ArgonCube 2x2
Cryogenic Infrastructure Demonstration

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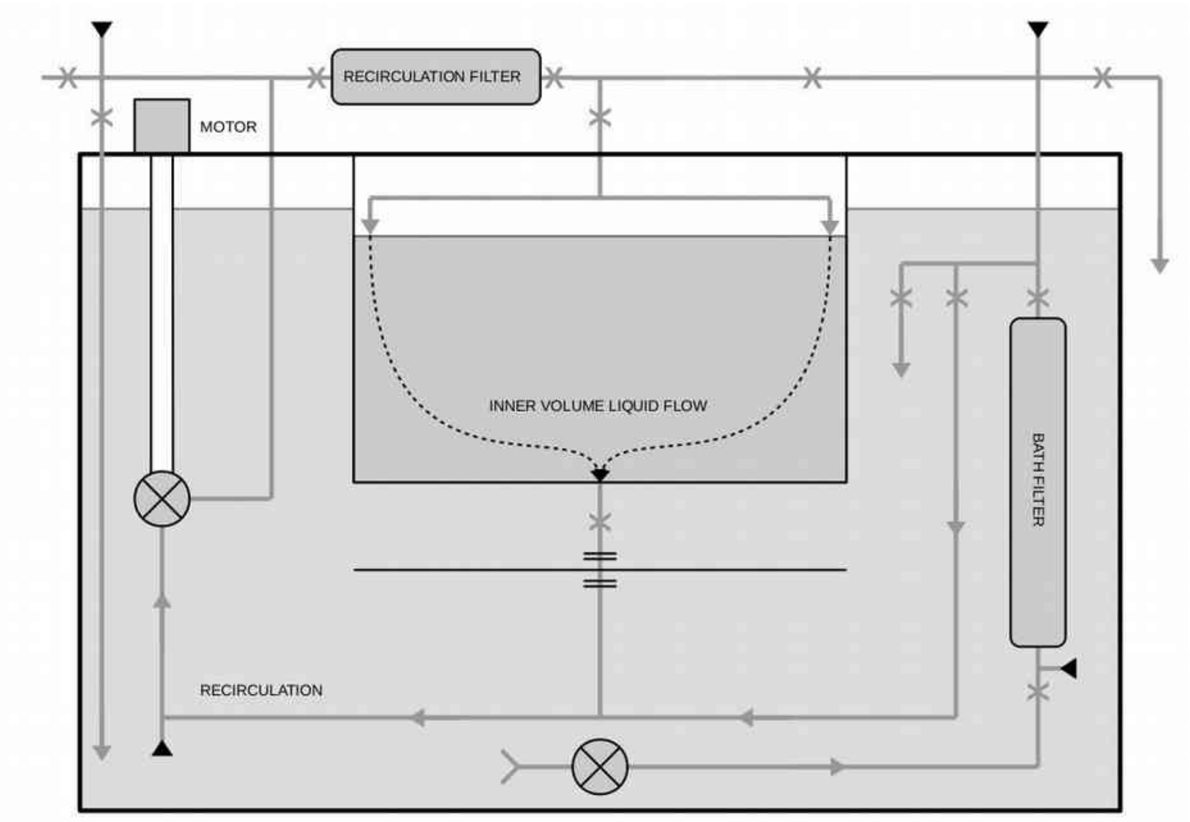
DUNE Collaboration Meeting, September 27th 2019, Fermilab

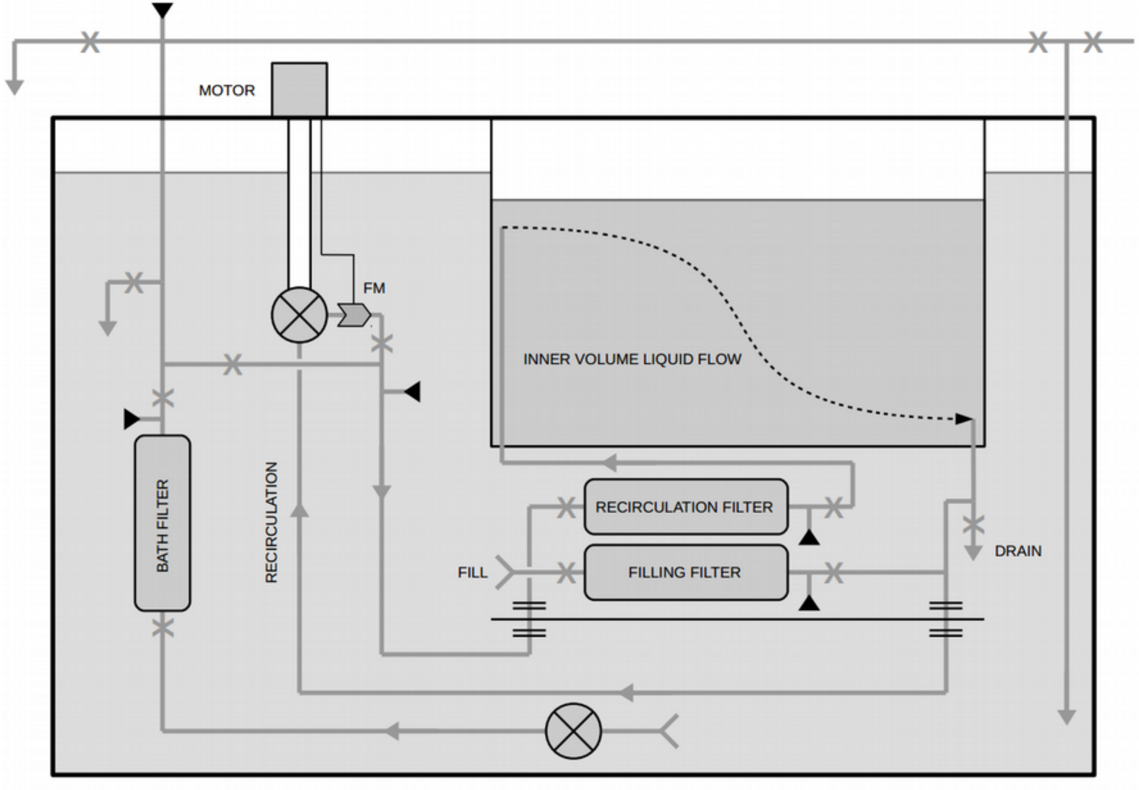
Goal for the ArgonCube 2x2 Demonstrator



X control-valve

Cryostat LAr purification done outside

Current Setup



X control-valve

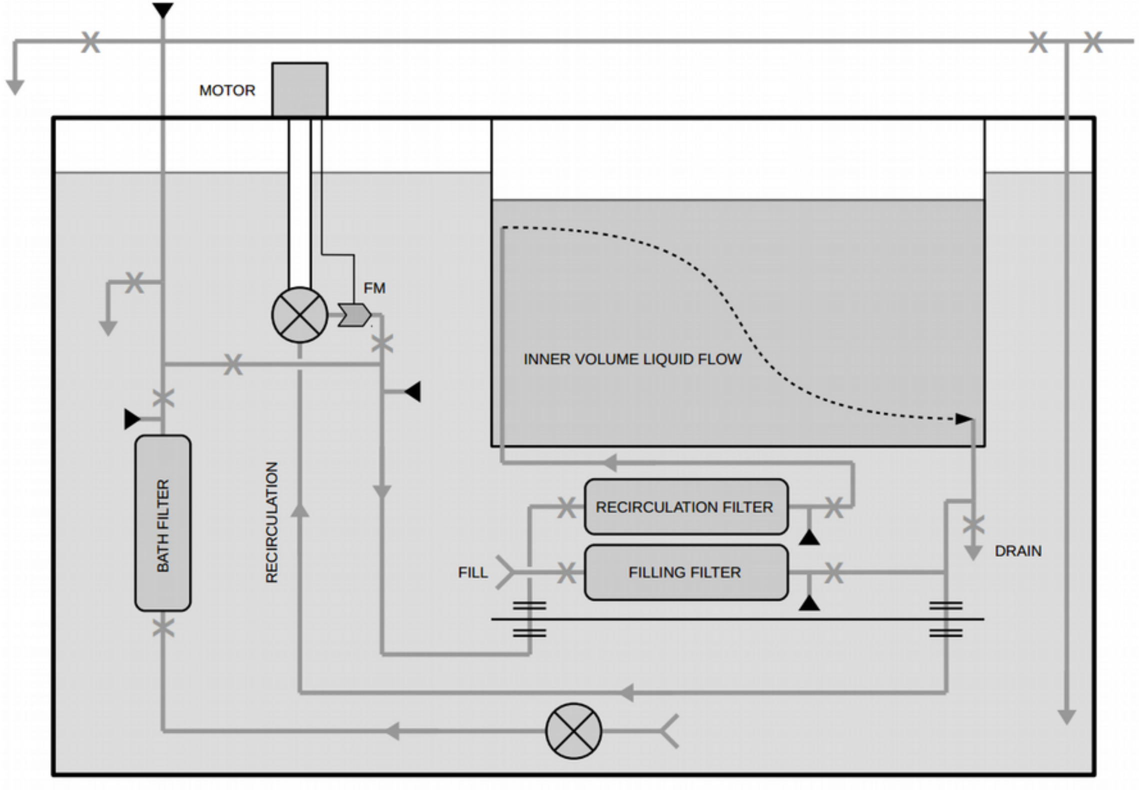
FM flow meter

Different setup due to the module we have at the moment (min. investment, max. outcome)

To finalise 2x2 design, testing:

- Novel cryogenic control valves (p. 7, 8)
- Gas pressure control system (p. 9, 10)
- LAr Filter designs (p. 11, 12)
- Recirculation pump & Sump pump (p. 13)
  → VFD noise suppression (p. 14)
- Fermilab's PLC (p. 15)

Running Since August 26th



X control-valve

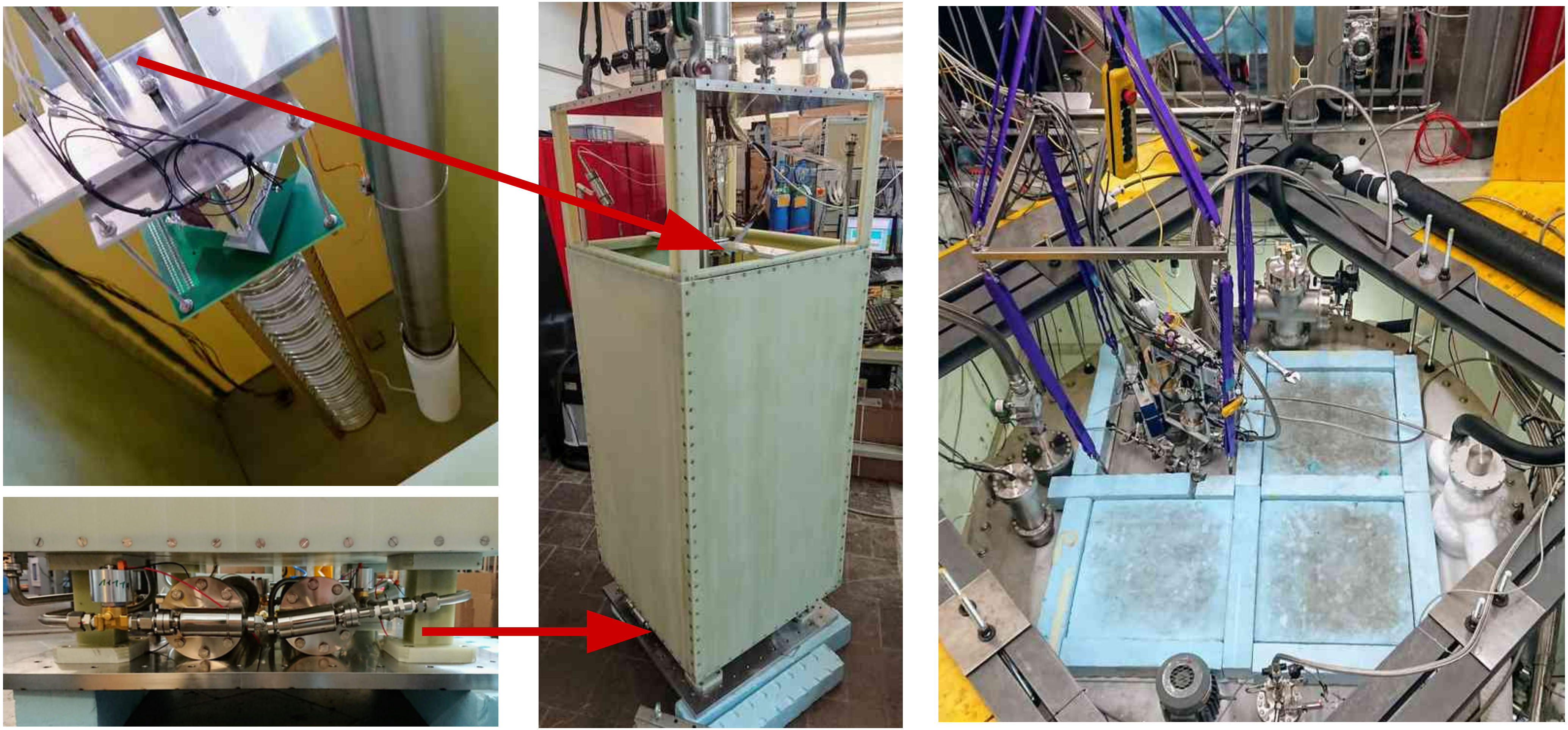
FM flow meter

2x2 cryostat with test module (60cm drift TPC):

- Fast **gas pressurisation system**: $|P_{module} - P_{cryostat}| < 5$ mbar (avoid deflections of module walls)
- Module LAr level control from bath
- Safe and stable **operating parameters** (pressure, LAr level, valves, pumps, recirculation flow, …)
- **Purity within module***
- Module extraction & reinsertion

*Module filters used in this setup: Very small (<1kg active material)

Current Setup

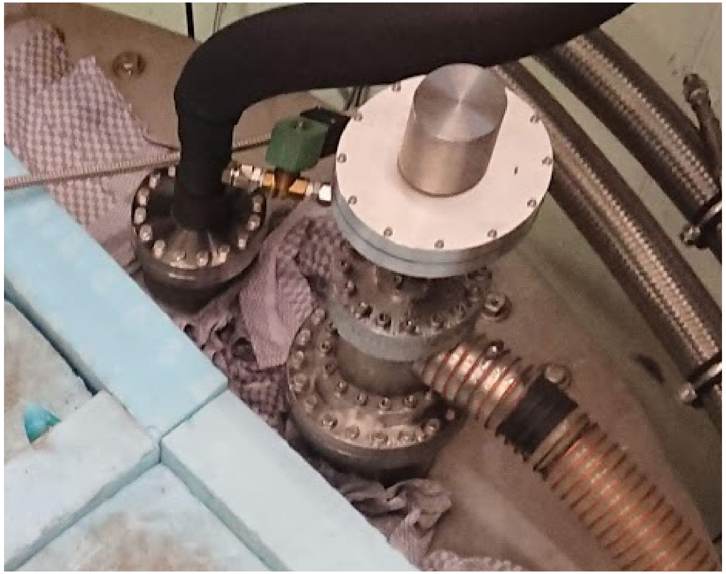


Cryostat Exhaust Valve

Lessions learned from first engineering run (April) → Replaced exhaust valve:
Opening at ~20 mbar, stable operation for last ~30 days.
Works as desired, no problems encountered.

Rubber O-Ring based exhaust valve.
Got stuck when cold (April).

Custom designed valve with steel shaft and brass guide



Design / manufacture: F. Piastra / L. Meier

Cryogenic Control Valves

Developed bi-stable, EM control for an ASCO solenoid valve.

Certified cryogenic ASCO part is left intact, only solenoid replaced.

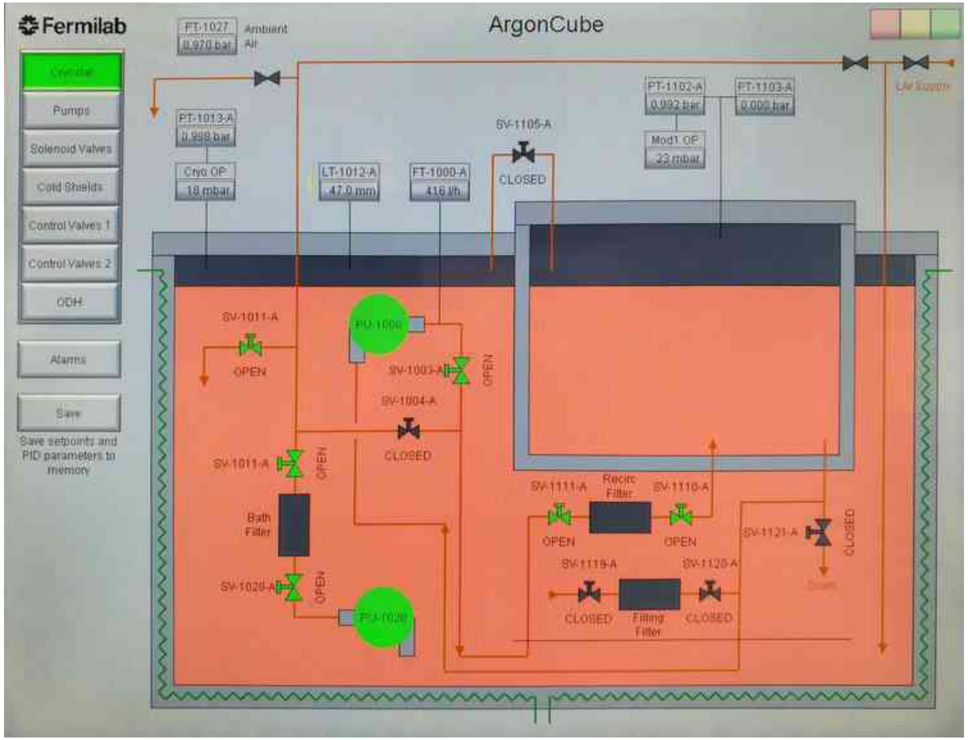
State of valve (open or closed) determined via coil inductance.

Basis: ASCO Solenoid Valve (www.asco.com)

Cryogenic control valve
Designed by I. Kreslo

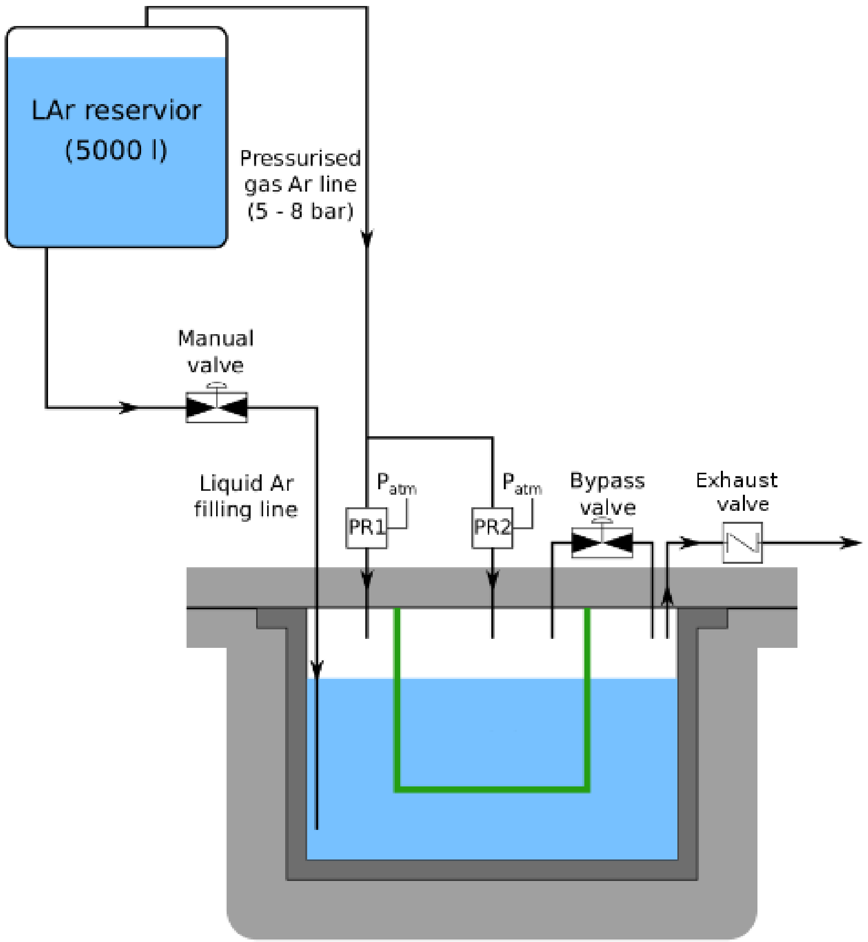
- Switching on all valves at same time
  - → Large current draw in PLC
  - → Developed sequential ramp-up for the valve control unit

- Coil inductance L reduces with temp.
  - → Valve state could change in PLC
  - → Adjusted value for L in PLC



Control screen of the PLC, showing the valve's states (green=open, gray=closed)

Valve's operating parameters now well understood → Ready for use in 2x2

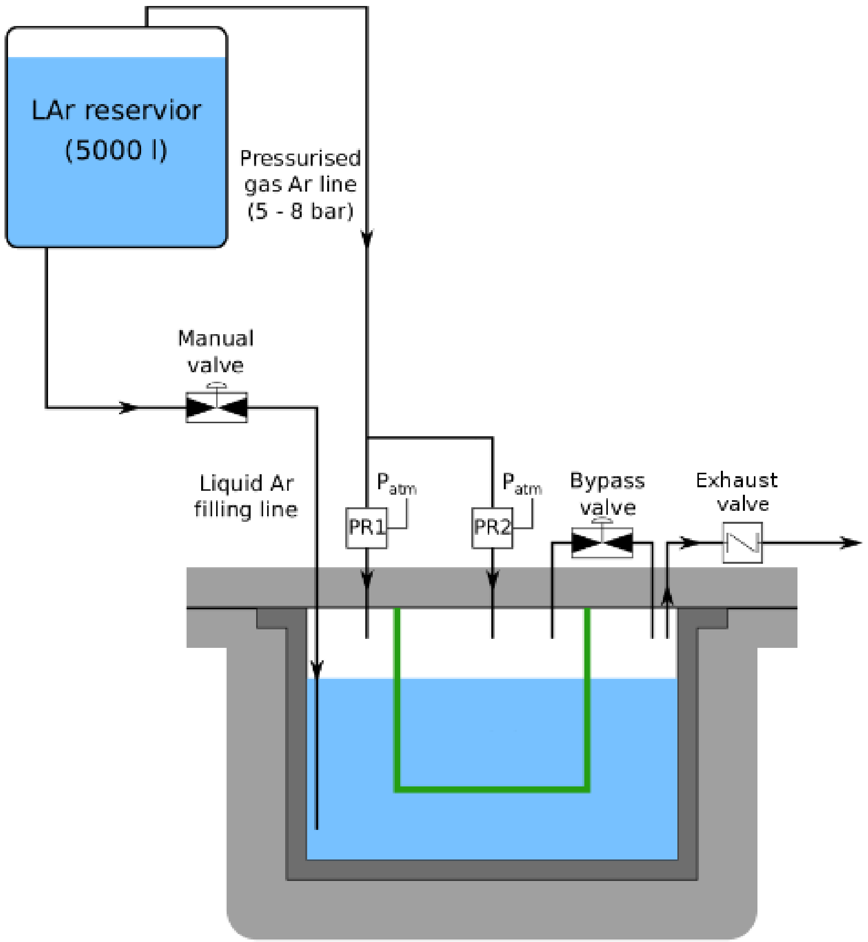


- Module and cryostat **underpressure**:
  Controlled via PR1 and PR2 (fwd press. regulators)
  → Fast* overpressure recovery in case of a sudden pressure drop in cryostat or module

PR1/2: Equilibar Series 41

*flow rate O(100 slpm)

Gas Pressurisation System



- Module and cryostat **underpressure**:
  Controlled via PR1 and PR2 (fwd press. regulators)
  → Fast* overpressure recovery in case of a sudden pressure drop in cryostat or module
- Module **overpressure**:
  Controlled by solenoid bypass valve
  → Need to move to check valve with linear action

*flow rate O(100 slpm)

LAr Purification Filters – Setup

Bath filter at cryostat wall:
H_2O and O_2 absorption based on activated copper
Active mass: ~10 kg

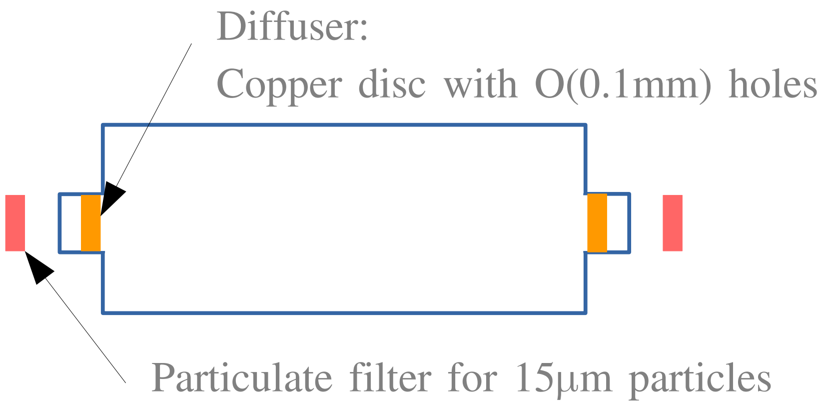
Open cryostat showing bath filter

Two module filters:
Moisture absorption with molecular sieve [RCI-DRI 5A],
O_2 absorption with Copper-Zinc Oxide [GetterMax 133],
both purchased from Research Catalysts, Inc.
Active mass: <1 kg each (2x2 will be much larger)

Two LAr purification filters below module (only one used in recirculation, see p. 4)

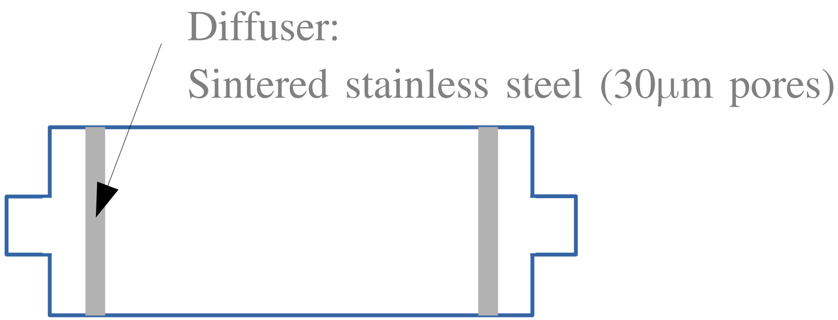
Module Filters

Current design:



- Particulate filters at inlet and outlet:
  - → High impedance as too finely pored
  - → Takes up overall length
- Cu disc: Inhomogeneous diffusion across filter
- Low active filter mass (<1kg), saturates fast

Improved design for 2x2:

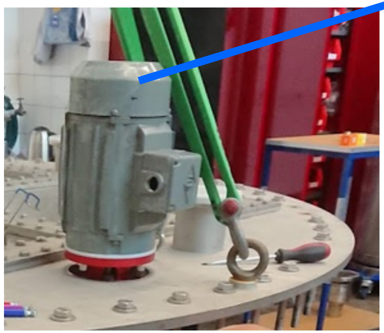


- **Smaller impedance**, higher flow rate
- Reduced component count
- **Homogeneous diffusion** across filter
- No need for additional particulate filters, allows for **larger active filter mass**

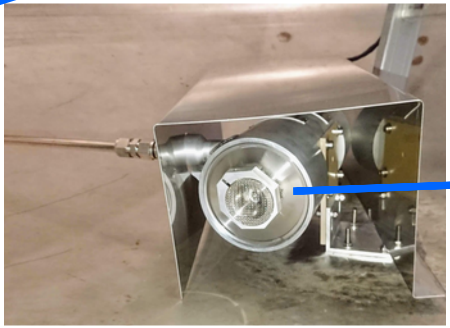
LAr Recirculation Pumps

Minor problems:

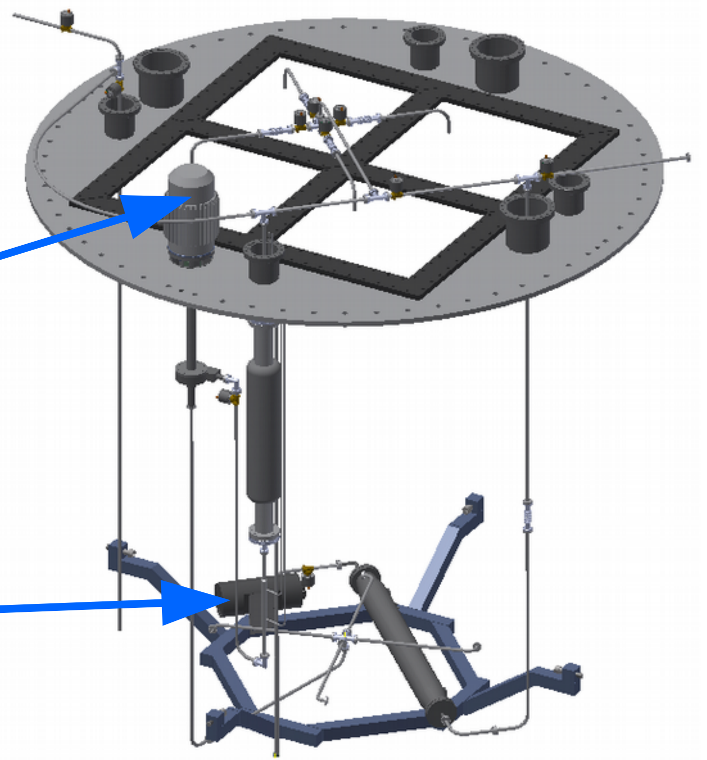
- Recirculation pump: Impeller not deep enough (boiling)
  - **→ Will extend the shaft and lower impeller**
  - → Pump control via PLC (workaround found)
- Sump pump: At certain frequencies, resonant effects in loop
  - **→ Will put oscillation mitigation**



Recirculation pump

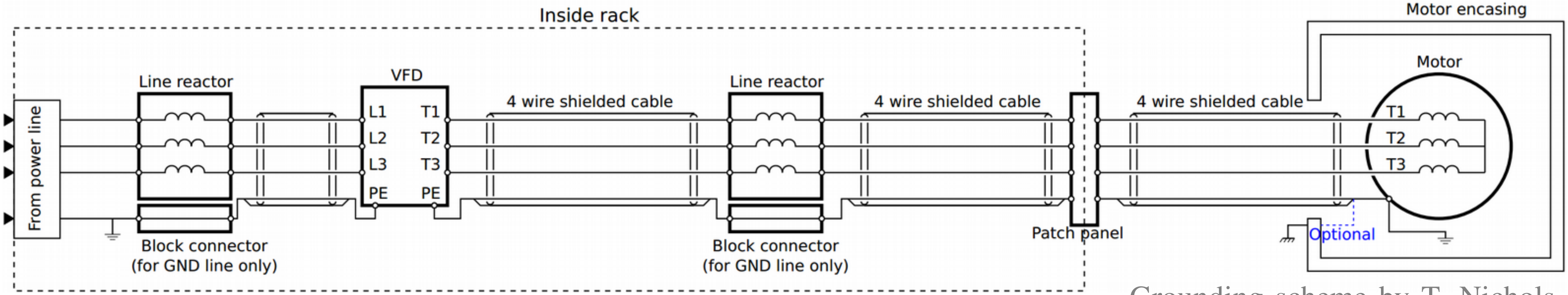


Sump pump



Cryogenics scheme for the 2x2

Pump Grounding



Grounding scheme by T. Nichols

LAr pumps:

- VFD between line reactors → **reduced** voltage spikes
- Electrically isolated LAr recirculation pumps from cryostat
- Power GND, motor and cable shield on same potential
- Minimal length of unshielded phase wires

Vacuum pump:

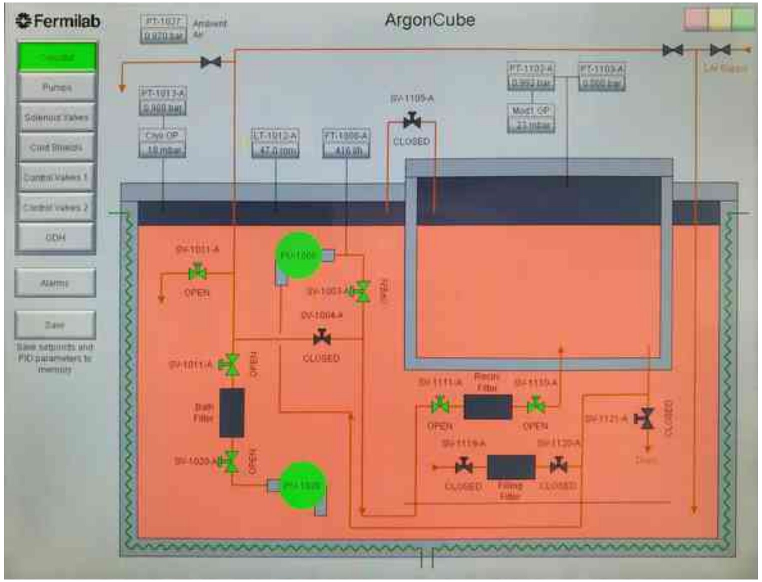
- On building ground instead of clean ground

However, **can take TPC data whilst pumps are running**

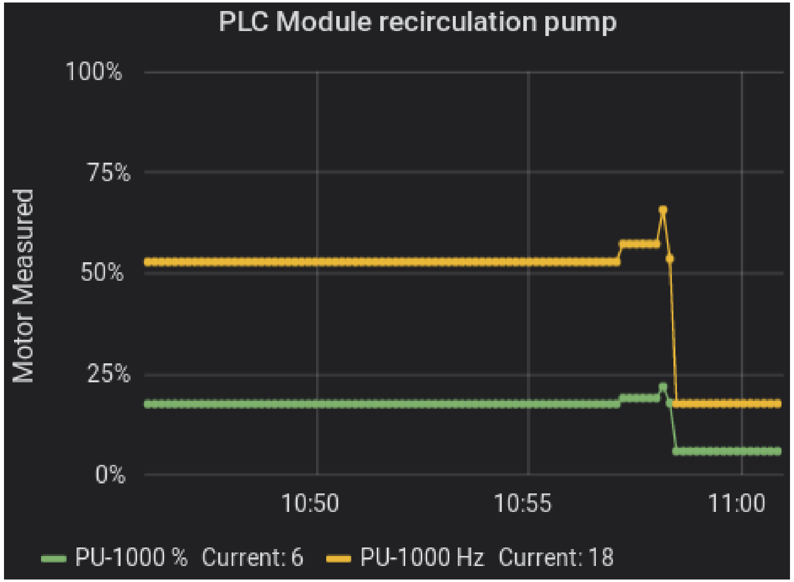
Programmable Logic Controller (PLC)

Using PLC from FNAL → simplifies 2x2 integration at FNAL

PLC Control Unit



Touch Screen on PLC

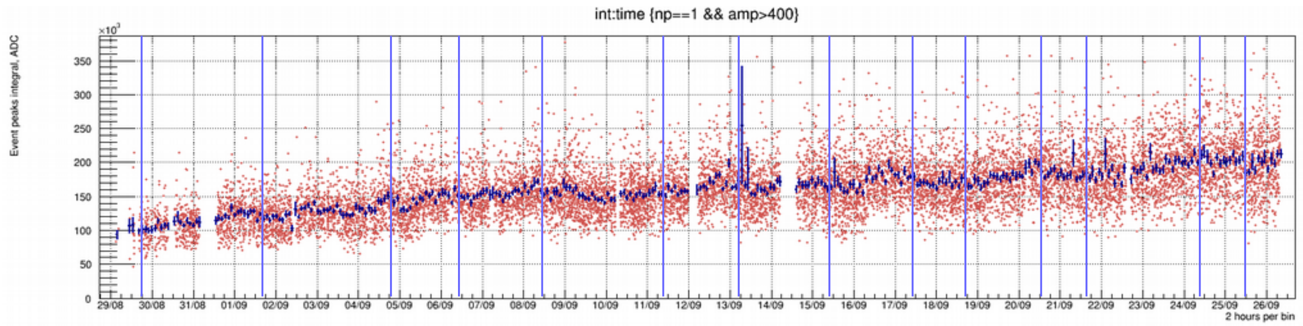


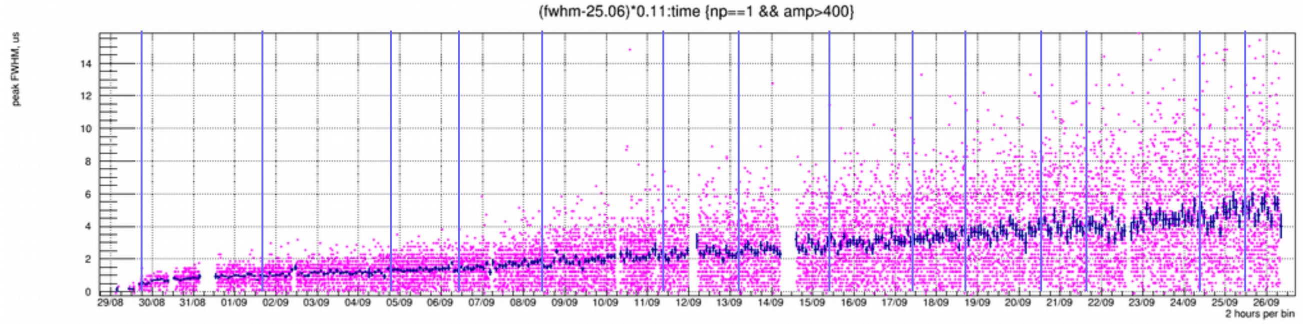
PLC data logging with InfluxDB and Grafana

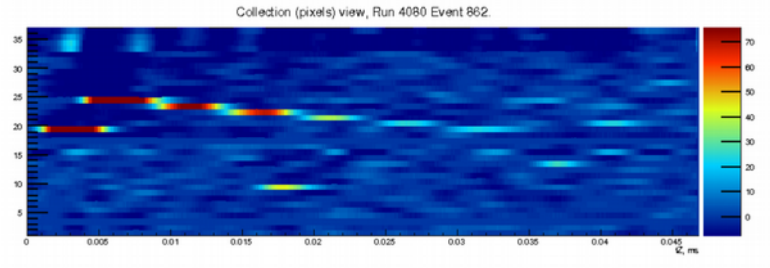
→ Data logging with Grafana (control valve's status, recirculation pump speed, etc.)

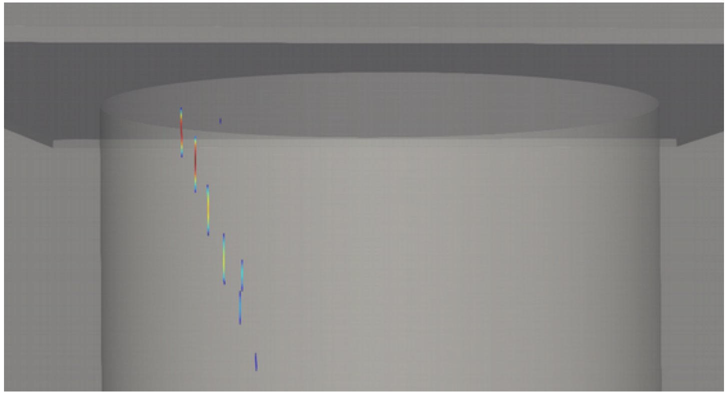
LAr Purity

- Purification for 4 weeks, 14 LAr refills (each ~450 l)
- Electron lifetime estimation: < 1µs → 10 – 20µs









→ Indication: **LAr purification is working**

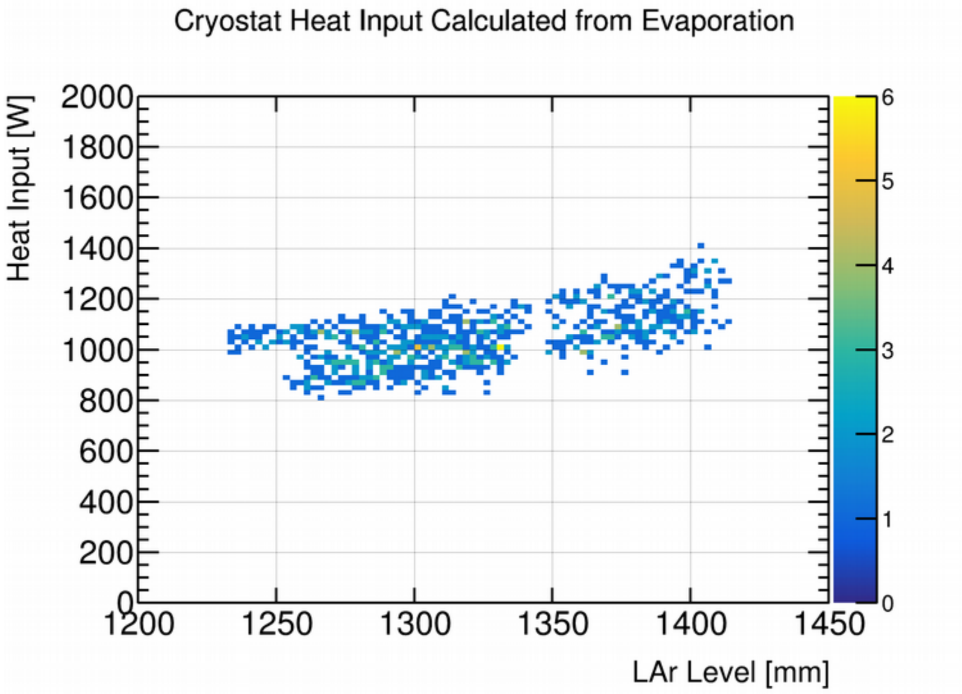
Piston Purge

- Piston purge:
  Only very short purge (3-4 hours on August 26th), with cold gas

- For next experiment:
  Longer piston purge (2-3 days, maybe with break to allow for outgassing)
  with warm gas (to prevent condensation of air in cryostat and module).
  Additionally, monitor O_2, N_2, H_2O (and others) with gas chromatograph.

Cryostat Operation & LAr Consumption

- **Cryostat operation: >1 month, very stable**, minimal input from shifters required (only for refilling every ~2 days, and restarting DAQ)
- LAr consumption: **~14 liters/hour** (no active LN_2 cooling)



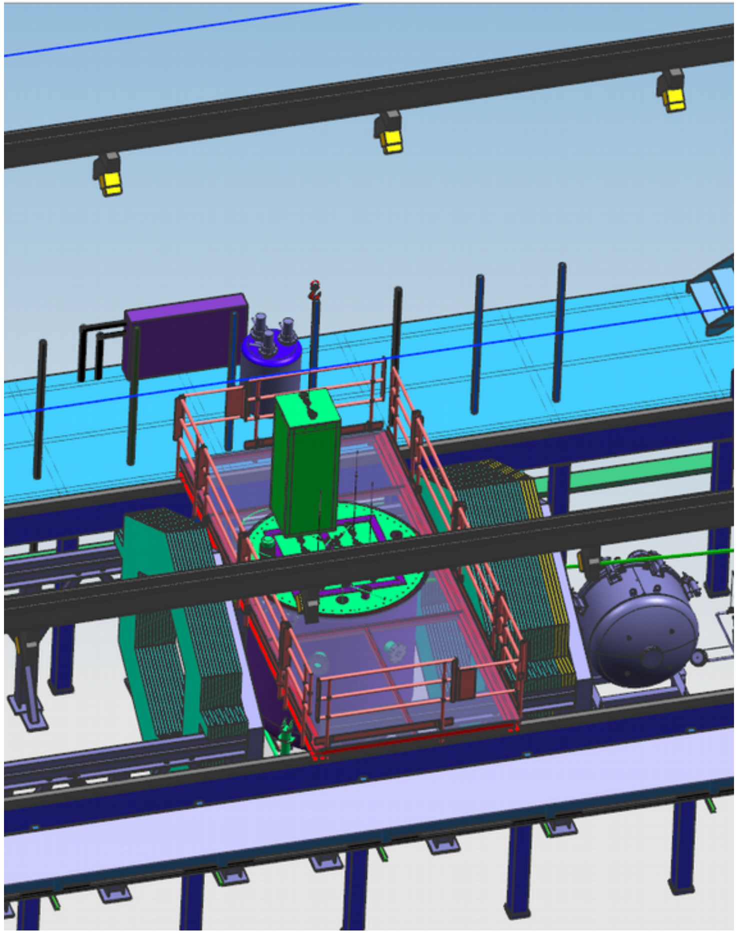
Outlook

- Proceed with LAr purification
  Goal: Reach electron lifetime of ~1ms

- Module extraction & reinsertion
  → Determine effect on electron lifetime
  → Can good enough electron lifetime be achieved?

- October onwards:
  Begin construction of final 2x2 scheme

- November:
  2x2 module construction



Summary

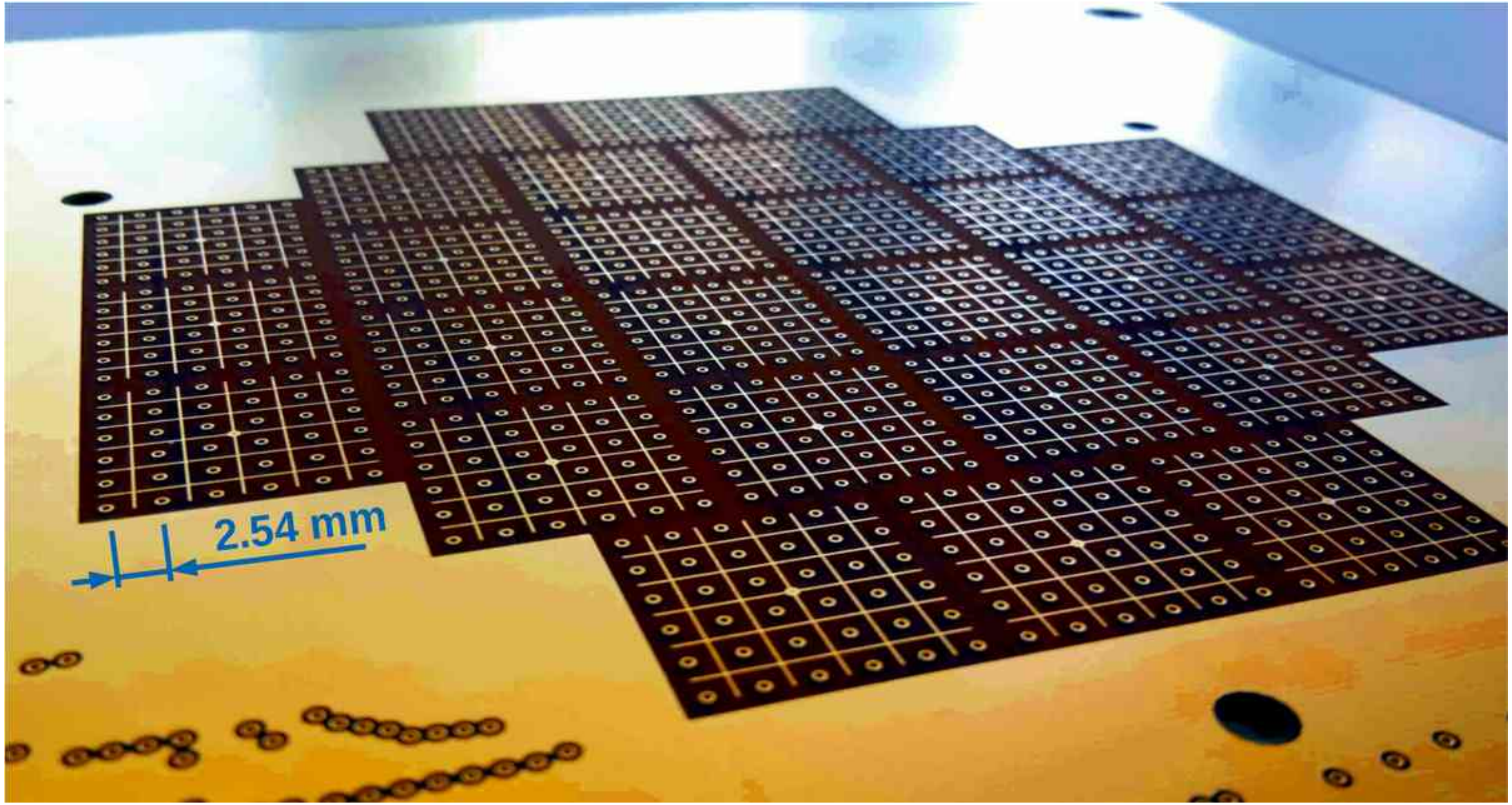
- ✓ Very stable cryostat operation
- ✗ Piston purge might have spoiled LAr purity

- ✓ Cryostat exhaust valve
- ✓ Cryogenic control valves
- ✓ Gas pressurisation system

(✓) LAr purification filters	→	Realisation of new design
(✓) LAr sump pump	→	Hydrodynamic noise mitigation needed
(✓) Pump PLC control	→	Modify driver settings
(✓) Groundings	→	Vacuum pump & cryostat

Thank You

Pixel Plane used on the 60 cm Drift TPC



28 ROIs in total, each with 6 x 6 pixels