EIC Beryllium Pipe Section Steady State Thermal Analysis

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The Electron Ion Collider beam pipe has a central section, which is planed to be made of beryllium material, and operate at 100°C at its inner face to achieve with the physics requirements, the first layer of silicon sensors ID is about 1.24 mm away from beam pipe OD. Due to this close proximity the thermal effect over the silicon sensor is critical to ensure the actual design satisfies with all required specifications.

I generated a simplified model of the beryllium section which consists on three components: the beryllium pipe (Be pipe), the silicon sensor layer 1 (Si sensor L1) and the ambient enclosure. The Be pipe and Si sensor L1 were created using NX12 software and the ambient enclosure was created in Ansys Desing Modeler software. Simplified model was created based on the actual dimension and component locations provided from the original design but with the length of the Be pipe (actual length 1450 mm) shortened to 320.5 mm, which is the length of the Si sensor L1. The enclosure created represents the ambient volume surrounding the model, its dimensions were selected randomly; I selected 100 mm as the outer diameter.

Once the geometry was completed, I proceeded with material assignment, meshing and setting of the thermal conditions and boundaries for the model.

In the process, I had issues to simulate the thermal effect between two separate bodies, I noted that in steady state thermal analysis all bodies must be in contact to have a thermal effect to each other. To prove this assumption, I generated five models with separations of 1.24 (original design), 2, 3, 4, and 5 mm separation between the Be pipe and the Si sensor L1. The results for all models were as expected, the temperature of the Si sensor L1 did not change, it was kept at the preset ambient temperature of 22°C.

- **Utilized Ansys Steady-State Thermal software to simulate convection and given thermal conditions to find the temperature of the silcon layer. Run simulation for models with different separation between Be pipe and Si sensor L1**
- **Next step is the thermal analysis with the implementation of Computational Fluid Dynamic software**

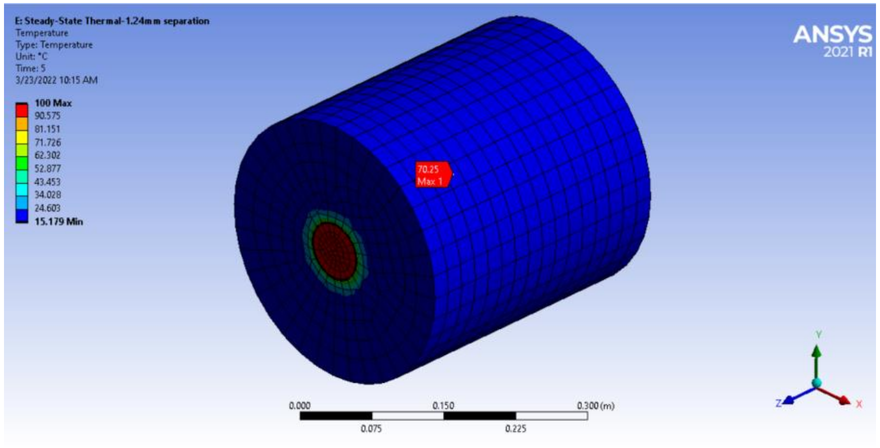

Fig. 1. Temperature profile for model with 1.24 mm of separation between Be pipe and Si sensor L1 with air at 15°C

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To solve this issue, I implemented volumes between the OD of the Be pipe and ID Si sensor L1, this is the annulus space between the two concentric cylinders; another volume was added for the inner space of the Be pipe (but later not used since assumed temperature for the Be pipe inner face was fixed at 100 °C). The volumes were defined as fluid domains and the Si sensor L1 and Be pipe as solid domains. The volumes dimensions for the annulus space and the enclosure were vary based on the each model with different separation between the Be pipe and Si sensor L1.

I ran multiple simulation for each simplified model at different temperatures for the air in the annulus space and enclosure, 20, 15, 10, and 5°C, see fig. 2. Table 1 below shows the results with air temperature in the annulus space and in the enclosure (ambient) at 15°C with convection heat transfer, and film coefficient for the air of 5 W/m2*°C

Measured Temperature			
Separation between Be-Pipe and Si-Sensor L1 [mm]	Be Pipe Outter face Temp [°C]	Max. Si Sensor L1 Temp [°C]	ΔT between Be Pipe & Si Sensor L1 [°C]
1.24	100.00	70.25	29.75
2.00	100.00	59.56	40.44
3.00	100.00	50.81	49.19
4.00	100.00	44.75	55.25
5.00	100.00	40.14	59.86

Table 1. Ansys steady state thermal analysis results

I plan to continue with the thermal analysis implementing a Computational Fluid Dynamics tools available in in Ansys Fluid Flow Fluent software, which will allow the implementation of the desired flows velocity for the air in the annulus and ambient spaces.

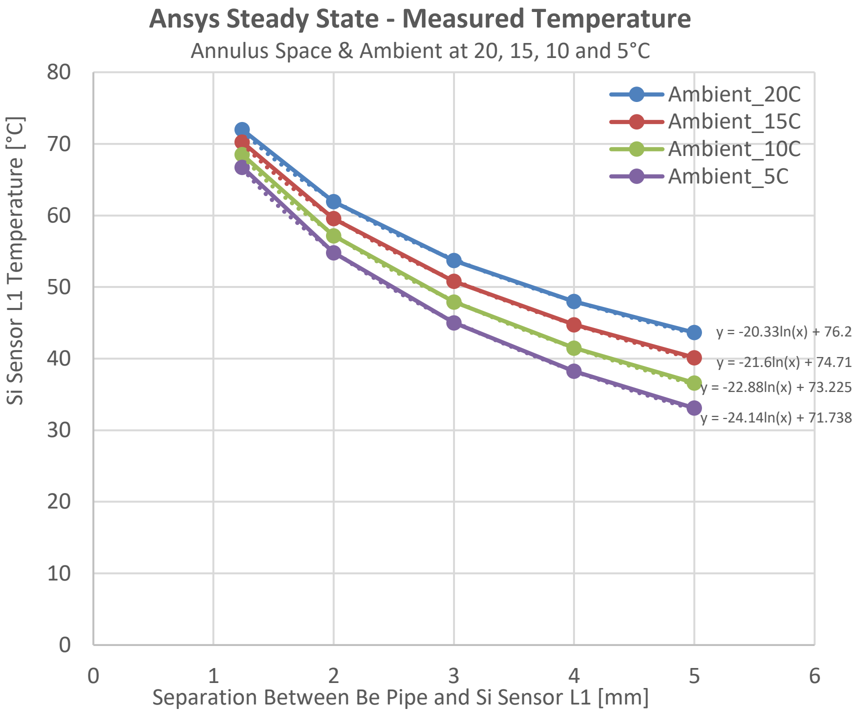

Fig. 2. Temperature Vs separation between Be ppe and Si sensor L1 with at different air fluid temperatures from 5 to 20°C