The Injection Channel of the muEDM Experiment

Anastasia Doinaki

New Frontiers in Lepton Flavor

Pisa, 16.05.2023

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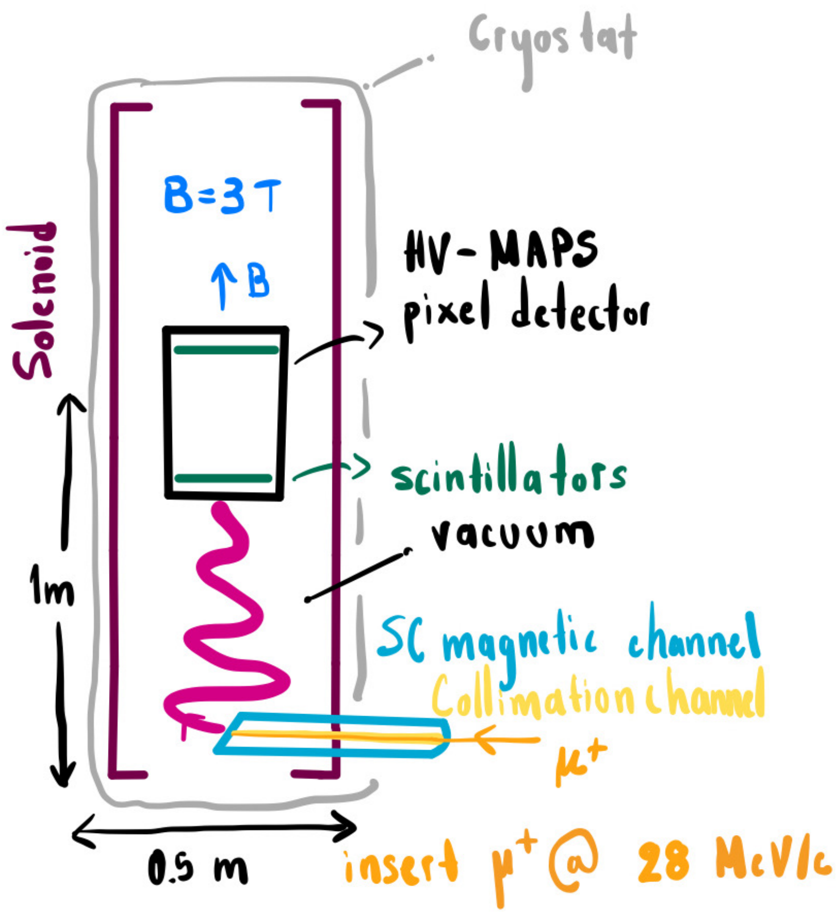
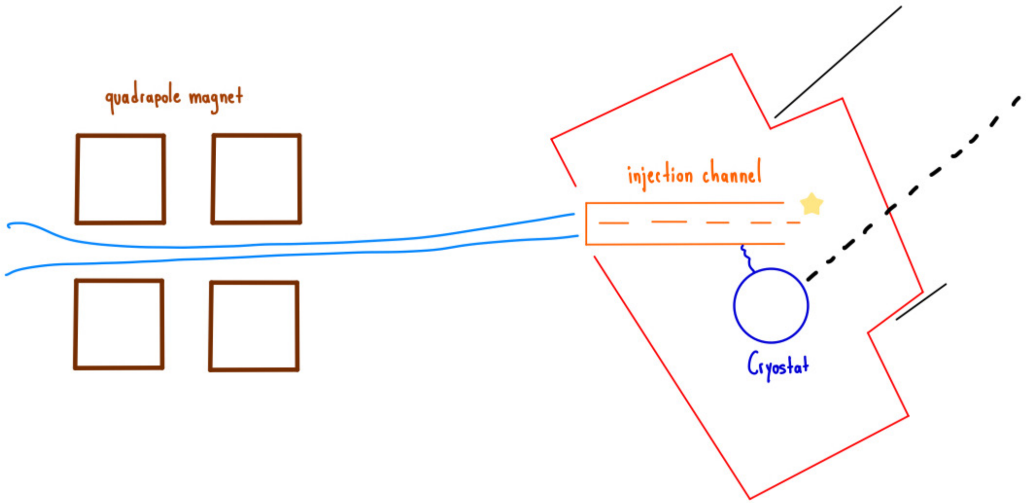
Injection Channel





Goal Off-axis injection of muons into a solenoid.

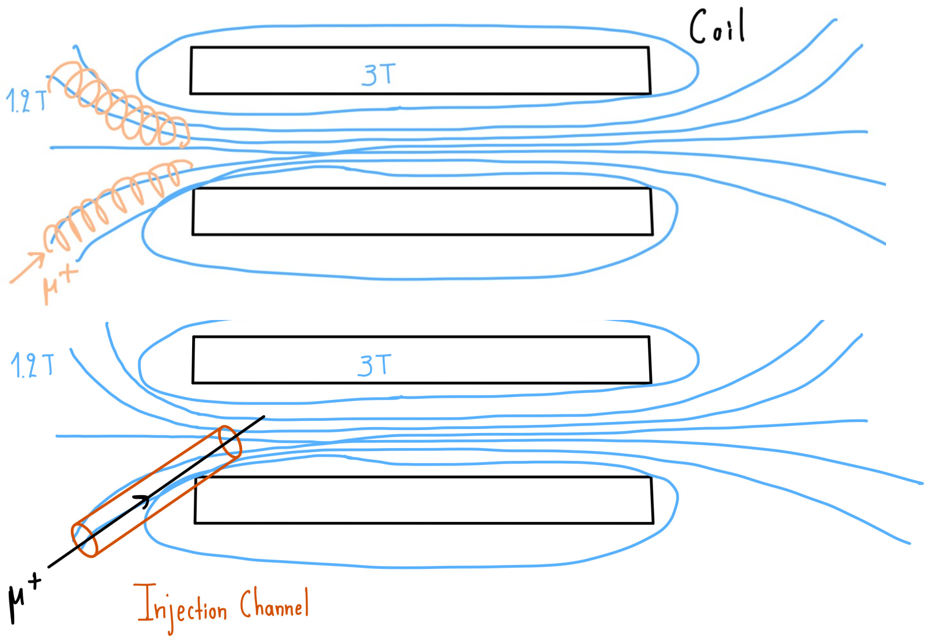
Muons (p≈ 28 MeV/c) from pion decay at rest (πE_1).

Muons injected through a Collimation Channel (ID=15 mm, l=800mm).

Around the Collimation Channel, a SuperConducting (SC) Shielded Channel (SC-Channel) to magnetically shield the Injection Channel.

Magnetically Shielded Channel

Muons transported from a low-field (fringe field<1T) to a high-field region (solenoid~3T) ➡ muons will spiral in and then spiral out (Magnetic Mirror Effect).



A magnetically shielded channel is needed for the transportation of the muons from the exit of the πE1 beamline in the solenoid, and it consists of:

<u>Fringe field<1T</u>: Thick Iron Tubes

<u>Solenoid~3T</u>: SC-Shielded Tubes

Superconductivity and Superconducting-Shielded Prototypes

Supercoductivity (SC) is observed in many metals when they are cooled down below a certain, critical, temperature.

- ➢ zero resistance

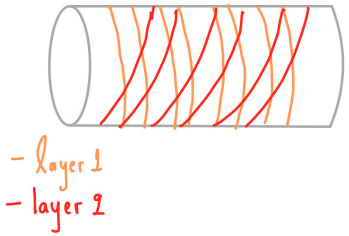
Electric current loops appear on the surface of the metal when it becomes superconducting. These currents (eddy currents), create a magnetic field that compensates the external, applied magnetic field.

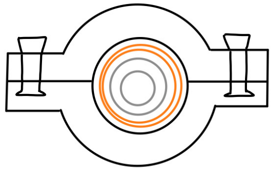
- ➢ Total magnetic field becomes zero in the SC-volume.

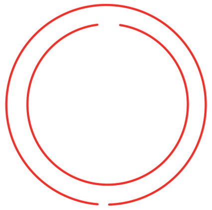
Prototype I: High-Temperature Superconducting (HTS) Tape, helically coiled around a copper tube.

Prototype II: Copper tubes wrapped with Nb-Ti/Nb/Cu SC-Sheets (borrowed from CERN).

Prototype III: Combination of a Bi-2223 casted tube with superconducting tape wrapped around it.







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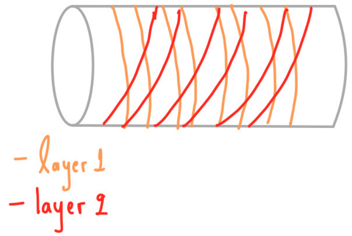

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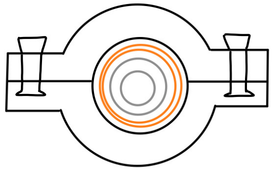
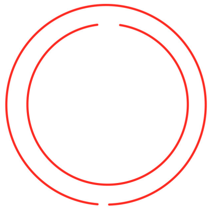




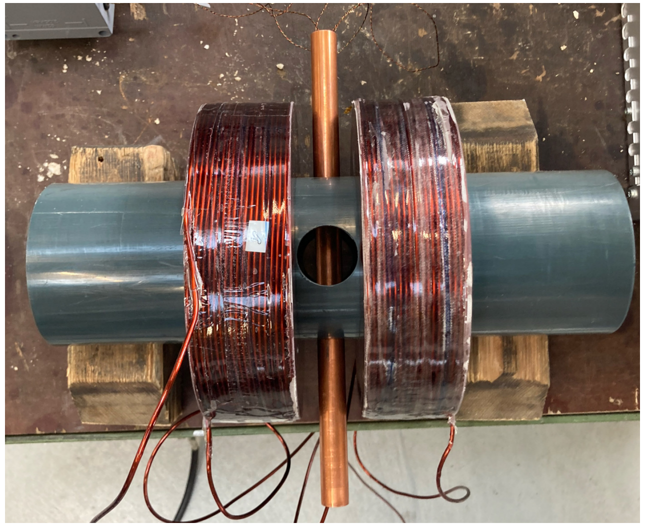
Prototype III: Combination of a Bi-2223 casted tube with superconducting tape wrapped around it.

Prototype 0

Setup SC-shielding Test

Study of the SC- shielding effectiveness of SC-shielded injection tubes under the magnetic field of a Helmholtz coil:

✓ By measuring the magnetic field in SC–tubes with and without SC-shielding at room and cryogenic temperatures.



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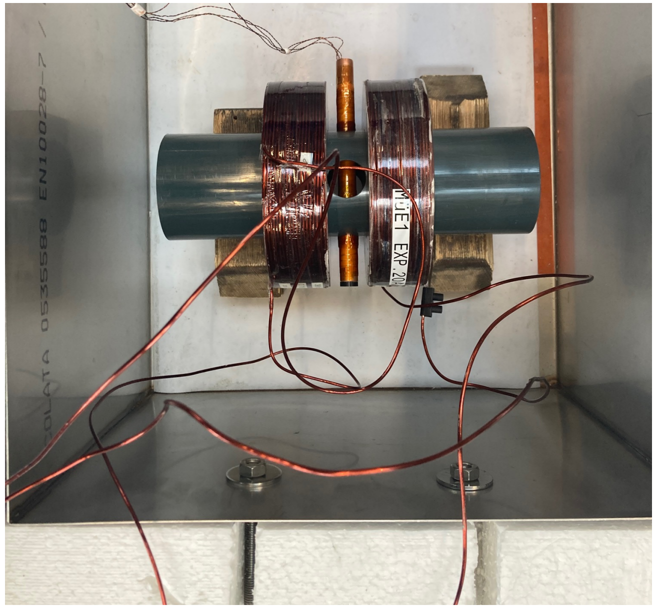

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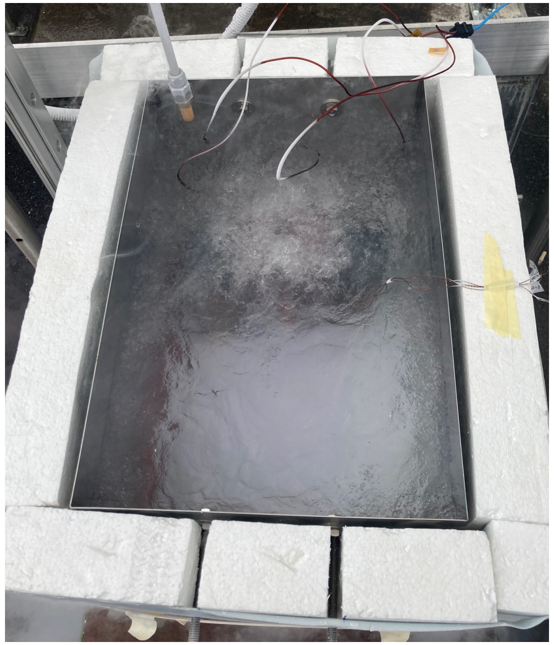

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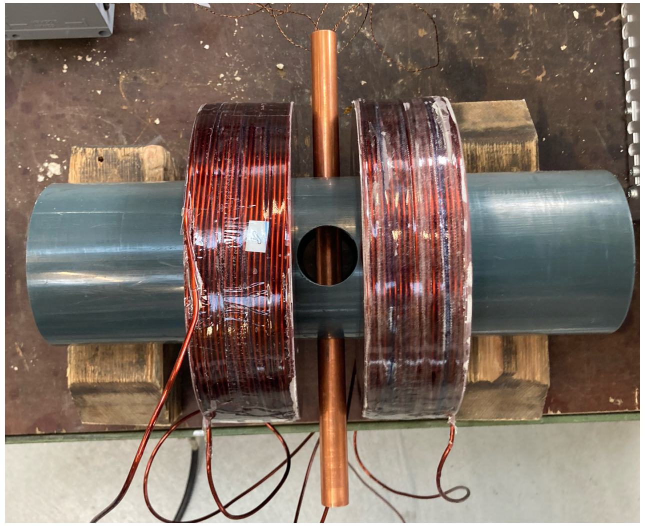
- ✓ In correlation with the different mounting techniques and layers of the SC-shield.



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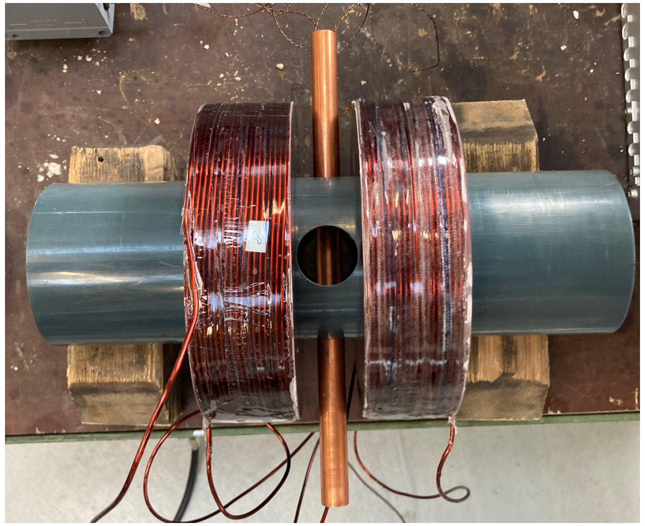

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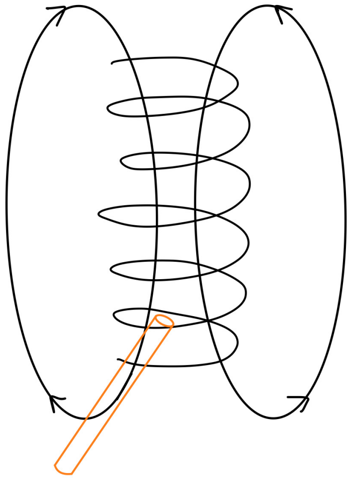
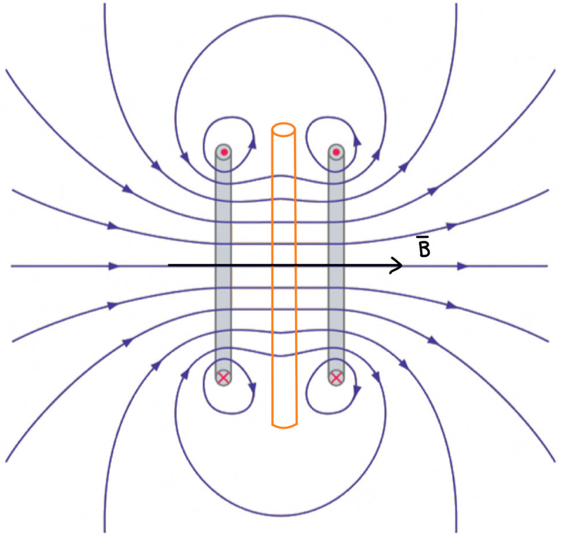
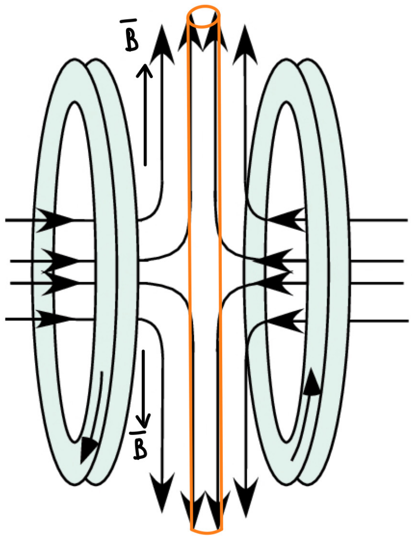
Why a Helmholtz coil?

- ➢ We want to study both transverse and axial fields applied on our injection tubes. Also, it provides a relatively uniform magnetic field.

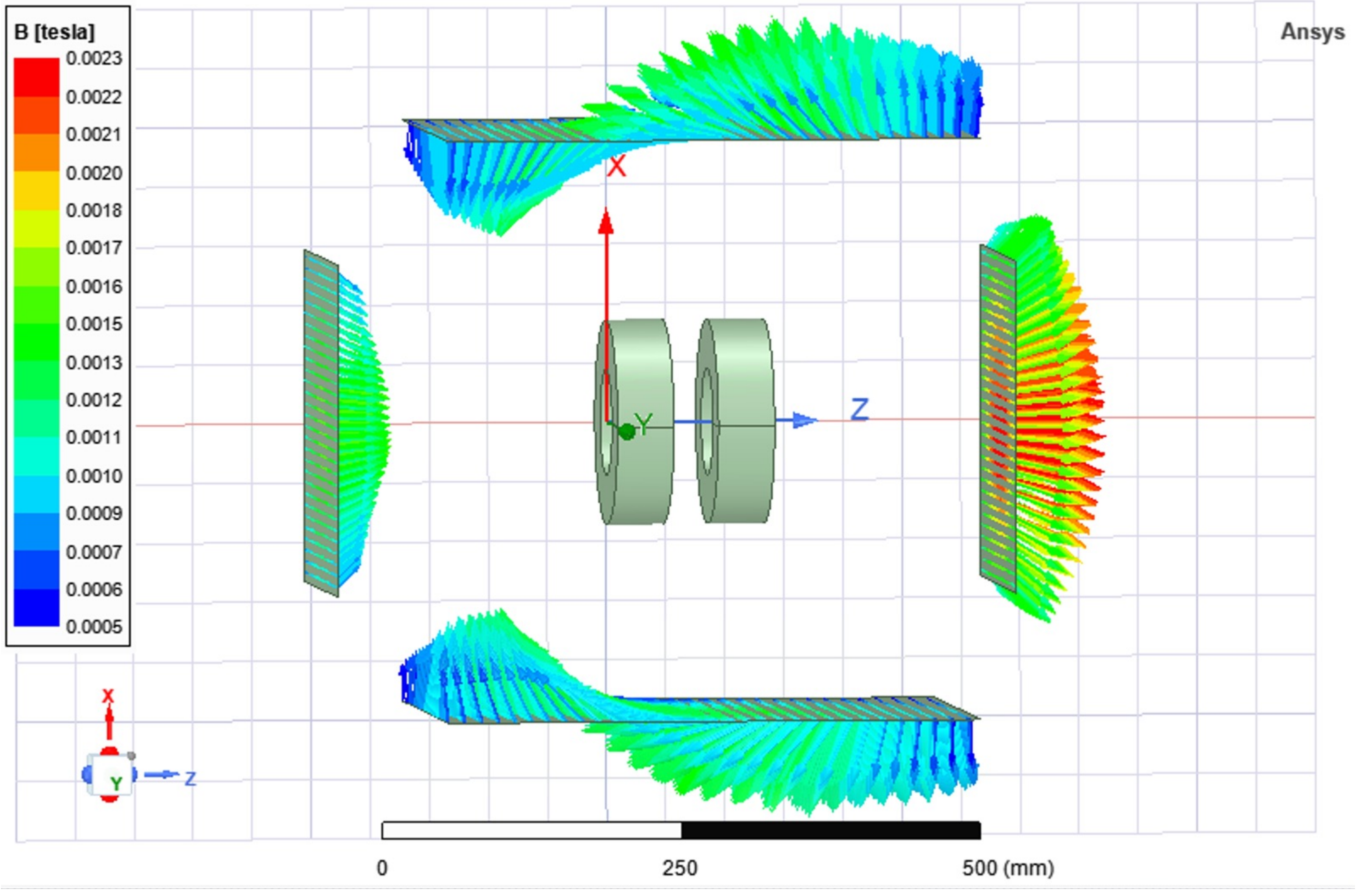


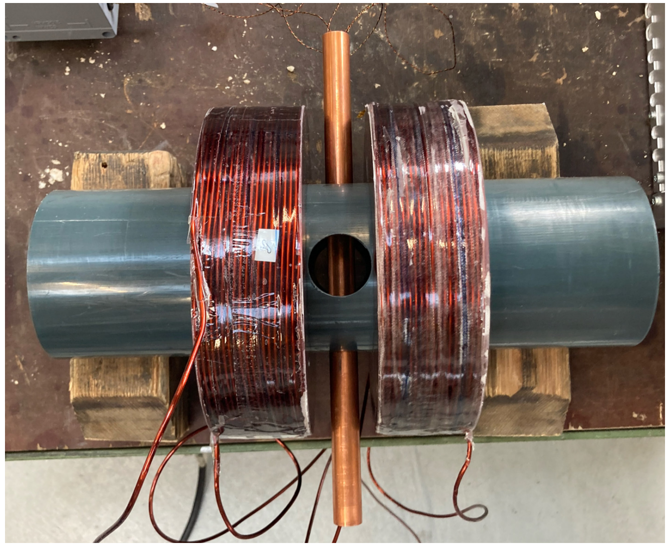


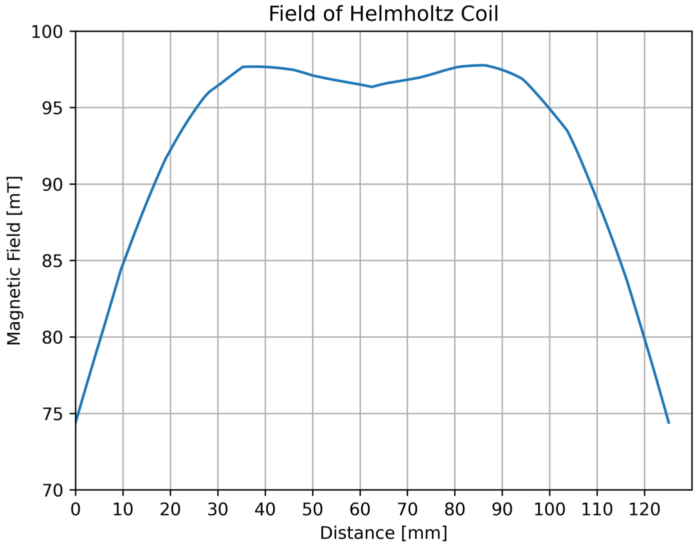


Setup SC-shielding Test, Helmholtz Coil

Designed and constructed a Helmholtz coil; 100 mT at the center of the coil when inducing a current of I=20 Amps while the coils are connected in series.







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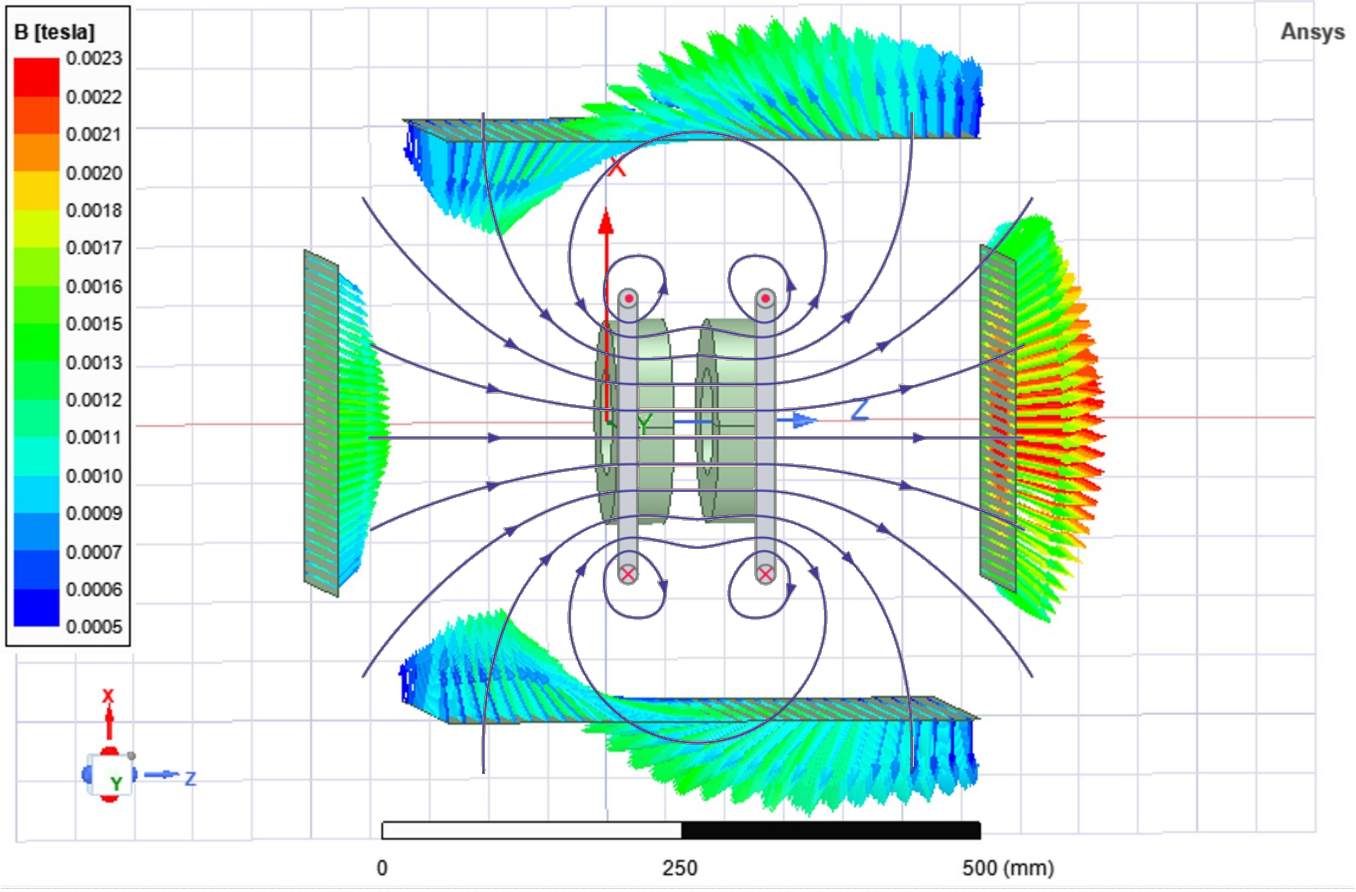
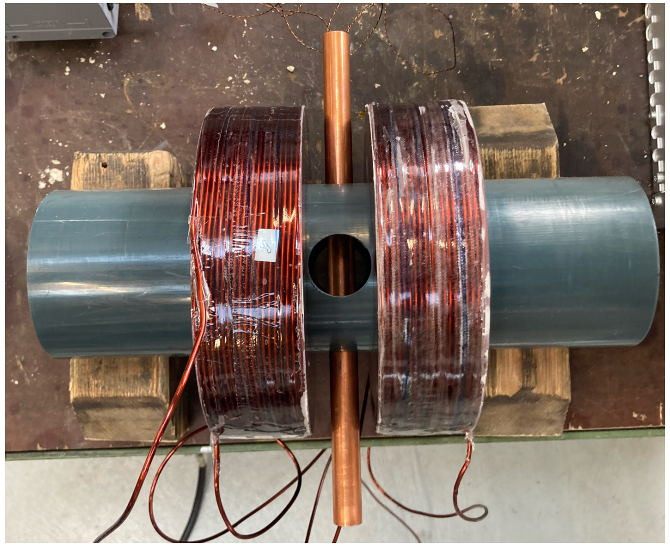
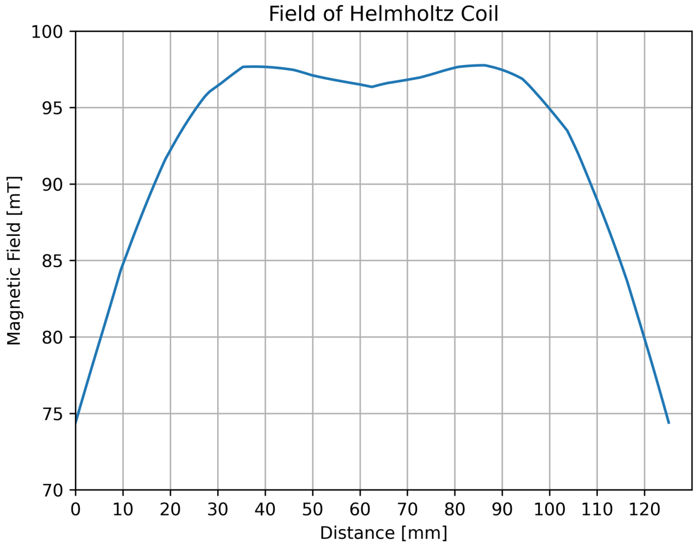


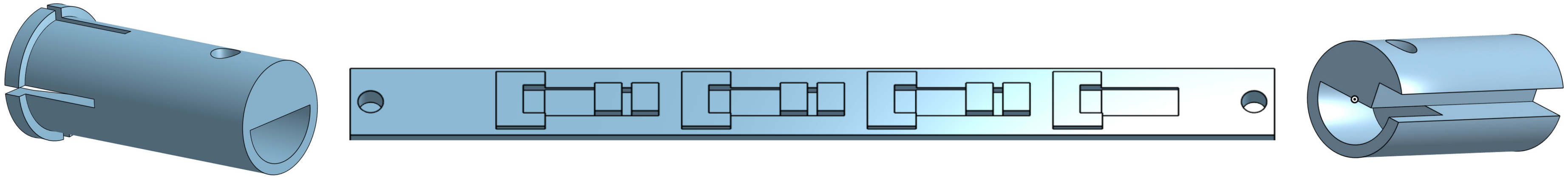


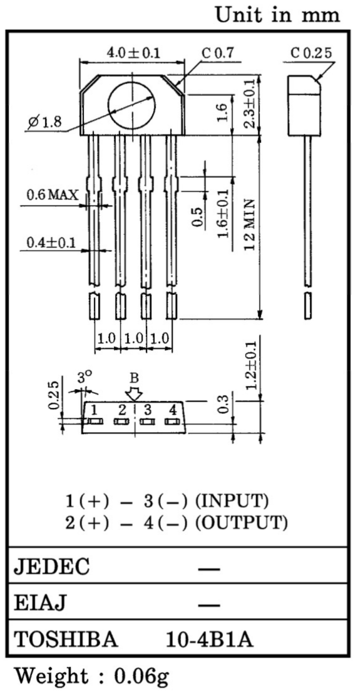


Setup SC-shielding Test, Hall Sensor Support System

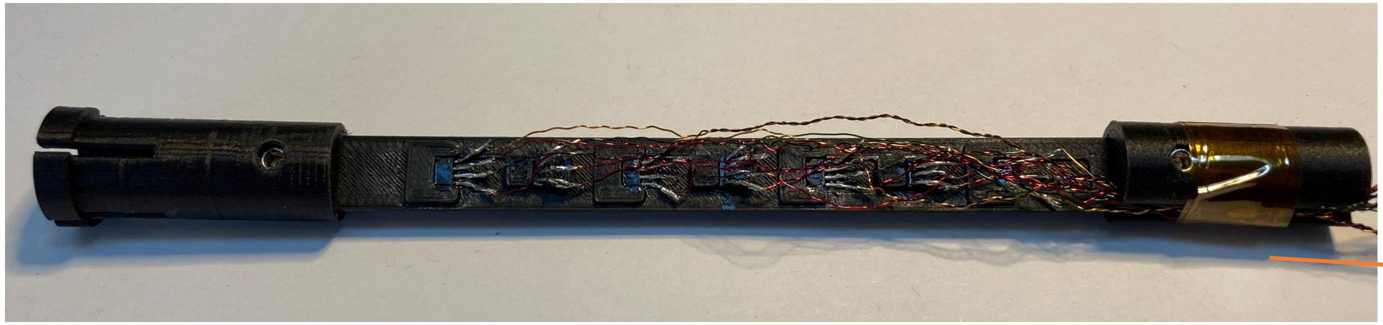
In order measure the magnetic field inside the SC-shielded tube; 3D designed and printed a Hall Sensor Support system that fulfilled the following requirements:

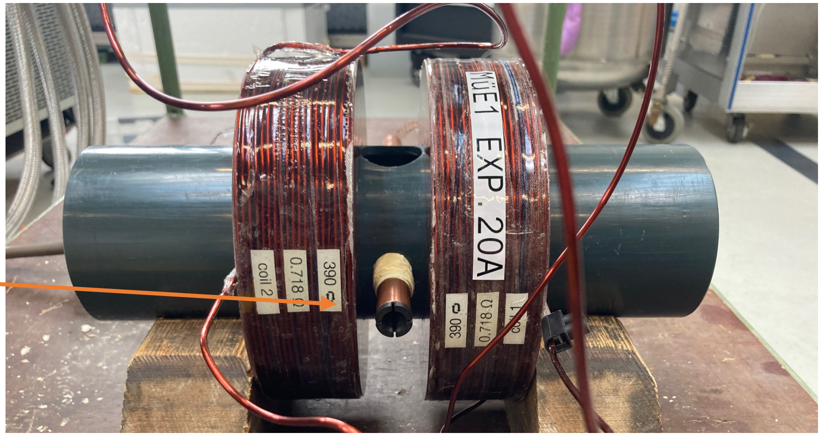
- ✓ Cryogenic-proof material, Onyx.
- ✓ The support remaining fixed inside the SC-tube ➡ 7 sensor slots (4 horizontal, 3 vertical).





- ➢ Glued and soldered seven Toshiba THS119 Hall Sensors on the support system.





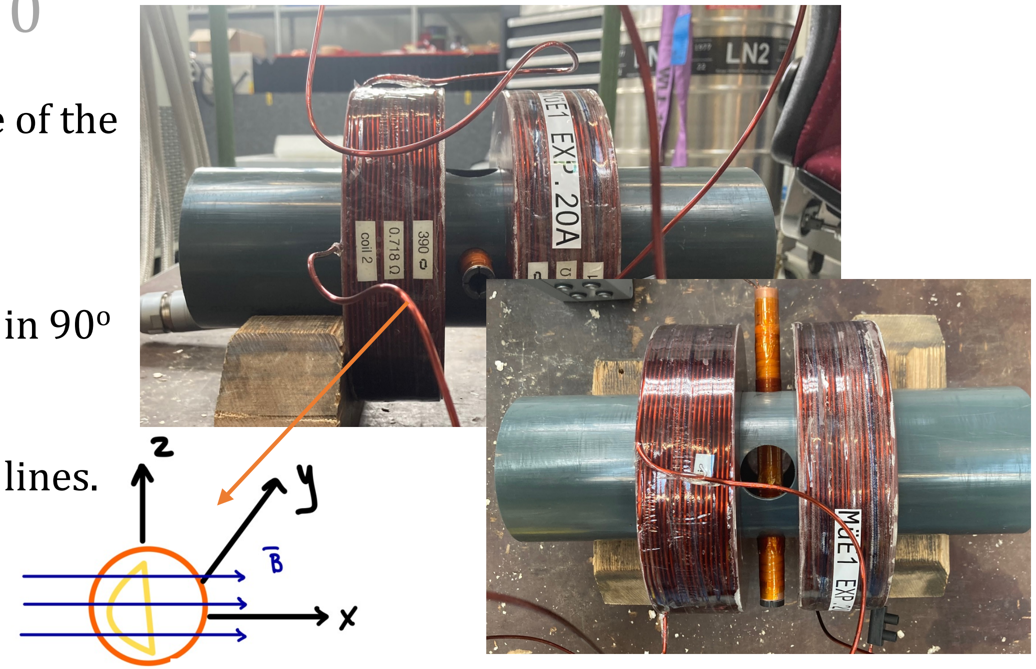
Testing the SC-Shieled Injection Tube, Prototype 0

First measurements taken at **<u>room temperature</u>** along the injection plane of the SC-tube, Prototype 0.

➢ Coils connected in parallel.

The Hall Sensor support was centered inside the SC tube and was placed in 90° angle:

✓ Horizontal sensors facing the opposite direction of the magnetic field lines.

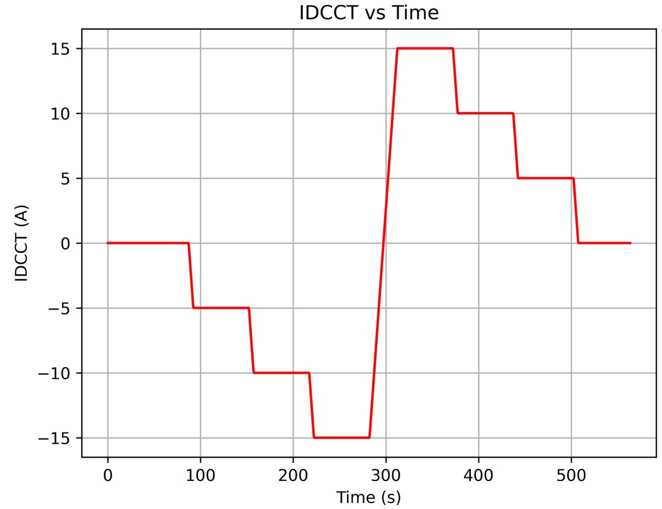


Measurement Plan:

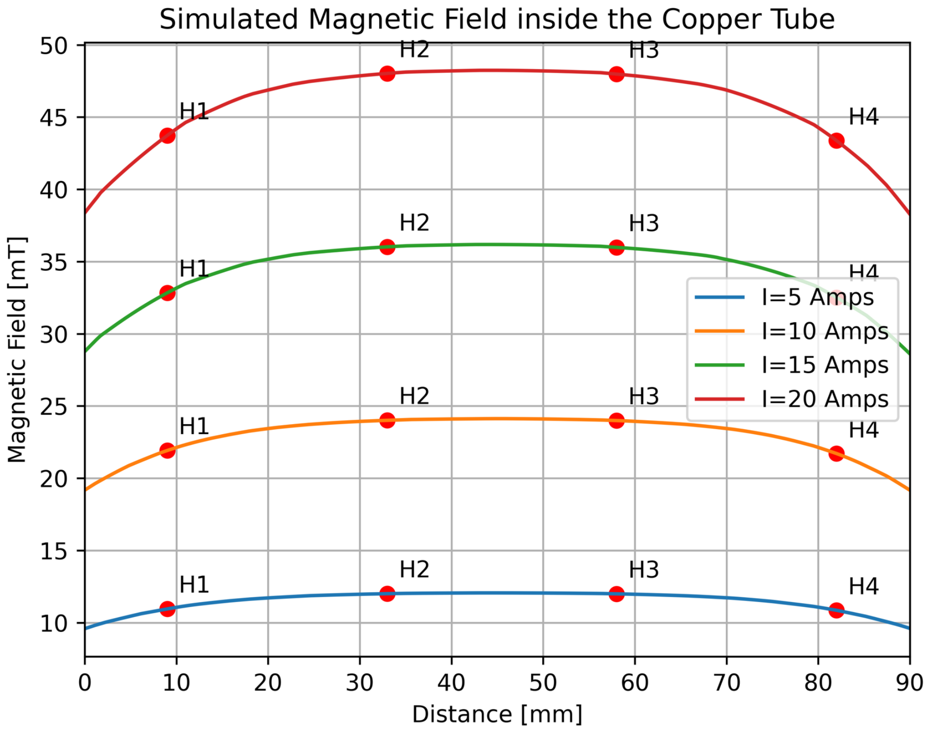
- Ramping up the magnetic field with 1Amps/s ramping up rate.
- Plateue at the following current I=-5, -10, -15, 15, 10 and 5 Amps for 60 seconds each.

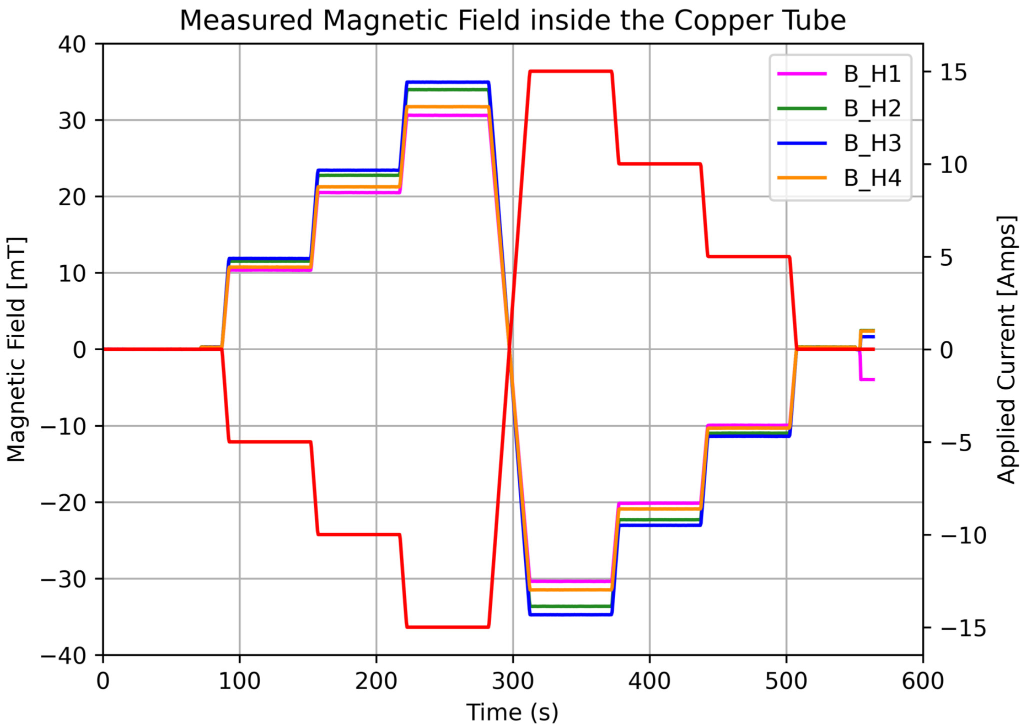
<u>Note</u> At Room Temperature measurements we don't induce 20 Amps;

➢ Overheating of the Coil



Testing Prototype 0, Room Temperature





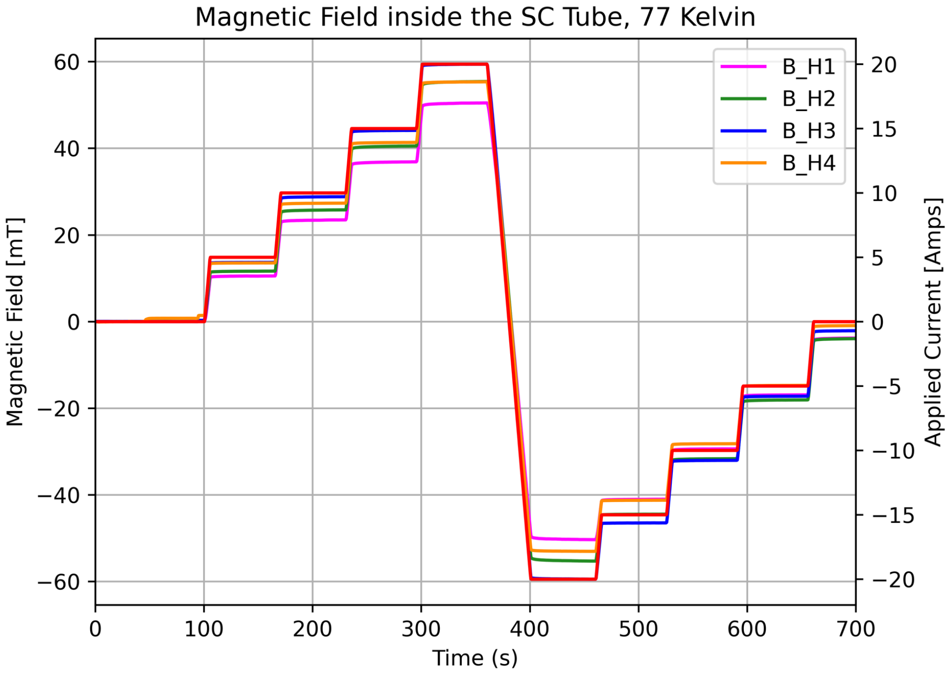
- For I= 15 Amps :

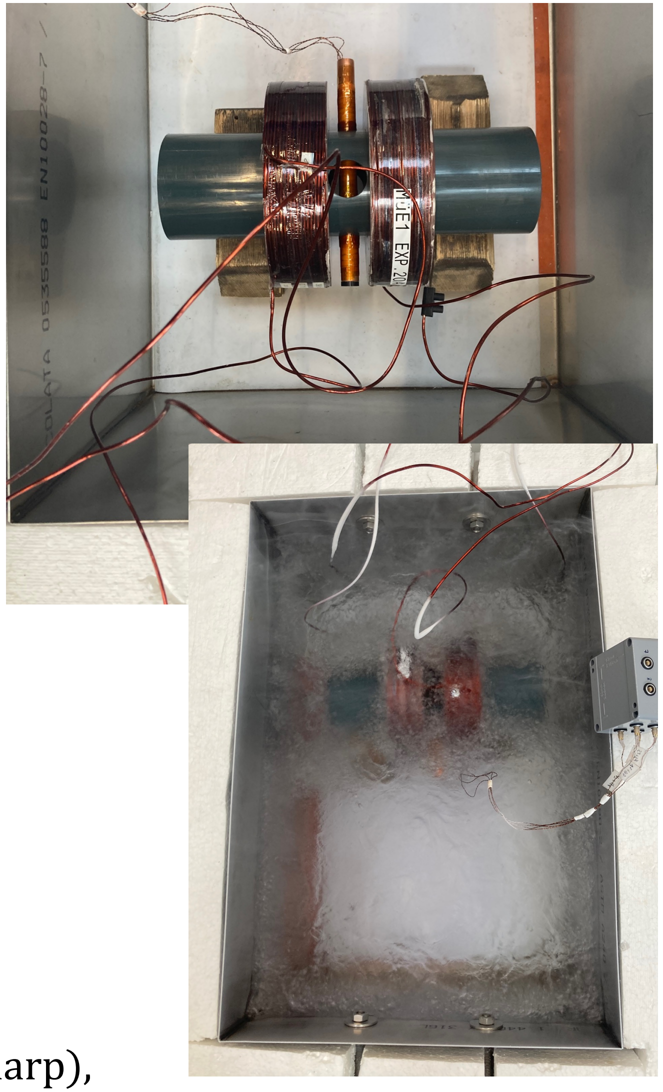
Horizontal Hall Sensor	Position [mm]	Simulated Magnetic Field [mT]	Measured Magnetic Field [mT]
H1	9	32.83	30.59
H2	33	36.02	33.96
H3	58	35.98	34.93
H4	82	32.51	31.72

Testing Prototype 0, Cryogenic Temperature

The system, Helmholtz Coil and SC-tube, was submerged in a cryogenic bath filled with LN_2 (77K).

- ➢ Ramping up the magnetic field with 1Amp/s, ramping up rate, up to I=20 Amps, induced current.





- ➢ The **Prototype 0** did not superconduct, although we can observe curved plateus (not sharp), indicating the existance of eddy currents.

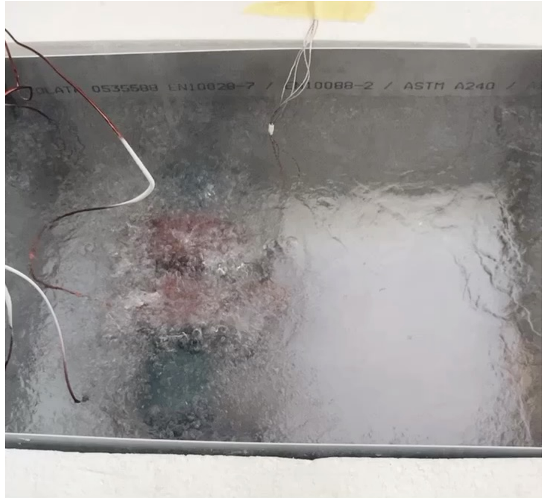
Conclusion

- ➢ A superconducting shielded channel is needed for the injection of muons from the exit of the πE1 beamline, low fringe field, to a 3T storage magnet, high magnetic field, for the muEDM experiment.

- ➢ Three prototypes are being developed and tested in the magnetic field of a Helmholtz coil.
- ✓ Study of the SC-shielding effectiveness.

- ➢ Running first tests with Prototype 0 in room and cryogenic temperatures.

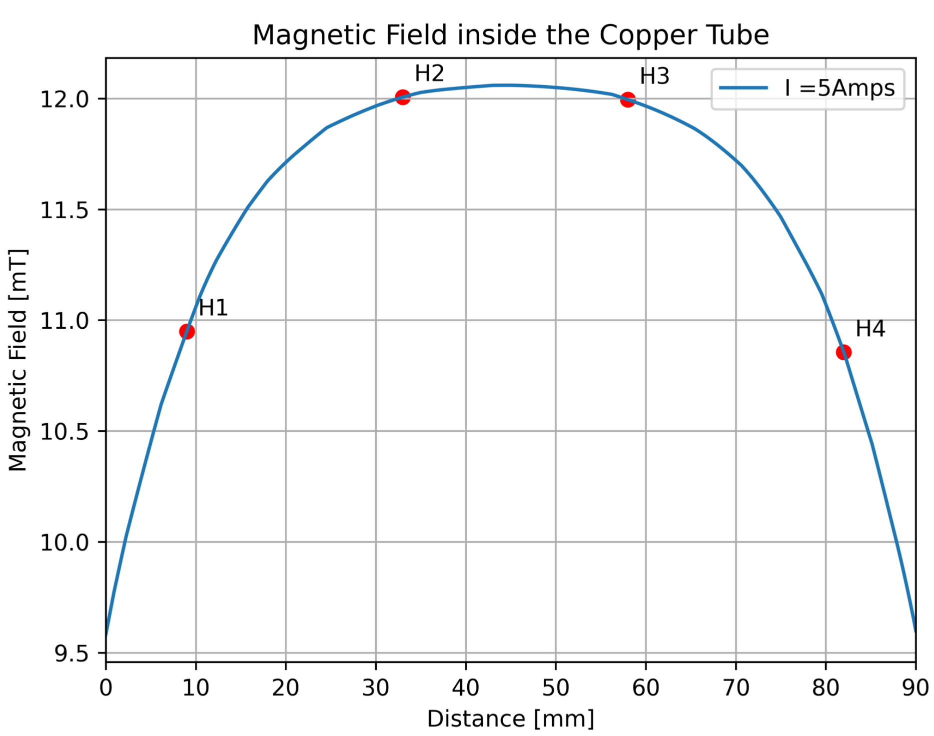
- ➢ <u>Next Steps</u>: Study the shielding efficiency as a function of :
- ✓ Different ramping up rates of the applied magnetic field.
- ✓ Different coiling/mounting techniques and layer numbers of the SC-shield.

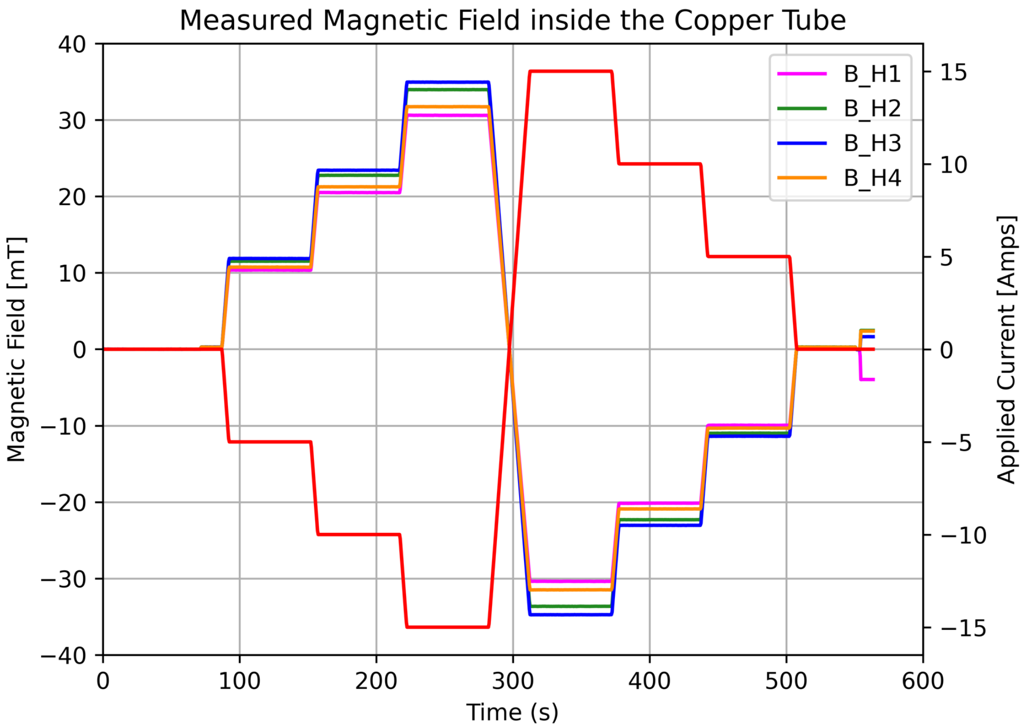


Thank you for your attention!

Backup Slides

Testing Prototype 0, Room Temperature, I=5 Amps

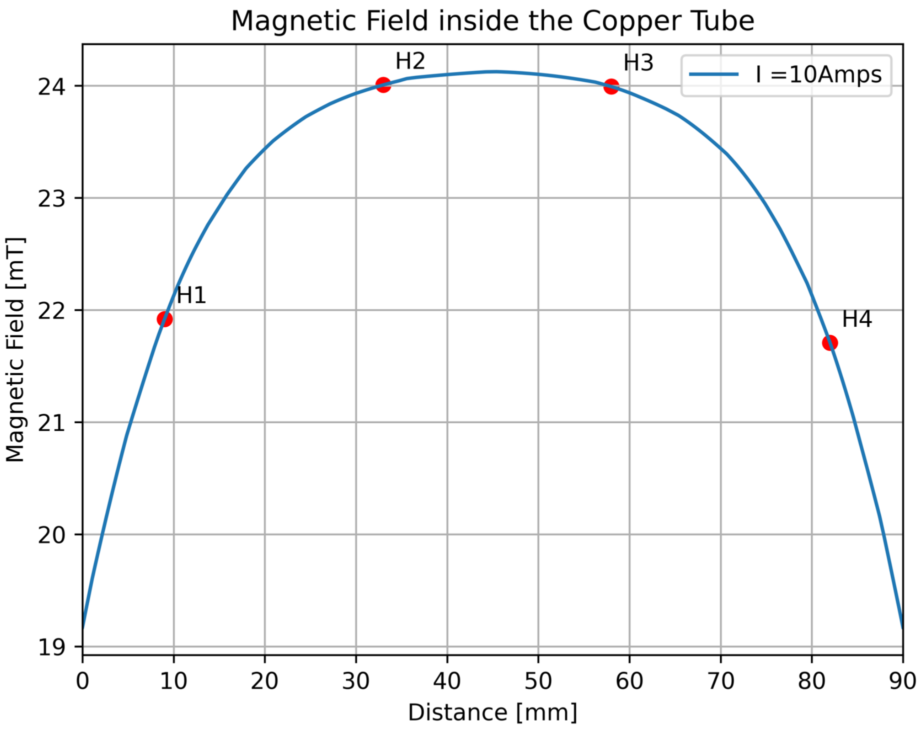


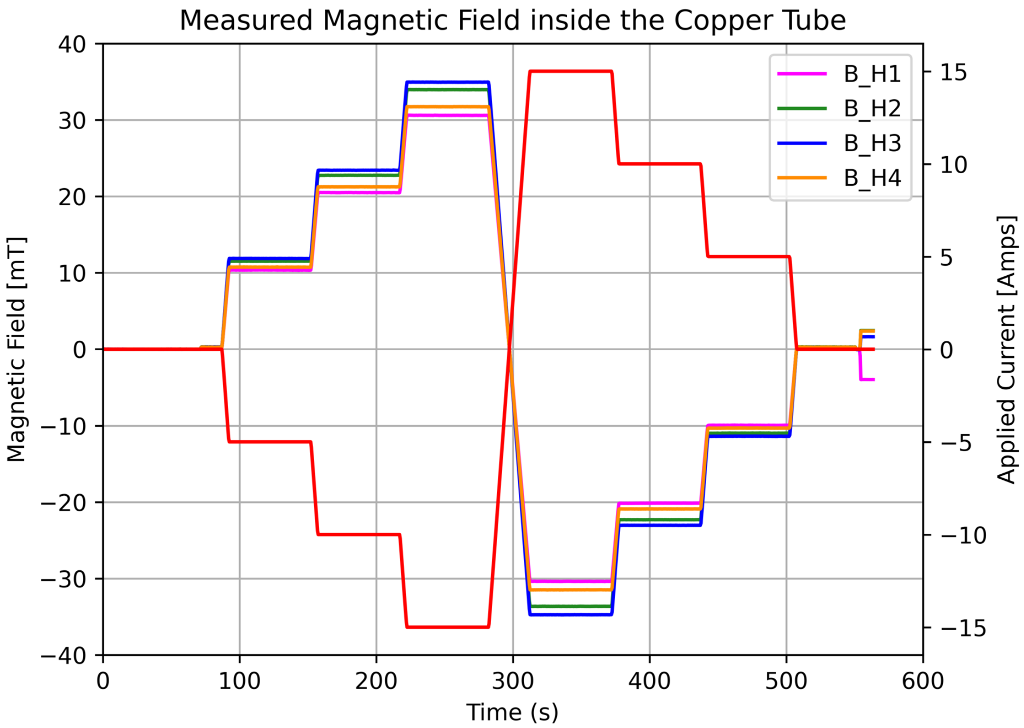


- For I= 5 Amps :

Horizontal Hall Sensor	Position [mm]	Simulated Magnetic Field [mT]	Measured Magnetic Field [mT]
H1	9	10.95	10.36
H2	33	12.00	11.51
H3	58	11.99	11.87
H4	82	10.86	10.74

Testing Prototype 0, Room Temperature, I=10 Amps

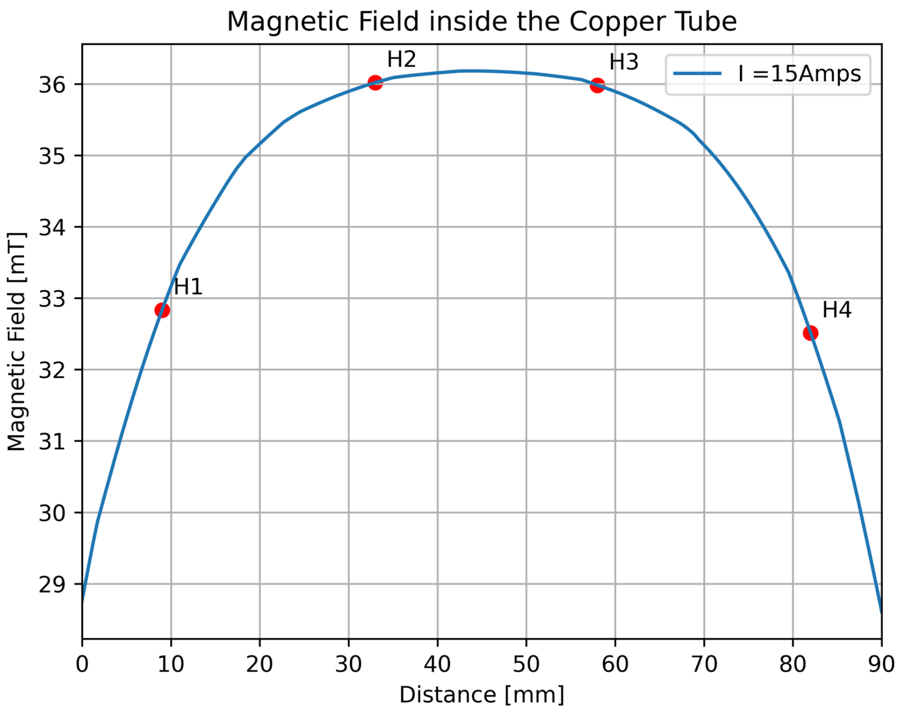


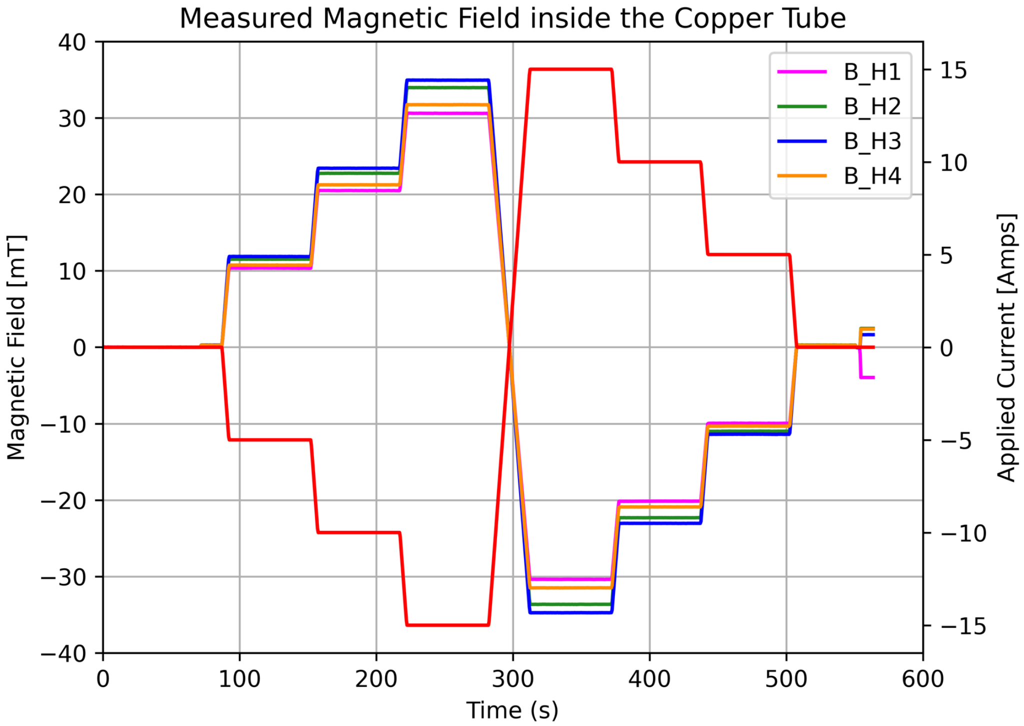


- For I= 10 Amps :

Horizontal Hall Sensor	Position [mm]	Simulated Magnetic Field [mT]	Measured Magnetic Field [mT]
H1	9	21.92	20.49
H2	33	24.00	22.75
H3	58	23.99	23.41
H4	82	21.71	21.24

Testing Prototype 0, Room Temperature, I=15 Amps





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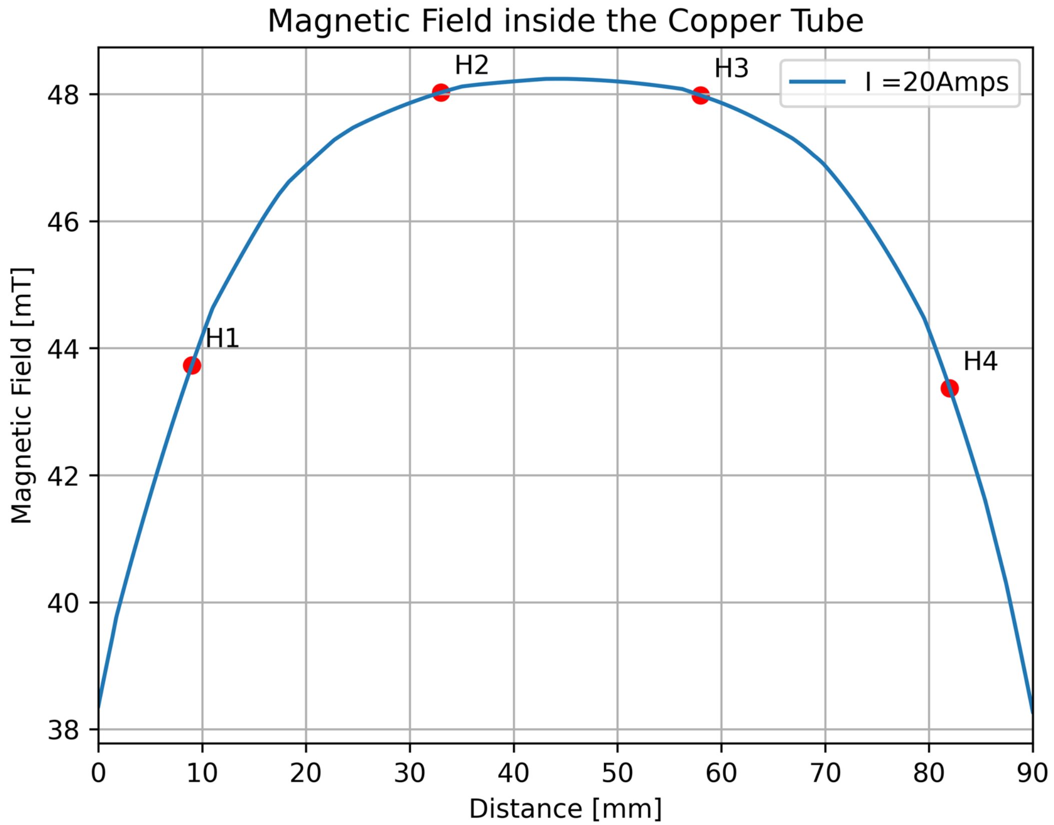
Testing Prototype 0, Room Temperature, I=20 Amps



- For I= 20 Amps :

Horizontal Hall Sensor	Position [mm]	Simulated Magnetic Field [mT]
H1	9	43.73
H2	33	48.03
H3	58	47.98
H4	82	43.37

Different Ramping up Rates in Cryogenic Temperatures