CERN and High Luminosity LHC project

Frédérick Bordry

31 October 2016

2ND HILUMI
INDUSTRY DAY

INSTITUTO SUPERIOR TÉCNICO (IST)
31 October 2016
LISBON

AN EVENT FOR COMPANIES WILLING TO TAKE ON THE HL-LHC TECHNICAL CHALLENGES

More information on HL-LHC and future procurement needs
https://project-hl-lhc-industry.web.cern.ch

Registration before 30 September 2016
https://indico.cern.ch/event/557233/

HiLumi HL-LHC PROJECT

CERN

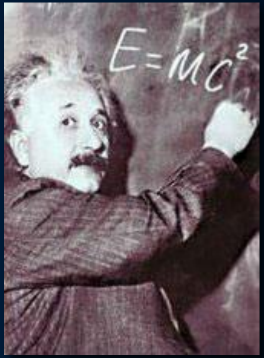
FCT Fundação para a Ciência e a Tecnologia

Innovation
Education
CERN
uniting people
Research

The Mission of CERN

- **Push back** the frontiers of knowledge

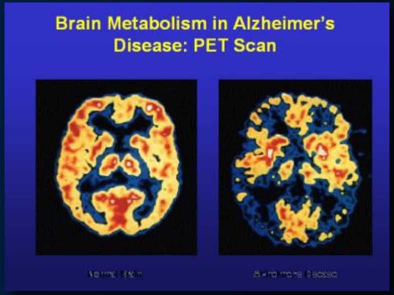
  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe’s existence?



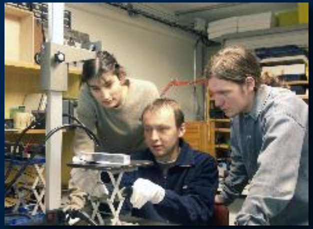
- **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow



- **Unite** people from different countries and cultures

CERN: founded in 1954: 12 European States

“Science for Peace”

Today: 22 Member States

~ 2300 staff
~ 1600 other paid personnel
~ 12700 scientific users

Budget (2016) ~1000 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: Pakistan, Turkey

States in accession to Membership: Cyprus, Serbia

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

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

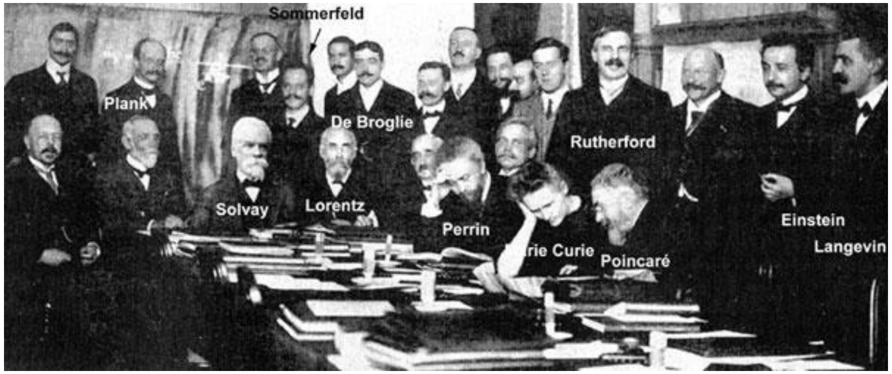
Portugal and CERN

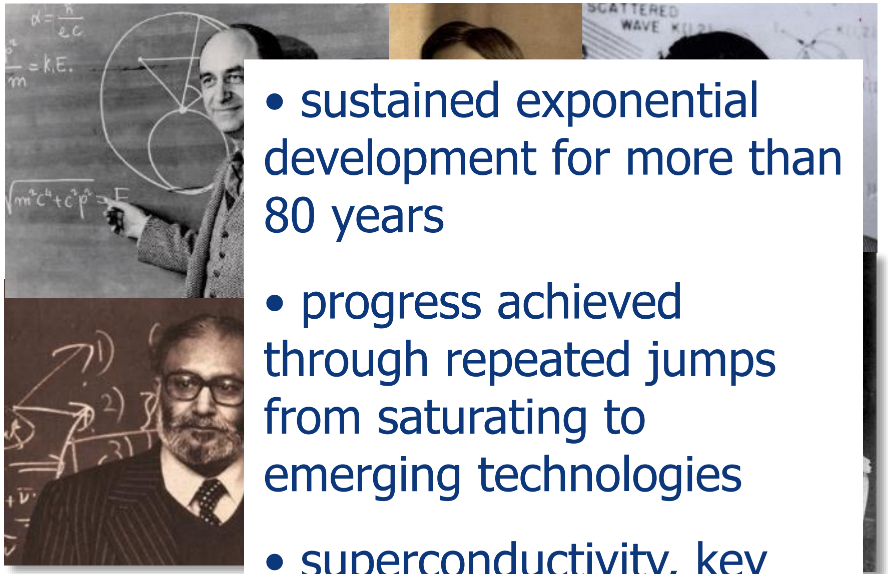
- Portugal joined CERN as a Member State in 1986
- The Laboratório de Instrumentação e Física Experimental de Partículas (LIP) was created at the same time to carry out all activities related to experimental particle physic
  universities as well as LIP's
- Strong participation in LHC
  ISOLDE, nTOF) programme an
- Strong participation in R&D
  PET consortium)
- Training/Education:
  - Excellent example of engineer
  - Very successful teacher trainin
- Very balanced approach be
  at home and very good indu

High Energy physics is international

By nature:

science has no national borders

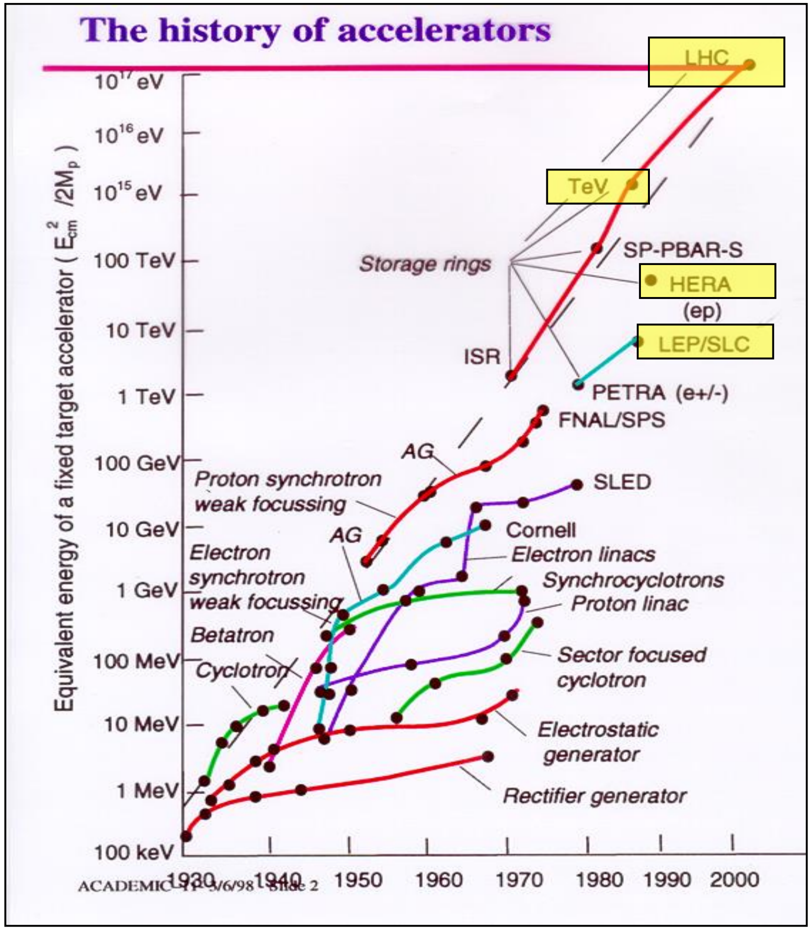




- sustained exponential development for more than 80 years
- progress achieved through repeated jumps from saturating to emerging technologies
- superconductivity, key technology of high-energy machines since the 1980s

By necessity:

pooling resources to afford large instruments



superconductivity

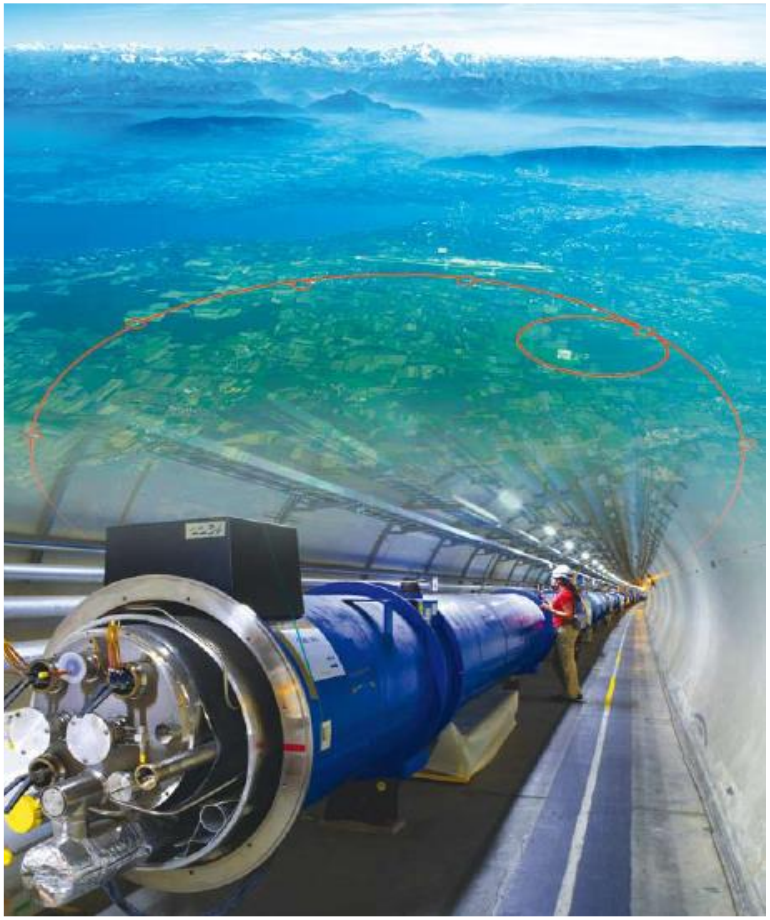
LHC (Large Hadron Collider)

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 : Declaration of Public Utility & Start of civil engineering
1998-2000 : Placement of the main production contracts
2004 : Start of the LHC installation
2005-2007 : Magnets 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



LHC: experiments LHC: accelerator of 27 km **the coopetition**

LHCB Collaboration :
15 Countries, 54 Institutes
and 754 members

ALICE Collaboration :
33 Countries, 116 Institutes
and over 1000 members

CMS Collaboration :
39 Countries, 169 Institutes
and 3170 members

ATLAS Collaboration :
38 Countries, 174 Institutes
and 3000 members

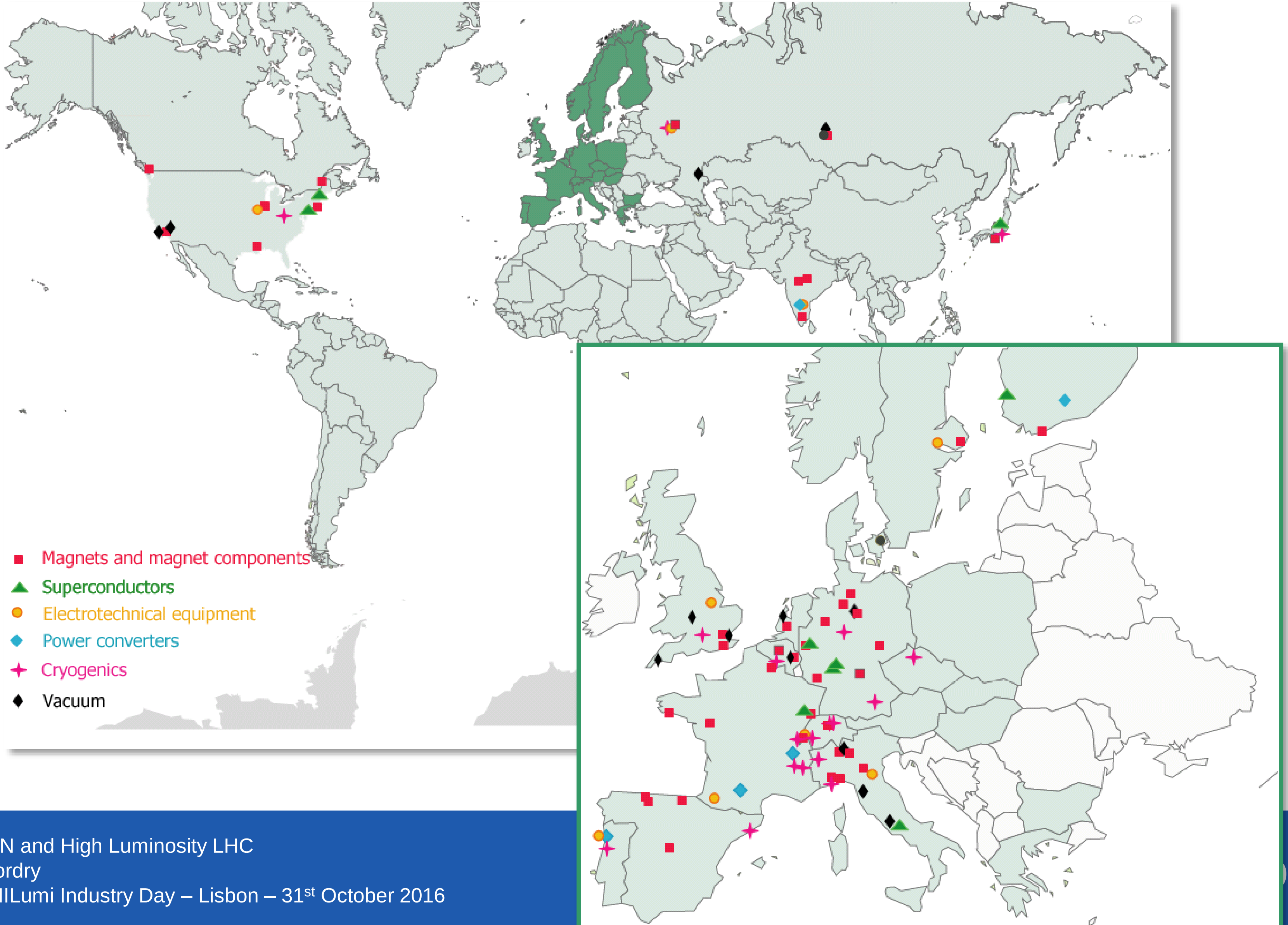
LHC:
technological challenges

The specifications of many systems were over 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 down 37'000 tons)**
- **Ultra-high cryogenic vacuum for the particle beams (10^{-13} atm, ten times lower than on the Moon)**
- **The highest currents controlled with high precision (up to 13 kA)**
- **The highest precision ever demanded from the power converters (ppm 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

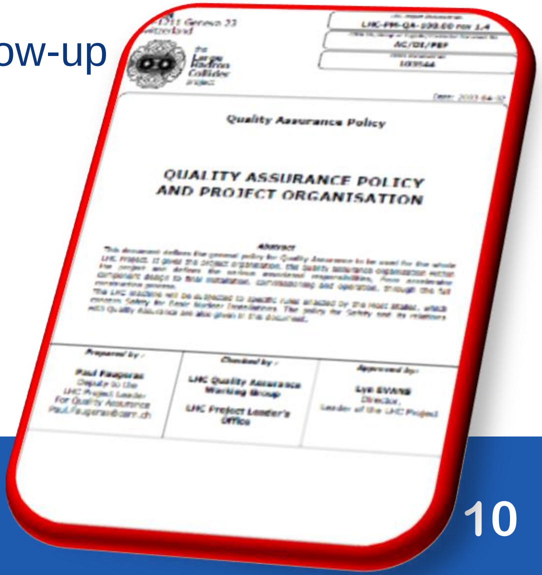
- CERN purchasing rules
- Seeking « fair return » among CERN Member States
- Handling special « in-kind» contributions

- Call for tenders

- Selecting the right companies
- Building know-how & maintaining interest through prototyping, preseries 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

Abstract

Prepared by :

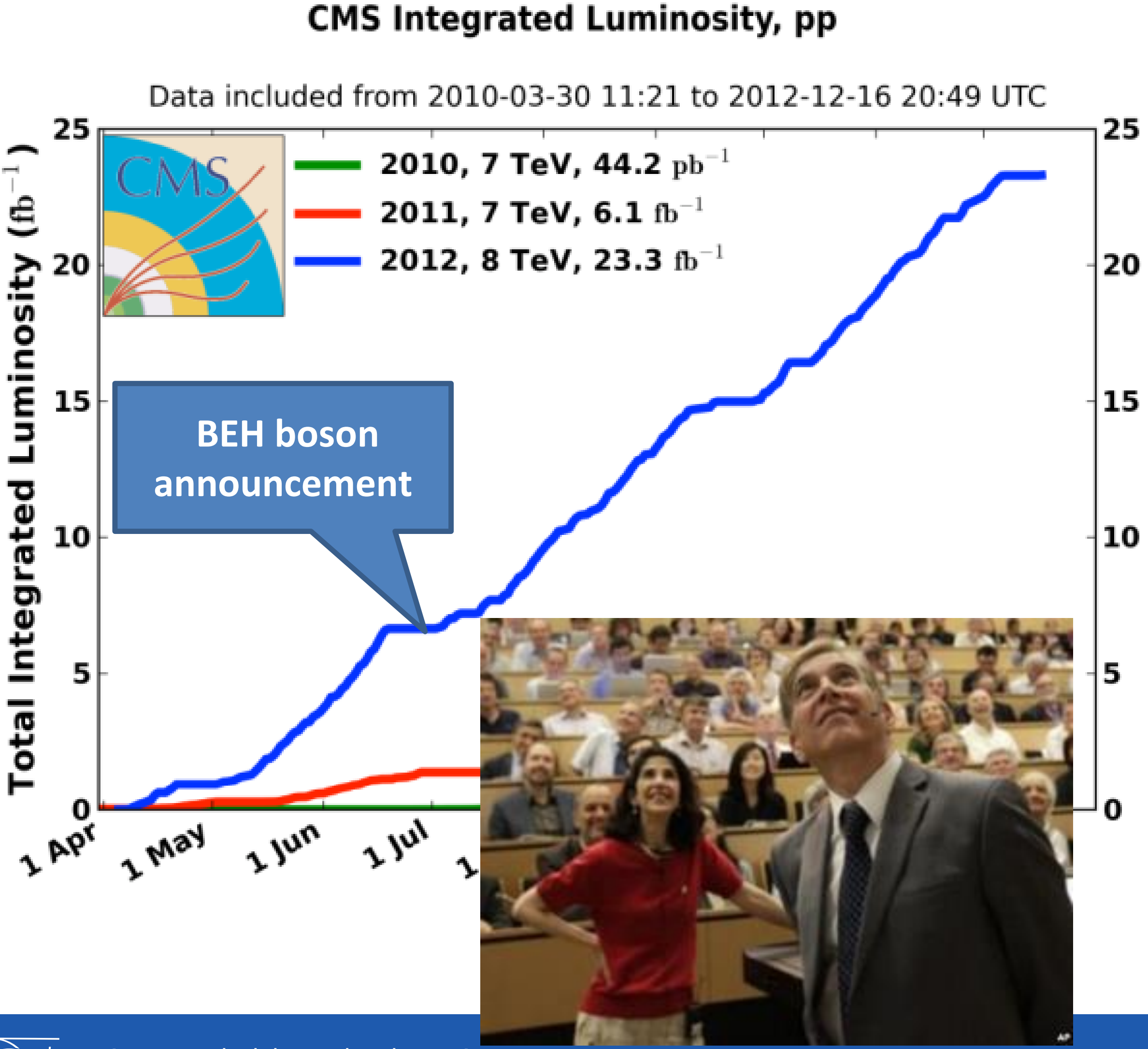
Checked by :

Approved by:

LHC Quality Assurance Working Group

LHC Project Leader's Office

LHC 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

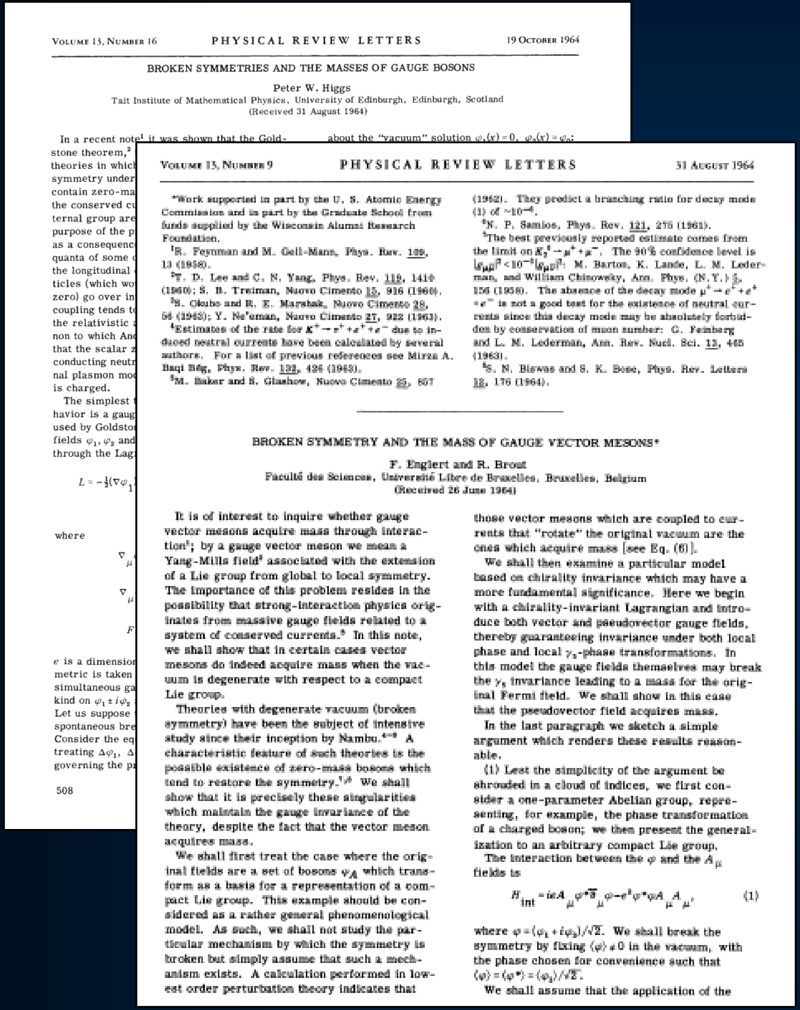
7 TeV in 2010-2011 and 8 TeV in 2012

Discovery 2012, Nobel Prize in Physics 2013

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".*

From **individual** theoretical physicist **idea**….

…to **collective innovation** !



Volume 13, Number 16 PHYSICAL REVIEW LETTERS 19 October 1964

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

In a recent note[1] it was shown that the Gold-
stone theorem,[2]
theories in which
symmetry under
contain zero-ma
the conserved cu
ternal group are
purpose of the p
as a consequence
quanta of some
the longitudinal
ticles (which wo
zero) go over in
coupling tends to
the relativistic
non to which And
that the scalar z
conducting neutr
nal plasmon mod
is charged.
The simplest
havior is a gaug
used by Goldstor
fields φ_1, φ_2 and
through the Lag

$L = -\frac{1}{2}(\nabla\varphi_1$

where

∇_μ

∇_μ

F

e is a dimension
metric is taken
simultaneous ga
kind on $\varphi_1 \pm i\varphi_2$
Let us suppose
spontaneous bre
Consider the eq
treating $\Delta\varphi_1$, Δ
governing the pr

about the “vacuum” solution $\varphi_1(x) = 0$, $\varphi_2(x) = \varphi_0$:

508

Volume 13, Number 9 PHYSICAL REVIEW LETTERS 31 August 1964

*Work supported in part by the U. S. Atomic Energy Commission and in part by the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

[1] R. Feynman and M. Gell-Mann, Phys. Rev. 109, 13 (1958).

[2] T. D. Lee and C. N. Yang, Phys. Rev. 119, 1410 (1960); S. B. Treiman, Nuovo Cimento 15, 916 (1960).

[3] S. Okubo and R. E. Marshak, Nuovo Cimento 28, 56 (1963); Y. Ne'eman, Nuovo Cimento 27, 922 (1963).

[4] Estimates of the rate for $K^+ \to \pi^+ + e^+ + e^-$ due to induced neutral currents have been calculated by several authors. For a list of previous references see Mirza A. Baqi Bég, Phys. Rev. 132, 426 (1963).

[5] M. Baker and S. Glashow, Nuovo Cimento 25, 857 (1962). They predict a branching ratio for decay mode (1) of $\sim 10^{-6}$.

[6] N. P. Samios, Phys. Rev. 121, 275 (1961).

[7] The best previously reported estimate comes from the limit on $K_2^0 \to \mu^+ + \mu^-$. The 90 % confidence level is $|g_{\mu\mu}|^2 < 10^{-3}|g_{\mu\nu}|^2$: M. Barton, K. Lande, L. M. Lederman, and William Chinowsky, Ann. Phys. (N.Y.) 5, 156 (1958). The absence of the decay mode $\mu^+ \to e^+ + e^+ + e^-$ is not a good test for the existence of neutral currents since this decay mode may be absolutely forbidden by conservation of muon number: G. Feinberg and L. M. Lederman, Ann. Rev. Nucl. Sci. 13, 465 (1963).

[8] S. N. Biswas and S. K. Bose, Phys. Rev. Letters 12, 176 (1964).

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

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Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

It is of interest to inquire whether gauge vector mesons acquire mass through interaction[1]; by a gauge vector meson we mean a Yang-Mills field[2] associated with the extension of a Lie group from global to local symmetry. The importance of this problem resides in the possibility that strong-interaction physics originates from massive gauge fields related to a system of conserved currents.[3] In this note, we shall show that in certain cases vector mesons do indeed acquire mass when the vacuum is degenerate with respect to a compact Lie group.

Theories with degenerate vacuum (broken symmetry) have been the subject of intensive study since their inception by Nambu.[4-6] A characteristic feature of such theories is the possible existence of zero-mass bosons which tend to restore the symmetry.[7,8] We shall show that it is precisely these singularities which maintain the gauge invariance of the theory, despite the fact that the vector meson acquires mass.

We shall first treat the case where the original fields are a set of bosons φ_A which transform as a basis for a representation of a compact Lie group. This example should be considered as a rather general phenomenological model. As such, we shall not study the particular mechanism by which the symmetry is broken but simply assume that such a mechanism exists. A calculation performed in lowest order perturbation theory indicates that those vector mesons which are coupled to currents that “rotate” the original vacuum are the ones which acquire mass [see Eq. (6)].

We shall then examine a particular model based on chirality invariance which may have a more fundamental significance. Here we begin with a chirality-invariant Lagrangian and introduce both vector and pseudovector gauge fields, thereby guaranteeing invariance under both local phase and local γ_5-phase transformations. In this model the gauge fields themselves may break the γ_5 invariance leading to a mass for the original Fermi field. We shall show in this case that the pseudovector field acquires mass.

In the last paragraph we sketch a simple argument which renders these results reasonable.

(1) Lest the simplicity of the argument be shrouded in a cloud of indices, we first consider a one-parameter Abelian group, representing, for example, the phase transformation of a charged boson; we then present the generalization to an arbitrary compact Lie group.

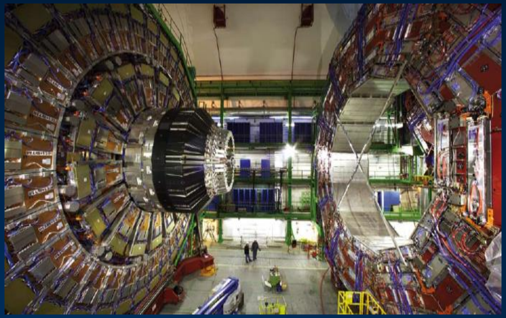
The interaction between the φ and the A_μ fields is

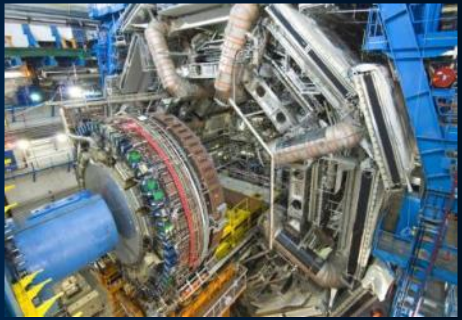
$$H_{\text{int}} = ieA_\mu \varphi^* \overleftrightarrow{\partial}_\mu \varphi - e^2 \varphi^* \varphi A_\mu A_\mu, \qquad (1)$$

where $\varphi = (\varphi_1 + i\varphi_2)/\sqrt{2}$. We shall break the symmetry by fixing $\langle\varphi\rangle \neq 0$ in the vacuum, with the phase chosen for convenience such that $\langle\varphi\rangle = \langle\varphi^*\rangle = \langle\varphi_1\rangle/\sqrt{2}$.

We shall assume that the application of the

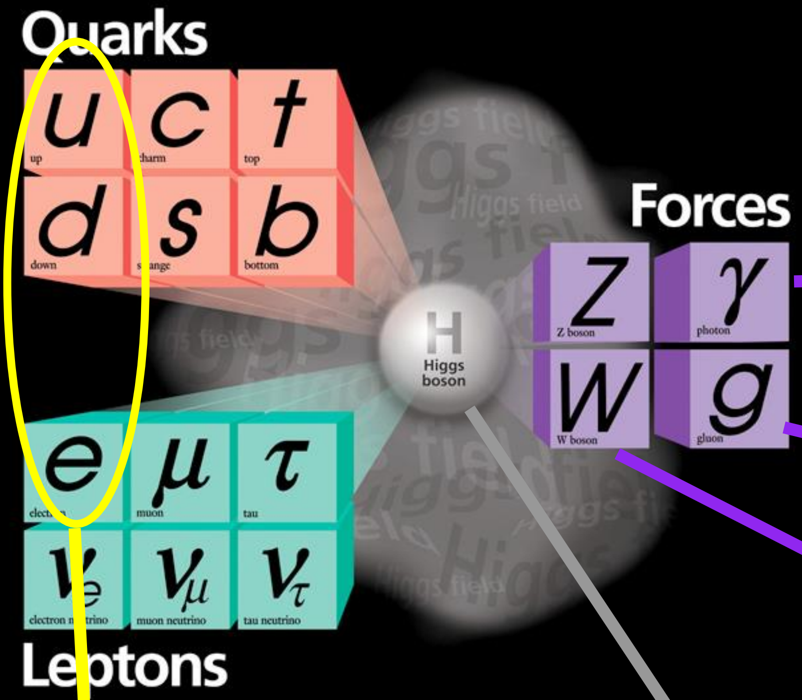
1964

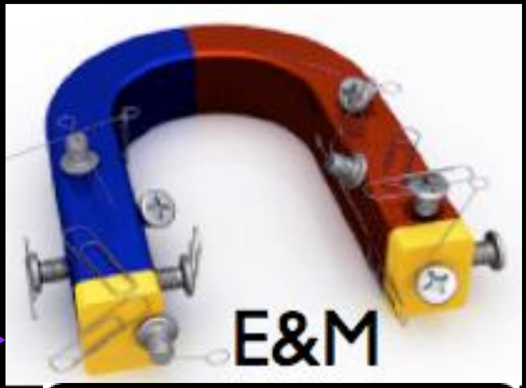


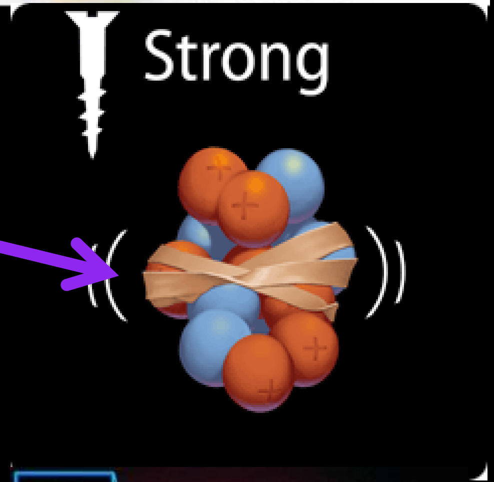


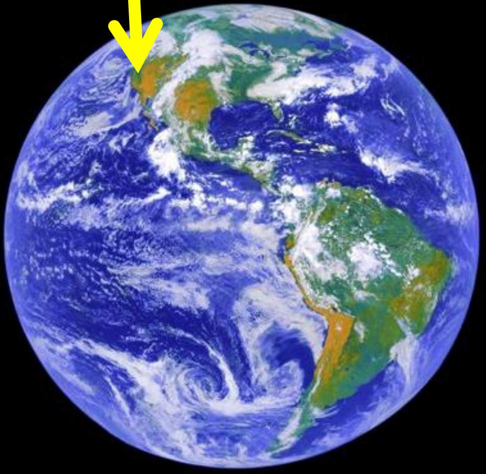
1964-2012

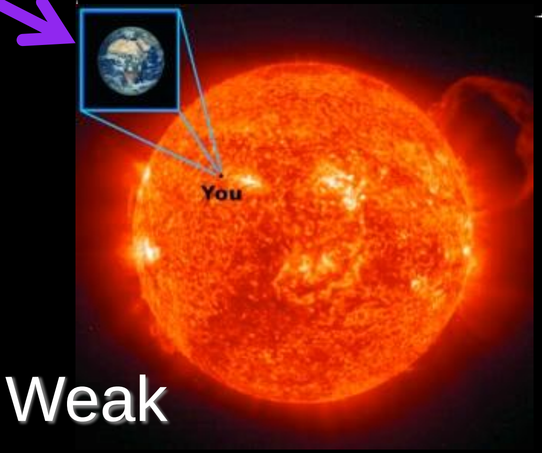
The Standard Model











Standard Model:
Only 4% is ordinary (visible) matter

The DARK Universe (96%):
73% Dark Energy
23% Dark Matter

DARK …. MATTERS !

2013 - 2015

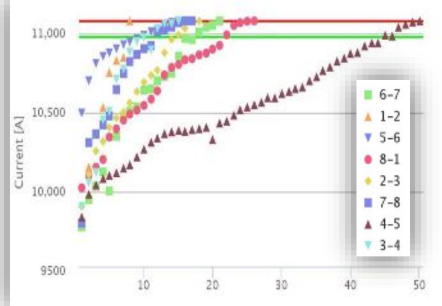
April ‘13 to Sep. ‘14

5th April

3rd June
First Stable Beams

28th October
Physics with record number of bunches
Peak luminosity 5 x 10^{33} $cm^{-2}s^{-1}$

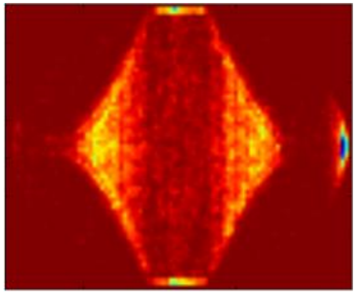
13-14 | Aug 14-Apr | 2015



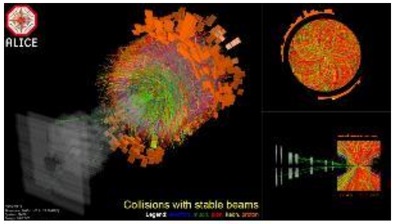
Dipole training campaign

10th April
Beam at 6.5 TeV

Struggle



IONS

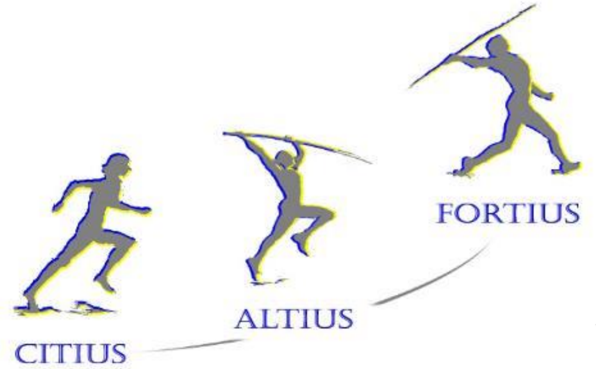


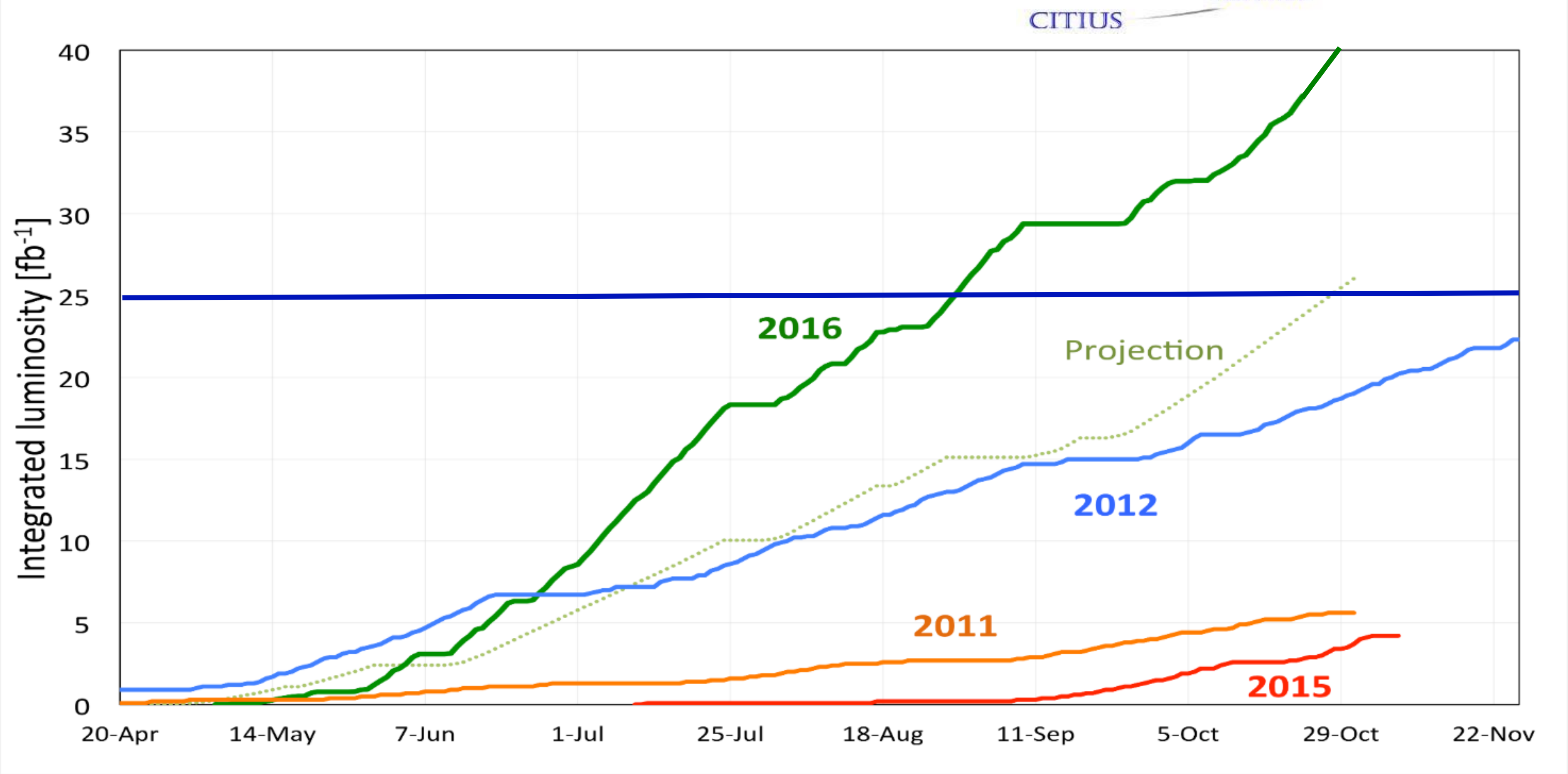
Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

2016 goals

Peak luminosity > 1.4 x 10^{34} cm^{-2}s^{-1}

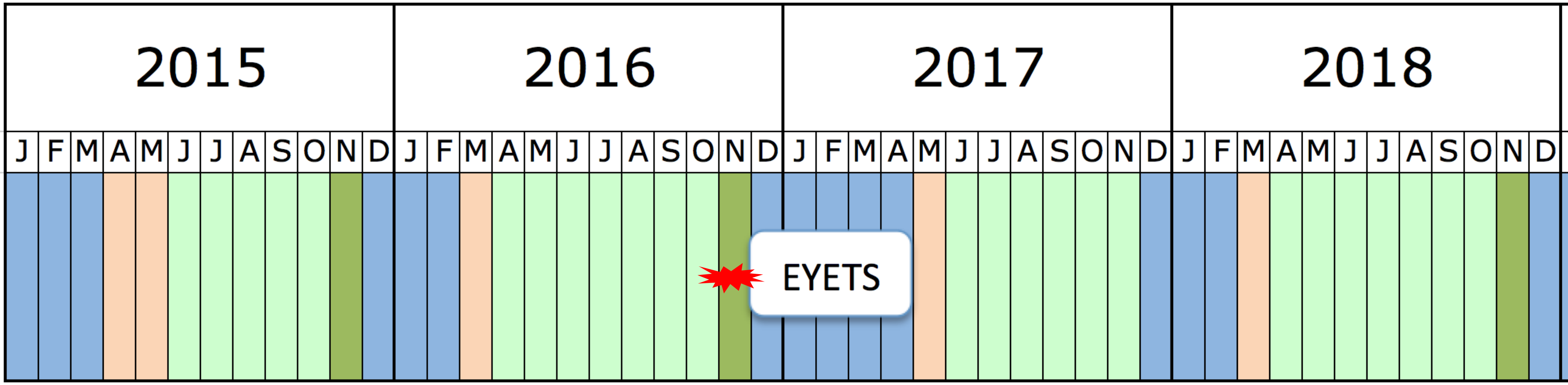
OVER 25 fb^{-1} in both ATLAS and CMS ☺





Progress represents a phenomenal ongoing effort by all the teams involved

Run 2 and Run 3



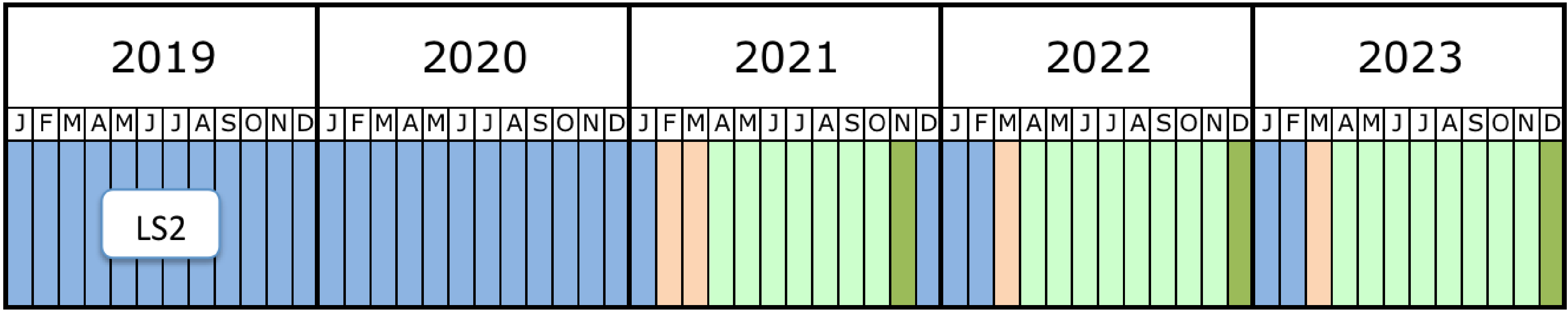
	J	F	M	A	M	J	J	A	S	O	N	D
2015	🟦	🟦	🟦	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟫	🟦
2016	🟦	🟦	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟫	🟦
2017	🟦	🟦	🟦	🟦	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟦
2018	🟦	🟦	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟫	🟦

EYETS

🟦 Shutdown/Technical stop
🟩 Protons physics
🟧 Commissioning
🟫 Ions

>100 fb^{-1}

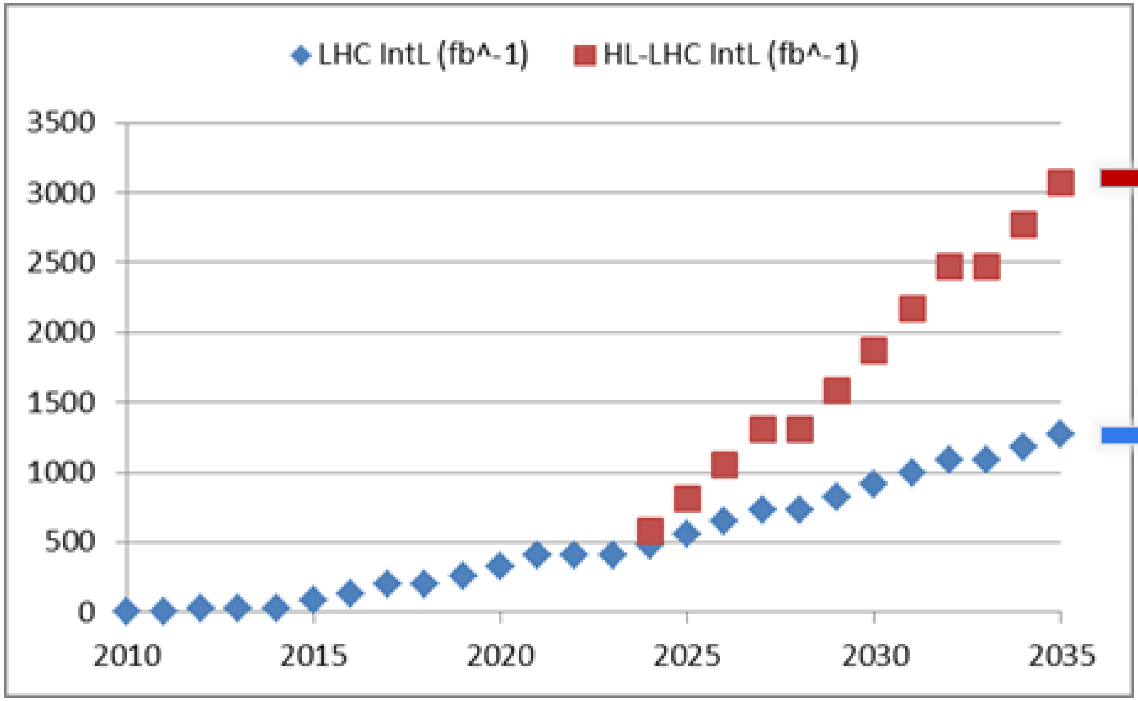
300 fb^{-1}



	J	F	M	A	M	J	J	A	S	O	N	D
2019	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
2020	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
2021	🟦	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟫	🟦
2022	🟦	🟦	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟫
2023	🟦	🟦	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟫

LS2

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 European Strategy for Particle Physics
Update 2013

Europe's top priority should be the ***exploitation of the full potential of the LHC****, including the high-luminosity upgrade of the machine and detectors with a view to collecting* ***ten times more data than in the initial design, by around 2030****. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

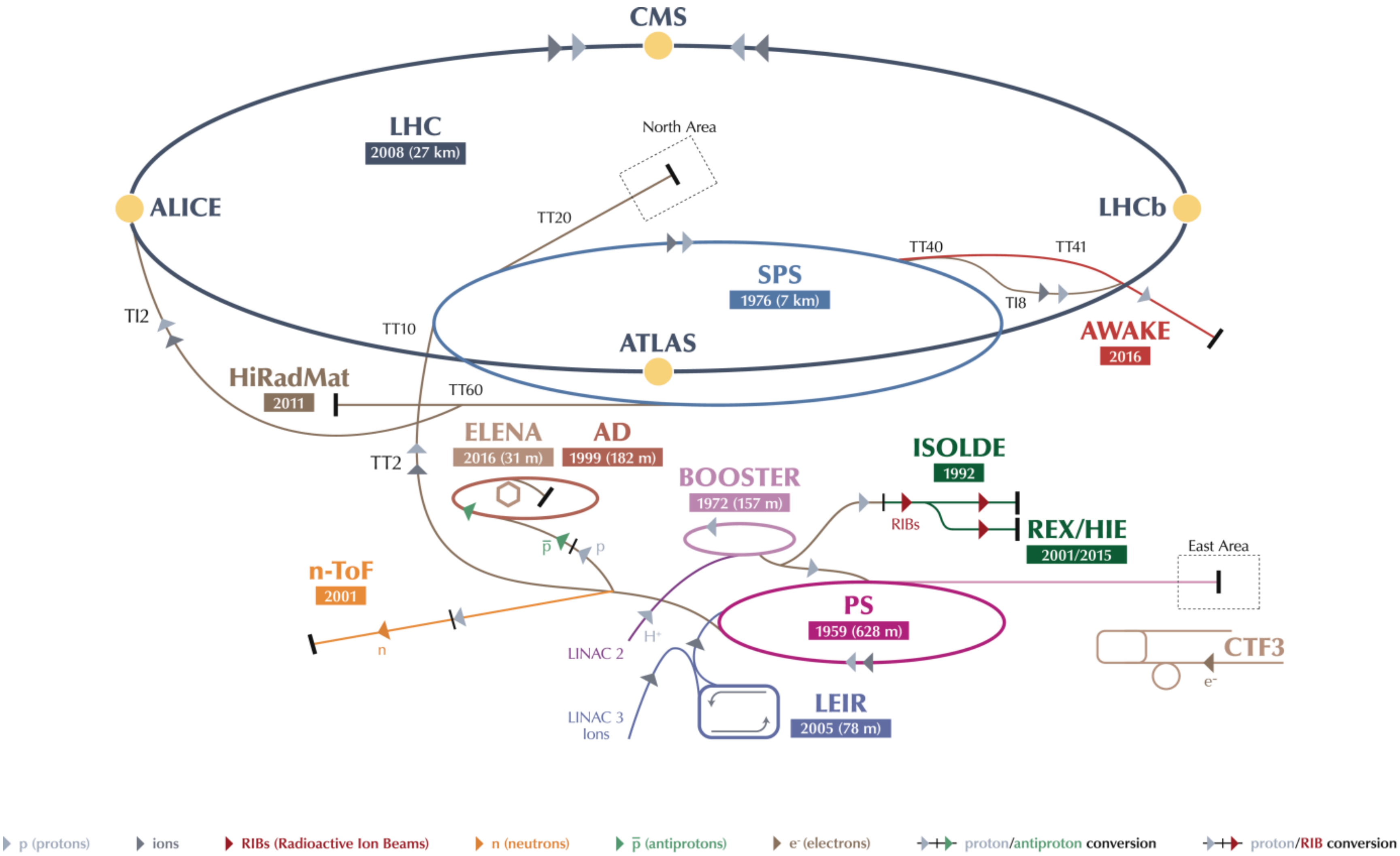
HL-LHC from a study to a PROJECT

$300\ \text{fb}^{-1} \rightarrow 3000\ \text{fb}^{-1}$

including LHC injectors upgrade **LIU**

(Linac 4, Booster 2GeV, PS and SPS upgrade)

CERN accelerators

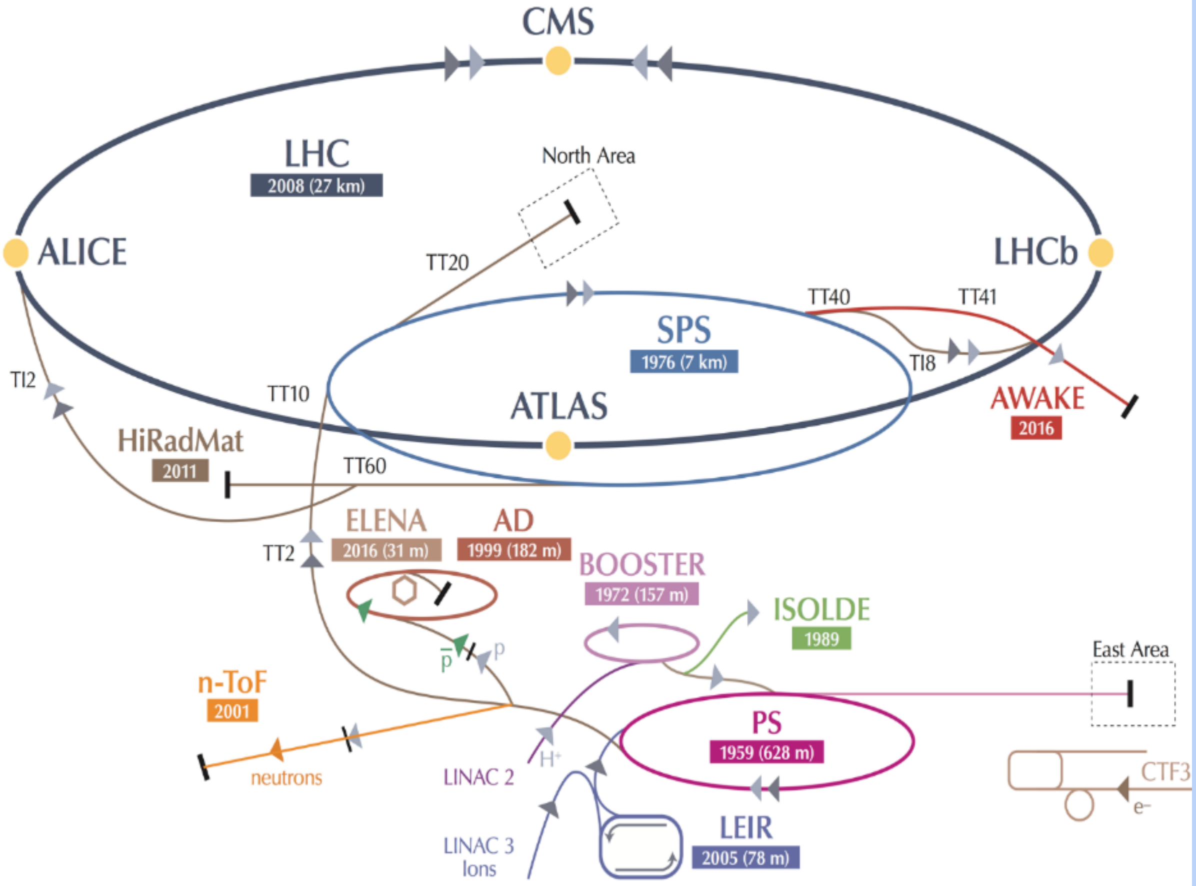


LHC Large Hadron Collider **SPS** Super Proton Synchrotron **PS** Proton Synchrotron **AD** Antiproton Decelerator **CTF3** Clic Test Facility

AWAKE Advanced WAKefield Experiment **ISOLDE** Isotope Separator OnLine **REX/HIE** Radioactive EXperiment/High Intensity and Energy ISOLDE

LEIR Low Energy Ion Ring **LINAC** LINear ACcelerator **n-ToF** Neutrons Time Of Flight **HiRadMat** High-Radiation to Materials

CERN’s scientific diversity programme



~20 experiments, > 1200 physicists

AD: Antiproton Decelerator for antimatter studies

AWAKE: proton-induced plasma wakefield acceleration

CAST, OSQAR: axions

CLOUD: impact of cosmic rays on aeorosols and clouds → implications on climate

COMPASS: hadron structure and spectroscopy

ISOLDE: radioactive nuclei facility

NA61/Shine: heavy ions and neutrino targets

NA62: rare kaon decays

NA63: radiation processes in strong EM fields

NA64: search for dark photons

Neutrino Platform: **ν** detectors R&D for experiments in US, Japan

n-TOF: n-induced cross-sections

UA9: crystal collimation

Goals and means of the LHC Injectors Upgrade: LIU project

Increase injector reliability and lifetime to cover HL-LHC run (until ~2035) closely related to consolidation program

⇒ Upgrade/replace ageing equipment (power supplies, magnets, RF…)

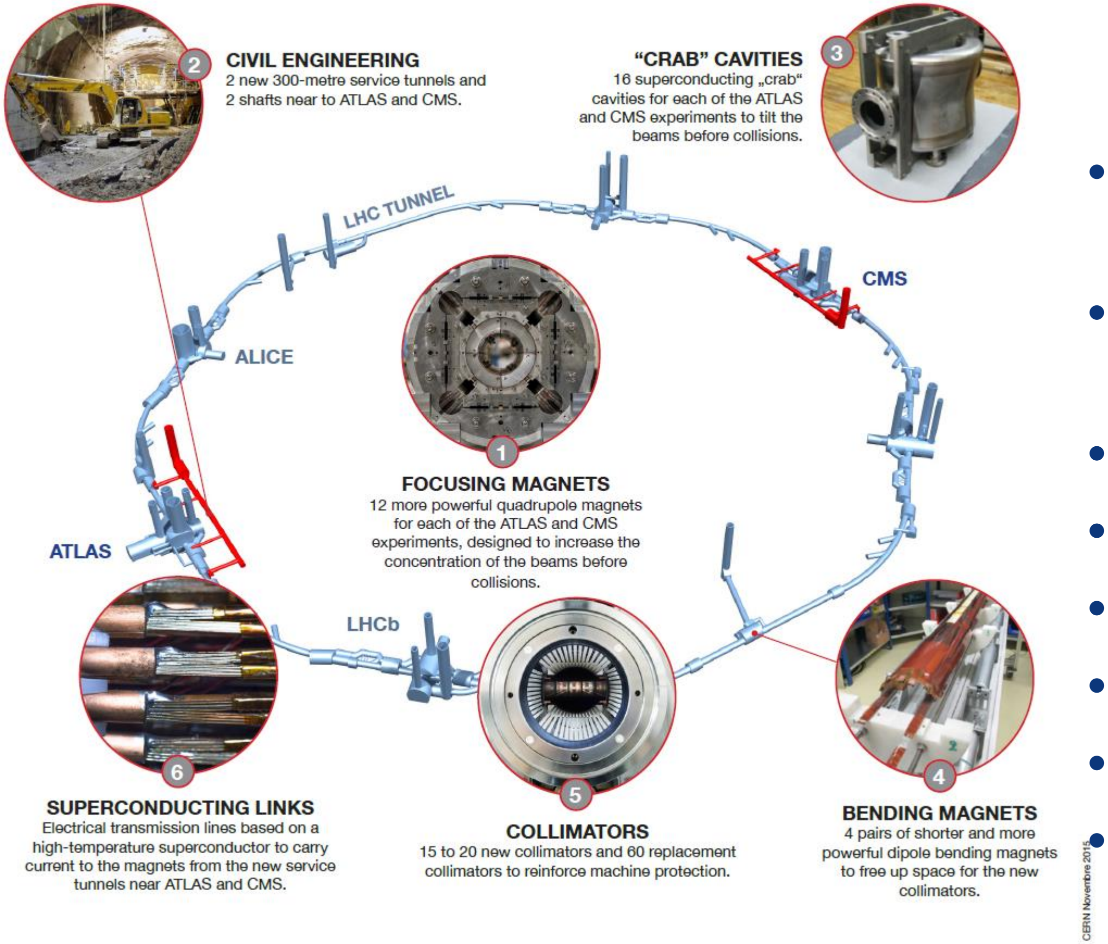
⇒ Improve radioprotection measures (shielding, ventilation…)

Increase intensity/brightness in the injectors to match HL-LHC requirements

⇒ Enable Linac4/PSB/PS/SPS to accelerate and manipulate higher intensity beams (efficient production, space charge & electron cloud mitigation, impedance reduction, feedbacks, etc.)

⇒ Upgrade the injectors of the ion chain (Linac3, LEIR, PS, SPS) to produce beam parameters at the LHC injection that can meet the luminosity goal

The HL-LHC Project



CIVIL ENGINEERING
2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.

"CRAB" CAVITIES
16 superconducting „crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.

FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.

SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.

COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.

BENDING MAGNETS
4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

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

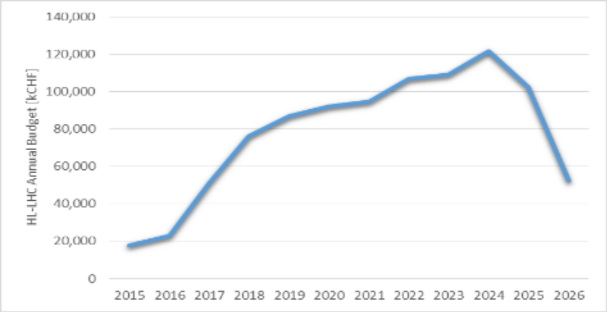
Major intervention on more than 1.2 km of the LHC

HL-LHC project: formal approval by CERN Council (June 2016)

The High-Luminosity LHC Project

Abstract

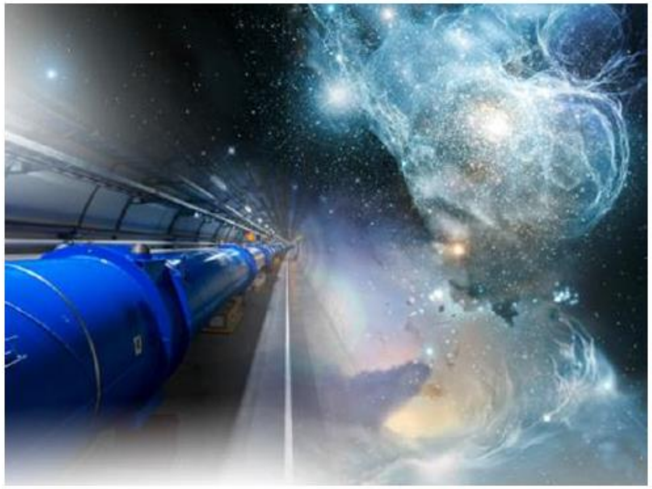
The scientific case for a luminosity upgrade of the Large Hadron Collider (High-Luminosity LHC, HL-LHC) is presented. It includes measurements of the Higgs boson properties with unprecedented precision and increased potential in the search for new physics. Construction is expected to be completed by the mid-twenties, and by the mid-thirties the HL-LHC should have provided a tenfold increase in the integrated luminosities recorded by the experiments. Main upgrade components include new-technology supercoducting magnets and current leads. The cost of the collider upgrade, which will be realised within a constant CERN Budget, is estimated to be 950 MCHF. The main technical challenges, as well as the ongoing R&D work and the main milestones of the implementation plan, are described.

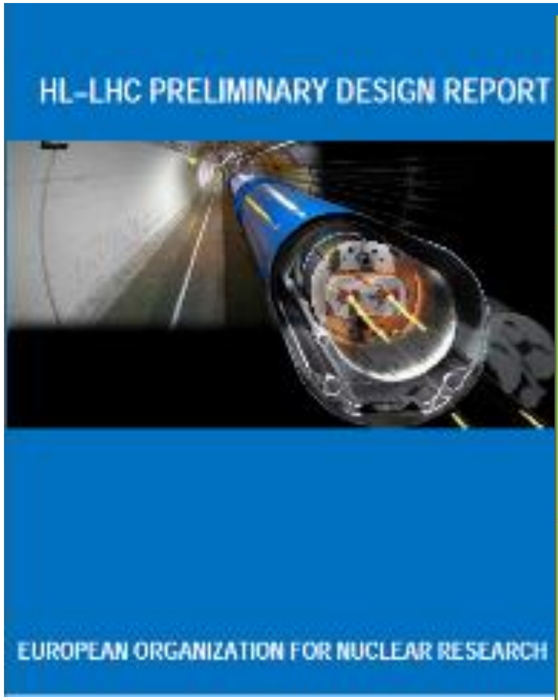


Cost to Completion

Material : 950 MCHF

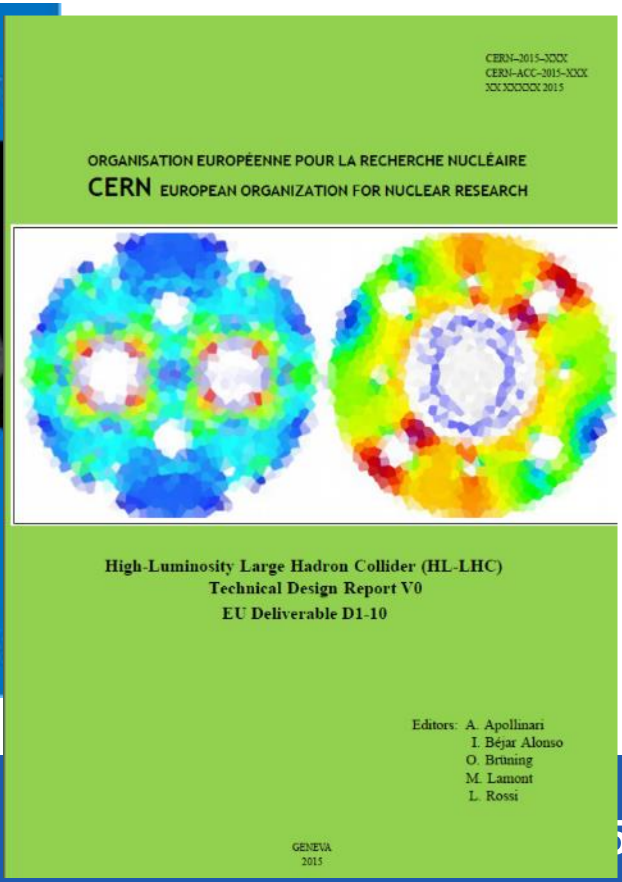
Personnel: 1600 FTE-years





HL-LHC PRELIMINARY DESIGN REPORT

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



CERN–2015–XXXX
CERN–ACC–2015–XXXX
XX XXXXXX 2015

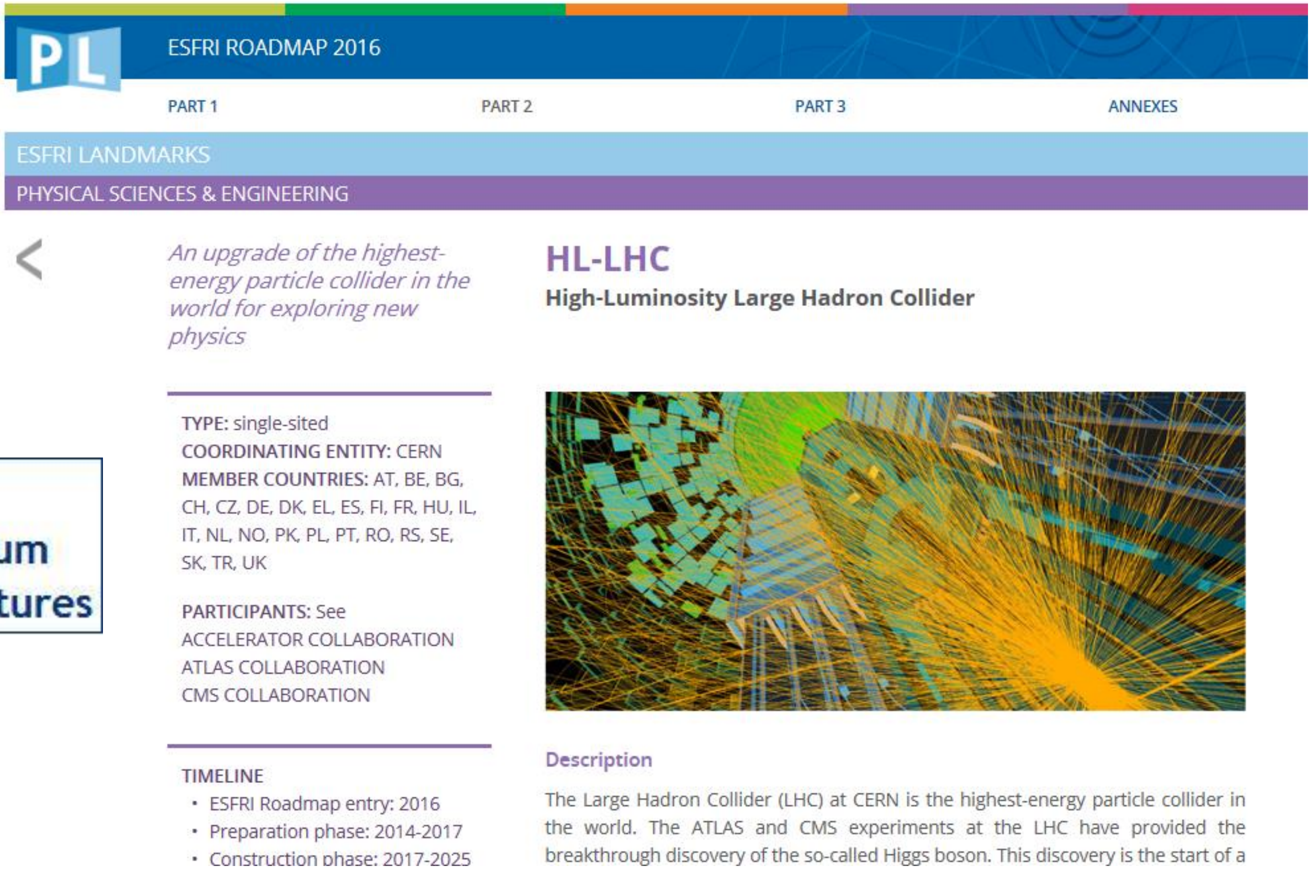
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

High-Luminosity Large Hadron Collider (HL-LHC)
Technical Design Report V0
EU Deliverable D1-10

Editors: A. Apollinari
I. Béjar Alonso
O. Brüning
M. Lamont
L. Rossi

GENEVA
2015

HL-LHC – ESFRI Landmark – Roadmap 2016



ESFRI ROADMAP 2016

PART 1 PART 2 PART 3 ANNEXES

ESFRI LANDMARKS

PHYSICAL SCIENCES & ENGINEERING

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

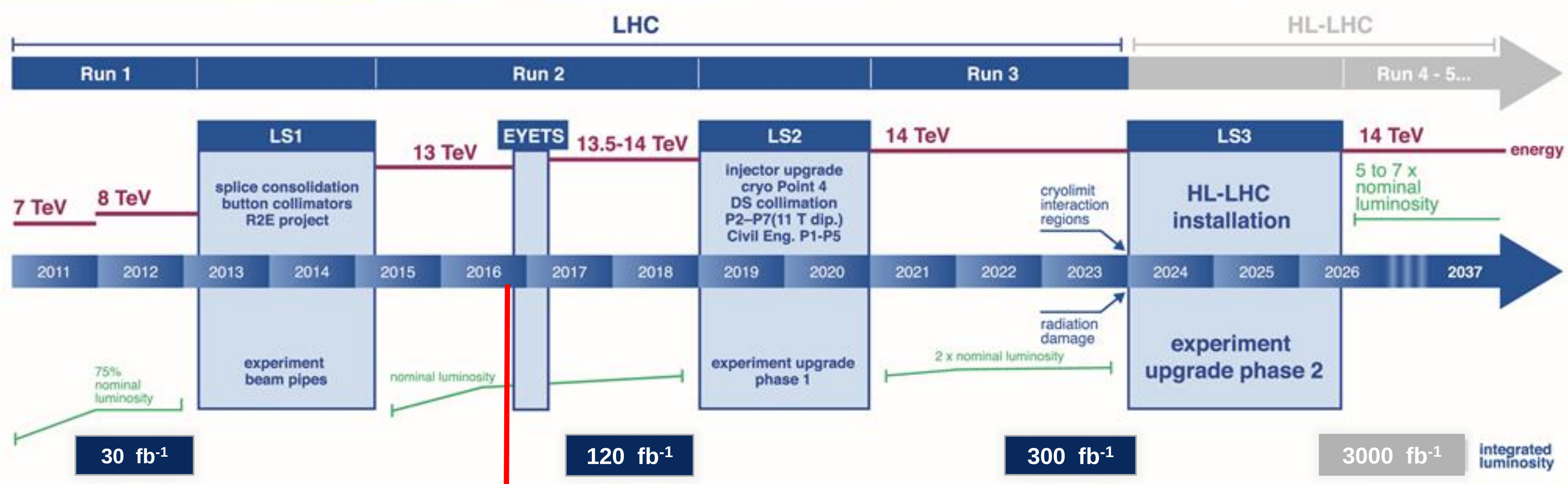
The Large Hadron Collider (LHC) at CERN is the highest-energy particle collider in the world. The ATLAS and CMS experiments at the LHC have provided the breakthrough discovery of the so-called Higgs boson. This discovery is the start of a

ESFRI European Strategy Forum on Research Infrastructures

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

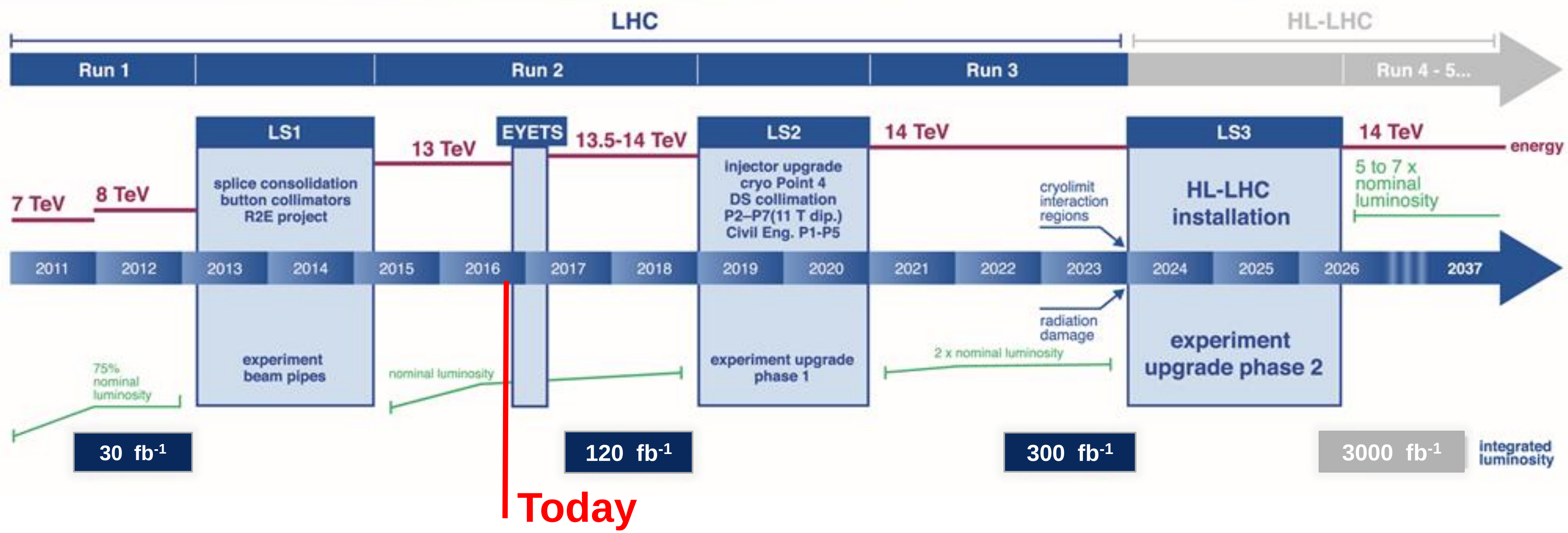
LHC / HL-LHC Plan

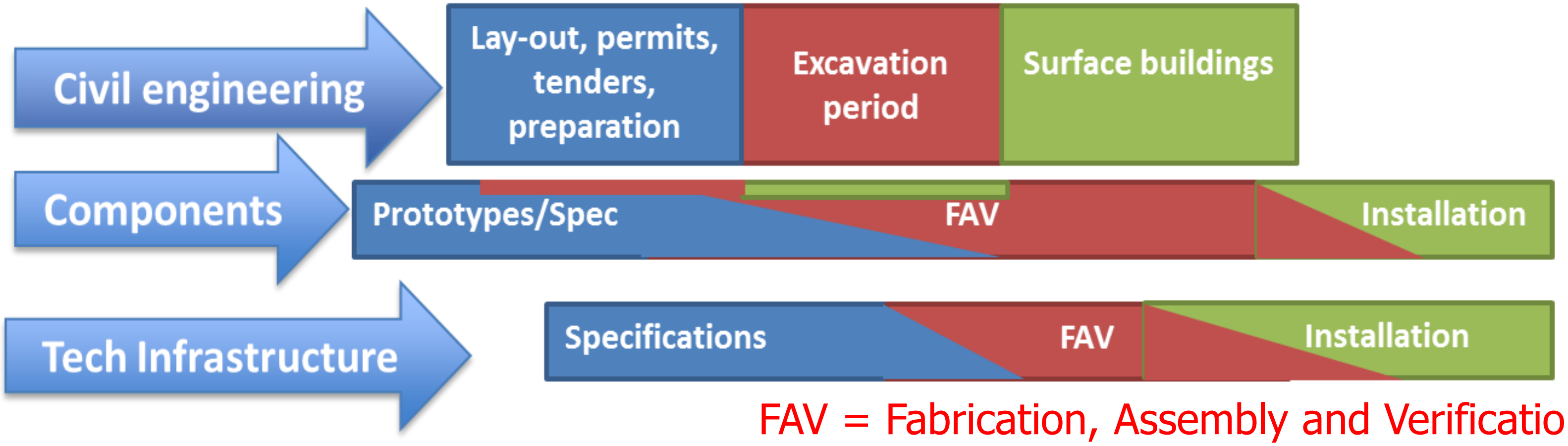


Today

HL-LHC Plan

LHC / HL-LHC Plan





Civil engineering

Lay-out, permits, tenders, preparation

Excavation period

Surface buildings

Components

Prototypes/Spec

FAV

Installation

Tech Infrastructure

Specifications

FAV

Installation

FAV = Fabrication, Assembly and Verification

Courtesy Isabel Bejar

HL-LHC and industries

- 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.

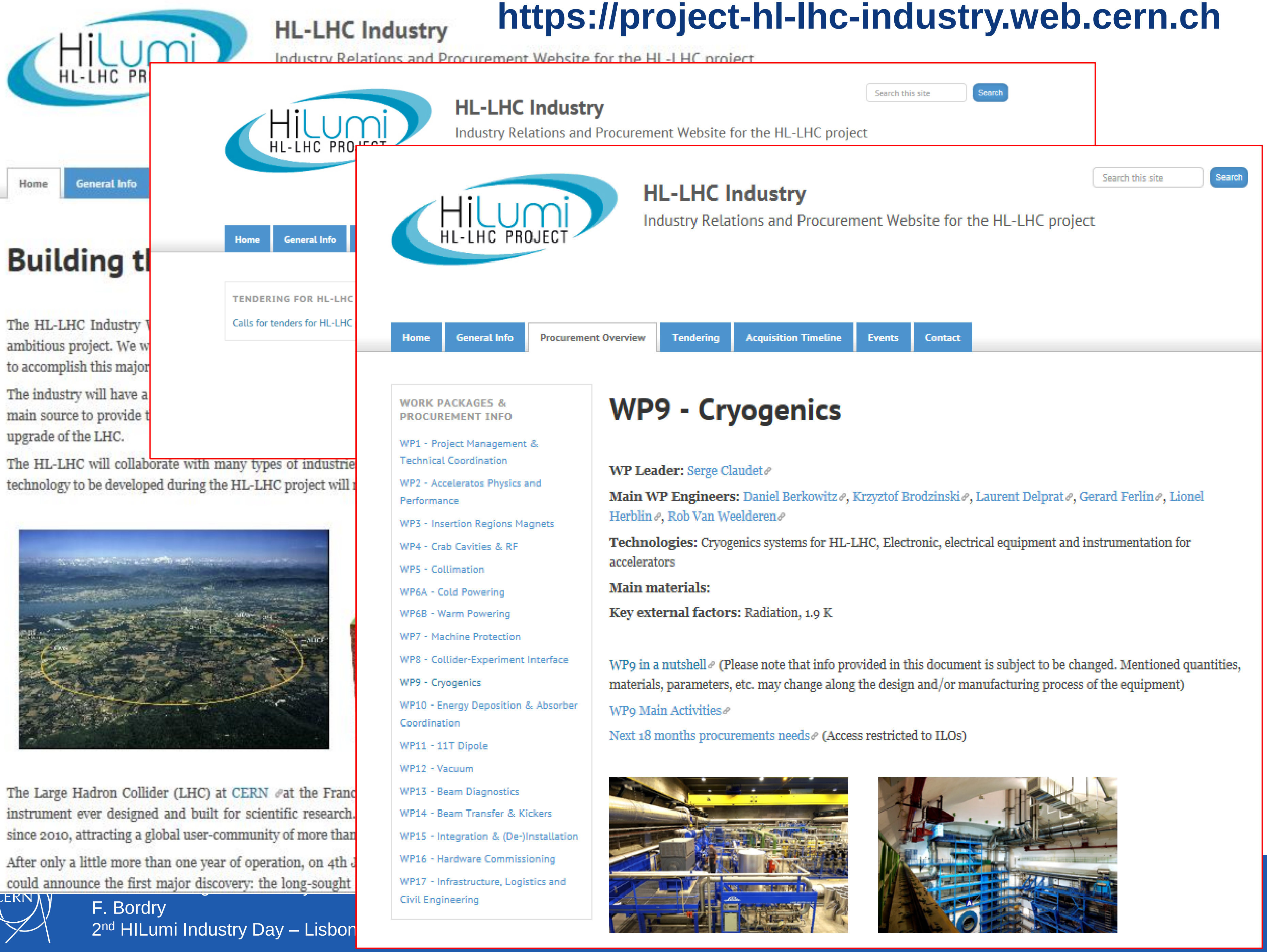
HL-LHC and industries

Provide timely information of what CERN requires and for when

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



HL-LHC Industry

Industry Relations and Procurement Website for the HL-LHC project

Home | General Info

Building tl

The HL-LHC Industry
ambitious project. We w
to accomplish this major

The industry will have a
main source to provide t
upgrade of the LHC.

The HL-LHC will collaborate with many types of industrie
technology to be developed during the HL-LHC project will

The Large Hadron Collider (LHC) at CERN at the Franc
instrument ever designed and built for scientific research.
since 2010, attracting a global user-community of more than

After only a little more than one year of operation, on 4th J
could announce the first major discovery: the long-sought

HL-LHC Industry

Industry Relations and Procurement Website for the HL-LHC project

Search this site | Search

Home | General Info

TENDERING FOR HL-LHC

Calls for tenders for HL-LHC

HL-LHC Industry

Industry Relations and Procurement Website for the HL-LHC project

Search this site | Search

Home | General Info | Procurement Overview | Tendering | Acquisition Timeline | Events | Contact

WORK PACKAGES & PROCUREMENT INFO

- WP1 - Project Management & Technical Coordination
- WP2 - Accelerators Physics and Performance
- WP3 - Insertion Regions Magnets
- WP4 - Crab Cavities & RF
- WP5 - Collimation
- WP6A - Cold Powering
- WP6B - Warm Powering
- WP7 - Machine Protection
- WP8 - Collider-Experiment Interface
- WP9 - Cryogenics
- WP10 - Energy Deposition & Absorber Coordination
- WP11 - 11T Dipole
- WP12 - Vacuum
- WP13 - Beam Diagnostics
- WP14 - Beam Transfer & Kickers
- WP15 - Integration & (De-)Installation
- WP16 - Hardware Commissioning
- WP17 - Infrastructure, Logistics and Civil Engineering

WP9 - Cryogenics

WP Leader: Serge Claudet

Main WP Engineers: Daniel Berkowitz, Krzyztof Brodzinski, Laurent Delprat, Gerard Ferlin, Lionel Herblin, Rob Van Weelderen

Technologies: Cryogenics systems for HL-LHC, Electronic, electrical equipment and instrumentation for accelerators

Main materials:

Key external factors: Radiation, 1.9 K

WP9 in a nutshell (Please note that info provided in this document is subject to be changed. Mentioned quantities, materials, parameters, etc. may change along the design and/or manufacturing process of the equipment)

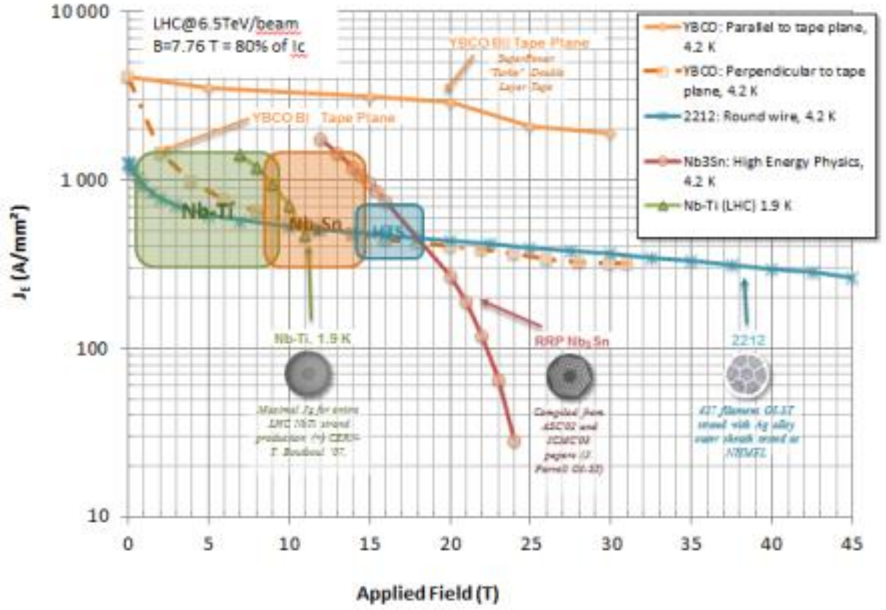
WP9 Main Activities

Next 18 months procurements needs (Access restricted to ILOs)

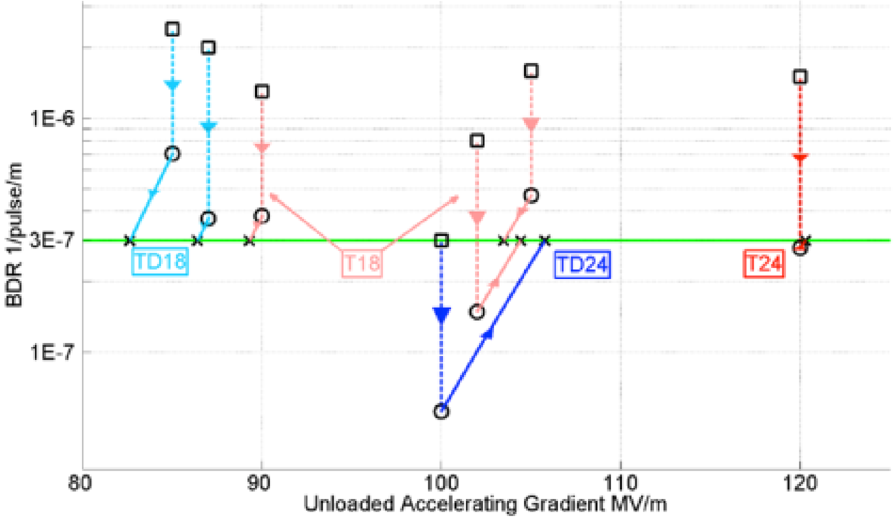
“to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update”

d) *CERN should undertake design studies for accelerator projects in a global context,* *with emphasis on **proton-proton and electron-positron high-energy frontier machines**. These design studies should be coupled to a vigorous accelerator **R&D programme**, including **high-field magnets** and **high-gradient accelerating structures**, **in collaboration with national institutes, laboratories and universities worldwide.***

HFM – FCC-hh

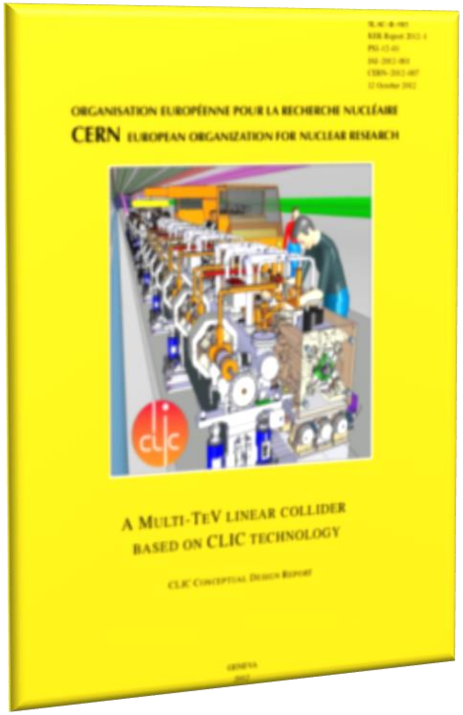


HGA



And also R&D on Proton-Driven Plasma Wakefield Acceleration (AWAKE Expt at CERN)

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



ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
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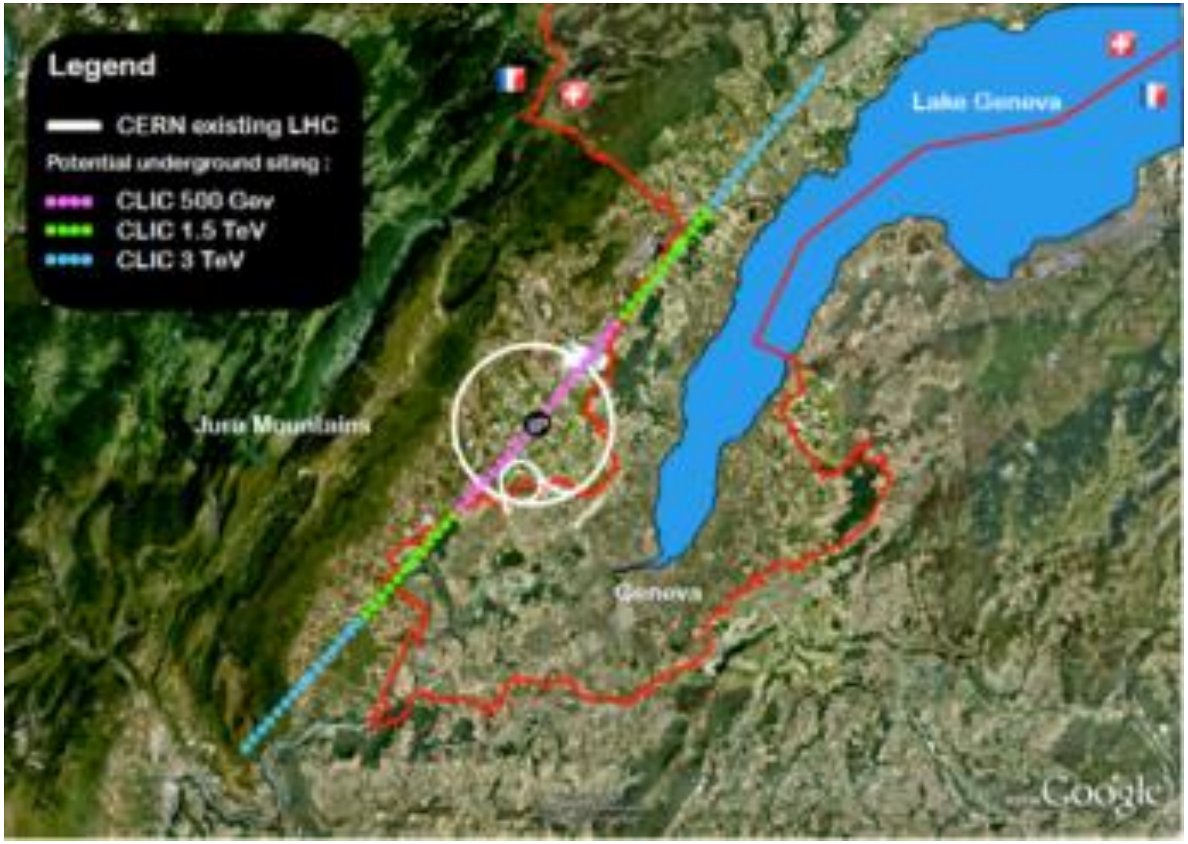
A MULTI-TEV LINEAR COLLIDER
BASED ON CLIC TECHNOLOGY

CLIC CONCEPTUAL DESIGN REPORT

GENEVA



Highest possible energy e⁺e⁻

with CLIC (CDR 2012)

Multi-lateral collaboration

Future Circular Collider Study - SCOPE
CDR and cost review for the next ESU (2019)

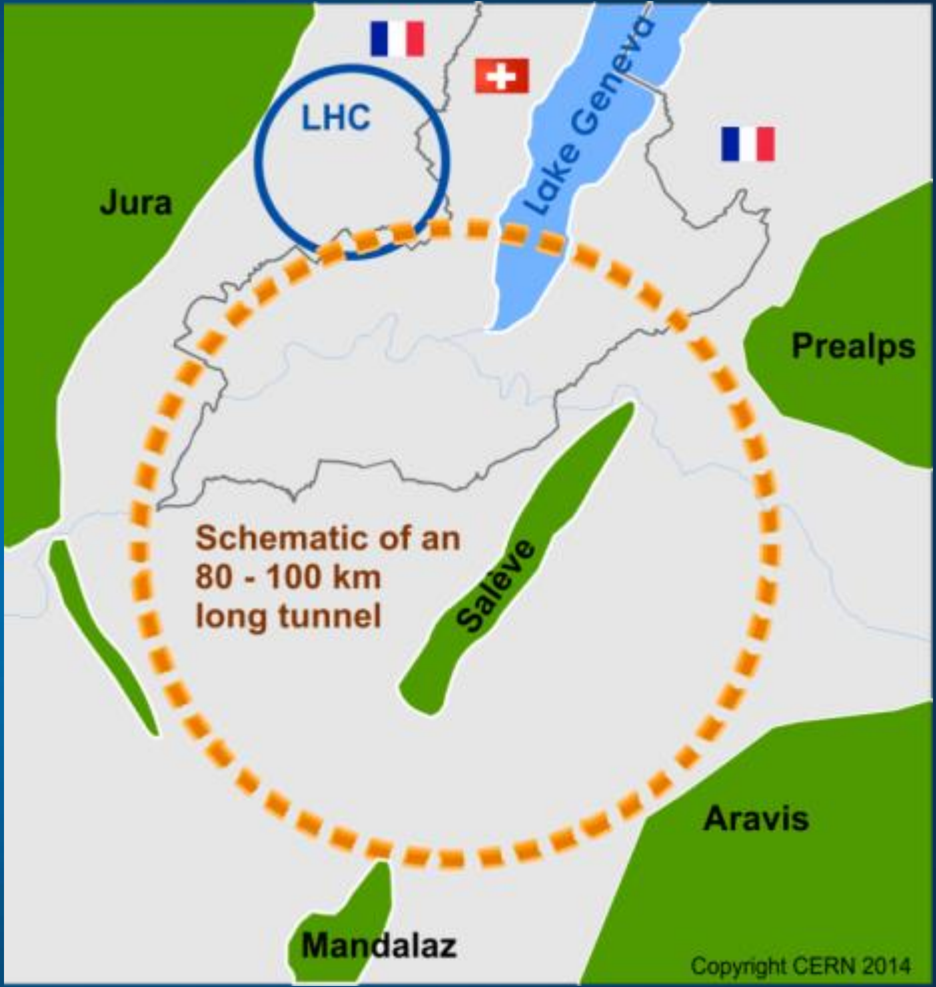
Forming an international collaboration to study:

- ***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 ~ 30 TeV in LHC**



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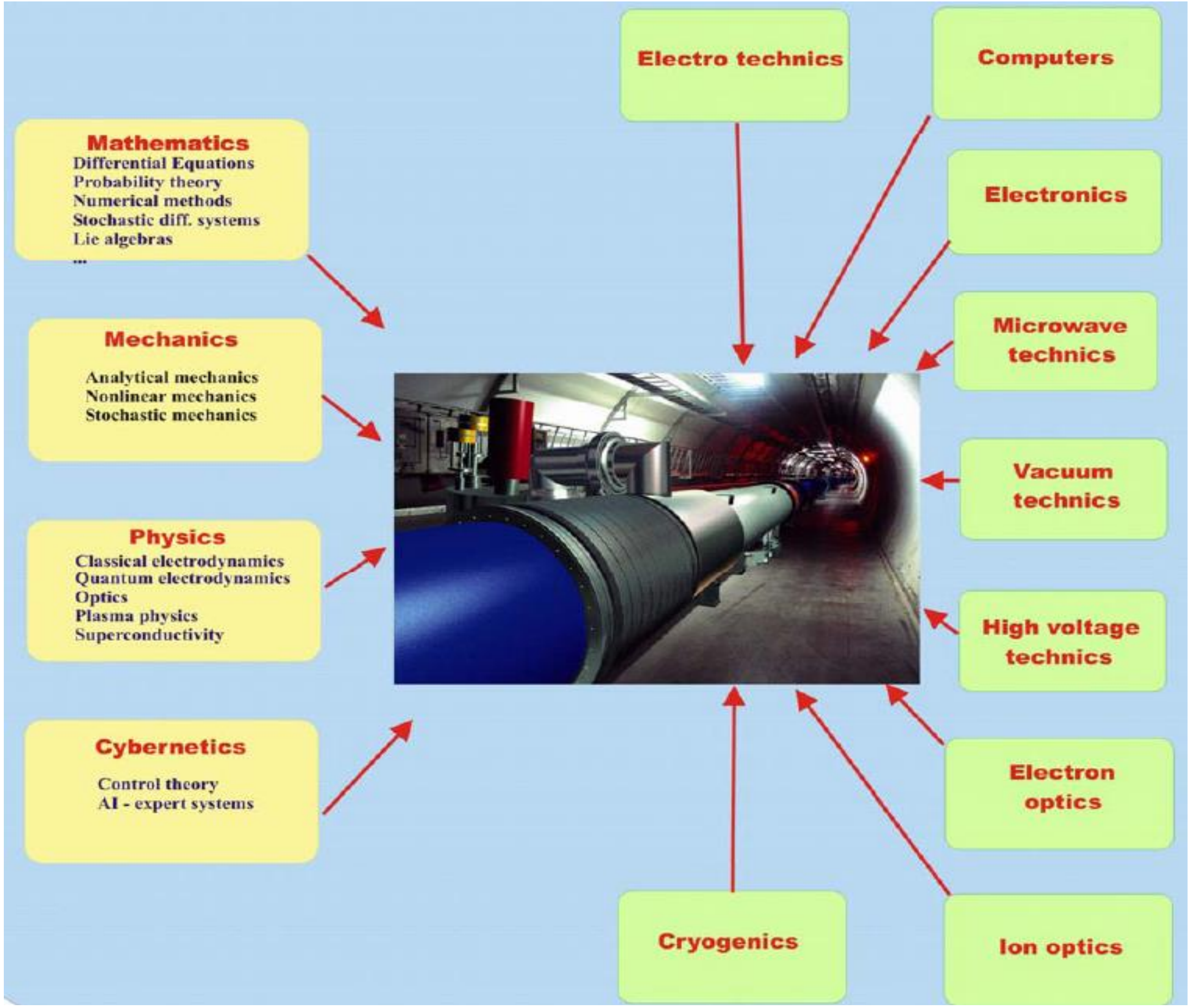
FCC: 80-100 km infrastructure in Geneva area

List of Technologies needed for building and exploiting Accelerators



Electrical engineering
Electronics
Mechanical engineering
Beam-materials science
Computer engineering
Civil Engineering
Large scale simulations
……

A multidisciplinary domain !

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***

The 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

Obrigado pela sua atenção

www.cern.ch

"A função mais básica do ser humano, é criar o futuro"
Paul Valéry