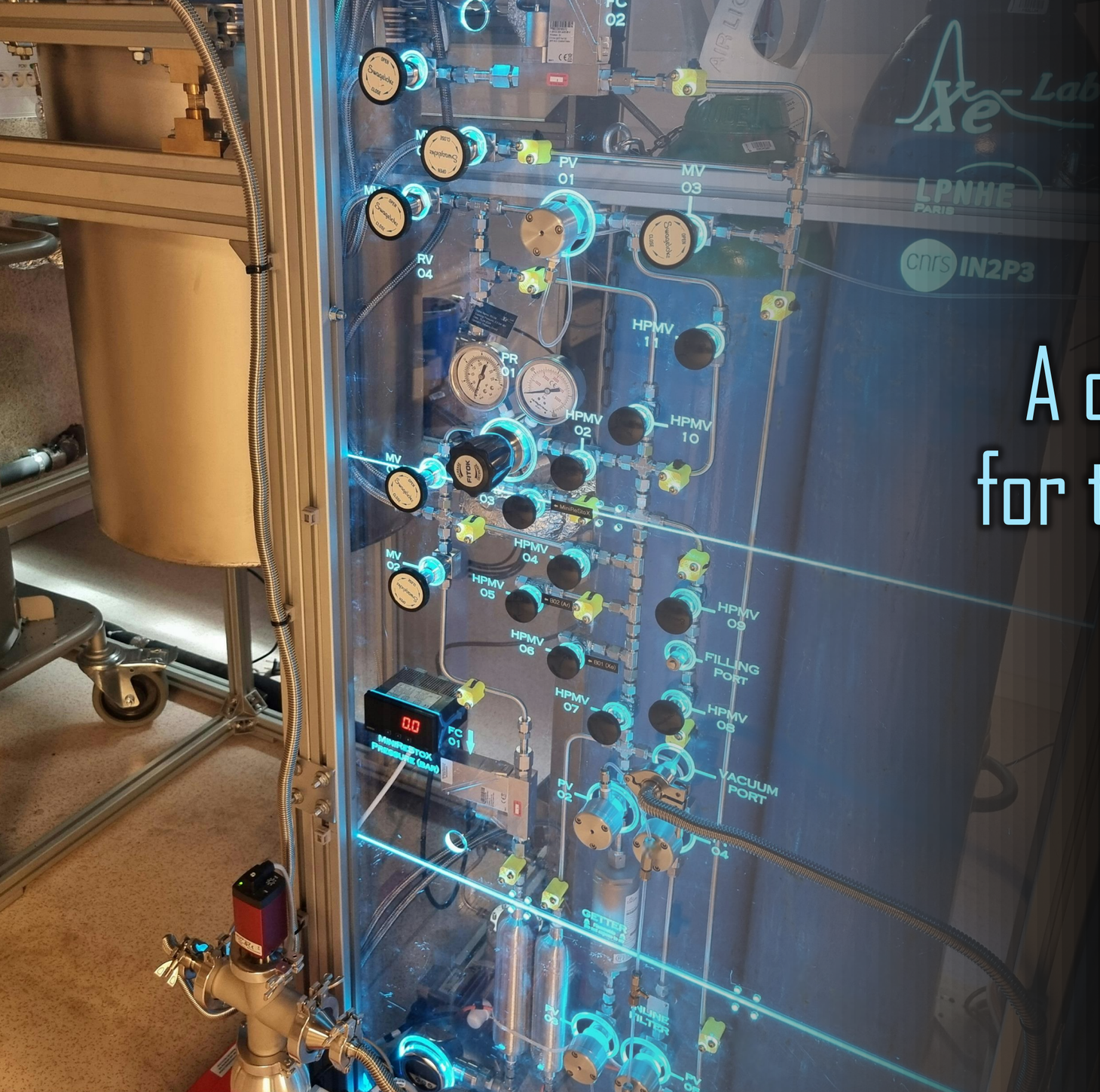


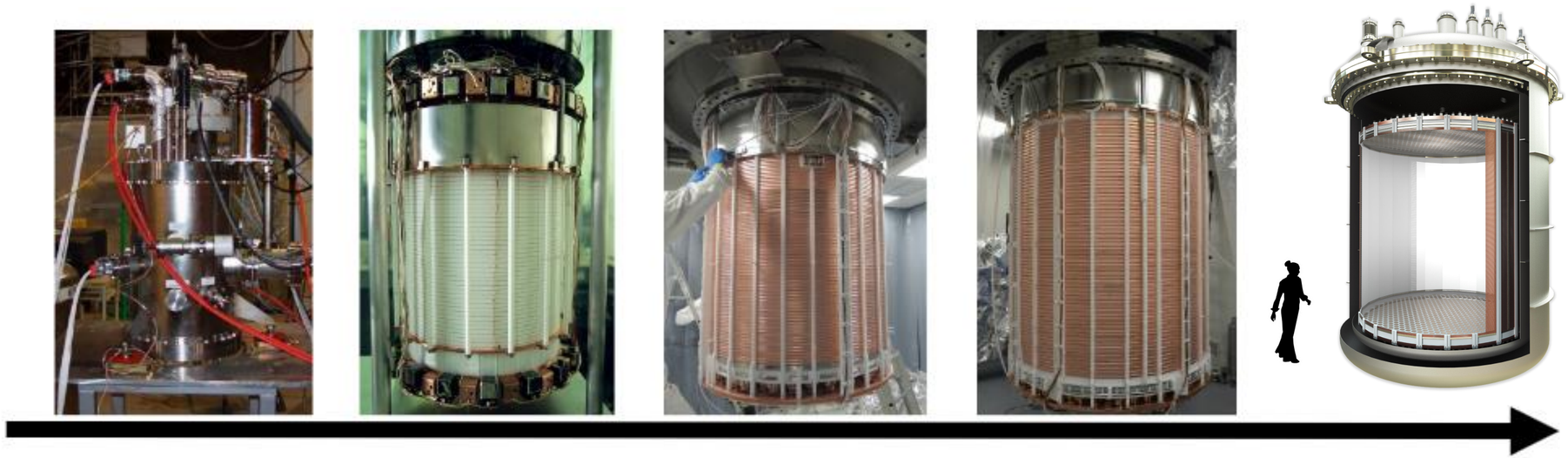
XeLab

A cryogenic R&D platform for the DARWIN Experiment

Frédéric Girard
LPNHE-Paris

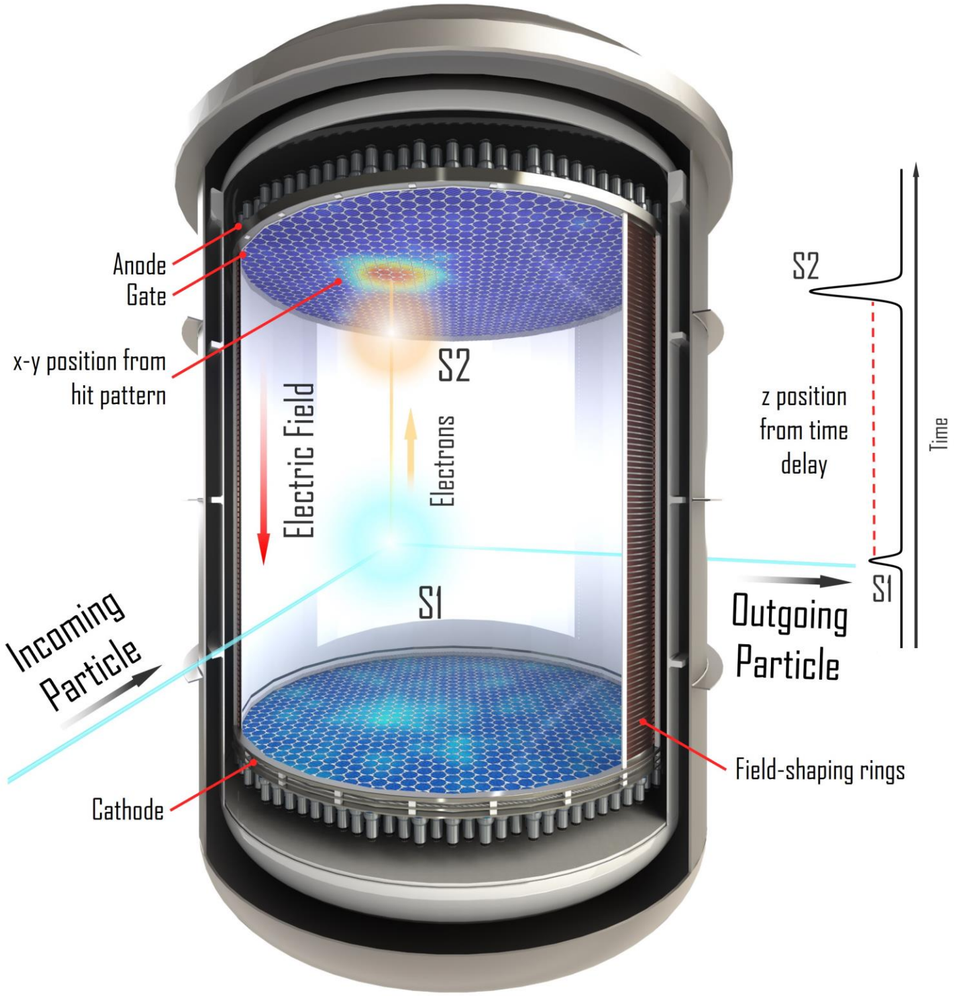
DMLab
18 Oct. 2024

XENON → DARWIN/XLZD

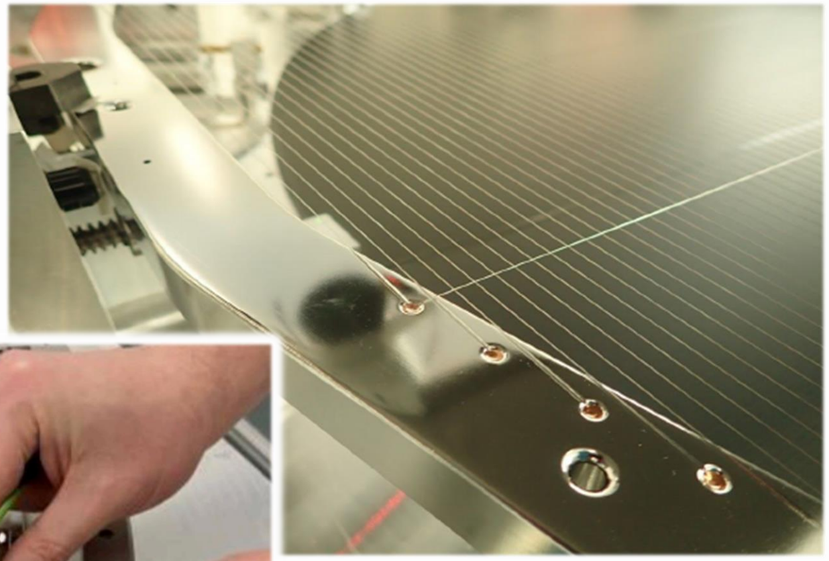


	XENON10	XENON100	XENON1T	XENONnT	DARWIN/XLZD
Operation period	2005-2007	2008-2016	2012-2019	2020-2026	2032
Xenon Mass	14 kg (active)	62 kg (active)	2 t (active)	5.9 t (active) 8.5 t (total)	40 t / 60 t (active) 50 t / 75 t (total)
Height Diameter	15 cm 14 cm	30 cm 30 cm	96 cm 97 cm	148 cm 133 cm	260 cm / 297 cm 260 cm / 298 cm

Dual-Phase TPC



One of the main challenges for next-generation large-scale TPCs will be the development of large electrodes with high optical transparency



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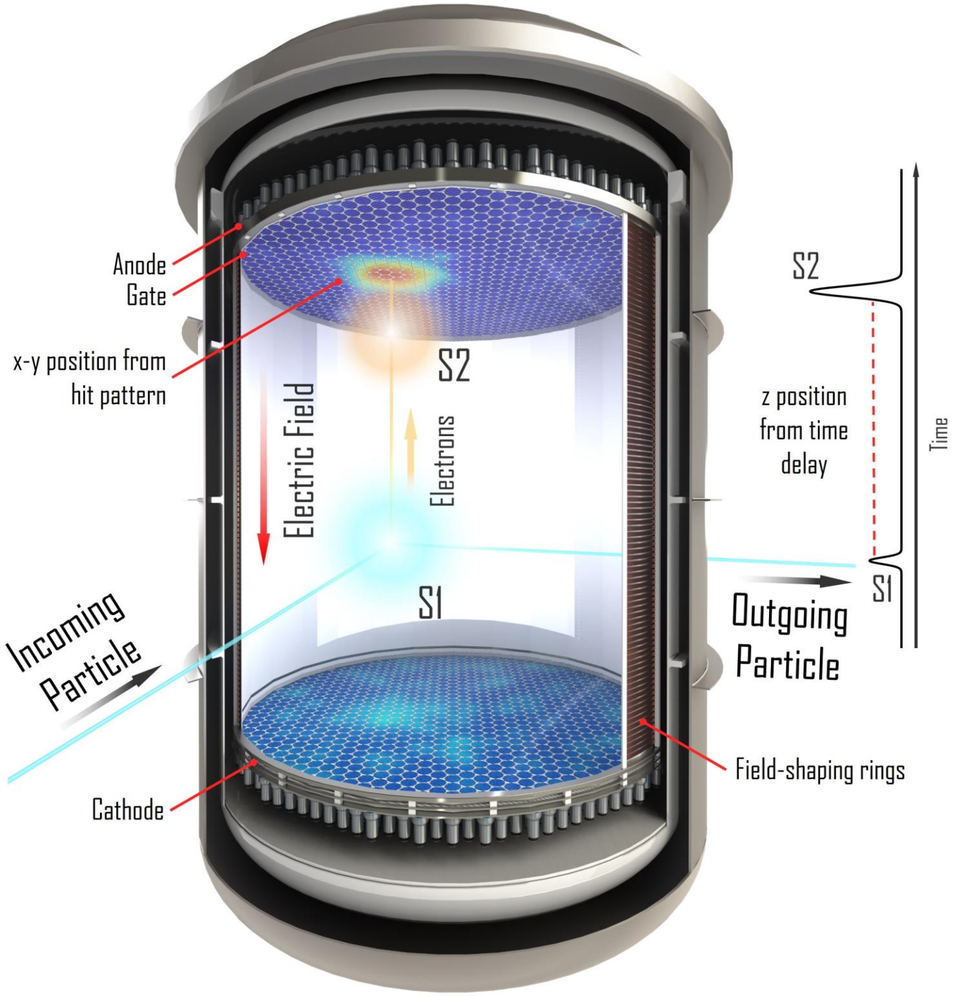

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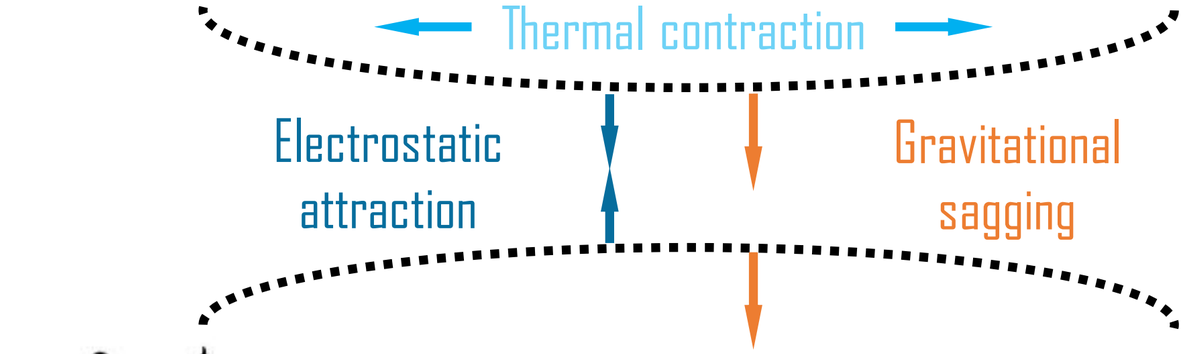
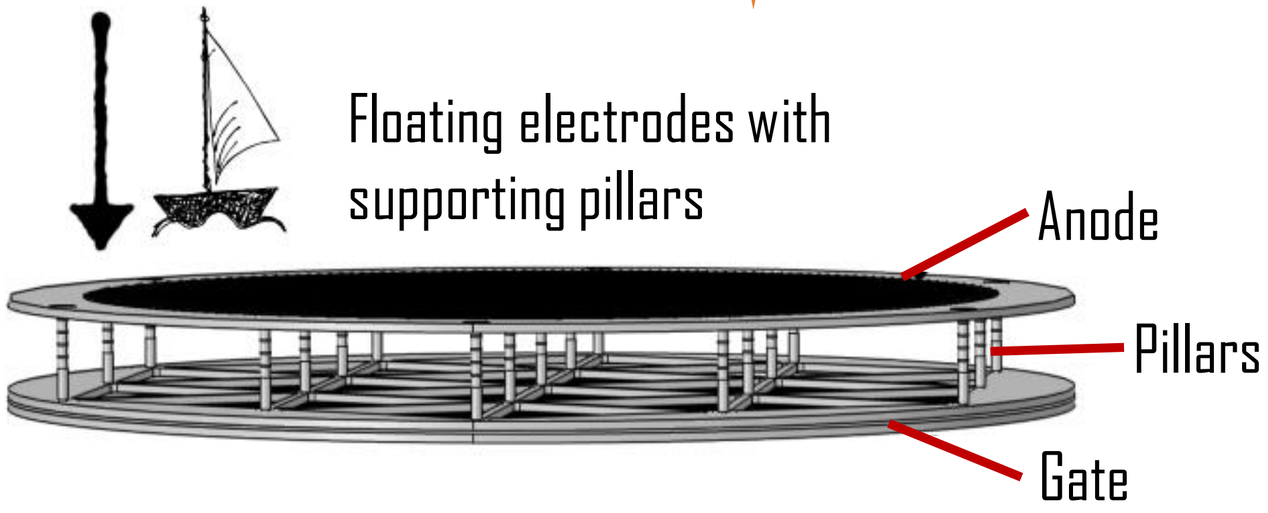
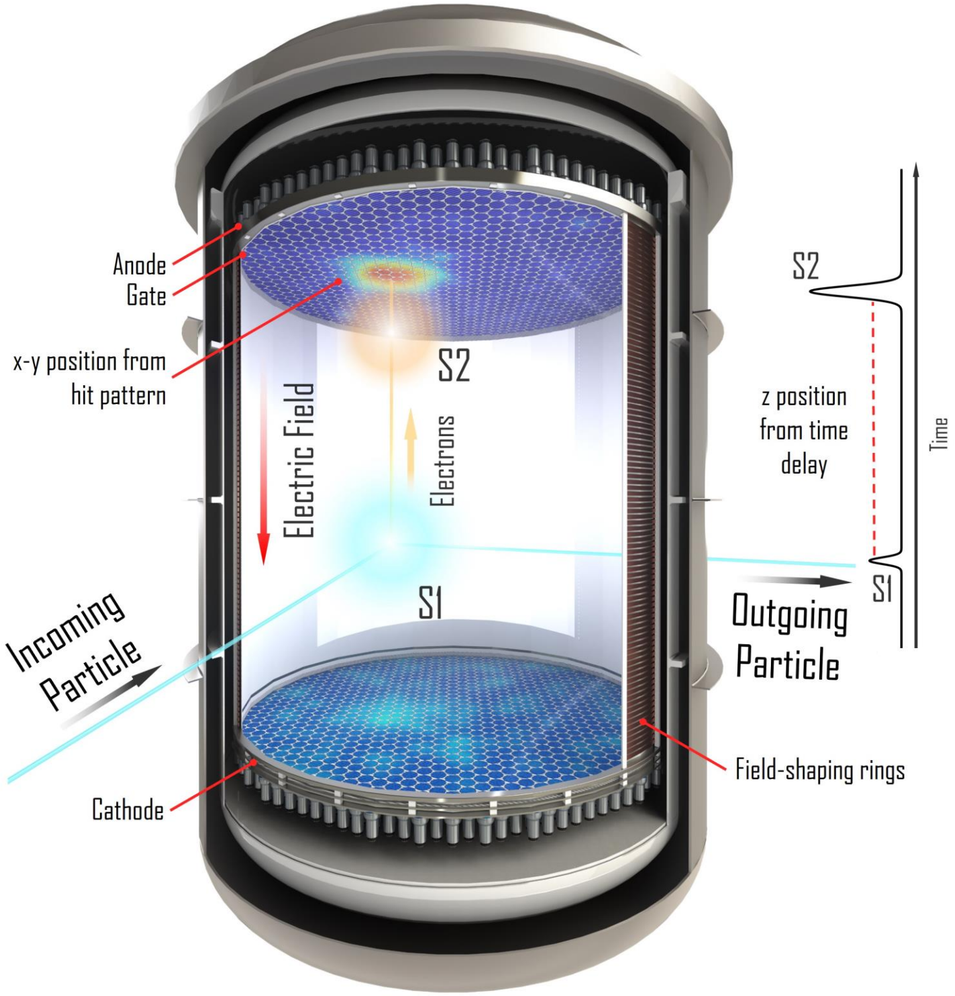




Dual-Phase TPC



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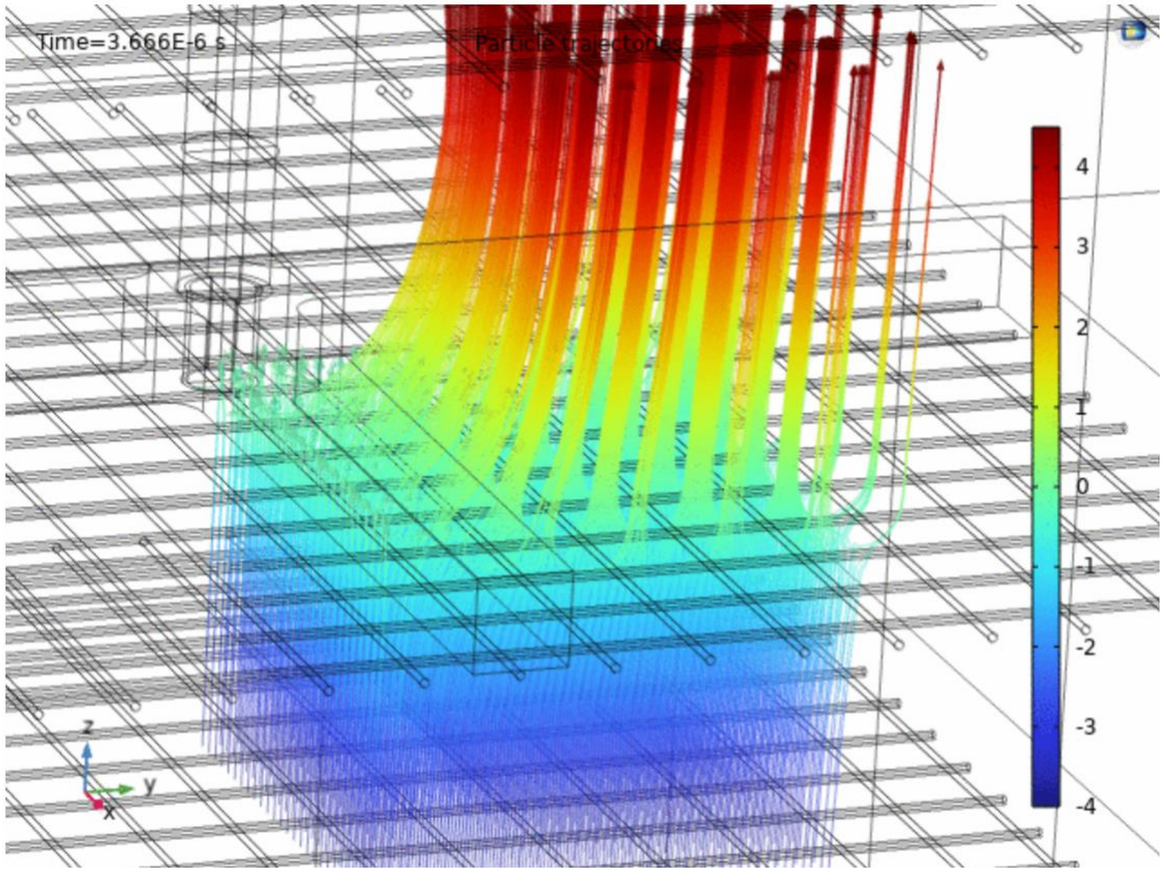
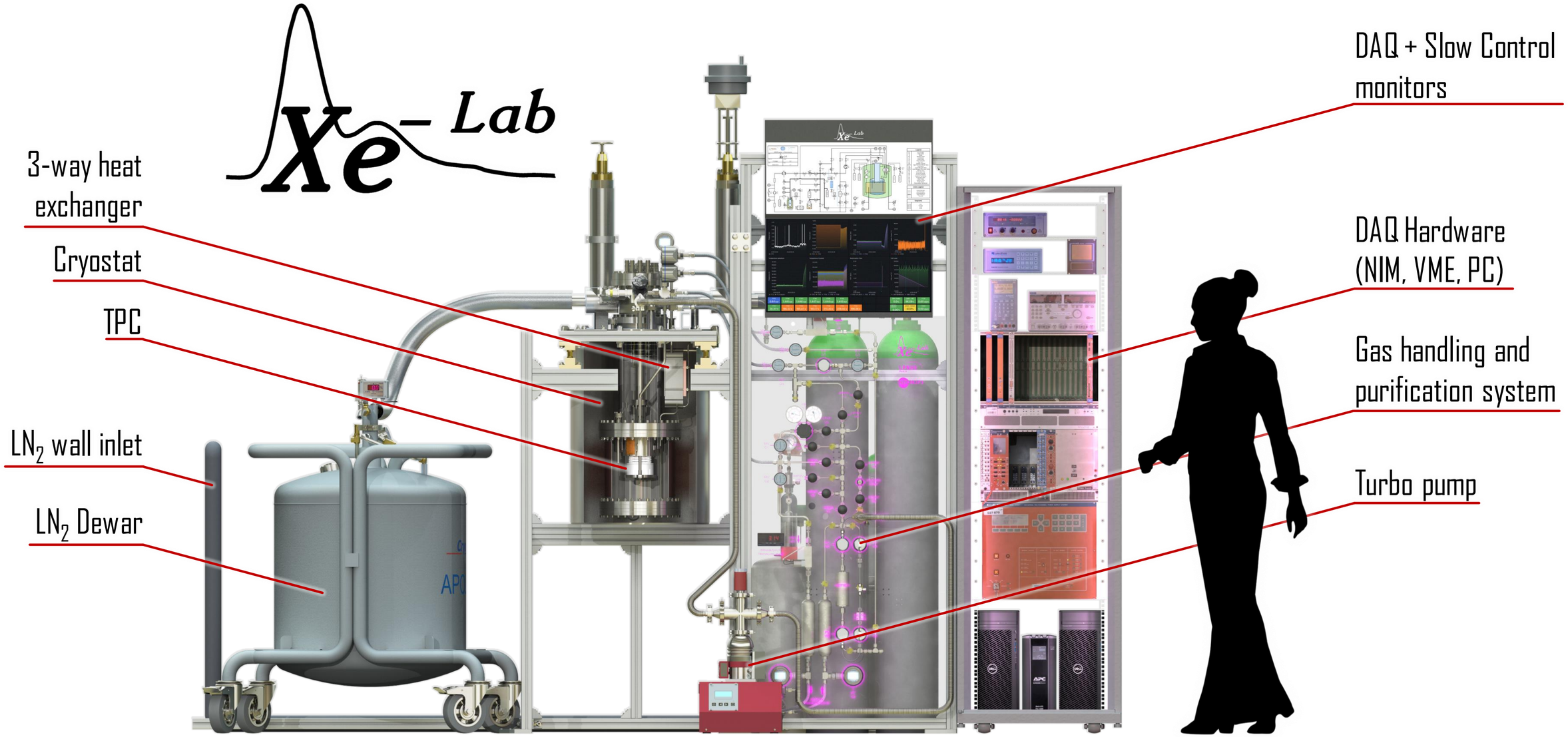
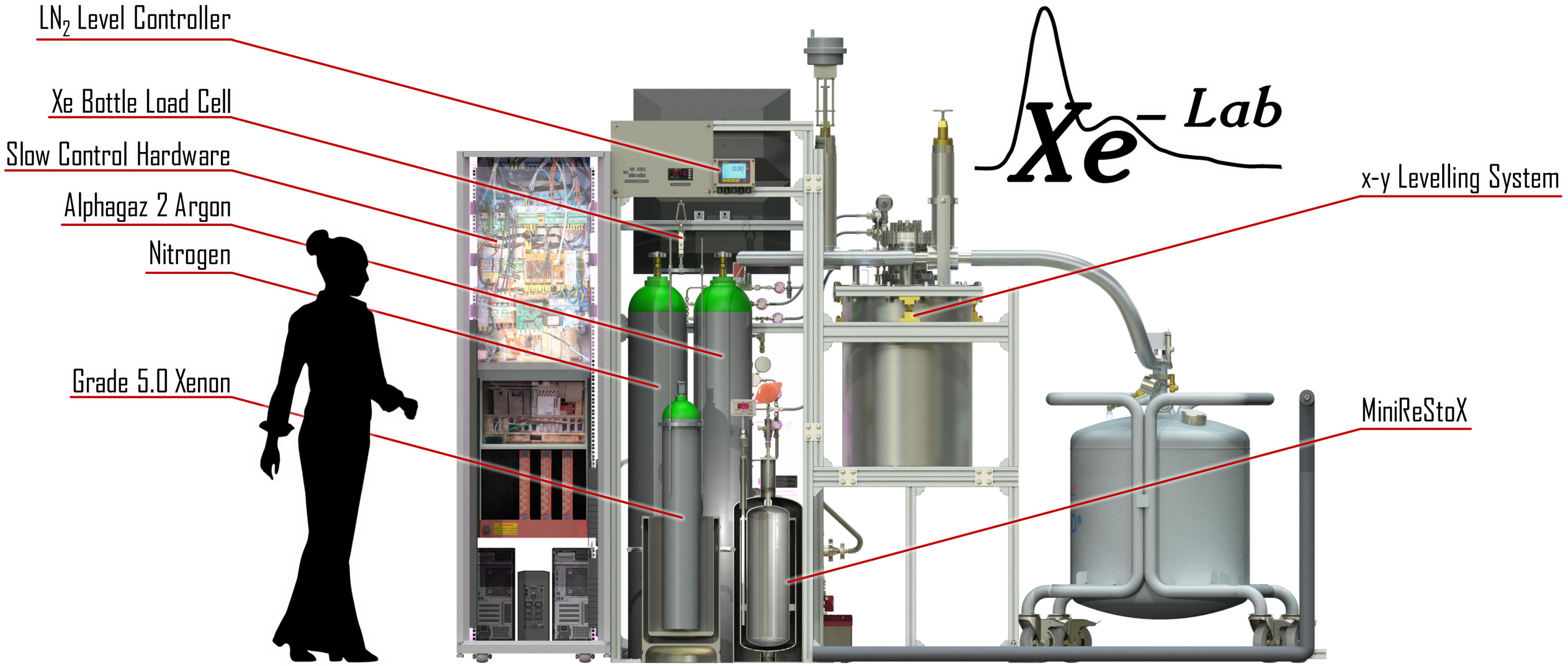
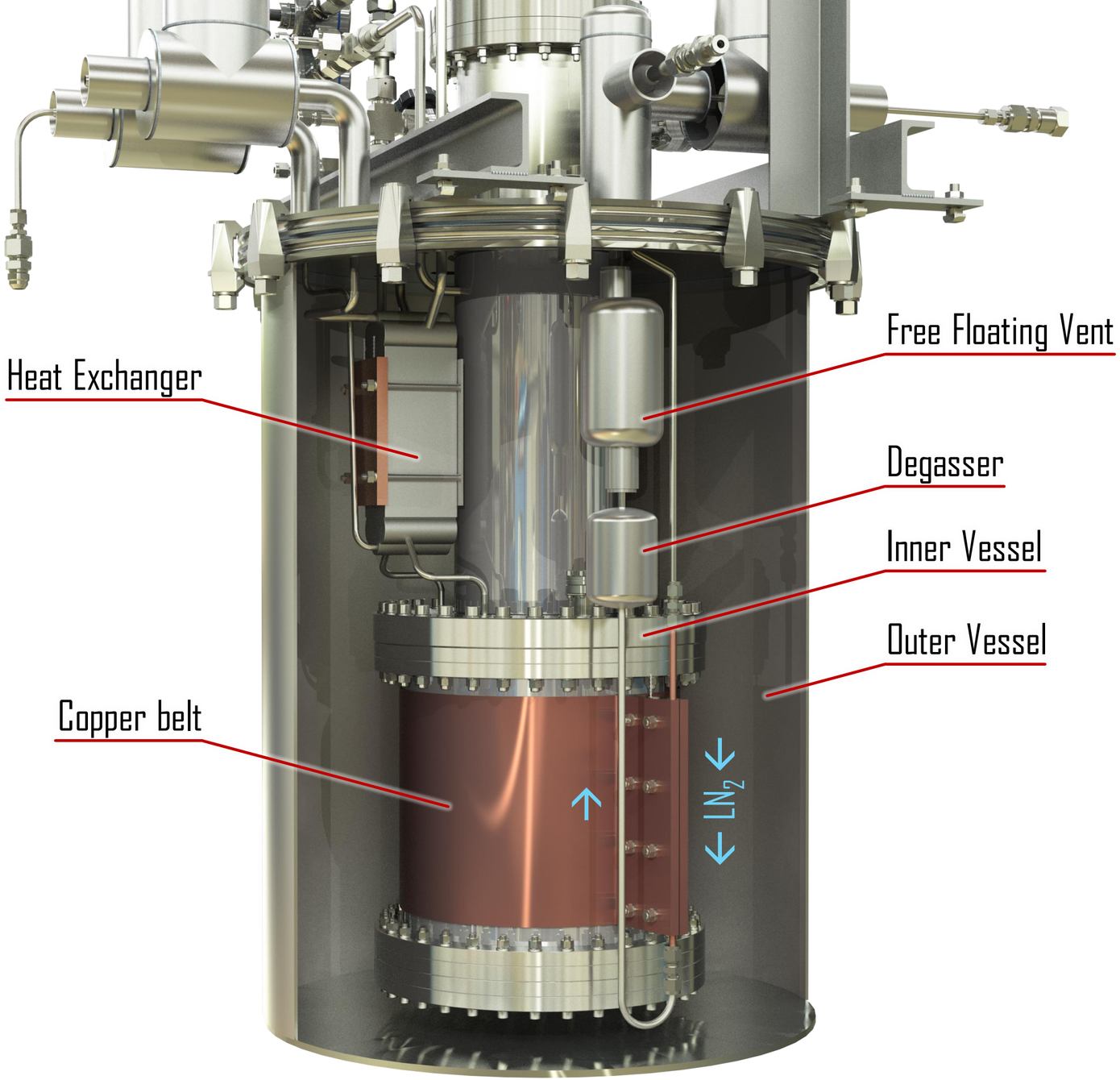



3-way heat exchanger
Cryostat
TPC
LN2 wall inlet
LN2 Dewar
DAQ + Slow Control monitors
DAQ Hardware (NIM, VME, PC)
Gas handling and purification system
Turbo pump


LN_2 Level Controller
Xe Bottle Load Cell
Slow Control Hardware
Alphagaz 2 Argon
Nitrogen
Grade 5.0 Xenon
x-y Levelling System
MiniReStoX

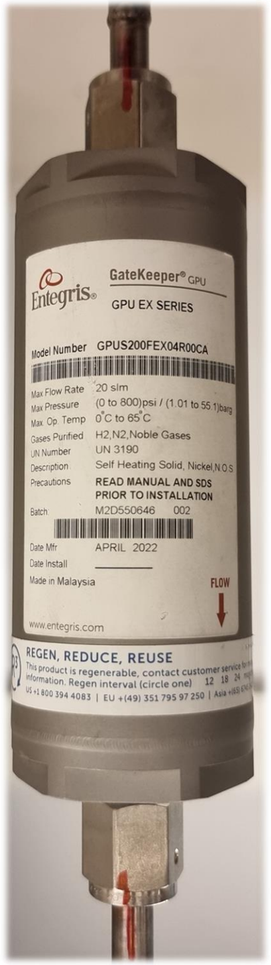


Cryostat

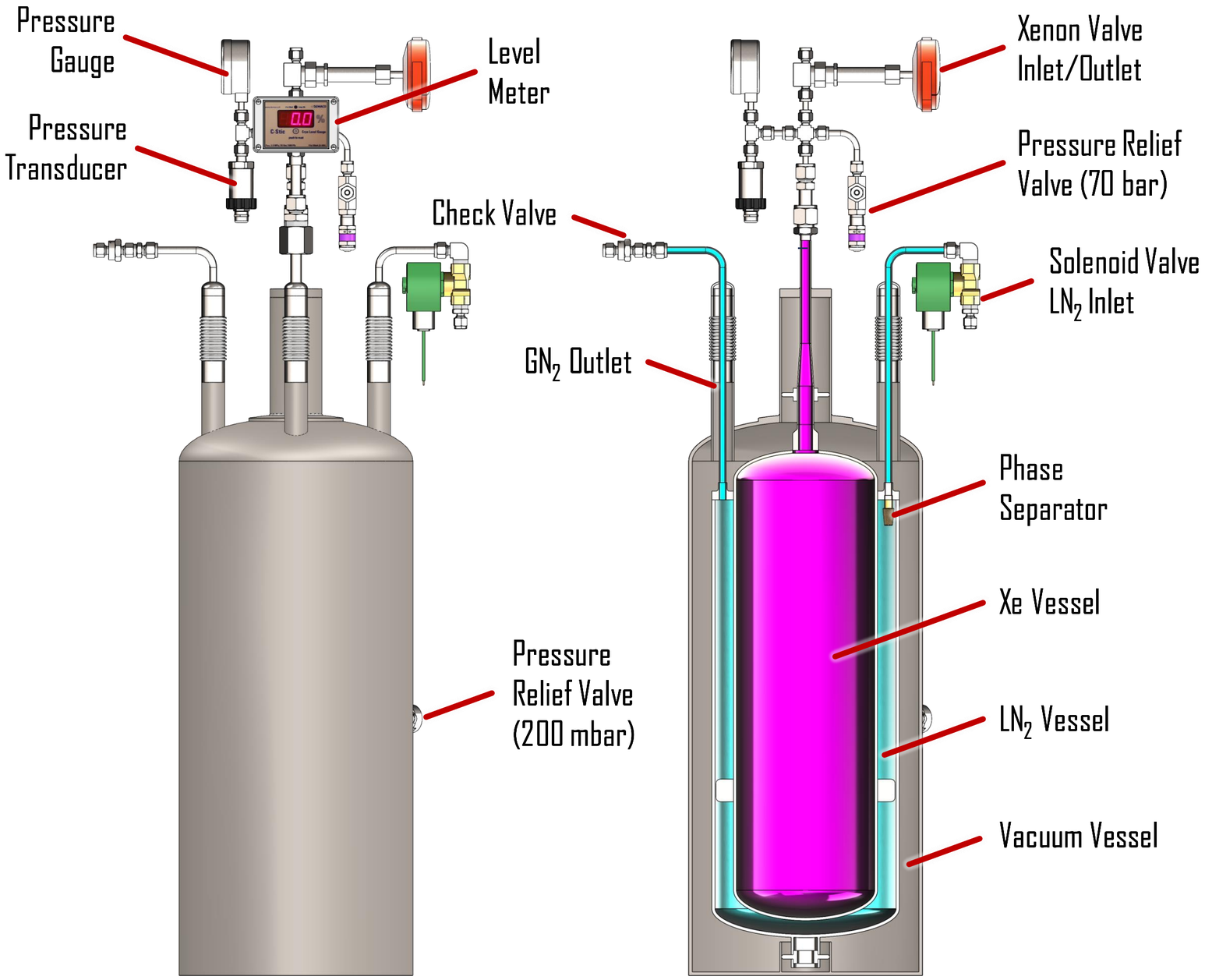
- Vacuum insulated, double-walled
- Main cooling mode: copper belt
  - LN_2 from pressurized Dewar
  - Overflow prevention from free floating vent
  - Temperature control from heating resistor
- Secondary cooling mode: Heat Exchanger
  - Temperature control from heating resistor
- Multi-layer insulation to prevent radiative losses (not shown)

Gas Handling and Purification

- Transfer and purification of the xenon
- High-pressure side: Up to 200 bar
- Low-pressure side: 2 bar nominal, max. 3.5 bar
- Recirculation with neoprene membrane compressor
- Purifier: Nickel-based, self heating solid
  - < 1 ppb of O_2, H_2O, CO_2, N_2, H_2, CH_4, N_2O

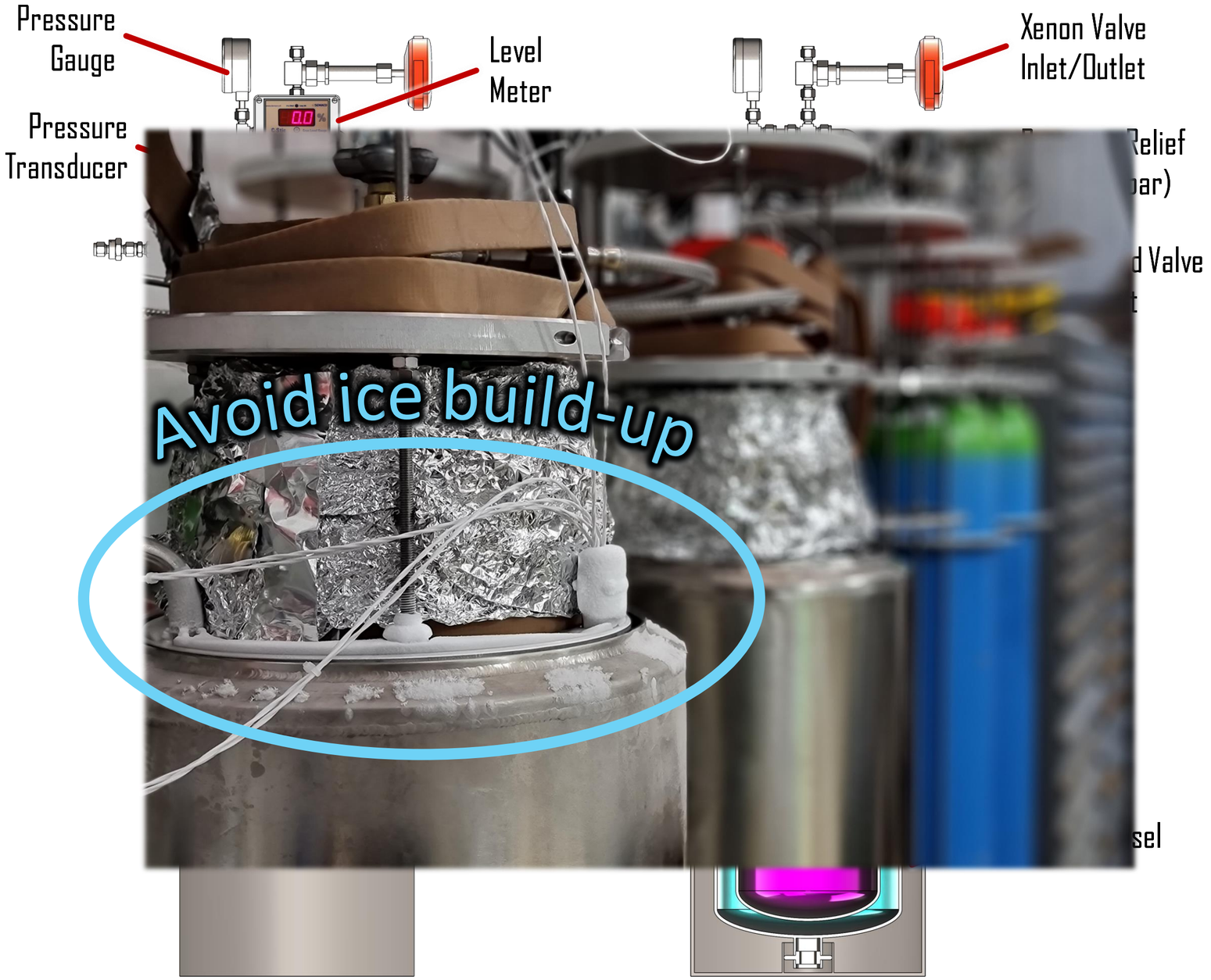


Entegris Xenon Purifier



MiniReStoX

- Xenon recuperation and storage
- Three nested vessels
  - Vacuum insulation + MLI
  - Liquid nitrogen (from 15 000 L reservoir)
  - Xenon (max 70 bar)
- Can be kept cold at all time during XeLab operation
  - Immediate xenon recuperation trigger, as needed



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Slow Control

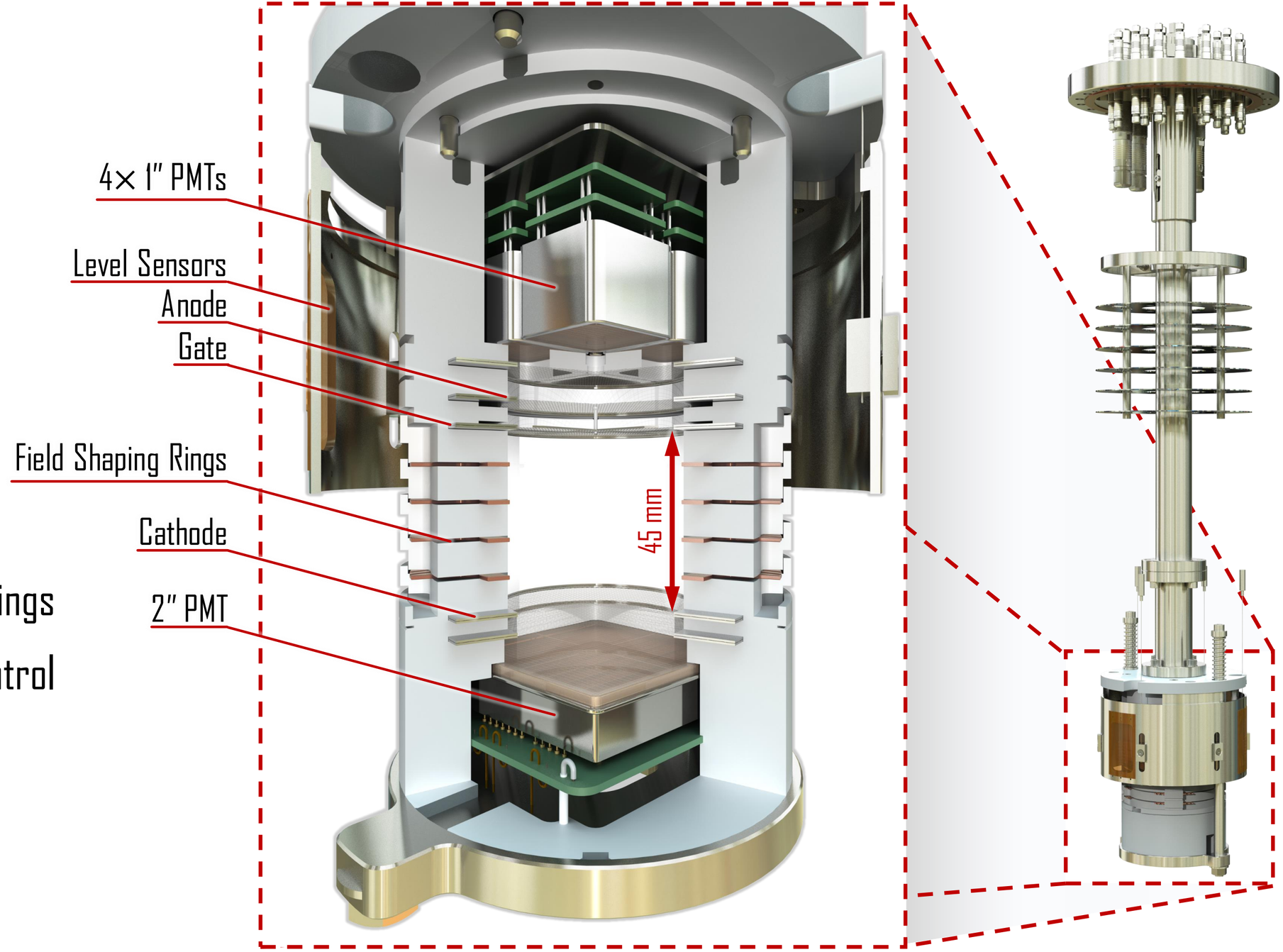
- Based on the Revolution Pi technology
- Home-made code (CODESYS)
- Home-made PT100 readout board
- Python MQTT broker to pull the data
- Storage in InfluxDB database
- Data Visualization with Grafana

Data Visualization - Grafana

Slow Control Hardware

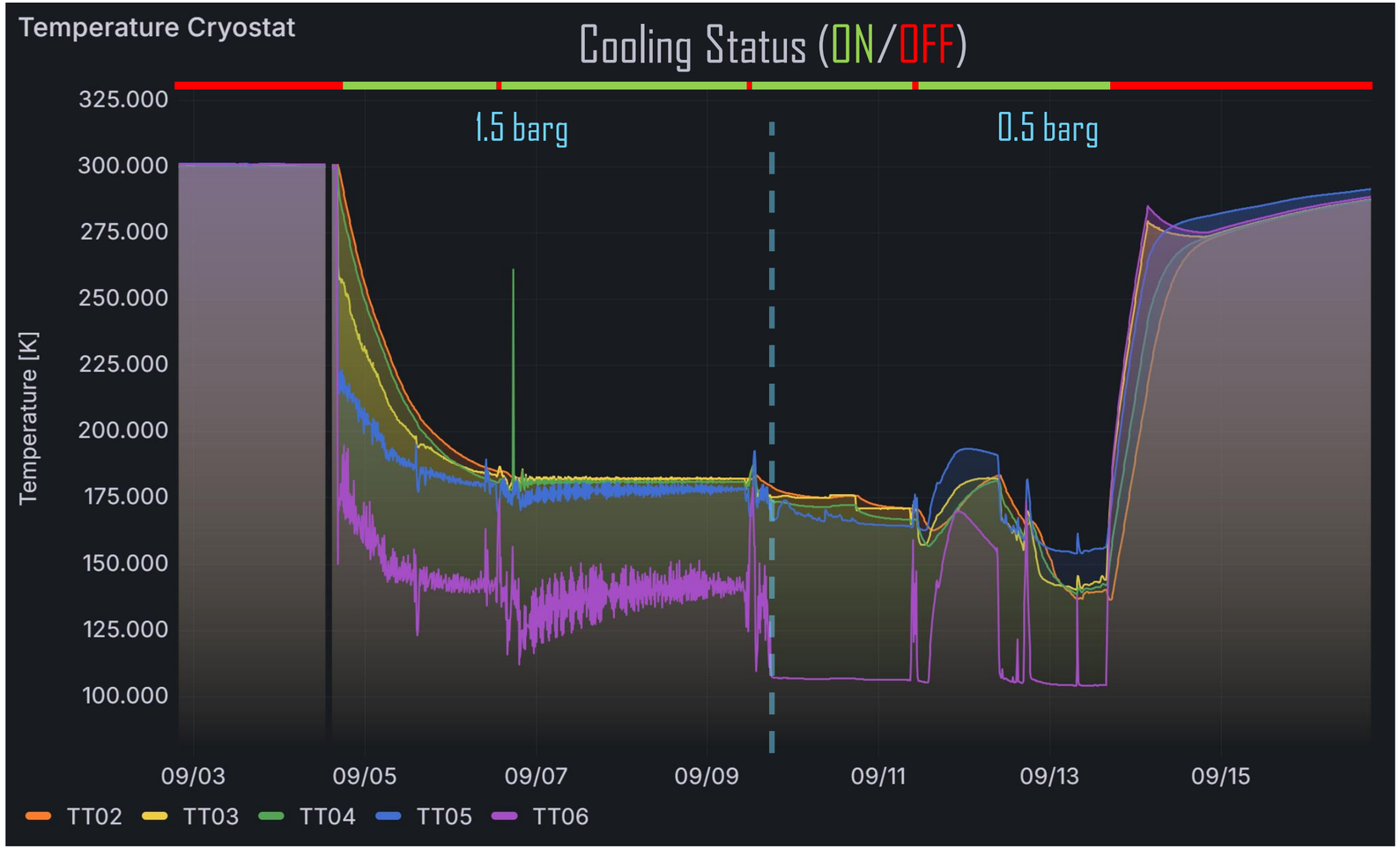
XeLab TPC

- Designed by Subatech
- Dual-phase TPC to test new electrode designs
- PTFE body (reflector)
- Stainless steel field-shaping rings
- Liquid level monitoring and control
- Hamamatsu Photosensors
  - Top: 4× 1″ PMT
  - Bottom: 1× 2″ multi-anode PMT



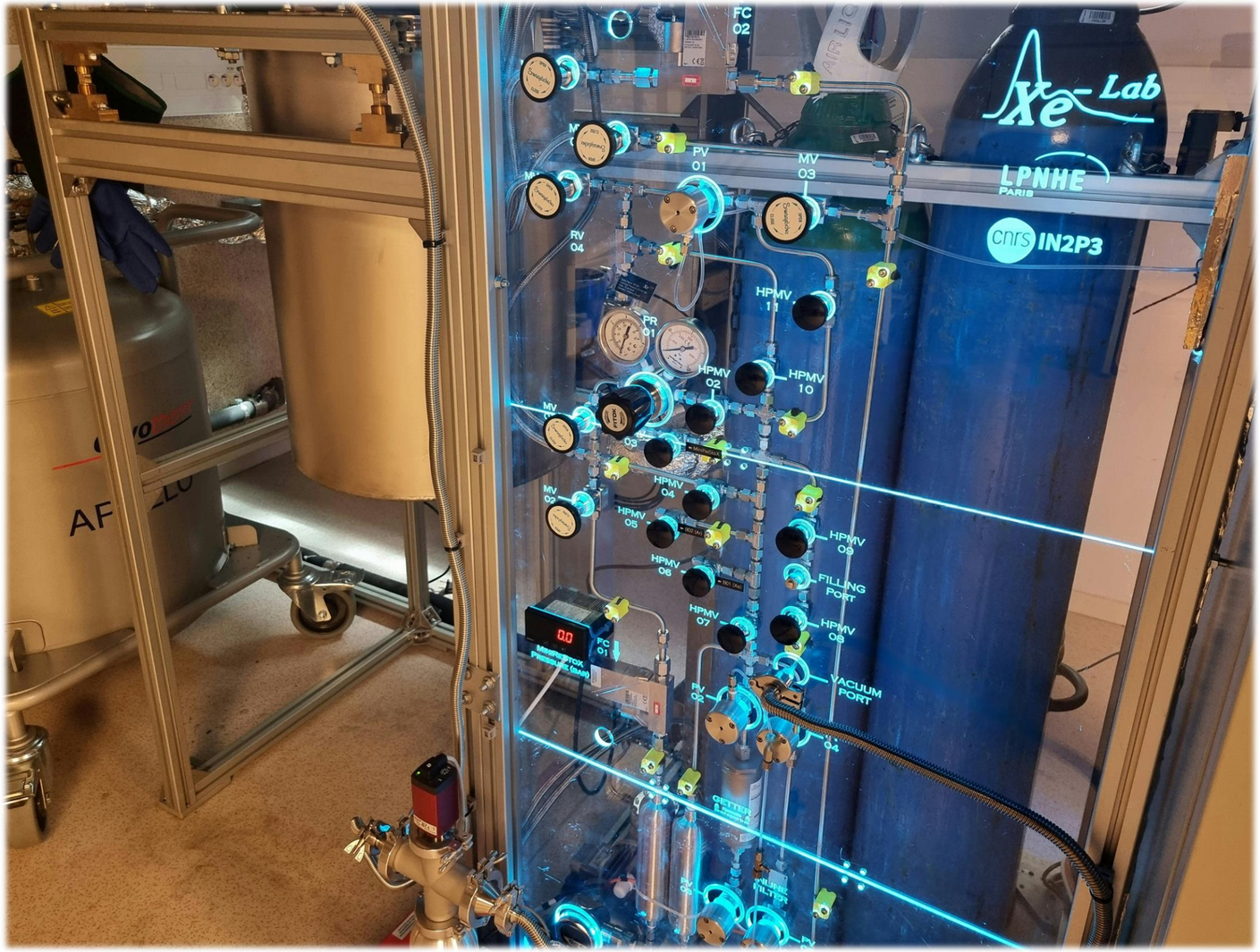
XeLab – Commissioning Run 3

- Runs 1 and 2 with 2 bar argon
  - Not enough cooling power
- Run 3 also with 2 bar argon
- Duration: 9 days
- First liquefaction of argon
  - Demonstration of continuous, stable operation
- At 2 bar:
  - T_{LAr} = 94.29 K
  - T_{LXe} = 177.88 K
- Next step: LXe fill



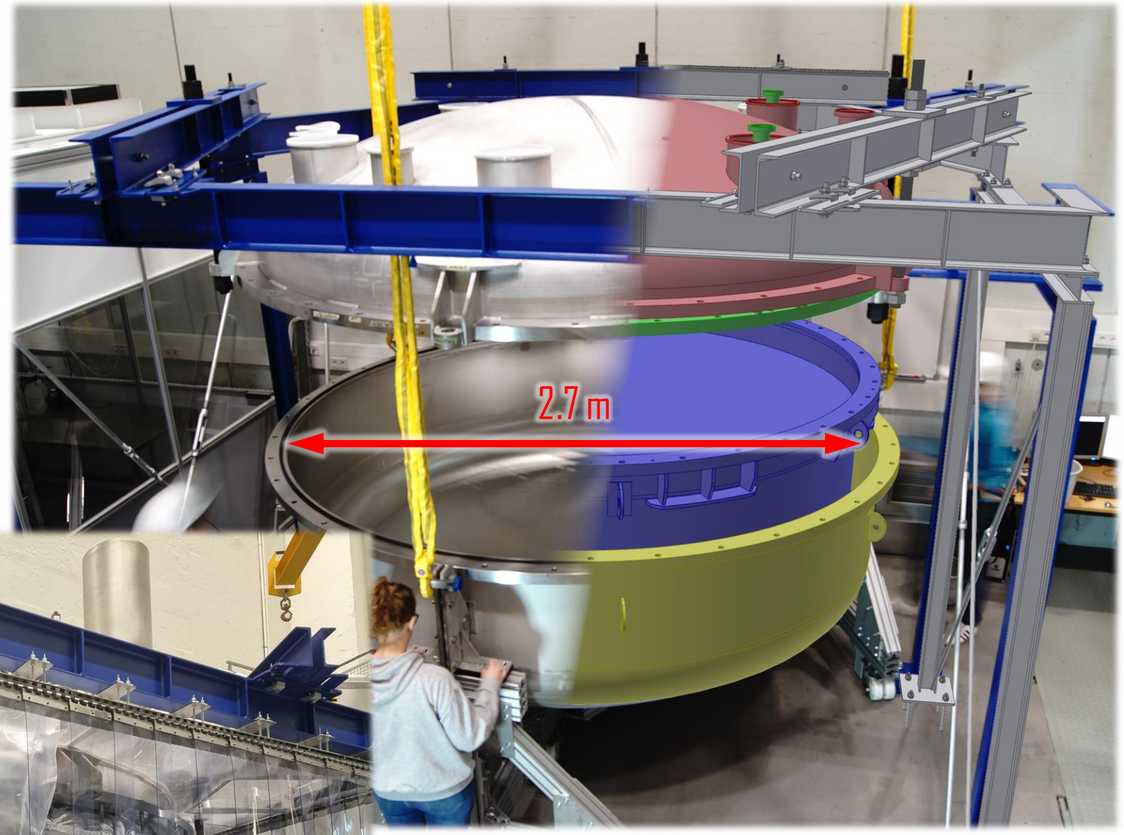
What's next?

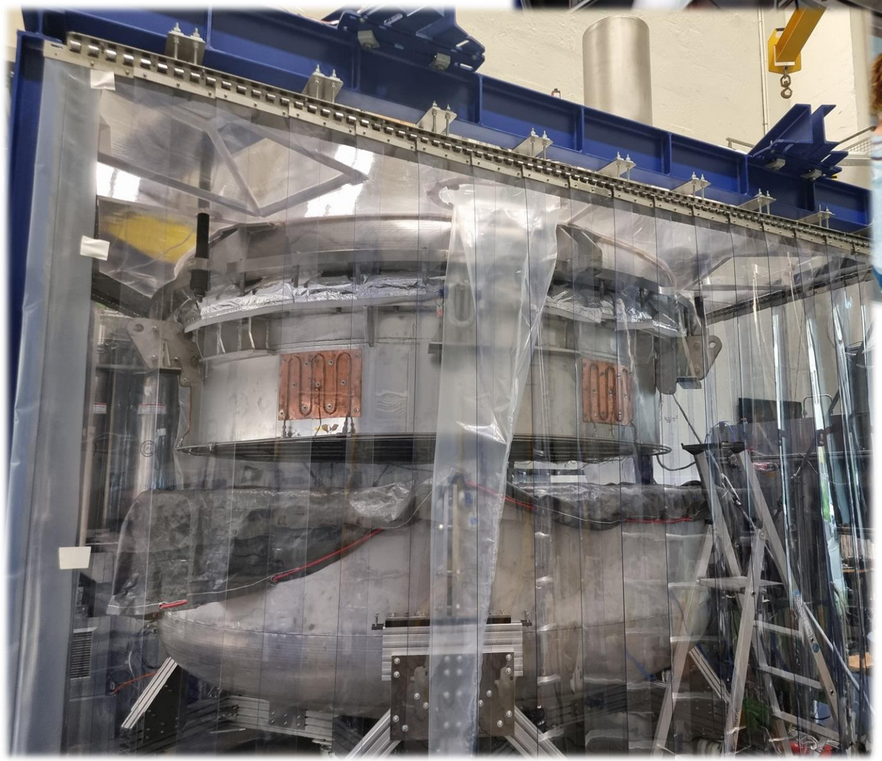
- First LXe fill
  - Waiting for xenon bottle load cell components
- Installation of the dual-phase TPC
  - Parts production at Subatech
  - Completion by the end of 2024
  - First tests in XeLab expected early 2025
- Development of new electrodes
  - Subject of the next internships + theses
  - **Looking for candidates!**



Pancake – Freiburg im Brisgau

- Test platform for full-scale DARWIN electrodes
  - End goal of XeLab R&D
- Also used to test XENON-sized electrodes, built by KIT
- Thanks to DMLab, I could spend 2 × 2 week in Freiburg to help with the tests
  - June 2024
  - Oct. Nov. 2024





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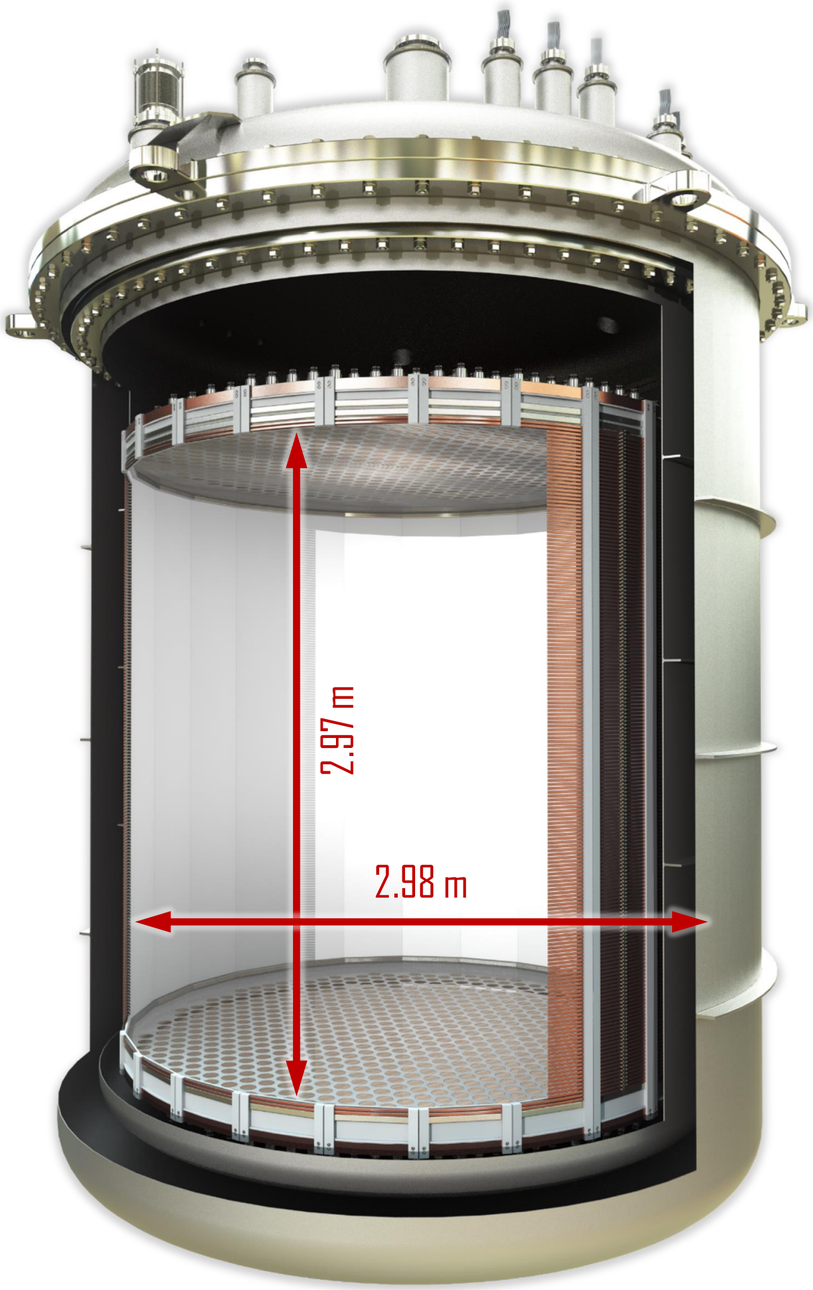
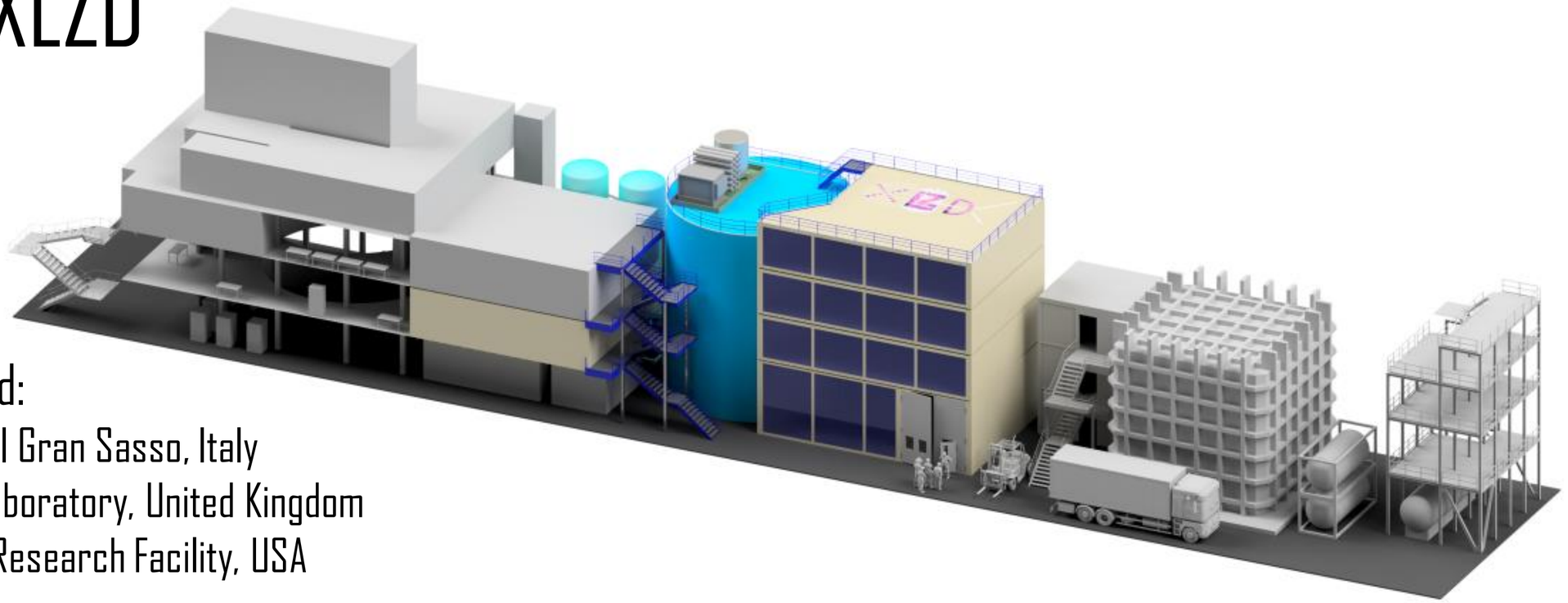
DARWIN → XLZD

- As of September 2024, the XLZD consortium is now the XLZD collaboration
  - 72 institutions
  - 163 senior scientists
- XLZD detector: 60 t LXe active target
- DARWIN will continue as an R&D collaboration, working towards XLZD



Conceptual drawing of XLZD, F. Girard, LPNHE

DARWIN → XLZD



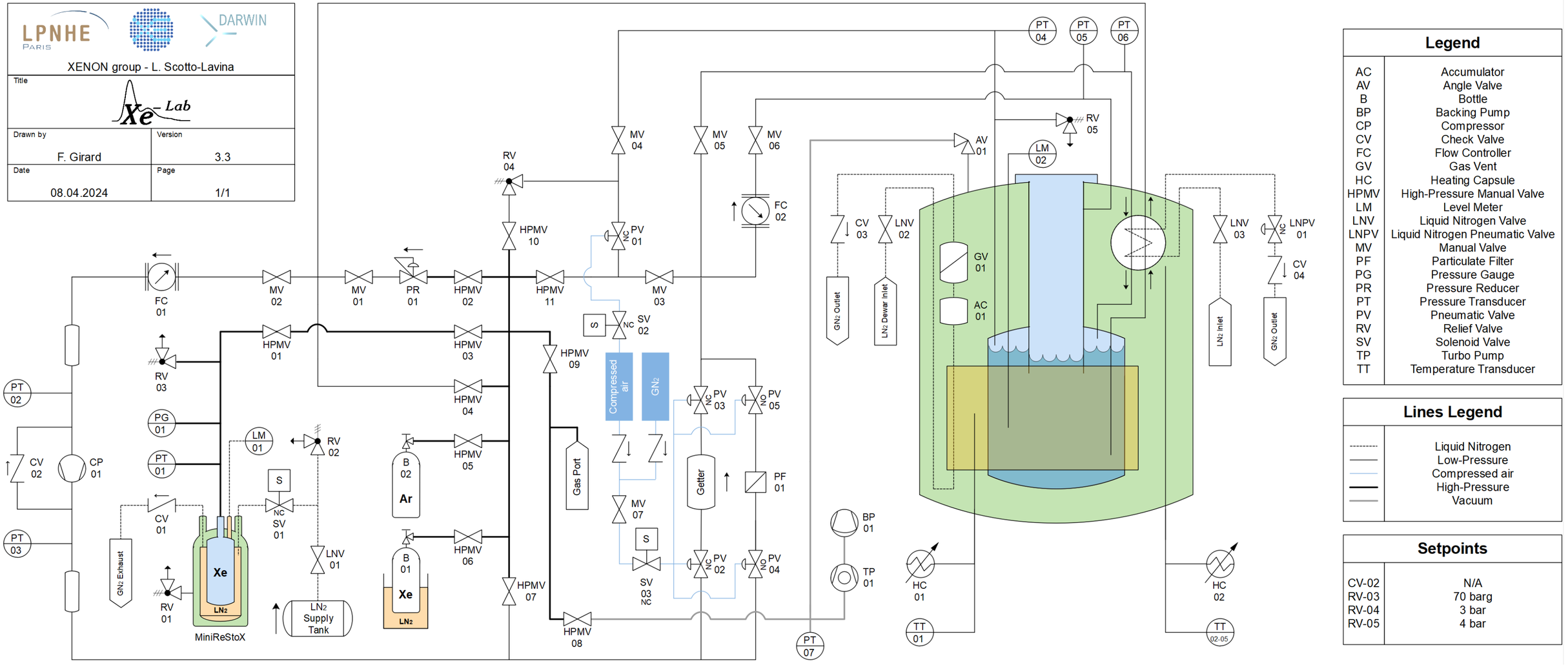
- Multiple sites considered:
  - Laboratori Nazionali del Gran Sasso, Italy
  - Boulby Underground Laboratory, United Kingdom
  - Sanford Underground Research Facility, USA
- XLZD endorsement:
  - APPEC Mid-Term Roadmap
  - Helmholtz Roadmap
  - P5 report
  - UKRI infrastructure funds allocated for design study
  - Several national roadmaps in Europe

Conceptual drawing of XLZD at LNGS, Adrian Schwenck, KIT

Thank you!

Frédéric Girard
LPNHE-Paris

DMLab
18 Oct. 2024



Legend

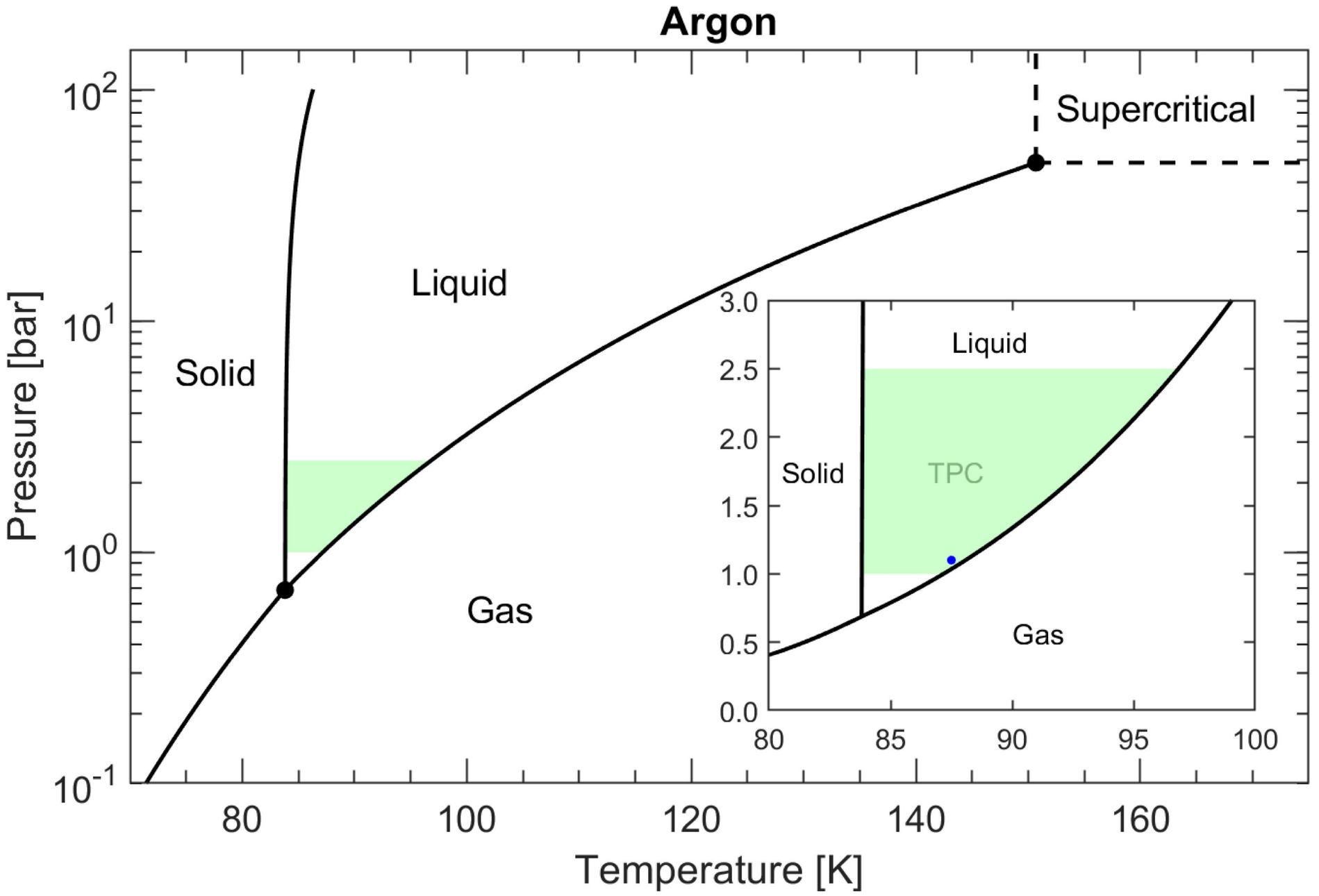
AC	Accumulator
AV	Angle Valve
B	Bottle
BP	Backing Pump
CP	Compressor
CV	Check Valve
FC	Flow Controller
GV	Gas Vent
HC	Heating Capsule
HPMV	High-Pressure Manual Valve
LM	Level Meter
LNV	Liquid Nitrogen Valve
LNPV	Liquid Nitrogen Pneumatic Valve
MV	Manual Valve
PF	Particulate Filter
PG	Pressure Gauge
PR	Pressure Reducer
PT	Pressure Transducer
PV	Pneumatic Valve
RV	Relief Valve
SV	Solenoid Valve
TP	Turbo Pump
TT	Temperature Transducer

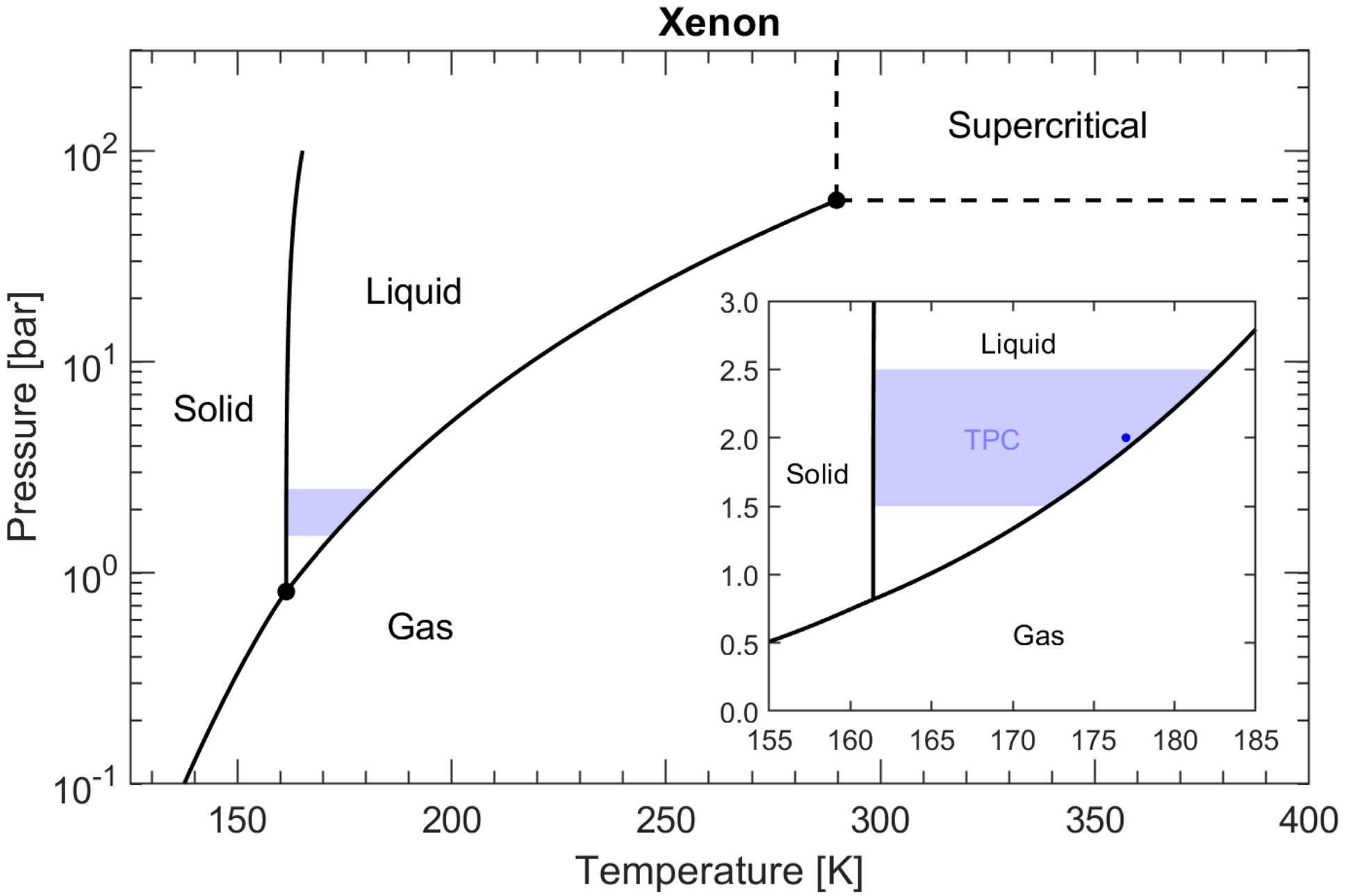
Lines Legend

-------	Liquid Nitrogen
———	Low-Pressure
———	Compressed air
———	High-Pressure
———	Vacuum

Setpoints

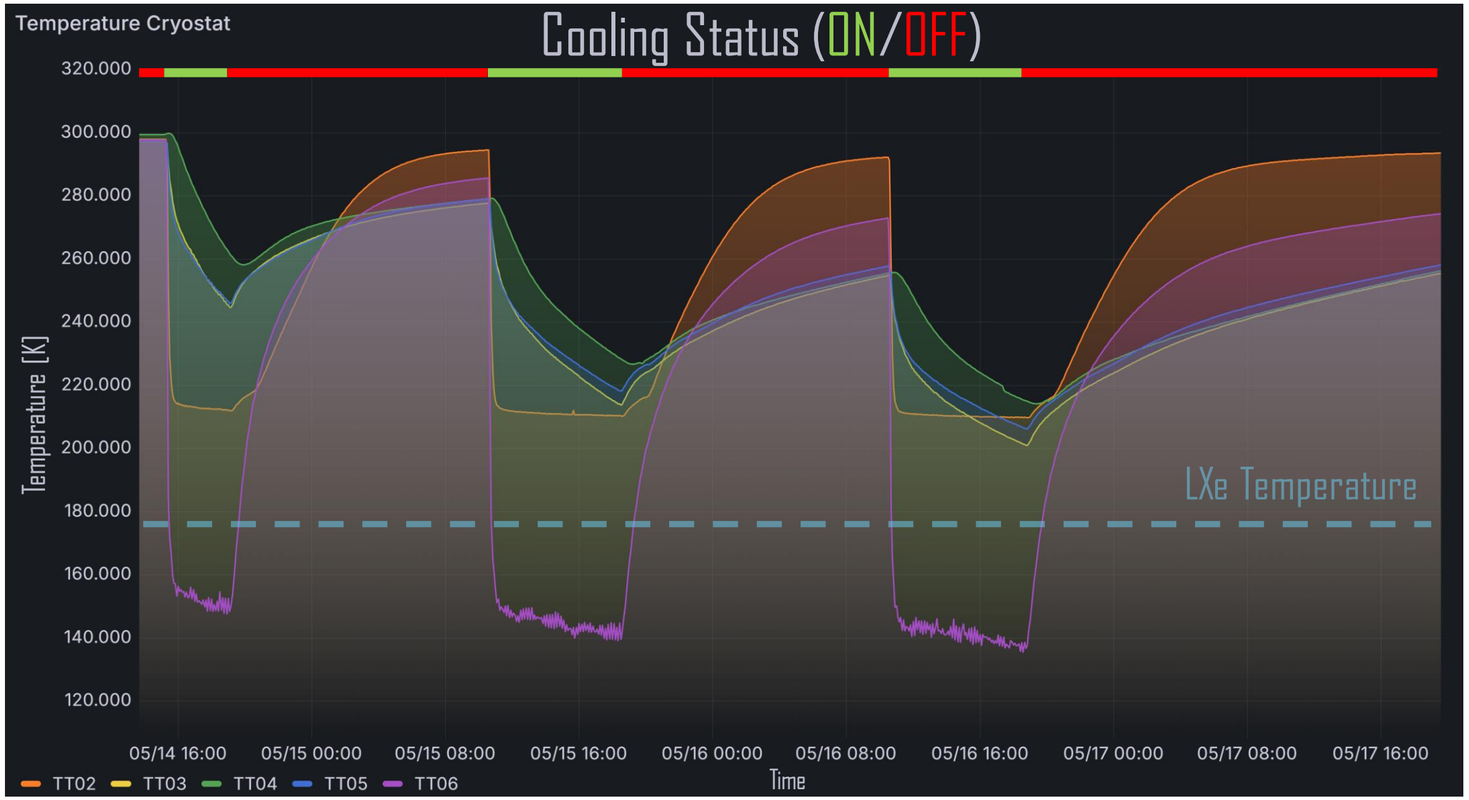
CV-02	N/A
RV-03	70 barg
RV-04	3 bar
RV-05	4 bar


Argon
Supercritical
Liquid
Solid
Gas
Pressure [bar]
Temperature [K]
10^2
10^1
10^0
10^{-1}
80
100
120
140
160
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Liquid
Solid
TPC
Gas
80
85
90
95
100


Xenon
Supercritical
Liquid
Solid
Gas
Pressure [bar]
10^2
10^1
10^0
10^{-1}
150
200
250
300
350
400
Temperature [K]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Liquid
TPC
Solid
Gas
155
160
165
170
175
180
185

XeLab – Commissioning Run 1

- First cooldown test of Xelab in May 2024
- Inner vessel filled with 2 bar argon
  - Cheaper than xenon
- Cooling underwhelmingly poor
- Upgrades:
  - Exchange stainless steel tubing with copper tubing
  - Apply mixture of silver power (2 µm) and Apiezon N cryogenic grease (thermal paste)



Commissioning Upgrades

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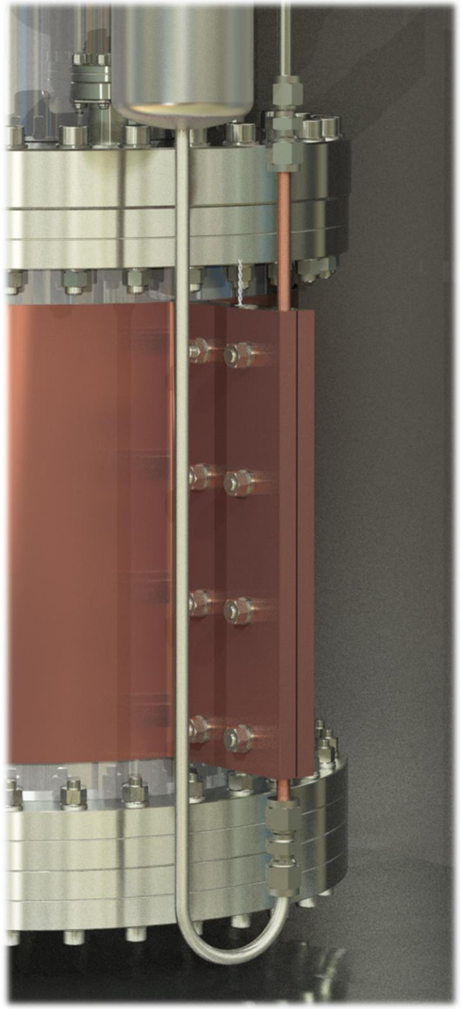
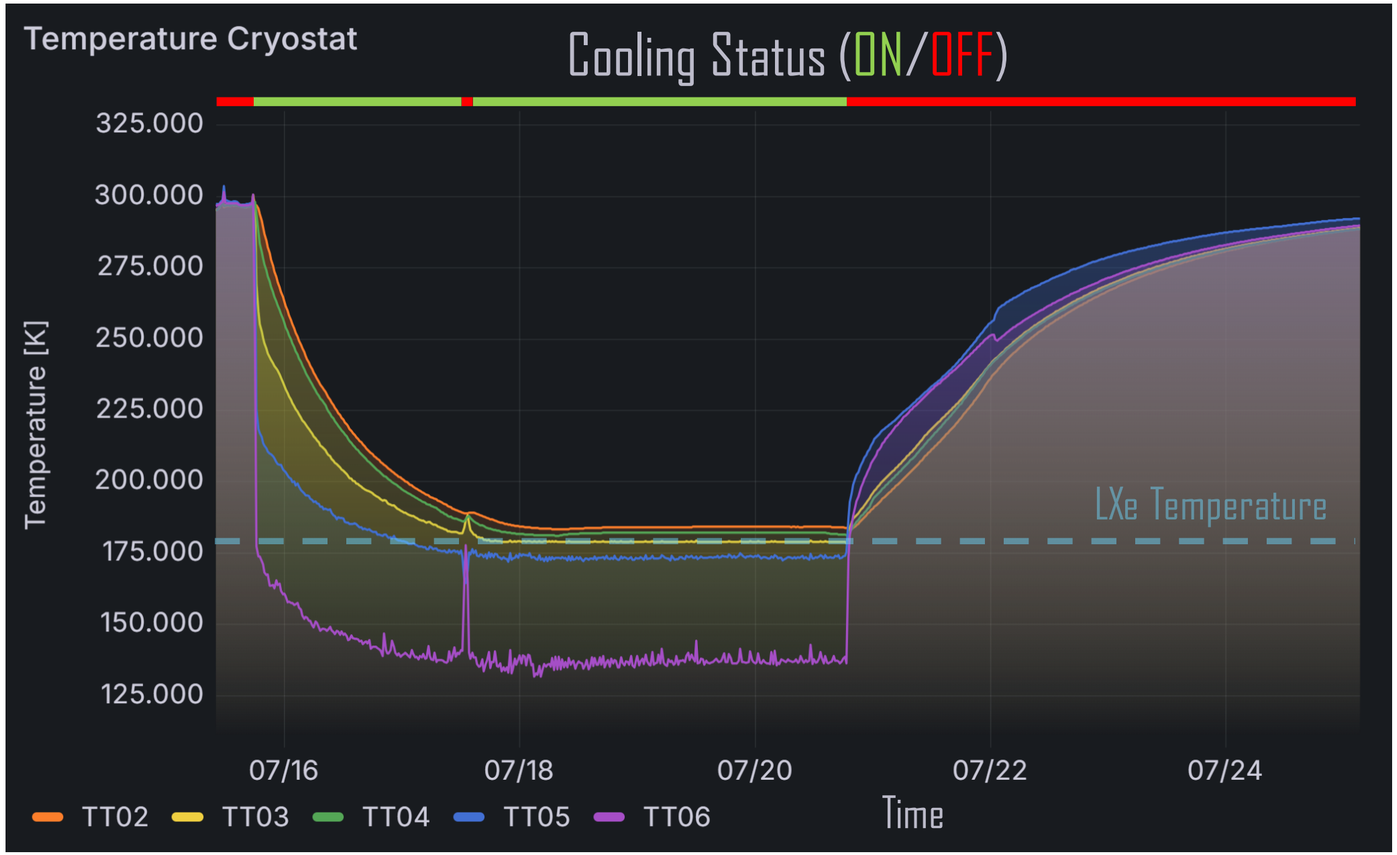


Copper tube

Application of thermal paste

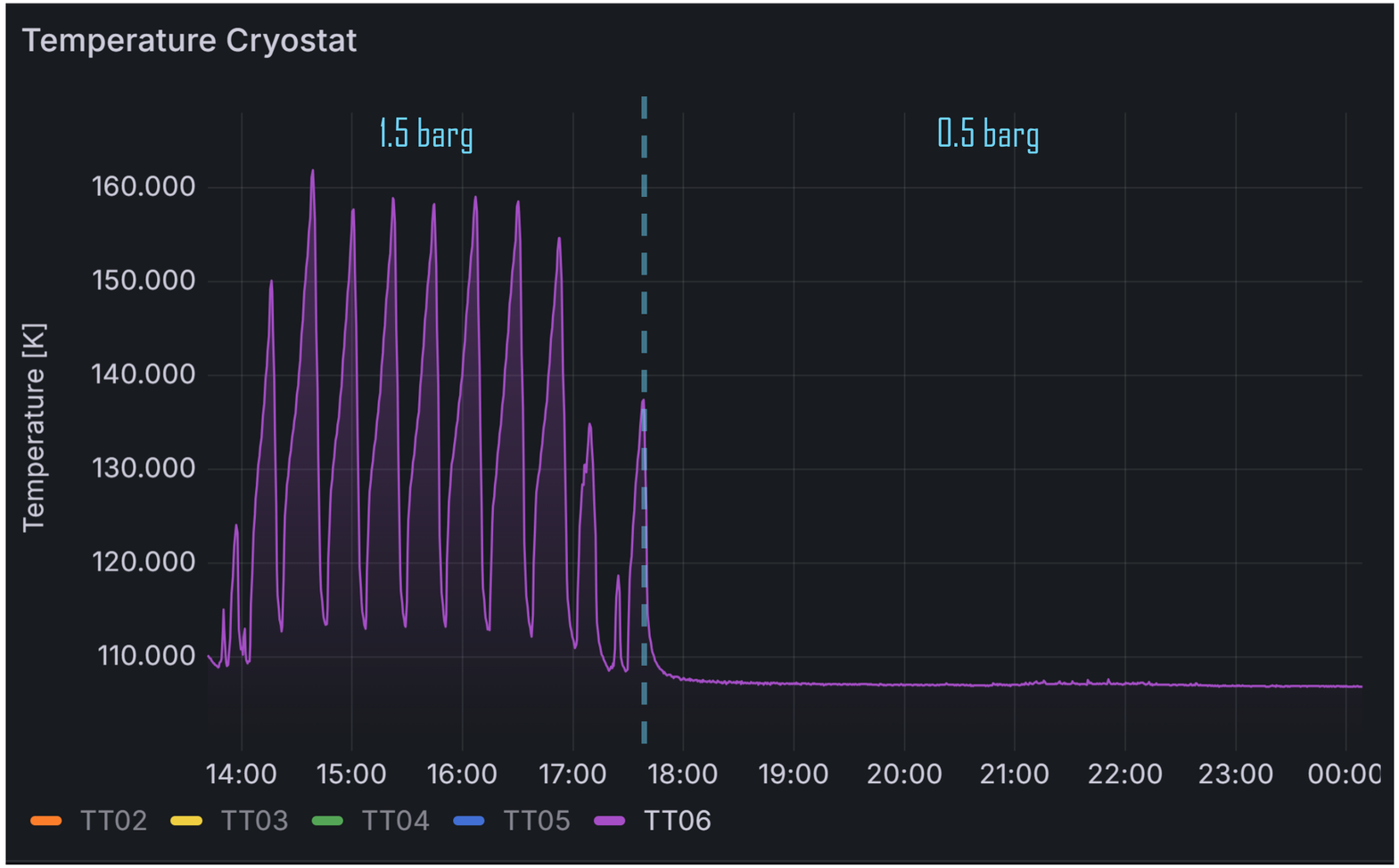
XeLab – Commissioning Run 2

- Second cooldown test of Xelab in July 2024 (remotely because of the Olympic Games)
- Duration: 5 days
- Cooling still not great, barely good enough
- Only 5 days of test until the LN_2 was depleted
- Reached LXe temperature in 2 days



XeLab – Commissioning Run 3

- Reduced pressure in Dewar
  - Slower LN_2 filling
  - Free floating vent bypassed, acts only as an overflow prevention
- Continuous cooling
- Increased cooling power



XeLab – Commissioning Run 3

- As the vessel cools down, the pressure drops (noble gas)
- Some fluctuations in the temperature are hints of the production of the first drops of liquid
  - They evaporate, cooling down the bottom flange
- The pressure drops sharply, with no drastic change in temperature at the start of liquid accumulation
- Argon filled continuously for ~ 2h