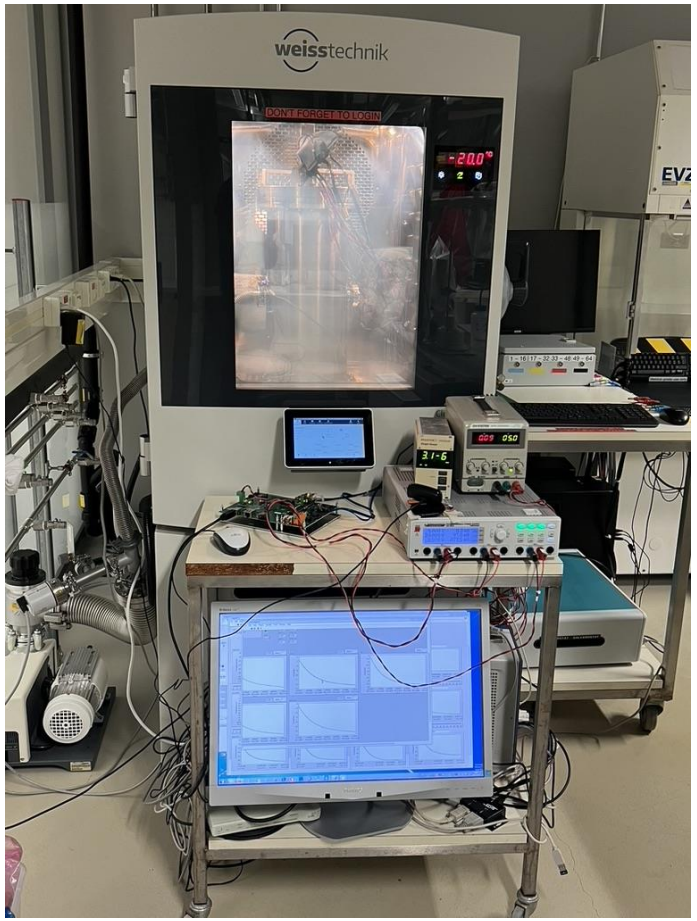
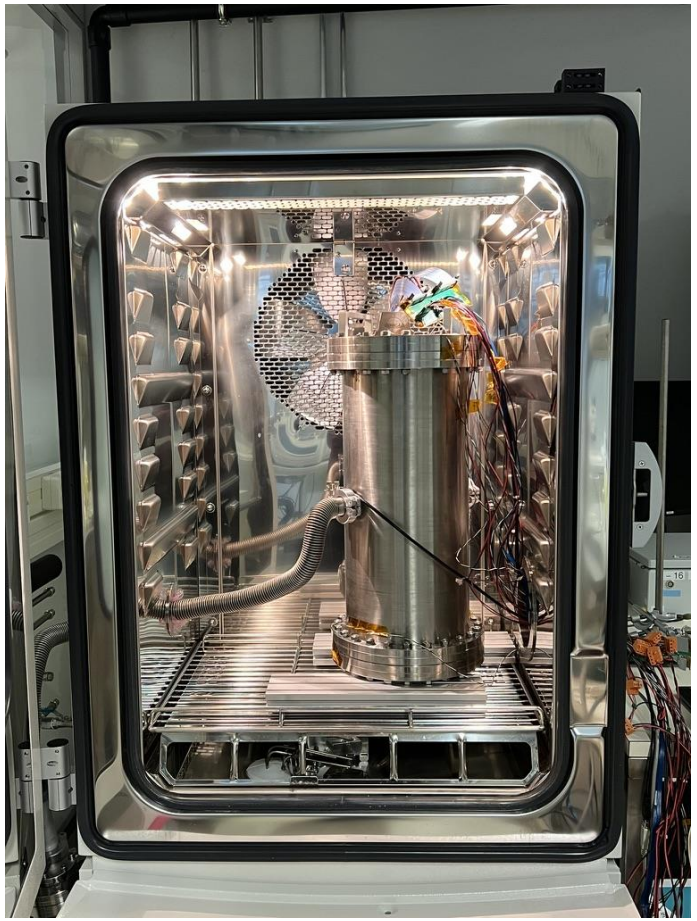
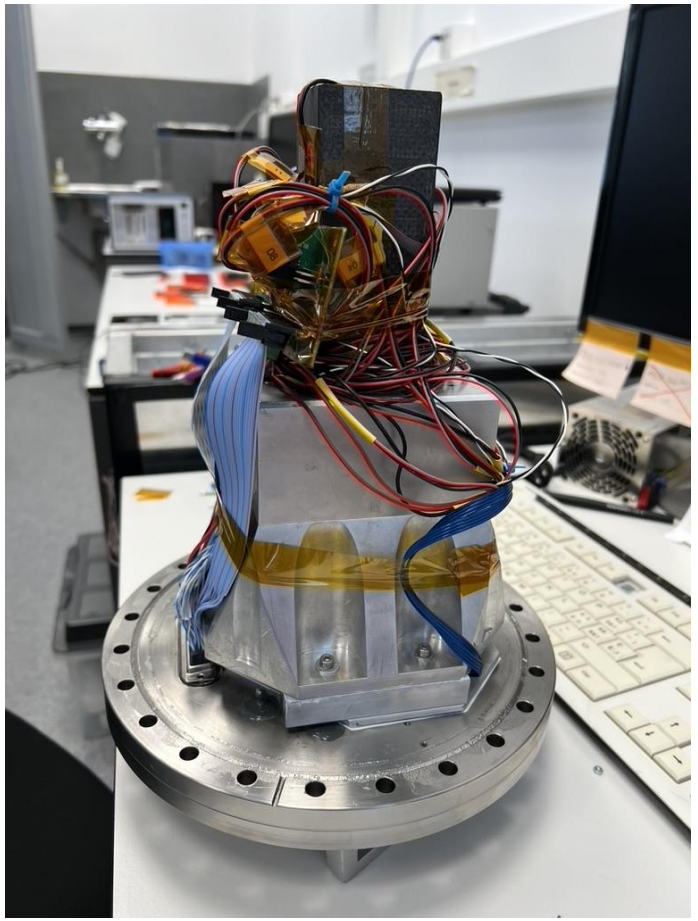
FEE 009 bias failure

DPNC454_02A PCB

FEE 009 test at Biotech

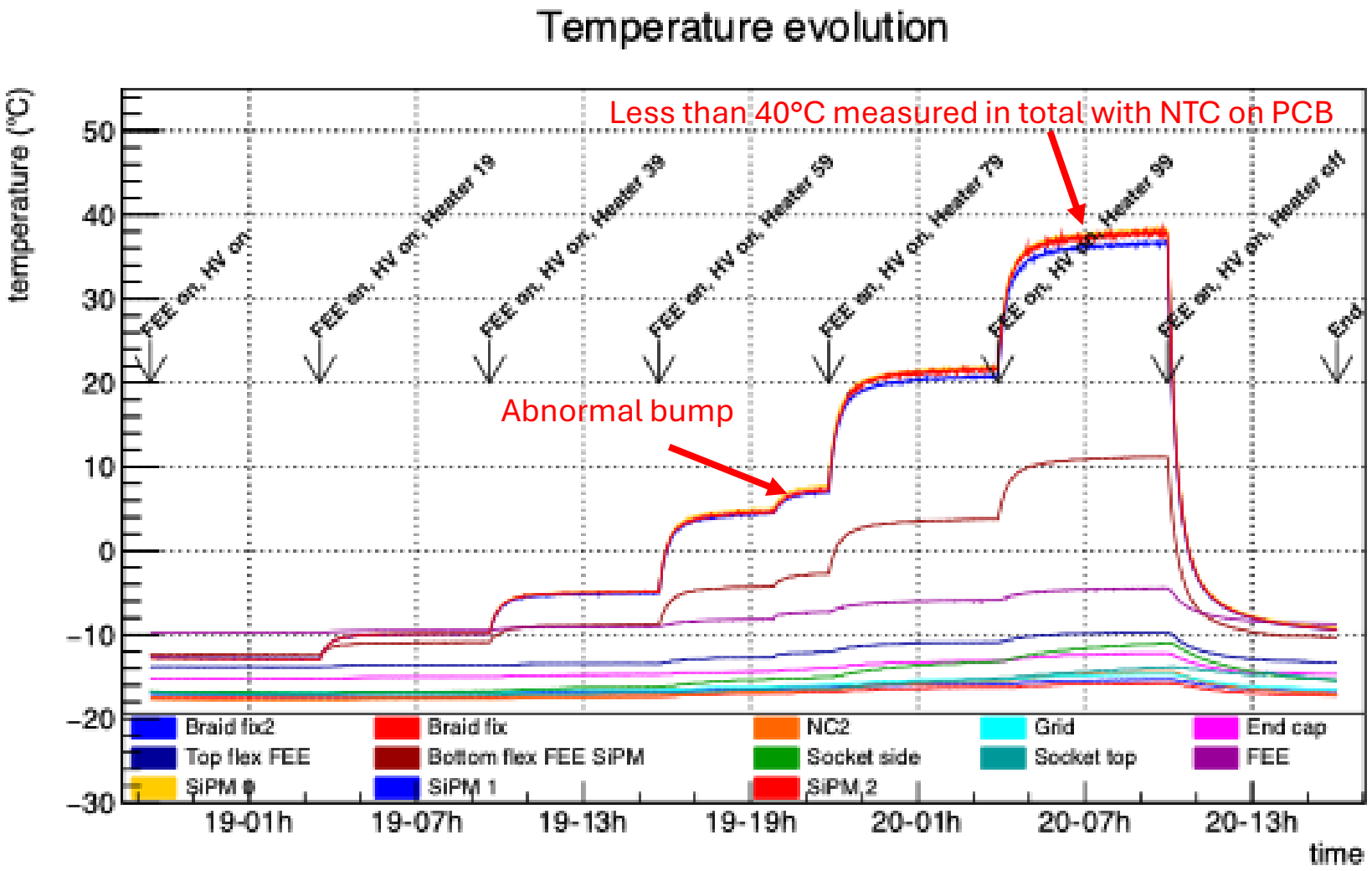






Vacuum and chamber temperature cycling while varying heater resistors voltage mounted on the PCB (PWM control)

Heater test (19.12 – 20.12)



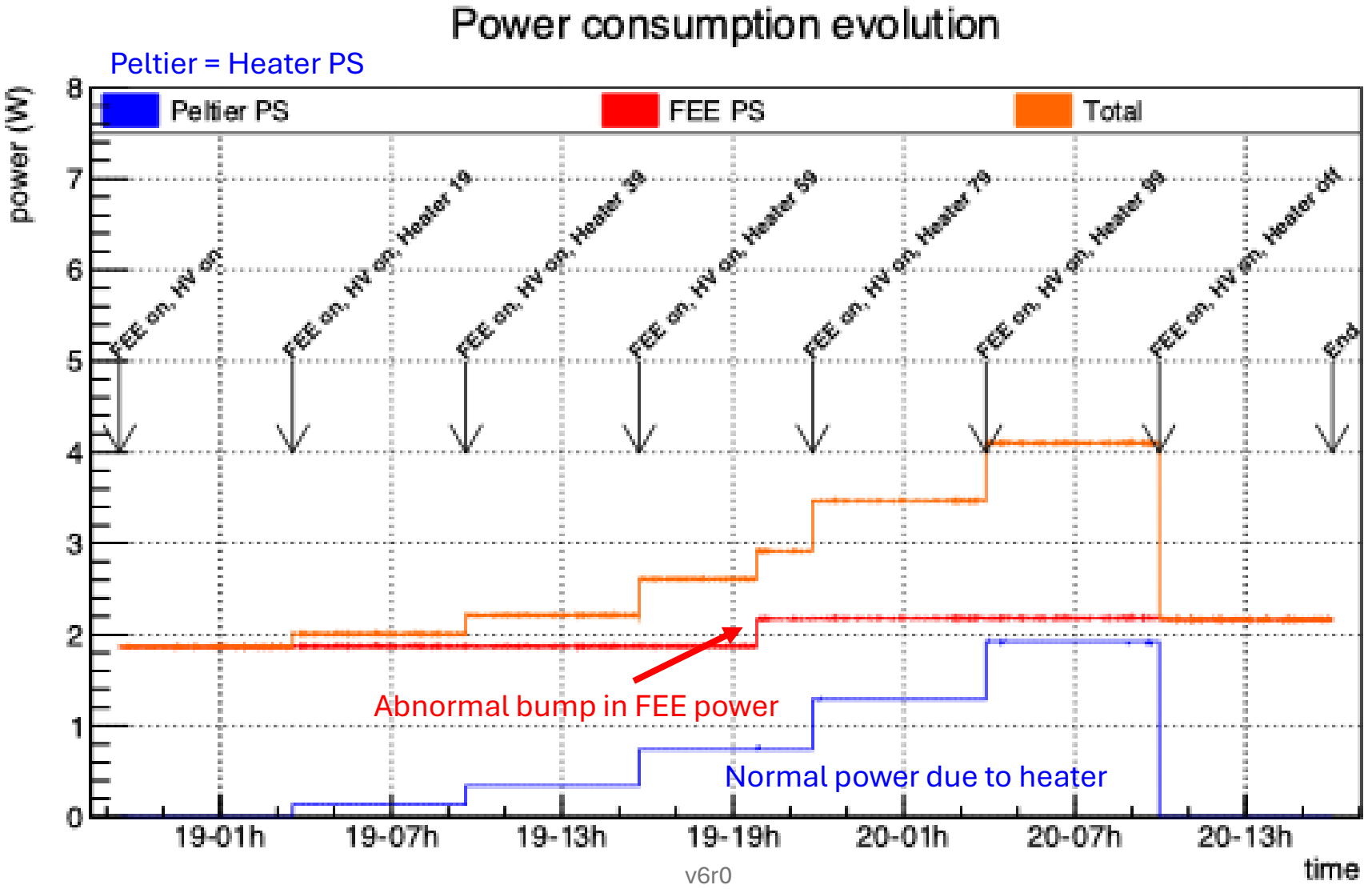
Heater resistors in red

NB: view from TOP

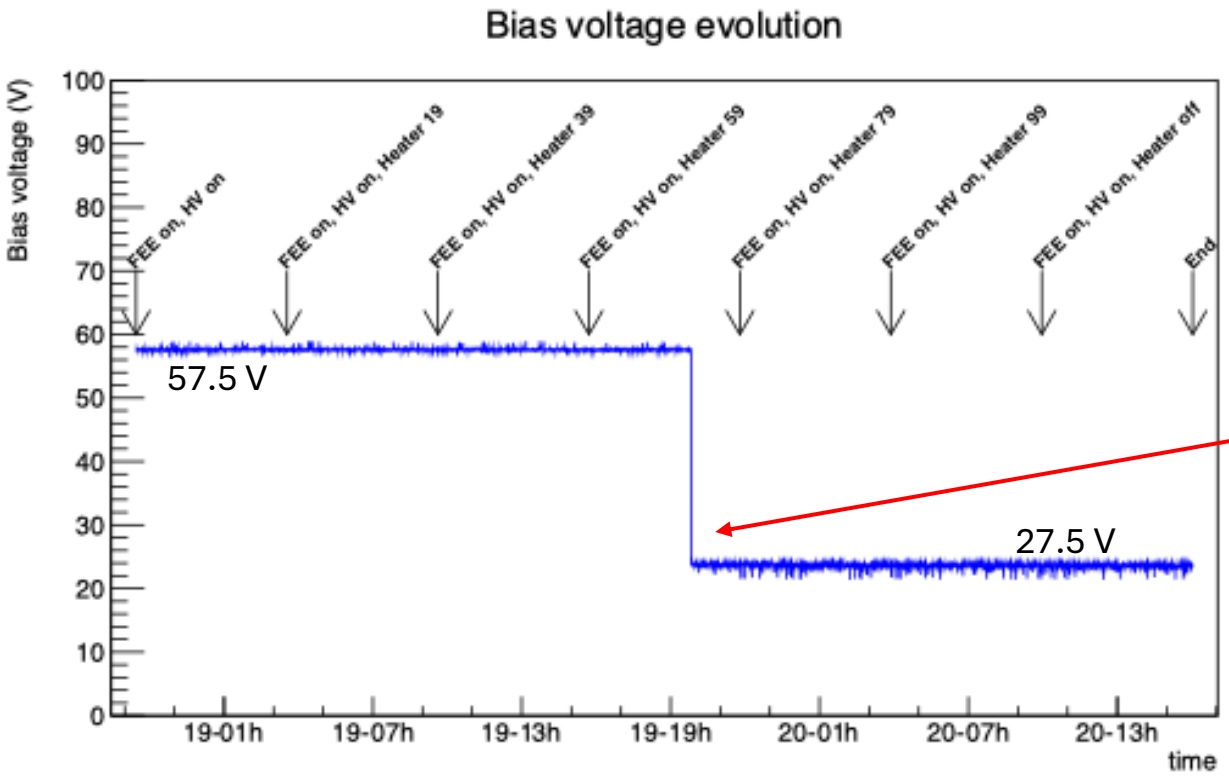
⇒ PWM voltage steps on heater resistors voltage mounted on the PCB (PWM control value 0, 19, 39, … 99%)

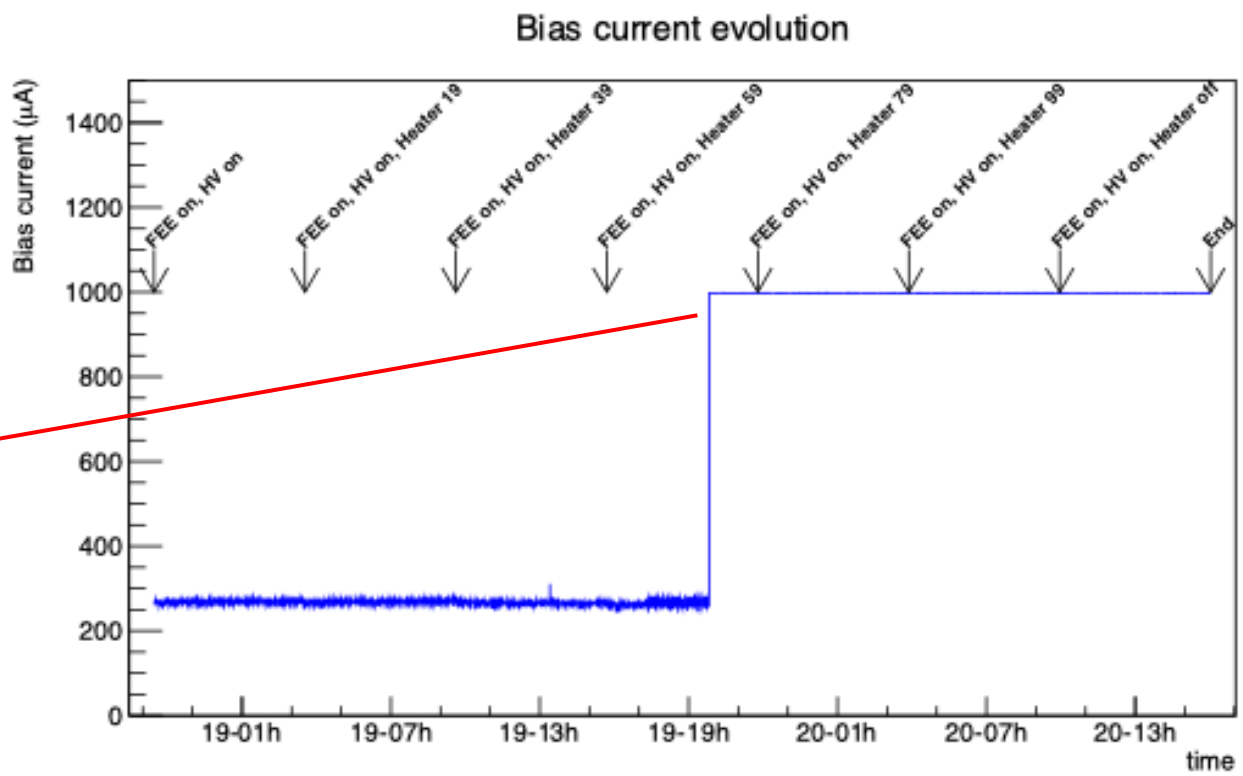
⇒ 100% power = 2W max balanced over 8 x 5R11 1206 resistors on Bottom of SiPM arrays (R383-R389, R396)

Heater test (19.12 – 20.12)



Heater test (19.12 -20.12)





The bias voltage has a current limiter: too much current => voltage drop

What happened ?

During the heating phase with a duty cycle of 59%:

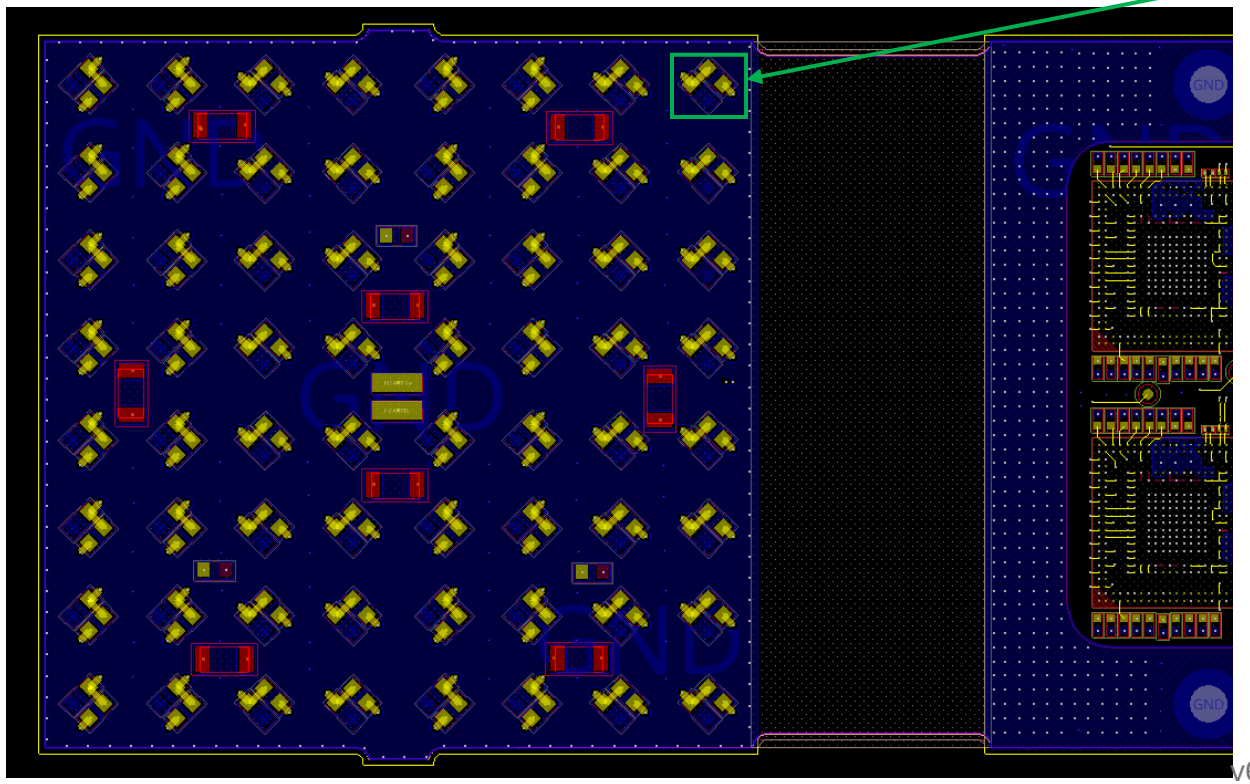
- Temperature of the SiPM sensors progressively increased by 2.5 C.
- Power consumption of the 3V9 line increased by 0.3 W.
- Bias voltage dropped from 53.5 V to 23.5 V.
- Bias current increased to > 1 mA (max. reading of the HK).

→ There must be a short circuit on the HV line, located on the SiPM PCB.

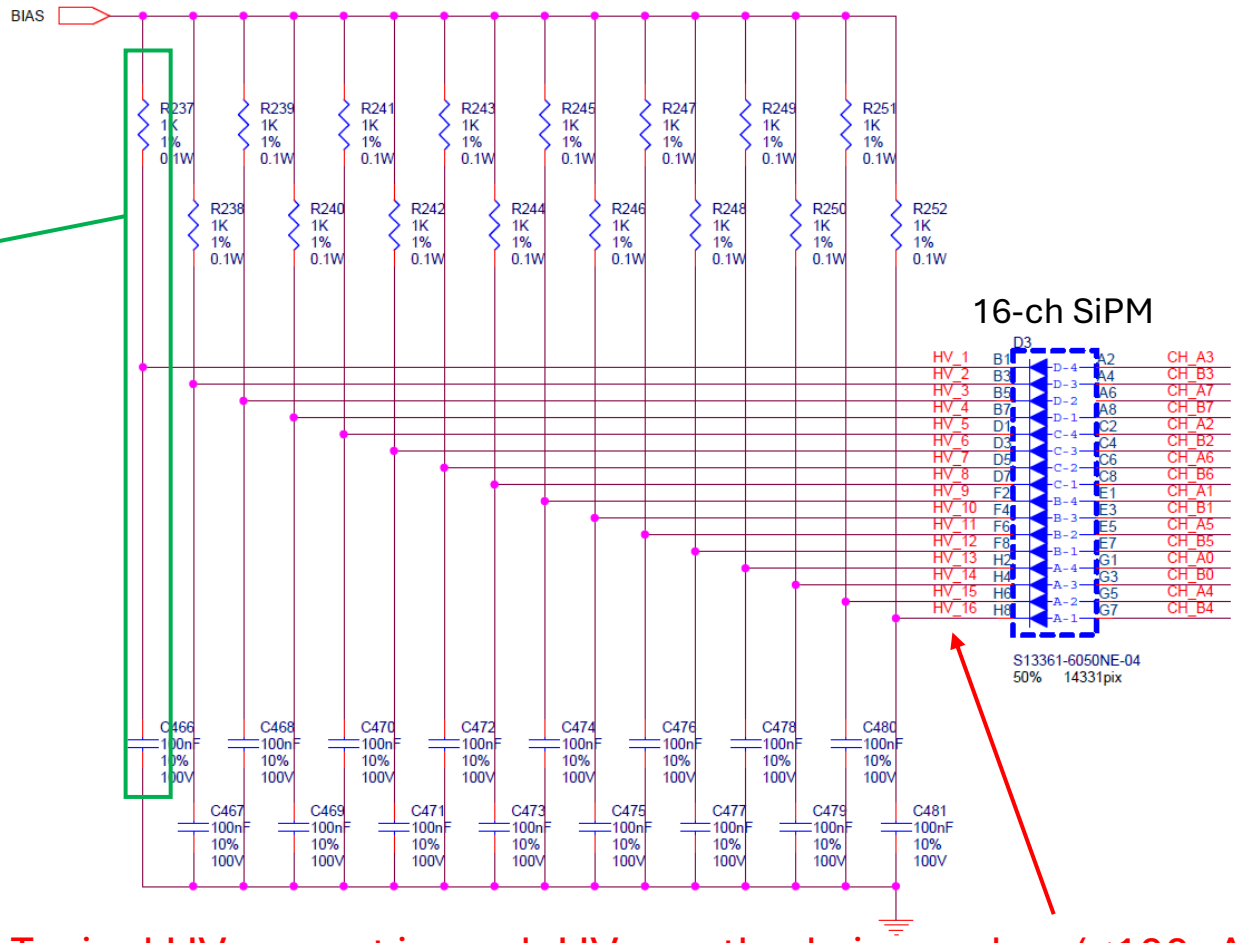
Bias distribution circuit

Repeated 4 x this 16-channels SiPM cell
= 64 channels on PCB

64 x 1K/100nF cells
on PCB bottom

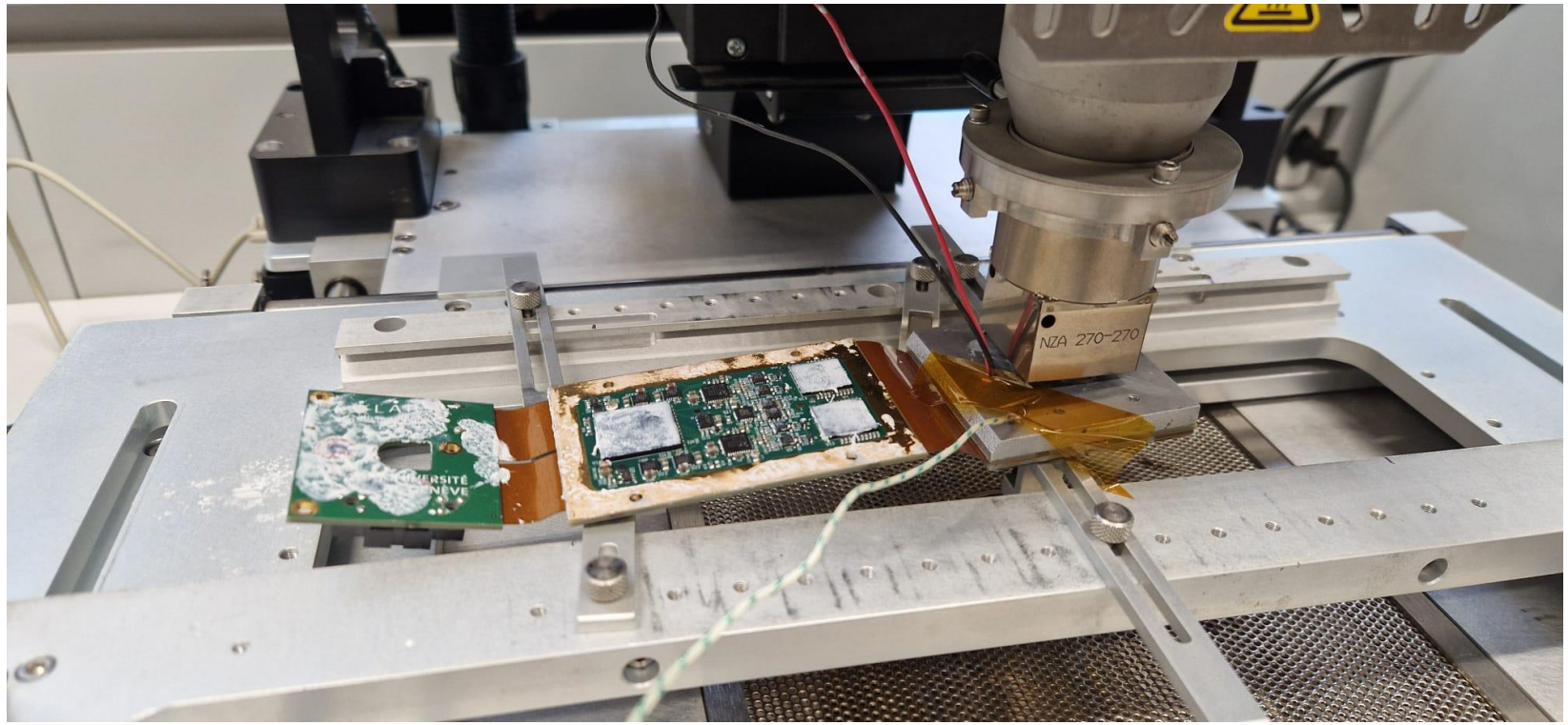


NB: view from TOP

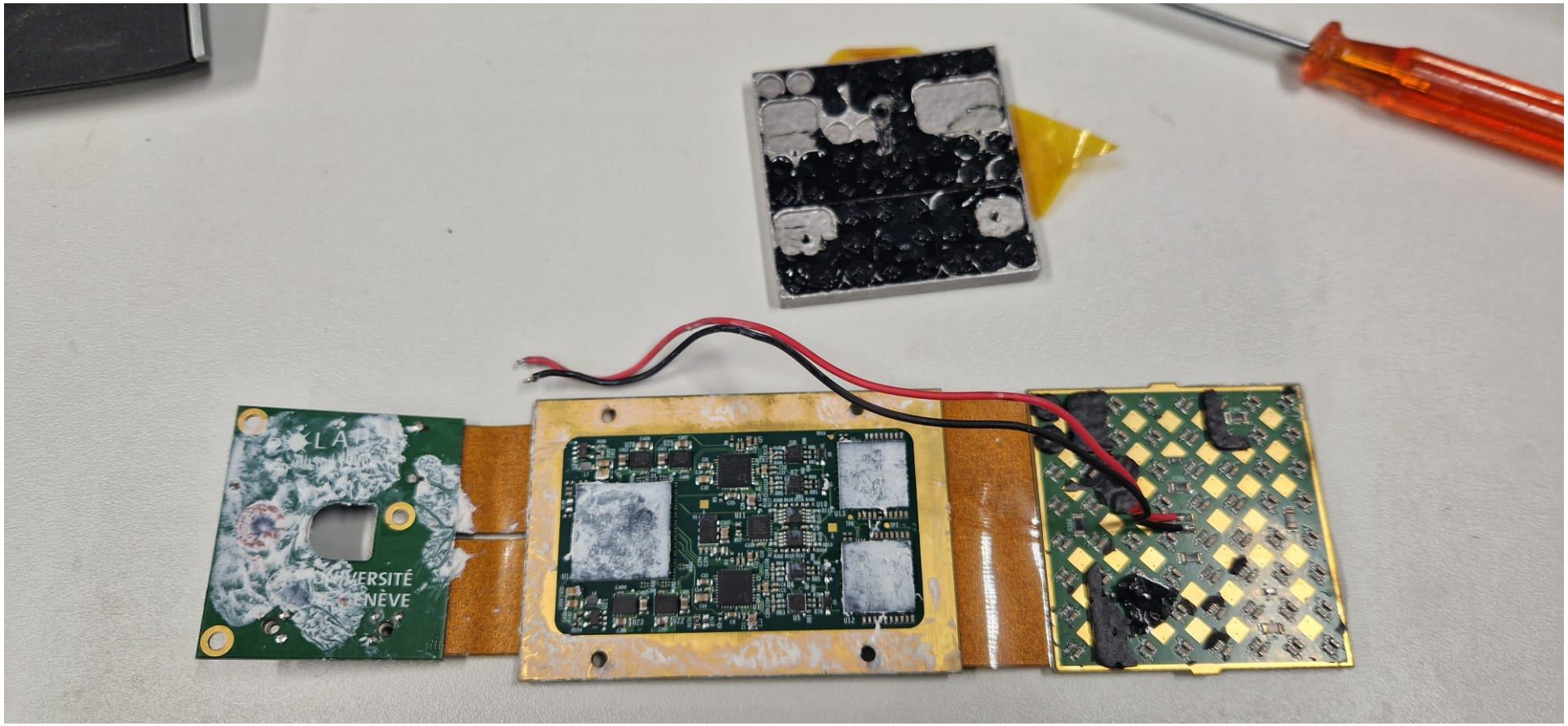


Typical HV current in each HV_x cathode is very low (<100µA)
A short to GND on HVx means $I_{BIAS}=V_{BIAS}/1K \sim= 5.7mA$

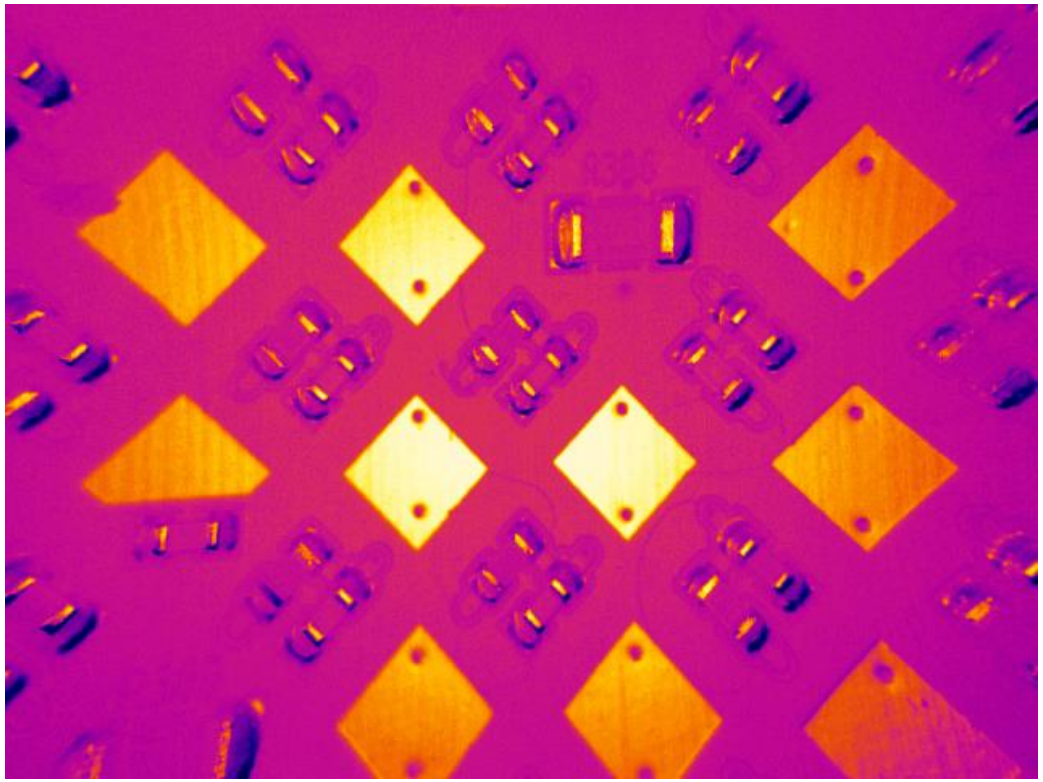
FEE dismounting



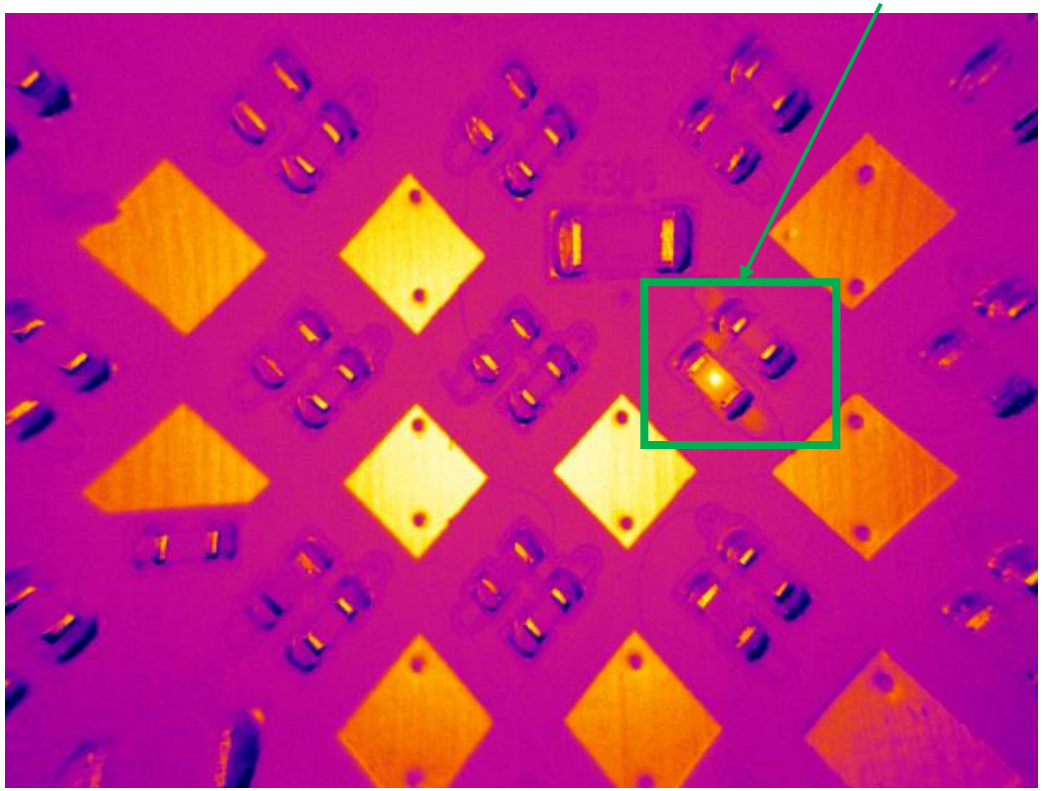
FEE dismouting



IR camera: 1K R215 heats when HV is on

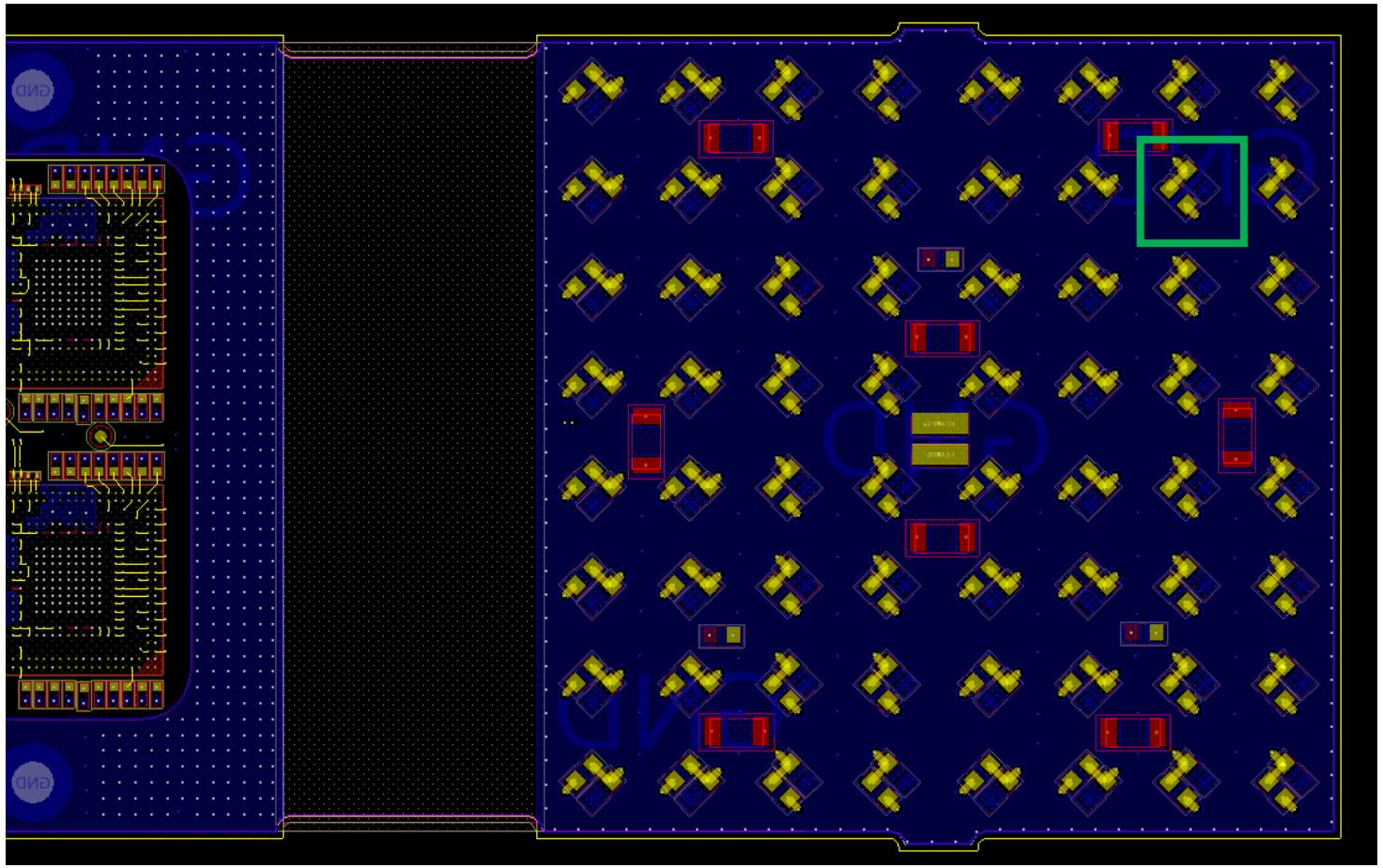


HV off



HV on (3550)

1st supposition : capa damaged



NB: view from BOT

- R (C444) = 200 Ohm (HV11-GND) : KO
- R (R215) = 1 kOhm (BIAS-HV11) : OK
- R (C447) = 2.2 kOhm (HV14-GND) : OK

→ Only one damaged component.

- Capacitor C444 damaged ?
- If yes thus shorts the HV BIAS to ground through 1K + 200R = 1.2 kOhm (i.e. ~5 mA)
- HV source cannot sustain such a connection to ground.
- HV voltage goes down to some 25 V.
- All the 64 SiPMs are biased below 57V V_{bd}. => all module channels are dead with this failure

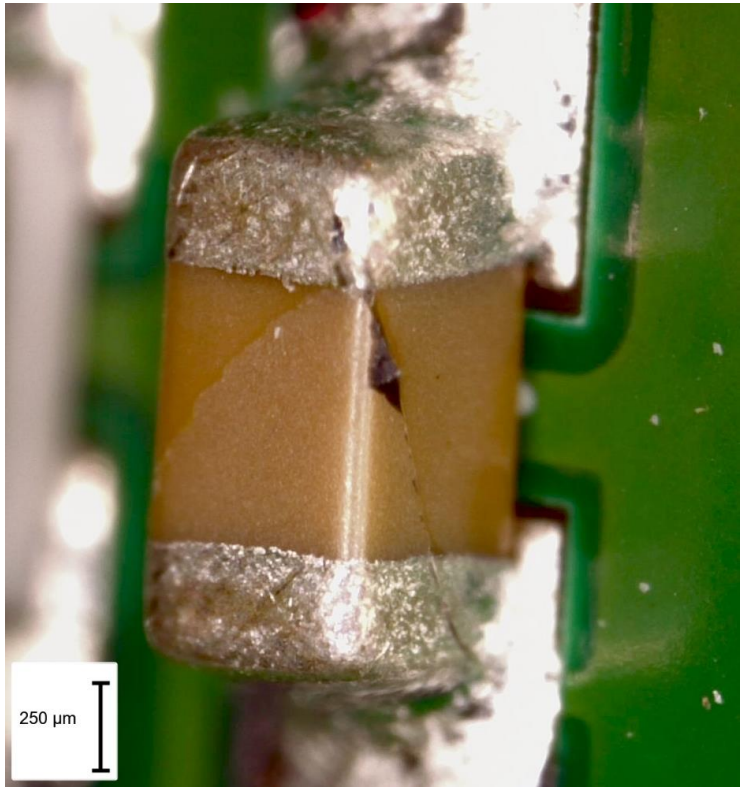
Capacitor type

The FEE 009 comes from a batch of 5 boards assembled at HybridSA. Most of the passive components have been procured by HSA, in particular the 100 nF capacitors of the bias filters.

- The capacitors are of the type CC0603KRX7R0BB104 (0.1 µF ±10% 100V X7R 0603) from YAGEO.
- The CC type corresponds to a “normal” grade, even if the X7R temperature range is extended, from -55°C to +125°C.
- Still, it is not of the automotive type (would be AC0603KRX7R0BB104).
- The same indeed applied to all the components procured by HSA for this production.

Visual inspection

- The capacitor *seems* cracked, as show the pictures below. We can also note some resine deposits. To be understood if this ok.

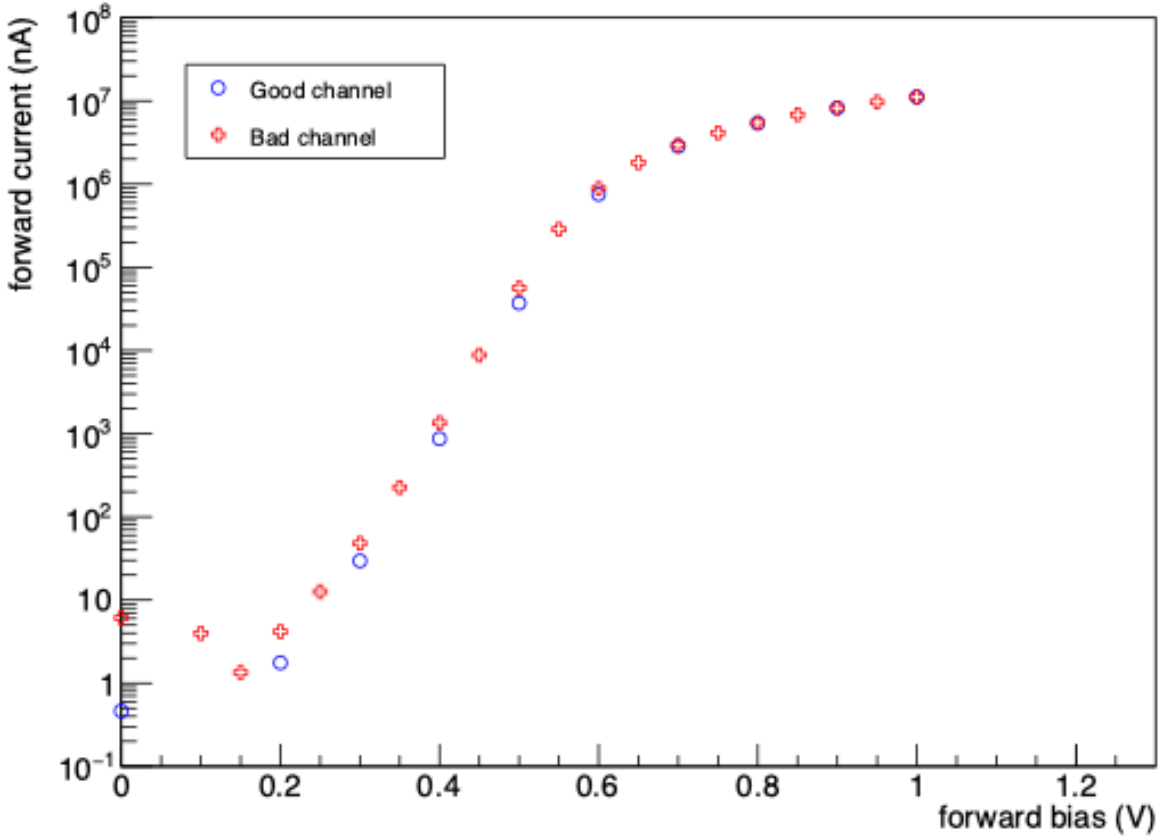


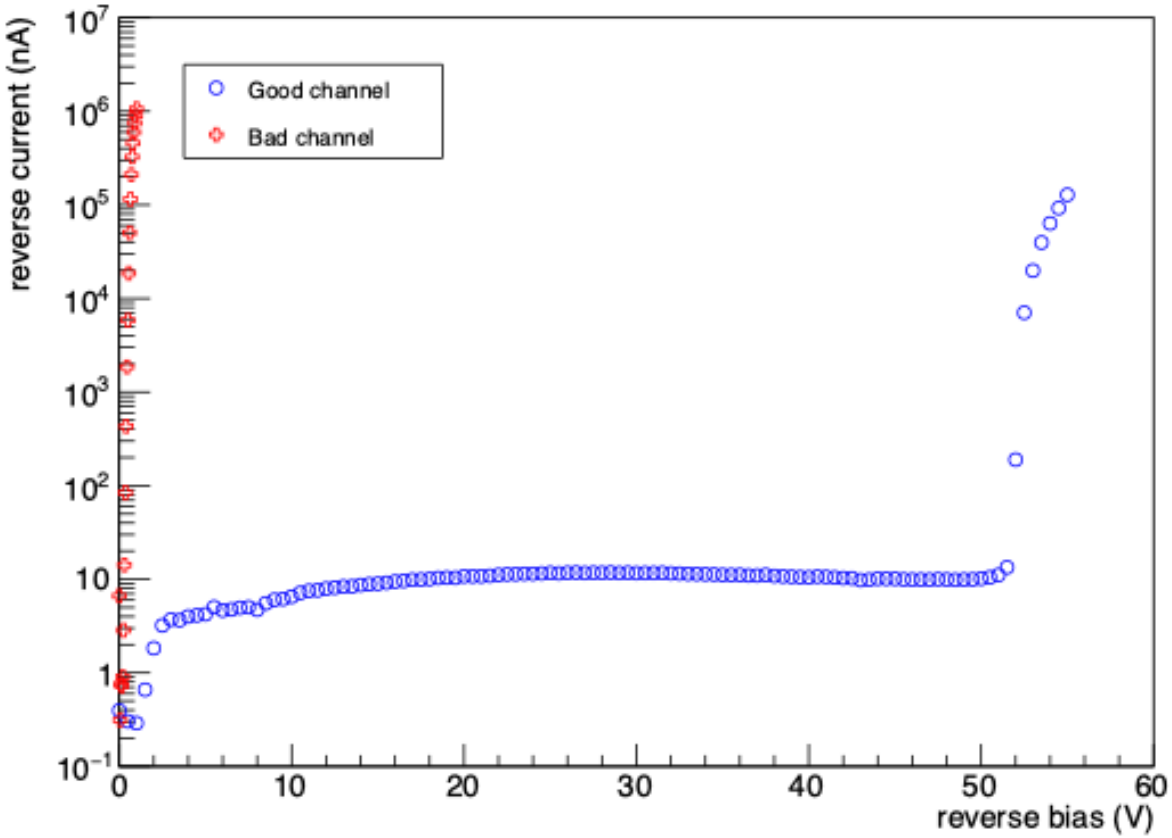
Further steps

- C444 has been replaced.
  - Remark: the removed cracked capa did not break during removal.
- The resistive connection to ground is still present.
- Various tests have been done, in particular I-V mesurements on a good SiPM channel and on the bad one, by removing the 1K resistor and soldering wires to the Cathode and Anode SiPM lines.
  - Good channel shows normal SiPM behaviour.
  - Bad channel shows a too high current when operated in reverse bias.
  - A 200 Ohm resistor has been soldered in parallel between the HV line and GND to simulate the problem of the bad channel: the I-V curves are similar.

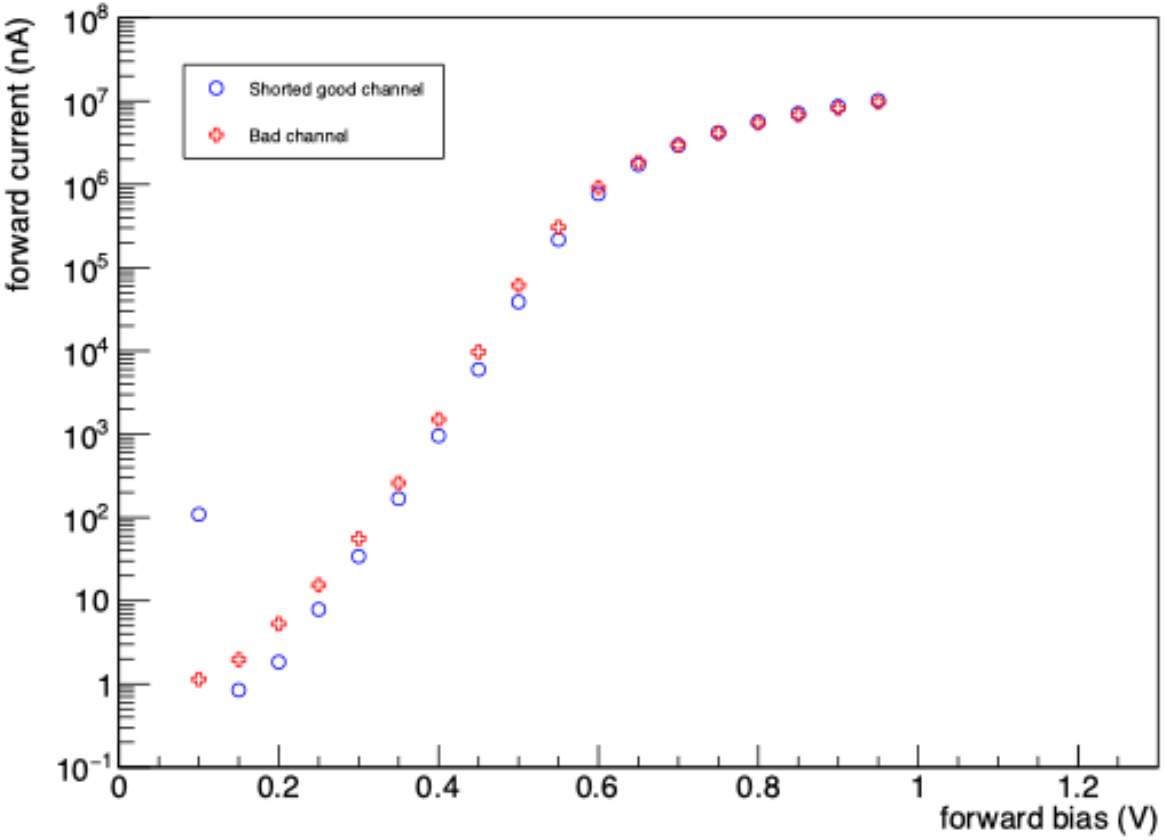
  => The SiPM seems good and the PCB seems in failure

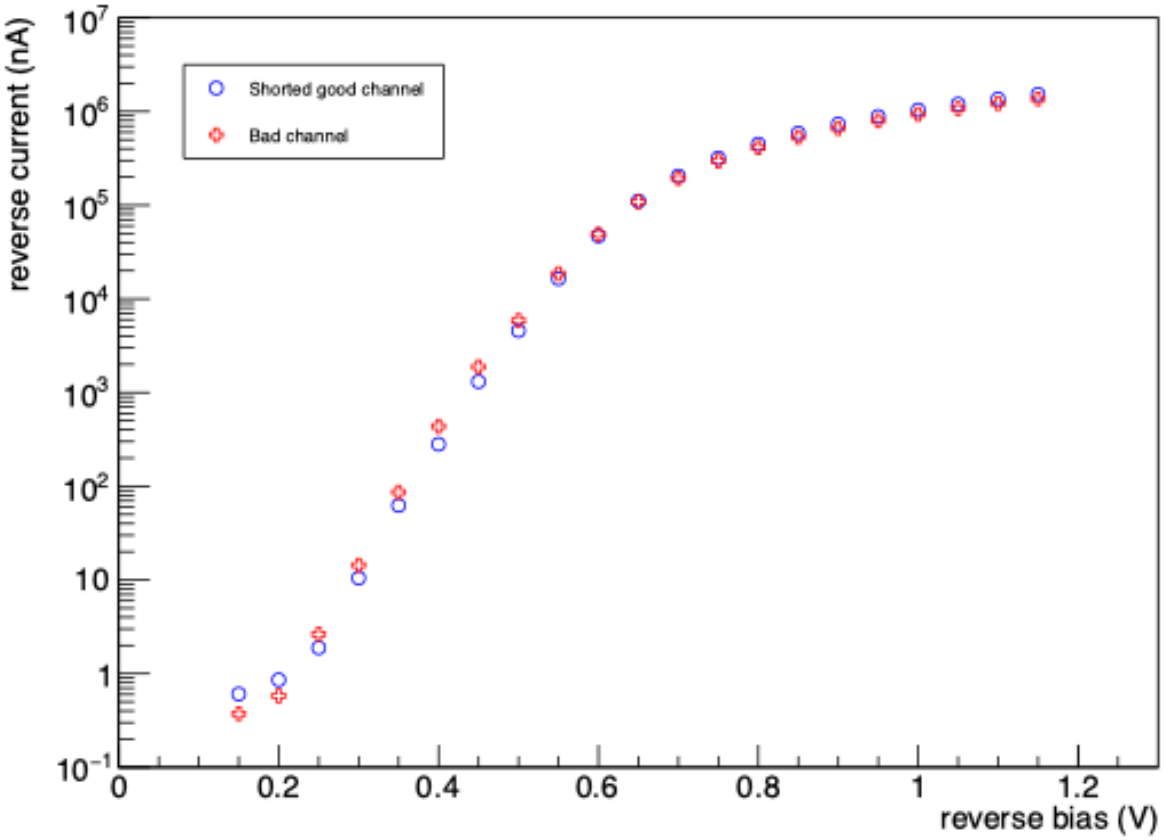
IV SiPM array measurements





IV SiPM array measurements

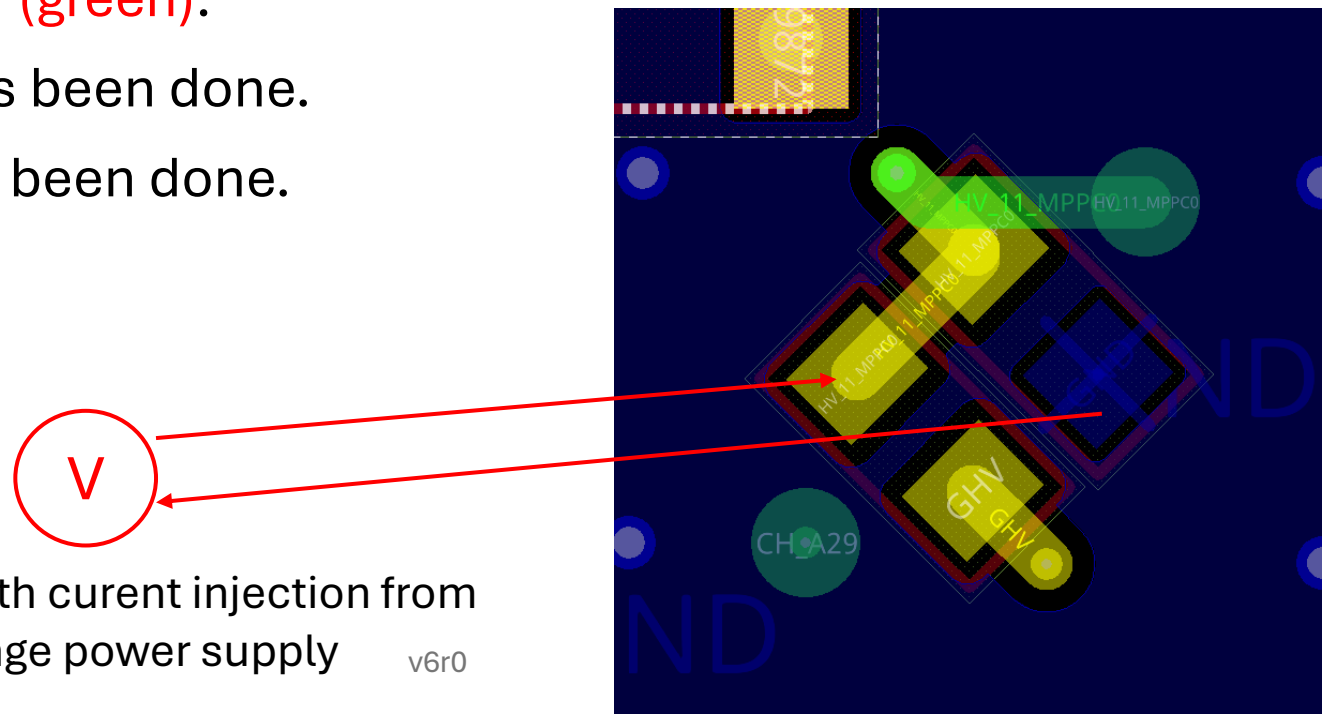




=> Same curve on forward and reverse biasing for bad channel and good channel with 200R to GND

SiPM array removal

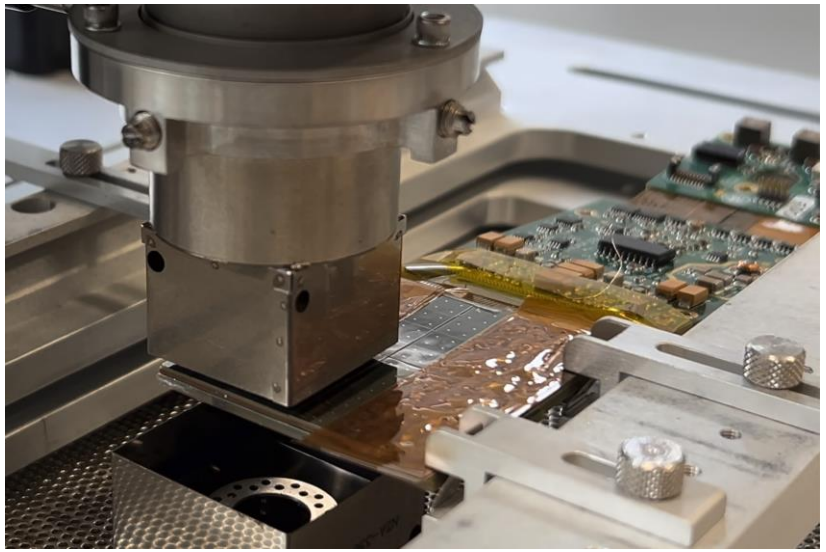
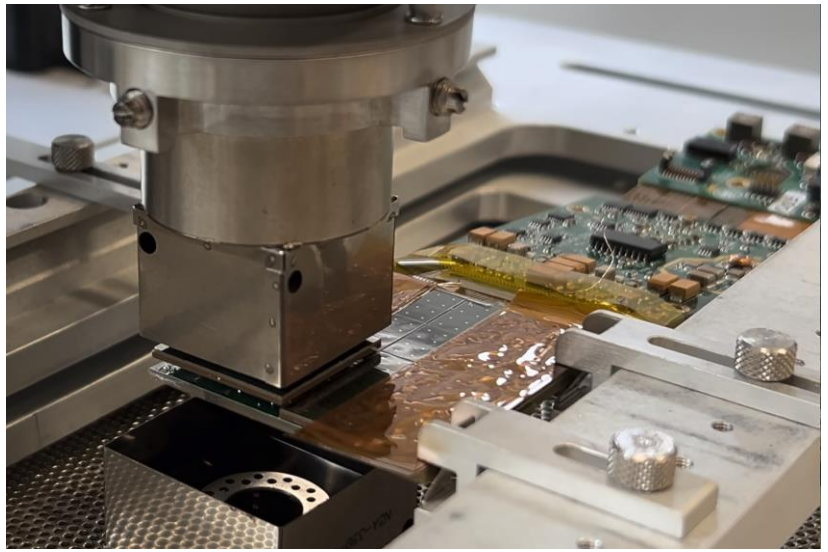
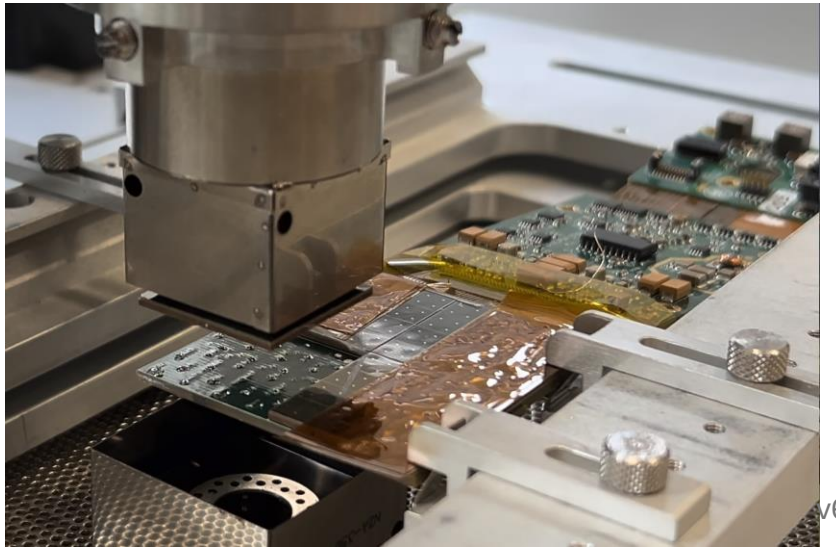
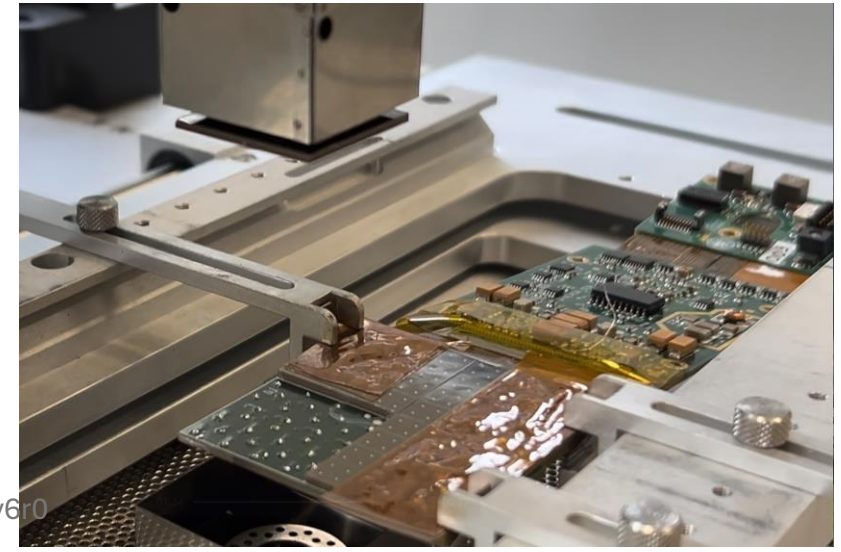
- As it is not possible to clearly identify the origin of the problem, we have decided to remove the SiPM array, the capacitor and 1K resistor (only PCB traces remain)
- The array still has to be measured.
- But the resistive connection between the HV11 line and GND is still present on the PCB and now on a very limited area : 1 small trace on BOT (yellow) + 1 through via to TOP + 1 small trace on TOP (green).
- A new IR measurement has been done.
- And X-ray examination has been done.



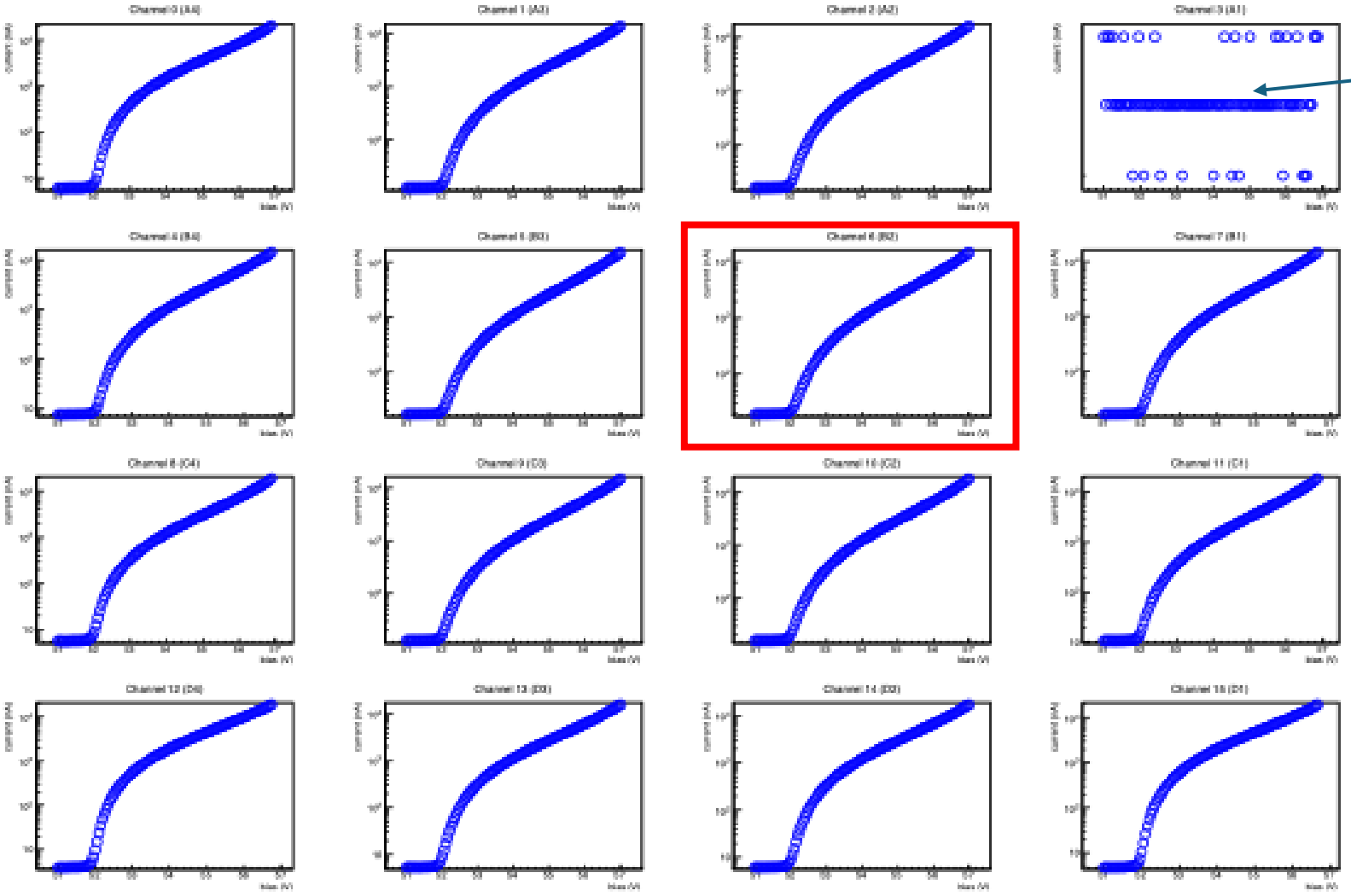
IR with curent injection from Voltage power supply

NB: view from BOT

SiPM removal

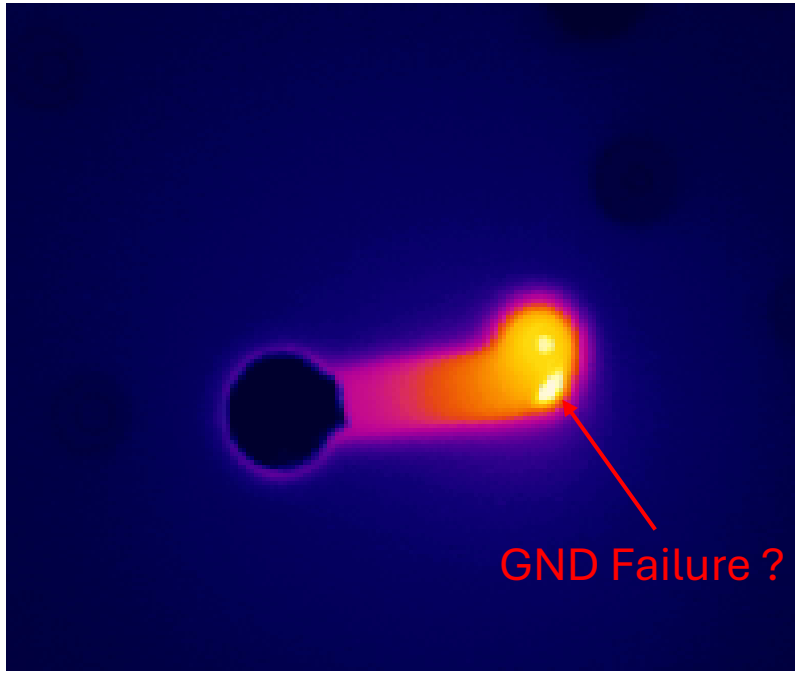
Array I-V curves



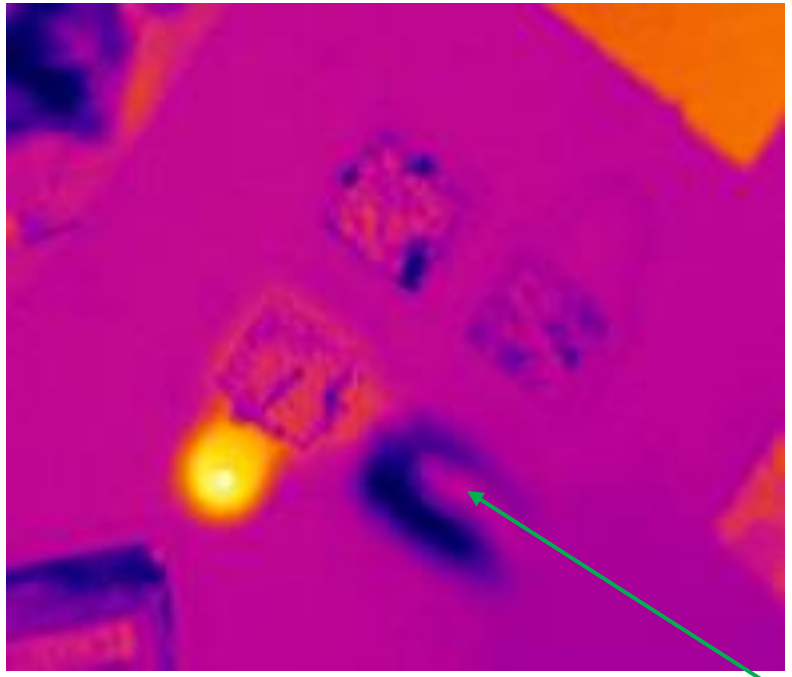
Broken pad/
damaged SiPM
during dismounting

Same curve on bad channel (red rectangle) than others
=> SiPM is not in cause
=> PCB failure

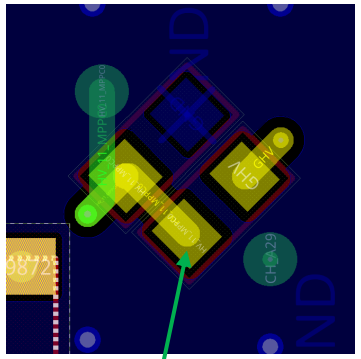
IR camera measurement



Top side



Bottom side

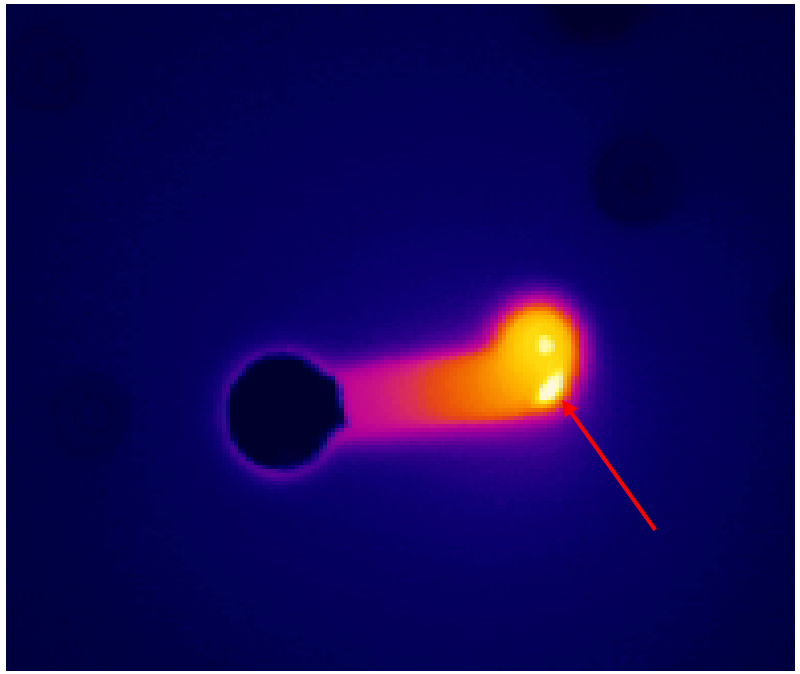


Injection wire

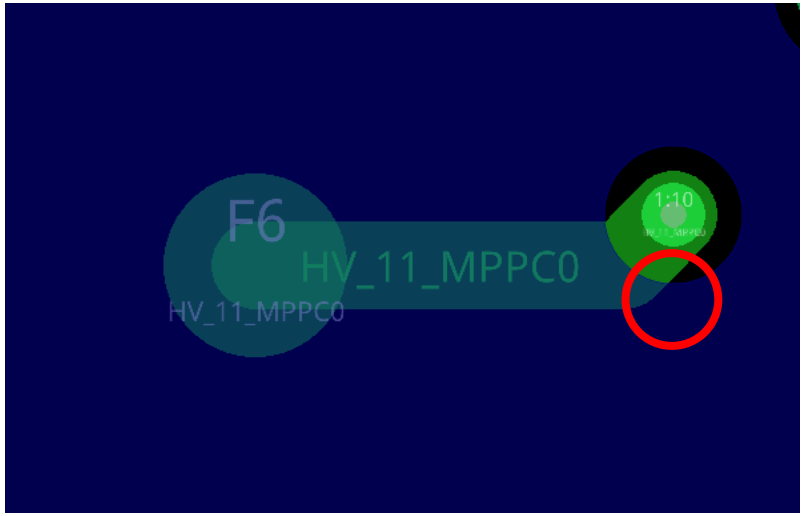
Injecting current between BOT trace to GND:
We see current in the via from BOT to TOP and seems the TOP trace corner is shorted to GND

We noted that during that test, the resistance of the connection to ground decreased to some 24 Ohms.

IR camera measurement

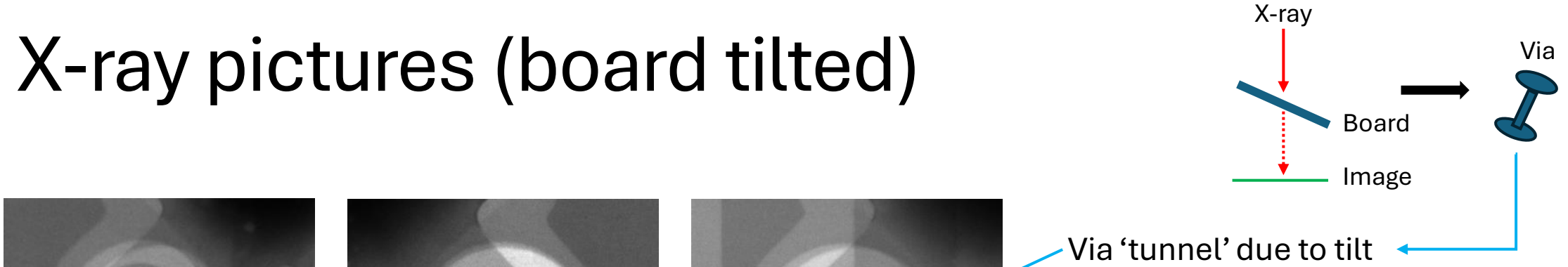


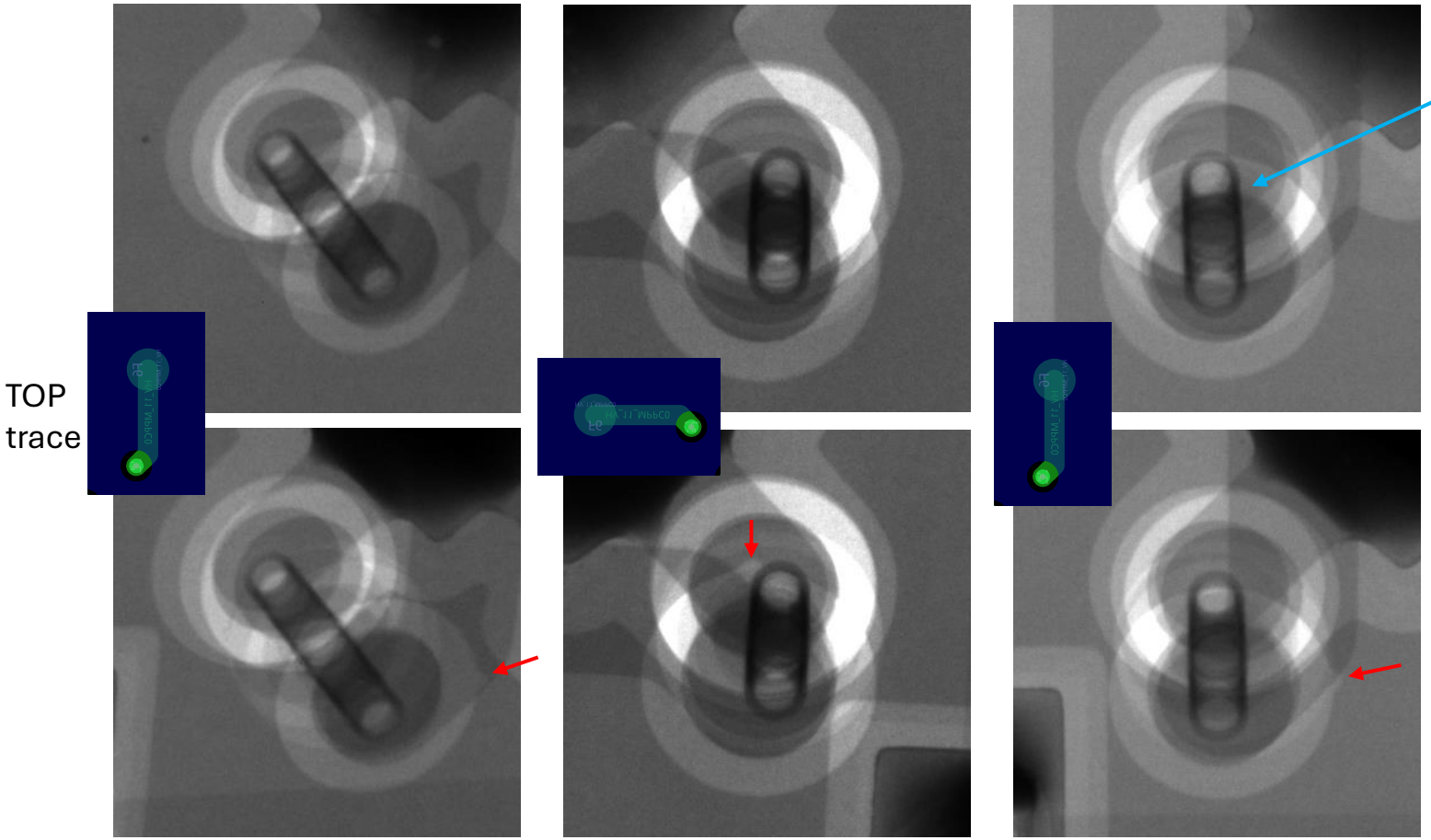
Top side



Top layer (green) and Layer 2 (GND, blue)

X-ray pictures (board tilted)





Via ‘tunnel’ due to tilt

Reference location, with no problem.

Via with the problem, note the material (copper ?) **depletion** close to the “elbow” of the HV line (red arrow).

=> Could it be a CAF issue and this depletion some copper missing due to CAF copper migration in the FR4 from L2 (GND) to TOP (V=57V)?