Light Detection System Status

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On behalf of CIEMAT and IFAE

Status PMT Acquisition

- 20 (IFAE) + 20 (CIEMAT) PMTs aquired from Hamamatsu
- Order was placed summer 2016
- All PMTs were delivered December 2016 to CIEMAT

PMT Characterization Tests

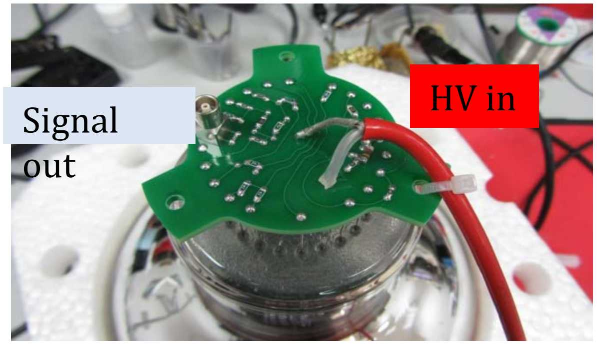
1. **Validation** of PMT base and detailed characterization of PMT response at warm and cold

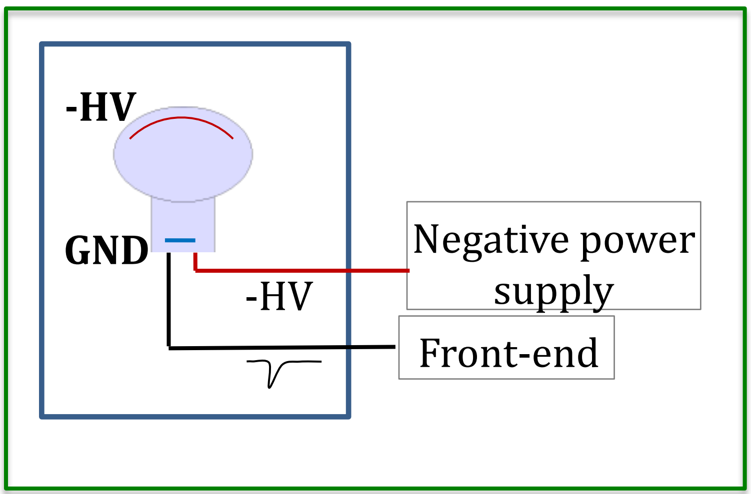
2. **Characterization** of the 40 PMTs before their installation in the 6x6x6 m^3 detector

Different experimental setups are needed

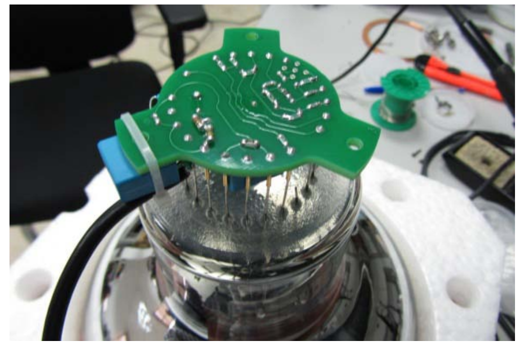
PMT Voltage Divider Options

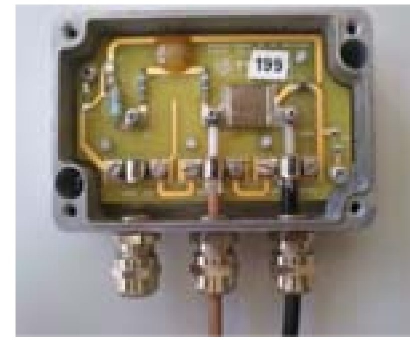
A) 2 cable base (negative HV)

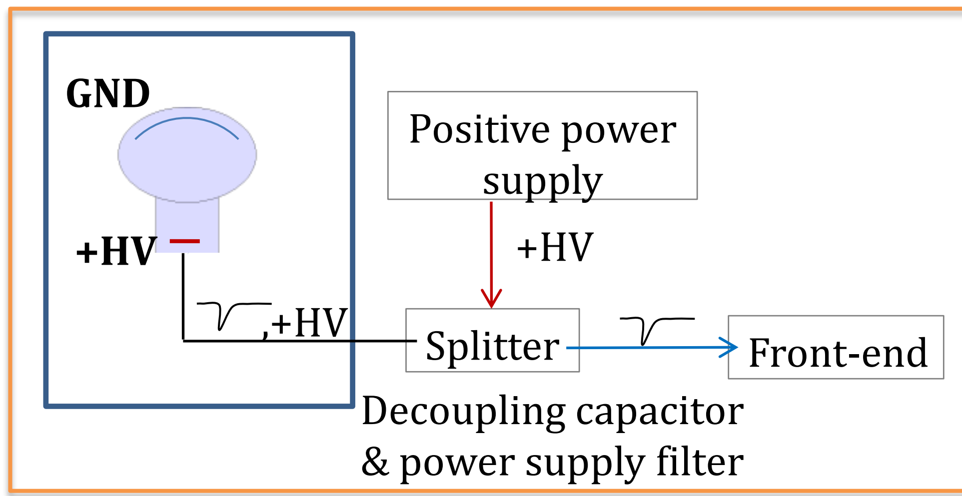




B) 1 cable base (positive HV) + ext. splitter



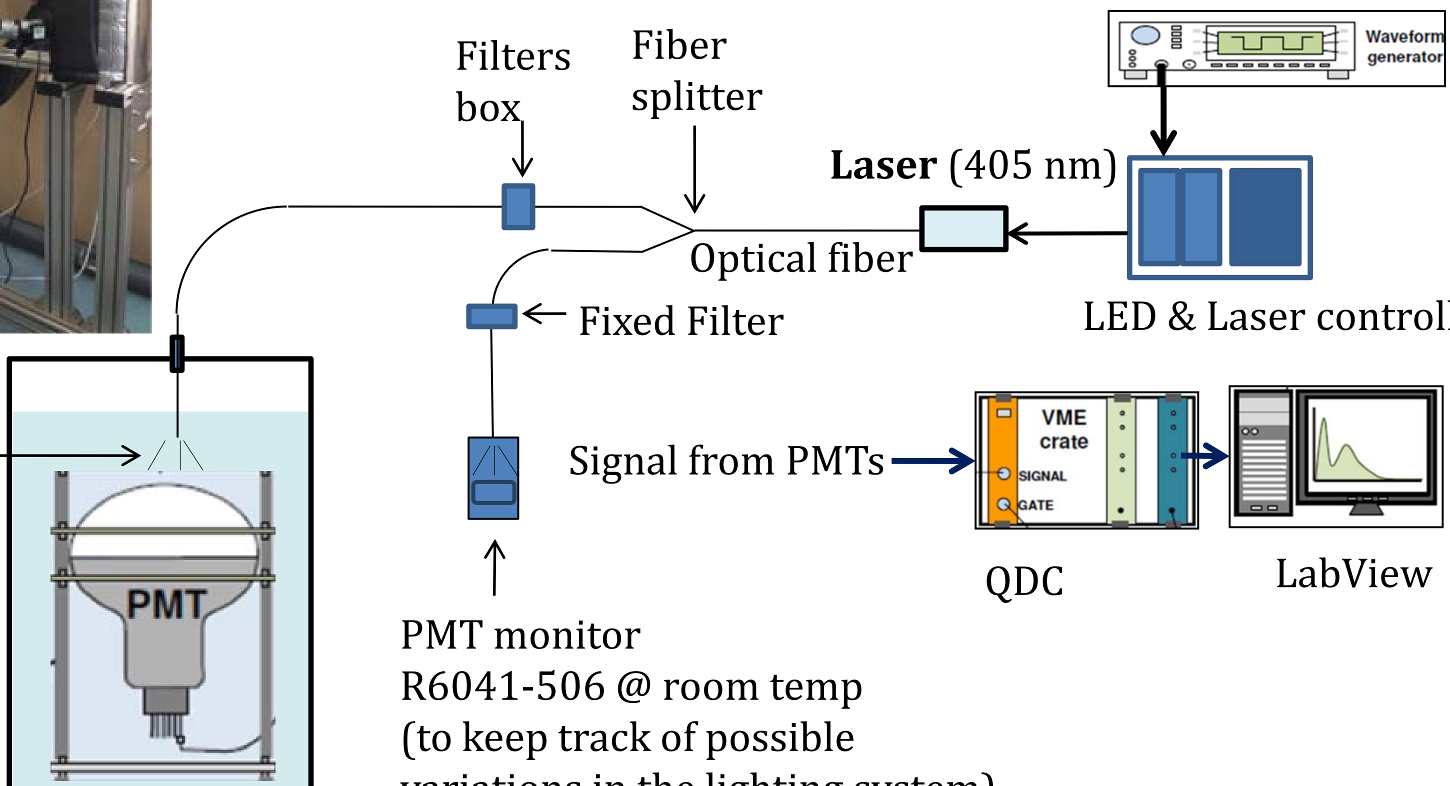




Main difference: The splitter in the PB decreases the effective voltage by a small percentage, but reduces the number of cables.

Experimental Setup@CIEMAT

- Designed to test one PMT immersed in LN2 with a configurable amount of light



PMT Characterization@CIEMAT

Dedicated tests to optimize the PMT base and understand the PMT response at cryogenic (CT) and room temperature (RT)

Measurements:

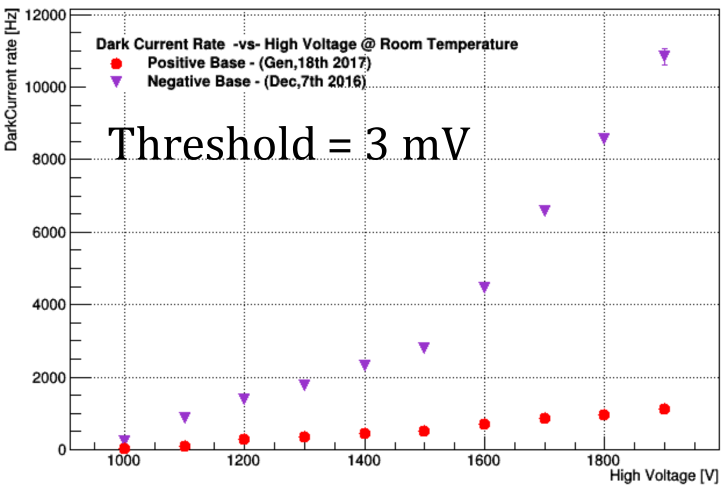
- Gain → to find the optimum operating HV
- Dark current rate → to reject noisy PMTs
- Light Linearity → to define the dynamic range in terms of photoelectons
- Frequency linearity → at high frequency the PMTs response is Saturated

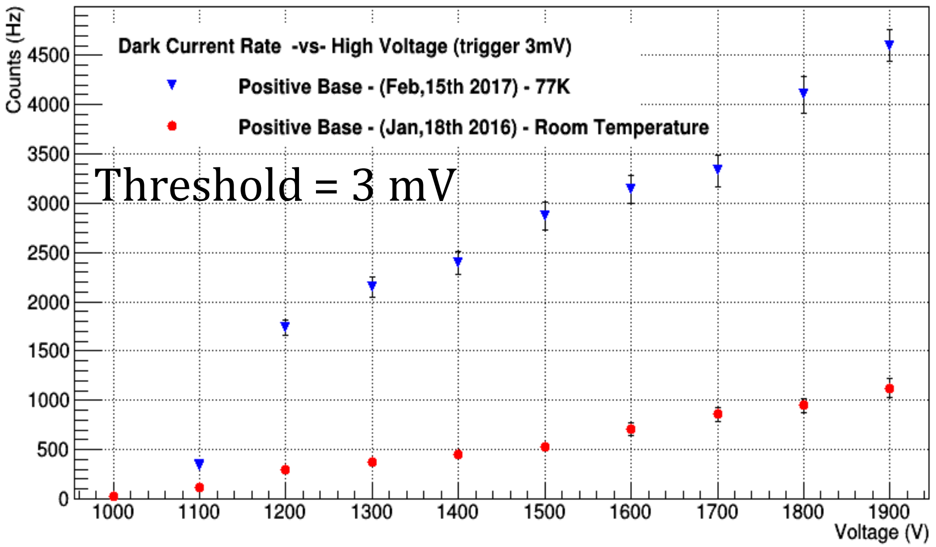
Configurations:

- Two different bases: Positive Base (PB), Negative Base (NB)
- Comparison of the behaviour at RT and CT

PMT Characterization@CIEMAT

Dark current (DC)

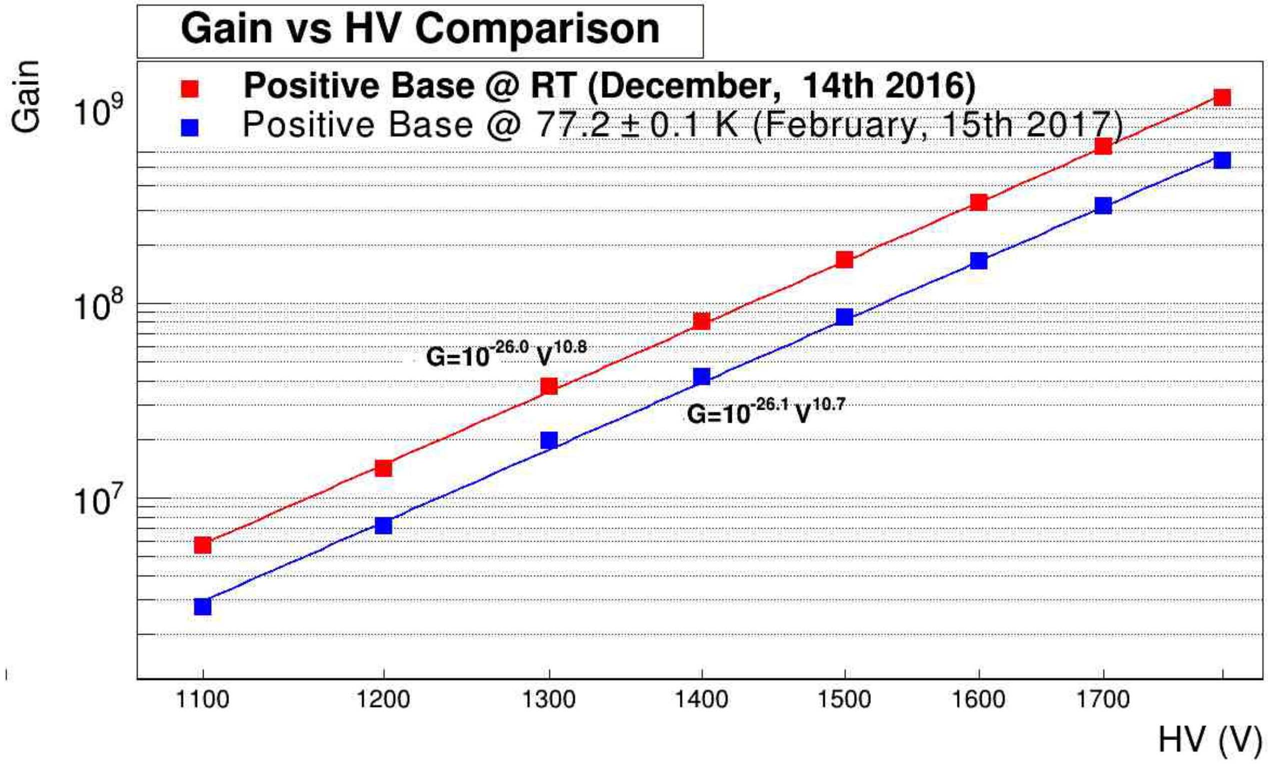




- Positive base lower DC than negative base at RT
- DC at CT higher than at RT

PMT Characterization@CIEMAT

Gain vs HV



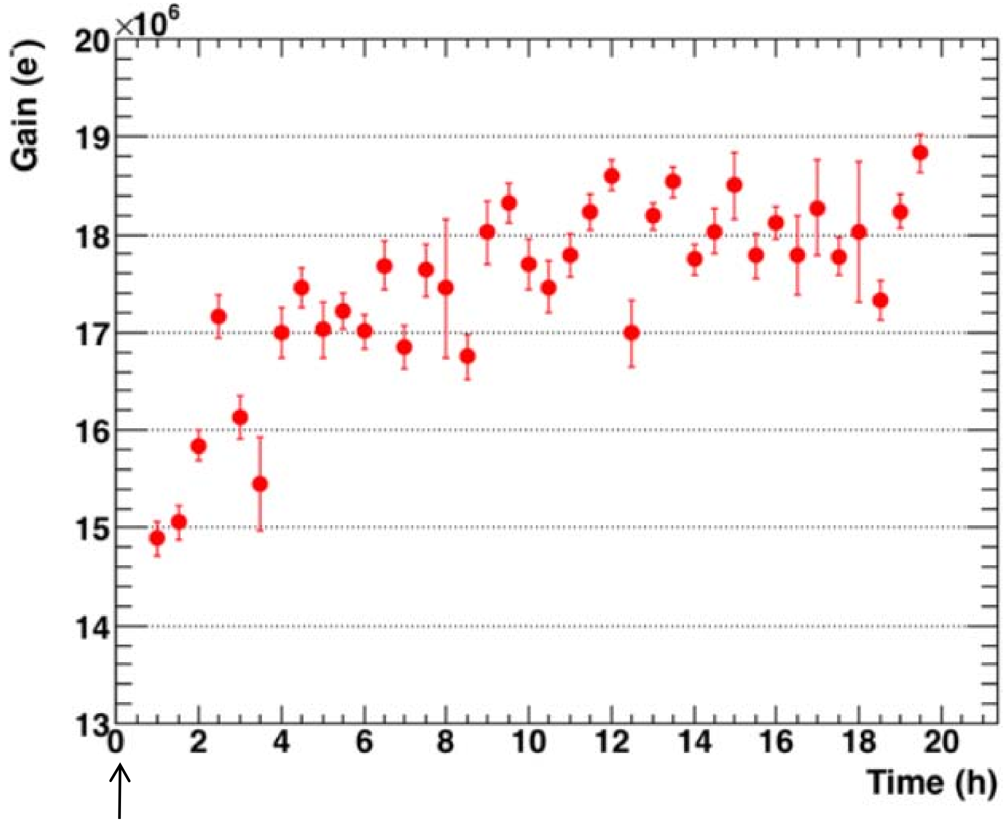
- Gain at CT lower than at RT

PMT Characterization@CIEMAT

Gain vs time at CT

Gain: ~$18 \cdot 10^6$ e^-
However, gain after applying 1900 V: ~$16 \cdot 10^6$ e^-

- takes >15 h to get back to ~$18 \cdot 10^6$ e^-
- Effect not observed at RT

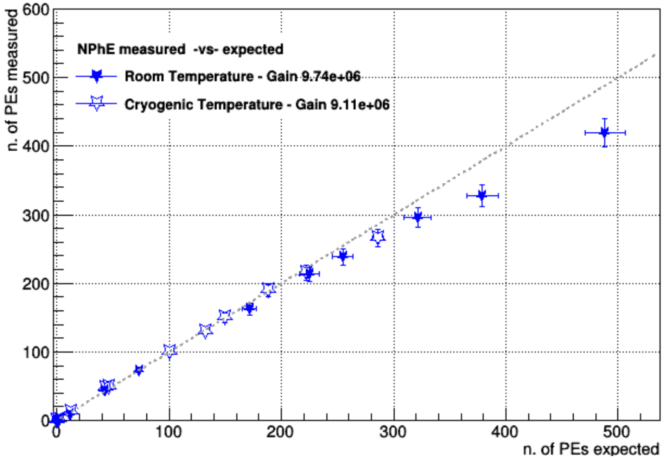


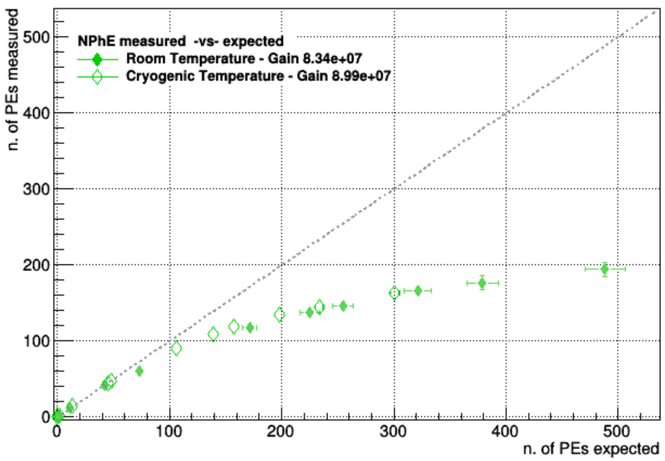
3 h after applying 1900 V

PMT Characterization@CIEMAT

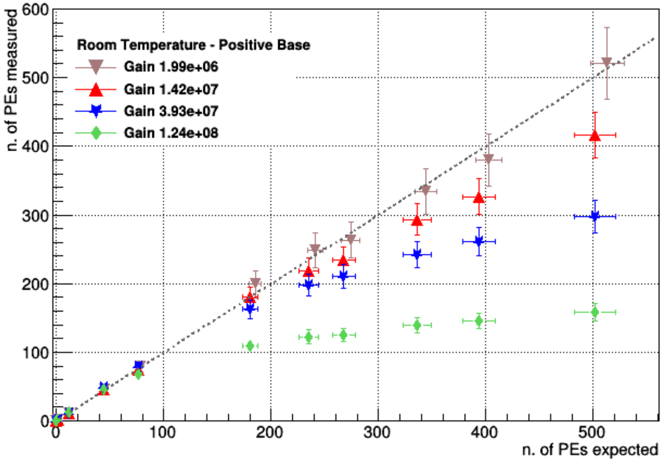
Linearity with incident light

- No difference observed comparing RT to CT



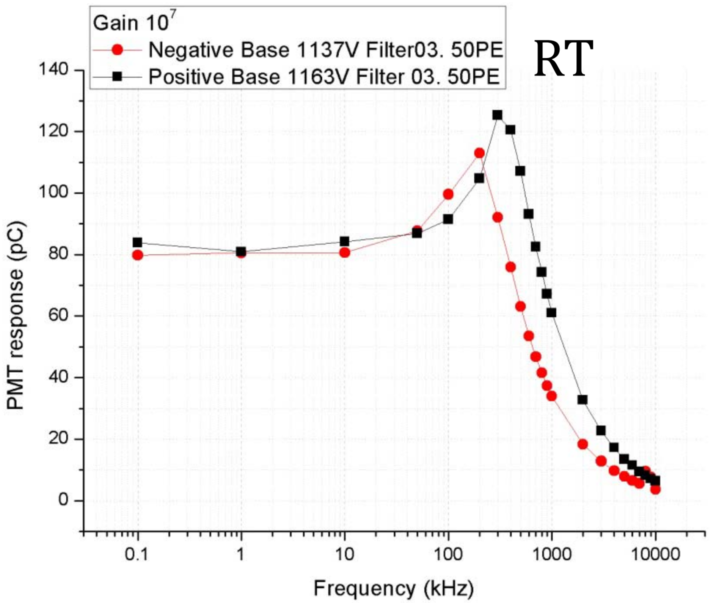


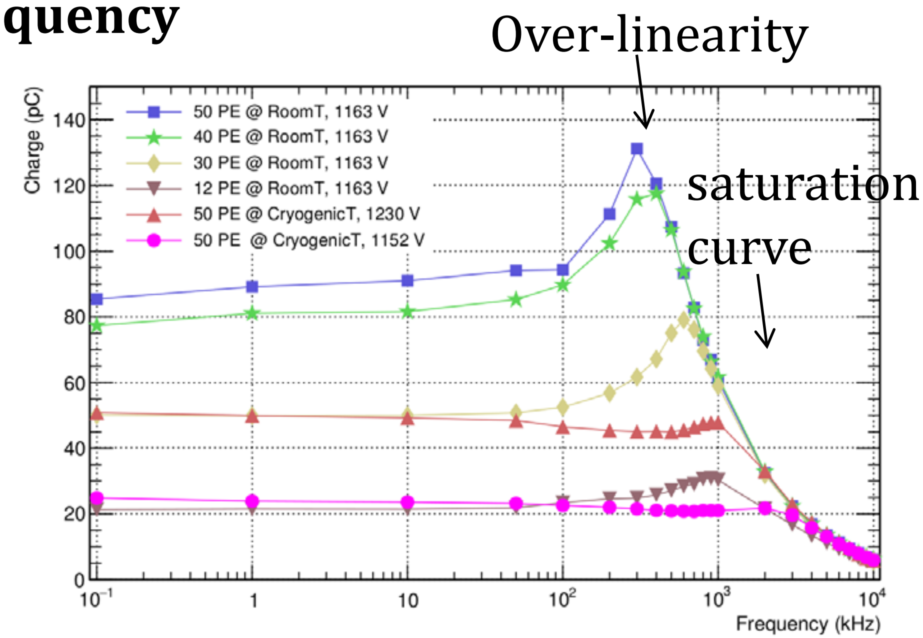
- Light linearity loss with ~250 phe at 10^7



PMT Characterization@CIEMAT

PMT response vs pulsed **light frequency**

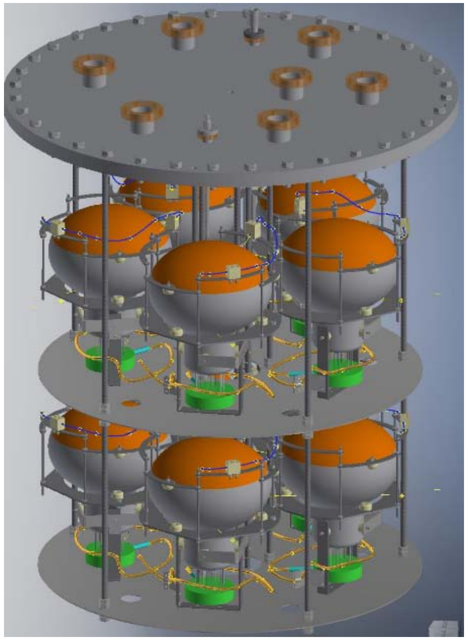


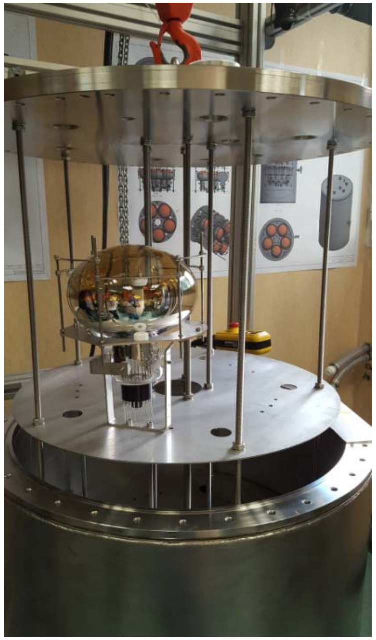


- There is a characteristic saturation curve.
- Over-linearity effect is observed previous to the PMT saturation.
- Negative base saturates at lower frequency than the positive base.
- High frequency decreases the PMT gain at cryogenic temperature.

Setup for Testing 40 PMTs@CIEMAT

- New vessel with capacity for 10 PMTs (300 litres)
- Cryogenic system is almost ready
- Final mechanical support being assembled into PMTs
- Characterization and validation of the 40 PMTs at room and cryogenic T with the final mechanical support and HV divider base (to start April)



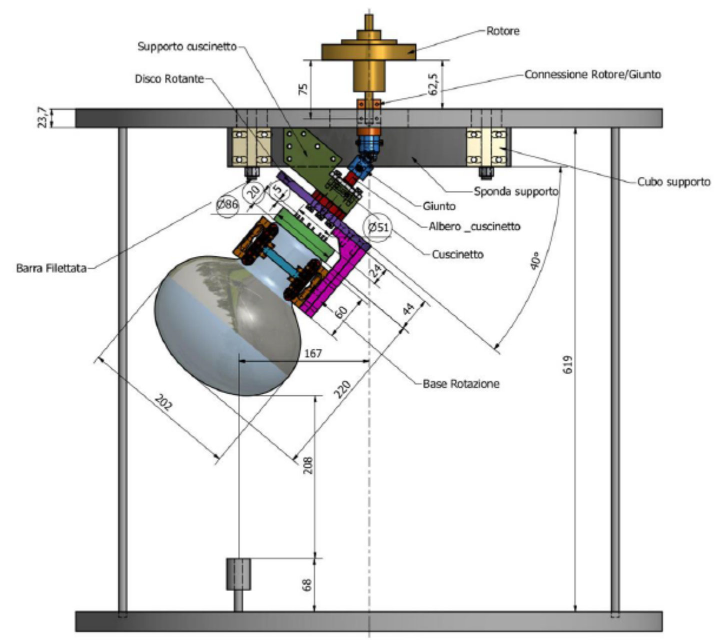



Assembly & Testing Procedure

	TIME
PMTs mounting into the support (clean room). Steps: • Support and PMT assembly • PMT base and cable soldering • PMT transport box modification to accommodate PMT+ support • PMT storage into the box with double black bag	2 weeks (on-going)
Tests at RT (GAr to test the PMT bases). Measurements: • Gain vs HV • Dark current vs HV • PMT Pulse shape (with the scope) for $G = 10^7$	2 weeks (10 x 2,5 d)
Cryogenic tests (LN2). Measurements: • - Gain vs HV • - Dark current vs HV • - PMT Pulse shape (with the scope) for $G = 10^7$	4 weeks (10 x week, sequence to be repeated Firday to Friday)

TPB Coating

- Characterization@CIEMAT of bare PMTs by IFAE and CIEMAT groups
- Shipping to CERN of tested and characterized PMTs beginning of September 2017
- Coating of PMTs with WA104/ICARUS facility

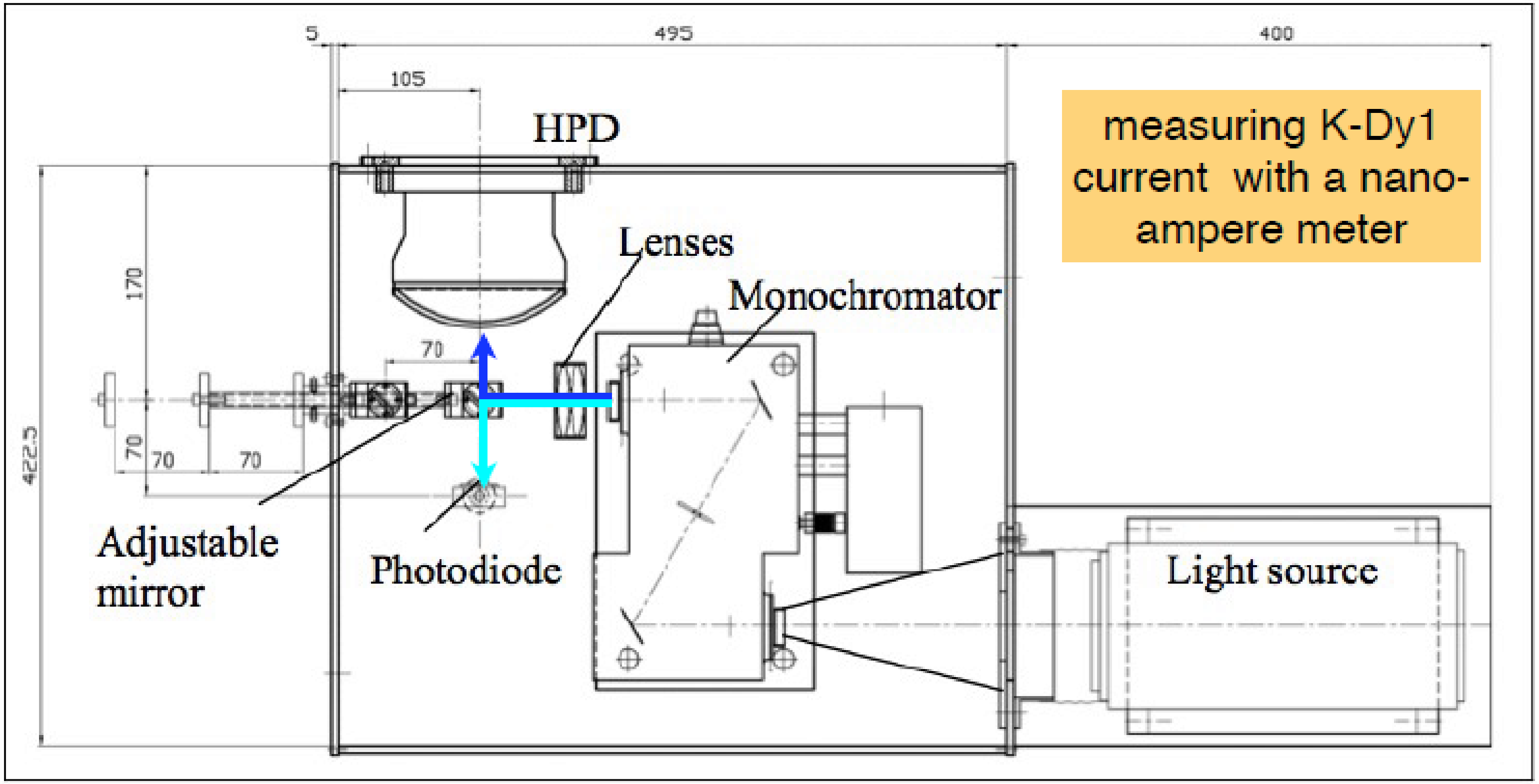


TPB Coating

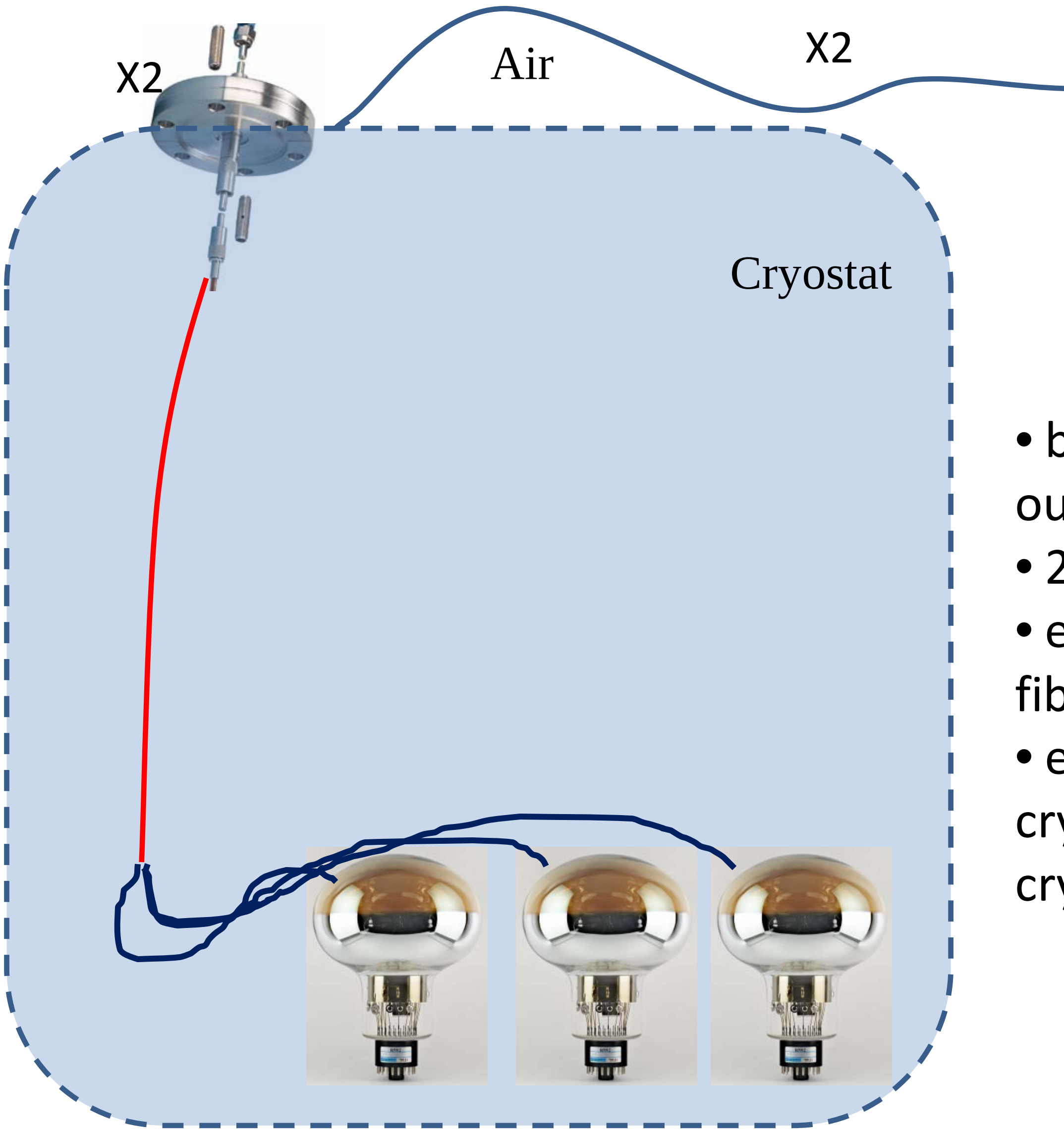
- System prepared for direct coating
- No experience with PMMA coating
- 1 person needed from our side for about 6 weeks (4 weeks for 40 PMTs + 2 weeks for training)
- Facility available in autumn (Sep to Nov 2017)
- No setup available for PMT testing after coating but space to install one from our side (“black box” + power supply) for DC measurements
- Quality for ICARUS was excellent
- Evaluating the possibility to use Qeff setup at CERN to test 4 to 8 coated PMTs

TPB Coating

- Same setup as used for 311 PMTs
- In contact with T. Schneider (CERN) to see if setup available and costs

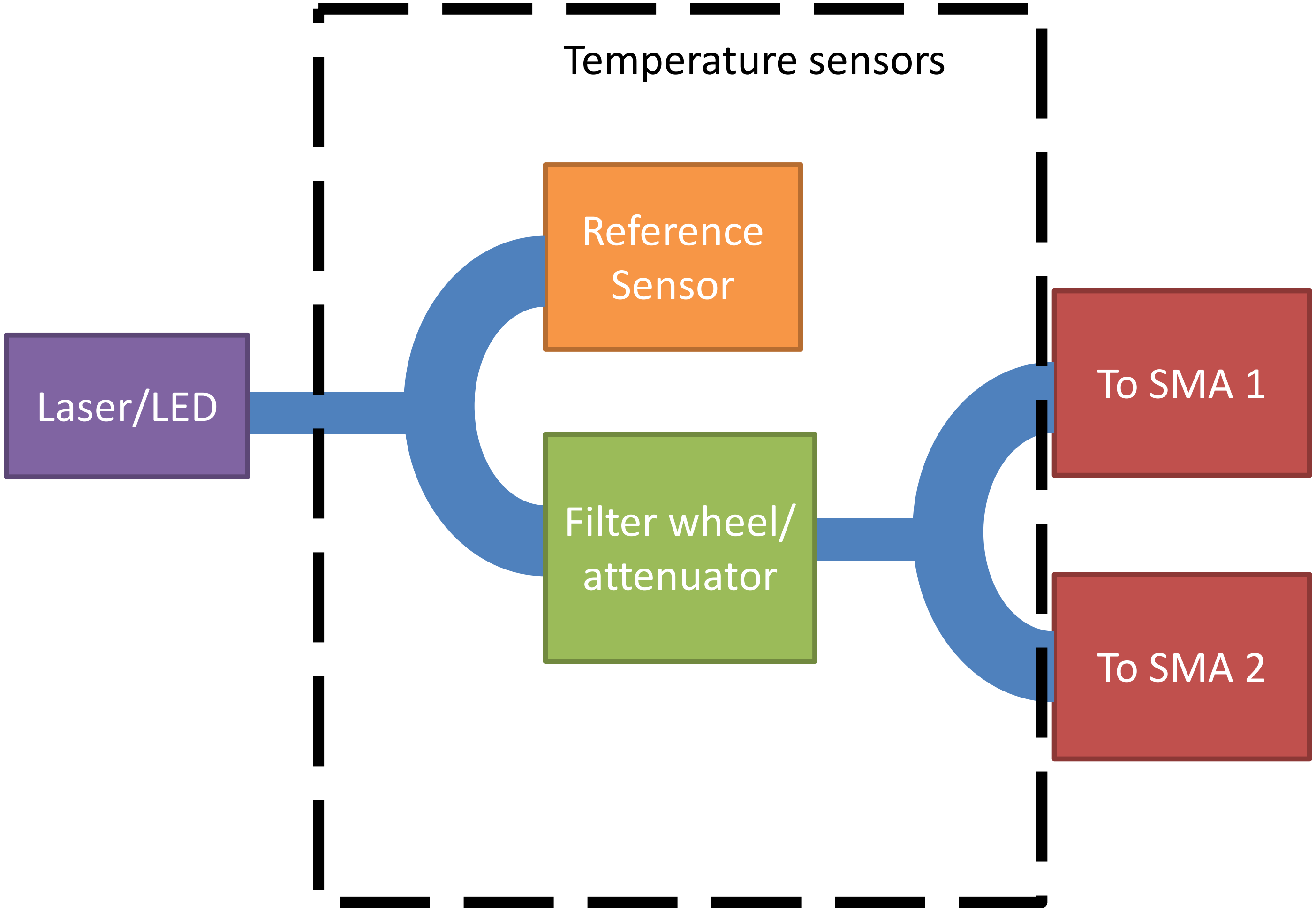


Light Monitor System



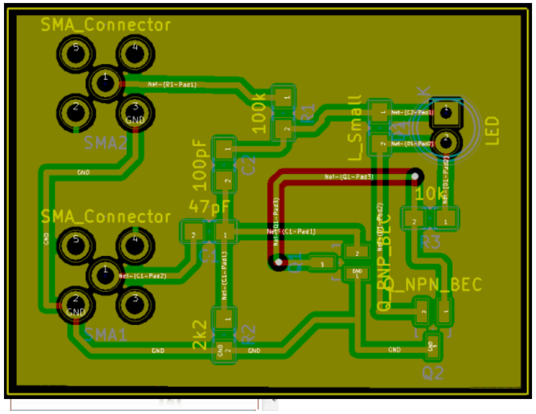
- black box with light source outside of cryostat
- 2 fibers going to cryostat
- each splitting into 20 micro fibers (~100 μm thick)
- either directly on top of cryostat or at bottom of cryostat

Light Monitor System



Light Monitor System

- commercial enclosure from Thorlabs
- includes small bread board e.g 30x45 cm^2
- only need to add feedthroughs
- Light source:
  - Laser (408 or 450 nm) => 30-40 ns pulses
  - LED with Kaputschinsky driver => <=10 ns pulses

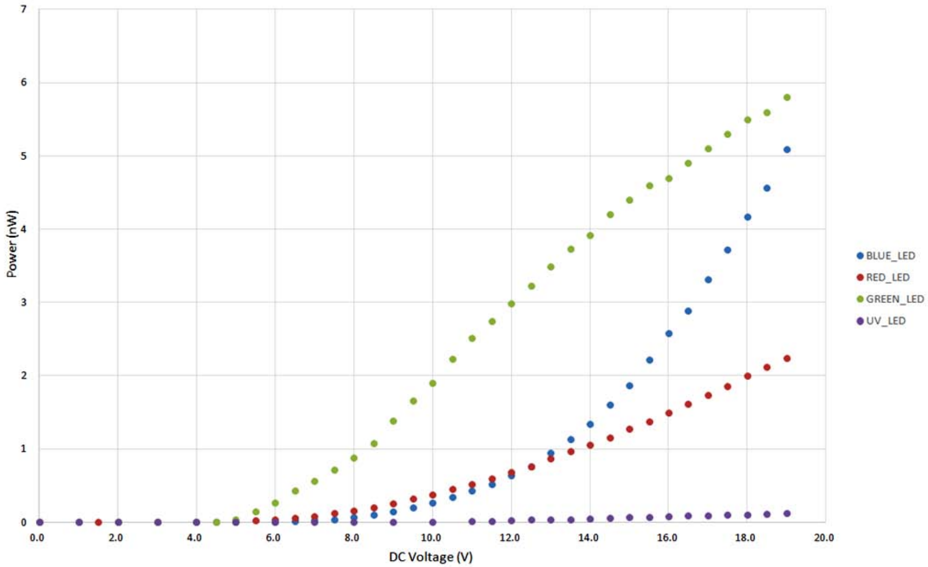


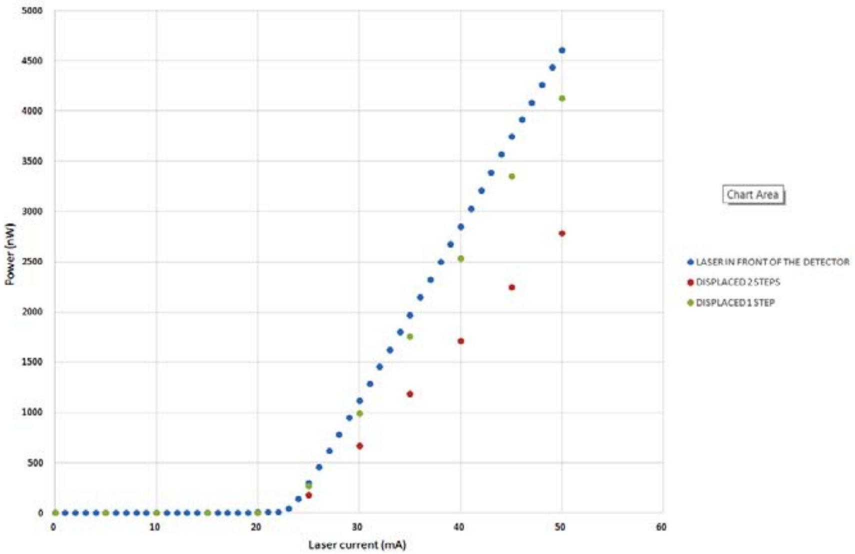
Matching Products in 405 - 488 nm Pigtails

Item #	Info	Wavelength	Power (Typ.)[a]	Typical/Max Drive Current[a]	Pin Code[b]	Package	Compatible Socket	Wavelength Tested	Recommended Mount(s)	Recommended Driver
LP405-SF10	i	405 nm	10 mW	50 mA / 60 mA	B	Ø5.6 mm SM Pigtail, FC/PC	S7060R[c]	Yes	LDM9LP or CLD1011LP	ITC4001[d]
LP405-SF30	i	405 nm	30 mW	100 mA / 150 mA	G	Ø5.6 mm SM Pigtail, FC/PC	S7060R[c]	Yes	LDM9LP or CLD1010LP	ITC4001[d]
LP406-SF20	i	406 nm	20 mW	75 mA / 100 mA	G	Ø5.6 mm SM Pigtail, FC/PC	S7060R[c]	Yes	LDM9LP or CLD1010LP	ITC4001[d]
LP450-SF15	i	450 nm	15 mW	85 mA / 120 mA	E	Ø9 mm SM Pigtail, FC/PC	S8060 or S8060-4	Yes	LDM9LP or CLD1010LP	ITC4001[d]

Light Monitor System

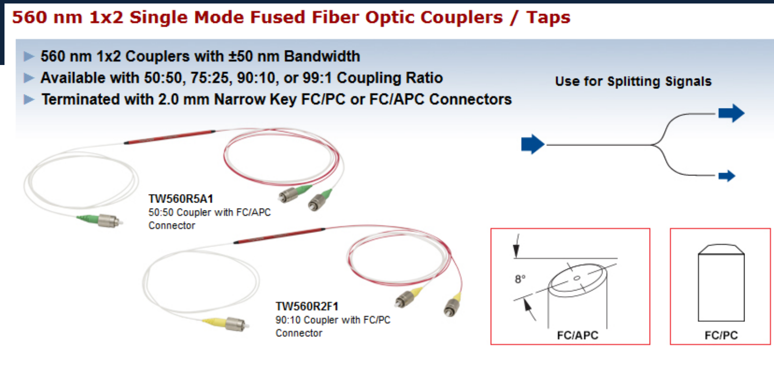
- Light sources available at IFAE for tests
- Characterization of light sources ongoing at IFAE
- LED tested already in pulsed mode
- Laser in constant current too
- Laser pulses of 30 ns width measured with PMT
- Detailed analysis of laser data in pulsed mode ongoing





Light Monitor System

- Beam splitler based on fiber coupler from Thorlabs (ordered)
- Reference light source (already at IFAE):
  - Powermeter (default if sensitive enough for pulsed mode)
  - PMT or SiPM (alternative)
- Multi-bundle fiber ordered and delivered this week to IFAE, further tests at CIEMAT:
  - Mechanical / robustness with the final mounting
  - Attenuation / Maximum light transmission
  - Light distribution over the different fibers
  - Long terms stability
  - Direct coupling to feedthrough or at bottom of cryostat?



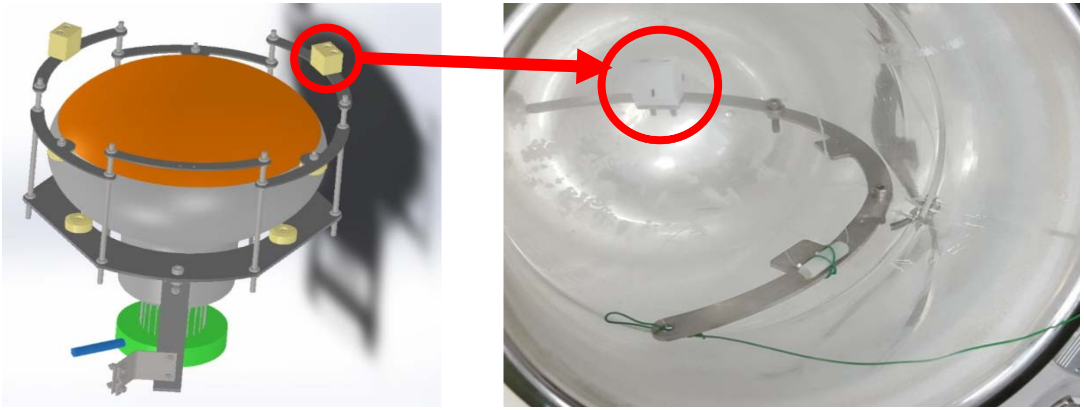
Light Monitor System

Single fiber testing at LN2 on-going at CIEMAT

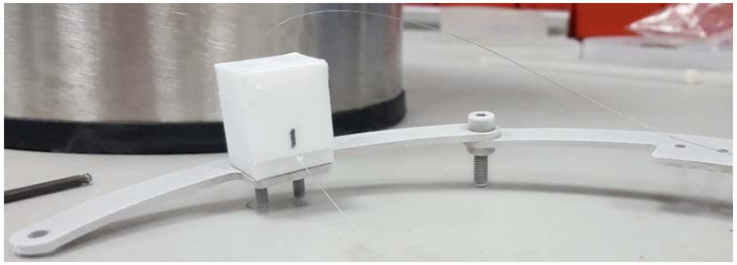
- **Fiber Holder Cryogenic Tests**

  Goal: check that the fibers stay in place at cryogenic temperature.

  Two configuration tested: one as it is, and the other, with a groove and a strip of Teflon → Both worked fine.



The fiber remains in the same position as before being submerged in LN2 and the light transmission looks fine.



We plan to measure if there is any light loss due to mechanical stress

Light Monitor System

- **Connector performance**

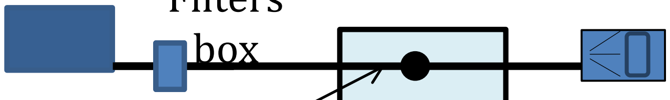
  Goal: Decide if the bundle at the bottom of the detector or directly attached to the flange at the top.

  Measurement: Study the relative light loss due do adding an extra connector (on-going).

  Preliminary results:

  Big light loss observed, studying systematics.

  Will measure it also with a power sensor



- **Next:** Characterize the bundle and new connectors to determine the light output difference among fibers (bundle ordered).

Summary I

- **All 40 PMTs acquired and delivered to CIEMAT**
- **Positive base will be used at the 6x6x6 m^3**
  - The light linearity is independent from the base used
  - the DC rate is smaller in the PB than in the NB
  - the over-linearity effect appears at higher frequency in the PB
  - less cables are needed in the installation
- **PMT characterized at RT and CT**
- **40 PMTs are at CIEMAT ready to be characterized**
  - Cryogenic setup almost ready with vessel for 10 PMTs
  - PMT base design final, at production phase
  - PMT mechanics: final support being assembled
- **Next steps**:
  - Testing of the 40 light detection units
  - Finalize the design of the light calibration system and testing
  - PMT shipment to CERN after Summer 2017
  - Installation and testing in the detector by end 2017

Summary II

- **TPB Coating:**
  - Coating will be done at ICARUS/WA104 setup at CERN
  - Direct coating of PMTs logical consequence
  - 1 person needed for 6 weeks
  - Investigating possibility to measure Qeff for 4-8 PMTs at CERN
- **Light Monitor System:**
  - Basic concept developed
  - Most parts available or delivered this month
  - First tests ongoing:
    - Light source characterization@IFAE
    - Fiber tests in cryogenics@CIEMAT
  - Postponed for the moment:
    - SMA fiber between black box and cryostat
    - Choice of filter/attenuator (needs first estimation of light output and end of fibers)
  - Dimensions still not possible to be defined
  - Aim: Deliver system by September/October 2017