

Mini stave Thermal Finite Element Analysis

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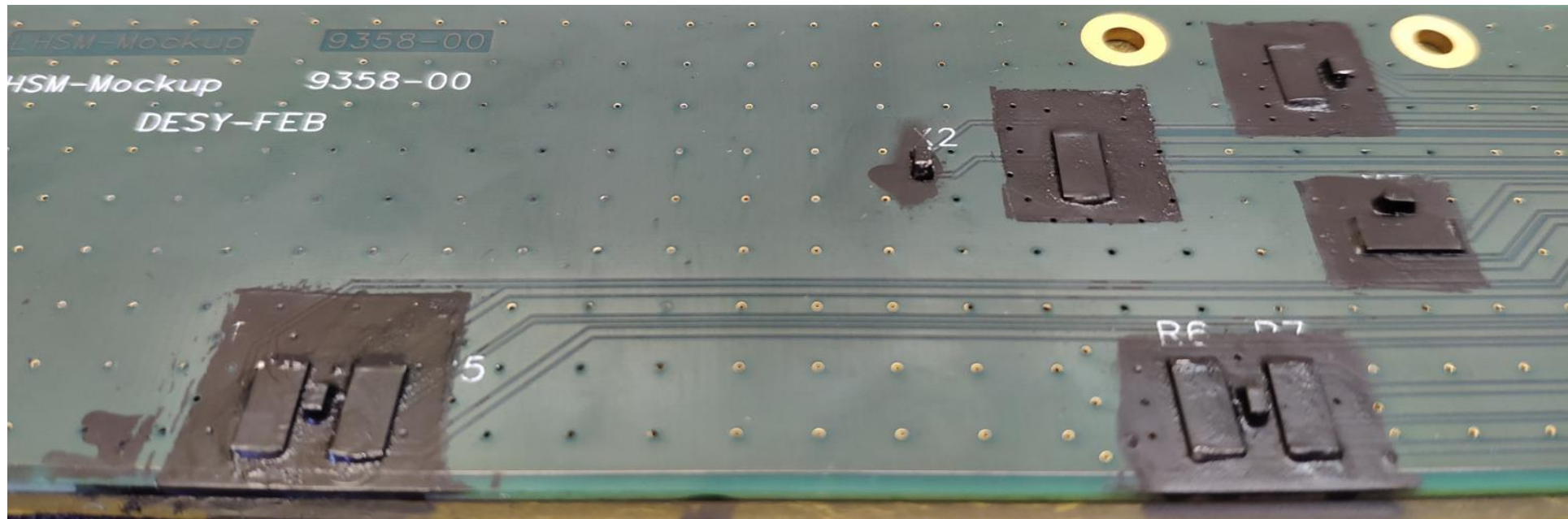


Mini stave with dummy End of Stave (EOS) PCB

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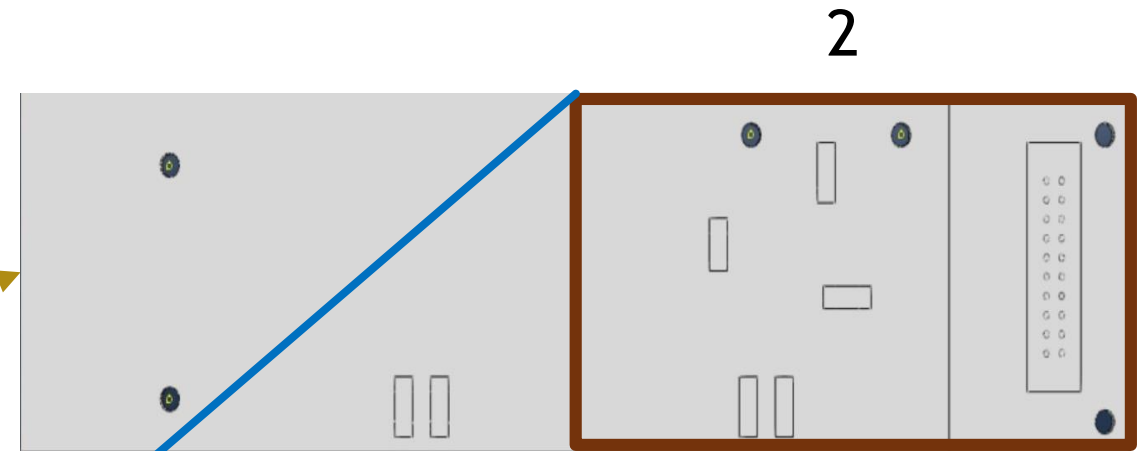
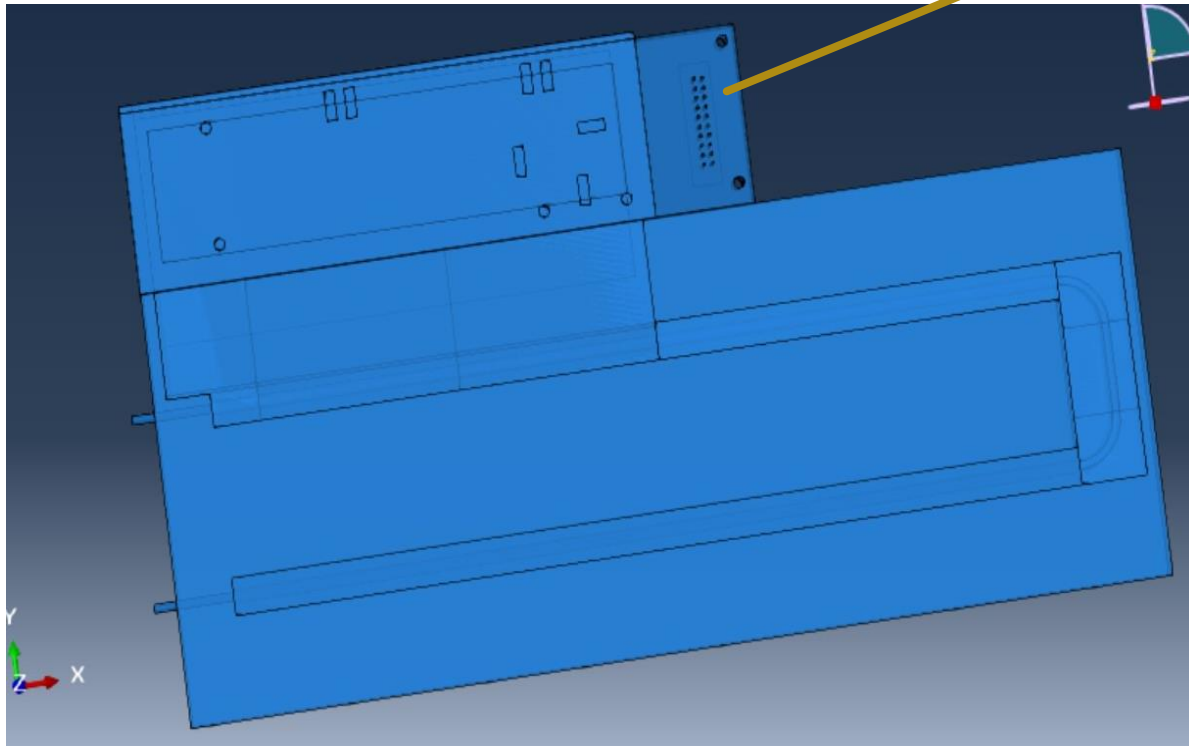
Features: A 3-module long stave ~300 mm, design is similar to the normal 14-module stave
Two dummy PCBs glued on EOS card region
Seven resistors (~100 ohm) and five thermistors on each PCB
Resistors are used for simulating heat dissipation from chips on PCB

Objective: Fiber optics chips transfer signal collected by detector
Chips must function during life time of detector
FEA helps understanding the operating temperature range for the chips

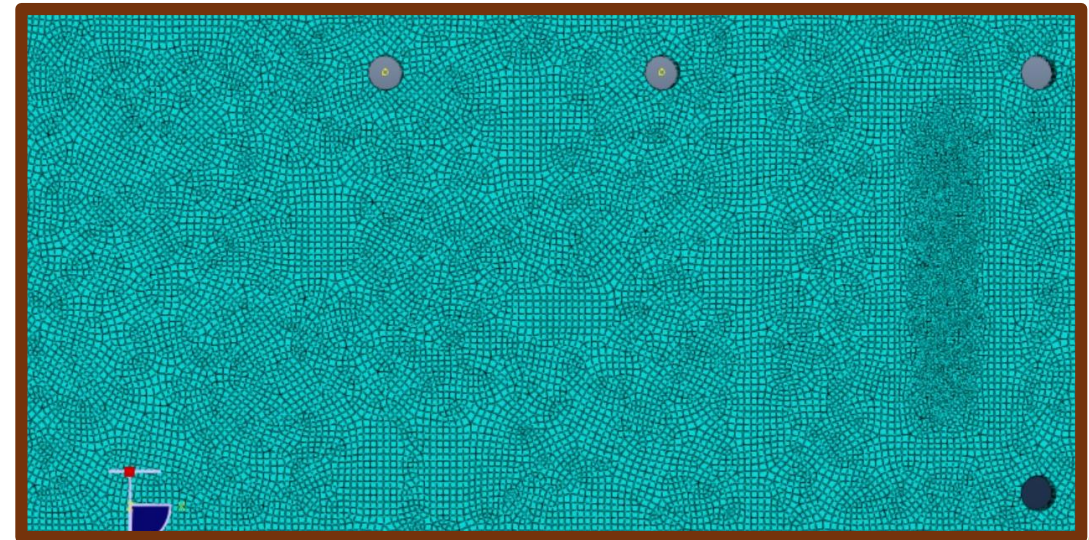


Mini stave FEA model

FEA software: Abaqus 2018



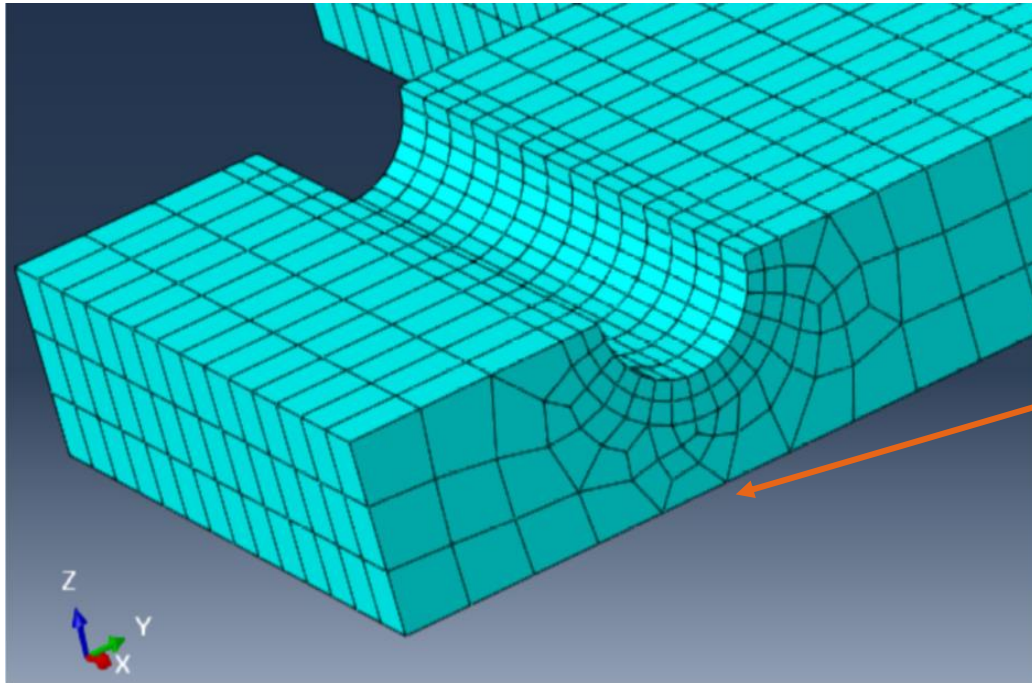
PCB model



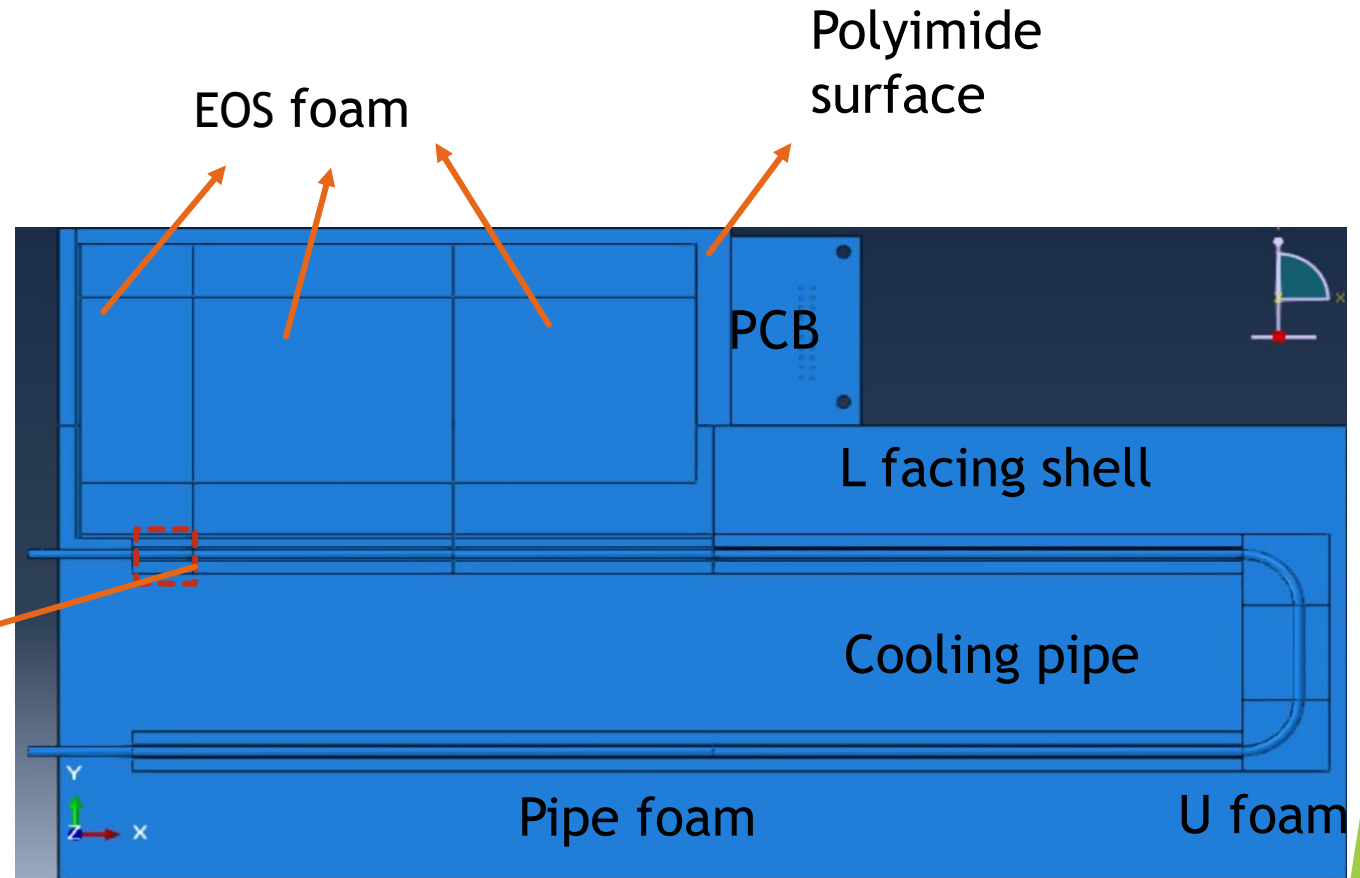
Meshed PCB region (in rectangle)
entire model: ~406K elements

Mini stave FEA model

Parts are modeled individually then assembled together

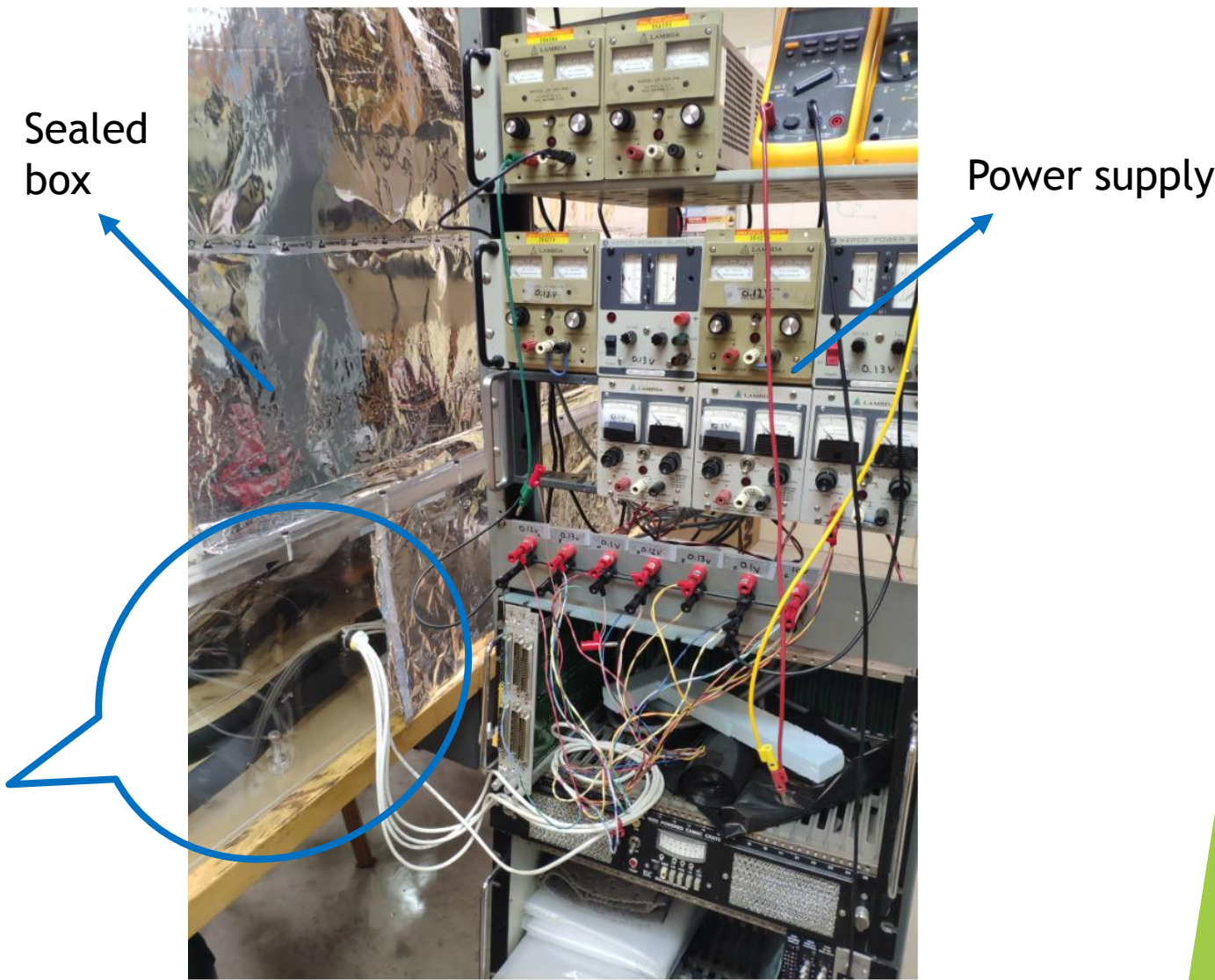
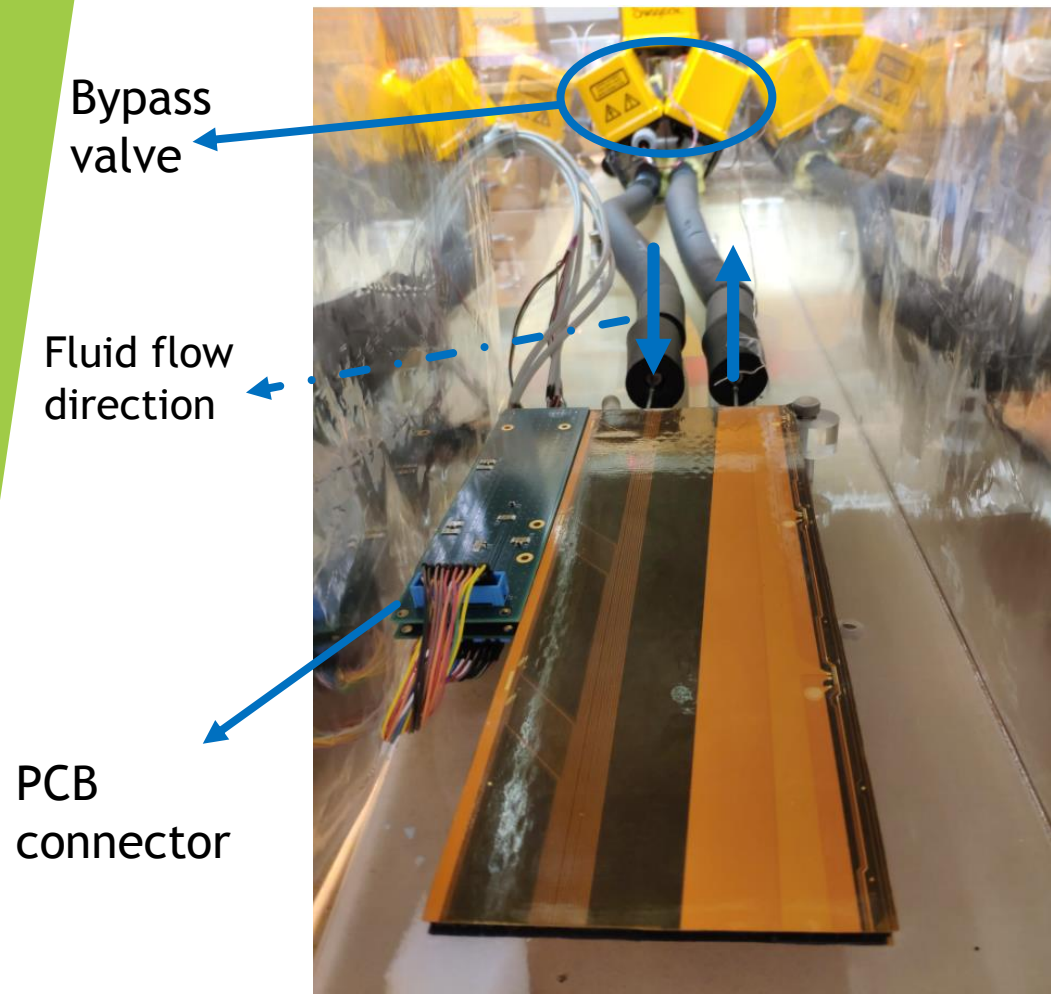


meshed EOS foams
Element size $\sim 1\text{mm}^3$



X-Y cross section view of mini stave model
(only lower half shown)

Measurement setup



Mini stave thermal measurement at -15C

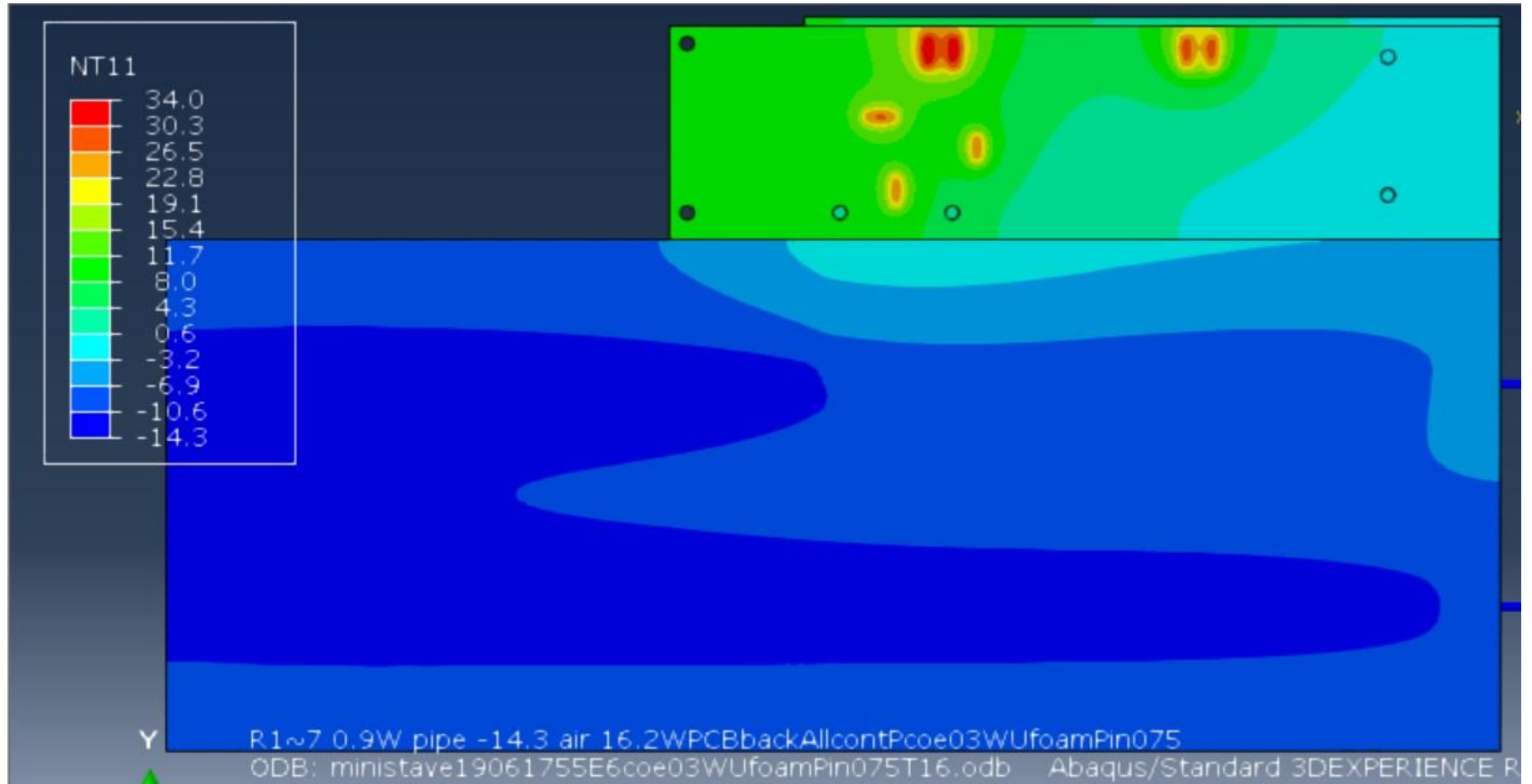
5

- ▶ Chiller set T -26C, bypass inlet -15.0C, outlet -13.6C
- ▶ Resistor power: only top PCB (LHSM), R1~R7 each ~0.9W
- ▶ Fluid flow rate: ~0.34L/min
- ▶ Dry nitrogen flow ~3L/min
- ▶ Pixel area: ~ 0.6*0.6 mm²

FEA simulation

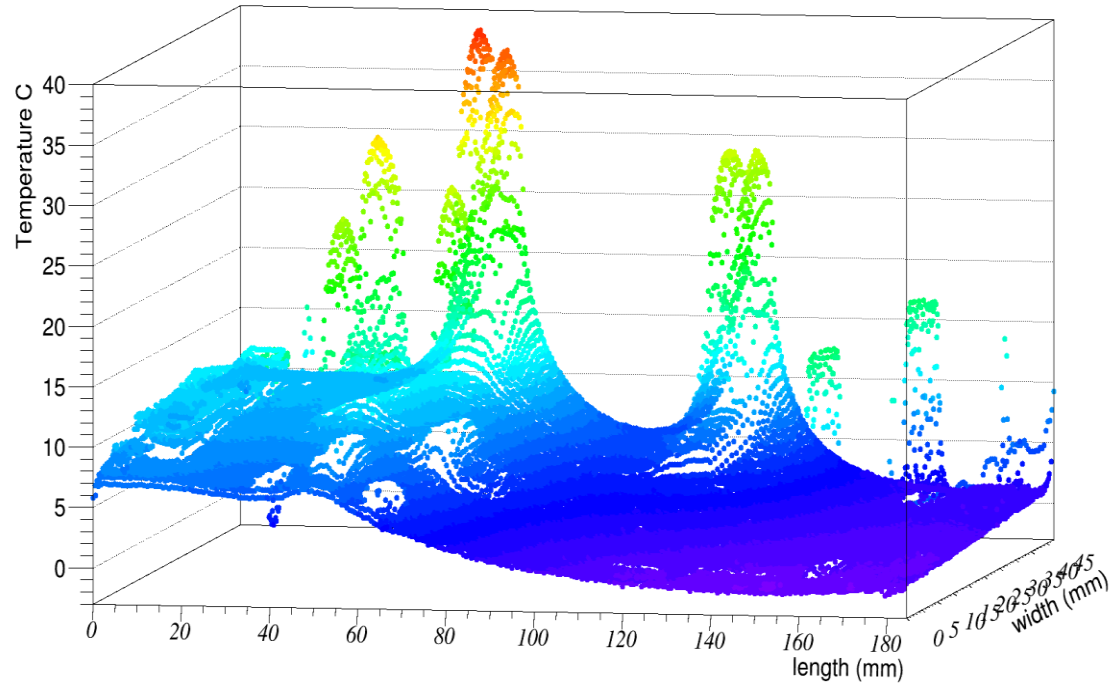
- ▶ Input parameters: fluid & ambient temperature, resistor power loads, conductivities for individual parts
- ▶ Ambient contact region: PCB & main stave surface, both sides

Result: FEA mini stave top PCB surface temperature (inlet -15C)

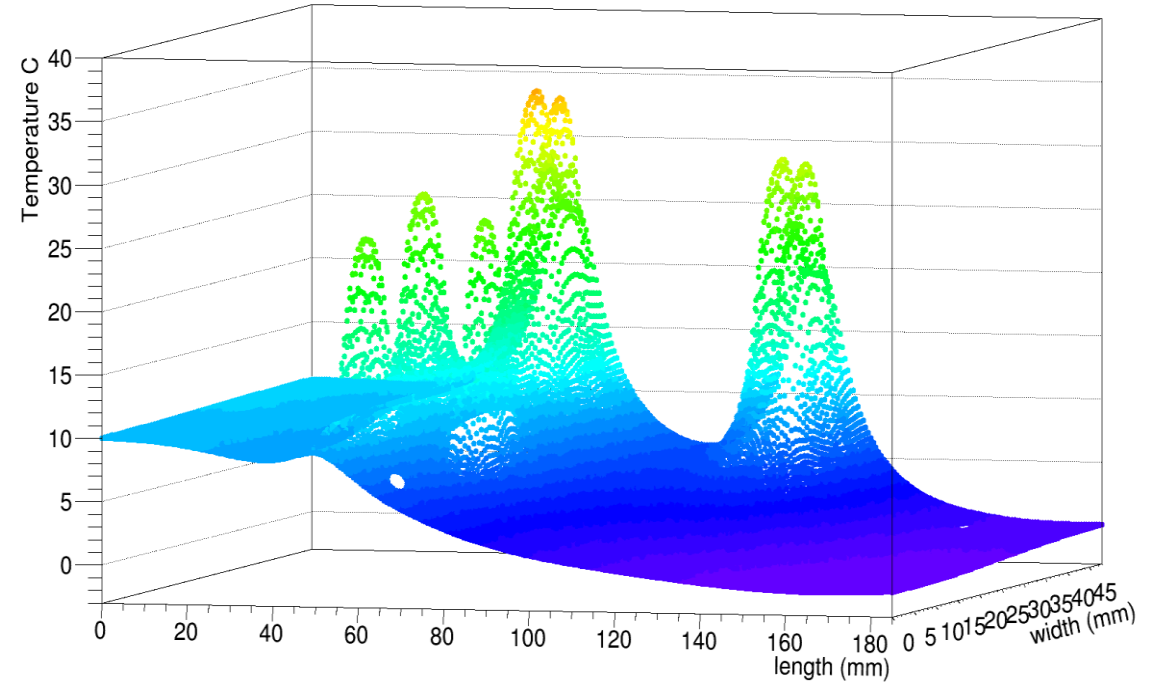


Mini stave PCB surface temperature (inlet -15C)

PCB measured surface Temperature



Simulated PCB surface Temperature

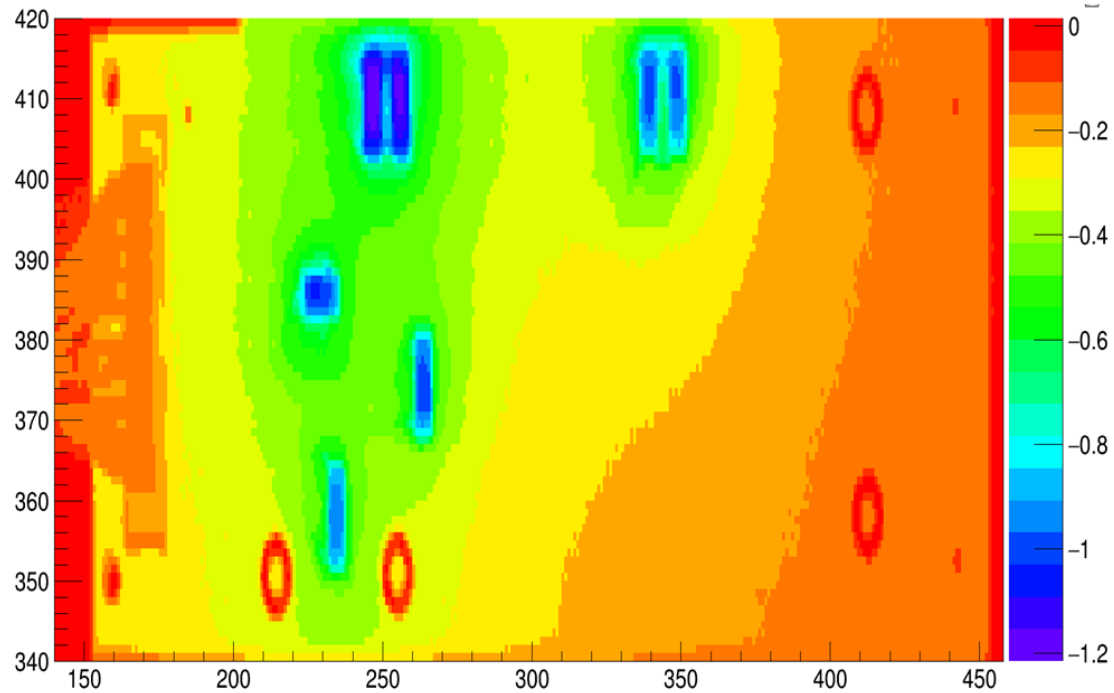


Mini stave PCB surface temperature (inlet -15C)

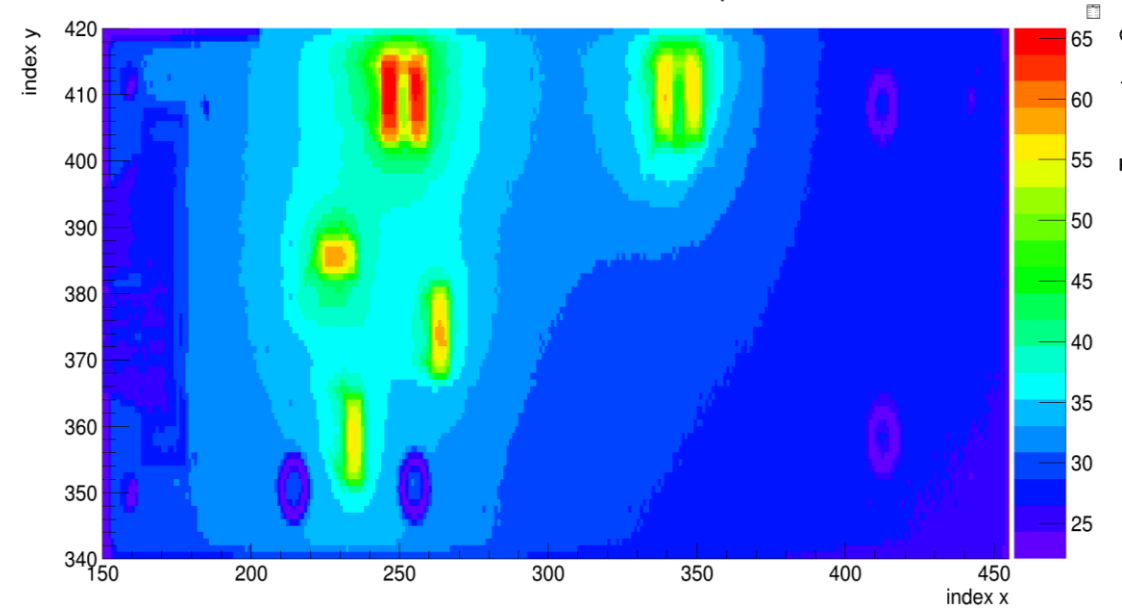
Paint emissivity: 0.89

PCB emissivity: 0.92

PCB T difference 0.92 - 0.89

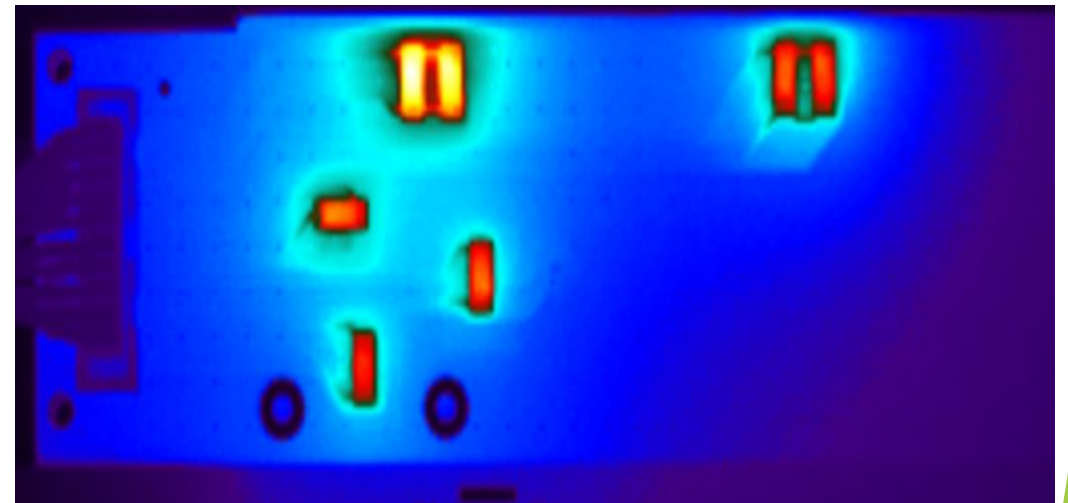


Measured ministave surface Temperature



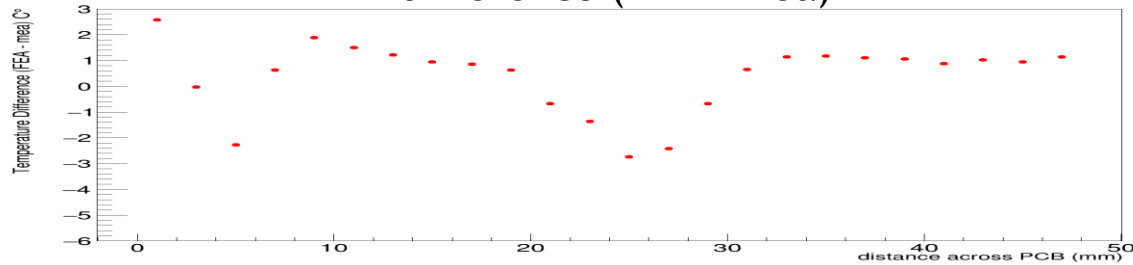
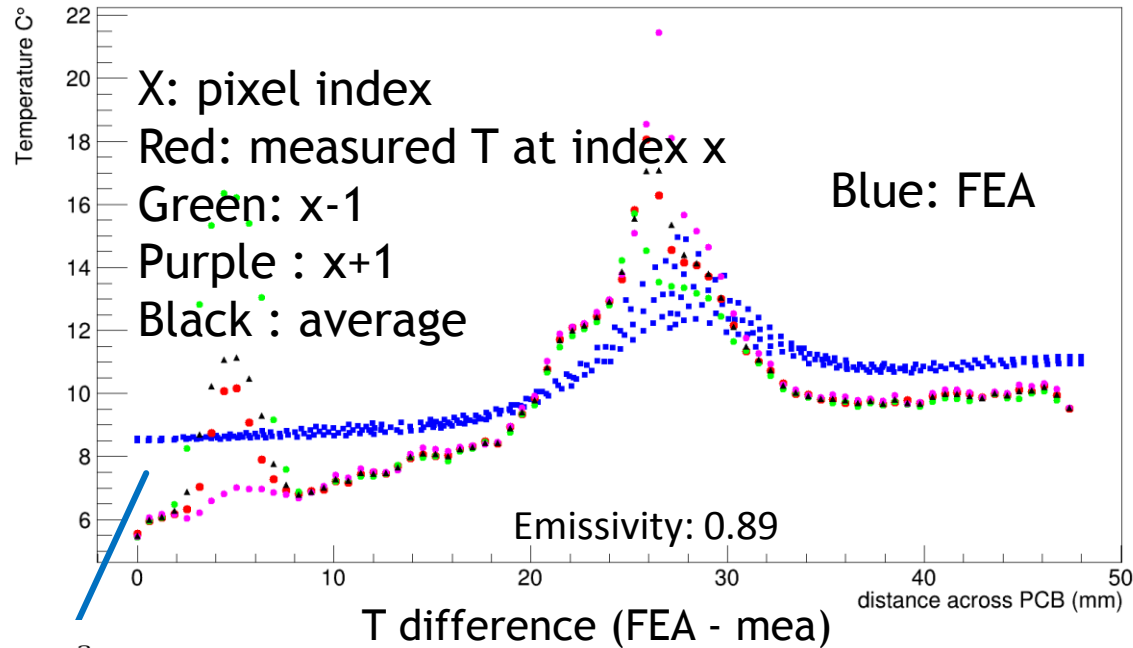
T difference: ~1C difference at resistor
~0.5C near resistor
~ 0.3C other area

IR image

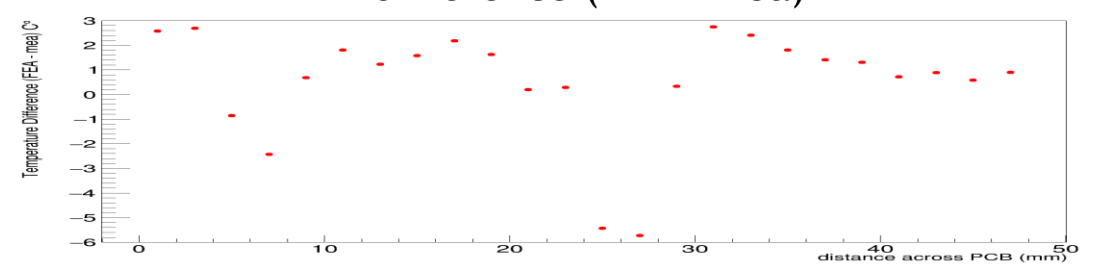
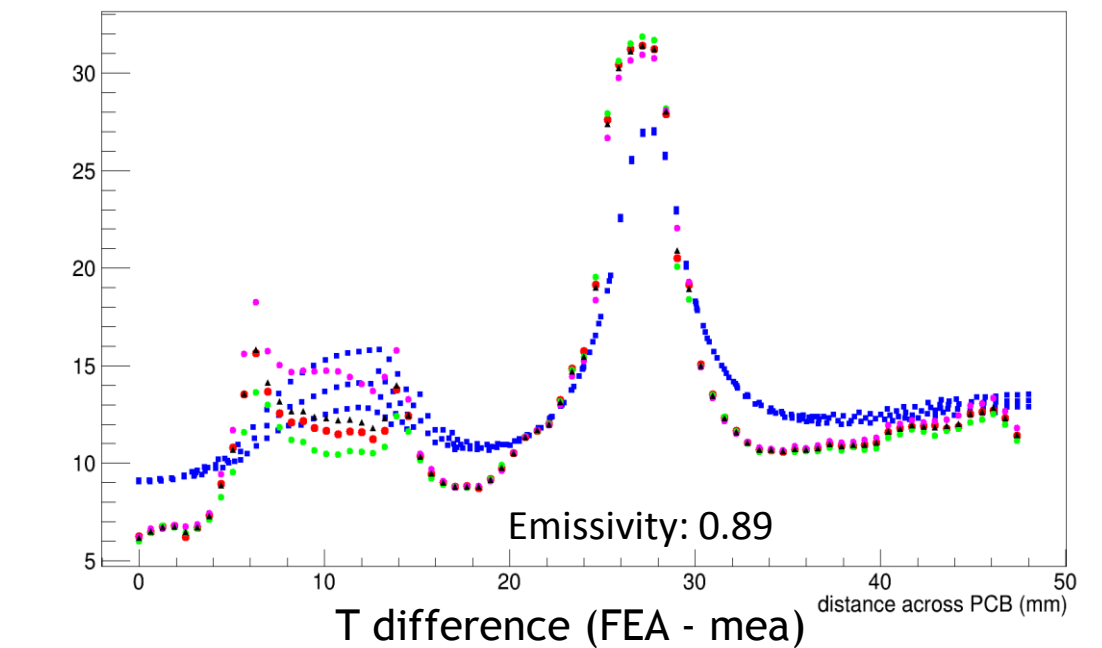


Temperature across PCB (inlet -15C)

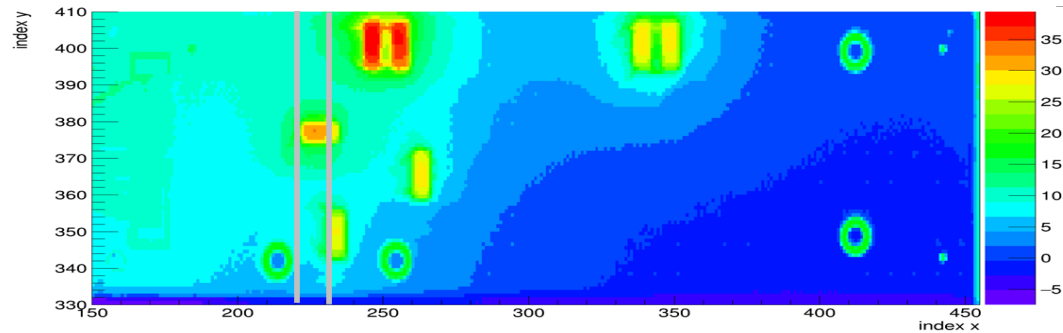
Temperature across PCB $\chi=220$



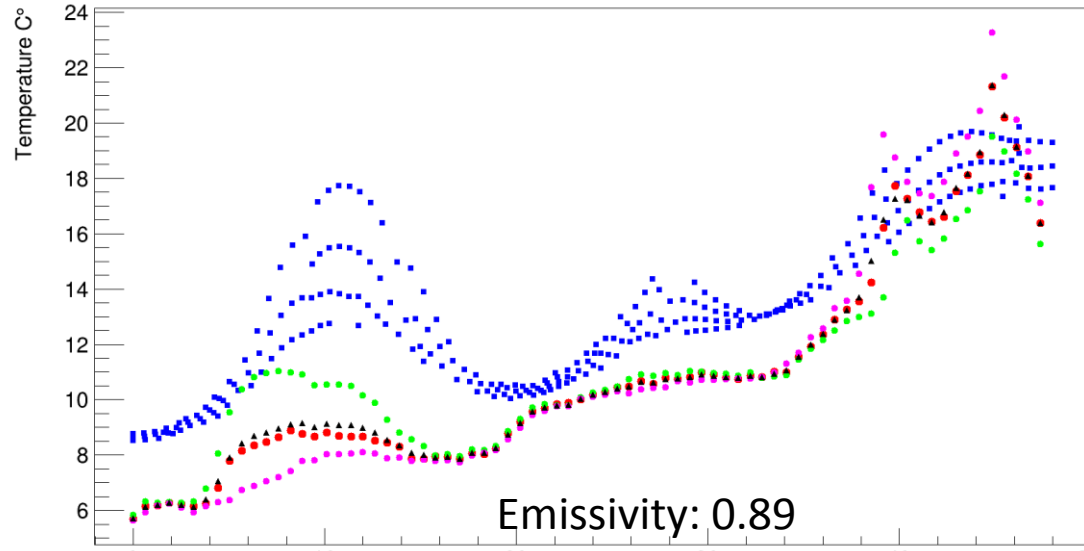
Temperature across PCB $\chi=230$



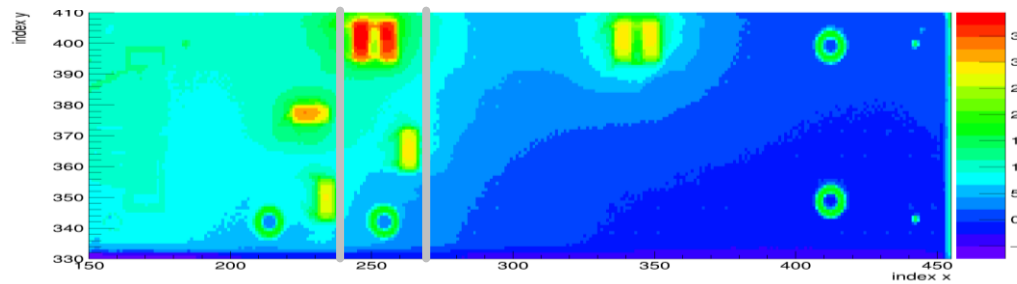
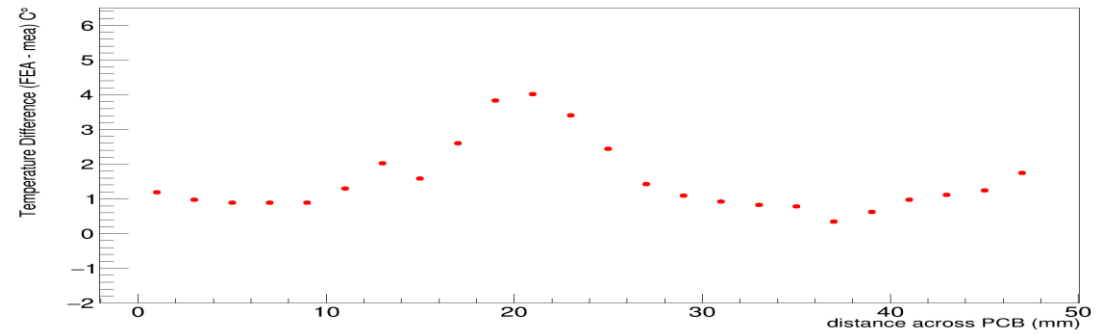
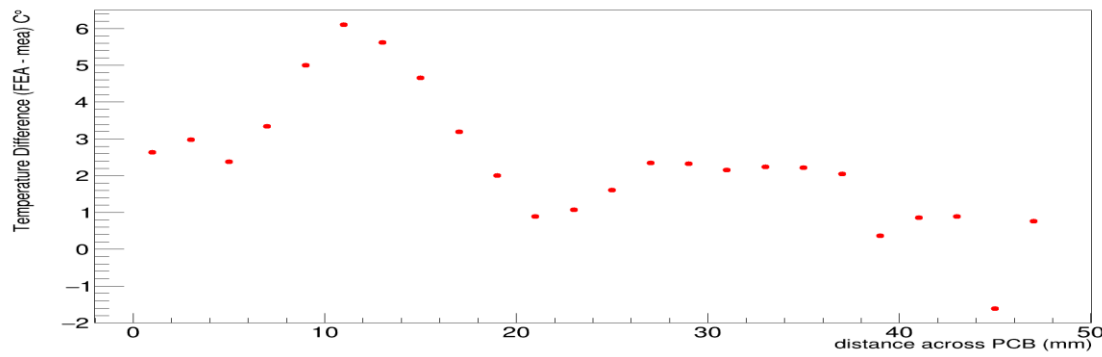
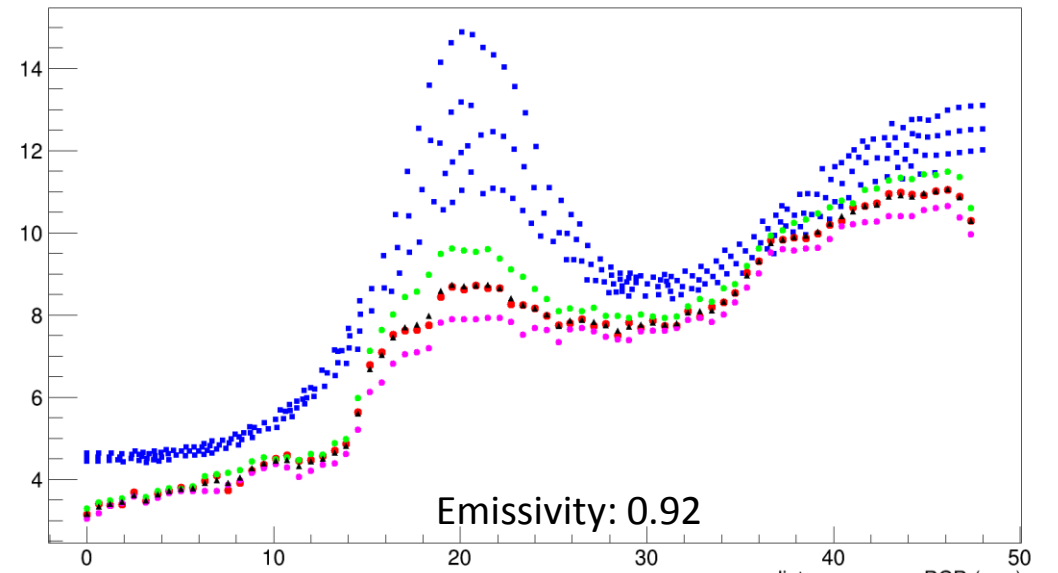
Copper ring reflection



Temperature across PCB $X=240$

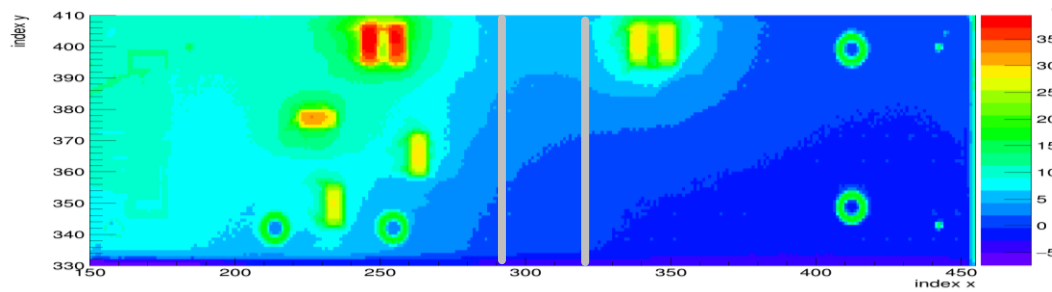
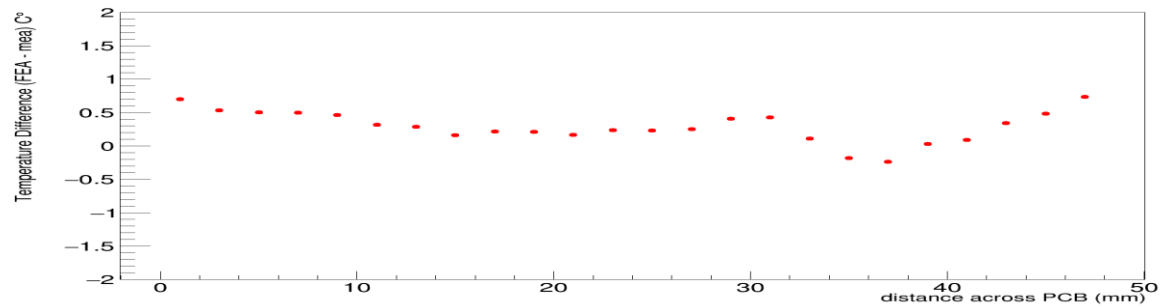
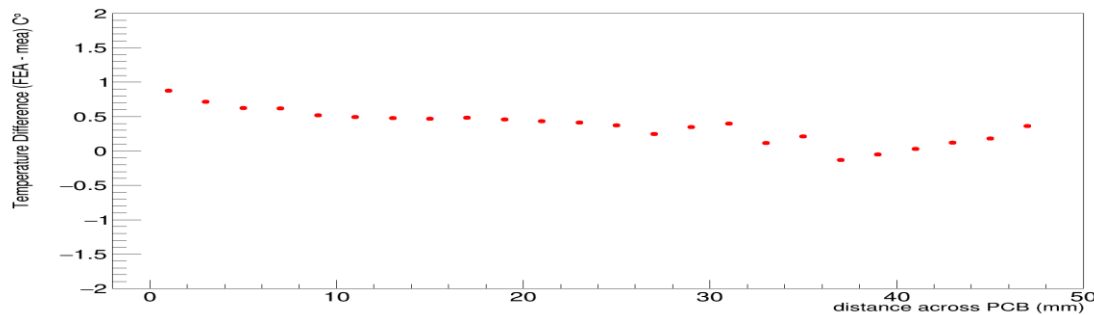
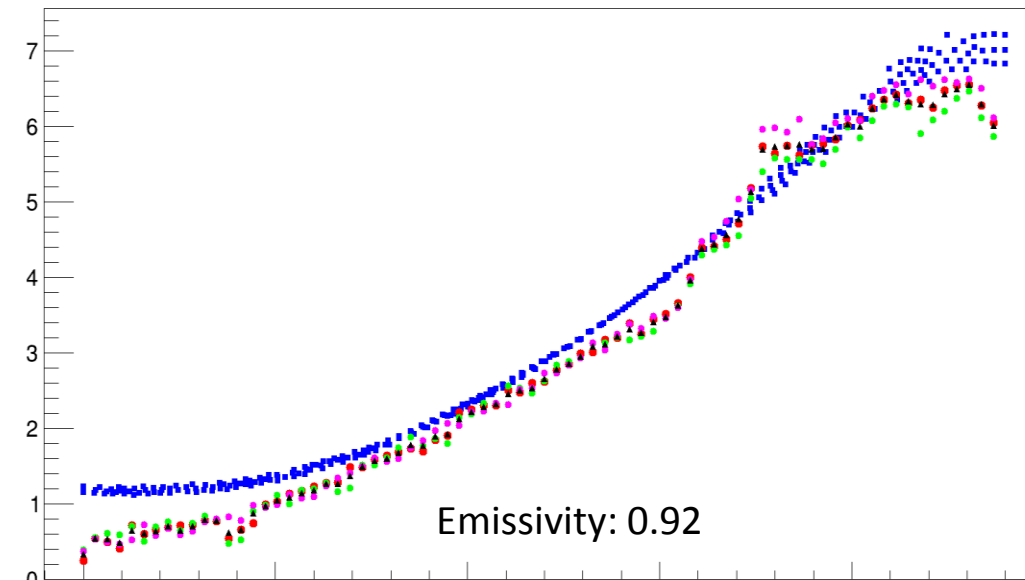
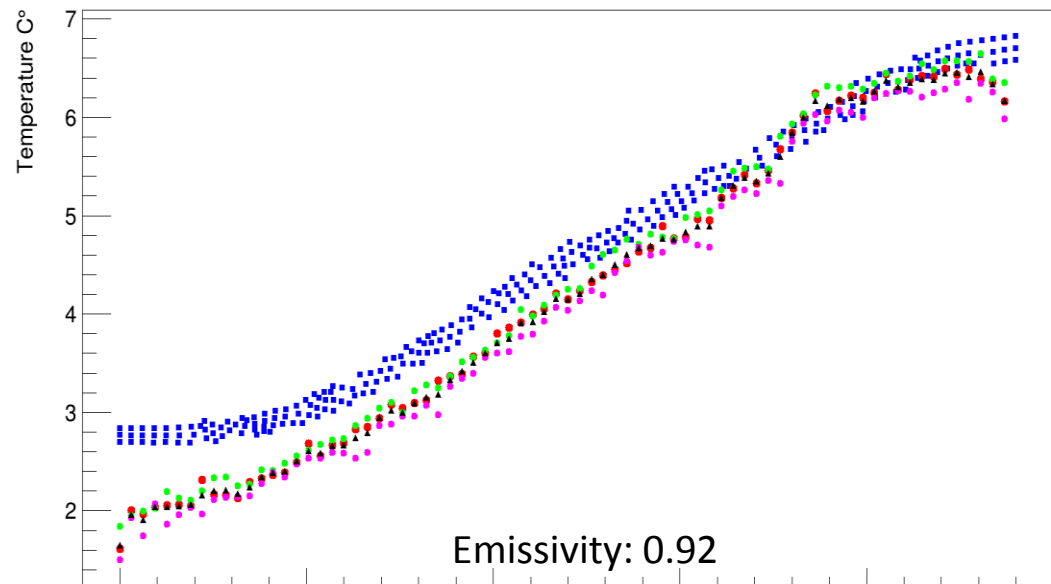


Temperature across PCB $X=270$

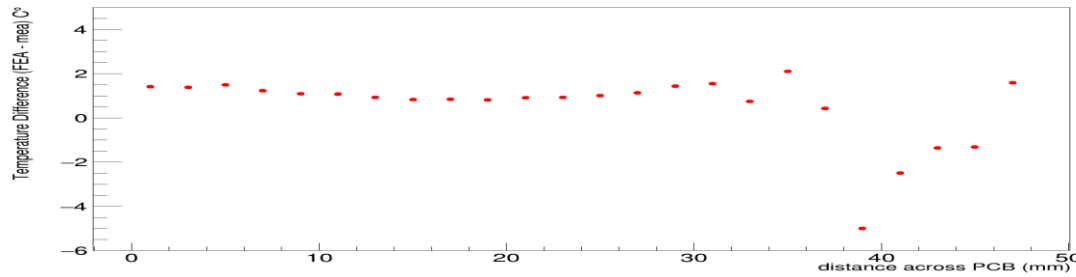
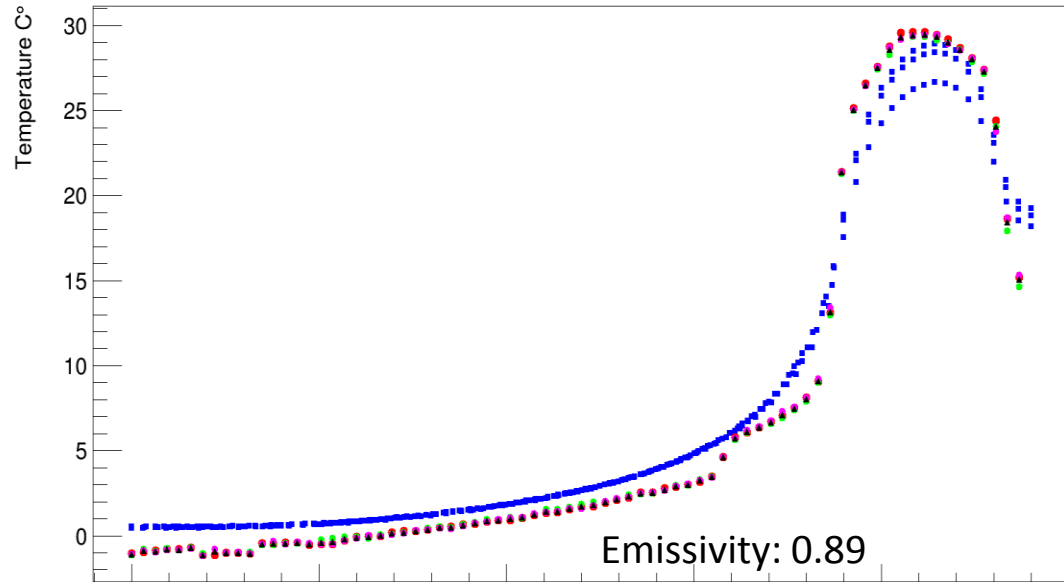


Temperature across PCB X=290

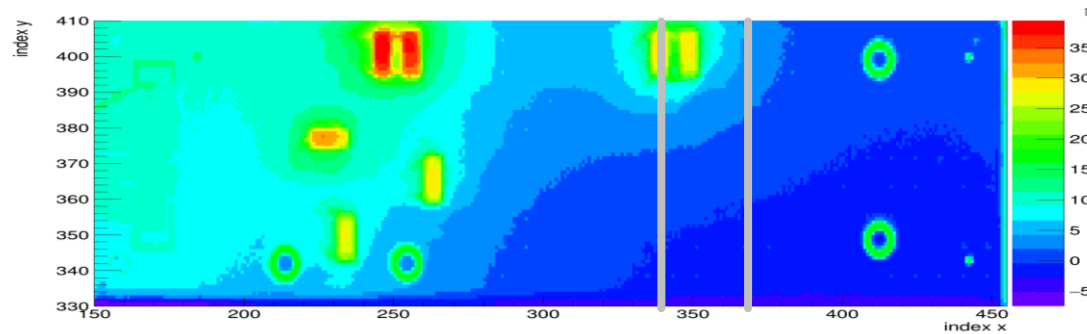
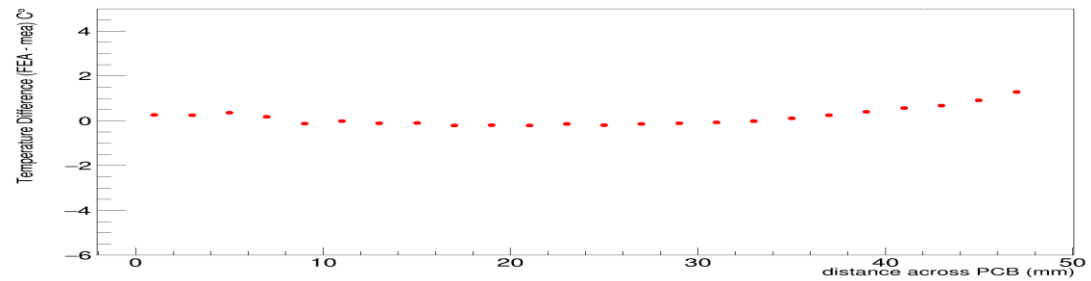
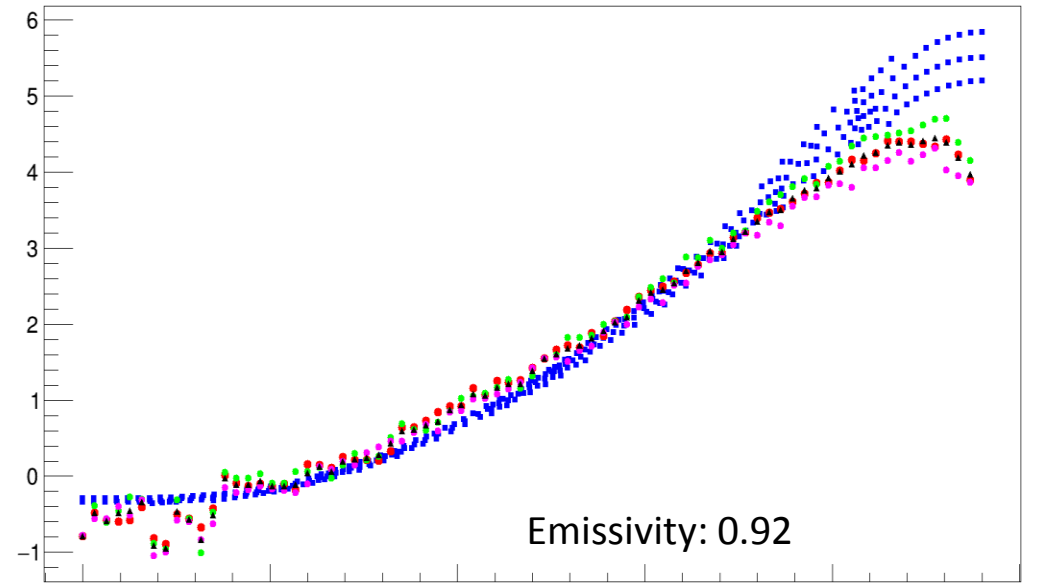
Temperature across PCB X=320



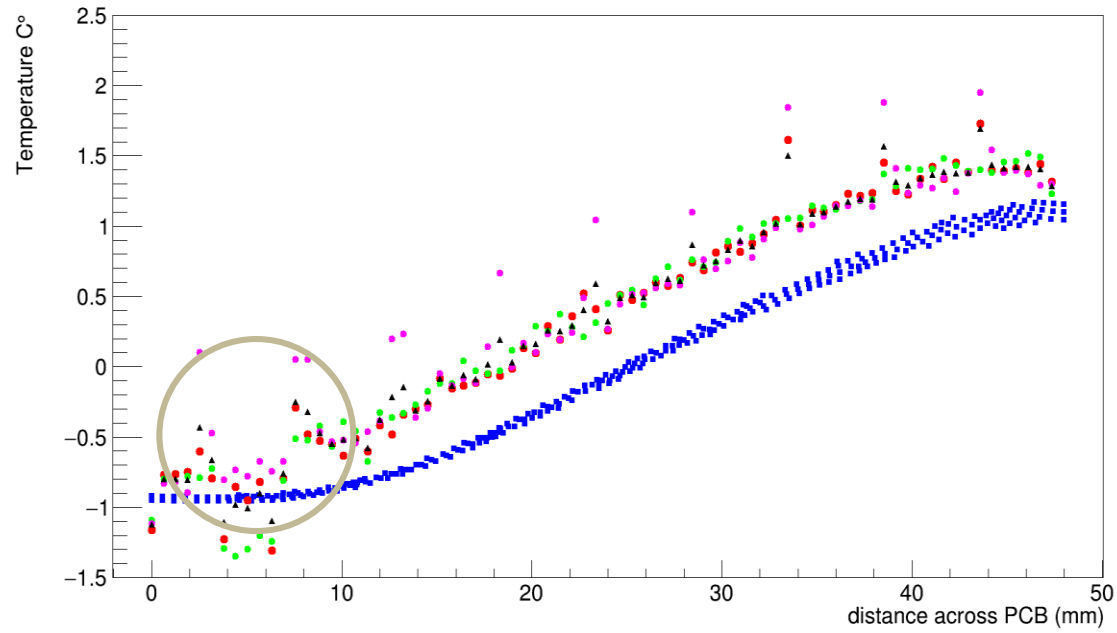
Temperature across PCB X=340



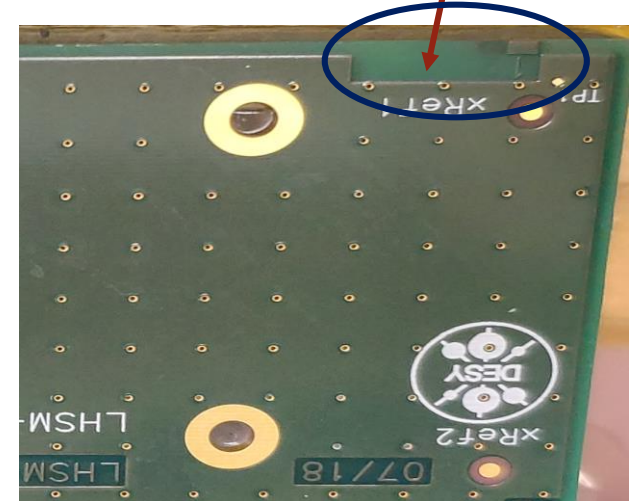
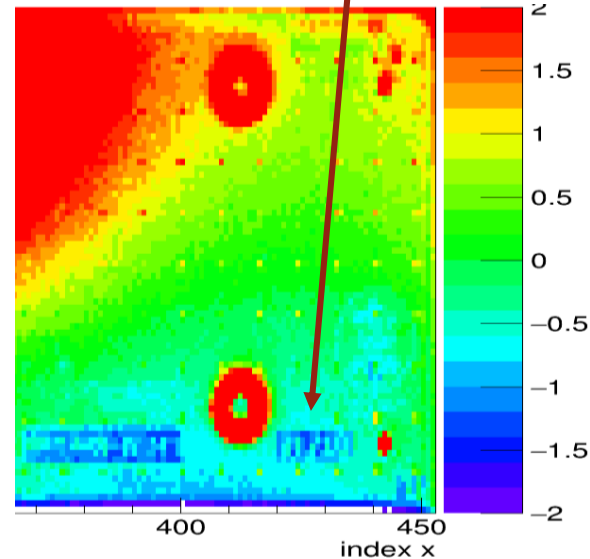
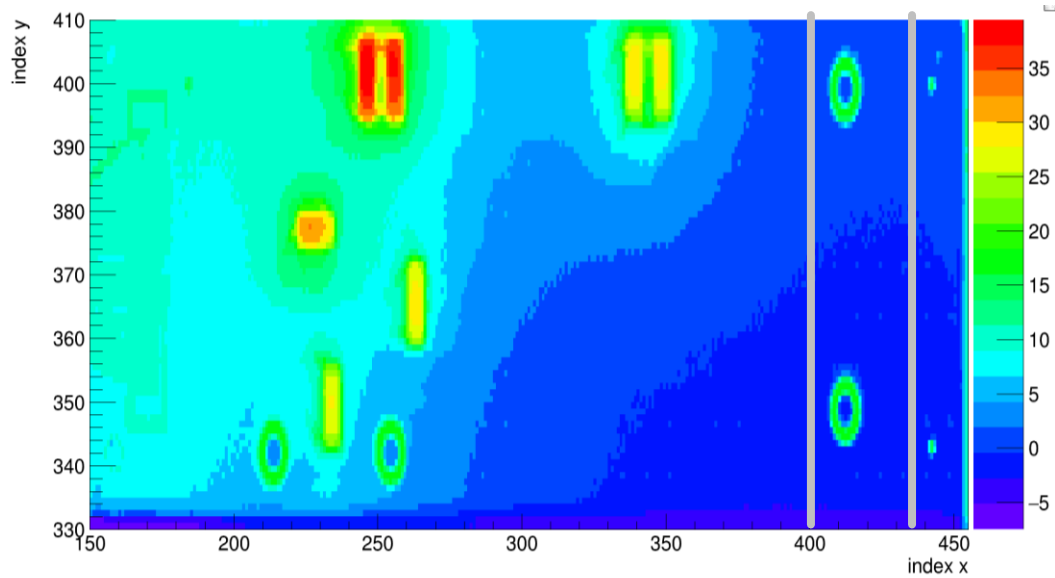
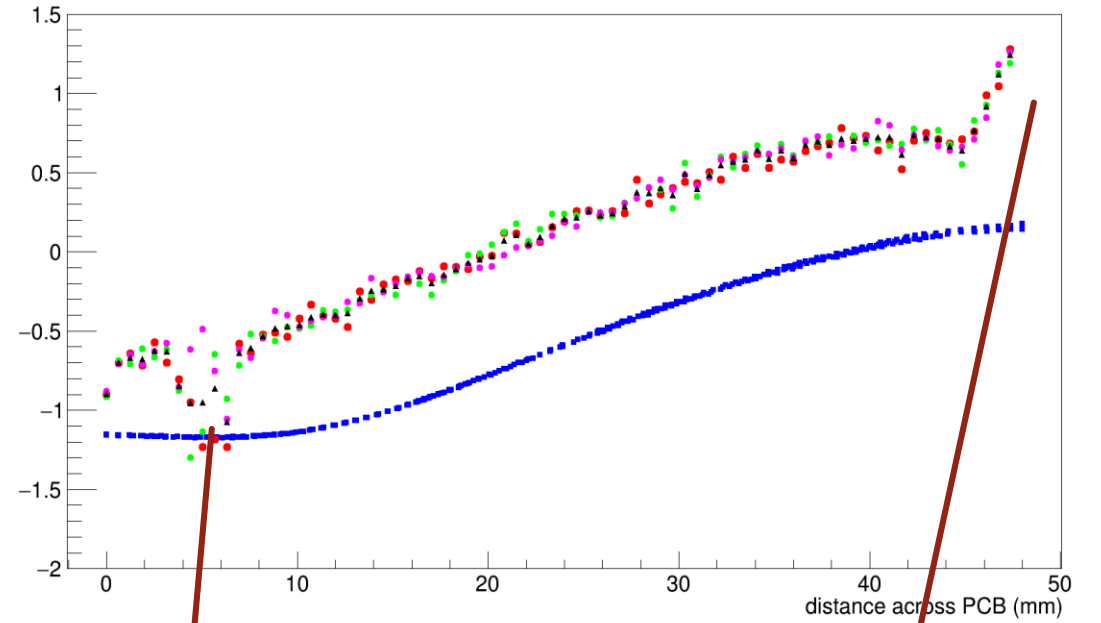
Temperature across PCB X=370



Temperature across PCB X=400

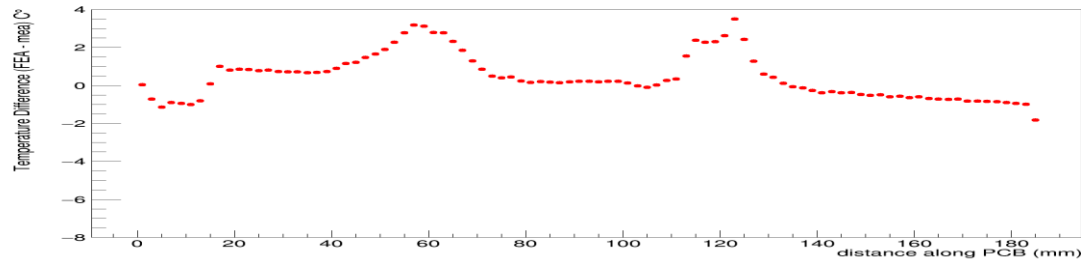
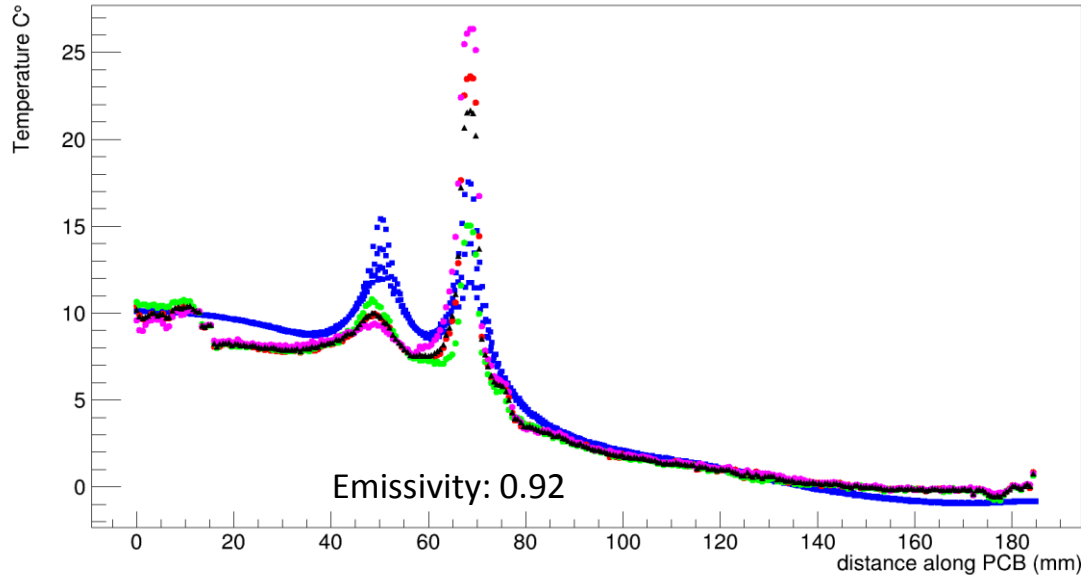


Temperature across PCB X=430

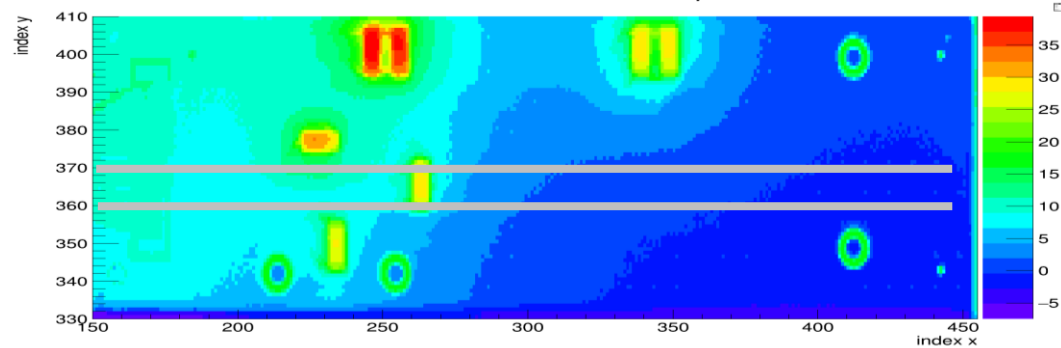
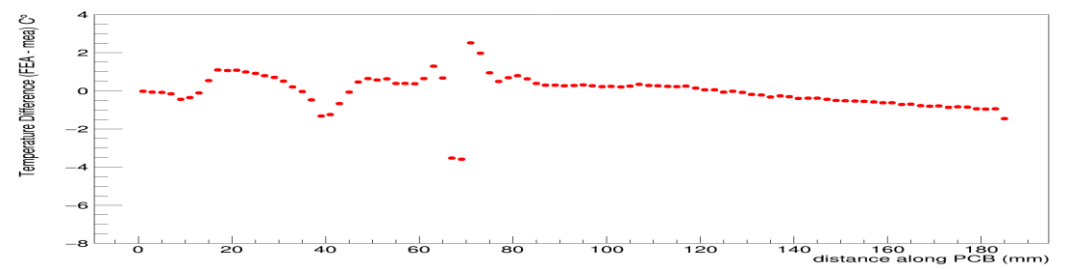
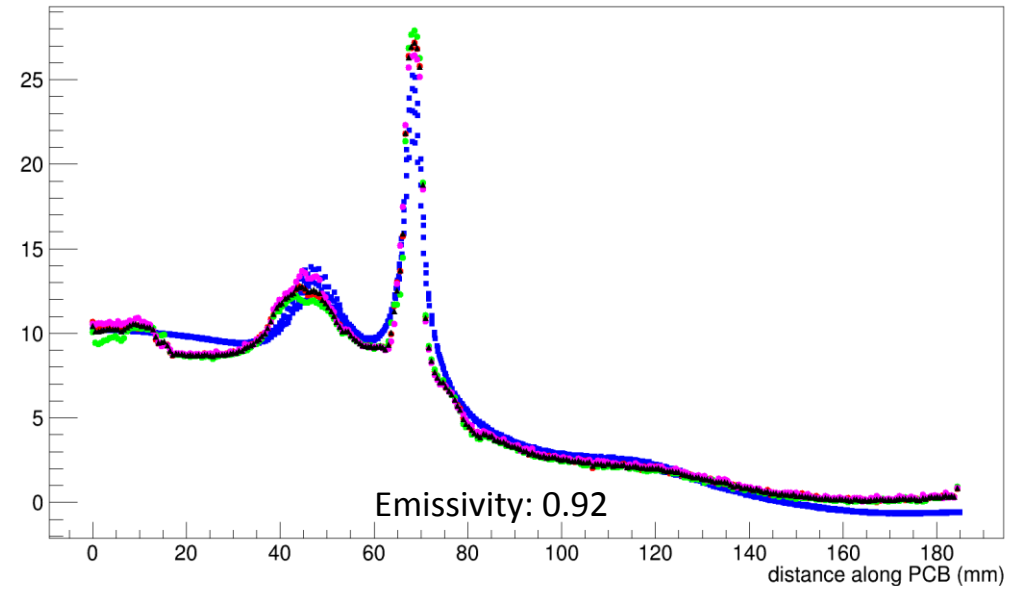


Temperature along PCB (inlet -15C)

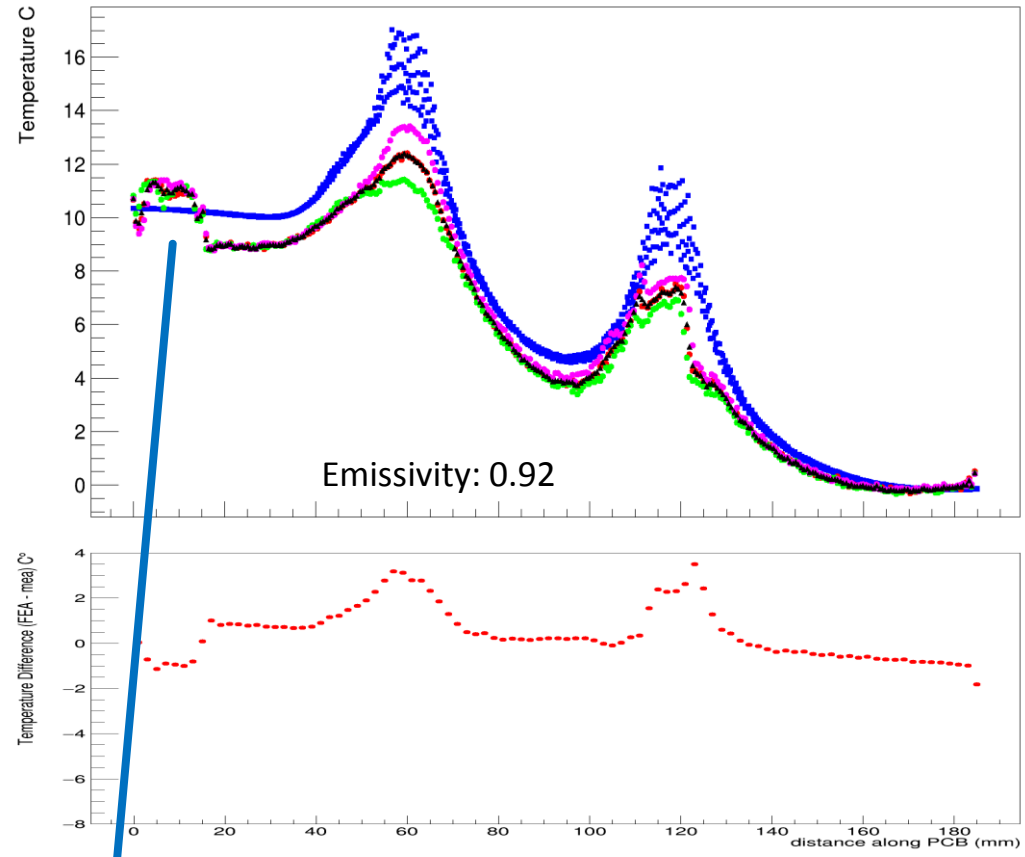
Temperature along PCB Y=360



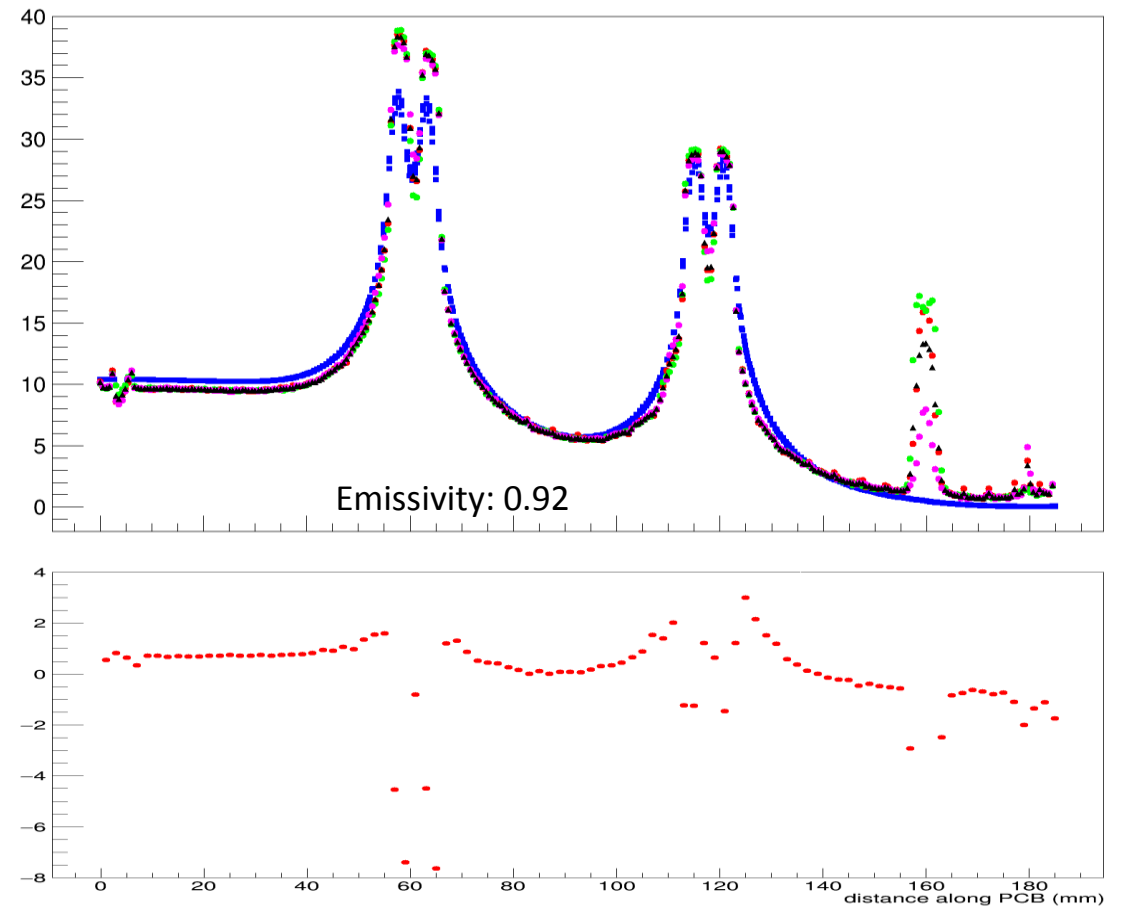
Temperature along PCB Y=370



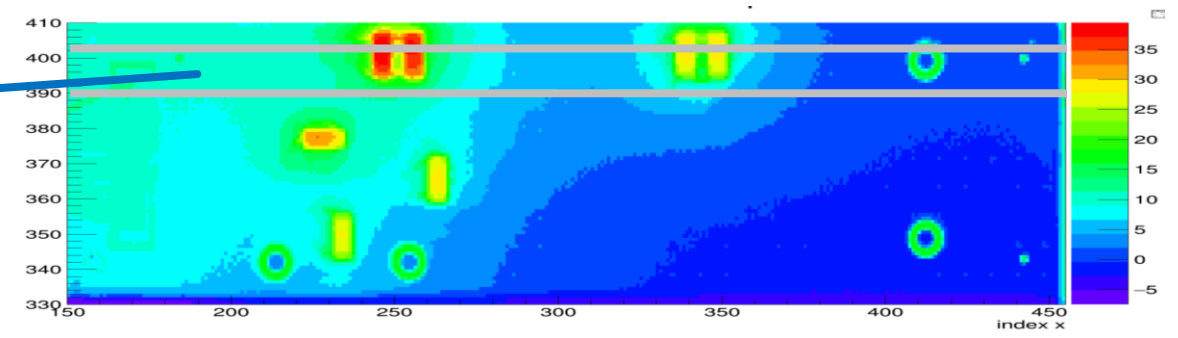
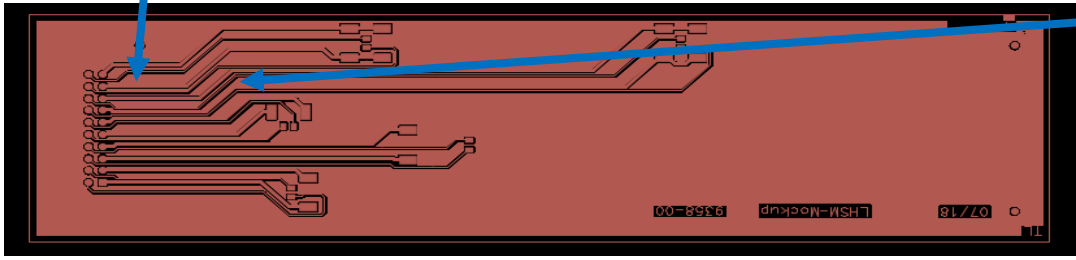
Temperature along PCB $\gamma=390$



Temperature along PCB $\gamma=404$



Copper trace high conductivity



Summary

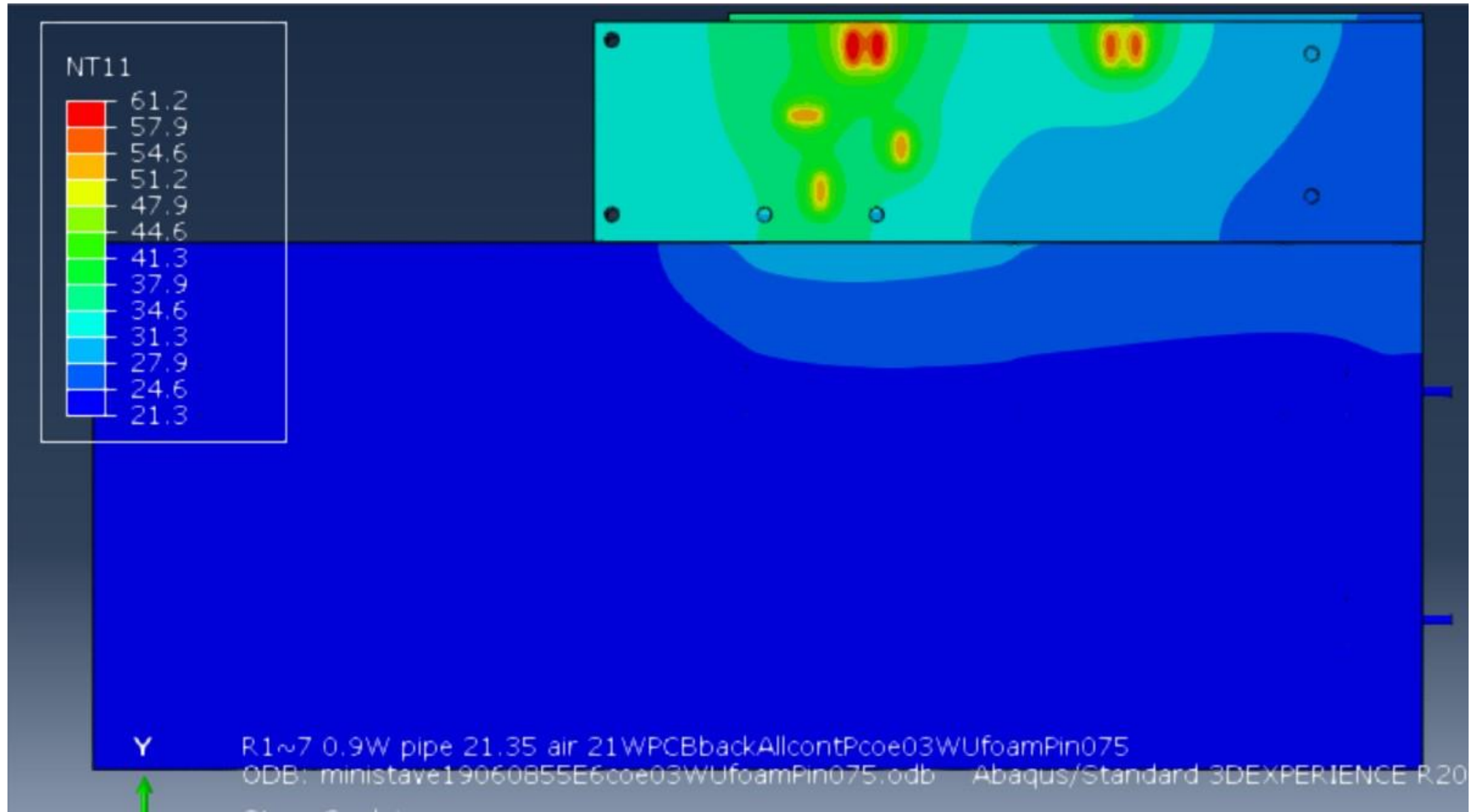
- ▶ Overall FEA simulation (away from resistor) is about 2C higher than measurement T -15C
- ▶ Measured T at resistor is about 5C higher than FEA
- ▶ Temperature profile at T +21C measurement (in backup) is similar as T -15C

run measurement at +21C, set up remains same as -15C

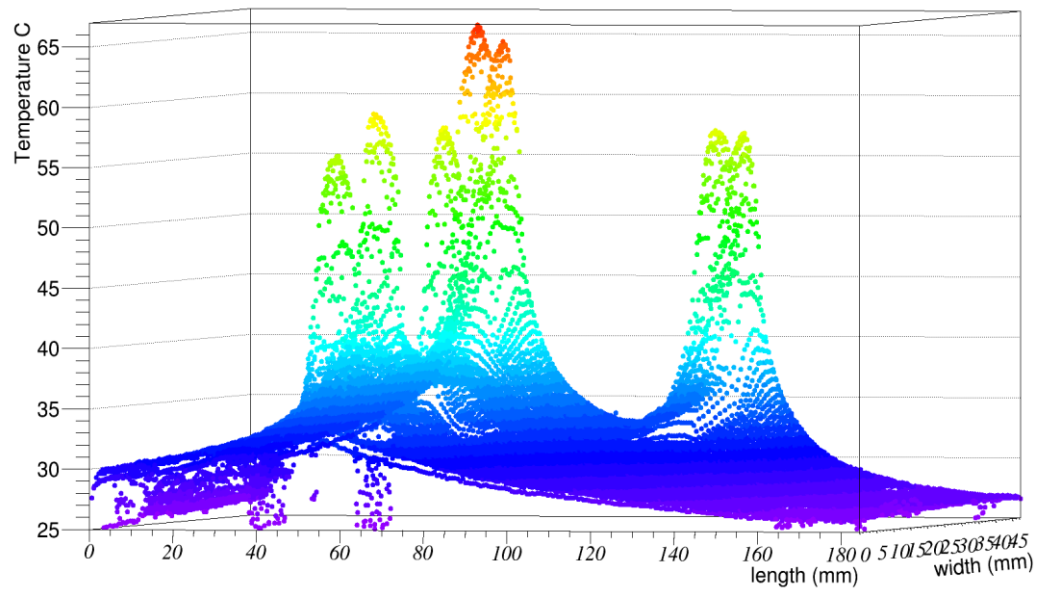
FEA simulation parameters

- ▶ Bypass T: inlet 21.1C, outlet 21.6C
- ▶ Pipe T: average of bypass in/out T
- ▶ Ambient T: 21.4C
- ▶ Ambient contact coefficient: $5.5 \times 10^{-6} \text{ W/mm}^2\text{K}$
- ▶ Cooling fluid contact coefficient: $3 \times 10^{-3} \text{ W/mm}^2\text{K}$
- ▶ PCB conductivity:
on plane $k_{11} = k_{22} = 0.0258 \text{ W/mm K}$
through board $k_{33} = 0.0007 \text{ W/mm K}$

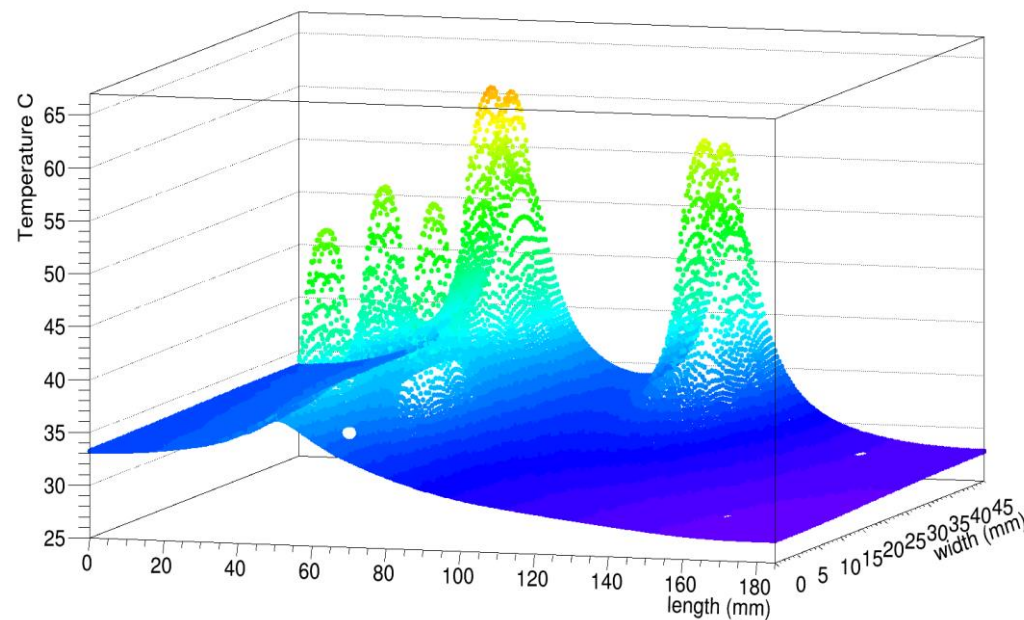
Resistor	Input V	Current A	Power W
1//2 (parallel powered)	9.50	0.1892	1.7974
3	9.50	0.0948	0.9006
4//5	9.50	0.1881	1.7870
6//7	9.50	0.1888	1.7936



PCB measured surface Temperature



Simulated PCB surface Temperature

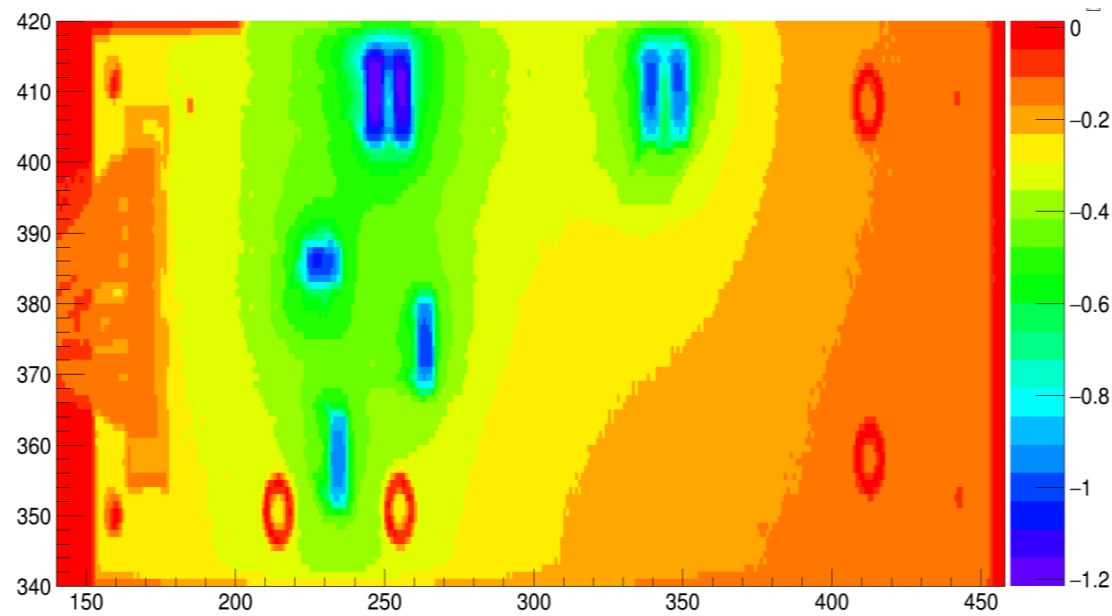


Temperature across PCB (inlet T +21C)

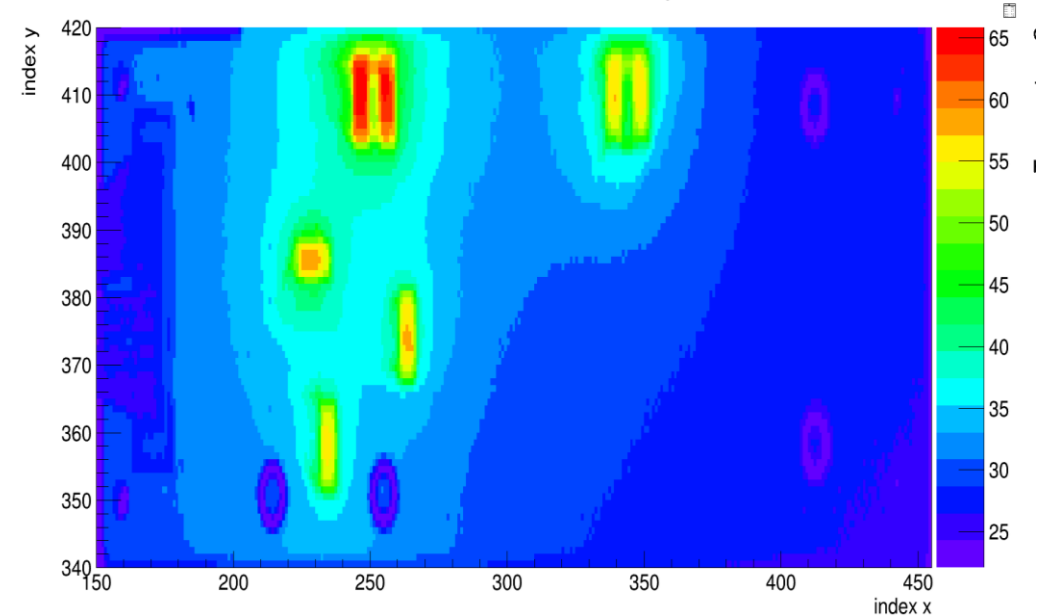
Paint emissivity: 0.89

PCB emissivity: 0.92

PCB T difference 0.92 - 0.89



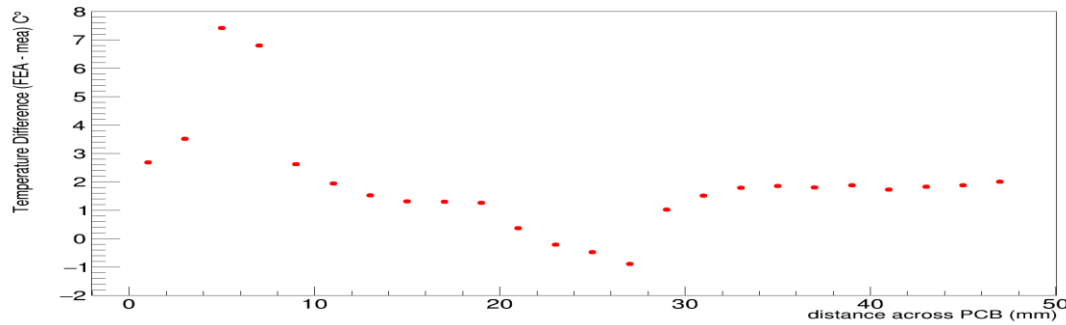
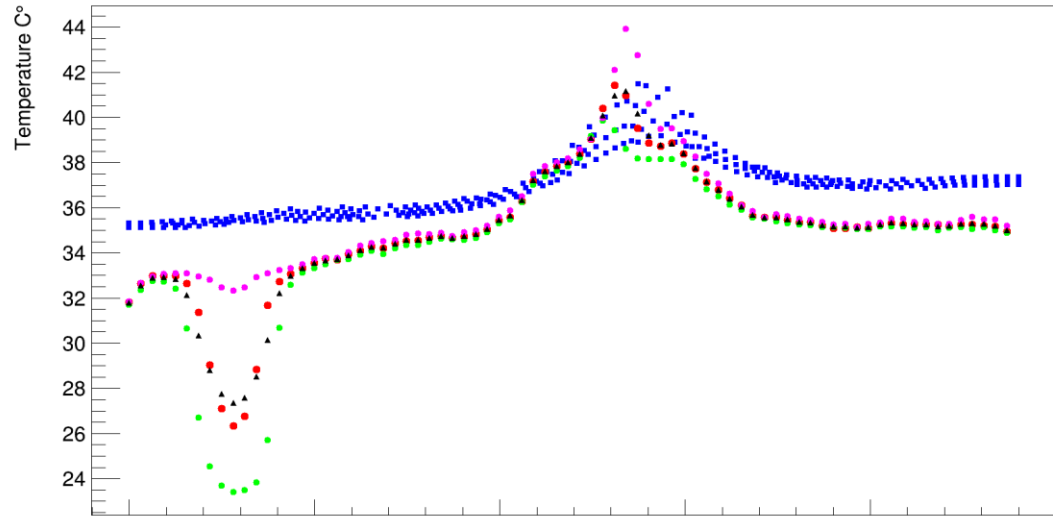
Measured ministave surface Temperature



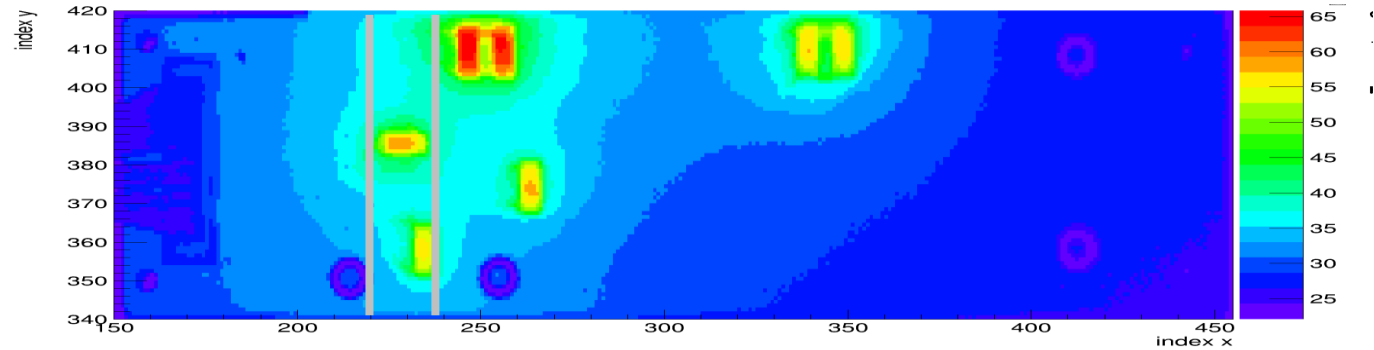
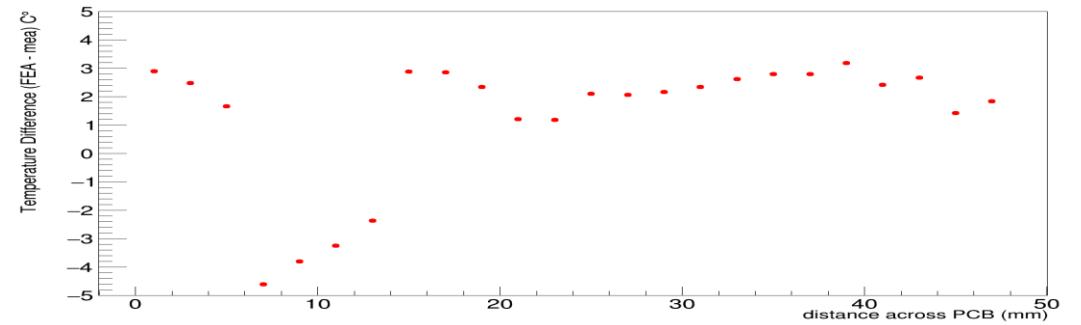
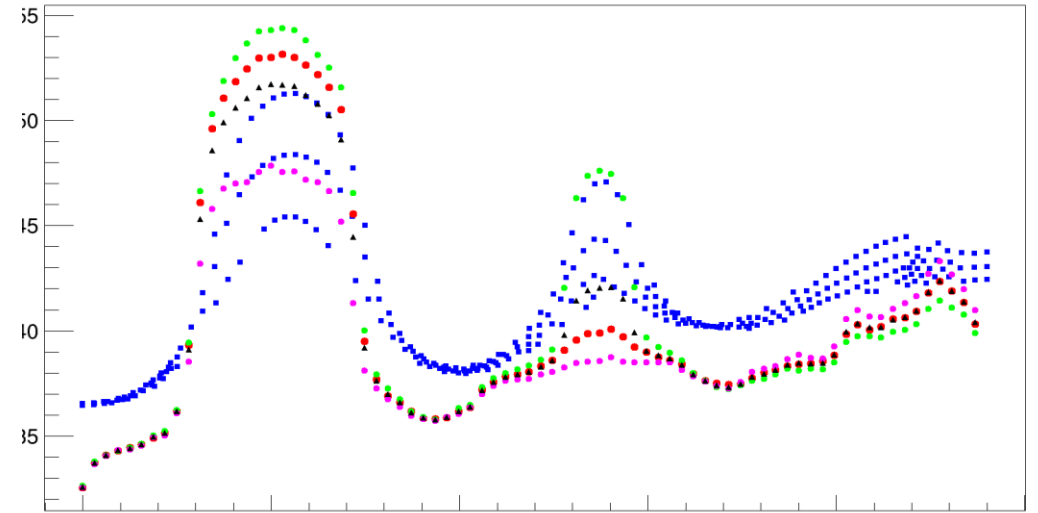
T difference: ~1C difference at resistor
~0.5C near resistor
~ 0.3C other area

Temperature across PCB (inlet +21C)

Temperature across PCB X=220

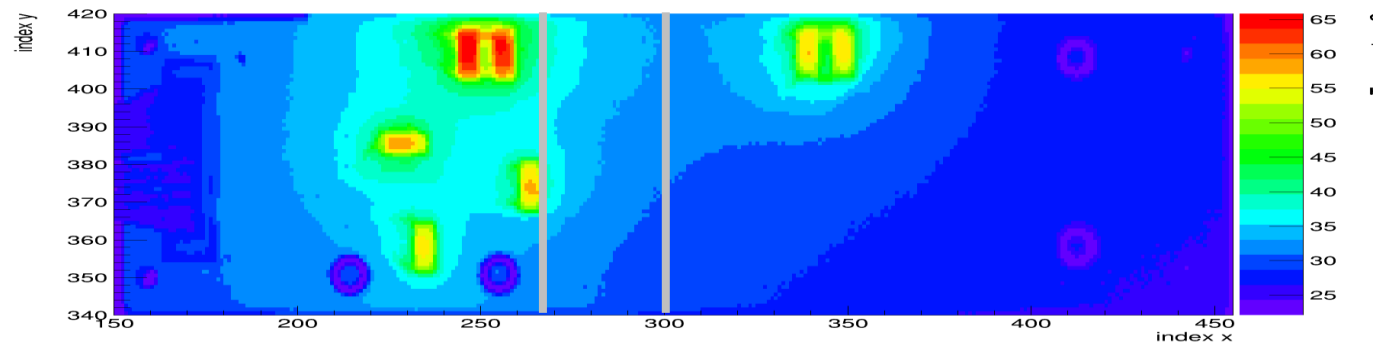
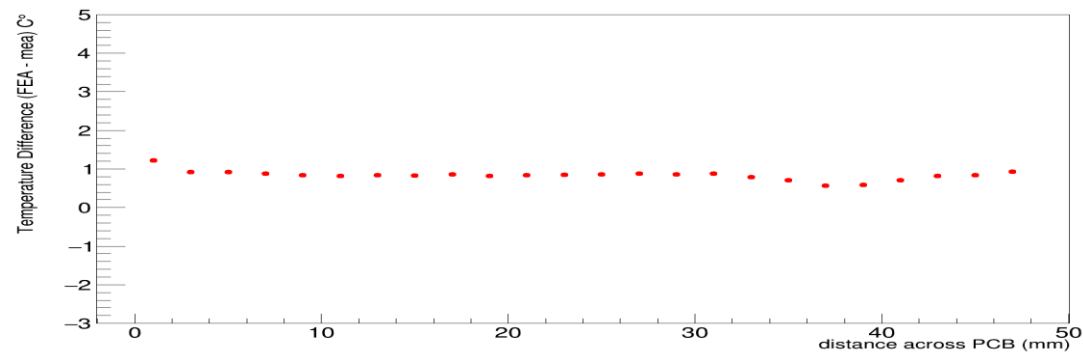
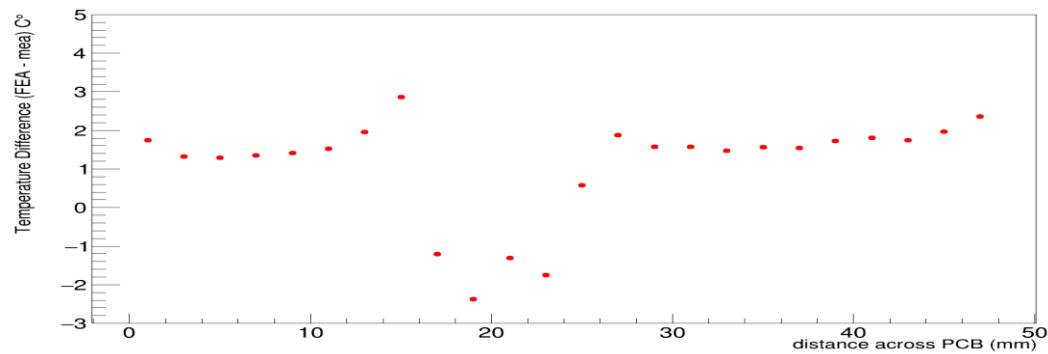
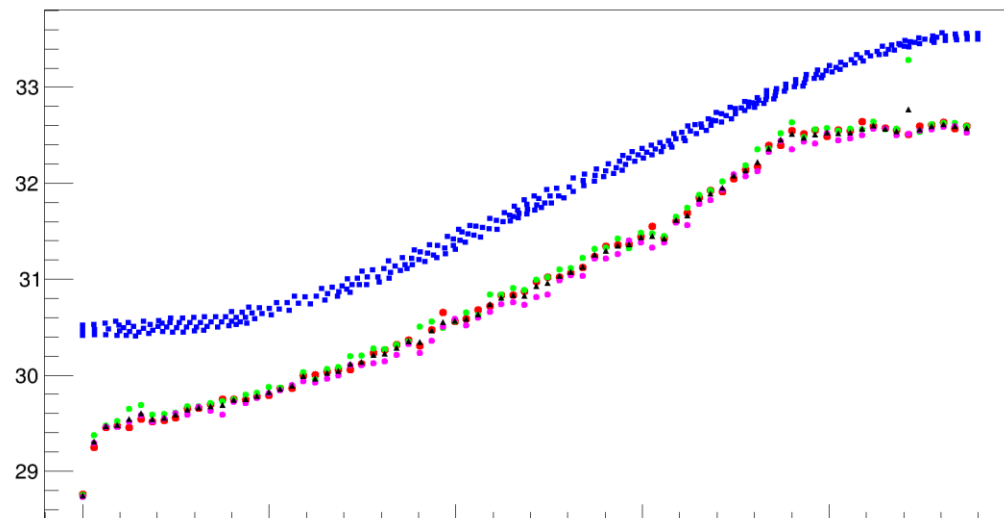
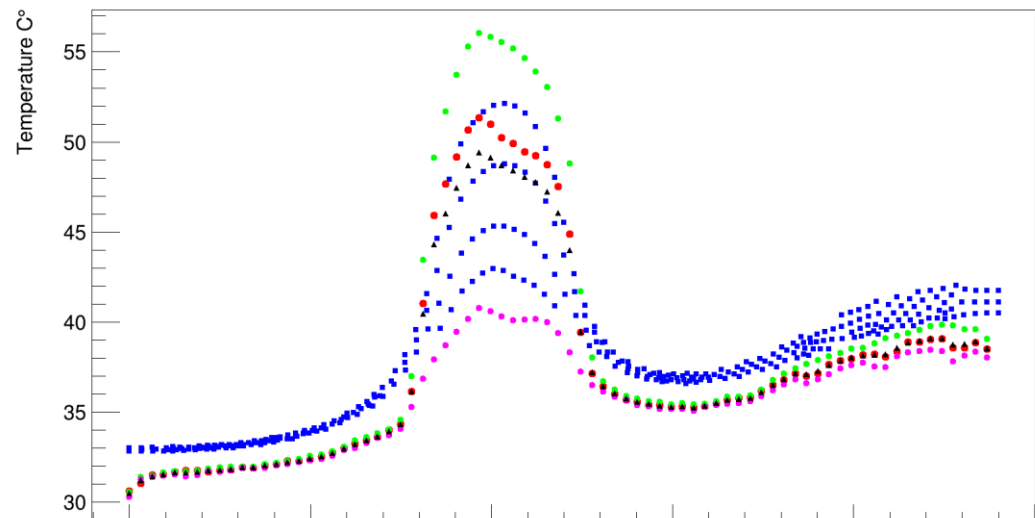


Temperature across PCB X=237



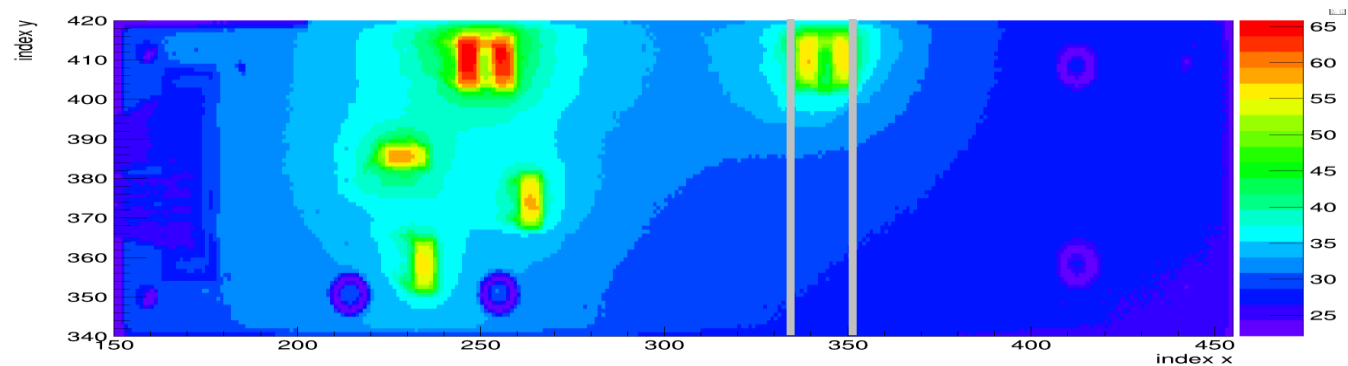
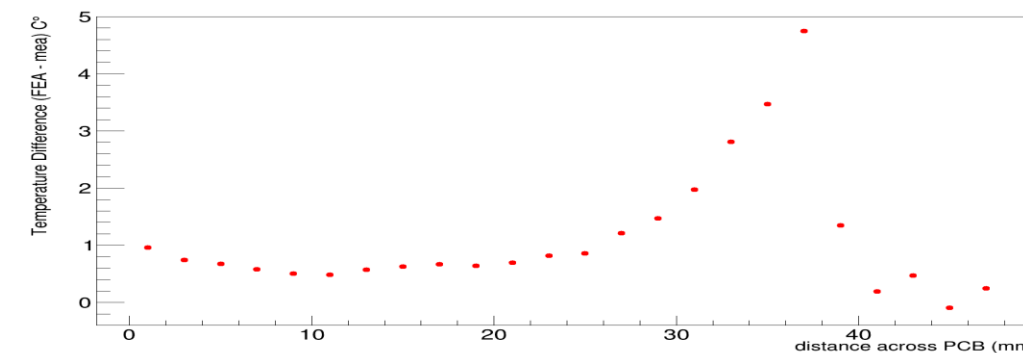
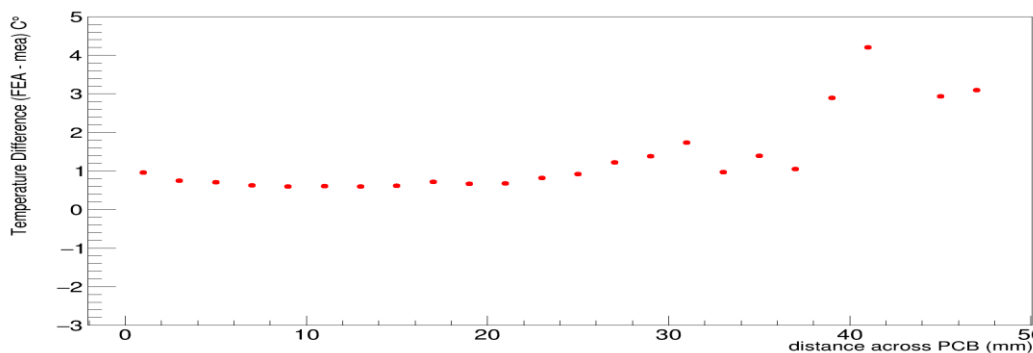
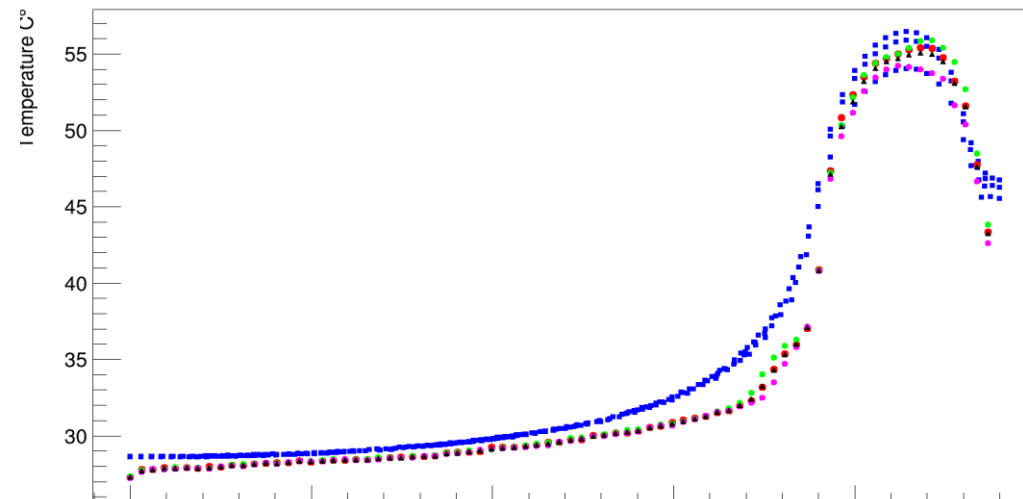
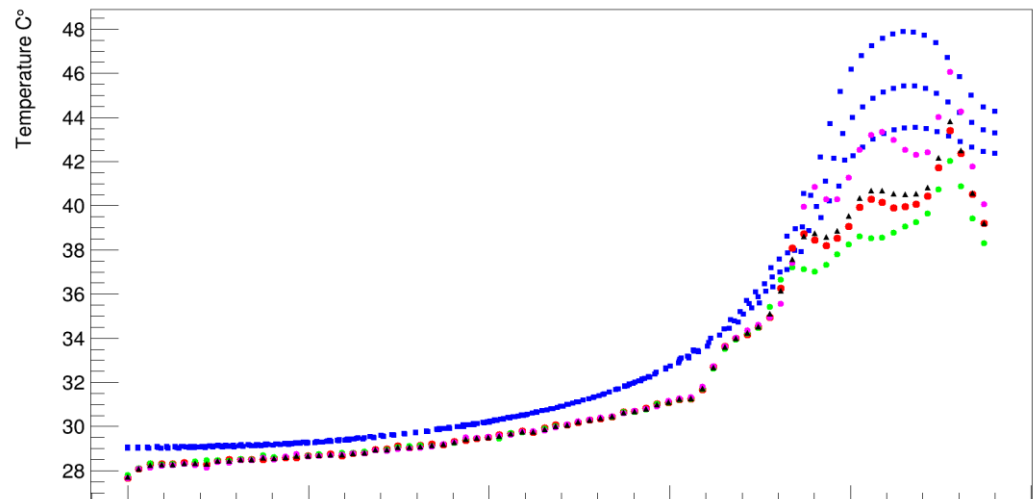
Temperature across PCB X=267

Temperature across PCB X=300

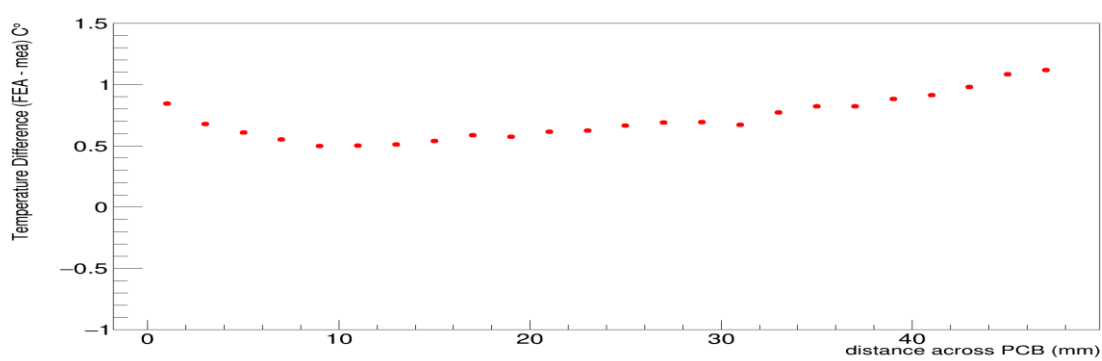
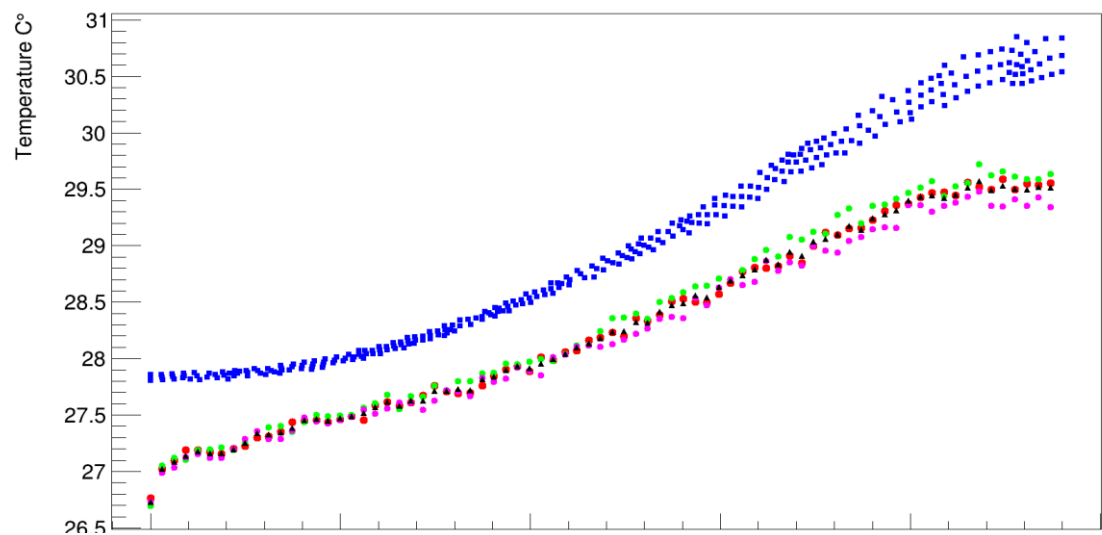


Temperature across PCB X=335

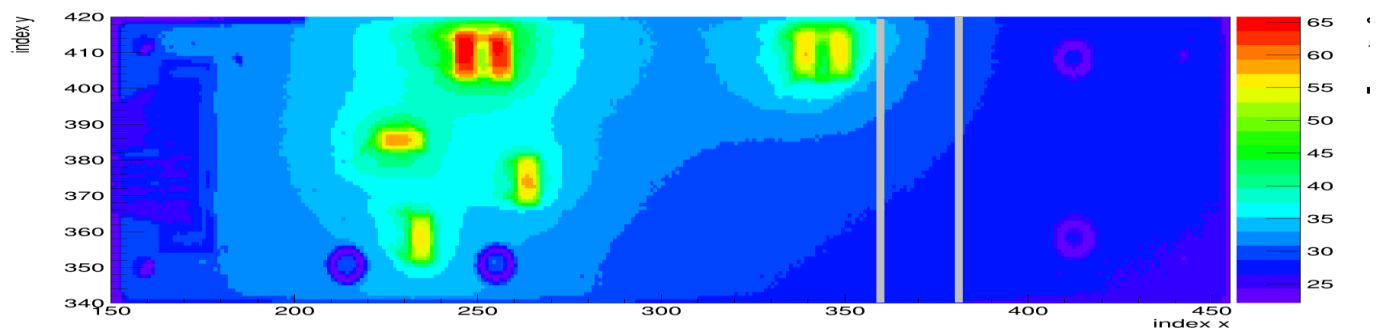
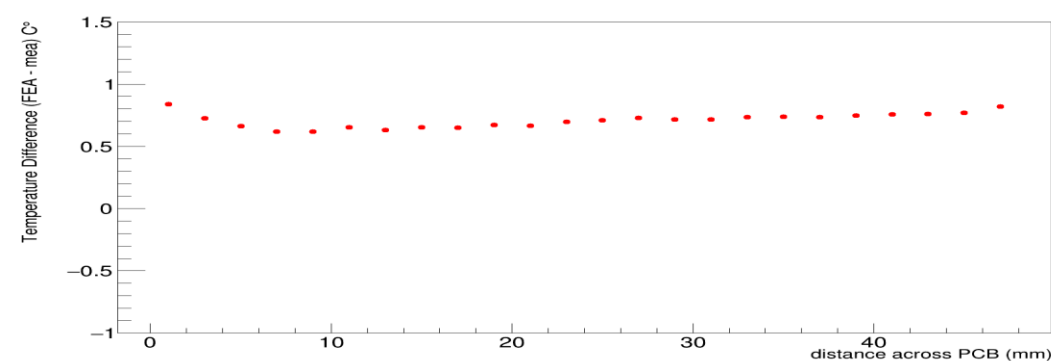
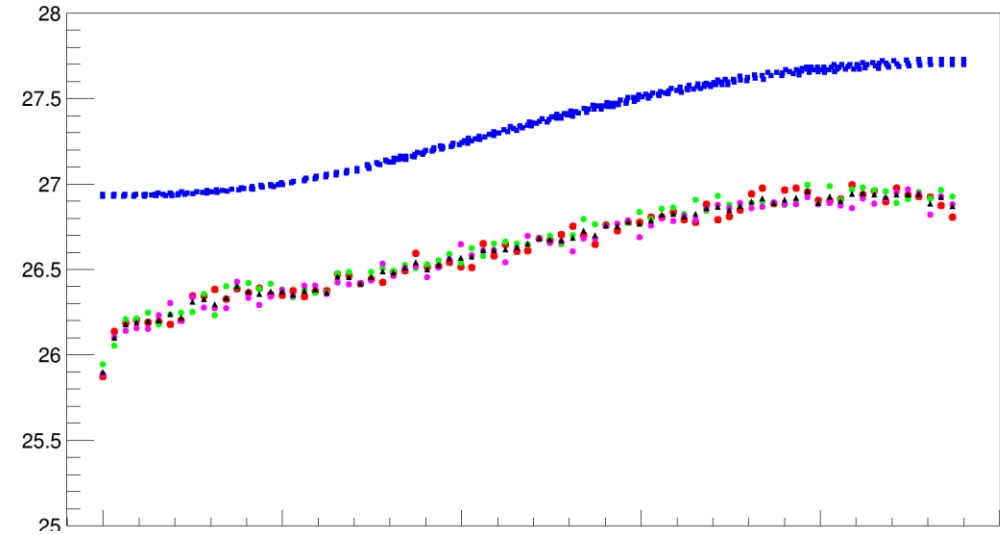
Temperature across PCB X=350



Temperature across PCB $X=380$

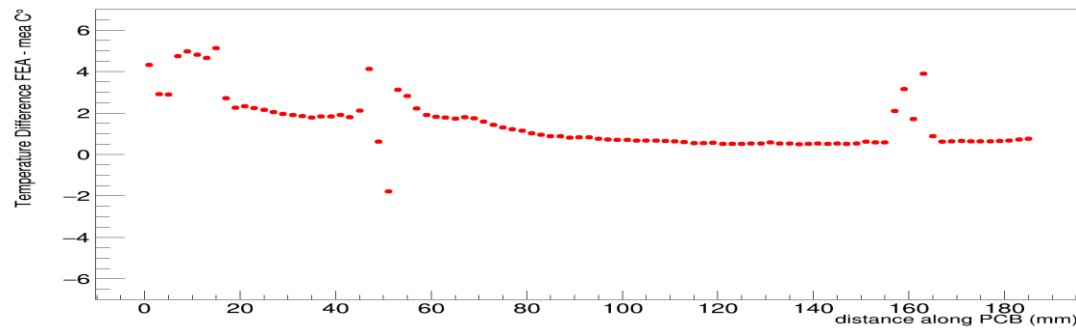
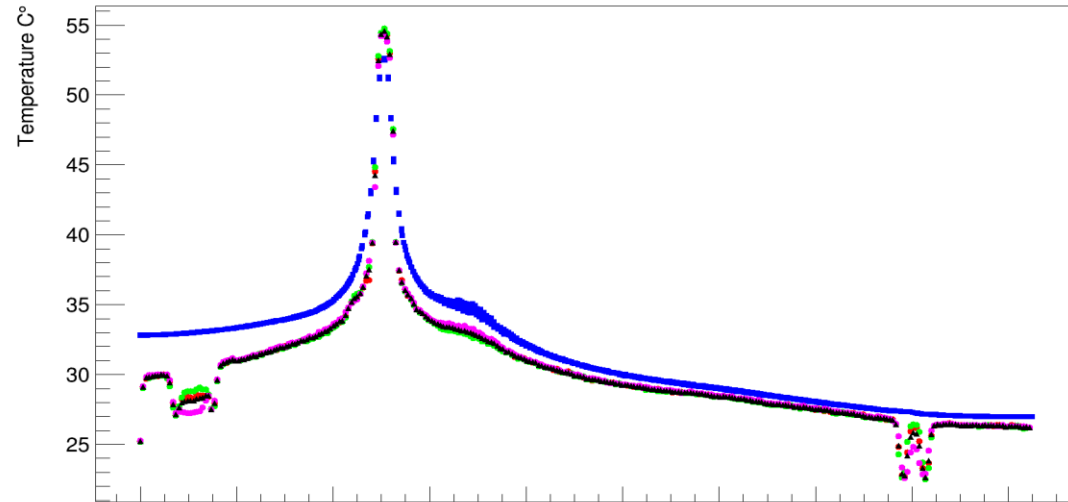


Temperature across PCB $X=430$

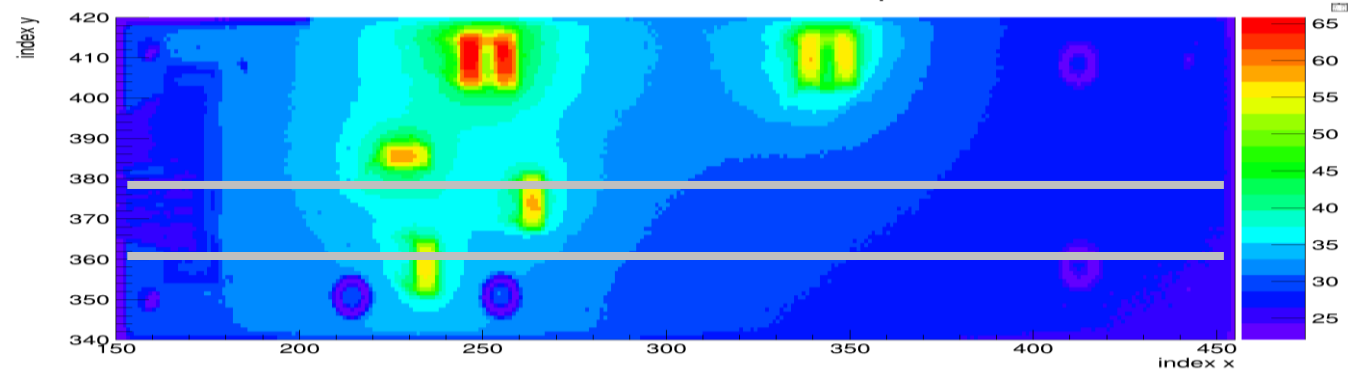
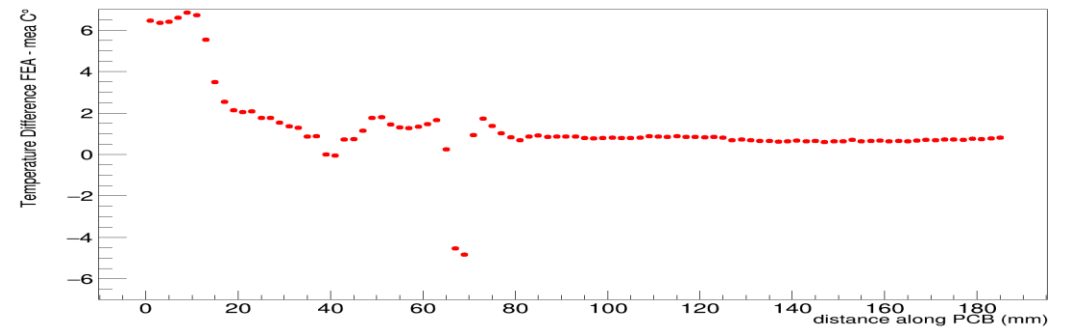
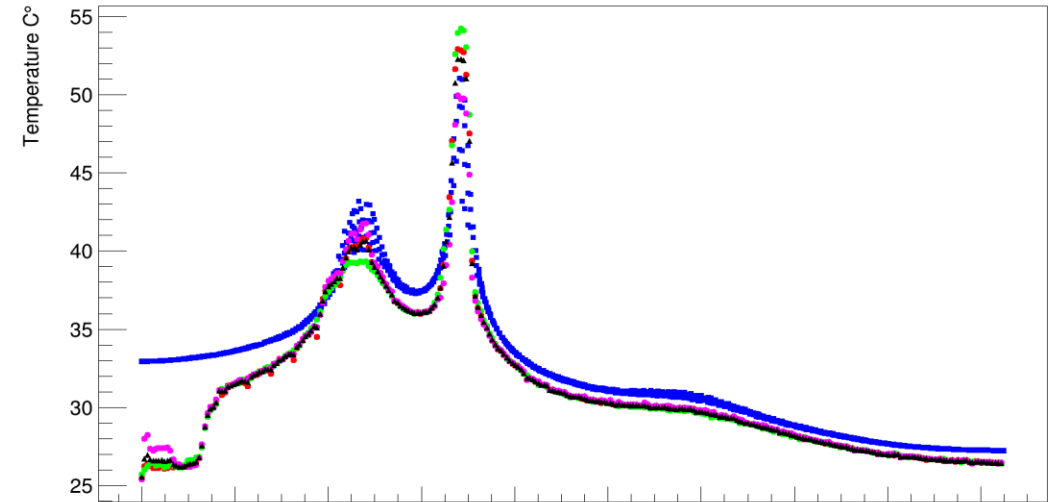


Temperature along PCB (inlet T +21C)

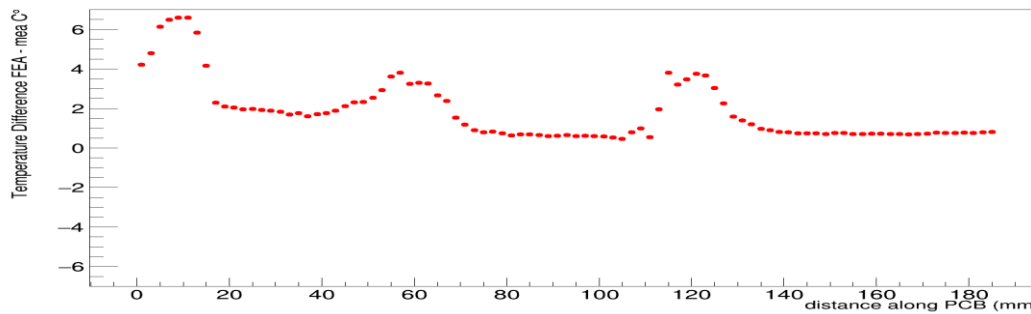
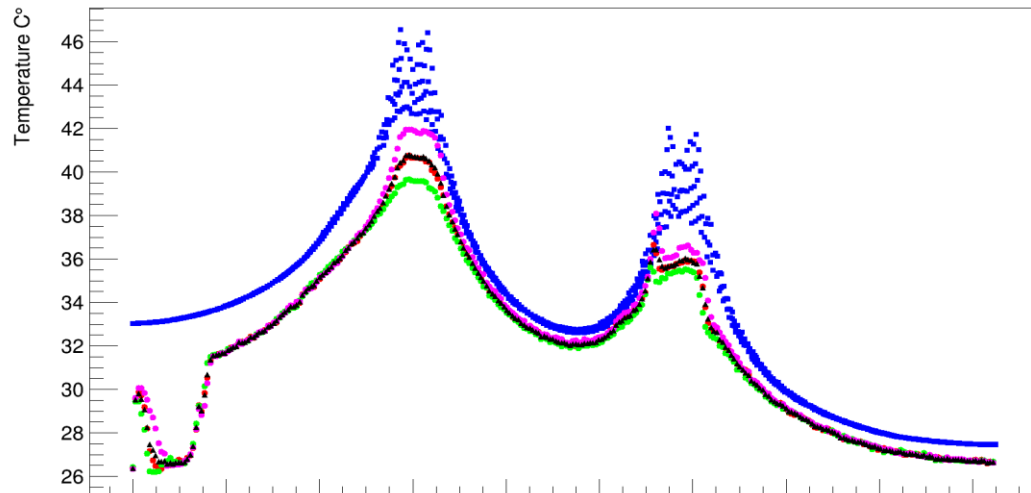
Temperature along PCB $Y=360$



Temperature along PCB $Y=380$



Temperature along PCB Y=400



Temperature along PCB Y=410

