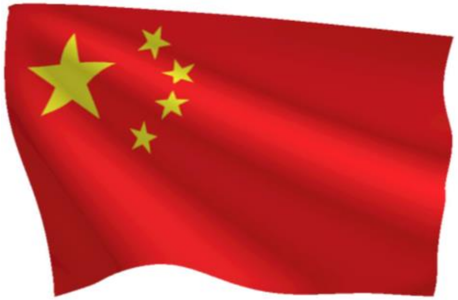
The future of Particle Physics
……
from an accelerating point of view

Isabel Bejar Alonso with slides coming from all the physics community

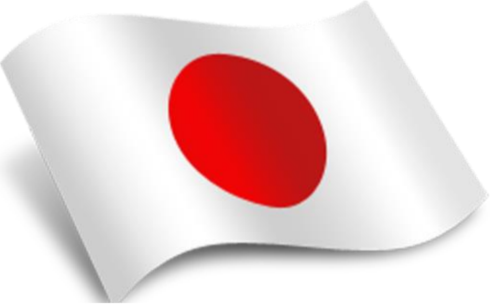
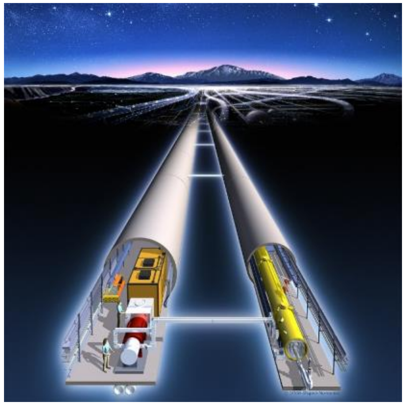
HL-LHC Configuration, Quality, Risk and Sourcing Officer

¿Qué será … será ….?

Habrá que preguntarse ...
¿En las manos de quienes está …?



O ... ¿Quienes tienen dinero para financiar ciencia básica?

O son los lideres que inspiraran a nuestros politicos …

Lo que sabemos es que hoy en día hay una estrategia Europea que se esta repensando en este momento,
una estrategia Estadounidense que se presentó en 2014,
una estrategia japonesa y planes de crear grandes aceleradores en China …

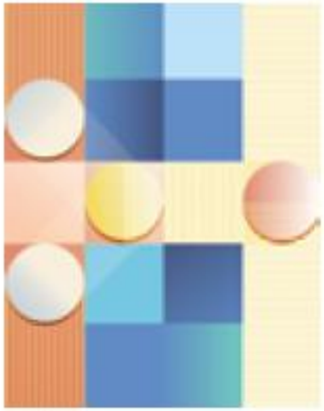
Strategy USA - 2014

Particle physics is a highly successful, discovery-driven science. It explores the fundamental constituents of matter and energy, and it reveals the profound connections underlying everything we see, including the smallest and the largest structures in the Universe. Earlier investments have been rewarded with recent fundamental discoveries, and upcoming opportunities will push into new territory. Particle physics inspires young people to engage with science.

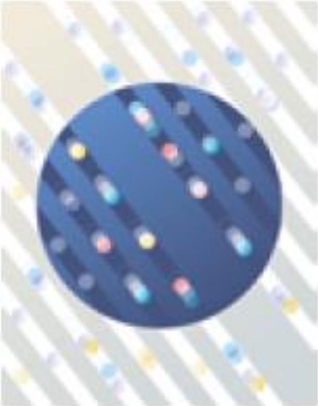
Drivers

Five intertwined scientific Drivers were distilled from the results of a yearlong community-wide study:

- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles

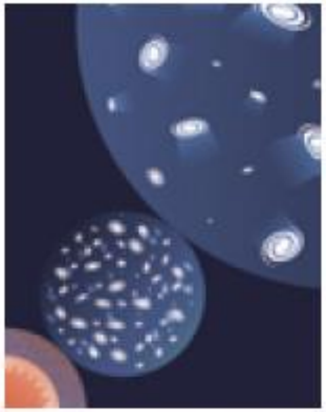


Higgs boson



Neutrino mass

Dark matter



Cosmic acceleration

Explore the unknown

HiLumi HL-LHC PROJECT

Strategy USA

- Large projects, in time order, include the **Muon g-2** and **Muon-to-electron Conversion (Mu2e)** experiments at Fermilab, strong collaboration in the high-luminosity upgrades to the Large Hadron Collider (**HL-LHC**), and a U.S.-hosted Long Baseline Neutrino Facility (**LBNF**) that receives the world's highest intensity neutrino beam from (PIP-II) at Fermilab.
- U.S. involvement in a Japanese-hosted International Linear Collider (**ILC**).
- Areas with clear U.S. leadership in which investments in medium- and small-scale experiments have great promise for near-term discovery include dark matter direct detection, the Large Synoptic Survey Telescope (LSST), the Dark Energy Spectroscopic Instrument (DESI), cosmic microwave background (CMB) experiments, short-baseline neutrino experiments, and a portfolio of small projects.

Strategy Europe

- Exploit its current world-leading facility for particle physics, the LHC, to its full potential over a period of many years, with a series of planned upgrades (**HL-LHC**);
- Continue to develop novel techniques leading to ambitious **future accelerator** projects on a global scale;
- Be open to engagement in a range of unique basic physics research projects alongside the LHC;
- Be open to **collaboration** in particle physics projects beyond the European region;
- Maintain a healthy base in fundamental physics research, with universities and national laboratories contributing to a strong European focus **through CERN**;
- Continue to invest substantial effort in communication, **education and outreach** to engage global publics with science.

CERN scientific roadmap today

Full exploitation of the LHC:

❑ Run 2 started last year → goal this year is $L=10^{34}$ at $\sqrt{s}$ =13 TeV, ~25 fb^{-1}

❑ building upgrade of injectors (LIU), collider (HL-LHC) and detectors (Phase-1 and Phase-2)

Diversity programme serving a broad community:

❑ ongoing experiments and facilities at Booster, PS, SPS and their upgrades (ELENA, HIE-ISOLDE)

❑ participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through the CERN Neutrino Platform

Preparation of CERN's future:

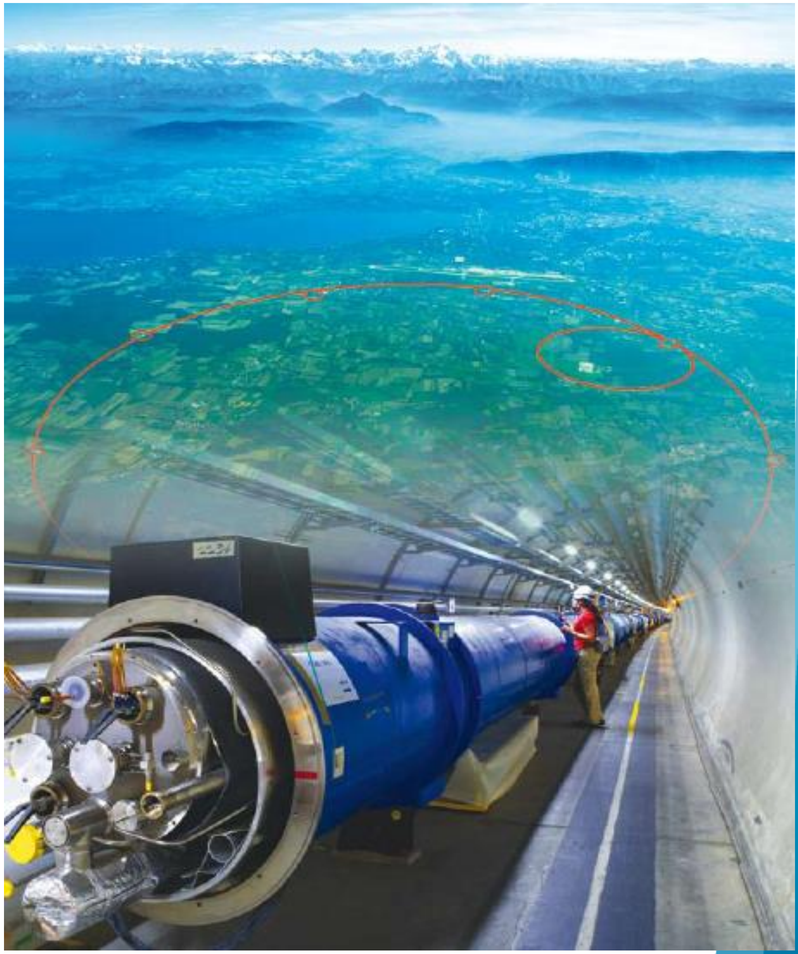
❑ vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, AWAKE, etc.)

❑ design studies for future accelerators: CLIC, FCC (includes HE-LHC)

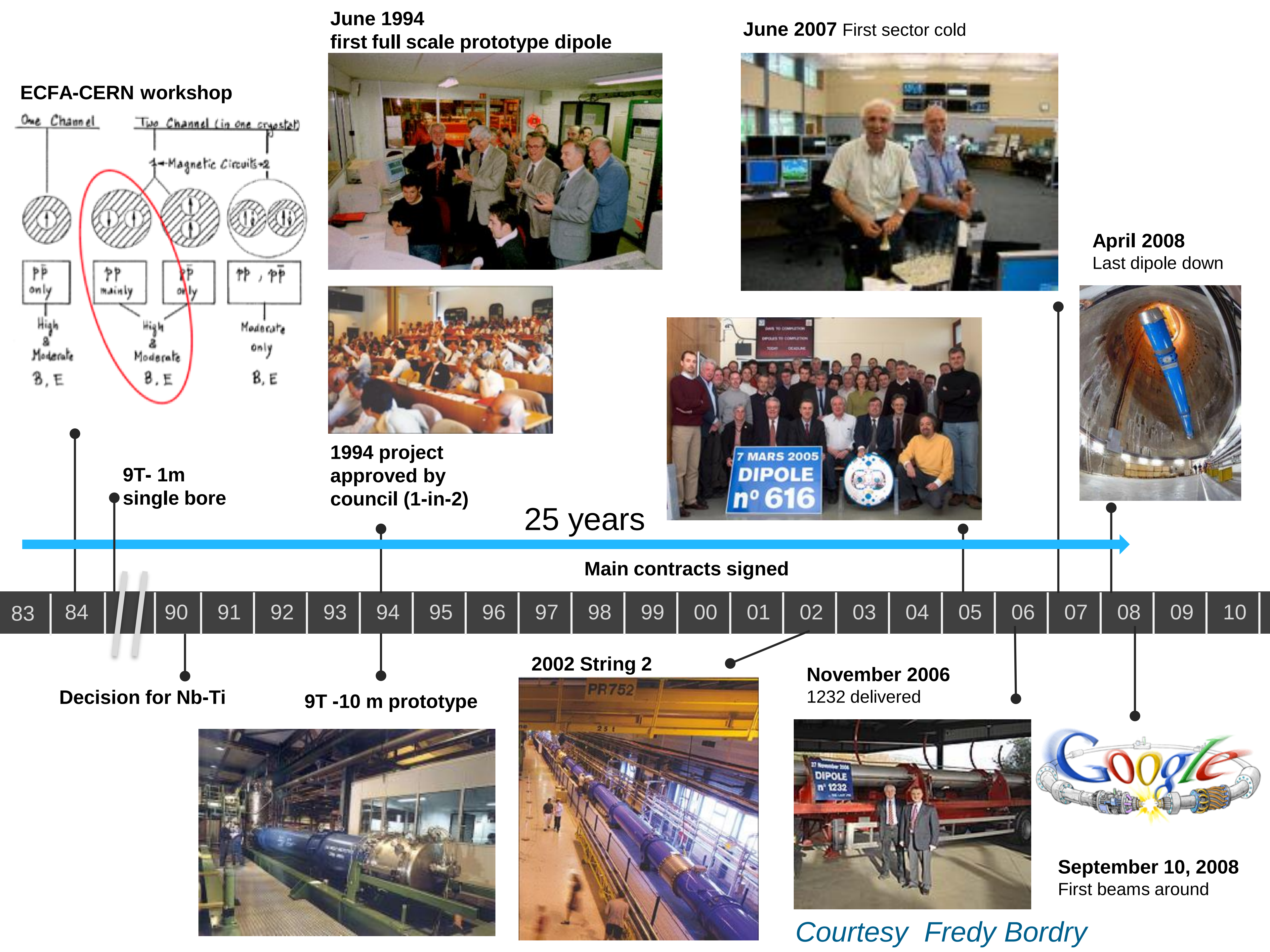
❑ future opportunities for scientific diversity programme (new)

Full exploitation of the LHC: The LHC

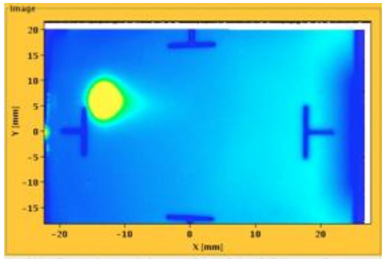
1983 : First studies for the LHC project
1988 : First magnet model (feasibility)
1994 : Approval of the LHC by the CERN Council
1996-1999 :Series production industrialisation
1998 : Declaration of Public Utility & Start of civil engineering
1998-2000 :Placement of the main production contracts
2004 : Start of the LHC installation
2005-2007 :Magnets Installation in the tunnel
2006-2008 :Hardware commissioning
2008-2009 :Beam commissioning and repair
2009-2035 :Physics exploitation



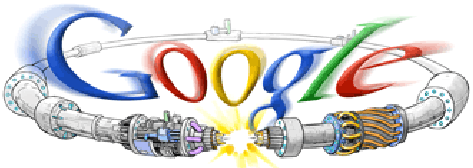
Courtesy Fredy Bordry


ECFA-CERN workshop
One Channel
Two Channel (in one cryostat)
1←Magnetic Circuits→2
High & Moderate B, E
High & Moderate B, E
Moderate only B, E
June 1994
first full scale prototype dipole
June 2007 First sector cold
April 2008
Last dipole down
9T- 1m
single bore
1994 project
approved by
council (1-in-2)
7 MARS 2005
DIPOLE
nº 616
25 years
Main contracts signed
83
84
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
Decision for Nb-Ti
9T -10 m prototype
2002 String 2
PR752
November 2006
1232 delivered
DIPOLE
nº 1232
Google
September 10, 2008
First beams around
Courtesy Fredy Bordry

August 2008
First injection test

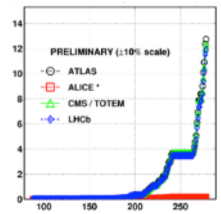


Sept. 10, 2008
First beams around

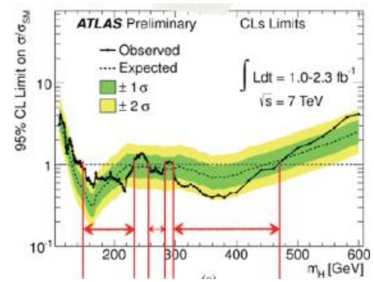


Repair and Consolidation

November 29, 2009
Beam back



October 14, 2010
L= $1x10^{+32}$
248 bunches

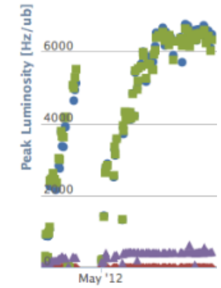


October, 2011
$3.5x10^{+33}$, 5.7 fb^{-1}

First Hints!!

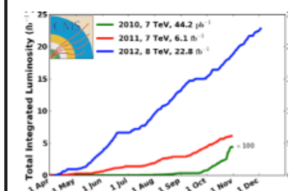
June 28 2011
1380 bunches

1380

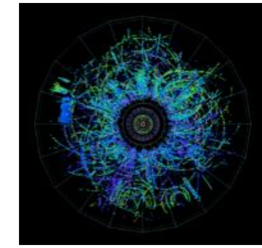


May 2012
Ramping
Performance

March 14th 2012
Restart
with Beam

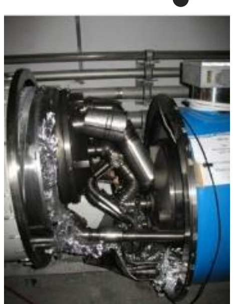


Nov. 2012
End of p^+ Run 1



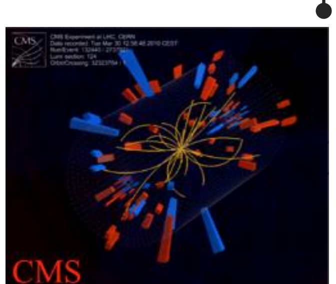
Feb. 2013
p-Pb^{82+}
New Operation
Mode

2008	2009	2010	2011	2012	2013

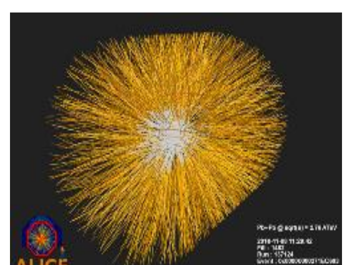


Sept. 19, 2008
Incident

March 30, 2010
First collisions at 3.5 TeV

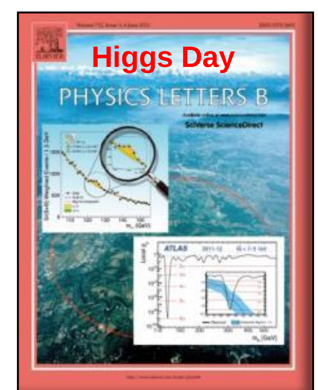


November 2010
Pb^{82+} Ions



November 2011
Second Ion Run

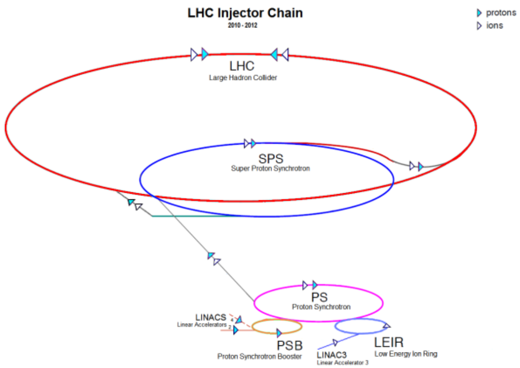
Higgs Day



LS1

Courtesy Fredy Bordry

Full exploitation of the LHC: LIU LHC Injector Upgrades

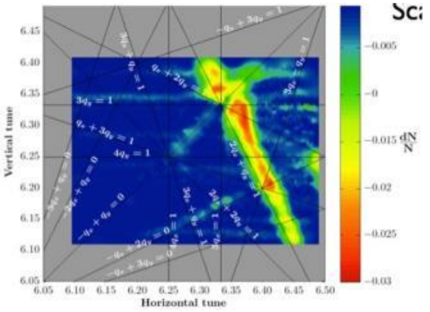


LINAC4 – PS Booster:

- H$^-$ injection and increase of PSB injection energy from 50 MeV to 160 MeV, to increase PSB space charge threshold
- New RF cavity system, new main power converters
- Increase of extraction energy from 1.4 GeV to 2 GeV

PS:

- Increase of injection energy from 1.4 GeV to 2 GeV to increase PS space charge threshold
- Transverse resonance compensation
- New RF Longitudinal feedback system
- New RF beam manipulation scheme to increase beam brightness



SPS

- Electron Cloud mitigation – strong feedback system, or coating of the vacuum system
- Impedance reduction, improved feedbacks
- Large-scale modification to the main RF system

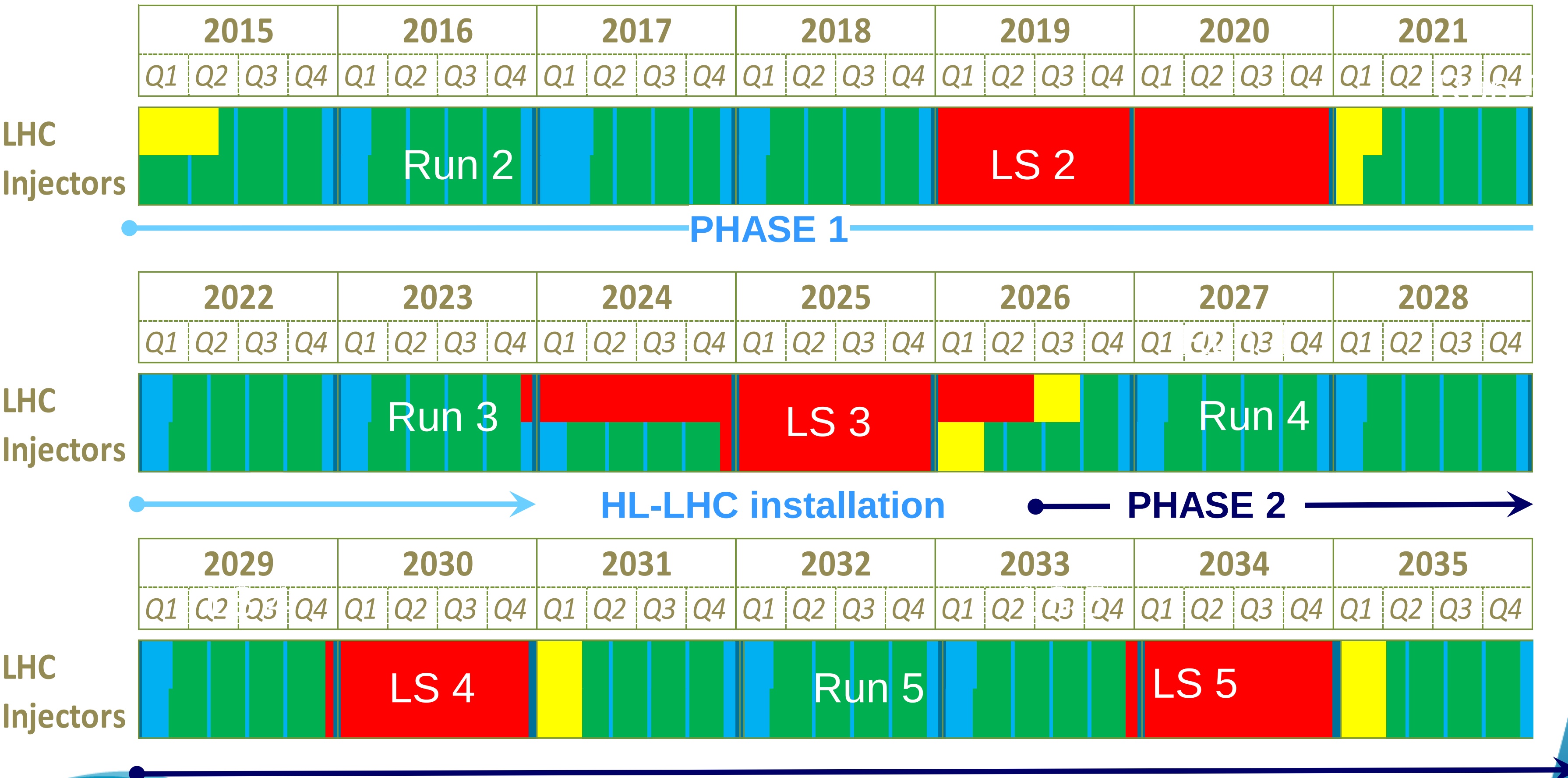
These are only the main modifications and this list is far from exhaustive

Project leadership: M. Meddahi

LHC roadmap: according to MTP 2016-2020 V1

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop



The European Strategy for Particle Physics Update 2013

c) *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

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

including LHC injectors upgrade **LIU**

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

Update ESPP ~2019-2020!

Que se dice en este momento …

European Strategy 2019 – 2020!!!

- Due to be updated by May 2020,
- Calling to submit written input by 18 December 2018.
- Strategy secretariat chaired by Halina Abramowicz, including Keith Ellis (SPC chair), Jorgen D'Hondt (ECFA Chair) and Lenny Rivkin (the Chair of the European Laboratory Directors group).
- The European Strategy update will take into account the worldwide particle-physics landscape and developments in related fields.
- Understanding the properties of the Higgs boson will remain a key focus of analysis at the LHC and future colliders, as will precision measurements of other Standard Model (SM) parameters and searches for new physics beyond the SM.
- Neutrino physics is another key area of interest, with much experimental activity having taken place since the last update.
- A Physics Beyond Colliders programme has also been established by CERN to explore projects complementary to high-energy colliders.
- The European astroparticle and nuclear-physics communities have launched their own strategies, which will also feed into the ESG update.

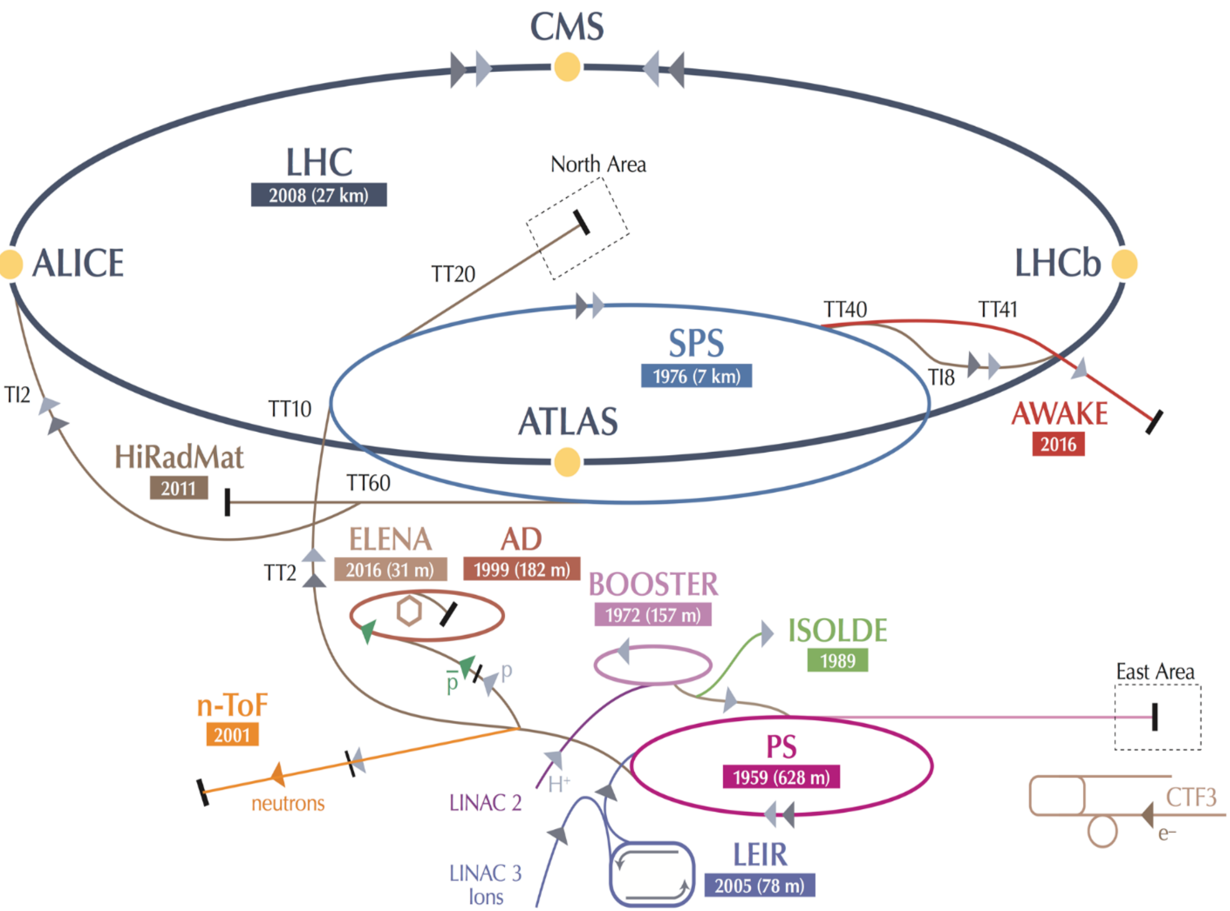
Y en otros sitios?

Diversidad …

y colaboración

(Neutrinos, muones y no sólo)

Diversity programme serving a broad community



~20 experiments > 1200 physicists

AD: Antiproton Decelerator for antimatter studies

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: ions and neutrino targets

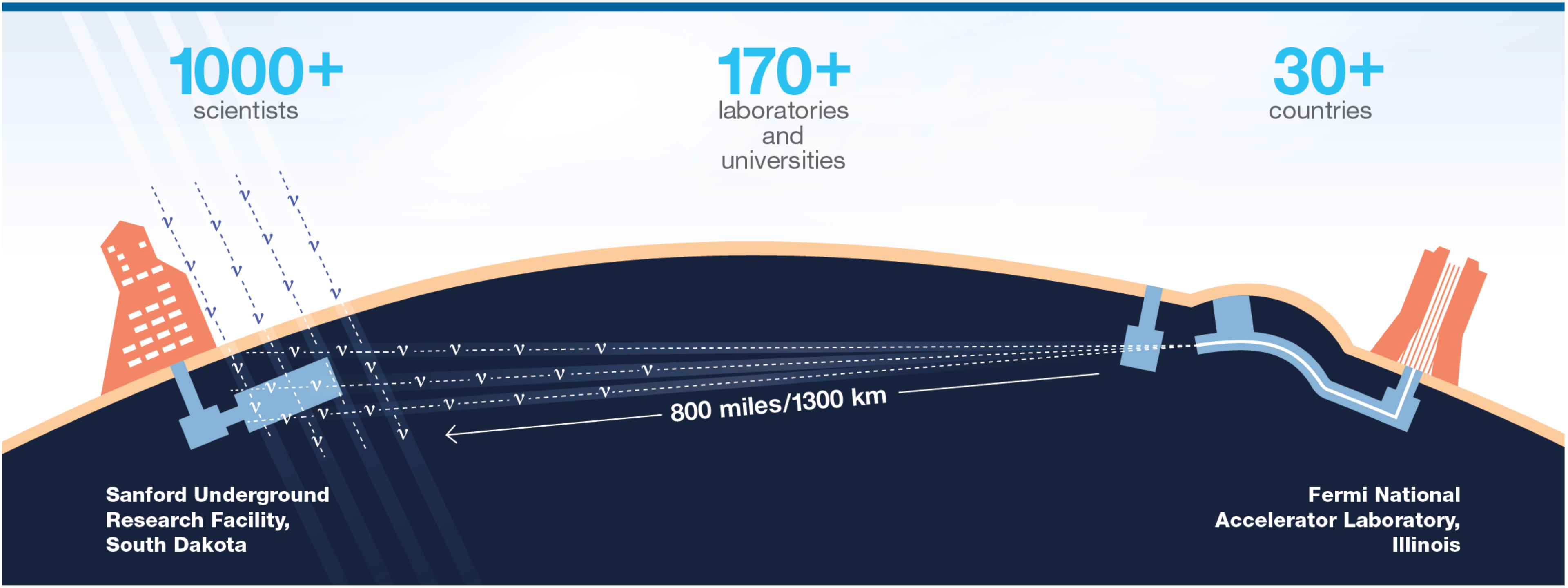
NA62: rare kaon decays

NA63: radiation processes in strong EM fields

n-TOF: n-induced cross-sections

UA9: crystal collimation

Neutrino Platform: collaborating with experiments in US and Japan → see later



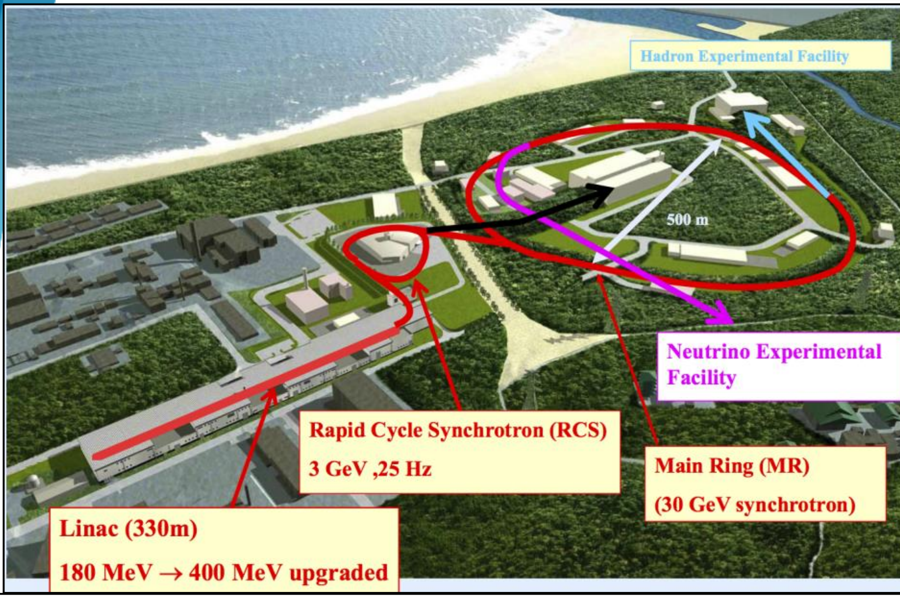
Three major discovery areas

Origin of Matter

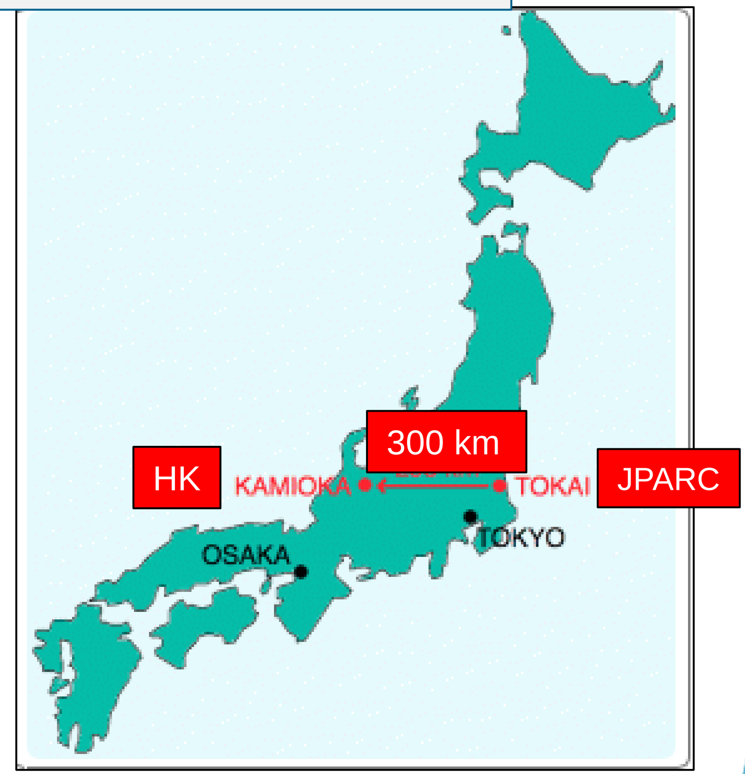
Unification of forces

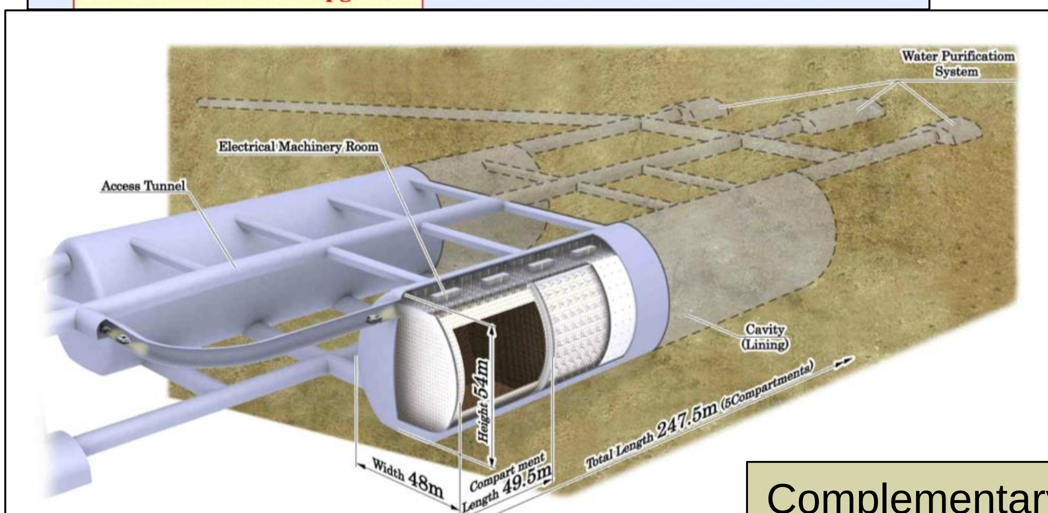
Black hole formation

Hyper-Kamiokande, JPARC: construction could start ~2018



0.38 → 0.75 → > 1 MW p source
E_p = 30 GeV → E_ν~ 0.6 GeV
Narrow-band ν beam
→ high intensity at oscillation peak



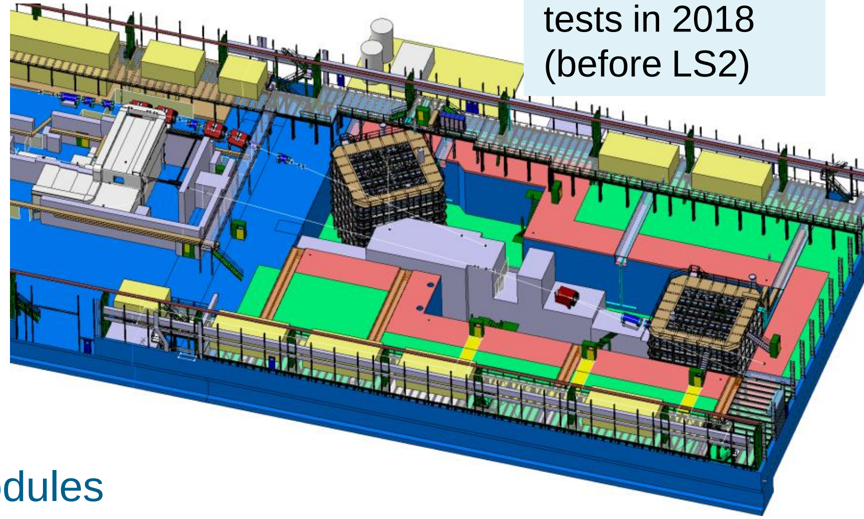


~0.5 Mton Water Cerenkov detector (~20 x Super-K)
~ 1 km underground
~ 2.5^0 off-axis → narrow-band beam

Complementary to LBNE: different detector technology, shorter baseline (→ less sensitive to mass hierarchy), narrow-band beam (→ high statistics of ν/anti-ν at oscillation peak but limited measurement of oscillation spectrum)

CERN Neutrino Platform

ready for beam tests in 2018 (before LS2)



Mission:

- ❑ Provide charged beams and test space to neutrino community → North Area extension
- ❑ Support European participation in accelerator neutrino experiments in US and Japan:

→ R&D to demonstrate large-scale LAr technology (cryostats, cryogenics, detectors)

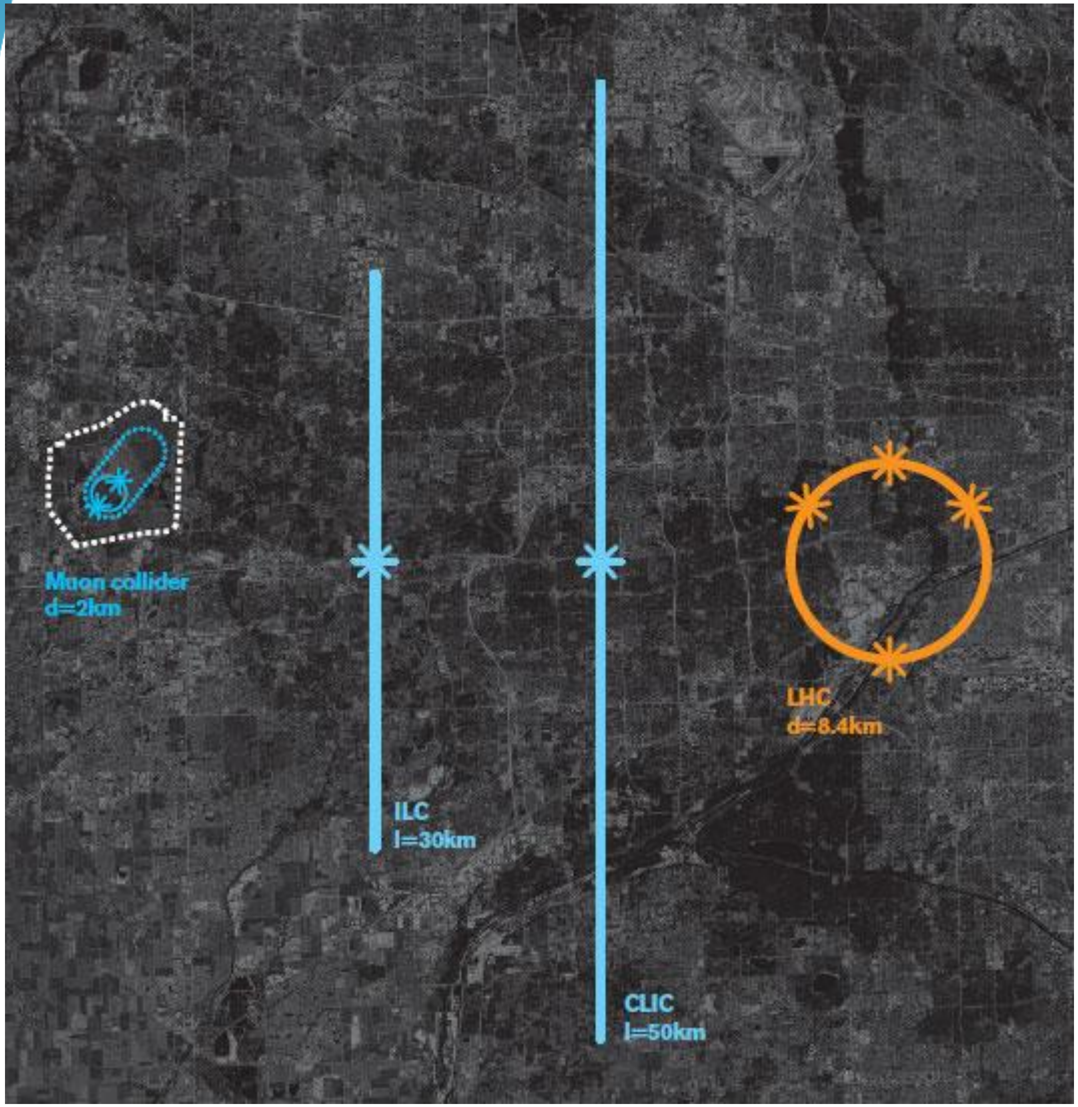
→ Construction of one cryostat for DUNE detector modules

→ Construction of BabyMIND magnet: muon spectrometer for WAGASCI experiment at JPARC

Refurbishment of ICARUS T600 for short baseline programme → ship to FNAL beg 2017

Construction and test of “full-scale” prototypes of DUNE drift cells: ~ 6x6x6 m^3, ~ 700 tons

Muones?


Muon collider
d=2km
ILC
l=30km
CLIC
l=50km
LHC
d=8.4km


Muon Collider Workshop
ARIES

FUTURO ….

¿¿Futuro??

Preparation of CERN's future

FCC-hh: 100 TeV
- ❑ explore directly the 10-50 TeV E-scale
- ❑ provide conclusive exploration of EWSB dynamics
- ❑ study nature the Higgs potential and EW phase transition
- ❑ say final word about heavy WIMP dark matter
- ❑ etc.

FCC-ee: 90-350 GeV
- ❑ indirect sensitivity to E scales up to O(100 TeV) by measuring most Higgs couplings to O(0.1%), improving the precision of EW parameters measurements by ~20-200, $\Delta M_W < 1$ MeV, $\Delta m_{top} \sim 10$ MeV, etc.
- ❑ sensitivity to very-weakly coupled physics (e.g. light, weakly-coupled dark matter)
- ❑ etc.

FCC-ep: ~ 3.5 TeV
- ❑ unprecedented measurements of PDF and α_s
- ❑ new physics: leptoquarks, eeqq contact interactions, etc.
- ❑ Higgs couplings (e.g. Hbb to ~ 1%)
- ❑ etc.

Machines are complementary and synergetic, e.g. from measurement of ttH/ttZ ratio, and using ttZ coupling and H branching ratio from FCC-ee, FCC-hh can measure ttH to ~ 1%

Future opportunities other than high-energy colliders

A “Physics Beyond Colliders" Study Group has been put in place

Mandate
Explore opportunities offered by CERN accelerator complex and infrastructure to address outstanding questions in particle physics through projects:

- ❑ complementary to future high-energy colliders (HE-LHC, CLIC, FCC)
- ❑ exploiting unique capabilities of CERN accelerator complex and infrastructure
- ❑ complementary to other efforts in the world → optimise resources of the discipline globally

Examples: searches for rare processes and very-weakly interacting particles, electric dipole moments, etc.

→ Enrich and diversify CERN’s future scientific programme

- ❑ Will bring together accelerator scientists, experimental and theoretical physicists
- ❑ Kick-off meeting in Summer 2016
- ❑ Final report end 2018 → in time for European Strategy

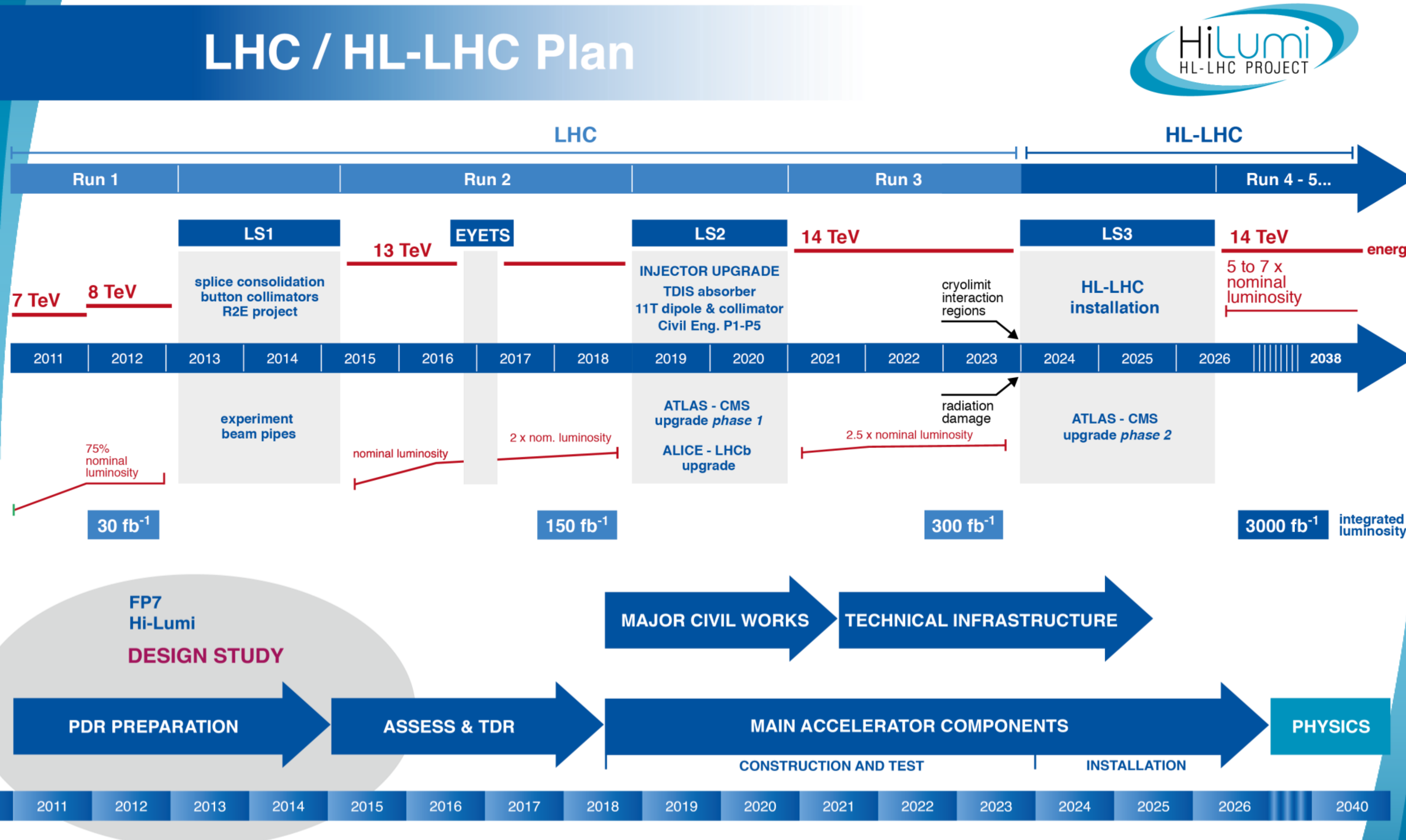
One of the goals is to involve interested worldwide community, and to create synergies with other laboratories and institutions in Europe (and beyond)

29

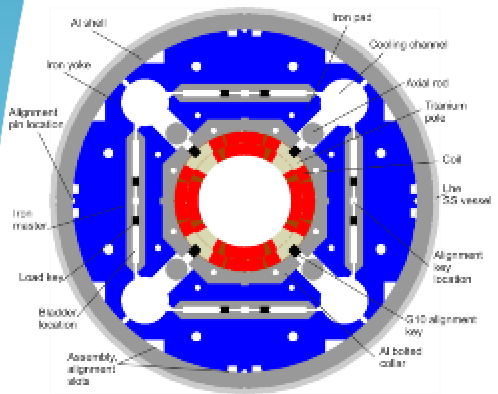
PRESENTE ….

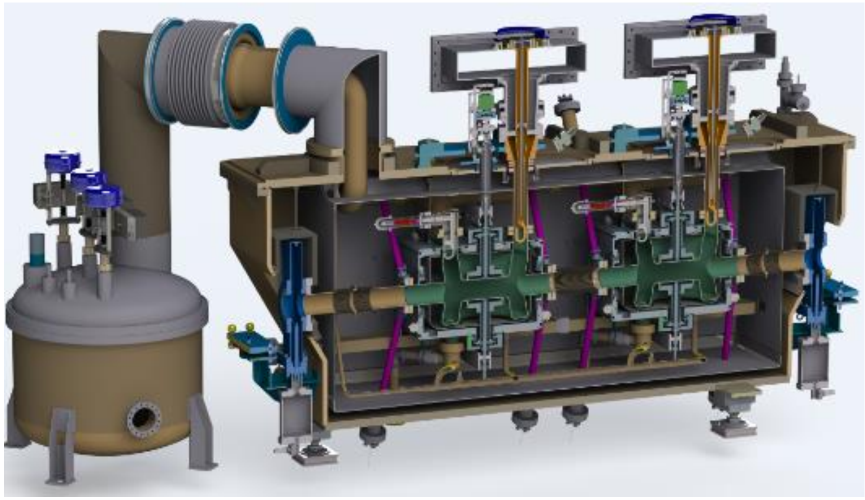
¿¿Presente??

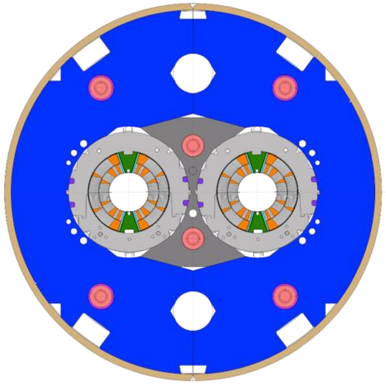
… and what comes now

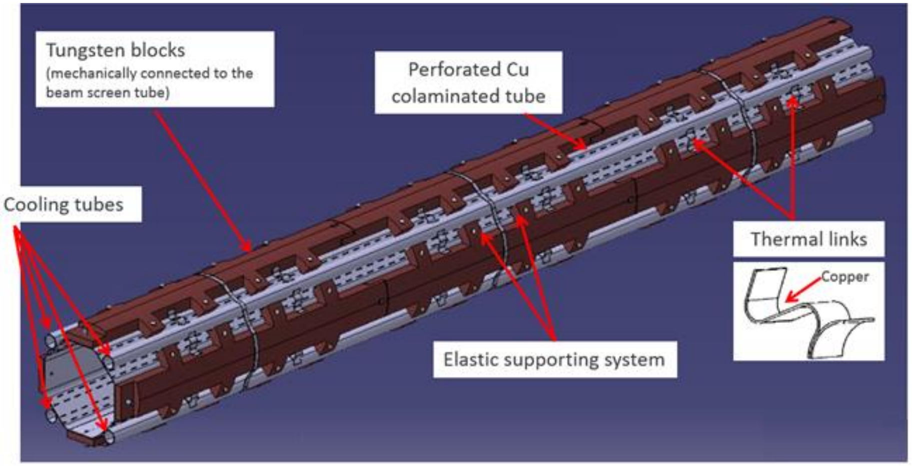


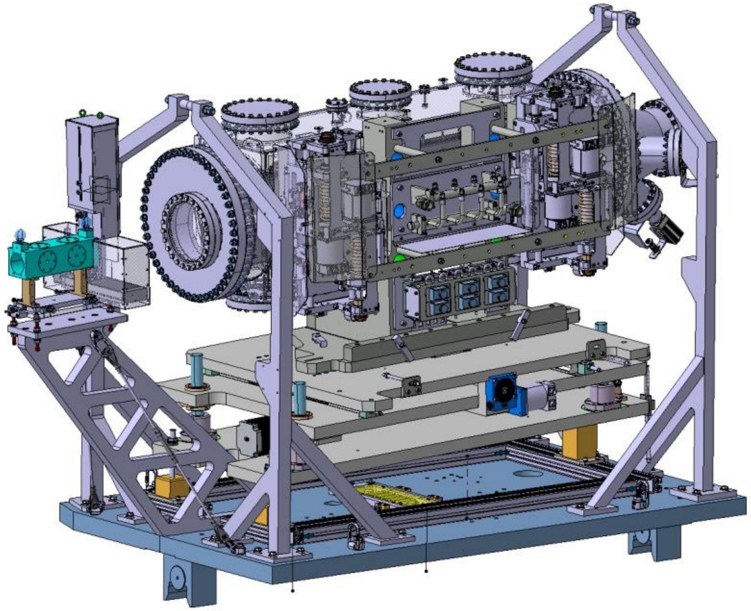
2011-2019: Design and prototypes



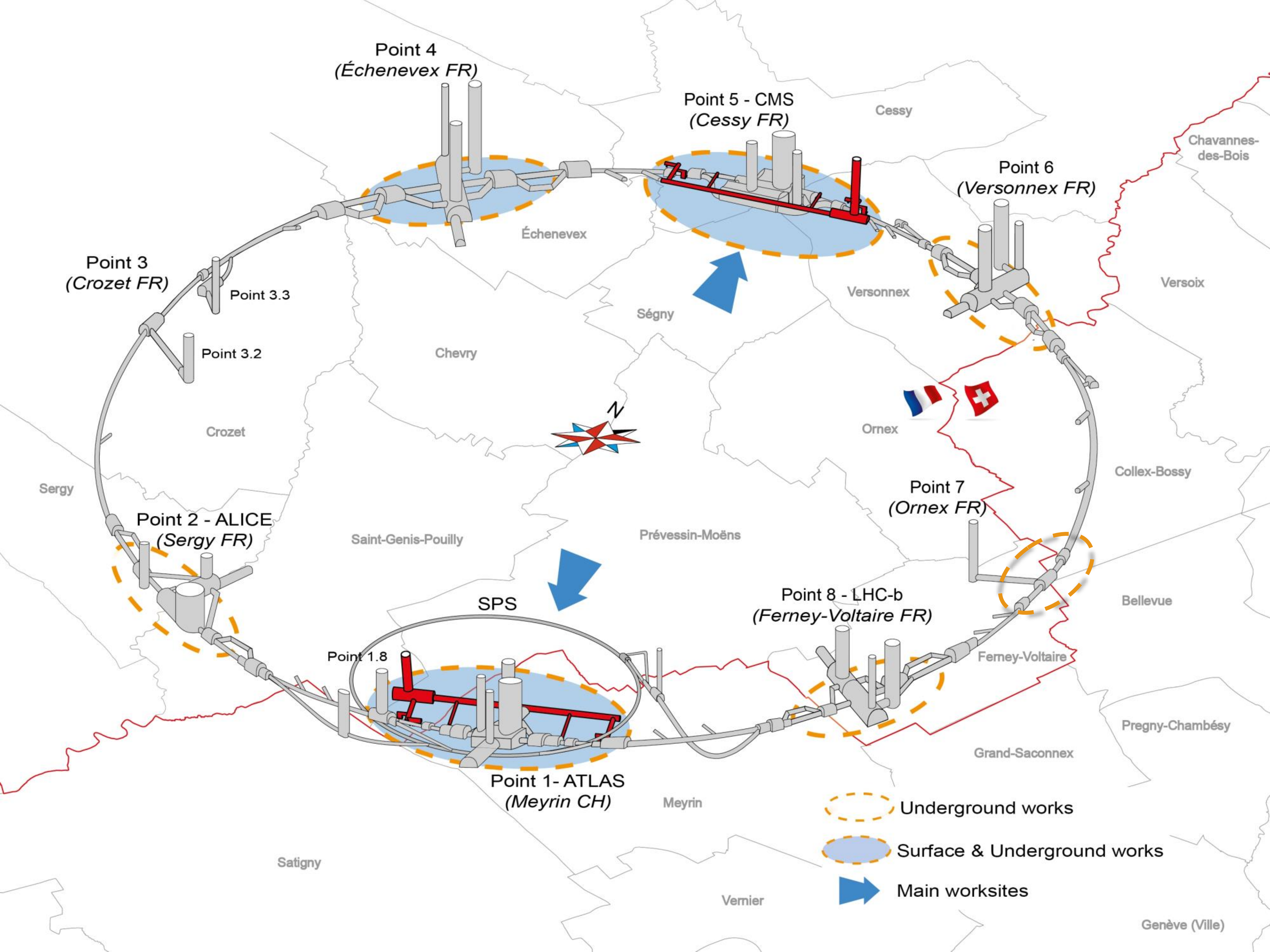









ARRET D'URGENCE
GENERAL
EMERGENCY STOP



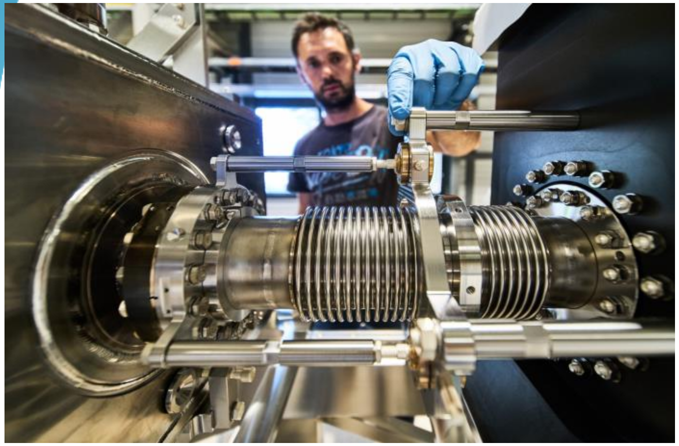
Point 4
(Échenevex FR)
Point 5 - CMS
(Cessy FR)
Cessy
Chavannes-des-Bois
Point 6
(Versonnex FR)
Échenevex
Point 3
(Crozet FR)
Point 3.3
Point 3.2
Ségny
Versonnex
Versoix
Chevry
Crozet
Ornex
Collex-Bossy
Sergy
Point 7
(Ornex FR)
Point 2 - ALICE
(Sergy FR)
Saint-Genis-Pouilly
Prévessin-Moëns
Bellevue
SPS
Point 8 - LHC-b
(Ferney-Voltaire FR)
Point 1.8
Ferney-Voltaire
Pregny-Chambésy
Grand-Saconnex
Point 1- ATLAS
(Meyrin CH)
Meyrin
Underground works
Surface & Underground works
Main worksites
Satigny
Vernier
Genève (Ville)

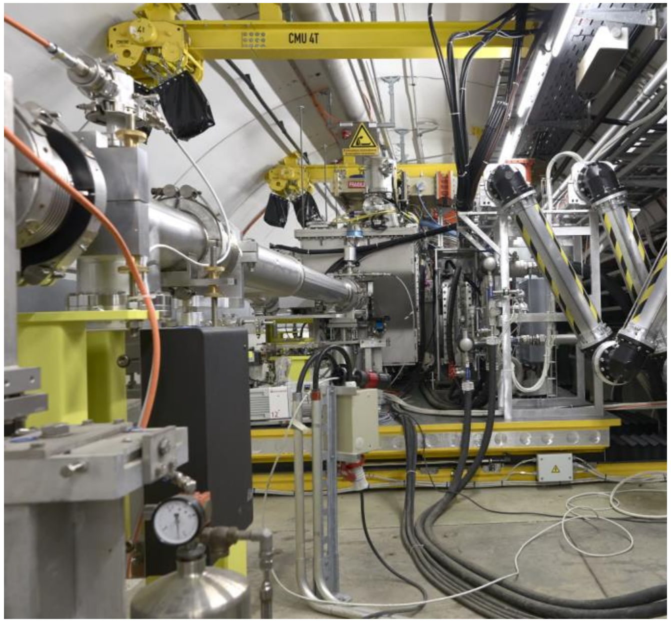
2018–2021: Major civil engineering works

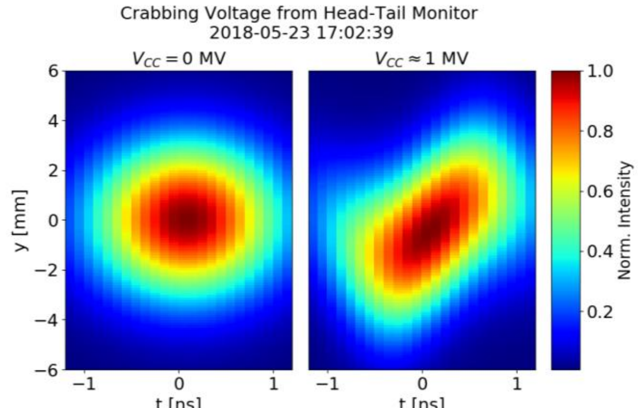
Walk inside … see it with your eyes

https://play.google.com/store/search?q=hilumi3d

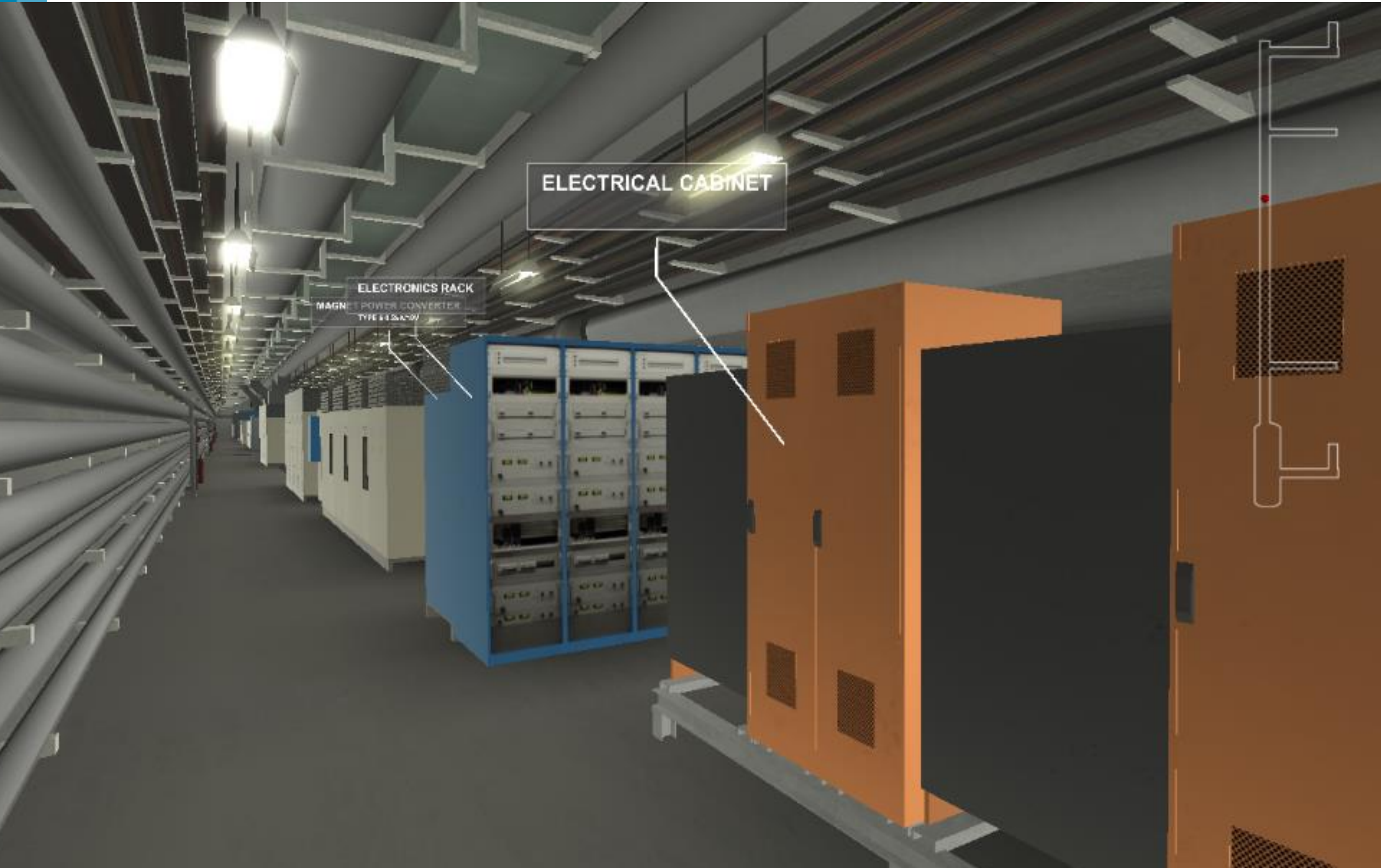
2018–2024: Construction and test of hardware components



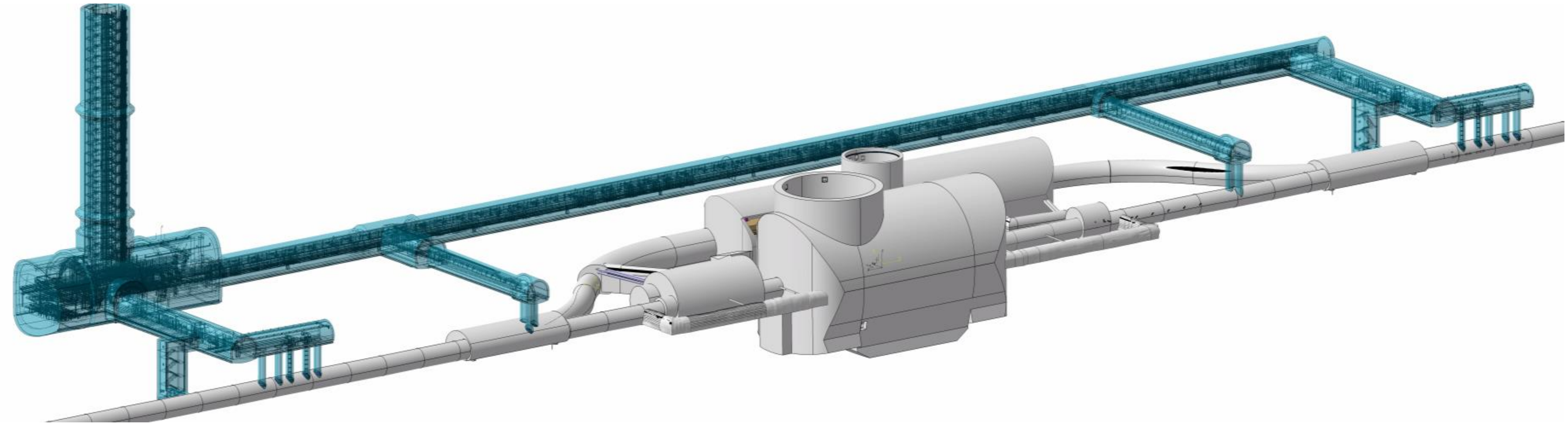


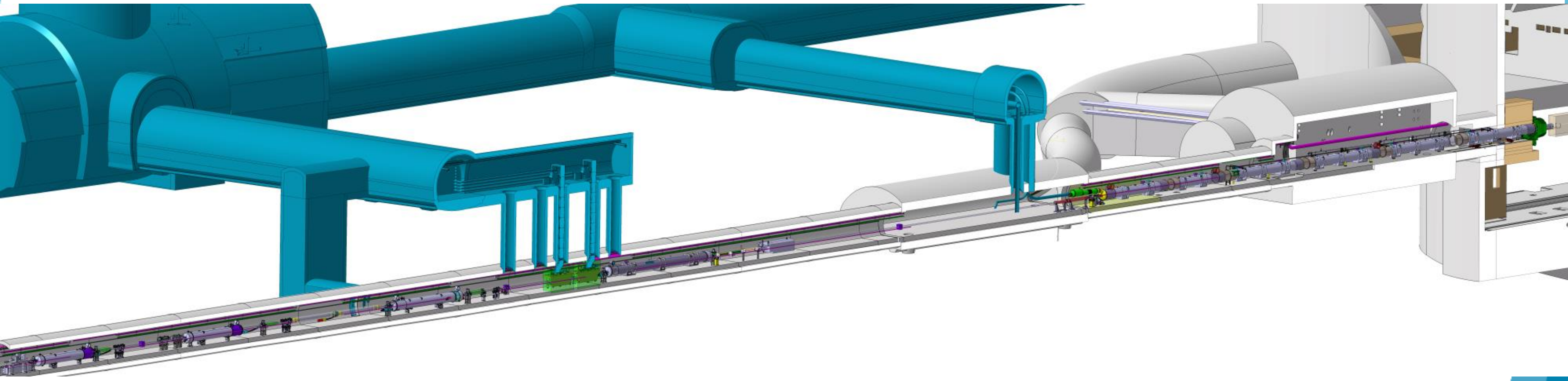


2021–2025: Preparation of infrastructure in the tunnel and new service galleries

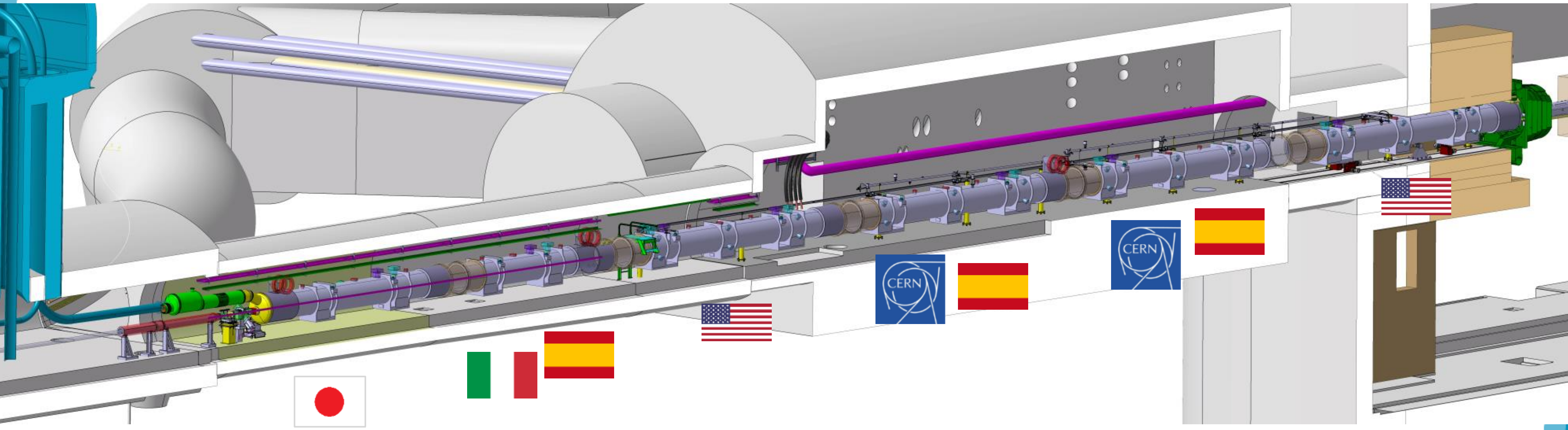


2024–2026 Long shutdown (LS3)

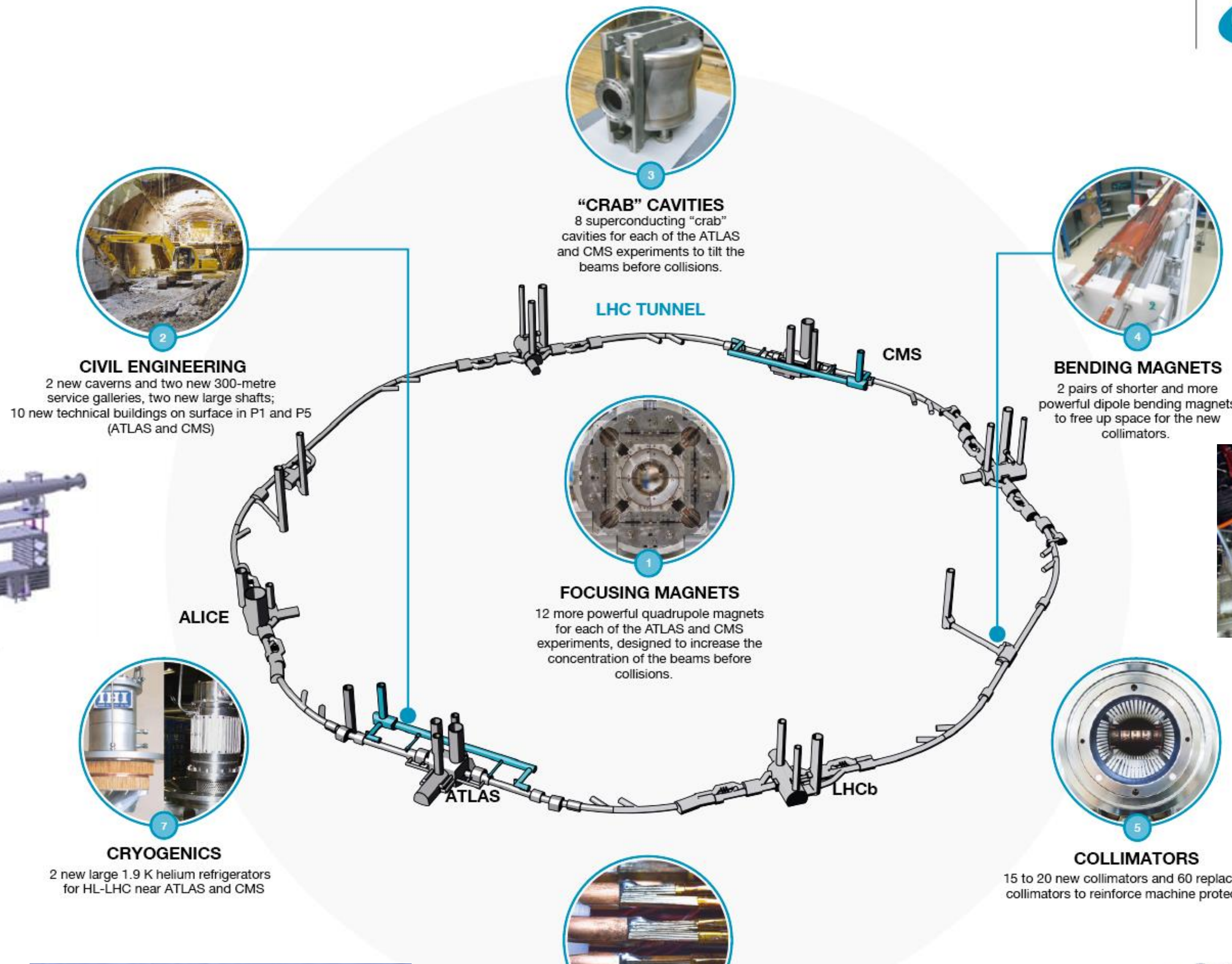


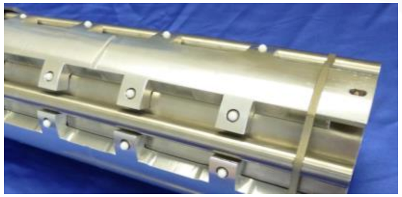


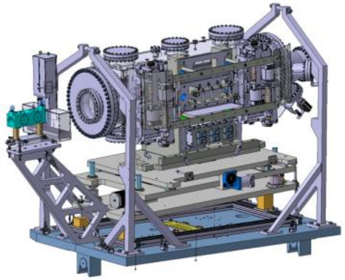
2024–2026 Long shutdown (LS3)



HL-LHC: Pushing the technology!





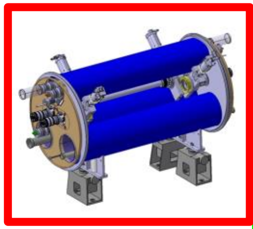


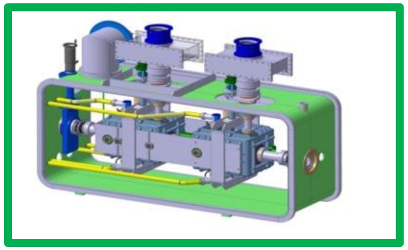
Global collaboration

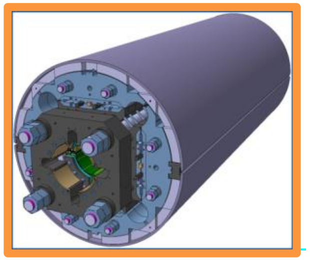
- BNL – Brookhaven National Laboratory
- CEA – Commissariat à l'Énergie Atomique
- CIEMAT – Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
- CERN – Conseil Européen pour la Recherche Nucléaire
- CI – Cockcroft Institute
- SOTON – University of Southampton
- UNIUPP – Uppsala University
- USDOE – United States Department of Energy
- STFC – Science & Technology Facilities Council
- FNAL – Fermilab
- INFN – Istituto Nazionale Fisica Nucleare
- KEK – KEK Japan
- ULAN – University of Lancaster
- LBNL – Lawrence Berkeley National Laboratory
- UNILIV – University of Liverpool
- UNIMAN – University of Manchester
- RHUL – Royal Holloway University
- SLAC – National Accelerator Laboratory
- BINP – Budker Institute of Nuclear Physics
- UDUN – University of Dundee
- EPFL – École Polytechnique Fédérale De Lausanne
- UHUD – University of Huddersfield
- IHEP – Institute of High Energy Physics
- JLAB – Jefferson Lab
- JINR – Joint Institute for Nuclear Research
- LAPIN AMK – Lapland University of Applied Sciences
- NCBJ – National Centre for Nuclear Research
- ODU – Old Dominion University
- TRIUMF – TRIUMF

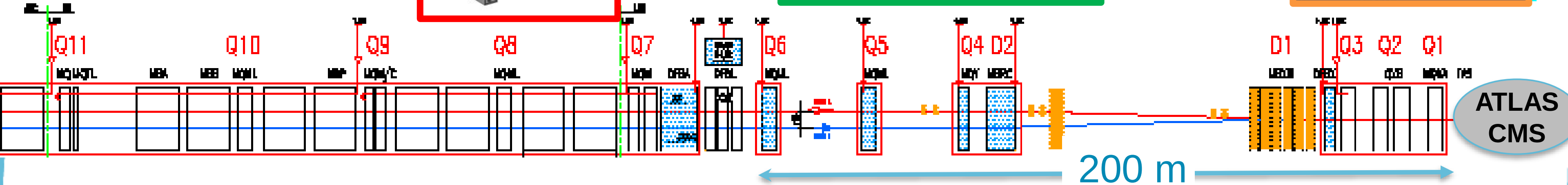
HiLumi HL-LHC PROJECT

The largest HEP accelerator in construction









Dispersion Suppressor (DS)

Modifications

1. In IP2: new DS collimation in c. Cryostat
2. In IP7 new DS collimation with 11 T

Cryogenics, Protection, Interface, Vacuum, Diagnostics, Inj/Extr… extension of infrastructure

Matching Section (MS)

Complete change and new lay-out

1. TAN
2. D2
3. CC
4. Q4
5. All correctors
6. Q5
7. New MQ in P6
8. New collimators

Interaction Region (ITR)

Complete change and new lay-out

1. TAXS
2. Q1-Q2-Q3
3. D1
4. All correctors
5. Heavy shielding (W)

> 1.2 km of LHC

Y si el futuro es la física de partículas sin aceleradores….

Gracias a todos los que trabajan y aportan su granito de arena para resolver los misterios que nos entornan

Gracias a aquellos que contribuyen para que nuestro trabajo sea posible

Gracias a todos los que son curiosos y despiertan la curiosidad en los que les rodean