High Granularity HCal Cooling Design for CEPC

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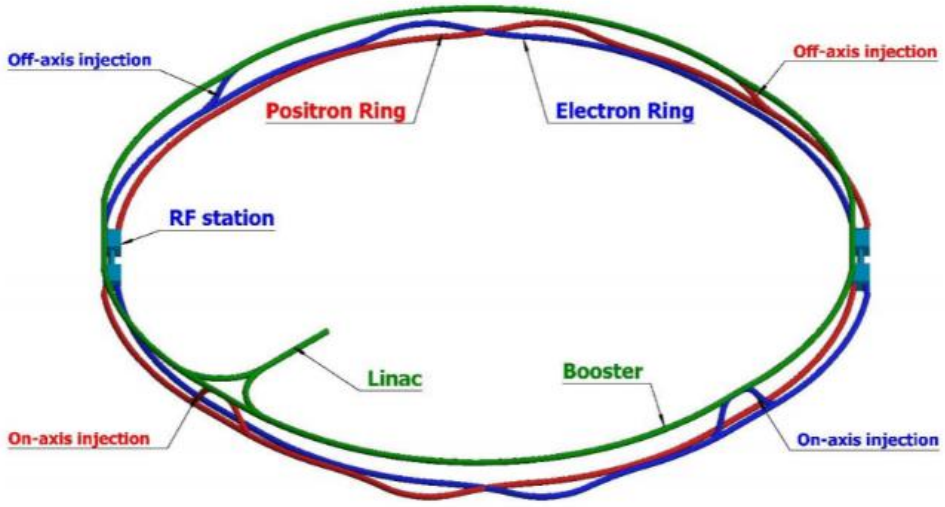
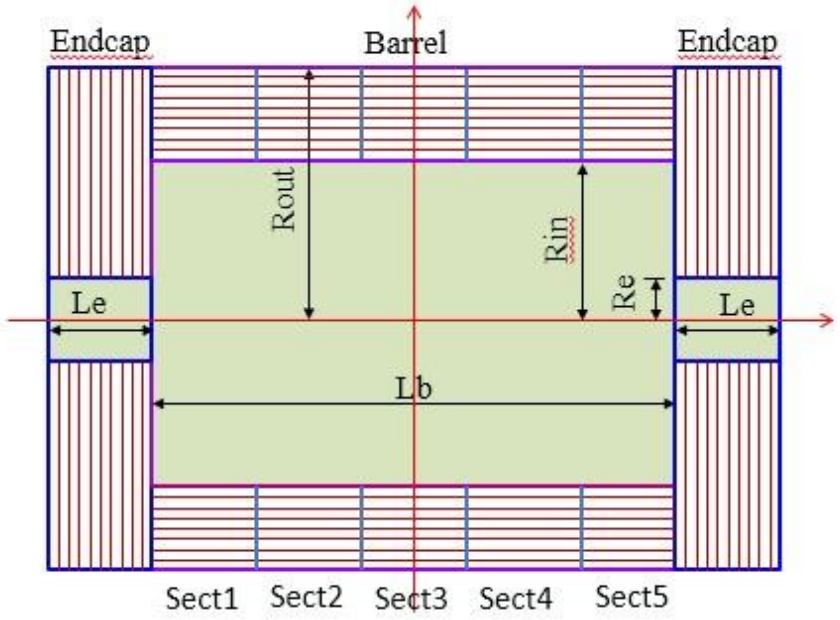
Why cooling system for CEPC SDHCAL

- CEPC
  - Circular Electron-Positron Collider
  - a new Higgs boson factory
- Work at 240GeV to produce over 1 million Higgs in 10 years

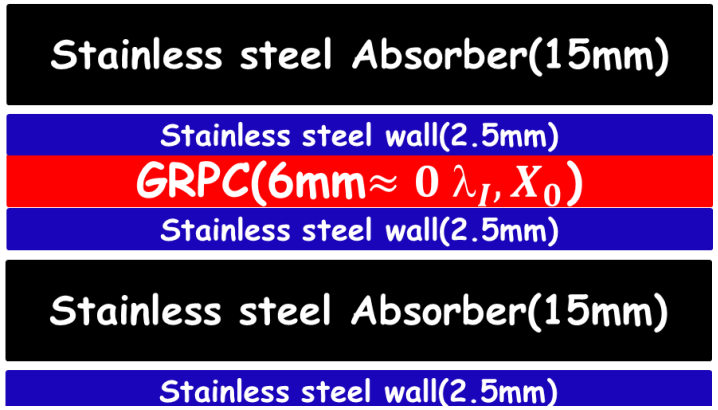


Why cooling system for CEPC SDHCAL

- SDHCAL(Semi-Digital Hadron Calorimeter)
  - inner radius R_{in} = 2300mm
  - outer radius R_{out} = 3340mm
  - inner & outer of HCAL endcap in Z-axis are 2670mm and 3710mm
- Area of the active layers
  - 40 active layers in barrel and endcap
  - ~3800m² (barrel) + ~2800m² (endcap) in total

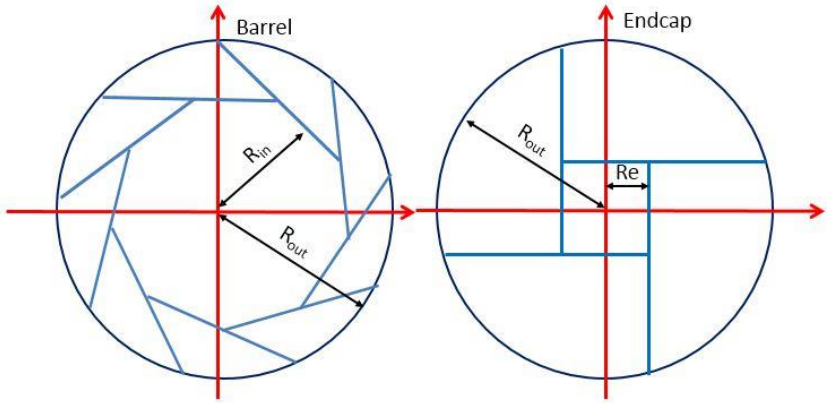


$(0.12\lambda_I, 1.14X_0)$



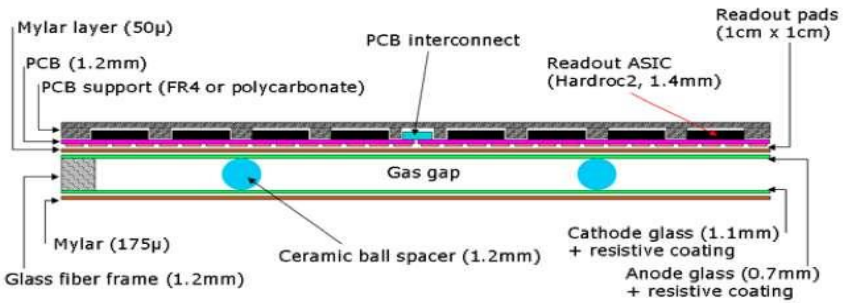
→ 3 mm RPC (glass)
1.2 ~ 1.4 mm PCB
1.6 mm ASIC (Hardroc)

→ 1mm gap between absorber and RPC detector

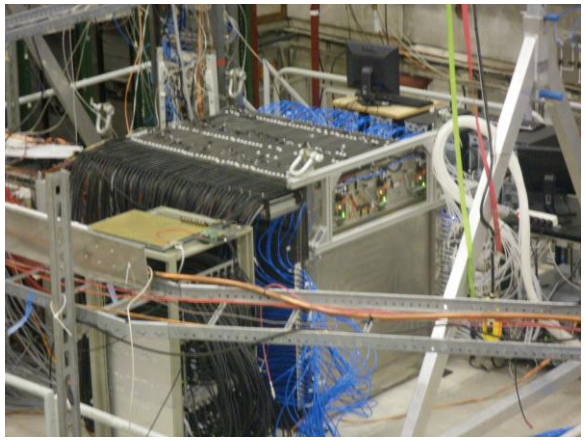


Why cooling system for CEPC SDHCAL

- Small RPC detecting cell is important for particle identification and shower reconstruction
- Total heat power
  - detecting cell: ~1×1cm² → over 60M signal channels
  - ASIC chips: ~1mW/channel → over **60kW**
  - plus readout boards etc.
- An active cooling system is demanding for CEPC HCAL
  - **cheap, safe, simple, steady**
- Heat affects:
  - electronics stability, detector unit performance, structure deformation



high granularity RPC structure



SDHCAL prototype

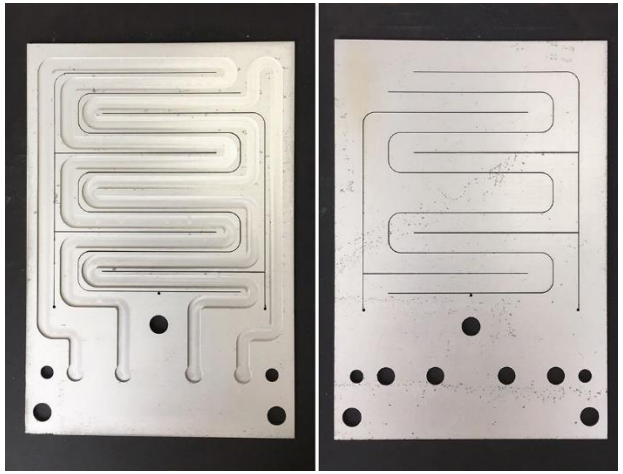
SDHCAL PCB with ASICs

Cooling plan: cooling plates

- Cooling plates: water pipes imbedded in metal plates
  - cooling ability: ~kW/m^2
  - **safety**(water is not so good)
- Stainless steel
  - poor heat transmission
  - difficult to produce → **high cost**
  - can work as the absorber
- Aluminum
  - good heat transmission
  - easy to produce
  - 5 times the radiation length than steel

- Air cooling: no space for air flow (1mm gap)
  - or at very low temperature flowing in cooling plates
- Heat pipe/vapor chamber?

Cooling plates

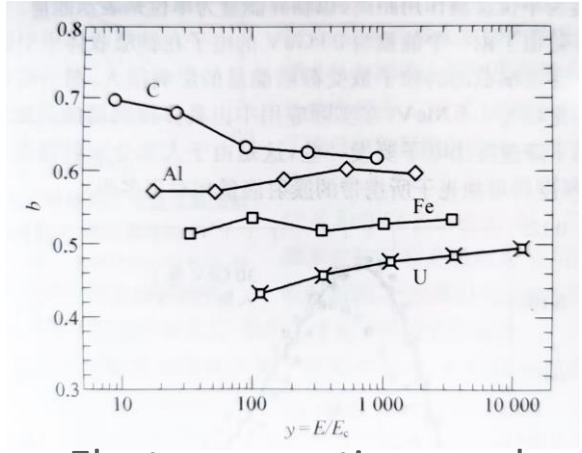


Cooling plan: cooling plates

- Stainless steel cooling plates work as absorber
  - 500mm×350mm×15mm
  - 8000 yuan(~€1000)/piece

- Aluminum
  - 500mm×350mm×10mm
    - 758 yuan (~€97)/piece for 500pcs
    - 608 yuan (~€77)/piece for 3000pcs
  - 10mm Al = 2mm stainless steel absorber in radiation length → **8mm thicker per layer(15+13mm in total)**

- Keep in touch with the companies



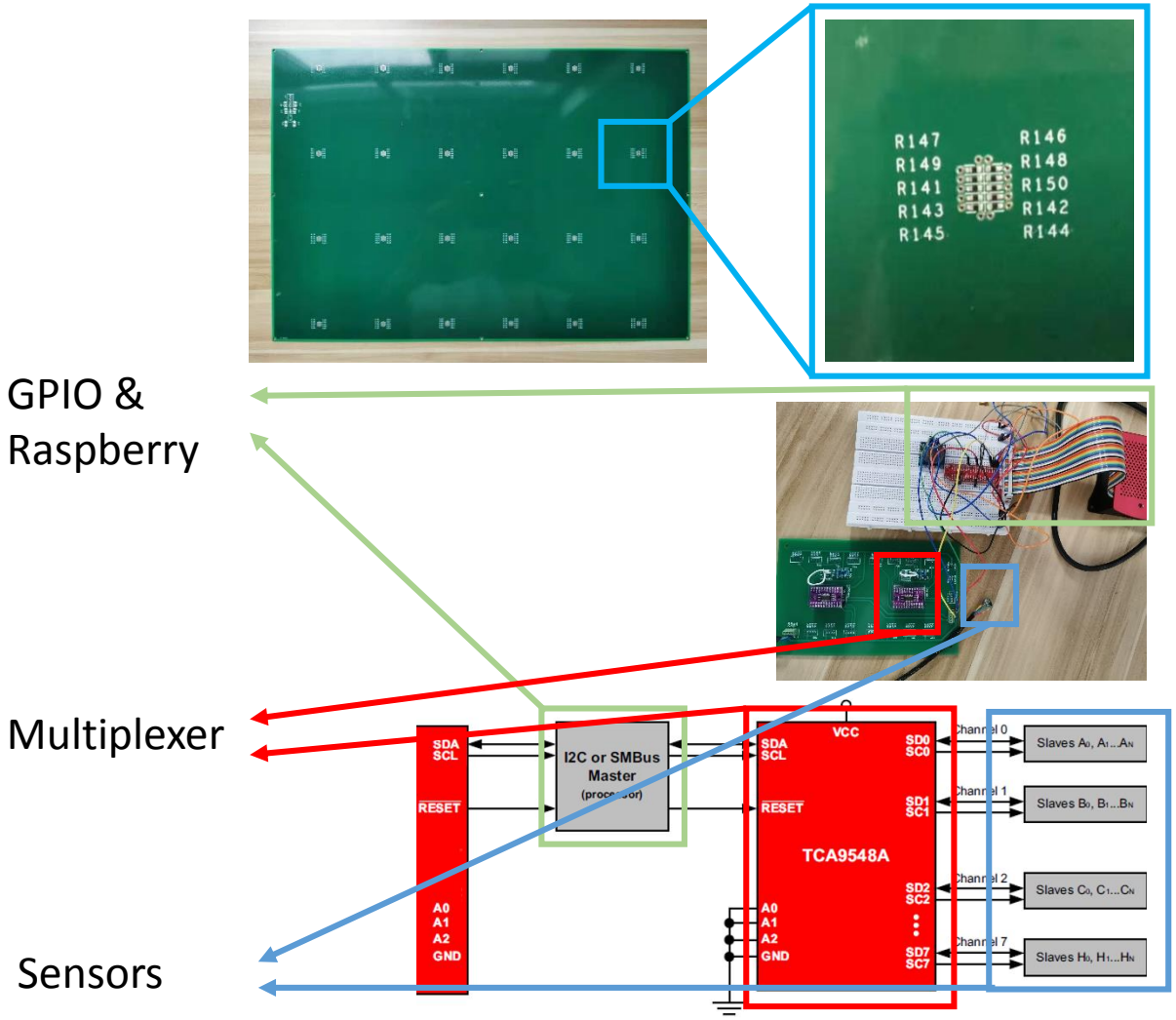
Electromagnetic cascade property

Radiation/interaction length comparison

	radiation length (cm)	interaction length (cm)
Fe	1.75	10.6
Al	8.89	39.4

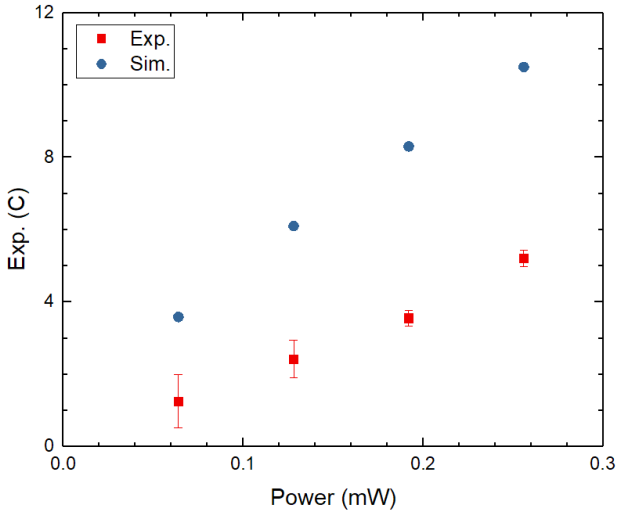
Detecting system

- Use resistors substituting for ASICs
  - Resistors: 4*6*10 per PCB
  - Total resistance of a group of 10 parallel-connected resistors: 470Ω
  - ASICs in SDHCAL: **~0.064W/chip** → ~5.5V on resistors
- Sensor: Si70xx, high precision temperature & humidity sensor
  - range: -40~125℃
  - accuracy: **0.1℃** at most
- 8*8 sensors monitored simultaneously with multiplexers based on I^2C

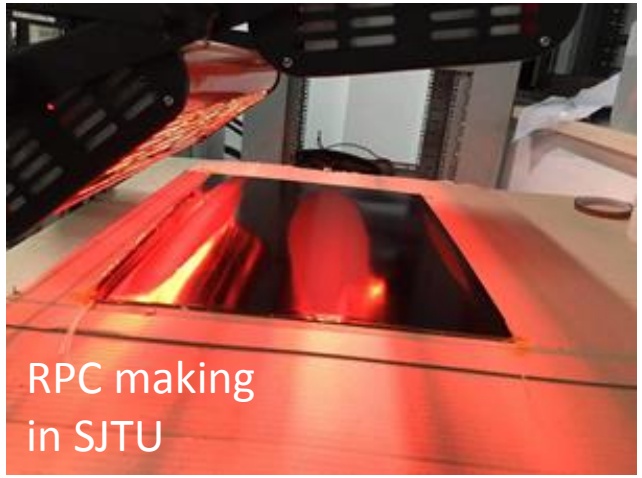


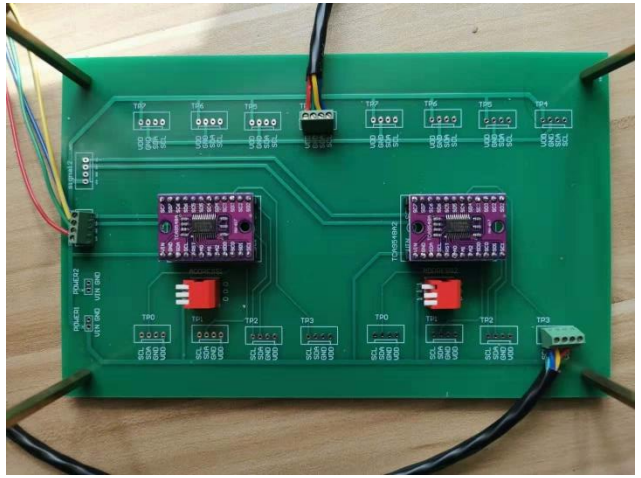
Detecting system

- Difference between simulation & test is too big
- Possible reasons:
  - bad touch between sensors & resistors
  - simulation setting:
    - joule heating vs simple heat power in Icepak
    - material properties



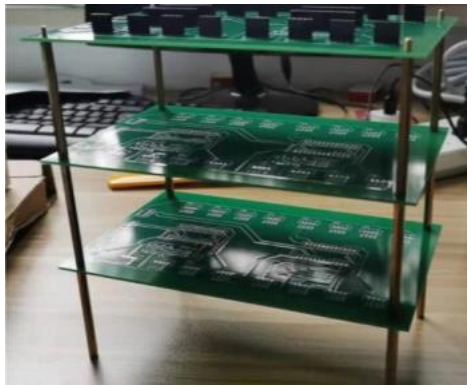
Comparison between experiment(red) & simulation(blue) without cooling





One layer of detecting PCB

Whole detecting structure

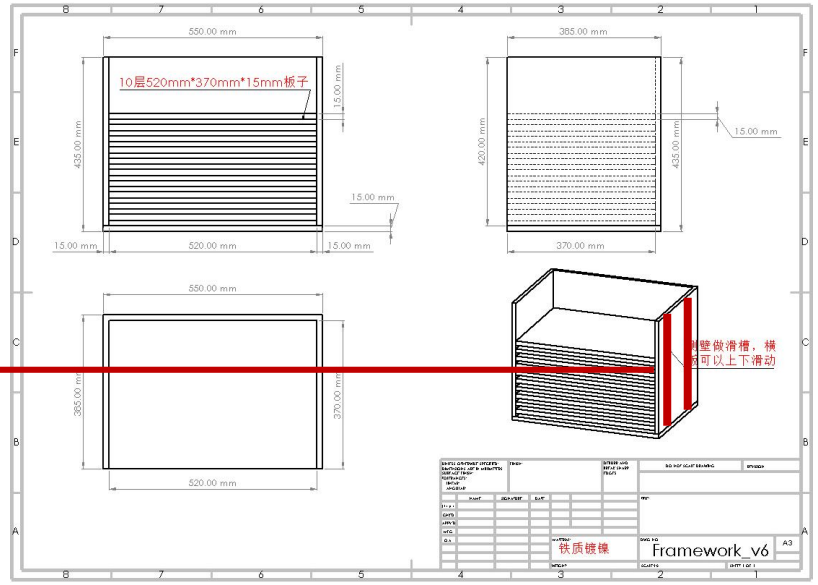


A flexible absorber framework

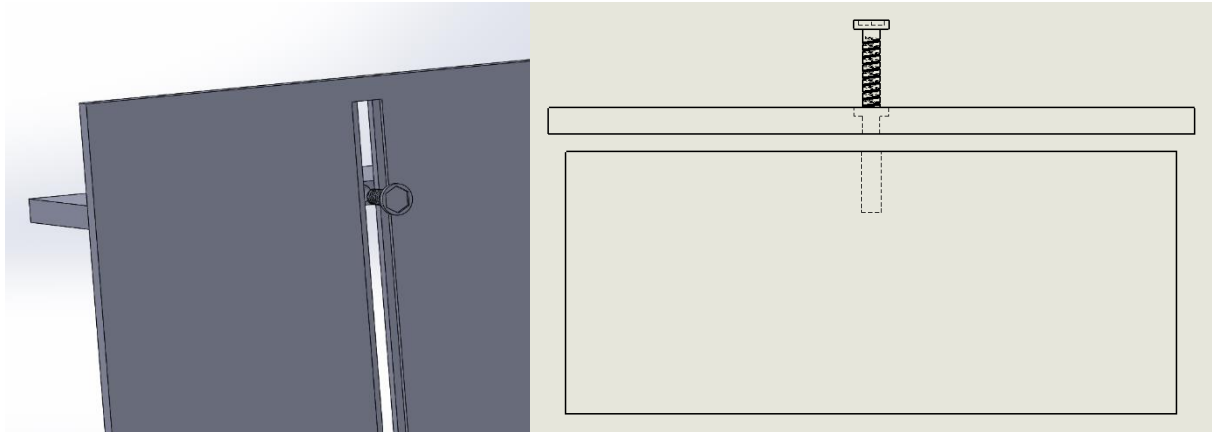
- Total flexible design:
  - each layer is fixed with slots and screws to allow adjustment and disassembly
  - wheels at the bottom
- Iron with nickel overlay
  - easy to produce than stainless steel but with similar heat behavior and radiation length
- Weight: 313kg, 22kg each layer
  - PCB + RPC: 1.4kg
  - 1.5mm aluminum cooling plates: 7kg
- Price: ~12,000 yuan

Two slots on two sides

A flexible absorber framework design

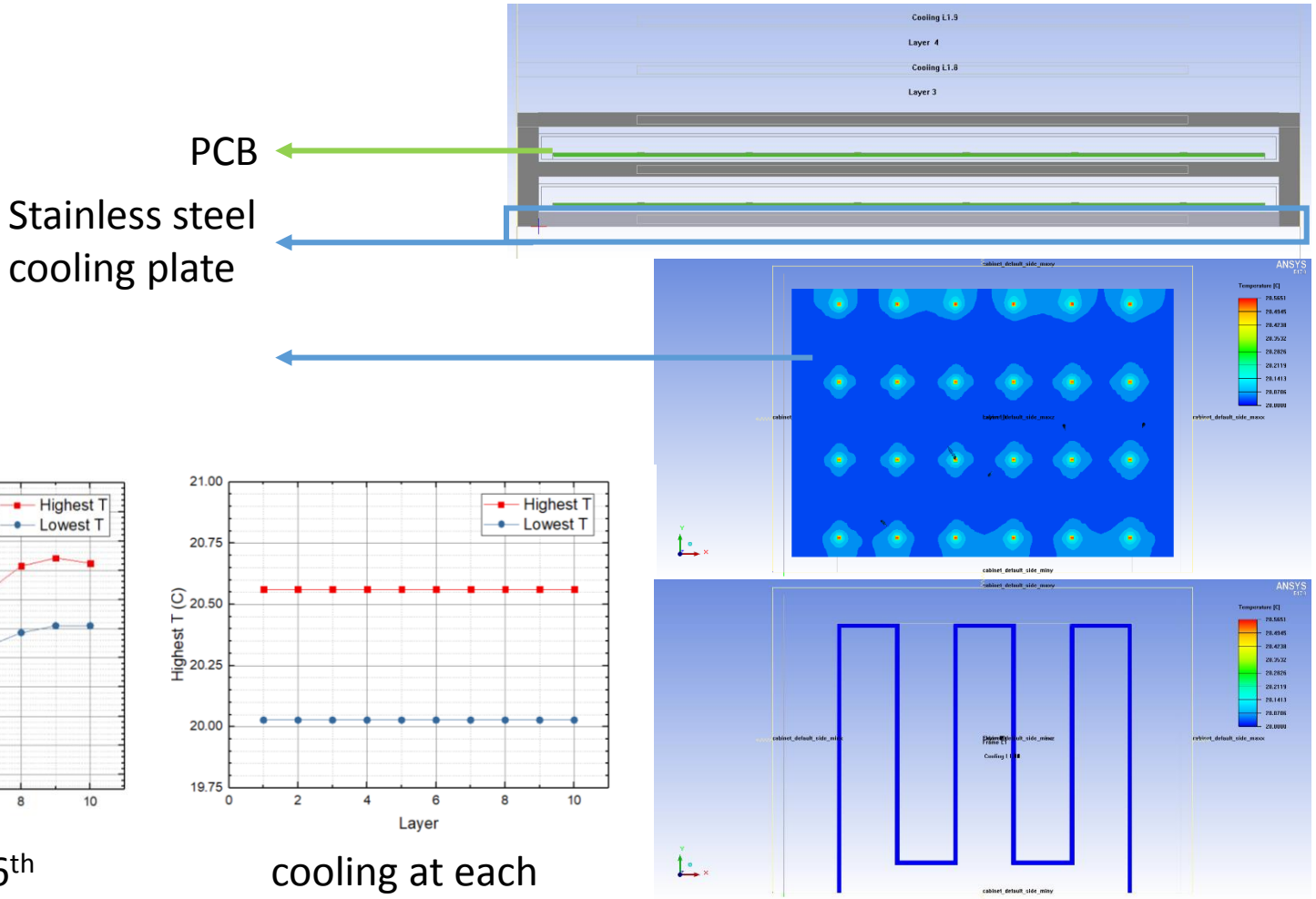


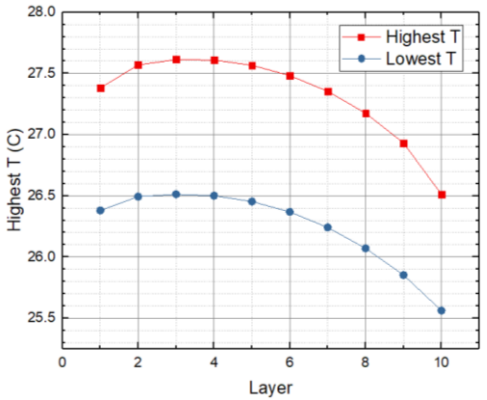
Detailed illustration for slots



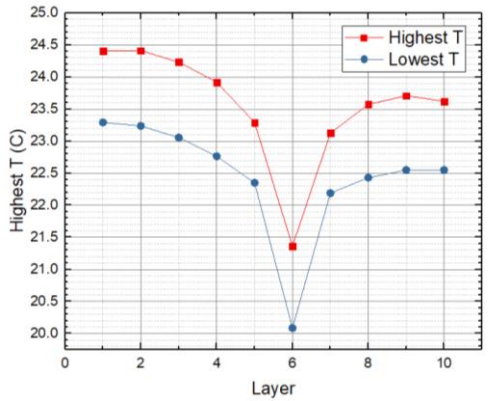
Rough simulation

- Icepak, resistor models
- 10 layers, flow rate: 1m/s
- With cooling at 6th layer:
  - uneven among layers
- With cooling each layer:
  - uniform among layers
  - cooling power: ~1.53W/layer
    → enough





no cooling



cooling at 6th

cooling at each

Summary

- Plan of cooling needs to be determined
- Based on current results:
  - Simulation needs to be optimized with a more precious electrothermal coupling model
  - Touch between sensors & PCB/resistors need to be modified

Thank you!