Tests of stave cooling

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PANDA Collaboration Meeting
Gießen, March 17th, 2015

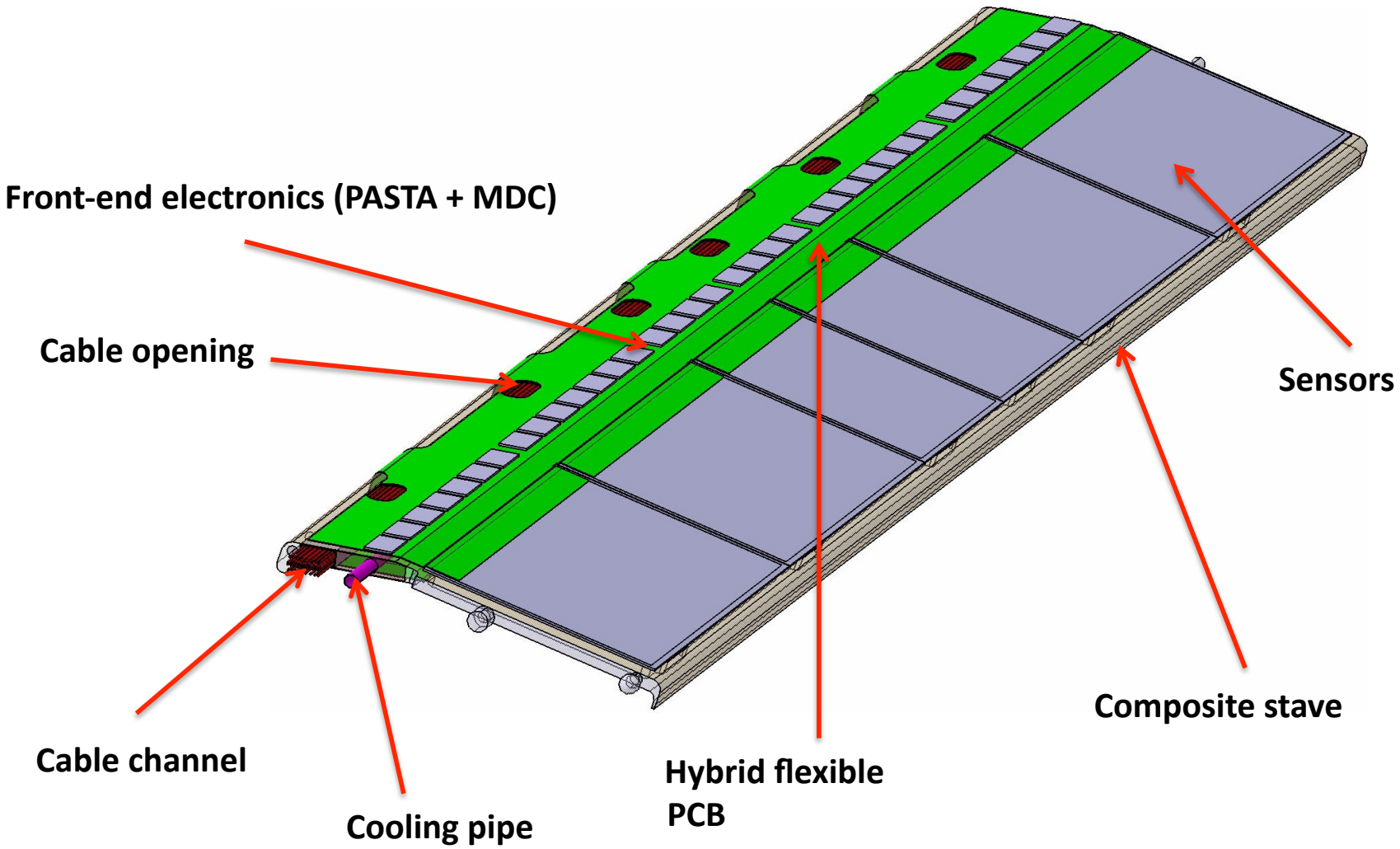
II. Physikalisches Institut

Tests of stave cooling

- First validation of full-scale cooling system on one strip barrel stave
- Performed at ZEA-1, Jülich*, in March 2015

* thanks to V. Fracassi, D. Grunwald, E. Rosenthal, S. Wolf

Stave design



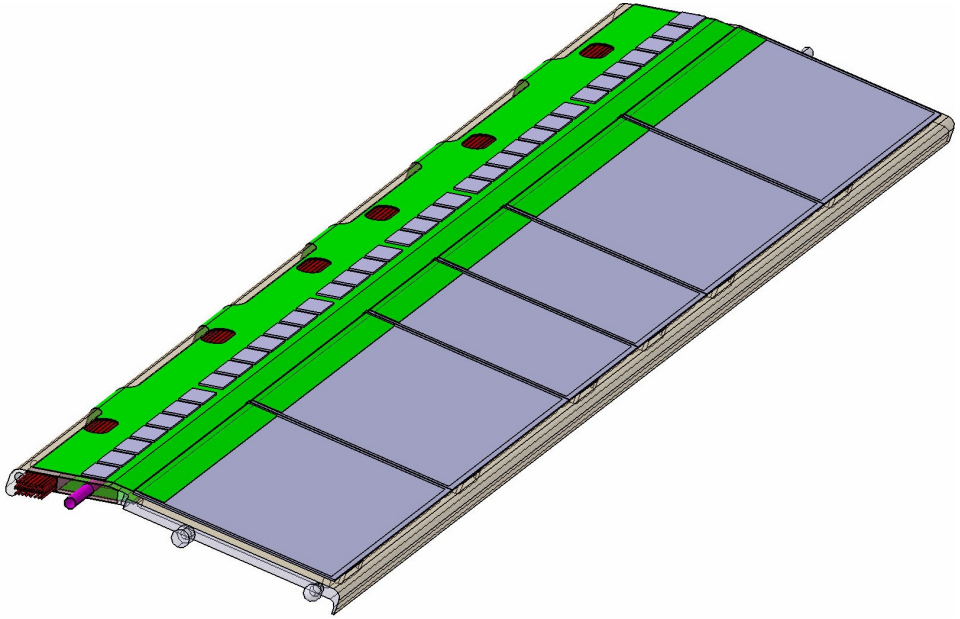
Stave design

p-side (“top”):

- 36 PASTA chips
- 256 mW per chip
- Active area 4.5 × 3.4 = 15.3 mm^2 (power density 1.7 W/cm^2)
- Total power: 9.2 W

n-side (“bottom”):

- 24 PASTA chips
- 6 MDC chips → assumed identical to PASTA
- Total power: 7.7 W

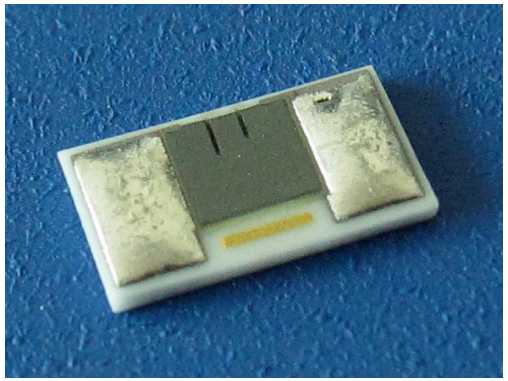


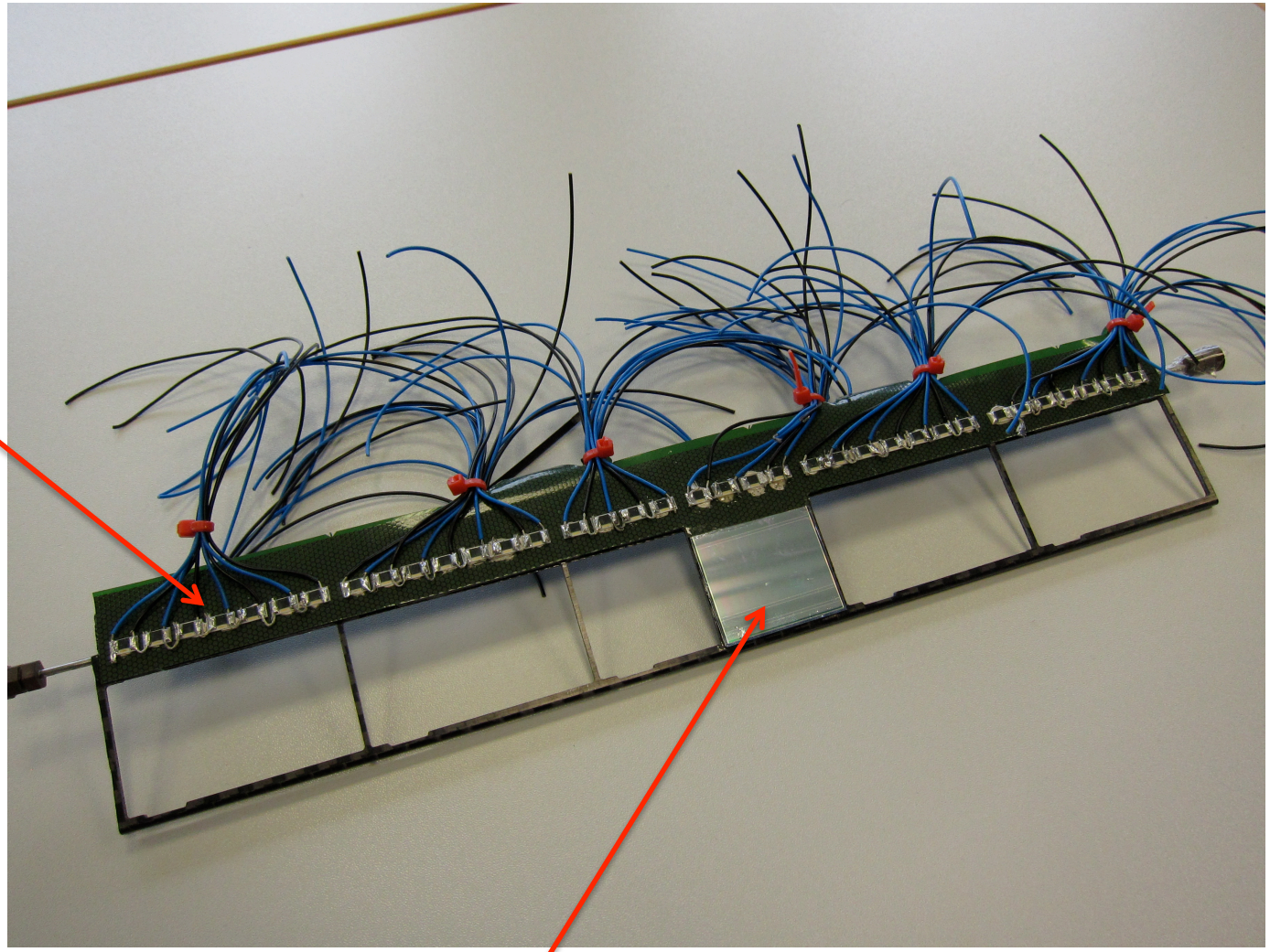
Total Power: 16.9 W

Test stave

Dummy-chip resistors:

- Area 7.15 × 4 mm^2
- Active area 3 × 3 mm^2
- Nominal power 256 mW (max. 600 mW)
- High power density: 2.8 W/cm^2

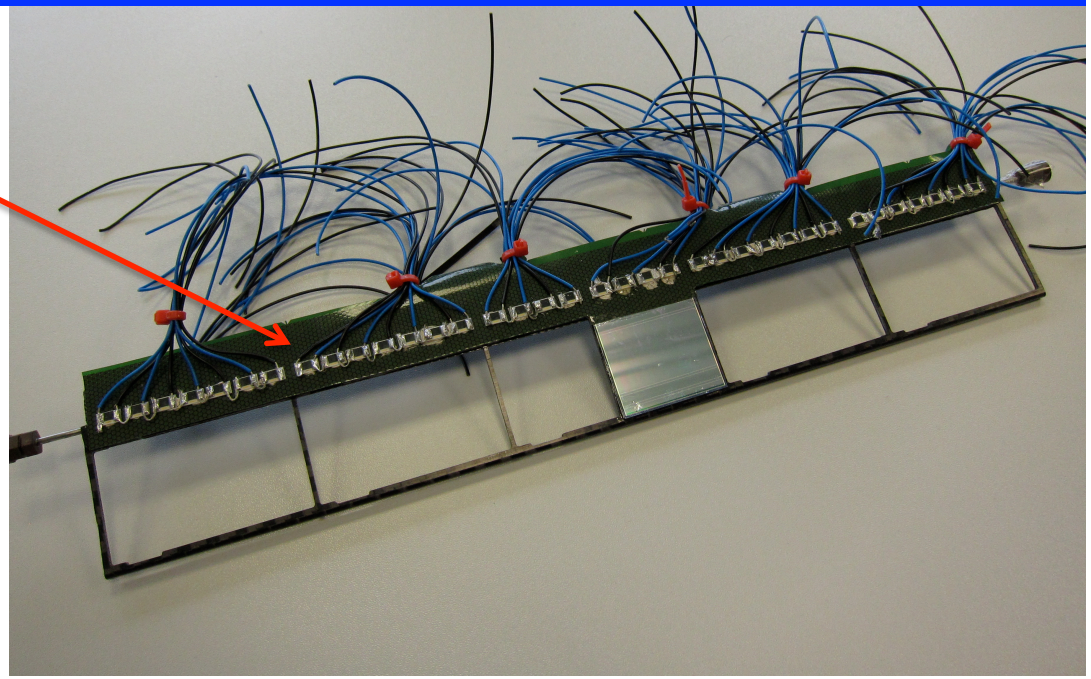




Square PANDA sensor

Test stave

Flex PCB (Kapton-copper)



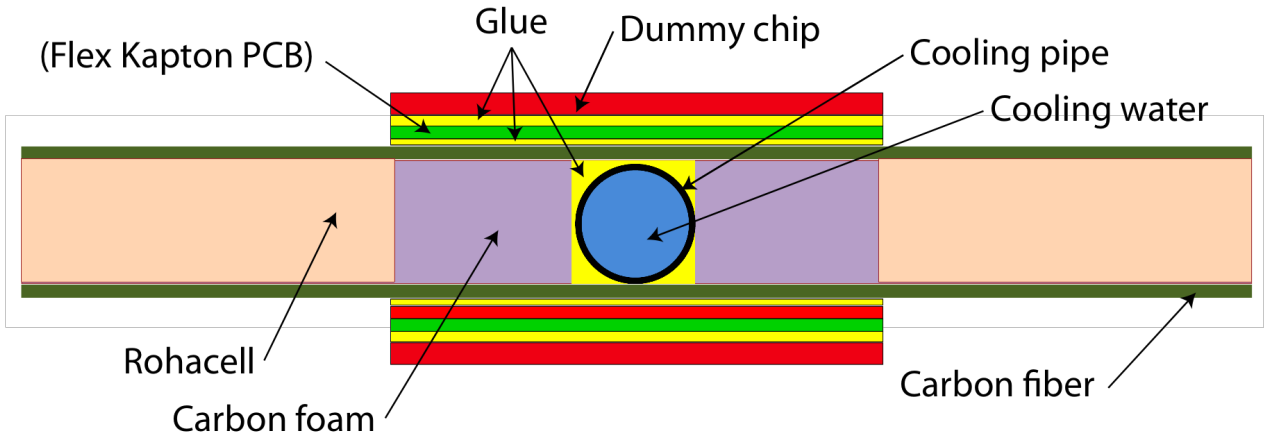
Lack (15 µm)

Copper (12 µm)

A-2003ED
Glue-PI-Glue
(50 µm)

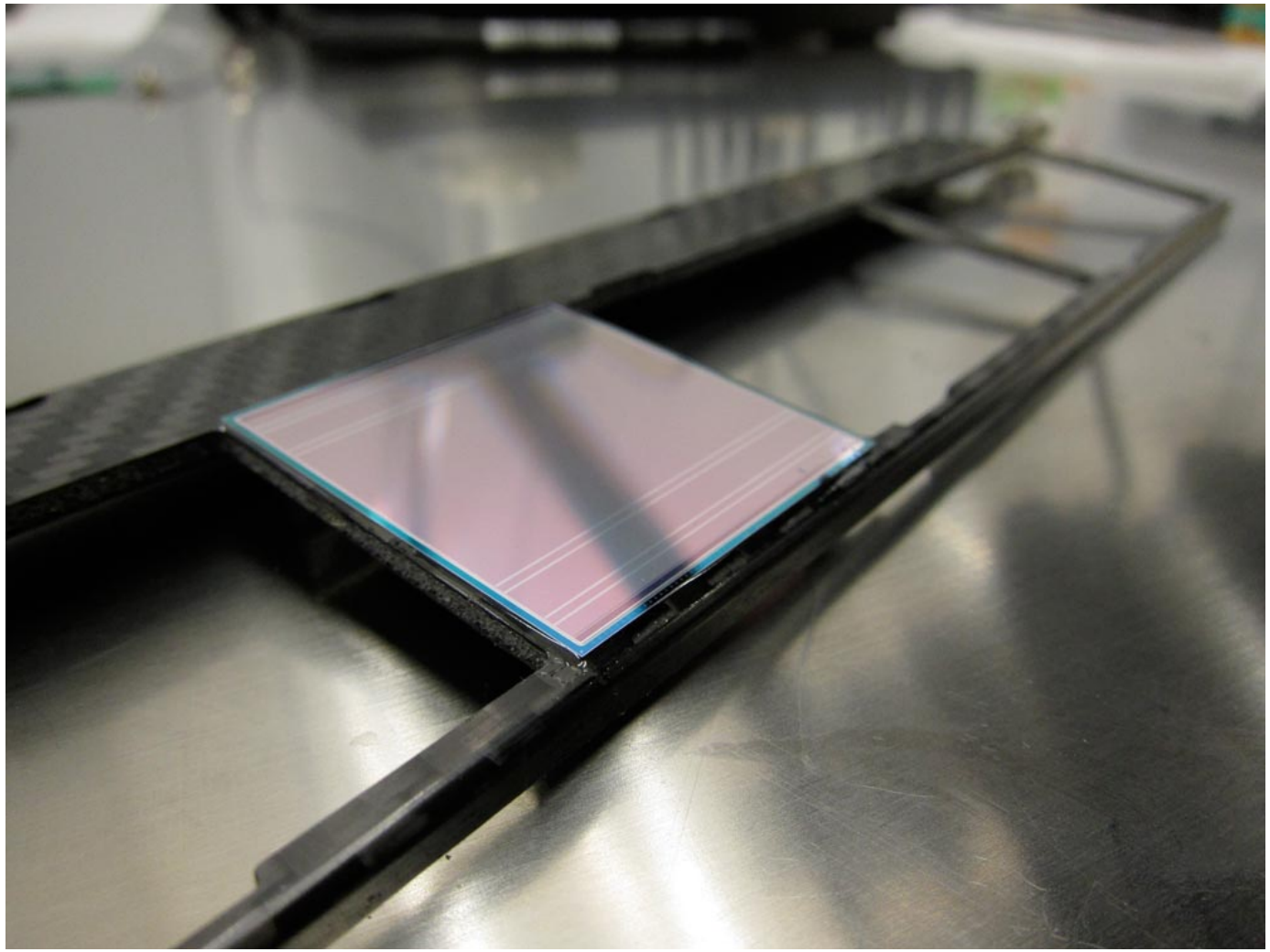
Copper (12 µm)

Lack (15 µm)



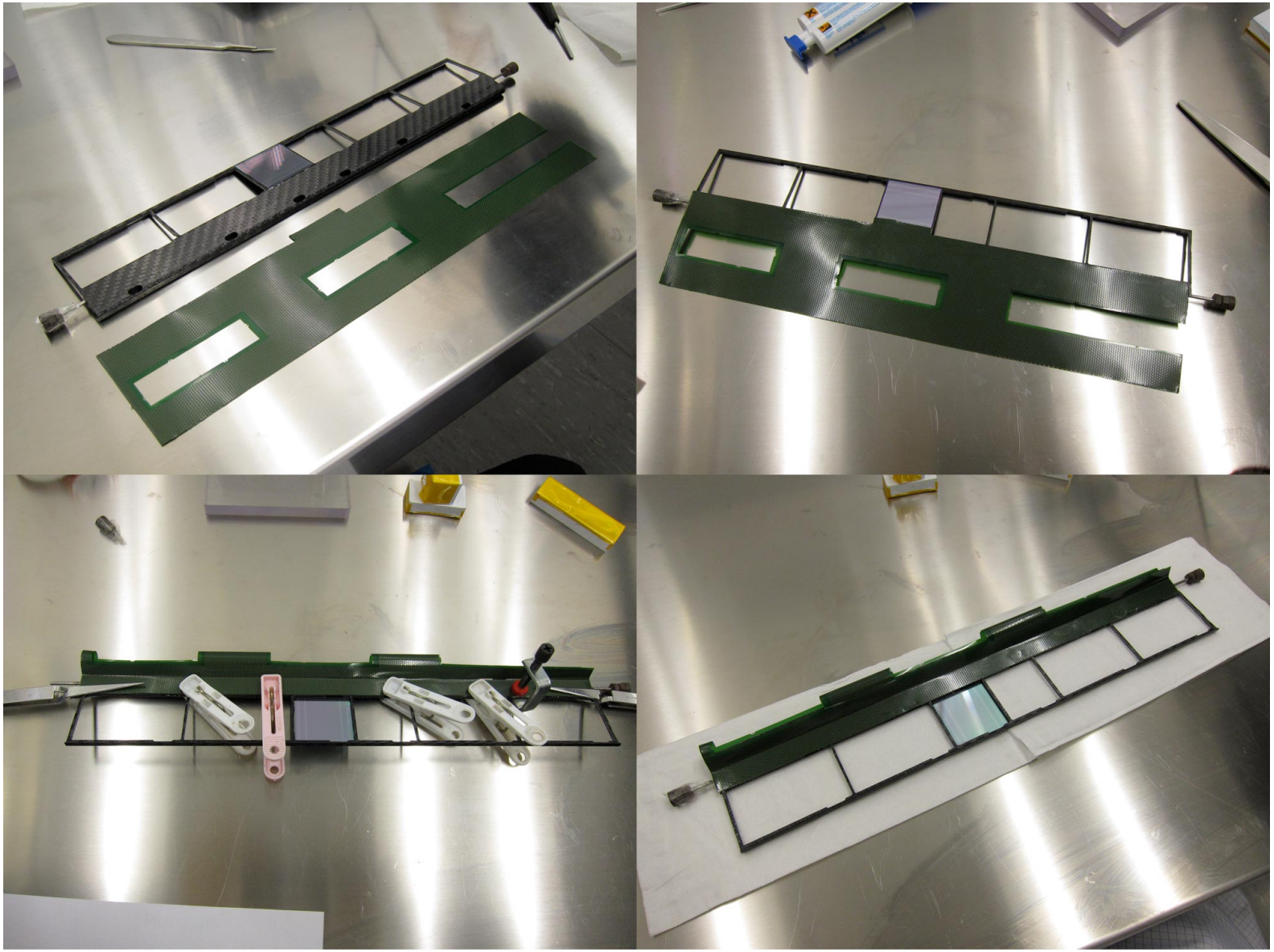
Test stave

1. Sensor glued on the stave



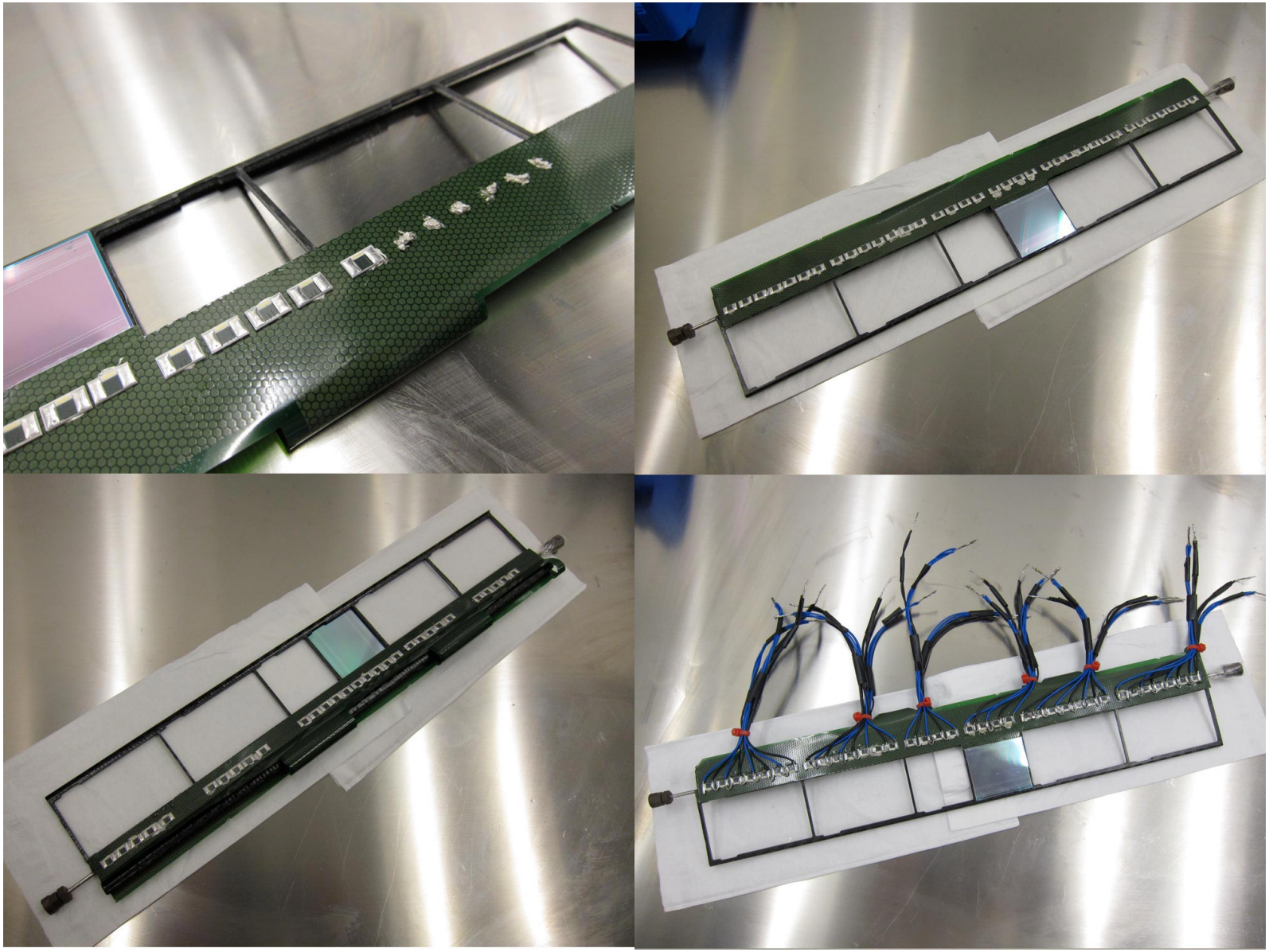
Test stave

2. Flex cut out, glued on p-side, folded, glued on n-side



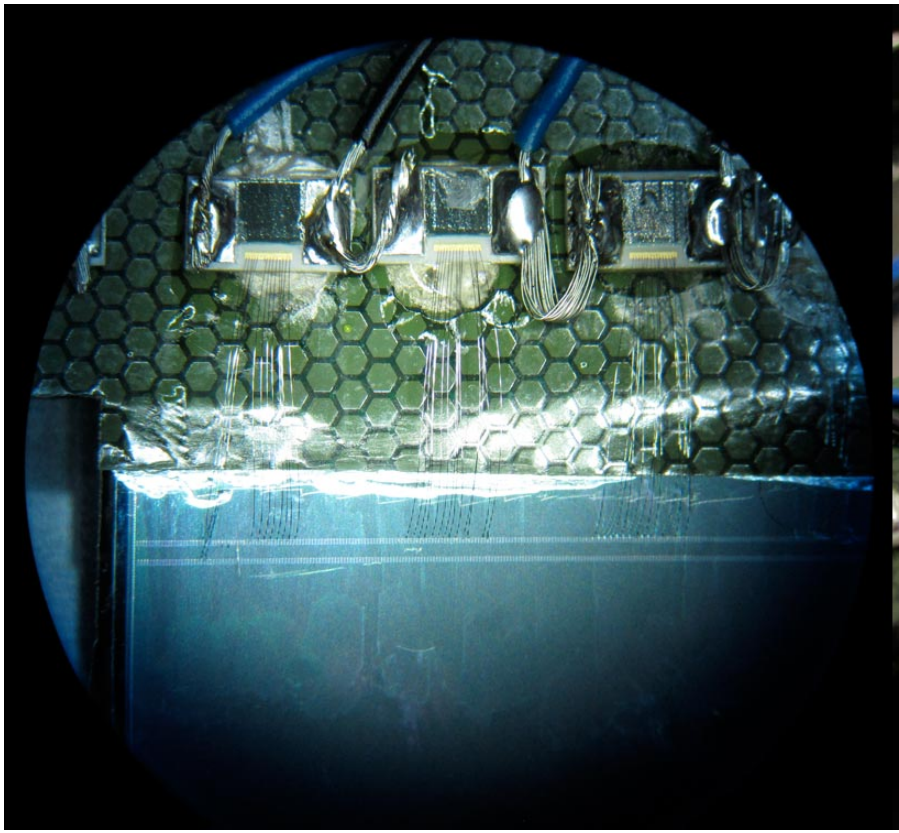
Test stave

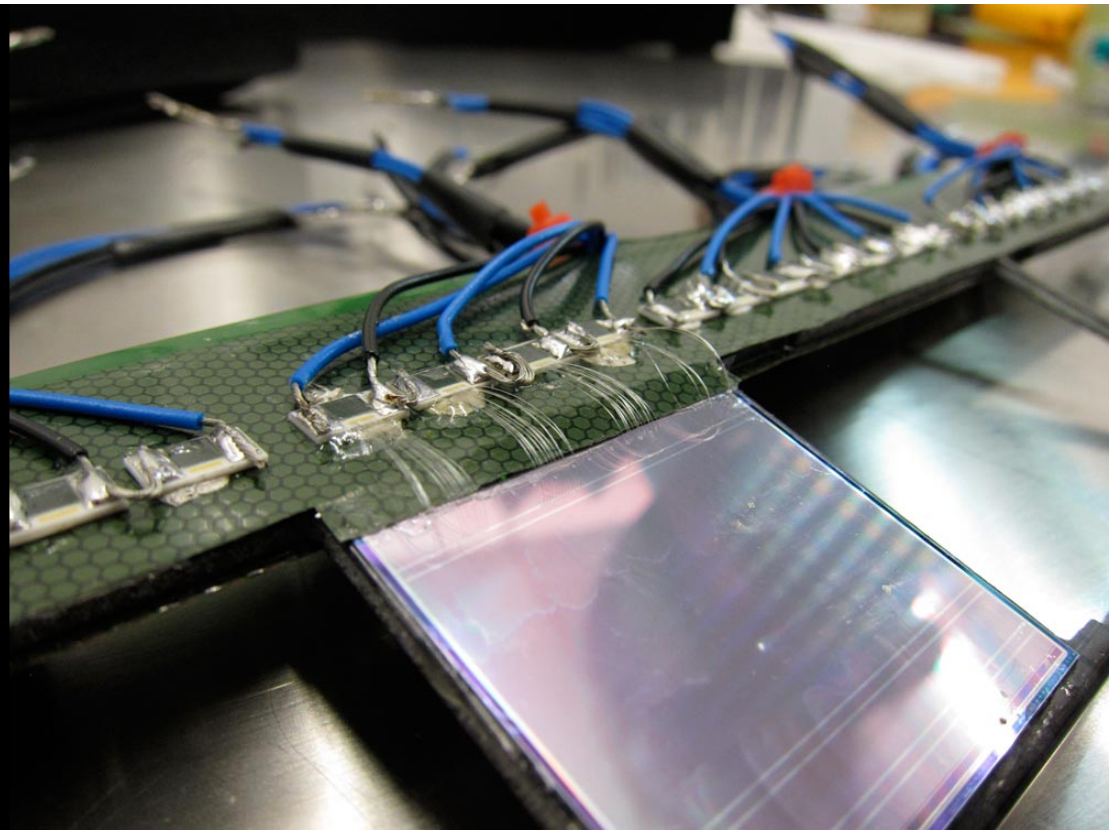
3. Resistors are glued on p-side (36) and n-side (30) and cabled in parallel in 12 groups



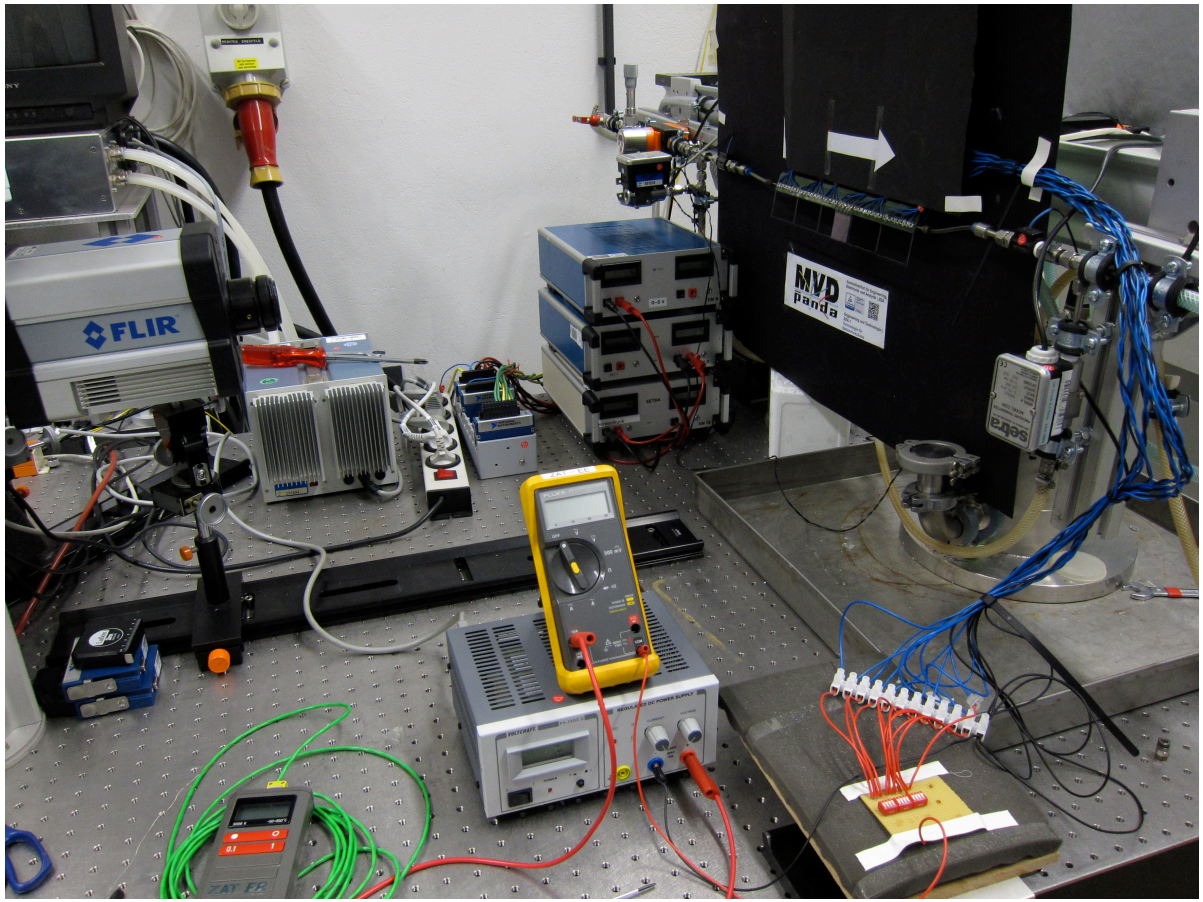
Test stave

4. Wire bonding (on p-side only) between resistors and sensor





Stave cooling test system



FLIR SC6000

- Spectral range 8 – 9.2 µm
- Resolution 640 × 512 pixel
- Frame rate 1 – 125 Hz

Available Measurements:

- Inlet and outlet water temperature
- Closed, underpressure water cooling circuit
- Water temperature control
- Volume flow
- Pressure

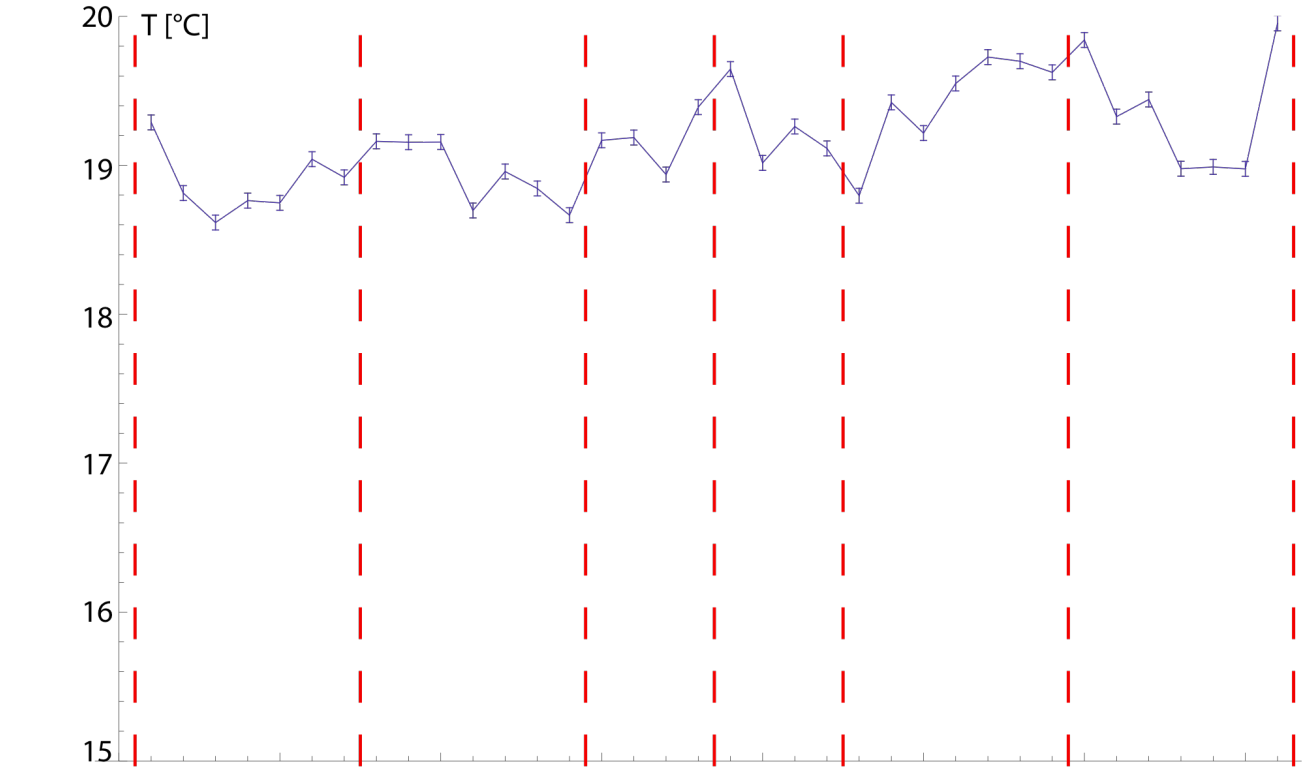
Performed measurements

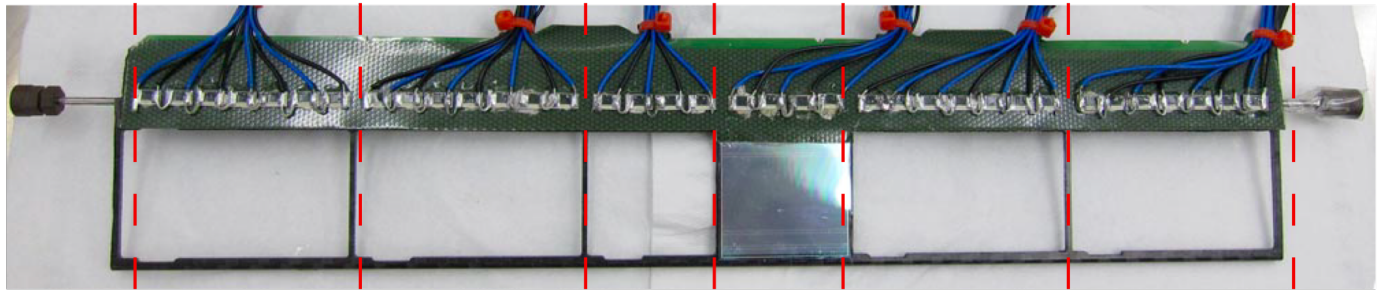
- Scan over different water fluxes (150 – 350 mL/min)
- Different power configurations:
  - Nominal power (17W)
  - Nominal power, only front side (9.2 W)
  - Nominal power density (1.67 W/cm2) → 10 W or 150 mW/chip
  - Nominal power density, only front side (5.5 W)
- Temperature profile along the stave (measured on the 36 resistors)
- Temperature measured on the sensor and on some points on the stave

Results – base measurement

Temperature profile without heating (cooling flux 135 mL/min @ 18°C)

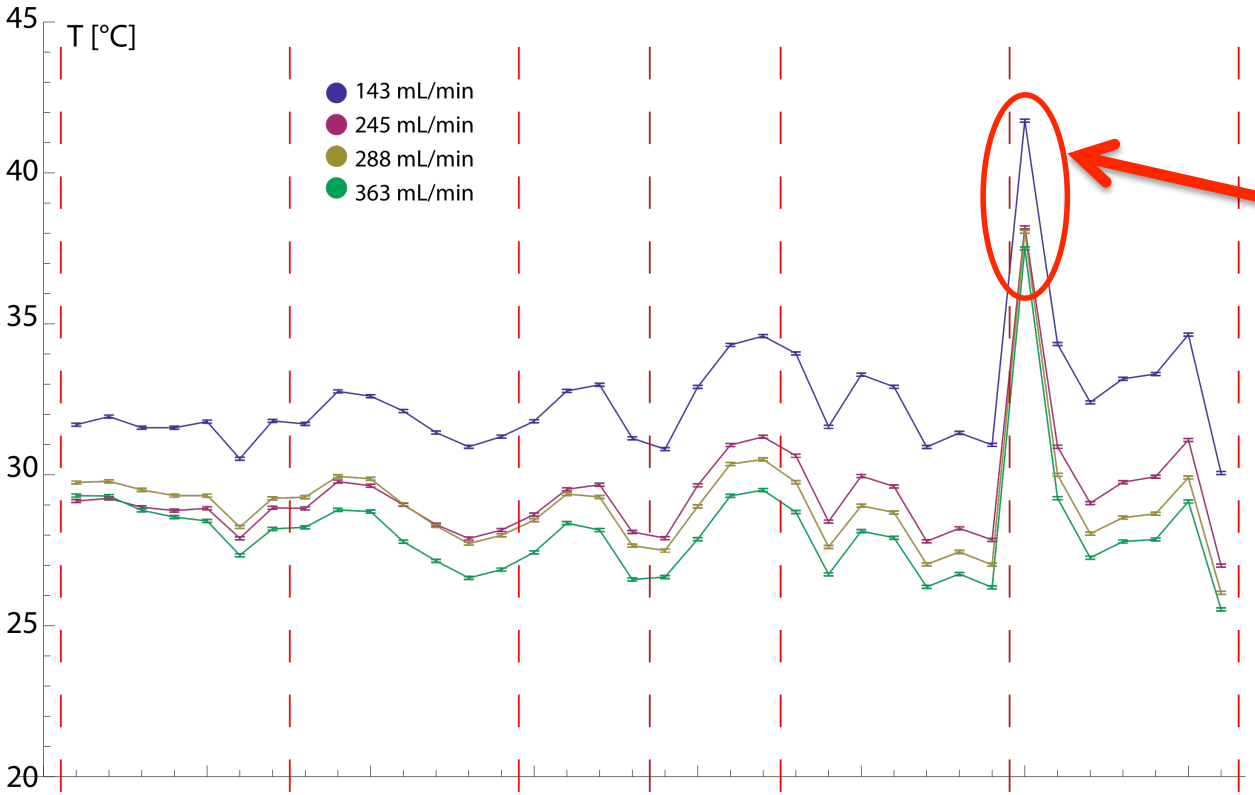
Room temperature ~20 °C



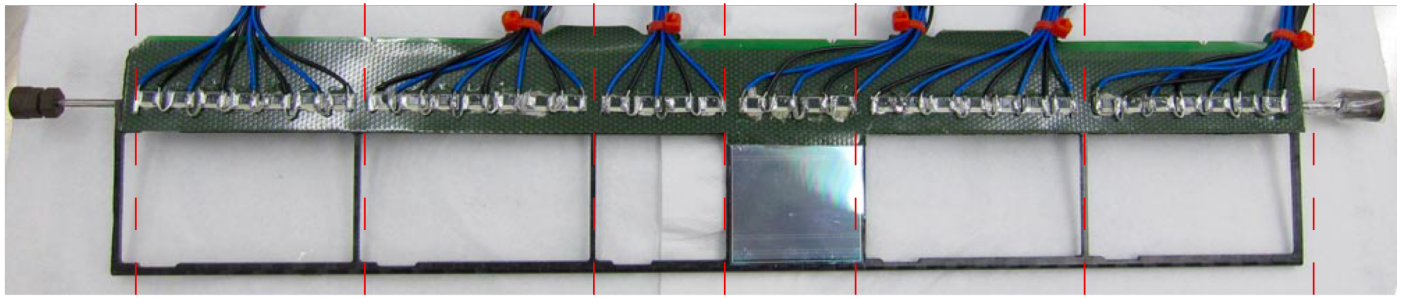


Results – nominal power

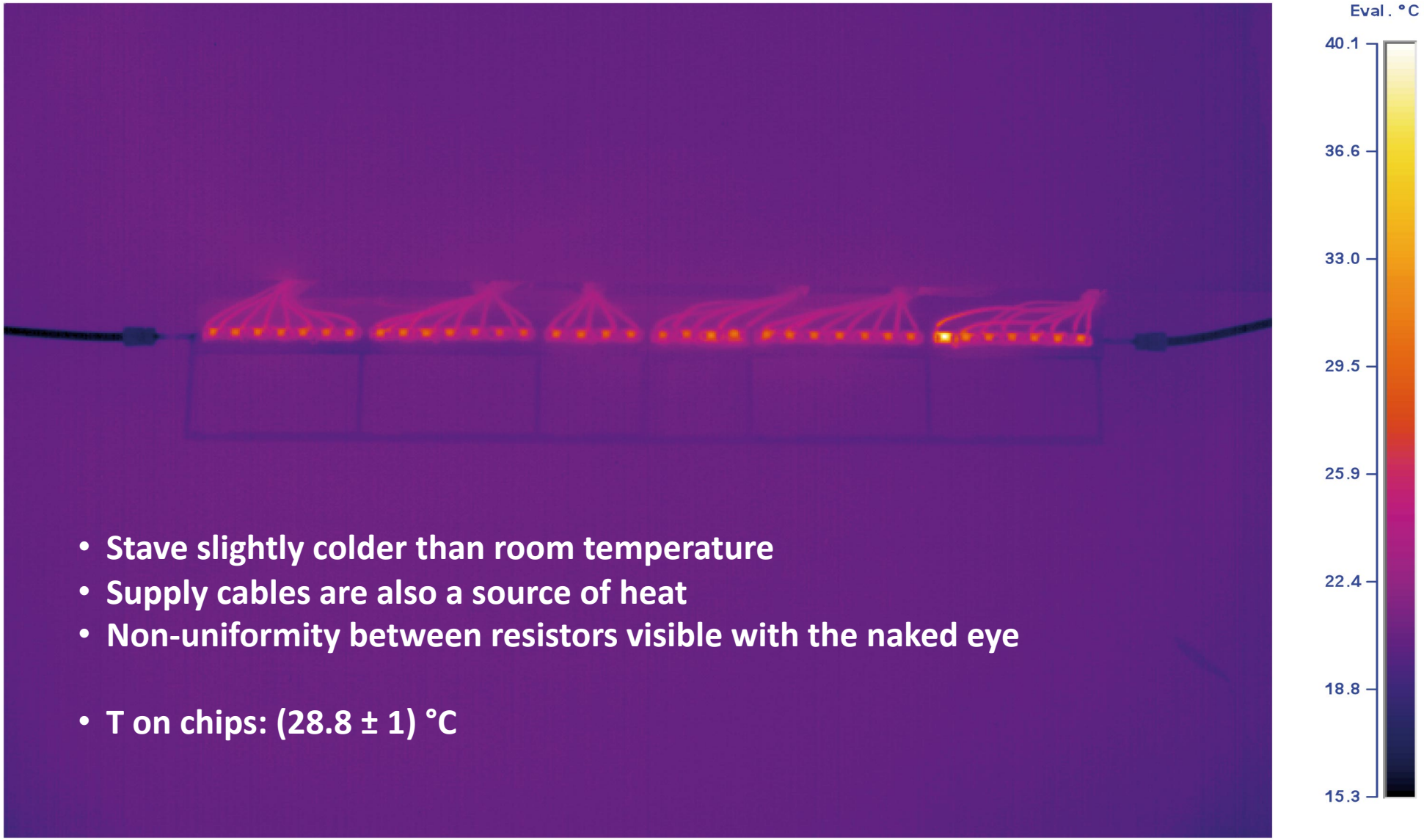
Temperature profile with heating at nominal power (16.9 W); cooling water @ 18°C, different fluxes. Room temperature ~20 °C



10 – 15 °C warmer than other resistors: Glue layer originally too thick, then damaged



Results – nominal power

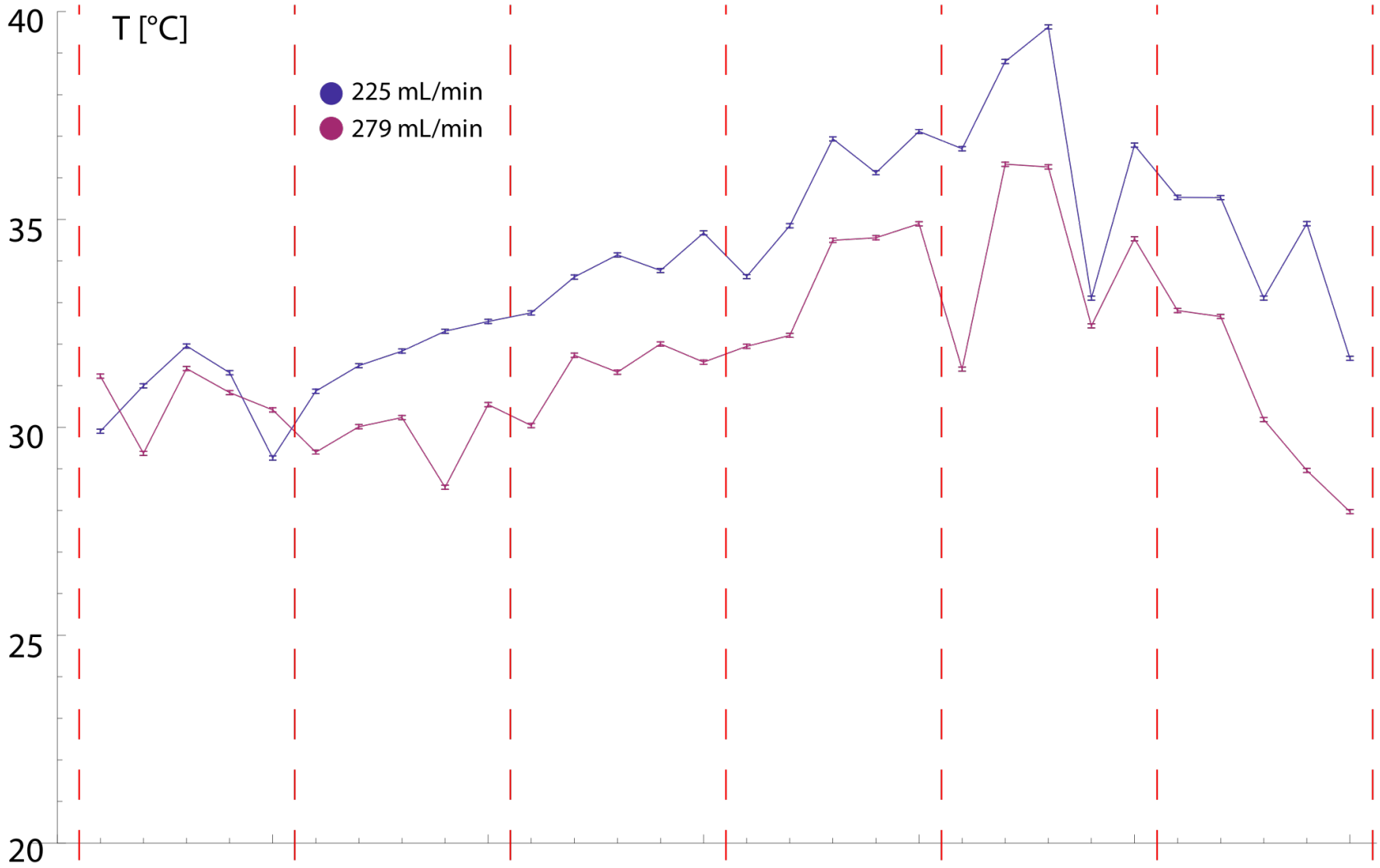


- Stave slightly colder than room temperature
- Supply cables are also a source of heat
- Non-uniformity between resistors visible with the naked eye

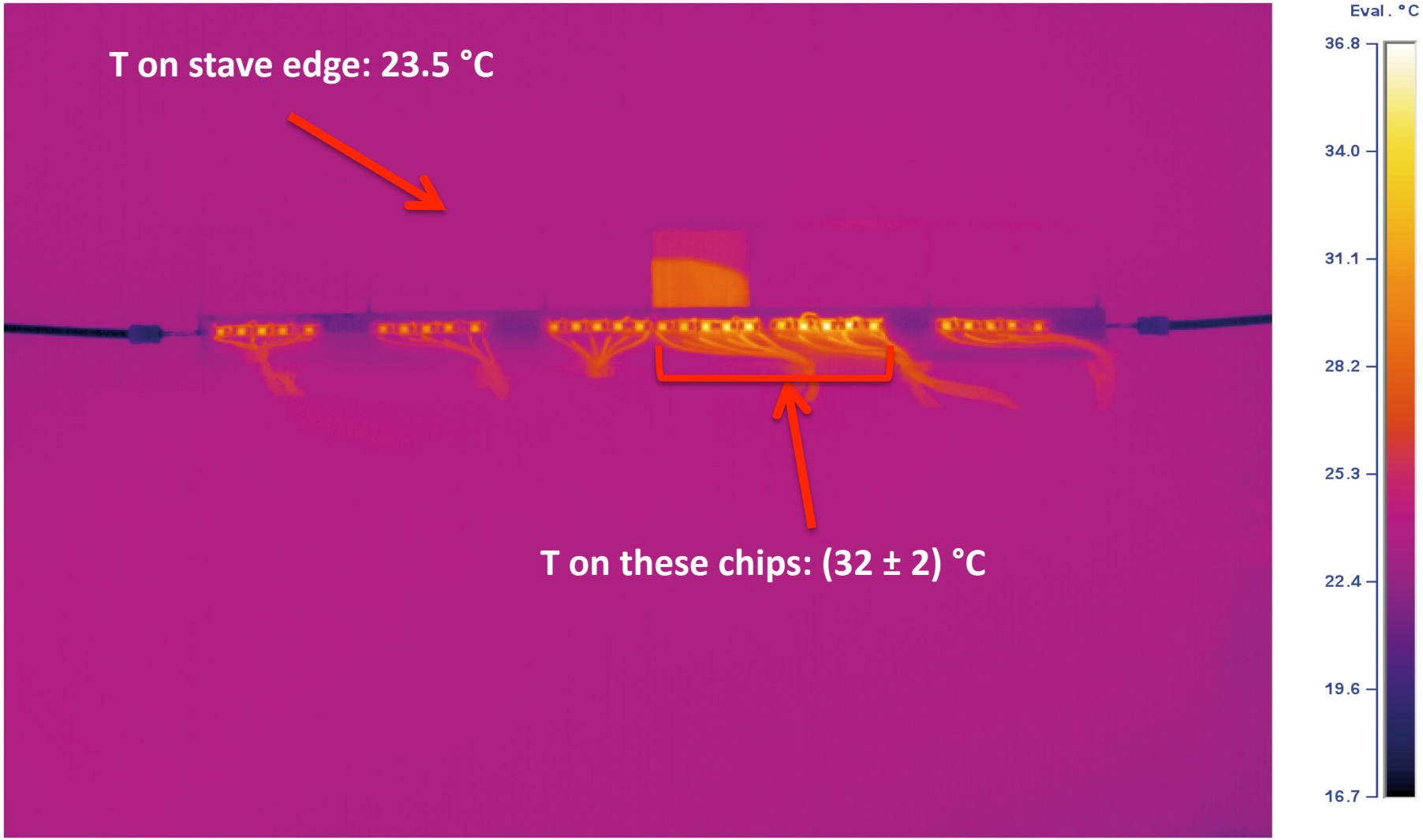
- T on chips: (28.8 ± 1) °C

Results – nominal power (back side)

Temperatures generally higher than on the front side

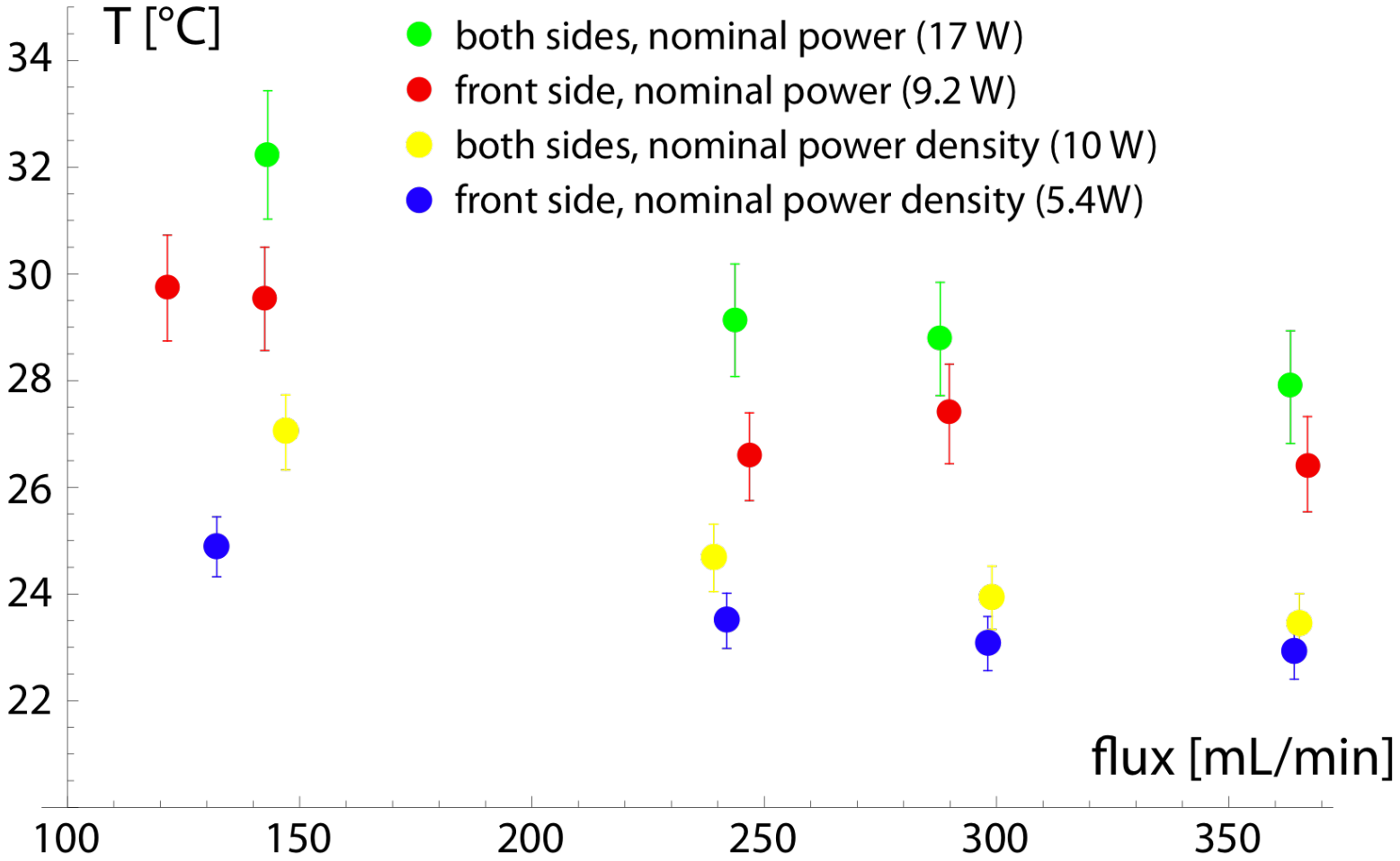


Results – nominal power (back side)



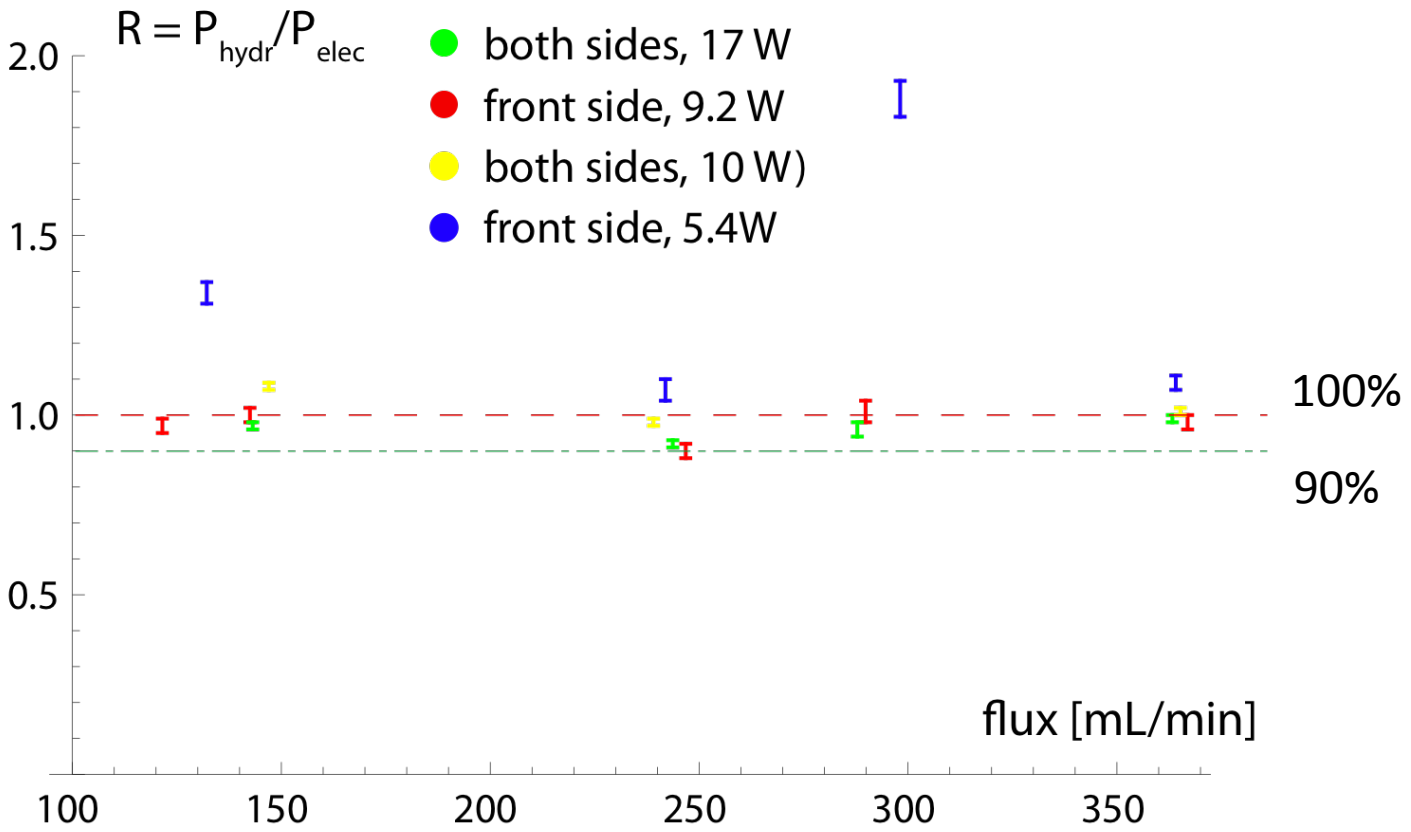
Results – different power configurations

Temperatures generally higher than on the front side



Results – dissipated power

- Power dissipated by the cooling water is $P_{hydr} = \Delta T \cdot C_{water} \cdot \Phi/60$
- All values above 90%; many are above 100%
- ΔT is small and difficult to measure precisely

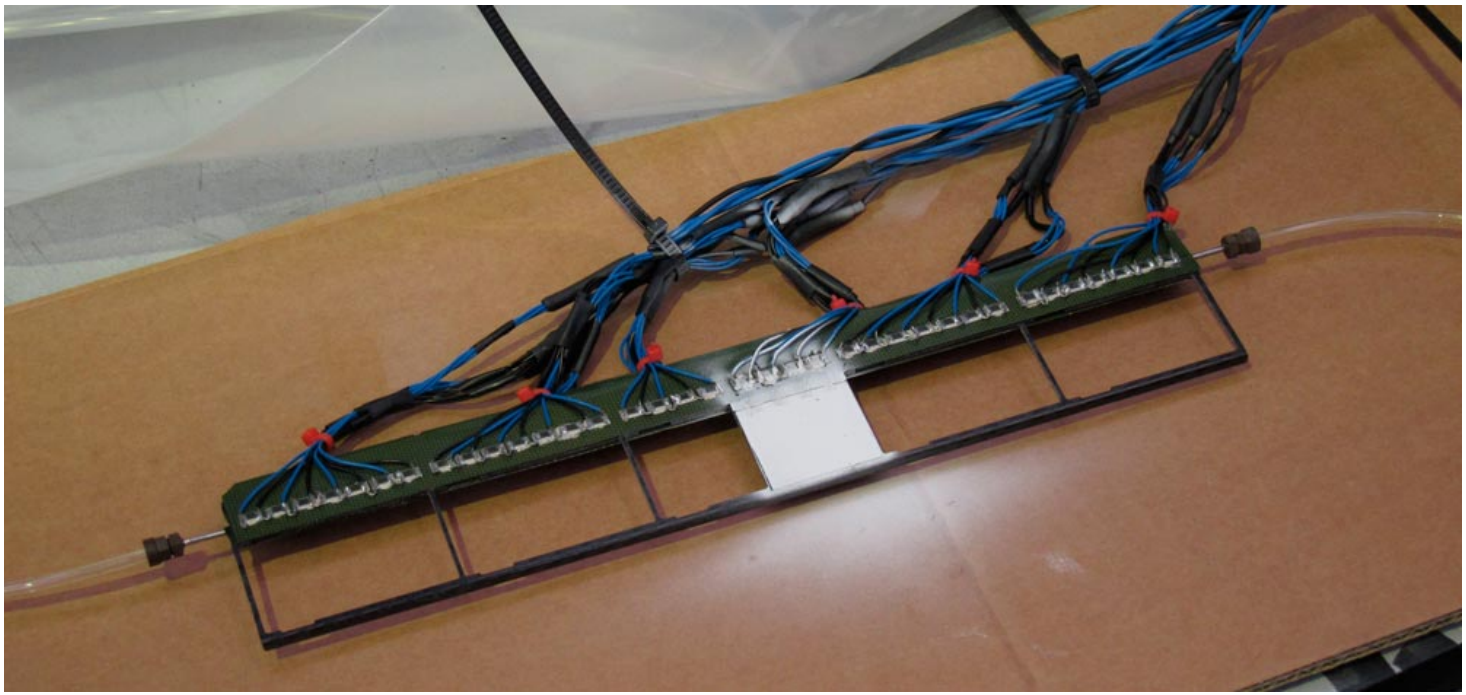


Results – measurement with sensor

The sensor has very low emissivity → cannot be measured with IR as it is.

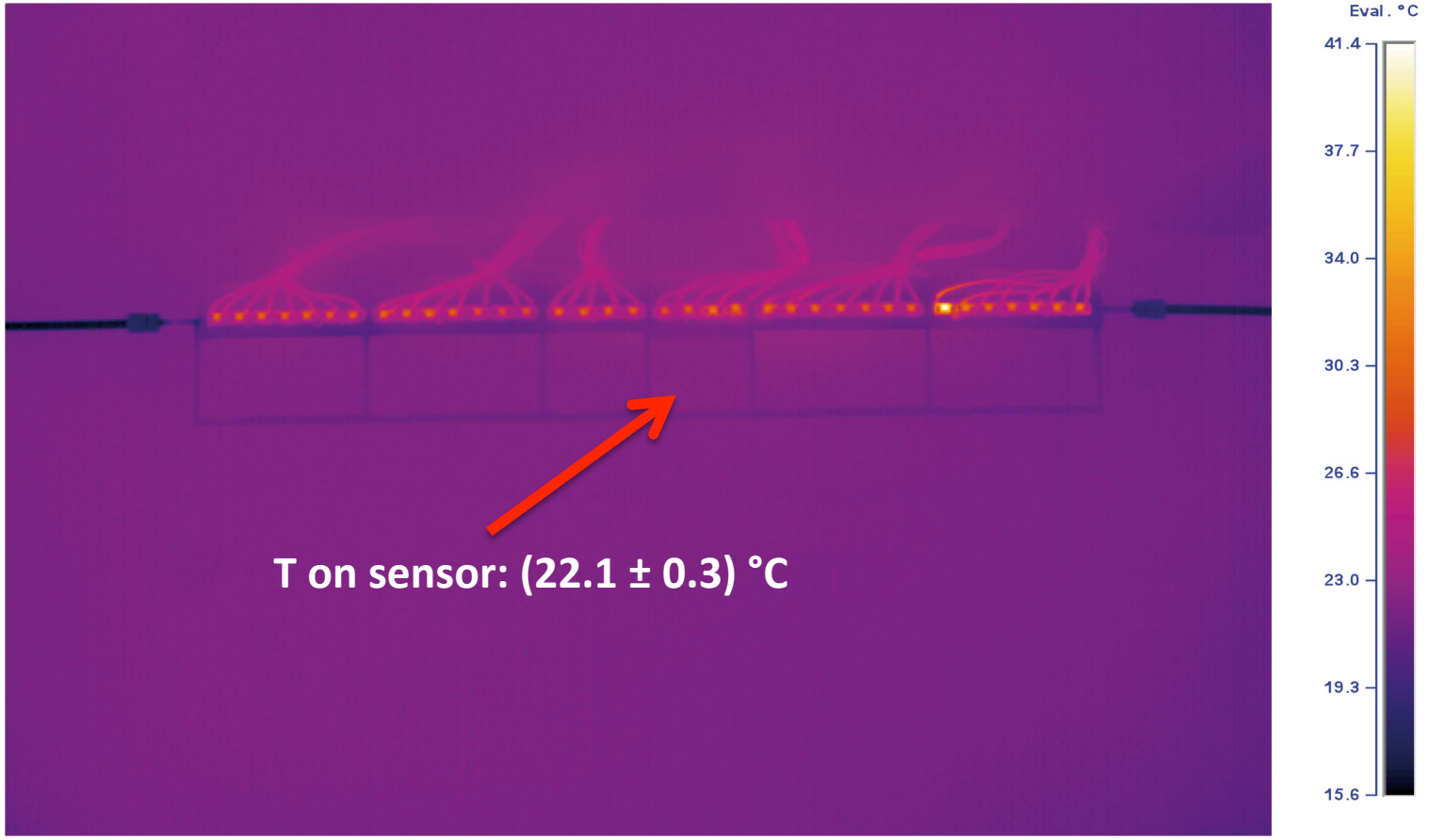
Possible solution: thin layer of white powder.

Reflection strongly reduced (although still present)



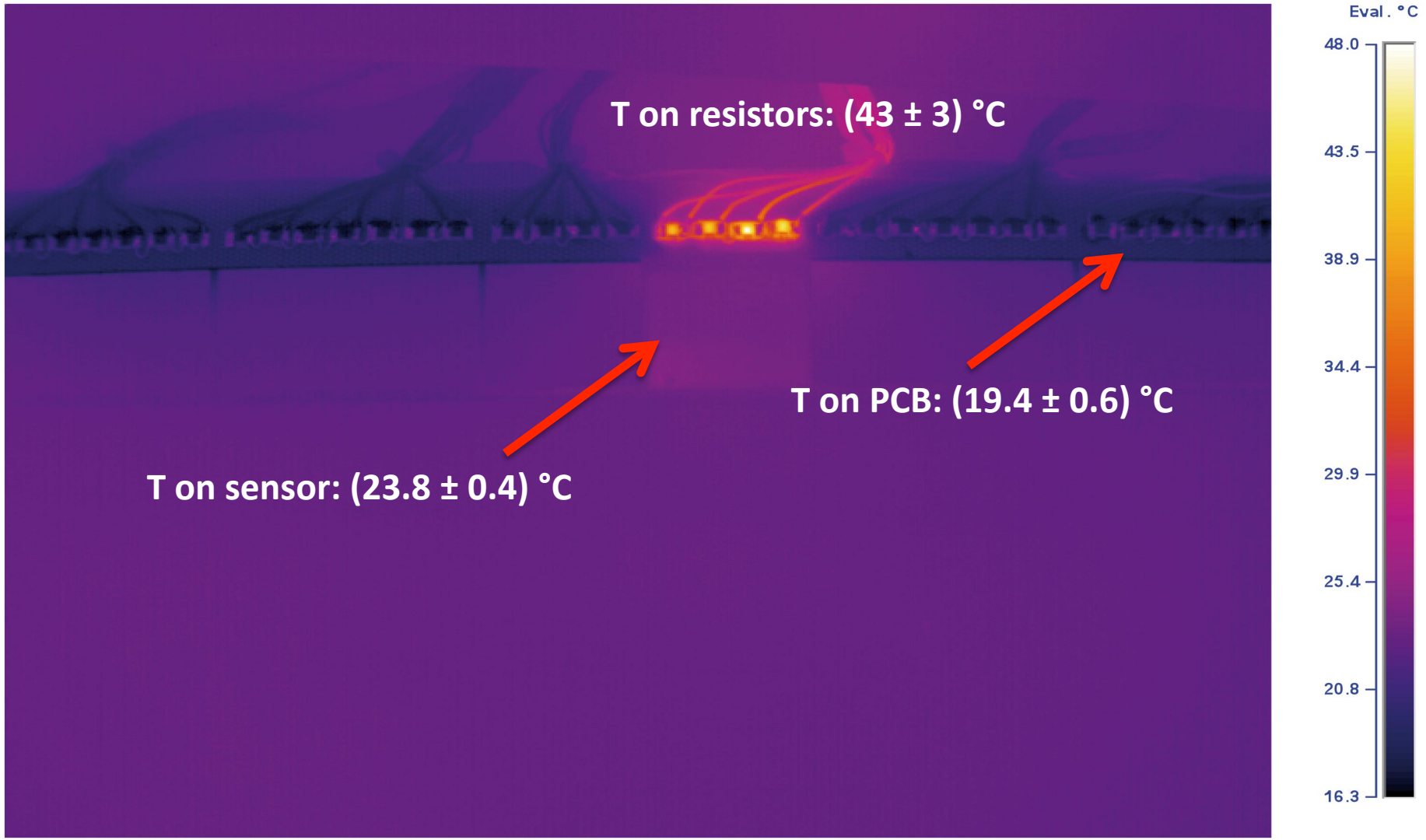
Results – measurement with sensor

The temperature on the sensor approaches the room temperature



Results – measurement with sensor

Additional test with double power (512 mW per chip), only on 9 resistors around the sensor



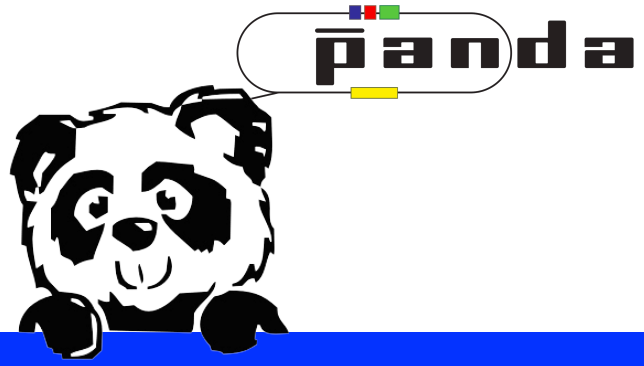
Summary

- First validation of stave cooling system: satisfactory results!
- Negligible heat transfer from the chips to the sensor
- The uniformity of the glue layer is crucial
- With maximum power, $T_{chip} < 35°C$ and $T_{sensor} < 25°C$

Summary

- First validation of stave cooling system: satisfactory results!
- Negligible heat transfer from the chips to the sensor
- The uniformity of the glue layer is crucial
- With maximum power, $T_{chip} < 35°C$ and $T_{sensor} < 25°C$
- CAVEAT: influence of room temperature not studied!

  → New tests with higher room temperature are required.



Thank you for your attention!

Results – nominal power (back side)

Several measurements performed beside the resistors: