INTERACTION REGION MAGNETS

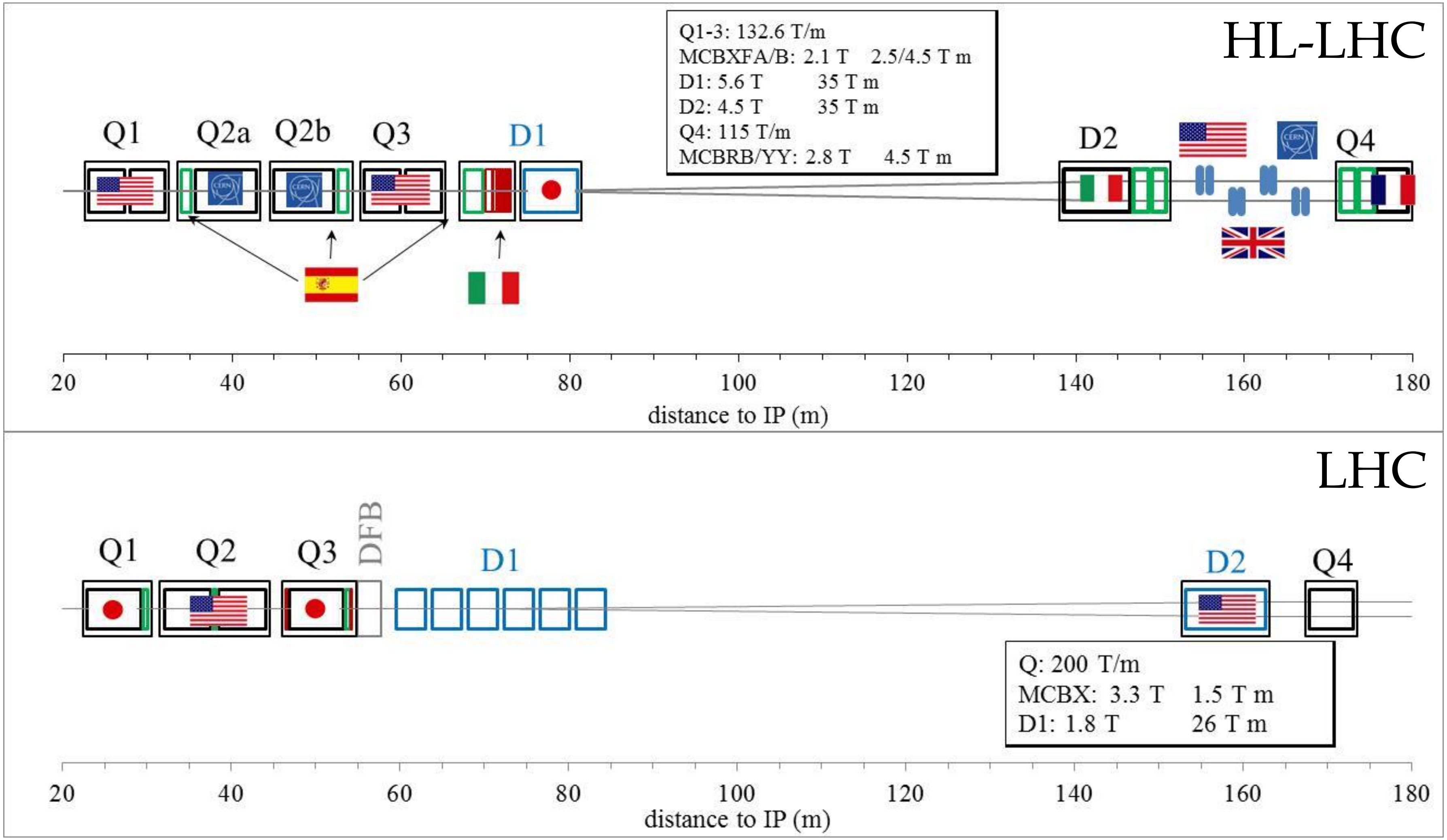
E. Todesco
On behalf of the WP3 collaboration

CERN, Geneva, Switzerland

CONTENTS

- A short summary of the past 4 years
- Changes in the baseline
- Progress report and next steps

A SHORT SUMMARY



A SHORT SUMMARY

120/140 mm
Nb_3Sn Nb-Ti

150 mm aperture
Nb_3Sn

Start of D2 design

Start of orbit corrector design

Start of nonlinear corrector design

Triplet coils

Sextupole coils

D1 coils

2012	2013	2014	2015

Start of D1 design

Start of triplet design

Start of Q4 design

Apertures, technology, field, lengths, margin
first baseline Q1-D1
Radiation damage, shielding, heat loads, cooling scheme

First layout Q1 to Q4

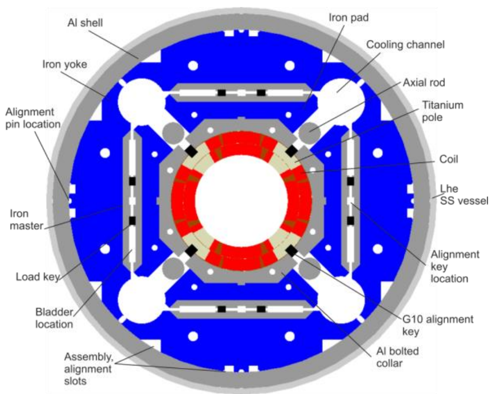
Cost and schedule

Target: first Models tested

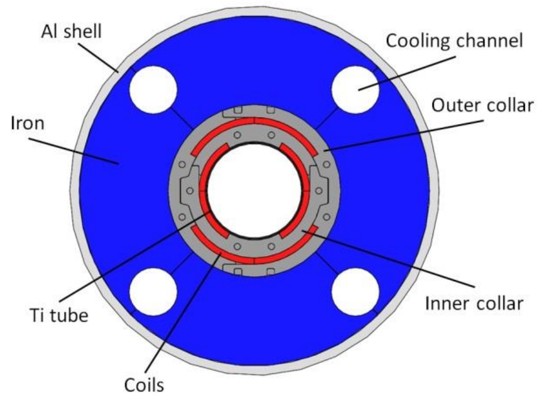
THE IR REGION MAGNET ZOO

- 92 magnets of 13 different types plus spares
  - 11 different cross-sections
  - Lengths between 0.1 m (correctors) to 7-8 m (D2, triplet)
  - Total of ~240 m of magnets (60 per IP side)
- Technologies
  - Nb_3Sn (triplet)
  - Nb-Ti (with nested option for orbit correctors)
  - Superferric (correctors)
- 5 collaborations
  - US LARP → US-HiLumi (half of the triplet)
  - KEK (separation dipole D1)
  - Ciemat (orbit correctors prototypes)
  - INFN (high order correctors prototypes and D2 design)
  - CEA (Q4 short model)

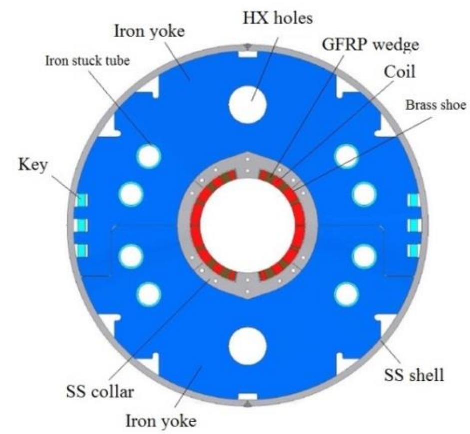
The IR Region Magnet Zoo



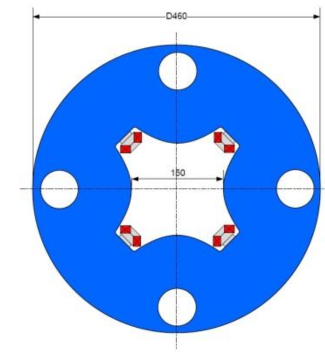
Triplet QXF (LARP and CERN)



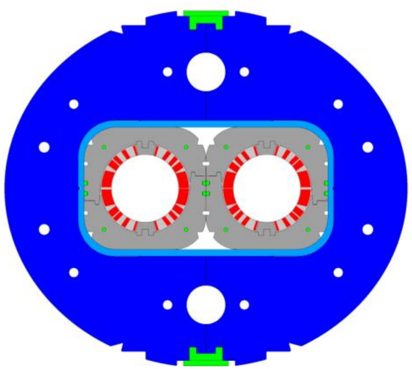
Orbit corrector (CIEMAT)



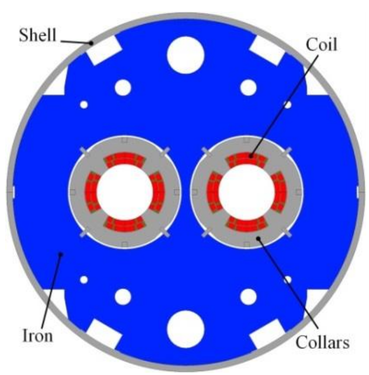
Separation dipole D1 (KEK)



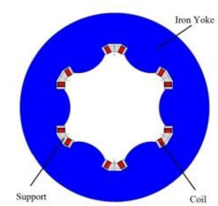
Skew corrector (INFN)



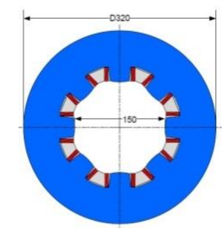
Recombination dipole D2
(INFN design)



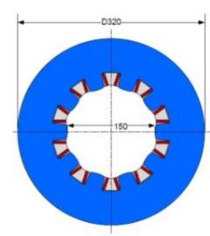
Q4 (CEA)



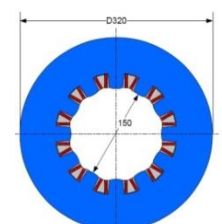
Corrector sextupole (INFN)



Corrector octupole (INFN)



Corrector decapole (INFN)



Corrector dodecapole (INFN)

Cross-sections in scale

CONTENTS

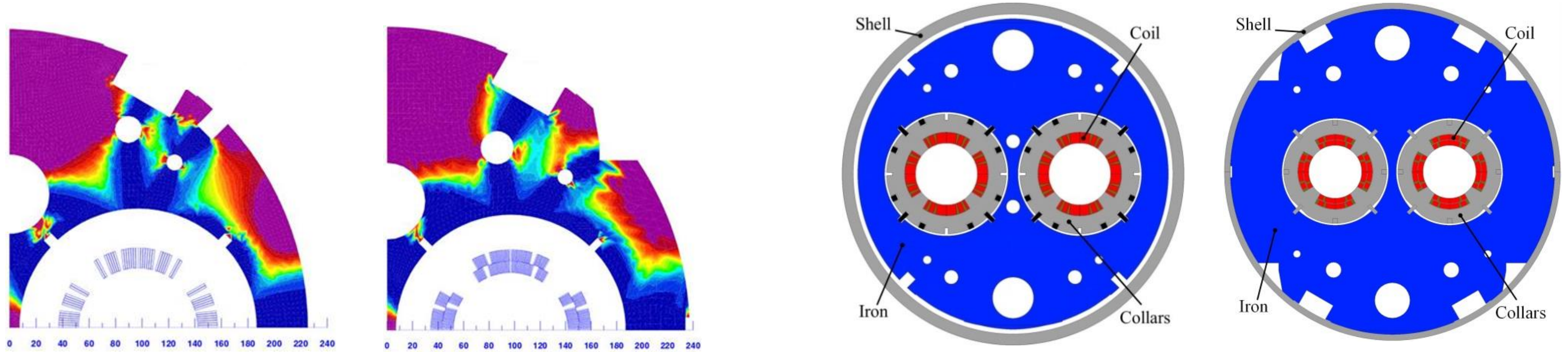
- A short summary of the past 4 years
- Changes in the baseline
- Progress report and next steps

Recent changes in the baseline

- Major changes
  - Q4 design from one to two layer
    - Reason: reduce cost
  - Protection D1, Q4 from dump resistors to quench heaters
    - Reason: reduce cost
- Fine tuning
  - Triplet gradient lowered by 5% to increase margin from 18% to 23%
    - Reason: reduce risk
  - Specification on current density lowered from 1400 to 1280 A/mm^2
    - Reason: reduce cost
  - Keystone angle reduced from 0.55° to 0.40°
    - Reason: reduce degradation and improve performance
  - Strenght of orbit correctors from 4.5 T m to 5 T m
    - Reason: not enough operational margin

Recent changes in the baseline

- Q4 change
  - Initial studies considered either a double layer or a single layer

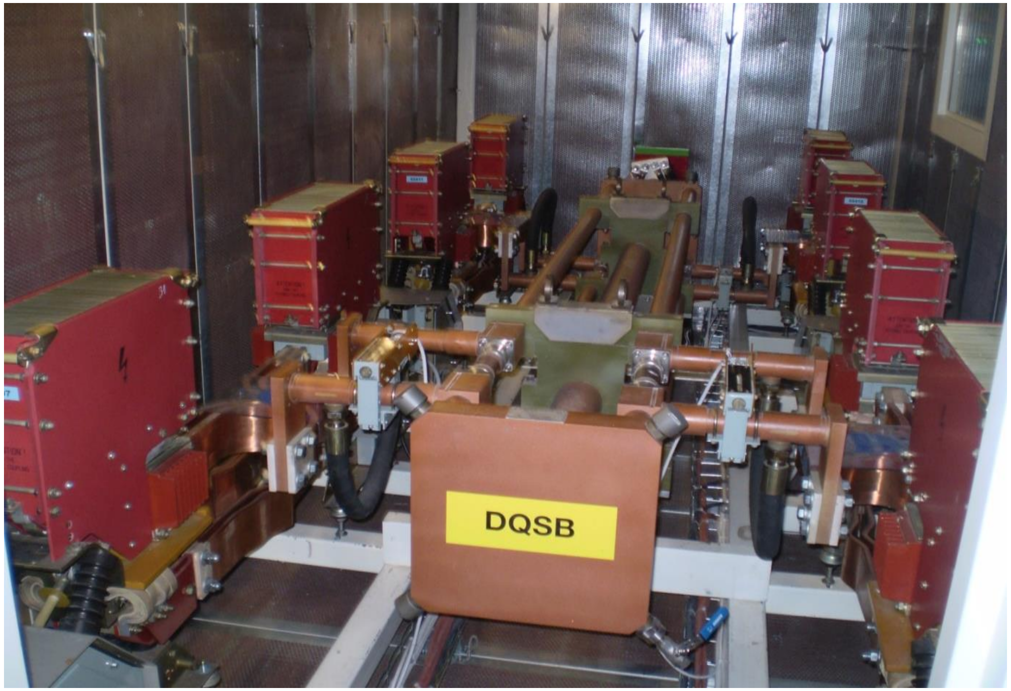


Single layer (left) and double layer (right) coil [M. Segreti, J. M. Rifflet]

  - Single layer advantage: cable free of charge (reusing shorter lengths of LHC dipole cable)
  - Double layer advantage: power converters free of charge (reusing 6 kA power converters), less current to bring in the tunnel
- Decision to change to double layer in June 2015
  - One year delay, compatible with schedule
  - PCP EU initiative [M. Losasso] providing funds for prototype

Recent changes in the baseline

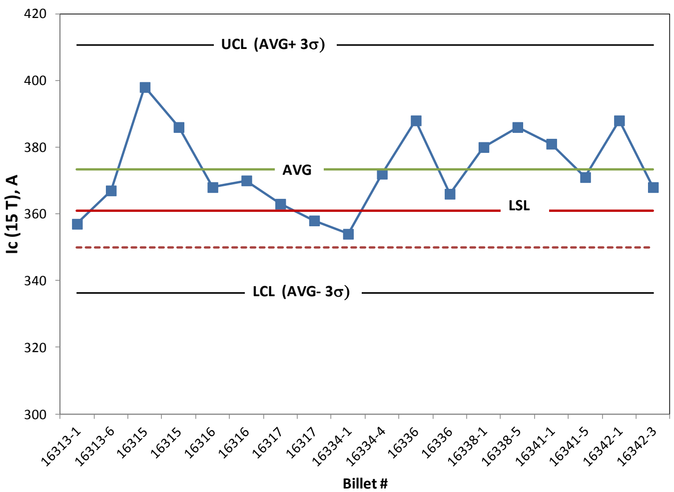
- Change of protection strategy
  - Initial hypothesis: energy extraction for D1 and Q4
    - No need of quench heaters, risk minimization
  - Large cost and infrastructure for energy extraction (switches)
  - Decision to go for quench heaters

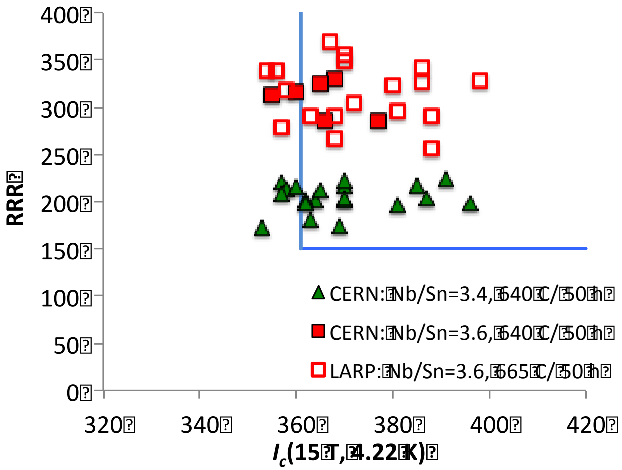


13 kA switches [G. Jan Coealingh]

Recent changes in the baseline

- Decrease of specification of current density
  - Initial value for current density at 15 T was set at 1400 A/mm^2
  - First results of production showed a good fraction below spec

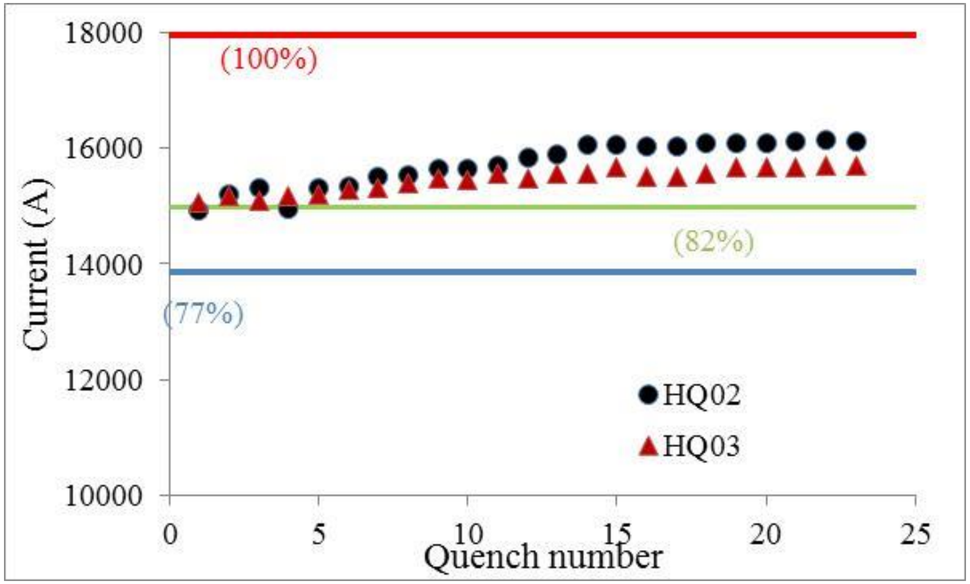




Current density measured in QXF strand [A. Ghosh and B. Bordini]

- Possibilities
  - Increase number of superconducting elements
    - Discarded since protection was already critical –we need copper
- We decided to accept a lower current density: 1280 A/mm2
    - Loss of 3% margin on the loadline

- Decrease of the operational gradient to recover additional margin
  - Initial choice for the margin: 140 T/m, 20% on the loadline
  - Going through the details of the design, margin reduced to 18%
  - HQ results showed that 20% can be reached with very limited training



Training of HQ [G. L. Sabbi and LARP collaboration]

- Decrease of the operational gradient to recover additional margin
  - Initial choice for the margin: 140 T/m, 20% on the loadline
  - Going through the details of the design, margin reduced to 18%
  - HQ results showed that 20% can be reached with very limited training
  - BUT
    - No experience with Nb_3Sn 7 m long coils
    - Only three Nb_3Sn magnets with 3.4 m long coils
    - Reduction of 3% margin due to critical current specfication (previous slide)
  - So to minimize the risk and relax stress on conductor performance we lowered from gradient 140 to 132.6 T/m and we increased lenght by 5%
    - Now margin is at 23%

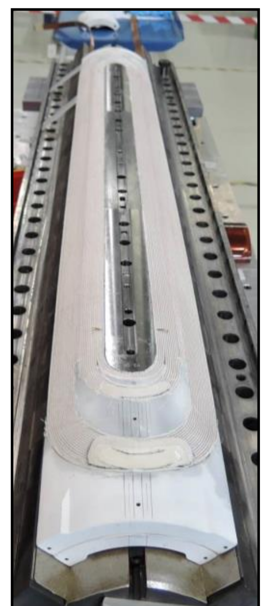
CONTENTS

- A short summary of the past 4 years
- Changes in the baseline
- Progress report and next steps

Triplet [Ambrosio, Ferracin talk]

- 13 short model coils built (US and CERN, PIT and RRP)
  - US and CERN models very similar – coil exchange possible
- First assembly test of QXF short model coming soon
  - Magnet in the cryostat
    - Non conformity during assembly, but decision to test the assembly
  - Second test in early 2016
  - Full size prototype:
    - Coil fabrication in progress
    - Test in 2017

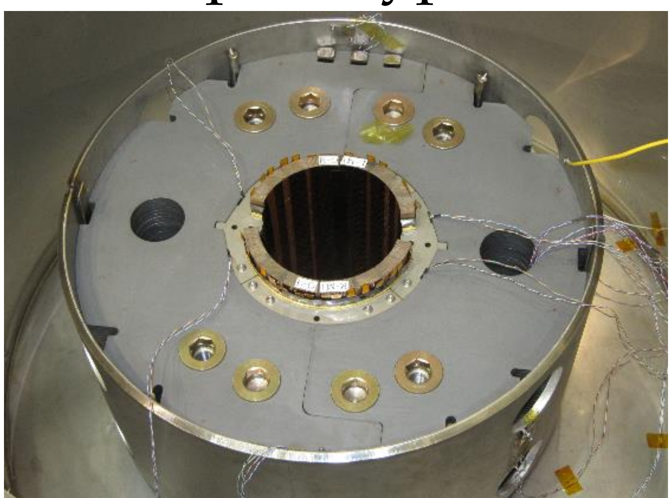
LARP

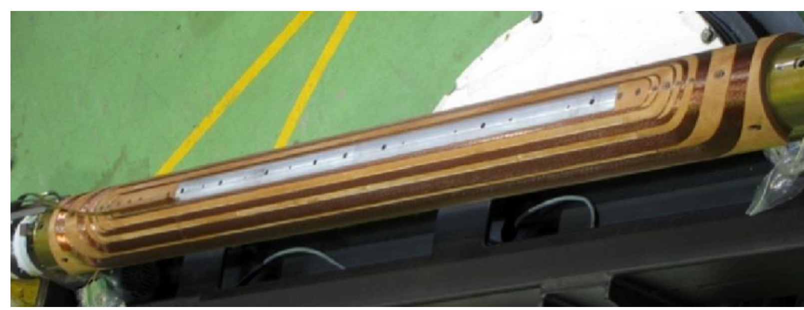



QXF coils and assembly [P. Ferracin, G. Ambrosio]

D1 [NAKAMOTO TALK]

- 3 short model coils built in 2015
  - First coil was cut to make a slice – iteration on iron
  - Second and third to be assembled in November-December
  - Test in early 2016
- Second model built in 2016
  - 5.5 T magnet with large aperture is interesting to test R&D
- Full size prototype in 2019

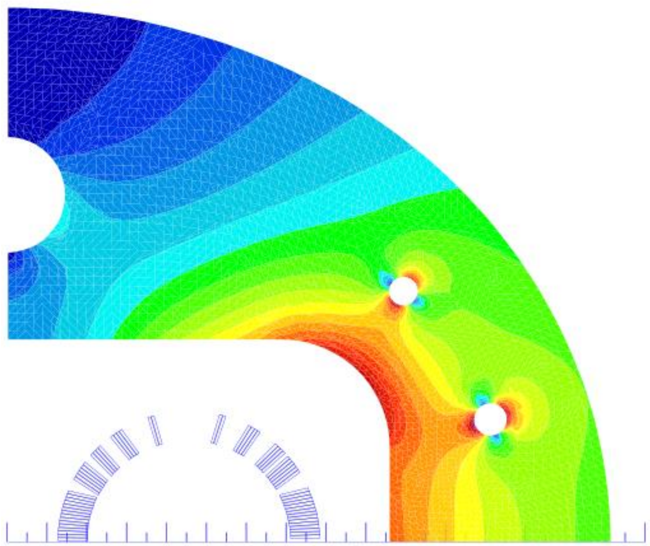


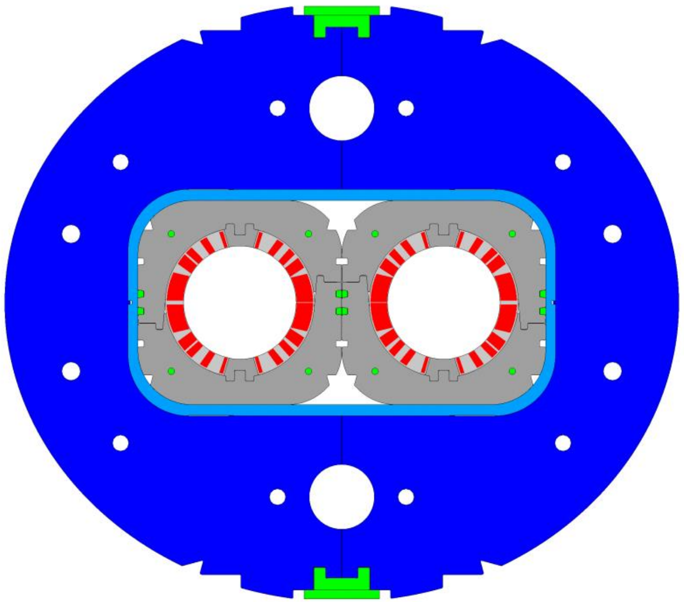


Slice of D1 (left) and D1 coil (right) [T. Nakamoto, M. Sugano]

D2 [Fabbricatore talk]

- Challenging design
  - 4.5 T, 8 m long, strong cross-talk
  - Asymmetric coils to solve the coupling
- Short model to be built in industry in 2016
- Full size prototype in 2019



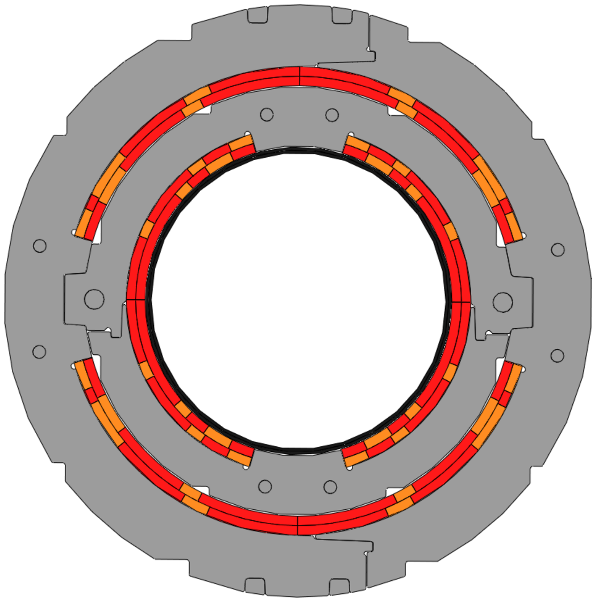


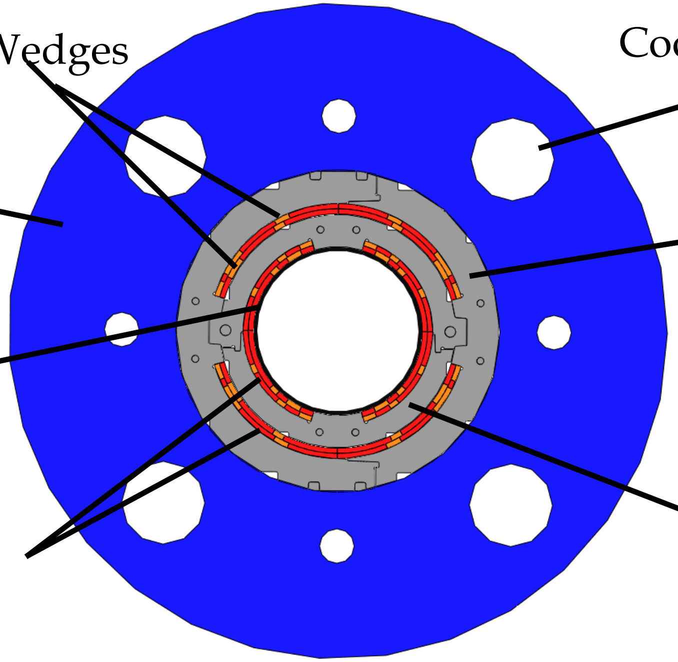
D2 coil (left) and cross-section (right) [P. Fabbricatore, S. Farinon]

Nested orbit correctors
[Toral talk]

- Low field (2.1 T on each plane), but
  - Nested design
  - Peak field of 4 T
  - Mechanical lock to control torque
  - Good field quality in any operational condition in H and V

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

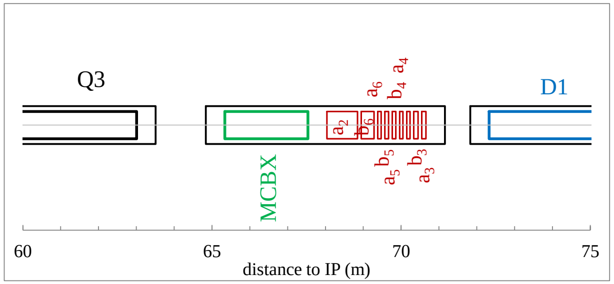




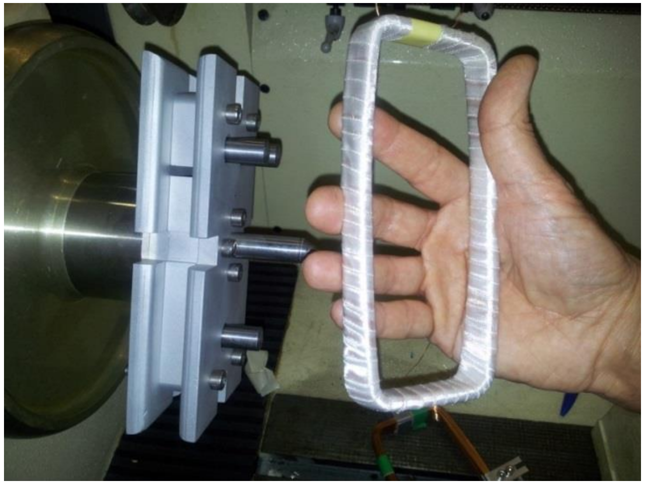
Orbit corrector collared coil and cross-section [J. A. Garcia-Matos, F. Toral, P. Fessia]

HIGH ORDER CORRECTORS
[VOLPINI TALK]

- Superferric design as developed by CIEMAT (S-LHC)
  - Nb-Ti coil made of strands, iron pole
  - Sextupole coils being wound
  - Fine tuning
    - Protection studies to avoid energy extraction in progress
    - Lower the current to match the 120 A power converters
  - Succesful coil test in 2015
  - First sextupole test in early 2016



Detail of corrector lay-out



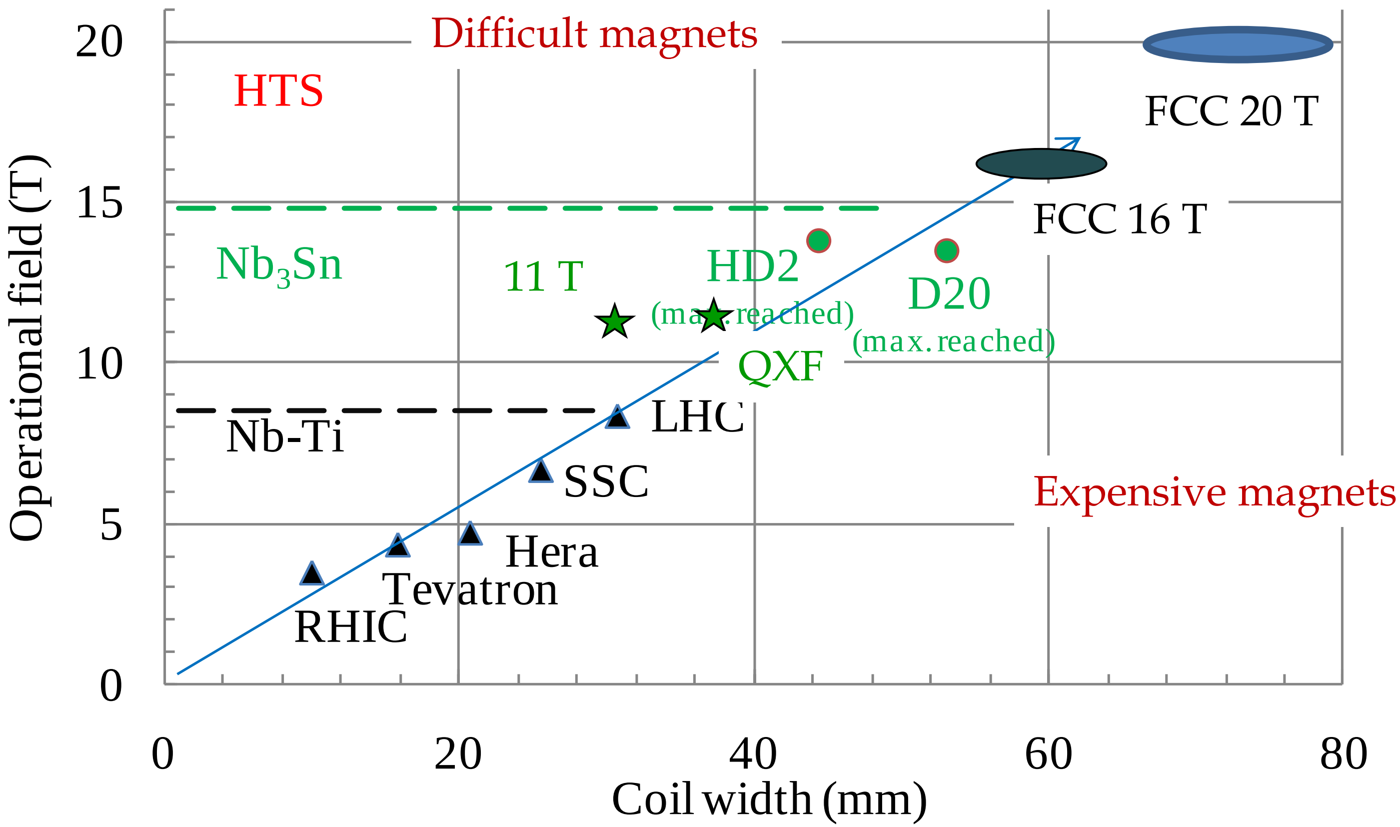
Coil wound in LASA [G. Volpini et al.]

Cost and Schedule

- Steps to reduce the cost
  - Get rid of energy extraction for D1 and Q4 (~6 M)
  - Laminated structure for QXF (~7 M)
  - Reduce current of Q4 (~2 M)
  - PCP project for Q4 prototypes (1-3 M)
  - Reduce the critical current (~4 M extra cost avoided)
- Other options under study
  - One circuit for the triplet (3.2 M)
  - D1 and D2 in series (1.4 M)
  - Keep Q6 at 4.5 K (0.5 M)
  - D2 Q4 correctors at 500 A (4 M)
- Comparison 11 T / QXF
  - Bladder and key not more expansive than collars

WHERE ARE WE GOING (BOTTURA TALK)

- 11 T and QXF will be first Nb_3Sn installed in a particle accelerator
- 3-4 T more than present LHC dipoles, another 4 T for the FCC



CONCLUSIONS

- Long way since 2011
  - Baseline defined and iterated
  - Cost estimated and second optimization
- Collaborations set up and personnel progressively allocated
  - Engineering and first tests
    - Two positive coils tests (QXF and sextupole)
- In 2016 results of QXF, D1, high order correctors
- Full scale prototypes in 2018-19 will be the next critical step