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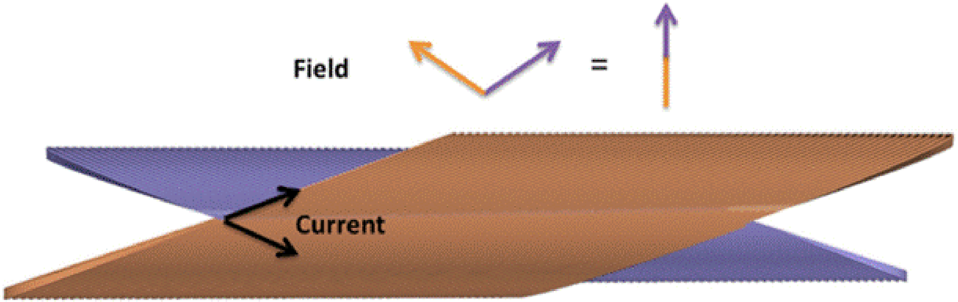
Electromechanical Design of a 16-T CCT Twin-Aperture Dipole for FCC

28.08.2017, MT25, Amsterdam, NE
Work supported by the Swiss State Secretariat for Education, Research and Innovation SERI.

Overview

- CCT for FCC
  - Electromagnetic design
  - Mechanical design
- The PSI CCT model program
  - Roadmap
  - Status



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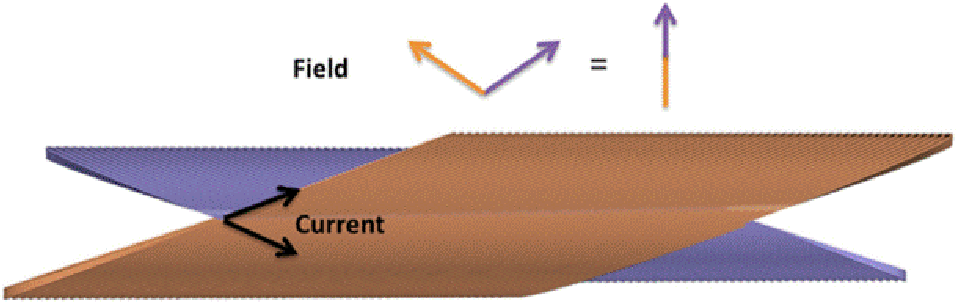
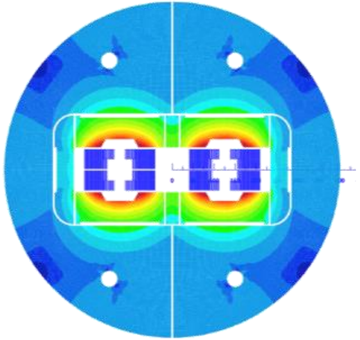
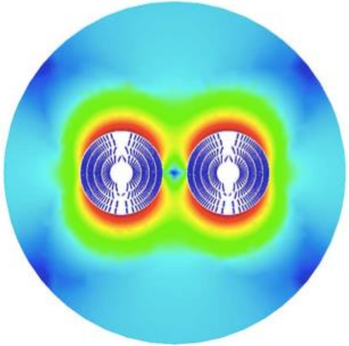


Preliminary designs as of Nov. 16’

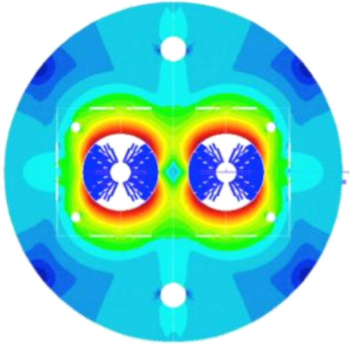
Block coil



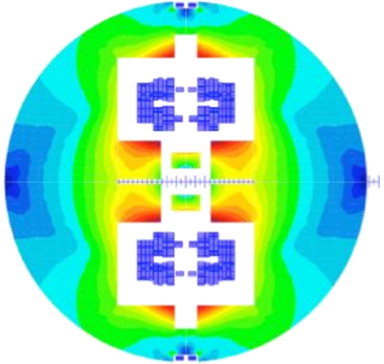
Canted Cosine Theta



Cos-theta



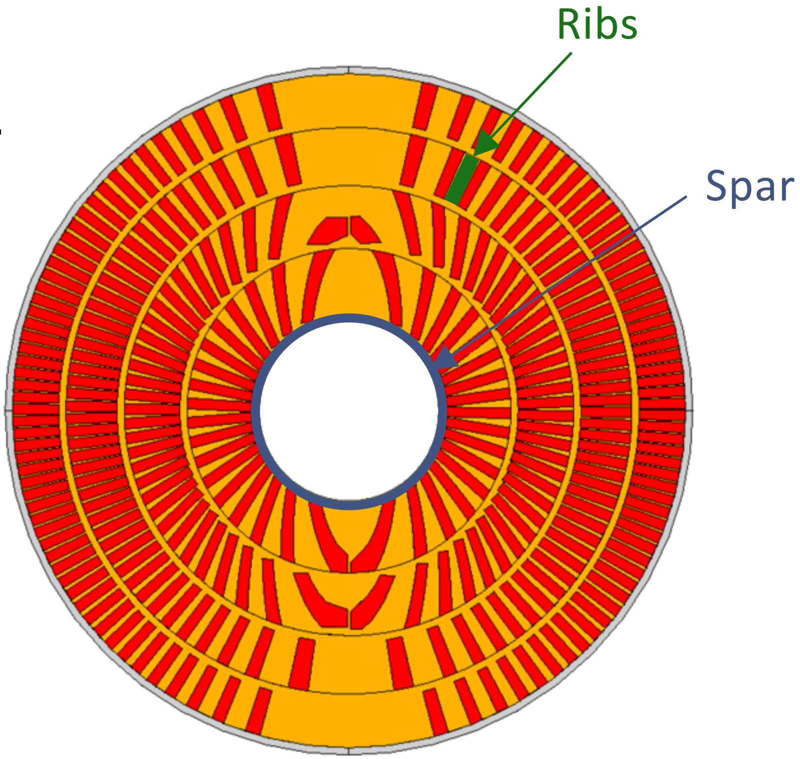
Common coils



CCT Design for FCC

- Keys to an efficient CCT design:
  1. Thin spars
  2. Wide cable, large strands
  3. Thin ribs.

  } Increase J_e.



PSI's CCT Design for FCC

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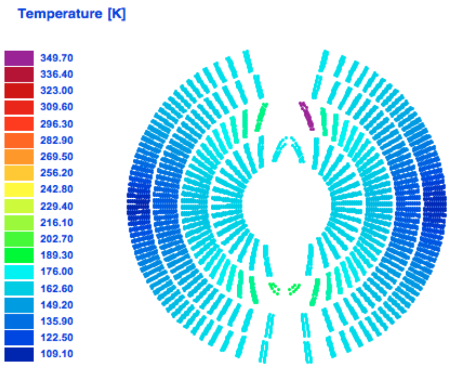
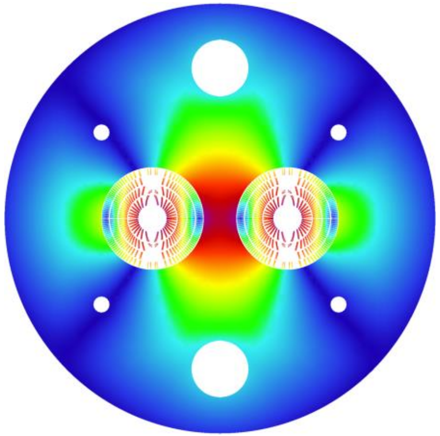
- Current: 18055 A

Layer #	n_S	cuNc	loadline marg. [%]	current marg. [%]	T_{peak} [K]	V_{grnd} [V]	J_{cu} [A/mm²]
1	29	0.8	14.2	111	292	1133	1237
2	25	1.1	14.4	95	342	1264	1217
3	22	1.95	14.4	74	310	1156	1096
4	20	2.6	15.7	70	338	1144	1103

Homogeneous coil temperature after quench.



- FCC-wide conductor use:
  - Total: 9.77 kt (+30% wrt. cosine theta/block)
  - NonCu: 3.75 kt
  - Cu: 6.02 kt
- Total inductance: 19.2 mH/m
- Total energy: 3.2 MJ/m

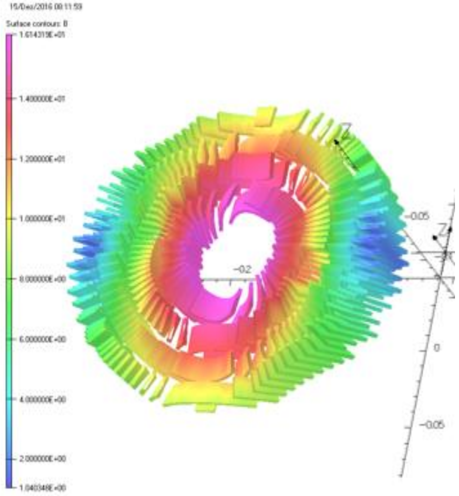


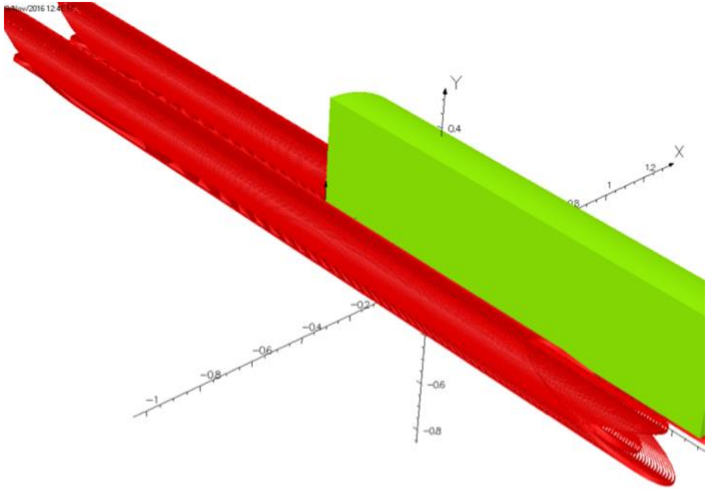
Geometric/nl. iron harmonics:
b2 <= 6 units
b3,4,5, .. <= 1 unit

3-D Magnetic Design

3-D modeling results:

- **Yoke cut-back** not needed (20 mT peak-field enhancement in ends).
- **Magnetic length** with yoke equal to that of bare coil.
- **Physical length** minus magn. length = 53 cm; equal to 11 T magnet.
- **Peak field** minus main field at 16-T bore field: 0.14 T excluding self field.
  - comparable or lower than cos-theta due to continuous current distribution.





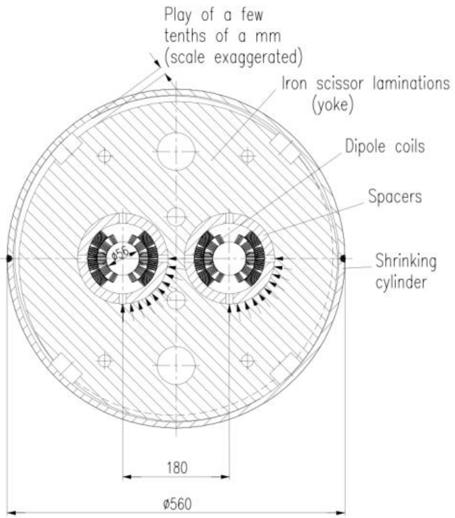
Courtesy M. Negrazus

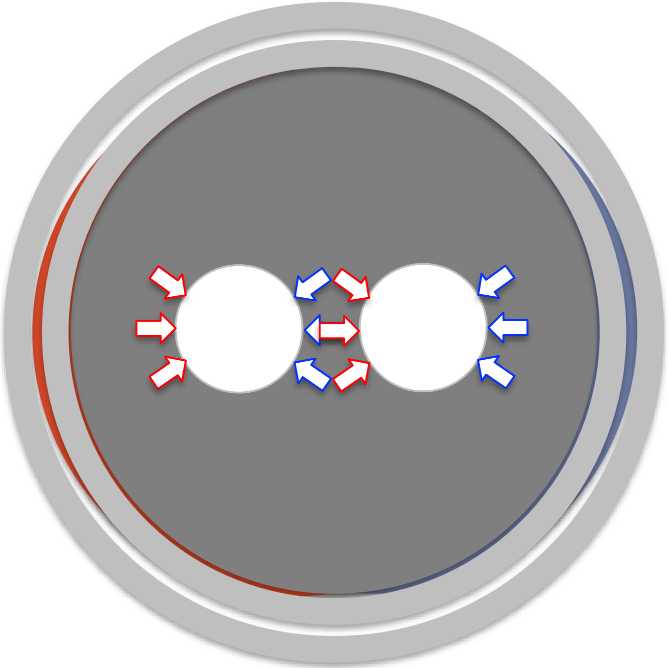
Mechanical Structure

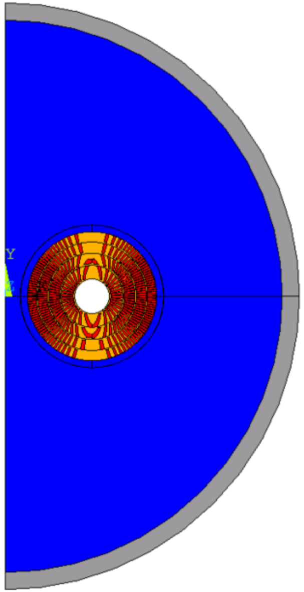
- CCT does not require azimuthal prestress.
- Radial prestress on the midplane provided by “scissor” laminations

SUPERCONDUCTING COIL COMPRESSION BY SCISSOR LAMINATIONS

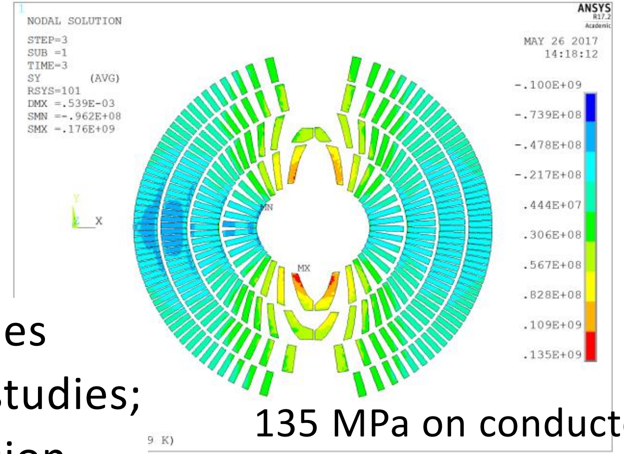
Albert Ijspeert, Jukka Salminen, CERN, Geneva, Switzerland

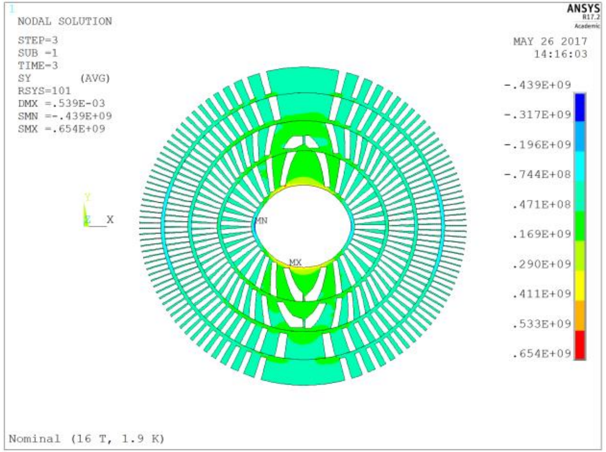






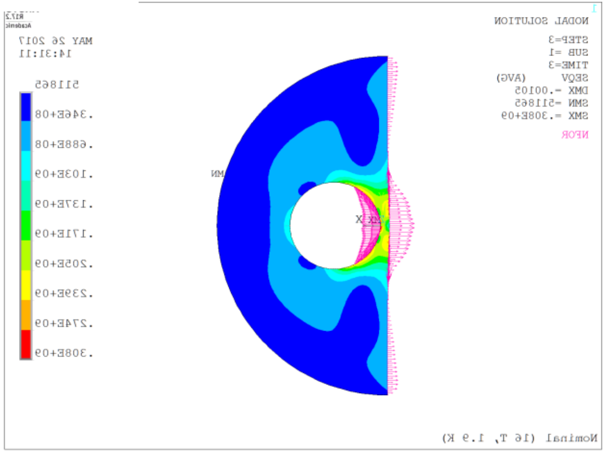
2D Mechanical Design

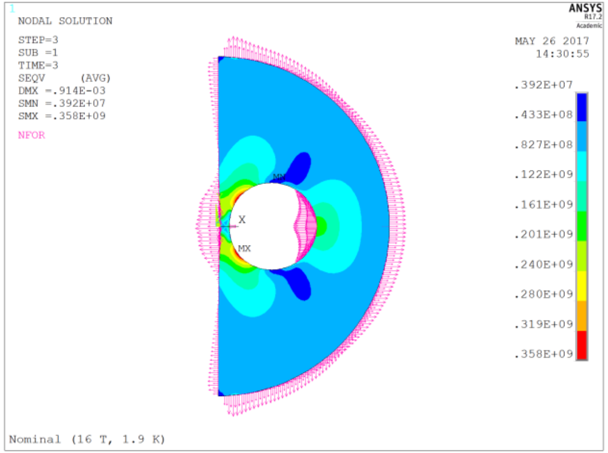




Material properties
as in EuroCirCol studies;
see previous session.

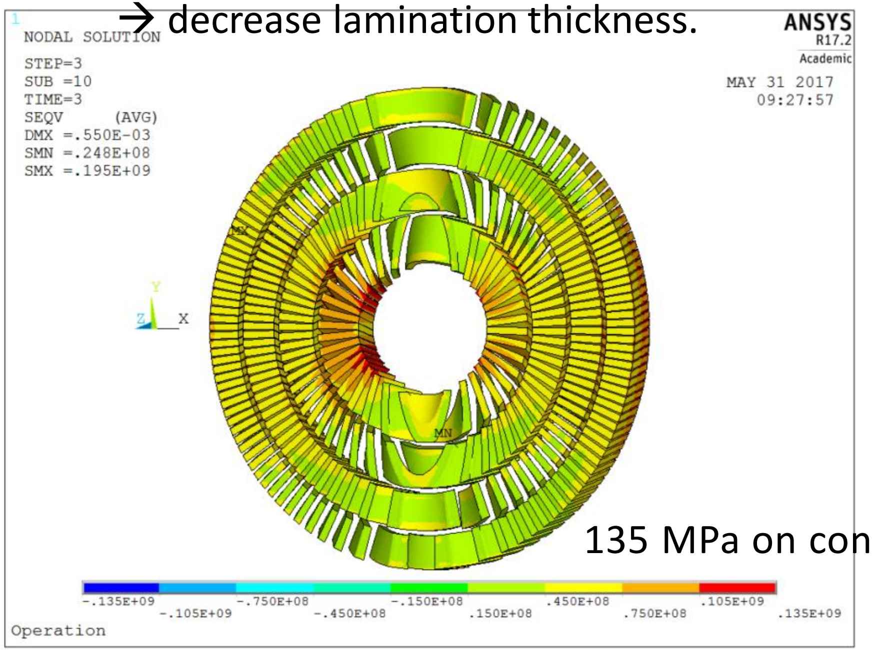
135 MPa on conductor





3-D Periodic Simulation

- Generalized plane stress condition applied (following D. Arbelaez, L. Brouwer, LBNL)
- Initial 3-D results confirm 2D, but show distinct imprint of scissors lams
  → increase protective shell thickness, change its material to iron
  → decrease lamination thickness.



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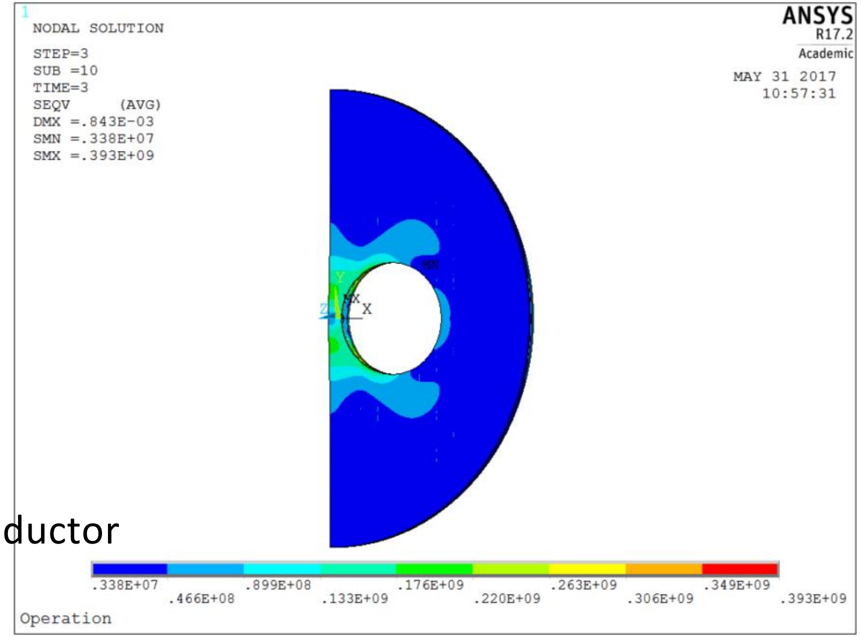
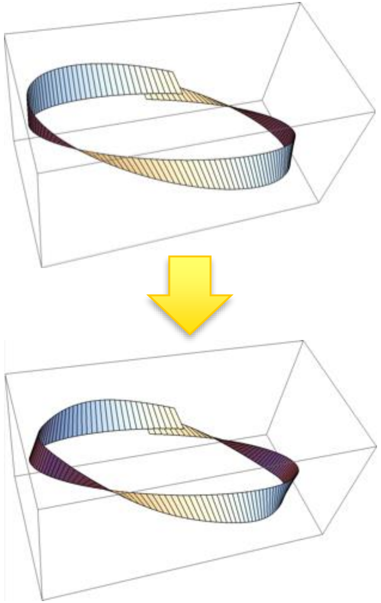


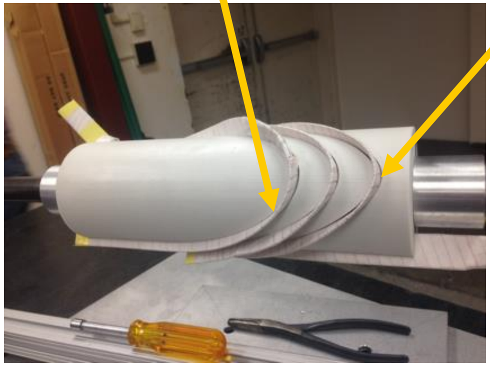
Windability

- Improve windability through inclined channels.
- Winding tests at LBNL and PSI.
- Successful tests with LD1 cable (@LBNL), LBNL CCT cable, and 11-T cable (@PSI).



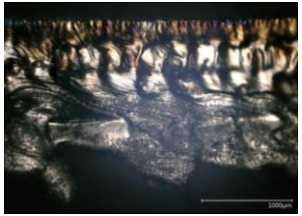
inclined channel: successful

radial channel: de-cabeling



Manufacturability and Cost

- Deep channels, aspect-ratio ~10.
- Inclined channels → 5-axis machining on long rotating cyl., **machining tests under way**.
- Selective Laser Melting (3-D printing) not successful.
- **Collaboration with IWS Fraunhofer** on fabrication of **thin-lamination formers**.
  - Laser weld-cutting.
  - Goal: improve scalability and cost.



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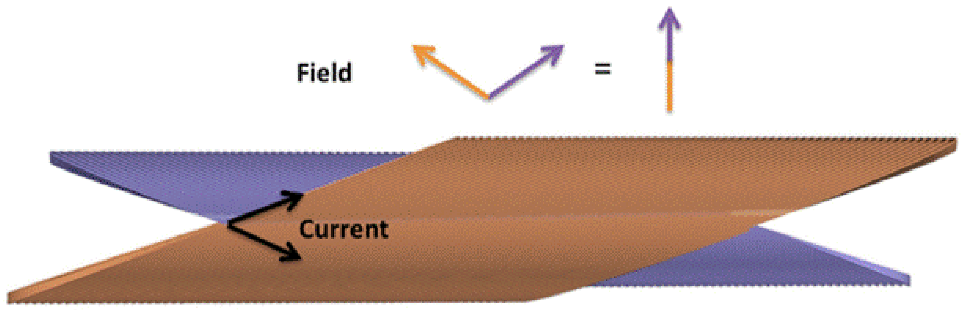
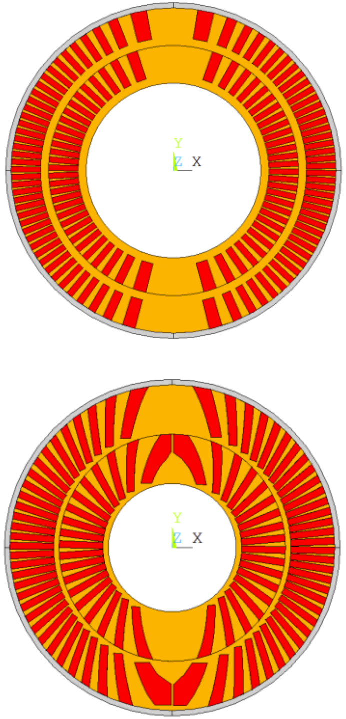


PSI Goals towards FCC Requirements

- Thin spars
- Exterior Bladder and Key structure
- Impregnation system (NHMFL resin, etc.).
- Fast quench detection and CLIQ protection.
- Wide Rutherford cable.
- Inclined channels manufacturing.
- Former manufacturability and cost reduction (with Fraunhofer/industry).

CD1 (first four items)

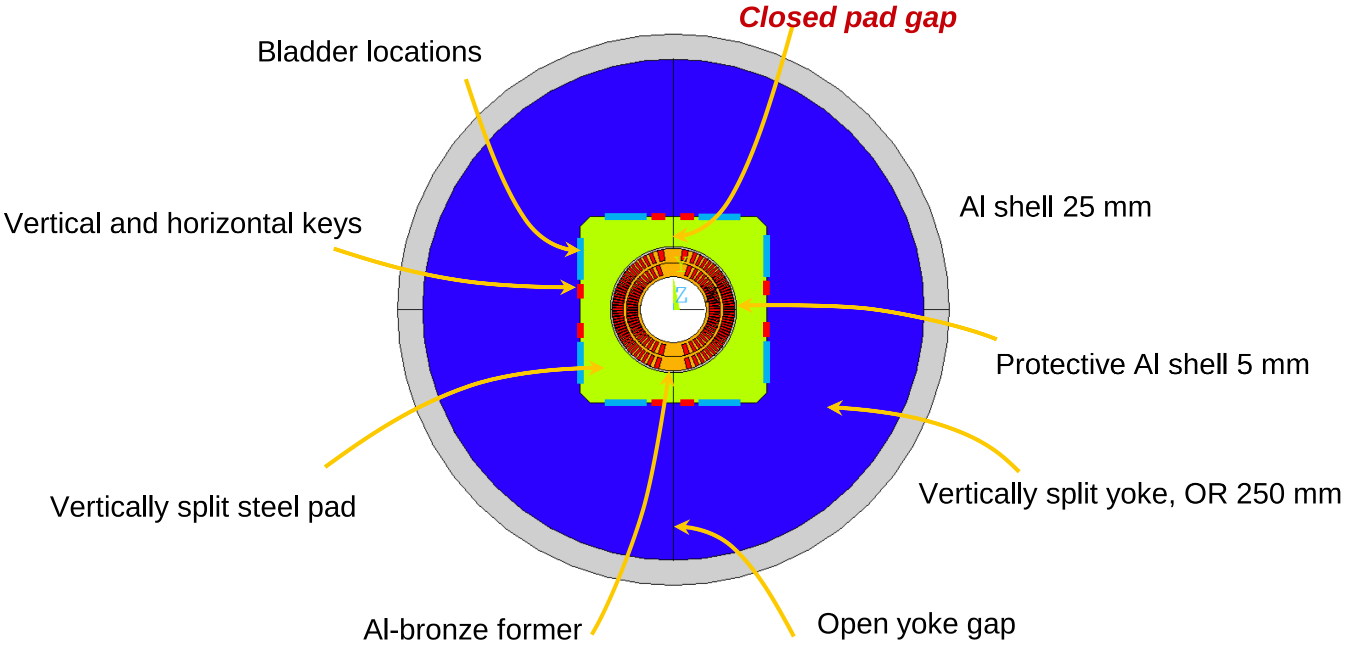
CD2 (first six items)



Mechanical Structure

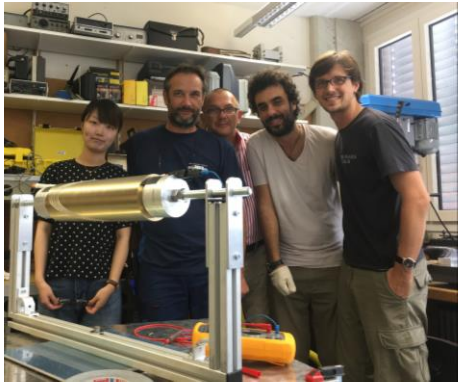
Bladder and Key technology chosen for tuneability and relative simplicity.

- Closed and pre-loaded pad gap for maximum-rigidity cage around coils.
- Steel pads to better match coil differential contraction.



Conceptual Design Review and Arrival of First Hardware

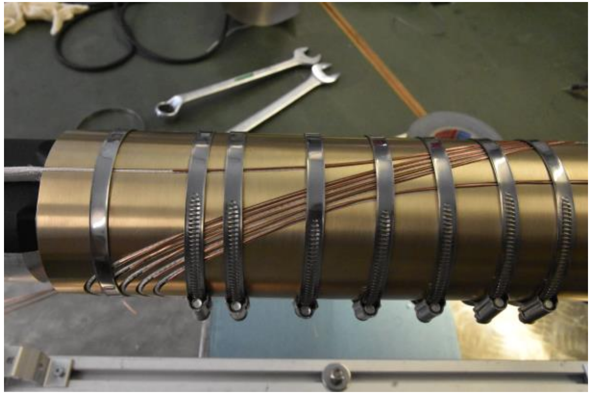
- International conceptual design review of CD1 on June 26 at CERN (http://indico.cern.ch/e/cd1cdr).
- Green light to start procurement of a short mechanical structure for test purposes.
- First machining-, winding-, and reaction-trials under way. Impregnation trials to start shortly.



CCT Program Team

Test formers delivered.

Test winding completed.



Preparation for heat treatment.

Summary

- The CCT option was established as a valid contender in the FCC design study.
- The PSI program has been designed to be complementary to and closely coordinated with the LBNL program, pushing towards specific features needed in an FCC magnet.
- Former manufacturing process-development was started with IWS Fraunhofer.
- PSI benefits from generous support by LBNL, integrating deeply with their program, as well as from regular exchanges with many a CERN staff who share freely and are most helpful – THANK YOU!

END