Review of the separation dipole D1

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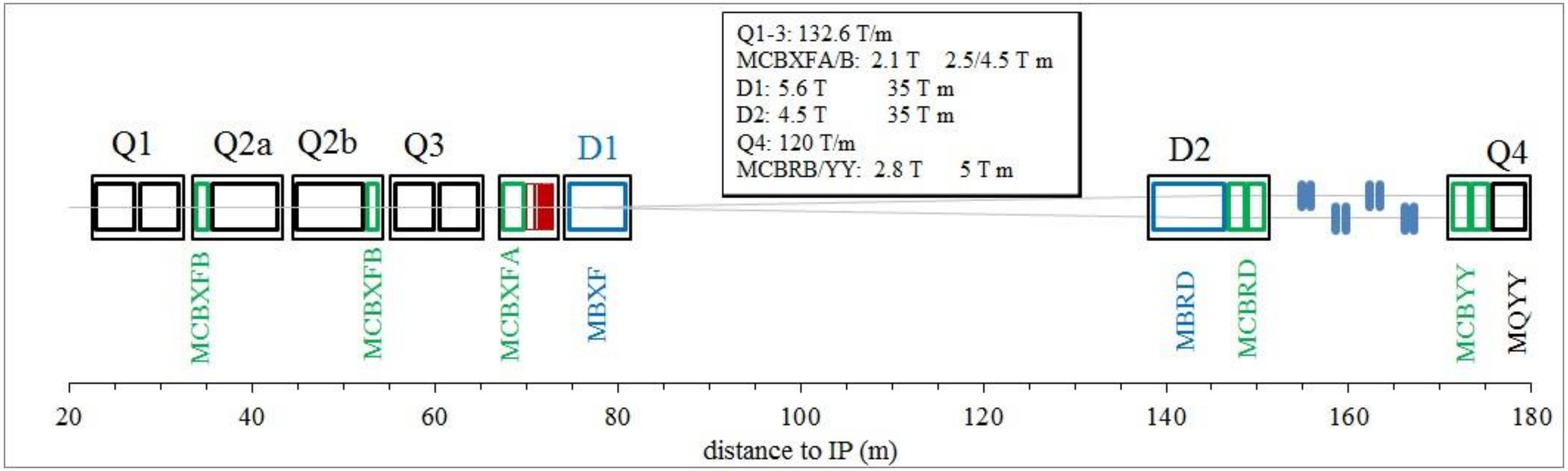
Review panel

- Toru Ogitsu (KEK, Chair)
- Davide Tommasini (CERN)
- Shlomo Caspi (LBNL)
- Kiyosumi Tsuchiya (KEK)

General remarks

- D1 is the separation dipole in HL LHC
  - It replaces the resistive D1 in LHC, with increase in the kick from 26 to 35 T m
  - At the same time it reduces the magnetic length from 24 m to 6.3 m, making space available for the triplet and for the crab cavities

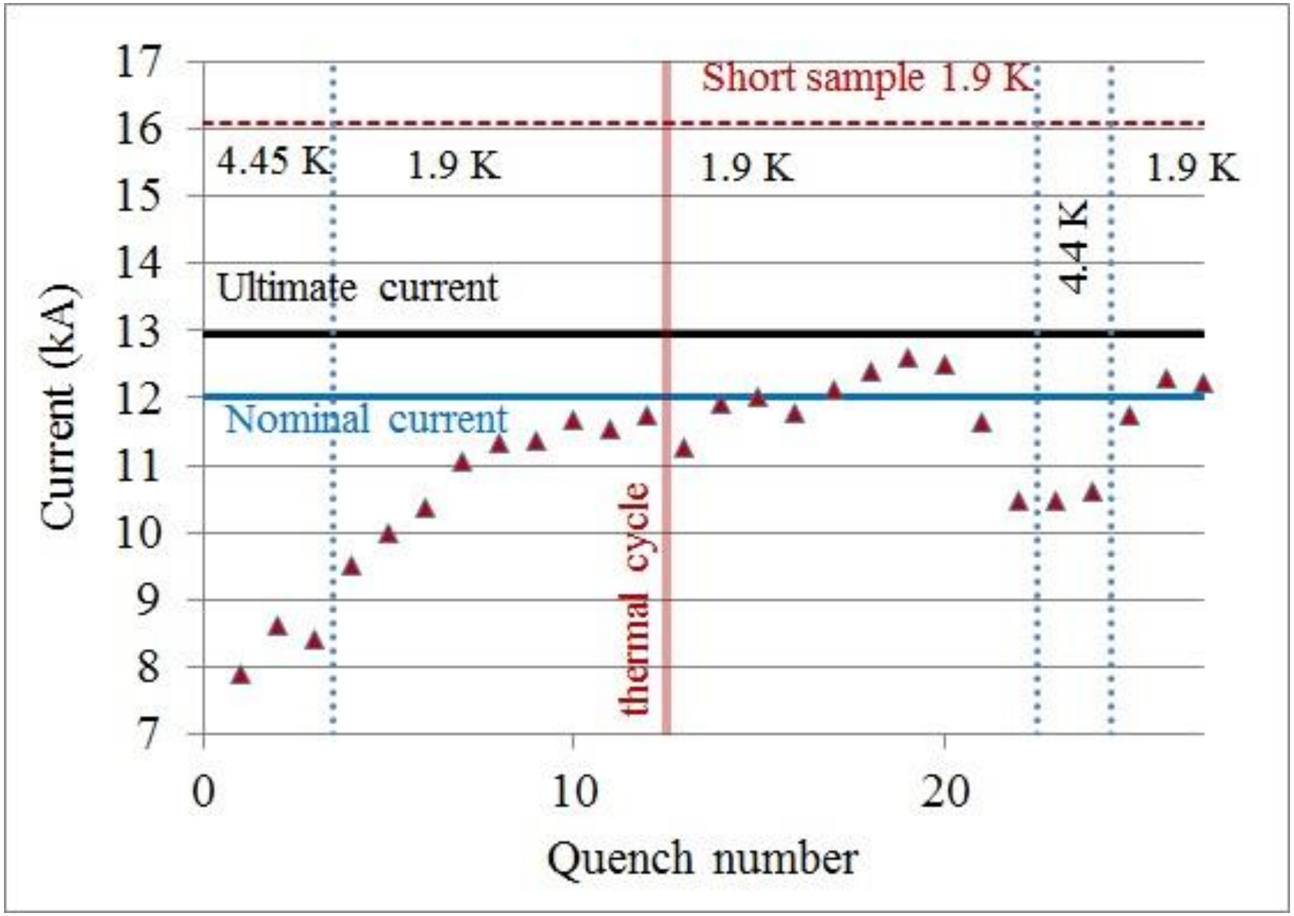


Present status and plan

- D1 short model program implies the construction of two 2-m-long models
  - First to be tested in late 2015, then shifted by six months due to iteration on the yoke
  - Second to be built in 2016 and tested at the end of the year

- First short model tested in April 2015
  - Nominal reached, good memory after thermal cycle
  - Quench performance not fully satisfactory – reached 500 A less than ultimate
  - Evidence of complete unloading of the coil at 6 kA
  - Issues on the field quality – relevant difference between 2D and 3D estimates for saturation (to be understood)

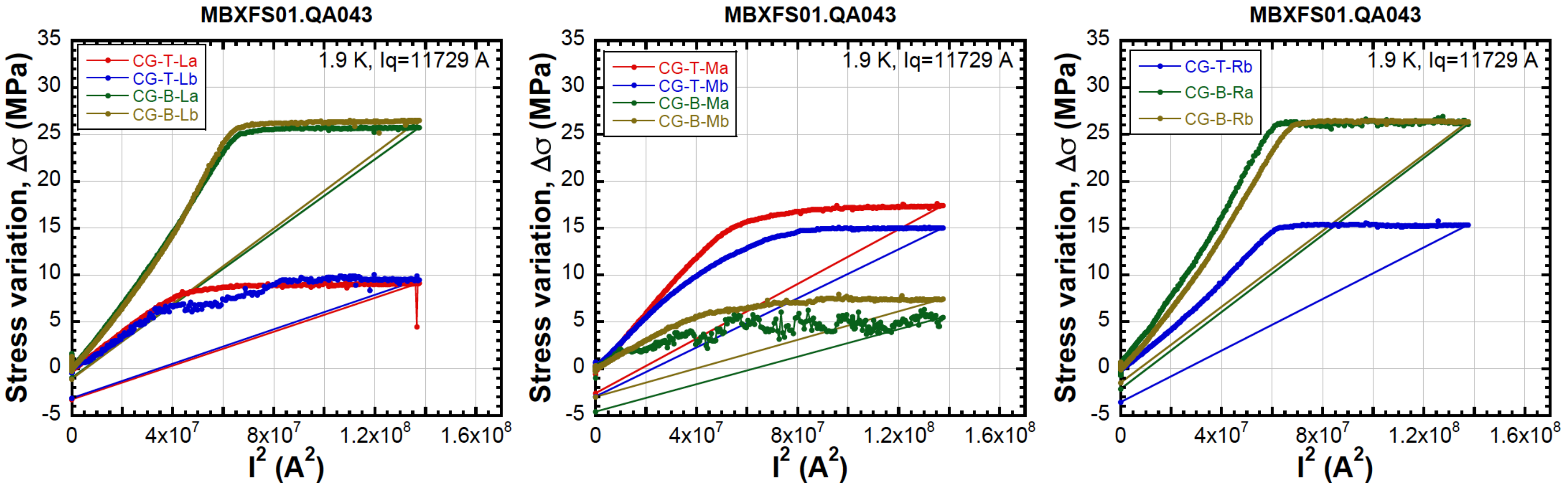
Quench performance



Quench performance of the first D1 short model [M. Sugano, T. Nakamoto, et al.]

Coil unloading during powering

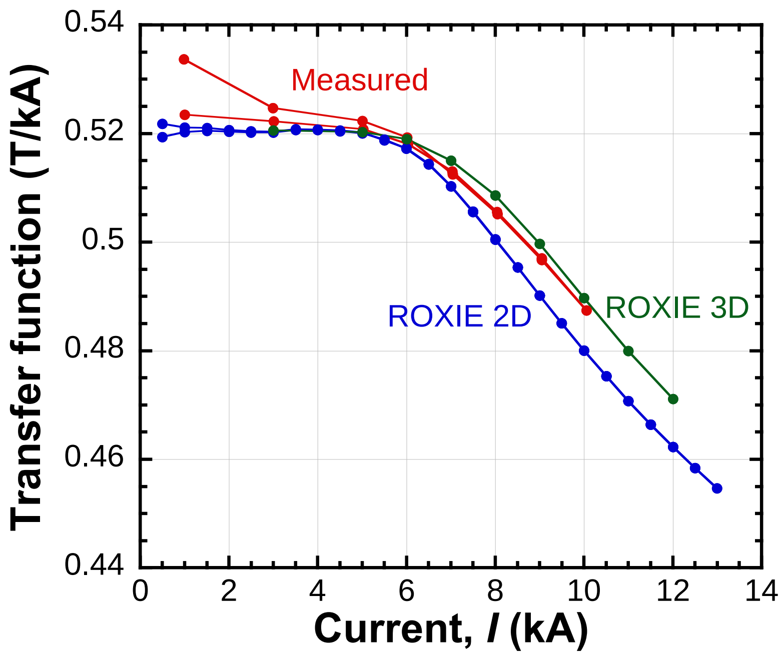
- Clear evidence of coil unloading at 8.5 kA (nominal is 12 kA)
  - Larger prestress loss than expected during cool-down
  - Not clear if quenches are in the heads or in the straight part

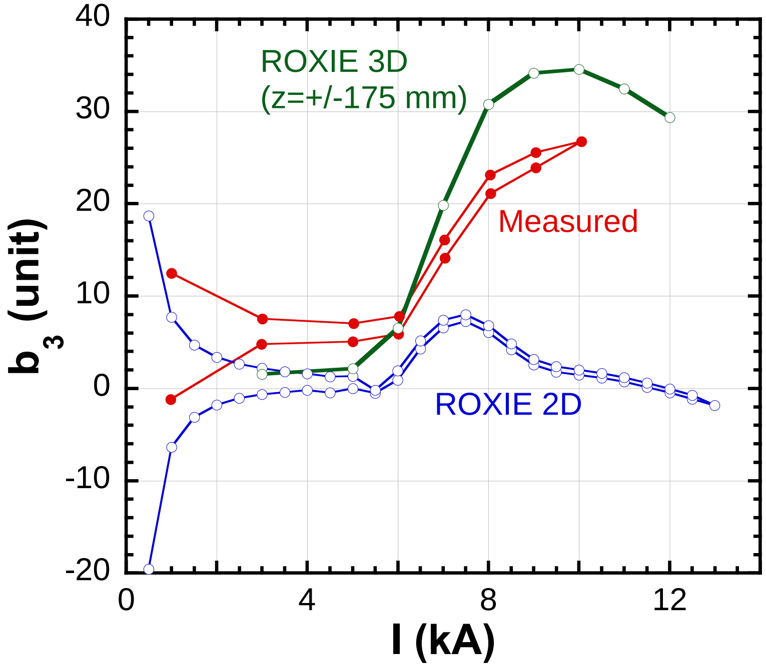


Coil unloading during powering of the first D1 short model [M. Sugano, T. Nakamoto, et al.]

Field quality

- Geometric b_3 was centered within 5 units
  - This can be considered as normal, to be recovered with shimming of the coil in the production
- Large impact of coil ends on b_3 saturation in the straight part – to be understood

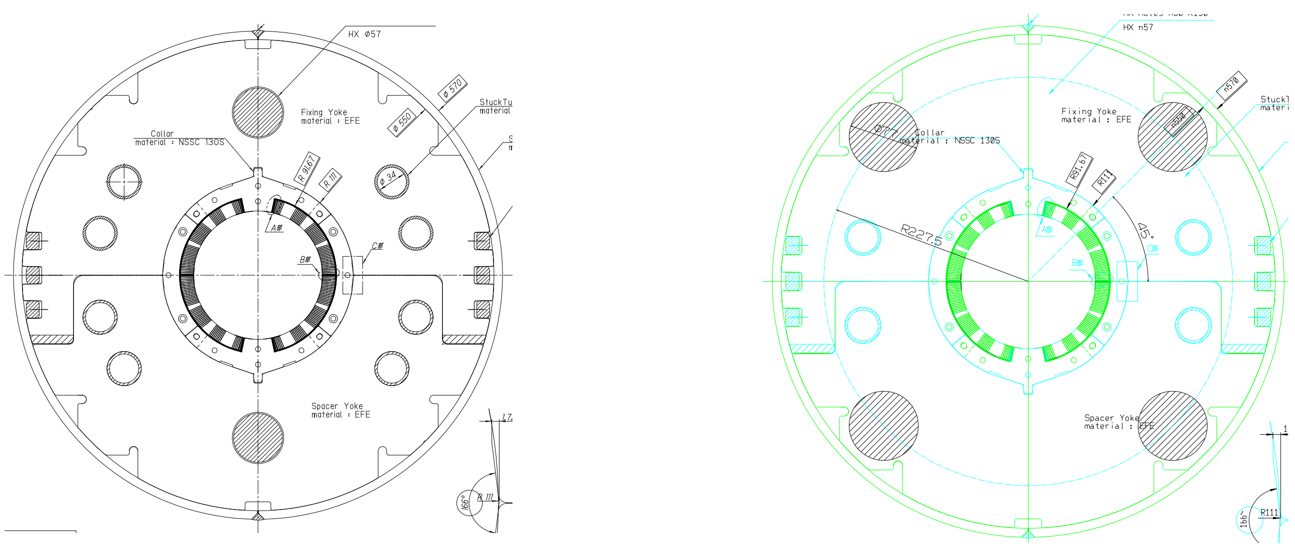




Model and measurements of transfer function and b3 [M. Sugano, T. Nakamoto, et al.]

The issue of cooling channels

- Recently it has been realized that heat exchangers in the triplet and in D1 has to be in the same longitudinal position [H. Prin, D. Duarte Ramos, July 2016]
  - This implies putting the holes at 45 (larger saturation) and redesign the iron
  - Moreover, these holes would be very close to the shell
    - We could have to increase the yoke diameter – major change



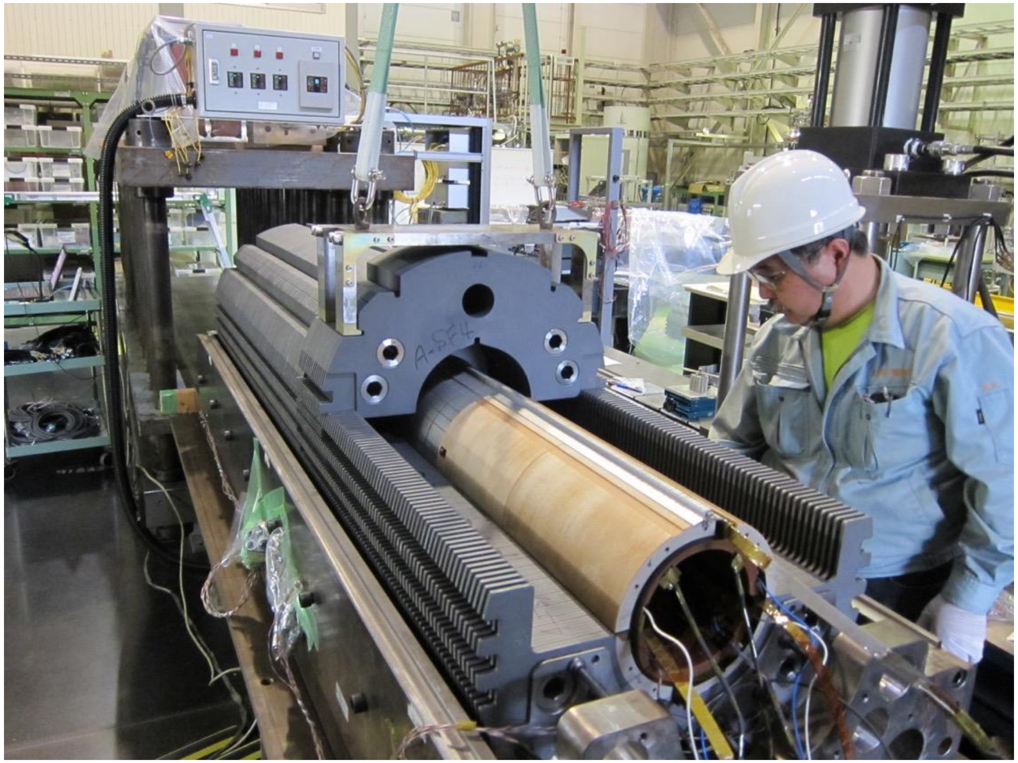
Old (left and possible new (right) position of the HX holes [M. Sugano, T. Nakamoto, et al.]

Decisions

- Disassemble MBXFS1 and increase load, with second test at the end of the year – beginning 2016
- Understand the field quality issue
- Delay the second model and include in it the new design compatible with new hole position

Present situation

- Yoke removed, collared coil ready to be disassembled



MBXFS1 disassembling [M. Sugano, T. Nakamoto, et al.]

Main suggestions from the reviewers (my rewording)

Design

- Coil design is ok, but consider increasing the iron yoke diameter
- Coil ends could be too long
- Consider having 2 m long extruded copper wedges instead of several short pieces (gap could be a problem)
- Keep present design for the first magnet, make it work, and implement modifications on the second one

Future steps

- Reassemble the first model with larger prestress – take care in the head shimming

Field quality

- Not enough understood, use also Opera model for the 3D saturation

Main suggestions from the reviewers (my rewording)

Measurements and test

- Have quench antenna giving localization
- Improve the coil mechanical characterization to be able to model the prestress loss

Appendix

Charges and answers

Can we keep the current design for the next 2m long model magnets or the 7m long prototypes?

- In addition to revisions in the specifications for D1 and future modification requests, consider increasing yoke outer diameter as much as possible and eventually consider elliptic collar to improve and reduce yoke saturation effects.

- Consider shorter ends with fewer spacers; perform 3D analysis with OPERA including models with and without iron yoke over the end.

- Consider introducing extruded copper wedges to avoid gaps in between, short wedges may become an issue for long magnets

Charges and answers

Based on the cold test results of the 1st model, how can we improve the quench performance of the 2nd model?

- The 2nd model (MBXFS02) should include as many of the modifications needed for the first prototype. However priority should be given to the re-assembly of the 1st model magnet. At this time we do not see a reason to change the basic design concept of the first model.

Charges and answers

<u>Should we re-assemble the 1st model with enhancing the coil preload to prove the better quench performance?</u>

- Yes, the present measured pre-stress at cold is about half of the expected one and assumes to impact the magnet performance. Increasing the pre-stress at warm upto 130 MPa in the straight section and gradually reducing it over the end should improve the magnet training performance and remove the erratic behavior. The magnet re-assembly and enhanced pre-stress will address quench performance and leave field quality issues as a second priority.

- Adding shims along the straight-section and the ends should be used and confirmed by coil size measurements.
- Mid-plane shims are more preferable to avoid discontinuity between straight section and ends.

Charges and answers

<u>Should we re-assemble the 1st model with enhancing the coil preload to prove the better quench performance?</u>

- End potting should be carefully examined and decided.
- End structure may need to be reinforced for preload enhancements at least for coil size measurement.
- Azimuthal pre-load in the end should be less than the straight section and further reduced over the last 2 blocks near the end shoe.
- End plates bullets should be instrumented with strain gauges and reduced to 3 per coil.
- Consider putting additional voltage taps over coil block 2.

Charges and answers

Do we sufficiently understand the field quality of the magnet?

- Not really, 3D effects are not fully understood
- Opera3D computation should be made and harmonic values computed at different saturation levels. Use the model to reduce the number of end spacers while addressing the field at the conductor
- Consider computing the model with and without iron over the ends.

Charges and answers

Is further specific R&D for magnet sub-systems (parts, tooling, etc.) or fabrication process needed?

- Yes, measurements using the quench antenna should be improved
- Perform better characterization of the thermal and mechanical properties of the coil in order to improve the mechanical computation model.