MEASUREMENT AND CONTROL ARCHITECTURE OF RESEARCH CRYOSTATS

ICEC29, GENEVA

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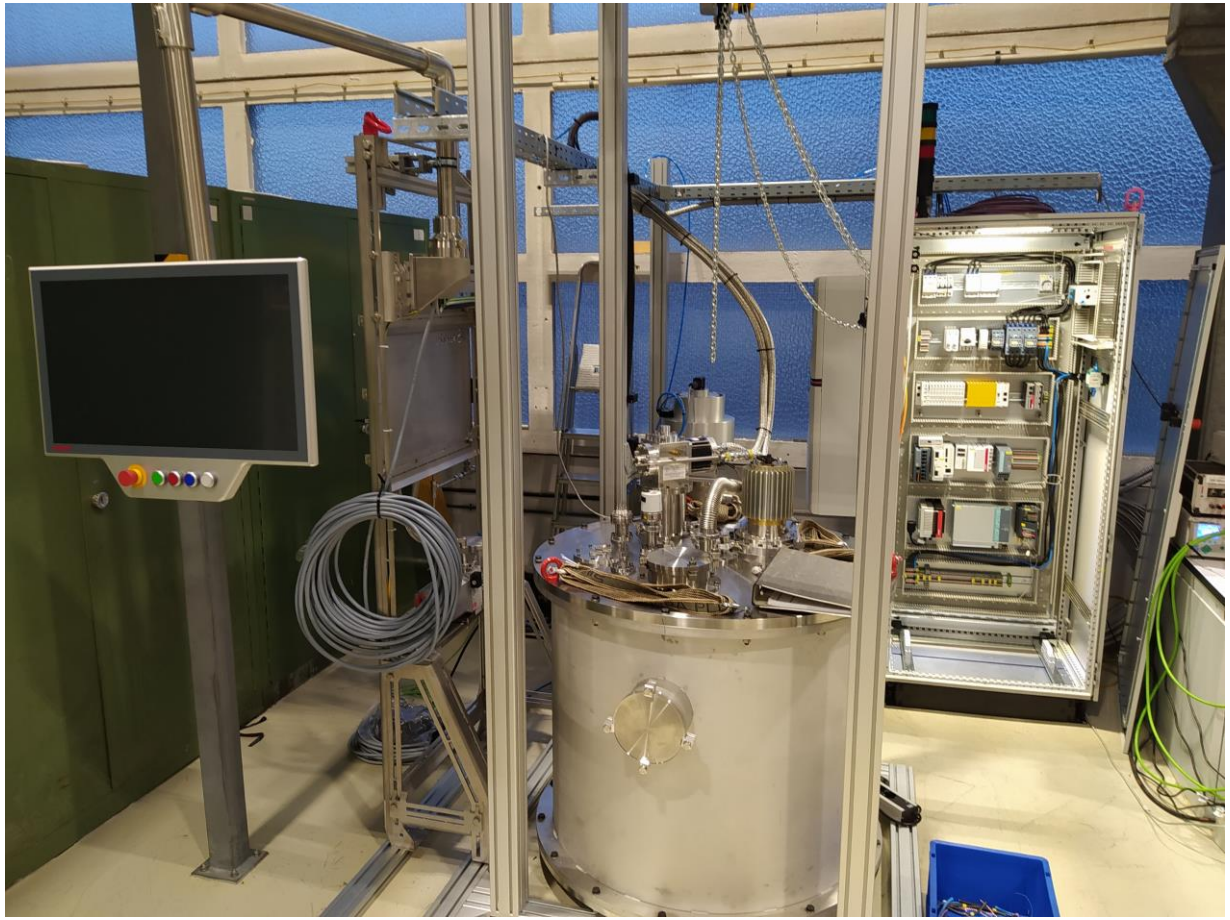
WHY CHANGE A RUNNING SYSTEM?

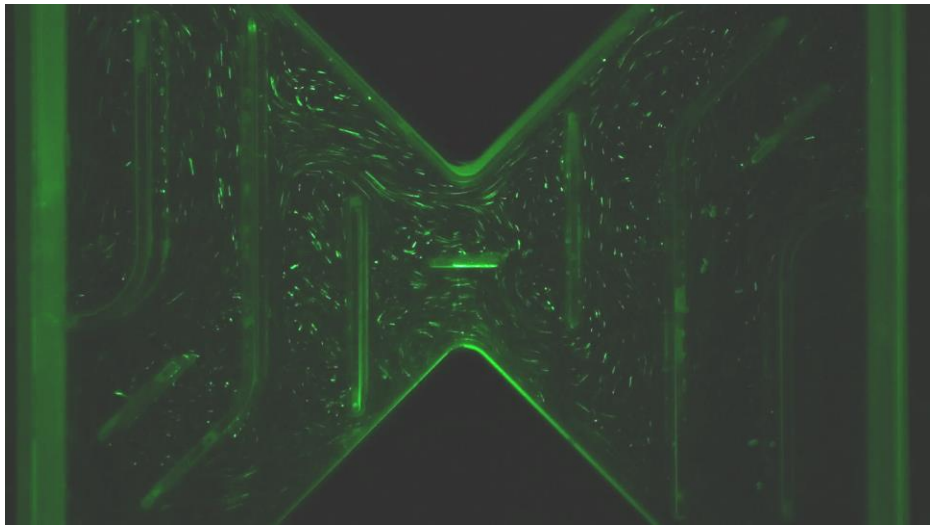


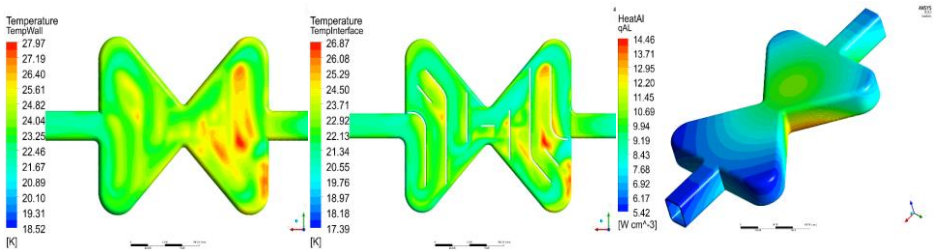
ZEA-1 Research Cryostat

- Closed-Loop
- RDK-500 Coldhead (45W@20K)
- Barber-Nichols' LH2 pump
- Liquid content approx. 1.5l
- Vacuum chamber large enough to contain the vaporized liquid without exceeding atmospheric pressure. (safety barrier)

- Viewports to analyze the fluid
- Prepared for Catalyst
- A variety of feedthroughs (fluid, power, optical and electrical signal)

NUMEROUS CHALLENGES





<u>Once operational, the cryostat aroused many wishes</u>:

- Particle image velocimetry (PIV) using cryogenic liquids (PhD)
- Investigations of solid moderators (mesitylene & methane at T<40K) (PhD)
- Standard diodes and transistors as low temperature sensors (Bachelor)
- Testing PT sensors down to 15K (Industry)
- Catalyst performance test (LH2 ortho/para) (Industry)
- Raman spectroscopy on liquid hydrogen (PhD)
- Providing LH2 for neutron moderation (Science)
- Testing of sapphire view ports at 15K and 10 bar LH2
- Characterization of superfluid helium (PhD)
- …

SWITCHING BETWEEN EXPERIMENTS

Rewiring to change, remove and integrate new hardware components

(Re-) Programming the PLC

Adjusting the safety systems

Adaption of the documentation

Testing the system

→

Time consuming

Experts were needed

Students can provide little support during maintenance

→

slow & costly

NEW APPROACH

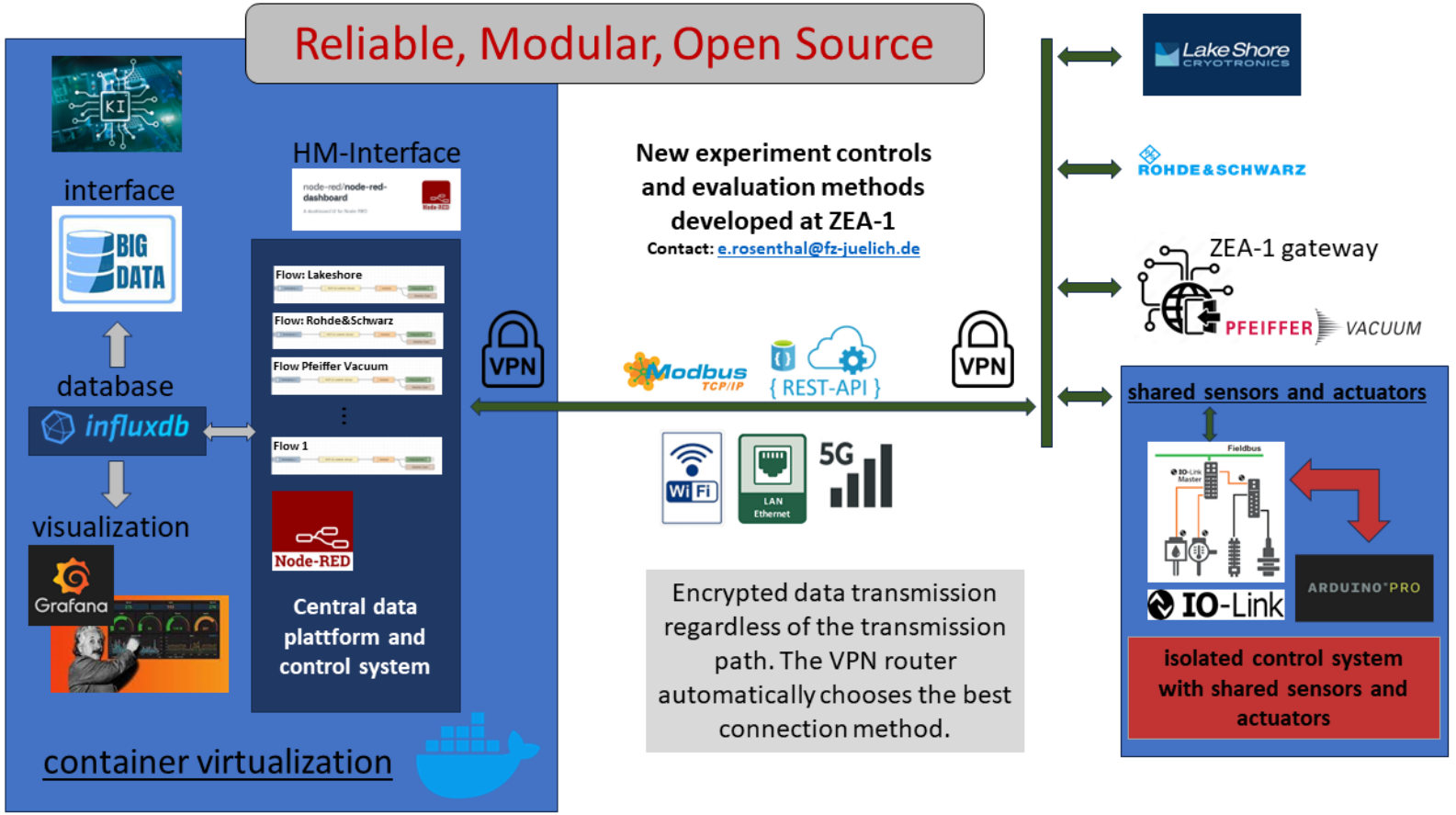
Key Points:

Digitization of all signals (instrumentation and control) as close as possible to the sensor/actuator

Common communication standards
(IEEE 802.3 Ethernet)

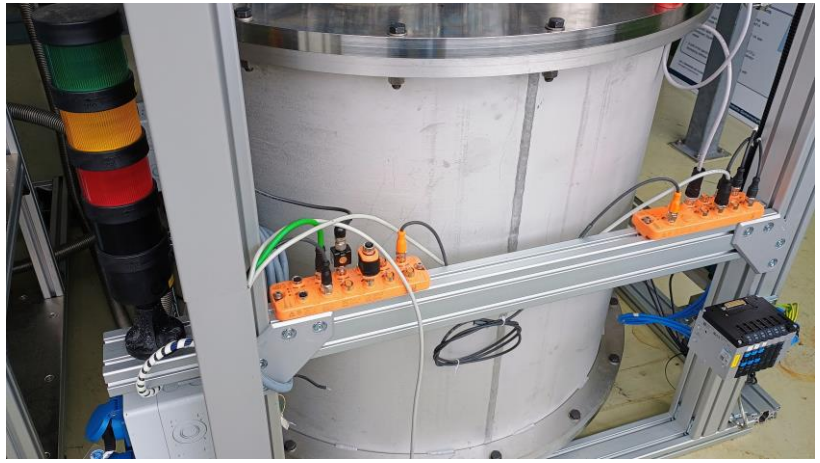
Virtualization of the control logic, controls and display of measurement data. (HMI)

Open-source software



DIGITALIZATION CLOSE TO THE SENSORS/ACTUATORS

	volume [m³]	weight [kg]	costs [EUR]
Cabinet	1	175	7500
ZEA-1 Modules	0.05	4.5	1500
IFM IO-Link	0.005	1.2	1500



Ex approval of the Turck block I/O families TBEN-S and TBEN-L enables cabinet-free modularization up to ATEX zone 0 for the first time
https://www.turck.de/de/produktneuheiten-2860_dezentrale-ioloesungen-fuer-den-exbereich-42635.php

The use of certified modules and components means significantly less documentation effort

SAFETY AND RELIABILITY

Back to the roots:
Unplug the system from the socket and it must warm up in a safe way

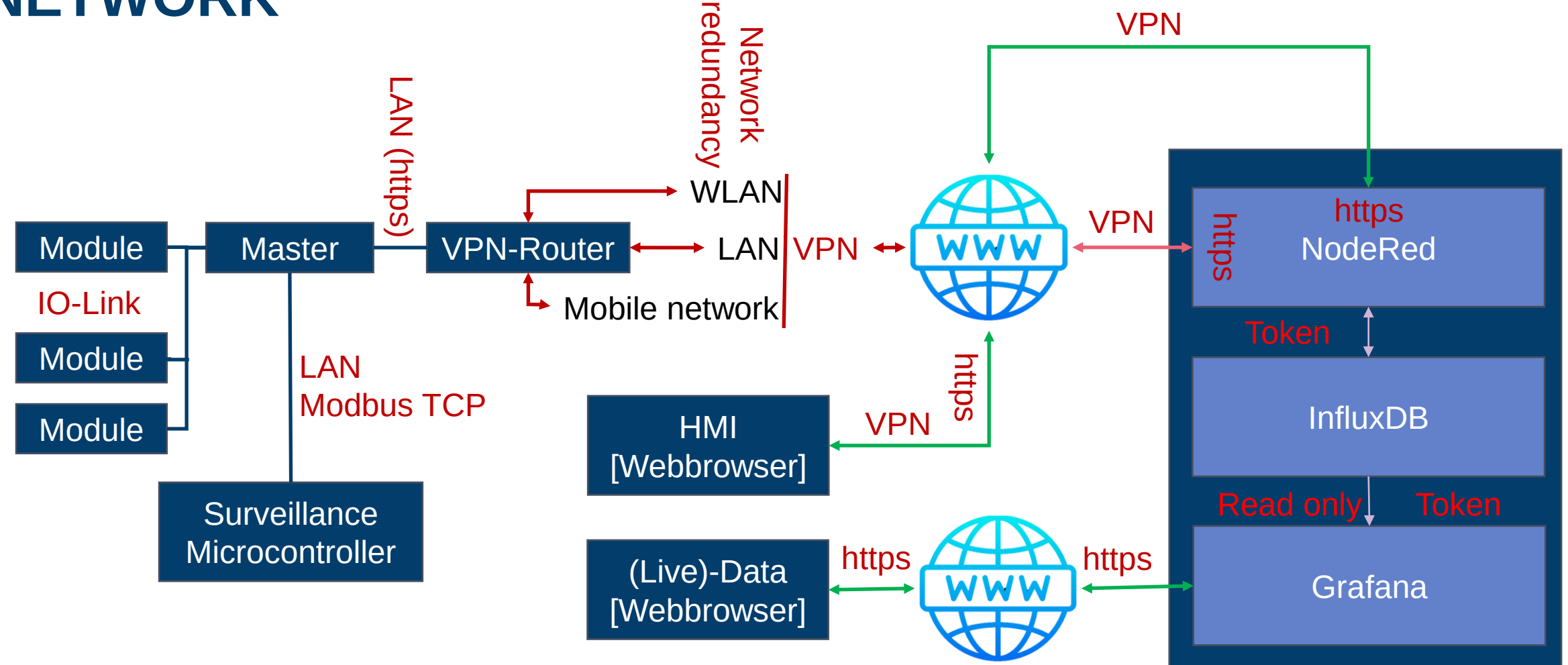


Buffer volumes to stabilize the two-phase flow, passive mechanical safety devices and (pneumatic) fail-save valves help a lot

certified modules
With encrypted protocols and fail save operation modes increases the reliability (and safety)

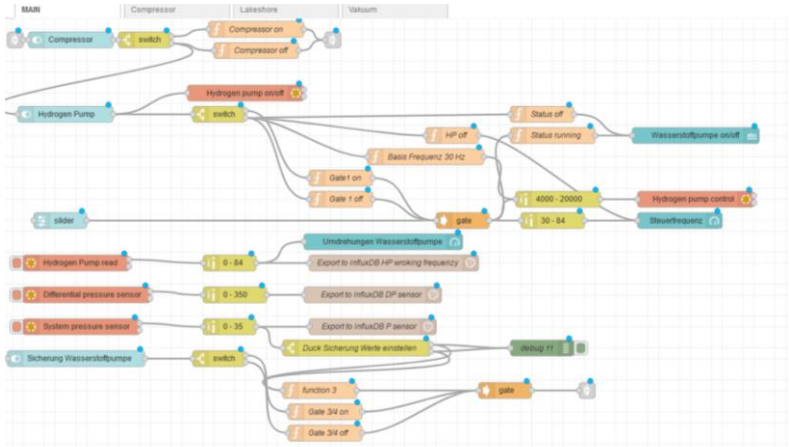

Misuse and hacking protection
Two totally separated networks (modbus TCP and TCP-IP) using the same sensor and actuators data. A microcontroller on the industrial bus reads and checks all the data. If there are discrepancies, it disconnects the module-server connection, takes over control and brings the cryostat into a safe state

NETWORK



VIRTUALIZATION

Control and HMI
Node-RED: flow-based, low-code development tool for visual programming developed originally by IBM, License: Apache 2.0

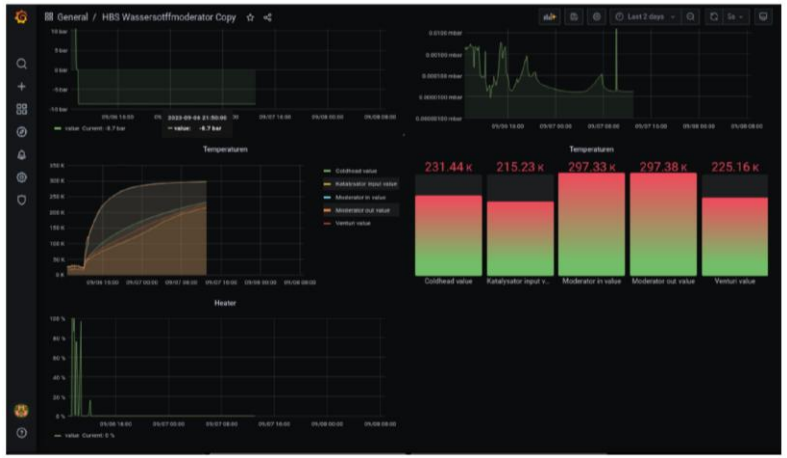


Highlight: Deploying of new software while the cryostat is running, filled with LH2

Database
InfluxDB: open-source time series database
License: MIT

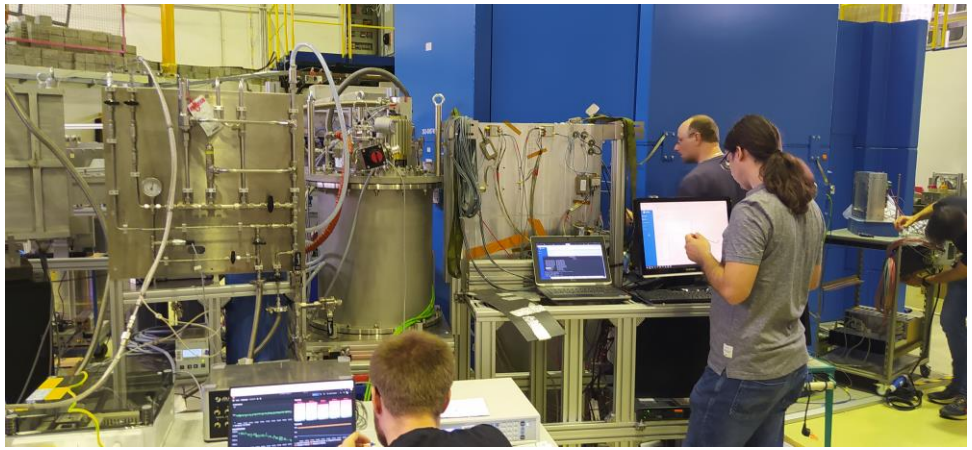
Highlight: Lifetime database. You can view the history of your cryostat and even integrate the (raw) data from leak test devices into the database (“real time”, without manual data export)

Visualization of measurement data
Grafana: multi-platform open-source analytics and interactive visualization web application, Licence: GNU Affero General Public 3.0



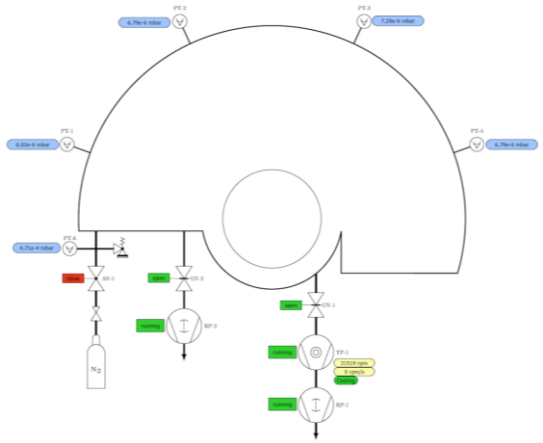
Highlight: Read-only web access for everyone interested. Share your live data worldwide

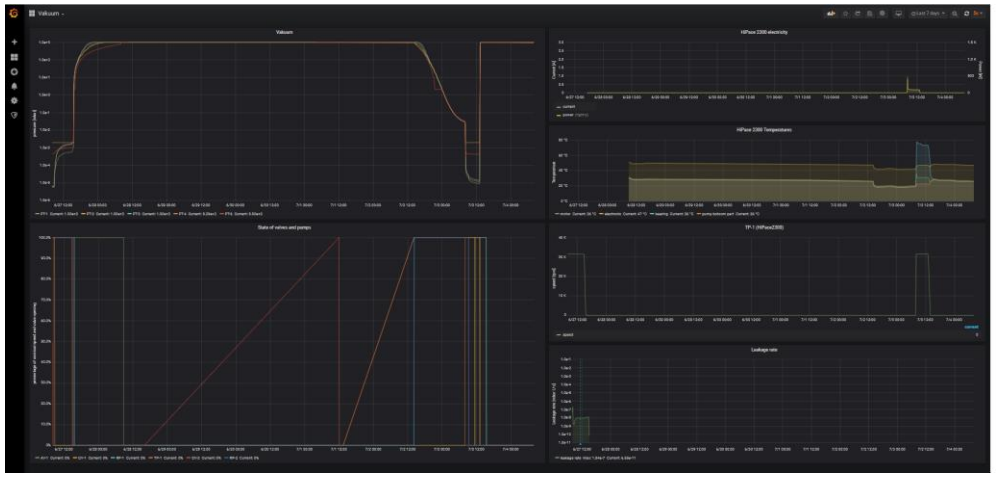
ADVANTAGES AND EXPERIENCES



Operating the HBS cryostat for three beam times using a virtual server-based control system, database and HMI providing LH2 to a cold neutron moderator. **Over 850 hours of failure-free operation in the radiation protection area**.
Within a week: warming up and dismantling the cryostat in Jülich (Germany), transporting the system to Hungary, setting up the system at the Budapest Research Reactor (BRR) inside the safety area and integrating it into a neutron experiment, using a virtual control system running on a local server inside safety area.

TRANSFERABILITY TO OTHER PROJECTS





Installation and testing of the T-Rex neutron scattering spectrometer for the European Spallation Source (ESS). Vacuum chamber corresponds to a semi-cylinder 4.3 m in diameter and 3.5 m high, with an enclosed volume of 90 m³
Control and monitoring of (water-cooled) turbomolecular pumps (up to HiPace 2300) ,rough vacuum pumps, gate valves (VAT & Pfeiffer), valves, Pirani/cold cathode, leak detectors (ASM 340),…
Life-time database over the entire installation and testing process

OUTLOOK

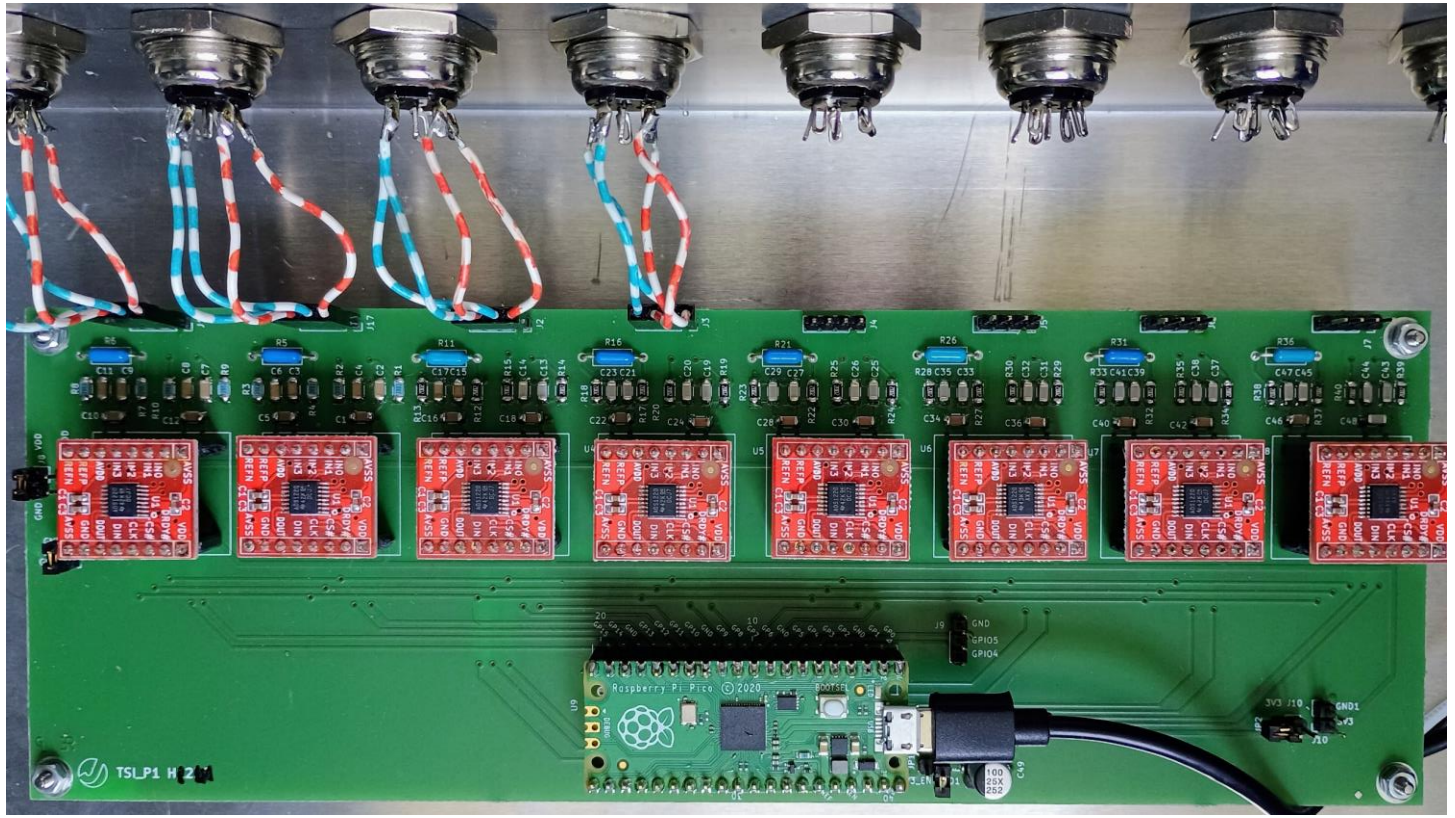
Development and integration of a universal read out unit for Cernox, Diodes (semiconductors) and PT sensors (master theses)

Modification of the hydrogen cryostat for HBS using virtual control

Extension of the concept to electron microscopy

Penetration test @ZEA-1 cryostat

AI-assisted error and failure detection for H2 cryostats (PhD theses)



If you are interested, please do not hesitate to contact us

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https://www.fz-juelich.de/de/zea/zea-1/