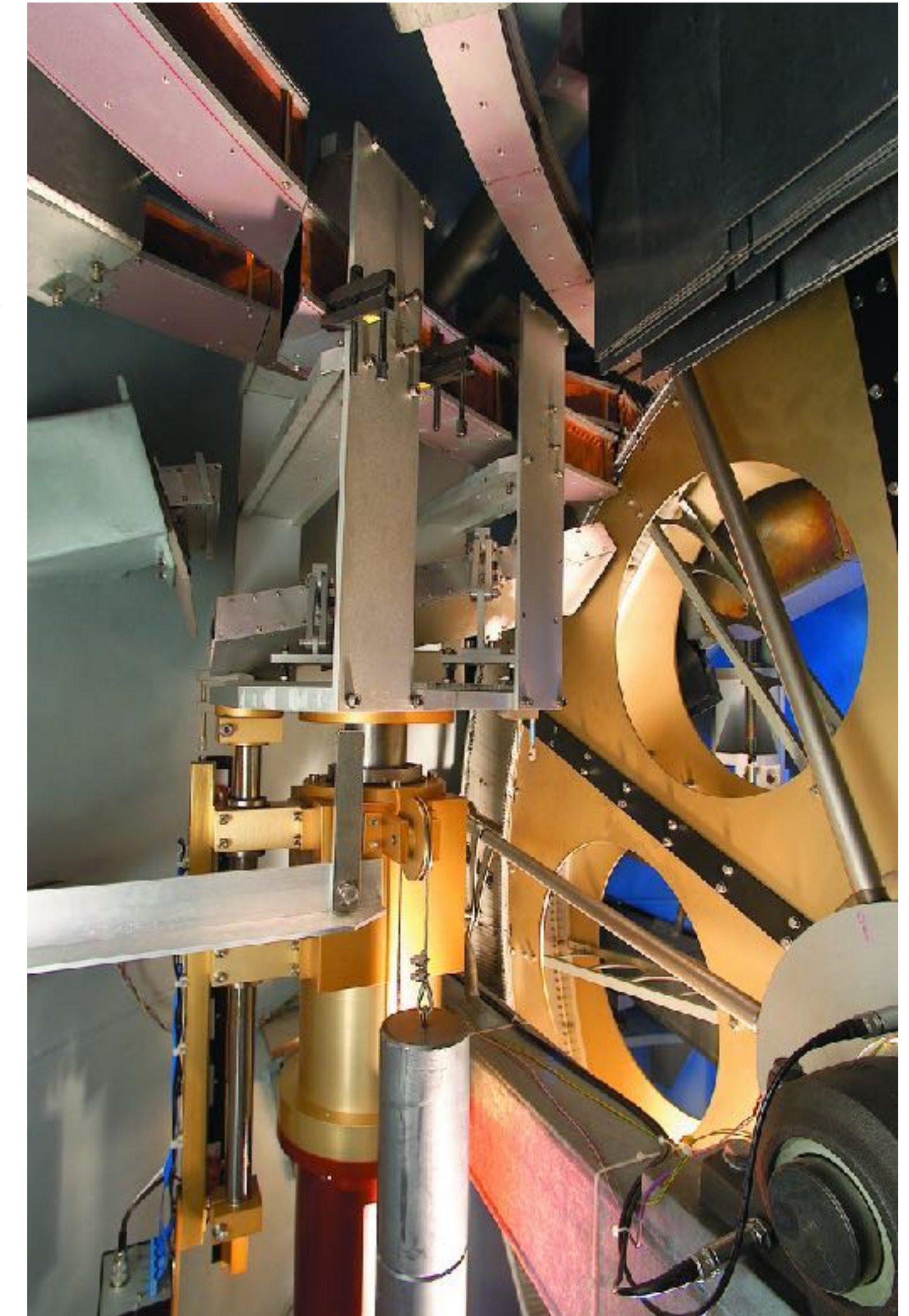
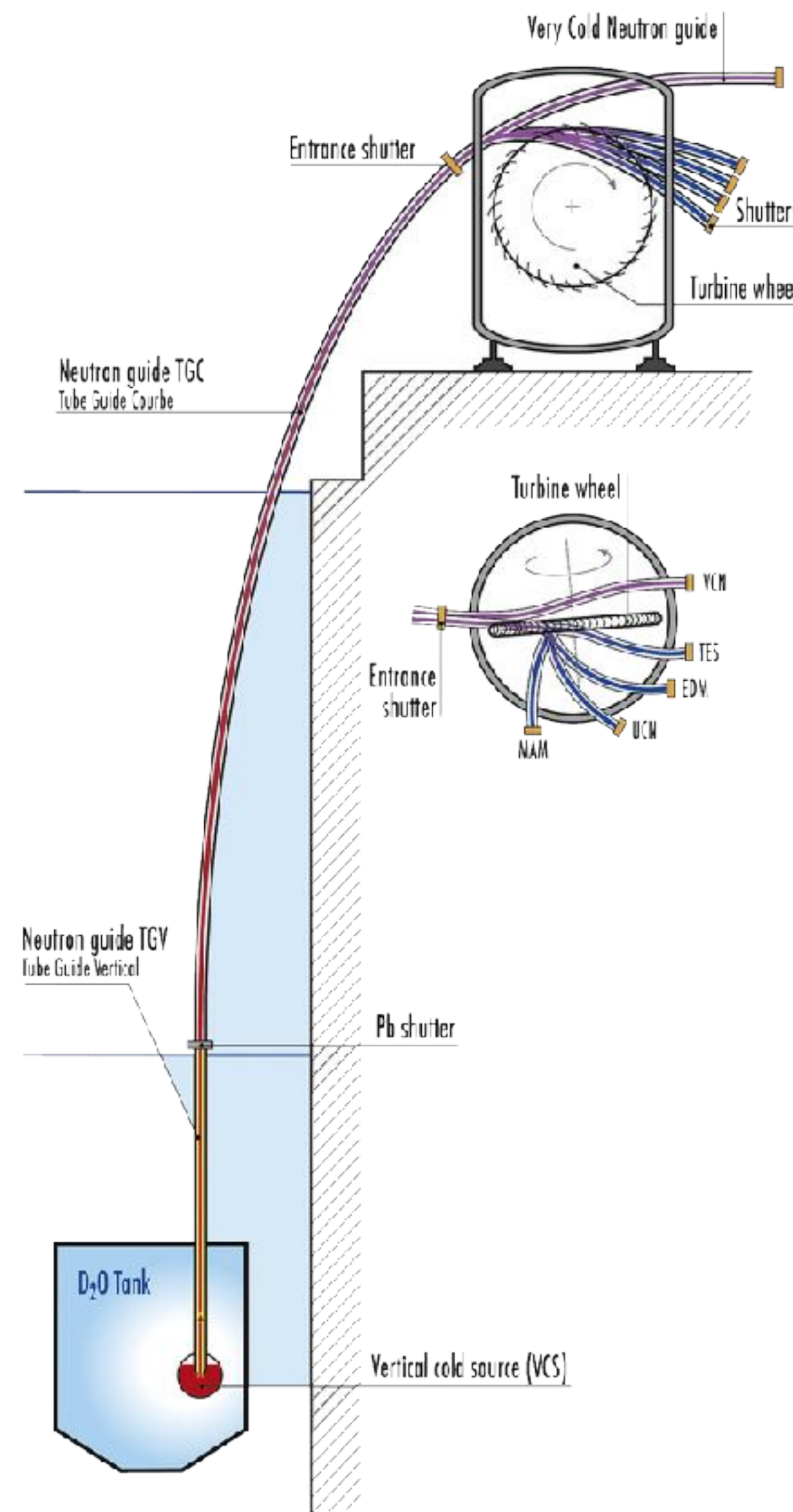


Measuring techniques

Nuclear & particle physics

- dedicated instruments or beam facilities shared by a community
- MeV, cold (meV) and ultra-cold (neV) neutron sources
- often long experiments for testing fundamentals models or measuring constants
- experiments studying nuclei



turbine wheel

Measuring techniques

Nuclear & particle physics

World-record UCN density established in July 2023!

^3He Cryostat

Superfluid He production, UCN extraction

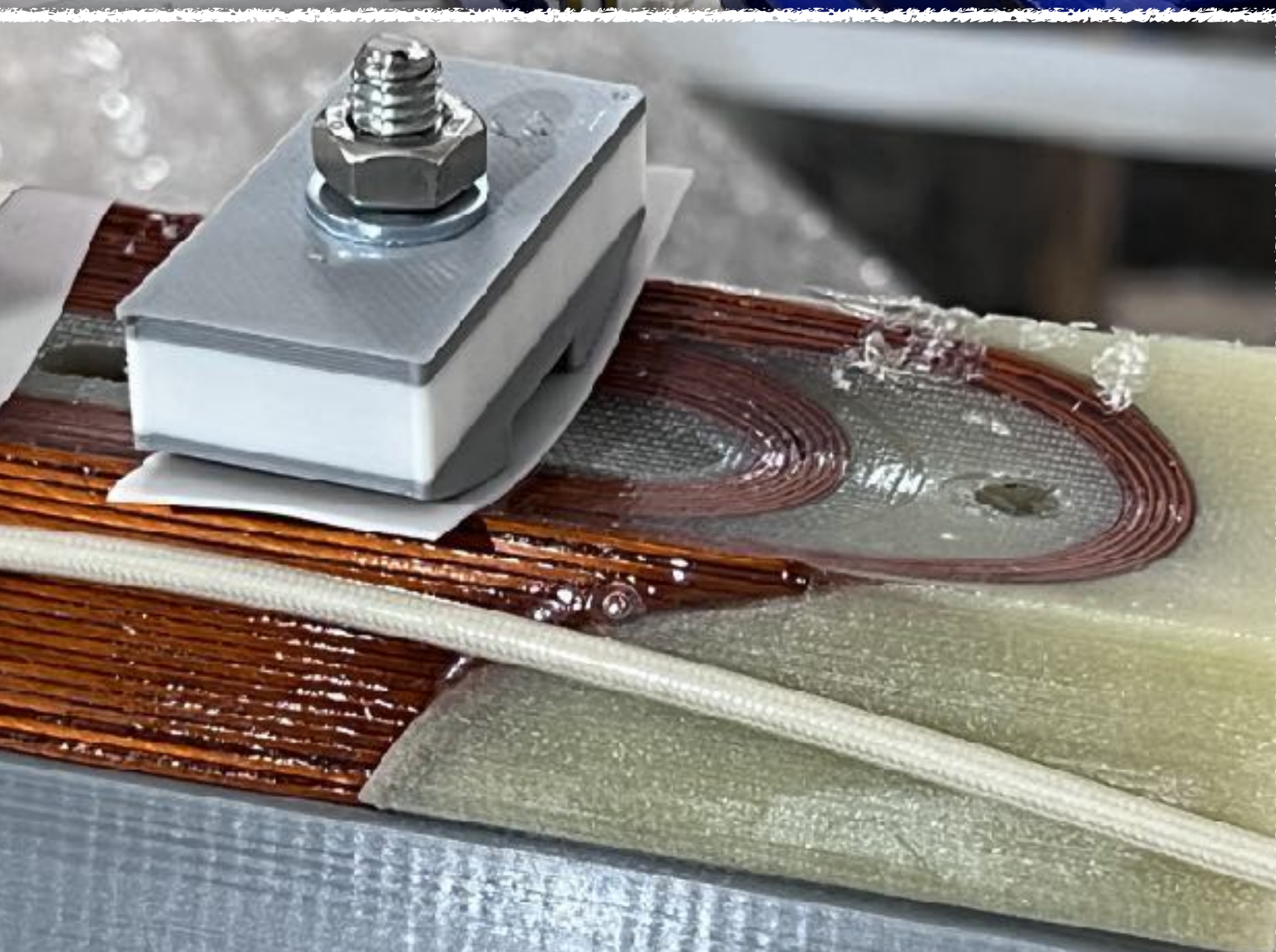
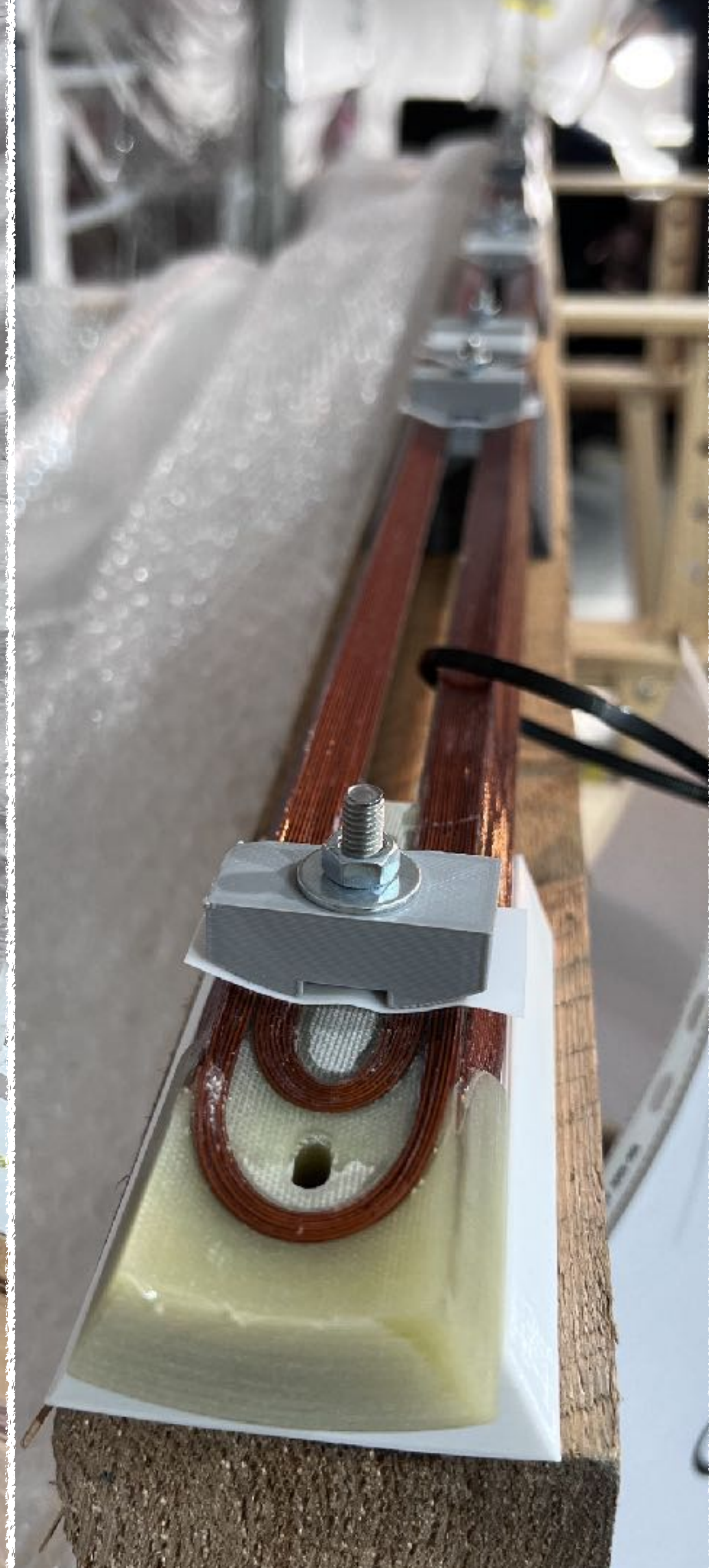
Conversion and storage of UCNs

Octagonal guide end

3,2 m



20 litres superfluid He — 100 mW @ 0.6 K



octupole + solenoid trained @ CERN

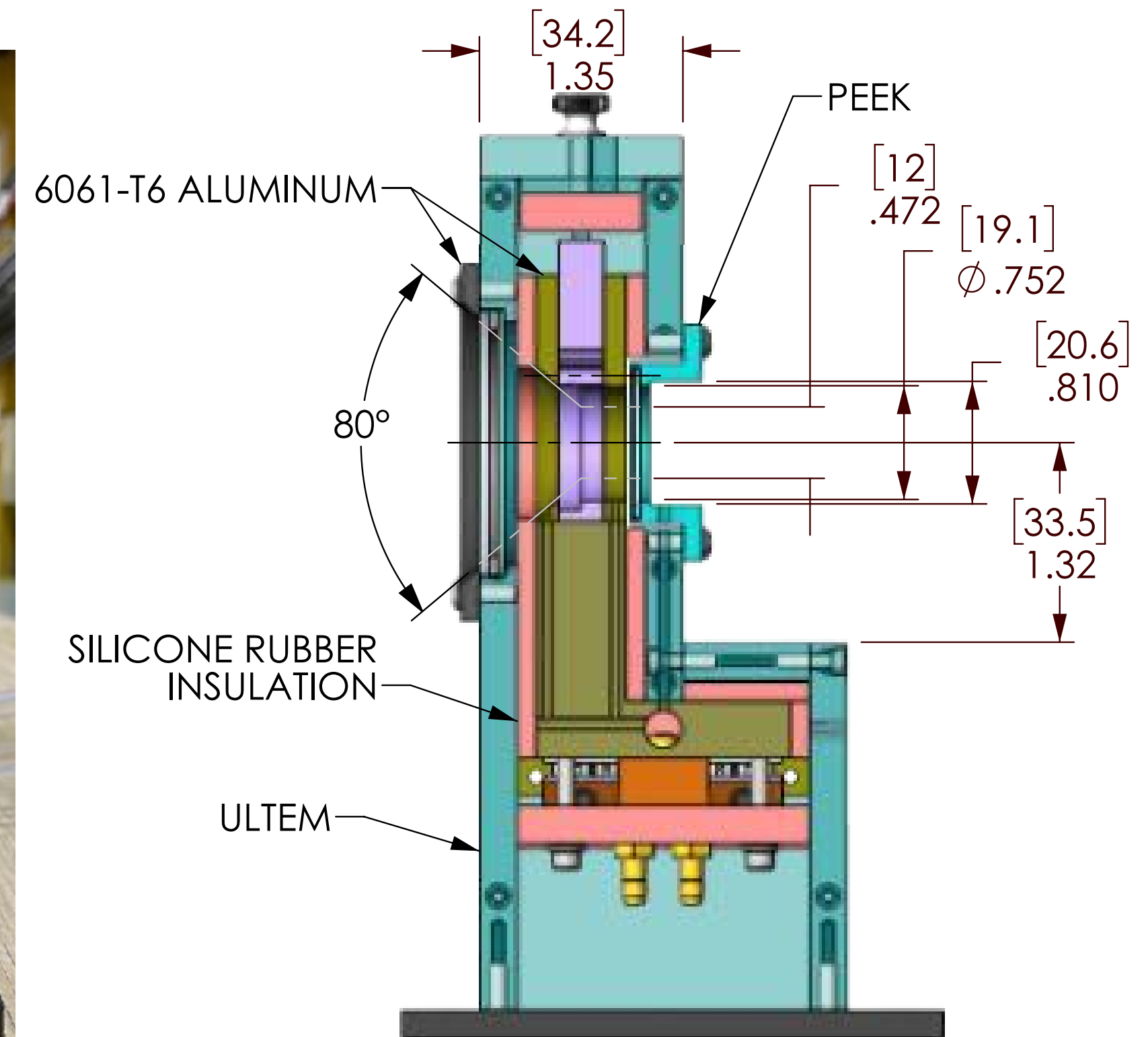
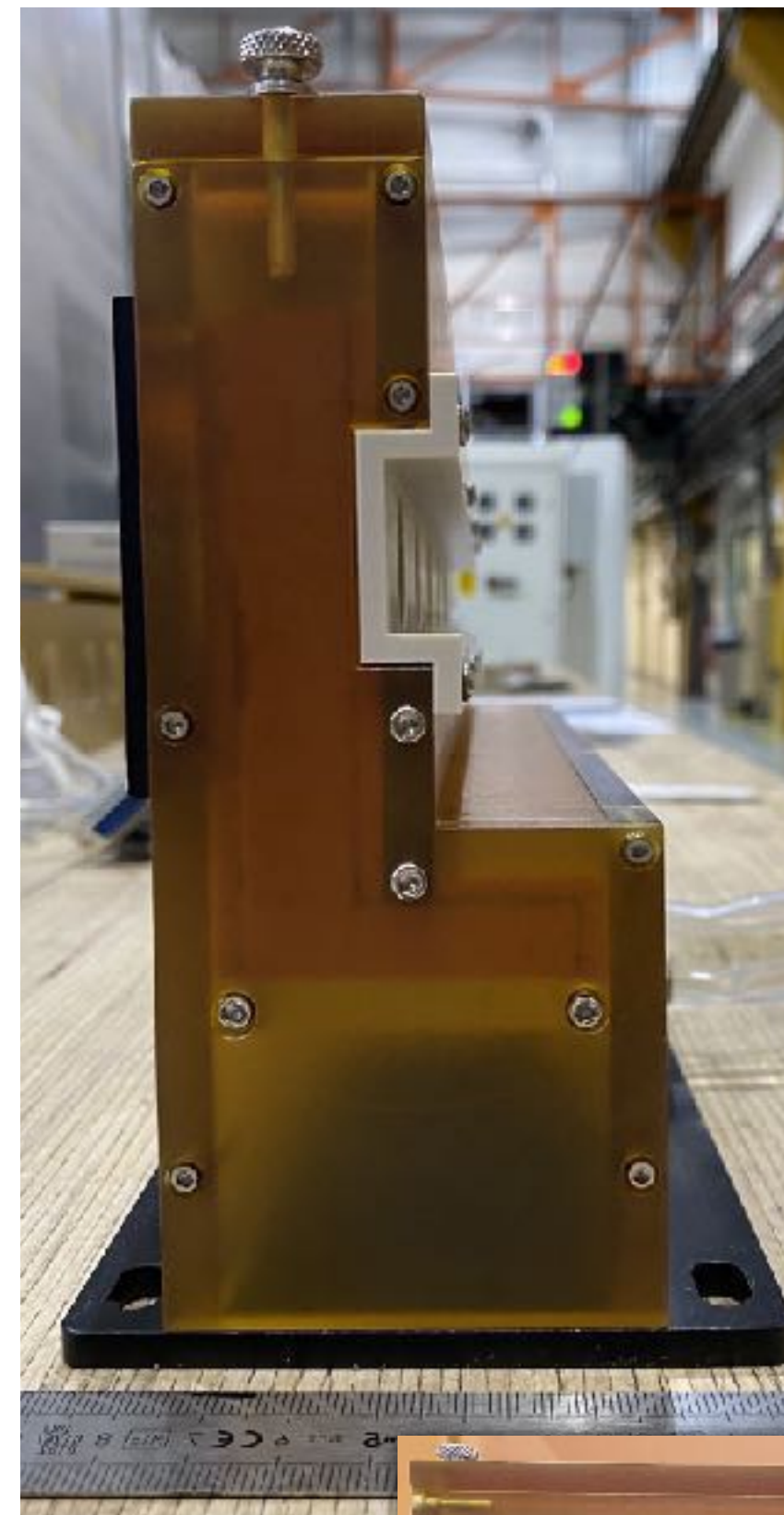
Neutron instrumentation

- What do we measure and need?
- Neutron guides & shielding
- Measuring techniques
- **Sample environments**
- Neutrons detectors
- Data acquisition system

Sample environments

Ambient environments

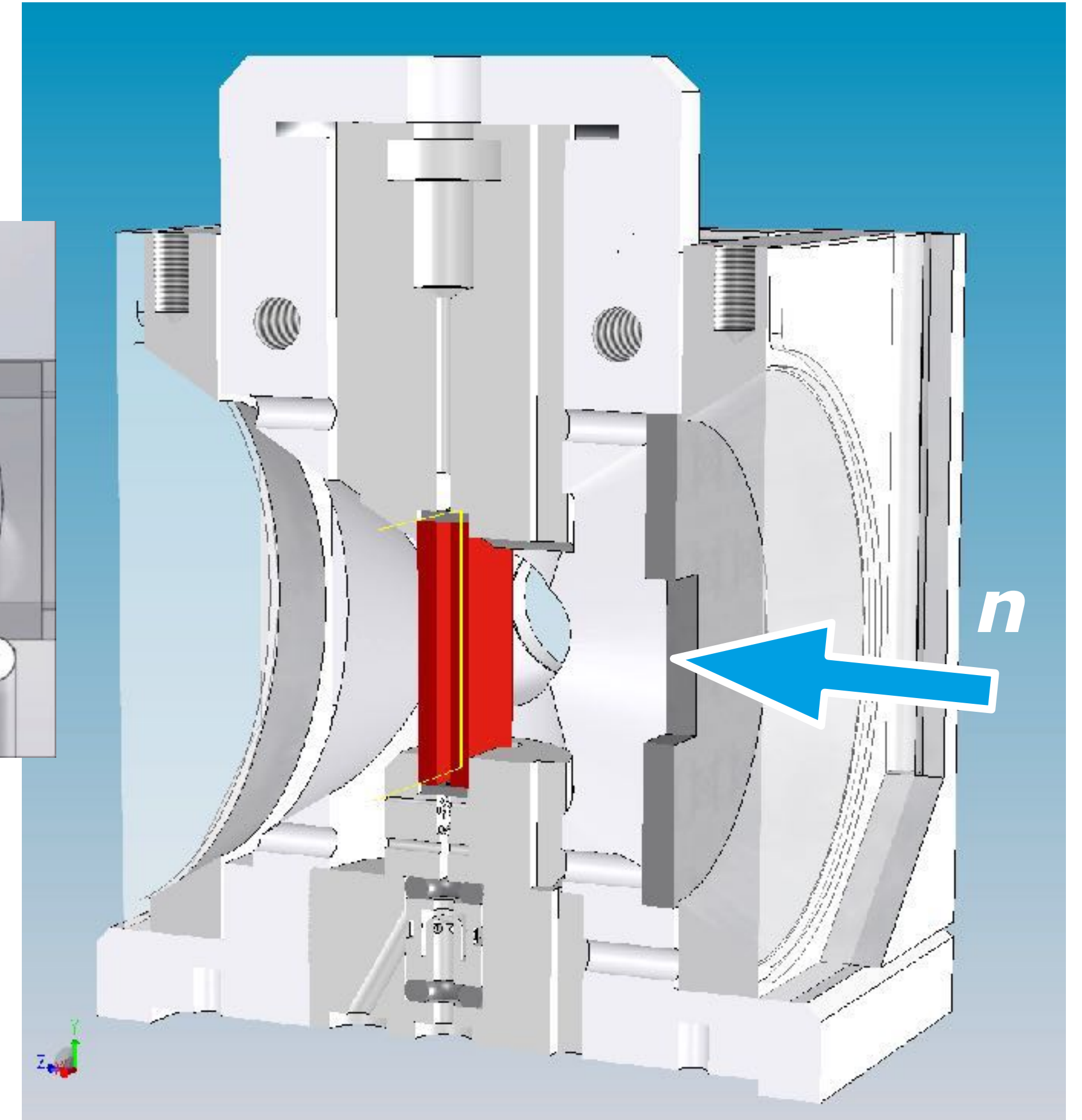
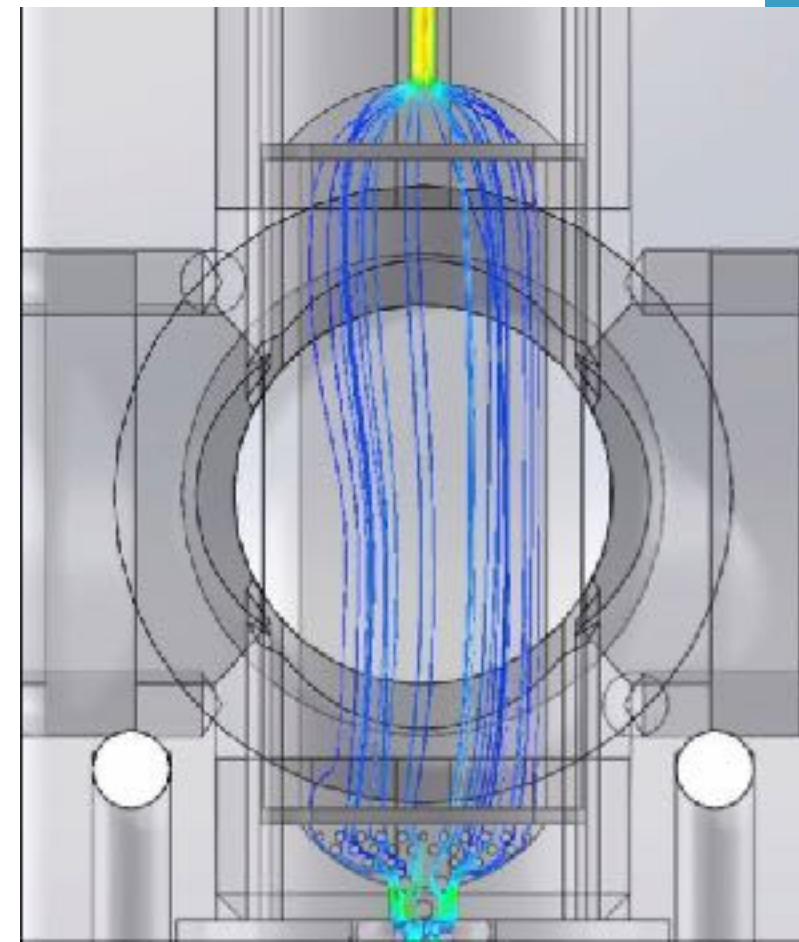
- SANS sample changers
 - up to 24 samples
 - -20 to +150°C
 - independently settable temperature or not
 - compatible with in-situ dynamic light scattering
 - low-background design
 - sample mixing option



Sample environments

Ambient environments

- Stopped-flow observation heads for SANS
 - reduced sample volume
 - controlled temperature
 - B₄C neutron slits
 - reversible with SF system
 - compatible with two types of Hellma cells (1, 2 mm neutron path)
 - side windows provided for in-situ dynamic light scattering



Sample environments

Ambient environments

- Humidity chambers
 - up to 100%RH
 - 10%RH steps in 10-25'
 - 0.1%RH stability
 - sample mounted, aligned and stabilised off-line
 - electronics providing T and %RH direct control
 - H₂O or D₂O

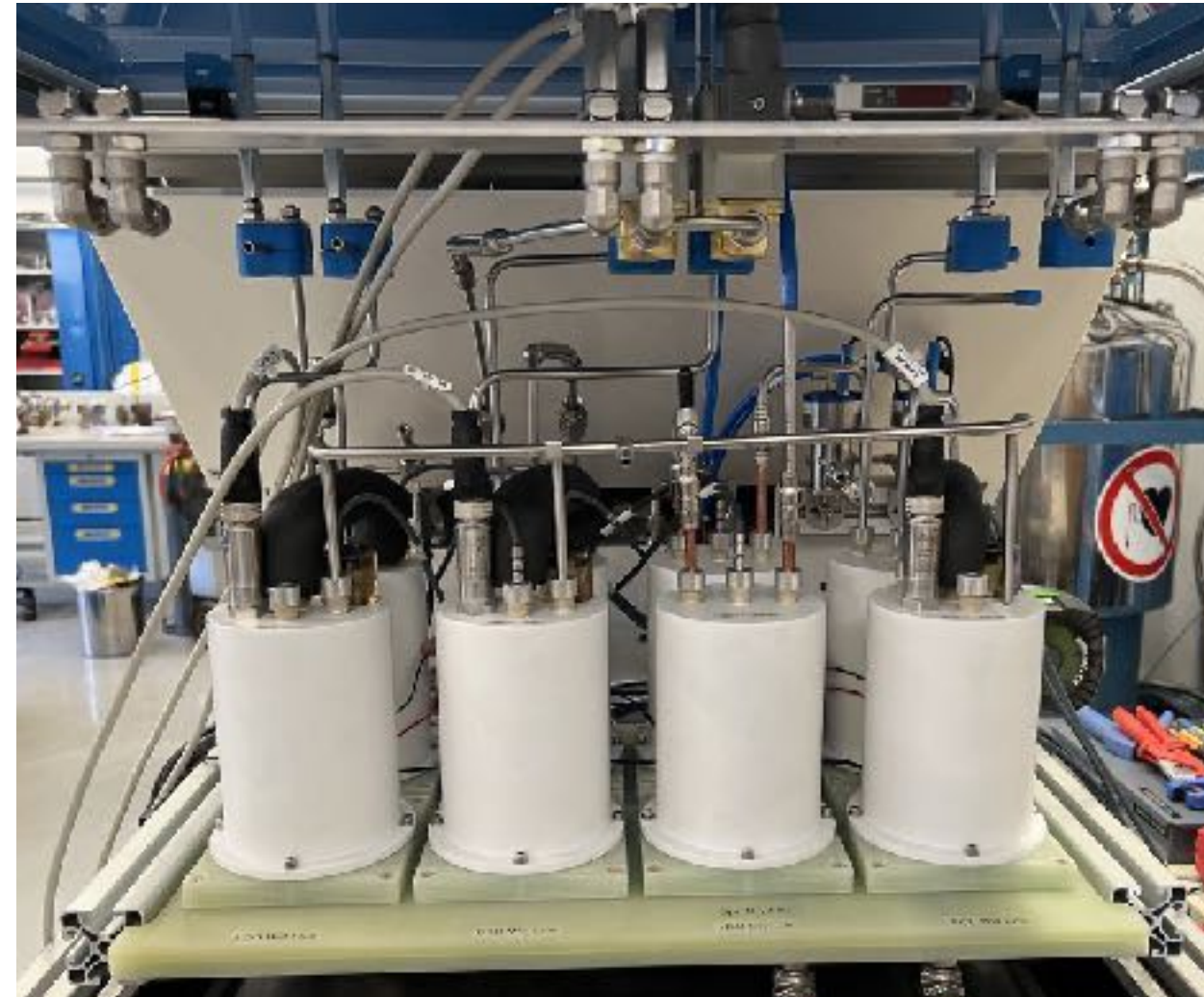


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Sample environments

Ambient environments

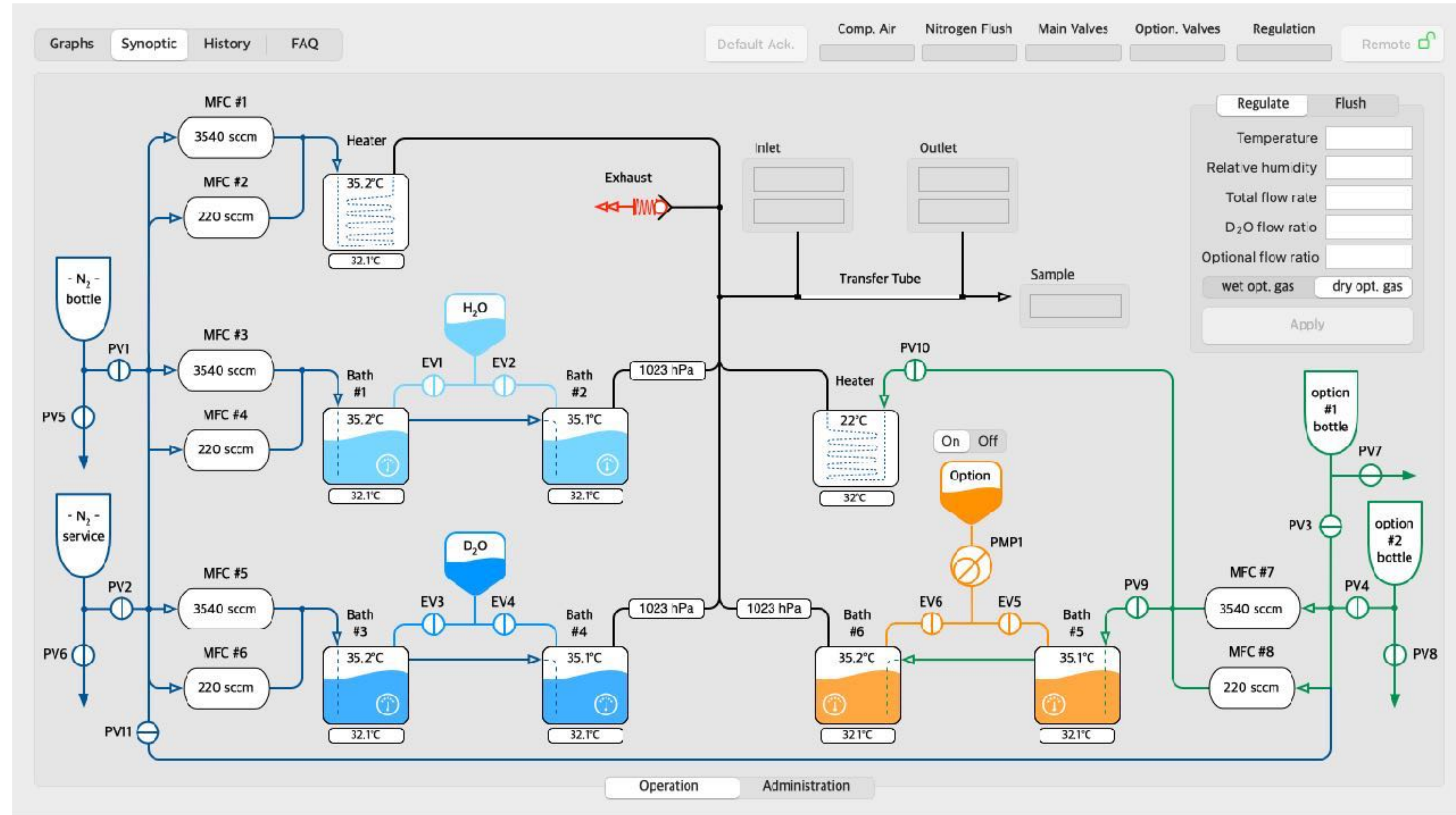
- Humidity generator
 - H₂O and D₂O
 - up to 85 %RH
 - from 10 to 80°C
 - Optional gas, liquid
 - Fully automatic



Sample environments

Ambient environments

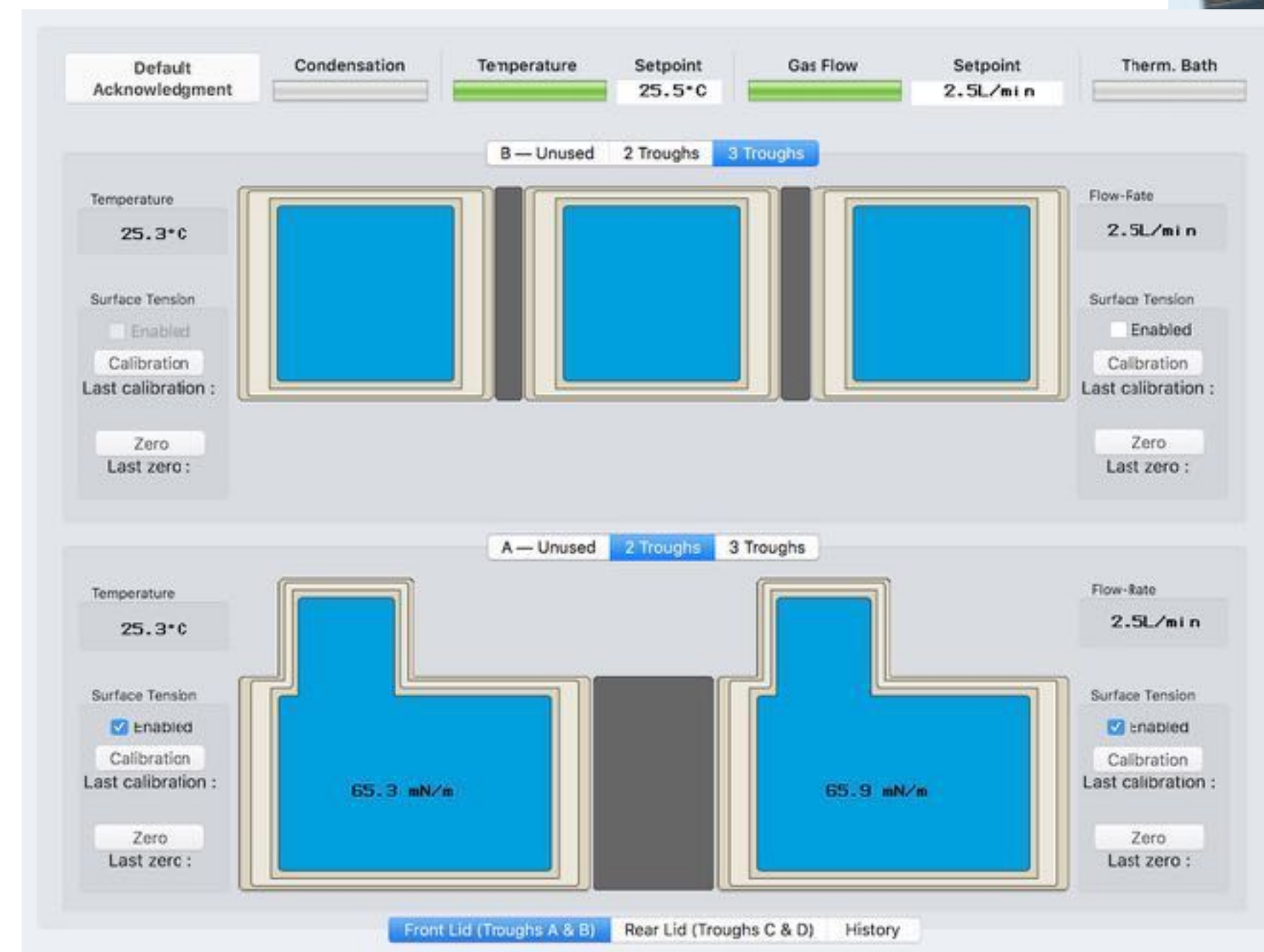
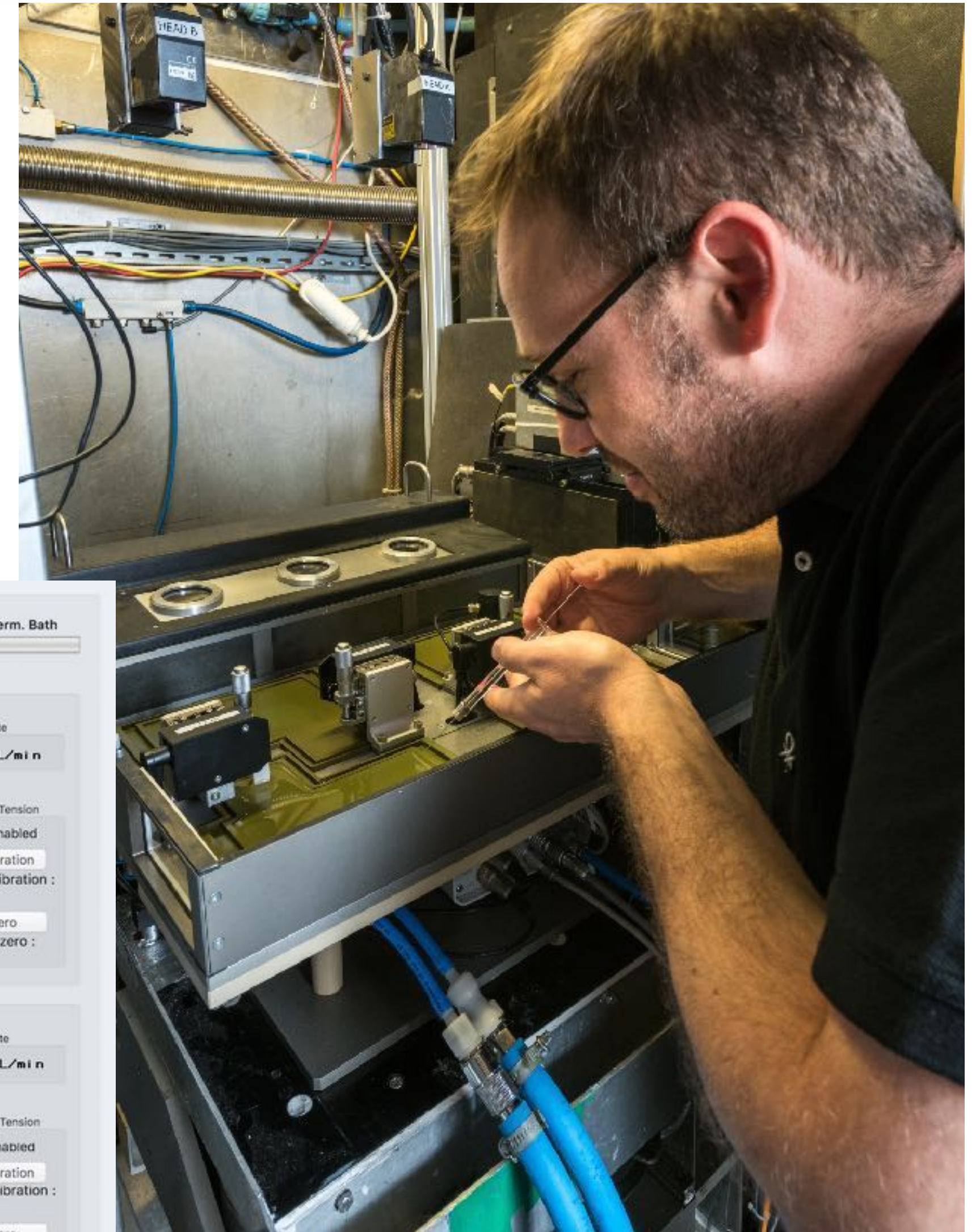
- Humidity generator
 - H₂O and D₂O
 - up to 85 %RH
 - from 10 to 80°C
 - Optional gas, liquid
 - Fully automatic



Sample environments

Ambient environments

- Adsorption troughs for reflectometry
 - up to 12 troughs
 - 2 different volumes
 - in-situ surface tension monitoring
 - temperature ctrl
 - gas sorption ctrl
 - no condensation
 - B₄C absorbers

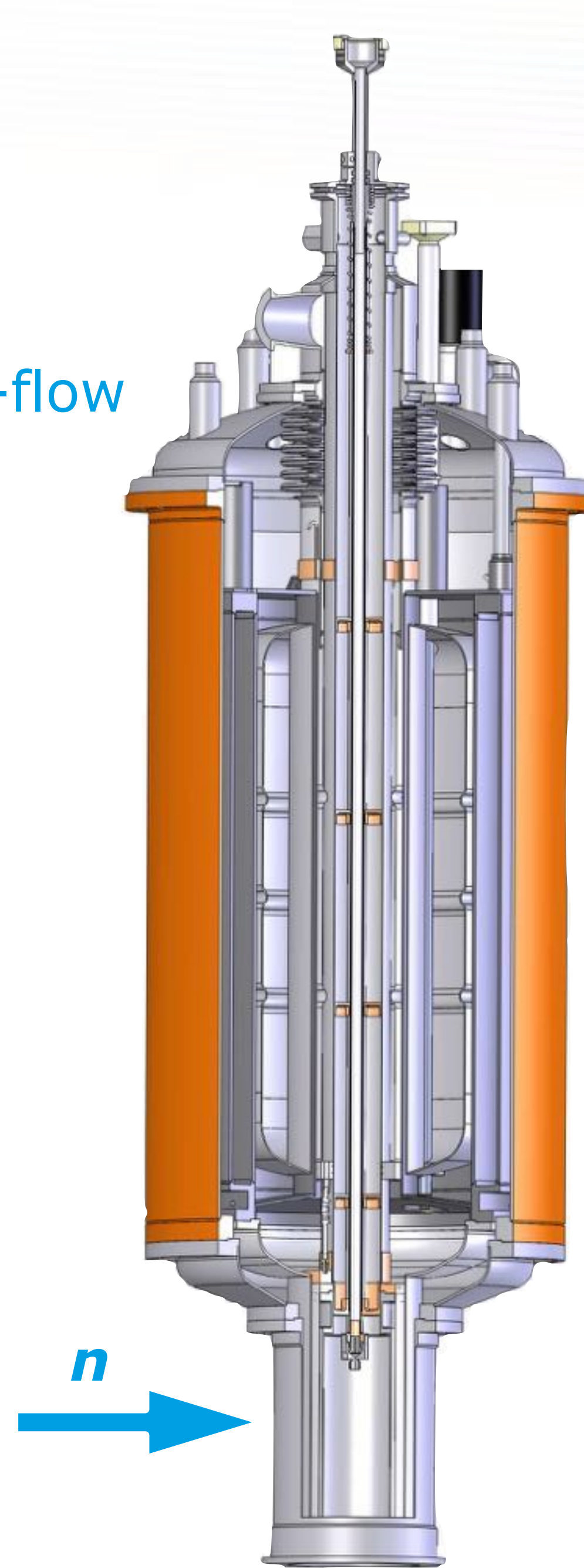


Sample environments

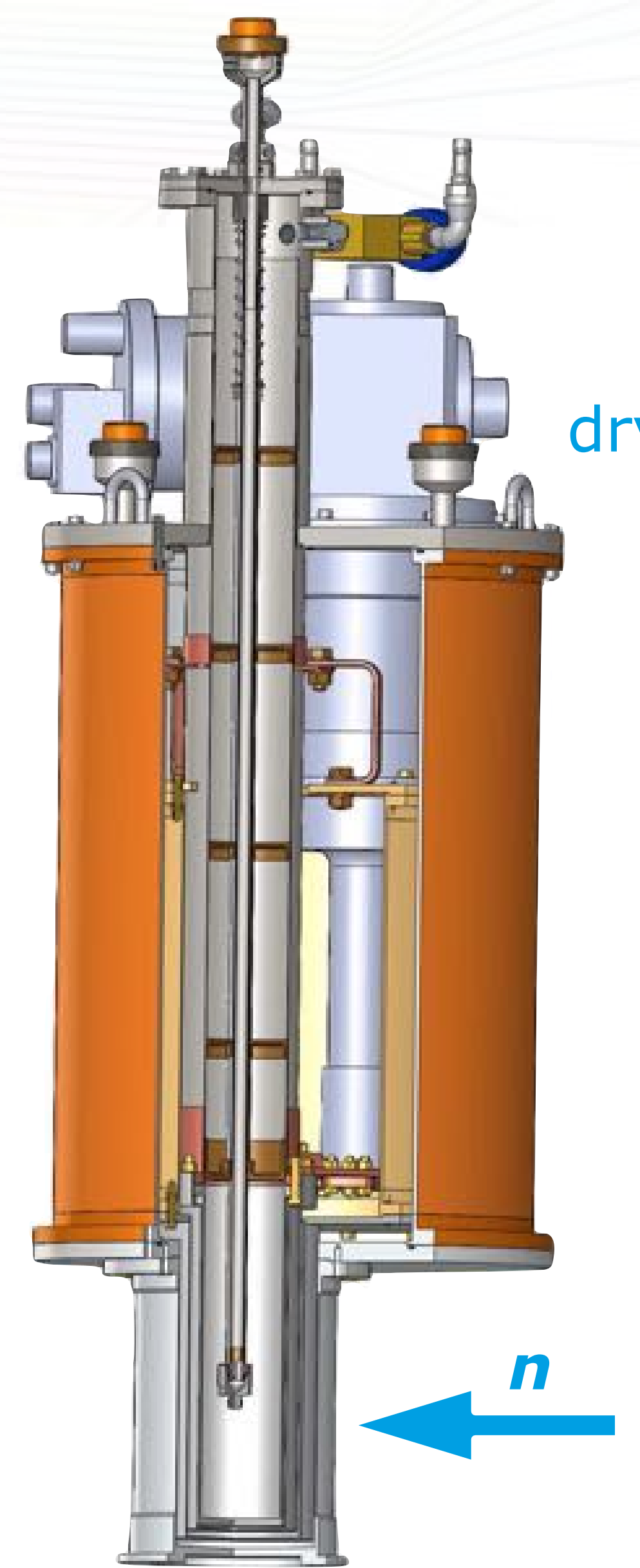
Low temperatures

- He-flow cryostats
 - 1.5 / 2.8 to 320 K
 - Ø330-450 mm
- He-flow cryofurnaces
 - 1.5 to 550 / 650 K
 - Ø330-450 mm
- Dry cryostats (cryogen-free)
 - 1.8 to 320 K with JT
 - 2.7 to 620 K without JT

He-flow



dry

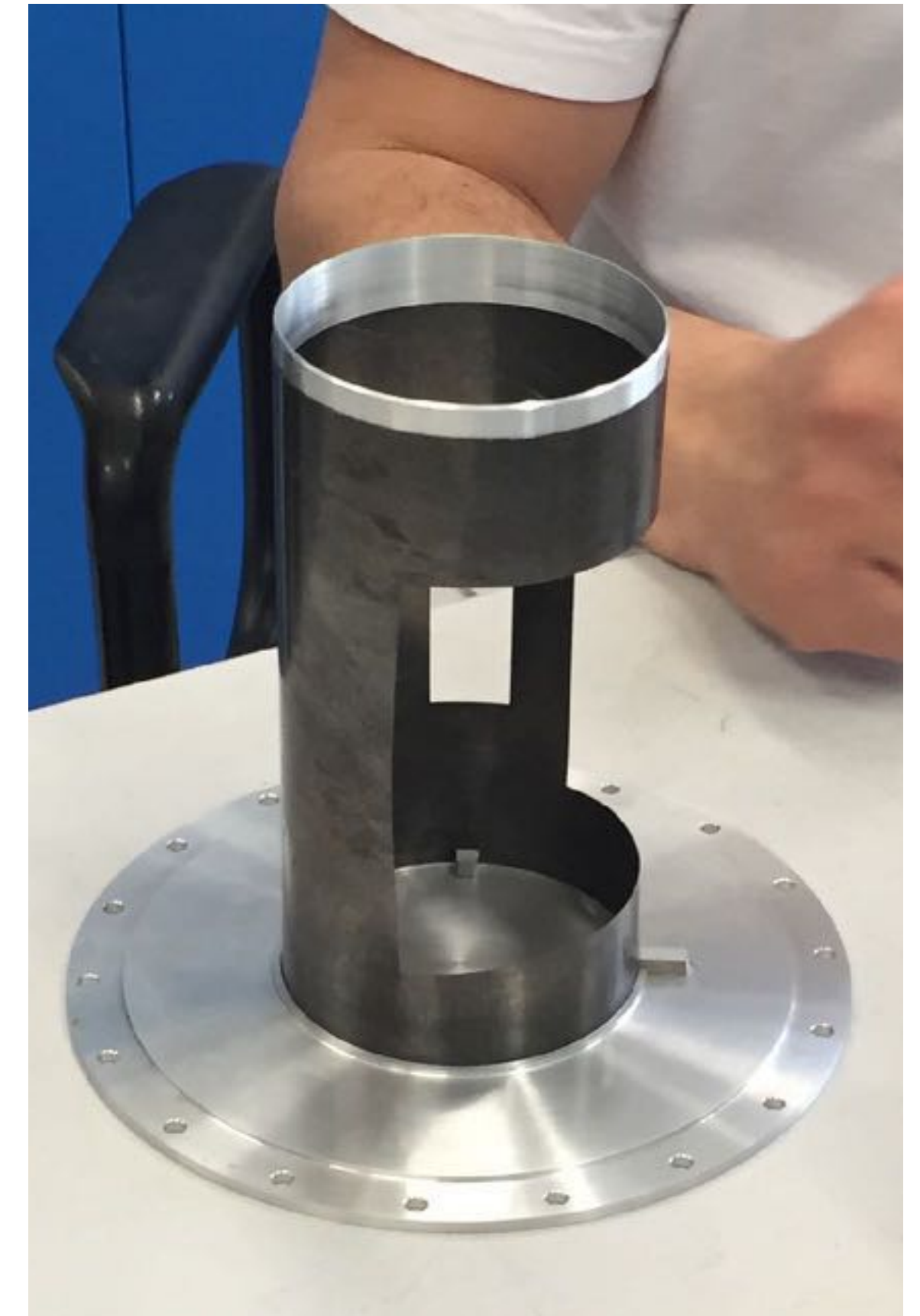
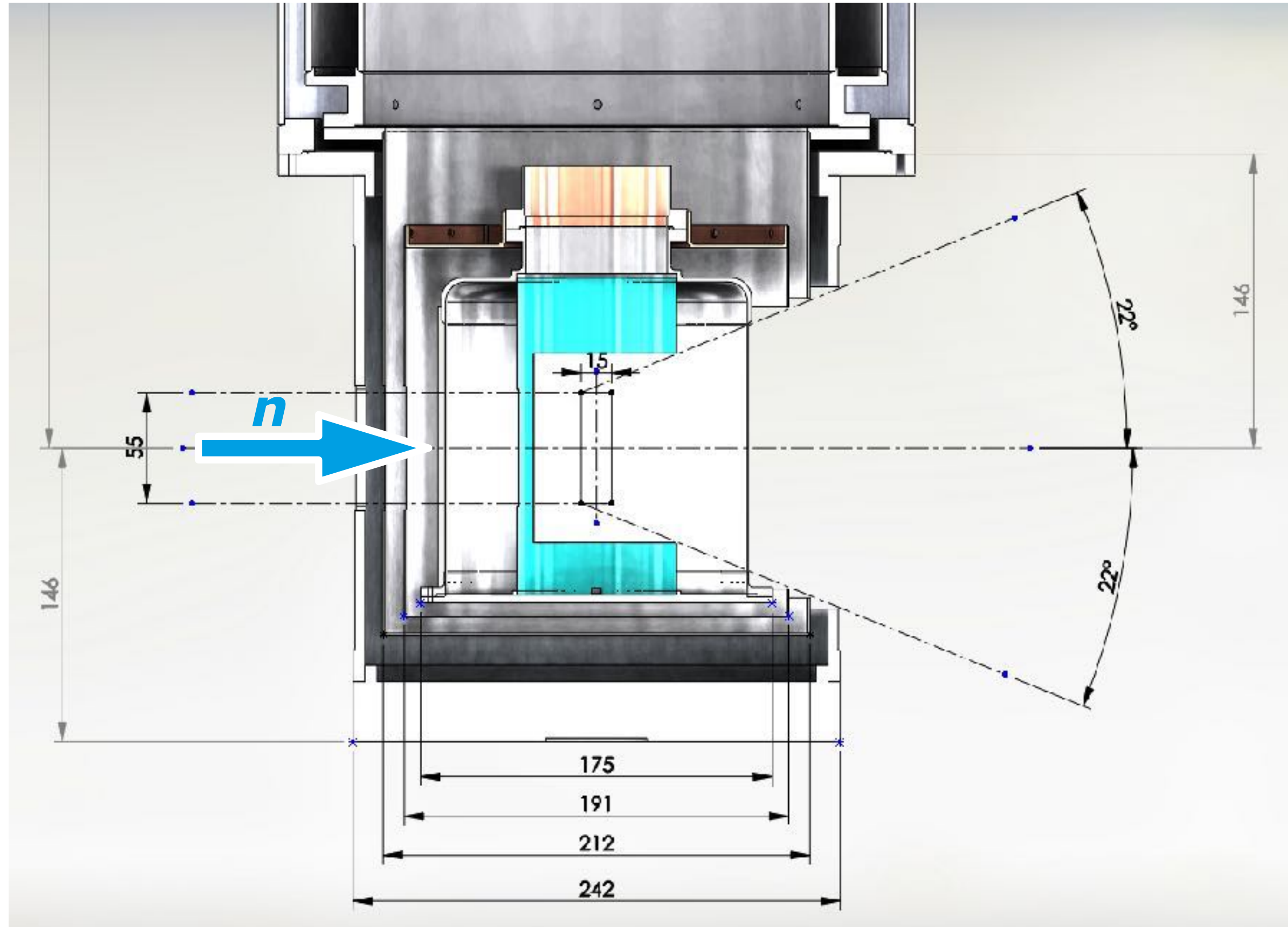


Sample environments

Low-background cryostat tail



Science & Technology Facilities Council
ISIS Neutron and Muon Source



Sample environments

Align crystals remotely at low-T

- Goniostick

- non-magnetic
- $\pm 7^\circ$ sample tilting
- $\pm 0.02^\circ$ reproducibility
- ± 10 mm vertical tuning
- $\pm 180^\circ$ vertical rotation
- fits inside $> \varnothing 36$ mm bore cryostats/magnets
- available inside cryostats and magnets



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Sample environments

Align crystals remotely at low-T

- Cryocradle

- non-magnetic, fits inside zero-field polarimeter Cryopad
- flexible arms to cancel backlash and manage thermal expansion

$$3 < T < 300\text{K}$$

$$-30 < \chi < +210^\circ$$

$$-180 < \varphi < +180^\circ$$

$$-40 < 2\theta < +120^\circ$$



Sample environments

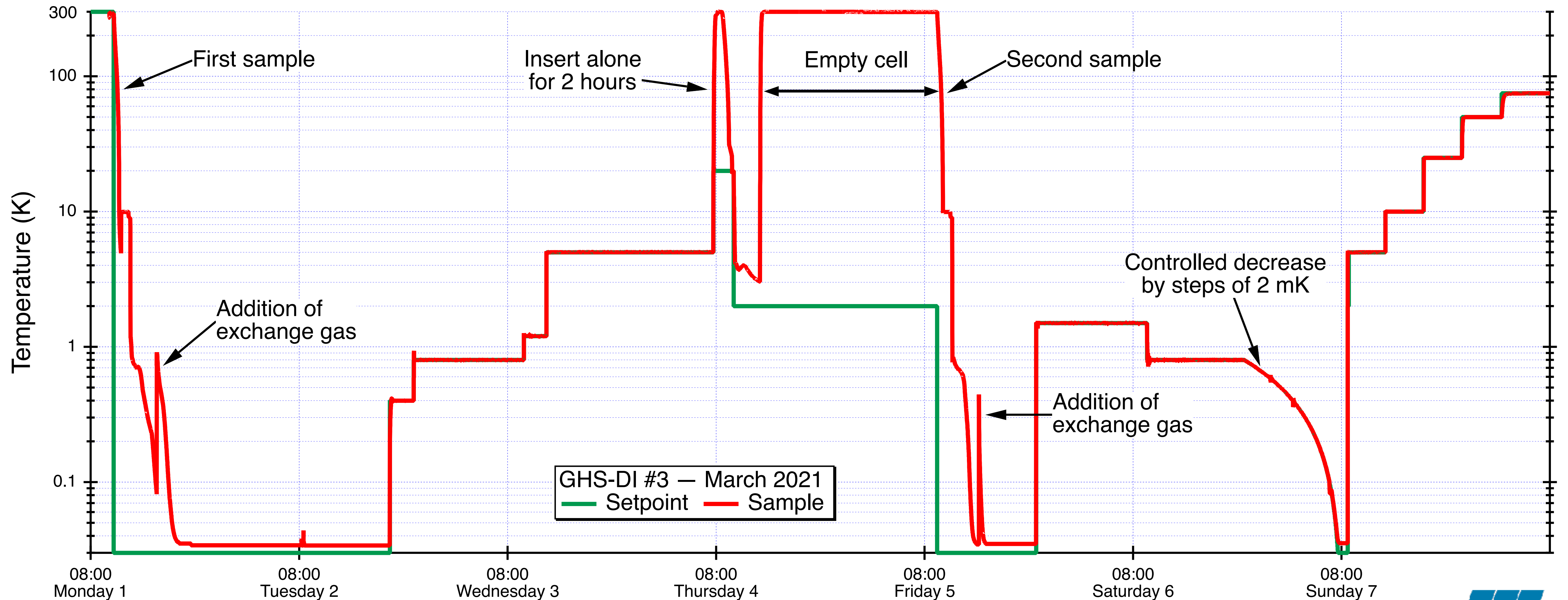
Ultra-low temperature systems

- ^3He fridges/inserts
 - down to 350 mK
- Dilution fridges/inserts
 - down to 15 or 40 mK
- Compact dilution fridge
 - down to 100 mK
- Large dilution cryostats
 - for high-pressure cells, complex environments



Sample environments

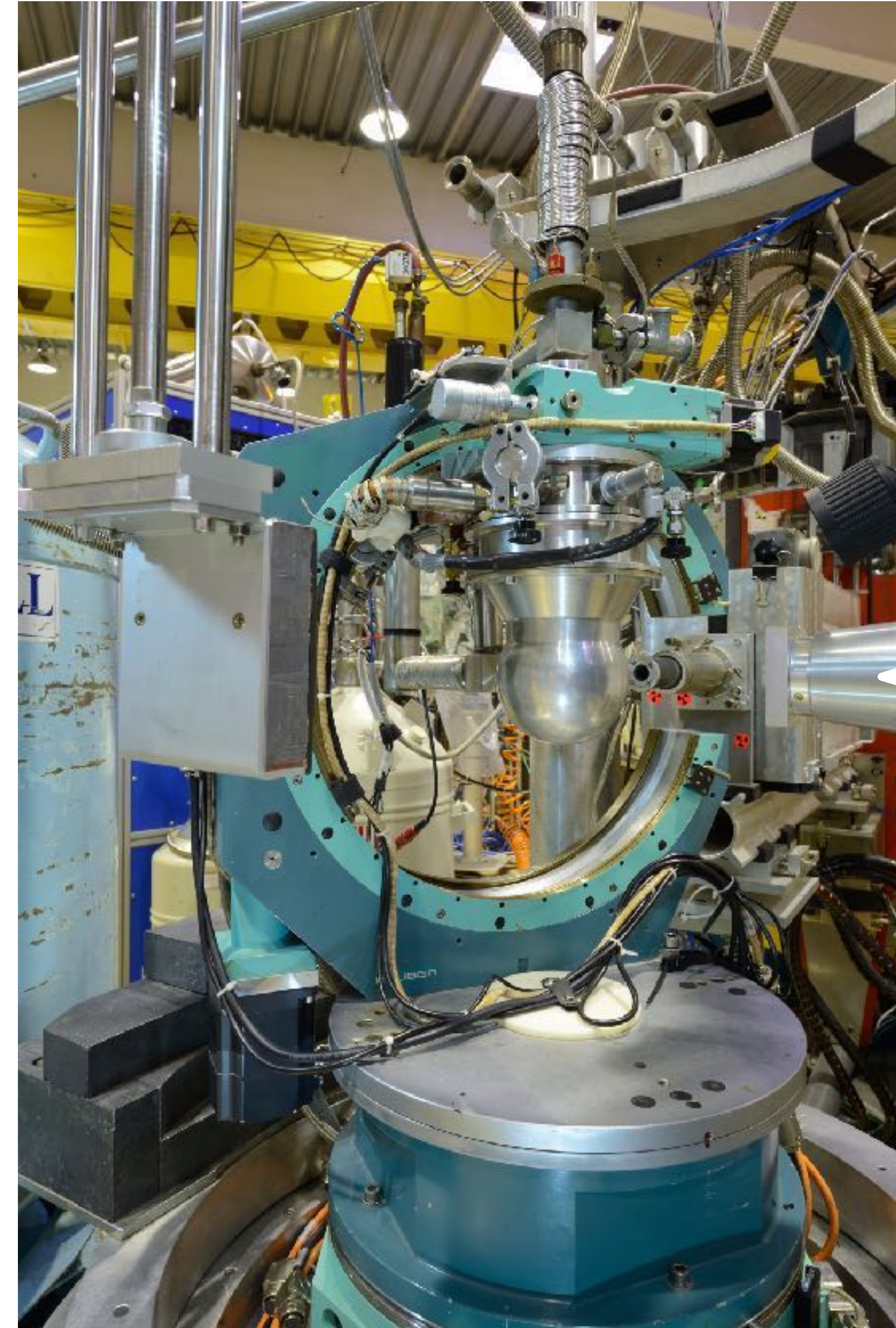
Ultra-low temperature systems



Sample environments

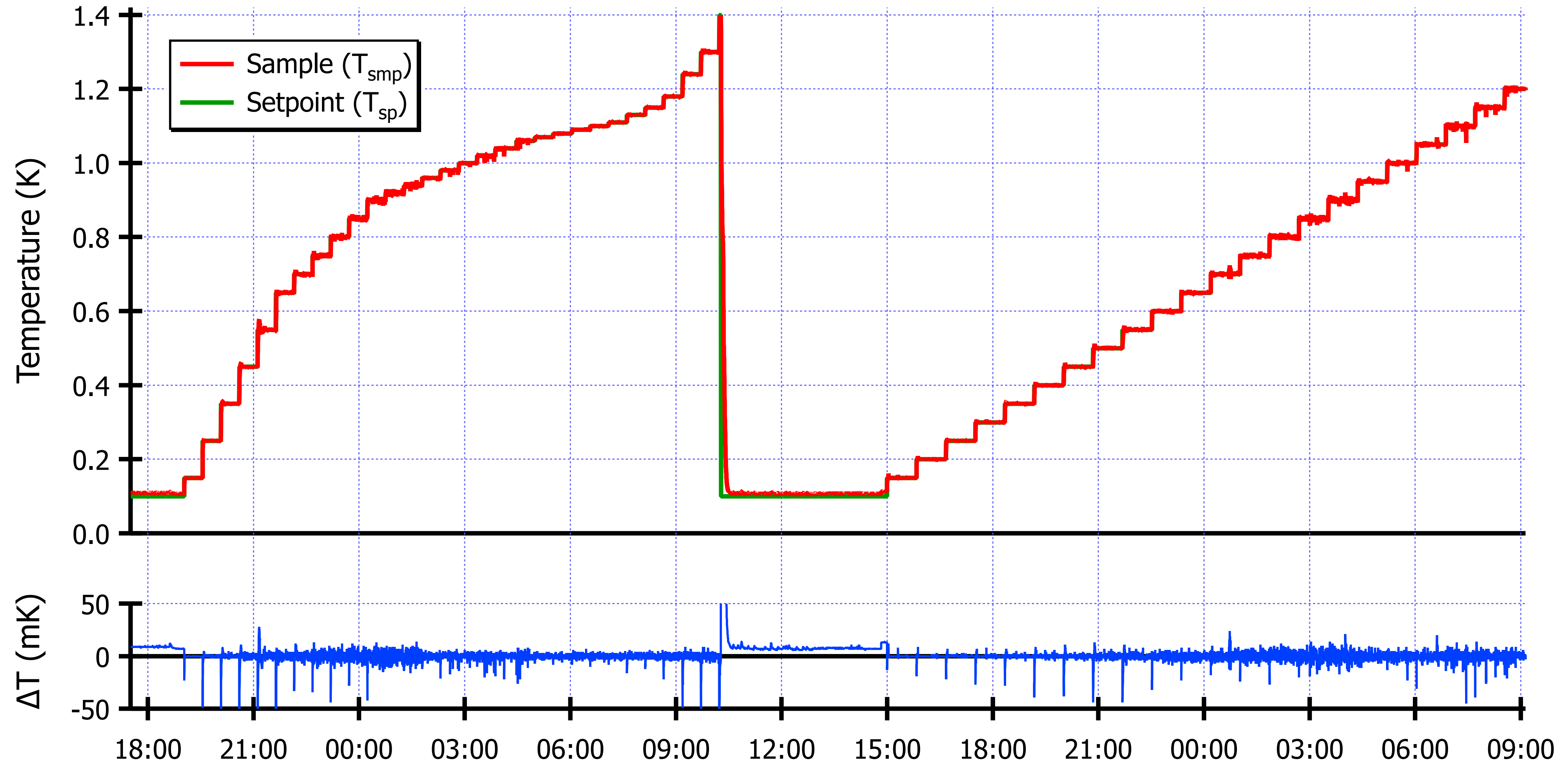
Ultra-low temperature systems

- ^3He fridges/inserts
 - down to 350 mK
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 - down to 15 or 40 mK
- Compact dilution fridge
 - down to 100 mK
- Large dilution cryostats
 - for high-pressure cells, complex environments



Sample environments

Gravity insensitive dilution refrigerator on D10 (ILL)



Sample environments

Standard resistive furnaces

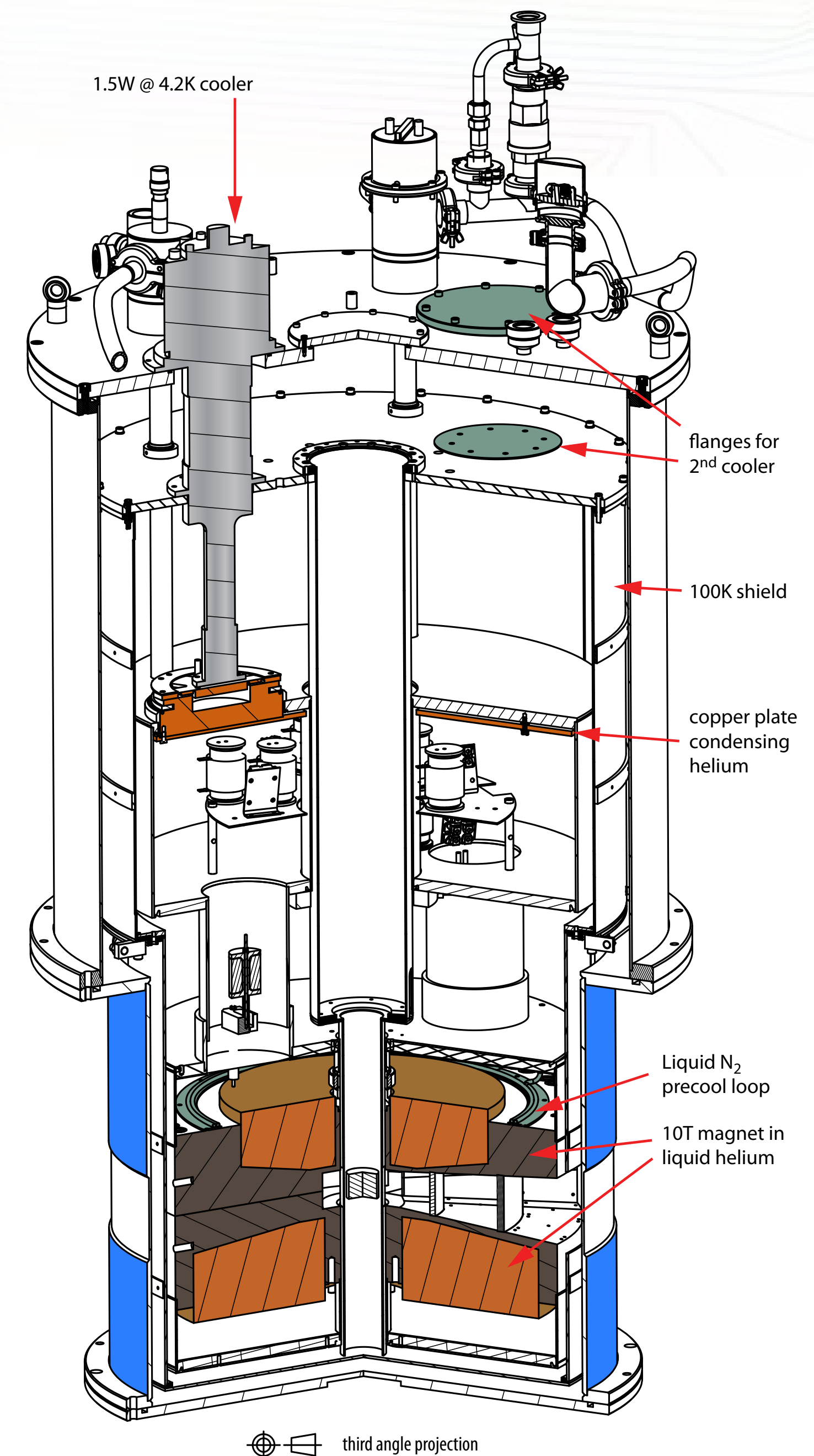
- 320 to 2000 K
- V or Nb in beams
- automated control
- 2 and 3.5 kVA
- Ethernet
- 3 versions:
 - standard
 - cradle (single crystal diffraction)
 - sapphire windows (SANS)



Sample environments

Static high-field cryomagnets

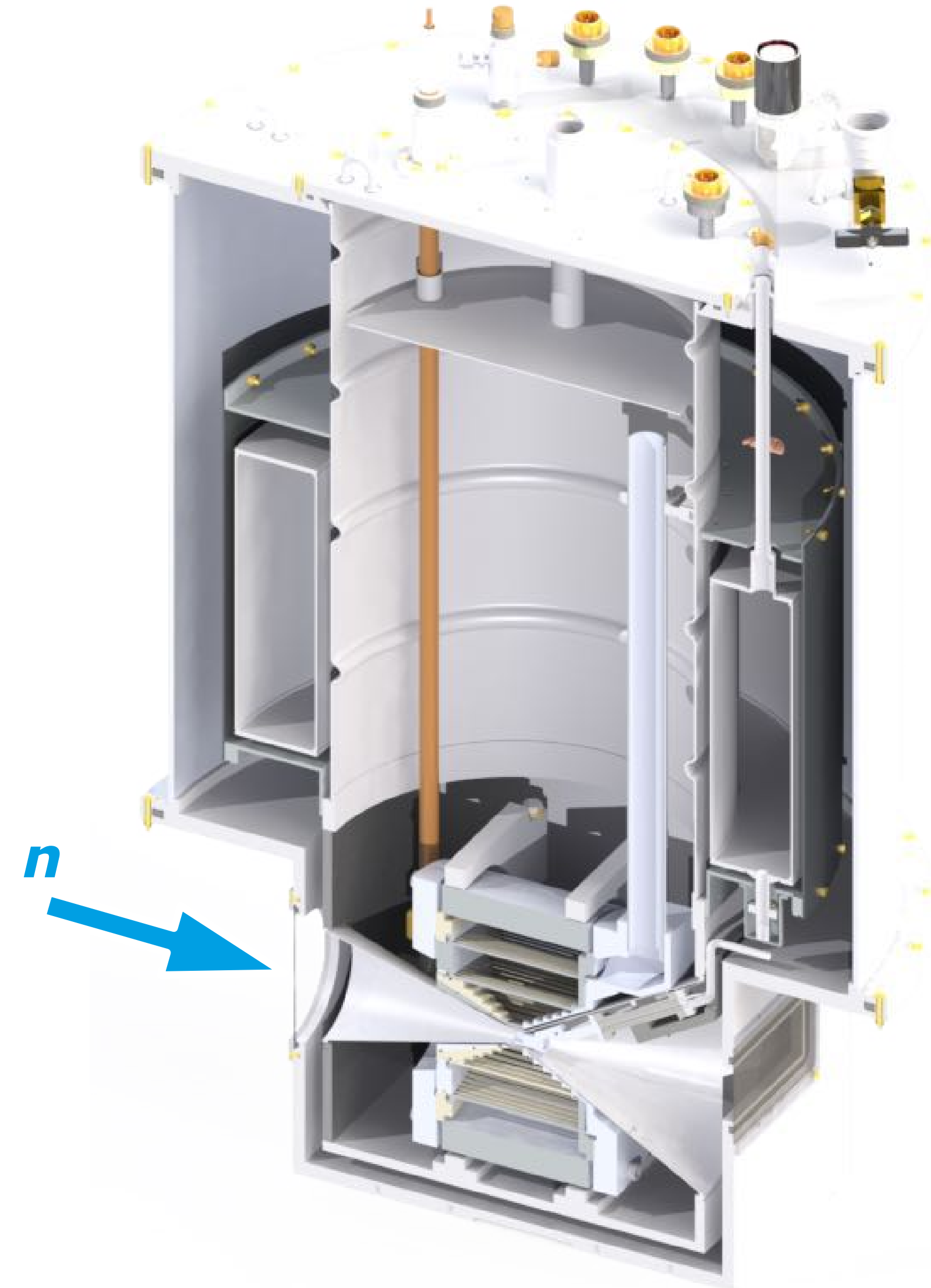
- Vertical field ($\varnothing 800$ mm)
 - up to 15T, top-loading
 - 40 mK dilution insert,
 - symmetric or asymmetric
 - self-shielded or not
 - 2T Dy booster + focusing
- Horizontal field (≈ 400 mm)
 - up to 17T, bottom-loading



Sample environments

40T pulsed-field cryomagnet

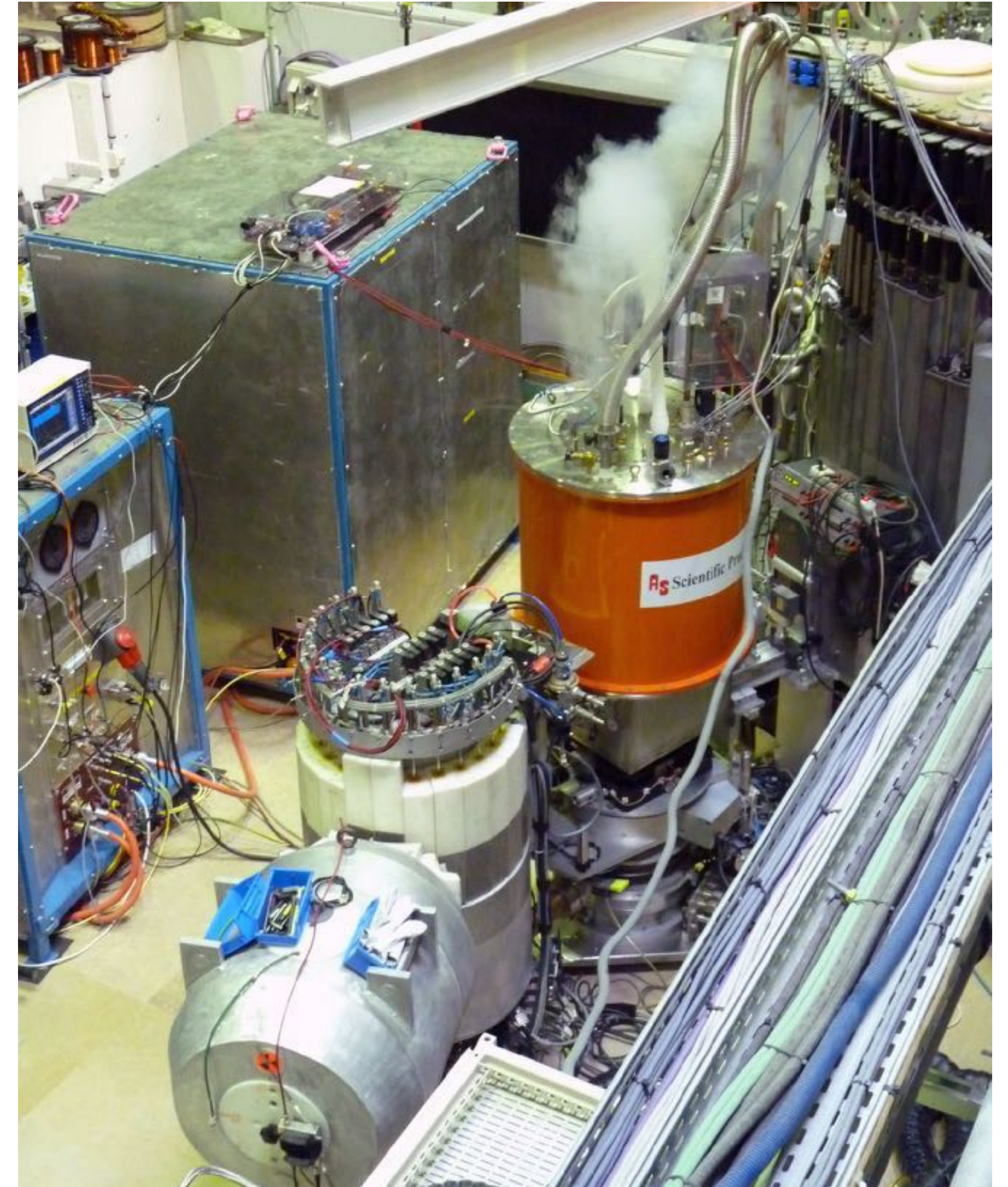
- Available at ILL through collaboration with CNRS/LNCMI Toulouse
- $\varnothing 8$ mm sample
- 2K base temperature
- $\pm 15^\circ$ incident horizontal access
- $\pm 30^\circ$ outgoing horizontal access
- $\pm 7^\circ$ outgoing vertical access
- ... and 1.000L liquid N₂ / day at 40T



Sample environments

40T pulsed-field cryomagnet

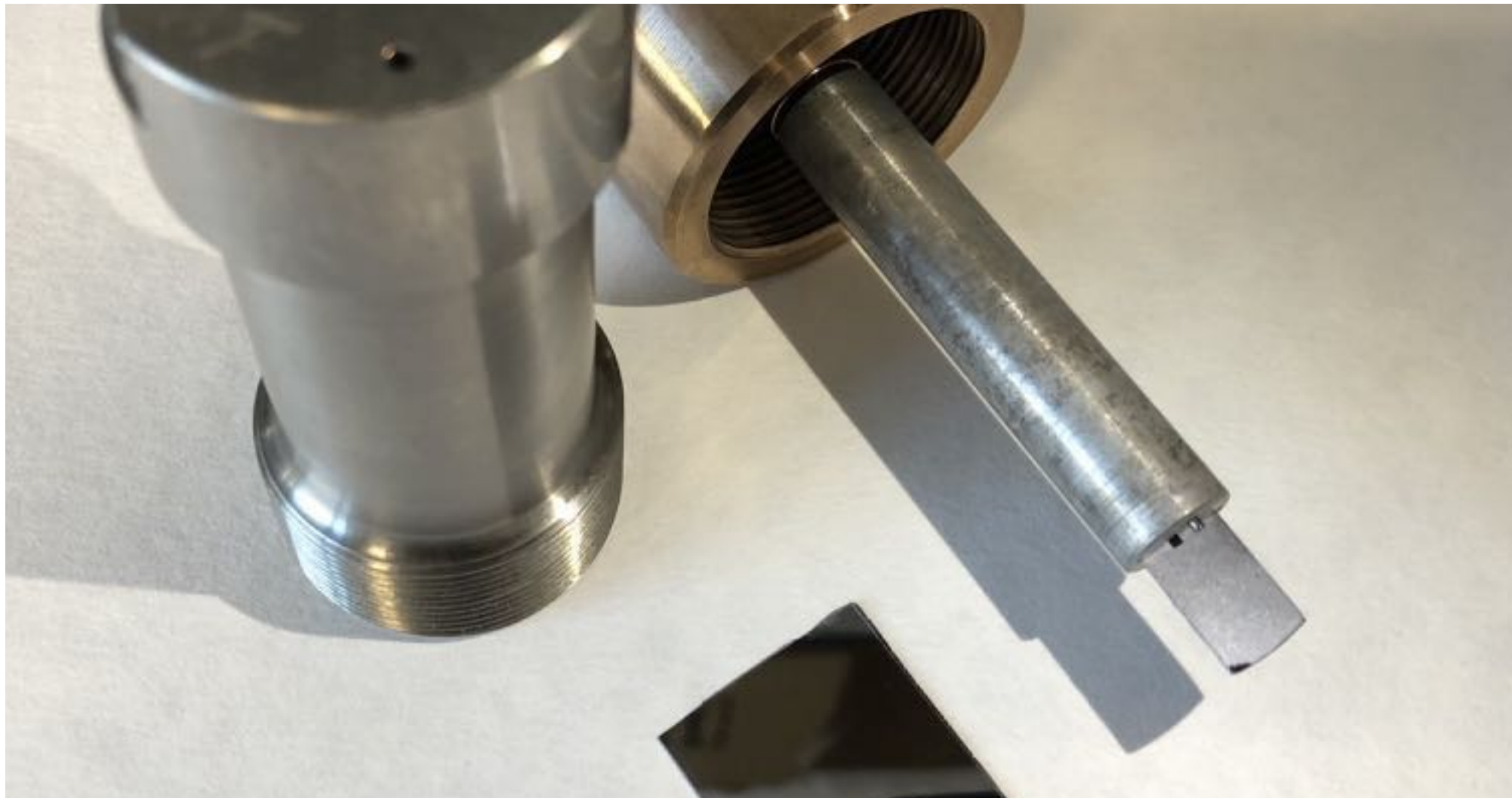
- Available at ILL through collaboration with CNRS/LNCMI Toulouse
- Ø8 mm sample
- 2K base temperature
- $\pm 15^\circ$ incident horizontal access
- $\pm 30^\circ$ outgoing horizontal access
- $\pm 7^\circ$ outgoing vertical access
- ... and 1.000L liquid N₂ / day at 40T



Sample environments

High-pressure cells for membrane layers and systems in solutions

- Al, TiZr and CuBe versions
- 250, 600 and 700 MPa cells
- compatible with "non-freezing" stick
- hosts samples on substrates



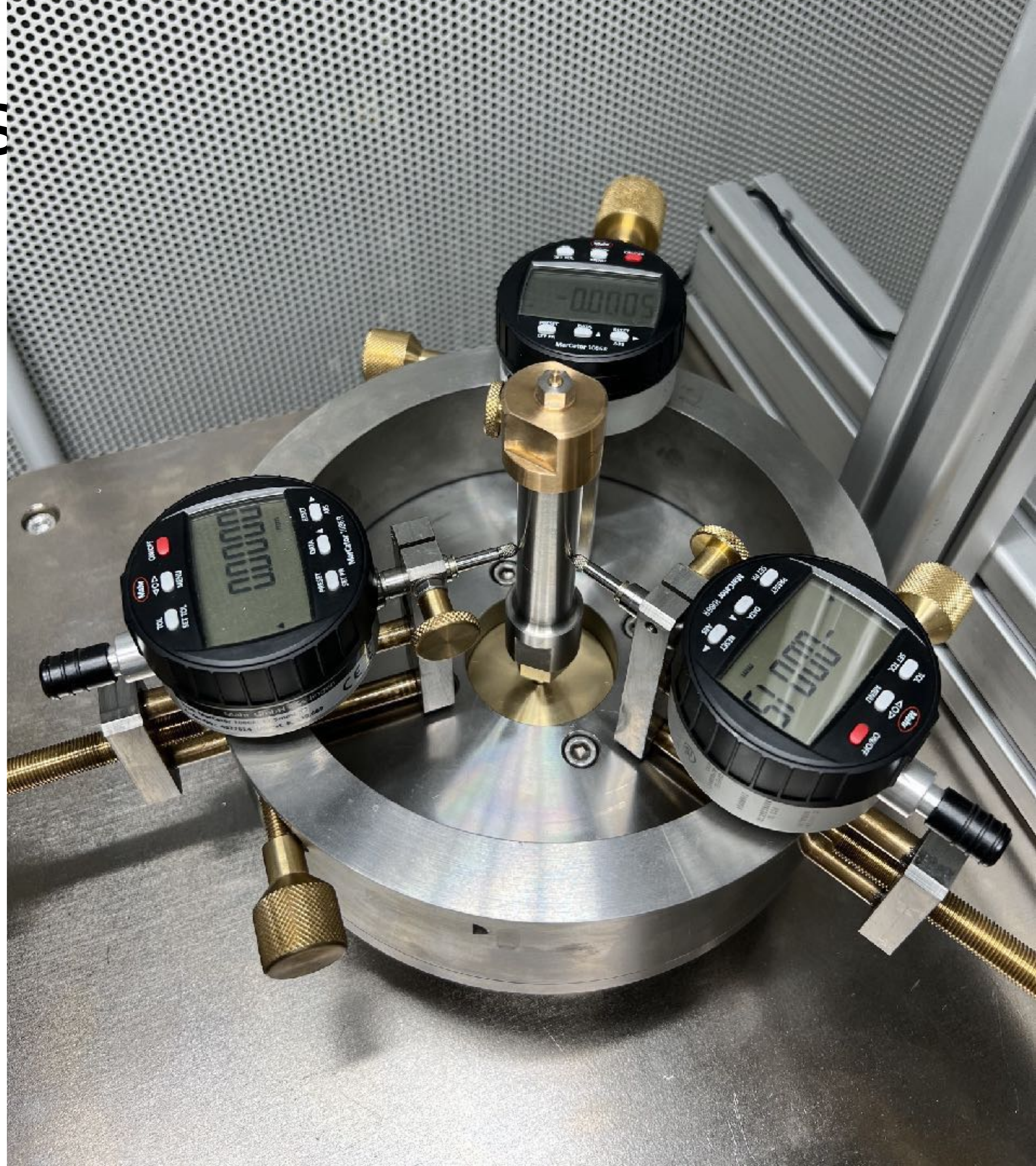
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THE EUROPEAN NEUTRON SOURCE

Sample environments

High-pressure cells for (poly)crystals

- TA6V/CuBe2 1 GPa cells tested successfully, more in production
- TiZr/TiZr cell being designed for diffraction (no Bragg peaks)
- In-situ pressure measurement for future clamp cells under development



Sample environments

300 MPa cells for SANS: 84% transmission at 6 Å

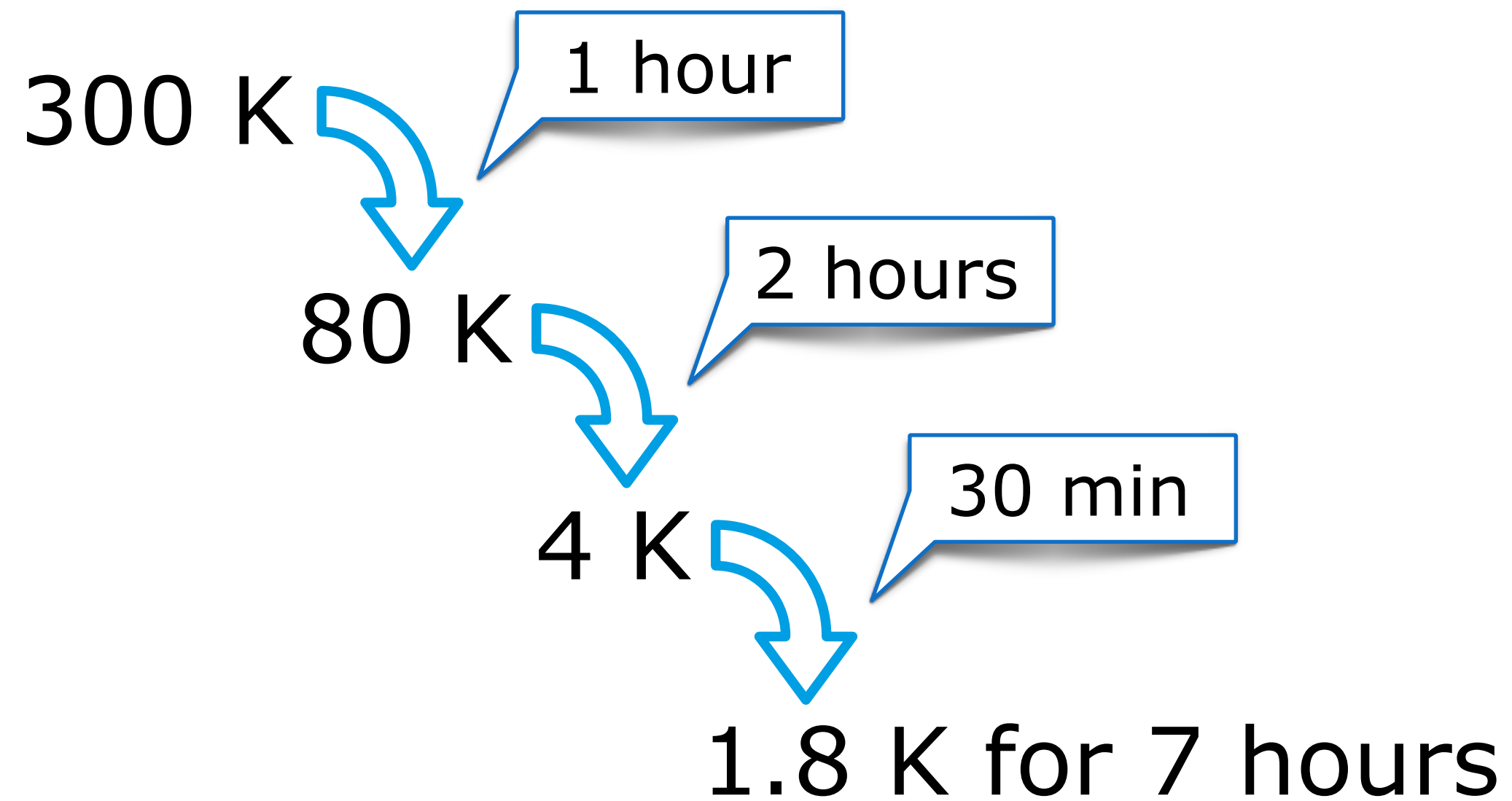


Project funded by the European Union (GA n°283883)

Sample environments

High-pressure at low-T for diffraction

- 23 GPa max
- Automated pressure & temperature control



High Pressure Research **36:1** (2016) 73

Neutron instrumentation

- What do we measure and need?
- Neutron guides & shielding
- Measuring techniques
- Sample environments
- **Neutrons detectors**
- Data acquisition system

Neutron detectors

Remarks...

- We cannot directly detect slow neutrons: they carry too little energy and have no charge.
- We need to use nuclear reactions to convert neutrons into energetic charged particles.
- Then, we can use some of the many types of charged particle detectors

Neutron detectors

Common charged particle detector types

- Ionisation mode: Electrons drift to anode, producing a charge pulse with no gas multiplication. Typically employed in low-efficiency beam-monitor detectors.
- Proportional mode: If voltage high enough, electron collisions ionise gas atoms producing even more electrons. Gas amplification increases the collected charge.
- Other techniques: CCD cameras, image plates (Laue), scintillation detectors, boron detectors.

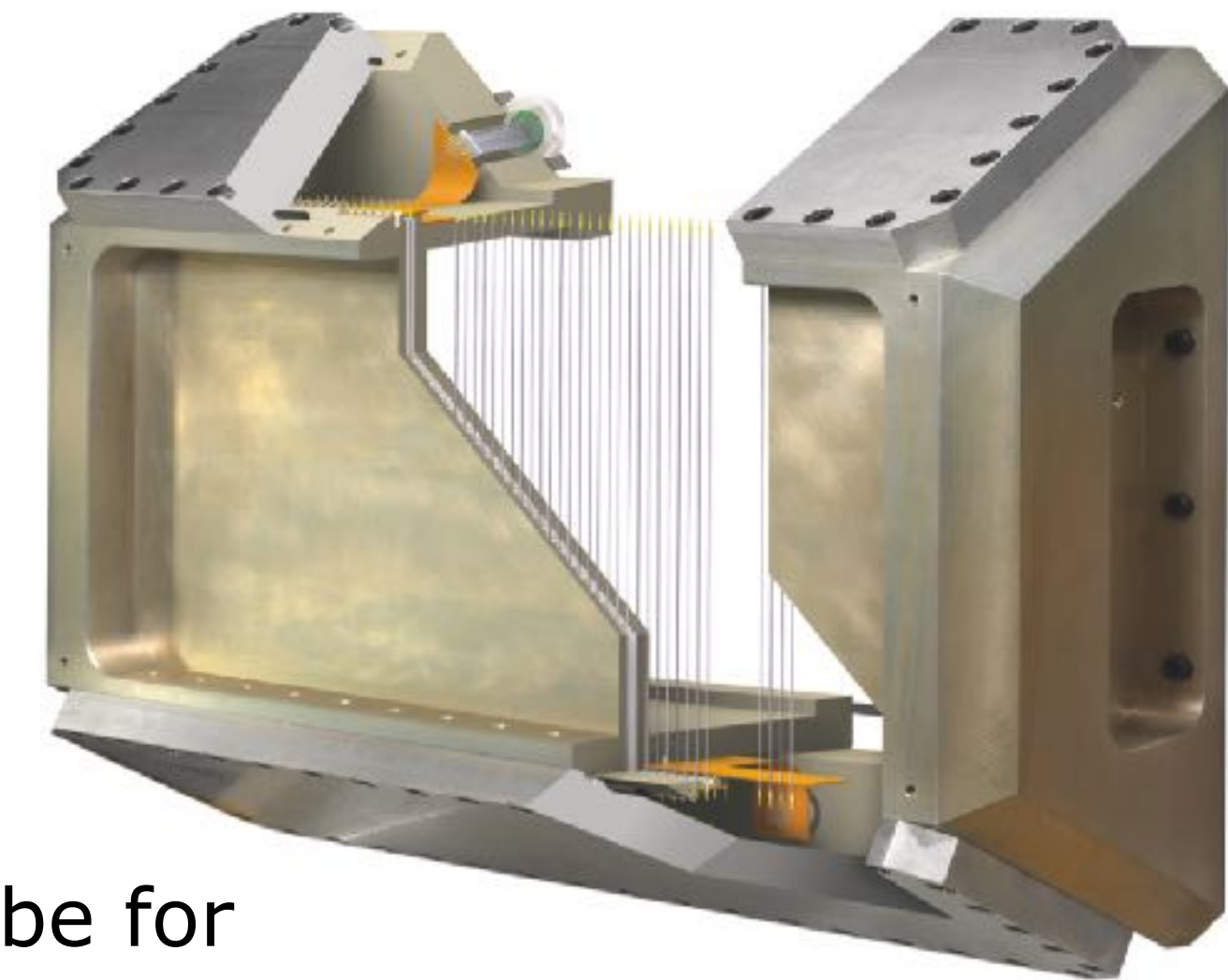
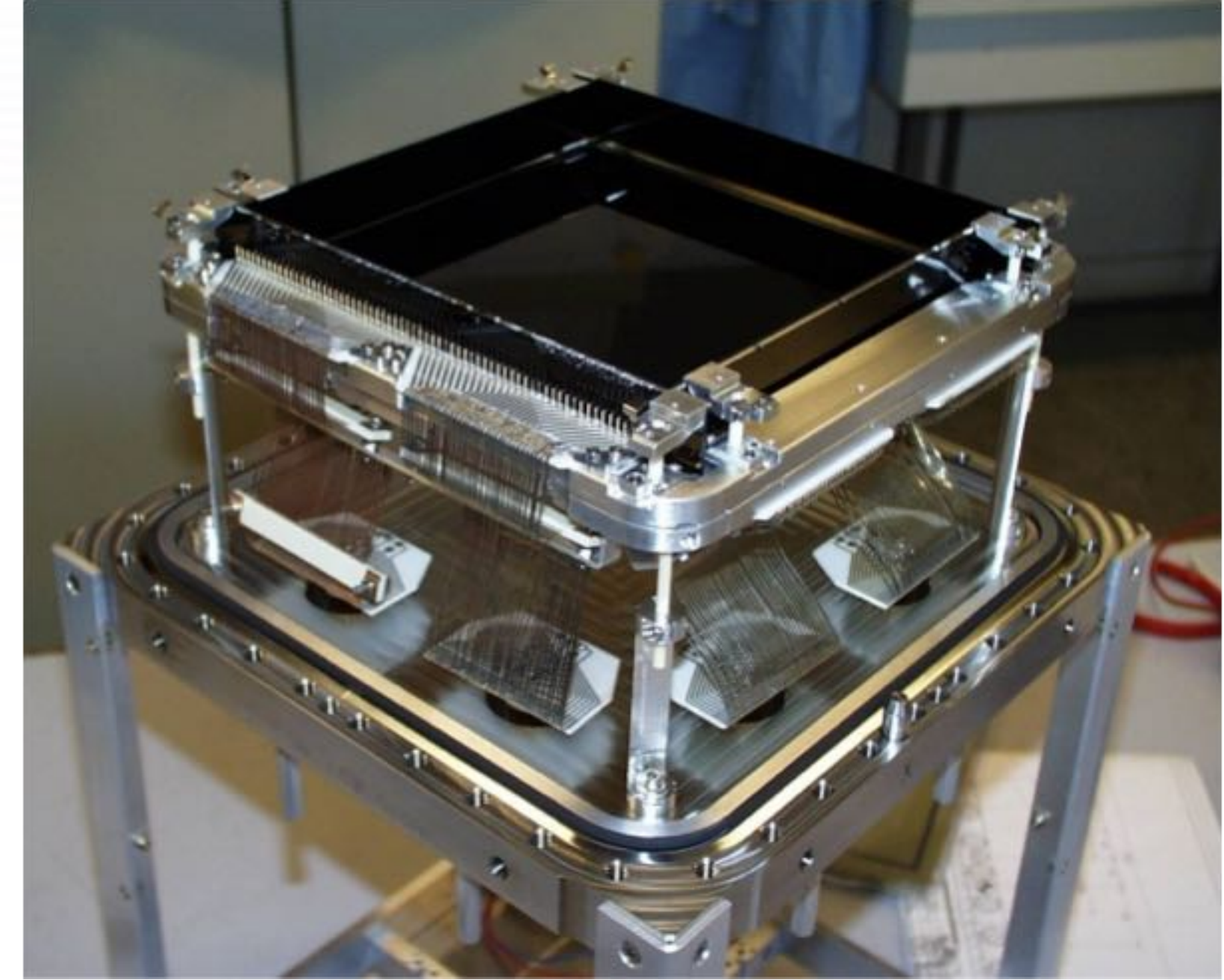
Neutron detectors

- Spatial resolution is “generally” not an issue, in the range of 1-10 mm i.e. \approx sample size
- Fast neutrons, electronics and gammas lead to background noise. Counting mode is more appropriate than integrating mode.
- High detection efficiency required for scattered neutrons, low efficiency enough for incident beam.

Neutron detectors

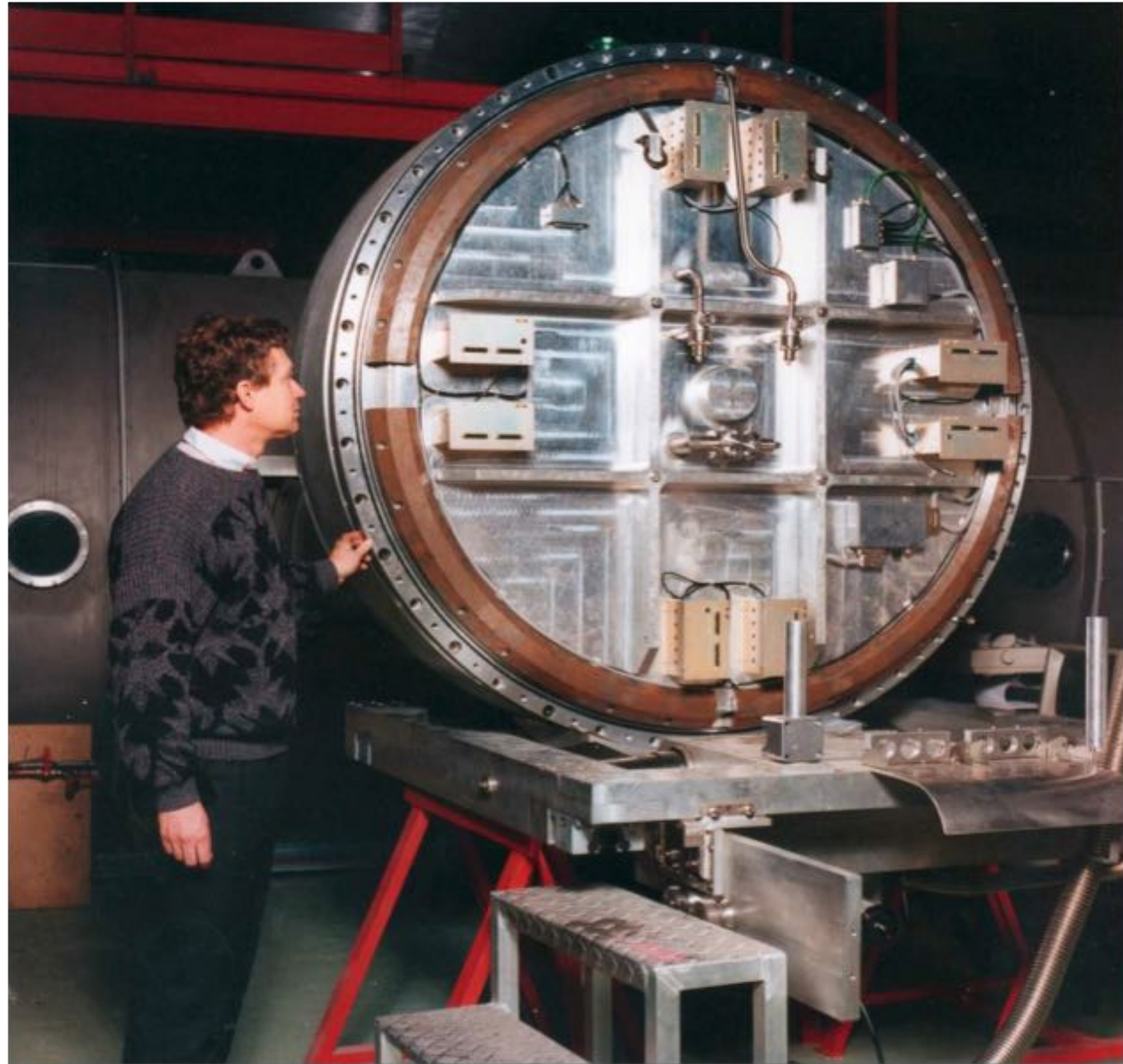
19x19 cm² high res,
high count rate for
diffraction

30 m² low-res, low count rate for time of flight

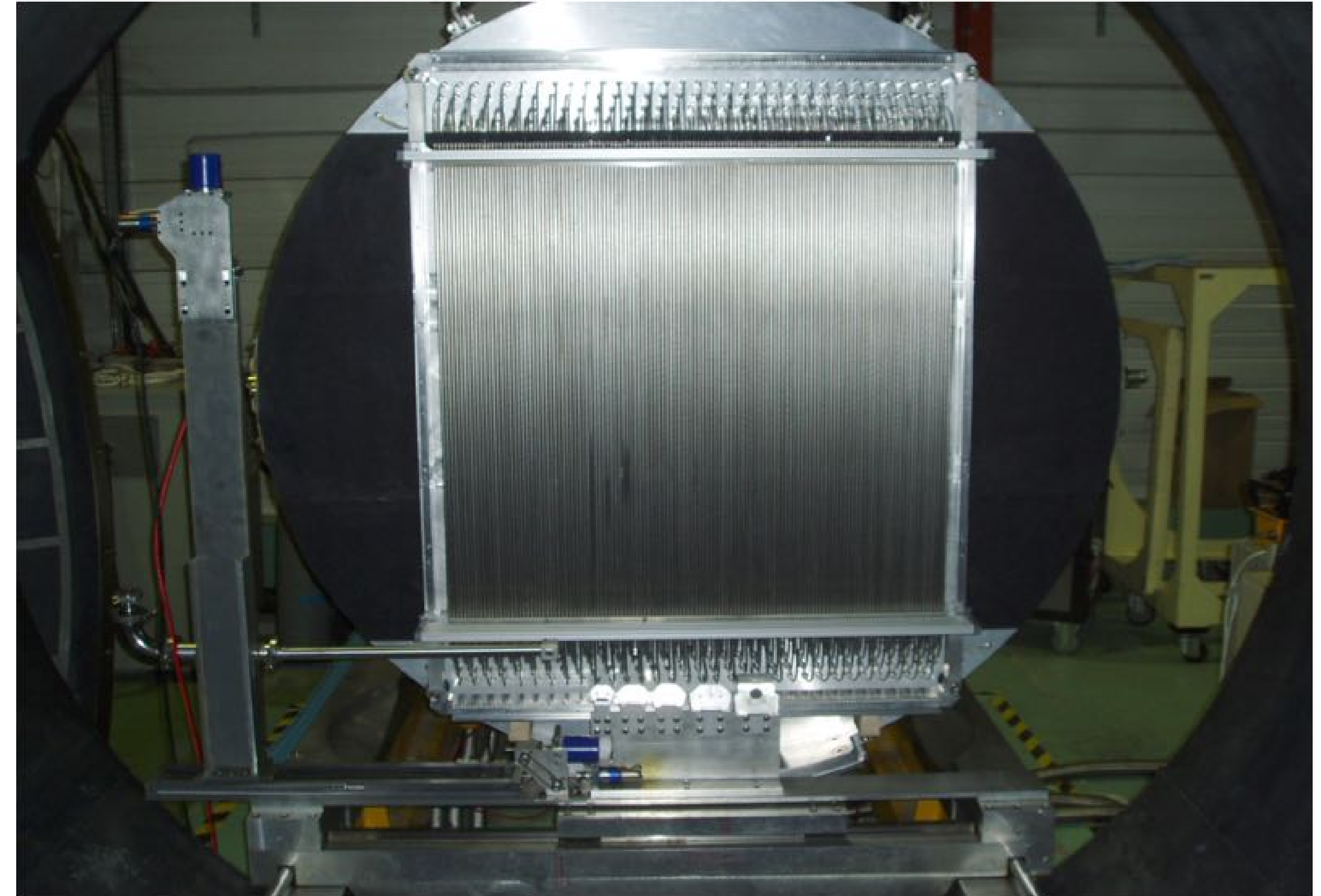


Monobloc multitube for
Reflectometry, SANS

Neutron detectors



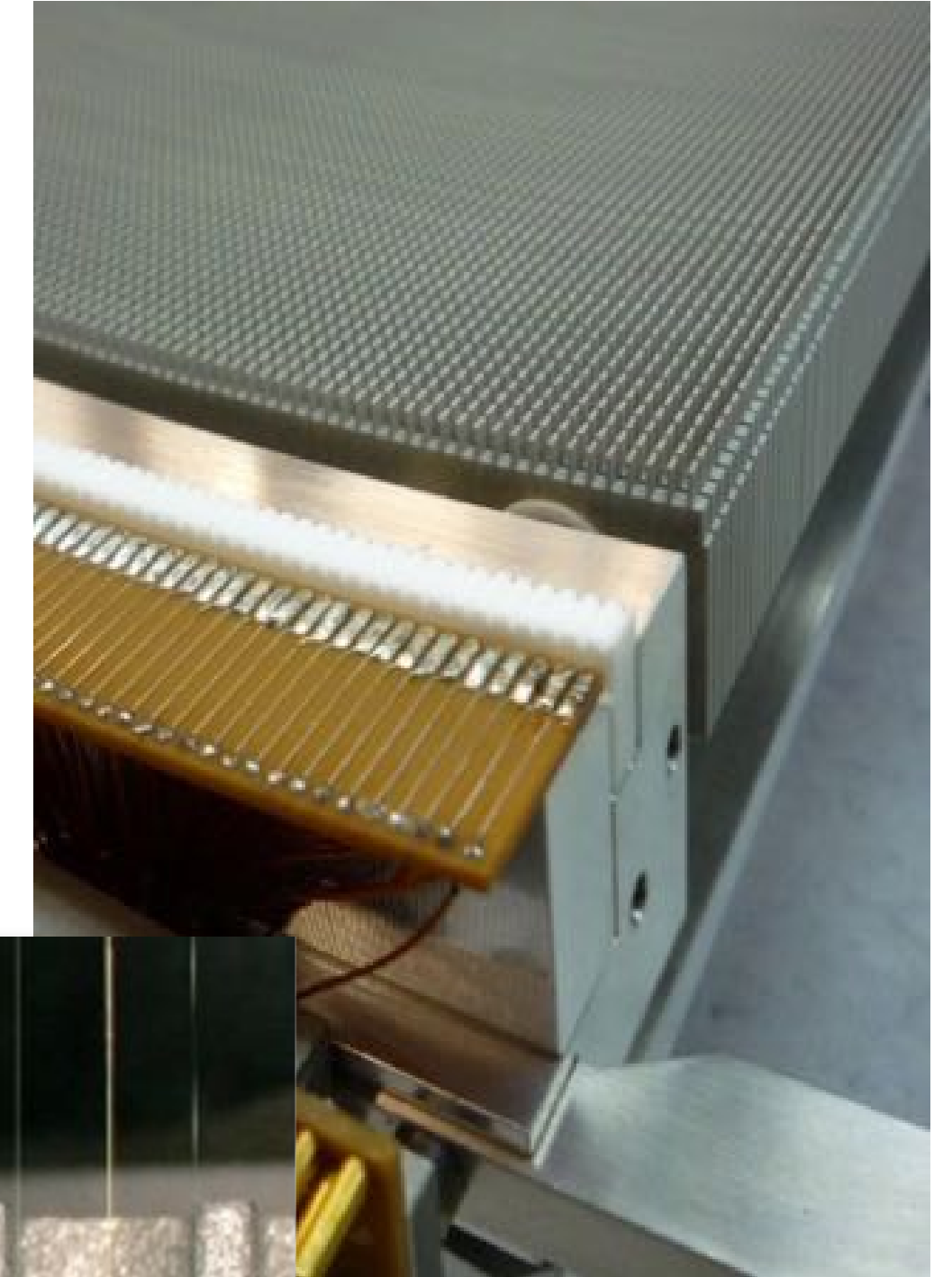
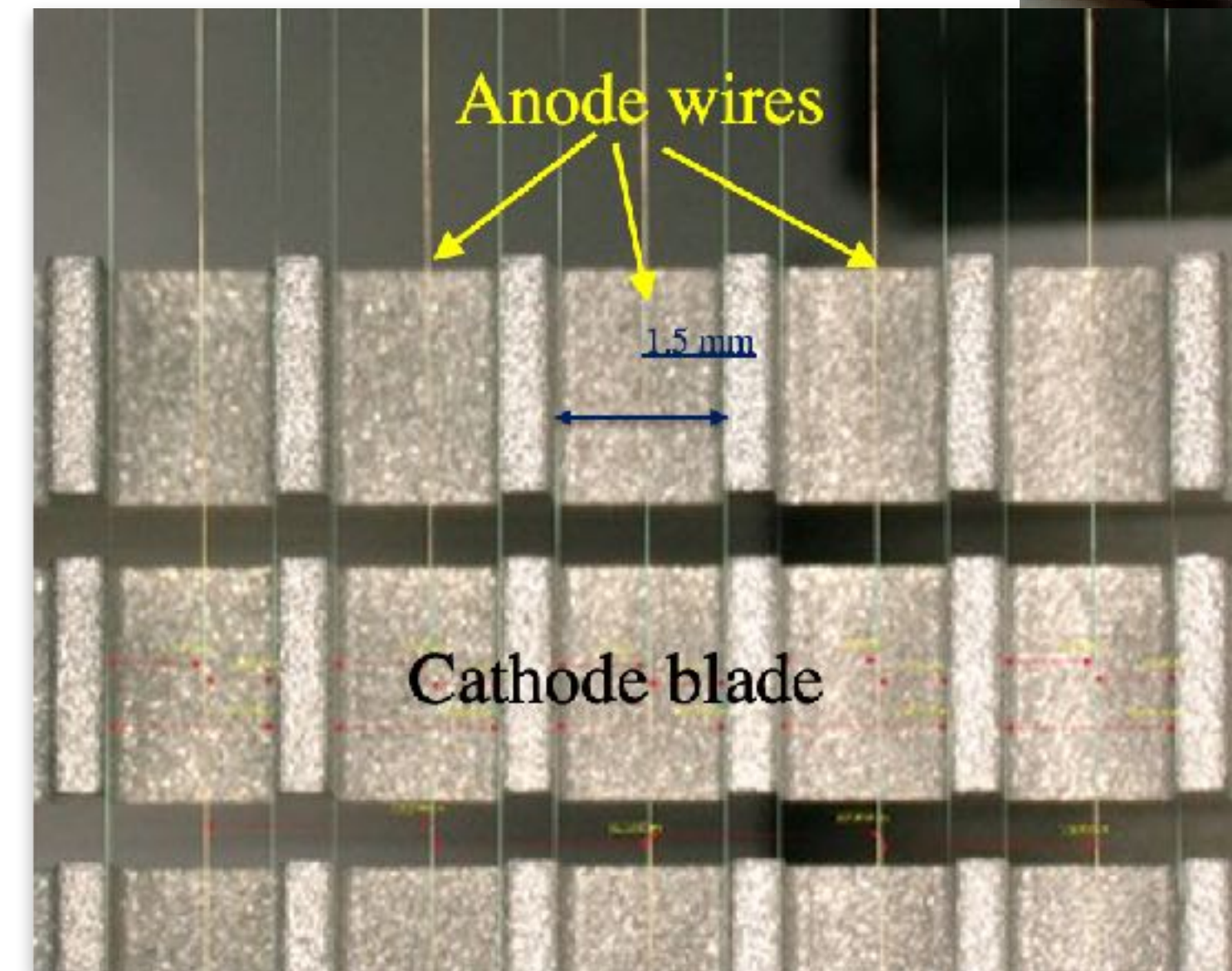
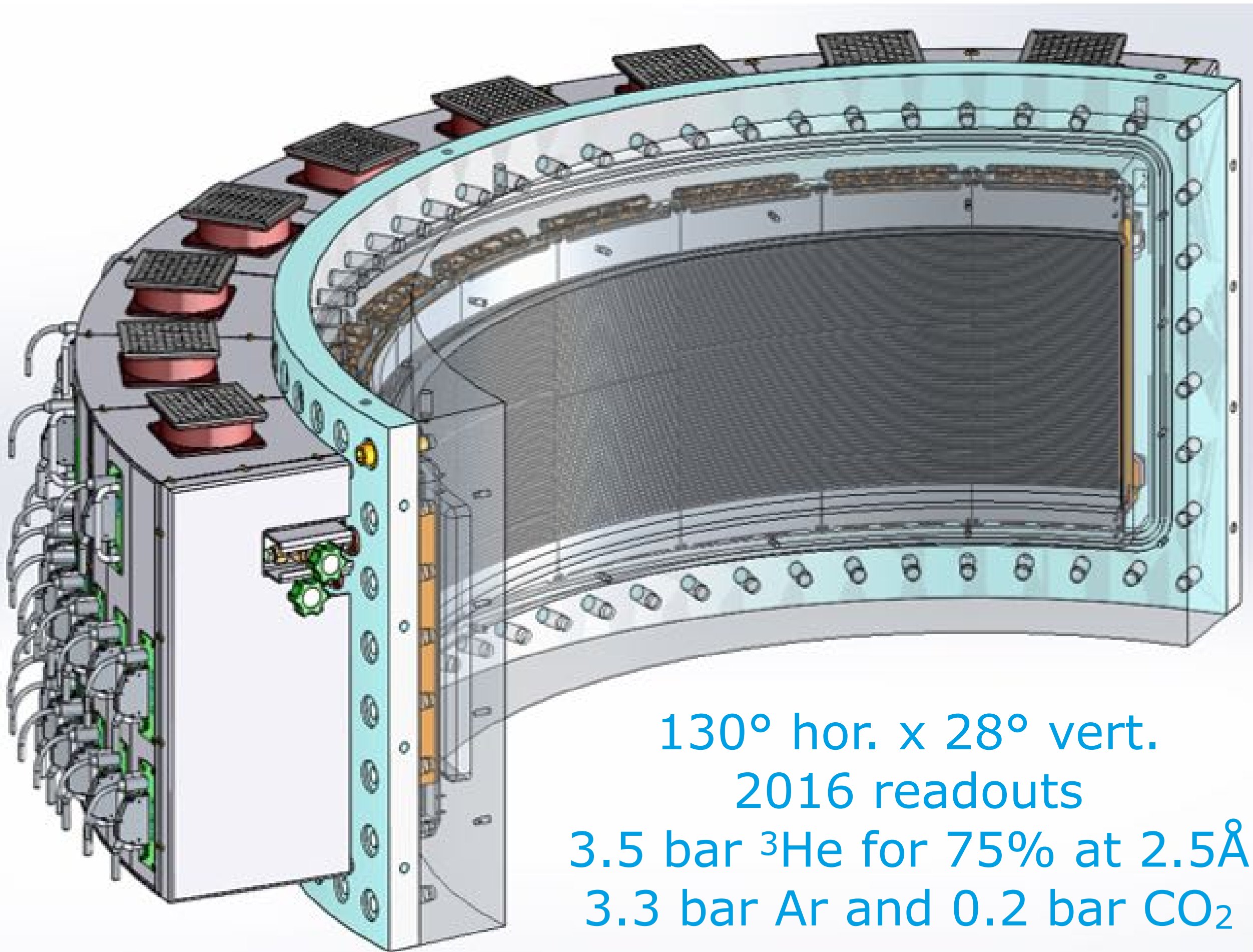
Old XY counter — 200 kHz max



New 128 PSD counter — 10 MHz max

Neutron detectors

XtremeD diffractometer

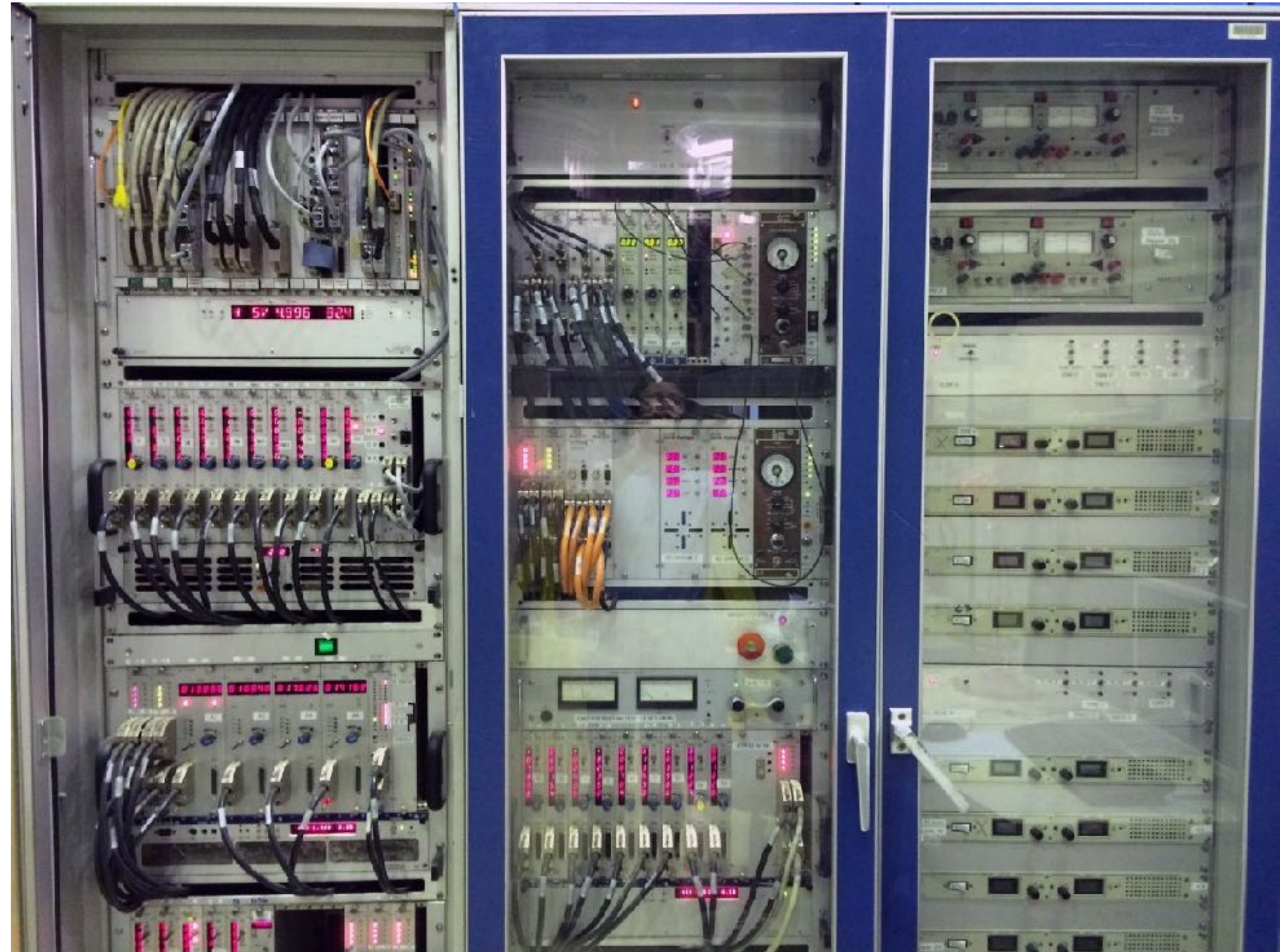


Neutron instrumentation

- What do we measure and need?
- Neutron guides & shielding
- Measuring techniques
- Sample environments
- Neutrons detectors
- **Data acquisition system**

Data acquisition hardware

- VME crates (low power)
- NIM crates (high power)
- Power supplies for DC and stepper motors, flippers, guiding fields, etc.
- Sample env. controllers



Data acquisition software

- Speaks in physical units
- Acts as a “super-calculator” for the local contact to access complex instrument’s configurations
- Provides performance optimiser for fine adjustments or advanced regulations
- Checks jobs, estimates run-time, executes jobs safely
- Provides command-line tools, remote access, etc.

Data acquisition software

The screenshot shows the Nomad software interface with the following callouts:

- Jobs Selection:** Points to the list of jobs on the left sidebar.
- Job in Loop:** Points to the top of the active job windows.
- Elementary Box:** Points to the configuration area of a 'SingleCount' job window.
- Progress Bar:** Points to the progress indicator at the bottom of the job windows.
- Play | Stop | Pause:** Points to the control buttons at the bottom right of the interface.
- session status:** Points to the top right status bar containing three lock icons.
- connection status:** Points to the top right status bar containing two 'NOMAD' connection icons.
- text chat:** Points to the chat icon in the top right status bar.
- video chat:** Points to the video chat icon in the top right status bar.
- connected users:** Points to the user icon in the top right status bar.

Special thanks to...

I. Anderson — ORNL (USA)

P. Courtois — Neutron Optics, ILL

B. Guérard — Neutron Detectors, ILL

M. Kreuz — Neutron Guides, ILL

P. Mutti — Instrument control, ILL

... and you!

