

Naples PMTs test facility status and first results

F.C. T. Barbato, C. Aramo, F. Guarino, R. Colalillo, L. Valore

INFN Sezione di Napoli
Università di Napoli "Federico II"

M. Buscemi, D. Bonanno, D. Bongiovanni, R. Caruso,
F. Longhitano, D. Lo Presti

INFN Sezione di Catania
Università di Catania

A dedicated facility

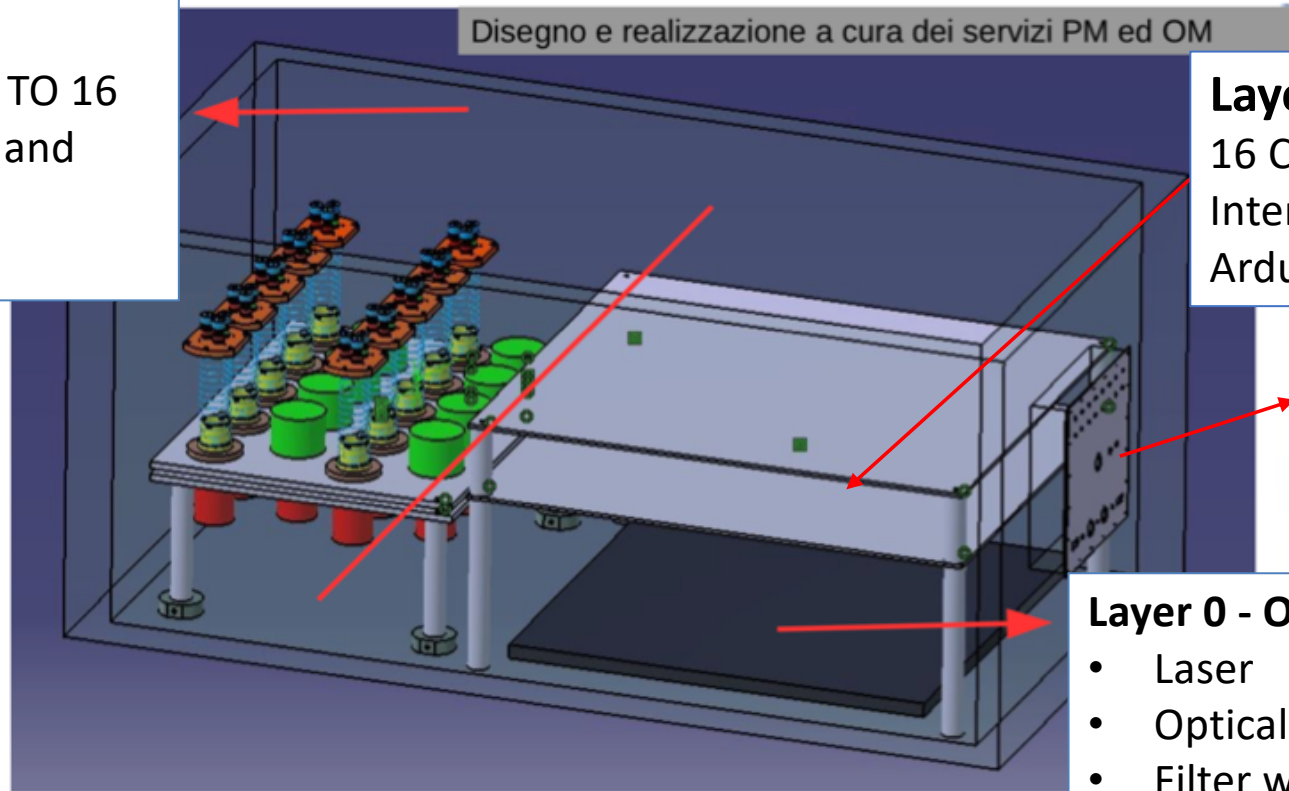
KEY POINTS OF THE NAPLES TESTS FACILITY

- ✓ 16 PMTs tested simultaneously
- ✓ Measurement of Gain curve
- ✓ Measurement of Non-Linearity as a function of peak current
- ✓ Automated acquisition procedure (LabVIEW)
- ✓ Dedicated software analysis and storage (C++, QT, ROOT, MySQL)
- ✓ Comparison with Hamamatsu results (using Hamamatsu R8619)

The facility

PMTs

Equipped to test simultaneously UP TO 16 PMTs (both R8619 and R9420) and their mechanics



Layer 1 – HV system:

16 CAEN HV modules
Interface board
Arduino

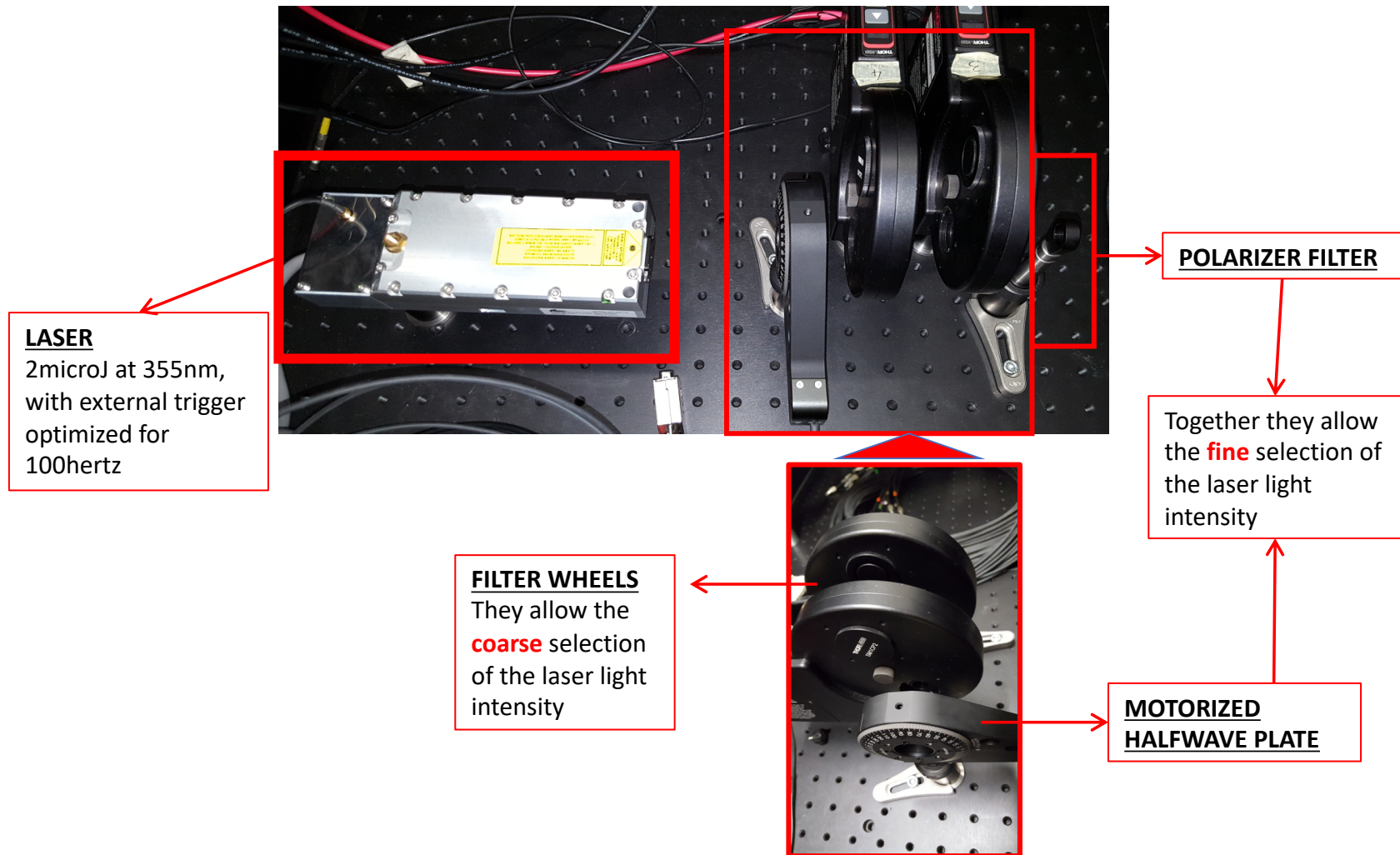
Cabling panel

Layer 0 - OPTICS:

- Laser
- Optical splitters
- Filter wheels
- Polarizer

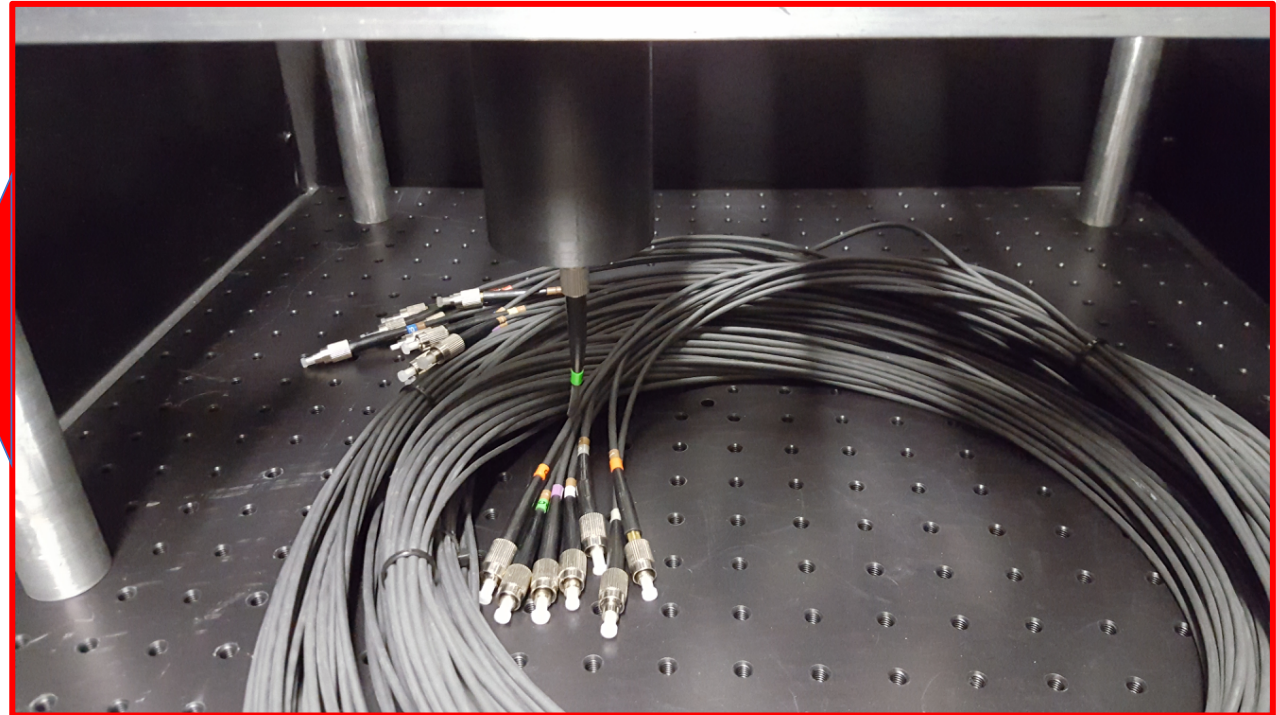
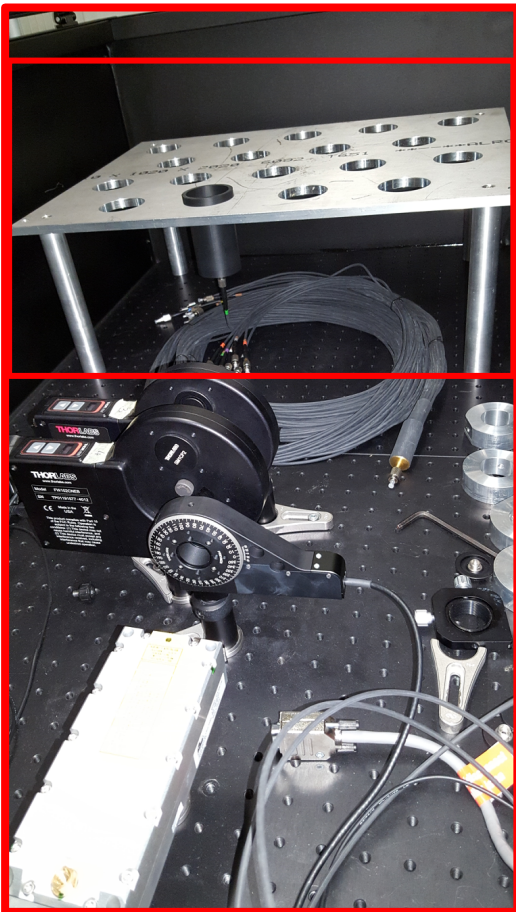
The facility

LAYER 0 - OPTICS



The facility

PMTs HOUSING - LIGHT DISTRIBUTION

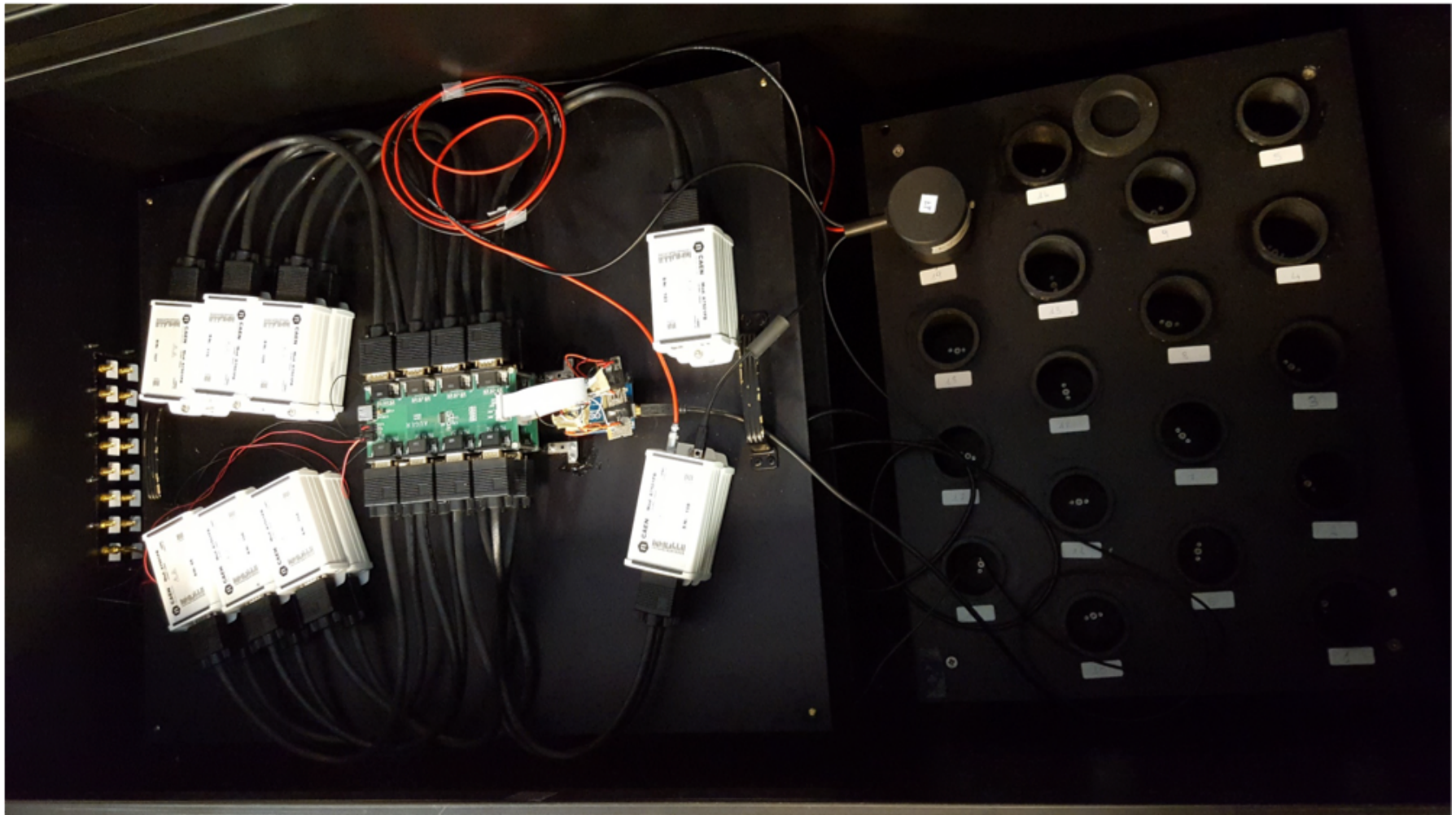


PMTs HOUSING

Each PMT is housed in a dark cylinder equipped with fiber feedthrough. The 1 to 20 beam splitter supplies the laser light to each PMT.

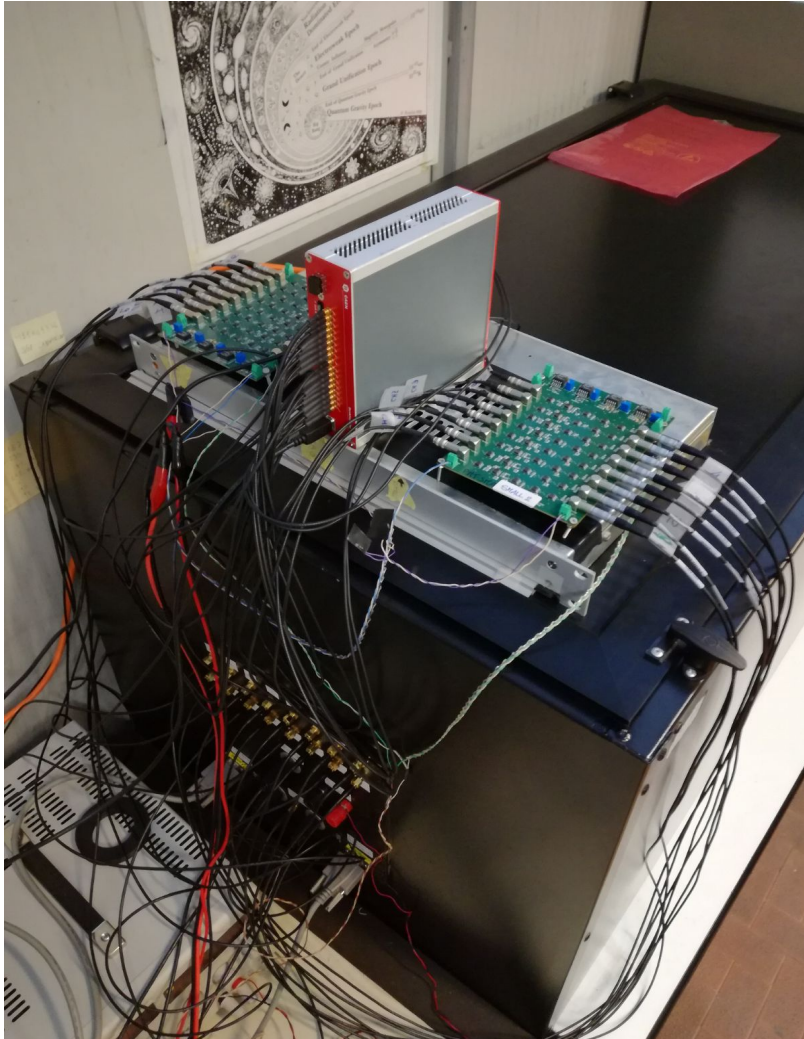
The facility

LAYER 1 – HV SYSTEM



The facility

DAQ and FRONT END ELECTRONICS



Double dynamics front-end developed in Catania:

FE adapts 16 input signal to digitizer dynamic range (1Vpp)

Amplifier 14X for SPE measurements

Attenuator 7X for non linearity

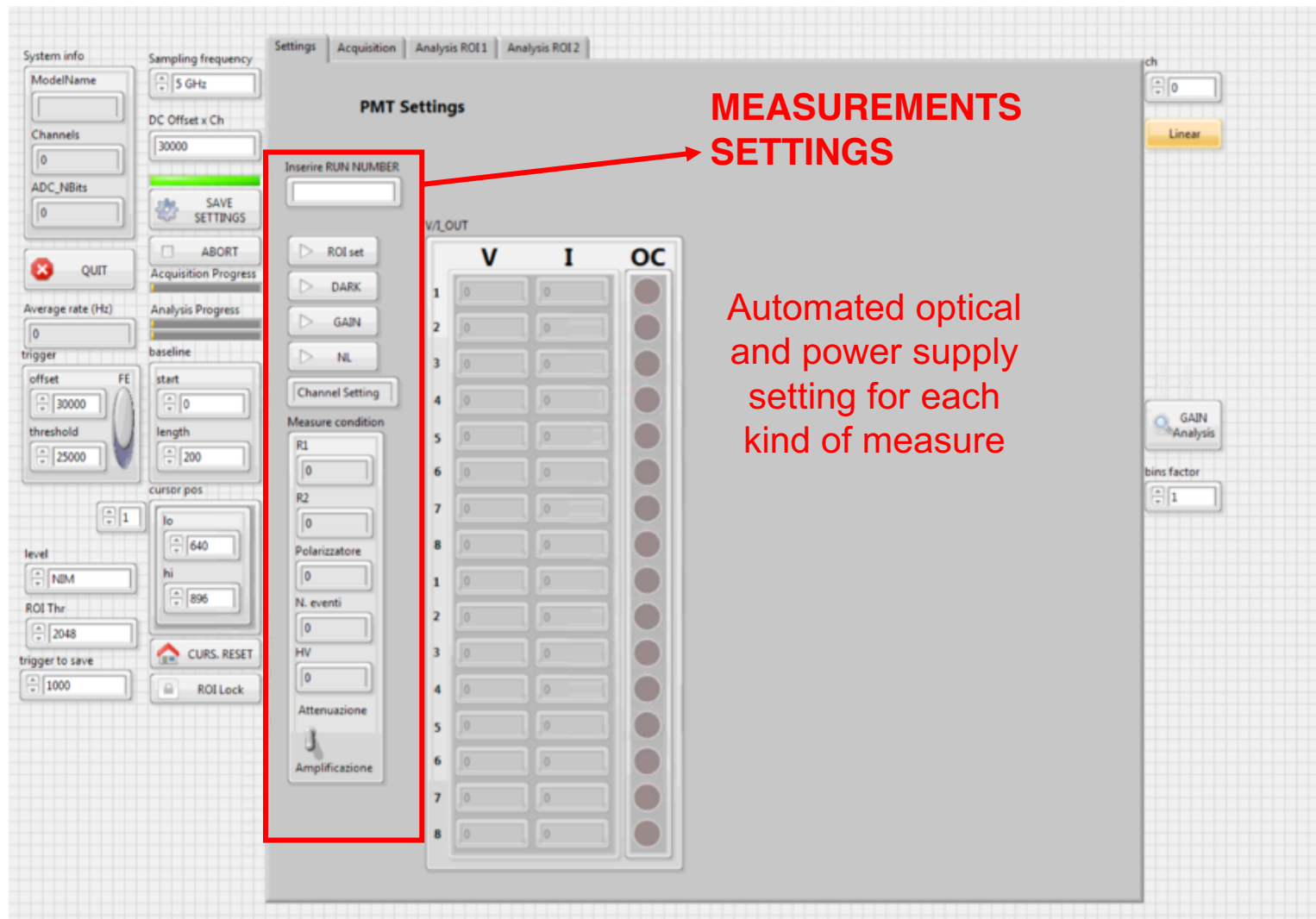
Automated DAQ

**DIGITIZER
CONTROLS**

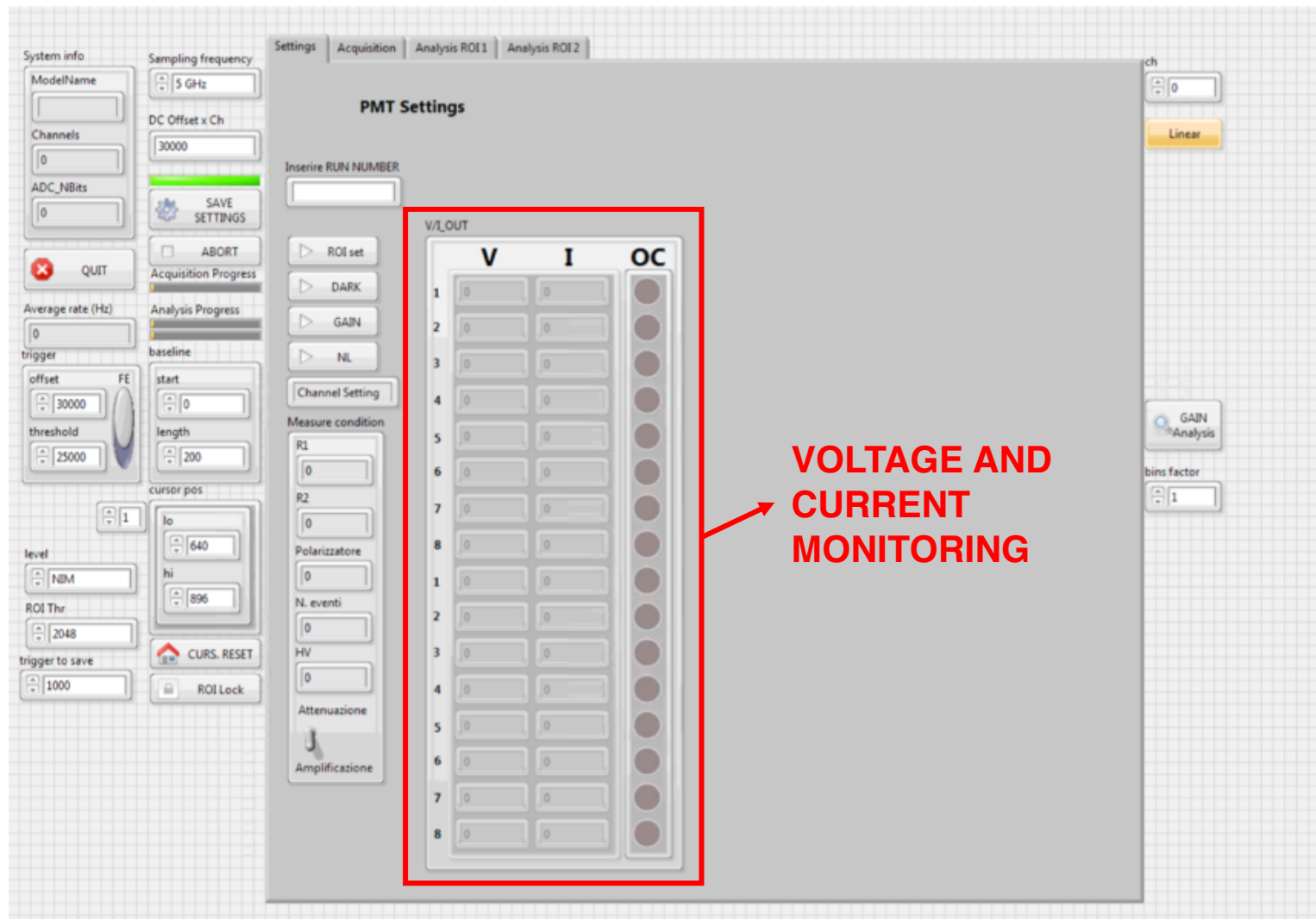
The screenshot displays the Automated DAQ software interface, which is organized into several functional panels. A red box on the left highlights the 'DIGITIZER CONTROLS' section, which includes fields for ModelName, Channels, ADC_NBits, Average rate (Hz), trigger offset, threshold, level, ROI Thr, trigger to save, Sampling frequency, DC Offset x Ch, and buttons for SAVE SETTINGS, ABORT, and QUIT. The central area features a 'PMT Settings' panel with a table for V/I_OUT measurements across 8 channels for V, I, and OC. To the right of this table are buttons for ROI set, DARK, GAIN, and NL, along with a 'Channel Setting' button. Below these are 'Measure condition' settings for R1, R2, Polarizzatore, NL eventi, HV, and Attenuazione. On the far right, there are additional controls for 'ch' (set to 0), a 'Linear' button, 'GAIN Analysis', and a 'bins factor' (set to 1). The interface also includes tabs for Settings, Acquisition, Analysis ROI 1, and Analysis ROI 2.

PMT Settings			
V/I_OUT			
	V	I	OC
1	0	0	
2	0	0	
3	0	0	
4	0	0	
5	0	0	
6	0	0	
7	0	0	
8	0	0	

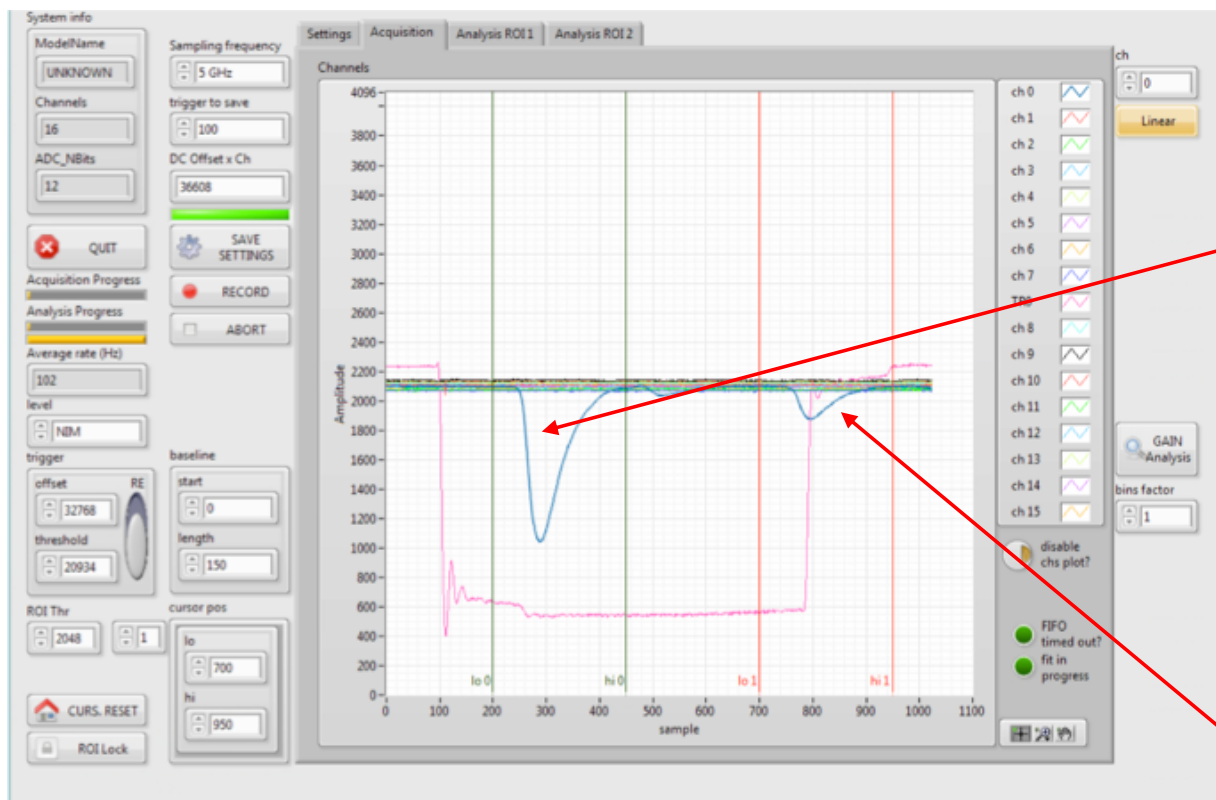
Automated DAQ



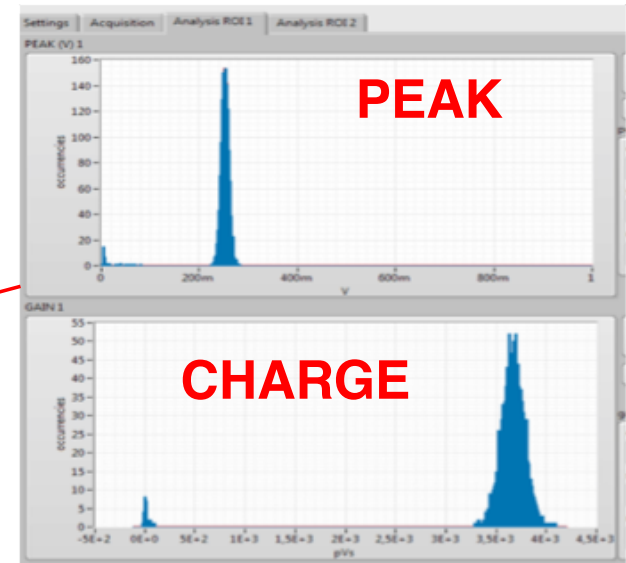
Automated DAQ



Automated DAQ



ROI 1

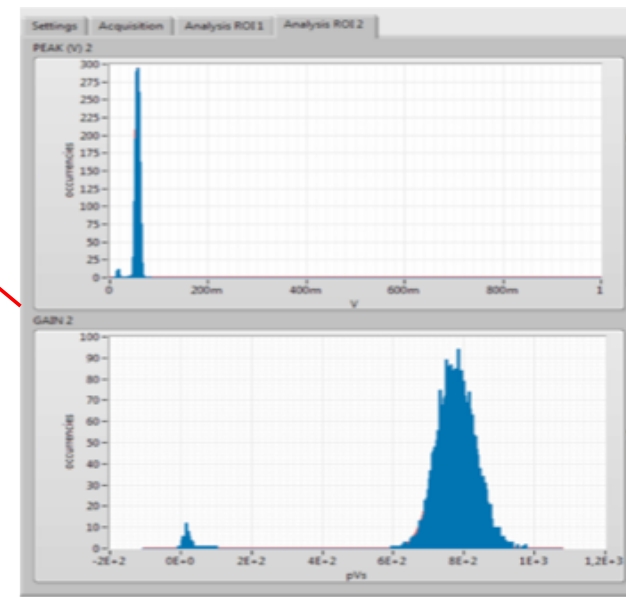


Simultaneous measure of the reference signal (ROI 2) and actual measure signal (ROI 1).



TIME SAVING IN NL MEASURE

ROI 2



Gain analysis tool

AugerPrime PMT Test Facility
Gain Analysis Tools

Analysis

Choose Files: /home/auger/Desktop/QT-analisi-v2.2/NA_03_2018/RUN_003

Analyze

Analysis Status: Completed

Draw Gain Curve

Select PMT ID: RY4404

Draw All

Charge and Amplitude Histograms

Choose File

Analyze

Analysis Status

☐ SPE

Connect to DB **DB Status**

User: Disconnected

Password: Connect

Disconnect

Store Data

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch00	<input type="checkbox"/> RY4481	2.94e-17	7.44	732	1019
ch01	<input type="checkbox"/> RY4435	2.63e-17	7.5	706	980
ch02	<input type="checkbox"/> RY4405	2.27e-17	7.51	715	992
ch03	<input type="checkbox"/> RY4399	4.11e-17	7.41	718	1001
ch04	<input type="checkbox"/> RY4407	5.09e-17	7.41	695	968
ch05	<input type="checkbox"/> RY4419	2.36e-17	7.47	731	1016
ch06	<input type="checkbox"/> RY4439	4.28e-17	7.36	743	1038
ch07	<input type="checkbox"/> RY4397	9.97e-17	7.29	705	988

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch08	<input type="checkbox"/> RY4401	1.11e-17	7.63	707	976
ch09	<input type="checkbox"/> RY4406	1.57e-16	7.22	710	998
ch10	<input type="checkbox"/> RY4485	3.95e-17	7.43	711	990
ch11	<input type="checkbox"/> RY4420	8.28e-18	7.64	724	999
ch12	<input type="checkbox"/> RY4457	2.89e-17	7.44	733	1021
ch13	<input type="checkbox"/> RY4404	1.6e-17	7.59	697	964
ch14	<input type="checkbox"/> RY4410	4.45e-17	7.43	695	967
ch15	<input type="checkbox"/> RY4447	7.77e-18	7.63	741	1023

Store All Store Selected PMT Clear

Read DB Data

PMT ID: Read

p0: p1:

HV: HV:

(G=6x10⁹) (G=7x10⁹)

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Graphical user interface written using QT libraries (C++ based)

- integrated with **ROOT** for data analysis
- integrated with **MySQL** database for data storage

Gain analysis tool

RAW DATA SELECTION AND ANALYSIS
GAIN CURVE DRAWING

AugerPrime PMT Test Facility
Gain Analysis Tools

Analysis

Choose Files:

Analyze

Analysis Status:

Draw Gain Curve

Select PMT ID:

Draw All

Charge and Amplitude Histograms

Choose File:

Analyze

Analysis Status:

☐ SPE

Connect to DB

DB Status:

User:

Password:

Connect

Disconnect

Store Data

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch00	<input type="checkbox"/> RY4481	<input type="text" value="2.94e-17"/>	<input type="text" value="7.44"/>	<input type="text" value="732"/>	<input type="text" value="1019"/>
ch01	<input type="checkbox"/> RY4435	<input type="text" value="2.63e-17"/>	<input type="text" value="7.5"/>	<input type="text" value="706"/>	<input type="text" value="980"/>
ch02	<input type="checkbox"/> RY4405	<input type="text" value="2.27e-17"/>	<input type="text" value="7.51"/>	<input type="text" value="715"/>	<input type="text" value="992"/>
ch03	<input type="checkbox"/> RY4399	<input type="text" value="4.11e-17"/>	<input type="text" value="7.41"/>	<input type="text" value="718"/>	<input type="text" value="1001"/>
ch04	<input type="checkbox"/> RY4407	<input type="text" value="5.09e-17"/>	<input type="text" value="7.41"/>	<input type="text" value="695"/>	<input type="text" value="968"/>
ch05	<input type="checkbox"/> RY4419	<input type="text" value="2.36e-17"/>	<input type="text" value="7.47"/>	<input type="text" value="731"/>	<input type="text" value="1016"/>
ch06	<input type="checkbox"/> RY4439	<input type="text" value="4.28e-17"/>	<input type="text" value="7.36"/>	<input type="text" value="743"/>	<input type="text" value="1038"/>
ch07	<input type="checkbox"/> RY4397	<input type="text" value="9.97e-17"/>	<input type="text" value="7.29"/>	<input type="text" value="705"/>	<input type="text" value="988"/>

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch08	<input type="checkbox"/> RY4401	<input type="text" value="1.11e-17"/>	<input type="text" value="7.63"/>	<input type="text" value="707"/>	<input type="text" value="976"/>
ch09	<input type="checkbox"/> RY4406	<input type="text" value="1.57e-16"/>	<input type="text" value="7.22"/>	<input type="text" value="710"/>	<input type="text" value="998"/>
ch10	<input type="checkbox"/> RY4485	<input type="text" value="3.95e-17"/>	<input type="text" value="7.43"/>	<input type="text" value="711"/>	<input type="text" value="990"/>
ch11	<input type="checkbox"/> RY4420	<input type="text" value="8.28e-18"/>	<input type="text" value="7.64"/>	<input type="text" value="724"/>	<input type="text" value="999"/>
ch12	<input type="checkbox"/> RY4457	<input type="text" value="2.89e-17"/>	<input type="text" value="7.44"/>	<input type="text" value="733"/>	<input type="text" value="1021"/>
ch13	<input type="checkbox"/> RY4404	<input type="text" value="1.6e-17"/>	<input type="text" value="7.59"/>	<input type="text" value="697"/>	<input type="text" value="964"/>
ch14	<input type="checkbox"/> RY4410	<input type="text" value="4.45e-17"/>	<input type="text" value="7.43"/>	<input type="text" value="695"/>	<input type="text" value="967"/>
ch15	<input type="checkbox"/> RY4447	<input type="text" value="7.77e-18"/>	<input type="text" value="7.63"/>	<input type="text" value="741"/>	<input type="text" value="1023"/>

Store All Store Selected PMT Clear

Read DB Data

PMT ID:

Read

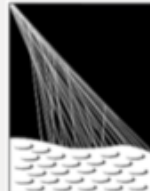
p0: p1:

HV: HV:

(G=6x10⁹) (G=7x10⁹)

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**PIERRE
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OBSERVATORY

Gain analysis tool

CHECK TOOL FOR SPE AND NPE SPECTRA

AugerPrime PMT Test Facility
Gain Analysis Tools

Analysis
Choose Files: /home/auger/Desktop/QT-analisi-v2.2/NA_03_2018/RUN_003
Analysis Status: Completed
Draw Gain Curve: Select PMT ID: RY4404, Draw All

Charge and Amplitude Histograms
Choose File:
Analysis Status: ☐ SPE
Analyze

Connect to DB
DB Status: Disconnected
User:
Password:
Connect, Disconnect

Store Data

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch00	<input type="checkbox"/> RY4481	2.94e-17	7.44	732	1019
ch01	<input type="checkbox"/> RY4435	2.63e-17	7.5	706	980
ch02	<input type="checkbox"/> RY4405	2.27e-17	7.51	715	992
ch03	<input type="checkbox"/> RY4399	4.11e-17	7.41	718	1001
ch04	<input type="checkbox"/> RY4407	5.09e-17	7.41	695	968
ch05	<input type="checkbox"/> RY4419	2.36e-17	7.47	731	1016
ch06	<input type="checkbox"/> RY4439	4.28e-17	7.36	743	1038
ch07	<input type="checkbox"/> RY4397	9.97e-17	7.29	705	988

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch08	<input type="checkbox"/> RY4401	1.11e-17	7.63	707	976
ch09	<input type="checkbox"/> RY4406	1.57e-16	7.22	710	998
ch10	<input type="checkbox"/> RY4485	3.95e-17	7.43	711	990
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ch12	<input type="checkbox"/> RY4457	2.89e-17	7.44	733	1021
ch13	<input type="checkbox"/> RY4404	1.6e-17	7.59	697	964
ch14	<input type="checkbox"/> RY4410	4.45e-17	7.43	695	967
ch15	<input type="checkbox"/> RY4447	7.77e-18	7.63	741	1023

Store All, Store Selected PMT, Clear

Read DB Data
PMT ID:
p0: p1:
HV: HV:
(G=6x10⁹) (G=7x10⁹)
Read

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PIERRE AUGER
OBSERVATORY

Gain analysis tool

SAVING DATA ON MySQL DATABASE

AugerPrime PMT Test Facility
Gain Analysis Tools

Analysis
Choose Files: /home/auger/Desktop/QT-analisi-v2.2/NA_03_2018/RUN_003
Analysis Status: Completed
Draw Gain Curve: Select PMT ID: RY4404, Draw All

Charge and Amplitude Histograms
Choose File:
Analysis Status:
SPE: ☐

Connect to DB
DB Status: Disconnected
User:
Password:
Connect:
Disconnect:

Store Data

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch00	<input type="checkbox"/> RY4481	2.94e-17	7.44	732	1019
ch01	<input type="checkbox"/> RY4435	2.63e-17	7.5	706	980
ch02	<input type="checkbox"/> RY4405	2.27e-17	7.51	715	992
ch03	<input type="checkbox"/> RY4399	4.11e-17	7.41	718	1001
ch04	<input type="checkbox"/> RY4407	5.09e-17	7.41	695	968
ch05	<input type="checkbox"/> RY4419	2.36e-17	7.47	731	1016
ch06	<input type="checkbox"/> RY4439	4.28e-17	7.36	743	1038
ch07	<input type="checkbox"/> RY4397	9.97e-17	7.29	705	988

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch08	<input type="checkbox"/> RY4401	1.11e-17	7.63	707	976
ch09	<input type="checkbox"/> RY4406	1.57e-16	7.22	710	998
ch10	<input type="checkbox"/> RY4485	3.95e-17	7.43	711	990
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ch13	<input type="checkbox"/> RY4404	1.6e-17	7.59	697	964
ch14	<input type="checkbox"/> RY4410	4.45e-17	7.43	695	967
ch15	<input type="checkbox"/> RY4447	7.77e-18	7.63	741	1023

Store All Store Selected PMT Clear

Read DB Data
PMT ID:
Read:
p0:
p1:
HV (G=6x10⁹):
HV (G=7x10⁹):

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Gain analysis tool

AugerPrime PMT Test Facility
Gain Analysis Tools

Analysis
 /home/auger/Desktop/QT-analisi-v2.2/NA_03_2018/RUN_003
 Analysis Status: Completed
Draw Gain Curve
 PMT ID: RY4404

Charge and Amplitude Histograms

 Analysis Status: ☐ SPE


Connect to DB DB Status: Disconnected
User:
Password:

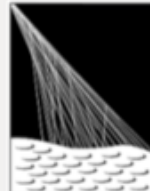
Store Data

	PMT ID	p0	p1	HV (G=6x10 ⁹)	HV (G=7x10 ⁹)
ch00	<input type="checkbox"/> RY4481	2.94e-17	7.44	732	1019
ch01	<input type="checkbox"/> RY4435	2.63e-17	7.5	706	980
ch02	<input type="checkbox"/> RY4405	2.27e-17	7.51	715	992
ch03	<input type="checkbox"/> RY4399	4.11e-17	7.41	718	1001
ch04	<input type="checkbox"/> RY4407	5.09e-17	7.41	695	968
ch05	<input type="checkbox"/> RY4419	2.36e-17	7.47	731	1016
ch06	<input type="checkbox"/> RY4439	4.28e-17	7.36	743	1038
ch07	<input type="checkbox"/> RY4397	9.97e-17	7.29	705	988

ch08	<input type="checkbox"/> RY4401	1.11e-17	7.63	707	976
ch09	<input type="checkbox"/> RY4406	1.57e-16	7.22	710	998
ch10	<input type="checkbox"/> RY4485	3.95e-17	7.43	711	990
ch11	<input type="checkbox"/> RY4420	8.28e-18	7.64	724	999
ch12	<input type="checkbox"/> RY4457	2.89e-17	7.44	733	1021
ch13	<input type="checkbox"/> RY4404	1.6e-17	7.59	697	964
ch14	<input type="checkbox"/> RY4410	4.45e-17	7.43	695	967
ch15	<input type="checkbox"/> RY4447	7.77e-18	7.63	741	1023

Read DB Data
PMT ID:
p0: p1:
HV: HV:
(G=6x10⁹) (G=7x10⁹)


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Fit parameters and HV values @ desired Gains to be stored in the DB

NL analysis tool

AugerPrime PMT Test Facility
Linearity Analysis Tools

Analysis

 Analysis Status

Draw Linearity Curve

Charge and Amplitude Histograms

 Analysis Status

Connect to DB **DB Status**
User
Password


Disconnected

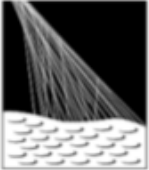
Store Data

	PMT ID	Peak Current [mA] (NL = 5%, G=7 · 10 ⁹)		PMT ID	Peak Current [mA] (NL = 5% G=7 · 10 ⁹)	
ch 00	<input type="checkbox"/> RY4481	<input type="text" value="76.8"/>		ch 08	<input type="checkbox"/> RY4401	<input type="text" value="69"/>
ch 01	<input type="checkbox"/> RY4435	<input type="text" value="71.2"/>		ch 09	<input type="checkbox"/> RY4406	<input type="text" value="61.1"/>
ch 02	<input type="checkbox"/> RY4405	<input type="text" value="46.1"/>		ch 10	<input type="checkbox"/> RY4485	<input type="text" value="73.6"/>
ch 03	<input type="checkbox"/> RY4399	<input type="text" value="7.16e-322"/>		ch 11	<input type="checkbox"/> RY4420	<input type="text" value="37"/>
ch 04	<input type="checkbox"/> RY4407	<input type="text" value="32.8"/>		ch 12	<input type="checkbox"/> RY4457	<input type="text" value="10.7"/>
ch 05	<input type="checkbox"/> RY4419	<input type="text" value="8.65"/>		ch 13	<input type="checkbox"/> RY4404	<input type="text" value="69.7"/>
ch 06	<input type="checkbox"/> RY4439	<input type="text" value="12.8"/>		ch 14	<input type="checkbox"/> RY4410	<input type="text" value="16.1"/>
ch 07	<input type="checkbox"/> RY4397	<input type="text" value="68.6"/>		ch 15	<input type="checkbox"/> RY4447	<input type="text" value="77"/>

Read DB Data
PMT ID

p0
HV (G=6x10⁹) [V]
**Peak Current [mA]
(NL = 5%)**
p1
HV (G=7x10⁹) [V]


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MySQL database

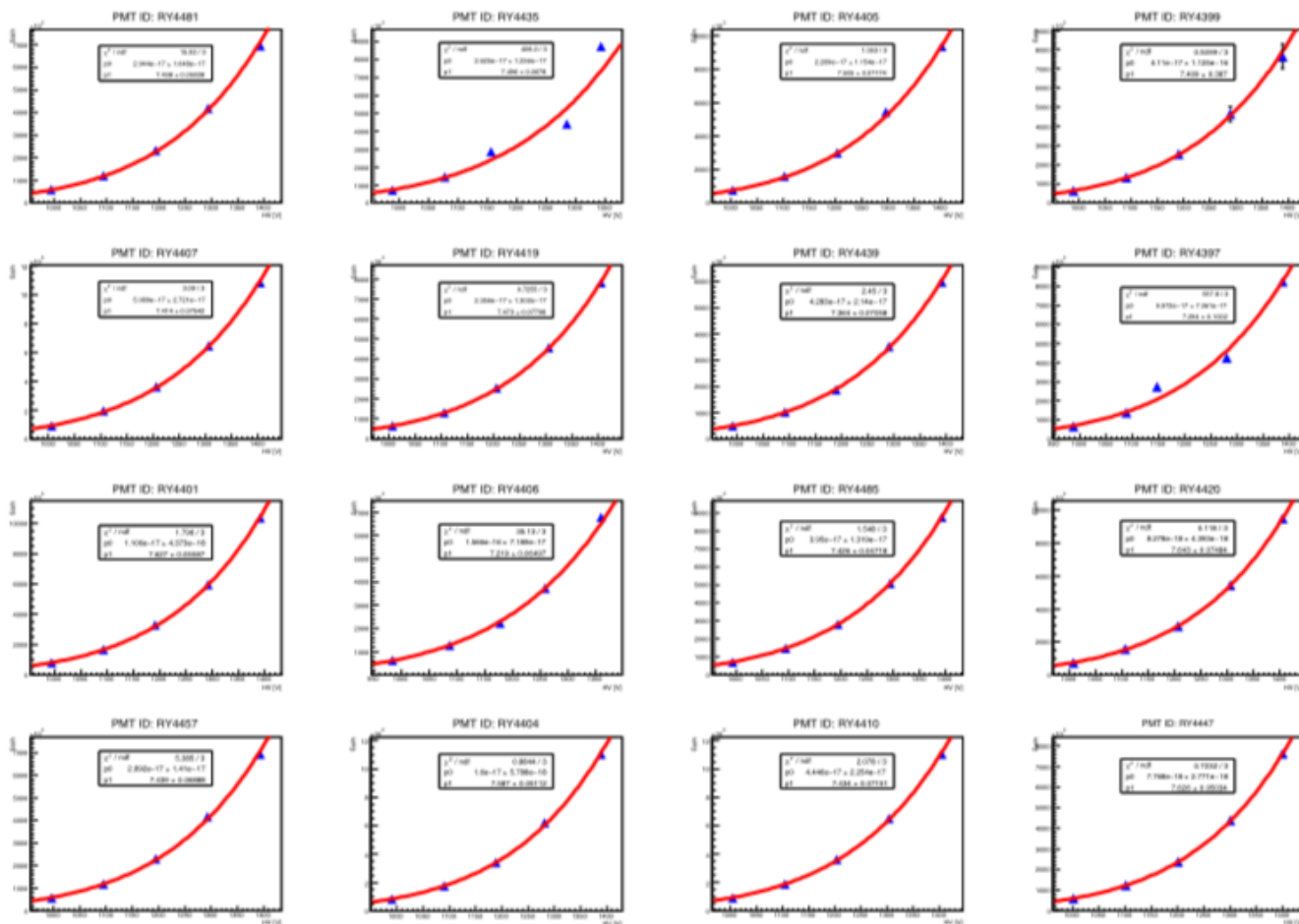
Small PMTs preproduction (16 SPMTs) results

```
Database changed
mysql> select * from pmt;
+-----+-----+-----+-----+-----+-----+
| ID      | p0      | p1      | HV1    | HV2    | current |
+-----+-----+-----+-----+-----+-----+
| RY4481  | 2.94e-17 | 7.44    | 732    | 1019   | 78      |
| RY4435  | 2.63e-17 | 7.5     | 706    | 980    | 71.1    |
| RY4405  | 2.27e-17 | 7.51    | 715    | 992    | 49.4    |
| RY4399  | 4.11e-17 | 7.41    | 718    | 1001   | 4.09    |
| RY4407  | 5.09e-17 | 7.41    | 695    | 968    | 32.5    |
| RY4419  | 2.36e-17 | 7.47    | 731    | 1016   | 8.51    |
| RY4439  | 4.28e-17 | 7.36    | 743    | 1038   | 11.5    |
| RY4397  | 9.97e-17 | 7.29    | 705    | 988    | 68.8    |
| RY4401  | 1.11e-17 | 7.63    | 707    | 976    | 69.9    |
| RY4406  | 1.57e-16 | 7.22    | 710    | 998    | 73.9    |
| RY4485  | 3.95e-17 | 7.43    | 711    | 990    | 74.6    |
| RY4420  | 8.28e-18 | 7.64    | 724    | 999    | 35.2    |
| RY4457  | 2.89e-17 | 7.44    | 733    | 1021   | 9.95    |
| RY4404  | 1.6e-17  | 7.59    | 697    | 964    | 69.7    |
| RY4410  | 4.45e-17 | 7.43    | 695    | 967    | 13      |
| RY4447  | 7.77e-18 | 7.63    | 741    | 1023   | 76.4    |
+-----+-----+-----+-----+-----+-----+
16 rows in set (0.00 sec)

mysql>
```

ID	PMT serial number
p0	Gain fit parameter
p1	Gain fit parameter
HV1	HV@G=6x10 ⁴
HV2	HV@G=7x10 ⁵
current	Peak current [mA] @5% NL

Results on R8619:GAIN

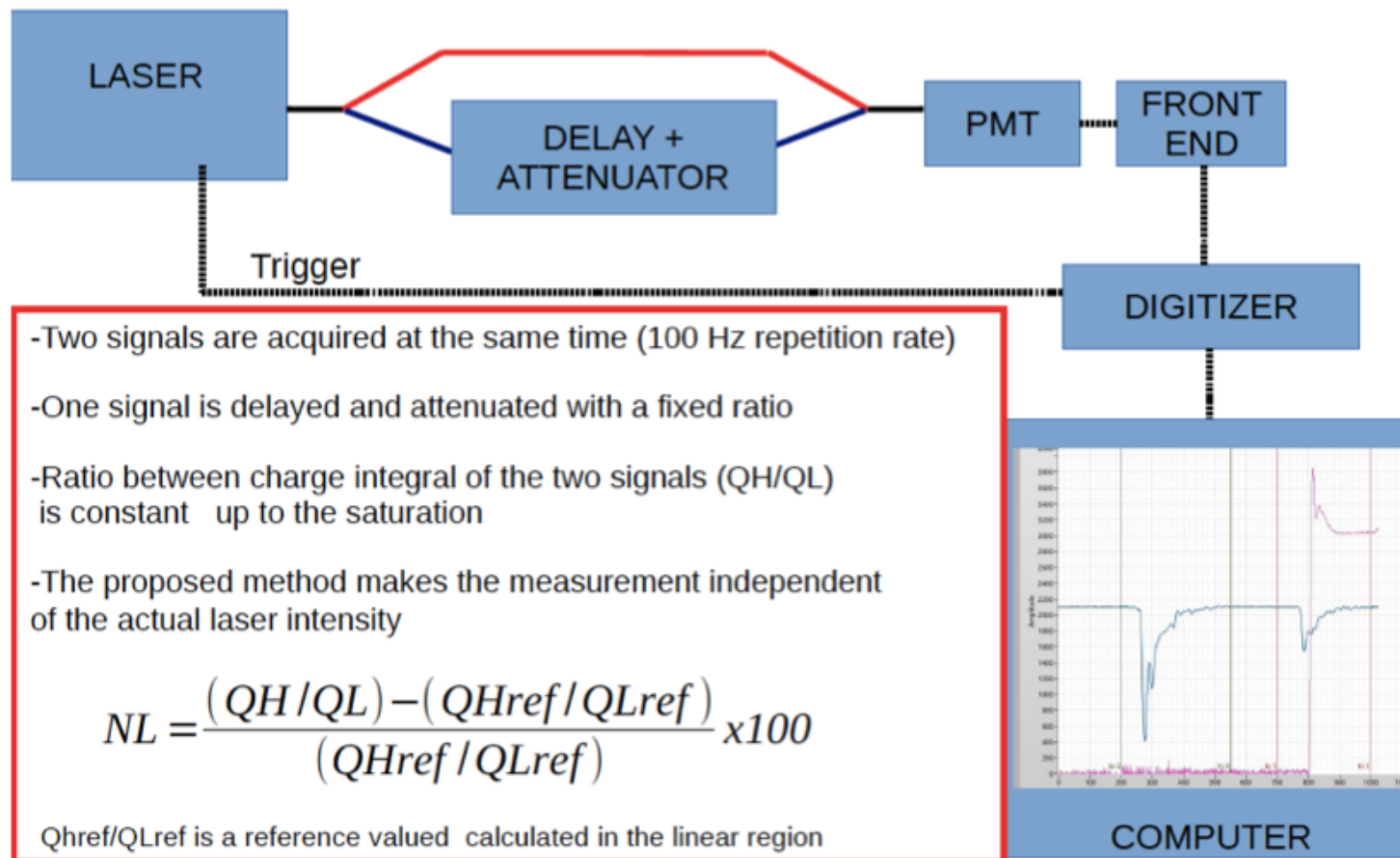


HV@G=7x10⁵

S/N	Hamamatsu	Us
RY4397	995V	988V
RY4404	966V	964V
RY4410	969V	967V
RY4435	974V	980V
RY4457	1026V	1021V

NL measurement

A NEW METHOD FOR NON-LINEARITY MEASUREMENTS

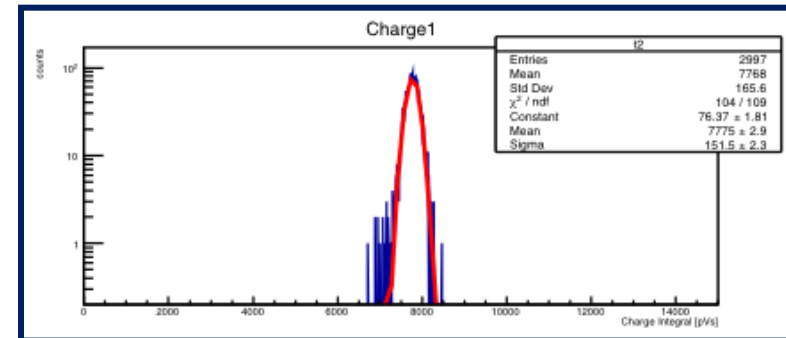
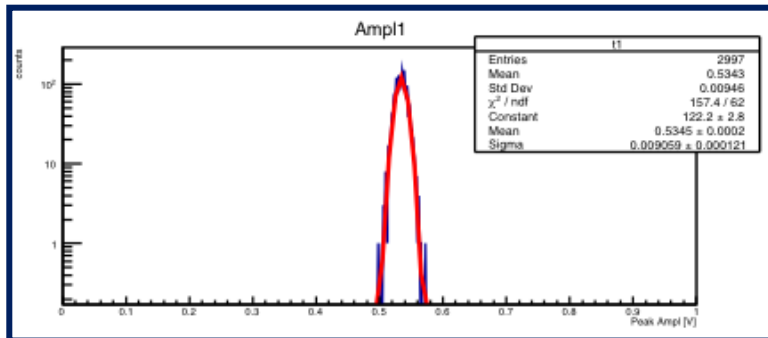


NL measurement

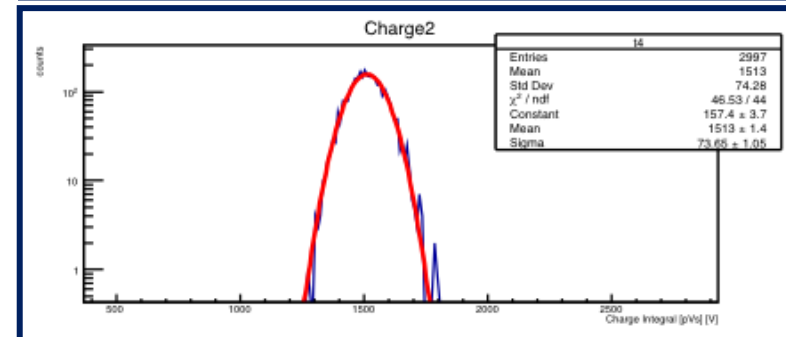
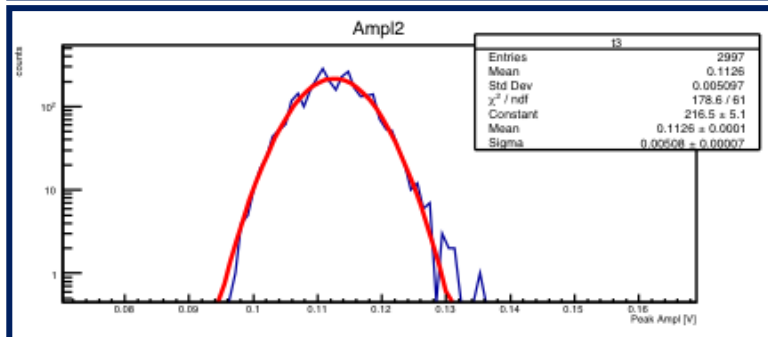
PEAK

CHARGE

HIGH



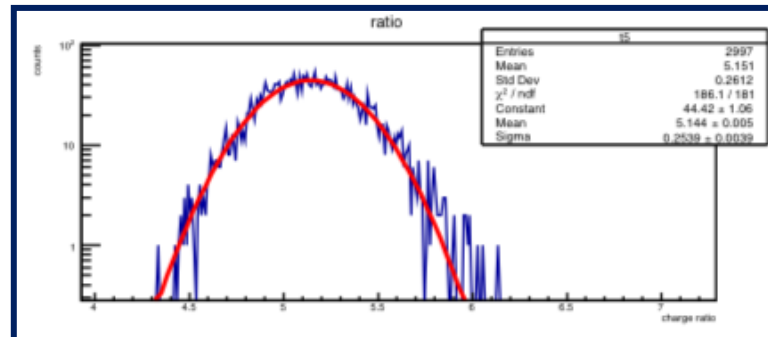
LOW



RATIO

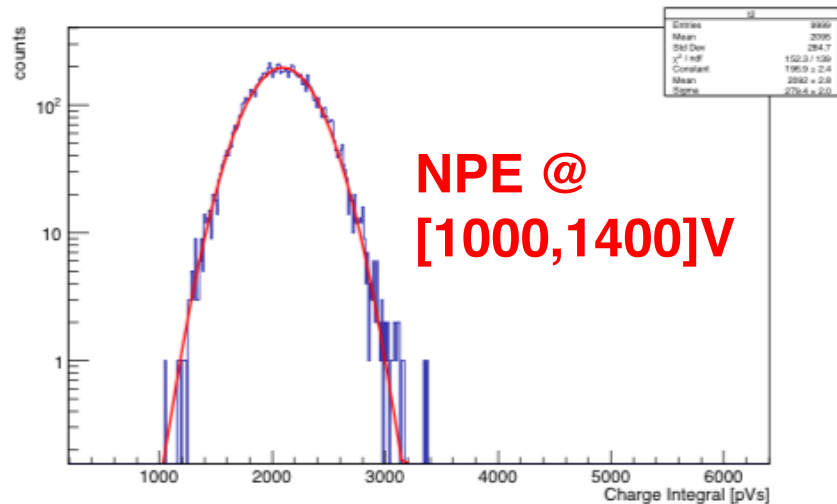
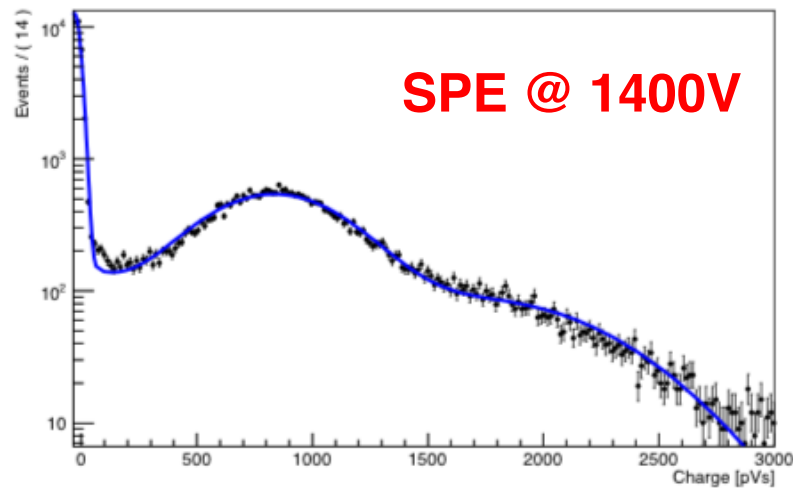


CONSTANT
VALUE UP TO
SATURATION

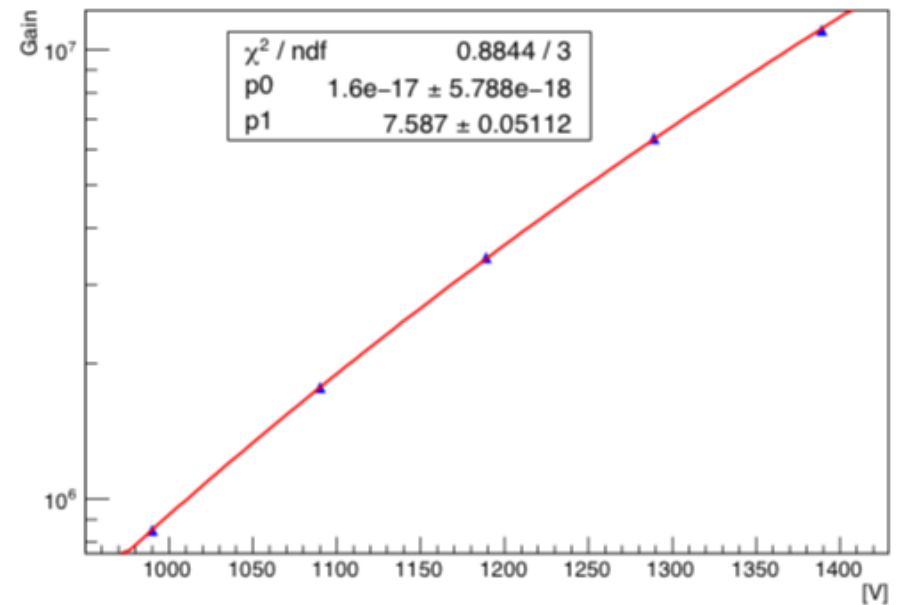


RY4404: Gain

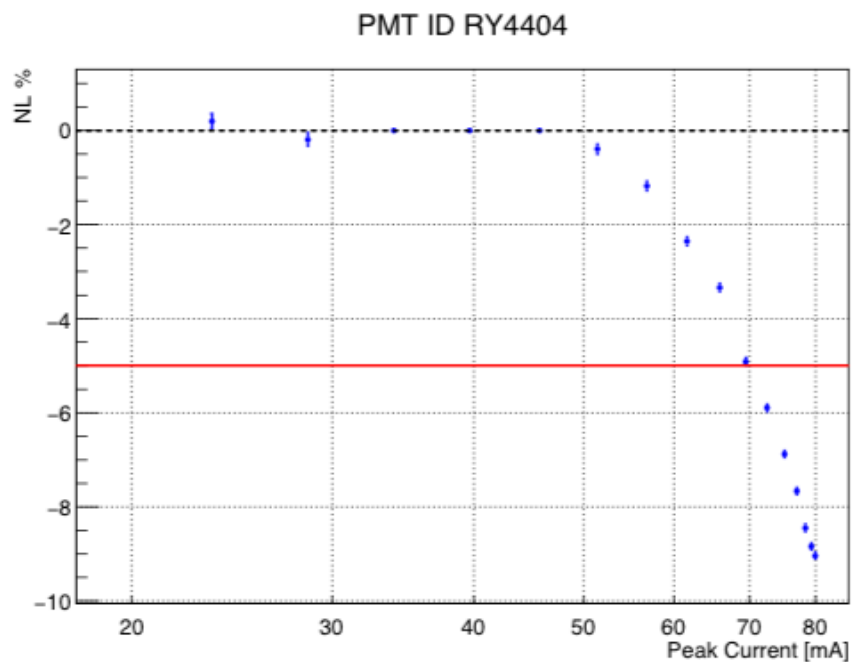
SPE Charge Spectrum



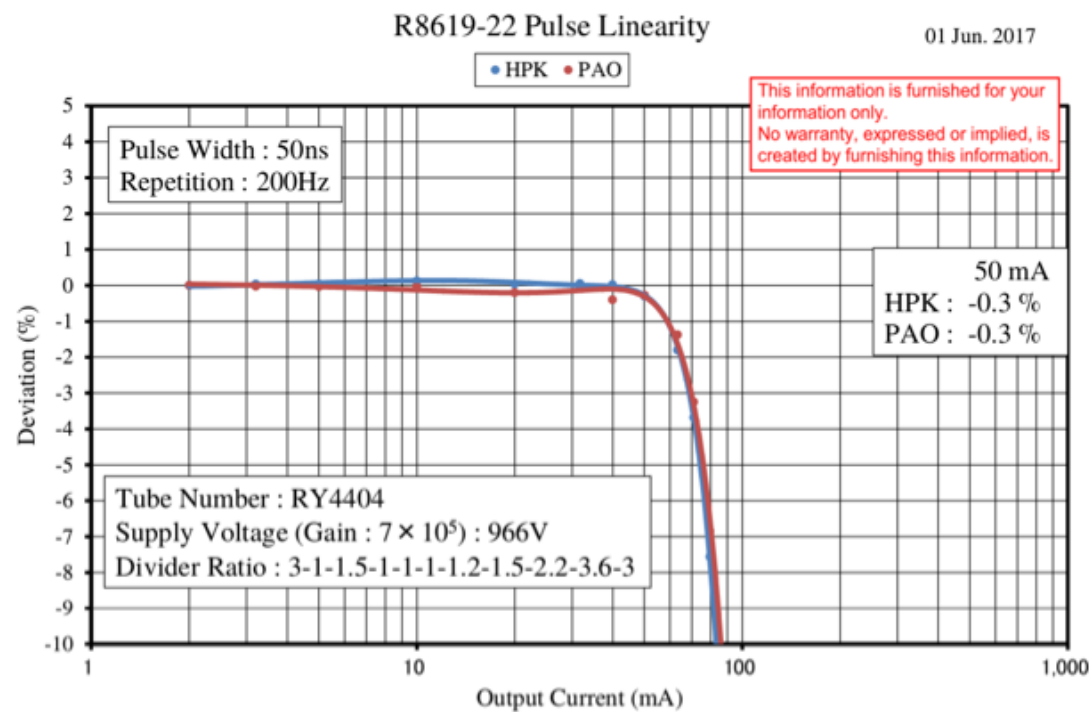
PMT ID: RY4404



RY4404: NL



NL @5% = 70mA
NL @50mA <0.5%



Conclusions

- ✓ 16 small PMTs tested simultaneously using an automated acquisition procedure (LabVIEW) and a dedicated software analysis and storage (C++, QT, ROOT, MySQL)
- ✓ Comparison with Hamamatsu results (using Hamamatsu R8619)
- ✓ The whole characterization of 16 PMTs stands for about 10 hours
- ✓ Spare Dark Box to test individually the PMTs who failed the massive test.
- ✓ 508 small PMTs already commissioned to Hamamatsu
- ✓ We **need** a prototype of a PMT for the SSD in order to both find the right settings for the automation of the measure and to organize the production.



The facility

LAYER 0 - OPTICS



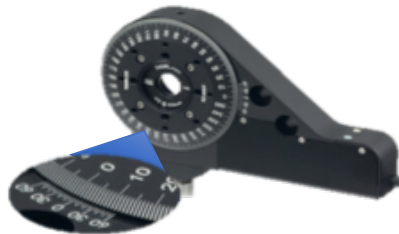
LASER

2microJ at 355nm, with external trigger optimized for 100hertz



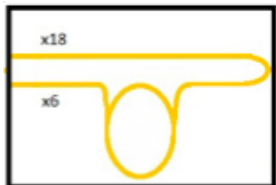
FILTER WHEELS

Thorlabs filter wheels equipped with 12 filters with different OD to lessen the laser light intensity



POLARIZER

System of motorized half-wave plate and polarizer filter by Thorlabs

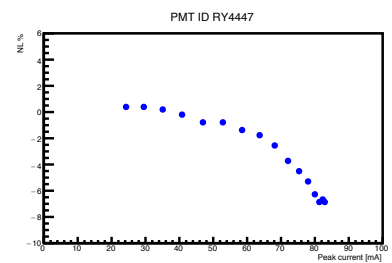
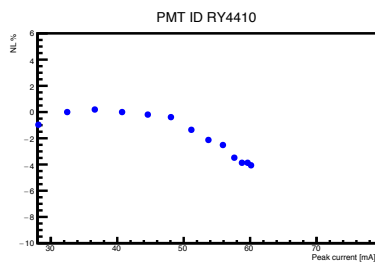
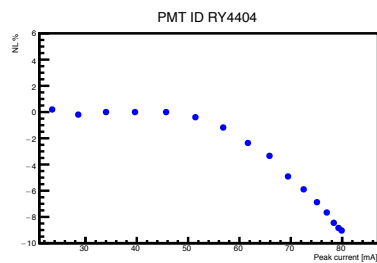
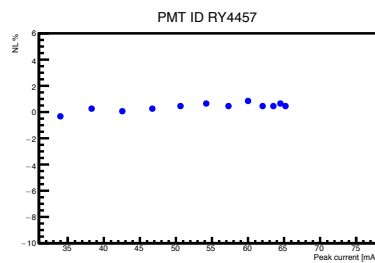
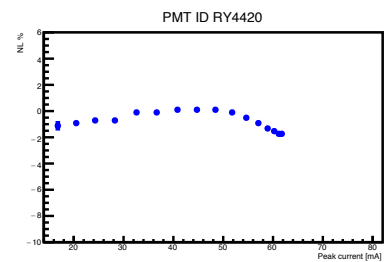
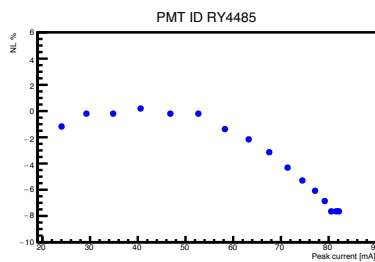
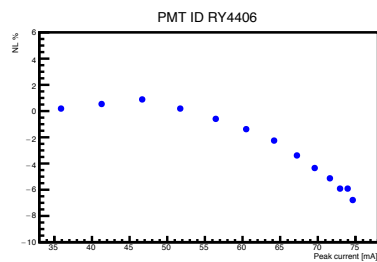
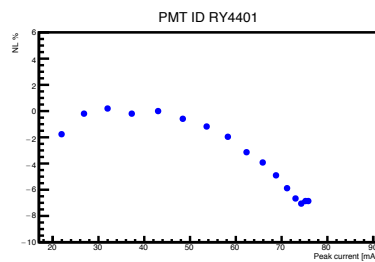
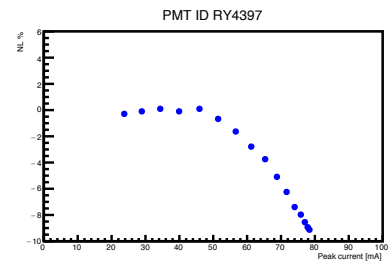
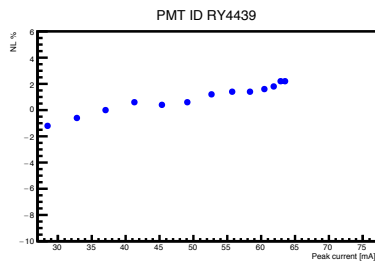
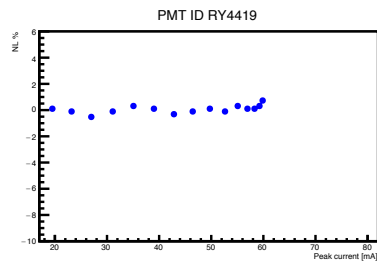
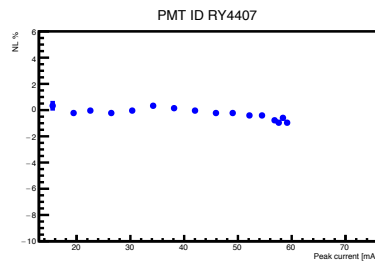
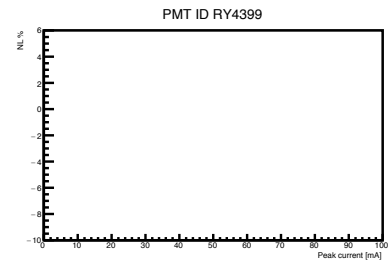
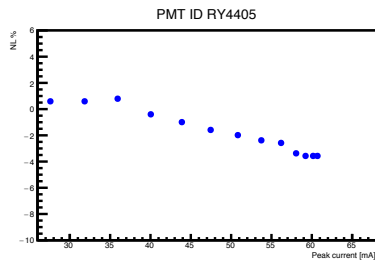
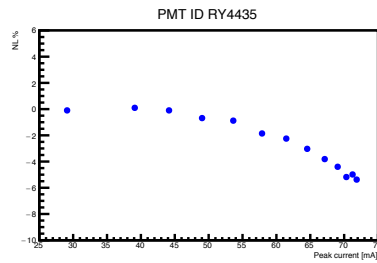
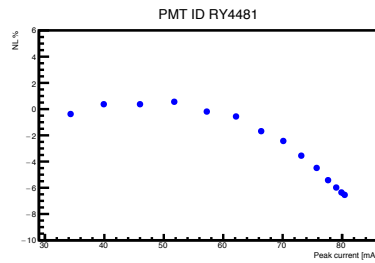


OPTICAL SPLITTERS

Delay splitter

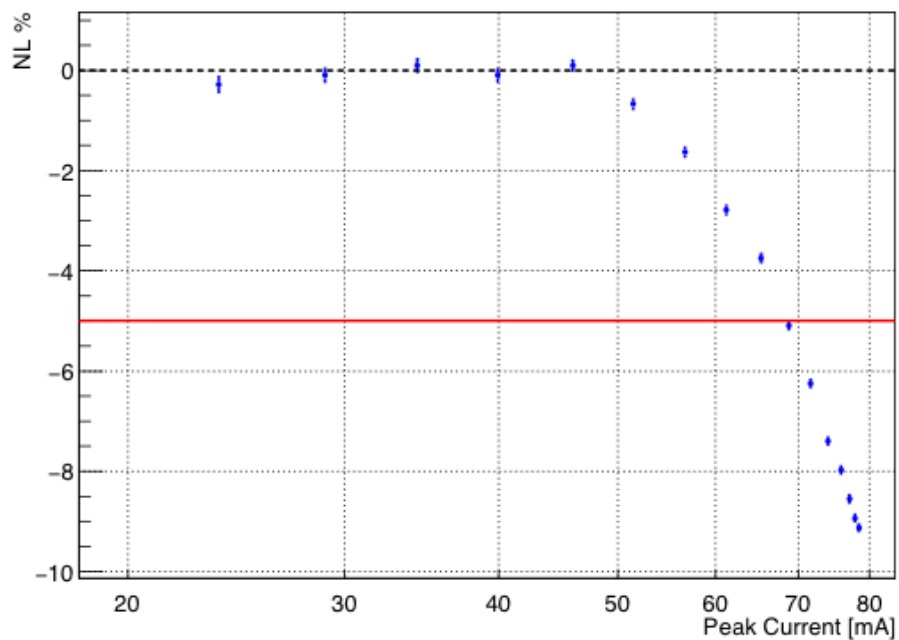
1 to 20 fiber splitter to light simultaneously the 16 PMTs (4 spare fibers)

NL



RY4397

PMT ID RY4397



NL @5% = 70mA
NL @50mA ~0.5%

R8619-22 Pulse Linearity

01 Jun. 2017

