INITIAL CONDITIONS:

Less than 1 ppm of oxygen will be left in the evacuated chamber before filling it with argon (larger oxygen traces may quench the scintillation signal produced by the liquid argon), **pumping the chamber down to 10^{-3} mbar** when still at room temperature. Refer to Fig 12 for the following. The chamber may be flushed with atmospheric argon (cylinder B50, AAr) and pumped again further decreasing the oxygen content and other possible contaminants. For this purpose we use a pumping system equipped with a turbo pump connected to valve v11. **Such a flush and pump procedure may be repeated** (e.g., for two procedures, we will use ~4 l of STP argon gas each).

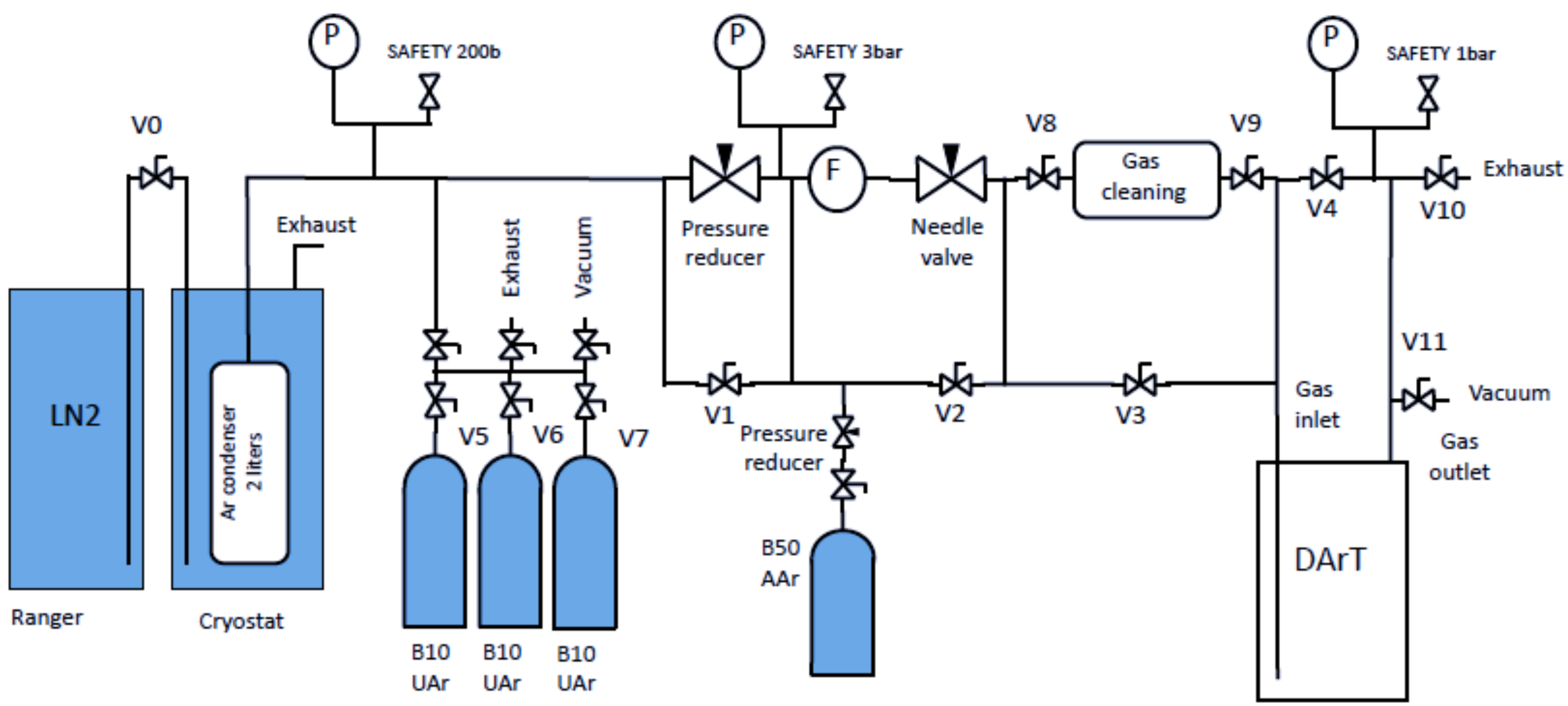


FIG. 12. Schematics of the gas handling system and cryogenics for the operation of the DArT chamber.

An inspection with a helium leak detector at room temperature is performed to assure there are not leaks in the DArT chamber and in the lines at room temperature, where some oxygen might potentially enter. For this purpose the system must be proven leak tight at a level better than 10^{-7} mbar l/s (<0.5 ppm of O_2 in 1 day). The turbo pump should be anyway kept on until the system is warm. As an option, being the chamber and pipes volume very small, we may use the leak detector itself, equipped with a turbo pump, to reach the expected level of vacuum. **The set of pressure gauges, indicated with P, include a mechanical pressure gauge, a pirani and a cold cathode penning gauge.**

After the chamber has been proved leak tight, we have now *two slightly different options for the argon condensation:*

Option 1)

The DArT chamber is inserted in the underground ArDM cryostat (or the cryostat located at a surface laboratory that will be used during the preliminary tests) **that is filled with atmospheric liquid argon and consequently the DArT chamber (still under vacuum) will cool down**, its temperature being monitored by the three PT1000 inside the chamber itself.

The SiPM's will cool down slowly enough by conduction through the DART chamber (that is now at 87 K) avoiding unnecessary large thermal stresses.

The Turbo pump can now be switched off, v11 closed and the static vacuum pressure in the DArT chamber, read out by the penning pressure gauge, is constantly monitored. We expect the pressure to further decrease with the temperature.

Then the DArT chamber may be filled as described in the next section **“Filling the DArT chamber with argon”.**

Option 2)

This alternative solution may be preferable, especially in case the system will need to stay for a long time in vacuum before being filled with argon gas. **The advantage is to avoid any possible contamination due to air entering from the outside.**

After the leak check, **the DArT chamber may be immediately filled with argon** (AAr or UAr depending on the test) **with a slight overpressure of ~50 mbar above 1 atm before being inserted in ArDM.**

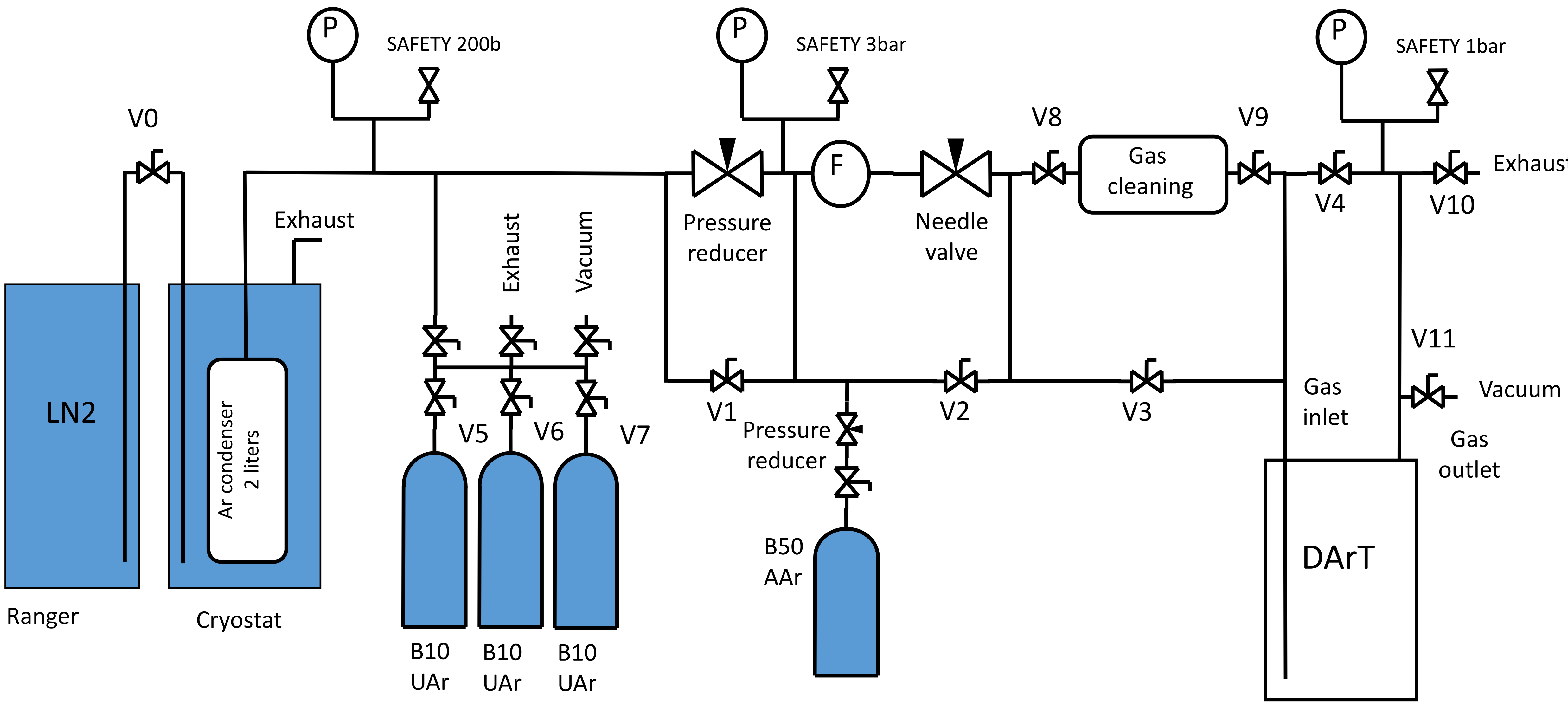
Then the DArT chamber is inserted in ArDM (or the cryostat at the surface lab) **and consequently ArDM will be filled with liquid argon.**

The procedure now follows the one described in the section "Filling the DArT chamber with argon".

Filling the DArT chamber with argon
(same procedure for UAr or AAr):
About 900 litres of STP atmospheric argon gas, stored in the B50 cylinder (e.g. 18 bar, 50 litres) equipped with a pressure reducer, **will condense in the DArT chamber, that is immersed in the ArDM liquid argon**. The gas/liquid density ratio for argon is about 840 referring to gas at STP. The argon will flow through a SAES getter for purification ("Gas cleaning" in Fig. 12) before reaching the DArT chamber. **The pressure** in the DART chamber, and in all the lines, **must be kept at few tens of mbar above the atmospheric pressure**, e.g. ~50 mbar, to assure that in case of a small leak the argon in **the chamber will not be contaminated**. This will also facilitate the condensation process. To monitor precisely the pressure, a mechanical pressure gauge working in the range 0-1 barg is placed, at room temperature, between the v4 and v10.

The argon will **slowly flow in the DArT chamber and condense therein** (without using any pumping system). The speed of the process will be compatible with the ArDM liquid argon temperature and the slight DArT chamber over-pressure.

The final pressure of the argon gas in the lines, after the full condensation of the liquid argon in the chamber, will be approximately 1 bara (0 barg).
We estimate that **eventually about 840 litres** at STP of argon gas **will be condensed in the DArT chamber**, 50 litres will remain in the cylinder and only a few litres in the room temperature lines (including the 2 litre argon condenser).



SAFETY 200b
SAFETY 3bar
SAFETY 1bar
P
P
P
V0
V8
V9
Gas cleaning
Exhaust
F
V4
V10
Exhaust
Pressure reducer
Needle valve
Exhaust
Vacuum
LN2
Ar condenser 2 liters
V1
V2
V3
V11
Vacuum
Gas inlet
Gas outlet
V5
V6
V7
Pressure reducer
B50 AAr
DArT
Ranger
Cryostat
B10 UAr
B10 UAr
B10 UAr

For the underground argon we will use **the same procedure, but the source will be the set of cylinders B10** (10 litres each).

The liquid argon level of the DArT chamber will be monitored by three PT1000 sensors used as level sensors, exploiting the different steady state self heating of the platinum resistance in the gas (3.2mW/K) and in liquid (32mW/K) phase.
(current should be defined here - is that 1 mA?)

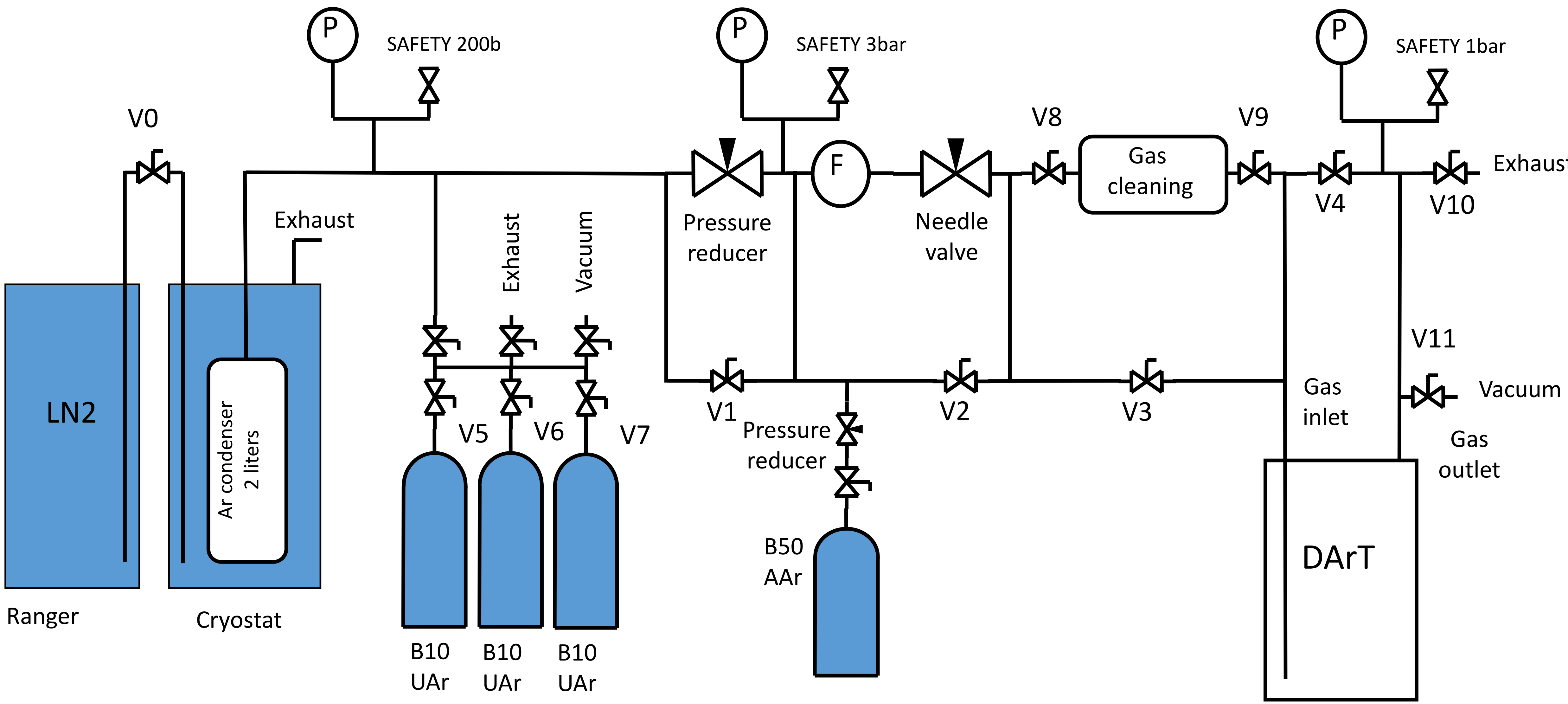
Argon Recovery procedure

To recover the argon in the cylinders (B50 for AAr or B10 for UAr) at room temperature, the procedure is the following: **the evaporation is achieved by applying a proper power to two platinum resistors PT100 fitted in the DArT chamber, driven by a custom made circuit.**

Due to the poor argon thermal conductivity the heater inside the chamber will assure convection therefore facilitating the argon evaporation. *The energy required to vaporize the DArT liquid argon is 247kJ* **(163 kJ/kg)** . With two resistors powered with 3.5W the chamber can be emptied in about 10h. A system test in the laboratory at CIEMAT was performed and worked well. **A liquid nitrogen dewar (**"cryostat") **will be used to cool a 2 litre cylinder** ("Ar condenser") **where the argon will be condensed, solidified and stored during the recovery procedure.**

The vapour pressure of solid argon at ~77 K is about **270 mbar.** A needle valve along the argon path will assure a pressure in the DArT chamber between 700 and 800 mbar, facilitating the evaporation procedure.

The different pressure gauges will be used to monitor the pressure inside the "Ar condenser" and inside the DArT chamber. The pressure reducer will assure the desired flow, measured by the flow meter F, of about 90 litres/hour. **Once the static pressure inside the DArT chamber is less than 300 mbar we may consider the argon fully recovered.** At this stage, the "Ar condenser" may be slowly warmed up to room temperature and the argon gas is recovered in the proper cylinders (AAr or UAr).



P
SAFETY 200b
P
SAFETY 3bar
P
SAFETY 1bar
V0
V8
Gas cleaning
V9
V4
V10
Exhaust
F
Pressure reducer
Needle valve
Exhaust
Exhaust
Vacuum
LN2
Ar condenser 2 liters
V11
V1
V2
V3
Gas inlet
Vacuum
V5
V6
V7
Pressure reducer
Gas outlet
B50 AAr
DArT
Ranger
Cryostat
B10 UAr
B10 UAr
B10 UAr