A Versatile Cryogenic System for Liquid Argon Detectors

LIDINE 2022: LIght Detection In Noble Elements - Conference
Warsaw - Sep 21-23, 2022

G. Grauso, N. Canci, F. Di Capua, Y. Suvorov, G. Fiorillo
INFN-Napoli, Università degli studi di Napoli Federico II

on behalf of the **DarkSide** collaboration

DARKSIDE

INFN

Outline

- Introduction
- Cryogenic system overview
- First commissioning test
- Second commissioning test
- Performances before vs. after the upgrades
- Future Upgrades
- Conclusions

Introduction

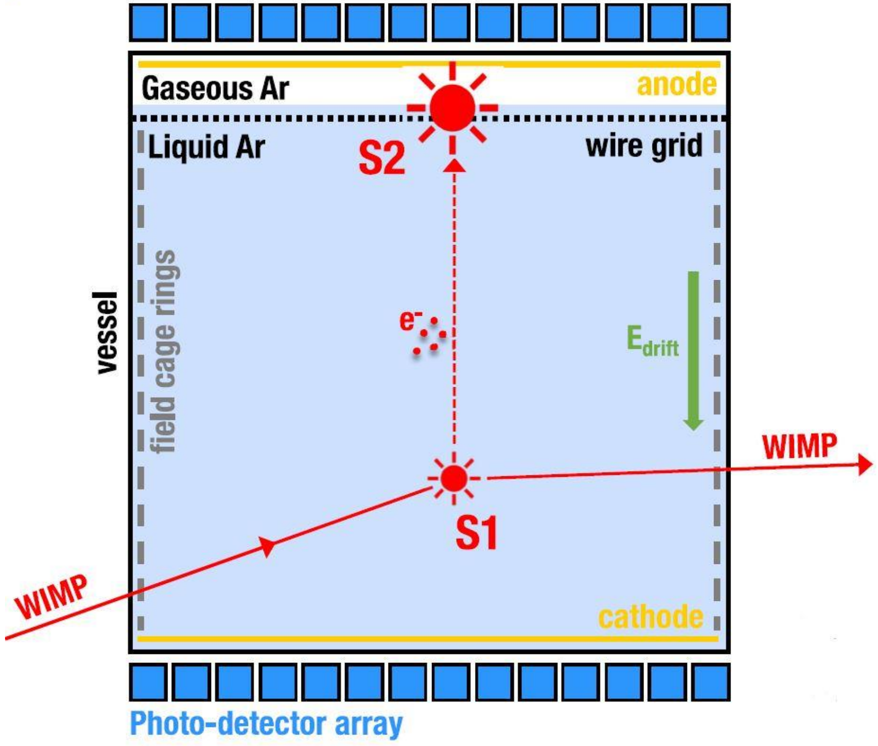
- Liquid phase noble gases detectors for direct dark matter search and neutrino experiments need **liquefying, purifying and recirculation systems**.

- Within the DarkSide-20k project we have built a detector prototype to study the scintillation and ionization signals detected by SiPMs arrays.

- The detector, a double phase LAr TPC, is connected to a **dedicated cryogenic system** to liquefy and purify the gaseous argon used as the scintillator.

- This system has been built and has been operated at the INFN laboratory in Naples since October 2021.

Introduction

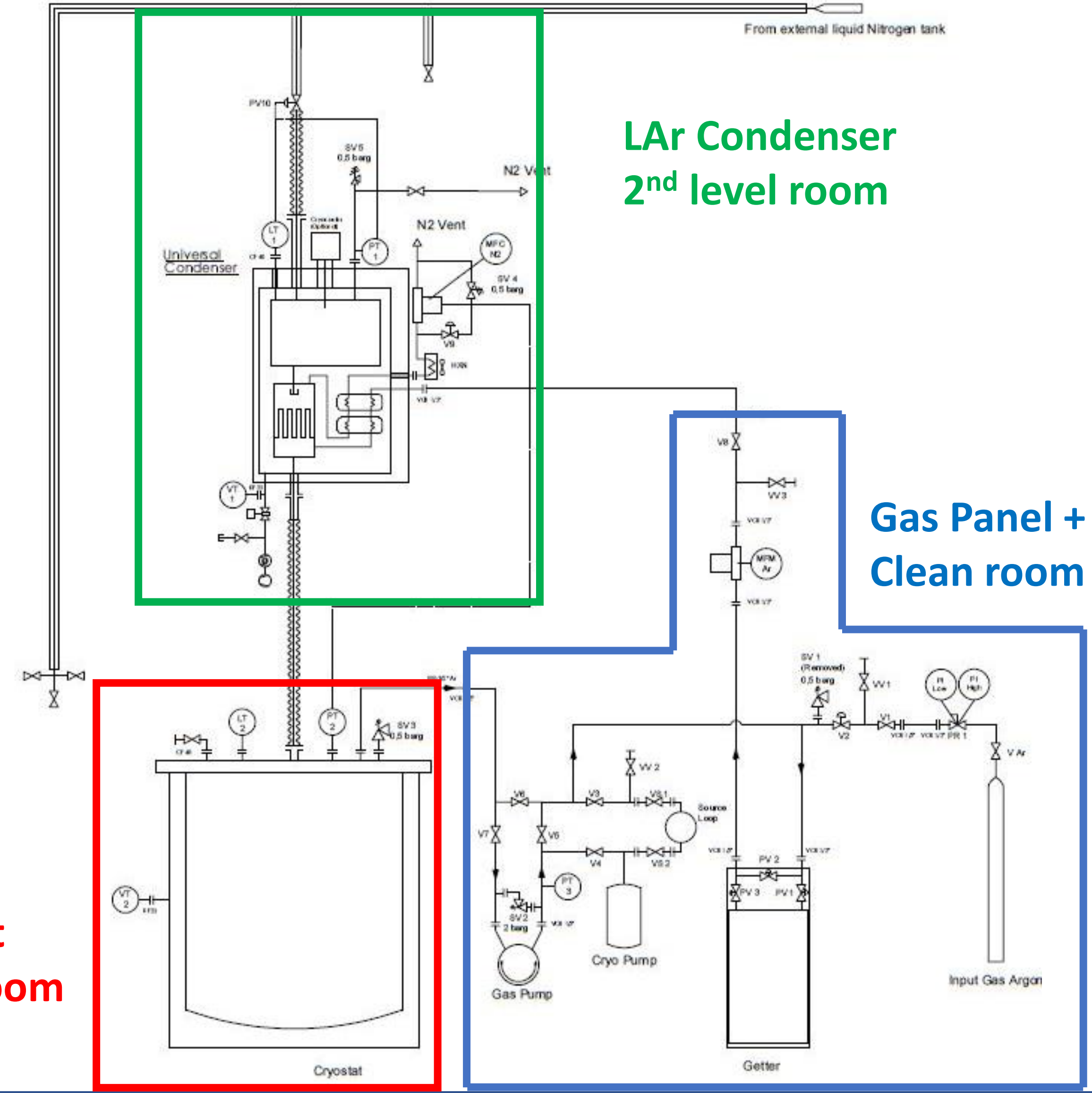


- The purpose of the system is to **purify** and **recirculate** the Ar gas.
- The starting point is the 6.0 Ar gas, i.e. with a grade of purity of 1 ppm.
- This type of detectors needs a LAr purity at least **1 ppb**.
- Need to **evaporate, purify and liquefy the Ar continously**.
- Key feature **gas pocket stablility.**

↓

Cryostat pressure monitoring

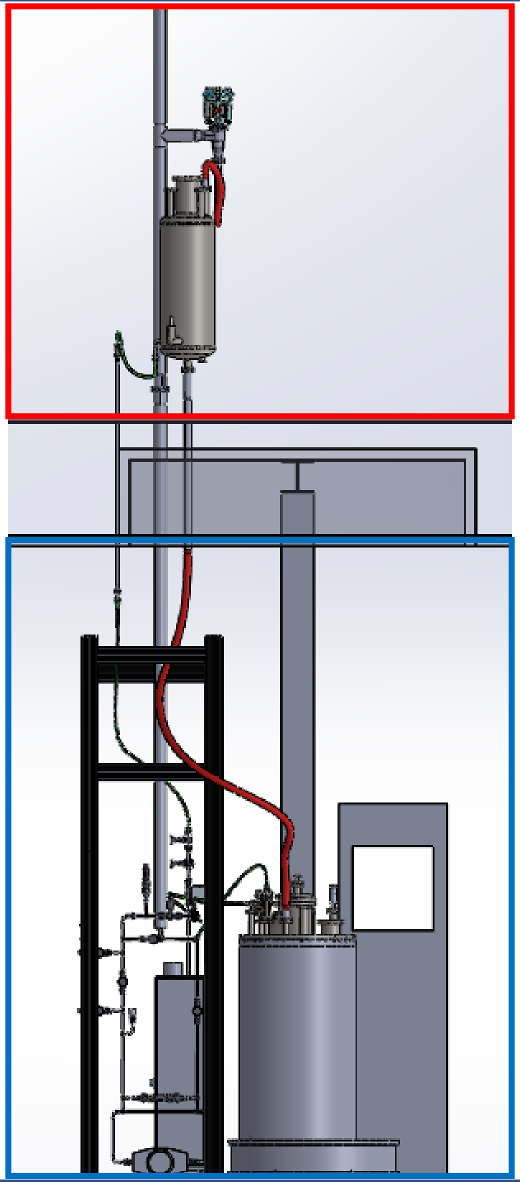
Cryogenic system overview



LAr Condenser
2nd level room

Gas Panel + Getter
Clean room

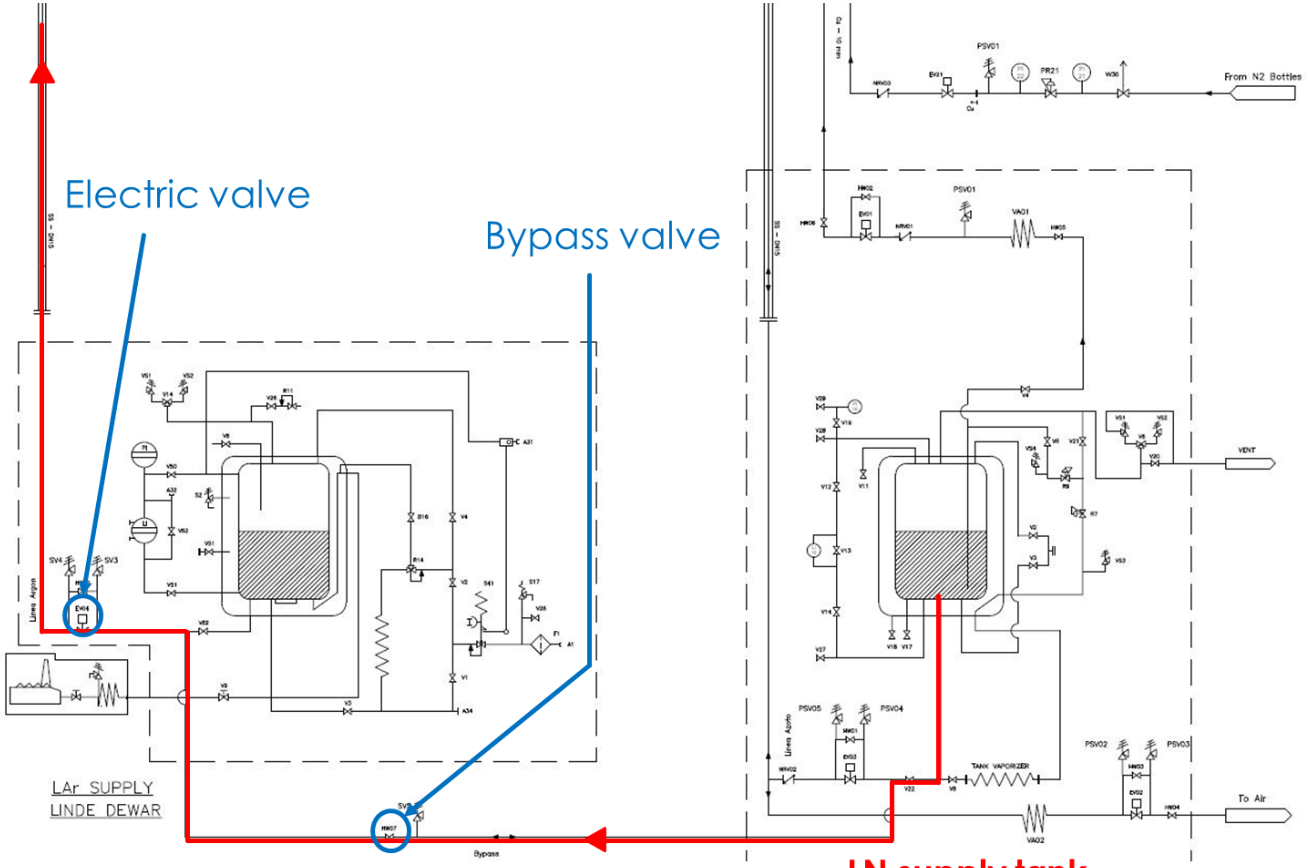
Cryostat
Clean room



2° level room

clean room

Cryogenic system overview



Cryogenic system overview

In the current configuration the condenser works with a continuous supply of liquid nitrogen.

Level of the liquid nitrogen stored in the condenser is kept stable by a **PID controlled proportional valve** (PV10).

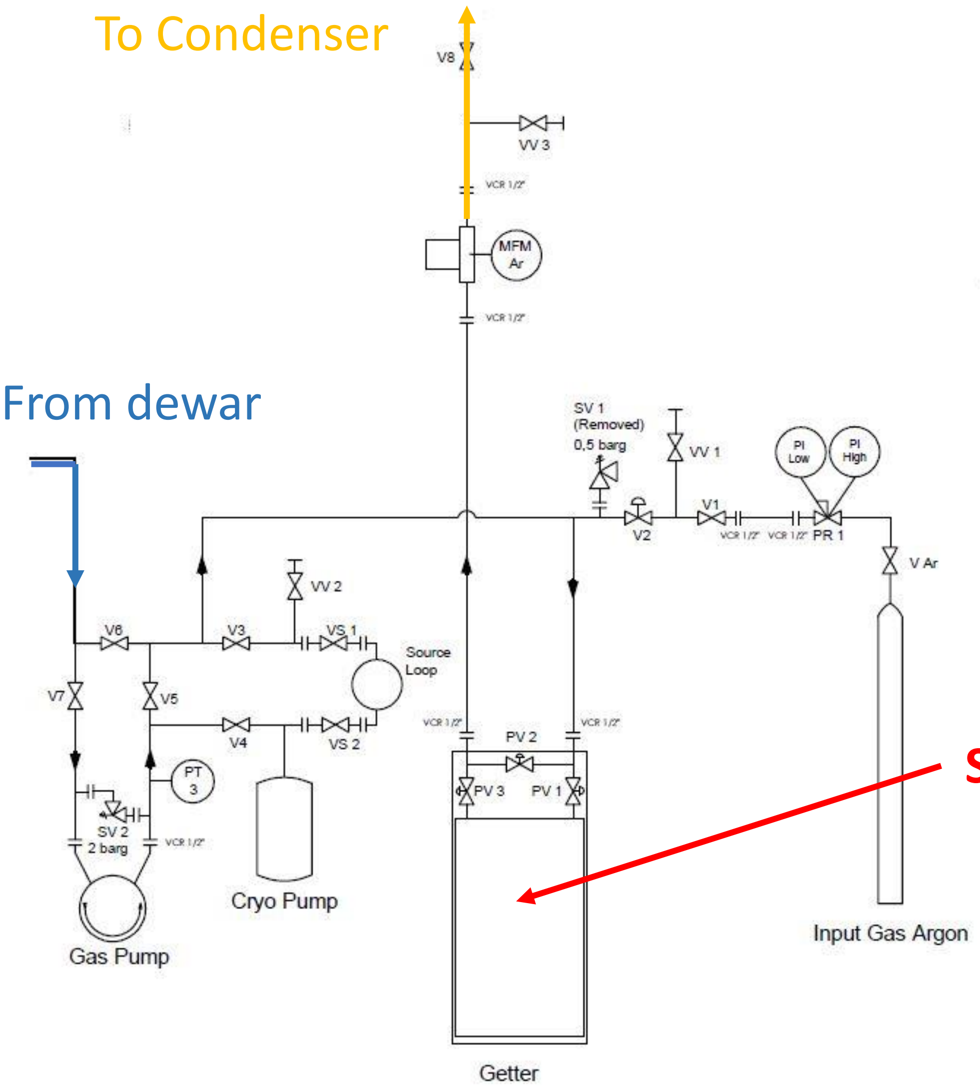
The **cooling power** of the condenser is regulated by the amount of LN coming in the heat exchanger.

The resulting amount of GAr liquefied affects the pressure of the Ar in the cryostat.

Cryogenic system overview

To Condenser

From dewar

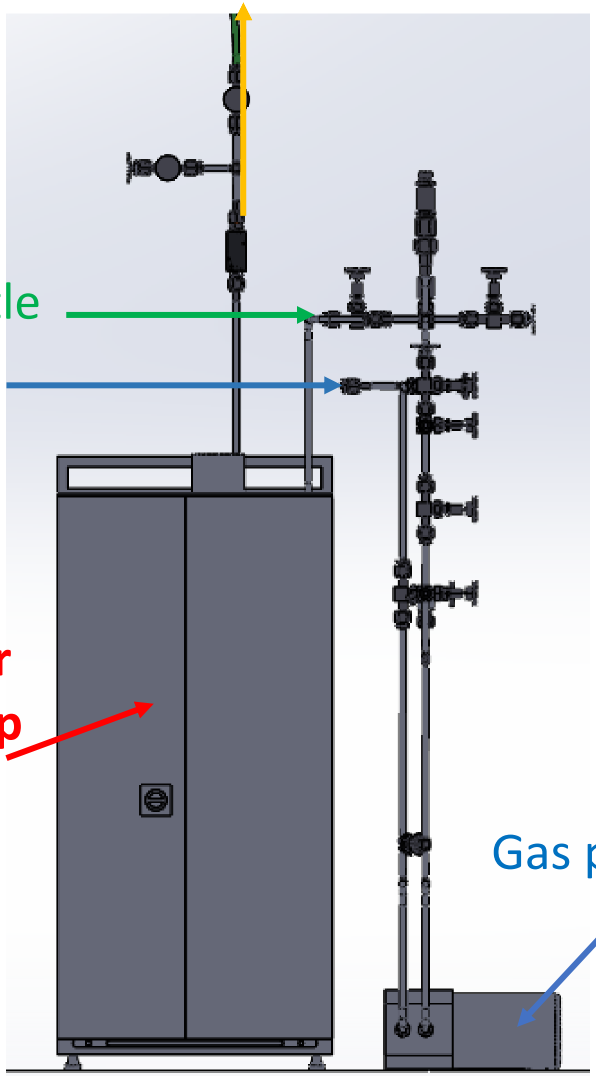


Purification Getter
SAES Getters Group
PS4-MT50-R

To Condenser

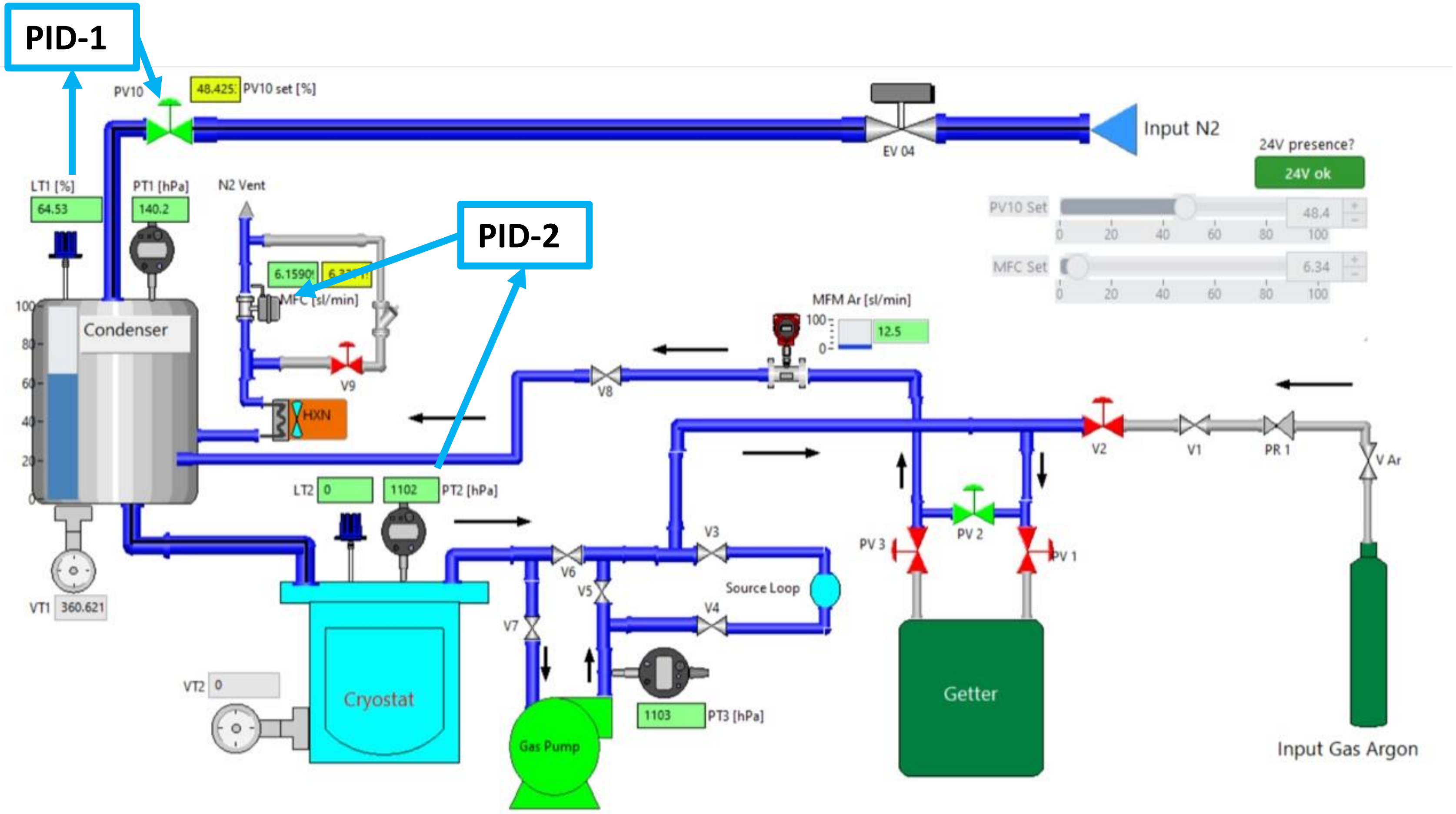
From Ar bottle

From dewar



Gas pump

Cryogenic system overview



<u>S</u>low control system - NI system (cRIO + LabVIEW Real Time Application).

LT1 (Condenser's LN_2 level) maintained constant controlling the PV10(Proportional Valve) opening).

PT2 (Cryostat Pressure) controlled via condenser's cooling power adjustment (regulation of the amount of Ar gas liquefied).

First commissioning test

First commissioning test:

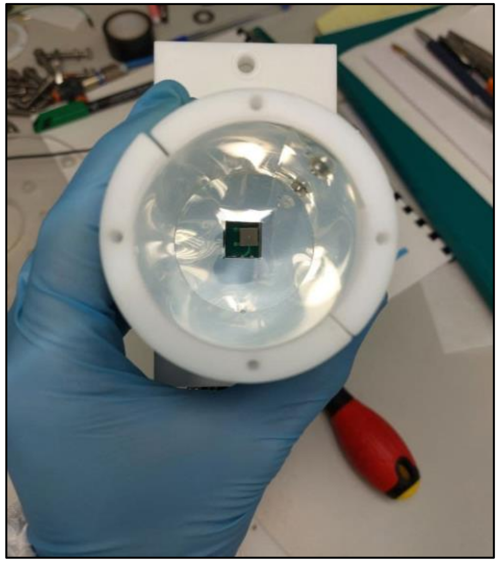
Use of 12.9 liters **double wall vacuum insulated dewar**.

Metal Bellows **gas pump** (fixed motor speed - 2875 rpm) utilized (SeniorAerospace MB-602).

Cryostat **filling** done liquefying 6.0 Ar gas from pressurized bottles.

The system worked with all the components active, including the Getter.

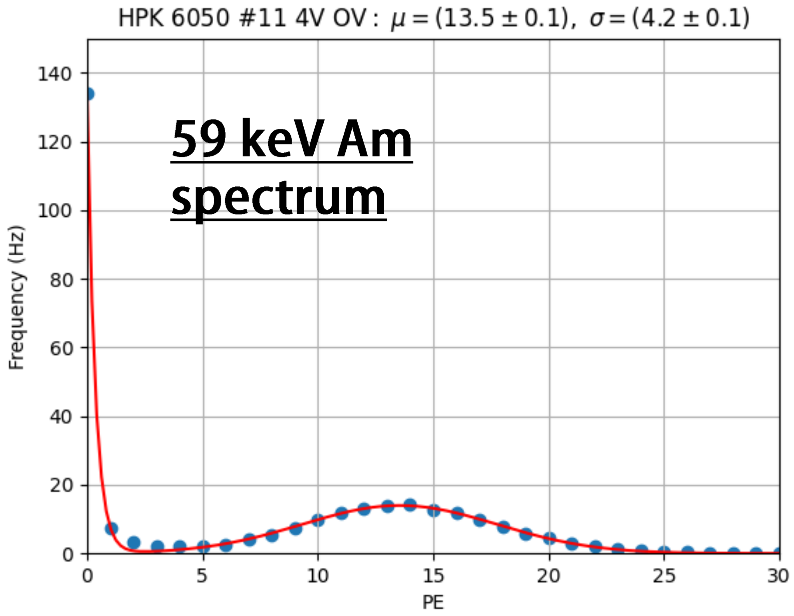
First test – Getter purification

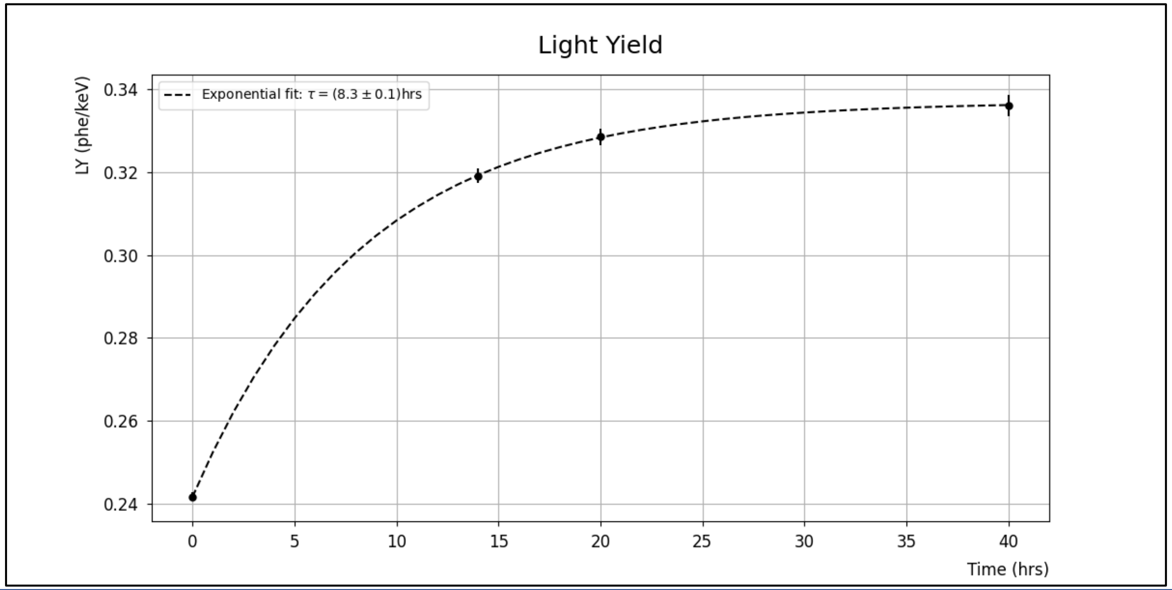


Light Yield as function of getter time operations

Evaluated with an Hamamatsu SiPM (6 x 6 mm^2)

Small chamber internally lined-up with PEN and ESR reflector

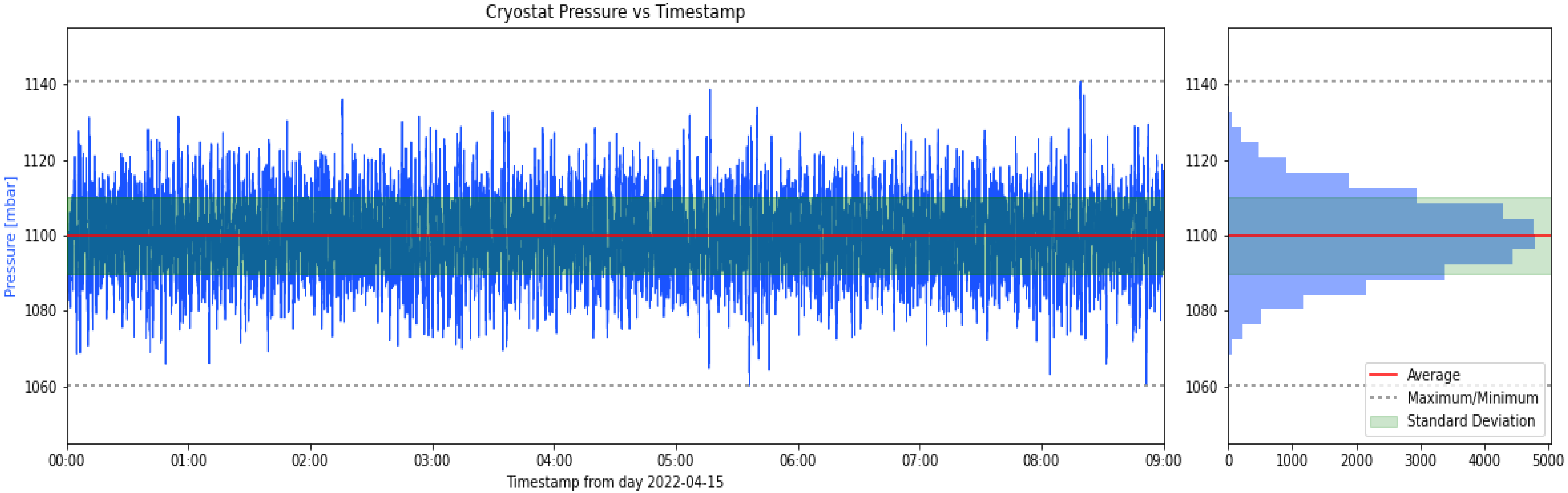




Peak spectrum vs getter operation time: after 1 day operations in small dewar maximum is reached

First test – Pressure stability

Avg = 1100 mbar
Std = 10.25 mbar
Max = 1141 mbar
Min = 1060 mbar



- Pressure in the cryostat evaluated during the whole running period.
- Maximum pressure variation +/- 40 mbar around the set point (1100 mbar) with standard deviation of 10 mbar.
- The obtained performances in pressure stability were different from the desired ones (≤ +/- 10 mbar) for the detector sensitivity.

Second commissioning test

Second phase of tests to improve the performances of the system.

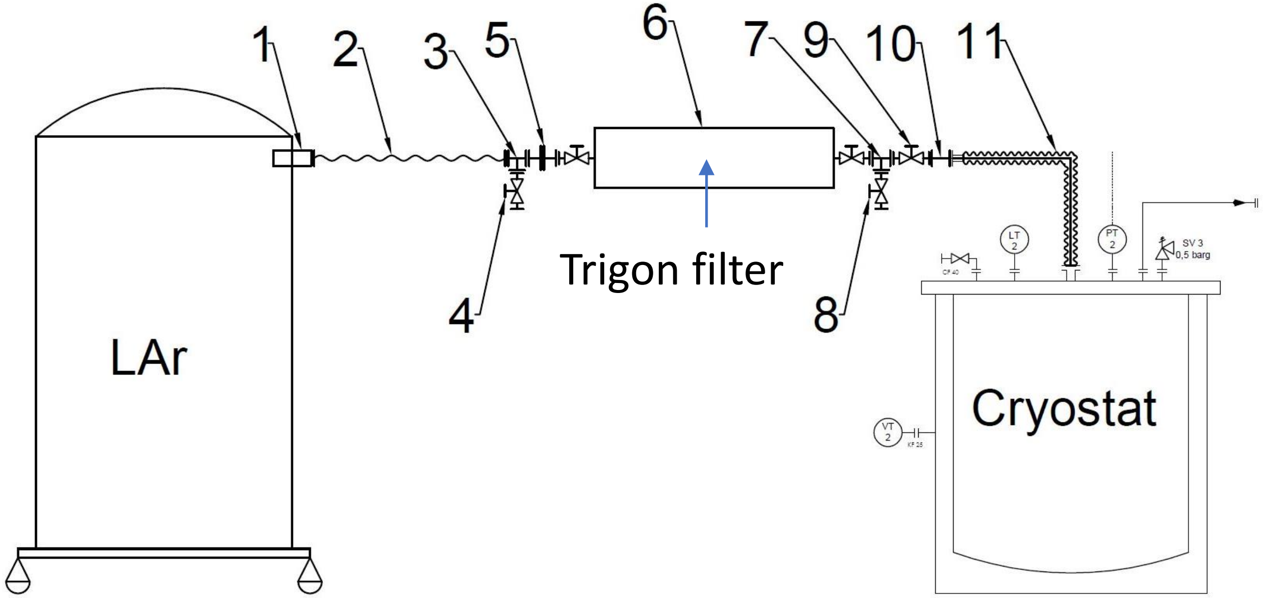
Cryogenic system upgraded:

- Use of **300L cryostat.**
- Gas pump replaced with a tunable speed **Qdrive pump.**
- Installation of **expansion tanks** to reduce mechanical vibration due to the recirculation pump.
- No Getter used for this second test.

Second commissioning test

Cryostat directly filled with 5.0 LAr.
Use of a trigon filter for LAr purification.

LAr filling allowed to speed up the process previously requiring several days and bottles of Ar gas.



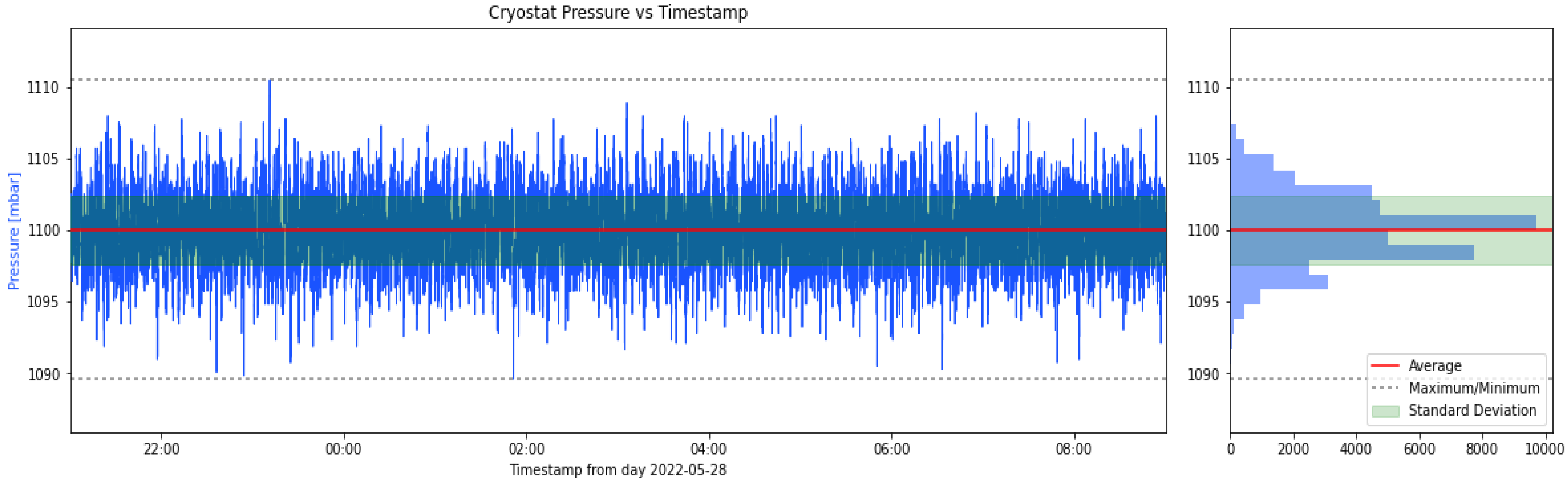
Second test – gas pump speed variation

Gas pump speed [%]	7 %	15 %	20 %	25 %	30 %
MFM flow [sl/m]	13 sl/m	22 sl/m	26 sl/m	30 sl/m	34 sl/m
MFC flow [sl/m]	5 sl/m	8 sl/m	9 sl/m	10 sl/m	11 sl/m

- Set of working parameters of gas pump speed
- Ar recirculation flow changed according with the gas pump speed
- Parameters selected in order to avoid the freezing of the Ar gas outlet line (45%), and the nitrogen MFC instability (5%)

Second test – Pressure stability

Avg = 1100 mbar
Std = 2.41 mbar
Max = 1110 mbar
Min = 1090 mbar

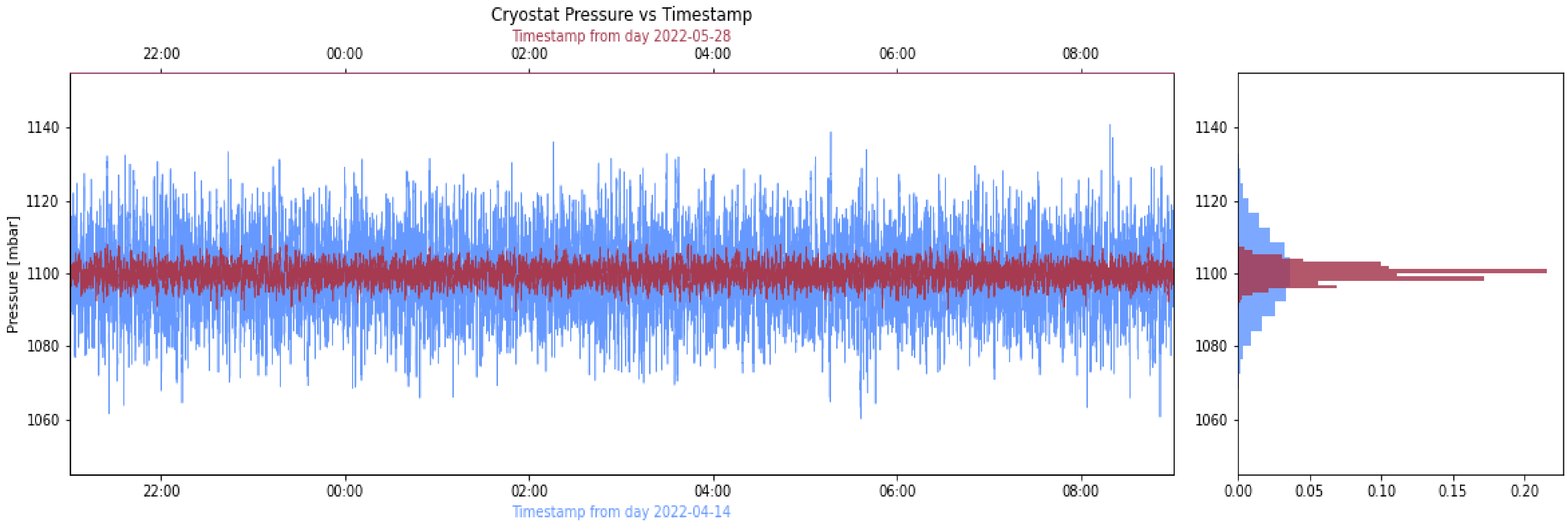


- Pressure in the cryostat evaluated during the whole running period (10 days).
- System ran at stable conditions.
- Maximum **pressure variation +/- 10 mbar around the set point of 1100 mbar with a standard deviation of 2.4 mbar.**

Comparison after the upgrades

Avg = 1100 mbar
Std = 10.28 mbar
Max = 1141 mbar
Min = 1060 mbar

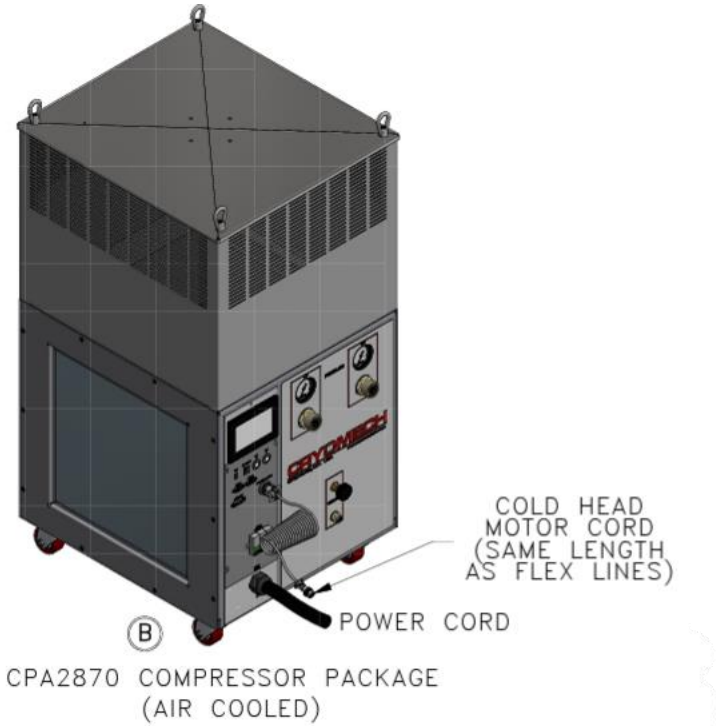
Avg = 1100 mbar
Std = 2.41 mbar
Max = 1110 mbar
Min = 1090 mbar



- Consistent improvements obtained with the upgrades to the system.
- First goal reached: pressure in the cryostat with a maximum variation of +/- 10 mbar.
- Next step: further reduction of cryostat pressure variation.

Future Upgrades

Cryocooler AL300 installation (change of condenser operation method) – Late Autumn 2022



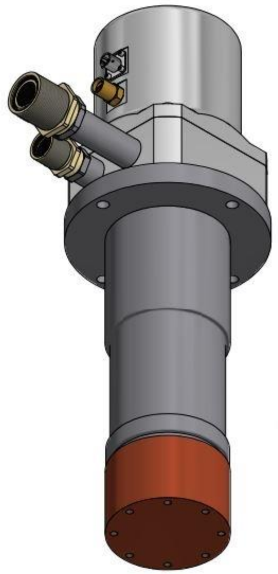
AL300 cryocooler with its **CP2870 Cryomech compressor** and a dedicated **Chiller** installation.

↓

Nitrogen gas refill (no more LN needed).

↓

No more LN barrel vent needed.



Conclusions

- The cryogenic system composed of **double wall cryostat**, a **purification stage**, the argon **condenser**, a recirculation gas panel equipped with a **custom gas pump** is ready to work.

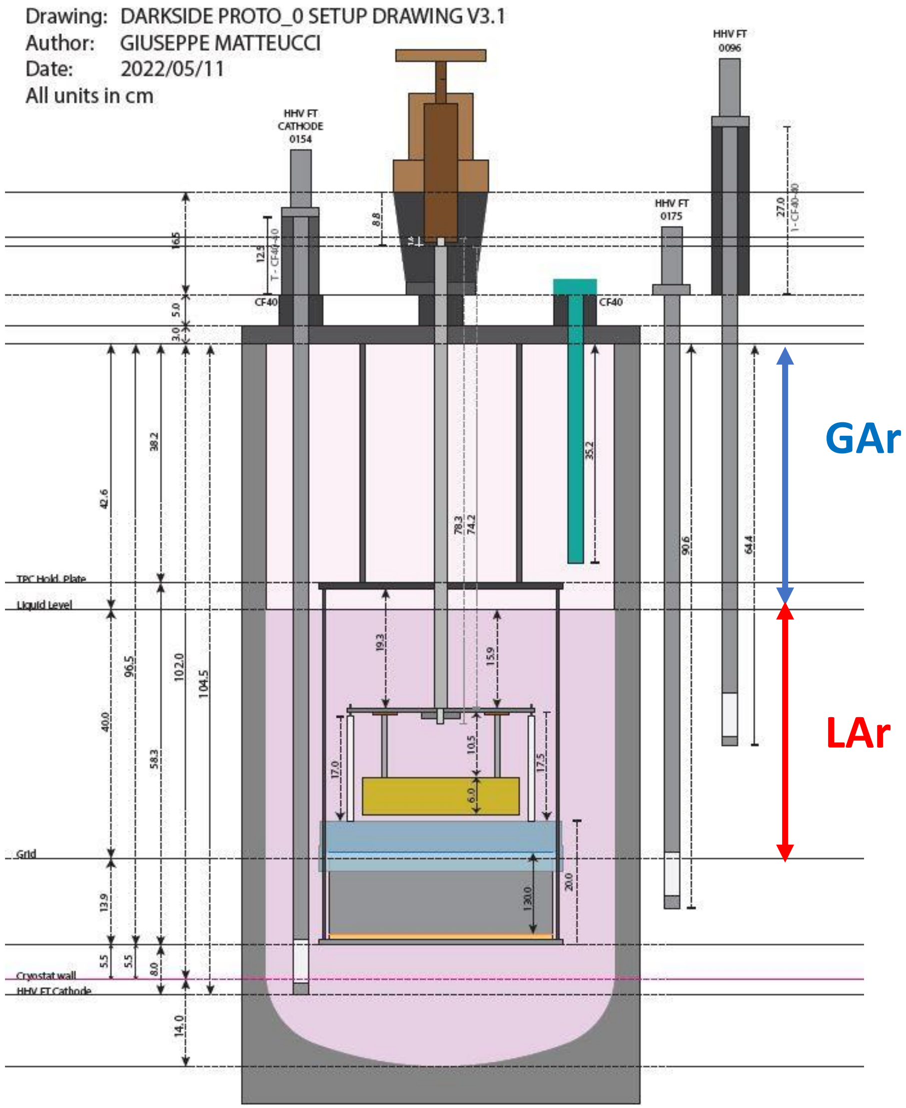
- 2 tests were performed to validate the system functioning and to calibrate the process.

- The improvements made to stabilize the pressure brought us close to the goal.

- The presented upgrades will be shortly implemented.

BACKUP SLIDES

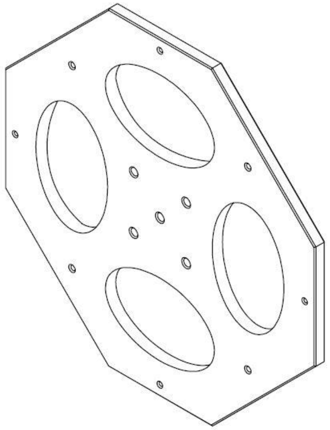
Proto-0 Setup

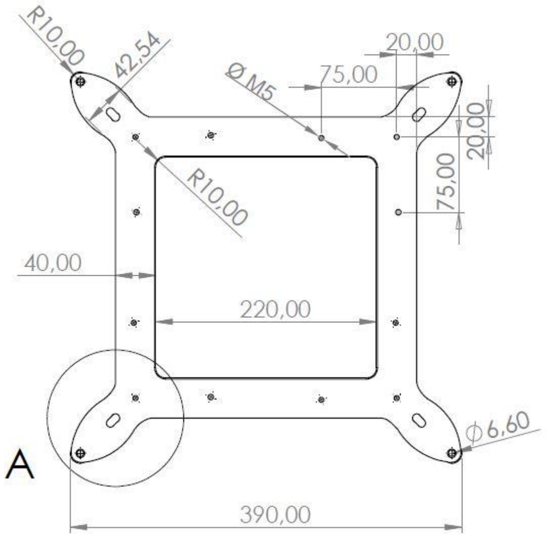


Mechanical support systems :

1. Holding plate and Motion feedthrough bar compatible with MB2 and PDU+

2. Supporting plate compatible with TPC and HV feedthroughs layout imposed by the flange displacement





Argon levelling in the cryostat:

- 40 cm of LAr over the TPC Grid

- At least 40 cm of GAr between the LAr surface and the top flange