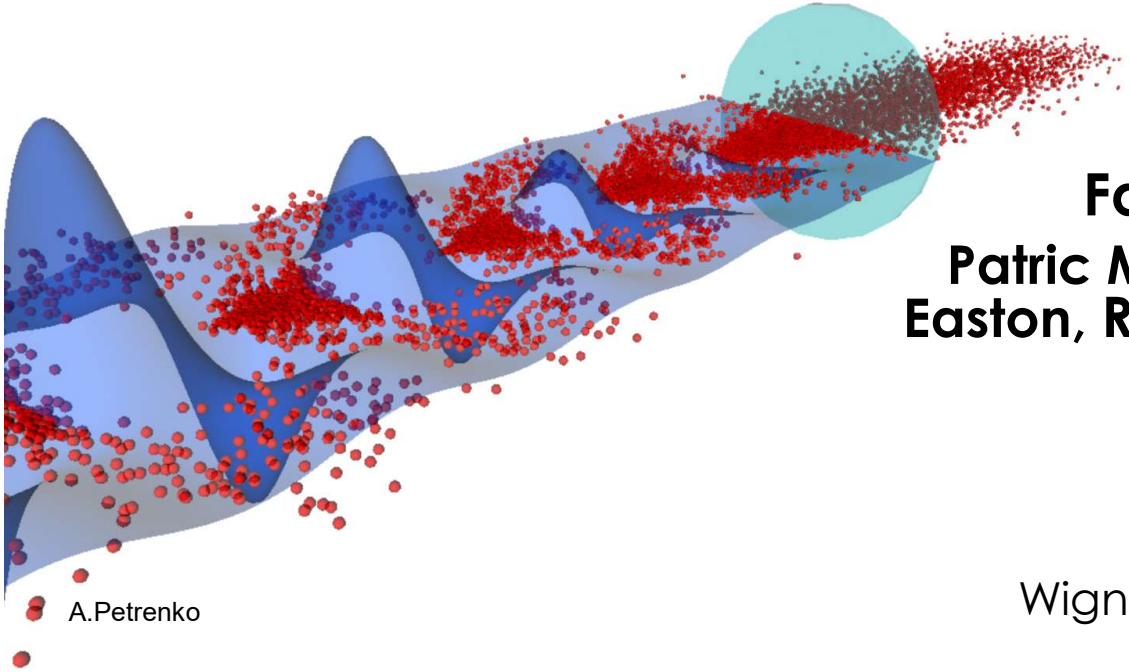
# Overview, control & status of AWAKE plasma cell



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**Patric Muggli, Erdem Öz, Daniel Easton, Roberto Speroni & AWAKE team**

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Wigner-MPP-AWAKE workshop
Budapest

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

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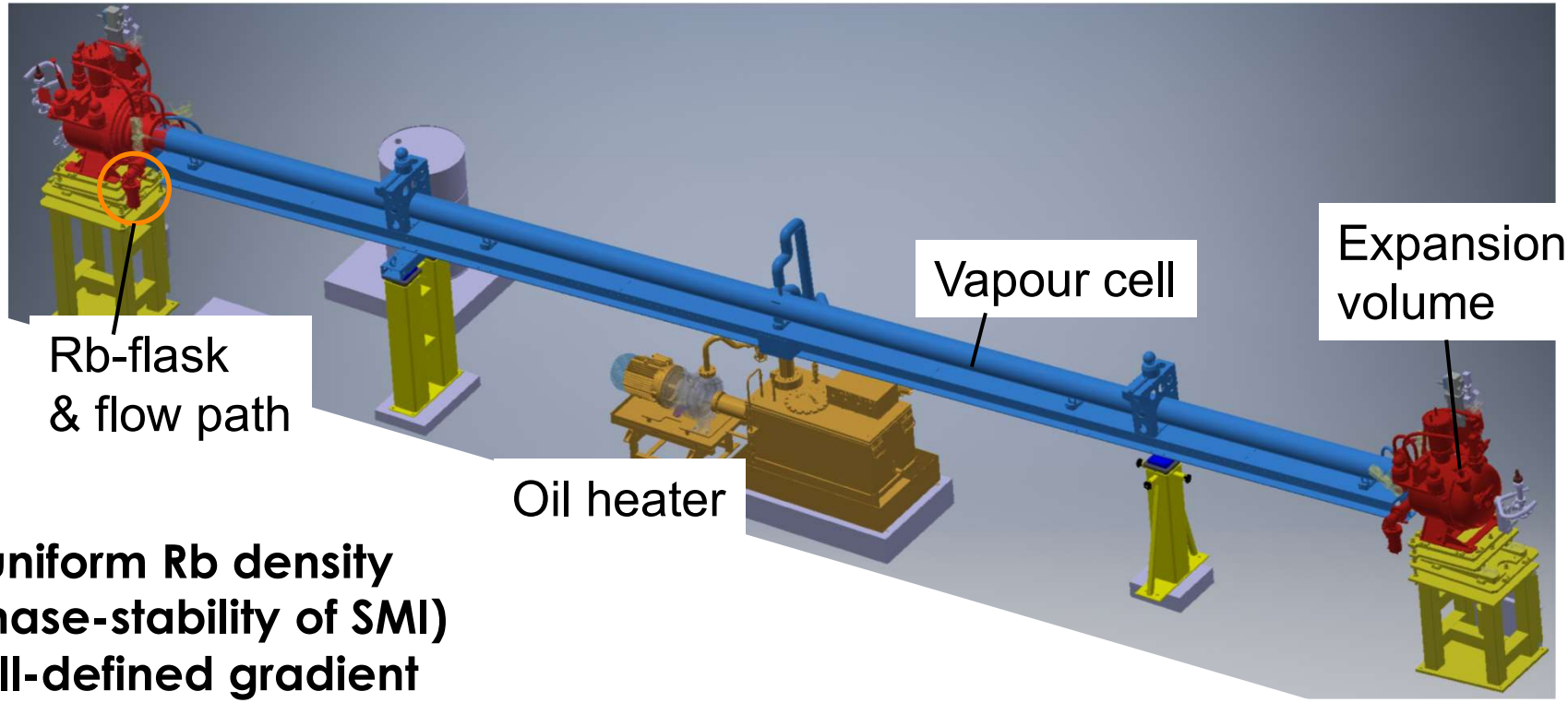
# Outline

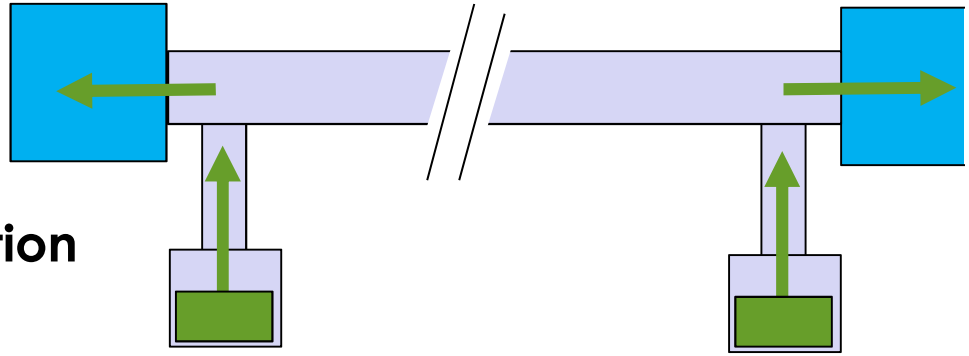
- Vapour cell overview
- Vapour cell control system
- Operation essentials
- Density calibration
- Status & modifications

# Vapour cell and vapour source

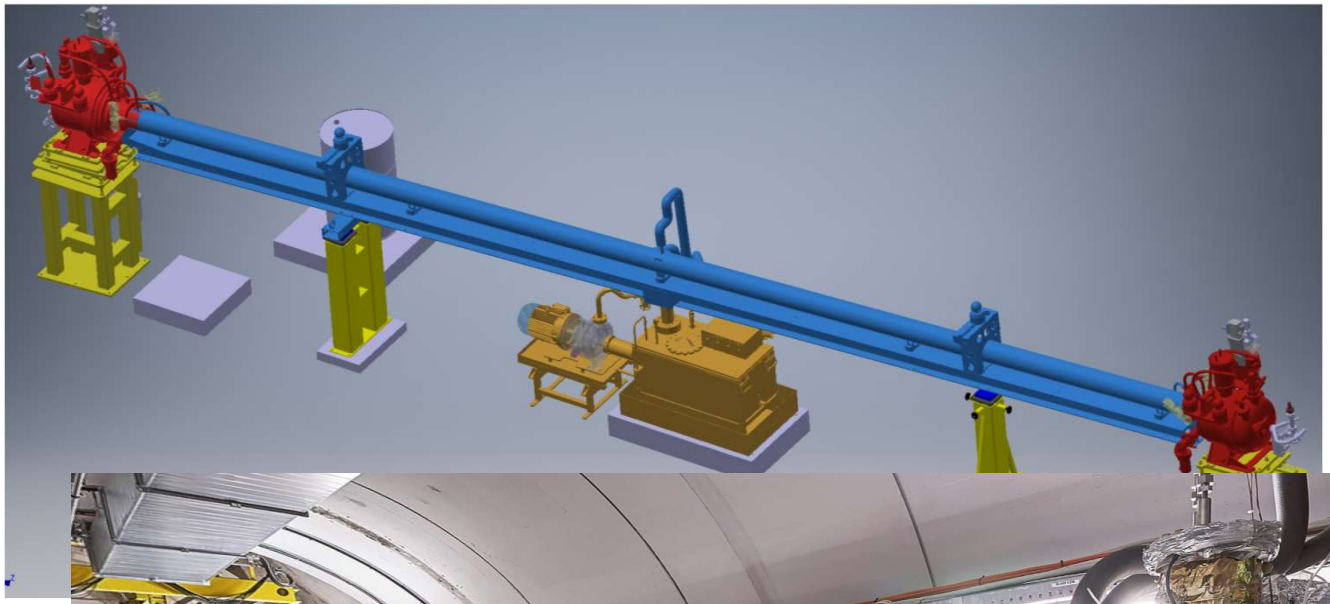


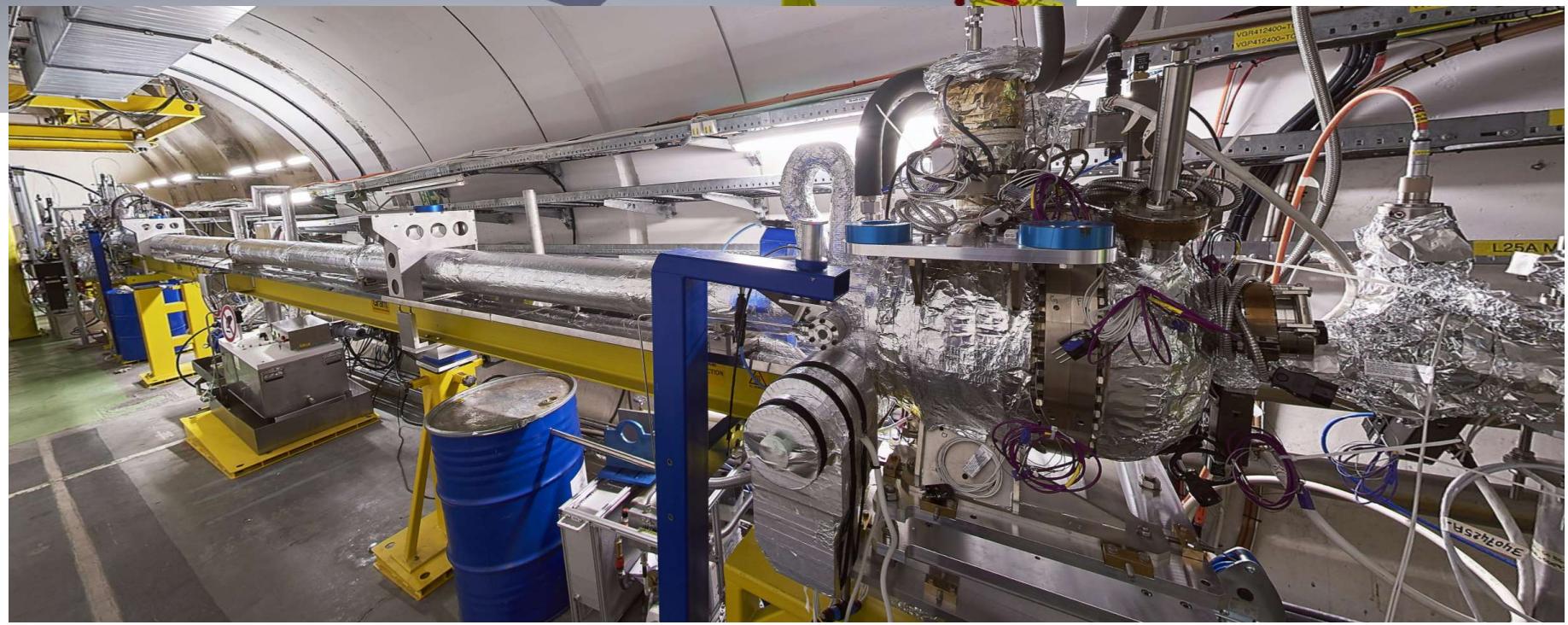

**Very uniform Rb density**
**(→ phase-stability of SMI)**
**or well-defined gradient**

- **Vapour cell (10m): Temperature uniformity achieved by oil heat exchanger**
- **Continuous Rb flow from evaporation in Rb-sources through orifices**



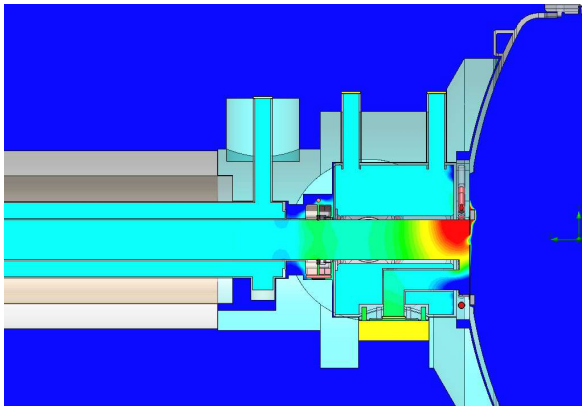
# Vapour cell and vapour source

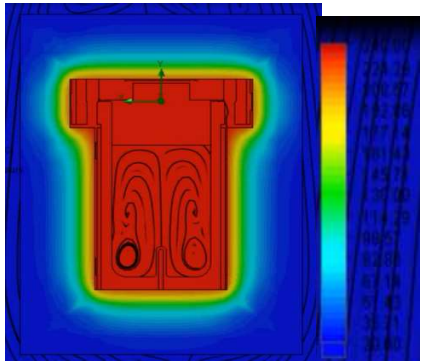




# Vapour cell overview

- **Rb-sources & vapour cell ends:**
  - **Electrical heating zones, distributed according to thermal simulation**
  - **Heater power defined by control system**
- **Expansion volumes kept cold by chillers**
- **Valves for Rb flow-path, Ar-flush and windows**





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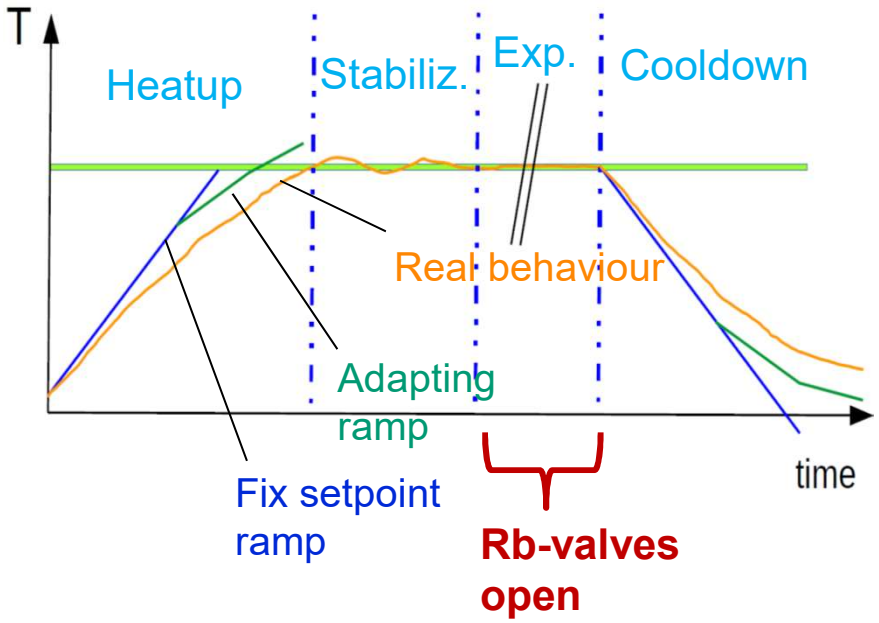
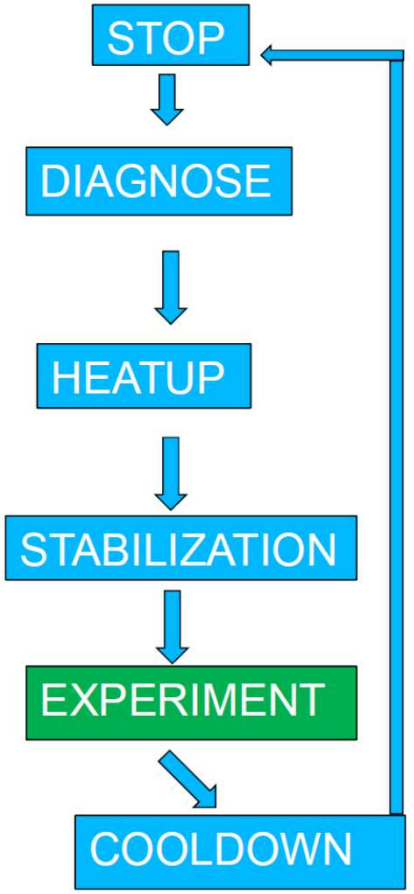
# Vapour cell control system

**Control of heaters & valves**

- **Controlling to well-defined target temperature**
- **Stepper: Default cycle**

  **Stop – Self-test – Heat-up – Stabilization – Experiment – Cooldown – Stop**

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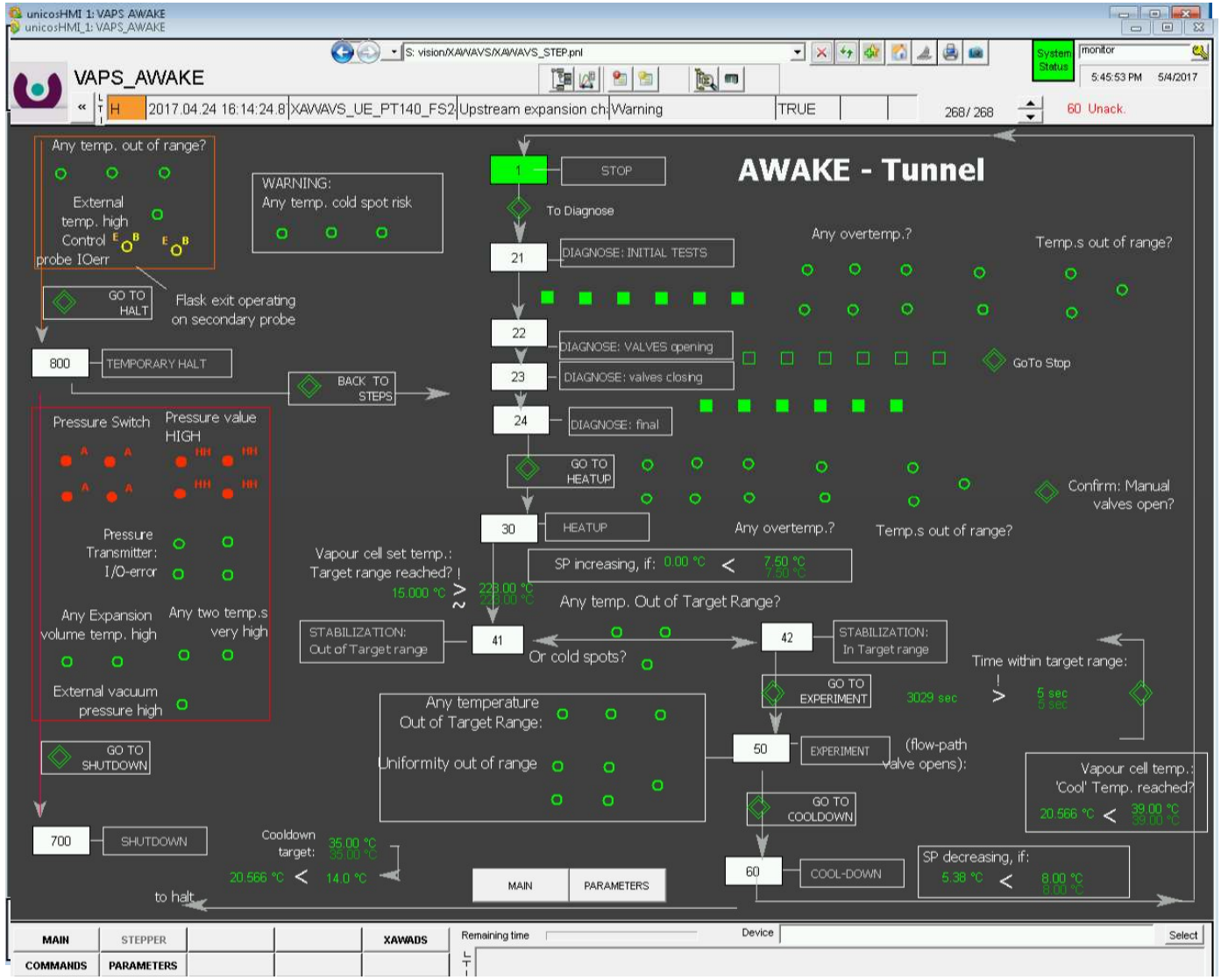
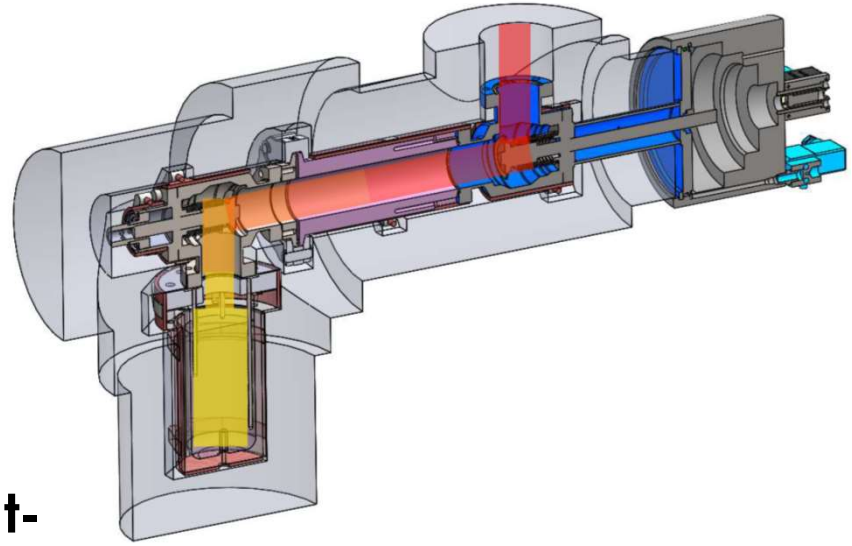
# User interface 1/3: Stepper




Stepper acts in programmed way in each step

# Vapour cell operation

- **Keep flask always coldest point: 15° C below vapour cell to prevent cold spots**
- **Control via $T_{vapour\text{-}cell}$ & offsets for electrical heaters**
- **> 30 hours cooldown / 17 hours heat-up (limiting during experiment)**
- **Rb valve only open for measurements**
  - **10 min stabilization time: Rb flow + temperature re-adjustment**

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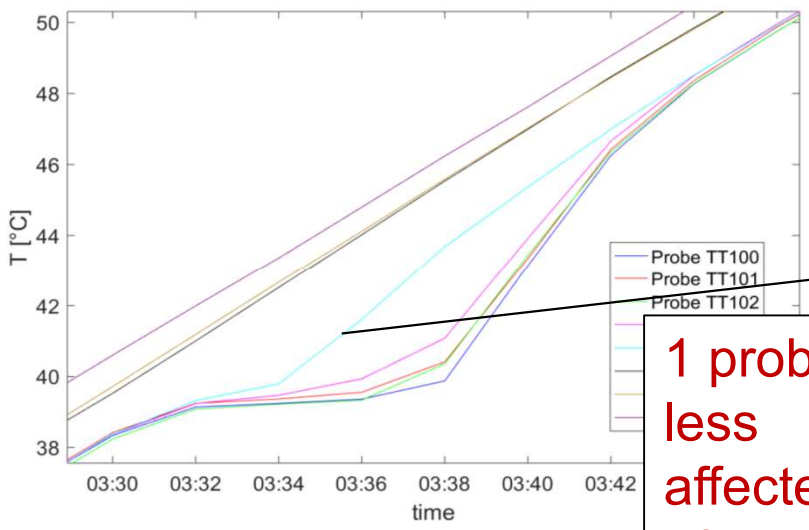
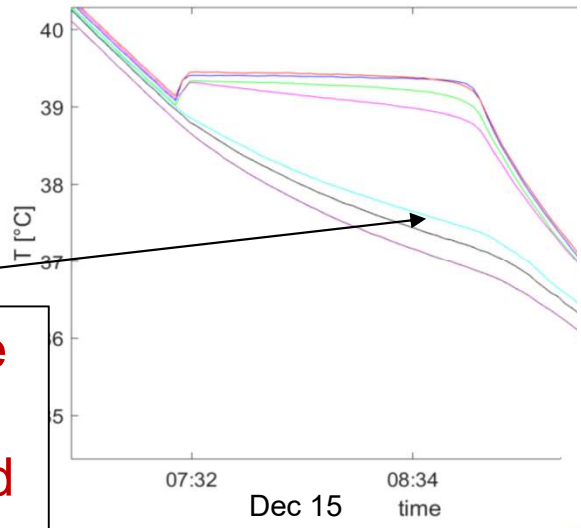
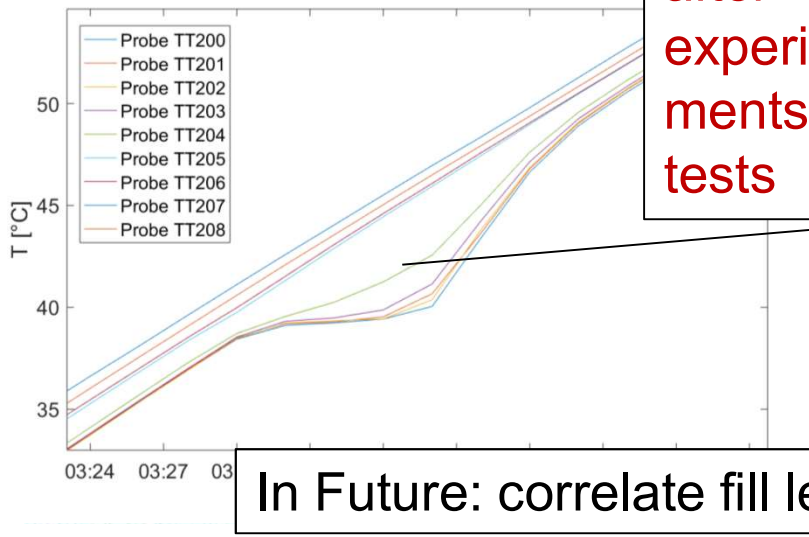
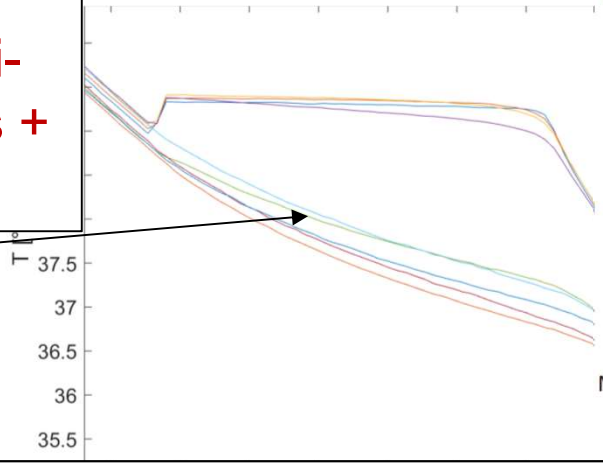
# Measurement of Rb-level



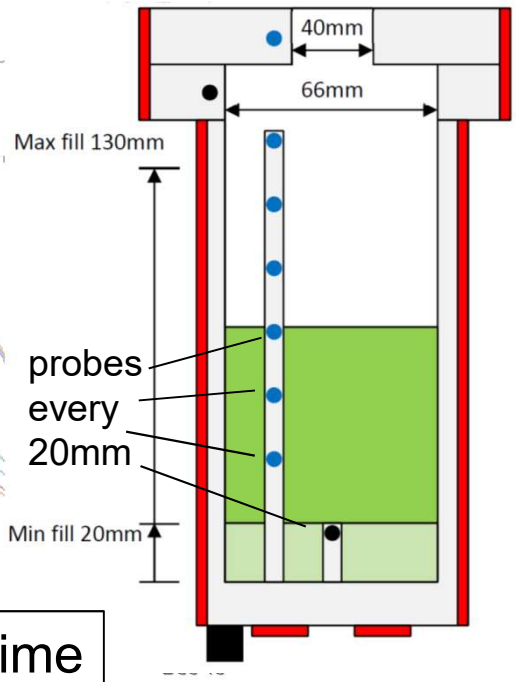




1 probe less affected after experi-ments + tests



Indirect measurement of Rb-level when passing freezing point:
Nº of probes remaining at constant temperature




In Future: correlate fill level with Rb-valve open time

# Vapour cell density calibration

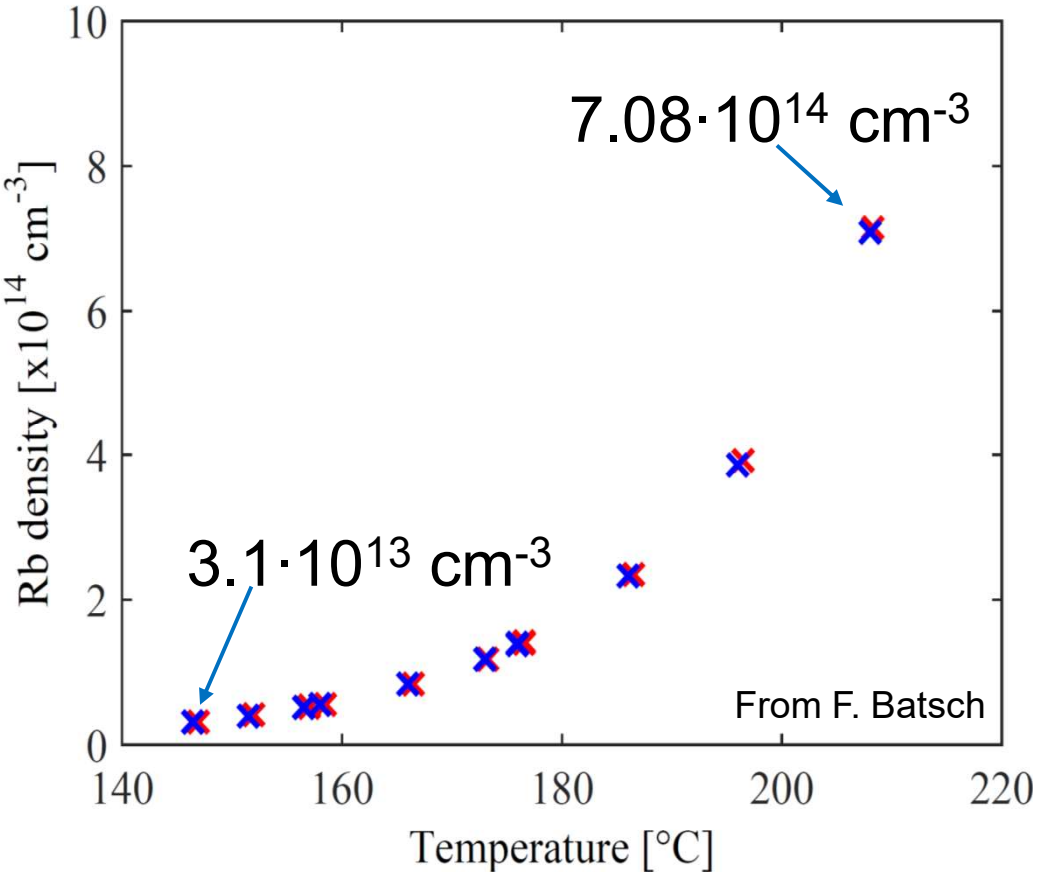
- From $T=T_{min}$ (pump heating) to $T \approx T_{max}$ (safety threshold)
- Characterization every 10-12° C

→ Measurement intervals $n_2/n_1 < 1.9$

- Gradient kept at <1%
- Limitation of calibration:

Flow dependent on temperature profile

→ Might change due to insulation modifications (incl. manual valve opening procedure)

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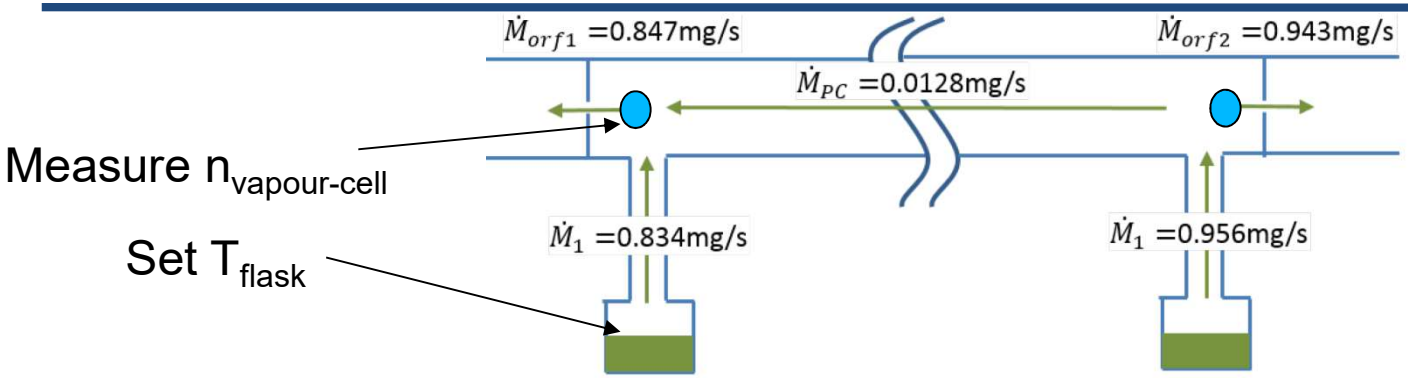
# Comparison with flow-simulations




**Measurement:**

T≈ 208°C for

$n= 7.1 \cdot 10^{14}$ cm$^{-3}$

**Simulations (G.Plyuschev):**

$T_1 \approx 202°C$ & $T_2 \approx 204°C$ for

$n_1= 7.0 \cdot 10^{14}$ cm$^{-3}$ & $n_2= 7.7 \cdot 10^{14}$ cm$^{-3}$

➔ **Need higher temperature than predicted**

➔ **Affects Rb consumption (~150g/24h predicted)**

**Deviations from:** - **Simplified flow-path geometry**

- **Evaporation rate from restricted surface**
- **Rb-viscosity value**

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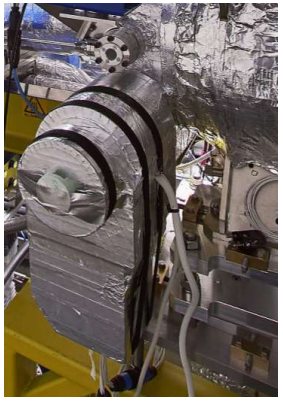
# Planned Improvements

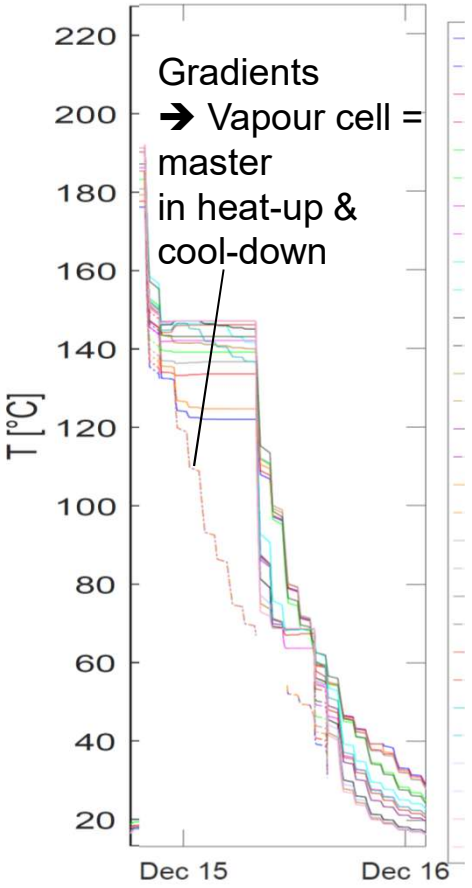
- Calibrated temperature probes
- Recycling procedure
- New design of flasks (difficult handling in filling procedure)
- Heating slower than would be possible from hardware ratings

→ Increase of heating power

- Temperature non-uniformities: improvement before e-s

  → insulation & heating power



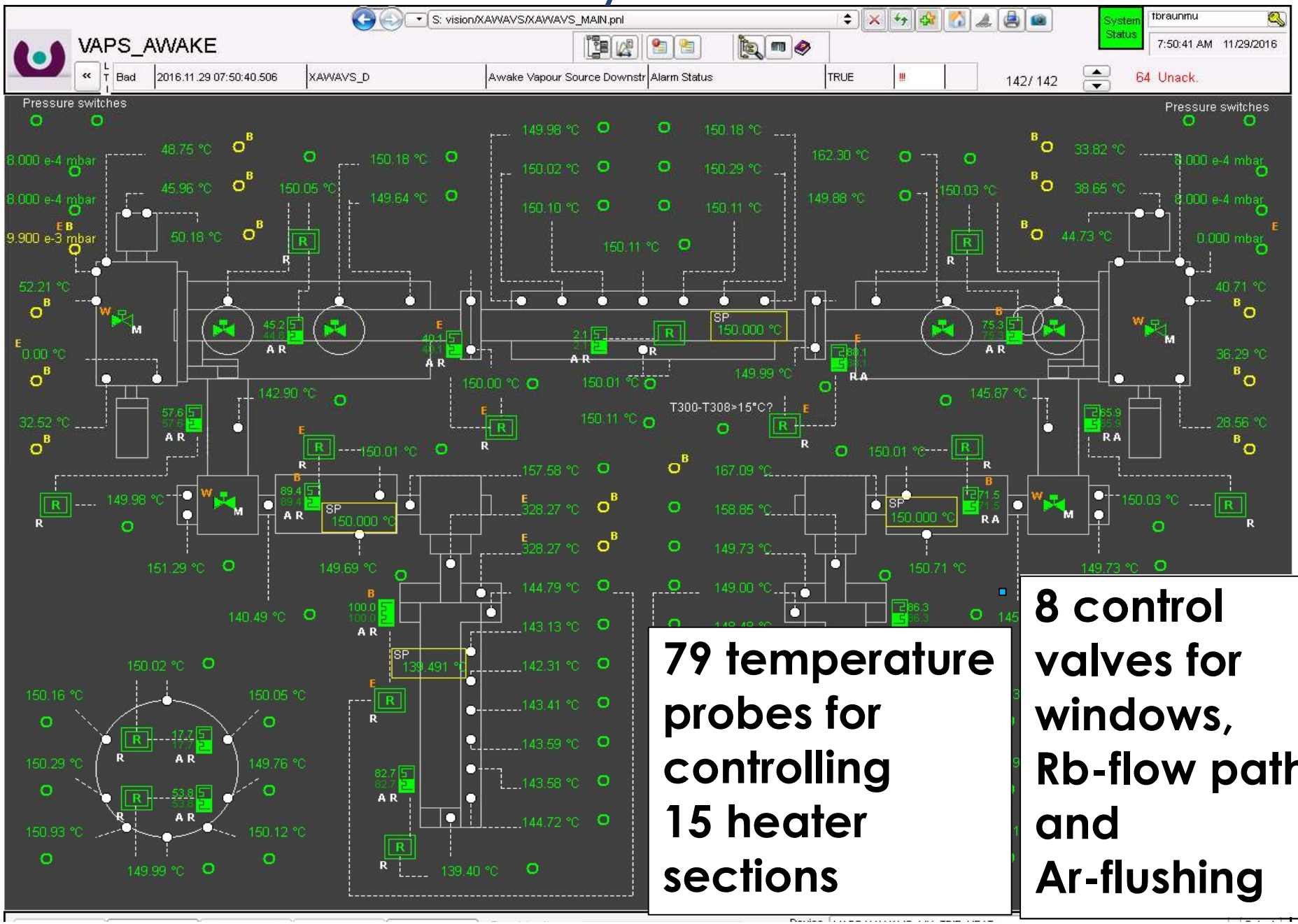


# Summary

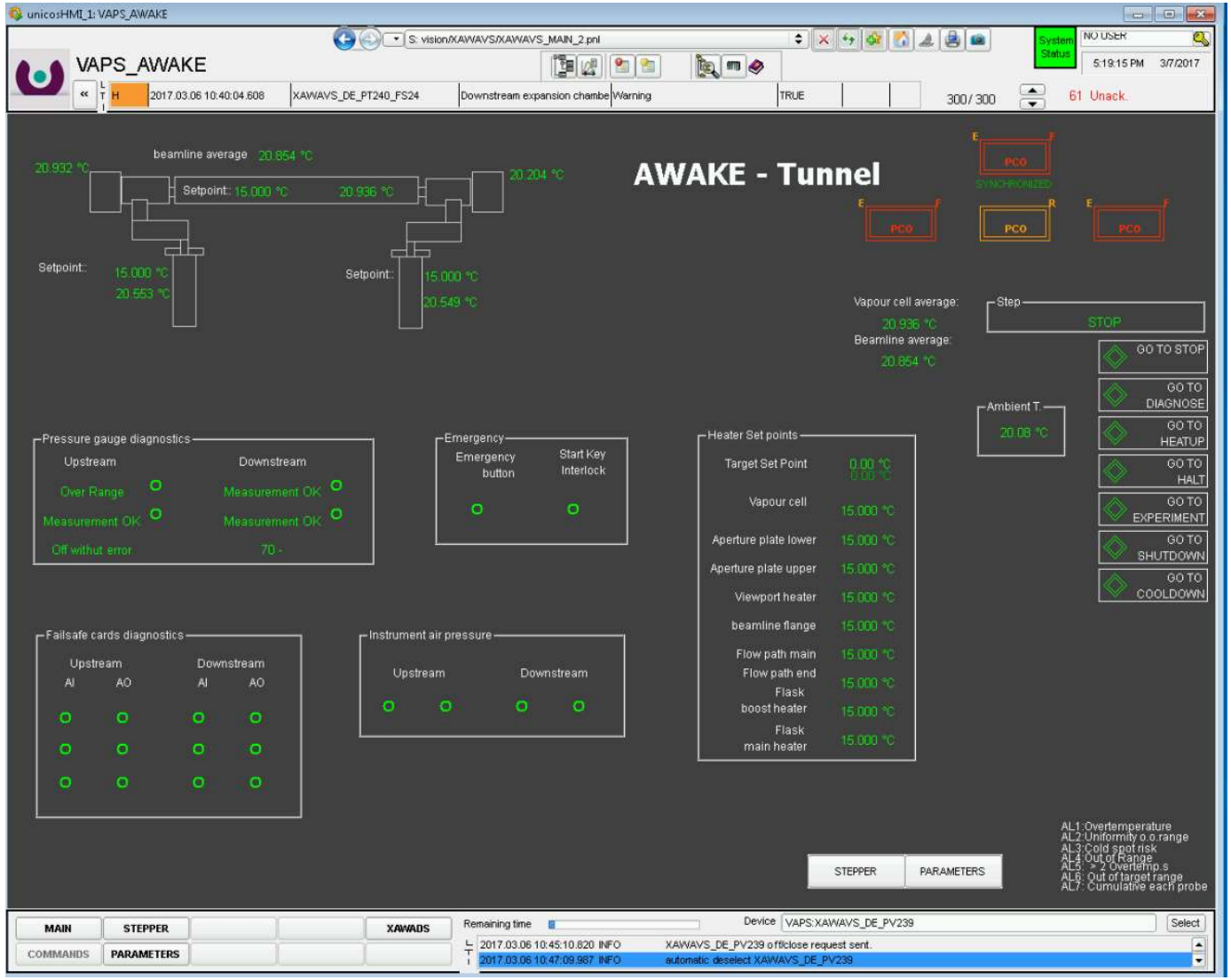
- **Vapour cell operation with elaborate control system**
- **Rb-level  monitoring via temperature probes**
- **Density-calibration with deviations from simulation**
- **Modifications planned**

# Thank you for your attention!

# User interface 2/3: Instrumentation



# User interface 3/3




Overview control panel

- User friendly operation page
- Most important information at a glance

+ parameter control panel

# Vapour cell control system

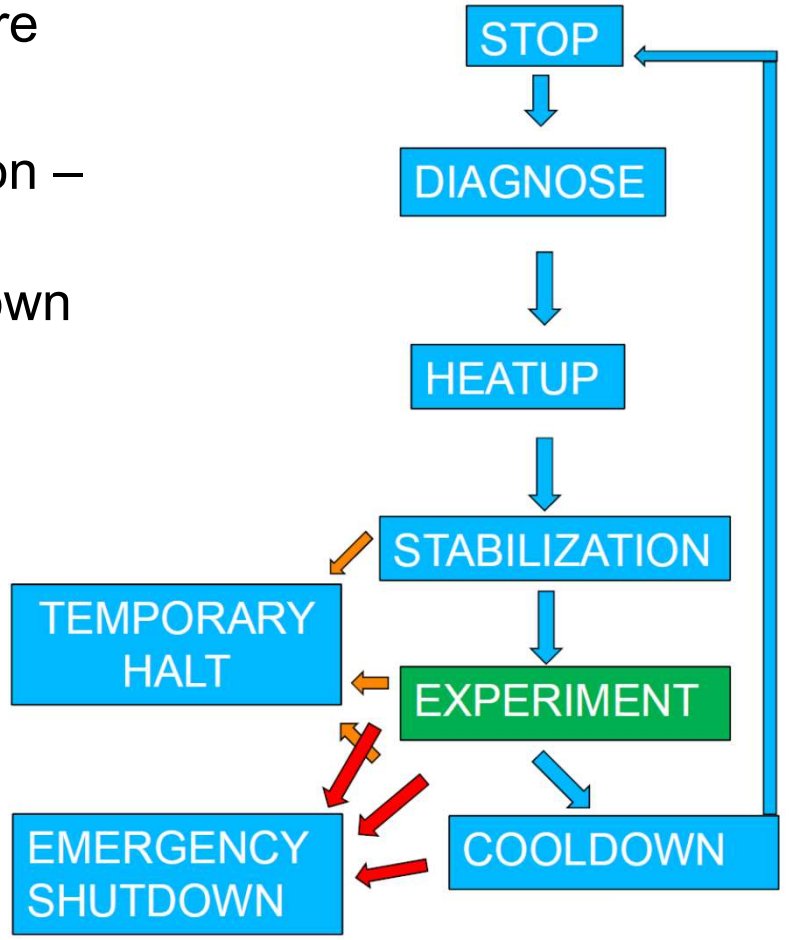
Control of heaters & valves

- Controlling to uniform target temperature
- Stepper:

  Stop – Self-test – Heat-up – Stabilization – Experiment – Cooldown – Stop

  + Temporary Halt & Emergency Shutdown
- Emergency system:
  - Probe failure detection
  - Pressure increase detection
  - Manual stop
  - Overtemperature
- Prevention of cold-spots & too large temperature gradients
- User management:

operation only by ‘experts’

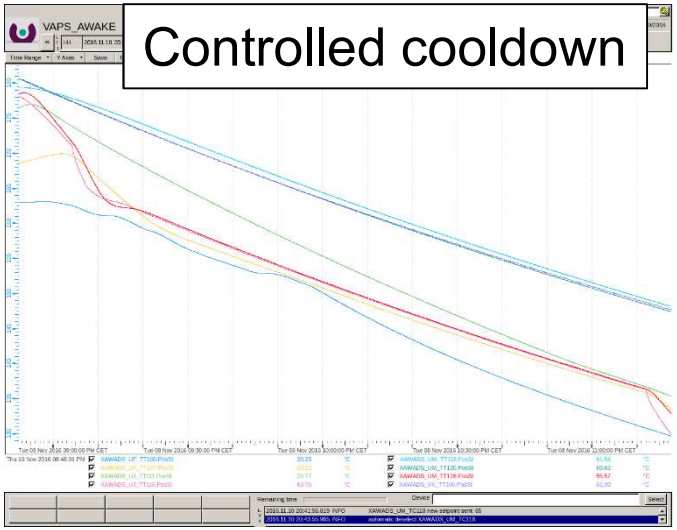


# Vapour cell commisioning

- Extremely tight schedule before experiments ➔ Priority to get working system
- Hardware commissioning:
  - all probes & heaters tested
  - Wiring finished and tested
  - Oil bath commissioning

- Control system commissioning:
  - Test of stepper & emergency functions
  - Test of all functionalities before operation for safety approval

- Not yet included:
  - Recycling procedure
  - Calibration of temperature probes (except plasma cell)



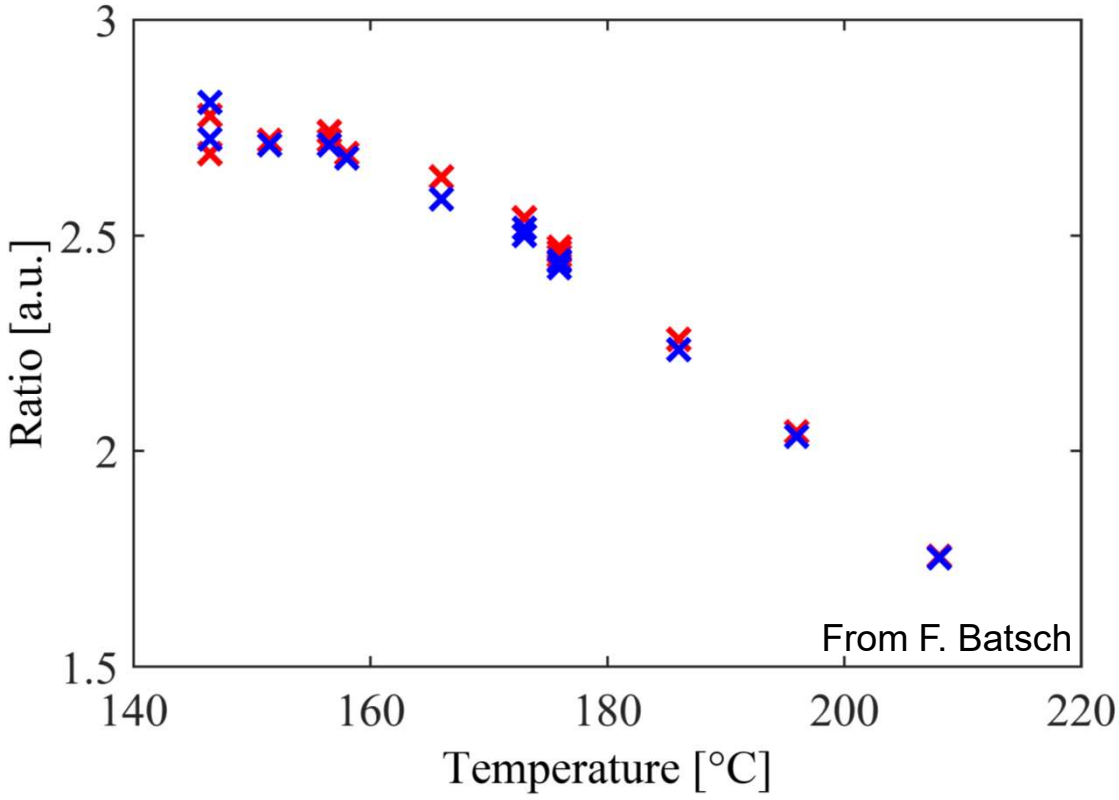
# Vapour cell calibration

**Influence of flow:**

- **Continuous dependence on temperature**
- **Depends on gradient**
- **Limitation of calibration:**

- **Flow dependent on temperature profile**
- **Might change due to manual valve opening procedure**

**Ratio:** $\frac{\text{Calculated density at Rb-surface}}{\text{Measured density in vapour cell}}$

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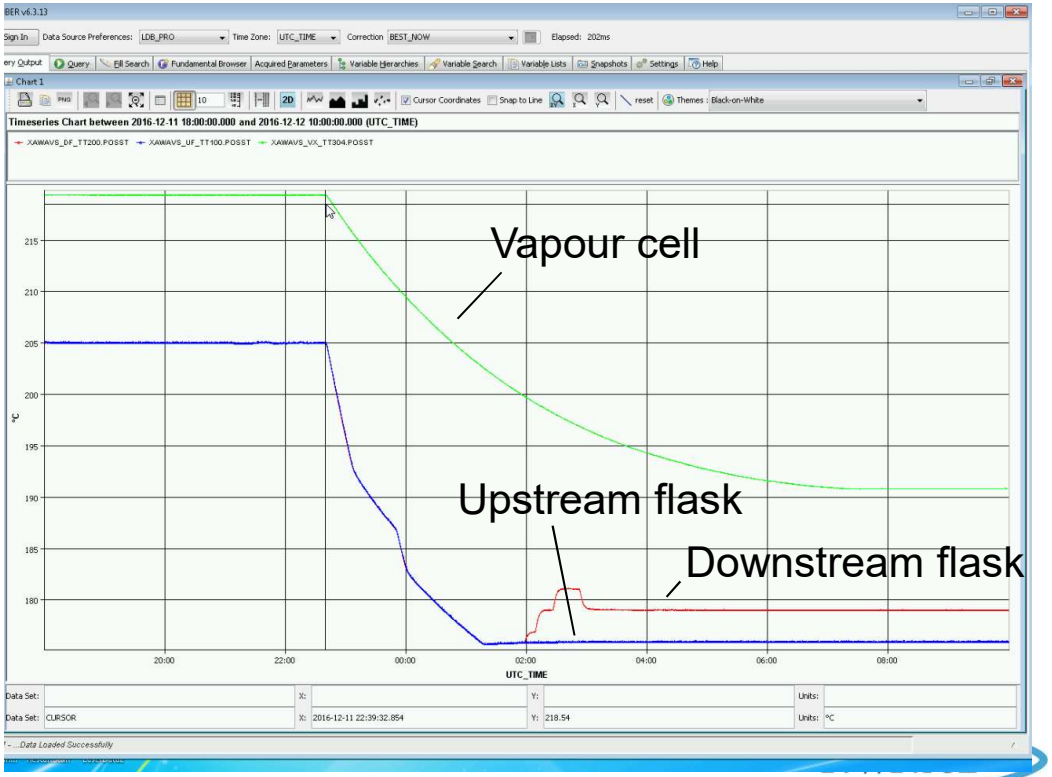
# System operation in December

- Modifications till last-minute before experiment run
- **Well-behaved during experiments, flexible operation**
- Simultaneously test run to identify possible improvements in real operation
- Slow reaction to changes of temperature
- Temperature profile will be further improved
- Density uniformity measurement for vapour source validation: Incomplete (see presentation F. Batsch)

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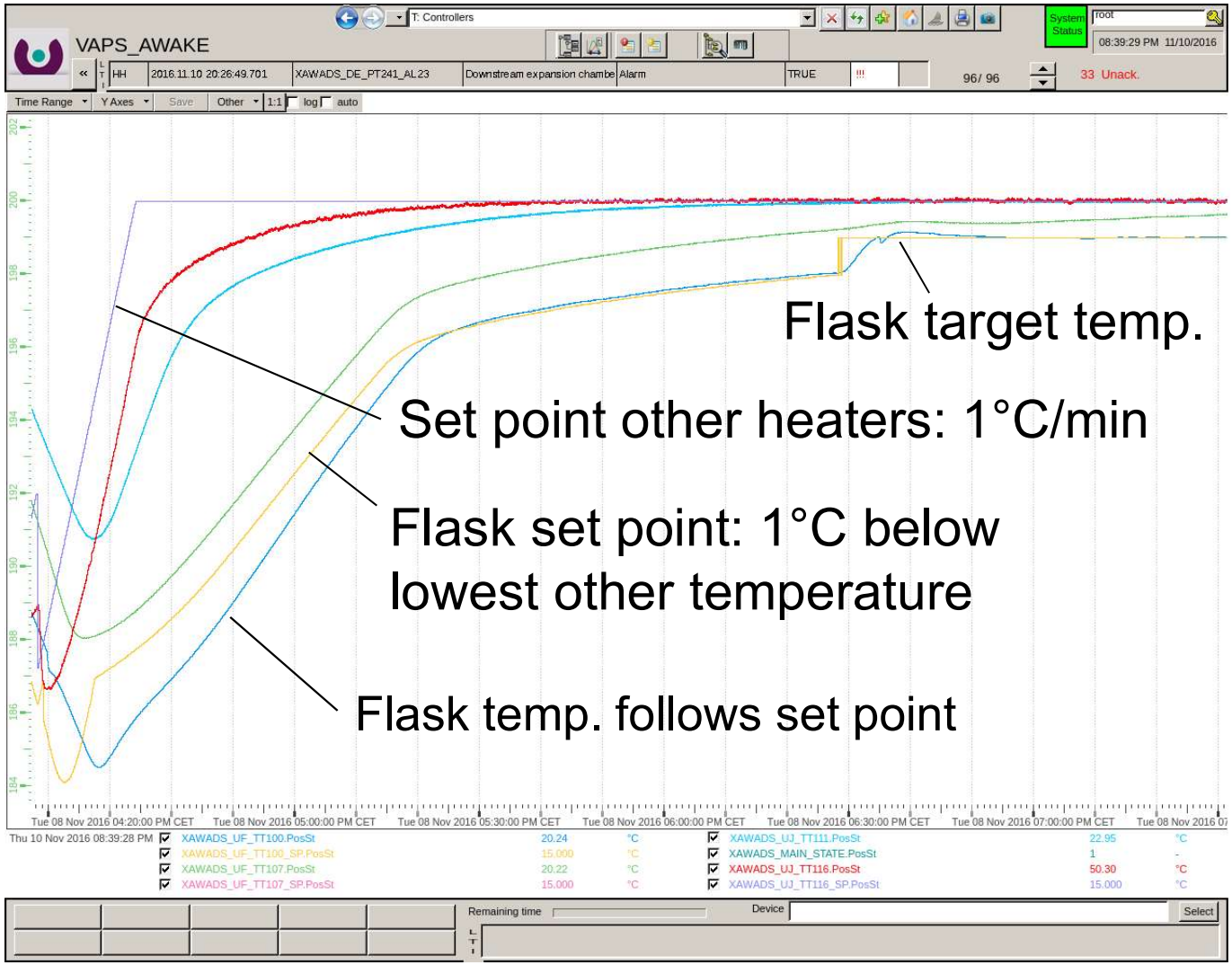
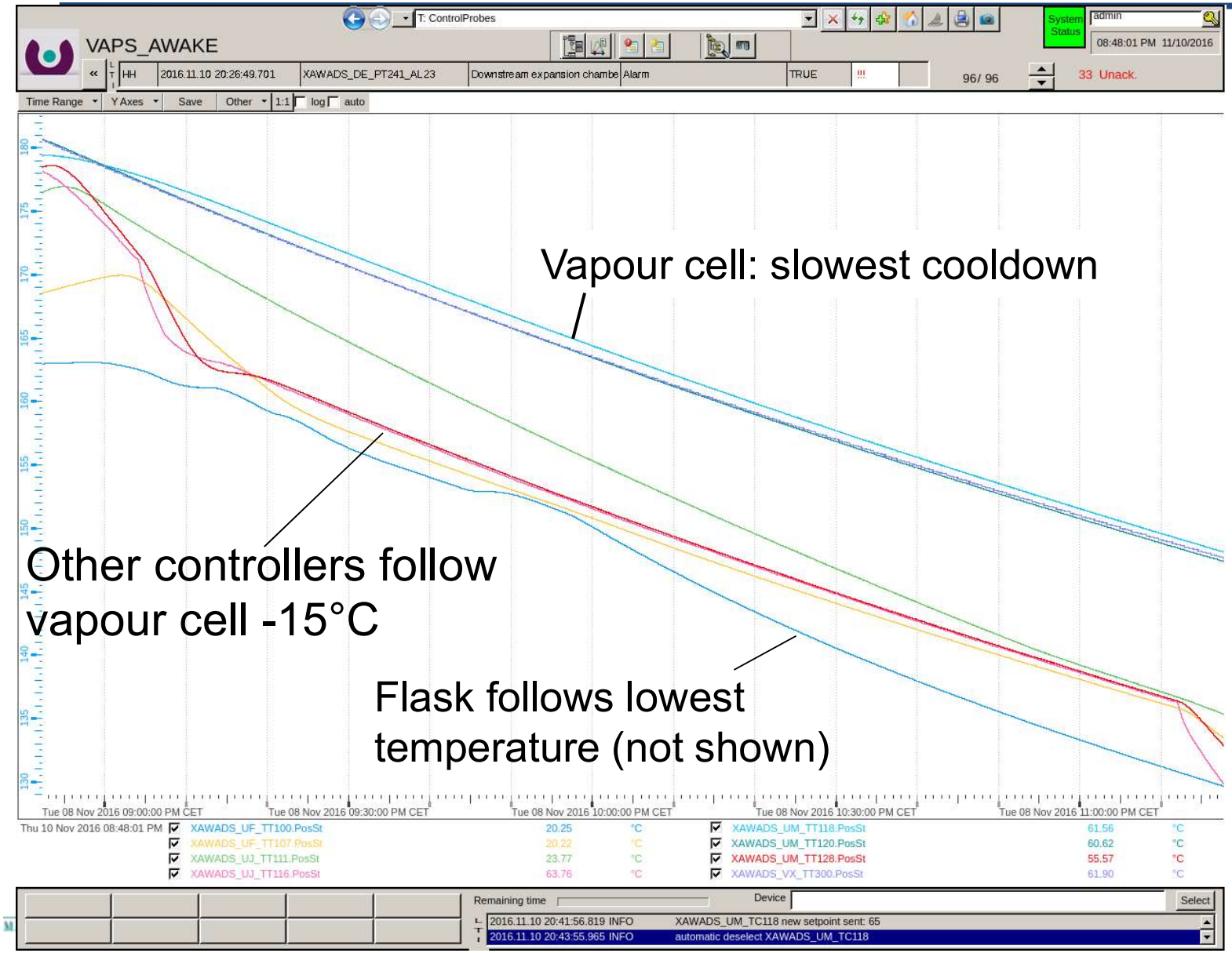
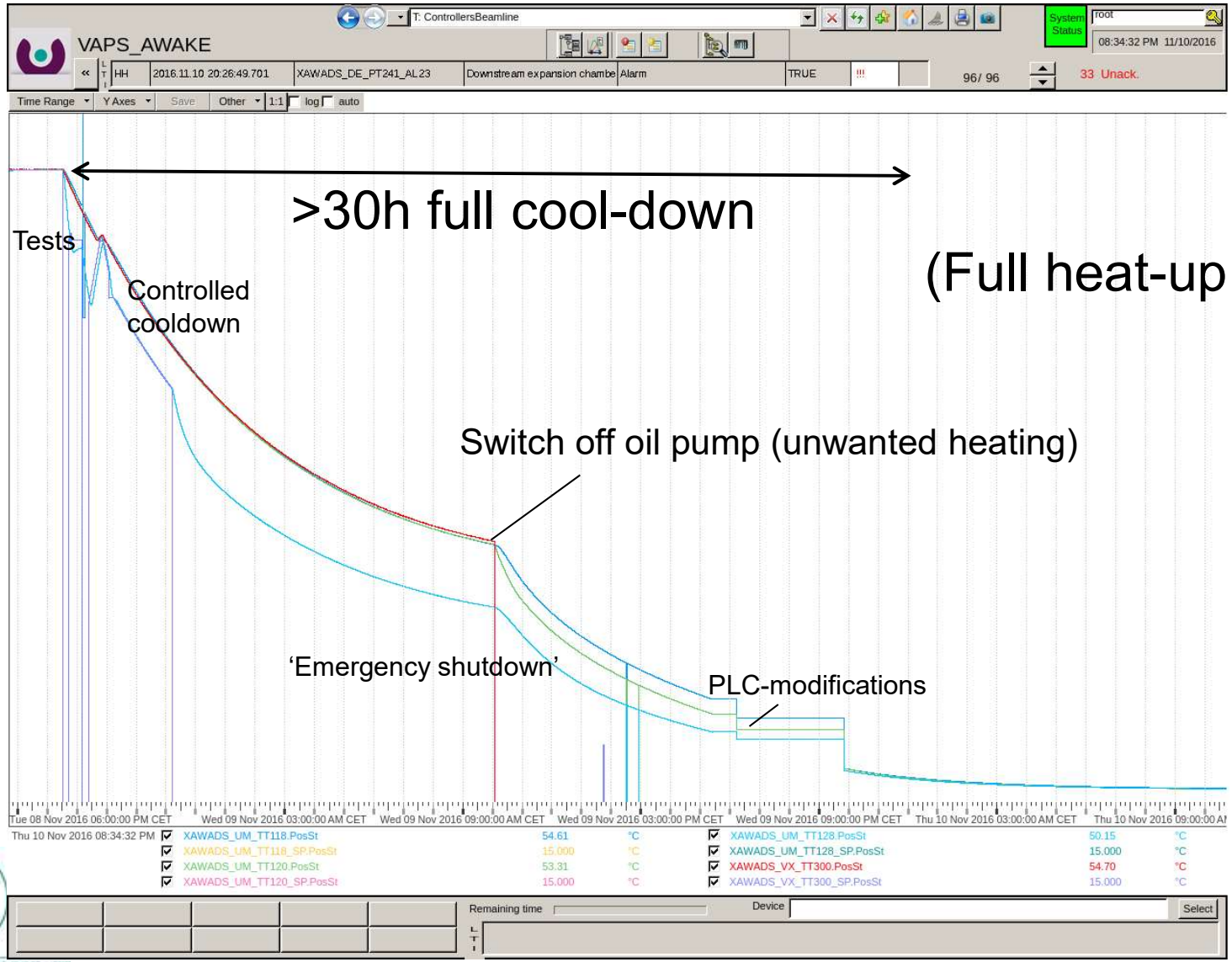
# Cold spot prevention



# Controlled cool-down



# Full cool-down



# Heat-up


Adapting to slowest heating
to prevent gradients & cold spots

Initially limited to 1°C/min due to valves



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