LAGO: the Latin American Giant Observatory Status and Perspectives

XIV SILAFAE, Quito, nov 17, 2022

Luis Otiniano[1] on behalf of the LAGO Collaboration[3]

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[3]https://lagoproject.net

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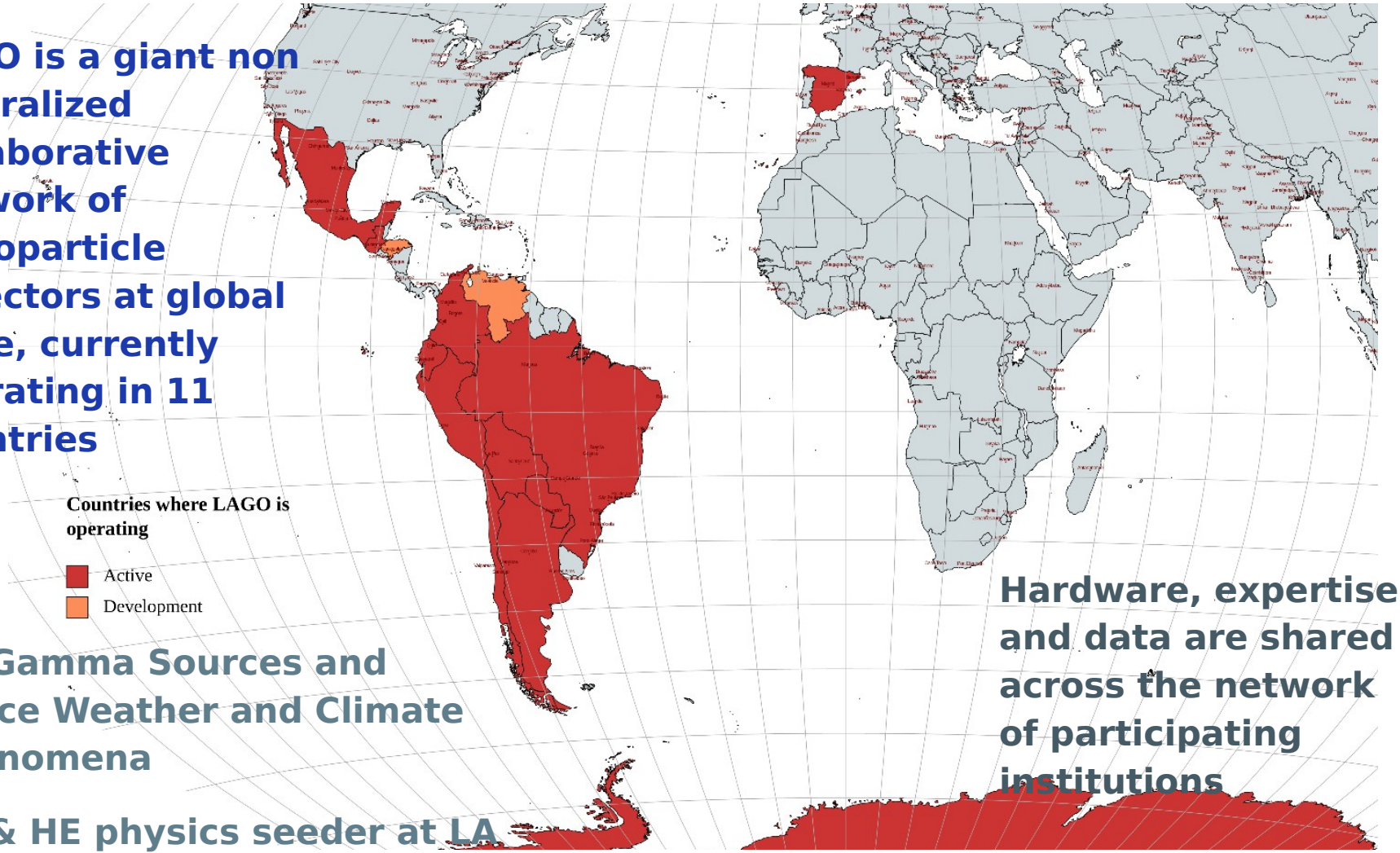
Latin America Giant Observatory

lagoproject.net

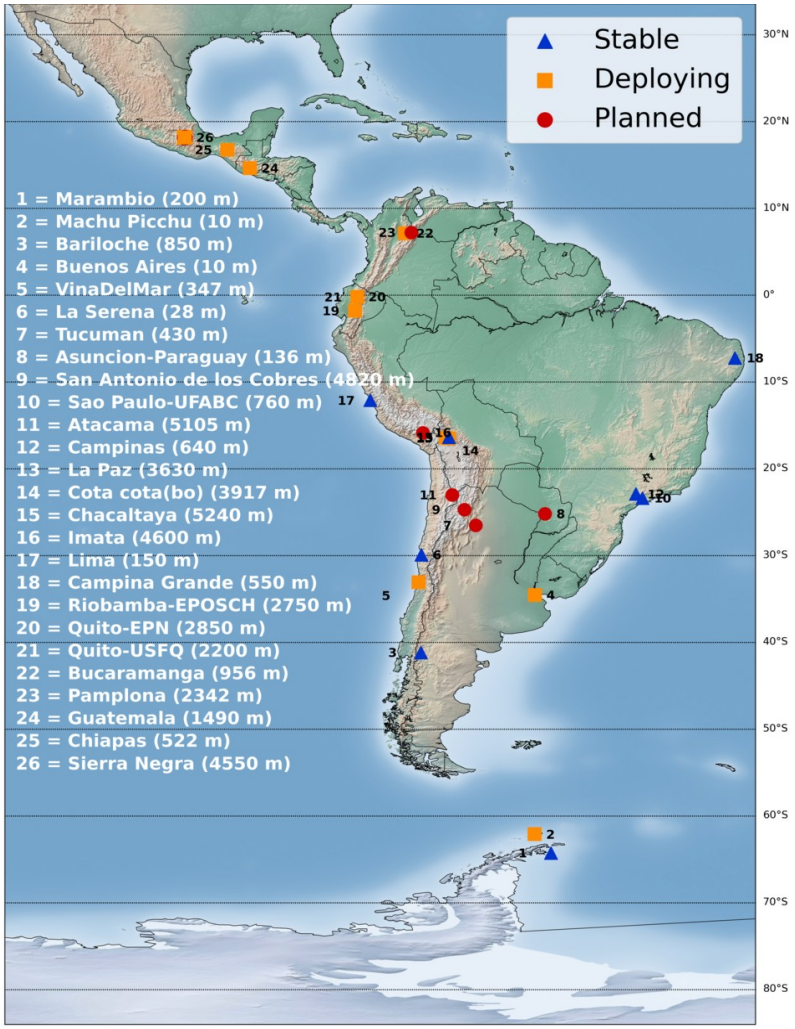
LAGO is a giant non centralized collaborative network of astroparticle detectors at global scale, currently operating in 11 countries



HE Gamma Sources and Space Weather and Climate phenomena

AP & HE physics seeder at LA

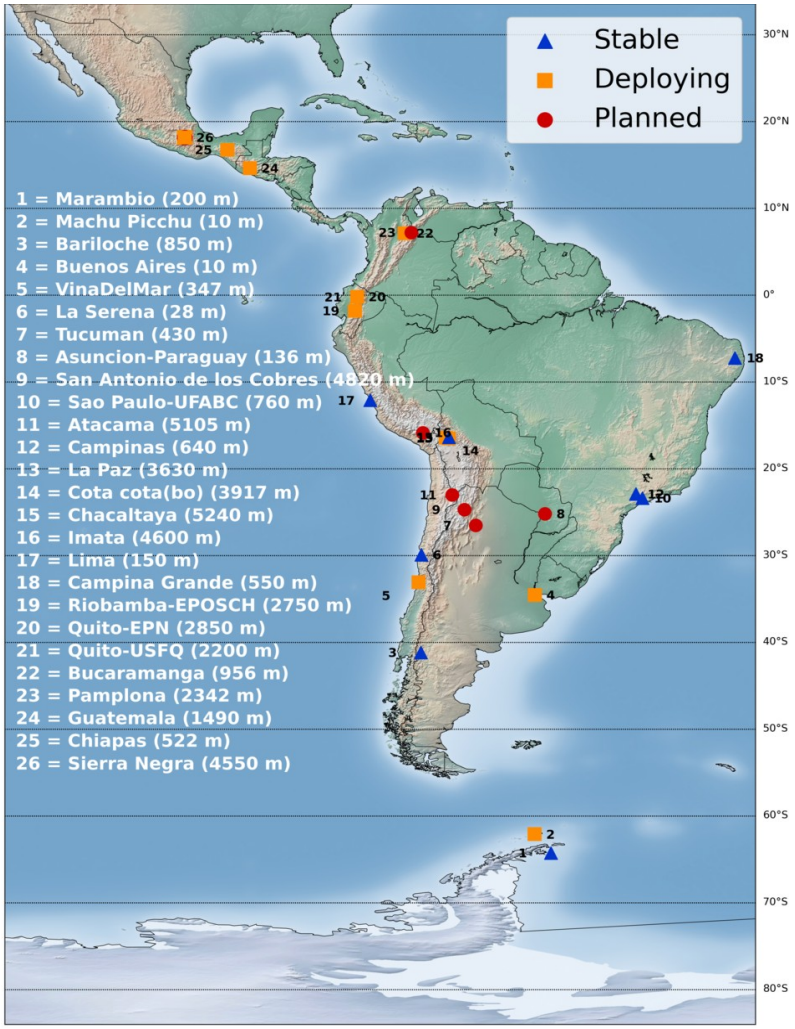
Hardware, expertise and data are shared across the network of participating institutions



The Latin American Giant Observatory

LAGO is an extended astroparticle observatory at continental scale: from México to Antarctica

- **Scientific goals**
  - **Astroparticle physics to study the extreme universe**
  - **Transient and long term space weather phenomena trough Solar modulation of Cosmic Rays**
  - **Measurement of background radiation at ground level**
- **Academic goals**
  - **Train Latin American students in High Energy and Astroparticle physics**
  - **Build a Latin American network of Astroparticle and Cosmic Rays researchers**



The Latin American Giant Observatory

LAGO is an extended astroparticle observatory at continental scale: from México to Antarctica

1-10 m3 water Cherenkov detectors (WCD) deployed at **very different** altitudes and geomagnetic coordinates

The **time evolution of individual particles signals** registered at all the WCD are transferred and stored in a **central repository**

Synthetic signals produced by EAS are calculated for **any detector** of **any type**, in any site **around the World** under **realistic time-evolving conditions**

The Latin American Giant Observatory

LAGO-High Energy:

- Small arrays of WCD
- High energy components of GRB
- Low energy astroparticles

LAGO-Universities:

- Astrophysics and particle physics in undergraduate courses
- Muon decay
- Construction and characterization of particles detectors
- Detector physics and radiation-matter interactions
- Data analysis and statistic

LAGO-Space Weather:

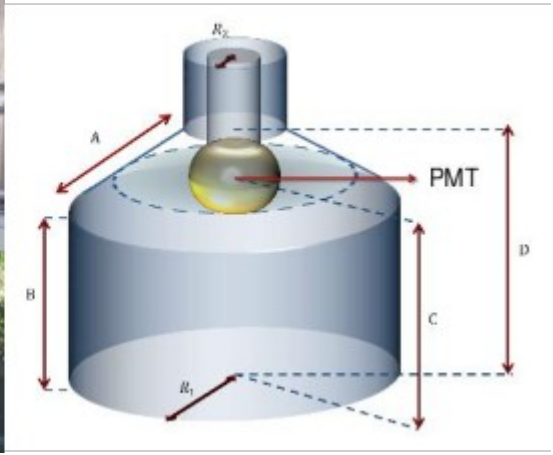
- Space Weather phenomena from ground level
- Possible connections: atmospheric physics
- Background radiation at ground (and flight) level

LAGO-Virtual:

- Acquire, produce, collect and preserve LAGO data
- Integration with EOSC services
- Toolkit development $\rightarrow$ ARTI (integration of MAGCOS, CORSIKA and Geant 4)

The Latin American Giant Observatory

Autonomous, reliable, simple, cheap and smart (based on SBC and COTS) WCD with a single PMT (usually provided by LAGO in most of the participating countries)



New own designed electronic based on SteamLab RedPitaya
H. Arnaldi et al, IEEE2020

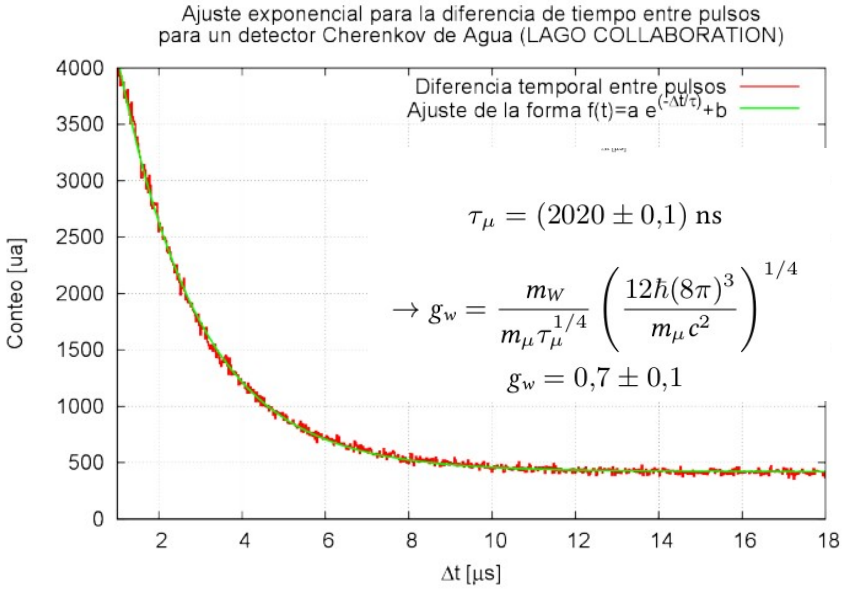
SaaS (Sensors as a Service) Concept
H. Asorey et al, PoS(ICRC2015)

LAGO detectors diversity

LAGO difficulties @ LA

LAGO Universities

Yearly LAGO workshop and AP&HE physics schools (combined mode since 2012!)
More than 400 participating students in total



Experimental, astro-ph & hep-ph courses
Muon decay: electroweak theory, python, data analysis, simulations, detector physics, statistics, ...
H. Asorey et al, Rev. Bras. Ensino Fís. 40 (4)

Last in person meeting previous to the pandemic - Dec. 2019 - @ CAC – CNEA Bs As, Argentina

LAGO Universities

Yearly LAGO workshop and AP&HE physics schools

This year edition Feb. 2022 @ Tucuman, Argentina

The Latin American Giant Observatory (LAGO)

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13th LAGO Workshop

Tucumán, Argentina

The workshop will be held between the 21st and 26th of February, 2022, in Tucuman, Argentina.

Chair: Maria Graciela Molina (FACET - UNT)

co-Chair: Iván Sidelnik (CONICET-CNEA)

Registration is closed!

However, if you need an invitation letter please send an email to Graciela <gmolina@herrera.unt.esu.ar>

Abstract submission and finance support

The Abstract subsmission and the procees to request financial support is now closed. Thanks for participating.

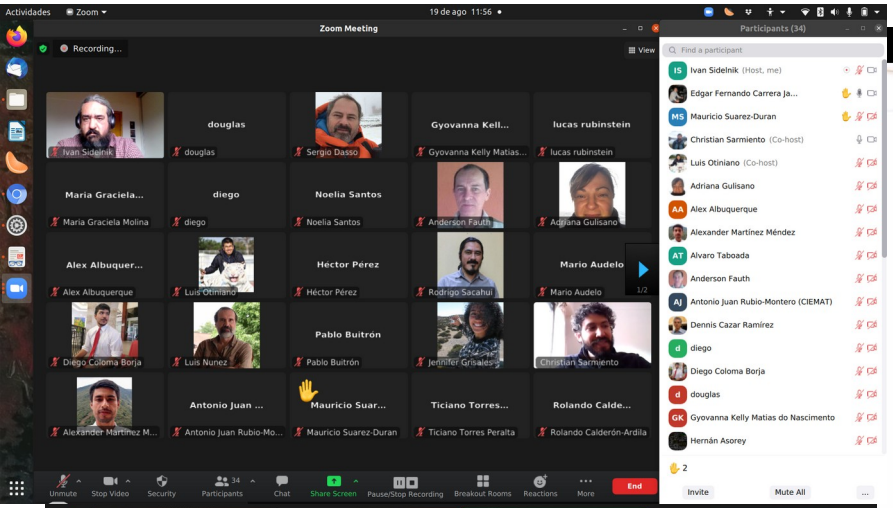
Local Organizing Comitee (Facultad de Ciencias Exactas y Tecnología (FACET) – Universidad Nacional de Tucumán (UNT))

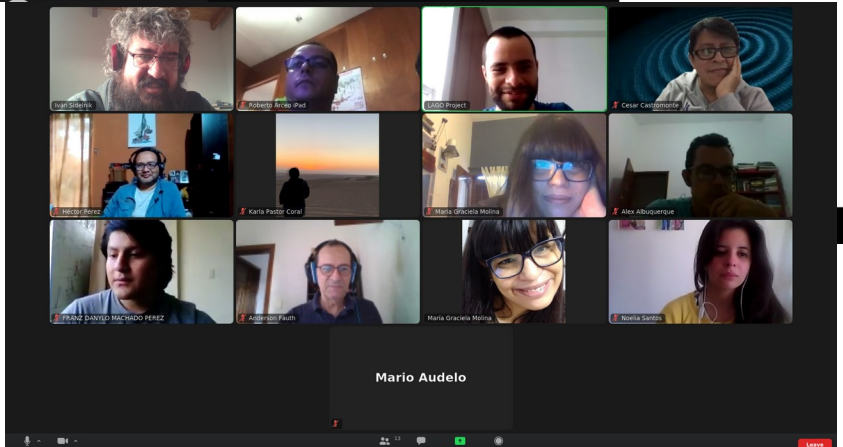
- Maria Graciela Molina
- Ticiano Torres Peralta
- Juan Ise

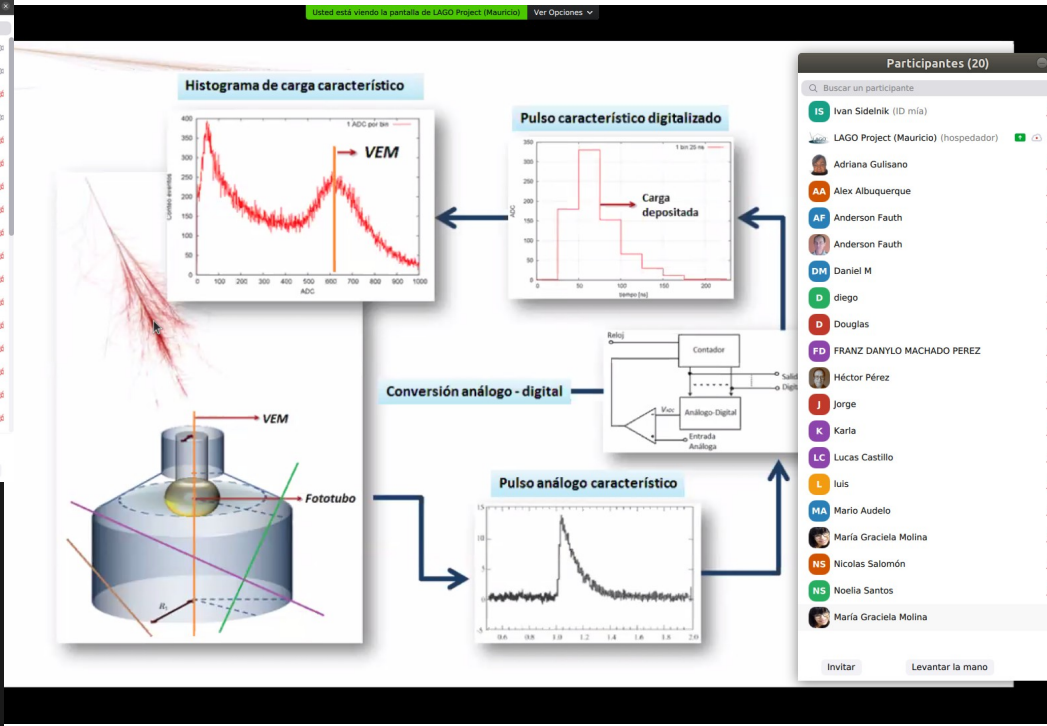
Scientific Comitee

- Hernán Asorey (Instituto de Tecnologías en Detección y Astropartículas (ITeDA), Centro Atómico Constituyentes, CNEA/CONICET/UNSAM, Buenos Aires, Argentina.)
- Iván Sidelnik (Departamento Física de Neutrones, Centro Atómico Bariloche, CNEA/CONICET, San Carlos de Bariloche, Argentina)
- Sergio Dasso (Instituto de Astronomía y Física del Espacio, IAFE (UBA-CONICET))
- Anderson Fauth (Universidade Estadual de Campinas [IFGW])
- Luis Nuñez (Universidad Industrial de Santander [UIS])

LAGO Universities – Virtual data analyses workshops







2020-2021-2022
Virtual workshops and working groups meetings
Trough the network

LAGO Universities

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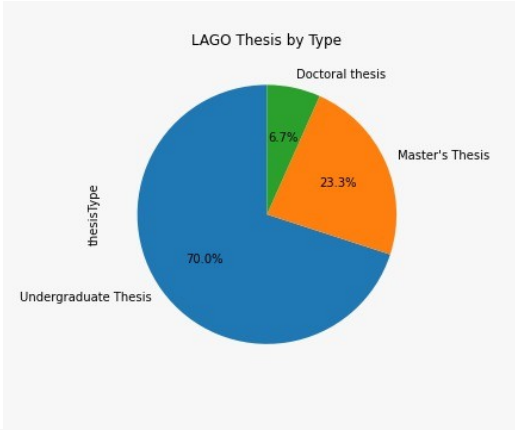
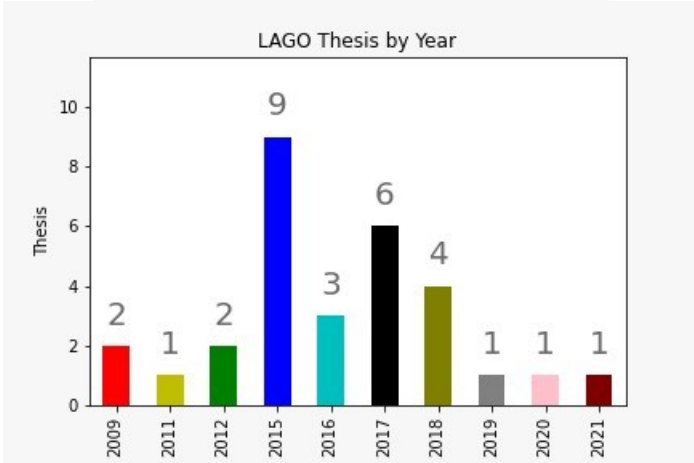
LAGO Thesis

Title	Author [*Director*]	Thesis Type	School	Year
Caracterización de perfiles atmosféricos para la cadena de simulación de la colaboración LAGO	Grisales-Casadiegos, J. [ ]	Undergraduate thesis	Escuela de Física, Universidad Industrial de Santander, Bucaramanga, Colombia	2019
Estimación de la respuesta de un detector Cherenkov de agua al fondo de rayos cósmicos en Bucaramanga(956 m s.n.m)	Jaimes-Motta, A. [ ]	Undergraduate thesis	Escuela de Física, Universidad Industrial de Santander, Bucaramanga, Colombia	2018
Procedimiento de instalación, calibración y sincronización del arreglo de detectores cherenkov de agua (guane), para la detección y estudio de rayos cósmicos en Bucaramanga	Hernández-Barajas SP, León-Carreño YF. [ ]	Undergraduate thesis	Escuela de Ingeniería Eléctrica, Electrónica y de Telecomunicaciones , Universidad Industrial de Santander, Bucaramanga, Colombia	2018





30 thesis / 44 publications / 15 astroparticle schools in LA

efficiency: (scientific production / investment) tends to infinity

I. Sidelnik for LAGO, LAS4RI forum, 2020

LAGO Universities

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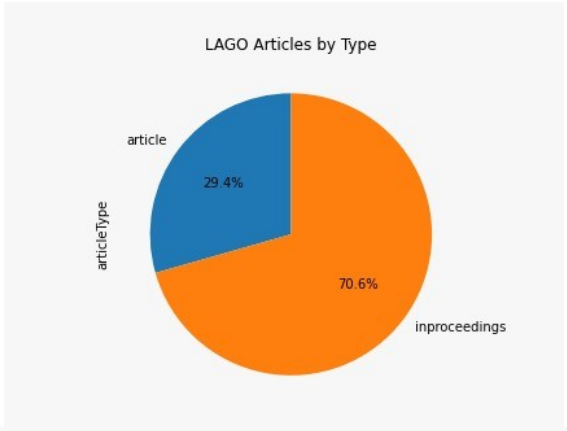

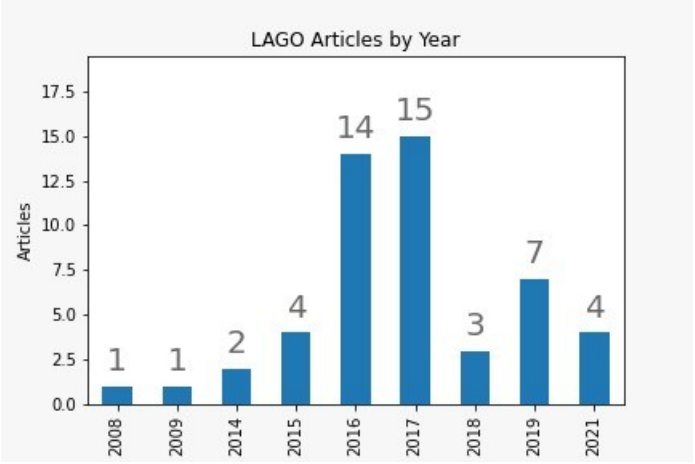

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I. Sidelnik for LAGO, LAS4RI forum, 2020

LAGO Virtual

Own designed hierarchical data analysis and virtualized docker-based tools

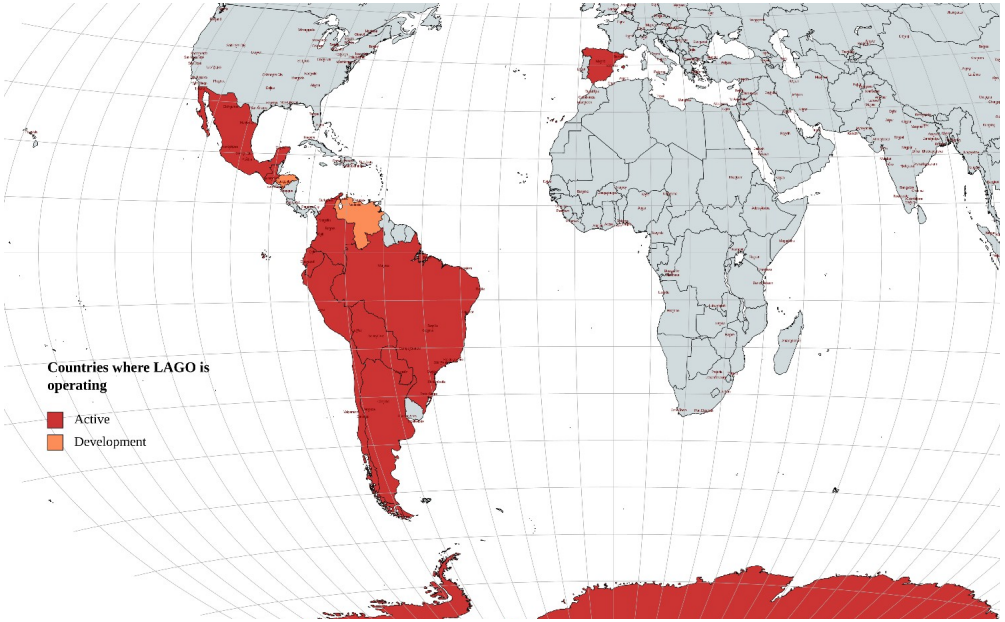
Measured: 2 TB/year-detector. 4 quality levels: L1: raw data, L2: preliminary, L3: Data Quality, L4: High Quality.

L. Otiniano, https://indi.to/P7x8x

Simulated: Up to 1 PB (estimated), EOSC-Synergy thematic service lead by CIEMAT: S0: raw data, S1: simulated and modulated particles at ground, S2: simulated signals at detector level.

Data is transferred to the central repository and is mirrored to several sites (+ each site has its own local data)

H. Asorey, Red Clara symposium, 2021



LAGO Capabilities: Multi-spectral analysis

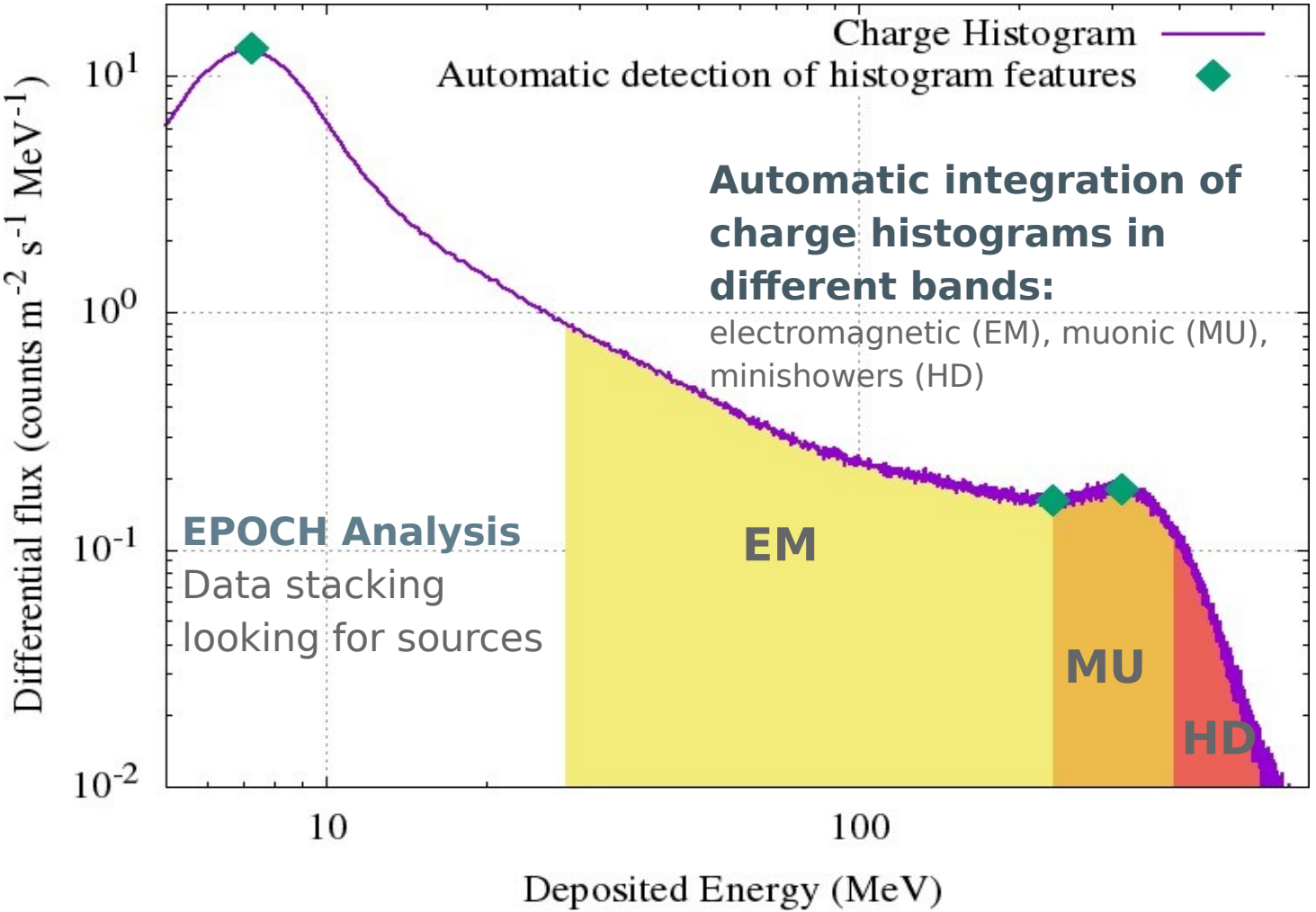
- Simultaneous measurements of secondaries at ground level
- Intensive simulation and data analysis frameworks

Connections

CR Flux	$\xrightarrow{\text{Astrophysics transients}}$	Modulated flux $\cdots$
$\cdots$ Modulated flux	$\xrightarrow{\text{Geomagnetic field}}$	Primaries $\cdots$
$\cdots$ Primaries	$\xrightarrow{\text{Atmospheric conditions}}$	Secondary particles $\cdots$
$\cdots$ Secondary particles	$\xrightarrow{\text{Detector response}}$	**Signals**

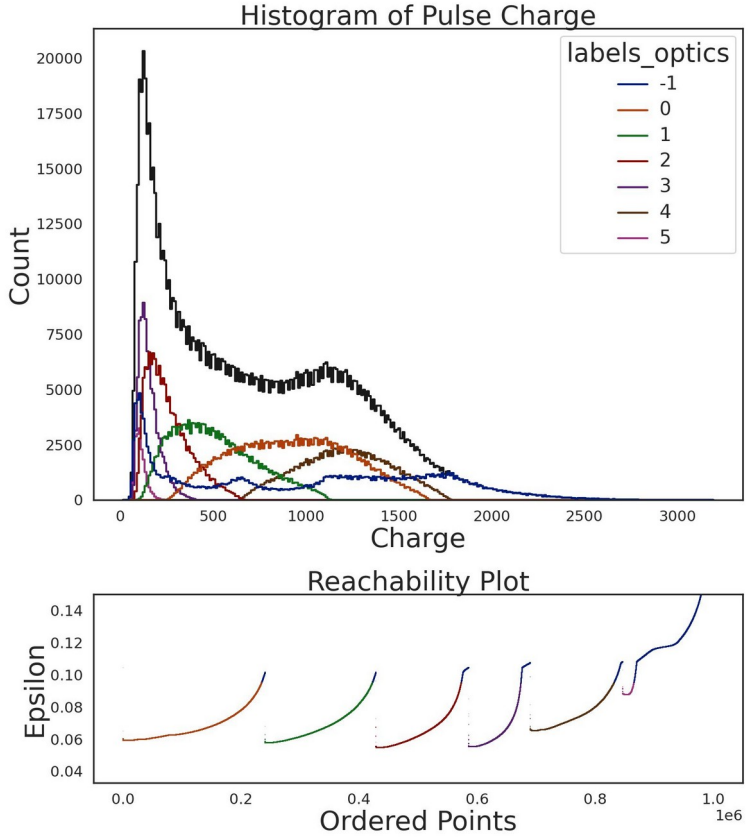
Synergy

Flux variation of signals at detector level$\Leftrightarrow$Transients


Charge Histogram
Automatic detection of histogram features
Automatic integration of charge histograms in different bands:
electromagnetic (EM), muonic (MU), minishowers (HD)
EPOCH Analysis
Data stacking
looking for sources
EM
MU
HD
Differential flux (counts m-2 s-1 MeV-1)
Deposited Energy (MeV)
10
100
10^1
10^0
10^-1
10^-2

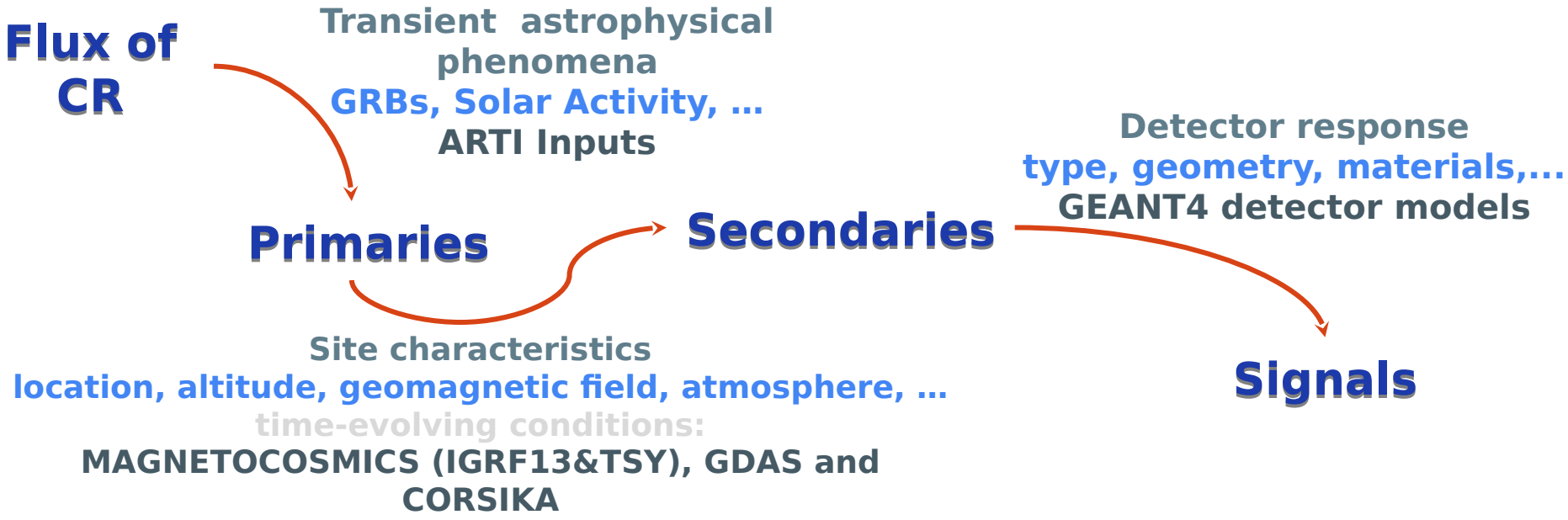
Machine learning applied to particle classification

Applied hierarchical density-based clustering algorithm Ordering Points To Identify Clustering Structure (OPTICS).



T. Torres Peralta, Machine learning applied to particle classification in LAGO Water Cherenkov Detectors, https://indi.to/2x43y

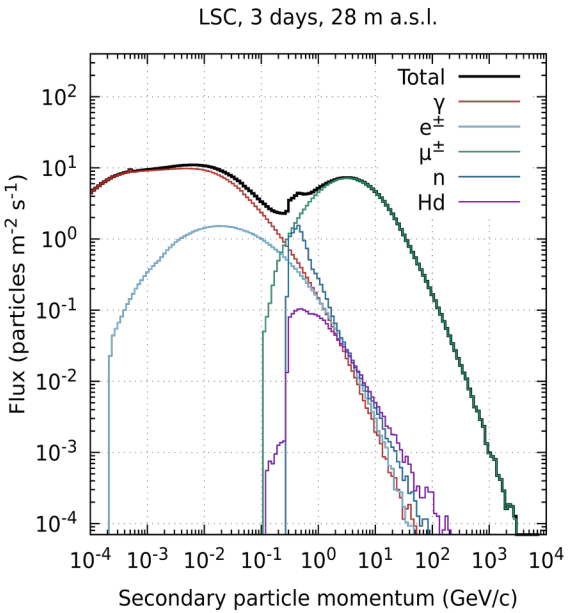
ARTI, the LAGO simulation framework

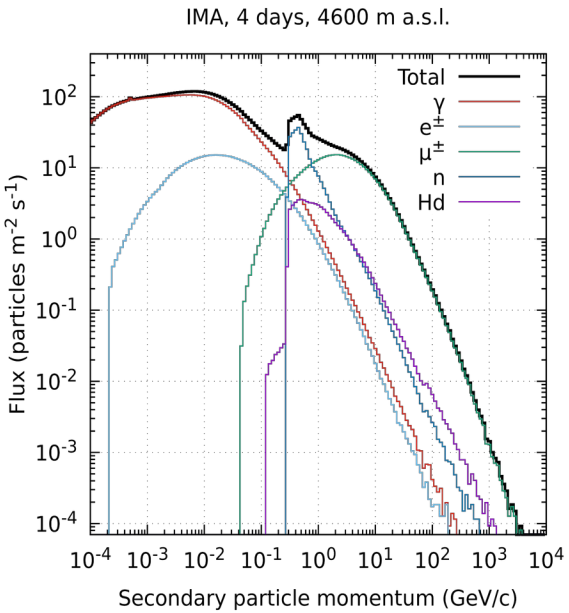


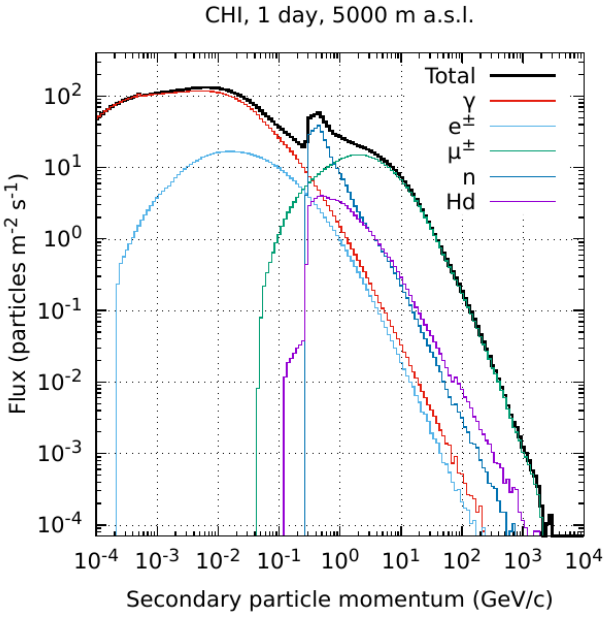
ARTI inputs —`do_sims`→ **S0: raw Corsika** —`do_showers`→ **S1: secondaries** —`do_signals`→ **S2: signals**

The EOSC-Synergy cloud services implementation for the Latin American Giant Observatory (LAGO), H. Asorey et al, PoS(ICRC2021)261 **,A novel cloud-based framework for standardized simulations in the Latin American Giant Observatory,** A. J. Rubio- Montero, et. al., WSC ‘21

1st run: >10^{11} sim EAS in 150 kh·proc (now 500 kh·proc)







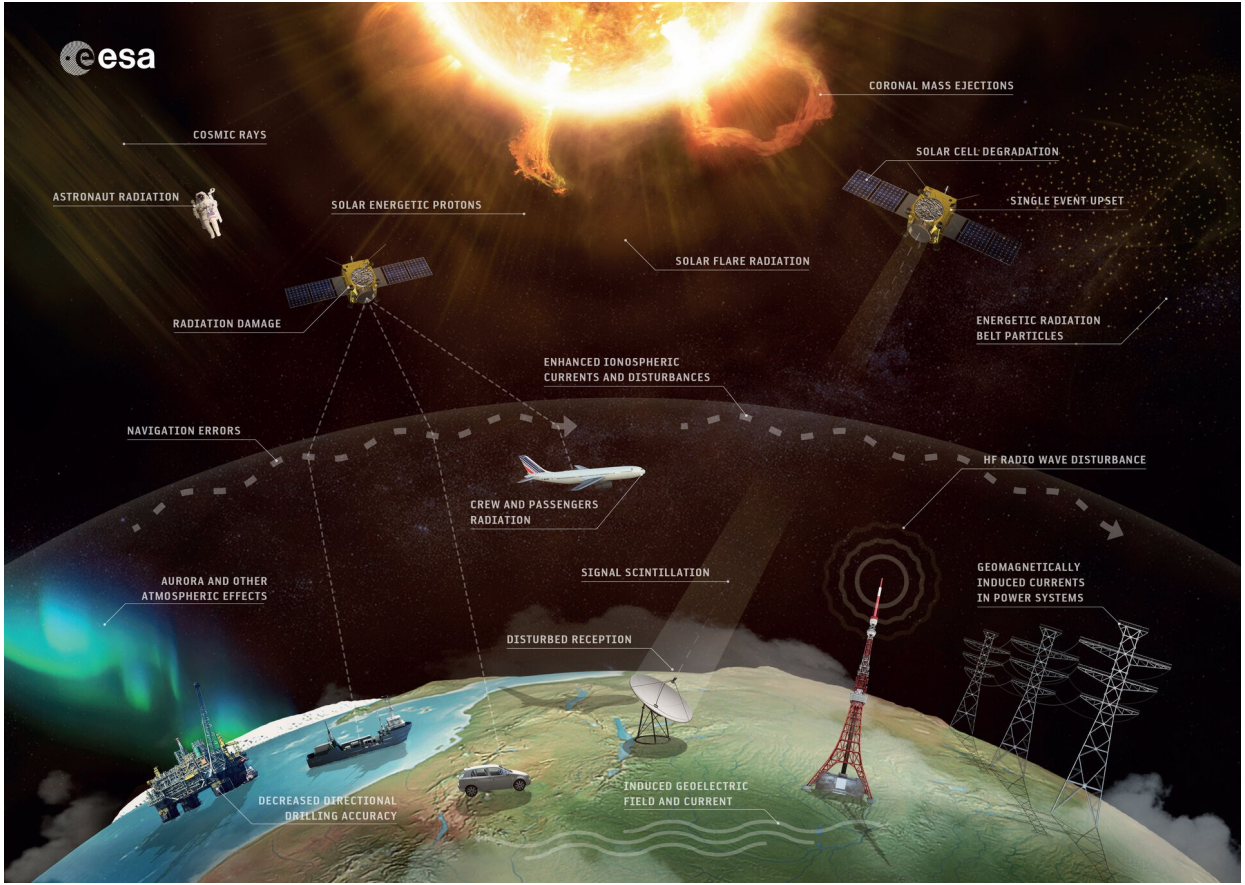
Detailed flux of of secondary particles at detector level for all LAGO sites and other locations **around the World.**

The EOSC-Synergy cloud services implementation for the Latin American Giant Observatory (LAGO), H. Asorey et al, PoS(ICRC2021)261 **A novel cloud-based framework for standardized simulations in the Latin American Giant Observatory,** A. J. Rubio- Montero, et. al., WSC '21

LAGO SW

LAGO studies Earth-Sun connection by measuring the time-evolving secondary signals from ground level. Atmospheric and geomagnetic conditions are continuously monitored

H. Asorey et al, PoS(ICRC2015)142



LAGO SW

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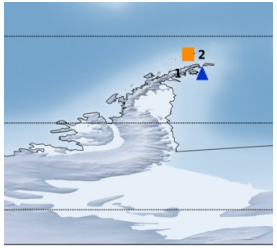
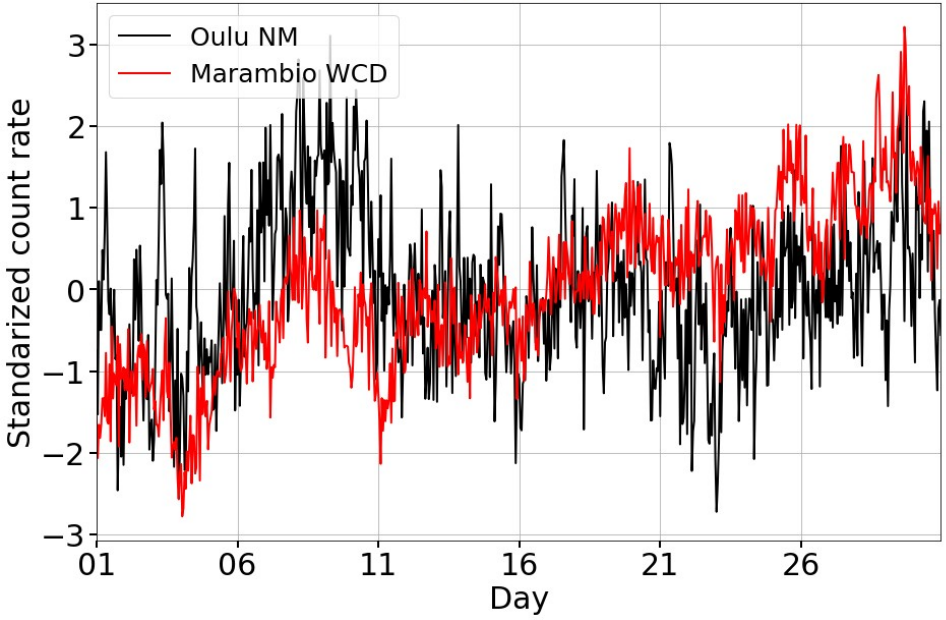
Antarctic dedicated SW sites

LAGO SW

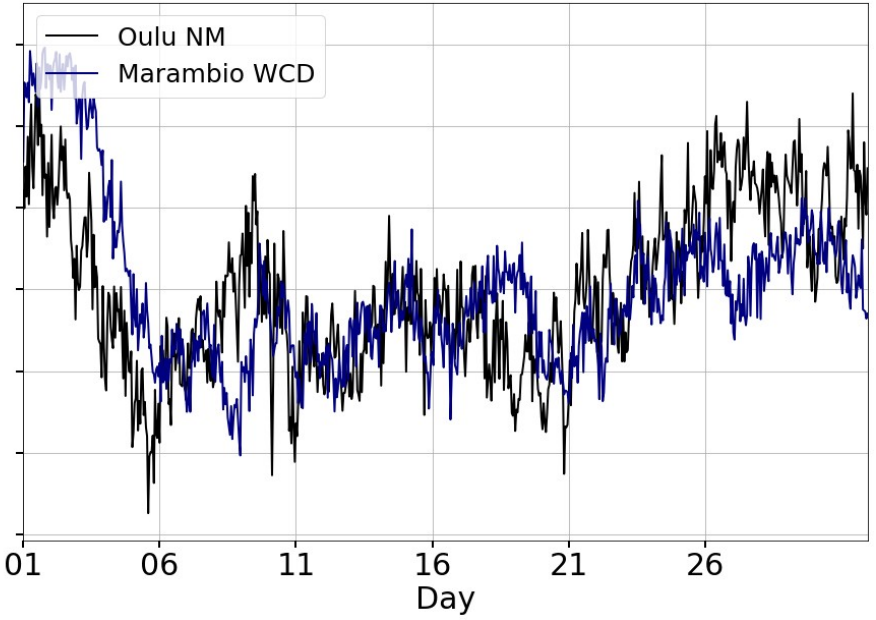
Long term analysis for space climate at low rigidity sites: LAGO observations at the Antarctica Peninsula (N. Santos et al, PoS(ICRC2021)304)



April 2019



December 2020



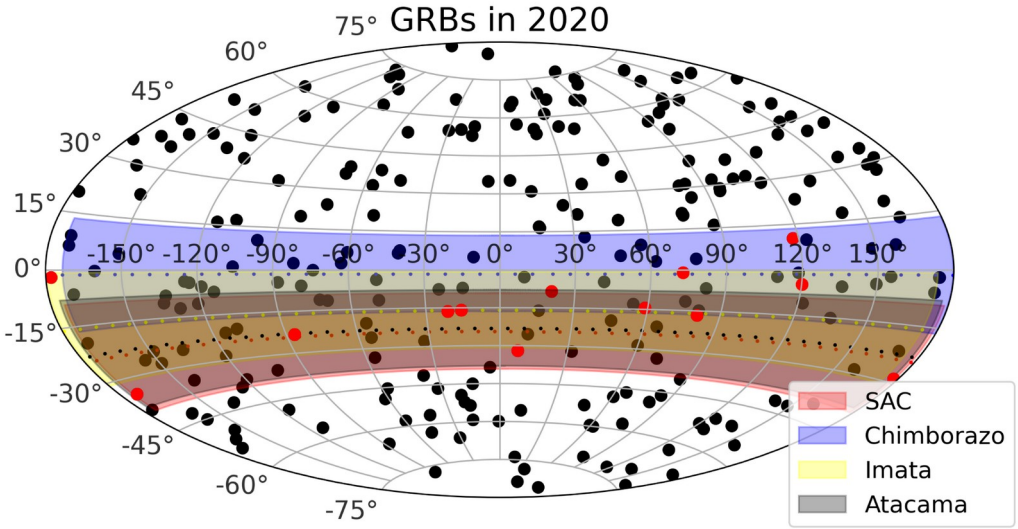
LAGO HE program

New high altitude site projects!

Small arrays of WCD at very high altitude sites (<4500 m asl)

FOV overlapped by design for simultaneous measurements

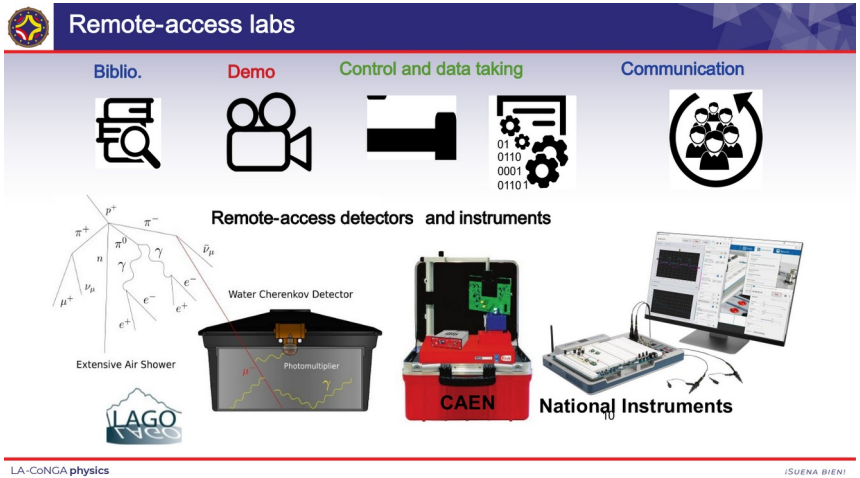
- **Mt. Chimborazo @ Ecuador (ESPOCH) [Just started]**
- **Atacama @ Chile (Apex site) [application for funding ongoing]**
- **Imata @ Perú**
- **San Antonio de los Cobres @ Argentina**

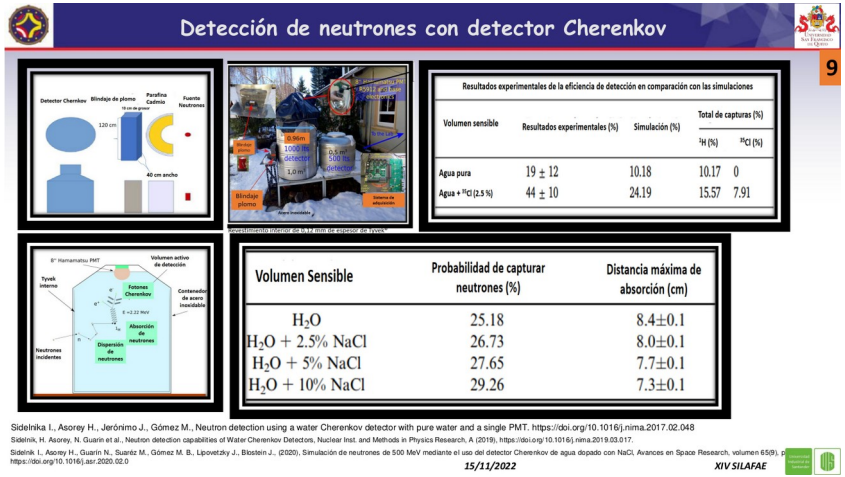


Ch. Sarmiento et al, LAGO studies to detect Gamma-Ray Burst and High Energy Astrophysics sources using water Cherenkov detector arrays. https://indi.to/hK9p6

LAGO Spin-offs: LA-CoNGA

Open science education collaboration between Latin America and Europe.





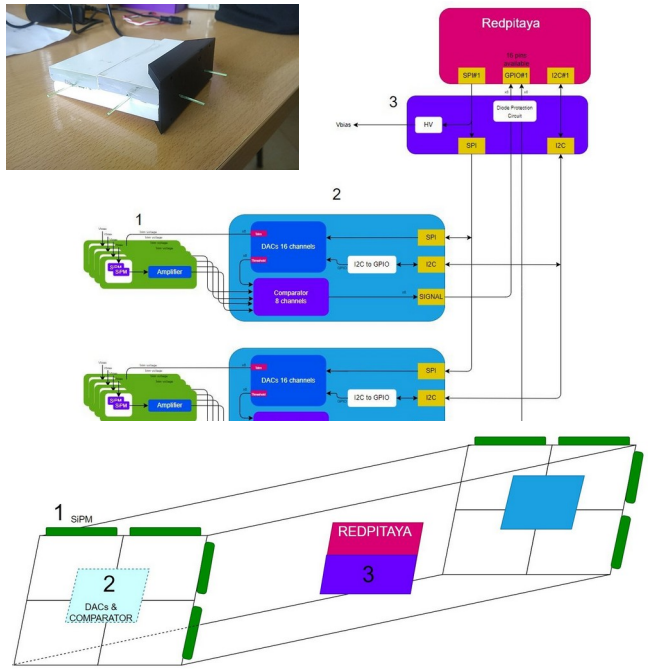
D. Cazar, LA-CoNGA physics: a case study for open science education collaboration between Latin America and Europe, https://indi.to/BxZFS.

J. Betancourt, Measuring soil moisture level using cosmic rays neutron detectors, https://indi.to/pLmPn

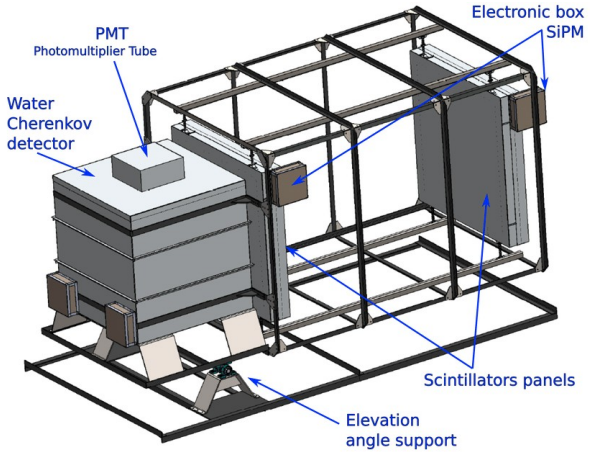
LAGO Spin-offs: Muography

Modified LAGO simulation chain

One-year averaged flux of high-energy secondary particles at ground (p S > 800 GeV/c)



C. Castromonte, Status of the construction of a Muon Tomography Detector for the Study of Geophysical Objects, https://indi.to/HJ3bg



J. Peña-Rodríguez, Design and construction of MuTe: a hybrid Muon Telescope to study Colombian volcanoes

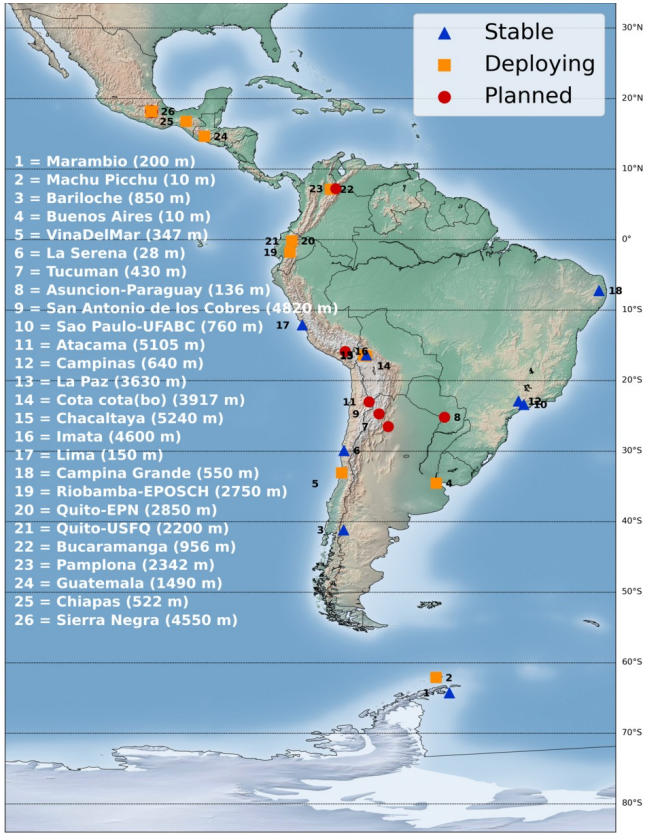
Conclusion

- **LAGO major activities are focused in Latin America**
- Long base **WCD** array **from Mexico to Antarctica**
- High and low altitude sites that allow us to perform space weather, high energy physics and background radiation measurements
- Complete simulation chain from the primary cosmic rays flux to signal at the WCD
- Multispectral analysis
- **New sites @ Latin America with projects and fund requested**

- **Local and regional integration of universities and institutes**
- Student training in high energy physics @LA: schools and experiment @ different sites
- **Very active LA community with several project funded and ongoing @ different institutions**

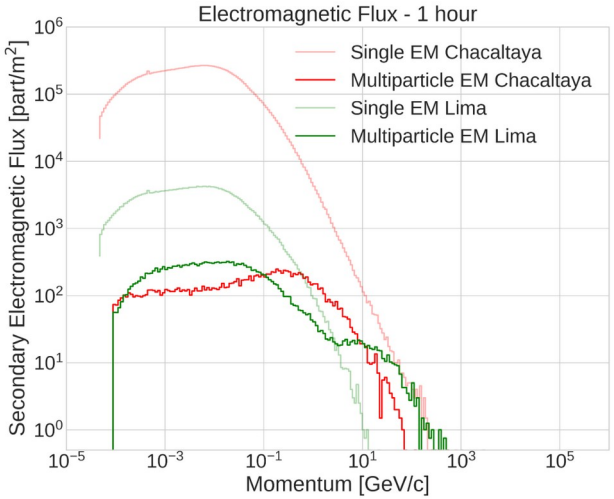
LAGO constitutes a **Latin American** network of students and researchers in astroparticle and high energy physics

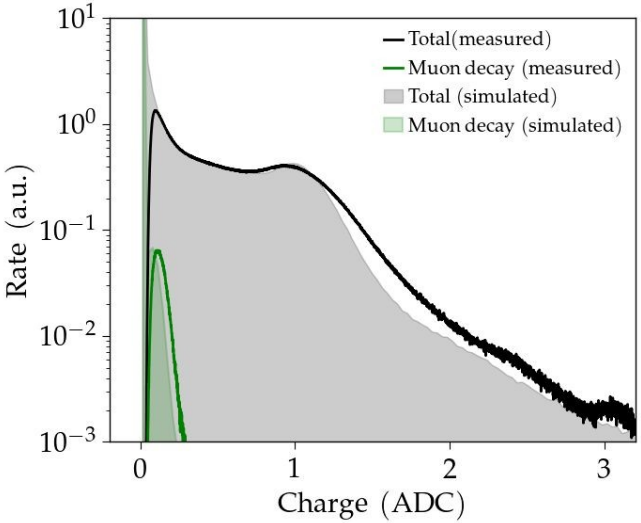
¡Gracias!



Latin America Giant Observatory
lagoproject.net

LAGO
Multiparticles





L. Otiniano
/https://pos.sissa.it/395/267/pdf