Underground Muon Detector Operations Readiness Review

Malargüe Meeting, 22-27 March 2026

Detailed frame of the Review:

- UMD electronics boards, hardware and on-board software and firmware;
- UMD electrical interfaces and interconnection with SD;
- UMD communications interfaces;
- Detector mechanics;
- UMD Power supply;

The review should assess, but not be limited to, the following issues:

Equipment availability and readiness

- Are components and software fully commissioned, operating reliably, and meeting performance requirements?
- Are all the hardware, power and software interfaces fully functional, compatible and operational?
- Are special tools and testing equipment required for routine maintenance present and available to the Observatory staff?
- Are the most common failures are yet known, understood and have a mitigation plan?
- Is there a long-term plan for component repairs or replacement?
- Has a reliable source for all spare parts, tools, and consumables been identified for future procurements? Are spares available on site as required?

Data Management

- Is UMD data well integrated into the data stream?
- Is the UMD data consistent and reliable?
- Is the communication interface with UUB stable?
- Can CDAS handle the volume of data produced by UMD?
- Is the monitoring of UMD in place and well understood?

Technical Documentation

- Are drawings, schematics, and any other relevant documents complete and posted to CERN EDMS and/or PMS?
- Are instructions for operating and maintaining software code, as well as the code itself, available and organized?
- Is a complete list of equipment and components including part numbers and vendor contact information available?

Procedures. The following procedures must be complete:

- General operation.
- Hardware and software troubleshooting and maintenance.
- Process for handling major repairs.
- Inclusion of safety considerations in all procedures.

Training.

- Has an appropriate number of observatory personnel been trained to operate and provide routine maintenance?

Operations costs.

- Evaluate the annual resources (person-power & costs) required for routine operation and maintenance for each subsystem, including materials and equipment. Discuss anticipated rates of failures and frequency of repairs and replacements.

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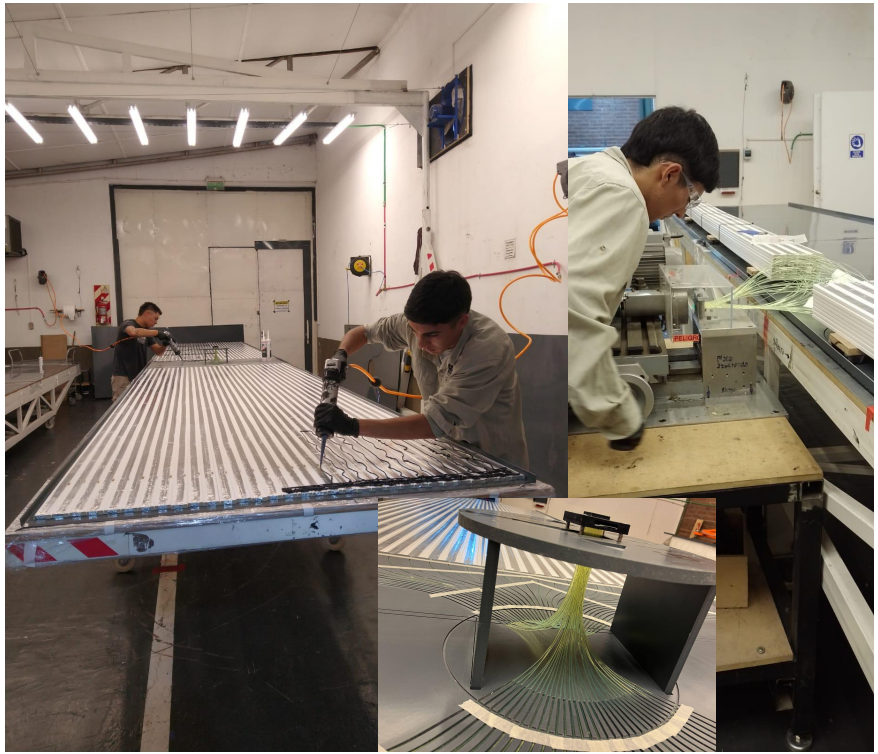
Objective:

The Auger Project Management Plan defines the objective of the Operations Readiness Review as:

"A subsystem only becomes part of the operation of the Observatory when it has passed an Operations Readiness Review. This review ensures that the subsystem is in effective, stable operation, all documentation has been filed, spares are available and the staff has been trained."

The purpose of the review is to determine if the UMD subsystem is ready to be included in the operation of the observatory for science production. Additionally, the review committee should asses if all the necessary resources needed for operation and maintenance are existing and available.

Overview of the Underground Muon Detector



- Modules composed of 64 plastic scintillation bars
- Direct counting of air-shower muons by measuring fluorescence light yield produced by traversing particles
- Silicon photomultipliers as optical sensors

UMD Assembly & Deployment Status

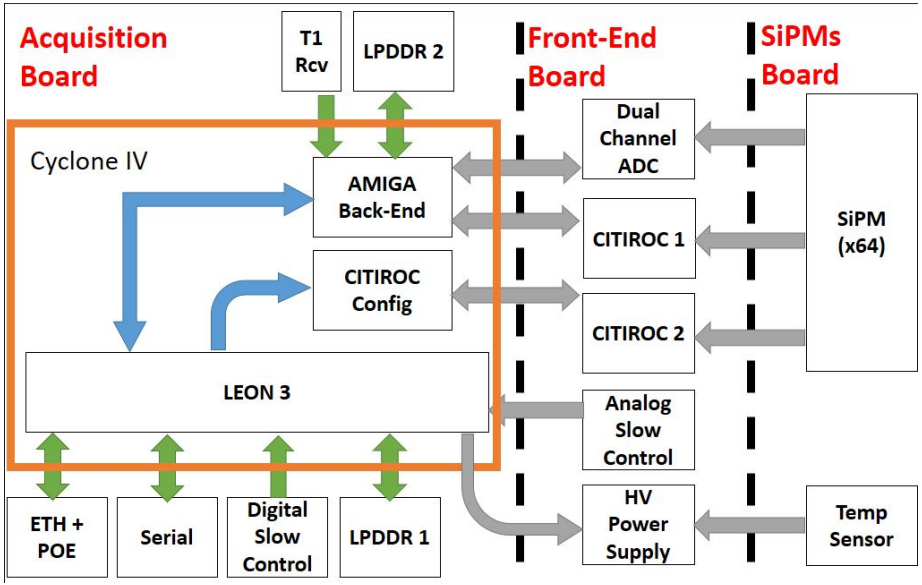
232 modules assembled & deployed:

- 32 @ ITeDA Bs. As.
- 200 @ Malargüe
  - 57 @ AB
  - 143 @ SDECo

Last position deployed on 12-Feb-2026: Gimena (1827)

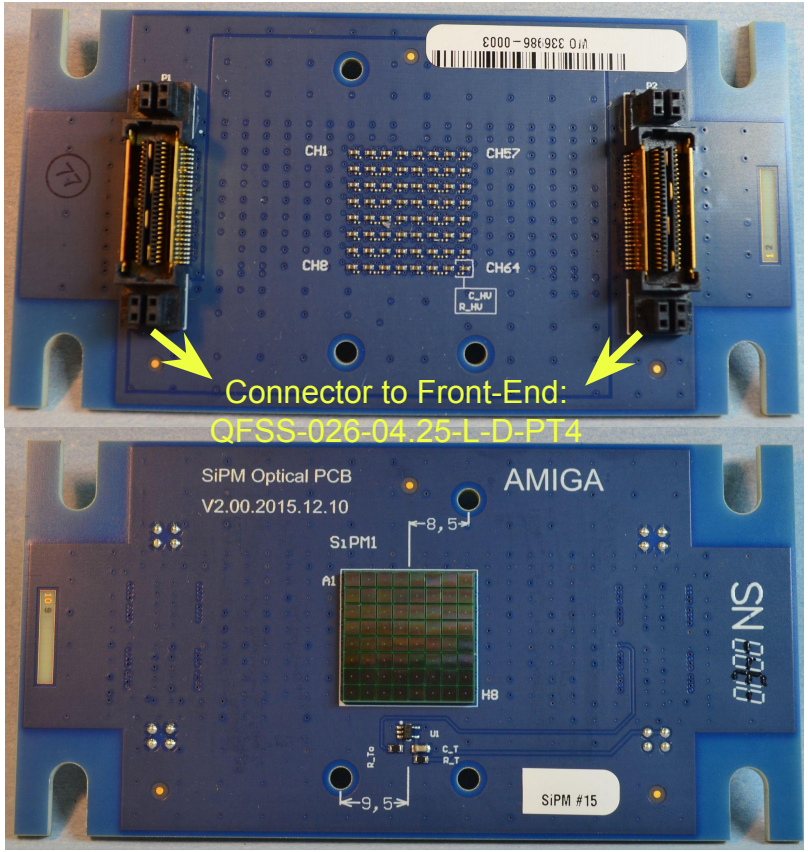
Total Assembled UMDs	Total Installed UMDs	Positions with UMDs	Completion Progress
233	232	72	100.0%

Architecture of the buried electronics (“eKit”)



- Weight-bearing support case and pin support (https://gitlab.ahuekna.org.ar/amiga/mechanical/ekit_mechanics)
- Back-end board (https://gitlab.ahuekna.org.ar/amiga/electronics/umd-electronics/BackEnd)
- Front-end board (https://gitlab.ahuekna.org.ar/amiga/electronics/umd-electronics/frontEndSiPM)
- SiPM board (https://gitlab.ahuekna.org.ar/amiga/electronics/umd-electronics/sipm)

SiPMs Board



64 Channels: 64 silicon photomultipliers based on pixels of single-photon avalanche diodes (SPADs).

Integrated Thermal Monitoring: Includes an on-board temperature sensor to enable real-time **High Voltage compensation in the HV power supply** (see next slide), ensuring stable gain despite temperature fluctuations.

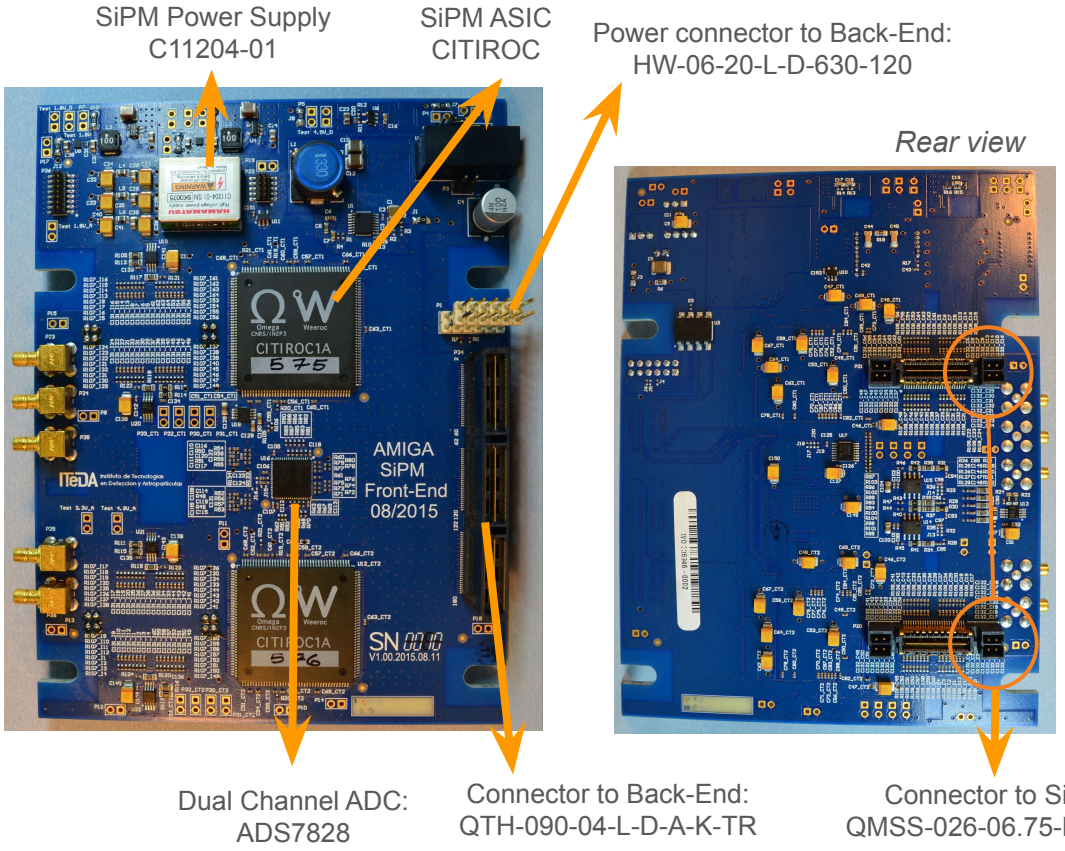
Connectivity: Uses Samtec QFSS connectors to interface with the front-end electronics (CITIROC ASIC).

SiPM model: S13361-2050NE-08.

"Muon counting using silicon photomultipliers in the AMIGA detector of the Pierre Auger observatory", The Pierre Auger Coll., 2017 JINST 12 P03002 10.1088/1748-0221/12/03/P03002

“Design, upgrade and characterization of the silicon photomultiplier front-end for the AMIGA detector at the Pierre Auger Observatory”. The Pierre Auger Coll., 2021 JINST 16 P01026, 10.1088/1748-0221/16/01/P01026

Front-End Board



Core Architecture & Readout

- **Dual CITIROC ASICs:** Manages 64 optical channels with integrated **15 ns fast shapers** designed to match SiPM pulse widths and prevent muon pile-up.

Charge Measurement

- **Dual HG/LG Channels:** Signals are summed and split into High and Low Gain branches continuously **digitized by a 14-bit ADS4246 ADC**.

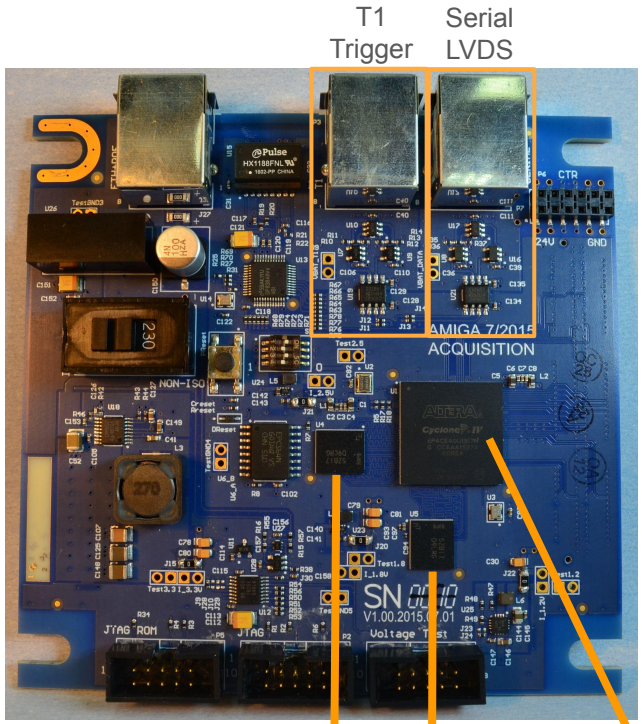
Power & Monitoring

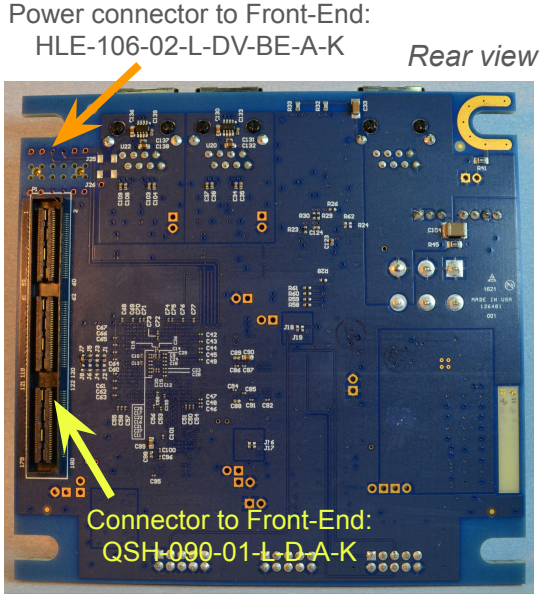
- **High-Efficiency Power System:** Consumption kept **below 2 W** for the entire FEB + SiPM board assembly.

- **Integrated Slow Control:** Uses an **ADS7828 ADC** to monitor all on-board supply voltages and ASIC temperatures in real-time.

“Design and implementation of the AMIGA embedded system for data acquisition”. The Pierre Auger Coll., 2021 JINST 16 T07008, 10.1088/1748-0221/16/07/T07008

Acquisition Board





Core Digital Architecture

- **FPGA-Based Embedded System:** Centered around an **Altera Cyclone IV FPGA** hosting a **LEON3 microprocessor (softcore)** running at 50 MHz.
- **Independent Dual Memory:** Features two physically-separated **1 Gb Low-Power DDR SDRAM** modules; one dedicated to the CPU and the other to the acquisition firmware (UMD data).

Acquisition

- **Trigger Synchronization:** Handles the **T1 Trigger** and clock signals via isolated LVDS lines.

Hardware Efficiency

- **Low-Power Design:** High-efficiency cascaded power system with a total board consumption of only **~1.8 W**.

Software and firmware: Key features

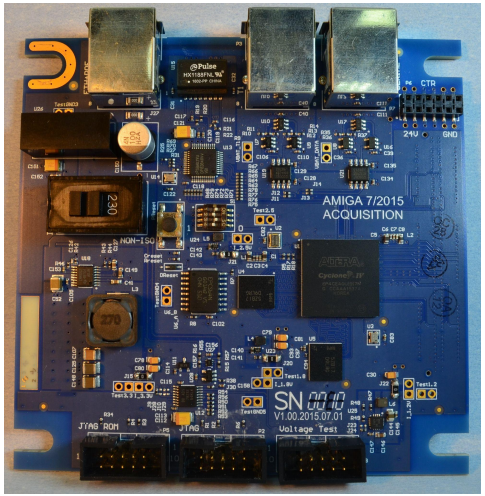
►Software and firmware are organized in three layers: FPGA firmware, boot image (Linux-based), and AMIGA-specific acquisition software

►**Remote upgradability:** FPGA firmware can be updated over the network -> no physical access to the station required

►**Fail-safe mechanisms:** The FPGA firmware includes protection against failed or accidental upgrades

►**Stateless configuration:** eKits boot from the network (PXE); all configuration is assigned dynamically

►**Modular on-board software suite:** covers data acquisition, electronics configuration, slow monitoring, SiPM monitoring, calibration, and analog signal monitoring



These features significantly reduce maintenance burden and on-site interventions

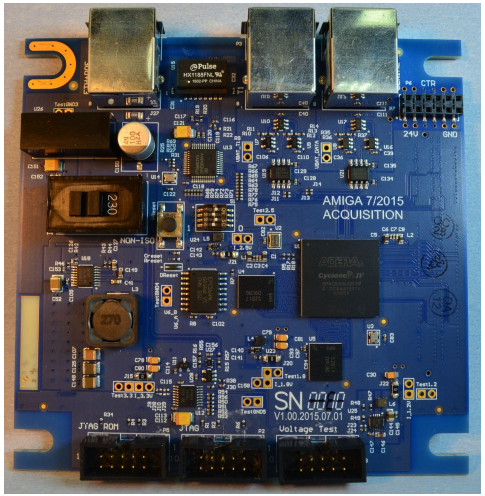
Software and firmware: Technical details

►**FPGA Firmware:** Leon 3 (GPL) + AMIGA-specific code, stored on NOR-FLASH chip; upgraded via Altera Remote System Upgrade over the network

►**Boot image:** Linux kernel 4.9 | GCC + uClibc-ng cross-compiler | Busybox | Dropbear (SSH) | pre-built AMIGA software | netboot image generation script

►**Network boot:** PXE via u-boot; Mikrotik radio acts as TFTP server + DHCP relay; DHCP server located at Auger central hub (Malargüe)

►**Configuration:** fully stateless -> hostname, LSID, and Module ID assigned by DHCP server; remainder handled by AMIGA software



eKit software processes:

`MdCfg`: electronics configuration (single source of truth*)
`MdSend`: data acquisition and transmission
`monitoring_client`: slow monitoring
`backpulse_client`: SiPM monitoring
`ADCT1_client`: integrator/analog signal monitoring
`MdCalib:` calibration listener

* `monitoring_client`, `MdSend` and `MdCalib` communicates with `MdCfg`

Interconnection with UUB: Overview

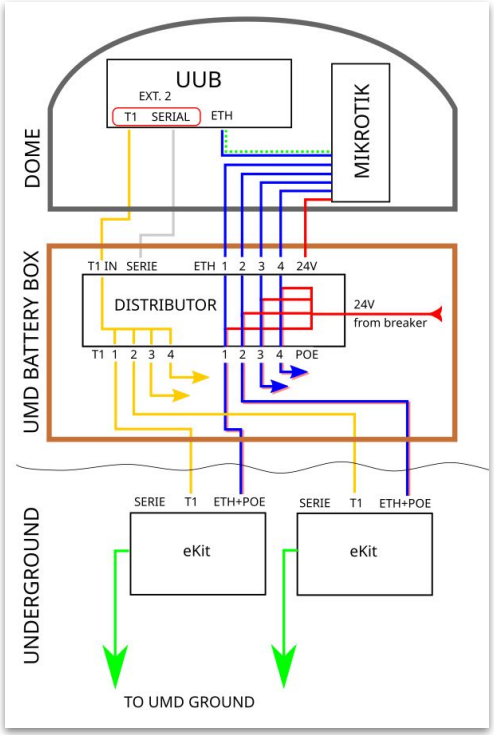
The AMIGA eKit interfaces with the UUB through three key connections: trigger, serial, and network (Ethernet)

►**Trigger:** Upon a T1 condition, the UUB sends a digital trigger signal carrying a Local TimeStamp (LTS) used for T3 matching; a Distributor Board relays this signal to up to 4 boards

►**Serial:** The Distributor Board provides remotely controllable power (Passive PoE) to the eKits via an LVDS serial connection from the UUB

►**Network:** The UUB broadcasts every successful T3 trigger (with its LTS) to the eKits over UDP

►The communication interface with the UUB has been verified to be stable based on T3 matching rate (more info on this later)



Interconnection with UUB: Technical details

The AMIGA eKit interfaces with the UUB through three key connections: trigger, serial, and network (Ethernet)

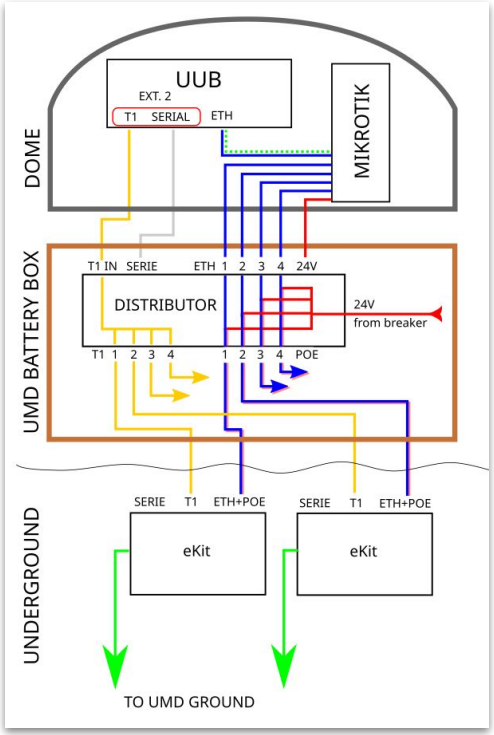
►**Trigger interface:** Uses one of the UUB's internal extension ports; a custom add-in board adds LVDS protections and outputs the T1 signal through a standard 8P8C (RJ45) jack

►**Trigger signal format:** Well-documented and reusable by other experiments requiring an external trigger (e.g., MARTA)

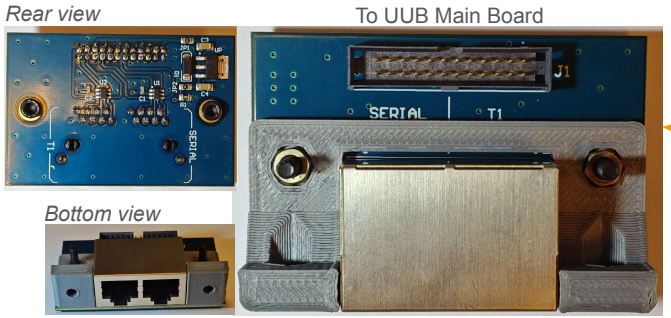
►**Passive PoE:** The Distributor Board injects 24 V from AMIGA's own power supply into the Ethernet cables feeding the eKits (blue (+) and brown (−) pairs; compatible with legacy Ubiquiti/Mikrotik Passive PoE standard)

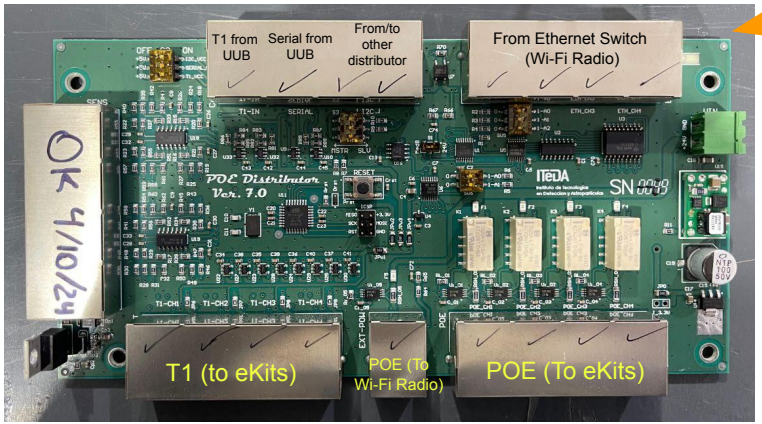
►**T3 broadcast:** Covers all Window 0 triggers and any other triggers for which the UUB successfully matched the LTS

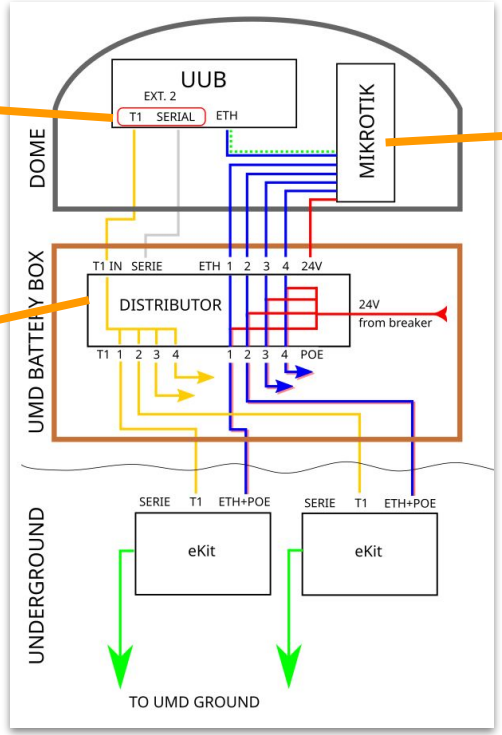
►**Ground scheme:** AMIGA 0 V connected to UUB 0 V (shared battery ground); AMIGA radio and Distributor Board chassis tied to UUB chassis/safety ground via Ethernet shielding.



Interconnection with UUB: Technical details







- ESD protection in all boards
- T1/Serial port handled by the UUB firmware, letting us turn on/off single modules remotely

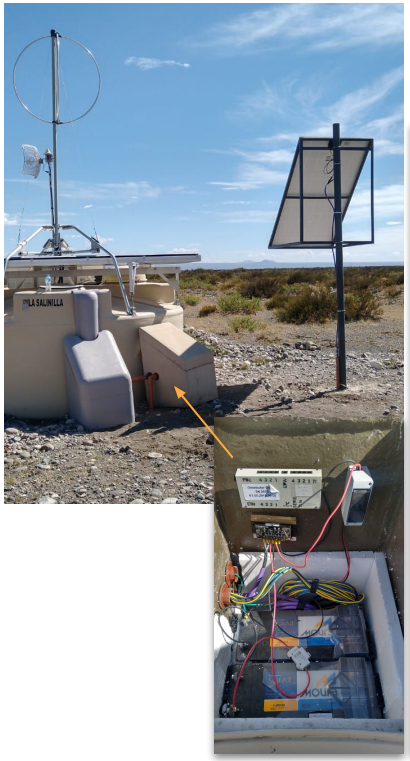
Repositories:
https://gitlab.ahuekna.org.ar/amiga/electronics/surface/uub-interface.git
https://gitlab.ahuekna.org.ar/amiga/electronics/surface/distributorboard.git

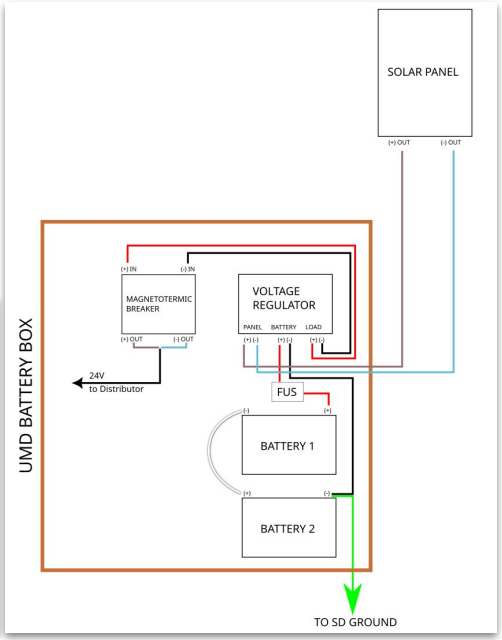
Power supply

► Each UMD station is powered by a **standalone 24 V solar system**, shared with the WCD, feeding a charge regulator, which charges **two 12 V lead-acid batteries connected in series.**

► A thermal breaker and fuse provide **overcurrent protection** before the 24V output is routed to the distributor.

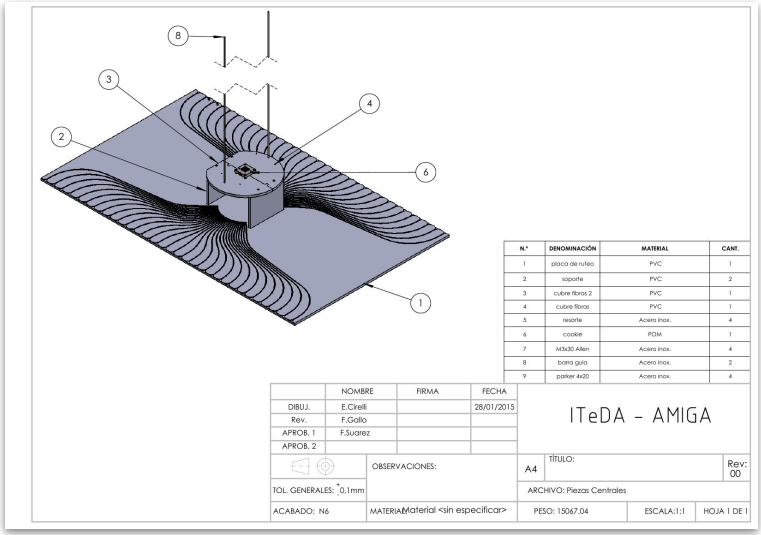
Component	Model	Deployed	Stock
Battery	Victron AGM Deep Cycle 12·165	36	0
Battery	Moura Clean Nano 12MF150	70	3
Battery	Moura Clean 12MF175	4	5
Battery	Moura VRLA 12MVA-150	10	0
Battery	Moura Solar MS 12MS162	4	21
Charge Regulator	Morningstar SS-10L 24V	62	29
Solar Panel	ATERSA 280W	51	19
Solar Panel	ATERSA 170W	5	60

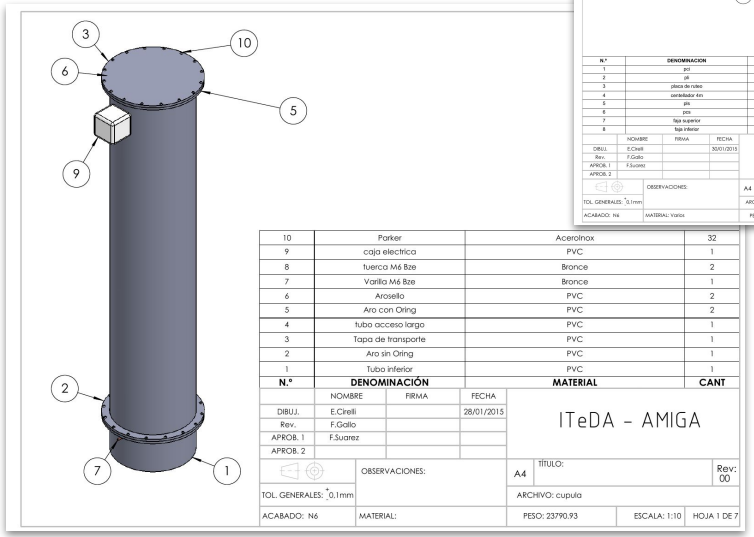


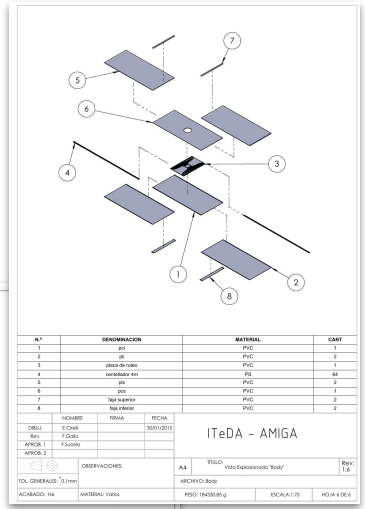


Mechanics

- Collection of mechanized components used in the assembly of UMD modules
- We include the machining files in .mcx and .dwg







https://gitlab.ahuekna.org.ar/amiga/mechanical/detector_module.git

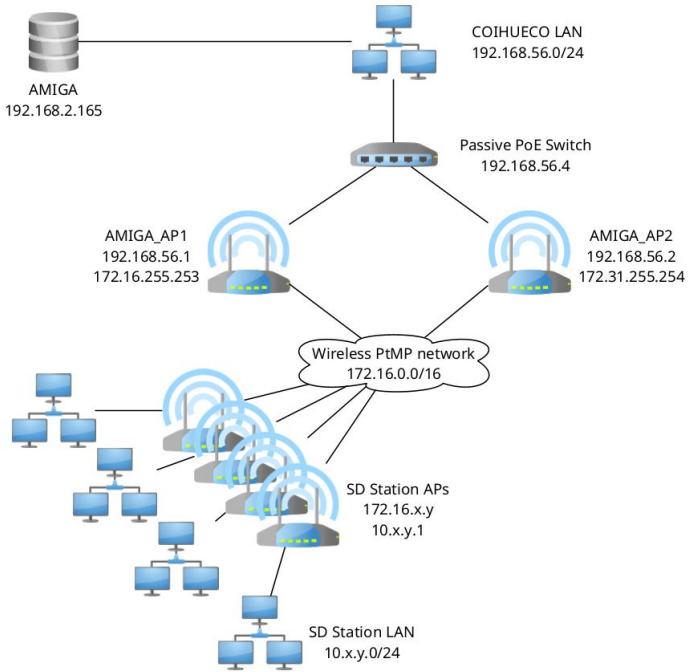
Telecommunications: Overview

► The AMIGA/UMD telecommunications system is based on a **Point-to-Multipoint (PtMP) wireless network** operating over the 802.11n standard, using Mikrotik commercial radios.

► The network infrastructure is centralized at the **Coihueco mast**, which serves as the main access point for the array. A **cold spare radio** provides redundancy.

► Station-side radio configuration is **fully automated via deployment scripts** using the radio's network address and hostname (Station Name).

► All deployed radio models currently have **active firmware support from Mikrotik**, ensuring long-term software maintenance coverage.



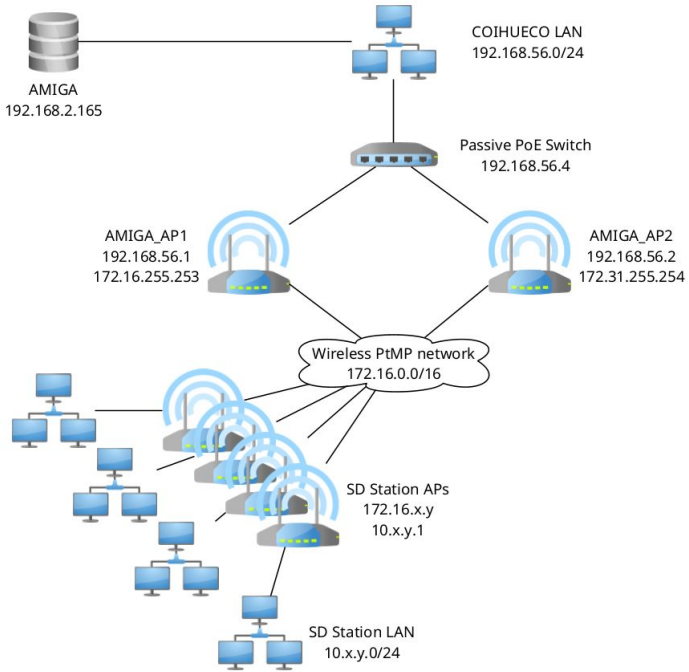
Telecommunications: Technical details

Three radio generations deployed (all Mikrotik):

- ►*RB493A:* First-generation radio; only present in a few Unitary Cell positions; **discontinued**.
- ►*RB493AH:* Most widely deployed model, including at Coihueco; **discontinued**.
- ►*hAP ac (RB962UiGS-5HacT2HnT):* Current replacement model; 5 Ethernet ports (vs. 9 in previous models); supports all positions **except twin stations**; reports of **elevated RF noise emissions** by the RD working group.

Firmware upgrade constraints:

- ►Some RB493A units will require an **on-site field trip** for their next firmware upgrades.
- ►hAP ac units **cannot be upgraded remotely**.
- ►Coihueco radios require **special care during upgrades** due to the high impact of any failure at that node.



Network topology: AMIGA backbone at 192.168.2.165, Coihueco LAN at 192.168.56.0/24, wireless PtMP network at 172.16.0.0/16, SD Station LANs at 10.x.y.0/24.

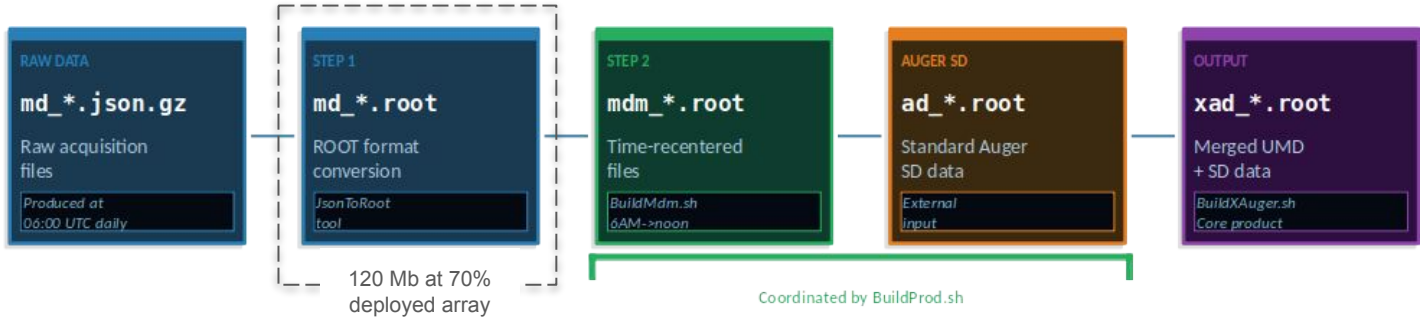
Coihueco hub: Two Mikrotik radios (AMIGA_AP1 at 192.168.56.1 / 172.16.255.253 and AMIGA_AP2 at 192.168.56.2 / 172.31.255.254) managed via a Passive PoE switch (192.168.56.4).

Data stream - md files

► **Data handling mirrors the SD pipeline.** Scripts use standard CDAS tools and follow conventions consistent with the rest of the Observatory's data production chain.

► **One master script running automatically at CNAF on a daily basis**, `BuildProd.sh`, which coordinates the full production chain.

► **The data pipeline consists of three sequential steps:**



- **JSON → ROOT conversion:** Raw UMD acquisition data is stored as compressed JSON files (`md_*.json.gz`), generated daily at 06:00 UTC when the active acquisition file is closed. These are converted into `md_*.root` files using the `JsonToRoot` code based on IoMd library

`/cdas/src/HdTools/script`
`/cdas/src/IoMd`

Data stream - mdm files

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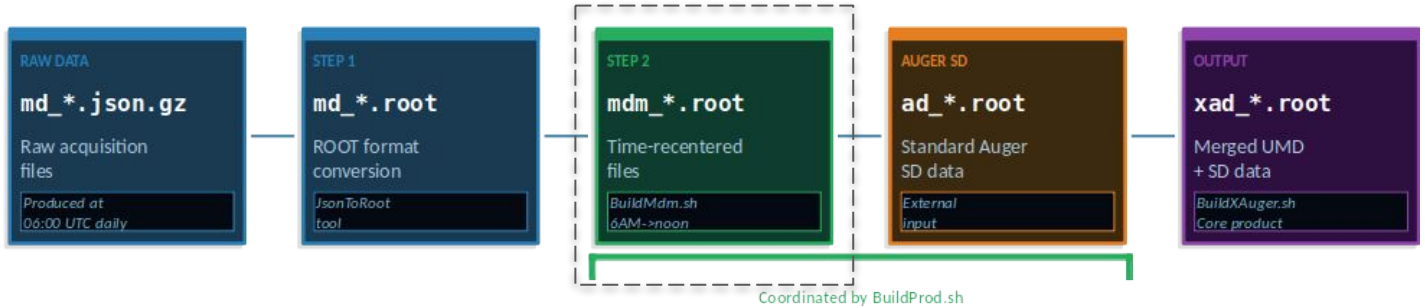

- **Time re-centering:** For each target day, the script merges two consecutive `md_*.root` files — one starting at 06:00 UTC of the target day and one from the following day — producing a `mdm_*.root` file centered at noon (12:00 UTC). If one of the input files is missing, the script still runs and produces output covering 18 or 6 hours, respectively.

`/cdas/src/HdTools/script/BuildMdm.sh`

Data stream - xad merged files

► **Data handling mirrors the SD pipeline.** Scripts use standard CDAS tools and follow conventions consistent with the rest of the Observatory's data production chain.

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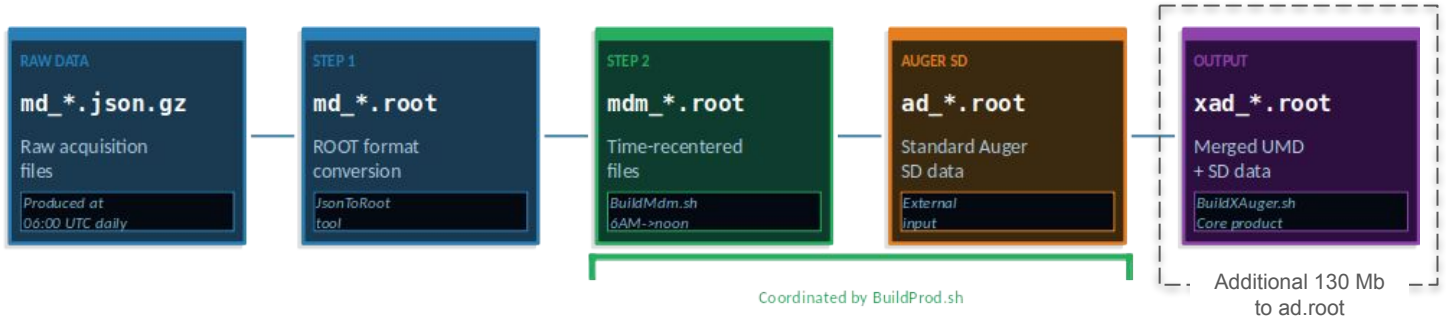


- **Merging with Auger data:** Each `mdm_*.root` file is matched against the corresponding standard Auger data file (`ad_*.root`). If both are present, they are merged into a combined `xad_*.root` file. If the `mdm` counterpart is missing, no `xad_*.root` file is produced and the block exits with a warning.

`/cdas/src/HdTools/script/BuildXAuger.sh`

Data stream - xad volume

CDAS handles UMD data correctly: XAD files are present for all days and show nominal size (except known issues)

UMD data volume with the complete array is expected to reach ~200 MB/day (currently ~120 MB/day)

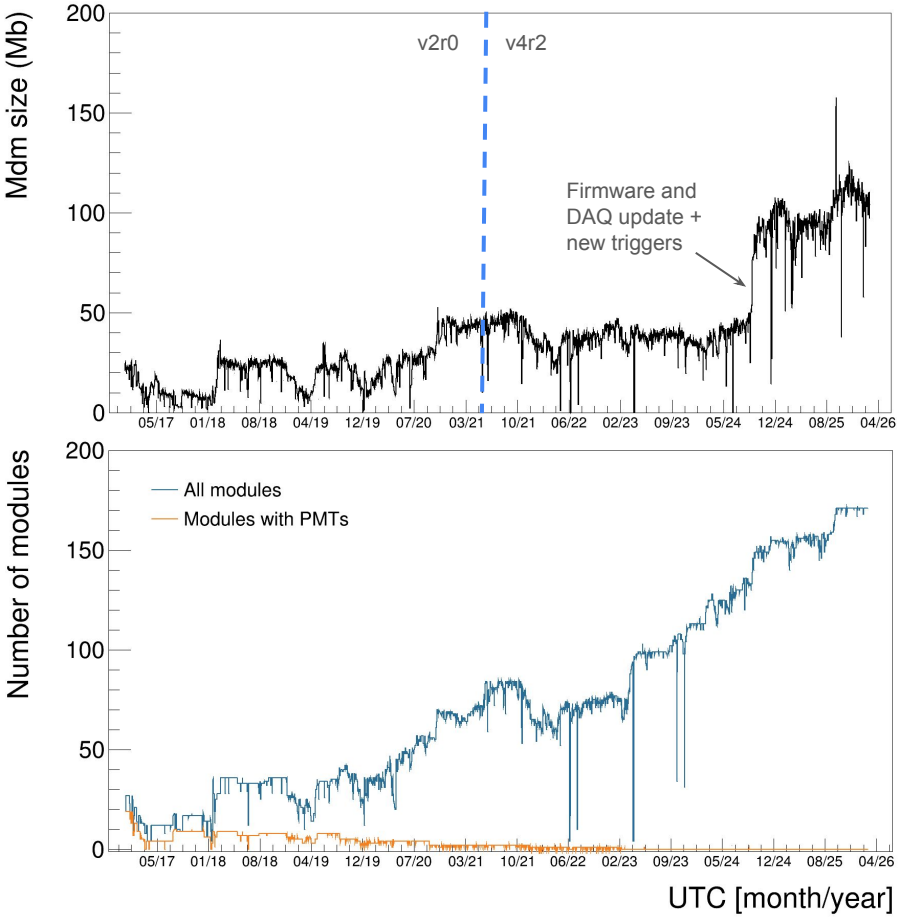
- For reference, the current AD files weigh 1.5-1.8 GB/day - UMD contribution is a small fraction
- No issues are anticipated as the array grows to full deployment

Monitoring of UMD data presence (MD, MDM, XAD files) is integrated into the SD shift checklist since its inception.

When a day with missing data is identified, the on-shift person notifies the `auger-dataprod` mailing list

- Reprocessing is carried out by researchers with access to CNAF data production (e.g., Isabelle, Julian, Lorenzo C.)

Data stream - mdm statistics



► Size of the MDM daily files since the beginning of the UMD production phase.

► Data production switched from version v2r0 to v4r2 on 1 May 2021.

► The MDM file size grows with the number of deployed modules, currently reaching approximately 120 Mb per day.

► Note a jump on the file size in mid-September 2024 -> full deployment of new UUB DAQ and firmware + activation of new triggers (similar jump seen in SDM and AD files).

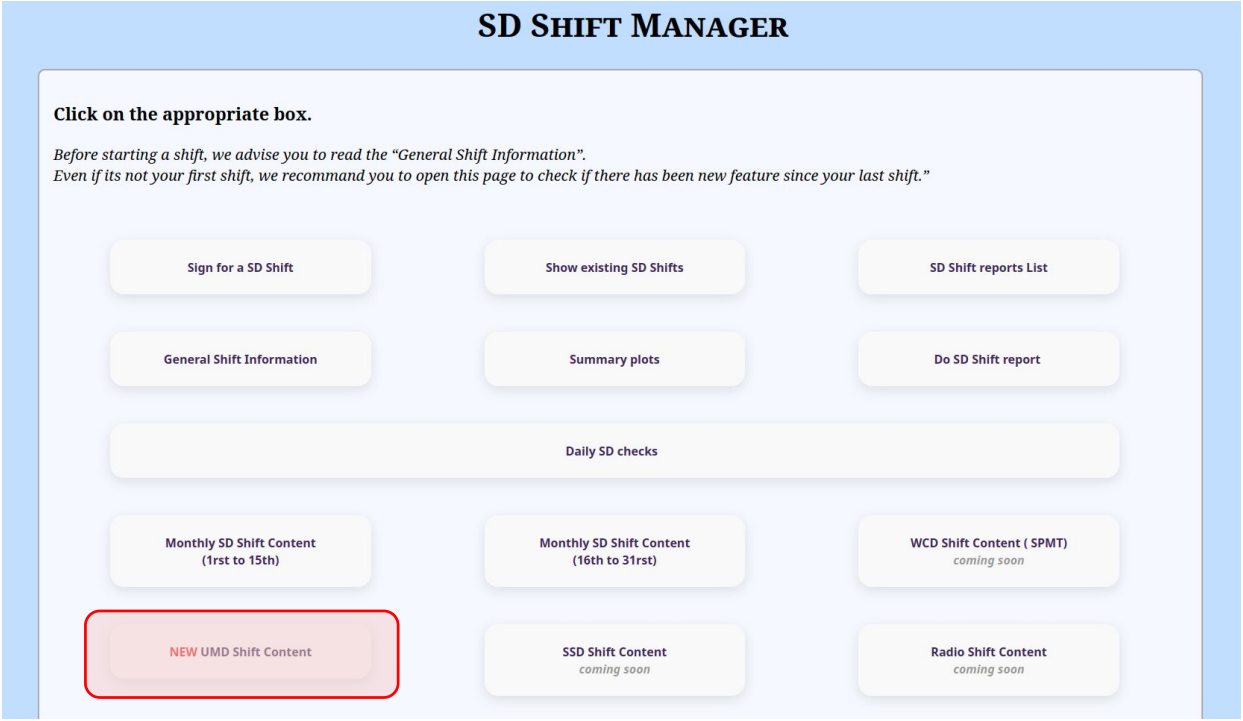
► Daily count of modules registering at least one T1 trigger

► The detector transitioned away from PMT-based modules progressively, with the last PMT module decommissioned in early 2023. The array currently comprises 171 operational modules

► Since 2018, the UMD data volume per day and per module has been stable at approximately 700 KB

UMD shift

UMD shift is integrated into SD shift tools. Included in the SD shift report which is revised every two weeks in the MOLTP task calls.



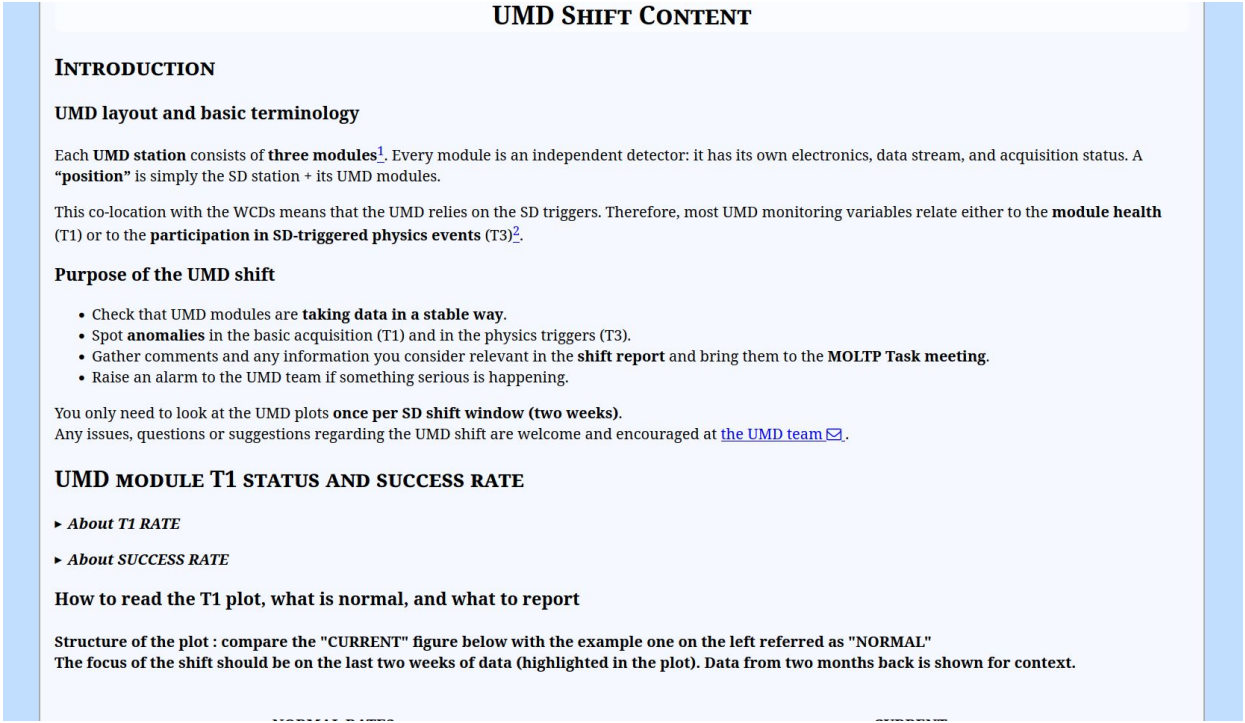
https://gitlab.ahuekna.org.ar/amiga/software/umd-shift.git

UMD shift

UMD shift is integrated into SD shift tools. Included in the SD shift report which is revised every two weeks in the MOLTP task calls.

Explanation on what the shift does is included in the SD shift web page.

Runs independently, on a weekly basis, currently at ITeDA server.



UMD Shift Content

Introduction

UMD layout and basic terminology

Each **UMD station** consists of **three modules**[1]. Every module is an independent detector: it has its own electronics, data stream, and acquisition status. A **"position"** is simply the SD station + its UMD modules.

This co-location with the WCDs means that the UMD relies on the SD triggers. Therefore, most UMD monitoring variables relate either to the **module health** (T1) or to the **participation in SD-triggered physics events** (T3)[2].

Purpose of the UMD shift

- Check that UMD modules are **taking data in a stable way**.
- Spot **anomalies** in the basic acquisition (T1) and in the physics triggers (T3).
- Gather comments and any information you consider relevant in the **shift report** and bring them to the **MOLTP Task meeting**.
- Raise an alarm to the UMD team if something serious is happening.

You only need to look at the UMD plots **once per SD shift window (two weeks)**.
Any issues, questions or suggestions regarding the UMD shift are welcome and encouraged at the UMD team.

UMD module T1 status and success rate

▸ *About T1 RATE*

▸ *About SUCCESS RATE*

How to read the T1 plot, what is normal, and what to report

Structure of the plot : compare the "CURRENT" figure below with the example one on the left referred as "NORMAL"
The focus of the shift should be on the last two weeks of data (highlighted in the plot). Data from two months back is shown for context.

https://gitlab.ahuekna.org.ar/amiga/software/umd-shift.git

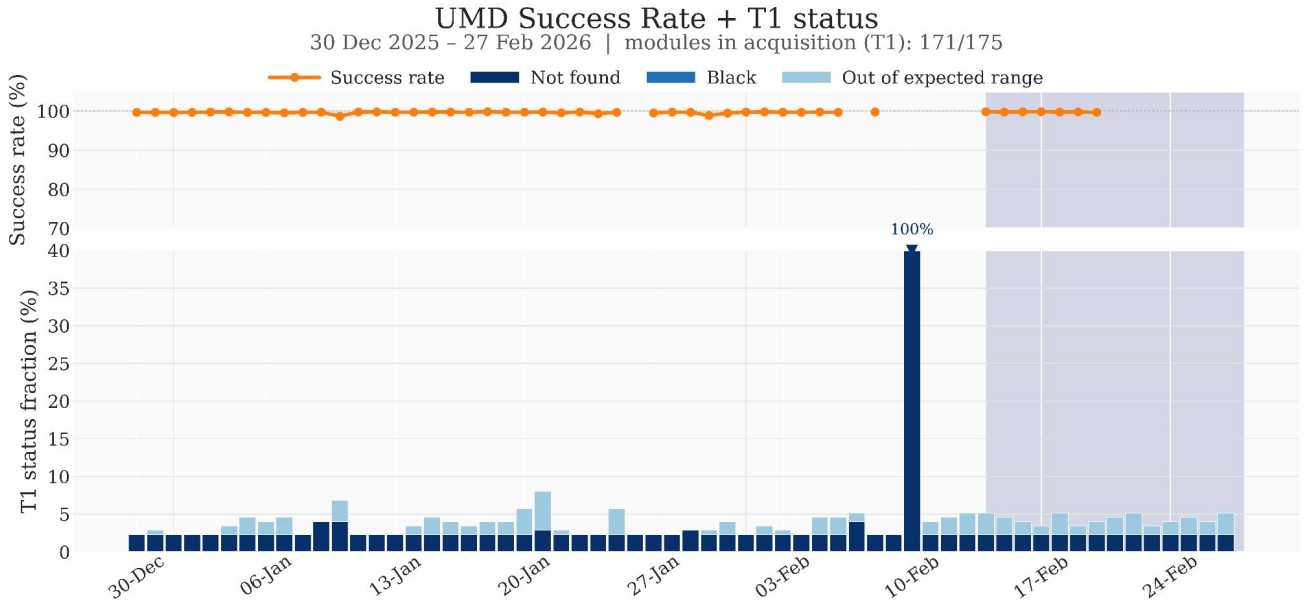
UMD shift

UMD T1 — Stations fully down (NA or 0 Hz for all modules)
11 Oct 2025 to 17 Oct 2025

Station ID	Station	Days down
47	guili-jr	2

Array level picture

- 2 months of data (shift period highlighted)
- # modules in acq
- success rate w.r.t. WCD (1 week behind)
- fraction of modules with issues in the T1 rate
- positions fully down



Success rate plot is always one week behind.
Bars: share of deployed modules by T1 status • Line: array success w.r.t. WCD %

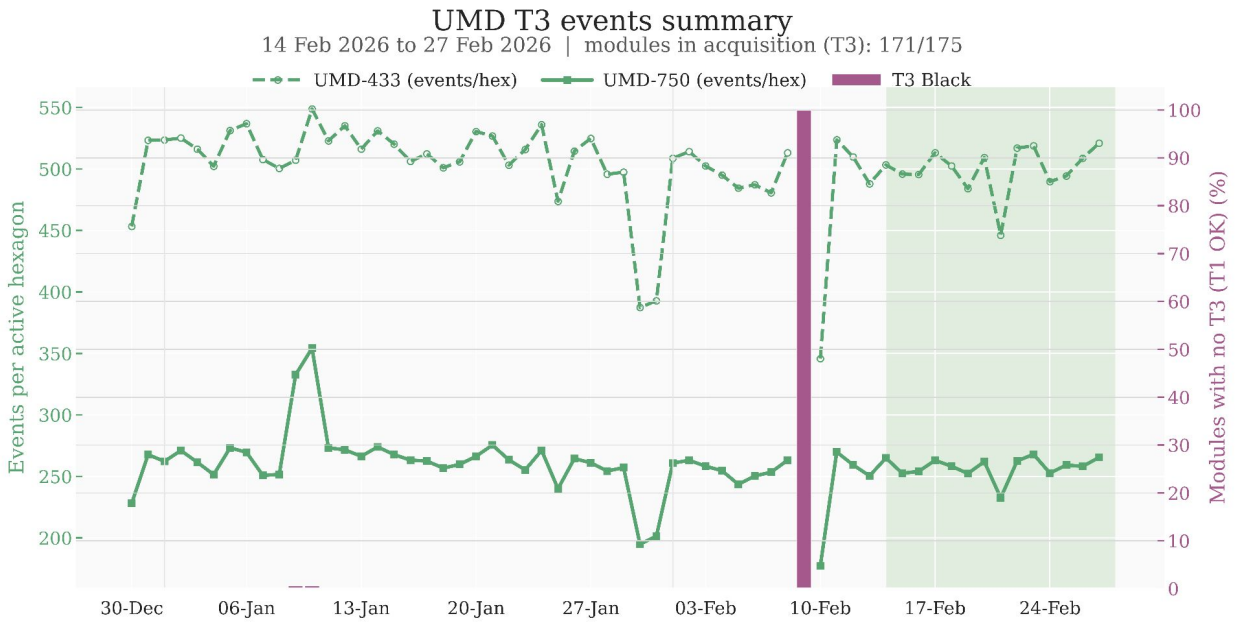
UMD shift

UMD T3 — Full-down Stations (no T3 events on all eligible modules)
14 Feb 2026 to 27 Feb 2026

No full-down stations in shift window.

Spotting acquisition problems early

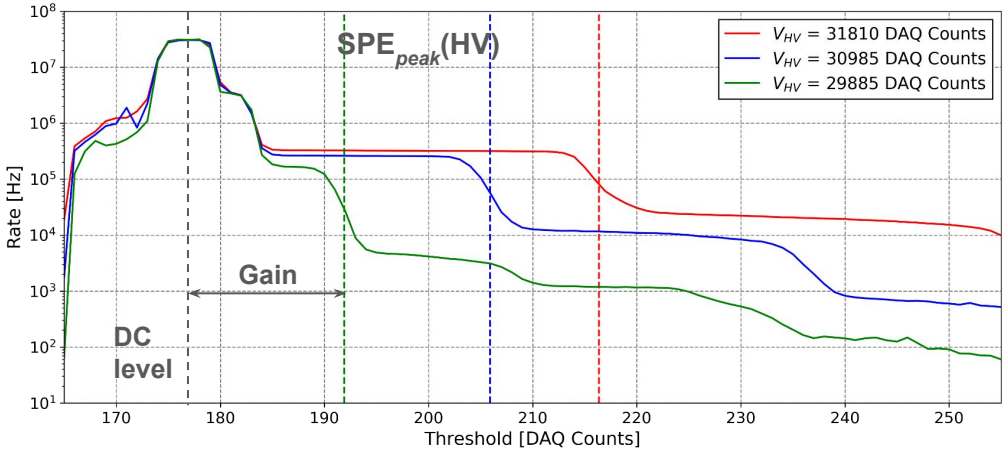
- 2 months of data (shift period highlighted)
- # modules in acq
- rough event rate for both arrays
- fraction of active modules with no events in the T3 files
- positions fully down



SiPM calibration stability

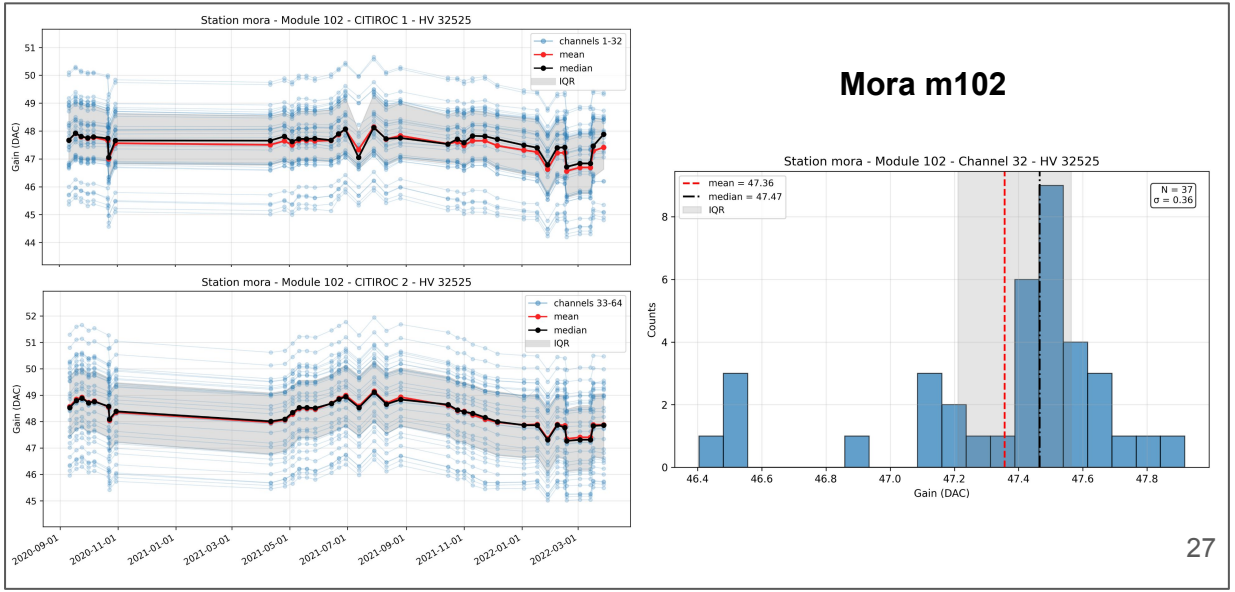
SiPM dark rate curve vs threshold for a single channel to obtain SPE_{peak} → **Calibration**

Gain depends on temperature and V_{bias}. HV source has a coarse and fine tuning to keep overvoltage (and therefore *Gain*) stable in time



Time series of **gain vs time for the 64 SiPM channels** grouped by CITIROC (32 channels) and distribution for a single channel. **Fluctuations in time are ≲1 DAC unit**.

The differences in gain between channels are due to the fact that the measurements were performed before the gain equalization.



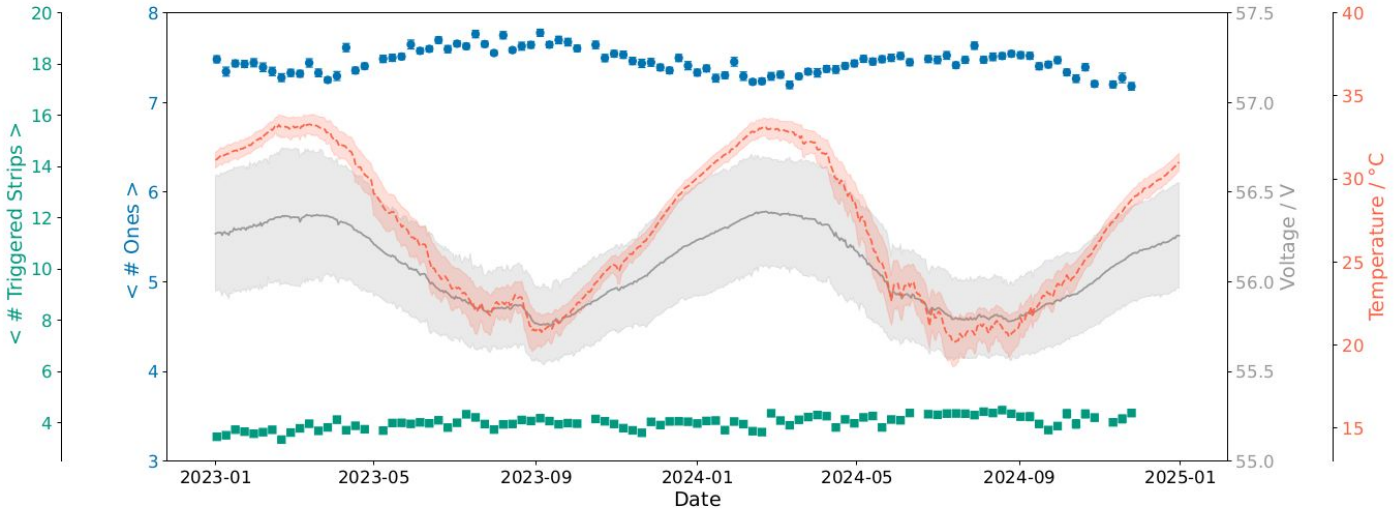
Long term performance

#Ones: small seasonal fluctuations and minor aging effects
#Triggered strips per event remains stable over time

2 years of data (Phase II)

Applied **HV** (to SiPMs) follows **temperature**: robust gain compensation

Stable response of binary mode over time

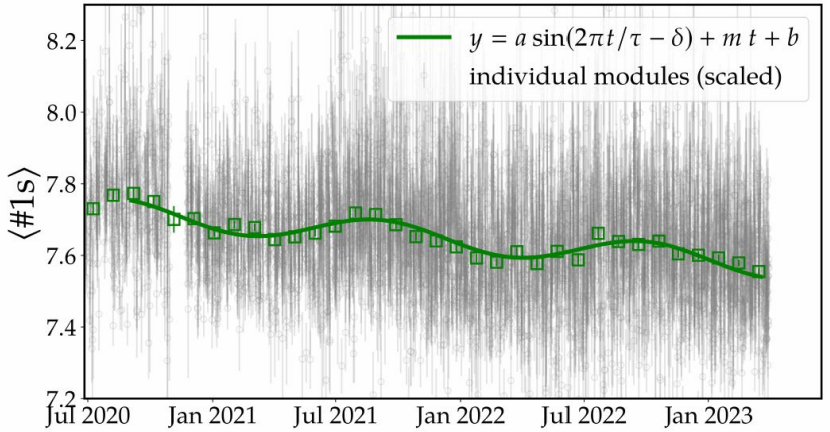


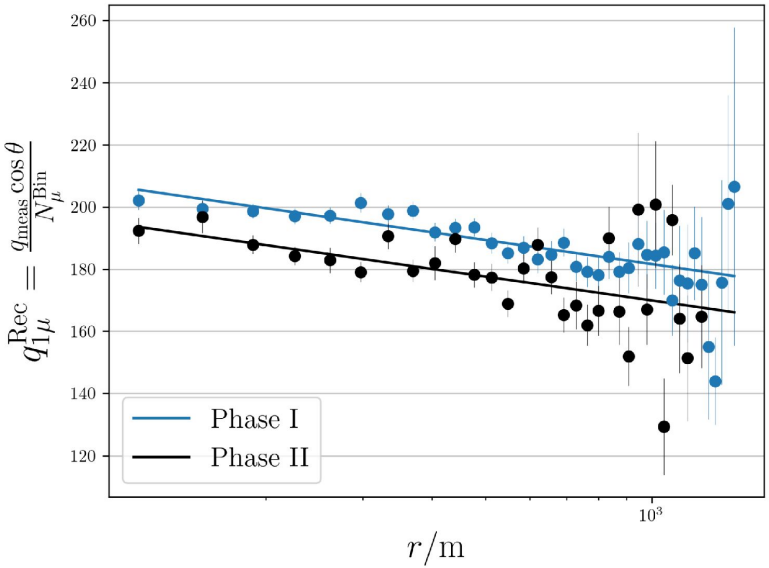
Robust Gain Compensation: Real-time monitoring indicates that despite seasonal temperature fluctuations that affect SiPM gain, the **automatic temperature-compensation system** for high voltage ensures that the average number of triggered strips per event remains **stable over time.** Thus, the muon pattern recognition and event-level response are not compromised by environmental fluctuations

Long term performance

Predictable Aging Effects: The observed aging rate of **<1%** per year in the binary mode and roughly **-2.5% per year** in the ADC mode is consistent with other large-scale scintillator experiments like MINOS, allowing it to be accurately modeled as a **systematic uncertainty in long-term analyses.**

Joaquín de Jesús @ ICRC 2023
Marina Scornavacche @ ICRC 2025



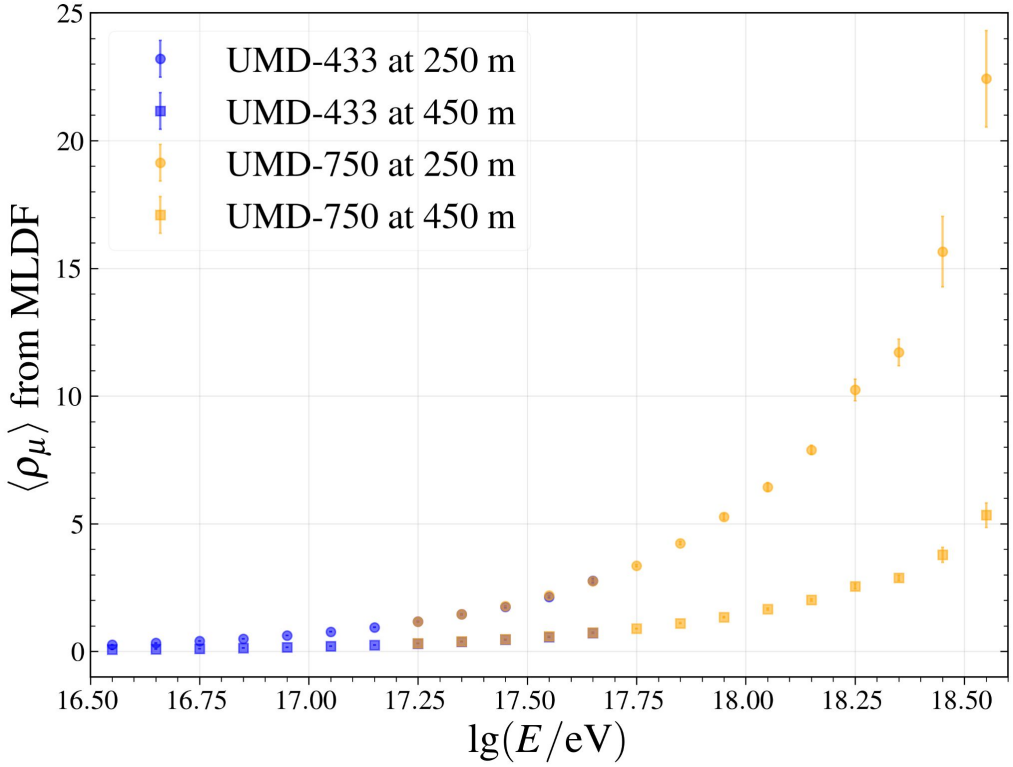


Data stream - array compatibility

A high-level validation is obtained by assessing the **compatibility between** the reconstructed data of the **UMD-433 and UMD-750** arrays.

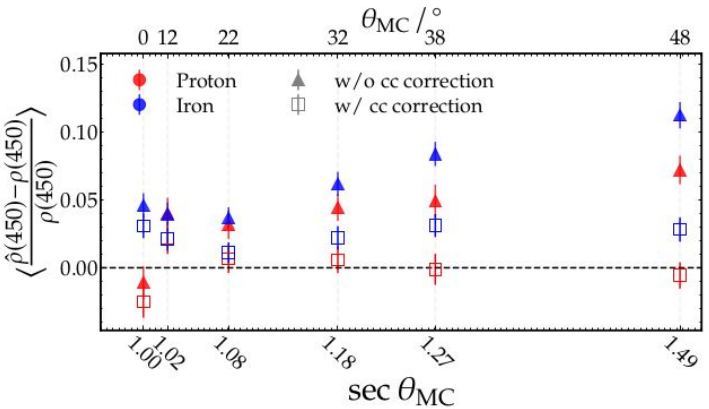
Reconstruction sequences are already in place for both UMD-433 and UMD-750.

Even when the reconstruction involves several intermediate steps before obtaining the muon density from the MLDF, the final observables at the reference distances show **good agreement between the two arrays**.



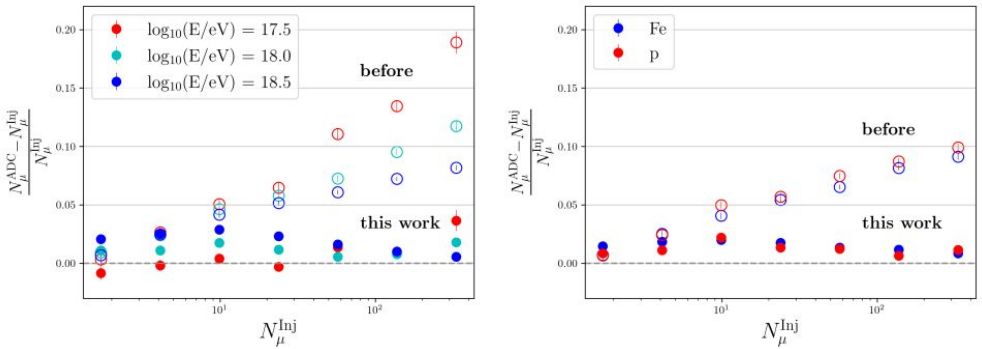
Data stream - high-level physics

From digital traces to muon density measurements: systematic effects studied and **corrections were designed**



Refined binary mode precision: Several improvements, including **data-driven corrections for corner-clipping muons** and leaving the shower core position free during LDF fits, have kept muon shower size, ρ(450), bias **below 3%**.

Joaquin de Jesús @ ICRC 2025

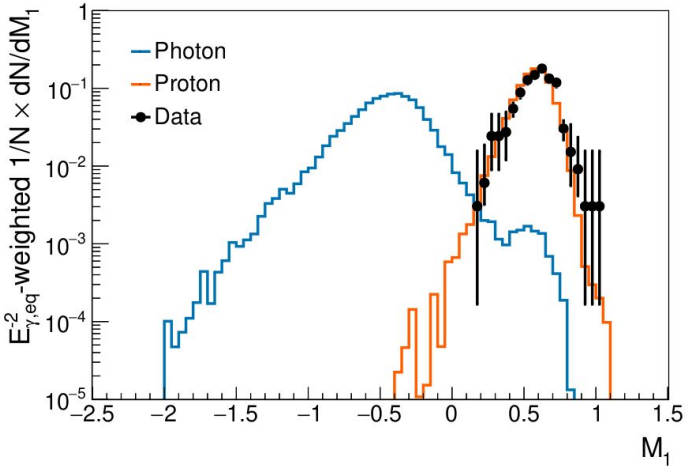


Significant Bias Reduction in ADC mode: Accounting for energy deposition from knock-on electrons generated in the soil, reconstruction bias has been reduced from approximately 20% to **less than 5%** across all energies, primary masses, and zenith angle

Marina Scornavacche @ ICRC 2025

Data stream - high-level physics

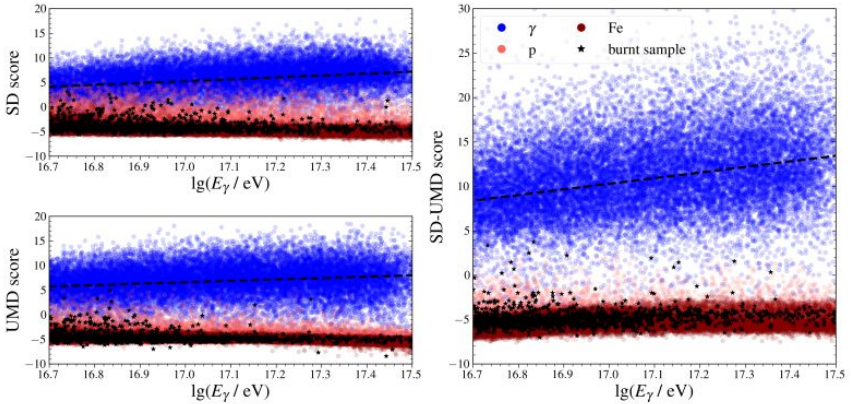
UMD data are both **consistent with physical models** and **reliable for high-level physics**



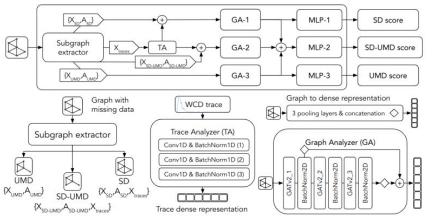
Photon search programme: First search for a diffuse photon flux in the 50 PeV to 200 PeV range conducted from the Southern Hemisphere

Excellent Data-to-Simulation Agreement: Initial validation using a **"burnt sample"** (10% of the high-quality dataset) showed that the M_1 distribution of UMD data is **perfectly consistent with simulated hadronic expectations**

The Pierre Auger Coll, JCAP 05 (2025) 061



Proven Physical Performance in Advanced Analyses: The UMD data has been successfully integrated into **Graph Neural Networks** for photon searches. When applied to the same experimental burnt sample, all events followed the expected hadronic score distributions



Ezequiel Rodriguez @ ICRC 2025

UMD issues & mitigation plans - module/station level

Description of the problem	How we can detect it	How we can solve it	Frequency
eKit produces no data due to a software live-lock state[1]	Station appears silent in monitoring; no data reported, but eKit responds to ping	Log into the affected eKit remotely and issue a reboot	Weekly
eKit produces no data due to full resource exhaustion	Same as above, but remote login also fails	Power-cycle the eKit remotely via the UUB console[2]	Monthly
eKit produces no data due to a hardware, firmware, or local network fault	eKit does not respond to ping; radio, UUB, and neighboring eKits are reachable and functional	Field trip required; eKit and/or Distributor Board must be replaced and sent to Malargüe for repair	Yearly
One or more stations produce no data due to a network outage	Station-level or array-level data loss, typically correlated with power or antenna monitoring alerts	Field trip required; Power, antenna or, less frequently, radio repair needed	Unfrequent (mostly due to storms)

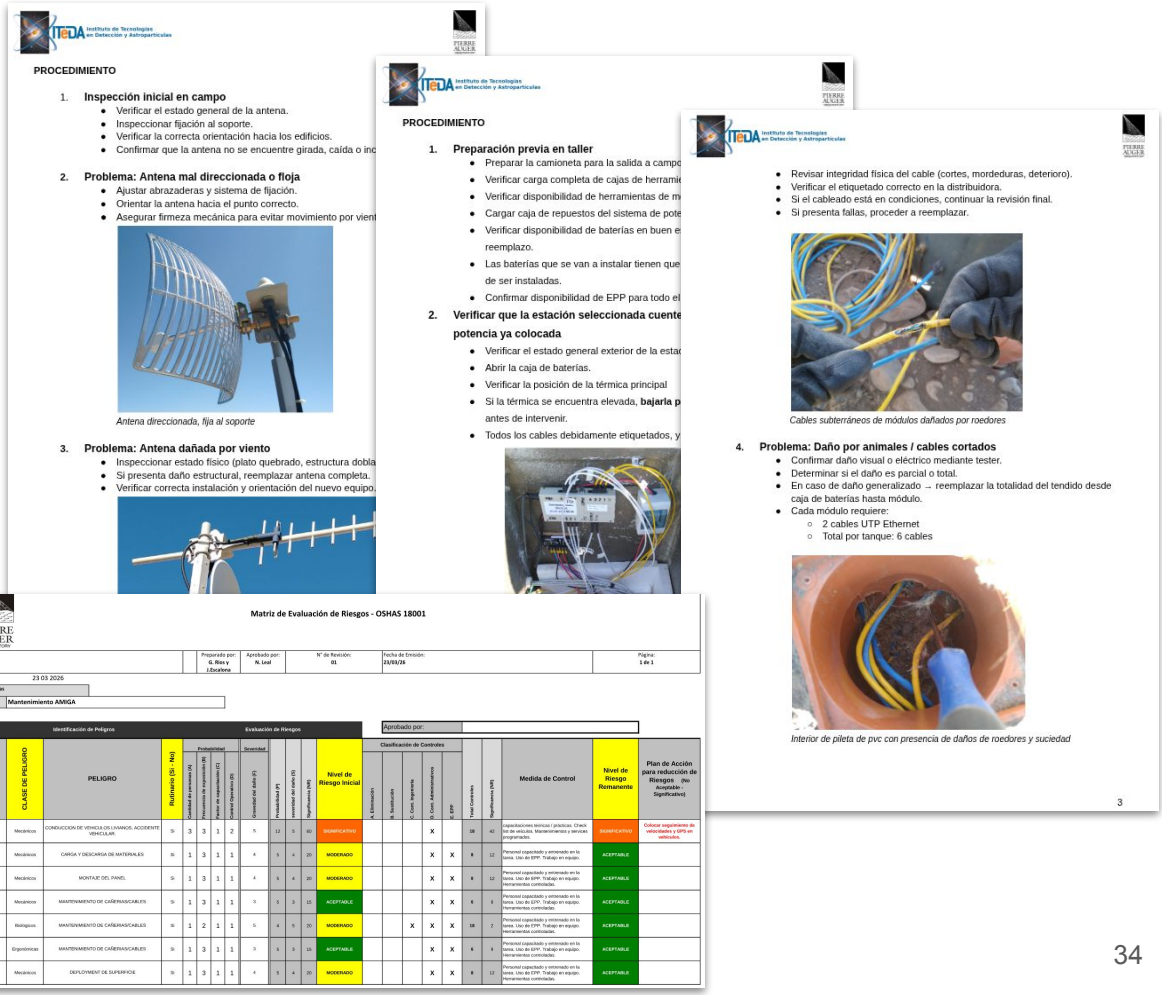
[1] A live-lock is a situation where a process is still actively running and consuming resources, but is making no useful progress.
[2] A software-only recovery is possible in principle but requires very precise timing and is not the standard procedure

https://gitlab.ahuekna.org.ar/amiga/documentation

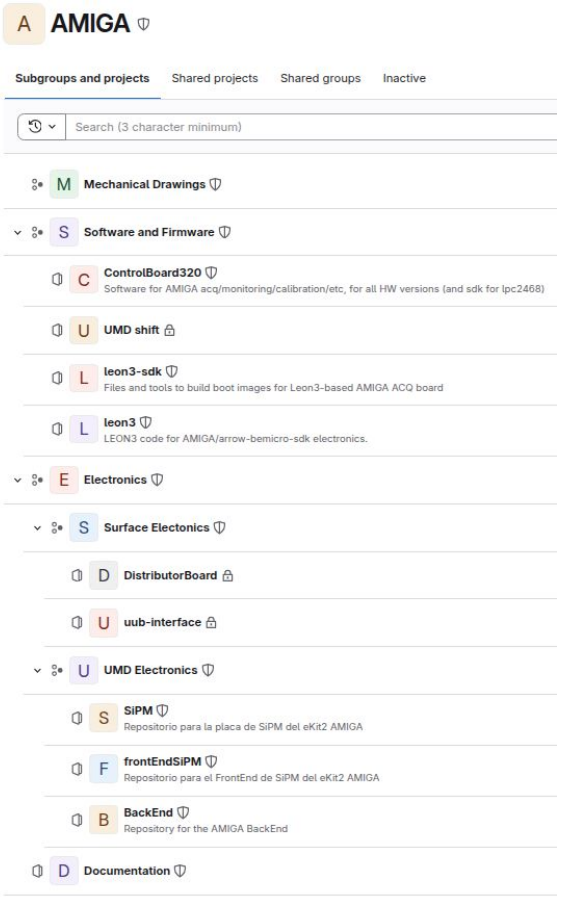
Maintenance procedures

- Comms:
  [Amiga_Communications_Maintenance.md]
- Power System:
  [Amiga_Power_System_Maintenance.md]
- Underground:
  [Amiga_Underground_Infrastructure_Maintenance.md]
- Safety (placeholder):
  [Amiga_Safety_procedures.md]

The documentation developed in Spanish (left figs) during the production phase is being translated and migrated to the repositories above



Maintenance: technical documentation & repositories

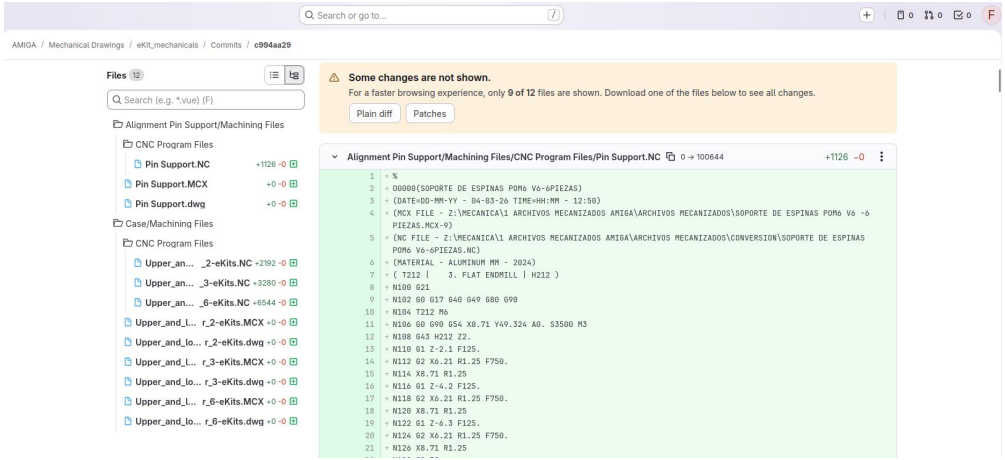


Documentation is currently being gathered in a dedicated repository hosted at the ITeDA GitLab, covering:

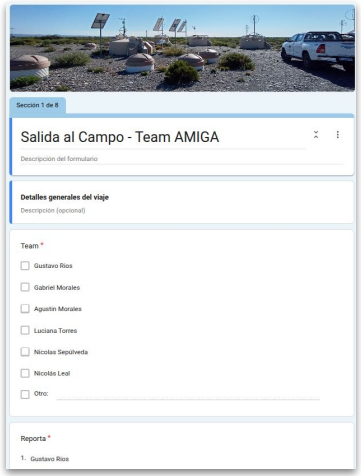
- ►Mechanical design
- ►Firmware and software code
- ►Electronics schematics

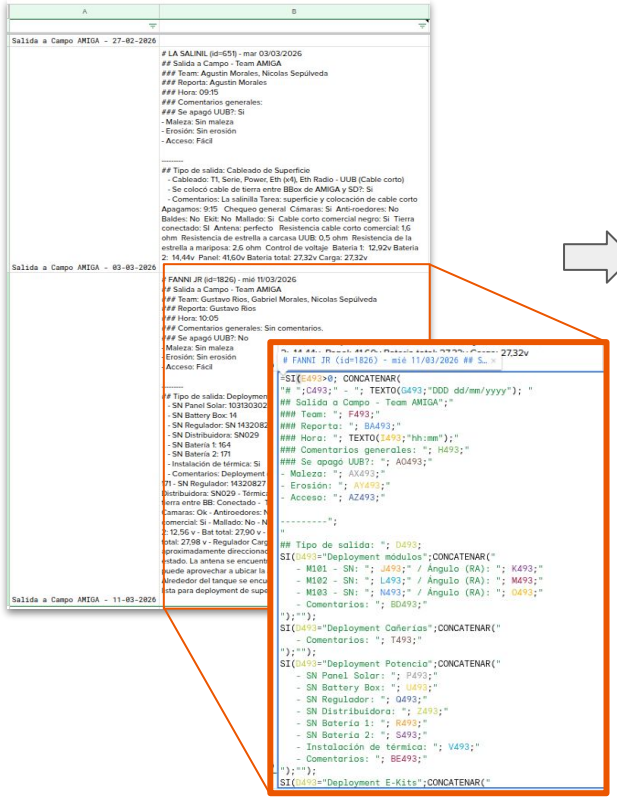
Repository contents will be migrated to CERN EDMS / PMS upon completion.

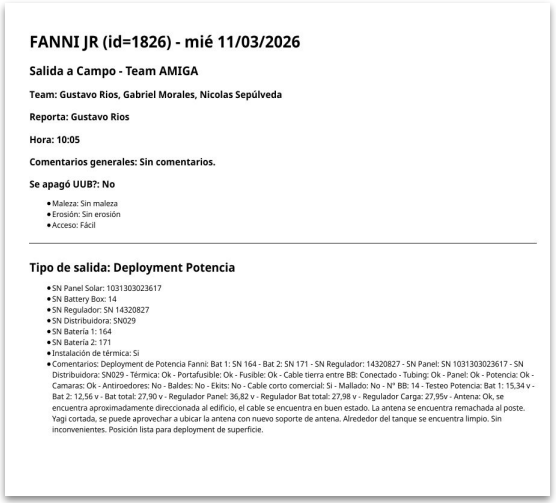
Please note that the browser version of our GitLab may not display files correctly. Downloading the repos as zip or cloning them is recommended.



Maintenance - Field reports







FANNI JR (id=1826) - mié 11/03/2026

Salida a Campo - Team AMIGA

Team: Gustavo Rios, Gabriel Morales, Nicolas Sepúlveda

Reporta: Gustavo Rios

Hora: 10:05

Comentarios generales: Sin comentarios.

Se apagó UUB?: No

- Maleza: Sin maleza
- Erosión: Sin erosión
- Acceso: Fácil

Tipo de salida: Deployment Potencia

- SN Panel Solar: 1031303023617
- SN Battery Box: 14
- SN Regulador: SN 14320827
- SN Distribuidora: SN029
- SN Batería 1: 164
- SN Batería 2: 171
- Instalación de térmica: Si
- Comentarios: Deployment de Potencia Fanni Bat 1: SN 164 - Bat 2: SN 171 - SN Regulador: 14320827 - SN Panel: SN 1031303023617 - SN Distribuidora: SN029 - Térmica: Ok - Portafusible: Ok - Fusible: Ok - Cable tierra entre BB: Conectado - Tubing: Ok - Panel: Ok - Potencia: Ok - Camaras: Ok - Antiroedores: No - Baldes: No - Ekits: No - Cable corto comercial: Si - Mallado: No - N° BB: 14 - Testeo Potencia: Bat 1: 15,34 v - Bat 2: 12,56 v - Bat total: 27,90 v - Regulador Panel: 36,82 v - Regulador Bat total: 27,98 v - Regulador Carga: 27,95v - Antena: Ok, se encuentra aproximadamente direccionada al edificio, el cable se encuentra en buen estado. La antena se encuentra remachada al poste. Yagi cortada, se puede aprovechar a ubicar la antena con nuevo soporte de antena. Alrededor del tanque se encuentra limpio. Sin inconvenientes. Posición lista para deployment de superficie.

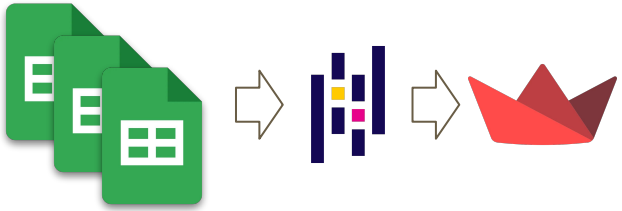
Field reports integrated to the elog

Standard workflow since 2023

PDF sent to sd@auger.org.ar
Report added to elog

https://gitlab.ahuekna.org.ar/amiga/documentation

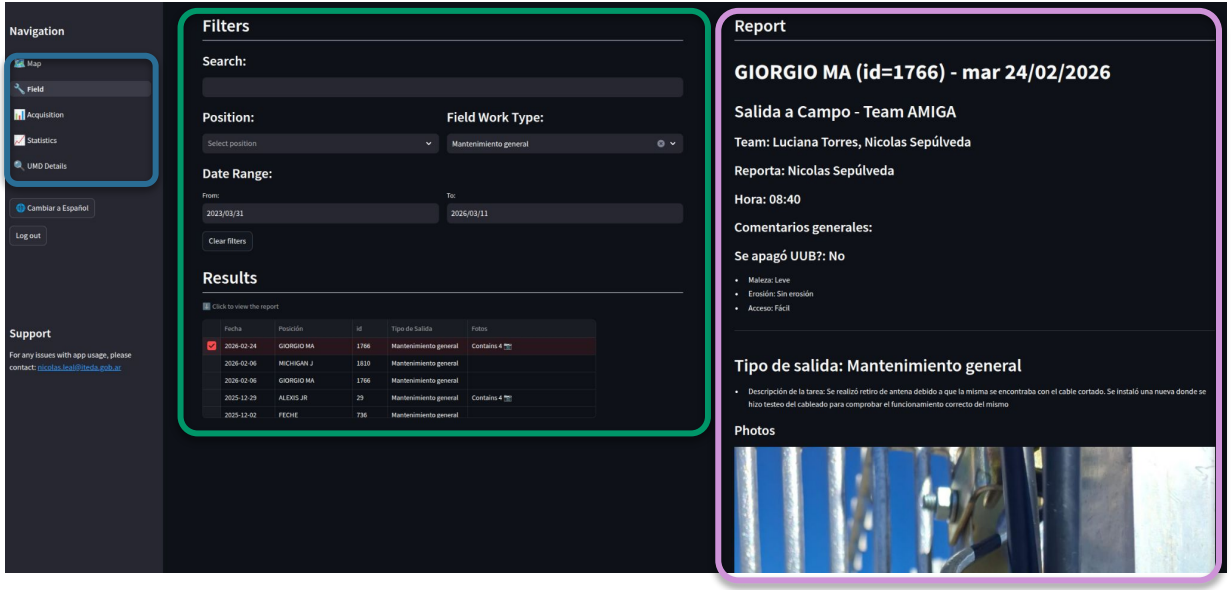
Maintenance - Reports viewer, map & details



This application utilizes **pandas** dataframes and **Streamlit** (turns data scripts -fully Python- into web apps) to visually present data sourced from different **Google Sheets**.

Key Features:

1. **Combined Data Visualization:** Access all relevant information in one place.
2. **Specific Filters:** By date, location, type of intervention, and more.
3. **Report Generation:** For quick analysis and effective communication.



https://amiga-trips.streamlit.app/
(accessible with Auger credentials)

Maintenance - Reports viewer, map & details

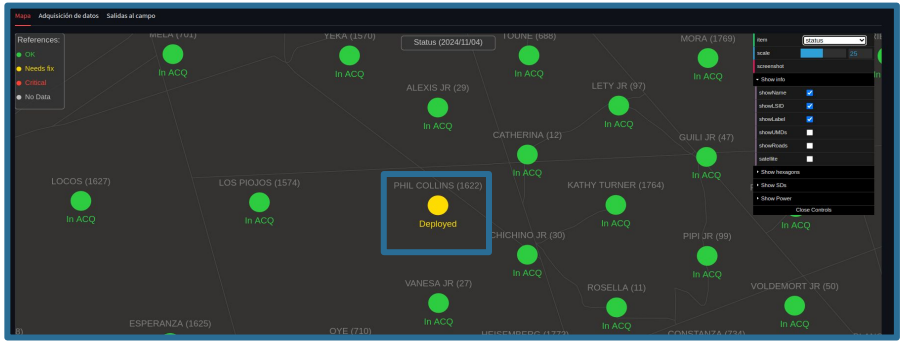
The map utilizes **p5.js** library to show data sourced from a connected **Google Sheet**.

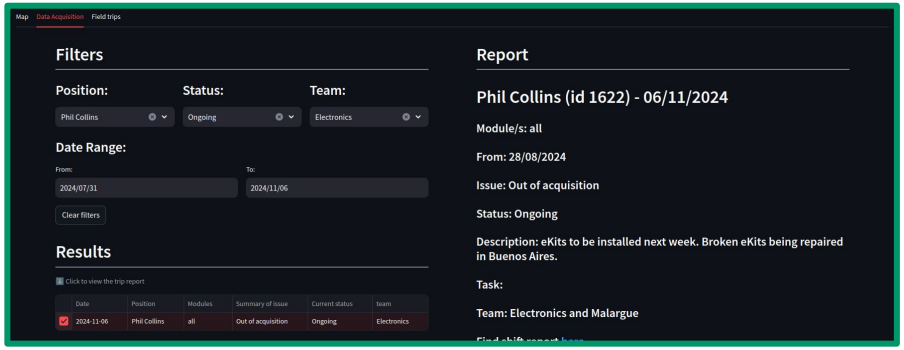
1. **Visualization of UMD status** with color indicators by condition.
2. **Satellite view options**, roads, and UMDs location with respect to SDs.
3. **Options to show or hide SDs** based on classification.

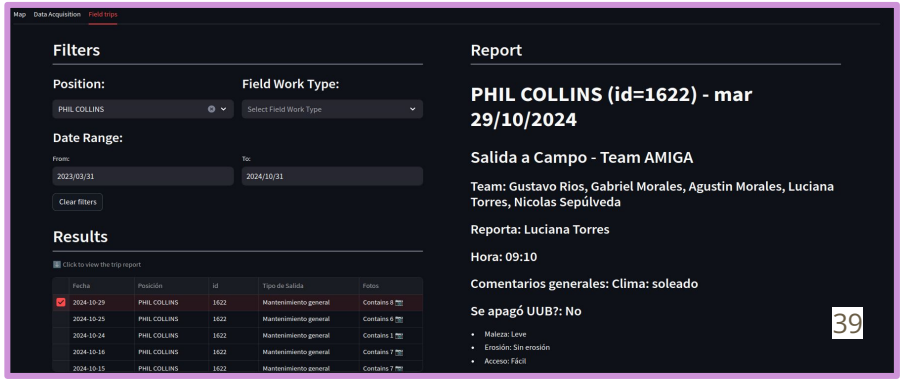
Maintenance - Reports viewer, map & details

- **Map** tab: showing a position with a warning color.
- **Data Acquisition** tab: Filtering by position shows an issue reported by the UMD weekly meetings*
- **Field Trips** tab: Filtering by position shows several maintenance trips.

* During production phase, this was done at UMD weekly meetings. Will be incorporated into regular shift procedures







Maintenance, operation and training

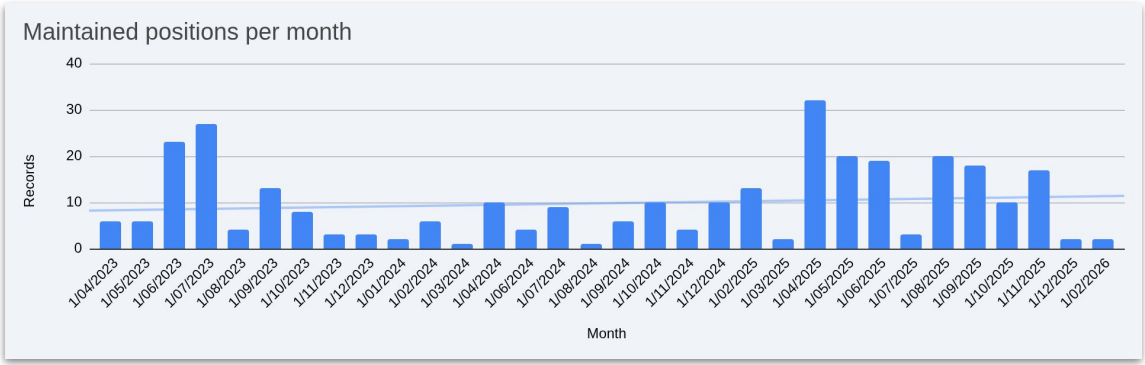
Knowledge transfer to Observatory staff -> Training plan for local personnel; part of the AMIGA team (e.g., Gustavo) transitions into Observatory staff, ensuring transfer of accumulated know-how and integration with pre-existing procedures for incoming technicians

Routine maintenance: Field campaigns for repairs and replacements tracked via the maintenance app (Apr 2023 -- Feb 2026):

- ~134 field maintenance visits → **~33.5 field days/year** (avg. 4.2/month)
- ~314 detector positions visited → **~78.5 positions/year** (avg. ~9.8/month)

Person-power needed: 2 technicians (Gustavo + 1)

Fecha	Posición	id	Tipo de Salida	Fotos
2026-02-24	GIORGIO MA	1766	Mantenimiento general	Contains 4
2026-02-06	MICHIGAN J	1810	Mantenimiento general	
2026-02-06	GIORGIO MA	1766	Mantenimiento general	
2025-12-29	ALEXIS JR	29	Mantenimiento general	Contains 4
2025-12-02	FECHE	736	Mantenimiento general	
2025-11-27	TRAUDEL	819	Mantenimiento general	Contains 5
2025-11-27	FECHE	736	Mantenimiento general	
2025-11-25	VANESA JR	27	Mantenimiento general	Contains 1
2025-11-25	BORBARAN	643	Mantenimiento general	Contains 2
2025-11-20	ISIDORITO JR.	1813	Mantenimiento general	Contains 2
2025-11-20	BORBARAN	643	Mantenimiento general	Contains 3
2025-11-13	HILDA	635	Mantenimiento general	Contains 5
2025-11-11	MICHIGAN J	1810	Mantenimiento general	



UMD Post-Deployment: ToDo

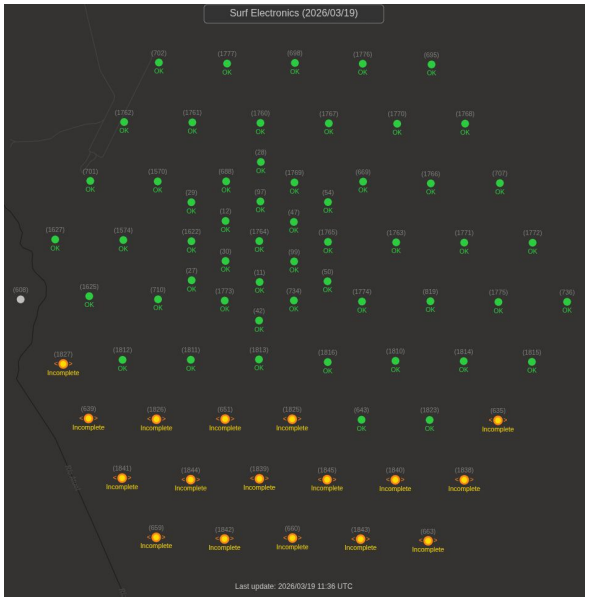
Power System deployment: 13 positions

Surface deployment: 17 positions

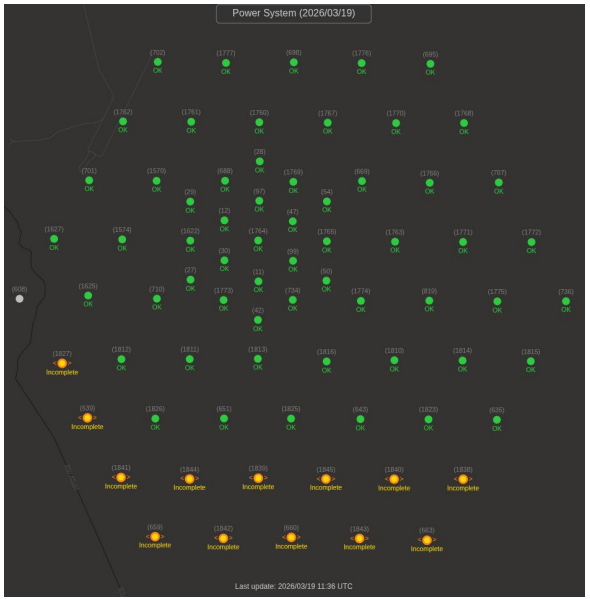
Underground electronics deployment: 17 positions

~ 3-4 months (ongoing)

Surface Electronics



Power System



Spares overview: buried electronics

The UMD spares inventory covers three main subsystems: buried electronics (eKits), surface electronics (UUB interface and Distributor boards), and telecommunications (radios and antennas).

Current eKit stock stands at 18 units; a production run of 40 new kits is planned for 2026, limited by the 2024/2025 budget constraints.

Effective spare fraction after the 2026 production run: 7 units (~3%).

Critical issue: The CITIROC chip (the core ASIC of the eKit front-end electronics) has been discontinued by the manufacturer.

Mitigation plan (short term): Negotiations are ongoing with the manufacturer to procure a last batch of CITIROC chips sufficient to support future production and increase the spare inventory.

Mitigation plan (long term): A redesign of the eKit electronics adapted to currently available components will be required if the last-batch procurement is insufficient.

Very low failure rate of eKits, mostly by catastrophic events (e.g. lightning).

Target number modules	224
Modules in operation	173
Modules without eKits	51
eKit stock	18
Production KIT 2026	40
Spares	**7 (3%)**

Description	Quantity	Unit Price	Taxes	Amount
[CIT1AQFP] CITIROC1A QFP Origin : France Custom Tarif : 85423990	60.00 Units	336.00	TVA 0%	20,160.00 €
[CIT1AQFP] CITIROC1A QFP Origin : France Custom Tarif : 85423990	80.00 Units	336.00	TVA 0%	26,880.00 €
[CIT1AQFP] CITIROC1A QFP Origin : France Custom Tarif : 85423990	100.00 Units	315.00	TVA 0%	31,500.00 €

Spares overview: surface electronics

The UMD spares inventory covers three main subsystems: buried electronics (eKits), surface electronics (UUB interface and Distributor boards), and telecommunications (radios and antennas).

Distributor Board

Total positions	72
Installed	59
Positions without Distributor	13
Stock	9
Production KIT 2026	25
Spares	**21 (29%)**

UMD - UUB interface

Total positions	72
Installed	72
Spares UUB with UMD interface	10
Stock	4
Spares	**14 (19%)**

Surface electronics spare levels are considered adequate for routine operations and near-term maintenance needs

Spares overview: telecommunications

► **11 antenna spares are available on-site**; however, procurement lead times are on the order of several months, so stock depletion must be anticipated.

► There is **not any spare for the Passive PoE switch at Coihueco (at least, 4 ports)**, which serves as the network backbone.

► The **radio spare inventory is currently insufficient**, primarily due to: (1) mass failures of the RB493AH model caused by improper installation and factory defects, and (2) spare hAP AC units having been deployed to the HEATLET extension.

► Replacement radio options have been evaluated:

- **hAP AC** (same model as currently deployed): field-proven, requires no station modifications; however, it is difficult to procure in Argentina, cannot be remotely upgraded[1], and has been flagged for electromagnetic (EM) noise by the RD team.
- **L009 / hAP AC3 / hAP AX3:** readily available locally, but unproven in field, possibly higher power requirements, require hardware modifications[2] at each station, and their EM noise is yet to be verified.

A decision on the preferred replacement radio model is pending; support for testing and a recommendation from the Collaboration is expected prior to procurement.

[1] Could be upgraded remotely if all radios are fitted with a Pendrive, but this is untested and it would incur in higher power consumption
[2] L009 implements standard 802.1af/at PoE-IN instead of the passive PoE we use. All three likely require 20 MHz channel width (we currently use 10 MHz channels).

Summary

Proven physics-ready detector: UMD data have enabled muon density measurements with reconstruction bias below 3% and supported the first Southern Hemisphere search for a diffuse photon flux in the 50-200 PeV range.

224 UMD modules deployed for operation, 17 positions pending installation of surface and/or buried electronics

Electronics: Fully custom eKit design (SiPM board, Front-End, Acquisition Board); low-power, FPGA-based system with remote upgradeability and fail-safe mechanisms

Software & Firmware: Three-layer architecture (FPGA / Linux / AMIGA software); stateless, network boot, remote configuration; all key processes remotely managed

Stable long-term performance: Robust SiPM gain compensation via HV feedback; aging effects below 1%/year (binary mode), well characterized.

Data stream fully operational: Automated daily pipeline at CNAF; ~120 MB/day; XAD files consistent and monitored; UMD data validated against physics models

Monitoring & Shift: Integrated into SD shift tools; weekly automated reports; field trip history accessible via dedicated web app

Spares: Surface electronics at adequate levels; last-batch of CITIROC chip procurement underway, redesign planned as fallback

Telecommunications: Functional PtMP network; radio spare inventory insufficient; replacement model evaluation pending Collaboration recommendation

Backup

UMD Post-Deployment: ToDo

Power System deployment: 13 positions

Surface deployment: 17 positions

Underground electronics deployment: 17 positions

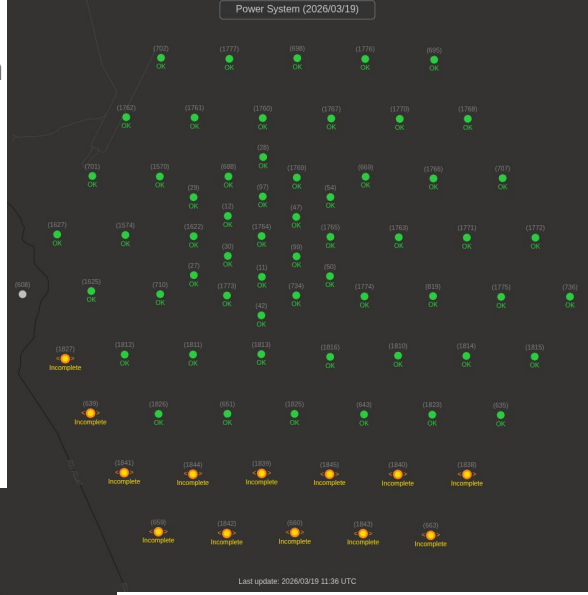
Currently inactive modules:

- Oye m101
- Kathy Turner m105

Discarded buried modules (9):

- Yeka M2 - ID: M025 - 10m²
- Yeka M3 - ID: MI 5.2 - 5m²
- Yeka M4 - ID: MI 5.4 - 5m²
- Toune M3 - ID: MI 5.1 - 5m²
- Toune M4 - ID: MI 5.3 - 5m²
- Phil Collins M12 - ID: M020 - 10m²
- Heisemberg M2 - ID: M021 - 10m²
- Heisemberg M3 - ID: M023 - 5m²
- Heisemberg M4 - ID: M024 - 5m²

Power System



Surface Electronics