Overview HL LHC Magnets of LHC, , FCC, and all kind of other

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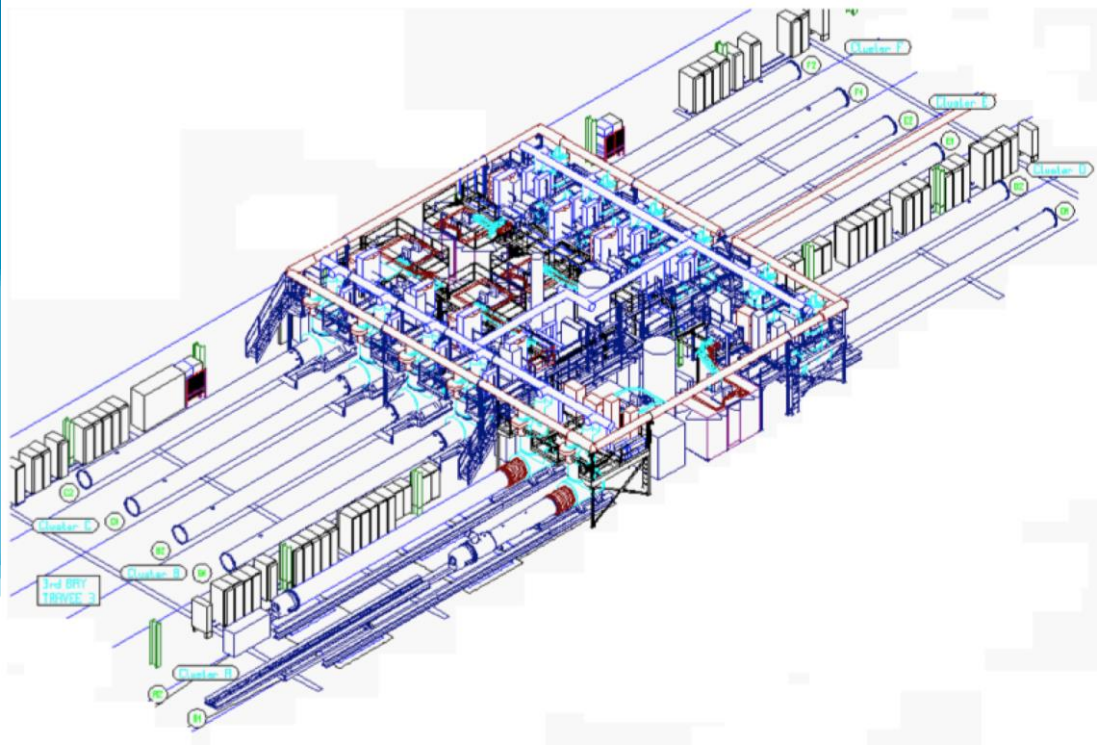
TE-MSC

1st International Workshop on the Superconducting Magnets Test Stands
CERN, June 13th-14th, 2016

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

SM-18 at the times of the LHC

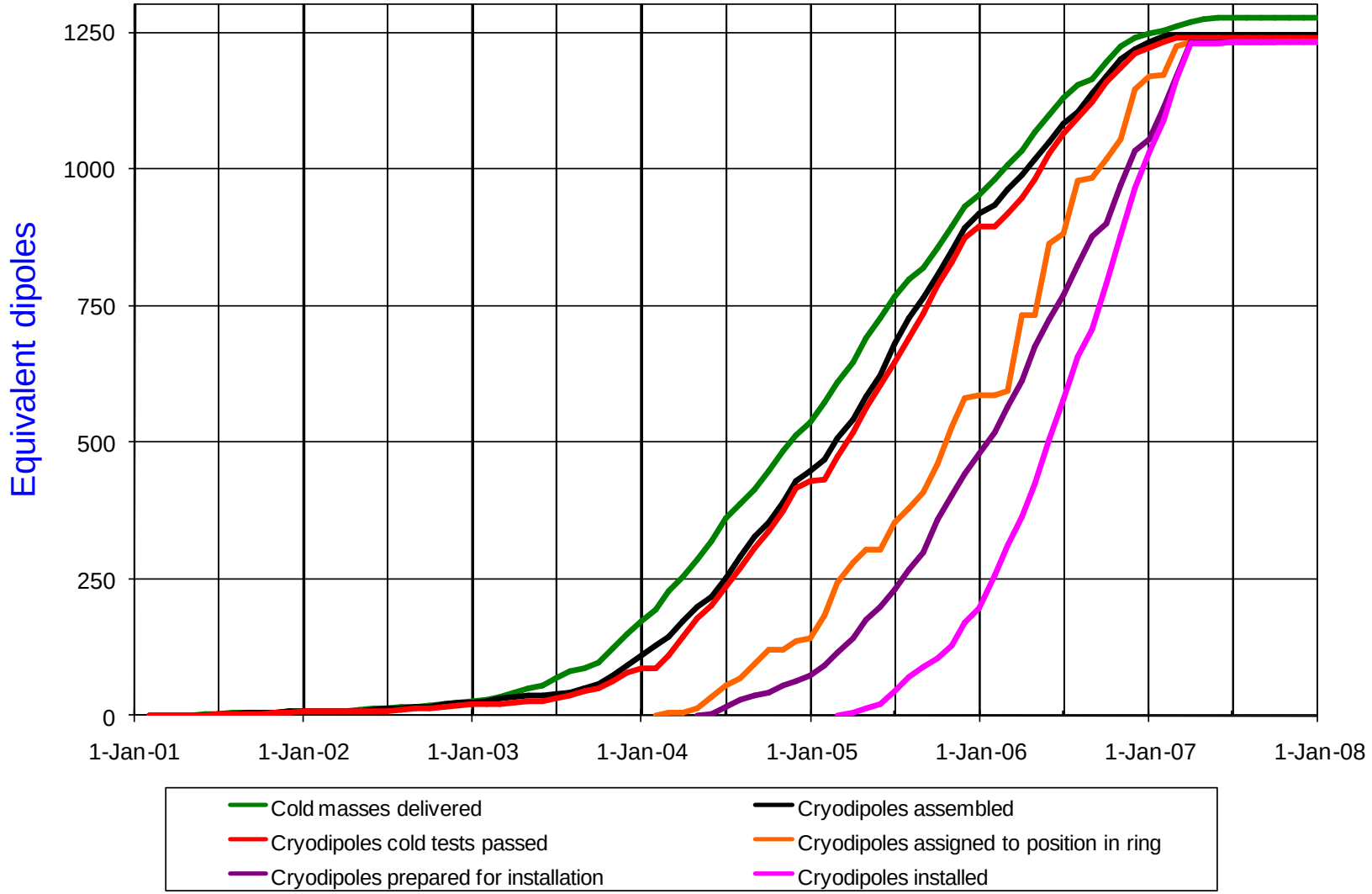
SM-18 test benches



- 12 fully equipped test benches arranged in 6 clusters which could run independently
- All test benches capable to operate, both at 4.2 and 1.9 K
- Cryomagnets could be equipped with anticryostats for:
  - Magnetic Measurements
  - Quench Localisation

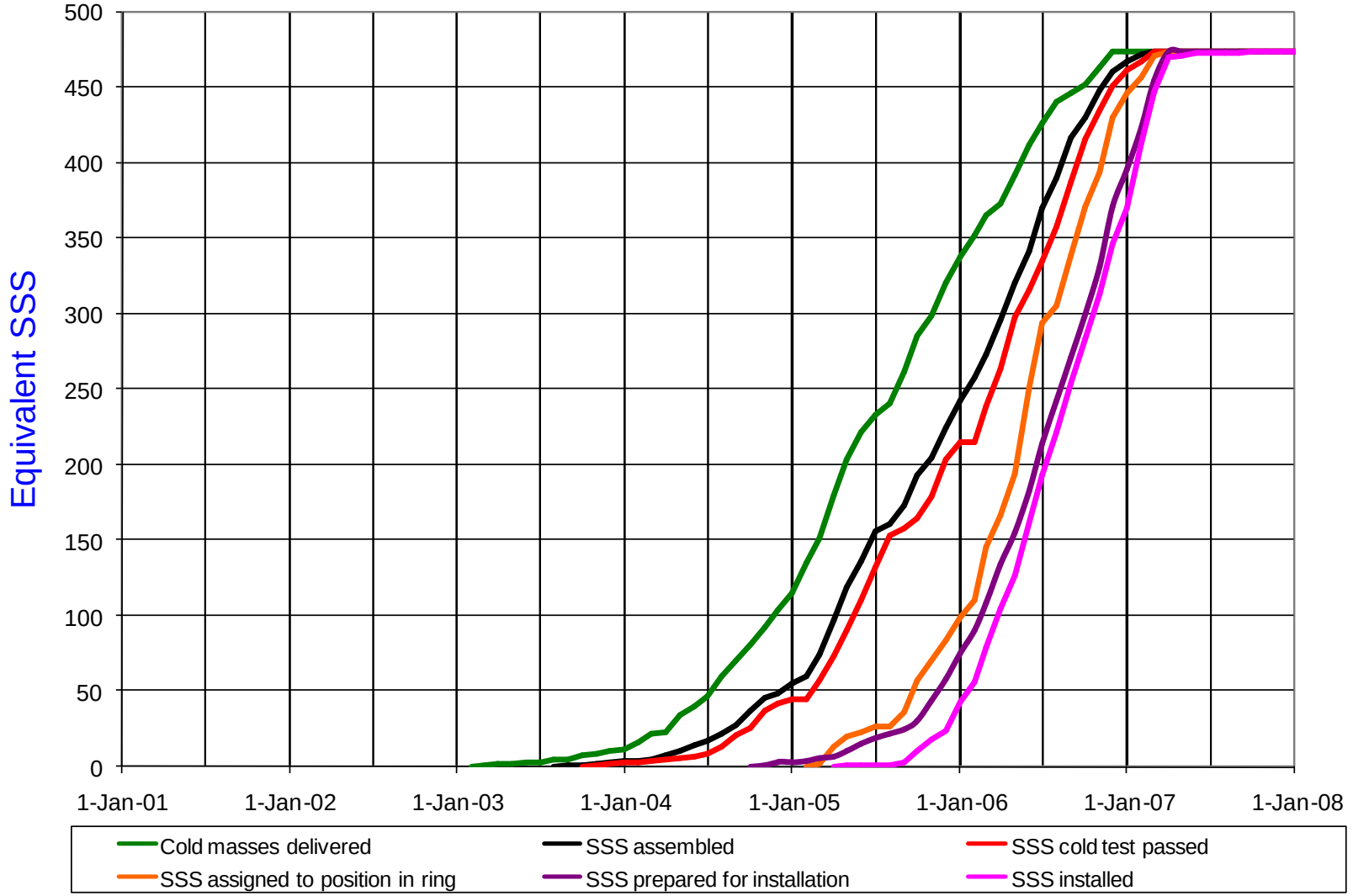
First test bench operational in 1994
Construction of final installation started early 2003
Fully completed in May 2004
Test facility was running 24/24, 7/7, 46weeks/year
Cold tests were completed in February 2007

Test mission - dipoles



Dashboards by courtesy of E. Delucinge

Test mission - quadrupoles



Dashboards by courtesy of E. Delucinge

The LHC experience

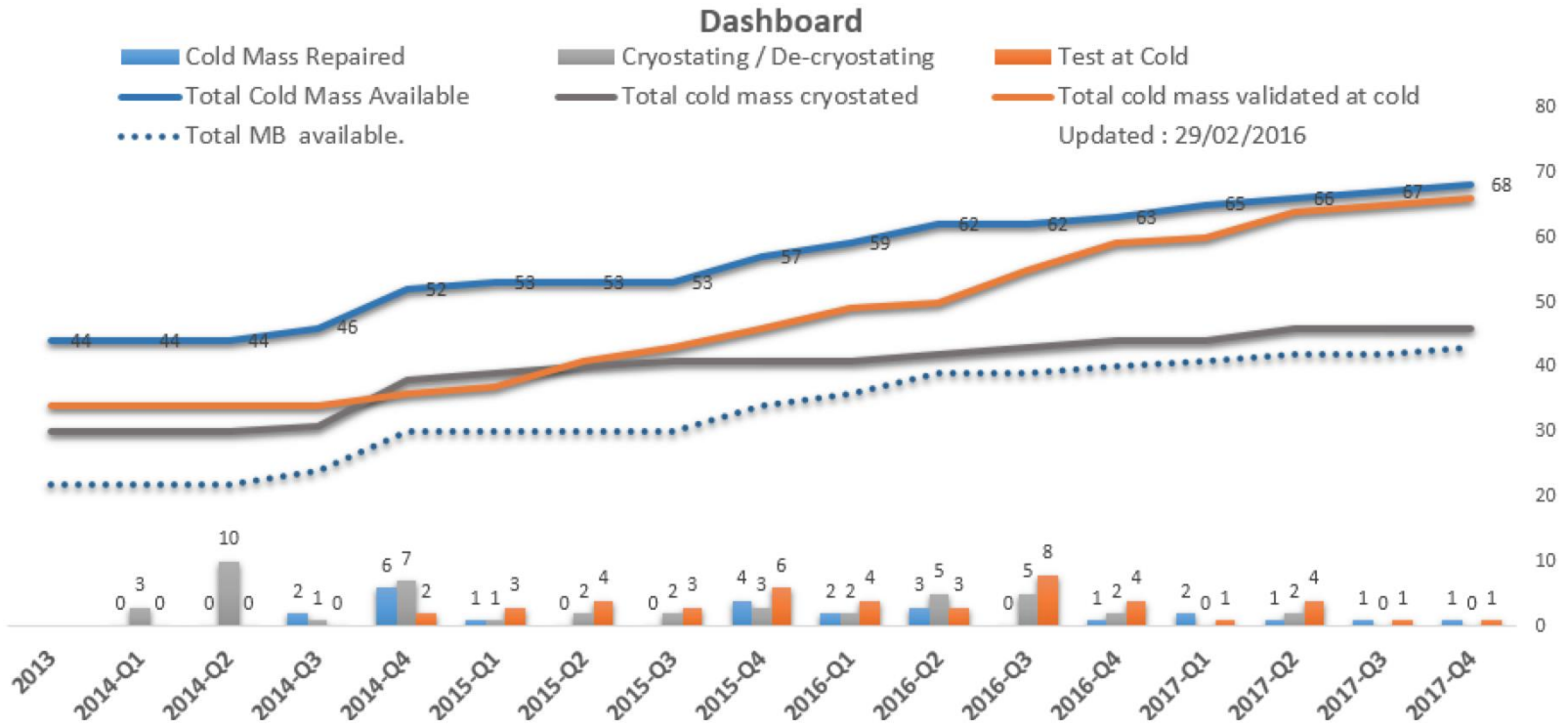
- About 2000 test runs in 3 and a ½ years, on approximately 1700 cryomagnet units, focused on:
  - quench performance
  - magnet protection
  - magnetic field quality (about 20% of magnets measured: magnetic length & multipoles)
  - cryogenic, vacuum, and electrical integrity

Type of NC	Total NCs	Average NC/magnet
Mechanical	1181	0.95
Electrical	583	0.47
Performance	94	0.08
Other	275	0.22
Total	2133	1.71

In total 31 dipoles were rejected because of training or electrical NC's

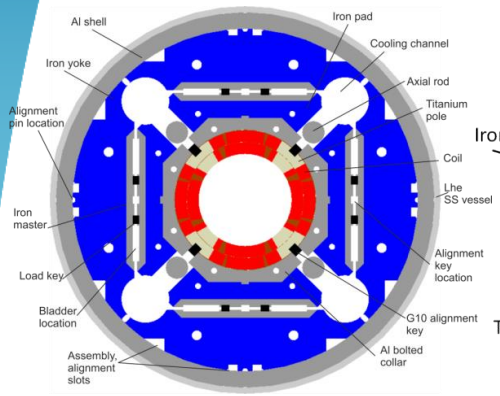
Statistics by courtesy of A. Siemko

The life of the LHC

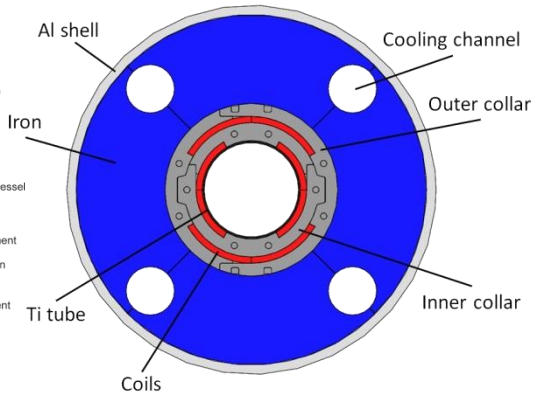


- It is not unreasonable to expect that **10 to 15 cryomagnets** will be exchanged every long shutdown (approximately 3 years)
- In addition, some **20…40 spare magnets** (MQ, MQY, MCBY, …) will be procured in the coming 5 years

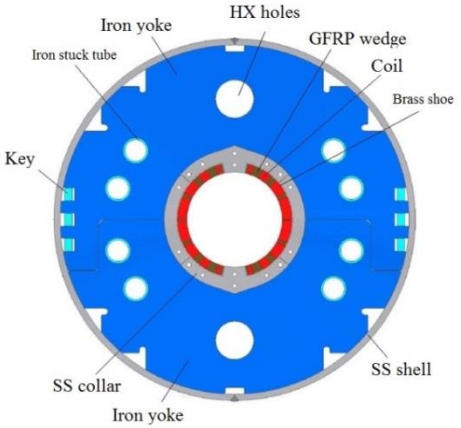
HL-LHC



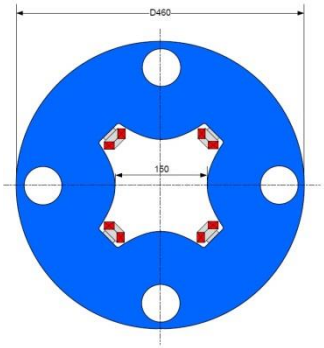
Triplet QXF (LARP and CERN)



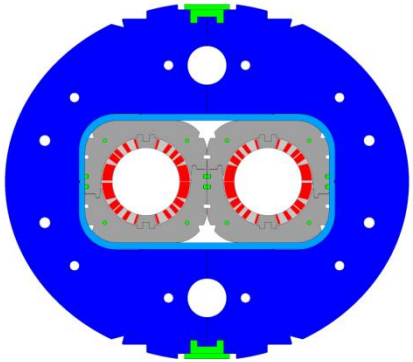
Orbit corrector (CIEMAT)



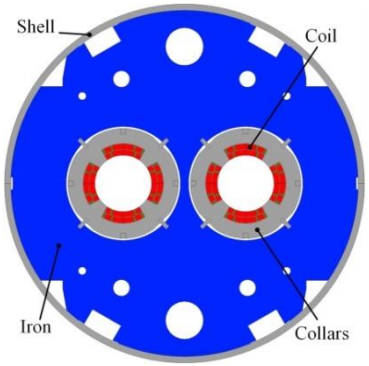
Separation dipole D1 (KEK)



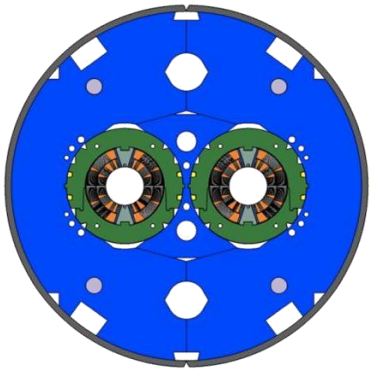
Skew quadrupole corrector (INFN)



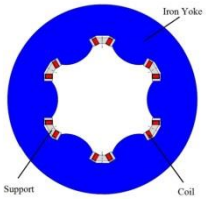
Recombination dipole D2 (INFN design)



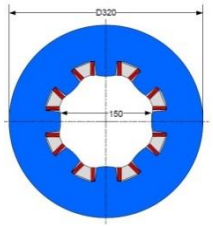
Q4 (CEA)



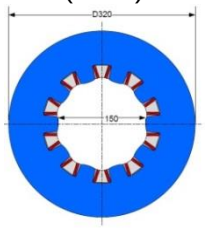
11 T (CERN)



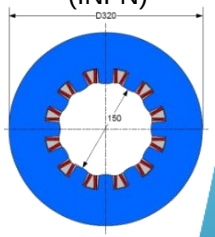
Corrector sextupole (INFN)



Corrector octupole (INFN)



Corrector decapole (INFN)



Corrector dodecapole (INFN)

Cross-sections to scale

HL-LHC test mission (as we stand today)

By LS2 (≈ 2020)

- 11 T models (≈6) and prototype (1)
- QXF models (5) and prototype (5)
- 11 T cryomagnets
  - (2 units +1 spare)
- MBFX (D1) models (2)
- MQYY (Q4) model (1) and prototypes (2)

By LS3 (≈ 2024)

- QXF (Q1/Q2/Q3) cryomagnets
  - (16 units + 4 spares)
- MBXF (D1) cryomagnets
  - (4 units + 2 spares)
- Corrector packages
  - (4 units + 2 spares)
- MBRD (D2) cryomagnets
  - (4 units + 2 spares)
- MQYY (Q4) cryomagnets
  - (4 units + 2 spares)
- Q5 cryomagnets
  - (4 units)

Approximately **50 cryomagnets** of very diverse geometry (supports and interfaces), characteristics (Nb_3Sn and Nb-Ti) and operating conditions, as well as more than **100 single magnets** to be tested as components before assembly in a cold mass

The CERN HFM Program

HL-LHC

- Demonstrate the maturity of Nb_3Sn through the application in the HL-LHC, in the range of peak magnetic field of 12 T

FCC
EuroCirCol

- Push Nb_3Sn magnet technology to its practical limit, with a target of 16 T dipole field as requested by the FCC

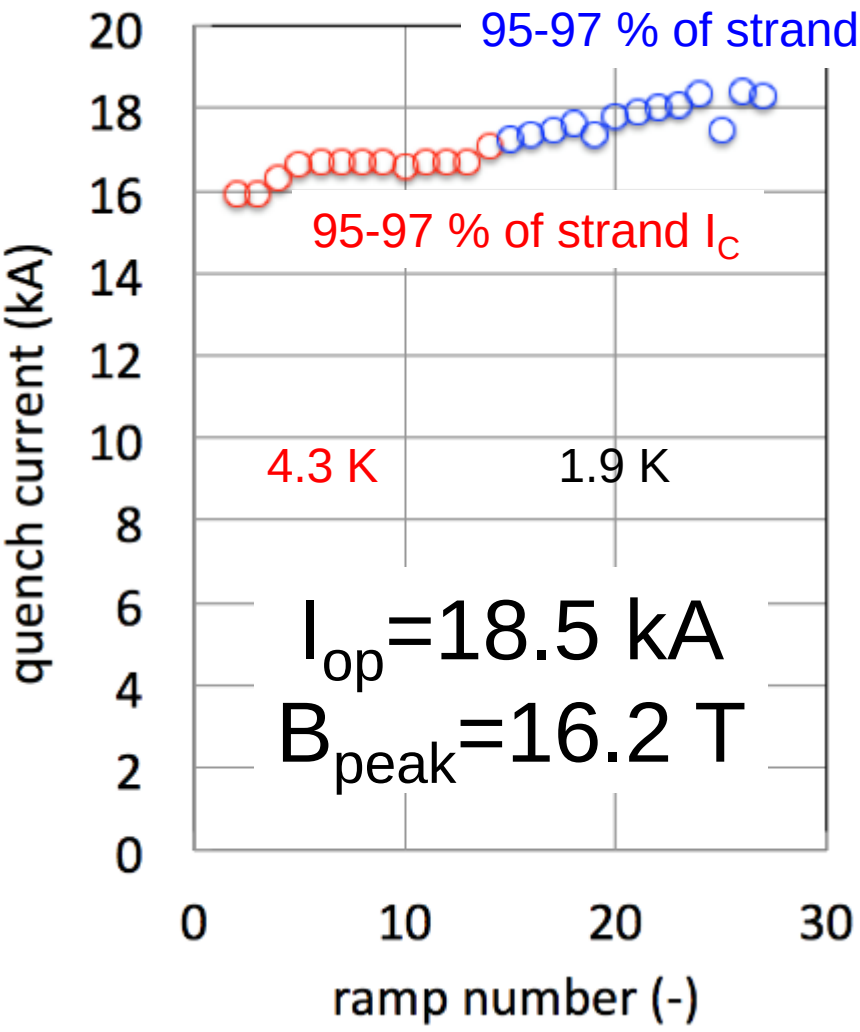
EuCARD2
(ARIES)

- Provide a proof-of-principle for HTS magnet technology beyond the reach of Nb3Sn, with a target of 20 T dipole field

SCM
(ORION)

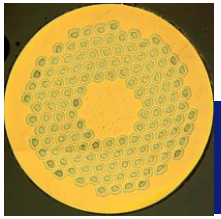
- Support the above programs with the necessary general material and magnet R&D and the evolution of the manufacturing and test infrastructure

RMC_3 test record



Fresca 2 Dipole cable

40 Strands, Width = 20.9 mm

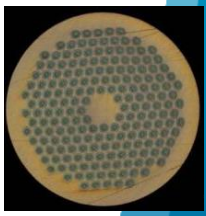


RRP 132/169

OXFORD INSTRUMENTS

BRUKER

PIT 192



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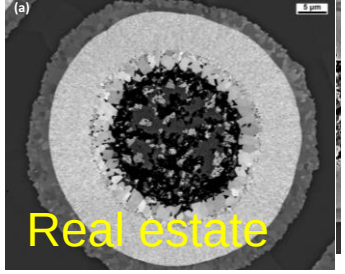
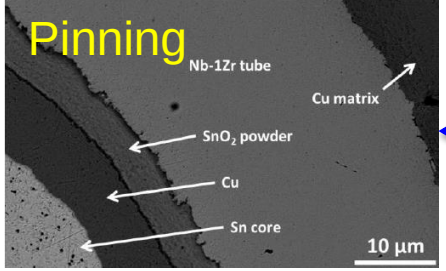
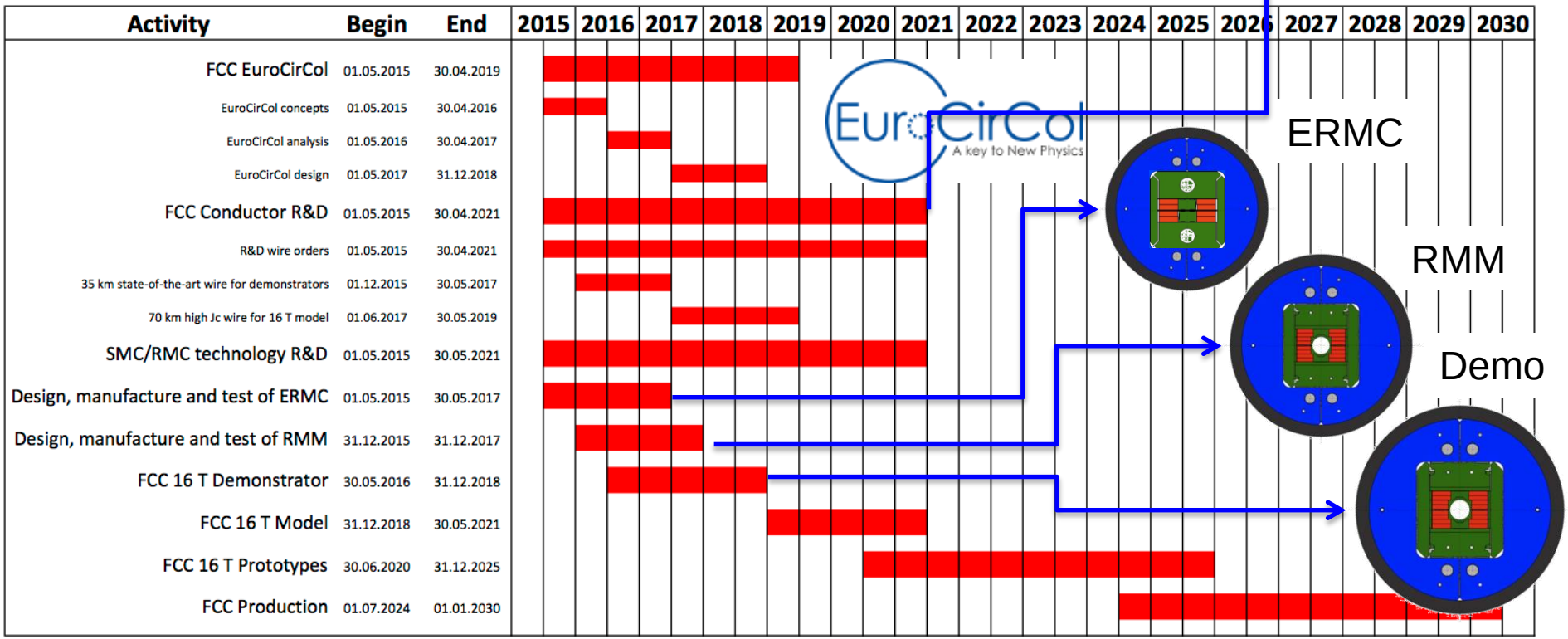
EuCARD

FCC plan





Activity	Begin	End
FCC EuroCirCol	01.05.2015	30.04.2019
EuroCirCol concepts	01.05.2015	30.04.2016
EuroCirCol analysis	01.05.2016	30.04.2017
EuroCirCol design	01.05.2017	31.12.2018
FCC Conductor R&D	01.05.2015	30.04.2021
R&D wire orders	01.05.2015	30.04.2021
35 km state-of-the-art wire for demonstrators	01.12.2015	30.05.2017
70 km high Jc wire for 16 T model	01.06.2017	30.05.2019
SMC/RMC technology R&D	01.05.2015	30.05.2021
Design, manufacture and test of ERMC	01.05.2015	30.05.2017
Design, manufacture and test of RMM	31.12.2015	31.12.2017
FCC 16 T Demonstrator	30.05.2016	31.12.2018
FCC 16 T Model	31.12.2018	30.05.2021
FCC 16 T Prototypes	30.06.2020	31.12.2025
FCC Production	01.07.2024	01.01.2030

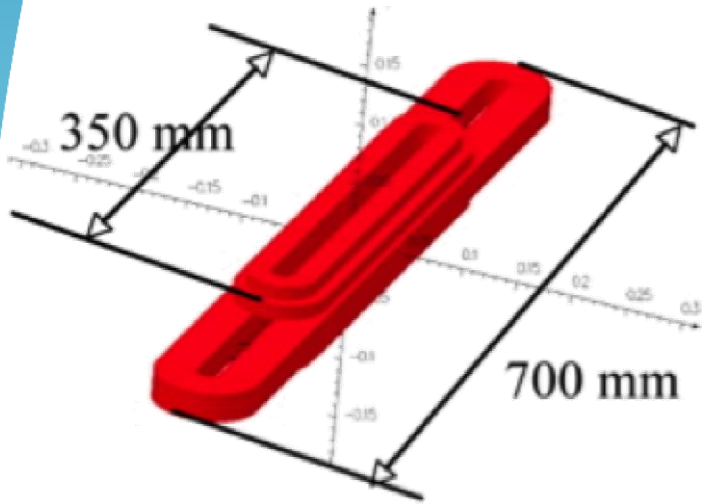


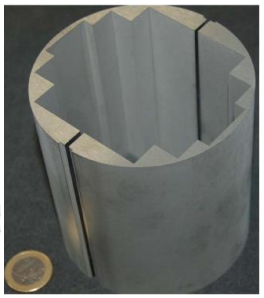
- Expect some **10 sub-scale and demonstration magnets** to come in the period 2017-2021

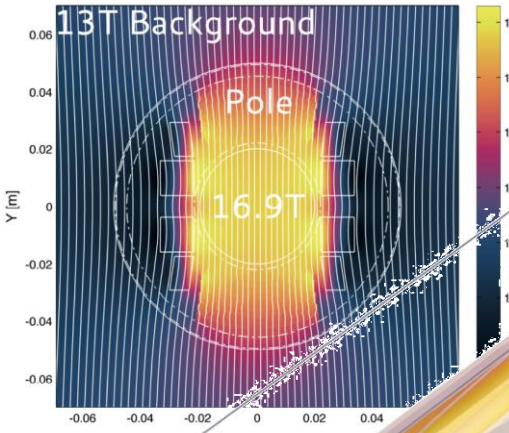
HTS for 20 T

6 T HTS (YBCO) insert for test in FReSCa2 (no bore)

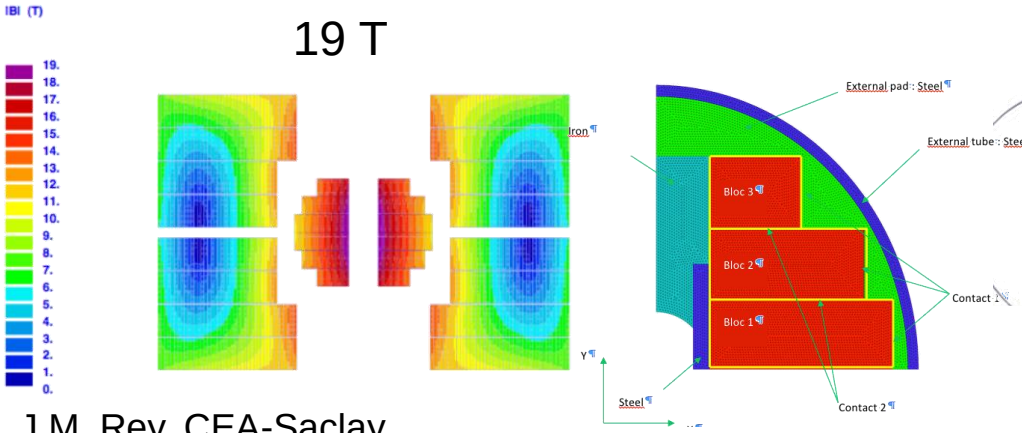
J. Van Nugteren, G. Kirby, G. de Rijk, CERN







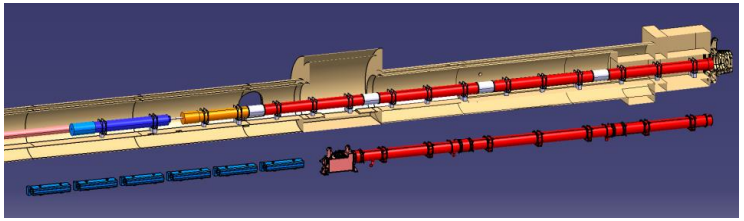
19 T

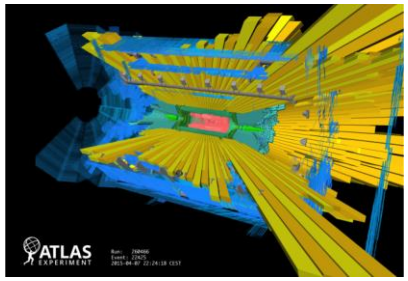


J.M. Rey, CEA-Saclay

5 T HTS (YBCO) stand-alone dipole for test in FReSCa2 (40 mm bore)

LHC Run-II provides results to define future HEP roadmap (European Strategy 2018)





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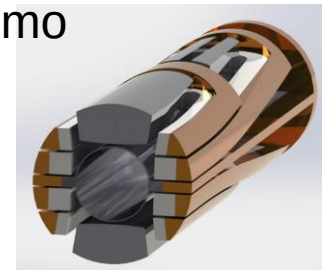
Accelerator-grade HTS **5 T** demo



HL-LHC demonstrates large-scale use of Nb_3Sn

High Luminosity LHC

End of LHC useful life

2015 2016 2017 2018 2019 2020 2025 2030 2035 2040

12 T accelerator technology

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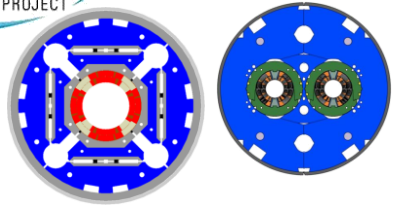
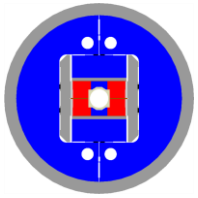
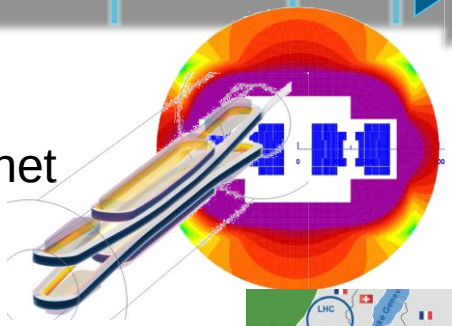
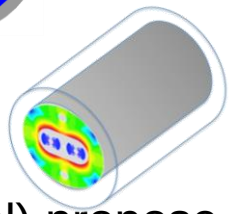




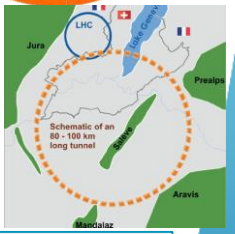
16 T magnet model(s)

20 T magnet model(s)





16 T accelerator technology



FCC hh ee he

FCC CDR (EuroCirCol) propose a new energy frontier accelerator

FCC construction decision

FCC production and test ?!?

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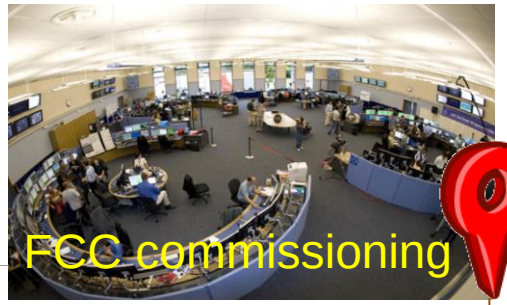
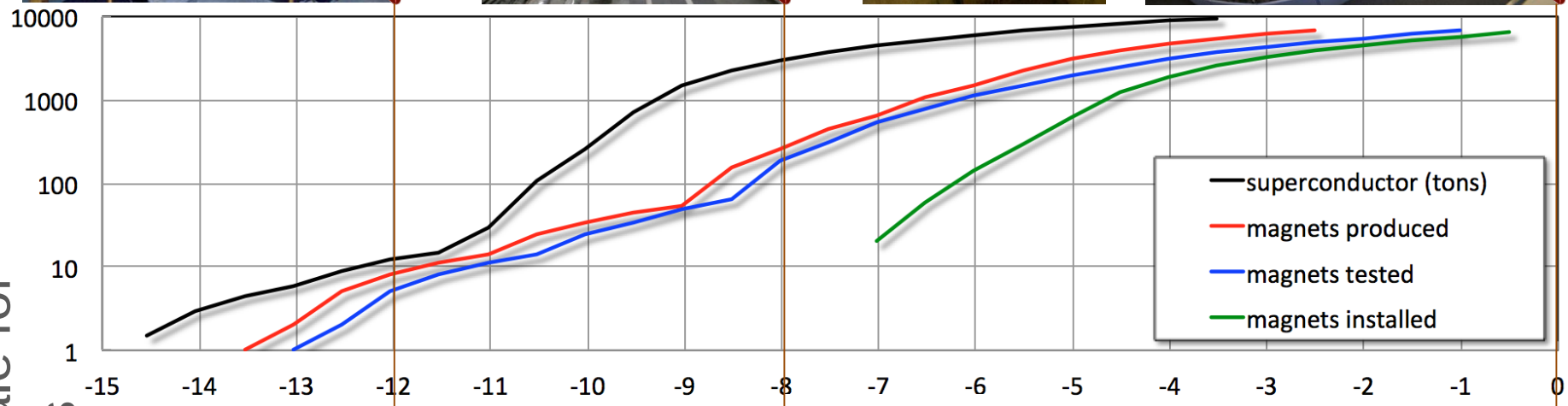




Note 1: log scale for produced units

Qualification → Scale up → Series production (1000 tons/y) — Superconductor

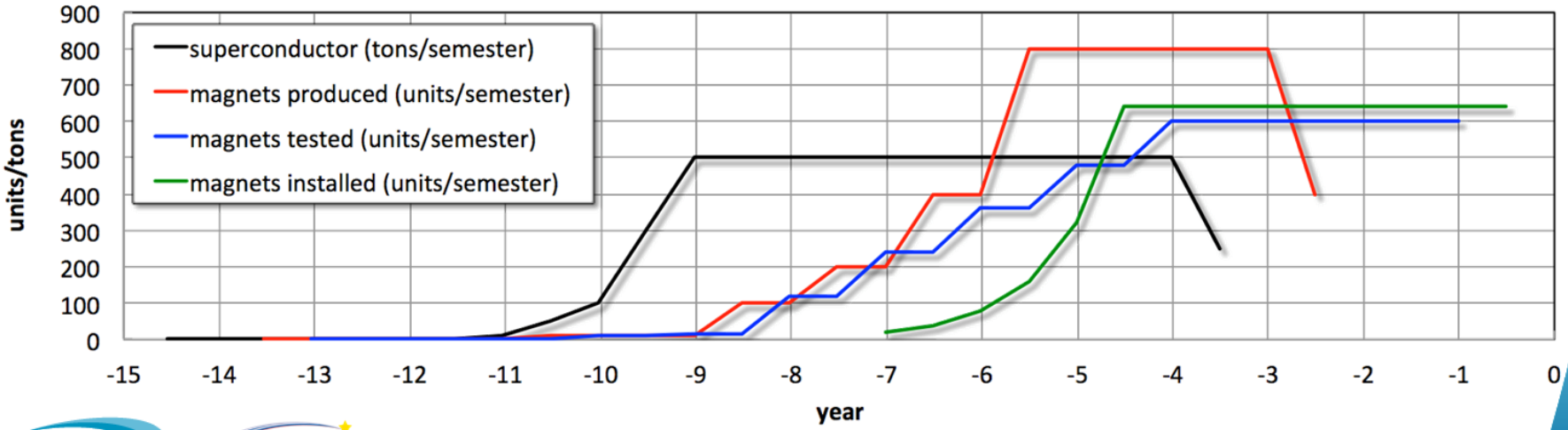
Prototypes → Pre-series → Series production (1600 magnets/y) — Magnets

Hub 1
Hub 2
Hub 3
→ Series tests (1200 magnets/y) — Cold tests

Note 2: B.C. = Before the Collider

High productivity

- Total magnets are 4500 MB + 1500 MQ
  - Total SC quantity is 9000 tons
  - Maximum SC production rate is 1500 tons/year
    - 1000 cable UL/year – **acceptance and qualification ?!?**
- Maximum cold mass production is 1600 CM/year
  - 133 CM/month (vs. 60 CM/month during LHC times)
- Maximum cold test rate is **1200 magnets/year**
  - 100 tests/month (vs. 40 tests/month during LHC times)



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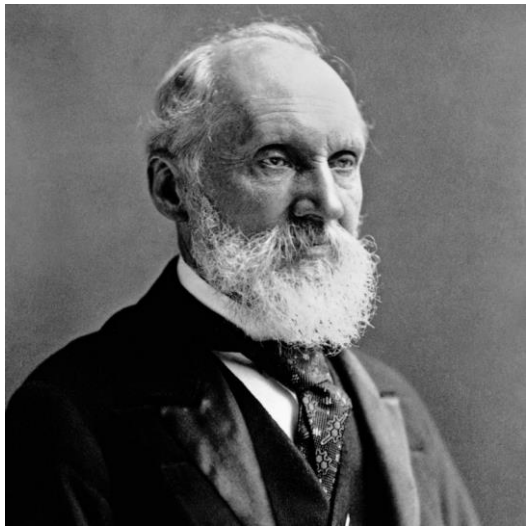
Conclusions, and encouragements

- The LHC, like a baby, requires our constant attention, pointing to the importance of a functioning test facility in support of operation
- New accelerator magnet technologies (Nb_3Sn, HTS) provide a topical focus and excellent motivation for the evolution of the test capabilities
- HL-LHC acts as a springboard in preparation of the scale-up for the next step (any future collider) which will require world-regional test capacity beyond what you see here at CERN

"There is nothing new to be discovered in physics now. All that remains is more and more precise measurement".



Sir William Thomson
a.k.a. Lord Kelvin

"X-rays will prove to be a hoax"

"Radio has no future"

"Heavier-than-air flying machines are impossible"

…