Temperature Regulation of the MEG II Detector Hut

Patrick Schwendimann

Paul Scherrer Institut

LTP Seminar
Monday, 20.5.2019

Overview

The MEG II Goal

Search for the charged lepton flavour violating decay

$$\mu \to e\gamma$$

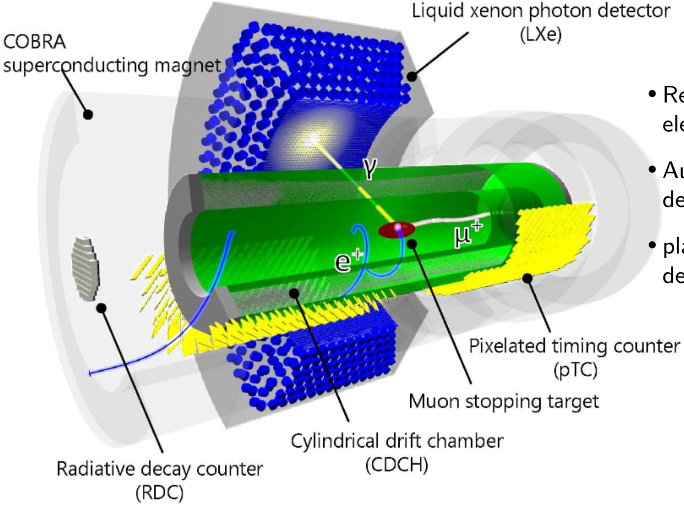
with a sensitivity to the branching ratio of

$$BR(\mu \to e\gamma) < 6 \cdot 10^{-14}$$

Improve the current best result by an order of magnitude.
$(BR(\mu \to e\gamma) < 4.2 \cdot 10^{-13}$, MEG)

A. M. Baldini et al. (MEG II Collaboration): *The design of the MEG II experiment*, Eur. Phys. J. C 78, 380 (2018)
A. M. Baldini et al. (MEG Collaboration): *Search for the lepton flavour violating decay $\mu^+ \to e^+\gamma$ with the full dataset of the MEG experiment*, Eur. Phys. J. C 76, 434 (2016)

The MEG II Setup

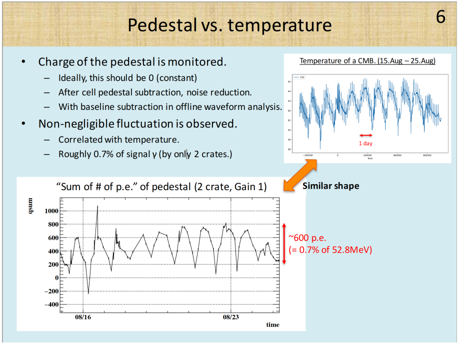


- Readout electronics
- Auxiliary devices
- placed in the detector hut

A. M. Baldini et al. (MEG II Collaboration): *The design of the MEG II experiment*, Eur. Phys. J. C 78, 380 (2018)

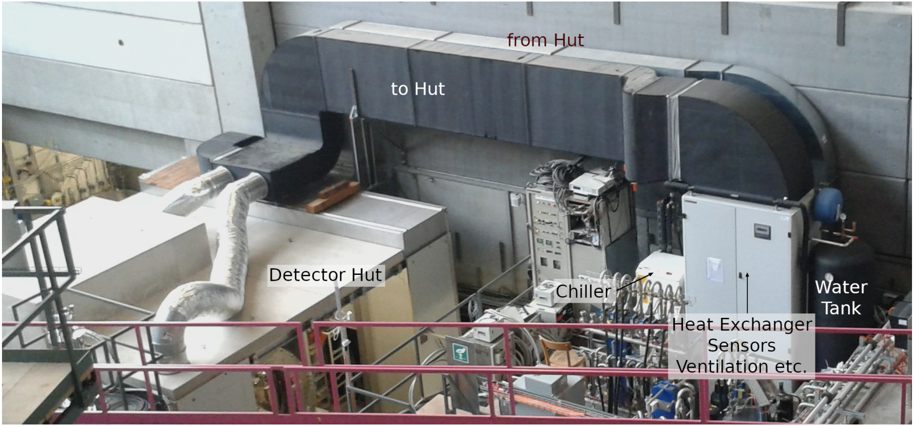
Temperature Fluctuations

From Shinji Ogawa's talk on 6.Sept.2018:

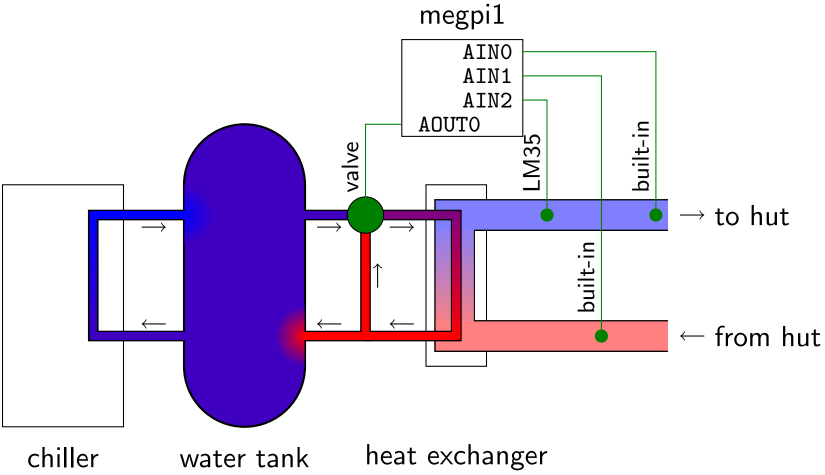


Temperature fluctuations cause fluctuations in the XEC pedestal.
Chiller on its own causes temperature fluctuations.
⇒ Need to regulate the cooling

Cooling System



Schematic Representation



PID-Control

In General

Tune the controlled variable according to three terms:

$$v = \underbrace{k_p \Delta T}_{\text{P}} + \underbrace{k_i \sum_n \Delta T_n}_{\text{I}} + \underbrace{k_d \frac{d\Delta T}{dt}}_{\text{D}} \quad (1)$$

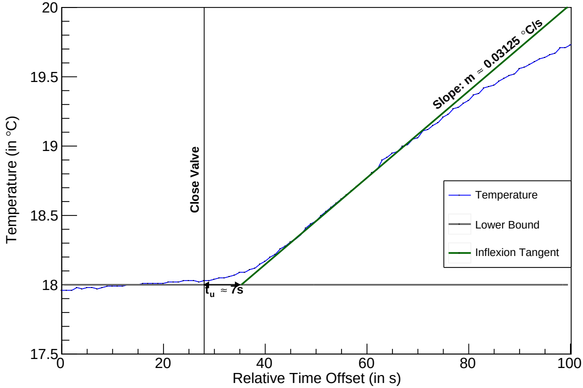
For the Hut Temperature Control

Use two connected PID controls:

- Control 1: adjust cooling water flow, regulate cold air temperature
  cancel chiller effects
- Control 2: adjust cold air temperature, regulate hut temperature
  cancel other slow effects

Parameter Estimation

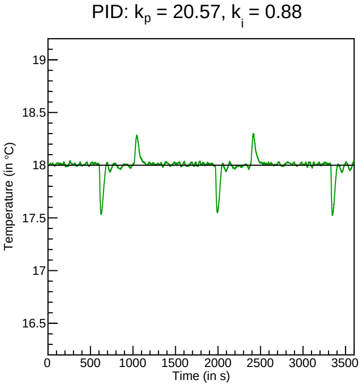
Nichols-Ziegler method: Consider pulse response to estimate k_p, k_i

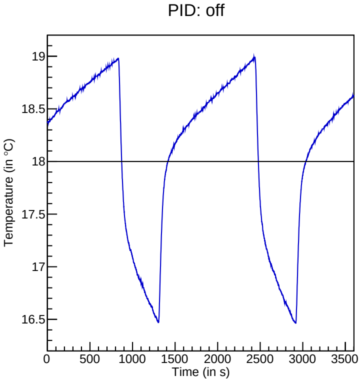


$$k_p = 0.9 \frac{1}{t_u m} \cdot 5 = 20.57 \, \frac{1}{°\mathrm{C}} \qquad k_i = 0.27 \frac{1}{t_u^2 m} \cdot 5 = 0.88 \, \frac{1}{°\mathrm{C\,s}}$$

Effect

- Run as PI control by setting the differential constant to 0.





- Stabilises temperature clearly. Deviations depend on cooling needed.
- Spikes remain as PI control reacts on deviations.

Additional Aspects

- Written in C++ running on Raspberry Pi
- Keeps history of temperatures and valve positions set
  - Use massive array in memory
  - Overwrite oldest entries when array fully filled
  - Write to files
- Writes configuration to file
  - resume last state when restarted
- Running lightweight web server in parallel
  - Accessible from PSI internal net
  - Monitor status and history
  - Switch control on/off
  - Adjust parameters
  - Download history log files

Default Interface

Monitoring only

Temperature

Air feed (built in)	17.43 °C
Air feed (LM35)	18 °C
Hut return (built in)	20.68 °C

Valve

Value (0...100): 67.91

Air Control

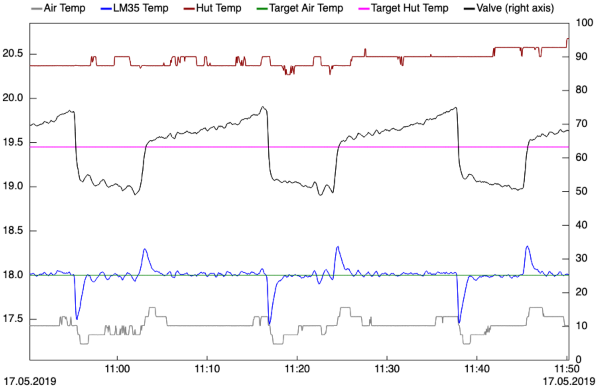
Status:	Active
Temp. requested:	18 °C

Hut Control

Status:	inactive
Temp. requested:	19.45 °C

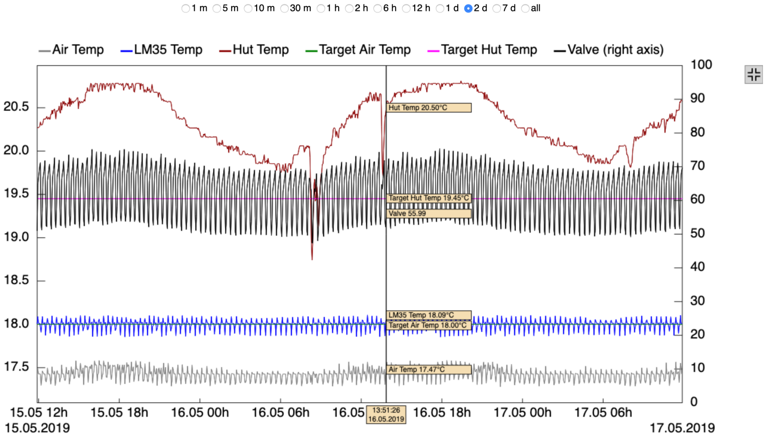
History

○ 1 m ○ 10 m ◉ 1 h ○ 6 h ○ 1 d ○ all



History Interface

Display History in Full Screen



- Mouse over canvas displays values at x-position of mouse.
- Click and drag to zoom, single-click to unzoom.

User Interface

Turn on/off, Temperature Adjustment

Temperature
Air feed (built in) 17.43 °C
Air feed (LM35) 18.03 °C
Hut return (built in) 20.57 °C

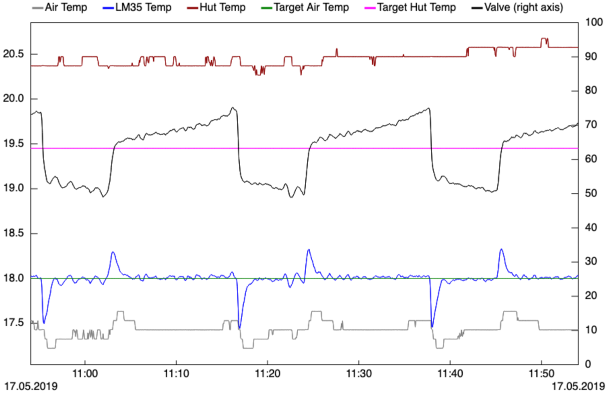
Valve
Value (0...100): 70.6

Air Control
Status: Active
Temp. requested: 18 °C

Hut Control
Status: inactive
Temp. requested: 19.45 °C

Settings
Set Hut Temperature:
0 Set
Overall PID control:
Activate Deactivate

History
1 m 10 m 1 h 6 h 1 d all



Expert Interface

Access to (almost) all parameters

With great power comes great responsibility.
DO NOT TOUCH ... unless you know what you do.

Temperature

Air feed (built in) 17.43 °C
Air feed (LM35) 18.03 °C
Hut return (built in) 20.57 °C

Valve

Value (0...100): 71.24
Set by Air control

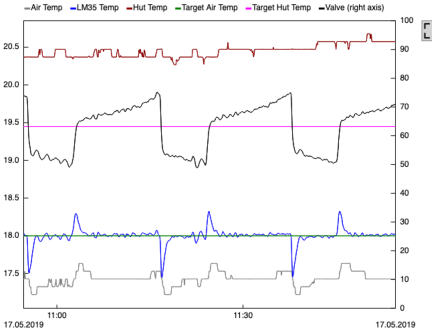
PID Controls

	Air			Hut		
Read:	LM35	To built in		built in		
Status	Active	Air Off		inactive	Hut On	
T_req	18	0	Set	19.45	0	Set
P	20.57	20.57	Set	5	5	Set
I	0.88	0.88	Set	0.01	0.01	Set
D	0	0	Set	0	0	Set

SetPID

History

1 m 10 m 1 h 6 h 1 d all



Status and Next Steps

Current Status

- Hardware and Software is ready
- Air feed control tuned and running stable

Next Steps

- Tune hut temperature control under final conditions
- Prepare MIDAS/ODB interface

Conclusion

- Short, sharp deviations from the chiller have no longer an effect on the hut temperature.
- Raspberry Pi provides huge flexibility and is running smoothly.

Final Words

Acknowledgements

Many thanks to ...

... **Stefan Ritt** for the instructions at the beginning and his feedback

... **Ueli Hartmann** for the engineering of the LM35 temperature sensor

... **Angela Papa** for her feedback

Try it yourself

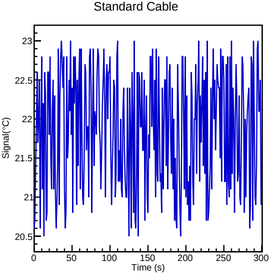
The server is accessible under: `http://megpi1.psi.ch:8080/`

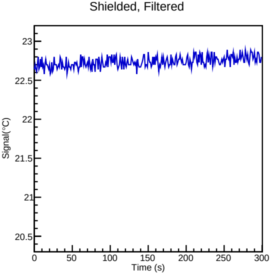
On the history canvas:

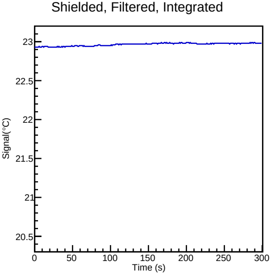
- mouse over (touch): display exact values at a given point
- click and drag (touch and drag below axis): zoom in
- single click (single touch below axis): zoom out

Contact me if you want something similar for your experiment.

The LM35 Temperature Sensor







- Connected with 3 twisted wires
- 1 readout per point

- shielded cable
- hardware filters
- 1 readout per point

- shielded cable
- hardware filters
- average over 10k readouts per point

Special thanks to Ueli Hartmann for the design and production of the shielded cable and the hardware filters!