PAUL SCHERRER INSTITUT

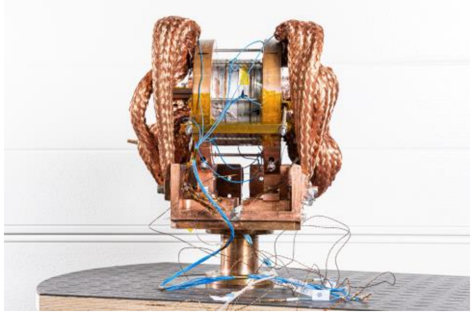
PSI

CHART

Swiss Accelerator Research and Technology

Jaap Kosse, Bernhard Auchmann, Michal Duda, Jeroen van Nugteren, Stephan Mueller, Henrique Rodrigues, Stephane Sanfilippo

HTS solenoids at PSI



Work supported by the Swiss State Secretariat for Education, Research and Innovation SERI

12/10/22

CHART2 MagDev @ PSI

"Swiss Accelerator Research and Technology – CHART" is a Swiss research network with PSI as a host institute and CERN, EPFL, ETHZ, and UniGE as additional members (http://chart.ch)

CHART2 MagDev at PSI:

1) – creates magnet-development infrastructure
   – LTS (Nb3Sn) technology development for the internat. high-field magnet project
   – HTS (REBCO) superbend demonstrator
   – bulk-HTS (REBCO) undulators
2) – HTS capture solenoid for a positron source

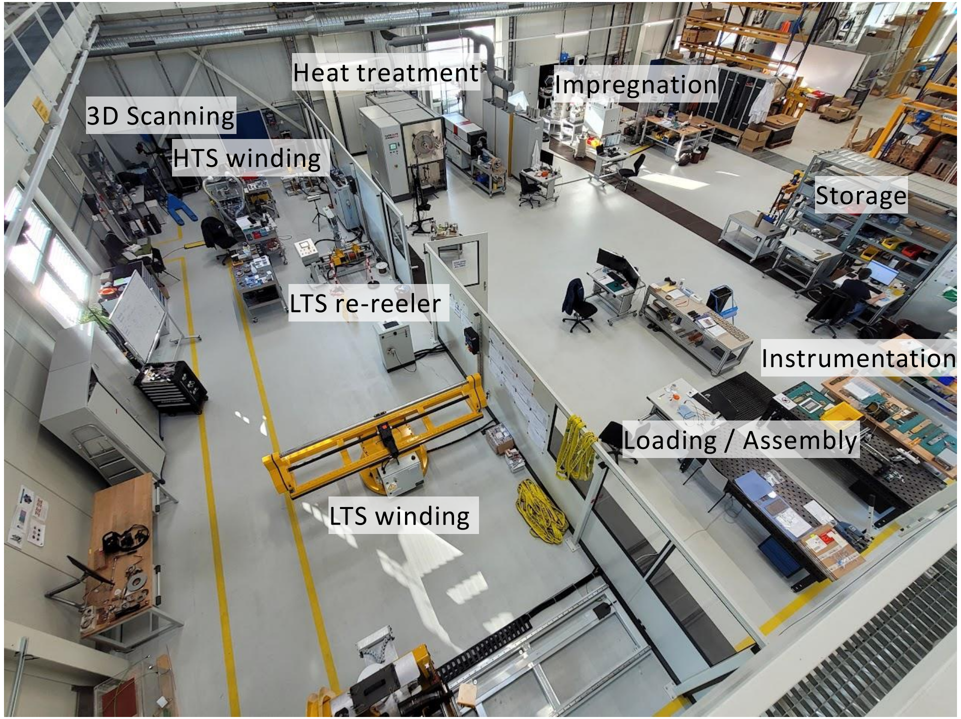
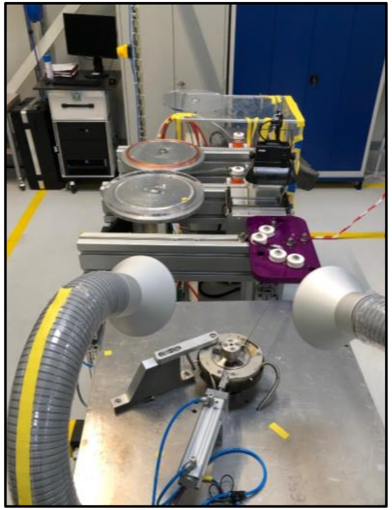


CHART2 MagDev: Technology Solenoid Program

Rapidly develop infrastructure for HTS coil manufacturing and testing via NI coil technology license agreement with Tokamak Energy

tokamak energy
a faster way to fusion

Winding



Tensioning system developed by Francois-Olivier Pincot, Jacky Mazet, CERN

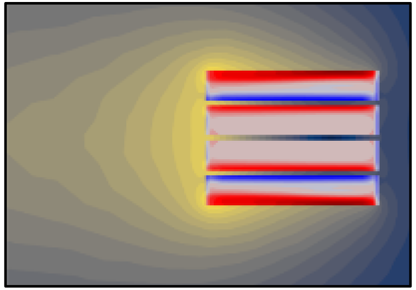
Soldering

Pre-tinning support by Davide Uglietti, PSI

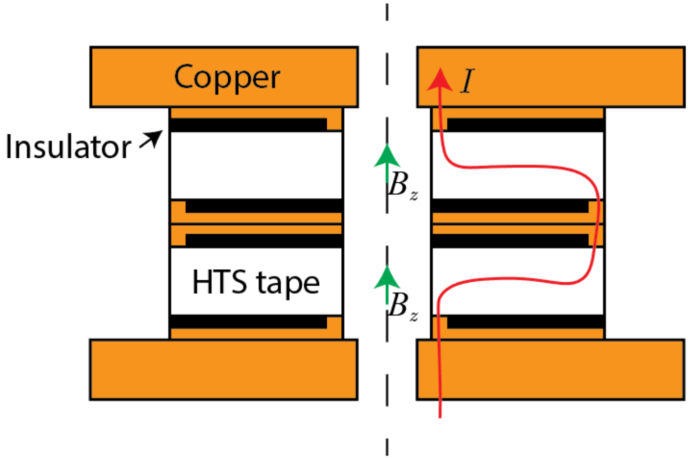
Testing

Cryogen-free test station (2 kA)

Modeling



NI HTS Technology Solenoid



Stacked, single layer pancakes

Axial joints

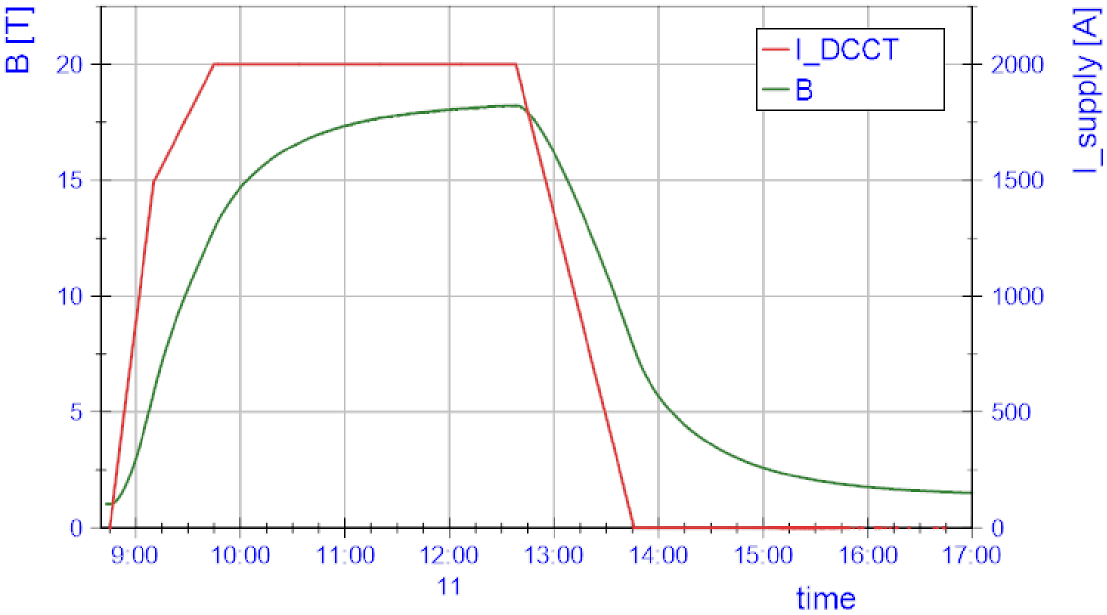
4 coils, 12 mm SuperOx tape

Solder-potted coils

r_i 25 mm

r_o 50 mm

18 T by 4 stack at 2 kA, 12 K

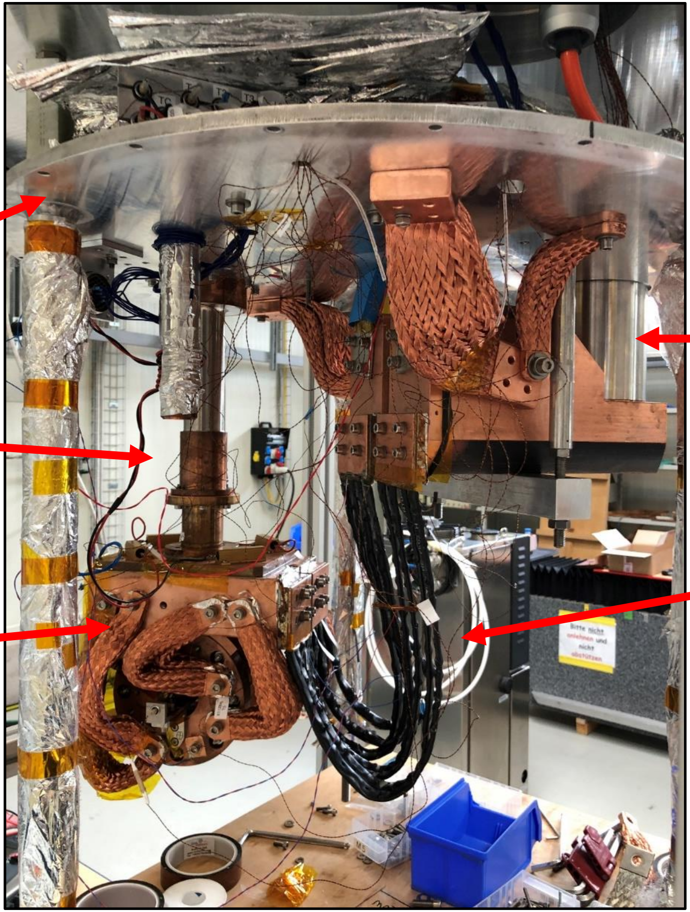


Cryogen-free test setup

radiation shield top plate

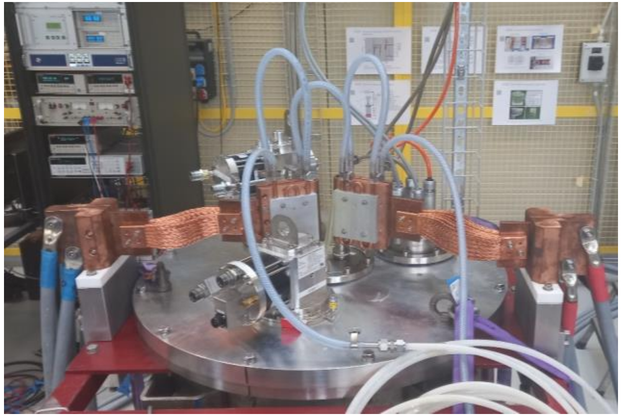
1st cryocooler 4K coldhead

stack of 4 NI HTS coils with thermal/current connectors



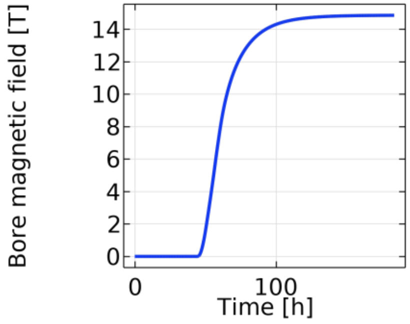
2nd cryocooler 20K coldhead

HTS leads

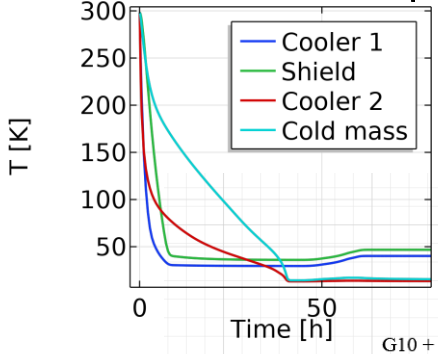


Modeling

NI charging effect



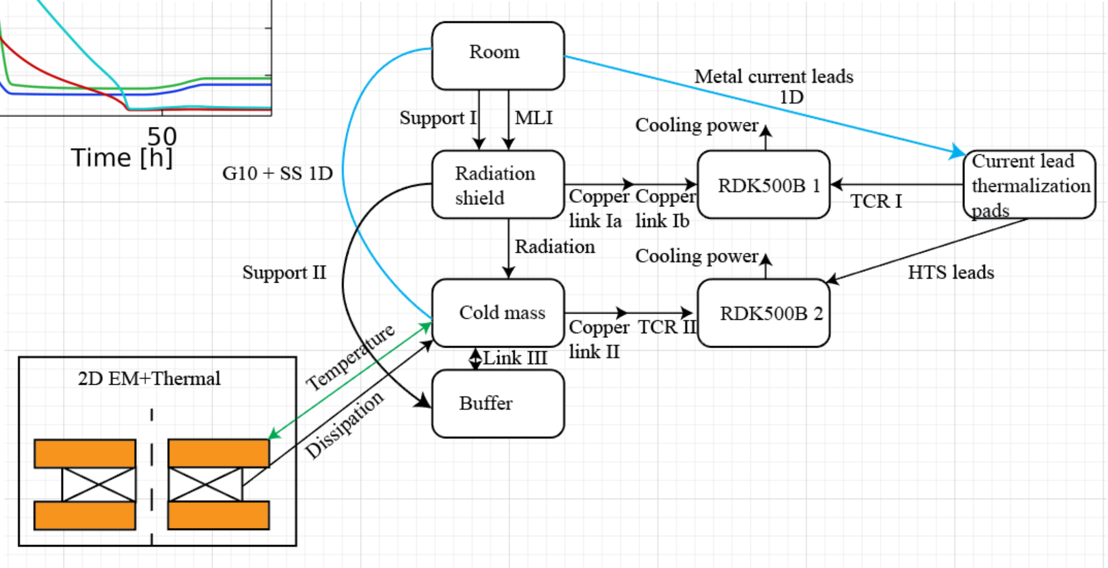
Cool-down and ramping



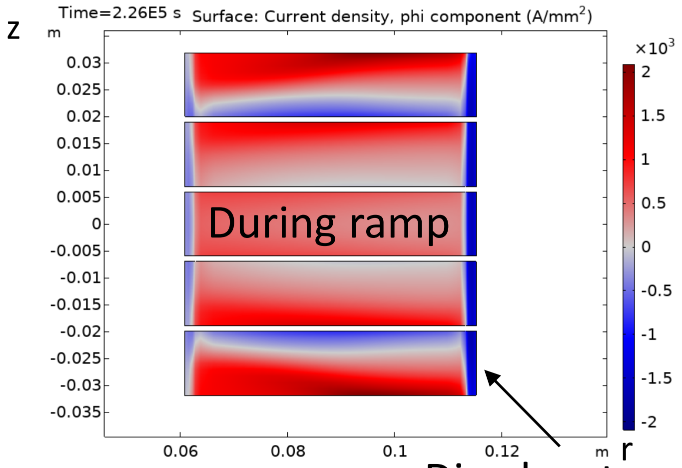
COMSOL 2D axisymmetric model

H-formulation based on [1]

coupled with thermal model



Screening currents



Disadvantage of axial joints

[1] R Mataira et al, "Finite-element modelling of no-insulation HTS coils using rotated anisotropic resistivity", 2020

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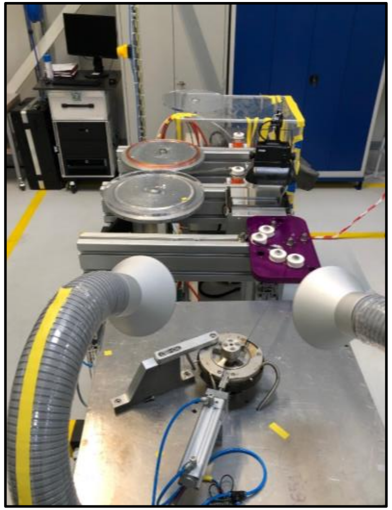

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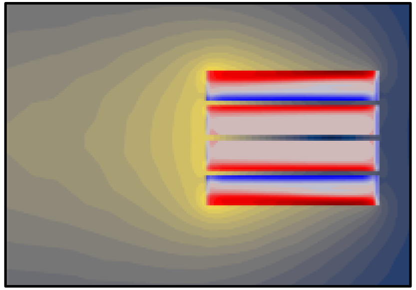
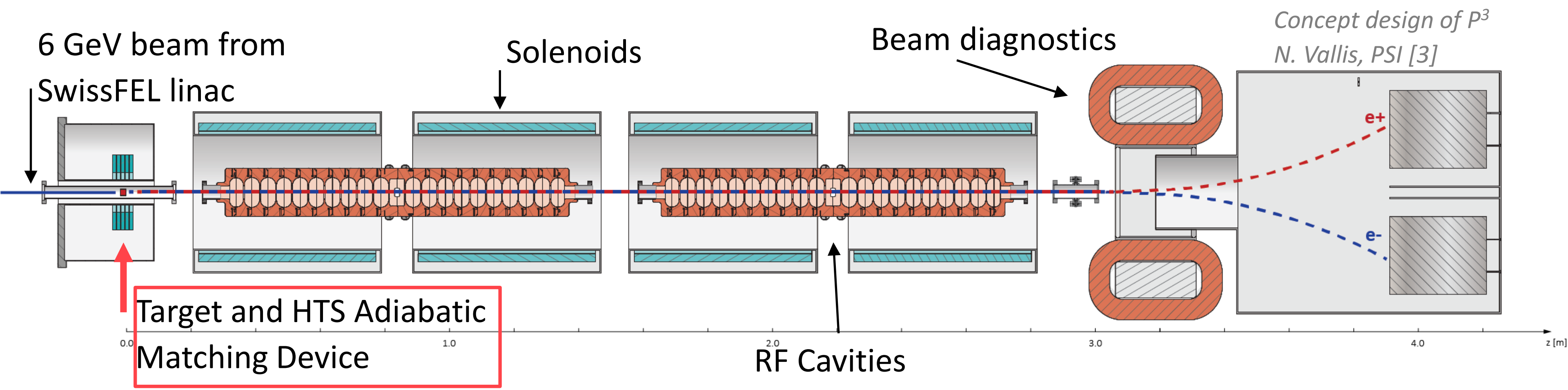
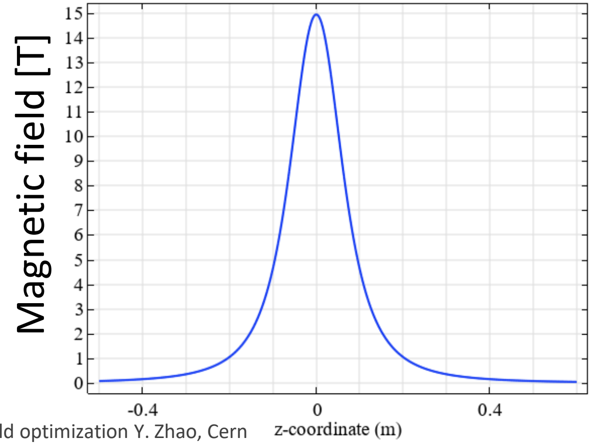


PSI Positron Production (P^3) Experiment

Goal: experimentally validate high yield in context of FCC-ee, in 2025





Yield optimization Y. Zhao, Cern

	Yield
SuperKEKB Factory (State of the art, 3 GeV) [1]	0.5
FCC-ee requirements [2]	2 (incl. safety factor 2)
P^3 simulations [3]	3 (0.4 T RF sol.)-8 (1.5 T RF sol.)

[1] K. Akai, K. Furukawa, and H. Koiso, "Superkekb collider", 2018.

[2] I. Chaikovska et al., "Positron source for FCC-ee", 2019.

[3] N. Vallis, “PSI The P^3 experiment: a Positron Source Demonstrator for FCC-ee”, 2022

NI HTS solenoid for P3

Compact DC

Radiation

NI magnet

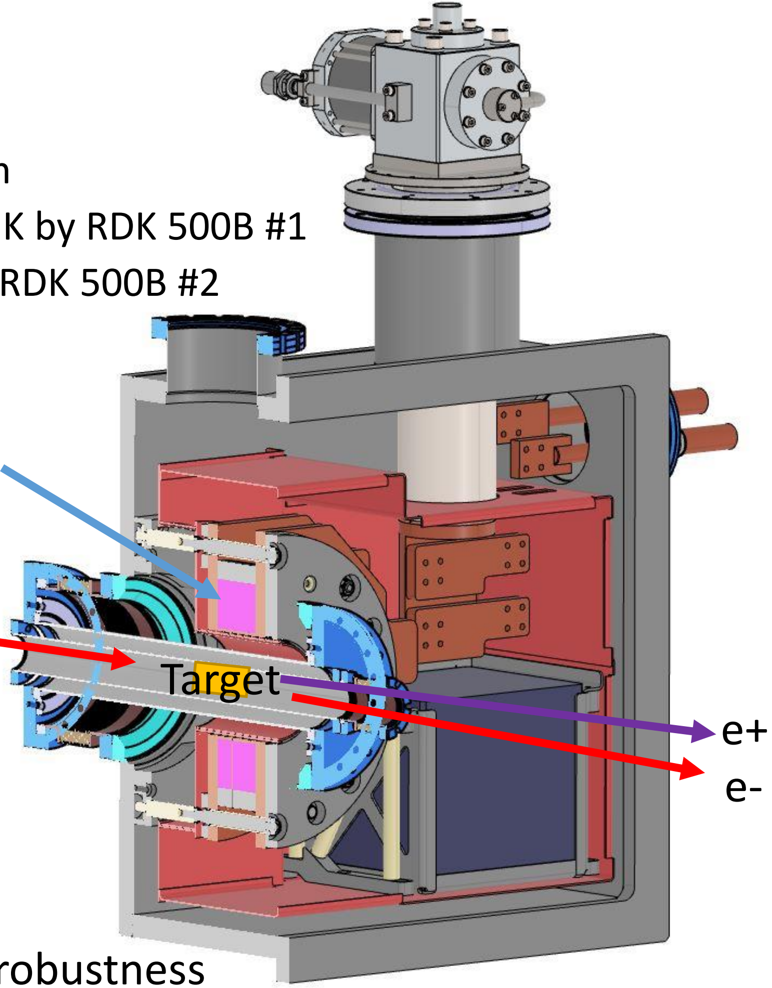
72 mm warm bore

Coil r_i/r_o 61/115 mm

Conduction cooled, 15 K by RDK 500B #1

1.2 kA leads cooled by RDK 500B #2

15 T bore, 21 T max

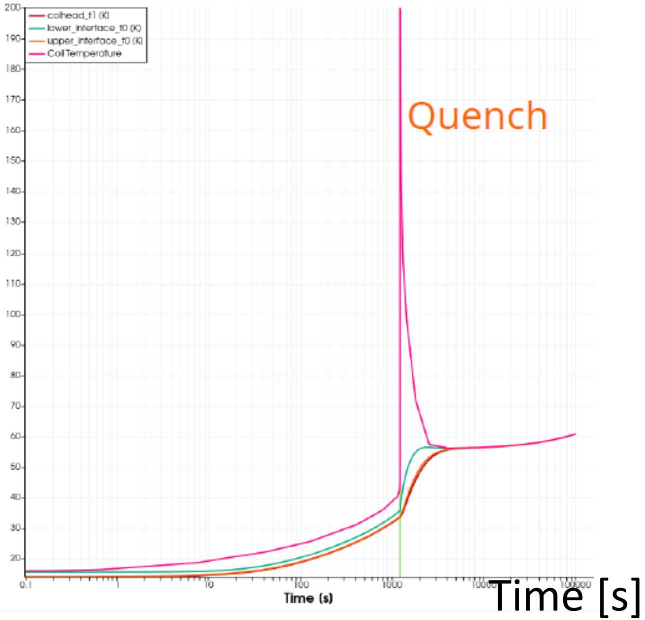


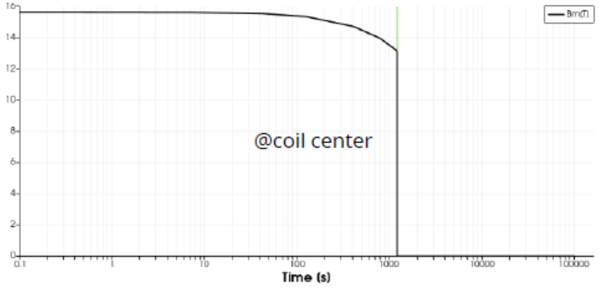
	FCC-ee	P3
Target power	13 kW	1 W
Shielding	~2 cm tungsten [1]	none

P3 experiment is unshielded & will not test radiation robustness

[1] B. Humann, CERN

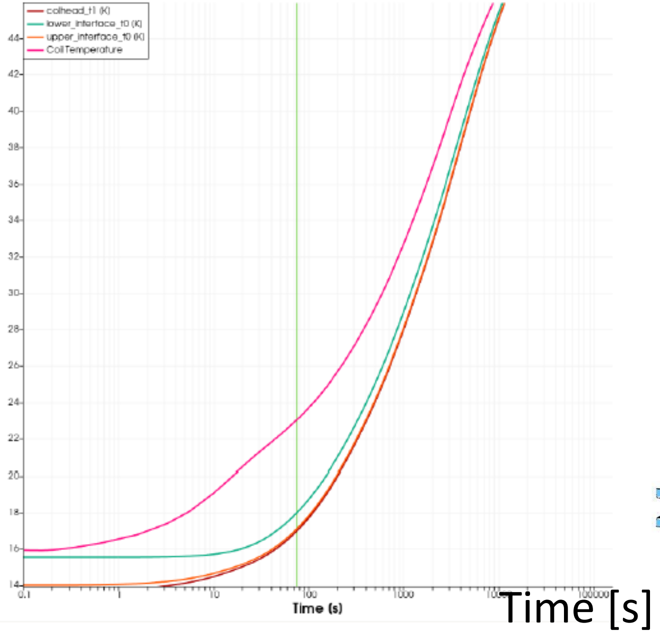
Case: HTS lead burn-out, no thermal buffer

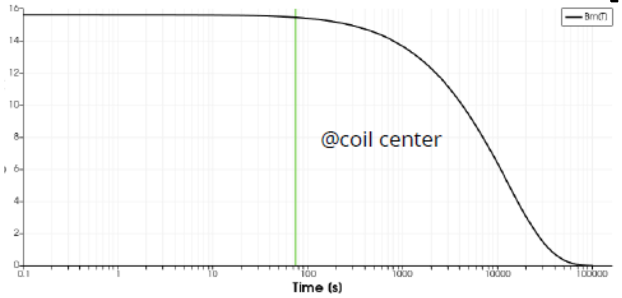




J. van Nugteren, Little Beast Engineering

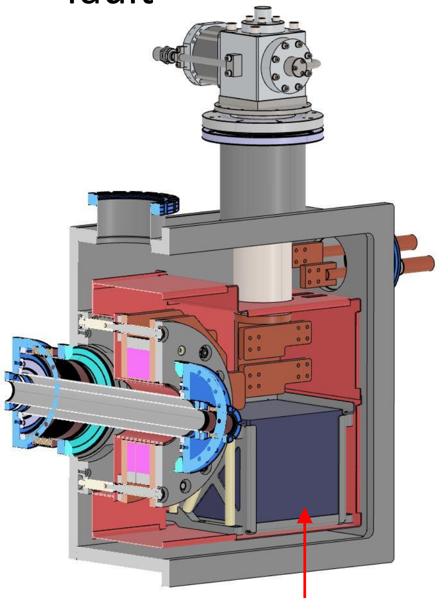
Case: HTS lead burn-out, thermal buffer





Time [s]

Rely on thermal buffer in case of fault

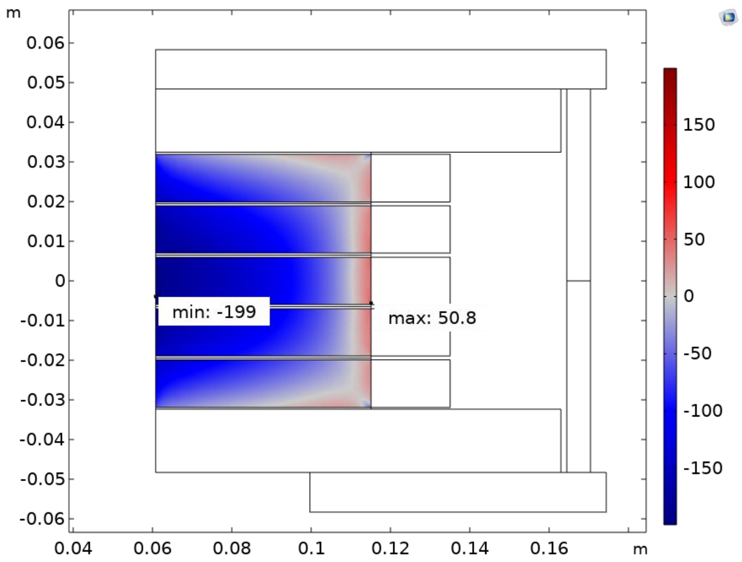


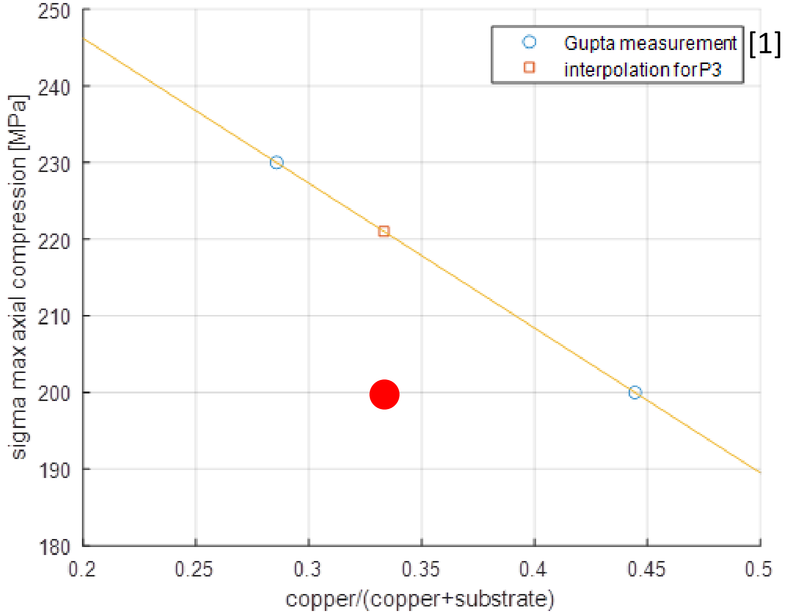
Copper/lead mass ~200 kg

Neon could work ~40 L

Main worry: axial compressive stress

σ_z [MPa]





We'll probably do destructive tests on our small soldered solenoids in LN2 to measure $I_c(\sigma_z)$

[1] 10.1109/TASC.2020.2966157

Conclusions

- PSI team created infrastructure to wind, solder, test and model HTS coils
- Test coil stack reached 18 T
- Scaled-up version to be used in positron source experience at PSI in 2025