Development of Integrated Cooling Solutions for the CALICE AHCAL

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Graduate School Particle Detectors

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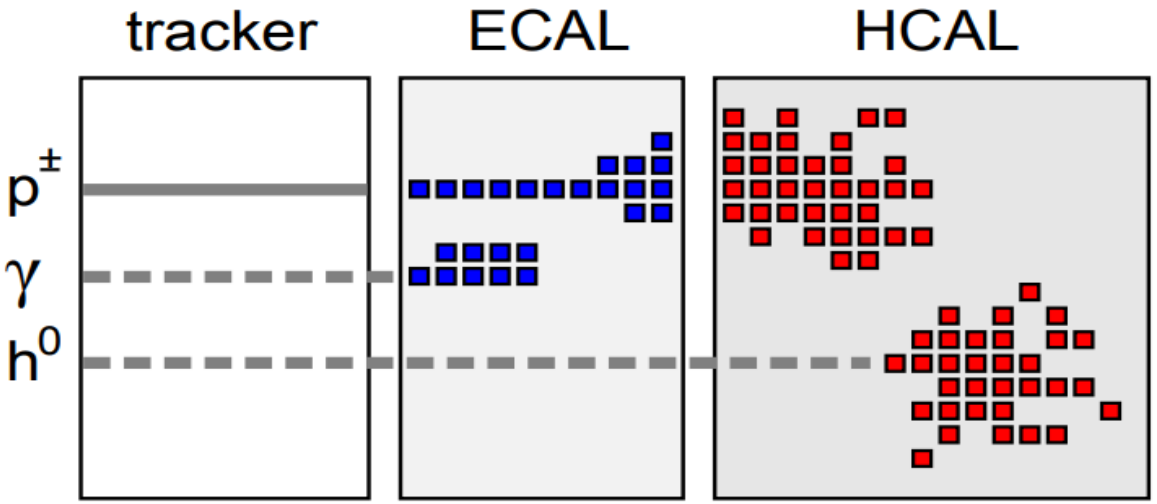
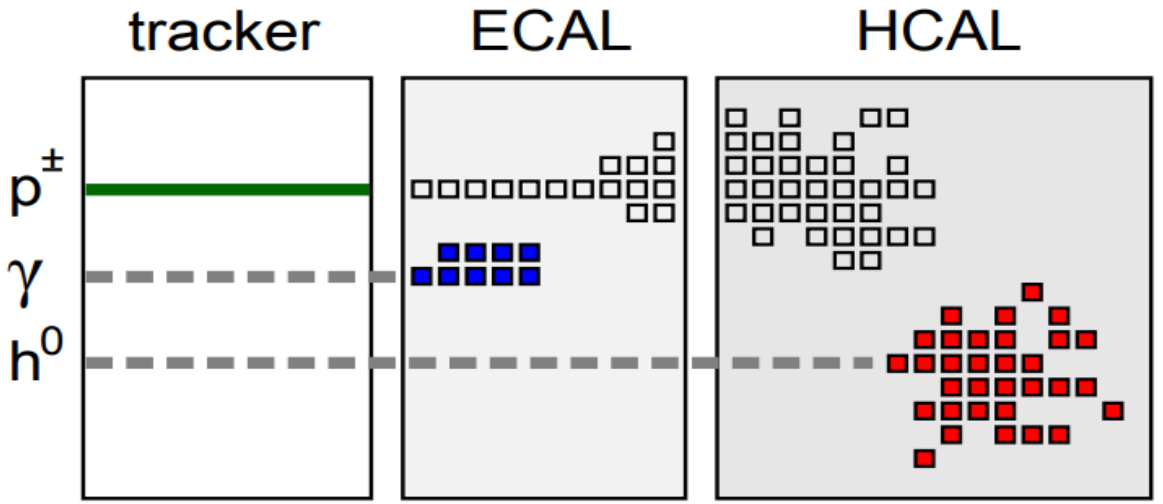
Particle Flow

- Combining information from all subdetectors to reconstruct jet energies
- Momentum of charges particles measured in tracker
- Photons and electrons measured in ECAL, hadrons in HCAL



Conventional Approach



Particle Flow Approach

Future of Particle Colliders

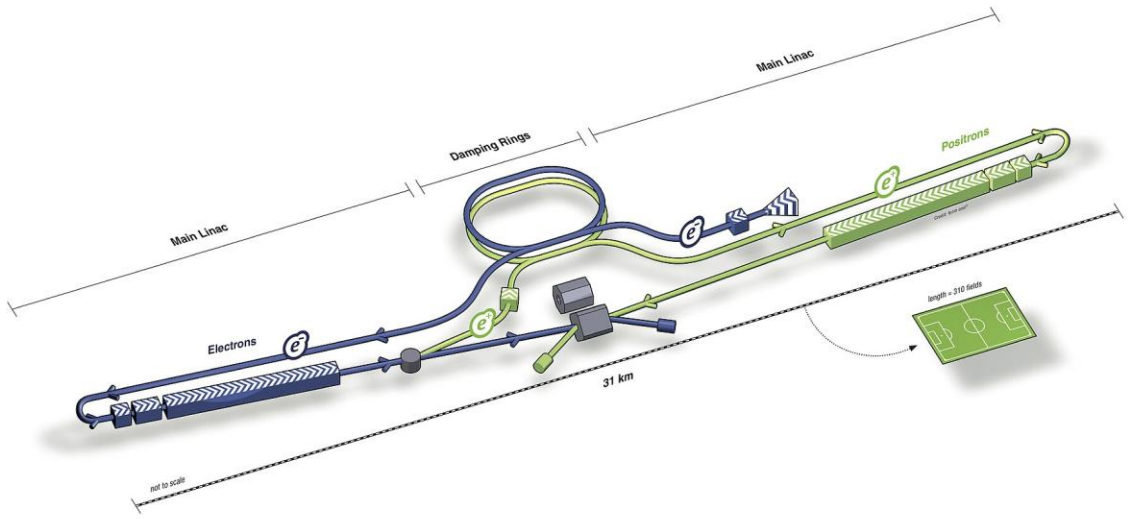
- 2012: Higgs-particle has been found at the LHC
- Measurement of some decay: $H \to \gamma\gamma$, $H \to b\bar{b}$, $H \to \tau^+\tau^-$
- LHC pp - Collider -> a lot of pile-up and QCD background

➢ e^+e^-- Collider for presicion measurement

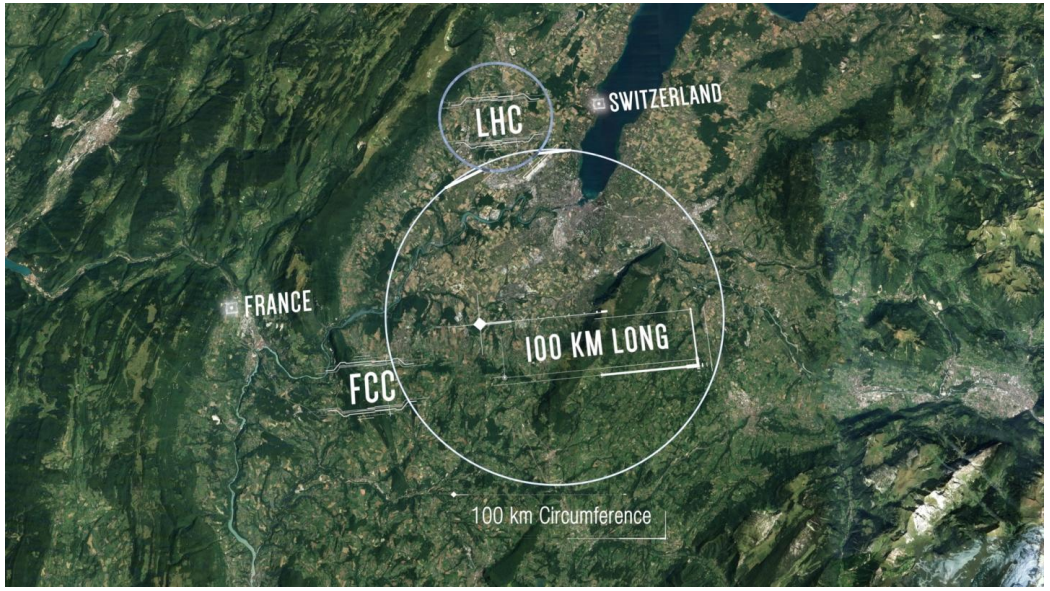
Linear vs. Circular Collider

ILC (International Linear Collider):

- Proposed linear particle accelerator
- Bunch crossing rate: 5 Hz

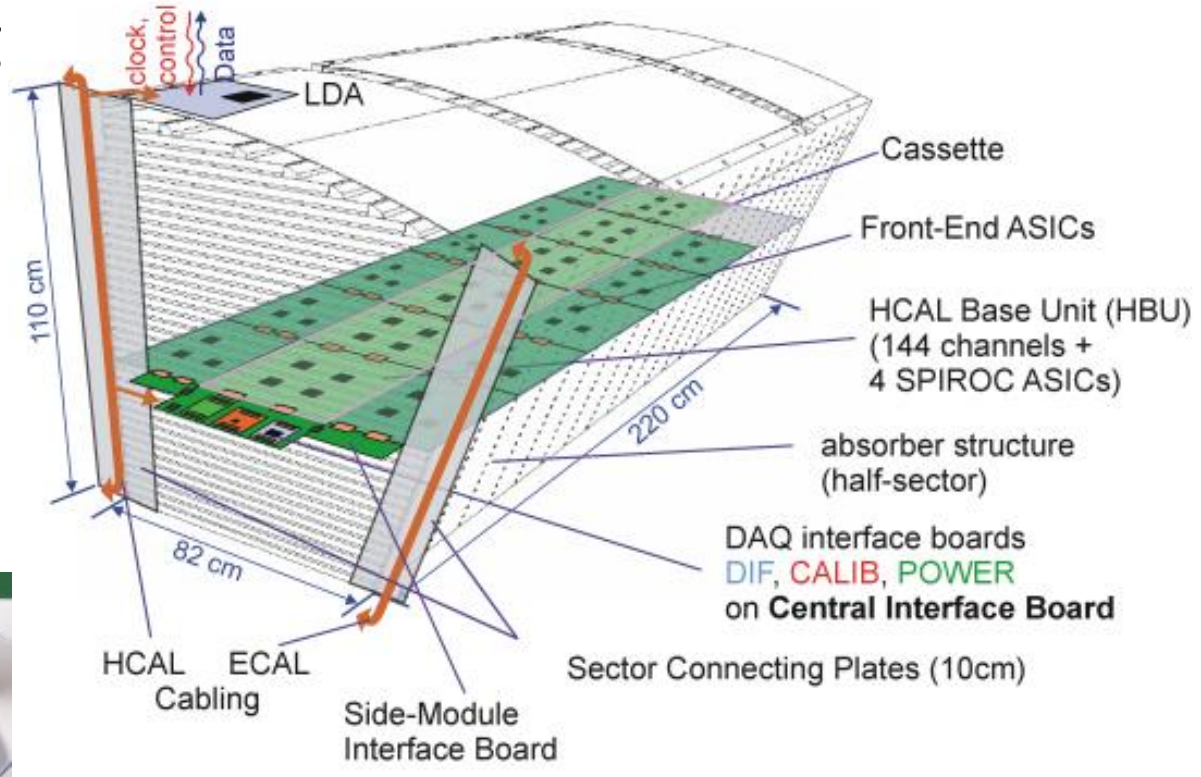


- FCC (Future Circular Collider):
- Proposed circular particle accelerator
- Bunch crossing rate: 40 MHz

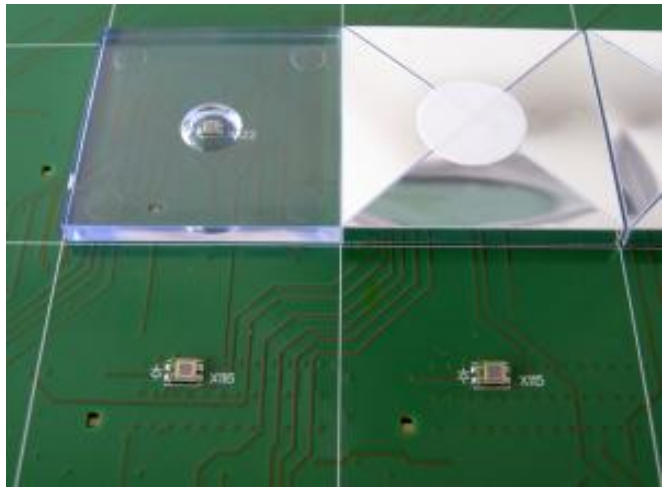


CALICE AHCAL

- CALICE collaboration developed an analog hadronic calorimeter (AHCAL) within the design requirements of the ILC
- Prototype build and tested with ca. 22000 channels
- HBUs with SiPM-on-Tile technology



Picture taken from "International large detector: Technical design report: Volume 4: Detectors" (https://arxiv.org/abs/1306.6329)

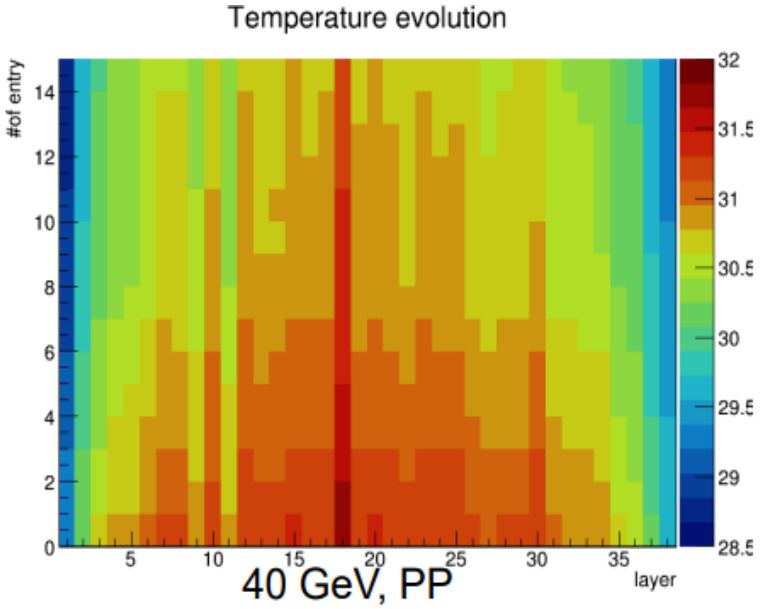


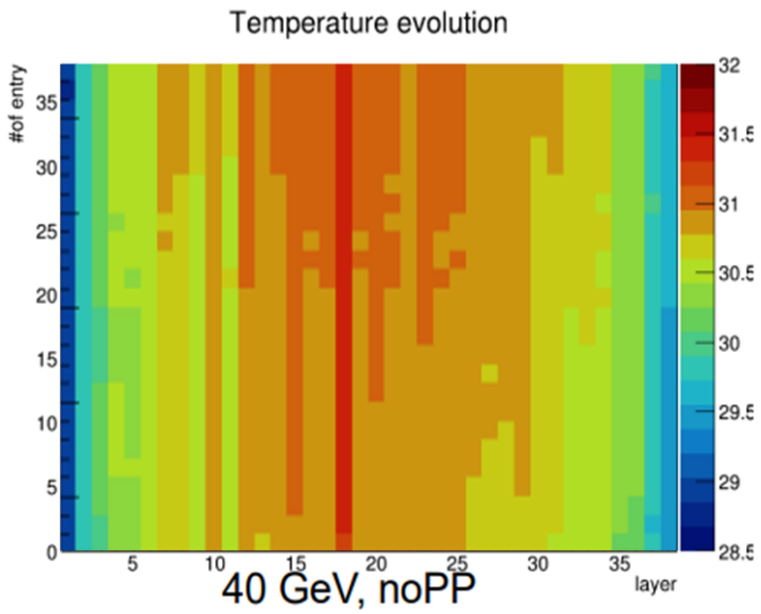
Picture taken from "A highly granular SiPM-on-tile calorimeter prototype" (https://arxiv.org/abs/1808.09281)

Cooling of the Front-End Electronics

- Power consumption managed through power pulsing (1ms bunch trains at 5 Hz)
- The AHCAL will now be modified to also fit into a FCC-ee type accelerator
  - Higher bunch crossing rates than at the ILC
  - ➢Power pulsing no longer possible

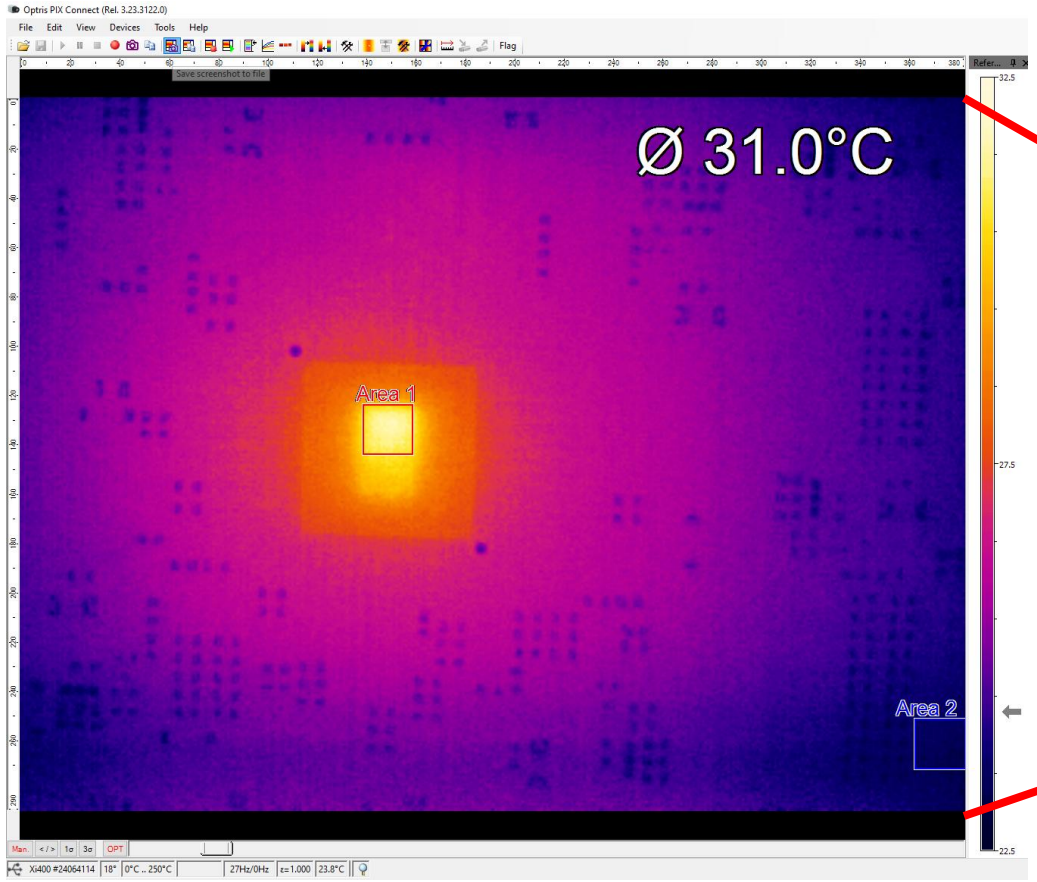
➢Need for integrated cooling

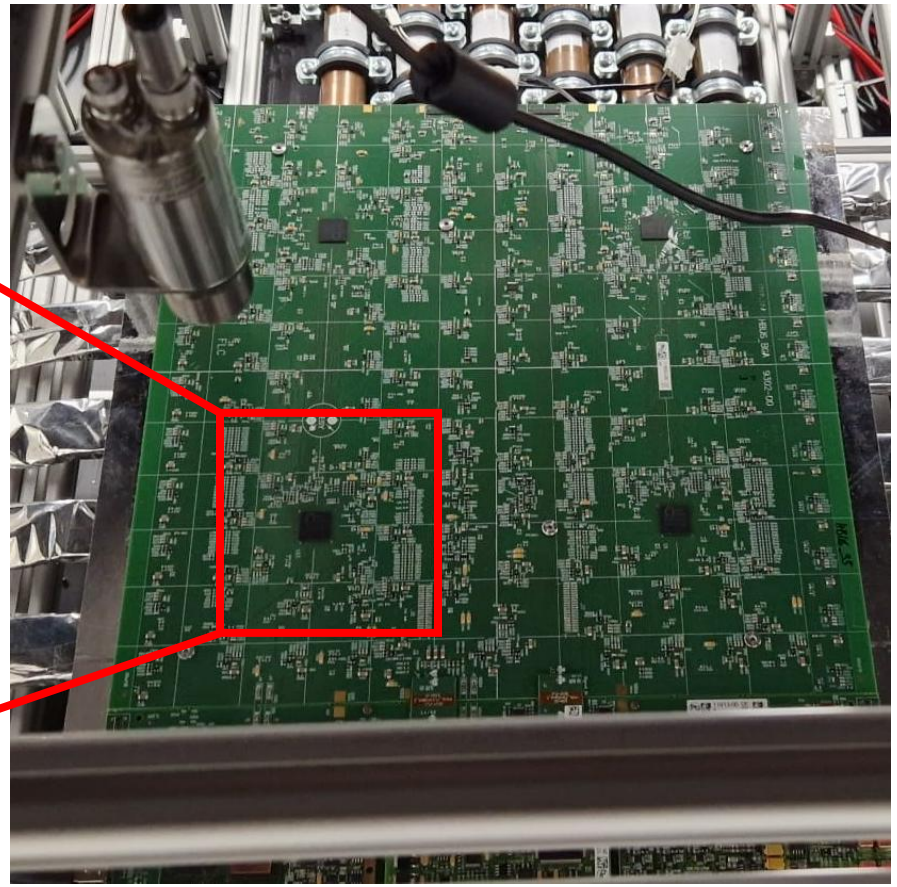




Temperature Distribution on the HBU

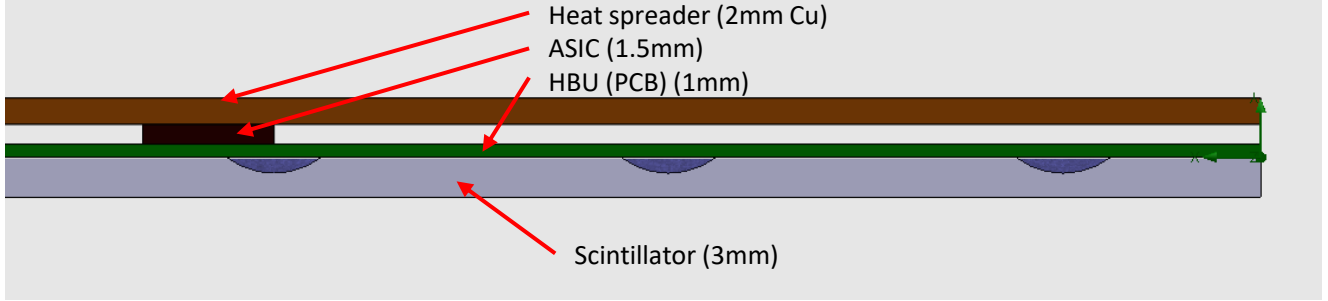
- Temperature measurements with thermal imaging camera

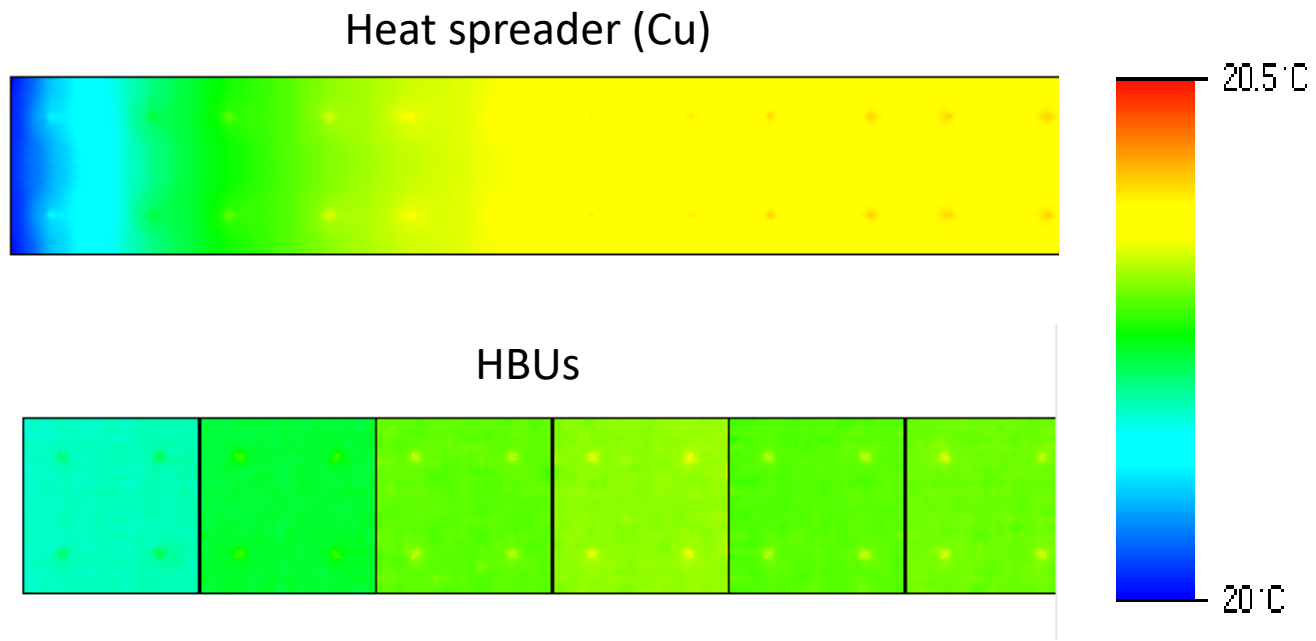




Simulation of the Temperature Gradient

- Simulation done by a group in Heidelberg
- Layout with a slab made of 6 HBUs
- Simulation needs more information:
  - Contact pressure
  - Material
  - Thickness of heat spreader
- Information gathered in Mainz

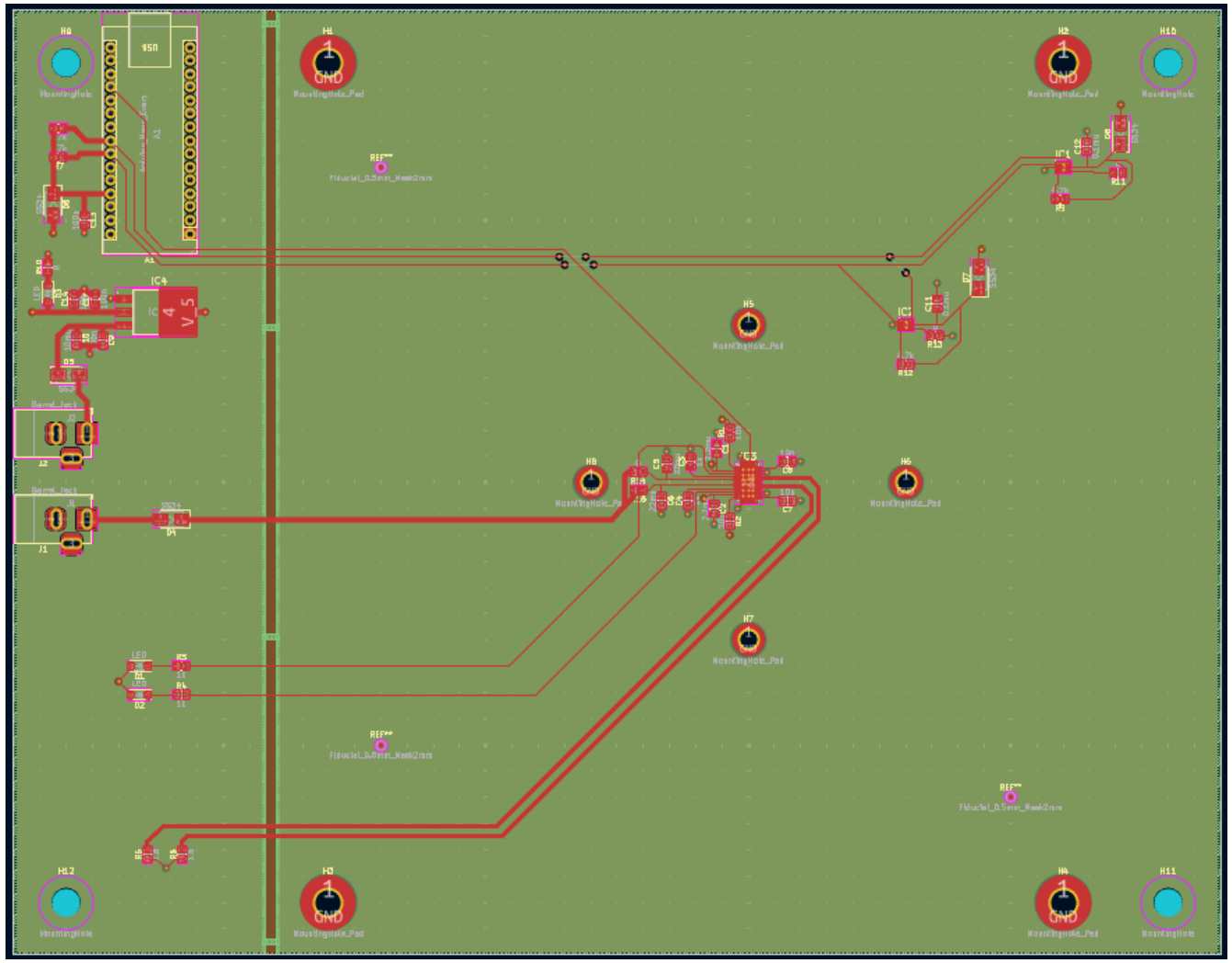




Pictures taken from Konrad Briggl (Uni Heidelberg)

Dummy HBU

- Dummy HBU to gather information in Mainz
- “Main board”:
  - 18cm x 18cm (1/4 of HBU)
  - Voltage regulator as heat source
  - Temperature sensors
- “Extension”:
  - 18cm x 5cm
  - Used for placement of power supply, sensors readout, etc.



Future Plans and Challenges

- Test and improve dummy HBU
- Scale dummy HBU to a full sized HBU
- Test different settings as:
  - Heat distribution with/without external copper plate
  - Thickness of the heat spreader (GND plane and copper plate)

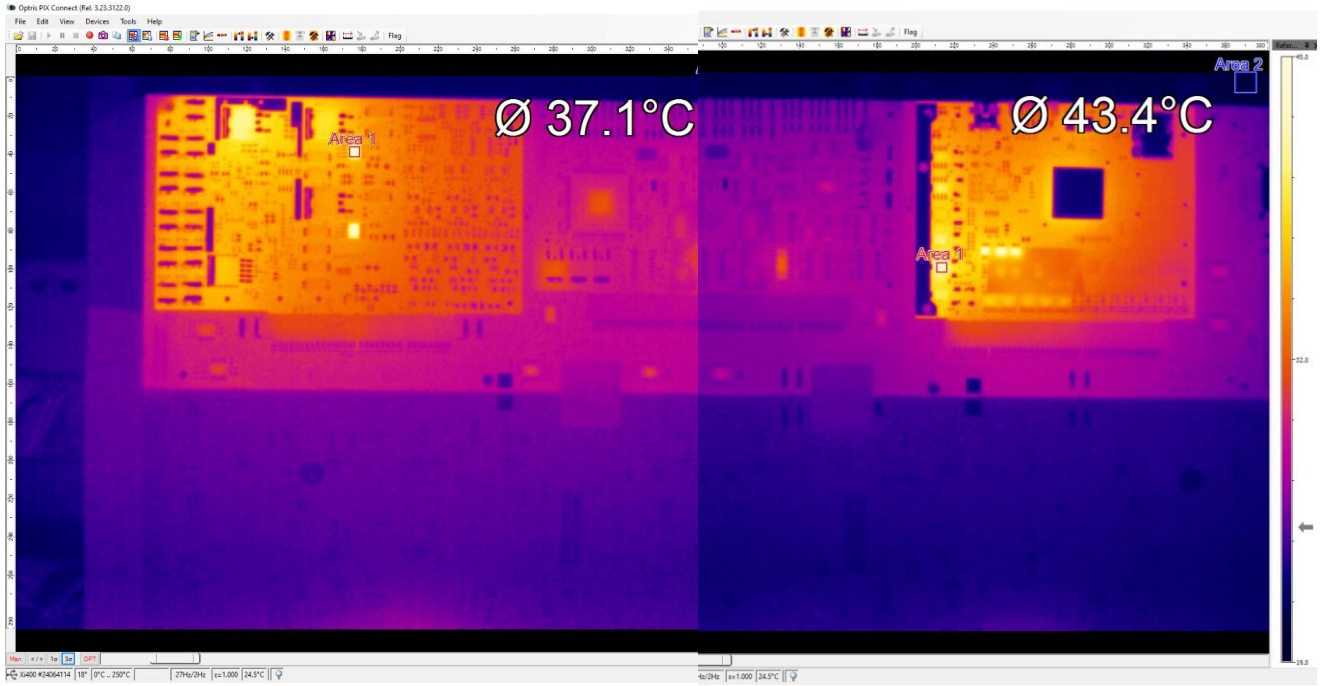
- Challenges:
  - Working within the mechanical design of the CLD for the FCC-ee

Backup

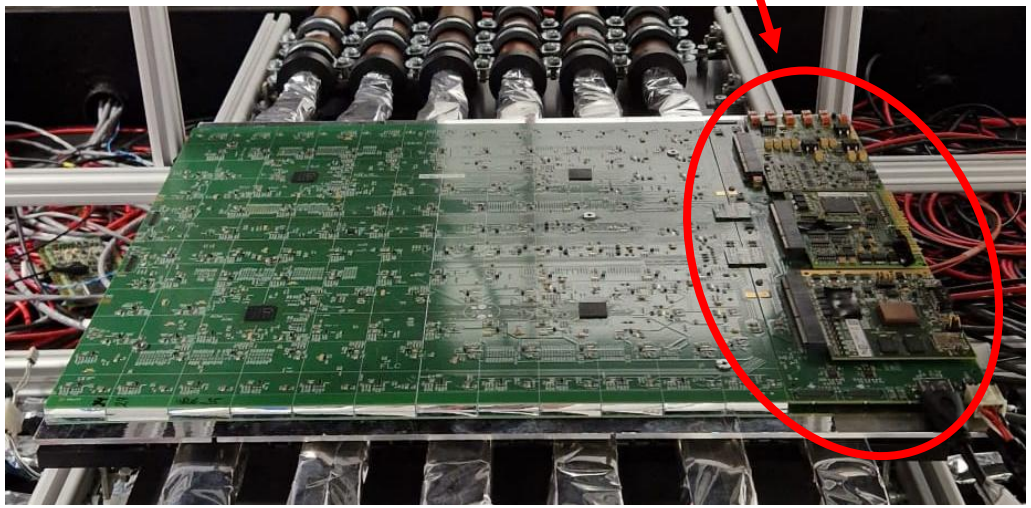
Temperature Distribution on the DAQ modules

Main heat source are the DAQ interface modules

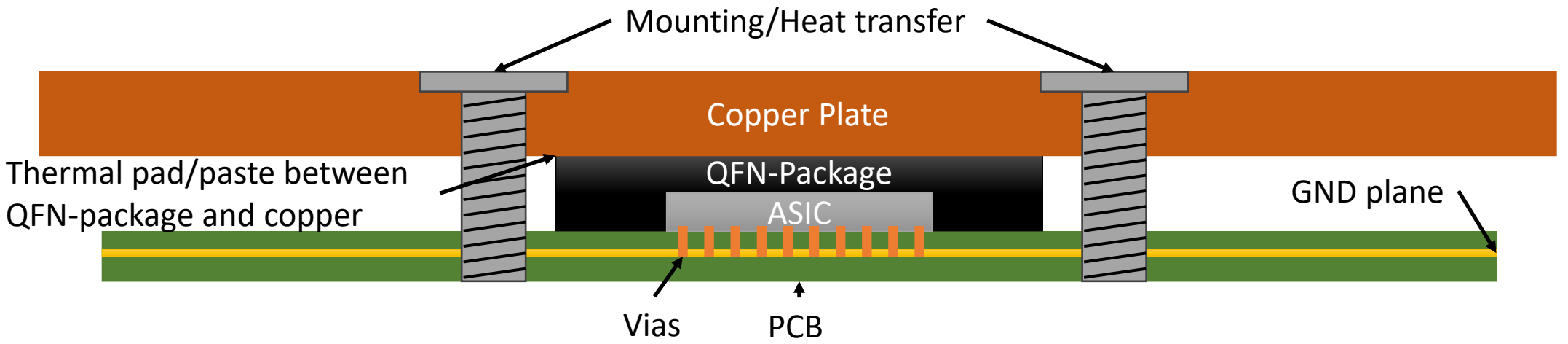
- will need an extra cooling system



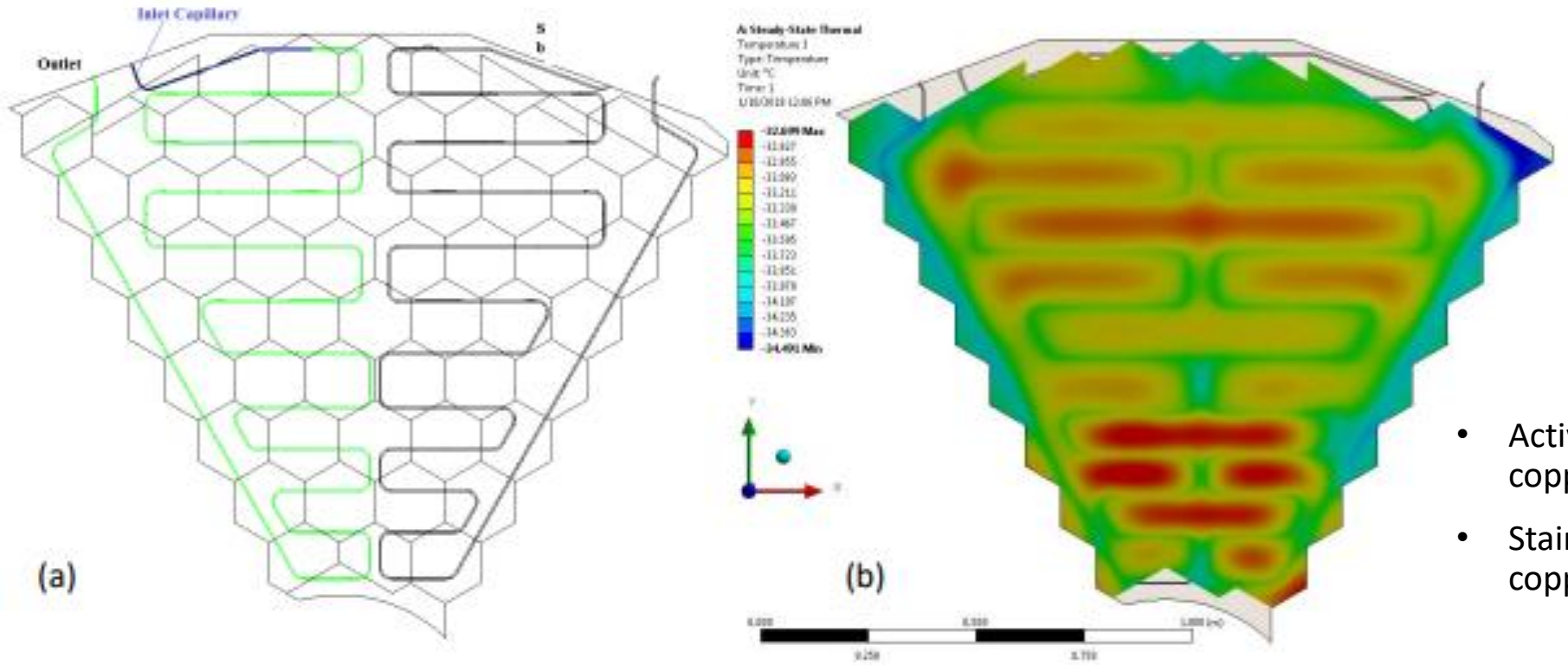
DAQ interface modules (POWER-, CALIB- and DIF-board)



Heat Transfer from ASIC to Copper Plate



CMS HGCAL cooling



- Active elements mounted directly onto copper plates
- Stainless steal tubes embedded in copper plates

Plot taken from: The Phase-2 Upgrade of the CMS Endcap Calorimeter - CERN Document Server