FCCW2016
Roma, April 13th , 2016

EU/CERN program on 16T dipoles for the FCC

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Reference parameters

FCC

Bore diameter : **50 mm**

Dipoles : $\int Bdl \sim 1\ MTm\ (4578\ magnets, 14.3\ m\ long, 16\ T)$

Quadrupoles : $\int Gdl \sim 2\ MT\ \ (762\ magnets,\ 6.6\ m\ long, 375\ T/m)$

LHC

Bore diameter : **56 mm**

Dipoles : $\int Bdl \sim 0.15\ MTm\ (1232\ magnets, 14.3\ m\ long,\ 8.3\ T)$

Quadrupoles : $\int Gdl \sim 0.28\ MT\ \ (392\ magnets,\ 3.15\ m\ long,\ 223\ T/m)$

A factor of 7 difference

Question addressed by the CERN/EU program

Initially, focused to provide a credible feasibility statement by end 2018

Are 16T accelerator magnets feasible?

- field amplitude & margin
- field quality
- conductor availability & performance
- protection
- structural aspects (conductor & magnet)
- manufacture

If yes, at which cost?

- conductor cost
- field amplitude & margin
- magnet cost model

16T R&D: EuroCirCol WP5

- [75] Preliminary design of a 16T costeta dipole for the FCC MARINOZZI, Vittorio
- [276] EuroCirCol - blocks VEDRINE, Pierre
- [277] EuroCirCol - common coils TORAL, Fernando
- [78] Requirements for the quench protection in the 16 T Nb3Sn dipole designs SALMI, Tiina
- [83] Comparison of magnet designs from a circuit protection point of view VERWEIJ, Arjan
- [290] Magnet cost model and targets SCHOERLING, Daniel

16T R&D: FCC 16T Technology Program

- [262] FCC Conductor development plans BALLARINO, Amalia
- [382] PIT Nb3Sn conductor for FCC: potentials and challenges Dr. SCHLENGA, Klaus
- [23] Development of Nb3Sn conductors in Japan OGITSU, Toru
- 270] Nb3SN developments in Russia PANTSYRNY, Victor
- [398] Nb3Sn developments in Korea Dr. KIM, Jiman

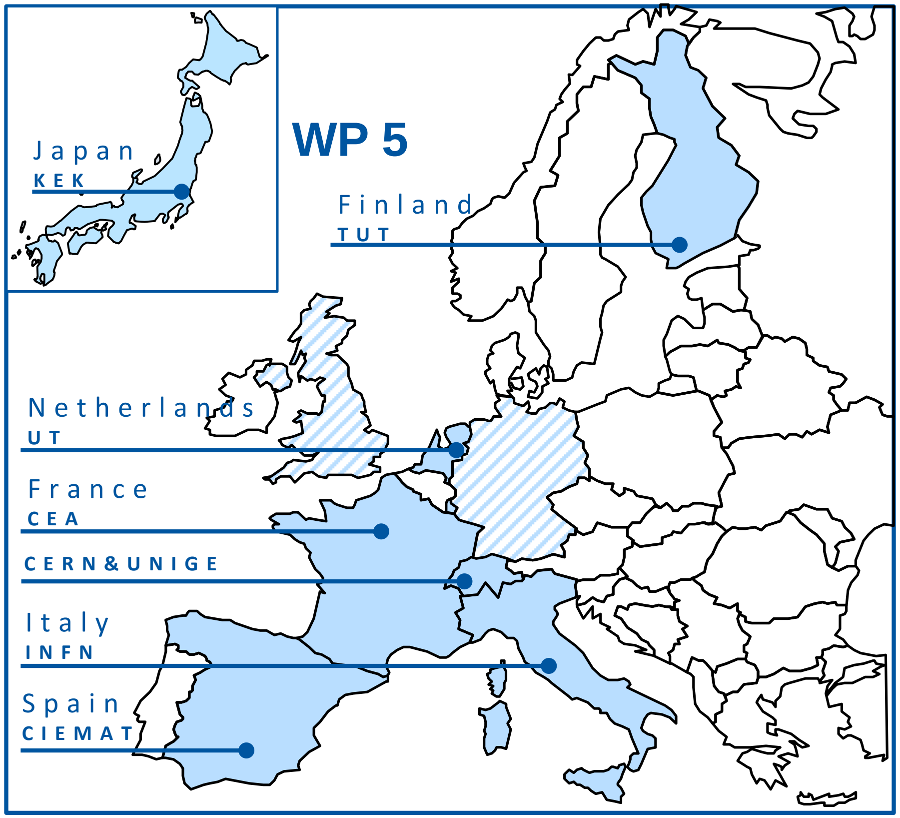
16T R&D: a US Program ?

- [413] LARP / US Hi Lumi magnet conductor and relevance to FCC COOLEY, Lance
- [186] Development of higher performance Nb3Sn conductors for the FCC PARRELL, Jeff
- [155] Review and Potential of 16 T (or more) Common Coil Dipole GUPTA, Ramesh
- [49] 60-mm aperture Nb3Sn dipole demonstrator for FCC at FNAL BARZI, Emanuela
- 279] development of CCT Nb3Sn dipole CASPI, Shlomo

EuroCirCol WP5

Deliverables of WP5 described in H2020-INFRADEV-1-2014-1

1) Explore design options for an accelerator dipole magnet producing 16 T
2) Identify the preferred dipole design options and perform a cost estimate
3) Develop a cost model (optimistic, likely and conservative)
4) Produce the engineering design of the selected configuration



Tasks:

1 Coordination
2 Design Options
3 Cost model
4 Magnet Conceptual Design
5 Conductor Studies
6 Quench Protection
7 Magnet engineering design

Intense activity: 10 video meetings since June 2015, in addition to special events

A Technical Review Committee is in place: 1st review on 11-12-13 May 2016

A model magnet will be built within the FCC Technology Program

FCC 16T Technology Program

TASKS

Task 0: Coordination

Task 1: Strand development & procurement

Task 2: Wound conductor test facilities

Task 3: 16T Enhanced Racetrack Model Coil

Task 4: 16T Racetrack Model Magnet

Task 5: 16T Demonstrator

SCHEDULE

End 2016: start winding the ERMC

2017: test ERMC

2018: test RMM

2019: test of Demonstrator

2019: availability of enhanced wire

2019: start winding the EuroCirCol Model with enhanced wire

2021: test EuroCirCol Model

FCC 16T Technology Program: conductor

Initially focussed to Jc increase : target Non-Cu Jc (16T, 4.2K) > 1500 A/mm2

Cost target 5 Euro/kAm, though, **first**, performance has to be achieved

A number of R&D and industrial initiatives are being explored:

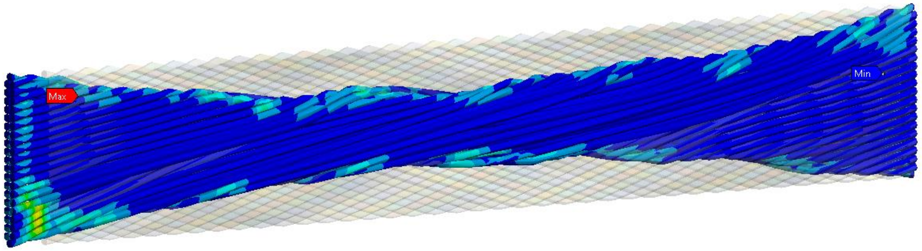
- Purchase of wires in Europe
- Industrial R&D in Europe
- Purchase of wires in US
- Collaboration agreement with KEK
- Collaboration agreement with Russia
- Program with Korean Industry being discussed
- Collaborations with several European Universities and Research Centres

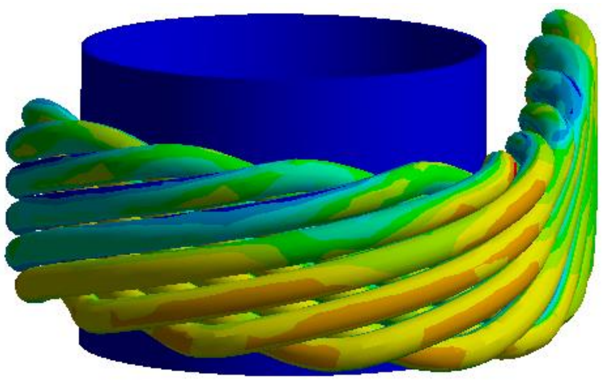
It is highly desirable that a strong industrial R&D program is established in the US

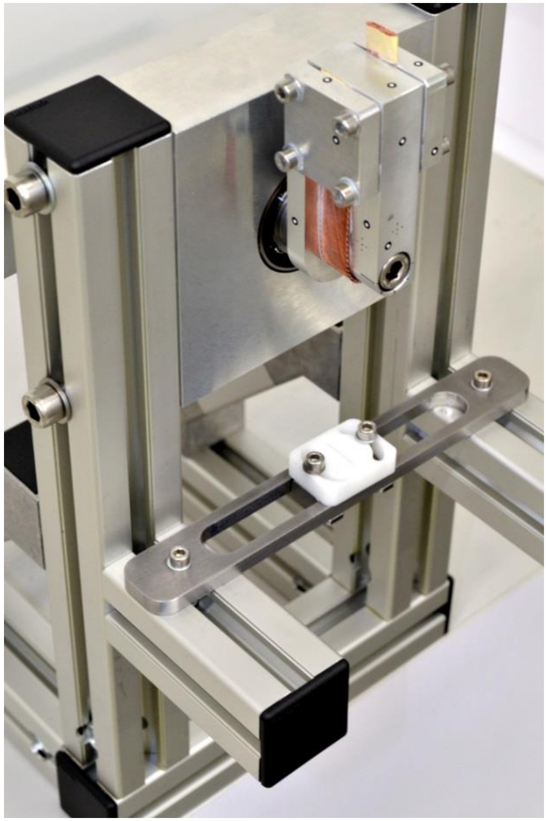
FCC 16T Technology Program: wound conductor

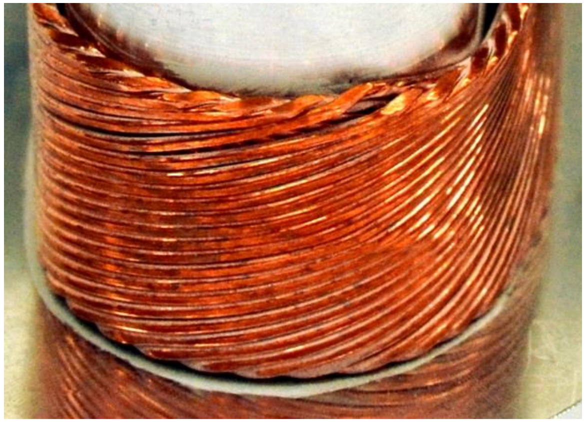
Parameters :

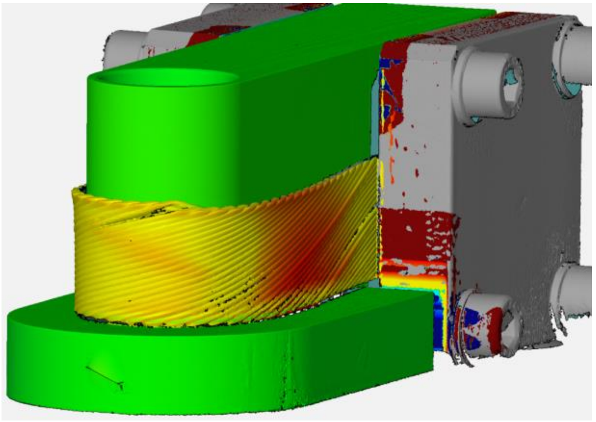
- Tensile force;
- Bending radius;
- Cable guide position and angle;
- Winding direction.











Courtesy Friedrich Lackner & Dariusz Pulikowski

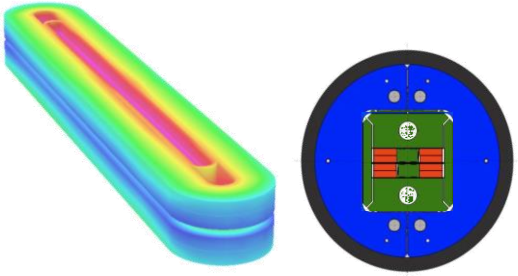
FCC 16T Technology Program: magnet models

4 stages
1. ERMC (different versions, non-graded and graded)
2. RMM (different versions, non-graded and graded)
3. Demonstrator
4. EuroCirCol model

ERMC

Enhanced Racetrack Model Coil
16 T midplane field

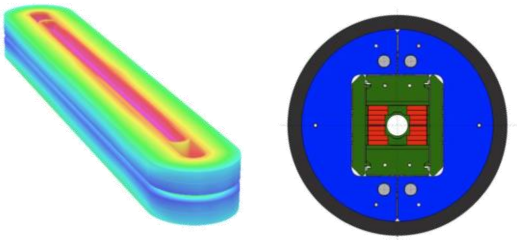
- Demonstrate field on the conductor
- Coil technology development (including "grading" splices)



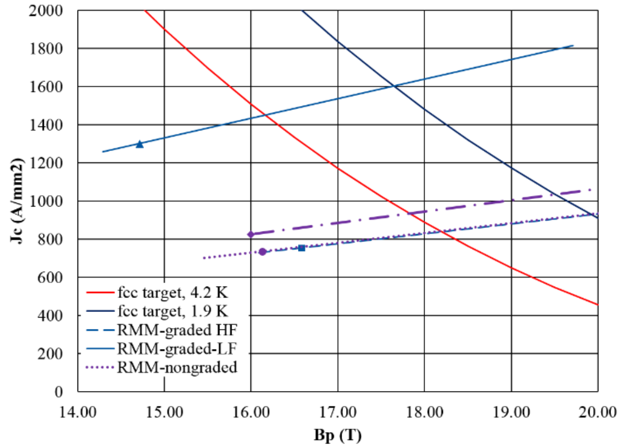
RMM

Racetrack Model Magnet
16 T in a 50 mm cavity

- Demonstrate field in the aperture
- Characterize field quality
- Mechanics (including inner coil support)



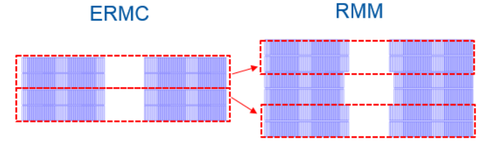
ERMC & RMM



Electromagnetic Design

Most promising option:

- 3 Decks Design (3 double pancakes)
- ERMC and RMM using the same structure and coils

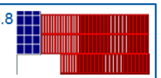


Next steps:

- Optimization of the coil lay-out considering grading
  - Without grading coil width w ~ 100 mm.
  - Aiming at reducing to w ~ 70 mm

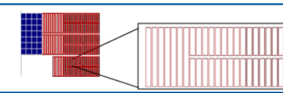
Combining 1 mm – 0.8 mm strands

Promising

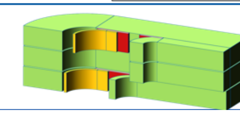


Only 1 mm strands, but double layer on the LF

Very difficult to manufacture

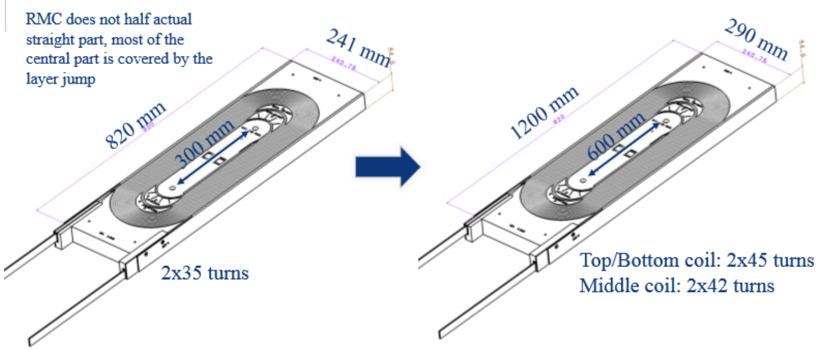


- 3D Magnetic Analysis and Conceptual Design of the splices needed for grading.



Coil length

- RMC coil dimensions
- Proposal for ERMC-RMM



Remark: For the "graded" solution, an option is to use the end region to do the splice.

Options:

- Have an structure that can accommodate 1.5 m coils even if the coils for the non-graded magnets will be 1.2 m.
- For the graded solution, reduce the magnet straight section to < 100 mm

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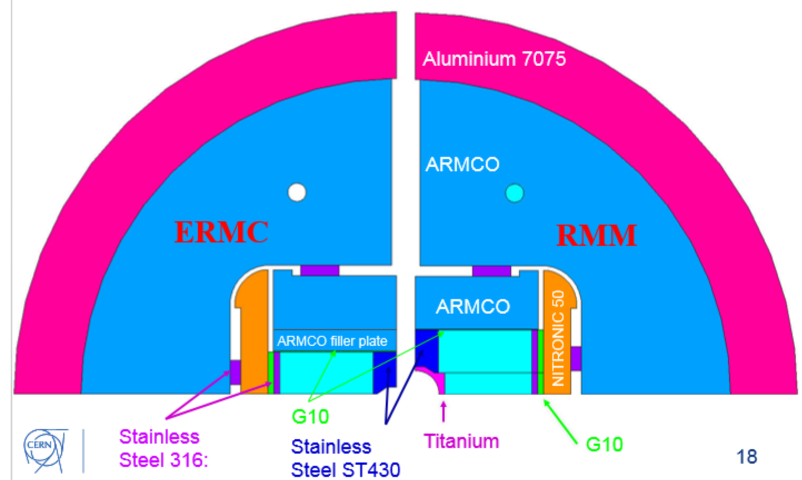
Mechanical design – Structural components

Aim: Have an unique support structure for ERMC and RMM.



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Courtesy Susana Izquierdo Bermudez & Juan Carlos Perez

Concluding Remarks

The EU/CERN 16T dipoles program established until 2019 is very ambitious, considering that during the same time most of efforts have to be devoted to HILUMI.

The magnet model work has been established such that it will provide important results even with presently available conductors, and remains flexible enough to accompany conductor development.

However, the conductor development remains an absolute necessity: it will be important to motivate an effective industrial R&D (in addition to production).

The FCC 16T Technology Program is synergic to the EuroCirCol: the model developed by the EuroCirCol will be built within the FCC 16T program.

It is highly desirable that the US enter vigorously into the program: in terms of magnet technology this would enable to explore in detail a second Demonstrator, and in terms of conductor development to extend the very successful R&D program that, in the past, gave impressive results on Nb_3Sn technology.

Thank you for your attention

EuroCirCol

CERN

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