Status Update on the VMM3

Investigation of the Cooling Requirements

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RD51 Mini Week, 14 DEC 2017

Motivation of the “VMM cooling project”

Motivation

- Manual: “[…] cooling of the VMM chips is mandatory.”

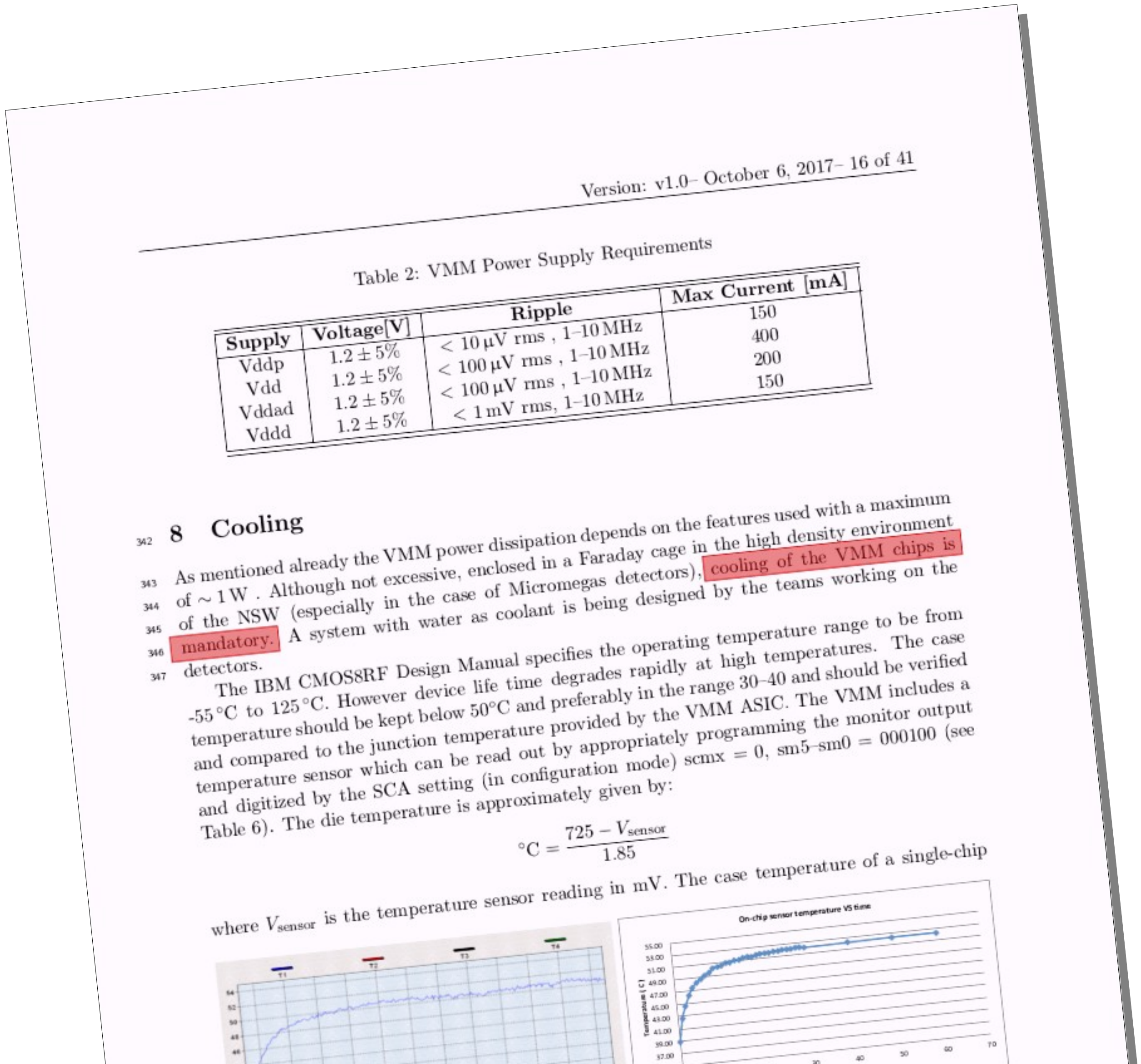

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Table 2: VMM Power Supply Requirements

Supply	Voltage[V]	Ripple	Max Current [mA]
Vddp	$1.2 \pm 5\%$	$< 10\,\mu$V rms , 1–10 MHz	150
Vdd	$1.2 \pm 5\%$	$< 100\,\mu$V rms , 1–10 MHz	400
Vddad	$1.2 \pm 5\%$	$< 100\,\mu$V rms , 1–10 MHz	200
Vddd	$1.2 \pm 5\%$	< 1 mV rms, 1–10 MHz	150

342 8 Cooling

343 As mentioned already the VMM power dissipation depends on the features used with a maximum
344 of ~ 1 W . Although not excessive, enclosed in a Faraday cage in the high density environment
345 of the NSW (especially in the case of Micromegas detectors), cooling of the VMM chips is
346 mandatory. A system with water as coolant is being designed by the teams working on the
347 detectors.

The IBM CMOS8RF Design Manual specifies the operating temperature range to be from -55 °C to 125 °C. However device life time degrades rapidly at high temperatures. The case temperature should be kept below 50°C and preferably in the range 30–40 and should be verified and compared to the junction temperature provided by the VMM ASIC. The VMM includes a temperature sensor which can be read out by appropriately programming the monitor output and digitized by the SCA setting (in configuration mode) scmx = 0, sm5–sm0 = 000100 (see Table 6). The die temperature is approximately given by:

$$°C = \frac{725 - V_{sensor}}{1.85}$$

where V_{sensor} is the temperature sensor reading in mV. The case temperature of a single-chip

Motivation

- Manual: “[…] cooling of the VMM chips is mandatory.”
- ATLAS uses water cooling
- GDD/ESS/RD51: Other kind of implementation

  → VMM still consumes about 2 W of power

Is water/active cooling required? Is passive cooling sufficient?

- Investigate performance of the VMM depending on the temperature

  → Create test set-up and perform measurements
- Why this effort?

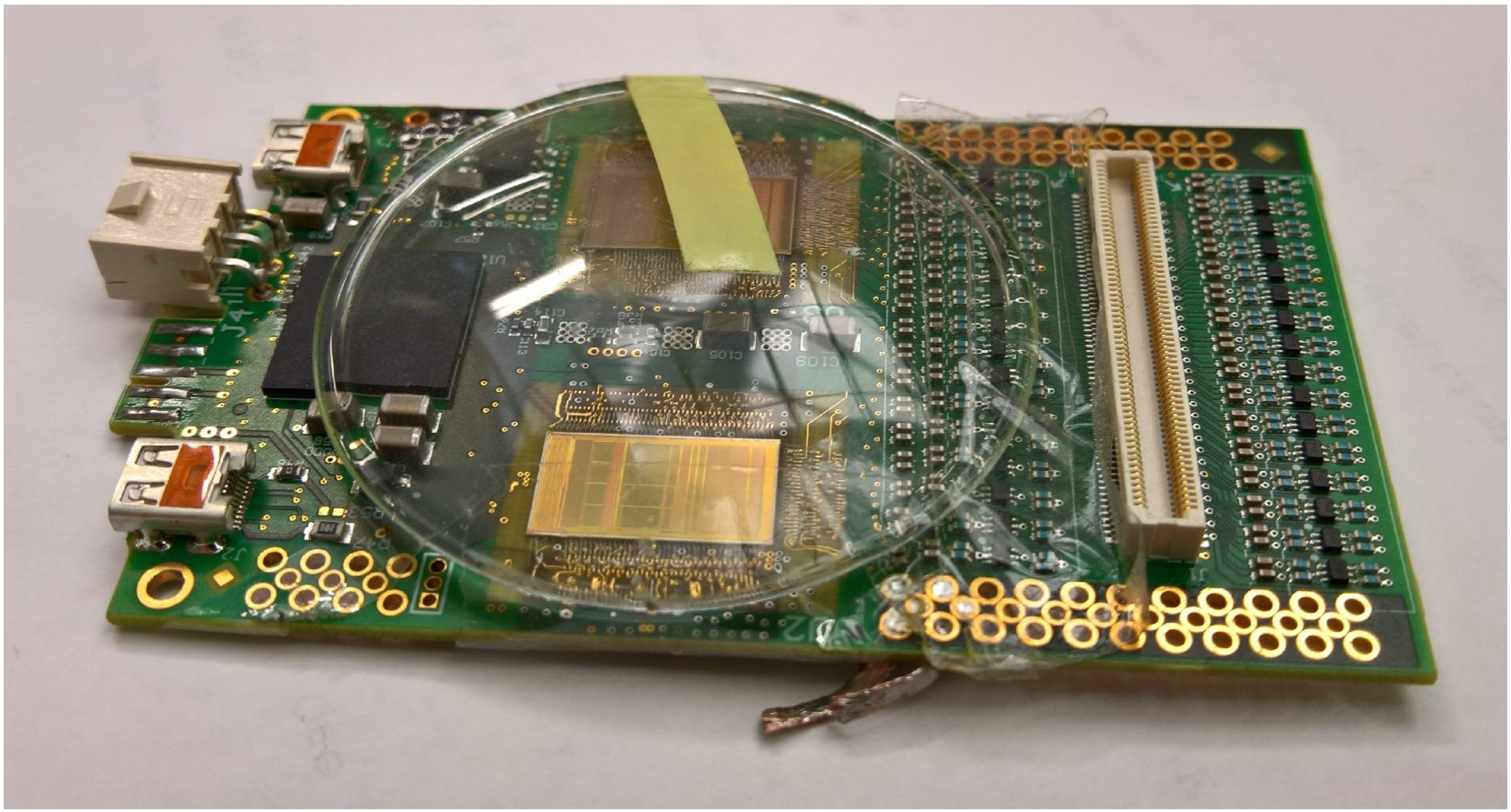
  → NMX Experiment has movable detectors

  → Neutrons scatter on hydrogen

  → Passive much simpler; easier to adapt for others

GDD/ESS/RD51 Implementation

- Replace APV25 cards with VMM hybrid:

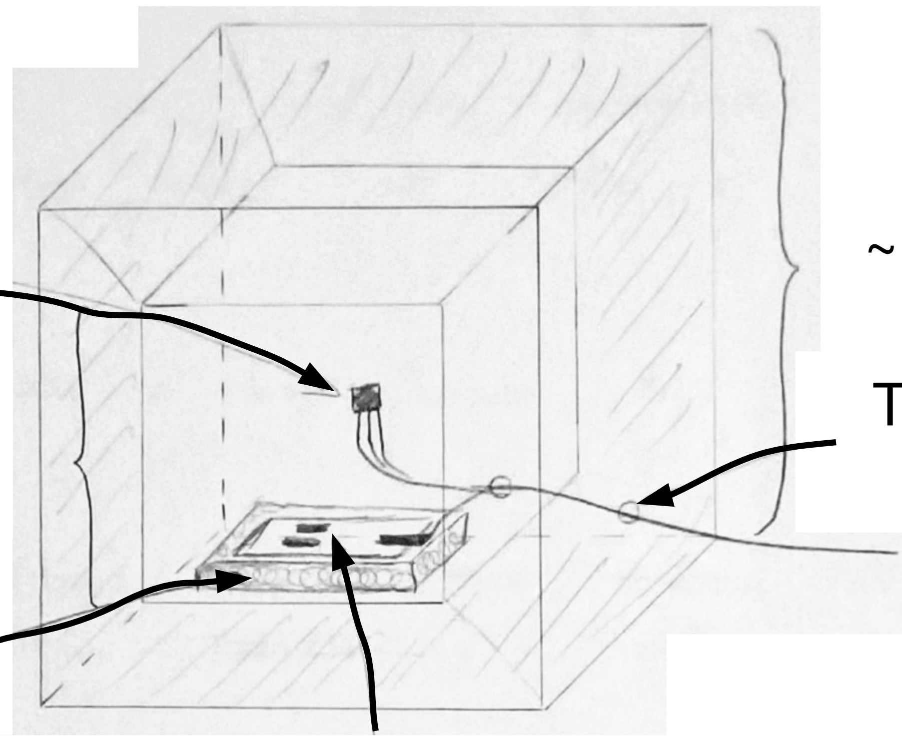


- For more details: See talks from Michael and Hans
- Build test set-up for hybrids

Design & Assembly of the Test Set-Up

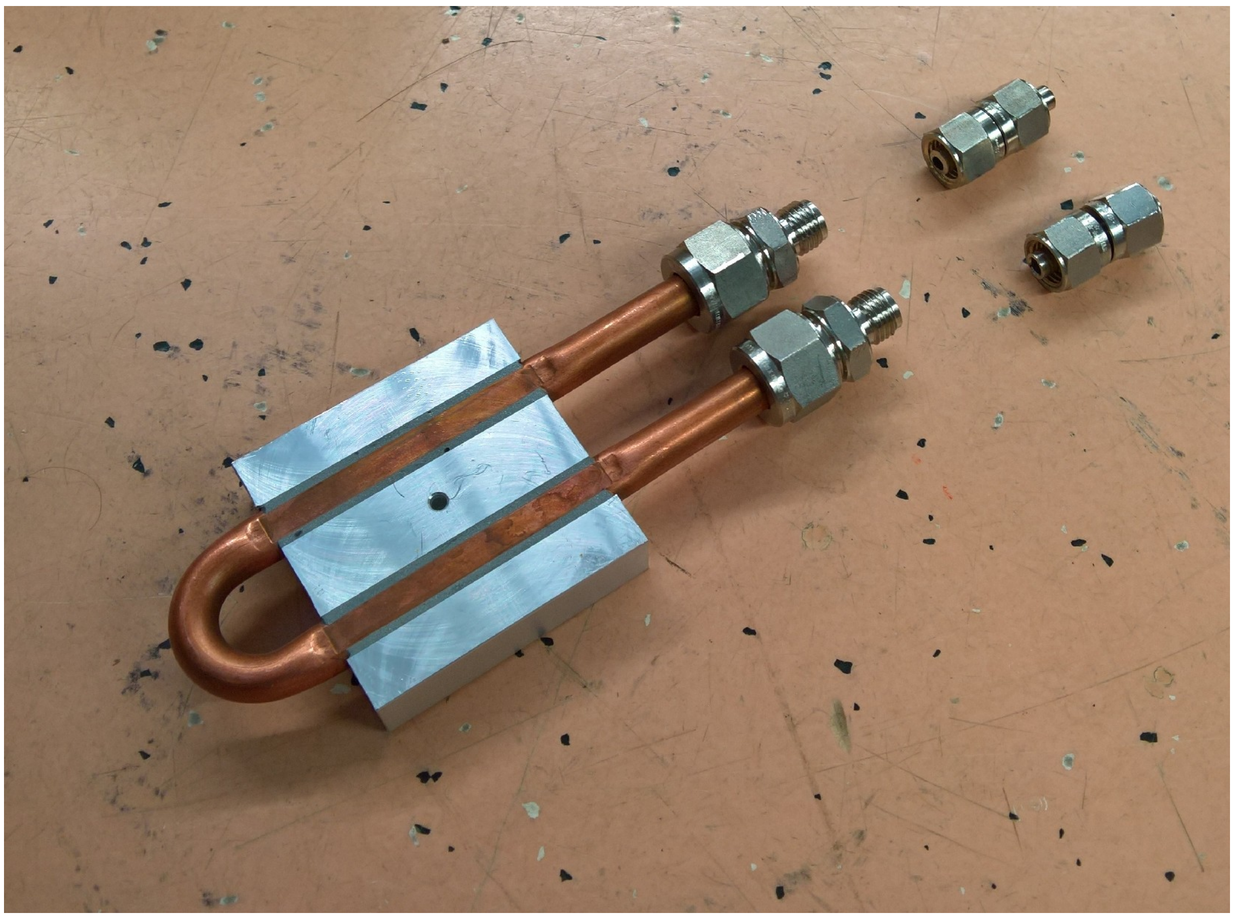
Design of the Test Set-Up

- First attempt...



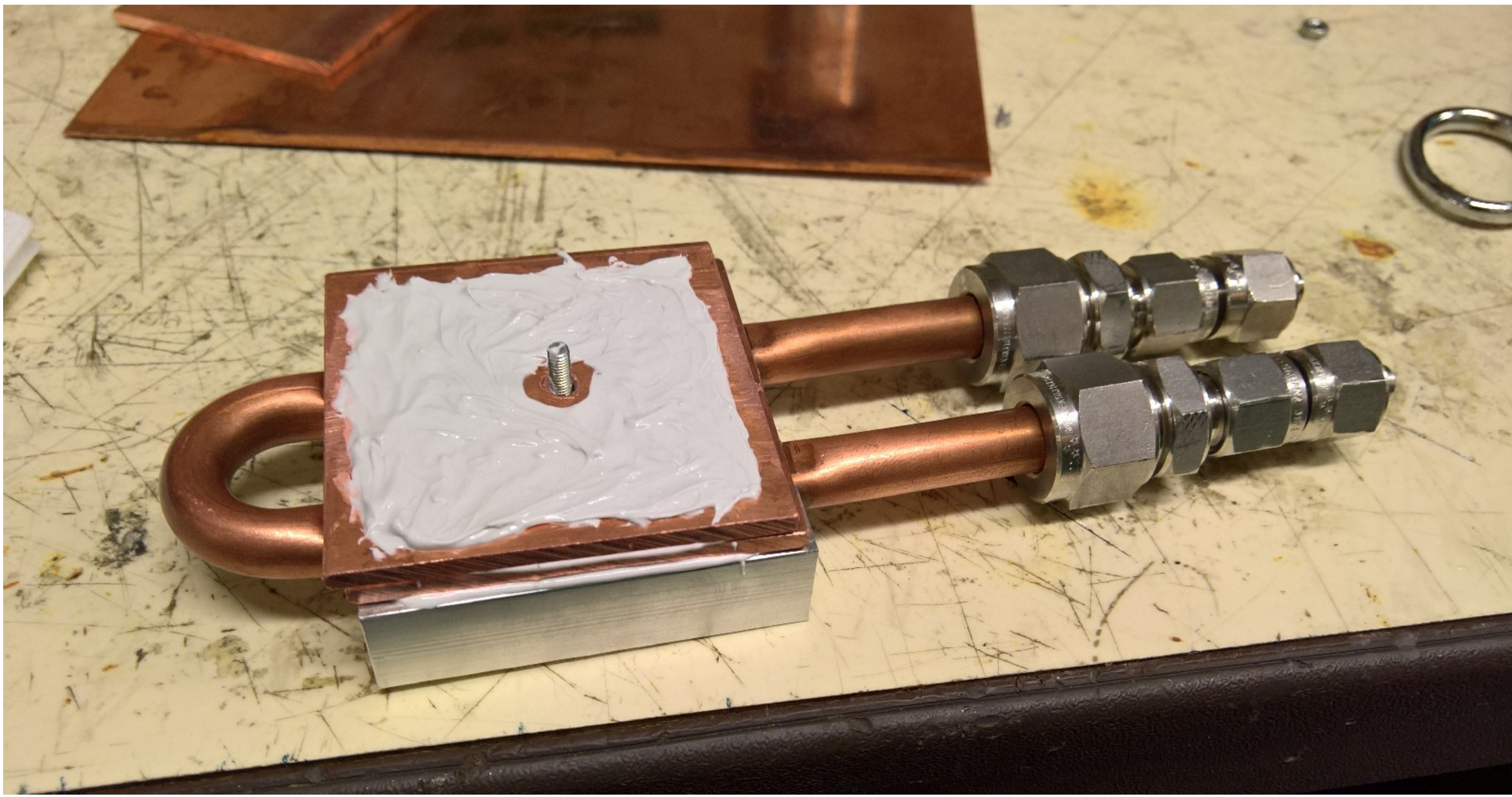
Assembly Process

- Key component: Aavid Hi-Contact™ 2-Pass Cold Plate
- In combination with: Julabo FN25-ED



Assembly Process

- For test set-up a good heat distribution is needed
  → Use copper plates and thermally conductive paste



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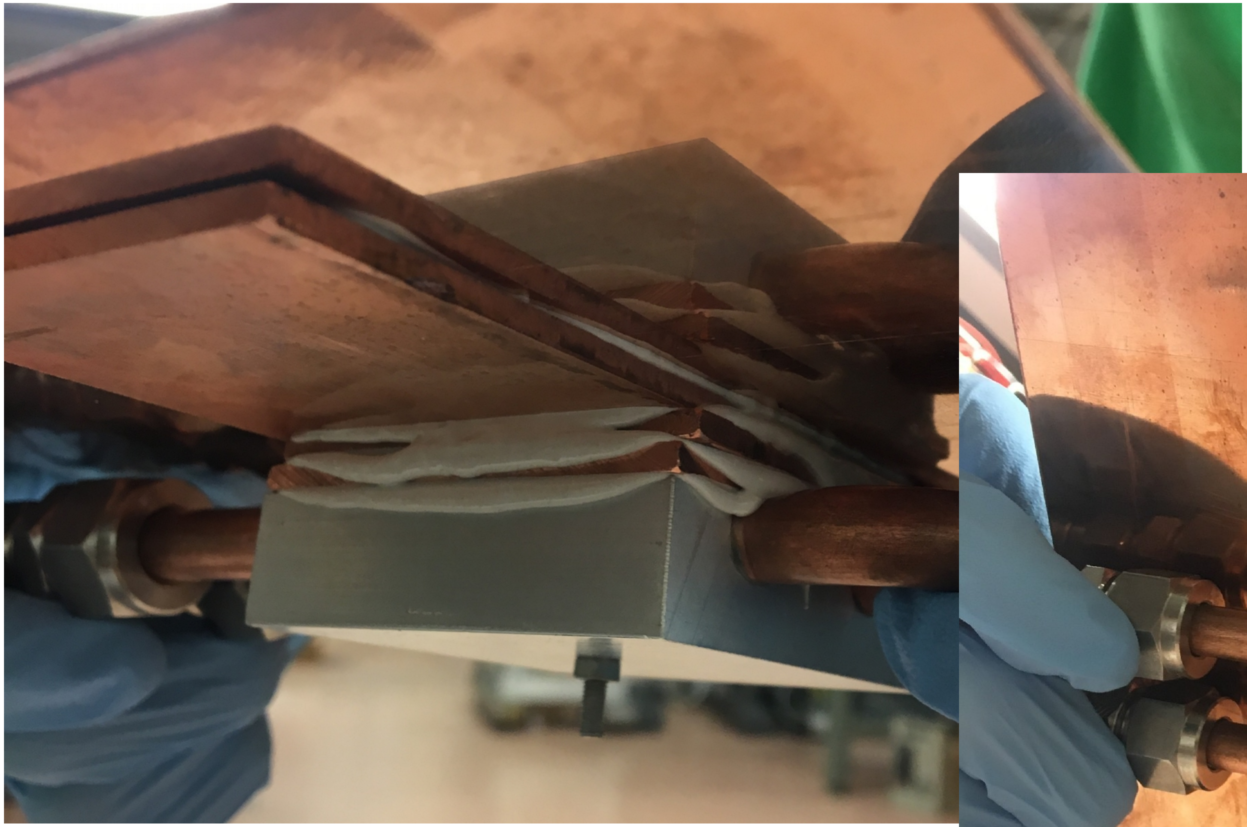
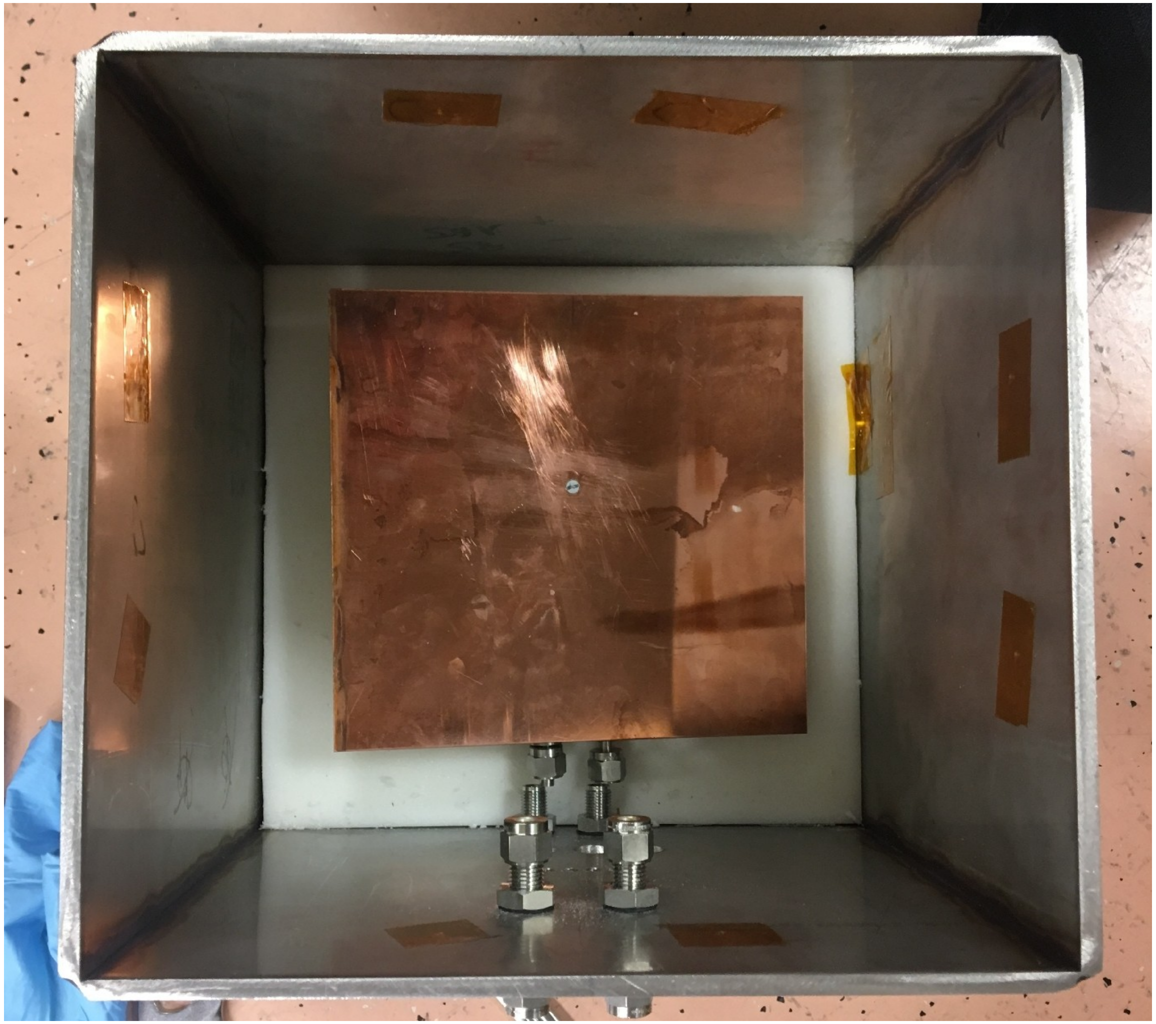


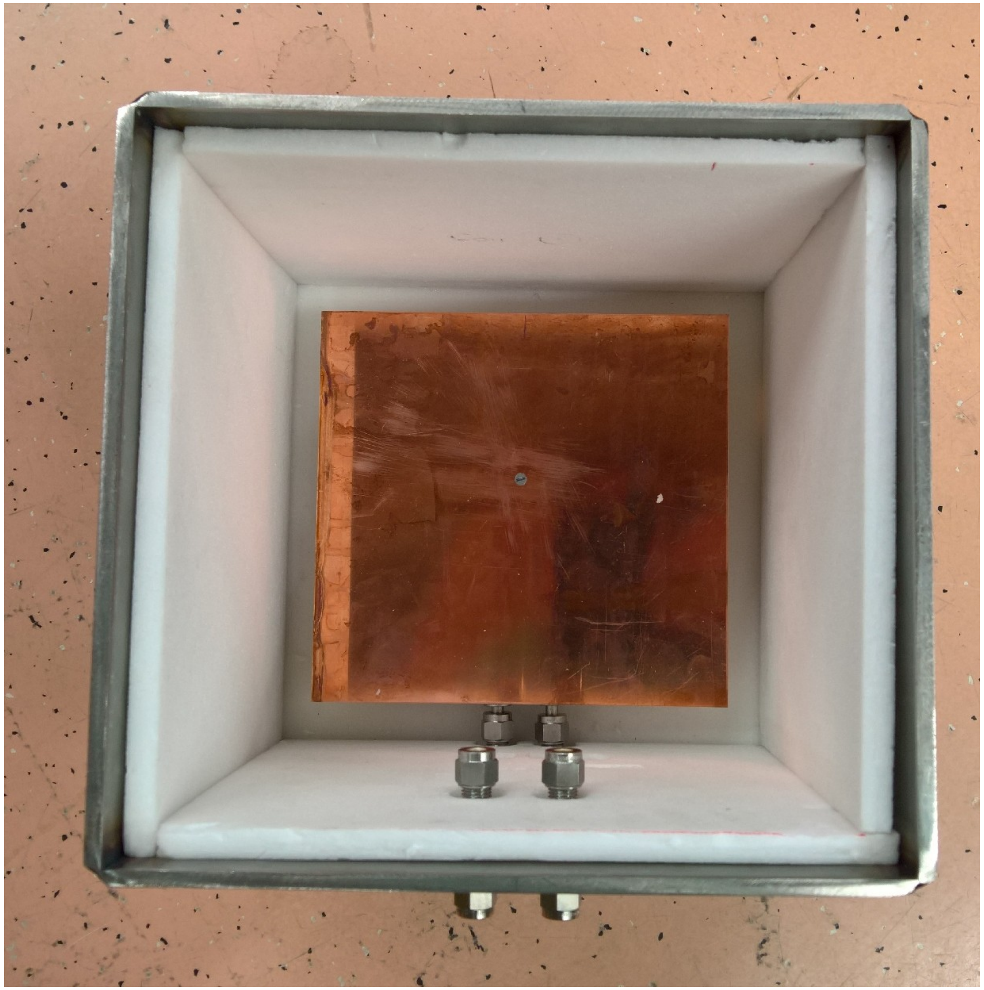
Assembly Process

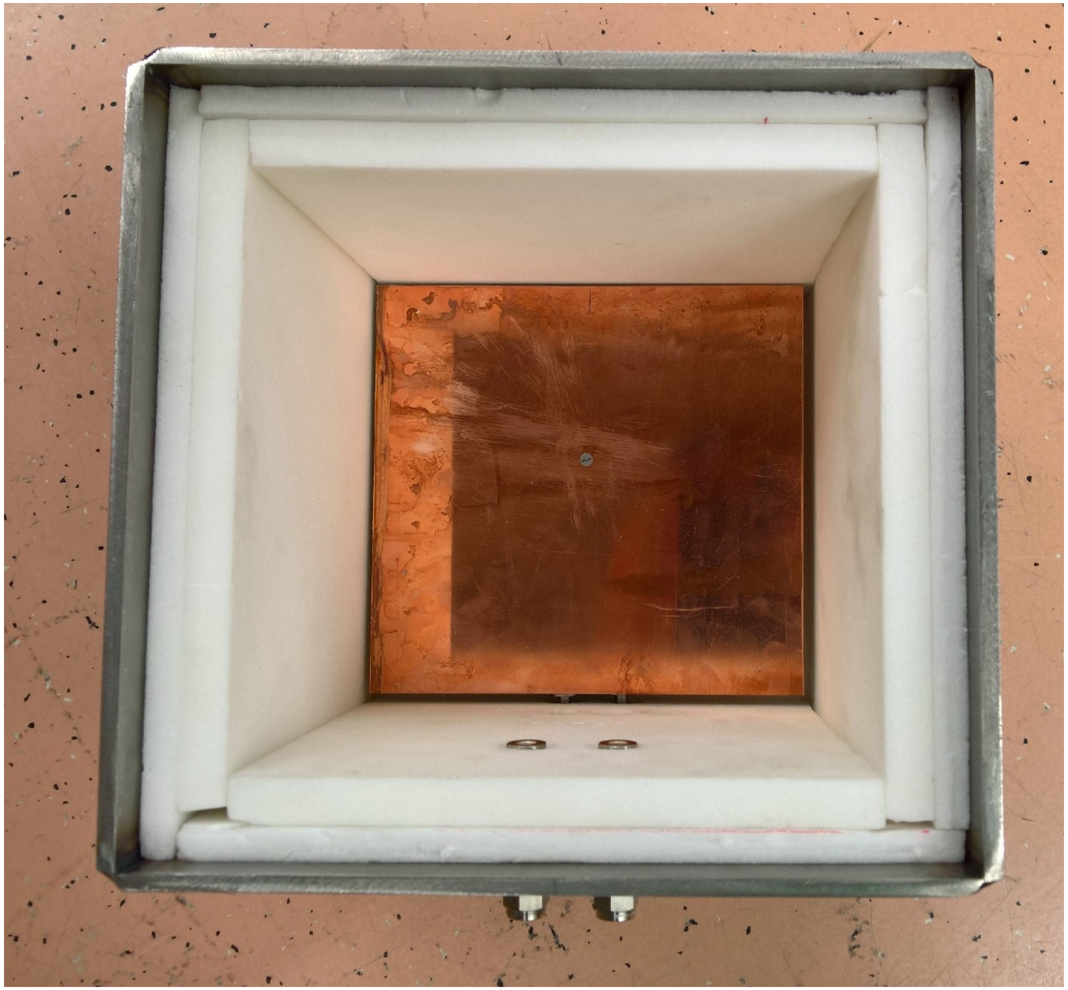
- Fit everything into box (little test environment) to protect from variations of conditions outside:



Assembly Process

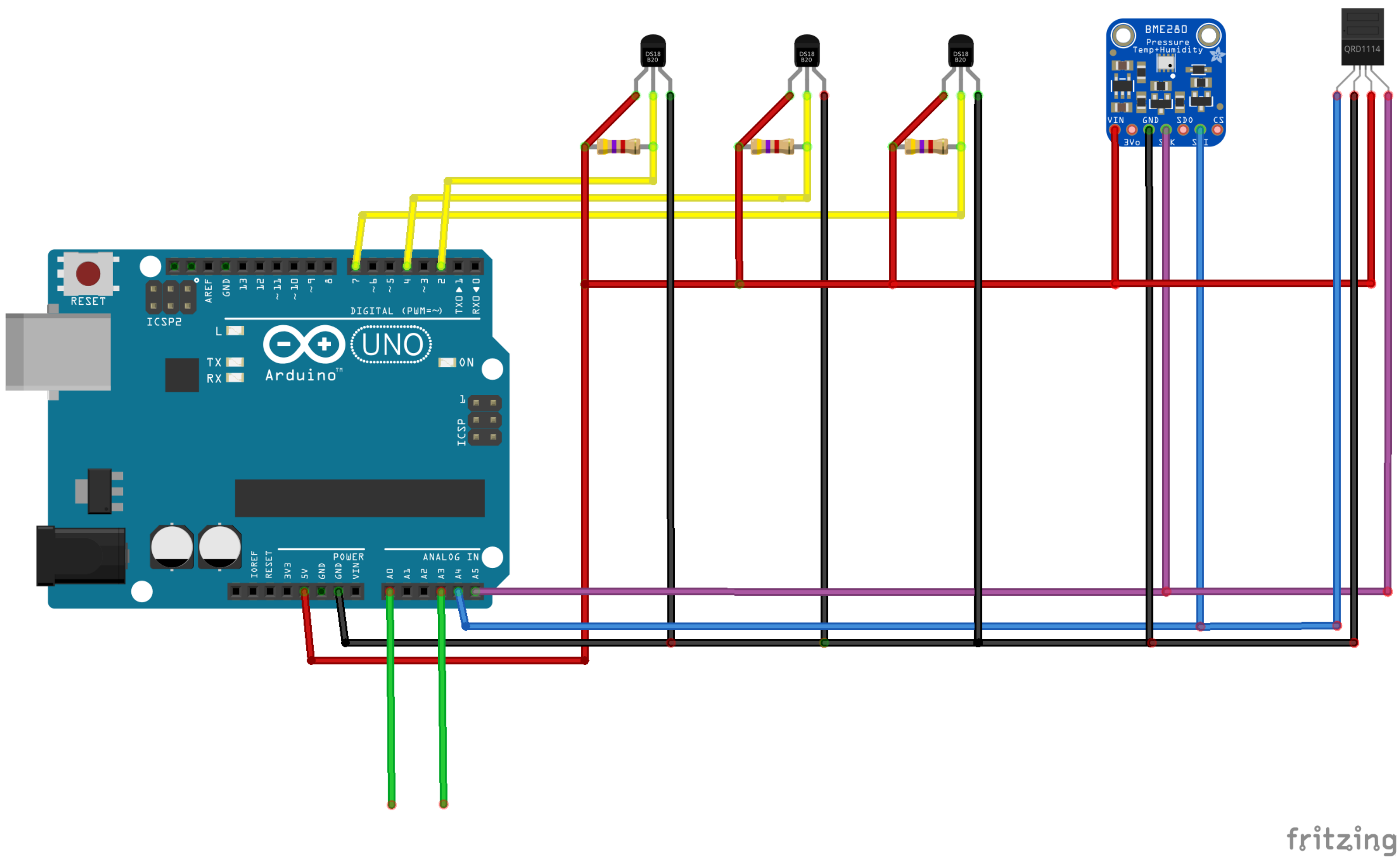
- Build even more controlled/stabilised environment
  → Use insulating material (polyurethane)





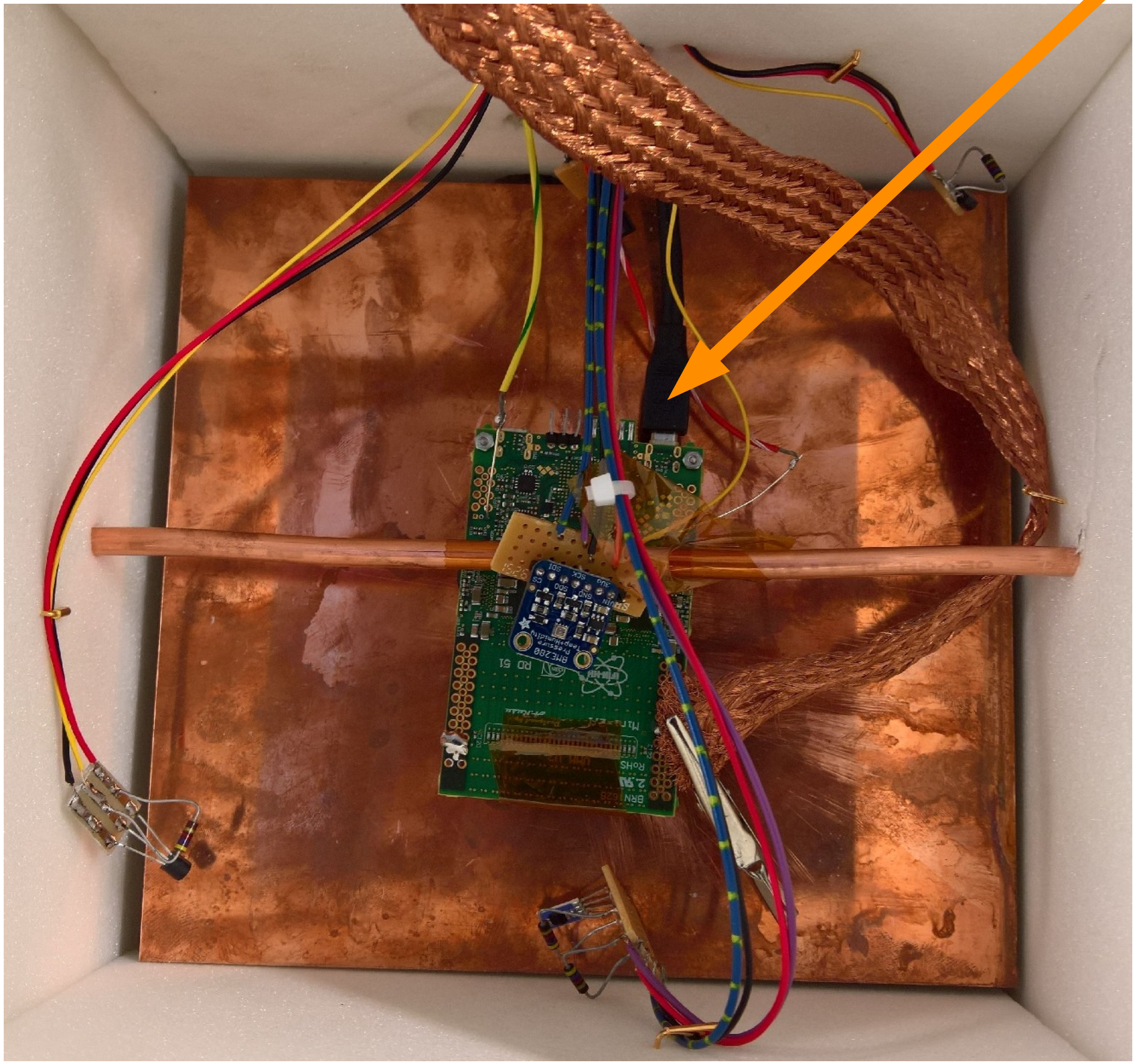
Electronics Assembly

- Mechanical set-up done
  → Move on to measurement circuit



Electronics Assembly

- Positions of sensors in box



HDMI: Power & Readout of VMM

Electronics Assembly

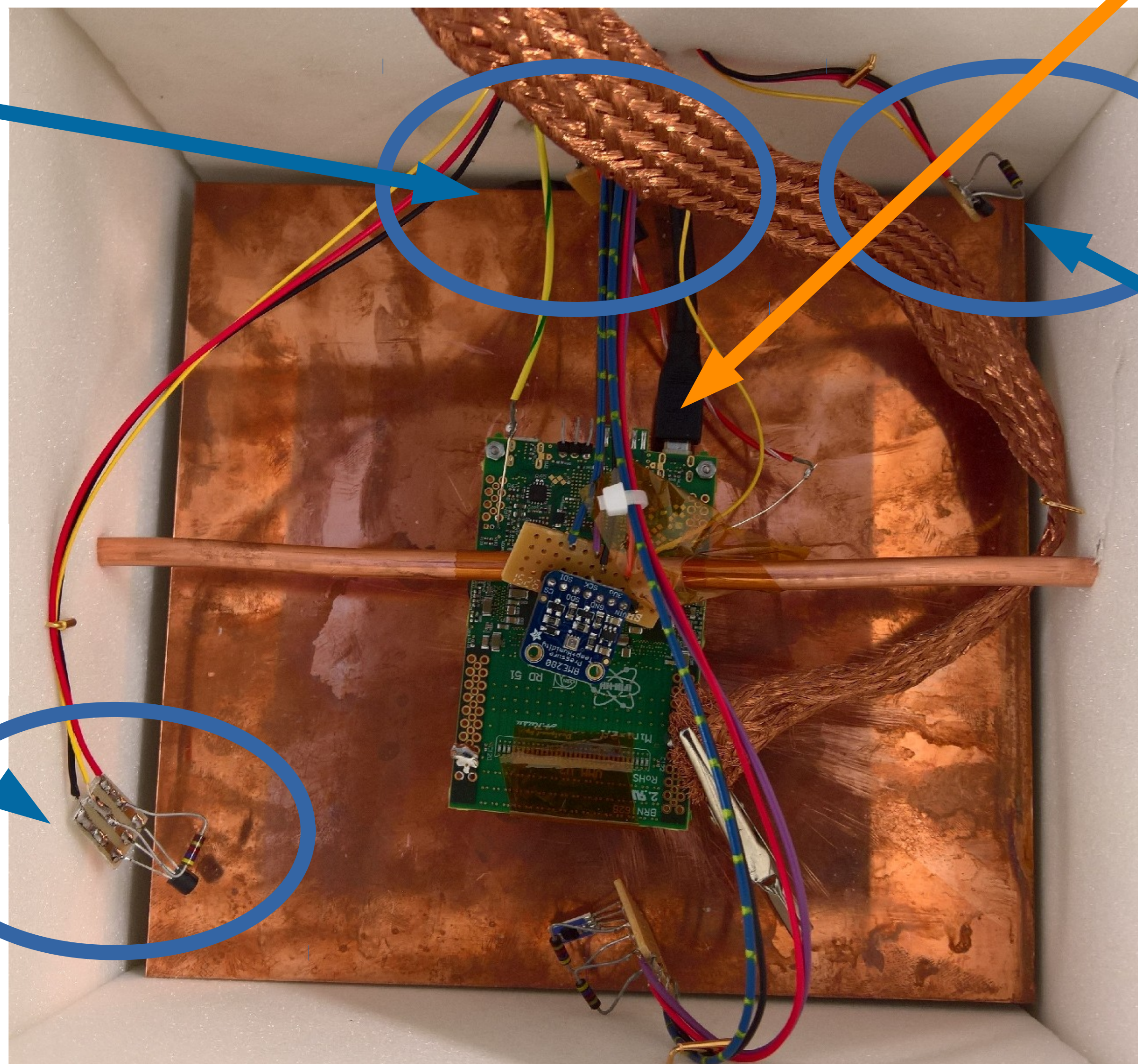
- Positions of sensors in box

DS18B20

HDMI: Power & Readout of VMM

DS18B20

DS18B20



Electronics Assembly

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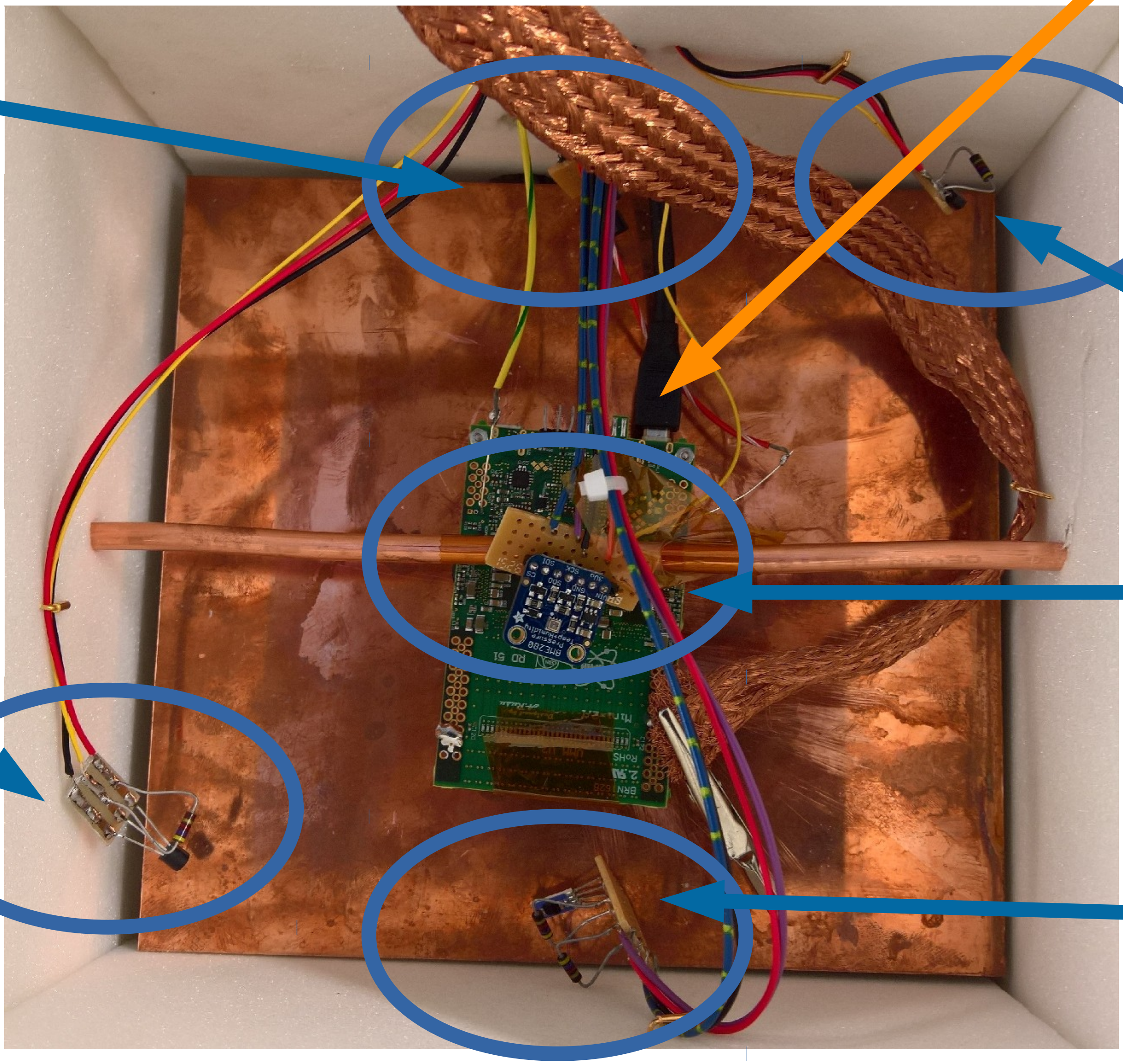

Electronics Assembly

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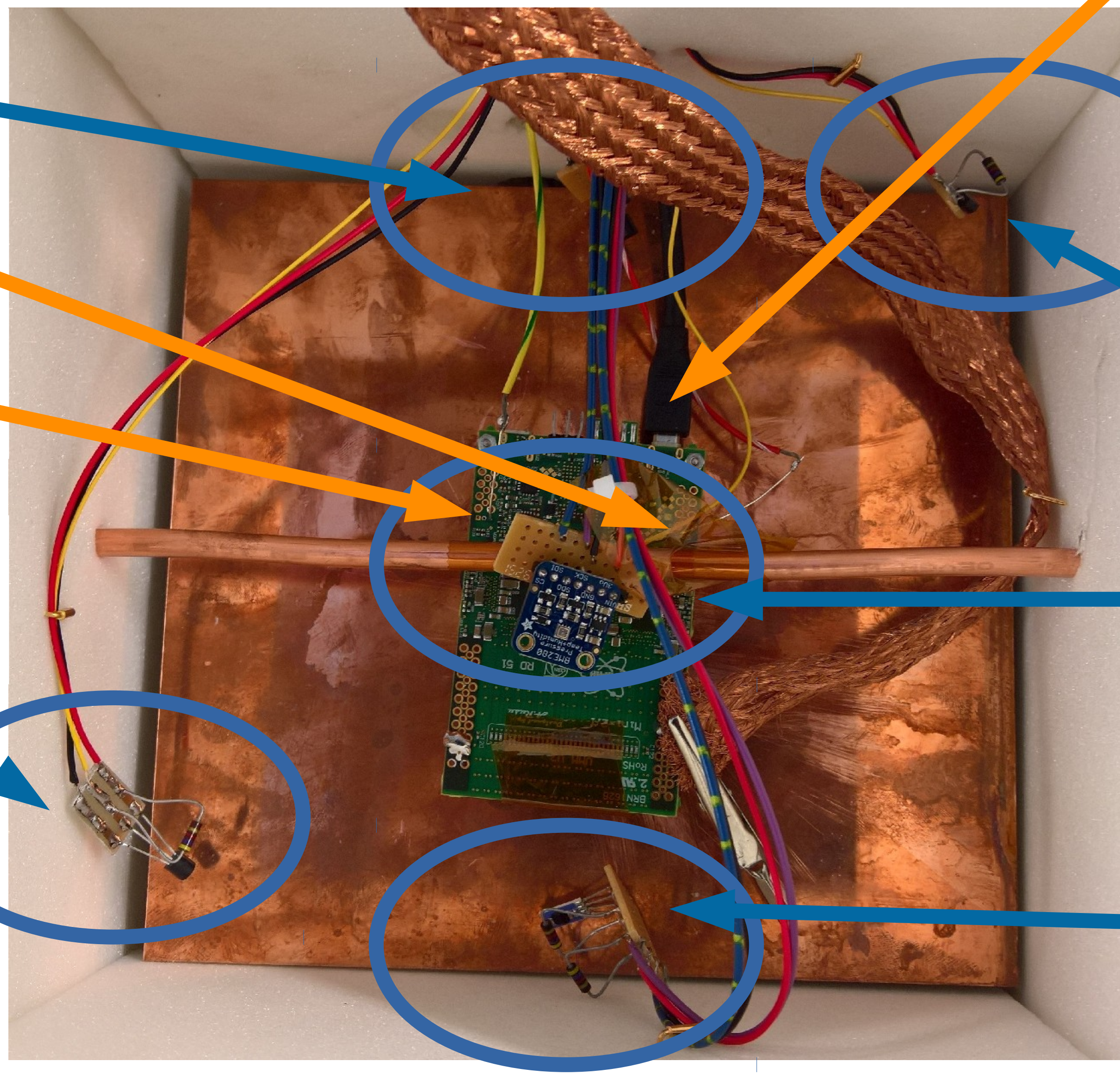


Electronics Assembly

- Several sensors to measure the temperature
- 10-bit ADC used for digitising the voltage output from integrated temperature sensor
- Conversion of sensor voltage to temperatur

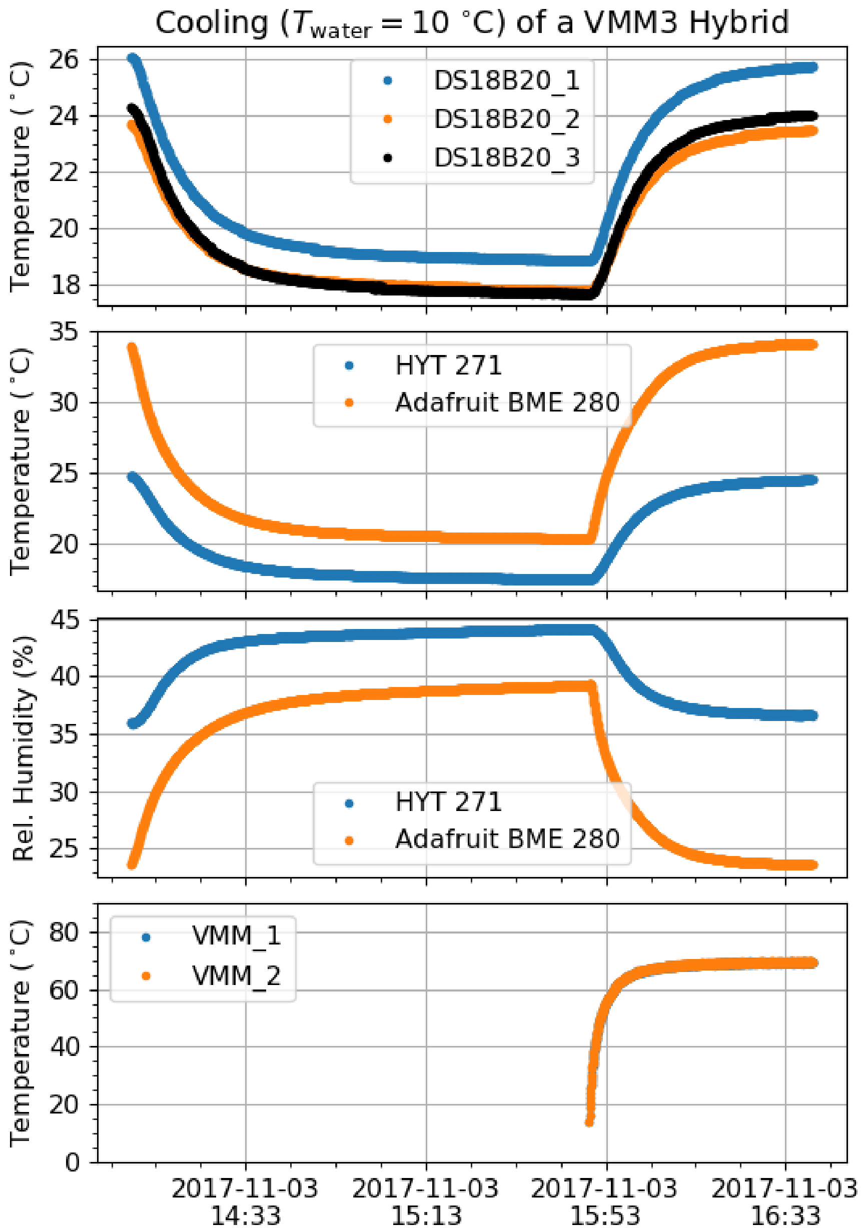
$$T\,(^{\circ}\mathrm{C}) = \frac{725 - V_{\mathrm{sensor}}\,(\mathrm{mV})}{1.85} \qquad (1)$$

- Start testing of set-up...

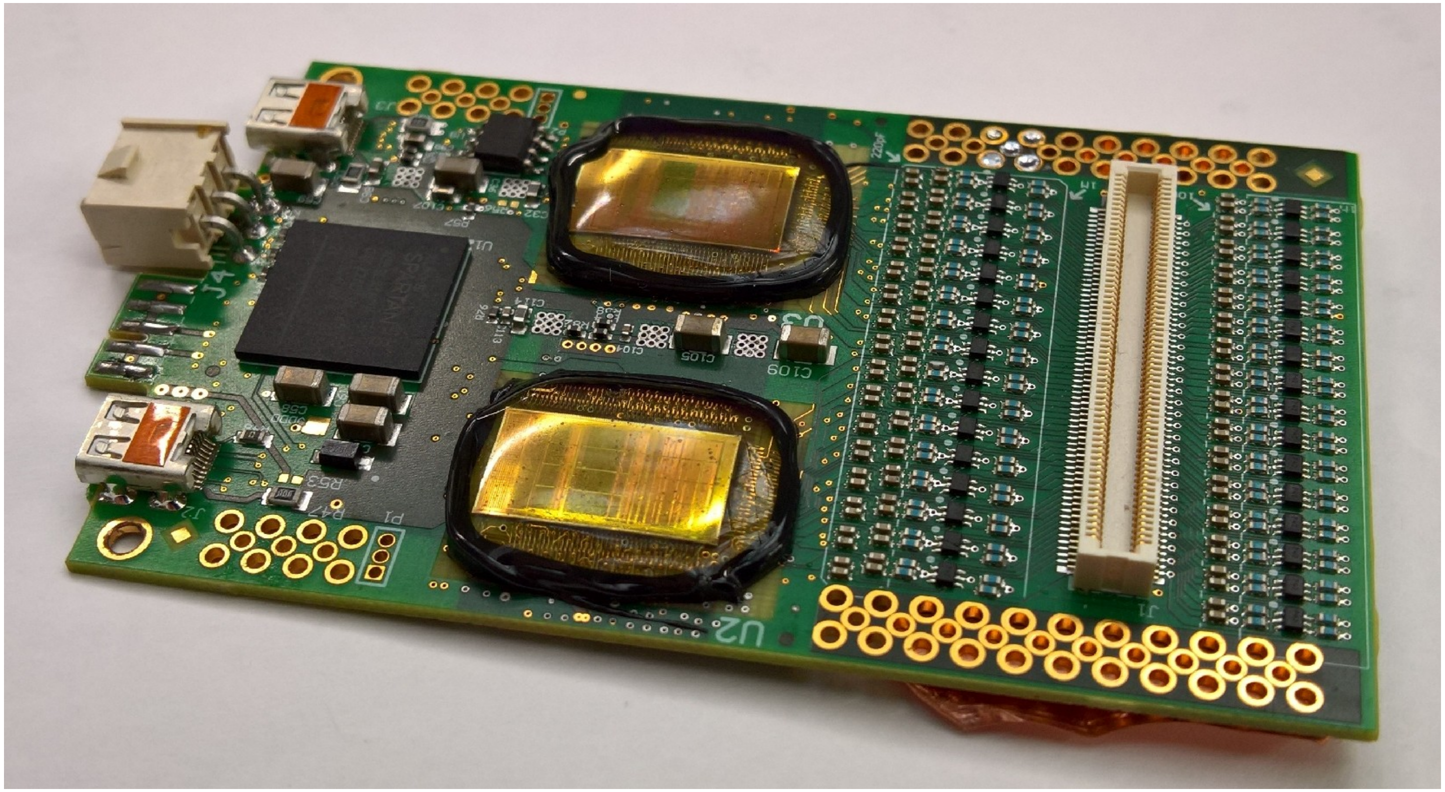
First Tests

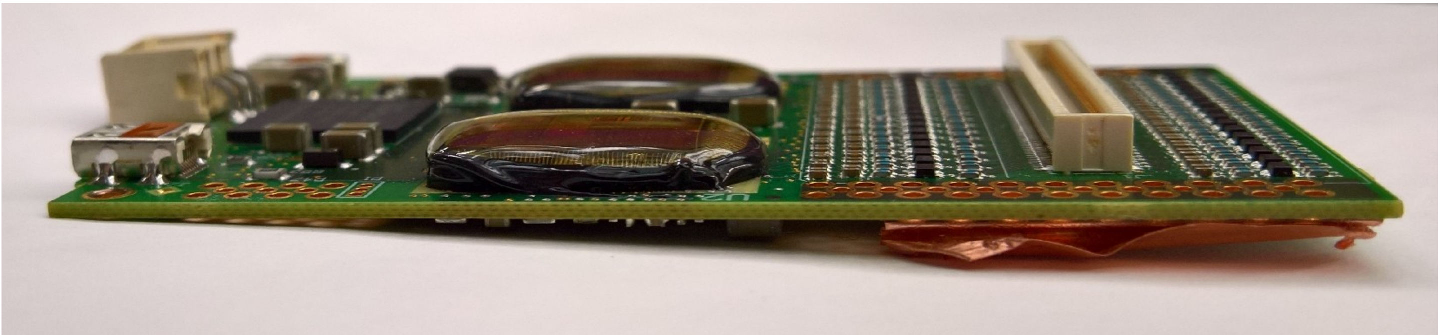
- One of the first test of set-up
- Still with glass protection
- Temperature inside chip reaches equilibrium state

- Unfortunately some of the external sensors died
- Further improvements of the set-up...



Prototype Glob Top

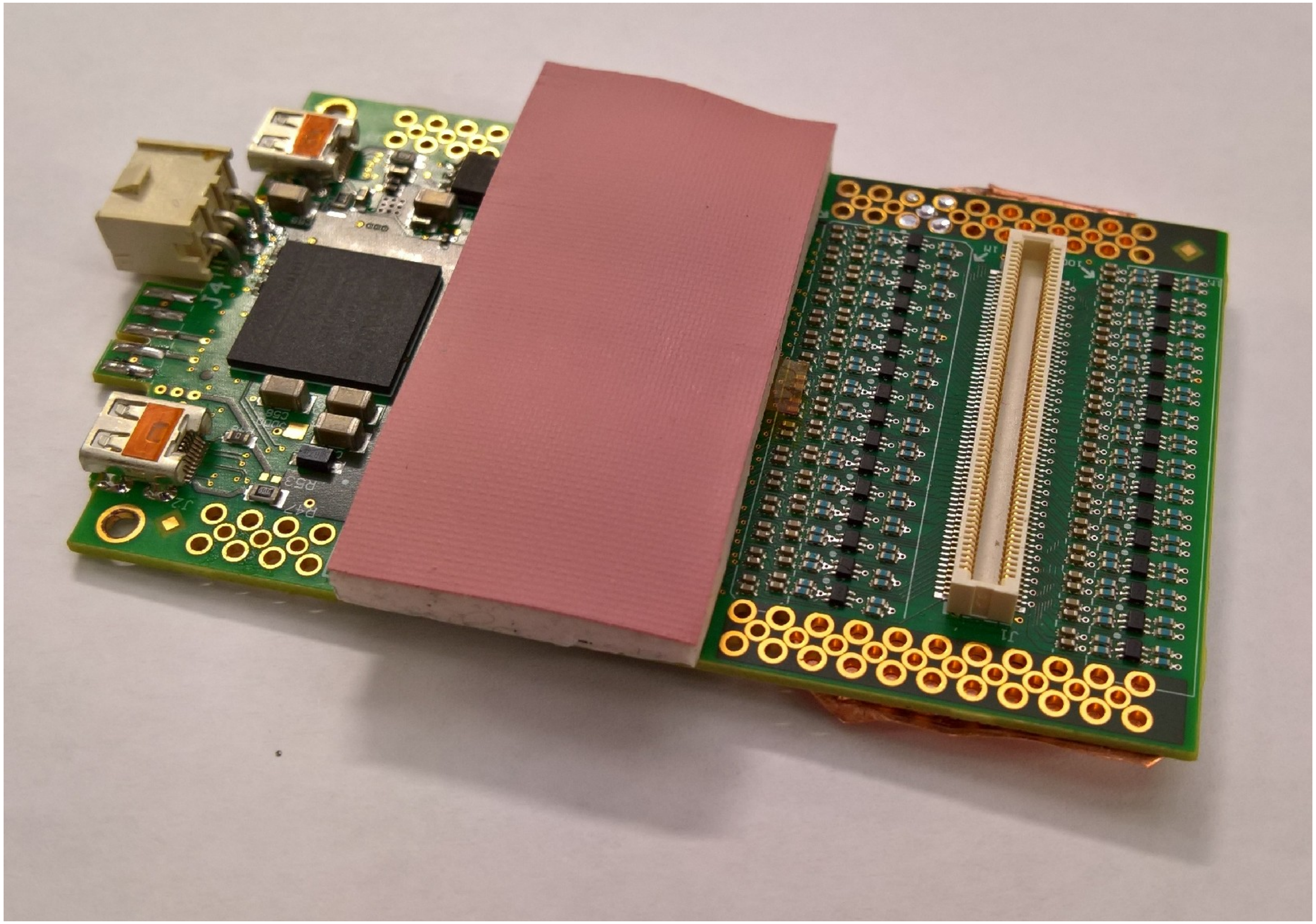




Great Thanks to Hans!

Further Improvement

- Get the temperature directly “inside” the chip:
  → Use thermally conductive tape



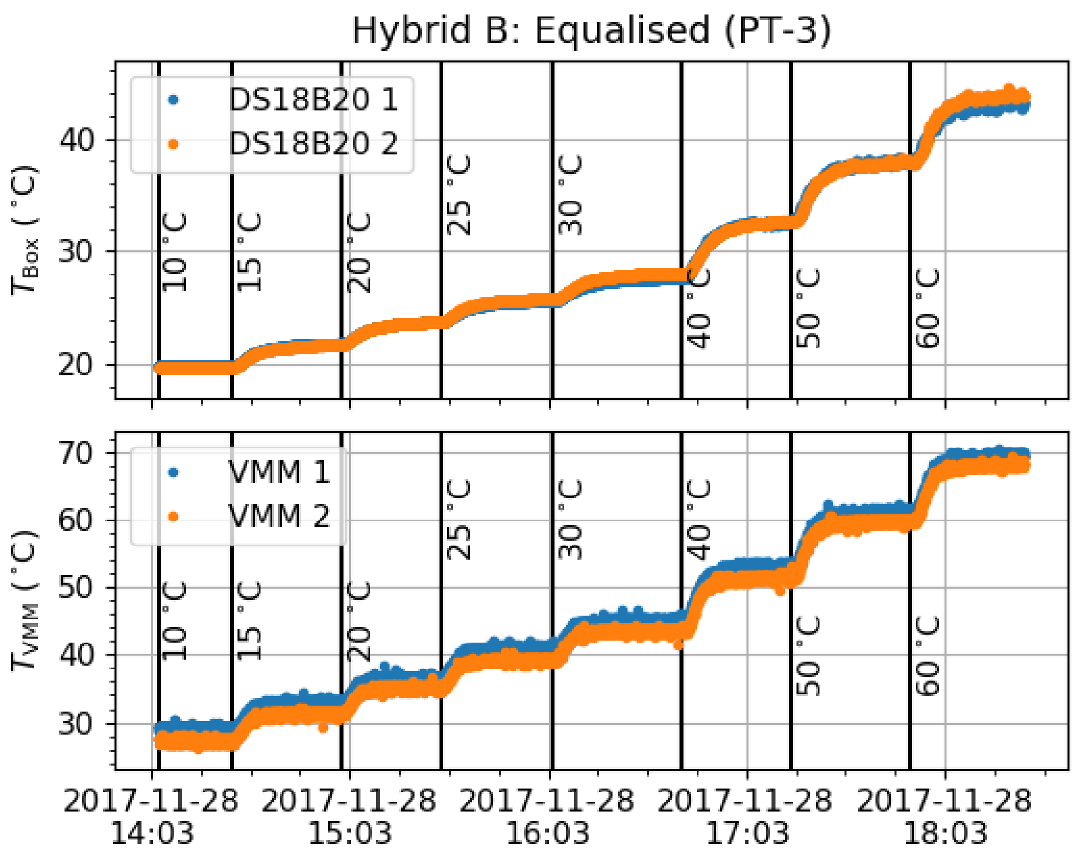
Data from the Performance Measurements

How to Quantify Performance?

- As mentioned: Quantify performance depending on temperature
- **How to achieve this?**
  → Take data and look how they change for different temperatures
- Problem: Data taking not possible, due to geometrical restrictions
  → Only hybrid fits in the box, but no complete detector
- Solution: Take test pulse spectra for different chip temperatures
- Test pulses on each channel → 64 t.p. per VMM
- Important: Makes only sense for equalised ADC baseline

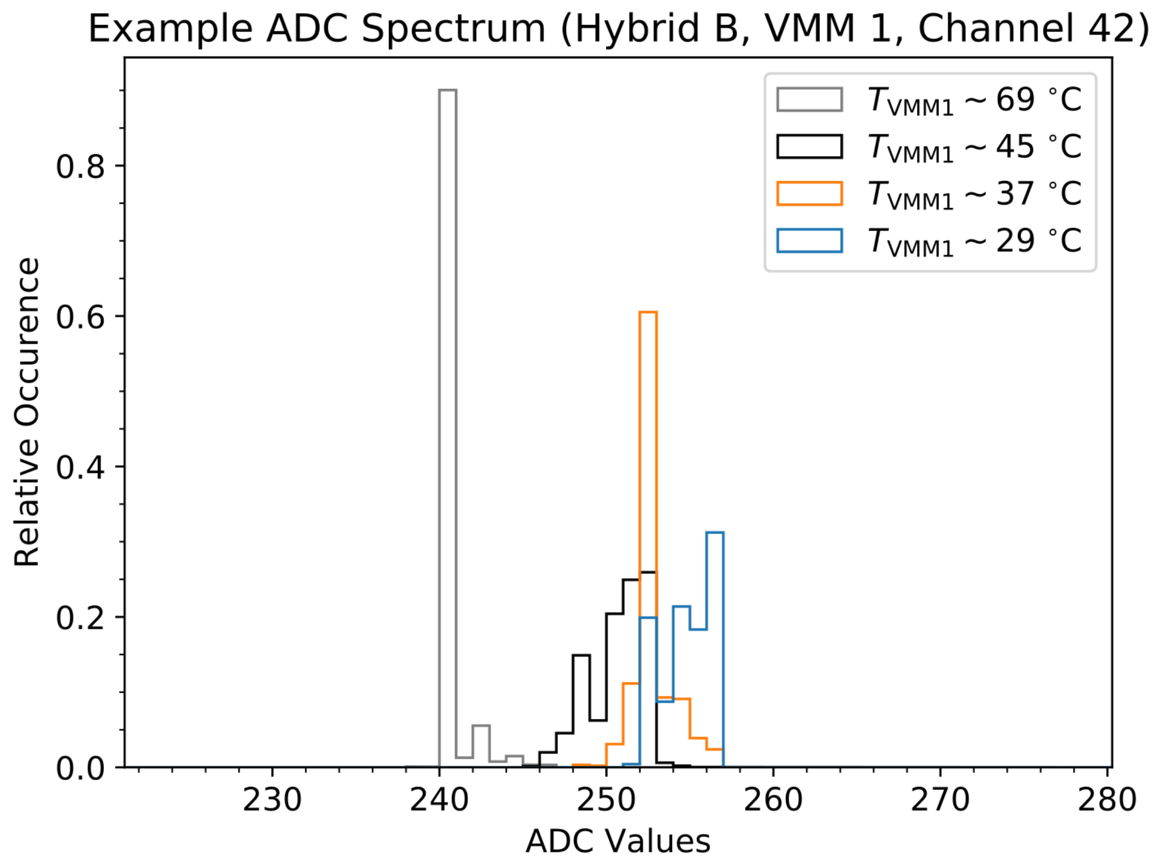
Measurement Process

1. Cool down environment
2. Connect Hybrid to power
3. Wait until equilibrium state is reached
4. Start measurement with test pulses
5. When measurement finished: Increase temperature and repeat process from 3.

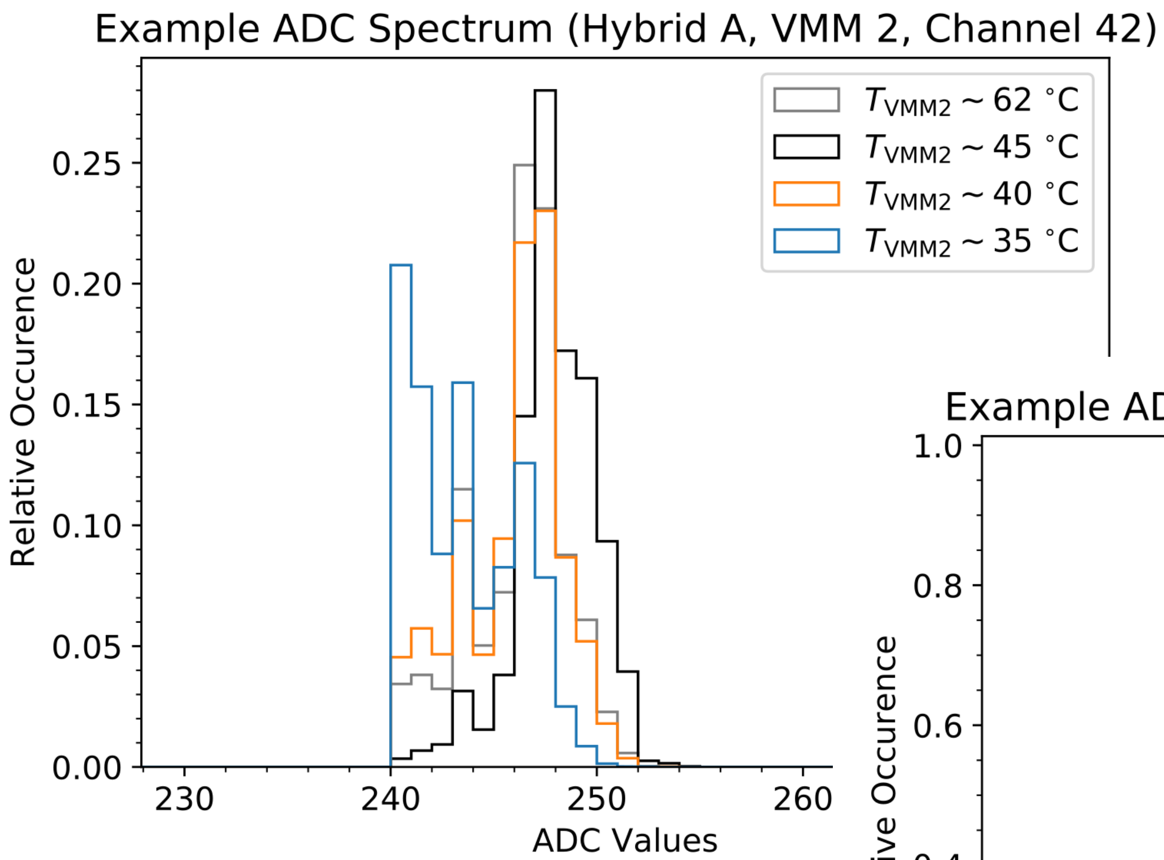


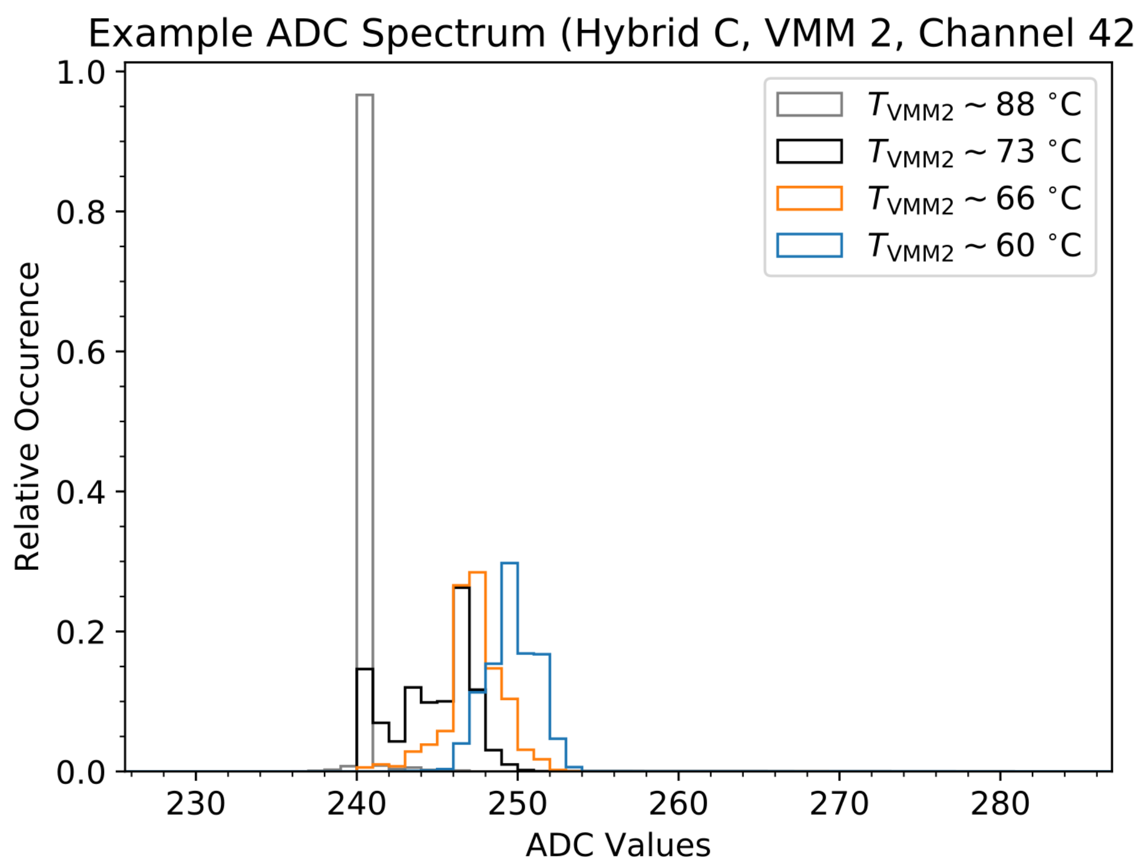
Starting Point of Analysis

- Look at ADC spectra for each channel for different chip temperatures
- **What can we extract?**
  → Mean ADC value
  → Width of ADC distribution



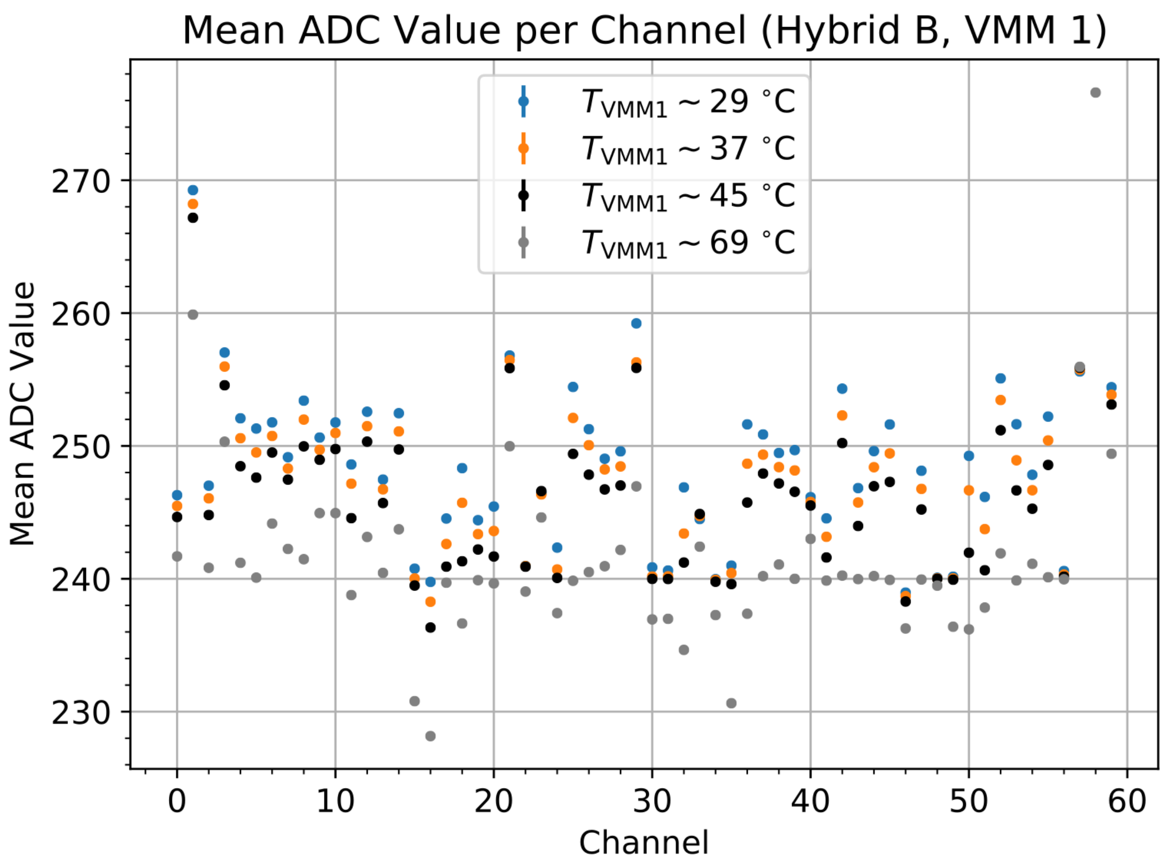
Some Examples





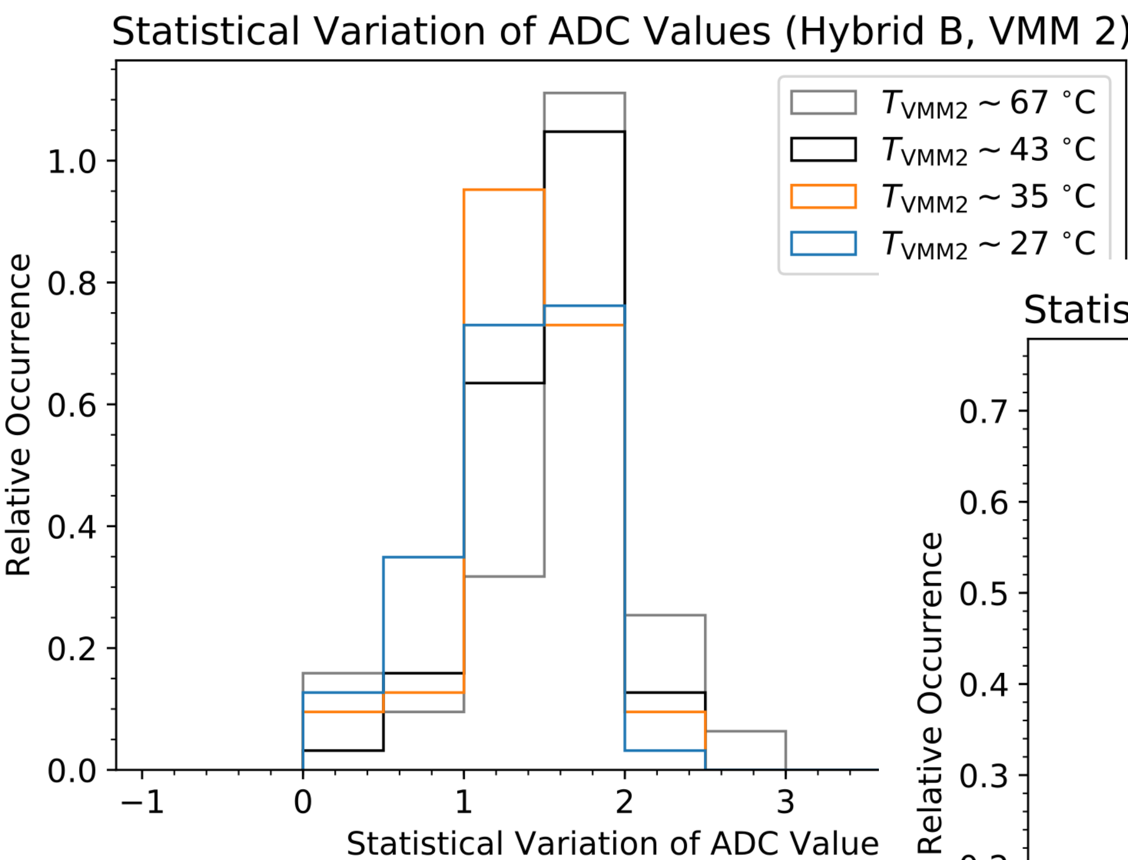
Mean ADC Value per Channel

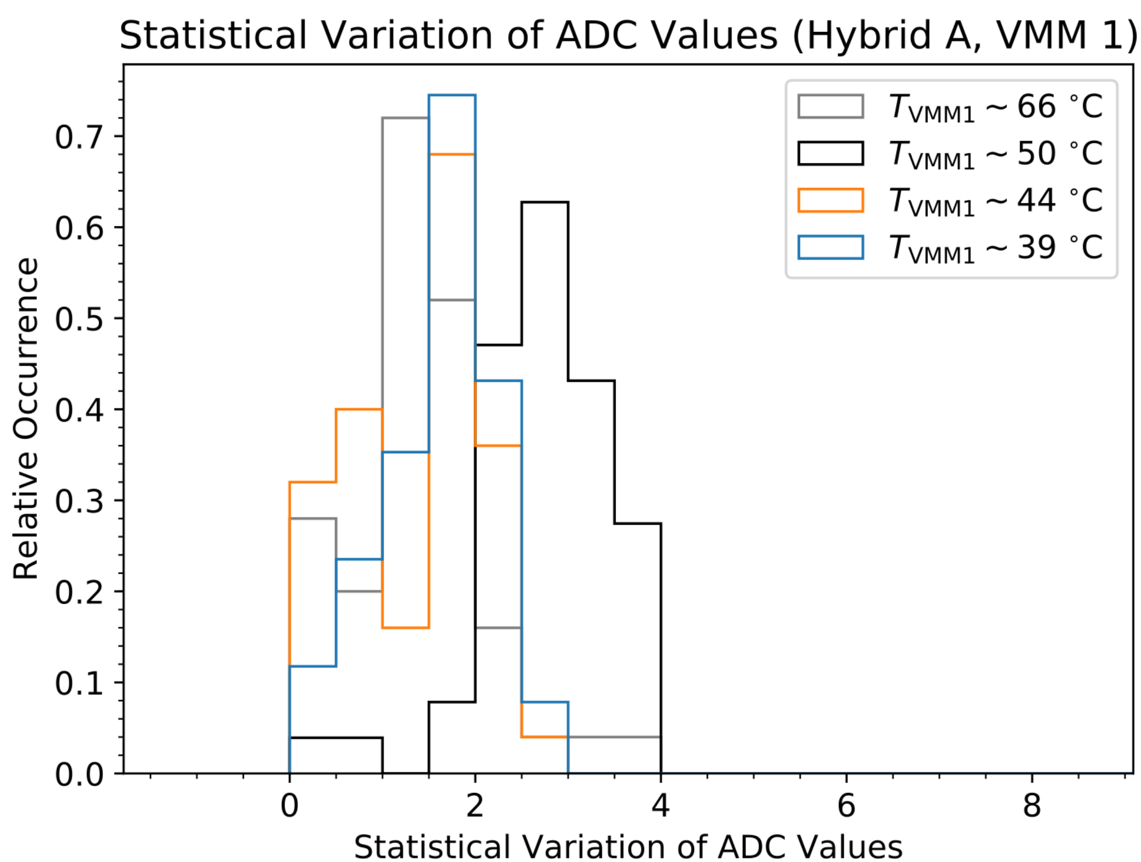
- Looking at every ADC spectrum is not useful



Width of ADC Spectra

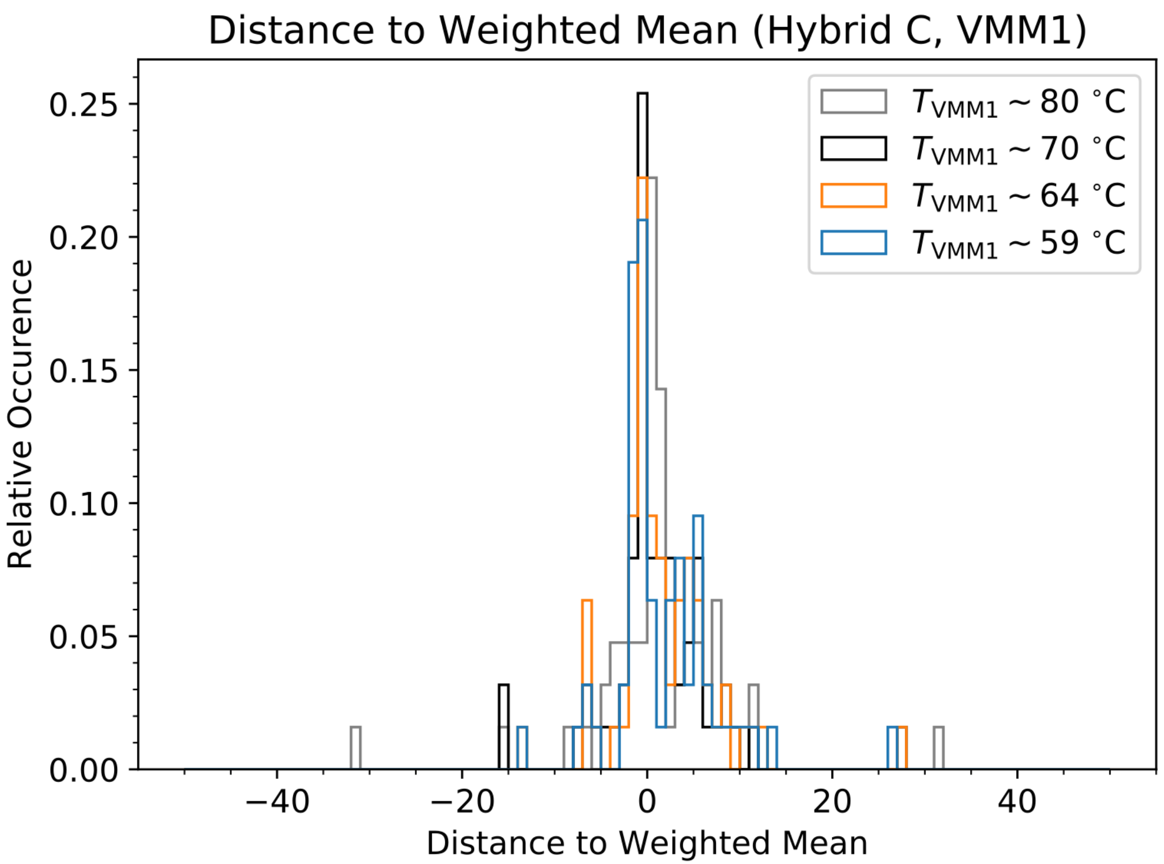
- Looking at every ADC spectrum is not useful





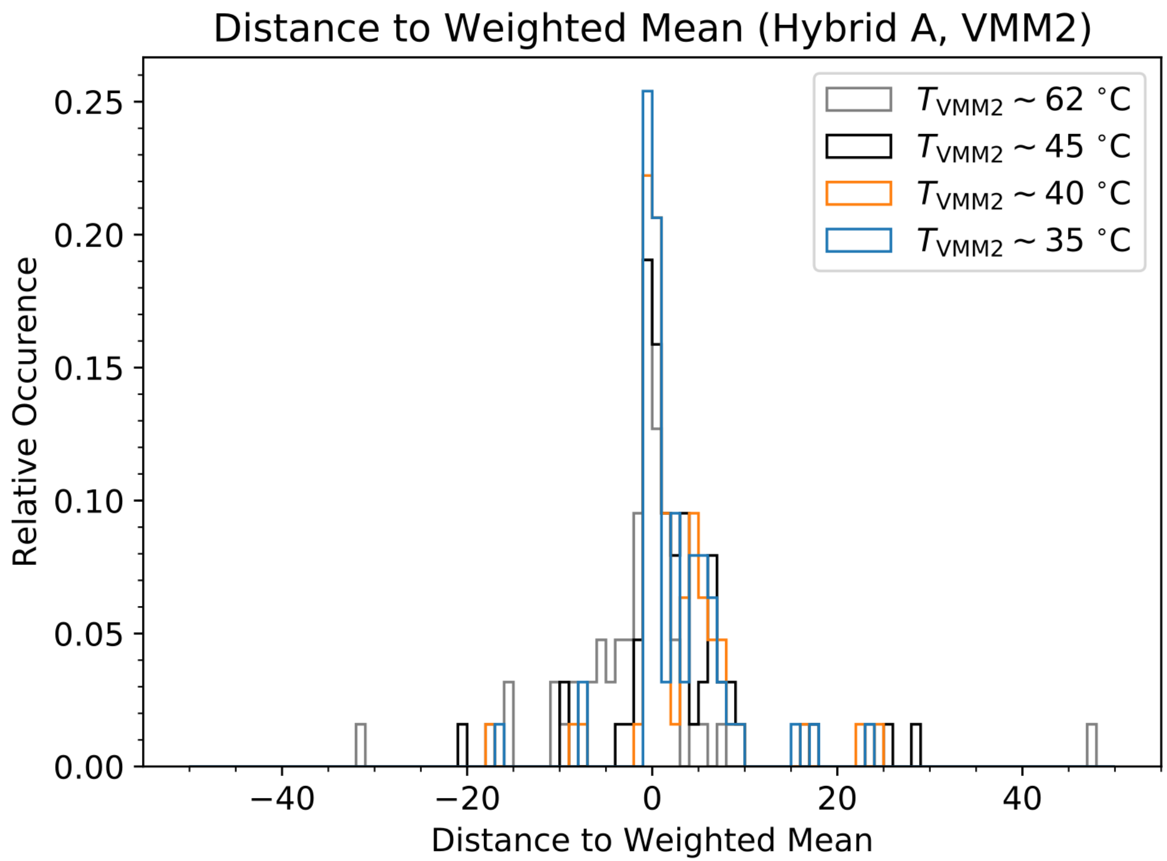
Behaviour of the Chip

- So far: Looked at every single channel independently
- Now: Look at overall chip behaviour
  → Distance of mean ADC (channel) to weighted mean ADC (chip)



Behaviour of the Chip

T_{VMM} (°C)	Weighted Mean ADC
39	228.7827 ± 0.0012
44	225.5148 ± 0.0012
50	224.1560 ± 0.0029
60	223.9634 ± 0.0014
35	240.44833 ± 0.00080
40	240.3689 ± 0.0012
45	240.3916 ± 0.0012
62	240.1308 ± 0.0012



Weighted mean for hybrid A

Top half: VMM 1, Bottom half: VMM 2

Conclusion & Summary

Conclusion & Summary

- Successfully build test set-up to investigate the thermal behaviour of the VMM3 readout ASIC
- Measured 3 hybrids → 6 Chips
- Temperature dependence seen: ADC baseline shifts
- **Only** baseline shifts: No change in behaviour for constant temperature
- **Proposal for cooling:** Cooling might help, but only necessary to stabilise the temperature. Cooling itself seems to have no influence on performance. Passive cooling should be sufficient
- Did not investigate very high temperatures (> 100 °C)
→ Not enough hybrids to risk destruction

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Thanks for your Attention.

Questions?