Compton HVMAPS Detector Work Update

Belle II Collaboration Meeting
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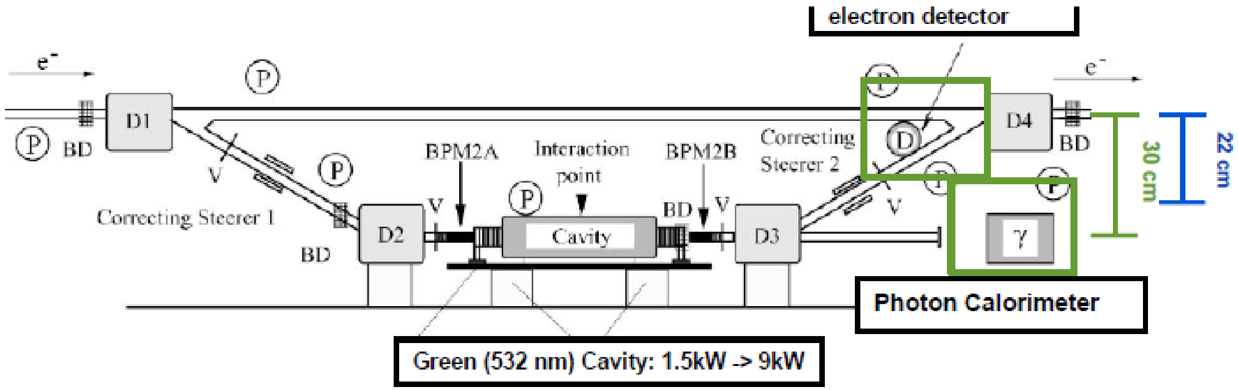
Savino Longo for the U. Manitoba Belle II / ChiralBelle Group

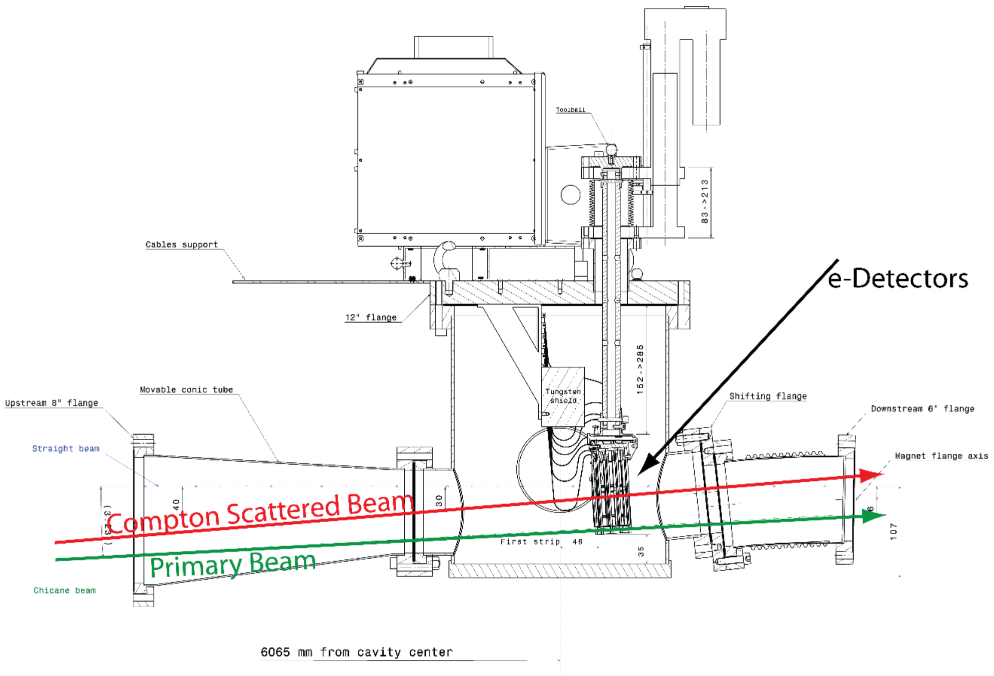
Shefali, Nafis Niloy, Kristofer Isaak, Laheji Mohammad, Michael Gericke, Juliette Mammei, Wouter Deconinck

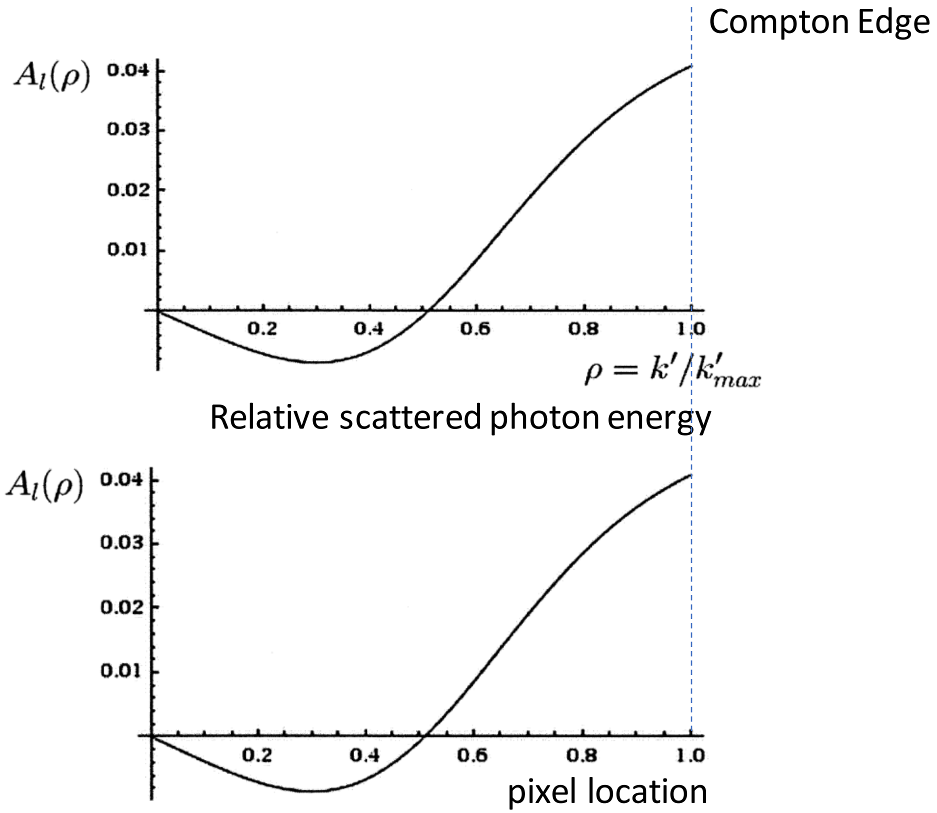
University of Manitoba

Initial Assumptions:

- Initial ideas were based on experience with JLab HallA & C polarimeters
  - Measure electron energy by deflection in dipole field (D3)
  - Higher photon energy -> lower electron energy
  - Lower electron energy -> more bending away from beam
  - build a detector that can accurately measure electron deflection







Realities:

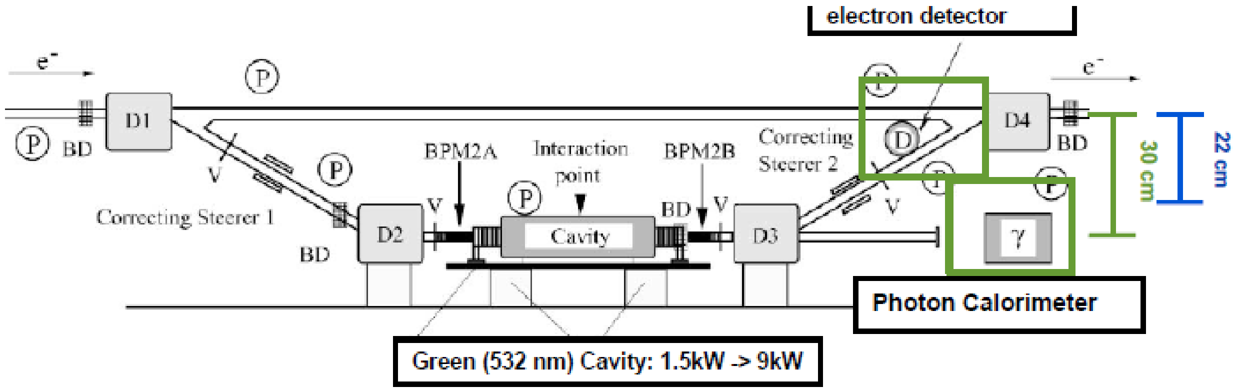
- Having a Chicane and separate Compton dipole not possible for SuperKEKB

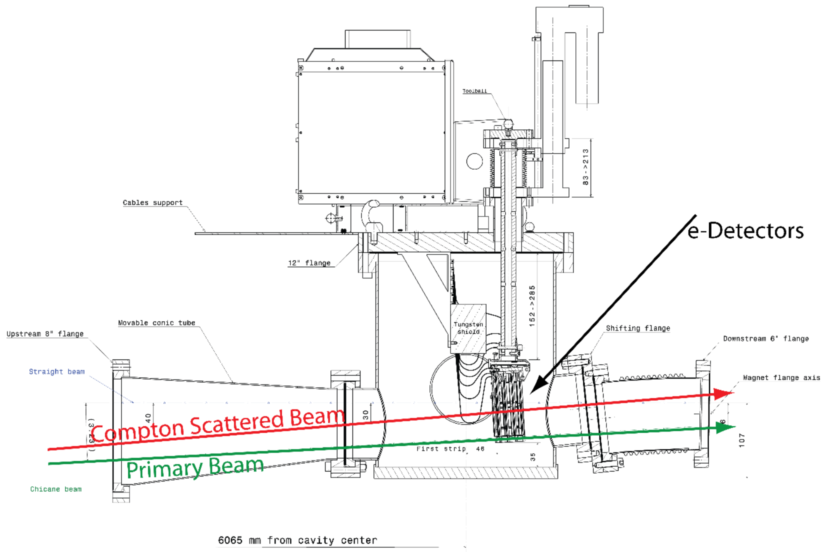
- Have to use existing beam line dipoles and fit Compton interaction region between them

    - It would not be in a straight line-of-sight to IP
    - Have to model transport or measure transverse polarization (EIC plans to use HVMAPS in front of the photon detector to measure the photon position asymmetry to determine transverse polarization)

- Possibly implement thin Beryllium window in beampipe to allow electrons to exit primary beam vacuum

    - Still build an analyzing dipole
    - Effect of position resolution at the EDet would need to be studied





Recent work updates and status:

- Cooling studies:
  - Even though detector would likely not be in vacuum at KEK, cooling the HVMAPS chips is still necessary in air
  - We have been focusing on mounting designs that allow cooling with chilled water
  - Mounting design for 4 planes of HVMAPS is complete
  - Cooling tests in vacuum using dummy (heater) chips is imminent
  - Larger surface area HVMAPS modules with in-air cooling structure is also being design and tested

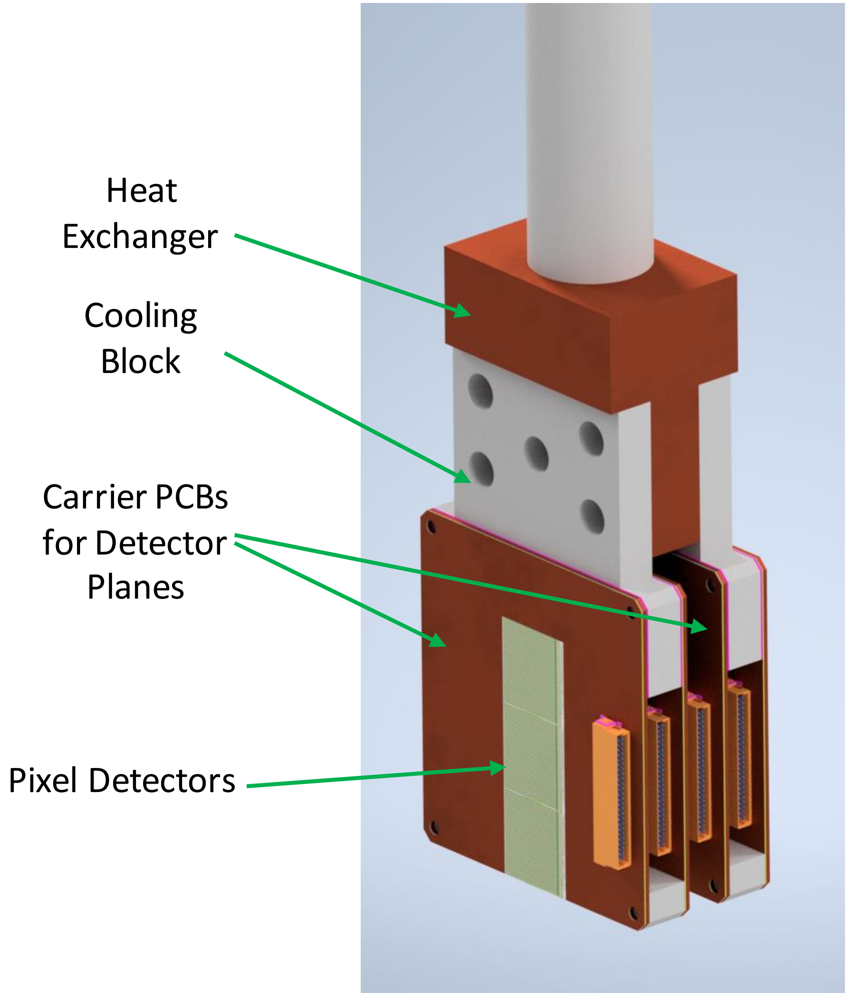
- Readout electronics
  - Readout board for the present version of the HVMAPS is being designed – expect prototype before the end of the year

- Chip level updates
  - Production of final chip for MOLLER and other experiments is underway
  - This chip may not be enough for ChiralBelle (or EIC) – timing maybe, but probably not readout – strongly depends on occupancy (event profile and rate)
  - M. Gericke Joined Canadian collaboration to participate in DRD3 effort toward faster chips – timeline for SuperKEKB upgrade?

Recent work updates and status:

Mounting and cooling structure design:
Nafis Niloy and Kristofer Isaac

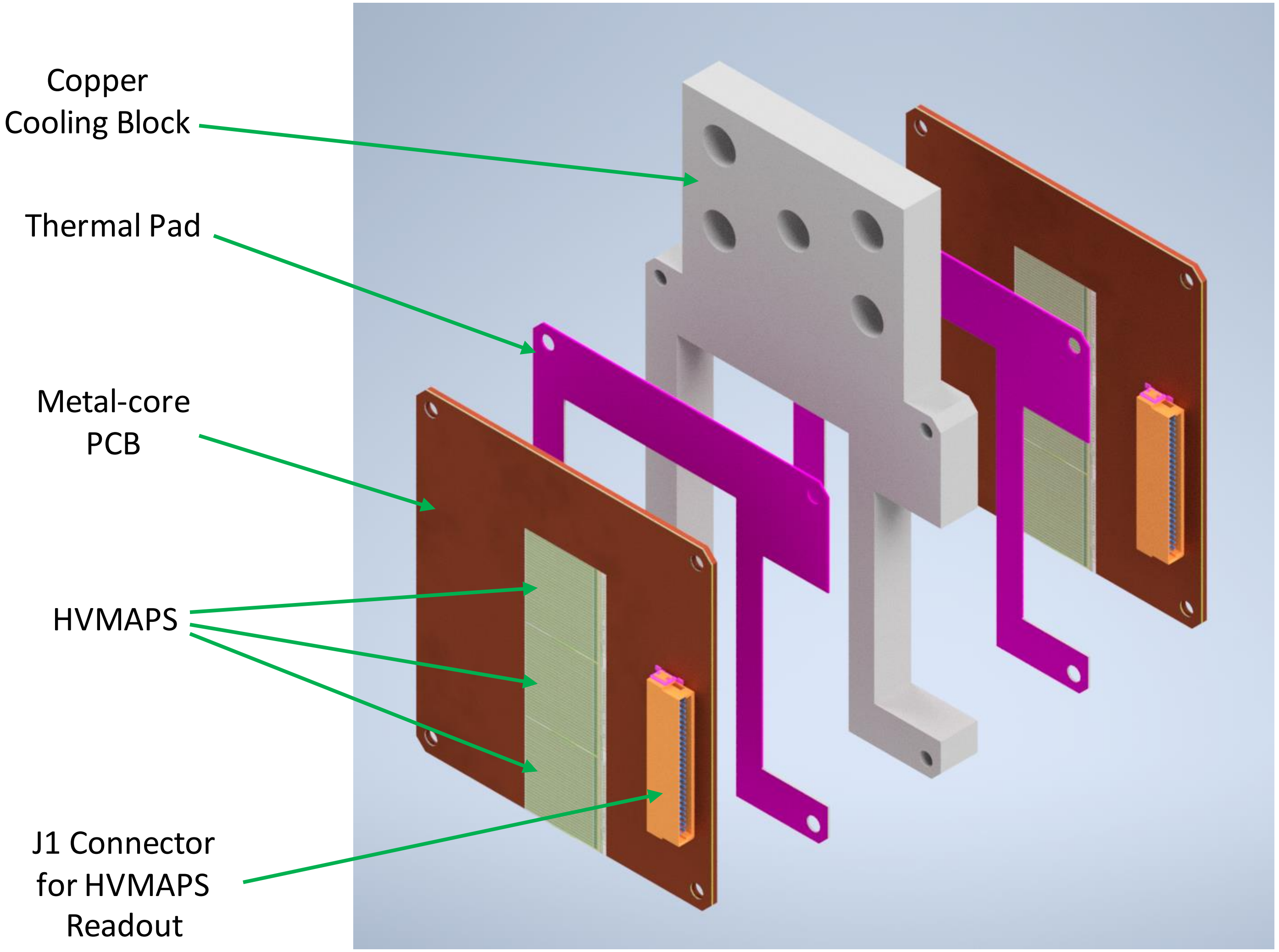
- Compton e-Detector design for in-vacuum operation:
  - 4 pixel detector planes
  - HVMAP pixel detectors
  - 3 $2 \times 2\ cm^2$ chips per plane (TBD based on profile)
  - $80 \times 80\ \mu m$ pixels
  - Original chip design based on ATLASPix & MuPix (designed at KIT, Heidelberg, Mainz)
  - Specific modifications for probably required for ChiralBelle (faster chip/readout)



New HVMAPS detector planes

Recent work updates and status:

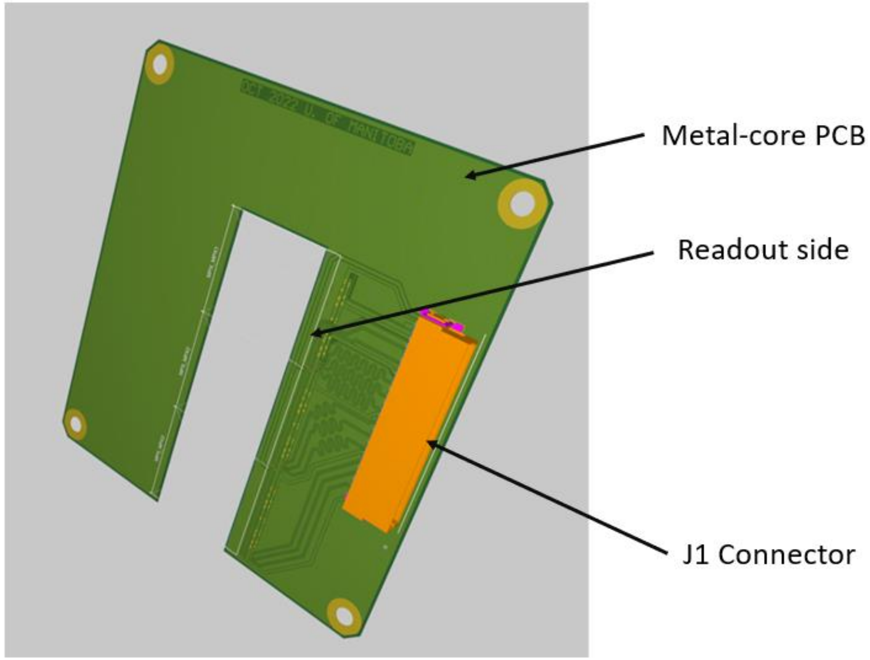
- Compton e-Detector design for in-vacuum operation :
  - Each detector plane consists of 3 HVMAPS wire-bonded to a metal-core PCB
  - Two planes will be attached to one cooling block, interfaced together using thermal pads
  - Cooling block will be a single piece of machined copper (different color used in figure for ease of visibility)

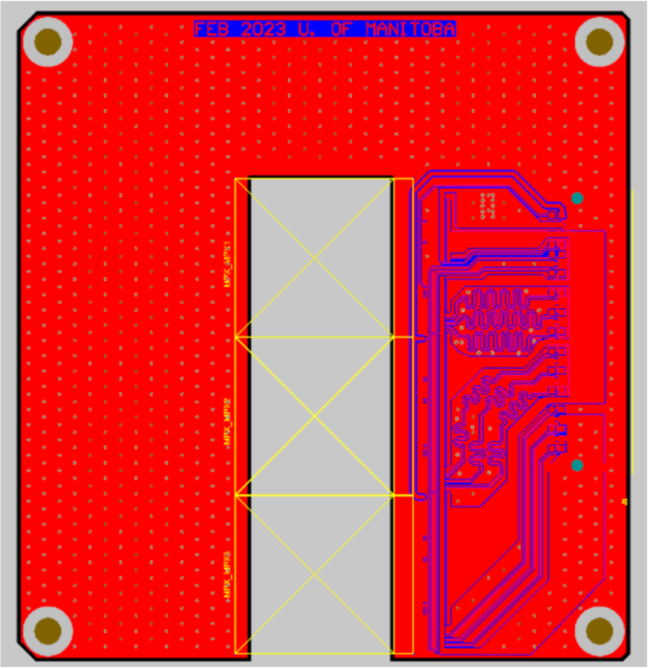


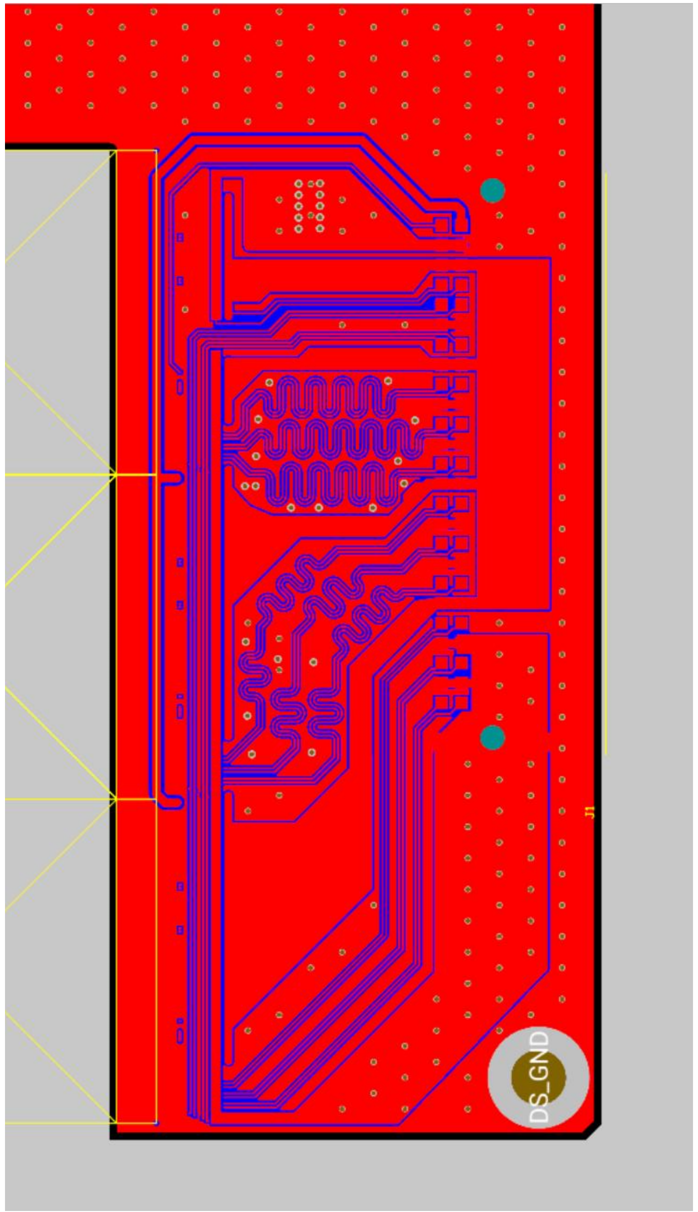
Recent work updates and status:

PCB and readout design: Jie Pan

- Compton e-Detector design for in-vacuum operation :
  - HVMAPS will be glued and wire-bonded to a PCB
  - Metal-core PCB will help conduct heat produced by the HVMAPS away for dissipation
  - Using thermal pads to improve thermal conduction between metal-core PCB and HVMAPS







Recent work updates and status:

➢ Compton e-Detector design for in-vacuum operation :

- A prototype of the Compton heat exchanger was designed and machined out of copper
- Rather than manufacturing the custom copper feedthrough cylinder planned for the final design, the prototype model utilizes separate chilled water lines fitted to the heat exchanger with compression fittings to reduce prototype costs and leverage existing vacuum infrastructure
- Next steps for prototype:
    - Pre-test seal of prototype heat exchanger using pneumatic pressure-differential test
    - Fully assemble Compton prototype heat exchanger, including chilled water lines
    - Assemble Compton test planes onto heat blocks

Fig. Prototype heat blocks

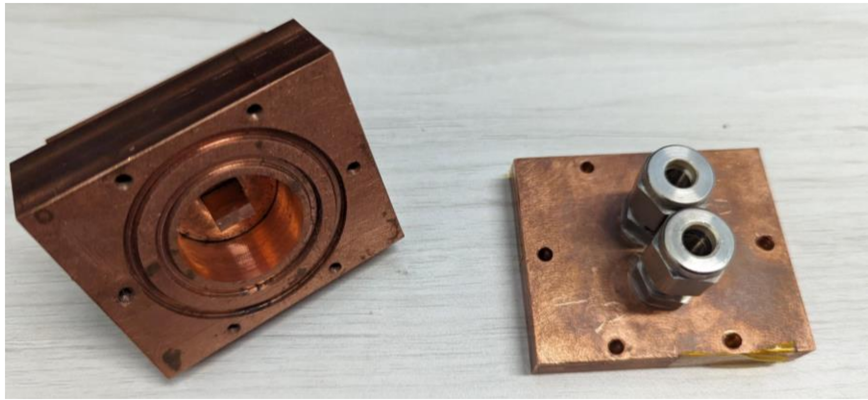


Fig. Prototype heat exchanger, featuring double o-ring grooves and turbulence-generator tab

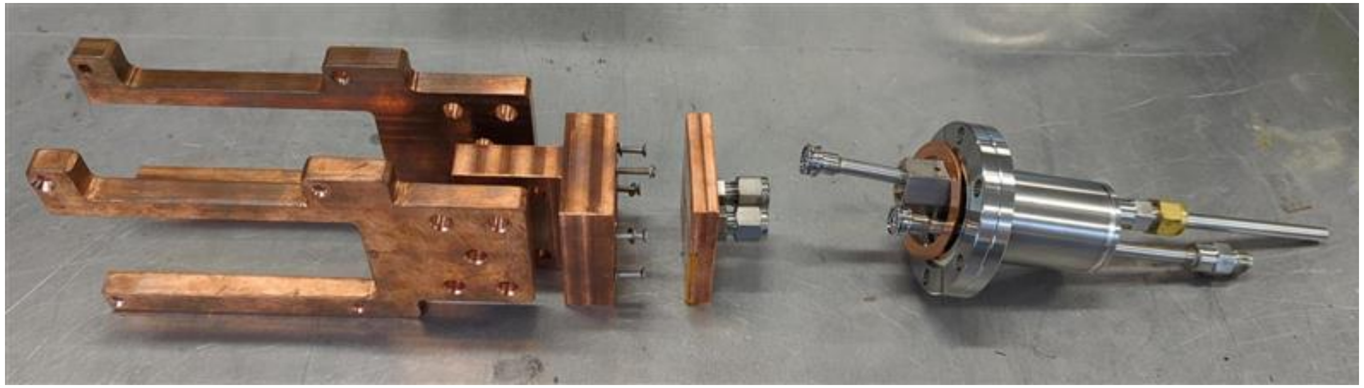
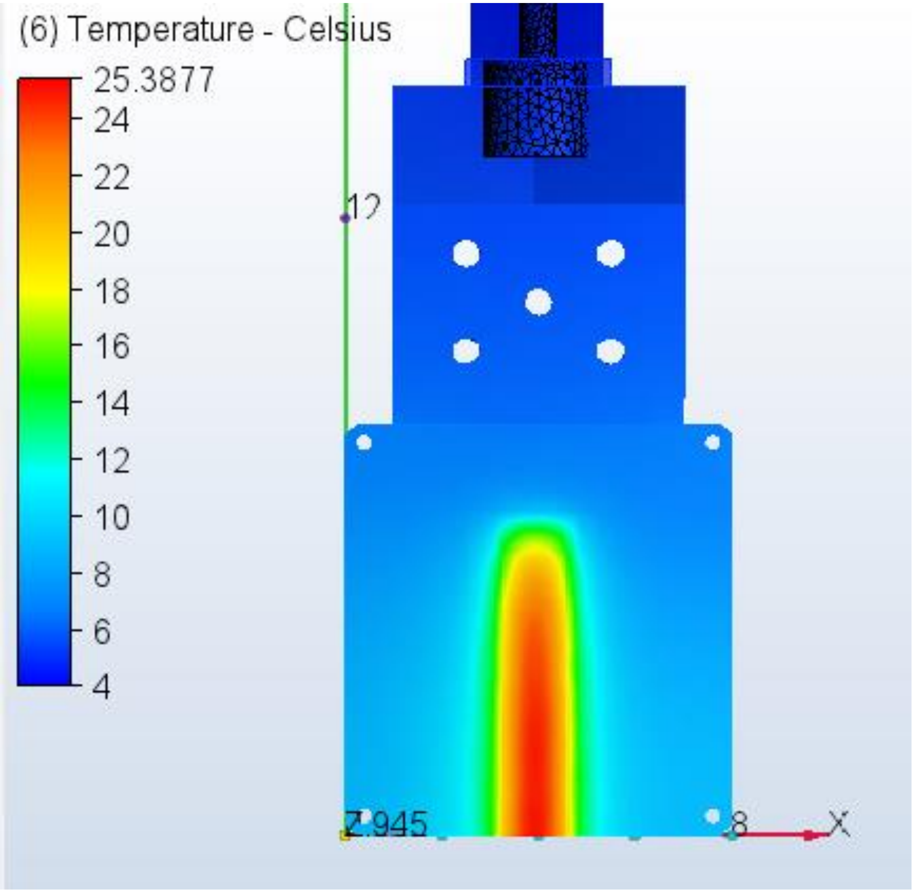


Fig. Rough layout of heat exchanger prototype, including chilled water feed-through flange

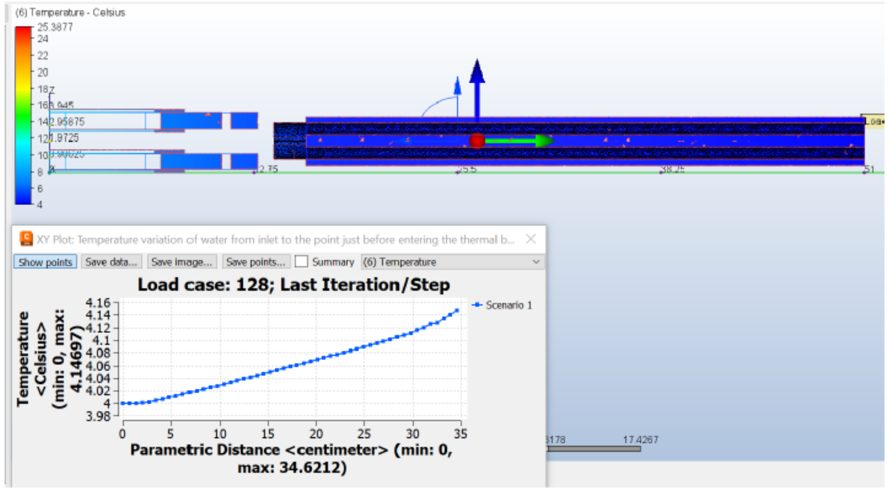
Recent work updates and status:

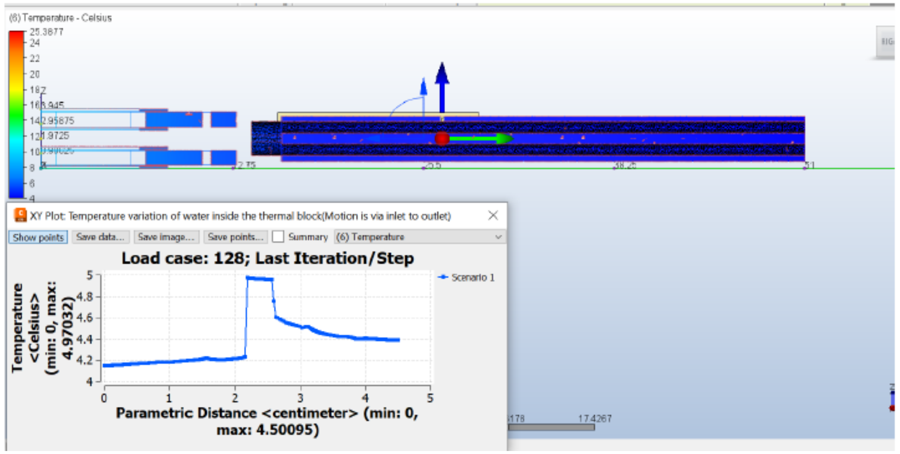
Thermal simulations and measurement setup: Shefali Prabhakar

- Cooling studies:



Temperature distribution of overall assembly





Temperature variation of coolant inside the heat exchanger

Recent work updates and status:

Thermal simulations and measurement setup: Shefali Prabhakar

- Cooling studies:
    - The aim of this setup is to test cooling capabilities in vacuum
    - Currently using dummy (heater) chips
    - Goal is to verify modeled cooling performance with measured temperature gradients at various positions
    - Thermal simulations of the same model as shown below.

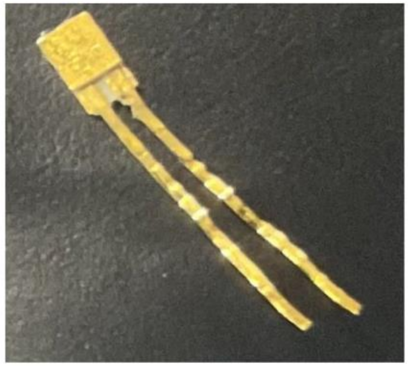


Fig.b

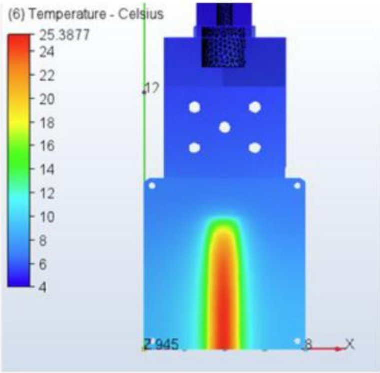
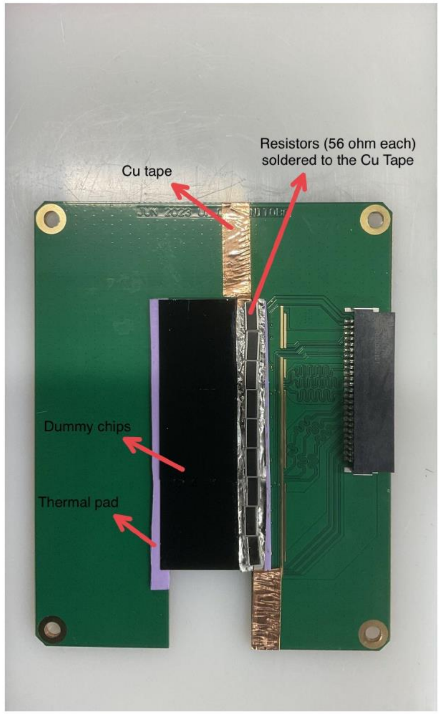
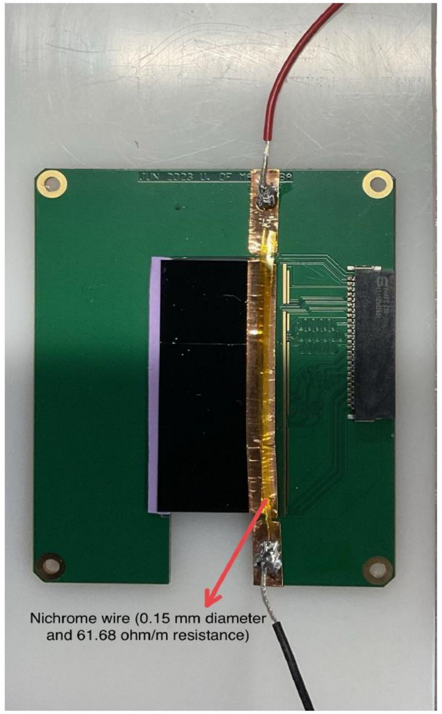


Fig.c



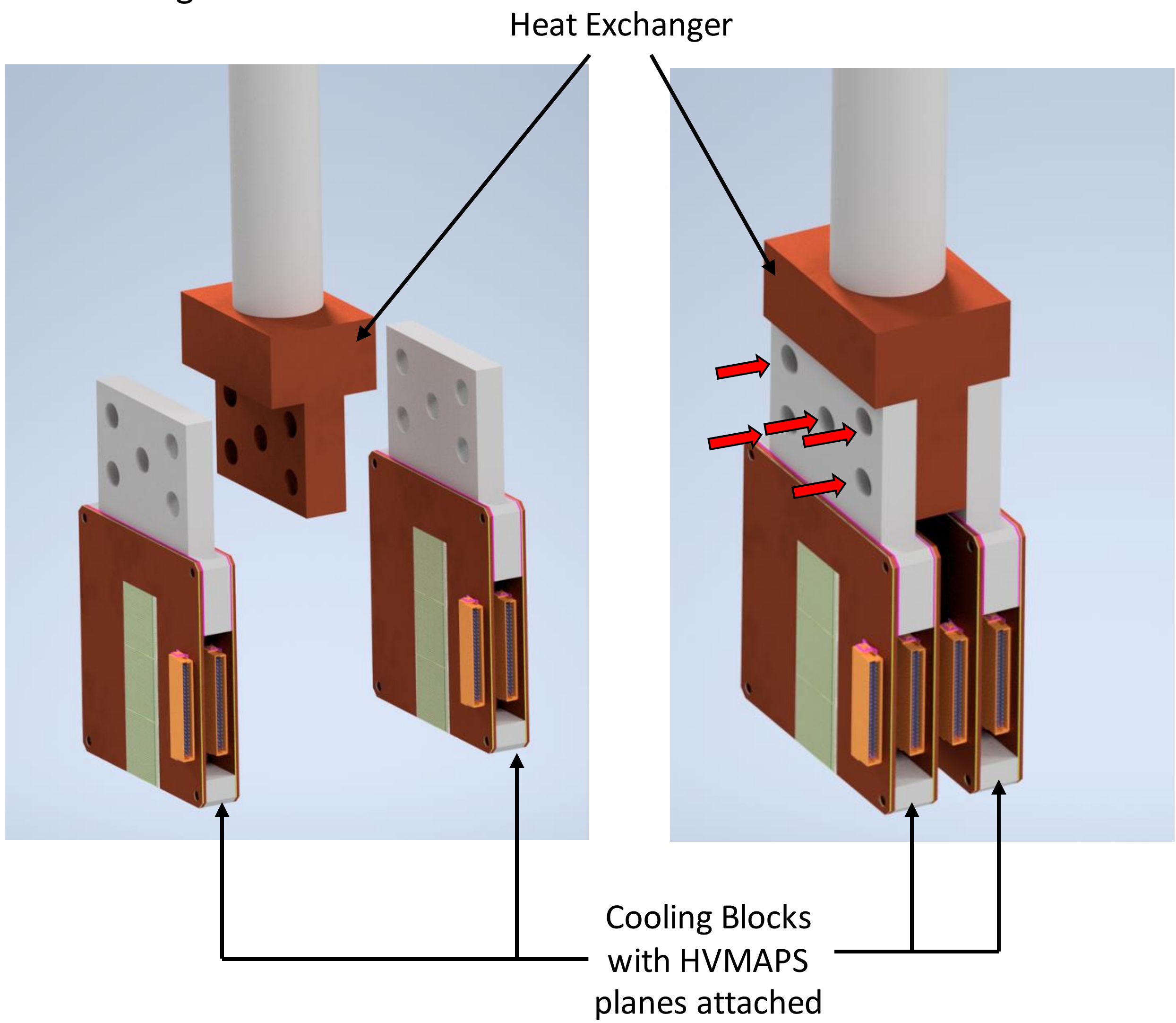
A.) Combination of resistors as a heating element.

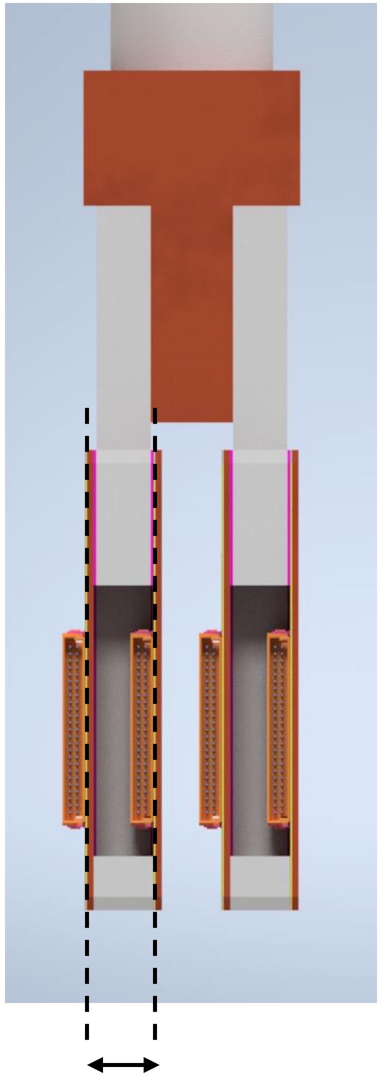


B.) Nichrome wire as a heating element

Recent work updates and status:

- Cooling studies:

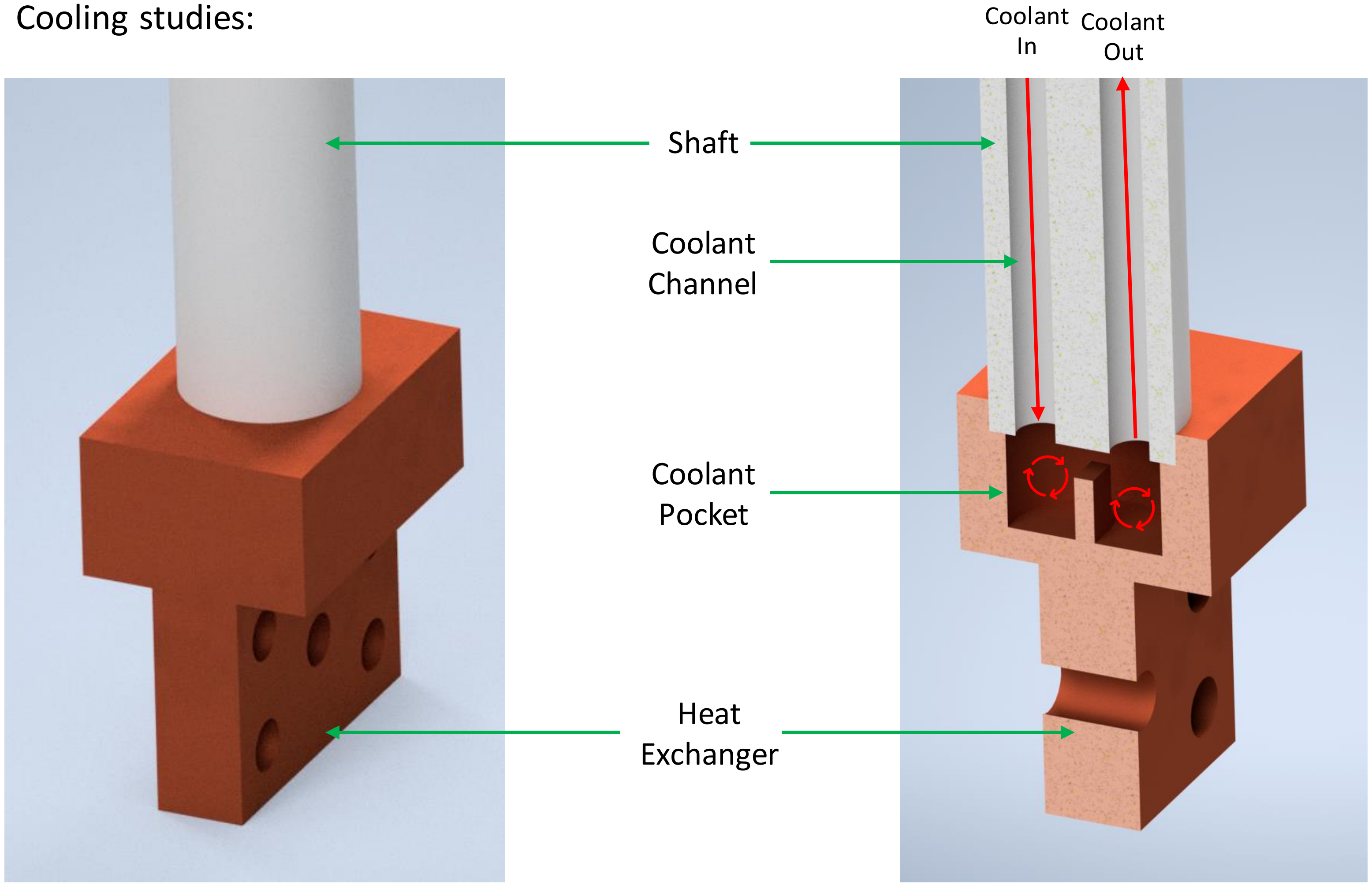




- Both cooling blocks will be attached to either side of the copper heat exchanger using 5 fasteners (red arrows)
- Applies a clamping pressure of 4000 psi between mating heat-exchanger components
- Maximizes conduction between components
- Heat exchanger will be machined out of a single block of copper
- Distance between two adjacent HVMAPS planes is 12.6 mm

Recent work updates and status:

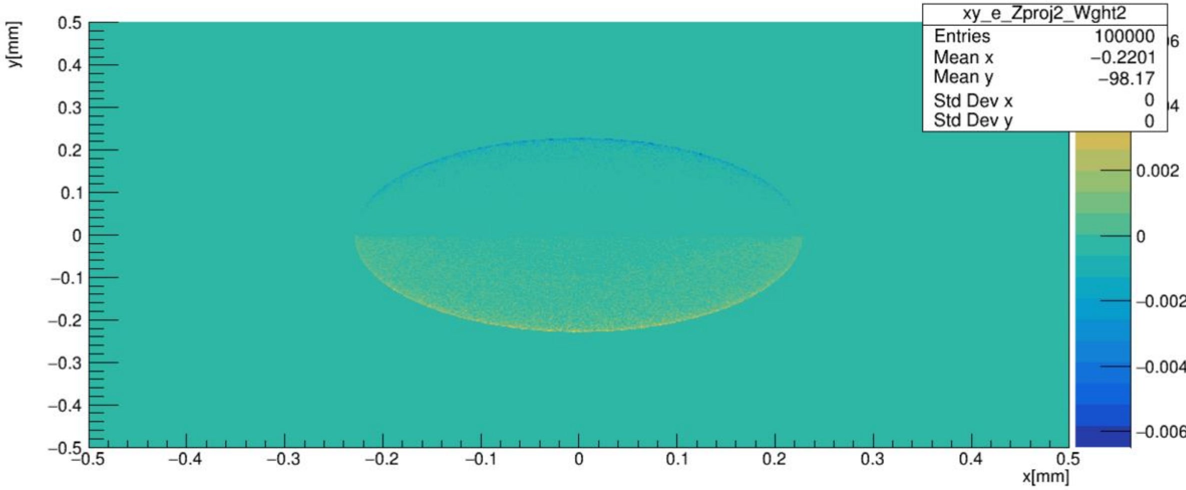
- Cooling studies:



- Shaft holding the assembly in beam line will be attached to a linear translation stage to move detector planes up and down
- Translation stage attached via a feed-through
- Shaft will be a copper rod with coolant channels bored along its length
- Will be using LCW (Low Conductive Water) as coolant
- Pocket is designed to make the flow of coolant turbulent, thereby increasing heat transfer to coolant
- Shaft and heat exchanger will be brazed to prevent possible leaks

Questions and outstanding activities:

- Assumptions about required detector size still based on simulation results from 2021 – may need to revisit these ?
- Presently have a poor understanding of the rates we will see on the detectors – we may need some follow up design/different chip and that will take time
- Will there be a dispersive (dipole) magnet in front of the detectors?
- How much room is there for physical implementation?
- What effect will beamline window have (how thick, material)?
  Requires additional simulations (?)
- What is the timing/trigger/readout interface with the rest of the experiment/DAQ?
- Is it really necessary to make an independent measurement for every (!) bunch crossing?
- If yes to the latter, how is ps level readout done for the other detector systems?



Electron polarized cross-section (transverse ePol) for z = 25 m from Compton IP