HL-LHC
Magnet components and assemblies

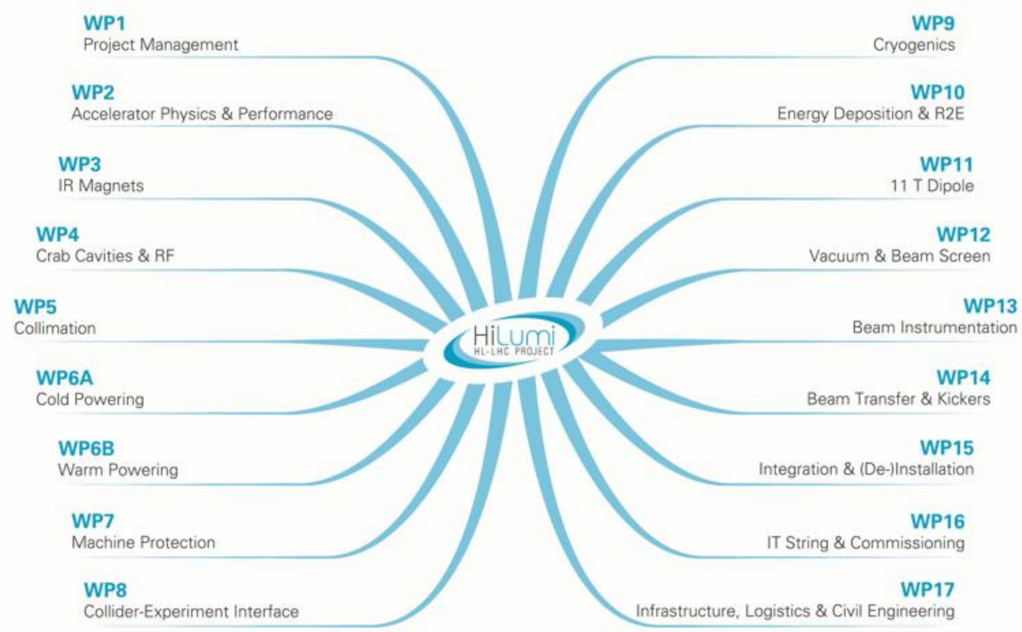
E. Todesco, F. Savary, D. Duarte Ramos on behalf of WP3 and WP11

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/

6th February 2018 – CERN

FOREWORD

- HL-LHC project
  - Magnets and cryostats (this talk)

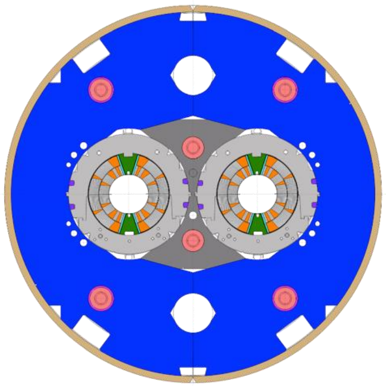


FOREWORD

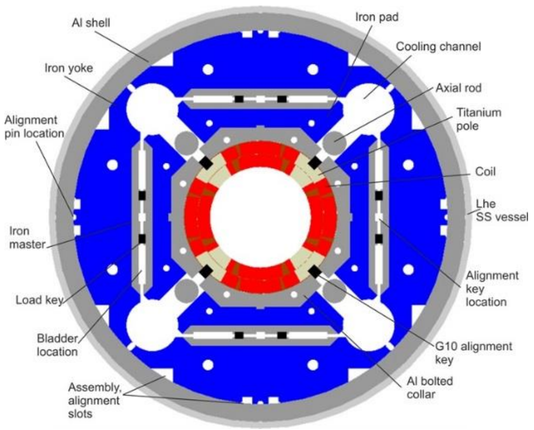
- HL LHC magnets are within WP3 and WP11
  - Different timeline (as shown by I. Bejar Alonso)
    - WP11: to be installed in 2019-20
    - WP3: to be installed in 2024-25
  - Together, they represent ¼ of the HL-LHC budget
  - About one third of magnets comes from in kind contributions or collaborations 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)

Nb_3Sn MAGNETS

- Two types of Nb_3Sn 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.]



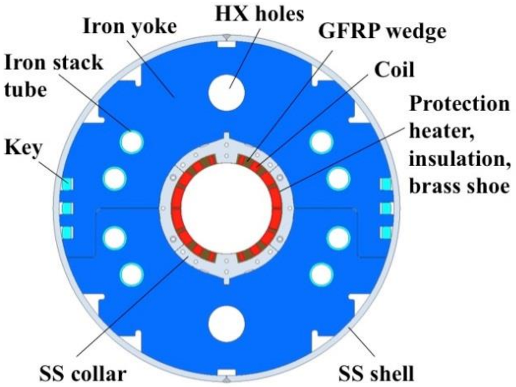
QXF cross-section [P. Ferracin, G. Ambrosio et al.]

Nb_3Sn MAGNETS

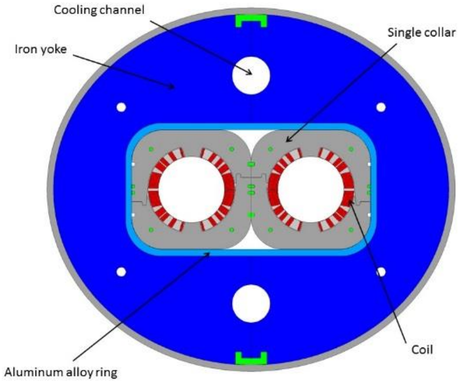
- Coil manufacturing is the dominant part (time, budget)
  - Same technology: winding, reaction at 650 C, impregnation, instrumentation
- Mechanical structure is different
  - 11 T: stainless steel collars, loading with collaring press
  - Triplet: Al shell loaded with bladder and key
- Production strategy:
  - 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

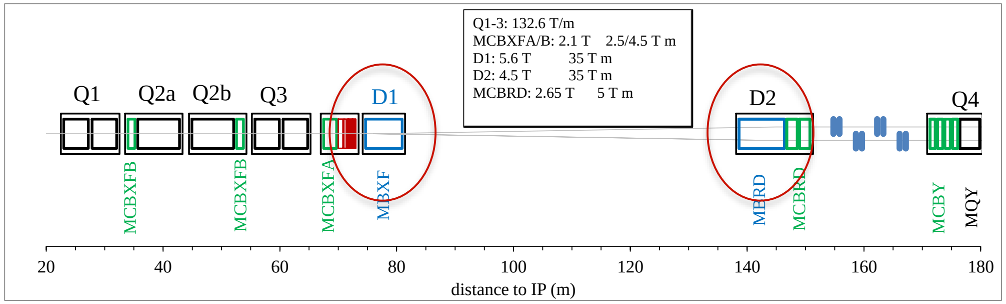
- Two main magnets: D1 and D2
  - Both with Nb-Ti classical technology
    - Rutherford cable
  - Bore field of 4.5 T to 5.6 T
  - Lengths and quantities
    - 6.2 m (D1) – 6 units from Japan
    - 7.8 m (D2) – 6 units (prototype from INFN)
  - Apertures: 150 mm for D1 - 105 mm for D2
  - Mechanical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



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

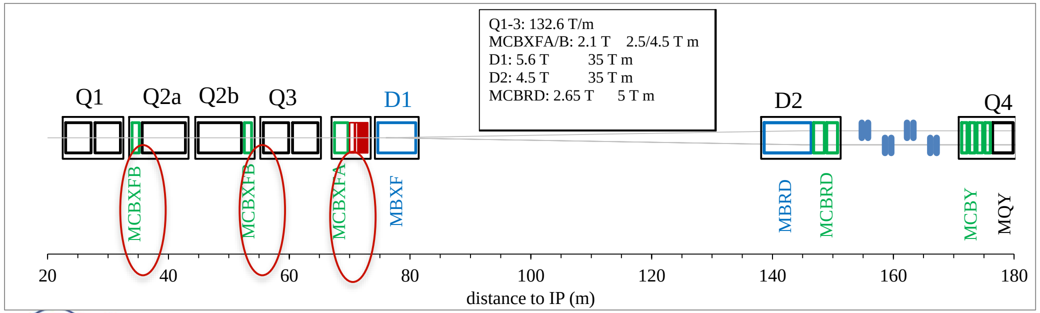


D2 cross-section [P. Fabbricatore, S. Farinon]



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 (from CIEMAT)
    - 2.1 m (long) – 12 units (from CIEMAT)
  - 150 mm aperture
  - Mechanical structure
    - Self standing collars, double collaring



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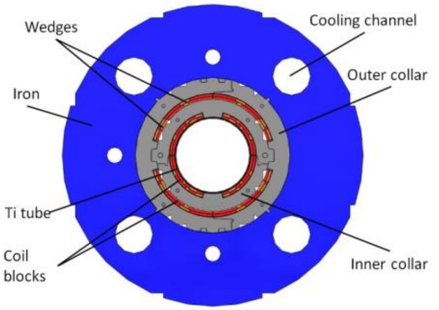
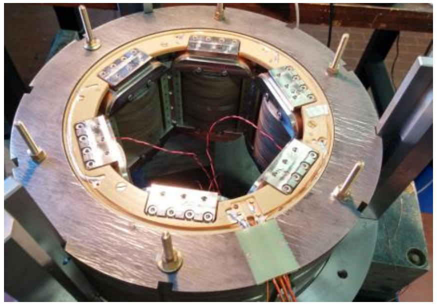


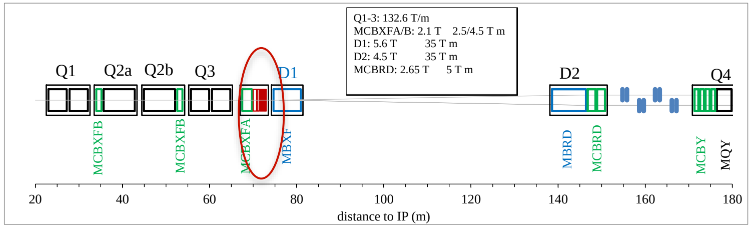
MCBXF cross-section
[F. Toral, J. Garcia Matos et al.]

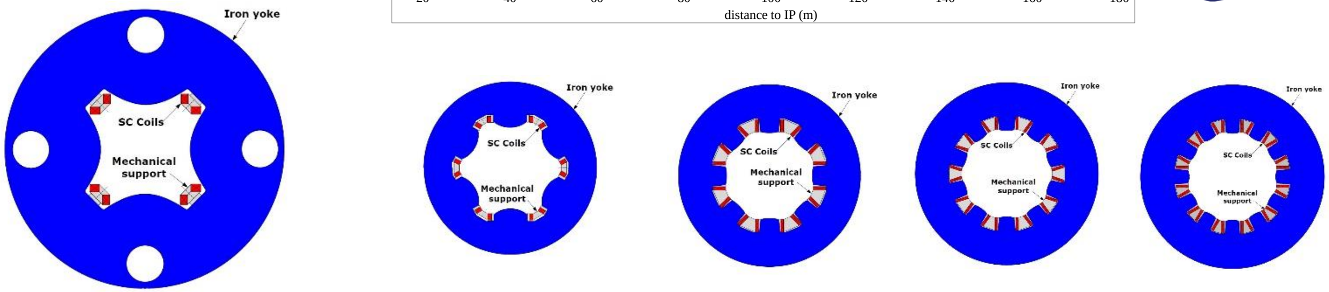
HiLumi HL-LHC PROJECT
CERN

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



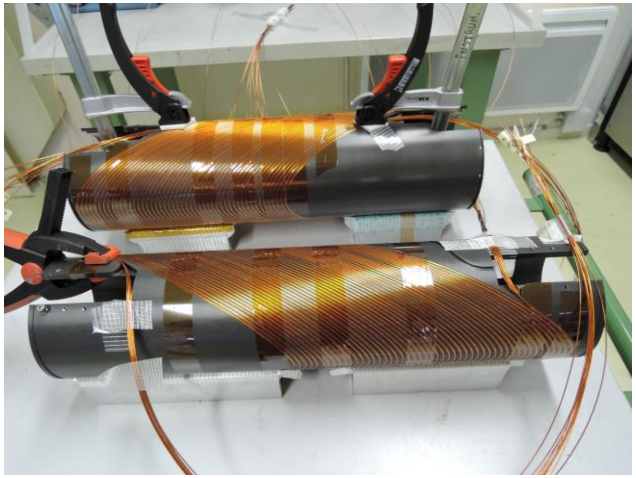




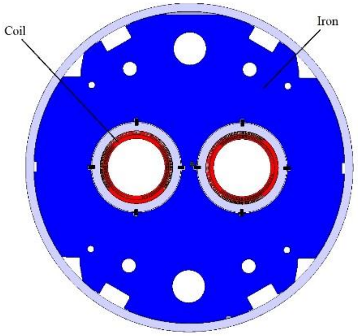
High Order correctors cross-section [G. Volpini, M. Statera, et al.]

CORRECTOR MAGNETS: CANTED

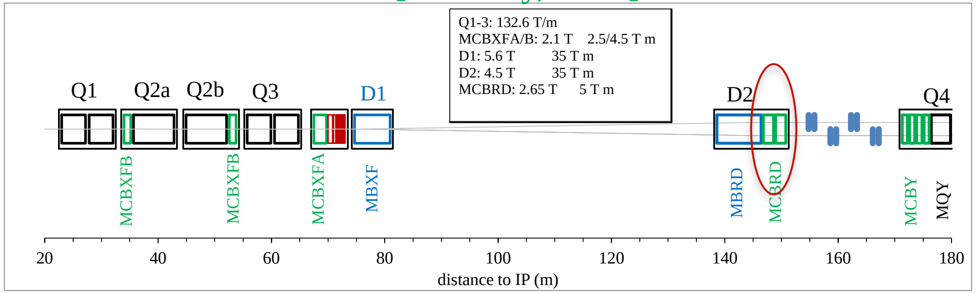
- Nb-Ti technology, canted design
  - High order correctors: peak field of 2-3 T (prototype at CERN)
    - Chinese or Sweden contribution under discussion
  - 2 m long, 12 units
  - 105 mm aperture



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

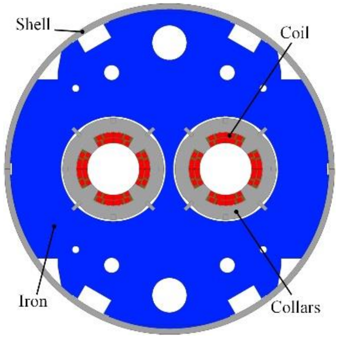


MBCRD cross-section
[G. Kirby]

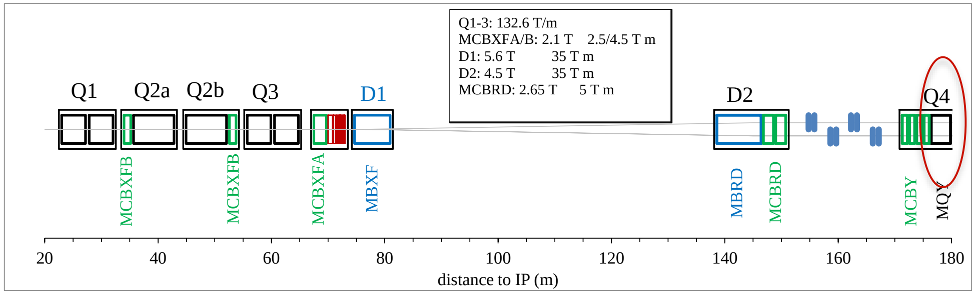


LARGE APERTURE Q4 DEVELOPMENT

- 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.]

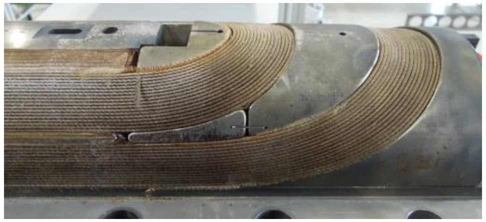


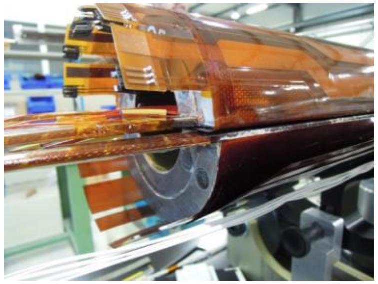
COMPONENTS

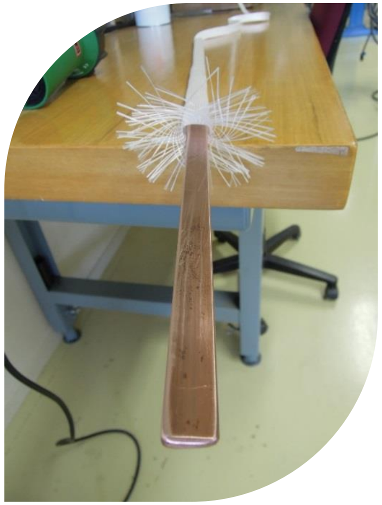
- Superconducting strand
  - Nb_3Sn: Procured by CERN and US collaboration, two producers
  - Nb-Ti: D1 and D2 reuse LHC cable, nested reuses SLHC cable, superferric and canted use existing strands
- For 11 T and triplet, CERN (and US) procure all main components
- For Nb-Ti main magnets and correctors, 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

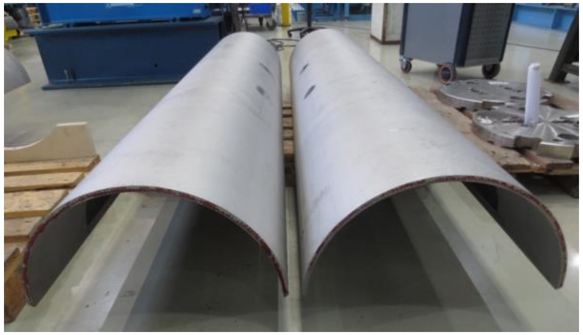
COMPONENTS

- 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



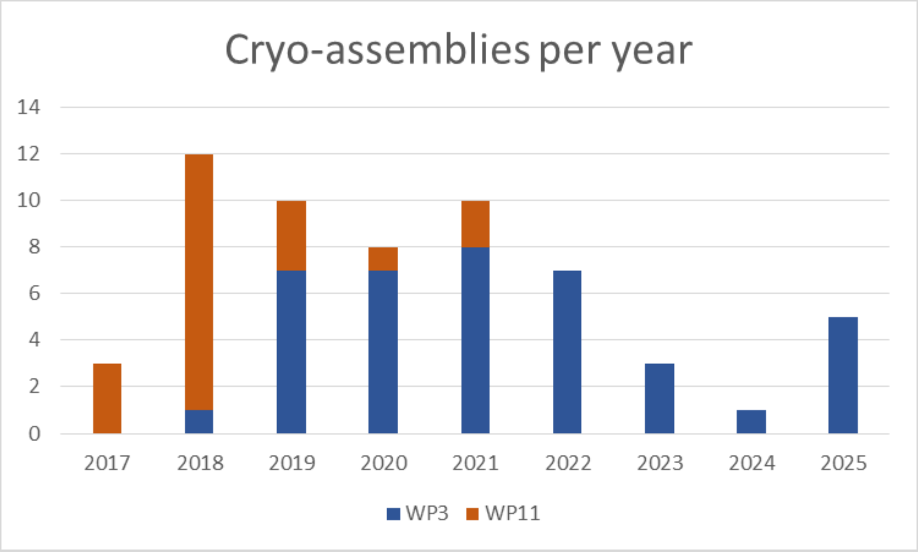






CRYOSTATS

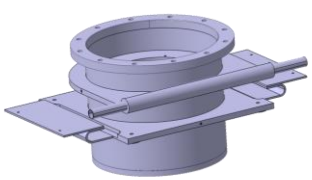
- 77 cryostat units | 70 procured by CERN, incl. prototypes and spares
- Diameter ~1 m
- Unit lenghts vary from 2 m up to 15 m
- Roughly 500 m of new cryostats to be installed in the LHC
- Carbon steel, stainless steel, aluminium, glass fiber composites…
- Production from now until 2025

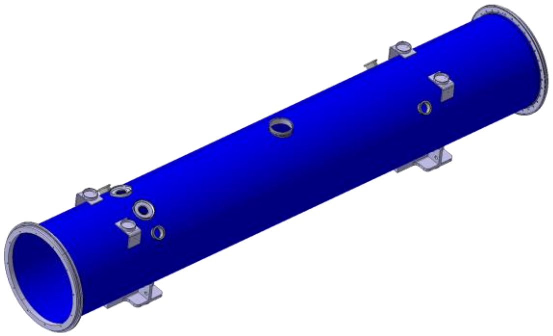


Assembly schedule at CERN

CRYOSTATS

- Design done at CERN (internal design office with service contractor)
- Procurement of components in industry, mostly as "build-to-print" supplies according to CERN drawings and detailed specifications
- Assembly at CERN with on-site support of industrial contractors (ex.: mechanical assembly, welding, quality control)





CONCLUSION

- We have a challenging project requiring substantial involvement of the industry
  - Effective partnership is crucial for the success
  - Several challenges
    - Some new tecnologies 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)