Strategy for Superconducting Magnet Development for a Future Hadron-Hadron Circular Collider at CERN

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The FCC-hh

LHC
27 km, 8.33 T
14 TeV (c.o.m.)
1232 LTS dipoles

FCC-hh
100 km, 16 T
100 TeV (c.o.m.)
5000 LTS dipoles
State-of-the-art: LHC

- Nominal field: 8.33 T
- Operating temperature: 1.9 K
- 1232 dipoles
FCC vs LHC dipole

- Twice the magnetic field →
  - 2 x more Ampere turns
  - 4 x higher forces/m
  - ~6 x more stored energy/m
- 4 x more magnets
Laboratory scale achievements

Cos-θ (D20, achieved bore field 13.5 T at 1.9 K)


Block (HD2c, achieved bore field 13.8 T at 4.3 K)


We need to achieve a much higher operational field than the laboratory world record.

• Better conductor
• Sufficient operational margin
• A suitable design & construction

Development program
Performance of Superconductor

- **16 T**
  - FCC ultimate
  - HL-LHC
  - Critical surface

- **5400 mm²**
  - ~10% margin
  - HL-LHC

- **3150 mm²**
  - ~10% margin
  - FCC ultimate

- **Not possible**
  - Nb-Ti

- **Different technology**

- **T = 4.5 K**

- **B in T**

- **Jc in kA/mm²**

- **~1.7 times less SC**
Operational margin

\[ T = 4.5 \, \text{K} \]

- 1880 mm², ~2% margin
- 3150 mm², ~10% margin
- 6250 mm², ~17% margin

- 1.7 times more SC
- 2 times more SC

Critical surface

\[ B \, \text{in} \, \text{T} \]

\[ J_c \, \text{in} \, \text{kA/mm}^2 \]
Development programs

- **WP 5**
  - Producing a design of a 16 T accelerator model magnet at 4.5 K and with 10% margin

- **FCC technology companion program**

- **Other programs (wire, design and manufacture of magnets)**
EuroCirCol

Producing a design of a 16 T accelerator model magnet at 4.5 K and with 10% margin
FCC Technology

- ERMC (16 T mid-plane field)
- RMM (16 T in a cavity of 50 mm)
- Demonstrator (16 T in a 50 mm gap)
- Procurement of 75 km Nb$_3$Sn wire for a short model

Demonstrator (cos- $\theta$ also under study)
## Schedule

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The schedule above shows the timelines for various activities under the programs EuroCirCol and FCC Technology. Each row represents a specific project or activity, with columns indicating the start and end dates, and a timeline representation for the years 2015 to 2021.
Conclusion

• CERN is presently strongly engaged in the development of the superconducting magnets for the HL-LHC project.
• The efforts devoted to this activity, appropriately complemented by more tailored programs, will be extremely beneficial for conceiving a realistic conceptual design study of the FCC within the next 4 years.
• The main scopes of these programs are the increase of the superconductor performance and the demonstration of the production of a 16 T magnetic field in a 50 mm dipole aperture with 10% margin at 4.5 K.