LTS 16 T dipole design options for FCC-hh

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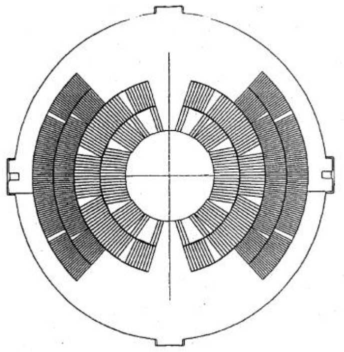
EuroCirCol Meeting at CERN, Geneva

3rd of June 2015

Design options MB

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



D. Dell'Orco et al., IEEE Trans. Appl. Supercond., Vol. 3, No.1, 1993

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

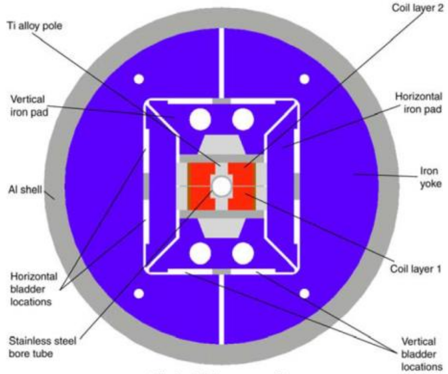


Fig. 2. HD2 cross-section.

P. Ferracin et al., IEEE Trans. Appl. Supercond., Vol. 19, No.3, 2009

Common coil (Rd3d, achieved bore field ~11 T)

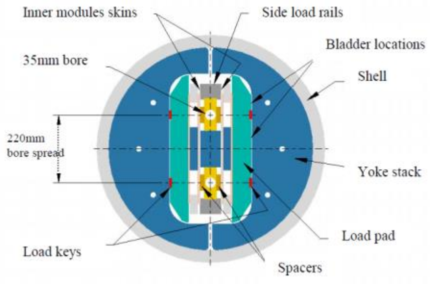
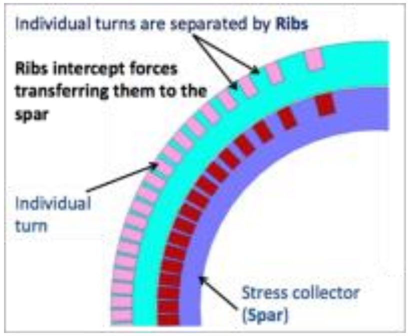
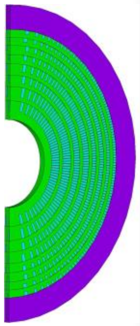


Figure 1: The magnet cross-section for RD3c.

A.F. Lietzke, IEEE Trans. Appl. Supercond., Vol. 13, No.2, 2003

Canted-Cos- θ (concepts)

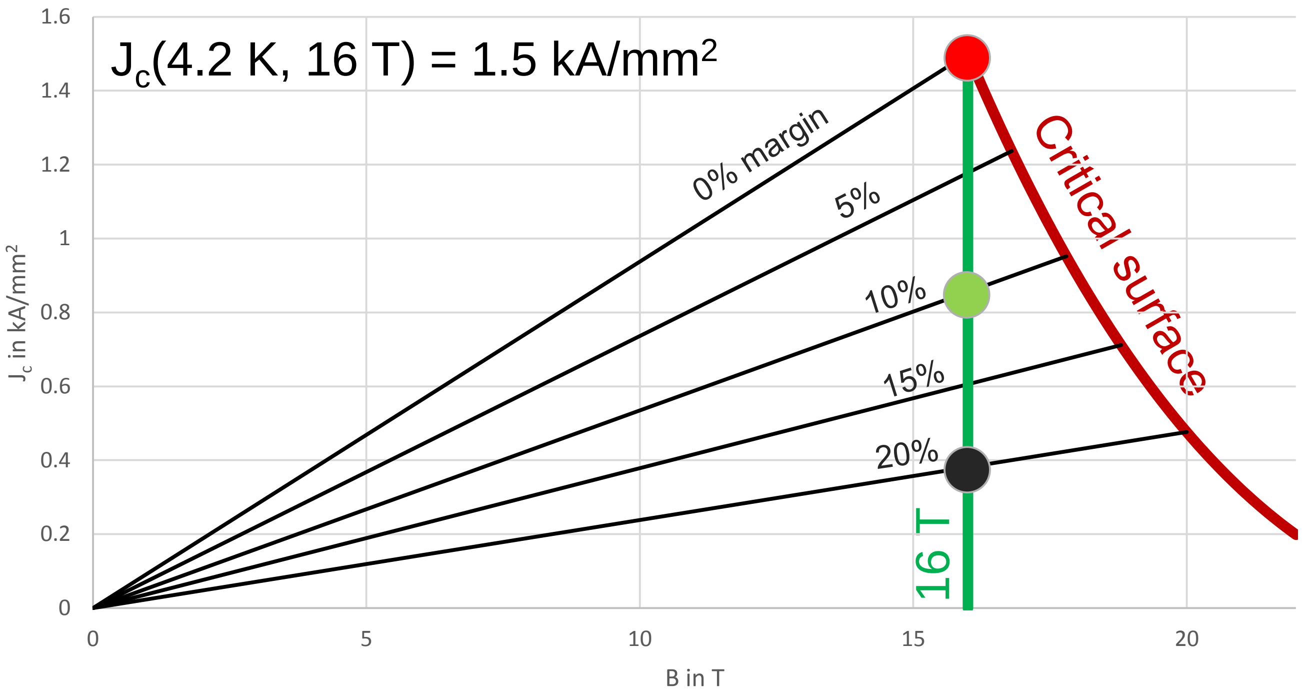




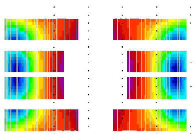
S. Caspi, FCC kick-off meeting, SC Magnet Development Toward 16 T Nb3Sn Dipoles

L. Brouwer, IEEE Trans. Appl. Supercond., Vol. 25, No. 3, 2015

Margin



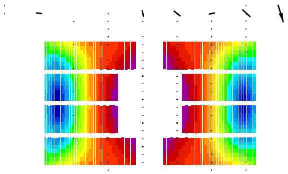
1900 mm²



~-2% margin

1.7 times more SC

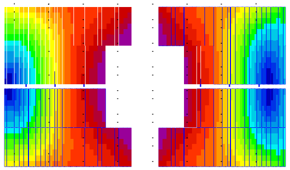
3150 mm²



~10% margin

2 times more SC

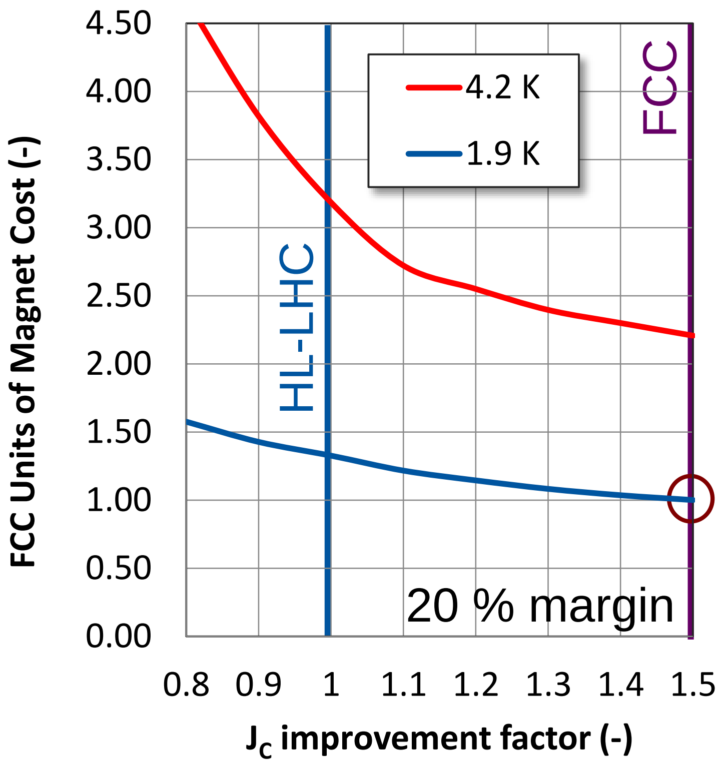
6250 mm²

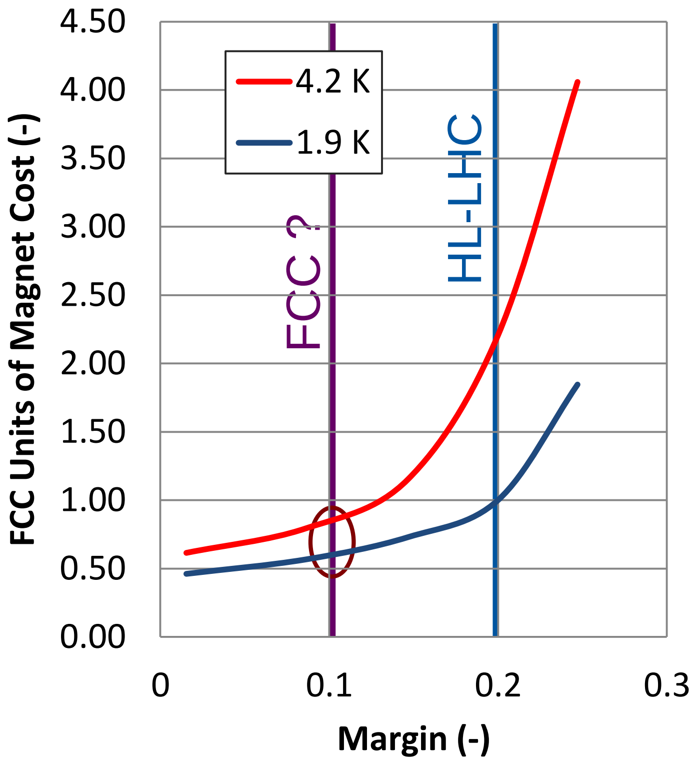


~17% margin

Strand improvement & margin

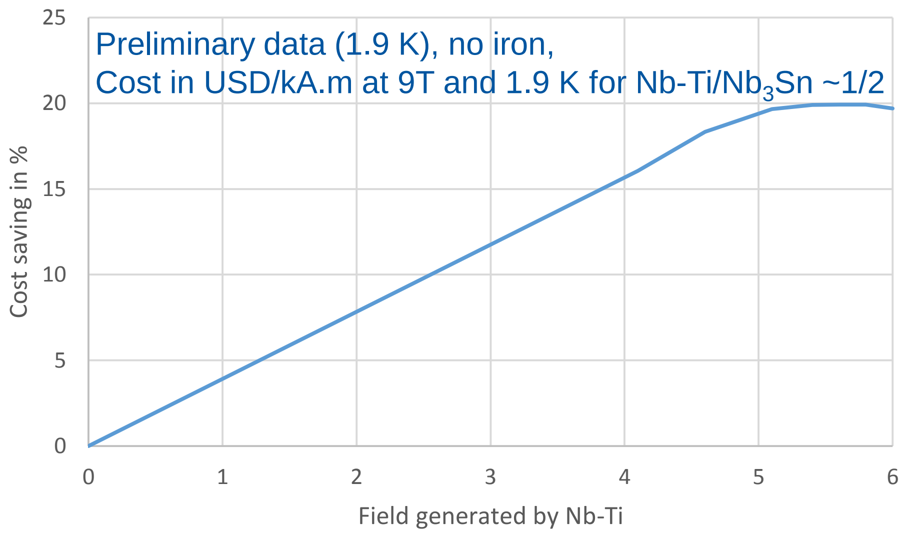
- J_C pays a lot at 4.2 K, less at 1.9 K.
- Margin is (very) expensive (at 4.2 K).





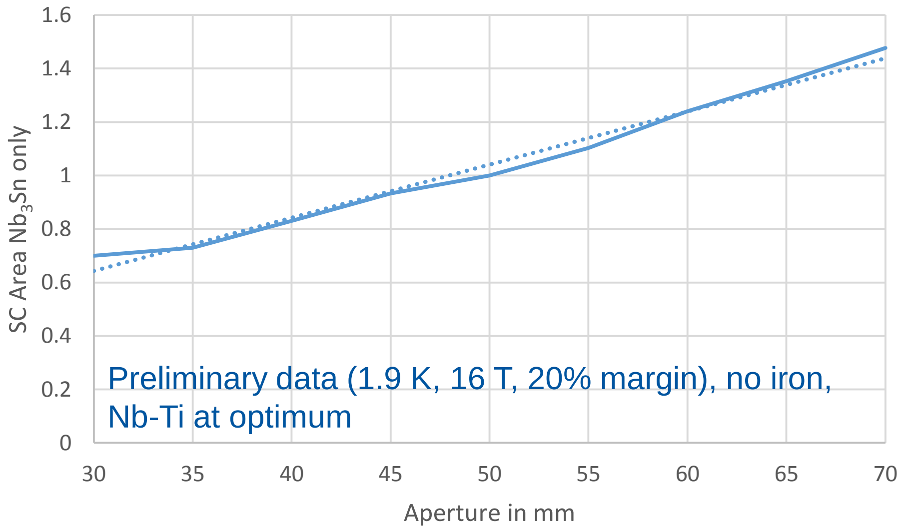
Grading

- Grading is essential (a factor >2 of SC saving for graded coil compared to a non-graded coil).
- How much grading/layers we really require?
- The target cost of FCC Nb_3Sn in USD/kA.m at 9T and 1.9 K is similar to the cost of LHC Nb-Ti SC at 9T and 1.9 K .
- In the frame of EuroCirCol we propose to consider Nb_3Sn only.

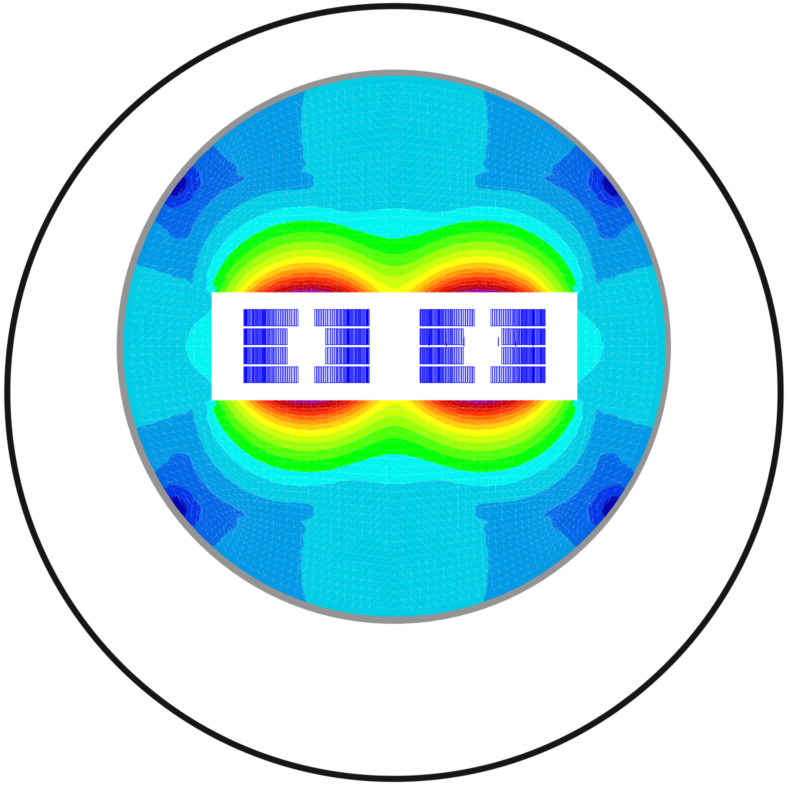


Aperture

- Increase of stored energy scales approximately like the amount of Nb_3Sn SC used.
- Decreasing the aperture from 50 mm to 40 mm would save about 20% of conductor, i.e., in the order of 10% on magnet cost.



MB – block @ 4.2 K

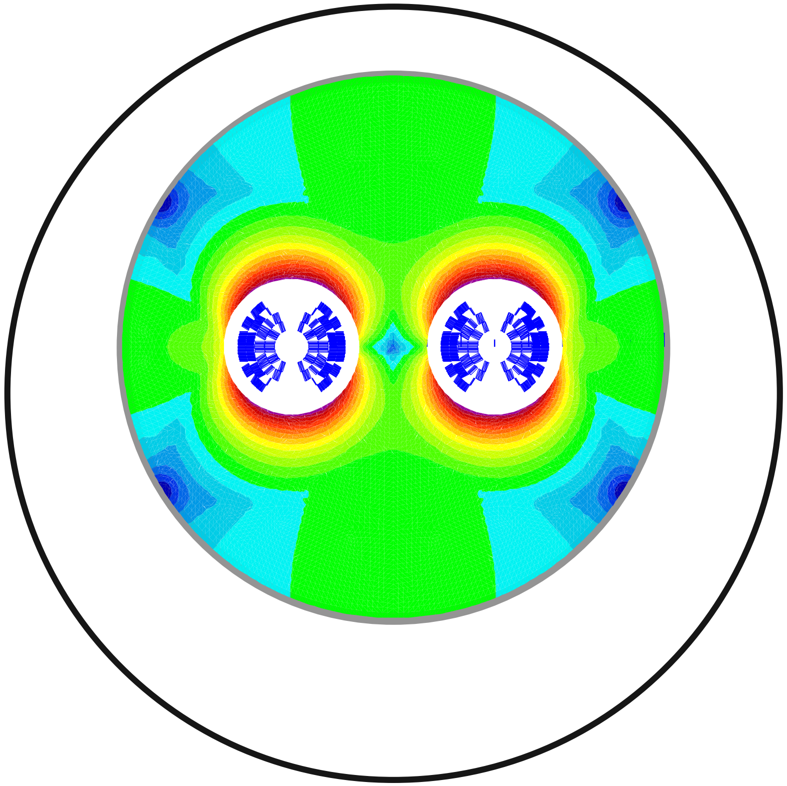


Number of apertures	(-)	2
Aperture	(mm)	50
Operating current	(kA)	16.4
Nominal field	(T)	16
Peak field/bore field ratio	(%)	2
Margin for FCC ultimate strand at 4.2 K	(%)	~10
Margin for HL-LHC strand at 4.2 K	(%)	~0
Stored magnetic energy per unit length	(MJ/m)	3.4
Inductance (magnet)	(mH/m)	24.2
Area of SC	(mm^2)	6300

1 m diameter "cryostat" envelope
Mechanical concept: Bladder-Key

Protection within reach for 2 m magnet (MIITs checked)

D20 (revisited) – cos-θ @ 4.2 K



Number of apertures	(-)	2
Aperture	(mm)	50
Operating current	(kA)	8.3
Nominal field	(T)	16
Peak field/bore field ratio	(%)	2
Margin for FCC ultimate strand at 4.2 K	(%)	~7
Margin for HL-LHC strand at 4.2 K	(%)	~0
Stored magnetic energy per unit length	(MJ/m)	2.7
Inductance (magnet)	(mH/m)	70.8
Area of SC	(mm^2)	6480

Protection challenging for 2 m long magnet: decrease inductance and potentially increase amount of Cu (here Cu/Sc 0.9)

1 m diameter "cryostat" envelope
Mechanical concept: Collared coils

Thanks to Ezio for providing the Roxie input file

Some concluding remarks…

- 16 T dipole magnet is within reach with HL-LHC LTS.
- Margin is extremely expensive.
- Nb-Ti may provide only marginal saving on overall magnet cost.
- Decreasing the aperture from 50 mm to 40 mm would save about 20% of conductor, i.e., in the order of 10% on magnet cost.