2nd EuroCirCol WP5 Review
Monday 9 -Tuesday 10 October 2017

Introduction to the review and road-map

Davide Tommasini

EuroCircOL WP5 Review

TODAY

10:30 → 10:45 **Introduction to the review and road-map**
Speaker: Davide Tommasini (CERN)

10:45 → 11:00 **Conductor characterization**
Speaker: Bernardo Bordini (CERN)

11:00 → 11:15 **Update on ERMC/RMM**
Speaker: Susana Izquierdo Bermudez (CERN)

11:15 → 11:45 **Quench protection**
Speaker: Tiina-Mari Salmi (Tampere University of Technology, Finland)

11:45 → 12:00 **Circuit**
Speaker: Marco Prioli (CERN)

12:00 → 12:15 **Cost model**
Speaker: Daniel Schoerling (CERN)

12:15 → 12:30 **Update on CCT**
Speaker: Bernhard Auchmann (CERN)

14:00 → 14:30 **Cosinetheta electromagnetic design**
Speaker: Vittorio Marinozzi (University of Milan / INFN)

14:30 → 15:00 **Cosinetheta mechanical design**
Speaker: Barbara Caiffi (INFN - National Institute for Nuclear Physics)

15:00 → 15:30 **Block-coil electromagnetic design**
Speaker: Clement Lorin (CEA)

15:30 → 16:00 **Block-coil mechanical design**
Speaker: Clement Lorin

16:00 → 16:30 **Common-coil electromagnetic design**
Speaker: Fernando Toral (Centro de Investigaciones Energéti cas Medioambientales y Tecno)

16:30 → 17:00 **Common-coil mechanical design**
Speaker: Javier Munilla Lopez (CIEMAT)

17:00 → 18:00 **Closed Session**
Convener: Stephen Gourlay (LBNL)

TOMORROW

08:30 → 09:30 **Tour of 927 for the reviewers**
Speaker: Juan Carlos Perez (CERN)

09:30 → 10:10 **Discussion with reviewers**

10:10 → 10:30 **Coffee break**

10:30 → 12:00 **Closed Session**
Convener: Stephen Gourlay (LBNL)

12:00 → 12:30 **Close-out**
Speaker: Stephen Gourlay (LBNL)

Recall of 1st review

- Work to date has shown that some parameters may be over restrictive
- None of the designs are advanced enough to make a decision on downselect
- No 3D analysis was presented and this is necessary to make a relevant downselect
- More flexibility on conductor parameters will benefit all designs

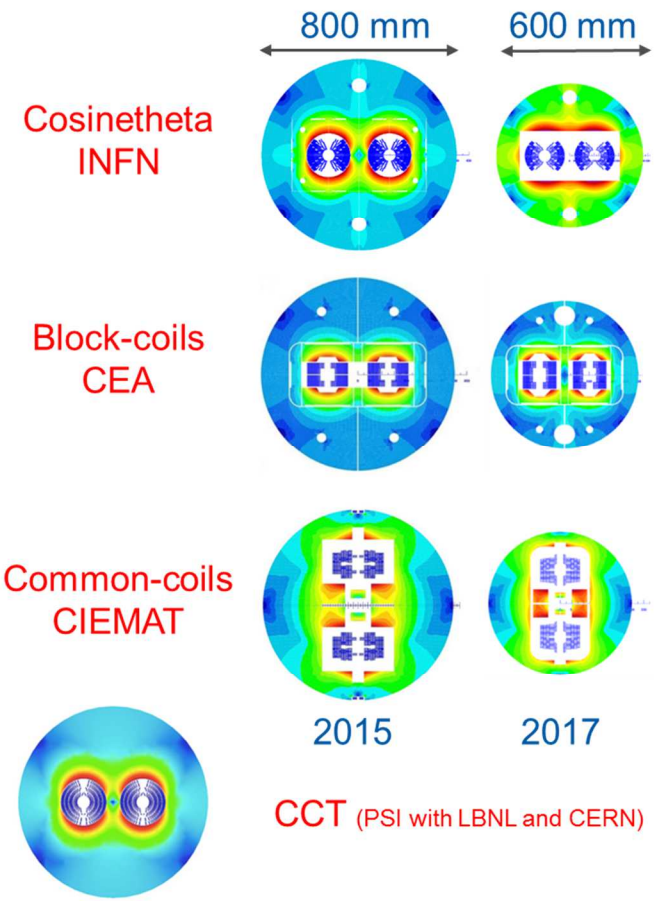
Recommendations

- Lower the margin , but not less than 10%
- Relax limits on
  - Number of strands from 40 to 60
  - Cu/non-Cu ratio from 1 to 0.8
  - Strand diameter from 1.1 mm to 1.2 mm
- Explore strain dependence of high J_c Nb_3Sn at high field and possibly at 1.9 K. Strain sensitivity is more of an issue at high field. Work on transverse load is difficult but important.
- In all three cases, integrate mechanical, EM and quench design
- All three cases need to do some 3D analysis
- Perform stress analysis for condition of 350 K peak temperature during worst case quench condition
- Incorporate results of coil modulus tests when available

Questions to the Reviewers

1) Are the baseline parameters considered in the study credible for a FCC CDR?
2) In the CDR we will describe a baseline design, with also a brief description of alternatives. The proposed baseline design is the cosinetheta: do you support this choice or would you suggest a different one?
3) Do you have any suggestions for improvements to the design options presented during the review?
4) Is there any specific additional study that you suggest to perform in view of the preparation of the FCC CDR?
5) Do you have any comments on the EuroCirCol WP5 Road-Map?

Evolution of the design options since the 1st review



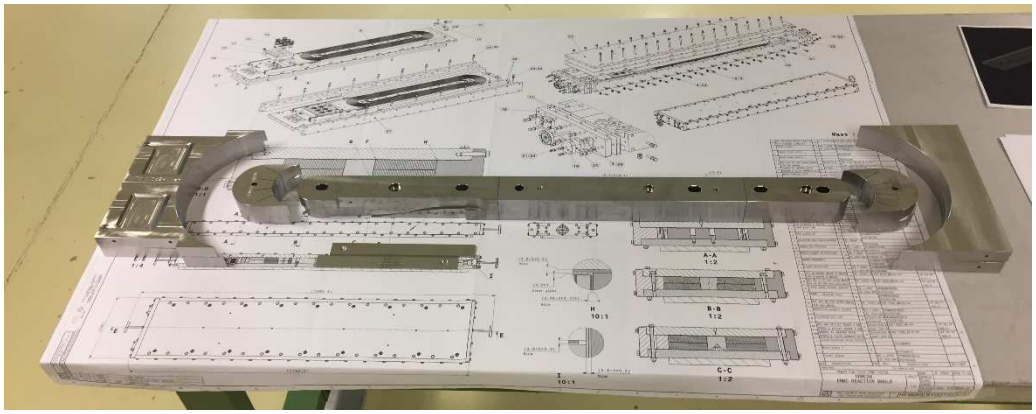
The reference parameter space has been finalized considering recommendations from the 1st WP5 EuroCirCol Review (11-13 May 2016, http://indico.cern.ch/event/516049) and follow-up of the 2017 FCC Week (http://indico.cern.ch/event/556692)

The considerable decrease of the coil size comes from a reduction of the margin on the load-line from 18% to 14%, and of the cold mass size from allowing a stray field of up to 0.2 T at the cryostat surface

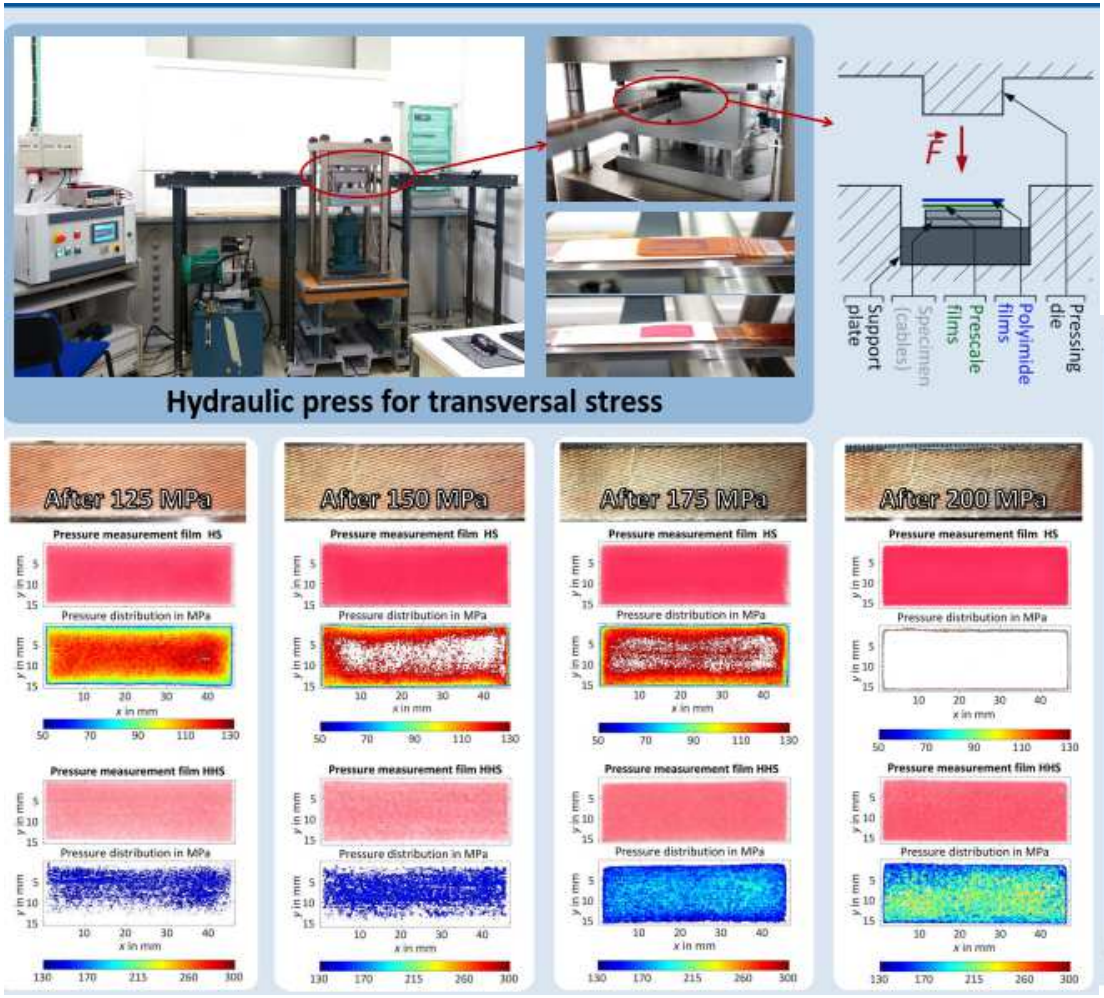
Magnet length	14.3 m	
Free physical aperture	50 mm	
Field amplitude	16 T	
Margin on the load-line @ 1.9K	14 %	
Total time margin	40 ms	
Critical current density @ 1.9 K, 16T	2300 A/mm^2	
Conductor fit (Jc/B)	EuroCirCol fit	
Degradation due to cabling	3%	
Minimum Cu/nonCu	0.8	also check 0.9-1.0
Maximum strand diameter	1.2 mm	also check 1.1 mm
Maximum stress on conductor at warm	150 MPa	
Maximum stress on conductor at cold	200 MPa	
Maximum hot spot temperature (@ 105% I_{nom})	350 K	
Maximum number of strands in a cable	40	check up to 60
Maximum voltage to ground (magnet contribution)	1.2 kV	set as tentative value
Maximum TOTAL voltage to ground	2.5 kV	
Conductor cost (performance based)	5 Euro/kAm	

A selective overview of activities

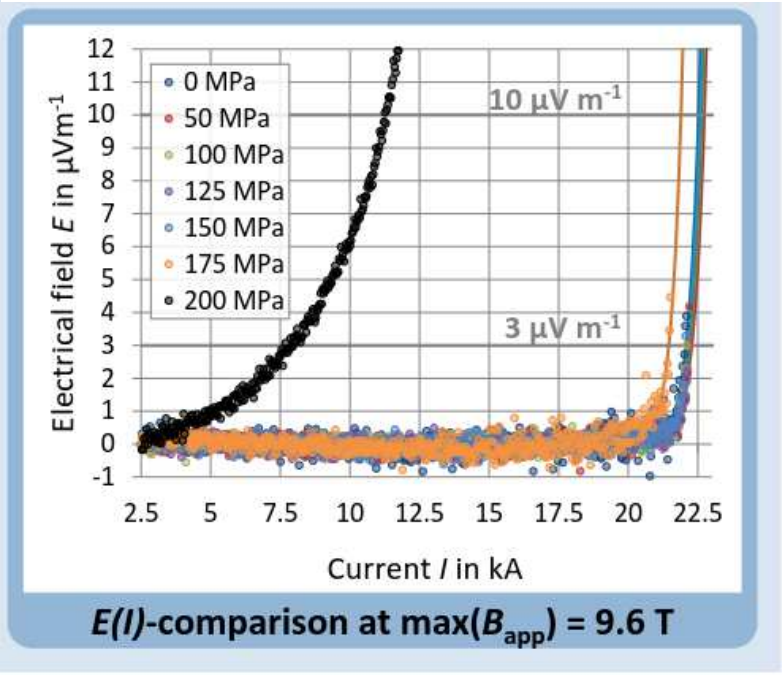
- New iteration on «compact» design options (ϕ_{yoke} ~ 600 mm, $\phi_{cryostat}$ ~ 1200 mm)
- Ad hoc meeting to discuss the effect of the fringe field (September 19th)
- Discussion on magnet losses during ramp (slow and fast) with L.Tavian
- Interesting output of the compression tests on cables at ambient temperature (magnet assembly): the baseline limit of 150 MPa seems to be confirmed as conservative
- Ready to start winding the first ERMC



Compression at ambient temperature



F.Wolf et al, Characterization of the Stress Distribution on Nb3Sn Rutherford Cables Under Transverse Compression, MT25, 2017
P.Eberman et al, Characterization of irreversible degradation of Nb3Sn Rutherford cables due to transversal compression stress at room temperature, EUCAS, 2017



The limit of 150 MPa seems to be (too?) conservative

Proposed baseline for the FCC CDR

Proposed baseline design option: cosinetheta magnet

operating at 16 T, 1.9K, with 14% of load line margin with respect to the «Target FCC Conductor» having a critical current density of 1500 A/mm^2 @ 4.2K, 16T (equivalent to 2300 A/mm^2 @ 1.9K, 16T)

The other options (block coil, common coil and perhaps canted costheta) will be also briefly described.

Remarks about the proposed baseline design option

The work performed within the EuroCirCol has shown that different design options can all of them effectively work on paper, respecting all constraints imposed by the EuroCirCol WP5. Each of the options has advantages and disadvantages with respect to the others (for example the common-coil uses more conductor than the costheta or the block but the coils are easy, the block-coil needs internal splice and longer ends than the costheta but the high stress region corresponds to the low field region).

We select the costheta option as the EuroCirCol WP5 proposal for the FCC-CDR-baseline. This is the design configuration in use in all superconducting colliders made so far: the Tevatron, Hera, RHIC, and the LHC. All of them have operated or are operating close or exceeding their nominal performance. Though all these magnets are based on Nb-Ti, we have no reasons for believing that a similar design would not work for the FCC.

Due to the lack of experimental evidence supporting the advantages of one solution with respect to the other, it has however been decided to explore in detail all options with an experimental program. It is not excluded that the relevant results will allow to identify in a future an even better solution than the one presented here as baseline.

EuroCirCol WP5 Road-Map

1. **9-10 Oct 2017** : EuroCirCol WP5 review
2. **Dec 2017**: 2 D designs, including insertion of cooling channels and optimization of magnetization, of all design options. First draft of summary FCC CDR book chapter on 16T.
3. **April 2018**: FCC Week
   - conceptual 3D study with integration in the cryostat for FCC week
   - overview of «alternative» assembly structures
   - reports for:
     - Task 5.3 Cost model
     - Task 5.5 Conductor studies
     - Task 5.6 Quench protection
4. **June 2018**: first draft of detailed FCC CDR book chapter on 16T
5. **Dec 2018**: compilation of FCC CDR
6. **April 2019**: final report for EU

Thank you for your attention