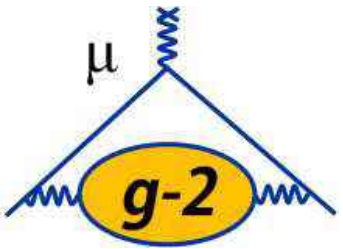
Monitoring and Data Acquisition of the Laser Calibration System of Muon g-2 Experiment

Atanu Nath
(On behalf of the Muon g-2 collaboration)



104° Congresso Nazionale
21st September 2018, Cosenza, Calabria

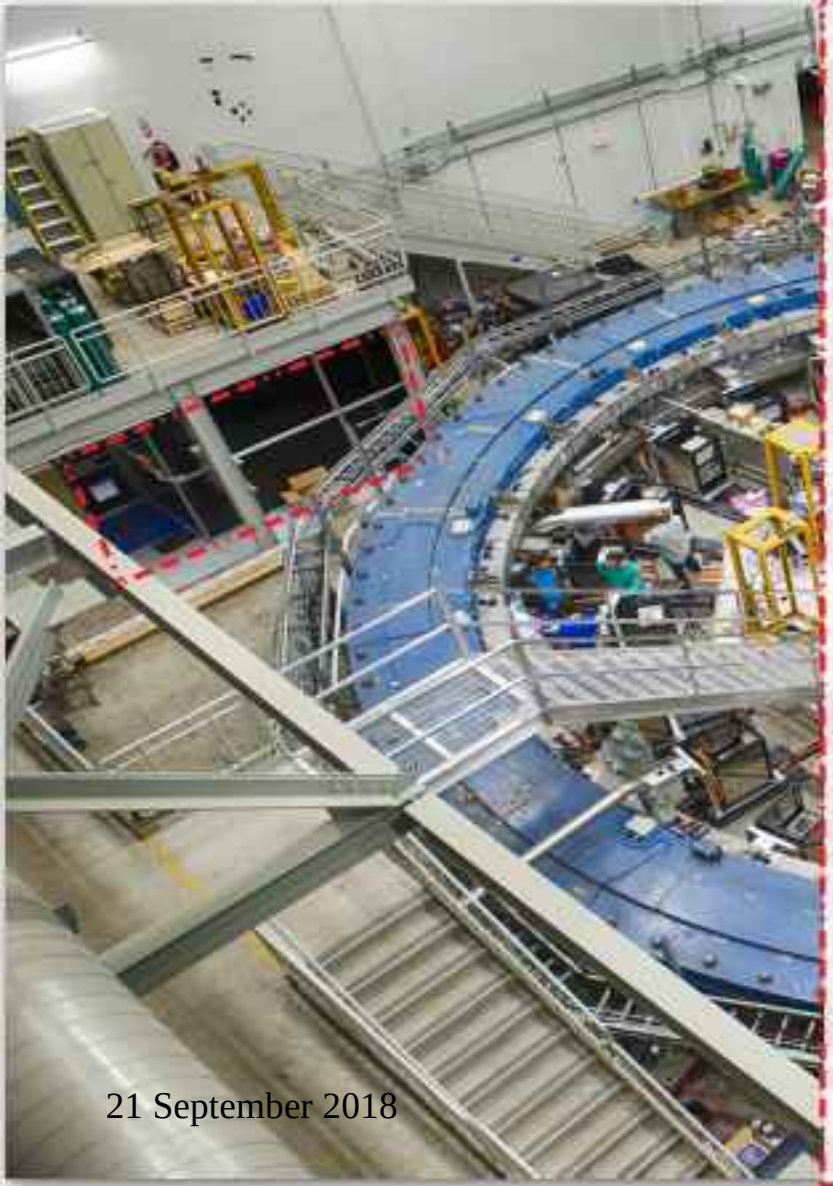
Outline

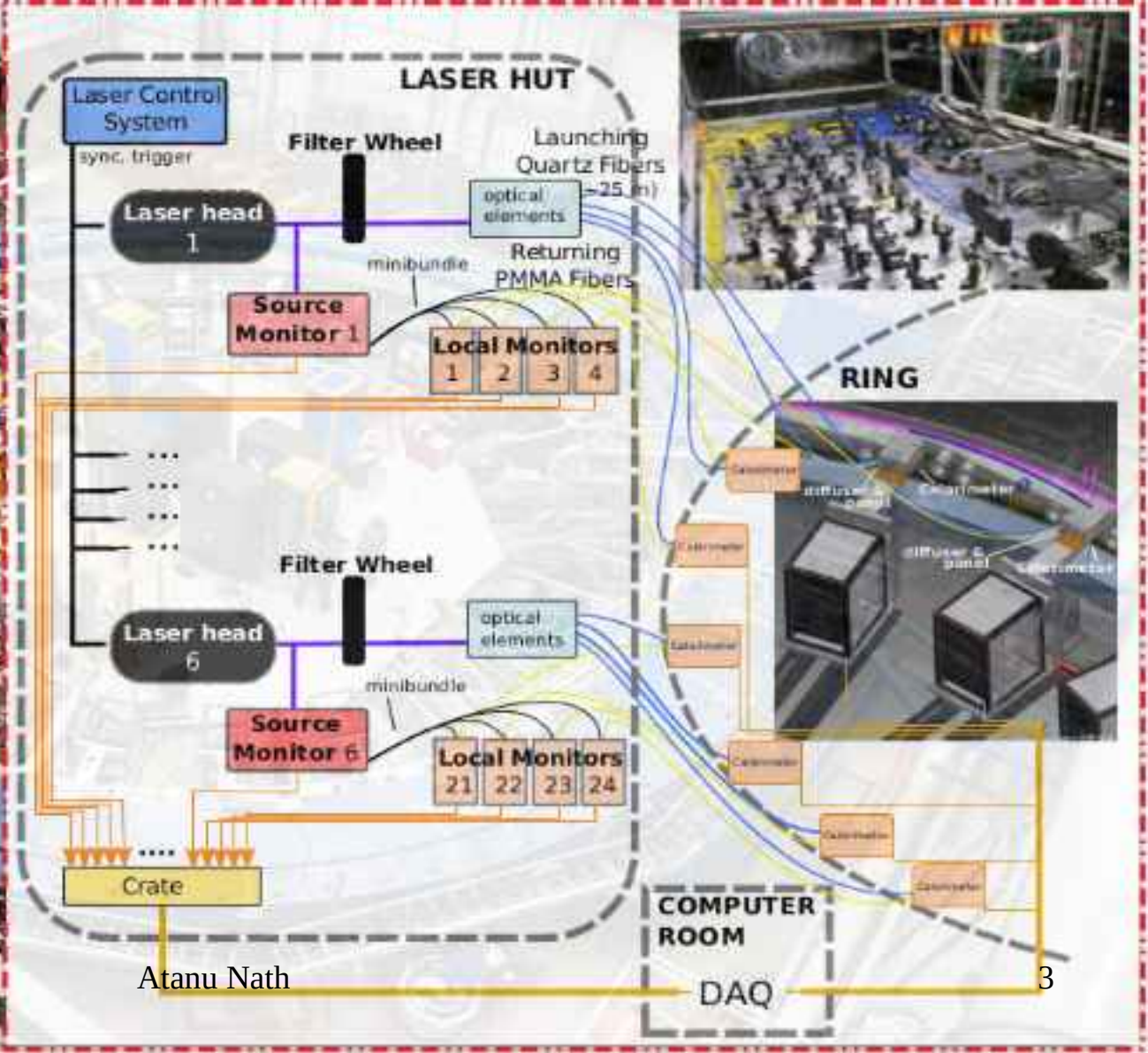
The main components

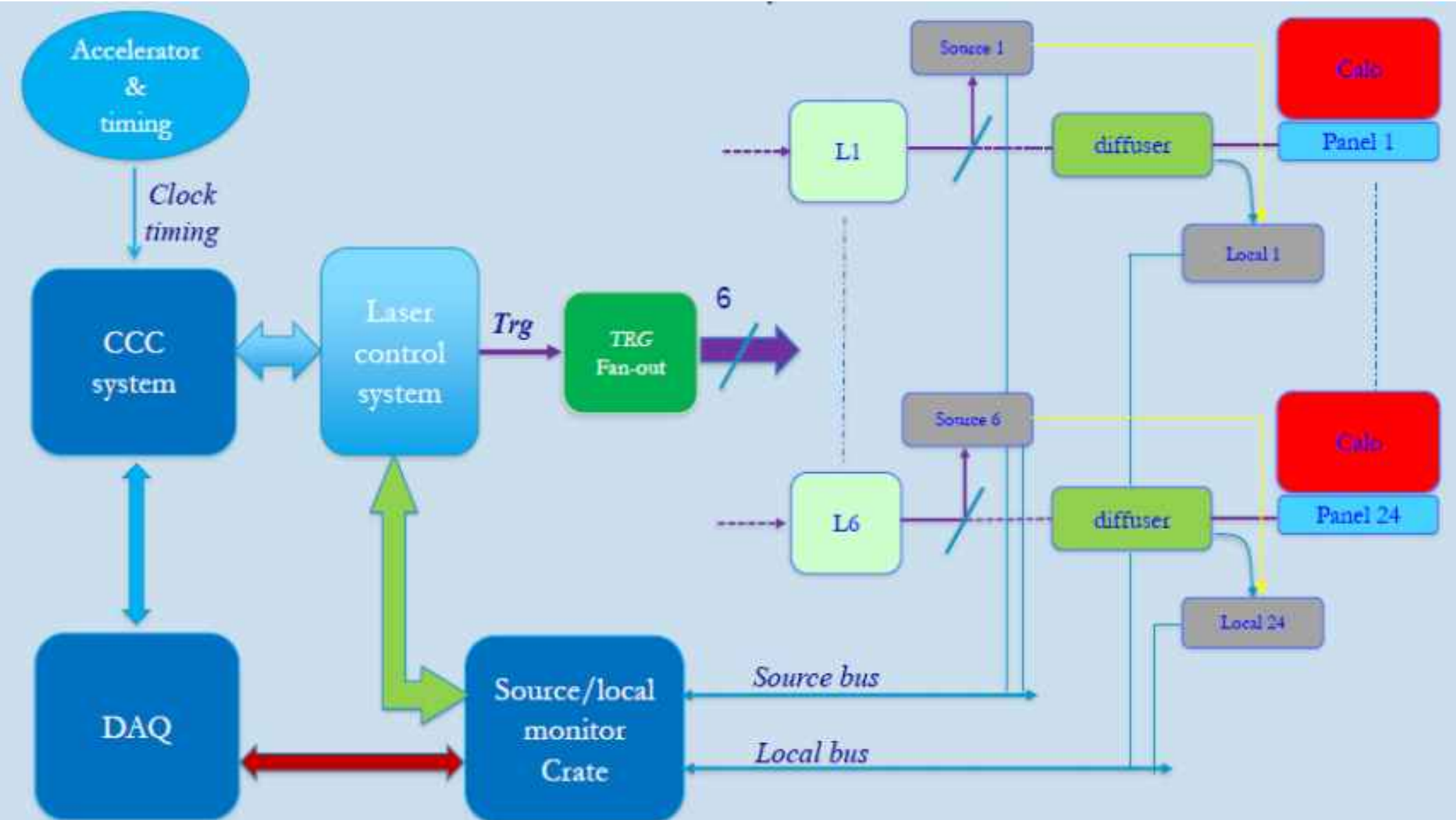
- Laser control system
- *Source Monitors*
- *Local* Monitors

Data acquisition & monitoring systems

- MIDAS DAQ
- Naples DAQ




LASER HUT
Laser Control System
sync. trigger
Filter Wheel
Launching Quartz Fibers (~25 m)
optical elements
Laser head 1
minibundle
Returning PMMA Fibers
Source Monitor 1
Local Monitors
1 2 3 4
RING
Filter Wheel
optical elements
Laser head 6
minibundle
Source Monitor 6
Local Monitors
21 22 23 24
Crate
COMPUTER ROOM
DAQ

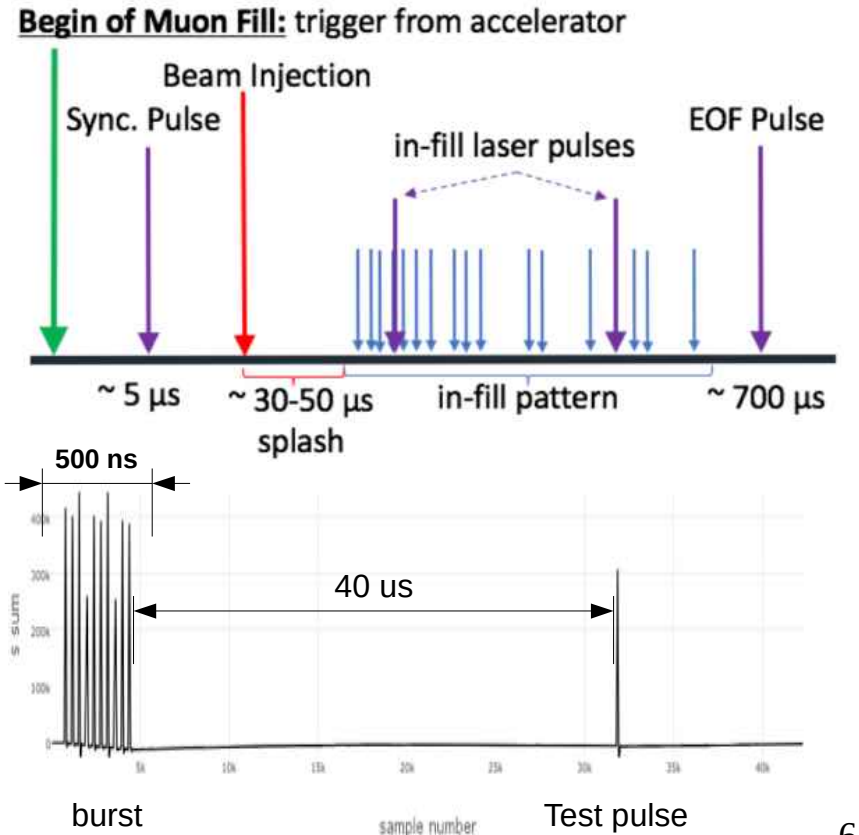

Accelerator & timing
Clock timing
CCC system
Laser control system
Trg
TRG Fan-out
6
DAQ
Source/local monitor Crate
Source bus
Local bus
Source 1
L1
diffuser
Calo
Panel 1
Local 1
Source 6
L6
diffuser
Calo
Panel 24
Local 24

Laser Controller

Laser Control System

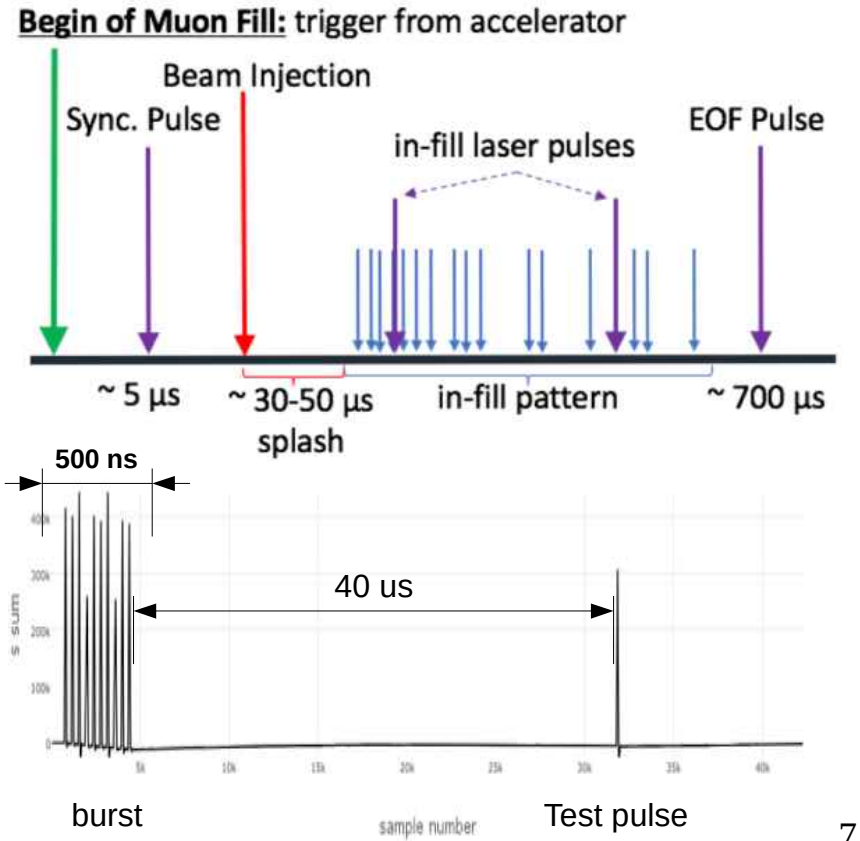
In-Fill : 2 pulses **200 us** apart are sent every fill to minimize the damage

Then these pulses are shifted by **5 us** to scan the whole range of **400 us** fill window.

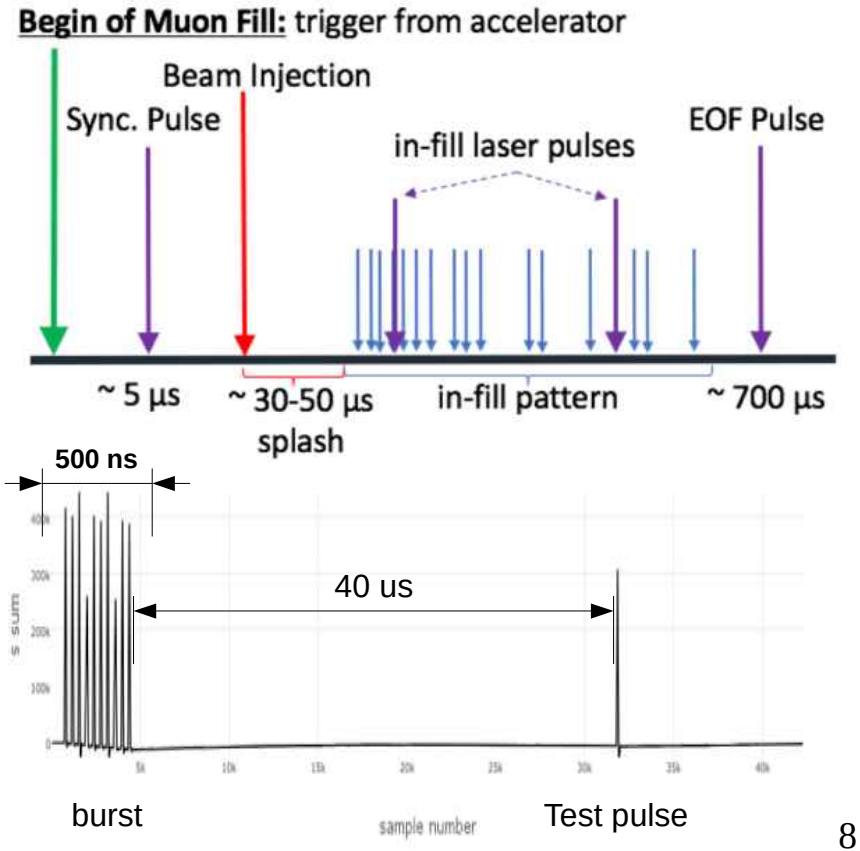


Laser Control System

- **Out of fill : laser** pulses sent outside the muon fill over longer period of time to study the long-term gain stability.
  - affects due **Temperature** variation, **aging** etc can be corrected.
  - **double-pulses :** additional **(1 %)** gain drop due to very close (~ 10 ns) positron hits, to study this two very close laser pulses are sent and the response is studied.
  - **flight-simulator : positron** events are simulated using laser pulses that can also mimic the infamous**splash.**



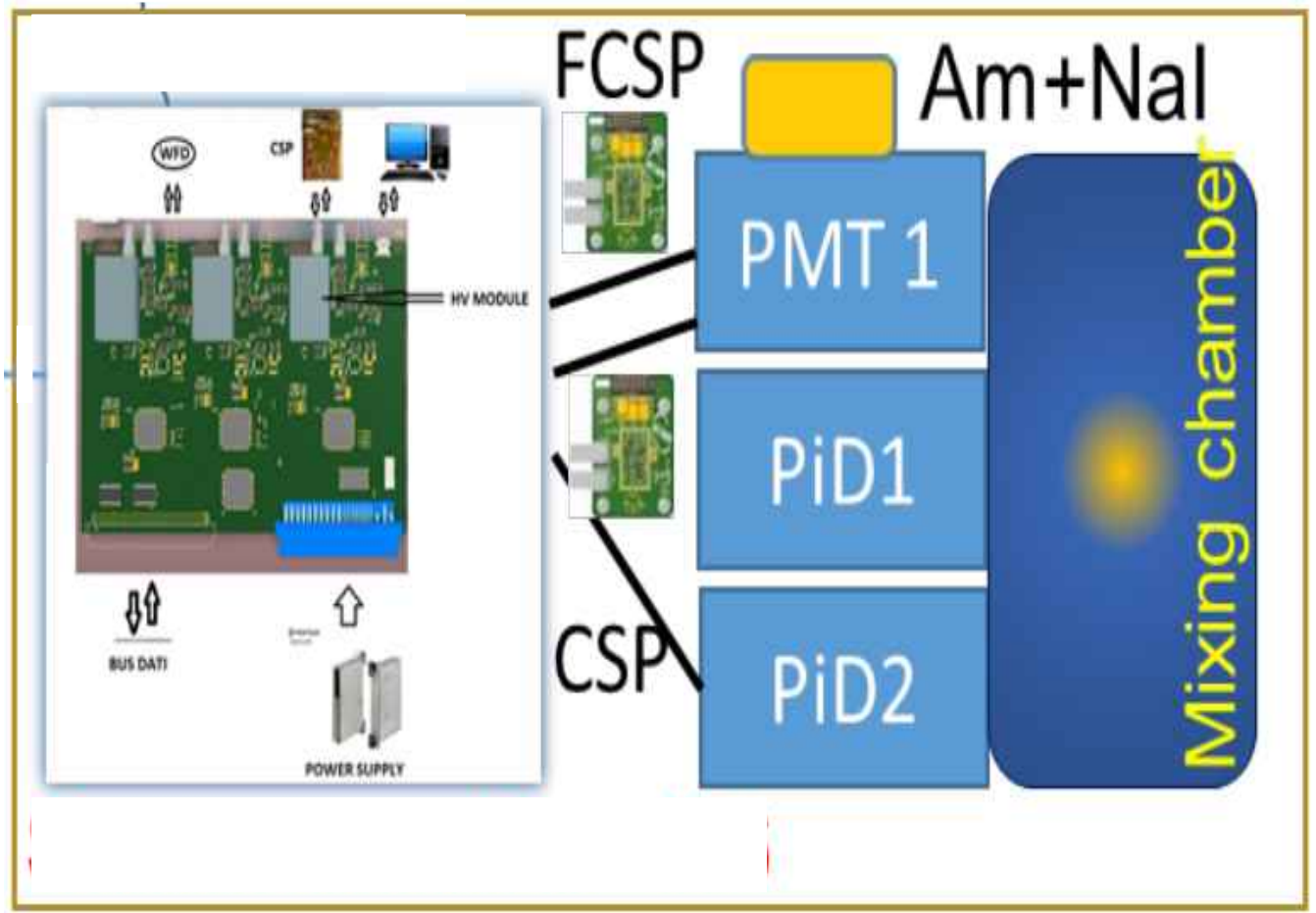
Laser Control System

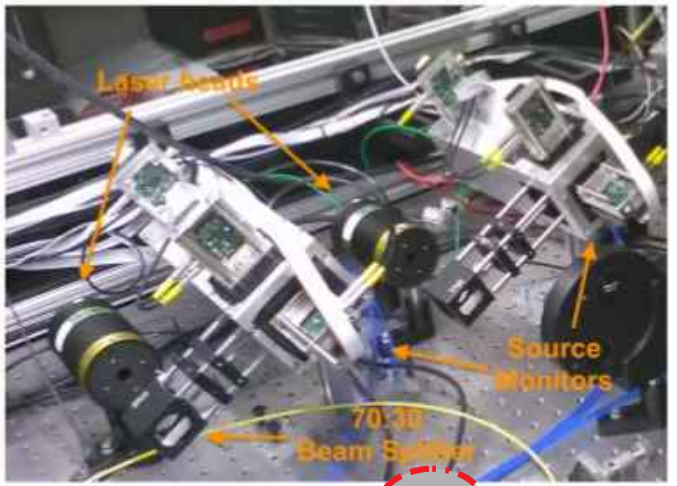


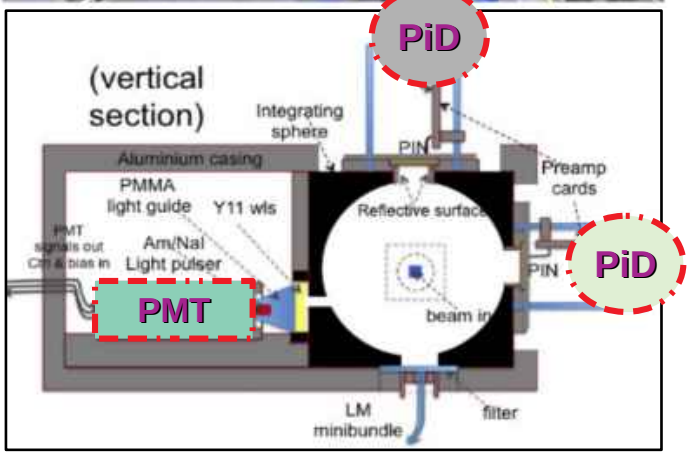
- **Laser Pulse Tagging :**
  - **1.8 GeV** pulse that is found almost (in more than 50 crystals) in all crystals is definitely a **laser**.

The Monitors...

Source Monitors × 6

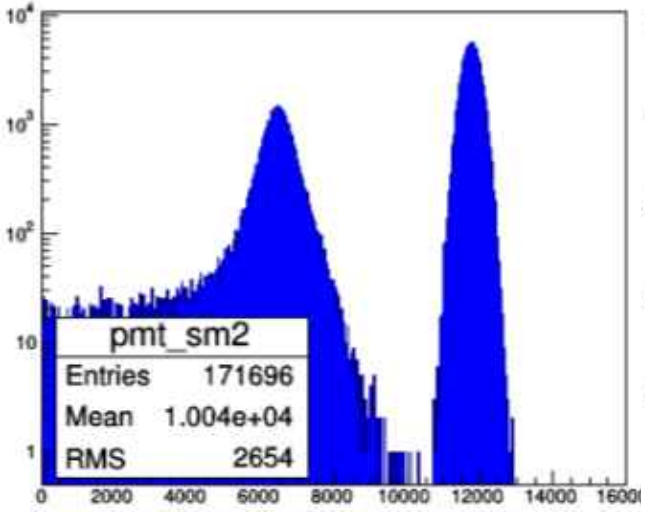




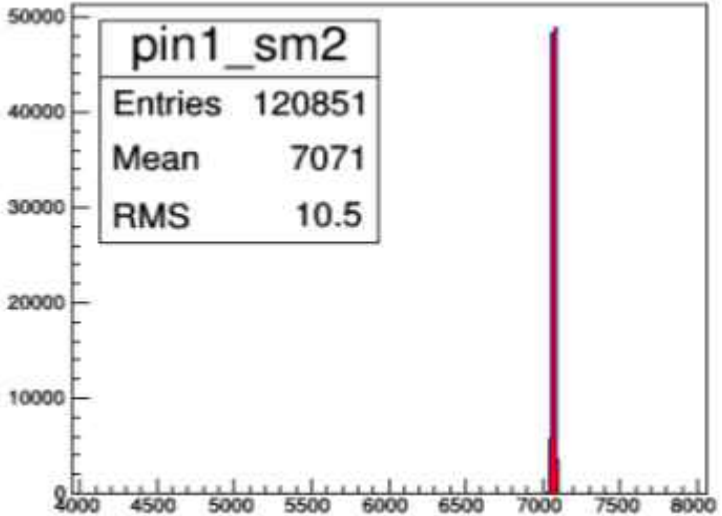


Source Monitors × 6

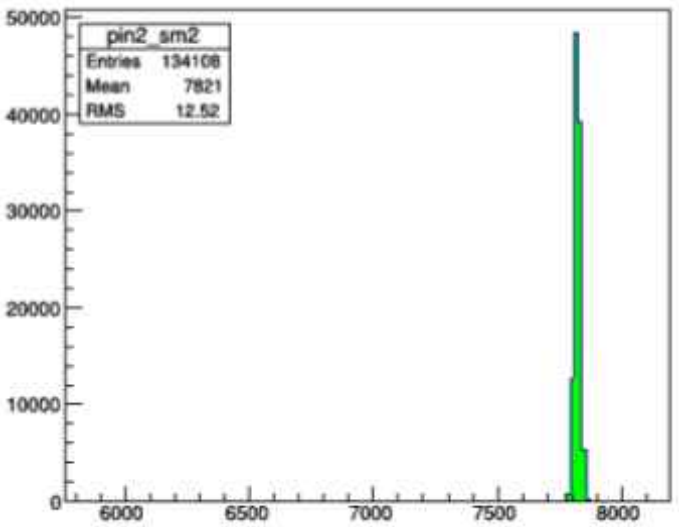
PMT



PiD-1



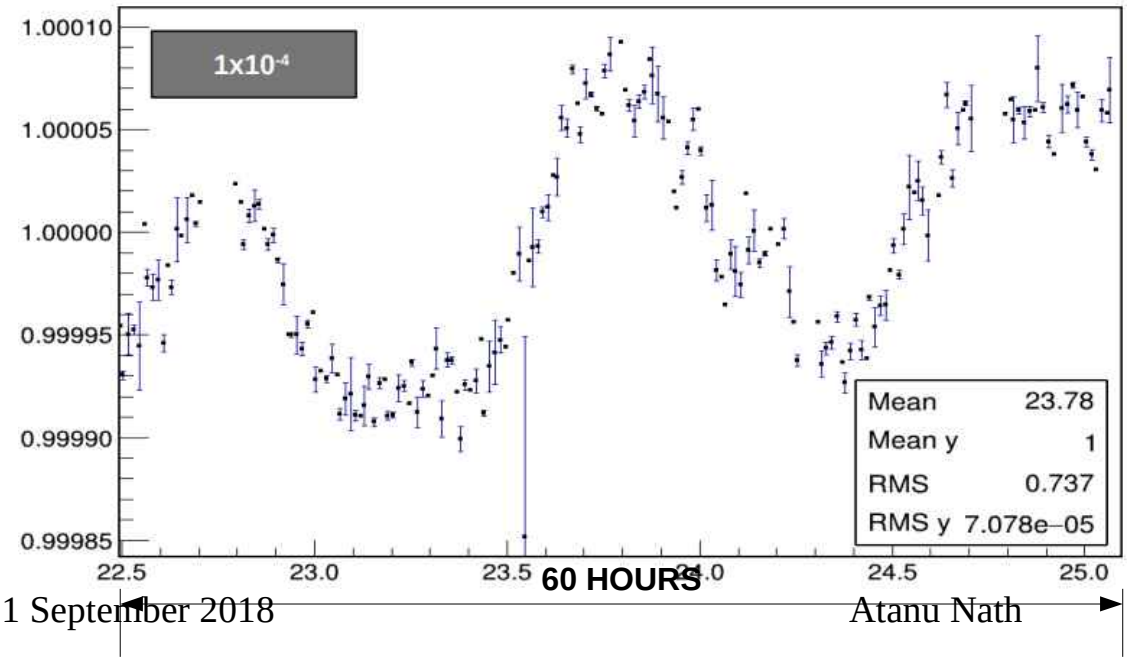
PiD-2

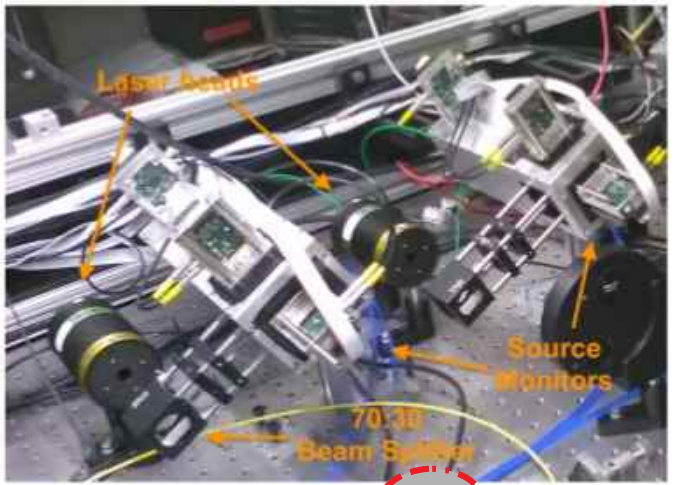


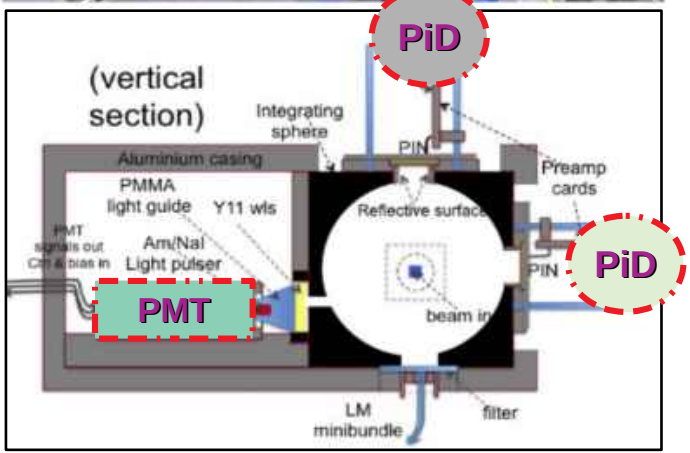
Source Monitors × 6

- **2 Pin Diodes** : receive **laser** pulses directly from the **source**.

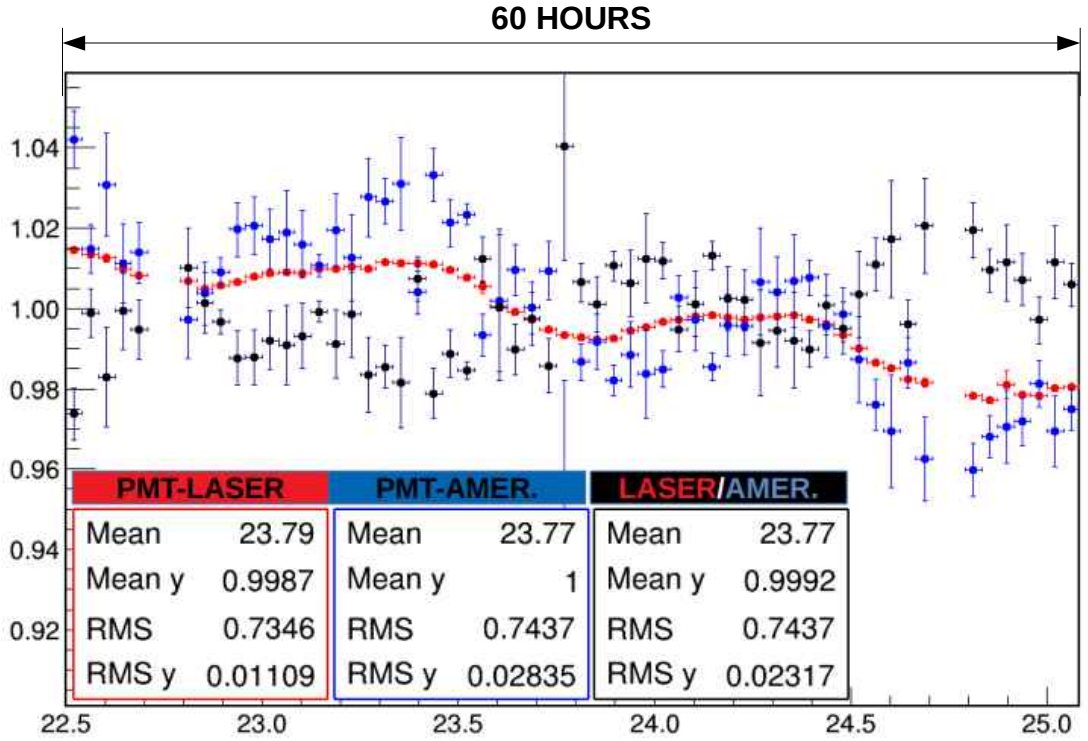
  Pin-1/Pin-2 ~ stability at ***sub per mil***

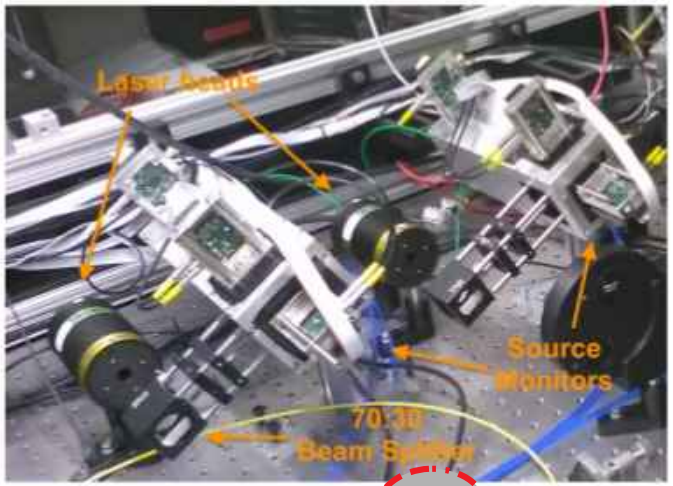


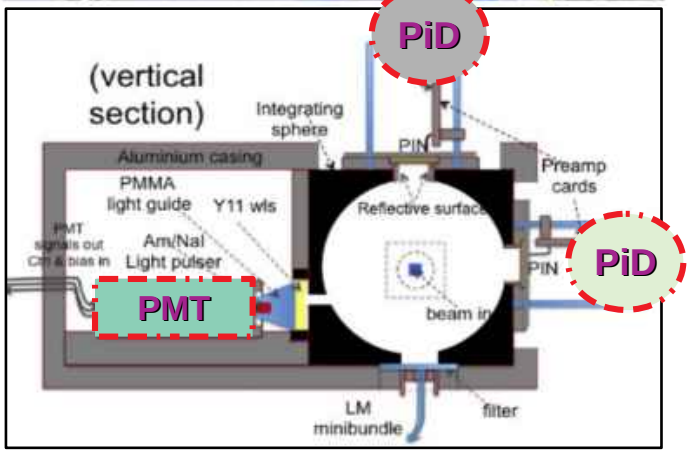




Source Monitors × 6

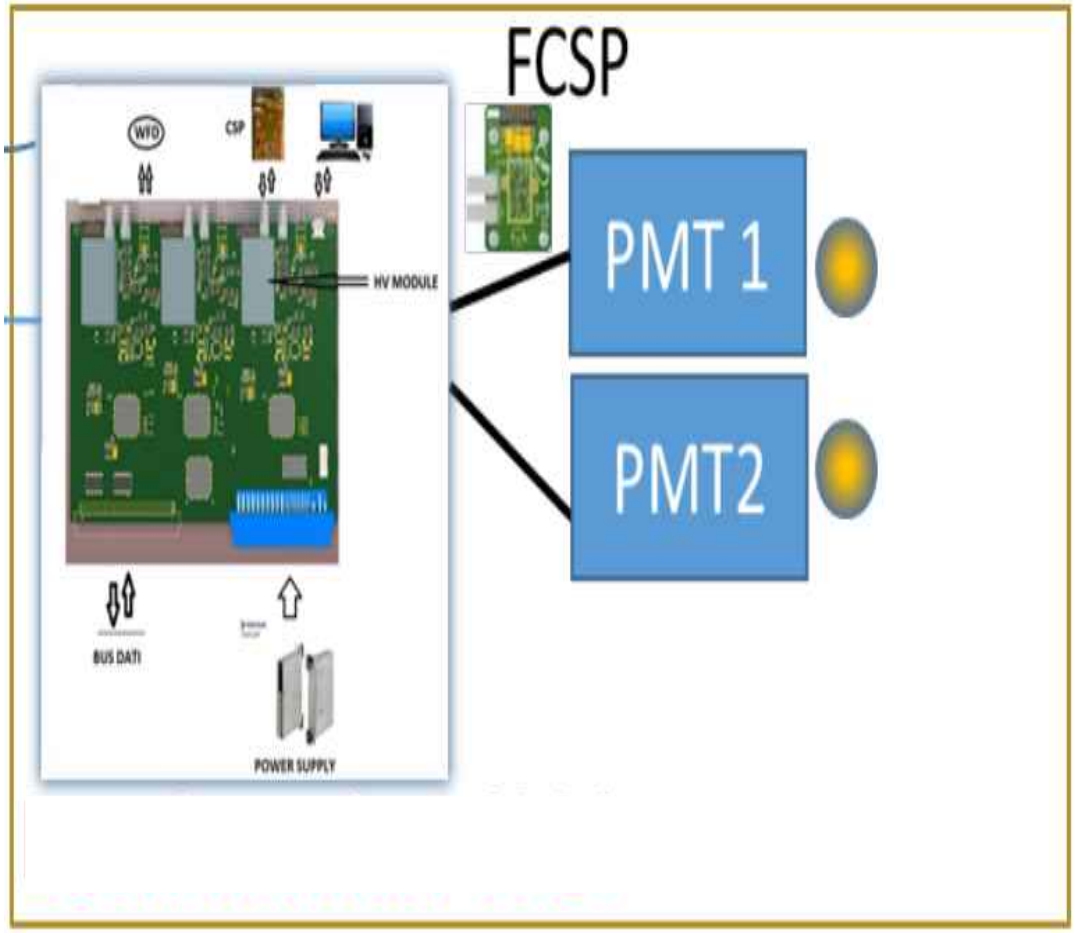


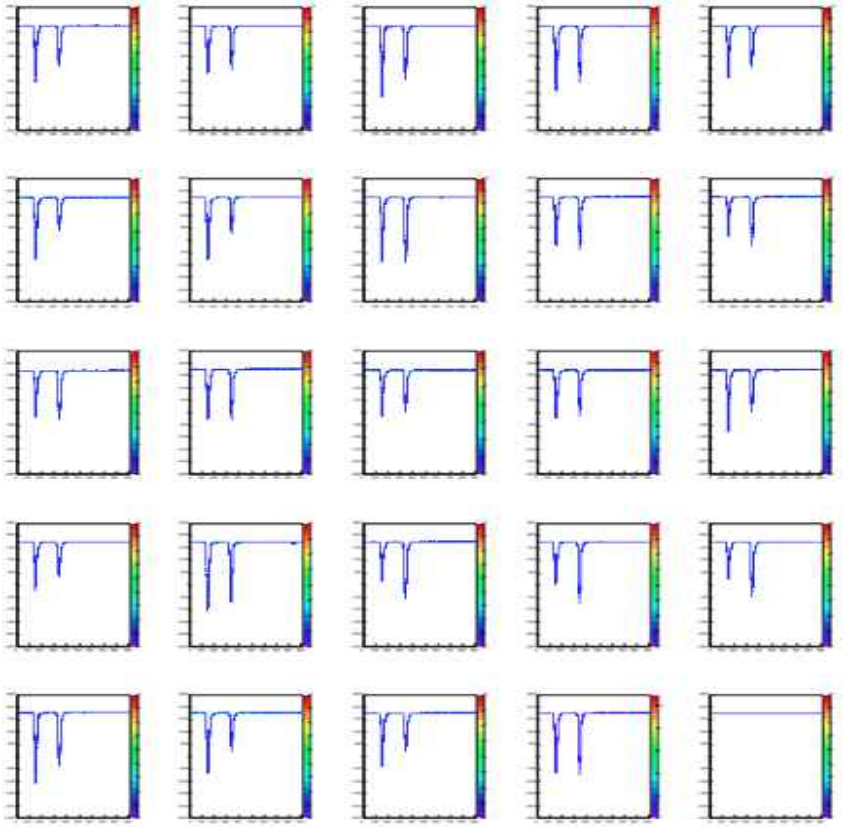




- **1 PMT** : receives laser light from **laser source** plus light generated by (***NaI***) an **americium** source.
  - **Laser**/**Americium** ~ the laser-**source** variation. which will be useful for the **long term** calibration.

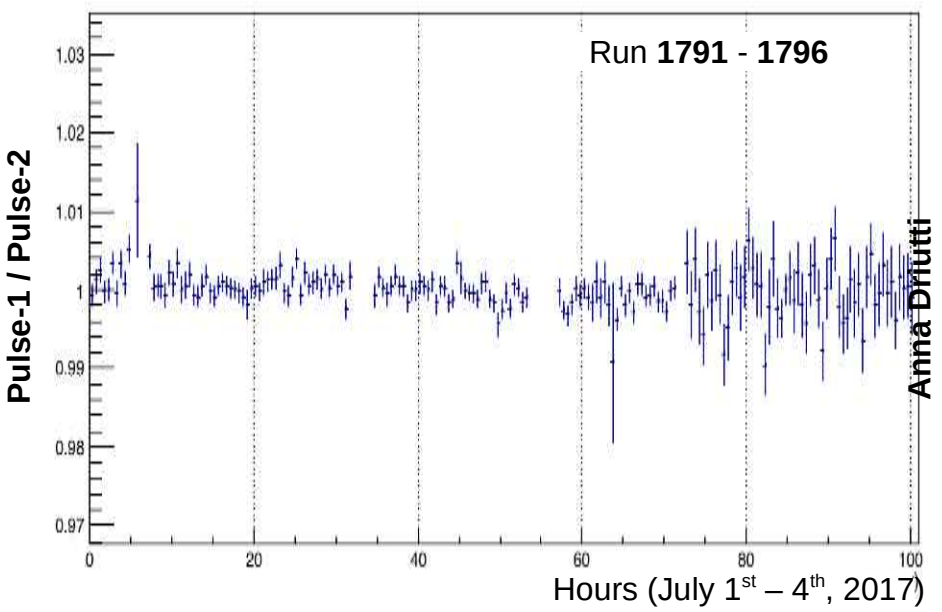
Local monitors × 24

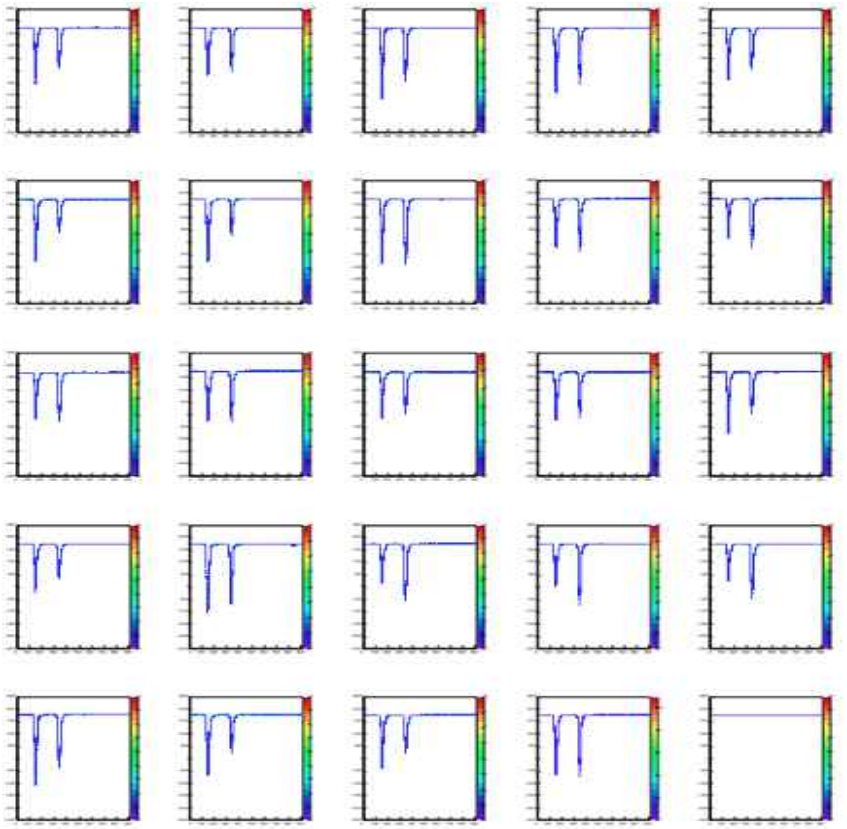




Local monitors × 24

- **1 PMT (Plan of 2 actually)** : receives **laser** pulses directly from the ***Source Monitors*** (Pulse-**1**) as well as light coming back from the **calorimeters** (Pulse-**2**).
  - **Pulse-1/Pulse-2** ~ stability of the **Local Monitors.**



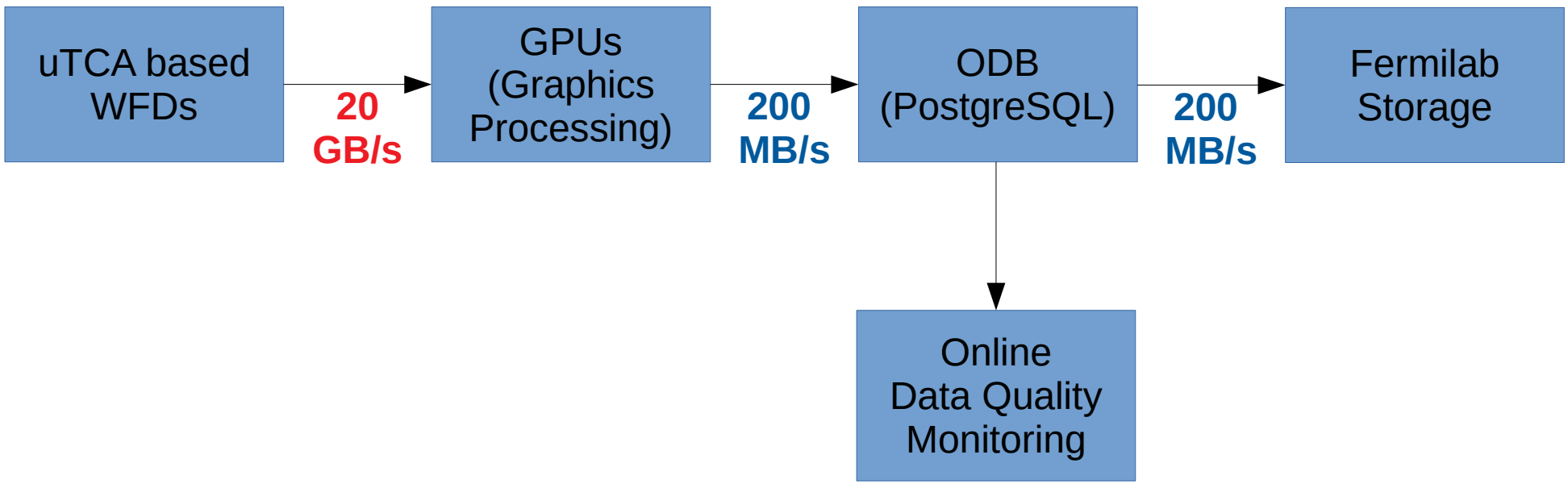


Data Acquisition Systems

MIDAS DAQ & Monitoring System

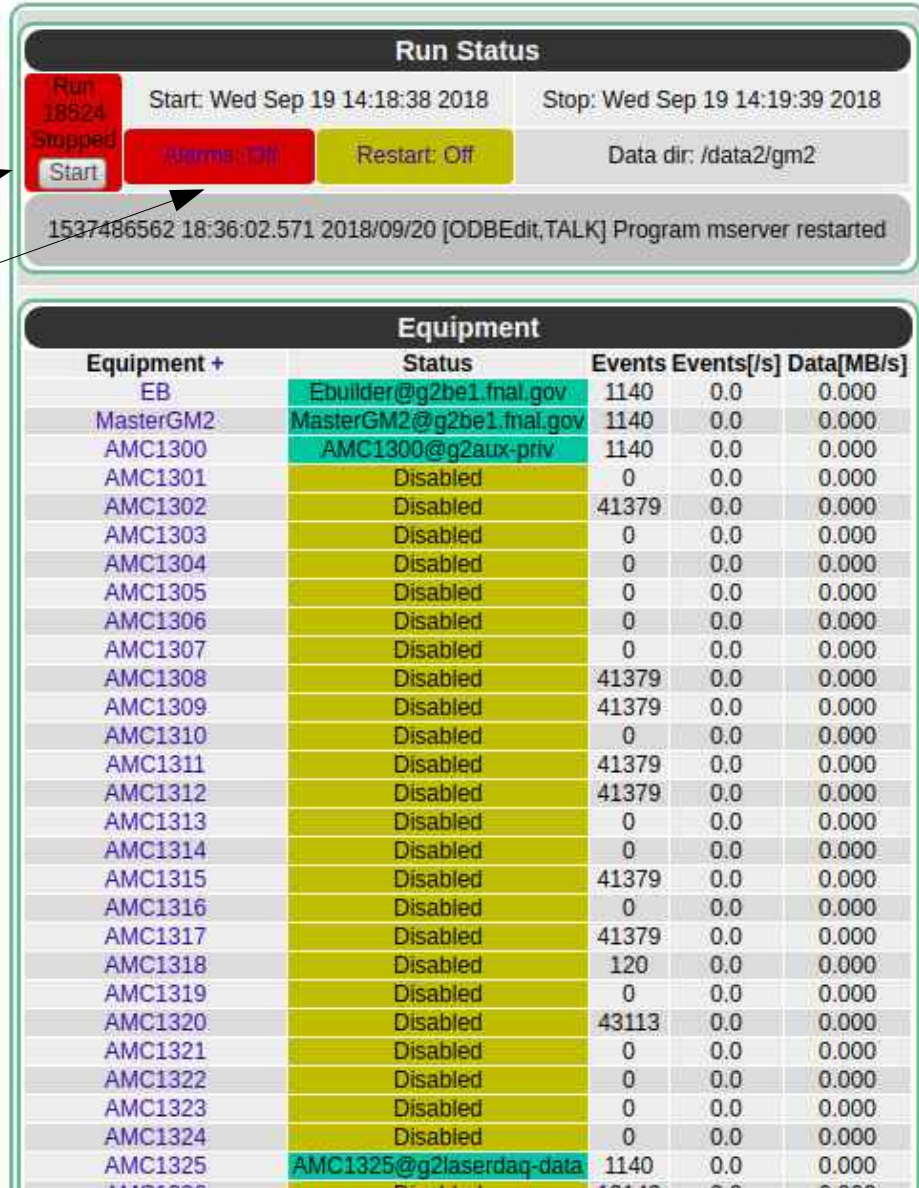
MIDAS DAQ

Maximum Integrated Data Acquisition System

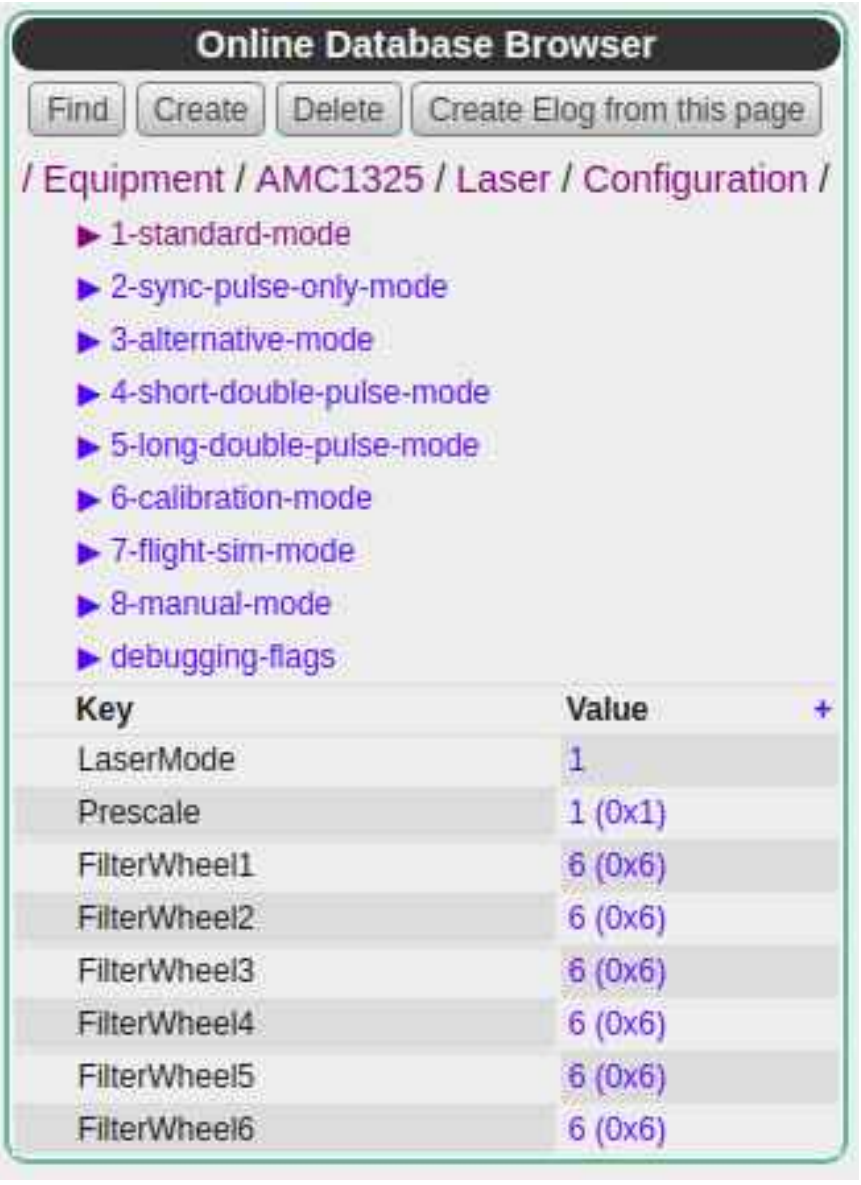


MIDAS DAQ

- **Runs** can be **start**ed and **manage**d from the web-interface.
- **Alarm** goes off when something goes wrong.
- Configurations can be changed in the **Online DataBase**.



Equipment +	Status	Events	Events[/s]	Data[MB/s]
EB	Ebuilder@g2be1.fnal.gov	1140	0.0	0.000
MasterGM2	MasterGM2@g2be1.fnal.gov	1140	0.0	0.000
AMC1300	AMC1300@g2aux-priv	1140	0.0	0.000
AMC1301	Disabled	0	0.0	0.000
AMC1302	Disabled	41379	0.0	0.000
AMC1303	Disabled	0	0.0	0.000
AMC1304	Disabled	0	0.0	0.000
AMC1305	Disabled	0	0.0	0.000
AMC1306	Disabled	0	0.0	0.000
AMC1307	Disabled	0	0.0	0.000
AMC1308	Disabled	41379	0.0	0.000
AMC1309	Disabled	41379	0.0	0.000
AMC1310	Disabled	0	0.0	0.000
AMC1311	Disabled	41379	0.0	0.000
AMC1312	Disabled	41379	0.0	0.000
AMC1313	Disabled	0	0.0	0.000
AMC1314	Disabled	0	0.0	0.000
AMC1315	Disabled	41379	0.0	0.000
AMC1316	Disabled	0	0.0	0.000
AMC1317	Disabled	41379	0.0	0.000
AMC1318	Disabled	120	0.0	0.000
AMC1319	Disabled	0	0.0	0.000
AMC1320	Disabled	43113	0.0	0.000
AMC1321	Disabled	0	0.0	0.000
AMC1322	Disabled	0	0.0	0.000
AMC1323	Disabled	0	0.0	0.000
AMC1324	Disabled	0	0.0	0.000
AMC1325	AMC1325@g2laserdaq-data	1140	0.0	0.000



Online Database

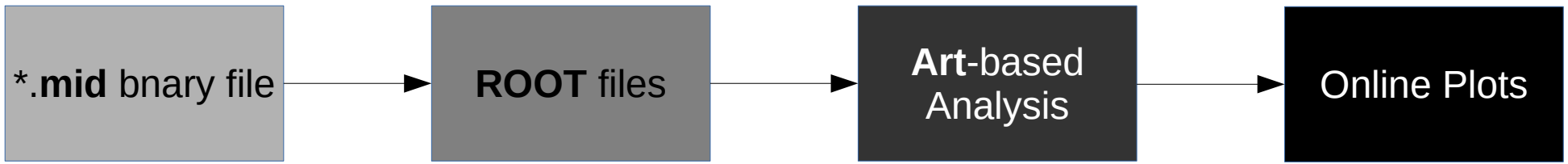
- Various configurations like

laser mode

filter-wheel position

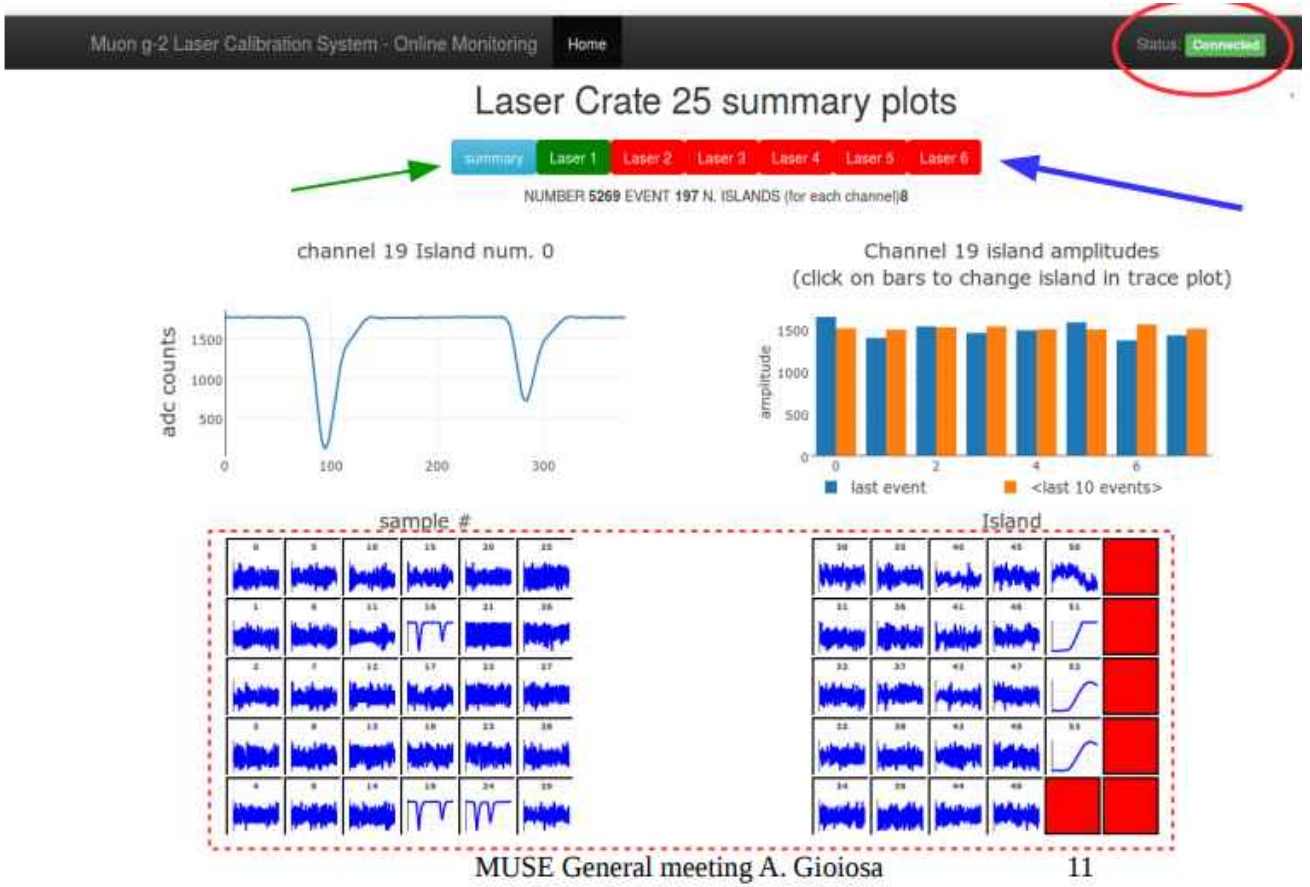
etc can be set in the ***Online DataBase*** page.

Online Data Quality Monitor



Online Data Quality Monitor

- Server **connection** status.
- **Traces** of laser signals.
- **Stability** of laser pulses over various runs.
- **Alarms** go off when things go wrong.



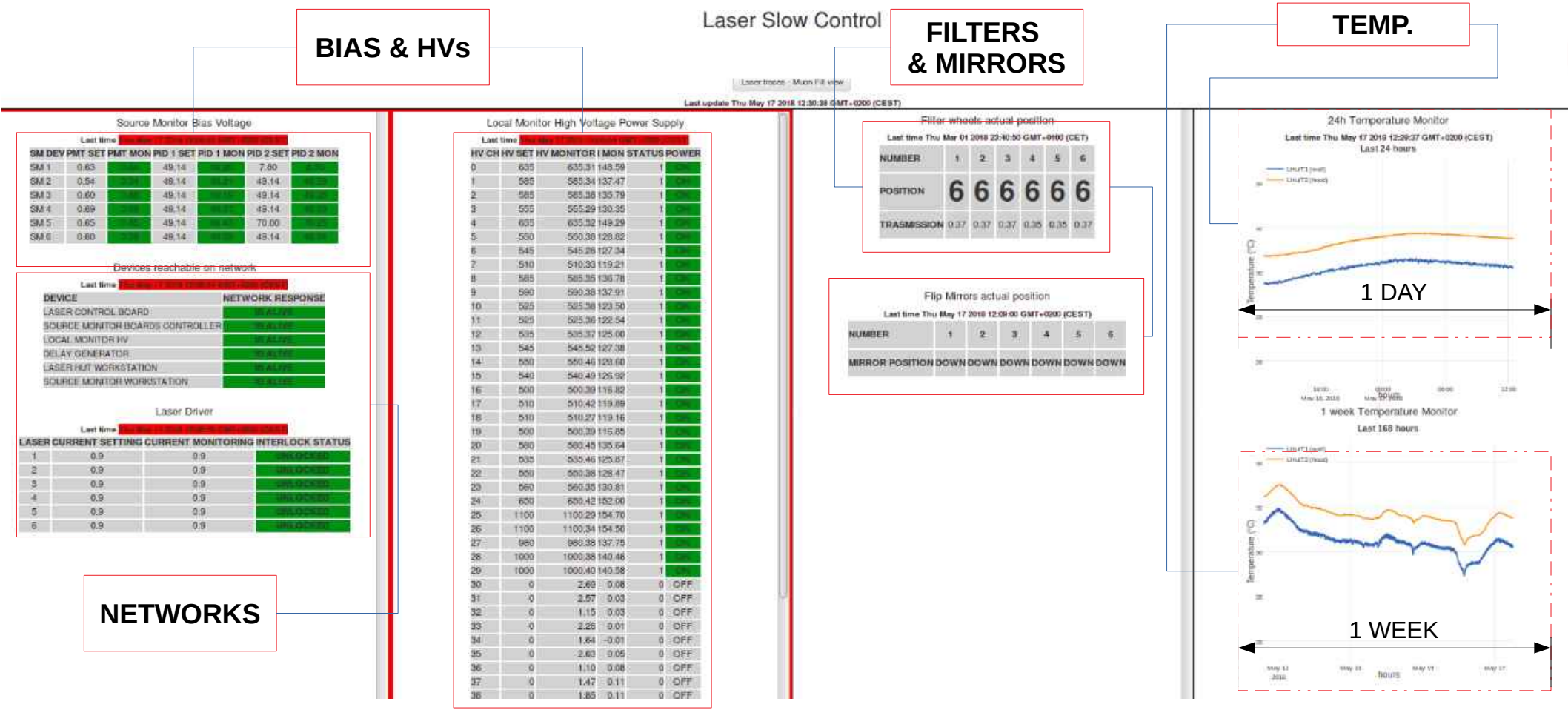
Slow-control DQM

BIAS & HVs

FILTERS & MIRRORS

TEMP.

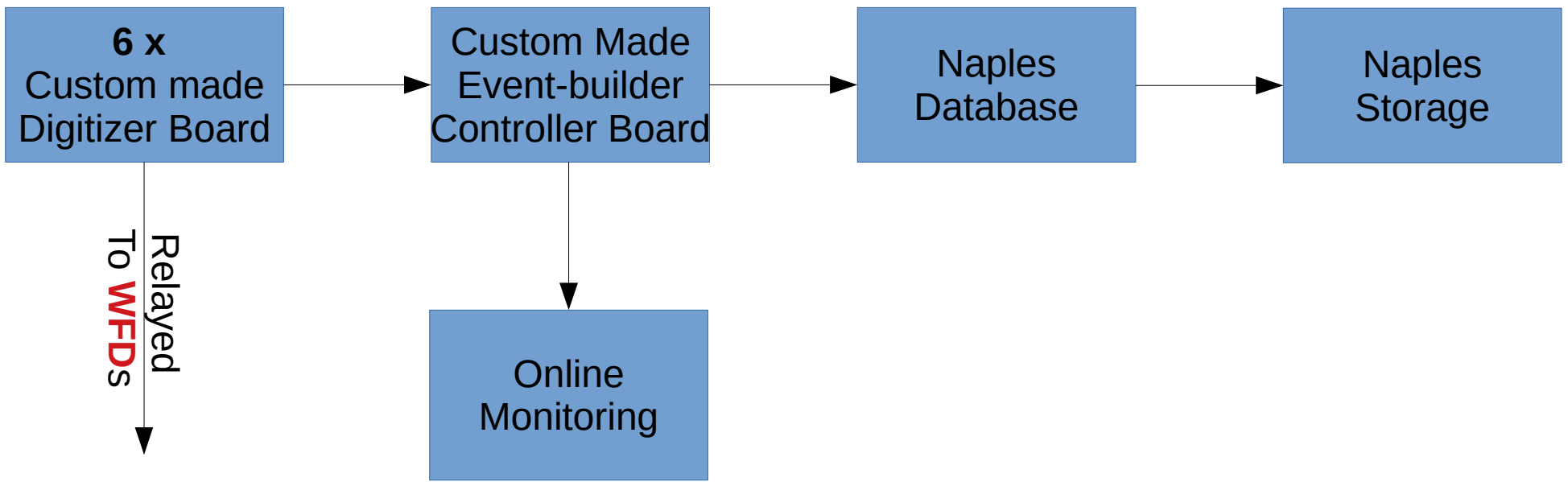
NETWORKS

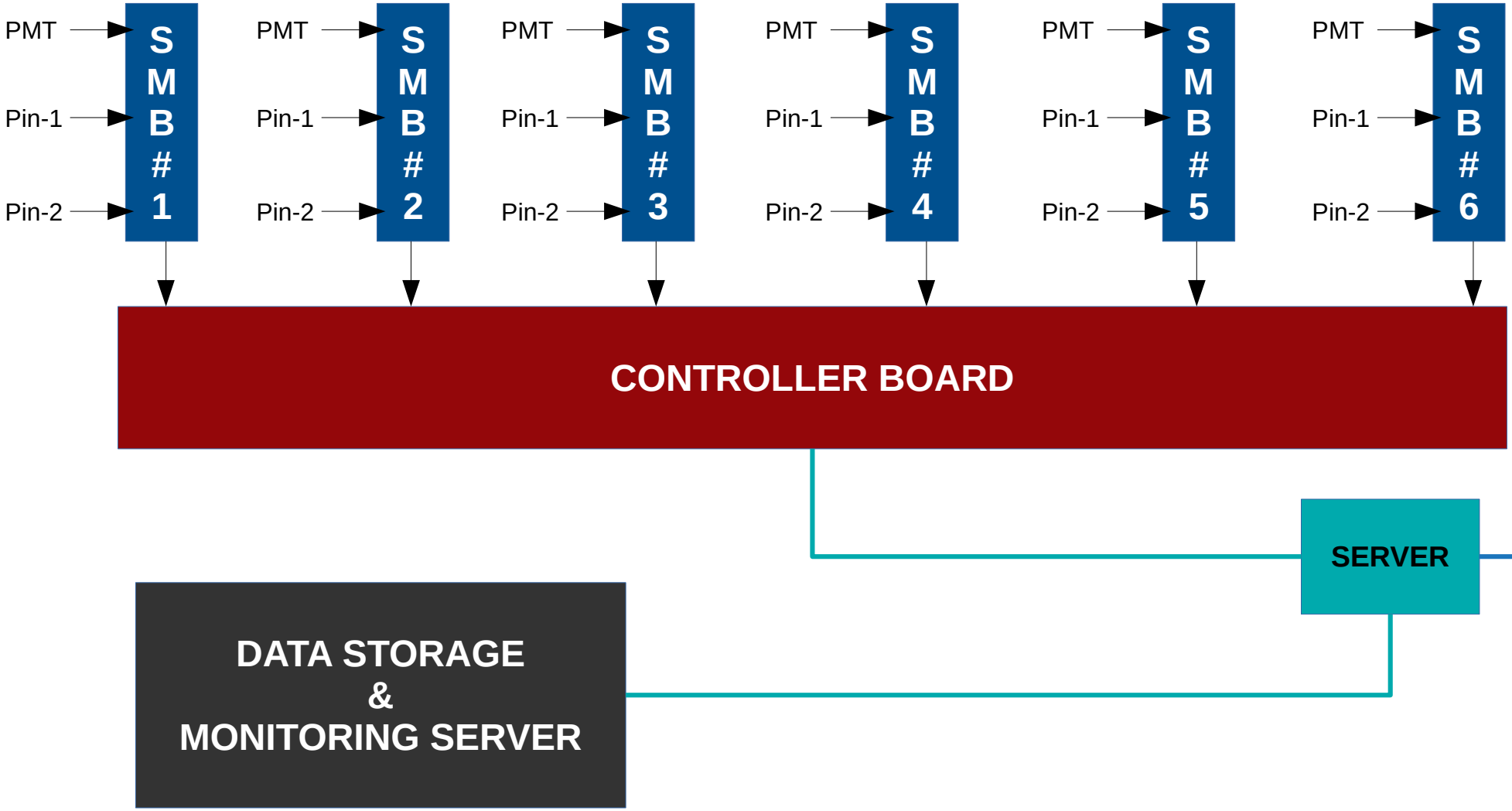


Naples DAQ & Monitoring System

Naples DAQ

Custom made (bash, c++, ROOT) Naples DAQ and Monitoring Package

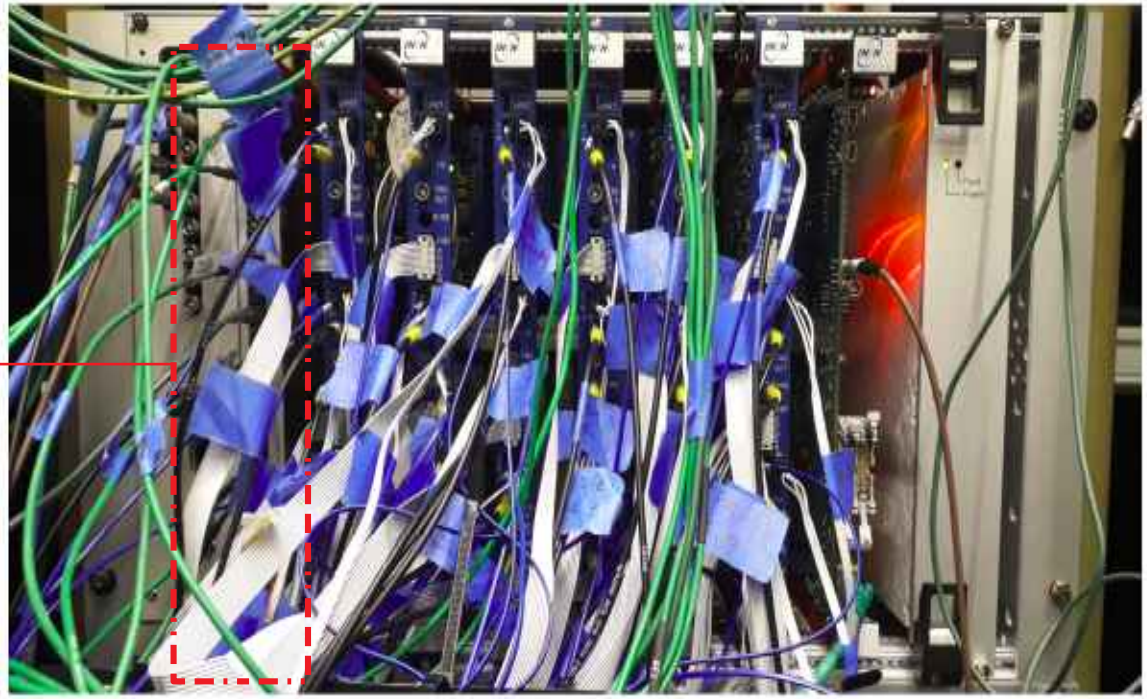



PMT
Pin-1
Pin-2
SMB#1
SMB#2
SMB#3
SMB#4
SMB#5
SMB#6
CONTROLLER BOARD
SERVER
DATA STORAGE
&
MONITORING SERVER
INTERNET

Naples DAQ

Laser Control

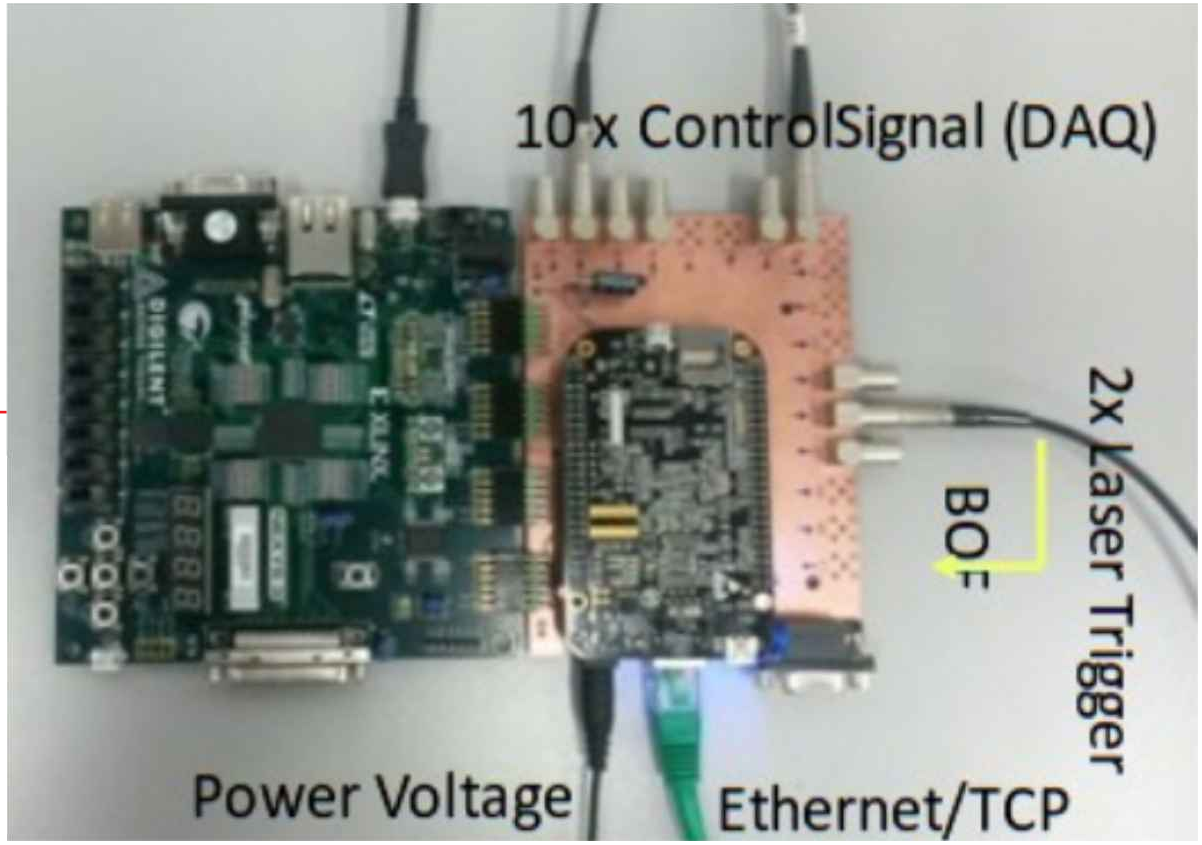
Custom made **Source Monitor** crate of **Naples.**



Naples DAQ

Laser Control

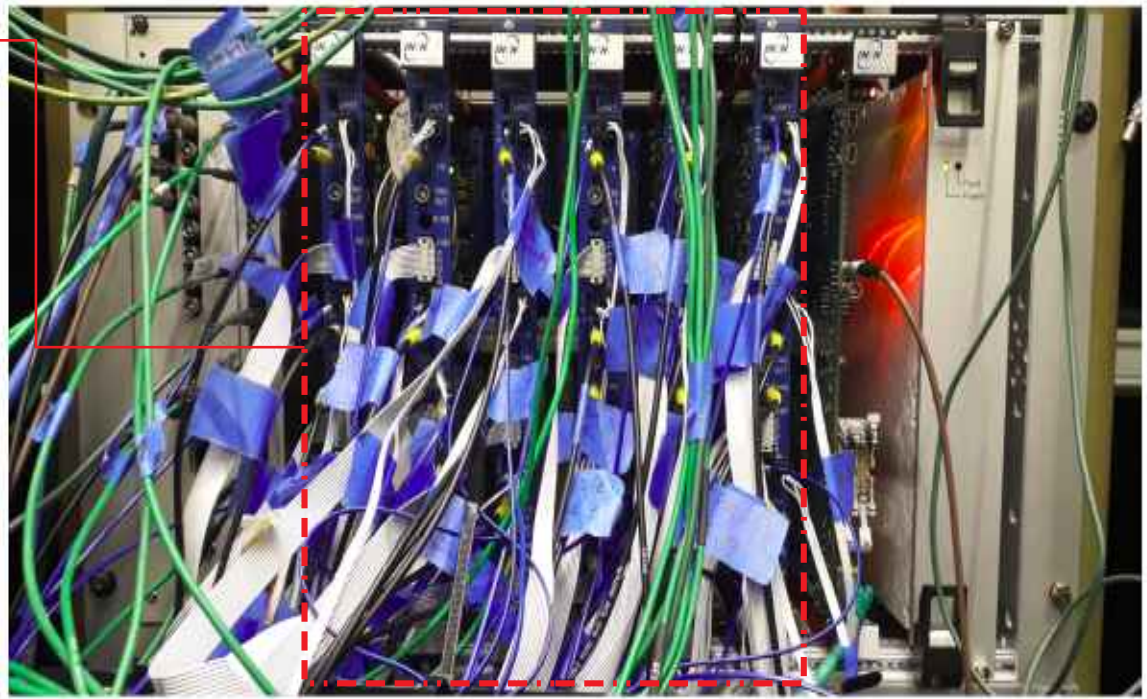
Custom made **Source Monitor** crate of **Naples.**



Naples DAQ

Custom made **Source Monitor** crate of **Naples.**

SM Digitizer – 1 to 6



Pre-amplifier
Shaper
Digitizer.

Provides bias/HV to the detectors.

Naples DAQ

Custom made **Source Monitor** crate of **Naples.**

SM Digitizer – 1 to 6

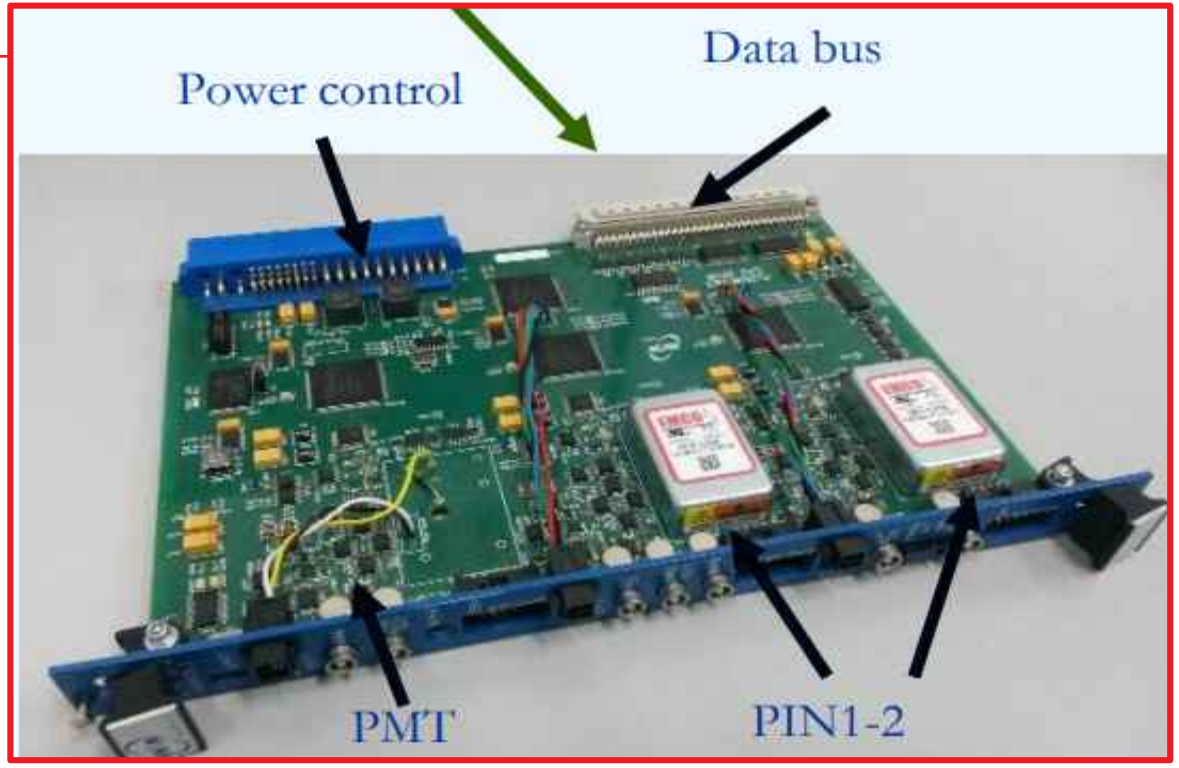
PiD/PMT Signal

Shaper
Long-tail (20 us)

Semi Gaussian)

Baseline restorer

Digitizer

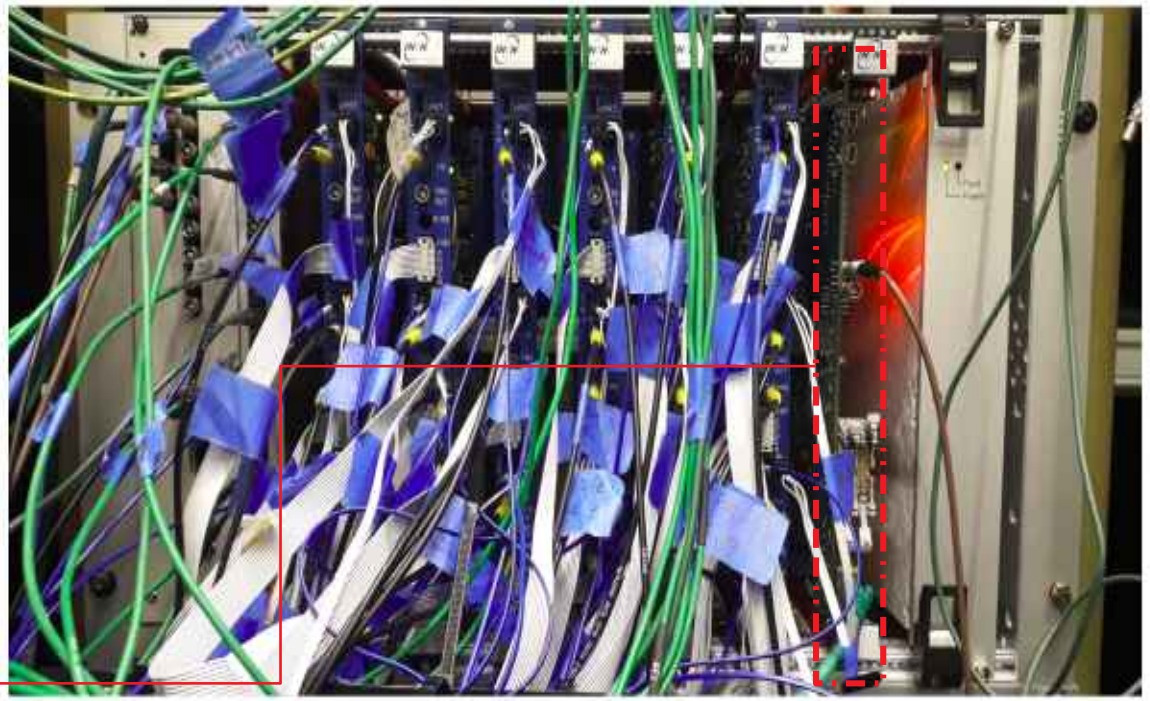


Naples DAQ

Custom made **Source Monitor** crate of **Naples.**

Receives data frame from all the 6 **SM boards** and checks for errors and then builds the final data frame containing information of 6x3 = 18 channels.

Sends the data frame to **Naples Database** over ethernet.



SM Event Builder (Controller Board)

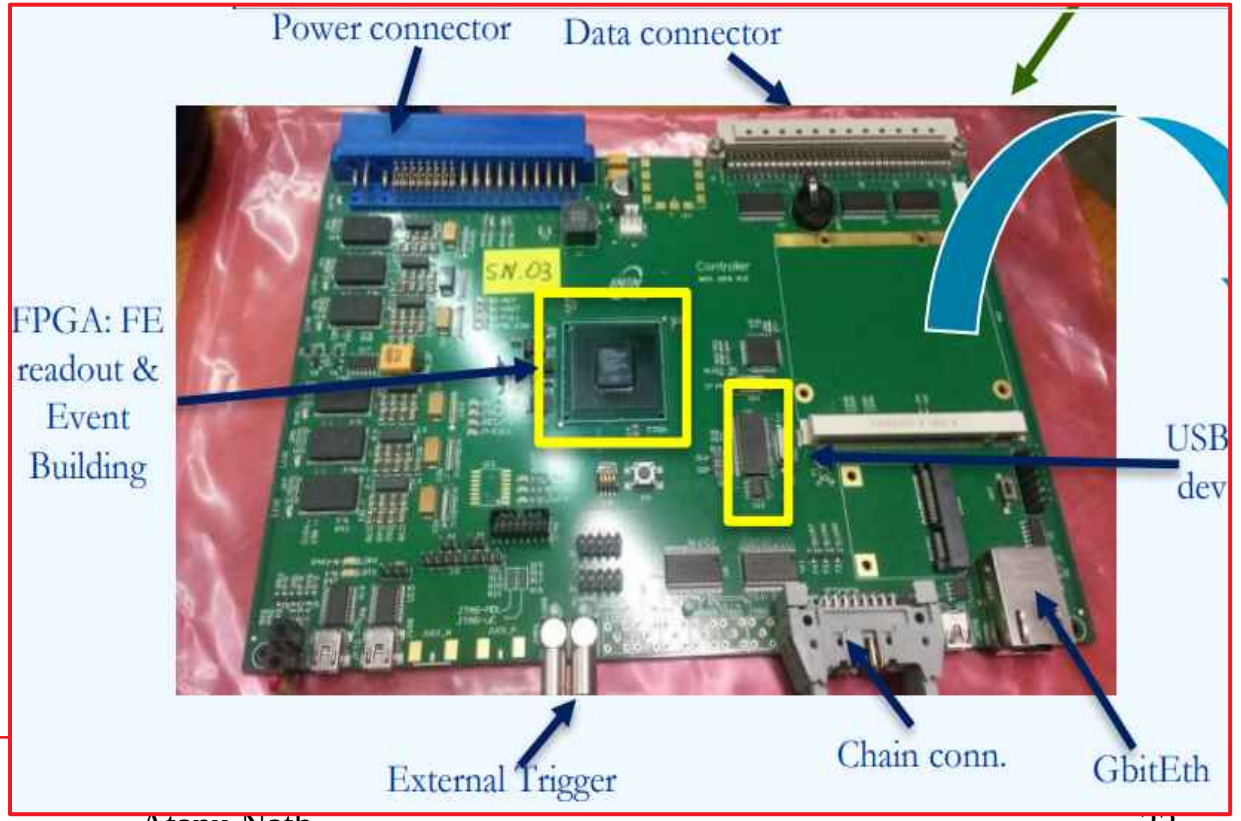
Naples DAQ

Custom made **Source Monitor** crate of **Naples.**

Receives data frame from all the 6 **SM boards** and checks for errors and then builds the final data frame containing information of 6x3 = 18 channels.

Sends the data frame to the data farm over ethernet.

SM Event Builder (Controller Board)



0.1 °C Sensitivity

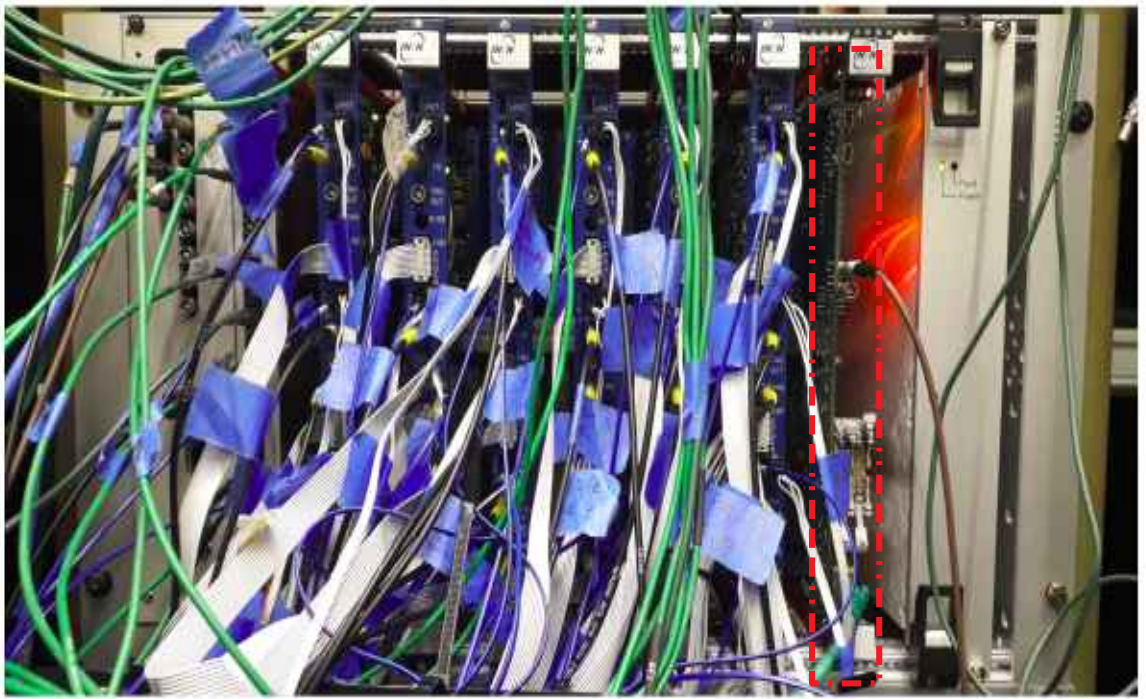
Naples DAQ

Custom made **Source Monitor** crate of **Naples.**

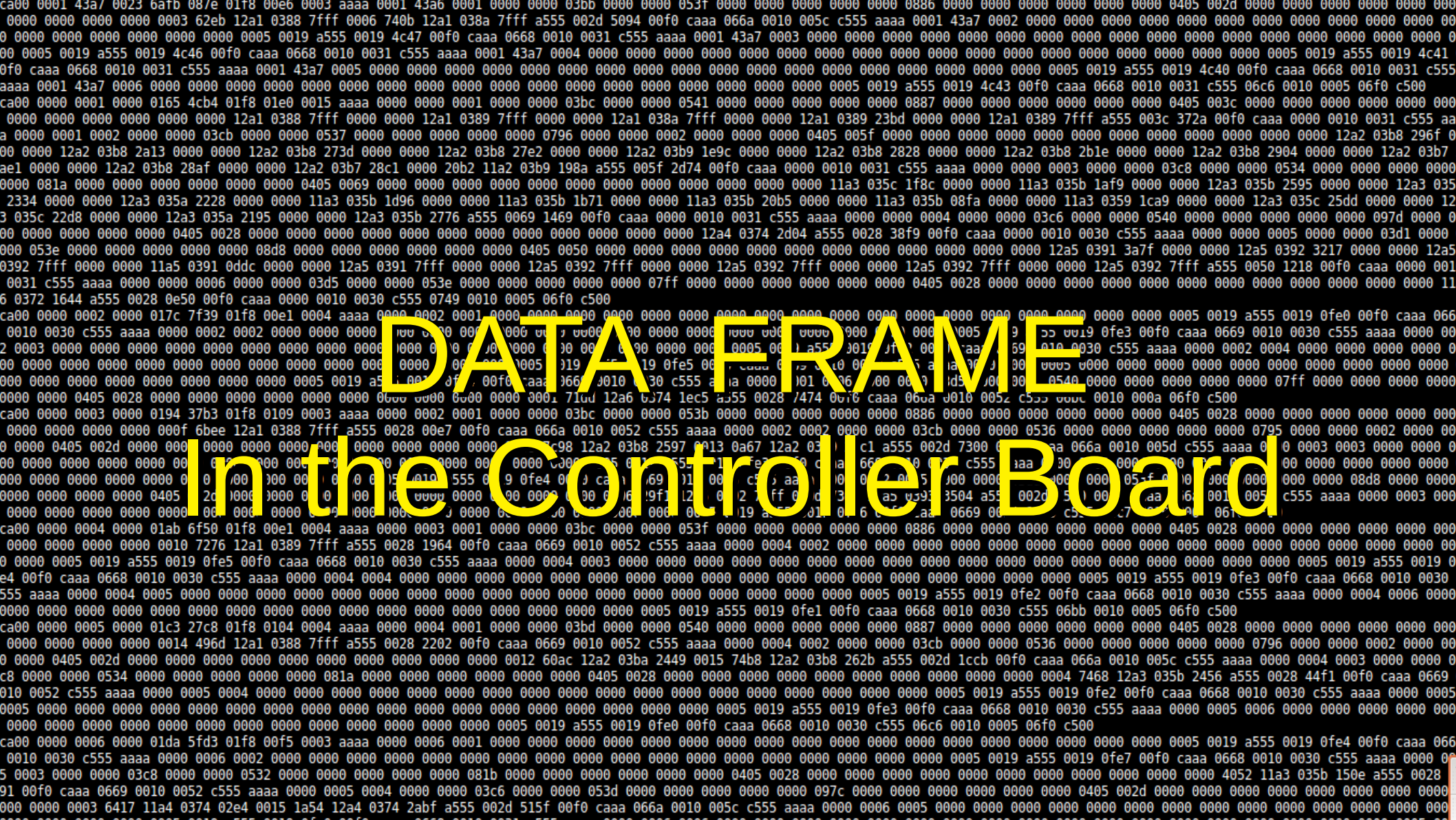
3 x 6 = 18 Board Temp. sensors

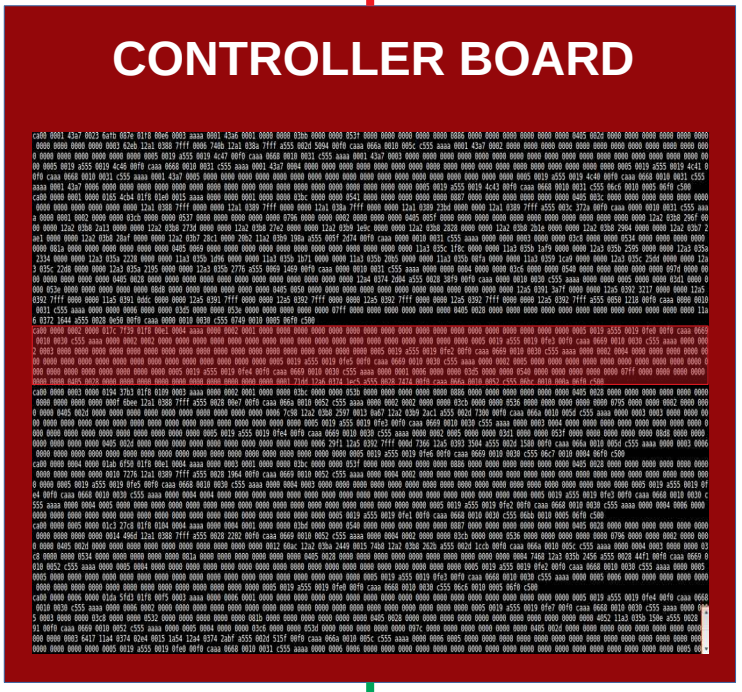
3 x 6 = 18 Pre Amp. Temp. sensors

2 x 6 = 12 Laser-hut Temp. sensors



Naples Monitoring...


DATA FRAME
In the Controller Board



MONITORING SERVER

Asks the controller board to send the latest data frame.

Analyzes the latest frame on arrival and stores the results in a buffer…

Displays the results of last minute.

Displays the results of last several hours.

Online Summary Table

Home Summary Stability Short Term Profiles Long Term Profiles

MIDAS DAQ	NAPLES DAQ	MONITOR STATUS	DATA STATUS	LASER STATUS	LASER MODE	FILL RATE
UP (N. 16724)	UP	UP	GOOD	UP	STANDARD	16 / sec

	SM-1	SM-2	SM-3	SM-4	SM-5	SM-6
MEAN ADC						
PIN-1	6820.72	NAN	4972.26	6792.38	6461.05	7973.67
PIN-2	7898.15	7766.04	6060.57	6825.66	7055.28	8337.45
PMT	11491	4432.21	5110.03	5364.04	5971.74	5060.85
MEAN BIAS (V)						
PIN-1	49.2044	49.2164	49.1879	49.2708	49.4163	49.5457
PIN-2	8.2948	49.2816	49.2979	49.039	70.2339	49.3447
PMT	0.6353	0.535	0.5965	0.6901	0.6496	0.5943
BOARD TEMP (°C)						
PIN-1	42.457	48.071	43.402	43.358	42.23	41.844
PIN-2	39.422	42.697	41.843	40.962	40.113	41.094
PMT	42.923	44.479	43.112	43.404	42.91	42.115
CSP TEMP (°C)						
PIN-1	35.427	34.761	35.081	35.215	35.739	34.956
PIN-2	35.274	35.33	35.342	35.442	35.138	35.042
PMT	35.915	34.593	34.77	35.016	35.345	35.478
EXT TEMP (°C)						
PIN-1	30.324	30.312	30.51	30.597	30.789	30.019
PIN-2	30.881	33.984	30.98	30.113	30.602	30.409

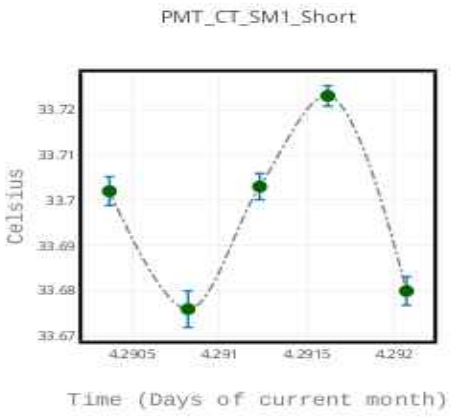
SOURCE-MONITOR STABILITY

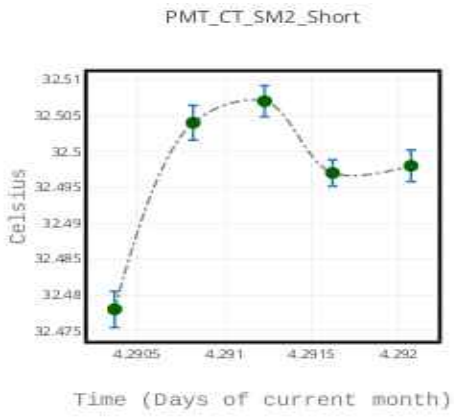
PIN-1/PIN-2 BAND SIZE						

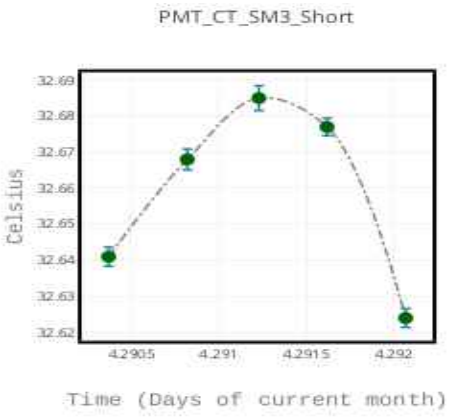
DAQ HEALTH

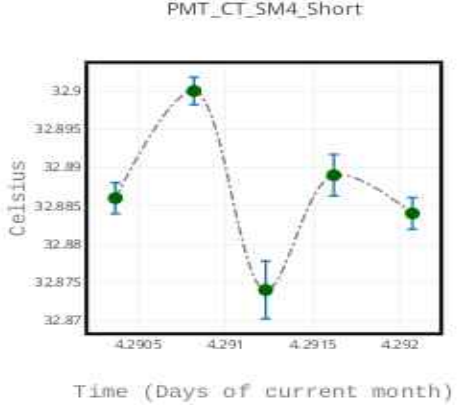
LAPTOP SPACE	LAPTOP MEMORY	CONTROLLER SPACE	CONTROLLER MEMORY
75 % FULL	15.29 % FULL	57 % FULL	34.86% FULL

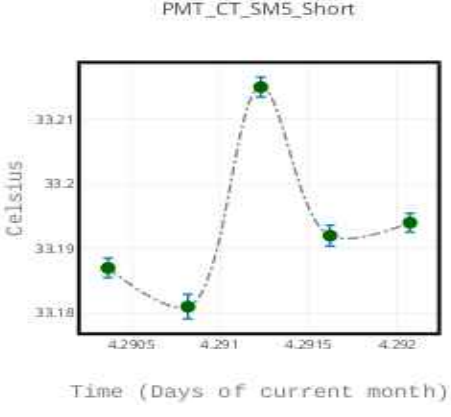
Short Term Trends

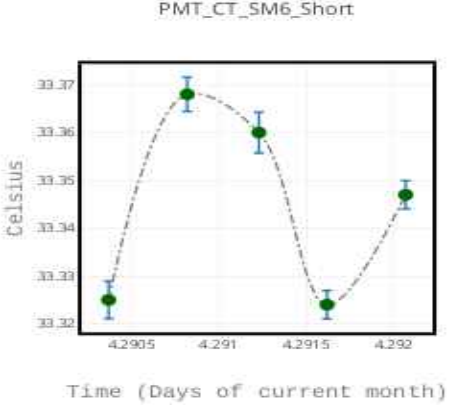




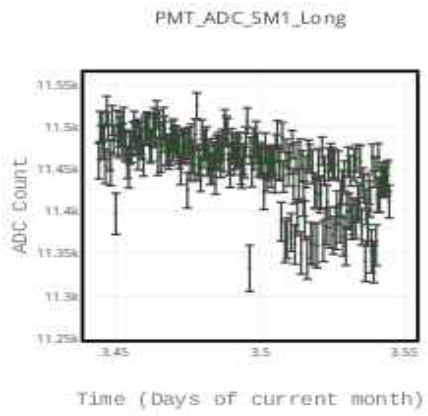


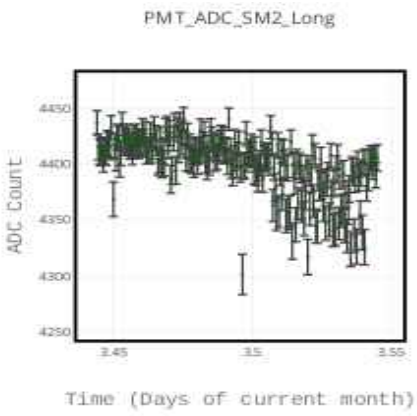


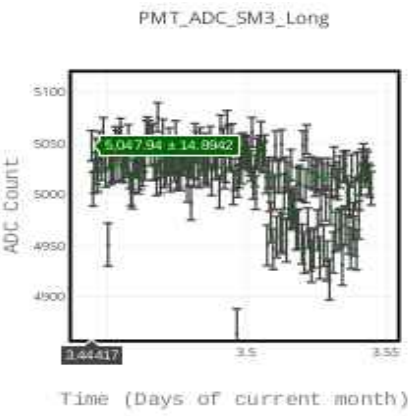


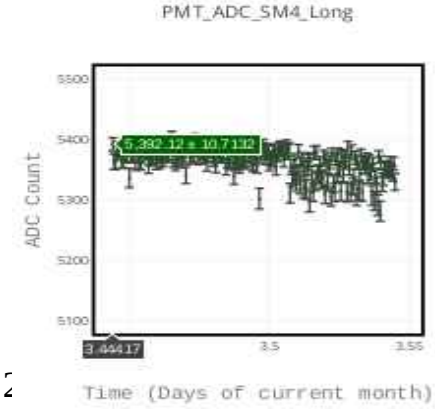


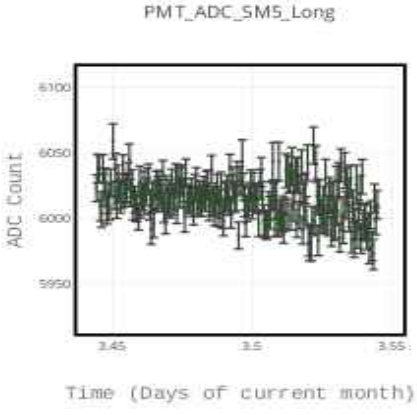
Long Term Trends

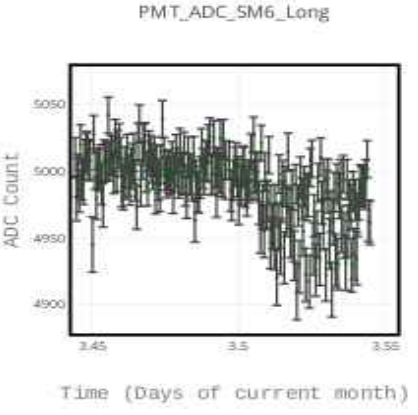






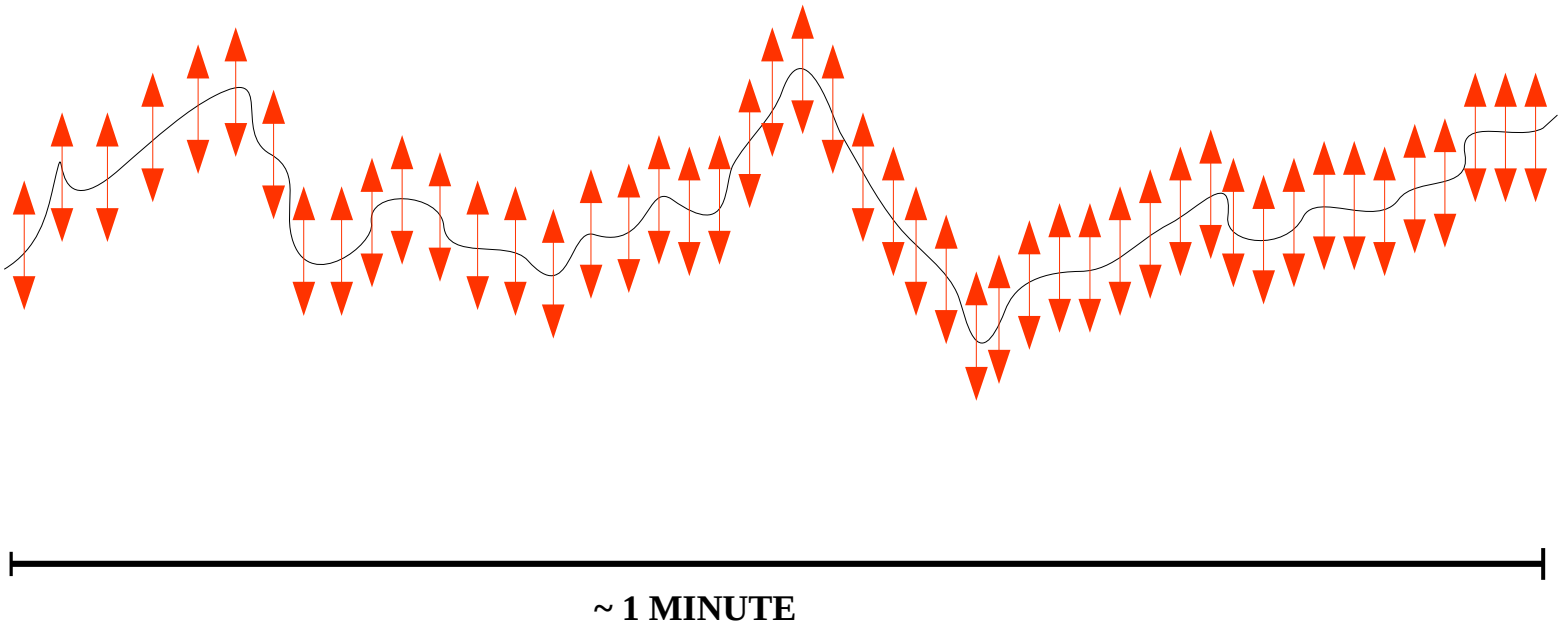






STABILITY OF THE MONITORS

CALCULATION OF STABILITY



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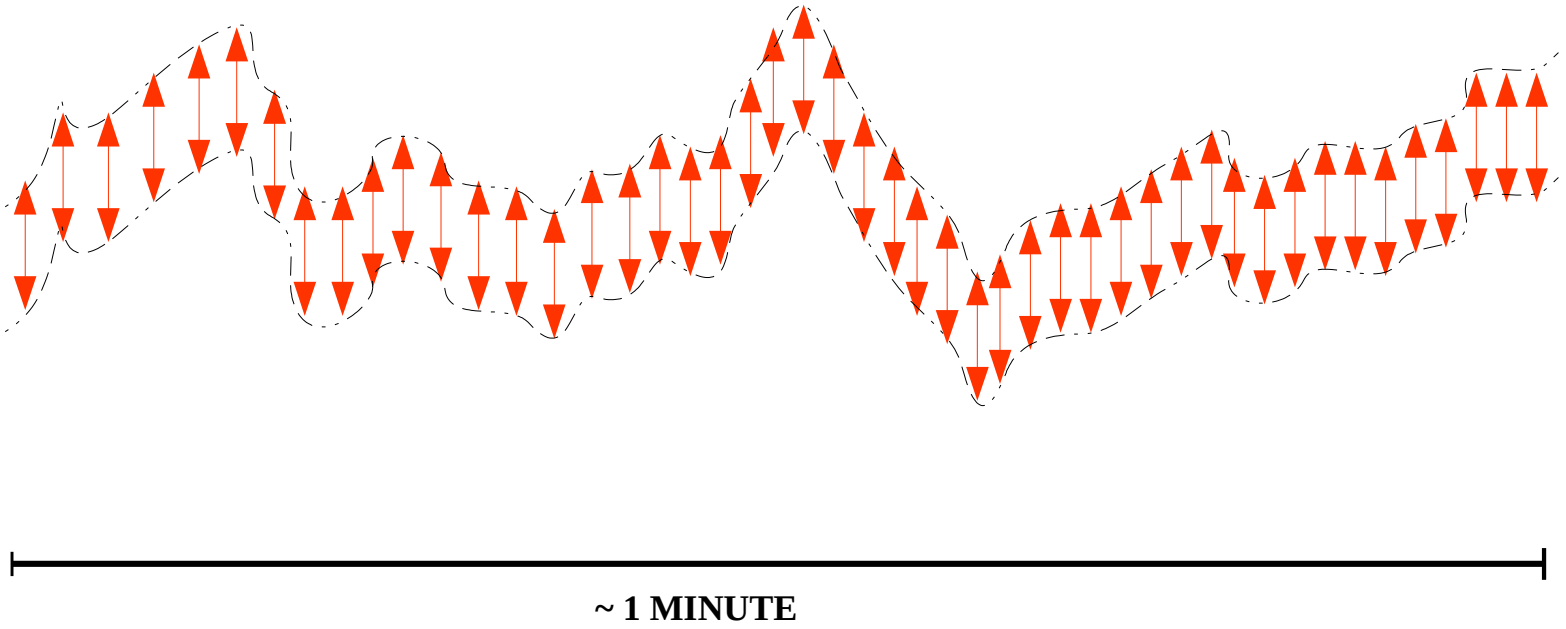

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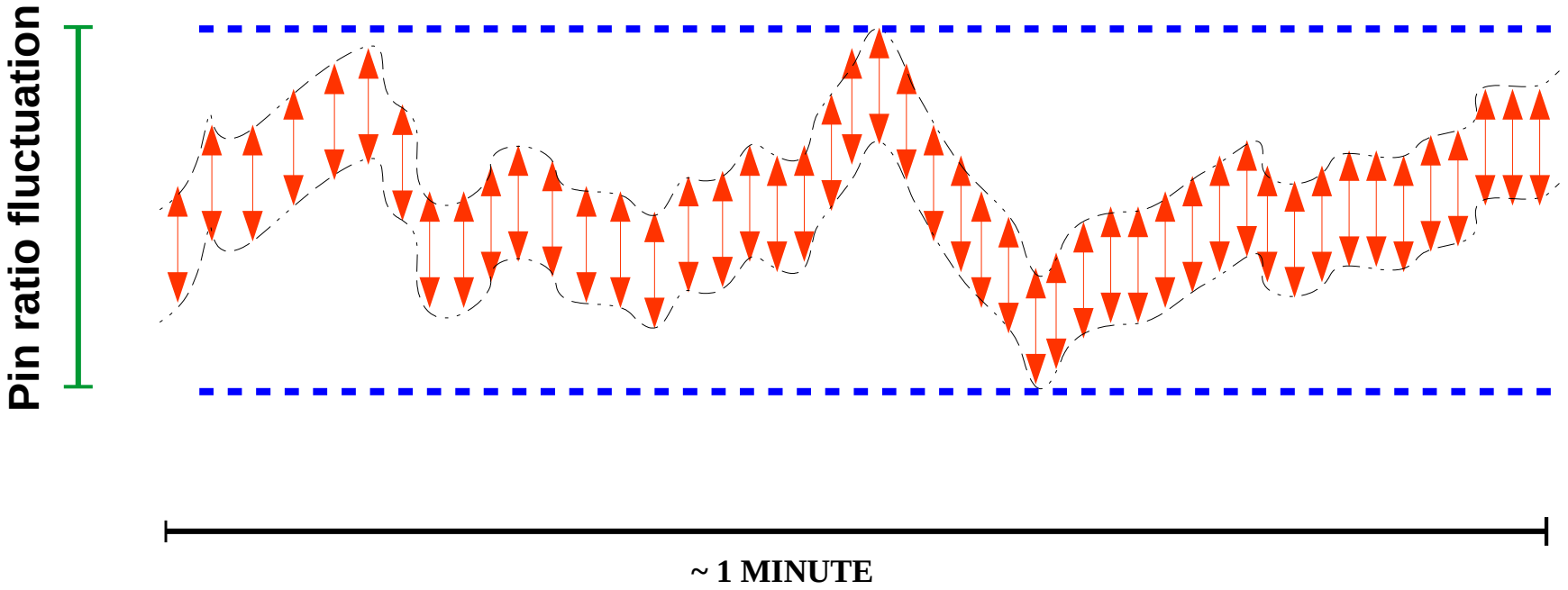
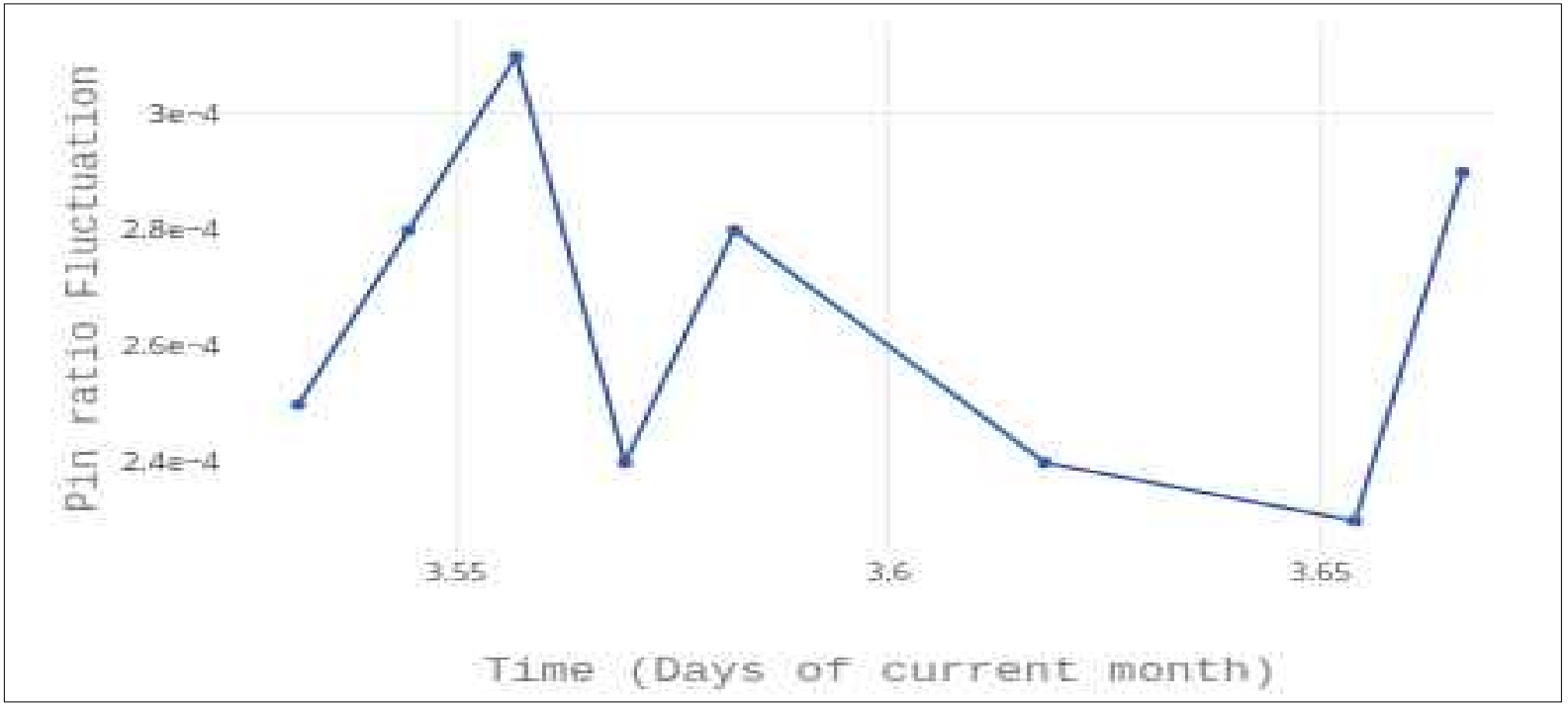
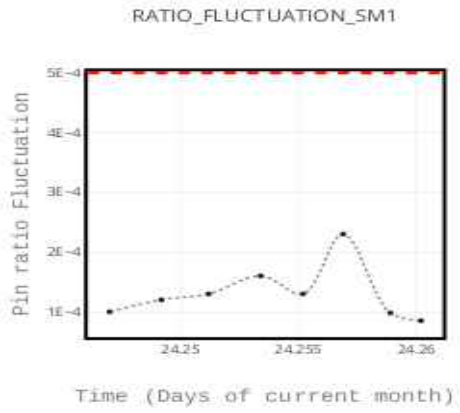
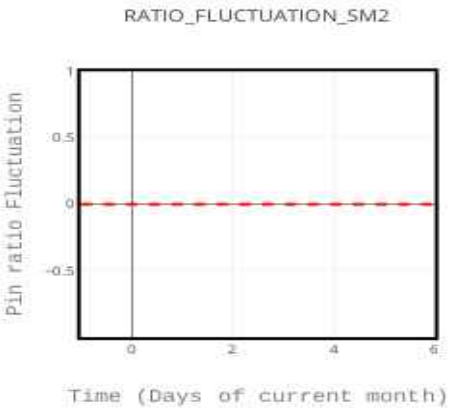


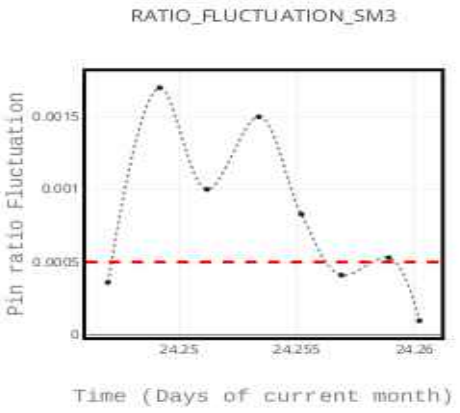
FLUCTUATION OVER LONGER TIME

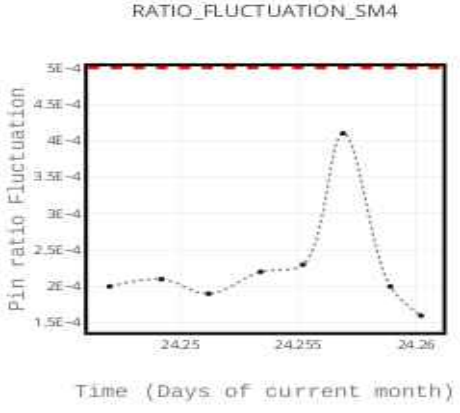


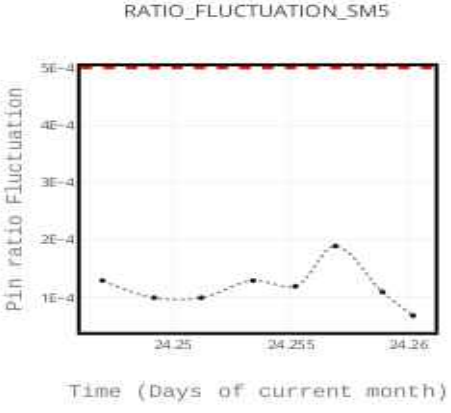
Stability Plots

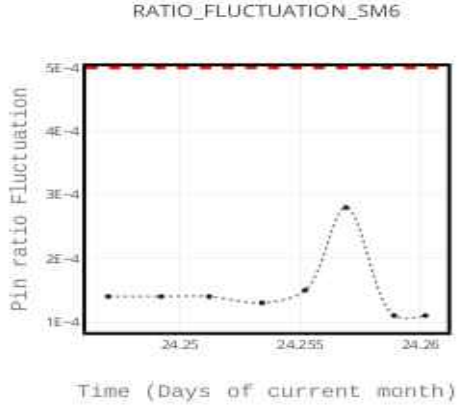






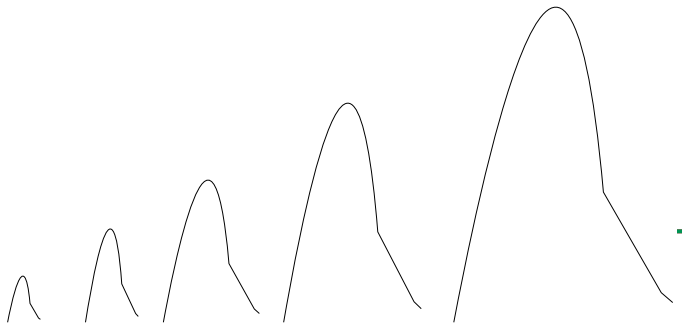




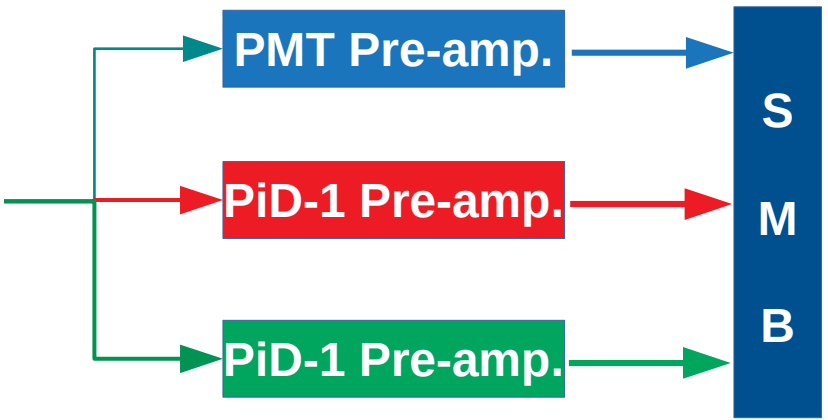


Electronic Calibration DAQ

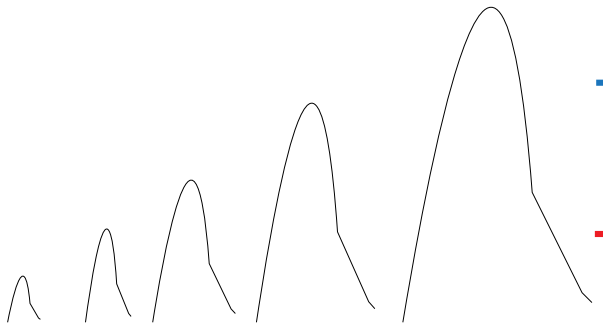
Calibration of The Electronics



A chain of known charge pulses
Called “DAC”s



Linearity Test



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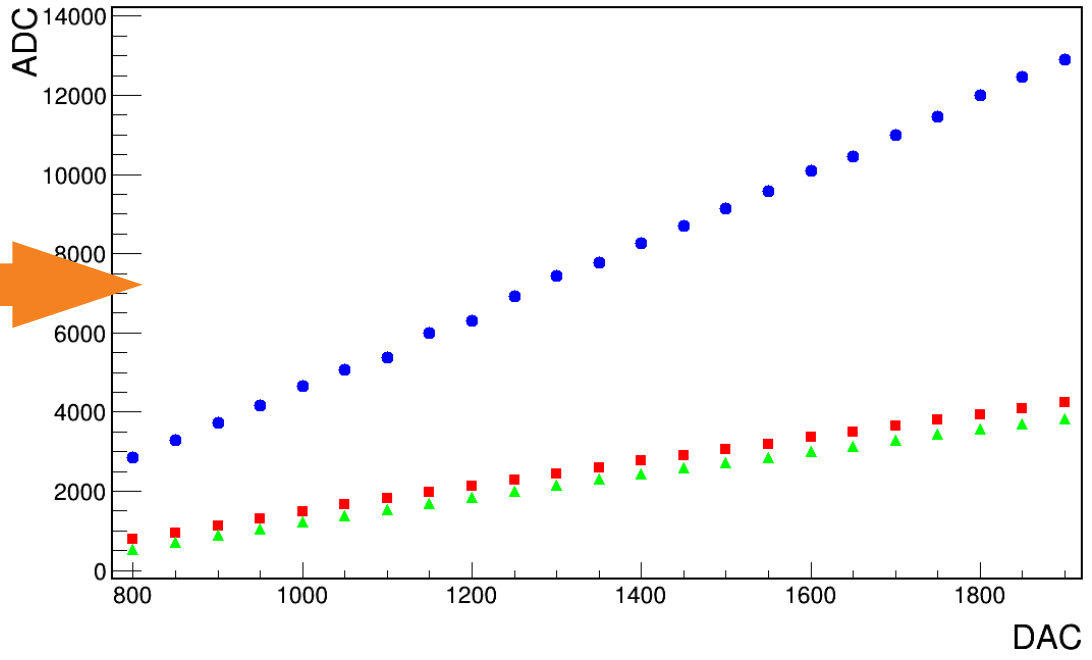
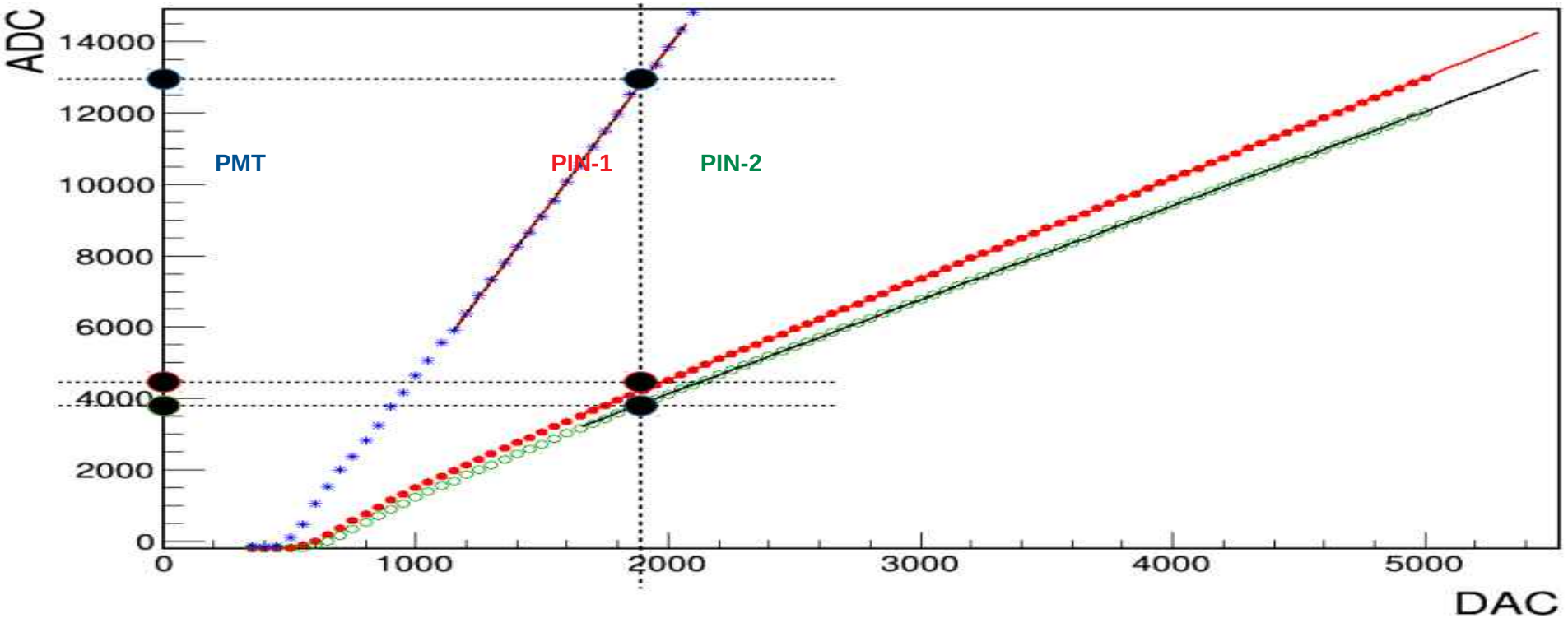
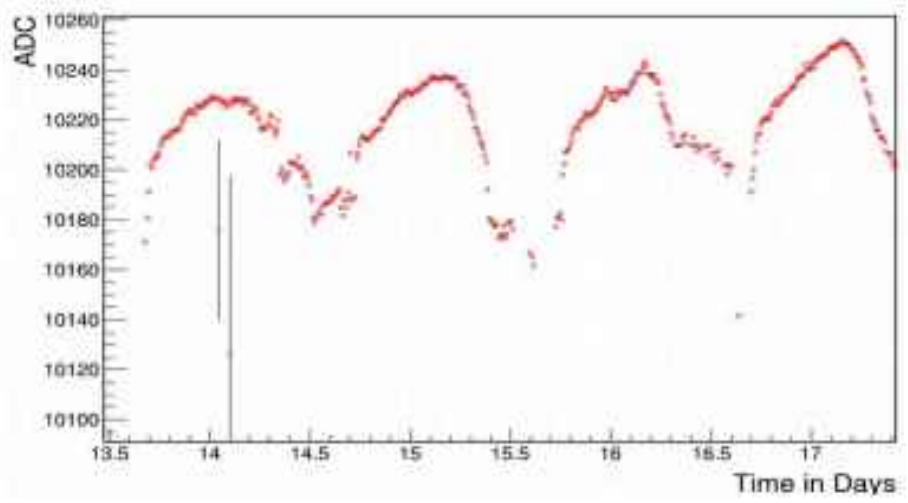


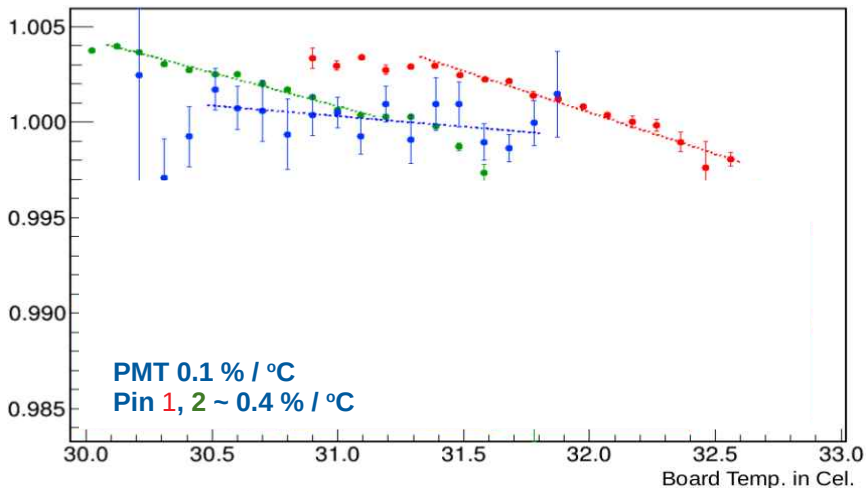
Temperature Correction



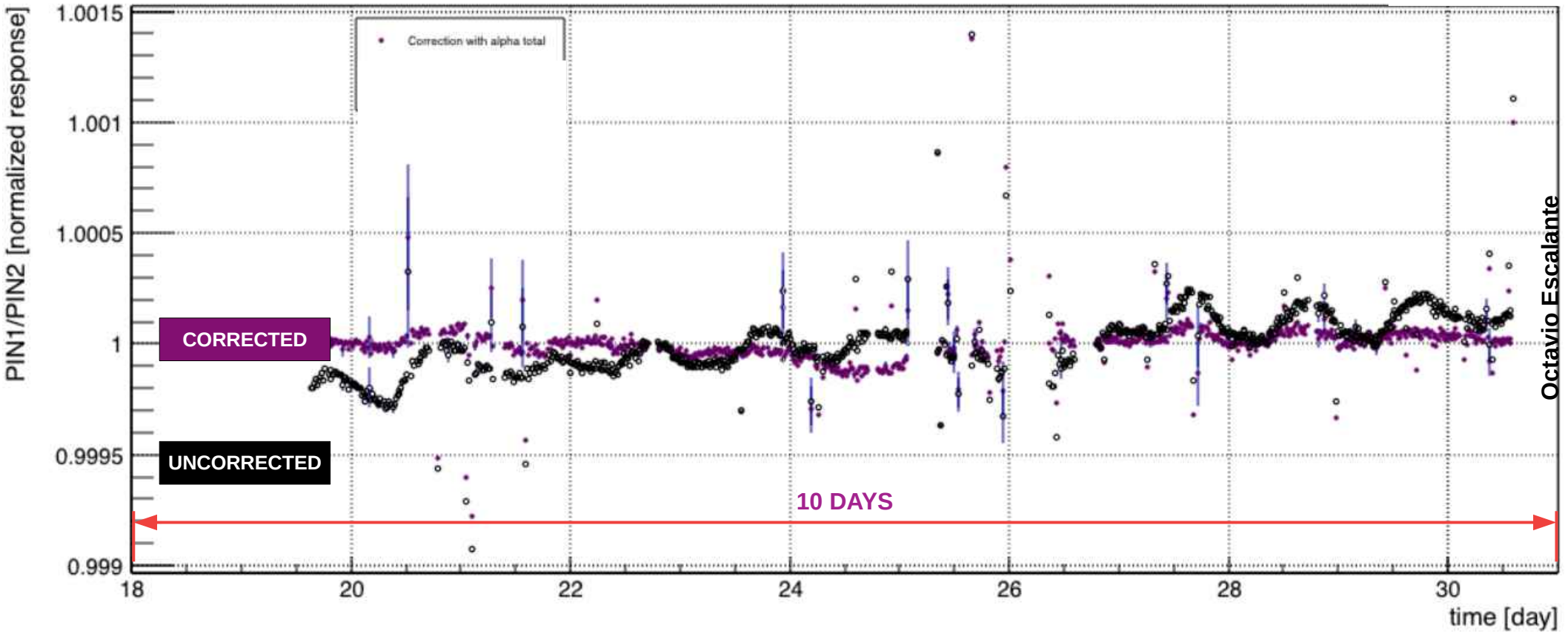
CALIBRATION RAMPING

Temperature Correction





Temperature Correction



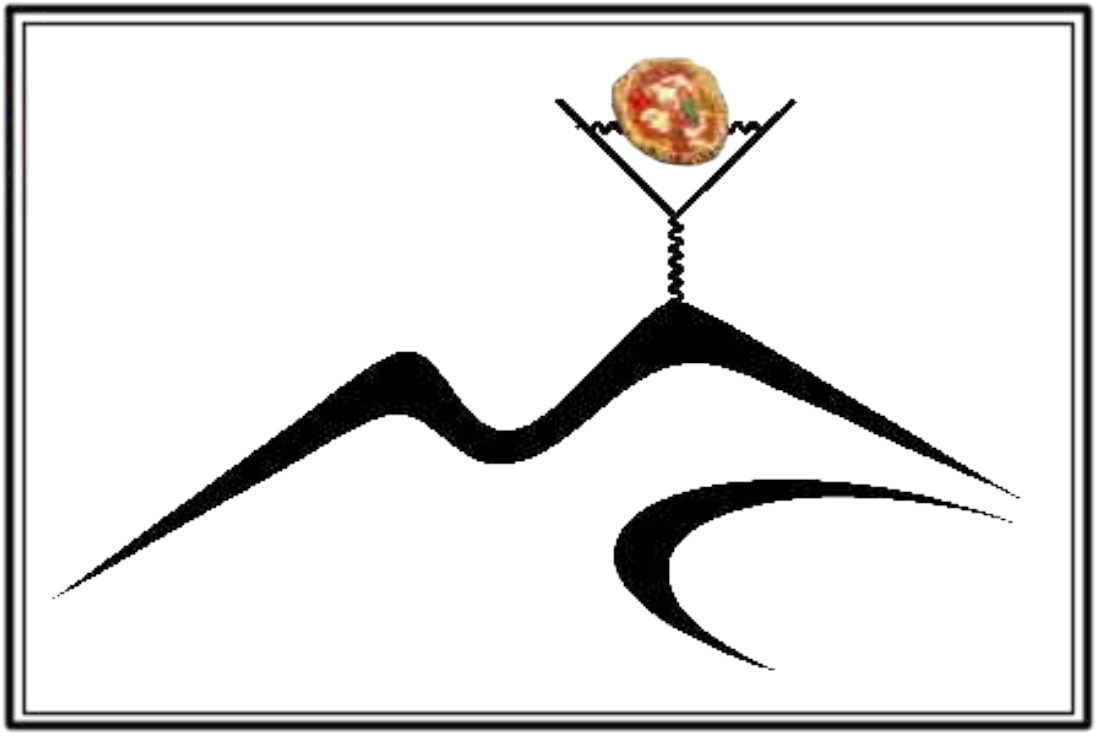
Current Status and Plans

- Laser DAQs (MIDAS & Naples) are running **24x7** flawlessly since the beginning (2017).
- Monitoring of **short**-term
  - **event** by event
  - last **minute**

  and
- **long**-term
  - last **24 hours** of laser trend
  - last **few weeks** of temperature trends

  are running smoothly.

GRAZIE



Numbers:

- SM input 150 pJ/pulse
- LM input 0.01 pJ/pulse
- Americium ~ 10 Hz

- Laser source: pico quant, 750 pJ @ 450 nm, average power 28 mW
-

Why Laser Calibration?

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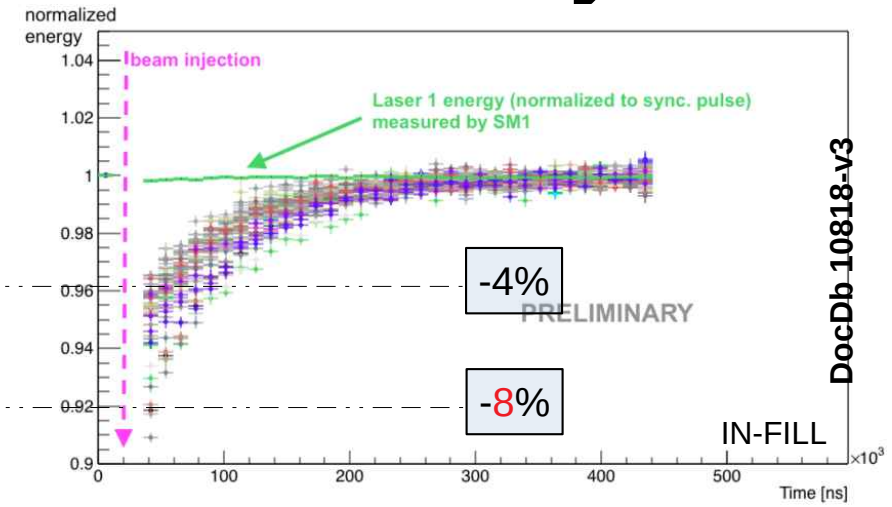


Time [ns]

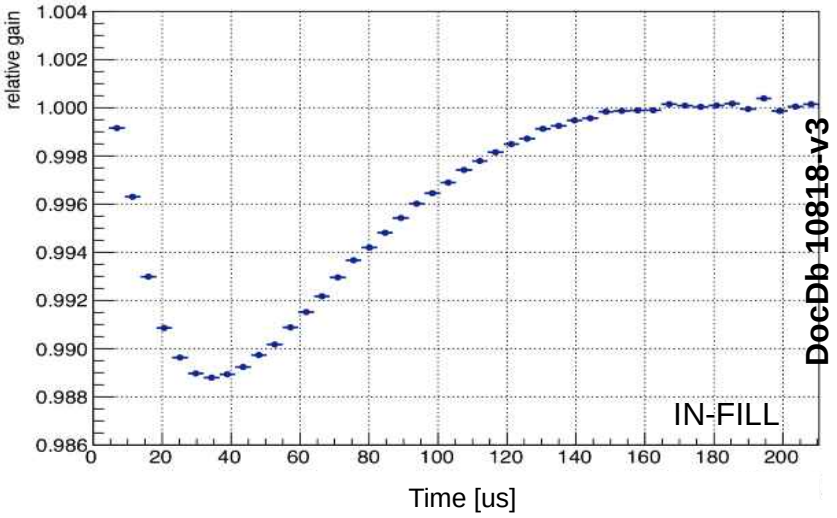
VERY SHORT

Two **nano-secs** apart particles hitting the calorimeter ~ typical SiPM charging up time.

Why laser calibration?

QUITE LONG

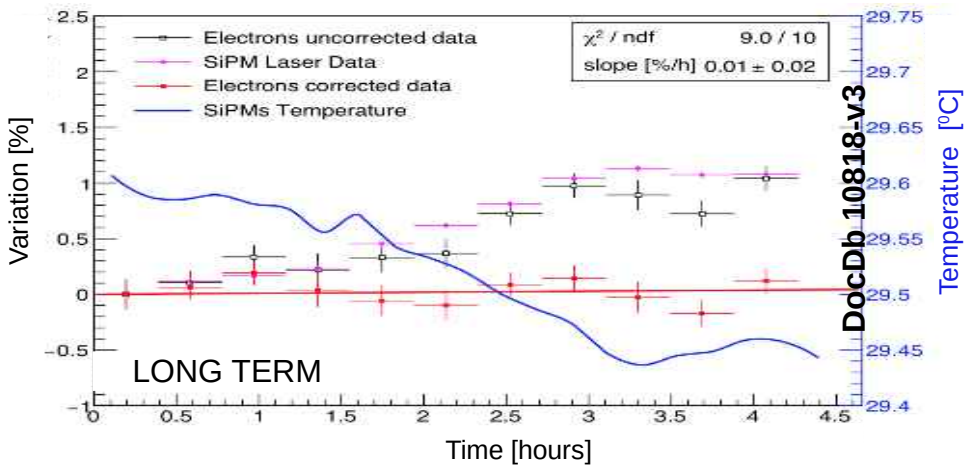
High load in the first few micro-secs after the injection results in a SiPM gain recovery time ~ few **tens** of **micro**-secs



Why laser calibration?

VERY LONG

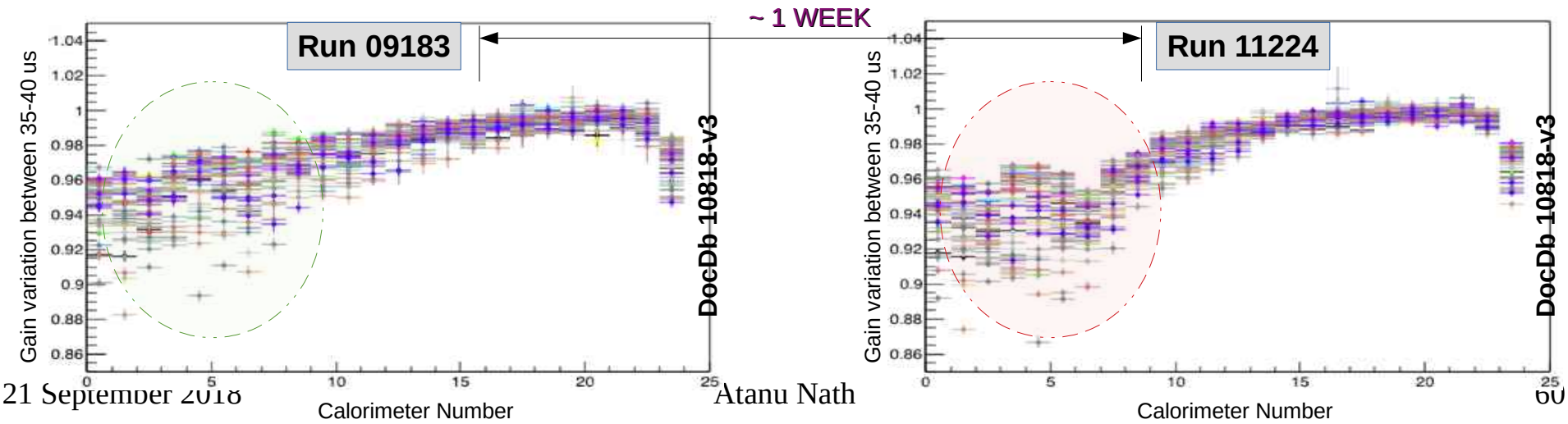
Much slower gain changes over longer time (**hours/days**) Can occur due to temperature change, aging etc.



Why laser calibration?

ANOTHER LONG ONE..
SAME CALO CAN SAG DIFFERENTLY @ DIFFERENT TIMES

In-fill gain function can be different in different runs separated by **weeks** due to different beam conditions.



The laser calibration system

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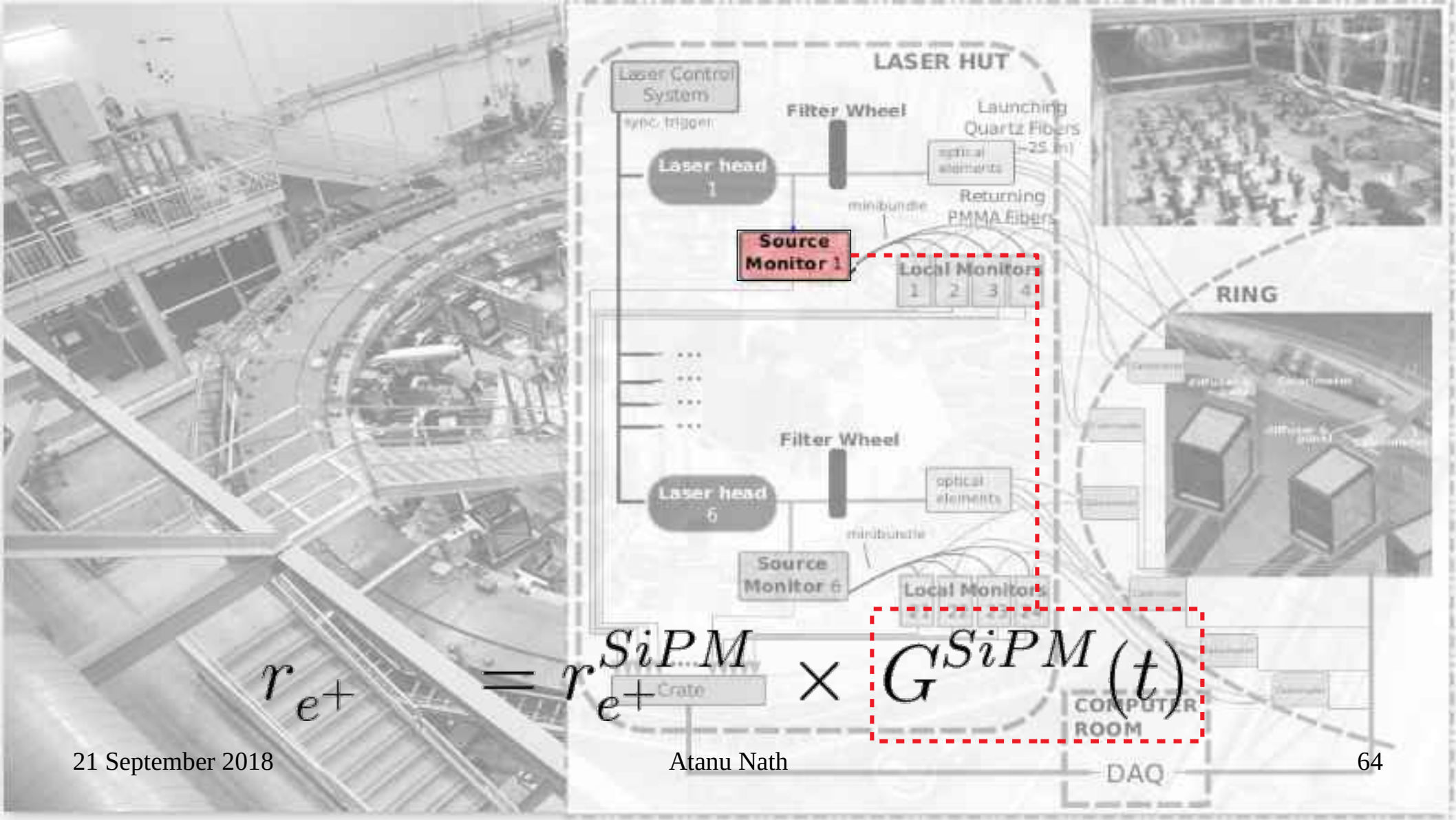
  But those pulses have to be **known**, stuff like temperature and aging can also affect the laser sources, that's why we need a ***monitor***ing system for the laser ***source***s right after the light leaves the source :

  - *the **Source Monitors***



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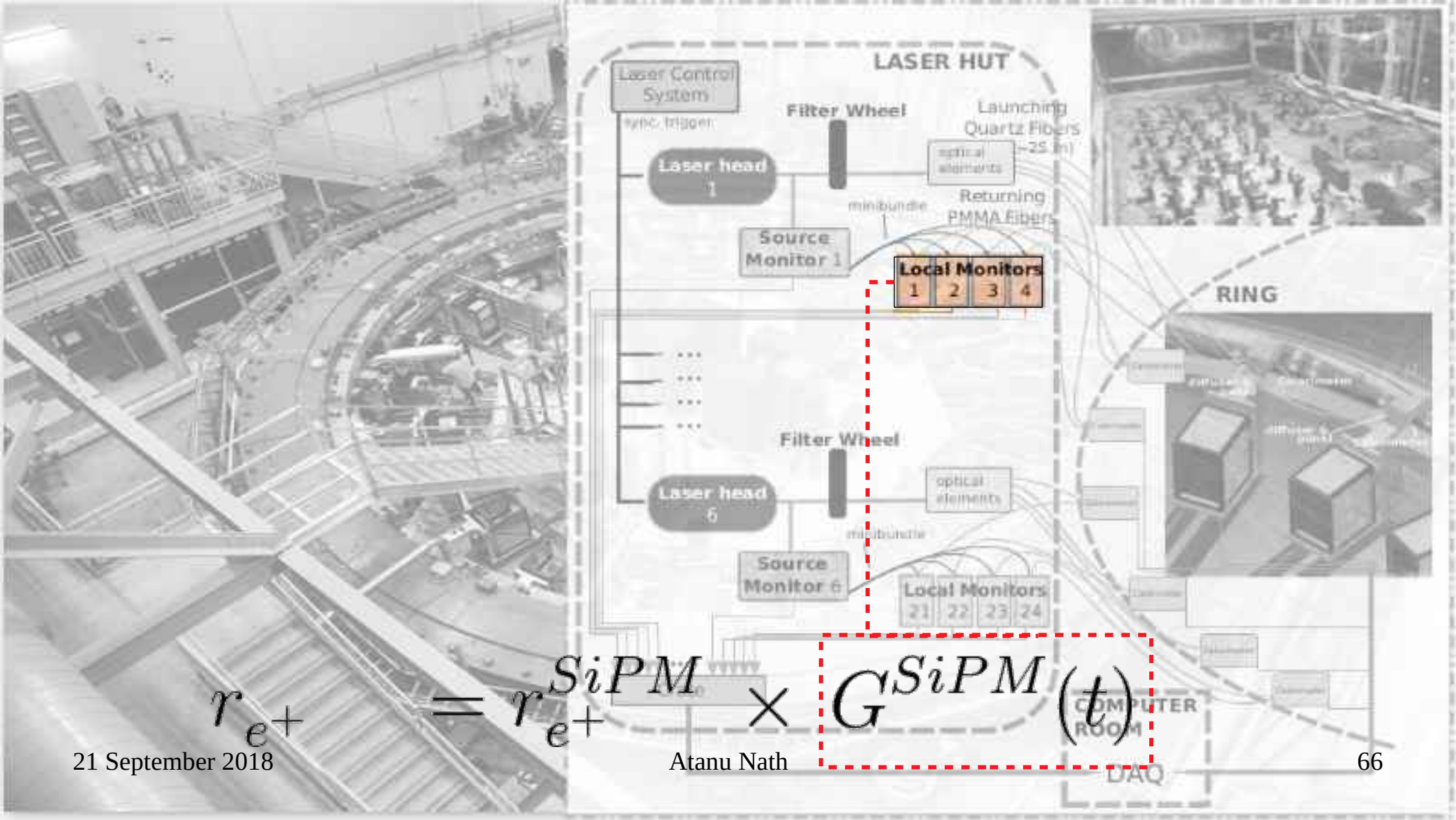

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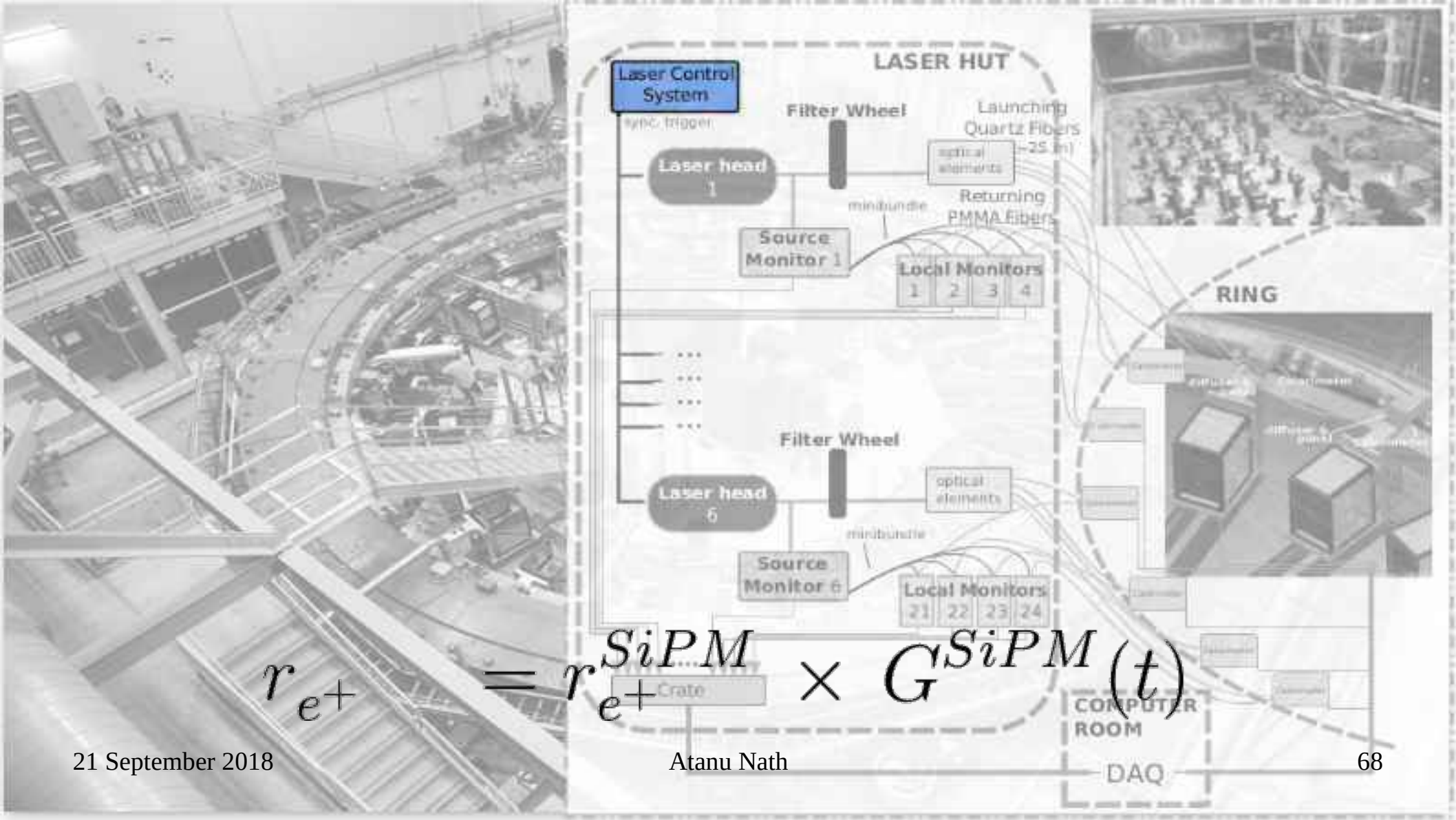
- But wouldn't these ***laser*** pulses mess with the ***positron*** signal? They would! That's why we need to ***control*** the ***laser*** pulses in a specific manner so that a few pulses during the ***muon fills*** and a few outside of that suffice to get us the gain function :

  - *the **Laser Control***



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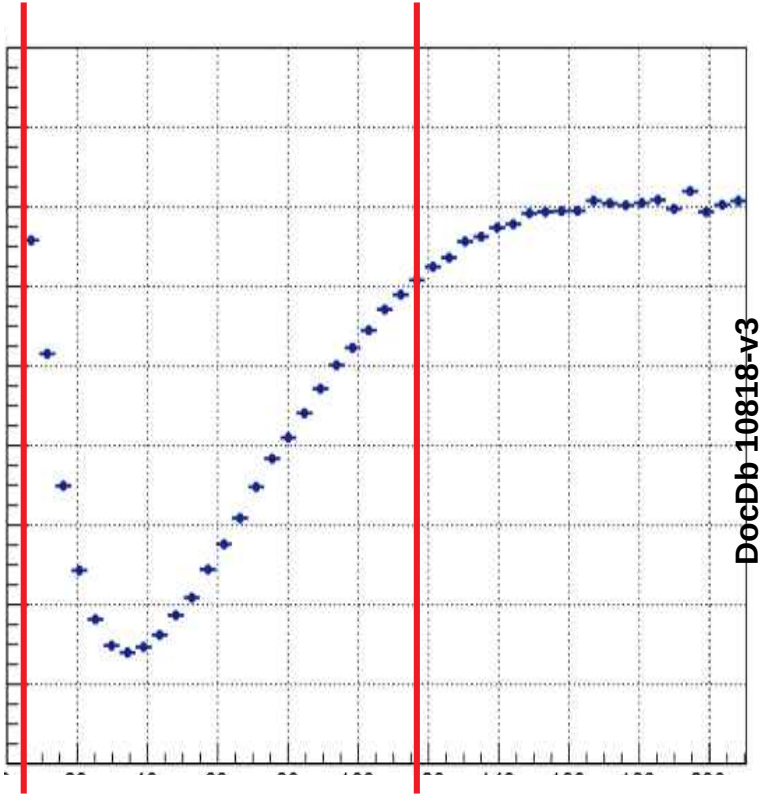
Laser Control System

- **In-Fill** : **2** pulses **200 us** apart are sent in a fill to minimize the damage
  - Then these pulses are shifted by **5 us**, it takes **40** such steps (**40** fills and not necessarily consecutive fills) to scan the whole range of **400 us** fill window.
  - In standard DAQ in-fill pulses are sent every ***10 fills***.



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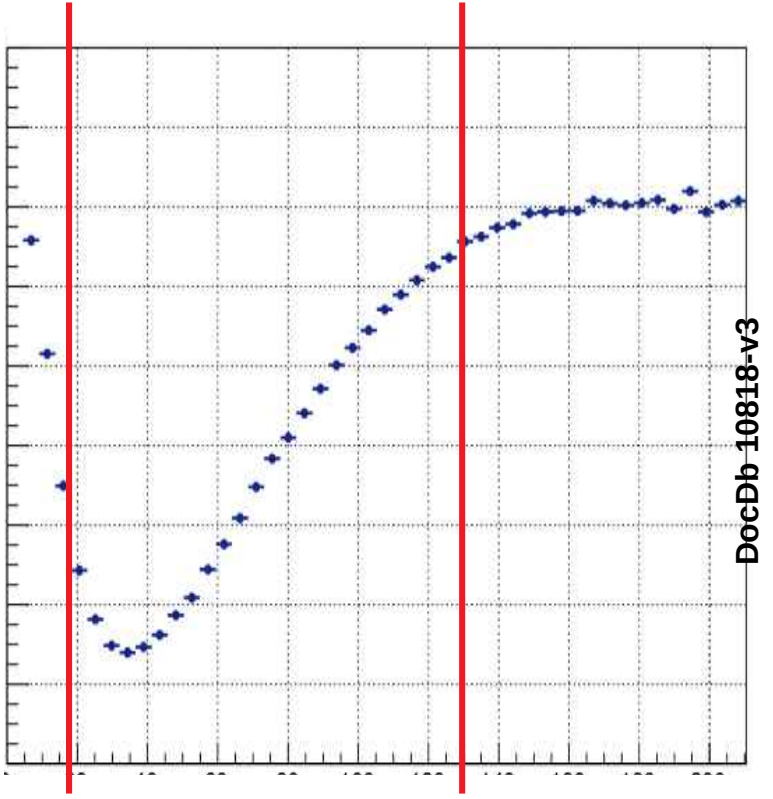

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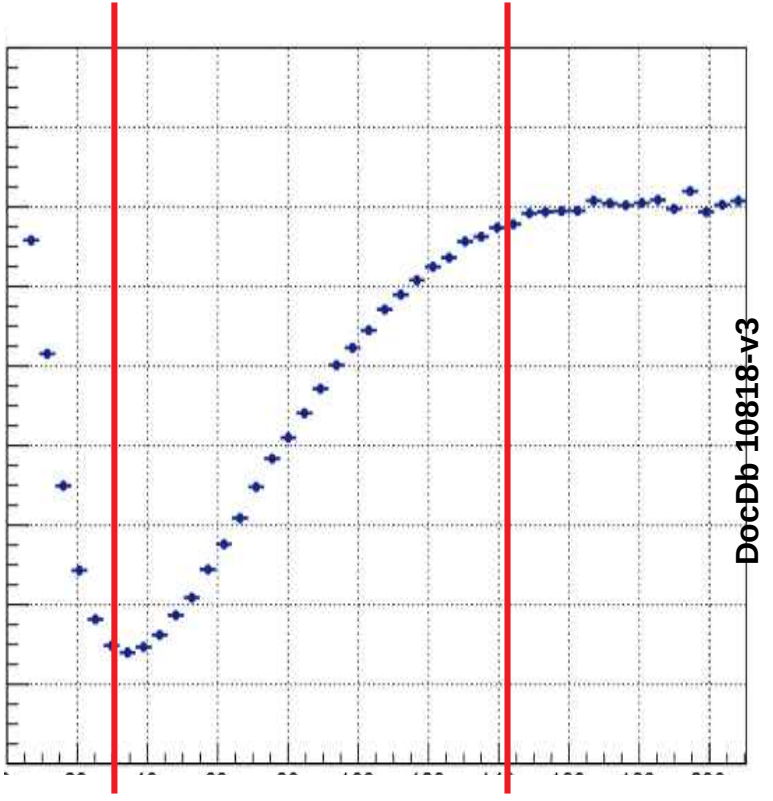

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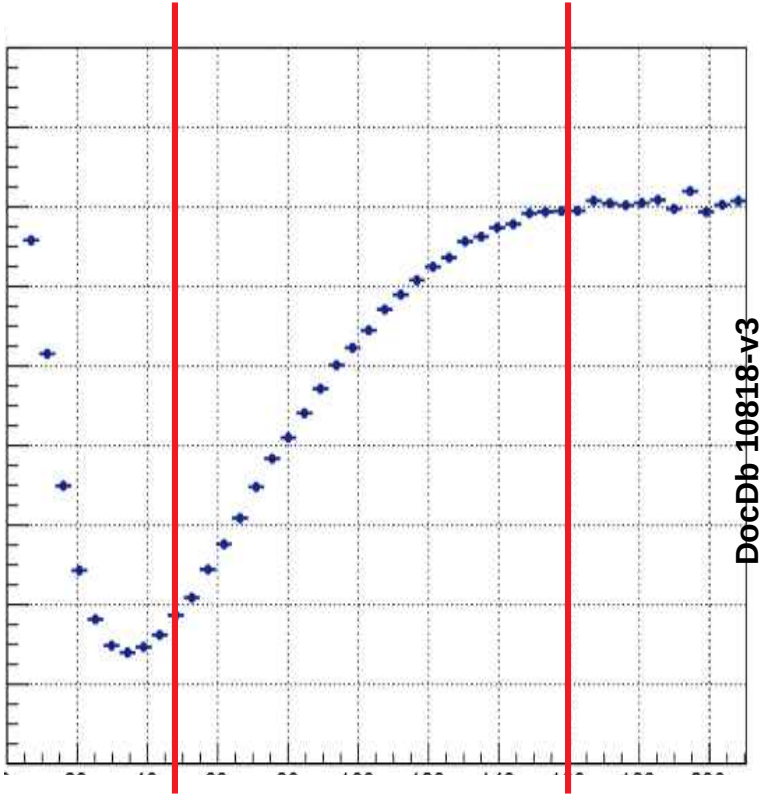

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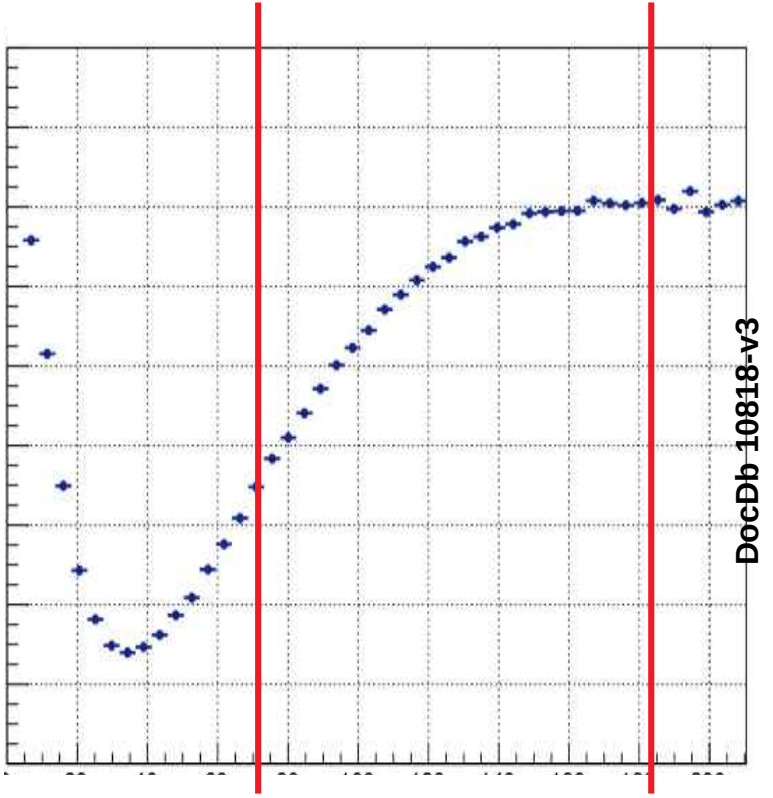
Parameter	Current value	Default value
T_{SYNC} (μs)	7	7
T_0 (first laser pulse) (μs)	30	30
prescale	1	10
N_{InFill}	2	2
Δt (μs)	200	200
T_{shift} (μs)	5	2.5

ODB: Laser pulse settings.



Temperature Correlations...