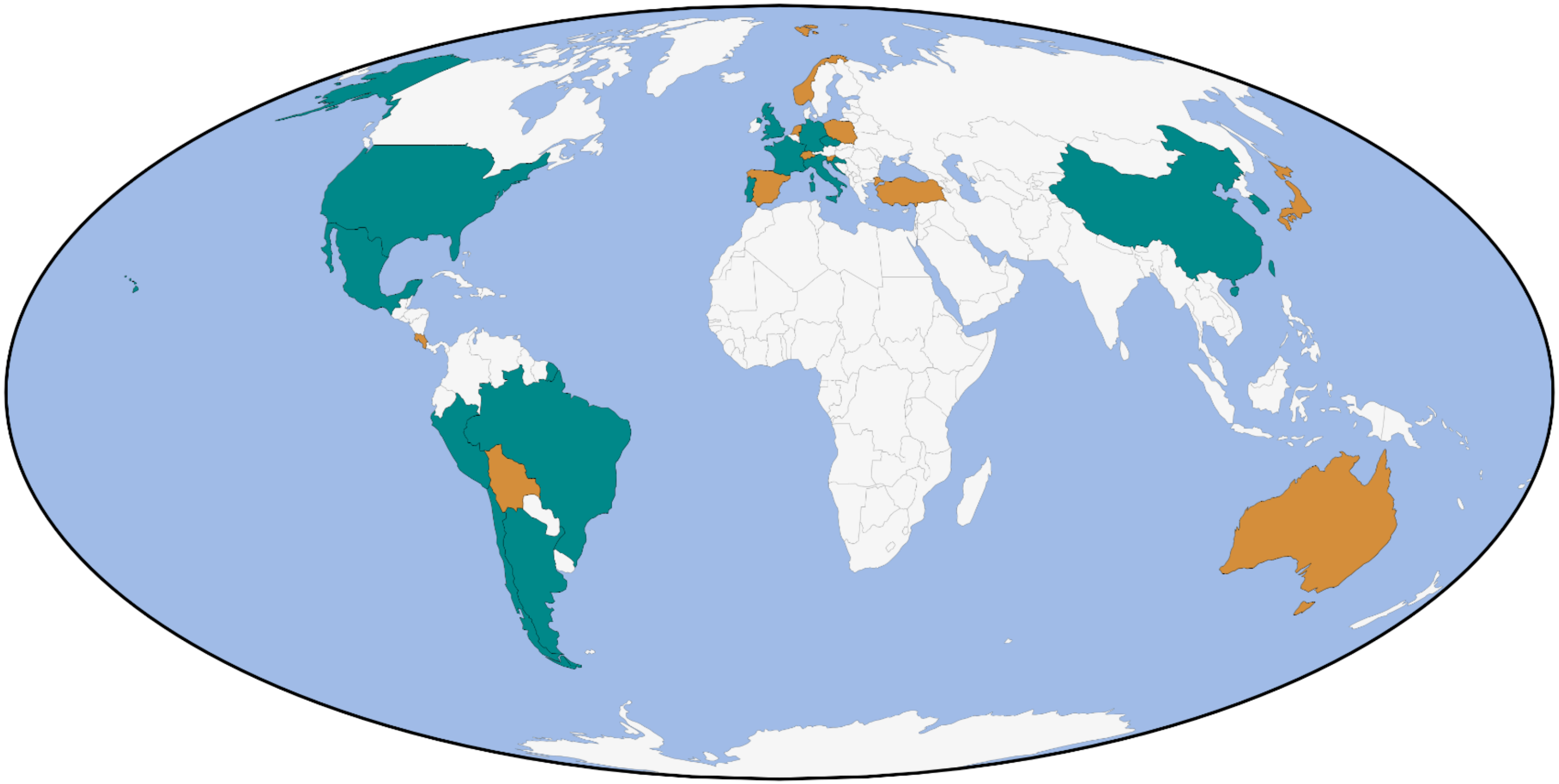
SWGO present and (near) future

Mário Pimenta
April 2025

LIP
TÉCNICO LISBOA
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

SWGO

Southern Wide-field Gamma-ray Observatory

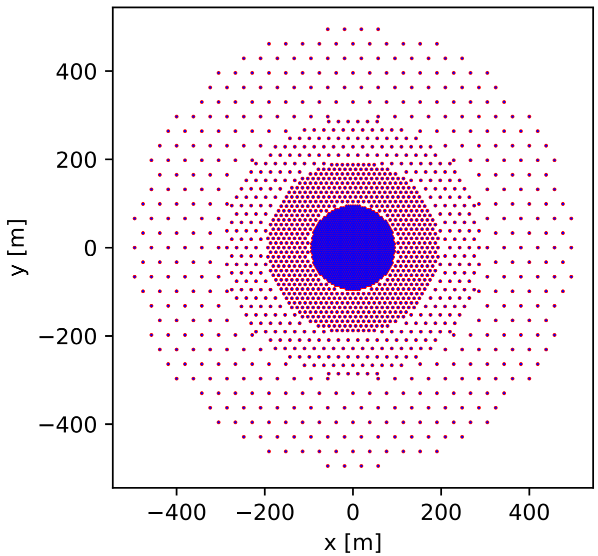


> 90 institutes, 16 countries

Argentina, Brazil, Chile, China, Croatia, Czech Republic, France, Germany, Italy, Mexico, Países Baixos, Peru, Portugal, South Korea, United Kingdom, United States

SWGO, 2024: the year of decisions

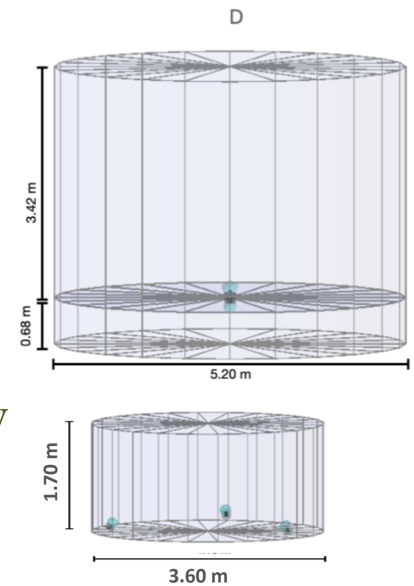
Baseline Layout and Detectors



Core

+

Outer Array



Mexico City
April 2024

Double Layer
metallic WCD

Mercedes
rotomolded WCD

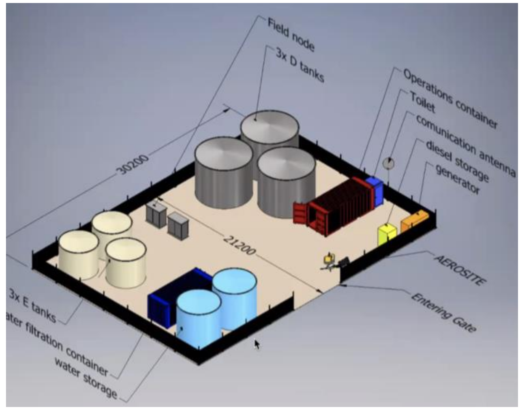
Site

Rio,
July 2024

SWGO near Future

Path Finder

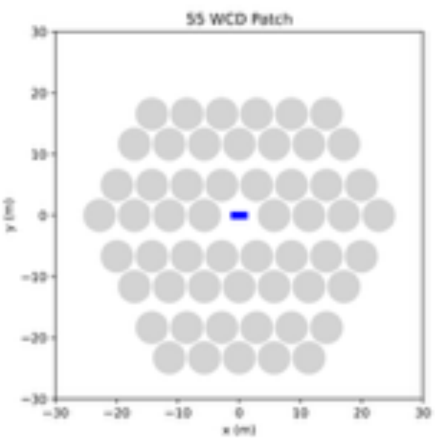
2025/26

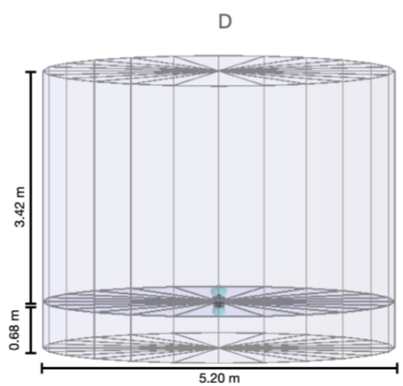


First activity @ site

2+1 metal D tanks,
2+1 plastic Mercedes tanks

SWGO-A

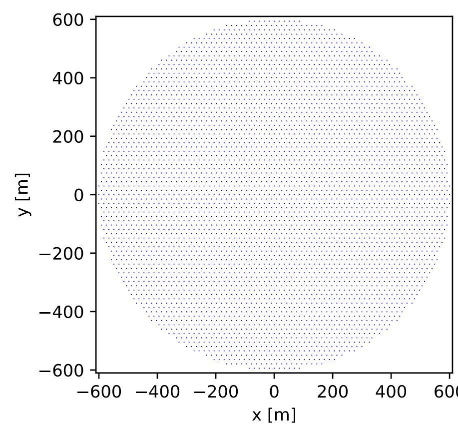


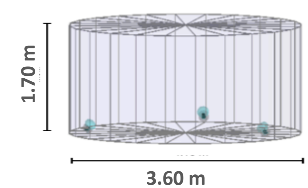


core array ～20 000 m^2

USA (NSF – 17M US$) +
Germany, …

SWGO-H





outer array 1 – 4% FF

Brazil, Italy +
Portugal, Czech Republic, Chile,..

And about LIP ???

PTDC FCT Grant (250 k €) approved yesterday!

LIP@Lower energies

- trigger
- pattern recognition
- tagging muon stations

LIP@Higher energies

- LCm
- Ptail
- …

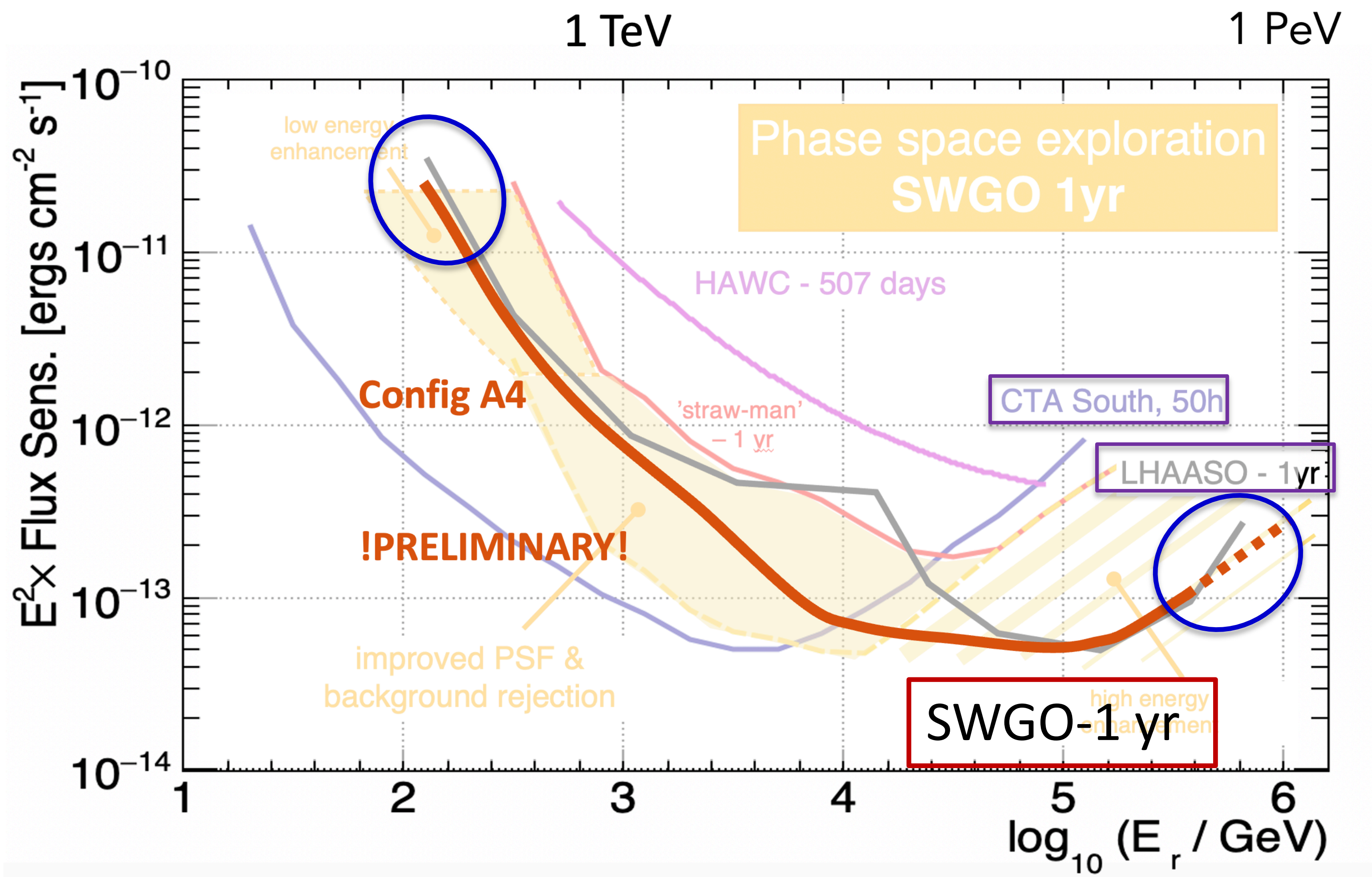
LIP@Detector,

- Mercedes (with CBPF)
- Layout optimization

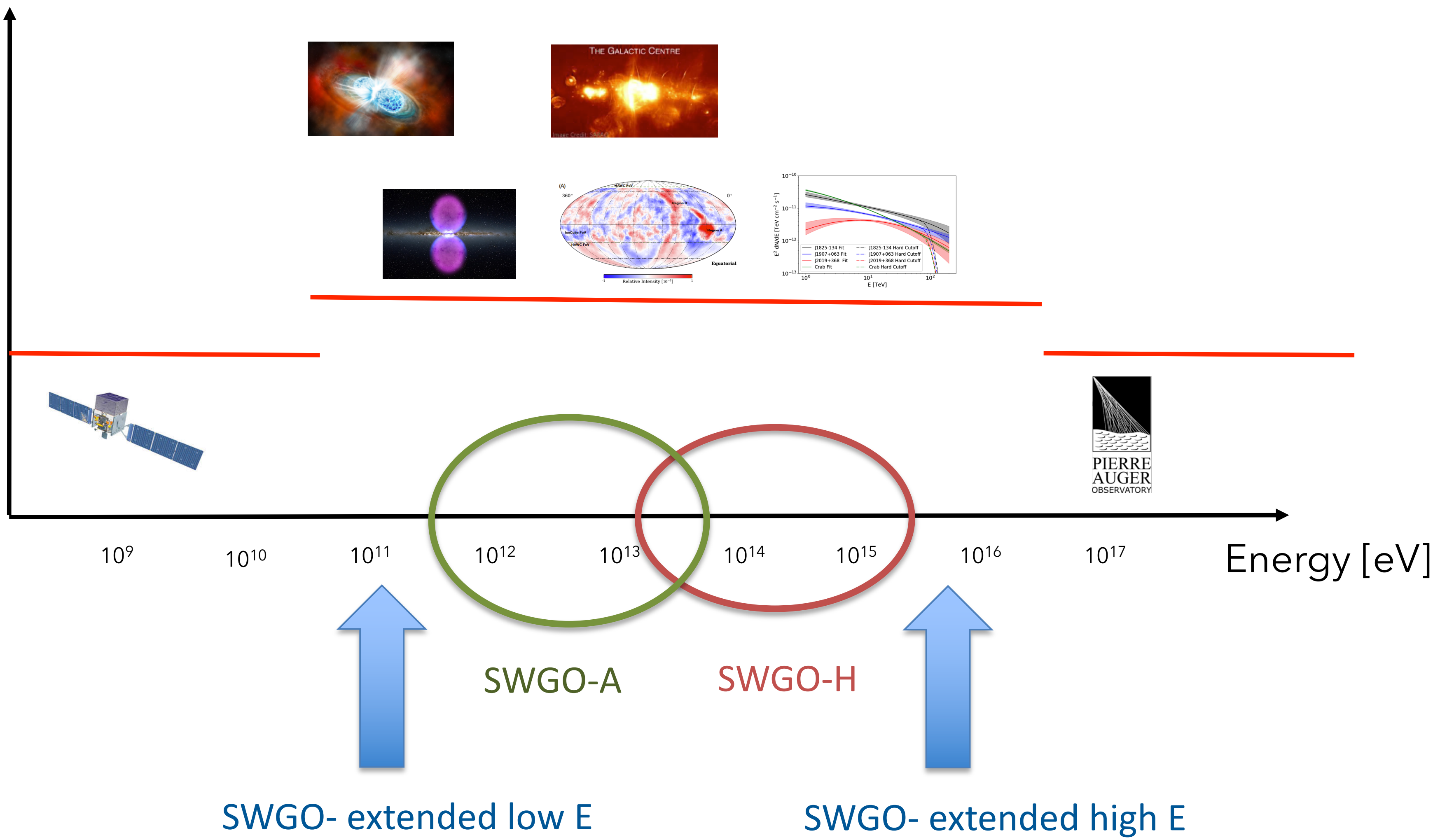
LIP@ …

- neutrinos
- hadronic interactions
- thermal simulations
- outreach
- …

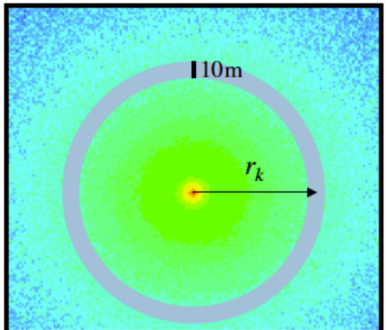
The sensitivity curve



SWGO Science vision



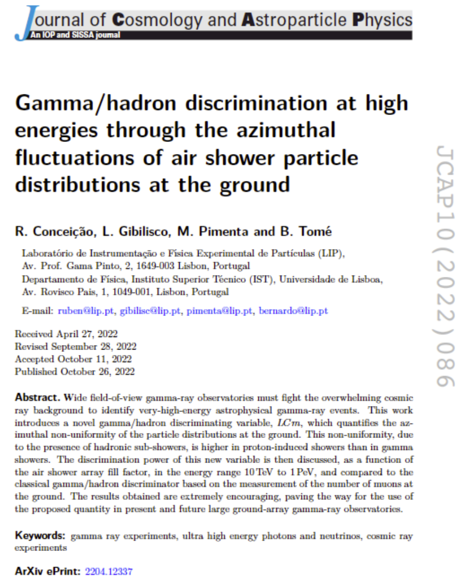
A new variable: LCm



Ring with n_k stations and mean signal $\langle S_k \rangle$

$$C_k = \frac{2}{n_k(n_k-1)} \frac{1}{\langle S_k \rangle} \sum_{i=1}^{n_k-1} \sum_{j=i+1}^{n_k} (S_{ik} - S_{jk})^2$$

$$LCm \equiv \log\left(C_k\right)\big|_{r_k=r_m}$$



Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Gamma/hadron discrimination at high energies through the azimuthal fluctuations of air shower particle distributions at the ground

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Abstract. Wide field-of-view gamma-ray observatories must fight the overwhelming cosmic ray background to identify very-high-energy astrophysical gamma-ray events. This work introduces a novel gamma/hadron discriminating variable, LCm, which quantifies the azimuthal non-uniformity of the particle distributions at the ground. This non-uniformity, due to the presence of hadronic sub-showers, is higher in proton-induced showers than in gamma showers. The discrimination power of this new variable is then discussed, as a function of the air shower array fill factor, in the energy range 10 TeV to 1 PeV, and compared to the classical gamma/hadron discriminator based on the measurement of the number of muons at the ground. The results obtained are extremely encouraging, paving the way for the use of the proposed quantity in present and future large ground-array gamma-ray observatories.

Keywords: gamma ray experiments, ultra high energy photons and neutrinos, cosmic ray experiments

ArXiv ePrint: 2204.12337

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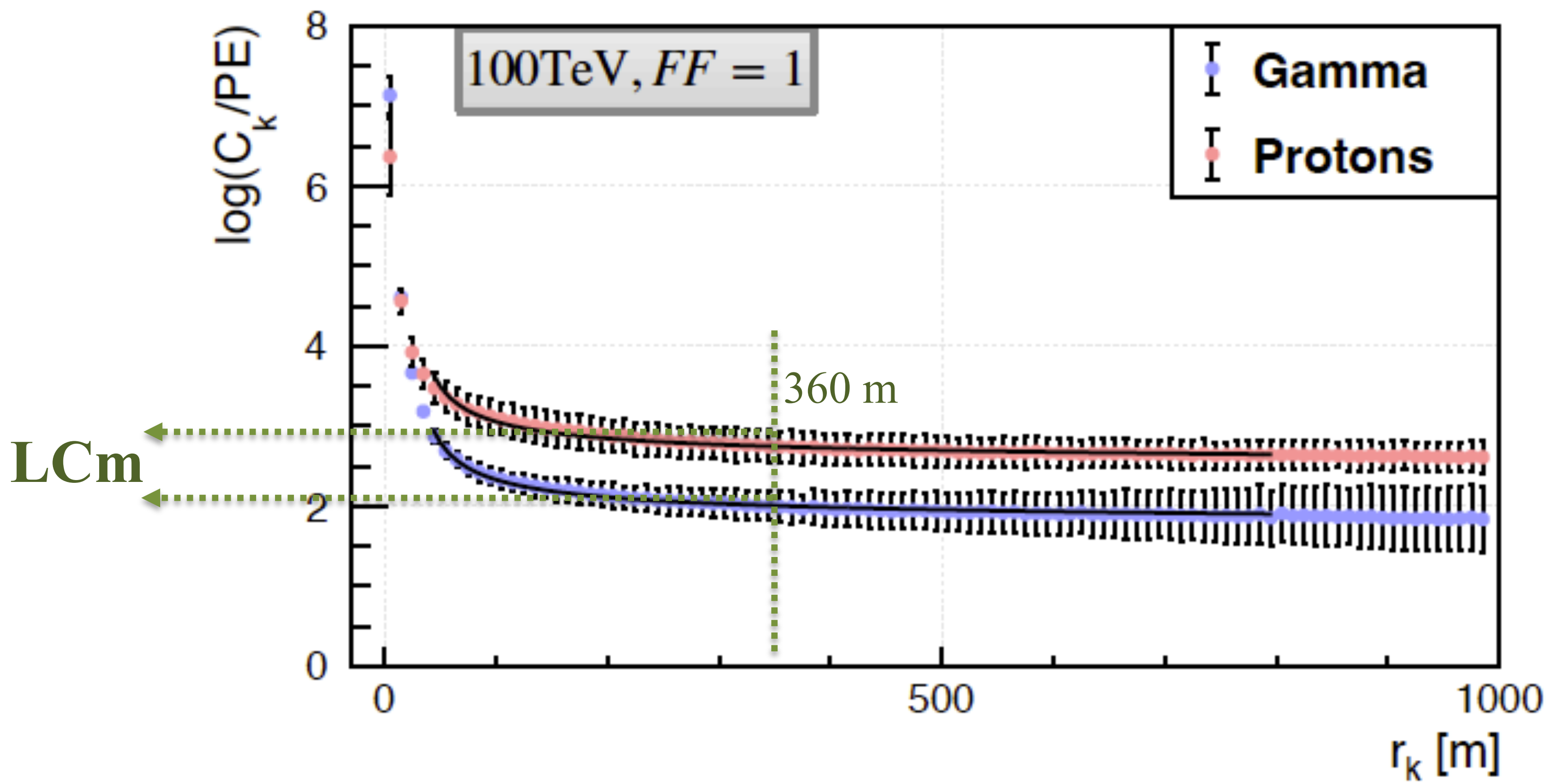
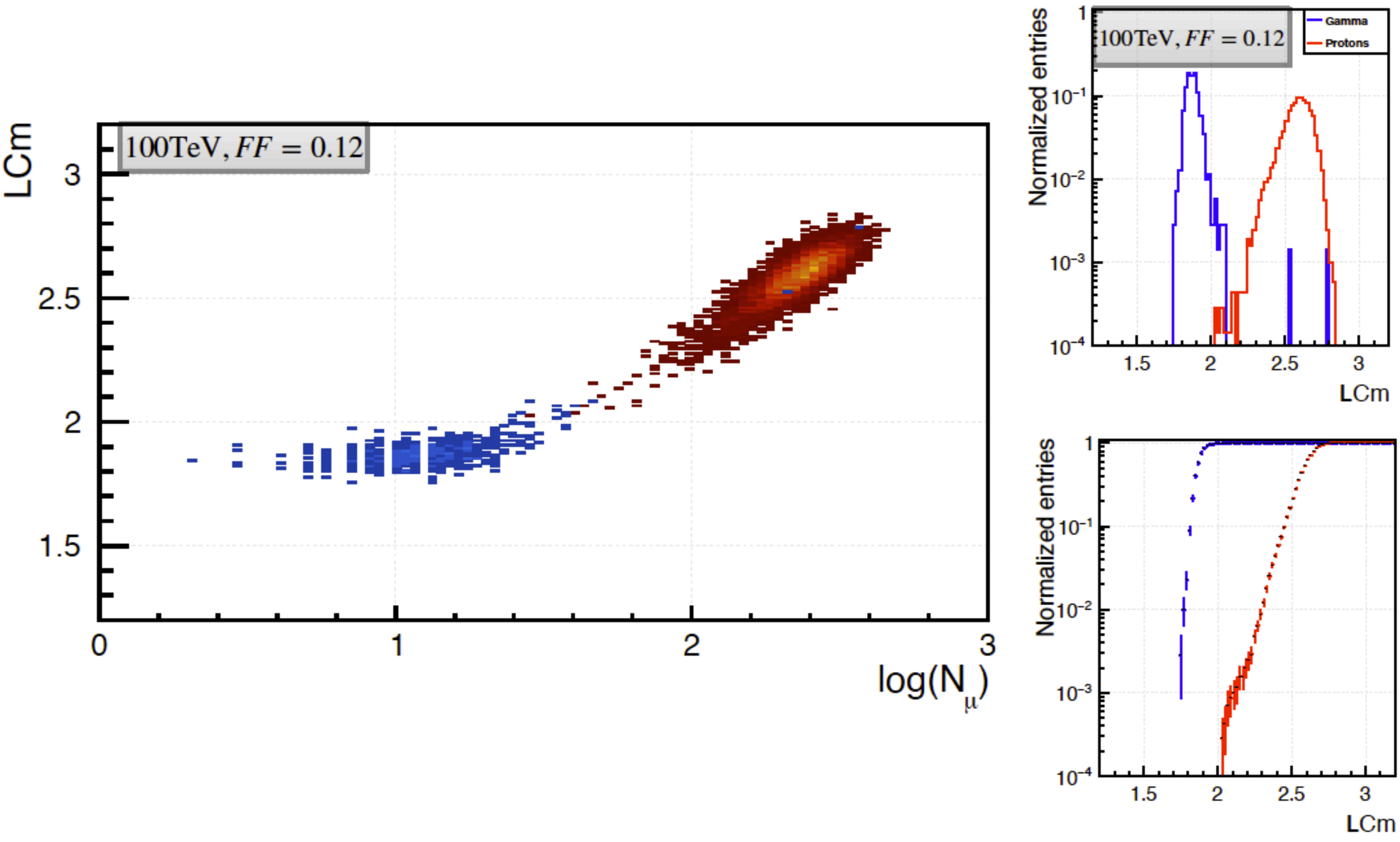


It works!

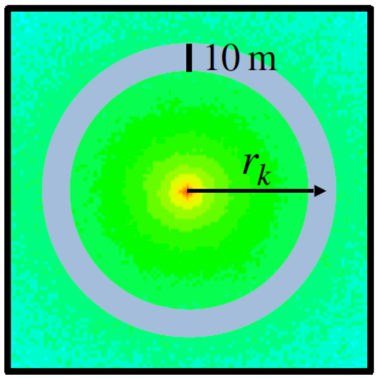


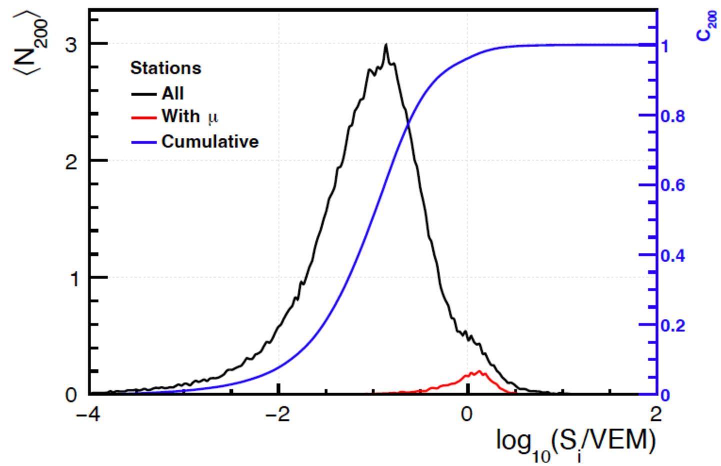
A new variable: P^{α}_{tail}

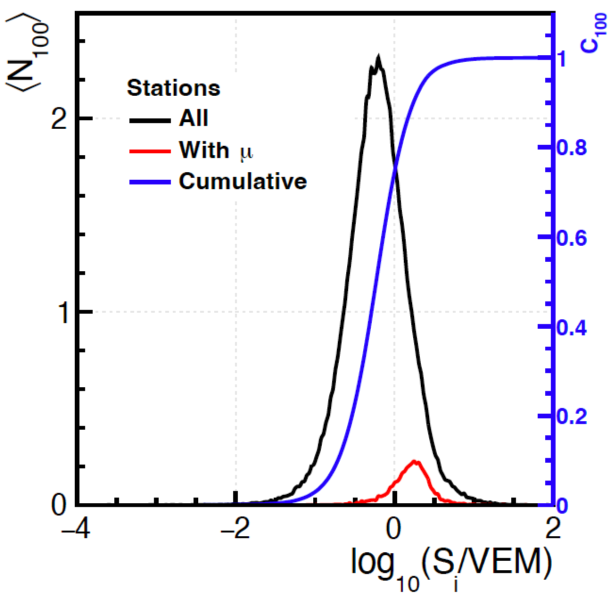
$$P_{\text{tail},i} = C_{r_i}(S_i) \;\rightarrow\; P^{\alpha}_{\text{tail}} = \sum_{i}^{n} (P_{\text{tail},i})^{\alpha}$$

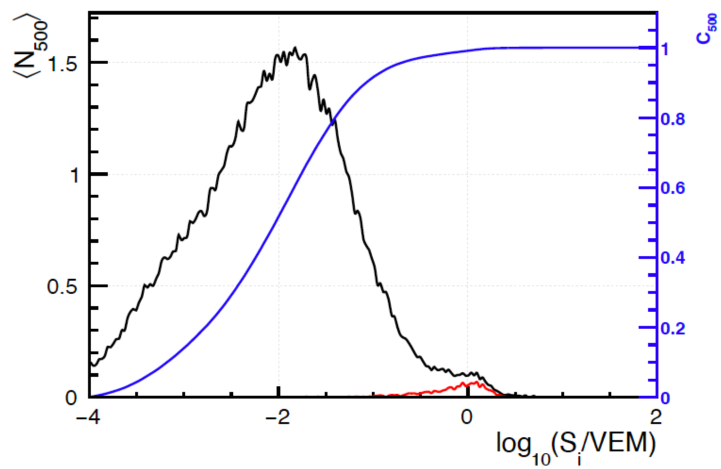
Station variable

Event variable









P^{α}_{tail}: a high resolution gamma/hadron and composition discriminant variable for Water-Cherenkov Detector cosmic-ray observatories

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(Dated: June 28, 2024)

[astro-ph.HE] 27 Jun 2024

The precise and efficient identification of the nature of the primary cosmic rays on an event-by-event basis stands as a fundamental aspiration for any cosmic ray observatory. In particular, the detection and characterization of gamma ray events are challenged by their occurrence within an overwhelmingly greater flux of charged cosmic rays spanning several orders of magnitude. The intricacies of distinguishing between cosmic ray compositions and the inherent uncertainties associated with hadronic interactions present formidable challenges, which, if not properly addressed, can introduce significant sources of systematic errors.

This work introduces a novel composition discriminant variable, P^{α}_{tail}, which quantifies the number of Water Cherenkov Detectors with a signal well above the mean signal observed in WCDs located at an equivalent distance from the shower core, in events with approximately the same energy at the ground. This new event variable is then shown to be, in the reconstructed energy range 10 TeV to 1.6 PeV, well correlated with the total number of muons that hit, in the same event, all the observatory stations located at a distance greater than 200 m from the shower core. The two variables should thus have similar efficiencies in the selection of high-purity gamma event samples and in the determination of the nature of charged cosmic ray events.

I. INTRODUCTION

The selection, with good efficiency and high purity, of highly energetic gamma rays or the determination of the nature of the charged cosmic rays is one of the major challenges for cosmic ray and gamma ray experiments.

The direct detection of neutral and charged cosmic rays by high-altitude balloons or satellites is excluded at high energies (above tens of TeV for gamma rays and thousands of TeV for charged cosmic rays) due to the scarcity of such particles and the limited detection area of such detectors (typically a few m^2) [1]. Thus, the only viable option is indirect detection, achieved by measuring the longitudinal development of the Extensive Air Shower (EAS) produced by the interaction of these particles in the Earth's atmosphere [2, 3], or by studying the distribution of the EAS particles that reach the ground [4, 5].

Several different experimental methods and discriminant variables have been developed to select gamma-ray events from the huge hadronic background and to discriminate between showers that might have been produced by different atomic nuclei (typically from hydrogen to iron) [6, 7]. No unique or perfect solution exists, although, above a few TeV, the direct measurement of the number of muons arriving at the ground is widely accepted as the best possible discriminator variable and has indeed allowed the detection of gamma rays with energies up to the PeV by the LHAASO collaboration [8, 9]. More recently, a new gamma/hadron discriminating variable, LCm, based on the measurement of the azimuthal non-uniformity of the particle distributions at the ground in Water Cerenkov Detectors (WCD) arrays, was introduced [10] and, through simulations, it has been claimed that it might reach equivalent background rejection factors of about 10^4 at energies about 1 PeV [11]. The latter quantity has, however, shown limited discrimination power for composition and hadronic interactions studies.

In this article, we introduce a novel variable denoted as P^{α}_{tail} designed for WCD ground arrays. By focusing on events falling within a specific energy range at the ground, we construct distributions of signals across stations, categorized into discrete distance bins from the shower core. These distributions can be either derived from available data or generated through simulation when data is lacking. P^{α}_{tail} provides a quantitative measure on an event-by-event basis, indicating the number of stations exhibiting signals within the upper tail of these signal distributions. The rationale behind this variable, inspired by a method developed by the IceTop/IceCube collaboration [12], lies in the observation that in events with comparable reconstructed energy, the signal recorded by the WCD stations tends to be higher when struck by energetic sub-showers. These sub-showers, composed of muons and highly energetic electromagnetic particles, serve as a distinct signature of hadronically-induced showers [13].

The manuscript is organised as follows: in Section II, all the simulation sets are described; in Section III, the new variable, P^{α}_{tail}, is introduced; in Section IV, the correlation of this new variable with the number of muons that hit the WCD stations in gamma, proton or iron events with reconstructed energy between 10 TeV and 1.6 PeV is analysed; in Section V, the efficiency of this new variable to select high purity gamma event samples, as well as to determine the nature of charged cosmic rays events is re-

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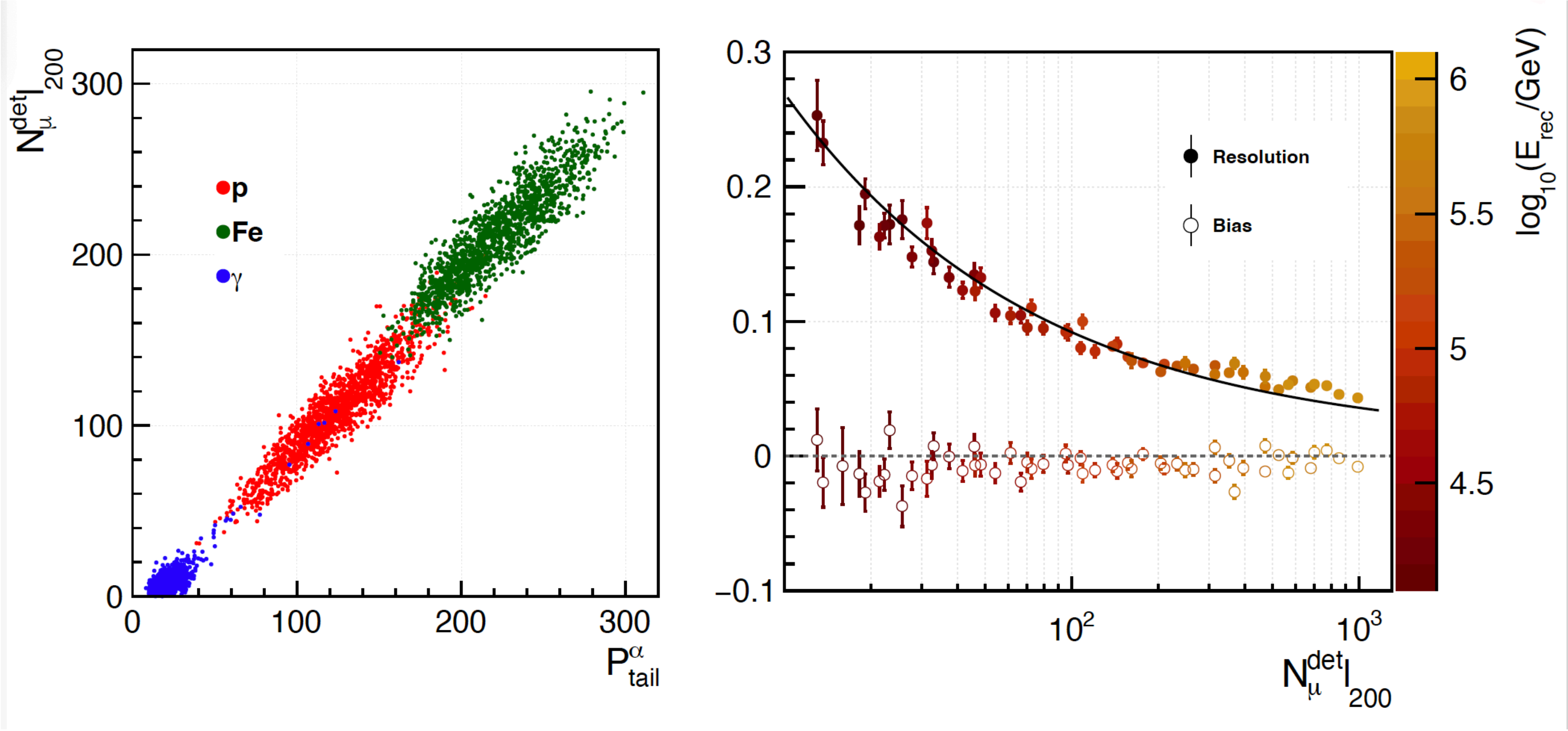
It works!



Access the number of muons without burying the WCDs !