CERN and the High Luminosity LHC Project

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22 May 2017

CERN: founded in 1954: 12 European States
"Science for Peace"
Today: 22 Member States

~ 2500 staff
~ 1800 other paid personnel
~ 13000 scientific users

Budget (2017) ~ 1100 MCHF

Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

Associate Member States: India, Pakistan, Turkey, Ukraine

Associate Members in the Pre-Stage to Membership: Cyprus, Serbia

Applications for Membership or Associate Membership: Brazil, Croatia, Lithuania, Russia, Slovenia

Observers to Council: Japan, Russia, United States of America; European Union, JINR and UNESCO

The United Kingdom and CERN

- **Founder member of CERN (1954)**
- Leading role in setting experimental agenda
- Participates in all four **LHC** experiments, non-LHC (ISOLDE,AD, nTOF …) and a strong partner in the GRID
- More than 900 registered users

  Including ~ 300 PhDs, ~ 200 PhD students, engineers, technicians, etc.; 24 institutions
- **STFC CERN Business Incubation Centre** at Sci-Tech Daresbury and at Harwell
- Leading role in public outreach

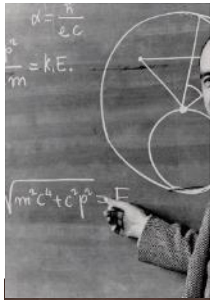
Peter Higgs visiting LHC

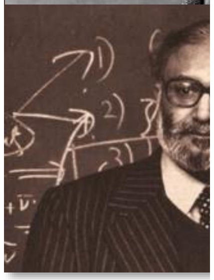
BBC full-day broadcast 2008

High Energy physics is international

By nature:

science has no national borders

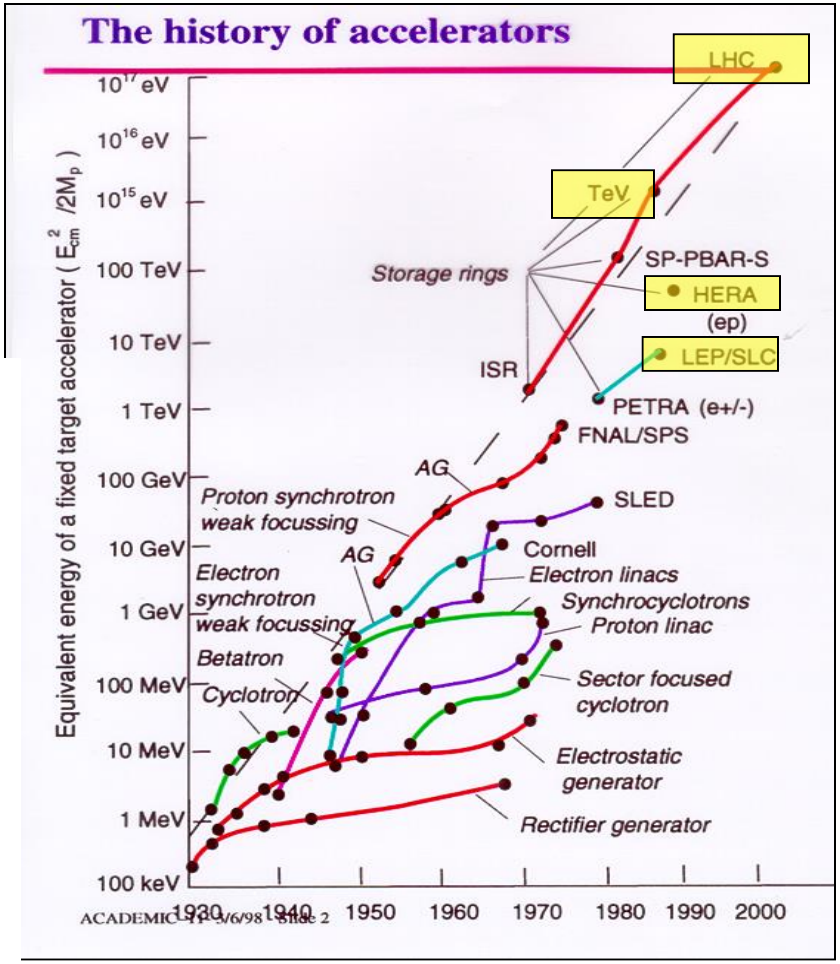




- Sustained exponential development for more than 80 years
- Progress achieved through repeated jumps from saturating to emerging technologies
- Superconductivity, key technology of high-energy machines since the 1980s

By necessity:

pooling resources to afford large facilities



superconductivity

LHC (Large Hadron Collider)

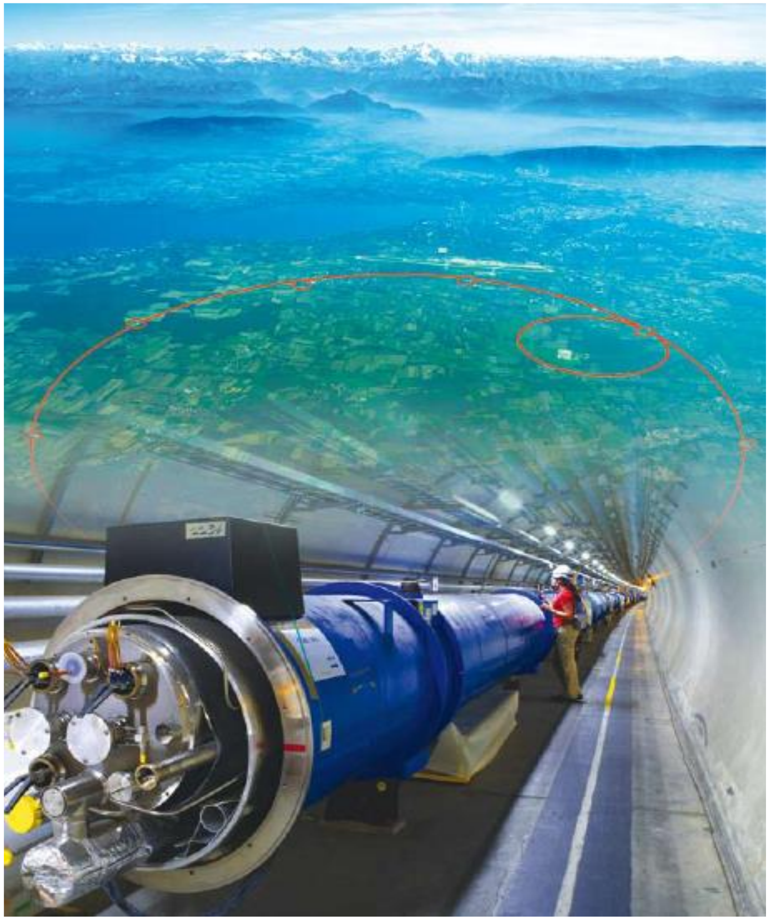
14 TeV proton-proton accelerator-collider built in the LEP tunnel

Lead-Lead (Lead-proton) collisions

1983 : First studies for the LHC project
1988 : First magnet model (feasibility)
1994 : Approval of the LHC by the CERN Council
1996-1999 : Series production industrialisation
1998 : DUP & Start of civil engineering works
1998-2000 : Main production contracts signed
2004 : Start of the LHC installation
2005-2007 : Magnet Installation in the tunnel
2006-2008 : Hardware commissioning
2008-2009 : Beam commissioning and repair

2010-2035: Physics exploitation
2010 – 2012 : Run 1 ; 7 and 8 TeV
2015 – 2018 : Run 2 ; 13 TeV
2019 – 2020 : LIU installation
2021 – 2023 : Run 3
2024 – 2025 : HL-LHC installation
2026 – 2035… : HL-LHC operation

HiLumi HL-LHC PROJECT



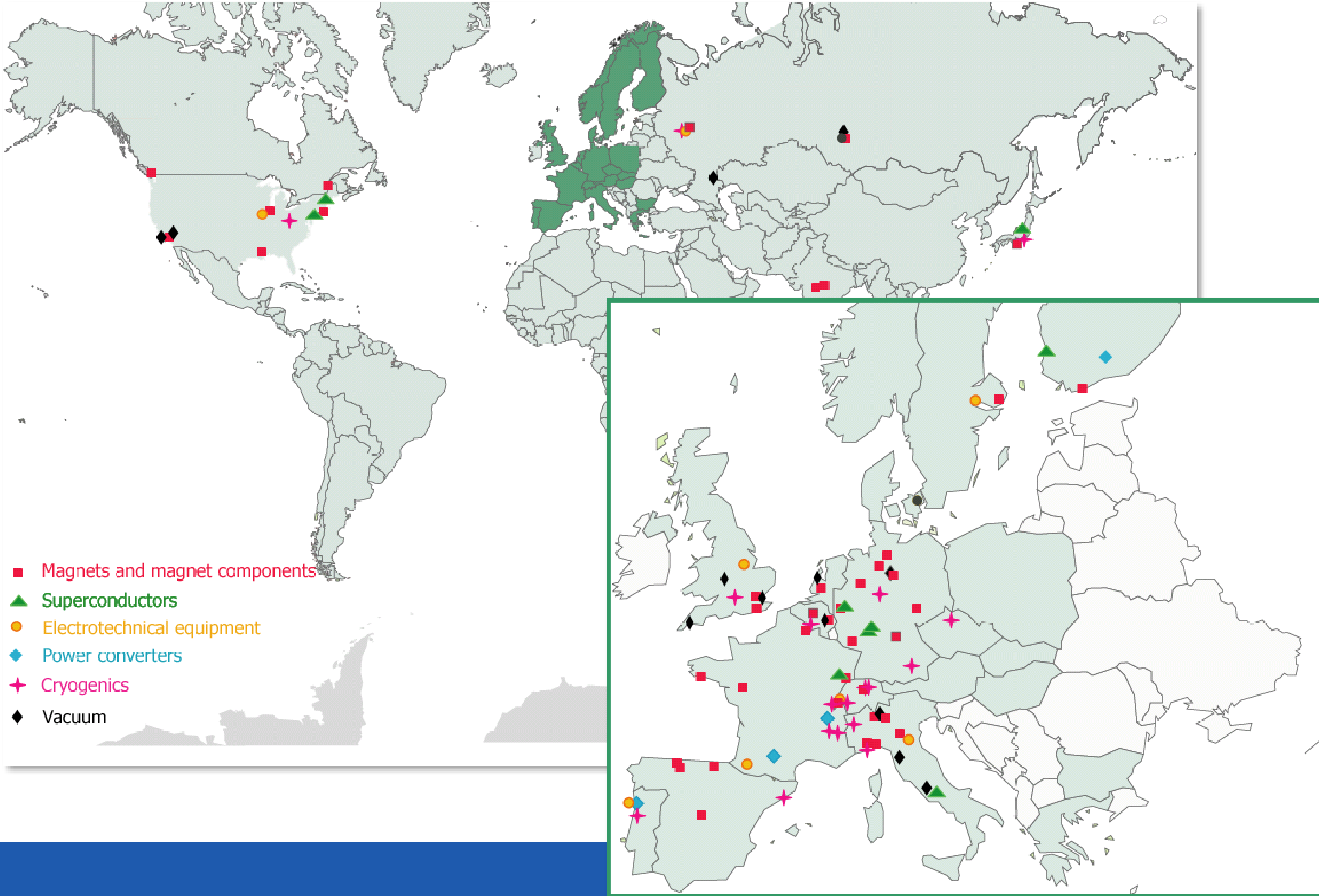
LHC:
technological challenges

The specifications of many systems were beyond the state of the art.
Long R&D programs with many institutes and industries worldwide.

- **The highest field accelerator magnets: 8.3 T** (1232 dipole magnets of 15 m)
- **The largest superconducting magnet system** (~10'000 magnets)
- **The largest 1.9 K cryogenics installation** (superfluid helium, 150 tons of LHe to cool 42'000 tons)
- **Ultra-high cryogenic vacuum for the particle beams** (10^{-13} atm, ten times lower than the Moon)
- **The highest currents controlled with high precision** (up to 13 kA)
- **The highest precision ever demanded from the power converters** (parts per million level)
- **A sophisticated and ultra-reliable magnet quench protection system**

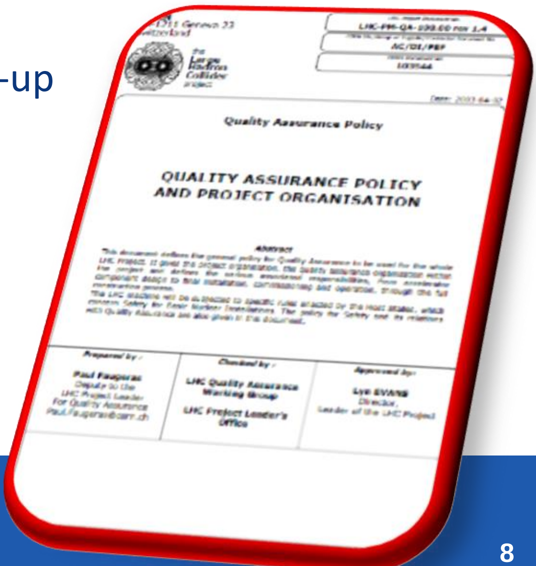
  (Energy stored in the magnet system: ~10 Gjoule, in the beams > 700 MJ)

LHC engineering & technology are also international
100 major high-tech industrial contracts



Industrial procurement: Strategy, constraints, management

- **Legal/regulatory framework**
  - CERN purchasing rules
  - Seeking « fair return » among CERN Member States
  - Handling special « in-kind» contributions
- **Call for tenders**
  - Selecting the right companies
  - Building know-how & maintaining interest through prototyping, pre-series and series
  - Technical specification: functional & interface versus build-to-print; Identify what can be done by the industry and what needs to be done by CERN (costs and risks: breakdown, assembly, performance responsibility, …)
- **Industrial Contracts**
  - Split: security of supply & balanced return versus additional follow-up (multiple contracts ; n+1 strategy : prototype and series)
  - Intermediate supply & logistics
  - (to ensure the supply of sensitive components)
  - JIT (Just In Time) versus production buffer & sorting
  - Industrialization, production ramp and de-ramp
  - Quality and inspection (a shared QAP is essential)

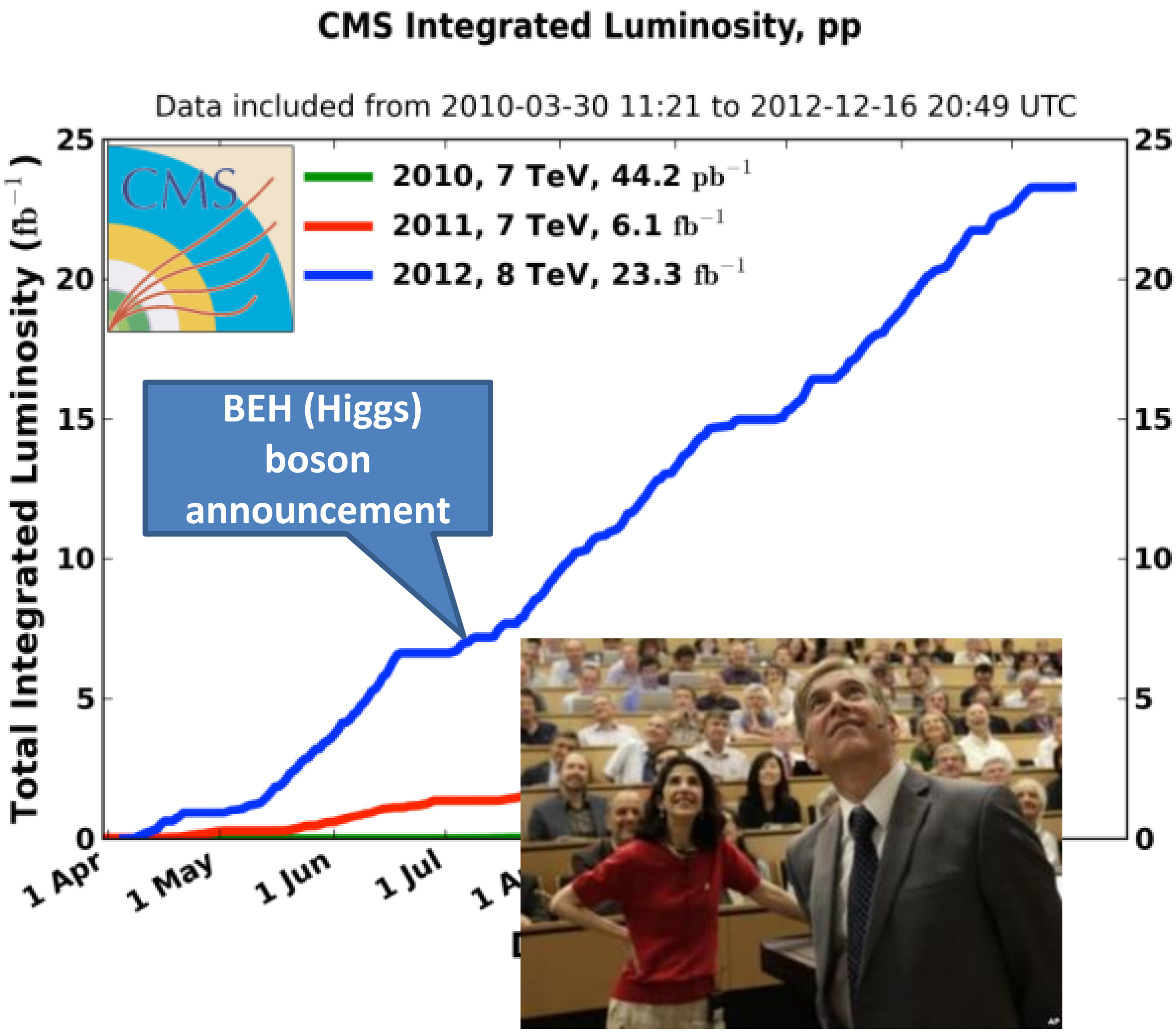


Quality Assurance Policy

QUALITY ASSURANCE POLICY AND PROJECT ORGANISATION

2010: a New Era in Fundamental Science

Run 1: 2010-2012: a rich harvest of collisions



Σ ~30 fb^{-1}
~ 2 10^{15} collisions

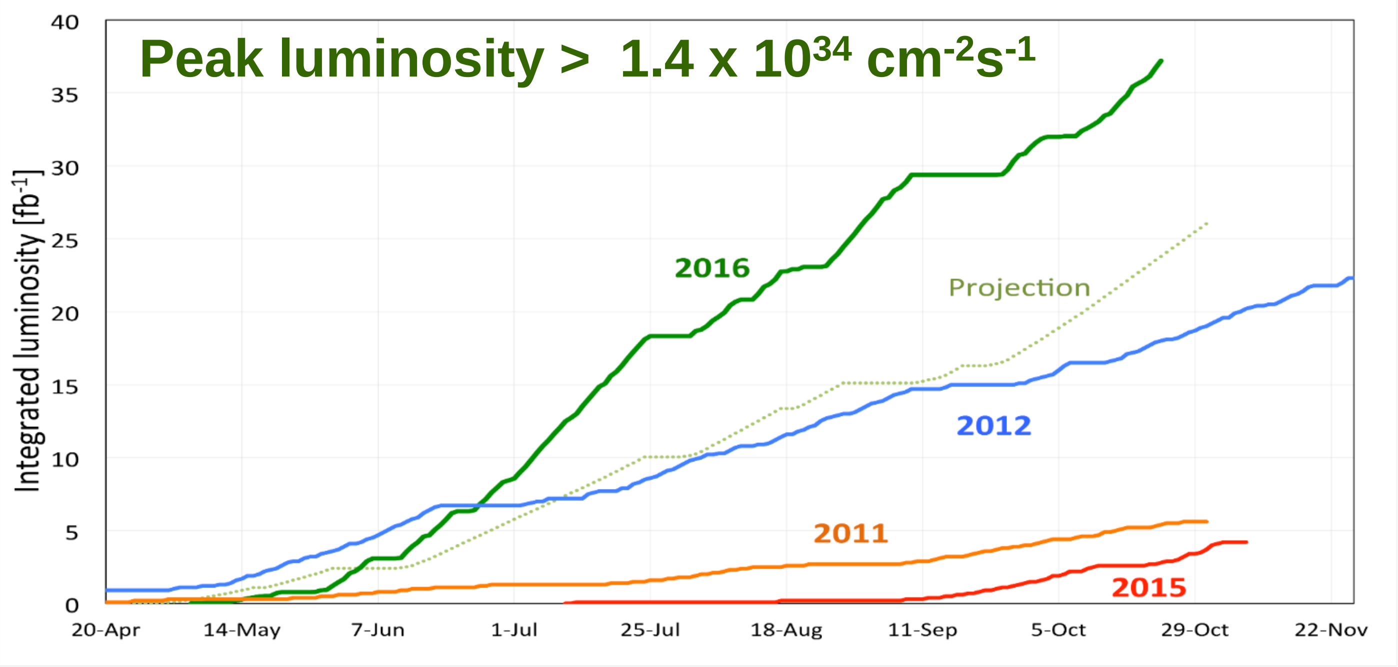
2010: **0.04 fb^{-1}**
7 TeV CoM
Commissioning

2011: **6.1 fb^{-1}**
7 TeV CoM
… exploring limits

2012: **23.3 fb^{-1}**
8 TeV CoM
… production

7 TeV in 2010-2011 and 8 TeV in 2012

Run2: 2015-2018: Production at 6.5 TeV/beam



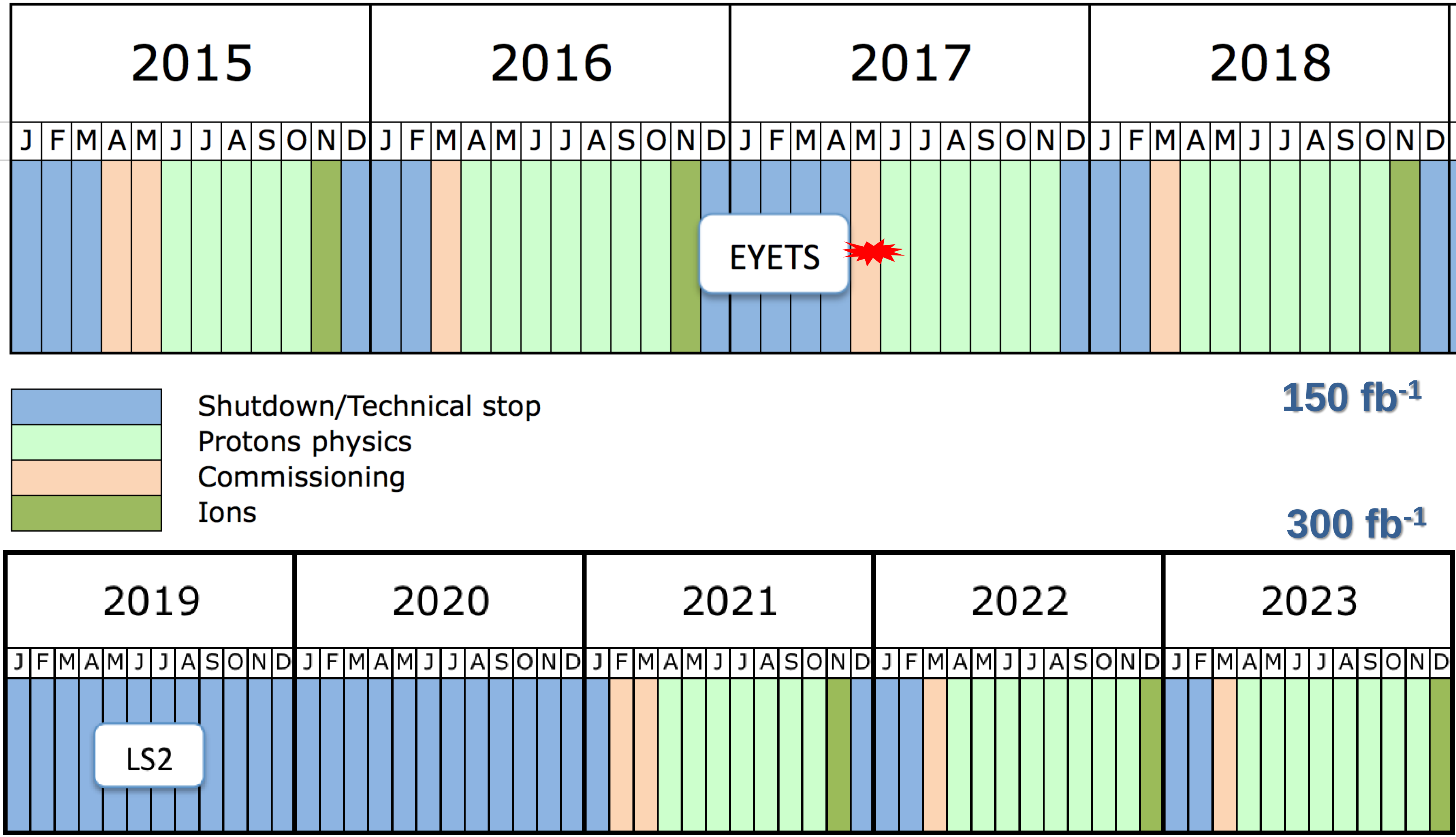
Ingredients for the excellent results in 2016:

- **Building on 2015 as the year to commission the machine at this energy**
- **High machine availability (many HW issues fixed)**
- **High luminosity lifetime (improved knowledge of machine parameters for operation)**
- **High peak luminosity (small beam size from injectors and stronger focussing)**

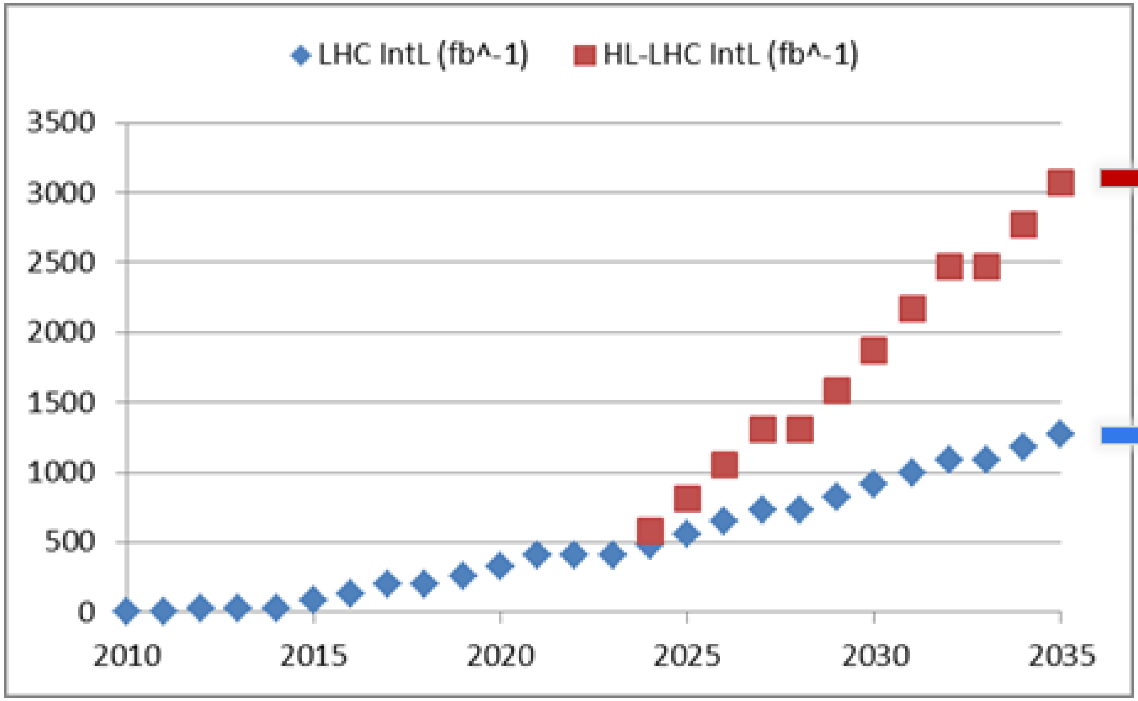
Still room for improvement in 2017 & 18

- **More bunches, higher bunch intensity, stronger focussing**
- **Aim for another ~90 fb^{-1} delivered by end of 2018**

Run 2 and Run 3



Why High-Luminosity LHC ?



By implementing HL-LHC

Almost a factor 3

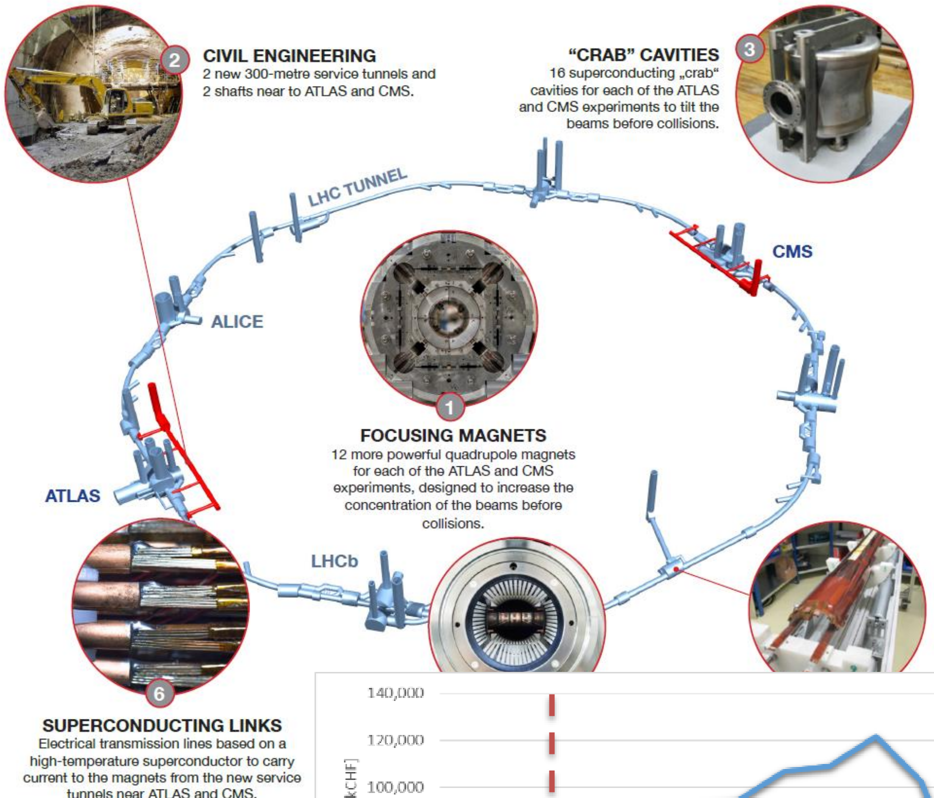
By continuous performance improvement and consolidation

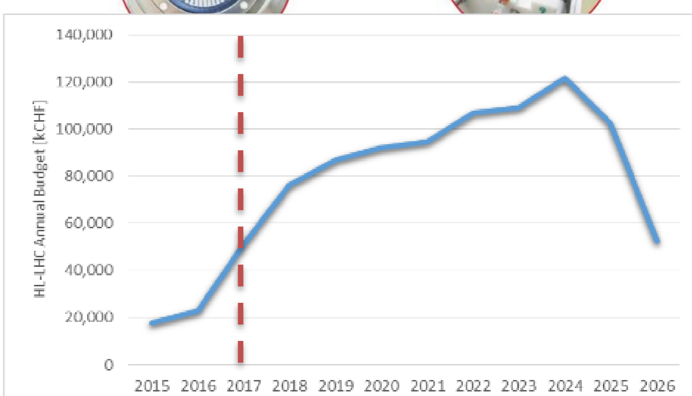
Around 300 fb^{-1} the present Inner Triplet magnets reach the end of their useful life (due to radiation damage) and must be replaced.

Goal of HL-LHC project:

- 250 – 300 fb^{-1} per year
- **3000 fb^{-1} in about 10 years**

The HL-LHC Project





Major interventions on more than 1.2 km of the LHC

- New IR-quads Nb_3Sn (inner triplets)
- New 11 T Nb_3Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection
- …

Cost to Completion
Material : 950 MCHF
Personnel: 1600 FTE-years

HL-LHC – ESFRI Landmark – Roadmap 2016

ESFRI ROADMAP 2016

PART 1 PART 2 PART 3 ANNEXES

ESFRI LANDMARKS

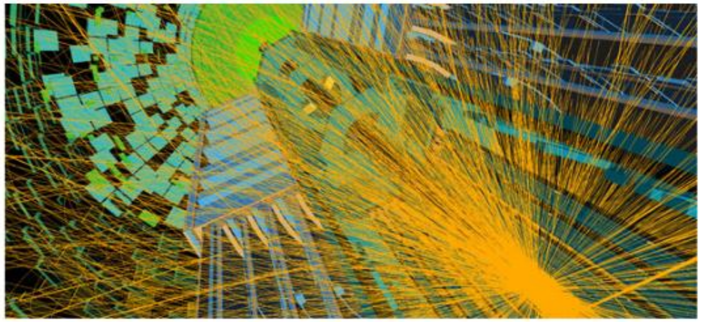
PHYSICAL SCIENCES & ENGINEERING

ESFRI European Strategy Forum on Research Infrastructures

An upgrade of the highest-energy particle collider in the world for exploring new physics

HL-LHC

High-Luminosity Large Hadron Collider



TYPE: single-sited
COORDINATING ENTITY: CERN
MEMBER COUNTRIES: AT, BE, BG, CH, CZ, DE, DK, EL, ES, FI, FR, HU, IL, IT, NL, NO, PK, PL, PT, RO, RS, SE, SK, TR, UK

PARTICIPANTS: See
ACCELERATOR COLLABORATION
ATLAS COLLABORATION
CMS COLLABORATION

TIMELINE
- ESFRI Roadmap entry: 2016
- Preparation phase: 2014-2017
- Construction phase: 2017-2025

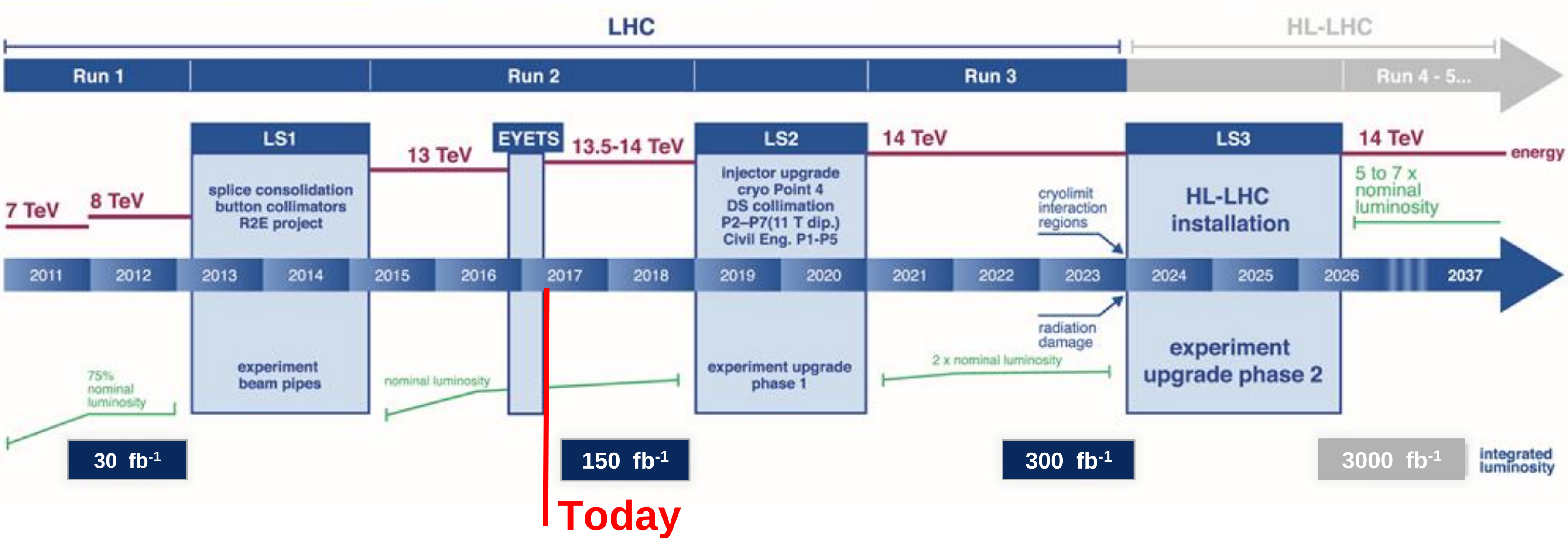
Description

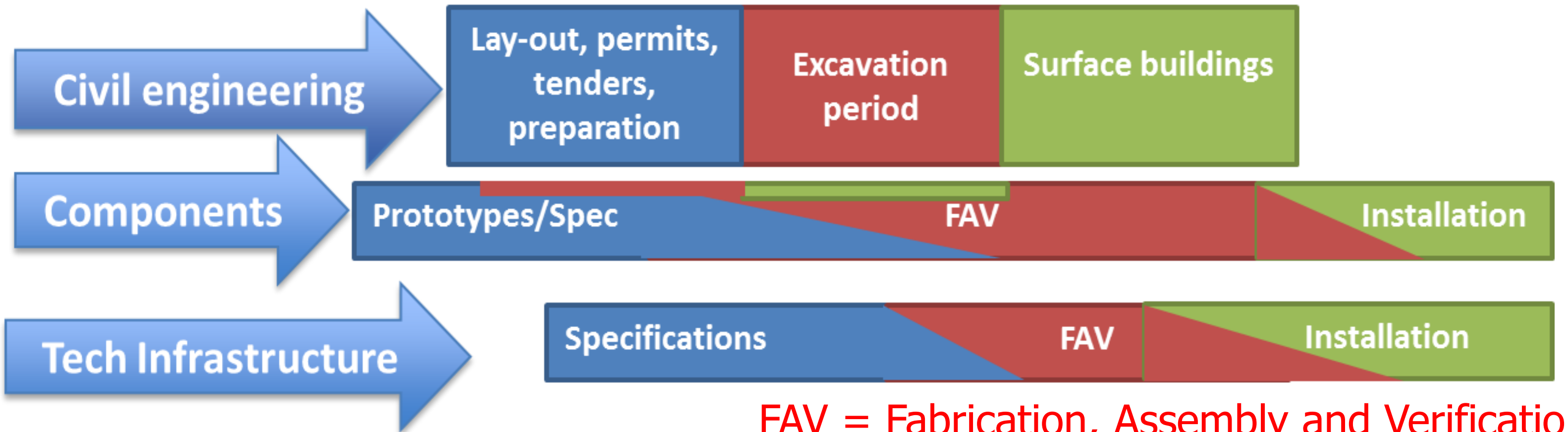
The Large Hadron Collider (LHC) at CERN is the highest-energy particle collider in the world. The ATLAS and CMS experiments at the LHC have provided the breakthrough discovery of the so-called Higgs boson. This discovery is the start of a

The 29 ESFRI Landmarks which have now reached the implementation phase are pan-European hubs of scientific excellence, generating new ideas and pushing the boundaries of science and technology. They are important pillars of European research and innovation for the next decades and they will require continuous support to fulfil their mission and ensure their long-term sustainability.

ESFRI 2016

LHC / HL-LHC Plan





FAV = Fabrication, Assembly and Verification

HL-LHC and industry

- The High Luminosity project seeks industrial suppliers and collaborations to start the construction phase and make the High Luminosity upgrade.
- CERN aims at fostering R&D collaborations and knowledge exchange also with SMEs, a perfect opportunity to match their capacity with the requirements of HL-LHC
- Next 4 years there will be intensive prototyping and the production of some of the first series of components.
- For CERN: understanding industry capabilities and the know how that could come from industry is the best way to specify equipment that can be built by industry
- For industries: understanding CERN needs are crucial to tender successfully.

HL-LHC and industry

HiLumi HL-LHC PROJECT

Provide timely information of what CERN requires and for when

A clear list of what CERN will need, their main characteristics and when the tendering process will start with easy access to the documents

https://project-hl-lhc-industry.web.cern.ch

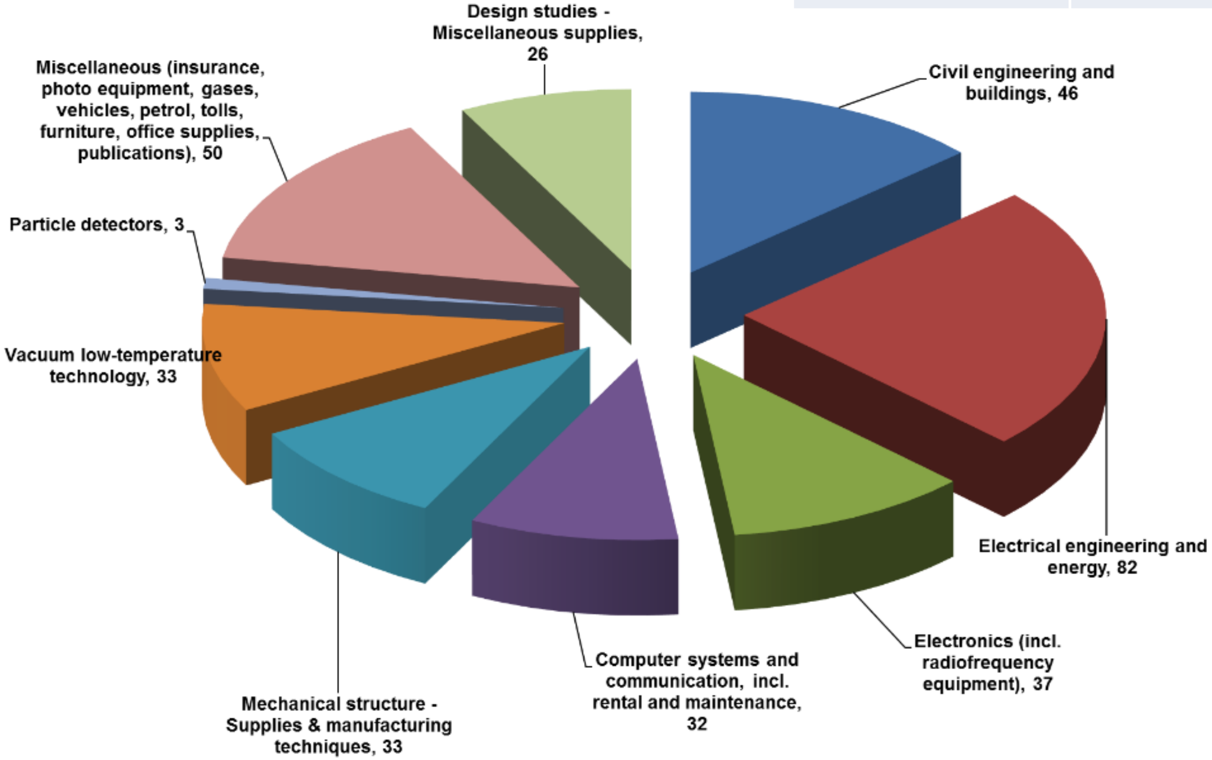
https://project-hl-lhc-industry.web.cern.ch

CERN Procurement is not Just for HL-LHC

Activities in 2016 vs 2015

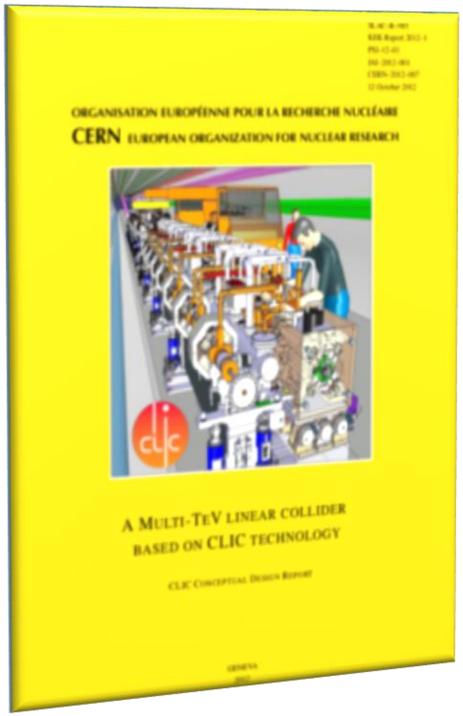
	2016	2015
Supplies	341 MCHF	297 MCHF
Services	147 MCHF	126 MCHF

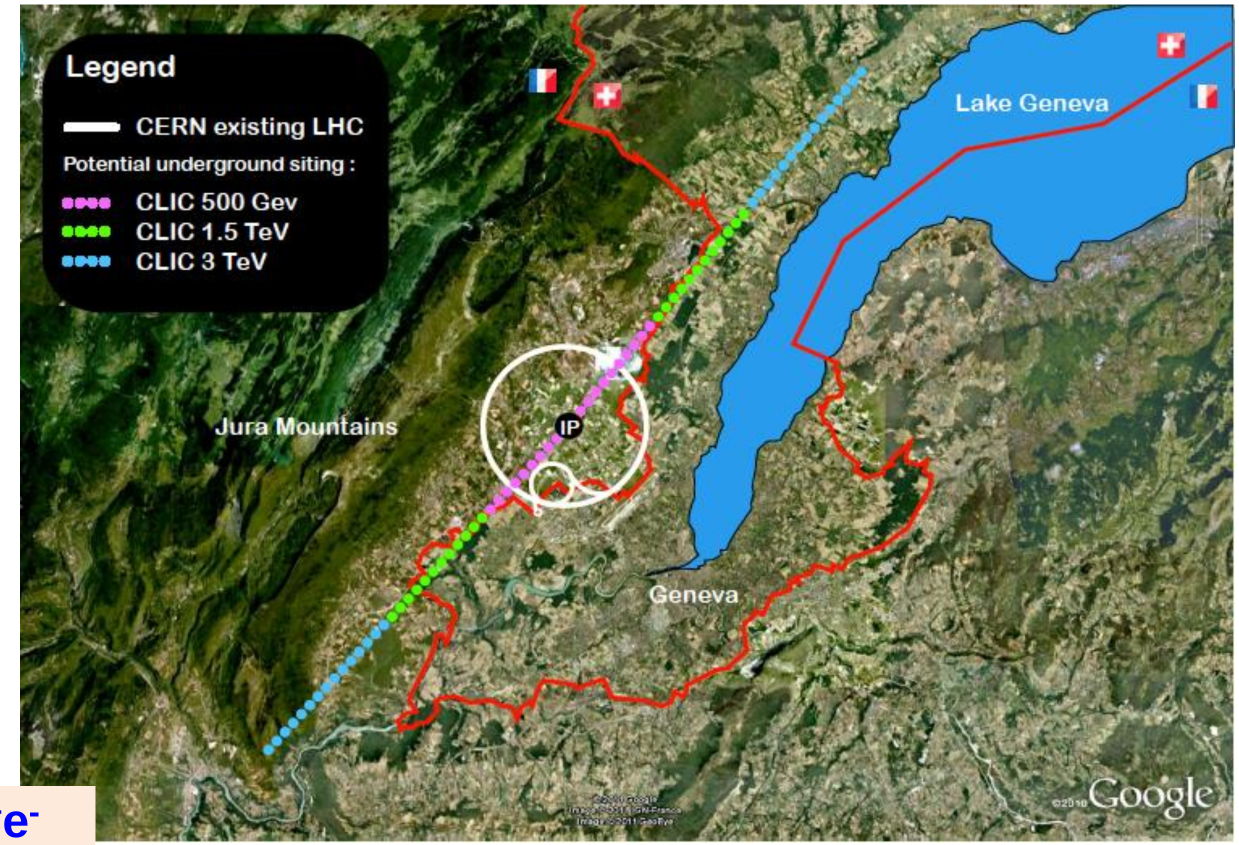
Supplies by type, 2016



Over the coming years, CERN's spending will increase mainly due to HL-LHC

*“CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and **electron- positron high-energy frontier machines.**”*





Highest possible energy e^+e^-
with CLIC (CDR 2012)
International collaboration

Future Circular Collider Study

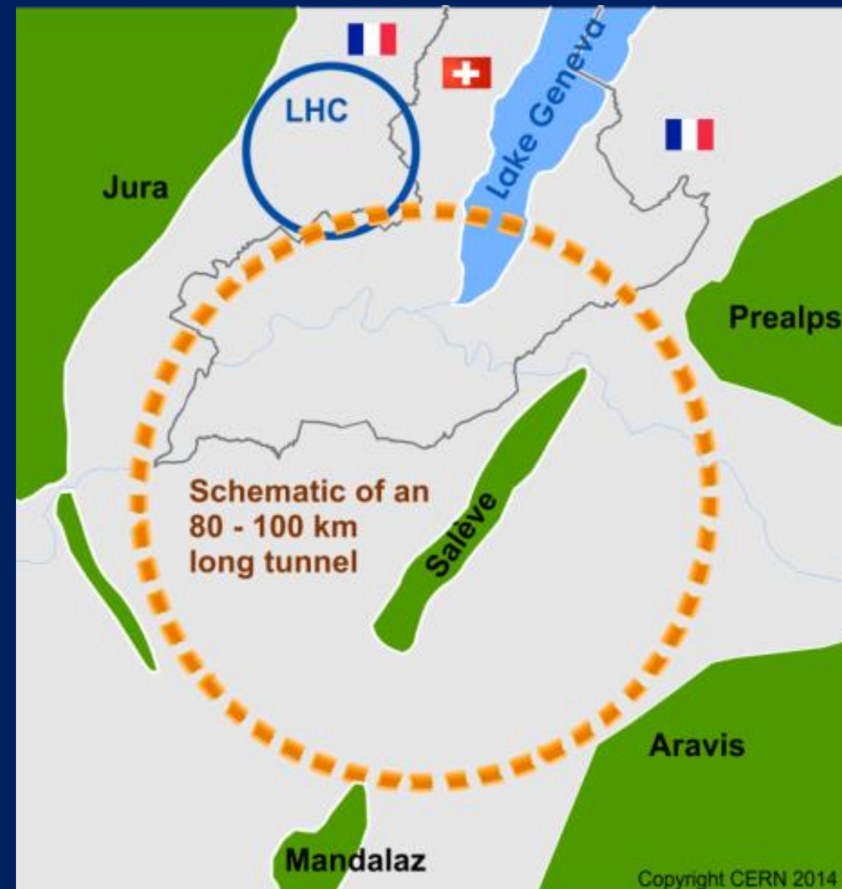
SCOPE CDR and cost review for the next ESU (2020)

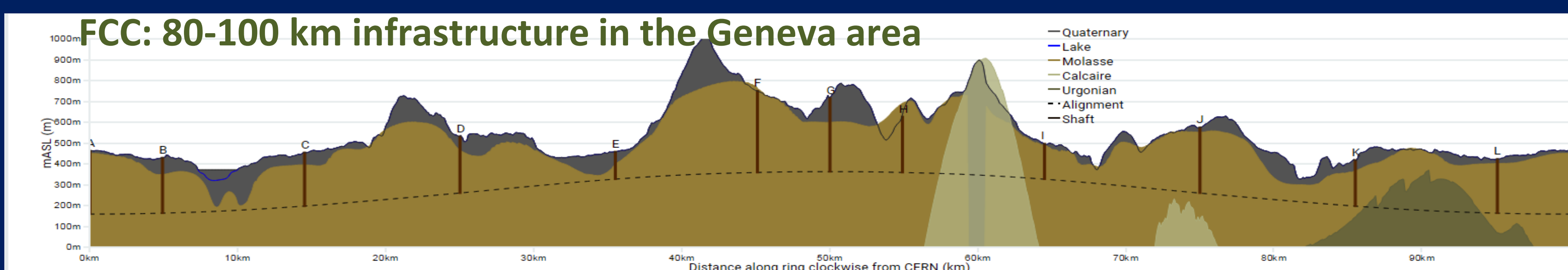
Forming an international collaboration to study:

- ***pp*-collider (*FCC-hh*)**
  →defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

- ***e⁺e⁻* collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **HE-LHC pp ~ 28 TeV in LHC**





Conclusions

Cooperation with industry is essential from early stages of the project in order to achieve success within business constraints

- *Develop and maintain interest in a one-off, technically risky supply*
- *Series production of innovative items at market prices*
- *Competition with other products/markets*

Industry will have a crucial role and will be heavily involved within the HL-LHC Project since it will be the main source to provide the technologies and equipment that are required to successfully achieve the goals of this upgrade of the LHC.

https://project-hl-lhc-industry.web.cern.ch

CERN