Case study 3

High field- large aperture magnet for a cable test facility

Design a superconducting dipole with an 100 mm aperture and capable of reaching 15 T at 1, 9 K

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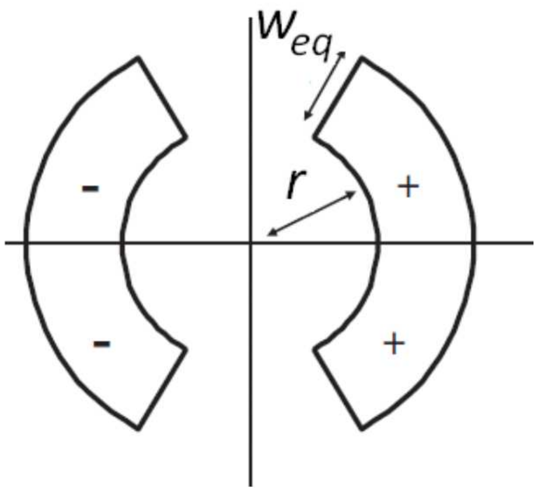
Sector coil scaling laws



<u>Hypothesis :</u>

We assume an unique sector coil of 60°

R= 50 mm

Weq = thickness of the coil

λ= ratio between peak field and central field scales (15T)

α = 0,045

Bss the short sample field

K filling factor =0,33

s=3,90.10^9 A/m2/T, b= 22 T, γ0 = 6, 63.10^{-7}Tm/A

<u>Scaling law for a dipole of one sector of 60° :</u>

$$B_{ss} = \frac{\kappa s \gamma_c}{2}\left(\sqrt{\frac{4b}{\lambda \kappa s \gamma_c}+1}-1\right)$$

$$\lambda(w,r) = 1 + \alpha \frac{r}{w}$$

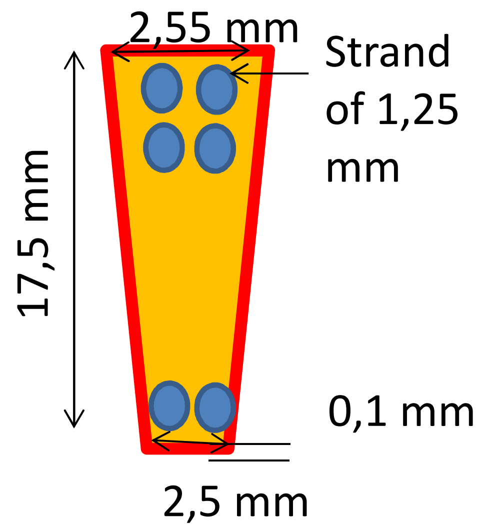
For Weq = 70 mm for a sector of 60°
B= 15T for 90% and Bpeak = 15,4 T
For 100%, B= 16,6 T

Conductor

- weq = 70 mm →

Number of layers	1	2	3	4
Bare conductor width (mm)	70	35	23,3	17,5

- 28 (14 x 2) strands/conductor of 1,25 mm diameter
- Mid-Thickness: 2,525 mm (bare)
- Insulation : 2x0,1 mm (glass fiber)
- Cu% = 54,5% and SC% = 45,5 % → $\frac{Cu}{Sc} = 1{,}2$
- Pitch angle : 17,65°



Area sc cable (mm²)	15,634
Area copper cable (mm²)	18,727
Area ins cable (mm²)	48,233

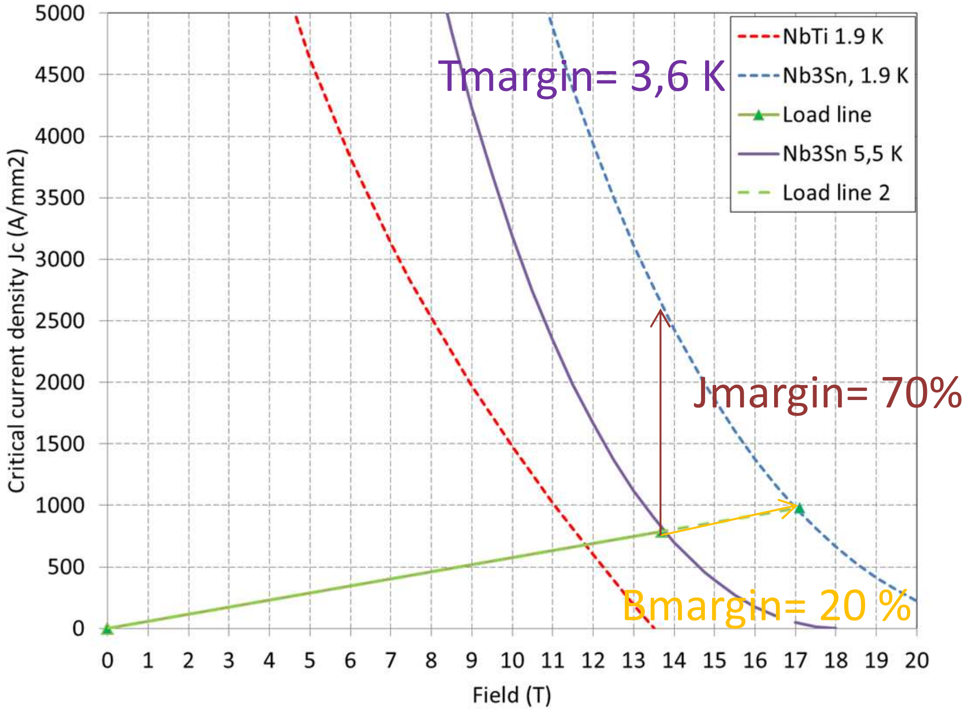
K = 0,324

Load lines

- B= 15T for I= 90% of $I_{,ss}$

→ Determination of short sample conditions (100%) and operational conditions (80%)

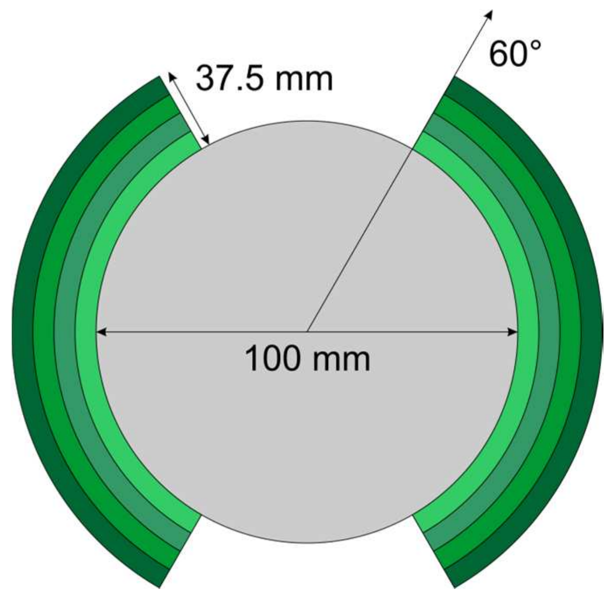
	Short sample conditions	Operational conditions
J, sc (A/mm²)	981	782
J0 (K jsc) (A/mm²)	317	254
I (A)	15279	12223
Bpeak (T)	17,1	13,7



- NbTi: this magnet can not work with NbTi conductor

Layout

- Cos(Θ) design with 4 layers
- Facility magnet (not accelerator magnet): do not need so « good » field quality: choice of no wedge, sector of 60°



Mechanics

$$F_x = +\frac{2\mu_0 J_0^2}{\pi}\frac{\sqrt{3}}{2}\left[\frac{2\pi-\sqrt{3}}{36}a_2^3+\frac{\sqrt{3}}{12}\ln\frac{a_2}{a_1}a_1^3+\frac{4\pi+\sqrt{3}}{36}a_1^3-\frac{\pi}{6}a_2a_1^2\right]$$

$$F_y = -\frac{2\mu_0 J_0^2}{\pi}\frac{\sqrt{3}}{2}\left[\frac{1}{12}a_2^3+\frac{1}{4}\ln\frac{a_1}{a_2}a_1^3-\frac{1}{12}a_1^3\right]$$

At 80%, with a1= 50 mm and a2= 120 mm, for a quadrant: Fx= 5,7 MN/m and Fy = -4,7 MN/m

σav = 89 MPa

At 90%, iron yoke thickness is 37,5 cm

Stainless steel collars of a thickness of 2 cm

Shrinking tube (stress is 200 Mpa), a thickness of 29 mm.

Additional questions

	YBaCuO	Bi2212
☺	- Commercially available - Mechanics	Round wires Thermal stability
☹	Expensive Only tape High anisotropy B// and B	Expensive (processing and Ag) Mechanical stability

	Cos(Θ)	Block
☺	- Self supporting structure - Circular aperture - Compact - Using less SC - Experience, commonly use	Ends wound in the easy side No keystoned angle Elegant
☹	- Keystoned angle	More SC (less effective) Supported structure Lack of experience

Additional questions (2)

	Collar based	Shell based
☺	- High accuracy for coil postioning - Work for high field with contribution of the structure - Room temperature - Time and cost for insdustrial scale	work very well for low field Less complicated
☹	Good knowldege of the coil properties Collar deformation must be taken into account (cooling down)	Work not for high field magnet Low temperature

	High pre stress	Low pre-stress
☺	- Stable plateau	Good quench performance
☹	Degradation possible (Nb3Sn and insulation)	Unloading