Report from EuroCirCol: Current status and magnet parameters

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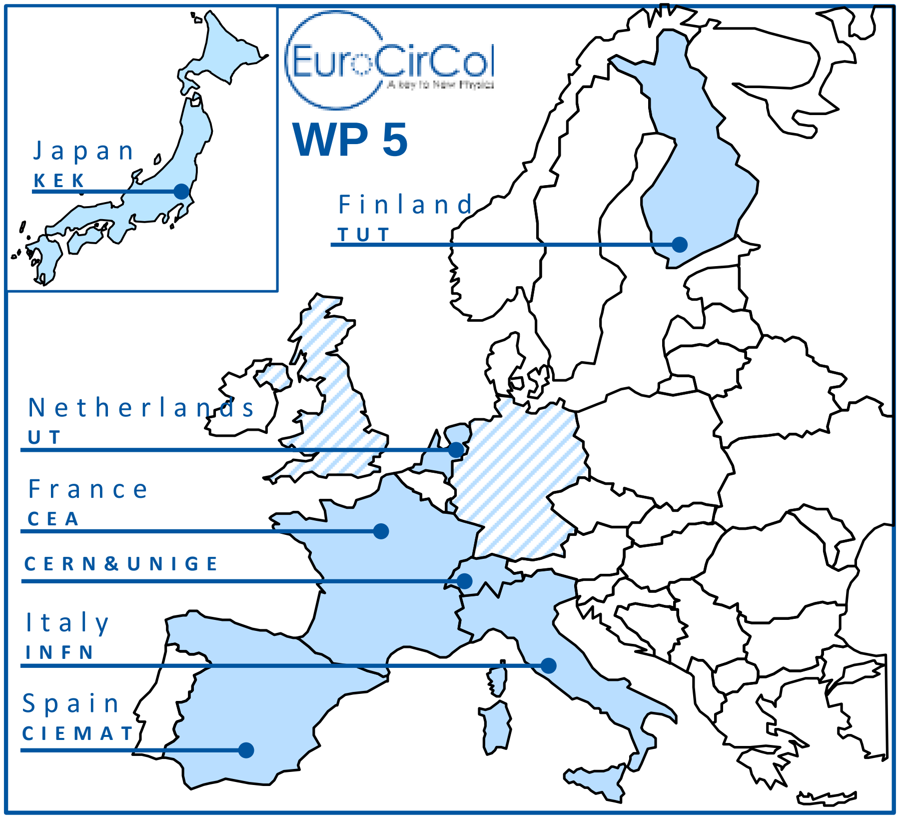

Task 5.2; Delivery 5.1 (Overview of magnet design options), deadline: March 31st, 2016:

- **CEA**: block design
- **CERN**: review of the state-of-the-art
- **CIEMAT**: common-coil design
- **INFN**: cos-theta design

The design options will be evaluated on the basis of a double aperture 2D design

KEK Inter-University Research Institute Corporation High Energy Accelerator Research Organization
cea
INFN Istituto Nazionale di Fisica Nucleare
CERN
Gobierno de España Ministerio de Economía y Competitividad Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
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University of Twente.
University of Tampere

Main parameters for study on design options

- Design for a double aperture dipole magnet (16 T, 50 mm gap, 4.5 K, 10% margin), injection energy 3.3 TeV (~1 T injection field)
- High Jc-Nb3Sn cable is used in the inner and outer layers, potentially with different Cu/Sc ratios.
- Comparison (for example cost study) will be performed for a double aperture magnet.

Dipole field at aperture	16	T
Aperture diameter	50	mm
Reference radius	17	mm
Beam-to-beam distance	250	mm
Outer diameter	750	mm
Cryostat outer diameter	1000	mm
Operating margin (current)	≥10	%
Working temperature	4.5	K
Cable insulation thickness	0.2	mm per conductor face
Inter-layer insulation thickness	0.5	mm
Ground insulation thickness	2	mm
X-section multipoles (geometric)	A few 10^{-4}	units at reference radius
b_{3geo}	<3	10^{-4}
b_{3sat}	≲10	10^{-4}
b_{5geo}	<5	10^{-4}
b_{7geo}	<3	10^{-4}
Overall coil length	14	m
Peak temperature	300	K (quench)
Peak voltage to ground	2000	V (quench)
Peak inter-turn voltage	100	V (quench)
Protection circuit delay	10-20-30	ms

Strand/cable parameters

- The number of strands: ≤40.
- Strand diameter: ~0.7 mm ≤d≤1.1 mm.
- Cu/Sc ratio to be defined (probably Cu/Sc 1:1 in the inner layer and >1.5/1 in the outer layer)
- Critical surface is given by (Bernardo):

$$B_{c2}(T) = B_{c20} \cdot (1 - t^{1.52})$$

$$J_C = \frac{C(t)}{B_p} \cdot b^{0.5} \cdot (1 - b)^2$$

$$C(t) = C_0 \cdot (1 - t^{1.52})^{\alpha} \cdot (1 - t^2)^{\alpha}$$

$$t = \frac{T}{T_{c0}} \; ; \; b = \frac{B_p}{B_{c2}(t)}$$

With T = 4.5 K, T_{c0} = 16 K, B_{c20} = 28.8 T, α = 0.96, C_0 = 255230 A/mm^2 T.

- Assumed cable degradation 5%.

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Structural analysis remarks

- Assumption: all materials are limited by the yield strength, or by the material degradation (coil).
- For ferromagnetic iron a limit of tensile stress of 200 MPa shall be considered at cold.
- The stress on the coil can vary considerably depending on the coil spot, in particular the interface conditions between coil and surrounding structure. We assume that the “reference coil pre-stress” in the 2D section is the one at the middle of the cable.
- For exploring and comparing design options, we consider that the pole tip is glued to the coil. If finite-element modelling is easier, pole and coil can be considered as independent parts (no opening). Later, a decision about a separate or glued coil/pole will have to be taken.
- Friction will be neglected at the moment. Later the use of a friction coefficient of around 0.2 for most contacts may be considered.
- Baseline design: Coil is loaded at least until the nominal magnetic field in the aperture of 16 T.

Structural analysis remarks

Table II: Material Data for the exploration of 16T dipole design options						
Material	**Stress limit (MPa)**		**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	150	200	EX=52 EY=44 GXY=21	EX=52 EY=44 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	180	720	213	224	0.28	2.0E-3
Pole (Ti6Al4V)	800	1650	130	130	0.3	1.7E-3

In accordance to the experience of the LARP program, we use the same coil elastic modulus at warm and at cold conditions.
This may evolve when performing the final design if new data will be available.
X cable side direction (radial in cos-theta), Y cable face direction (azimutal in cos-theta).

Timeline

- End of August: design parameters, constraints and evaluation criteria.
- End of October: first electromagnetic design.
- End of December: first mechanical design. Identification of problems for further analysis.
- End of March: overview of magnet design options.
- Within end of April: internal review and choice.

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