Photo Multipliers Tubes characterization for WA105 experiment

Chiara Lastoria
TAE – Benasque
07/09/2016

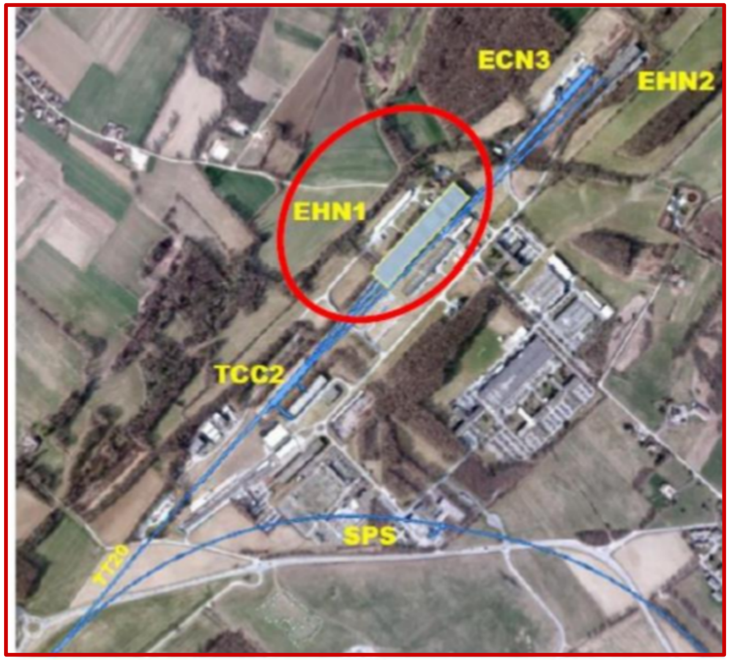
Outline

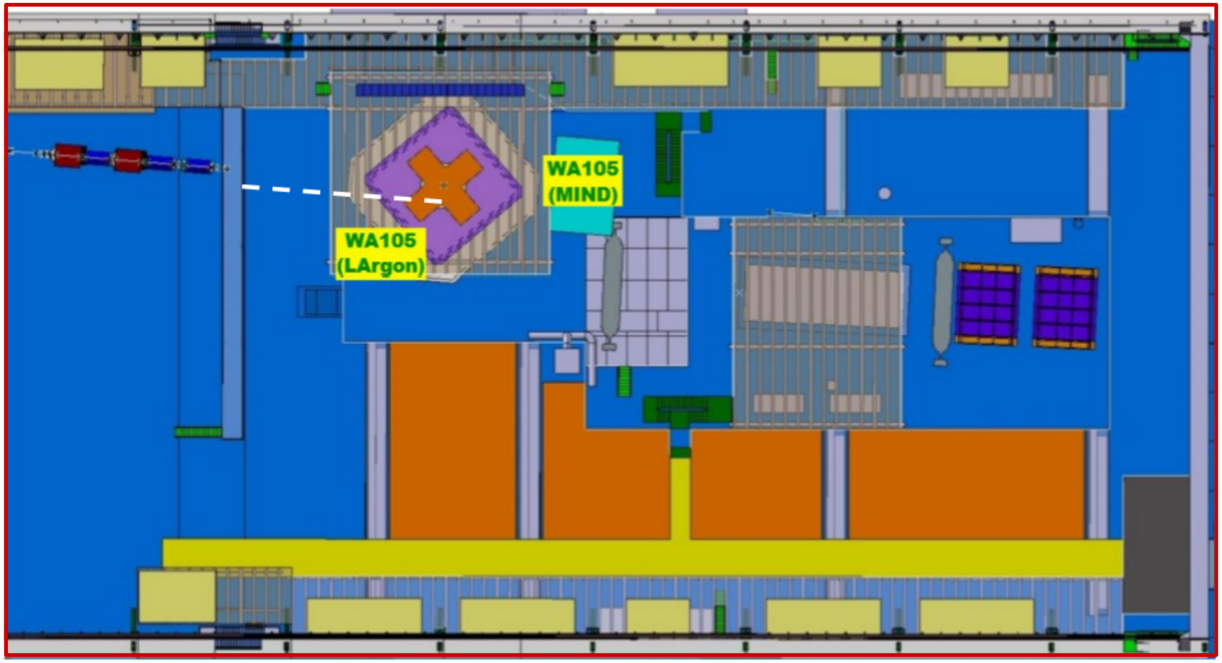
- WA105 experiment
- Dual Phase technology and TPC photon detection
- Photo Multipliers Tubes working
- Some results
- Conclusions

WA105 experiment

Where is it?

WA105 experiment is a 6x6x6 m^3 Dual Phase Liquid Argon (DLAr) detector installed in the CERN neutrino platform created to investigate and develop prototype for future giant neutrino detector generation.



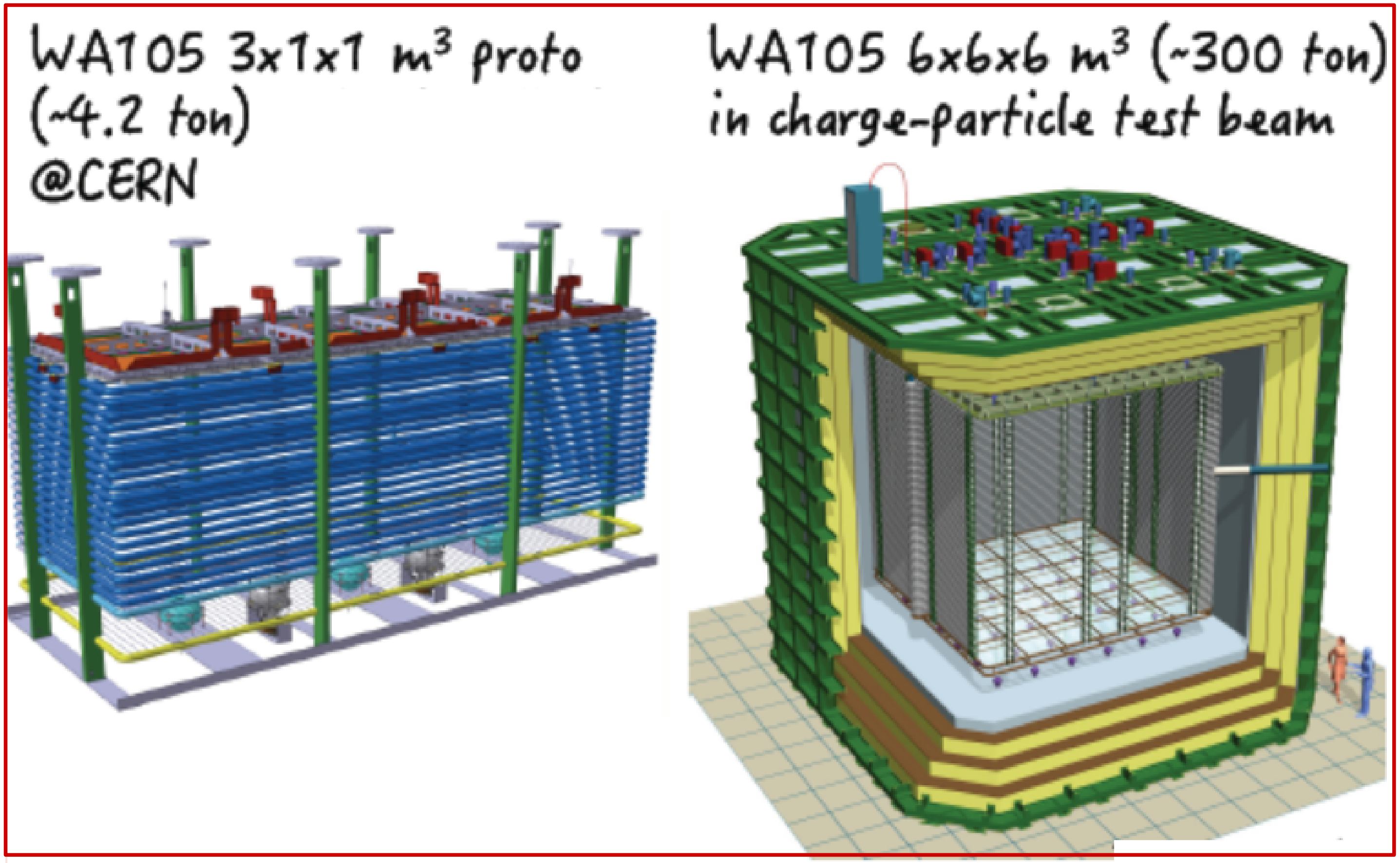


WA105 experiment

What is it?

WA105 experiment is done by a 3x1x1 m^3 prototype yet installed at CERN and 6x6x6 m^3 Dual Phase Liquid Argon (DLAr) detector that which installation is expected for 2017 at CERN.

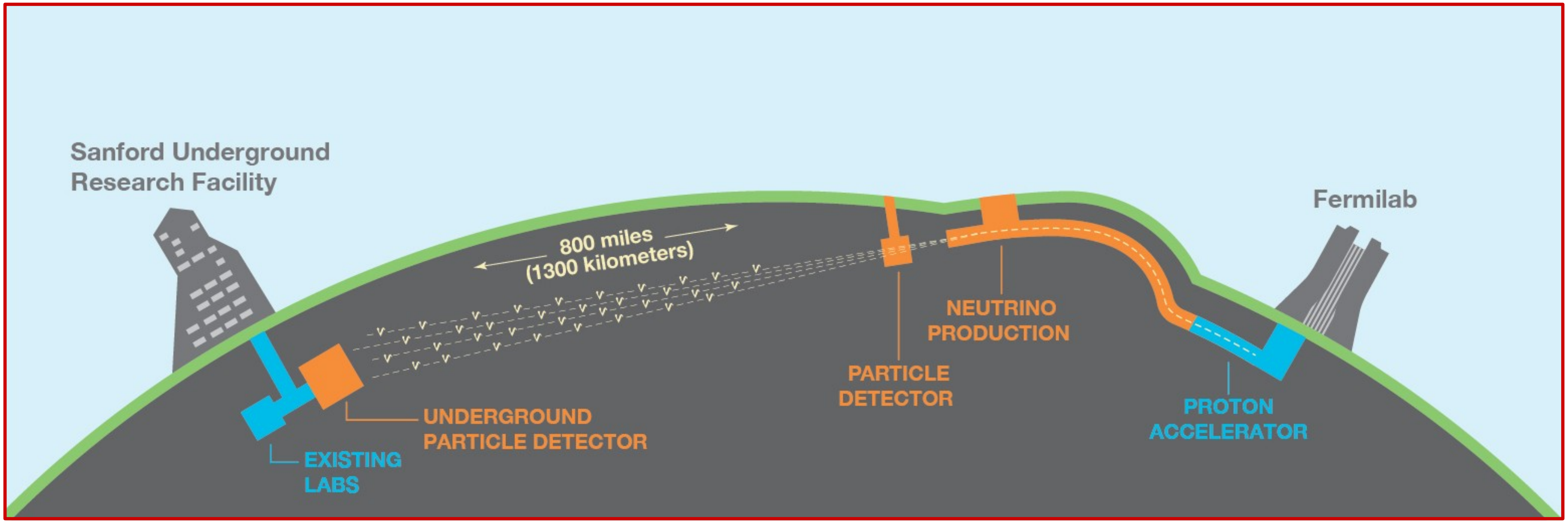
The CIEMAT group is in charge of the design, tests, installation and calibration of the light detection system for the WA105 experiment.
Design, characterization and installation of the 5 PMTs for the 3x1x1 m^3 prototype has be done by the CIEMAT group as well.
Tests and characterization to understand the behavior of the 36 PMTs in the 6x6x6 m^3 detector are on going in the CIEMAT laboratory.



WA105 experiment

Why?

The goal is to prove the dual phase liquid argon technology for large-scale detector at the kton scale as Deep Underground Neutrino Experiment (DUNE).
Long-baseline experiments want to improve the knowledge about neutrino oscillation regarding the determination of the mass hierarchy (Dm_{23}), searches about CP violation or atmospheric and supernova neutrinos.



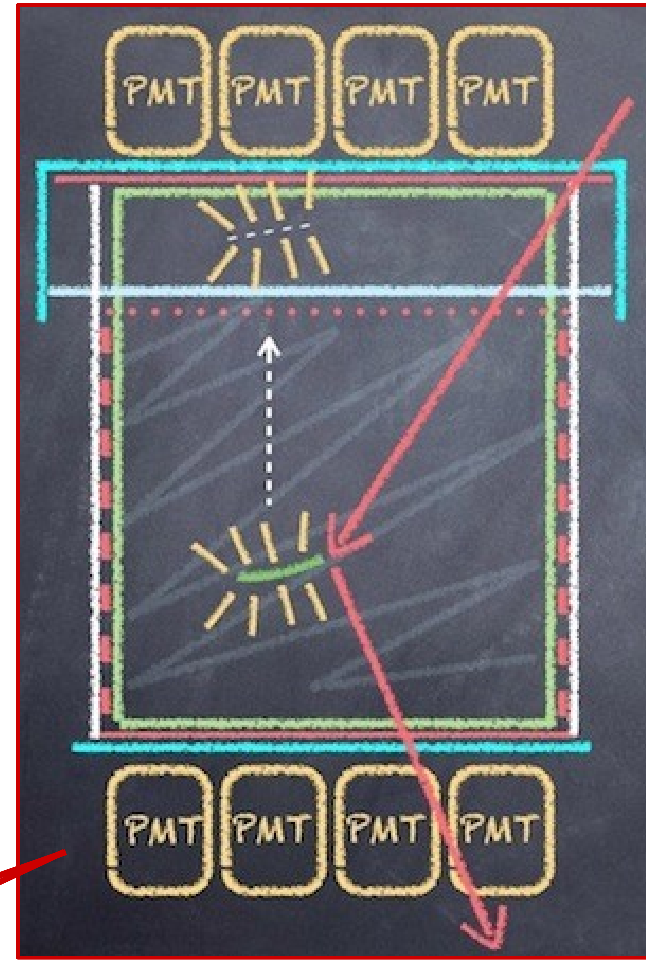
Double phase technology in Liquid Argon experiment

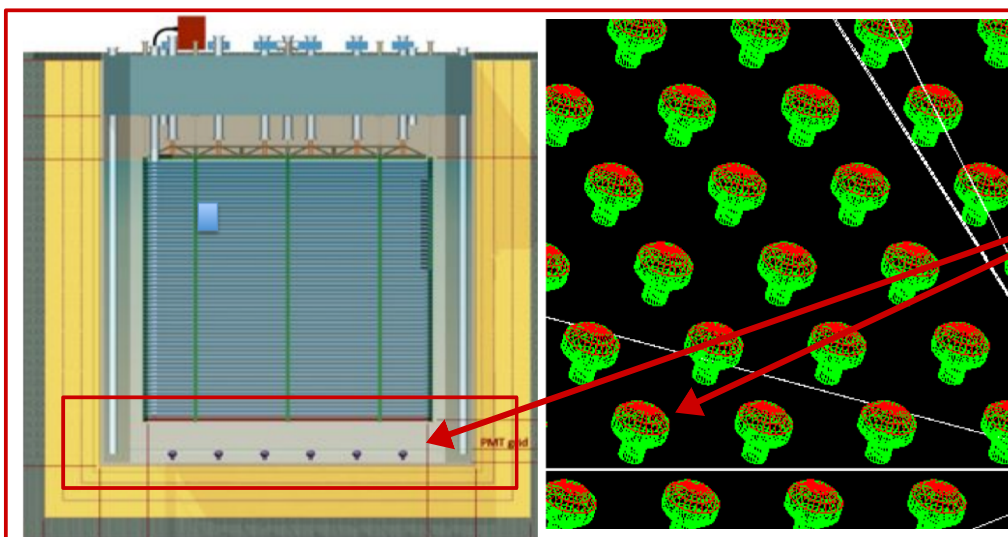
Dual Phase technology allows two measurements:

- charge ↔ ionization which allows both tracking and calorimetry of the particles
  → The dual phase technology let to enhance the multiplication that happens in the gas phase.

- scintillation light ↔ two signal at different time in liquid and gaseous phase; first signal is used both as a trigger and t_0

All these information are read by the light photodetection system done by several Photo Multipliers Tubes (PMTs).





36 PMTs

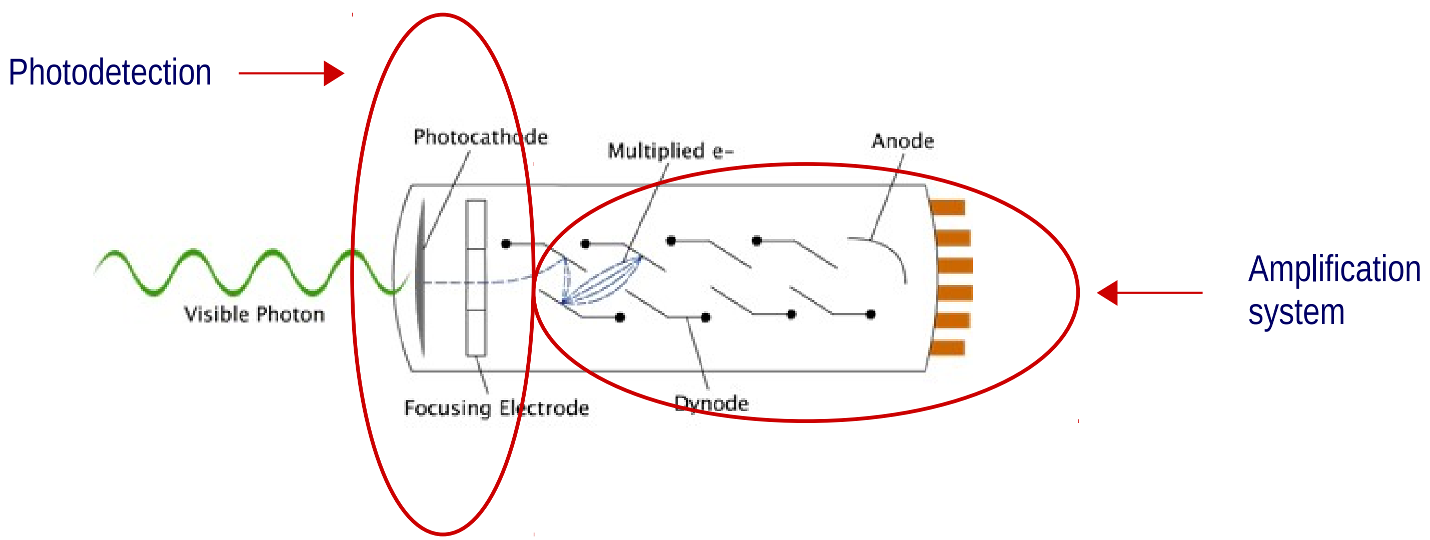
The photo detection light system of WA105 6x6x6 detector is done by 36 PMTs whose performance have to be studied.

Basic concepts about PMTs

The PMT is an object which convert the scintillation light that arrives on its surface into an amplified electronic signal.

A PMTs can be thought as divided into two main parts:
1) photodetector (photocathode + first dynode), where the flux of photons is converted into electrons
2) amplifier (dynode system), where the number of initial photoelectrons is increased

The response of a PMT in terms of number of photoelectrons (PEs) collected is determined by these two main processes: photo collection and conversion in photoelectrons and their amplification



Basic concepts about PMTs

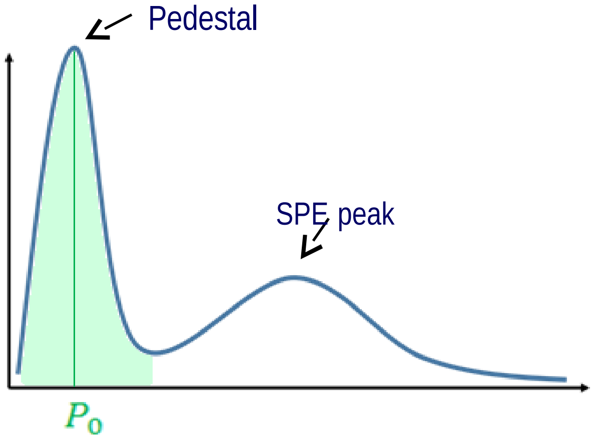
1. The number of PEs collected by the PMT is a Poisson distribution: $$P(n;\mu) = \frac{\mu^n \cdot e^{-\mu}}{n!}$$

   μ is the mean value of number of PEs and n the number of PEs observed.

2. Even if any amount of light is injected on the PMTs (→ any PEs should be counted), the PMTs can collect light from background processes
   → we'll see a gaussian peak in the charge distribution (Pedestal)

3. The probability to don't have any PEs allow to calculate μ: $$P(0;\mu) = \frac{N_0}{N_{tot}} = e^{-\mu}$$

4. When only one PEs is collected, the typical Single PhotoElectrons distribution is seen which is the convolution of the distribution of the Pedestal and the "pure" gaussian distribution of the single PEs is collected.

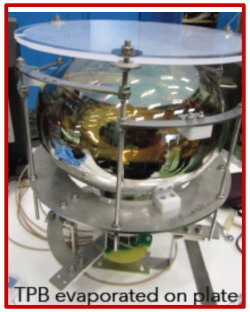


5. The Gain of the PMTs gives information about the amplification given by the dynode system

$$\textbf{Gain (G)} = \frac{<m_h> - P_0}{\mu \cdot q_e}$$

m_h average charge distribution of the histograms, P_0 the pedestal, μ the mean number of the PEs and q_e the electron charge.

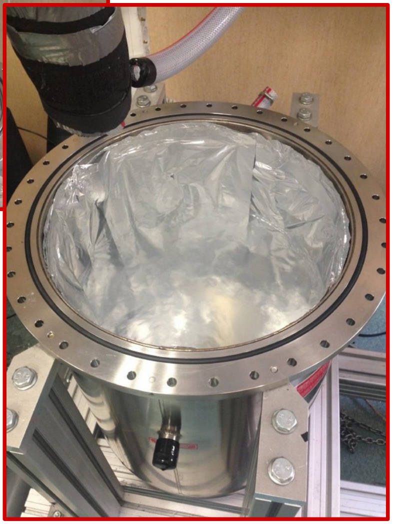
Experimental setup to characterize PMTs for WA105 experiment

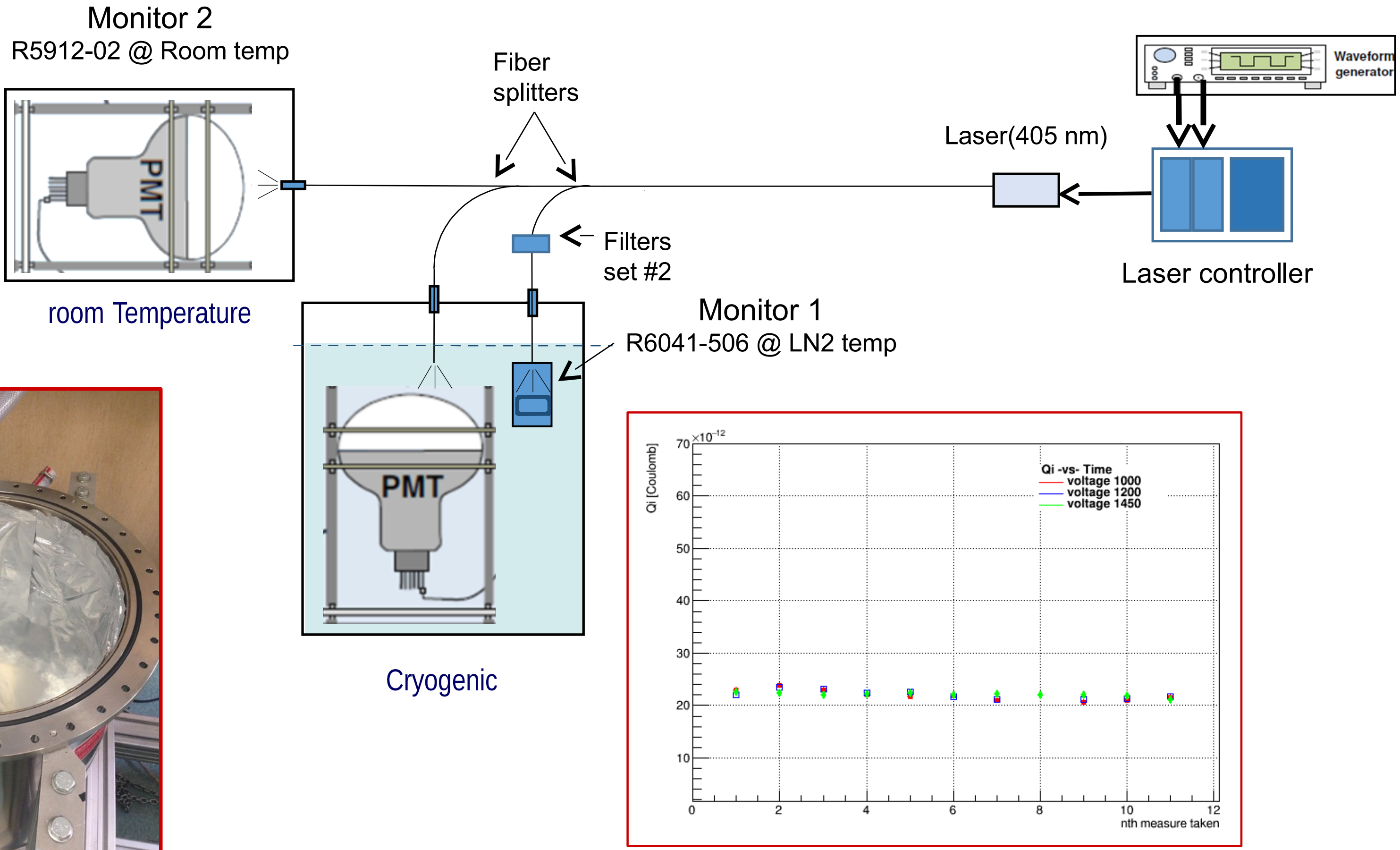


Hamamatsu R5912-02 mod 8" PMTs: tested in LAr condition, with excellent timing resolution.

Goal:

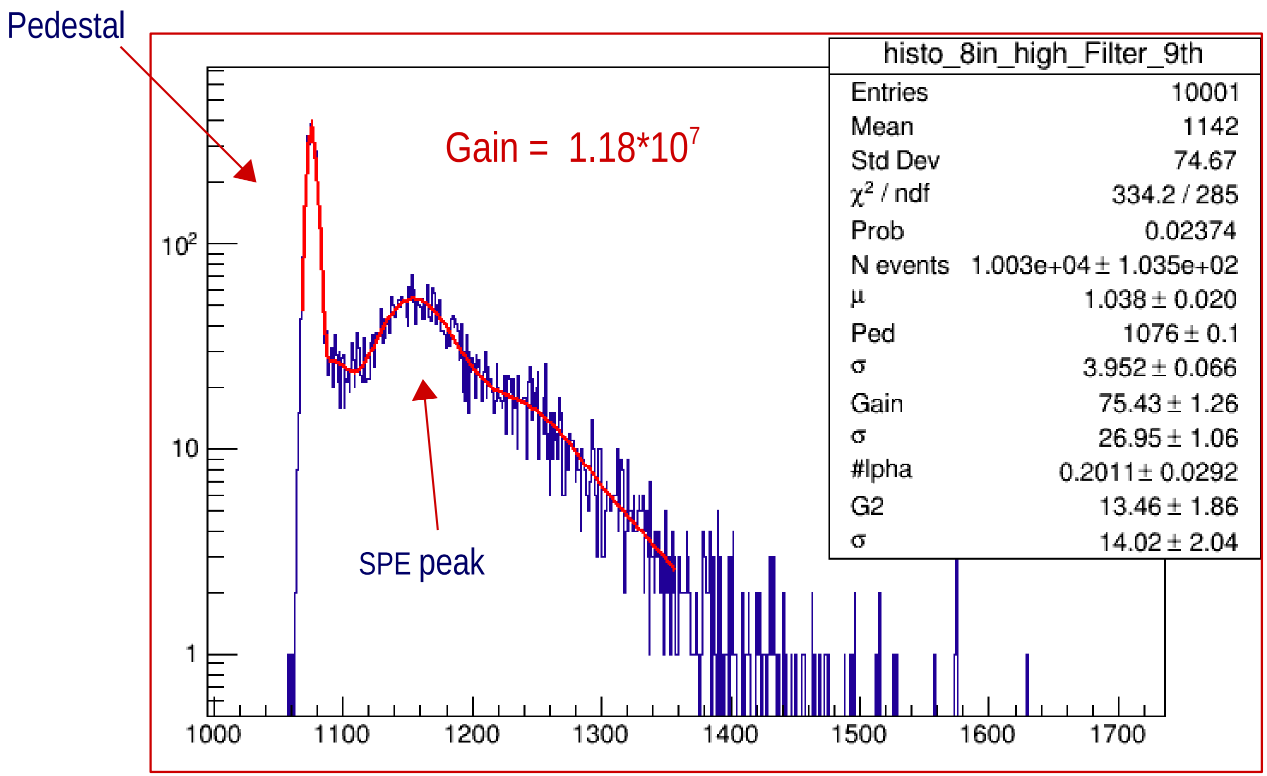
Comparison between two PMTs because in the final setup one of them will be at room temperature and the other will be in cryogenic condition. The results I'll show are related with the measurements taken at room temperature for both PMTs .





Quantities used for the PMTs characterzation

Gain calculation of the PMTs at different Voltages (e.g. here Voltage = 1200V) from the fit of the Single PhotoElectron distribution.



	1000V	1200V	1450V
Gain	$(2.08 \pm 0.02)*10^6$	$(1.18 \pm 0.02)*10^7$	$(9.35 \pm 0.18)*10^7$

Hamamatsu R5912-02 mod 8” inside

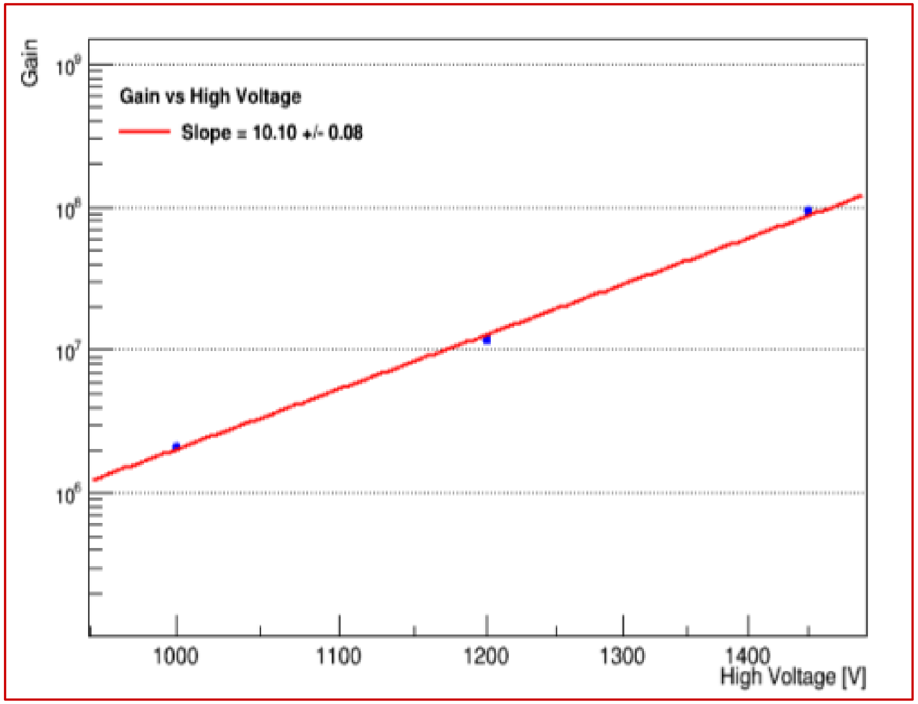
	1000V	1200V	1450V
Gain	$(1.70 \pm 0.02)*10^6$	$(1.26 \pm 0.01)*10^7$	$(1.00 \pm 0.02)*10^8$

Hamamatsu R5912-02 mod 8” outside

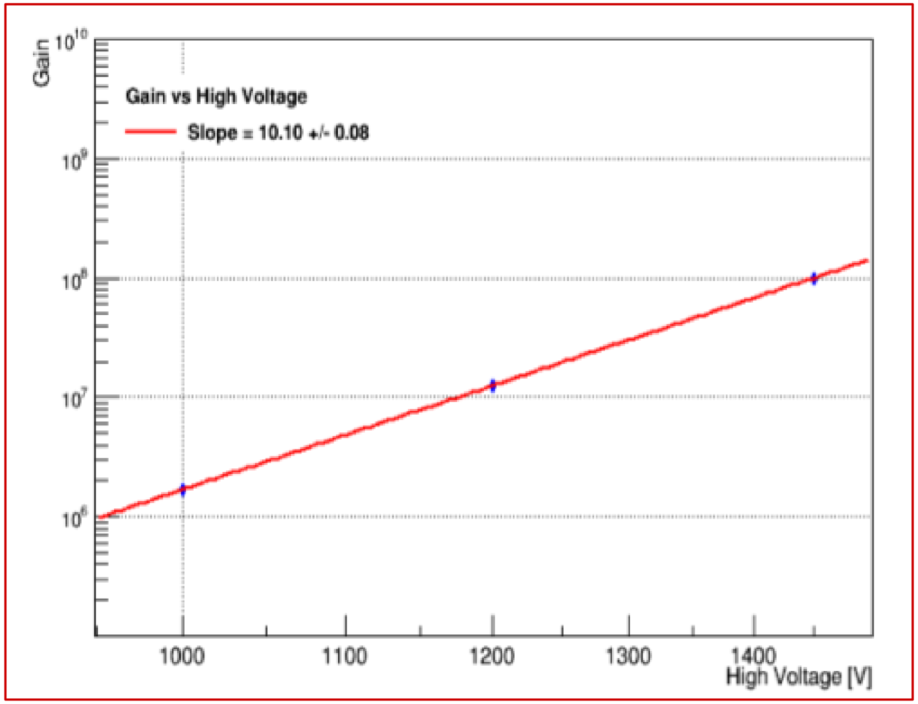
Gain vs Voltage applied to the PMT

Gain vs Voltage applied linearity ↔ because the power law $G = AV^{\alpha}$ is linear in a Log-Log scale

Results in agreement with the expected Hamamatsu results



Hamamatsu R5912-02 mod 8” inside



Hamamatsu R5912-02 mod 8” outside

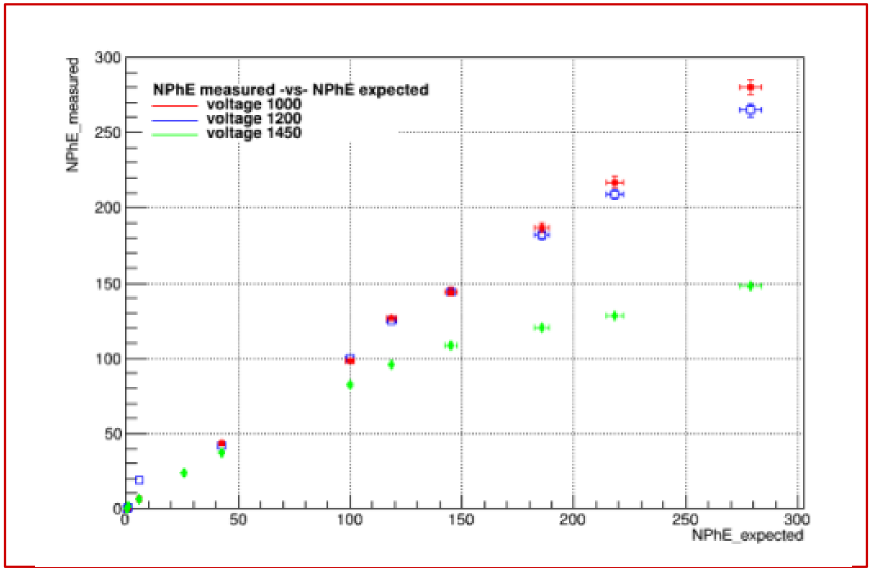
Number of PhotoElectrons detected and linearity response

Response linearity checked in terms of number of photoelectrons detected when a different amount of light arrives on the surface of the PMTs.

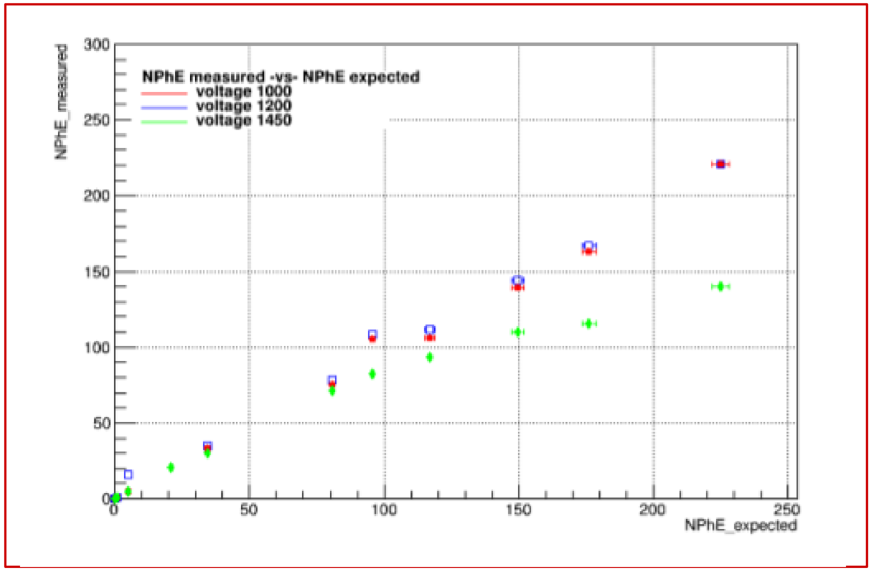
Transmission Factor of used filters

Filter 1 = 83.8%
Filter 2 = 65.6%
Filter 3 = 55.8%
Filter 4 = 43.6%
Filter 5 = 35.7%
Filter 6 = 30.1%

Filter 10 = 12.8%
Filter 13 = 7,7%
Filter 20 = 1.6%
Filter 30 = 0.2%
Filter 40 = 0.03%



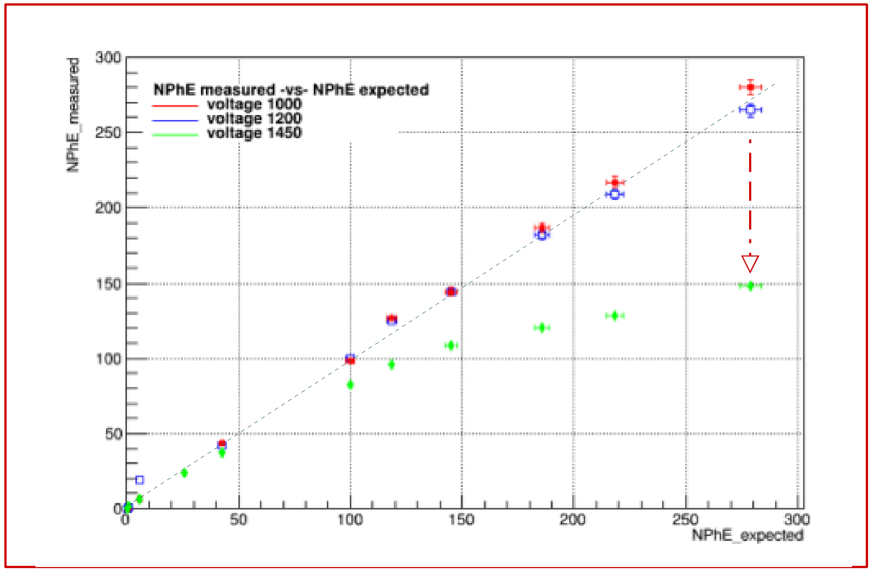
Hamamatsu R5912-02 mod 8” inside



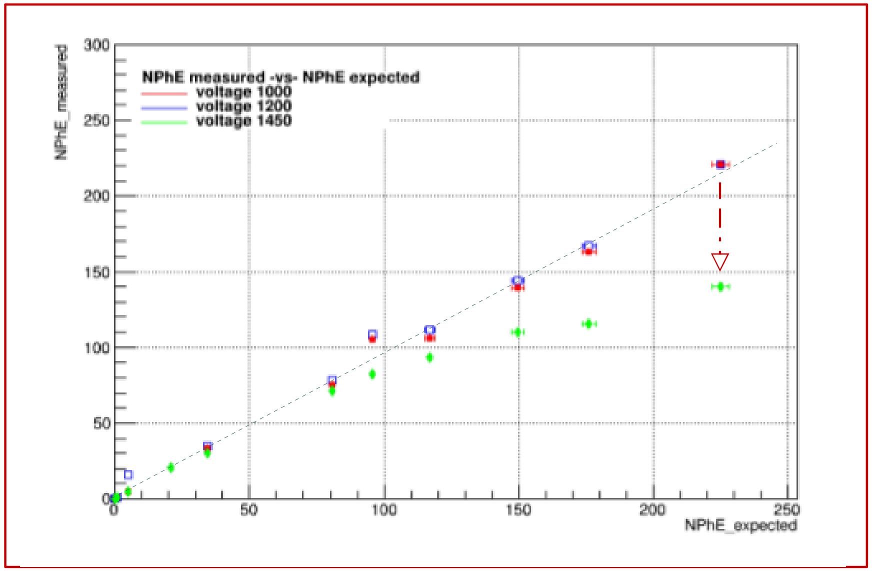
Hamamatsu R5912-02 mod 8” outside

Number of PhotoElectrons detected and linearity response

Hamamatsu R5912-02 mod 8" inside



Hamamatsu R5912-02 mod 8" outside



Studies done on the linearity shows that:

- linearity response of both two PMTs is conserved at least up to ~ 180 PEs in the normal gain voltage condition (1000 Volt and 1200 Volt applied ↔ G ~ 10^6 or 10^7)

- if the gain voltage increases (1450Volt ↔ G ~10^8), linearity response is preserved up to a lower n. of PEs (~ 50 PEs)
  - in this case the maximum deviation from this linearity reaches about the 47% - 37% for the thinest filter (the one which let inject more light)

Conclusions

- WA105 experiment is done by a 3x1x1 m^3 prototype 6x6x6 m^3 DLAr detector whose goal is to s to prove the dual phase liquid argon technology for large-scale detector at the kton scale (DUNE).

  - The CIEMAT group is in charge of the design, test, installation and calibration of the photodetection system

- Hamamatsu R5912-02 mod 8" PMTs that will be installed in 6x6x6 m^3 detector have been characterized at room temperture:

  - the gain linearity is studied when different voltage operation values have been used → the rsults are in agreement with Hamamatsu results for these PMTs

  - the response in terms of n. of PEs detected by the PMTs is linear in normal gain voltage condition (G~ 10^7) up to 180 n. of PEs collected by the PMTs

  - the linearity response is preserved only up to 50 PEs when PMTs are working in higher voltage condition respect to the normal ones (Voltage applied ~ 1450 Volt and G~ 10^8)

...thank you!

Backup Slides

<u>Basic concepts about PMTs</u>

Using a light source that gives a flux of photons that hit the photocathod,
- the number of photons is a Poisson distributed variable
- the conversion of photons into electrons and their collecton and amplification by the dynode system is a random binary process
- so, the number of collected photo-e at the anode is a Poisson distribution

Being mu = mean

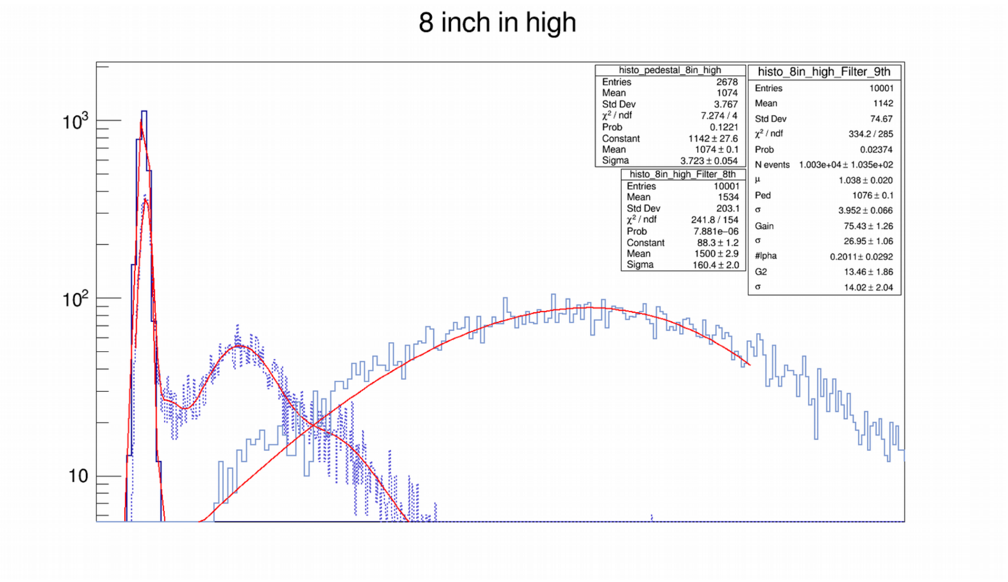
The number of PhE collected by the PMT is a Poisson distribution: $$P(n;\mu) = \frac{\mu^n \cdot e^{-\mu}}{n!}$$

Being mu the mean value of number of PhE and n the number of PhE observed. mu=mq is due to light source intensity <u>and</u> by the photocathode quantum efficiency

On the other hand, the response of a multiplicative dynode sys
related with charge collected by te PMT. The charge can be als
Q=ge.

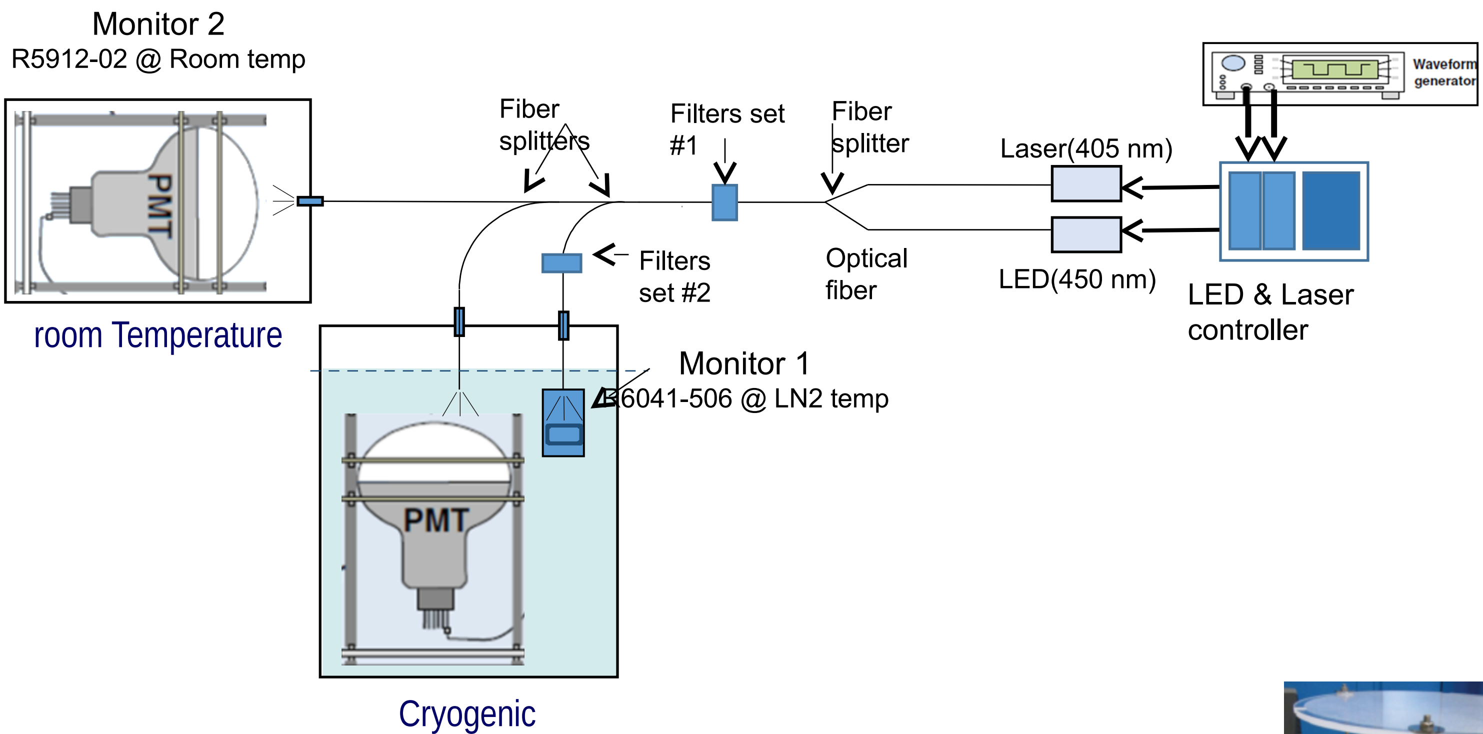
So, considering the PMT charge distribution it is possible to ca

<u>Background processes</u>
In a real PMT, also background process can generate addition
PMT.

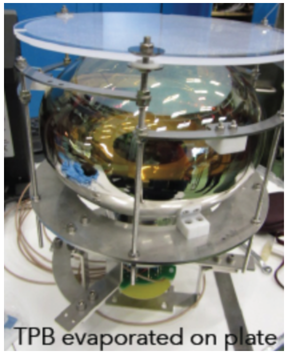


Experimental setup to characterize PMTs for WA105 experiment

Goal:
Comparison between two PMTs because in the final setup one of them will be at room temperature and the other will be in cryogenic condition.



Hamamatsu R5912-02 mod 8" PMTs: tested in LAr condition, with excellent timing resolution.



Number of PhotoElectrons detected and linearity response

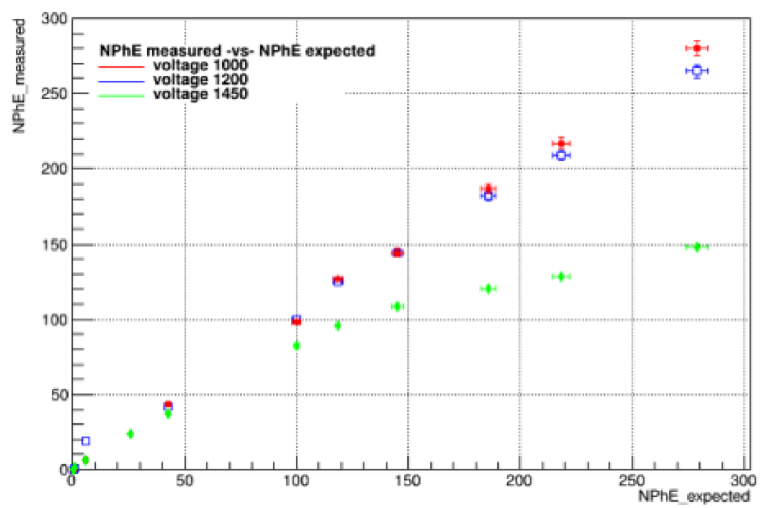
Response linearity checked in terms of number of photoelectrons detected when a different amount of light arrives on the surface of the PMTs.

Transmission Factor of used filters (x axis in the plot below)

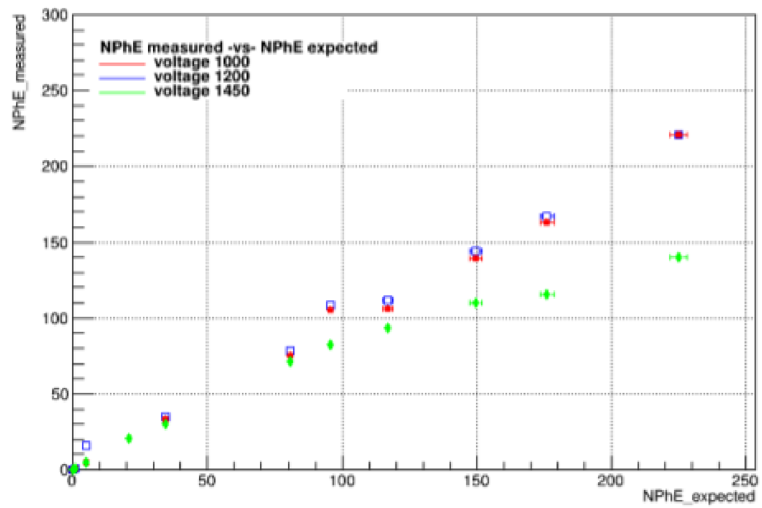
Filter 1 = 83.8%
Filter 2 = 65.6%
Filter 3 = 55.8%
Filter 4 = 43.6%
Filter 5 = 35.7%
Filter 6 = 30.1%
Filter 10 = 12.8%
Filter 13 = 7,7%
Filter 20 = 1.6%
Filter 30 = 0.2%
Filter 40 = 0.03%

When a SPE distribution is available the number of PEs is computed directly from the fit; while when more than one PEs is collected the n. of PEs is obtained dividing the charge (when the pedestal contribution is subtracted) by the gain.

$$\mathrm{N.PhEexpected} = \frac{\mathrm{N.PhE_{ref}}}{\mathrm{TF_{ref}}}.\mathrm{TF_i}$$



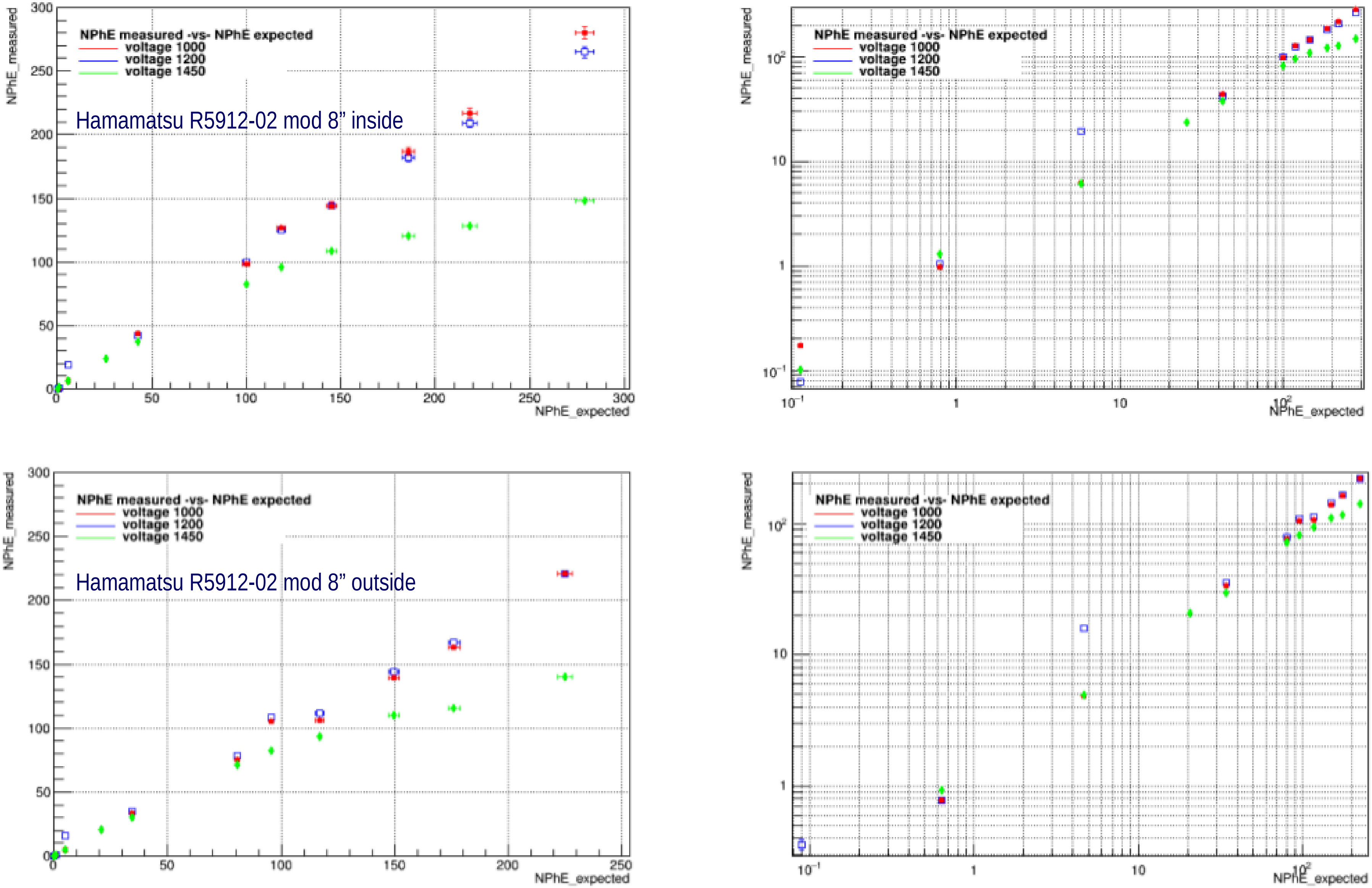
Hamamatsu R5912-02 mod 8” inside



Hamamatsu R5912-02 mod 8” outside

Number of PhotoElectrons detected and linearity response

Response linearity checked in terms of number of photoelectrons detected when a different amount of light arrives on the surface of the PMTs.



Number of PhotoElectrons detected and linearity response

Response linearity checked in terms of number of photoelectrons detected when a different amount of light arrives on the surface of the PMTs.

When a SPE distribution is availeble the number of PhE is computed directly from the fit; while when more than one PhE is collected the n. of PhE is obtained dividing the charge (when the pedestal contribution is subtracted) by the gain.

Transmission Factor of used filters
(x axis in the plot below)

Filter 1 = 83.810837
Filter 2 = 65.5973595
Filter 3 = 55.7853445
Filter 4 = 43.597176
Filter 5 = 35.627314
Filter 6 = 30.0486935
Filter 10 = 12.828397
Filter 13 = 7,747539
Filter 20 = 1.7505915
Filter 30 = 0.238925
Filter 40 = 0.0331625