# EL CERN CUMPLE 60 AÑOS


**MANUEL AGUILAR BENITEZ DE LUGO**
**REAL ACADEMIA DE CIENCIAS**

# 2014
# ANIVERSARIOS

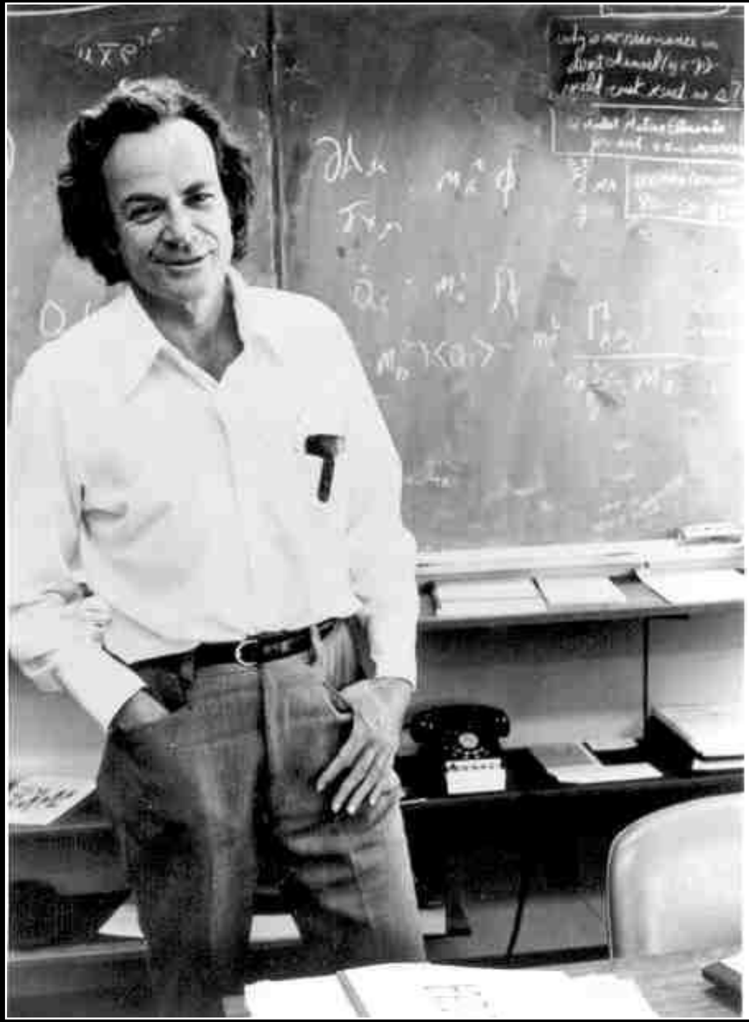
1954: CREACIÓN DEL CERN
1984: PREMIO NOBEL A RUBBIA, VAN DER MEER
1984: ESPAÑA RETORNA AL CERN

1964: “INVENCIÓN” DE LOS QUARKS
1964: VIOLACIÓN DE LA SIMETRÍA CP
1964: FORMULACIÓN DEL MECANISMO DE B-E-H

1974: DESCUBRIMIENTO DEL QUARK C

1964: DESCUBRIMIENTO DEL CMB

**THE AGE IN WHICH WE LIVE IS THE AGE IN WHICH WE ARE DISCOVERING THE FUNDAMENTAL LAWS OF NATURE, AND THAT DAY WILL NEVER COME AGAIN**



**R.P. FEYNMAN**

# CERN (1954–2014)

# FÍSICA DE PARTÍCULAS EN EL CERN

**ESTUDIO DE LOS CONSTITUYENTES ÚLTIMOS DE LA MATERIA, DE LAS FUERZAS FUNDAMENTALES A TRAVÉS DE LAS QUE INTERACCIONAN Y DE LAS LEYES QUE RIGEN LA EVOLUCIÓN DEL UNIVERSO**

- **HACER CRECER LAS FRONTERAS DEL CONOCIMIENTO**
- **AMPLIAR LAS FRONTERAS TECNOLÓGICAS**
- **EDUCAR A LOS CIENTÍFICOS E INGENIEROS DEL MAÑANA**
- **ACERCAR NACIONES A TRAVÉS DE LA CIENCIA**

"The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy."

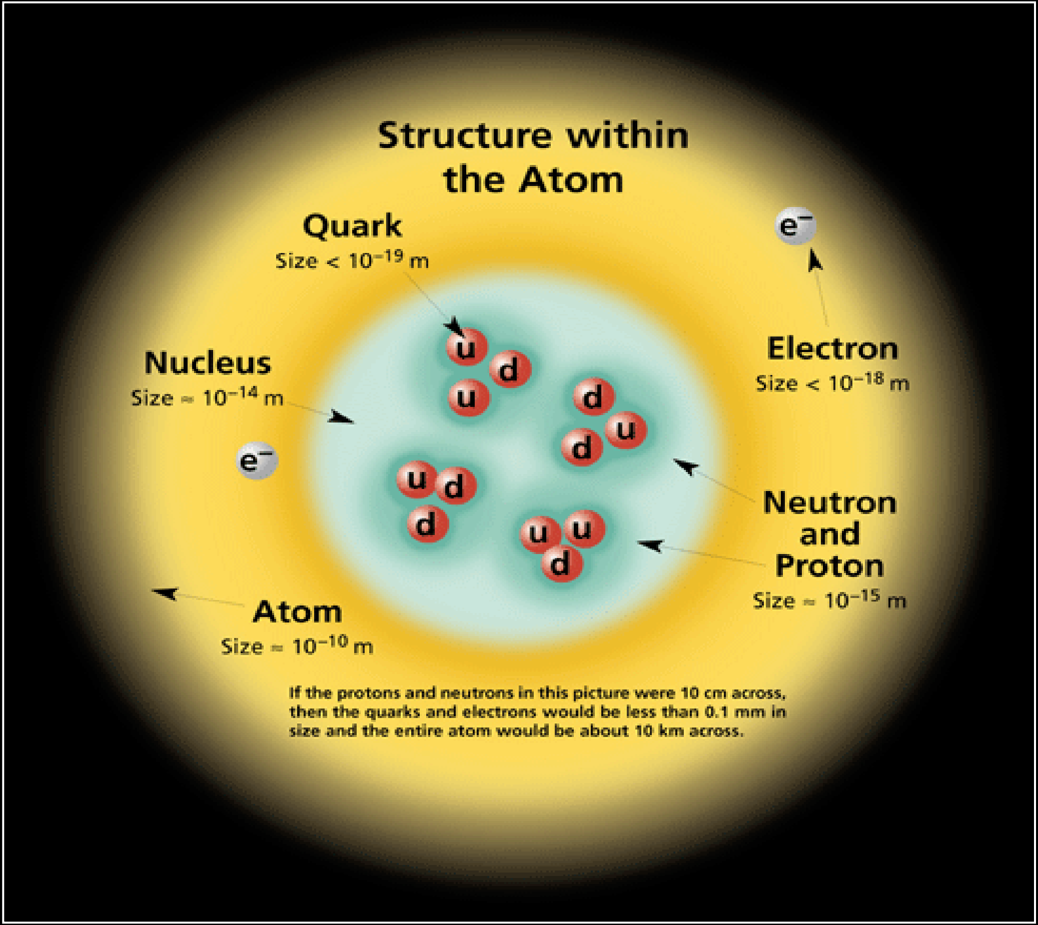
Steven Weinberg

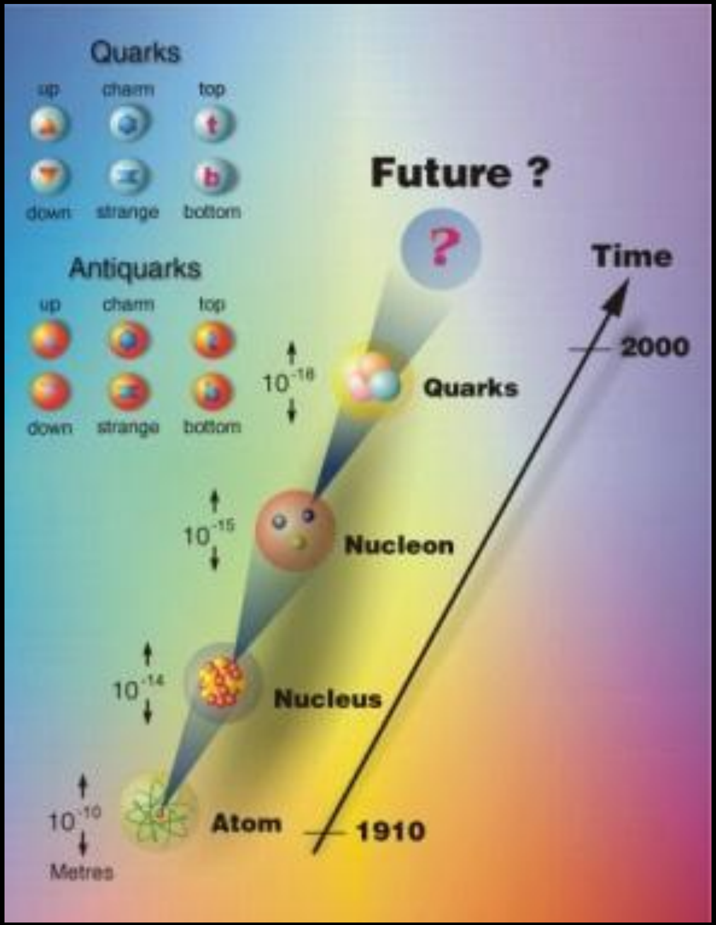
**“EL esfuerzo para entender el Universo es una de las muy pocas cosas que eleva la vida humana un poco por encima del nivel de la farsa, y le da algo de la elegancia de una tragedia”**

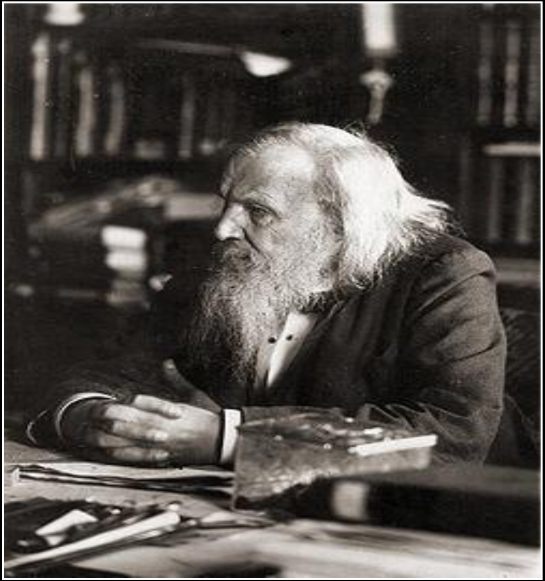
# LA MATERIA TIENE ESTRUCTURA ATÓMICA

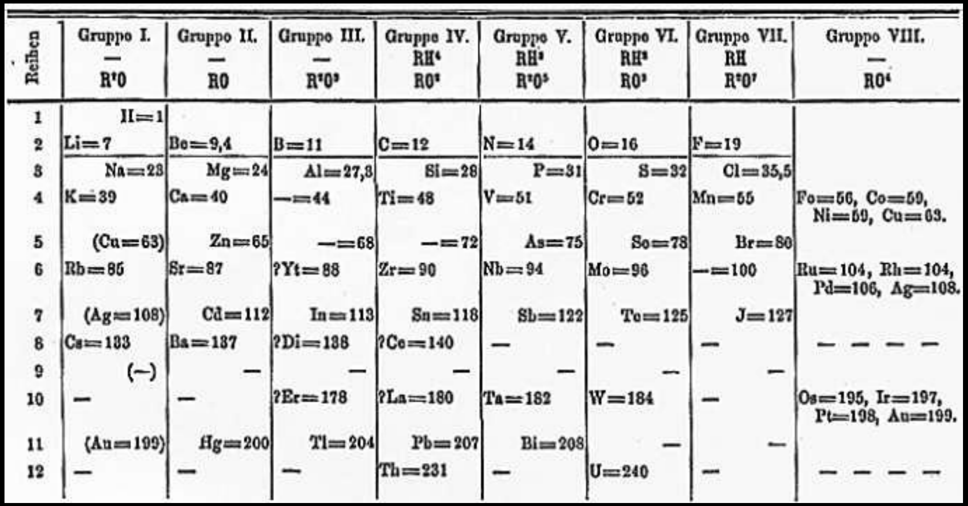
## LA MATERIA NO LLENA TODO EL ESPACIO QUE OCUPA

# ESTRUCTURA INTERNA DEL ÁTOMO



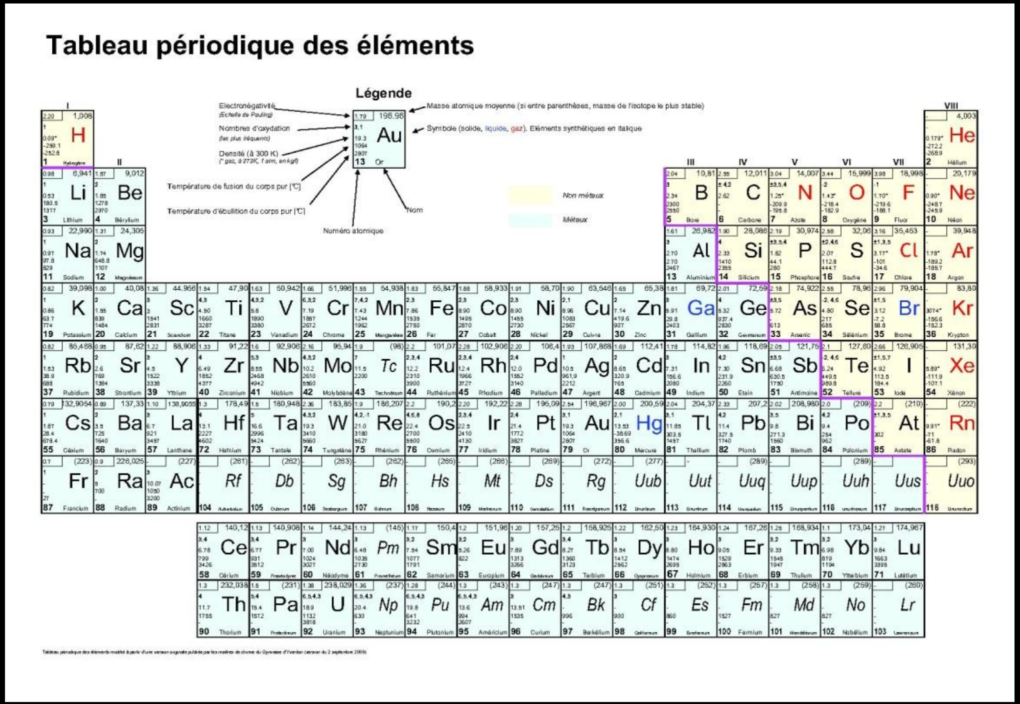




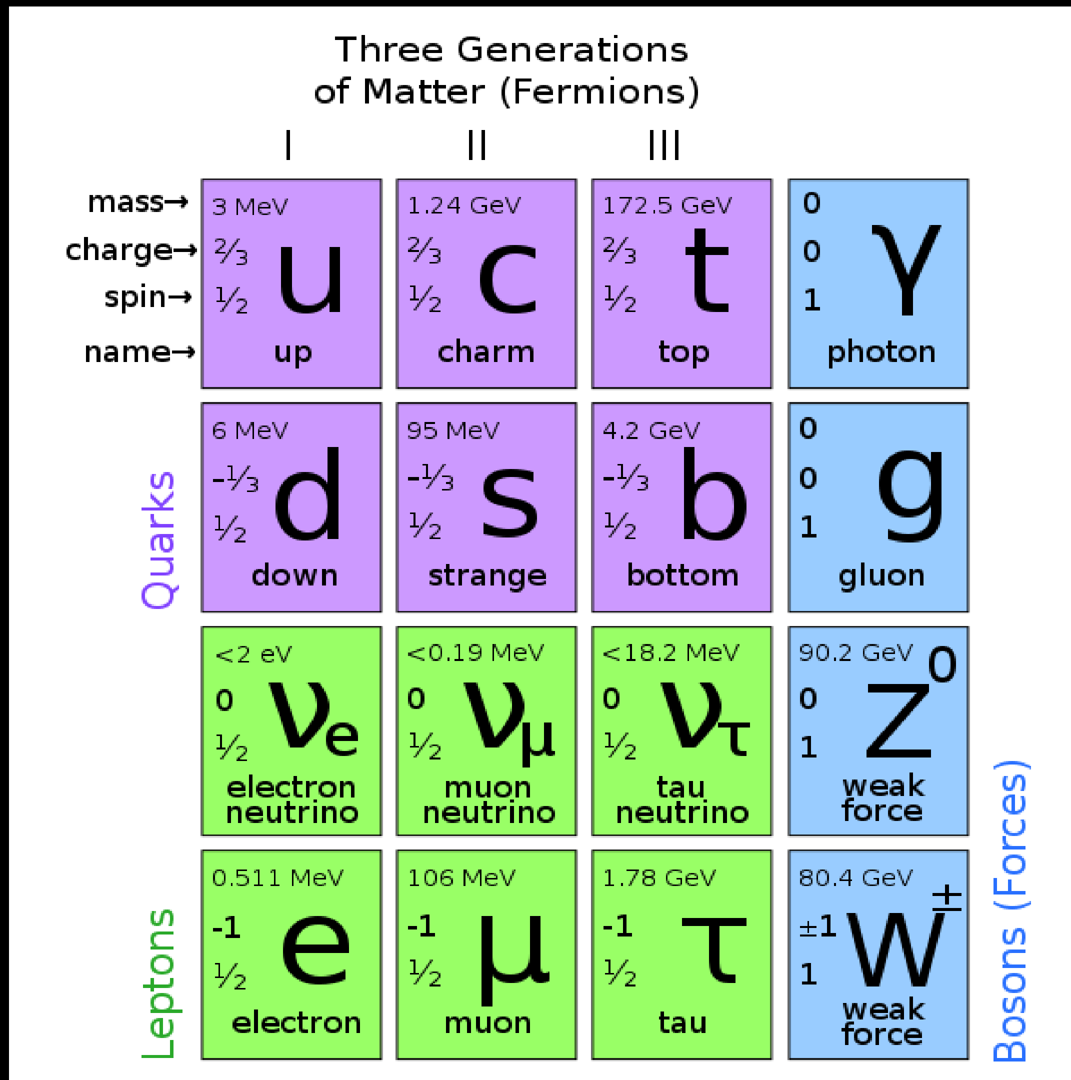
| Reihen | Gruppo I. — $R^2O$ | Gruppo II. — RO | Gruppo III. — $R^2O^3$ | Gruppo IV. $RH^4$ $RO^2$ | Gruppo V. $RH^3$ $R^2O^5$ | Gruppo VI. $RH^2$ $RO^3$ | Gruppo VII. RH $R^2O^7$ | Gruppo VIII. — $RO^4$ |
|---|---|---|---|---|---|---|---|---|
| 1 | H=1 | | | | | | | |
| 2 | Li=7 | Be=9,4 | B=11 | C=12 | N=14 | O=16 | F=19 | |
| 3 | Na=23 | Mg=24 | Al=27,3 | Si=28 | P=31 | S=32 | Cl=35,5 | |
| 4 | K=39 | Ca=40 | —=44 | Ti=48 | V=51 | Cr=52 | Mn=55 | Fe=56, Co=59, Ni=59, Cu=63. |
| 5 | (Cu=63) | Zn=65 | —=68 | —=72 | As=75 | Se=78 | Br=80 | |
| 6 | Rb=85 | Sr=87 | ?Yt=88 | Zr=90 | Nb=94 | Mo=96 | —=100 | Ru=104, Rh=104, Pd=106, Ag=108. |
| 7 | (Ag=108) | Cd=112 | In=113 | Sn=118 | Sb=122 | Te=125 | J=127 | |
| 8 | Cs=133 | Ba=137 | ?Di=138 | ?Ce=140 | — | — | — | — — — — |
| 9 | (—) | — | — | — | — | — | — | |
| 10 | — | — | ?Er=178 | ?La=180 | Ta=182 | W=184 | — | Os=195, Ir=197, Pt=198, Au=199. |
| 11 | (Au=199) | Hg=200 | Tl=204 | Pb=207 | Bi=208 | — | — | |
| 12 | — | — | — | Th=231 | — | U=240 | — | — — — — |

# 1871

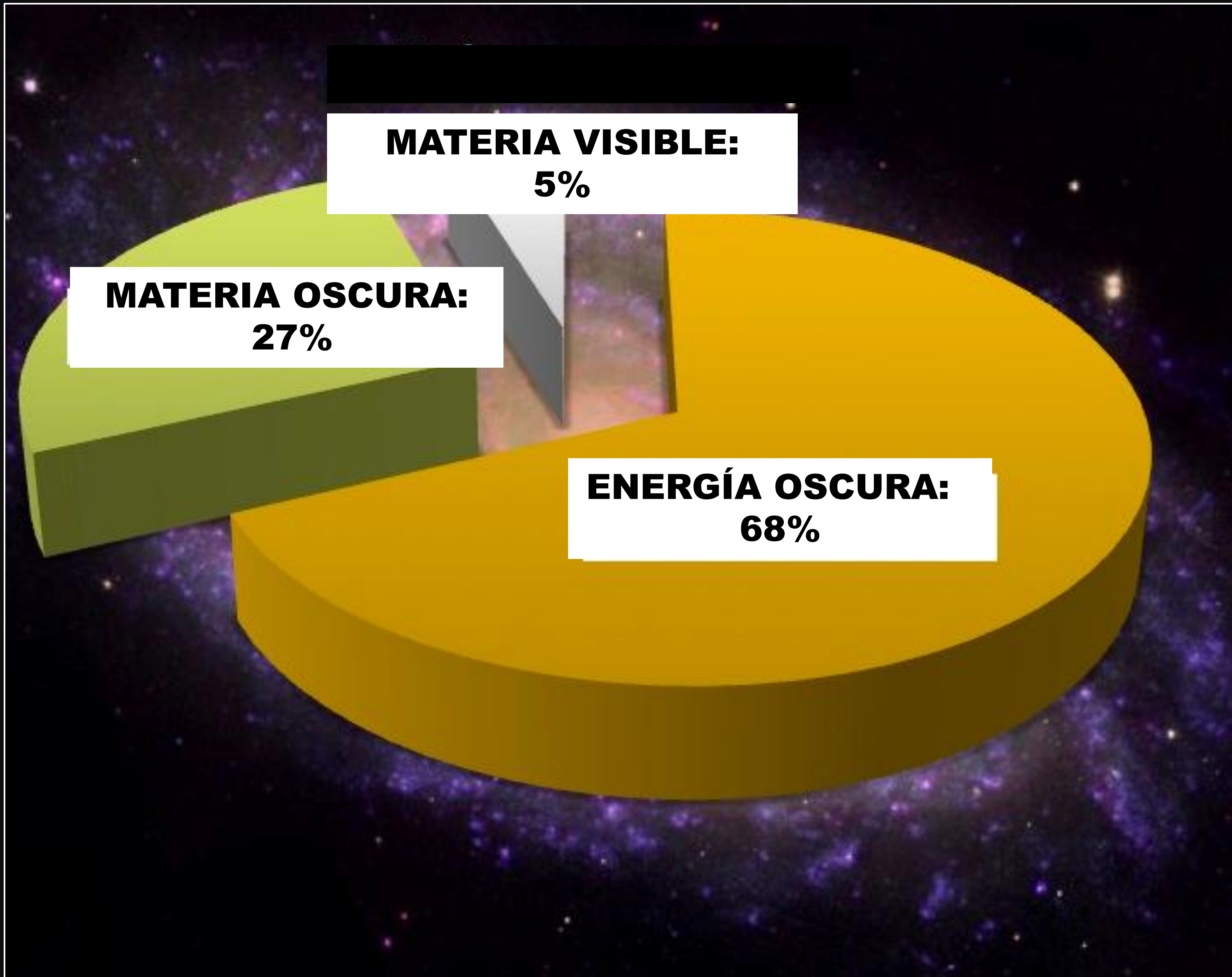
# D.I. MENDELEEV (1834-1907)

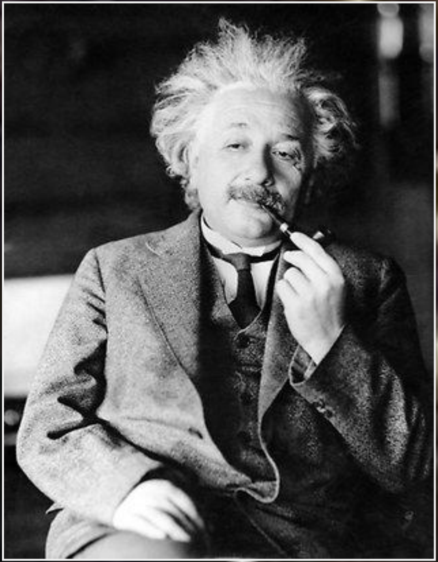


# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS



# CONTENIDO MATERIA – ENERGÍA DEL UNIVERSO





**EL SUPREMO DESAFÍO DEL FÍSICO ES LLEGAR A AQUELLAS LEYES ELEMENTALES A PARTIR DE LAS CUALES EL COSMOS PUEDE CONSTRUIRSE POR PURA DEDUCCIÓN**

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

**LAS LEYES QUE GOBIERNAN LOS PROCESOS ENTRE PARTÍCULAS ELEMENTALES PUEDEN DERIVARSE EXIGIENDO QUE SEAN INVARIANTES BAJO LAS TRANSFORMACIONES DE UN DETERMINADO GRUPO DE SIMETRÍA**

**¿QUÉ GRUPO?**

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$$

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

UNA DE LAS CREACIONES CIENTÍFICAS MÁS EXTRAORDINARIAS  DEL SIGLO XX

EJEMPLO PARADIGMÁTICO DE SÍNTESIS CIENTÍFICA

TEORÍA CONCEPTUALMENTE SIMPLE CONSTRUÍDA ESENCIALMENTE A PARTIR DE PRINCIPIOS DE SIMETRÍA

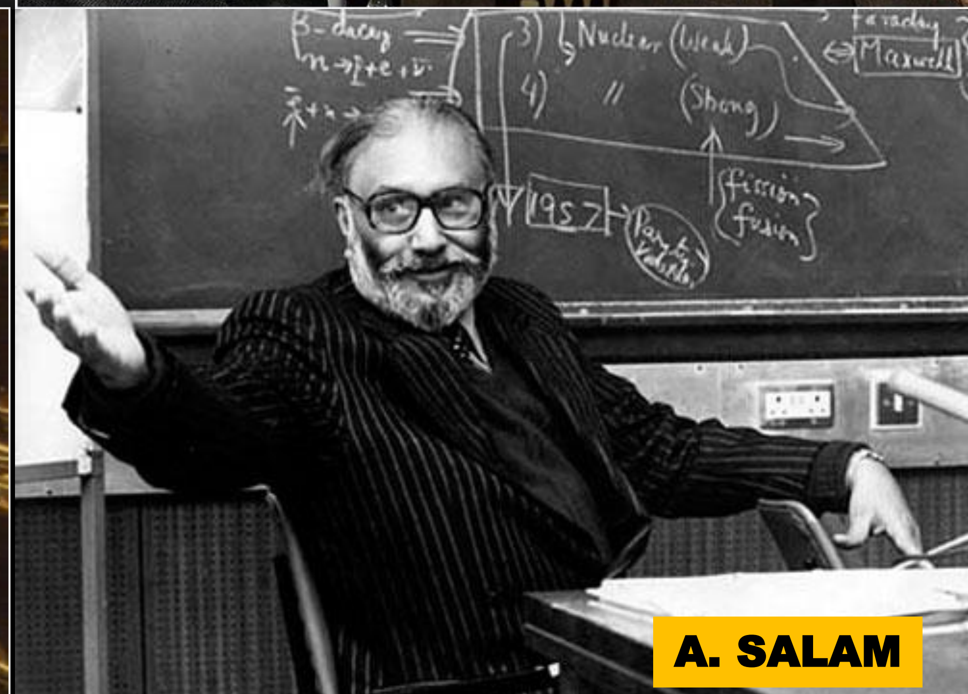
EXTRAORDINARIO PODER PREDICTIVO

- INVENCIÓN & DESCUBRIMIENTO DE LOS QUARKS (1964)
- DESCRIPCIÓN UNIFICADA DEL ELECTROMAGNETISMO Y LA FUERZA DÉBIL (1961-1967)
- COMPRENSIÓN DE LA FUERZA FUERTE (1973)

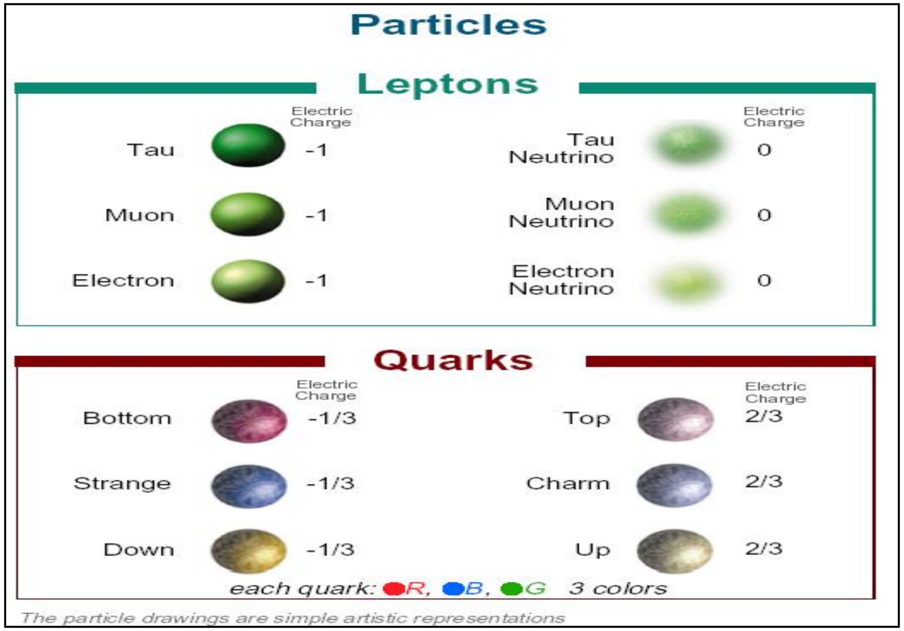

QUARKS
M. GELL-MANN


S. WEINBERG
S. GLASHOW


ACES
G. ZWEIG


Nuclear (Weak)
(Strong)
1957
fission
fusion
Maxwell
A. SALAM

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS




## PARTÍCULAS DE MATERIA

**LOS QUARKS Y LEPTONES TIENEN:**

- **ESPÍN = ½ (FERMIONES)**
- **MASA ≠ 0**
- **CARGA ELÉCTRICA = 0,1 (LEPTONES), +2/3, -1/3 (QUARKS)**

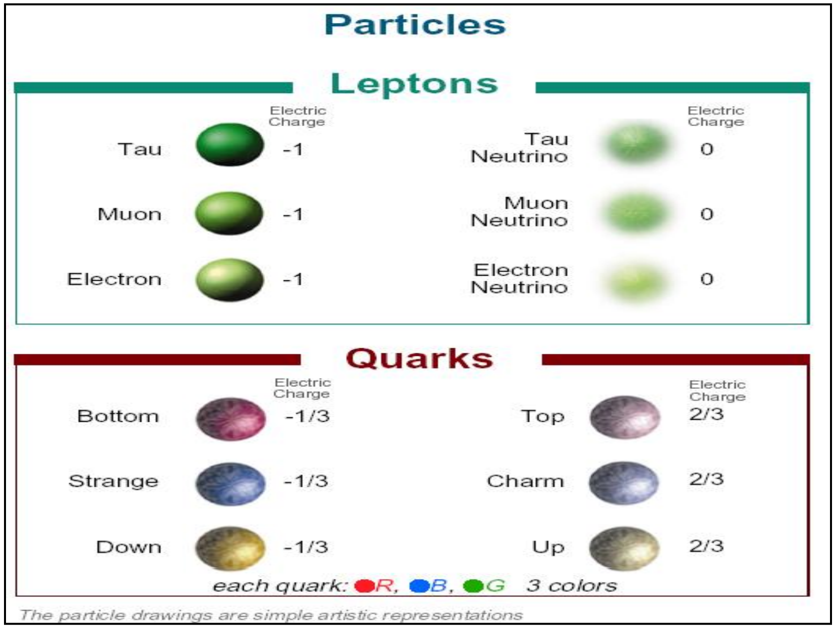
# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

**TODA LA MATERIA ORDINARIA EN EL UNIVERSO ESTÁ HECHA**

**DE QUARKS *u* , *d***

**Y LEPTONES *e* , $\nu_e$**

## *¿POR QUÉ?*



(

# Materia & Antimateria

Dirac predijo en 1926 que para cada **PARTÍCULA** debería existir su correspondiente **ANTIPARTÍCULA**.

**Las ANTIPARTÍCULAS** tienen las mismas propiedades estáticas (masa, vida media, spin, …) que las **PARTÍCULAS**, aunque algunas con signo opuesto (carga eléctrica, números cuánticos)

**Descubiertas en los rayos cósmicos**
**Estudiadas en los aceleradores**

**P.A.M. DIRAC (1902-1984)**
**Teoría del electrón (1926)**
**Premio Nobel de Física 1933**

**"We must regard it rather as an accident that the Earth (and presumably the whole solar system) contains a preponderance of negative electrons and positive protons. It is quite possible that for some stars it is the other way about, these stars being built mainly of positrons and negative protons. The two kinds of stars would both show exactly the same spectra, and there would be no way of distinguishing them by the present astronomical methods"**

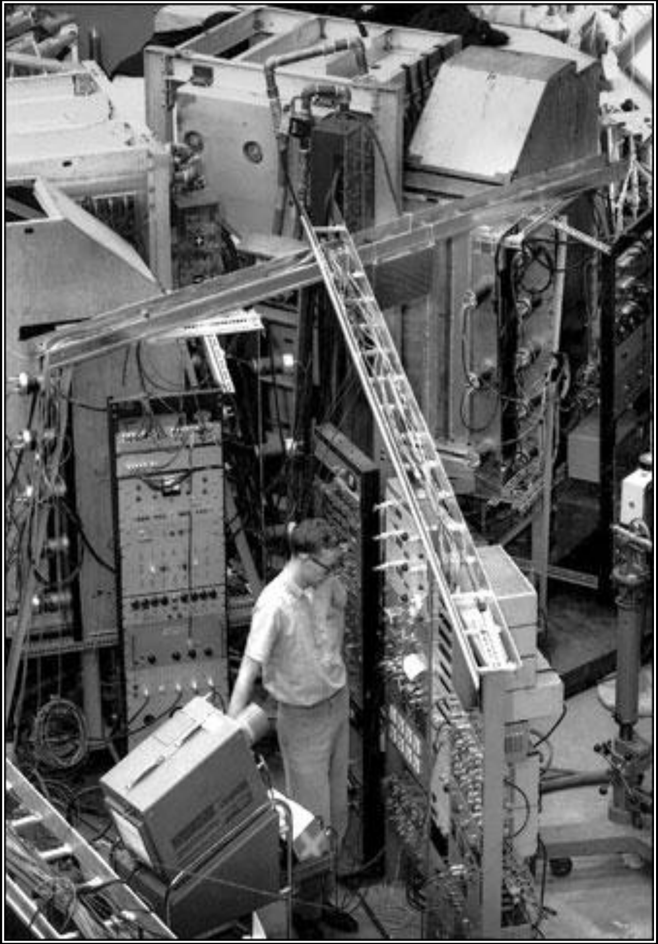
V.L. FITCH

J.W. CRONIN

S.C.C. TING

C.N. YANG

I.I. RABI



EXPERIMENTO BNL
VIOLACIÓN DE LA
SIMETRÍA CP (1964)

# LA HIPÓTESIS DEL BIG BANG ACERCA DEL ORIGEN DEL UNIVERSO IMPLICA IGUAL CANTIDAD DE MATERIA Y ANTIMATERIA EN EL UNIVERSO PRIMIGENIO


# ¿QUÉ HA OCURRIDO CON LA ANTIMATERIA PRIMORDIAL?

# Materia & Antimateria

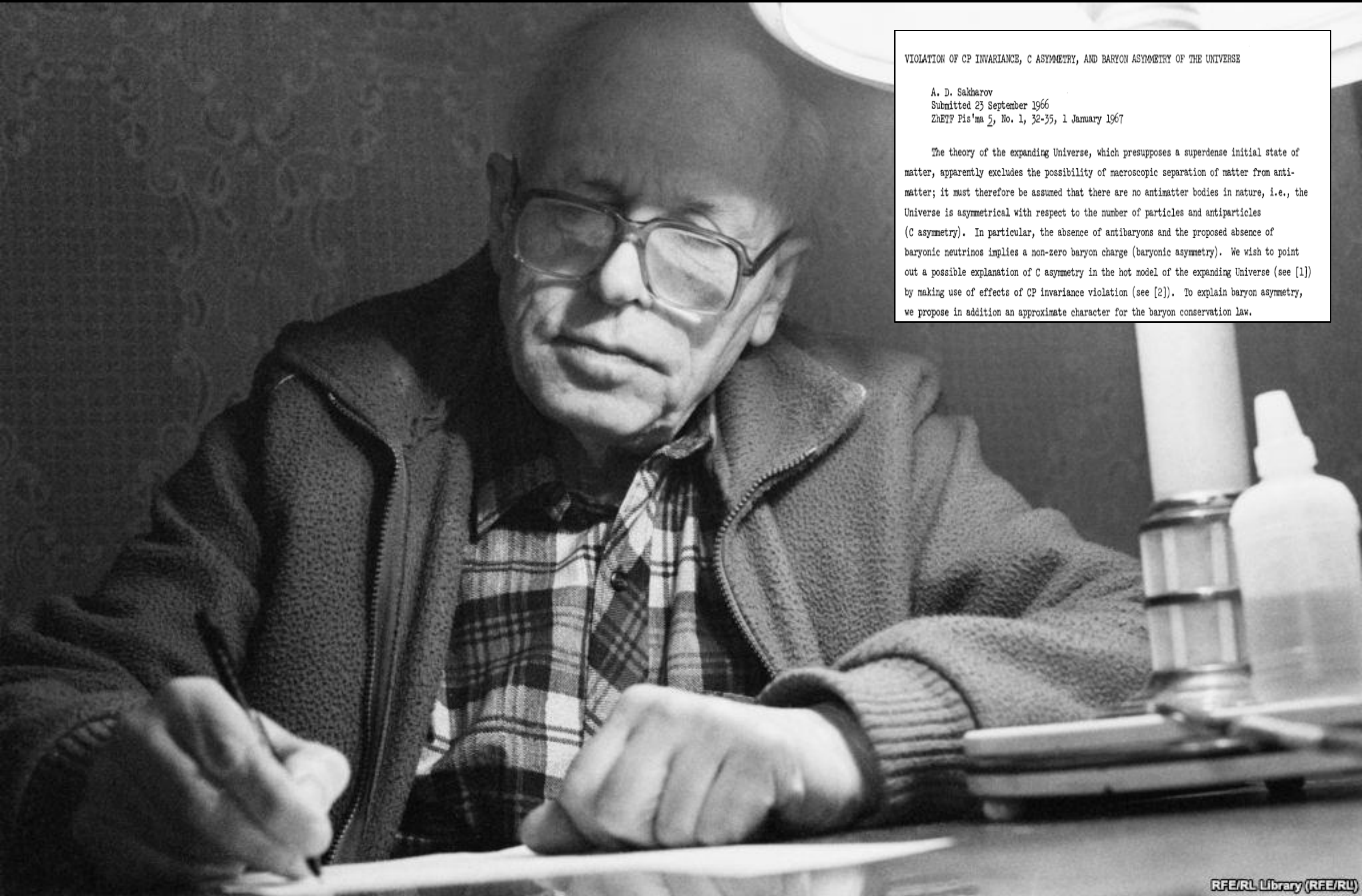
MATERIA $\neq$ ANTIMATERIA

¿POR QUÉ?

HASTA LA FECHA NO SE HA DETECTADO
ANTIMATERIA
EN LA RADIACIÓN CÓSMICA PRIMARIA

EL UNIVERSO PARECE ESTAR FORMADO
SÓLO DE MATERIA
¿POR QUÉ?

# ANDREI SAKHAROV (1921–1989)




VIOLATION OF CP INVARIANCE, C ASYMMETRY, AND BARYON ASYMMETRY OF THE UNIVERSE

A. D. Sakharov
Submitted 23 September 1966
ZhETF Pis'ma 5, No. 1, 32-35, 1 January 1967

The theory of the expanding Universe, which presupposes a superdense initial state of matter, apparently excludes the possibility of macroscopic separation of matter from antimatter; it must therefore be assumed that there are no antimatter bodies in nature, i.e., the Universe is asymmetrical with respect to the number of particles and antiparticles (C asymmetry). In particular, the absence of antibaryons and the proposed absence of baryonic neutrinos implies a non-zero baryon charge (baryonic asymmetry). We wish to point out a possible explanation of C asymmetry in the hot model of the expanding Universe (see [1]) by making use of effects of CP invariance violation (see [2]). To explain baryon asymmetry, we propose in addition an approximate character for the baryon conservation law.

**Hay ~ 100.000 millones de galaxias en el Universo, cada una con ~100.000 millones de estrellas.**

*Keep searching, Stephen Hawking*

)

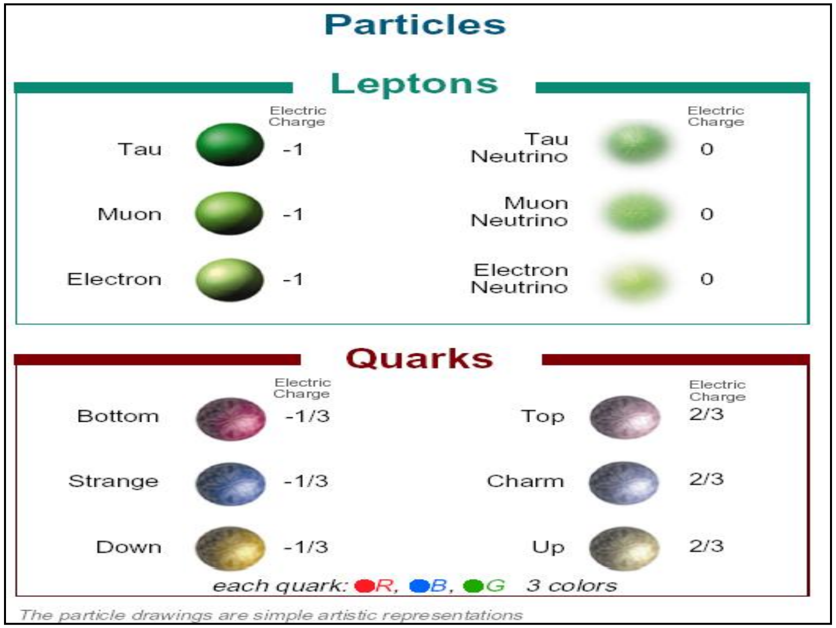
# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

**TODA LA MATERIA ORDINARIA EN EL UNIVERSO ESTÁ HECHA**

**DE QUARKS $\underline{u}$ , $\underline{d}$**

**Y LEPTONES $\underline{e}$ , $\underline{\nu_e}$**

***¿POR QUÉ?***

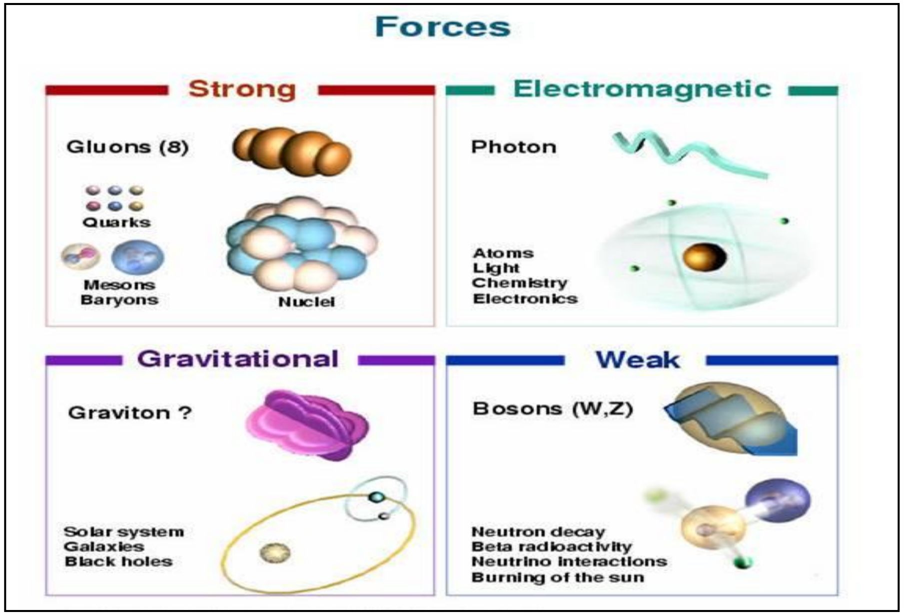



**MECANISMO DE KOBAYASHI–MASKAWA (PNF 2008)**

***SE NECESITAN 3 GENERACIONES DE QUARKS Y LEPTONES PARA EXPLICAR LA VIOLACIÓN DE CP EN EL MARCO DEL MODELO ESTÁNDAR (1973)***

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

## PARTÍCULAS DE FUERZA

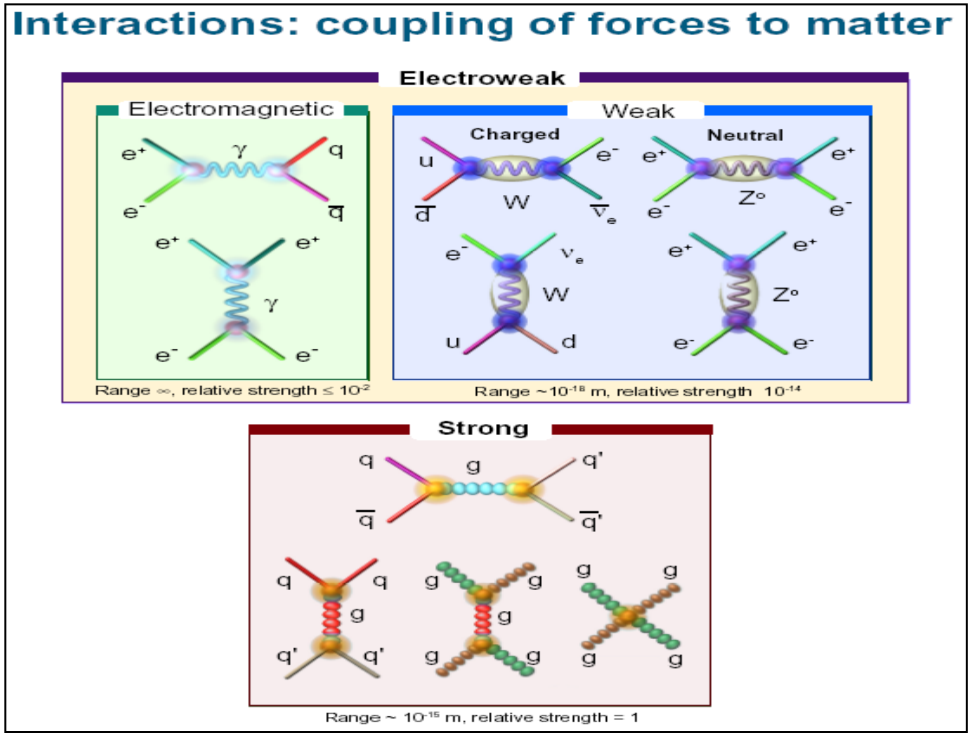



**LOS MENSAJEROS DE LAS FUERZAS (PROPAGADORES) TIENEN:**

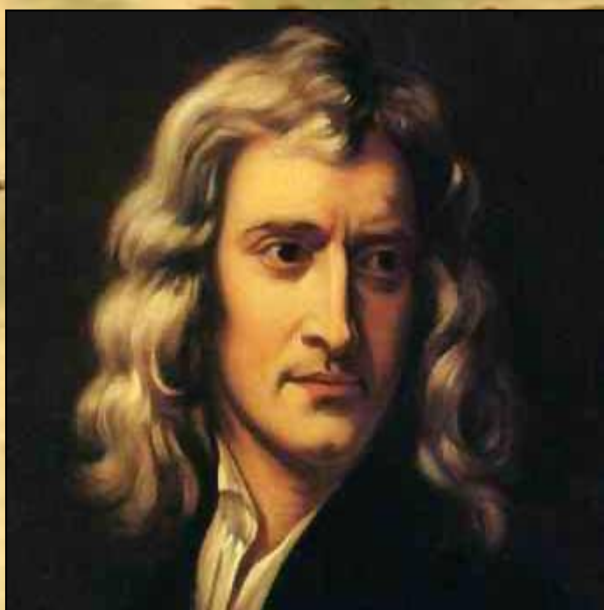
- **ESPÍN = 1-2 (BOSONES)**
- **MASA = 0 ($\gamma$, g, G), ≠ 0 ($W^{\pm}$, Z)**
- **CARGA ELÉCTRICA = 0 ($\gamma$, g, G, Z), ± 1 ($W^{\pm}$)**

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS

## INTERACCIONES: ACOPLAMIENTO PARTÍCULAS–FUERZAS

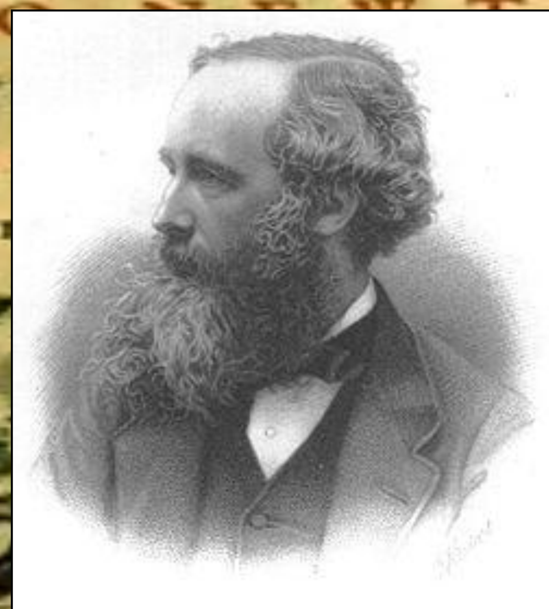


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.
AUCTORE



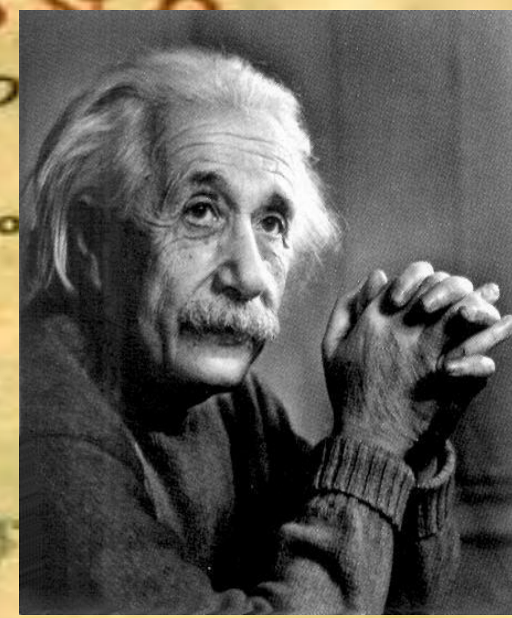
**I. NEWTON**

**1642-1727**



**J.C. MAXWELL**

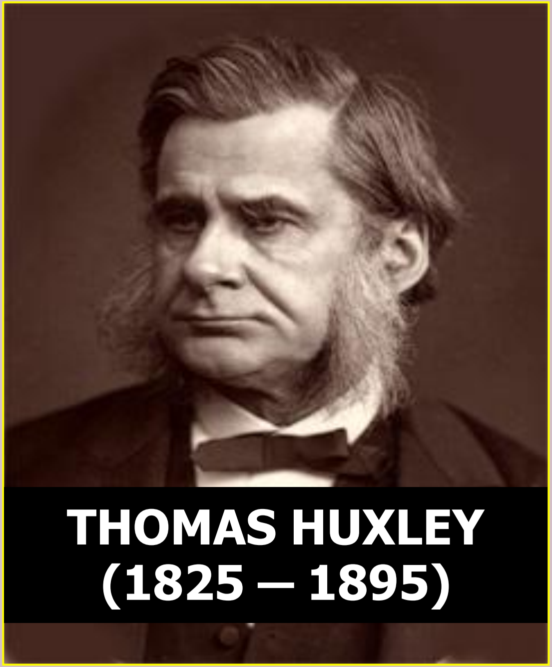
**1831-1879**



**A. EINSTEIN**

**1879-1955**

# MODELO ESTÁNDAR DE FÍSICA DE PARTÍCULAS



THOMAS HUXLEY
(1825 – 1895)

**"LA GRAN TRAGEDIA DE LA CIENCIA ES LA MUERTE DE UNA BELLA TEORÍA POR UN HECHO FEO"**

## TODOS LOS BOSONES *GAUGE* TIENEN MASA = 0

## 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 $\varphi_A$ 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 $\gamma_5$-phase transformations. In this model the gauge fields themselves may break the $\gamma_5$ 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 $\varphi$ and the $A_\mu$ fields is

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

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



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 Goldstone theorem,[2] that Lorentz-covariant field theories in which spontaneous breakdown of symmetry under an internal Lie group occurs contain zero-mass particles, fails if and only if the conserved currents associated with the internal group are coupled to gauge fields. The purpose of the present note is to report that, as a consequence of this coupling, the spin-one quanta of some of the gauge fields acquire mass; the longitudinal degrees of freedom of these particles (which would be absent if their mass were zero) go over into the Goldstone bosons when the coupling tends to zero. This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson[3] has drawn attention: that the scalar zero-mass excitations of a superconducting neutral Fermi gas become longitudinal plasmon modes of finite mass when the gas is charged.

The simplest theory which exhibits this behavior is a gauge-invariant version of a model used by Goldstone[2] himself: Two real[4] scalar fields $\varphi_1, \varphi_2$ and a real vector field $A_\mu$ interact through the Lagrangian density

$$L = -\tfrac{1}{2}(\nabla\varphi_1)^2 - \tfrac{1}{2}(\nabla\varphi_2)^2 - V(\varphi_1^2 + \varphi_2^2) - \tfrac{1}{4}F_{\mu\nu}F^{\mu\nu}, \quad (1)$$

where

$$\nabla_\mu \varphi_1 = \partial_\mu \varphi_1 - eA_\mu \varphi_2,$$

$$\nabla_\mu \varphi_2 = \partial_\mu \varphi_2 + eA_\mu \varphi_1,$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu.$$

$e$ is a dimensionless coupling constant, and the metric is taken as $-+++$. $L$ is invariant under simultaneous gauge transformations of the first kind on $\varphi_1 \pm i\varphi_2$ and of the second kind on $A_\mu$. Let us suppose that $V'(\varphi_0^2) = 0$, $V''(\varphi_0^2) > 0$; then spontaneous breakdown of U(1) symmetry occurs. Consider the equations [derived from (1) by treating $\Delta\varphi_1$, $\Delta\varphi_2$, and $A_\mu$ as small quantities] governing the propagation of small oscillations about the "vacuum" solution $\varphi_1(x) = 0$, $\varphi_2(x) = \varphi_0$:

$$\partial^\mu\{\partial_\mu(\Delta\varphi_1) - e\varphi_0 A_\mu\} = 0, \quad (2a)$$

$$\{\partial^2 - 4\varphi_0^2 V''(\varphi_0^2)\}(\Delta\varphi_2) = 0, \quad (2b)$$

$$\partial_\nu F^{\mu\nu} = e\varphi_0\{\partial^\mu(\Delta\varphi_1) - e\varphi_0 A^\mu\}. \quad (2c)$$

Equation (2b) describes waves whose quanta have (bare) mass $2\varphi_0\{V''(\varphi_0^2)\}^{1/2}$; Eqs. (2a) and (2c) may be transformed, by the introduction of new variables

$$B_\mu = A_\mu - (e\varphi_0)^{-1}\partial_\mu(\Delta\varphi_1),$$

$$G_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu = F_{\mu\nu}, \quad (3)$$

into the form

$$\partial_\mu B^\mu = 0, \quad \partial_\nu G^{\mu\nu} + e^2\varphi_0^2 B^\mu = 0. \quad (4)$$

Equation (4) describes vector waves whose quanta have (bare) mass $e\varphi_0$. In the absence of the gauge field coupling ($e = 0$) the situation is quite different: Equations (2a) and (2c) describe zero-mass scalar and vector bosons, respectively. In passing, we note that the right-hand side of (2c) is just the linear approximation to the conserved current: It is linear in the vector potential, gauge invariance being maintained by the presence of the gradient term.[5]

When one considers theoretical models in which spontaneous breakdown of symmetry under a semisimple group occurs, one encounters a variety of possible situations corresponding to the various distinct irreducible representations to which the scalar fields may belong; the gauge field always belongs to the adjoint representation.[6] The model of the most immediate interest is that in which the scalar fields form an octet under SU(3): Here one finds the possibility of two nonvanishing vacuum expectation values, which may be chosen to be the two $Y = 0$, $I_3 = 0$ members of the octet.[7] There are two massive scalar bosons with just these quantum numbers; the remaining six components of the scalar octet combine with the corresponding components of the gauge-field octet to describe

Volume 13, Number 20 PHYSICAL REVIEW LETTERS 16 November 1964

## GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England
(Received 12 October 1964)

In all of the fairly numerous attempts to date to formulate a consistent field theory possessing a broken symmetry, Goldstone's remarkable theorem[1] has played an important role. This theorem, briefly stated, asserts that if there exists a conserved operator $Q_i$ such that

$$[Q_i, A_j(x)] = \sum_k t_{ijk} A_k(x),$$

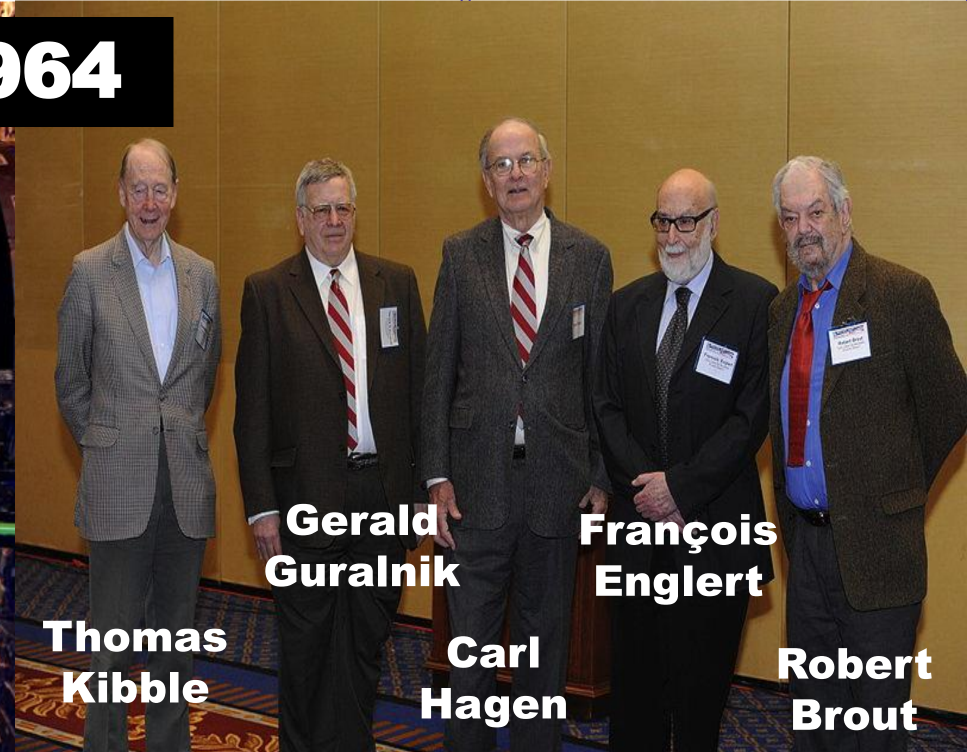
and if it is possible consistently to take $\sum_k t_{ijk} \langle 0|A_k(0)|0\rangle \neq 0$, then $A_j(x)$ has a zero-mass particle in its spectrum. It has more recently been observed that the assumed Lorentz invariance essential to the proof[2] may allow one the hope of avoiding such massless particles through the introduction of vector gauge fields and the consequent breakdown of manifest covariance.[3] This, of course, represents a departure from the assumptions of the theorem, and a limitation on its applicability which in no way reflects on the general validity of the proof.

In this note we shall show, within the framework of a simple soluble field theory, that it is possible consistently to break a symmetry (in the sense that $\sum_k t_{ijk} \langle 0|A_k|0\rangle \neq 0$) without requiring that $A(x)$ excite a zero-mass particle. While this result might suggest a general procedure for the elimination of unwanted massless bosons, it will be seen that this has been accomplished by giving up the global conservation law usually



# 1964


2008: Primer Higgs observado en CMS



Gerald Guralnik

François Englert

Thomas Kibble

Carl Hagen

Robert Brout

# EL MODELO ESTÁNDAR 1967

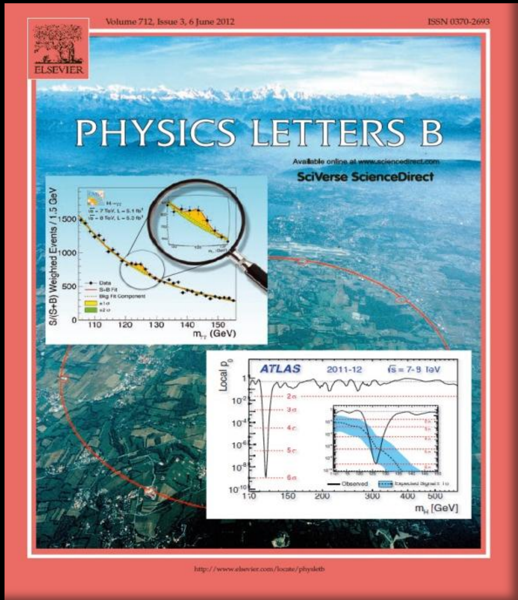
$$
\begin{gathered}
-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \\
\tfrac{1}{2}ig_s^2(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu + \bar{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \tfrac{1}{2}\partial_\mu H \partial_\mu H - \\
\tfrac{1}{2}m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \tfrac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \tfrac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\tfrac{2M^2}{g^2} + \\
\tfrac{2M}{g}H + \tfrac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - \\
W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - \\
W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \\
\tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \\
\tfrac{1}{8}g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2] - \\
gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - \\
W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \tfrac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \\
\phi^+\partial_\mu H)] + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\tfrac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + \\
igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + \\
igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \tfrac{1}{4}g^2W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] - \\
\tfrac{1}{4}g^2\tfrac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s_w^2-1)^2\phi^+\phi^-] - \tfrac{1}{2}g^2\tfrac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) - \tfrac{1}{2}ig^2\tfrac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \tfrac{1}{2}g^2s_wA_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) + \tfrac{1}{2}ig^2s_wA_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\tfrac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - \\
g^1s_w^2A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m_u^\lambda)u^\lambda_j - \\
\bar{d}^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_wA_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] + \\
\tfrac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 - \\
1 - \gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 - \gamma^5)d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + \\
(\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1 + \\
\gamma^5)u^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}\tfrac{m_e^\lambda}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] - \\
\tfrac{g}{2}\tfrac{m_e^\lambda}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5e^\lambda)] + \tfrac{ig}{2M\sqrt{2}}\phi^+[-m_d^\kappa(\bar{u}^\lambda_jC_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + \\
m_u^\lambda(\bar{u}^\lambda_jC_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar{d}^\lambda_jC^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m_u^\kappa(\bar{d}^\lambda_jC^\dagger_{\lambda\kappa}(1 - \\
\gamma^5)u^\kappa_j] - \tfrac{g}{2}\tfrac{m_u^\lambda}{M}H(\bar{u}^\lambda_ju^\lambda_j) - \tfrac{g}{2}\tfrac{m_d^\lambda}{M}H(\bar{d}^\lambda_jd^\lambda_j) + \tfrac{ig}{2}\tfrac{m_u^\lambda}{M}\phi^0(\bar{u}^\lambda_j\gamma^5u^\lambda_j) - \\
\tfrac{ig}{2}\tfrac{m_d^\lambda}{M}\phi^0(\bar{d}^\lambda_j\gamma^5d^\lambda_j) + \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \\
\tfrac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2Y + igc_wW^+_\mu(\partial_\mu\bar{X}^0X^- - \partial_\mu\bar{X}^+X^0) + igs_wW^+_\mu(\partial_\mu\bar{Y}X^- - \\
\partial_\mu\bar{X}^+Y) + igc_wW^-_\mu(\partial_\mu\bar{X}^-X^0 - \partial_\mu\bar{X}^0X^+) + igs_wW^-_\mu(\partial_\mu\bar{X}^-Y - \\
\partial_\mu\bar{Y}X^+) + igc_wZ^0_\mu(\partial_\mu\bar{X}^+X^+ - \partial_\mu\bar{X}^-X^-) + igs_wA_\mu(\partial_\mu\bar{X}^+X^+ - \\
\partial_\mu\bar{X}^-X^-) - \tfrac{1}{2}gM[\bar{X}^+X^+H + \bar{X}^-X^-H + \tfrac{1}{c_w^2}\bar{X}^0X^0H] + \\
\tfrac{1-2c_w^2}{2c_w}igM[\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-] + \tfrac{1}{2c_w}igM[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \\
igMs_w[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \tfrac{1}{2}igM[\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0]
\end{gathered}
$$

**S. GLASHOW, S. WEINBERG, A. SALAM / PNF 1979**

**M. VELTMAN, G. 'T HOOFT /PNF 1999**


**D.POLITZER, D. GROSS, F. WILCZEK /PNF 2004**

# CERN, 4 DE JULIO, 2012


Volume 712, Issue 3, 6 June 2012
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A power struggle at the Vatican
When Lonesome George met Nora
A giant leap for science
Finding the Higgs boson


Science
21 December 2012 | $10
BREAKTHROUGH of the YEAR
The HIGGS BOSON
AAAS

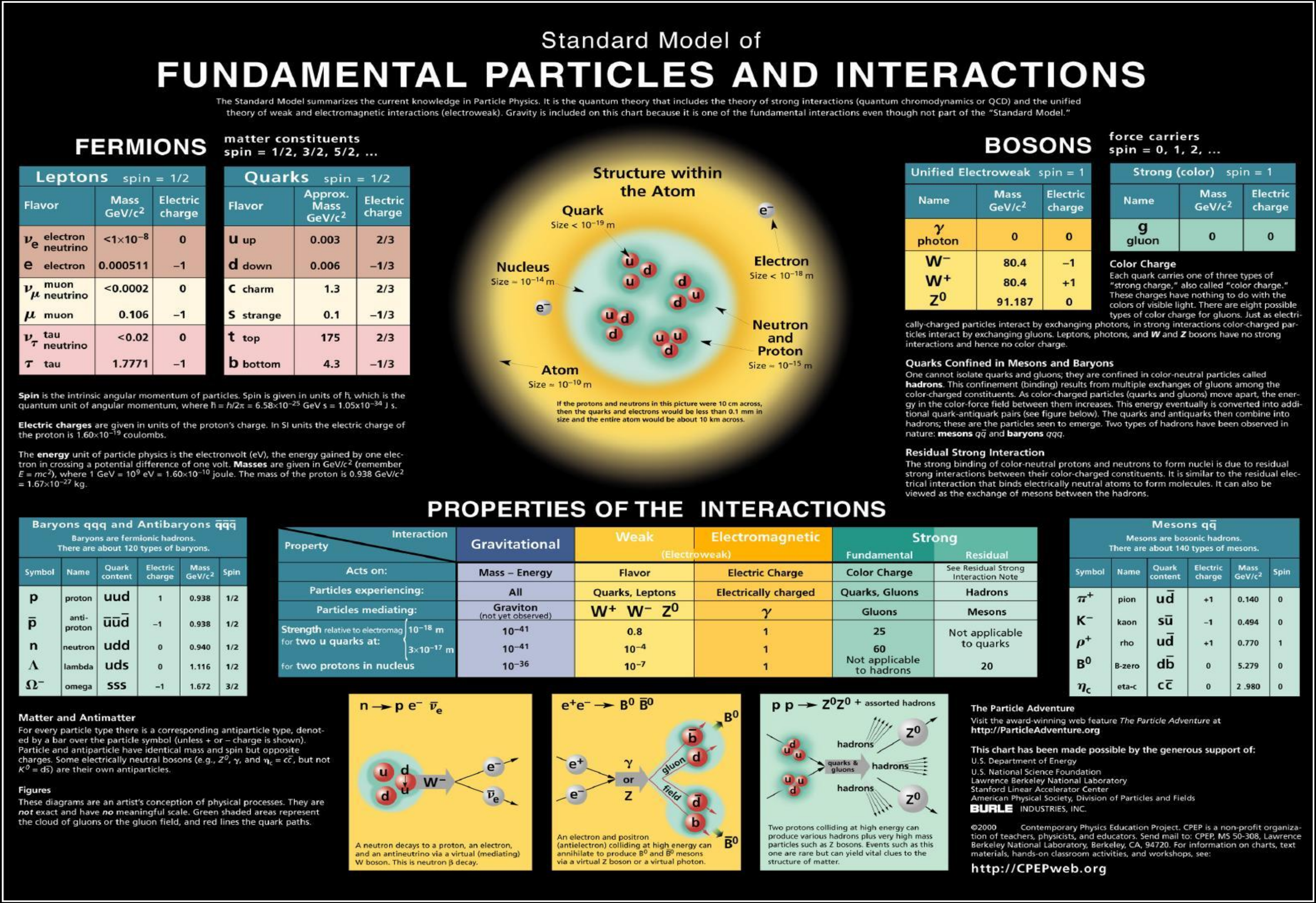

F. ENGLERT, P. HIGGS, CERN
Premio Príncipe de Asturias 2013
de Investigación Científica y Técnica


PREMIO NOBEL DE FÍSICA 2013
F. ENGLERT, P. HIGGS
"Por el descubrimiento teórico de un mecanismo que contribuye a nuestra comprensión del origen de la masa de las partículas subatómicas, y que recientemente se ha confirmado gracias al descubrimiento de la partícula fundamental predicha, en los experimentos ATLAS y CMS del LHC del CERN"

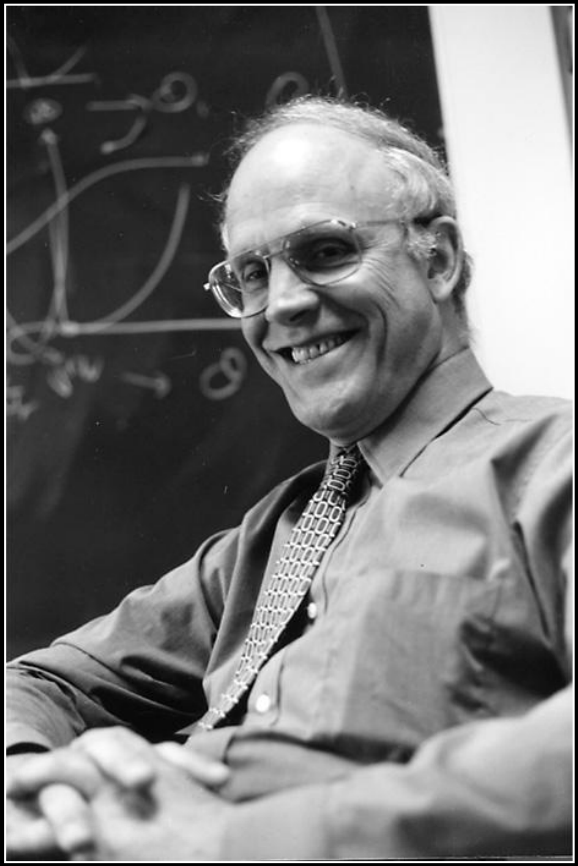
**F. ENGLERT**
**ORSAY, JULIO 2012**

**P. HIGGS**
**OVIEDO, OCTUBRE 2013**

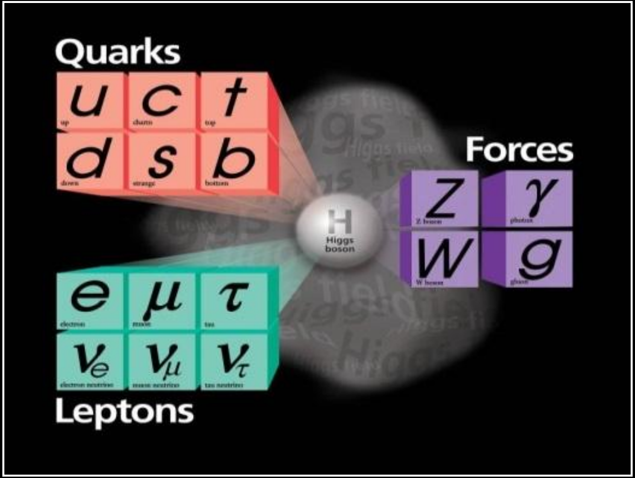
# BOSÓN B-E-H RELLENA EL HUECO EN EL CONOCIMIENTO DE LO ORDINARIO



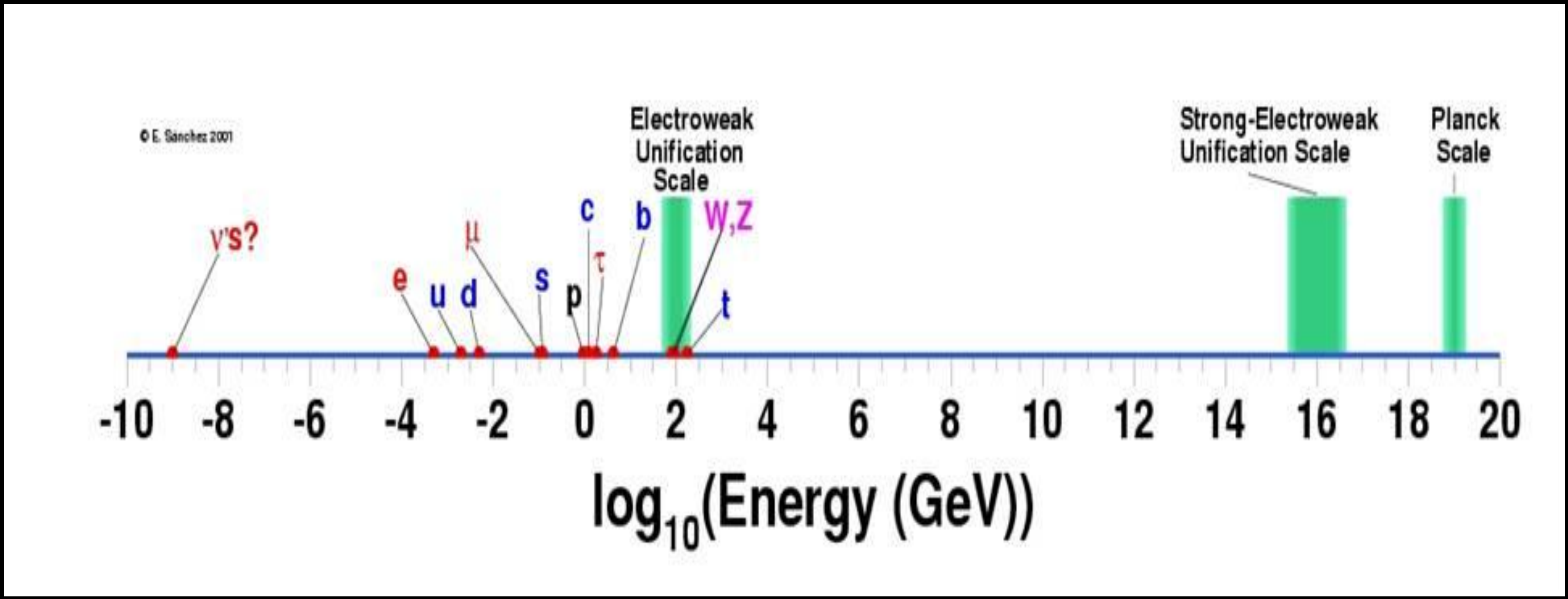
EL PRODUCTO
MÁS IMPORTANTE DE LA
INVESTIGACIÓN
ES LA IGNORANCIA

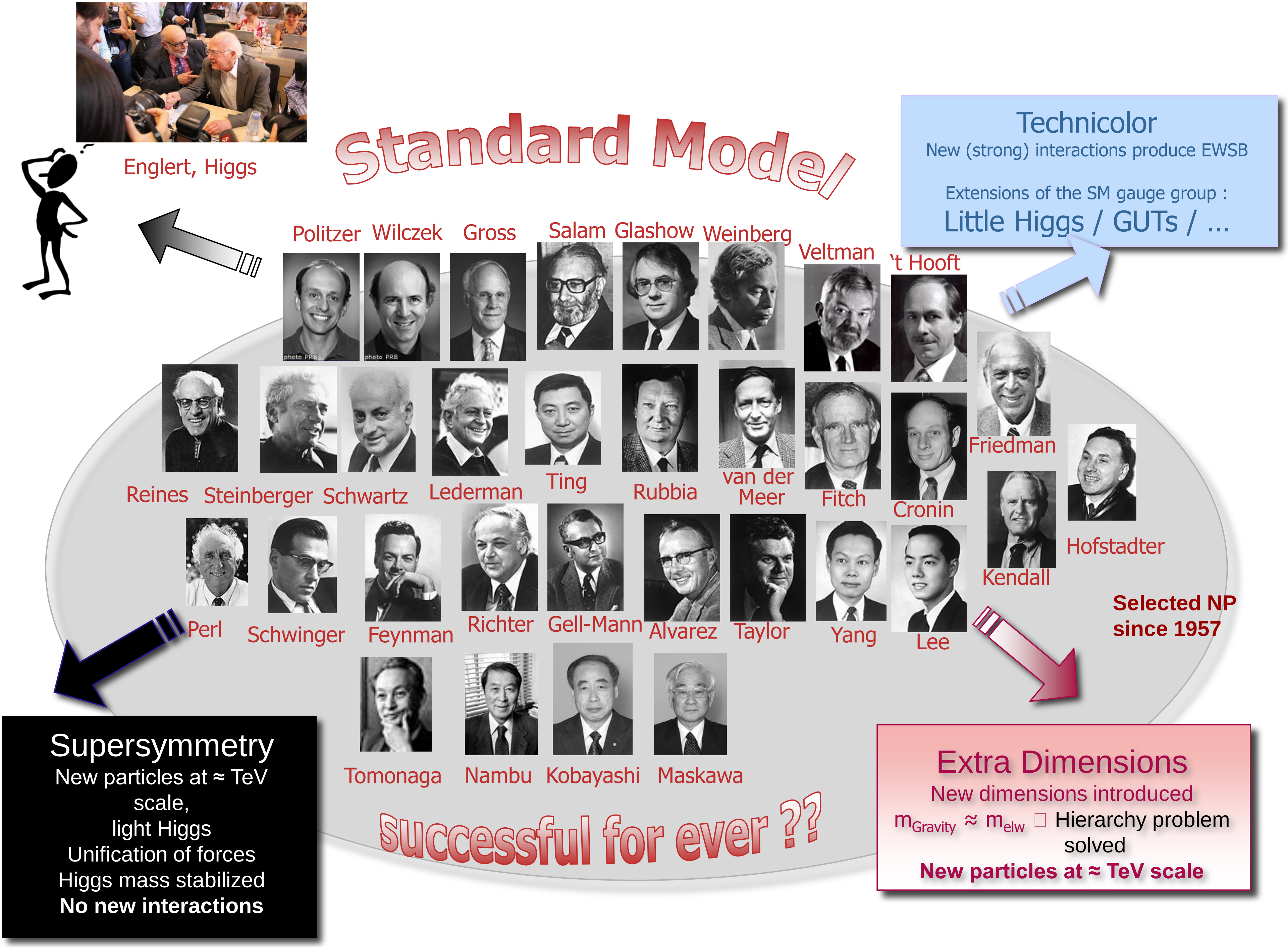


D. GROSS




- **JERARQUÍA & NATURALIDAD**
- **NATURALEZA DE LOS NEUTRINOS**
- **PROBLEMA DEL SABOR**
- **MATERIA & ENERGÍA OSCURA**
- **BARIOGÉNESIS**





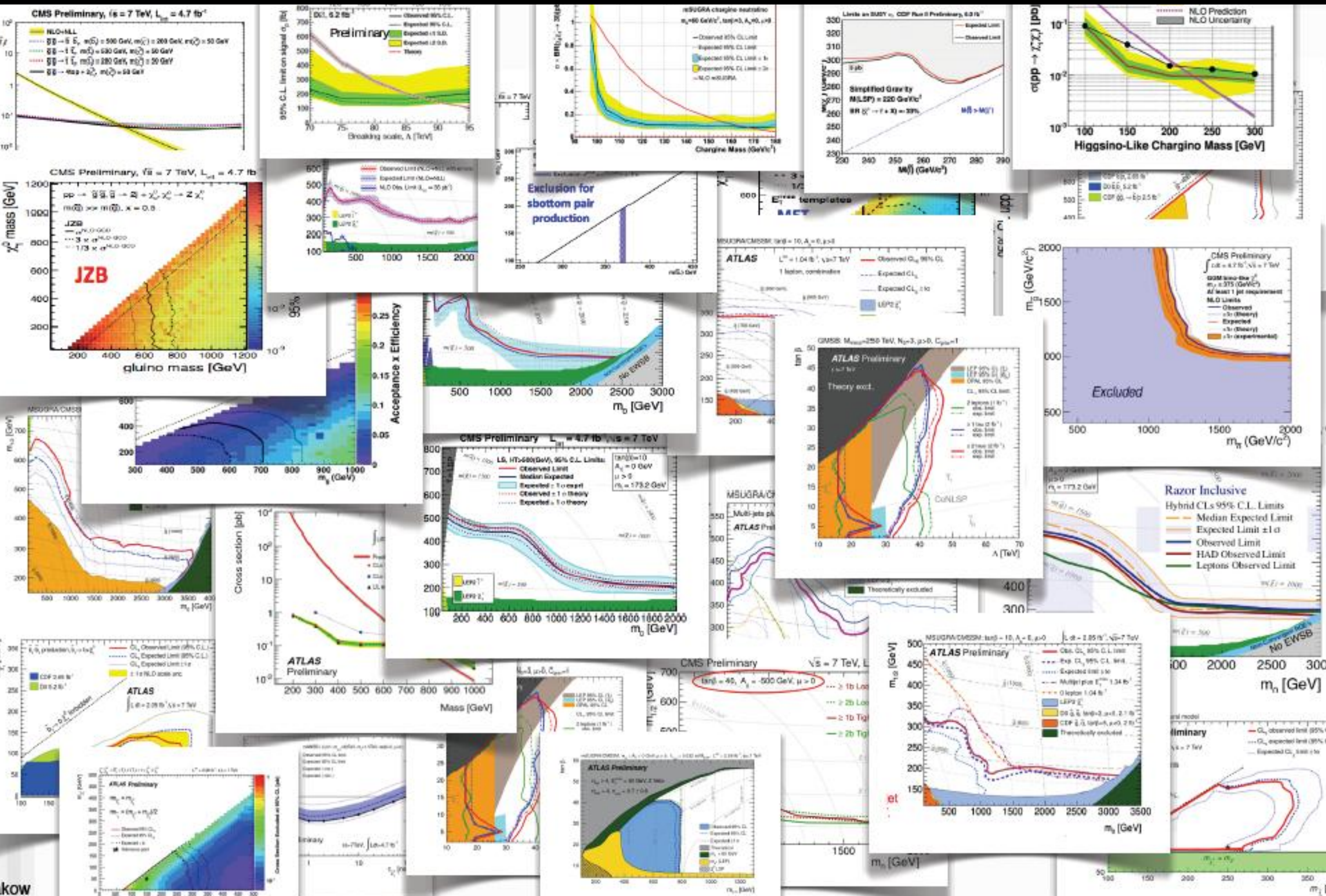
Englert, Higgs
Standard Model
Technicolor
New (strong) interactions produce EWSB
Extensions of the SM gauge group :
Little Higgs / GUTs / ...
Politzer
Wilczek
Gross
Salam
Glashow
Weinberg
Veltman
't Hooft
Friedman
Hofstadter
Reines
Steinberger
Schwartz
Lederman
Ting
Rubbia
van der Meer
Fitch
Cronin
Kendall
Perl
Schwinger
Feynman
Richter
Gell-Mann
Alvarez
Taylor
Yang
Lee
Selected NP since 1957
Tomonaga
Nambu
Kobayashi
Maskawa
Successful for ever ??
Supersymmetry
New particles at ≈ TeV scale,
light Higgs
Unification of forces
Higgs mass stabilized
**No new interactions**
Extra Dimensions
New dimensions introduced
$m_{Gravity} \approx m_{elw}$ □ Hierarchy problem solved
**New particles at ≈ TeV scale**

# PERSPECTIVAS

**PREDECIR ES ALGO MUY DIFÍCIL, EN PARTICULAR ACERCA DEL FUTURO,**
*Niels Bohr*

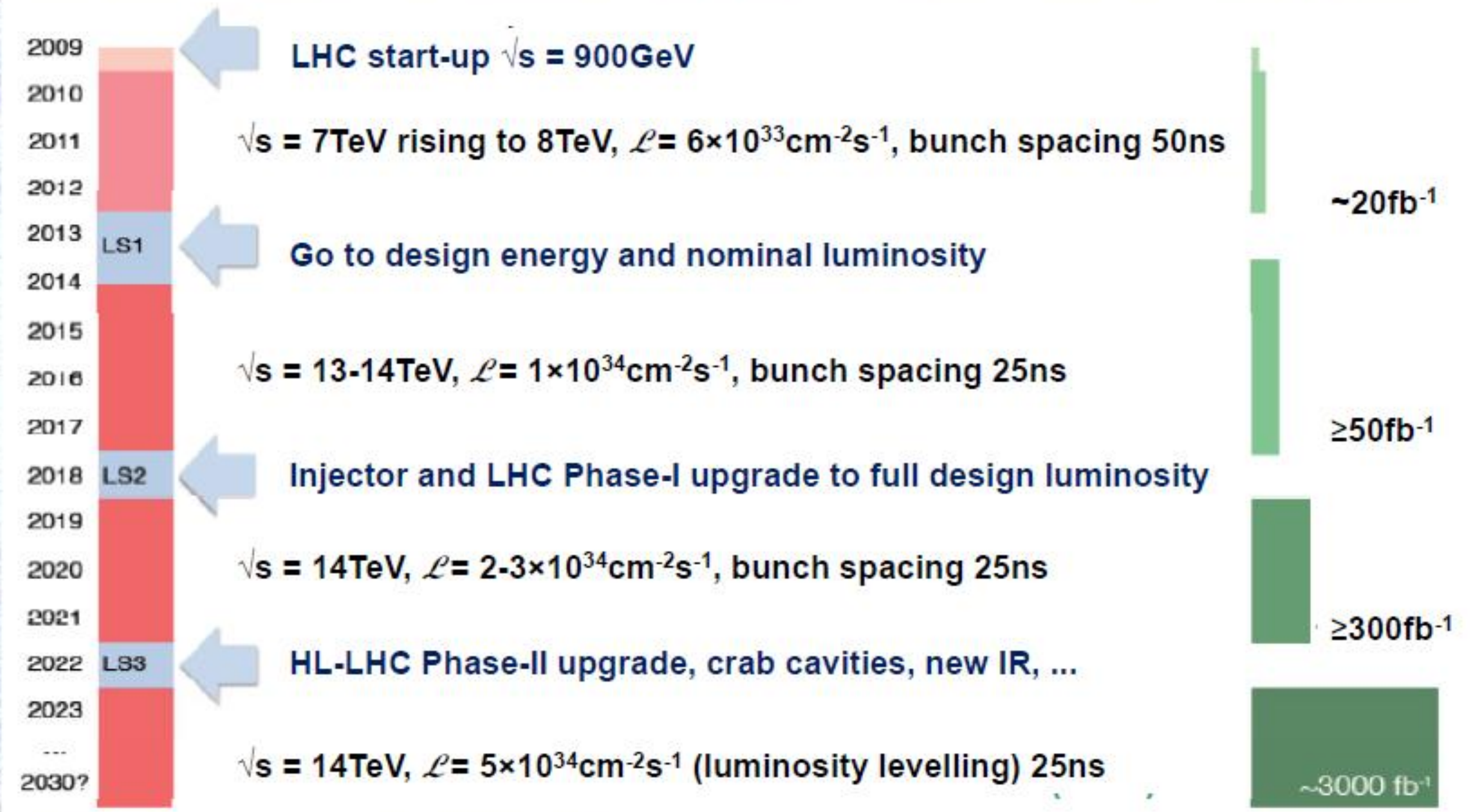
**YA ES BASTANTE DURO CONOCER EL PASADO; SERÍA INSOPORTABLE CONOCER EL FUTURO,**
*William Somerset Maughan*

# BÚSQUEDAS DE NUEVA FÍSICA

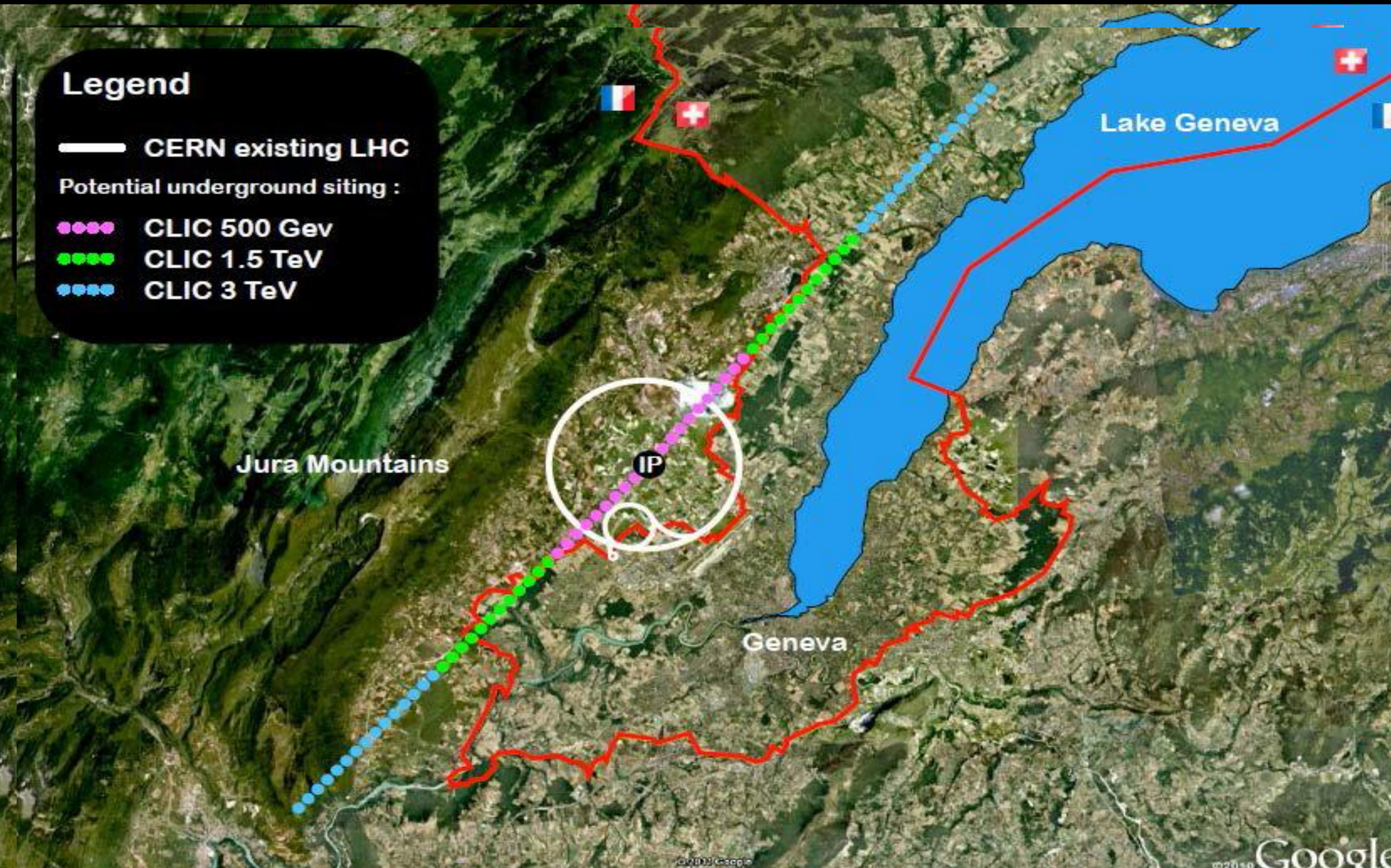



THE
FUN
IS JUST
BEGINNING

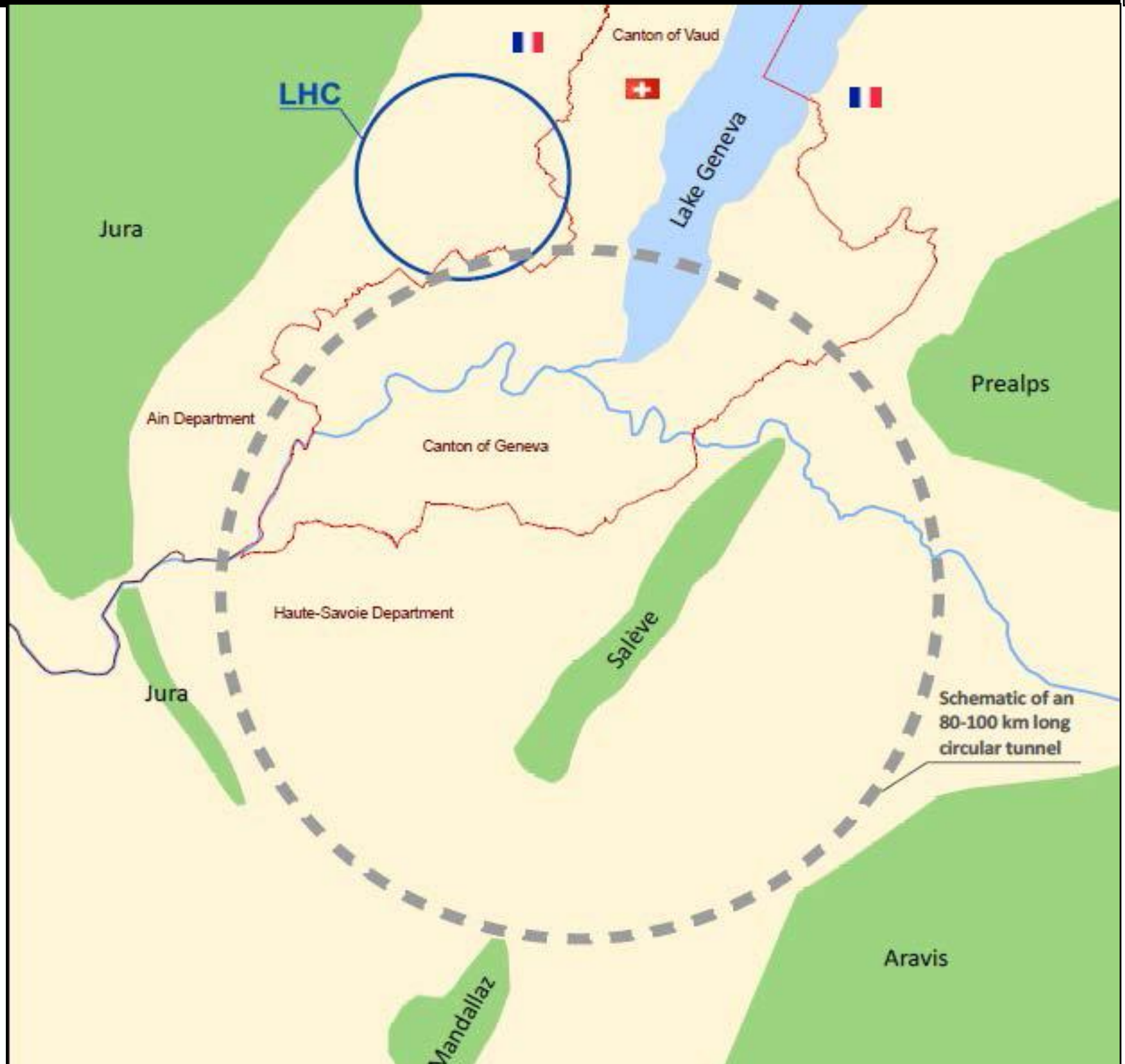
# LHC Schedule Assumptions

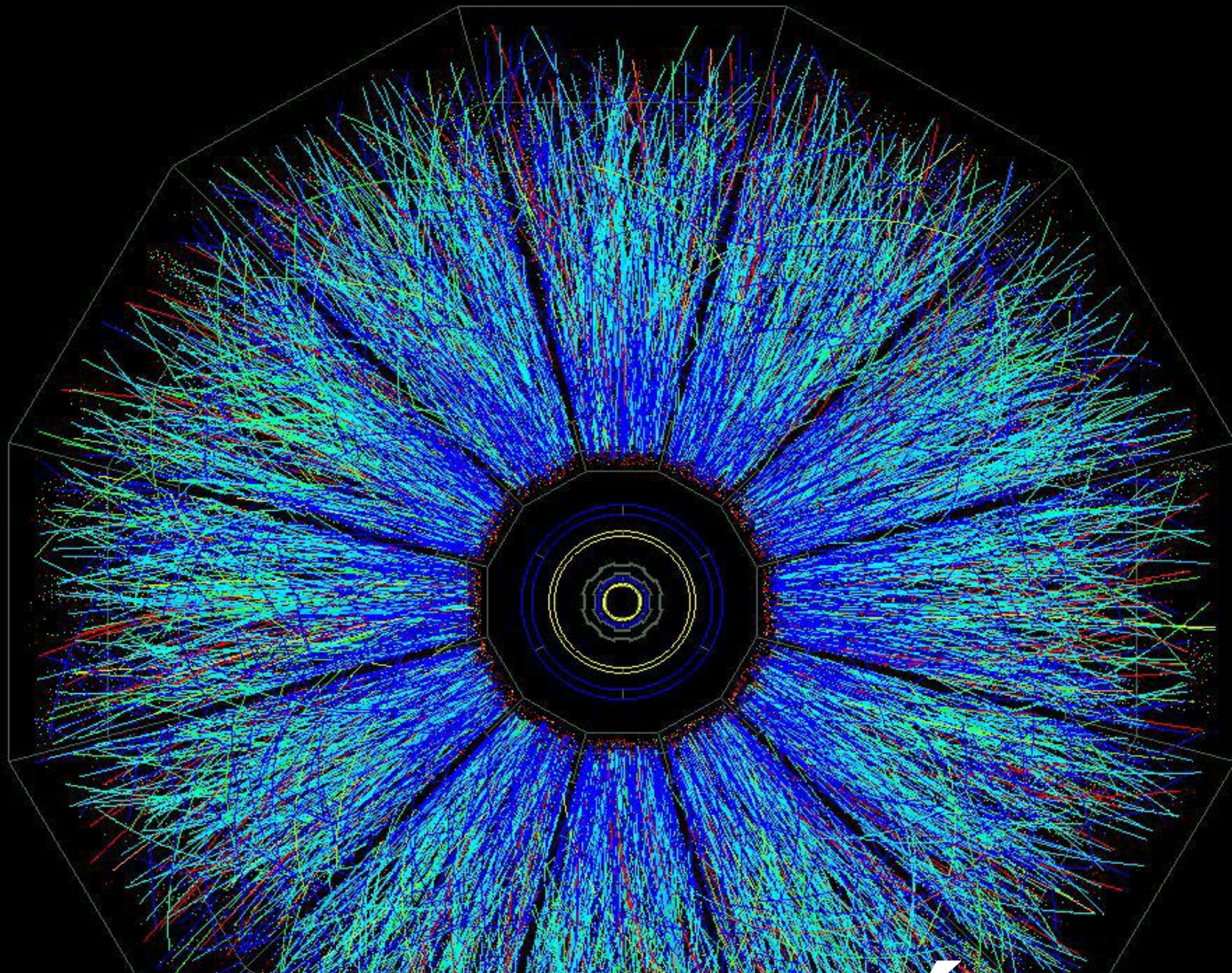


# FUTUROS COLISIONADORES LINEALES



# FUTUROS COLISIONADORES CIRCULARES





# LA CONSTRUCCIÓN DEL MODELO ESTÁNDAR

# CONSTRUCCIÓN EXPERIMENTAL DEL MODELO ESTÁNDAR

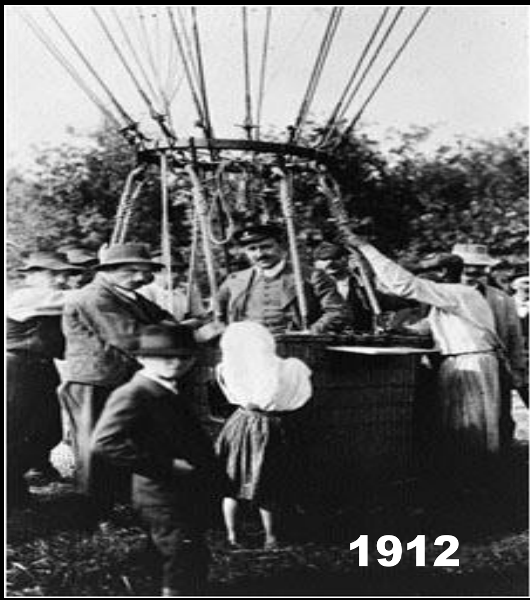
**EN LA PRIMERA MITAD DEL SIGLO XX EL ESTUDIO DE LOS RAYOS CÓSMICOS, DESCUBIERTOS POR V.F. HESS EN 1912, FUE LA HERRAMIENTA BÁSICA PARA DESCUBRIR NUEVAS PARTÍCULAS**

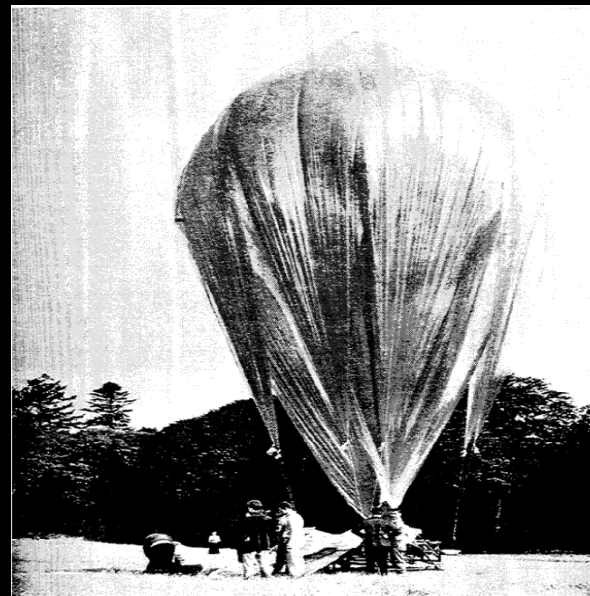
($e^+$, $\mu$ , $\pi$ , K , $K^0$, $\Lambda$, $\Sigma$, $\Xi$, ...)

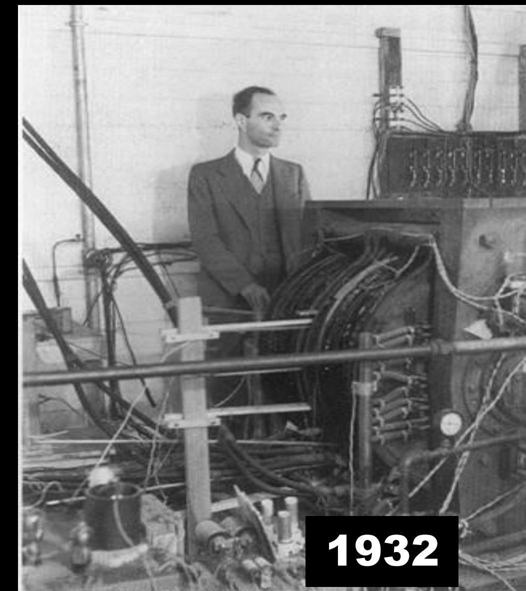
**EL DESCUBRIMIENTO DEL ANTIPROTÓN EN 1955, EN EL BEVATRON (LBL), MARCÓ UN PUNTO DE INFLEXIÓN EN LA FÍSICA EXPERIMENTAL DE ALTAS ENERGÍAS: LOS ACELERADORES TOMARON EL RELEVO, AUNQUE TODAVÍA HAY FASCINANTE CIENCIA QUE HACER CON LOS RAYOS CÓSMICOS (NEUTRINOS, MATERIA OSCURA, MATERIA–ANTIMATERIA)**

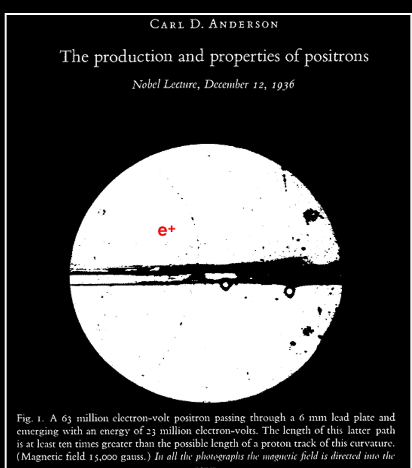
# RAYOS CÓSMICOS

# RAYOS CÓSMICOS





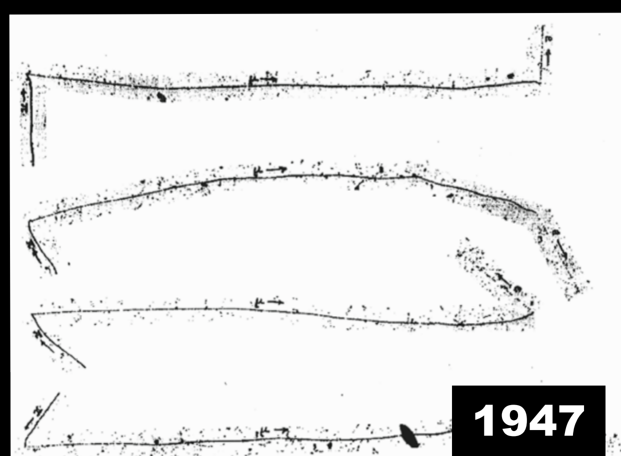


CARL D. ANDERSON

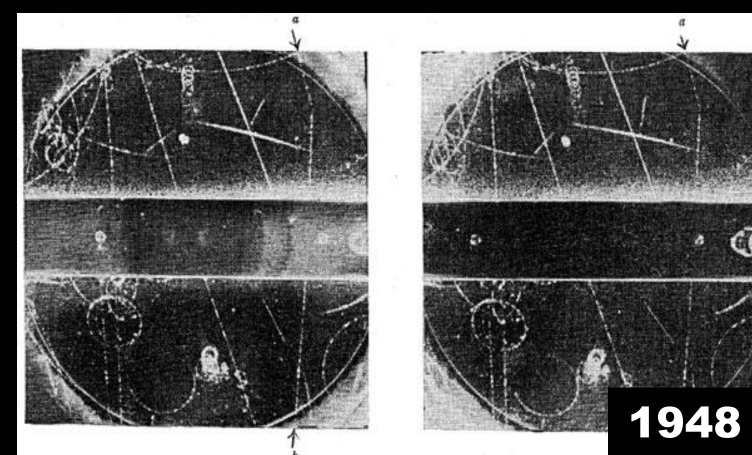
The production and properties of positrons

*Nobel Lecture, December 12, 1936*



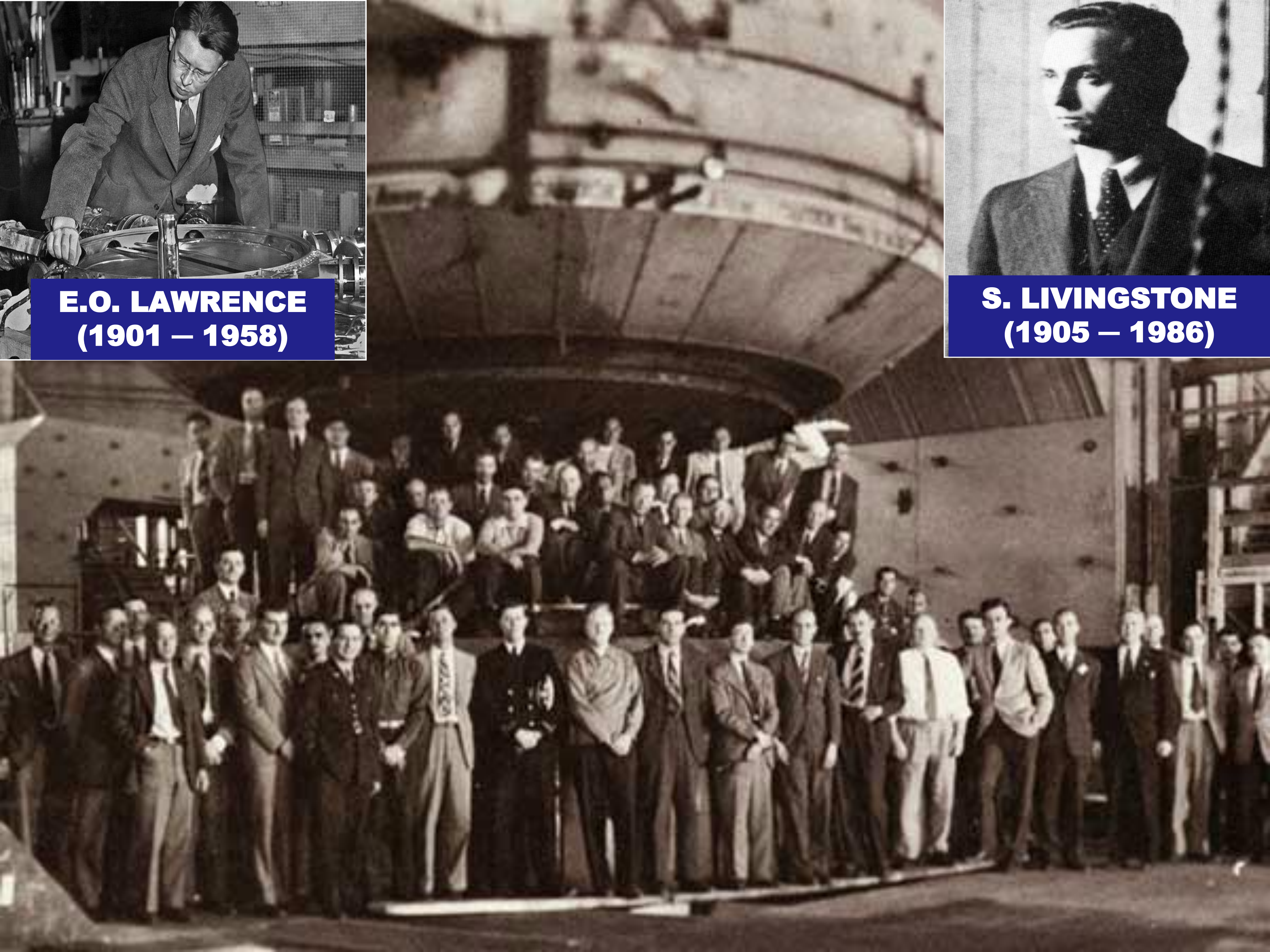
Fig. 1. A 63 million electron-volt positron passing through a 6 mm lead plate and emerging with an energy of 23 million electron-volts. The length of this latter path is at least ten times greater than the possible length of a proton track of this curvature. (Magnetic field 15,000 gauss.) *In all the photographs the magnetic field is directed into the paper.*

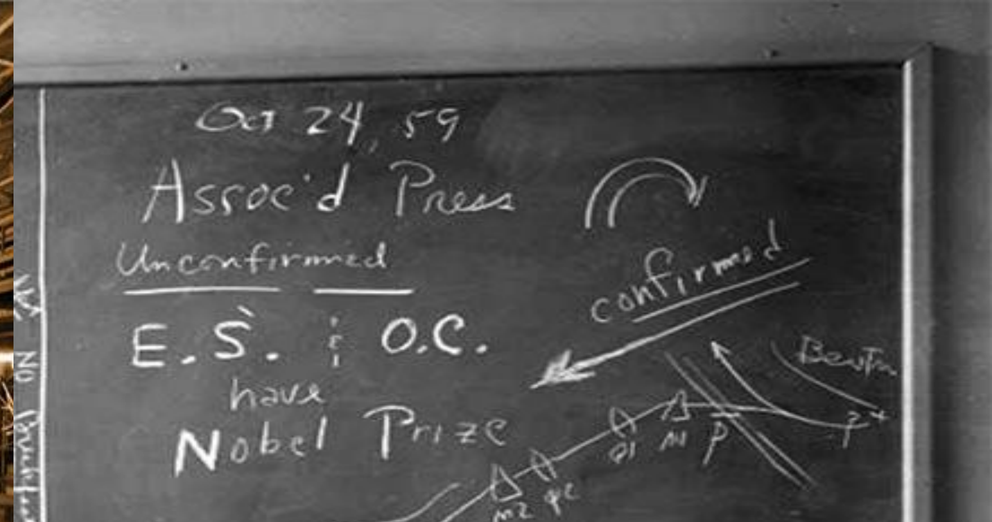


# GRANDES OBSERVATORIOS

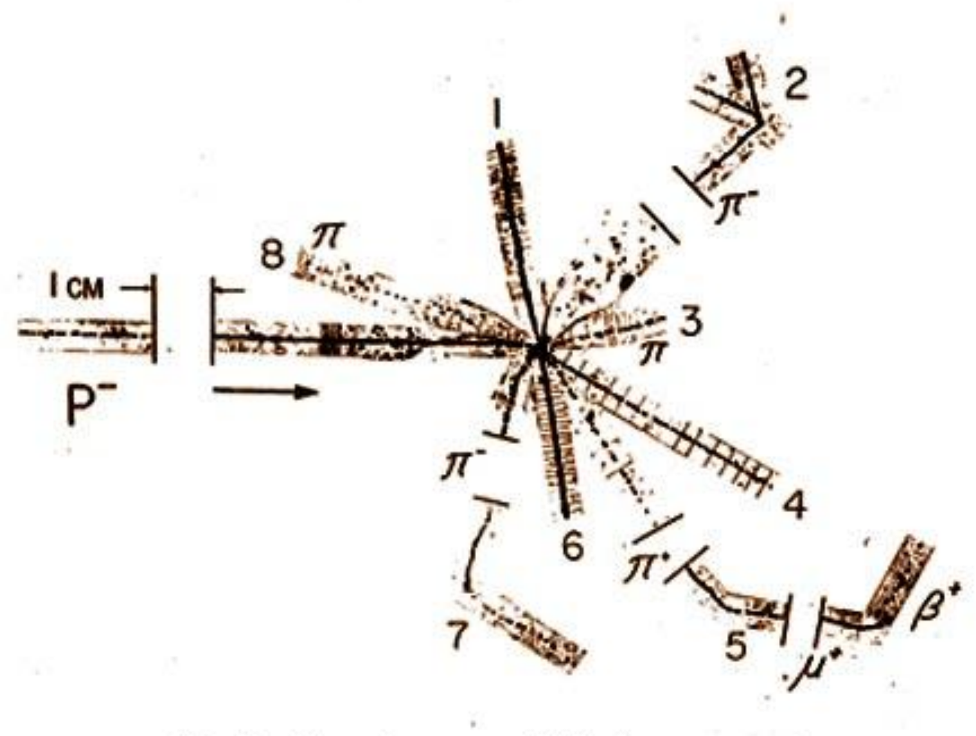


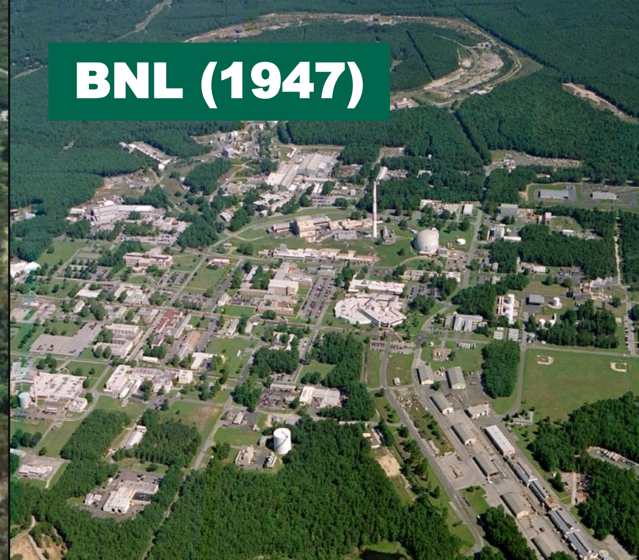

E.O. LAWRENCE
(1901 – 1958)
S. LIVINGSTONE
(1905 – 1986)




# 1955: DESCUBRIMIENTO DEL ANTIPROTÓN EN LBL

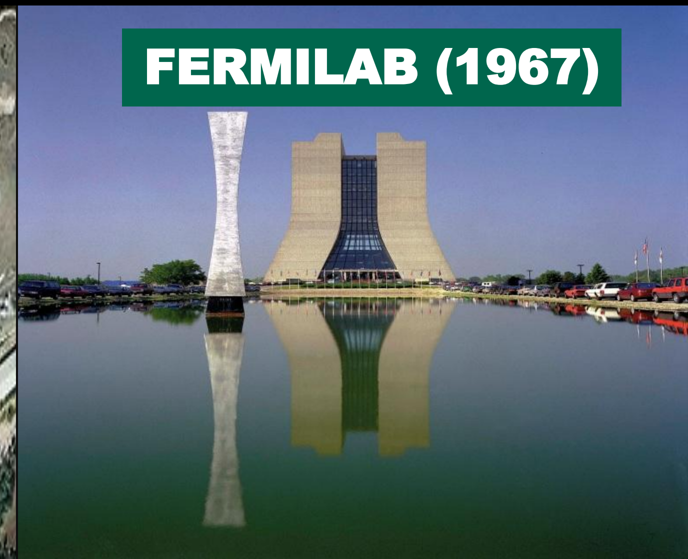
E. SEGRÉ, C.WIEGAND, E.J. LOFGREN,
O. CHAMBERLAIN, T. YPSILANTIS



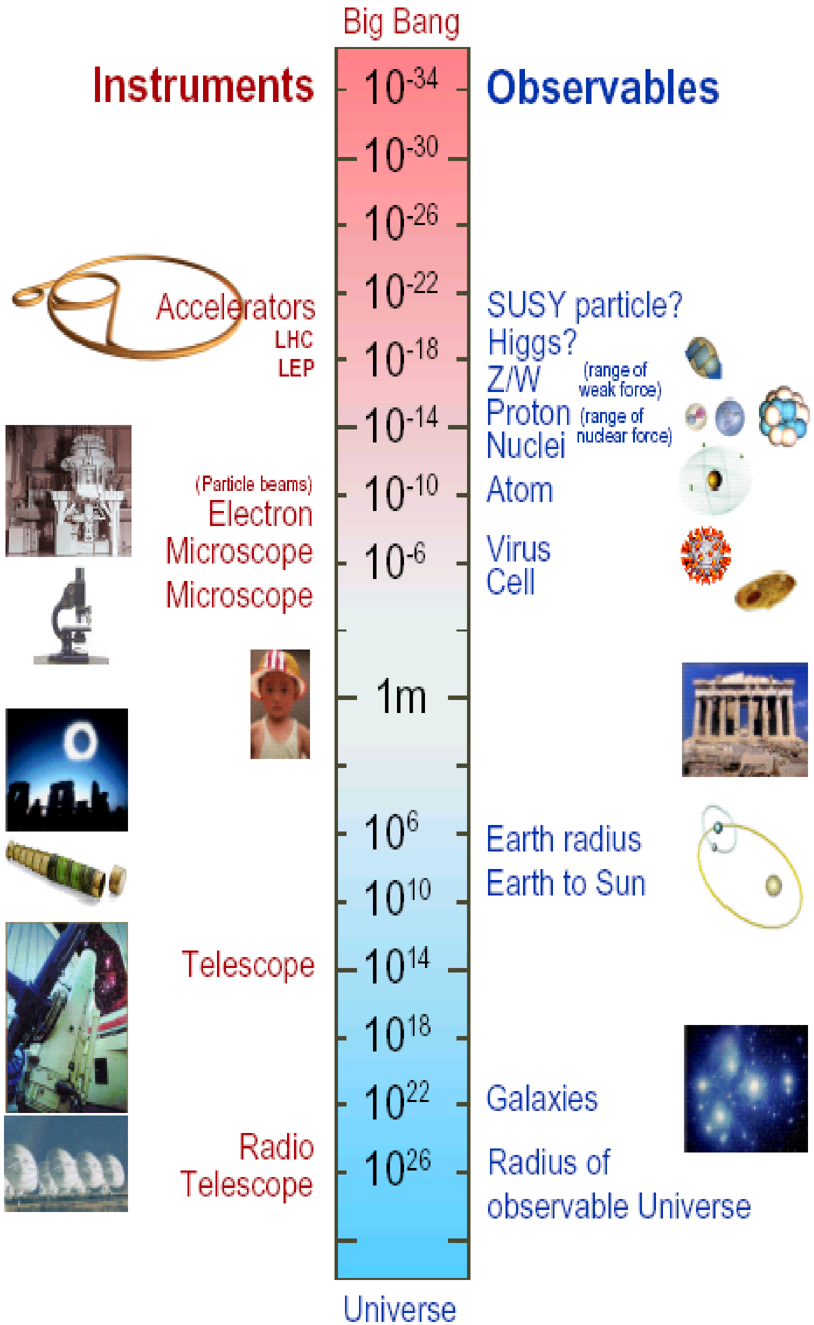





# GRANDES LABORATORIOS

## The size of things

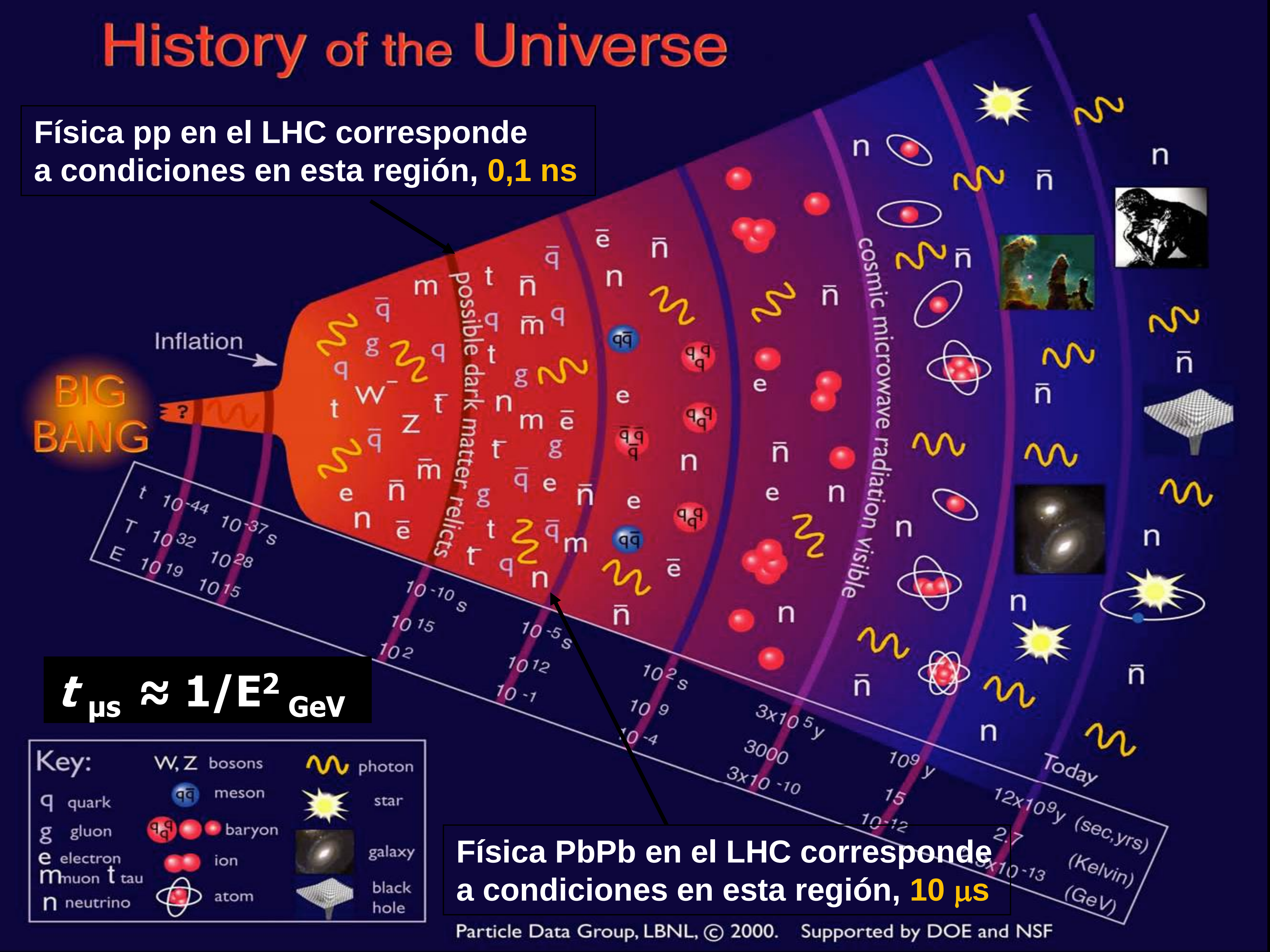



# $\lambda = h / p$

**$h = 4{,}135667516\ (91) \times 10^{-15}$ eV s**

- **$p = 1$ MeV/c ($10^{6}$ eV/c);**
  **$\lambda \approx 10^{-12}$ m**
- **$p = 1$ GeV/c ($10^{9}$ eV/c);**
  **$\lambda \approx 10^{-15}$ m**
- **$p = 1$ TeV/c ($10^{12}$ eV/c);**
  **$\lambda \approx 10^{-18}$ m**
- **$p = 10^{5}$ TeV/c ($10^{17}$ eV/c);**
  **$\lambda \approx 10^{-23}$ m**

**Zeptometro = $10^{-21}$ m**



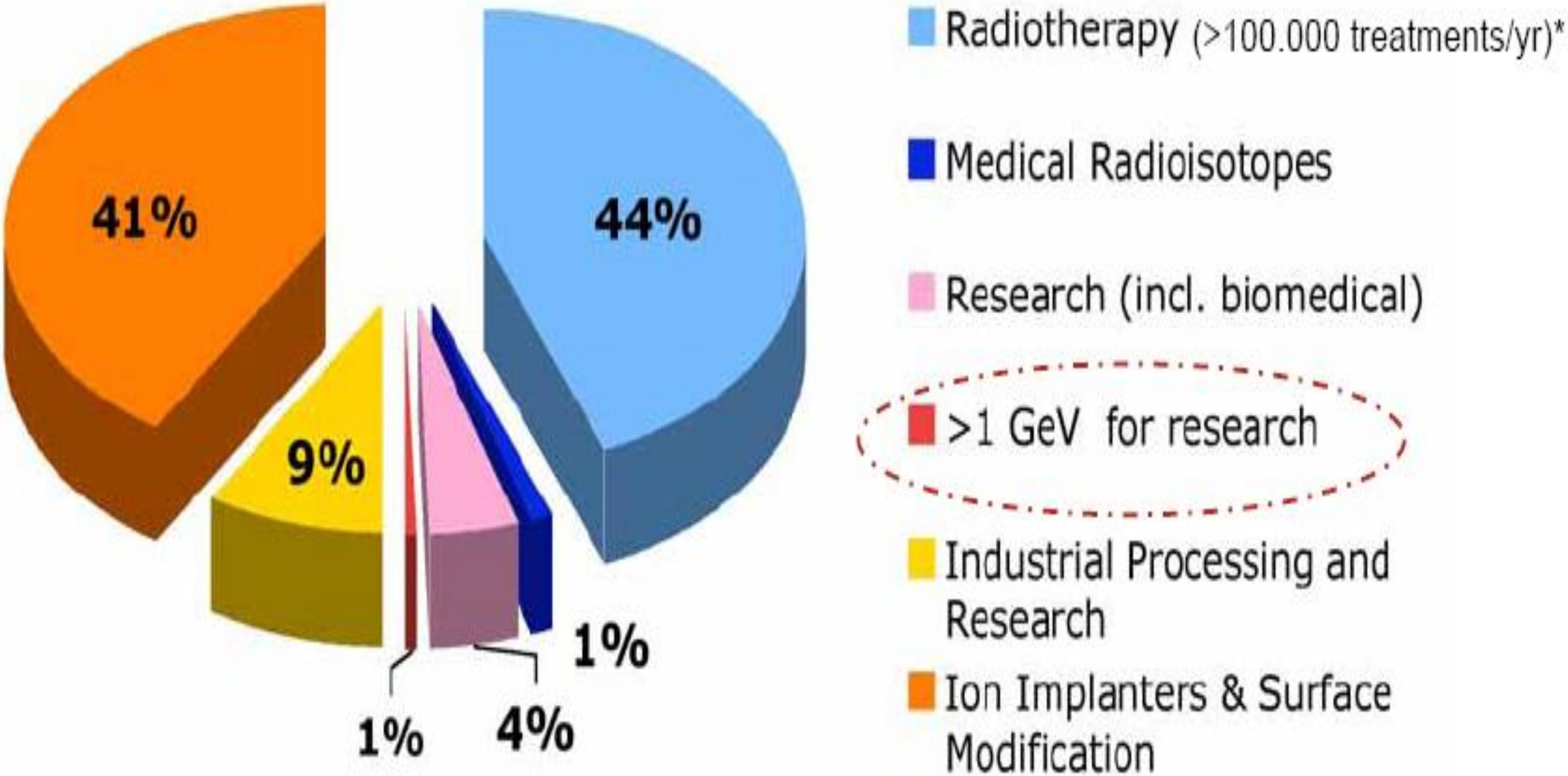

**Física pp en el LHC corresponde a condiciones en esta región, 0,1 ns**

$$t_{\mu s} \approx 1/E^2_{GeV}$$

**Física PbPb en el LHC corresponde a condiciones en esta región, 10 μs**

(

# Number of accelerators worldwide
# ~ 26,000




*Annual growth is several percent*

***Sales >3.5 B$/yr***

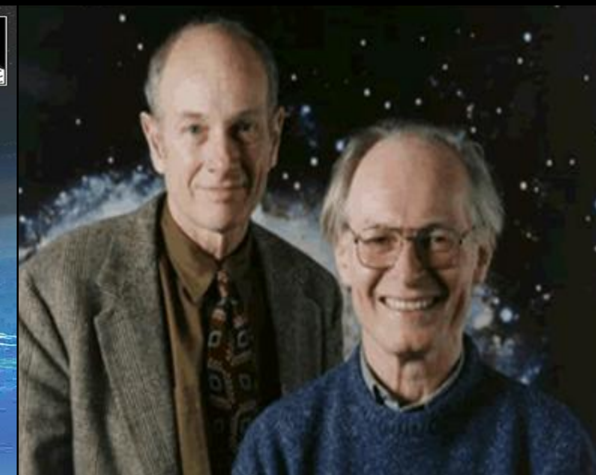
***Value of treated good > 50 B$/yr *****

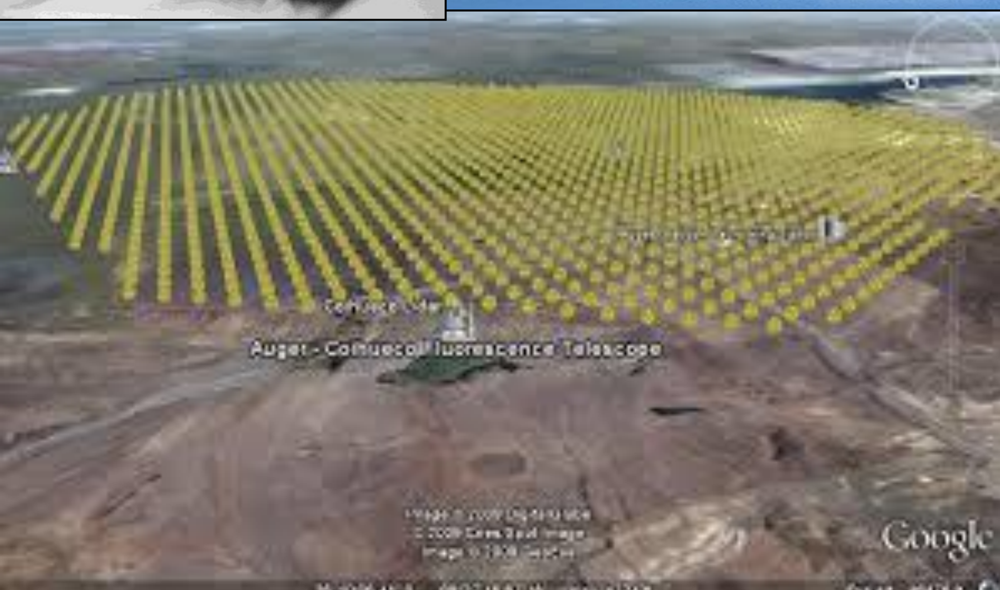
)

# OBSERVATORIOS SUBTERRÁNEOS



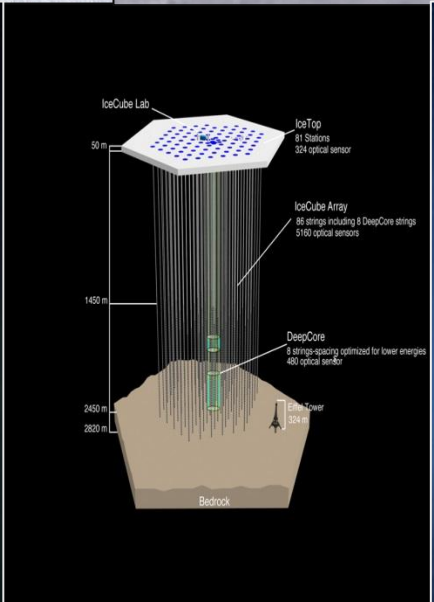
# OBSERVATORIOS EN SUPERFICIE



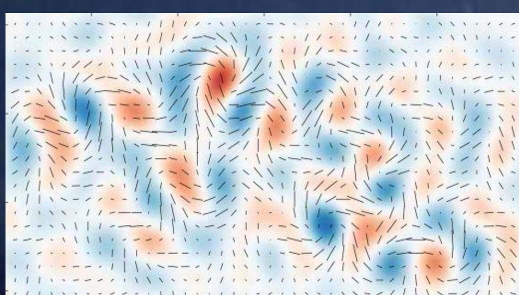

# PIERRE AUGER OBSERVATORY

# OBSERVATORIOS EN HIELO




# BICEP2 ---- BACKGROUND IMAGING COSMIC EXTRAGALACTIC POLARIZATION

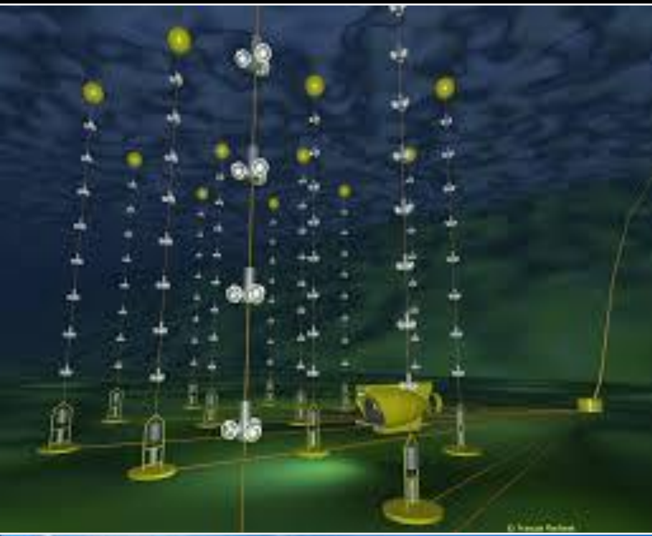
## MODO DE POLARIZACIÓN B DE LA RADIACIÓN CMB DEBIDA A LAS ONDAS GRAVITACIONALES GENERADAS POR LAS FLUCTUACIONES CUÁNTICAS PRODUCIDAS EN EL PROCESO INFLACIONARIO QUE TUVO LUGAR CUANDO EL UNIVERSO TENÍA ~$10^{-37}$ s, TEMPERATURA ~$10^{28}$ K, ENERGÍA ~$10^{15}$ GeV

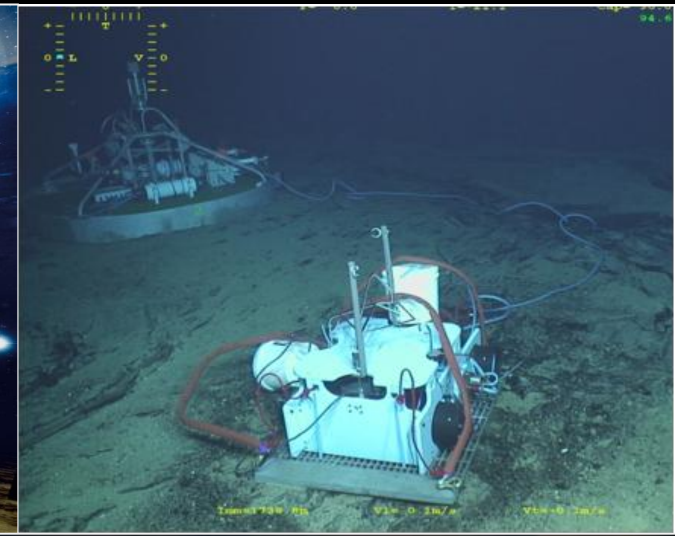



## TEORÍA DE LA INFLACIÓN CÓSMICA

**ALAN GUTH, ANDREI LINDE, ALEXEI STAROBINSKY (~1980)**

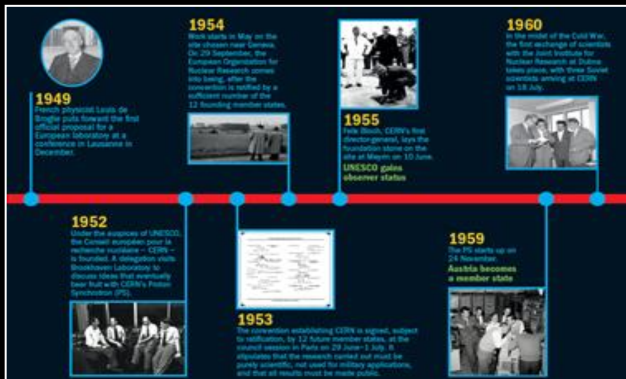
# OBSERVATORIOS EN AGUA

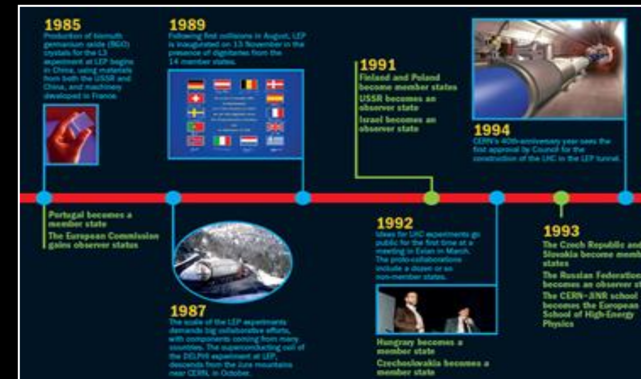


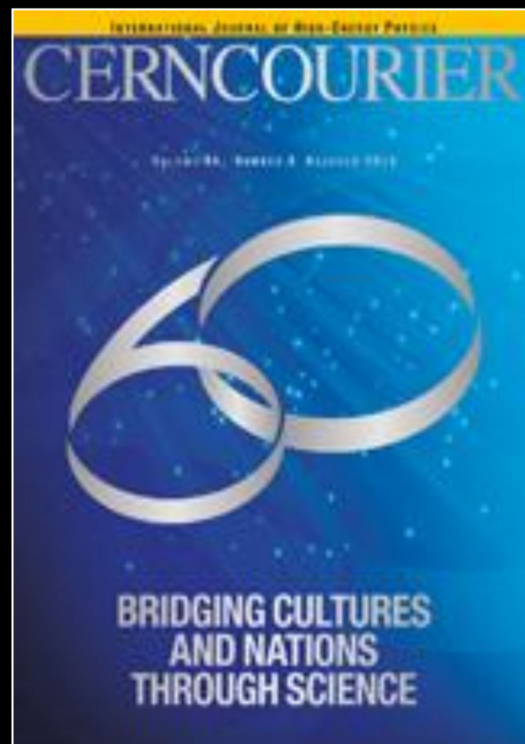


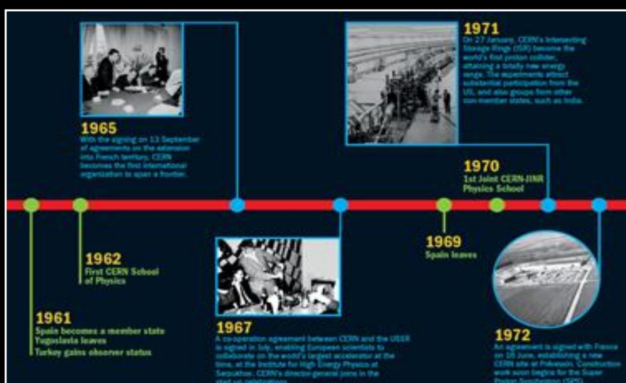
# OBSERVATORIOS ESPACIALES

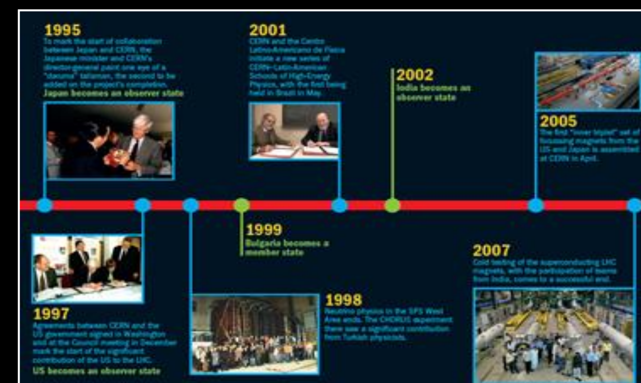
# CERN (1954–2014)

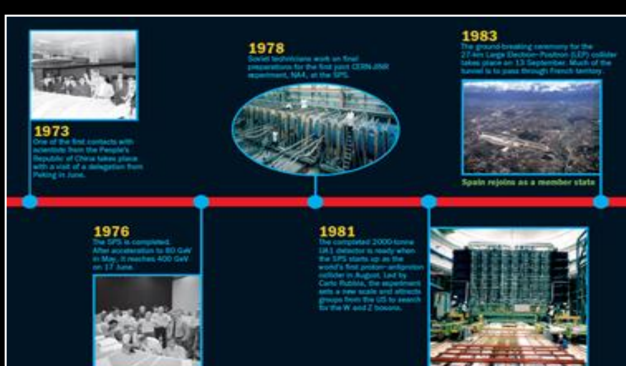


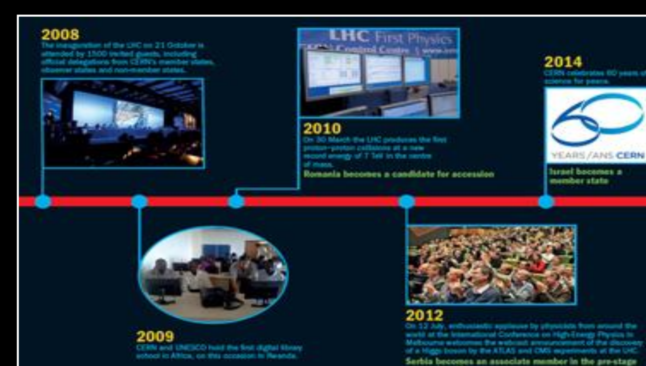



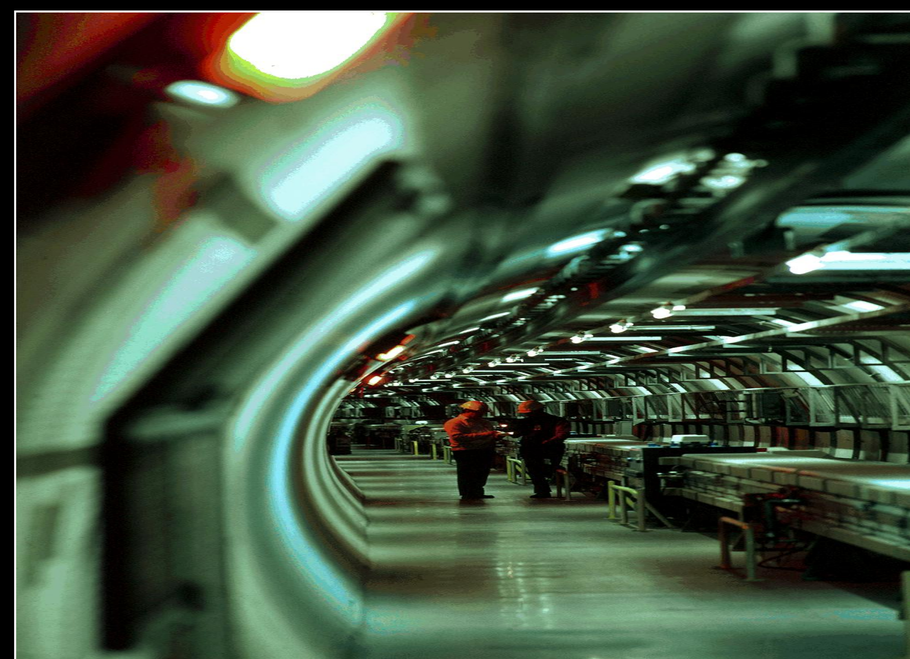



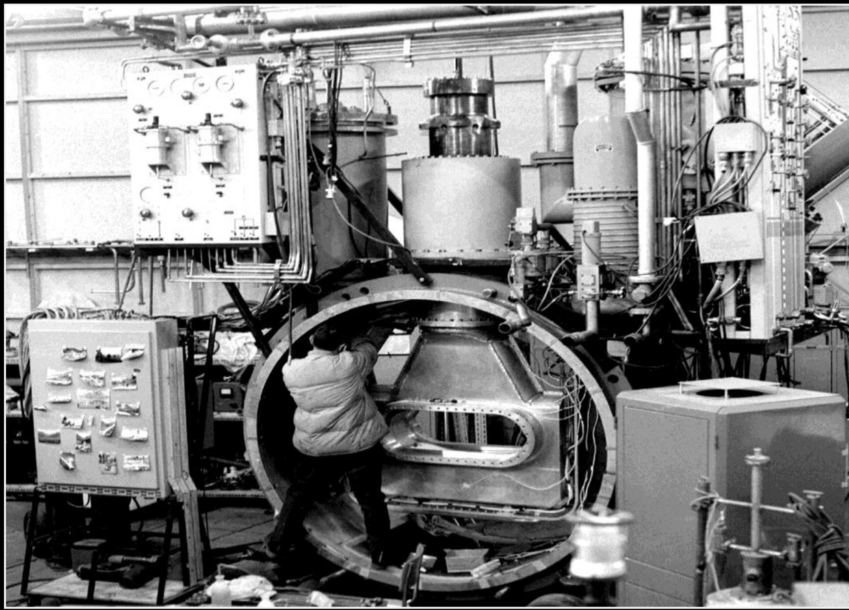



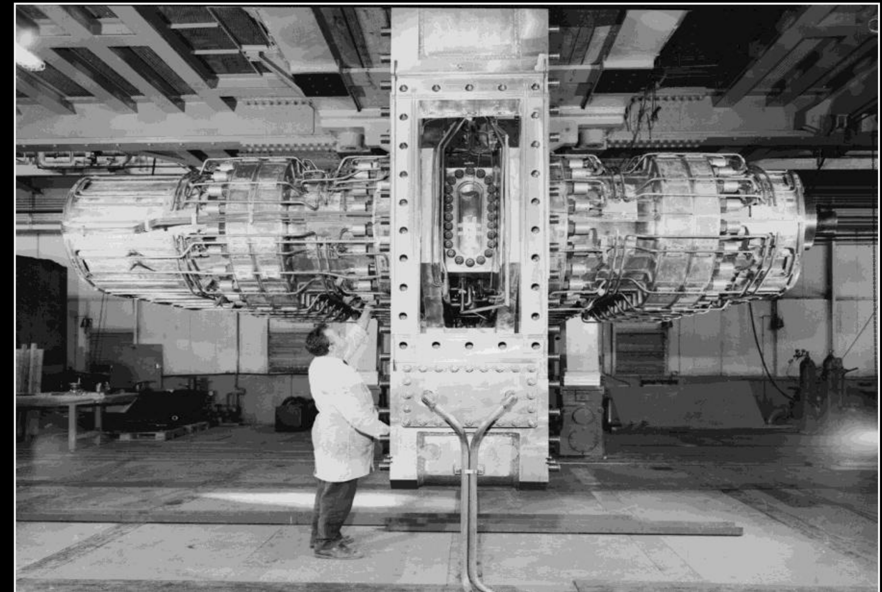



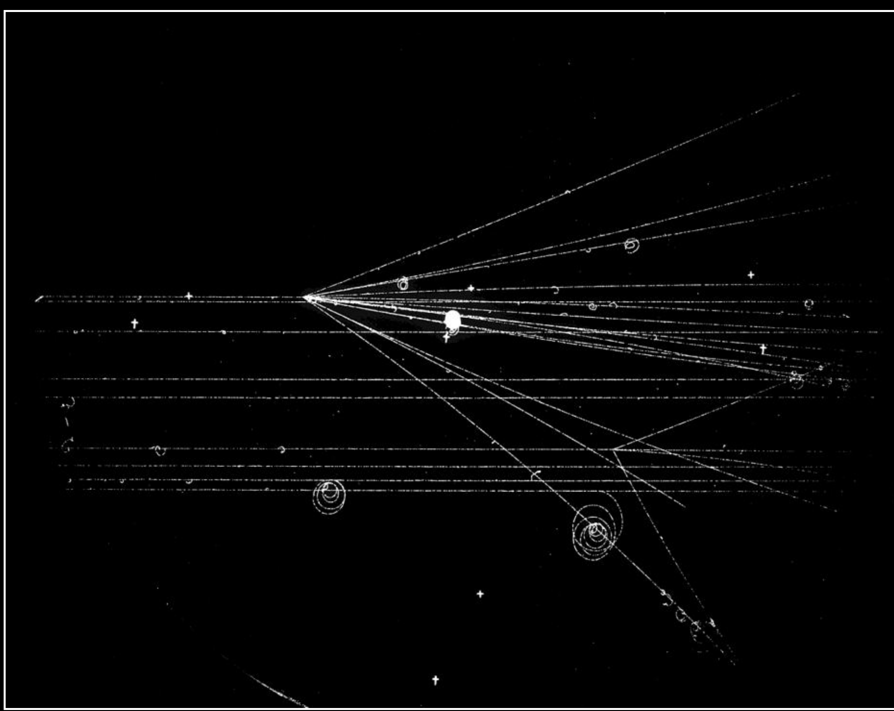



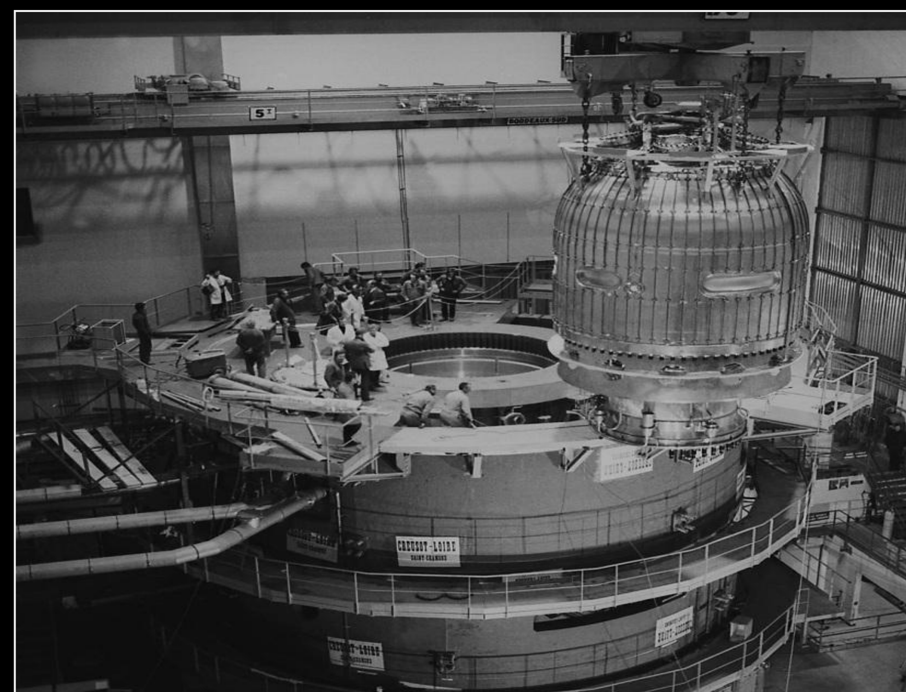

ITALIE







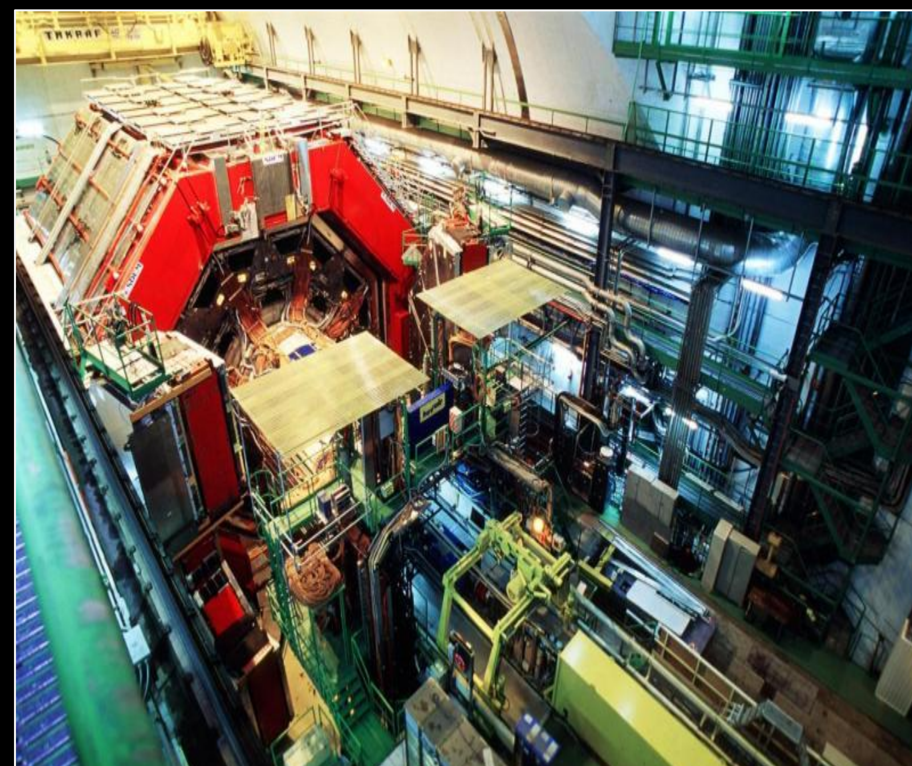



CREUSOT-LOIRE


NB 231


MAFI


HNA 386
EHS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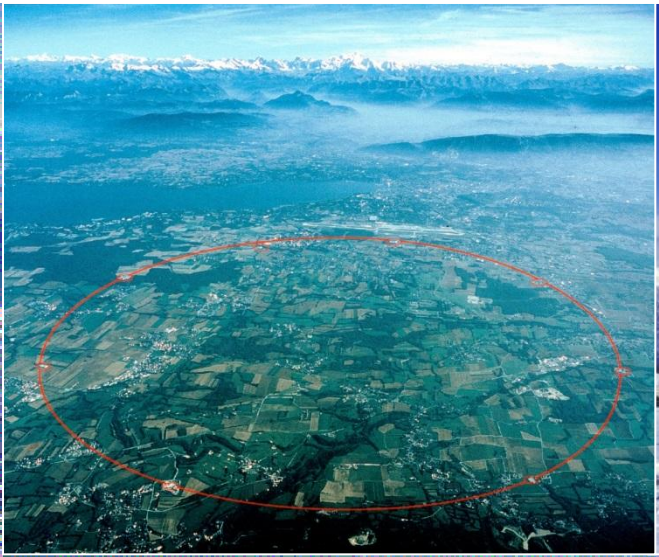
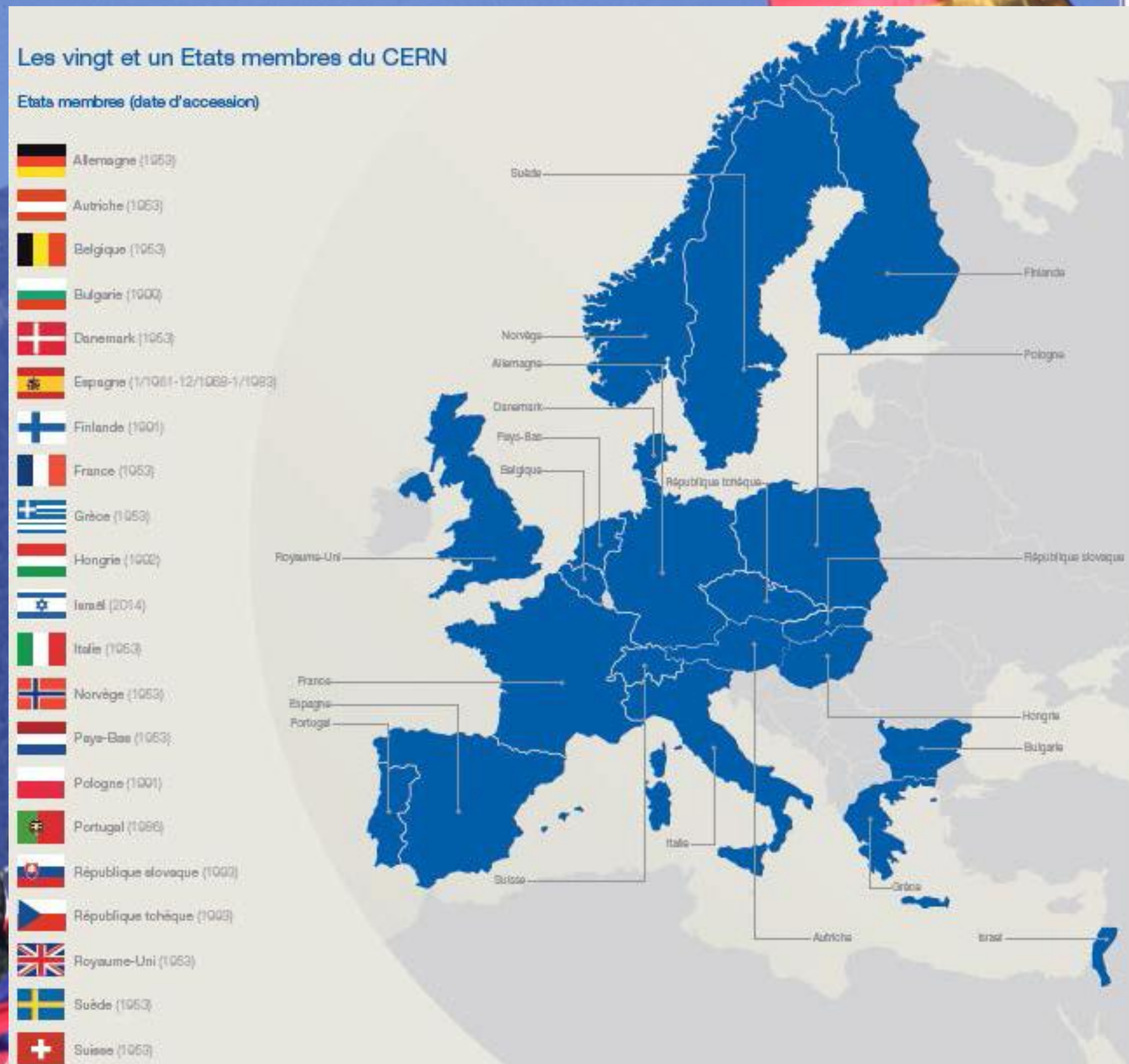


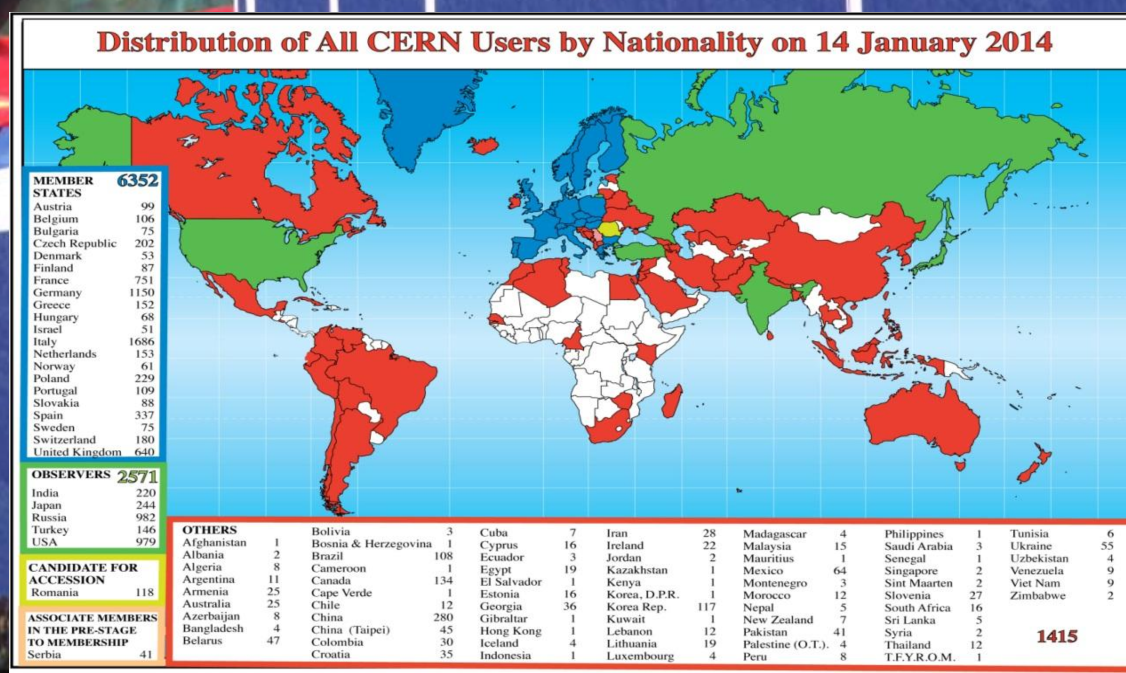

# CERN (2014)

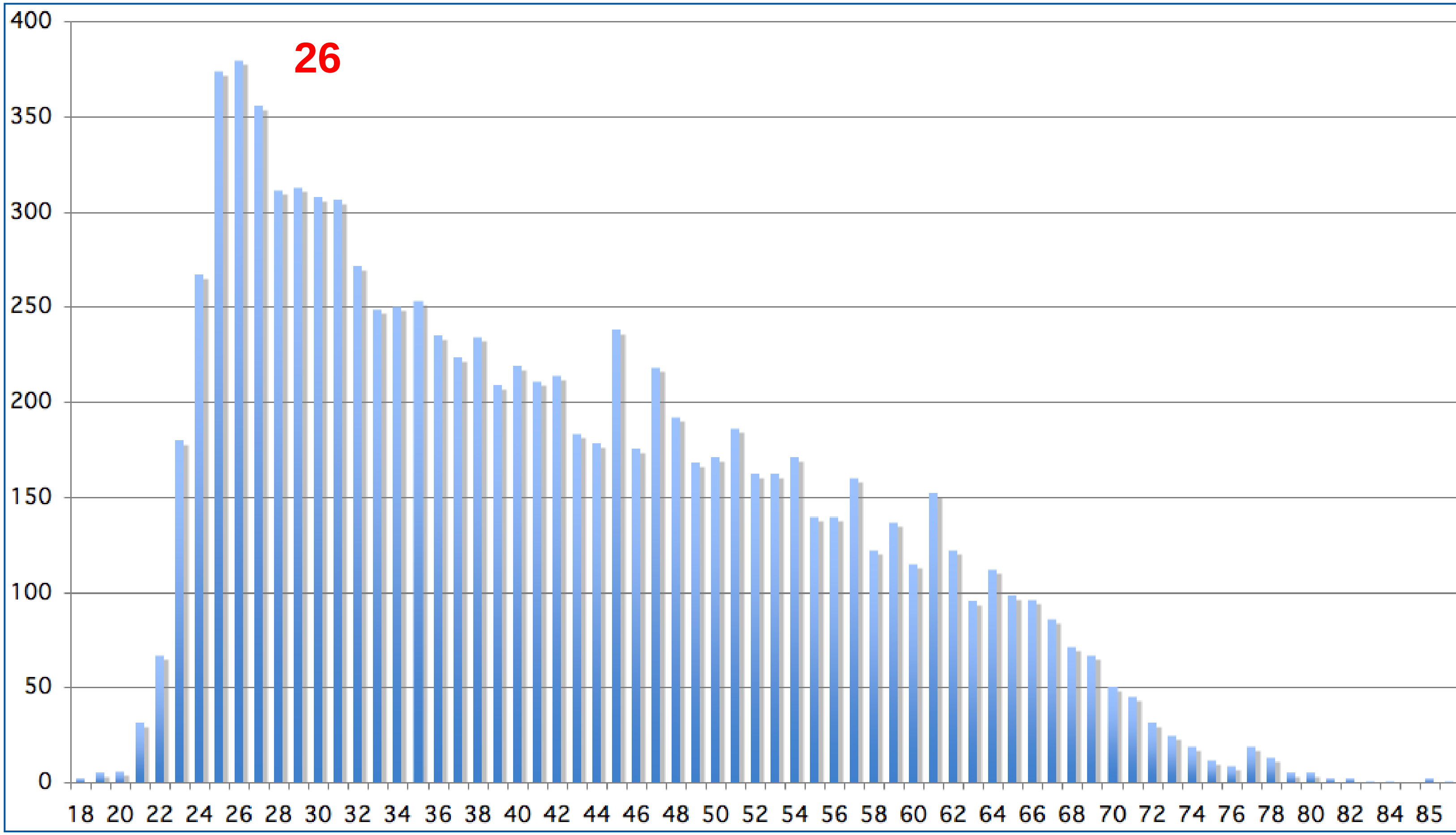

# CERN


Les vingt et un Etats membres du CERN
Etats membres (date d'accession)
Allemagne (1953)
Autriche (1953)
Belgique (1953)
Bulgarie (1999)
Danemark (1953)
Espagne (1/1961-12/1968-1/1983)
Finlande (1991)
France (1953)
Grèce (1953)
Hongrie (1992)
Israël (2014)
Italie (1953)
Norvège (1953)
Pays-Bas (1953)
Pologne (1991)
Portugal (1986)
République slovaque (1993)
République tchèque (1993)
Royaume-Uni (1953)
Suède (1953)
Suisse (1953)
Suède
Finlande
Norvège
Allemagne
Pologne
Danemark
Pays-Bas
Belgique
République tchèque
Royaume-Uni
République slovaque
France
Espagne
Portugal
Hongrie
Bulgarie
Italie
Suisse
Grèce
Autriche
Israël

# CERN

- 2513 Staff (31.12.2013)
- 10611 Usuarios
- 566 Becarios
- 1180 Estudiantes & Asociados
- Contribuciones EM (2014):
  1108,5 MCHF (~908,6 M Euros)




26
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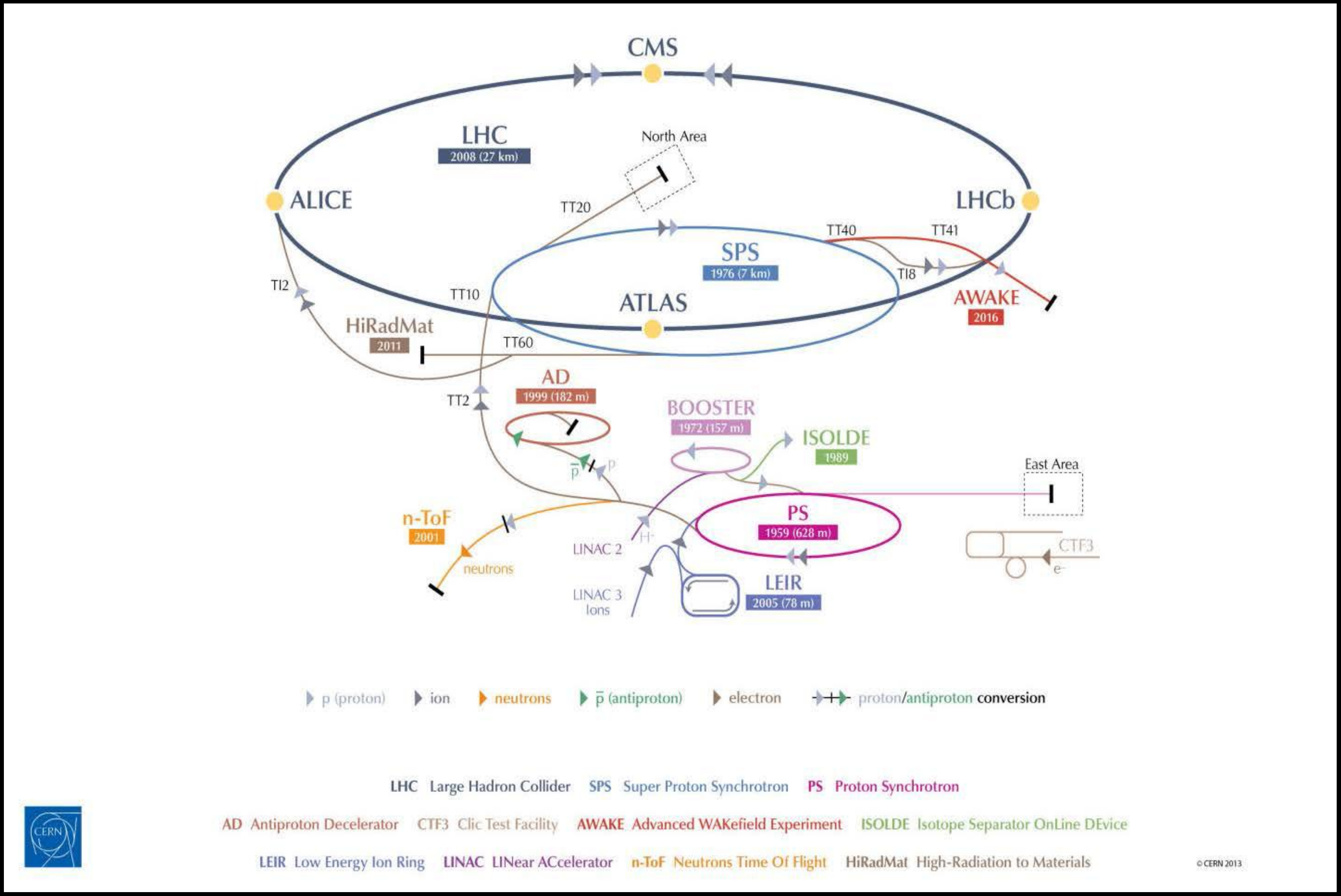
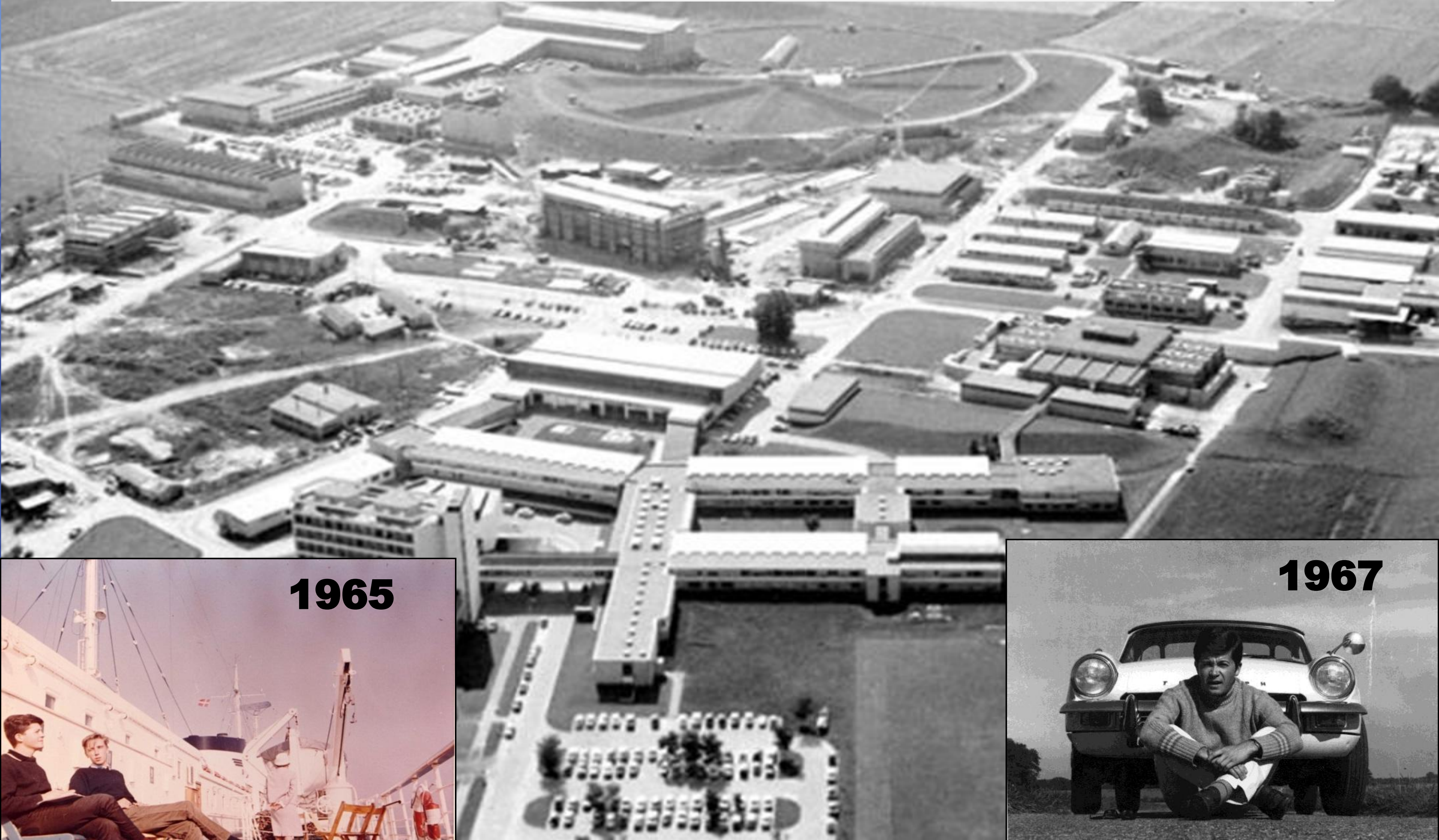
18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 85

# CERN: EL COMPLEJO DE ACELERADORES MÁS COMPLETO DEL MUNDO

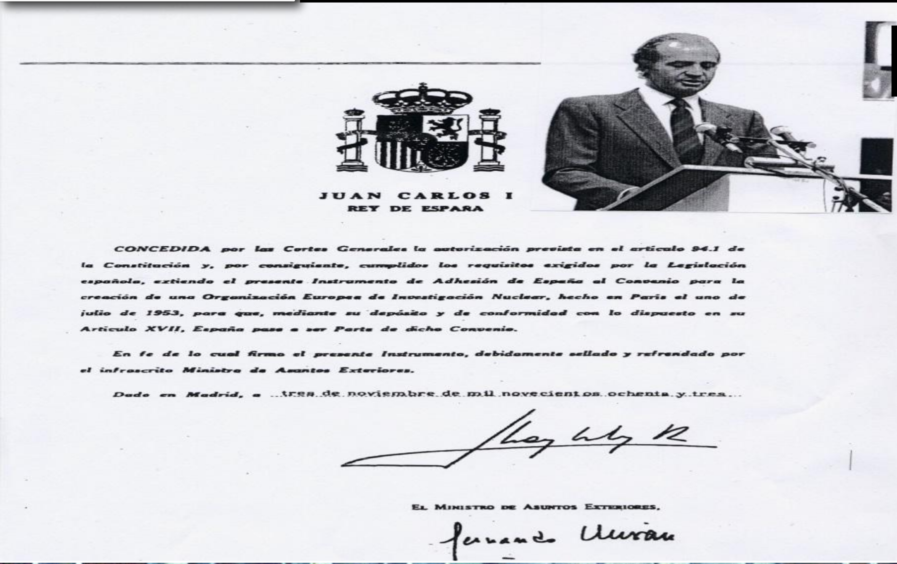


# ESPAÑA & CERN

## ESTADO MIEMBRO: 1961–1968; 1983–



# ESPAÑA & CERN


JUAN CARLOS I
REY DE ESPAÑA

*CONCEDIDA por las Cortes Generales la autorización prevista en el artículo 94.1 de la Constitución y, por consiguiente, cumplidos los requisitos exigidos por la Legislación española, extiendo el presente Instrumento de Adhesión de España al Convenio para la creación de una Organización Europea de Investigación Nuclear, hecho en París el uno de julio de 1953, para que, mediante su depósito y de conformidad con lo dispuesto en su Artículo XVII, España pase a ser Parte de dicho Convenio.*

*En fe de lo cual firmo el presente Instrumento, debidamente sellado y refrendado por el infrascrito Ministro de Asuntos Exteriores.*

*Dado en Madrid, a* tres de noviembre de mil novecientos ochenta y tres

EL MINISTRO DE ASUNTOS EXTERIORES,

**NOVIEMBRE 1983**

**1984: CERN 30 ANIVERSARIO**


**2004: CERN 50 ANIVERSARIO**

# ESPAÑA & CERN

- **126 Staff (5,0 %)**
- **316 Usuarios (3,1 %)**
- **75 Becarios (13,2 %)**
- **128 Estudiantes & Asociados (10,8 %)**
- **Contribución (2014): 8,28 %:**
  **91,78 MCHF (~ 75,2 M Euro)**

# CONTRIBUCIÓN DEL CERN A LA CONSTRUCCIÓN DEL MODELO ESTÁNDAR

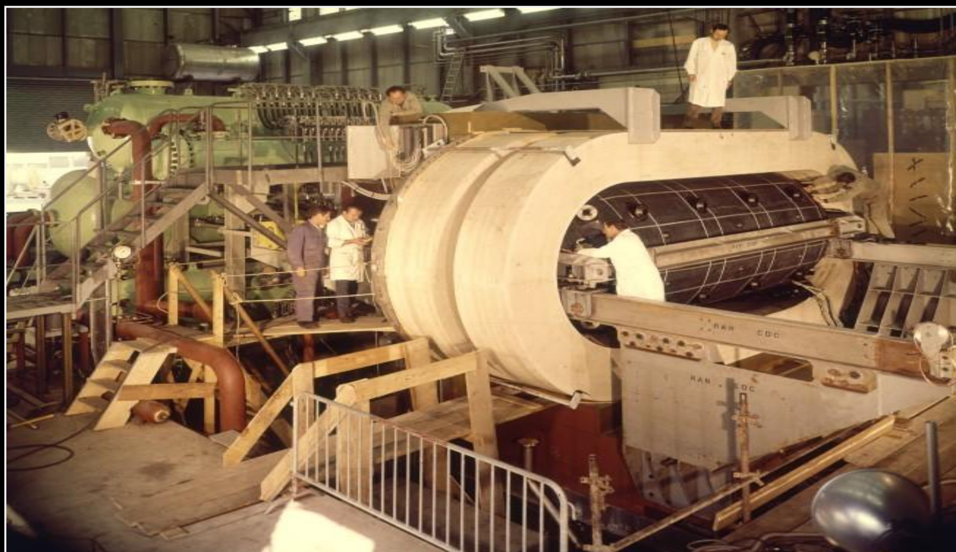
# LOS AVANCES EN EL ACOPIO DE CONOCIMIENTO SE BASAN EN:

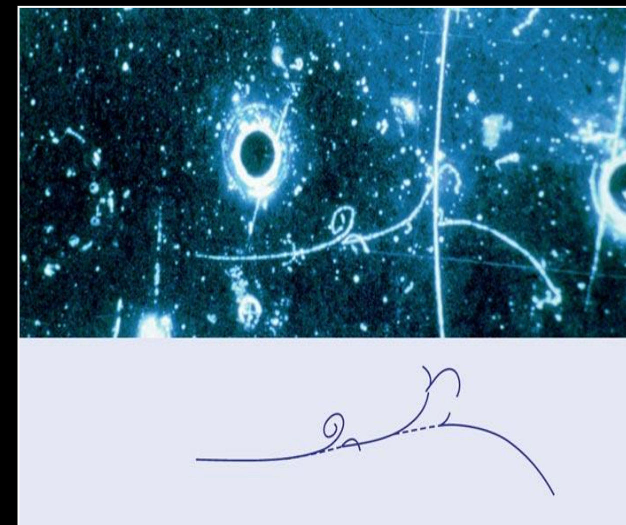
- DESARROLLOS INSTRUMENTALES
- DESCUBRIMIENTO DE NUEVOS PROCESOS
- DESCUBRIMIENTO DE NUEVAS PARTÍCULAS
- VIOLACIÓN DE LEYES DE CONSERVACIÓN
- MEDIDAS DE PRECISIÓN

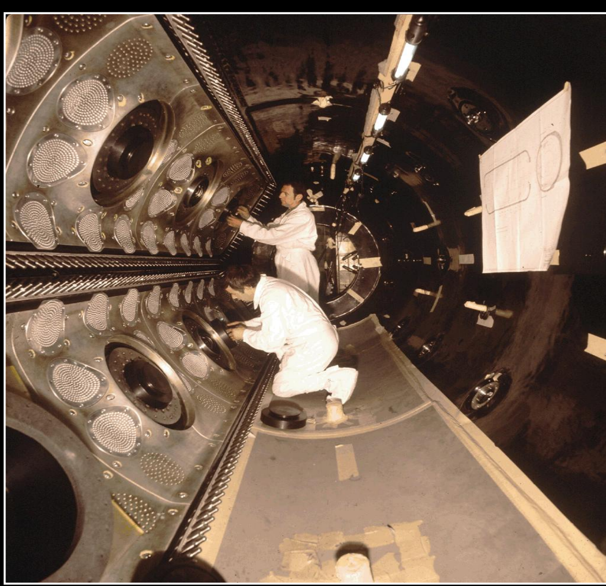
# CONTRIBUCIONES DEL CERN

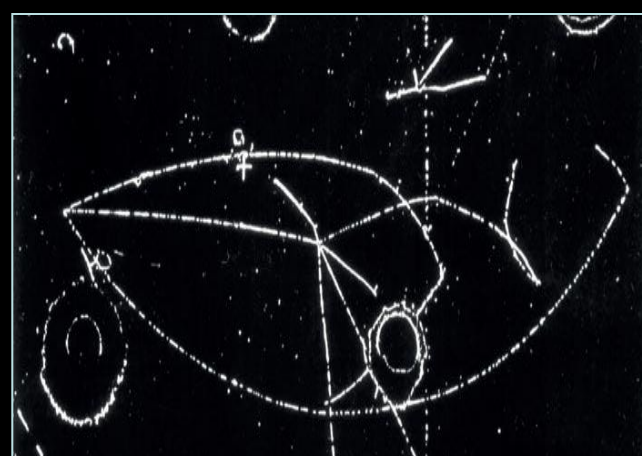
- ESPECTROSCOPÍA HADRÓNICA (1960-1980)
- INVENCIÓN DEL “NEUTRINO HORN” (1961)
- INVENCIÓN DE LAS CÁMARAS MULTIHILOS (1967)
- INVENCIÓN DEL ENFRIAMIENTO ESTOCÁSTICO (1971)
- DESCUBRIMIENTO DE LAS CORRIENTES NEUTRAS (1973)
- DISPERSIÓN INELÁSTICA DE NEUTRINOS (1973-1985)
- DESCUBRIMIENTO DE LOS BOSONES $W^{\pm}$ Y Z (1983)
- VIOLACIÓN DE LA SIMETRÍA CP ($\varepsilon'/\varepsilon$) (1985-2002)
- INVENCIÓN DEL WORLD WIDE WEB (WWW) (1989)
- DETERMINACIÓN DEL NÚMERO DE NEUTRINOS (1992)
- DESCUBRIMIENTO DE LAS CORRECCIONES EW (1992)
- DESCUBRIMIENTO DEL BOSÓN DE HIGGS (2012)

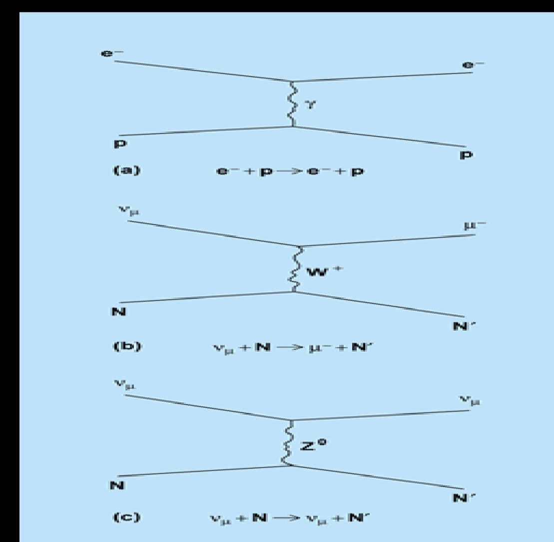
# 1973: DESCUBRIMIENTO DE LAS CORRIENTES NEUTRAS (GARGAMELLE)



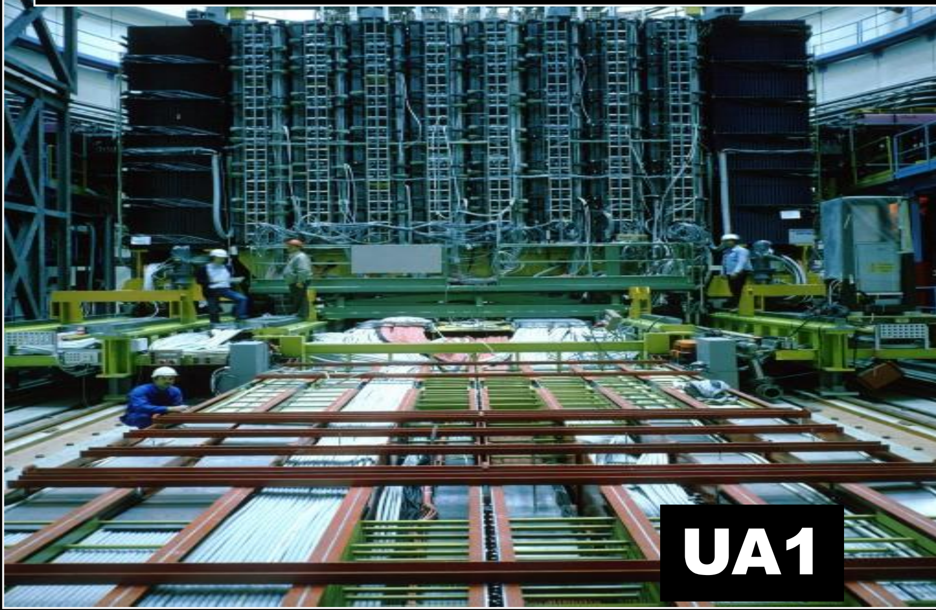


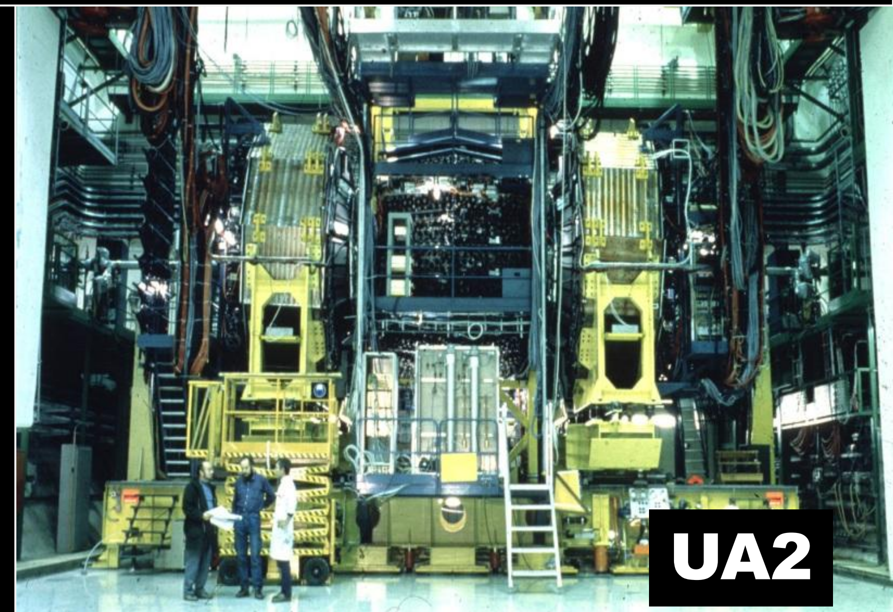


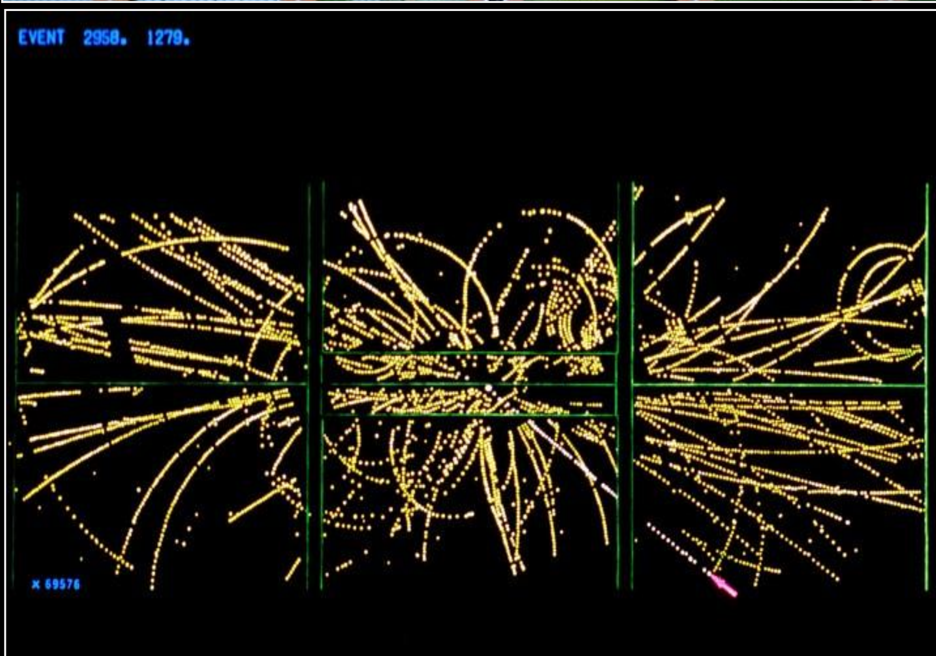




# 1983: DESCUBRIMIENTO DE LOS BOSONES $W^{\pm}$ Y Z

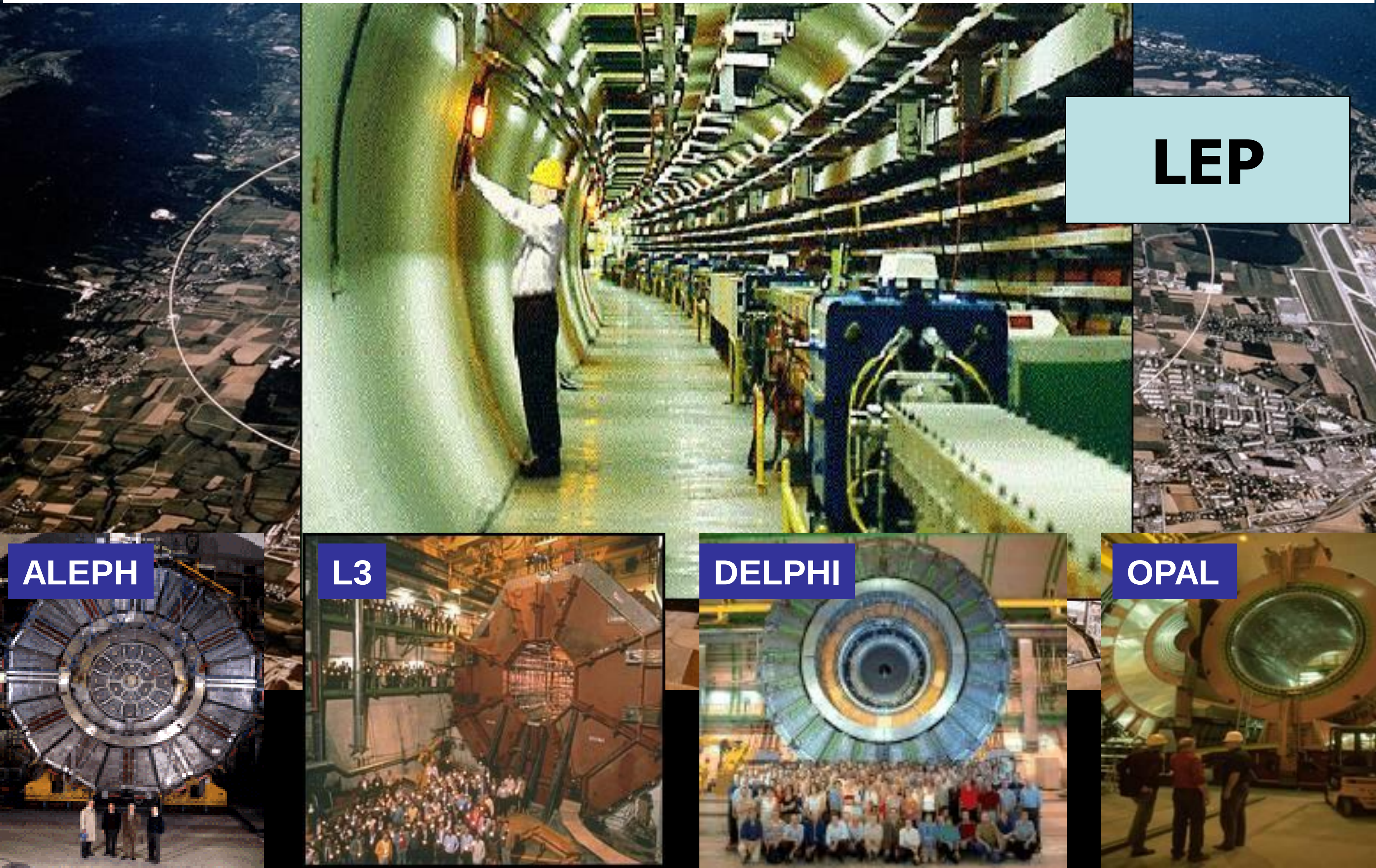


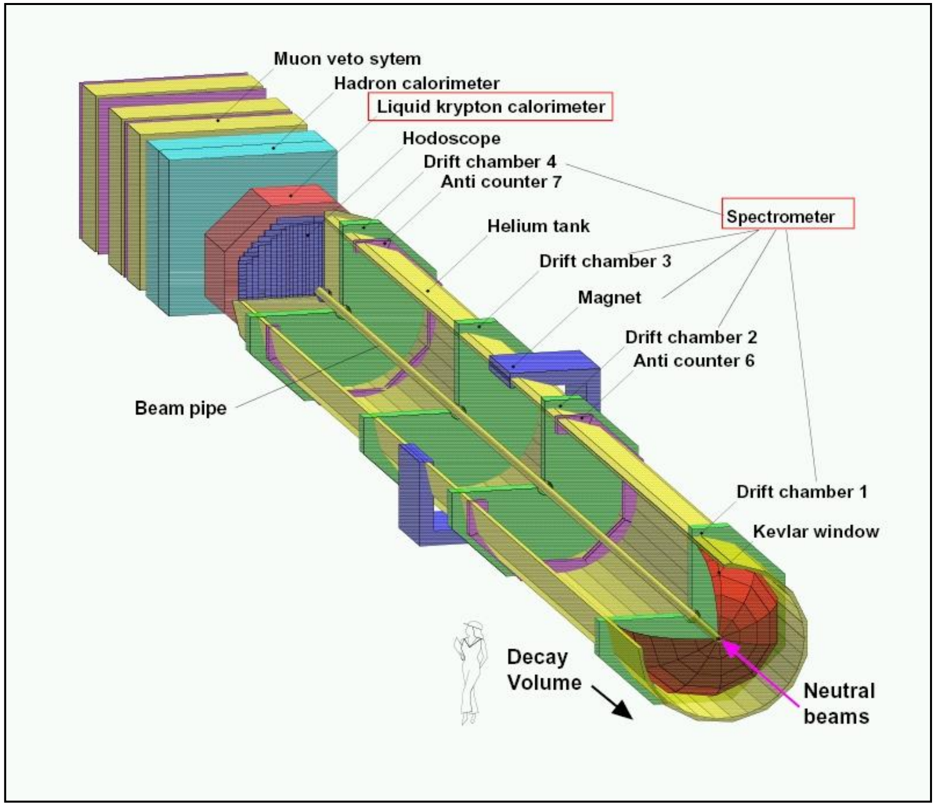



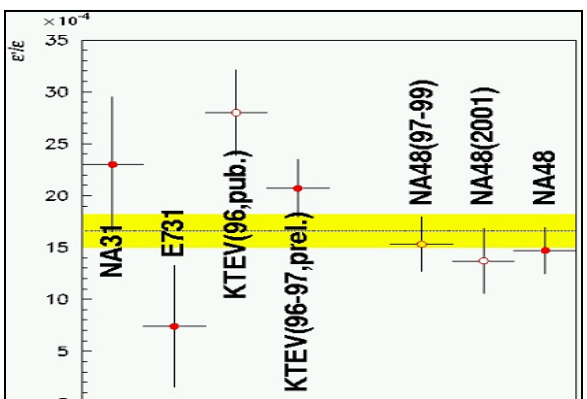

**C. RUBBIA, S. van DER MEER**
**PREMIOS NOBEL 1984**

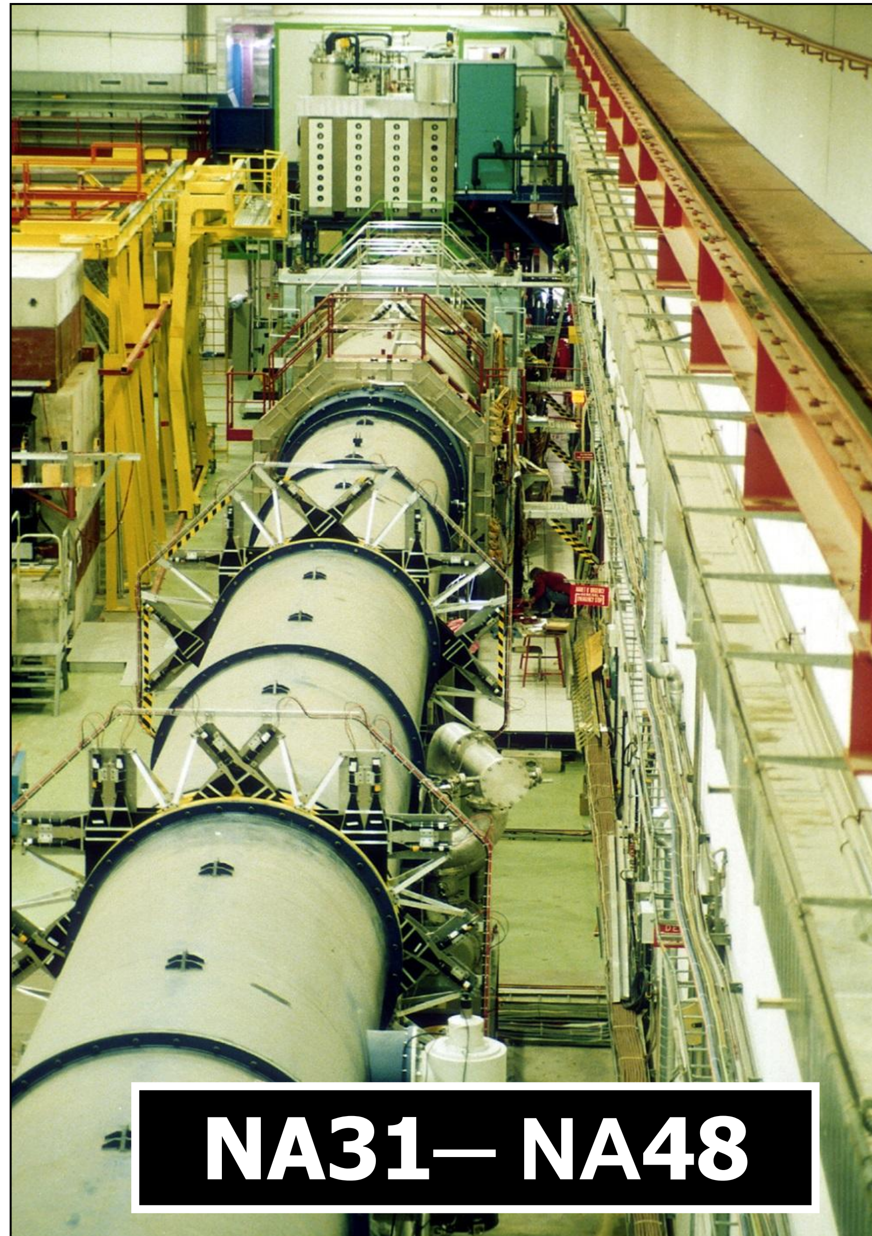
# 1989 — 2000:
# VALIDACIÓN DEL MODELO ESTÁNDAR



# 1986 — 2001: MEDIDA DE ε' / ε



**NA31— NA48**

# 1967: INVENCIÓN CÁMARA MULTIHILOS

G. CHARPAK (1924–2010), PREMIO NOBEL 1992

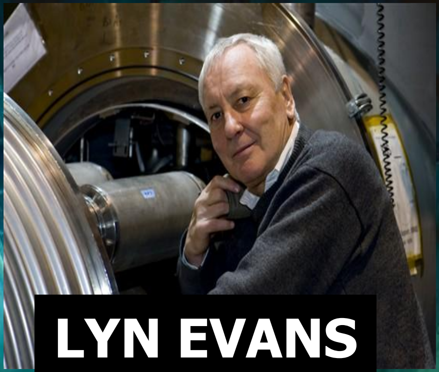
# 1989: INVENCIÓN DEL WWW


TIM BERNERS LEE

# DESCUBRIMIENTO DEL BOSÓN B-E-H EN EL LHC

# ¡¡ EL LHC !!

**UNA ODISEA ZEPTOESPACIAL,**
***A Journey into the Physics of the LHC,***
***Gian Francesco Giudice***



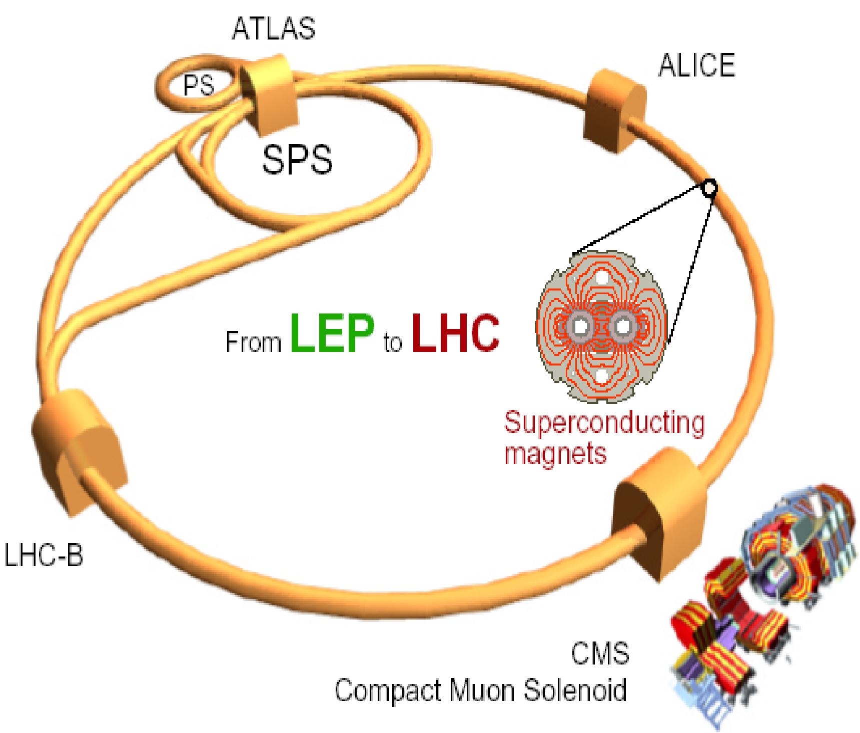



**Principales Objetivos Científicos**

- **Origen de la Masa**
- **Naturaleza de la Materia Oscura**
- **Estructura del Espacio–Tiempo**
- **Materia & Antimateria**
- **Plasma Primordial**

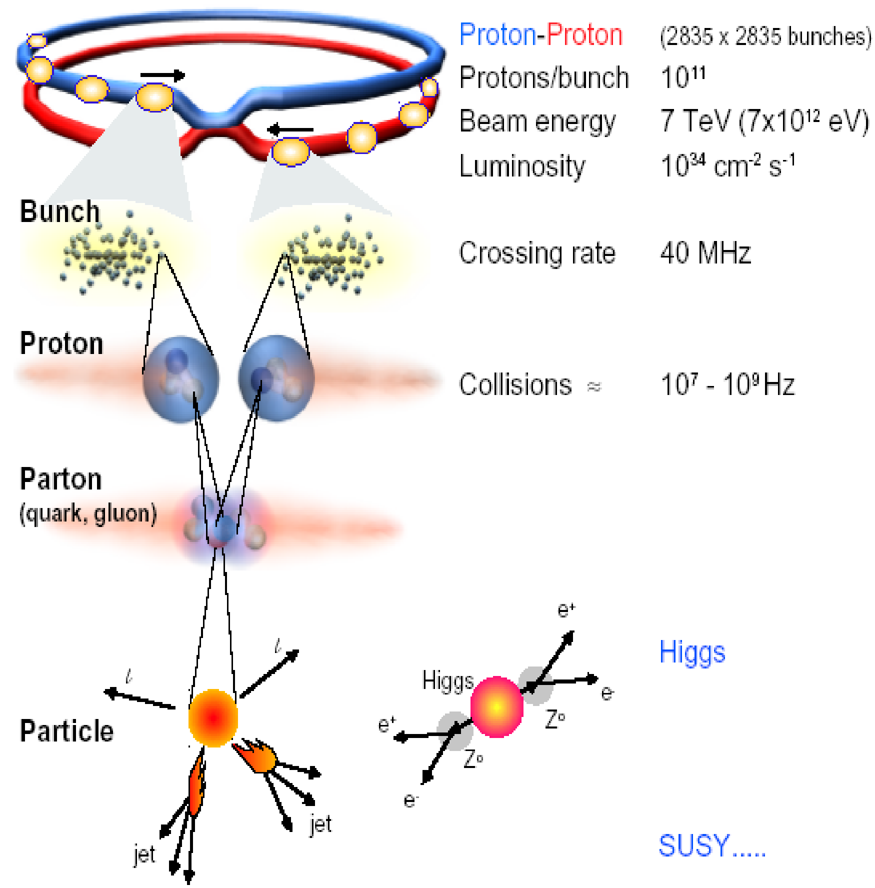
**EL LHC SEÑALARÁ EL FUTURO DE LA FÍSICA DE PARTÍCULAS**

# The Large Hadron Collider (LHC)




| | Beams | Energy | | Luminosity |
|---|---|---|---|---|
| LEP | e+ e- | 200 | GeV | $10^{32}\ cm^{-2}s^{-1}$ |
| LHC | p p | 14 | TeV | $10^{34}$ |
| | Pb Pb | 1312 | TeV | $10^{27}$ |

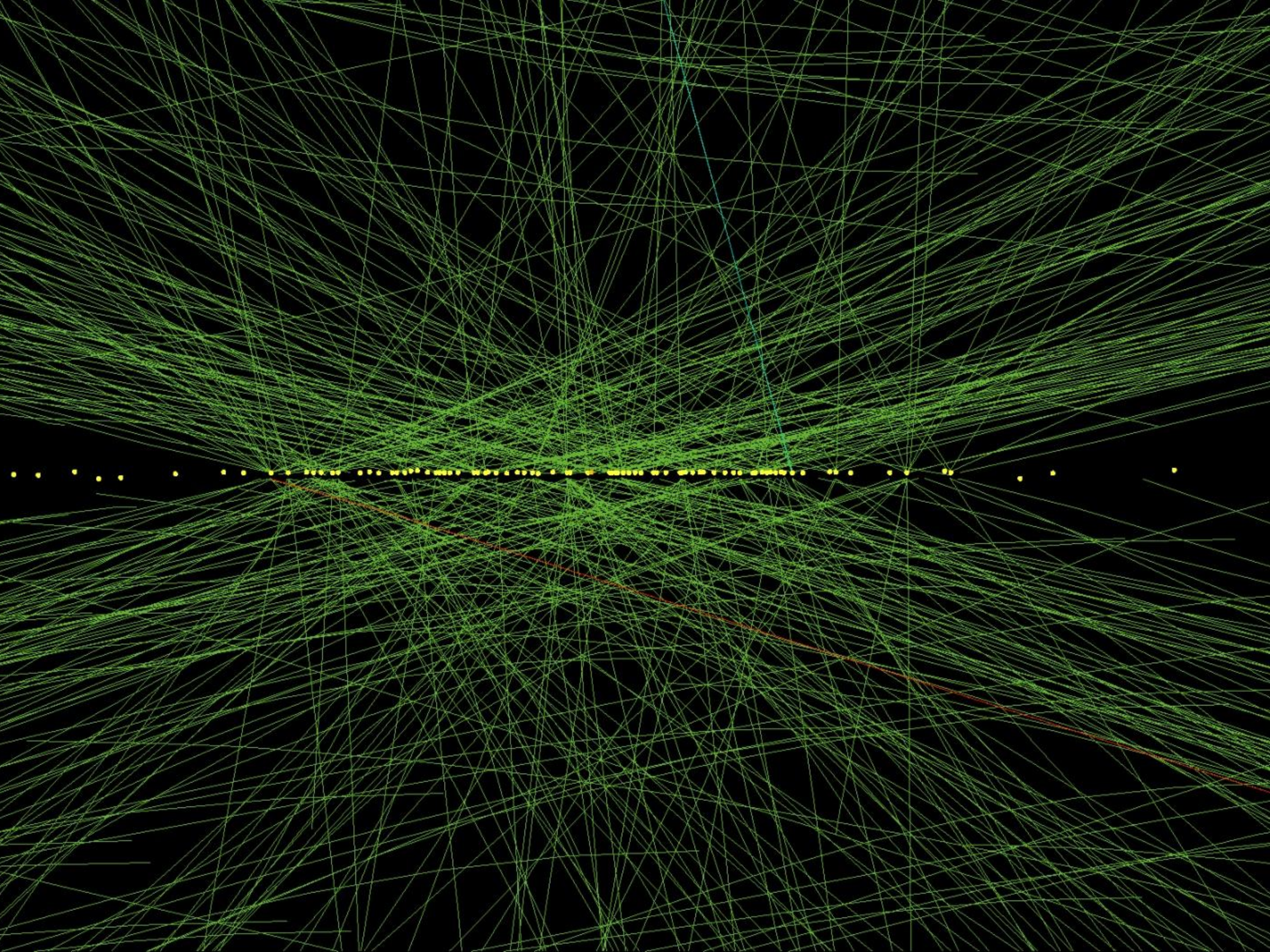
# Collisions at LHC



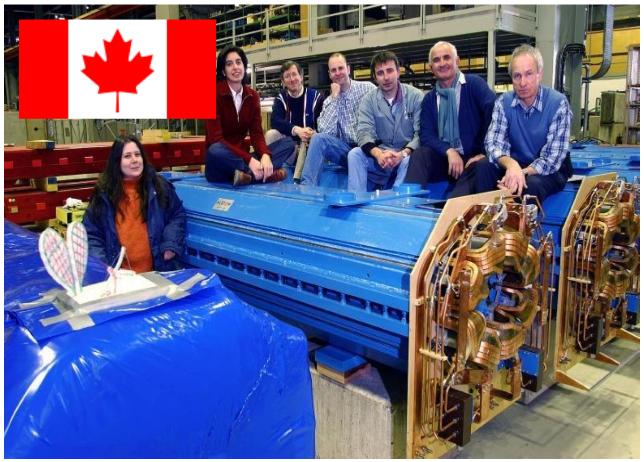

Selection of 1 in 10,000,000,000,000

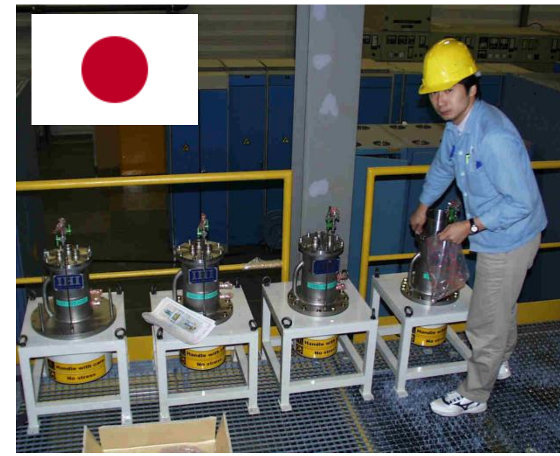
**SUPERCONDUCTIVIDAD, CRIOGENIA**

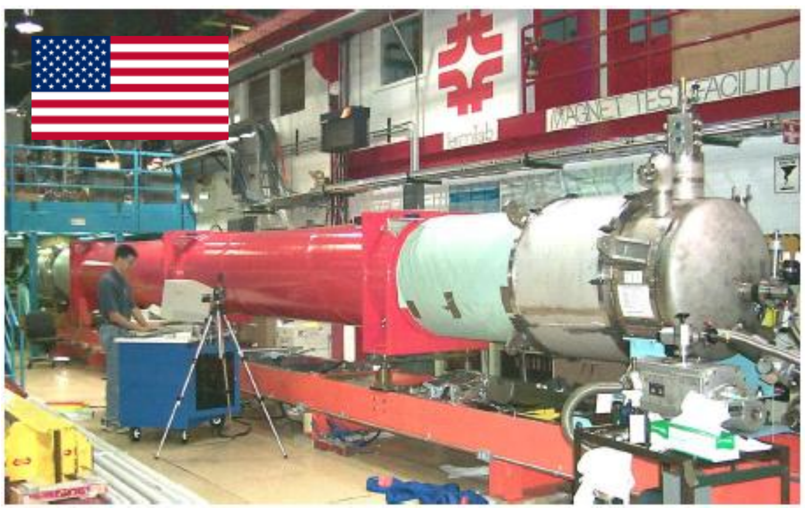
**TECNOLOGÍAS DE ACELERADORES, ELECTRÓNICA, DAQ, TRIGGER, ...**



# UN PROYECTO GLOBAL EN EL ESPACIO



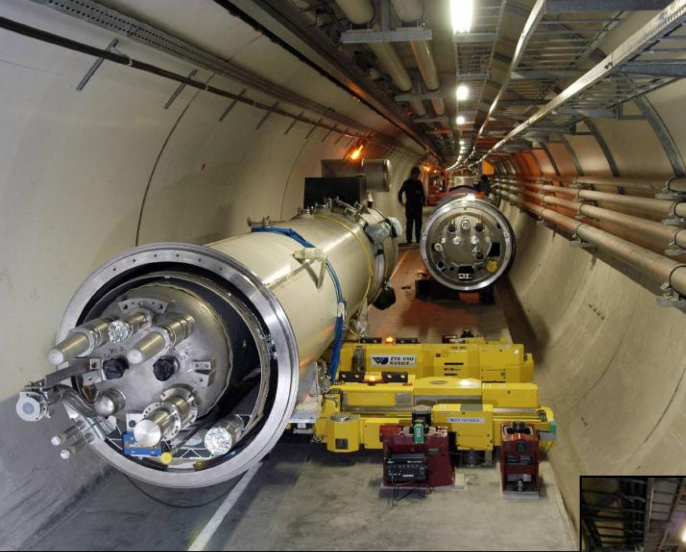




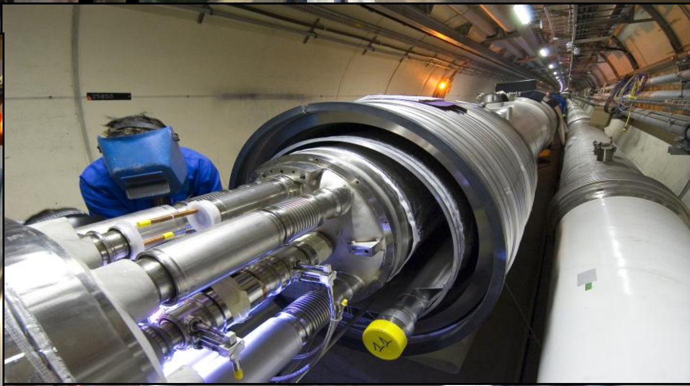
# ... Y EN EL TIEMPO

| | |
|---|---|
| • Estudios conceptuales preliminares | 1984 |
| • Primeros prototipos de imanes | 1988 |
| • Inicio de un programa estructurado de I&D | 1990 |
| • Aprobación del Consejo del CERN | 1994 |
| • Industrialización de la producción en serie | 1996-1999 |
| • Inicio de la ingeniería civil | 1998 |
| • Adjudicación de grandes contratos | 1998-2001 |
| • Inicio de la instalación en el tunel | 2003 |
| • Instalación de los crioimanes en el tunel | 2005-2007 |
| • Tests funcionales del primer sector | 2007 |
| • Comisionado del haz | 2008 |
| • Operación para Física | 2009-2030 |

# ... CON RECURSOS MULTIDISCIPLINARES







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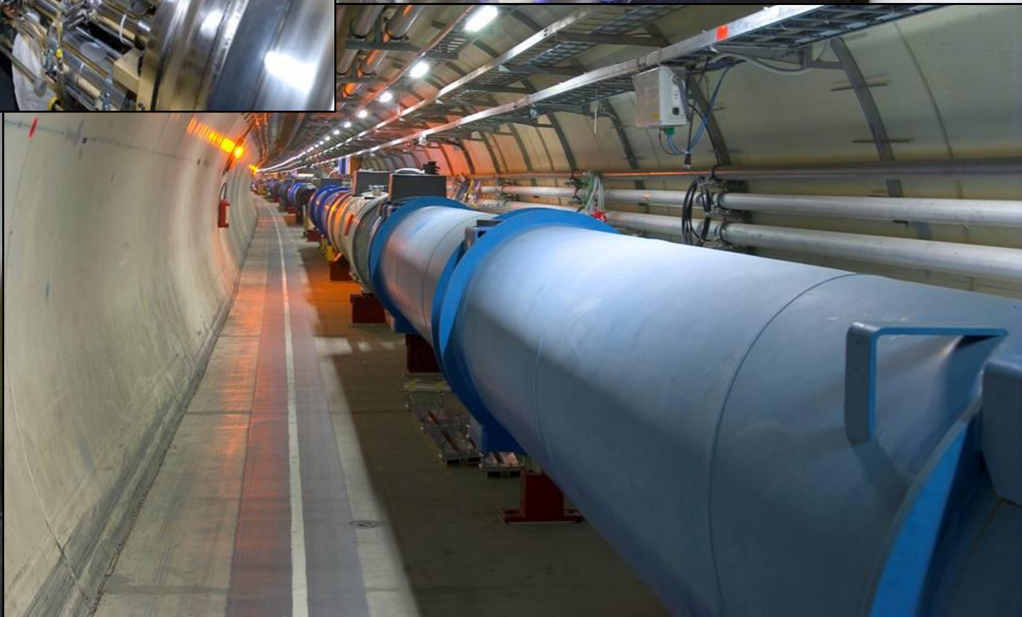
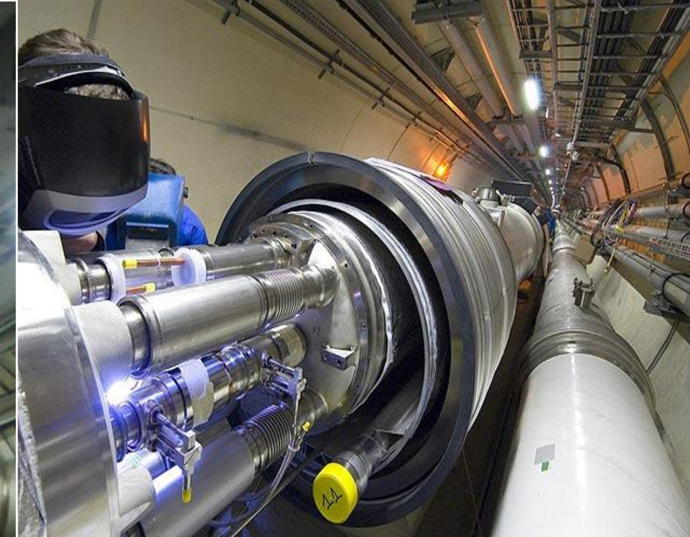
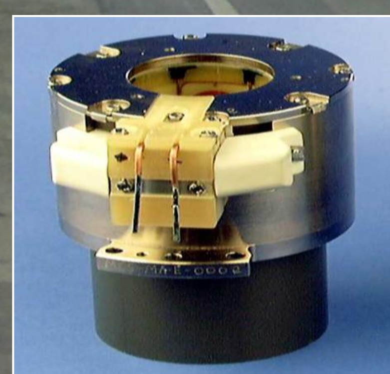




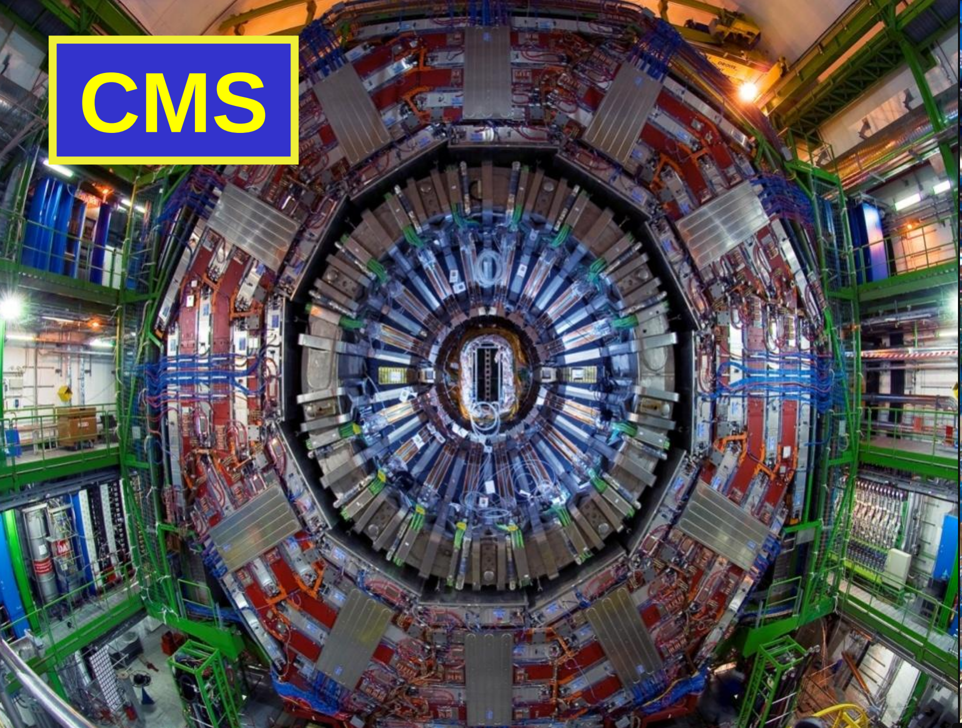


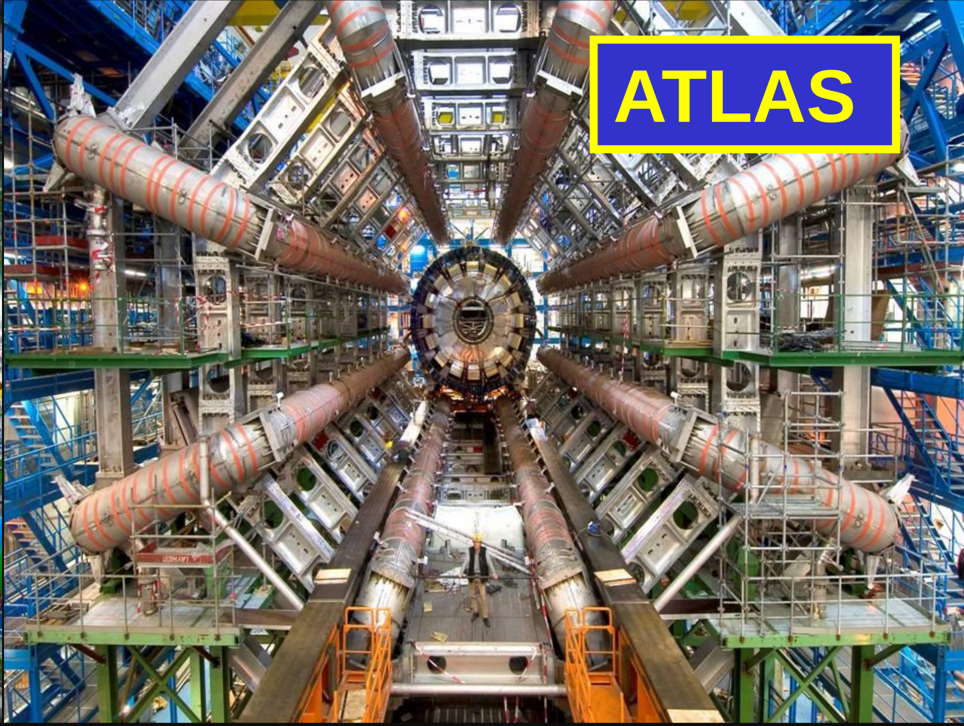
# CONTRIBUCIÓN ESPAÑOLA AL LHC

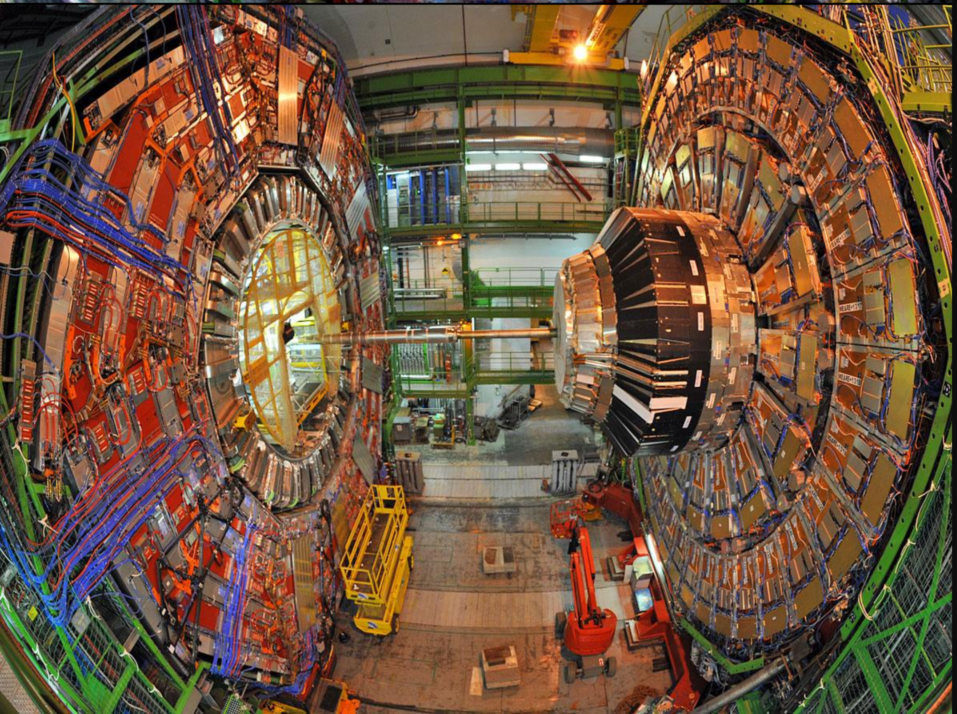



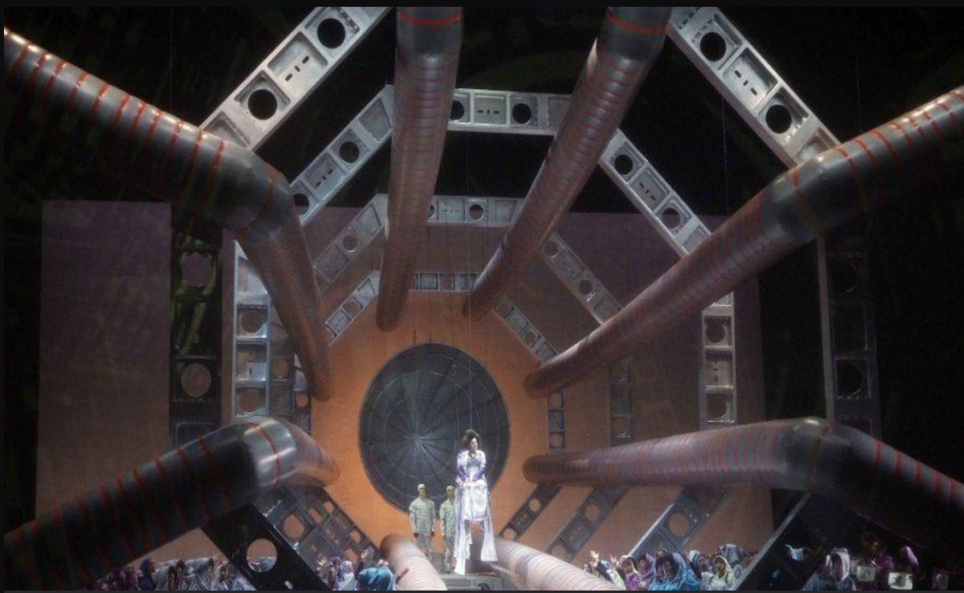


# LOS EXPERIMENTOS EN EL LHC

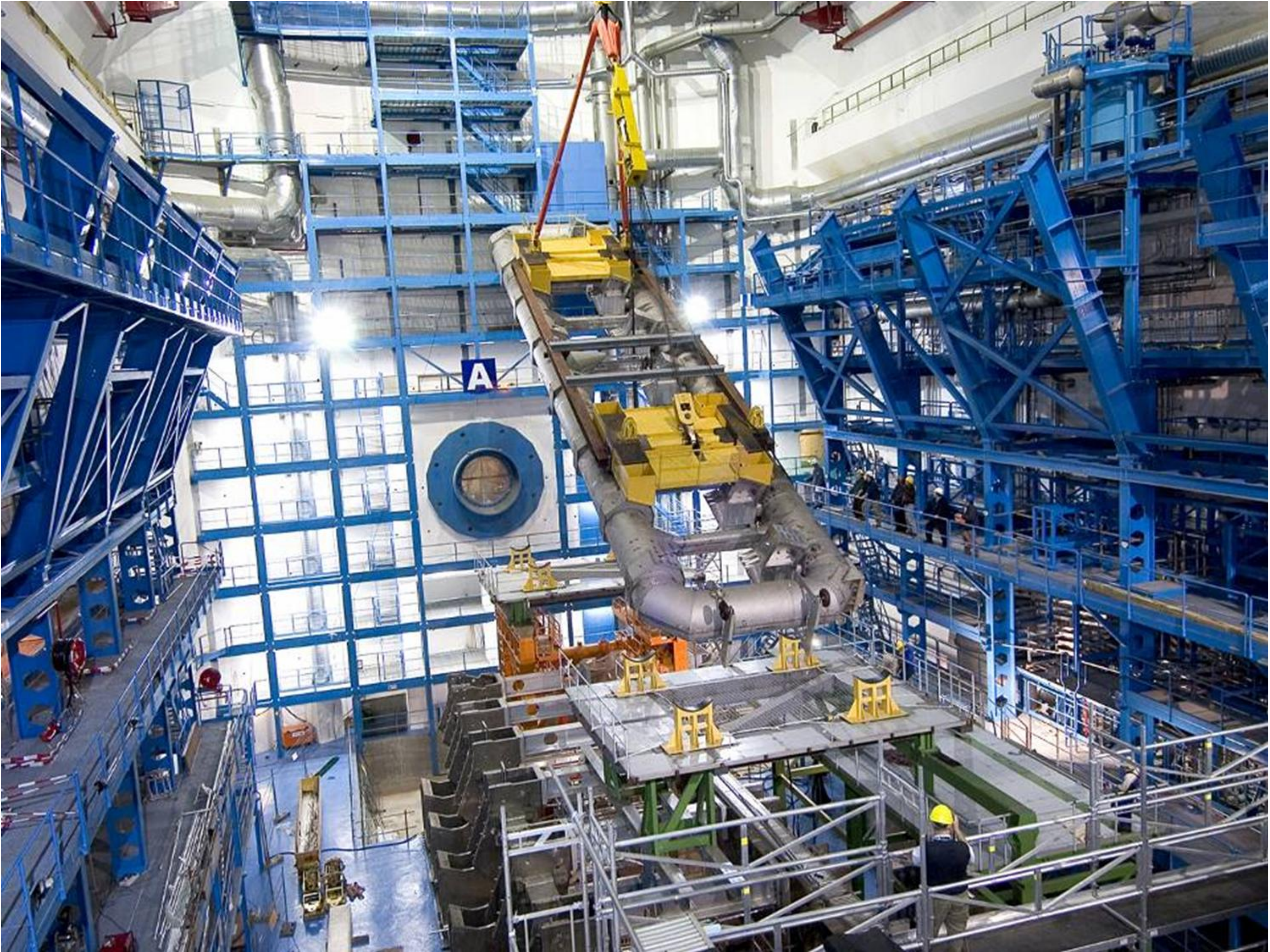


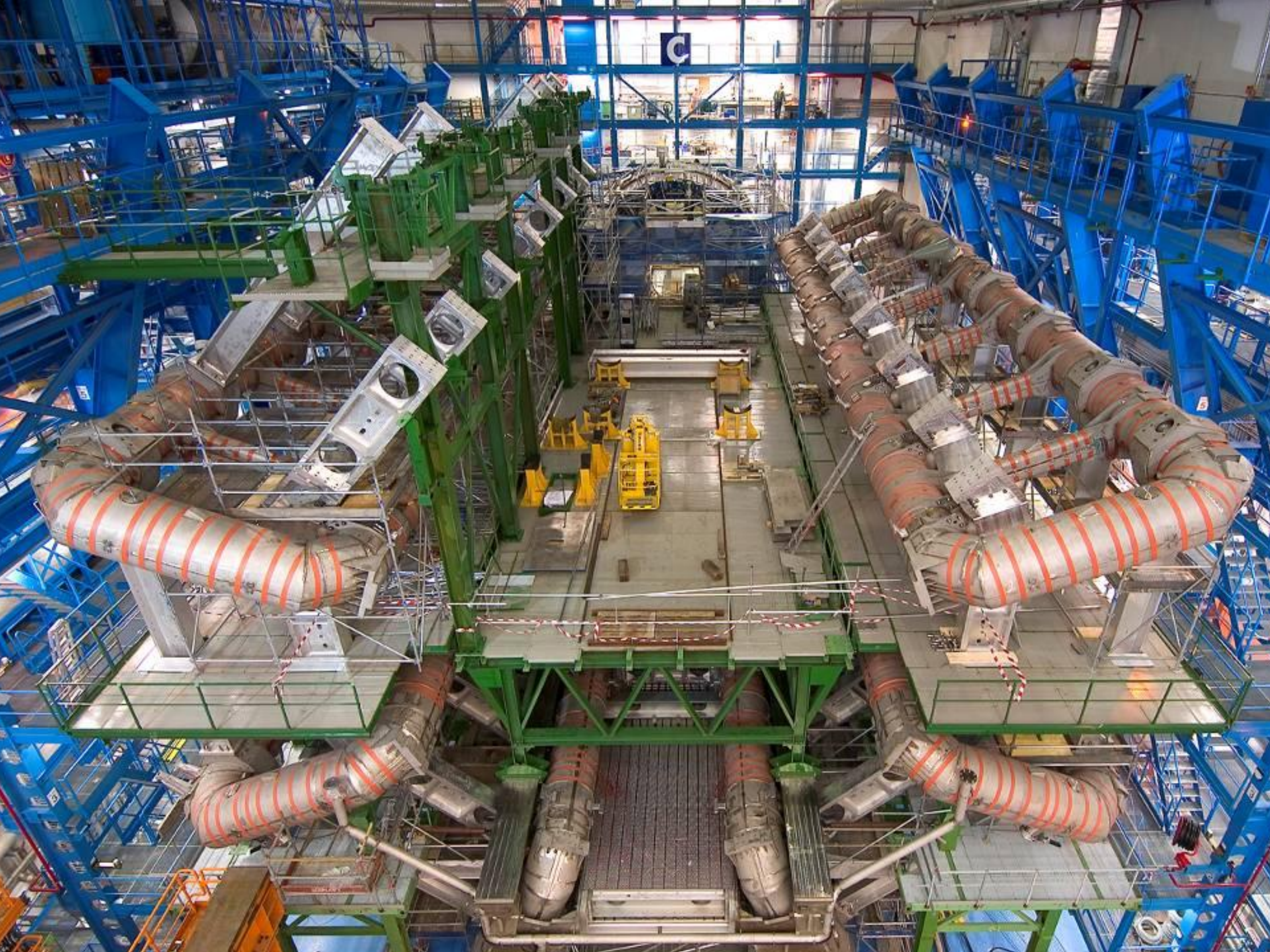


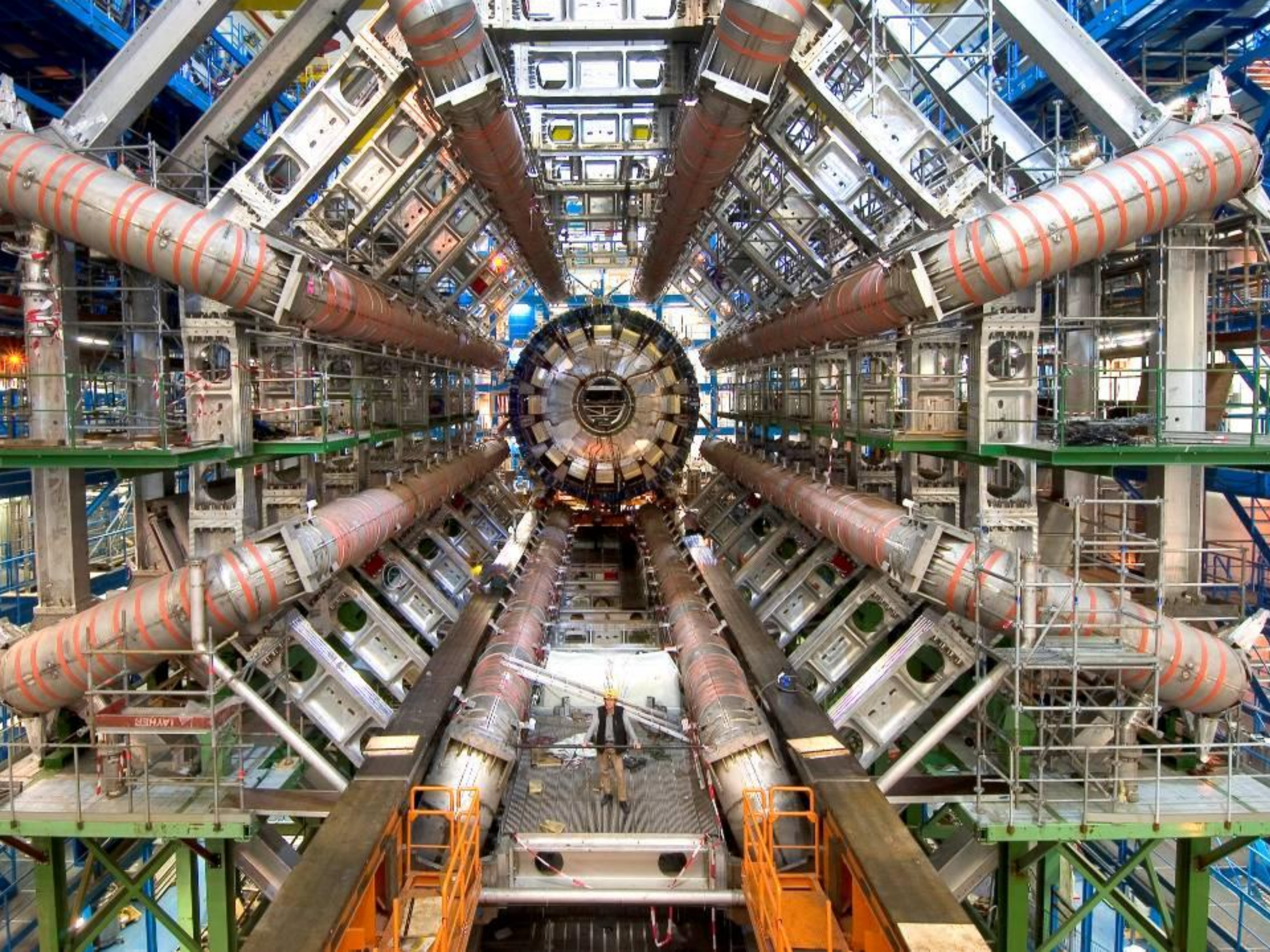
**Hector Berlioz, “Les Troyens”, Valencia, Palau de les Arts Reina Sofia, 2009**


A


C

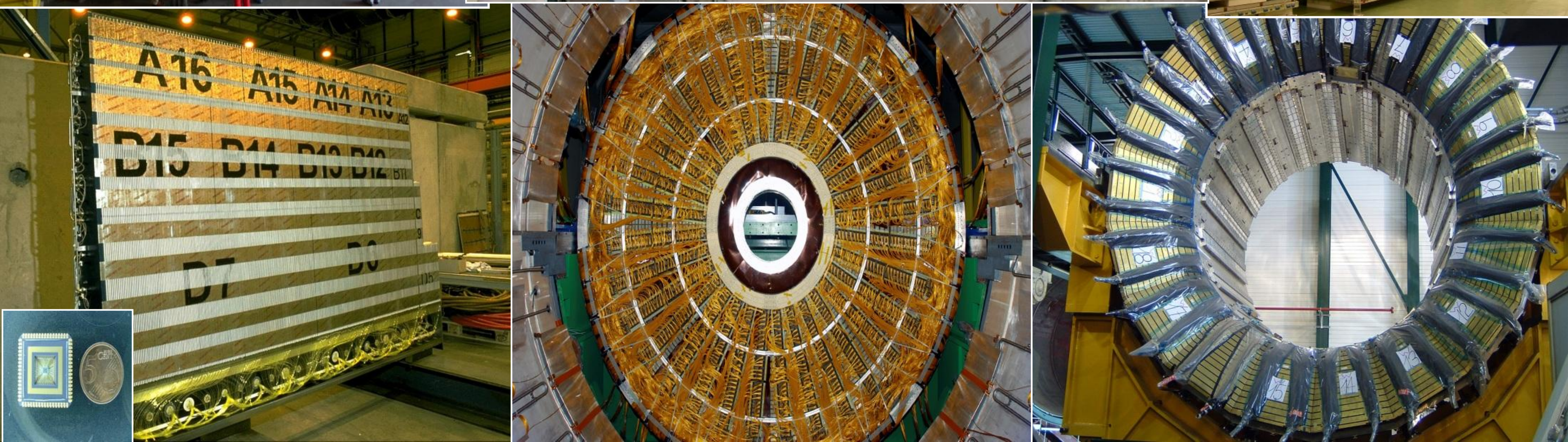

C

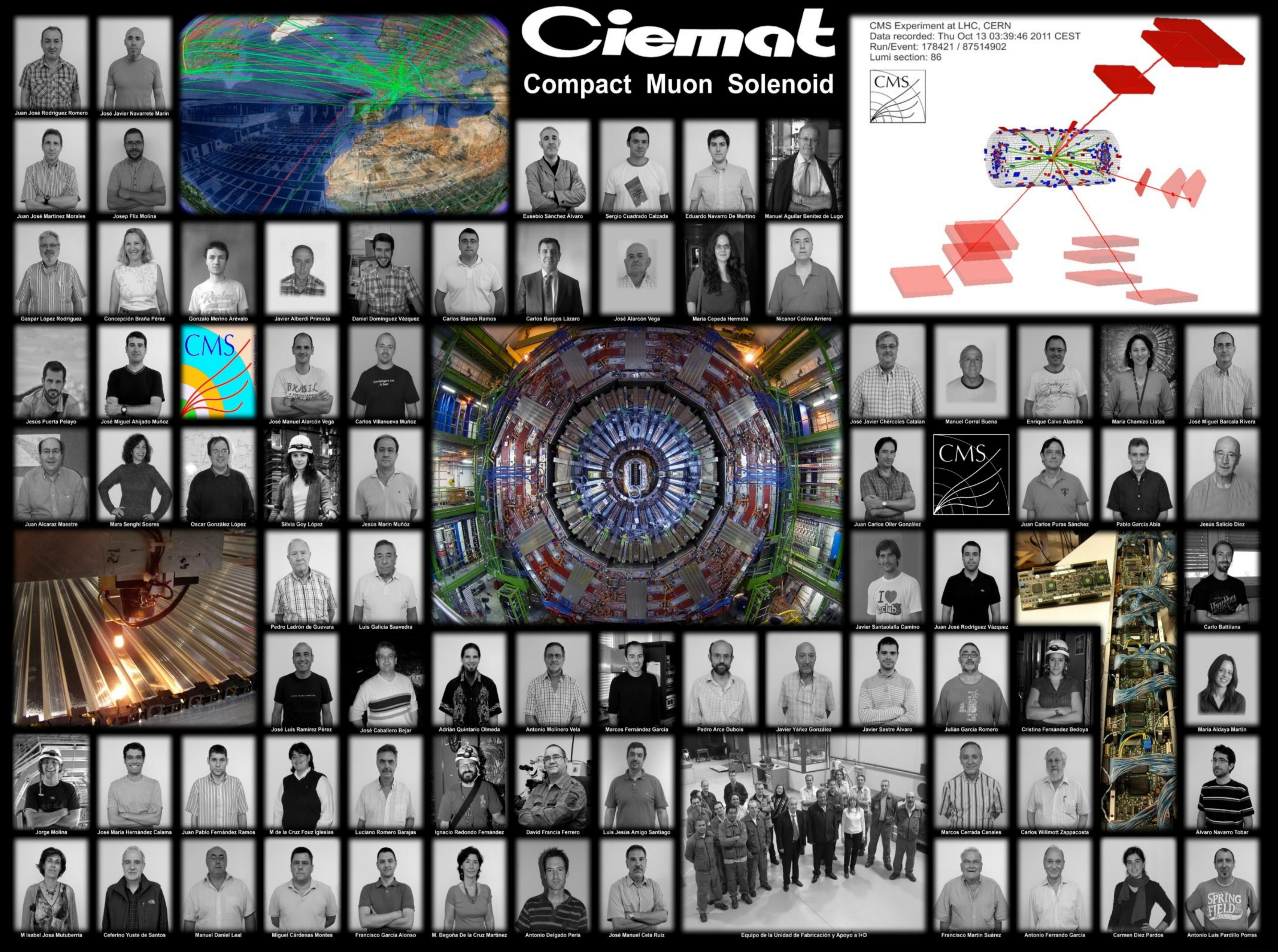

C



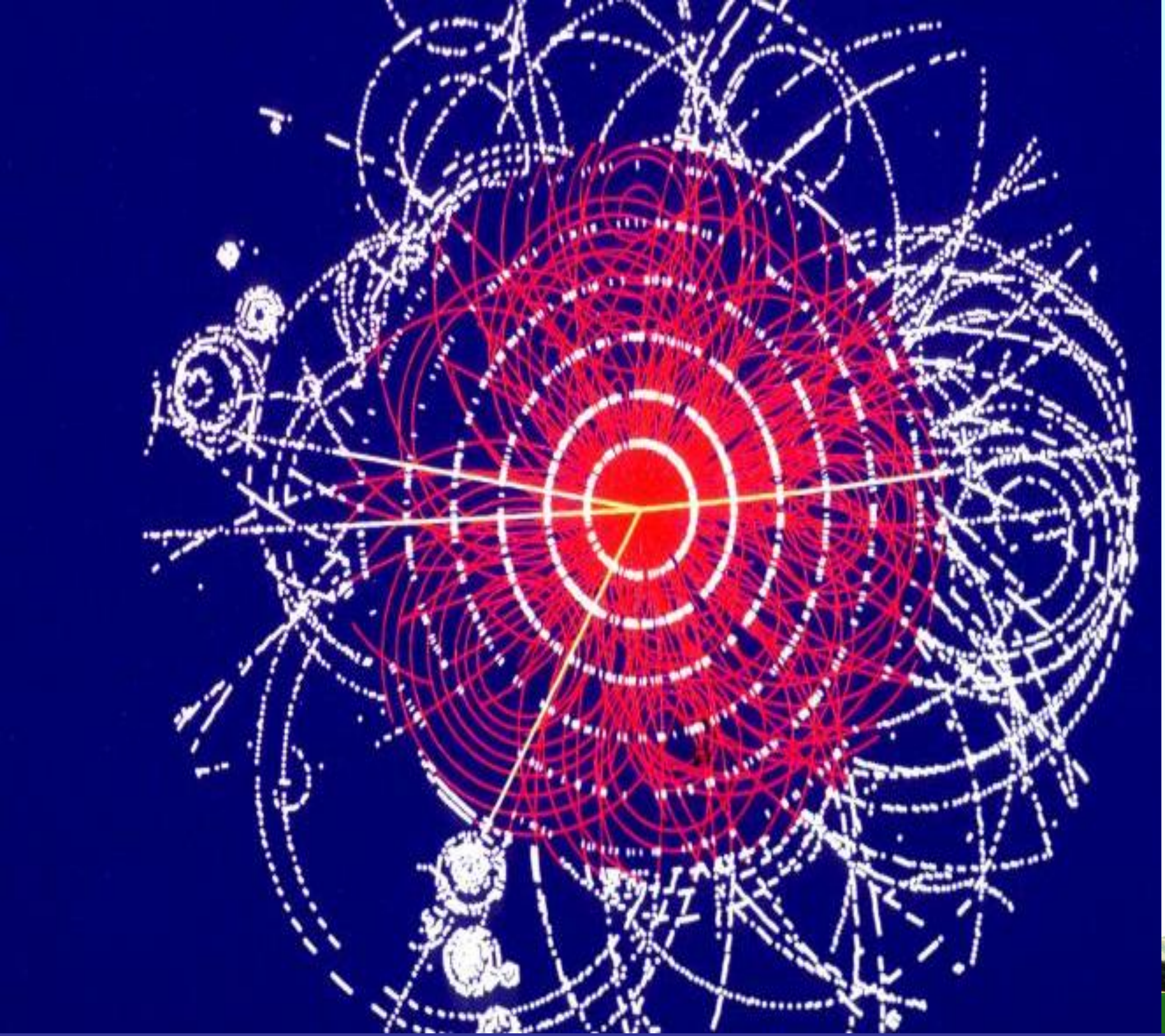
**40 PAÍSES, 193 INSTITUTOS**
**~ 3300 CIENTÍFICOS & INGENIEROS (~ 900 ESTUDIANTES)**

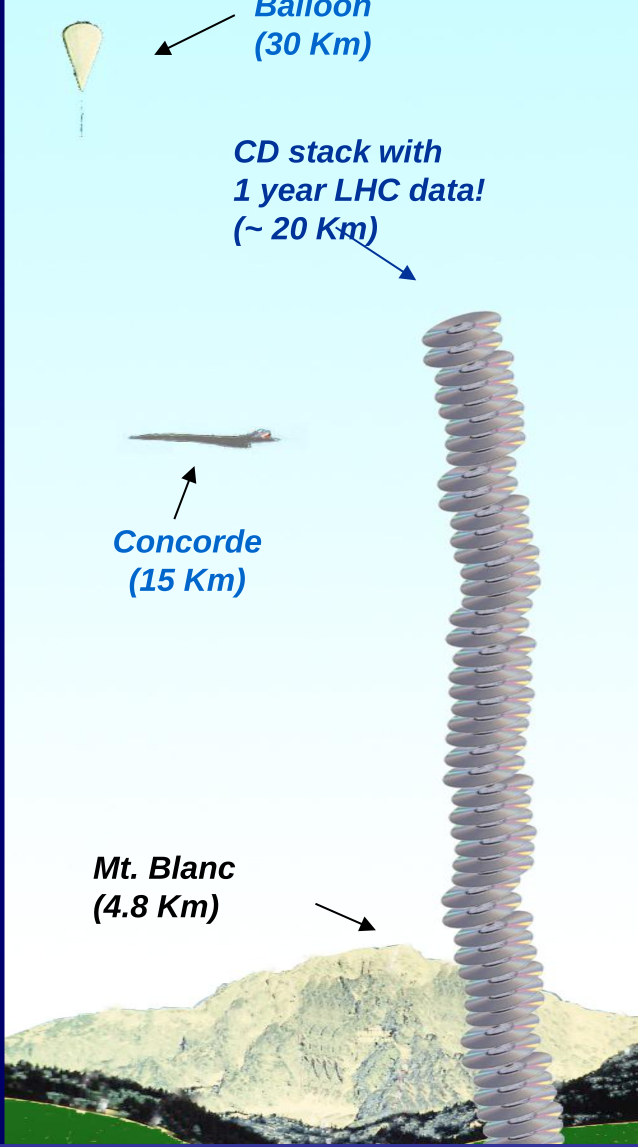

# CONTRIBUCIÓN ESPAÑOLA A LOS DETECTORES DEL LHC





Ciemat
Compact Muon Solenoid
CMS Experiment at LHC, CERN
Data recorded: Thu Oct 13 03:39:46 2011 CEST
Run/Event: 178421 / 87514902
Lumi section: 86
CMS
Juan José Rodríguez Romero
José Javier Navarrete Marín
Juan José Martínez Morales
Josep Flix Molina
Eusebio Sánchez Álvaro
Sergio Cuadrado Calzada
Eduardo Navarro De Martino
Manuel Aguilar Benítez de Lugo
Gaspar López Rodríguez
Concepción Braña Pérez
Gonzalo Merino Arévalo
Javier Alberdi Primicia
Daniel Domínguez Vázquez
Carlos Blanco Ramos
Carlos Burgos Lázaro
José Alarcón Vega
María Cepeda Hermida
Nicanor Colino Arriero
Jesús Puerta Pelayo
José Miguel Ahijado Muñoz
CMS
José Manuel Alarcón Vega
Carlos Villanueva Muñoz
José Javier Chércoles Catalan
Manuel Corral Buena
Enrique Calvo Alamillo
María Chamizo Llatas
José Miguel Barcala Rivera
Juan Alcaraz Maestre
Mara Senghi Soares
Oscar González López
Silvia Goy López
Jesús Marín Muñoz
Juan Carlos Oller González
CMS
Juan Carlos Puras Sánchez
Pablo García Abia
Jesús Salicio Díez
Pedro Ladrón de Guevara
Luis Galicia Saavedra
Javier Santaolalla Camino
Juan José Rodríguez Vázquez
Carlo Battilana
José Luis Ramírez Pérez
José Caballero Bejar
Adrián Quintario Olmeda
Antonio Molinero Vela
Marcos Fernández García
Pedro Arce Dubois
Javier Yáñez González
Javier Sastre Álvaro
Julián García Romero
Cristina Fernández Bedoya
María Aldaya Martín
Jorge Molina
José María Hernández Calama
Juan Pablo Fernández Ramos
M de la Cruz Fouz Iglesias
Luciano Romero Barajas
Ignacio Redondo Fernández
David Francia Ferrero
Luis Jesús Amigo Santiago
Marcos Cerrada Canales
Carlos Willmott Zappacosta
Álvaro Navarro Tobar
M Isabel Josa Mutuberria
Ceferino Yuste de Santos
Manuel Daniel Leal
Miguel Cárdenas Montes
Francisco García Alonso
M. Begoña De la Cruz Martínez
Antonio Delgado Peris
José Manuel Cela Ruiz
Equipo de la Unidad de Fabricación y Apoyo a I+D
Francisco Martín Suárez
Antonio Ferrando García
Carmen Díez Pardos
Antonio Luis Pardillo Porras
Designed by DaviZ Francia



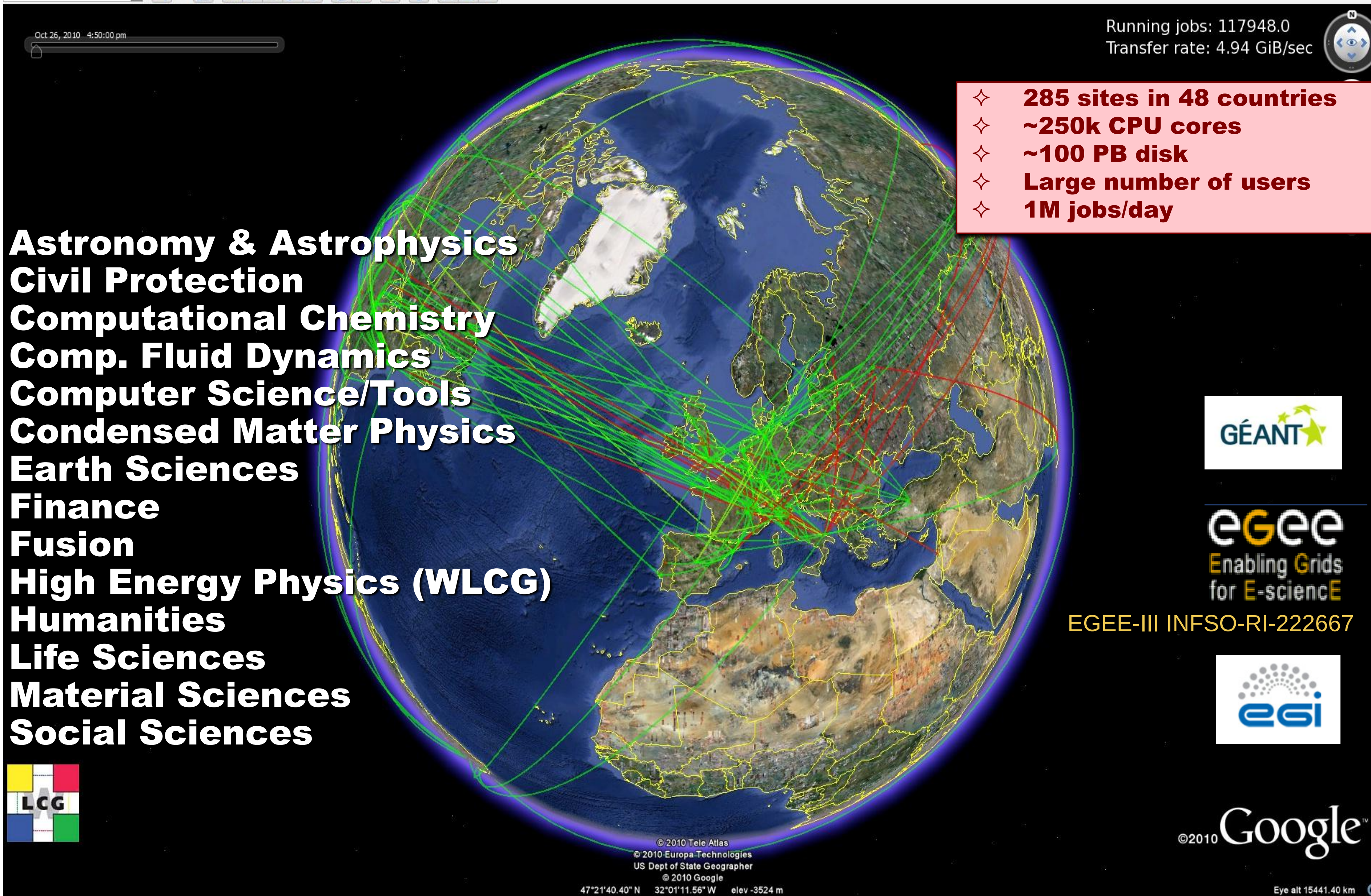



**ATLAS y CMS producirán ~15 millones de Gigabytes por año**

**(¡~5 millones DVDs!)**

**El análisis de los datos requerirá una potencia de cálculo equivalente a ~100,000 procesadores PC de última generación**

# CERN & COMPUTACIÓN GRID




- 285 sites in 48 countries
- ~250k CPU cores
- ~100 PB disk
- Large number of users
- 1M jobs/day

**Astronomy & Astrophysics**
**Civil Protection**
**Computational Chemistry**
**Comp. Fluid Dynamics**
**Computer Science/Tools**
**Condensed Matter Physics**
**Earth Sciences**
**Finance**
**Fusion**
**High Energy Physics (WLCG)**
**Humanities**
**Life Sciences**
**Material Sciences**
**Social Sciences**

GÉANT

egee
Enabling Grids for E-sciencE
EGEE-III INFSO-RI-222667

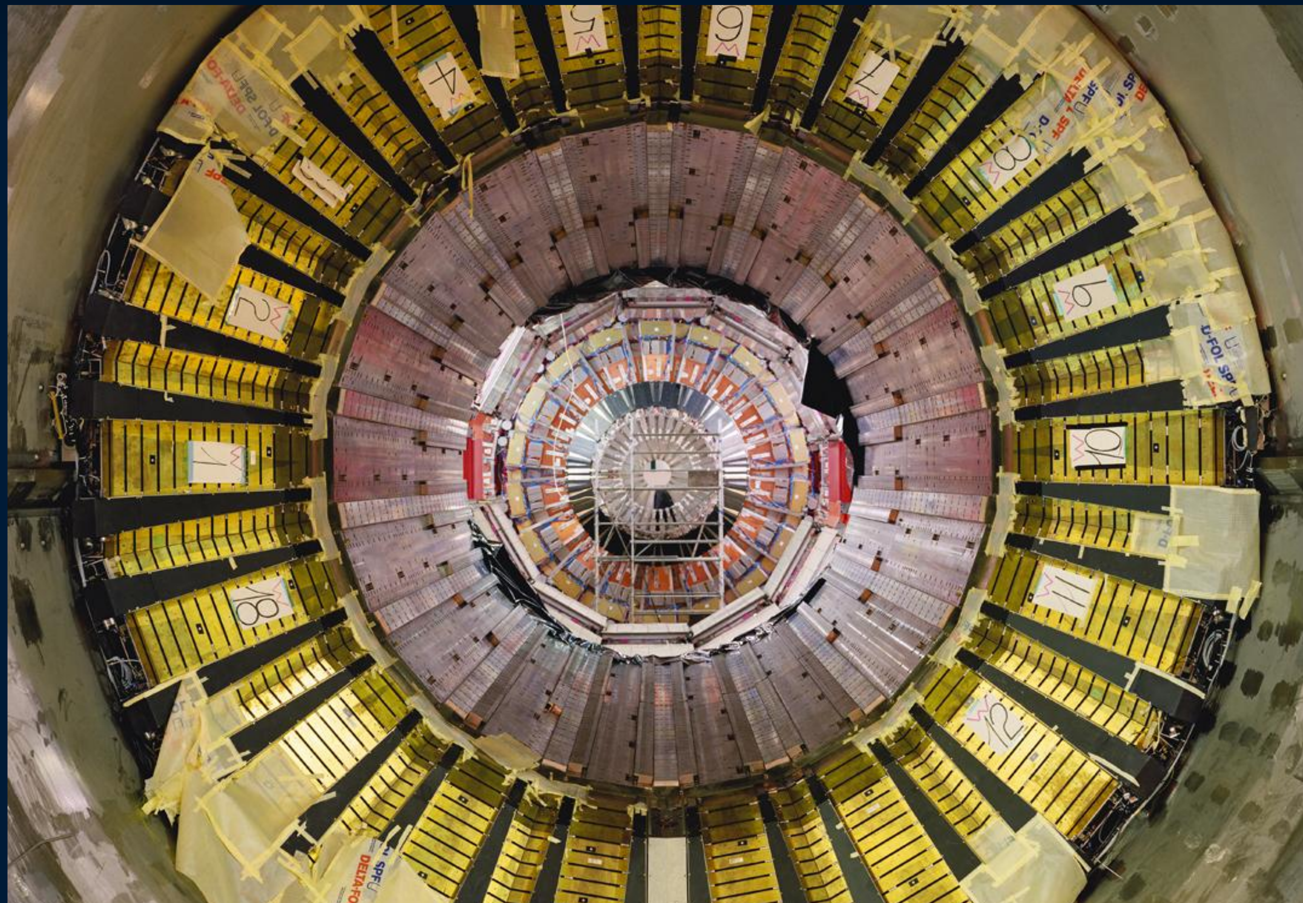
egi

LCG

# EL CERN COMO EDUCADOR

# INNOVAR, DESCUBRIR, PUBLICAR, COMPARTIR

**... Y CONTRIBUIR A HACER UN MUNDO MÁS INSTRUIDO, JUSTO Y SOLIDARIO**



***EL CONOCIMIENTO ES LIMITADO.***

***LA IMAGINACIÓN ABARCA TODO EL MUNDO…***

**Albert Einstein**


FELIZ ANIVERSARIO !!

# ... Y SUERTE !!


GRACIAS

# MENSAJES RELEVANTES

- COOPERACIÓN PACÍFICA EN LA FRONTERA DE LA CIENCIA CON INDEPENDENCIA DE DIFERENCIAS CULTURALES Y NACIONALES
- EL APOYO A LA INVESTIGACIÓN Y A LA INNOVACIÓN ES VITAL PARA ASEGURAR, EN UN ENTORNO GLOBAL COMPETITIVO, EL DESARROLLO SOSTENIBLE DE LA CIENCIA Y LA TECNOLOGÍA NECESARIAS PARA RESTABLECER EL CRECIMIENTO ECONÓMICO
- LA COOPERACIÓN Y LA COMPETICIÓN SON LOS CAMINOS HACIA EL ÉXITO
- EL ACCESO LIBRE Y EL COMPARTIR RESULTADOS PERMITE LA PARTICIPACIÓN Y EL DESARROLLO
- IMPLICAR Y COMPROMETER A LOS JÓVENES CON LA CIENCIA
- SUPERAR LA BRECHA ENTRE CIENCIA Y SOCIEDAD