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Accelerator magnets: A strong driver for industrial innovation

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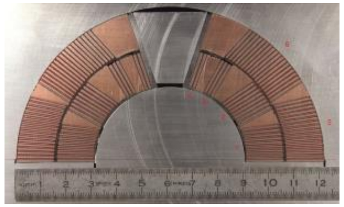
TE-MSC
26.11.2019

CERN

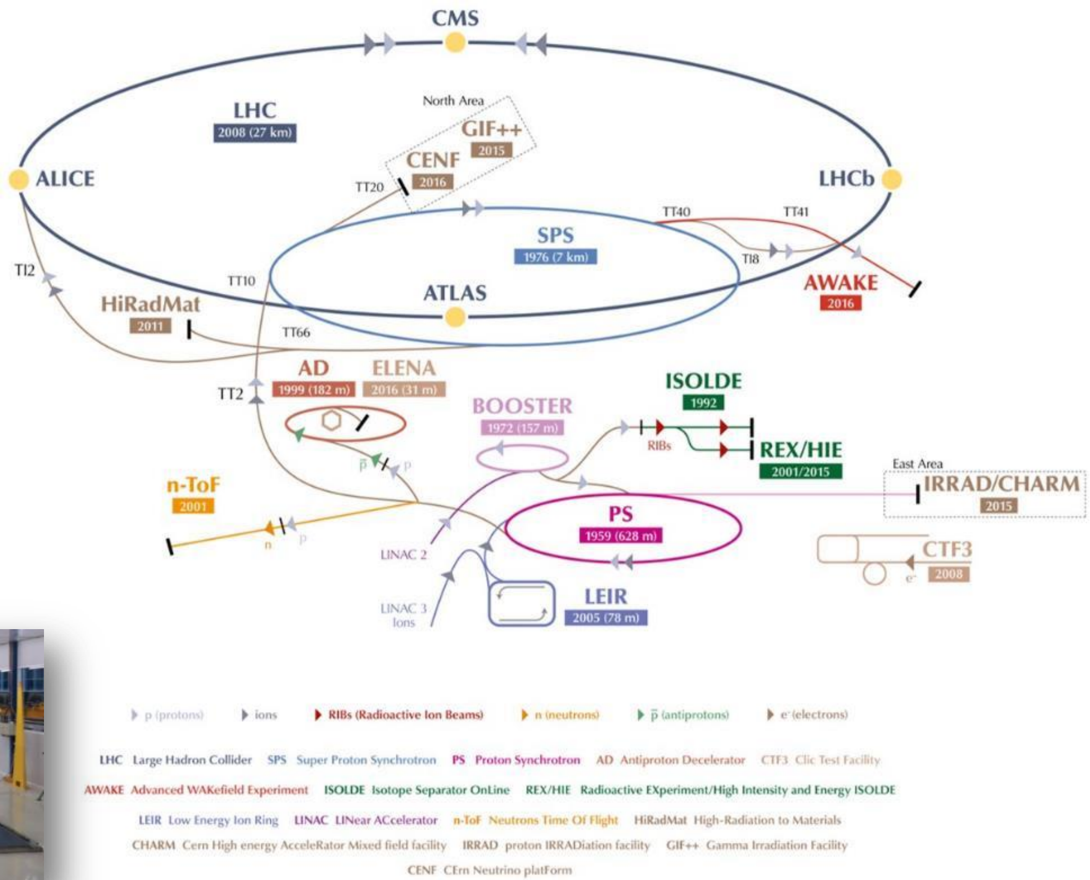
Overview

- CERN Infrastructure
- HL-LHC innovation in superconducting magnets
- Industrial involvement
- Overview on upcoming procurements in MSC
- Examples
- MSC – examples on successful industrial involvement
- The future scenarios
- Summary

CERN's infrastructure



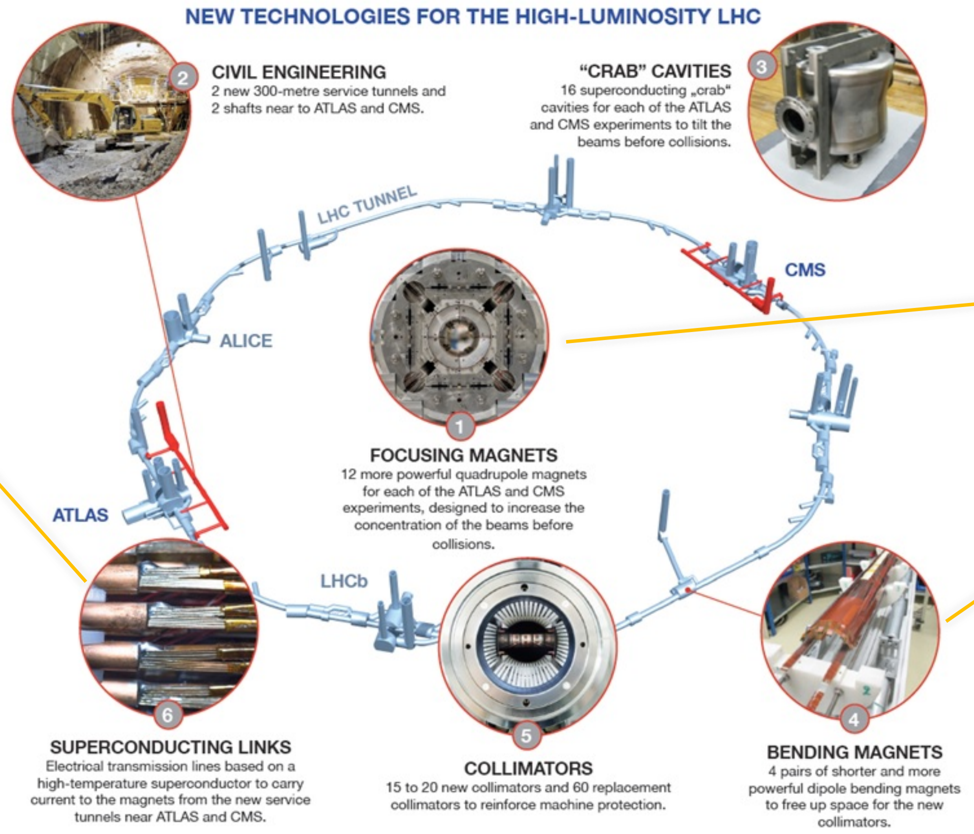
- 50 000 tons of normal conducting magnets
- 50 000 tons of superconducting magnets
- 490 tons of high homogeneity Nb-Ti alloy in LHC
- This requires 40,000 leak-tight pipe seals
- 120 tonnes of helium to keep the magnets at 1.9 K
- Total length of vacuum piping: 104 km
- 50 types of magnets to run LHC




Innovations to Boost Performances

- CERN's present big project is HL-LHC; it includes a number of technical innovations aimed at boosting performances and efficiency of the machine.

First use of ~100-m-long, MgB_2 sc links to power magnet strings in Interaction Regions



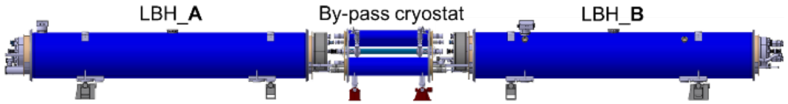
First sets of Nb_3Sn dipole and quadrupole magnets to be installed in an accelerator

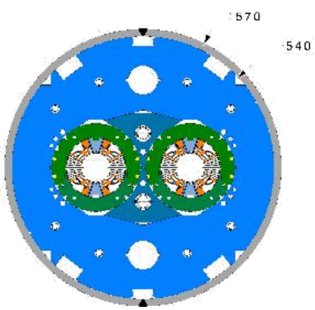
Nb_3Sn is an enabling technology for HL-LHC

Courtesy of L. Rossi, CERN

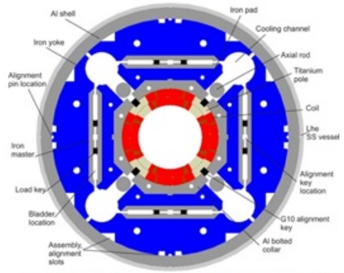
LHC, what next? HL-LHC!

- Achieve instantaneous luminosities a factor of five larger than the LHC nominal value
- Enable the experiments to enlarge their data sample by one order of magnitude compared with the LHC baseline programme

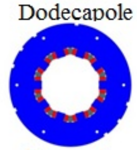


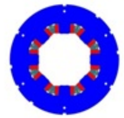


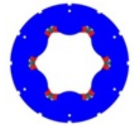
11 T dipole

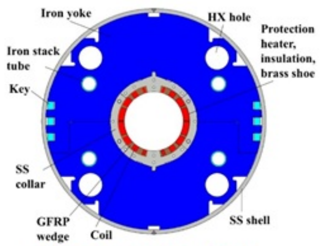

Triplet [G. Ambrosio, P. Ferracin et al.]


Dodecapole

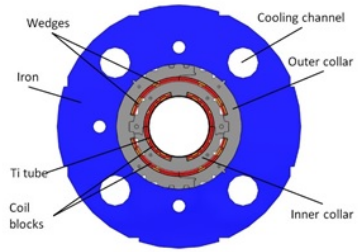

Decapole


Octupole

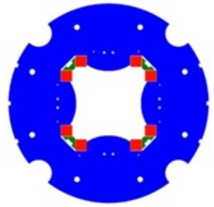


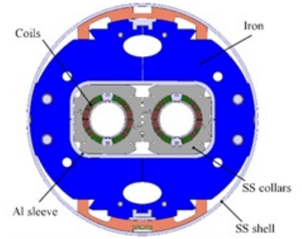


D1 [T. Nakamoto, et al.]

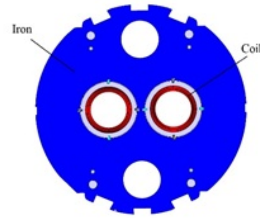


MCBXF [F. Toral, et al.]

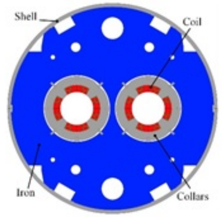

Skew quad
[M. Sorbi, M. Statera, et al.]



D2 [P. Fabbricatore, S. Farinon, et al.]



D2 correctors [G. Kirby]



MQYY [H. Felice, et al.]

Industry involvement

Magnet projects at different levels:

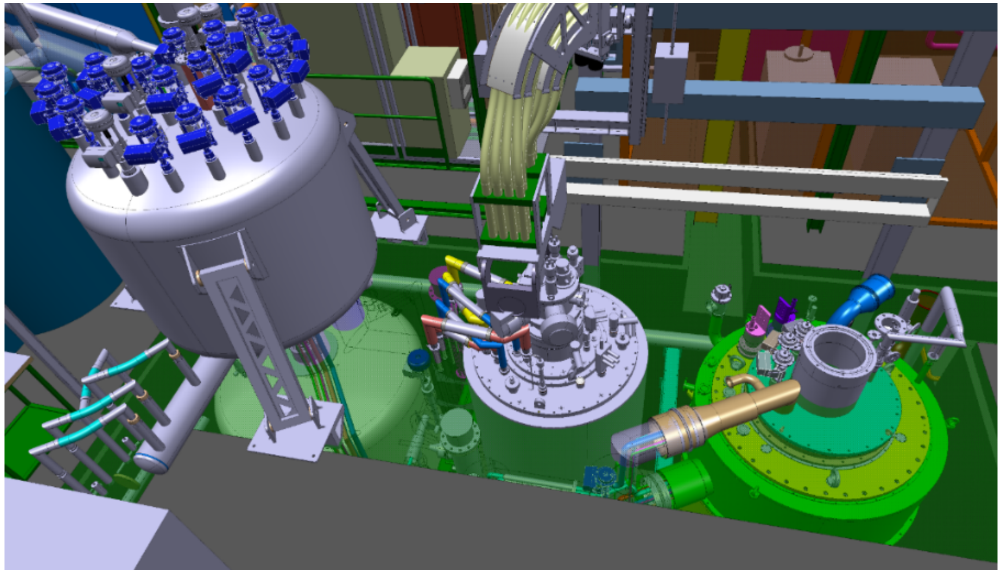
- **In-kind collaborations** with partner institutes and their industry partner
- **Delivery of magnets** following CERN's technical specification (competitive tender)
- **Service contract** at CERN premises using CERN tooling and specifications (competitive tender)
- **Delivery of parts/tooling** following build to print (competitive tender)
- **Delivery of insulation systems and conductor**
- **Delivery of raw materials**

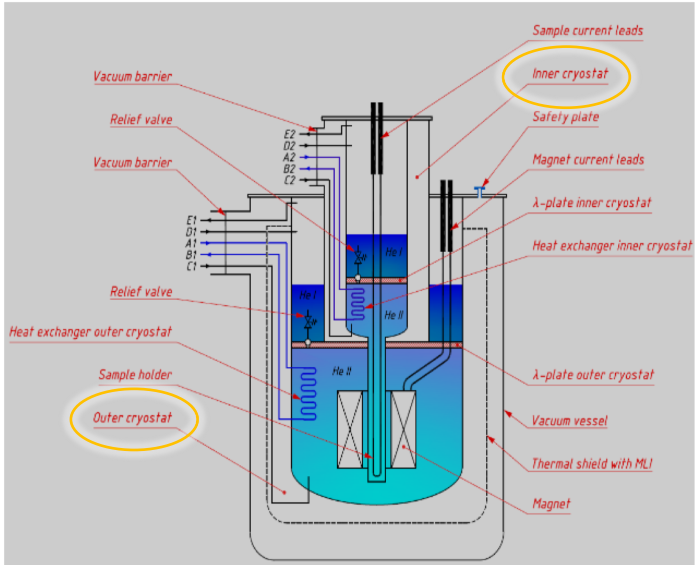
In almost all procurements the special requirements like tight tolerances, detailed quality assurance, or detailed documentation or design work are requested.

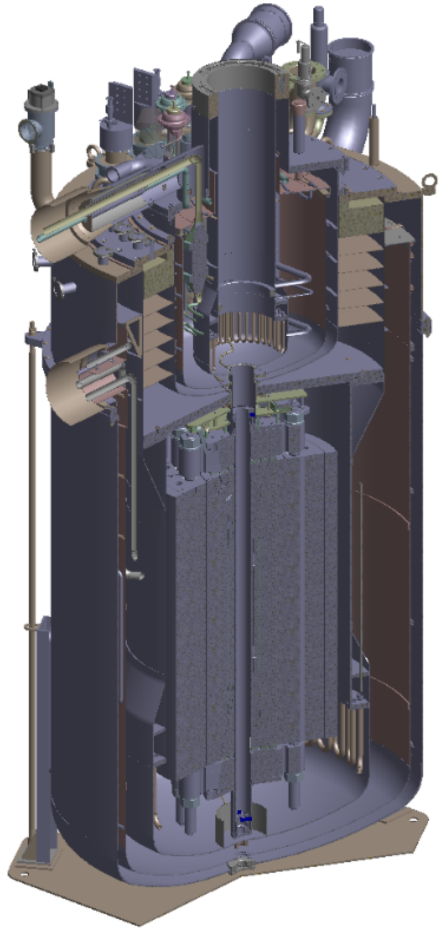
Upcoming procurement (12-18 months)

Title	Unit
Components of cryostat for MQXF	CMI
Diode **connection module**	CMI
Expansion **joints**	CMI
Fresca2 vertical **test cryostat**	CMI
Multilayer insulation	CMI
Phase separator He	CMI
Service contract for cryostating (around 100 FTE.y between 2021-2025)	CMI
Components for D2 magnets (**End spacers, wedges, flanges**)	LMF
IFS (**Instrumentation Flange System**) for HL-LHC magnets	LMF
Milling machine	LMF
Service contract for the fabrication of **MQXF coils** (Inner triplet quadrupoles)	LMF
Service contract MQXF cold mass and **cryostats**	LMF
DMA (**Dynamic mechanic analysis**) measure polymer viscoelastic behaviour, determining glass transition temperature	MDT
Large polymer **curing oven** up to 250°C	MDT
Mechanical components ERMC/RMM (**Magnet components for R&D magnets**)	MDT
Manufacture of half-shells (about 100 mm in diameter, 1.2 m long) in carbon fibre or fibre-glass epoxy (G11)	MM
Nb_3Sn solenoids, 16-18 T	SCD

FRESCA 2 Vertical Test Cryostat: Vacuum & Helium Vessel (304L)

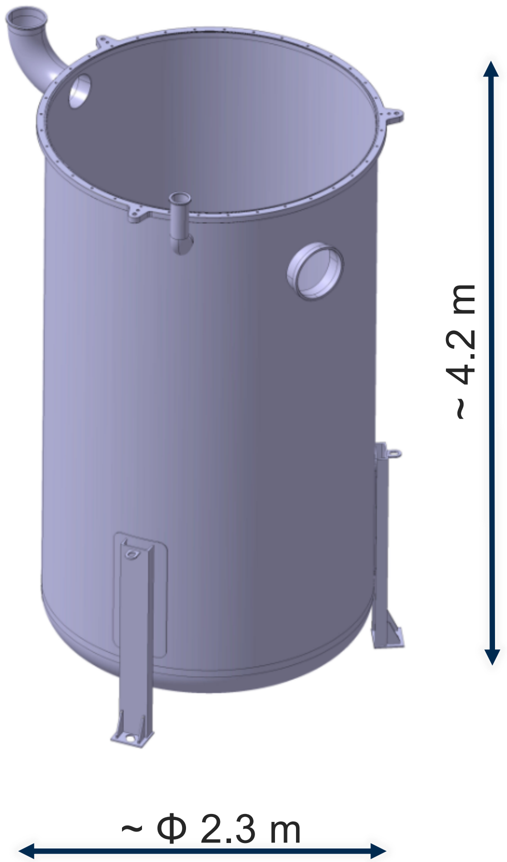


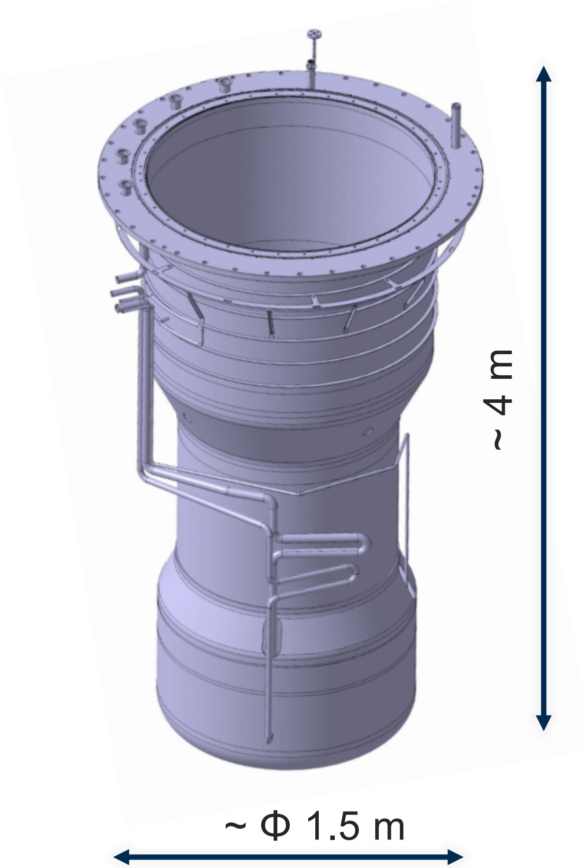




- A test station for qualifying new superconductors at CERN
- Two concentric HeII cryostats, the outer one containing a 13 T magnet
(Fresca 2), the inner one contacting samples of new superconducting cables

FRESCA 2 Vertical Test Cryostat: Vacuum & Helium Vessel (304L)

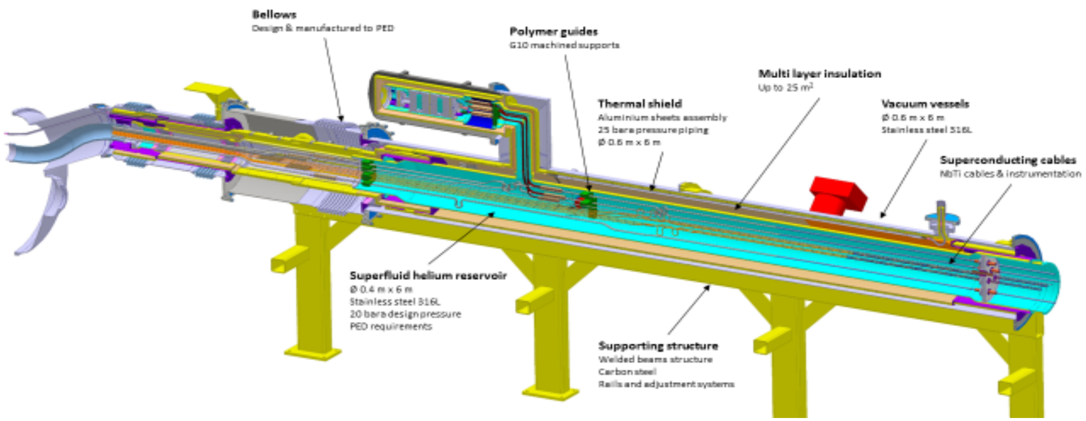


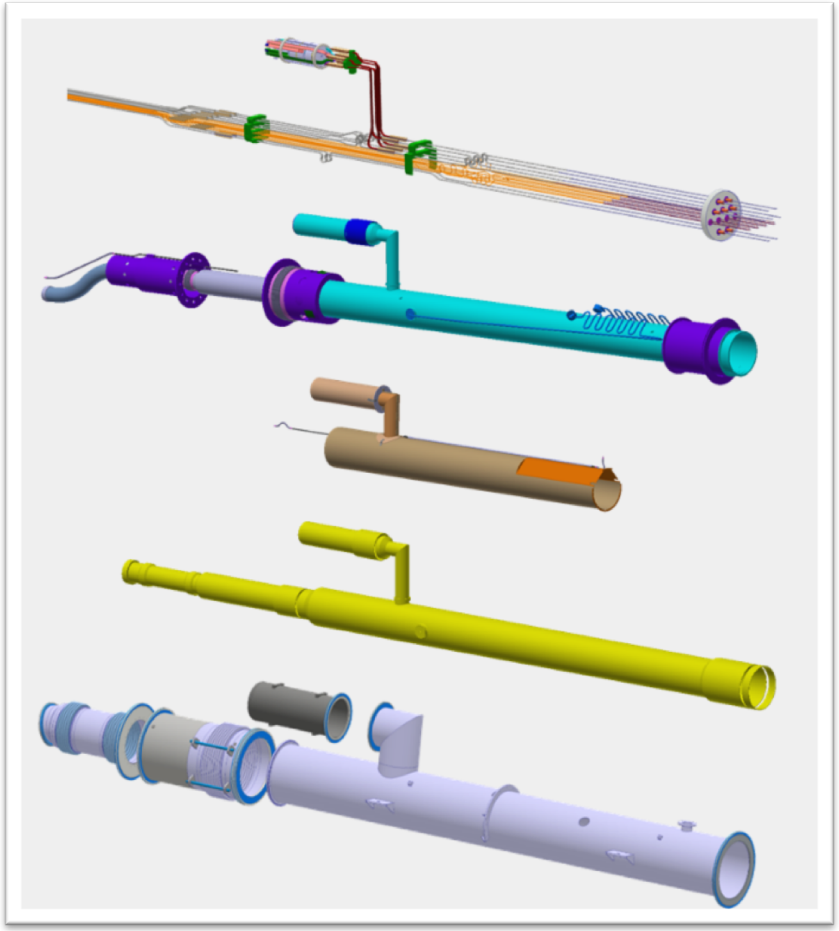


- Engineering and design being finalized at CERN
- Main parts to be constructed in industry starting in Autumn 2019
- Procurement for the cryostats to be launched in early 2020

Project Engineer in charge: Alessandro.Dallocchio@cern.ch
Technical responsible: Vittorio.parma@cern.ch

Diode Connection Module (DCM)



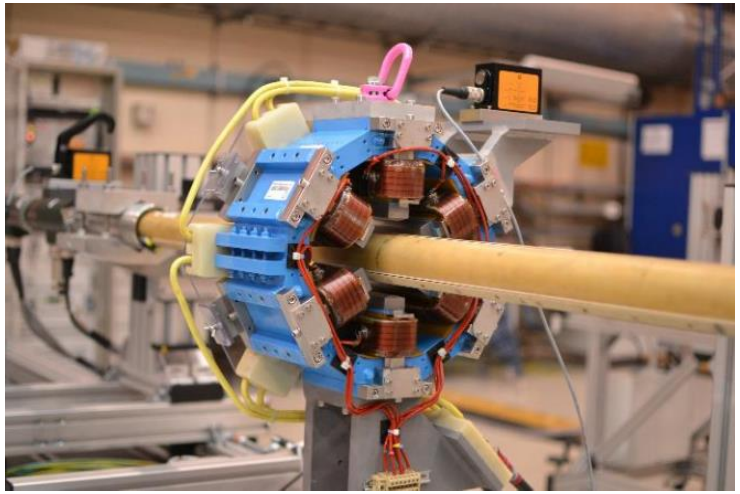


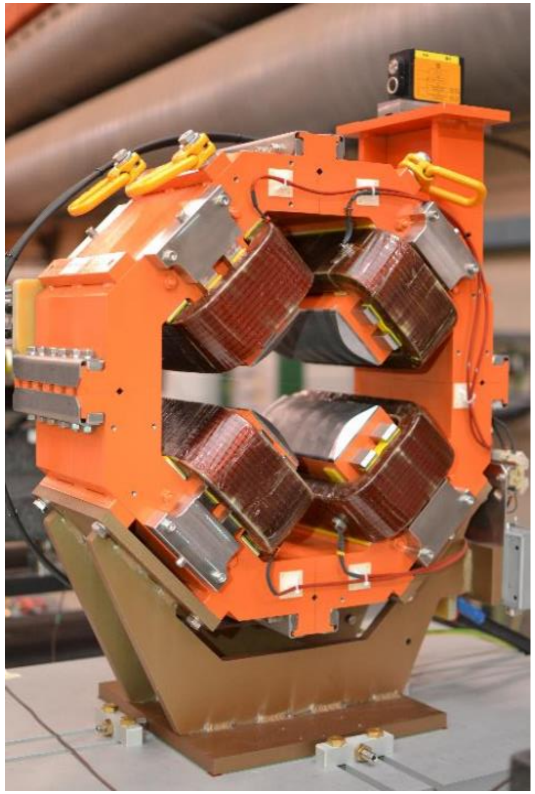
- Cryogenic assembly for feeding superconductors and cold diodes for HL LHC
- Cryostat vacuum and helium pressure vessels (304 L)
- EN 13480, EN 13455
- Helium vessel design pressure: 20 bar
- Qualified welders and welding procedures
- Extensive welding QC
- Cryostat GFRE supports, Al thermal shielding, MLI
- Flexible bellows
- Supporting cradle structure
- 5 assemblies needed: 1 prototype by 2020, 4 series by 2023
- **Note:** superconductors, bus-bars, cold diodes are not part of this supply

Example I: Delivery of magnets following CERN's technical specification: Scanditronix, Sweden

Detailed procurement process[1]

- Market survey
- Invitation to tender: Submission of bid
- Contract placement





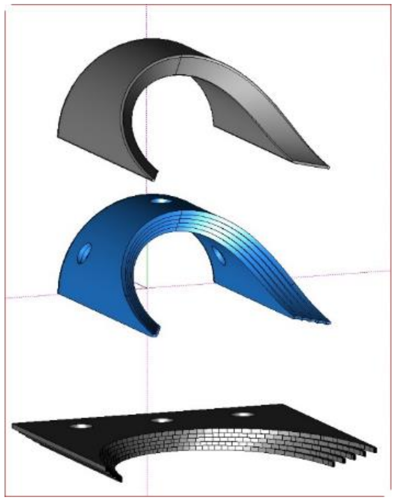
[1]https://procurement.web.cern.ch/en/procurement-process

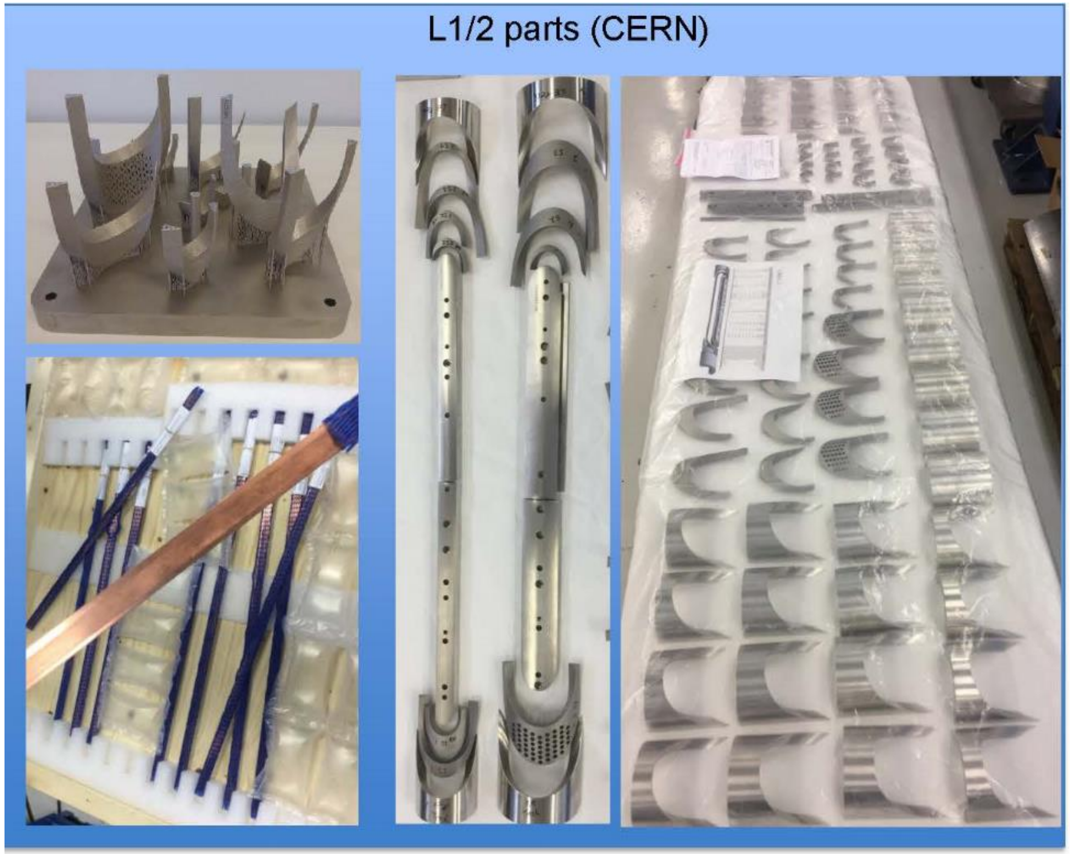
Example II: Service contract

Service contract for 11T magnet fabrication in the CERN Large Magnet Facility

Example III: Delivery of parts

- Procurement of machined parts according to functional drawings
- For example the saddles shown on this picture have been produced in Norway by DSM AS Machining (contract won after competitive tendering)





Ti and Cop Wedges Ti poles and spacers, SS saddles

Magnet Design Options: Future Circular Collider

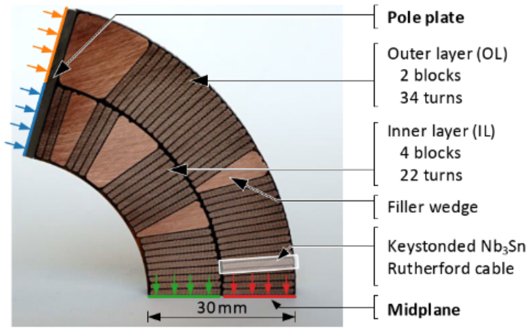
Timeline	~ 5	~ 10	~ 15	~ 20	~ 25	~ 30	~ 35
Lepton Colliders							
SRF-LC/CC	Proto/pre-series	Construction		Operation		Upgrade	
NRF—LC	Proto/pre-series	Construction		Operation		Upgrade	
Hadron Collier (CC)							
8~(11)T NbTi /(Nb3Sn)	Proto/pre-series	Construction		Operation			Upgrade
12~14T Nb_3Sn	Short-model R&D	Proto/Pre-series		Construction		Operation	
14~16T Nb_3Sn	Short-model R&D		Prototype/Pre-series			Construction	

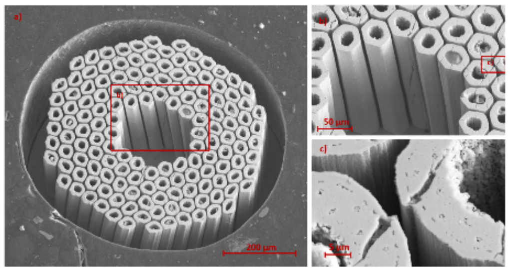
Courtesy A. Yamamoto, KEK - 2019

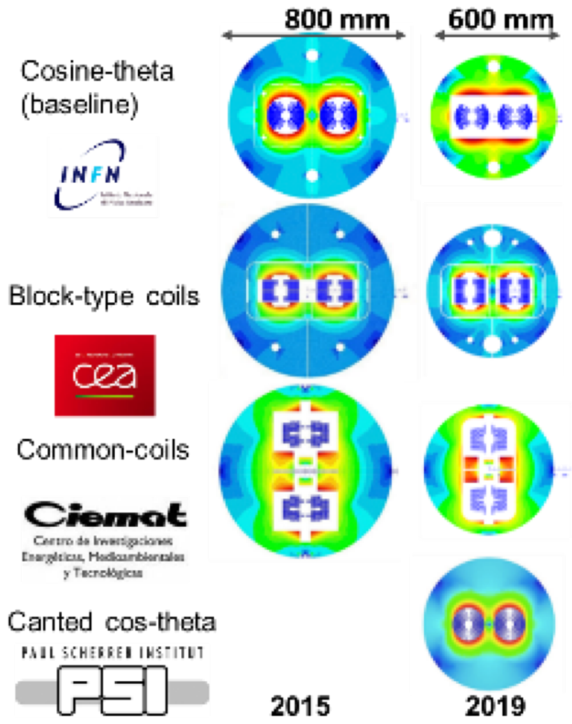
FCC study

International FCC collaboration (CERN as host lab) to study:

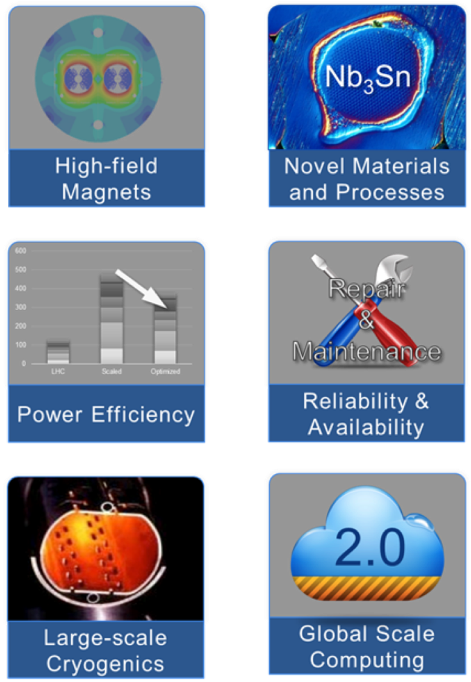
- 80-100 km tunnel infrastructure, different scenarios:
  - e^+e^- collider (*FCC-ee*) as potential first step
  - *pp*-collider (*FCC-hh*)
  - *p-e* (*FCC-he*) option
- HE-LHC with *FCC-hh* technology







Magnet design studies…



Challenges…

http://clic-study.web.cern.ch/

CLIC study

- **Electron-positron machine** (Linear machine, particles would otherwise loose an enormous amount of energy circulating in a circular structure as the LHC)
- Accelerating gradient: 360 GeV to 3 TeV
- Very high precision on the components! For some parts, the mechanical tolerances are 2 µm, a big challenge from the manufacturing point of view
- Requires a nm active stabilization system on main quadrupole magnets
- Key technology: High-gradient accelerating structures
- CLIC aims at an acceleration of 100 MV/m, 20 higher than the LHC

Courtesy H.M. Durand (EN-ACE), K. Artoos (EN-MME)

Summary

- CERN is working with industry for the procurement of accelerator magnets at all levels and with different sized companies
- Opportunities exist for conductor manufacturers, machining companies (parts), service providers, and the delivery of entire magnets (Normal - and Superconducting)
- Qualification through (smaller) contracts or collaborations with partner institutes

Contact persons :

Magnets Cryostats and Superconductors: Luca Bottura (TE-MSC)

Mechanical & Materials Engineering: Francesco Bertinelli (EN-MME)

Forthcoming market surveys and calls for tenders: https://found.cern.ch/java-ext/found/CFTSearch.do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Thank you !!!
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