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CHART Swiss Accelerator Research and Technology

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1 PSI, 2 CERN

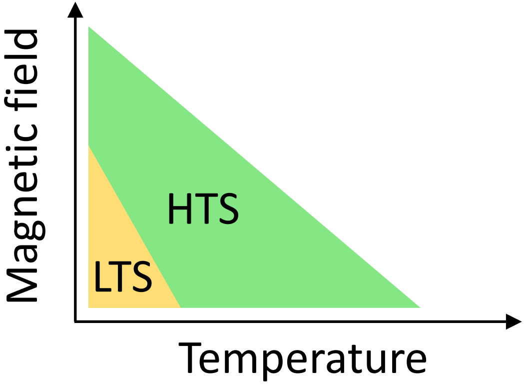
High temperature superconducting magnets for FCC-ee

Sep 7 2023, Basel

This work was performed under the auspices of and with support from the Swiss Accelerator Research and Technology (CHART) program www.chart.ch

High temperature superconductors (HTS)

- Superconducting devices *can**
  - Provide otherwise not achievable functionality
  - Reduce operation costs
  - Make operation more energy efficient
- HTS compared to LTS opens up the design space, both in terms of field and temperature



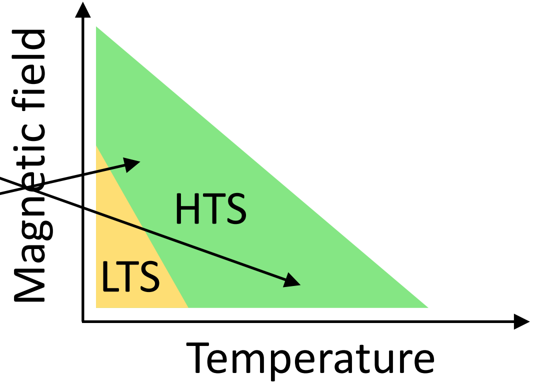
*Not always…

High temperature superconductors (HTS)

Within several CHART projects, we aim to demonstrate the potential added value of HTS for FCC-ee

FCC-ee HTS short straight sections
2 T, 40 K

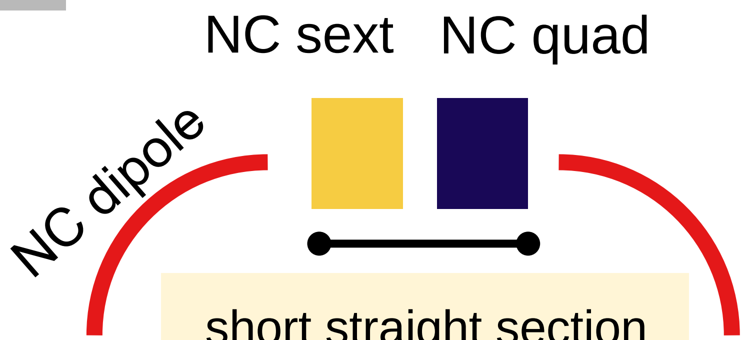
FCC-ee HTS positron production capture solenoid
15 T, 15 K



HTS4: HTS short straight sections

Baseline FCC-ee main ring:

normal conducting (NC)



short straight section

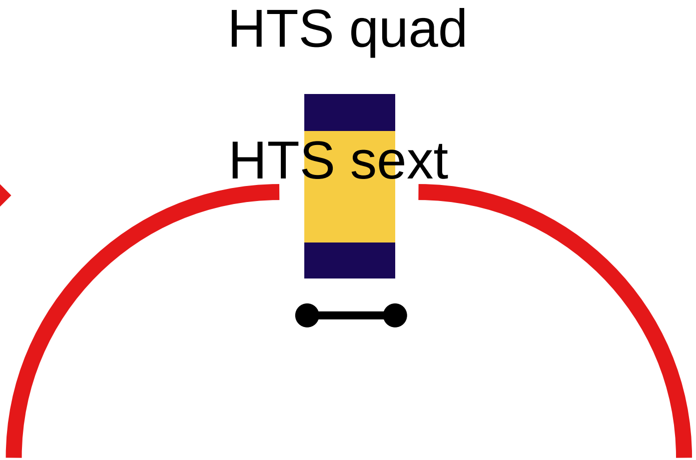
Dissipation

79 MW peak [1]

39 MW avg over 14 y

nested HTS

HTS4

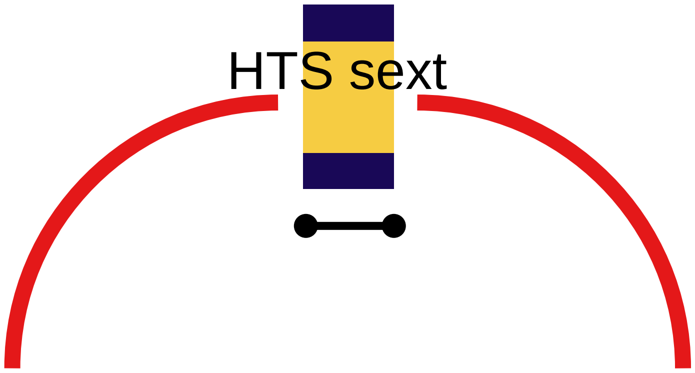


Cooling system <11 MW

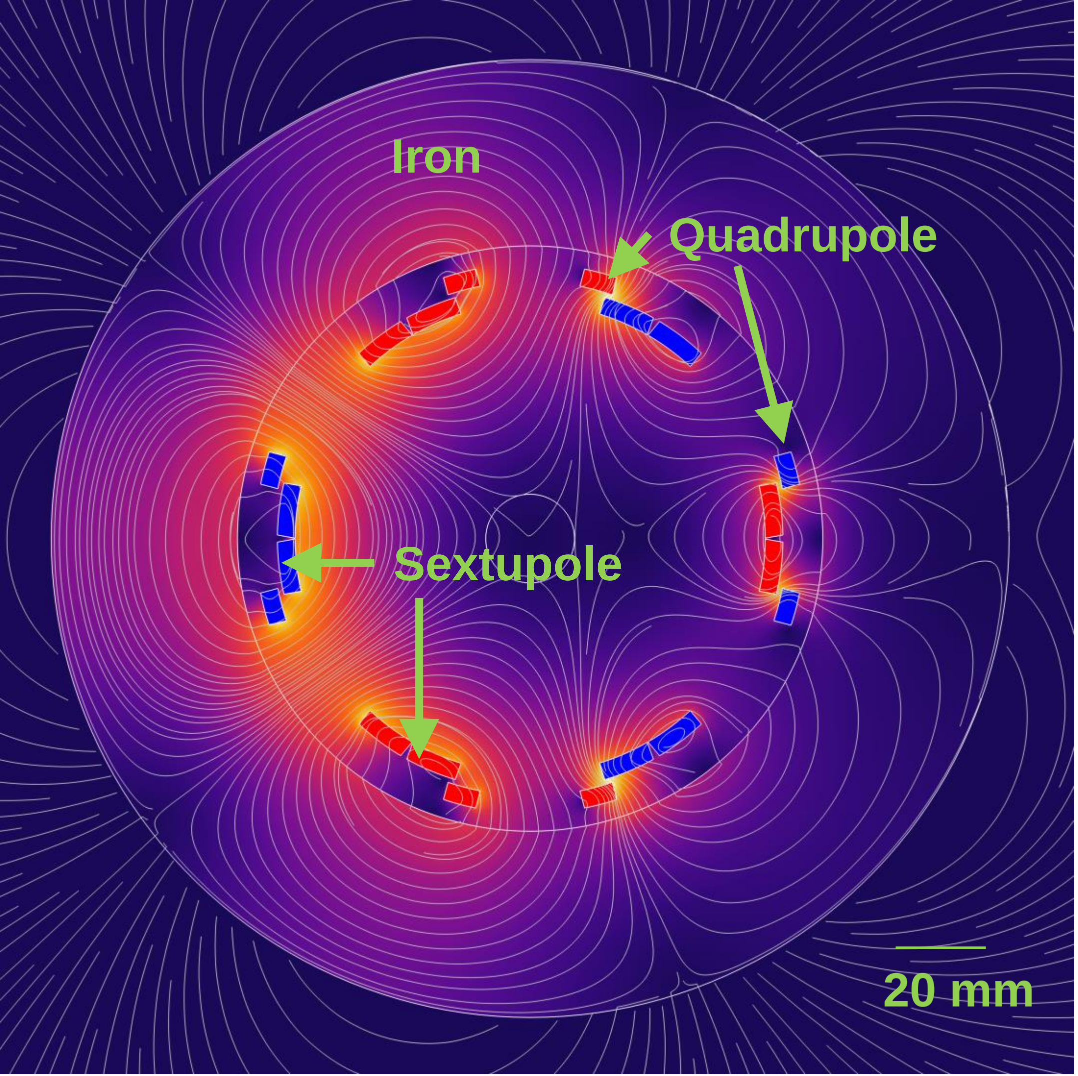
(we also consider 100% dipole filling)

[1] J.P. Burnet, *update of the power demand energy consumption. grid connection for FCC-ee*, FCC Week 2023

- **Increase dipole filling factor** [1]
- **Enhance optics flexibility** [1]
- **Save costs**



[1] C. Garcia, https://www.ipac23.org/preproc/pdf/MOPL066.pdf



Via a 1-m prototype by 2025,

we address :

- Windability
- Magnetic field quality
- Thermal aspects
- Protection

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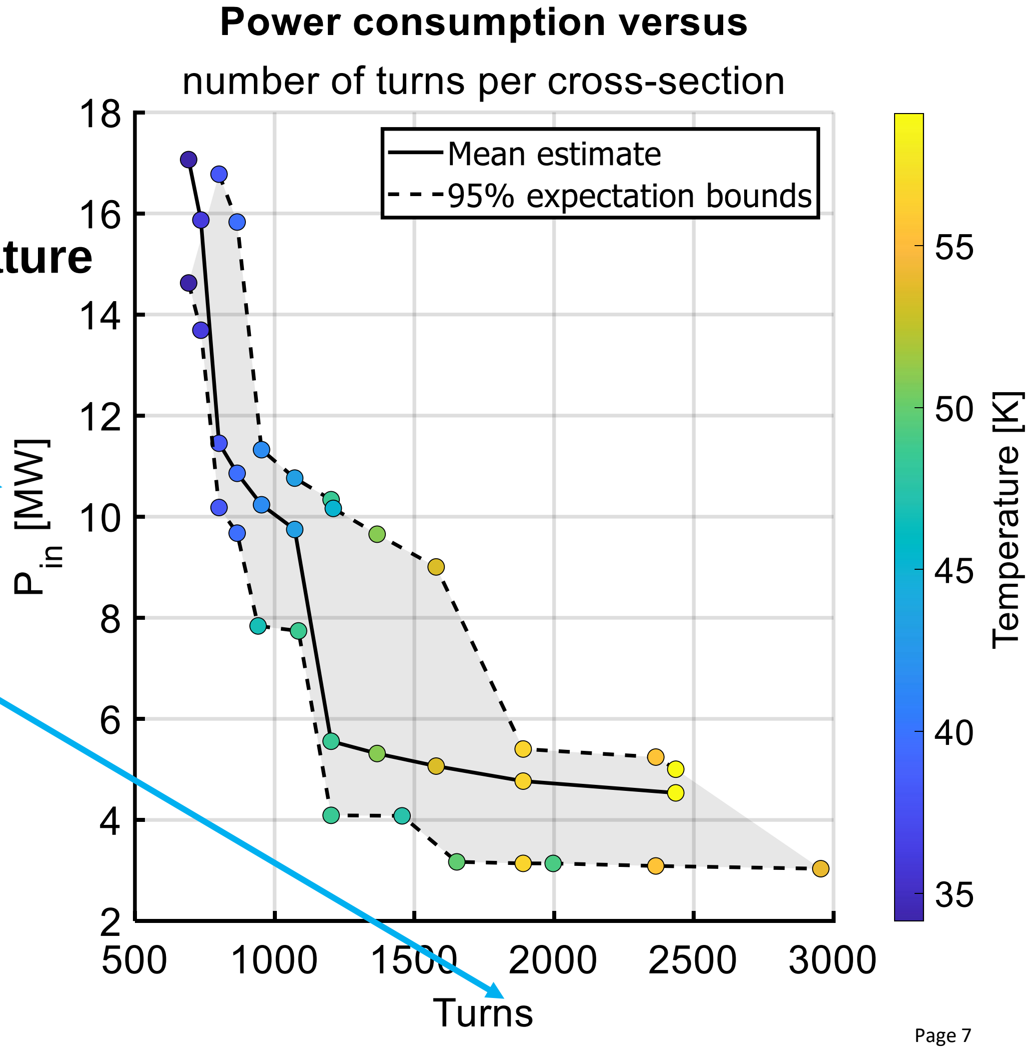
The **optimum operating temperature** depends on the price of

- electricity
- HTS conductor

The sweet spot is around **40 K** across a wide range of costs



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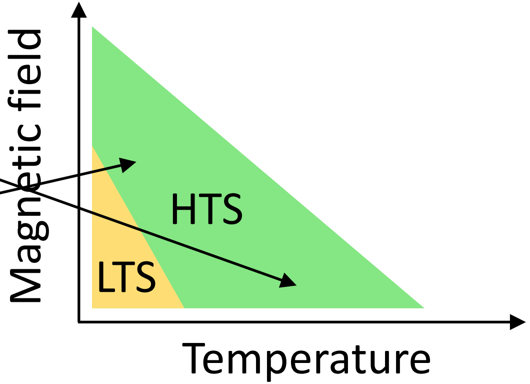
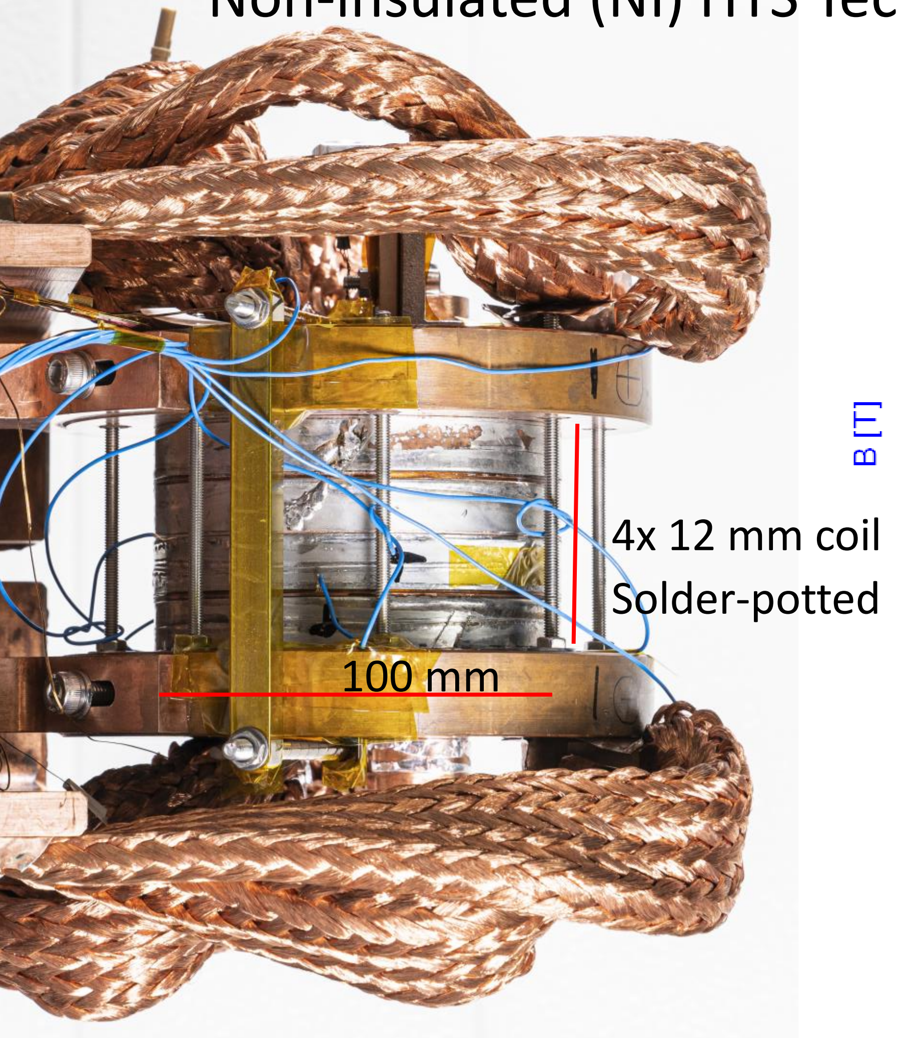


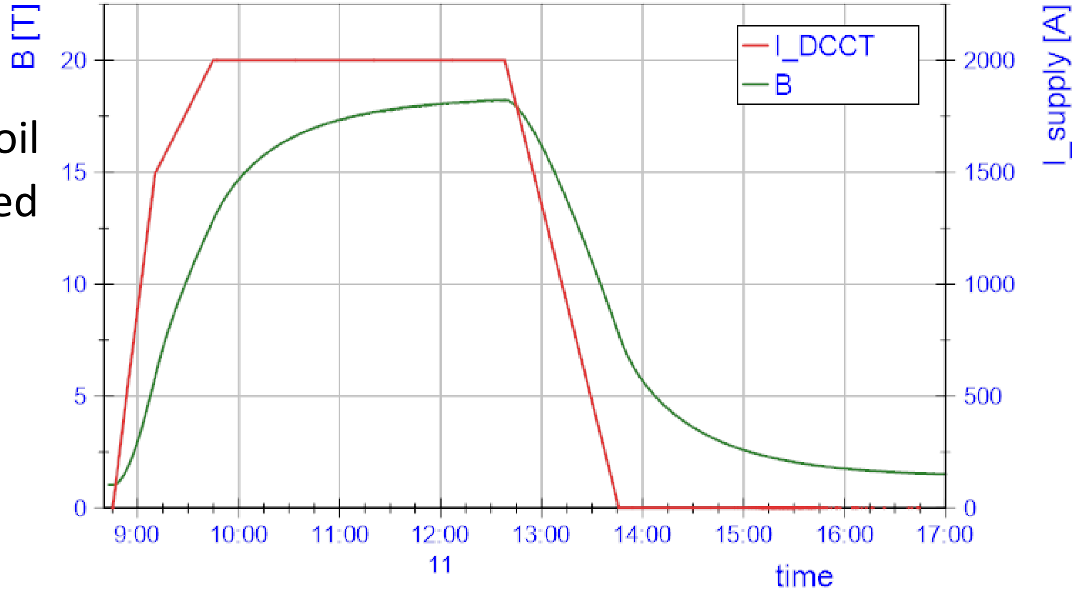
Non-insulated (NI) HTS Technology Solenoid



Rapidly develop infrastructure via license agreement with Tokamak Energy

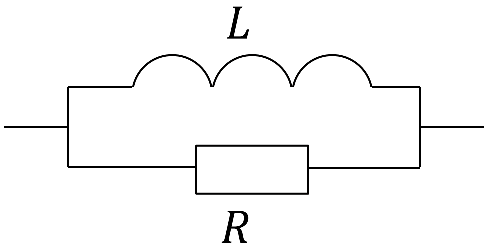
tokamak energy
a faster way to fusion

18 T by PSI 4 stack at 2 kA, 12 K



Non-insulated (NI) HTS Technology Solenoid

NI coil electrical representation:
- Inductor (HTS spiral path)
- Resistor (turn-turn contact)



Charging time constant $\tau = L/R$

Large NI magnets (large L) take a long time

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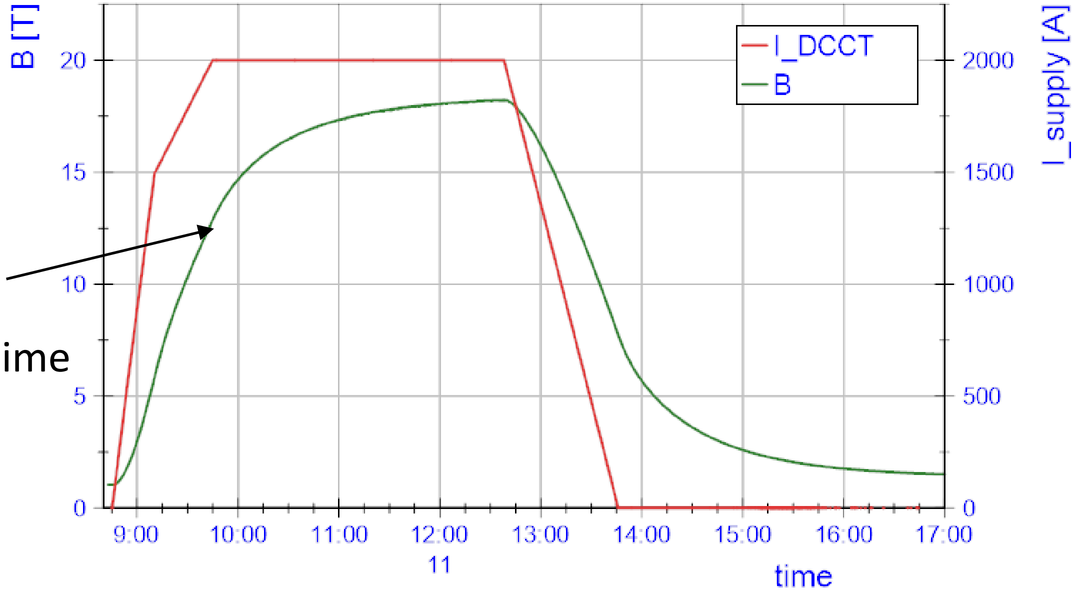

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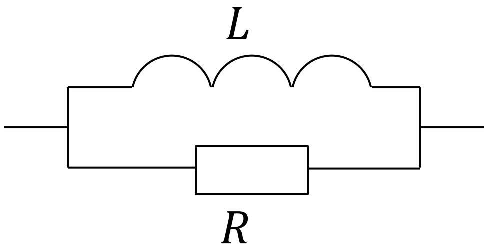

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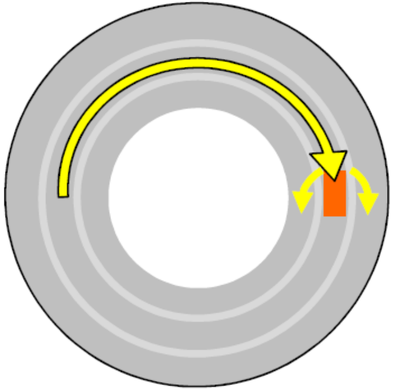
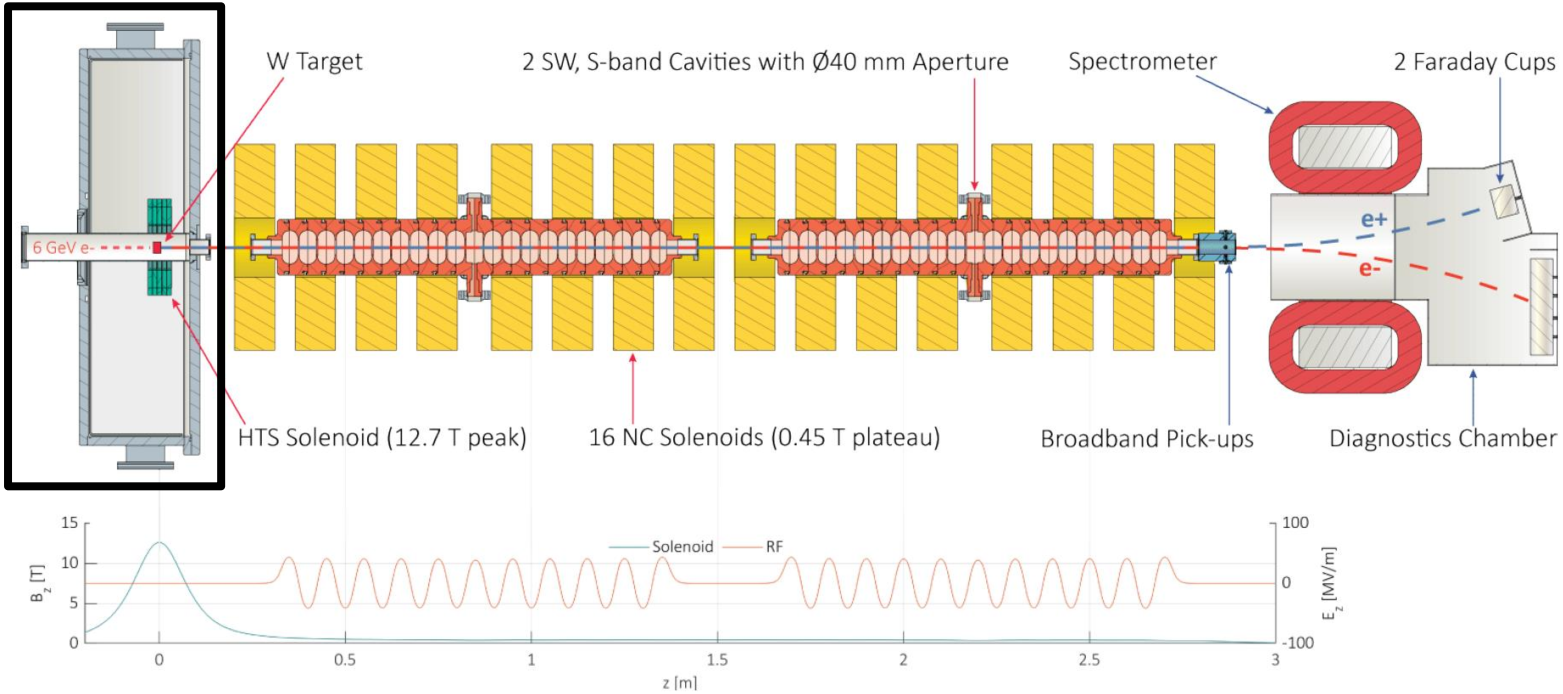


- *Very high current density* magnet
  → compact winding, lower cost
- Key benefits: compactness, operation reliability, mechanical robustness

S. Hahn, D. Park, J. Bascuñán, and Y. Iwasa,

“HTS Pancake Coil without Turn-to-Turn Insulation,” IEEE TAS, 2011.

PSI Positron Production (P3) Experiment



See: N. Vallis, *The P3 Experiment: A Positron Source Demonstrator at PSI in 2025*
7 Sept 2023, 14:00

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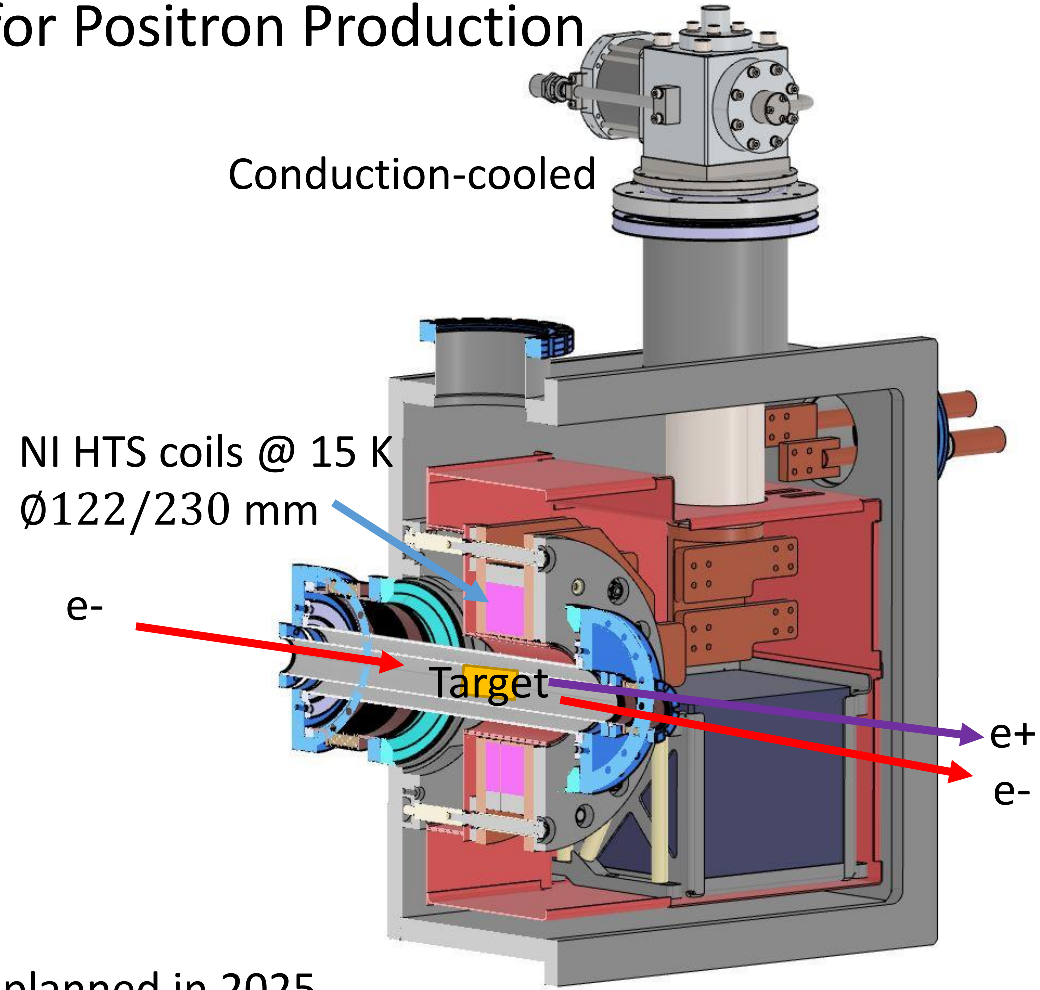
NI HTS solenoid for Positron Production

Compact DC

+

Radiation

→ NI magnet



Installation in P3 experiment planned in 2025

Conclusions

CHART projects

• HTS4	2 T, 40 K
• FCC-ee injector design	15 T, 15 K

plan to demonstrate the potential added value of HTS for FCC-ee

Nested HTS sextupoles & quadrupoles

- Save energy
- Increase dipole filling factor
- Enhance optics flexibility
- Save costs

Non-insulated HTS solenoid

- Enables high-yield positron source
- Robust compact magnet technology

perfectly suited for small DC applications

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