NOVEL STUDY ABOUT CURRENT LEADS FOR CRYOMODULES: A THERMAL ANALYSIS

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1. Current leads assembly
2. My model
3. Improvements
4. Results
5. Conclusion

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INTRODUCTION

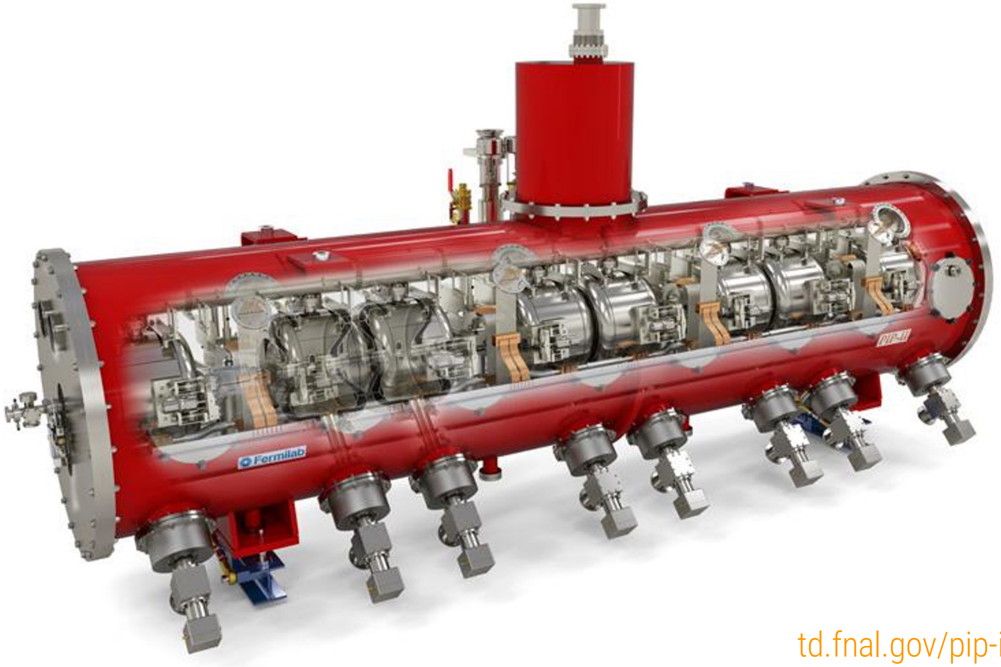
What I have learned about cryogenics
and what PIP-II is

CRYOGENIC TECHNIQUES

- Thermodynamics
- Cryogenic fluids
- Liquefaction
- Cryogenic properties of the materials

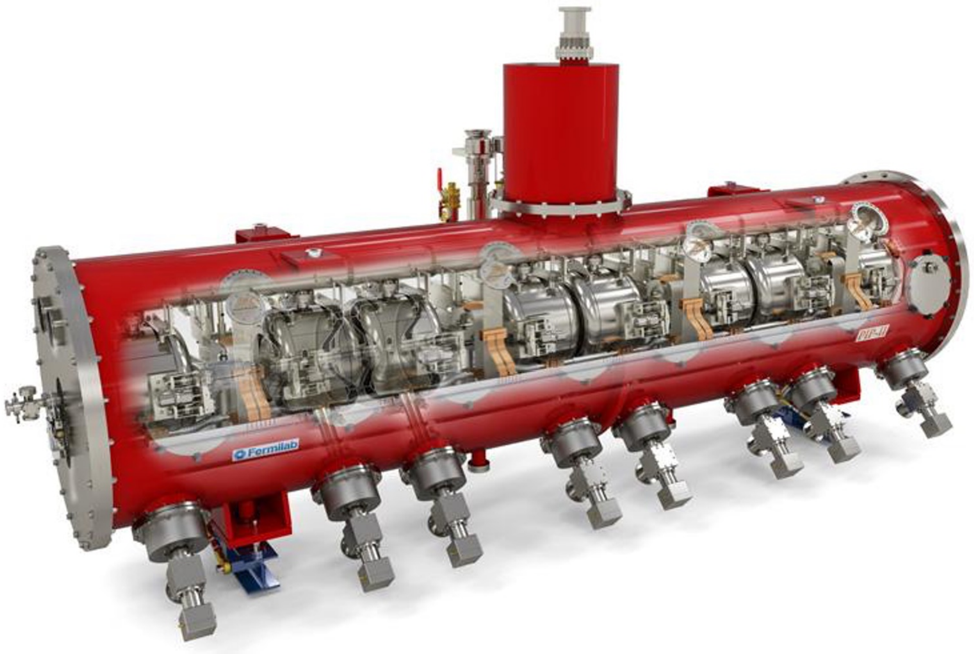
PIP-II

- Proton Improvement Plan-II
- Each cryomodule houses four magnet packages
- Each magnet package is powered by a current leads assembly



td.fnal.gov/pip-ii

PIP-II



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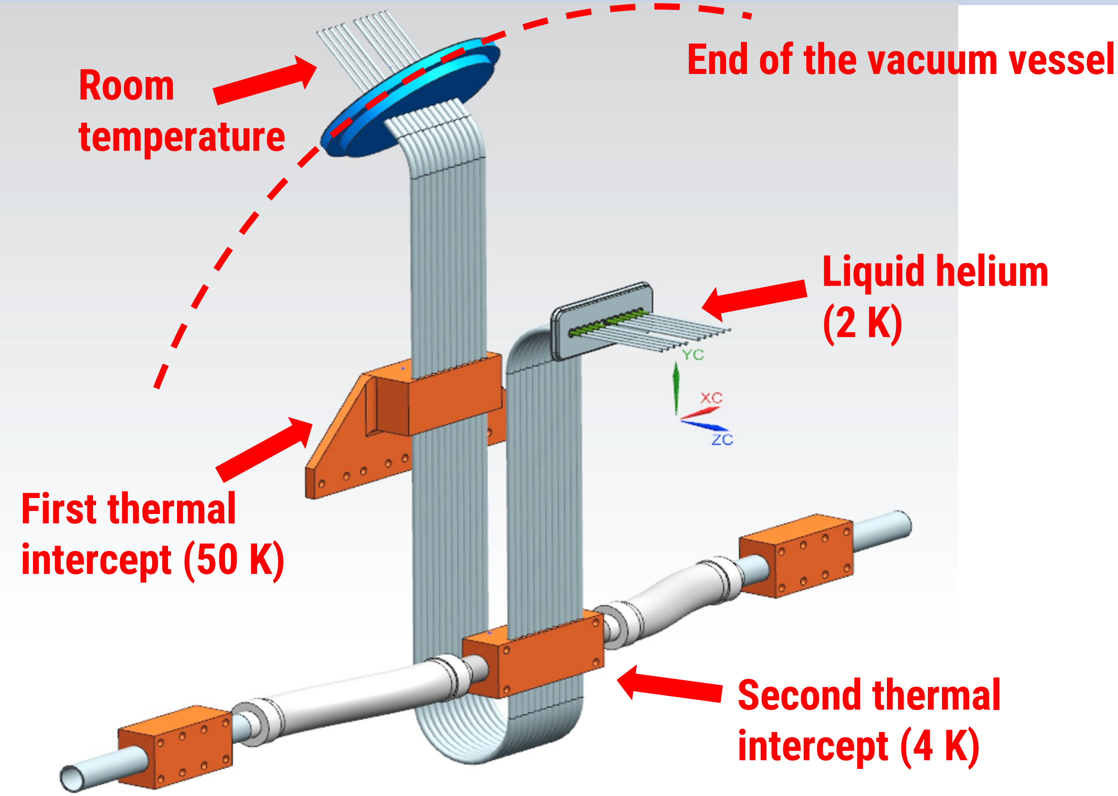
CURRENT LEADS ASSEMLBY

What is the issue?

CURRENT LEADS. CAD



11 copper wires

9 with 50 A

2 with 85 A

How can we be sure that the temperature of the wires reaches 2 K?

How can we decrease the amount of heat flowing into liquid helium?

How can we improve the system?

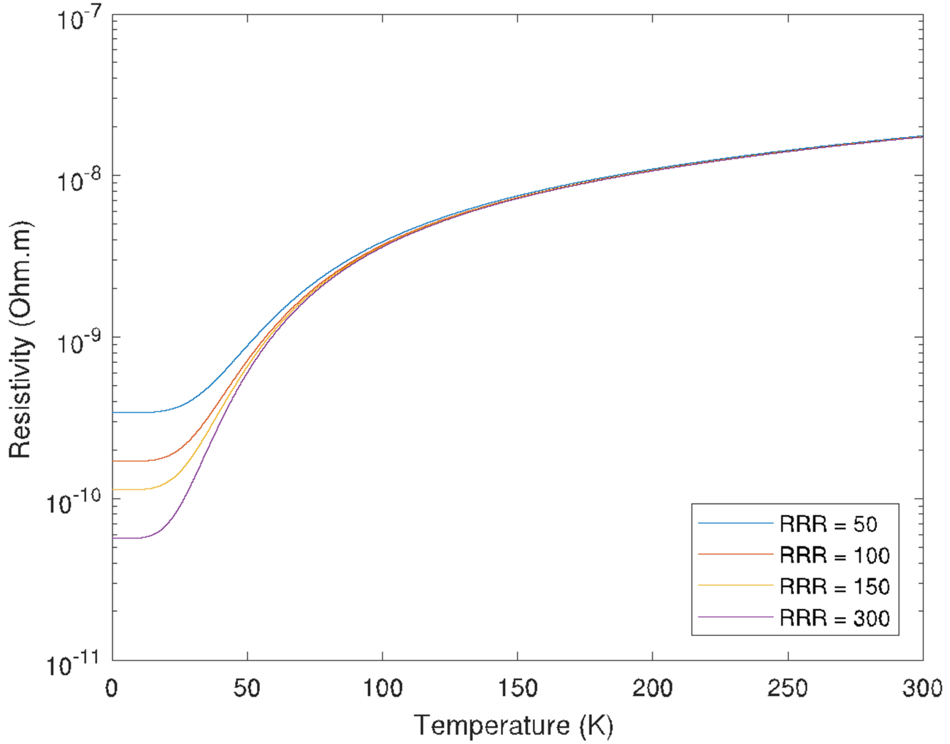
CAUSES OF HEAT

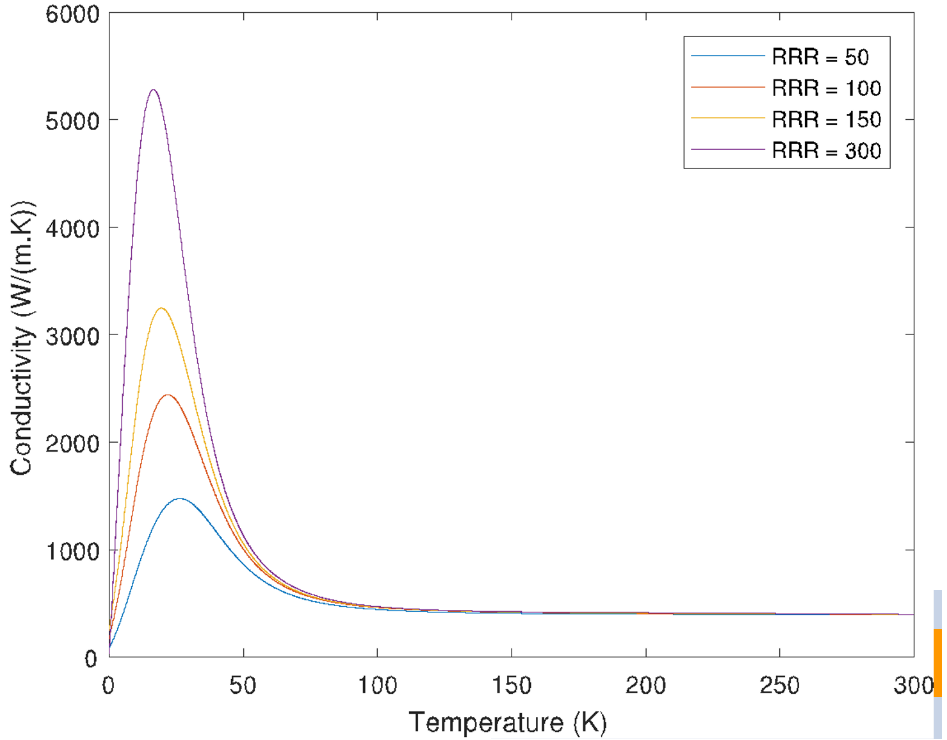
Joule effect

Low electrical resistivity

Heat conduction

Low thermal conductivity





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MY MODEL

How I decided to deal with the problem

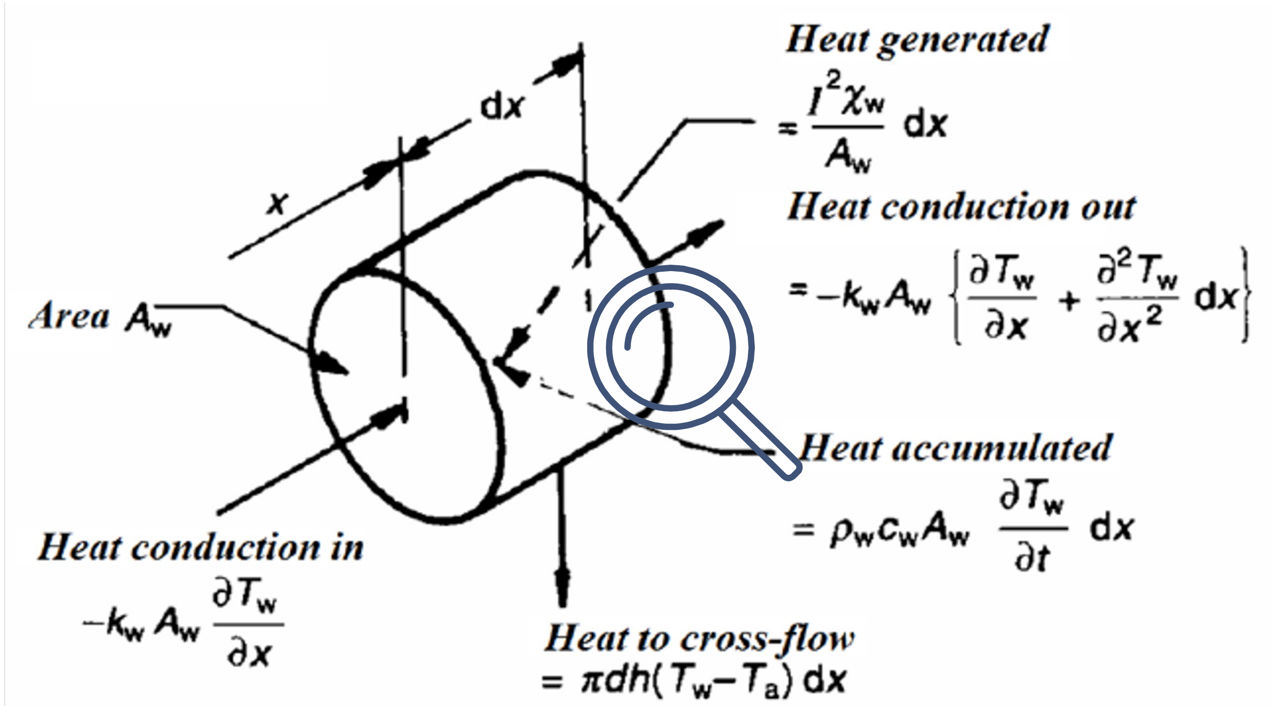
MY PROCESS

Collect all the data:
- Electrical properties
- Thermal properties

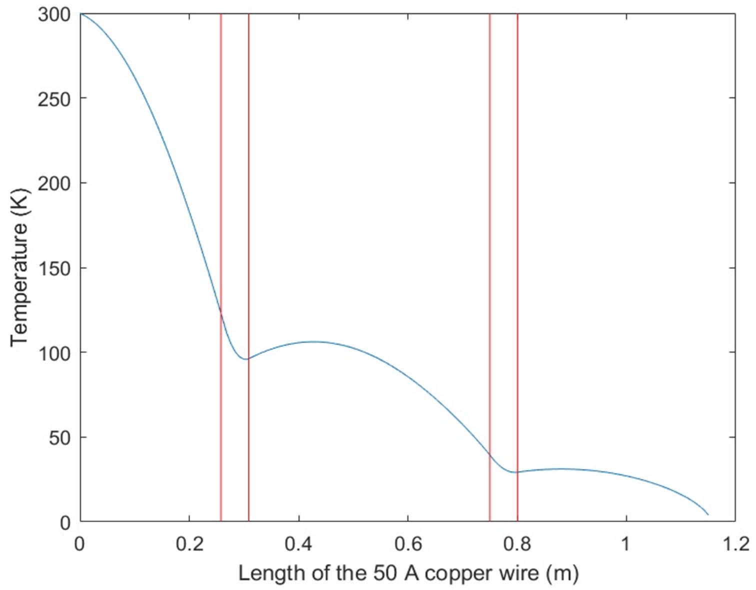
Write down all the phenomena and their equations:
- Joule effect
- Heat transfer
  - Conduction
  - Thermal intercept
  - Convection

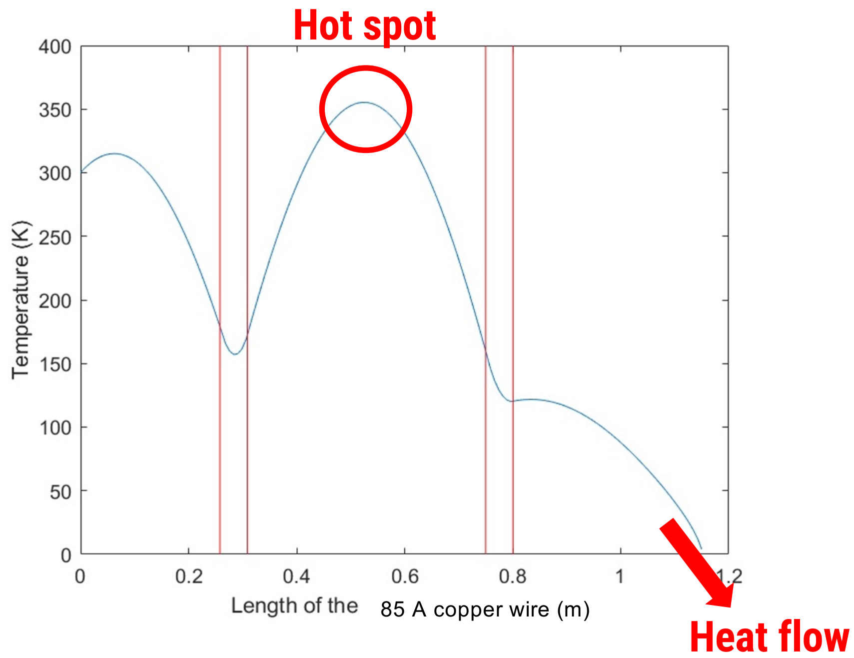
Discretization of the problem (finite difference method)

ELEMENT OF WIRE OF LENGTH dx



FIRST RESULTS





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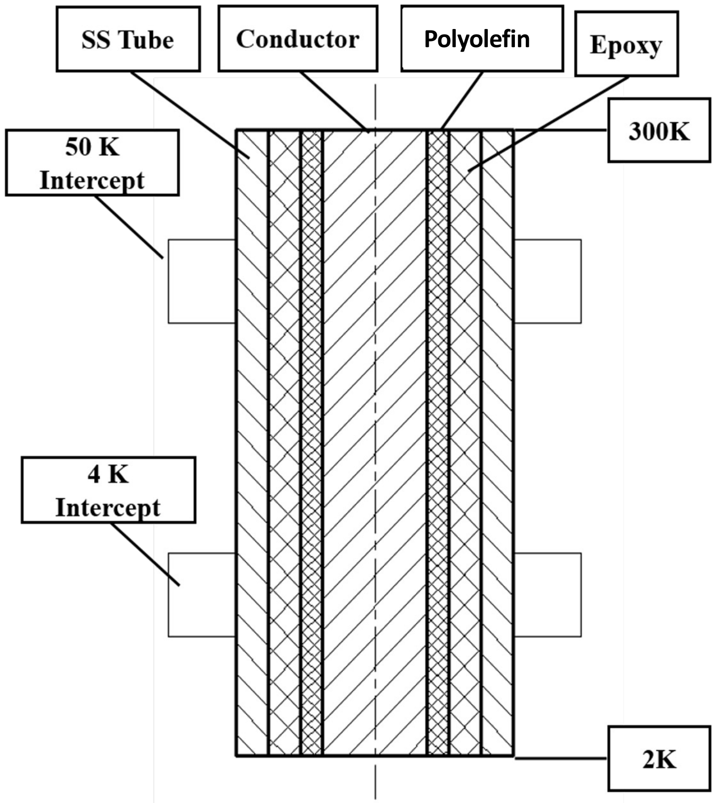
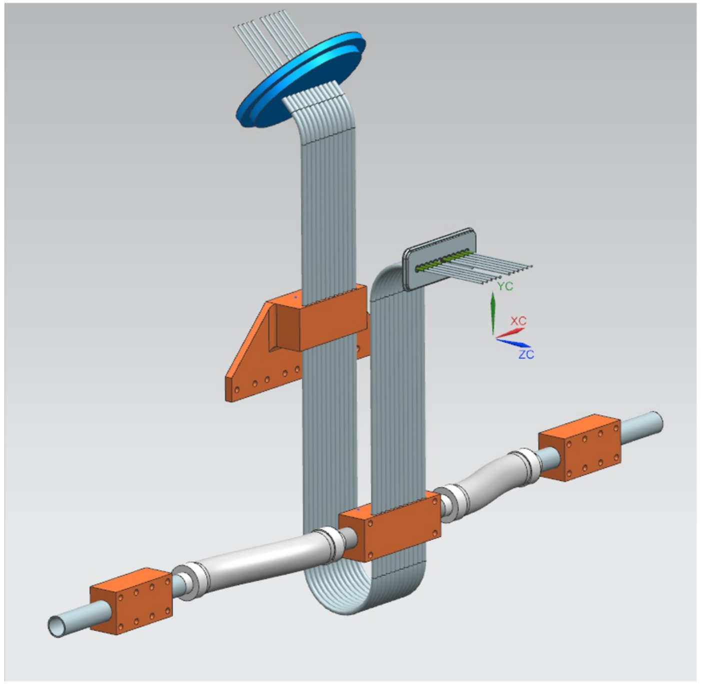
IMPROVEMENTS

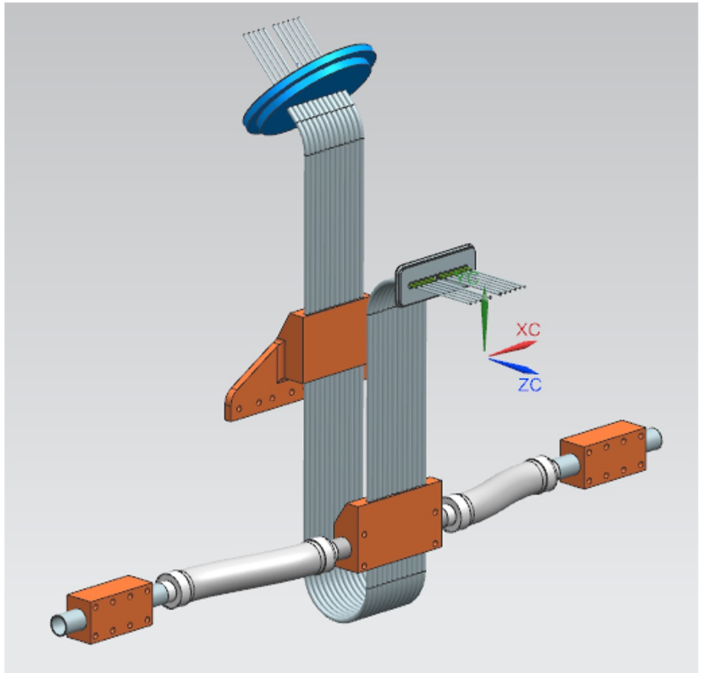
My suggestions to make the system more efficient

LONGER THERMAL INTERCEPT

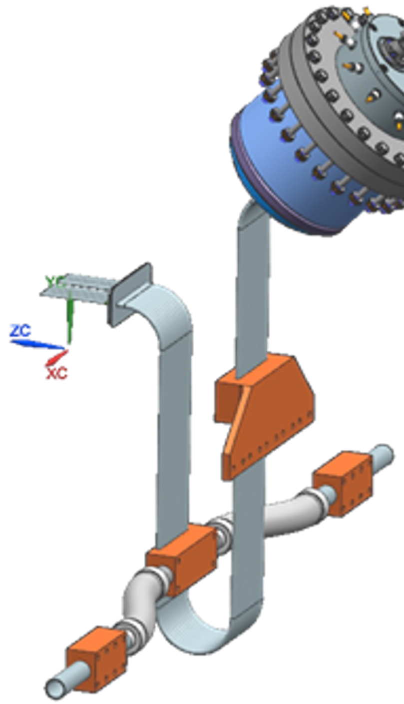


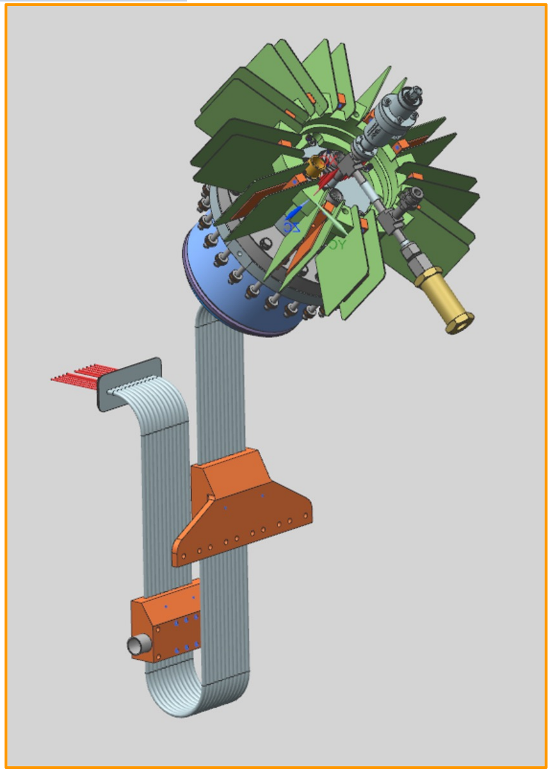
LONGER THERMAL INTERCEPT





FINS





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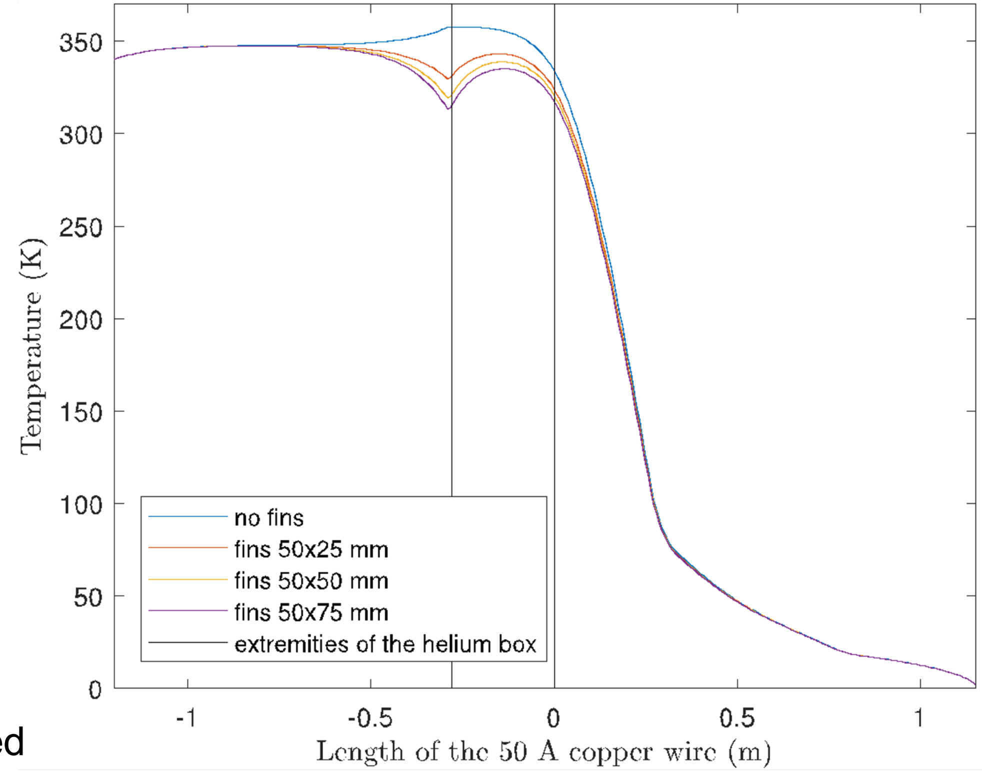

Fins are needed

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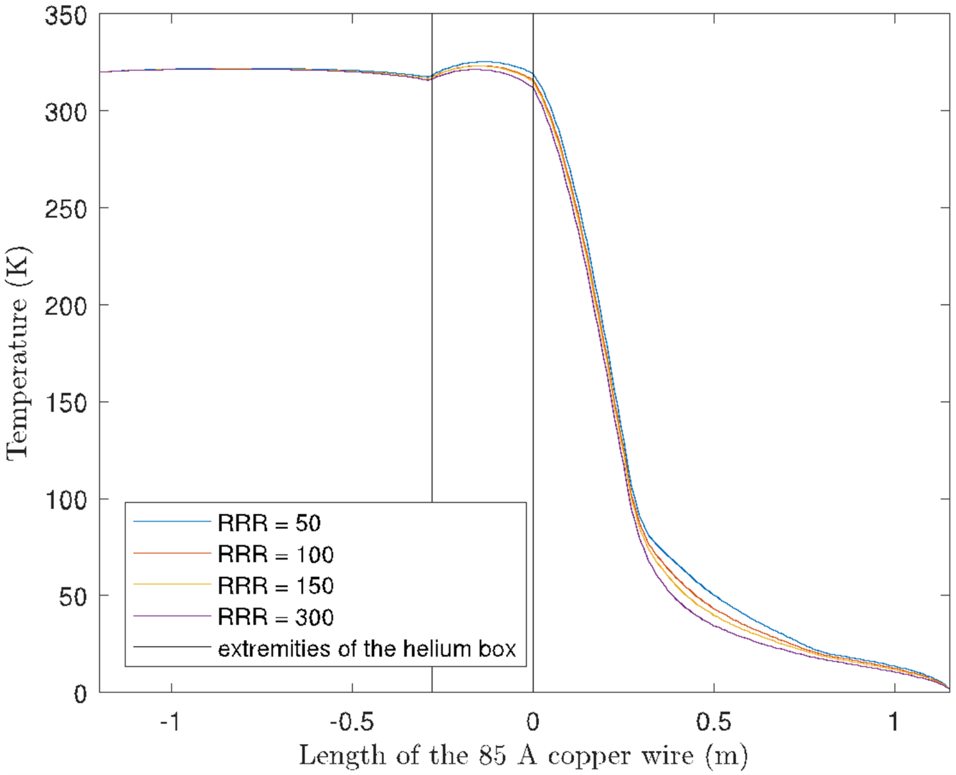
OTHER ANALYSES

What happens if we change some parameters

DIFFERENT QUALITY OF COPPER

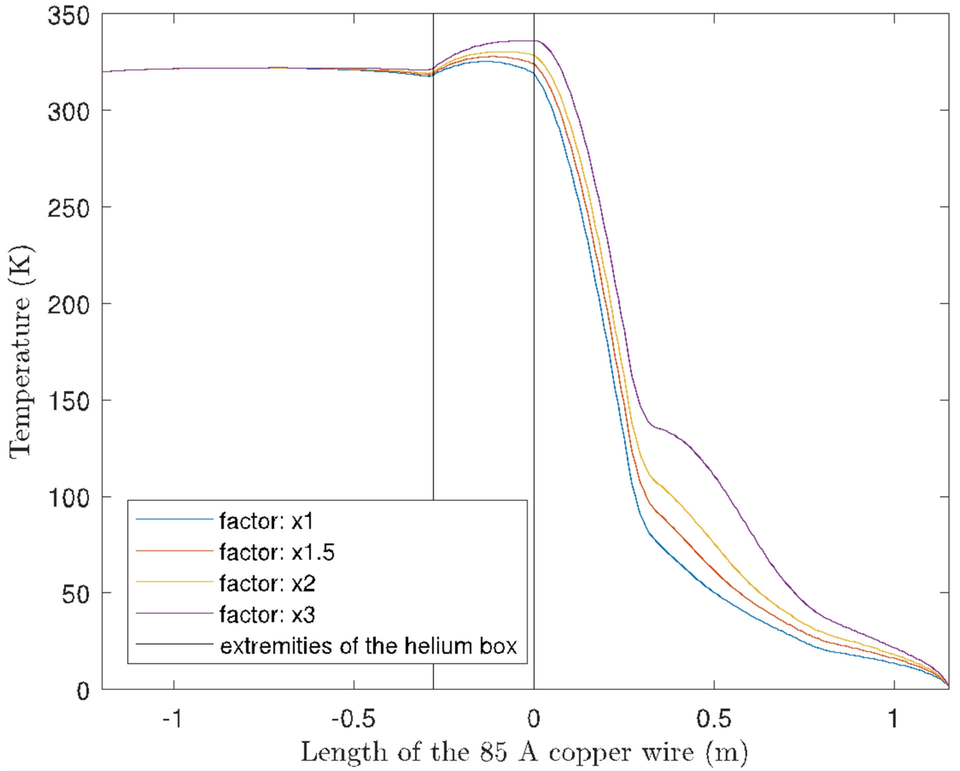


DIFFERENT QUALITY OF COPPER

RRR	fins	helium box	1^{st} st.	2^{nd} st.	liquid helium
50	14.44	12.3	21.16	6.06	2.84
100	14.05	21.16	21.13	5.75	4.73
150	14.05	11.04	19.38	5.46	6.30
300	13.66	10.40	15.59	4.88	9.99

Table 2: Heat extracted (W) by each cooling system, for different values of RRR.

RISK ANALYSIS: CONTACT RESISTANCE



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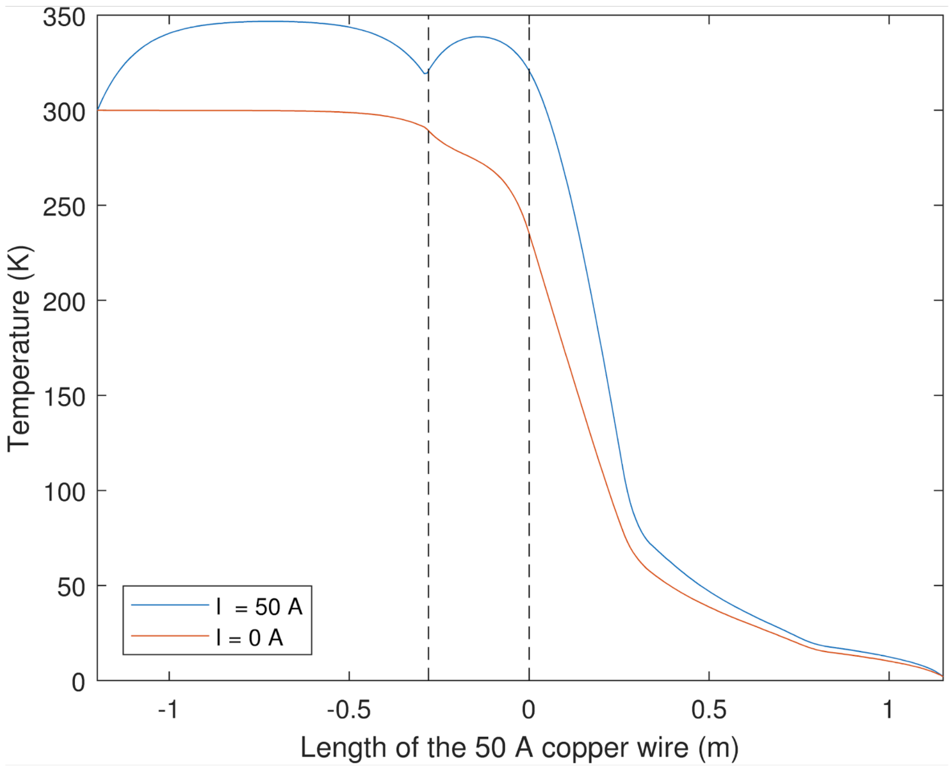
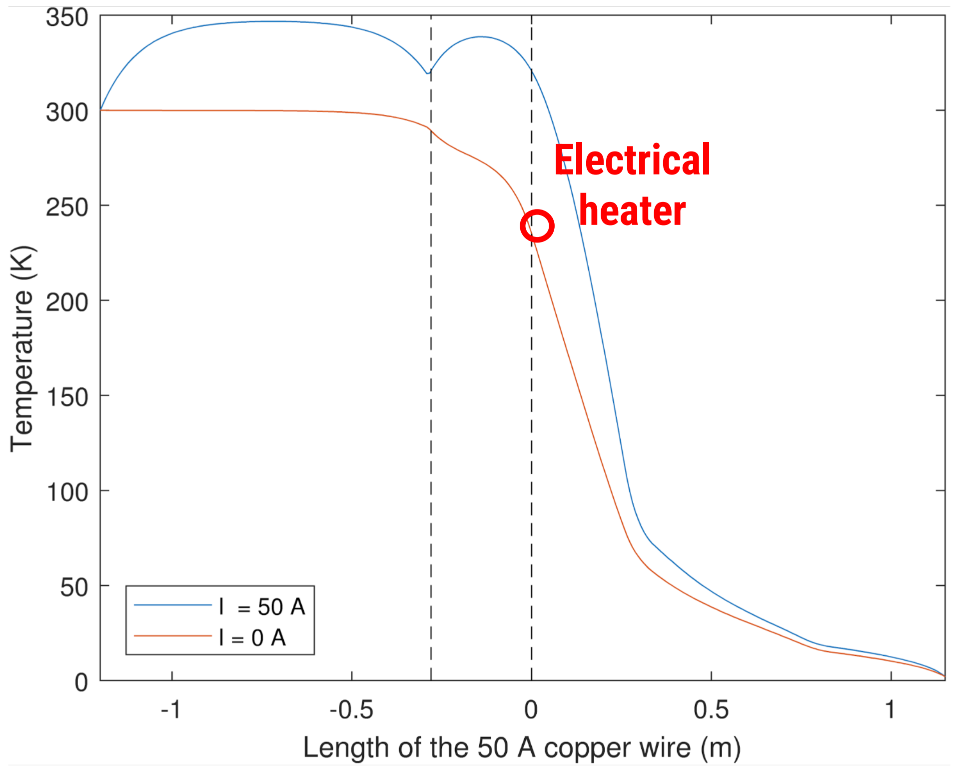
COOLING DOWN

Analysis with zero current

Zero current: what happens



Zero current: what happens



CONCLUSIONS

THANKS!

I will be glad to answer your questions

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Backup slides

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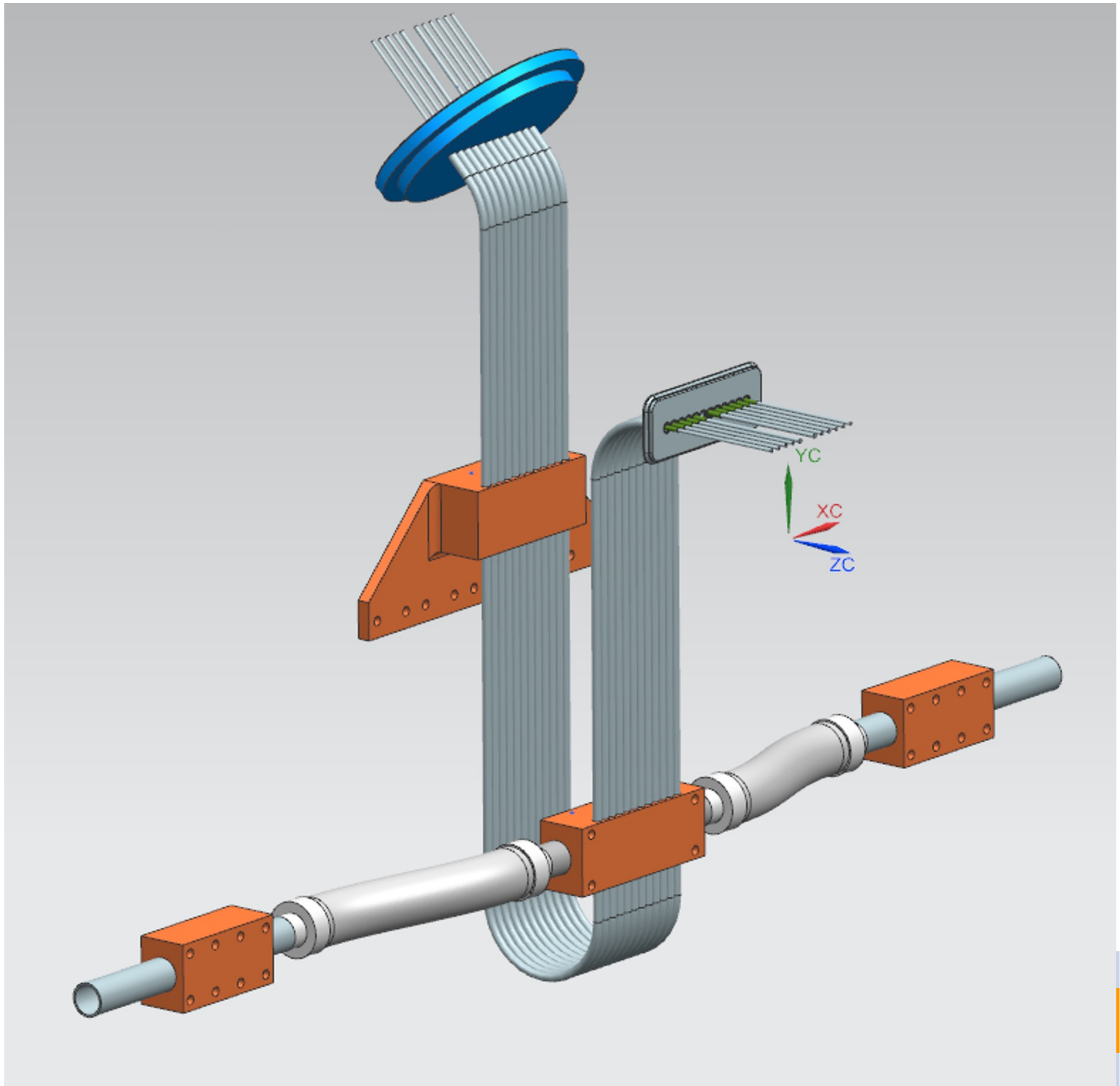
TEST SET-UP

How the contact resistance can be measured

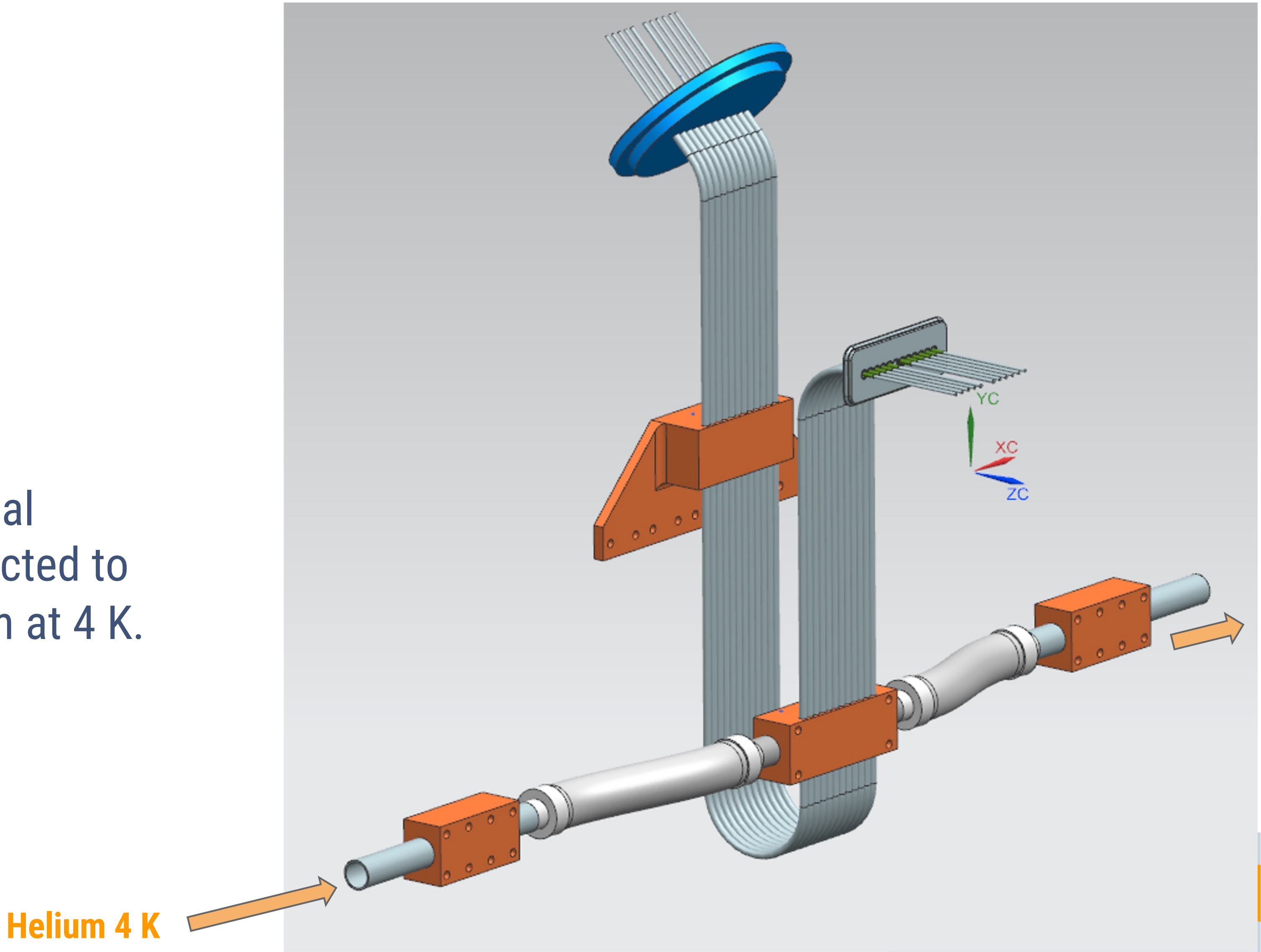
1.

The entire assembly is put in STC, totally insulated from room temperature



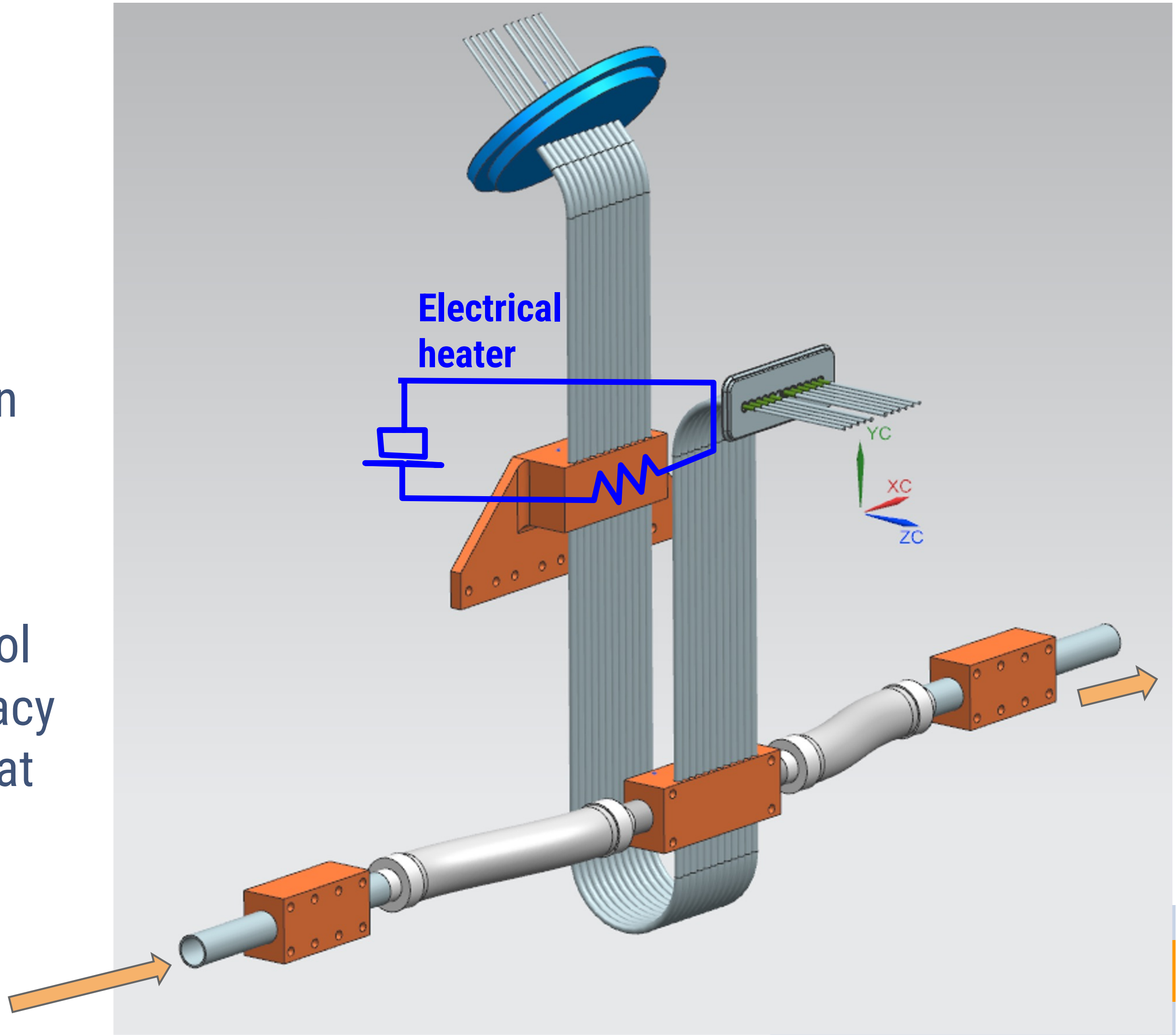
2.

The second thermal intercept is connected to helium distribution at 4 K.



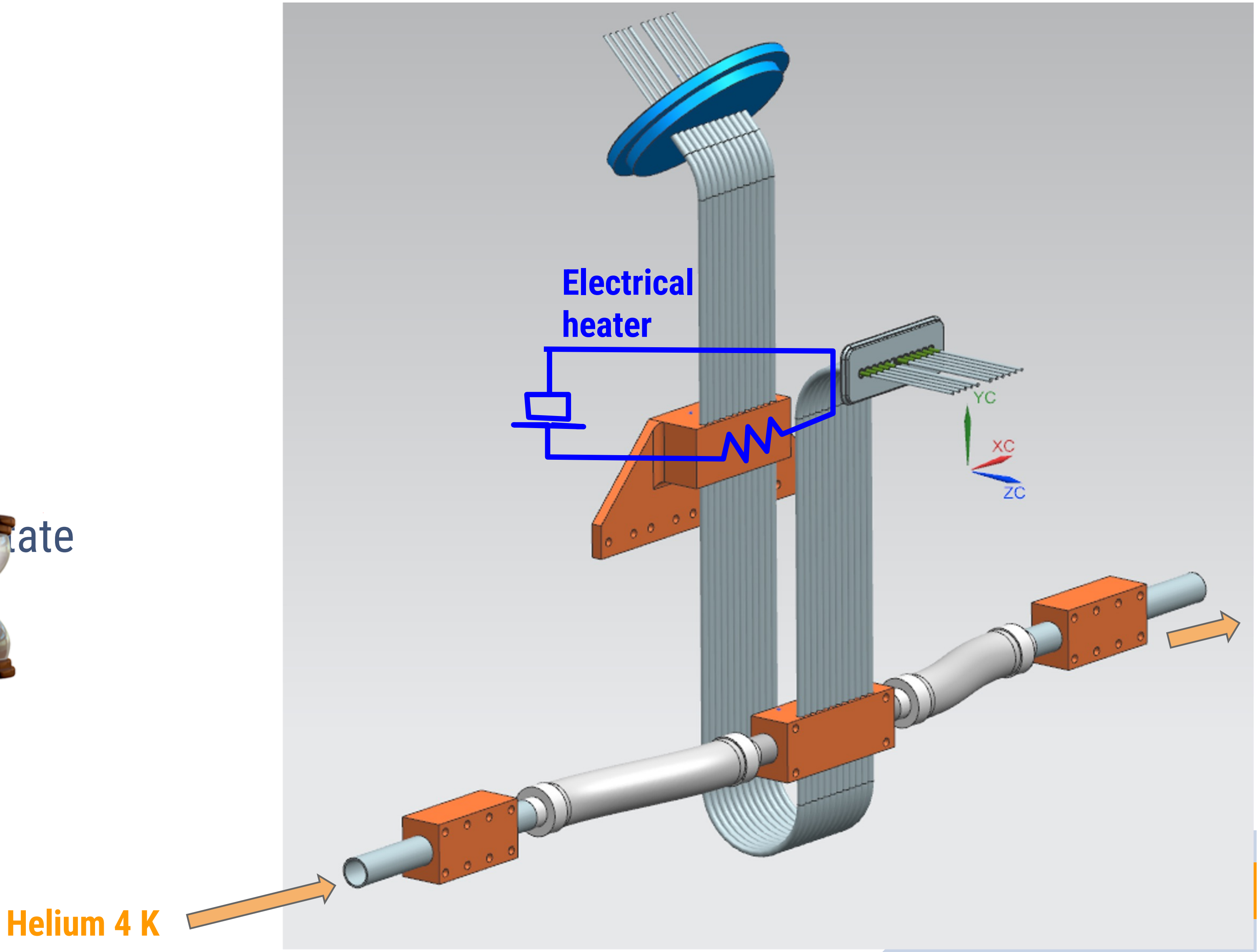
3.

The first thermal intercept in not connected to helium distribution. We put an electrical heater on the copper block. We can control the temperature with accuracy and we can measure the heat generated by the heater.



4.

We wait for ste  ate conditions



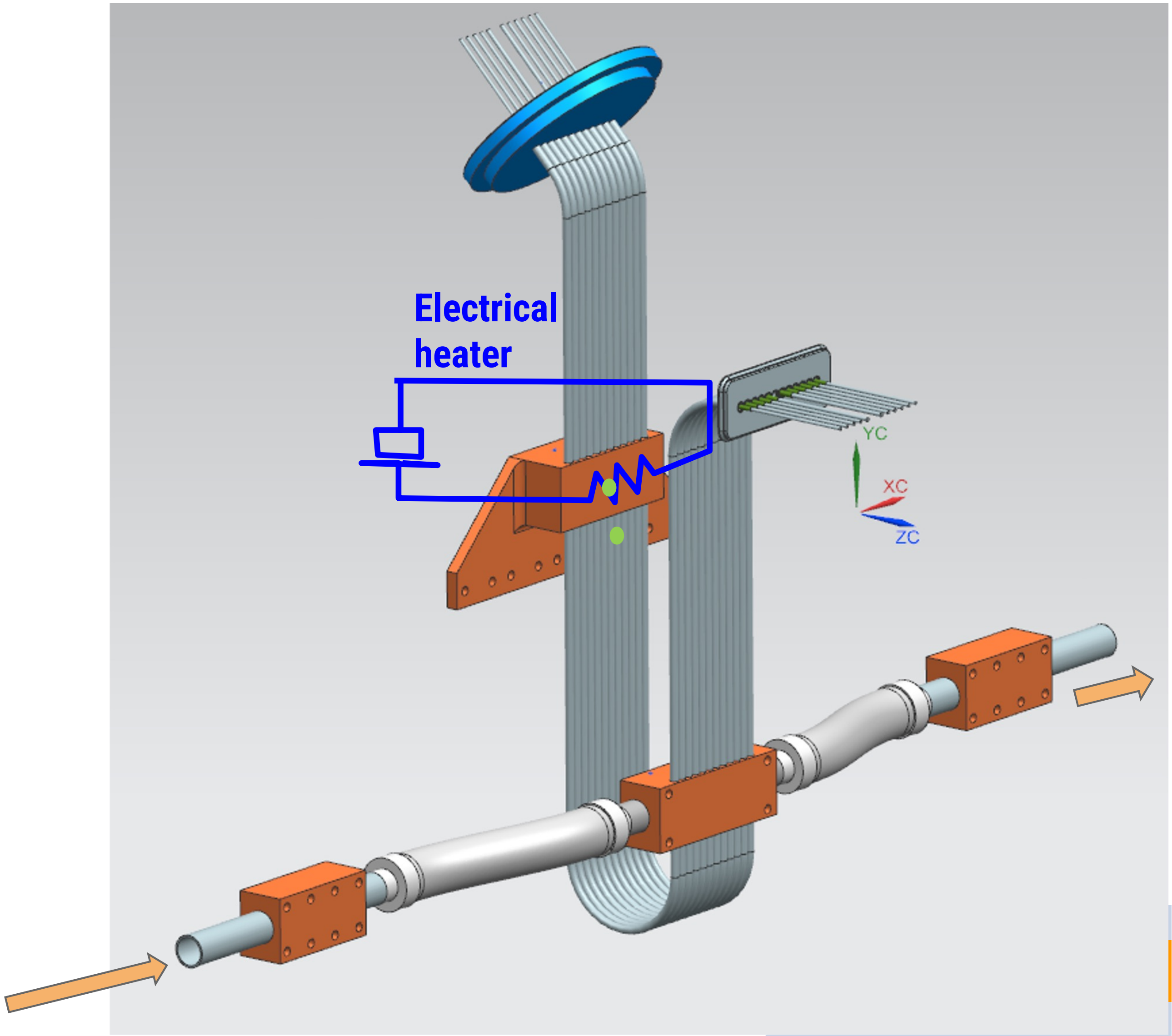
5.

We measure the ΔT between here...

...and here.

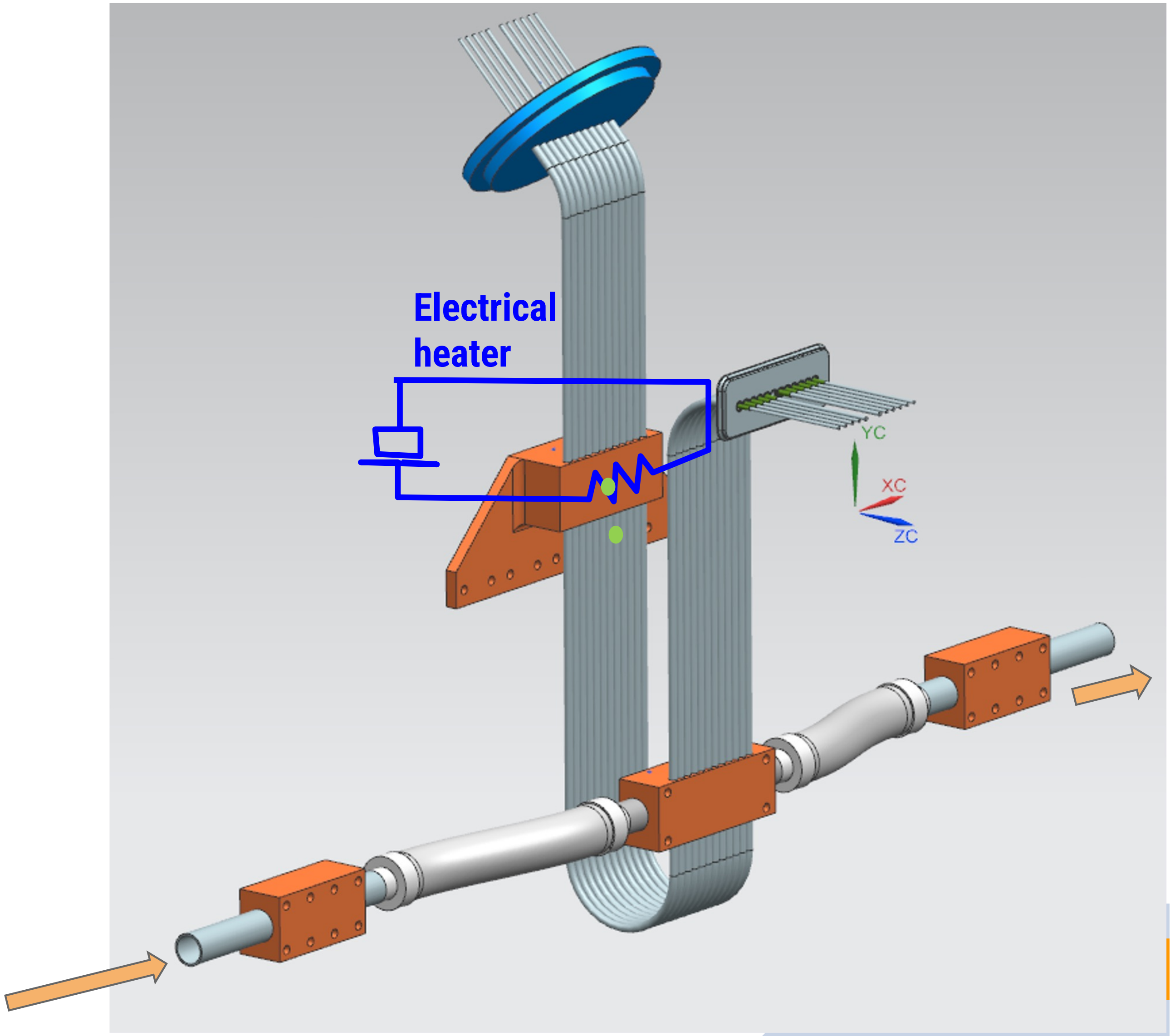
So we can know the contact thermal resistance between the thermal intercept and the wires.

Helium 4 K



6.

We can do the same with nitrogen at 77 K in order to have the temperature-dependence of the phenomenon more clear



Nitrogen 77 K