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Baseline parameters of the 16 T dipoles for the FCC

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The content of the CDR shall be CREDIBLE

We would like large currents (> 20 kA) with large cables (60 strands) and large wires (>1.2 mm) for minimizing the inductance and the number of layers, the high field conductor with a low Cu/non-Cu (0.6:1) for making compact coils, assembly at 250 MPa or more for enabling «conventional» collaring, 0.2 or higher cable compaction for an efficient costheta design, a margin on the loadline of 5-10% for not entering into the «extremely expensive margin zone».

All above may be hopefully achieved by the time of the FCC through an appropriate R&D process, however the information we have available today forces us to be more (excessively?) prudent when setting a baseline for the CDR.

We will then adopt what we believe to be «reasonable» baseline parameters, keeping in mind that new opportunities may arise enabling more advantageous designs with respect to what we will establish for the CDR.

Reference

The baseline parameters are described in the EuroCirCol document «**EuroCirCol-P1-WP5**»

16T Dipole design options: Input Parameters and Evaluation Criteria — EuroCirCol-P1-WP5 — Date: 04.04.2017

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NOTE

16T DIPOLE DESIGN OPTIONS: INPUT PARAMETERS AND EVALUATION CRITERIA

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Abstract:

This document summarizes the input parameters and the evaluation criteria to be considered for the exploration of the different design options of the 16T dipole.

16T Dipole design options: Input Parameters and Evaluation Criteria — EuroCirCol-P1-WP5 — Date: 04.04.2017

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Delivery Slip

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TABLE I

COMMON STARTING PARAMETERS FOR THE MAGNET OPTIMIZATION

Dipole field at aperture	16	T
Aperture diameter	50	mm
Reference radius	17	mm
Beam-to-beam distance	250	mm (larger if necessary)
Outer diameter	800	mm
Cryostat outer diameter	1000	mm
Operating margin (nominal current is 86% on loadline)	≥14	%
Nominal current	<20000	A
Working temperature	1.9	K
Cable insulation thickness	0.15	mm per conductor face
Inter-layer insulation thickness	0.5	mm
Minimum ground insulation thickness	2	mm
X-section multipoles (geometric)	A few 10^{-4}	units at reference radius
Overall coil length	14.3	m
Peak temperature	350	K (quench at 105% of nominal current)
Peak voltage to ground (circuit)	2500	V (quench at 105% of nominal current)
Peak voltage to ground (magnet alone)	1200	V (quench at 105% of nominal current)
Peak inter-layer voltage	1000	V (quench at 105% of nominal current)
Peak inter-turn voltage	100	V (quench at 105% of nominal current)
Protection circuit delay	40	ms

3. EVALUATION CRITERIA

TABLE III

CRITERIA FOR COMPARISON OF 16 T DIPOLE DESIGNS

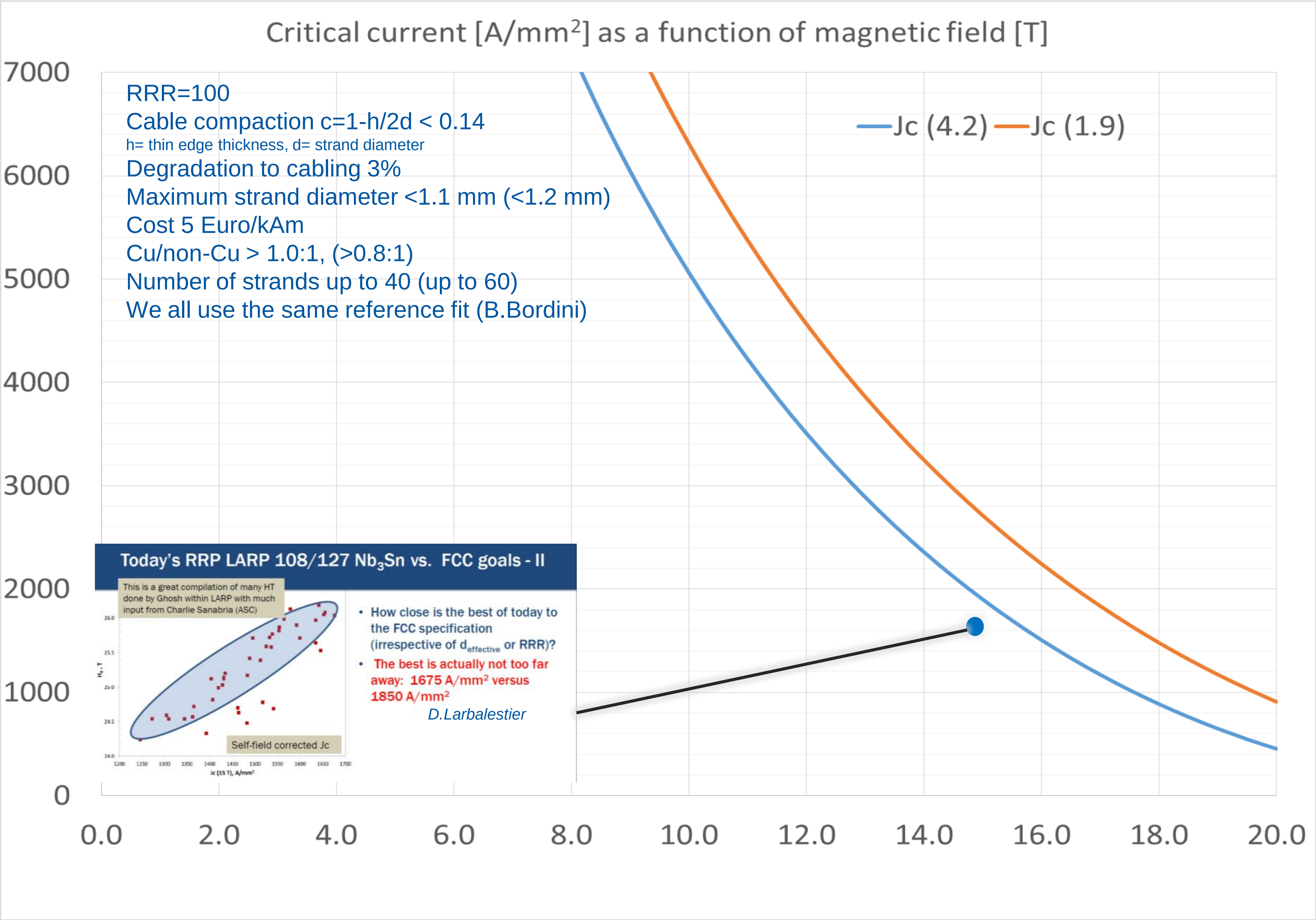
Magnet type	Cos-θ	Common coil	Block	Units
Area of bare conductors/aperture				mm^2
Area of insulated conductors/aperture				mm^2
Number of turns per aperture				
Outer iron yoke radius				mm

Table II: Material Data for the exploration of 16T dipole design options

Material	Stress limit (MPa, Von Mises)		E (GPa)		ν	α
	293 K	4.2 K	293 K	4.2 K	293 K /4.2 K	293 K→4.2 K
Coil X: Radial/broad direction Y: Azimuthal/narrow direction	150	200	EX=30 EY=25 GXY=21	EX=33 EY=27.5 GXY=21	0.3	X=3.1E-3 Y=3.4E-3
Austenitic steel 316LN	350	1050	193	210	0.28	2.8E-3
Al 7075	480	690	70	79	0.3	4.2E-3
Ferromagnetic iron	230	720*	213	224	0.28	2.0E-3
Pole (Ti6Al4V)	800	1650	115	126	0.3	1.7E-3

** 380 MPa is the allowed limit for first principal stress at cold conditions.*

Conductor



Critical current [A/mm²] as a function of magnetic field [T]
7000
6000
5000
4000
3000
2000
1000
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Jc (4.2)
Jc (1.9)
RRR=100
Cable compaction c=1-h/2d < 0.14
h= thin edge thickness, d= strand diameter
Degradation to cabling 3%
Maximum strand diameter <1.1 mm (<1.2 mm)
Cost 5 Euro/kAm
Cu/non-Cu > 1.0:1, (>0.8:1)
Number of strands up to 40 (up to 60)
We all use the same reference fit (B.Bordini)
Today's RRP LARP 108/127 Nb3Sn vs. FCC goals - II
This is a great compilation of many HT done by Ghosh within LARP with much input from Charlie Sanabria (ASC)
Self-field corrected Jc
How close is the best of today to the FCC specification (irrespective of d effective or RRR)?
The best is actually not too far away: 1675 A/mm² versus 1850 A/mm²
D.Larbalestier

Temperature

Operating temperature has been set to 1.9 K, following an analysis of cost and operational aspects for both magnets and cryogenic system.

Margin

Margin has been set with respect to the load line and is 14 % as for the LHC, as a result of an analysis of its impact on cost and complexity of the magnets

Quench protection

We consider:

RRR=100

350 K maximum hot spot temperature @ 105% I_{nom}

40 ms time delay (time from voltage tap signal to quench of the entire coil)

1.2 kV maximum voltage to ground (magnet contribution, excluding circuit)

Layout

Beam separation:
not a fixed constraint at this stage, with the aim of keeping the magnet size small to possibly fit in a HE-LHC. For the cosinetheta and the block a beam separation of 204 mm seems feasible.

Cold mass diameter (including shell):
We consider as reference to have enough iron to close the magnetic flux, with a tentative target to stay within 800 mm diameter or less.

In parallel, studies are being performed to explore more compact layouts once integrated in the vacuum vessel for a smooth fit in a HE-LHC.

Thank you for your attention