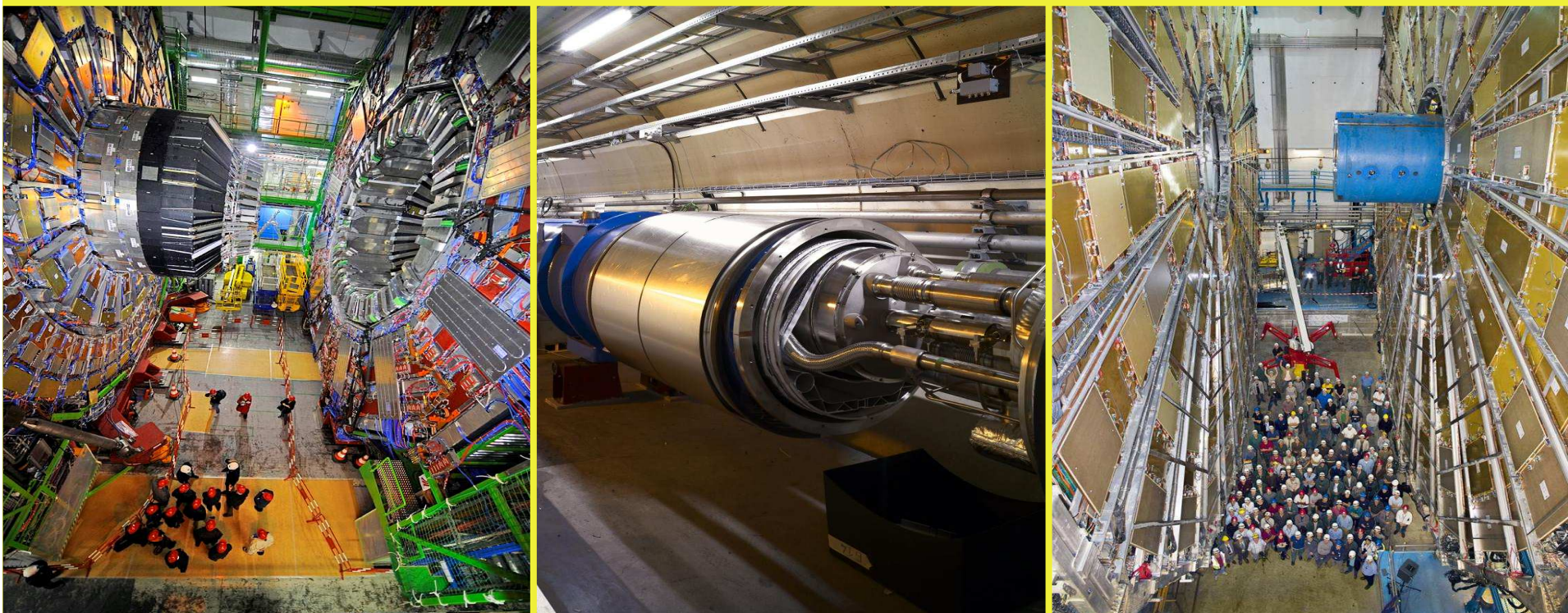


ESPAÑA Y EL CERN EN LA HORA DEL LHC

MANUEL AGUILAR BENÍTEZ DE LUGO (CIEMAT, RAC)



EXPOSICIÓN
"EL CERN A TRAVÉS DE LOS OJOS DE PETER GINTER,
LA VISIÓN DE UN POETA"

CSIC, 26 OCTUBRE 2009

**ORIGEN DEL UNIVERSO
ORIGEN DE LA VIDA
ORIGEN DE LA CONSCIENCIA**



ACERCA DEL UNIVERSO

**¿ DE QUÉ ESTÁ HECHO ?
¿ CÓMO ESTÁ HECHO ?
¿ CÓMO SE HA ORIGINADO Y
CÓMO HA EVOLUCIONADO ?**

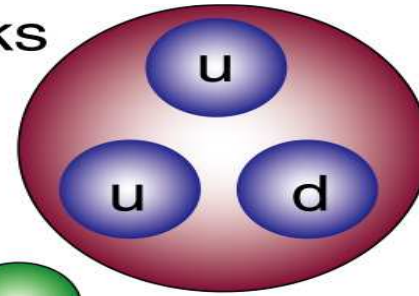
**DISCIPLINA CIENTÍFICA QUE TRATA
ESTAS CUESTIONES
FÍSICA DE PARTÍCULAS ELEMENTALES**



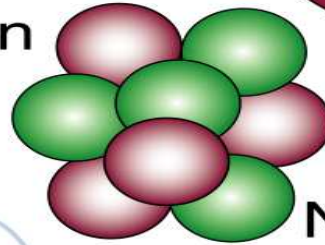
**En los últimos 100 años
hemos avanzado mucho,
pero todavía queda mucho
por conocer ...**

**... para rellenar los huecos
en el conocimiento de lo
ordinario y de lo
extraordinario**

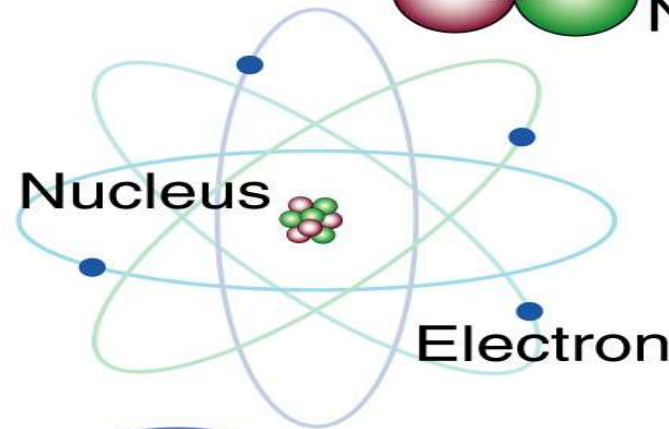
Quarks



Proton



Neutron



Nucleus

Electron



Atom

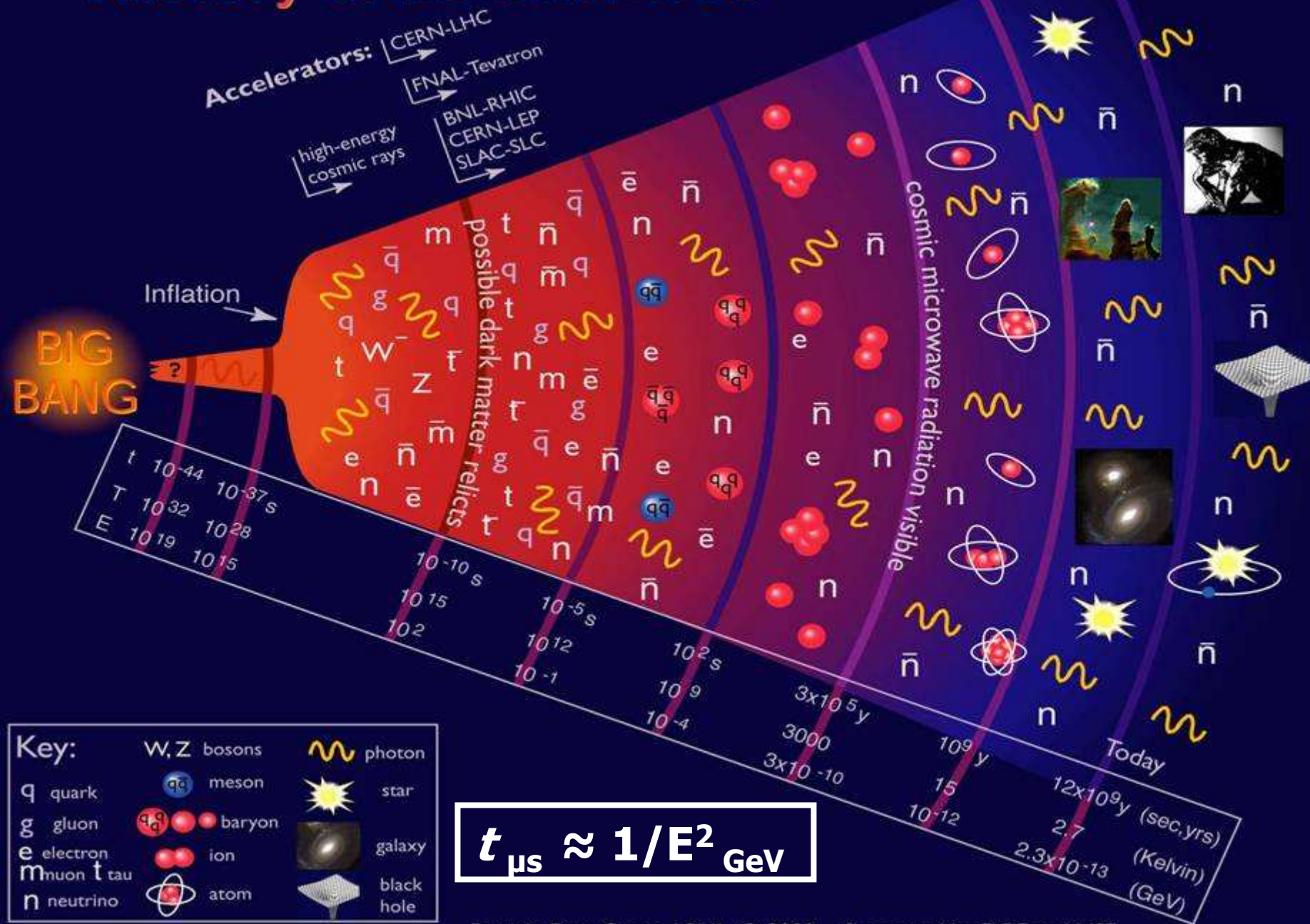


Molecule

Matter



History of the Universe

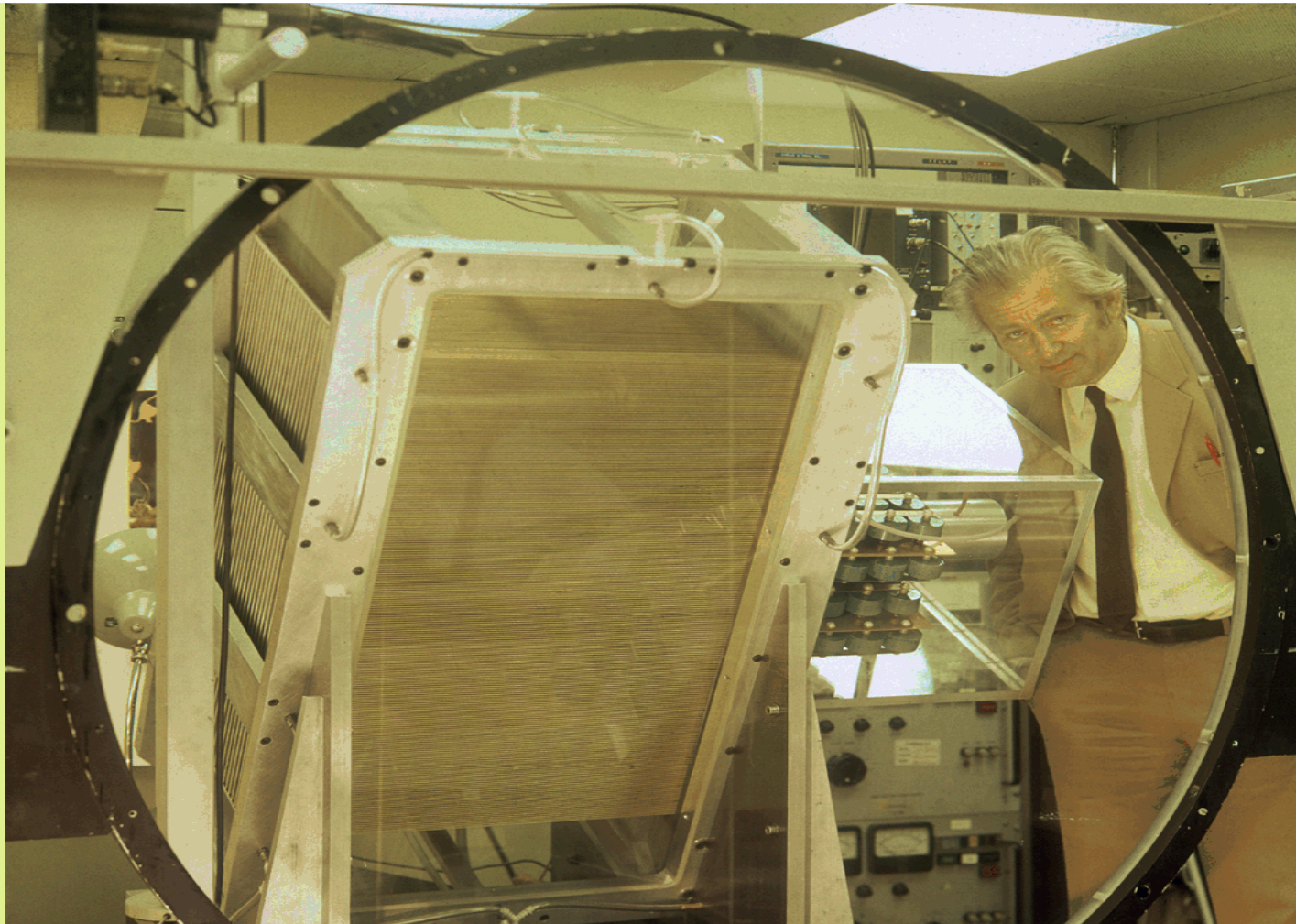


Física Fundamental

Diez Retornos a la Sociedad

1. Informática (www, GRID)
2. Ordenadores
3. Criptografía Moderna
4. GPS (Relojes Atómicos)
5. Haces de Partículas (Diagnosis, Terapia)
6. Digitalización Imágenes Médicas (CAT Scanners)
7. Superconductividad (SQUIDs)
8. Radioisótopos
9. Luz Sincrotrón
10. Fuentes de Neutrones

Sir Christopher Llewellyn-Smith, 2003



GEORGES CHARPAK
(Premio Nobel 1992)

INVENTOR DE LAS CÁMARAS MULTIFILOS

MONOCRISTALES CENTELLEADORES PETs



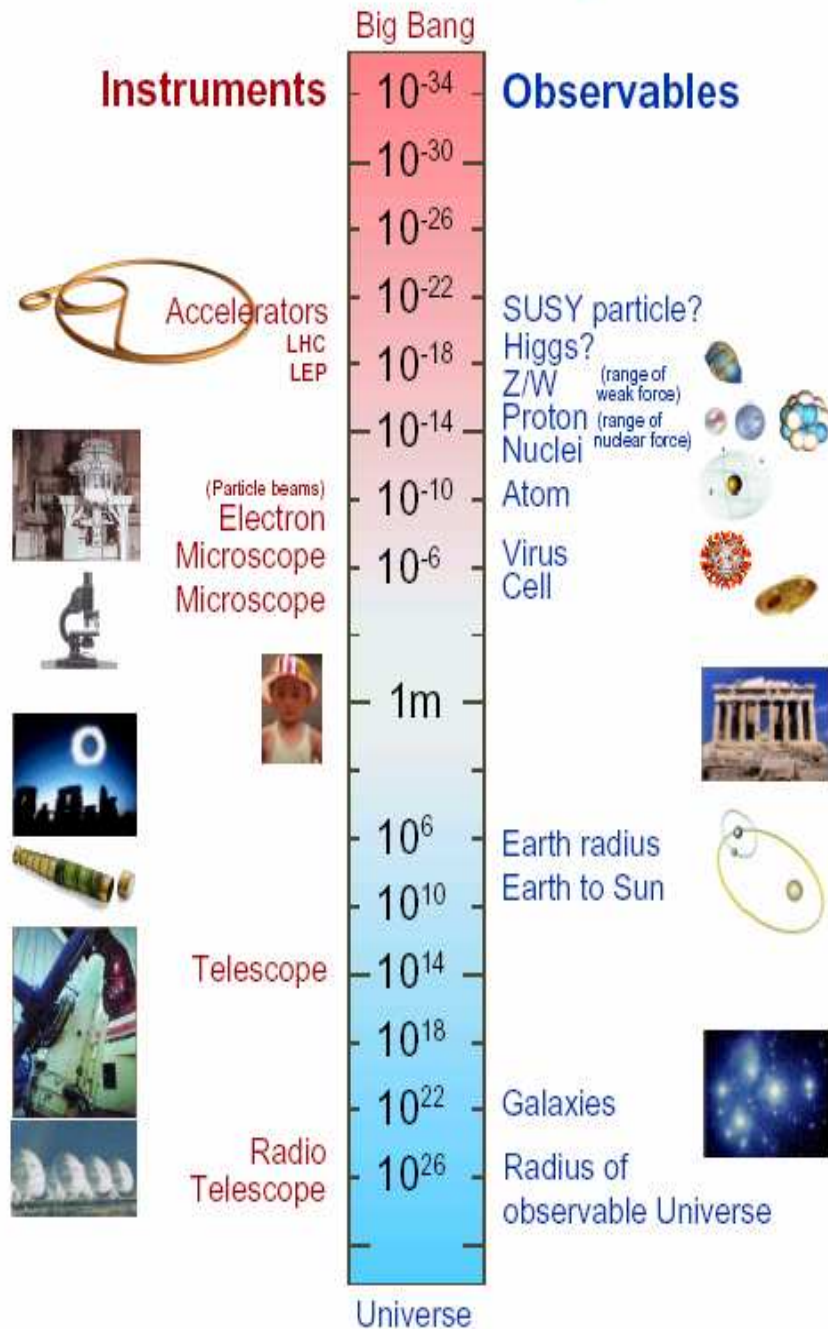
TIM BERNERS LEE INVENTOR DEL WWW 1999



FÍSICA DE PARTÍCULAS ELEMENTALES SITUACIÓN ACTUAL & PERSPECTIVAS

**Estudio de los constituyentes últimos de la materia,
las interacciones fundamentales y las leyes
que gobiernan la evolución del Universo**

The size of things



$$\lambda = hc / 2\pi p$$

- $p = 1 \text{ MeV} ; \lambda \approx 10^{-13} \text{ m}$
- $p = 1 \text{ GeV} ; \lambda \approx 10^{-16} \text{ m}$
- $p = 1 \text{ TeV} ; \lambda \approx 10^{-19} \text{ m}$

Particles

Leptons

Tau		Electric Charge -1	Tau Neutrino		Electric Charge 0
Muon		-1	Muon Neutrino		0
Electron		-1	Electron Neutrino		0

Quarks

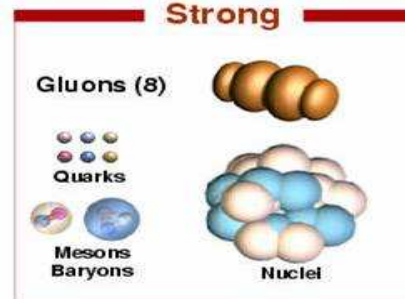
Bottom		Electric Charge -1/3	Top		Electric Charge 2/3
Strange		-1/3	Charm		2/3
Down		-1/3	Up		2/3

each quark: ●R, ●B, ●G 3 colors

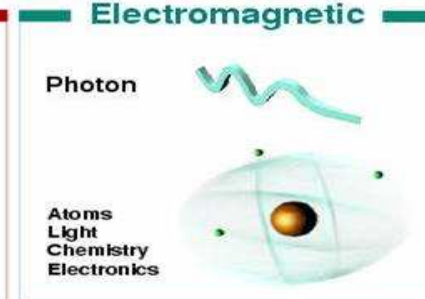
The particle drawings are simple artistic representations

Forces

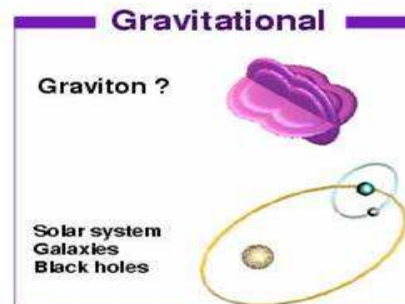
Strong



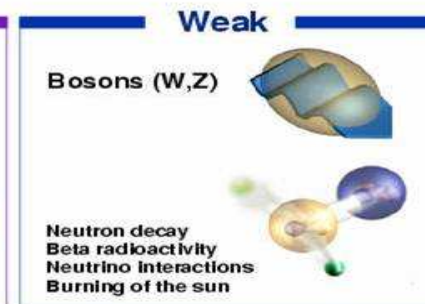
Electromagnetic



Gravitational

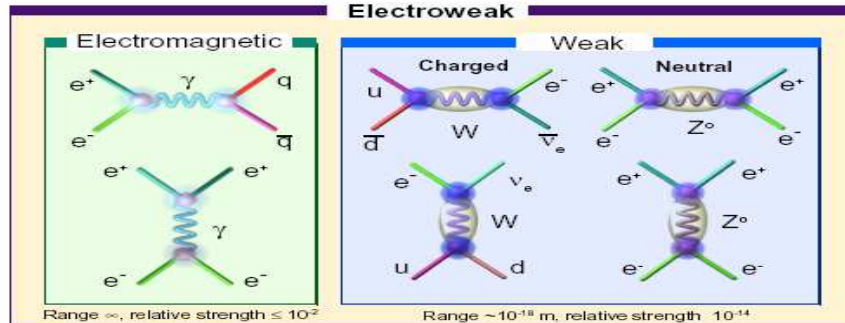


Weak

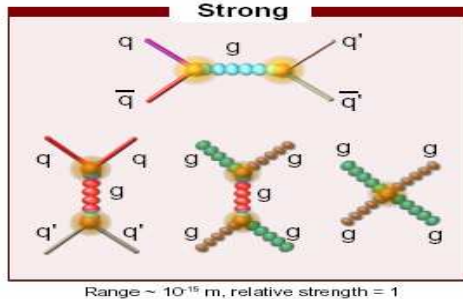


Interactions: coupling of forces to matter

Electroweak



Strong



**MODELO
ESTÁNDAR
DE PARTÍCULAS
E INTERACCIONES**

Elementary Particles

Quarks	u up	c charm	t top	γ photon
	d down	s strange	b bottom	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	
				W W boson

I II III
Three Families of Matter

+ BOSÓN DE HIGGS ...

**EL HUECO EN EL
CONOCIMIENTO DE LO
ORDINARIO**

Periodic Table of the Elements																	
1	2															3	4
1 H	2 He															5 B	6 C
3 Li	4 Be															7 N	8 O
11 Na	12 Mg															9 F	10 Ne
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106	107	108	109	110	111	112						
Naming conventions of new elements																	
* Lanthanide Series		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
+ Actinide Series		90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

The Standard Model

$$\begin{aligned}
 & -\frac{1}{2}\partial_\nu g_\mu^a \partial_\nu g_\mu^a - g_s f^{abc} \partial_\mu g_\nu^a g_\mu^b g_\nu^c - \frac{1}{4}g_s^2 f^{abc} f^{ade} g_\mu^b g_\nu^c g_\mu^d g_\nu^e + \\
 & \frac{1}{2}ig_s^2 (\bar{u}_i^\alpha \gamma^\mu u_j^\alpha) g_\mu^a + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu G^a G^b g_\mu^c - \partial_\nu W_\mu^+ \partial_\nu W_\mu^- - \\
 & M^2 W_\mu^+ W_\mu^- - \frac{1}{2}\partial_\nu Z_\mu^0 \partial_\nu Z_\mu^0 - \frac{1}{2c_w^2} M^2 Z_\mu^0 Z_\mu^0 - \frac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2}\partial_\mu H \partial_\mu H - \\
 & \frac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \frac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \frac{1}{2c_w^2} M \phi^0 \phi^0 - \beta_h \left[\frac{2M^2}{g^2} + \right. \\
 & \left. \frac{2M}{g} H + \frac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-) \right] + \frac{2M^4}{g^2} \alpha_h - igc_w [\partial_\nu Z_\mu^0 (W_\mu^+ W_\nu^- - \\
 & W_\nu^+ W_\mu^-) - Z_\mu^0 (W_\nu^+ \partial_\nu W_\mu^- - W_\mu^- \partial_\nu W_\nu^+) + Z_\mu^0 (W_\nu^- \partial_\nu W_\mu^+ - \\
 & W_\mu^+ \partial_\nu W_\nu^-)] - ig s_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^+)] - \frac{1}{2}g^2 W_\mu^+ W_\mu^- W_\nu^+ W_\nu^- + \\
 & \frac{1}{2}g^2 W_\mu^+ W_\nu^- W_\mu^+ W_\nu^- + g^2 c_w^2 (Z_\mu^0 W_\nu^+ Z_\nu^0 W_\mu^- - Z_\mu^0 Z_\nu^0 W_\nu^+ W_\mu^-) + \\
 & g^2 s_w^2 (A_\mu W_\nu^+ A_\nu W_\mu^- - A_\mu A_\nu W_\nu^+ W_\mu^-) + g^2 s_w c_w [A_\mu Z_\nu^0 (W_\mu^+ W_\nu^- - \\
 & W_\nu^+ W_\mu^-) - 2A_\mu Z_\mu^0 W_\nu^+ W_\nu^-] - g\alpha [H^3 + H\phi^0 \phi^0 + 2H\phi^+ \phi^-] - \\
 & \frac{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)^2 H^2] - \\
 & g M W_\mu^+ W_\mu^- H - \frac{1}{2}g \frac{M}{c_w^2} Z_\mu^0 Z_\mu^0 H - \frac{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)] + \frac{1}{2}ig [W_\mu^+ (H \partial_\mu \phi^- - \phi^- \partial_\mu H) - W_\mu^- (H \partial_\mu \phi^+ - \\
 & \phi^+ \partial_\mu H)] + \frac{1}{2}g \frac{1}{c_w} (Z_\mu^0 (H \partial_\mu \phi^0 - \phi^0 \partial_\mu H) - ig \frac{s_w^2}{c_w} M Z_\mu^0 (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \\
 & ig s_w M A_\mu (W_\mu^+ \phi^- - W_\mu^- \phi^+) - ig \frac{1-2c_w^2}{2c_w} Z_\mu^0 (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) + \\
 & ig s_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \frac{1}{4}g^2 W_\mu^+ W_\mu^- [H^2 + (\phi^0)^2 + 2\phi^+ \phi^-] - \\
 & \frac{1}{4}g^2 \frac{1}{c_w^2} Z_\mu^0 Z_\mu^0 [H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2 \phi^+ \phi^-] - \frac{1}{2}g^2 \frac{s_w^2}{c_w} Z_\mu^0 \phi^0 (W_\mu^+ \phi^- + \\
 & W_\mu^- \phi^+) - \frac{1}{2}ig^2 \frac{s_w^2}{c_w} Z_\mu^0 H (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu \phi^0 (W_\mu^+ \phi^- + \\
 & W_\mu^- \phi^+) + \frac{1}{2}ig^2 s_w A_\mu H (W_\mu^+ \phi^- - W_\mu^- \phi^+) - g^2 \frac{s_w}{c_w} (2c_w^2 - 1) Z_\mu^0 A_\mu \phi^+ \phi^- - \\
 & g^1 s_w^2 A_\mu A_\mu \phi^+ \phi^- - \bar{e}^\lambda (\gamma \partial + m_e^\lambda) e^\lambda - \bar{\nu}^\lambda \gamma \partial \nu^\lambda - \bar{u}_j^\lambda (\gamma \partial + m_u^\lambda) u_j^\lambda - \\
 & \bar{d}_j^\lambda (\gamma \partial + m_d^\lambda) d_j^\lambda + ig s_w A_\mu [-(\bar{e}^\lambda \gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}_j^\lambda \gamma^\mu u_j^\lambda) - \frac{1}{3}(\bar{d}_j^\lambda \gamma^\mu d_j^\lambda)] + \\
 & \frac{ig}{4c_w} Z_\mu^0 [(\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}_j^\lambda \gamma^\mu (\frac{2}{3}s_w^2 - \\
 & 1 - \gamma^5) u_j^\lambda) + (\bar{d}_j^\lambda \gamma^\mu (1 - \frac{8}{3}s_w^2 - \gamma^5) d_j^\lambda)] + \frac{ig}{2\sqrt{2}} W_\mu^+ [(\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) e^\lambda) + \\
 & (\bar{u}_j^\lambda \gamma^\mu (1 + \gamma^5) C_{\lambda\kappa} d_j^\kappa)] + \frac{ig}{2\sqrt{2}} W_\mu^- [(\bar{e}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{d}_j^\kappa C_{\lambda\kappa}^\dagger \gamma^\mu (1 + \\
 & \gamma^5) u_j^\lambda)] + \frac{ig}{2\sqrt{2}} \frac{m_h^2}{M} [-\phi^+ (\bar{\nu}^\lambda (1 - \gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1 + \gamma^5) \nu^\lambda)] - \\
 & \frac{g}{2} \frac{m_h^2}{M} [H (\bar{e}^\lambda e^\lambda) + i\phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}} \phi^+ [-m_h^2 (\bar{u}_j^\lambda C_{\lambda\kappa} (1 - \gamma^5) d_j^\kappa) + \\
 & m_u^\lambda (\bar{u}_j^\lambda C_{\lambda\kappa} (1 + \gamma^5) d_j^\kappa)] + \frac{ig}{2M\sqrt{2}} \phi^- [m_d^\lambda (\bar{d}_j^\kappa C_{\lambda\kappa}^\dagger (1 + \gamma^5) u_j^\lambda) - m_h^2 (\bar{d}_j^\kappa C_{\lambda\kappa}^\dagger (1 - \\
 & \gamma^5) u_j^\lambda)] - \frac{g}{2} \frac{m_h^2}{M} H (\bar{u}_j^\lambda u_j^\lambda) - \frac{g}{2} \frac{m_h^2}{M} H (\bar{d}_j^\lambda d_j^\lambda) + \frac{ig}{2} \frac{m_h^2}{M} \phi^0 (\bar{u}_j^\lambda \gamma^5 u_j^\lambda) - \\
 & \frac{ig}{2} \frac{m_h^2}{M} \phi^0 (\bar{d}_j^\lambda \gamma^5 d_j^\lambda) + \bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + \bar{X}^0 (\partial^2 - \\
 & \frac{M^2}{c_w^2}) X^0 + \bar{Y} \partial^2 Y + igc_w W_\mu^+ (\partial_\mu \bar{X}^0 X^- - \partial_\mu \bar{X}^+ X^0) + ig s_w W_\mu^+ (\partial_\mu \bar{Y} X^- - \\
 & \partial_\mu \bar{X}^- Y) + igc_w W_\mu^- (\partial_\mu \bar{X}^- X^0 - \partial_\mu \bar{X}^0 X^+) + ig s_w W_\mu^- (\partial_\mu \bar{X}^- Y - \\
 & \partial_\mu \bar{Y} X^+) + igc_w Z_\mu^0 (\partial_\mu \bar{X}^+ X^- - \partial_\mu \bar{X}^- X^+) + ig s_w A_\mu (\partial_\mu \bar{X}^+ X^- - \\
 & \partial_\mu \bar{X}^- X^+) - \frac{1}{2}g M [\bar{X}^+ X^+ H + \bar{X}^- X^- H + \frac{1}{c_w^2} \bar{X}^0 X^0 H] + \\
 & \frac{1-2c_w^2}{2c_w} ig M [\bar{X}^+ X^0 \phi^+ - \bar{X}^- X^0 \phi^-] + \frac{1}{2c_w} ig M [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \\
 & ig M s_w [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \frac{1}{2}ig M [\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]
 \end{aligned}$$



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



M. VELTMAN, G. 't HOOFT / PNF 1999



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

EL PREMIO NOBEL DE FÍSICA 2008



Elementary Particles

Quarks	u up	c charm	t top	γ photon
	d down	s strange	b bottom	g gluon
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	W W boson
I II III				Force Carriers
Three Families of Matter				



YOICHIRO NAMBU

MAKOTO KOBAYASHI TOSHIHIDE MASKAWA

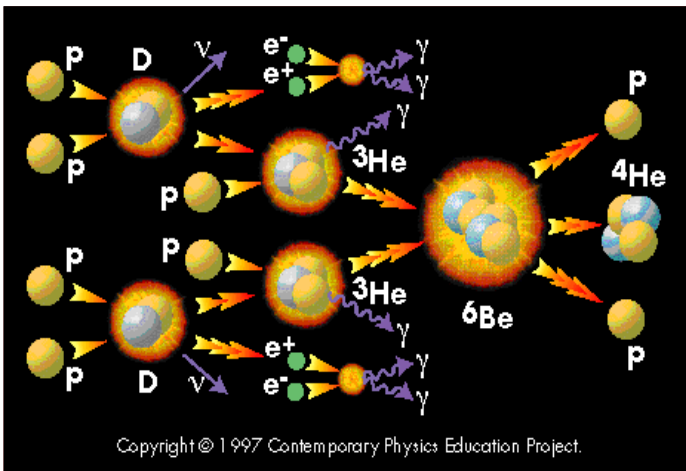
“por el descubrimiento del mecanismo de rotura espontánea de simetría en física subatómica”

“por el descubrimiento del origen de la rotura de simetría que predice la existencia de al menos tres familias de quarks en la naturaleza”

DIFICULTADES OBSERVACIONALES

- MASAS DE NEUTRINOS $\neq 0$
- MATERIA OSCURA
- MATERIA VS ANTIMATERIA





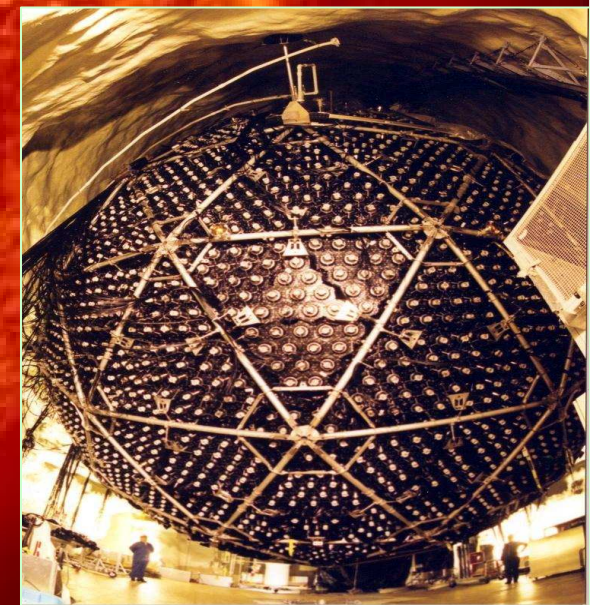
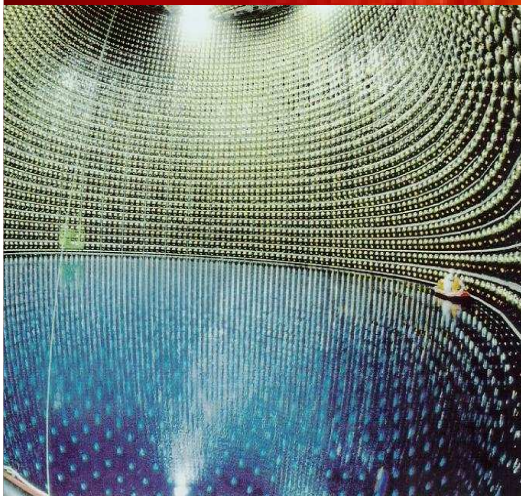
NEUTRINOS SOLARES



HOMESTAKE / R. DAVIS

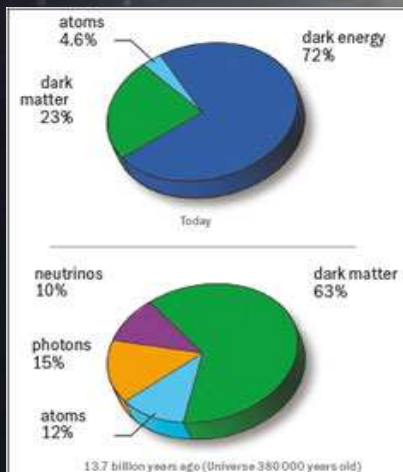
MASAS DE NEUTRINOS $\neq 0$

SUPERKAMIOKANDE / M. KOSHIBA



SNO

MASA Y ENERGÍA OSCURA

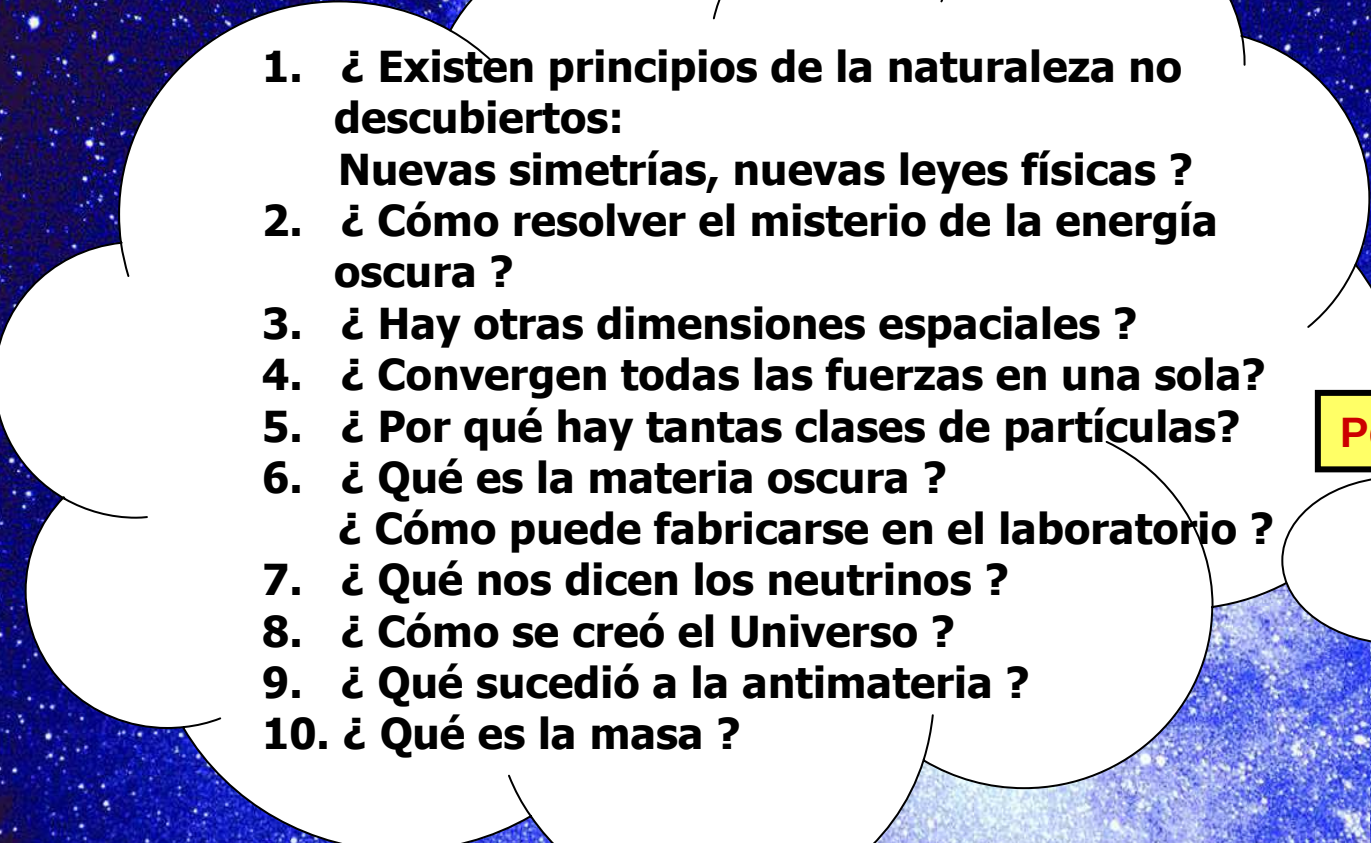


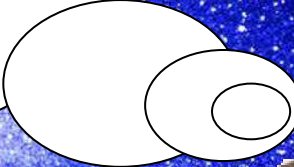
**HUECOS EN EL CONOCIMIENTO
DE LO EXTRAORDINARIO**

MATERIA vs ANTIMATERIA



**La hipótesis del Big Bang
para el origen del Universo implica
igual cantidad de materia y antimateria
en los primeros instantes de su existencia
¿ Dónde está la antimateria ?**

- 
1. ¿ Existen principios de la naturaleza no descubiertos:
Nuevas simetrías, nuevas leyes físicas ?
 2. ¿ Cómo resolver el misterio de la energía oscura ?
 3. ¿ Hay otras dimensiones espaciales ?
 4. ¿ Convergen todas las fuerzas en una sola?
 5. ¿ Por qué hay tantas clases de partículas?
 6. ¿ Qué es la materia oscura ?
¿ Cómo puede fabricarse en el laboratorio ?
 7. ¿ Qué nos dicen los neutrinos ?
 8. ¿ Cómo se creó el Universo ?
 9. ¿ Qué sucedió a la antimateria ?
 10. ¿ Qué es la masa ?



Pensador Evolucionado

PROGRAMA
"Descubrir el Universo Cuántico"

Descubrimientos Cruciales
Aceleradores en la Frontera de Energía (Tera Escala)

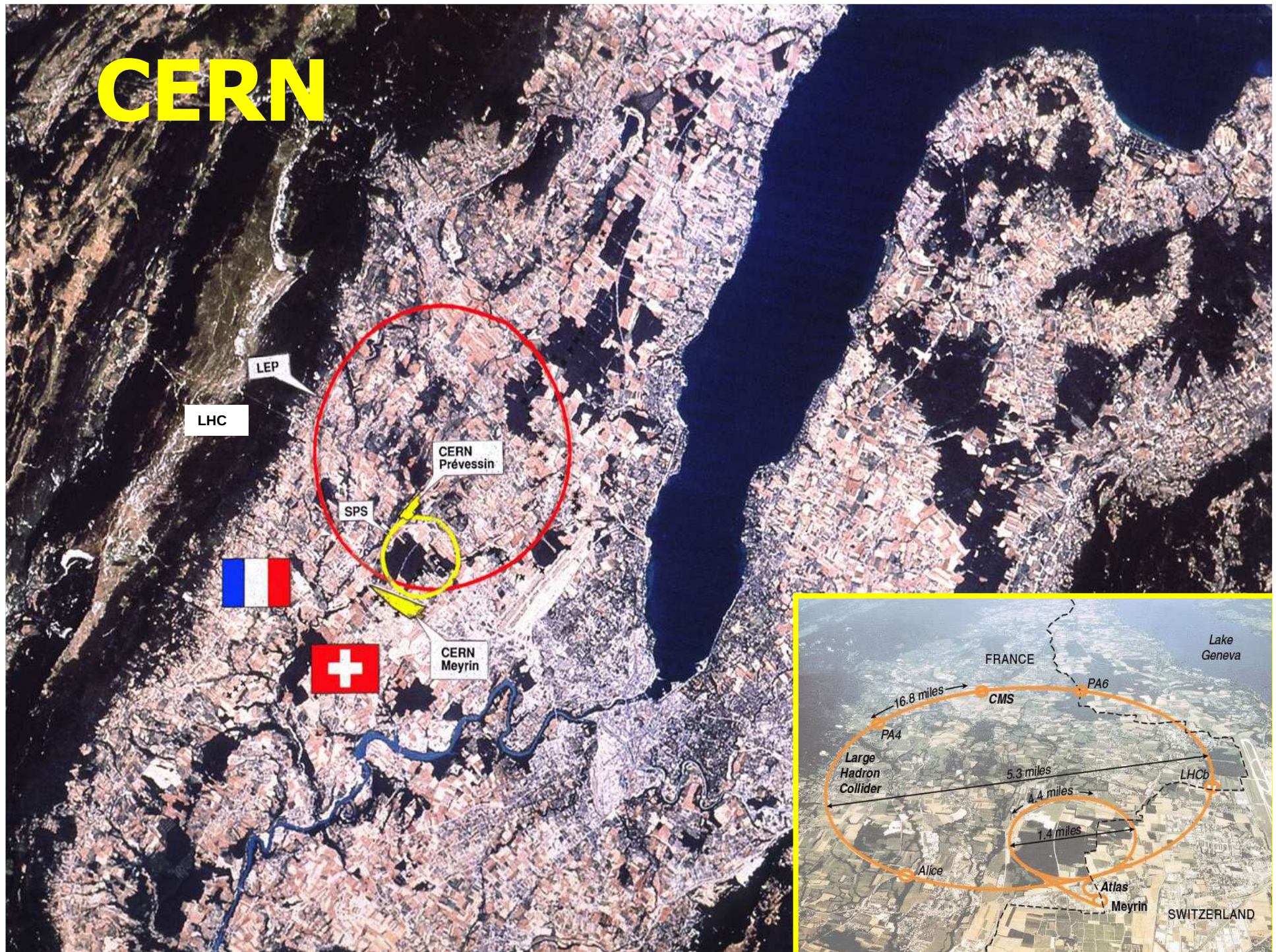




EL CERN

An aerial photograph of the CERN site in Switzerland. A red oval is drawn on the image, encompassing the main experimental area. Inside the oval, the text "EL CERN" is written in large, bold, yellow capital letters. The background shows a vast, flat landscape with a blue lake in the distance and a range of snow-capped mountains under a clear blue sky.

CERN



EL CERN c. 1954



EL CERN c. 1970





EI CERN c. 2009

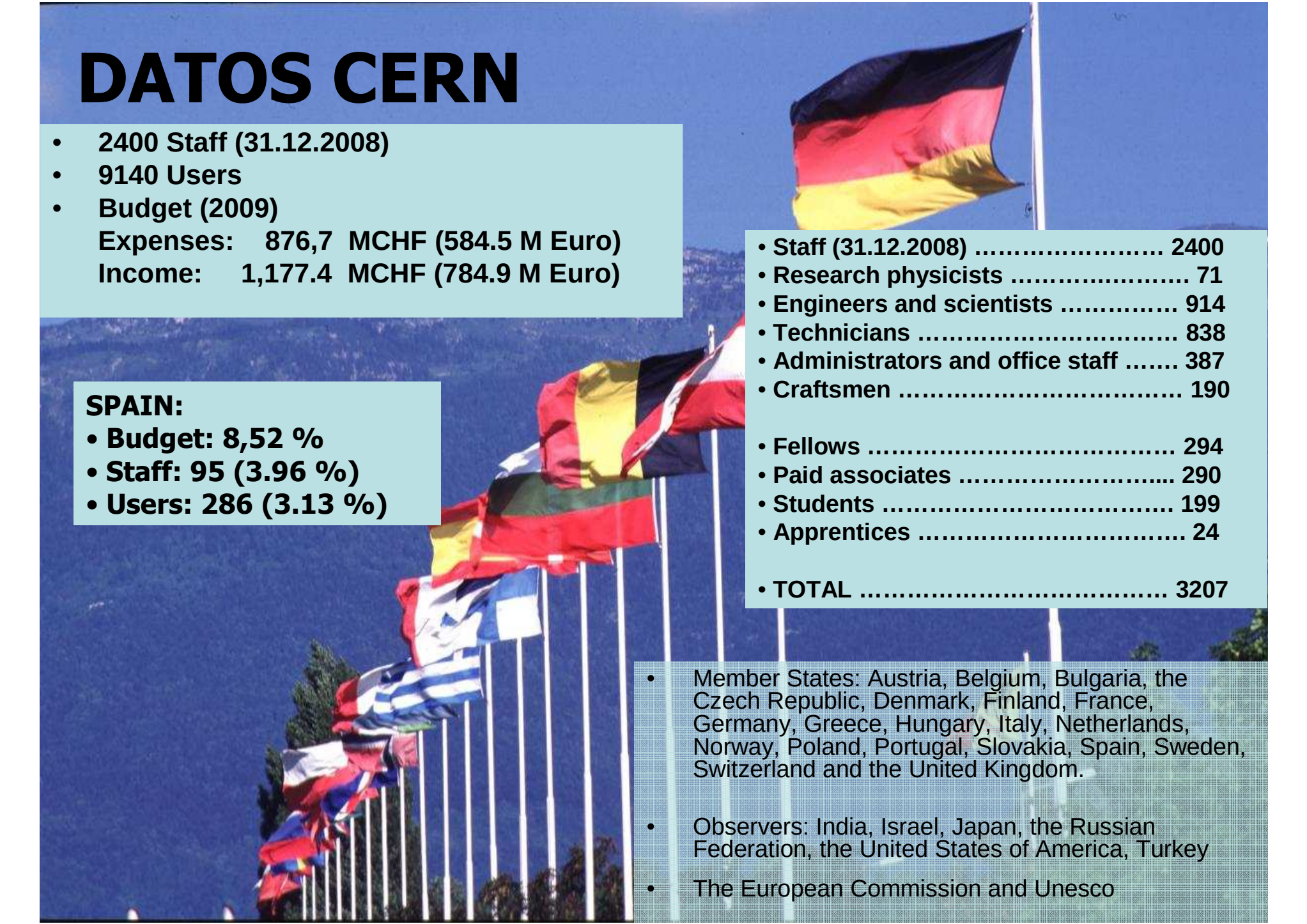


DATOS CERN

- 2400 Staff (31.12.2008)
- 9140 Users
- Budget (2009)
Expenses: 876,7 MCHF (584.5 M Euro)
Income: 1,177.4 MCHF (784.9 M Euro)

SPAIN:

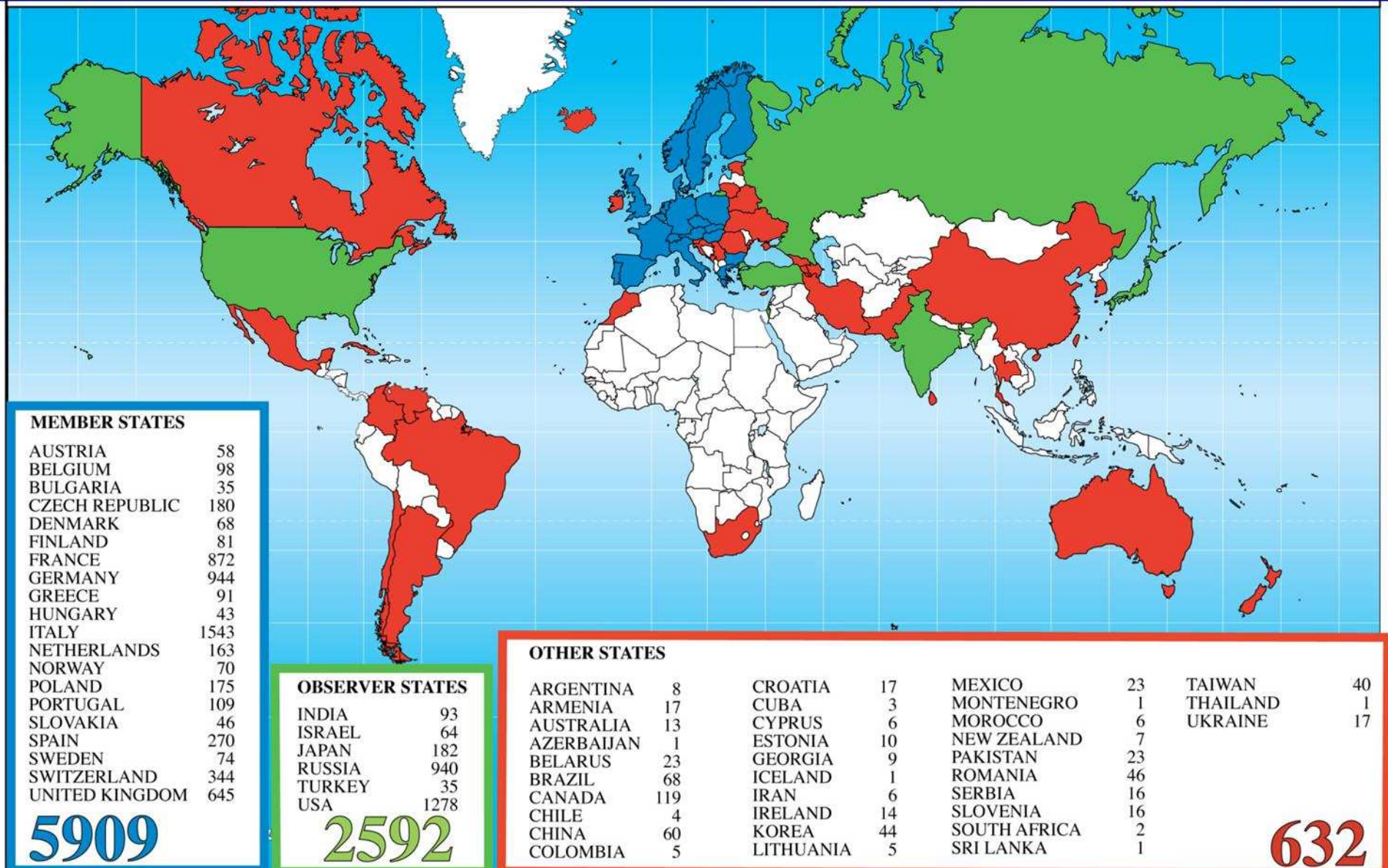
- Budget: 8,52 %
- Staff: 95 (3.96 %)
- Users: 286 (3.13 %)



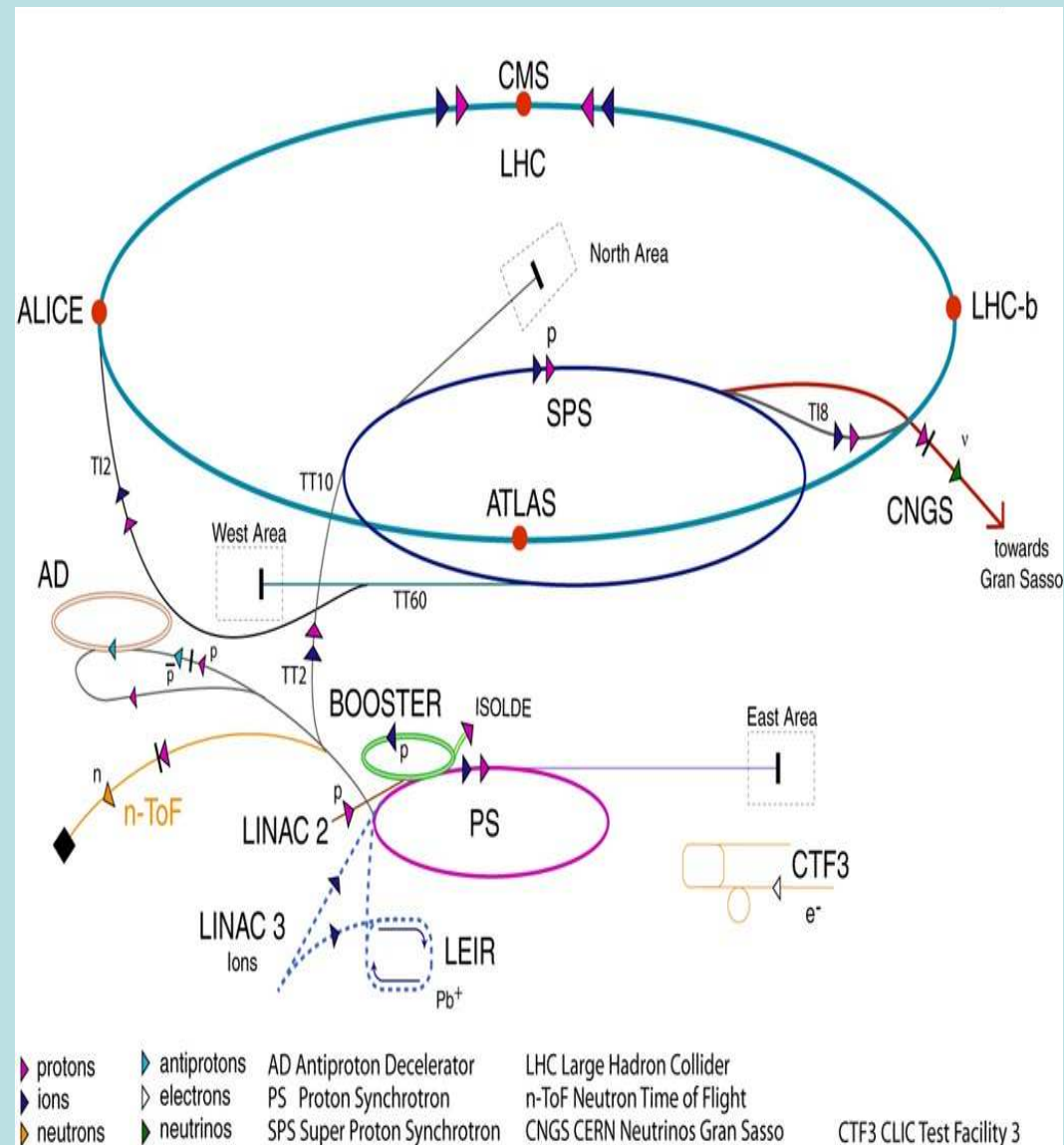
• Staff (31.12.2008)	2400
• Research physicists	71
• Engineers and scientists	914
• Technicians	838
• Administrators and office staff	387
• Craftsmen	190
• Fellows	294
• Paid associates	290
• Students	199
• Apprentices	24
• TOTAL	3207

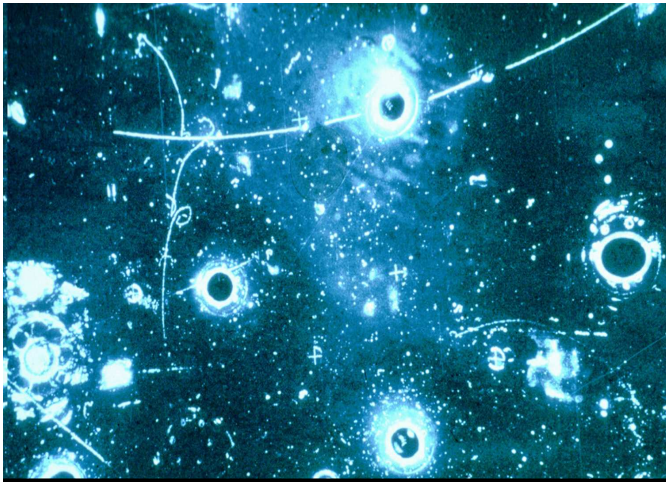
- Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.
- Observers: India, Israel, Japan, the Russian Federation, the United States of America, Turkey
- The European Commission and Unesco

Distribution of All CERN Users by Nation of Institute on 5 February 2008

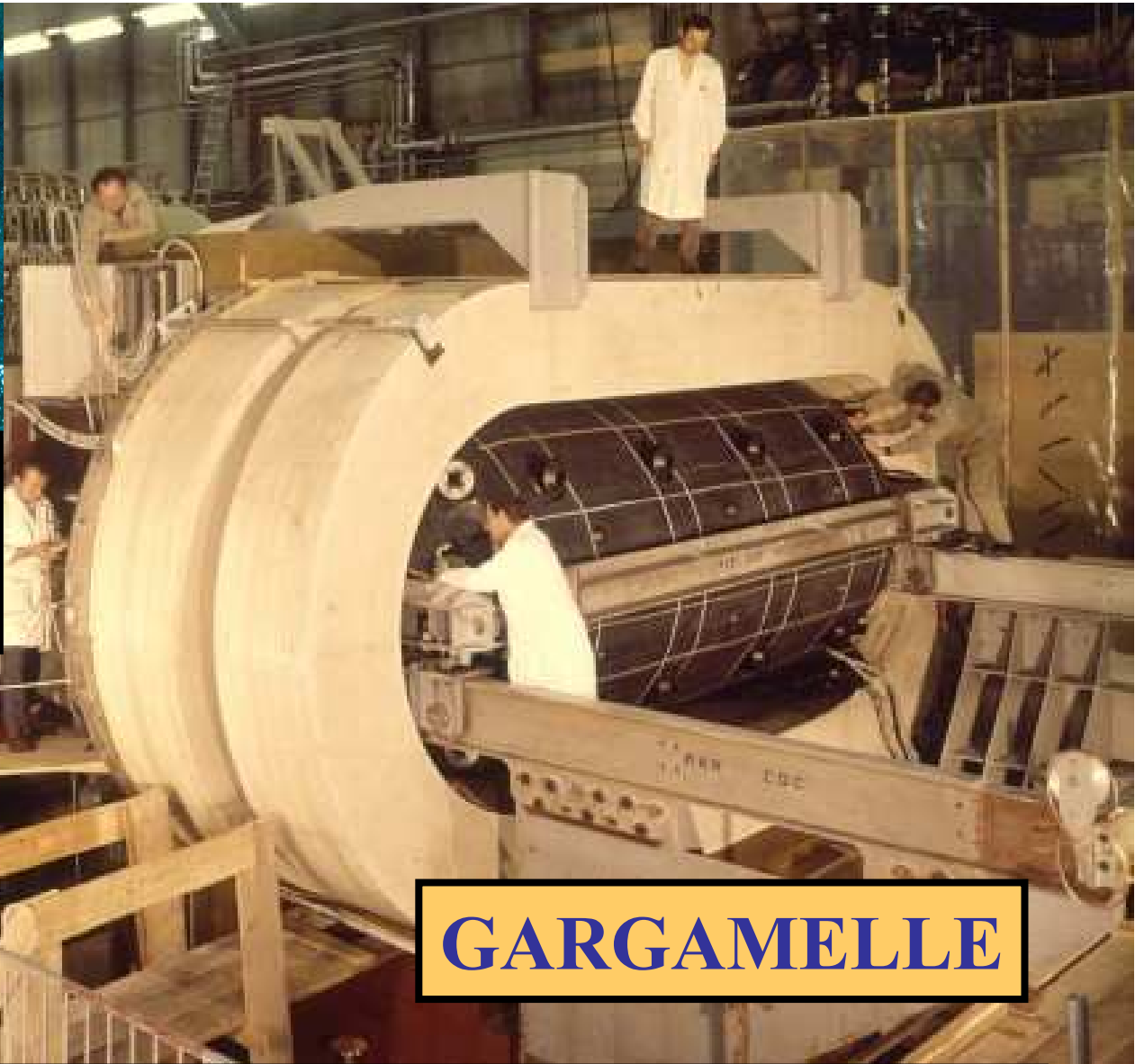


CERN: el Complejo de Aceleradores más Completo del Mundo





$$\nu_{\mu} e^{-} \rightarrow \nu_{\mu} e^{-}$$



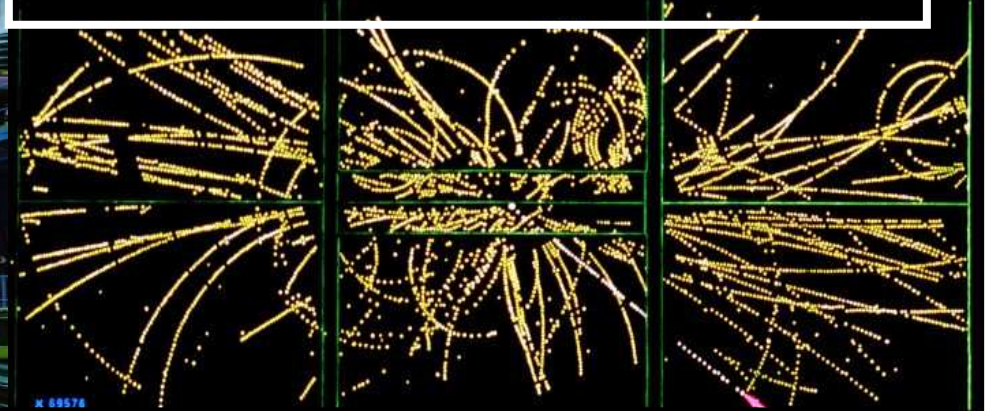
GARGAMELLE

**1973: DESCUBRIMIENTO DE LAS
CORRIENTES NEUTRAS**

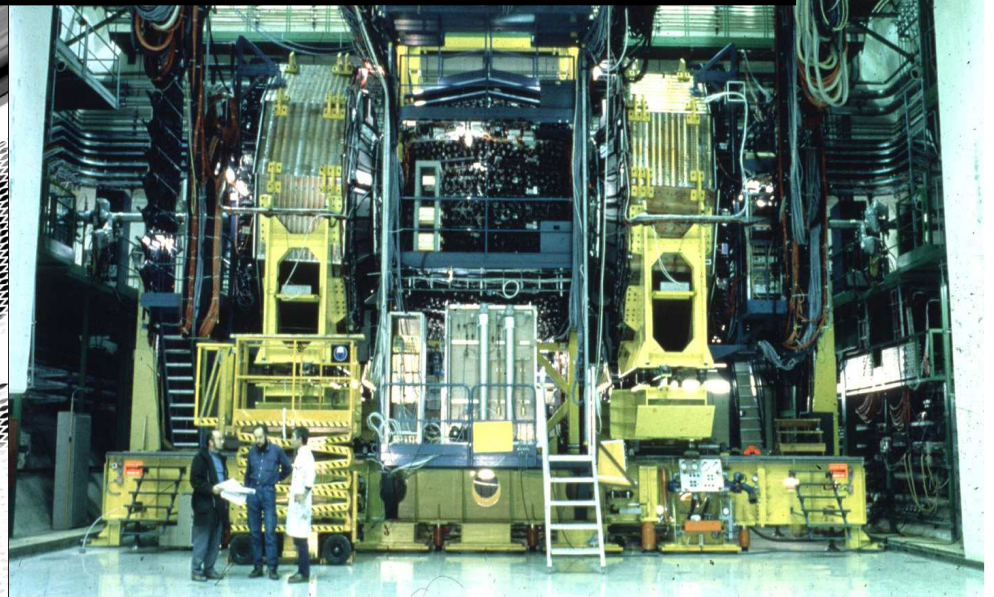


EVENT 2958. 1278.

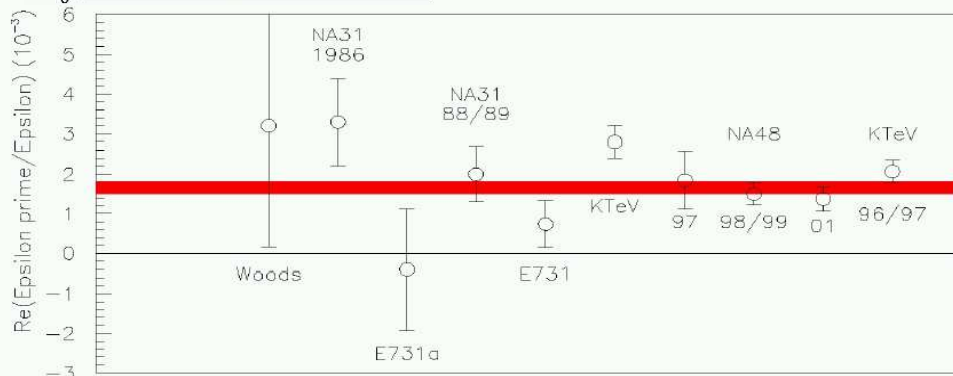
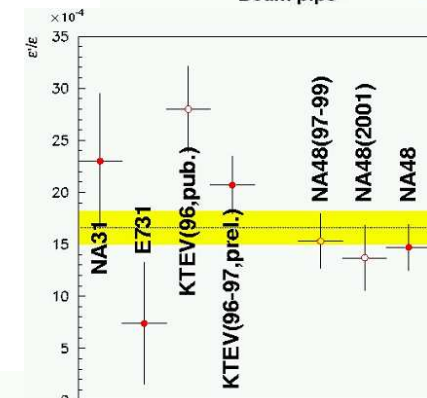
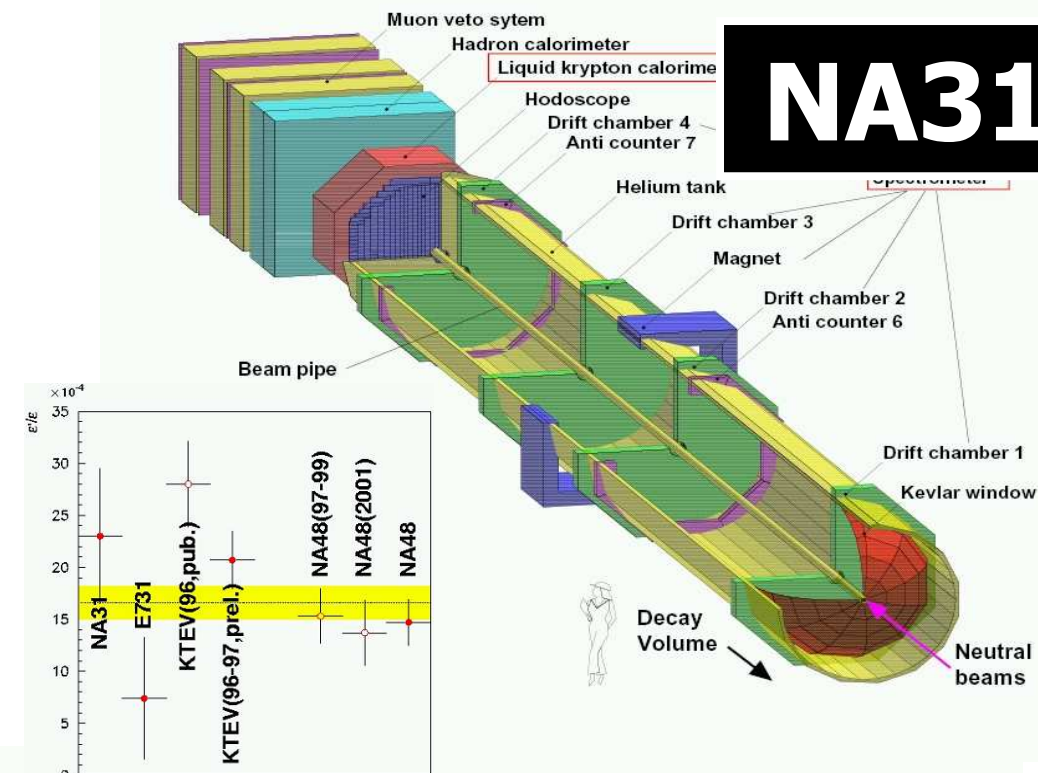
UA1 & UA2 - SPPS



**1983: DESCUBRIMIENTO DE
LOS BOSONES $W^{\pm}$, Z**



NA31—NA48



1986 — 2001: MEDIDA DE ϵ' / ϵ

1989 — 2000

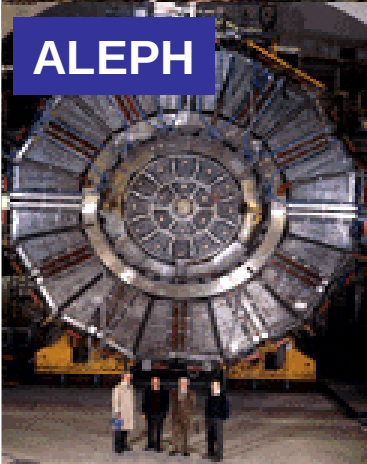
VALIDACIÓN DEL MODELO ESTÁNDAR



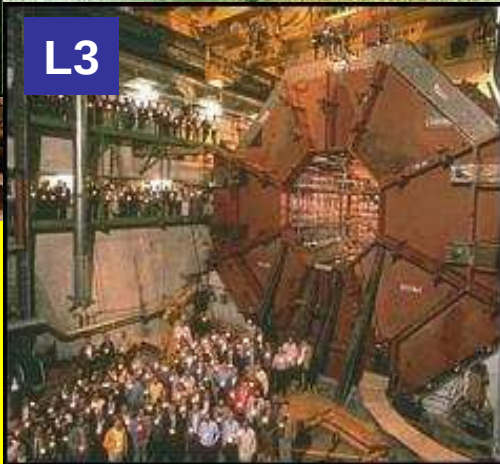
LEP



ALEPH



L3



DELPHI

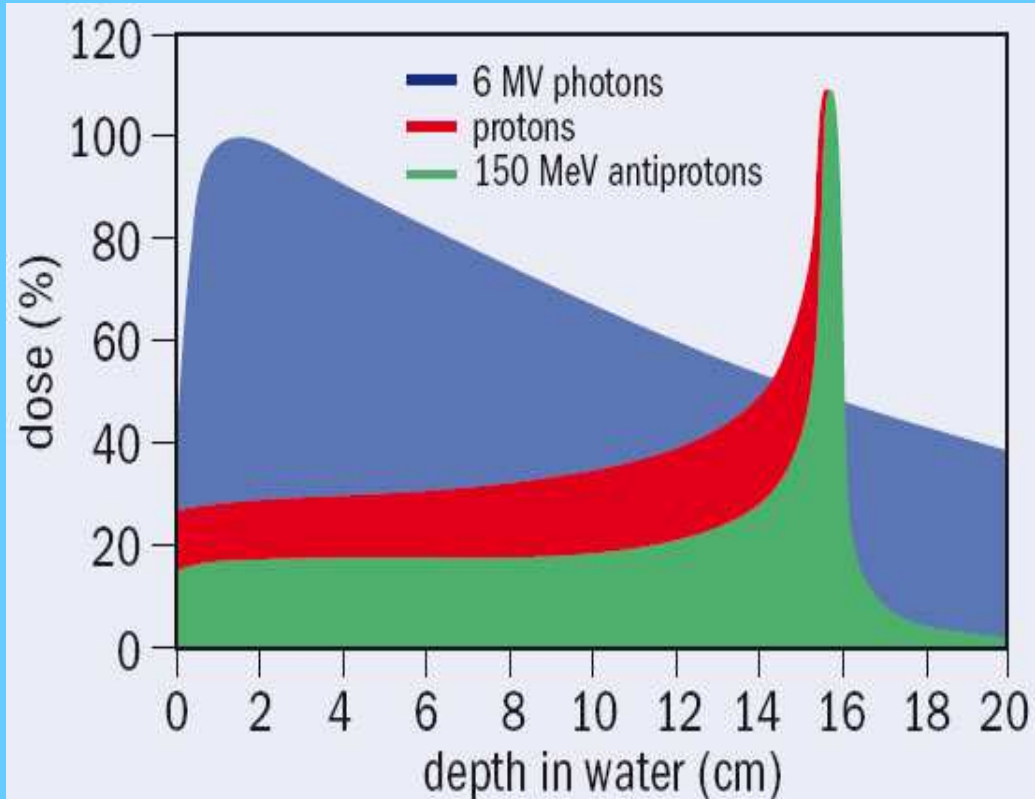


OPAL



ANTIPROTON CELL EXPERIMENT

CERN ANTIPROTON DECELERATOR



CLOUD

Cosmics Leaving Outdoor Droplets

That there is a causal connection between the observed variations in the forces of the Sun, the terrestrial magnetic field, and the meteorological elements has been the conclusion of every research into this subject for the past 50 years. The elucidation of exactly what the connection is and the scientific proof of it is to be classed among the most difficult problems presented in terrestrial physics. The evidence adduced in favor of this conclusion is on the whole of a cumulative kind, since the direct sequence of cause and effect is so far masked in the complex interaction of the many delicate forces in operation as to render its immediate measurement quite impossible in the present state of science.

F.H. Bigelow

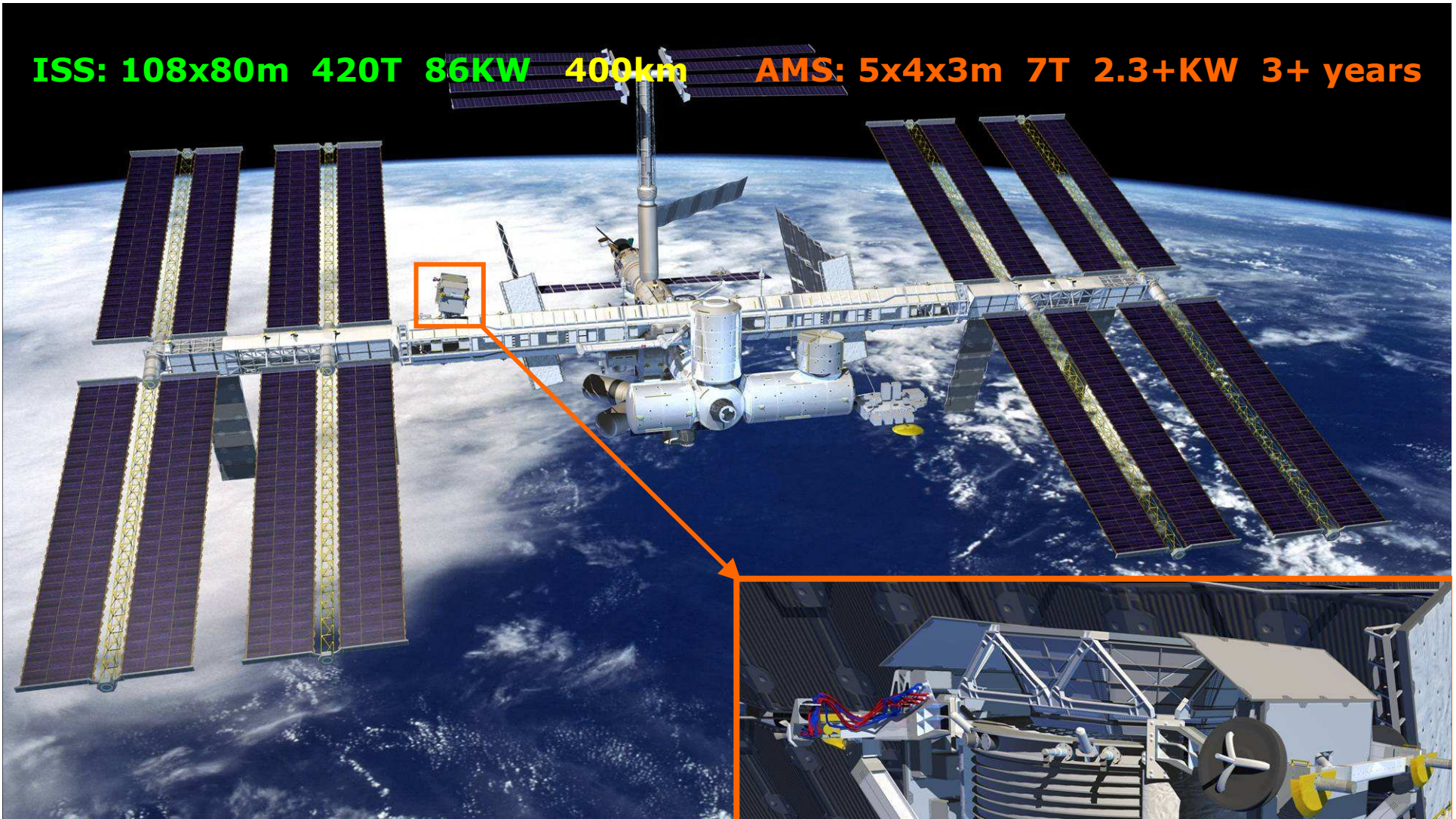
US Dept. Agriculture Weather Bureau

Bulletin No.21, 1898

CERN RECOGNIZED EXPERIMENTS

- [RE1](#)(AMS) Alpha Magnetic Spectrometer (AMS) for Extraterrestrial Study of Antimatter, Matter and Missing Matter on the International Space Station
- [RE3](#)(AUGER PROJECT) The Pierre Auger Observatory Project
- [RE5](#)(EXPLORER) The Gravitational Wave Detector EXPLORER
- [RE6](#)(ANTARES) ANTARES: An Undersea Neutrino telescope
- [RE7](#)(GLAST) GLAST
- [RE8](#)(LISA) LISA
- [RE9](#)(NESTOR) NESTOR-Neutrino Extended Submarine Telescope with Oceanographic Research
- [RE10](#)(ICECUBE) IceCube
- [RE11](#)(MICE) Muon Ionization Cooling Experiment
- [RE12](#)(MEG) MEG: search for the μe decay at PSI
- [RE13](#)(T2K) Neutrino Oscillation Experiment at JHF
- [RE14](#)(KATRIN) Tritium beta-decay experiment for direct measurement of the electron neutrino mass
- [RE15](#)(WARP) Search for cold dark matter using a cryogenic noble liquid detector
- [RE2A](#)(CAPRICE) Cosmic AntiParticle Ring Imaging Cerenkov Experiment
- [RE2B](#)(PAMELA) Search for Antimatter in Space

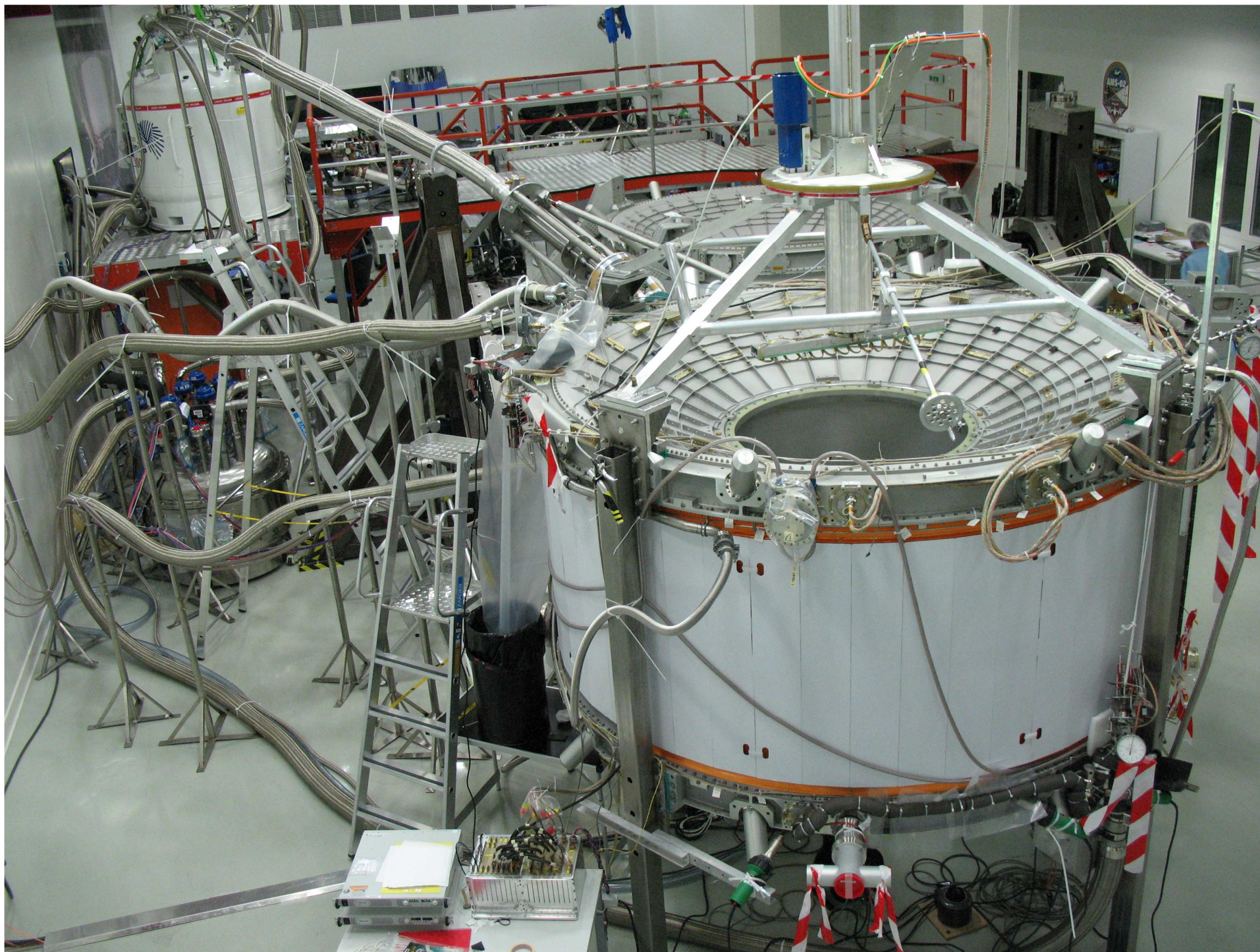
ISS: 108x80m 420T 86KW 400km AMS: 5x4x3m 7T 2.3+KW 3+ years



AMS-02 @ ISS







AMS ASTRONAUTS



Mark E. Kelly
(Captain, USN)



Gregory H. Johnson
(Colonel, USAF, Ret.)



E. M. "Mike" Fincke
(Colonel, USAF)



Roberto Vittori
(Italian Air Force Colonel)



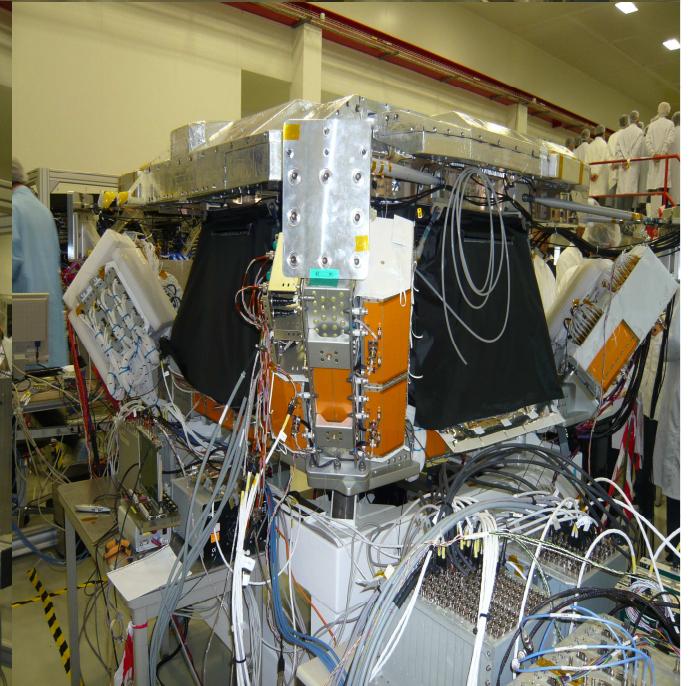
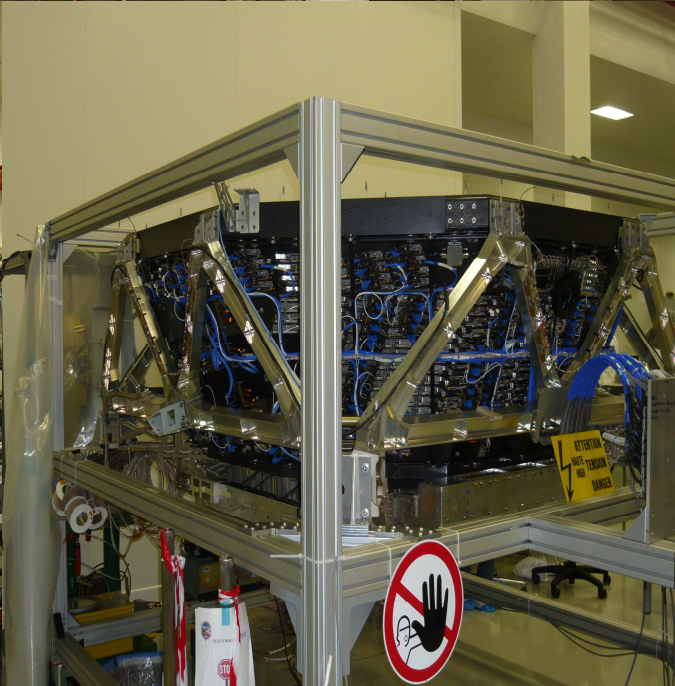
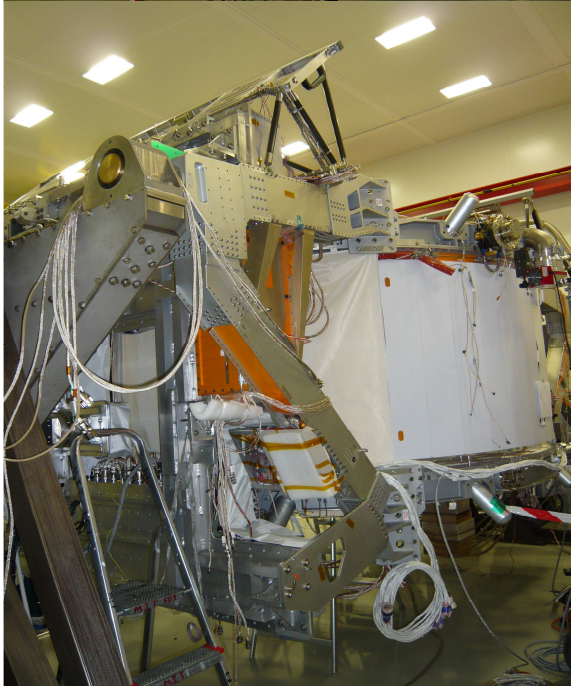
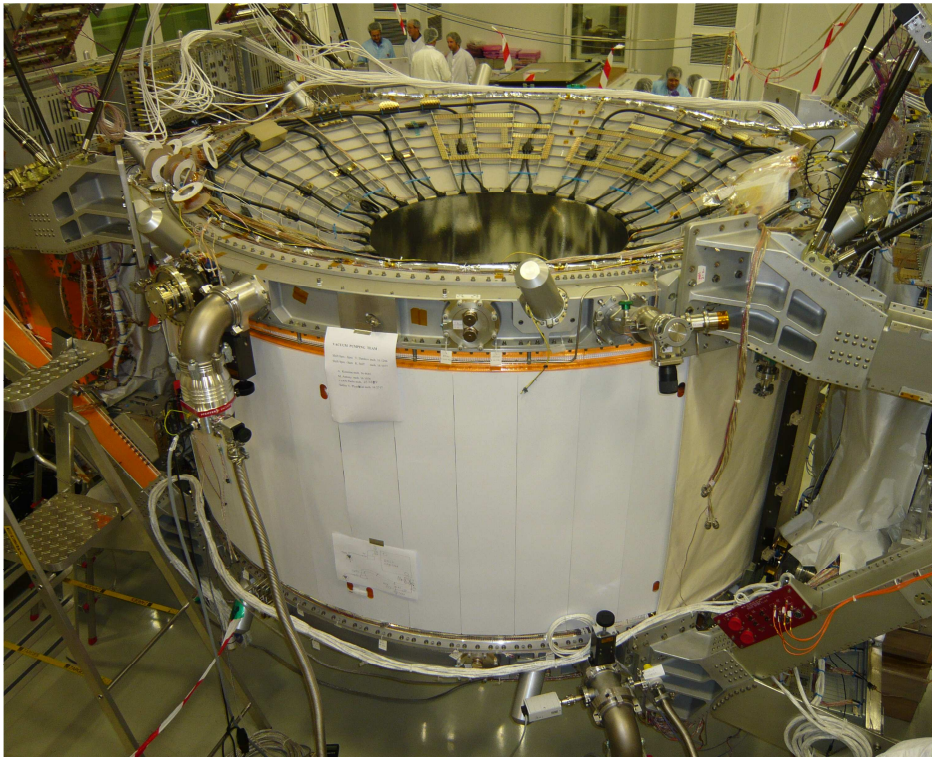
Andrew J. Feustel
(Ph.D.)

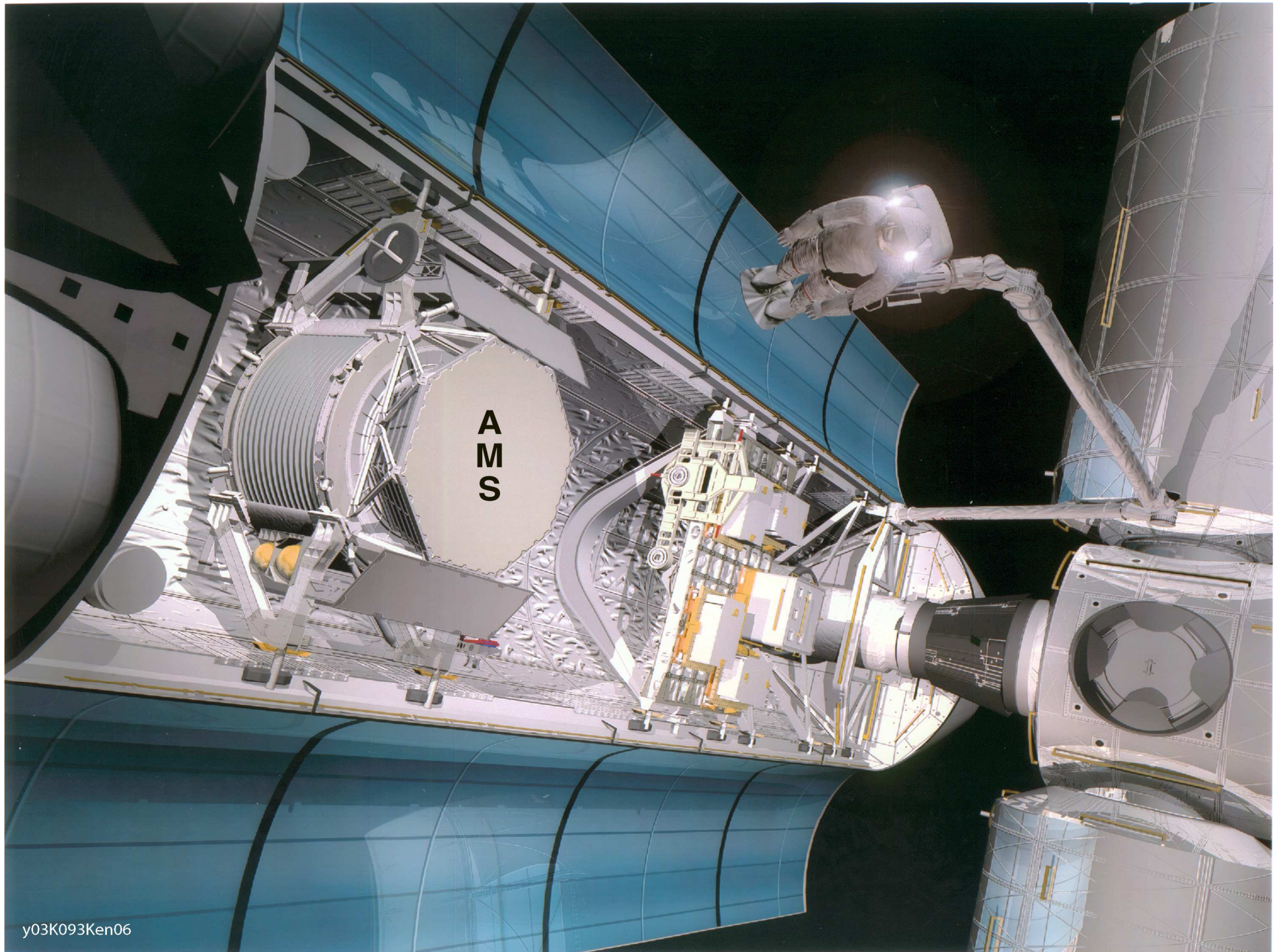


Gregory Errol Chamitoff
(Ph.D.)

At CERN on October 13 - 16, 2009







y03K093Ken06

ACELERADORES & HACES

Análisis de Muestras, Procesos de Modificación,

Investigación Física Básica Subatómica

Total > 17500

- **Alta Energía ($E > 1$ GeV): 120**
- **Baja Energía (Biomedicina): ≈ 1000**
- **Fuentes Radiación Sincrotrón: > 100**
- **Producción Radio-Isótopos (Medicina): ≈ 200**
- **Radioterapia : >7500**
- **Procesado & Investigación Industrial: ≈ 1500**
- **Implantación Iones & Superficies: >7000**

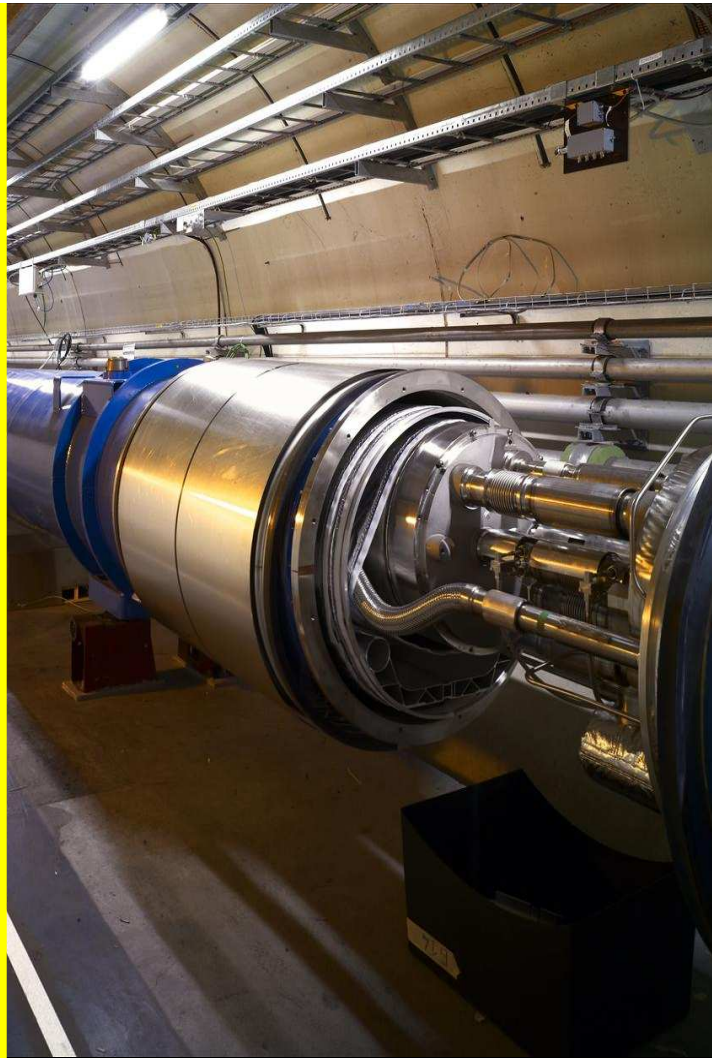
ACELERADORES

De A a Z

- **A**rte (AGLAE)
- **B**iólogía & Proteómica (XRD)
- **D**íagnos (PET, SPECT)
- **F**usión Inercial (FEL)
- **H**idroterapia (PIMMS)
- **P**lanetología (HPM)
- **T**ransmutación (ARC)
- **Z**oología (ESRF)

CERN as Educator





EL LHC DEL CERN

¡¡ EL LHC !!



Objetivos Físicos Principales

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

El LHC determinará el Futuro de la Física de Altas Energías

INGREDIENTES



1. Aceleradores



2. Detectores

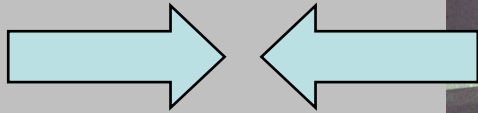
3. Computadores

4. Personas

El Large Hadron Collider (LHC)

Colisionador Protón - Protón

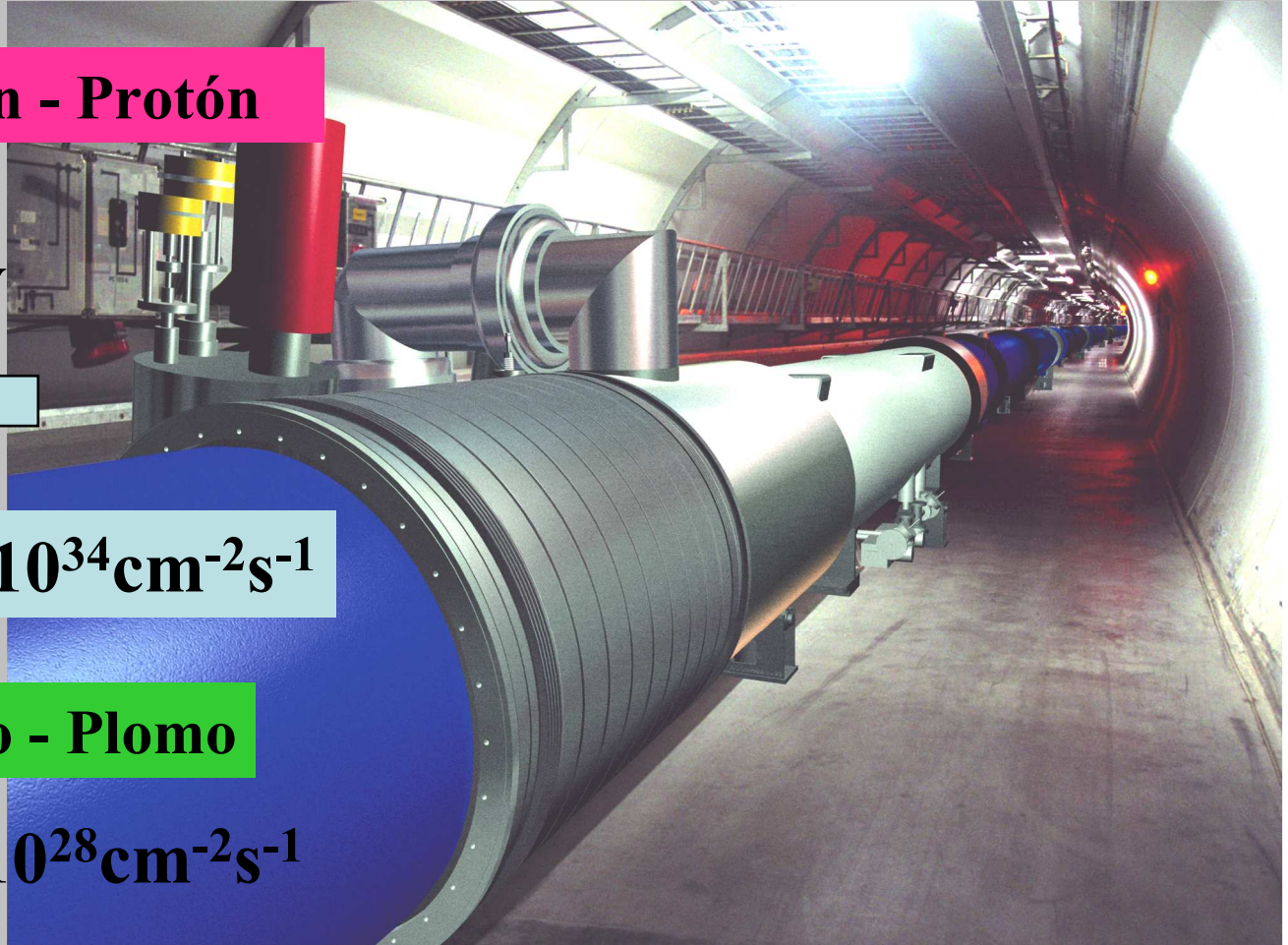
$7 \text{ TeV} + 7 \text{ TeV}$



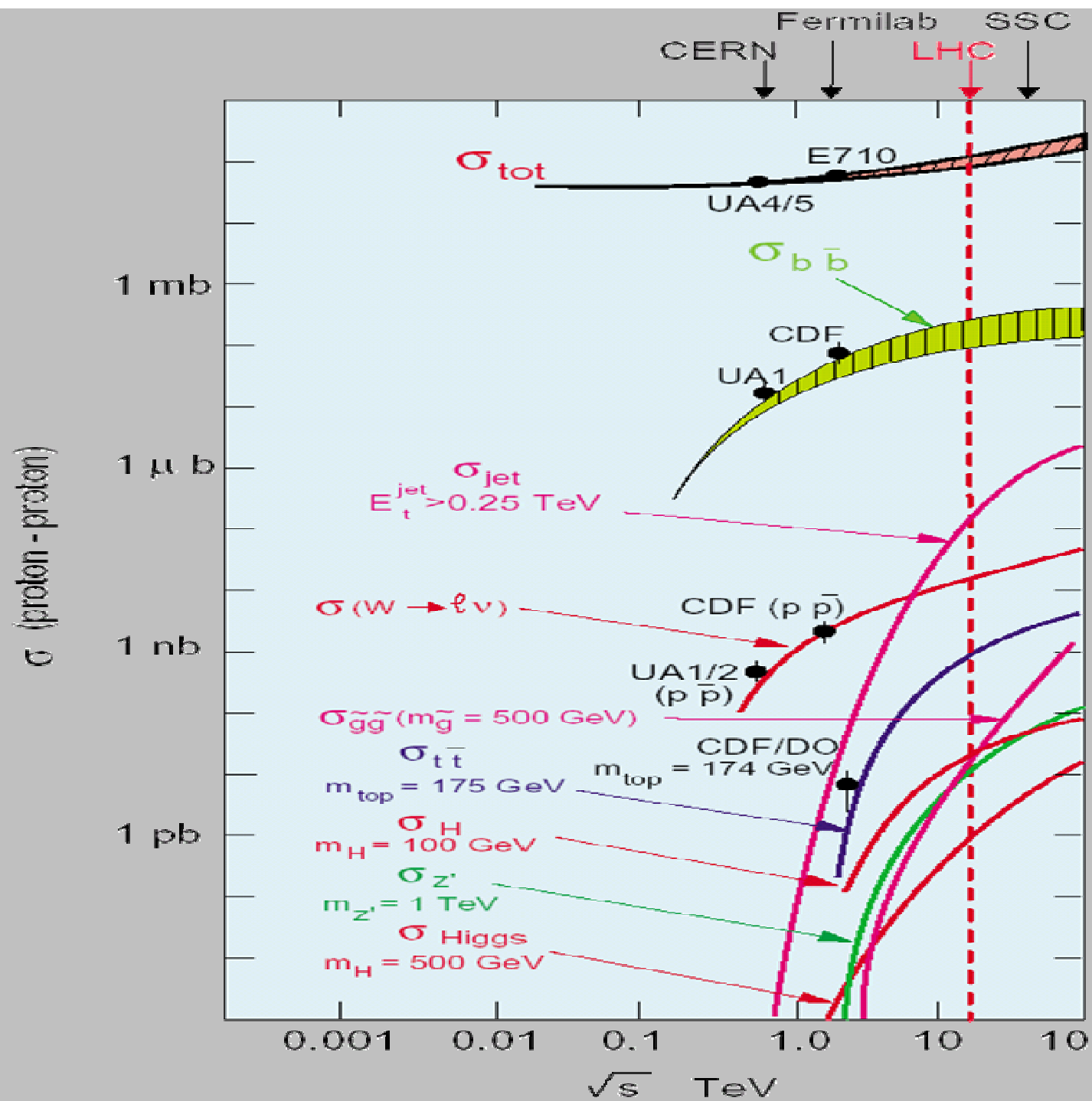
Luminosidad = $10^{34} \text{cm}^{-2} \text{s}^{-1}$

Colisionador Plomo - Plomo

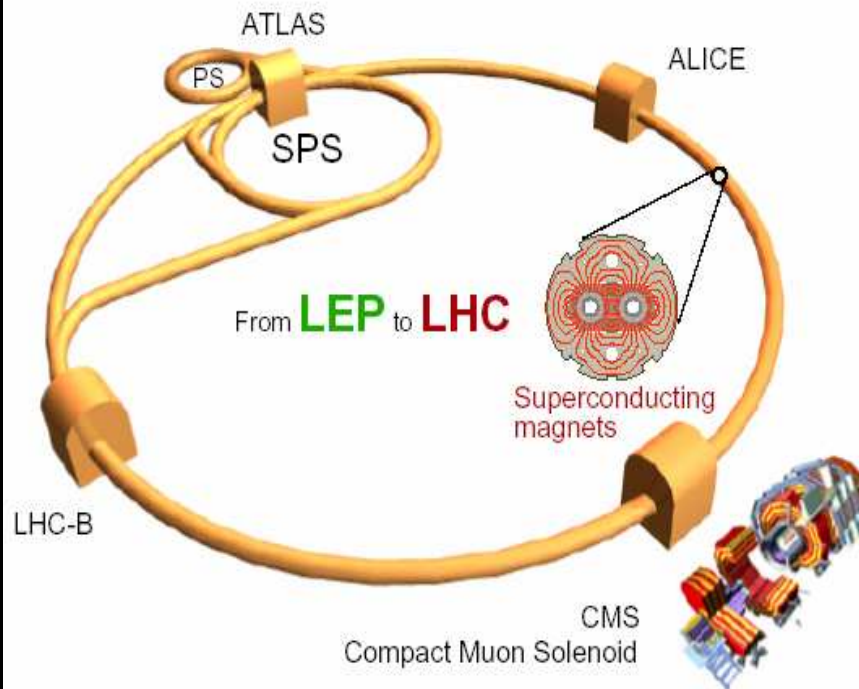
Luminosidad = $10^{28} \text{cm}^{-2} \text{s}^{-1}$



$1 \text{ TeV} = 1000 \text{ GeV}$
 ~ 1000 veces la masa del protón



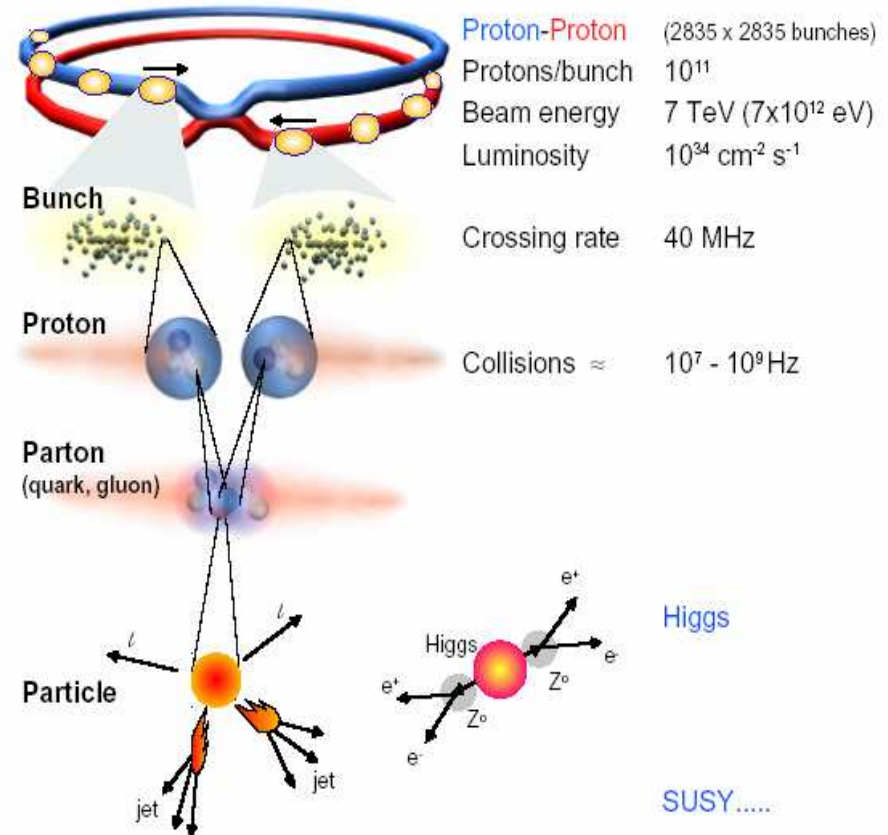
The Large Hadron Collider (LHC)



	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

ii SUPERCONDUCTIVIDAD !!

Collisions at LHC



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

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

LHC (algunos datos)

Parametros (protones):

- Energía: **7 TeV**
- Campo Magnético (dipolos): **8.3 T**
- **$2.8 \cdot 10^{14}$ protones / haz**
(en 2835 paquetes)
- Corrient: 0.56 A
- Luminosidad: 10^{34} cm²/s

Energía Almacenada:

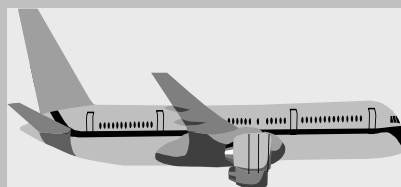
Energy in the two beams: **0.7 GJ**

Energy in the magnets: **10.4 GJ**

Total:
11 GJ

Imanes Superconductores, Criogenia:

12 millones de litros de nitrógeno líquido se vaporizan durante la fase inicial de enfriamiento de las 31000 toneladas de masa fría; 700000 litros de of helio líquido se necesitan para mantener la masa fría a 2K.

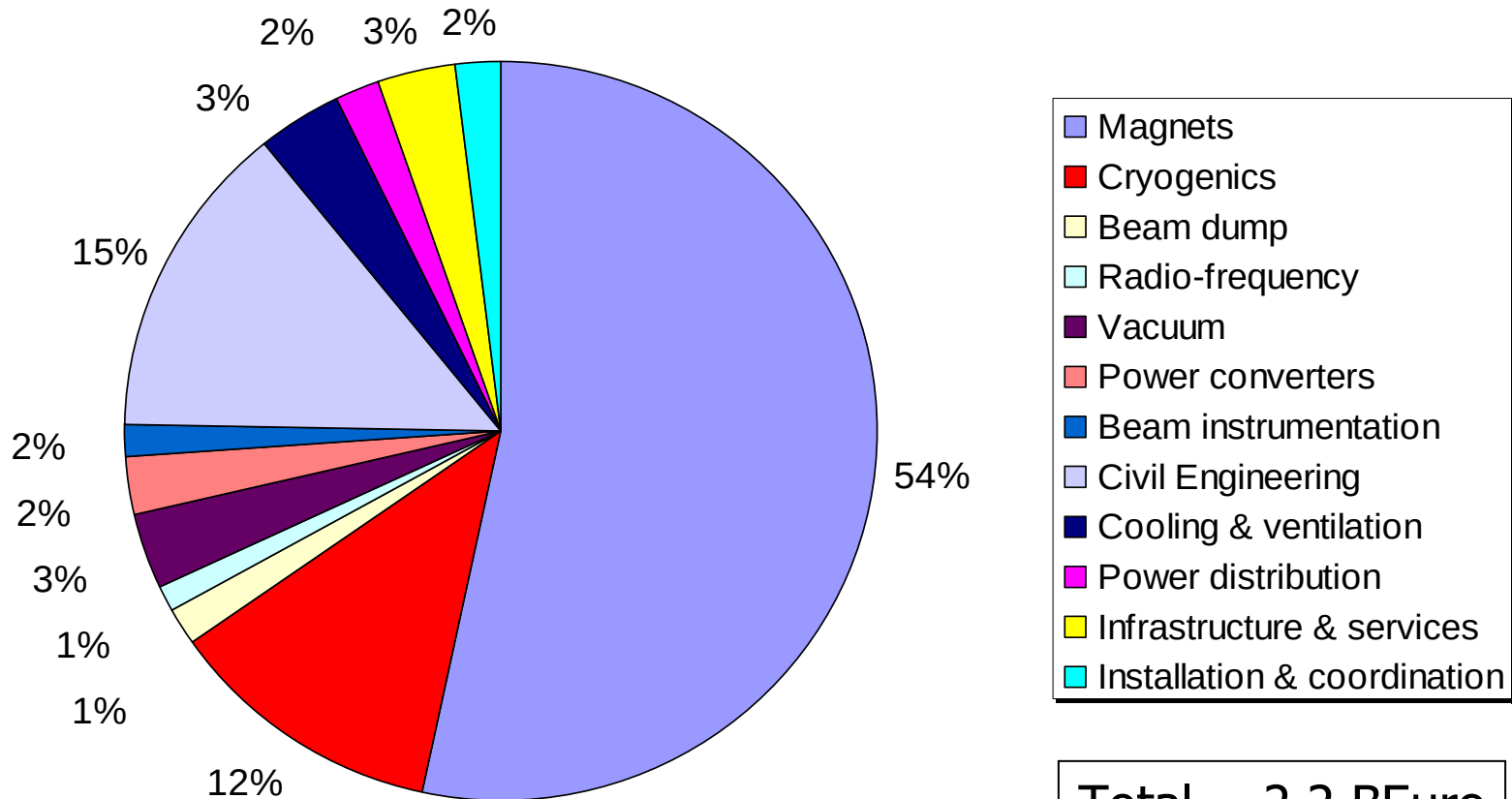


50 toneladas a 600 km/h



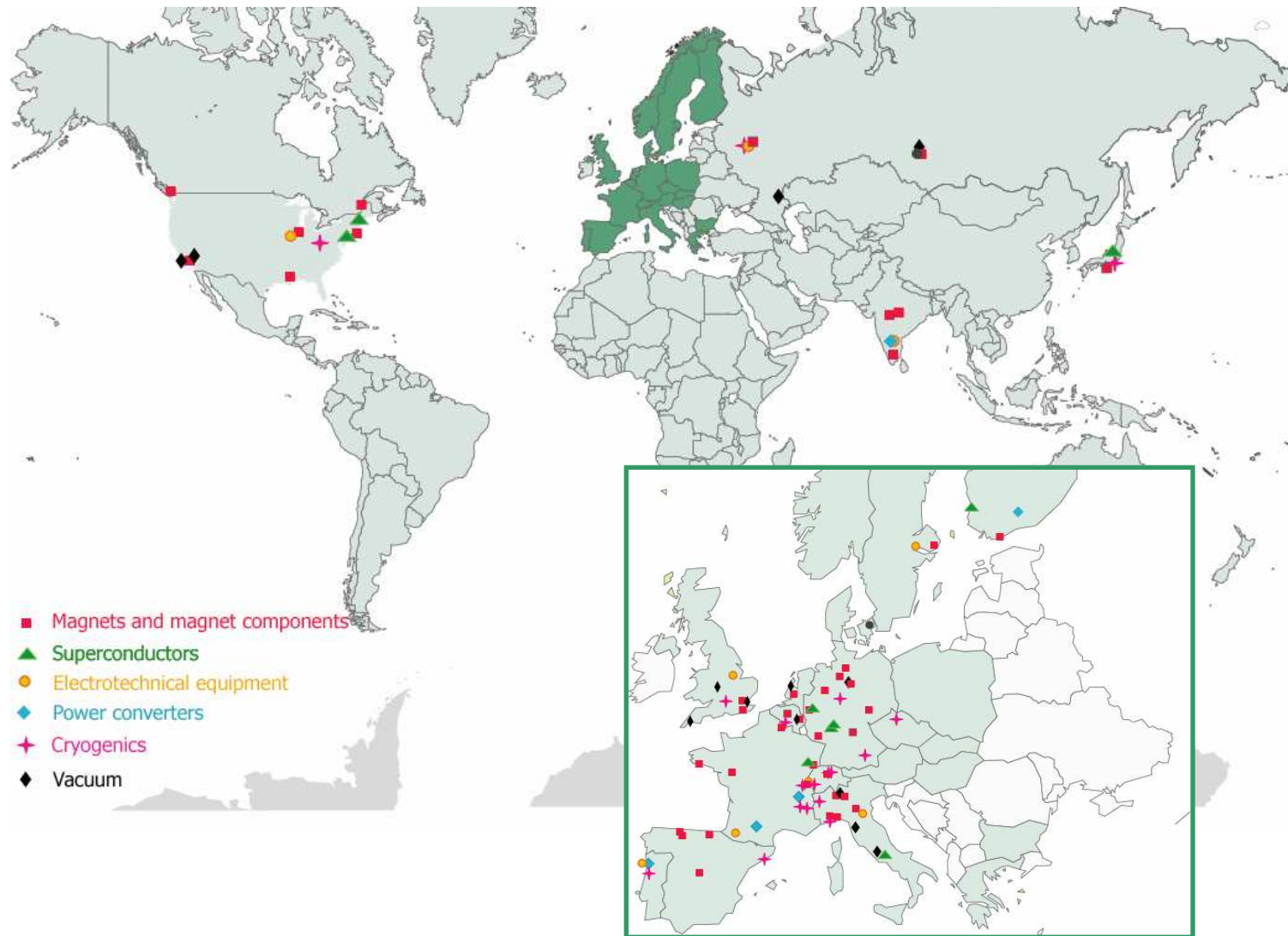
a 40 km/h

Estructura de Costes del acelerador LHC



Total ~ 2.2 BEuro

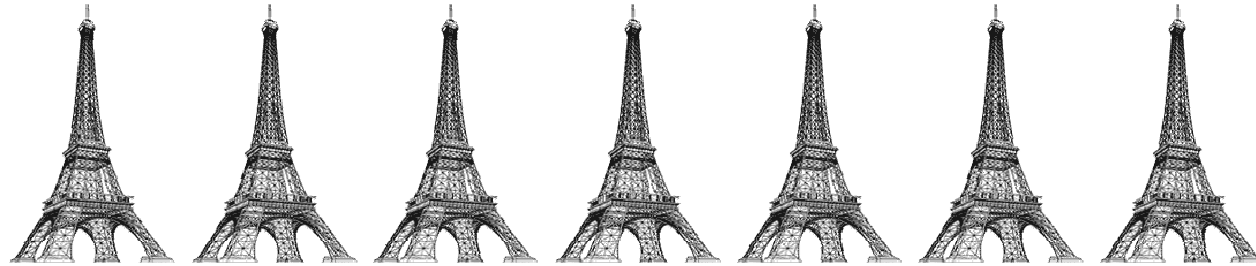
90 grandes contratos industriales



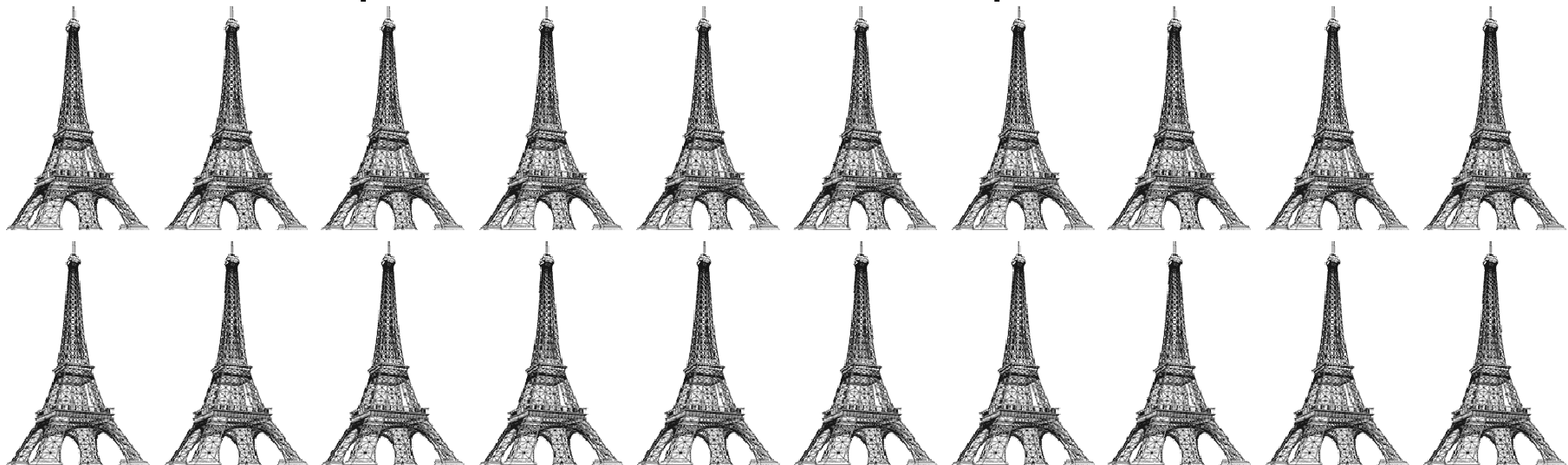
Logística de Suministro & Instalación

Calidad y cantidad en el momento y en el lugar adecuado

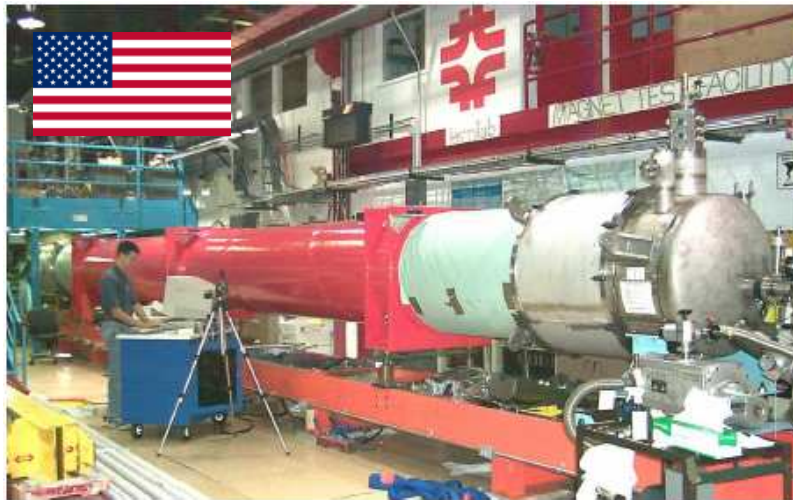
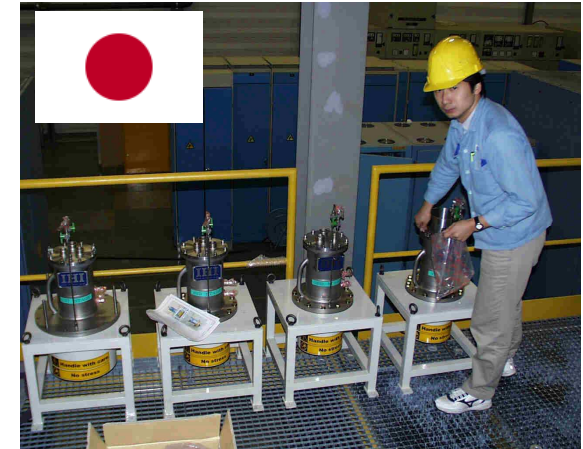
Instalados en el túnel del LHC: 50 000 t



Transportados a través de Europa: ~150 000 t



Un proyecto global en el espacio ...



... y en el tiempo

- **Estudios preliminares conceptuales** **1984**
- **Primeros modelos de imanes** **1988**
- **Inicio de un programa estructurado de I&D** **1990**
- **Aprobación por el Consejo del CERN** **1994**
- **Industrialización de la producción en serie** **1996-1999**
- **Inicio de los trabajos de ingeniería civil** **1998**
- **Adjudicación de los grandes contratos** **1998-2001**
- **Inicio de la instalación en el túnel** **2003**
- **Instalación de los crioimanes en el túnel** **2005-2007**
- **Prueba funcional del primer sector** **2007**
- **Comisionado con haz** **2008**
- **Operación para física** **2009-2030**



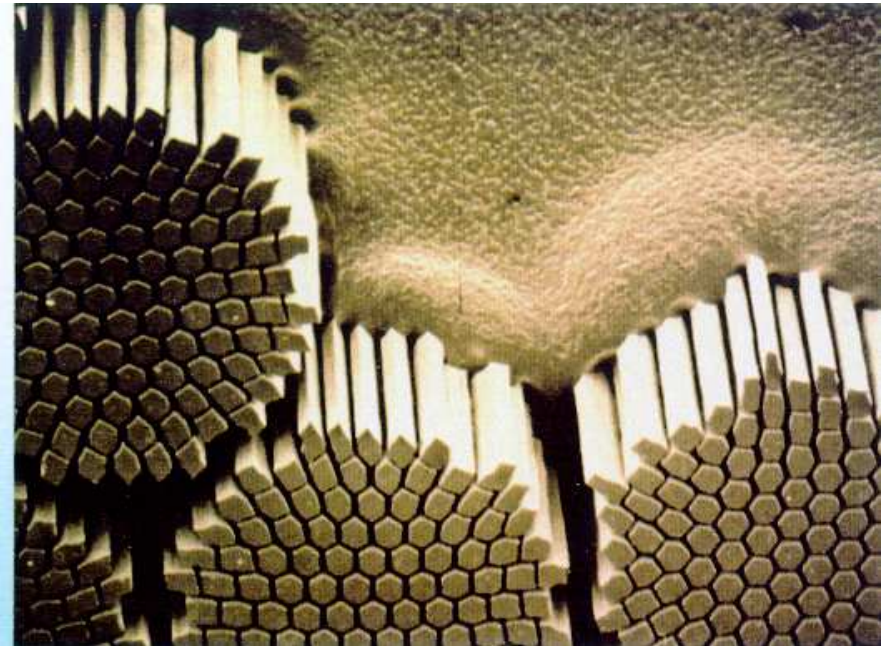
Inauguration du LHC LHC Inauguration

CERN 21-10-2008

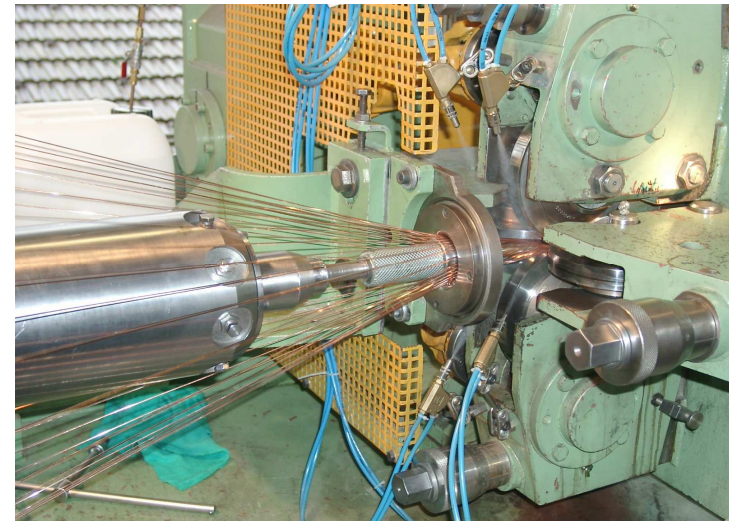
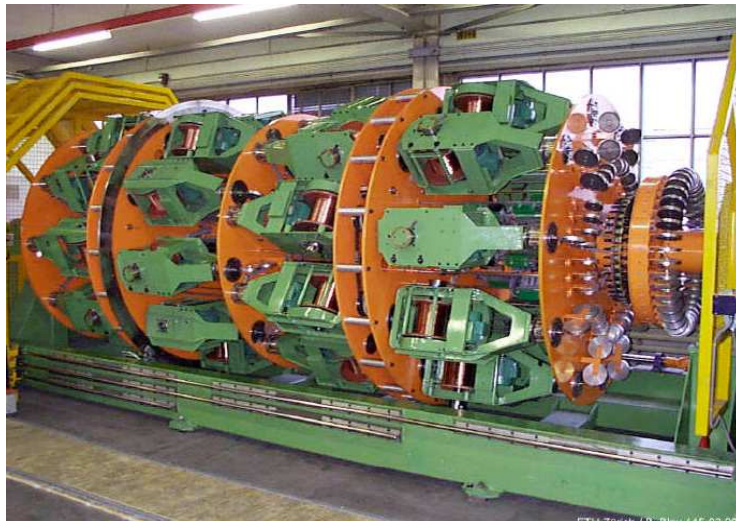


7000 km de cables superconductores con propiedades eléctricas y mecánicas controladas

	Cable Interno	Cable Externo
Número de strands	28	36
Diámetro del strand	1.065 mm	0.825 mm
Diámetro del filamentos	7 μm	6 μm
Número of filamentos	~ 8900	~ 6520
Anchura del cable	15.1 mm	15.1 mm
Semi-espesor	1.900 mm	1.480 mm
Ángulo Keystone	1.25 °	0.90 °
Longitud de transposición	115 mm	100 mm
Relación Cu/Sc	≥ 1.6	≥ 1.9



Producción de hilos & cables superconductores



Fabricación de bobinas superconductoras



Ensamblaje de las masas frías de los dipolos



Ensamblaje final de los crioimanes en el CERN



Pruebas criogénicas de imanes



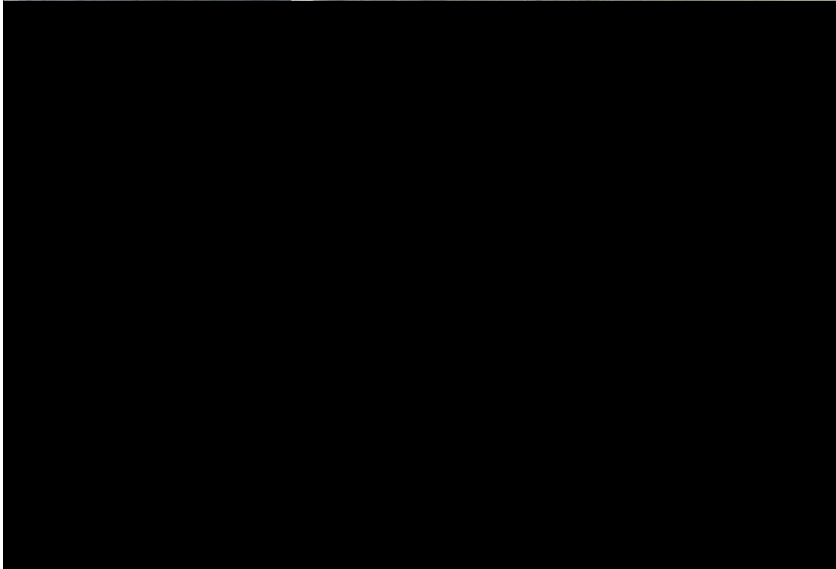
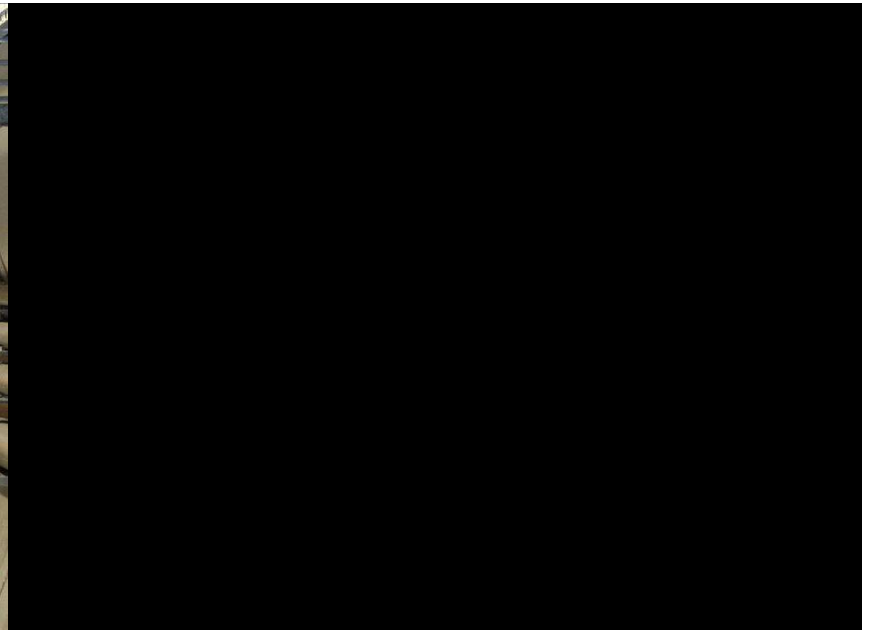
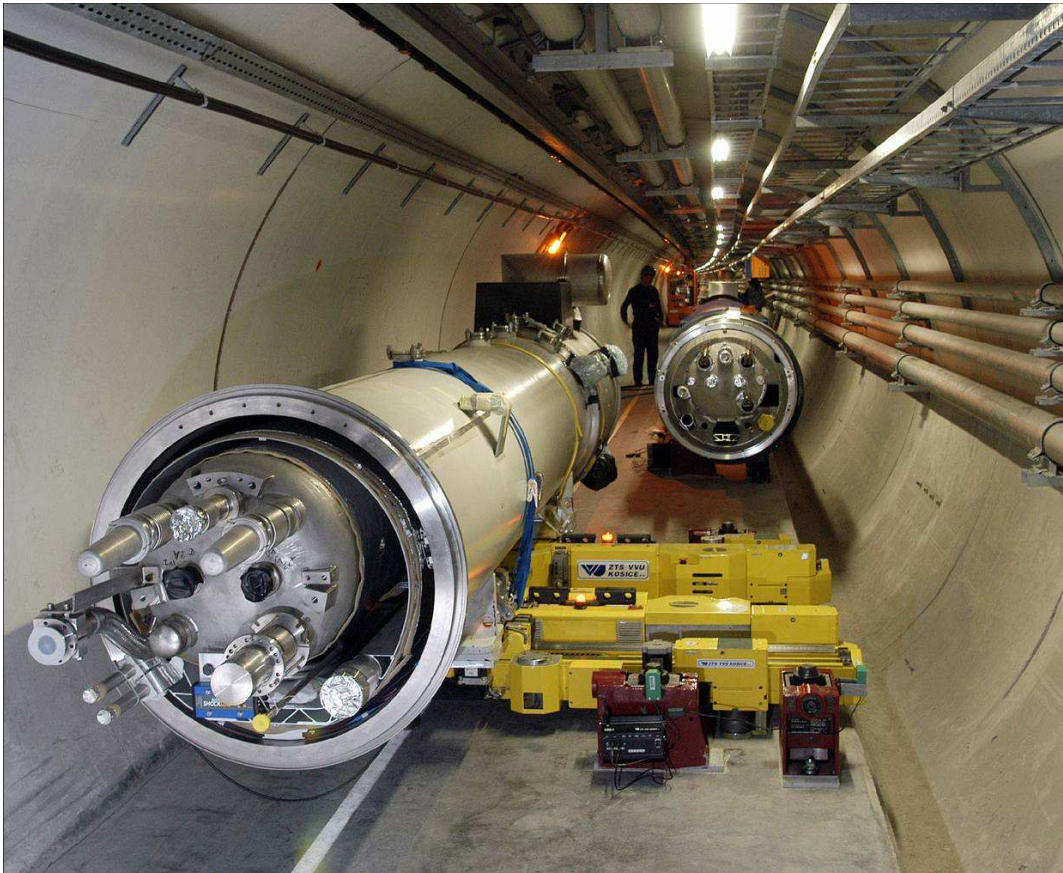
Primer criodipolo: 7 Marzo 2005







Último criodipolo: 26 Abril 2007







Interconexiones en el túnel

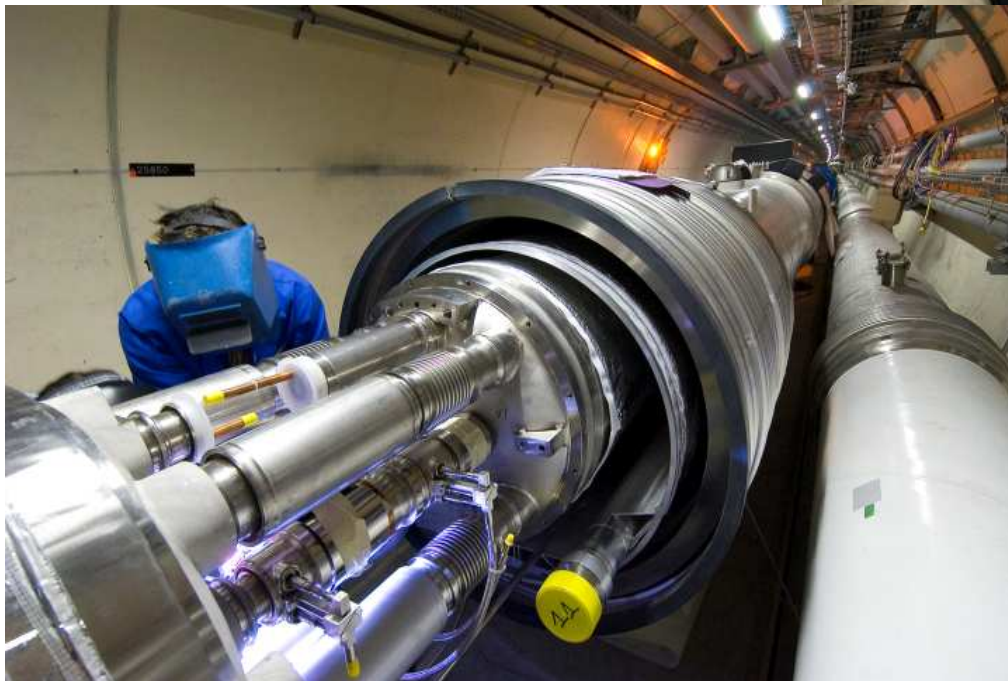
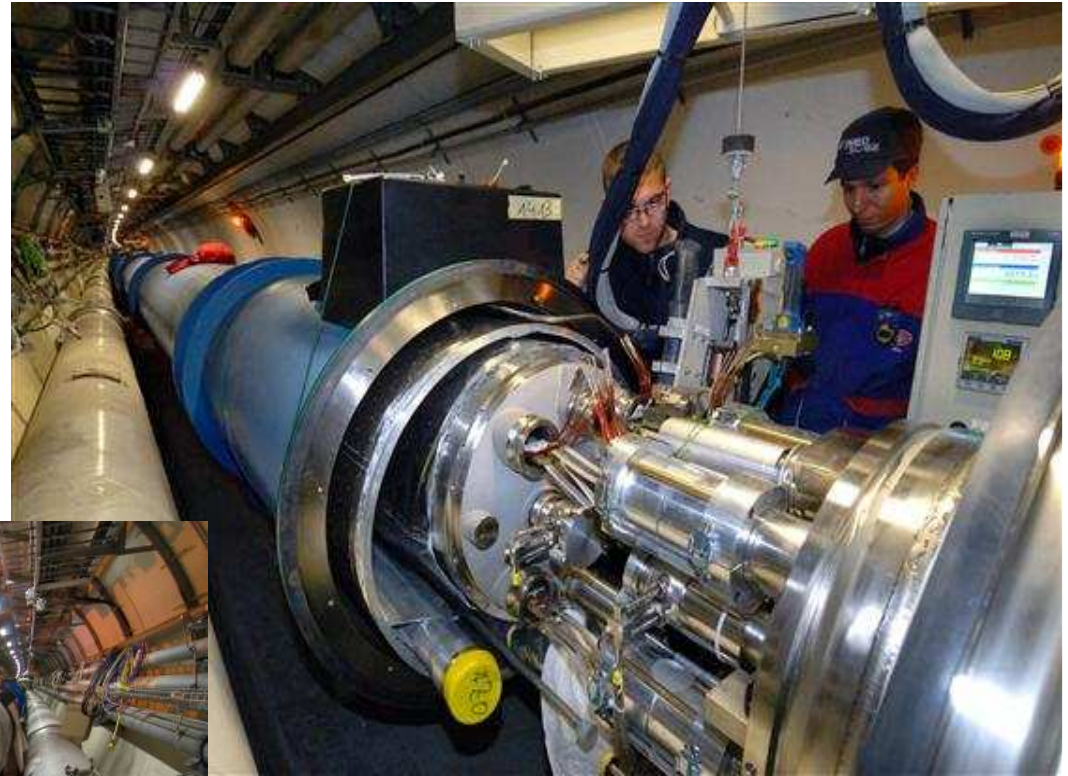
65'000 juntas eléctricas

Soldadura por inducción-térmica

Soldadura ultrasónica

Muy baja resistencia residual

Aislamiento eléctrico HV

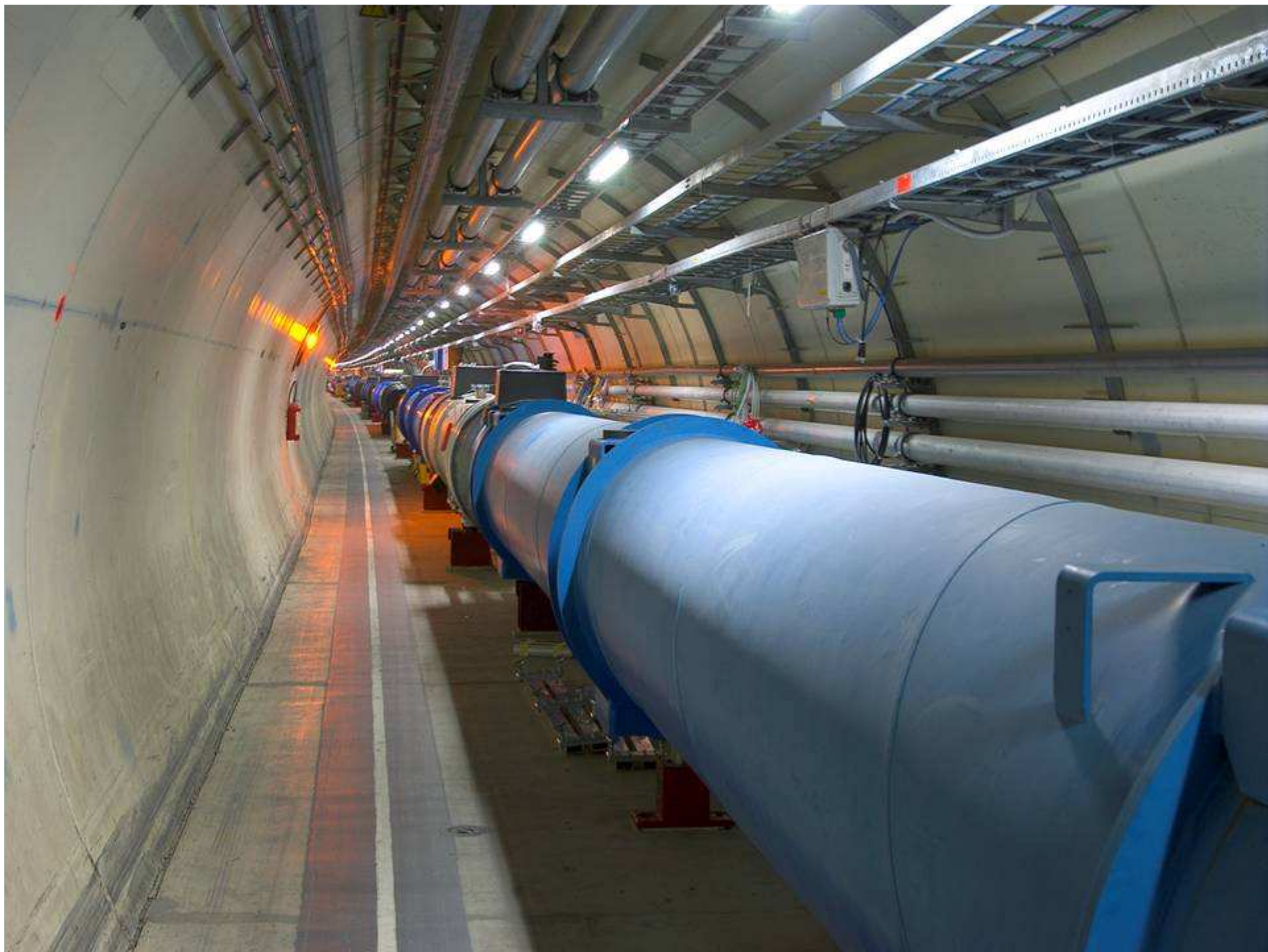


40'000 empalmes criogénicos

Soldadura orbital TIG

Calidad de soldadura

Estanqueidad fugas de Helio



Los Experimentos Large Hadron Collider

Lago Lemman

CMS

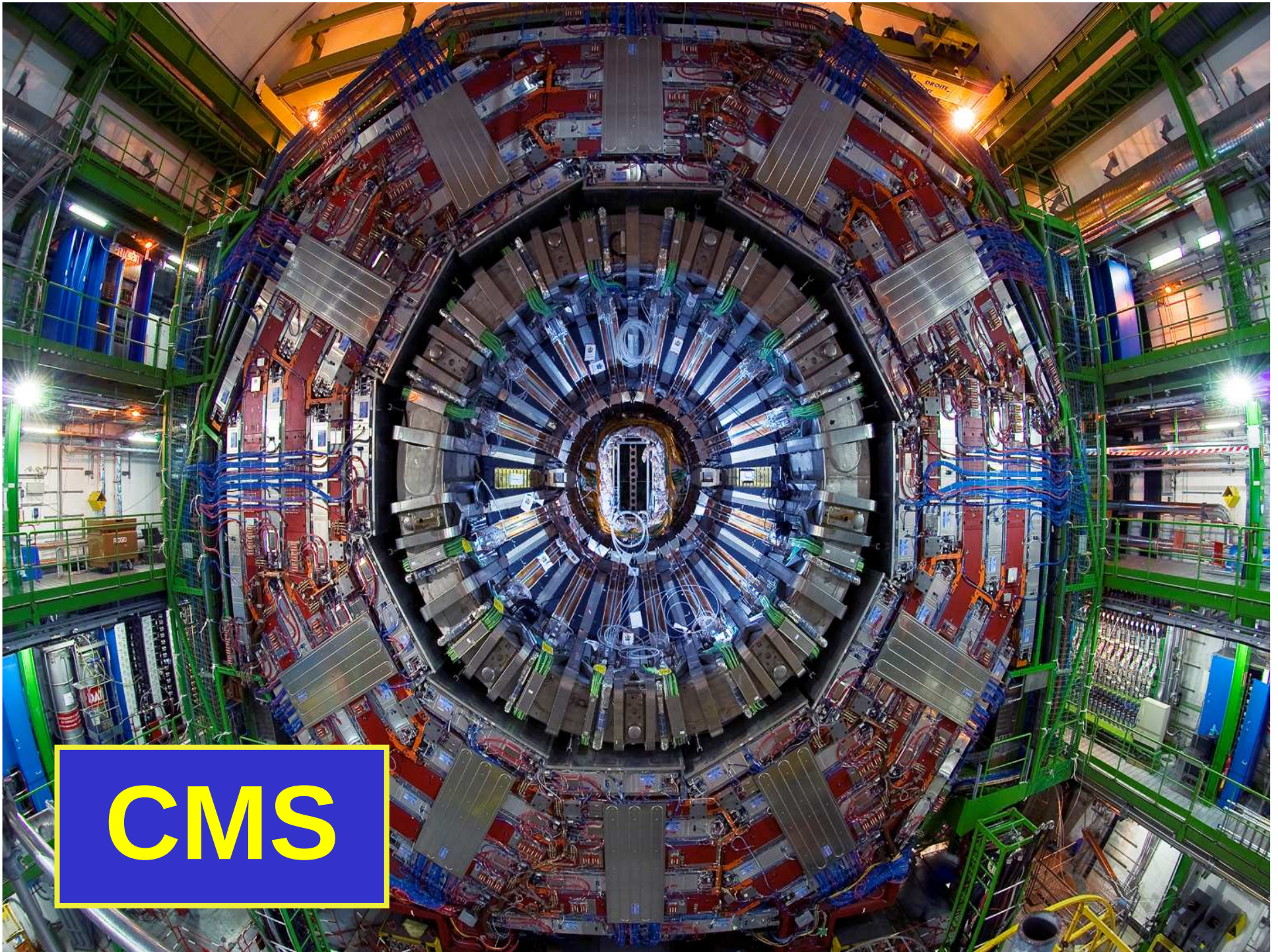
ALICE

ATLAS

LHCb





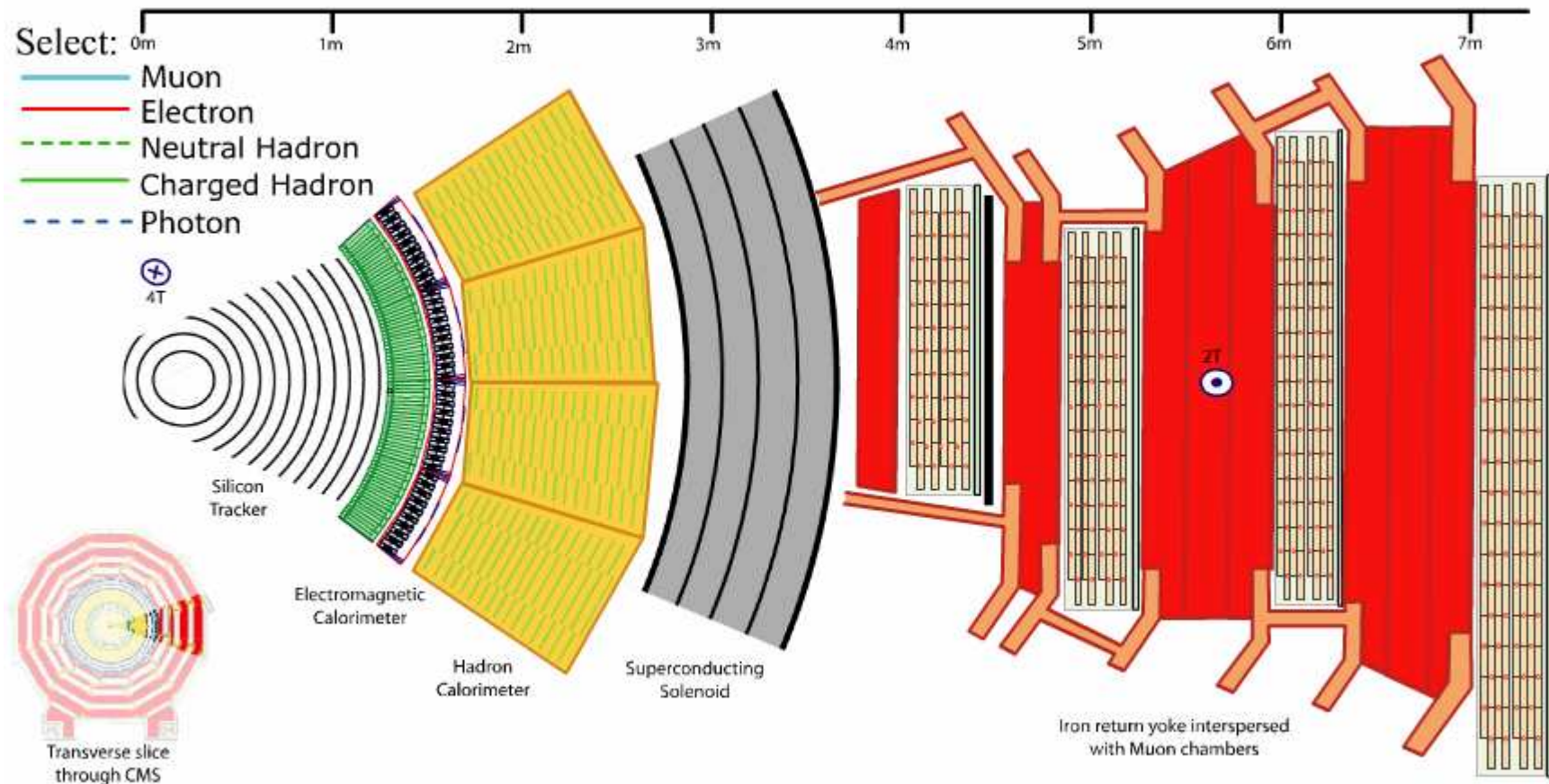


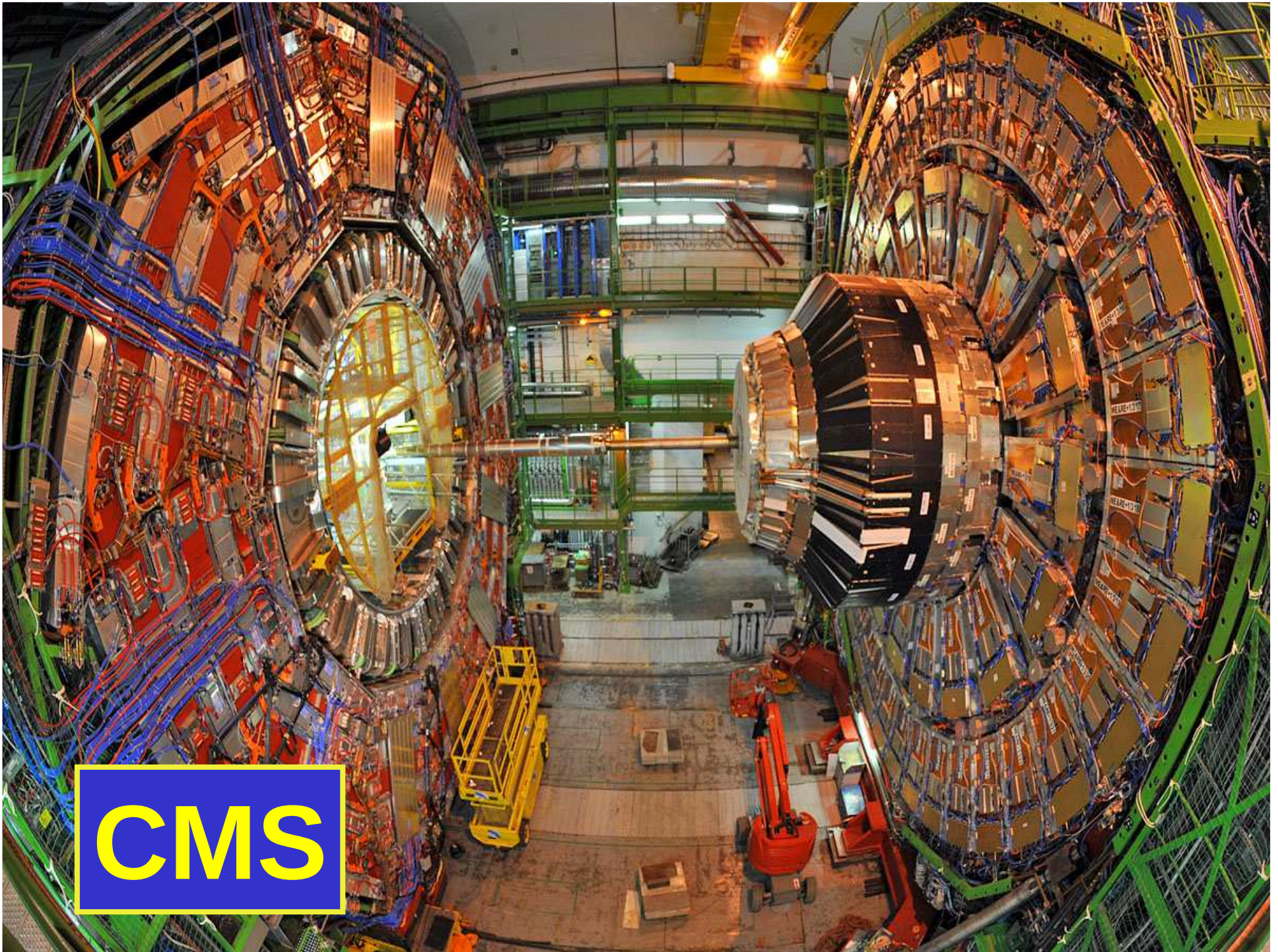
CMS

Transverse slice through CMS detector

Click on a particle type to visualise that particle in CMS

Press “escape” to exit



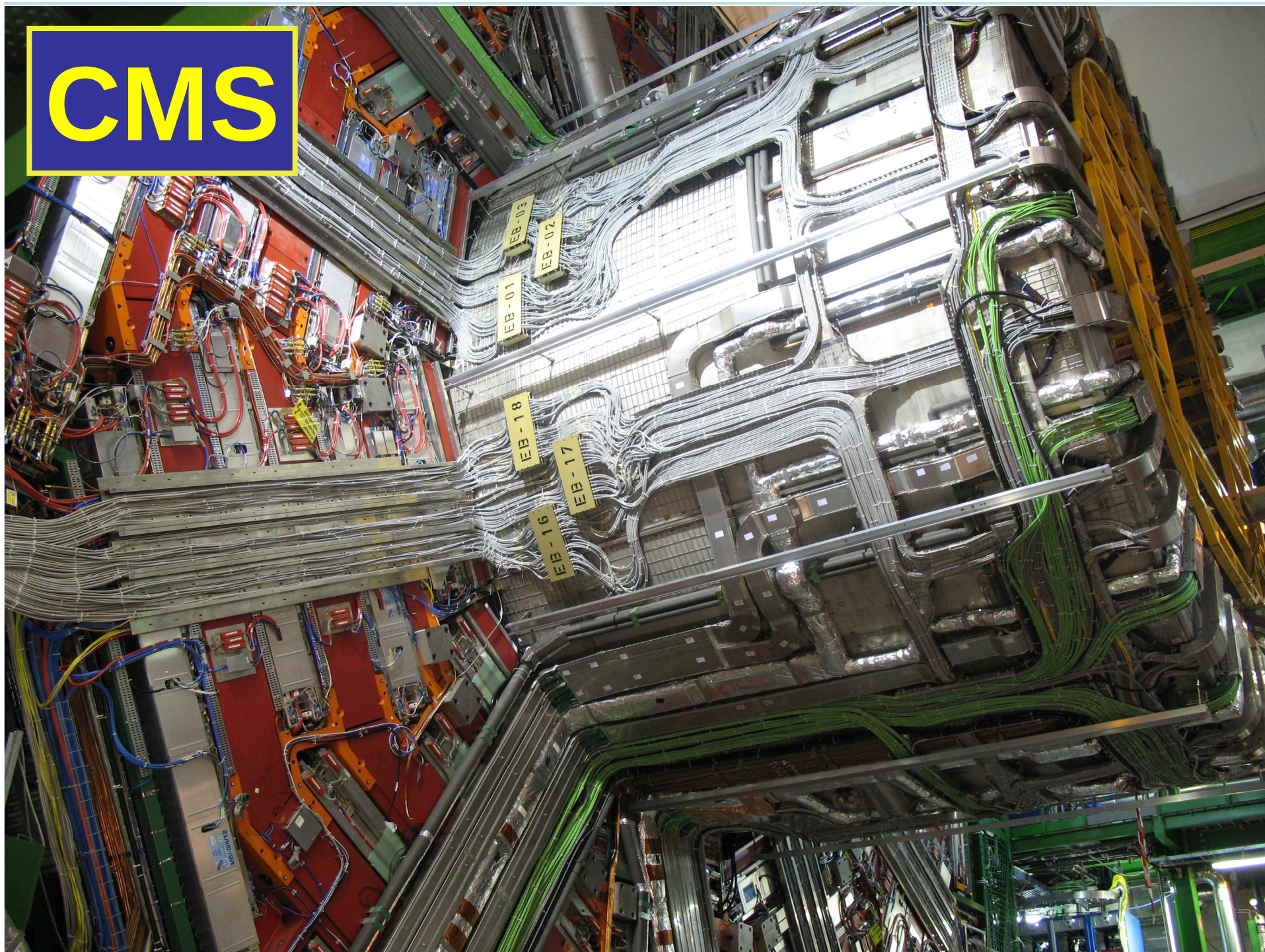


CMS

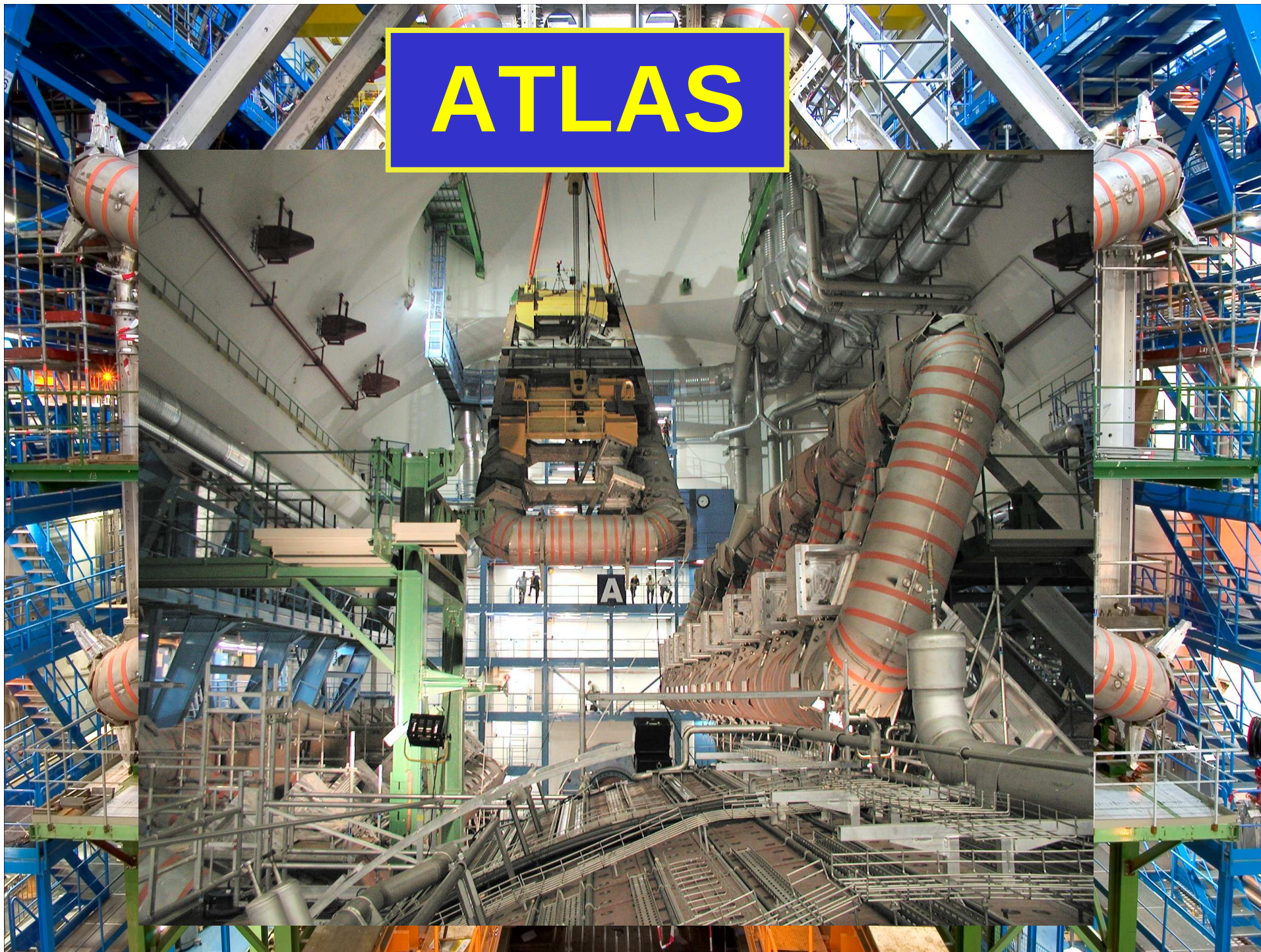
CMS

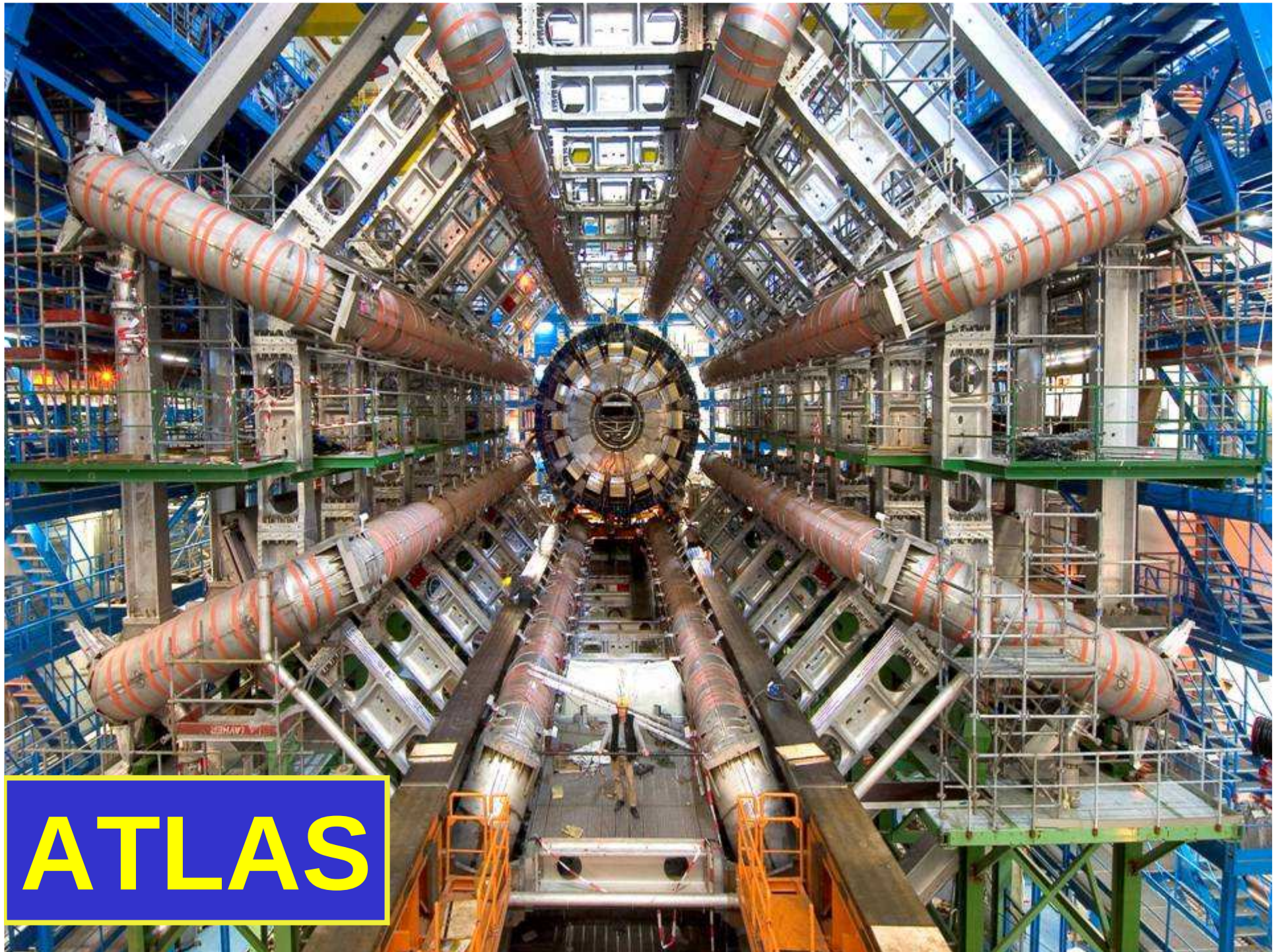


CMS



ATLAS

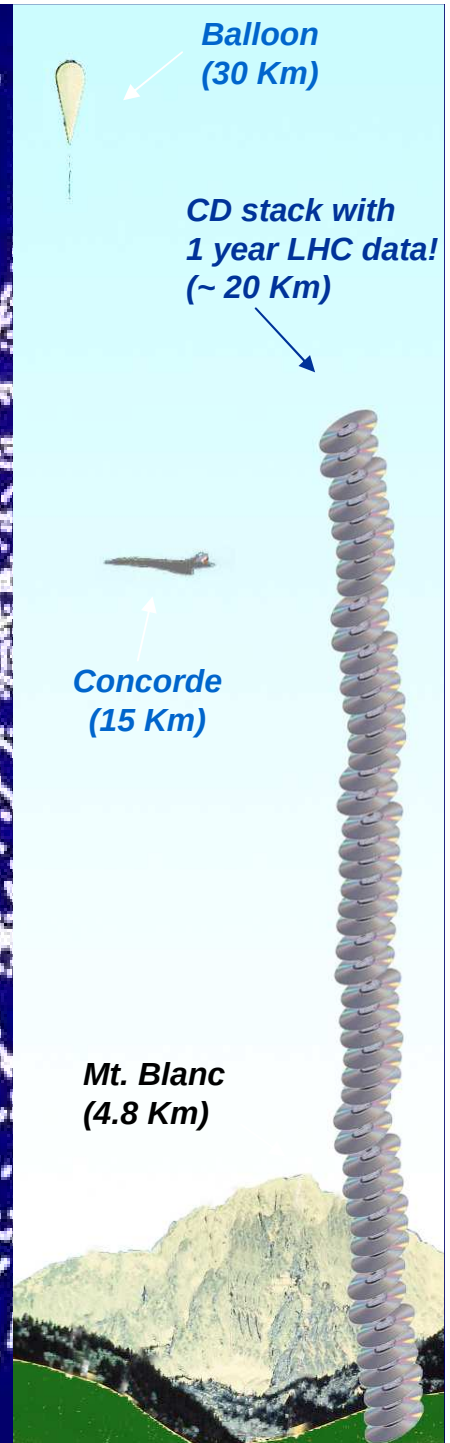
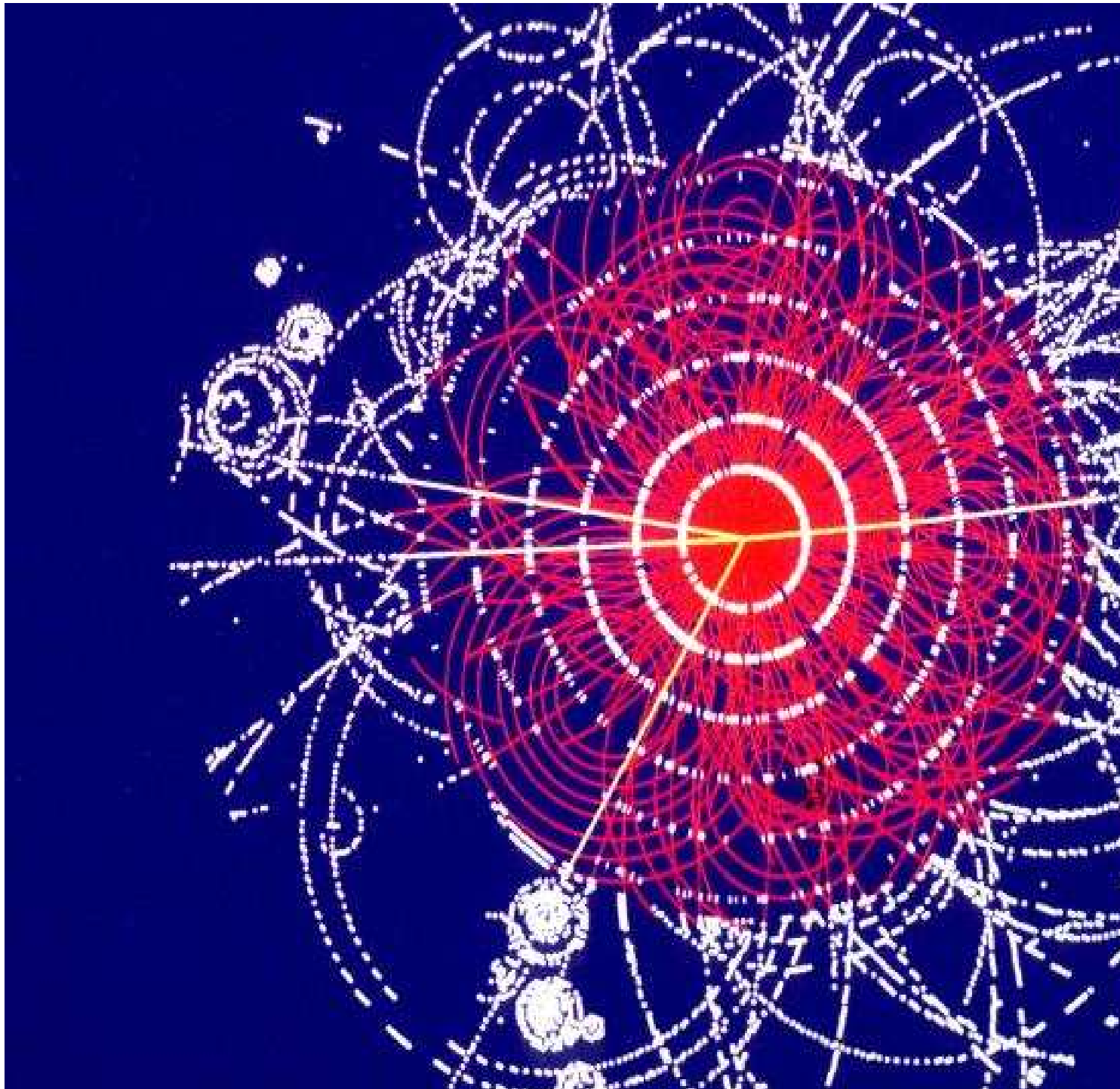




ATLAS

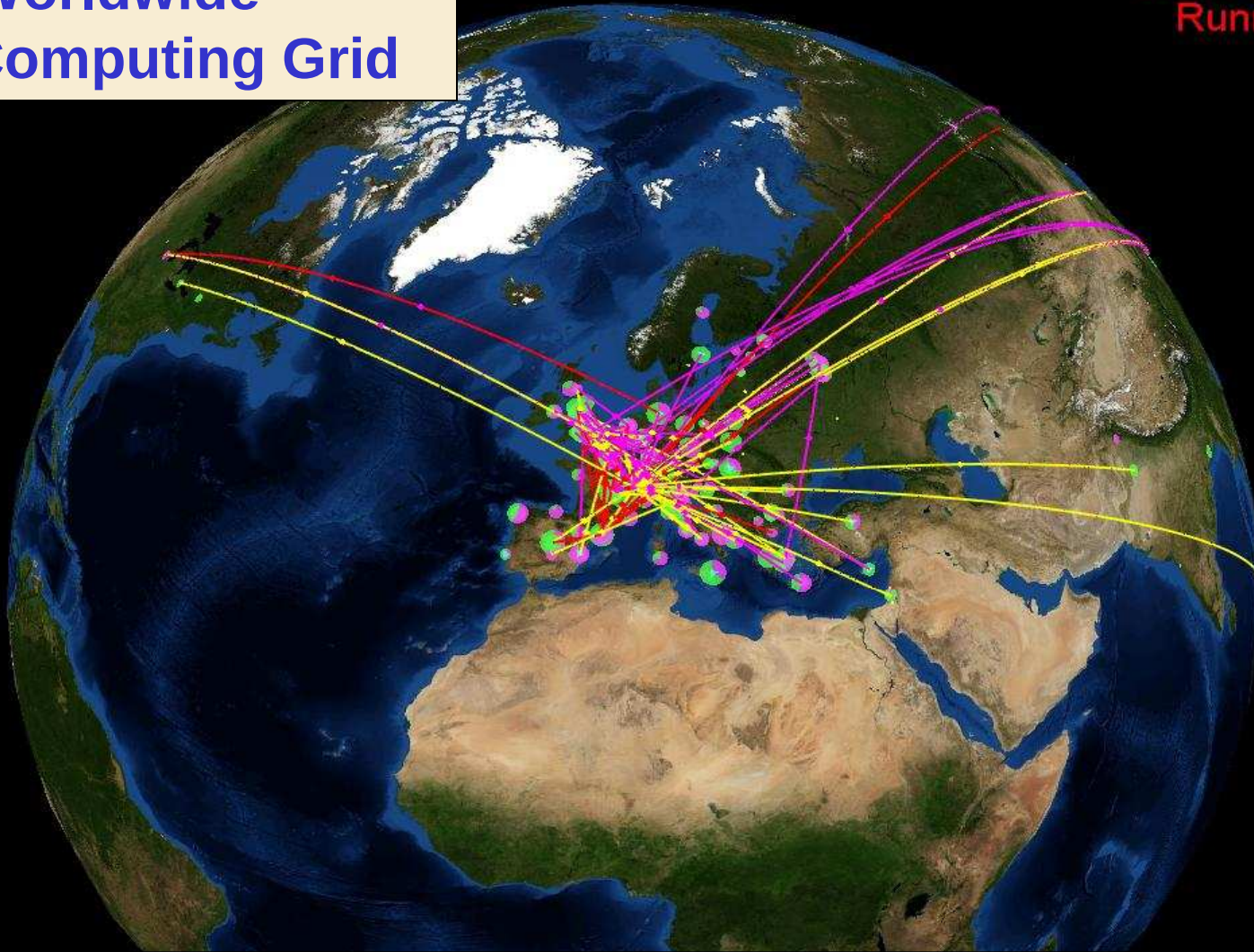
ANÁLISIS DE DATOS LHC





Worldwide LHC Computing Grid

Scheduled = 15301
Running = 10525



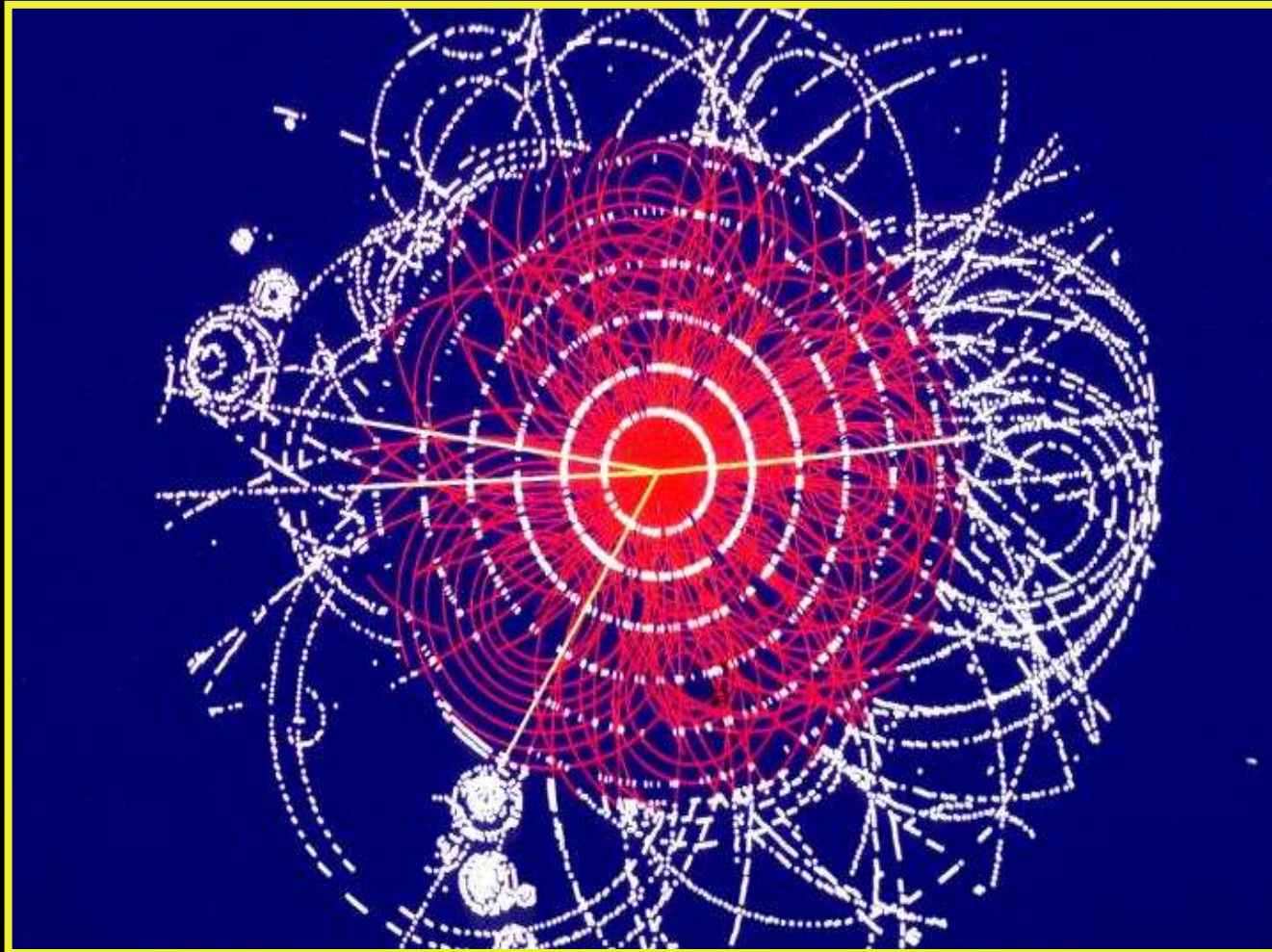
Los Experiments producirán ~15 Millones de Gigabytes de datos cada año (~ 5 millones de DVDs!)

El análisis de los datos del LHC requiere una potencia de cálculo equivalente a ~100,000 procesadores PC de última generación

An aerial photograph of a coastal region, likely in the Mediterranean, showing a mix of urban areas, agricultural fields, and a large body of water. A yellow rectangular box is superimposed on the image, containing the text 'FASCINANTE POTENCIAL CIENTÍFICO' in bold, yellow, sans-serif capital letters. The background image shows a coastline with a city, a large lake or bay, and surrounding land with various land uses including agriculture and urban development. A thin white line is also visible, possibly a road or a boundary.

**FASCINANTE
POTENCIAL
CIENTÍFICO**

BÚSQUEDA DEL BOSÓN DE HIGGS, LA PARTÍCULA DIVINA



THE GOD PARTICLE / LA PARTÍCULA DIVINA

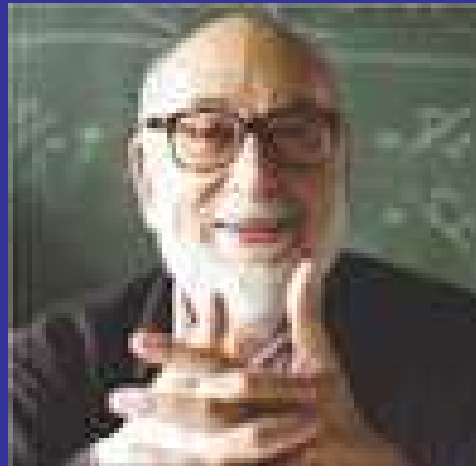


Elementary Particles				
Leptons	Quarks			Force Carriers
	u up	c charm	t top	γ photon
	d down	s strange	b bottom	g gluon
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	W W boson
	I	II	III	
Three Families of Matter				

LEON LEDERMAN, PREMIO NOBEL DE FÍSICA 1988



ROBERT BROUT



FRANÇOIS ENGLERT



PETER HIGGS

BÚSQUEDAS DEL BOSÓN DE HIGGS

Indirecta:

- Medidas de alta precisión en LEP, Tevatrón
- $m_H = 91^{+47}_{-31} \text{ GeV}$
- Límite superior a la masa del Bosón de Higgs:

$$m_H < 219 \text{ GeV}$$

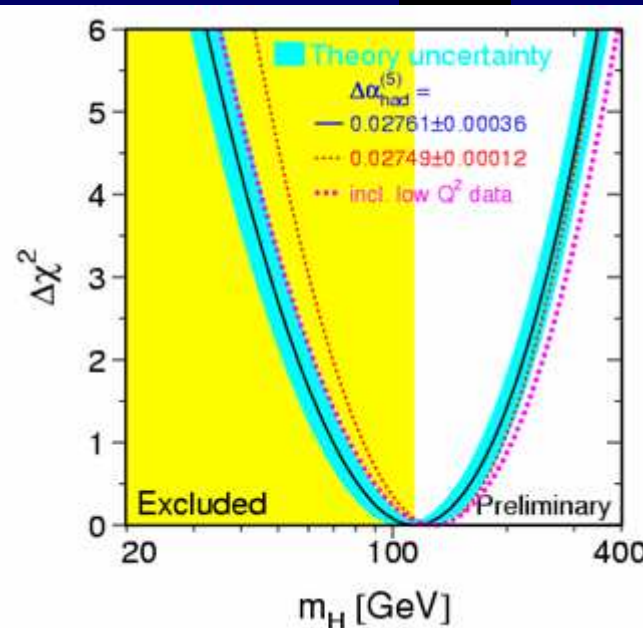


Directa:

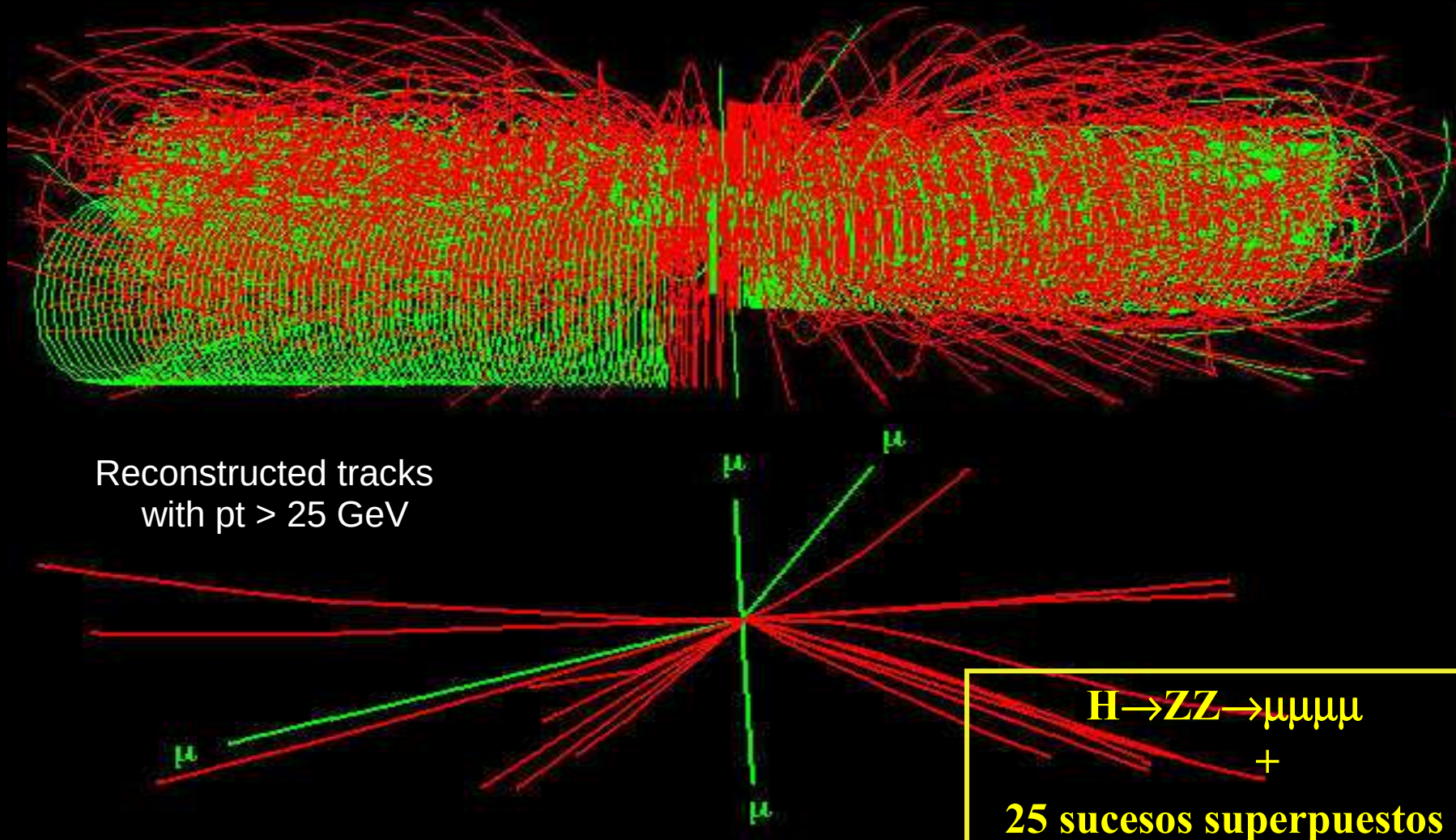
- LEP buscó sucesos $e^+ e^- \rightarrow Z + H$
- La 'señal' encontrada en el 2000 parece ahora insignificante

El límite actual:

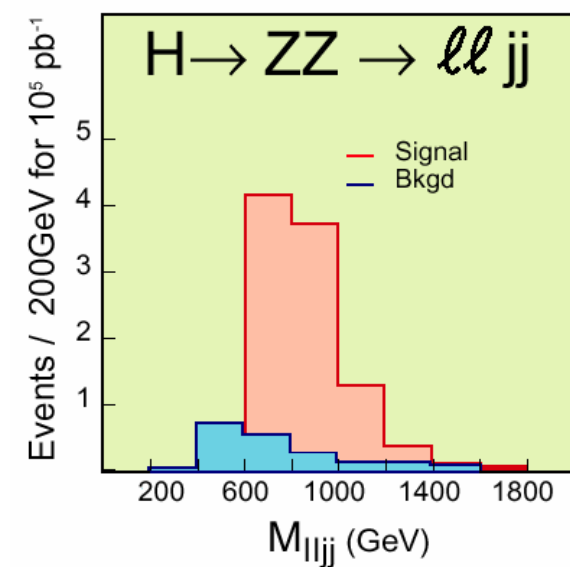
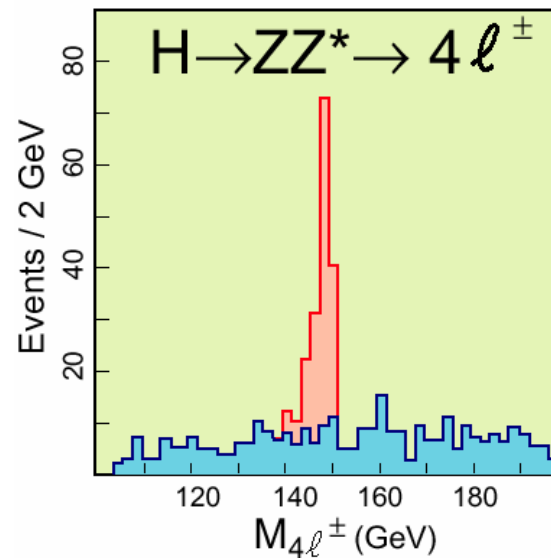
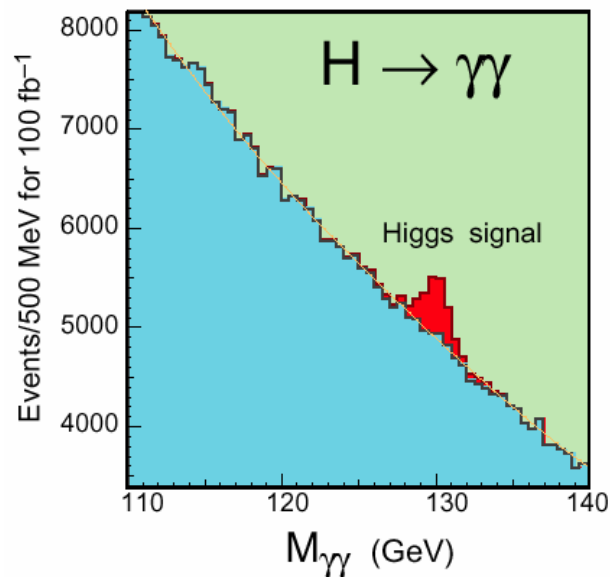
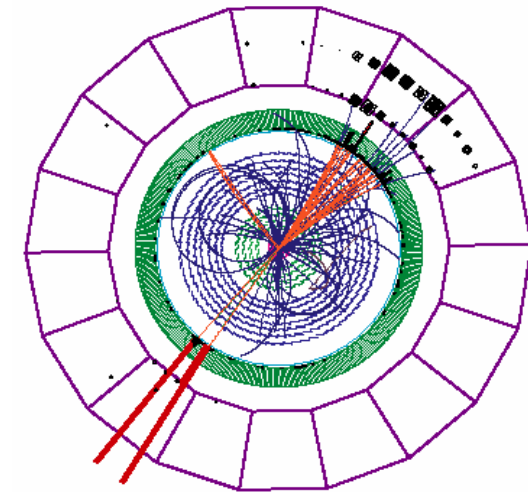
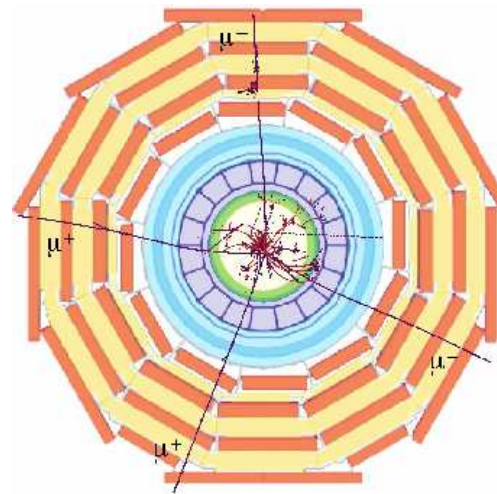
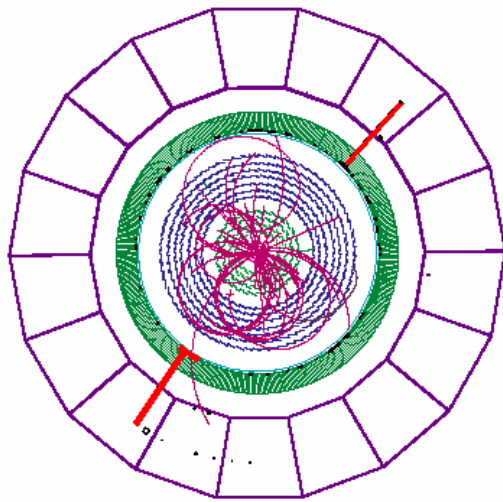
$$m_H > 114.4 \text{ GeV}$$



1 BOSÓN DE HIGGS / 10.000.000.000.000 INTERACCIONES



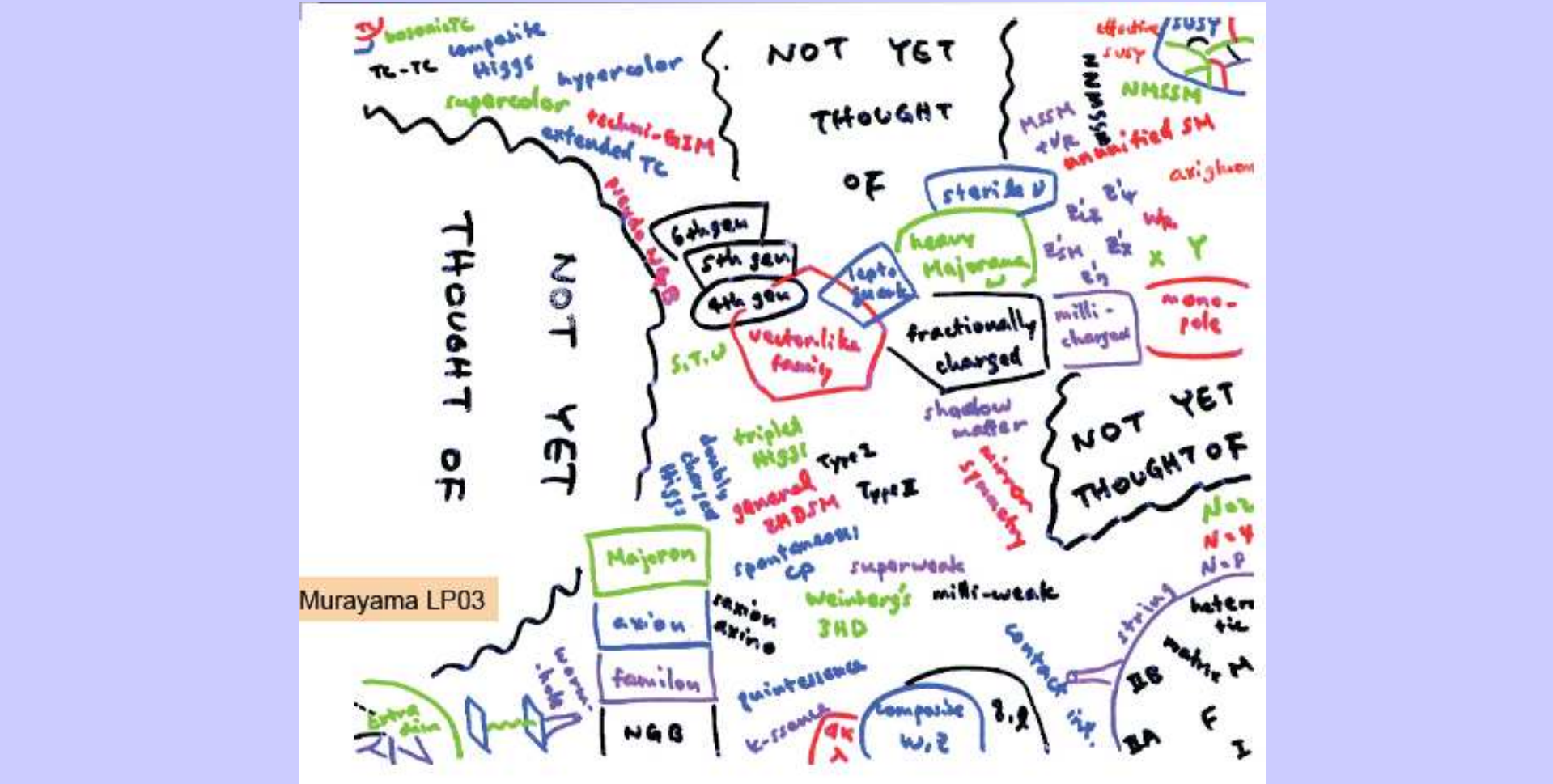
Búsqueda del Bosón de Higgs del SM





2008: Primer Higgs observado en CMS & ATLAS

MÁS ALLÁ DEL MODELO ESTÁNDAR...



TEORÍA + EXPERIMENTOS

A Cellar of New Ideas

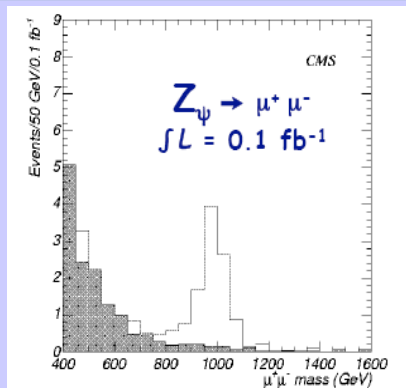
J. Hewett
LISHEP09

'67	The Standard Model	a classic! aged to perfection
'77	Vin de Technicolor	better drink now
'70's	Supersymmetry: MSSM	mature, balanced, well developed – the Wino's choice
'90's	SUSY Beyond MSSM	svinters blend
'90's	CP Violating Higgs	all upfront, no finish lacks symmetry
'98	Extra Dimensions	bold, peppery, spicy uncertain terror
'02	Little Higgs	complex structure
'03	Fat Higgs	young, still tannic needs to develop
'03	Higgsless	sleeper of the vintage what a surprise!
'04	Split Supersymmetry	finely-tuned
'05	Twin Higgs	double the taste

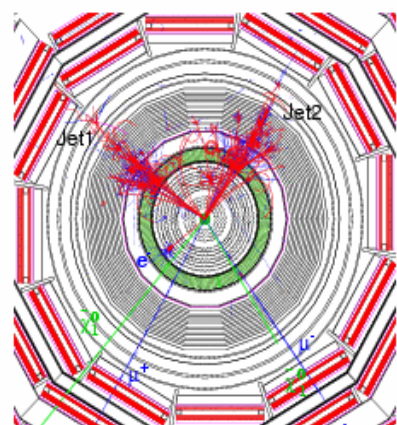
J. Hewett

Más Allá del Modelo Estándar

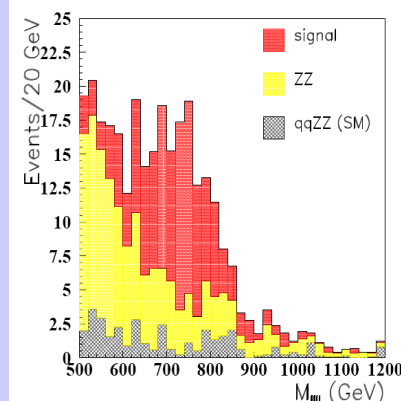
¿ Nuevos Bosones Gauge ?



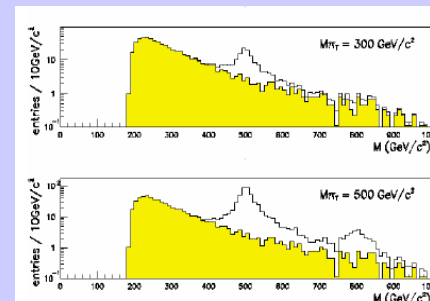
¿ Supersimetría ?



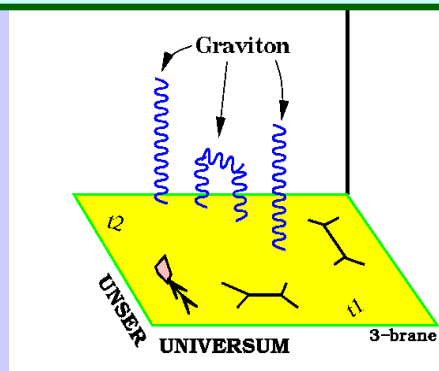
¿ Resonancias ZZ/WW ?



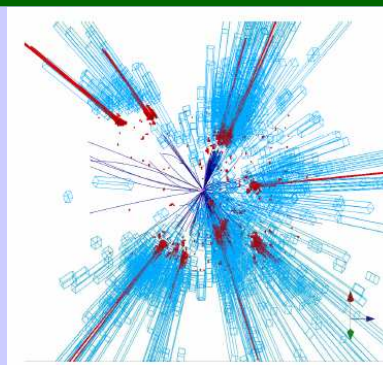
¿ Tecnicolor ?



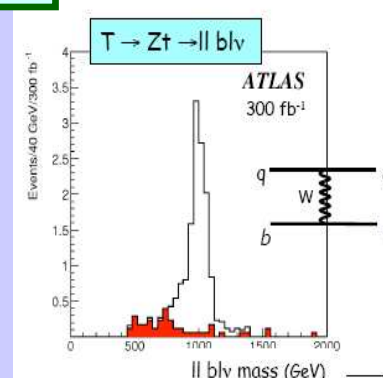
¿ Dimensiones Extra ?



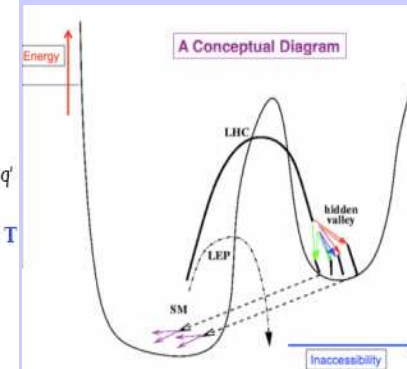
¿ A agujeros Negros ??



¿ Pequeño Higgs ?

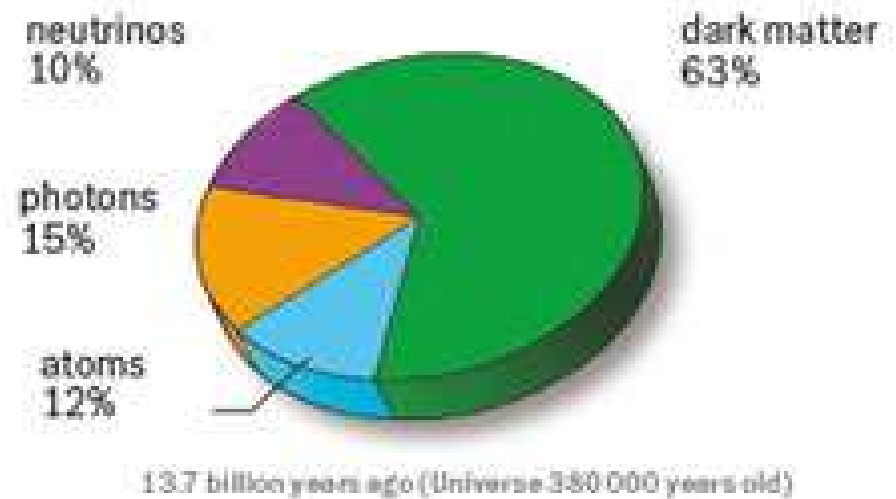
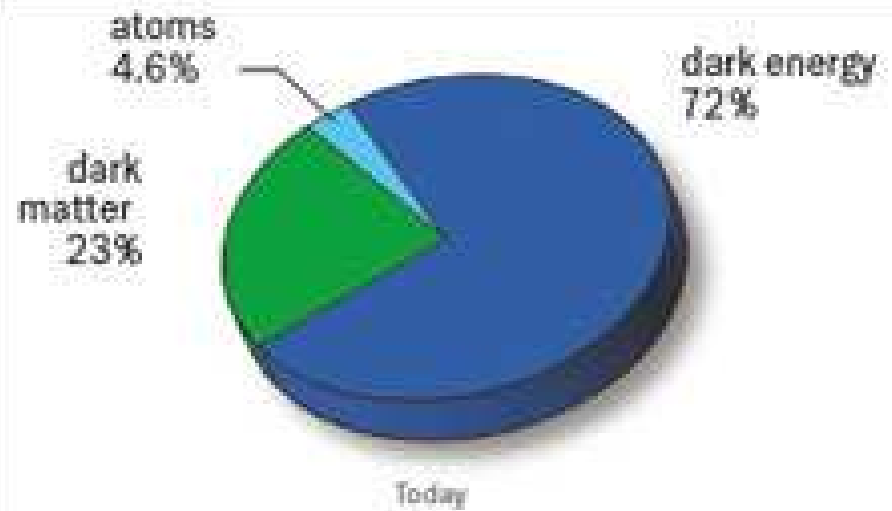
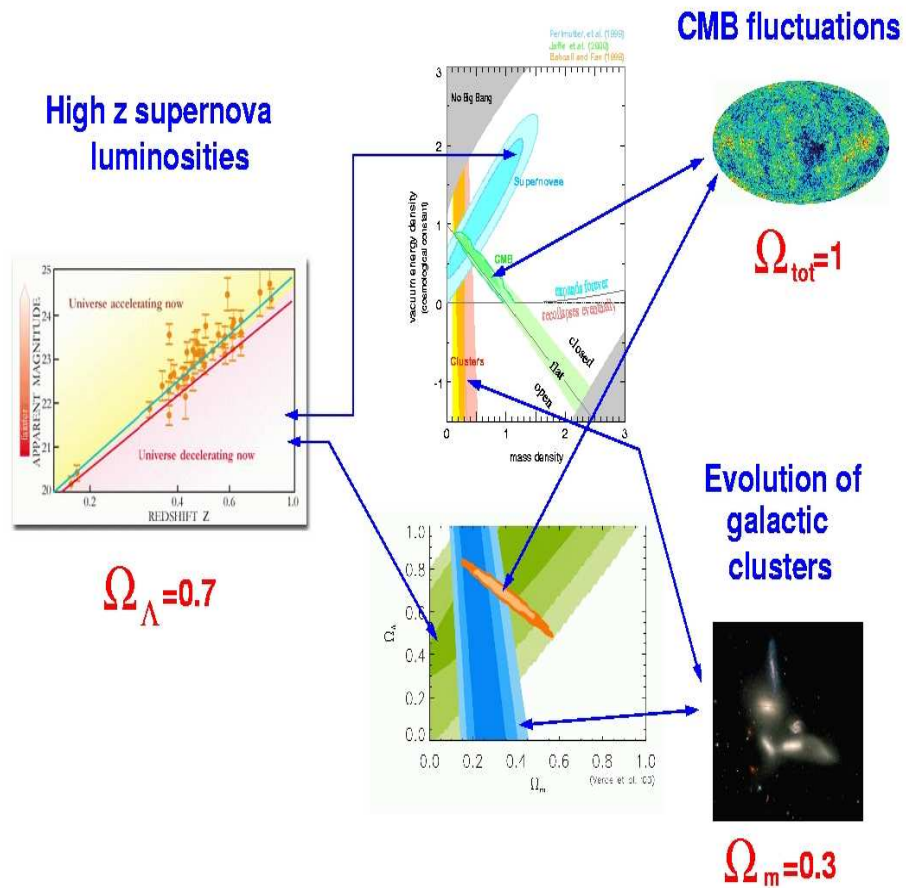


¿ Valles Escondidos ?



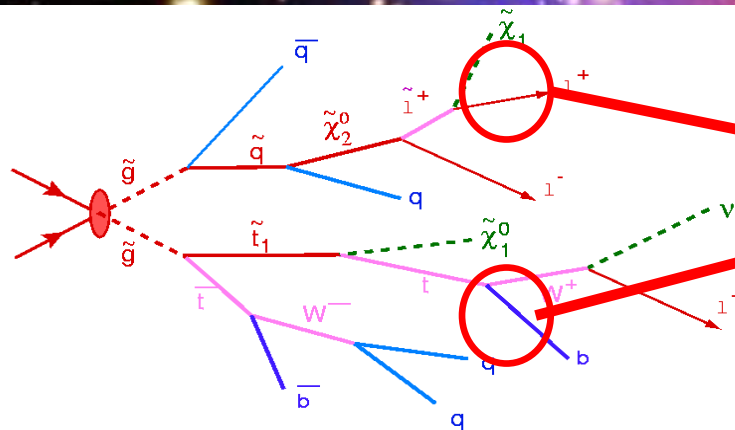
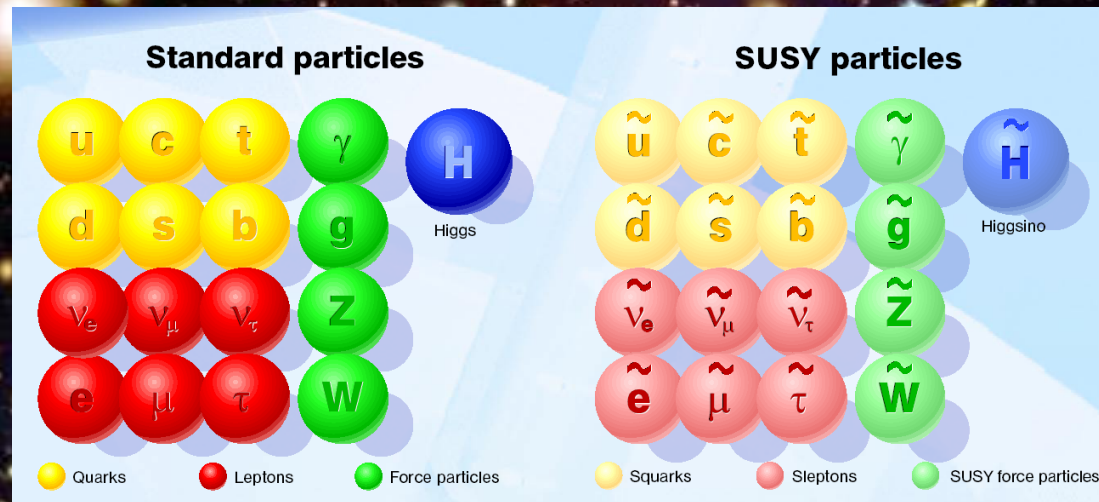
No sabemos lo que nos espera ... Una gran variedad de posibles señales.
¡ Hay que estar preparados !!

**BÚSQUEDA DE CANDIDATOS DE
MATERIA OSCURA**



WMAP 5—YEAR

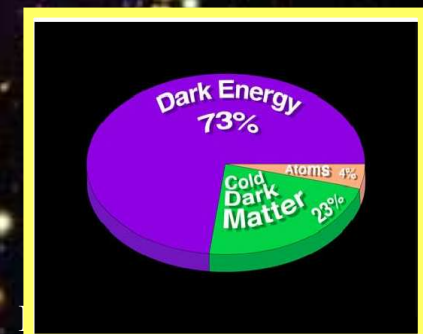
Supersimetría: Una Nueva Simetría en la Naturaleza



3 isolated leptons
+ 2 b-jets
+ 4 jets
+ E_t^{miss}

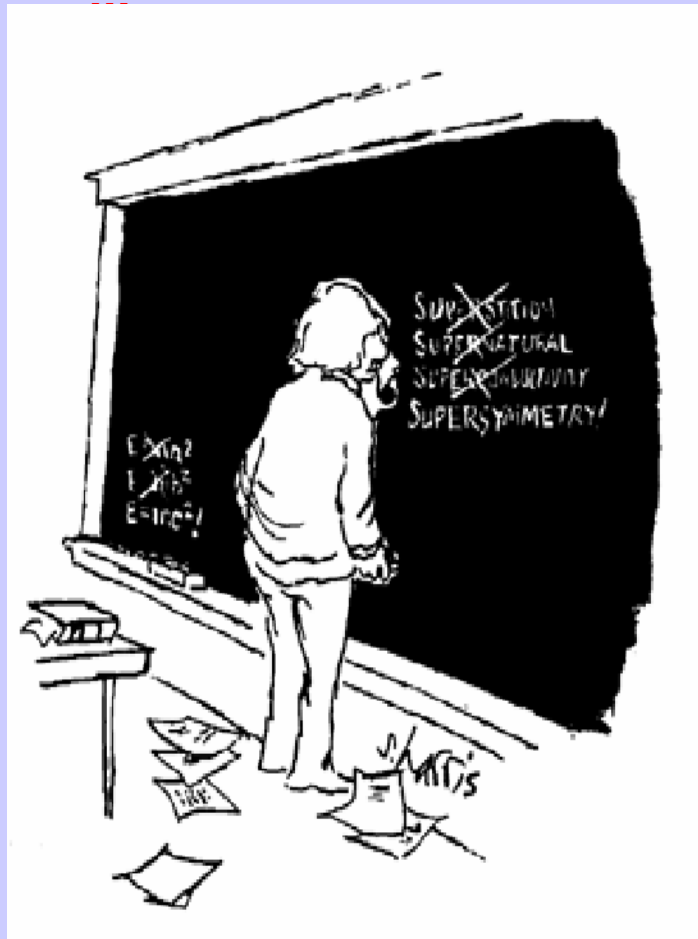
**Producción de partículas
SUSY en el LHC**

Partículas Candidatas de Materia Oscura
⇒ **Producción de Materia Oscura en el Laboratorio**



SUPERSIMETRÍA

Un banco de pruebas MUY popular



Más de 7000 artículos desde 1990 (Kosower)



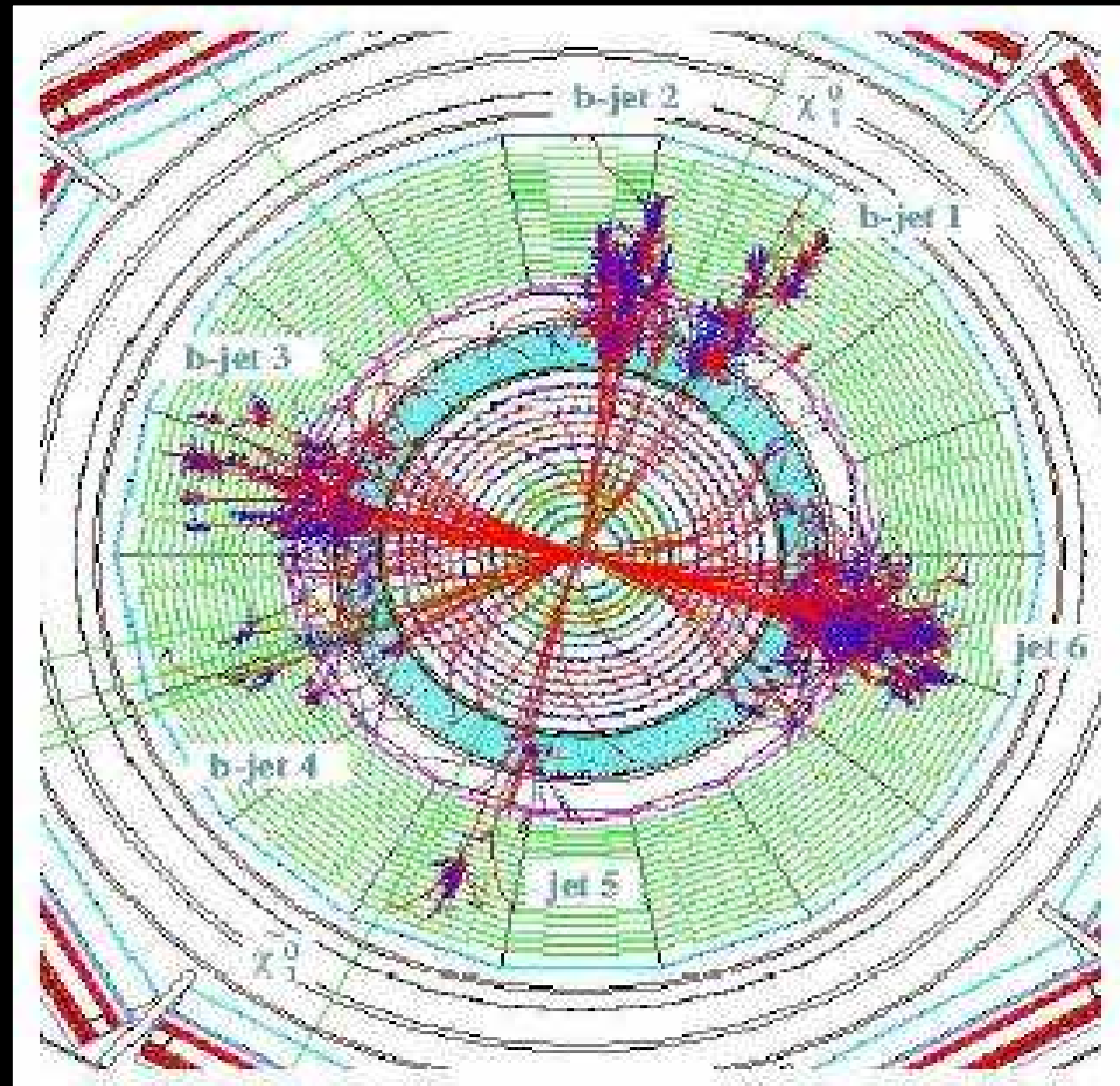
“Un día todos estos árboles serán artículos fenomenológicos SUSY”

Banco de pruebas para una amplia clase de Modelos de Nueva Física

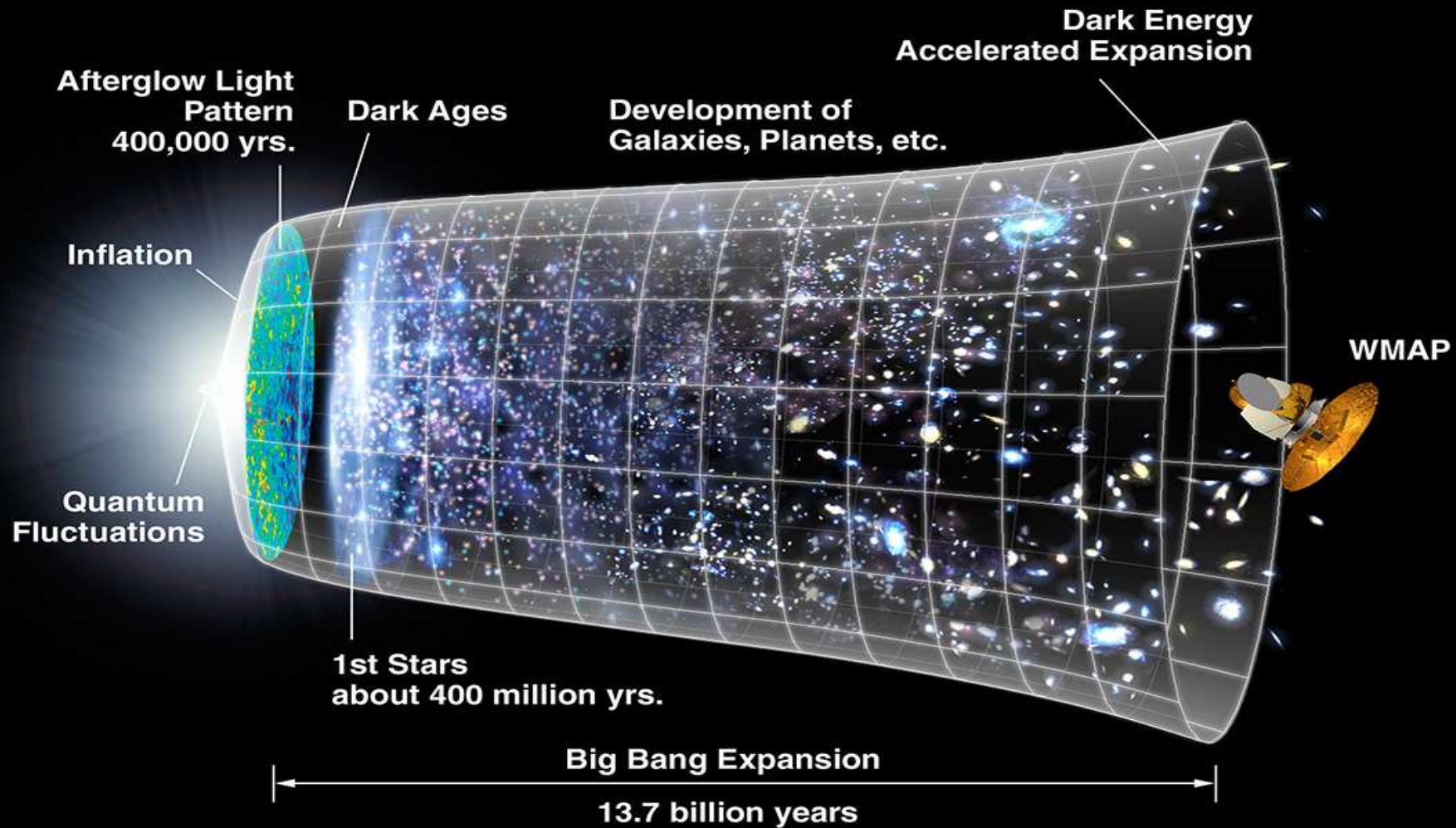
Búsqueda de Supersimetría

Un suceso 'típico'
supersimétrico
en el LHC

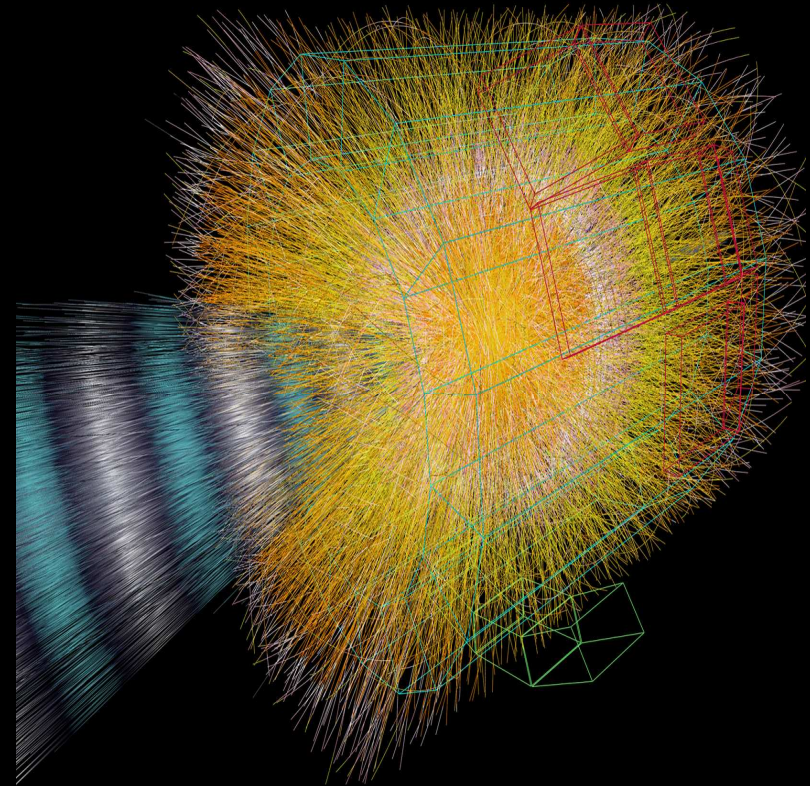
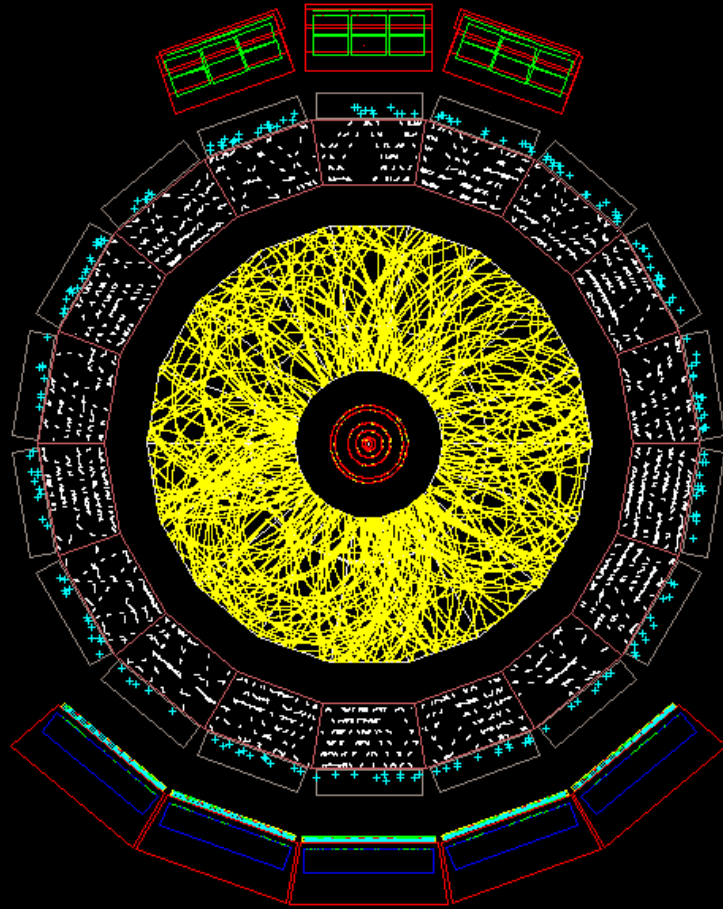
El LHC podría
validar la mayoría
de los modelos
supersimétricos
de la materia oscura



MATERIA vs ANTIMATERIA

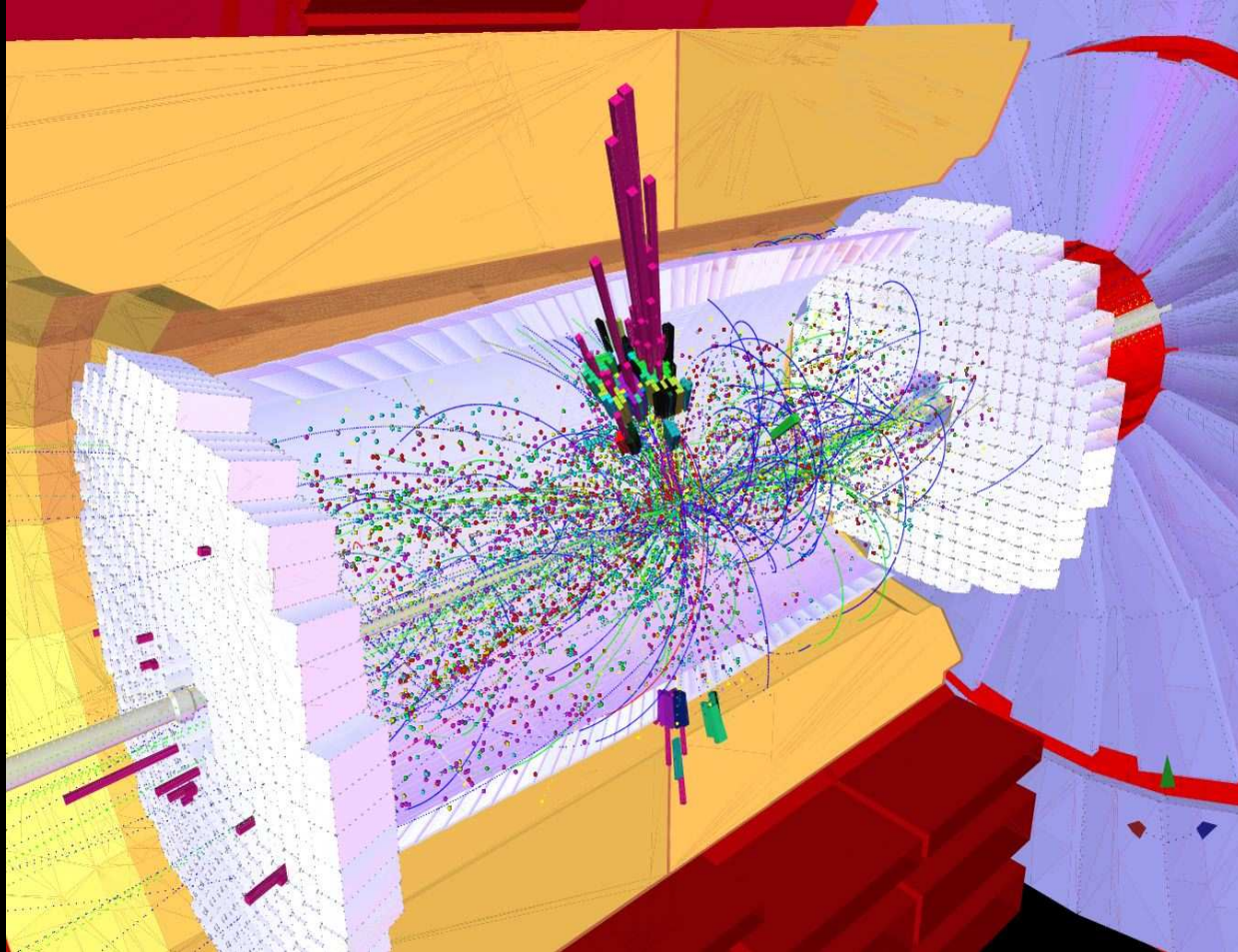


EL PLASMADE QUARKS Y GLUONES

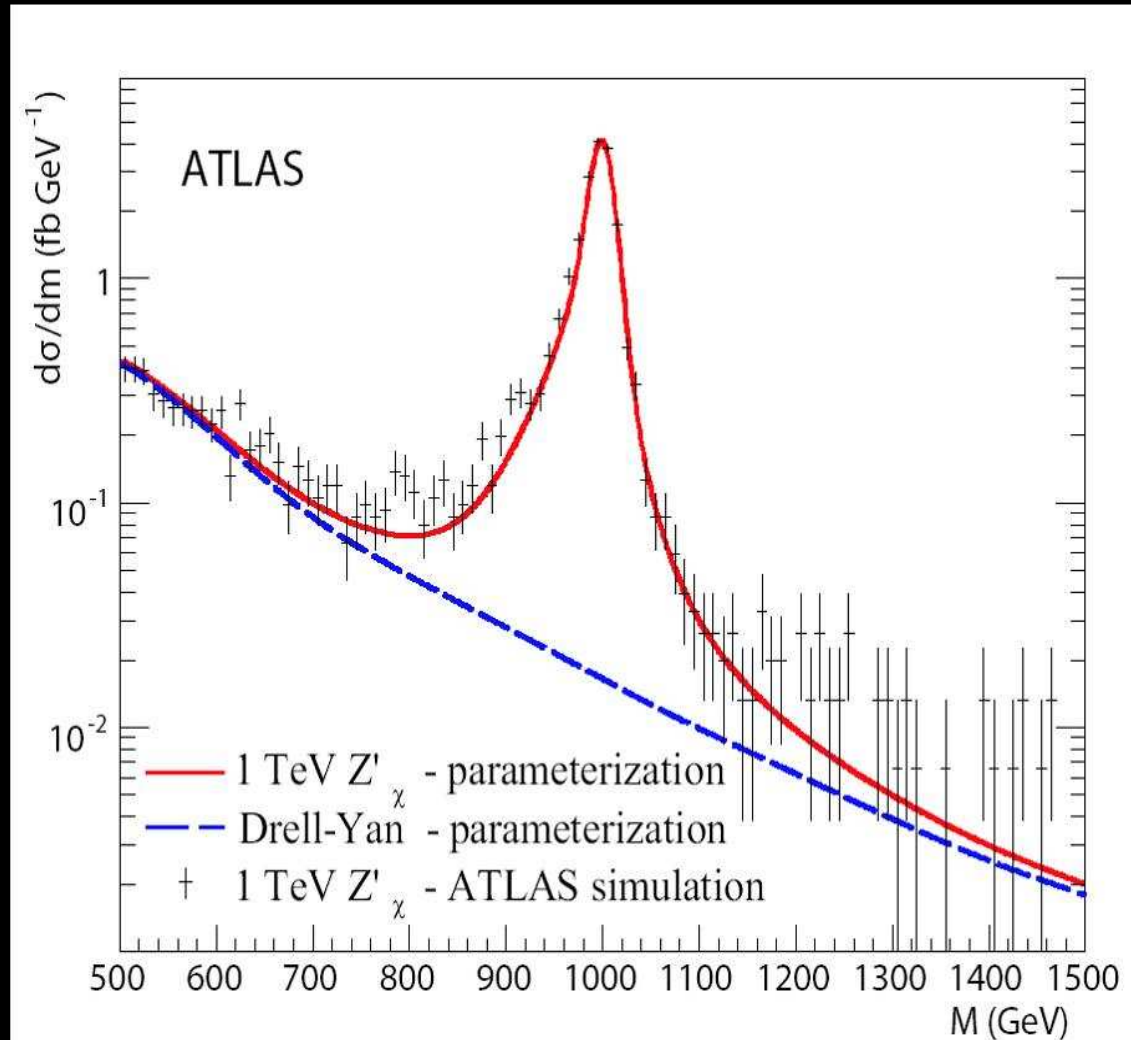


COLISIONES DE IONES PESADOS EN ALICE

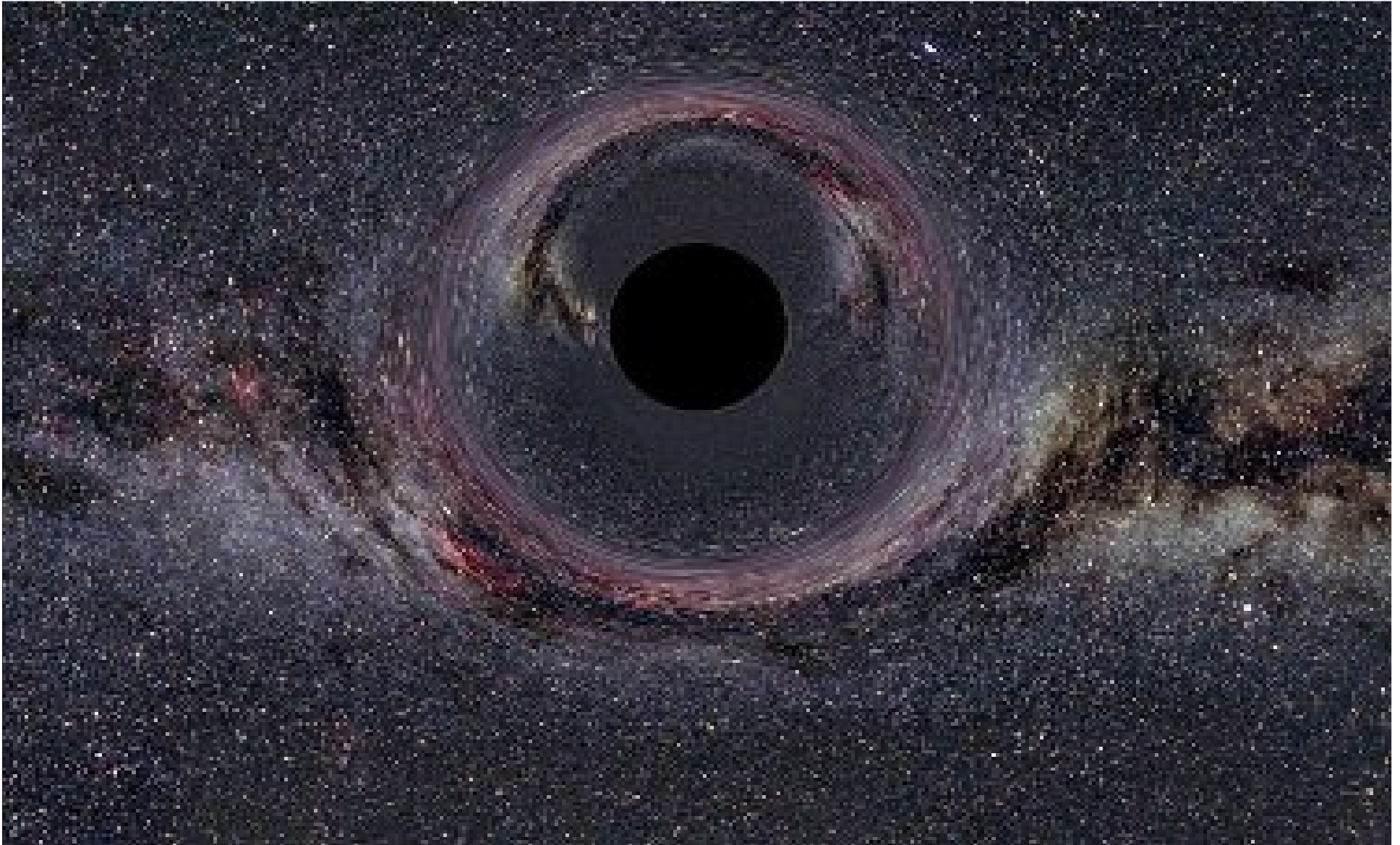
DIMENSIONES ESPACIALES EXTRA



NUEVOS BOSONES GAUGE (Z')



AGUJEROS NEGROS CUÁNTICOS





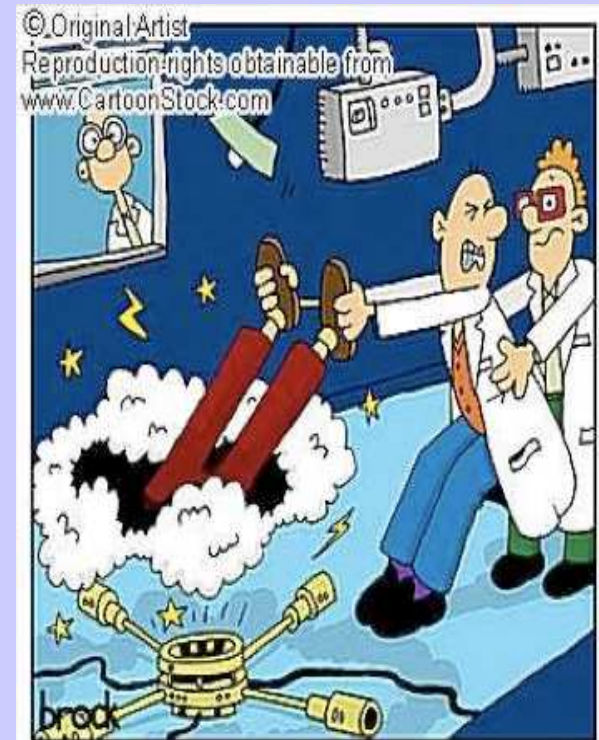
Buscadores de Agujeros Negros en el CERN

Agujeros Negros Cuánticos

- ¿ Puede el LHC producir “agujeros negros” cuánticos ?

¡ SÍ, puede !
(pero es poco probable)

- ¿ Puede el LHC destruir el planeta ?
¡ NO !



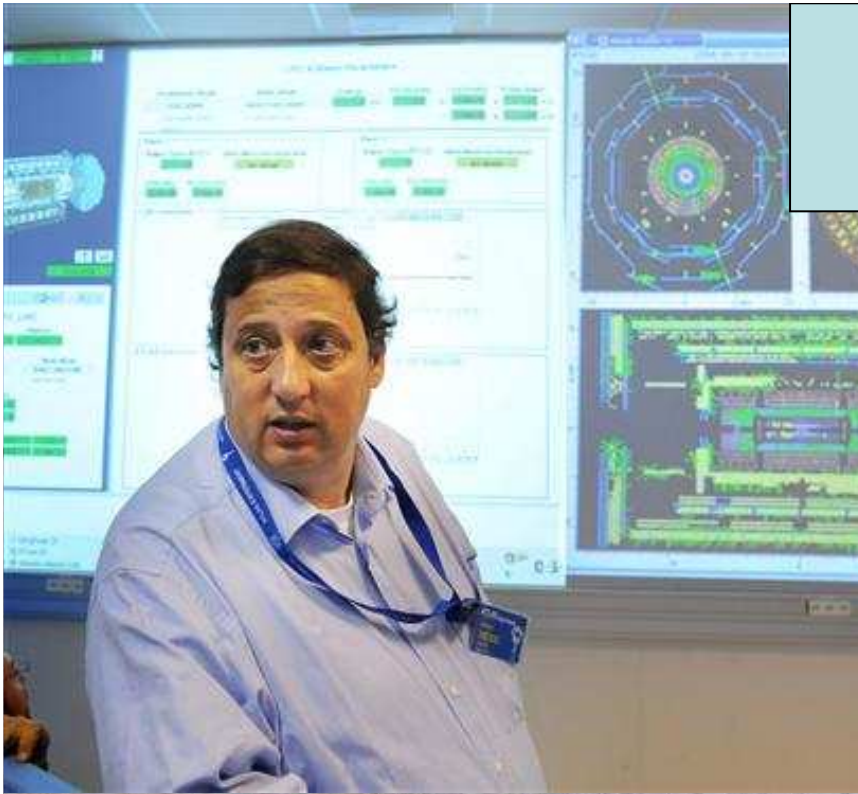
Professor Landsberg was fast regretting becoming the first man to successfully create a mini black hole in the laboratory.



10/09/2008



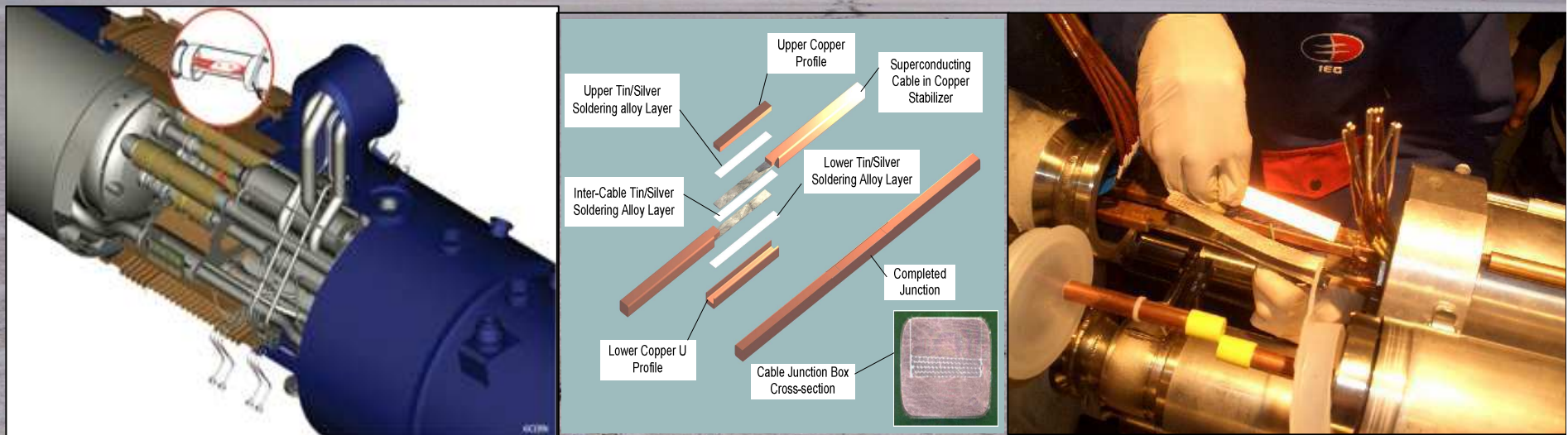
ii Funciona !!



**El LHC se
incorpora a
la cultura
popular**



Parada Temporal de las Operaciones, 19/09/2009



- **Fallo eléctrico en la conexión entre dos imanes**
- **Empalme en las barras superconductoras 12 kA**
- **Calentamiento ohmico perfora criostato, tubo de vacio**

Daños colaterales

**Desplazamientos
de imanes**

Soportes





**Retirada de un imán
del túnel**



**Reparación de
imanes en SMI2**

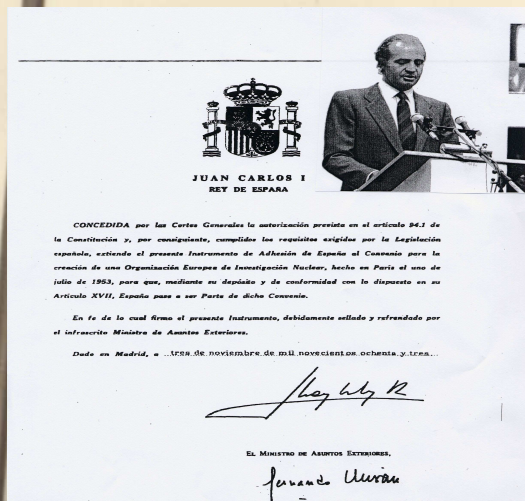


EXPECTATIVAS

- **Esperar 2 o 3 años para validar (excluir) el mecanismo de Higgs**
- **Difícil predecir cuando aparecerán señales de física más allá del Modelo Estándar**

LA FÍSICA DE PARTÍCULAS ELEMENTALES EN ESPAÑA





**1983: RETORNO DE ESPAÑA AL CERN
TRAS 14 AÑOS DE AUSENCIA**

FÍSICA EXPERIMENTAL ALTAS ENERGÍAS / 1983

Santander

Madrid
(CIEMAT)

Valencia
(IFIC)

PLAN MOVILIZADOR DE LA FÍSICA
DE ALTAS ENERGÍAS



FÍSICA EXPERIMENTAL ALTAS ENERGÍAS / 2009

Santiago

Oviedo

Santander
(IFCA)

Canfranc

Zaragoza

Barcelona
(IFAE, UAB,
UB, CSIC)

Madrid
(CIEMAT, UAM,
UCM, CSIC)

Valencia
(IFIC, UV, UPV)

Sevilla

Granada

Huelva

CERN, 1984

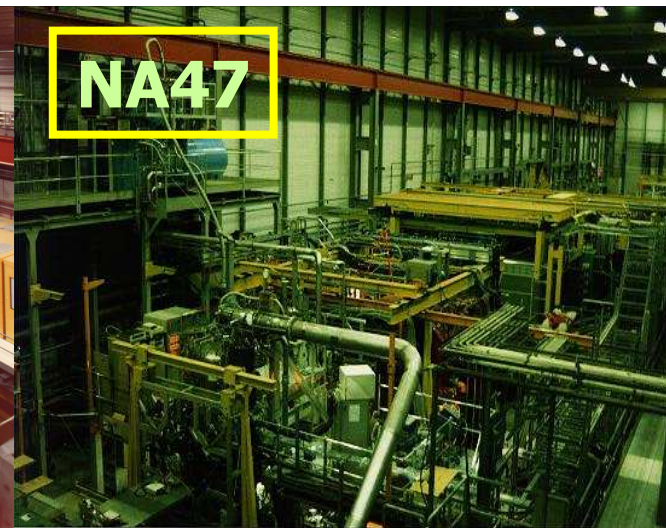
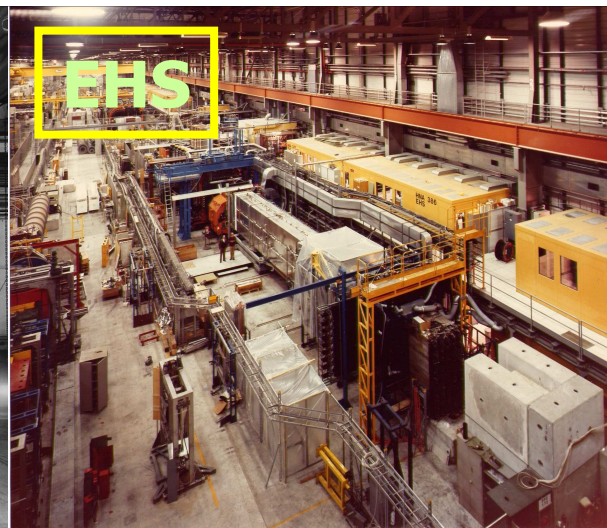
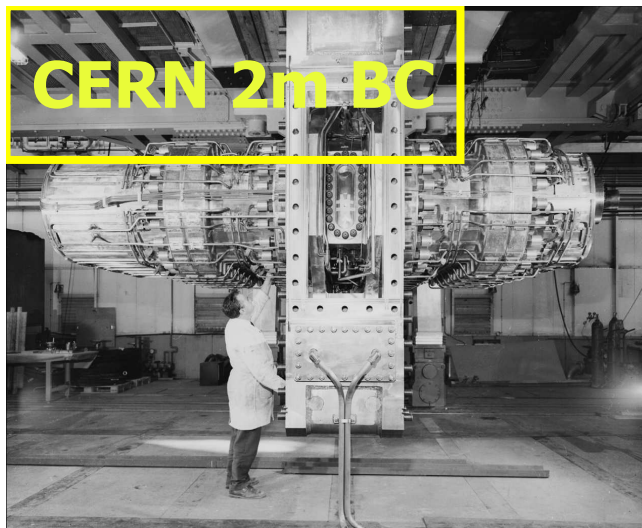


CERN, 2004

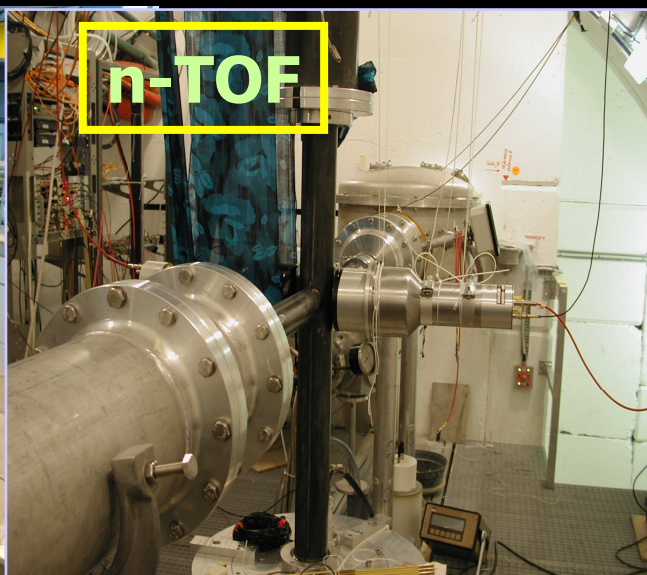


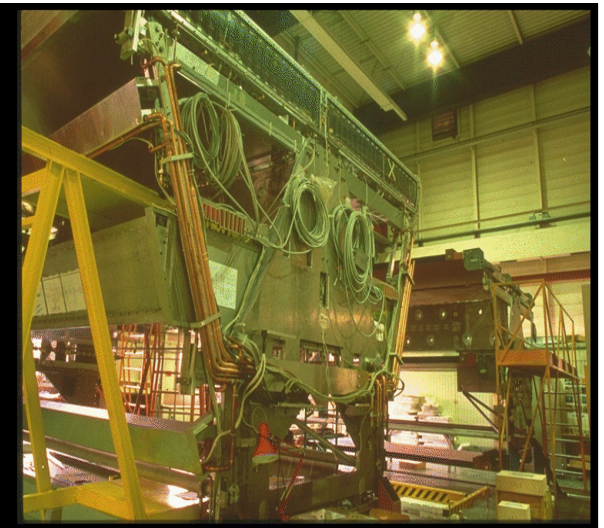
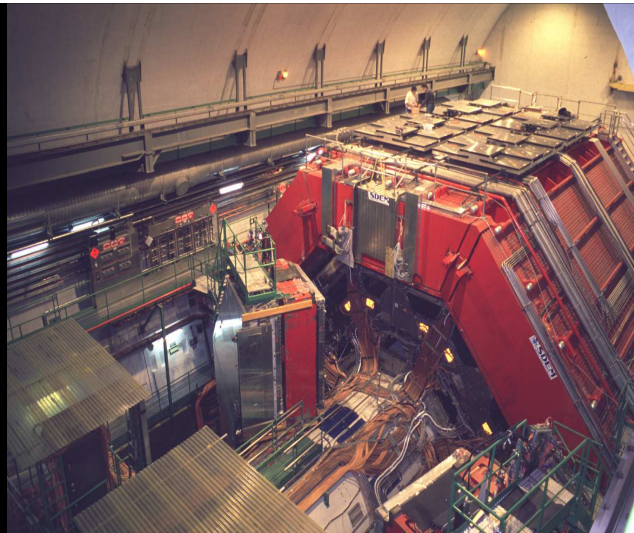
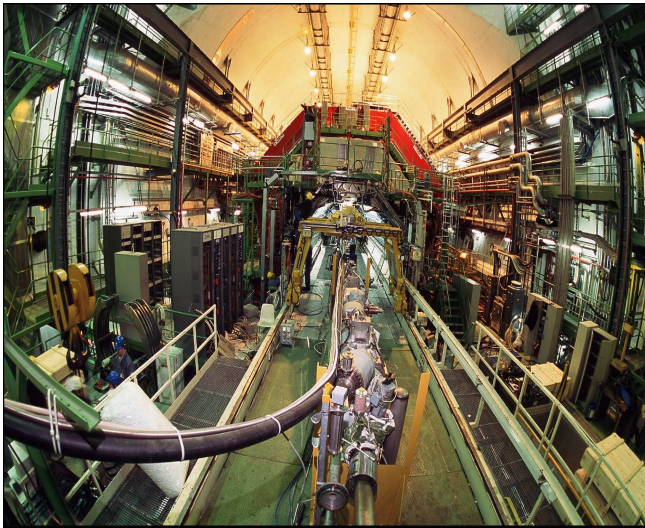
CERN, 2004



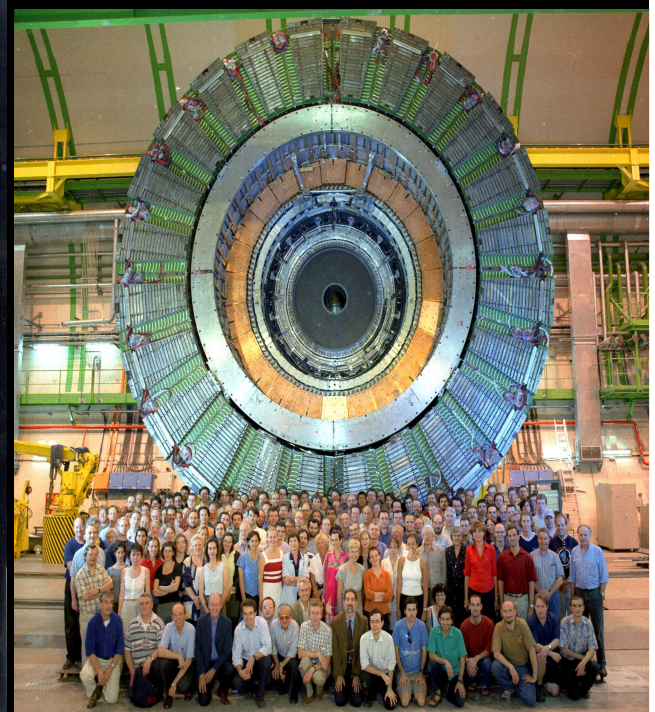
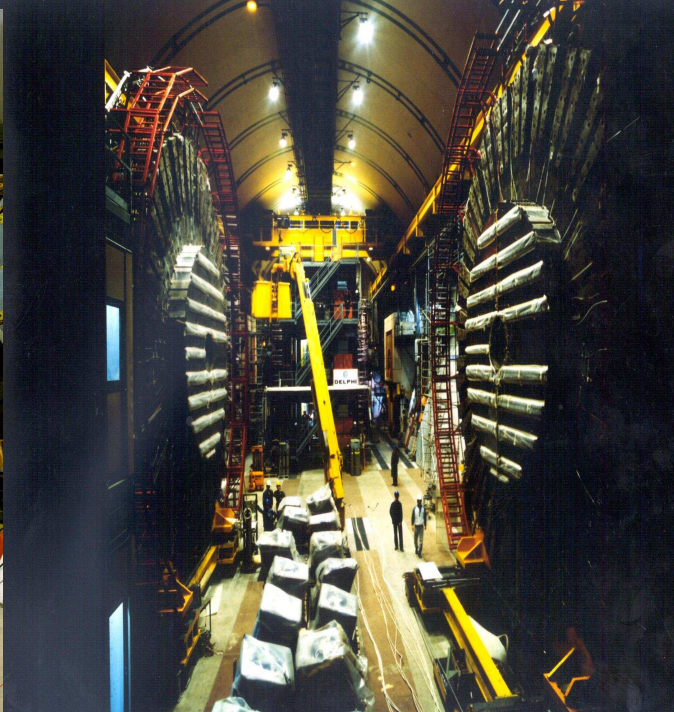
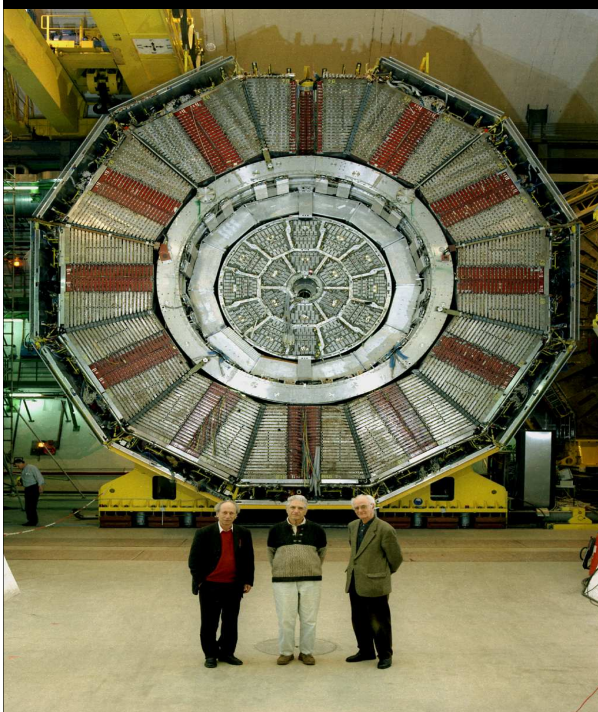


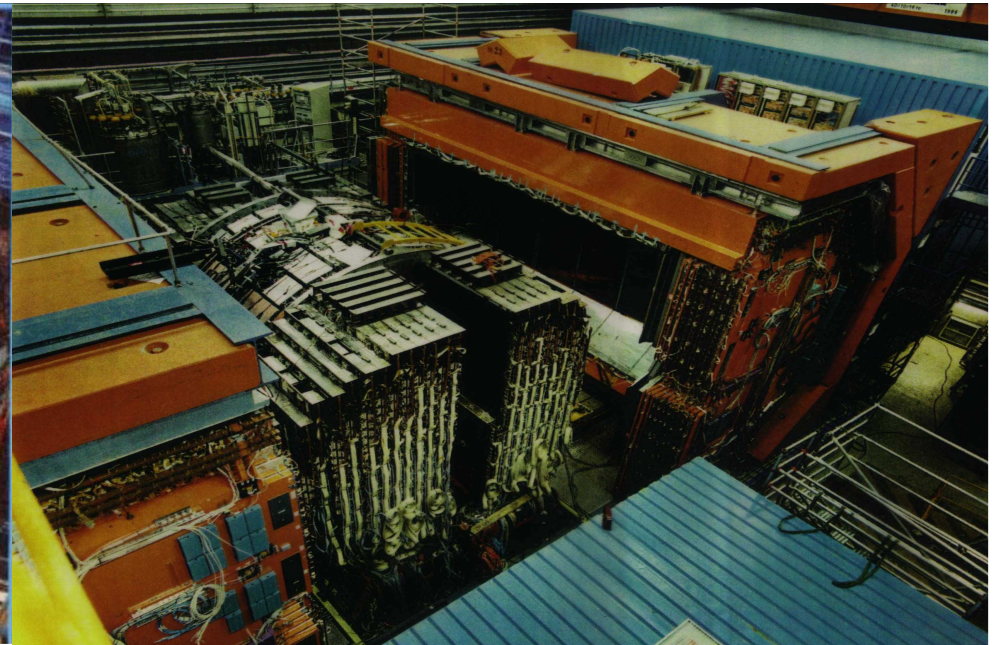
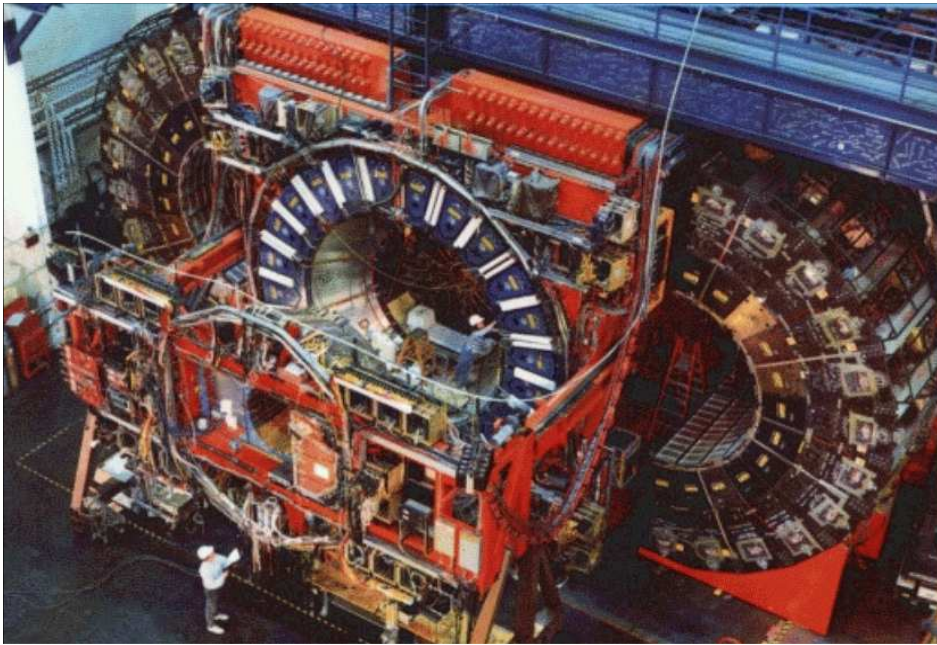
PS, SPS, ISOLDE, n-TOF



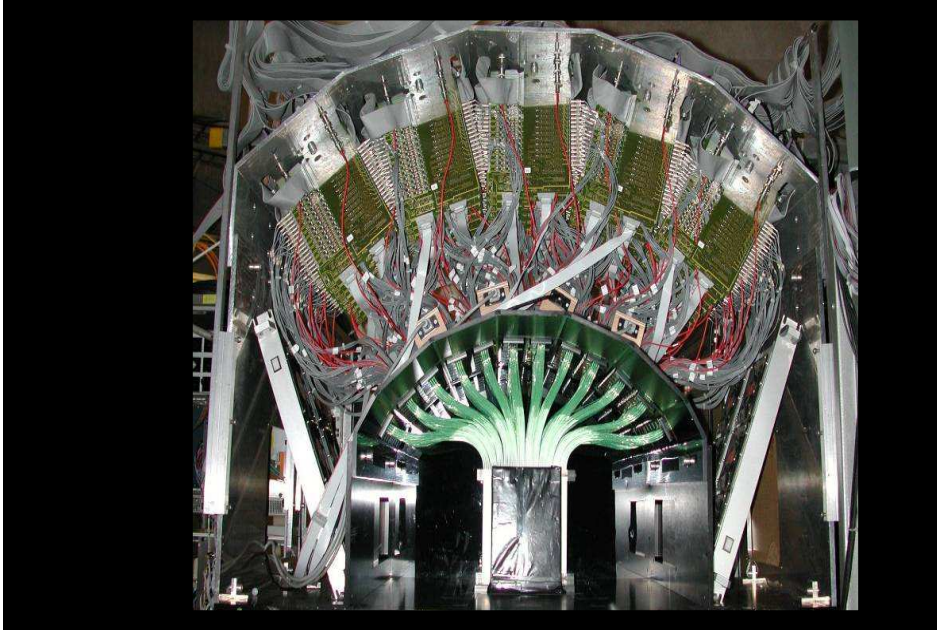


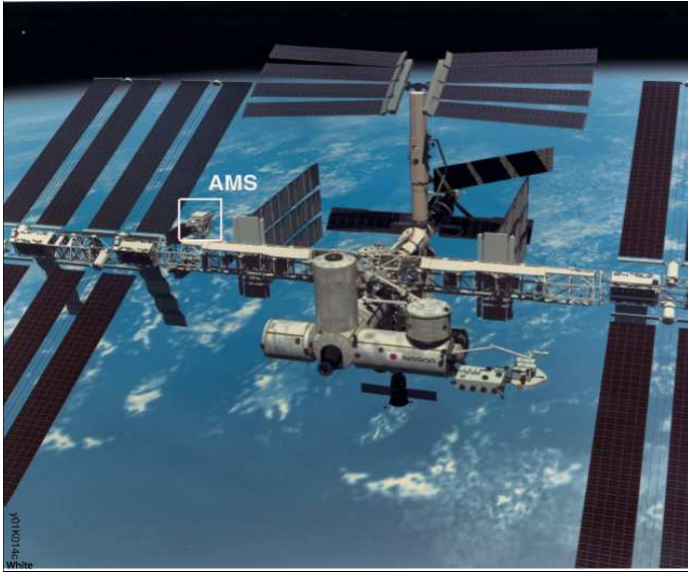
ALEPH, DELPHI, L3 @ LEP



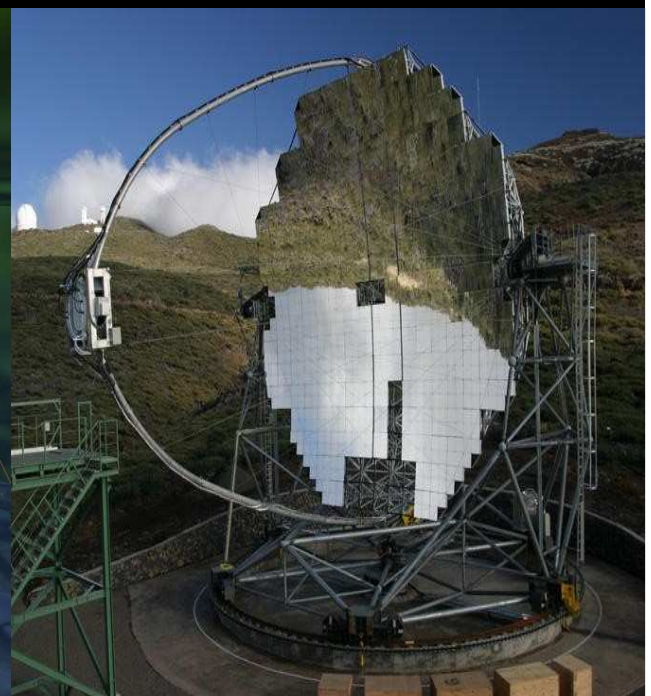
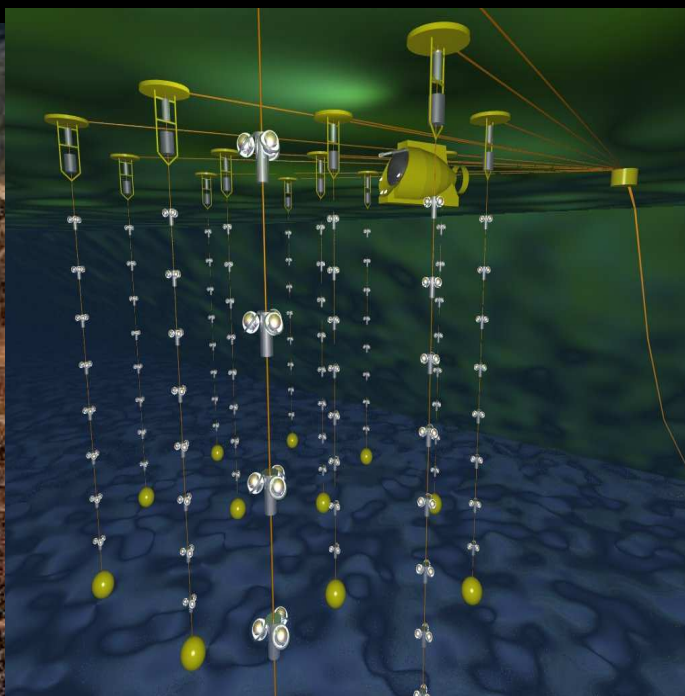
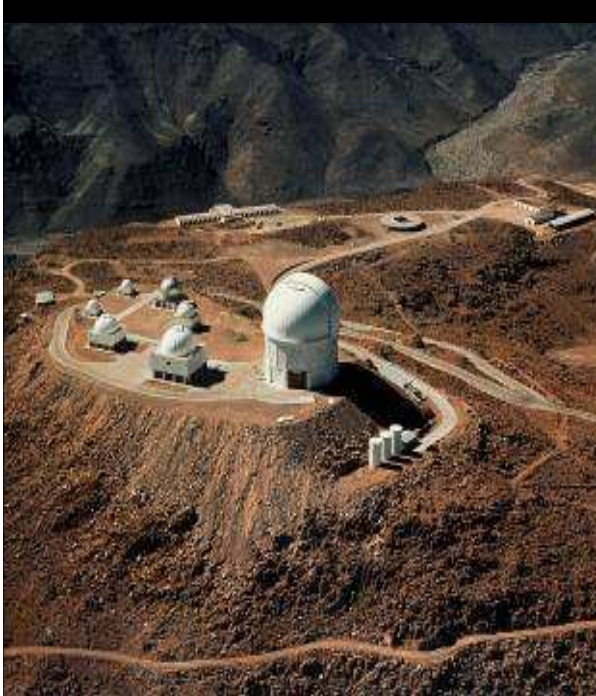


CDF @ TEVATRON (FERMILAB), ZEUS @ HERA (DESY), BABAR @ PEPB (SLAC), FAST (PSI), T2K (KEK), Double CHOOZ (CHOOZ)





AMS, AUGER, ANTARES, CTA, DES, MAGIC, PAU



ATLAS



IFAE (Barcelona)
CNM (Barcelona)
IFIC (Valencia)
UPV (Valencia)
UAM (Madrid)

CMS

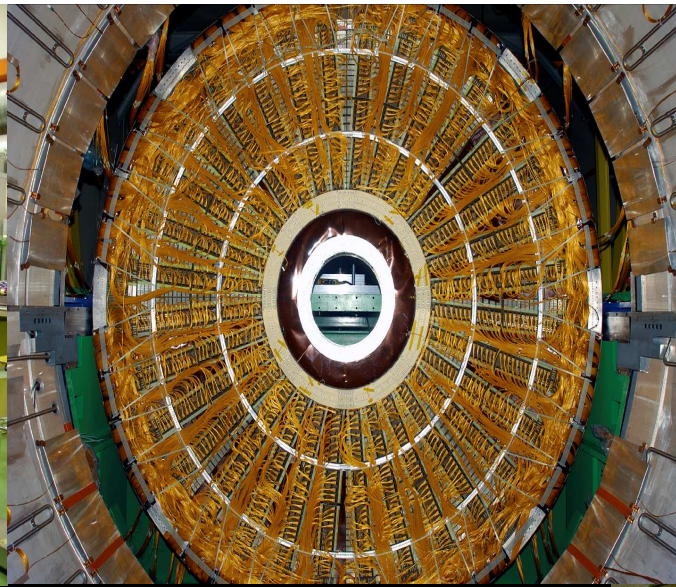
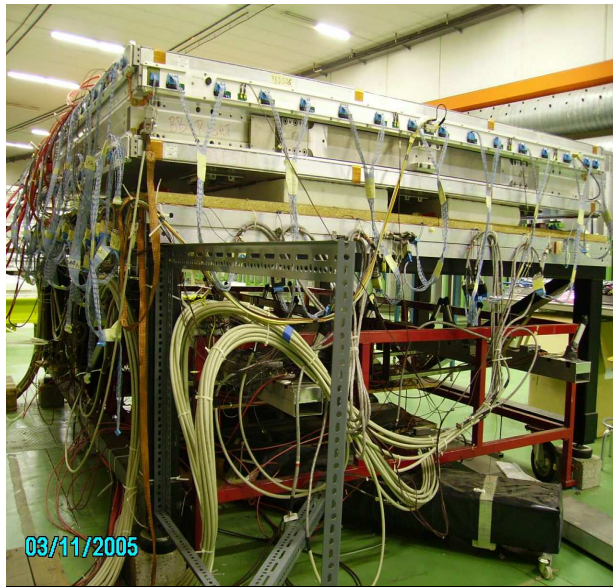


CIEMAT (Madrid)
IFCA (Santander)
UAM (Madrid)
UO (Oviedo)

LHCb 

UB (Barcelona)
USC (Santiago)
URL (Barcelona)





ATLAS, CMS, LHCb @ LHC



PIC-Puerto de Información Científica

CIEMAT-DIUE (GENERALITAT DE CATALUNYA)-UAB-IFAE

(2003)

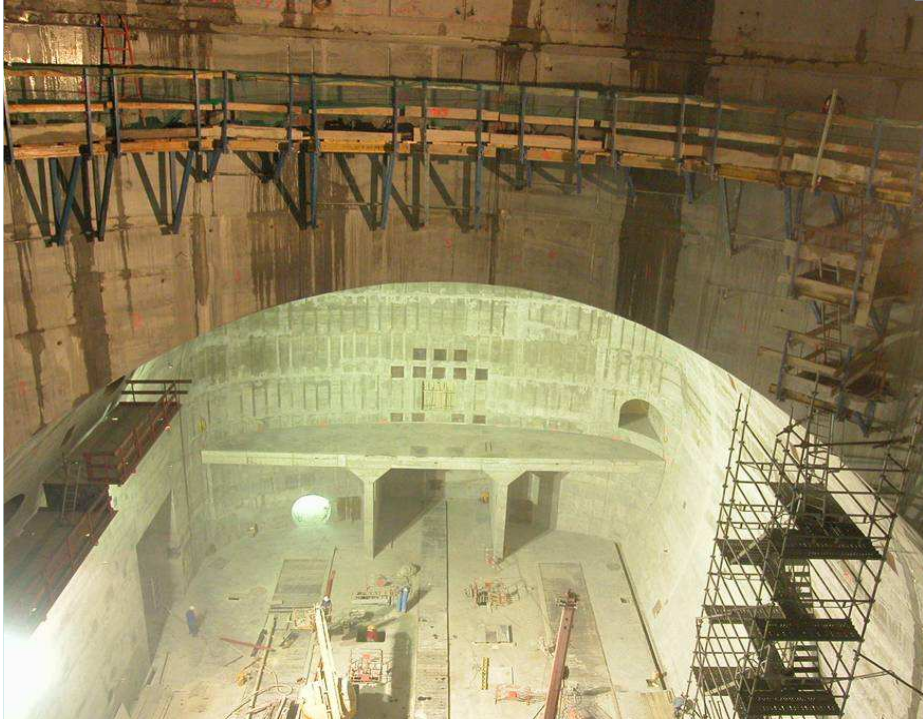
Tier1 LHC



2008 BUDGET
1,356 M€



2009 BUDGET
1,396 M€



**OBRA CIVIL P5
DRAGADOS**

**LÍNEA CRIOGÉNICA, CRIOSTATOS,
DETECTORES
FELGUERA CONSTRUCCIONES MECÁNICAS**



IAC, MAGIC, ROQUE DE LOS MUCHACHOS



ALBA, BARCELONA



LSC, CANFRANC



EPÍLOGO

In a decade or two, we can hope to ...

Understand electroweak symmetry breaking
Observe the Higgs boson
Measure neutrino masses and mixings
Establish Majorana neutrinos ($\beta\beta_{0\nu}$)
Thoroughly explore CP violation in B decays
Exploit rare decays (K , D , ...) [\[1\]](#)
Observe neutron EDM, pursue electron EDM
Use top as a tool
Observe new phases of matter
Understand hadron structure quantitatively
Uncover the full implications of QCD
Observe proton decay
Understand the baryon excess
Catalogue matter and energy of the universe
Measure dark energy equation of state
Search for new macroscopic forces
Determine GUT symmetry

Detect neutrinos from the universe
Learn how to quantize gravity
Learn why empty space is nearly weightless
Test the inflation hypothesis
Understand discrete symmetry violation
Resolve the hierarchy problem
Discover new gauge forces
Directly detect dark-matter particles
Explore extra spatial dimensions
Understand the origin of large-scale structure
Observe gravitational radiation
Solve the strong CP problem
Learn whether supersymmetry is TeV-scale
Seek TeV-scale dynamical symmetry breaking
Search for new strong dynamics
Explain the highest-energy cosmic rays
Formulate the problem of identity

... learn the right questions to ask ...
... and rewrite the textbooks!

**EL PRODUCTO MÁS IMPORTANTE
DEL CONOCIMIENTO ES
LA IGNORANCIA**

**DAVID J. GROSS
PREMIO NOBEL 2004**



A large, illuminated, golden, ribbed dome structure, possibly a modern architectural landmark, is shown at night. The dome is covered in a grid of horizontal and vertical ribs, giving it a segmented appearance. It is brightly lit from within, causing it to glow against the dark blue night sky. The word "GRACIAS" is overlaid in the center of the image in a large, bold, yellow, serif font. The background shows some dark silhouettes of trees and a fence in the foreground.

GRACIAS

