



HL-LHC

Magnet components and assemblies

E. Todesco, F. Savary, on behalf of WP3 and WP11

See also the presentation from F. Savary in 2015

<https://indico.cern.ch/event/387162>

And of E. Todesco and D. Duarte Ramos in 2016 (Lisbon)

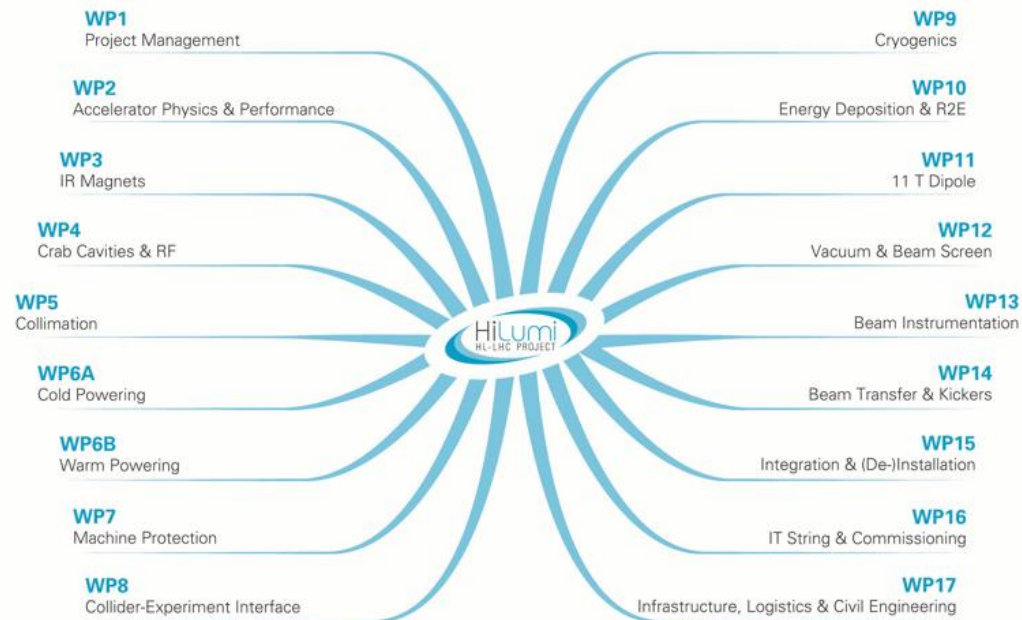
<https://indico.cern.ch/event/557233/>



21st May 2017 – Warrington (UK)

FOREWORD

- HL-LHC project
 - Magnets WP3 and WP11 (this talk)
 - Cryostats and links (next talk from V. Parma)

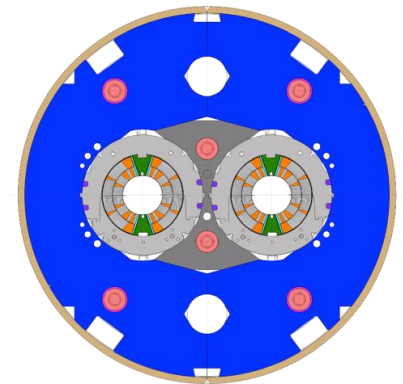


FOREWORD

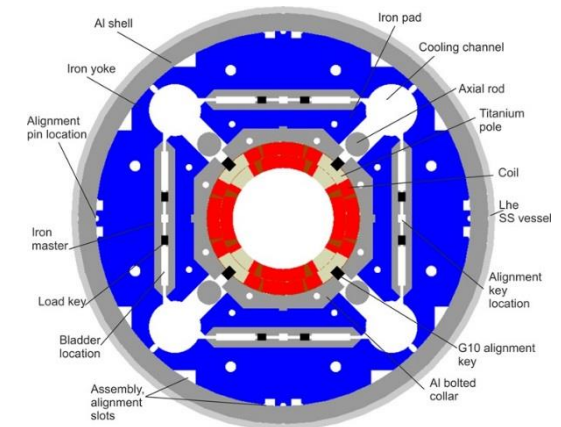
- HL LHC magnets are within WP3 and WP11
 - Different timeline (as shown by L. Rossi and P. Collier)
 - WP11: to be installed in 2019-20
 - WP3: to be installed in 2024-25
 - Together, they represent $\frac{1}{4}$ of the HL-LHC budget
 - About one third of magnets comes from in kind contributions or collaborations agreements
 - So this fraction is not steered directly by CERN
 - 7 types of new magnets, all built in industry
 - Except 11 T (CERN with industry personnel), Q1/Q3 (US labs)
 - 7 labs participating (LBNL, BNL, FNAL, KEK, CEA, INFN, CIEMAT)
 - Negotiations with other states ongoing (Canada, Sweden, China)

Nb₃Sn MAGNETS

- Two types of Nb₃Sn magnets: 11 T and the triplet
 - Both with wind and react technique
 - Both with peak field of 11.5 T
 - Lengths and quantities
 - 4.2 m (Q1/Q3) – 20 units from US (90 coils)
 - 5.5 m (11 T) – 6 units (30 coils)
 - 7.15 m (Q2a Q2b) – 10 units (50 coils)
 - Apertures
 - 60 mm for 11 T (LHC arc)
 - 150 mm for triplet (IR region)



D1 cross-section
[M. Karpinnen F. Savary et al.]



QXF cross-section [P. Ferracin, G. Ambrosio et al.]



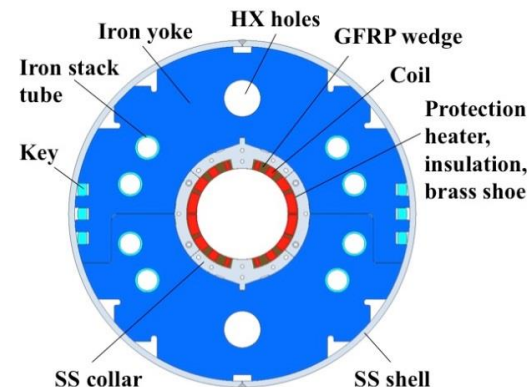
Nb₃Sn MAGNETS

- **Coil manufacturing is the dominant** part (time, budget)
 - Same technology: winding, reaction at 650 C, impregnation, instrumentation
- Mechanical structure is different
 - 11 T: stainless steel collars, loading with collaring press
 - Triplet: Al shell loaded with bladder and key
- Production strategy:
 - 11 T: at CERN with **manpower from industry**
 - Triplet: prototypes at CERN, **series in industry** with a plan-B option of doing at CERN

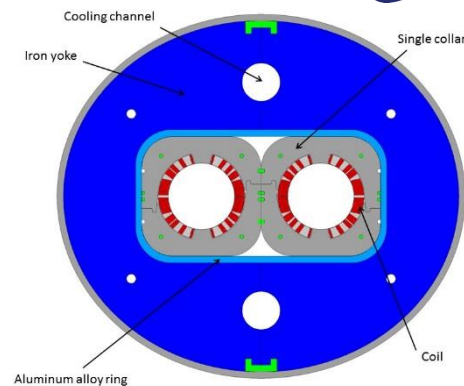


NB-Ti MAGNETS

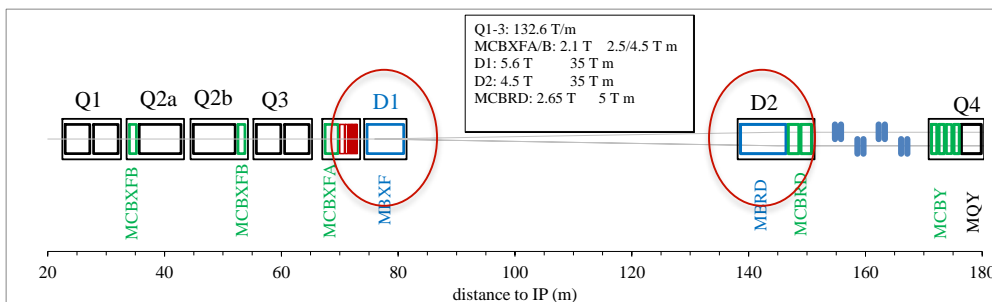
- Two main magnets: D1 and D2
 - Both with Nb-Ti classical technology
 - Rutherford cable
 - Bore field of 4.5 T to 5.6 T
 - Lengths and quantities
 - 6.2 m (D1) – 6 units from Japan
 - 7.8 m (D2) – 6 units (prototype from INFN)
 - Apertures: 150 mm for D1 - 105 mm for D2
 - Mechanical structure
 - Iron yoke (D1)
 - Self standing collars (D2)



D1 cross-section [T. Nakamoto, M. Sugano et al.]



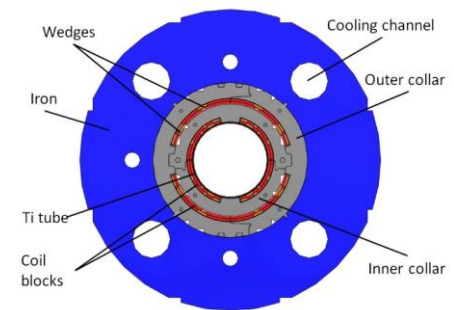
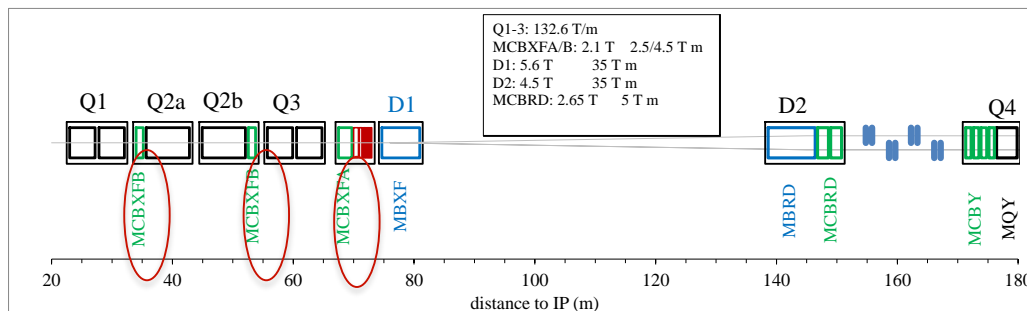
D2 cross-section [P. Fabbriatore, S. Farinon]



CORRECTOR MAGNETS: NESTED

- Nb-Ti technology, sector coil Rutherford cable
 - Nested correctors: bore field of 2.1 T in each plane
 - Lengths and quantities
 - 1.2 m (short) – 6 units (prototype from CIEMAT)
 - 2.1 m (long) – 12 units
 - Series from CIEMAT being discussed
- 150 mm aperture
- Mechanical structure
 - Self standing collars, double collaring

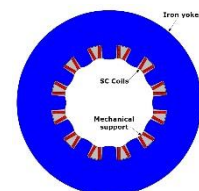
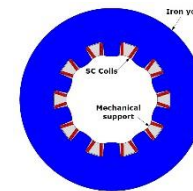
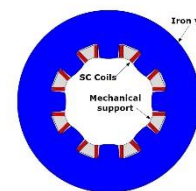
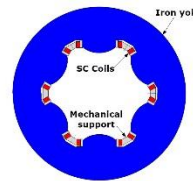
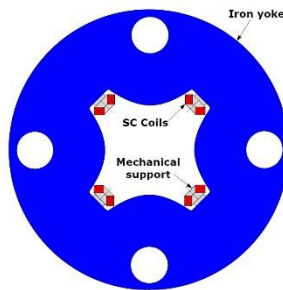
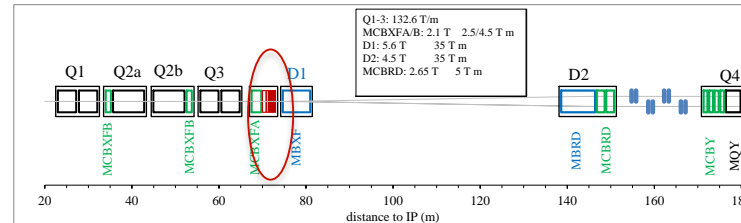
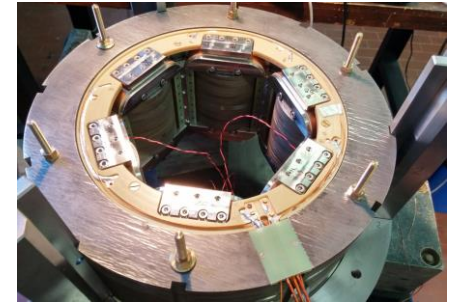
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 Energéticas, Medioambientales
 y Tecnológicas



MCBXF cross-section
 [F. Toral, J. Garcia Matos et al.]

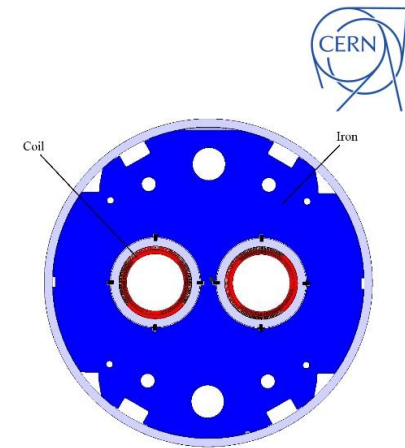
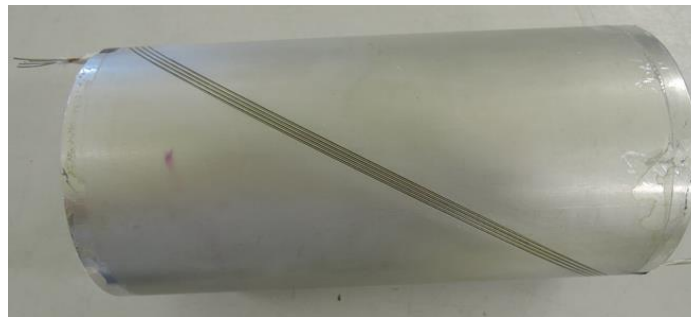
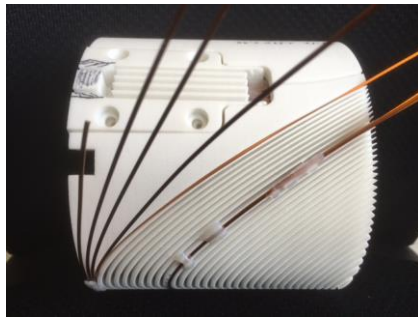
CORRECTOR MAGNETS: HIGH ORDER

- Nb-Ti technology, superferric design
 - High order correctors: peak field of 2-3 T (prototypes and series by INFN)
 - Lengths and quantities
 - About 1 m (quadrupole) – 6 units
 - About 0.5 m (dodecapole) – 6 units
 - About 0.1 m (sextupole, octupole, decapole) – 6*7 units
 - 150 mm aperture



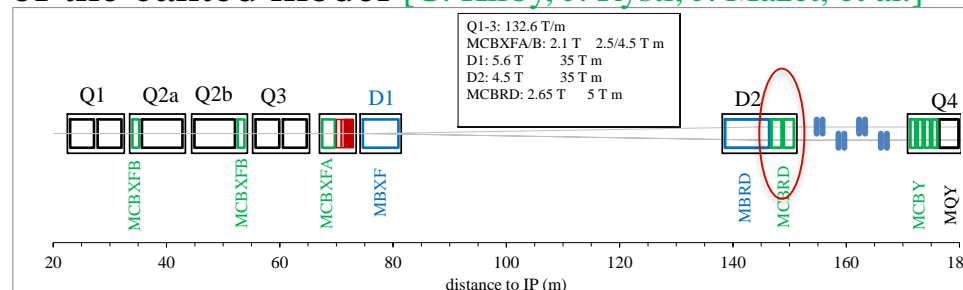
CORRECTOR MAGNETS: CANTED

- Nb-Ti technology, canted design
 - High order correctors: peak field of 2-3 T (prototype at CERN)
 - Chinese contribution under discussion
 - 2 m long, 12 units
 - 105 mm aperture



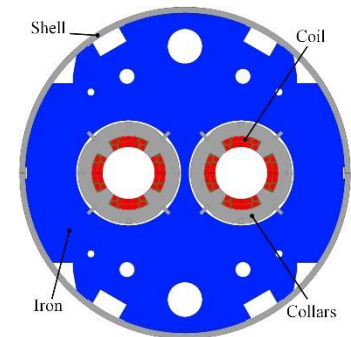
MCBRD cross-section
[G. Kirby, J. Rysti]

Winding tests of the canted model [G. Kirby, J. Rysti, J. Mazet, et al.]

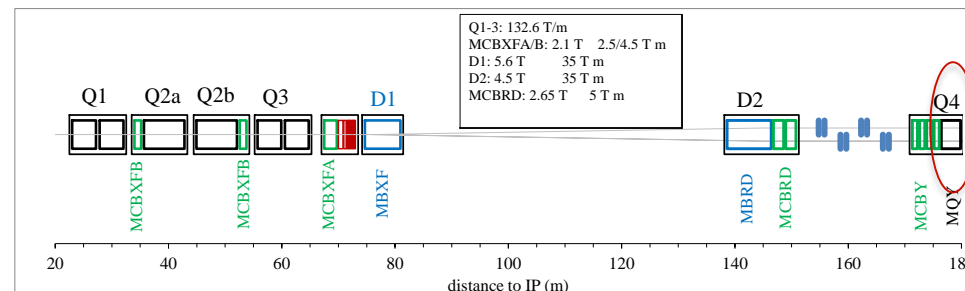


LARGE APERTURE Q4 DEVELOPMENT

- A large aperture Q4 (90 mm) was in the initial baseline (called MQYY)
 - Series removed in June 2016 to cope with budget reduction
 - Activities going on:
 - Short model development from CEA
 - Construction of two prototypes within QUACO EU initiative



MQYY [J. M. Rifflet, M. Segreti, et al.]

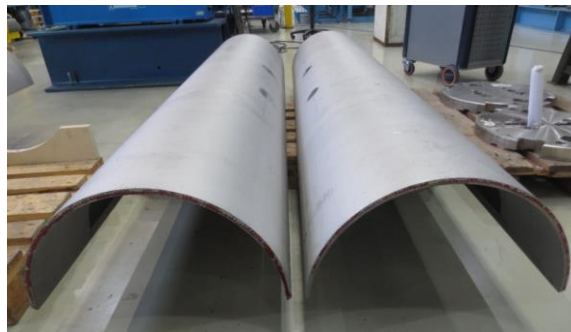
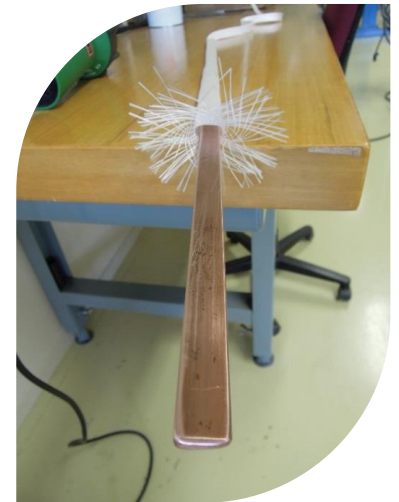
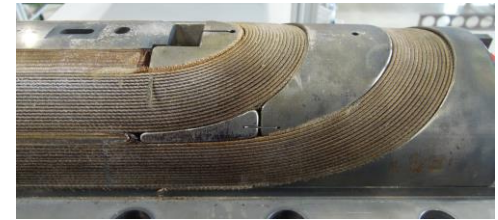
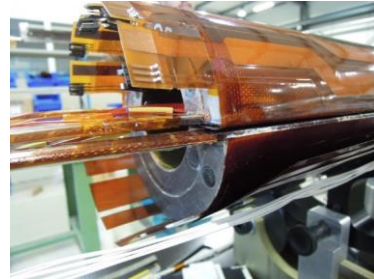


COMPONENTS

- Superconducting strand
 - Nb₃Sn: Procured by CERN and US collaboration, two producers
 - Nb-Ti: D1 and D2 reuse LHC cable, nested reuses SLHC cable, superferric and canted use existing strands
- For 11 T and triplet, CERN (and US) procure all main components
- For Nb-Ti main magnets and correctors, industry will be probably in charge of component procurement
- CERN will provide raw material (both magnetic and non magnetic steel) to guarantee magnetic performance and to minimize costs

COMPONENTS

- Non exhaustive list of components
 - Coil:
 - Cable insulation
 - Impregnation resin
 - Winding poles
 - End spacers
 - Wedges
 - Quench heaters
 - Magnet:
 - Collars
 - Yoke laminations
 - Cold mass:
 - End domes
 - SS half shells



CONCLUSION

- We have a challenging project requiring substantial involvement of the industry
 - Effective partnership is crucial for the success
 - Several challenges
 - Some new technologies to be applied for the first time in high energy accelerator magnets (Nb_3Sn , plus canted magnet)
 - More critical aspects
 - Relatively small series, little time to react
 - Many different magnets
 - Timeline of procurement
 - Many collaborations, interfaces management
 - Exchange of information (see www.cern.ch/hilumi/wp3 www.cern.ch/hilumi/wp11 <https://project-hl-lhc-industry.web.cern.ch>)