PSI Center for Accelerator Science and Engineering

Energy Saving Magnets

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PSI – Magnet Section, 31st July 2024.

Resistive Transport Solenoid

Length 30 cm.

100kCHF magnet costs (Gabard and Serguei).

4000 hours per year.

14kW per MuH3 coil, 2(3?) coils, and 16kW per MuH2 coil, 7 coils, assuming the coil is at 60 degrees Celsius.

13-15kCHF electricity costs per year.

Superconducting Transport Solenoid (1)

Startup costs (based on P3, Jaap Kosse):

Type	Cost / CHF	Notes
Cryostat	119500.00	
Vac and Cryo	50500.00	
Power Supply	52500.00	
Instrumentation	31066.00	
Installation	30000.00	From PSI itself
Total	283566.00	
Contingency 15%	326100.90	
Without Power Supply and installation	210566.00	
Contingency 15%	242150.90	

240kCHF = Startup cost

Superconducting Transport Solenoid (2)

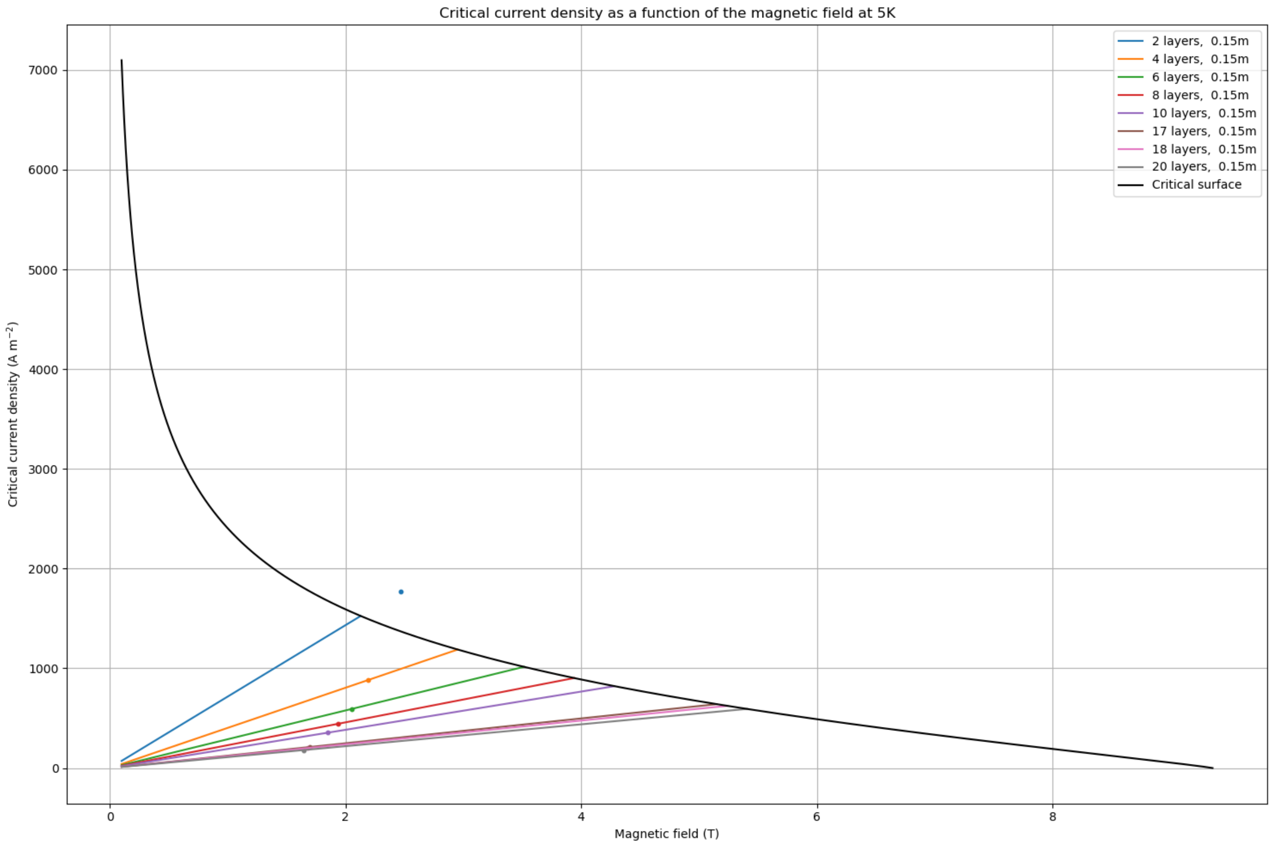
Length 15 cm.

Inner diameter 0.65 m.

138 turns per layer, up to 20 layers considered.

Maximum field about 2T.

Field profile to be checked by the beam dynamic colleagues .

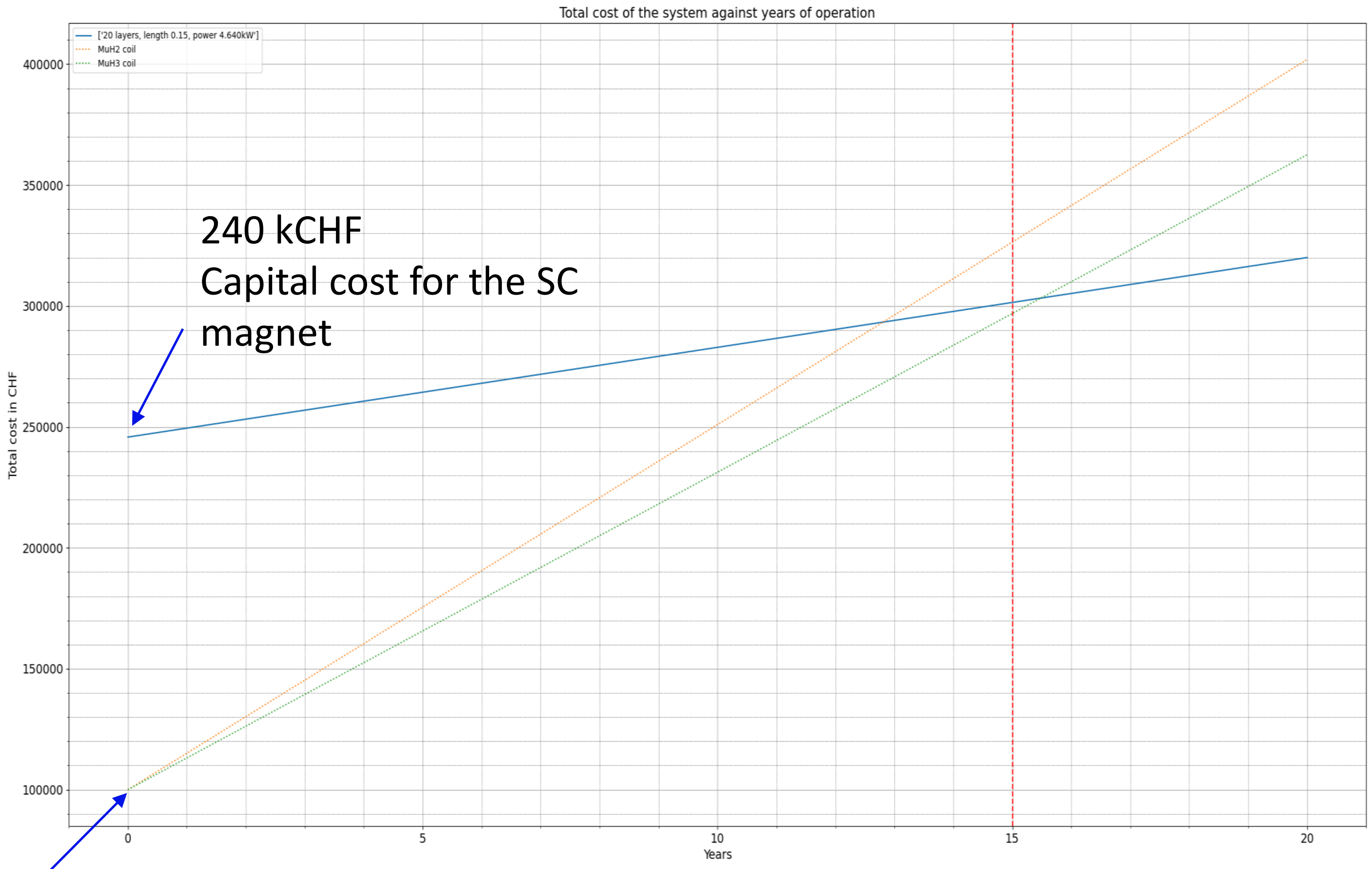


Economical Study: return of investment for 1 magnet

- Assumptions:
  - 0.20 CHF / kWh electricity cost (PSI data).
  - 4000 hours annually.
  - 35-45GWh saved annually.
  - CO2: 100g / kWh

  (Electricity Maps | Live 24/7 CO_2 emissions of electricity consumption)
  - 100A, 5V power supply.
- Break even in 13 years,
- ~ 4.6kW power consumption.
  - 3.6 kW cryocooler
  - 0.5 kW power supply
  - 0.5 kW vacuum system

- 90 tonnes of CO2 saved.



100 kCHF
Capital cost for 1 resistive transport solenoid

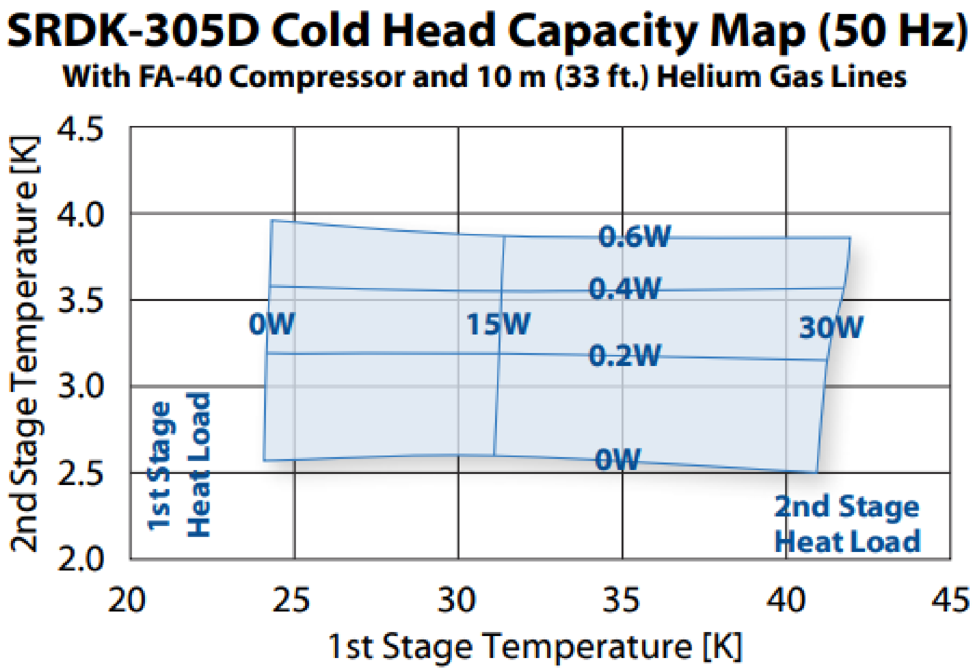
Heat budget

PSI

Heat budget	P [W]			
1st stage				
100 A Current leads	9.6			
Structural Support	1.2			
Thermal Radiation	1.6			
Sensor wires	0.3			
neutron dose	?			
Tot.	12.7			
2nd stage 2nd solenoid	P [W]		2nd stage 3rd solenoid	P [W]
HTS leads	0.04		HTS leads	0.04
Structural support	0.12		Structural support	0.12
Thermal radiation	0.13		Thermal radiation	0.13
Sensor wires	0.15		Sensor wires	0.15
neutron dose (Vadim)	0.17		neutron dose	0.007
Tot.	0.61		Tot.	0.45

Candidate cryocooler RDK-305D, 3.6kW

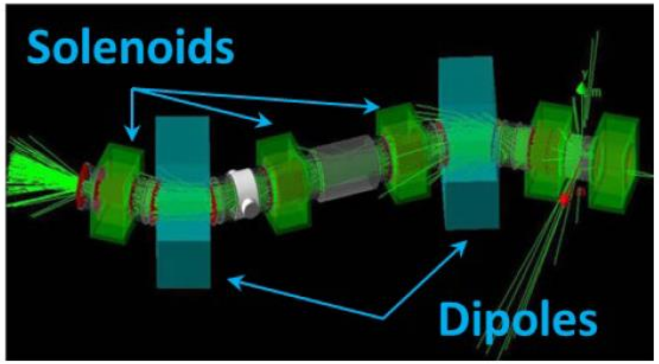
New generation compressors (with inverter) from Sumitomo?



Radiation Damage and integrated dose

Table: Maximal absorbed dose rate in the coils of the MUH2 magnets.

	m, kg	Gy/s
Dipole, 1st	41.1	8.08E-01
Solenoid, 1st	43.1	7.96E-01
Solenoid, 2nd	43.1	4.22E-03
Dipole, 2nd	41.1	5.85E-04
Solenoid, 3rd	37.9	1.71E-04



Vadim Talanov

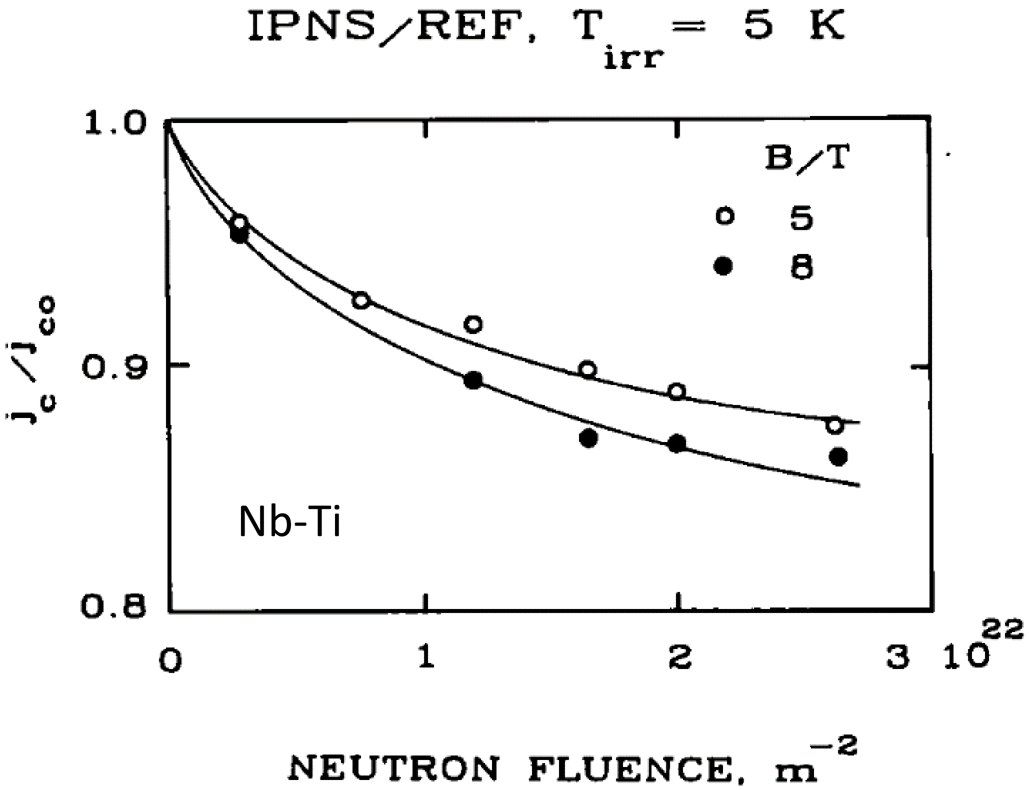


Fig. 2. Change of critical current densities with fast neutron fluence ($E > 0.1$ MeV) at 5 and 8 T. Conductor S-300-1 (used for the Swiss LCT-magnet).

Simulation of fusion reactor conditions for superconducting magnet materials - ScienceDirect

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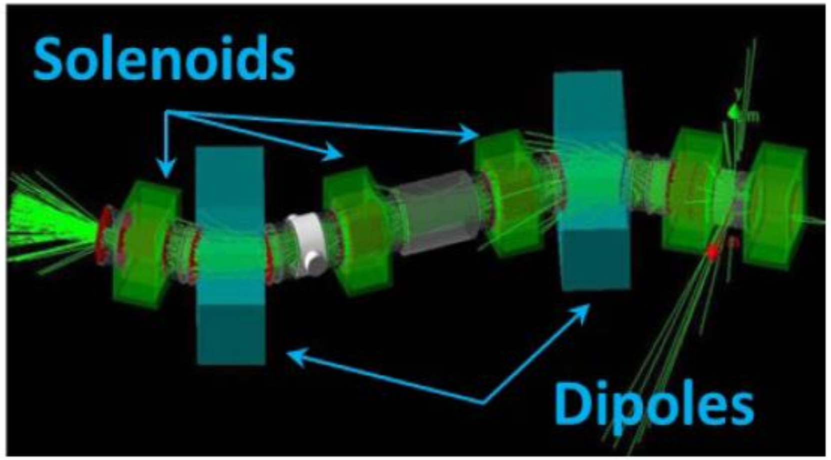

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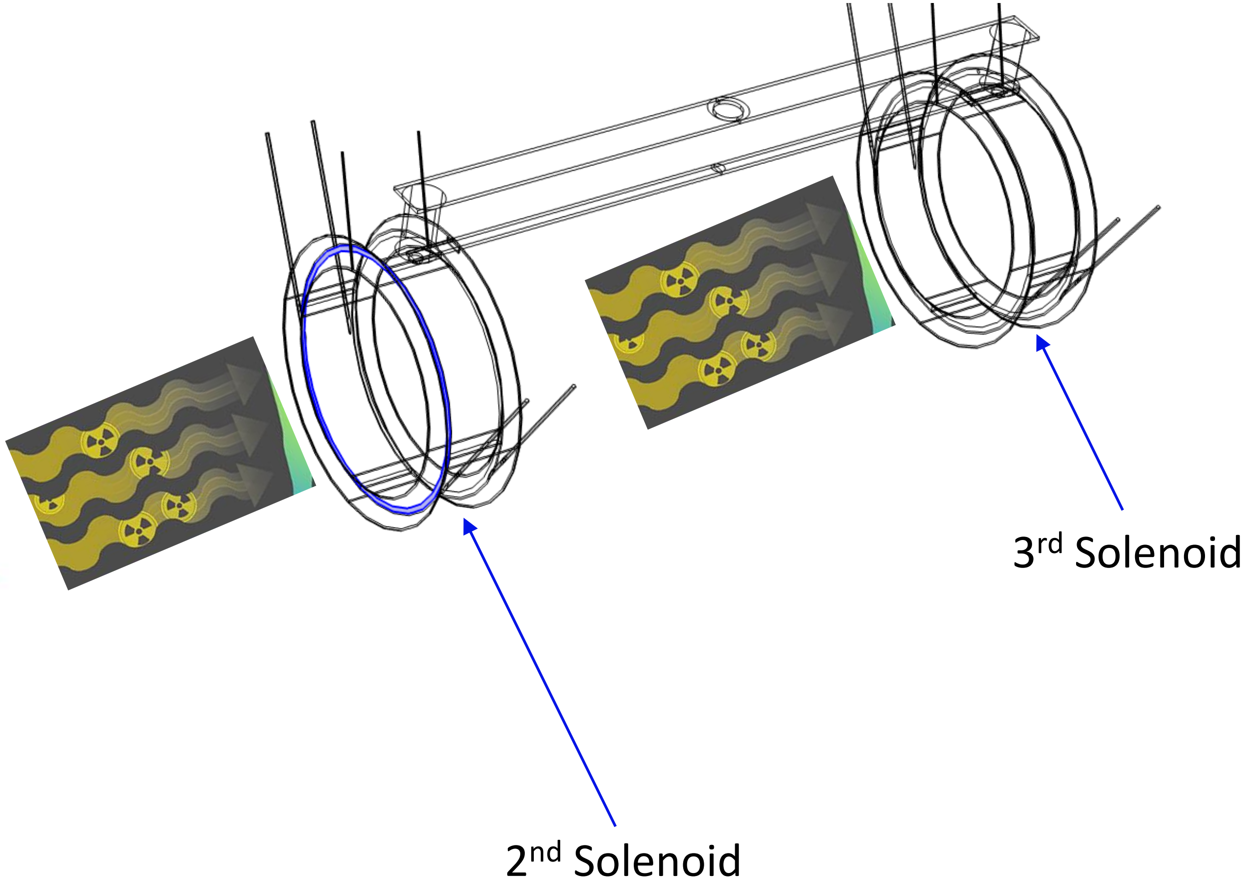

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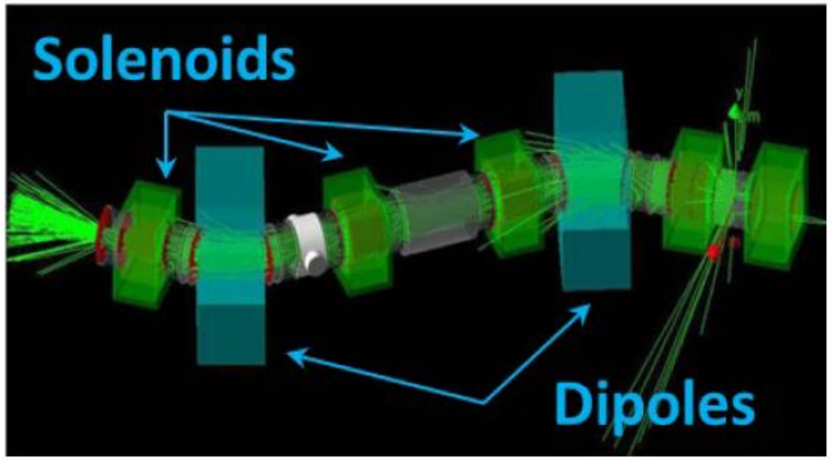
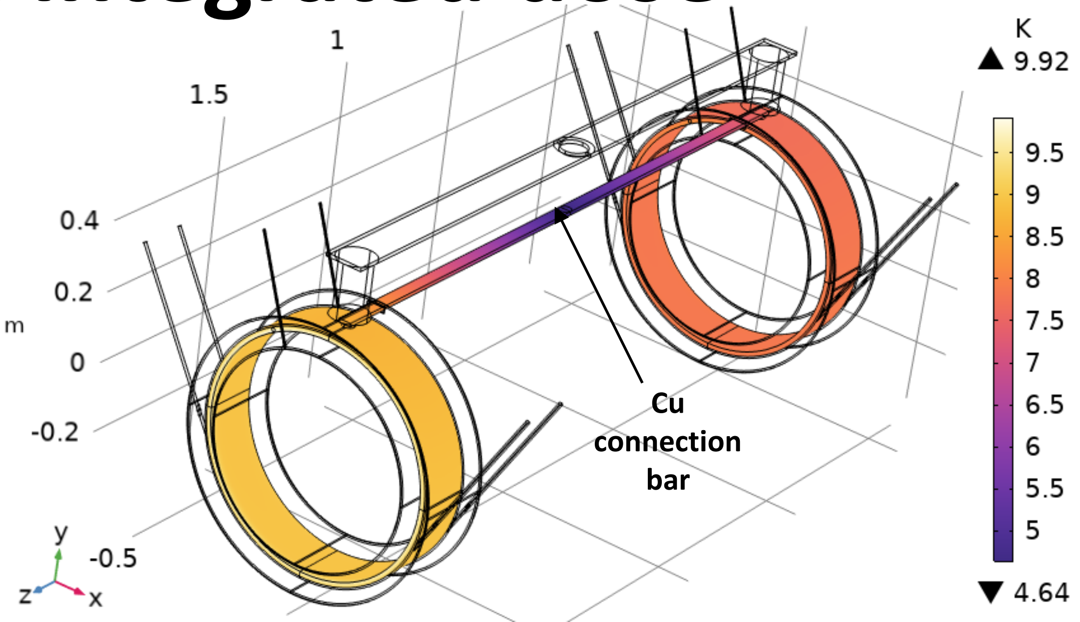
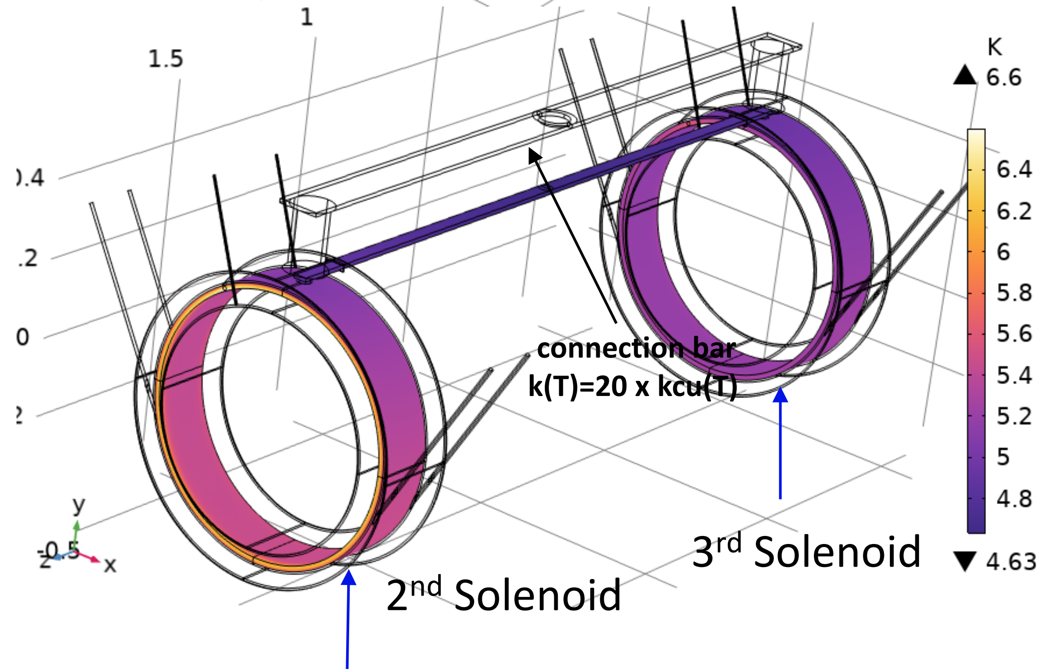


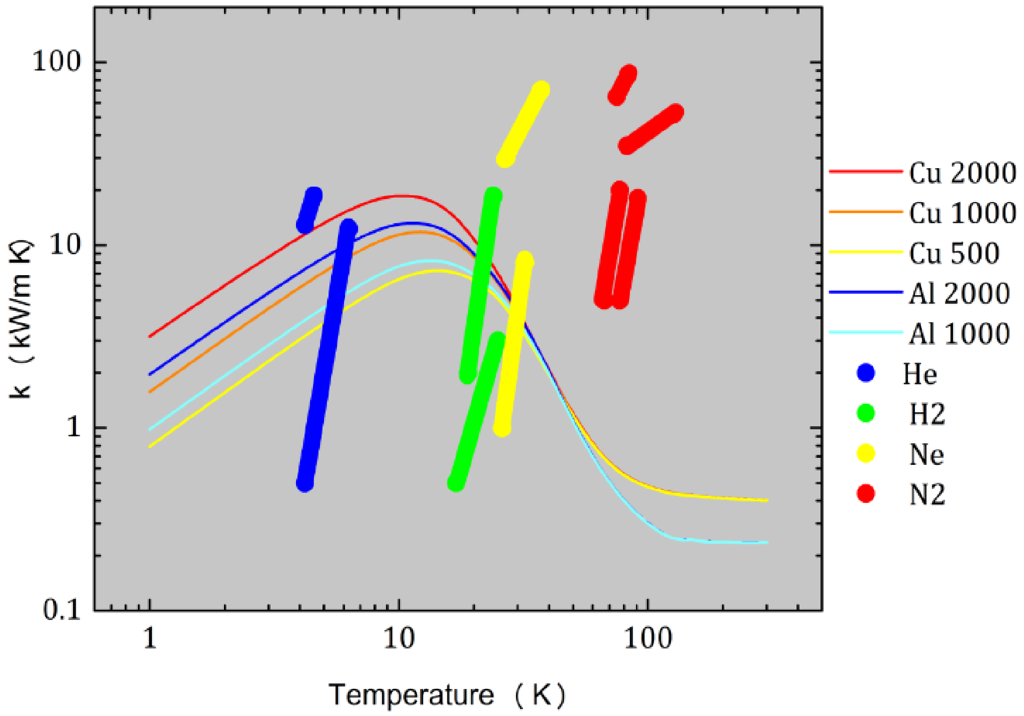


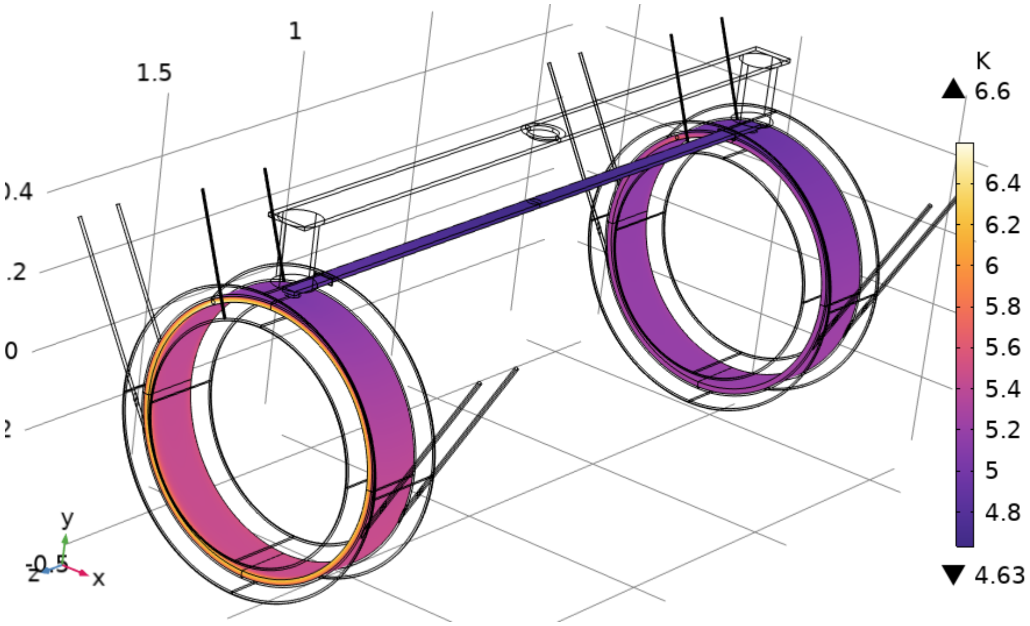


PHP – Pulsating heat pipe

Use PHP to thermally bridge two magnets.

Inter-solenoid distance varies, for MuH2 have 1.23 m, 1.23 m, 1.9 m, 2 m, 1.33 m.





Bertrand Baudouy

Conclusions / Questions / Comments

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- A crucial point for the project is the knowledge of the radiation environment in which we want to work.
  - We need detailed calculation of the neutron fluence in the different magnet components.
- We started by Nb-Ti mainly for its low cost (and what about its high radiation resistance??).
- We are open to exploring other superconductors: MgB2, ReBCO.
- We look for efficient ways to cooling systems for both single magnets and series of magnets.
  - Thermal link --> Pulsating heat pipe, heat pipe, thermosiphon…
  - Cryocooler+inverter

Radiation Damage - REBCO

Supercond. Sci. Technol. **31** (2018) 044006

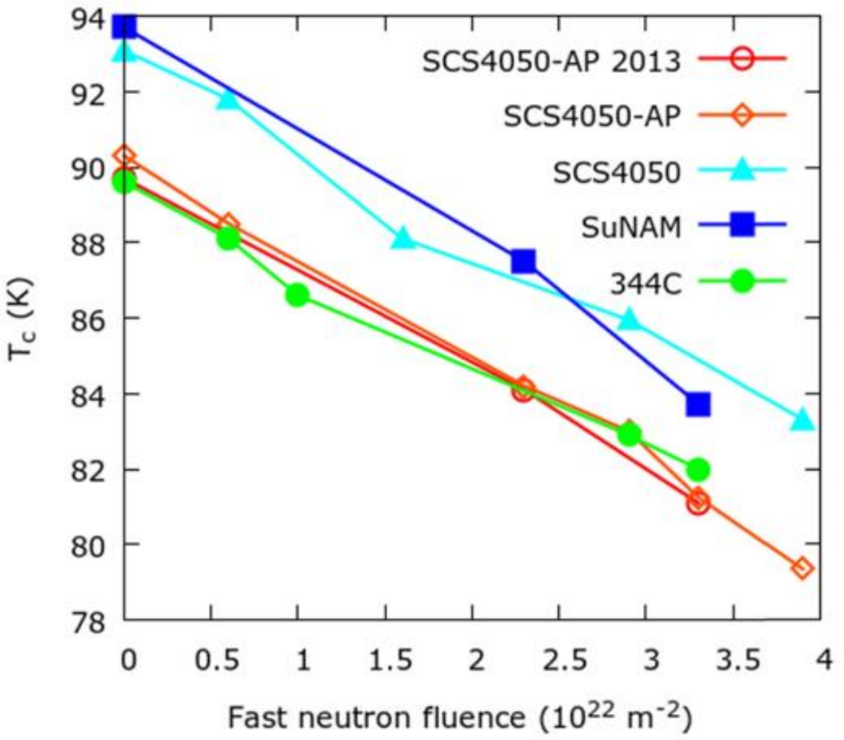

Figure 3. Fluence dependence of the critical temperature in various coated conductor tapes.

Neutron fluence affect on the critical surface of REBCO.

[The effect of fast neutron irradiation on the superconducting properties of REBCO coated conductors with and without artificial pinning centers - IOPscience]()