HiLumi
HL-LHC PROJECT

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

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Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

cea
SACLAY

INFN
Istituto Nazionale di Fisica Nucleare

LARP

31st October 2016 – Instituto Superior Técnico, Lisbon

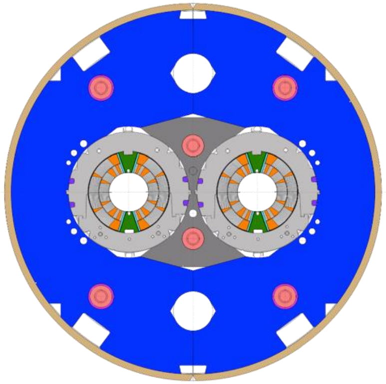
CERN

FOREWORD

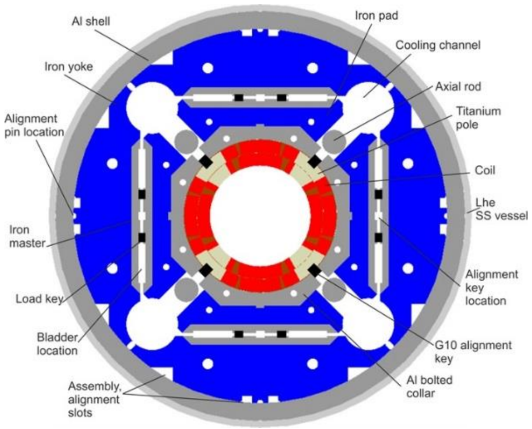
- HL LHC magnets are within WP3 and WP11
  - Different timeline (as shown by L. Rossi)
    - WP11: to be installed in 2019-20
    - WP3: to be installed in 2024-25
  - Together, they represent ¼ of the HL-LHC budget
  - About one third of magnets comes from in kind contributions or collaborations agreements
    - 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)
- Cryostats discussed by D. Duarte Ramos

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.]



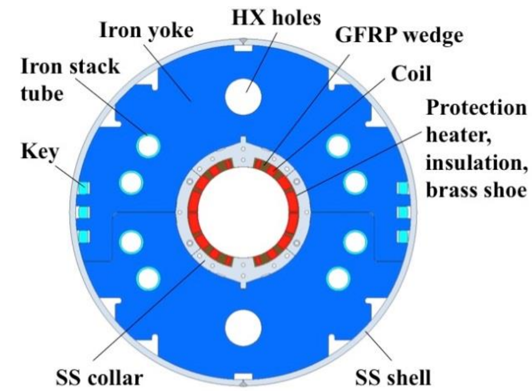
QXF cross-section [P. Ferracin, G. Ambrosio et al.]

Nb_3Sn MAGNETS

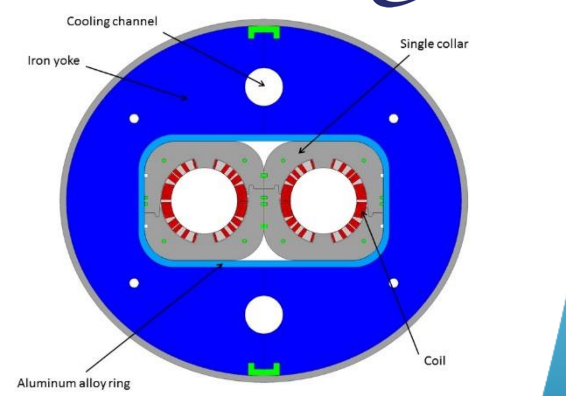
- Coil manufacturing is the dominant part (time, budget)
  - Same technology: winding, reaction at 650 C, impregnation, instrumentation
- Mechanical structure is different
  - 11 T: stainless steel collars, loading with collaring press
  - Triplet: Al shell loaded with bladder and key
- Production strategy: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

NB-Ti MAGNETS

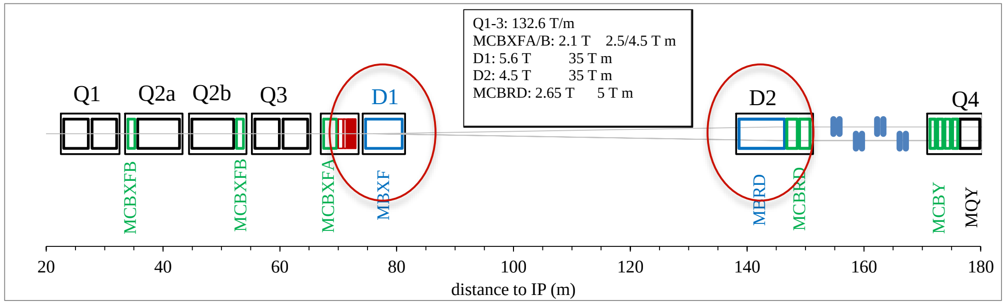
- Two main magnets: D1 and D2
  - Both with Nb-Ti classical technology
    - Rutherford cable
  - Bore field of 4.5 T to 5.6 T
  - Lengths and quantities
    - 6.2 m (D1) – 6 units from Japan
    - 7.8 m (D2) – 6 units (prototype from INFN)
  - Apertures: 150 mm for D1 - 105 mm for D2
  - Mechanical 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 (prototype from CIEMAT)
    - 2.1 m (long) – 12 units
  - 150 mm aperture
  - Mechanical structure
    - Self standing collars, double collaring

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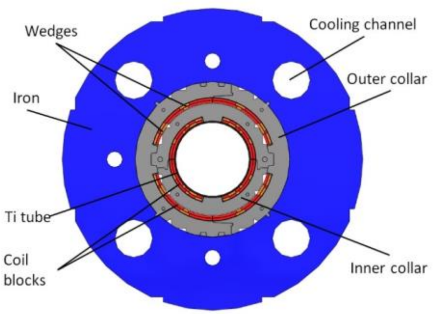
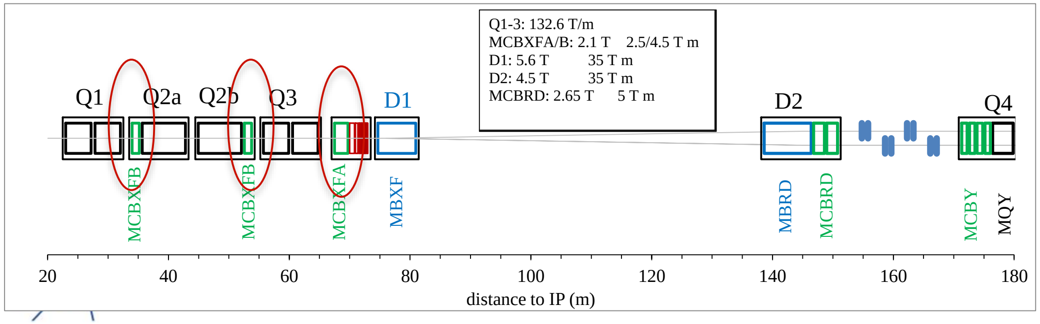
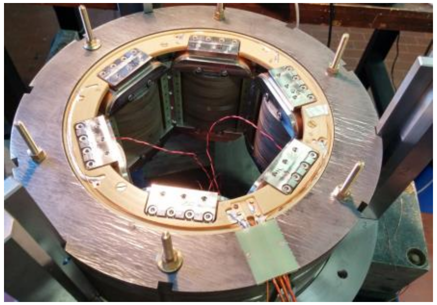


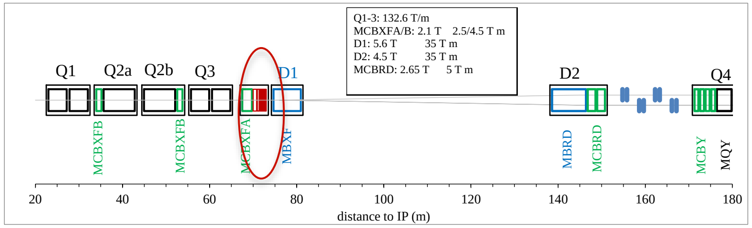
MCBXF cross-section
[F. Toral, J. Garcia Matos et al.]

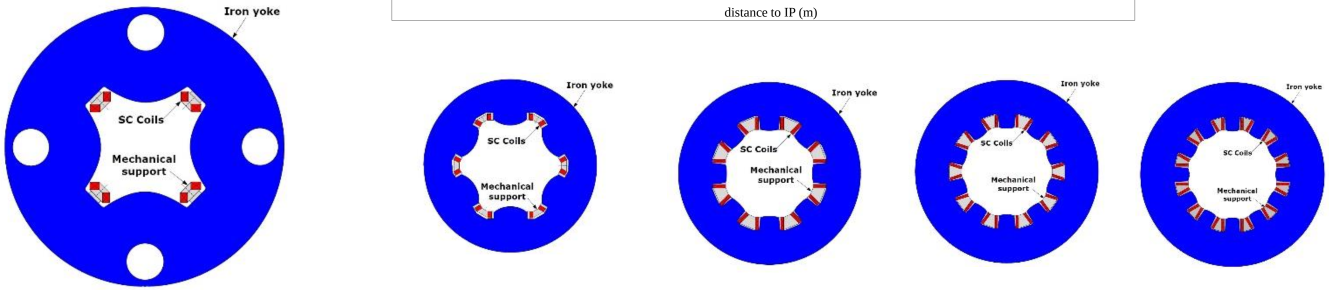


CORRECTOR MAGNETS: HIGH ORDER

- Nb-Ti technology, superferric design
  - High order correctors: peak field of 2-3 T (prototypes 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



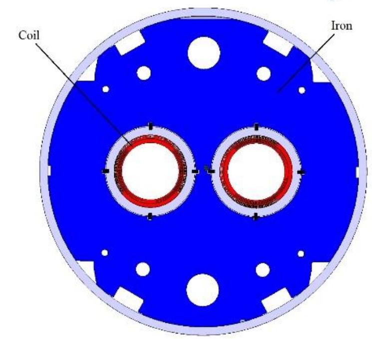




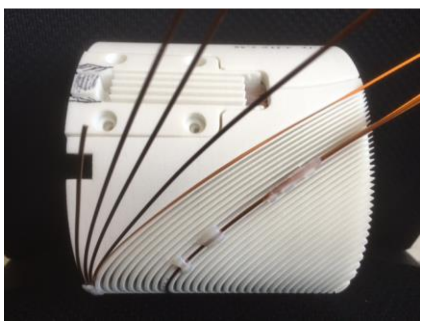
High Order correctors cross-section [G. Volpini, M. Statera, et al.]

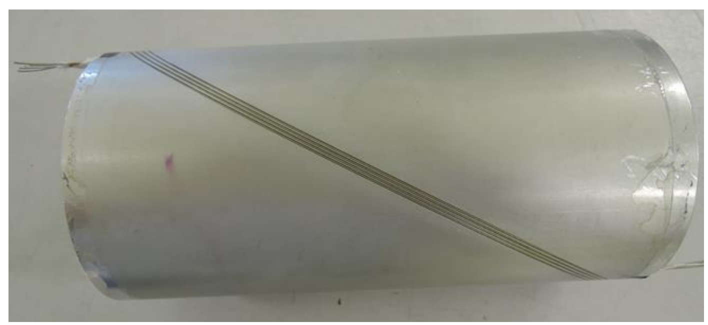
CORRECTOR MAGNETS: CANTED

- Nb-Ti technology, canted design
  - High order correctors: peak field of 2-3 T (prototypes by INFN)
  - 2 m long, 12 units
  - 105 mm aperture

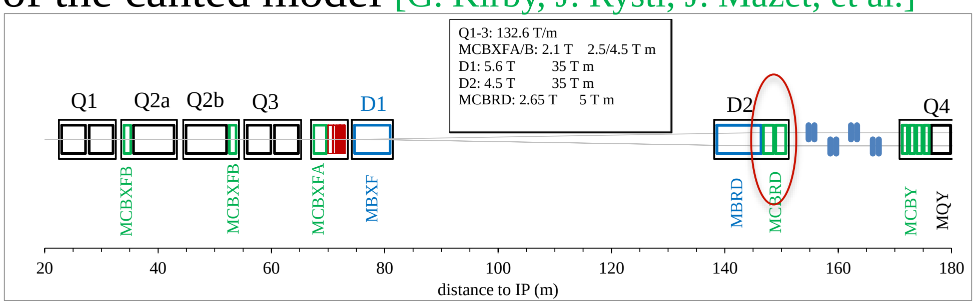


MBCRD cross-section
[G. Kirby, J. Rysti]



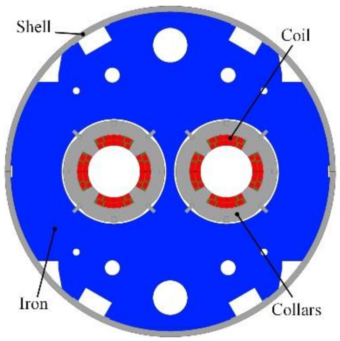


Winding tests of the canted model [G. Kirby, J. Rysti, J. Mazet, et al.]

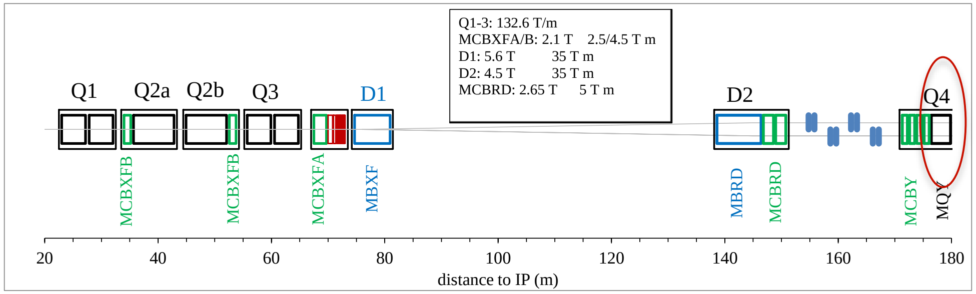


LARGE APERTURE Q4 DEVELOPMENT

- 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

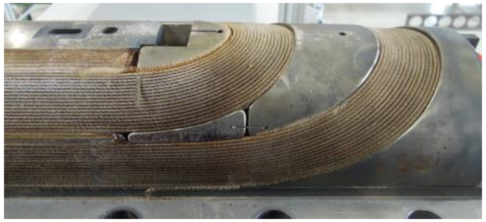
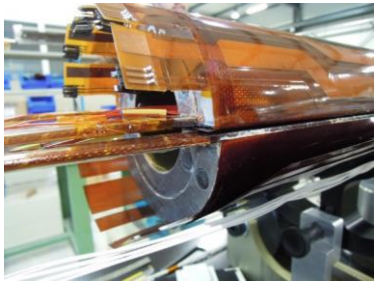
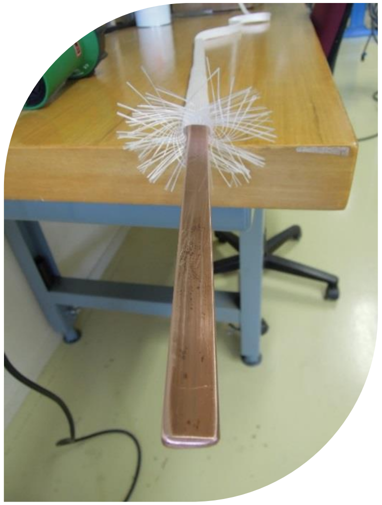


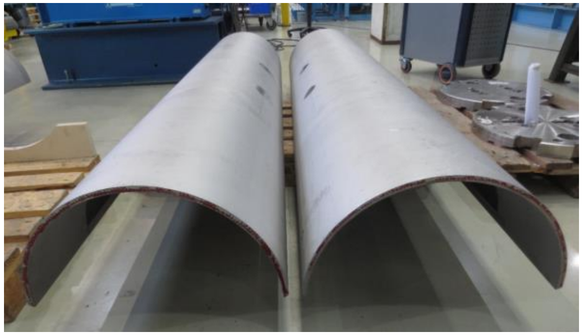
COMPONENTS

- Superconducting strand
  - 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




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)

HiLumi HL-LHC PROJECT CERN

A summary from F. Savary about status in 2015

Legend: We are covered | We need more suppliers | We desperately need suppliers

Item #	Description	Raw material	2018	Later	What is challenging
1	Coil keys	AISI 316 L – DIN 1.4435			Machining (accuracy & elasticity)
2	End spacers	SLS – AISI 316 L – DIN 1.4435			3D-metrology, electrical insulation is needed
3	Saddles	Impregnated glass fiber as per IEC/EN 61212-3-1 EP-GC22			5-axes machining, GC22, accuracy
4	Removable pole	TA6V annealed (Ti6Al4V; 3.7165)			Accuracy & material
5	Wedges – precision profiles	Aluminum oxide dispersion strengthened copper (ODS)			Accuracy, material ODS
6	Quench heaters	Polyimide – St.Steel – Copper			Flexible Printed Circuits
7	Collars	YUS-130S (High Mn Steel)			Fine blanking, accuracy
8	Collaring keys	AISI 316 L – DIN 1.4435			Accuracy
9	Yoke laminations & inserts	Low carbon steel			Fine blanking, accuracy
10	Heat exchanger tube	Oxygen Free Cu – UNS C10200			Cu quality
11	Bus bars – hollow bars	Oxygen Free Cu – UNS C10200			Length, Cu quality
12	Lyras	Oxygen Free Cu – UNS C10200			Cu quality
13	Shells	AISI 316 LN – DIN 1.4429			Raw material, thickness, accuracy
14	End covers	AISI 316 LN – DIN 1.4429			Raw material, accuracy