DE LA RECHERCHE À L'INDUSTRIE

FCC activities
Status and Update at CEA

MDP-FCC-ECC coordination meeting 6

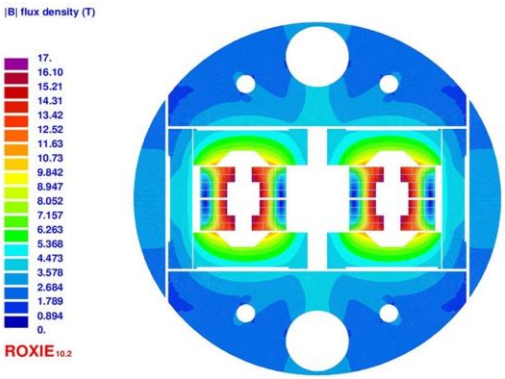
H. Felice, E. Rochepault, V. Calvelli, M. Durante, P. Mallon, J.M. Rifflet, C. Lorin, C. Pes, M. Segreti, P. Manil, J.F. Millot, G. Minier

03/12/2018

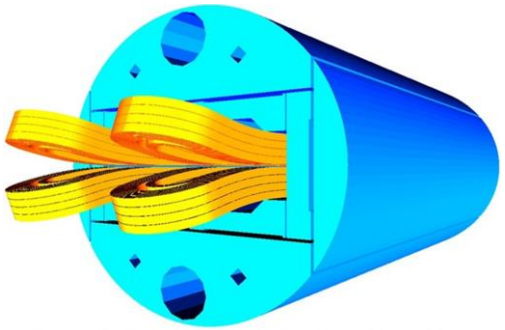
ECC ACTIVITY

- Within the ECC program => CEA Saclay in charge of the double aperture block-type configuration
  - ECC team: M. Durante, C. Pes, M. Segreti, C. Lorin, E. Rochepault

2D magnetic model

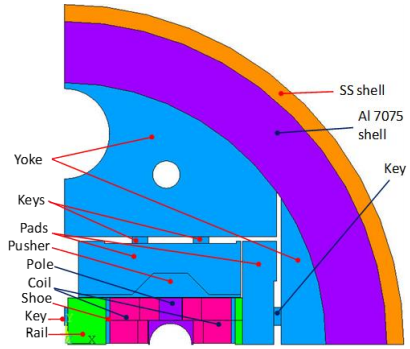


3D magnetic model



I_{op}	10176 A
LL margin HF	14.0 %
B_{bore}	16 T
B_{peak} HF	16.7 T
σ_x / σ_{VM}	
RT loading	-147 / 136 MPa
Cool-down	-180 / 165 MPa
Excitation	-185 / 167 MPa

2D mechanical model



- 3D mechanical model under development
- Ongoing CDR preparation

FROM ECC TO THE MODEL

- CERN-CEA collaboration agreement to design and fabricate a single aperture block model
  - FCC Flared-ends Dipole Demonstrator: F2D2
  - F2D2 team at CEA: H. Felice, E. Rochepault, V. Calvelli, M. Durante, P. Mallon, P. Manil, J.F. Millot, G. Minier, J.M. Rifflet
  - At CERN: S. Izquierdo Bermudez, D. Tommasini, J. Fleiter

Parameters	Specification
Coil size and block positions	As close as possible to EuroCirCol (ECC)
Magnet aperture	50 mm (same as ECC)
Cables	Min. 1000 A/mm^2 @ 16T, 4.2K Target 1200 A/mm^2 @ 16T, 4.2K
Field and margin	Maximum field at 14% of L.L. margin at 1.9K
2D harmonics	=ECC spec. at collision (<3 units)
Outer diameter	Representative of ECC (~570 mm) Fit in the CERN test station
Length of constant field (« Flat top »)	~1 m
Total length	~1.5 m Fit in the CEA oven
Coil transverse dimensions	Fit in the CEA oven (400 mm diameter)
3D harmonics	No specification

MAGNETIC 2D DESIGN

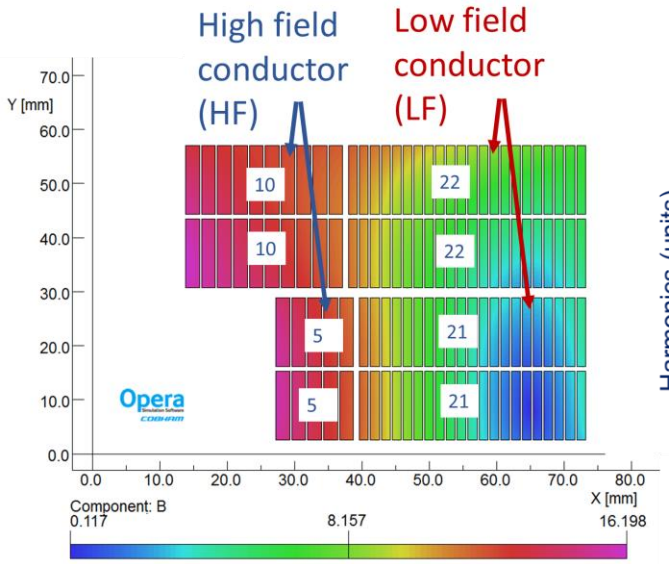
ECC cross-section

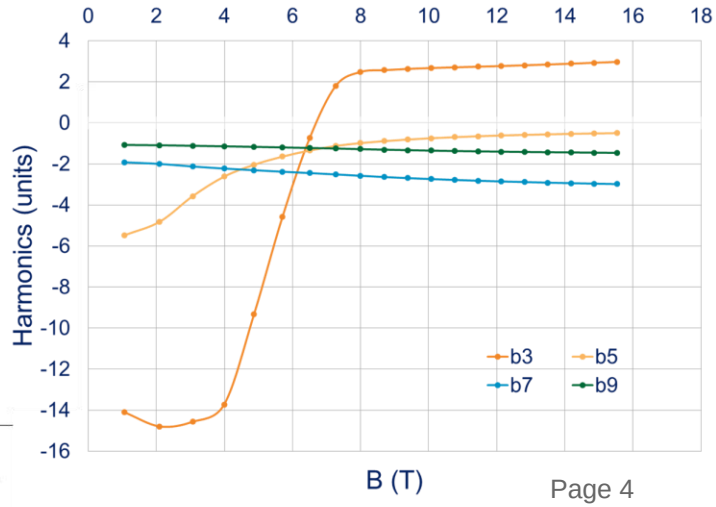
- Grading
- 4 layers of conductor
- some adjustments => manufacturability

2D magnetic parameters	
I_{op}	10469 A
LL margin HF	14.0 %
LL margin LF	15.4%
B_{bore}	-15.54 T
B_{peak} HF	16.20 T
B_{peak} LF	11.85 T
b_3 at nominal	2.98
b_3 at injection	-14.80
b_5	-0.50
b_7	-2.98
b_9	-1.46

Conductor parameters	HF	LF
Strand diameter	1.1 mm	0.7 mm
Cu/nonCu ratio	0,8	2
Jc at 4.2 K and 16 T	1200 A/mm2	
Cable number of strands	21	34
Unreacted bare cable width	12.579 mm	
Unreacted bare cable thickness	1.969 mm	1.253 mm
HT cable thickness dim. change	4.6 %	4.5 %
HT cable width dim. change	1.3 %	
Reacted bare cable width	12.74 mm	
Reacted bare cable thickness	2.06 mm	1.31 mm
Insulation thickness at 50 MPa	0.150 mm	

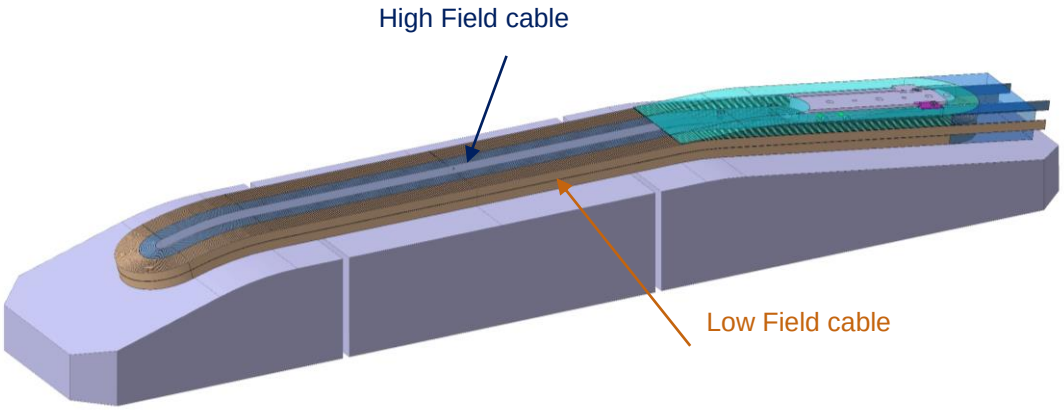
- 3D magnetic modeling ongoing
- Protection studies to start



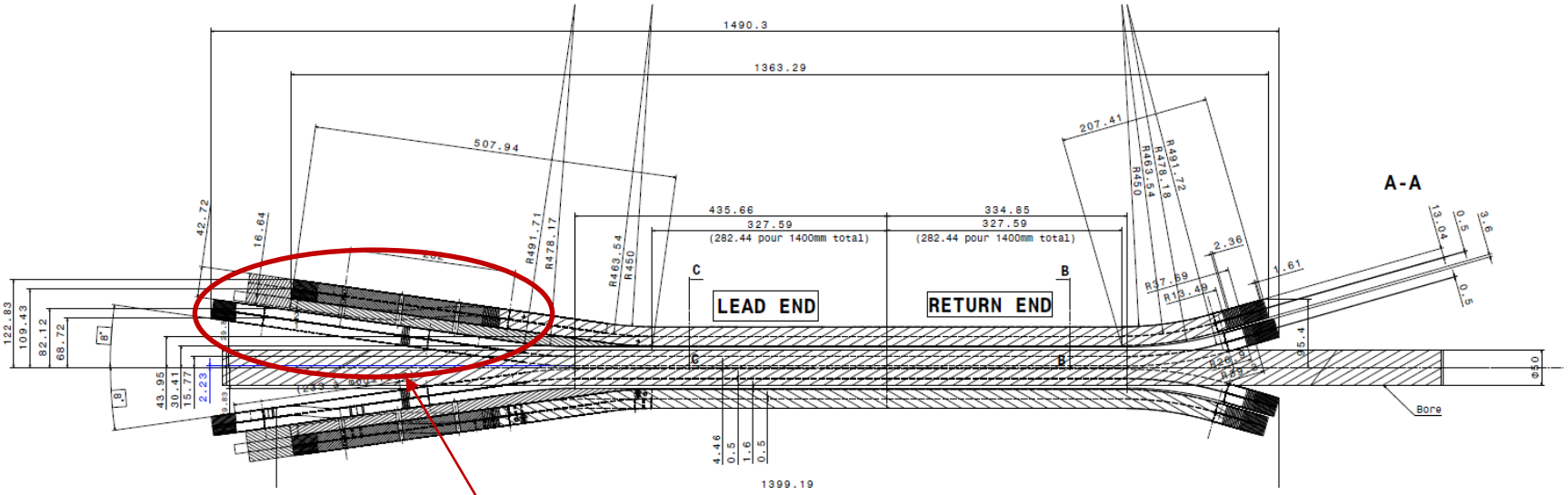


CHALLENGE

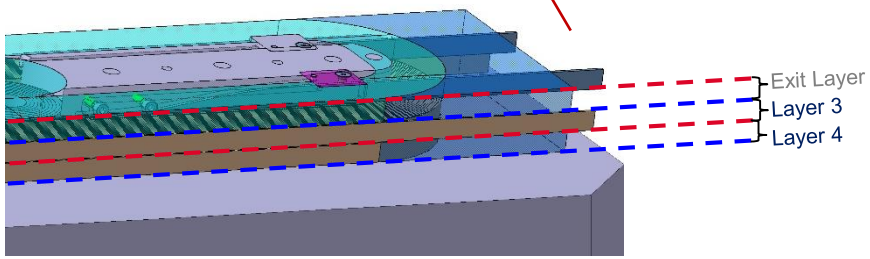
- **Key challenge**: **grading in Nb_3Sn coils => joint between conductor grades**
  - 1st scenario: Internal joints => inside the coils
    - EPFL/CERN collaboration on joint development by soldering (post-HT) or copper diffusion (during HT)
  - 2nd scenario: External joints => outside the coils
    - CEA baseline pending internal joint technique maturity
  - Winding technique and coil design are closely linked
    - 2 **nested** double pancakes (2 layer jumps)
    - Taking the leads out with reasonable bending radii and coil ends length

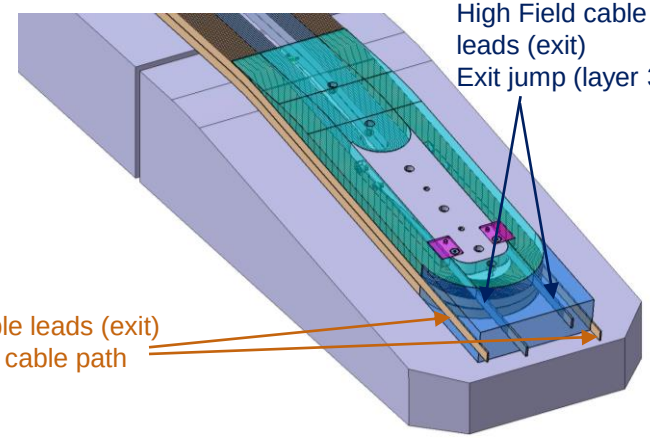


COIL AND TOOLING ENGINEERING DESIGN



Taking the leads out:
- Btw coil 1-2 and 3-1 for coil 3-4
- Toward the aperture for coil 1-2

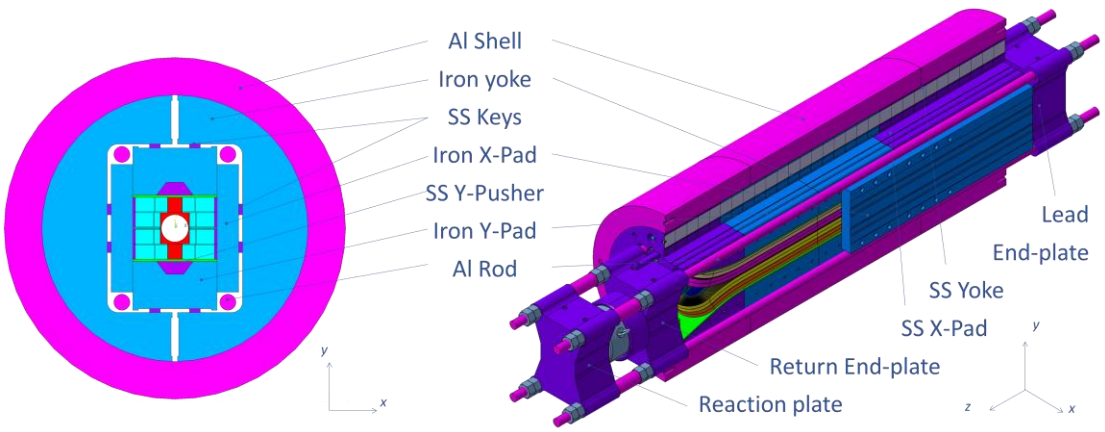


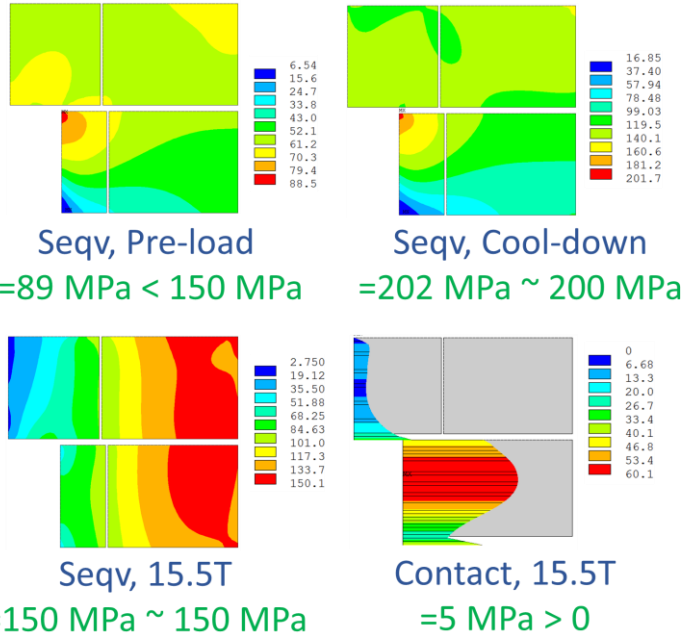


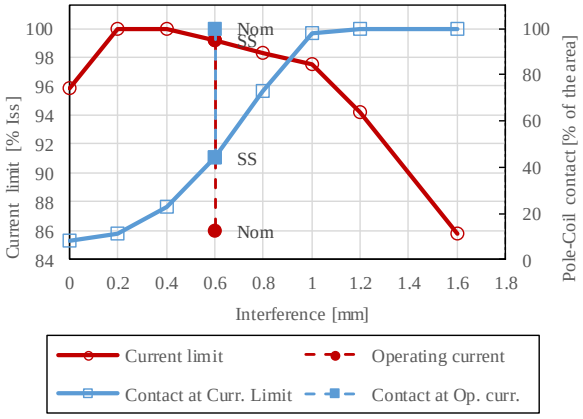
Ongoing activities
- Definition of the winding steps and parts design
- Winding Tooling preliminary design
- NbTi/Nb_3Sn splice area

MECHANICAL DESIGN

- 2D mechanical model => acceptable stress level in the coils
- Preliminary CAD model to assess constraints due to the vertical coil size







Study of the stress-induced Ic degradation

A. Bord, E. Rochepault, Computation of Current Limit in Nb_3Sn Superconducting Magnets Using Magnetic Field and Stress, to be published

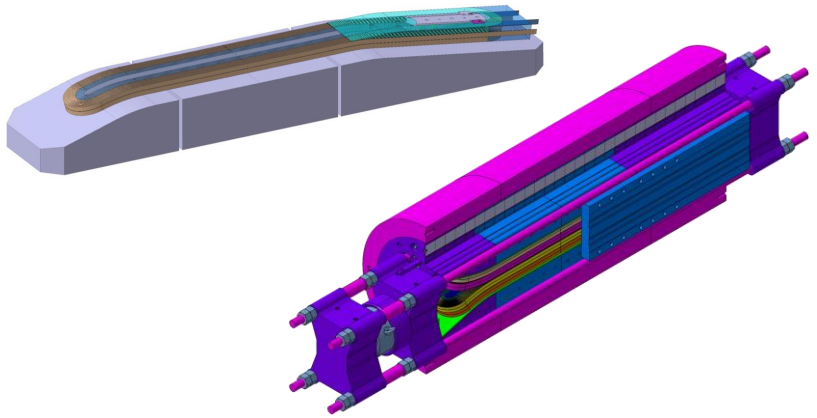
Next step:
3D ANSYS model

SUMMARY AND PLAN

Magnet Conceptual design

Coil and tooling preliminary design

Ongoing work



Coil and tooling engineering design

Magnet engineering design

Coil fabrication

Magnet assembly and Test

Schedule and content are being discussed within the CERN-CEA collaboration to reduce risk

- Strong ties to the CERN high field development program
- Possibility to include an intermediate milestone before F2D2 to prove all the concepts with less coils

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