PMT system production, QA and installation

Design Review of the Dual Phase ProtoDUNE

27 April 2017

Antonio Verdugo de Osa

On behalf of CIEMAT & IFAE

Summary

Production and QA of the PMT system components:

- Support structure
- PMT & HV divider Base
- Cabling
- HV splitters
- PMT Coating

Installation

- Procedure
- Planning

PMT Support structure status

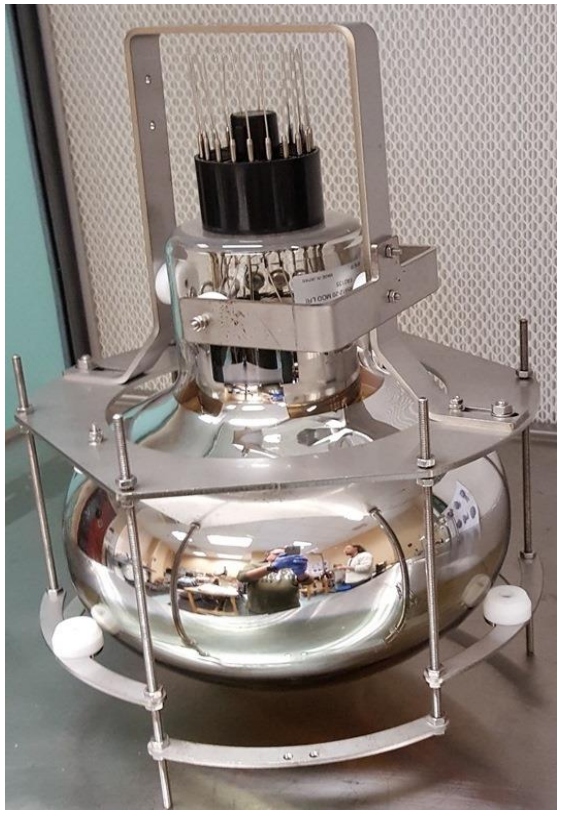
All parts were produced and cleaned in ultrasonic bath with isopropanol.

The assembly of the structures and PMTs has already been finished.

Production

Cleaning

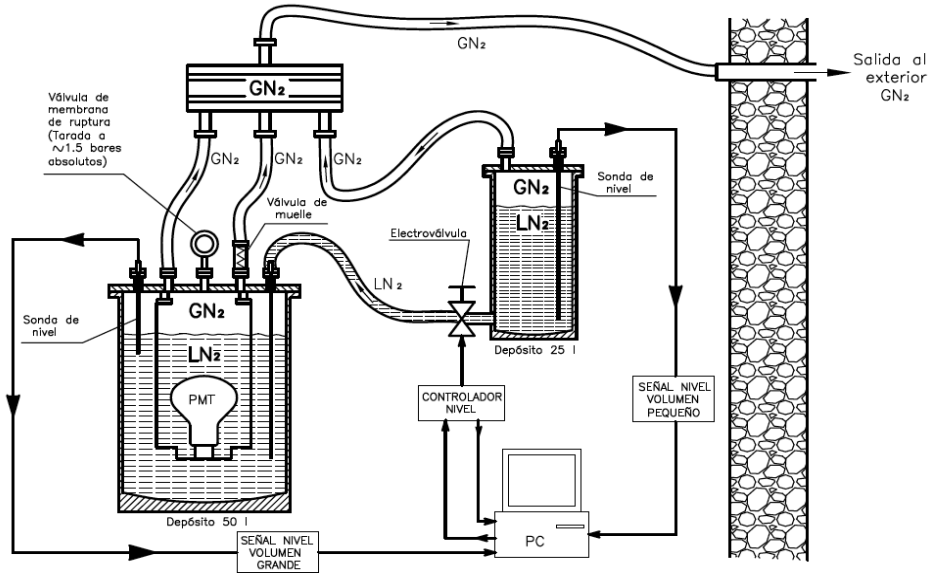
Storage



Mounting

PMT and support structure test

- ✓ We did a **pressure test** over one PMT with the support structure: The atmospheric pressure in Madrid is about 900mBar so we increase the absolute pressure to **1.9 Bar that is equivalent to about 7m of LAr pressure over the PMT**
- ✓ All the PMTs with the corresponding supports will be tested in LN2 before installation



PMTs

- 40 PMTs R5912-MOD-02 acquired from Hamamatsu (50% IFAE and 50% CIEMAT)
- All PMTs are already at CIEMAT (received at Dec-2016)
- PMT & base tests:

  Design validation tests (already finished). Intensive study to validate the new PMT base and to understand the different PMT behavior at room and cryogenic temperatures.

  Tests performed at room temperature and in LN2:

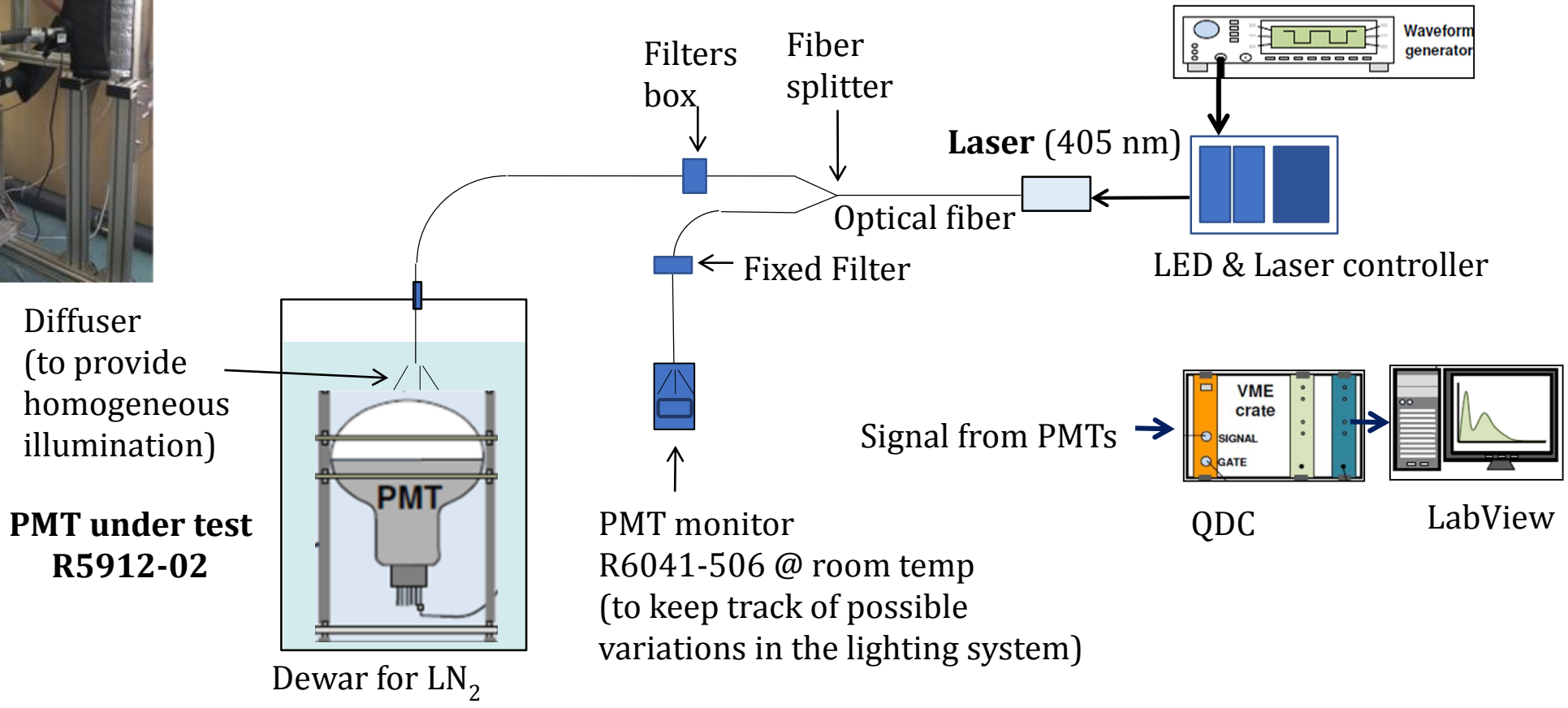
  - Gain vs HV
  - Dark current rate
  - Linearity vs light intensity
  - Linearity vs light pulses frequency

  Validation and characterization of all the PMTs to be installed:

  - Gain vs HV
  - Dark current rate vs HV
  - PMT Pulse shape (with the scope) for Gain = 10^7

Test setup for the Design Validation

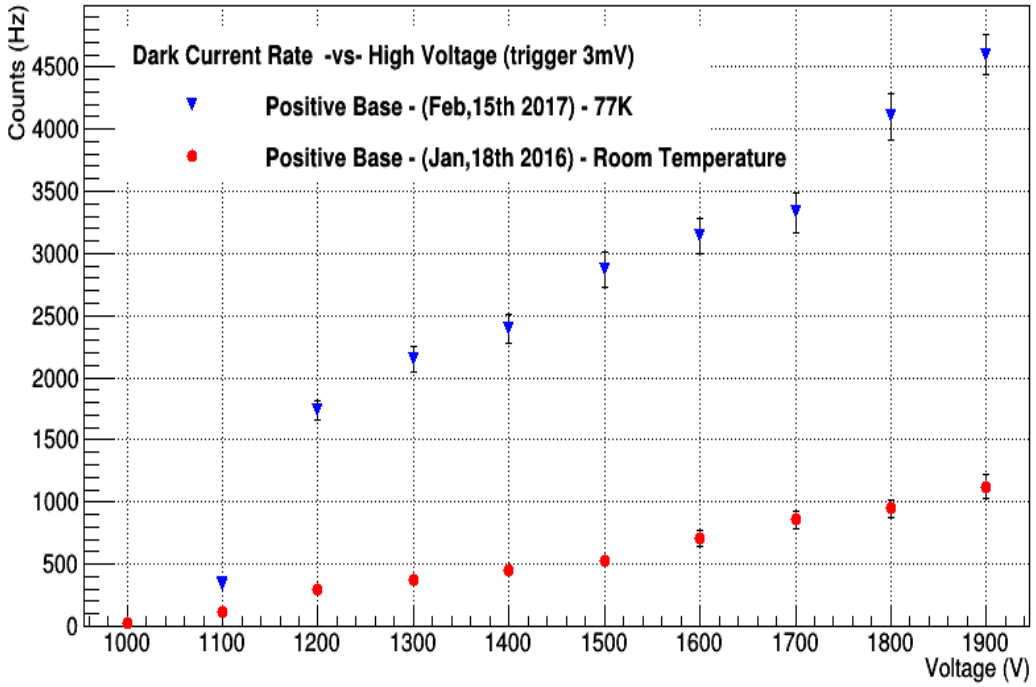
Designed to test one PMT immersed in LN2 with a configurable amount of light



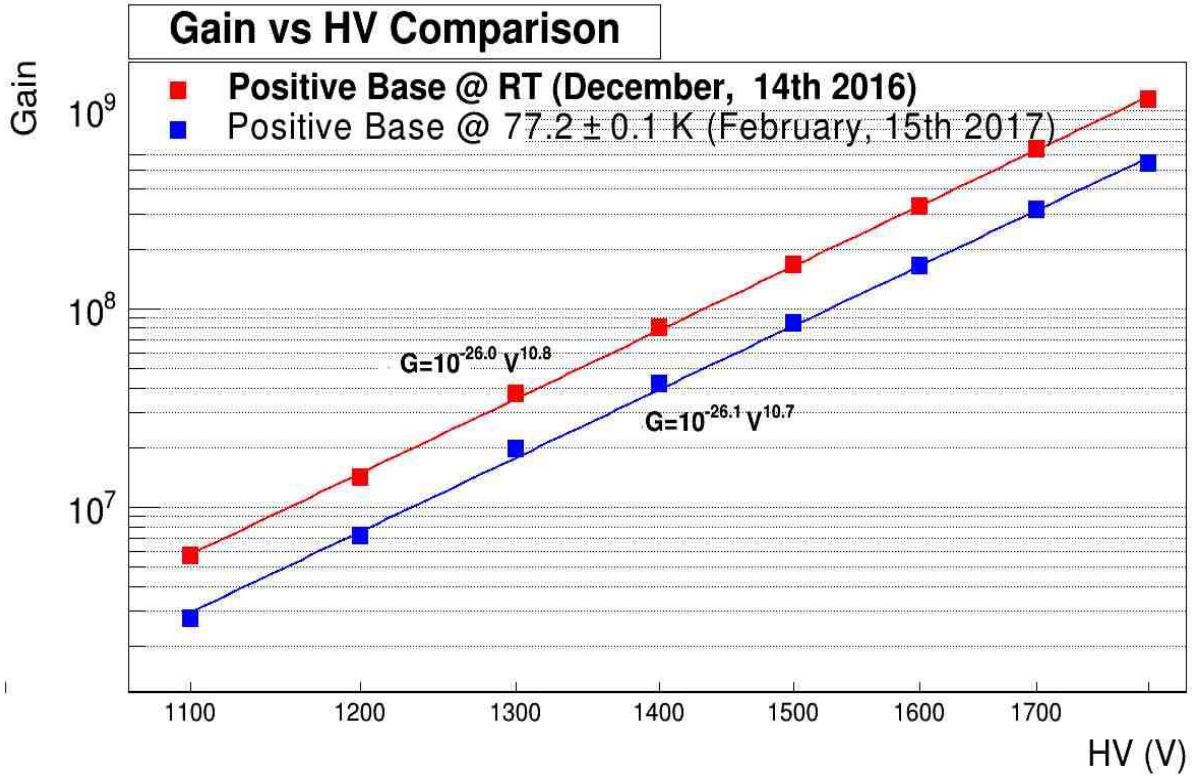
Test results during the Design Validation

Dark current frequency (DC)

Threshold = 3 mV

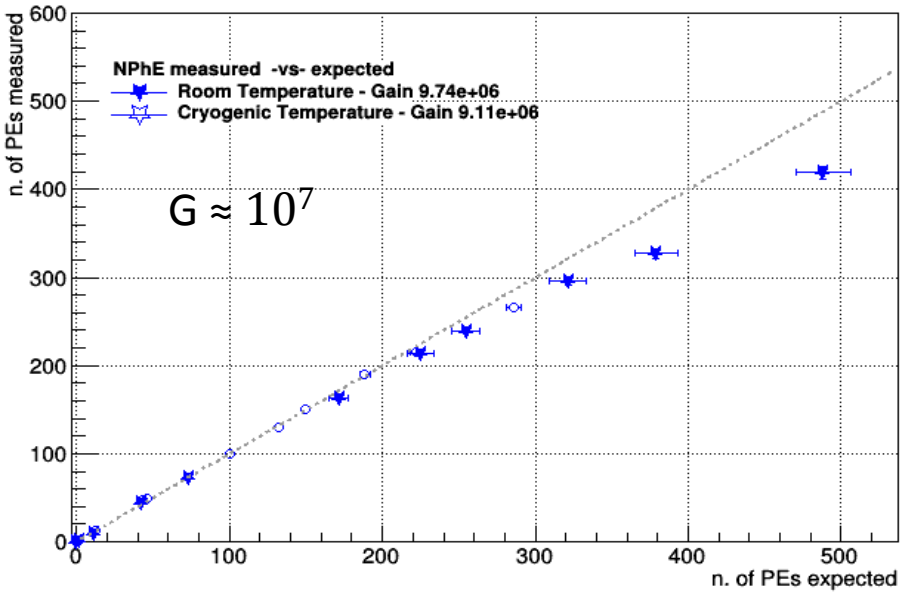


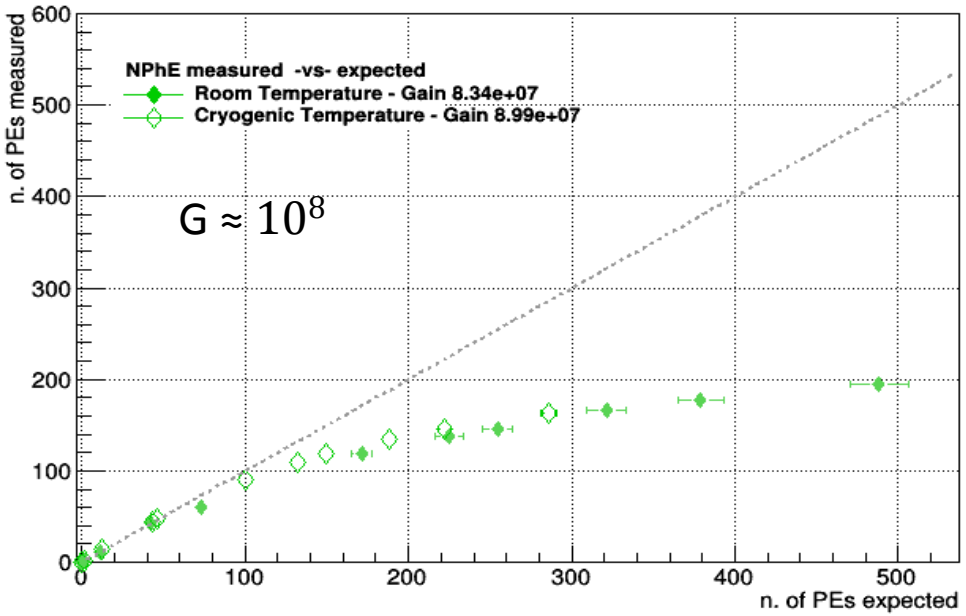
Gain vs HV

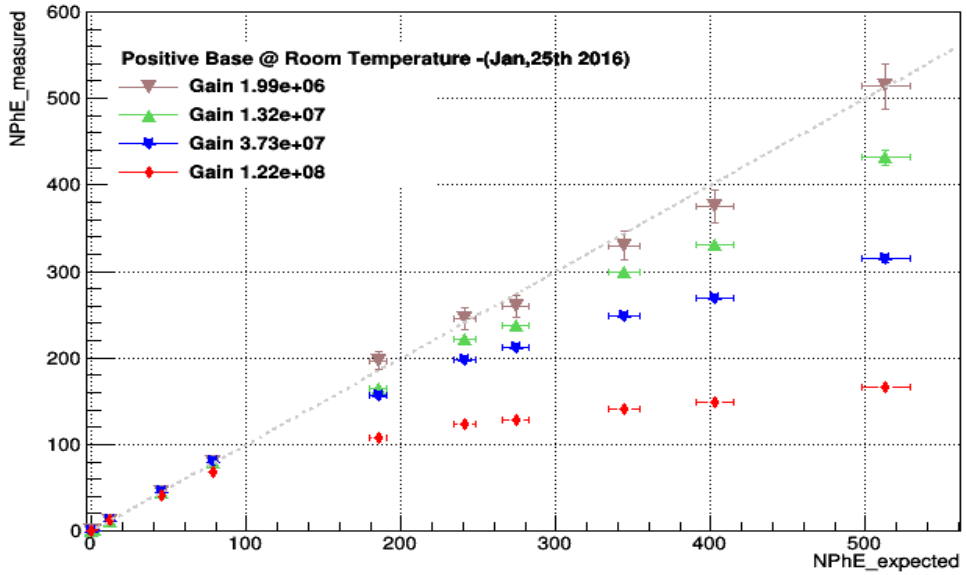


Lower gain and higher dark rate at cryogenic temperature than at room temperature

Test results during the Design Validation



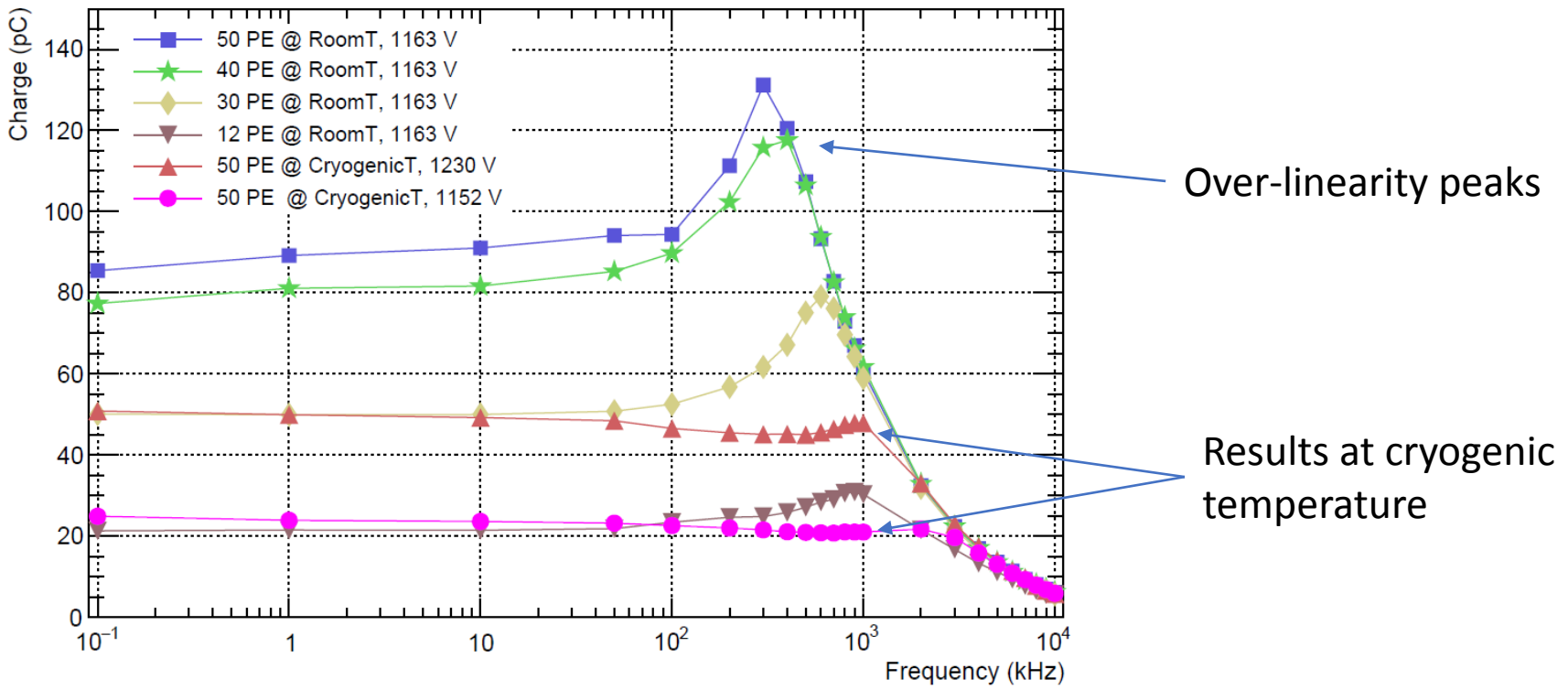




Linearity with incident light intensity:

- Light linearity loss with ~200 phe at 10^7 and ~100 phe at 10^8
- No difference observed comparing RT to CT

Test results during the Design Validation



Linearity vs light pulses frequency:

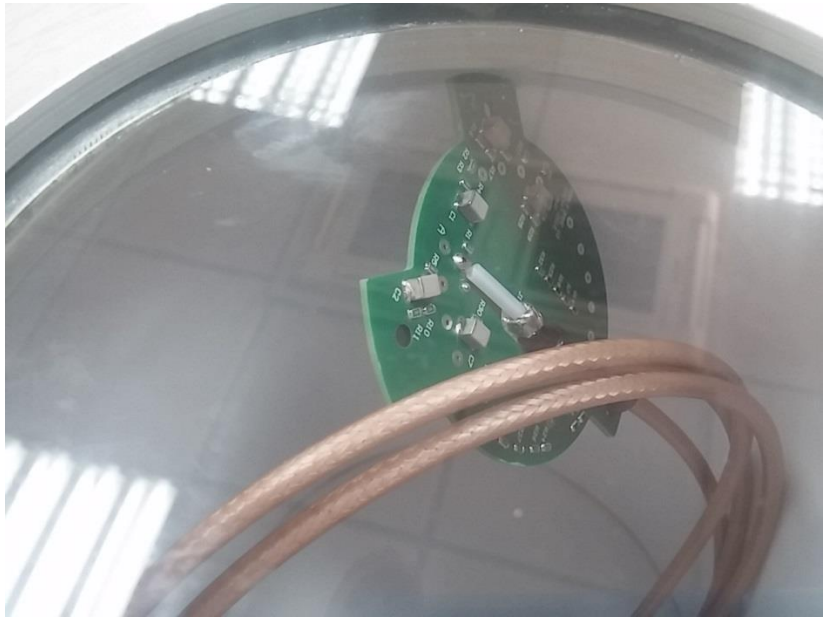
- Saturation depends on output charge (output current)
- For the same output charge, at CT the overlinearity peak is smaller than at RT but the saturation line follows the same trend.
- At **SPE levels the PMT can stand frequencies up to few MHz**

PMT Base circuit manufacturing and tests

- All the PMT bases have already been mounted, cleaned and tested at CIEMAT

- Two tests were performed before soldering to PMTs:
  - ✓ Total resistance is 13.430 MΩ (with the tolerance margin 0.1%)
  - ✓ Test at 2000V in Ar gas to verify there are no sparks

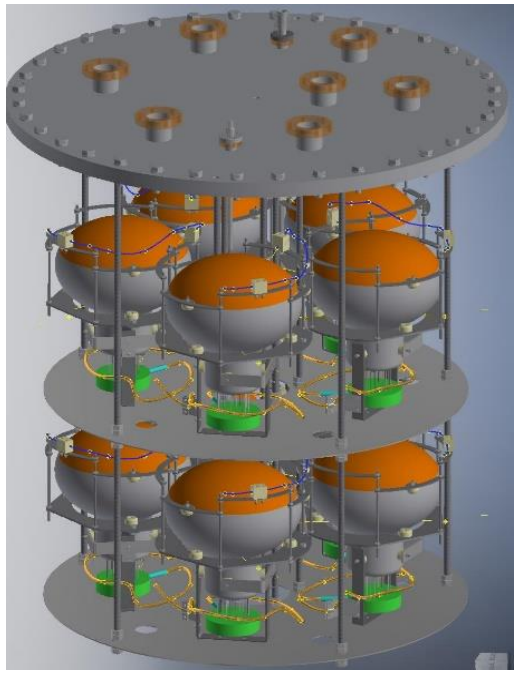
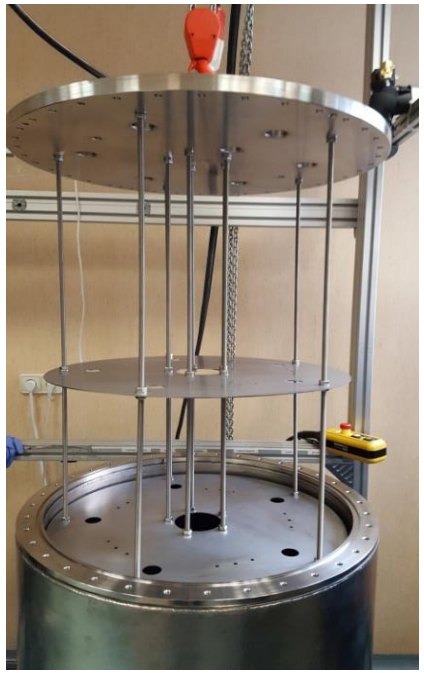
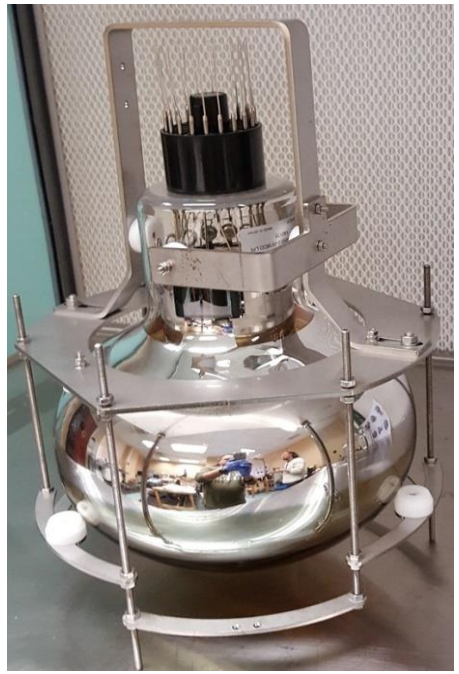
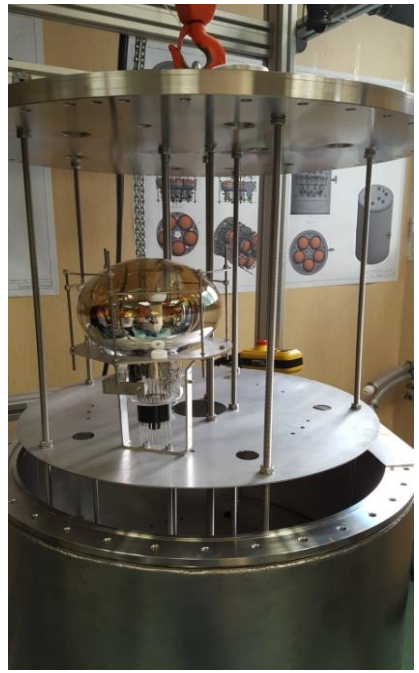
PMT base



Argon gas test setup

PMTs and bases Validation and Characterization

- New vessel with capacity for 10 PMTs (300 litres)
- Cryogenic system and electronic setup ready
- PMTs will be tested with the final base, 2m cable and support structure
- All the PMTs already assembled on the mechanical support
- All the PMT bases already assembled

PMTs and bases Validation and Characterization

- The same vessel will be used for testing at room and cryogenic temperatures.
- The test at room temperature will be done in GAr to verify that there are no sparks on the PMT bases.
- Tests will start in May and are expected to end in July.

	TIME
Tests at room temperature (GAr). Measurements: • Gain vs HV • Dark current vs HV • PMT Pulse shape (with the scope) for Gain = 10^7	2 weeks (20 PMTs /week)
Cryogenic tests (LN2). Requires more time for PMT cold down and stabilization (3-4 days). Sequence to be repeated: • Friday: Inmersion in LN2 • Monday to Wednesday: take measurements (same as room temp) • Thursday: Replace the tested PMTs by a new set of ten.	4 weeks (10 PMTs / week)

PMT cabling

RG-303 attached to one of the Double-Chooz PMT

We will use RG-303U cable from HUBER+SUHNER. It is the same type of cable than the RG-316 (used on Icarus and MicroBooNe) but with less attenuation and also bigger diameter: 4.3mm vs 2.5mm.

The total cable length needed inside the detector (23m) has been divided in two parts: one piece of 2m welded to the PMT base on one side and with an SHV connector on the other side, and, other cable of 21m, with SHV connectors on both sides, that will be routed from the flange to the bottom of the detector before the field cage installation.

The piece of cable attached to the PMT will allow the PMT test at any time and will also make easy the connection during the PMT installation.

PMT cabling

All the PMT cables for inside the detector have already been received and tested.

We have performed two tests performed on the PMT cables:

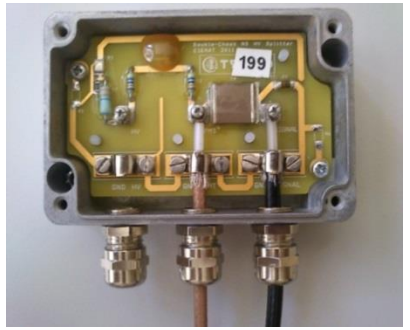
- Cable length by weighing each cable.
- Impedance match and transmission attenuation with a vectorial network analyzer

Splitters circuits

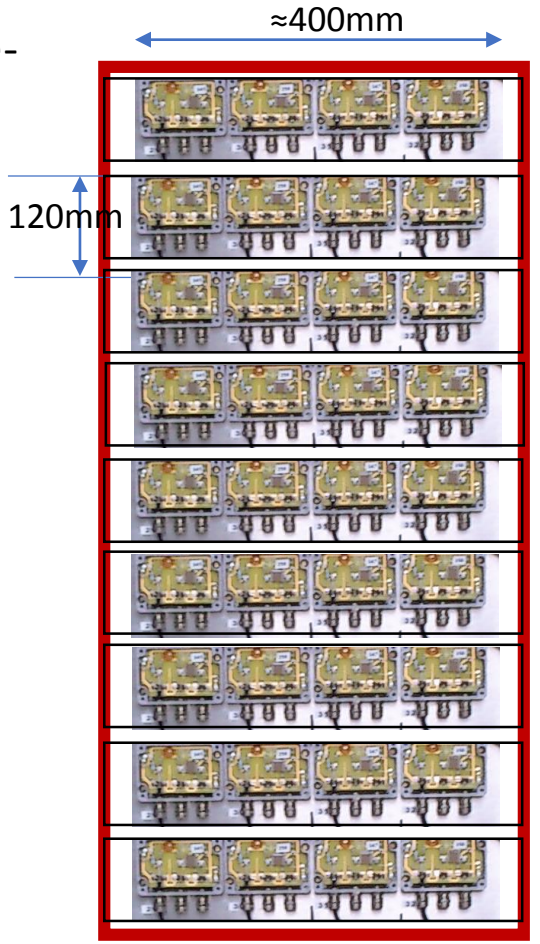
- For the HV and signal splitter circuit we plan to use the same that we used for the Double-Chooz experiment with proved reliability after 7 years of operation in the detector.
- Two of them are already installed in the 3x1x1 prototype.
- The production and tests will start on September 2017 and it will take about 2 months.

Double Chooz splitters cabinet

In Double-Chooz the splitters were mounted into cabinets IP66 cabinets because they were into a high humidity environment.
For WA105 they can be placed inside the Light Readout rack.
They will be mounted on aluminum plates by rows of four and they can be mounted on different positions: front, rear, vertically or horizontally



Single splitter



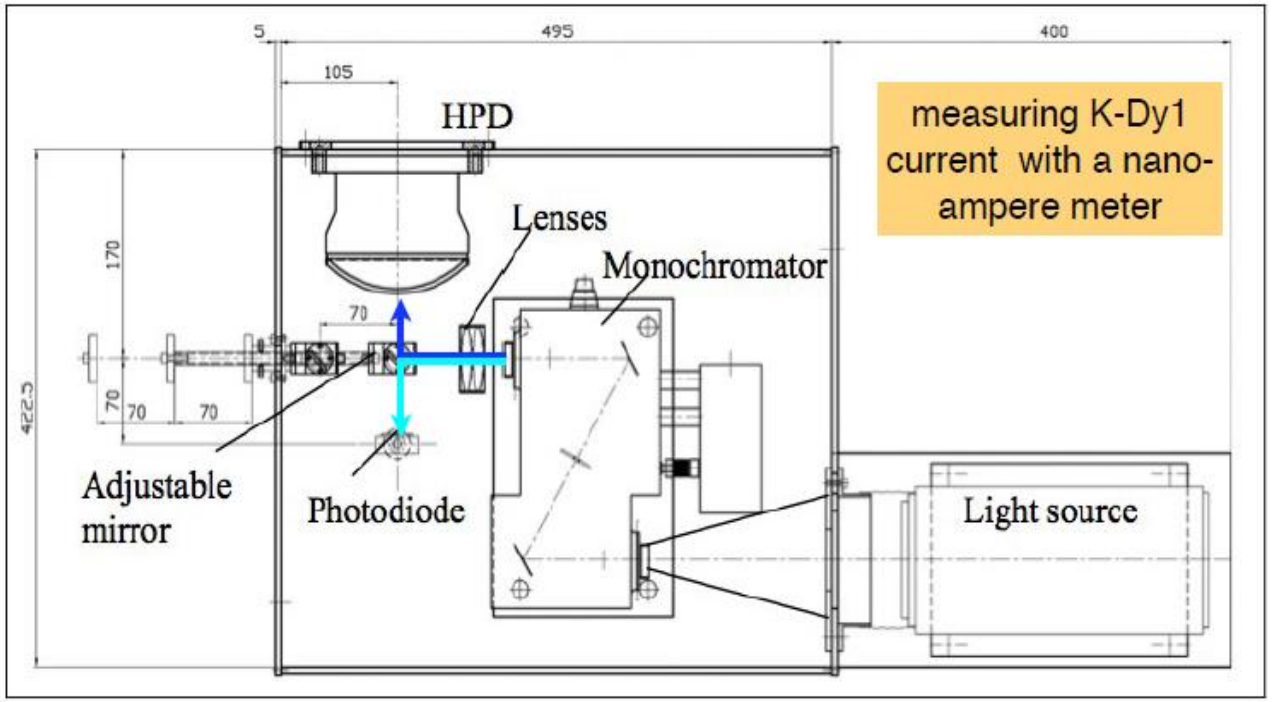
One option: all the 36 Splitters on 9 plates
All on the same side of the rack
Space required: 485(rack width) x 1080mm

TPB Coating

- We will reuse the setup available at CERN for the ICARUS experiment.
- Quality for ICARUS was excellent
- Facility available from September to November 2017
- Tested and characterized PMTs should be at CERN by beginning of September 2017
- 1 person needed from our side for about 6 weeks (4 weeks for 40 PMTs + 2 weeks for training)
- No setup available for PMT testing after coating but space to install one from our side ("black box" + power supply) for DC measurements
- Evaluating the possibility to use the quantum efficiency (Qeff) setup at CERN to test a sample of 4 to 8 coated PMTs
- After the coating, the PMTs will be stored on their box and inside a black plastic bag with the cable in a separate plastic bag. This will allow to test the PMTs before the installation on the same storage box.

TPB Coating Qeff test setup

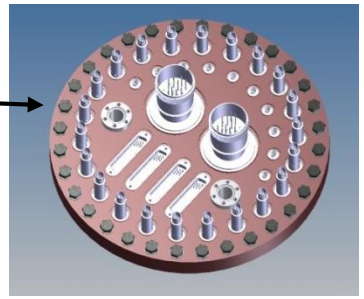
- Setup already used for the 3x1x1 PMTs
- In contact with T. Schneider (CERN) to see if setup available and costs



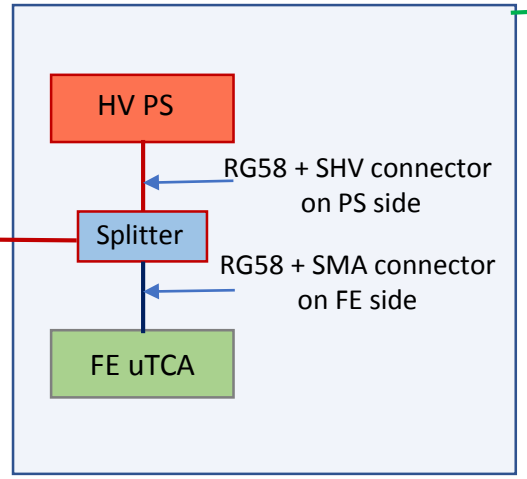
Setup diagram

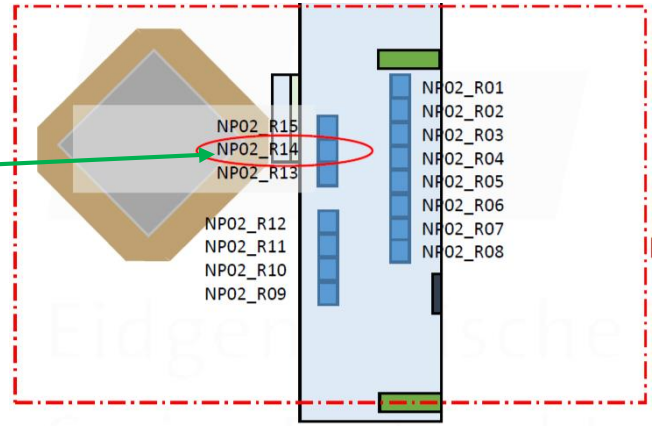
PMTs Connections

Dual side SHV ground isolated connectors Allectra 242-SHVDF50



2 Instrumentation Flanges
18 PMTs on each





Rack 14 – Light readout

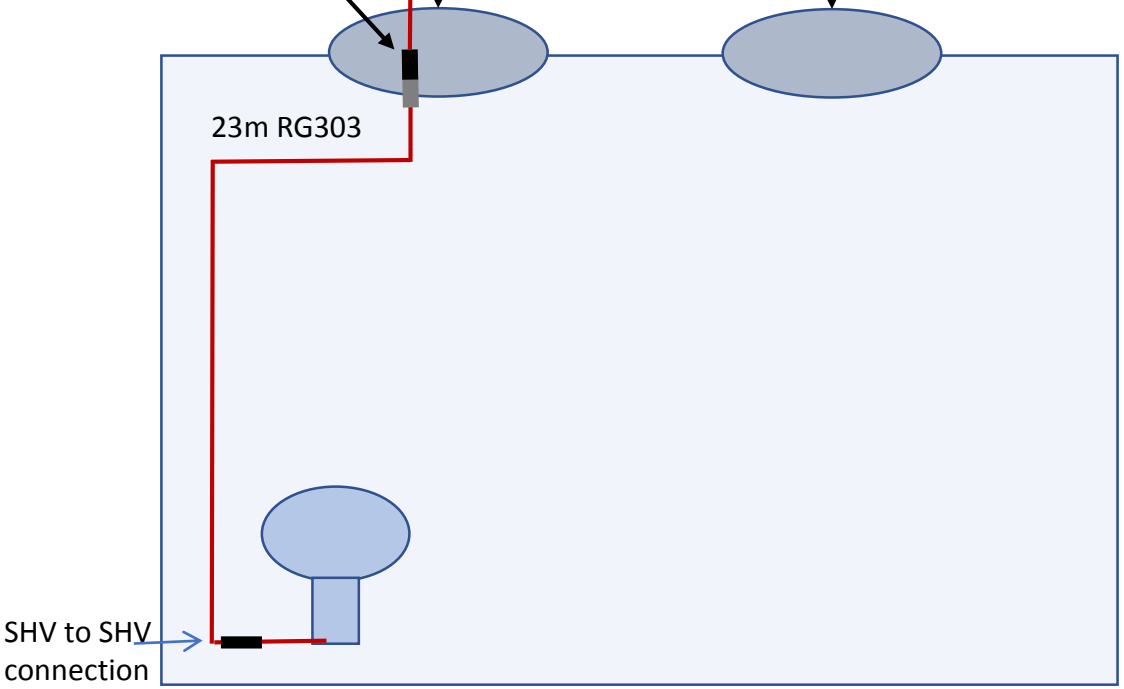


Diagram for a single channel

The PMT cables inside the detector are divided in two pieces:

- 21m cable connected to the flange and routed up to the detector bottom during the detector installation.
- 2m cable soldered to the PMT base (will arrive with the PMTs)

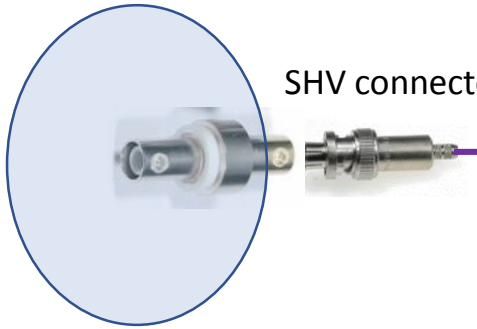
Both cables will be plugged during the PMT installation.

PMTs Connections in the Rack

Rack 14 – Light readout

Splitter

SHV connector

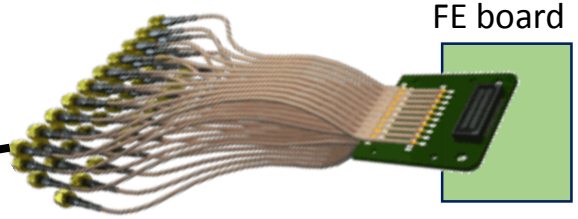


Instrumentation Flange

HTC-50-3-2
+ SHV connector

SMA Female bundle

FE board

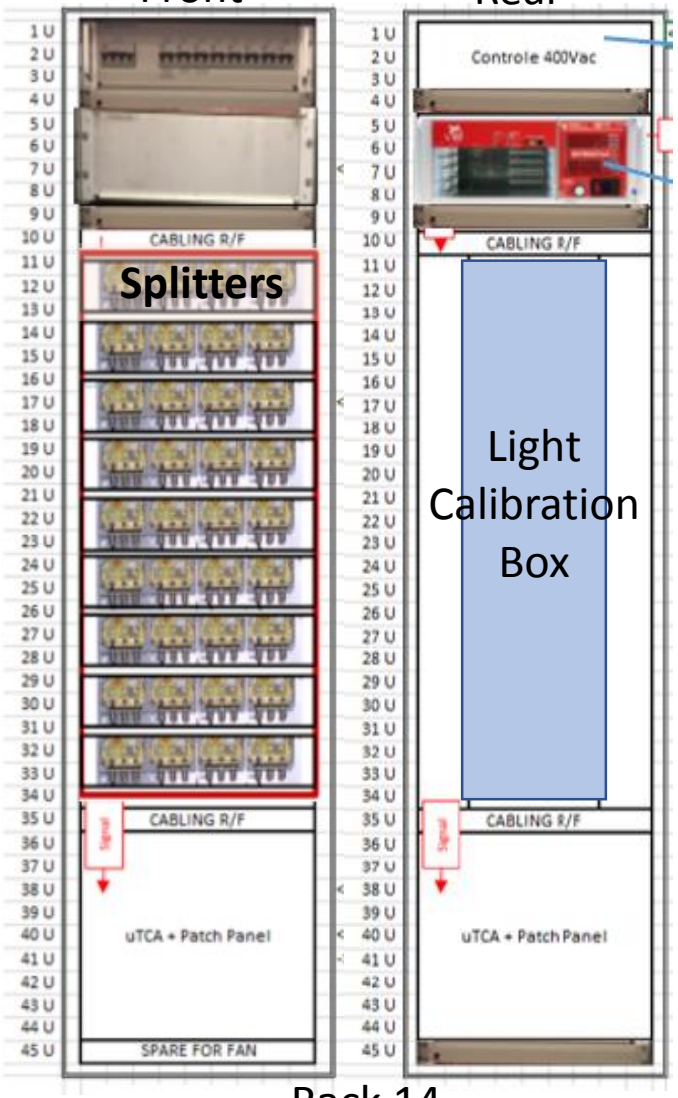


RG58 + SMA Male

HV Power Supply SY5527LC
+ 3 x A1536D CAEN modules
(12 channels each)

Front

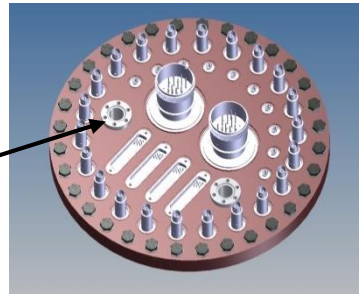
Rear



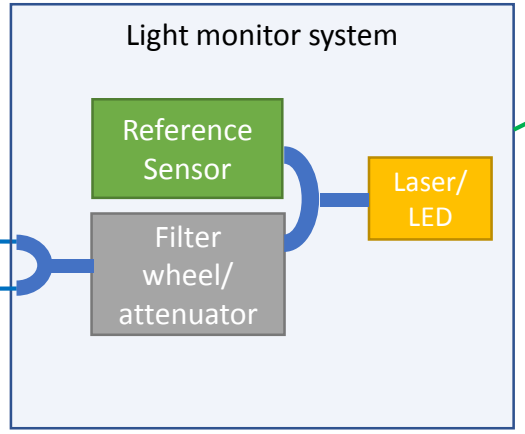
Rack 14

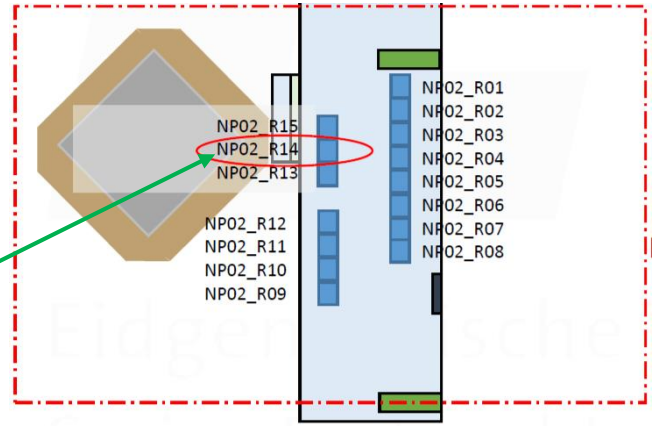
Fibers Connections

SMA Fibre FT
on CF-16 Flange

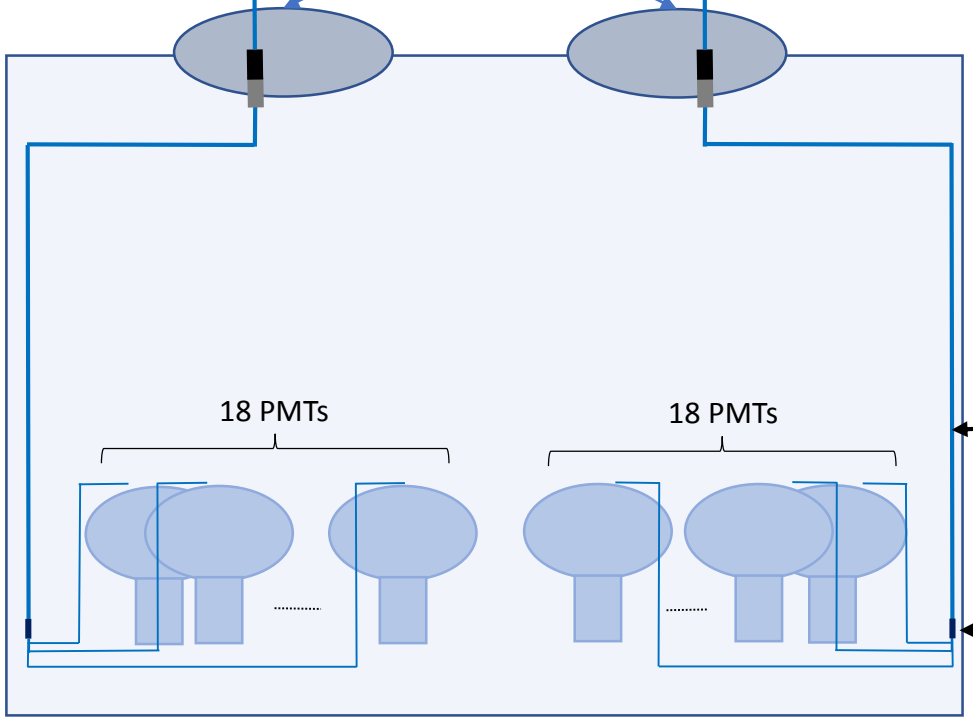


Instrumentation Flanges
1 fibre FT on each





Rack 14 – Light readout



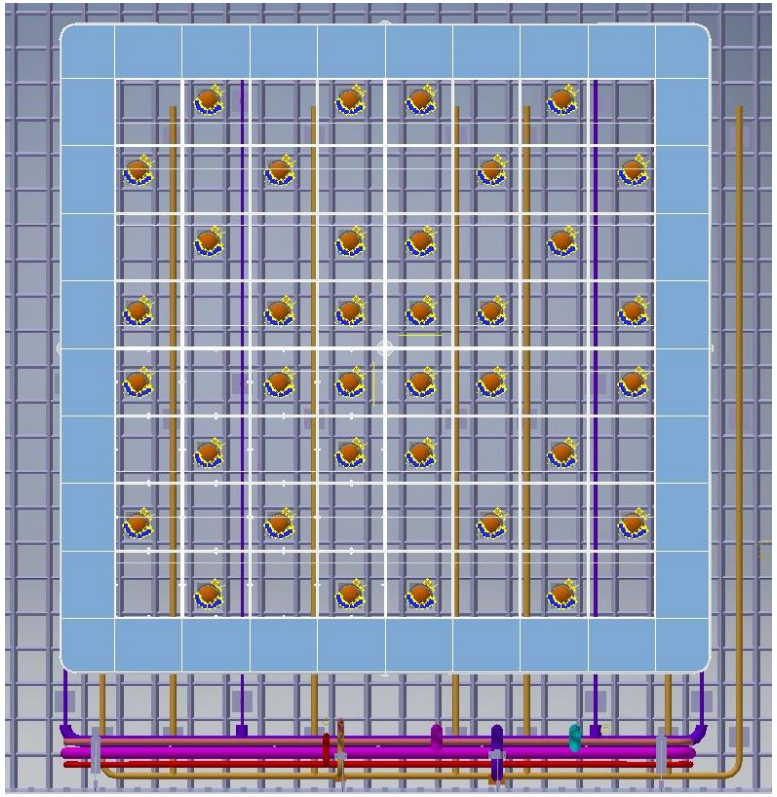
Single fibre
from the flange
to the bottom

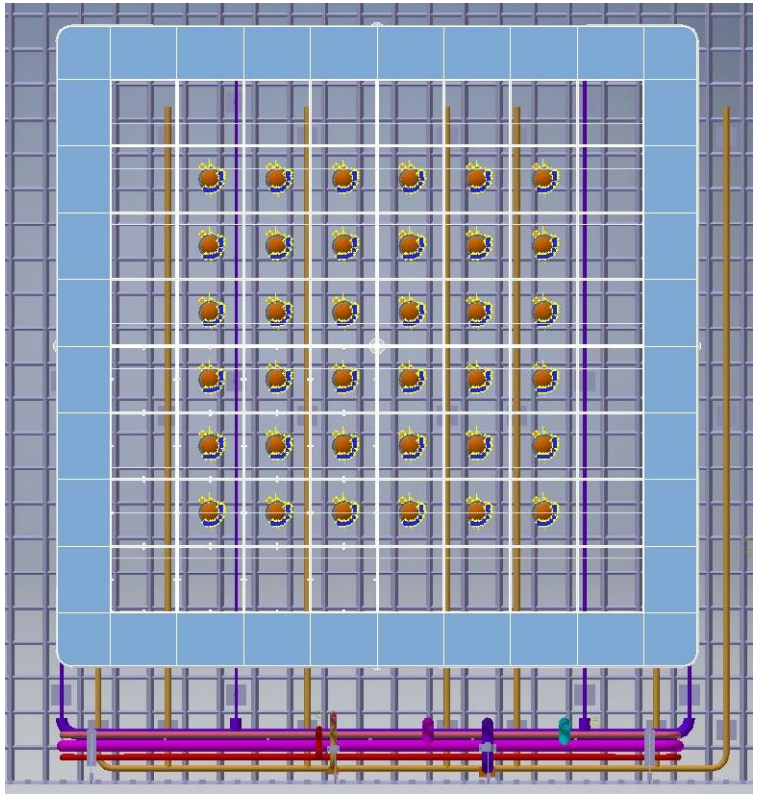
1 to 20 fibres bundle

There will be two single fibres from the instrumentation flange to the detector bottom. After the PMT installation, a 20 fibres bundle will be connected to each of the vertical fibres and each single fibre will be routed and attached to each PMT.

PMTs layout

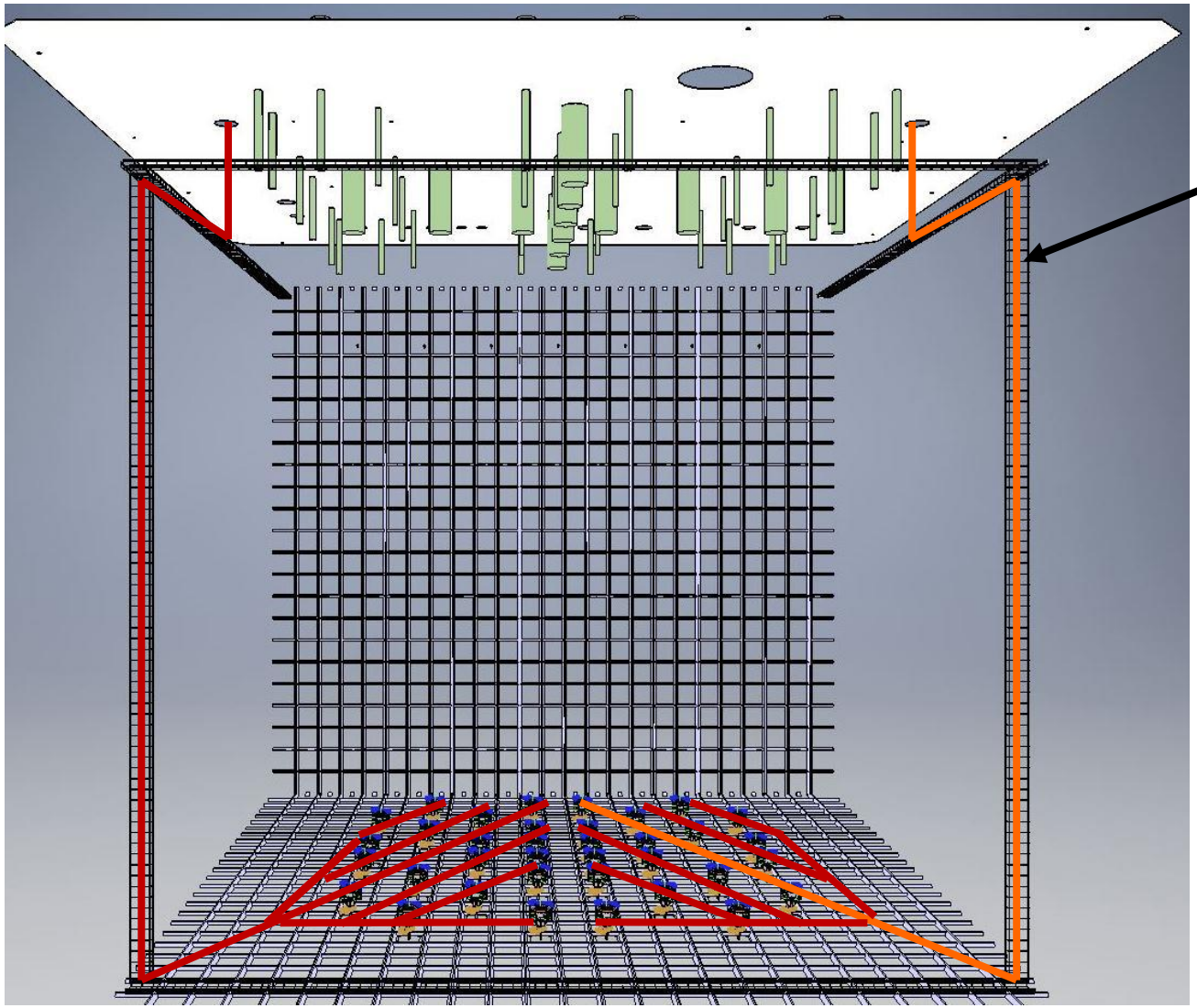
- Several options have been studied from the mechanical point of view to avoid interferences with filling tubes and to center the PMTs in the cathode frame structure.
- Simulations are on going for the two best layout candidates, in terms of collected light and cosmic muon tagging. Final decision will be taken based on simulations.
- PMTs system is ready for any of the two options, so, the layout has no impact on the integration.



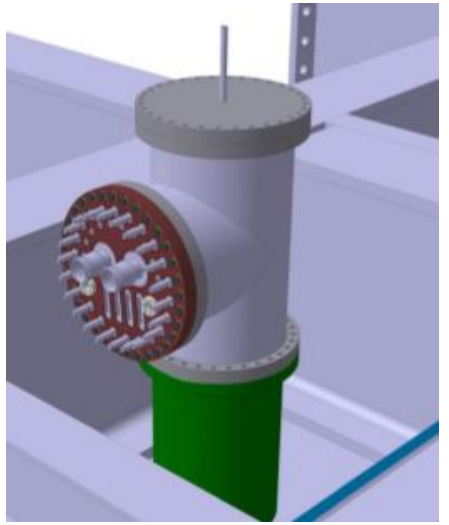


PMT cables and fibers routing inside the detector

Fibers will follow the same routing scheme as the PMT cables

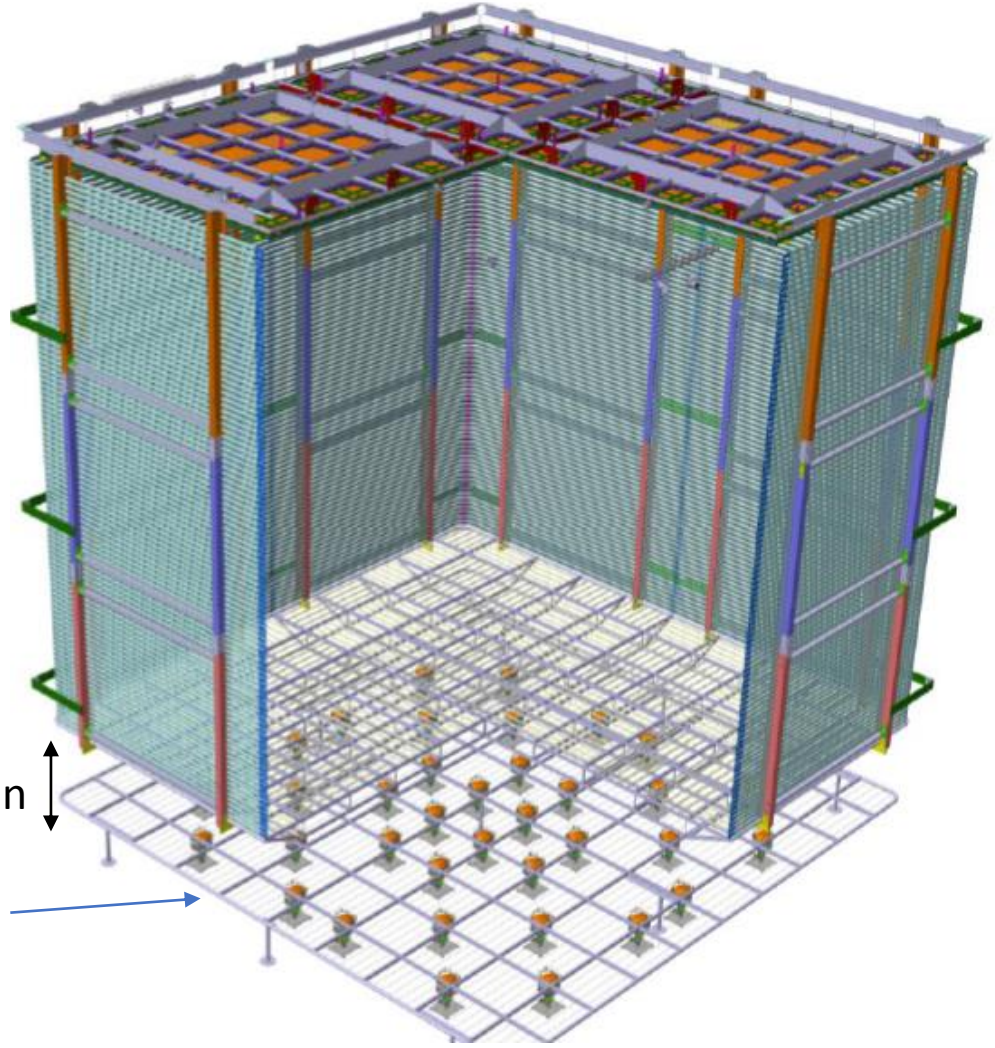


For worst case the longest distance from the flange to the PMT: 20.5m
Including the T at the instrumentation flange exit



PMTs Installation space

- As the PMTs installation is one of the final steps the space for the installation will be very reduced.
- The ground grid will be at few cm from the PMT photocathode and it must be raised to allow the entrance to the detector bottom for the PMT installation.
- The height available after raising the ground grid will be around 1m.



PMTs Installation procedure I

1) Before the field-cage installation all the 36 PMT **cables and the fibers** for light calibration will be connected to the instrumentation flange on one side and **routed by the vertical cable trays** down to the detector bottom.

2) Pre-Installation Tests:

- Just before the PMTs installation, **all the PMTs will be tested** one by one on their transport box. The PMTs will be stored with a black bag covering them inside the transport box with the PMT cable outside the bag to allow the PMT testing without exposing them to light before the test. We will check dark rate and SPE pulse shape.
- The **light calibration fibers integrity** will be checked placing a light source at the flange entry and measuring the light power at each fiber end.

PMTs Installation procedure II

3) PMT fixation and connection:

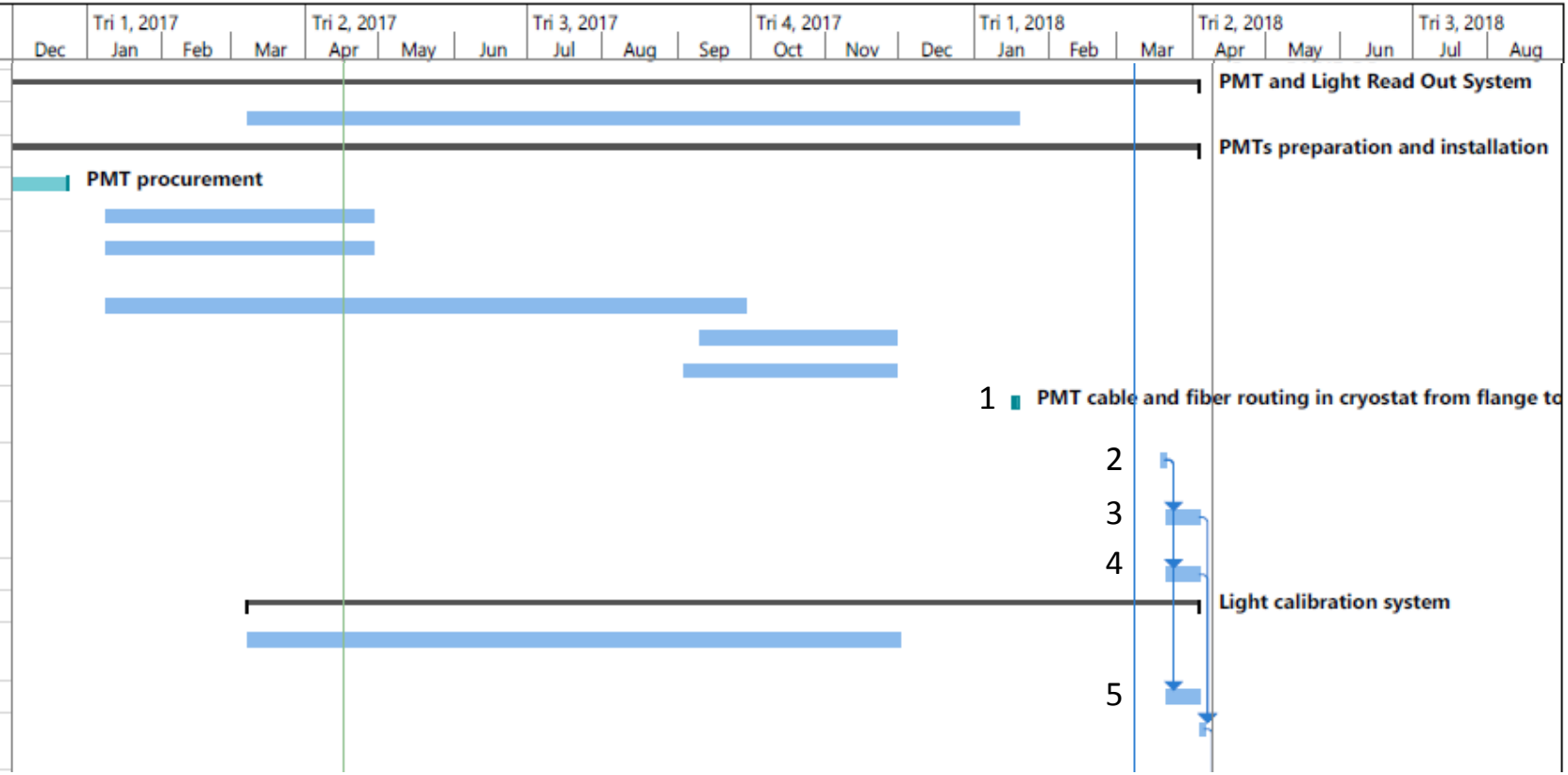
- For the PMT installation we need the **ground grid to be raised** as much as possible to be able to access and install the PMTs bellow it.
- We need also that the **supports for the PMT structure** to be already on place
- Before the PMT installation, the **cables and fibers will be routed** to the corresponding PMT position at the detector bottom.
- The installation will start at the opposite side of the detector entrance ending at the detector entrance.
- **PMTs mechanical fixation to supports and connections.** Each PMT will be connected to the corresponding RG-303 cable going to the feedthrough. It's an SHV male-female connection, so, no soldering is needed. Also light calibration fibers will be attached to each PMT at this time to avoid passing latter between the installed PMTs.

4) Post installation tests:

- Verify the electrical connection between the flange and the PMT base by measuring the PMT base resistance from the flange. Tests with HV can not be done while detector is open.

Installation planning

N°	Task name	Duration (days)	Start date (dd//mm/yy)	Finish date (dd//mm/yy)
227	**PMT and Light Read Out System**	**340 days**	**01/12/2016**	**04/04/2018**
228	LRO electronics	218 days	08/03/2017	19/01/2018
229	**PMTs preparation and installation**	**340 days**	**01/12/2016**	**04/04/2018**
230	PMT procurement	17 days	01/12/2016	23/12/2016
231	PMT base design and manufactur	80 days	09/01/2017	28/04/2017
232	PMT support structure production and assembly	81 days	09/01/2017	28/04/2017
233	PMTs characterization	190 days	09/01/2017	29/09/2017
234	TPB coating	59 days	11/09/2017	30/11/2017
235	Splitter production and tests	64 days	04/09/2017	30/11/2017
236	PMT cable and fiber routing in cryostat from flange to bottom	2 days	17/01/2018	19/01/2018
237	PMT support installation on the membrane	2 days	19/03/2018	21/03/2018
238	PMT testing, installation in cryostat and cabling	10 days	21/03/2018	04/04/2018
239	Splitter installation	10 days	21/03/2018	04/04/2018
240	**Light calibration system**	**271 days**	**08/03/2017**	**04/04/2018**
241	Fibers, light source tests and procurement	193 days	08/03/2017	01/12/2017
242	Fiber calibration system installati	10 days	21/03/2018	04/04/2018
243	Lower the Ground grid to its final position	2 days	04/04/2018	06/04/2018

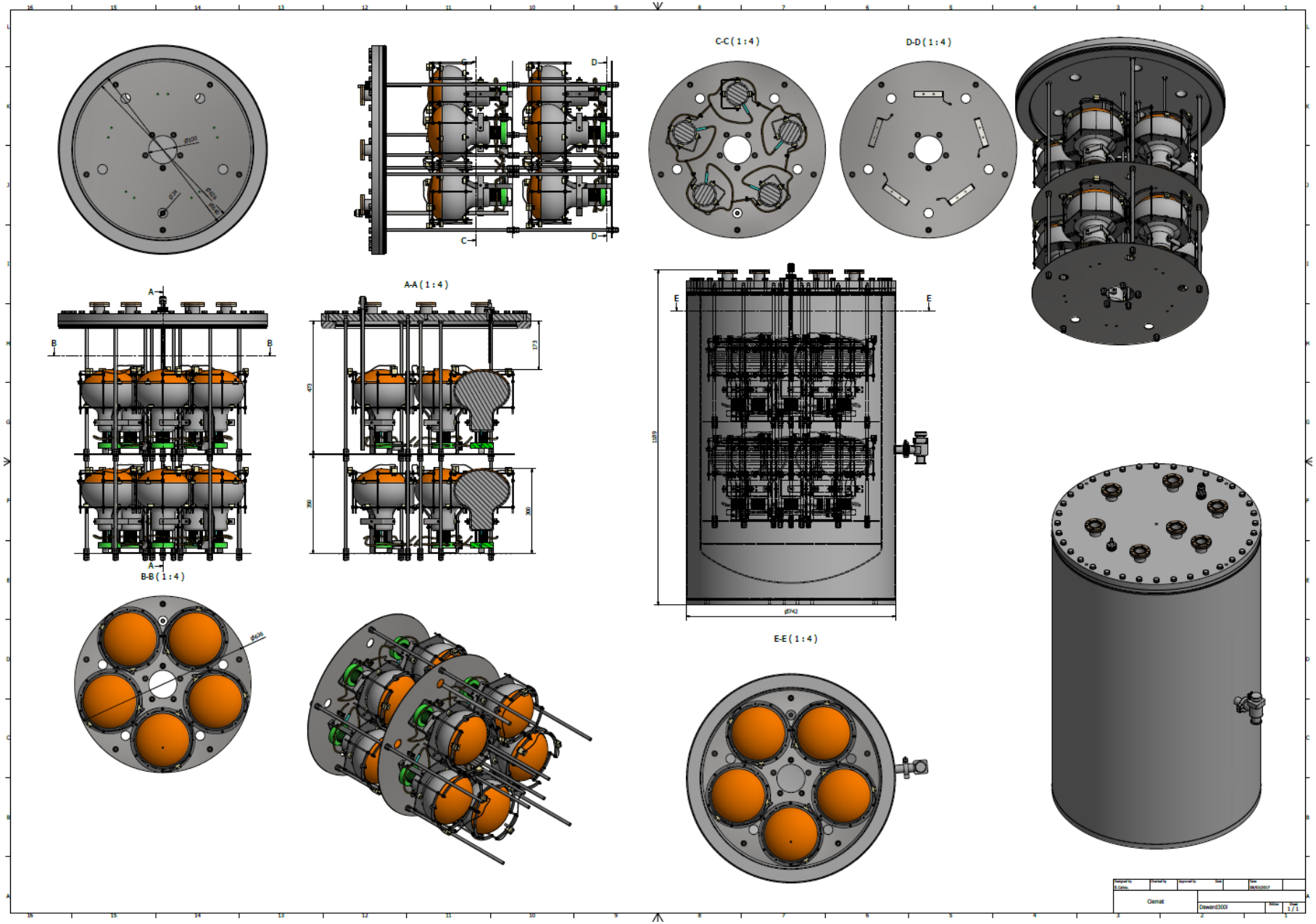


Summary:

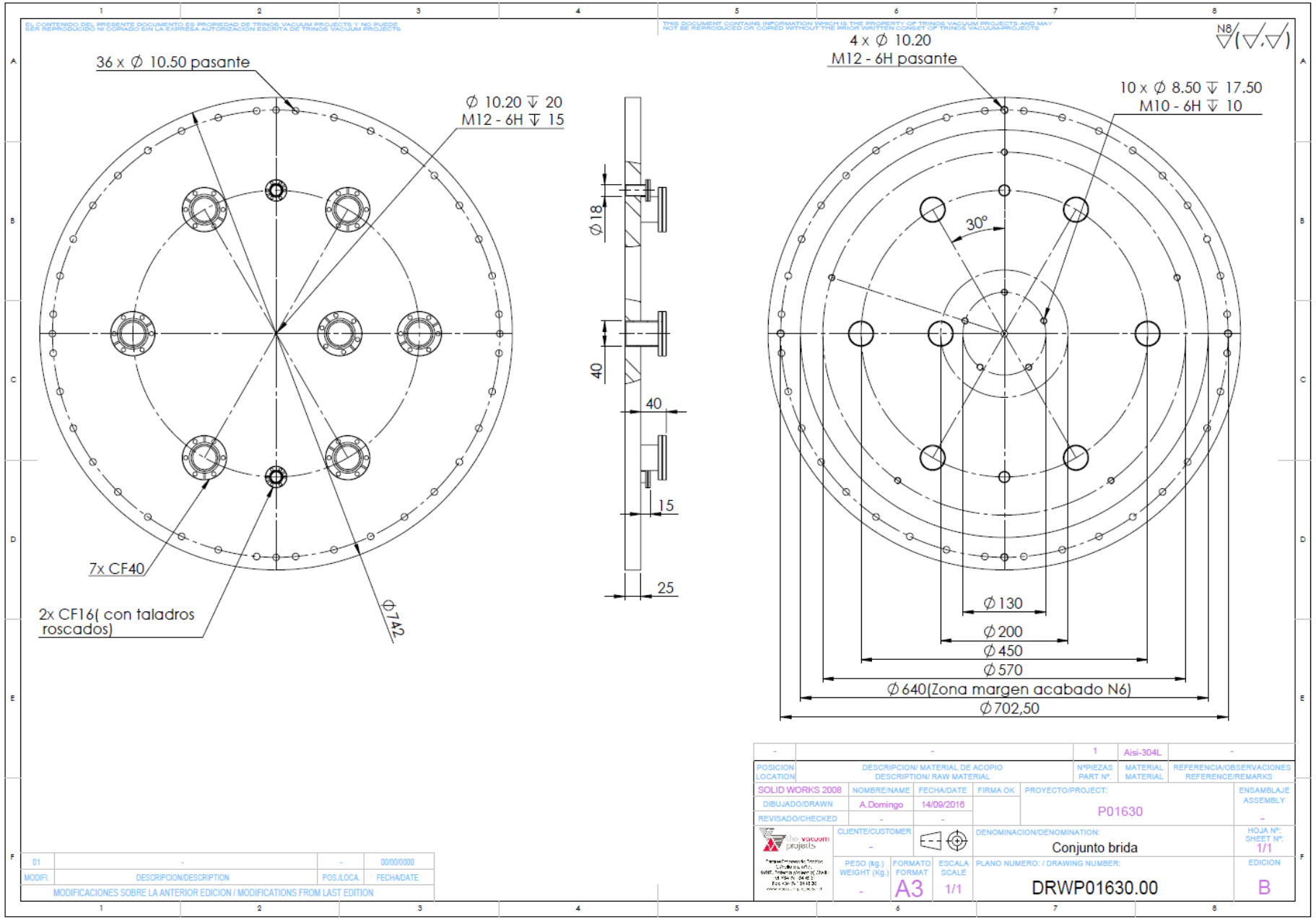
1) Before field cage installation: PMT cables and fibers routing from the instrumentation flange to the detector bottom
2) PMT support installation (2 days) before PMT installation. Could be in parallel with pre-installation tests.
3) PMT installation: Pre-installation tests (5 days) + PMT installation and connection (5 days)
4&5) Splitters and Light calibration system installation: in parallel with PMT installation.

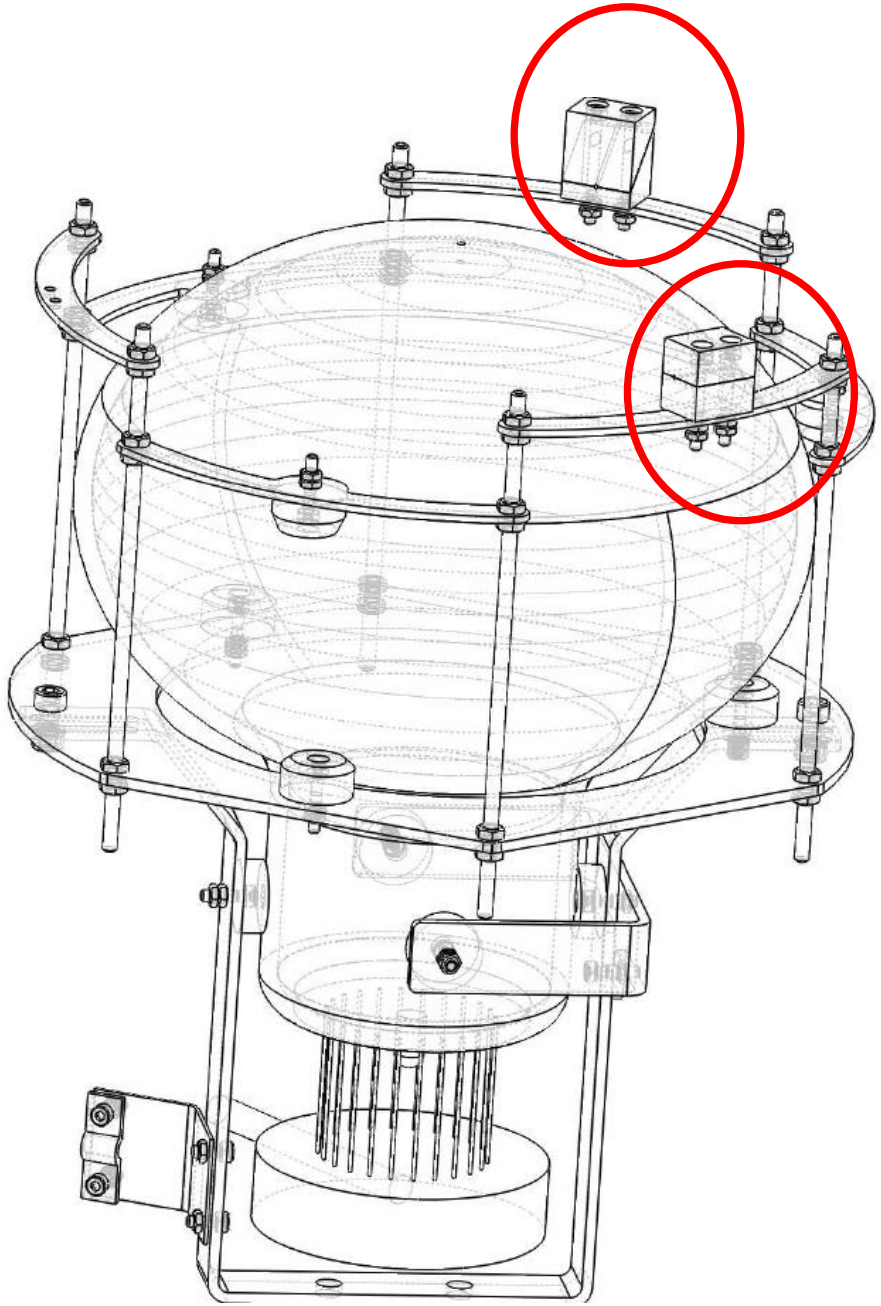
Backup

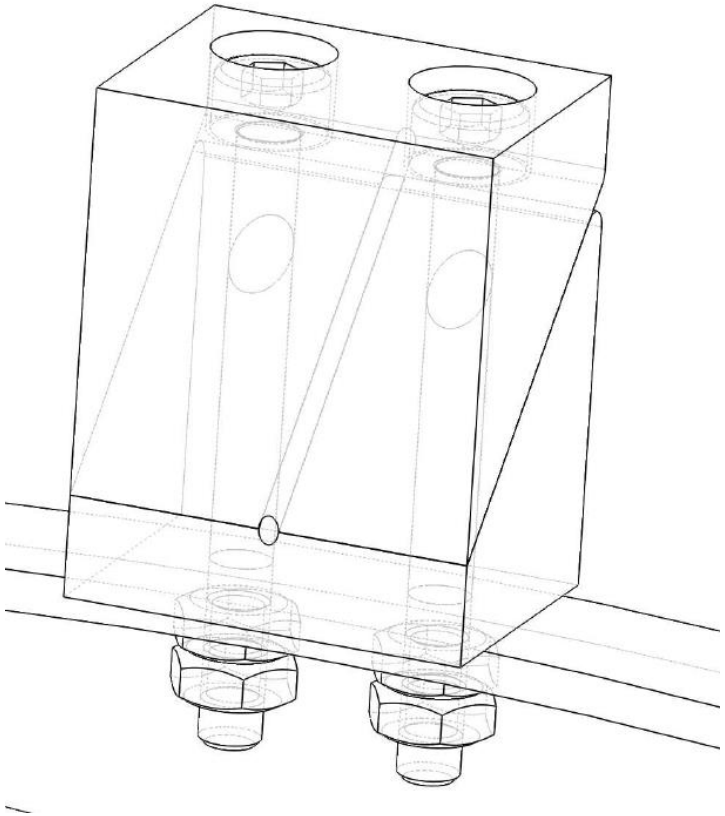
LN2 300L dewar

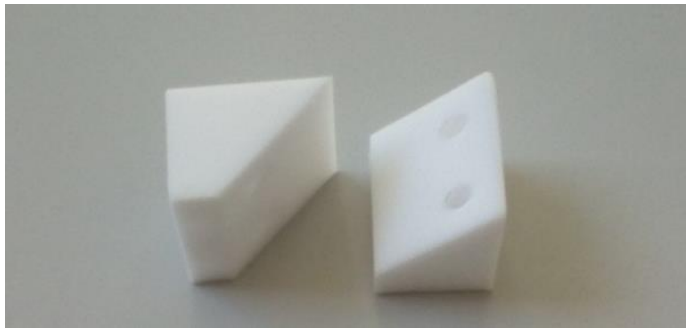


LN2 300L dewar cover



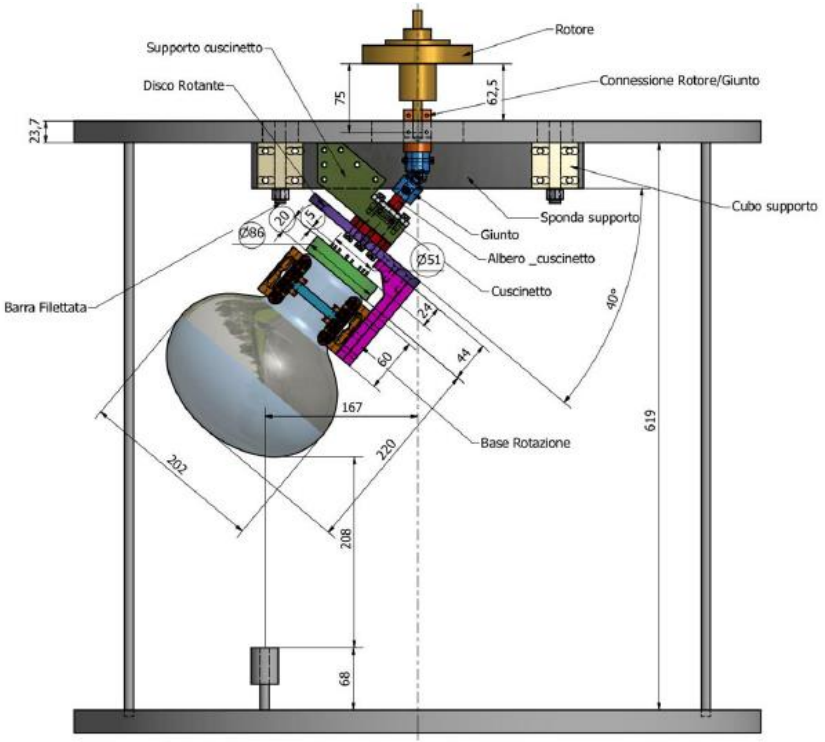






TPB Coating

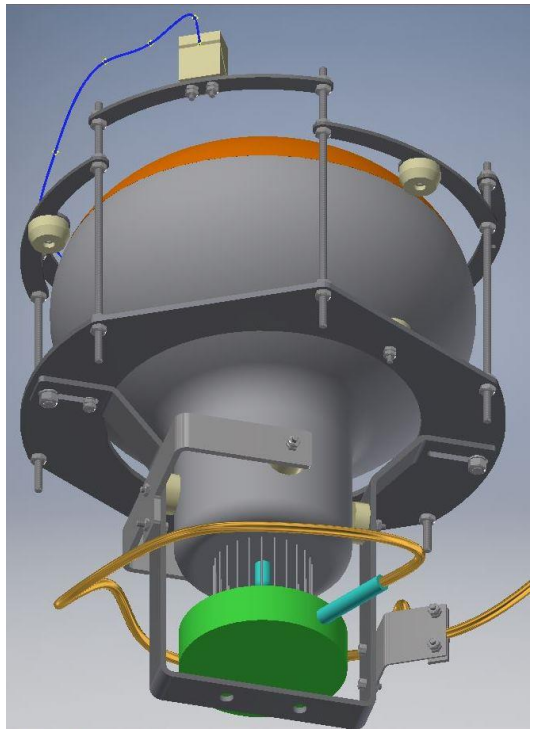
- Shipping to CERN of tested and characterized PMTs beginning of September 2017
- Reuse the setup available at CERN for the ICARUS experiment

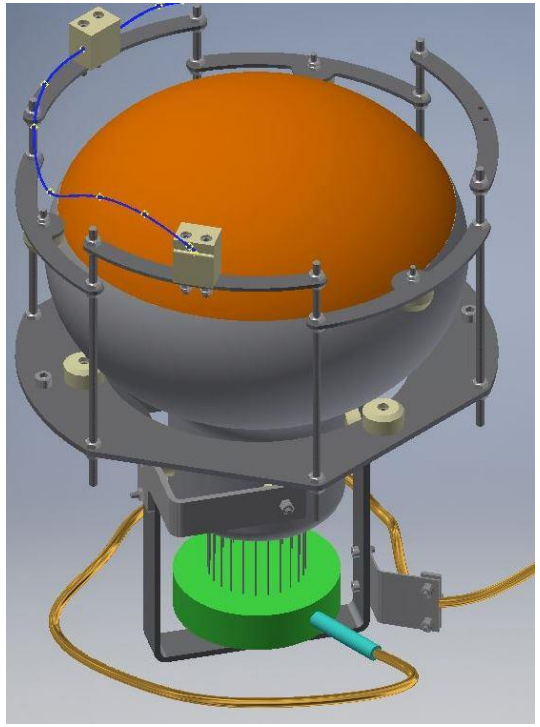


PMT Support structure

Assembly Composed by:

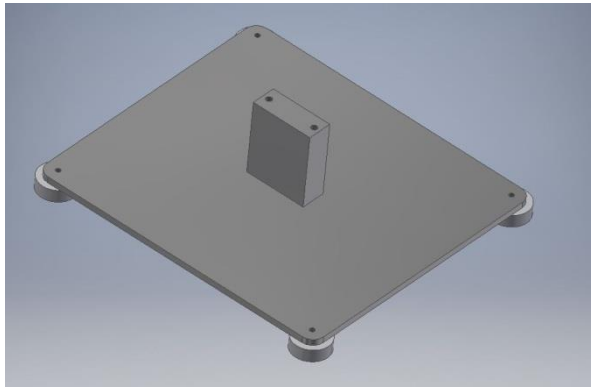
- 8’’ Hamamatsu PMT R5912-02 MOD with a custom voltage divider base
- Support frame structure of 304 L Stainless steel and Nylon 6.6 pieces fixed by A4 stainless steel screws.

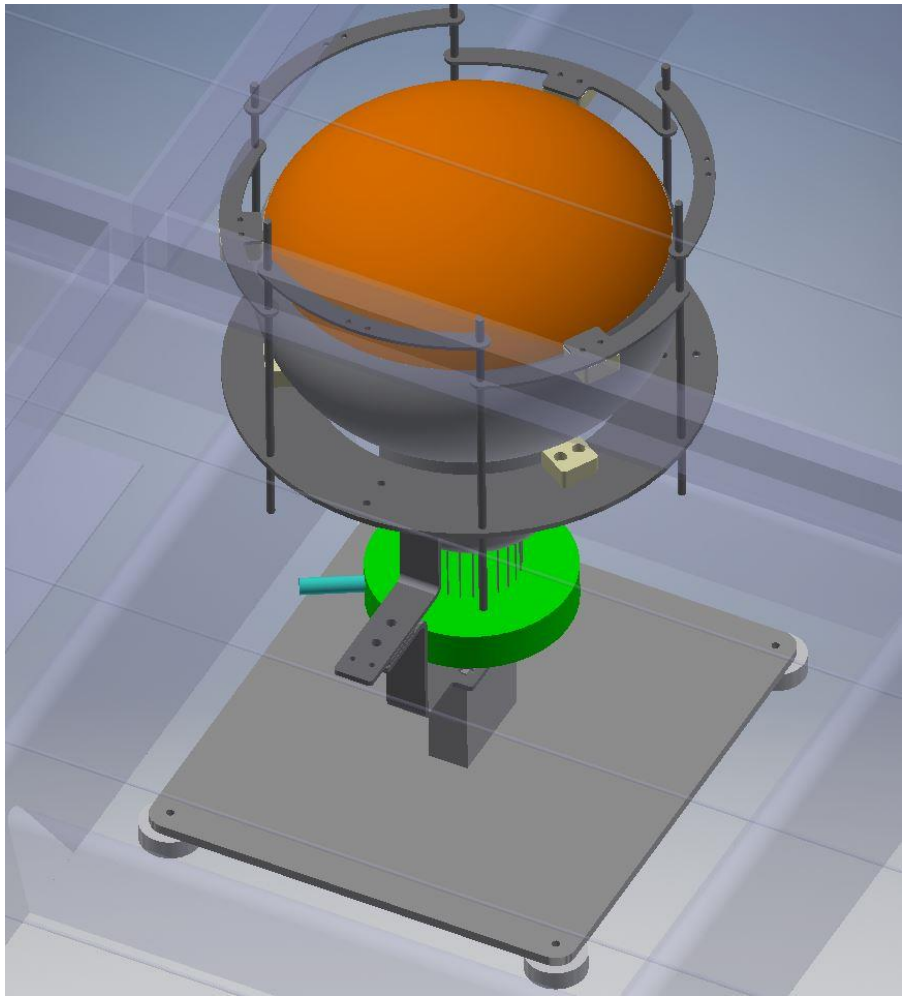




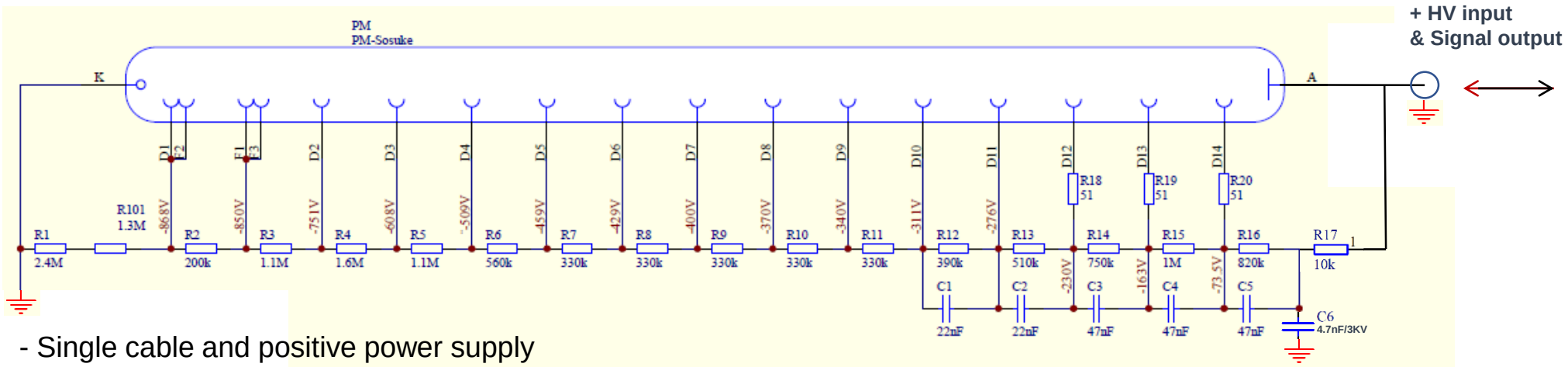
Weight of the PMT +support & base ~6,5 kg.
Buoyancy force of the system ~5,5 kg.

Stainless Steel support base of the PMTs:
4 PTFE Ø30 mm contact pieces on the shell.



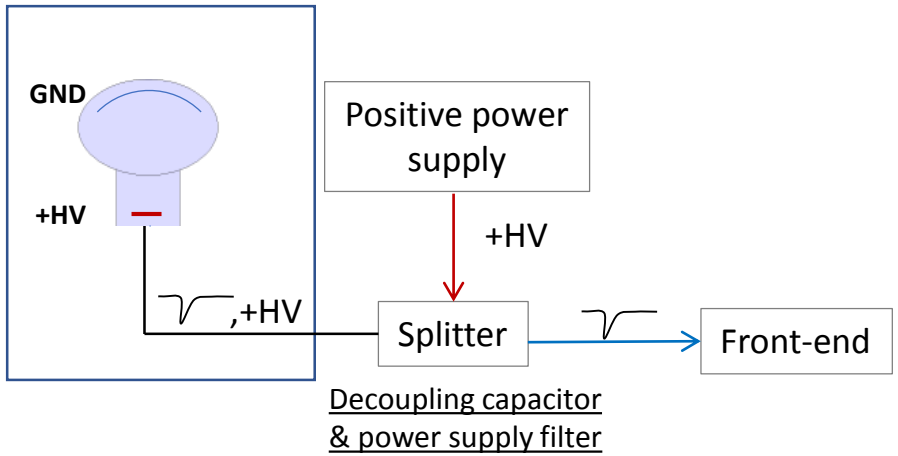


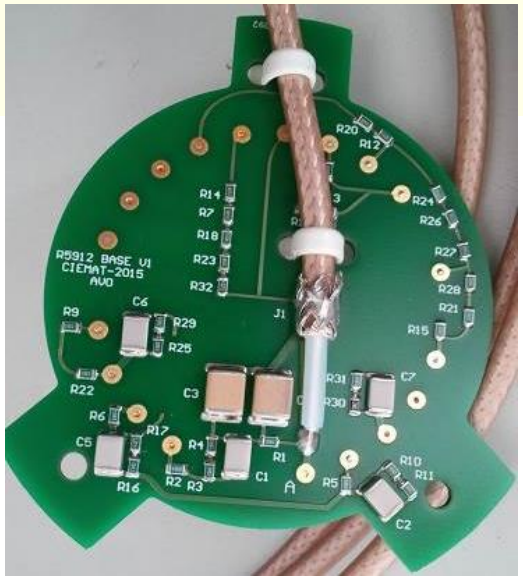
PMT Base circuit



- Single cable and positive power supply

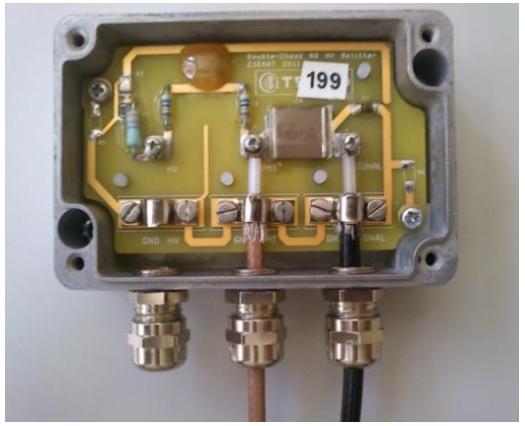
- Following the voltage divider ratio specified by Hamamatsu with a total resistance of 13.430 MΩ using low temperature coefficient resistors and capacitors

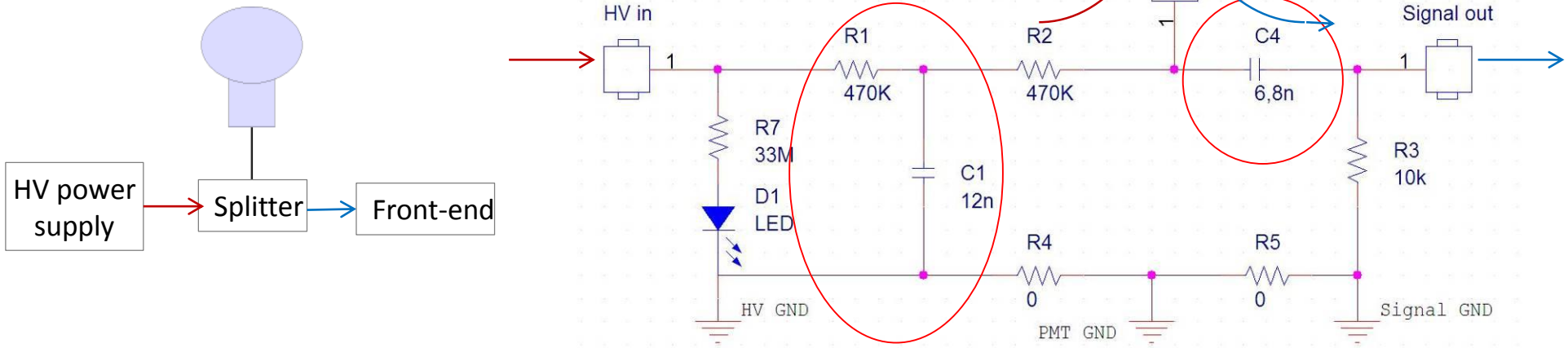




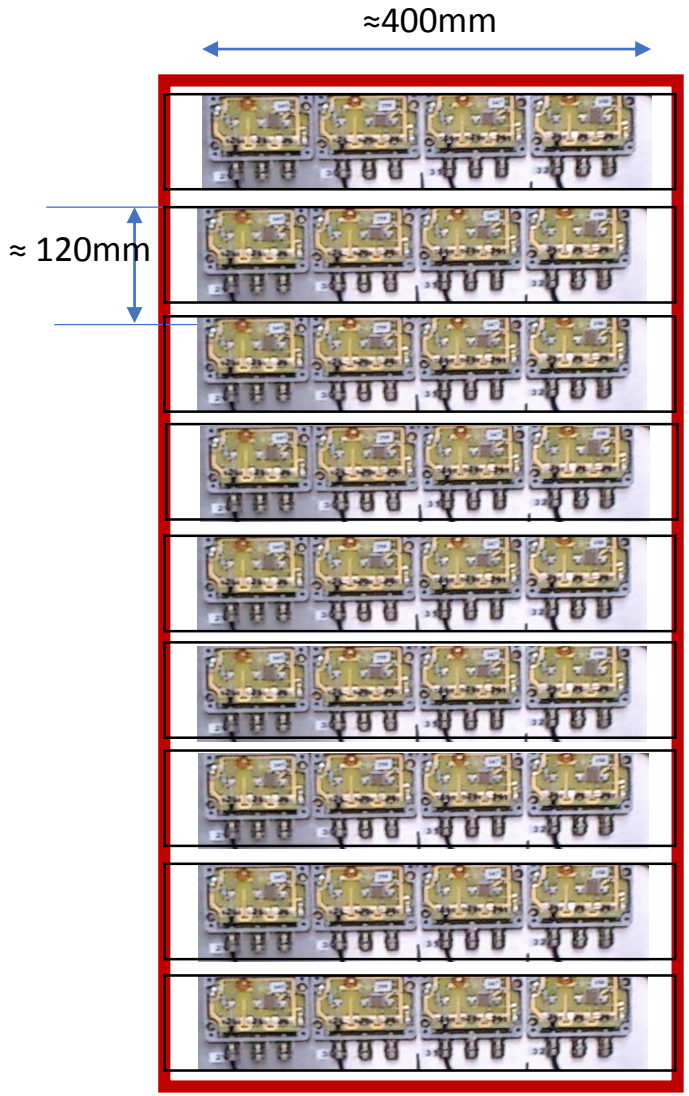
Splitter circuit

- For the HV and signal splitter circuit we plan to use the same that we used for the Double-Chooz experiment with proved reliability after 7 years of operation in the detector.
- Two of them are already installed in the 3x1x1 prototype.
- The production will start on September 2017 and will take about 2 months.





Splitters placement in the LRO rack



One option: all the 36 Splitters on 9 plates
All on the same side of the rack
Space required: 485(rack width) x 1080mm (red rectangle)

Each single splitter box is 98mm x 64mm x 26mm.

We can mount the splitters on aluminum plates by rows (4 splitters by row) to maximize the flexibility on the allocation inside the rack . Or we can mount them on larger plates.

Some options:
All the splitters (36) on one side of the rack distributed in 9 plates will require about 9 x 12cm = 108cm (vertically)

Oher option is to put 20 splitters on the rack front and 16 splitters on rear requiring about 55cm on each side.

And the third option is to mount the splitters on two trays (about 40cm x 60cm) and insert them in horizontally into the rack.