The Latin American Giant Observatory (LAGO) Project

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Overview

The Latin American Giant Observatory

The LAGO Collaboration

The LAGO Collaboration

- 99 members from 30 institutions in 11 countries: Argentina, Bolivia, Brasil, Chile, Colombia, Ecuador, Guatemala, México, Perú, Venezuela and Spain.
- LAGO is developing a network of cosmic ray detectors based on Water Cherenkov Detectors
- LAGO detectors span 90° latitude (from Mexico to Antartica) and 5230 meters of altitude (from 10 to 5240 masl).

The Latin American Giant Observatory

Goals & Activities

Scientific goals

- Astroparticle physics to study the Extreme Universe (EU)
- Transient and long term Space Weather phenomena trough Solar modulation of Cosmic Rays (CR)
- Measurements of background radiation at ground level

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Academic goals

- To Train Latin American students in HE and Astroparticle physics
- To Build a LA network of Astroparticle researchers

How does it works?

- Non-centralized, collaborative network of institutions and scientists
- 3 working groups, 9+2 members coordination committee, 1 P.I.
- Developments, expertise and data are shared across the network.
- Scientific goals are developed by dedicated LAGO working groups.
- Academic goals are developed trough Network schools and internships.

Working groups

- Physics (GRBs & Space Weather)
- Data (Simulation & Analysis)
- Detectors (Design & Construction)

Origins

- LAGO project was born as "spin-off" of Pierre Auger Observatory Mendoza (ARG).
- Researchers of LAGO were trained at PAO.
- First PMTs and electronics were recycled from PAO.

Scope of the Talk

In this talk we are going to describe the development of a low-budget WCD for LAGO project and future perspectives.

Water Cherenkov Detector

Block Diagram

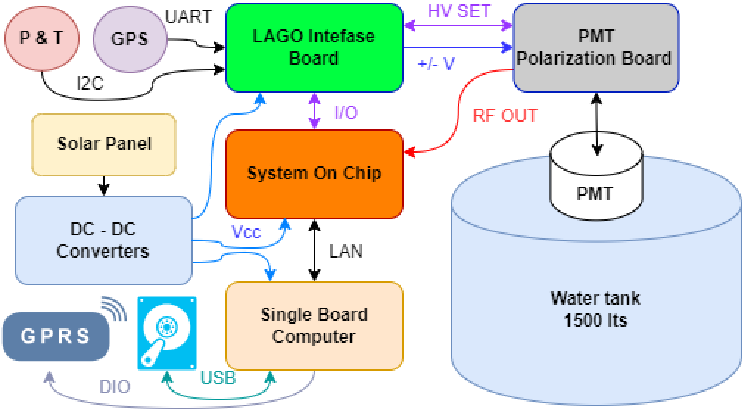

Figure: Block diagram of an autonomus LAGO WCD

Water Cherenkov Detector

Water tank

Characteristics

- Commercial PVC water tanks are commonlly used (1 to 2.5 sqm).
- External coating to reflect sunlight is mandatory.
- Internal coating with high diffusive and reflective material is used (Tyvek®), $r = 0.97$ at $400nm$.
- Tank detection area $A_{Tank} = 1.58m^2$
- Ultra pure water is used after filtering and adding H_2O_2 ($10ppm$) to ensure transparency for a long period of time, $t = 0.99$ at $400nm$.

Water Cherenkov Detector
Photomultiplier

Characteristics

- 8" Photomultiplier 10 stages (Hamamatsu R5912).
- Quantum Efficiency $QE = 25\%$ at $400nm$.
- Detection area $A_{PMT} = 380cm^2$.
- Anode and last dynode signals used to enhance dynamic range.
- LAGO designed a board to power, control and signal conditioning.
- Isolating PMT polarization board from moisture and condensation is crucial.

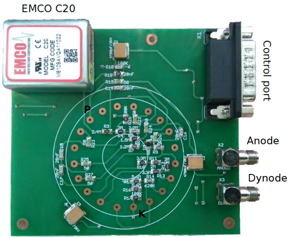

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Photo-electrons produced inside the tank

$$N_{pe} = N_{phot/cm} \times H \times QE \times \left(\frac{A_{PMT}}{A_{Tank}} \right) \times r \times t$$

Where:

- $N_{phot/cm}$ = amount of Cherenkov photons per cm [320].
- H = water height in cm.
- QE = PMT Quantum Efficiency.
- A_{PMT}/A_{Tank} = ratio between PMT detection area and Tank detection area.
- r = internal coating reflection coefficient
- t = water transmission coefficient.

For the WCD presented here 120 photons/cm are expected

Characteristics

- 2 fast inputs ($\pm 1V$ $1M\Omega$ digitized at $125Msps$, 14 bit).
- 4 slow inputs ($0 - 3.5V$ digitized at $100ksps$, 12 bit).
- 4 analog outputs (($0 - 1.8V$, PWM, 12 bit).
- Xlink System On Chip (Dual-Core ARM Cortex-A9 μP + $FPGA$ Xilinx Zynq 7010).
- Ethernet $1GB$, Wifi, USB 2.0.
- I2C, UART, SPI.

STEM LAB 125-14
cost under 500 EUR.

Data Aquisition System

Interface Board

Characteristics

- $+12V$ 1A input.
- $+12V$, $+5V$, $\pm 3.3V$ outputs.
- PMT HV source output control (0-2.5V ramp).
- PMT HV sense (0 - 3.3V).
- PMT temperature sensor reading.
- Pulse Per Second signal form GPS for synchronization.
- Atmospheric Pressure and Temperature monitoring.

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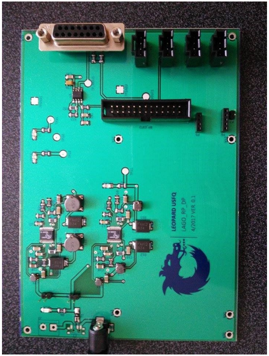
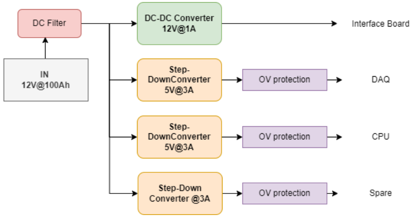


Leopard Interface board cost under 200 EUR.

Characteristics

- $+12V$ at 2A input.
- $+12V$ limited 1A.
- 3 $+5V$ at 3A outputs.
- Over-current protection.
- Isolate Solar panel battery from DAQ system.



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- Designed with commercial modules used for industrial applications
- Meet safety and compliance standards.
- cost under 100 EUR.

Data Aquisition System

Data Storage and Communication

Description

A Single Board Computer (Raspberry Pi 4) is used for configuration, data storage and communication.

Characteristics

- DAQ configuration scripts (PMT setup, trigger, metadata)
- Every hour a text file is saved.
- Wifi /Ethernet data transfer if available.
- GPRS communication (only for system status)
- $1 TB$ Solid State Disk for local storage.

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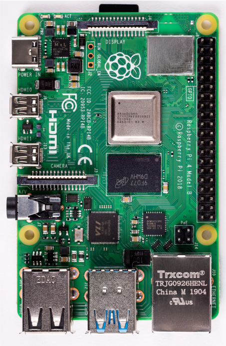
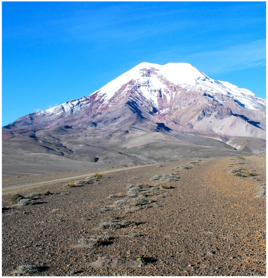
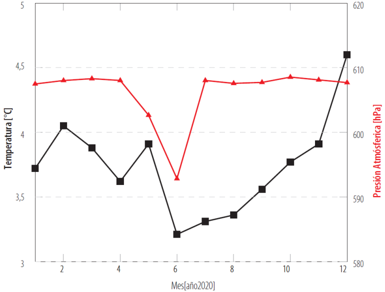


Location

- 2 WCDs installed near Chimborazo volcano at 4330 m.a.s.l.
- Stainless steel tanks will be deployed.





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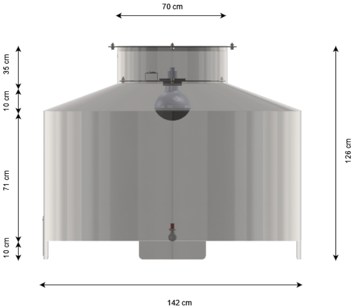
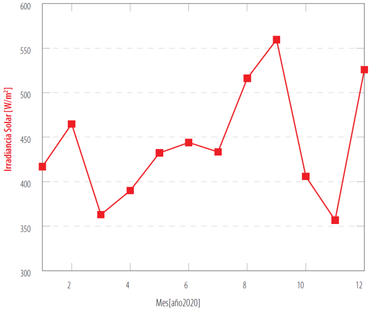
Atmospheric pressure: Max $= 608hPa$, Min $= 598hPa$
Temperature: Max $= 4.6^o C$, Min $= 3.2^o C$

Preliminary studies

Power generation & Communication

- DAQ powered with a $12V$ $100Ah$ solar panel.
- Only GPRS signal is available.





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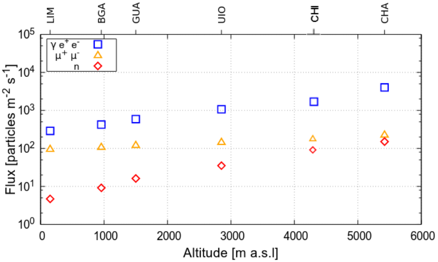
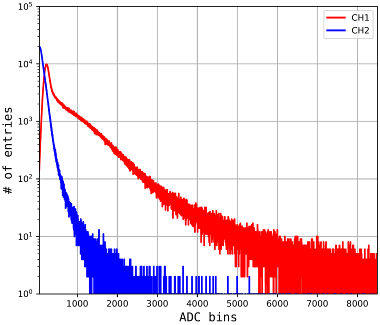
Medium Irradiance expected $450W/m^2$ equivalent to $390W$ at solar panel

Preliminary studies

Particle flux & Signal

- Expected flux simulated with ARTI framework.
- Preliminary data analyzed.





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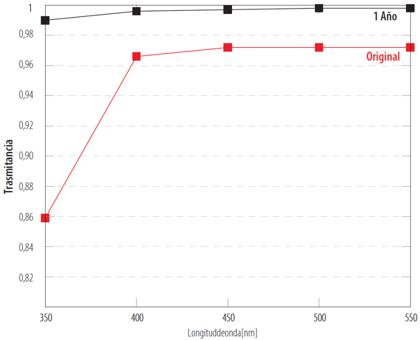
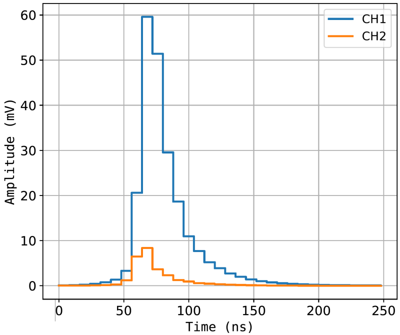
Signal rate expected $2KHz$. PMT HV level and trigger must be fine tuned.

Preliminary studies

Water transparency and Maintenance

- H_2O_2 shock treatment improves water transparency over time
- Time between water change minimum 2 years.





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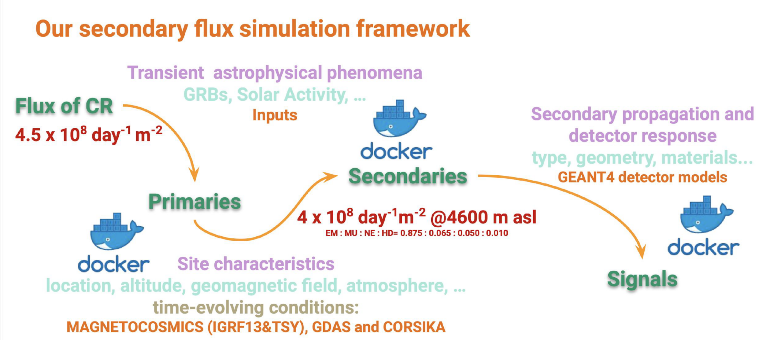
Signal level must be improved.

Simulations

Implementation

- A simulation framework from Primary CR to WCD response ARTI available.
- ARTI is a blend of CORSIKA, MAGCOS and GEANT4



Conclusions

So far

- An autonomous WCD detector can be implemented at low-budget (5K EUR),
- A small array of WCDs located at 4330 m.a.s.l. will be ready by March 2024.

The future

- WCD's performance at low energies could be improved adding a different CR detector.
- **RPC** detectors specially designed to work at high altitude are excellent candidates.

Further information can be found in `www.lagoproject.net`


grazie!