SLArchetto Operation Procedure

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General steps:

1. Precool the LAr filter first. During the precooling, vent to the venting line, but not to the SLArchetto vessel. This takes about 1 hour and we stop precooling when the temperature in the LAr filter is -100°C (the lower limit of the temperature readout).
2. Fill the SLArchetto vessel, monitor the LArPix noise during the filling. Stop LAr filling when RTD4 is submerged in LAr and RTD5 is about to be submerged, and/or the liquid level sensor is at 65 cm.
3. After LAr reaches the desired level, take pedestal data with LArPix.
4. Turn off LArPix and ramp up the high voltage.
5. Take pedestal data, set the trigger threshold of LArPix. Start data taking.

Safety:

- All the doors of the LNTF hut have to be open.
- The intake fan has to be turned on.
- The oxygen deficiency sensor and monitor (ODM) have to be checked.
- The pressure in the LAr filter must not exceed 150 psi. The pressure is shown on PG3.
- The pressure in the SLArchetto vessel must not exceed 10 psig. The cracking pressure of the burst disk is 10 psig but likely it will break at ∼6 psig. The pressure is shown on PG5 on top of the vessel and PT1 in the detector control system (Ignition).

Technical notes:

- V3, V5, V7, V9, V16/V17, V19 isolate the LAr filter. During the LAr filling, V5, V16, V17, V19 should be always closed. V17 is a metal valve, and we close V17 to prevent cold Ar gas from entering the gas heater.
- The ion gauge (PG1) has to be turned off before LAr filling by unplugging the cable. Otherwise it will be damaged (which costs $1500 and 2 – 3 months of lead time).
- The vacuum vessel surrounding the LAr filter should be evacuated from V4 all the time during LAr filling. The pressure can be read from PG6.
- Purge the venting line of SLArchetto with ultra high purity Ar gas when V12 and V13 are open. At least at the beginning of filling, dewar trasition, and the end of filling.
  - If using a gas cylinder outside the LNTF hut, the gas pressure at the outline of the regulator should be 20 psig.

  - You can use one LAr dewar to fill and the Ar gas (from the gas port) of another LAr dewar to purge. The LAr and Ar gas have to come from different dewars. In this case, also keep monitoring the usage of LAr so that we don't run out of LAr before getting to the desired LAr level.

- V9, V11, V12 (V13, V14, V15) isolate the SLArchetto vessel. V11, V14, V15 should be always closed, while V12 should be always open until LAr filling is completed. Make sure you know where V12 is; **the burst disk will rupture if V12 is closed.**
- After connecting a new LAr supply dewar, purge the air in the tube from V2.
- Cool down the LAr purifier by filling it with LAr from V3 and venting the gas Ar from V7. Monitor the temperature from the "LAr Filter Regeneration" tab. This takes about 1 hour.
- When starting filling LAr in SLArchetto (at the room temperature), all the LAr will evaporate. This is the time that pressure will rapidly build up in the system. Carefully control V13 to release the pressure.
- Keep the pressure in the SLArchetto vessel at 2 – 4 psig (16.5 – 18.5 psia). The pressure can be read from PG5 on the top of SLArchetto and from PT1 from the Iginition GUI.
- Keep the pressure in the LAr filter at 20 psig (TBC). The pressure can be read from PG3.
- We would like to control the filling so that it takes ∼5 hours to fill SLArchetto. The desired liquid level is 65 cm on the level sensor. Note that the filling rate is not linear because more LAr evacuates at the beginning.
- The torque for V3 is 25 foot-pound.
- Load ∼55 L of nitrogen in the thermosyphon line 11 (TSL11).
  - Start loading nitrogen after starting purging the venting line.
  - Use the "Thermosyphon" page from the DUNE detector control system (Ignition).
  - Use the "Purge" bottom to purge the thermosyphoton line.
  - Start with 10 L nitrogen at 5 slpm. Wait for the pressure in TSL11 to stablize.
  - Then load 5 L nitrogen at 5 slpm each time. Better to wait longer between each load.
  - After finishing LAr filling, monitor the pressure in SLArchetto and adjust the nitrogen amount accordingly (usually adding or removing 1-3 L of nitrogen).
- LArPix DAQ tutorial can be found at `https://github.com/SLACube/slacube-daq-tutorial`.
  - DO NOT run DAQ when the system is in vacuum.
  - Configure the hydra network, take pedestal runs and find bad channels at room temperature. Then do threshold and selftrigger tests at room temperature as well.
  - Monitor pedestal during LAr filling (after the vessel is at $\geq$ atmospheric pressure).
  - After LAr is filled, set threshold and test the trigger rate with HV = 0V.
  - After HV is ramped up, try a few selftrigger tests. Manually increase the trigger threshold if the trigger rate is too high (> 2Hz per channel).
- Turn off the LArPix tile while ramping up the high voltage.
- Once SLArchetto is filled, close V12, V13, V9. Open V7 to vent Ar in the LAr filter.
- RTD2 (the bottom one) is not available in this run, but it is repetitive to RTD1.
- RTD3 in this run is connected to Cryocon channel B.
- V9, V12 and V13 usually freeze during LAr filling, wait some time and close them again.
- The venting line vibrates during LAr filling and possibly during purging and makes noise. The flowmeter vibrates as well.

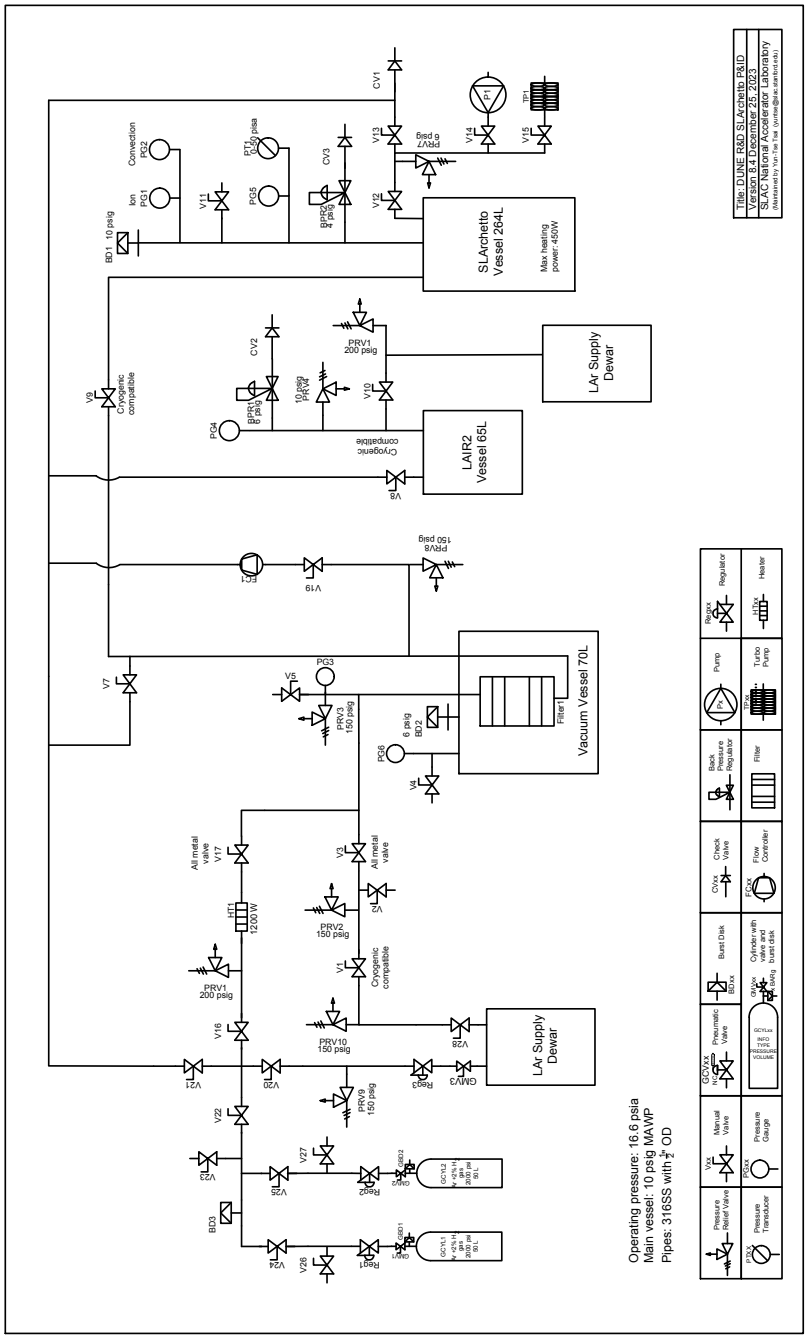
Title: DUNE R&D SLArchetto P&ID
Version 8.4 December 25, 2023
SLAC National Accelerator Laboratory
SLArchetto Vessel 264L
Max heating power: 450W
LAIR2 Vessel 65L
LAr Supply Dewar
Vacuum Vessel 70L
Operating pressure: 16.6 psia
Main vessel: 10 psig MAWP
Pipes: 316SS with ½" OD

Figure 1: P&ID

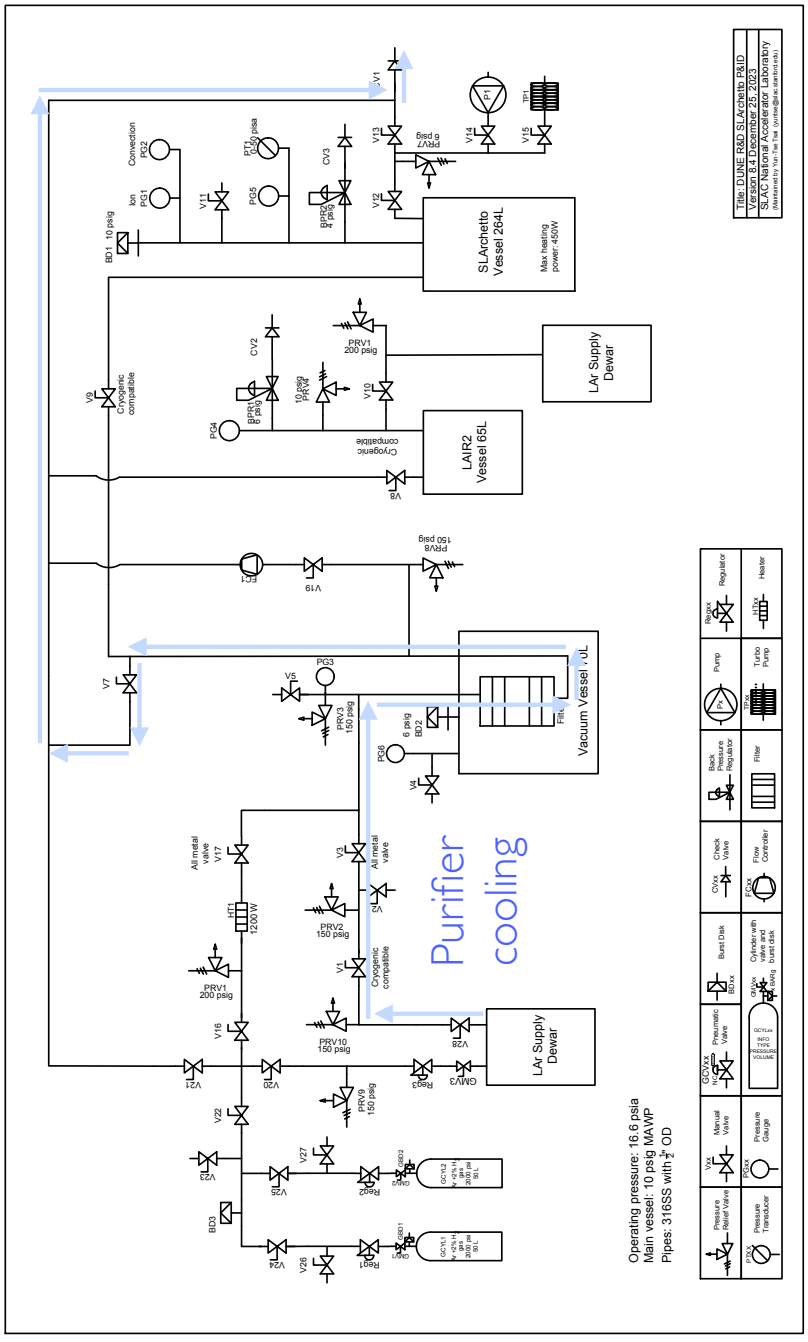

Figure 2: LAr flow direction for cooling the LAr purifier

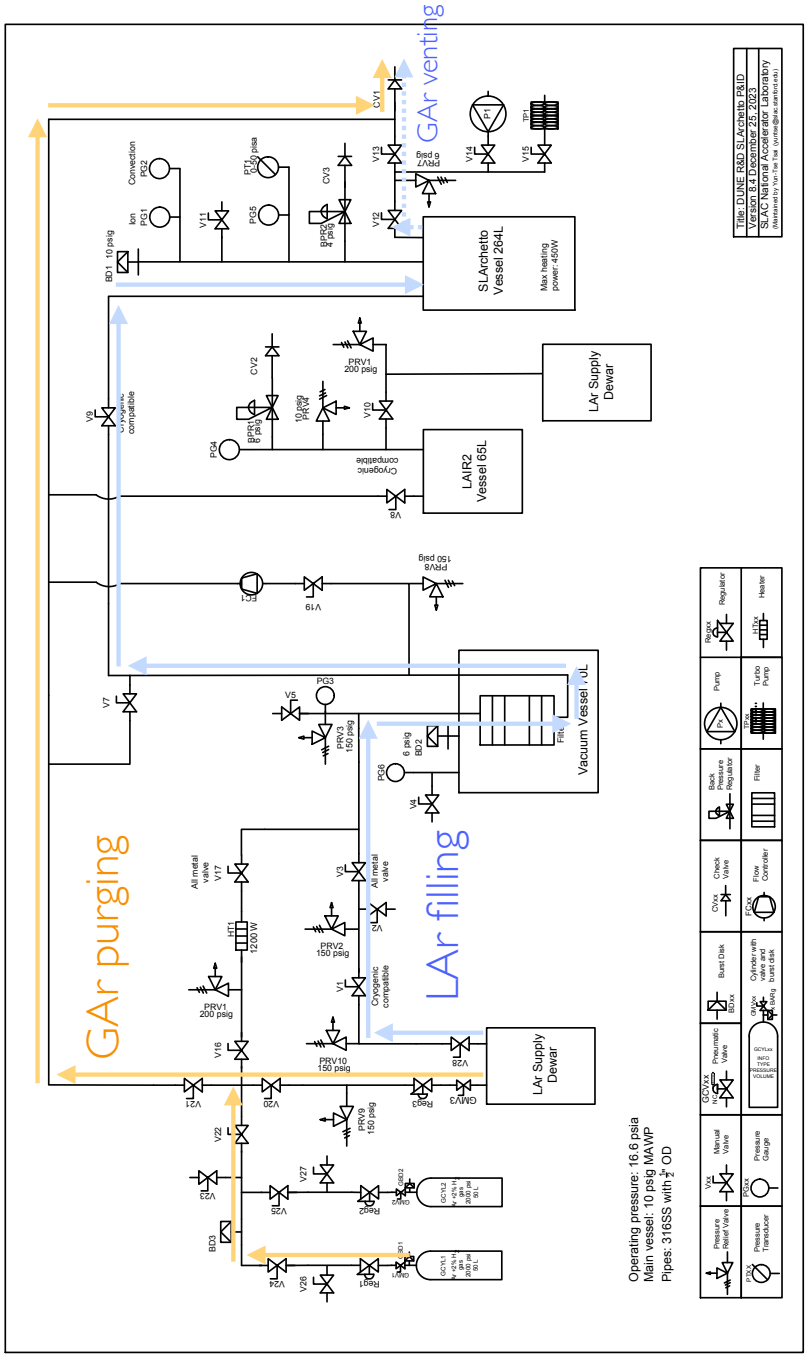

Figure 3: LAr flow direction for filling the SLArchetto vessel. The gas Ar for purging can be injected from the gas port of another LAr dewar, or from an ultra high purity gas argon cylinder. Do NOT use the same LAr dewar of LAr filling for gas Ar purging.

Checklist	What to Do and Detailed Description
Readiness	
3 ultra high purity LAr dewars lifted in the LNTF hut	
TPC grounding checked	
LArPix tests in the room temperature at atmosphere: Configure the hydra network, take pedestal runs, find bad channels, check the threshold and test selftrigger rates.	LArPix tutorial at `https://github.com/SLACube/slacube-daq-tutorial`
Vessel closed and tightened	
Leak checked	
All valves are closed	
V12, V14 are open	For pumping the vessel
P1 (scroll pump) on	Need to use the scroll pump first
P1 on for 30 minutes, PG5 (pressure gauge) way below 0 psig, PT1 (pressure transducer) at absolutely 0 for more than 10 minutes	Read PT1 from **Pressure** in the Ignition detector monitor
V14 closed	
P1 off	
V15 open	Prepare to start the turbo pump
TP1 (turbo pump) on for a few days	
V30 and the valve on the Hicube pump open	The Hicube pump is located behind the computer monitor. V30 is connected on the thermosyphon evaporator, and is not shown in the current version of P&ID
The HiCube pump on	Pump the thermosyphon vacuum jacket
LAr filter regenerated	See the procedure for LAr filter regeneration
Wrap the tubes along the LAr path with foam	
P1 connected to V4. V4 opened and P1 on	Evacuate the vacuum vessel insulating the LAr filter
Detector control (Ignition) set up	Instruction: `https://docs.google.com/document/d/17dsjQEY3hDOYmxKYikNqeVWEoB0qyarqYrbijNPSBfg/edit?usp=sharing`
Torque wrench and handle for V3 in hand	25 foot-pound torque wrench and the handle
Prepare LAr filling	
TP1 (turbo pump) pumped for a few days, PT1 (pressure transducer) at absolutely 0 for a few days, ion gauge at 10^{-3} mbar	Read PT1 from **Pressure** in the Ignition detector monitor. The ion gauge should be turned off when the pressure is greater than 6×10^{-2} mbar

The vacuum in the thermosyphon line jacket is at 10^{-3} hPa level or below	Read the display at the Hicube pump
Purge the thermosyphon line	Use thermosyphon page in DUNE Ignition (button in the main menu or on the thermosyphon temperature panel on the left in the monitor page), select line TSL11 by clicking on the right thermosyphon or on SLArchetto on the minimap on the top right; make sure no other valves in the thermosyphon system are being used (large button on the left grey and saying "No TS valve open"), so that the control panel and the pressure plot under it are visible and enabled. Click the top button `Purge` on the panel. Purge will take about 3 minutes; while still running the traffic light shows green, turning back off when over.
Safety Checks – Beginning of the Day	
All the doors of the LNTF hut opened	
Intake fan on	Press the red button on the east wall of the LNTF to turn the exhaust fan to high speed. Note: Button turns "yellow" when the fan is on high speed
Oxygen deficiency sensor in place, oxygen deficiency monitor green	
HEPAs speed high	HEPA control is in the back of the fans (outside the clean tent), and there are five HEPAs
Cool down the LAr filter	
LAr supply dewar has < 230 psi	If it is higher, vent the argon to lower pressure $\sim$230 psi. If it is too low (such as 30 psi), open the pressure builder to build the pressure to > 100 psi
Connect the LAr dewar	
PPE (cryo gloves, safety glasses) on	
V1, V2 open	Purge the air in the tube
LAr supply dewar (V28) opened	
When seeing LAr, V28, V2 closed	Stop purging
V3 opened	
LAr supply dewar (V28) opened, carefully opened V7 according to PG3	PG3 should be at 5 – 10 psig
Temperature in LAr filter at -100°C (the minimal of the readout device) or cooling for an hour, V28 (LAr supply dewar), V7 closed	
Fill the main vessel	

Start purging the SLArchetto venting line (downstream V13) with gas Ar	Two options: 1. Use gas Ar from the LAr dewar: Open GMV3, Reg3, V20, V21, DO NOT use the same LAr dewar for filling and purging, 2. Use UHP Ar gas cylinder: Hook the gas cylinder, close V26, open GMV1, Reg1, V24, V22, V21
V15 closed	
TP1 (turbo pump) off	Prepare for filling the main vessel
LArPix fan on	Plug the cable into the extension cord used for the turbo pump
Check V12 open	
Double check the closed valves: V2, V5, V7, V8, V9, V11, V13, V14, V15	
LAr dewar (V28) closed	
Double check the open valves: V1, V3, **V12 (IMPORTANT)**	V12 is on the top lid, connecting to the hose. If closed, the burst disk will crack when LAr just fills in.
Oxygen sensor shows <1% or plateaued	Oxygen sensor is displayed at the "LAr Filter" page of the Ignition GUI
One operator ready for adjusting V13 all the time according to the pressure in SLArchetto.	We want to keep the pressure at about 2 psig at PG5 (16.6 psia at PT1) and not to exceed 4 psig at PG5 (18.6 psia at PT1) all the time. We also don't want the vessel pressure to go below 0 psig at PG5 (14.6 psia at PT1), in which condition the air would come in and contaminate the LAr purity.
The second operator fully opens V9	
The second operator opens V28 (LAr dewar) gradually, and the first operator opens V13 according to the pressure in the vessel (PG5 or PT1)	
Thermosyphone load: Fill with 10 L at 10 slpm, and the pressure is less than 5 bar (better less than 3 bar)	Use the "Thermosyphon page". Fill the numbers 10 L (large box) at 10 slpm, and click `Add` N_2. Check the pressure on the purple graph under the controls.
LArPix power supply on. Voltage at 24 V, current limit at 1 A	
LArPix starts taking data when the pressure reaches ∼14.6 psia	Use `Pedestal Monitor` in the LArPix tutorial, `https://github.com/SLACube/slacube-daq-tutorial#pedestal-monitor`.
Equilibrium reached and ∼20 psig (TBC) at PG3 (pressure gauge on top of the LAr filter)	
Pressure in TSL11 stable and < 3 bar, add 5 L at 5 slpm. Totally 15 L	

Repeat slowly until reaching 55 L nitrogen in TSL11	
LAr dewar transition	
When the LAr dewar is almost empty, start to close the LAr dewar	Pressure at PG3 (pressure gauge for the LAr filter) will start dropping when the LAr dewar is almost empty
1 – 3 psig at PG5 (pressure gauge for SLArchetto) or 15.6 – 17.6 psia at PT1 (pressure transducer for SLArchetto) during the LAr dewar transition	Adjust V13 to control the pressure. May need to completely close it. Read PT1 from **Pressure** in the Ignition detector monitor
V1, V3 closed	
The first LAr dewar disconnected, the second one connected	
V1, V2 opened	Prepare to purge the air
V28 (LAr dewar) open	Purge the air in the tube
When seeing LAr from V2, V28 (LAr dewar), V2 closed	
V3 open	
Double check V9 opened	
One operator ready for adjusting V13 all the time according to the pressure in SLArchetto.	We want to keep the pressure at about 2 psig at PG5 (16.6 psia at PT1) and not to exceed 4 psig at PG5 (18.6 psia at PT1) all the time. We also don't want the vessel pressure to go below 0 psig at PG5 (14.6 psia at PT1), in which condition the air would come in and contaminate the LAr purity.
The second operator opens V28 (LAr dewar) gradually, and the first operator open/adjust V13 according to the pressure in the vessel (PG5 or PT1)	
Stop LAr filling	
Cryocon D (RTD 4) reaches ∼90 K at ∼16.1 psia, or drops significantly. Liquid level at 65 cm (SLArchetto page in Ignition)	This means the LAr reaches the desired liquid level. Read RTD values at the Ignition detector monitor or the Cryocon device
Liquid seen through the viewport	Turn on the flash light and place it on top of the viewport shield
When Cryocan E (RTD 5) shows the beginning of the significant temperature drop, two operators ready to close the valves	

One operator ready for adjusting V13 all the time according to the pressure in SLArchetto.	We want to keep the pressure at about 2 psig at PG5 (16.6 psia at PT1) and not to exceed 4 psig at PG5 (18.6 psia at PT1) all the time. We also don't want the vessel pressure to go below 0 psig at PG5 (14.6 psia at PT1), in which condition the air would come in and contaminate the LAr purity.
V28 (LAr dewar), V13 closed	
V1, V3, V9, V12 closed	
V7 open	Vent LAr filter to the venting line.
Stop purging the SLArchetto venting line (downstream V13)	
Electrical box plugged and switched on	Toggle up, switch on in case we need heaters
Take pedestal run	LArPix DAQ tutorial for `Pedestal Test`: `https://github.com/SLACube/slacube-daq-tutorial#pedestal-test`.
Set the threshold of LArPix channels with HV off and test the selftrigger rate	LArPix DAQ tutorial for `Threshold Setting`: `https://github.com/SLACube/slacube-daq-tutorial#threshold-setting`
Enable the warning, alert, and alarm for the pressure	Click the alarm button. Warning range: 14 – 17.7 psia; Alert range: 14 – 18.7 psia; Alarm range: 14 – 19.7 psia
Enable the warning, alert, and alarm for RTD 1, 3, and 4	Click the alarm button. Warning range: 87 – 91 K; Alert range: 85 – 92 K; Alarm range: 83 – 93 K
Enable the warning, alert, and alarm for RTD 5	Click the alarm button. Warning range: 87 – 130 K; Alert range: 85 – 130 K; Alarm range: 83 – 130 K
Enable the warning and alert for RTD 6	Click the alarm button. Warning range: 150 – 163 K; Alert range: 145 – 170 K
20-40 minutes for equilibrium	Check for example, if temperature at RTD 4 is rising, if the pressure is stable
Cryoncon A, B, C, D (RTD 1, 2, 3, 4) show < 90K at $\sim$16 psia	
V7 closed when LAr filter venting completed	
All valves closed	The valves likely were not closed because of the ice on them. Check them again and completely close them
Emergency exhaust fan button is red	Press the yellow button on the east wall of the LNTF to turn the exhaust fan to low speed. Note: Button turns "red" when the fan is on low speed

Ramp up high voltage

LArPix data taking stopped	
LArPix tile powered off	Instruction of LArPix `Power Management`: `https://github.com/SLACube/slacube-daq-tutorial#power-management`
High voltage power supply on	
PicoAmmeter on, set to the 'zcheck' mode	

PicoAmmter DAQ script running and field shell current updating	Log in `neutrino@nu-daq01-ir2.slac.stanford.edu` run
	`cd ~/kapton_daq`
	`source setup.sh`
	`nohup python3 daq.py --config config/config_keithley6485.yaml &`
	Check the `Current` in the `HV Control` panel in the main page, or `PicoAm Current` in the `SLArchetto High Voltage Control` page

HV status on and HV current set to 1mA	Go to the `HV Control` panel, and then go to `HV ramping`. Click `PS initialization`. Then the button `HV Status On/Off` should be On and green.
High voltage ramped up to 15 kV	Set `Target voltage` to 15 kV, and click `HV ramping Interlock ON`, disabling the interlock. Click `Start`. More details in RampingHighVoltage.pdf.
High voltage (Cathode voltage) at 15 kV, field shell current (PicoAm Current) at ∼9000 – 10000 nA (TBC)	Check `Cathode Voltage` and `PicoAm Current` in the SLArchetto High Voltage Control page, or `Voltage` and `Current` in the main monitor
Enable the alert and alarm for high voltage	Click the alarm button. Warning range: 14.95 – 15.05 kV; Alert range: 14.9 – 15.1 kV; Alarm range: 14.8 – 15.2 kV
Enable the warning, alert, and alarm for the current, and the alarms on updates of the current	Click the alarm button. Warning range: -20,000 – 0 nA; Alert range: -25,000 – 0 nA; Alarm range: -30,000 – 0 nA (TBC)
HV ramping Interlock ON	
Start data taking	
LArPix self-trigger tests	LArPix tutorial for `Self-Trigger Test`, `https://github.com/SLACube/slacube-daq-tutorial#self-trigger-test`, and `Threshold Adjustment`, `https://github.com/SLACube/slacube-daq-tutorial#threshold-adjustment`.

LArPix data taking	LArPix tutorial for `Taking Data`, `https://github.com/SLACube/slacube-daq-tutorial#taking-data`
Stop operation	
Stop data taking	LArPix tutorial for `Taking Data`: `https://github.com/SLACube/slacube-daq-tutorial#taking-data`.
LArPix tile powered off	LArPix tutorial `Power Management`: `https://github.com/SLACube/slacube-daq-tutorial#power-management`.
Archive LArPix configurations	LArPix tutorial `Archive Run Config`: `https://github.com/SLACube/slacube-daq-tutorial#archive-run-config`.
HV and current alarms disabled	Click the alarm button and disable the alarms
HV ramped down	Go to the `HV Control` panel, and then go to `HV ramping`. Set `Target voltage` to 0 kV, and click `HV ramping Interlock ON`, disabling the interlock. Click `Start`. More details in RampingHighVoltage.pdf.
High voltage (Cathode voltage) at 0 kV, field shell current (PicoAm Current) at 0 nA	Check `Cathode Voltage` and `PicoAm Current` in the SLArchetto High Voltage Control page, or `Voltage` and `Current` in the main monitor
HV Status off	Click `Switch On`, and the button will become grey and `HV Status Off` will show
V12 and V13 open	Prepare for boiling LAr
Removed liquid nitrogen in the thermosyphon line	Set the total amount of N_2 found in the thermosyphon drawing, e.g. 60 L, to be removed at 5 slpm (click on `Remove` N_2). When it's done, click on `Purge`.
Heater interlock off	Go to SLArchetto main page, turn off the `Heater ITLK ON`
Set up the heater range: 91 – 95 K	Go to `LAr evaporator`, set `Heater OFF temperature` to 95 K while `Heater ON temperature` to 91 K
Heater on	Click `Start`
Heat for 24 hours, and heater off	Go to `LAr evaporator`, click `Stop`
Heater interlock on	Go to the main page and turn on the heater interlock