Cooling Analysis of HVMAPS Detector in Vacuum Operation

Shefali

M.Sc. , University of Manitoba

Supervisor: Dr. Wouter Deconinck

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Outline

- Standard Model of Particle Physics
- Weak Mixing Angle
- Introduction to MOLLER Experiment
- Compton Polarimetry
- Upgrade requirement for Electron Detector
- HVMAPS
- CAD Designs and Cooling Analysis
- Conclusion

Standard Model of Particle Physics

- SM describes fundamental particles which constitute matter and their interactions.
- Particles: Leptons, Quarks, Exchange particles.

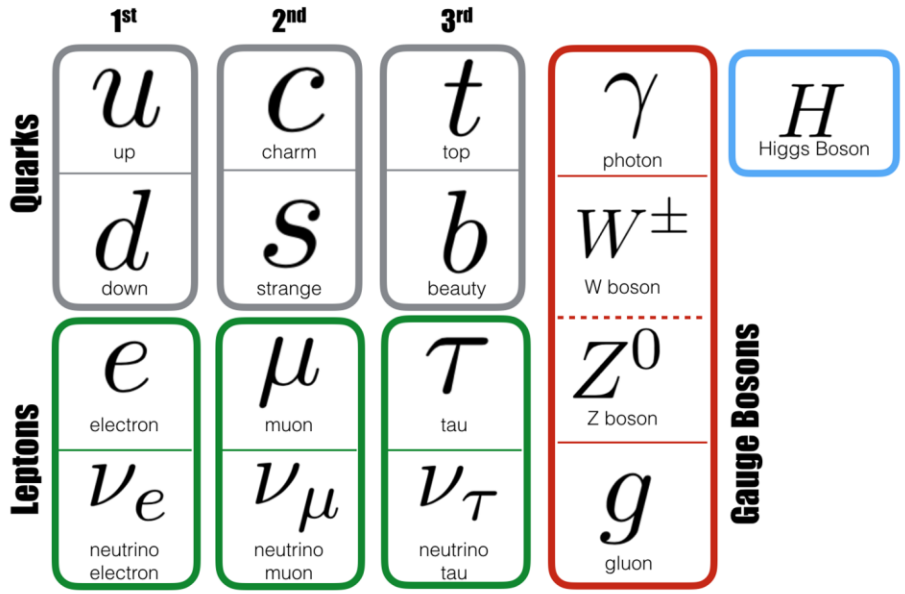
- Interactions in SM:

  Strong Interaction: Mediated by gluons.

  Electromagnetic Interaction: photons.

  Weak Interaction: Z and W boson.

- Higgs boson is a scalar boson (gives mass to all the fundamental particles).



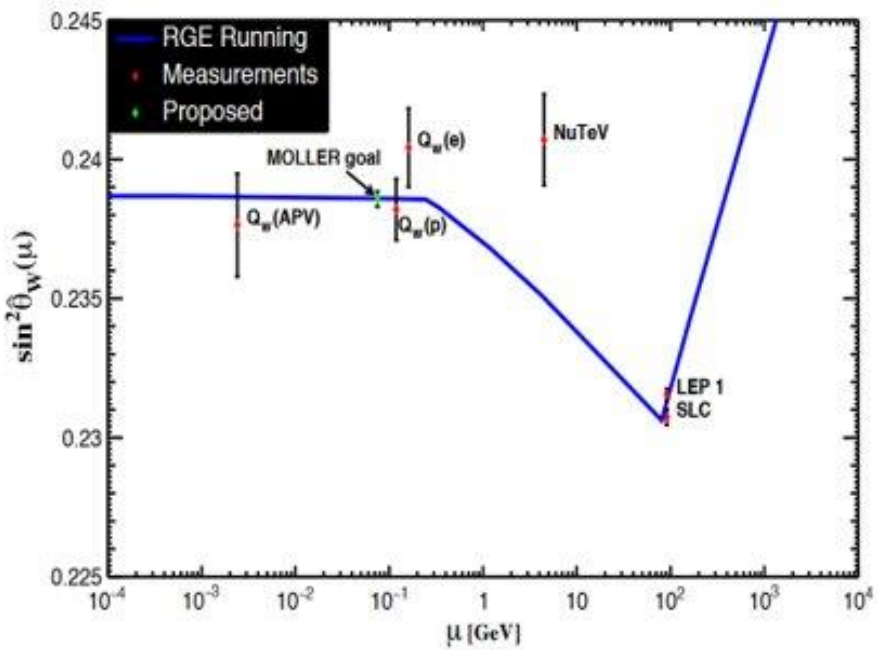
Weak Mixing Angle

- The probability that a particle will interact with a target to scatter the same particle plus the remains of the target is called weak mixing angle. This interaction happens via exchange of particles.

- Incoming particles: Electrons.
- Target: Liquid Hydrogen (LH_2).
- Exchange particle: Z^0
- Scattered particle from target: γ

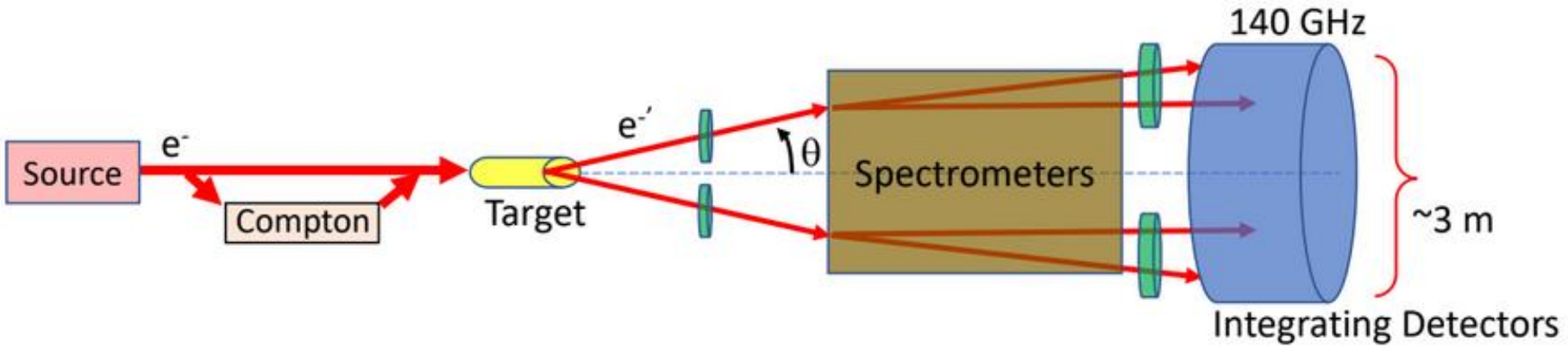
$$|\gamma\rangle = \cos\theta_W|B0\rangle + \sin\theta_W|W0\rangle$$

$$|Z0\rangle = -\sin\theta_W|B0\rangle + \cos\theta_W|W0\rangle$$



MOLLER Experiment

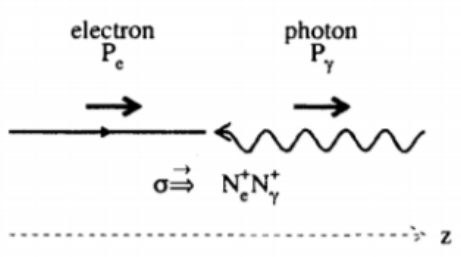
- MOLLER (Measurement of Lepton Lepton Electroweak Reaction) plans to take a longitudinal polarized beam of electrons, provided by JLab's Continous Electron Beam Accelerator Facility (CEBAF), scattering them off the unpolarised electrons in a liquid hydrogen target.



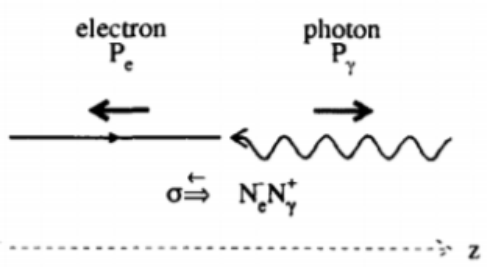
Compton Polarimetry

- Compton polarimetry works ---> Compton scattering.
- Dependance on Helicities,

Right-handed helicity state



Left-handed helicity state

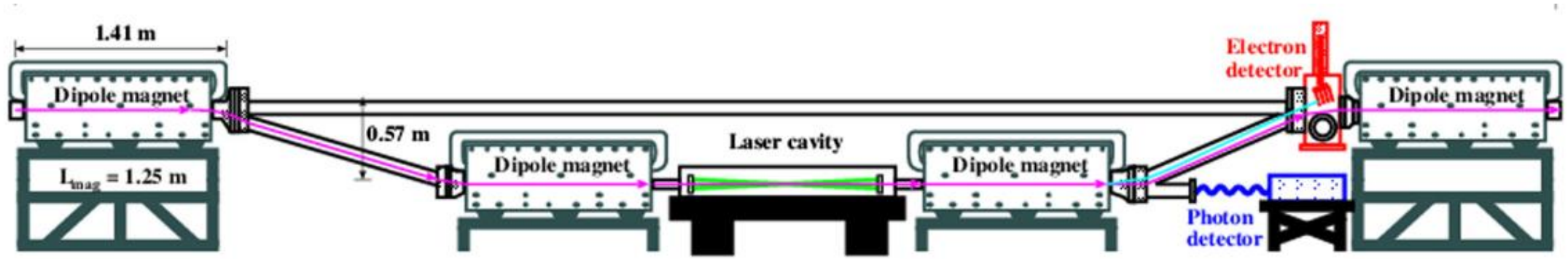


- Asymmetry:

$$A_{exp} = \frac{n_+ - n_-}{n_+ - n_-} = P_e P_\gamma A_l$$

Compton Polarimeter

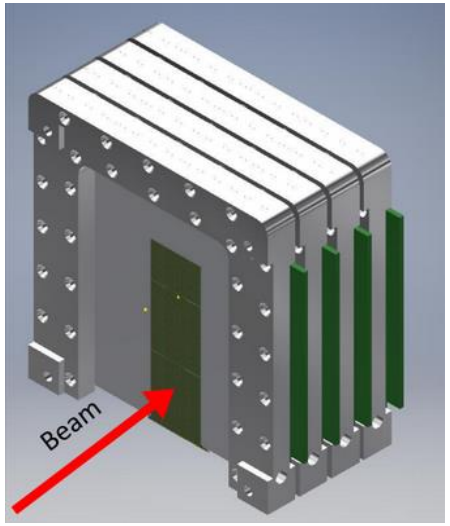
- The Compton Polarimeter is located in a chicane.
- It is about 15 m long.
- Chicane series
- Momentum analysis.

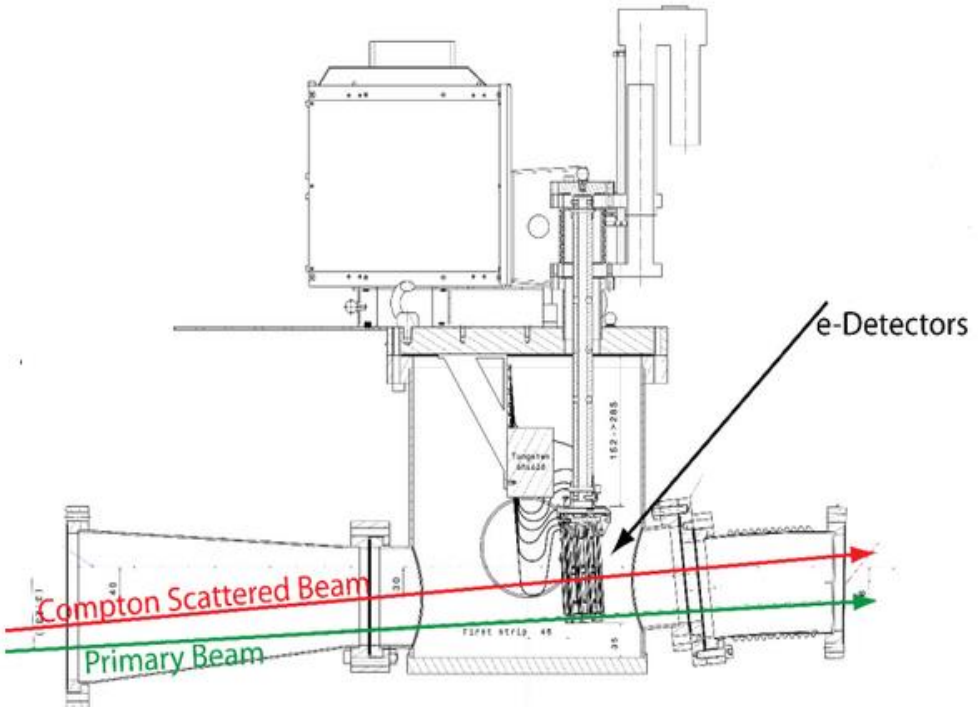


Upgrade Required for Electron Detector

- The current detector consists of silicon strip detectors technology.

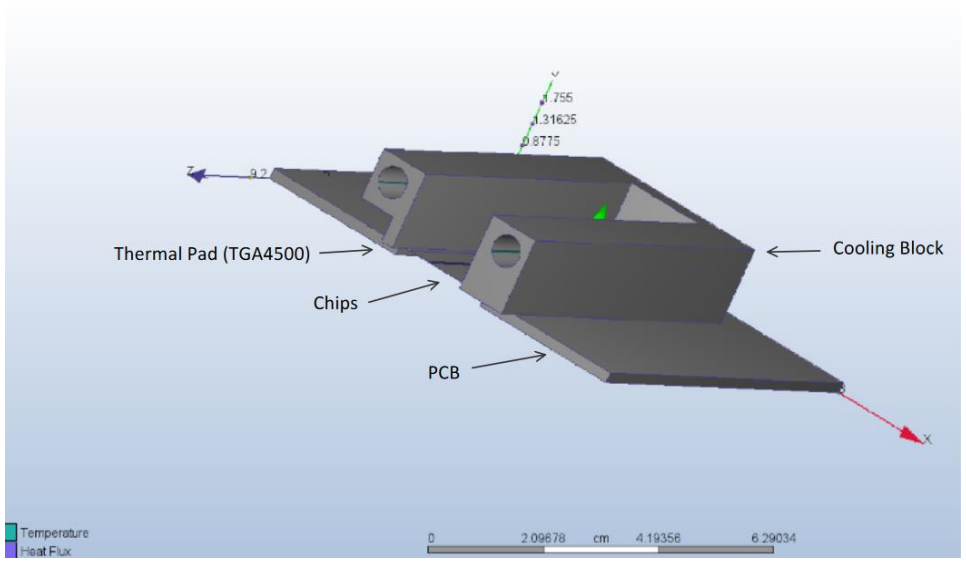
- There are plans to upgrade it to High Voltaic Monolithic Active Pixel Sensors (HVMAPS) technology.

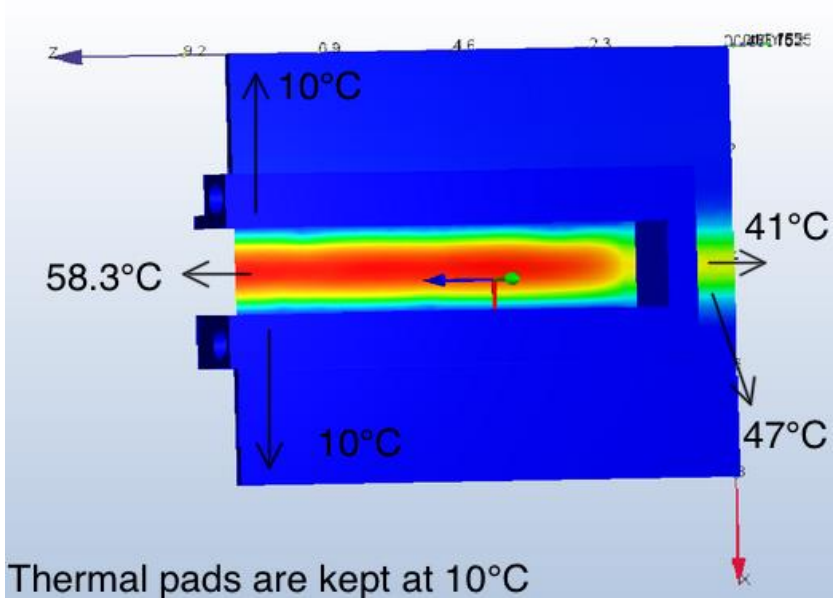




Cooling Analysis for the Model

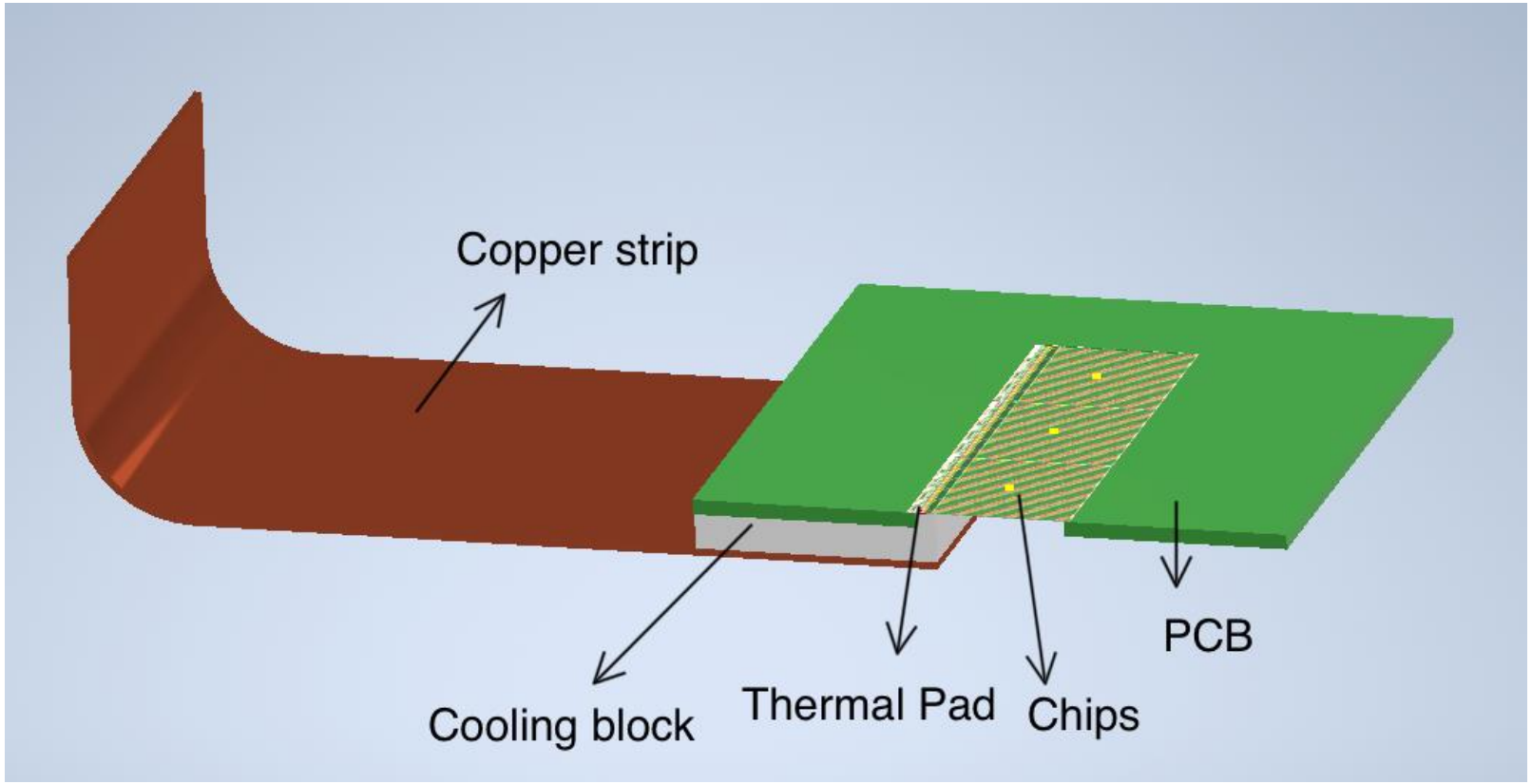
- All electronics produces thermal energy due to ohmic heating.
- In vacuum cooling requires a coolant which shouldn't be in direct contact with the heated surfaces.
- **Case 1: Cooling solution with thermal pads.**
- Cooling block --> Aluminum, Chips: silicon, Thermal Pad, PCB: FR4.



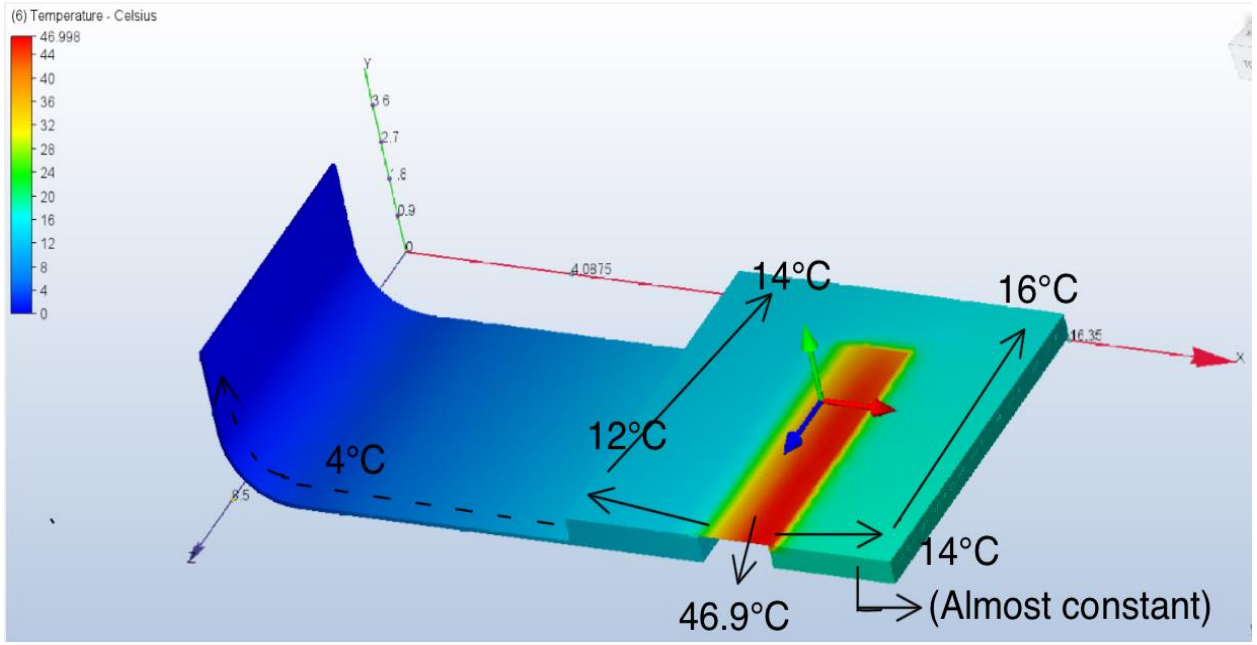


CAD geometries are being produced or modified by Prof. Michael Gericke, University of Manitoba and Nafis Rafat Niloy, grad. Student at the University of Manitoba.

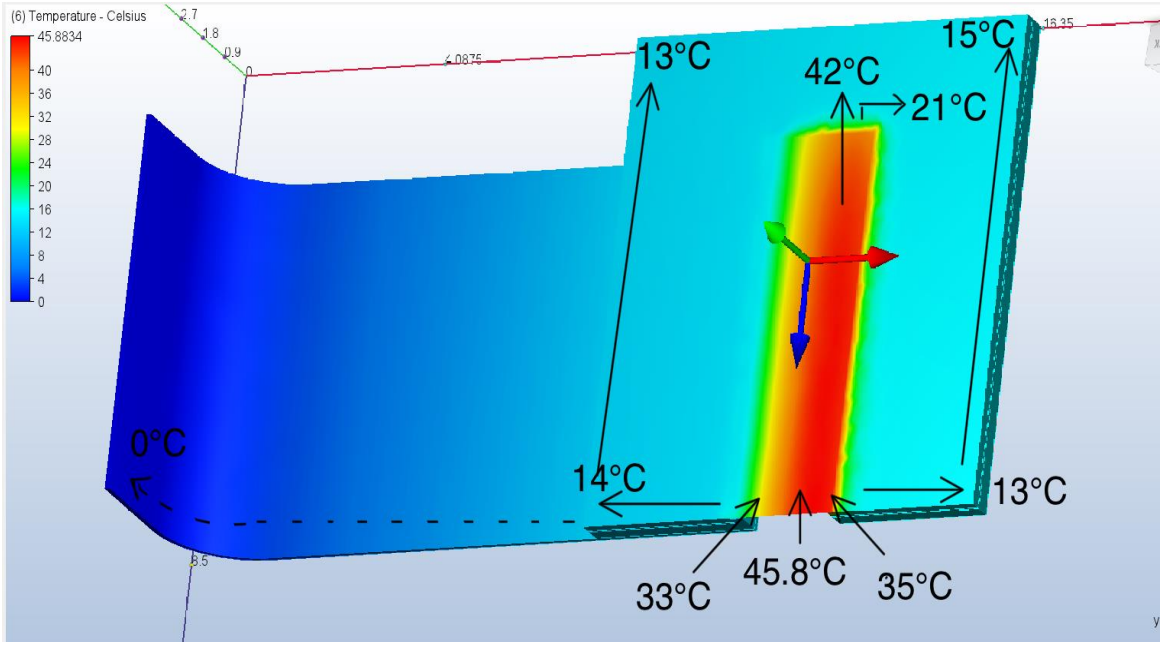
Case 2: Cooling solution with flexible copper strip.



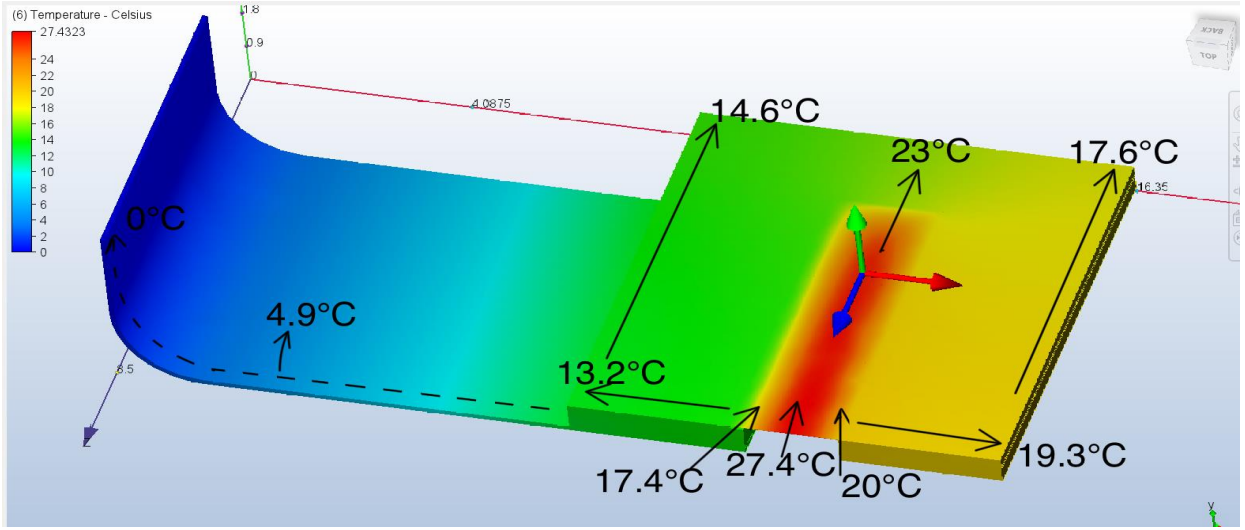
- Cooling block: Aluminum
- Chips: silicon
- Thermal Pad
- PCB: FR4
- Cooling strip: Copper



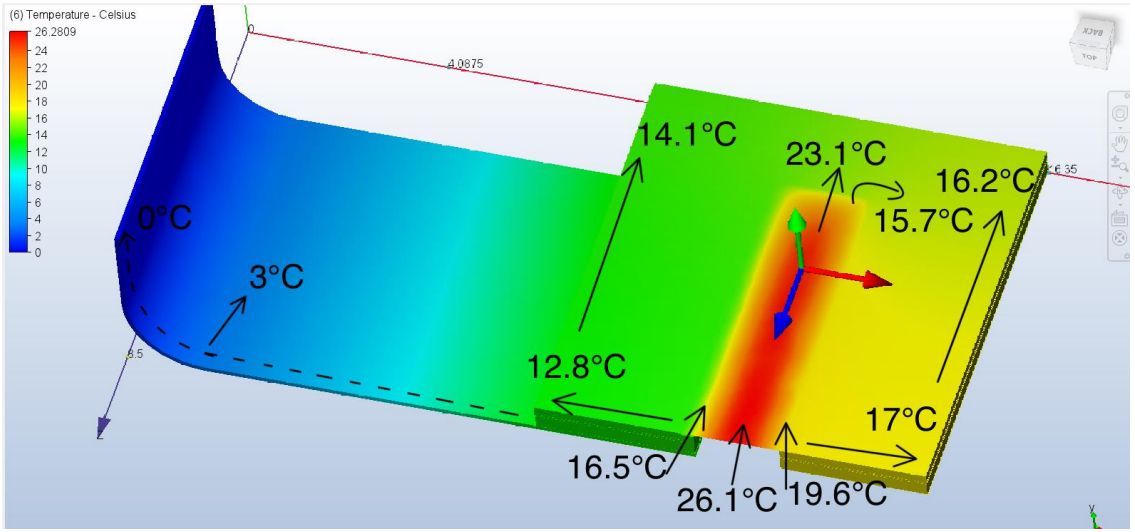
- Cooling block: Copper
- Chips: silicon
- Thermal Pad
- PCB: FR4
- Cooling strip: Copper



- Cooling block: Aluminum
- Chips: silicon
- Thermal Pad
- PCB: Aluminum
- Cooling strip: Copper

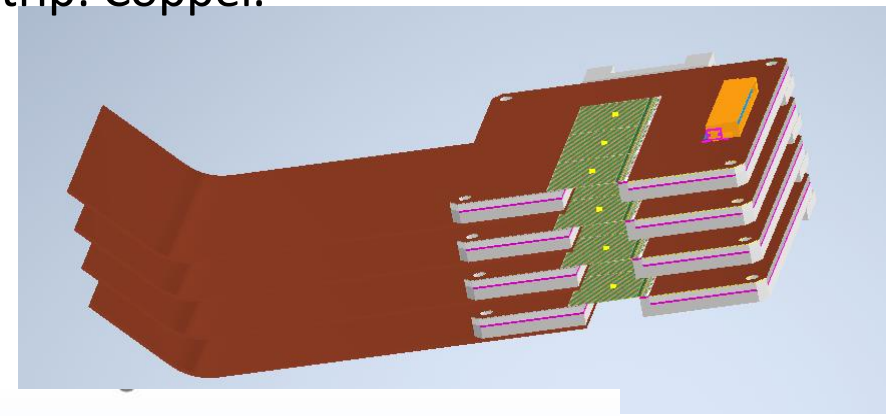


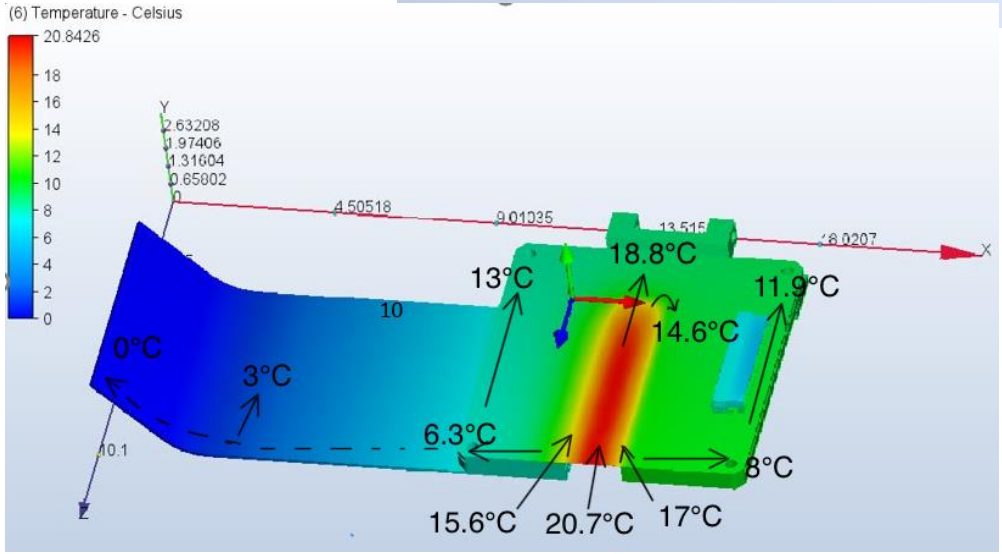
- Cooling block: Copper
- Chips: silicon
- Thermal Pad
- PCB: Aluminum
- Cooling strip: Copper



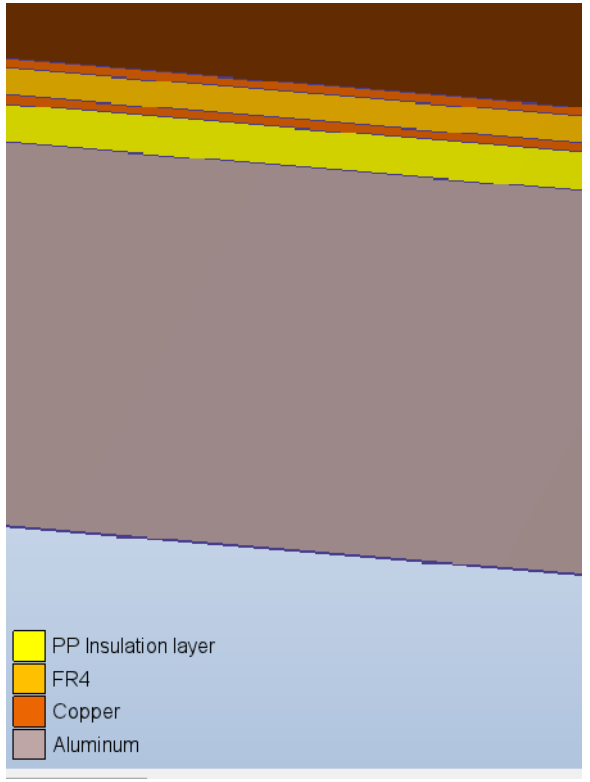
- **Case 3: Cooling solution with metal core PCB.**

- Cooling block: Copper
- Chips: silicon
- Thermal Pad
- PCB: 5 layered PCB
- Cooling strip: Copper.



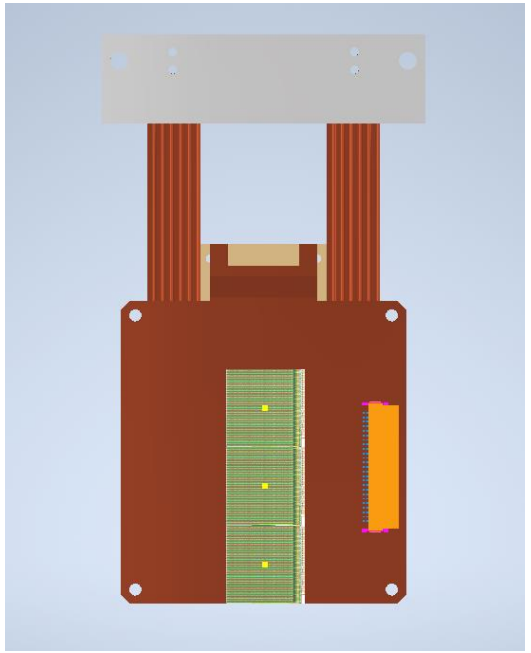


- 1st layer: Copper: 0.035 mm
- 2nd layer: FR_4: 0.105 mm
- 3rd layer: Copper: 0.035 mm
- 4th layer: PP layer: 0.150 mm
- 5th layer: Aluminum: 1.5 mm

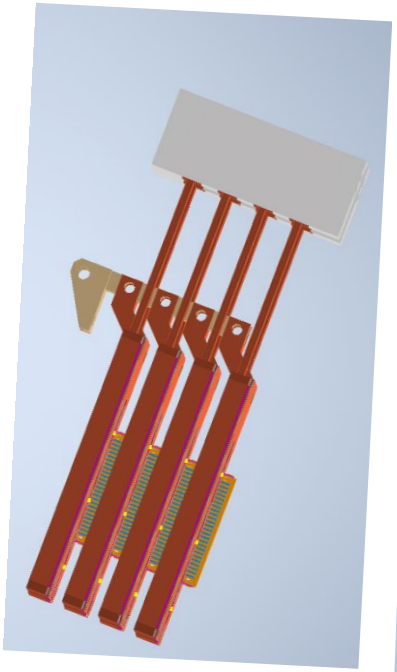


Case 4: Cooling solution with Cooling Pipe Line in addition to all other previous cooling techniques.

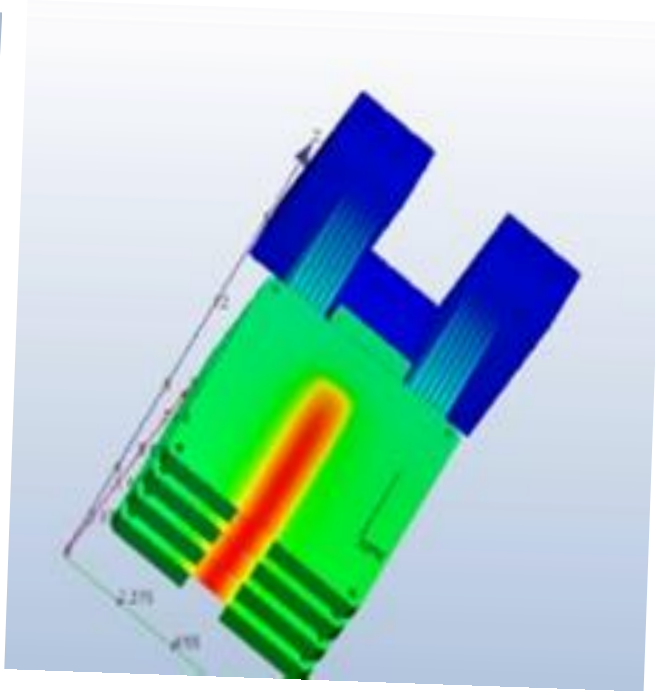
- Cooling block: Copper
- Chips: silicon
- Thermal Pad: TG A4500
- PCB: 5 layered PCB
- Cooling strip: Copper.
- Thermal block : Aluminum

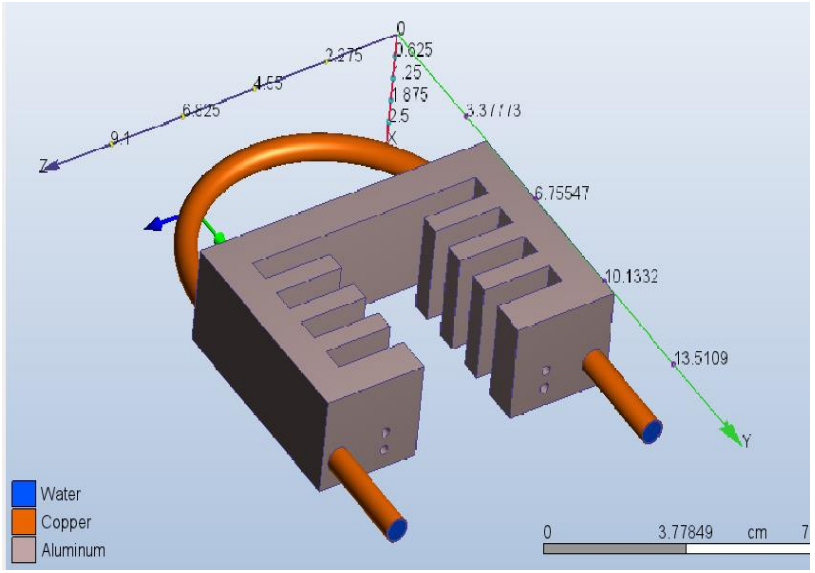


Front View

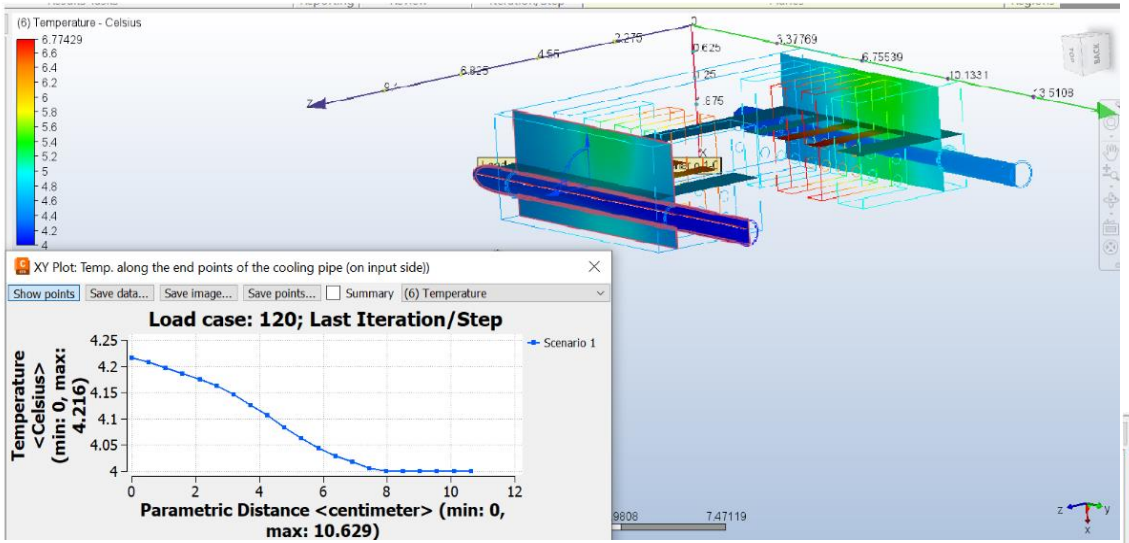


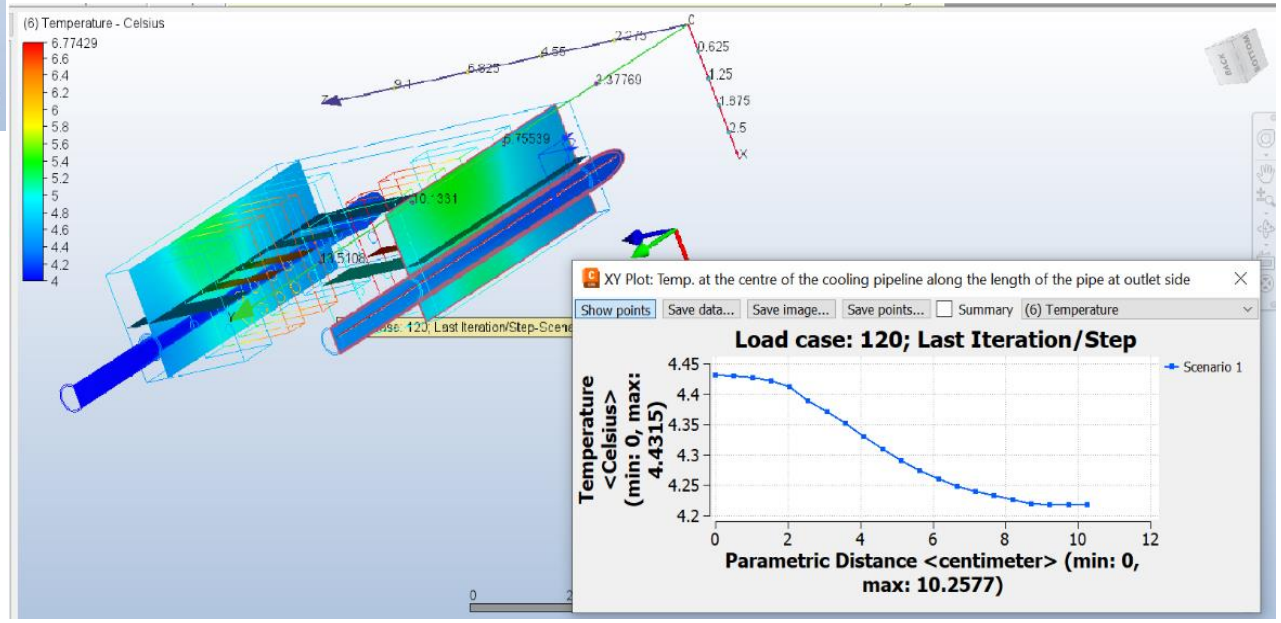
Side view





Sub part of the simulation adding cooling pipe line to the Heat Exchanger





Conclusion

- HVMAPS are required to perform the measurement with more precision as it provides better spacial resolution and less noise to signal ratio.

- Cooling is necessary for in vacuum operation of these detectors.

- Next steps are to modify the model according to cooling and manufacturing requirements, and to generate further simulations to build an efficient detector.

Thank You!