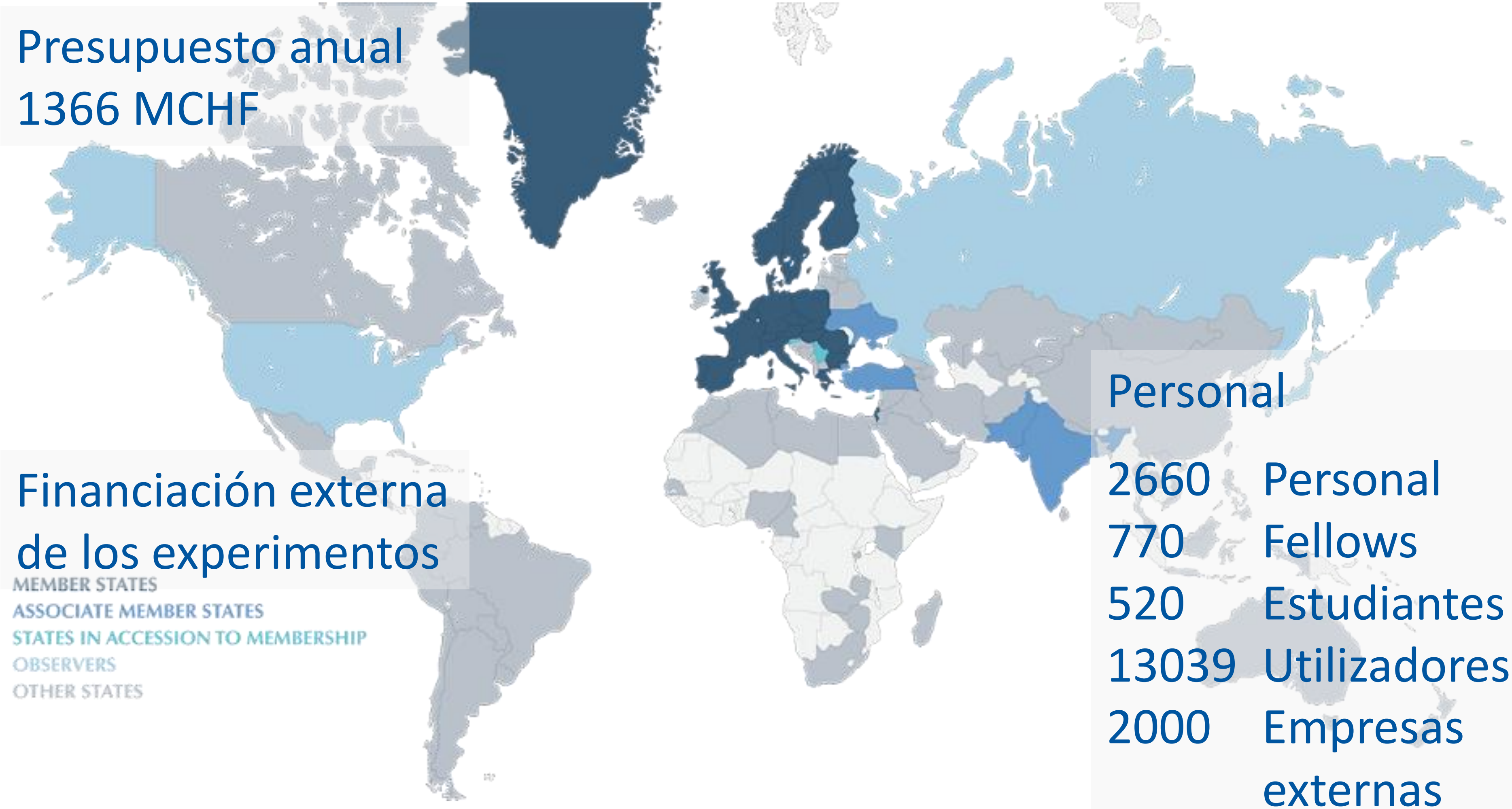
CERN

CERN: Acelerando Ciencia e Innovación

El laboratorio en física de partículas más grande del mundo

Presupuesto anual
1366 MCHF

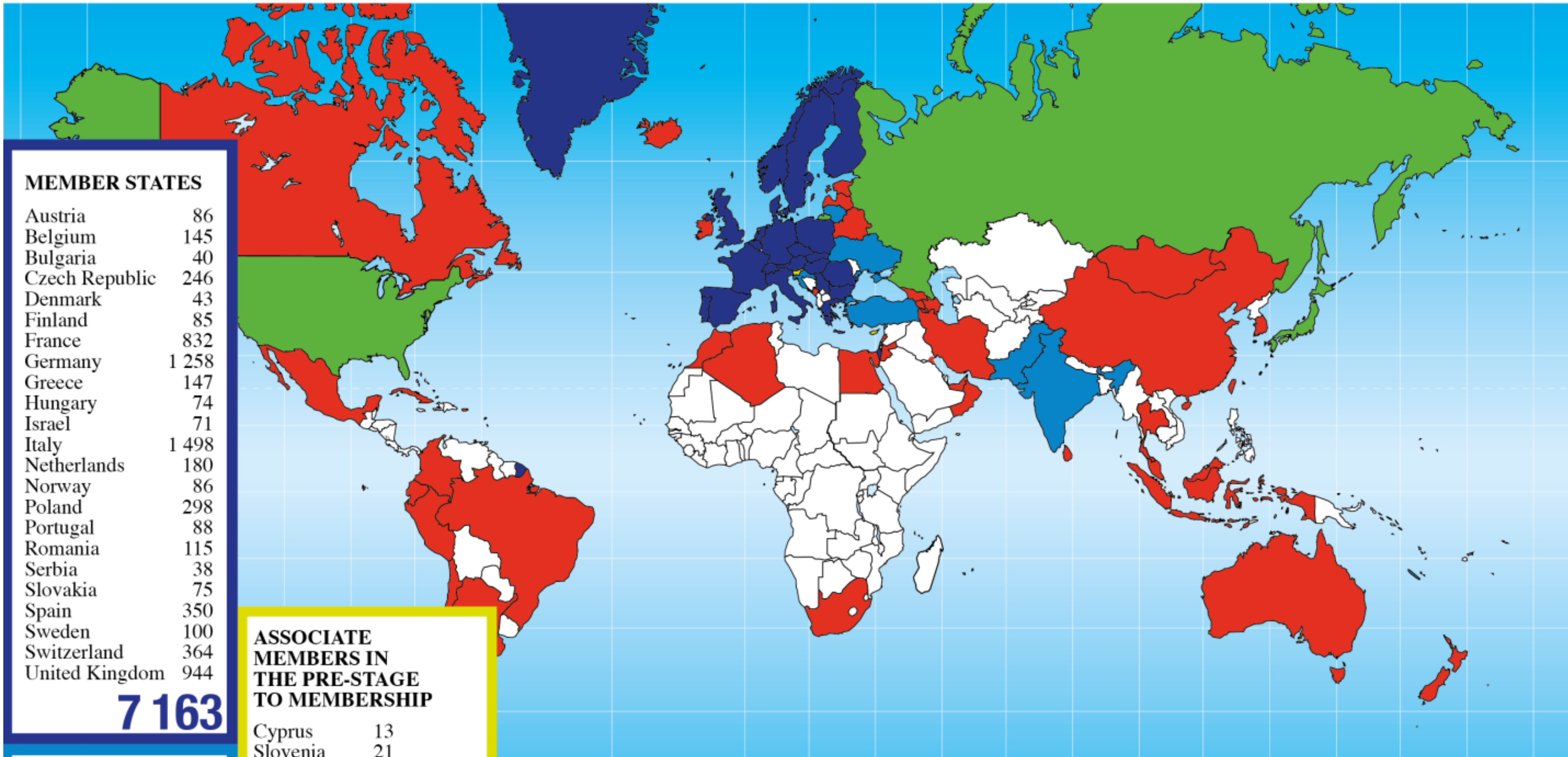


Financiación externa de los experimentos

Personal

2660	Personal
770	Fellows
520	Estudiantes
13039	Utilizadores
2000	Empresas externas

Distribution of All CERN Users by Location of Institute on 27 January 2020



MEMBER STATES

Austria	86
Belgium	145
Bulgaria	40
Czech Republic	246
Denmark	43
Finland	85
France	832
Germany	1 258
Greece	147
Hungary	74
Israel	71
Italy	1 498
Netherlands	180
Norway	86
Poland	298
Portugal	88
Romania	115
Serbia	38
Slovakia	75
Spain	350
Sweden	100
Switzerland	364
United Kingdom	944

7 163

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

Cyprus	13
Slovenia	21

34

ASSOCIATE MEMBERS

Croatia	41
India	186
Lithuania	21
Pakistan	39
Turkey	128
Ukraine	35

450

OBSERVERS

Japan	245
Russia	1 071
USA	1 960

3 276

OTHERS

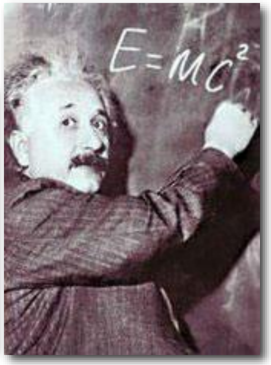
Algeria	3
Argentina	16
Armenia	13
Australia	23
Azerbaijan	2
Bahrain	3
Belarus	27
Brazil	114
Canada	206
Chile	22
China	362
Colombia	21
Cuba	3
Ecuador	4
Egypt	16
Estonia	24
Georgia	37
Hong Kong	21
Iceland	3
Indonesia	8
Iran	11
Ireland	7
Jordan	1
Korea	143
Kuwait	2
Latvia	2
Lebanon	15
Malaysia	9
Malta	4
Mexico	53
Mongolia	2
Montenegro	5
Morocco	16
New Zealand	11
Oman	1
Peru	3
Puerto Rico	1
Singapore	3
South Africa	80
Sri Lanka	8
Taiwan	55
Thailand	18
U.A.E.	2

1 380


Formación
Colaboración
Investigación &
Descubrimientos
Tecnología

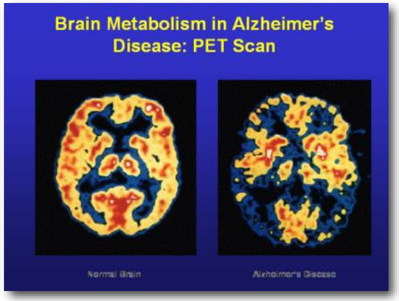
Innovación
Educación
CERN
uniendo pueblos
Investigación

Las Misiones del CERN



- **Empujar** las fronteras del conocimiento

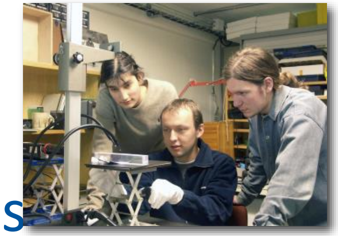
  Ej.: los secretos del Big Bang …¿como era la materia durante los primeros momentos de existencia del Universo?



- **Desarrollar** nuevas tecnologías en aceleradores y detectores

  Tecnología de la Información - la Web y la GRID

  Medicina - diagnosis y terapia



- **Entrenar** los científicos e ingenieros del mañana

- **Unir** gentes de países y culturas diferentes

Investigación & Descubrimientos

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)

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 ~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*

F. Englert and R. Brout
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.

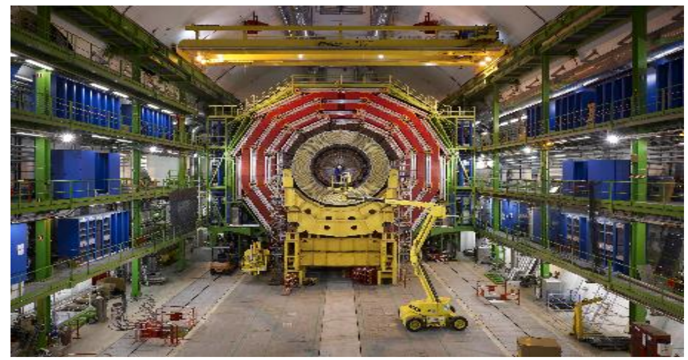
The interaction between the φ and the A_μ fields is

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

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



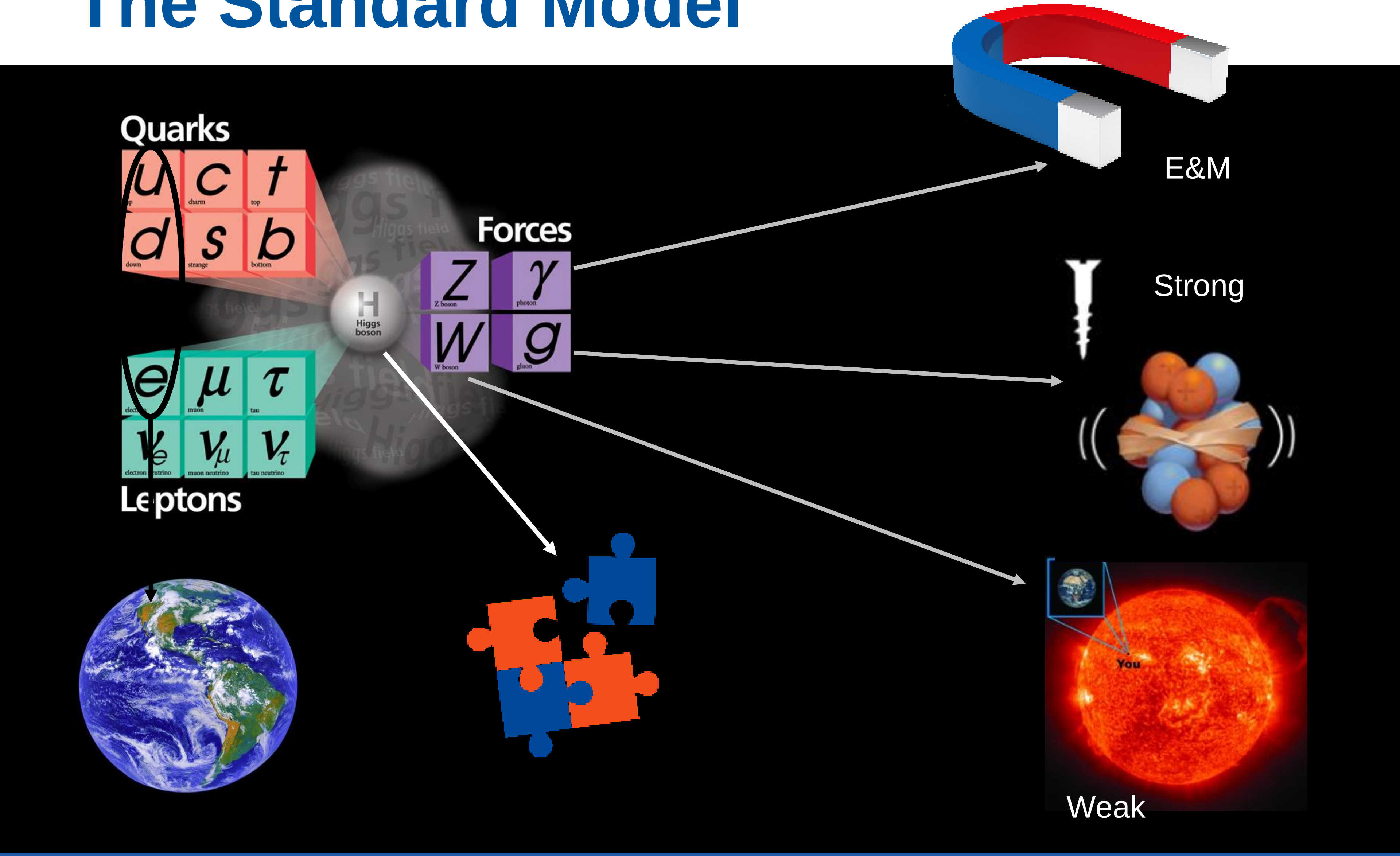
1964-2012

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".**

Y nuestro Premio Principe de Asturias

The Standard Model



Standard Model

Only 4%

is ordinary (visible) matter

The DARK Universe

96%

- 73% Dark Energy
- 23% Dark Matter

DARK …. MATTERS !

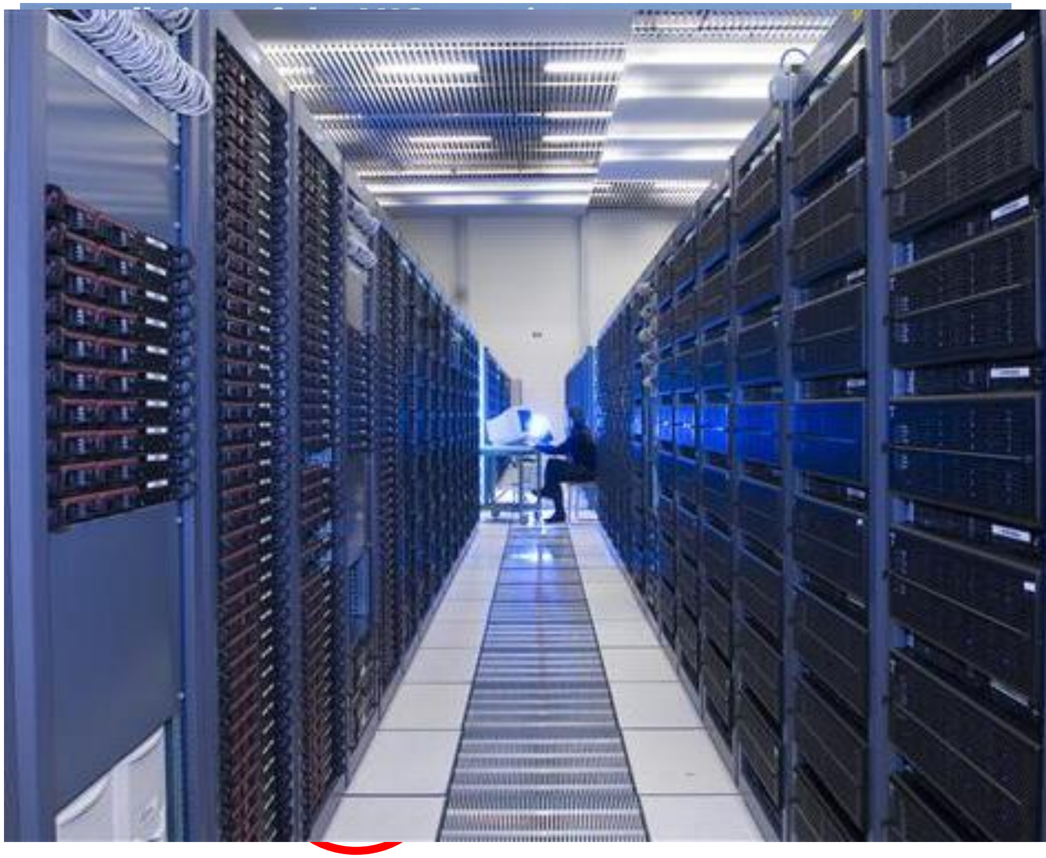
Tecnología

Las Herramientas

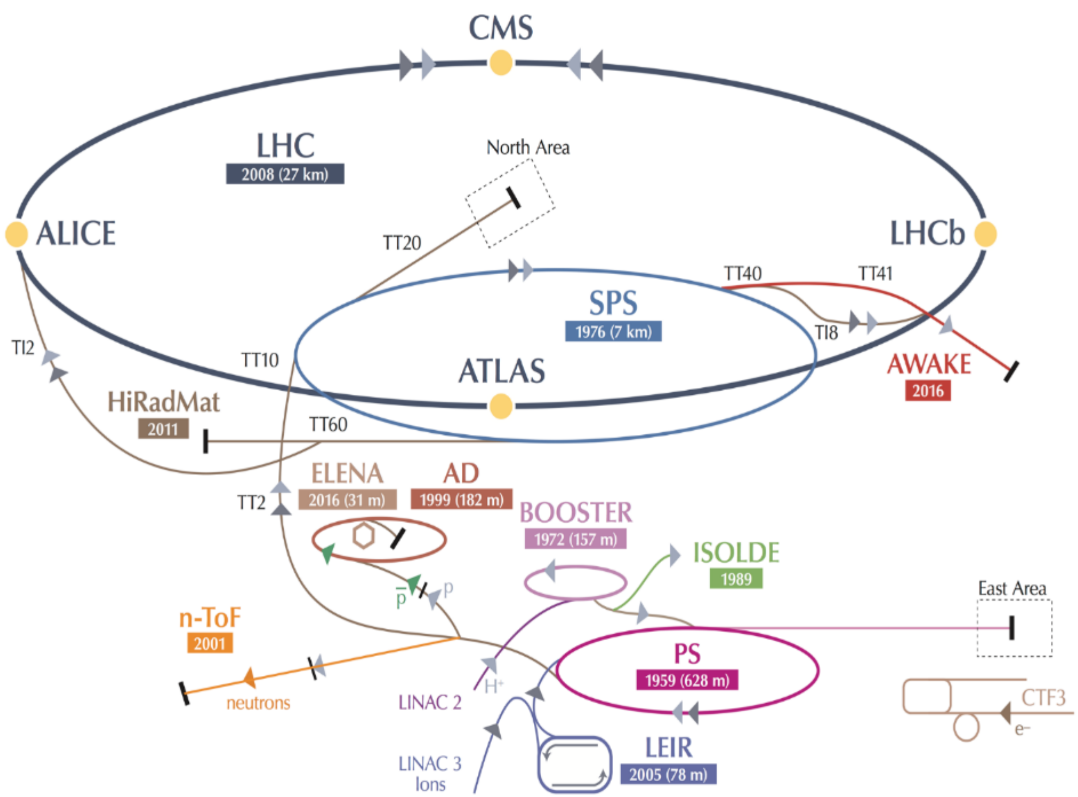
1. Aceleradores: Máquinas capaces de acelerar partículas a energías extremadamente altas y hacerlas colisionar

2. Detectores : Instrumentos gigantes que graban las trazas de las partículas

3. Ordenadores : Recogen, almacenan, distribuyen y analizan enormes cantidades de datos producidos por los detectores



CERN's accelerators
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 aerorosols 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

CERN

LHC: el acelerador más grande del mundo

27km de túnel 100 bajo tierra

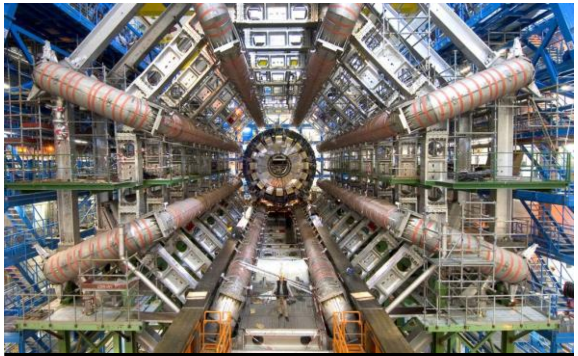
Miles de imanes superconductores (1.8×10^9 km de filamentos superconductores)

Ultra vacío:
10x más vacío que en la Luna

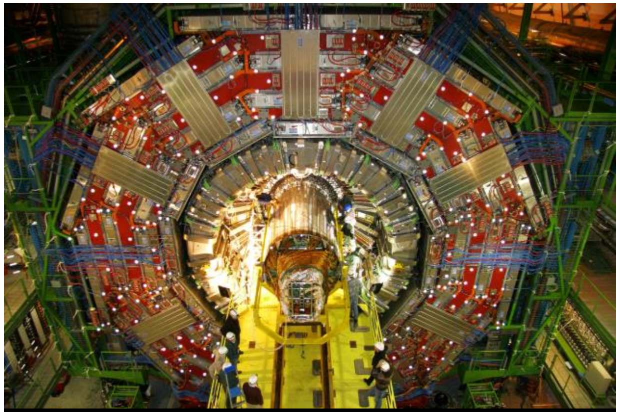
El lugar más frío del Universo:
-271° C

4 Experimentos: the coopetition

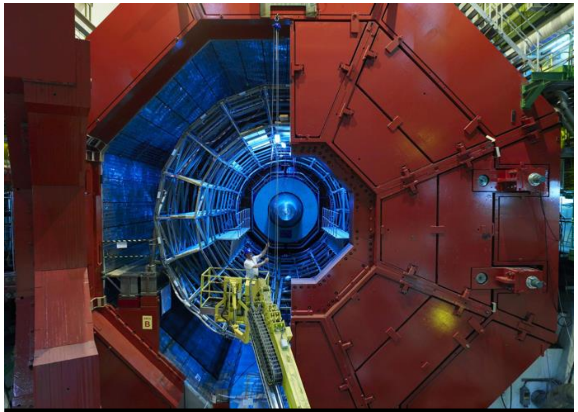
LHCB Collaboration:
19 Countries, 83 Institutes and 1339 members



ATLAS Collaboration:
38 Countries, 232 Institutes and 5500 members



CMS Collaboration:
51 Countries, 229 Institutes and 4488 members



ALICE Collaboration:
41 Countries, 176 Institutes and over 1800 members

Los detectores más grandes y más sofisticados

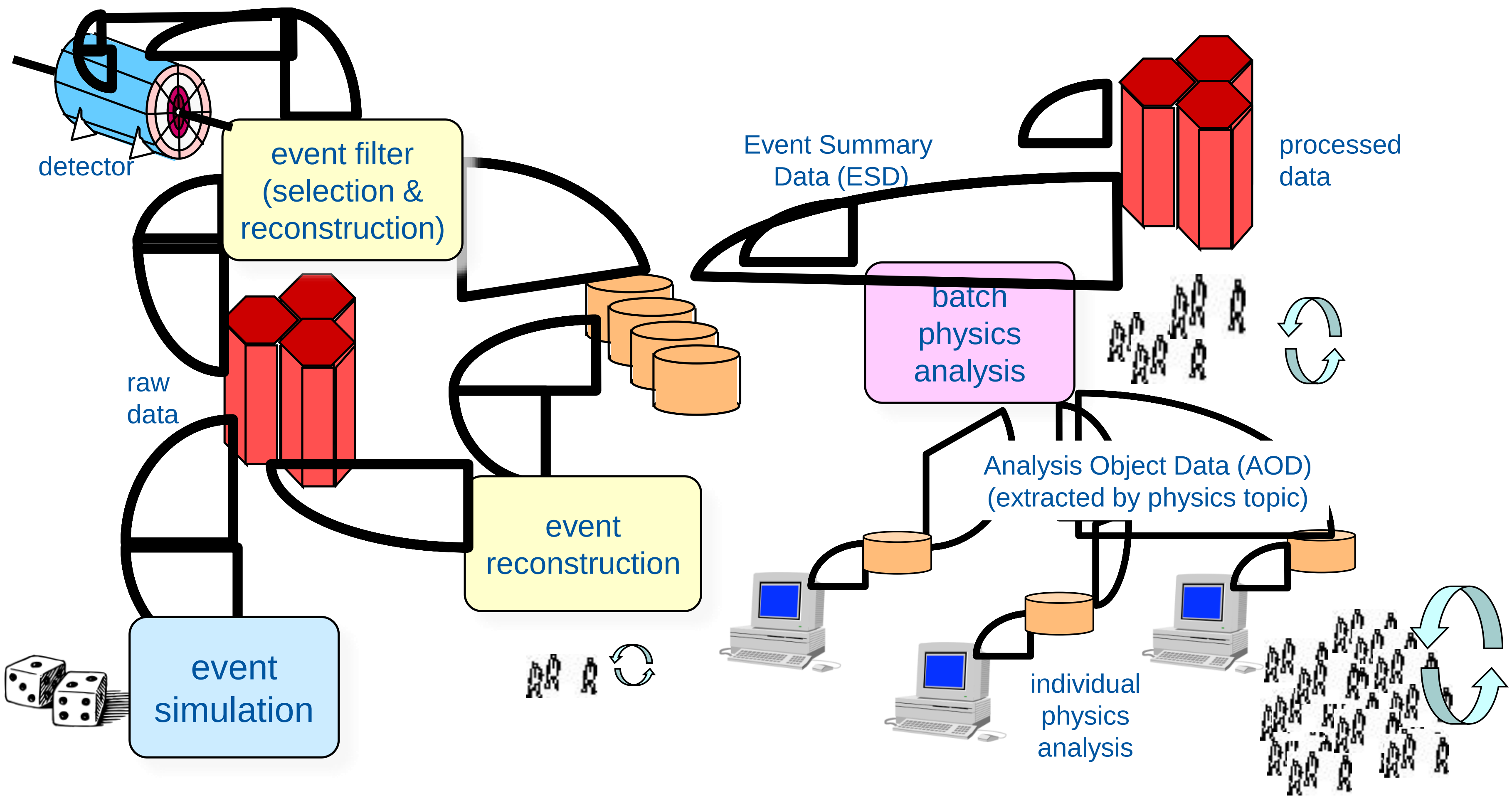
$E = mc^2$

Catedrales de la ciencia
100m bajo tierra

600 millones de colisiones/s detectadas
Por cientos de millones de sensores

Miles de colaboradores

Análisis de Datos



LHC (Large Hadron Collider)

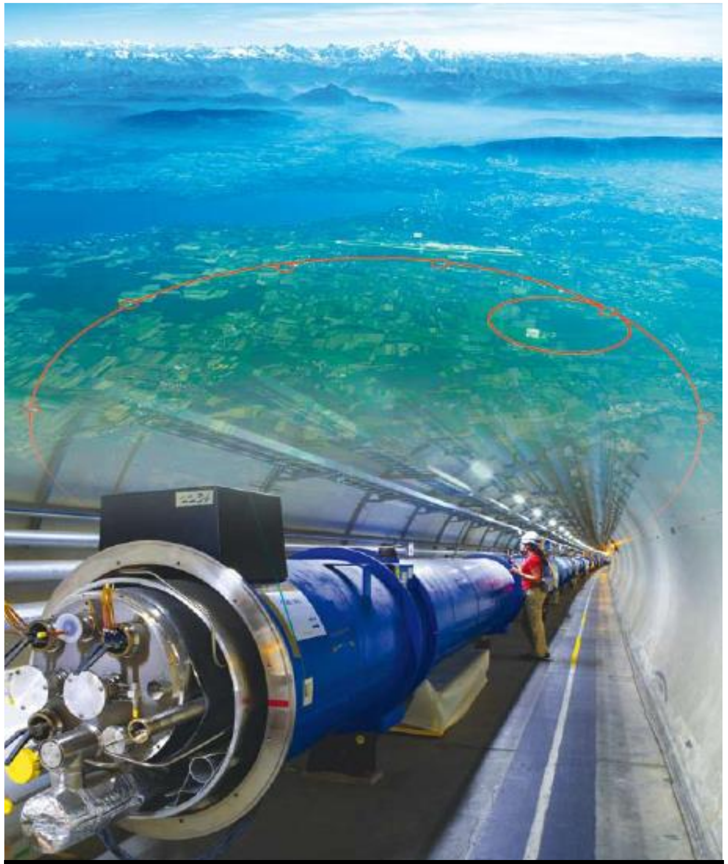
14 TeV proton-proton accelerator-collider built in the LEP tunnel

Lead-Lead (Lead-proton) collisions

1983	First studies for the LHC project
1988	First magnet model (feasibility)
1989	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*
2022 – 2024	Run 3 (14 TeV)
	2025 – 2027 HL-LHC installation
	2027 – 2035… HL-LHC operation

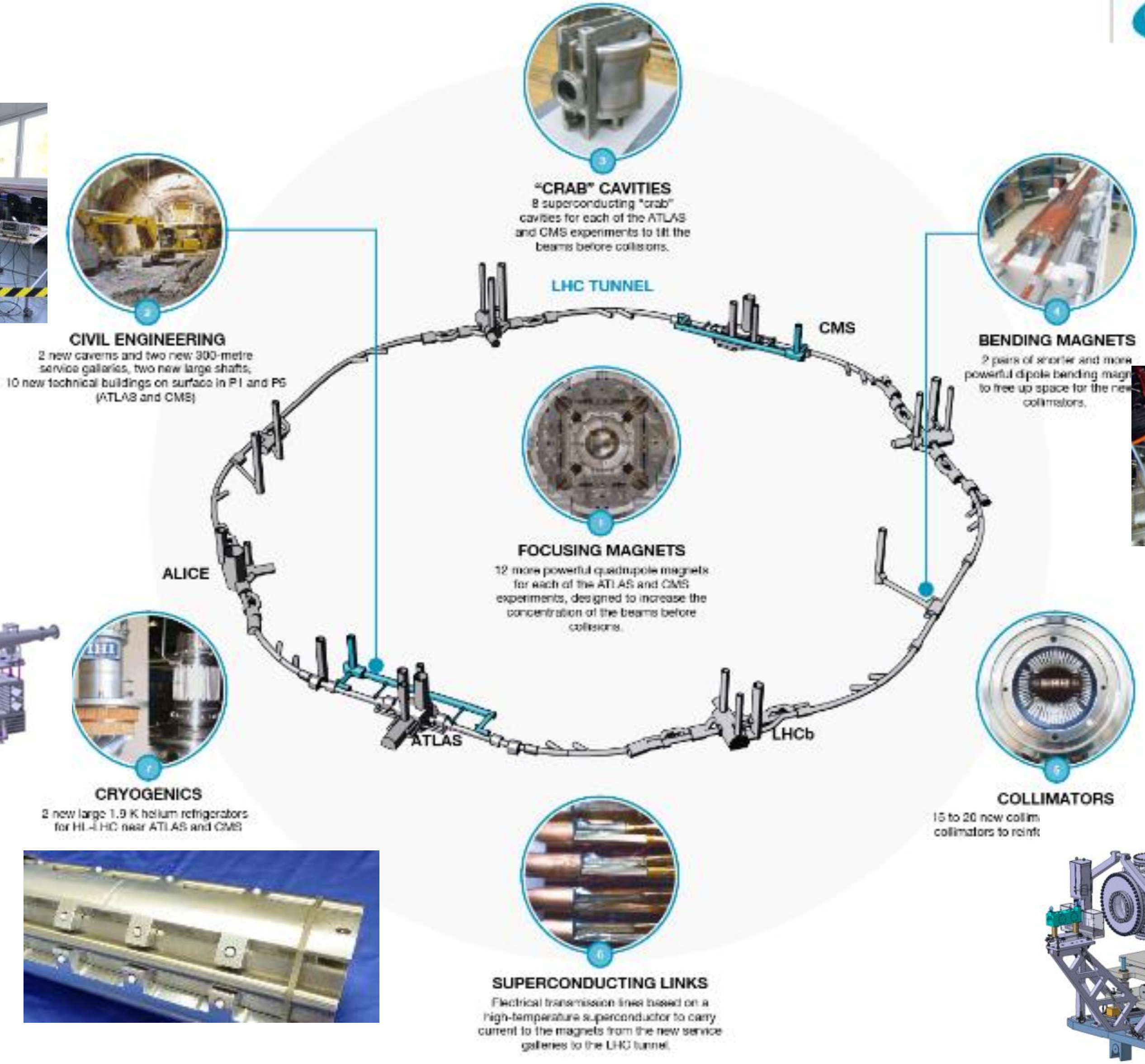
HiLumi HL-LHC PROJECT

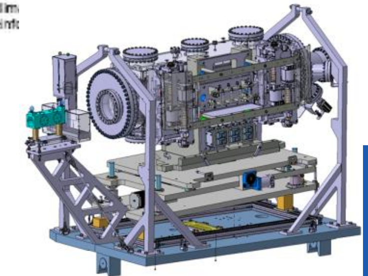


A 27 km circumference collider…

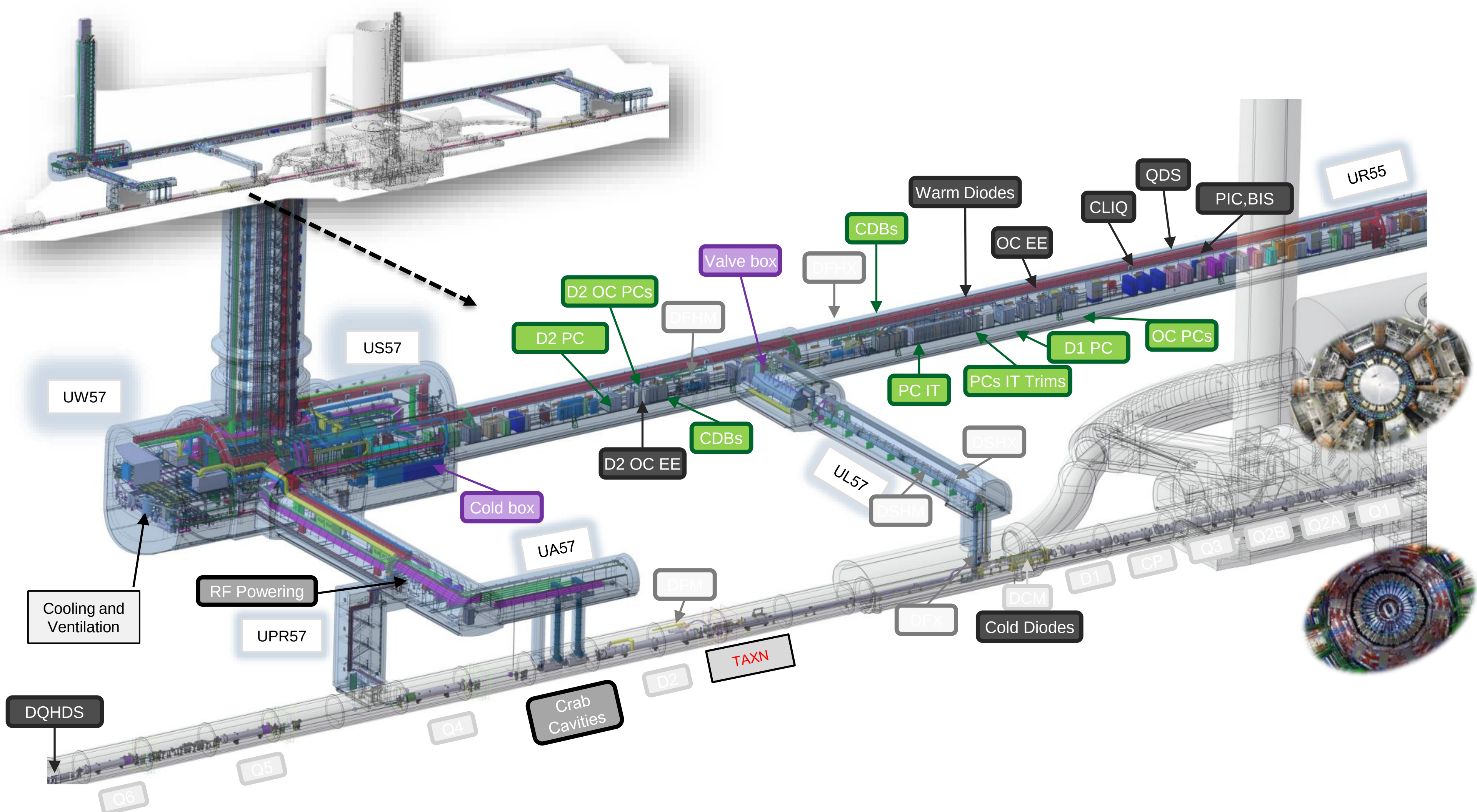
CERN

HL-LHC: Pushing the technology!



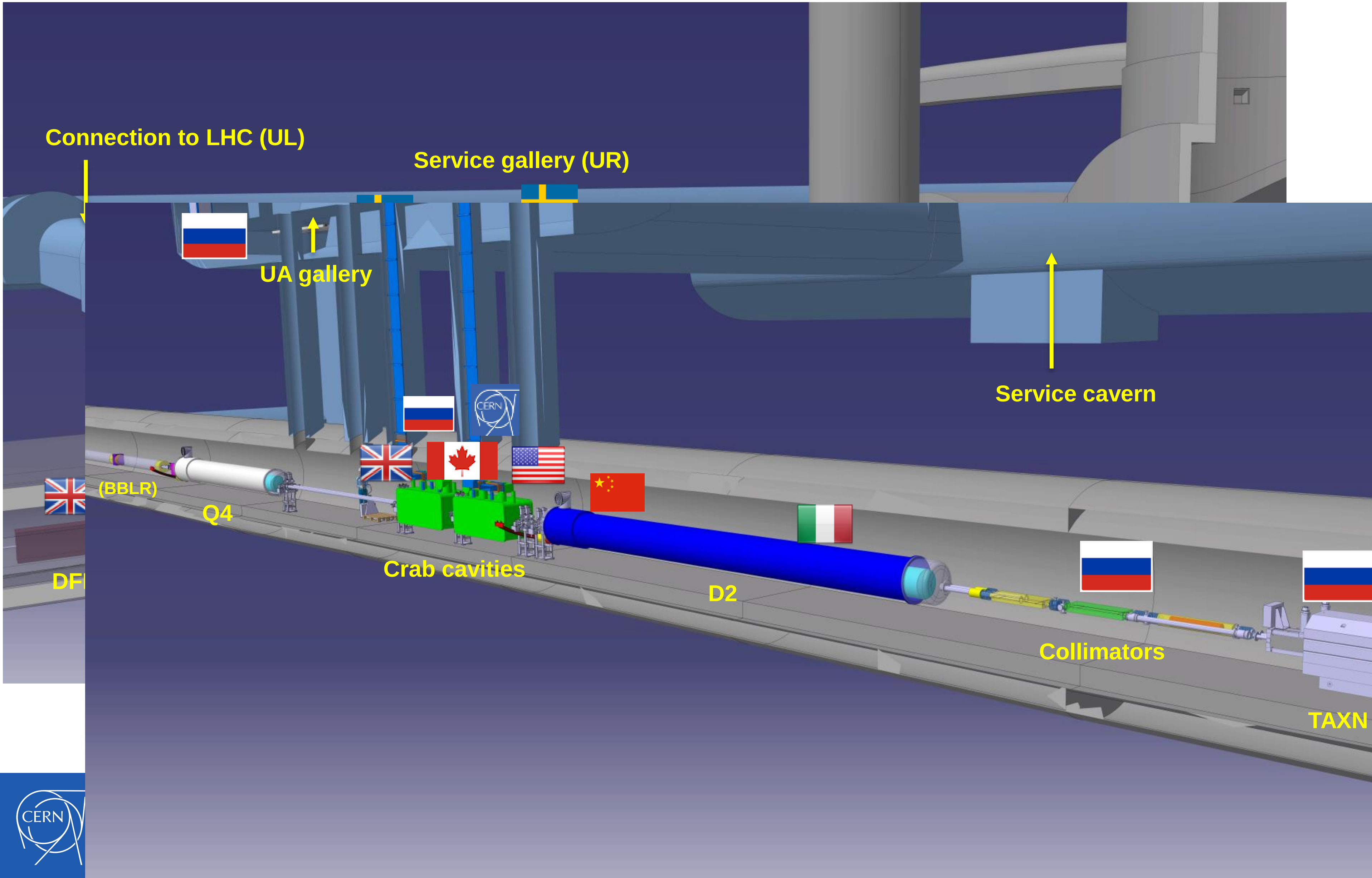


2025 – 2027 Long shutdown (LS3)



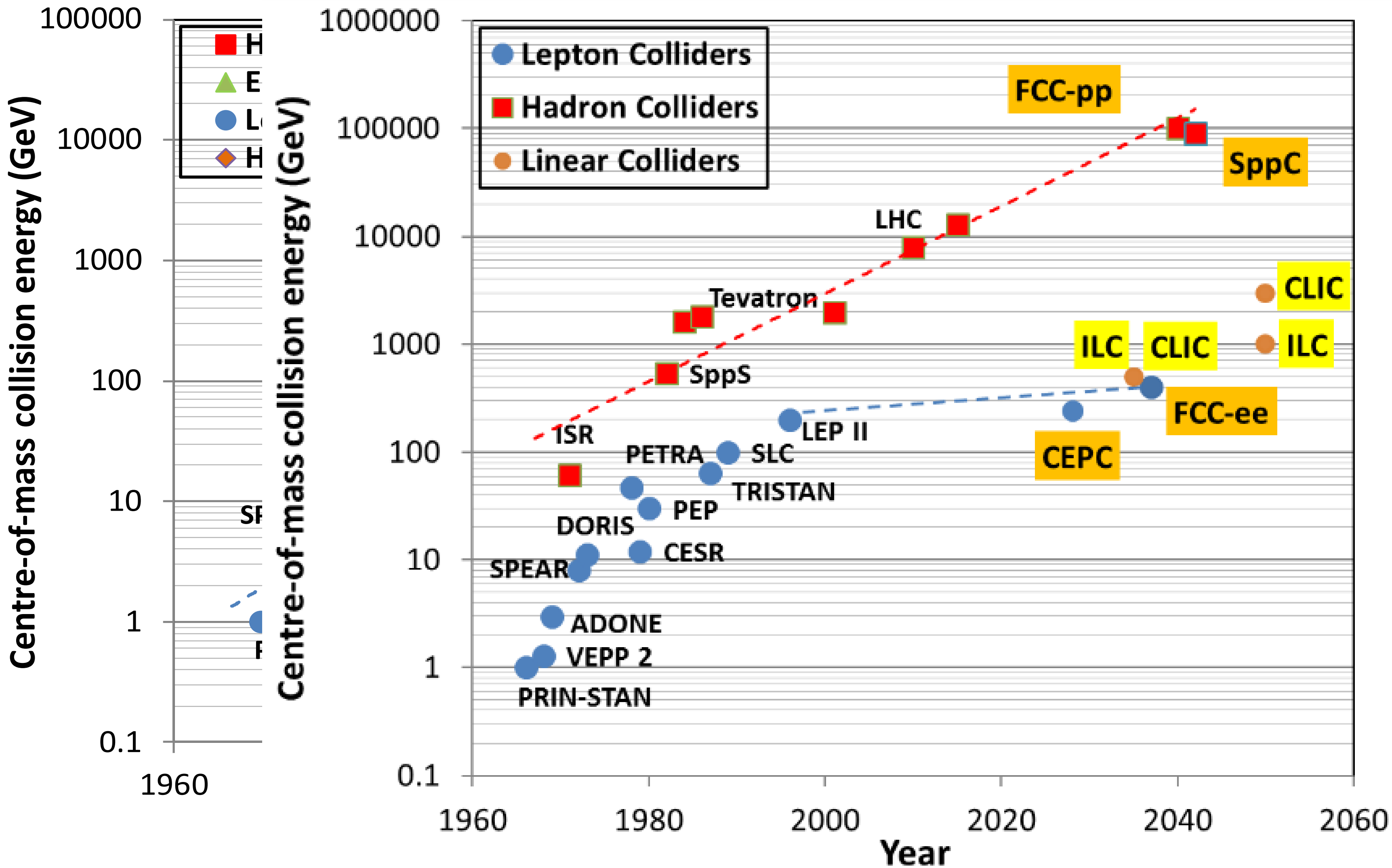
Underground Civil Engineering Excavation work to 95% completed!

2025–2027 Long shutdown (LS3)



A vibrant R&D on breakthrough technologies!

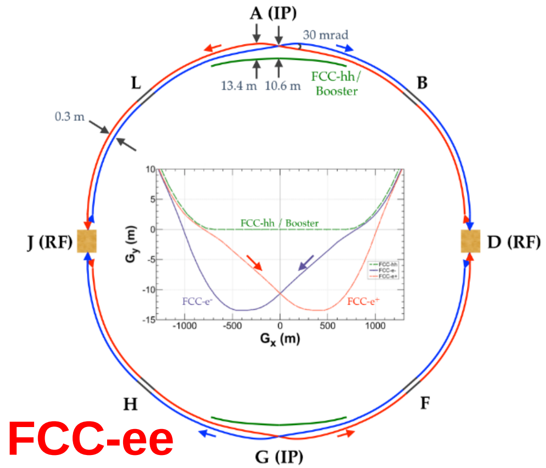
Fundamental role of Colliders

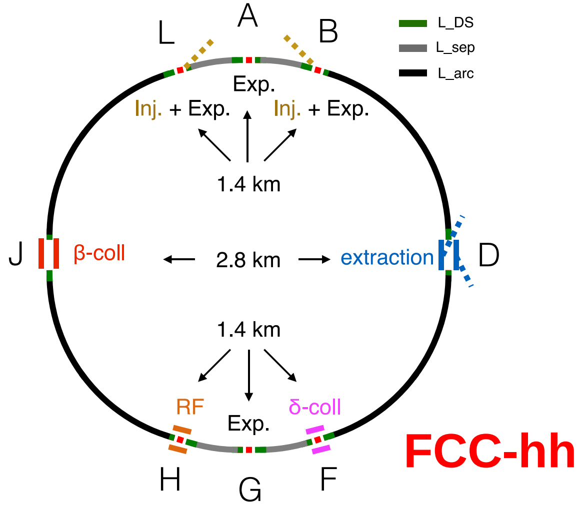


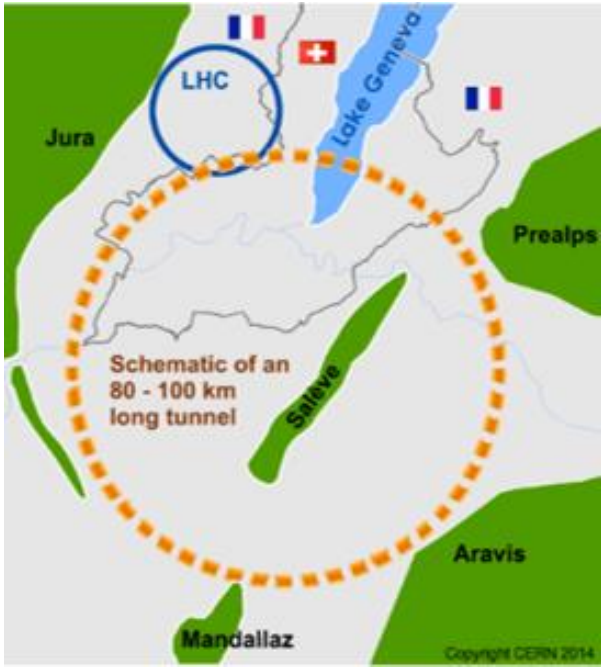
The FCC integrated program inspired by successful LEP – LHC programs at CERN

Comprehensive cost-effective program maximizing physics opportunities

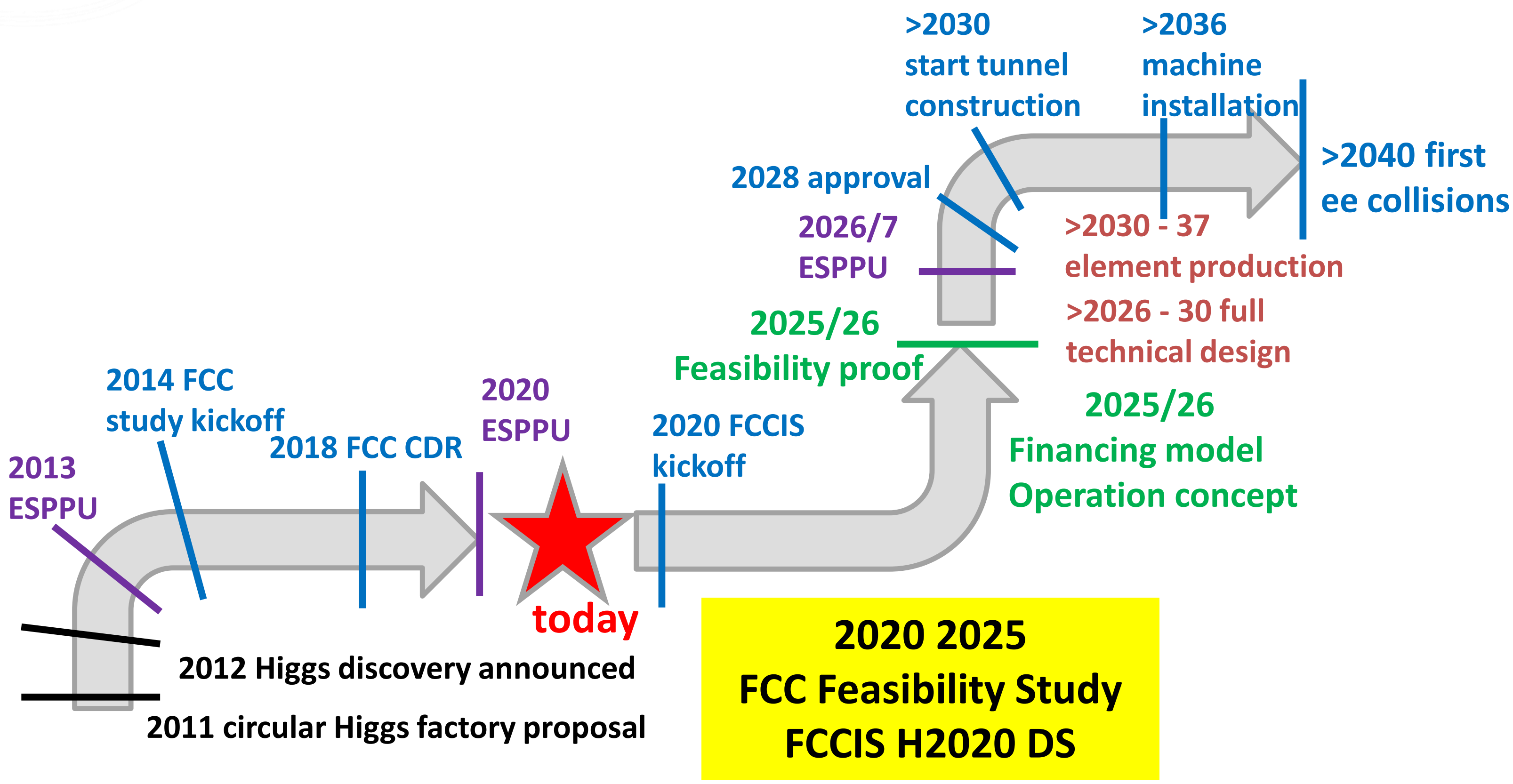
- **Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & and top factory at highest luminosities**
- **Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options**
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after HL-LHC







The FCC Road map



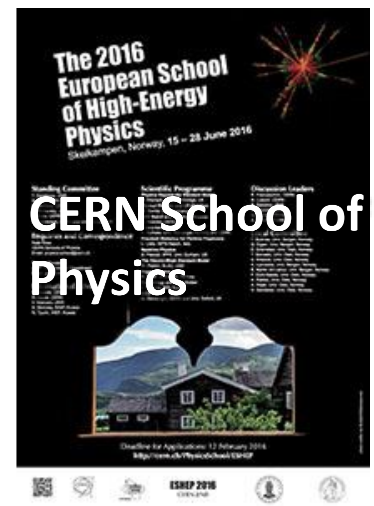
Formación

Actividades educativas del CERN

Científicos en el CERN
Programa de enseñanza académica

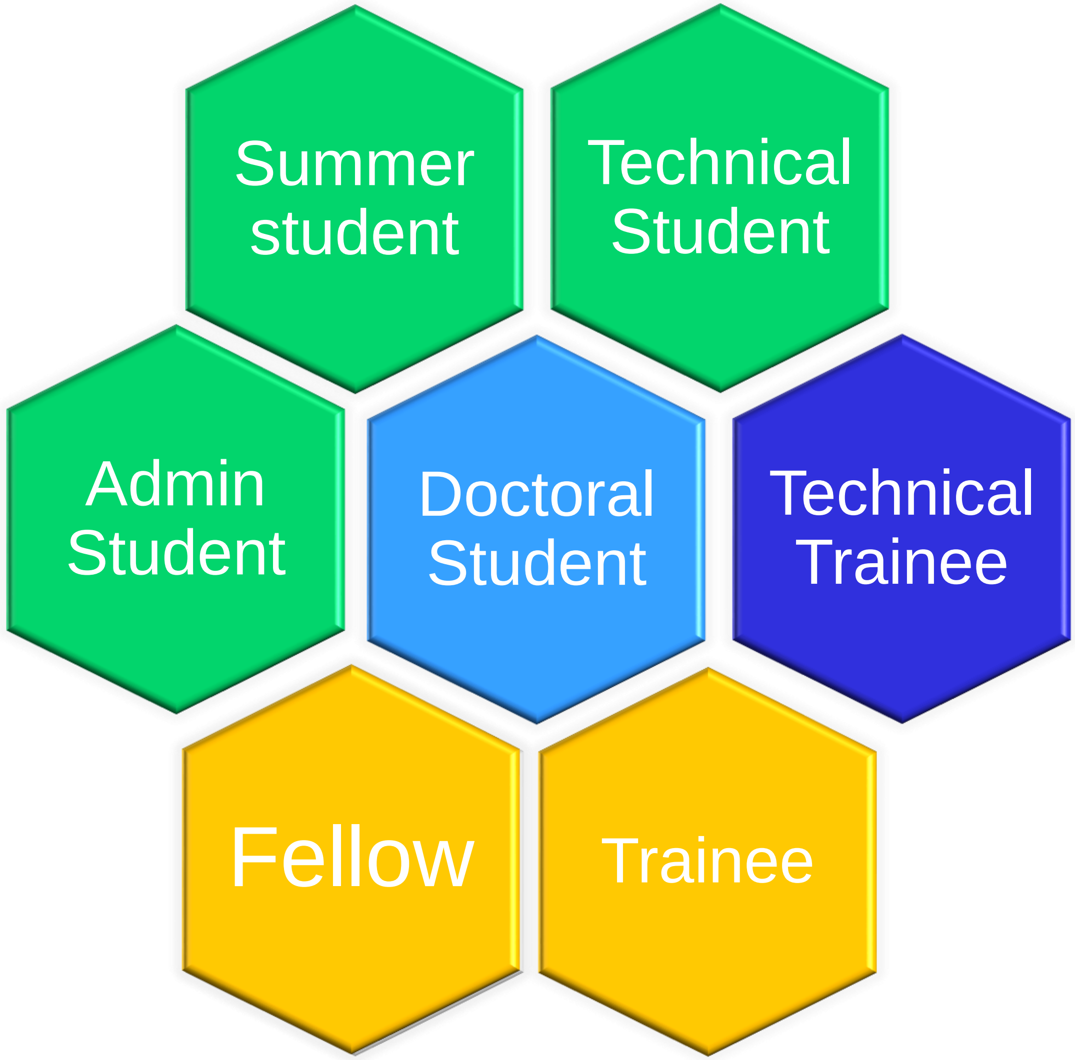
Jóvenes investigadores
Escuelas de física de altas energías
Escuela de computación
Escuela de aceleradores

Escuelas para profesores EM
Programas internacionales y nacionales



Estudiantes de física
Programa de estudiantes de verano

Actividades formativas del CERN



Bienvenidos al CERN

Esta es una presentación colectiva con contribuciones de decenas de personas.
Cooperando hasta lo imposible se consigue