Characterization and Validation of Irradiated Vacuum Sensors

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13 August, 2025

Supervision

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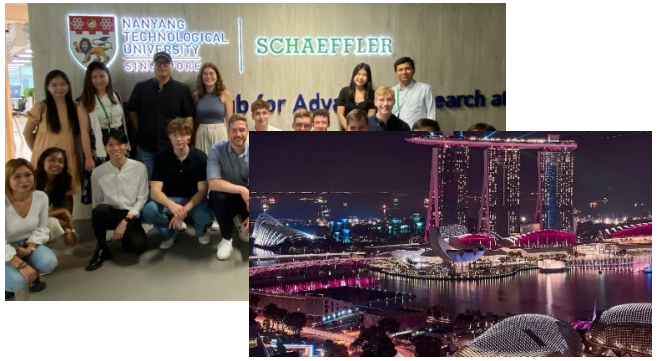
About myself

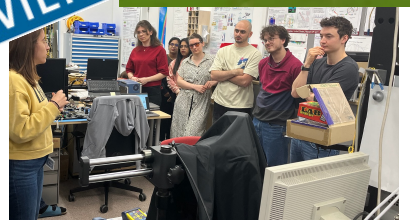


Exchange Programme – Singapore

FH University of Applied Sciences TECHNIKUM WIEN

Quantum Engineering

New Master's degree program: start 2024/25.



MSc. Quantum Engineering

BEng. Mechanical Engineering

HOCH SCHULE OFFEN BURG

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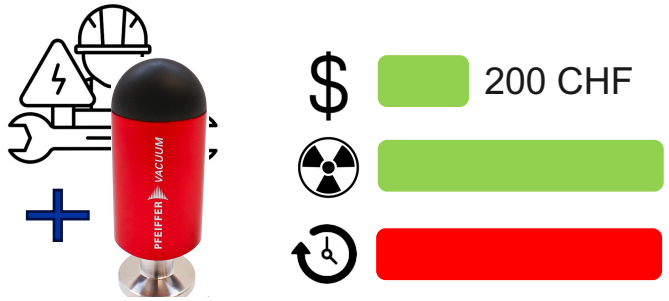
OpsEngineering Amazon

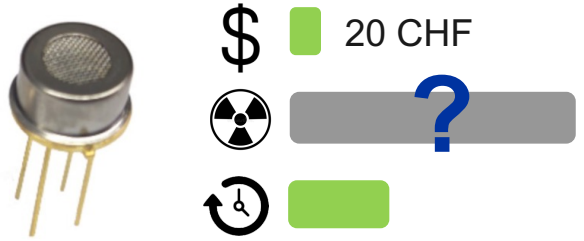
Project Overview

Challenge:

- HL-LHC radiation levels 10x higher - need radiation-tolerant vacuum sensors
- Current rad-hard sensors extremely expensive
- New low-cost Pirani Gauges available, but radiation tolerance unknown
- Need validation of performance after radiation exposure

Historical Workarounds:

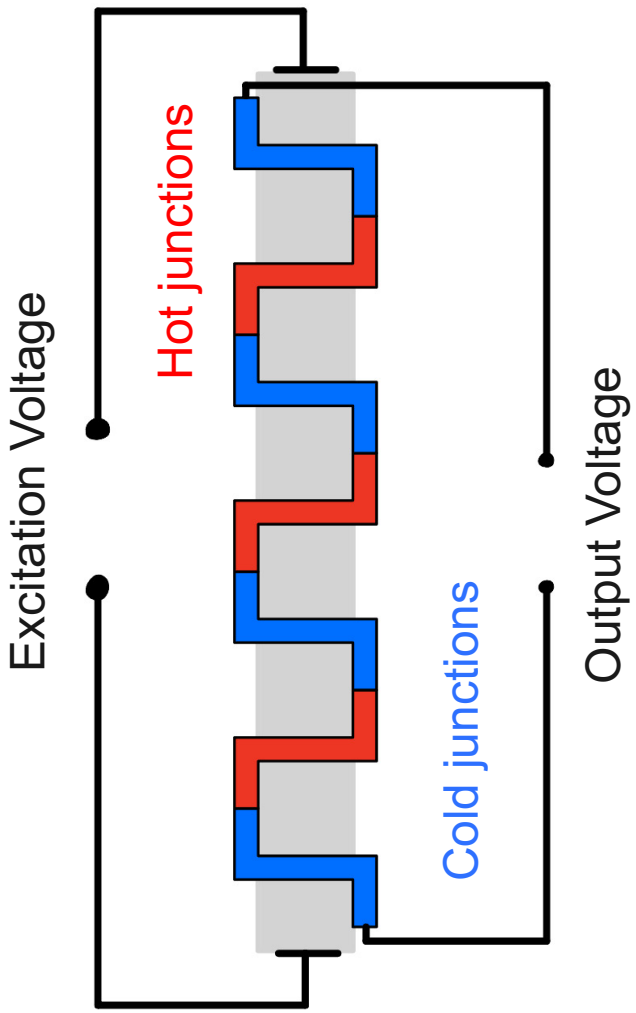




Approach:

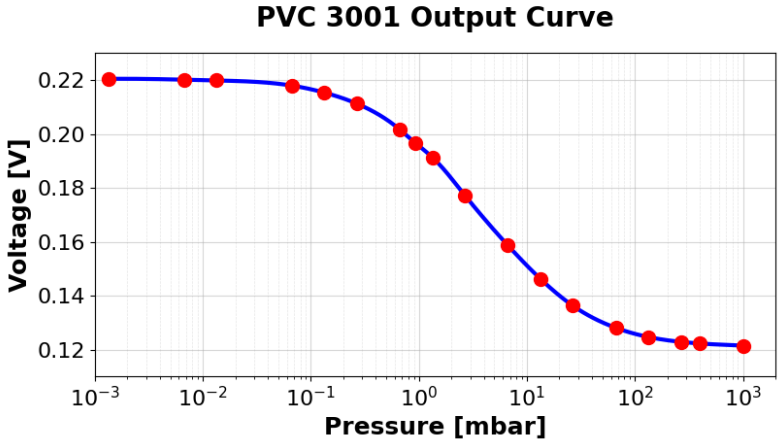
Build test setup → Baseline characterization → Controlled irradiation → Evaluate radiation effects

Thermopiles Working Principle



- **Based on Pirani gauge principle: Measures vacuum pressure via gas thermal conductivity**
- **Resistive heater (1.2 V excitation) dissipates power; heat loss through gas conduction ∝ pressure**
- **Thermopile (series thermocouples) detects temperature difference (ΔT) between hot heater membrane and cold substrate using Seebeck effect**
- **Output voltage ∝ ΔT, which increases at lower pressures (less heat loss); nonlinear S-shaped response**

Picture of the Sensor

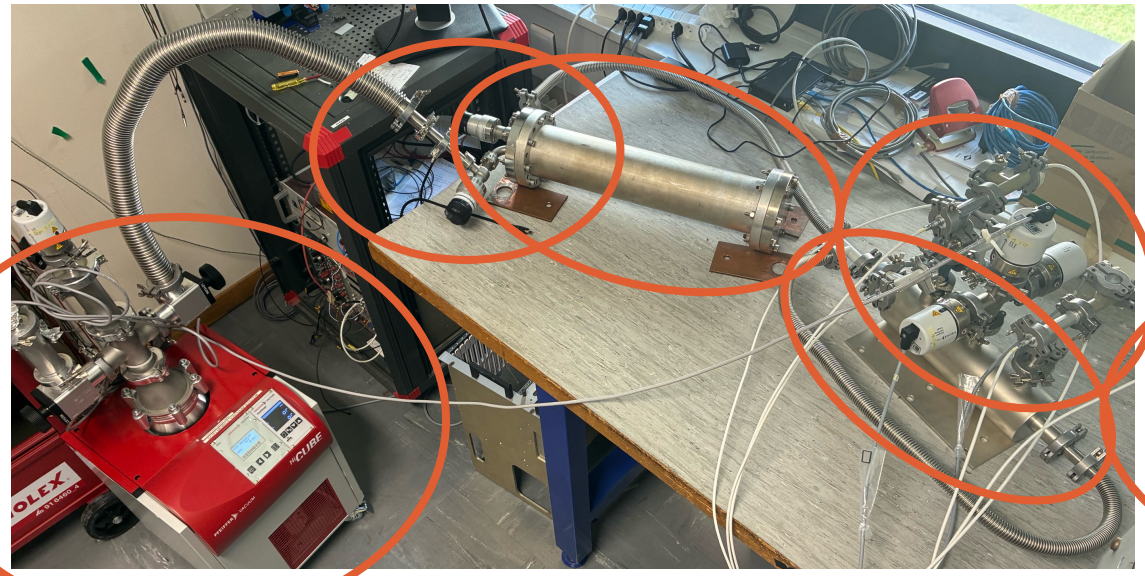


Calibration Curve according to datasheet [1]

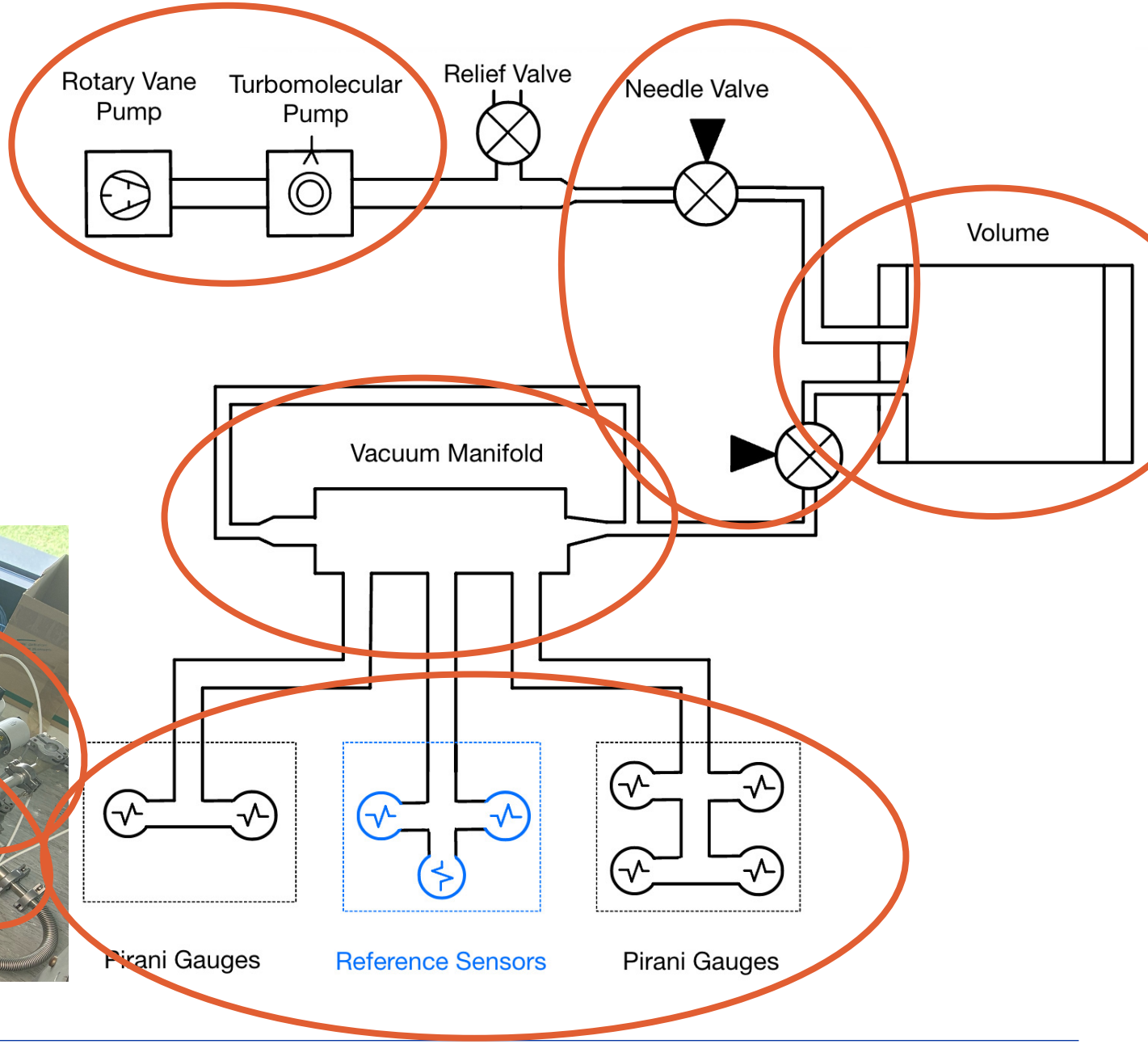
[1] Posifa Technologies. 'Datasheet_PVC3000_VaCuum_ReVC_C12'. Accessed:2025-08-15. (2021), [Online]. Available: https://posifatech.com/wp-content/uploads/2022/03/Datasheet_PVC3000_Vacuum_RevC_C12.pdf

Vacuum Setup

Cleaning Components in Ultrasonic Cleaner

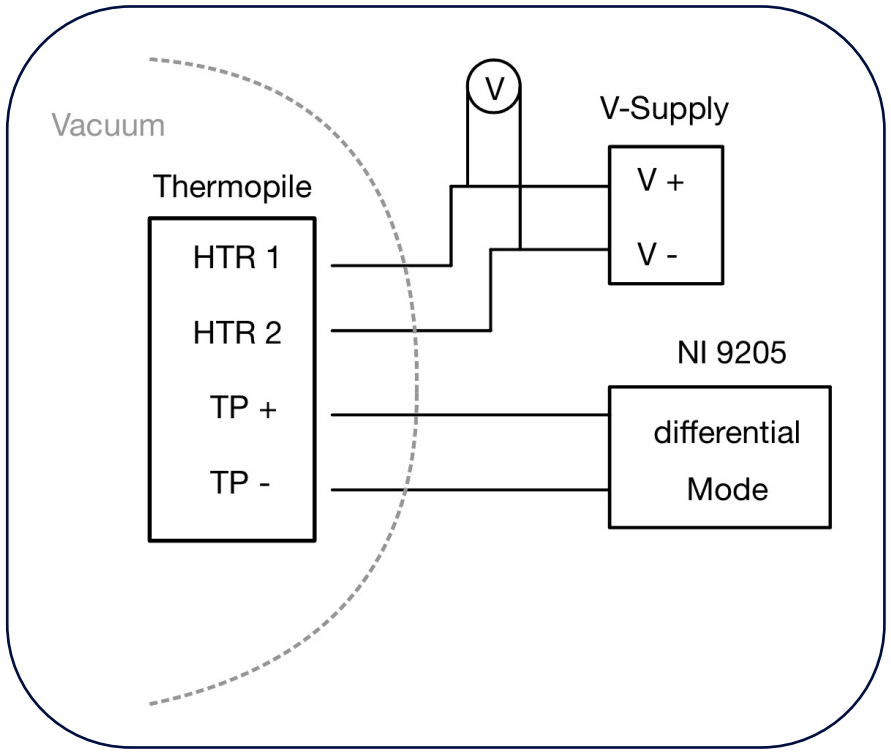


Mounted Setup



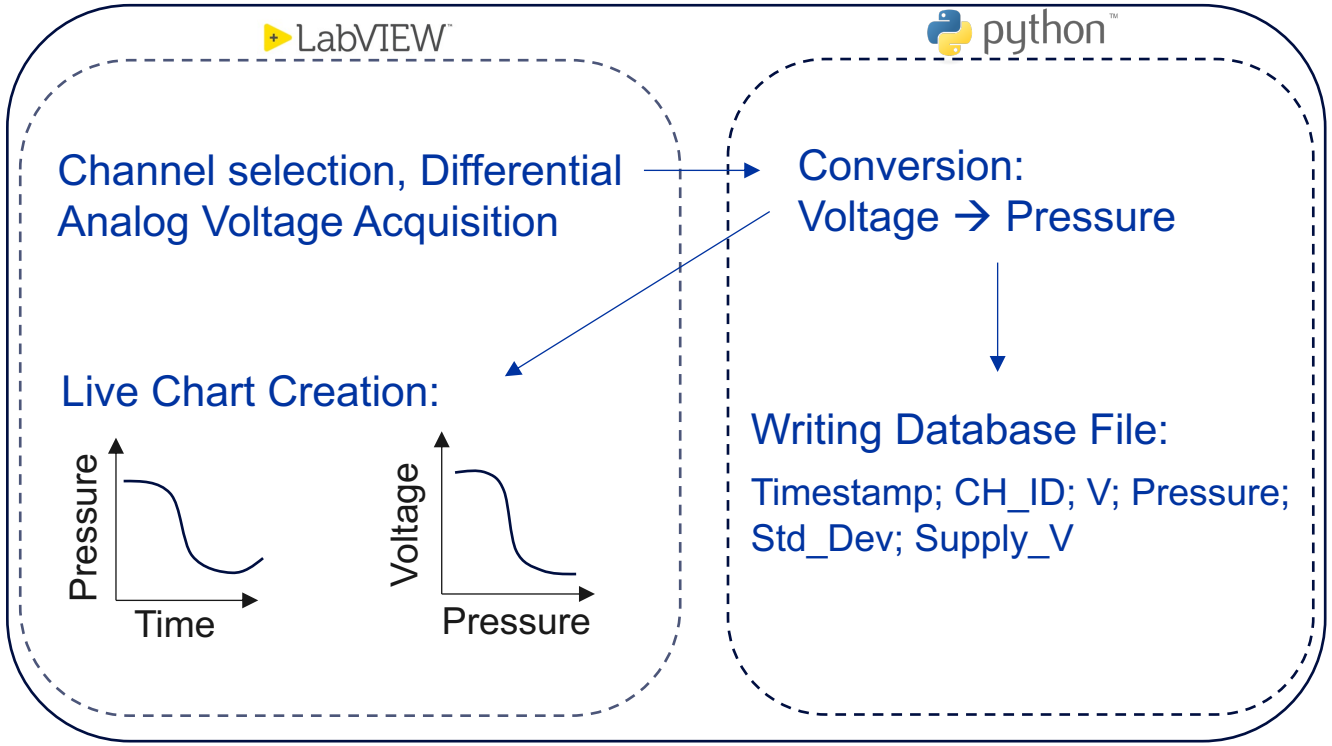
Readout System

Hardware Setup

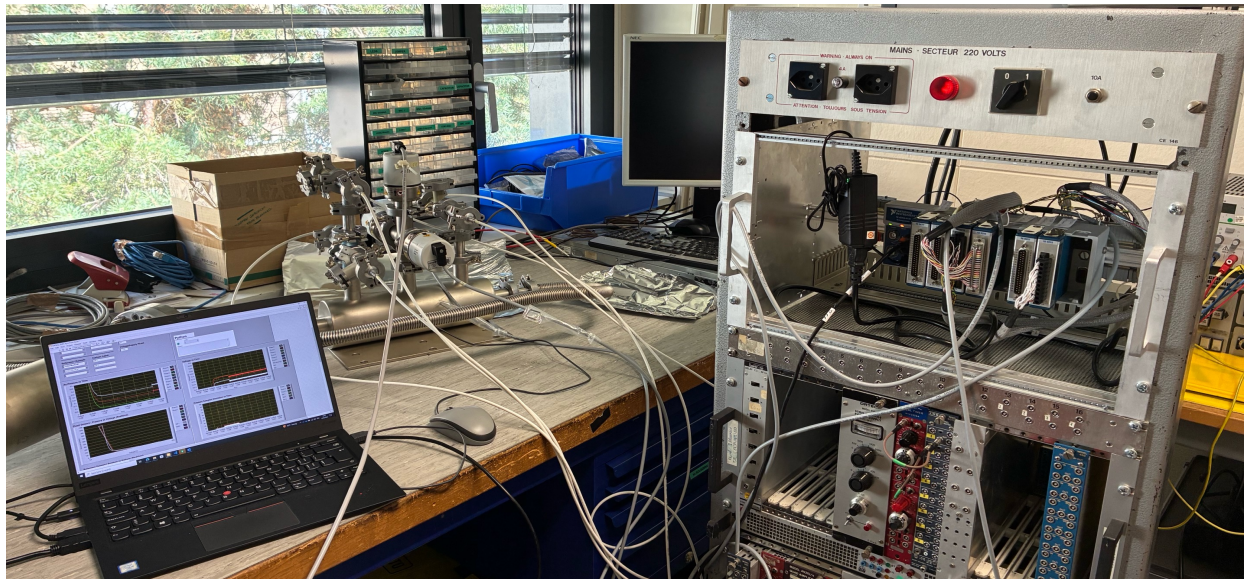


Voltage

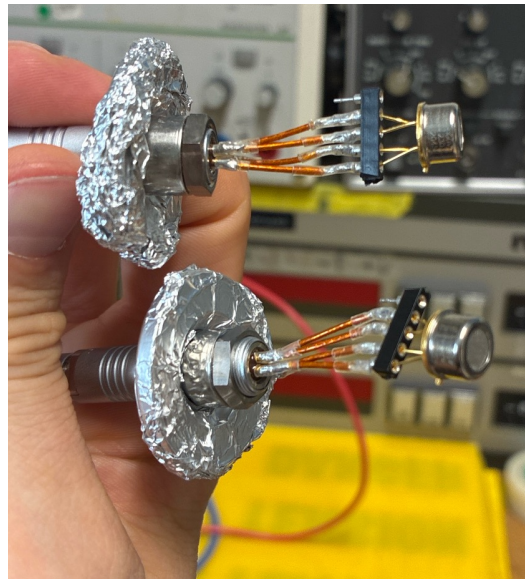
Live Monitoring and Data Saving



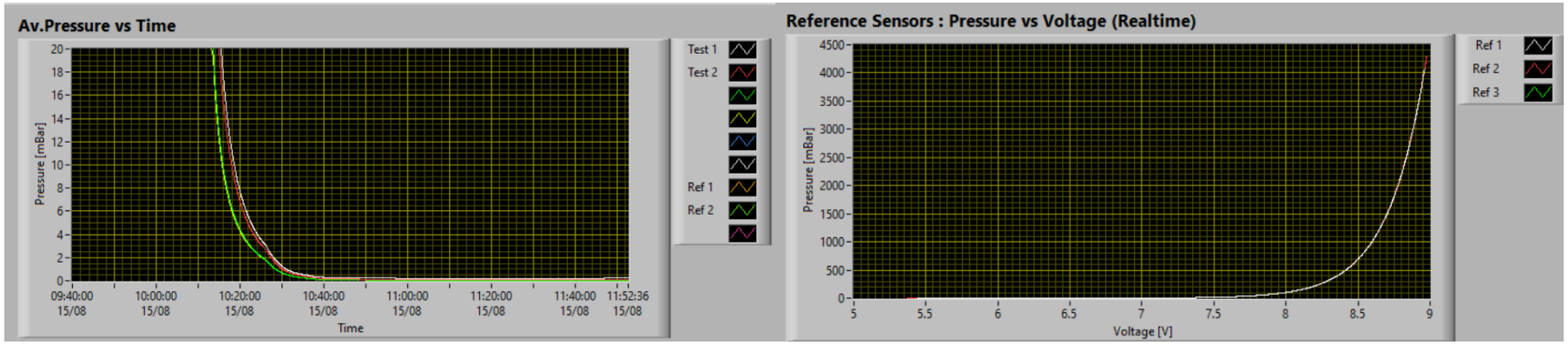
Readout System



Complete Readout System

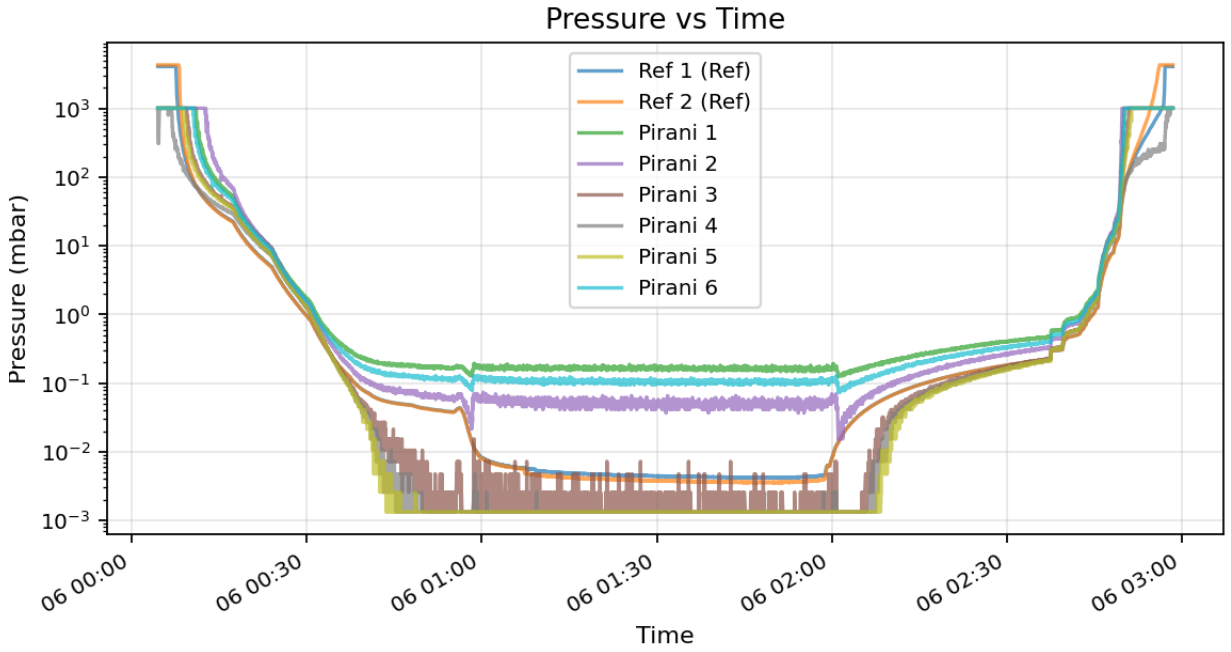


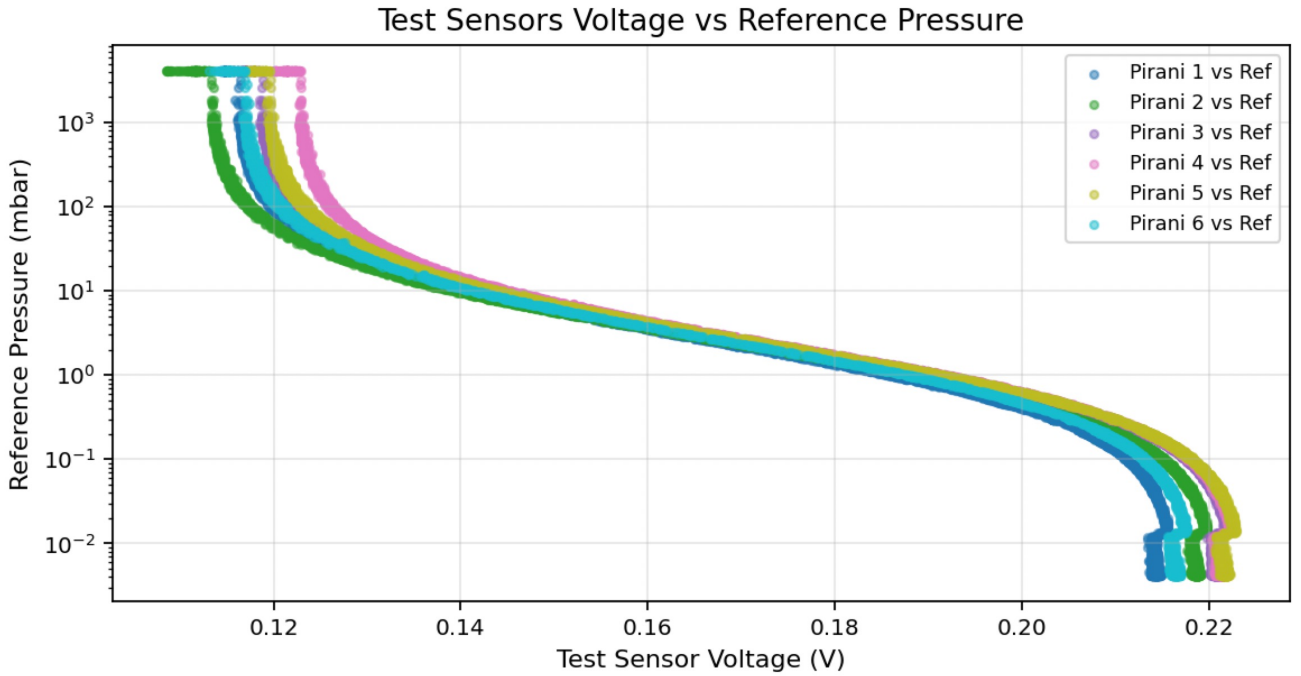
Sensor with feedthrough connector



Live Monitoring of System

Post-Processing and Analysis





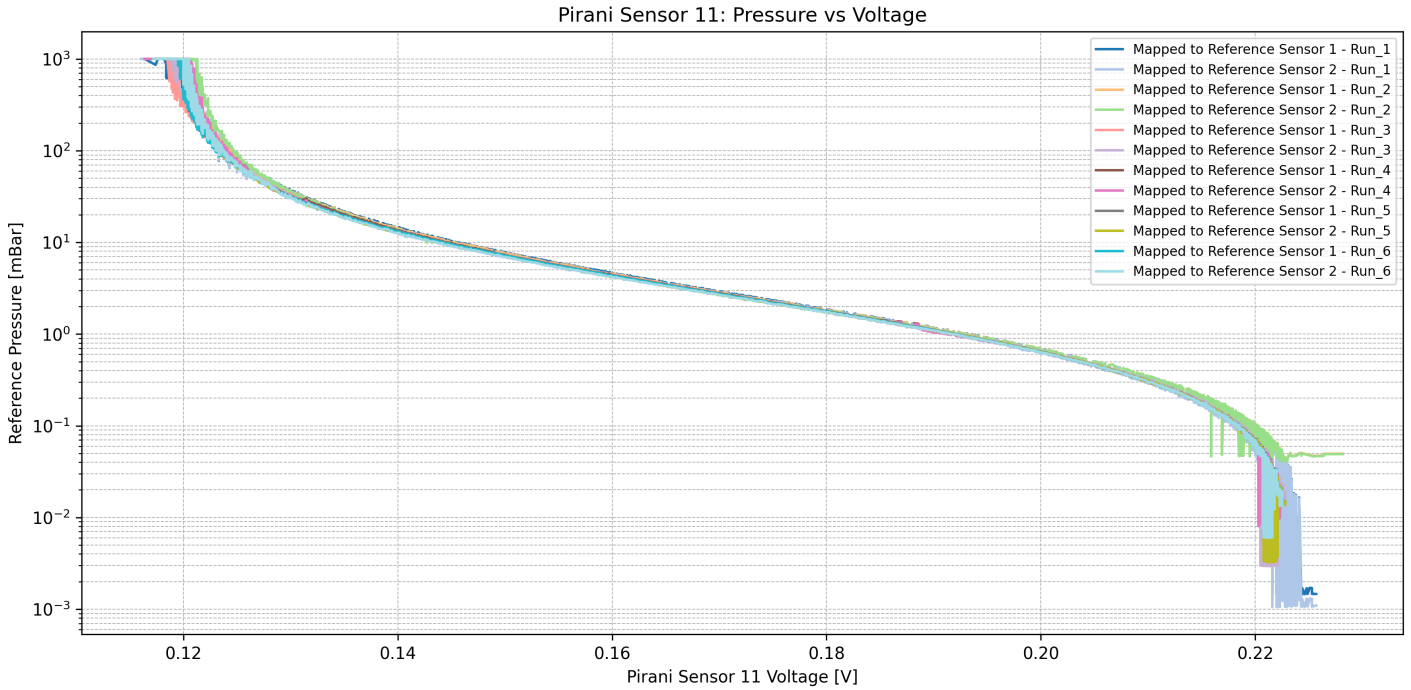
→ Conversion of Datasheet doesn't fit for all sensors

→ Each sensor has a different characteristic

→ Attempt: Try the same sensor across multiple test rounds

Characterization before Radiation

But: Sensor output is reproduceable across test runs



→ Solution: Individual calibration curves for characterization

Process Overview

Data Cleansing

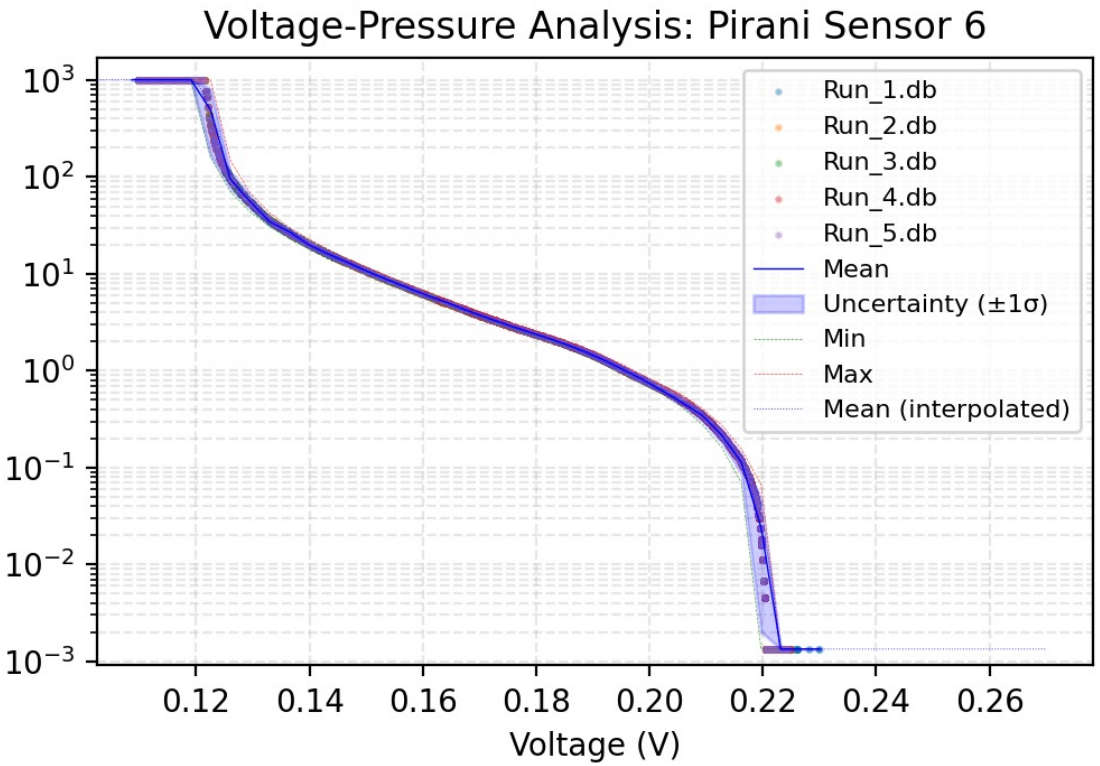
↓

Mapping: voltage output (test) → pressure values (ref)

↓

PCHIP Interpolation: Voltage → Pressure + individual Baseline creation

Characterization before Radiation



Preliminary Baseline Results

Baseline Establishment:

- Interpolation Baseline including uncertainty function
- Divided in 3 different ranges for better drift detection

Classification of radiation effects:

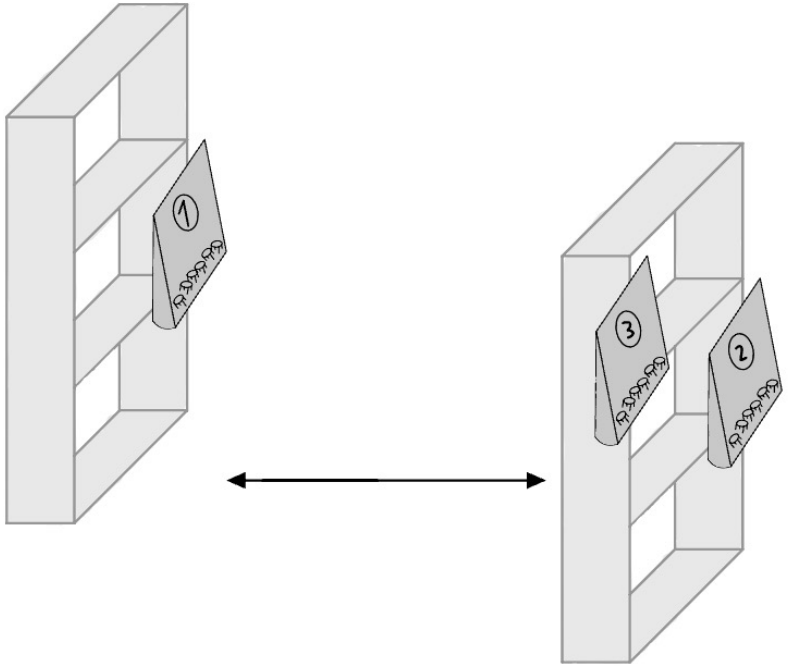
- Offset drift → consistently high or low
- Gain drift → sensitivity changes
- Non-linear drift → response curve gets warped
- Noise increase → becomes less precise
- Complete break down

Acceptance:

- No specified threshold, depends on application

Radiation Exposure in CHARM

Batches of 6 Sensors each were placed in different positions for certain radiation exposure levels



Proton beam on target simulating LHC conditions

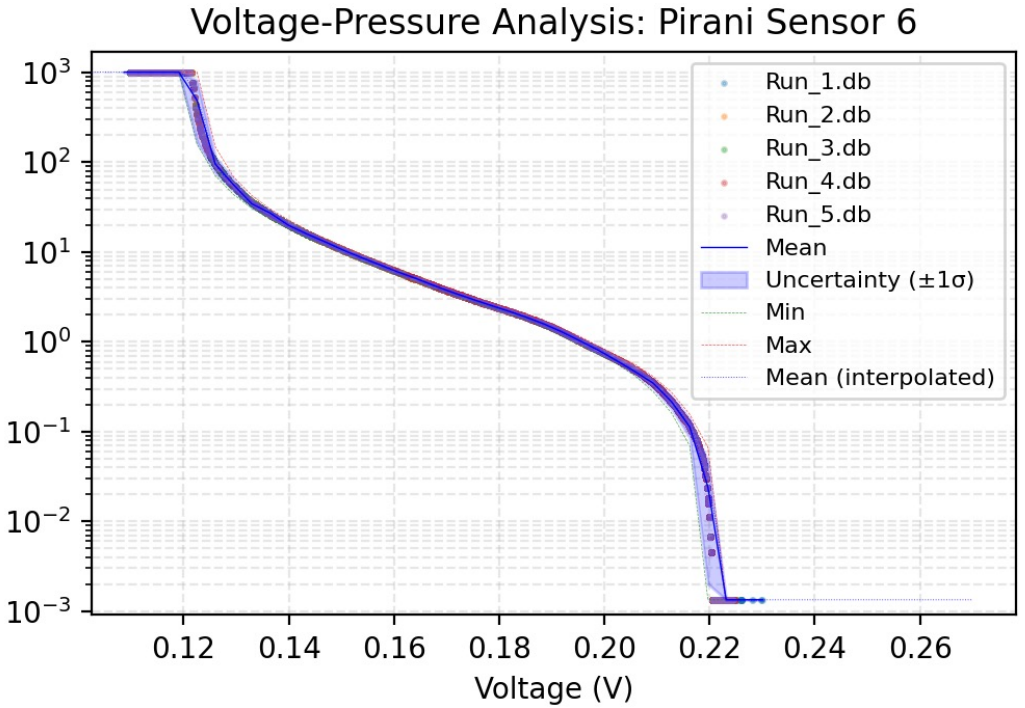
Batch	Duration	Radiation Dose
1	1 week	~ 30 Gy
2	1 week	~ 500 Gy
3	3 weeks	~1500 Gy
4	10 weeks	~5000 Gy

Batch 1 positioned at a distance to the proton beam

Current Progress & Preliminary Results

Current state

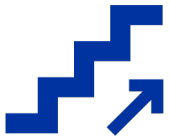
Build test setup → Baseline characterization → Controlled irradiation → Evaluate radiation effects



Preliminary Baseline Results

Irradiated Sensors waiting for clearance

Outlook



Next steps:

- Evaluation of irradiated sensors
- Standardized Framework

Future Tasks:

- Improved vacuum setup
- Expand readout to other types of sensors
- Automatization of evaluation process
- Irradiate 4th batch with higher radiation dose

Thanks!

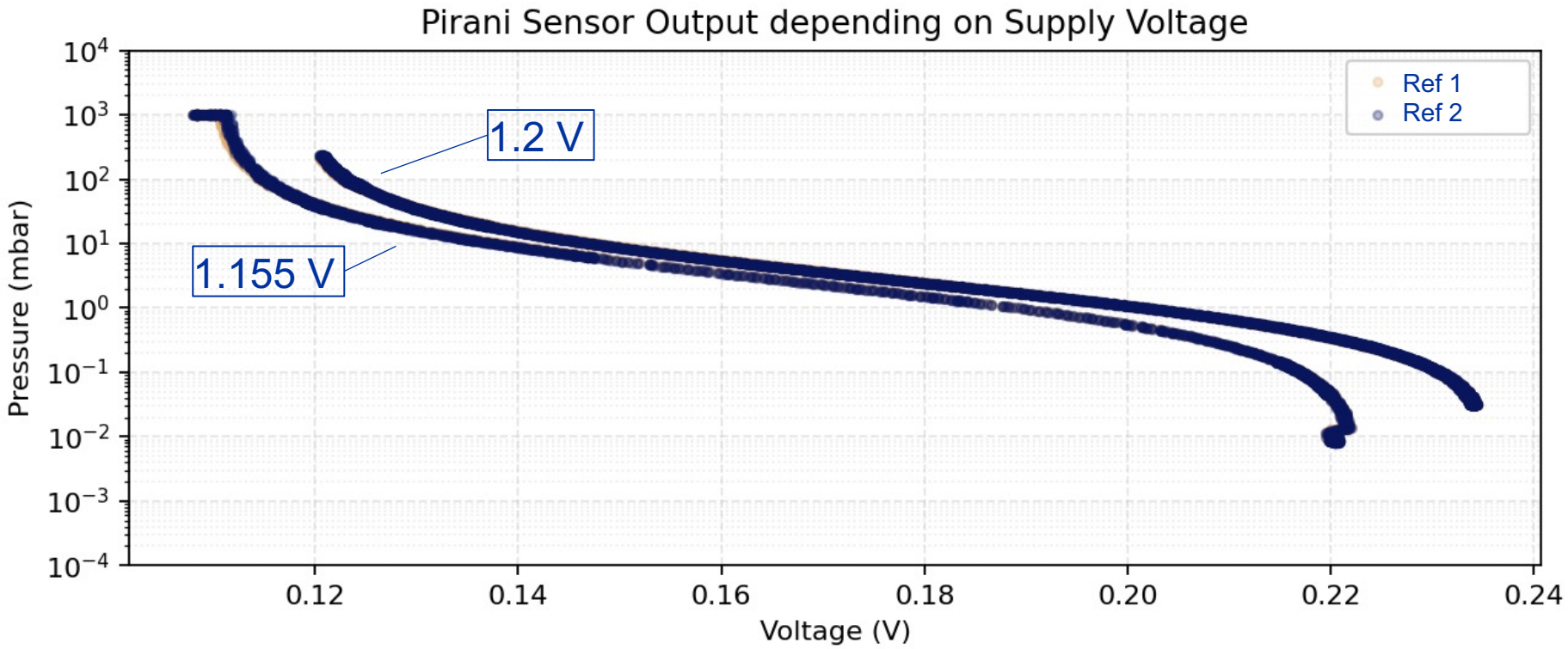
Especially to my supervisors and contributors:

Sune Jakobsen (EP-DT-TP)
Valentina Reynaud (EP-DT-DI)
Maciej Ostrega (EP-DT-DI)
Xavier Pons (EP-DT-DI)
Miranda Van Stenis (EP-DT-EF)
Marc Carrichon and Bayram Dinger (EP-DT-DI Workshop)
Wil Vollenberg (TE-VSC-SCC)

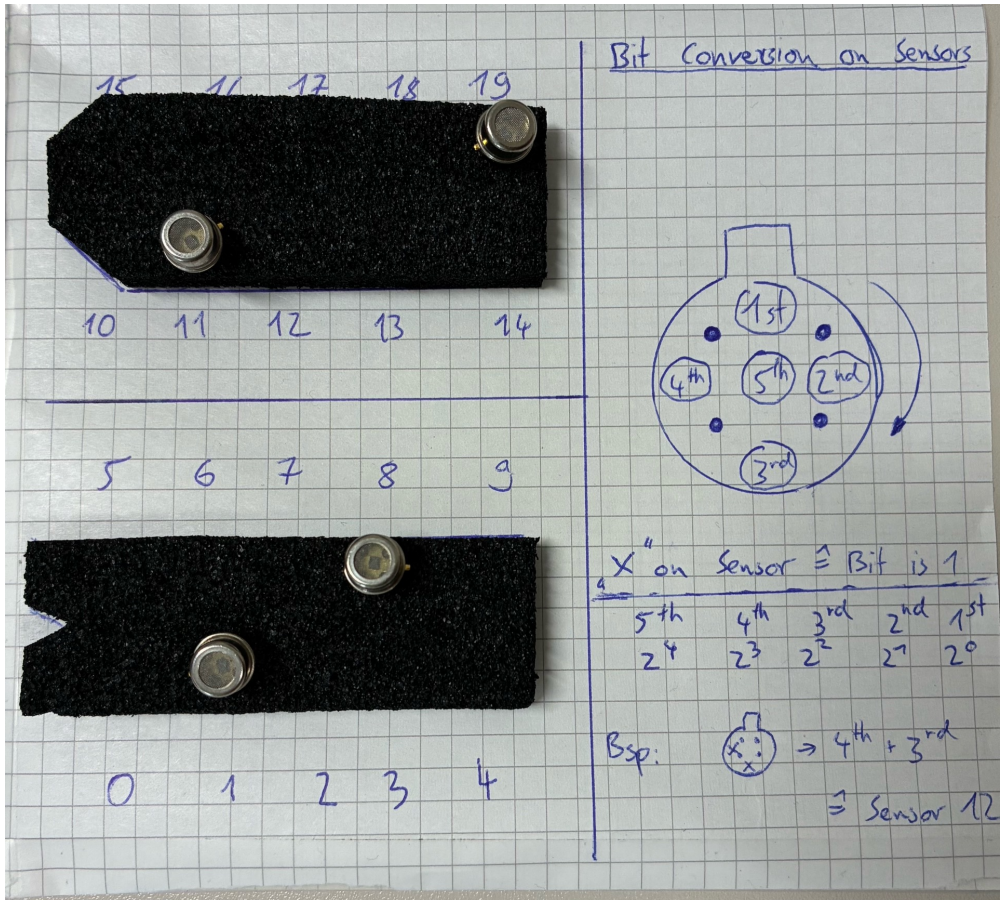
home.cern

Backup Slides

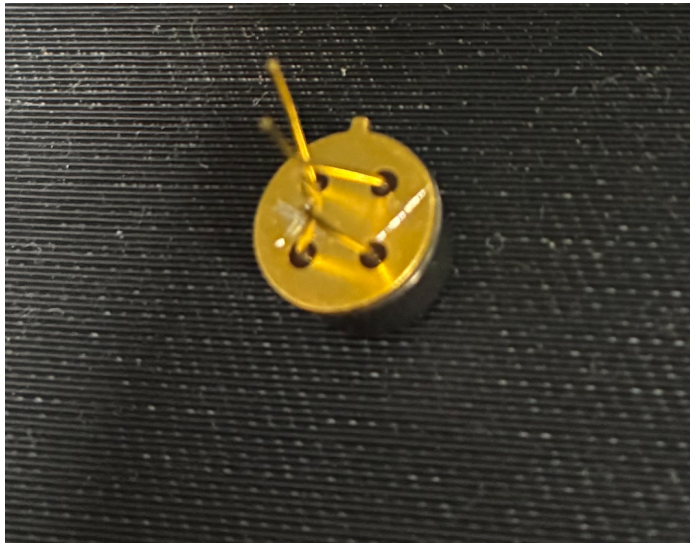
Supply Voltage Dependence



Sensor Identification



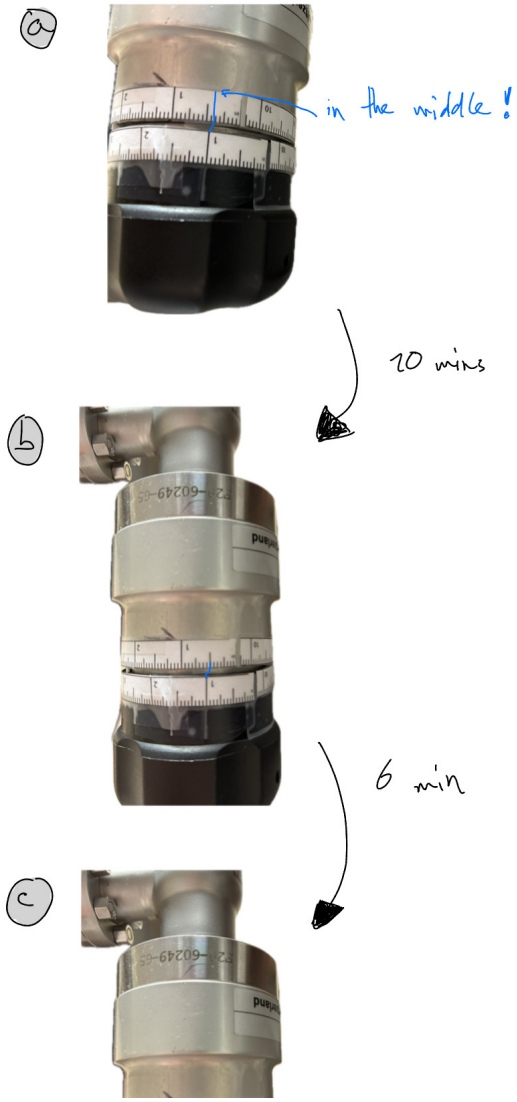
Dedicated Sensor Positions and Explanation of Marking



Binary Marking on Sensor

Needle Valve Settings

Attached Scale on Needle Valve



Excerpt of the Settings for Test Rounds