# Procedures for calibration and monitoring of Digital Optical Modules

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Pack Meeting - Bari 16-17

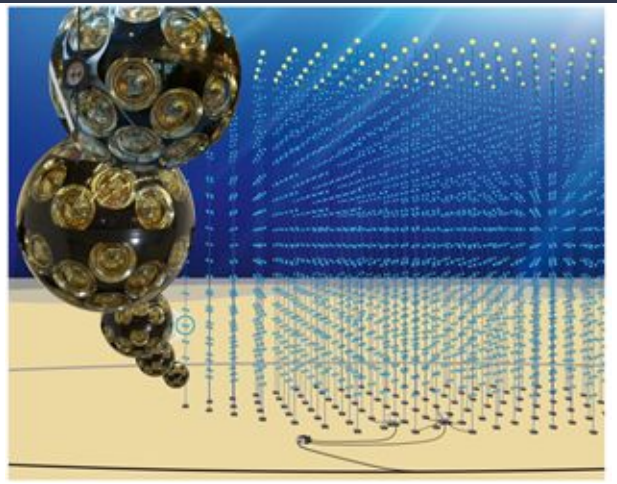
# Outline

- **Introduction**
- **K40 Calibration**
  - PMTs efficiency/gain evaluation monitoring
- **Difference between PMTs type**
- **Gain comparison**
- **Next steps**

# Introduction

# KM3NeT Experiment

- 2 neutrino telescopes: **ARCA** and **ORCA**
- Same technology: based on the *Digital Optical Module* (**DOM**), hosting 31 PMTs. Arranged in 3D array
- Different location:
  - **ARCA:** Off the coast of Sicily (Capo Passero) - *~3.5 km of depth*
  - **ORCA:** Off the coast of France (Toulon) - *~2.5 km of depth*
- Different aims:
  - **ARCA:** studies on astrophysical neutrino sources
  - **ORCA:** studies on neutrino oscillations and mass ordering




**Principle**

Instrumenting a large volume of water to exploit the production of Cherenkov light induced by charged particles produced by the interaction of neutrinos

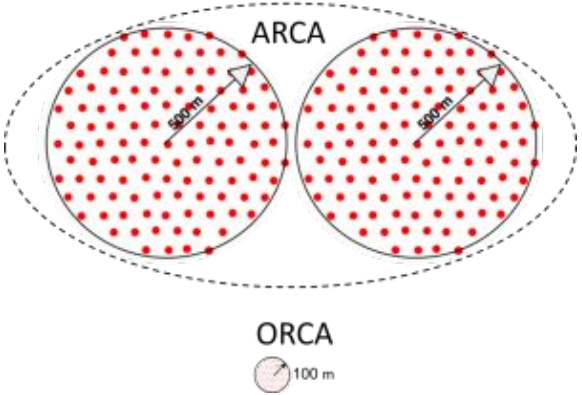
# ORCA Detector

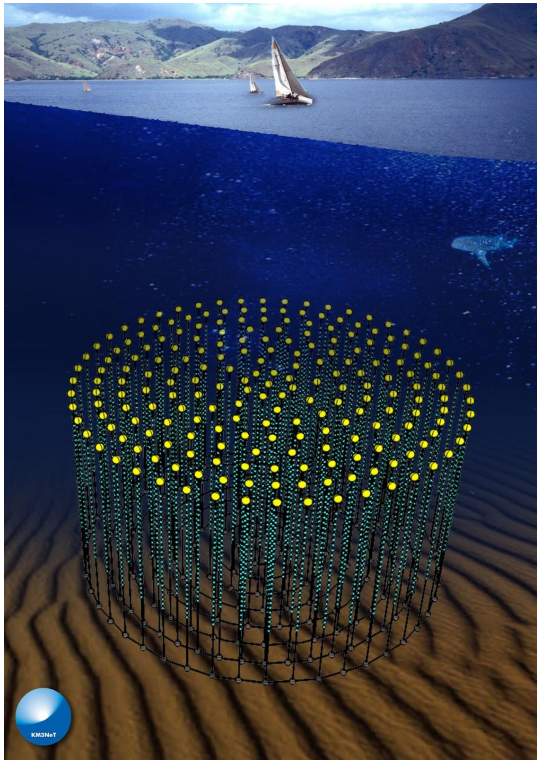
ORCA - *Building Block* (BB) of 115 *Detection Units* (DU) with 18 DOMs

ARCA - 2 x *Building Block* (BB) of 115 *Detection Units* (DU) with 18 DOMs

Distance of strings = 20m (90m) ORCA (ARCA)
Distance of DOMs = 9m (35m) ORCA (ARCA)

*1xBB ->64170 PMTs*



# Technology

Detection of Cherenkov radiation⇒**neutrino interaction**

Reconstruction of:

- **Energy**
- **Direction**

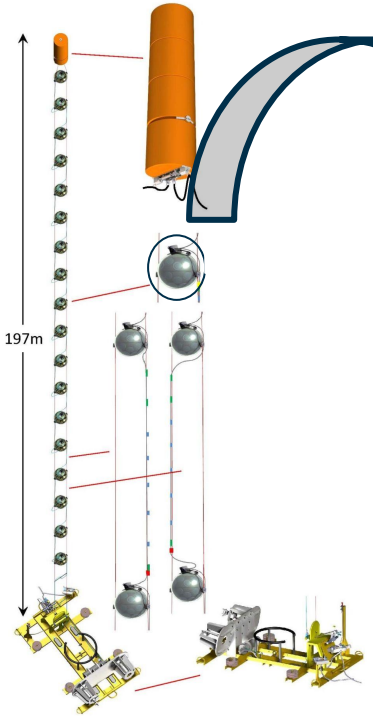
Of the incoming particle

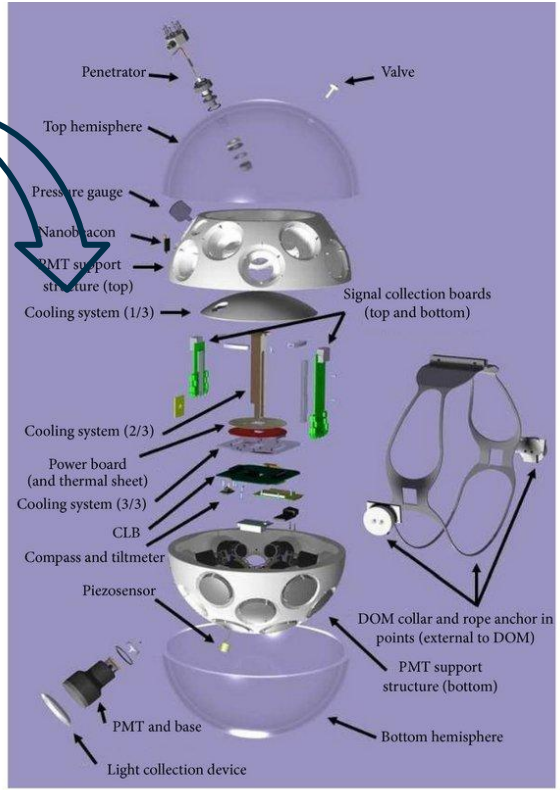
Calibration in position:

- Accuracy level ~ **20 cm**

Calibration in **time:**

- Accuracy level ~**ns**



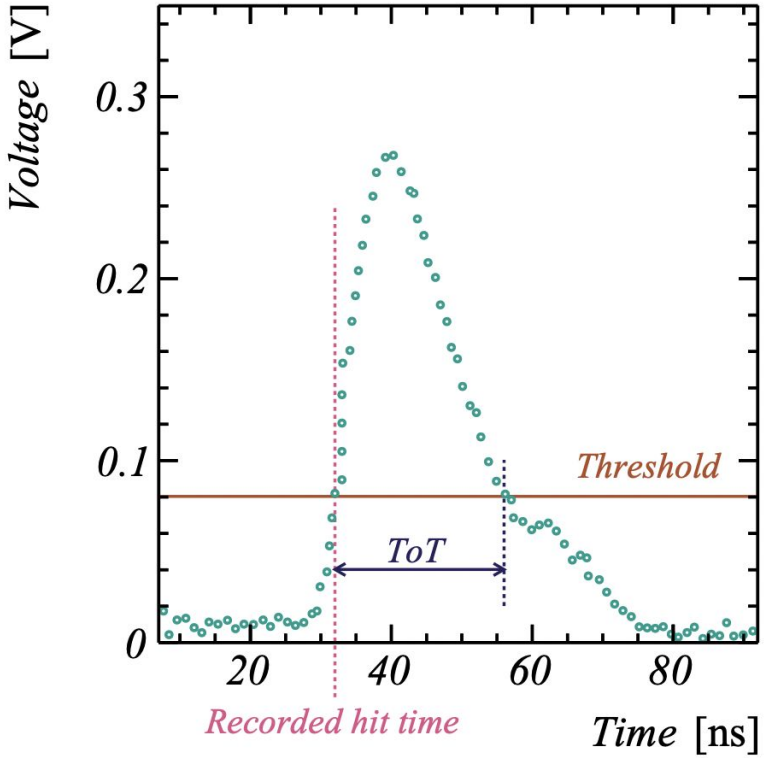
# Time over Threshold

**Recorded signals** are characterised by two quantities:

- the time at which the PMT waveform passes the *threshold* (the hit time)
- the period it stays above the threshold, called the **time over threshold** (**ToT**)

ToT -> **0.3 photo-electron equivalent**

ToT gives a measurement of the amplitude of the signal and it is related to the **PMTs gain** and relative **efficiency**

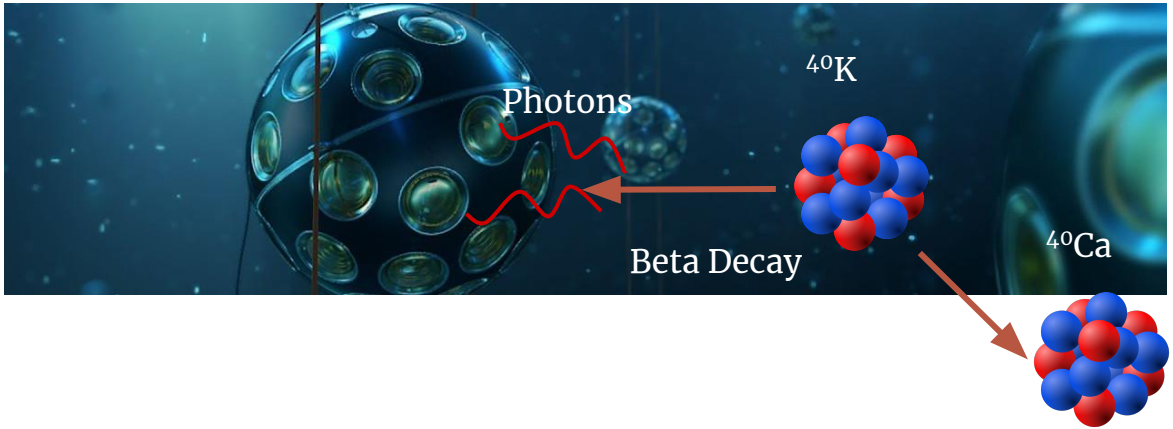


# K40 Calibration

# K40 Calibration

The inter-PMT (or intra-DOM) calibration makes use of multi-PMT coincident hits on the same DOM originating from the Cherenkov light produced in 40K decays. In more detail, it exploits the following principles:

- The distribution of the time difference between hits on different PMTs within the same DOM should peak at zero, given that the systematic differences related to the lights emission point average out (a decay close to A will give a hit on A earlier than on B, but will be compensated by a decay occurring close to B).
- The width of each distribution gives a measure of the PMT transit time spreads (TTS).
- The amplitude of the distribution scales with the PMT efficiencies.



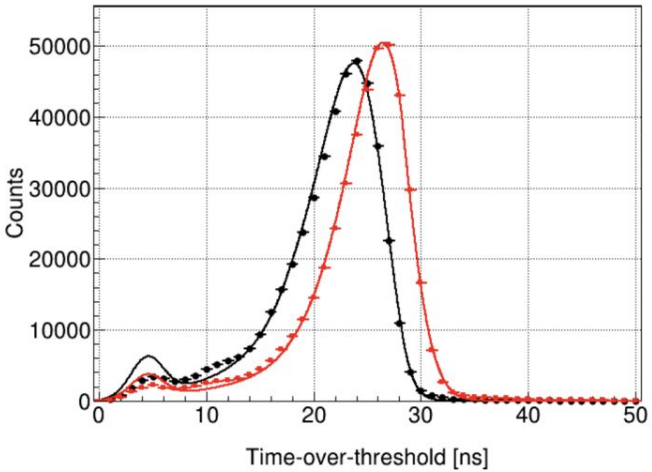
# K40 Calibration

The intra-DOM calibration exploits the ToT distribution of single photo-electron hits from Cherenkov photons originating from the $^{40}K$ decay to evaluate efficiency and gain of PMTs

The PMT **gain** calibration

Inference from the statistical behaviour of the ToT

Model based on conversion of the measured ToT values in charge



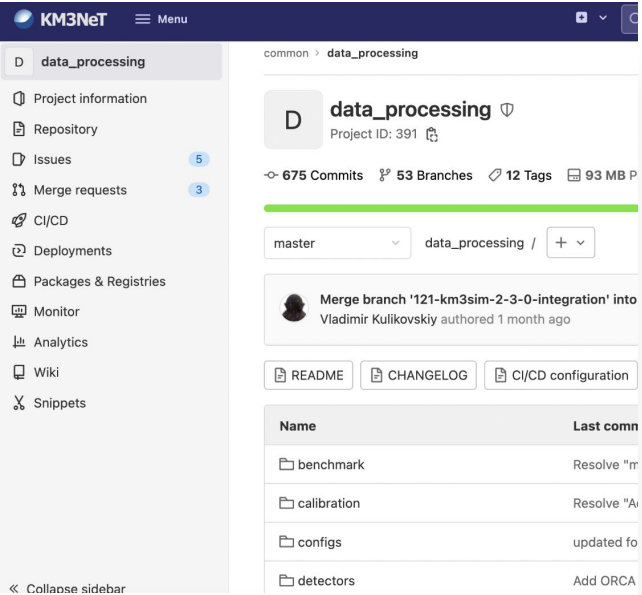

**ORCA PMTs**
**HV = -1130 V**
**HV = -1180 V**

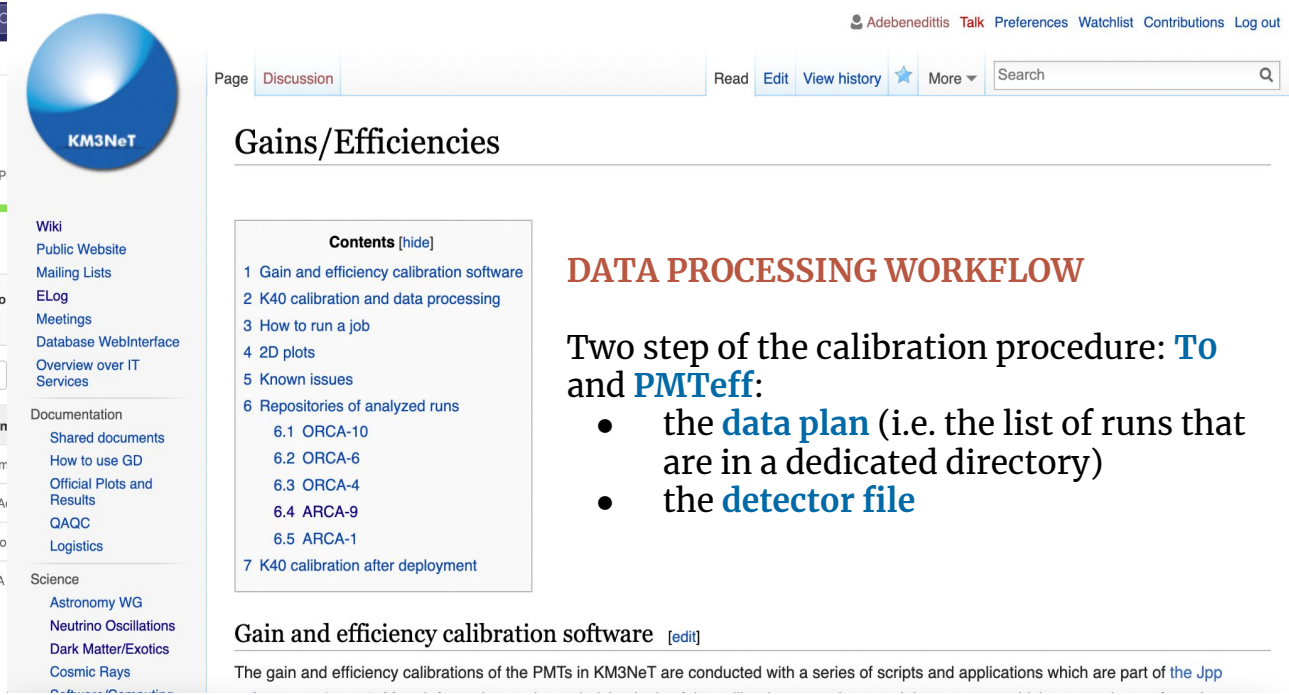
A regular tuning of the high voltage (HV) supplied to the PMTs is needed to equalize the gains of the PMTs

$$G = A \times HV^{kN}$$

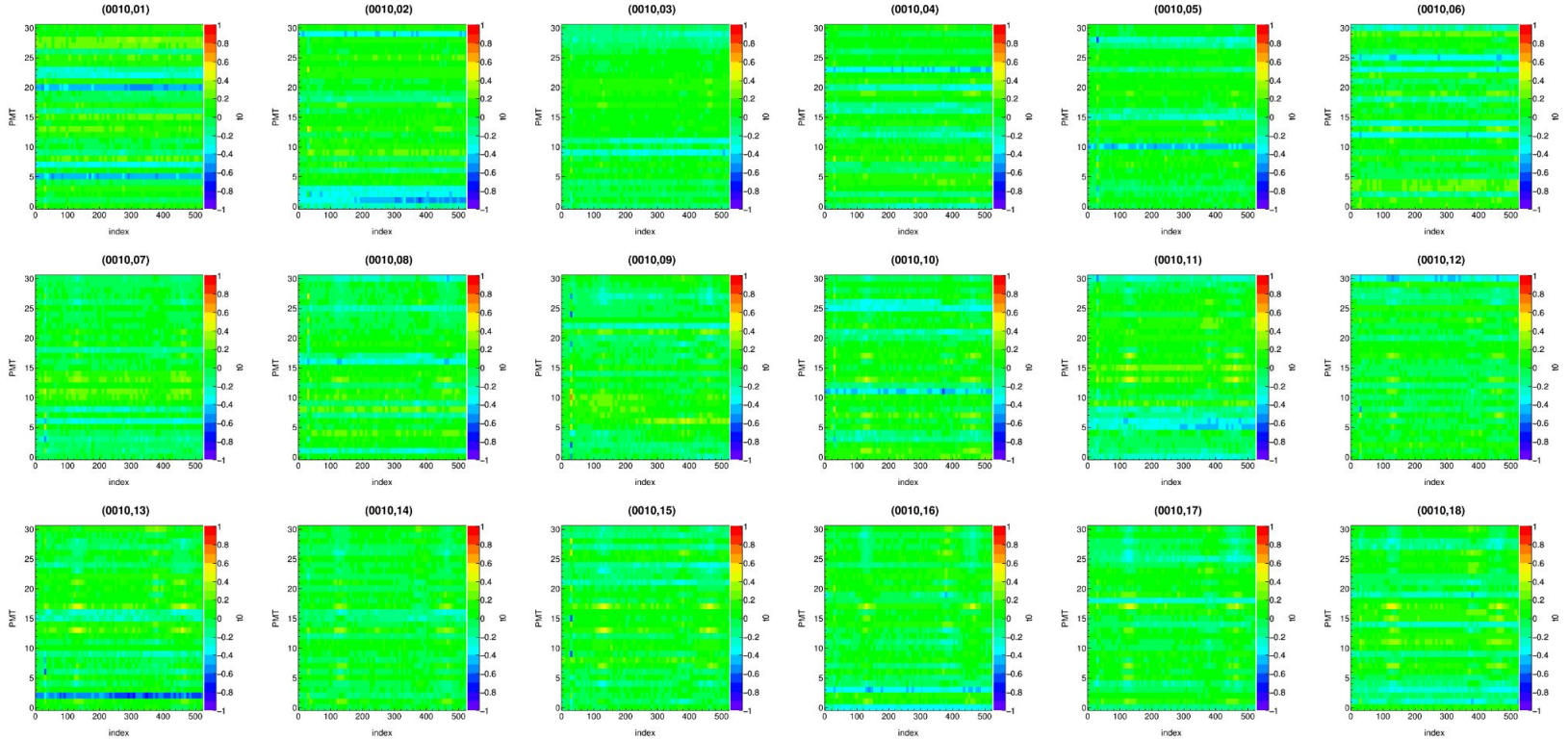
*A, k, N constants related to the dynode system of PMTs*

# Documentation



# ARCA – T0 – DU10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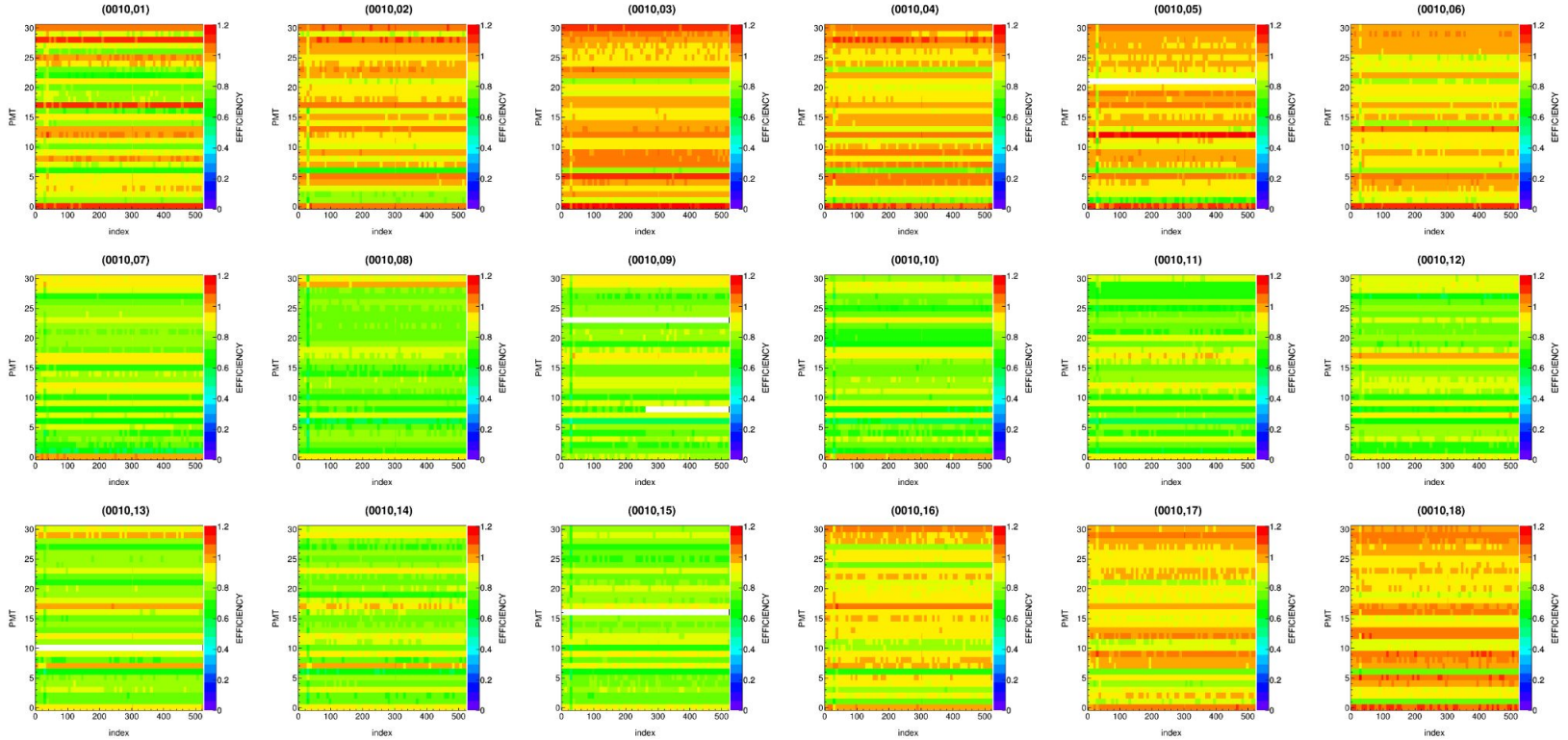
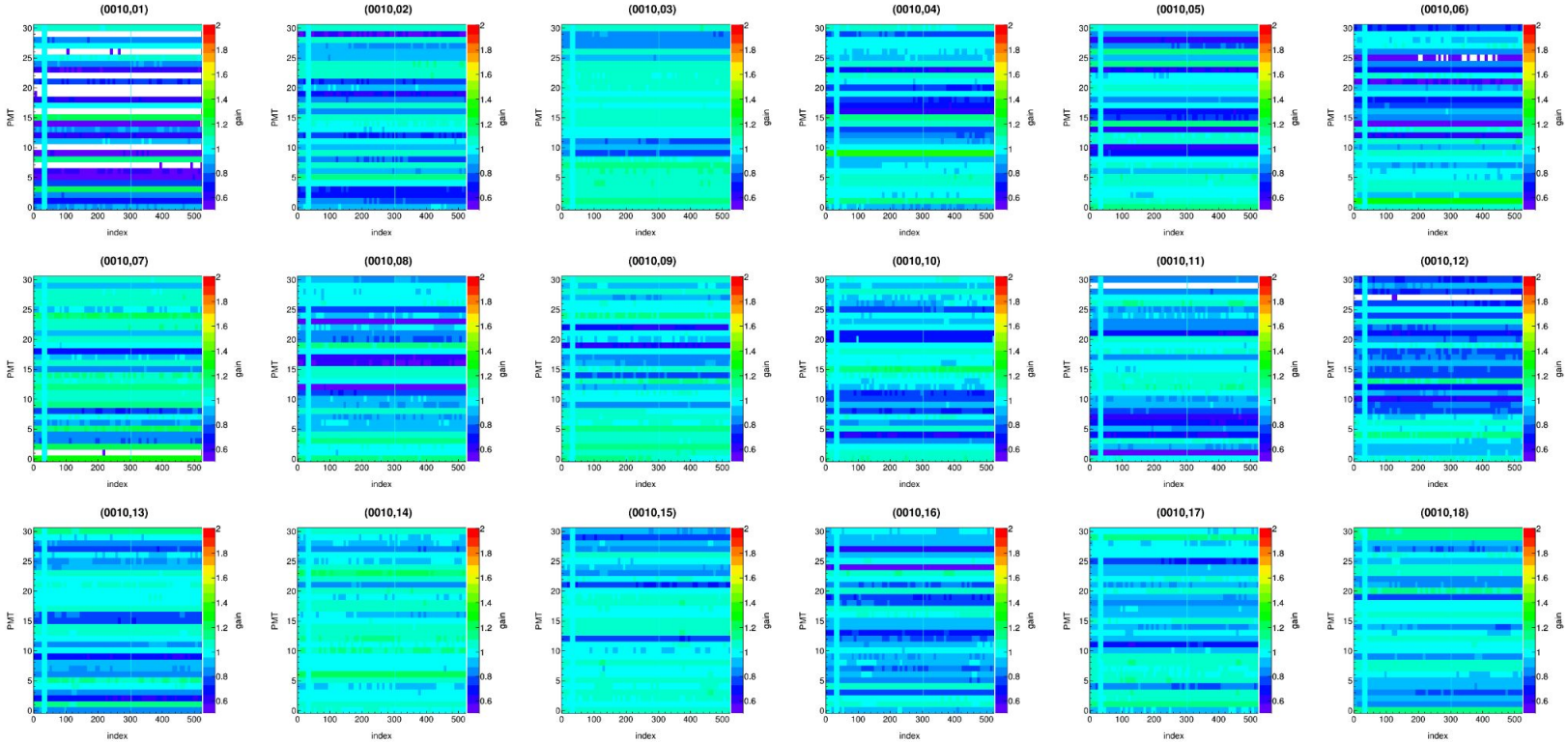
(0010,12)
(0010,13)
(0010,14)
(0010,15)
(0010,16)
(0010,17)
(0010,18)
PMT
index
t0

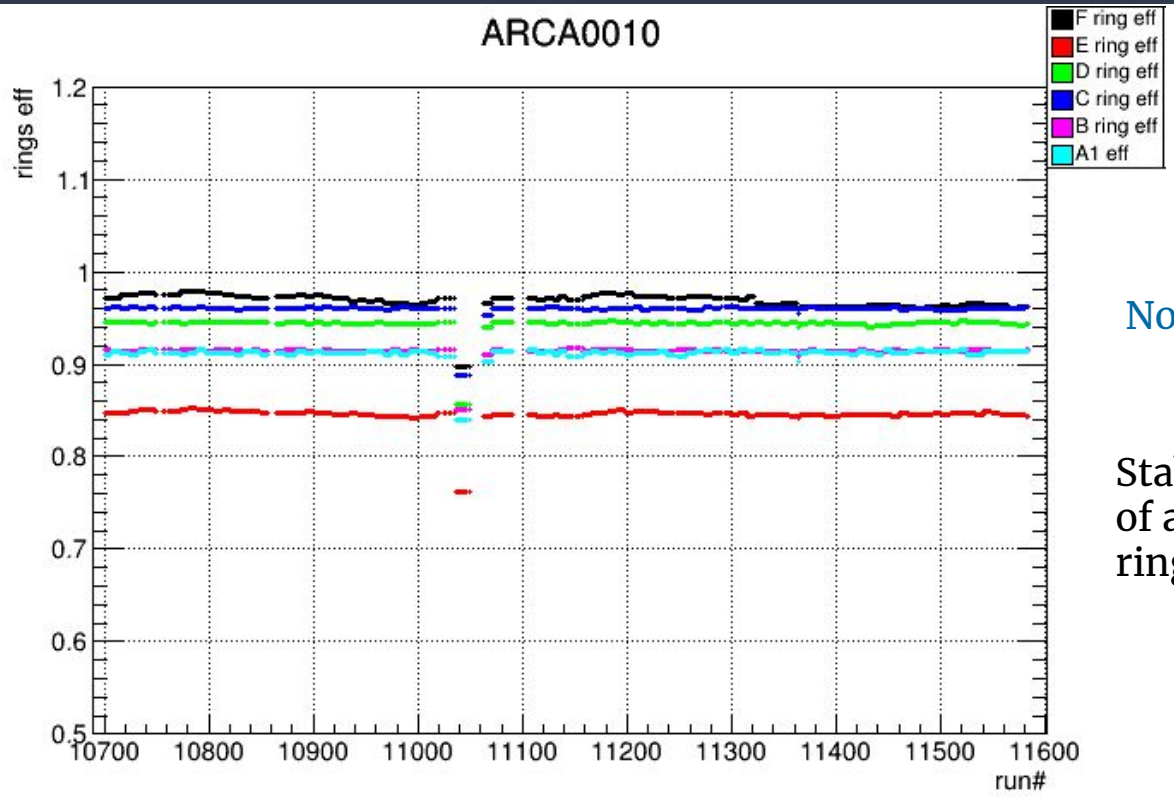
# ARCA - Efficiency - DU10



# ARCA - Gain - DU10



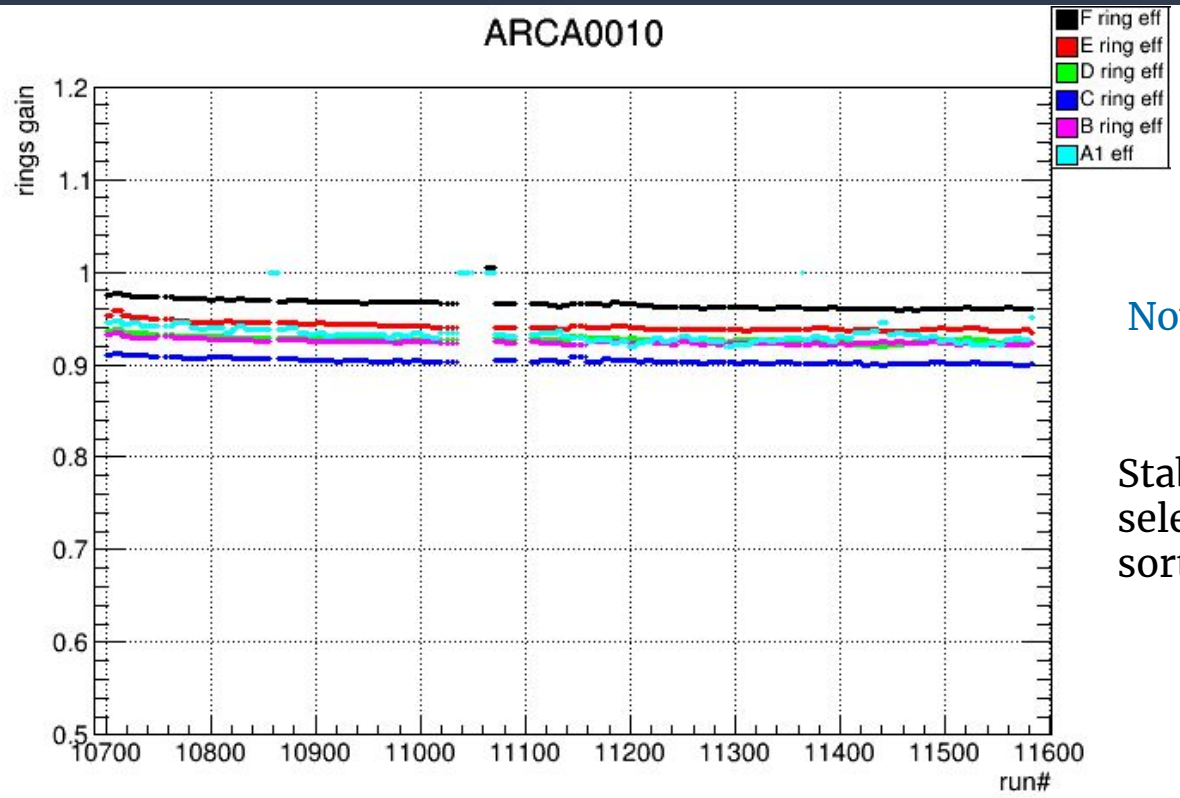
# ARCA - Ringwise Efficiency DU10




November 2021 - March 2022

Stability over time of the PMTs efficiency of a selected DU of ARCA detector ringwise sorted

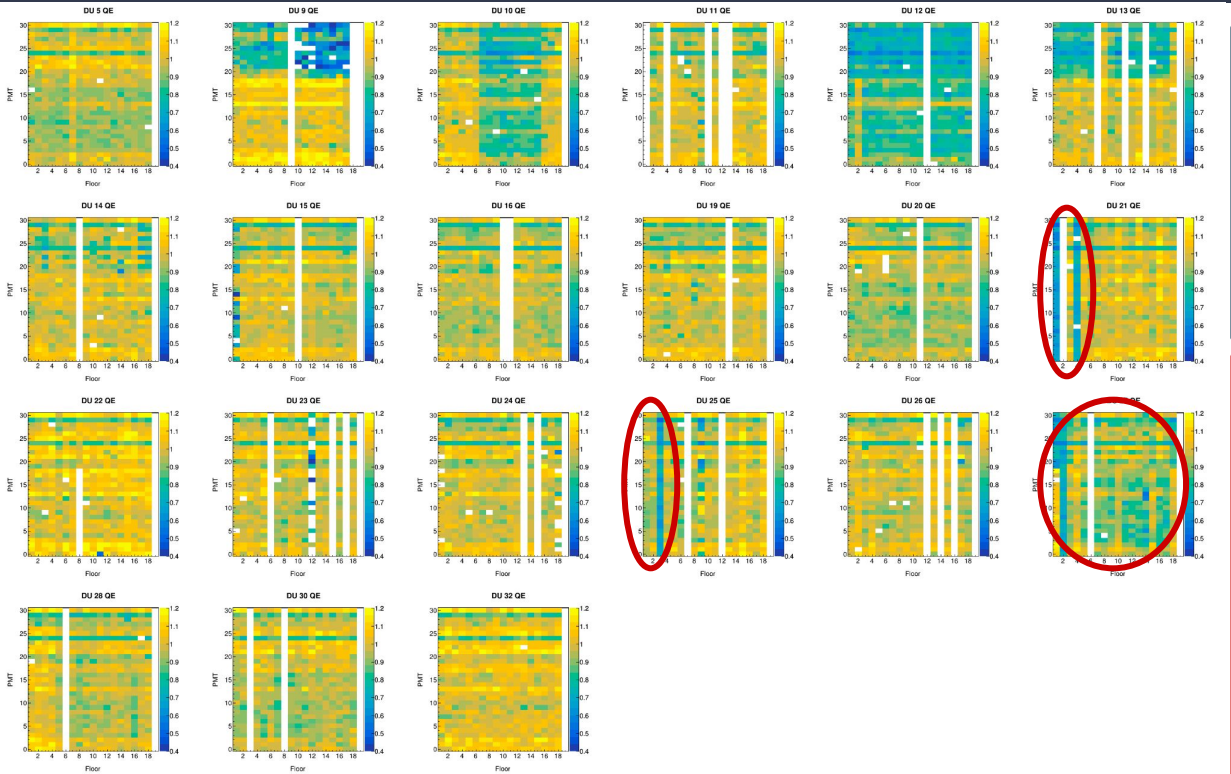
# ARCA - Ringwise Gain DU10




November 2021 - March 2022

Stability over time of the PMTs gain of a selected DU of ARCA detector ringwise sorted

# ARCA 21 - Efficiency status (runs: 13268 - 13274)



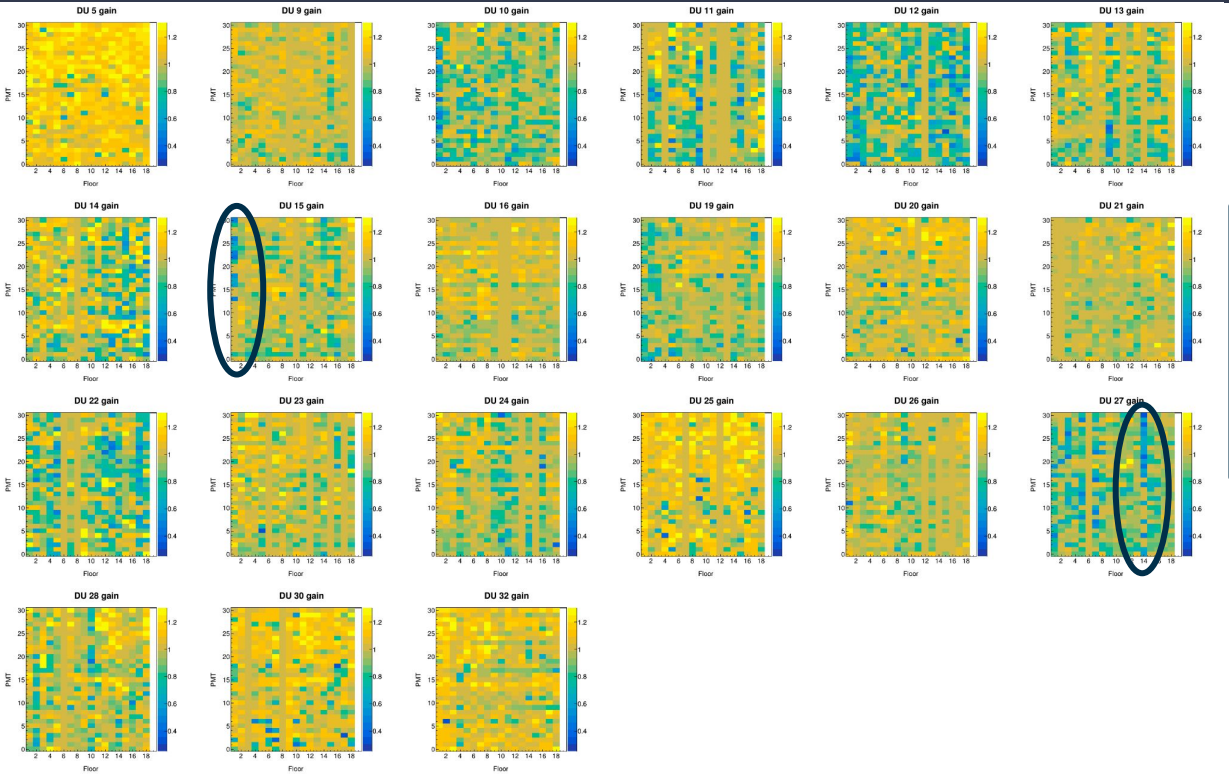

All channels present efficiency values around 1 with the exception of:

- ARCA.0012
- Upper hemisphere of ARCA.009 and ARCA.0013
- Central DOMs of ARCA.0010

**ARCA.1021 DOM 1, 4, ARCA.1025 DOM 3:** these 3 DOMs belong to the first production: they are very old objects, which mounted collection rings at a different angle to the one later officially adopted. It is therefore an expected behaviour

**ARCA.1027**: produced in Catania. Non-Conformity Report on Optical Gel

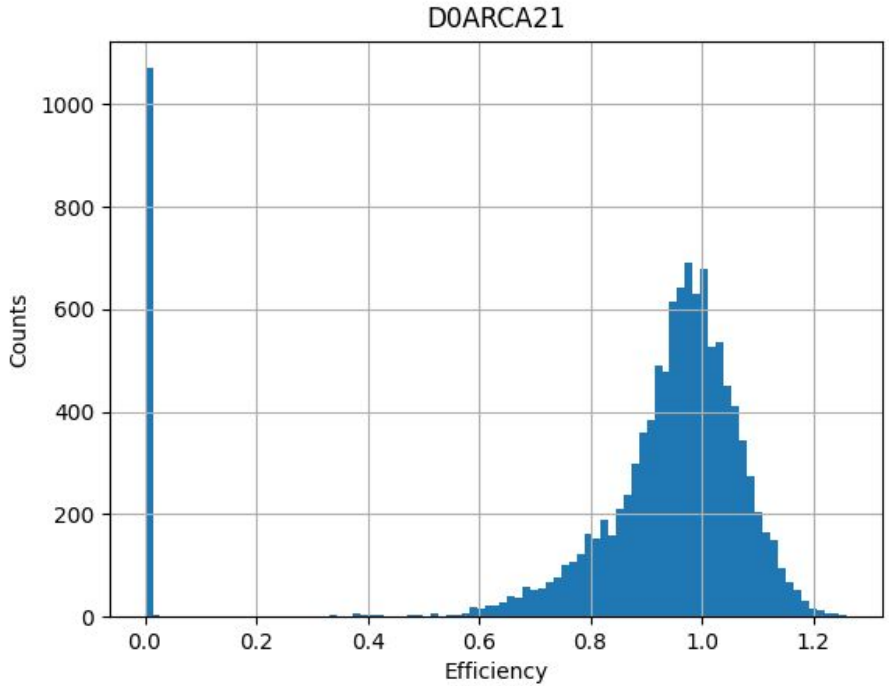
# ARCA 21 - Gain status (runs: 13268 - 13274)

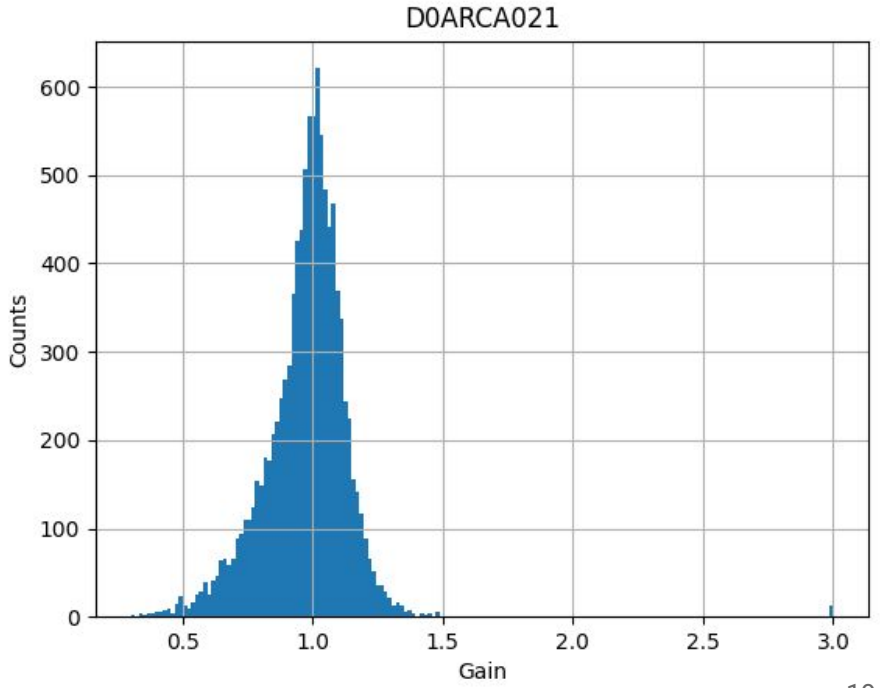



All channels present gain values around 1 with the exception of:

- ARCA.1015 DOM 1
- ARCA.1027 DOM 14

# ARCA 21 - Efficiency/Gain distribution (runs: 13268 - 13274)



# E-log documentation

All calibration readouts and monitoring are documented in dedicated entries e-log

KM3NeT Calibration Topics — Logged in as "Member of the KM3NeT collaboration"

|< < > >| List | New | Edit | Delete | Reply | Duplicate | Find | Logout | Help

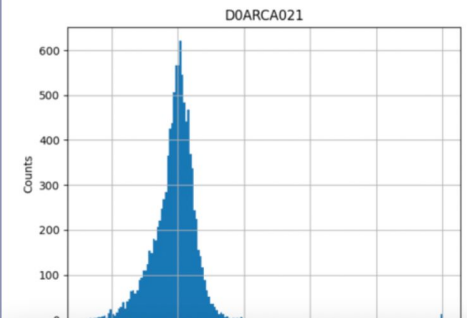
Message ID: **562** Entry time: **Tue Sep 27 16:40:14 2022**

| | |
|---|---|
| Author: | DeBenedittis A |
| Type: | gain changes |
| Subject: | First look at the channel gain of D0ARCA021 |

Gain evaluation made on the following runs:

13268 TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21
13272 TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21
13273 TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21
13274 TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21

- **1D gain channel distribution**




KM3NeT Calibration Topics

|< < > >| List | New | Edit | Delete | Reply | Duplicate | Find | Logout | Help

Message ID: **560** Entry time: **Thu Sep 22 15:12:14 2022**

| | |
|---|---|
| Author: | DeBenedittis A |
| Type: | D0ARCA021 |
| Subject: | sea time calibration |

Attached to this entry the detector file K10 calibrated with the standard procedure for sea time calibration.

**Data sample**

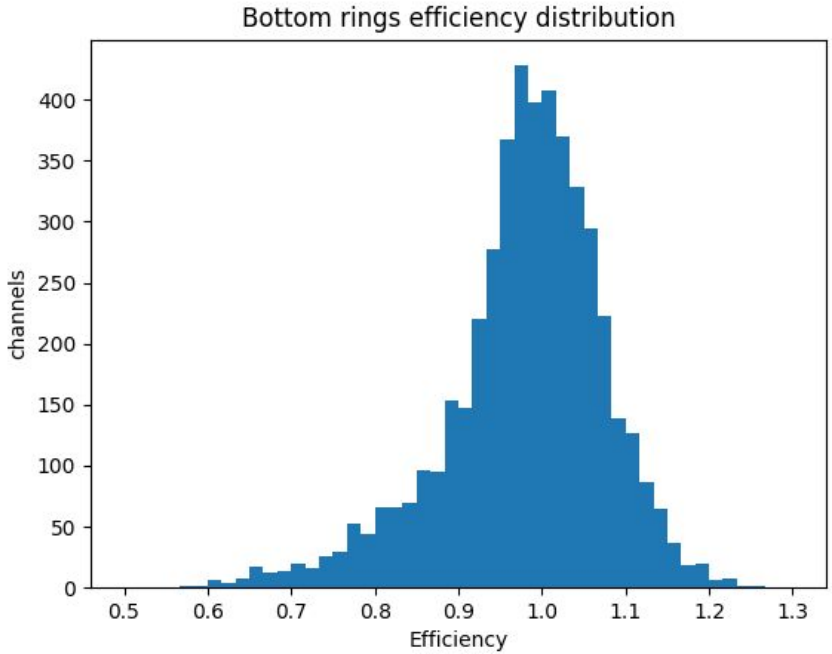
- input detx file: KM3NeT_00000133_20220917.detx

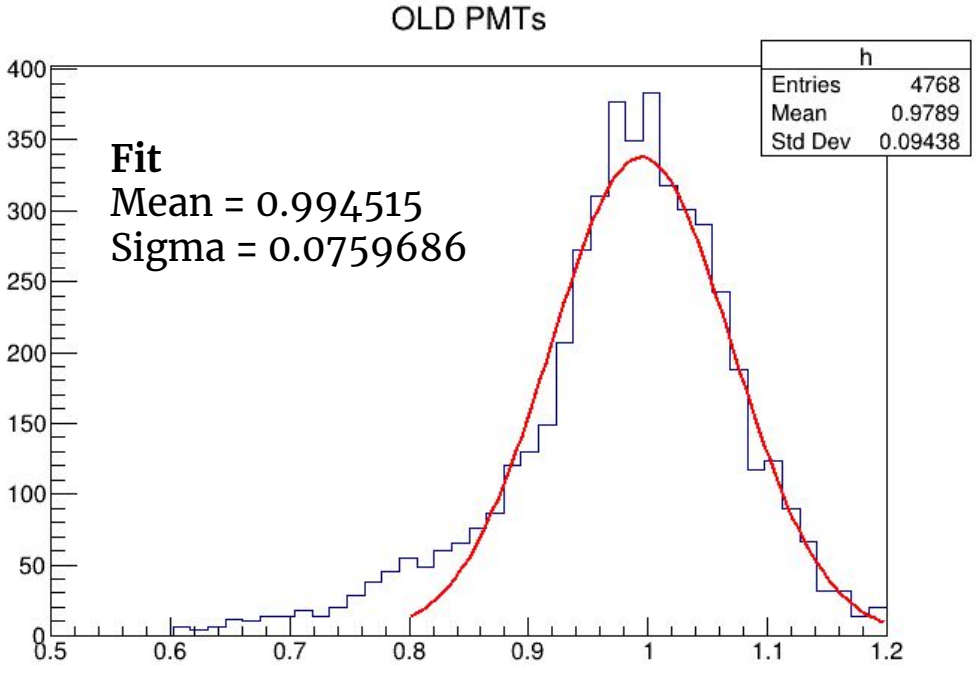
- run# 13268, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13272, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13273, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13274, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13275, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13276, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13277, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);
- run# 13278, setup: TEST.2209v1-HVTUNED-AllTrig-No.NB-No.L0-L1.100-Test01.ARCA21 (A03758339);

- reference PMT 2: https://elog.km3net.de/Calibration/550 (DU32);
- reference PMT 7: https://elog.km3net.de/Calibration/550 (DU05)

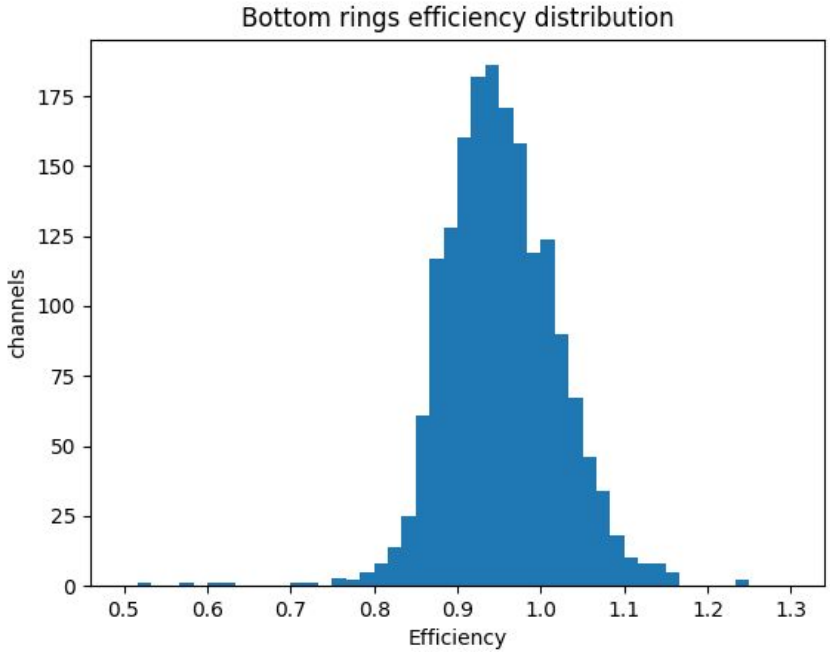
# OLD vs NEW PMTs

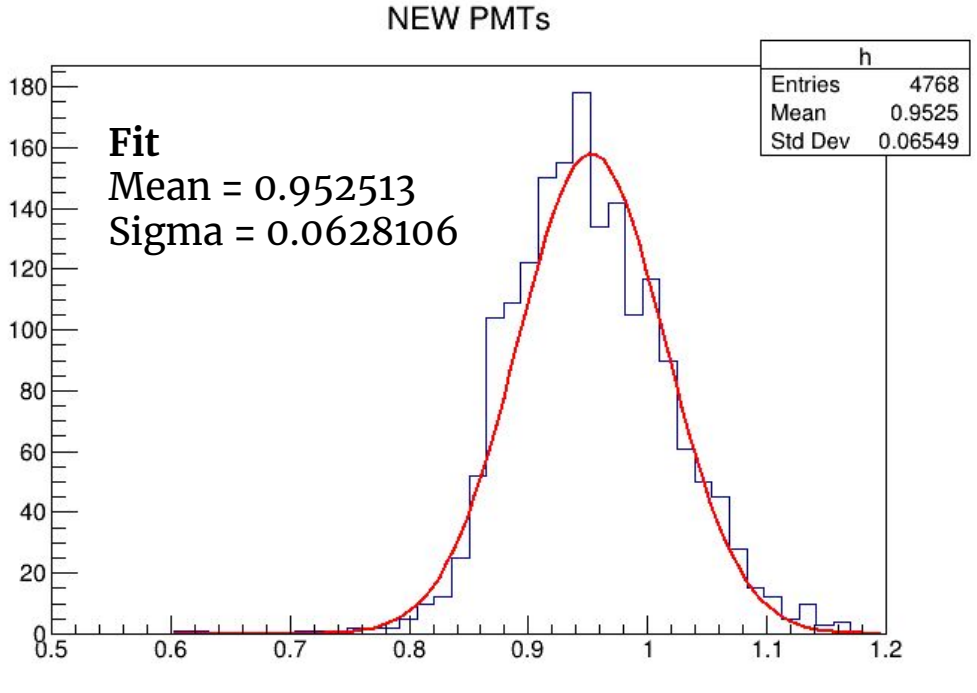
# OLD PMTs – R12199



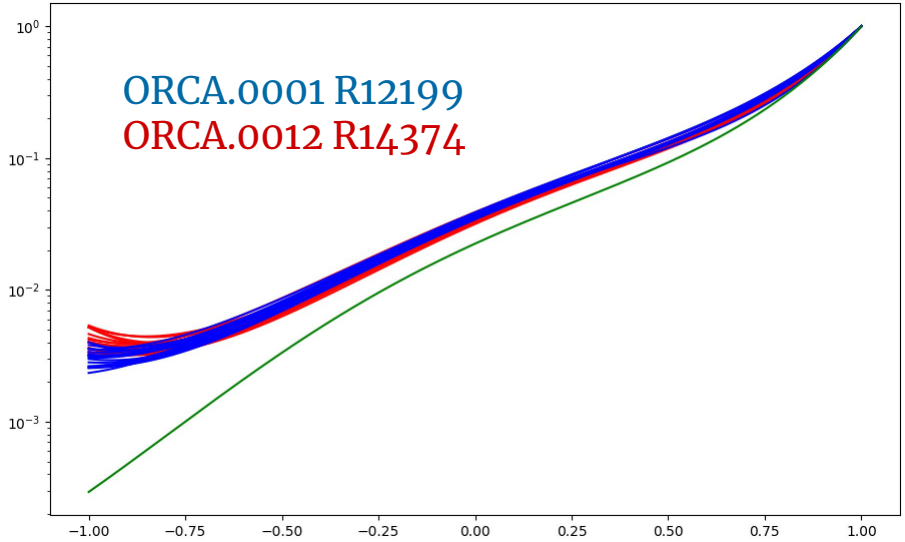



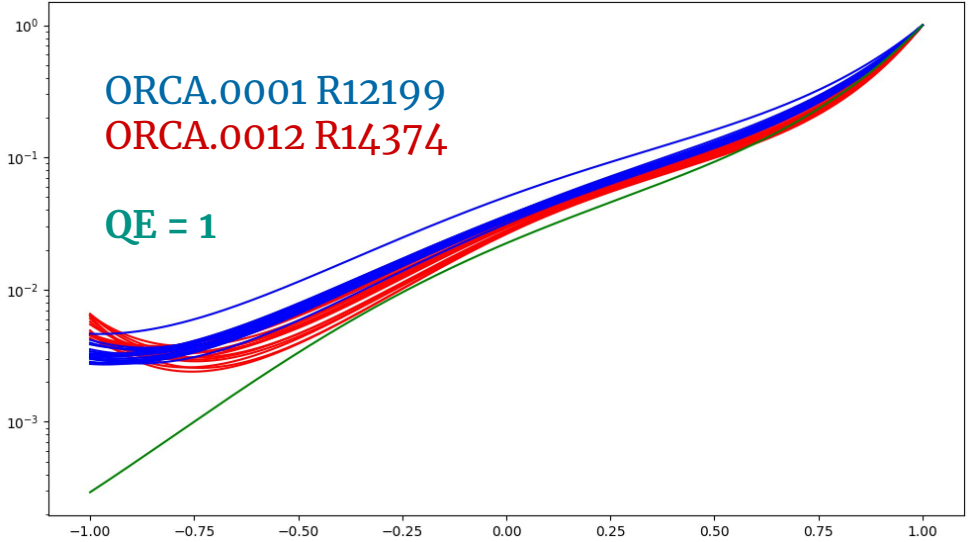
# NEW PMTs - R14374



# Angular distribution - New vs Old PMTs



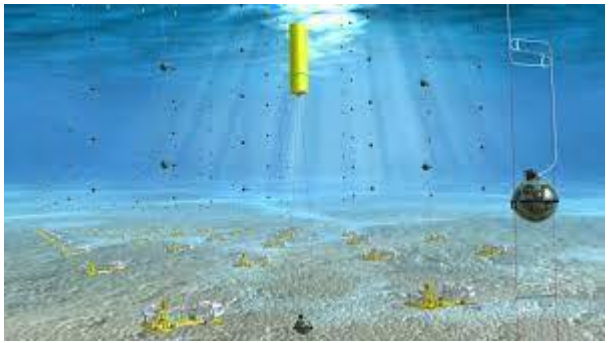
# Gain comparison

# Gain comparison

**In order to constantly monitor the status of PMTs and find any possible anomalies**

**HV Vendor**

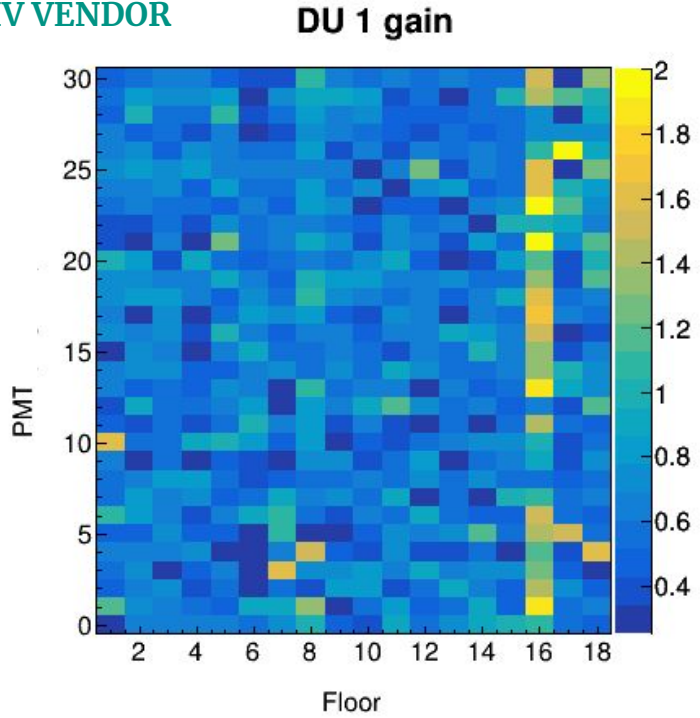
**HV Tuned (DR)**



**HV Sea**

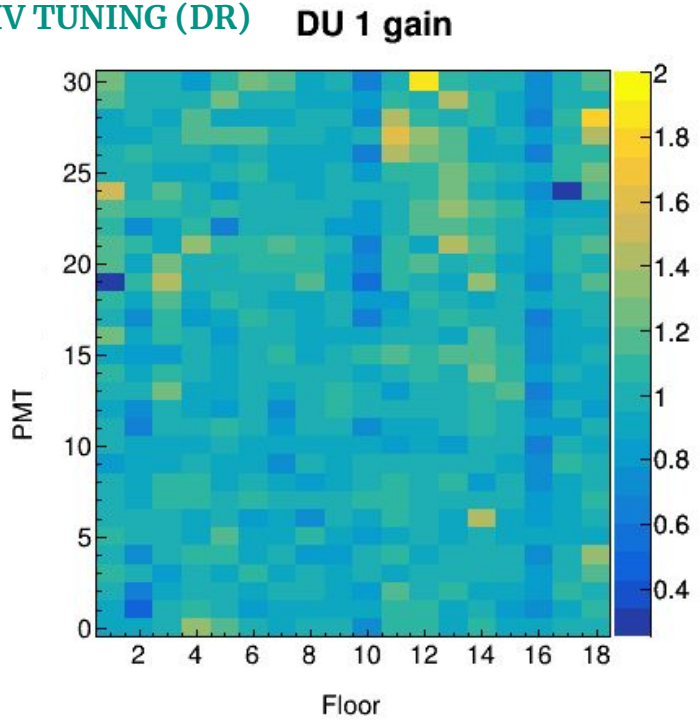
# DU54 - GAIN COMPARISON

HV VENDOR




https://elog.km3net.de/DU+Integration/810

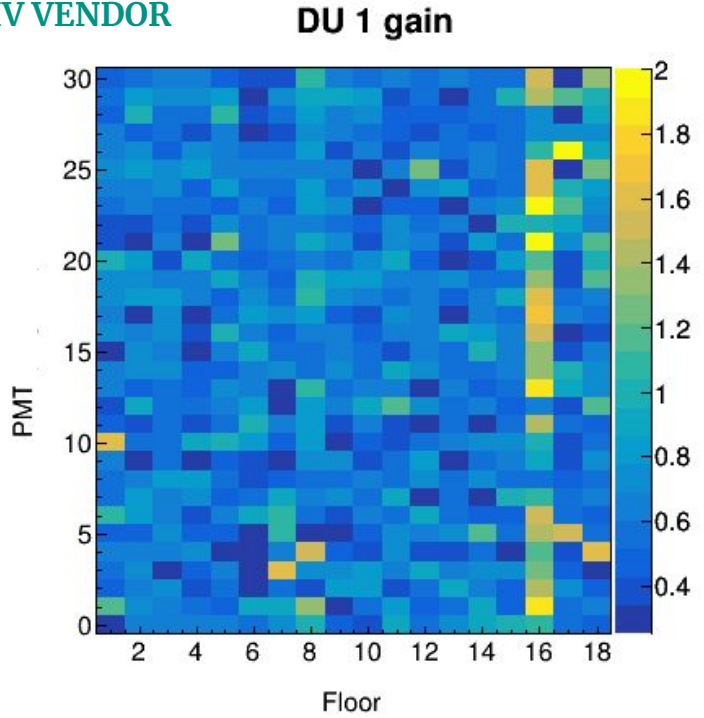
HV TUNING (DR)




jpp/16.0.1 - fit range "0 -1"

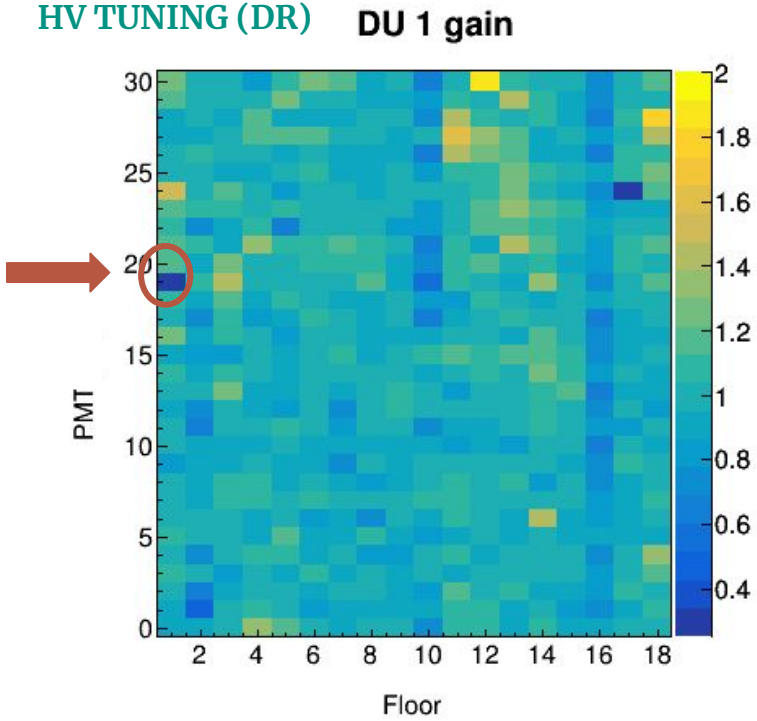
# DU54 - GAIN COMPARISON

HV VENDOR




https://elog.km3net.de/DU+Integration/810

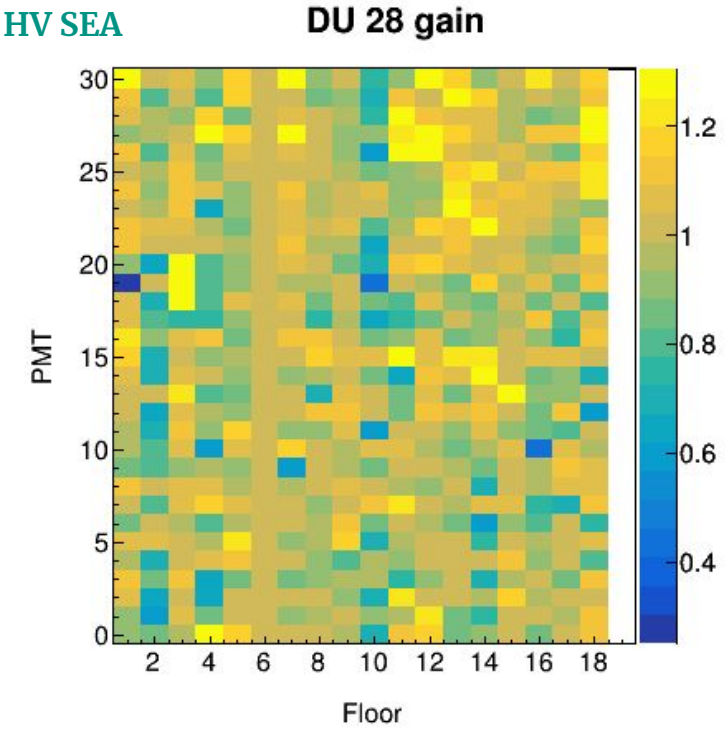
HV TUNING (DR)




jpp/16.0.1 - fit range "0 -1"

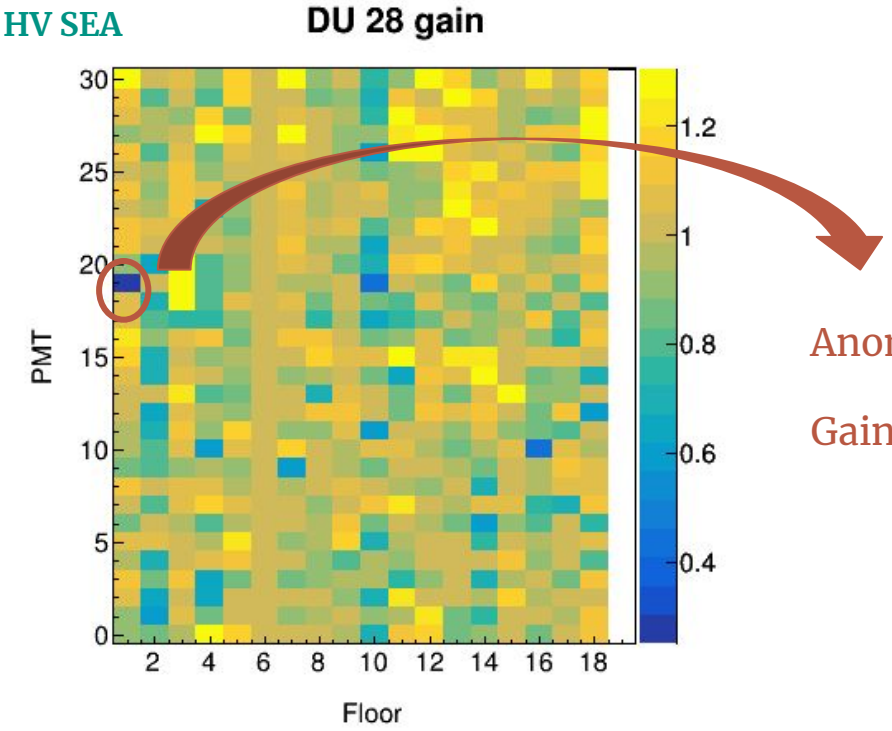
# DU54 - GAIN COMPARISON

**HV SEA**



# DU54 - GAIN COMPARISON

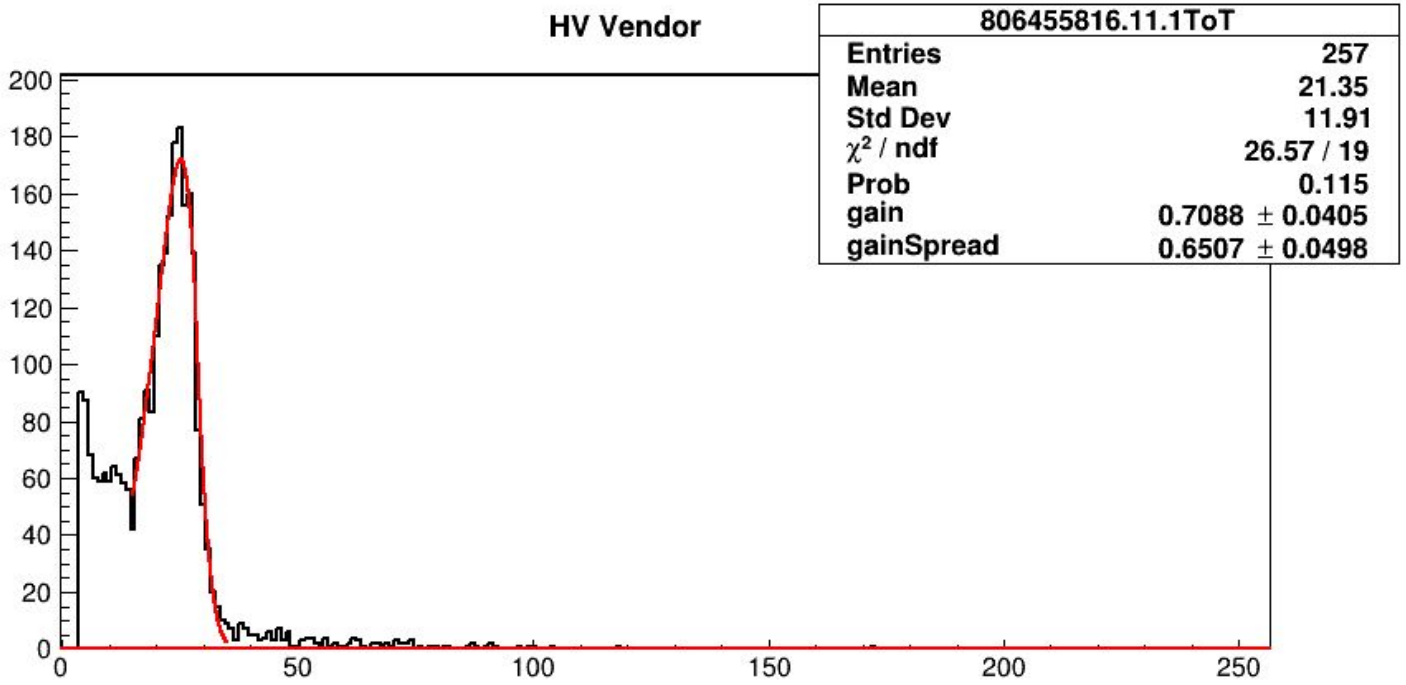
HV SEA




Anomalous channel

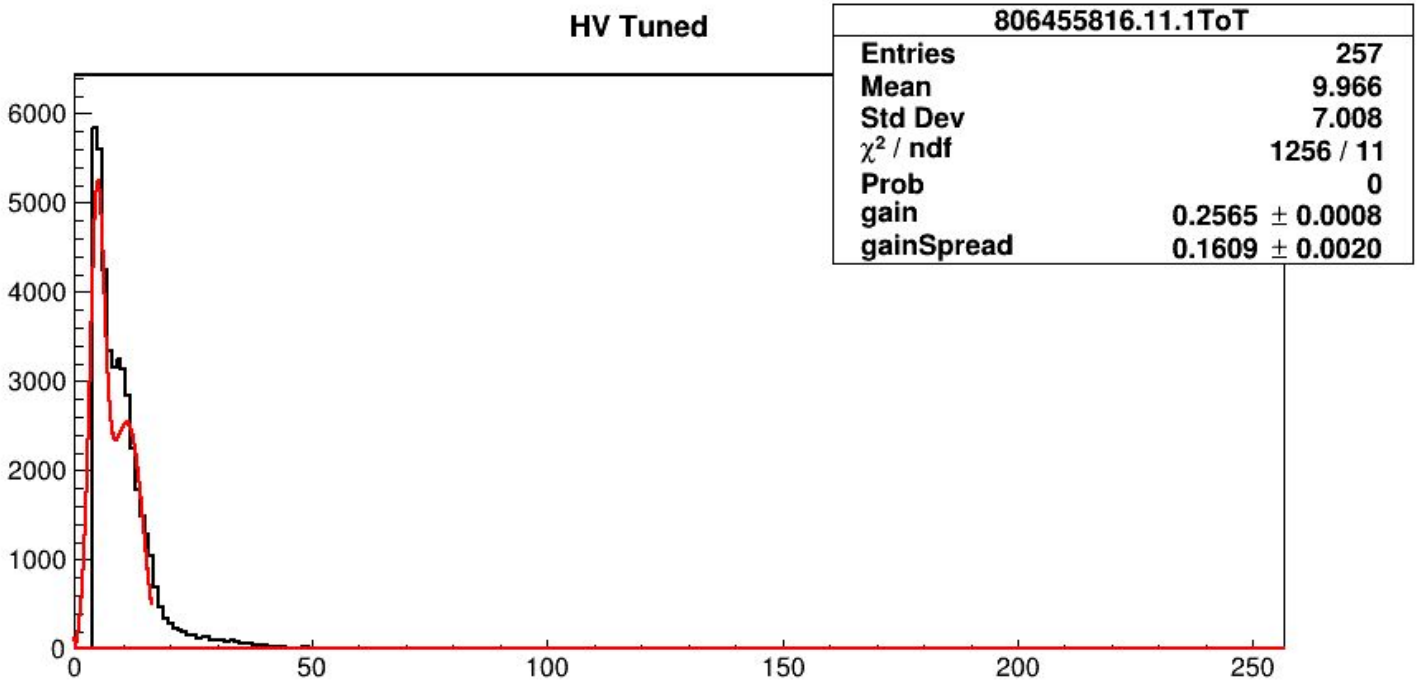
Gain out of acceptance range (G<0.25)

# DU 54 ID DOM 806455816 - 11



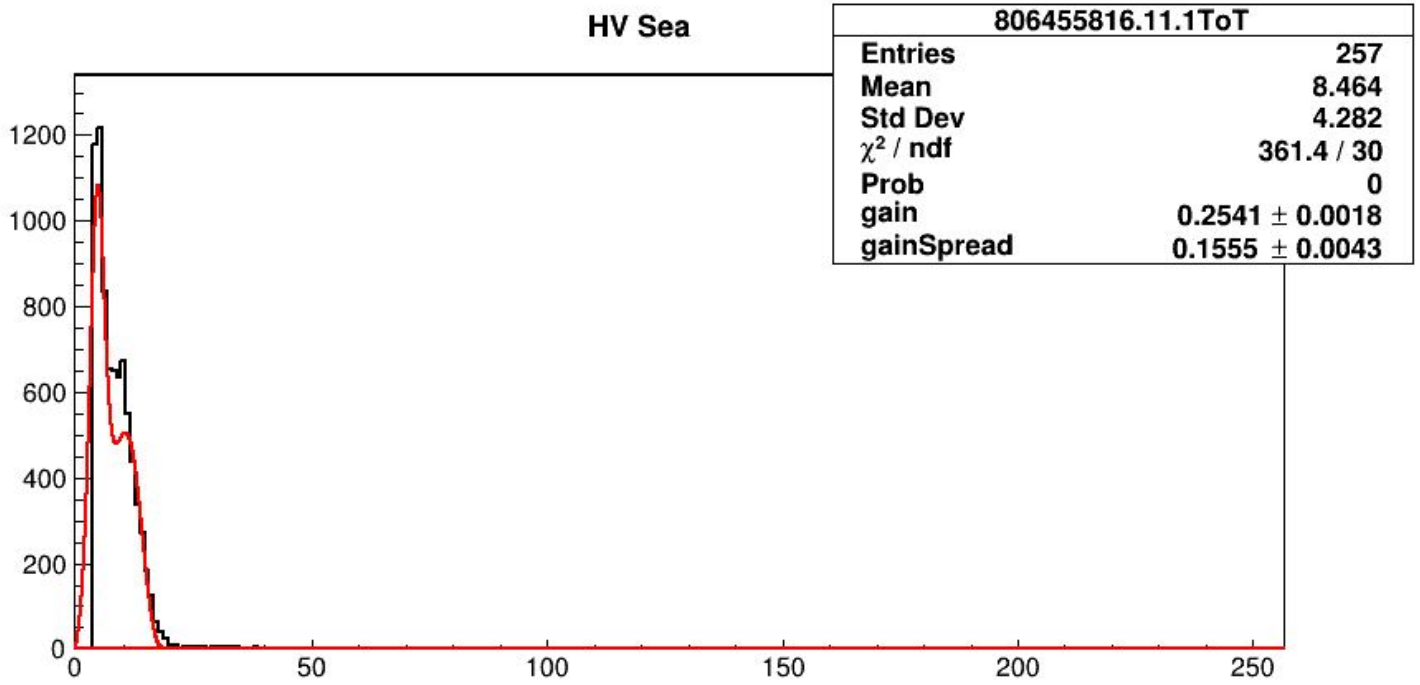

**Fit of the ToT distribution gives the gain value of the channel**

# DU 54 ID DOM 806455816 - 11




**Fit of the ToT distribution gives the gain value of the channel**

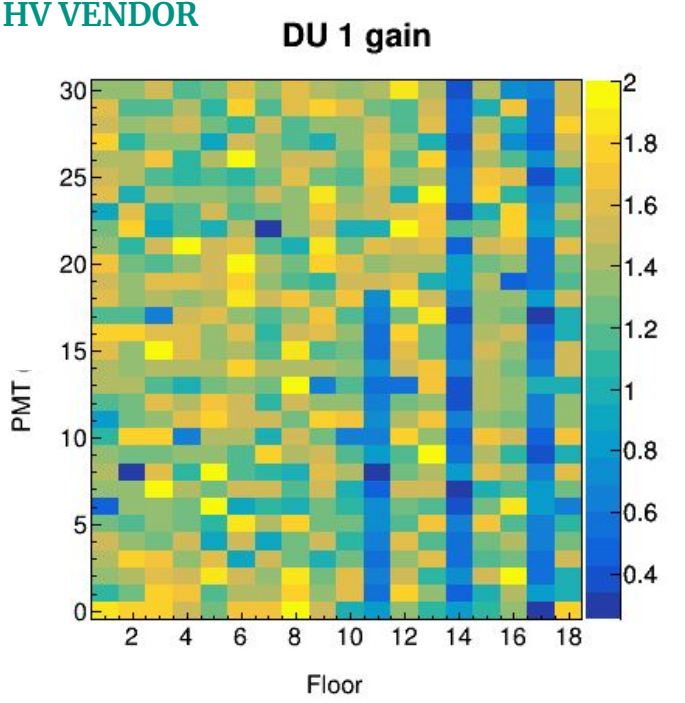
# DU 54 ID DOM 806455816 - 11



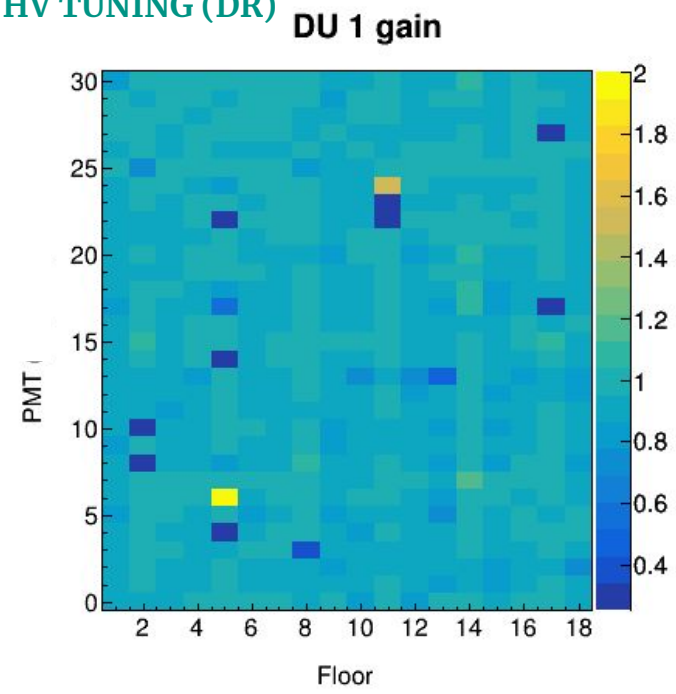

**Fit of the ToT distribution gives the gain value of the channel**

# DU52 - GAIN COMPARISON

**HV VENDOR**



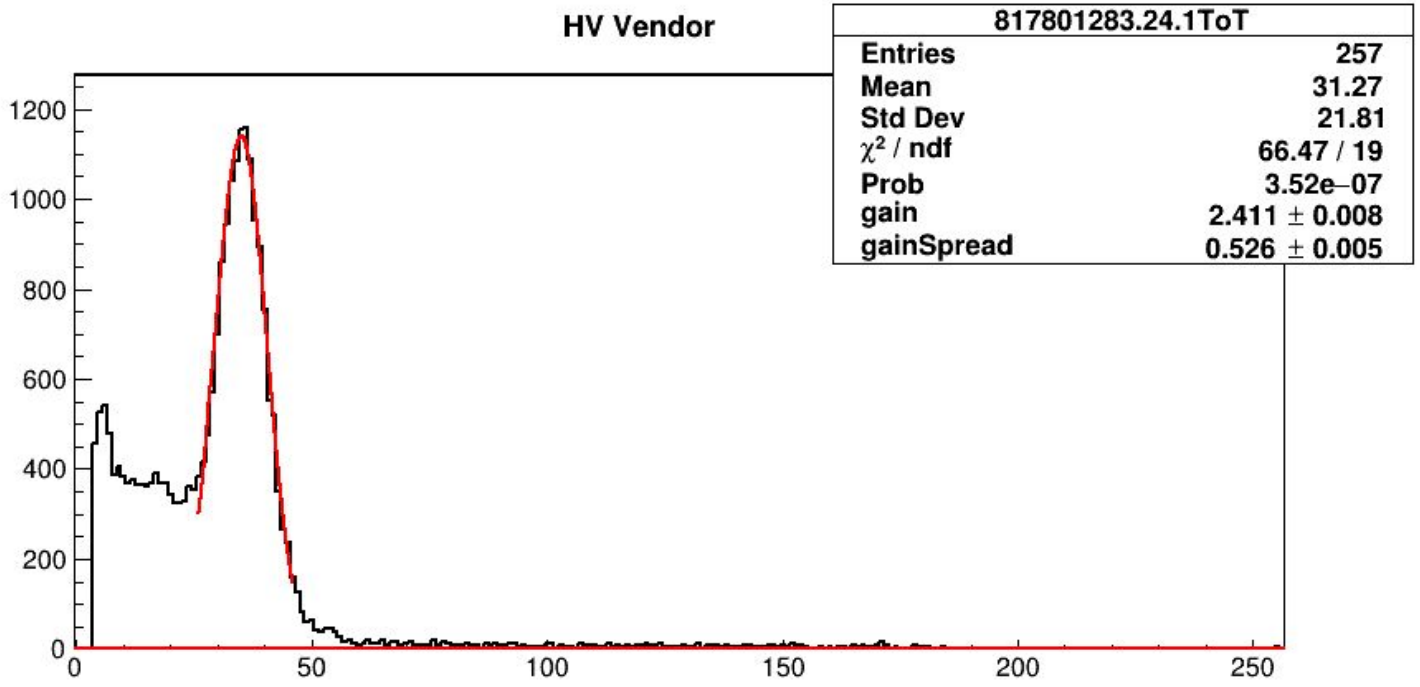

**HV TUNING (DR)**



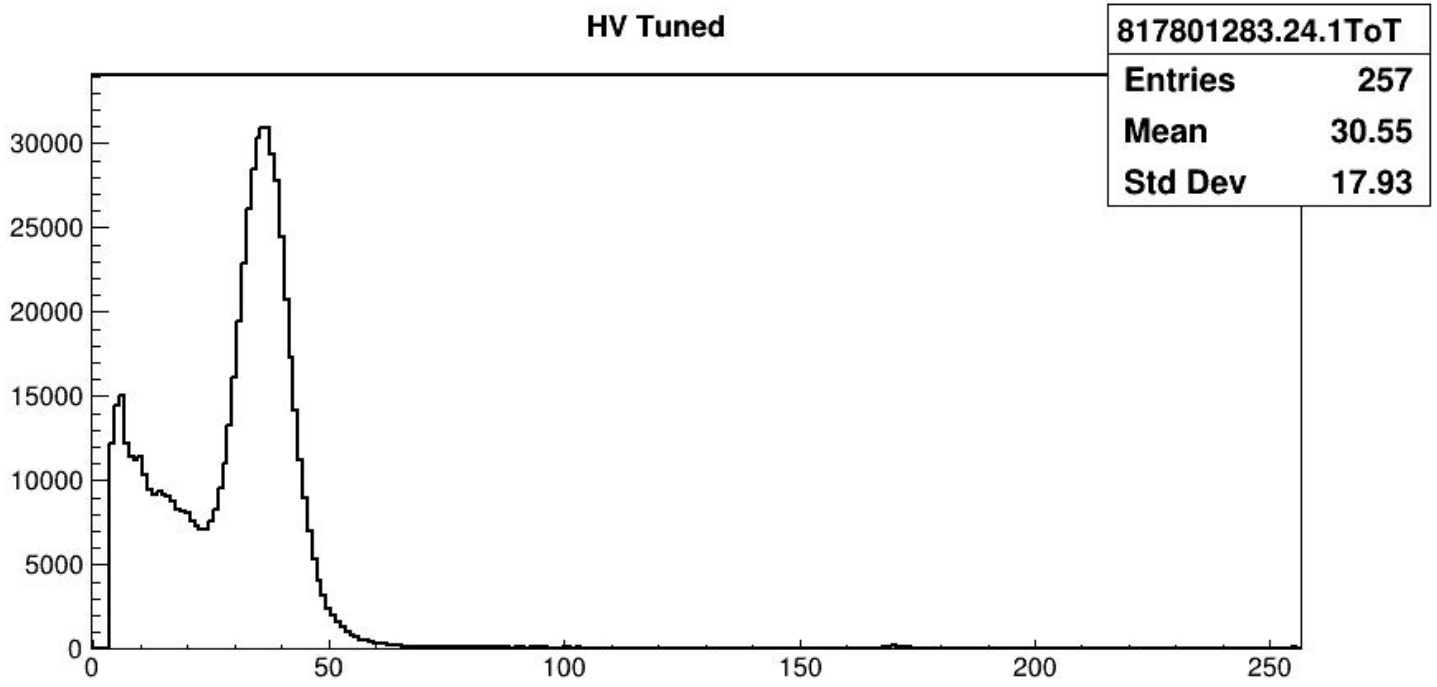

https://elog.km3net.de/DU+Integration/790

**jpp/16.0.1 - fit range "0 -1"**

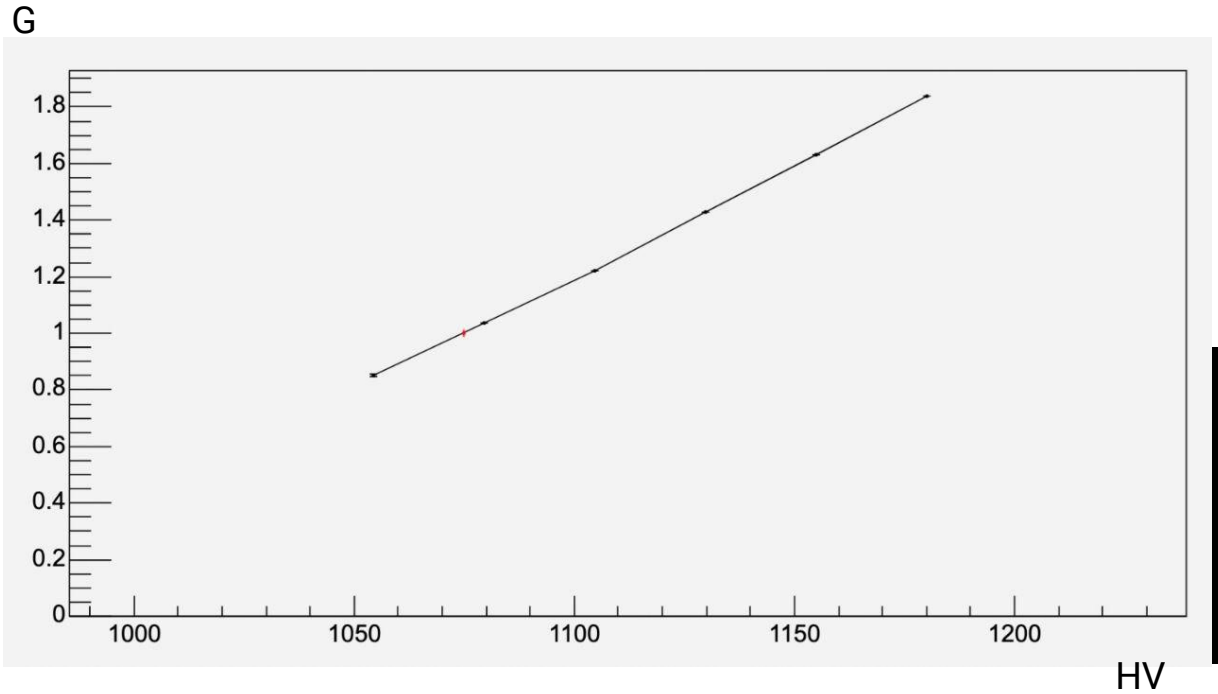
# DU 52 ID DOM 817801283 - 24

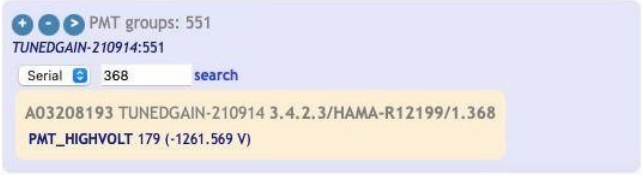


# DU 52 ID DOM 817801283 - 24



# DU52 ID DOM 817801283 - 24 - HV setting




HV Setting after process 3


Json file

# Next steps

- Inventory all possible types of anomalies:
  - issue in Dark Room Calibration
  - gain/efficiency failures
  - incorrect offset
  - inconsistencies between old and new PMTs
  - ...

- Update Jpp tools in order to automatically recognise such anomalies and prevent them, where possible, during processing