

H2020-MSCA-RISE-2015 – Grant Agreement N° 690835

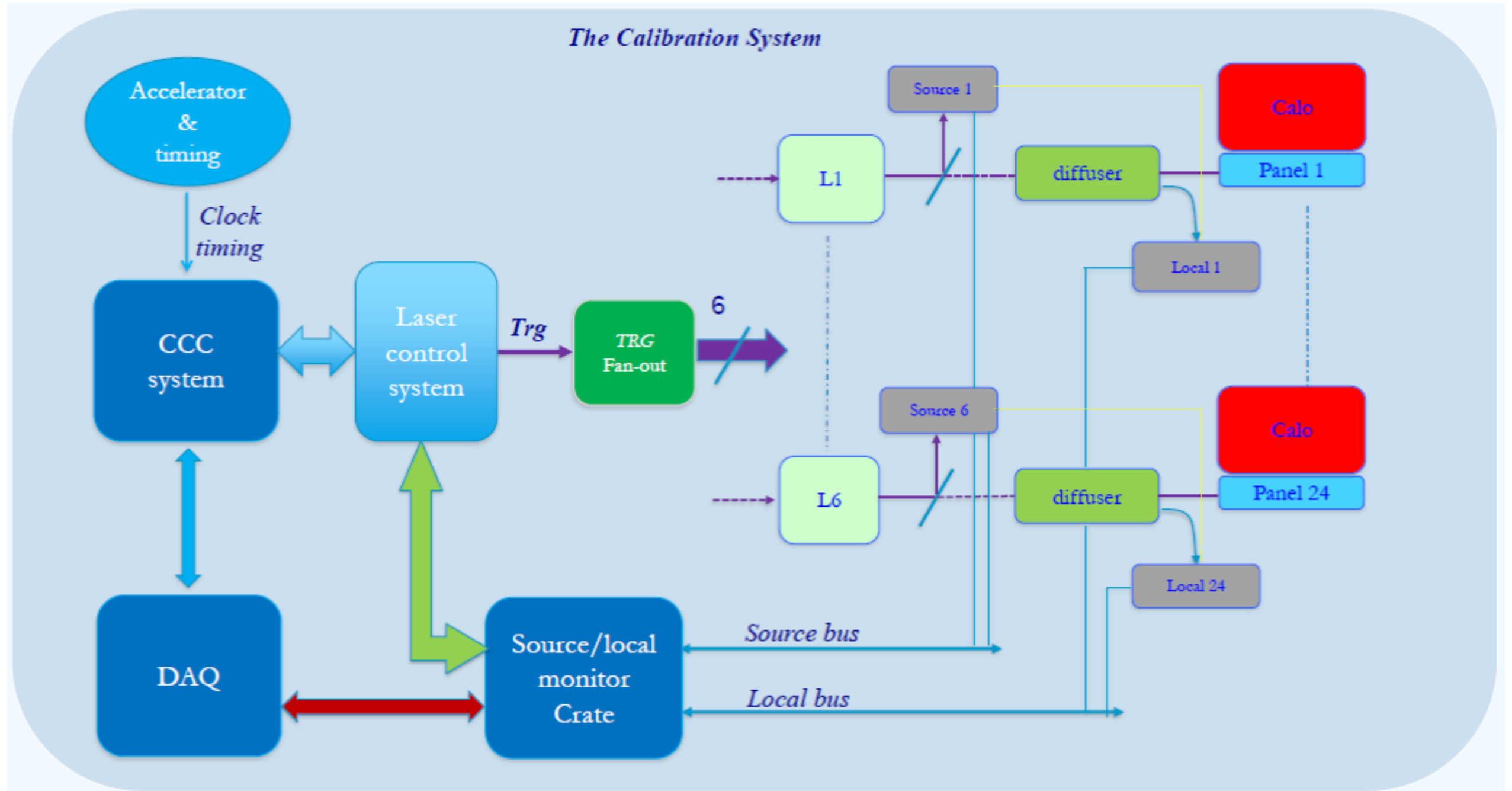
Monitoring of the Laser calibration system in the g-2 experiment at Fermilab: DAQ description, electronics and performance

O. Escalante (INFN – Napoli)

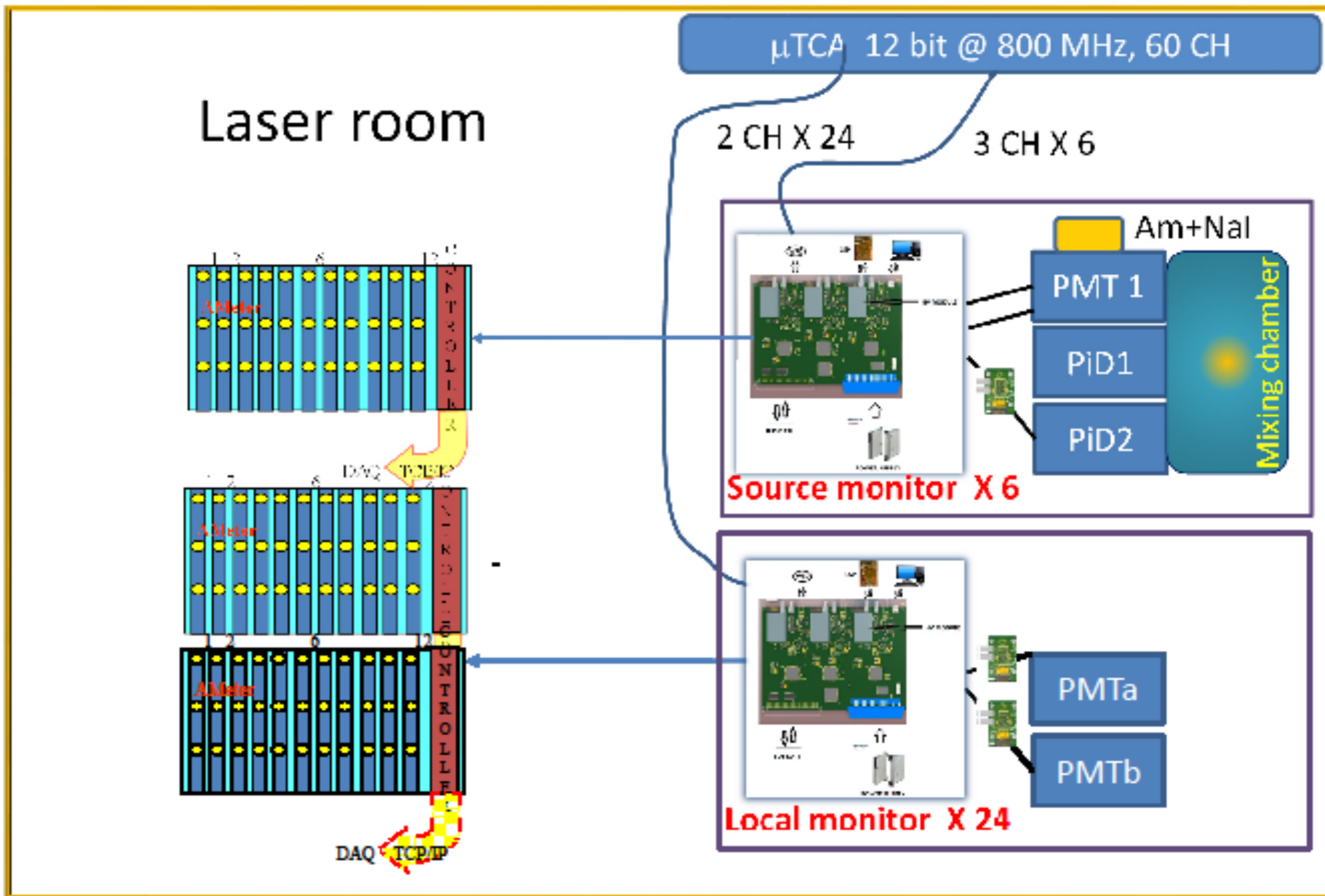
MUSE Mid Term Meeting Frascati - 12-May-2017

- ❖ Naples *DAQ system*; installation and data flow
- ❖ Source Monitor data structure and *analysis*
- ❖ Real-time *monitoring*

Laser Calibration System



Monitoring DAQ



Laser system functions

◉ Interface with the Trigger system

- Synchronization with the clock, control and command system (**CCC**)

◉ Provides the calibration pulses according the following modes

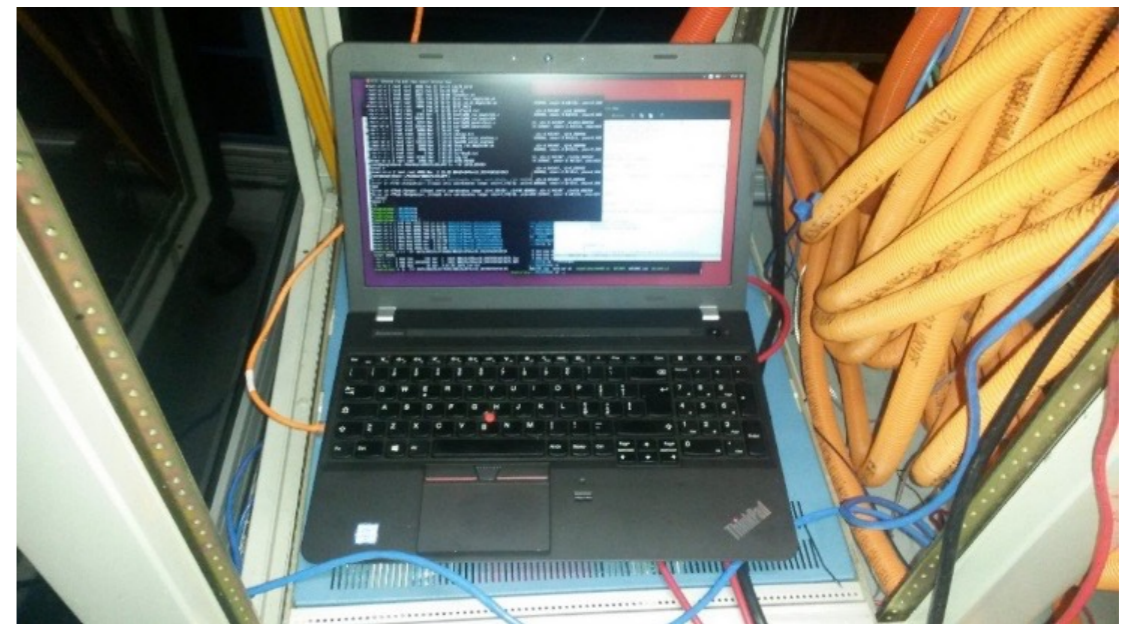
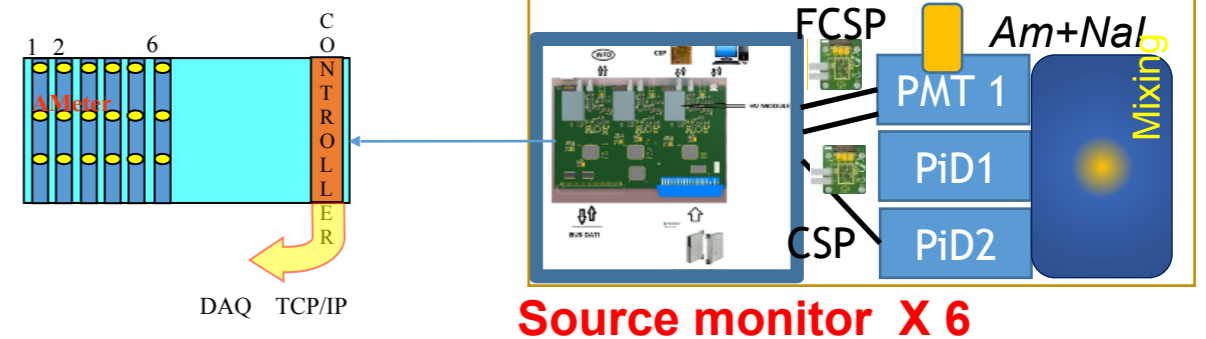
- **In-fill mode**: pulse train generation at programmable frequencies superimposed to the real data during 700 μ s fill window;
- **Out-of-fill mode**: pulse train generation at programmable frequencies between two adjacent 700 μ s fill windows;
- Physics event simulation with “**flight simulator**” mode by triggering the laser according to an exponential function $\exp(-t/\tau)$, as expected from muon decay:
 - Detector/electronics/DAQ test and characterization
- **Time reference** signal for reset, synchronization and initialization of DAQ and electronics (BOF/EOF/RST)
 - Alignment between channels and time measurements

◉ Interface with the monitor system electronics

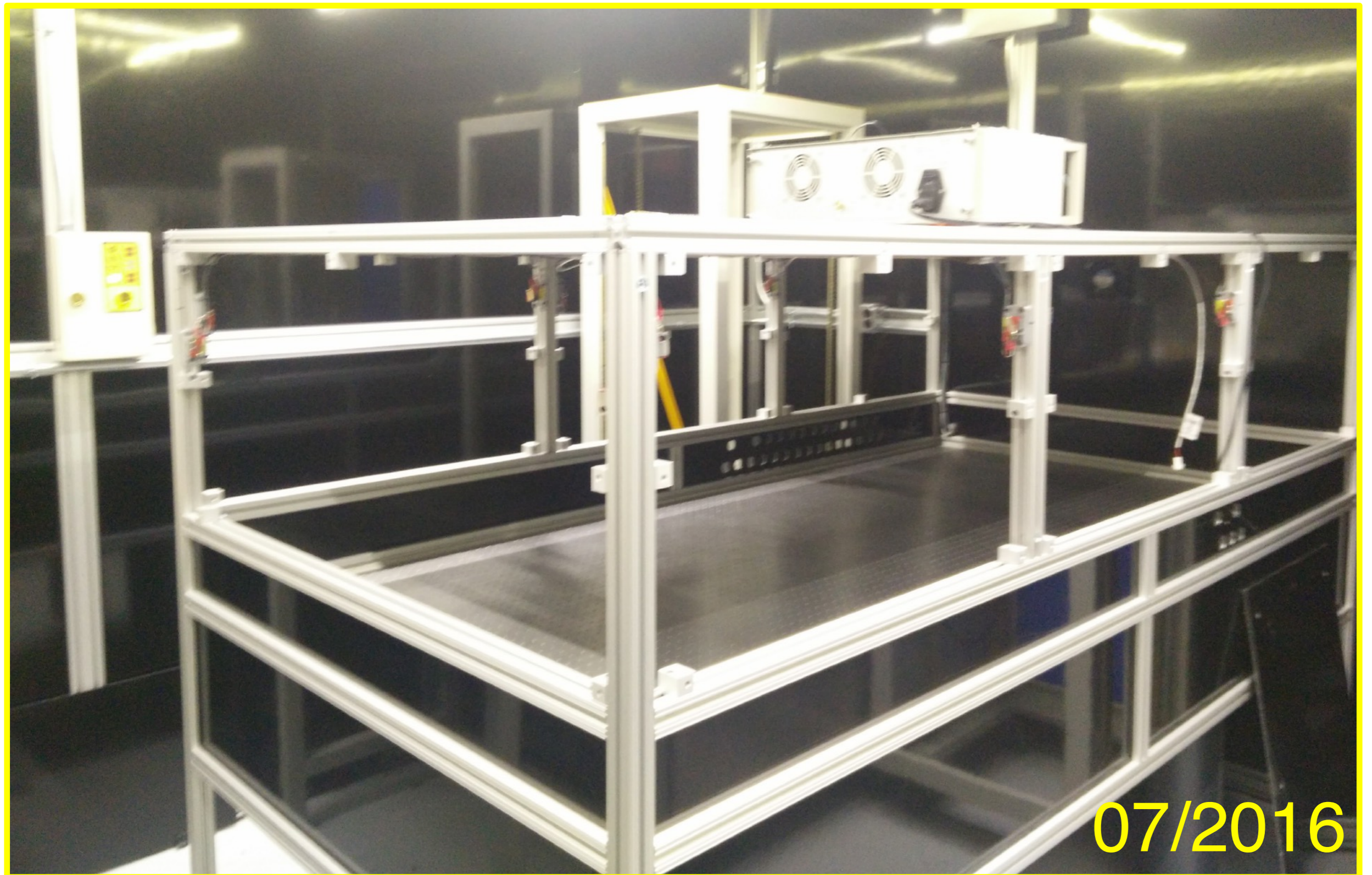
- Time reference signals for **data processing** and **readout**
- Status and activity of the monitor system

Installation at Fermilab

- On March 3rd **three lasers** were put in operation by the LCB (equipped with new firmware under test)
- Data from the 3 SM boards were acquired by the **local DAQ** system (3 BeagleBones + laptop)
- Laser pulses; 7 in 700 μ s + 80 outside in \sim 200 ms.
- Cycle repetition of 200 ms, 5 Hz rate
- Mean Pulse Rate of **\sim 400 Hz**
- Data throughput for (3 BB/SM): 10 MB/h
- Single SM throughput: 2.8 kB/s
- Limit : 115 kb/s
- On April 7th system was completed

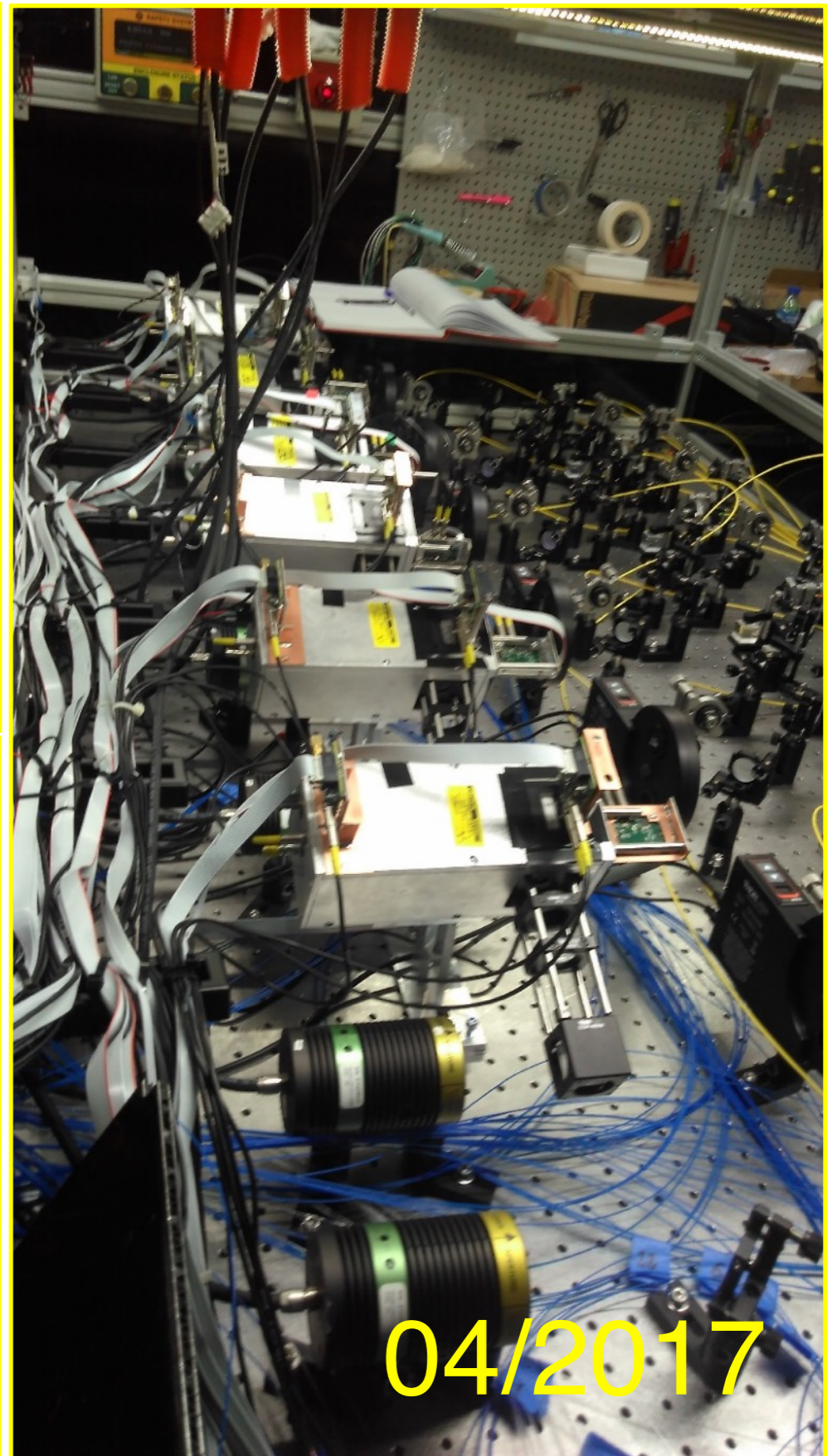
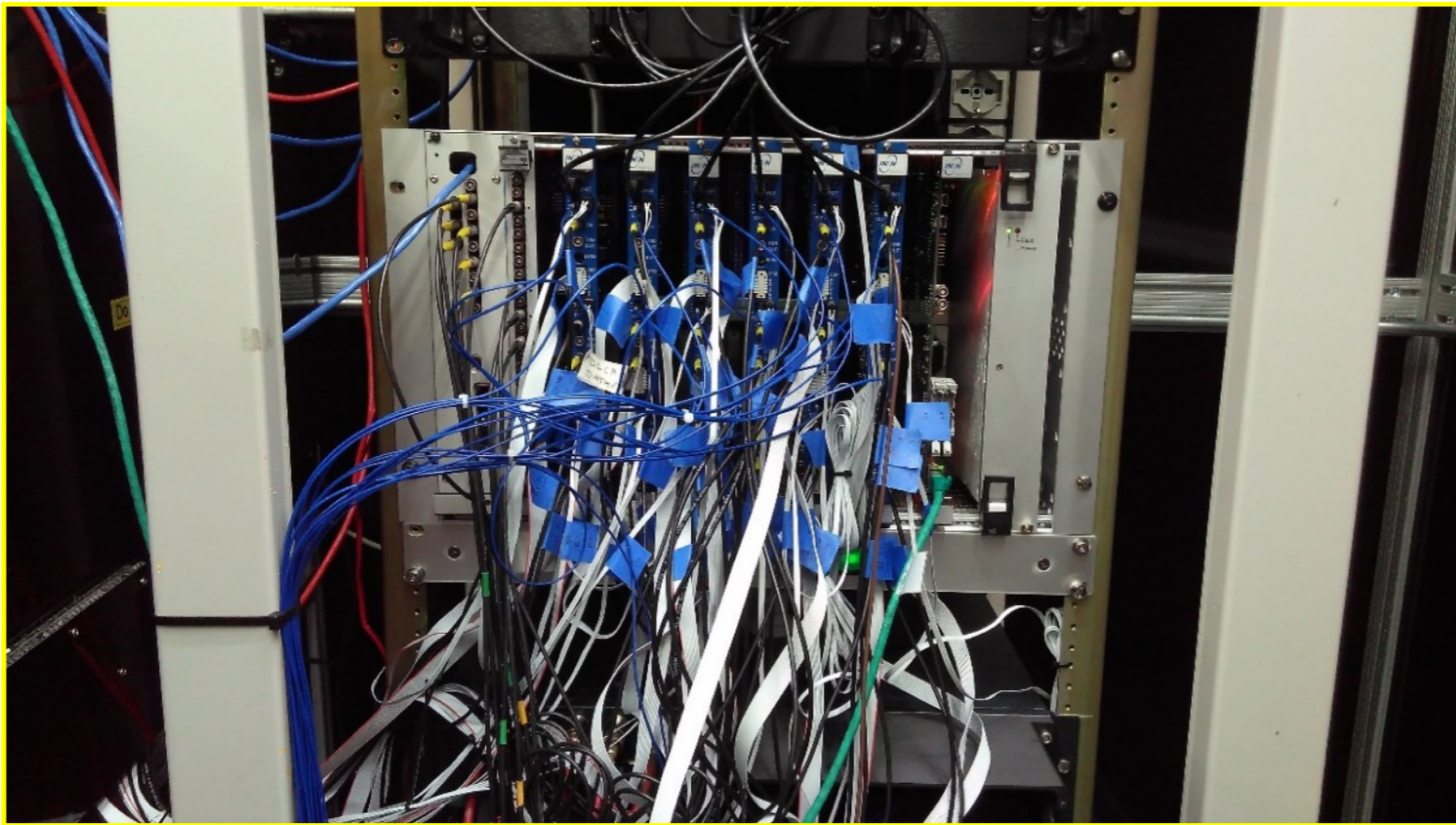


Installation at Fermilab

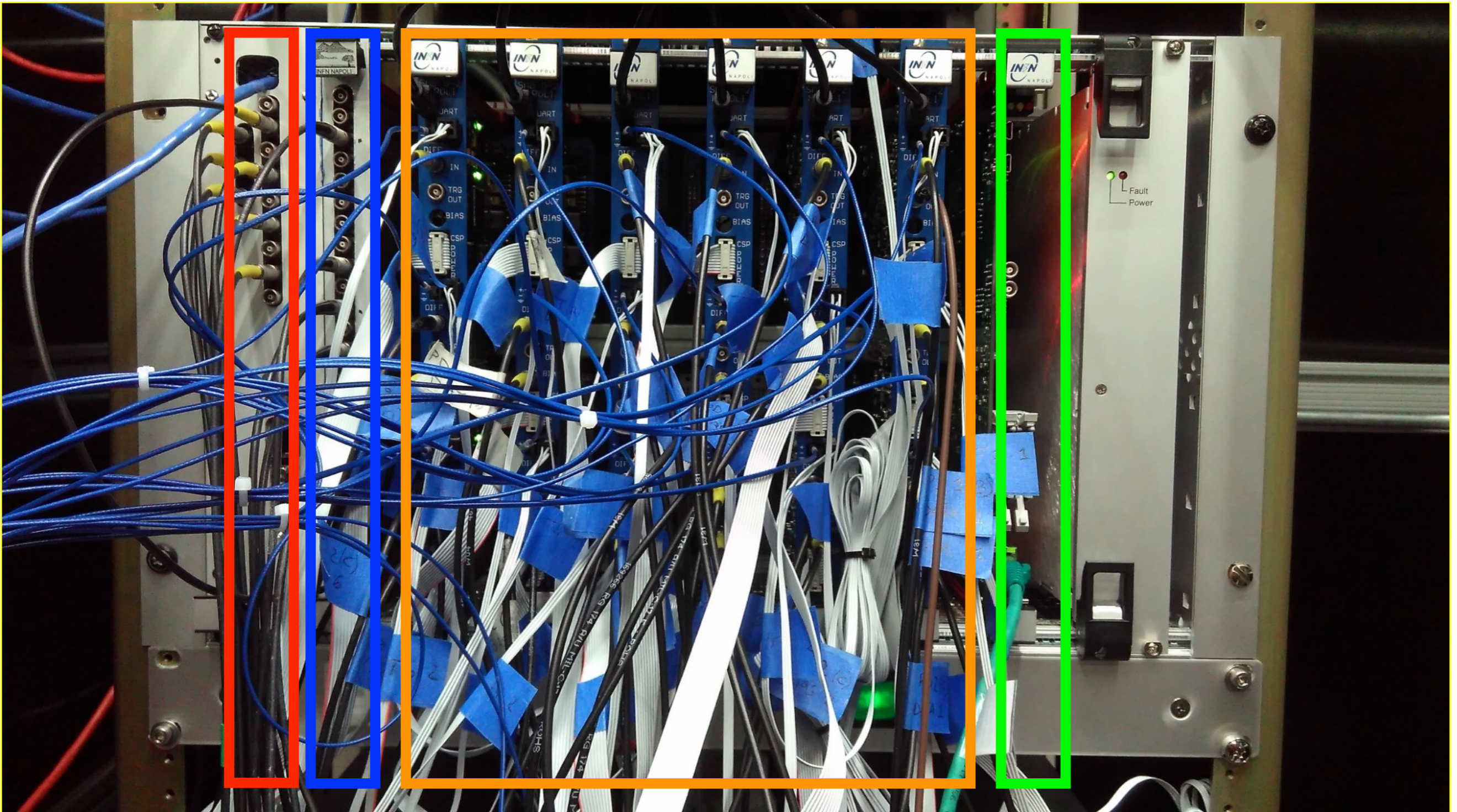


07/2016

MUSE



04/2017



LASER
CONTROL

FANOUT

SM 6

SM 5

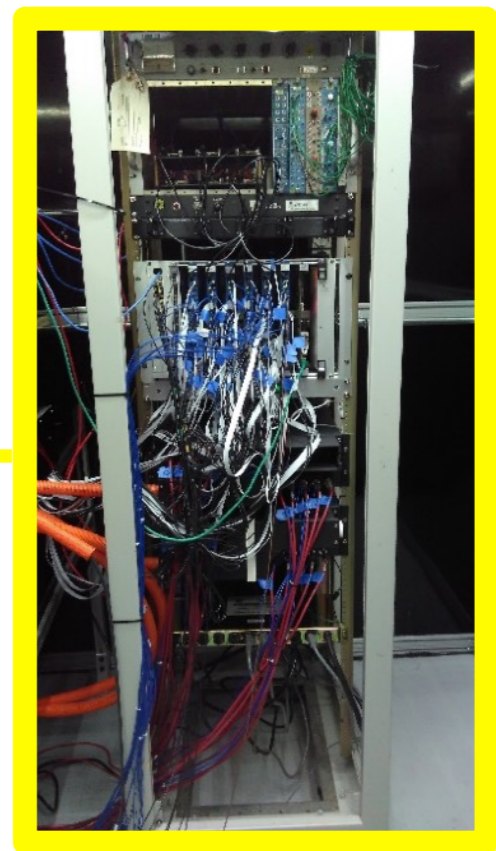
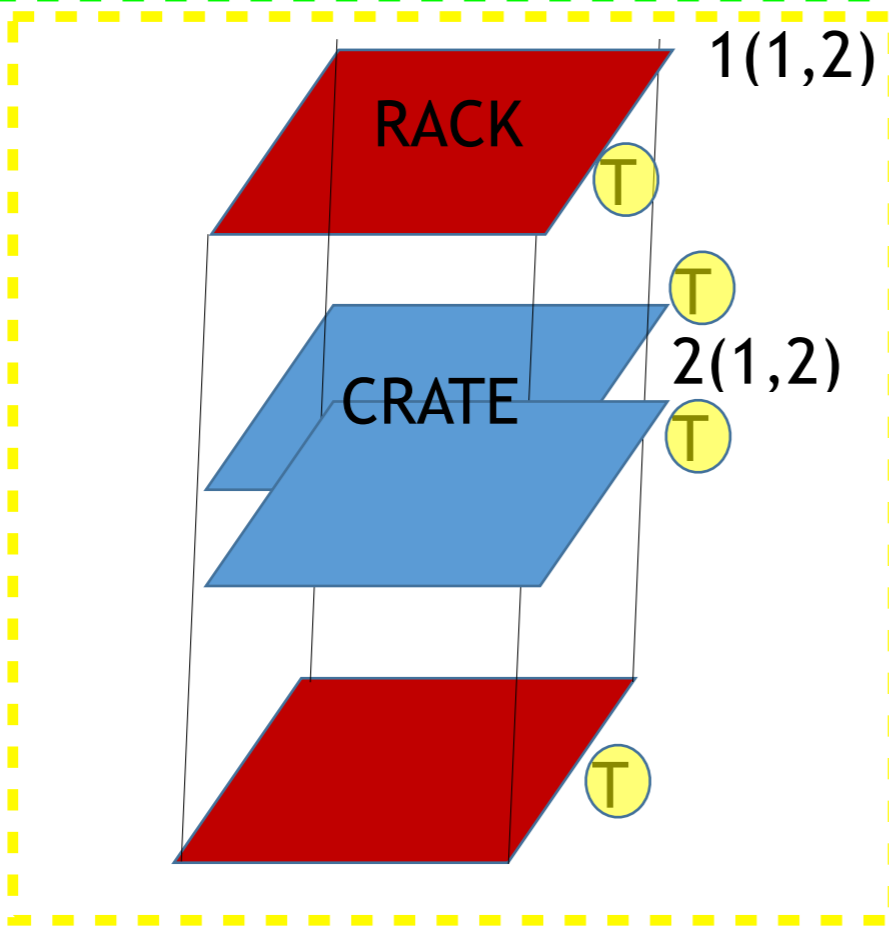
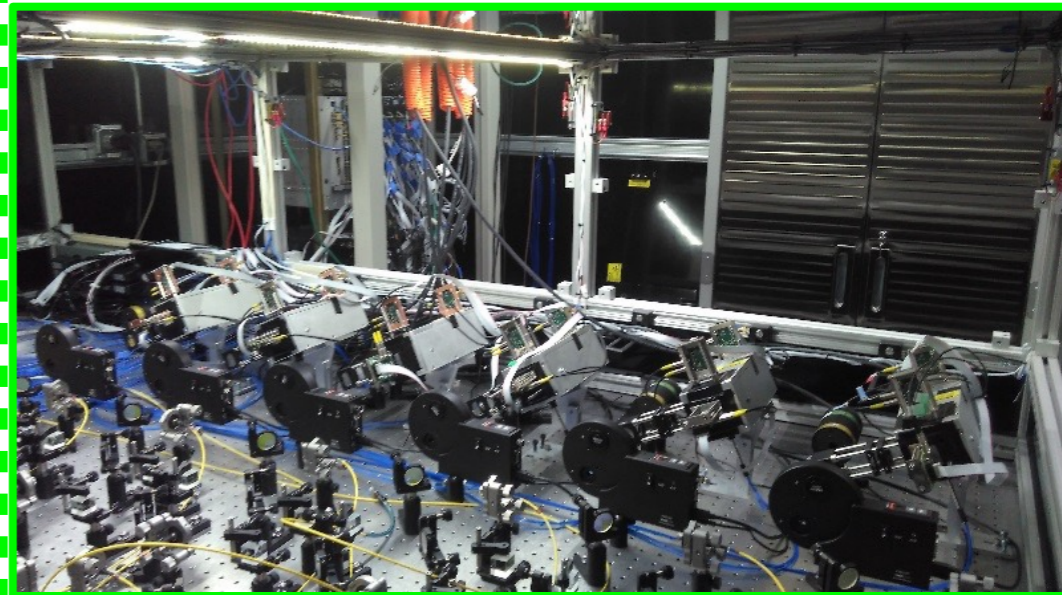
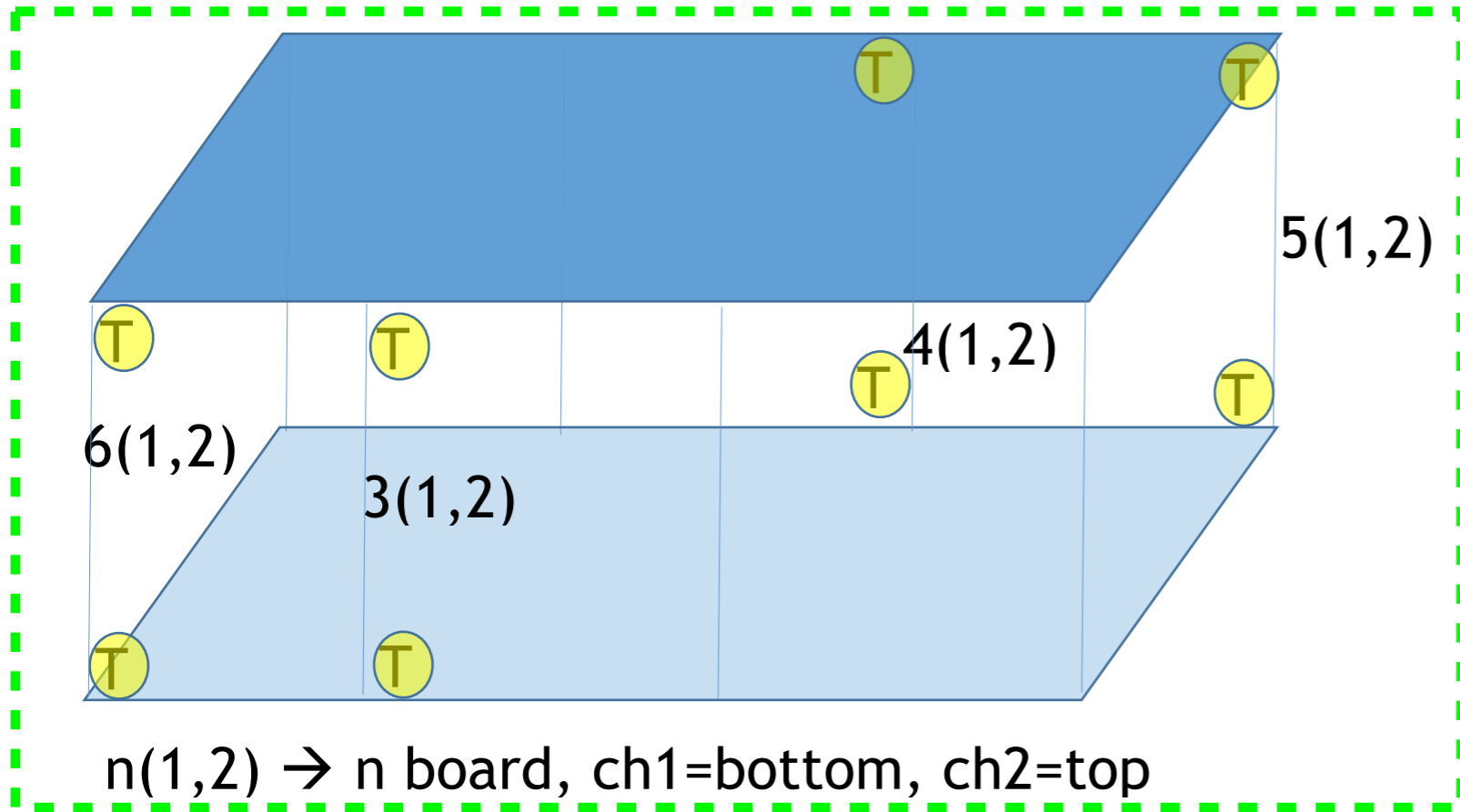
SM 4

SM 3

SM 2

SM 1

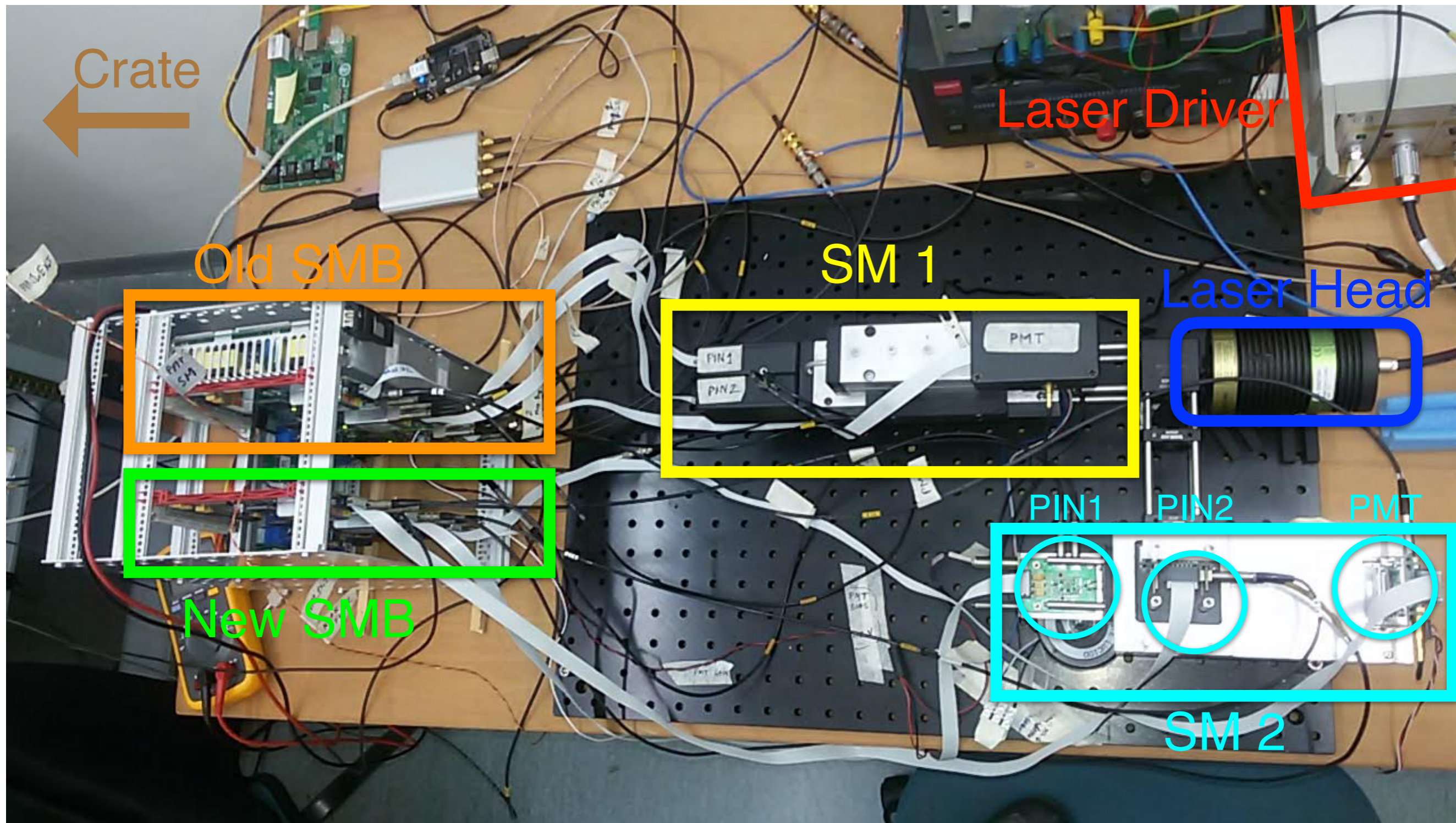
CONTROLLER



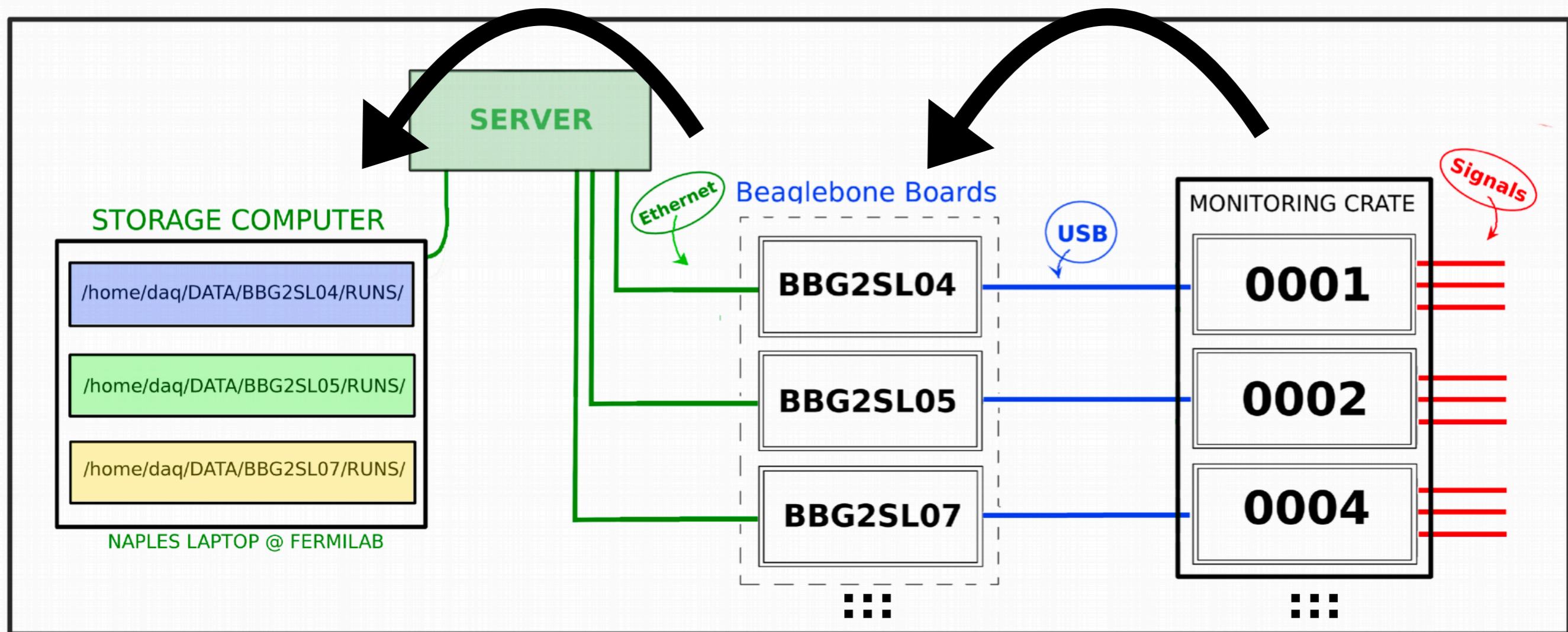
Test stand at Naples



Test stand at Naples



Naples-DAQ system @ Fermilab



A loop process acquires data and transfers it to specific directories in the storage computer (`*laptop@napdaq*`) every “N” hours

Decoding Loop

Raw data

DIRECTORY PATH

STORAGE COMPUTER

/home/daq/DATA/BBG2SL04/RUNS/

/home/daq/DATA/BBG2SL05/RUNS/

/home/daq/DATA/BBG2SL07/RUNS/

NAPLES LAPTOP @ FERMILAB

decode.sh

Creates .root files and saves in same
DIRECTORIES

Analysis Loop

Raw data (containing decoded .root file)

DIRECTORY PATH

analyze.sh

STORAGE COMPUTER

/home/daq/DATA/BBG2SL04/RUNS/

/home/daq/DATA/BBG2SL05/RUNS/

/home/daq/DATA/BBG2SL07/RUNS/

NAPLES LAPTOP @ FERMILAB

Creates plots and saves in same

DIRECTORIES

(plots in .png and .C ROOT macro)

Preliminary analysis for 1 hour run, 03/17 (#2)

Voltage Setting: PIN1: 50 V, PIN2: 50 V, PMT(ref Voltage): 720 mV

	PIN1	PIN2	PMT
<ADCCount>	10040	10220	13800 (Laser)
			3400 (Am)

Laser/Am : OK
PIN: OK

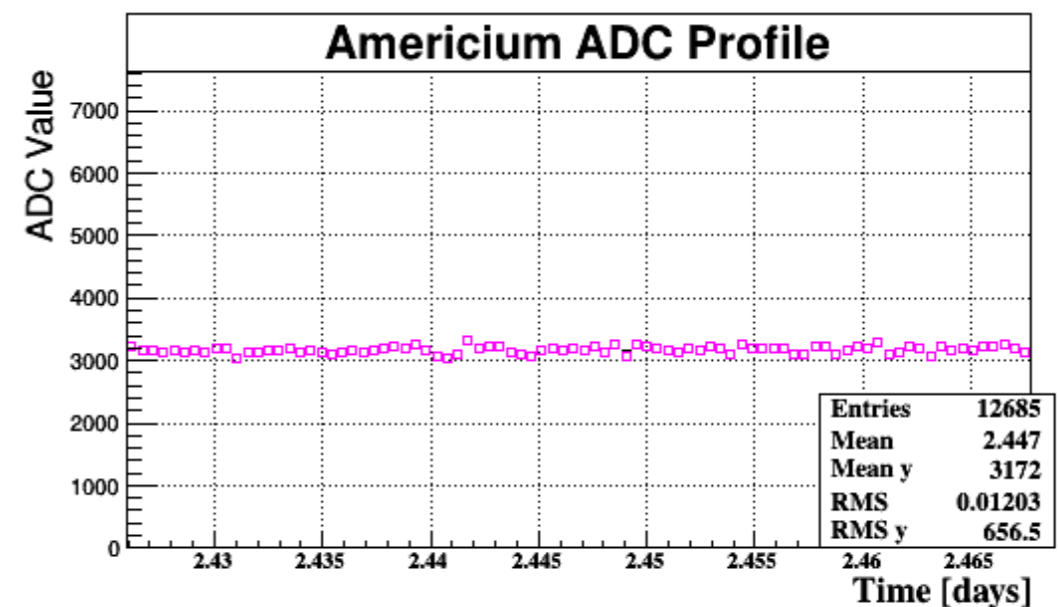
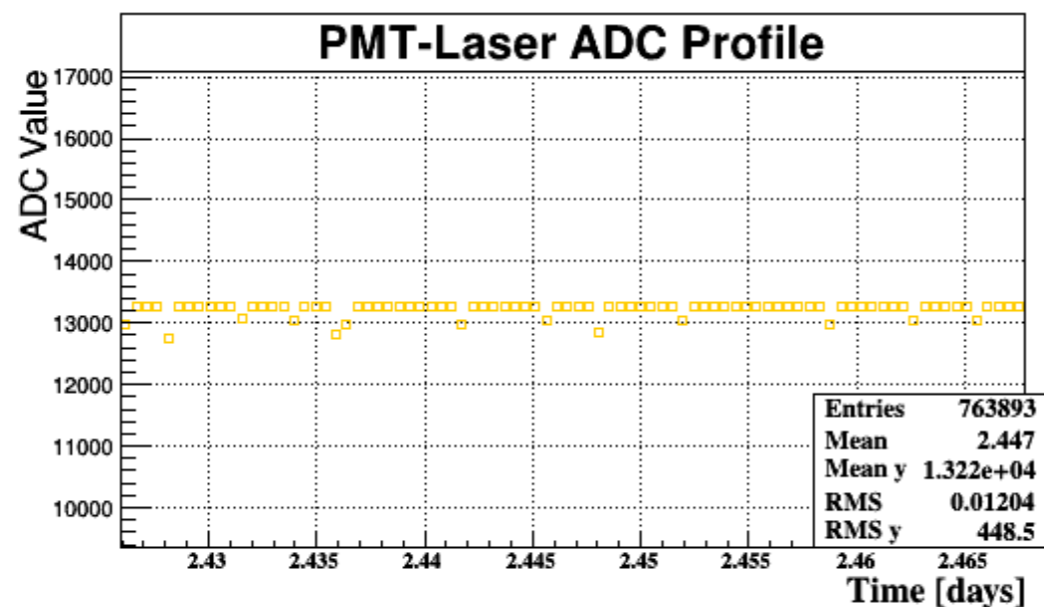
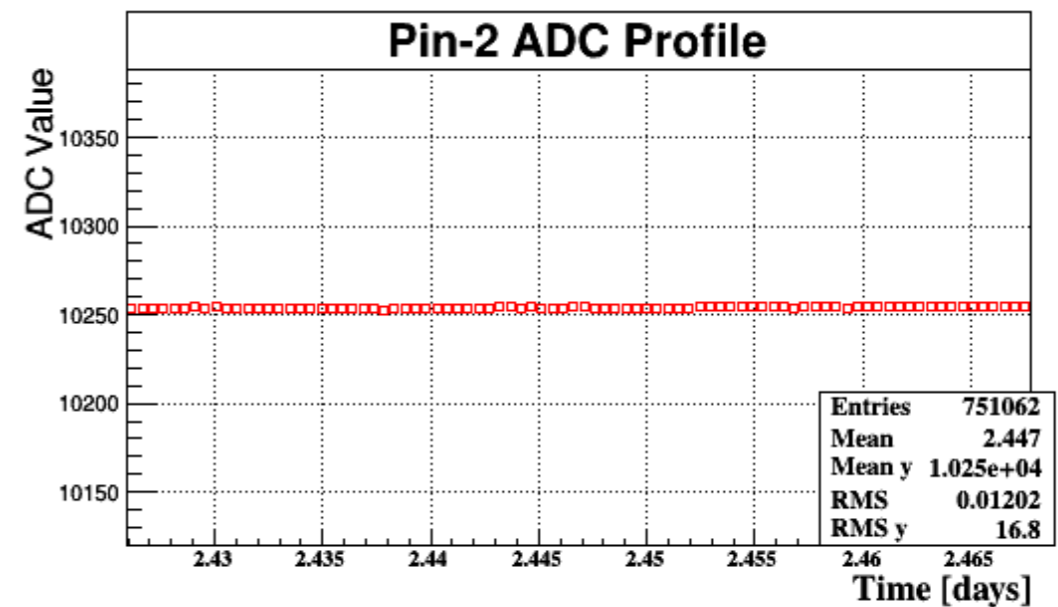
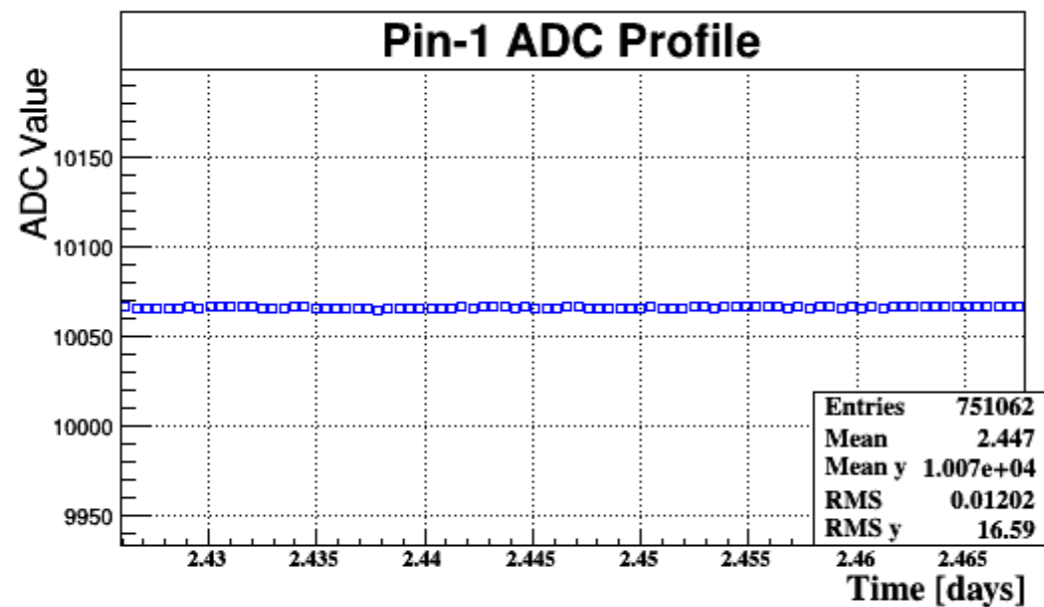
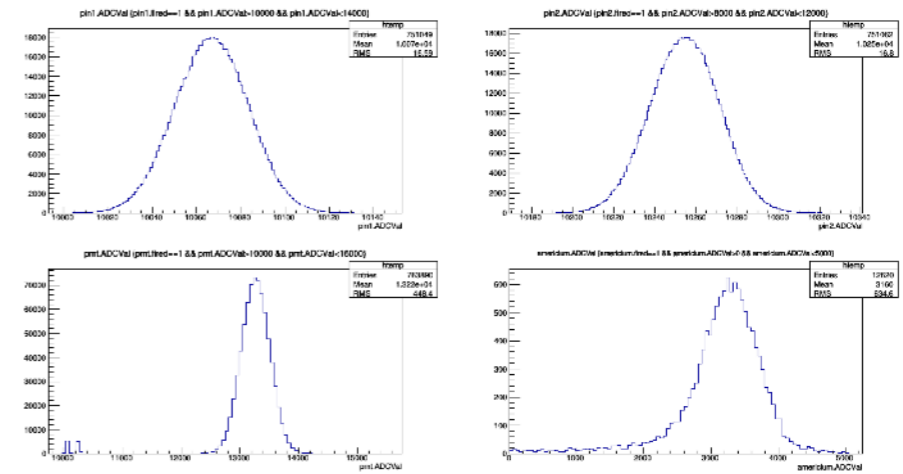
Δ ADCcount (PIN): about few counts/h

	PIN1	PIN2	PMT
T(CSP) °C	27.3 , $\Delta = 0.6$	27.6, $\Delta = 0.6$	27.3, $\Delta = 0.6$
T(Board) °C	31.8 , $\Delta = 0.5$	30.7, $\Delta = 0.4$	32.0, $\Delta = 0.4$
T(Ext) °C	22.5 , $\Delta = 0.5$	22.4 , $\Delta = 0.5$	-----

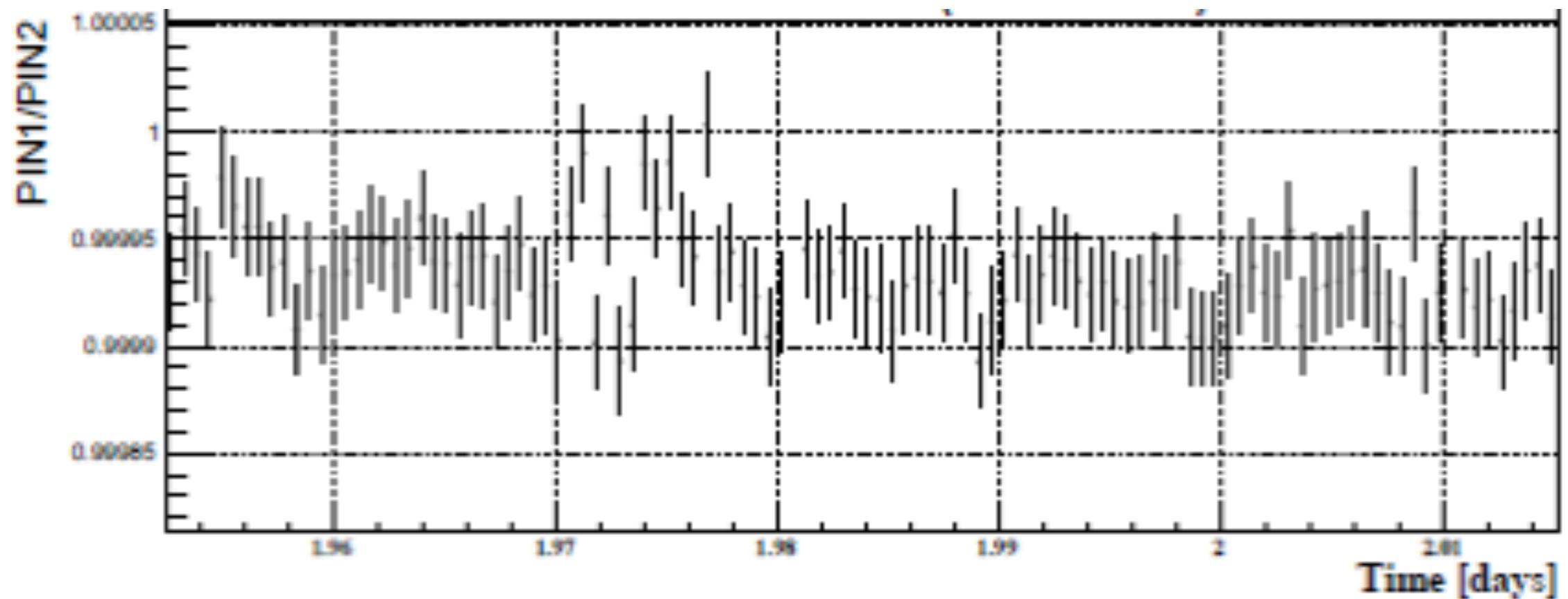
Very good temperature control and homogeneity, although the fan is underpowered (220 V).

* $\Delta = 1$ h excursion

Preliminary analysis for 1 hour run taken on 03/17 (#2)

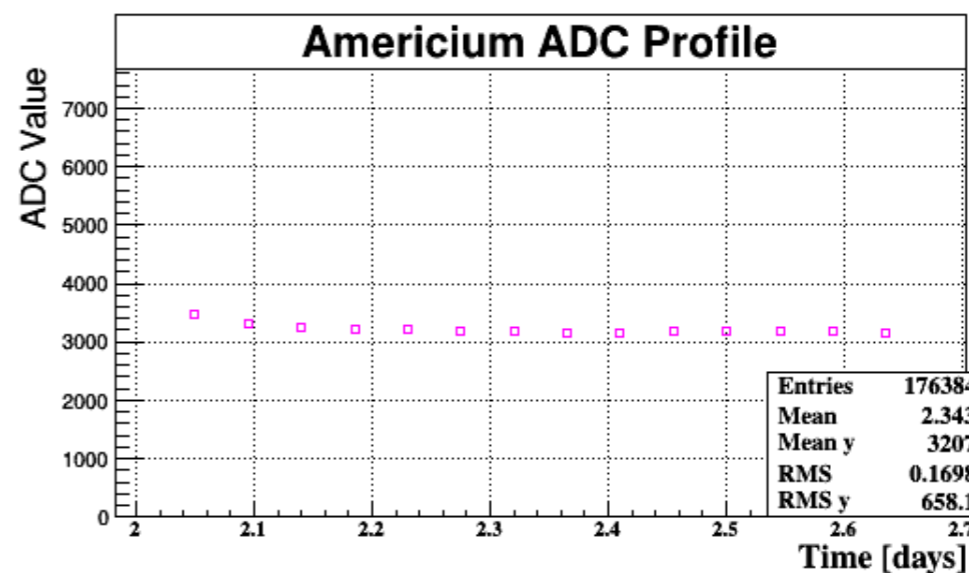
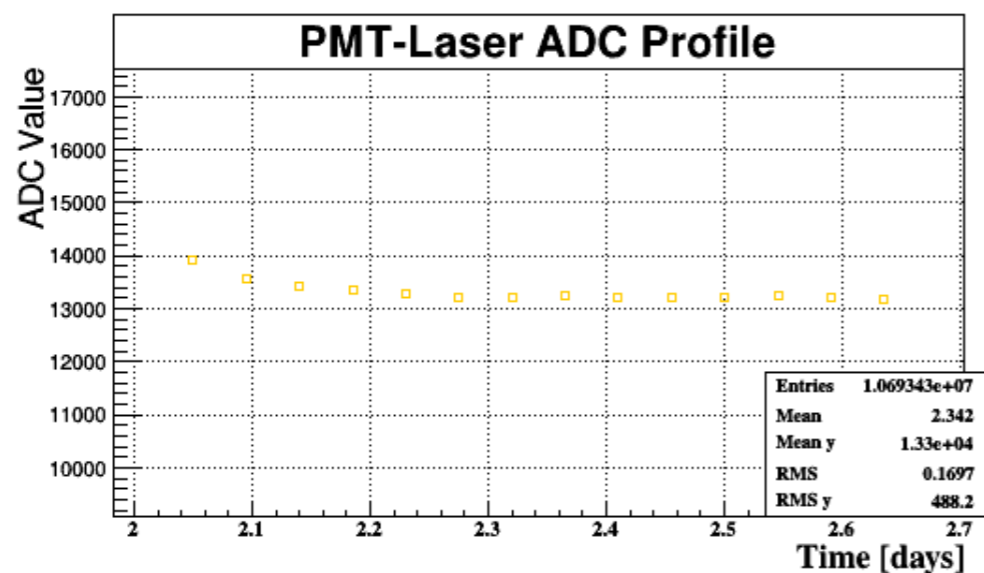
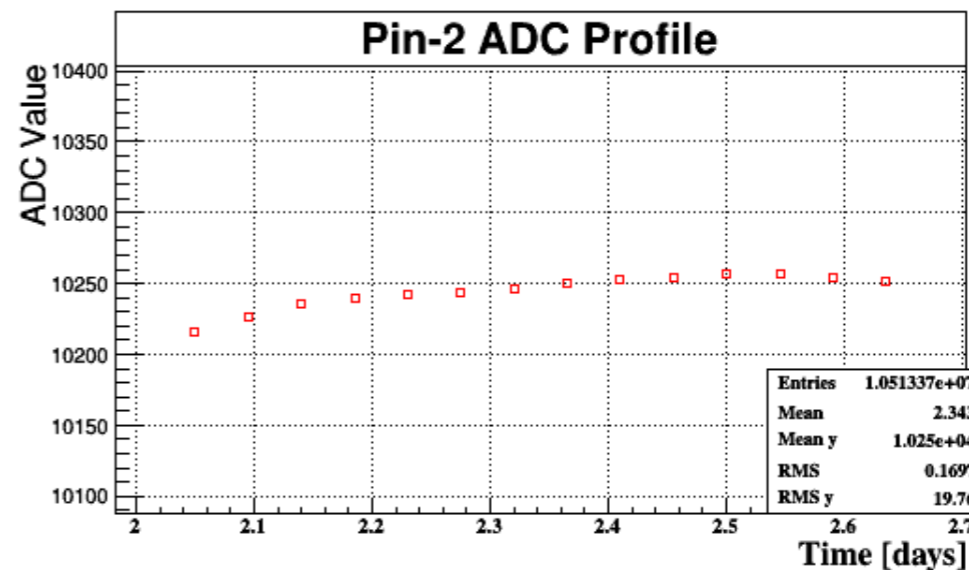
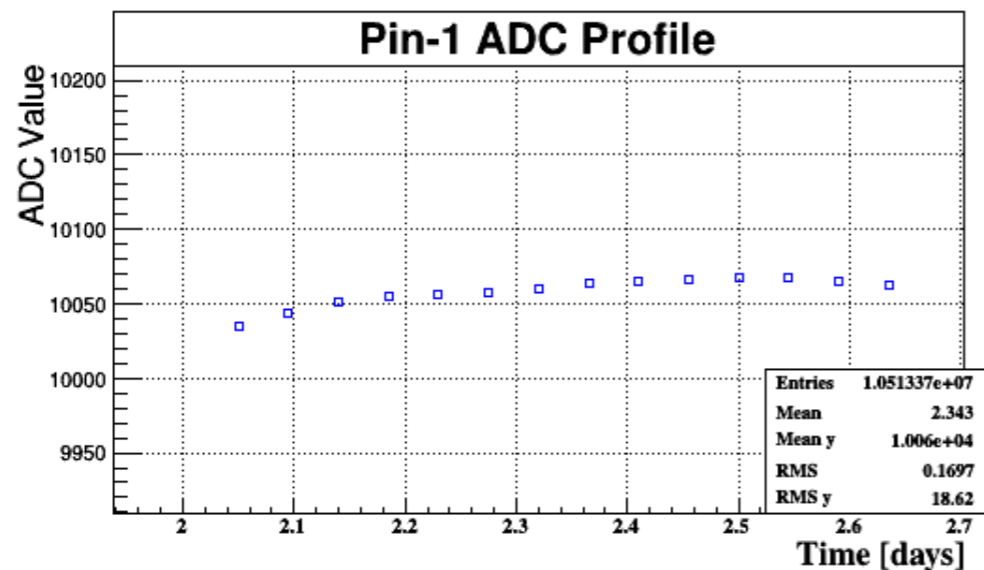


Preliminary analysis for 1 hour run, 03/17 (#2)

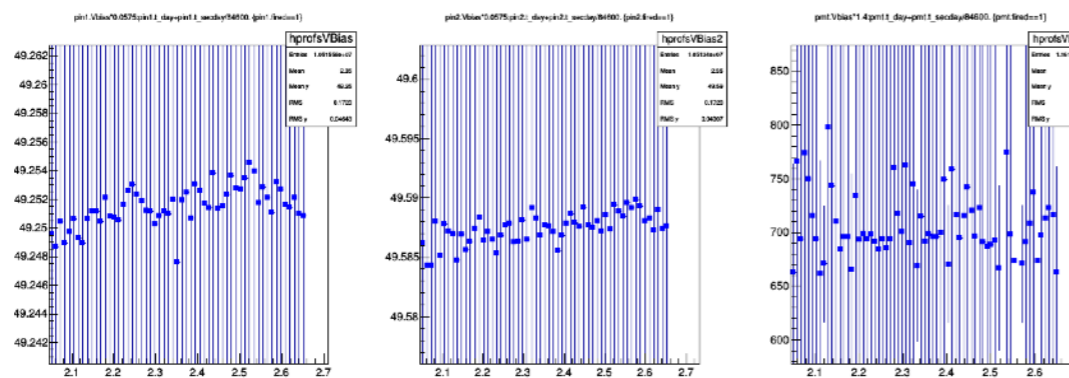


PIN Ratio: $\Delta R < 5 * 10^{-5}$

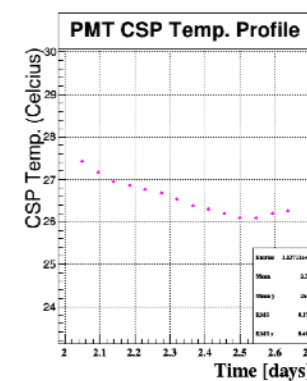
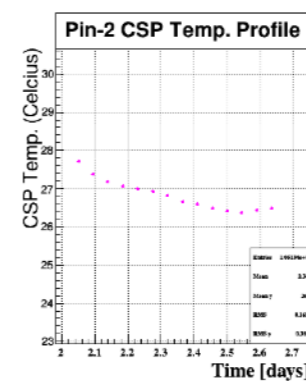
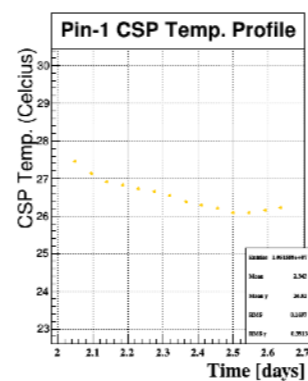
Preliminary analysis for 12 hour run, 03/17 (#4)



Bias Volt.

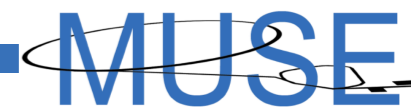


Bias Voltage control: 2×10^{-4}

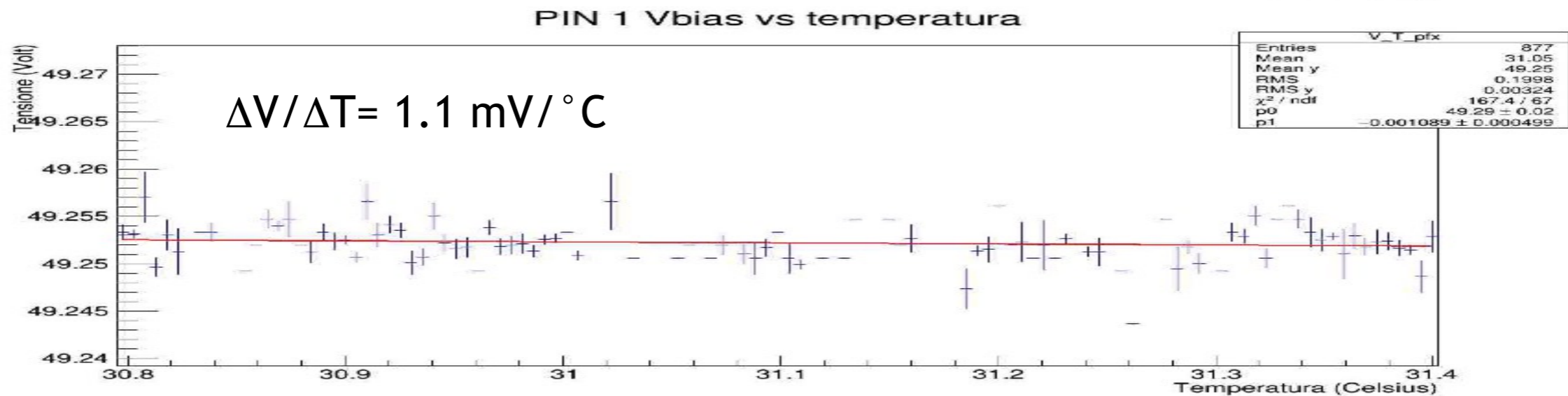
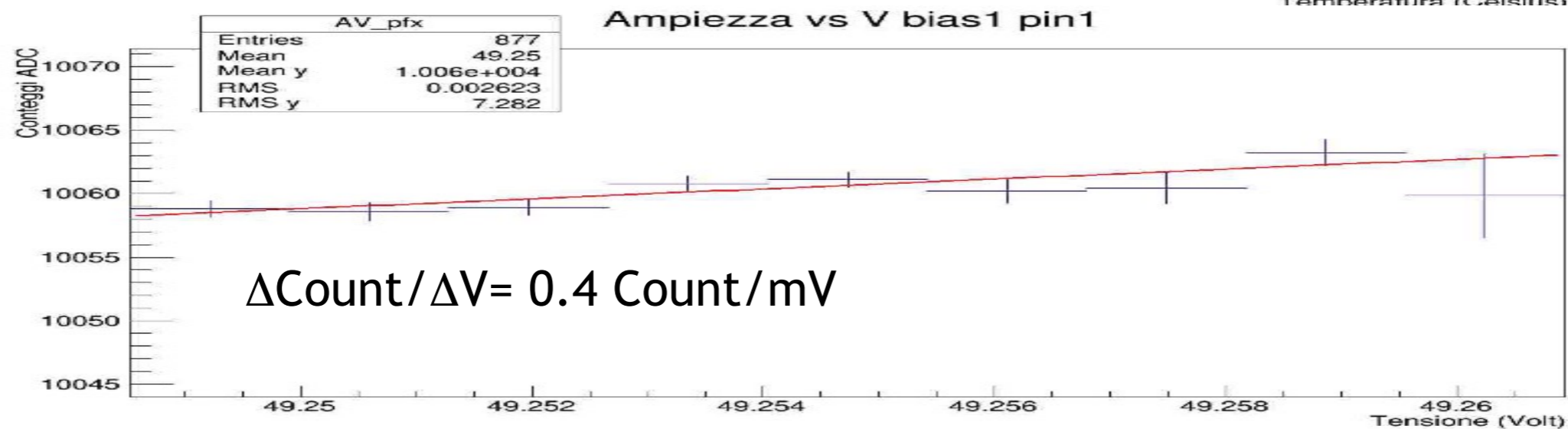
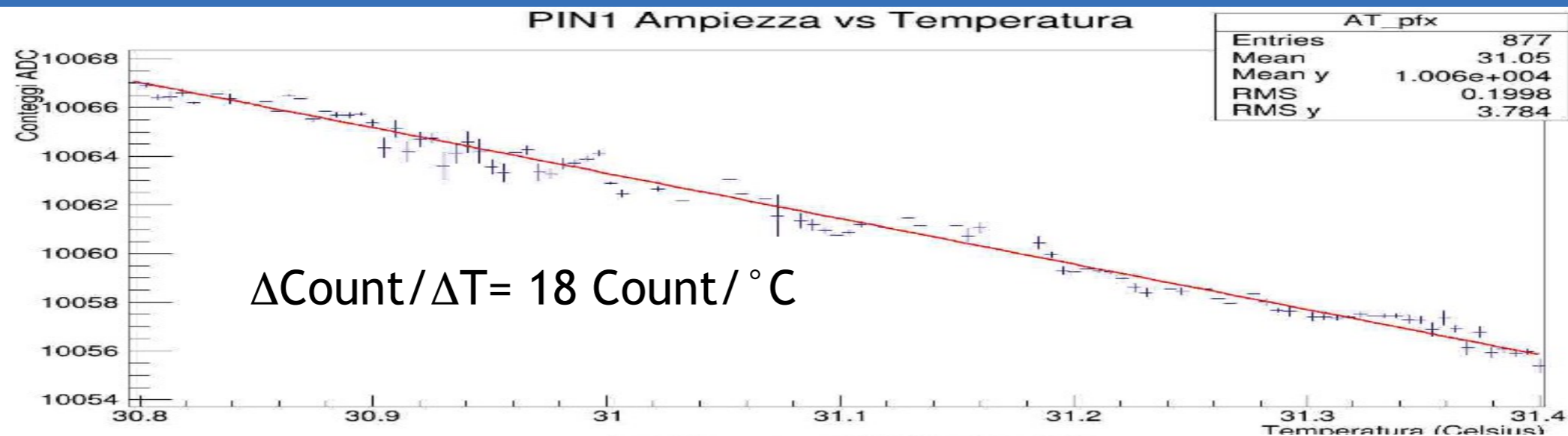


CSP Temp

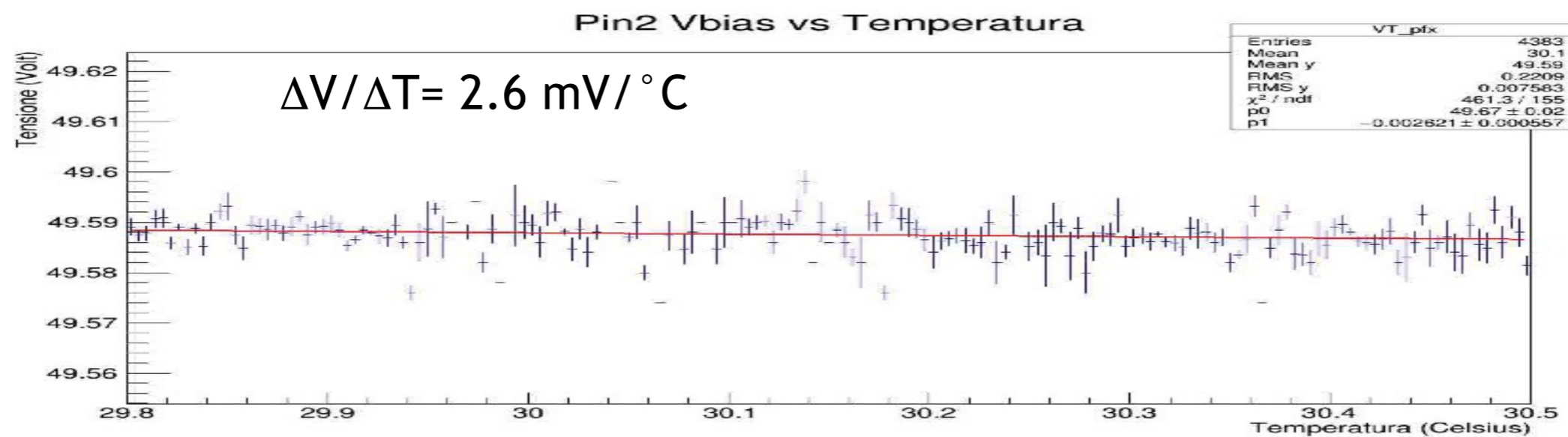
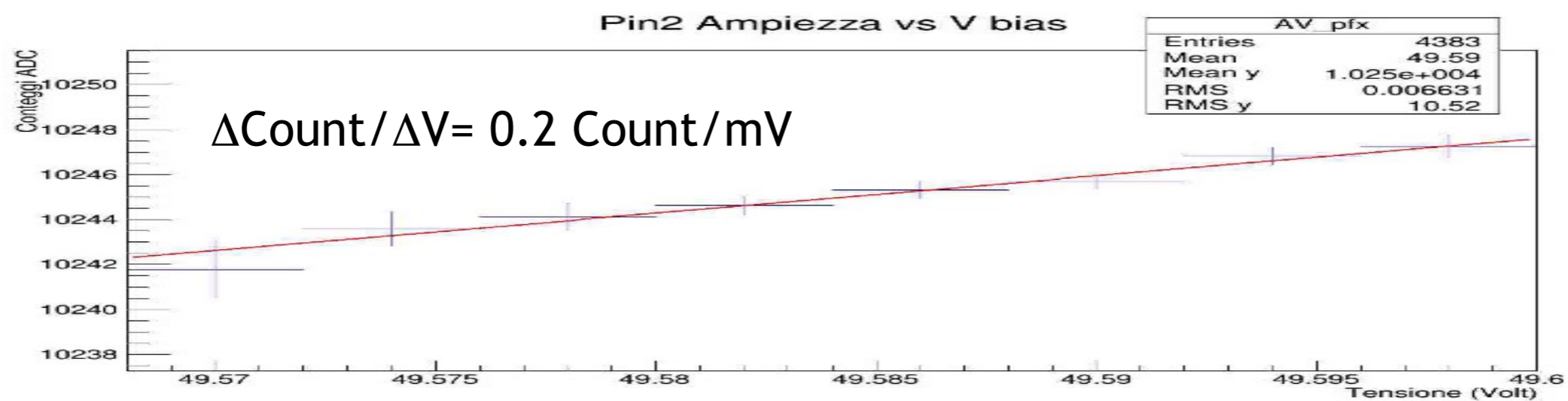
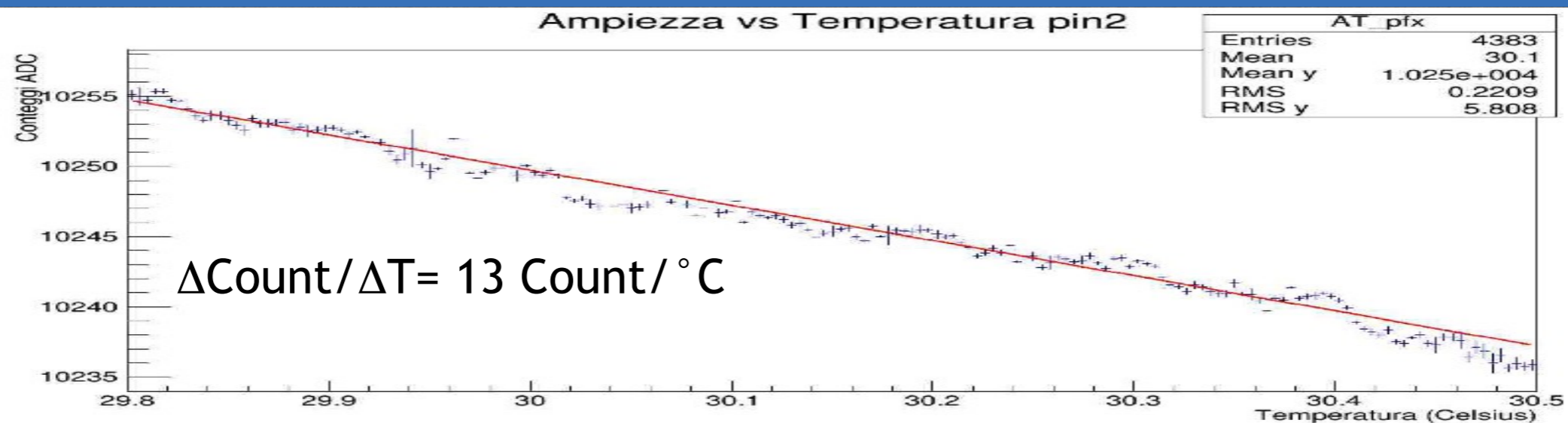
Temp control: $1 \times 10^{-1} \text{ } ^\circ\text{C}$



PIN1 temperature and bias dep. 12 hour, 03/17 (#4)

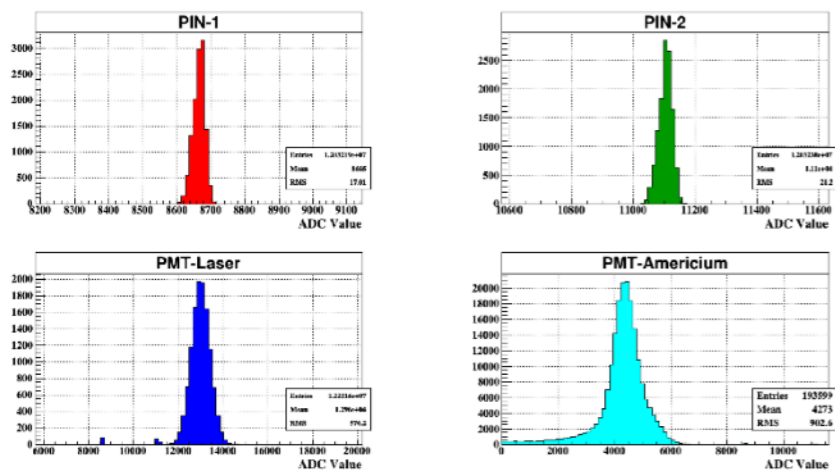


PIN2 temperature and bias dep. 12 hour, 03/17 (#4)

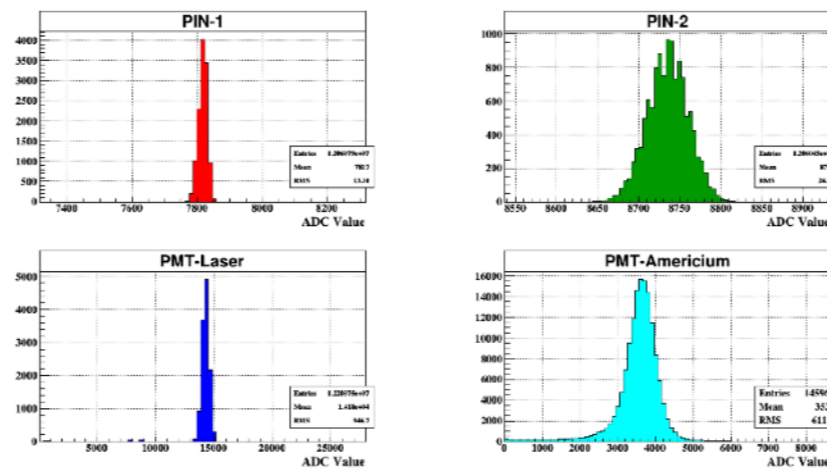


Preliminary analysis for 15 hour, 04/17

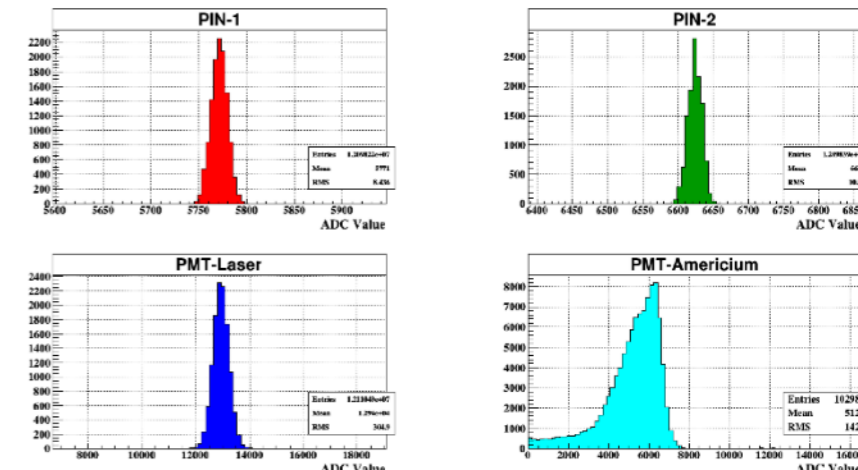
Board # 0001



Board # 0002

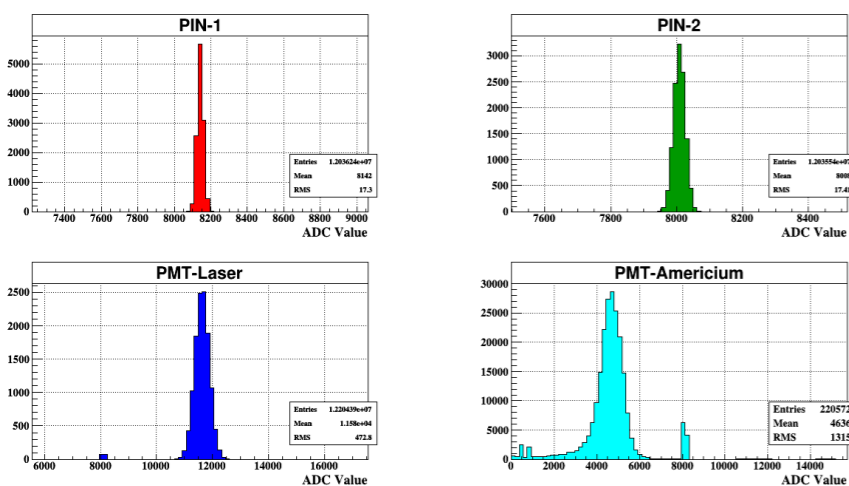


Board # 0003

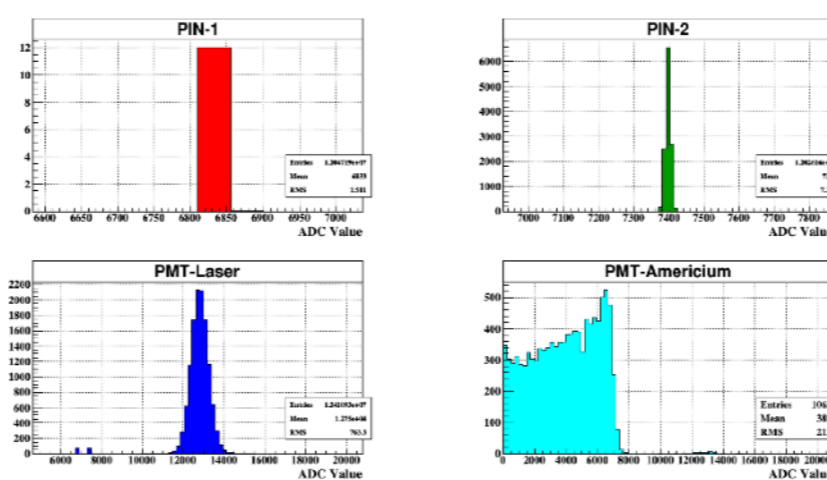


ALL SIX BOARDS

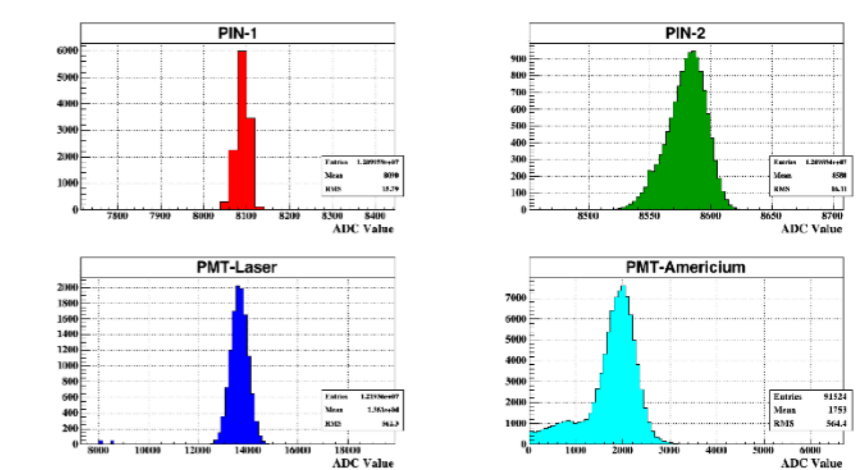
Board # 0004



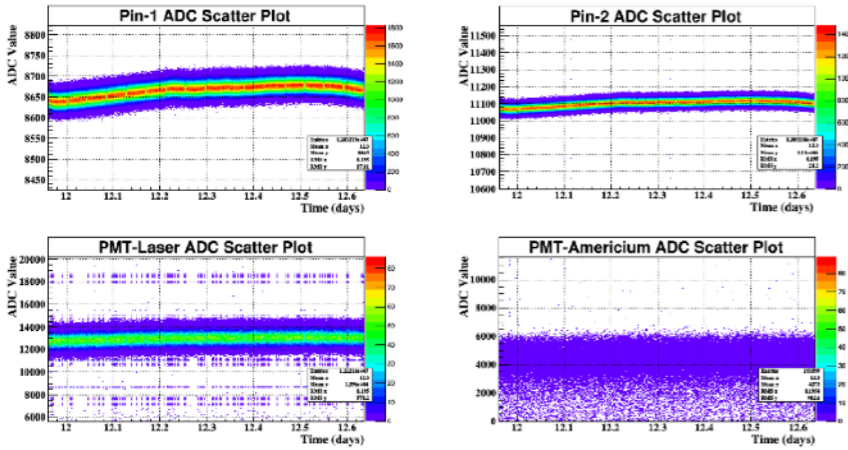
Board # 0005



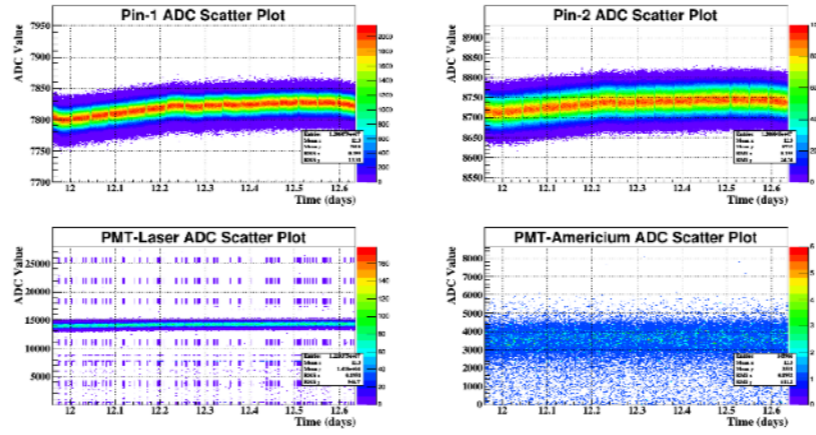
Board # 0006



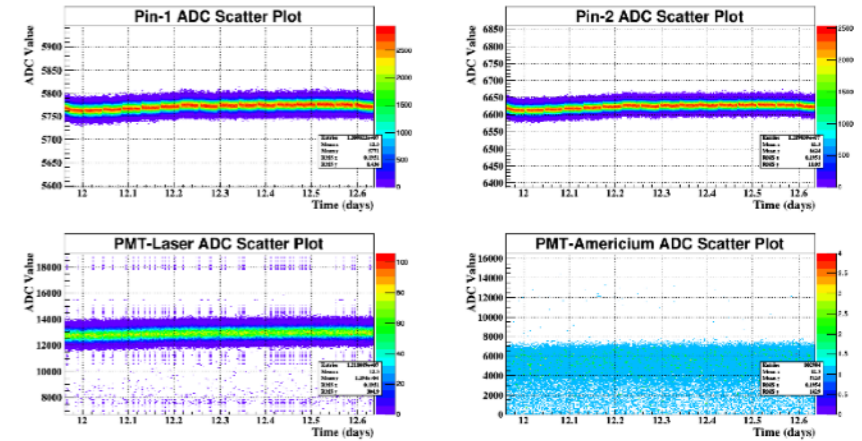
Board # 0001



Board # 0002

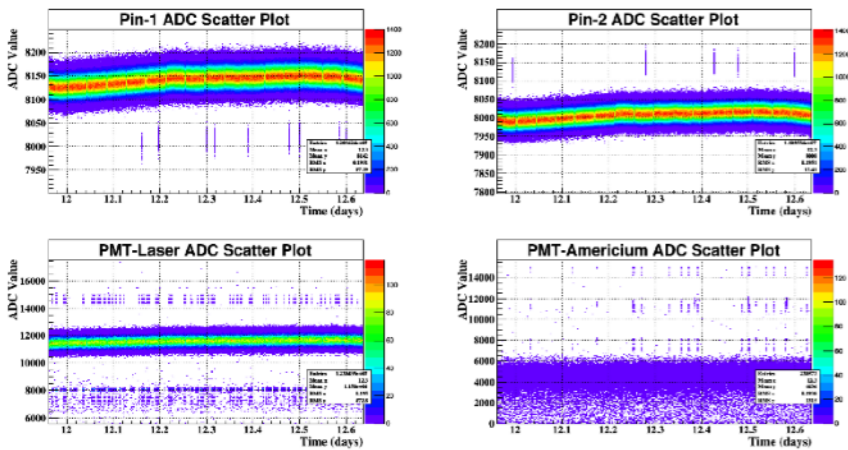


Board # 0003

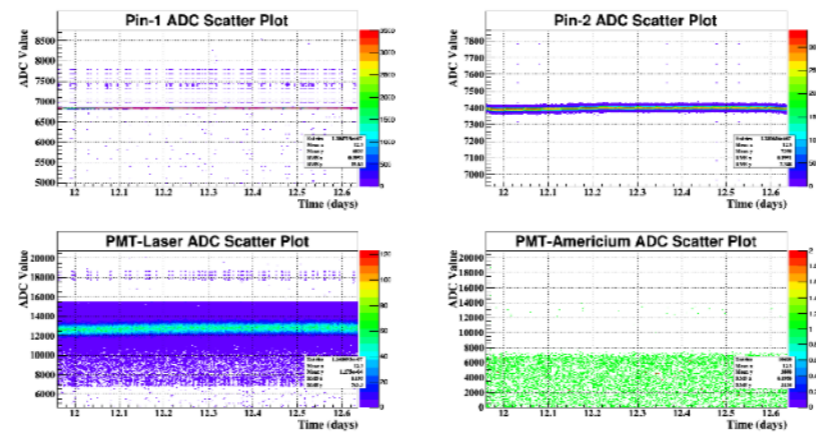


ALL SIX BOARDS

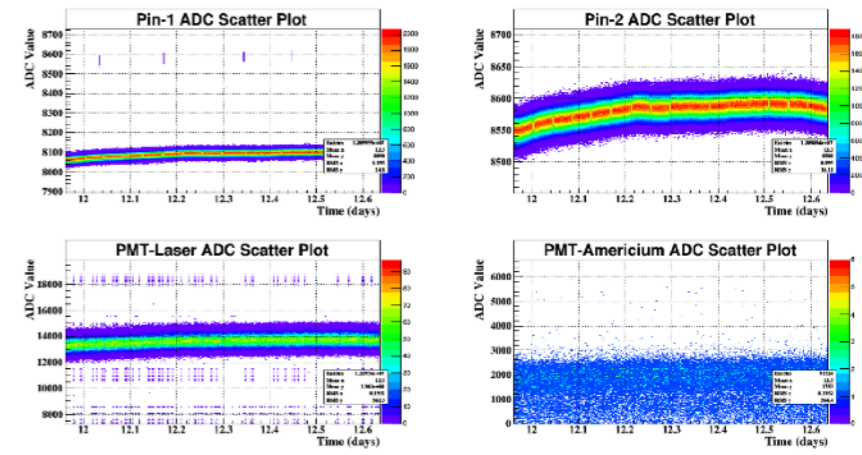
Board # 0004



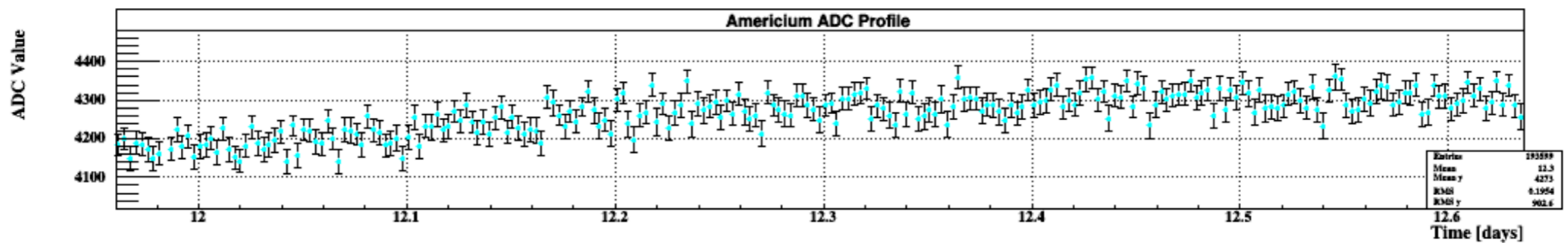
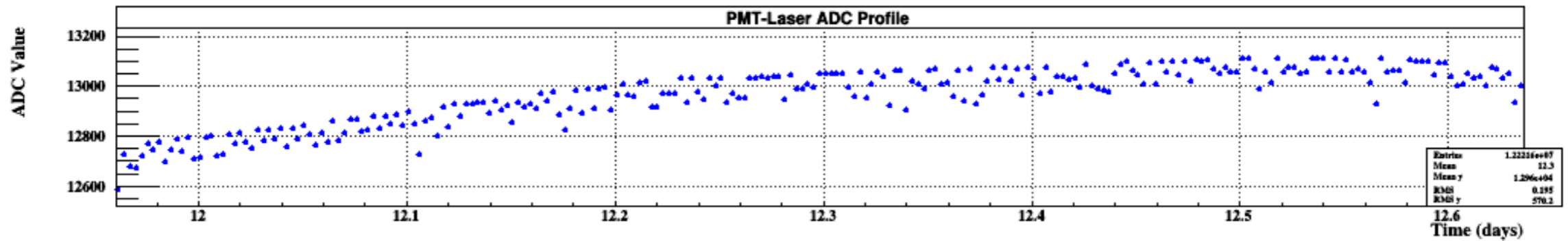
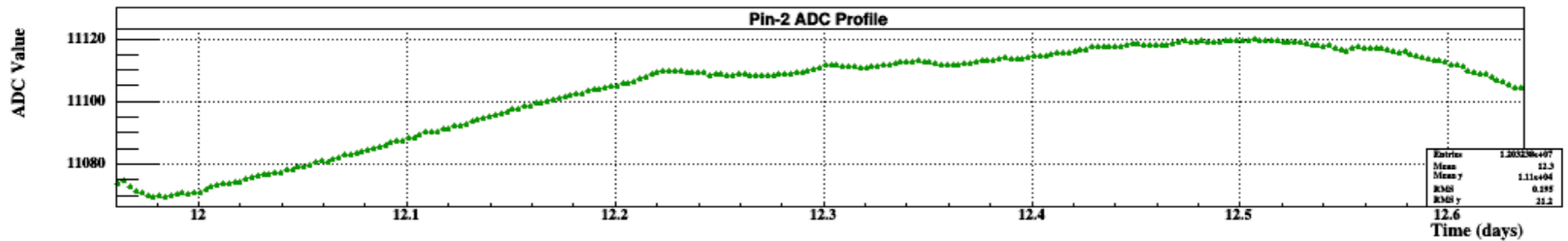
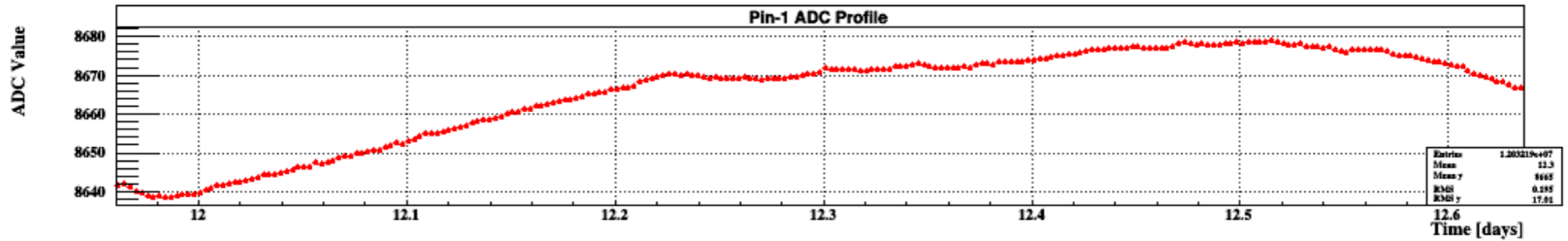
Board # 0005



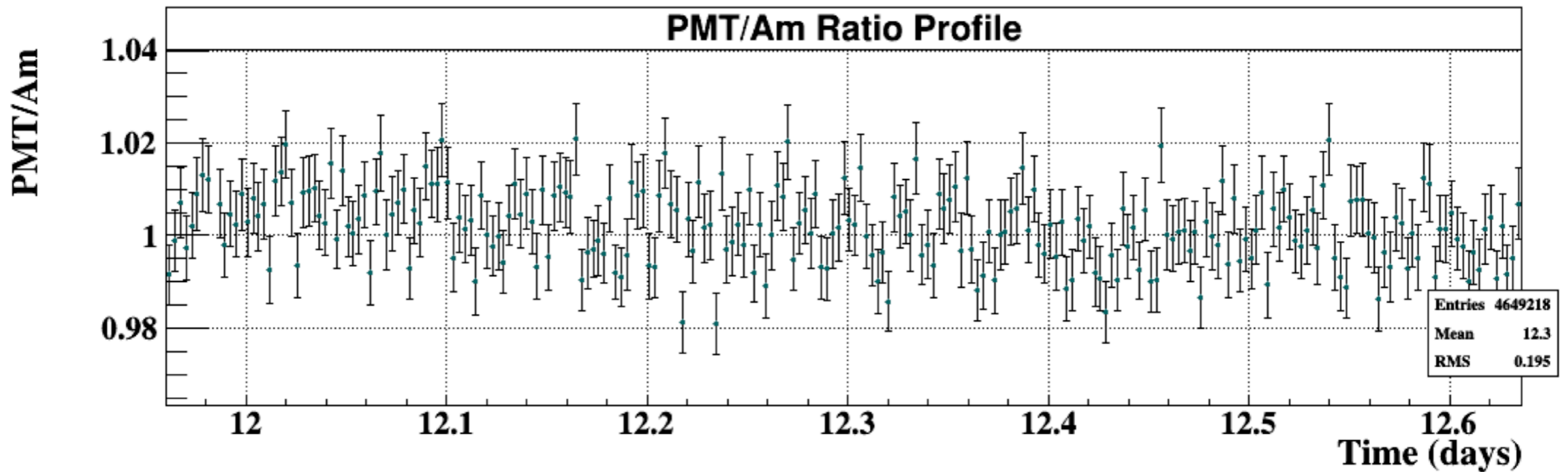
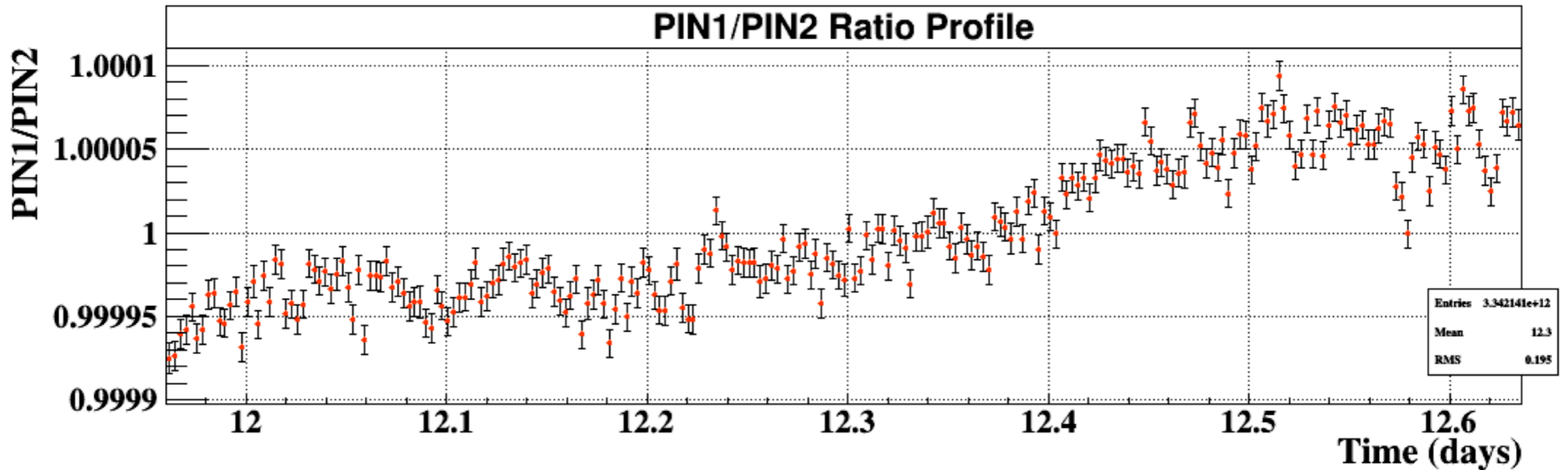
Board # 0006



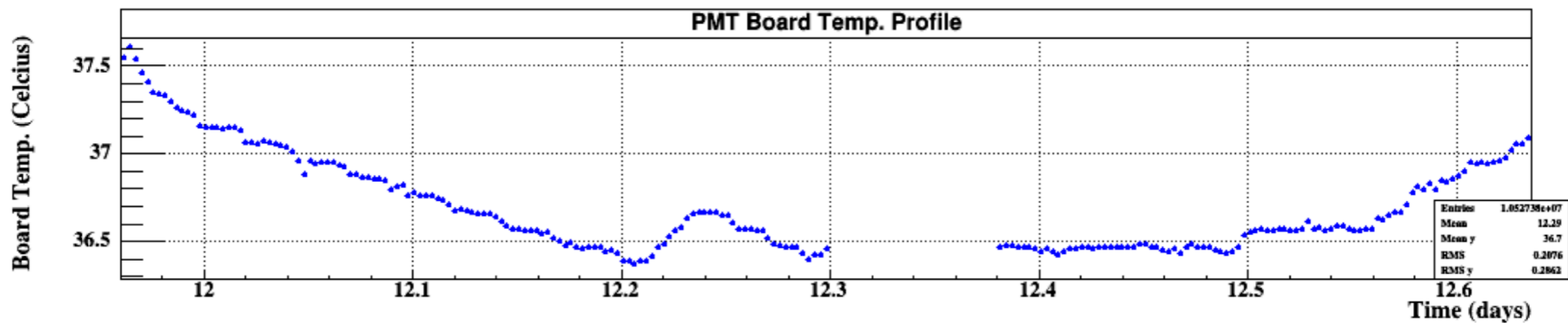
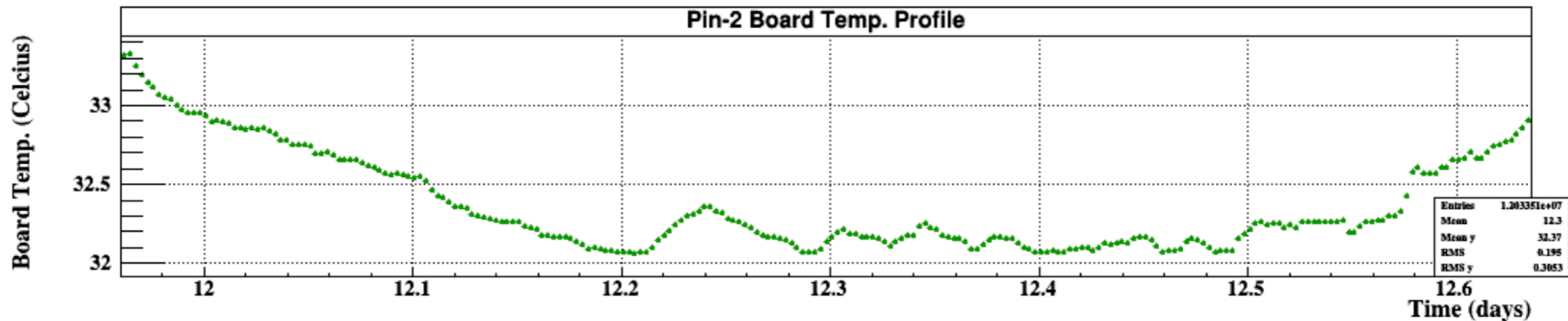
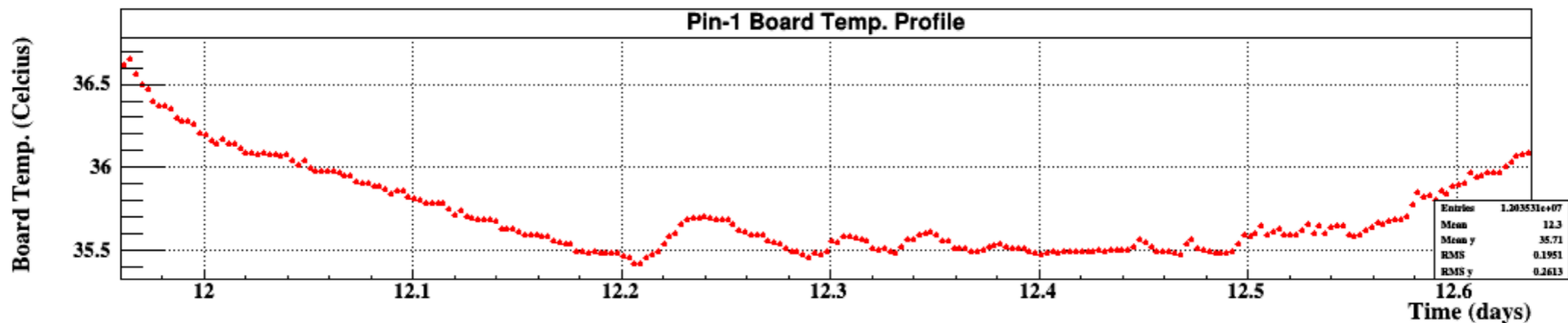
Board # 0001



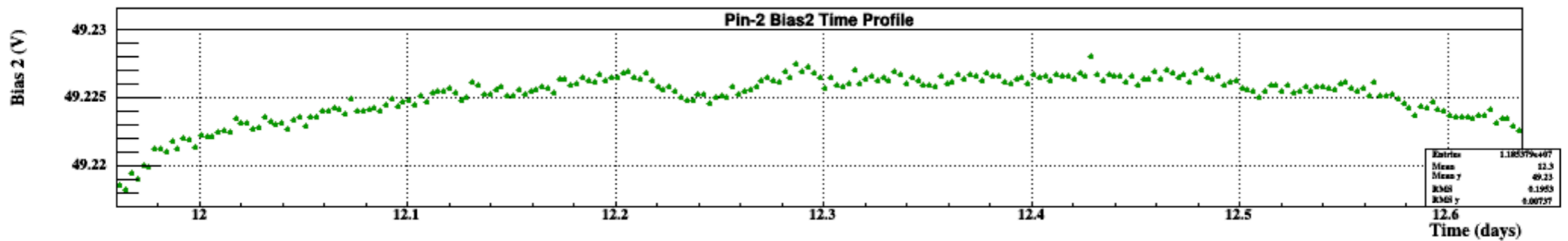
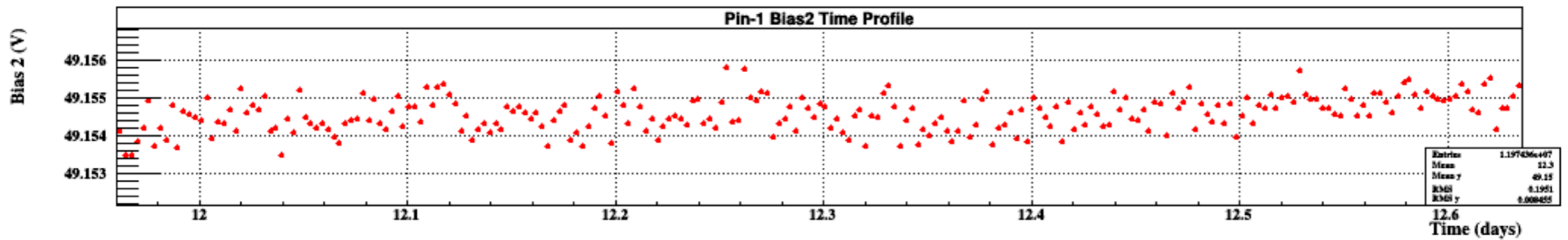
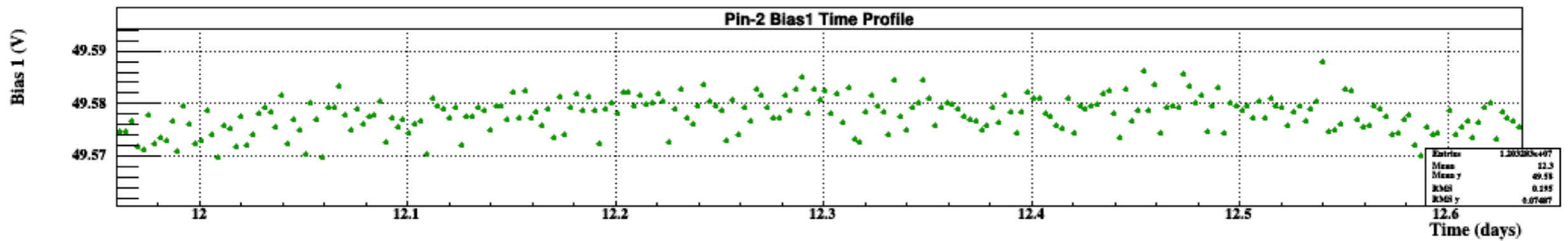
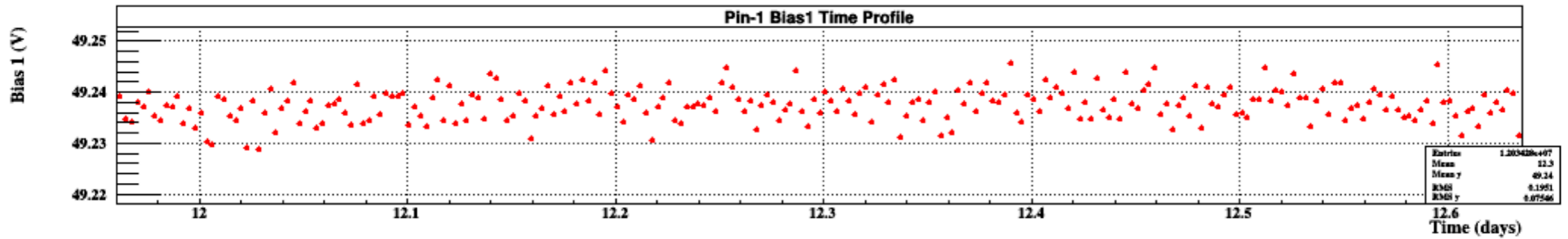
Board # 0001



Board # 0001



Board # 0001



Current Status

1. SM electronics installed and in operation
2. version_0 of Monitoring_DAQ running
3. Laser control (new firmware, operation)
4. Fan-out/Laser synchronization at 100 ps
5. Source Monitor resolution and stability

- a. Bias voltage control at 2×10^{-4}
- b. Temperature better than $0.1 \text{ }^\circ\text{C}$

Fundamental in containing error within 10^{-4}

Monitoring

- Takes **single data frame** (BOF) from MB data output and prints on screen via SSH
- Image on right is for a **single board**, but all boards can be displayed
- **Warnings** implanted for potential failures (high board temperature, no signal, abnormal value, etc.)
- Single frame is **~5kB** in size
- Monitoring script will be made available to anyone interested

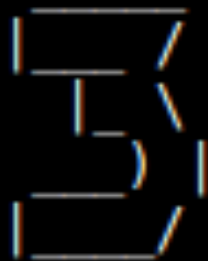
```
#####  
#  
# REALTIME DISPLAY OF NAPLES GMINUS 2 LAB DATA ACQUISITION #  
#  
#####  
  
FILE NAME: US0P02Run54_20170313175306.000  
TIME: Mon Mar 13 20:04:16 2017  
BOARD ADDR: 000a  
CTRL WORD: 0701  
N. PULSES: (185 - 25)/5 = 32  
ACTIVE CH: ALL 4 CHANNELS ARE ACTIVE  
NBOF: 2818  
  
*****  
BOARD TEMP [CELCIUS] CSP TEMP [CELCIUS]  
*****  
PIN-2: 48.6810 PIN-2: 29.6700  
PIN-1: 47.5085 PIN-1: 29.2360  
PMT : 43.5027 PMT : 28.9880  
  
*****  
BIAS VOLTAGE [ VOLTS ] CURRENT [NANO AMPS]  
*****  
PIN-2: 49.2775 PIN-2: EMPTY !  
PIN-1: 48.9325 PIN-1: EMPTY !  
PMT : 0.6524 PMT : EMPTY !  
  
*****  
AMPLITUDE BASELINE  
*****  
PIN-2: 10101 PIN-2: 919  
PIN-1: 12435 PIN-1: 920  
PMT : 8600 PMT : 865  
AMER : 1813 AMER : 864  
  
*****
```

NAPLES DAQ MONITORING

The display refreshes roughly every B0F (~ 2 s).

UNITS : Temperatures in °C, Bias Voltages (I, II) in Volts.

Monitoring will start in :



1. `ssh *user@naples.matrix*`
2. `ssh *lab@naples-lab*`
3. **monitor**

Monitoring — @Naples

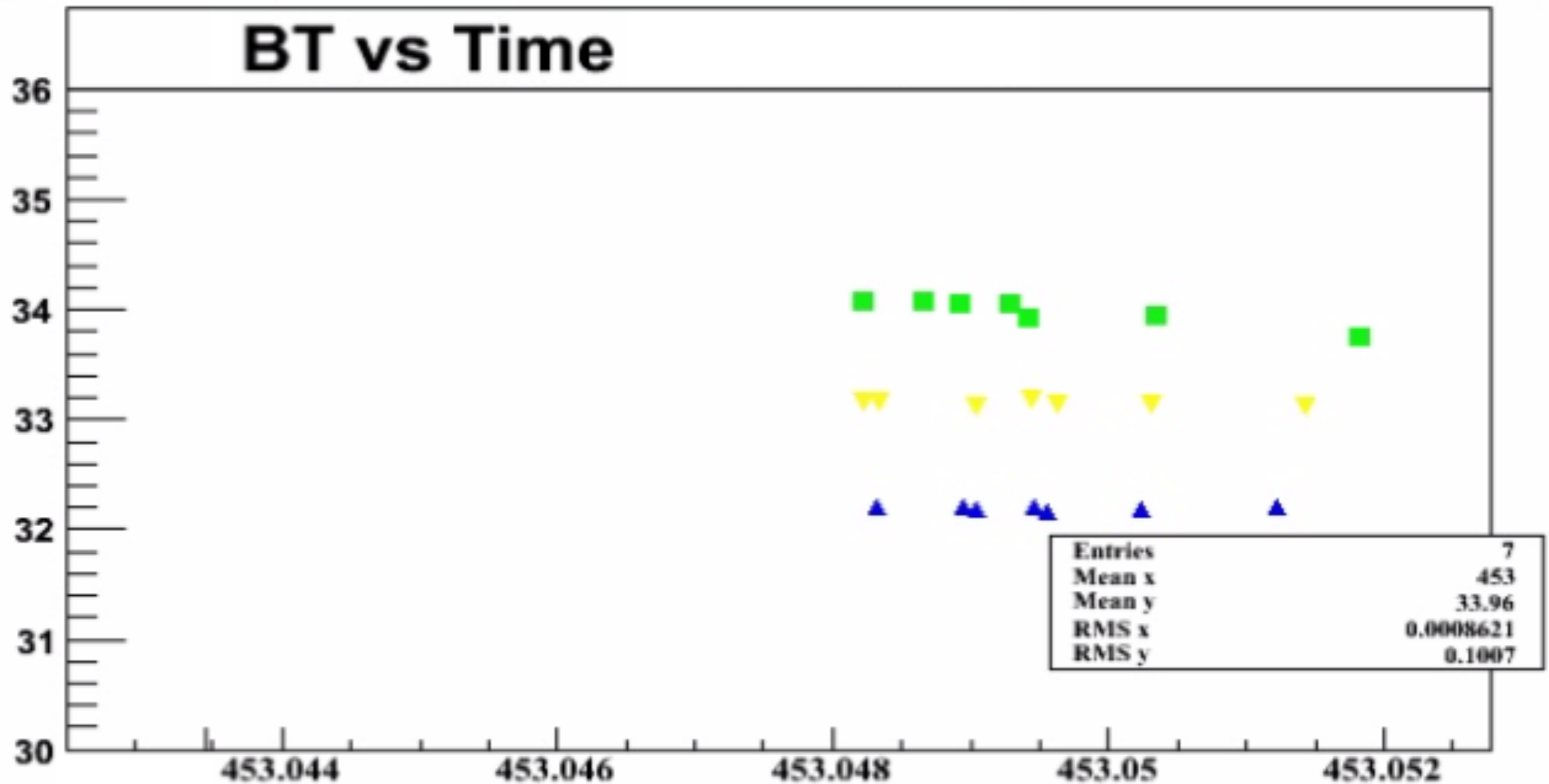
```

NAPLES DAQ MONITORING
*****
          BOARD ADDR : 0001          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     30.352     0.000     0.654     ---     7756     875 |
|AMER :      ---      ---      ---      ---      ---     1975     874 |
|PIN-1:      36.273     29.918     0.000     48.990     0.000    12233     929 |
|PIN-2:      33.537     29.794     0.000     49.278     0.000     9883     926 |
|-----|-----|-----|-----|-----|-----|-----|-----|
*****
          BOARD ADDR : 0002          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     29.298     0.000     0.654     ---     7893     874 |
|AMER :      ---      ---      ---      ---      ---     2077     875 |
|PIN-1:      36.175     29.422     0.000     48.990     0.000    12225     928 |
|PIN-2:      33.830     29.670     0.000     49.278     0.054     9881     926 |
|-----|-----|-----|-----|-----|-----|-----|-----|
*****
          BOARD ADDR : 0003          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     29.608     0.000     0.654     ---     7840     875 |
|AMER :      ---      ---      ---      ---      ---     1869     874 |
|PIN-1:      36.273     29.732     0.000     48.990     0.000    12226     927 |
|PIN-2:      33.830     29.856     0.000     49.278     0.100     9884     925 |
|-----|-----|-----|-----|-----|-----|-----|-----|
Press Ctrl + C to quit.

```



REAL-TIME DISPLAY



Monitoring — @Fermilab

```
FERMILAB DAG MONITORING
FERMILAB DAG MONITORING
*****
          BOARD ADDR : 0001          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     30.352     0.000     0.654     ---     7756     875 |
|-----|-----|-----|-----|-----|-----|
|AMER :      ---      ---      ---      ---      ---     1975     874 |
|-----|-----|-----|-----|-----|-----|
|PIN-1:     36.273     29.918     0.000     48.990     0.000    12233     929 |
|-----|-----|-----|-----|-----|-----|
|PIN-2:     33.537     29.794     0.000     49.278     0.000     9883     926 |
|-----|-----|-----|-----|-----|-----|
*****
          BOARD ADDR : 0002          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     29.298     0.000     0.654     ---     7893     874 |
|-----|-----|-----|-----|-----|-----|
|AMER :      ---      ---      ---      ---      ---     2077     875 |
|-----|-----|-----|-----|-----|-----|
|PIN-1:     36.175     29.422     0.000     48.990     0.000    12225     928 |
|-----|-----|-----|-----|-----|-----|
|PIN-2:     33.830     29.670     0.000     49.278     0.054     9881     926 |
|-----|-----|-----|-----|-----|-----|
*****
          BOARD ADDR : 0003          NBOF : 8053          TIME : Sun Mar 19 23:59:42 2017
*****
|CH.\ QNT.  BOARD TEMP  CSP TEMP  EXT TEMP  BIAS-I  BIAS-II  AMPLITUDE  BASELINE |
|-----|-----|-----|-----|-----|-----|-----|
|PMT :      33.732     29.608     0.000     0.654     ---     7840     875 |
|-----|-----|-----|-----|-----|-----|
|AMER :      ---      ---      ---      ---      ---     1869     874 |
|-----|-----|-----|-----|-----|-----|
|PIN-1:     36.273     29.732     0.000     48.990     0.000    12226     927 |
|-----|-----|-----|-----|-----|-----|
|PIN-2:     33.830     29.856     0.000     49.278     0.108     9884     925 |
|-----|-----|-----|-----|-----|-----|
*****
Press Ctrl + C to quit.
```

Ongoing work — Long term display

NAPLES DAQ MONITORING

```
*****
BOARD ADDR : 000a      NBOF : 8053      TIME : Sun Mar 19 23:59:42 2017
*****
```

CH.\ QNT.	BOARD TEMP	CSP TEMP	EXT TEMP	BIAS VOL	CURRENT	AMPLITUDE	BASELINE
PMT :	33.244	28.120	0.000	0.654	0.000	8379	869
AMER :	---	---	---	---	---	2067	868
PIN-1:	34.025	28.058	0.000	49.047	0.000	12309	927
PIN-2:	32.267	28.678	0.000	49.278	58.500	9972	930

```
*****
BOARD ADDR : 000a      NBOF : 8053      TIME : Sun Mar 19 23:59:42 2017
*****
```

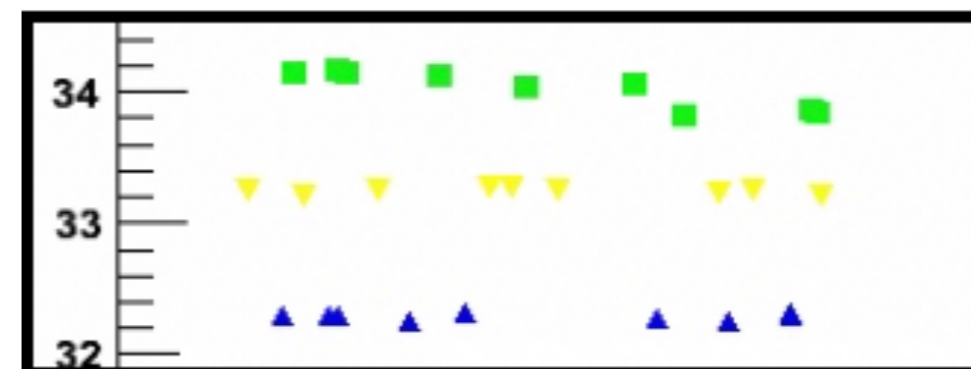
CH.\ QNT.	BOARD TEMP	CSP TEMP	EXT TEMP	BIAS VOL	CURRENT	AMPLITUDE	BASELINE
PMT :	33.244	28.120	0.000	0.654	0.000	8379	869
AMER :	---	---	---	---	---	2067	868
PIN-1:	34.025	28.058	0.000	49.047	0.000	12309	927
PIN-2:	32.267	28.678	0.000	49.278	58.500	9972	930

```
*****
BOARD ADDR : 000a      NBOF : 8053      TIME : Sun Mar 19 23:59:42 2017
*****
```

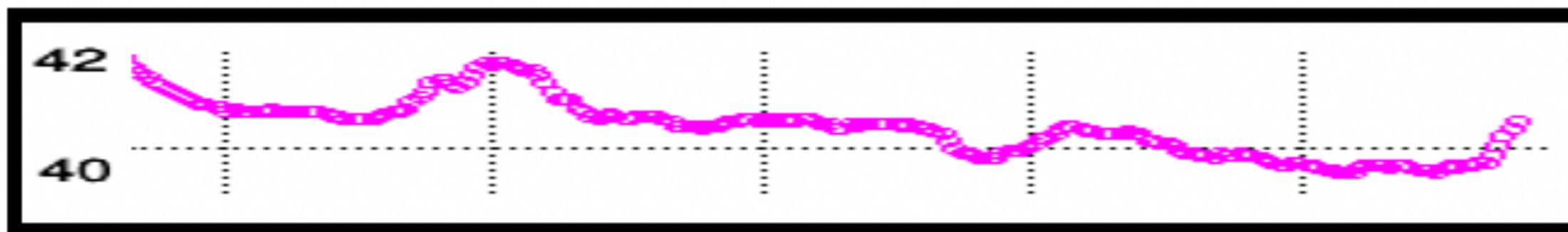
CH.\ QNT.	BOARD TEMP	CSP TEMP	EXT TEMP	BIAS VOL	CURRENT	AMPLITUDE	BASELINE
PMT :	33.244	28.120	0.000	0.654	0.000	8379	869
AMER :	---	---	---	---	---	2067	868
PIN-1:	34.025	28.058	0.000	49.047	0.000	12309	927
PIN-2:	32.267	28.678	0.000	49.278	58.500	9972	930

Press Ctrl + C to quit.

Short term display

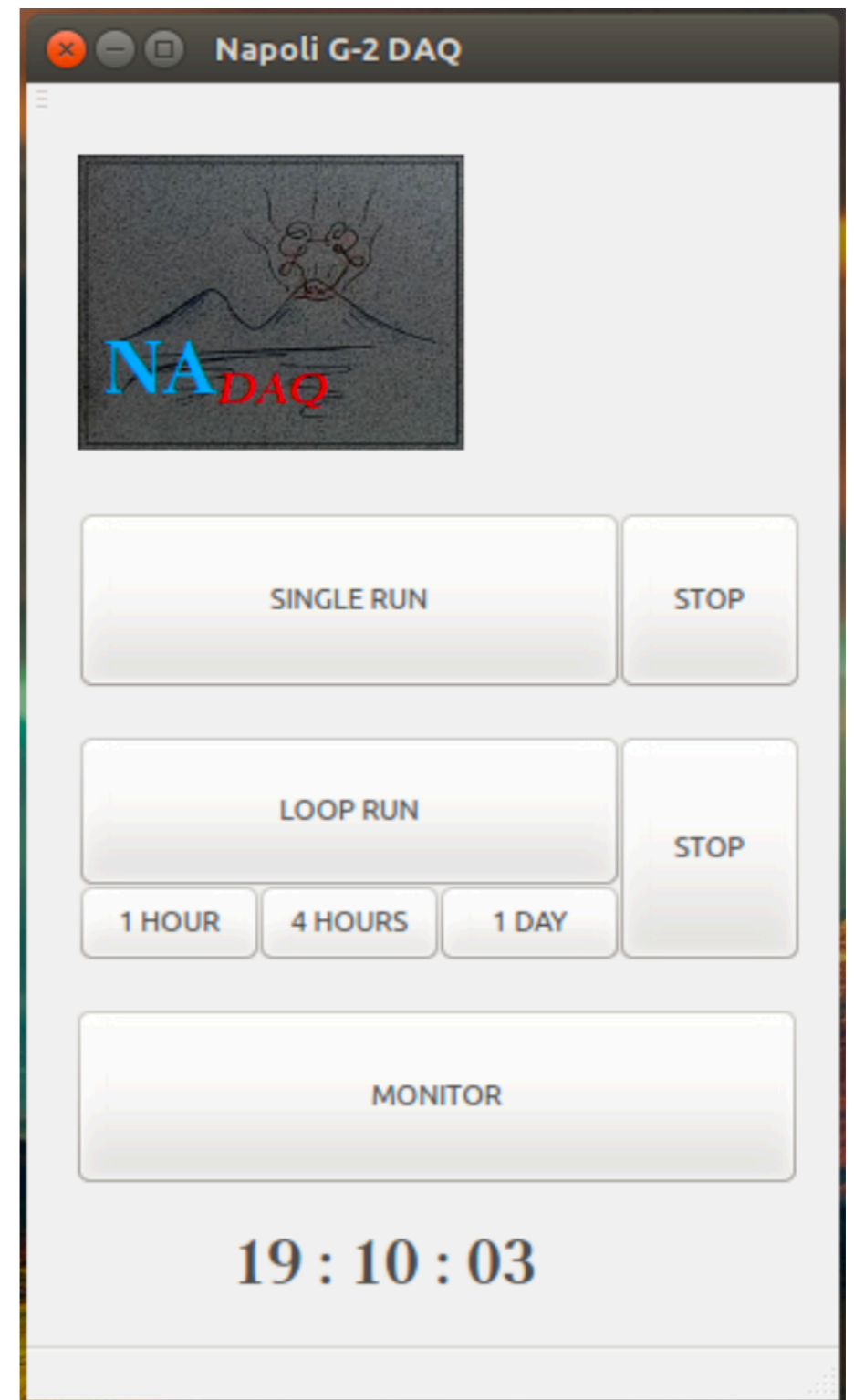


Long term display



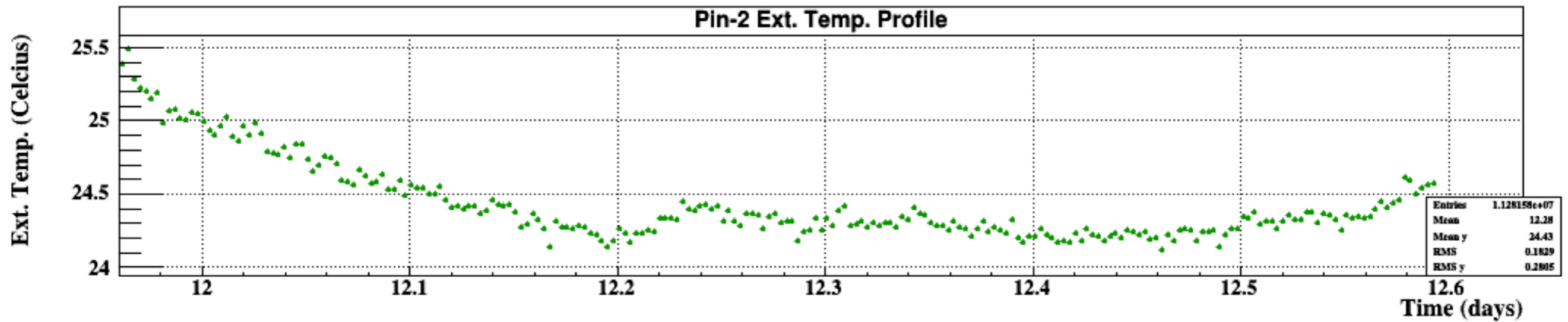
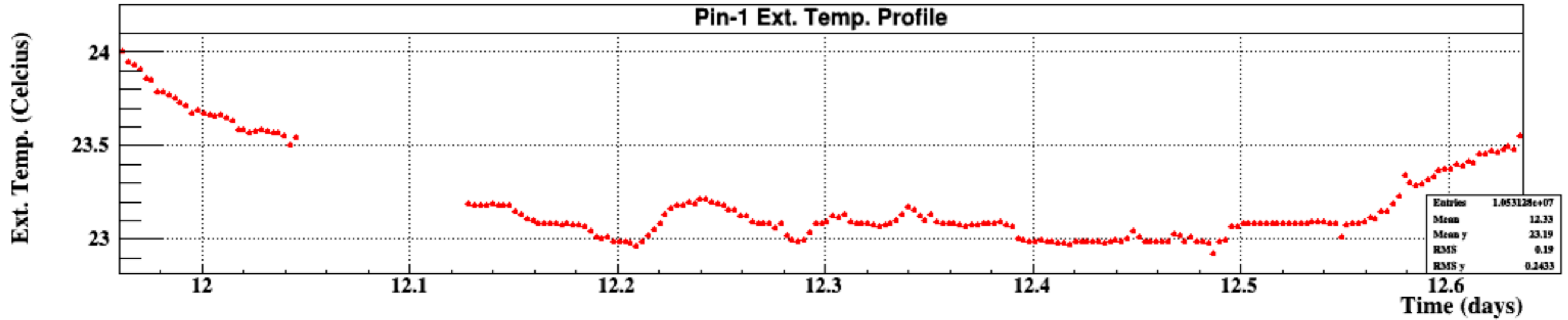
Ongoing work — GUI

- Working on developing a simple and single User interface that will include;
 - Various Settings (SMB and LCB)
 - DAQ (test, calibration, normal)
- Two versions in development
 - **HTML based** version that also communicate with LCB to modify the laser settings
 - **Qt-C++** version with fundamental DAQ operations (image on right)

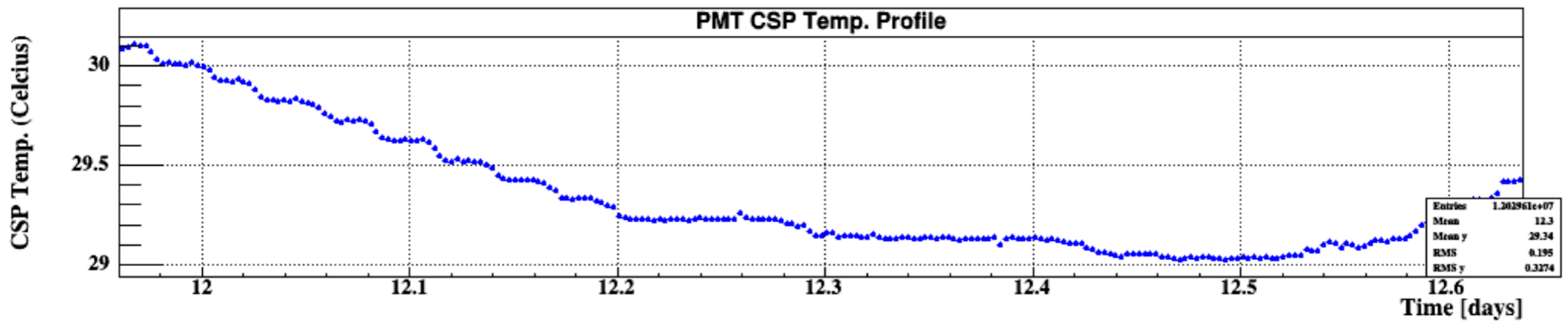
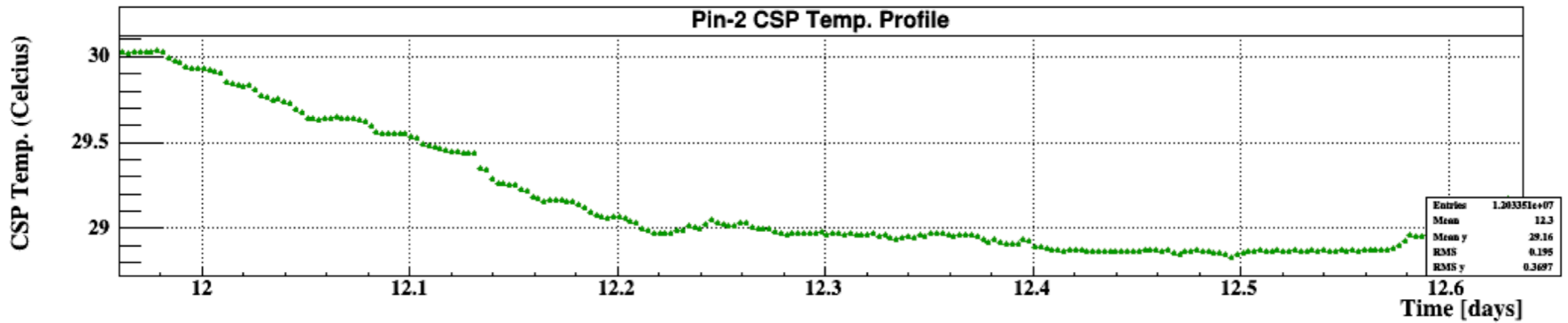
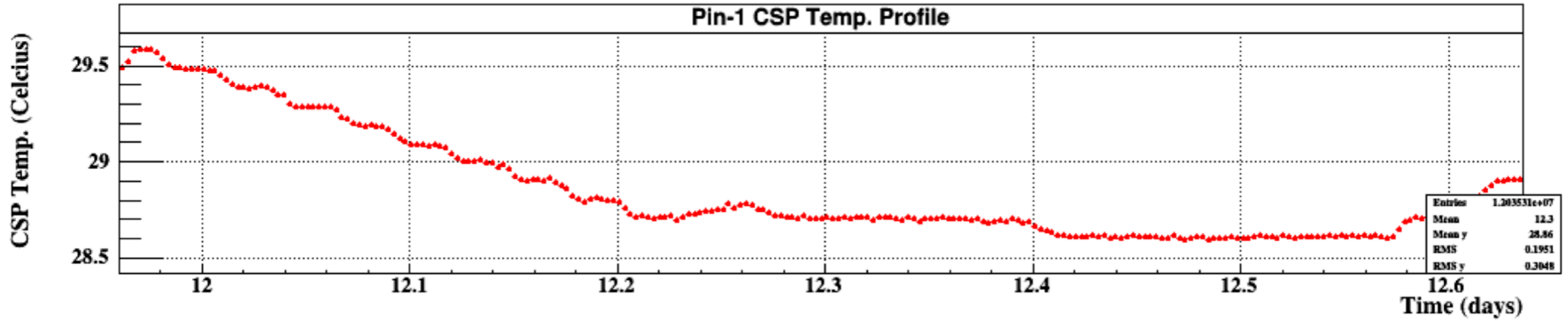


BACKUP

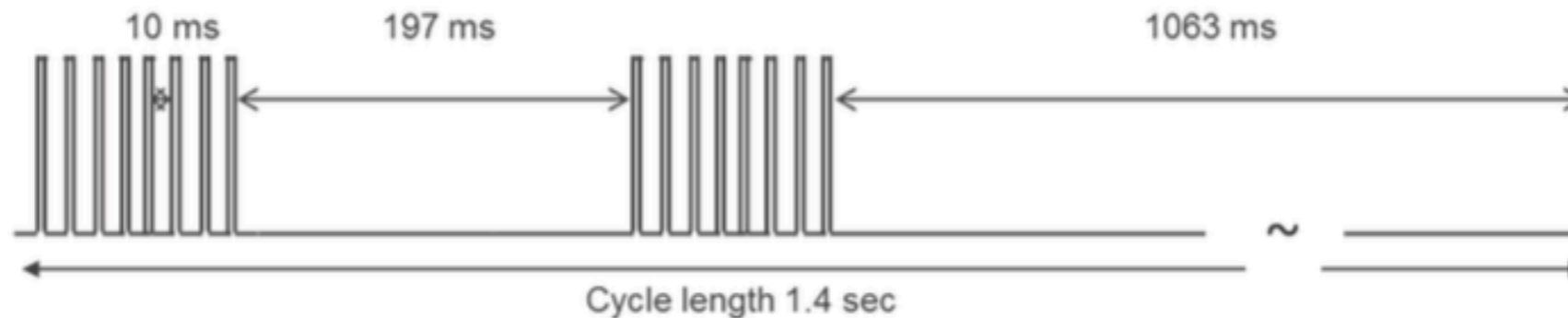
Board # 0001



Board # 0001



Accelerator cycle @ FNAL



3 different time gaps between Fill windows

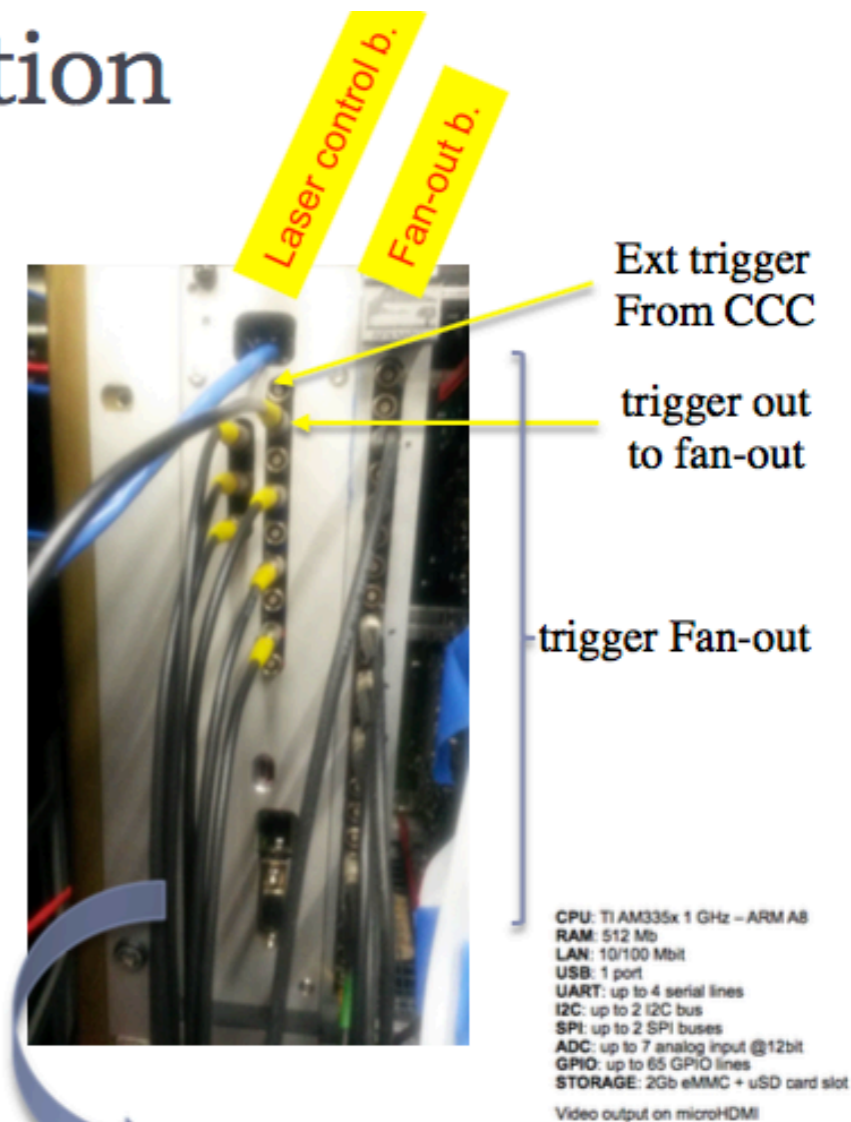
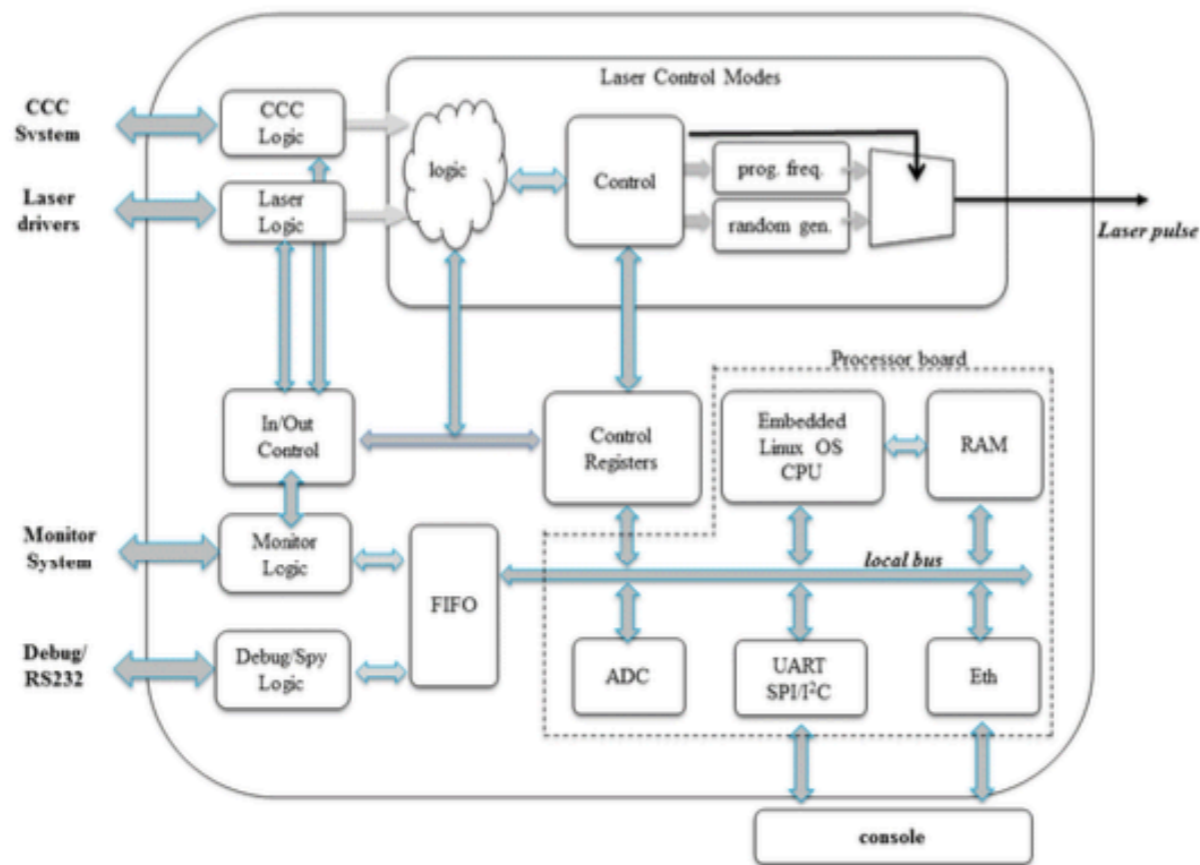
- 10 ms
- ~200 ms
- ~1000 ms

BOS pulse from CCC used to codify four different in-fill/inter-fill programs



New firmware/software update to manage the new interface with CCC system

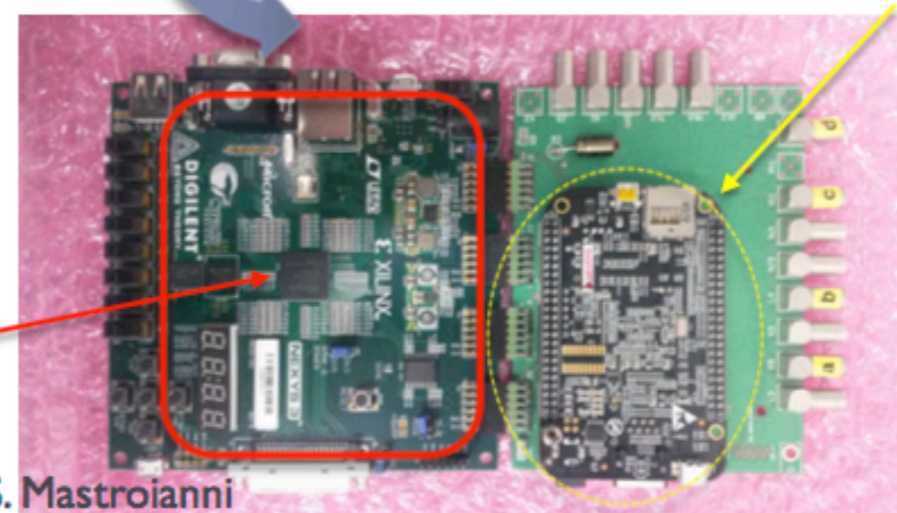
Architecture & implementation



Platform for embedded applications:

- Complete managing of the laser pulse generations
- Fully managed remotely
- Based on ARM8 board
- Running Linux OS

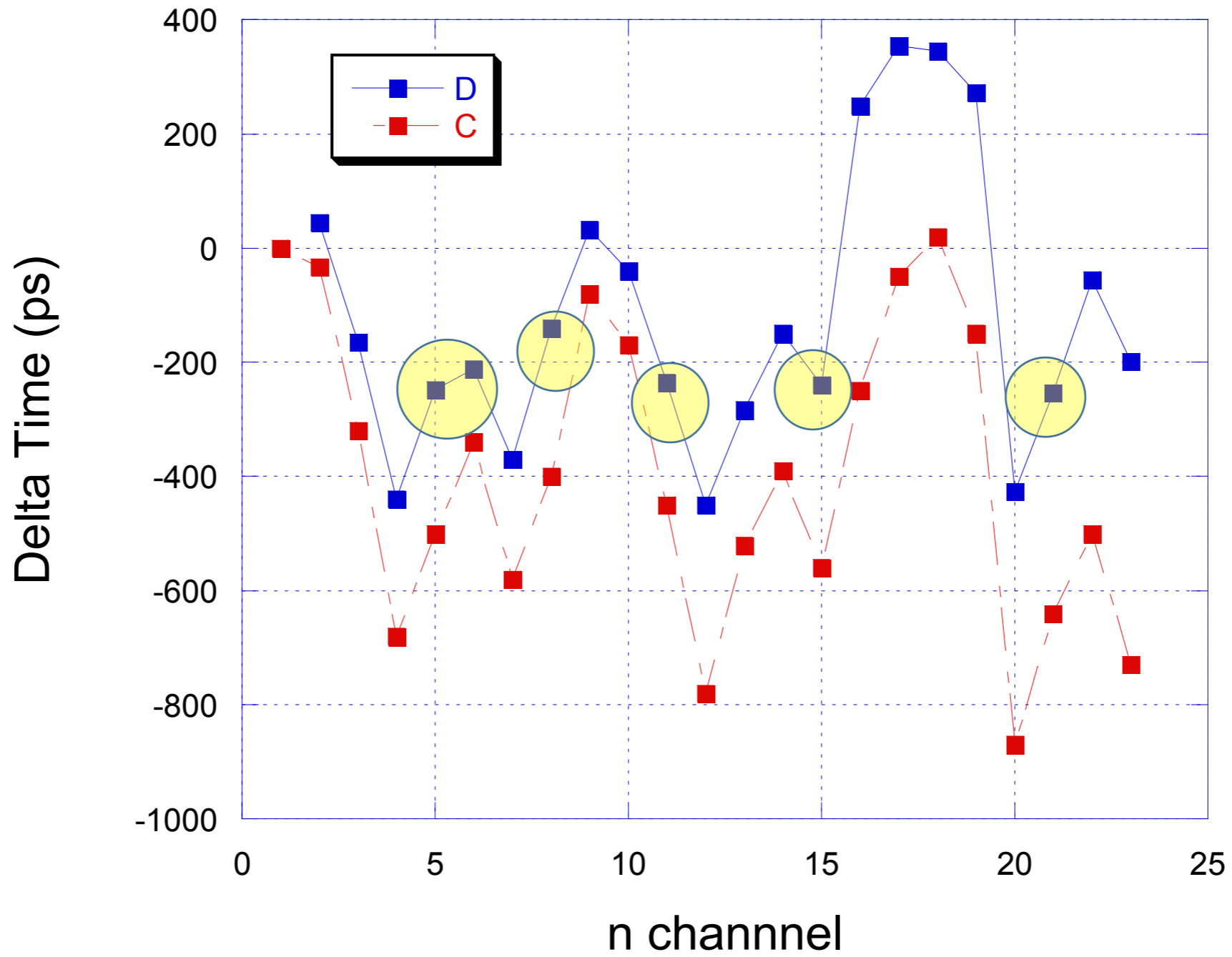
Xilinx Spartan-6 XC6LX16-CS324
 16Mbyte Micron Cellular RAM
 16Mbyte Micron Parallel PCM
 16Mbyte Micron Quad-mode SPI PCM
 100 MHz fixed-frequency oscillator
 10/100 SMSC LAN8710 PHY
 USB-UART



S. Mastroianni

g-2it Meeting, April 2017

Fan-out



```
DATA WILL BE ACQUIRED FOR 10 SECONDS...MEANING : ROUGHLY 6 # OF BOFS AT ONCE...
```

```
PRESS CTRL + C TWICE TO QUIT.
```

```
Calling the beaglebone...
```

```
ENTERED THE BEAGLEBONE, 6 # OF BOFS WILL BE COLLECTED.....
```

```
Data arrives in : 0
```

```
Data arrived...
```

1. `ssh *user@naples.matrix*`
2. `ssh *lab@naples-lab*`
3. `graph N (N = num. of seconds)`

Monitoring — @Fermilab

1. Obtain KERBEROS ticket
2. `ssh *PC@g2gateway01*`
3. `ssh *laptop@napdaq*`
4. **monfermi**

```
FERMILAB DATA MONITORING
FERMILAB DATA MONITORING

The display refreshes roughly every BOF ( ~ 2 s ).

UNITS : Temperatures in °C, Bias Voltages ( I, II ) in Volts.

Monitoring will start in :

  _ _ _
 | | |
 | | |
 | _ |
  | |
```