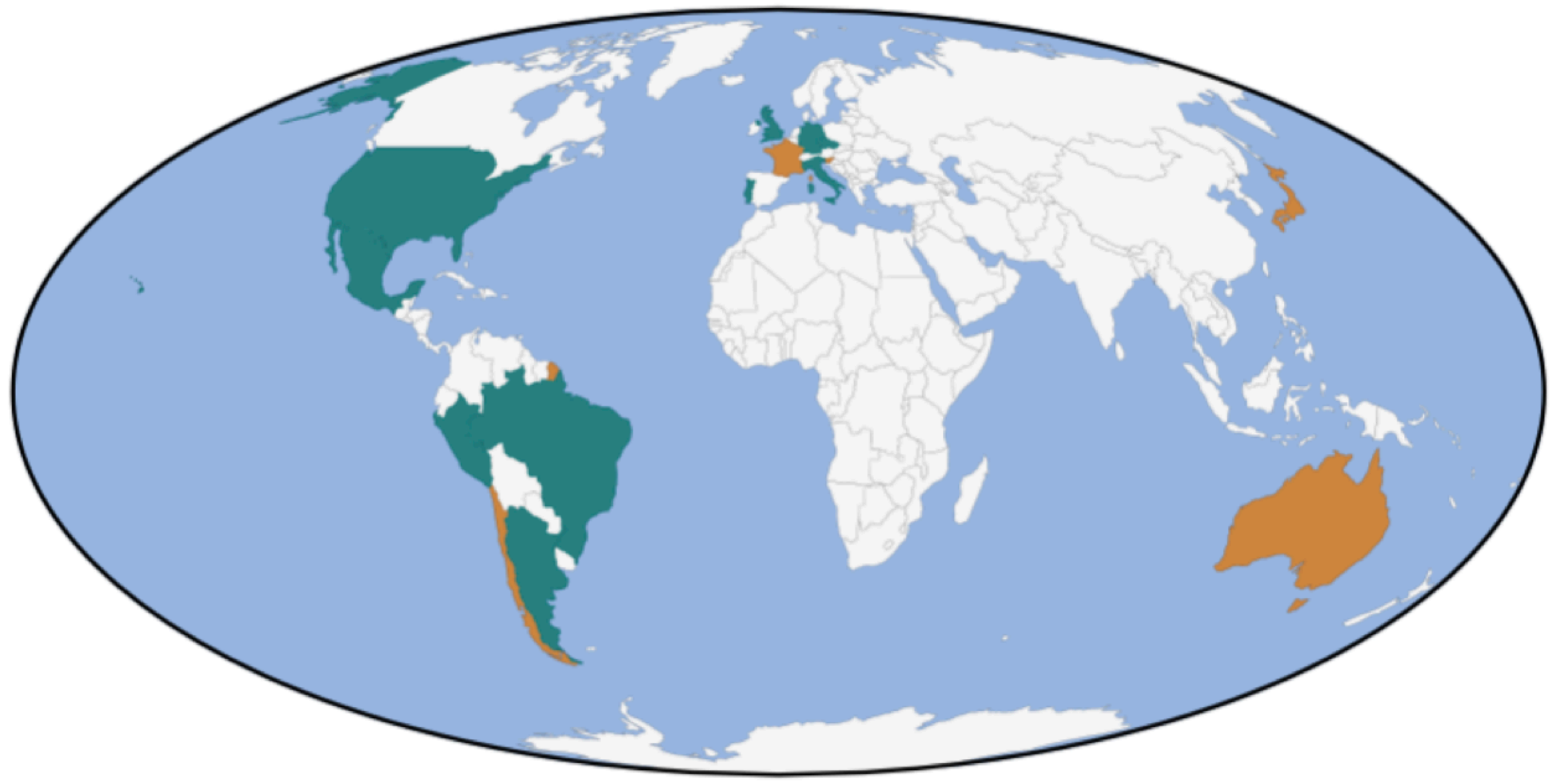
Outreach

Detector R&D

SWGO collaboration

LIP

3-year R&D project to design and plan the next generation wide field-of-view gamma-ray able to survey and monitor the Southern sky



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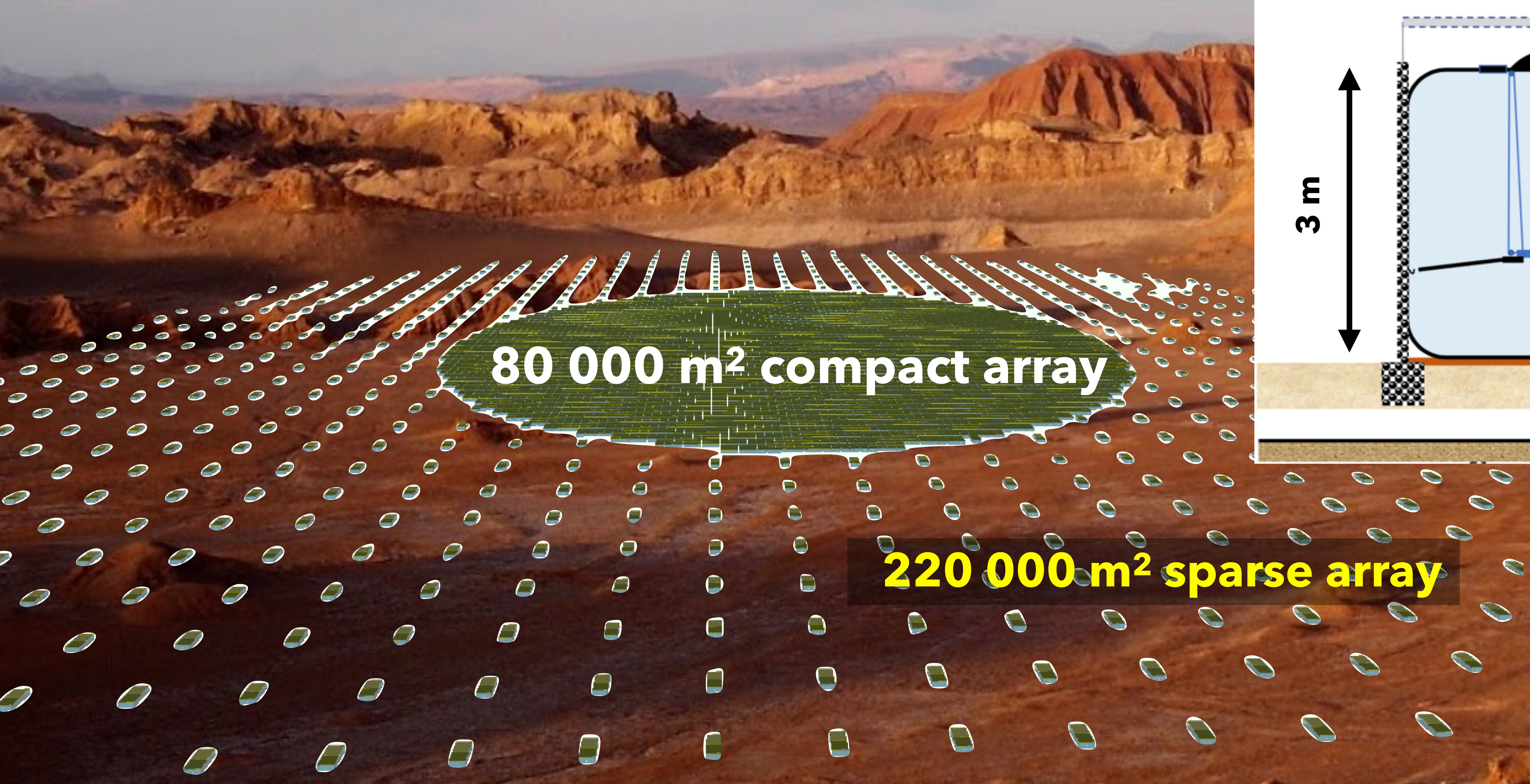
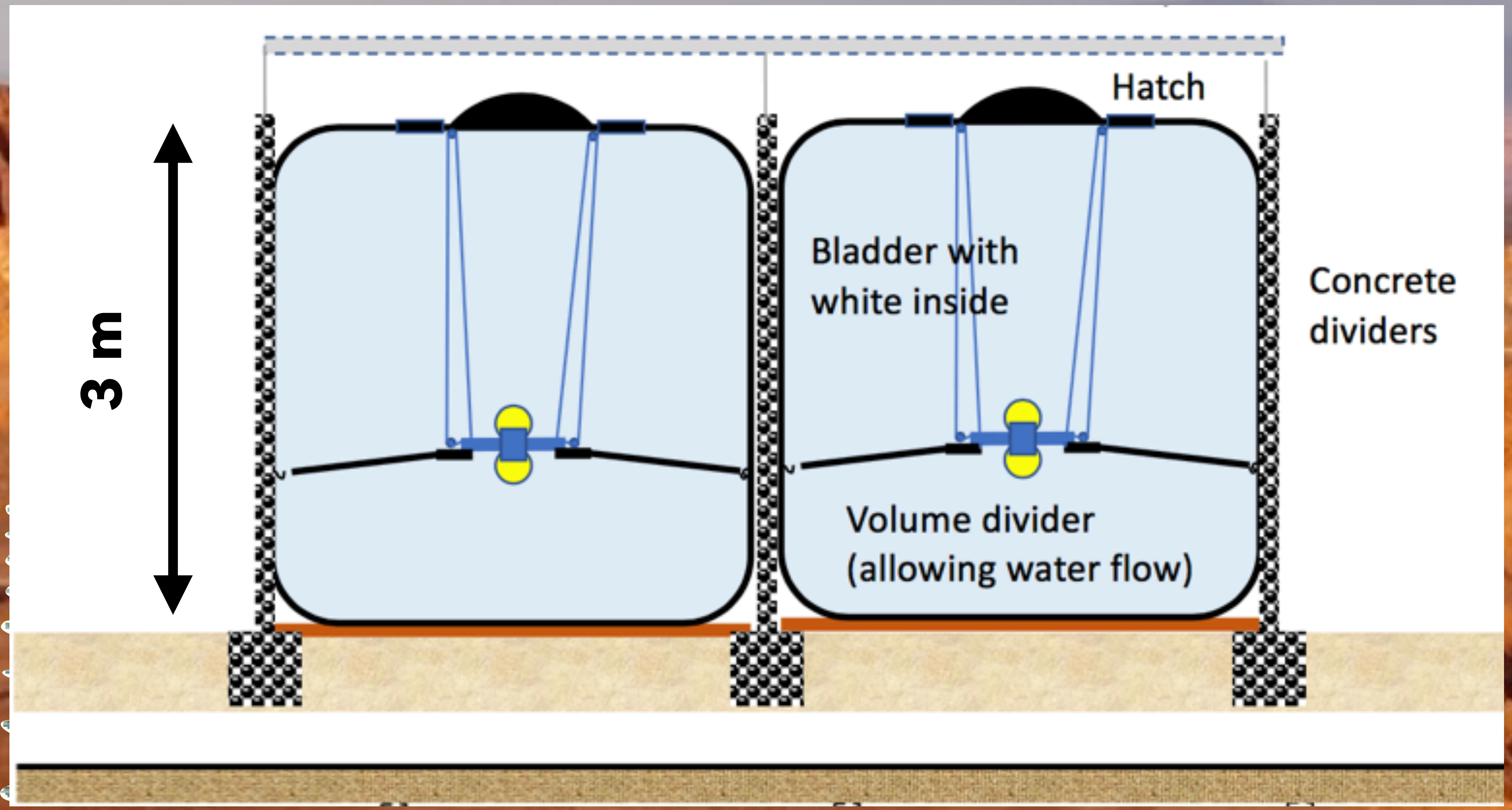
The challenge

Build a huge array at an altitude of **5000 m** based on the **Water Cherenkov detection** technology

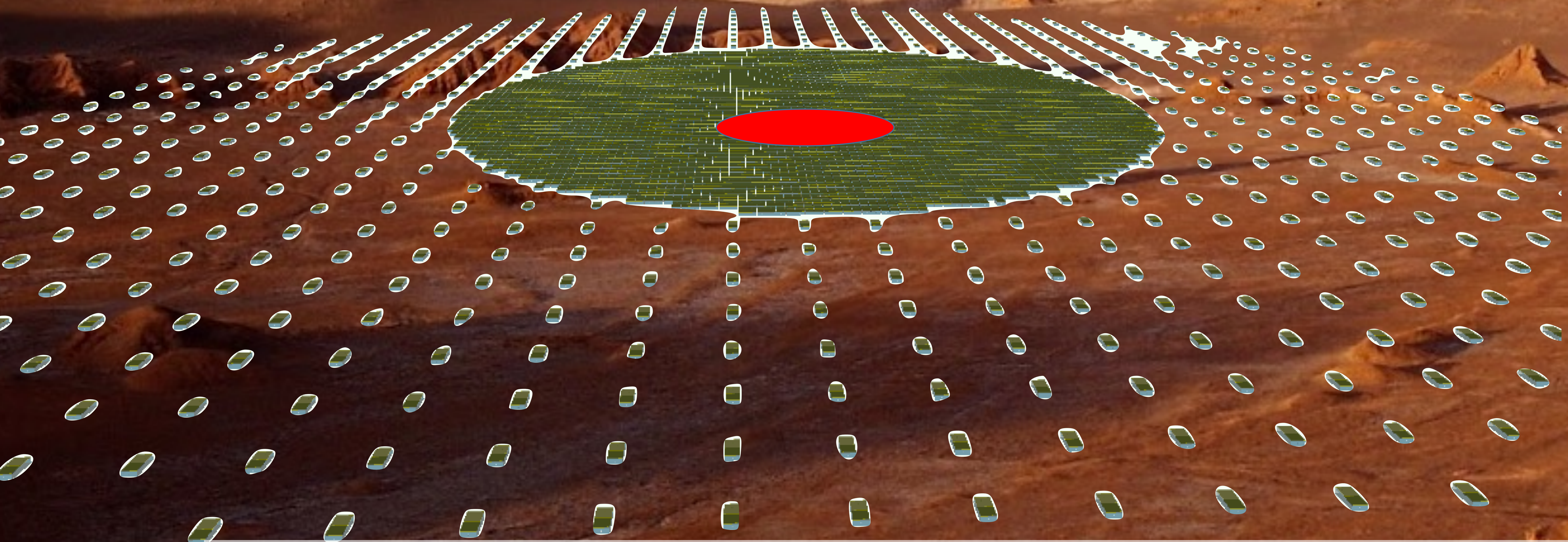
The station unit

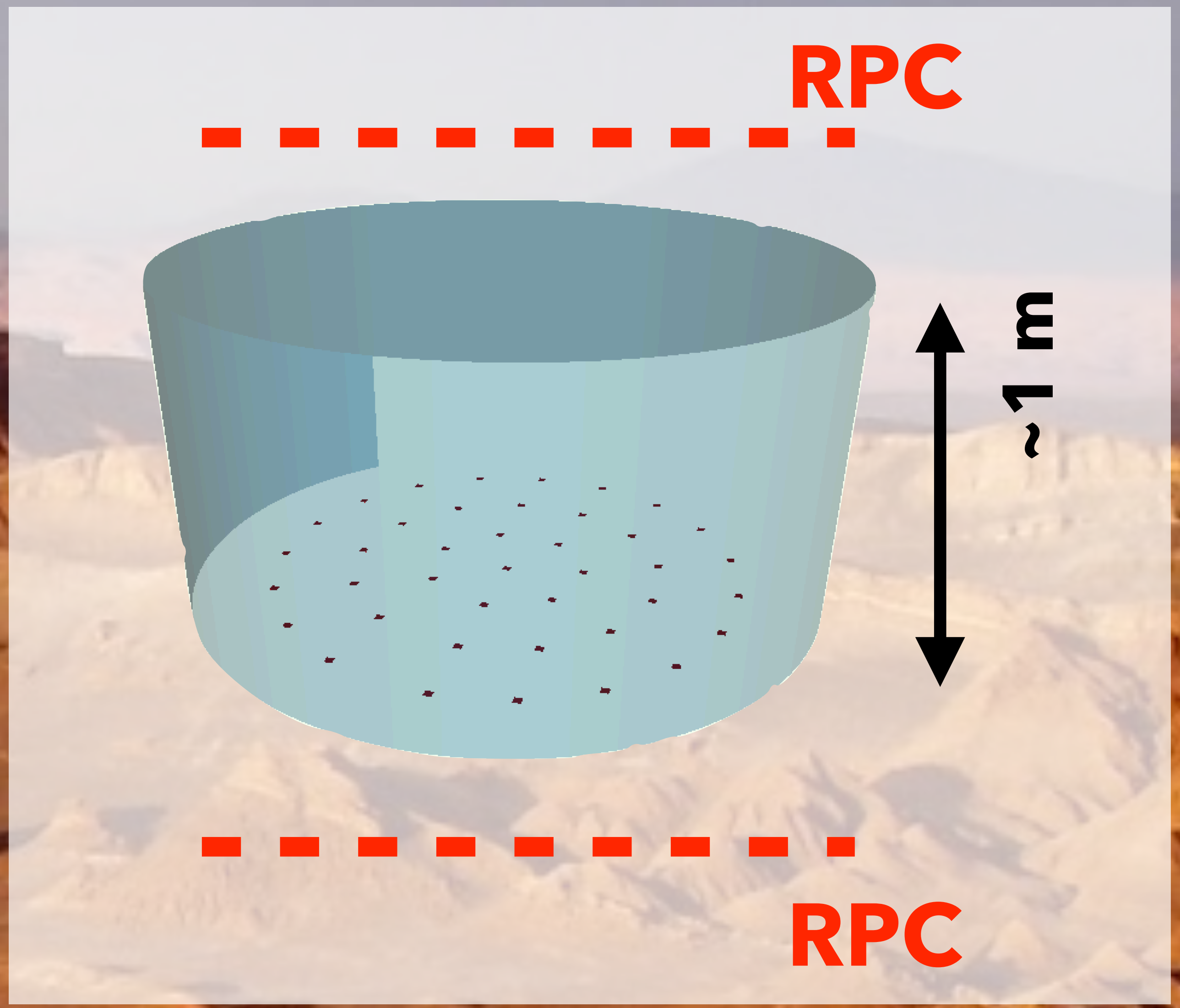




Build a huge array at an altitude of **5000 m** based on the **Water Cherenkov detection** technology

LIP's view





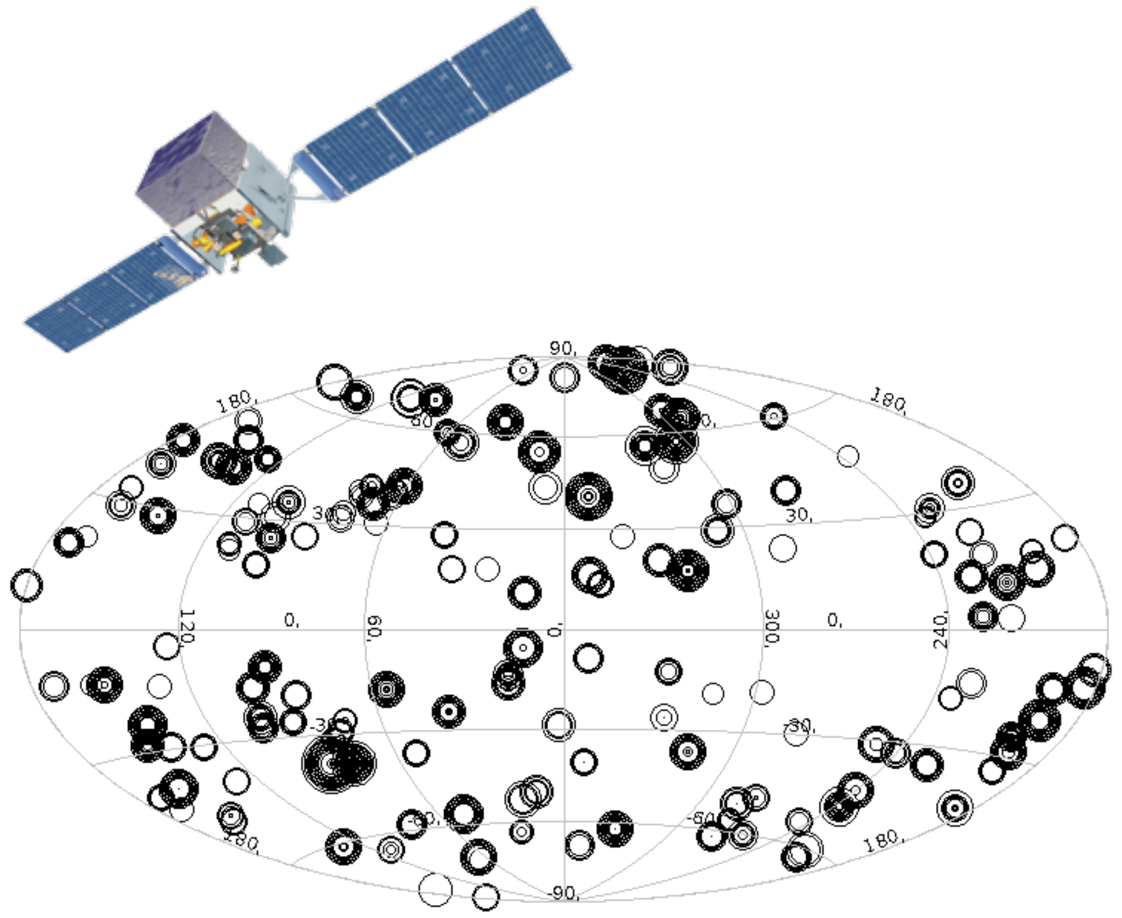
Explore a detector concept with a **smaller height** combined with a **matrix of photo-detectors** at the bottom

Install **RPCs** in a small portion of the array to create **hodoscopes**

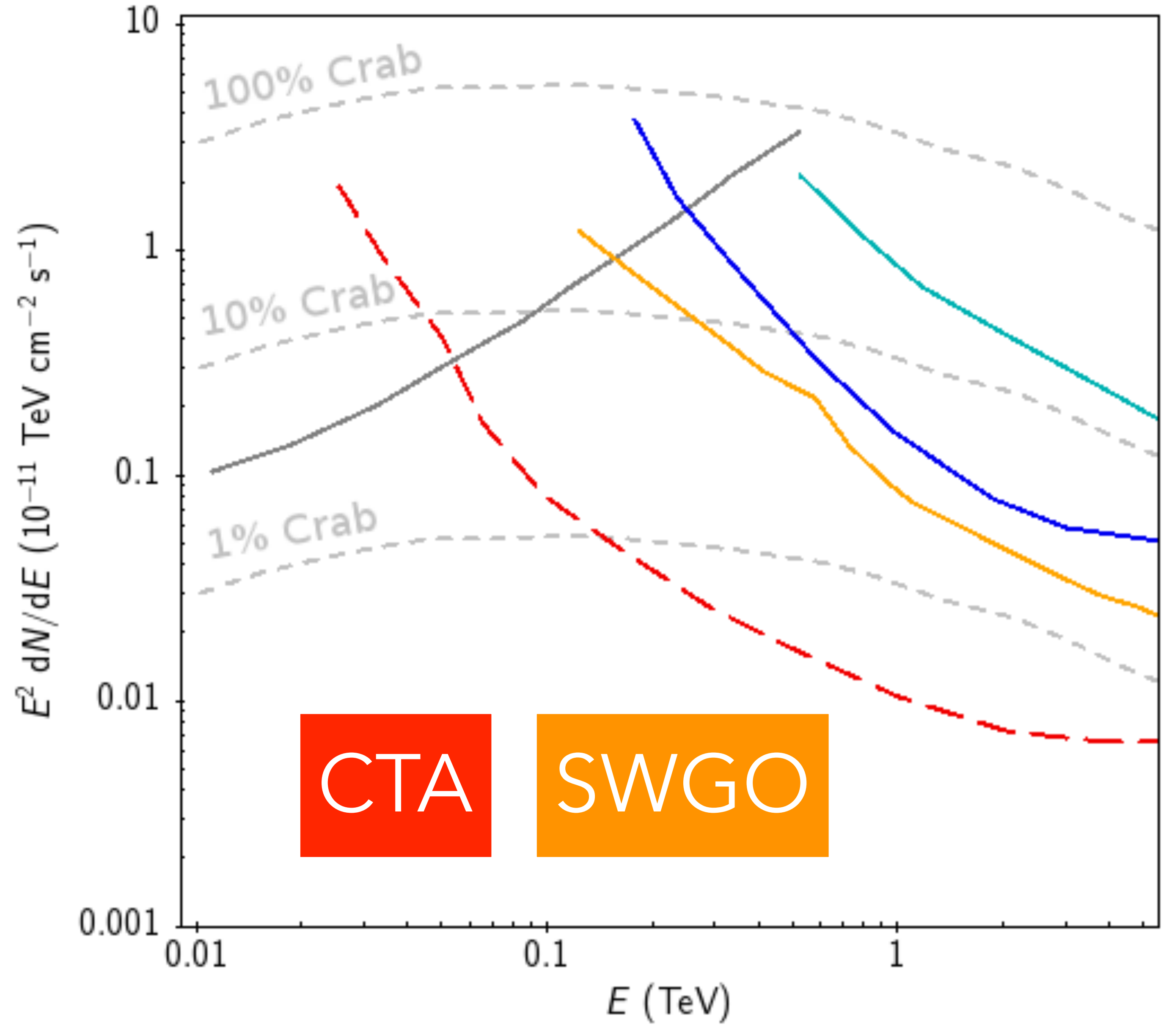
Highlights of activities at LIP

Science

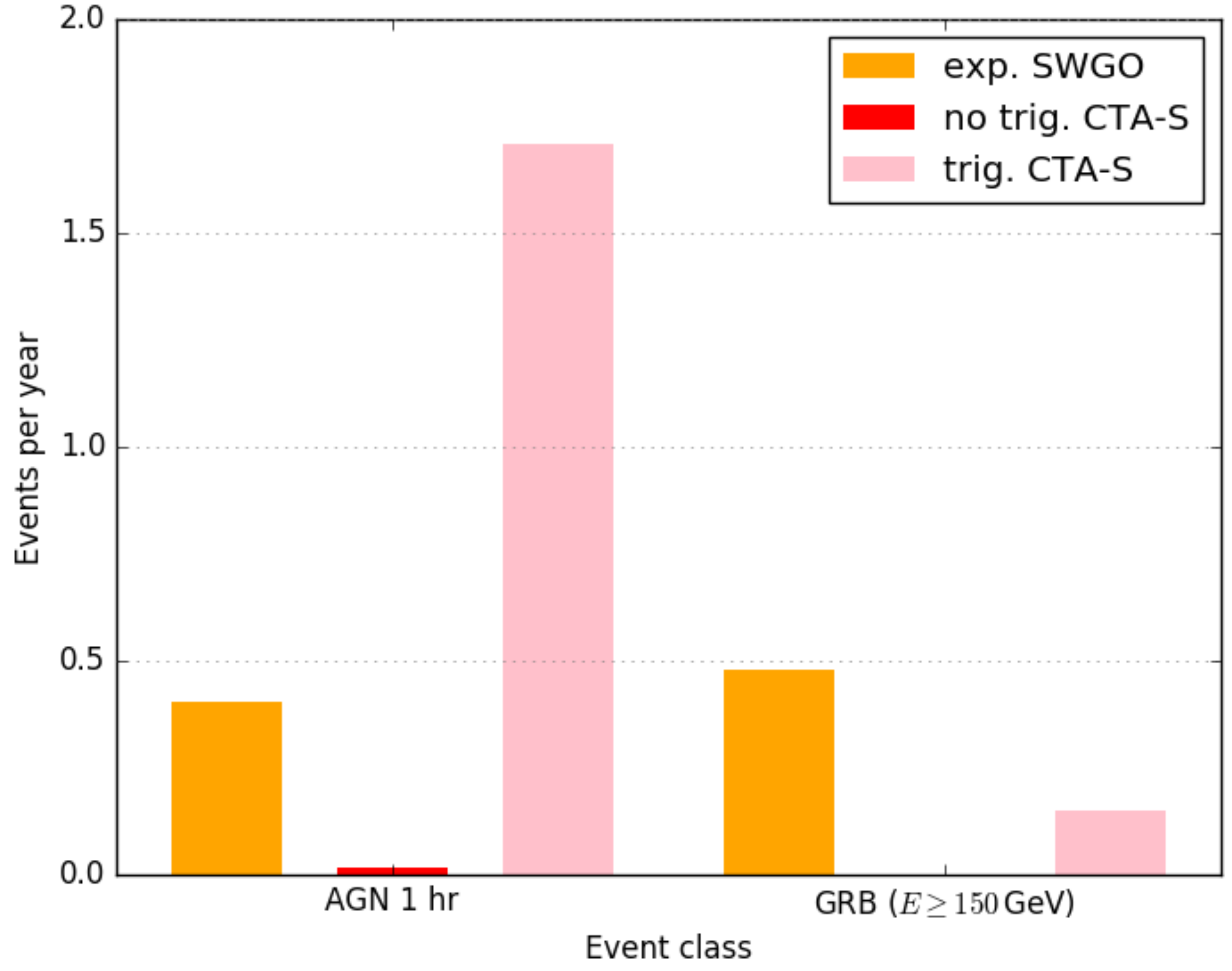
- Investigate capability of SWGO to detect **transient phenomena at sub-TeV** energies



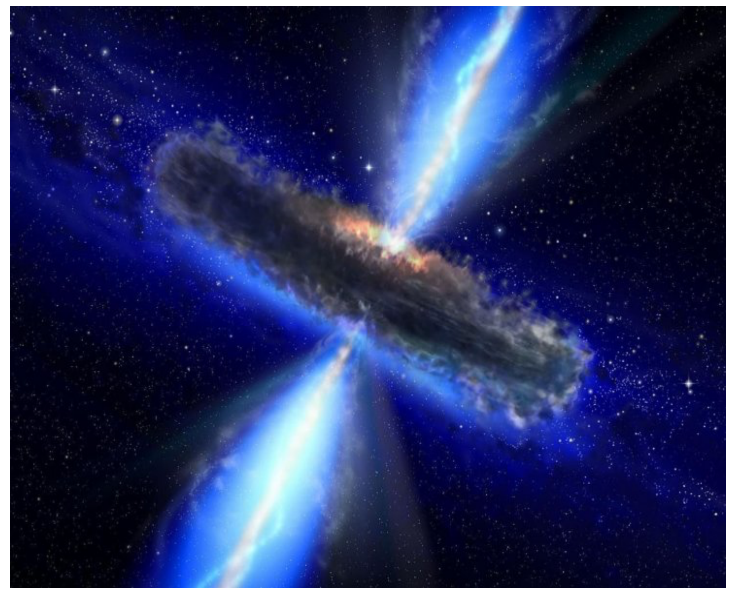
Flares distribution observed by Fermi



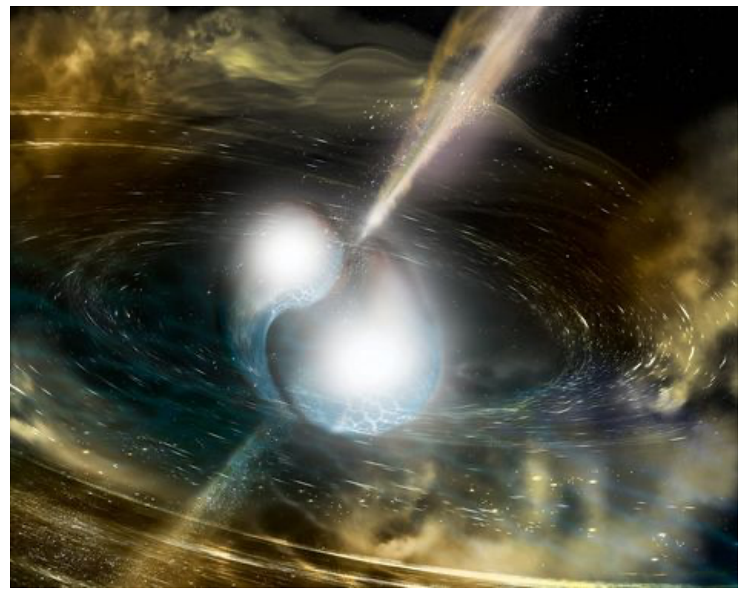
Submitted to MNRAS, arXiv:2001.04503



AGN flare



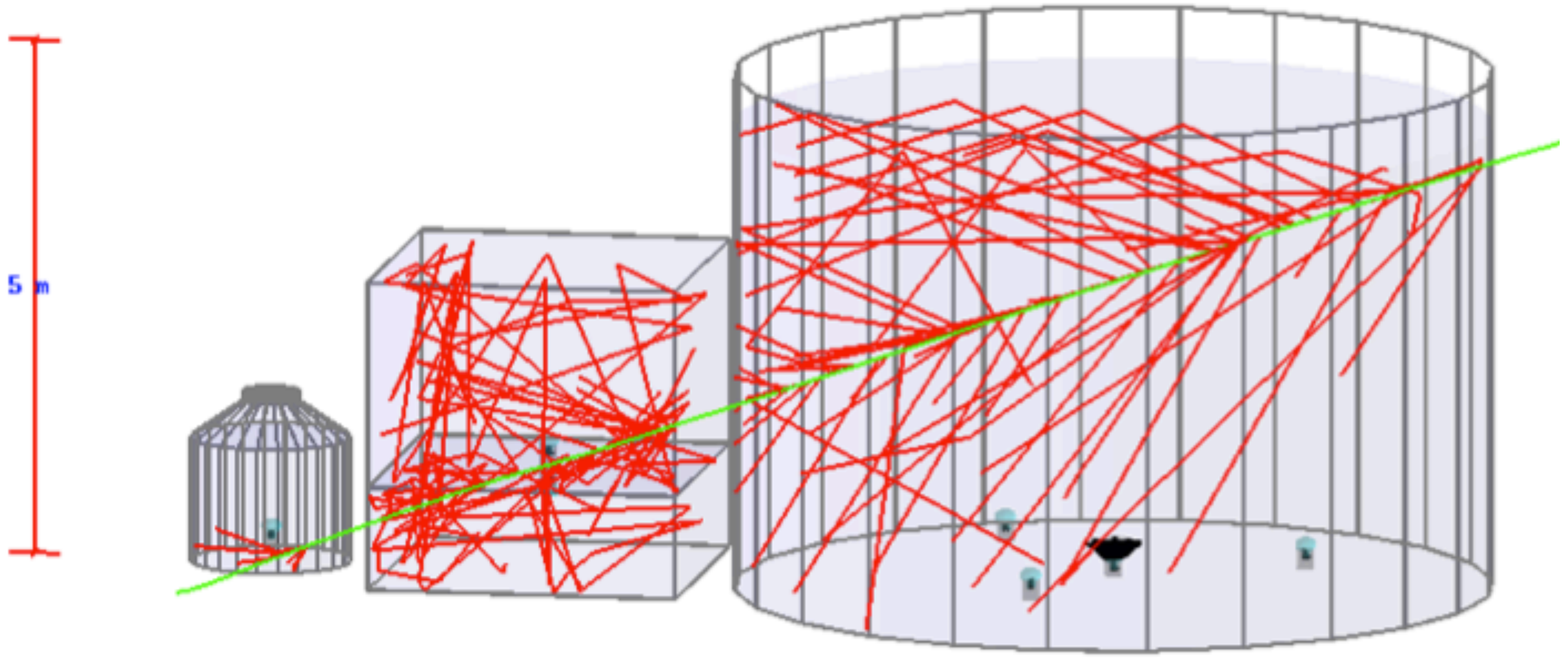
Neutron Stars Merger



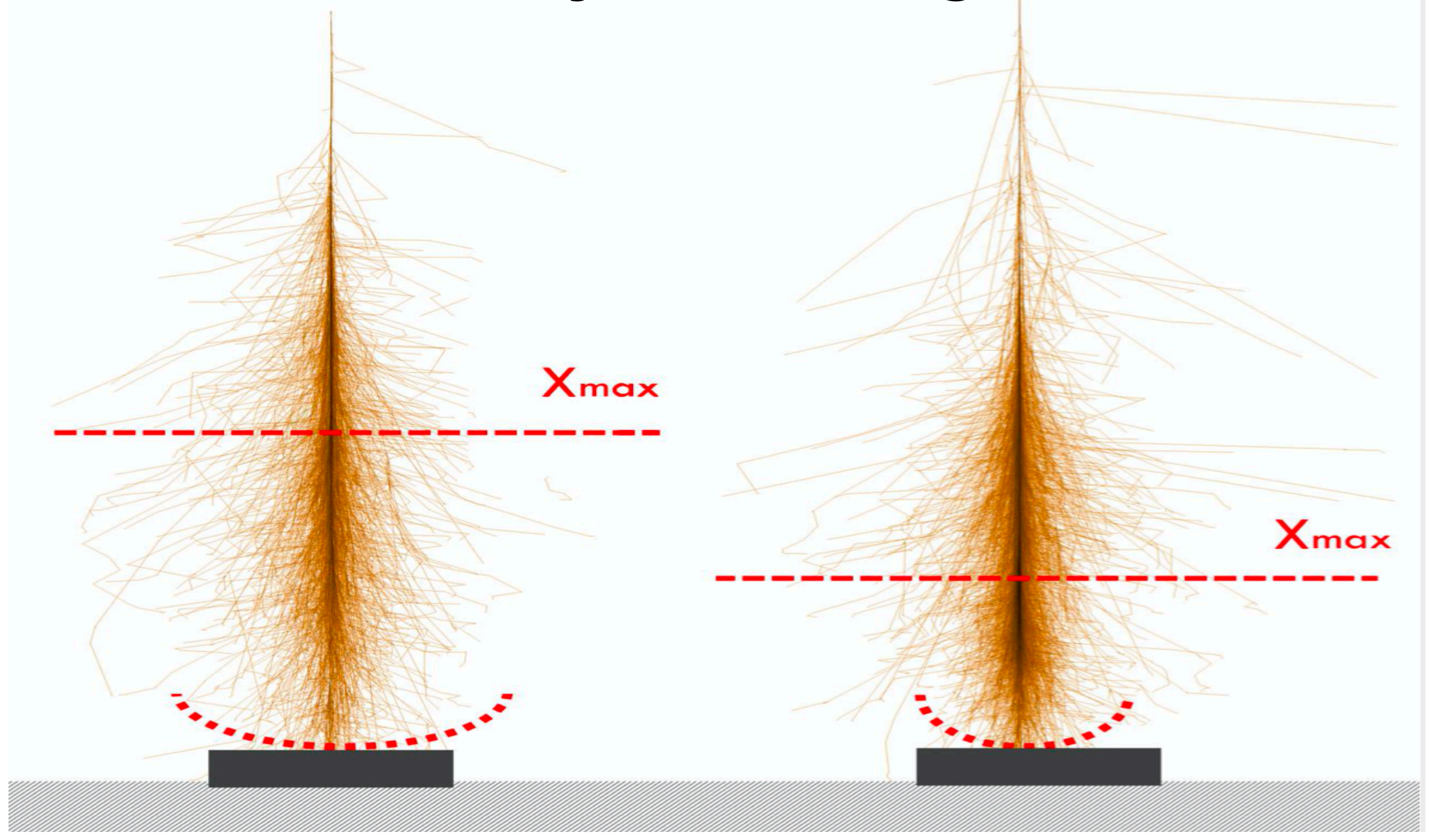
Highlights of activities at LIP

Simulation and Analysis

- Develop a common simulation framework
  - Coordinated by LIP member
- Design and concept WCD station with a matrix of photo-detector
  - Use of SiPM
- Novel analysis strategies to improve:
  - Primary energy reconstruction
  - Gamma/hadron discrimination

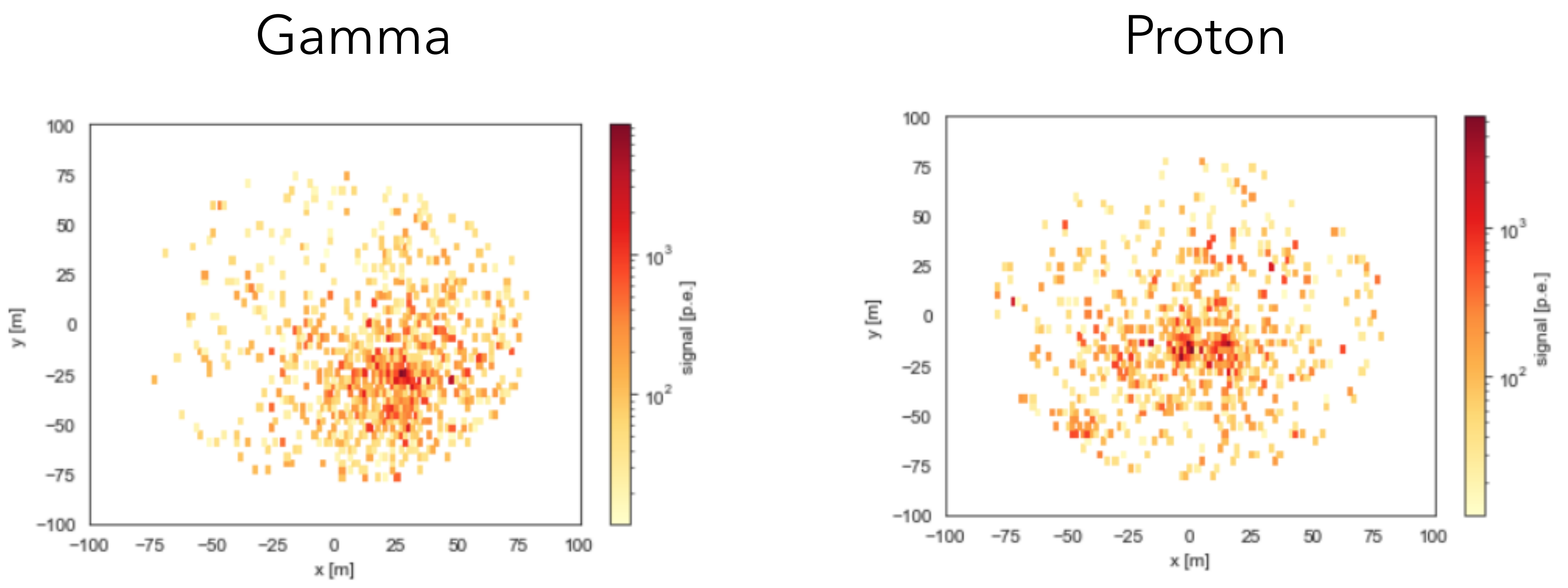


Combine shower curvature and signal to identify shower age

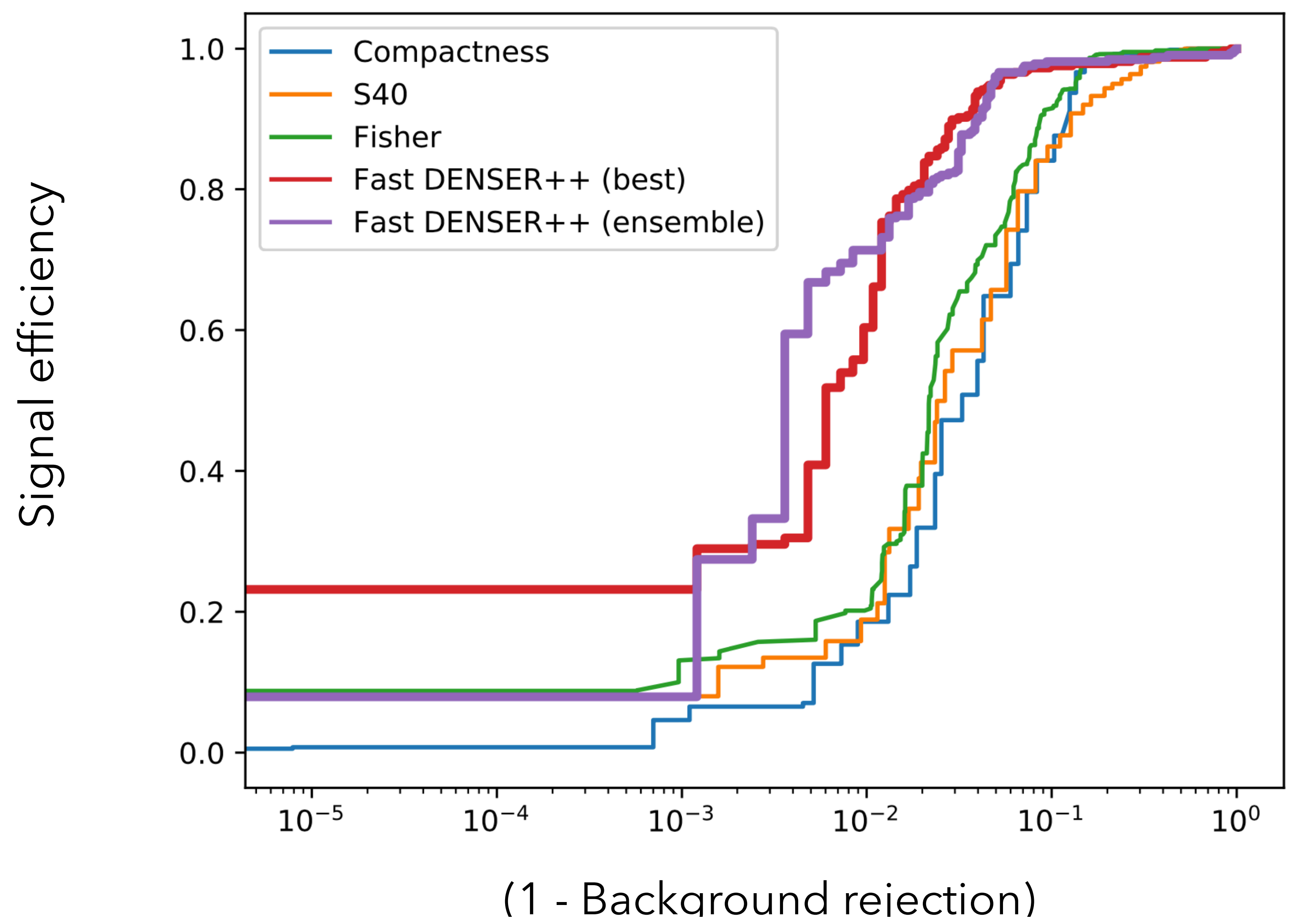


Enhanced gamma/hadron discrimination at SWGO

- Use Machine Learning algorithms
  - Analysis of **shower patterns at the ground**
    - Joint work with the computer science group at DEI Coimbra
  - Identify the presence of muons at WCD
    - Joint work with the Granada university (physics and computing departments)



Improvement of a factor of 2 in the sensitivity at 1 TeV



IEEE Access, vol. 7, pp. 110531-110540, 2019

Enhanced gamma/hadron discrimination at SWGO

Universidad de Granada

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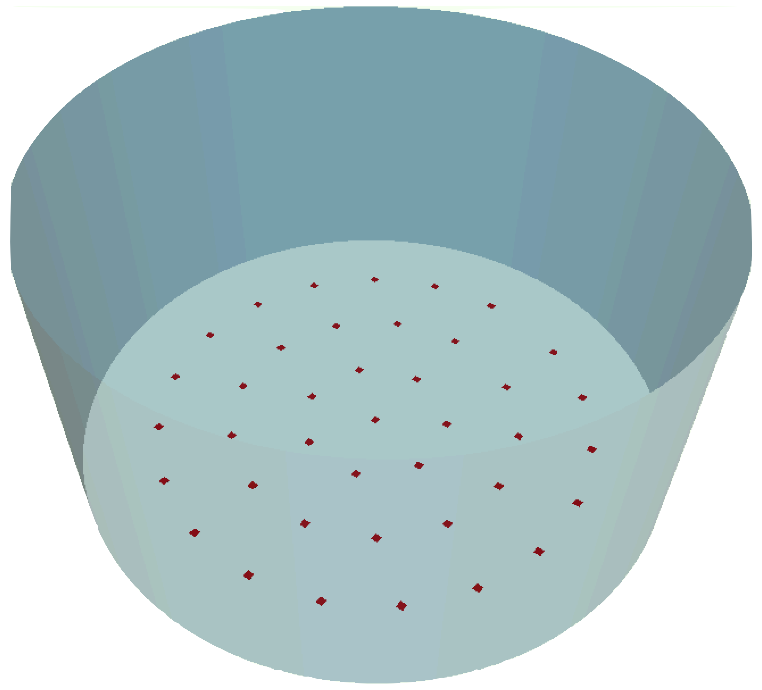
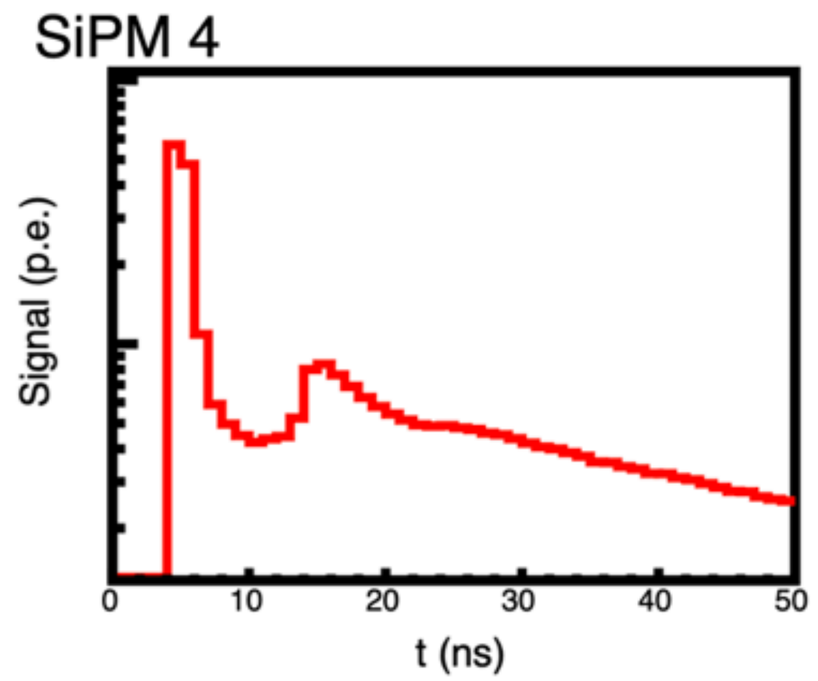
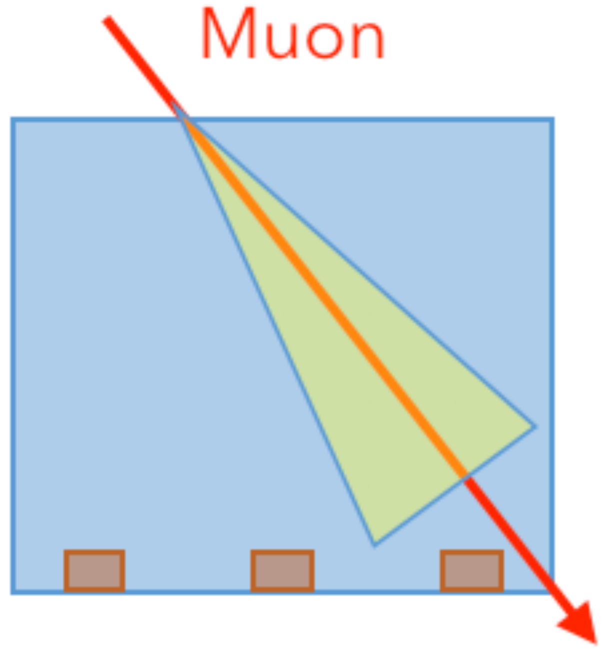
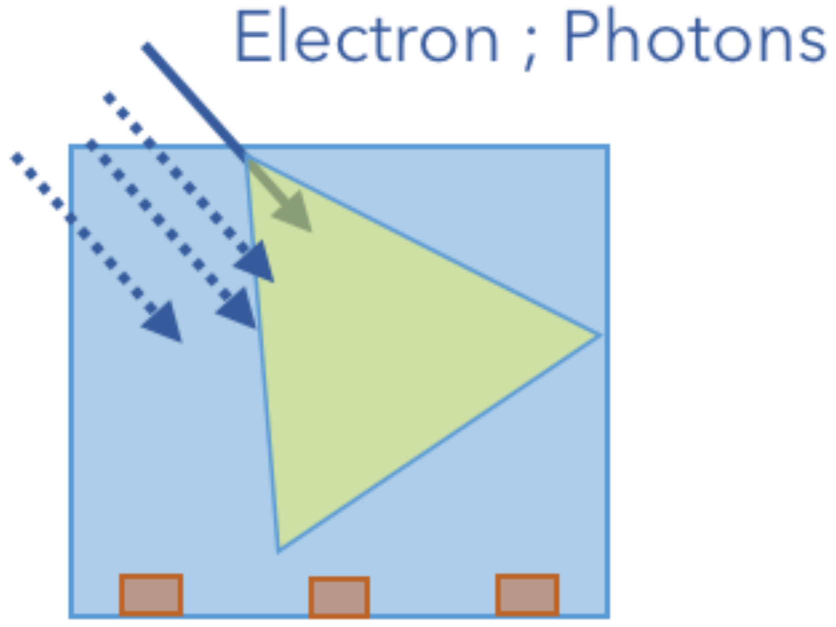


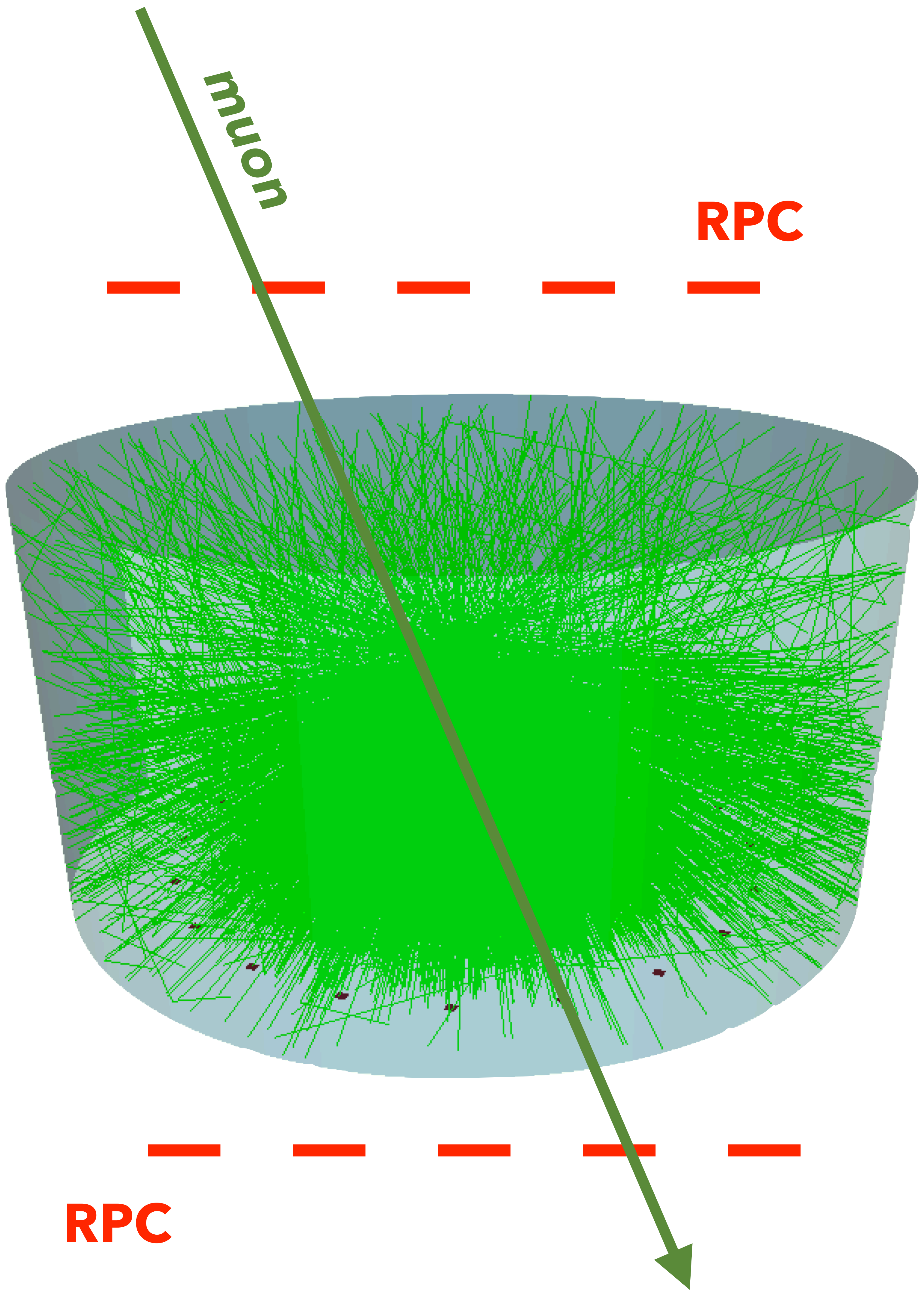






Machine Learning algorithms at SWGO

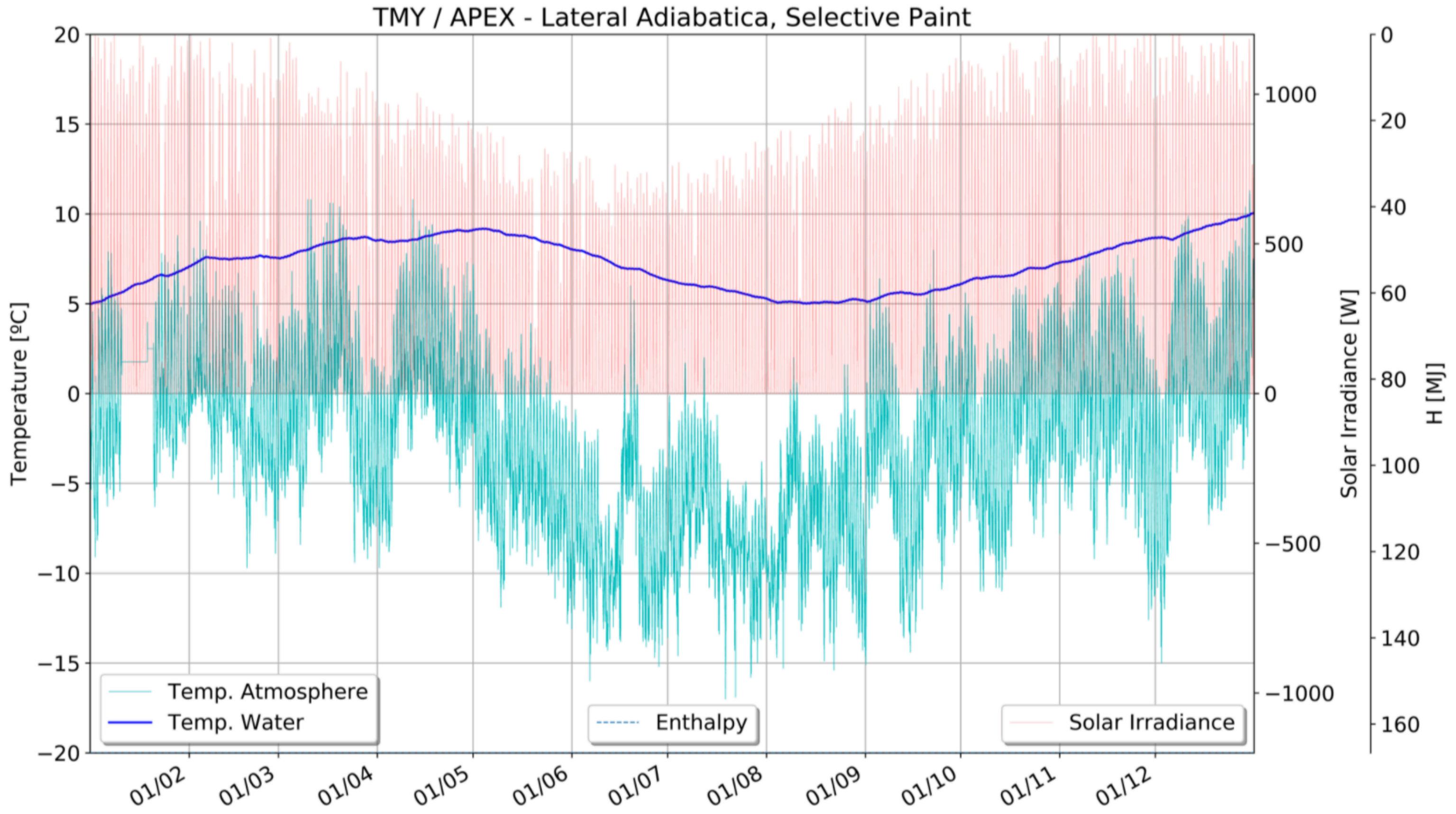
- ✧ All analyses are based in simulations
- ✧ It is crucial to **perform calibration with real data**
- ✧ **RPC hodoscopes** would be able to provide such data



Highlights of activities at LIP

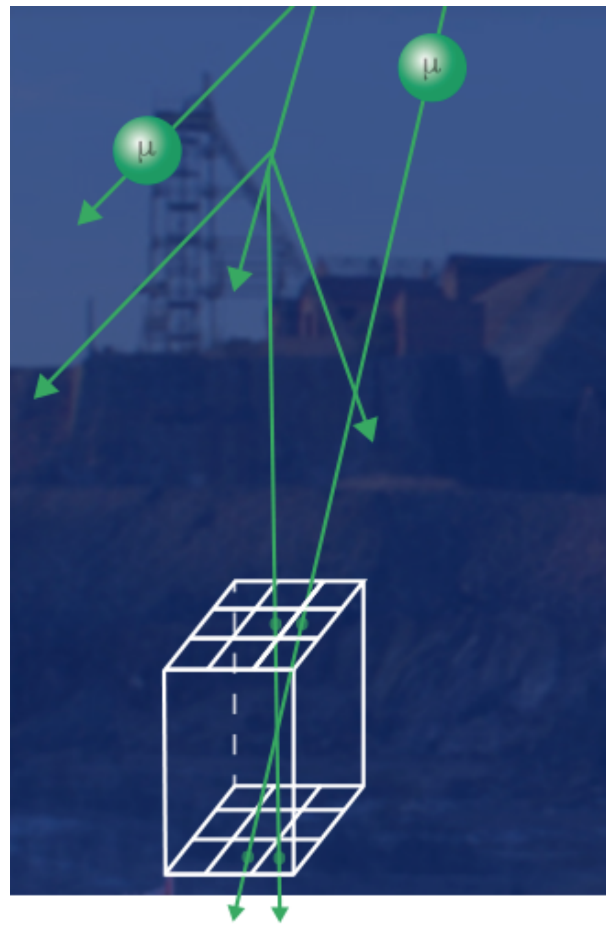
Detector R&D

- Prototype **RPCs** able to perform at high-altitude (**low pressure**)
  - Hypobaric chamber built to perform LAB studies
- Develop **thermal simulations** to investigate behaviour of **WCD** and propose insulation strategies



Outreach

- Installation of a muon hodoscope at the Lousal Mine
- Outreach talks at Lousal Ciência Viva



Summary

- **SWGO R&D phase ends in November 2022**
  - Physics case
  - Detector design
  - Site

- LIP plays a major role in:
  - **Explore sub-TeV energy region**
    - Science and detector design
  - **Explore new analysis methods**
    - ML and complementary detector core

Acknowledgements

FCT Fundação para a Ciência e a Tecnologia

Lisb@20^20

COMPETE 2020
PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO

PORTUGAL 2020

UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

LIP

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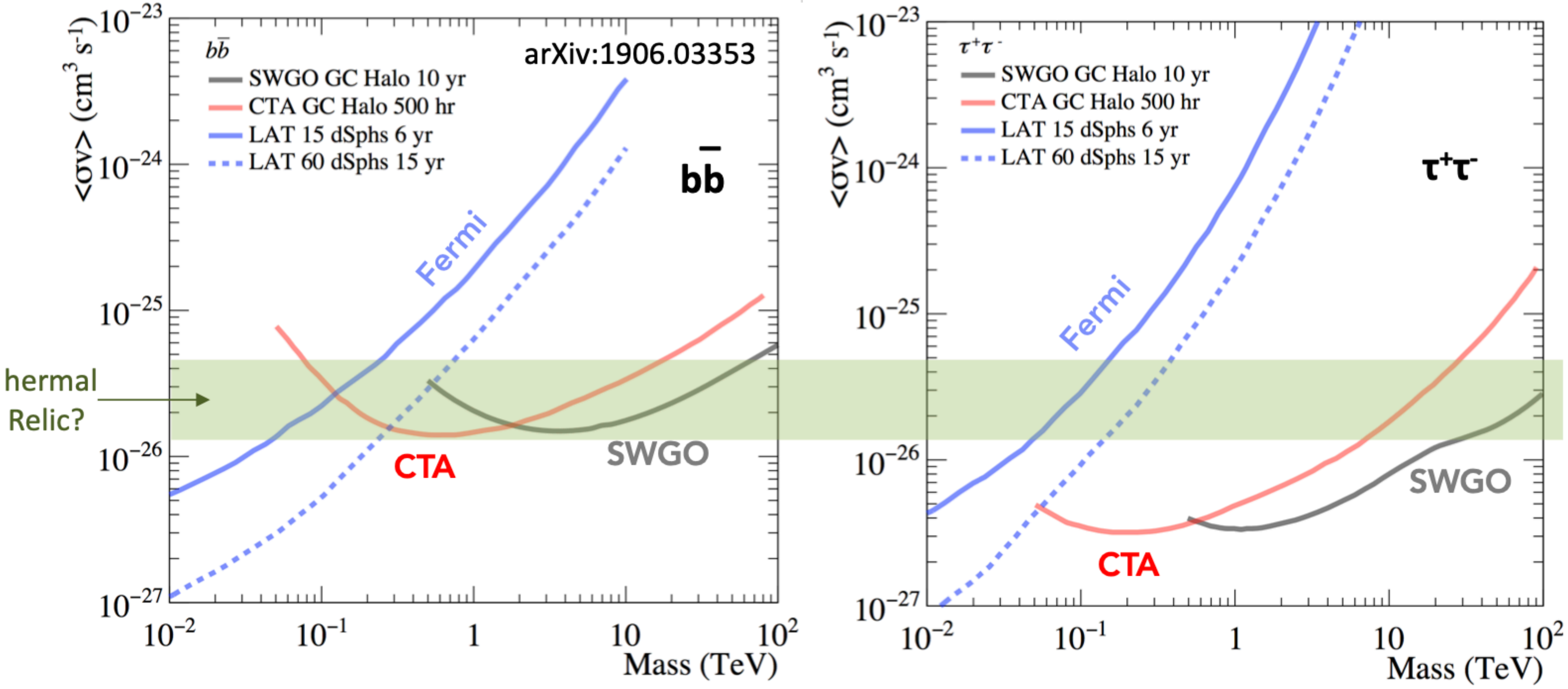
Backup slides

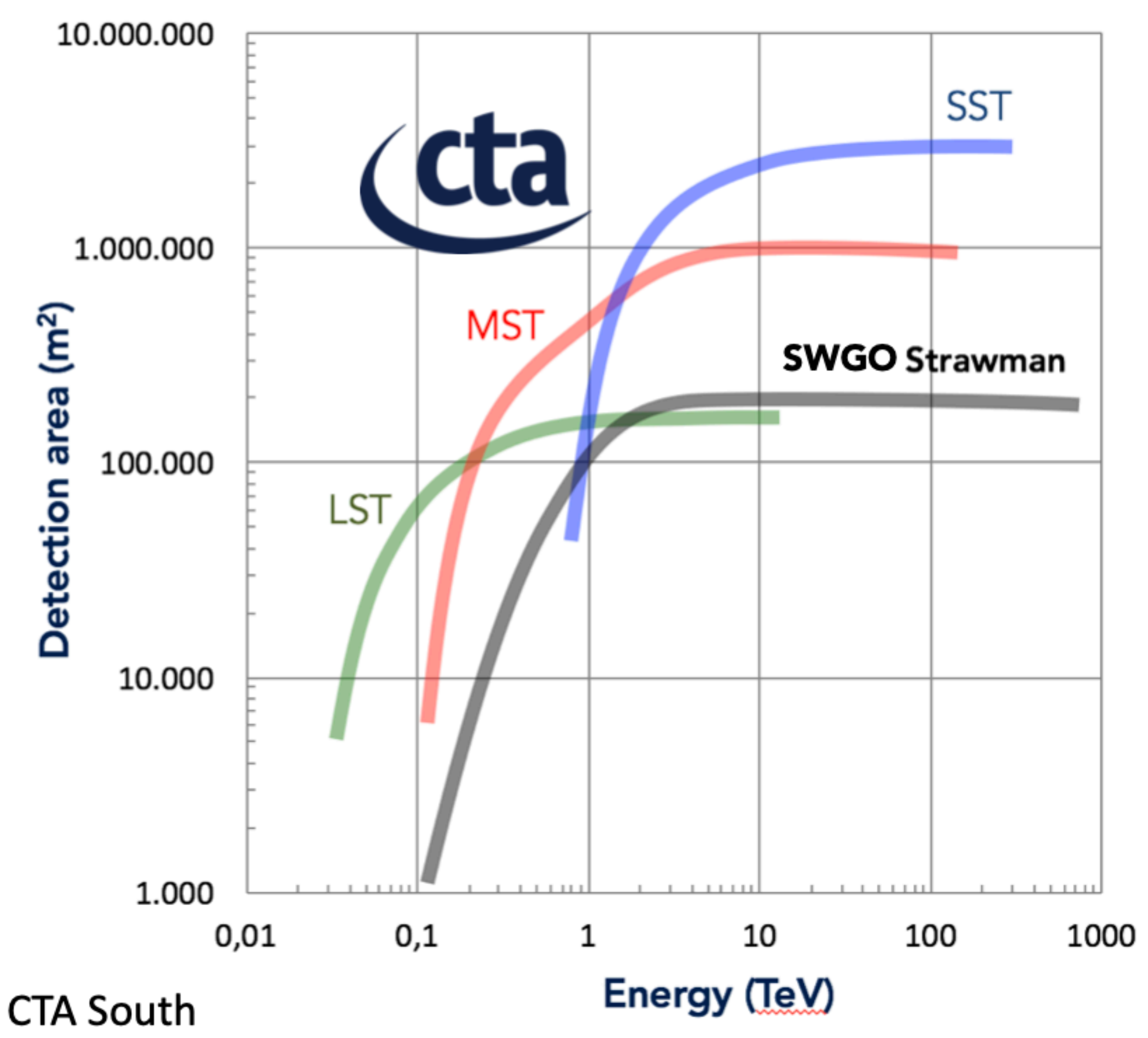
Possible sites

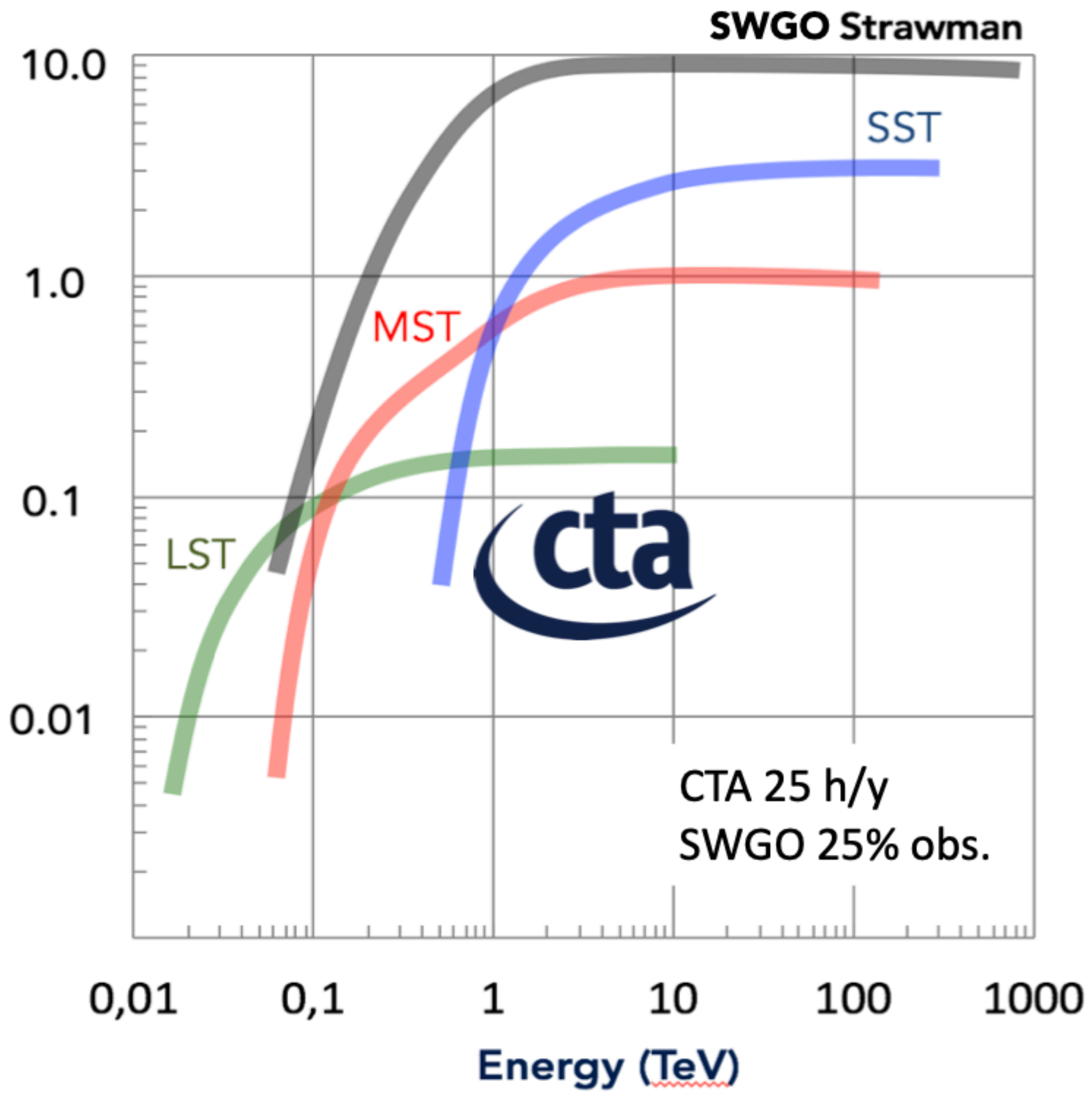
WIMP annihilation

- New generation of instruments reaches the critical sensitivity
- Thermal relic WIMP accessible over a very wide mass range (Galactic Centre/Halo observations @ VHE)



CTA and SWGO: complementary

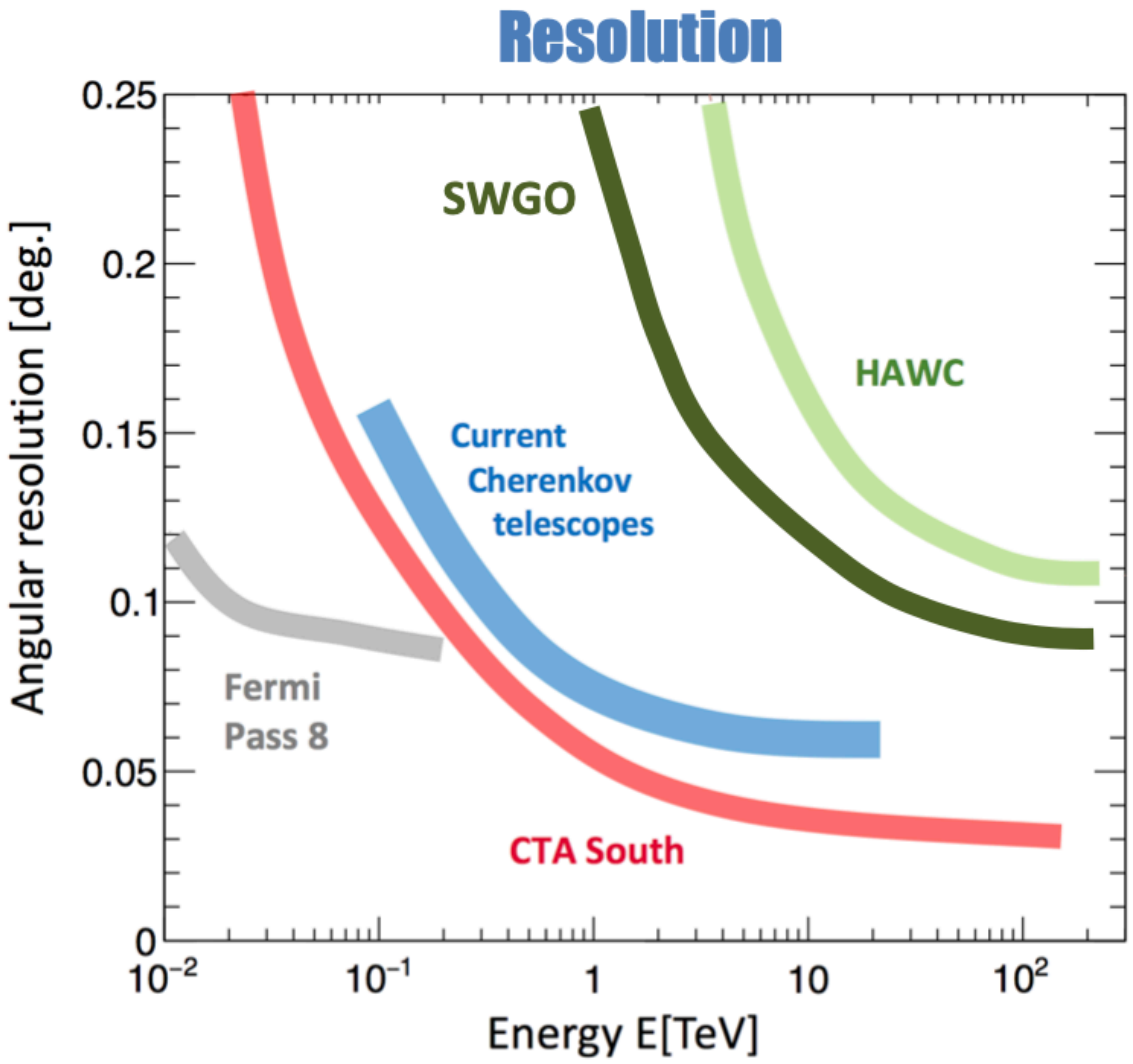


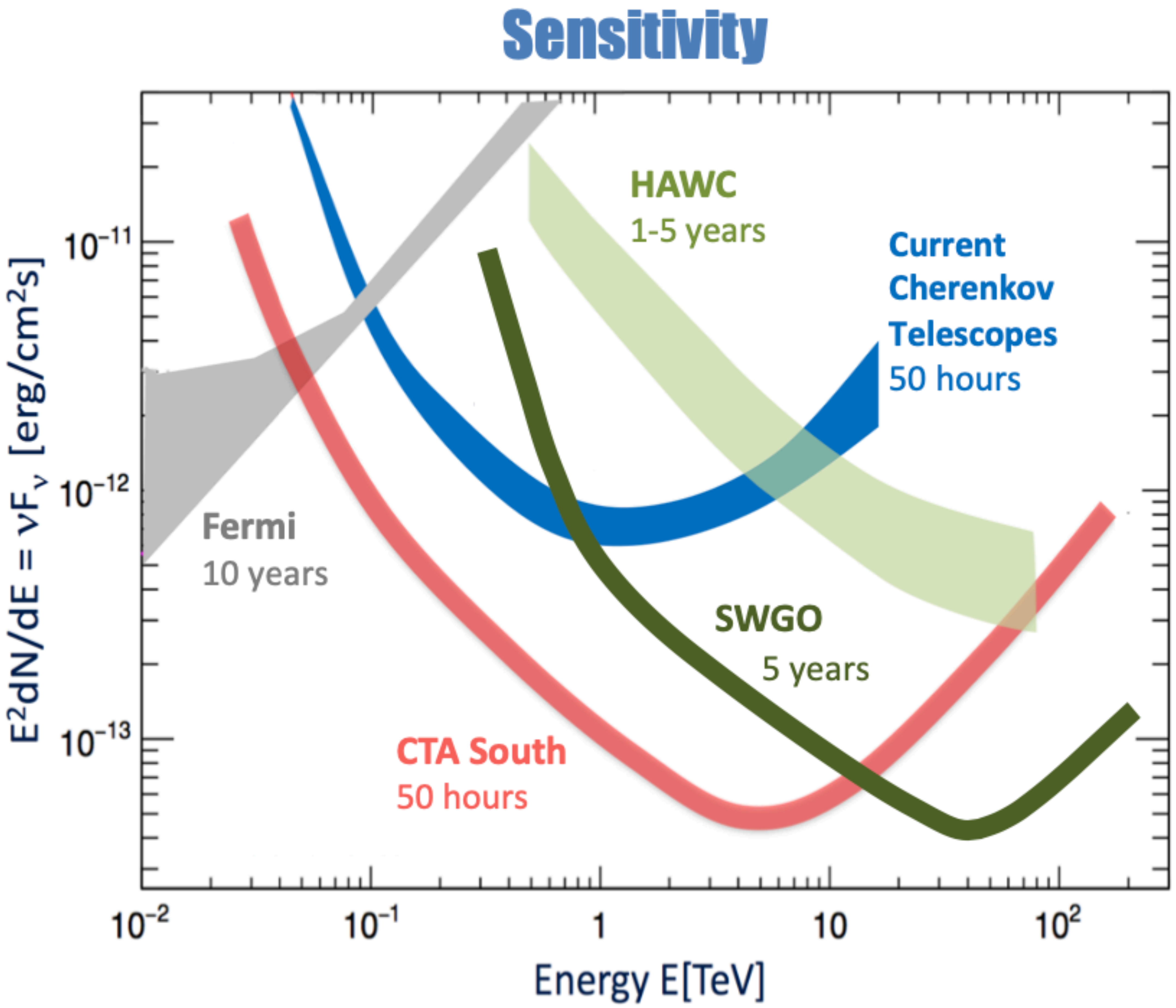


Detection Area **Annual Exposure**

- Short timescales: If CTA can get there → more sensitivity
- Steady sources: If background can be suppressed → more sensitivity than CTA over several years

Reaching the highest energies





Ruben Conceição

Gamma or Hadron?

Using the same data set

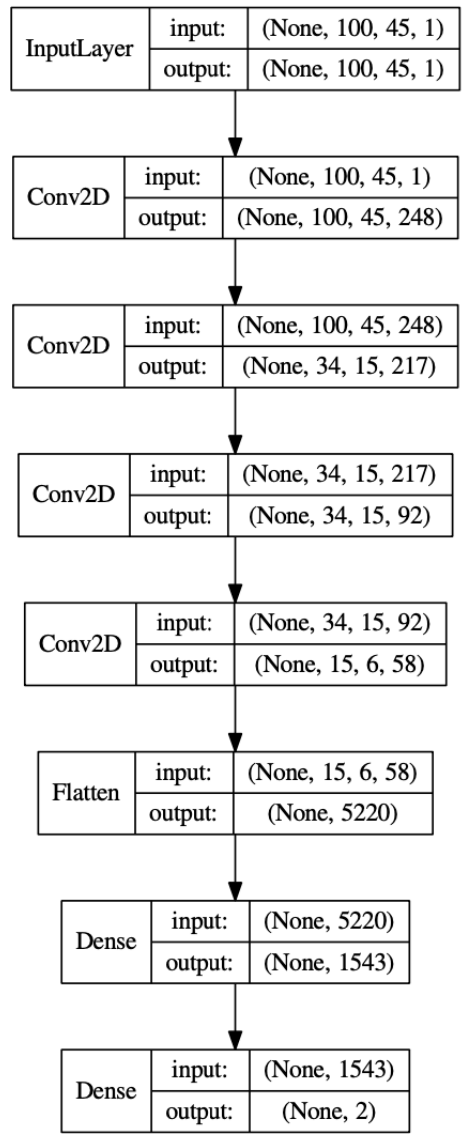
- Use "classical" discrimination variables
  - Steepness and bumpiness of LDF - **Compactness**
  - Cluster far away from shower core - **S40**
    - *Astropart.Phys. 99 (2018) 34-42*
    - Similar results published by HAWC in *Astrophys.J. 843 (2017) no.1, 39*

- Use Machine Learning (ML) techniques
  - Fully explore patterns at the ground
  - **Evolution of convolutional neural networks**
    - https://cdv.dei.uc.pt/denser/

UNIVERSIDADE D COIMBRA

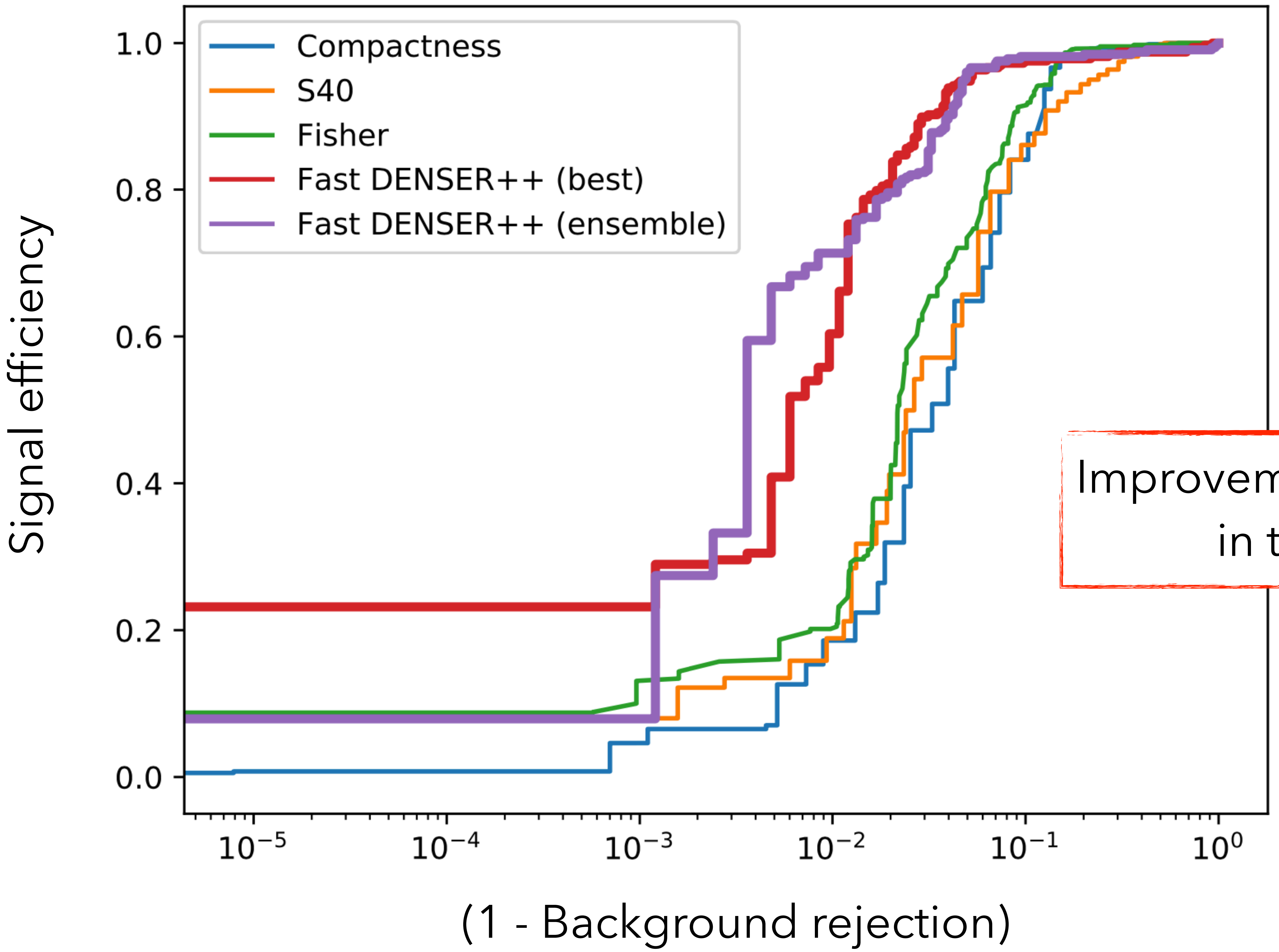
Computer science department

Fittest CNN



Exploring the pattern of showers at the ground

IEEE Access, vol. 7, pp. 110531-110540, 2019

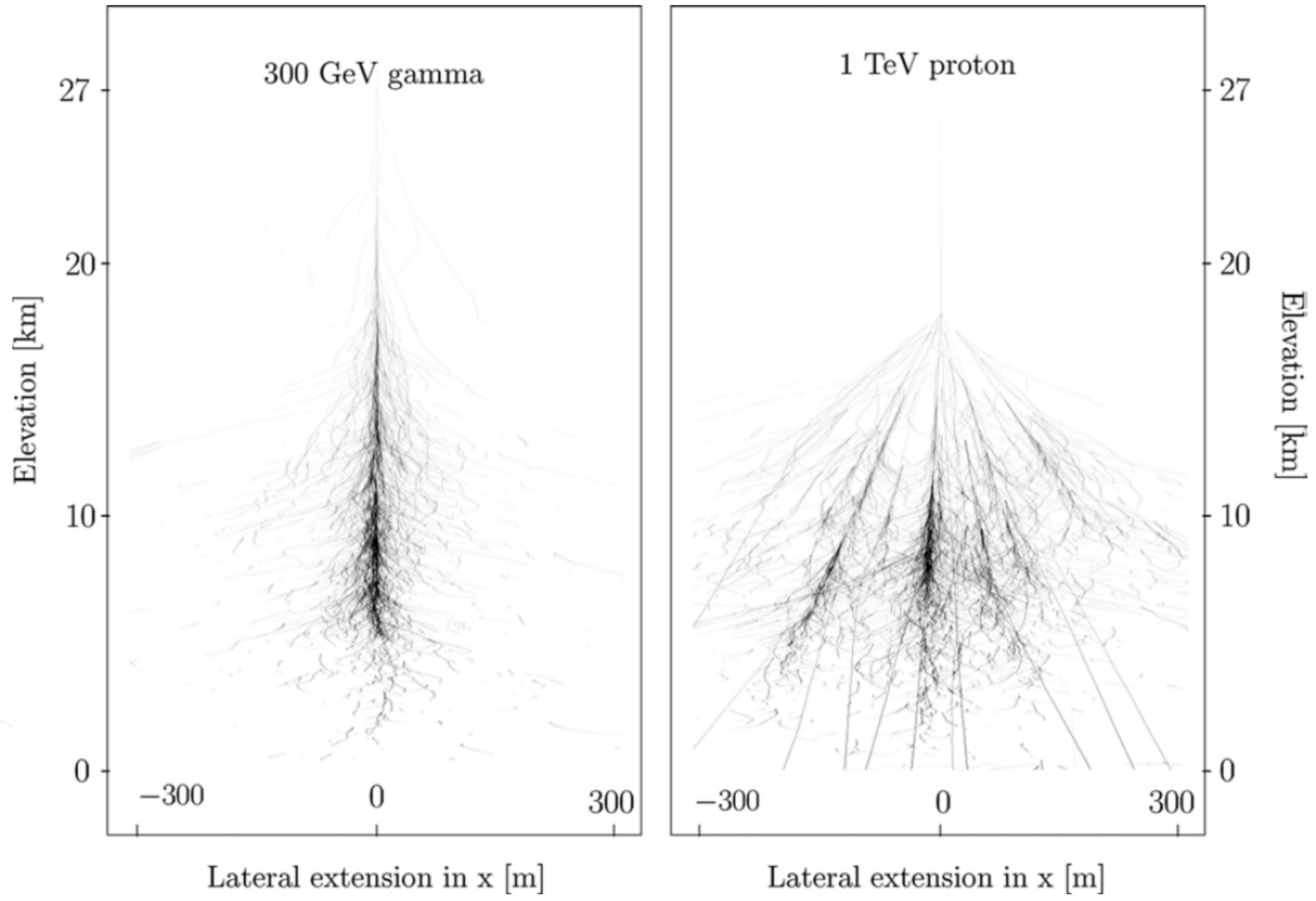


Improvement of a factor of 2 in the sensitivity

Gamma/hadron discrimination

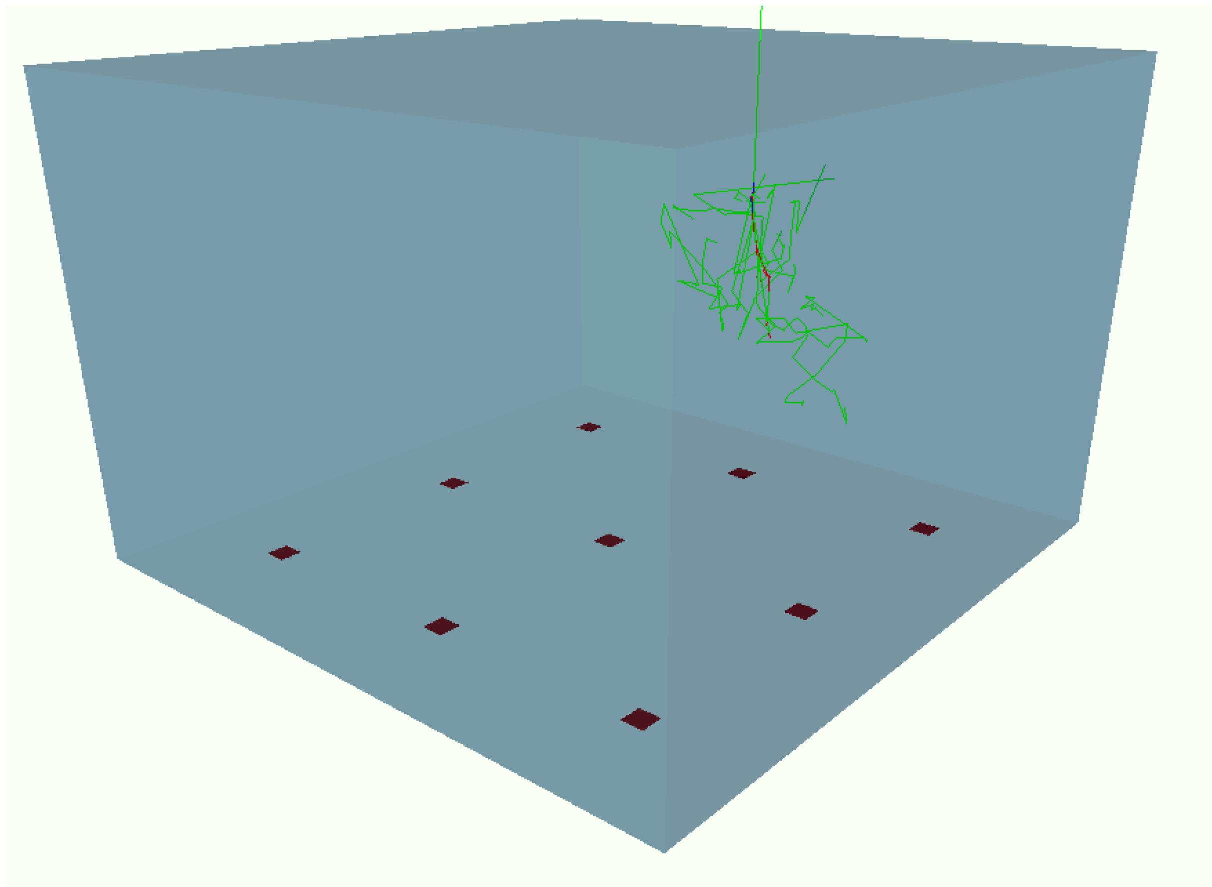
- Look for difference in the patterns at the ground

- Look for **muons** or/ and high-energy sub-showers



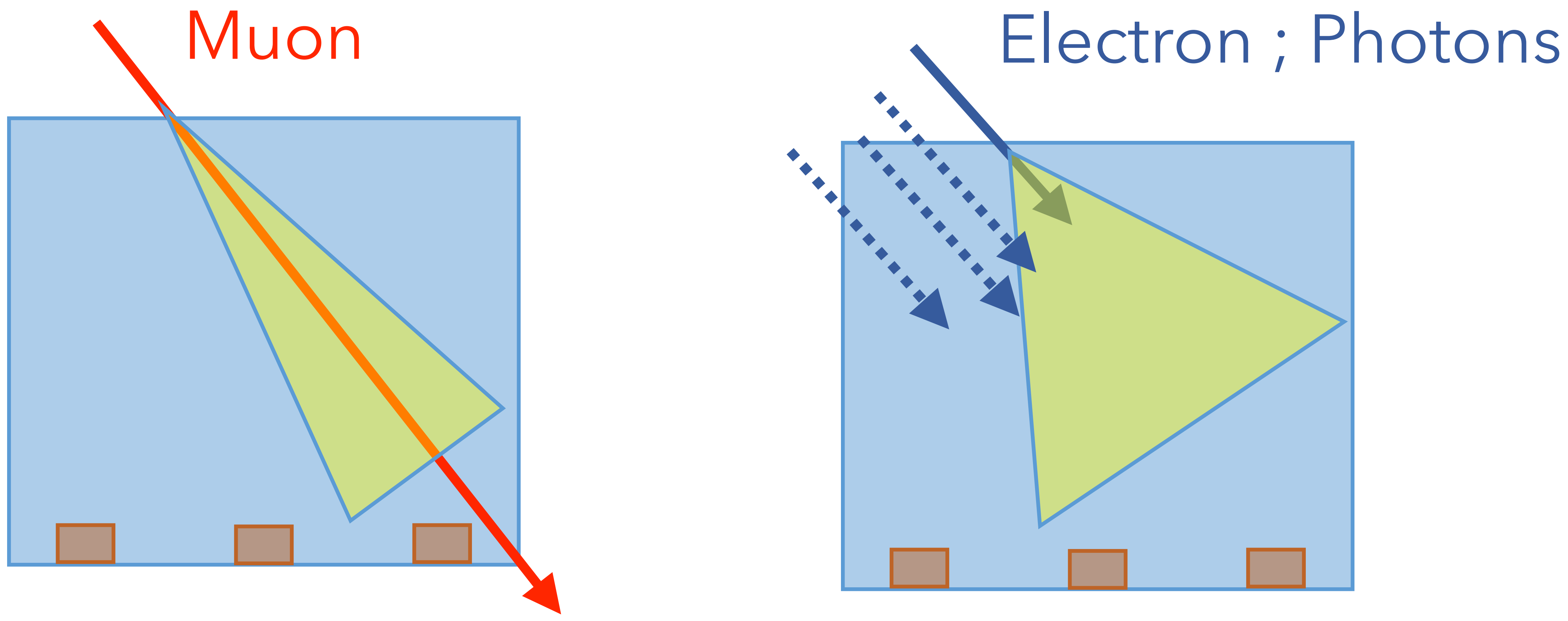
Gamma/hadron discrimination

- Look for difference in the patterns at the ground

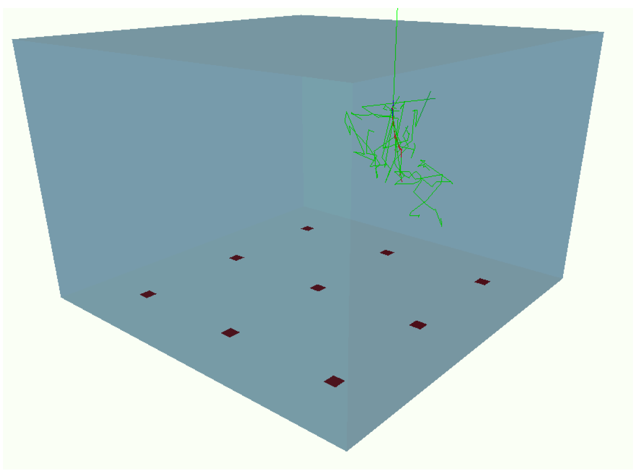


WCD 1.5 x 1.5 x 1 m^3

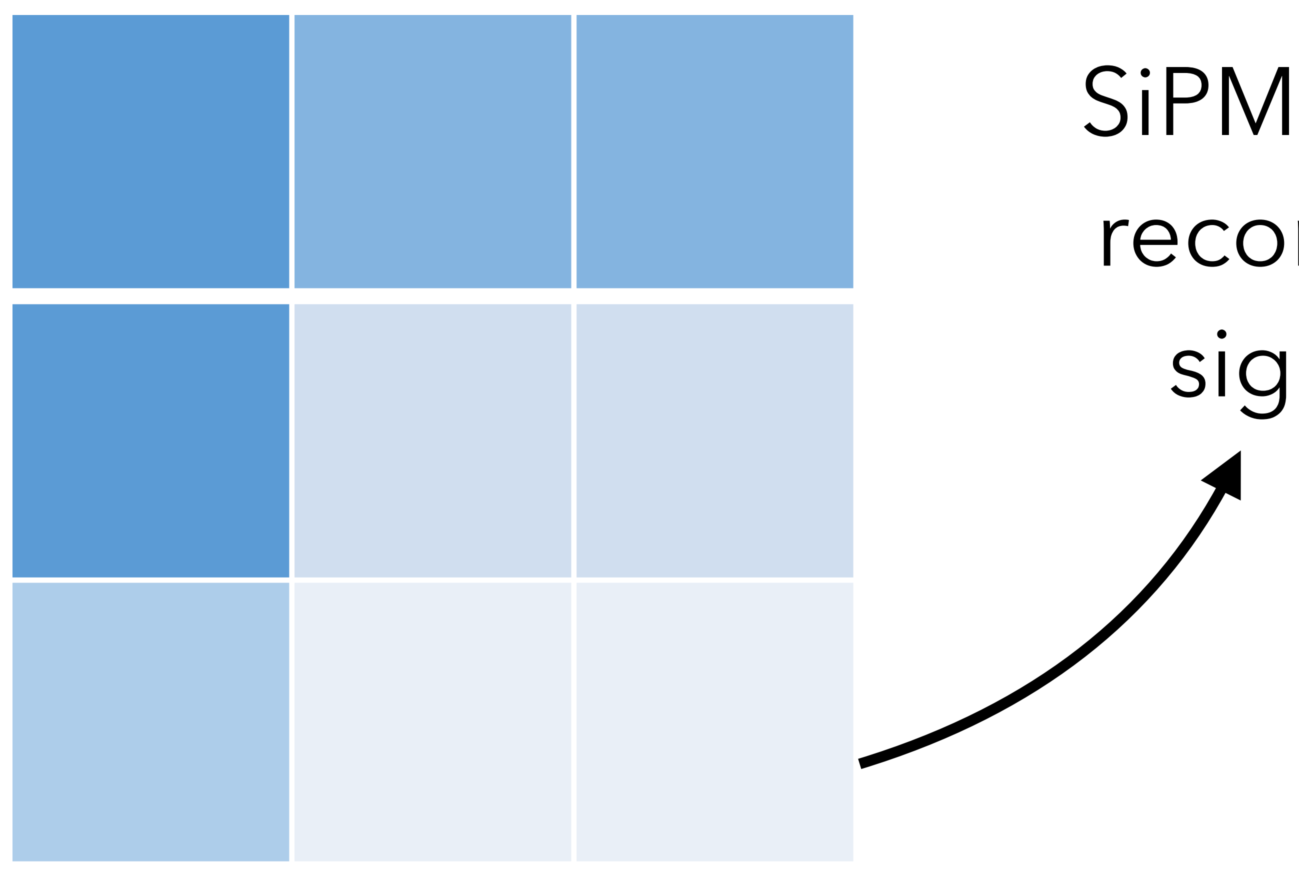
- Look for **muons** or/ and high-energy sub-showers



Is there a muon in the station?



- SiPM total measured signal
- **Asymmetry between SiPM**
- Use a DNN to estimate the **probability** of a station to contain a **muon**
  - Train with single muons in station
  - Needs to be optimized but first results are encouraging
- On-going work
  - a new master student joined this project very recently



Challenge identify the muon with nearly no false positives

Preliminary results

$T_{e.m.} \sim 99.94\%$ - $T_{\mu} \sim 29\%$

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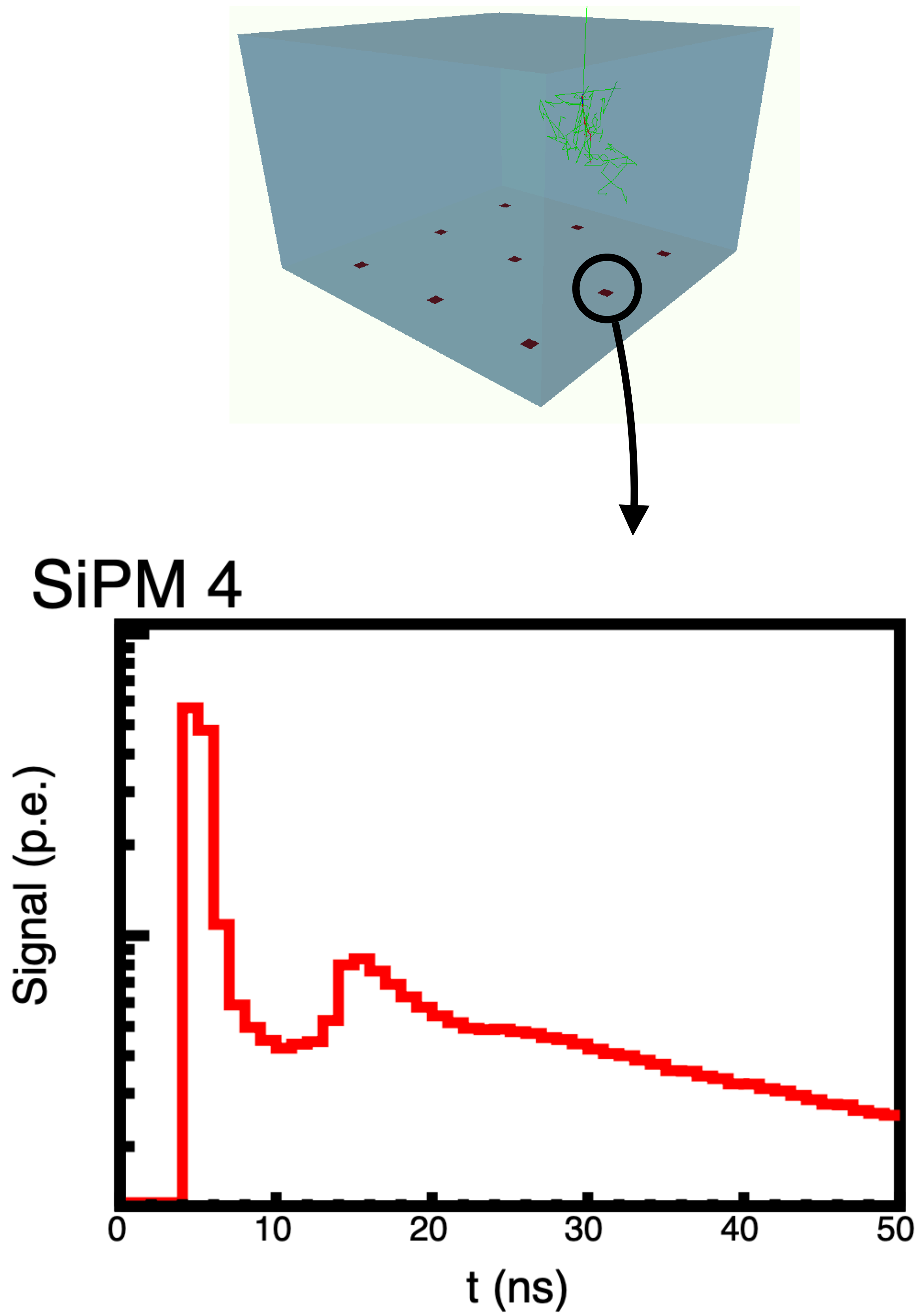
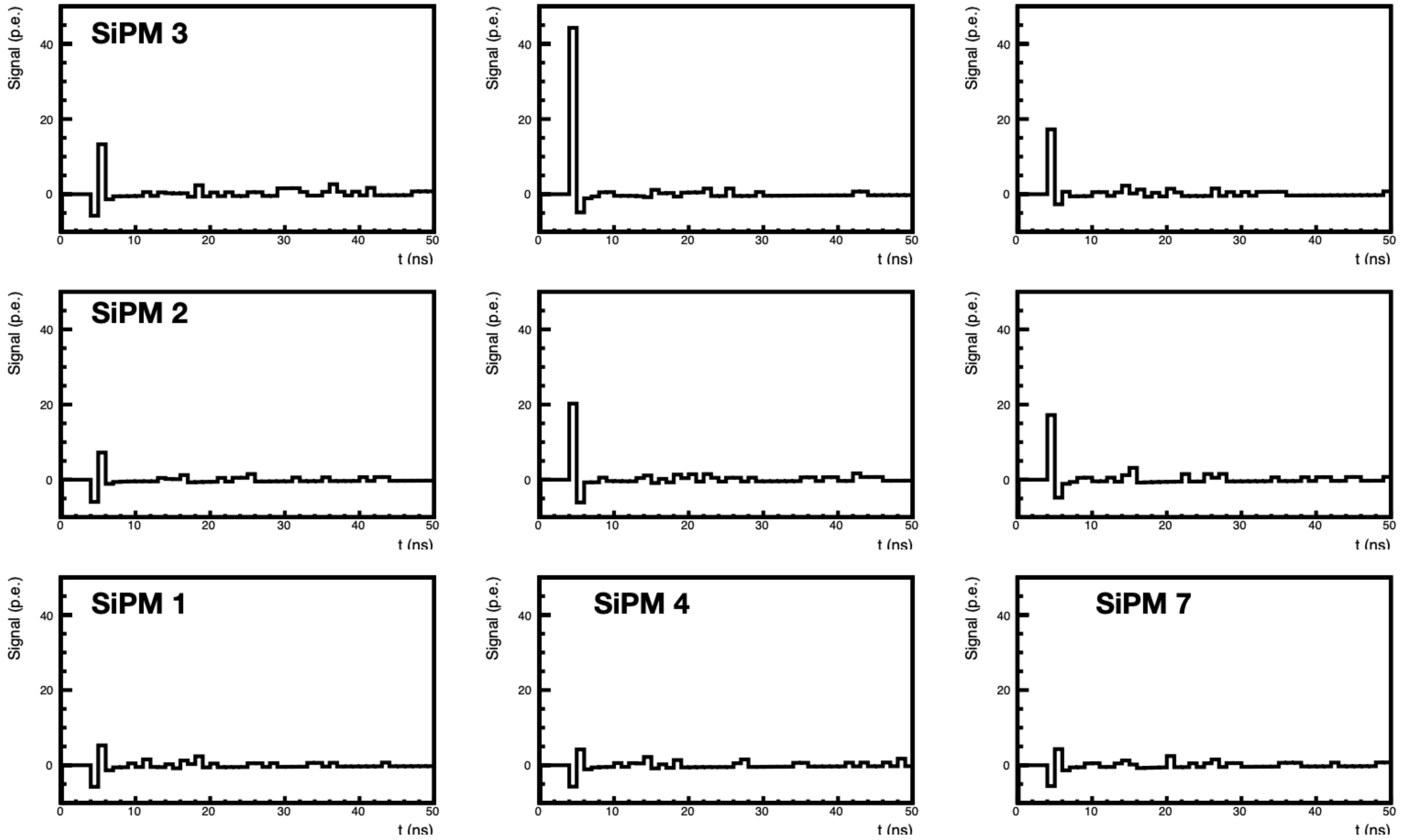
Future

- Use a CNN to exploit the complex features of each **individual SiPM signal time trace**



S_{μ} - ⟨ $S_{e.m.}$ ⟩



Event-by-event level

A road towards an enhanced gamma/hadron discrimination

Low energy showers

\ nearly no muons

\ patterns at ground (clusters)

Assess patterns at the ground with a CNN

High energy showers

\ many muons

\ uniform shower footprint

Assess WCD signal with a DNN to find muons

Shower Reconstructed Energy

100 GeV — 1 TeV — 10 TeV — 100 TeV

A road towards an enhanced gamma/hadron discrimination

Low energy showers

\ nearly no muons

\ patterns at ground (clusters)

High energy showers

\ many muons

\ uniform shower footprint

Assess patterns at the ground with a CNN

Input: *Probability of having a muon in WCD station*

Assess WCD signal with a DNN to find muons

Combined algorithm to perform g/h discrimination

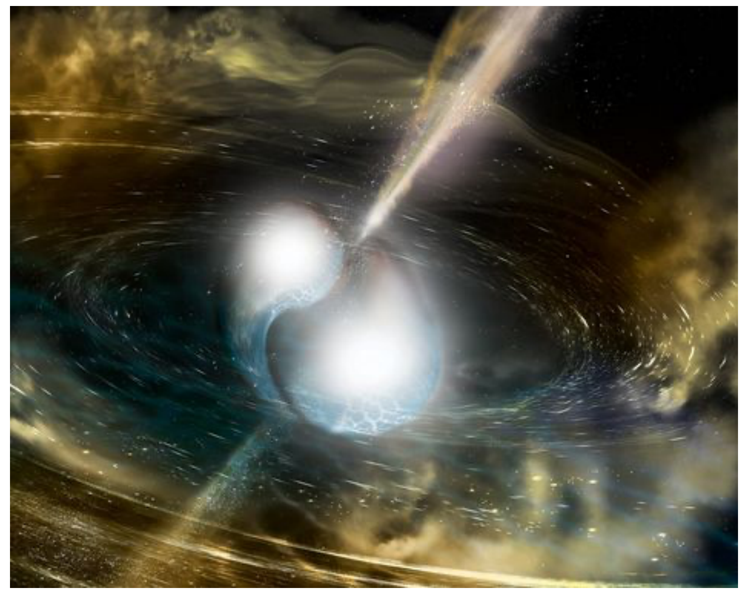
Shower Reconstructed Energy

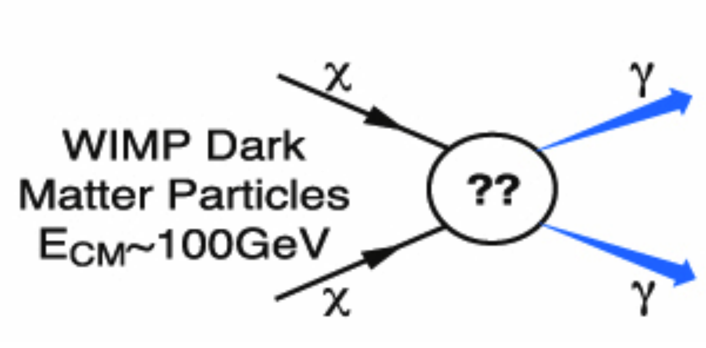
100 GeV — 1 TeV — 10 TeV — 100 TeV

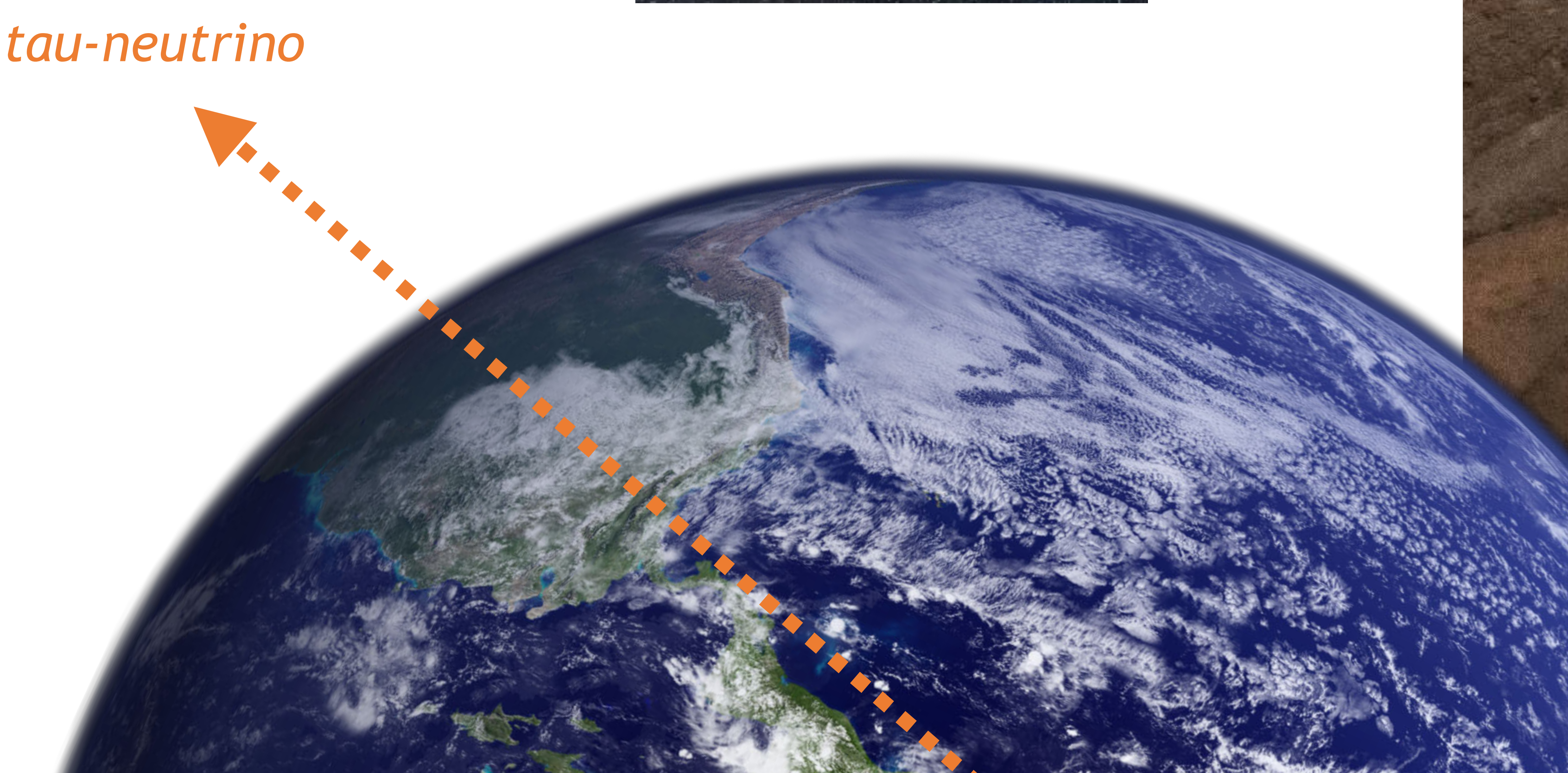
Activities @ LIP

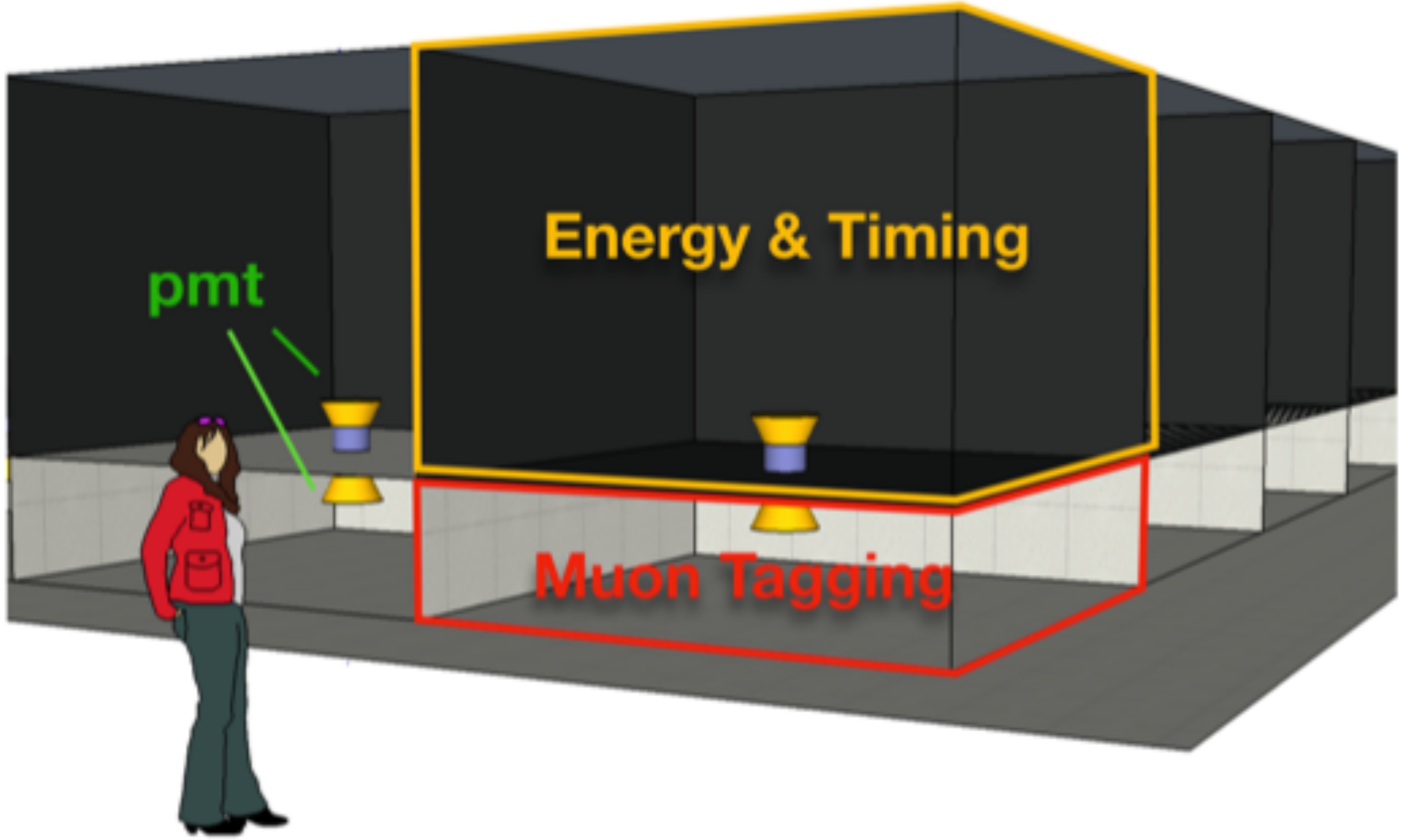
- Science capabilities
  - Studies on the sensitivity to:
    - Transient astrophysical phenomena
    - Explore hadronic interactions the forward region
    - Dark matter annihilation
    - Detect Neutrino physics
    - BSM physics

Neutron Stars Merger





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