

CMS

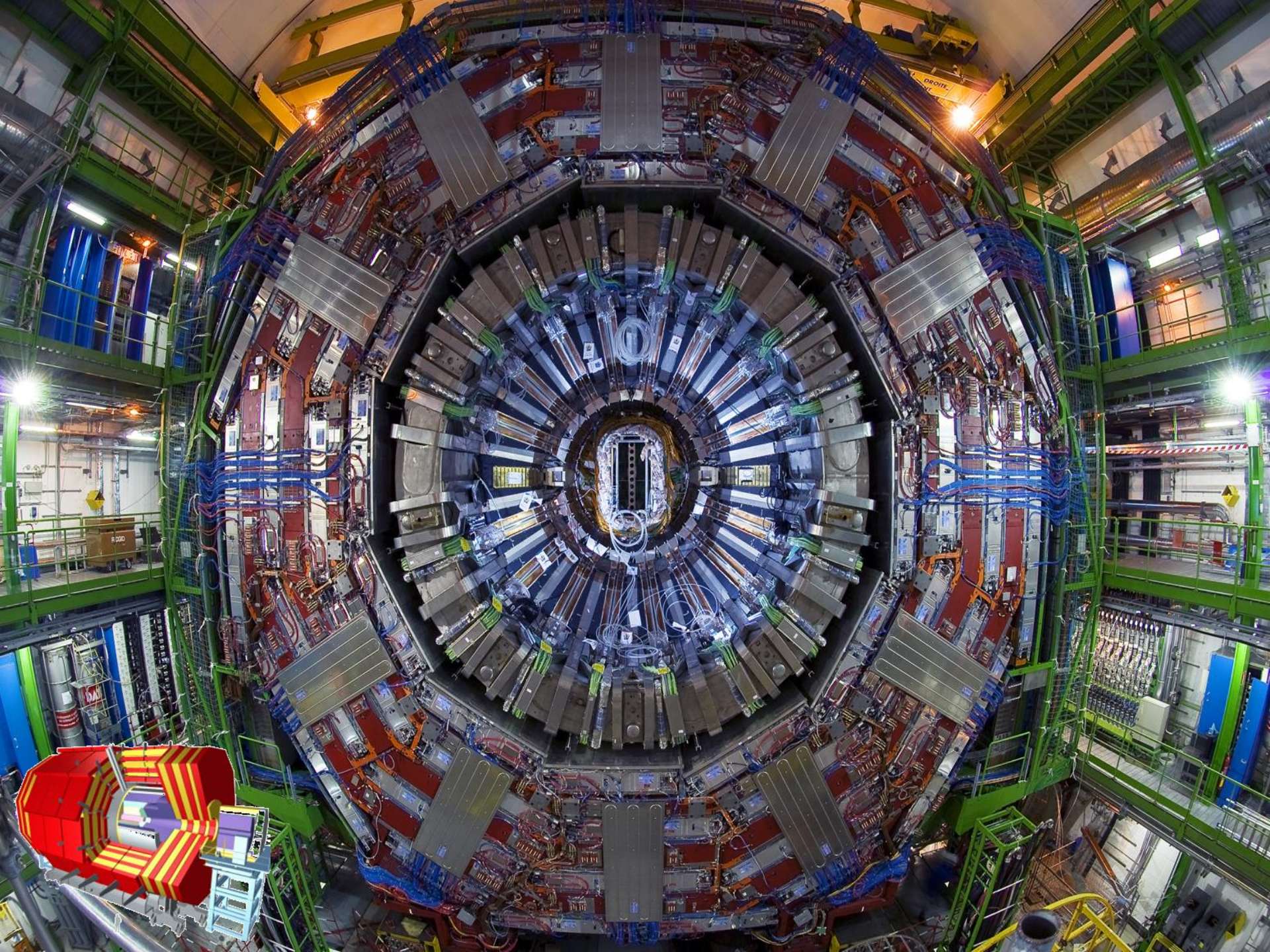
Spanish teachers programme

Javier Santaolalla Camino

26 Junio 2013

MINISTERIO
DE CIENCIA,
E INNOVACIÓN

Ciemat
Centro de Investigaciones
Energéticas, Medioambientales
y Tecnológicas

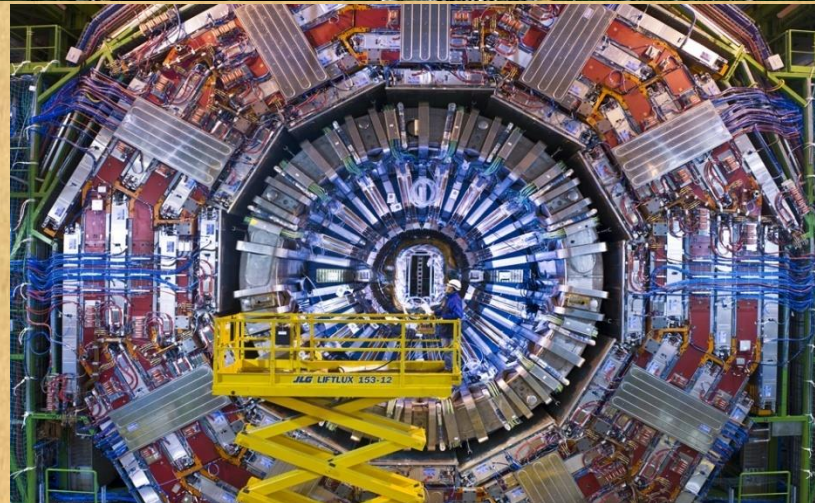
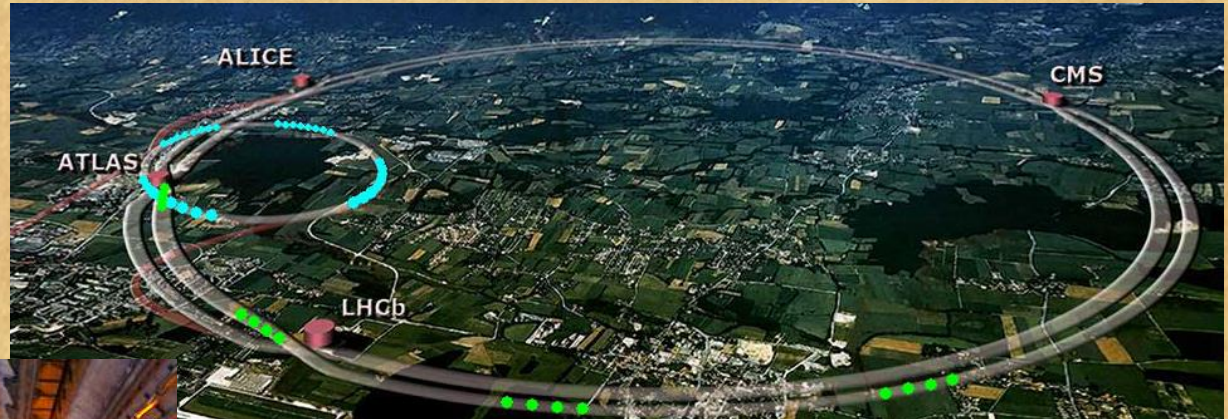


Introducción

En otras presentaciones...

CERN

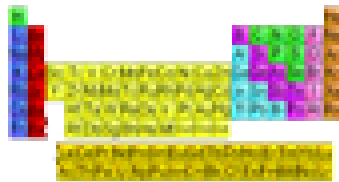
LHC



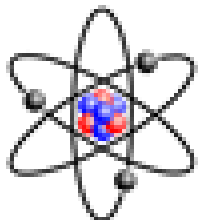
Presocráticos



Mendeleev

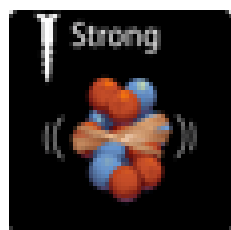
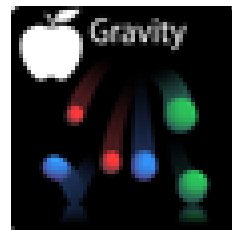
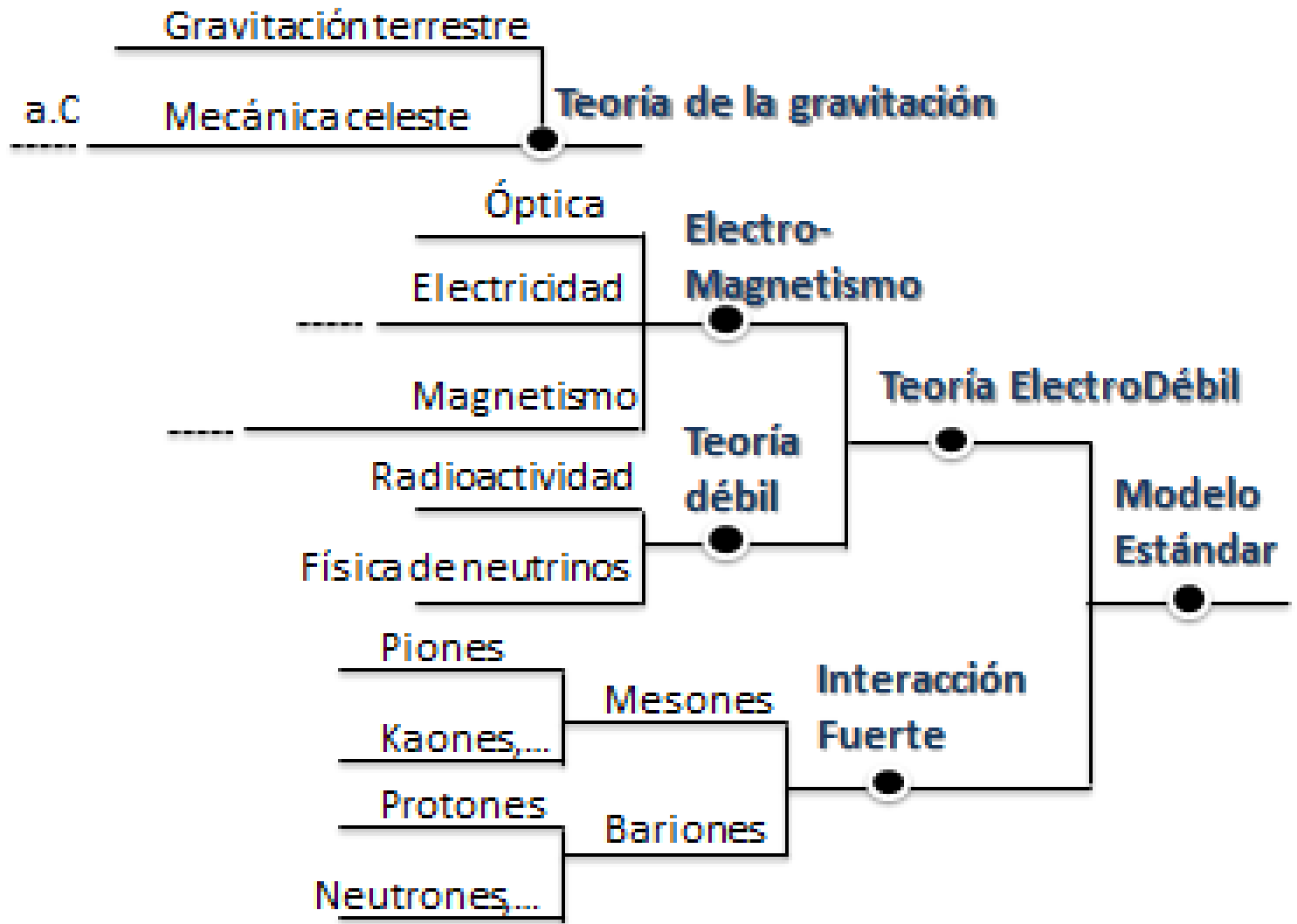


Partículas subatómicas

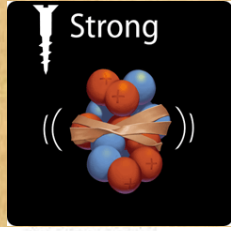
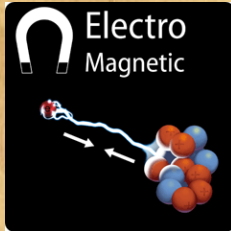


M. Estándar

u	c	t	Y
d	s	b	g
u	u	u	Z
e	p	T	W



MODELO ESTÁNDAR



$$\begin{aligned}
 & -\frac{1}{2}\partial_\nu g_\mu^\alpha \partial_\nu g_\mu^\alpha - 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{q}_i^\sigma \gamma^\mu q_j^\sigma) g_\mu^\alpha + \\
 & \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{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} + \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_\nu^0 (W_\mu^+ \partial_\nu W_\mu^- - W_\mu^- \partial_\nu W_\mu^+) + Z_\mu^0 (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^+)] - \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_\mu^+ Z_\nu^0 W_\nu^- - Z_\mu^0 Z_\nu^0 W_\mu^+ W_\nu^-) + g^2 s_w^2 (A_\mu W_\mu^+ A_\nu W_\nu^- - \\
 & A_\mu A_\nu W_\mu^+ W_\nu^-) + 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] - gMW_\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}g [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^+) + igs_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^+) + igs_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 + igs_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{4}{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_e^\lambda}{M} [-\phi^+ (\bar{\nu}^\lambda (1 - \\
 & \gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1 + \gamma^5) \nu^\lambda)] - \frac{g}{2} \frac{m_e^\lambda}{M} [H (\bar{e}^\lambda e^\lambda) + i\phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}} \phi^+ [-m_d^\kappa (\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^\lambda C_{\lambda\kappa}^\dagger (1 + \gamma^5) u_j^\kappa) - m_u^\kappa (\bar{d}_j^\lambda C_{\lambda\kappa}^\dagger (1 - \\
 & \gamma^5) u_j^\kappa)] - \frac{g}{2} \frac{m_u^\lambda}{M} H (\bar{u}_j^\lambda u_j^\lambda) - \frac{g}{2} \frac{m_d^\lambda}{M} H (\bar{d}_j^\lambda d_j^\lambda) + \frac{ig}{2} \frac{m_u^\lambda}{M} \phi^0 (\bar{u}_j^\lambda \gamma^5 u_j^\lambda) - \frac{ig}{2} \frac{m_d^\lambda}{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) + igs_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^+) + \\
 & igs_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^-) + igs_w A_\mu (\partial_\mu \bar{X}^+ X^+ - \\
 & \partial_\mu \bar{X}^- X^-) - \frac{1}{2}gM [\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} igM [\bar{X}^+ X^0 \phi^+ - \\
 & \bar{X}^- X^0 \phi^-] + \frac{1}{2c_w} igM [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + igMs_w [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + \\
 & \frac{1}{2}igM [\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]
 \end{aligned}$$

Three Generations of Matter (Fermions)

	I	II	III	
mass	3 Mev	1.24 Gev	172.5 Gev	0
charge	2/3	2/3	2/3	0
spin	1/2	1/2	1/2	1
name	u up	c charm	t top	γ photon
Quarks	6 Mev	95 Mev	4.2 Gev	0
	1/3	1/3	1/3	0
	1/2	1/2	1/2	1
	d down	s strange	b bottom	g gluon
<2 ev	<0.19 Mev	<18.2 Mev	50.2 Gev	0
0	0	0	0	1
1/2	1/2	1/2	1	1
e _e electron neutrino	ν _μ muon neutrino	ν _τ tau neutrino	Z ⁰ weak force	
0.511 Mev	106 Mev	1.78 Gev	80.4 Gev	1
-1	-1	-1	1	1
1/2	1/2	1/2	1	1
e electron	μ muon	τ tau	W [±] weak force	

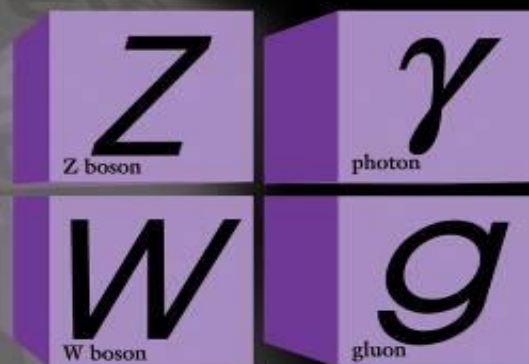
Bosons (Forces)

$$\begin{aligned}\mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\ & + i \bar{\psi} \not{D} \psi + \text{h.c.} \\ & + \chi_i \gamma_{ij} \chi_j \phi + \text{h.c.} \\ & + |D_m \phi|^2 - V(\phi)\end{aligned}$$

Quarks



Forces



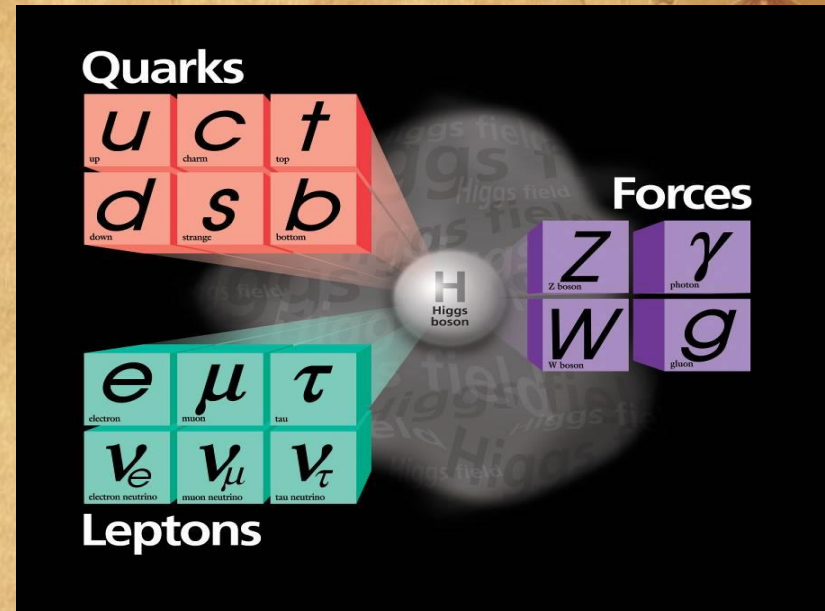
Leptons

+ antipartículas

$$\begin{aligned}
 \mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\
 & + i\bar{\psi} \not{D} \psi + h.c. \\
 & + \chi_i Y_{ij} \chi_j \phi + h.c. \\
 & + |D_\mu \phi|^2 - V(\phi)
 \end{aligned}$$

Interacciones

+

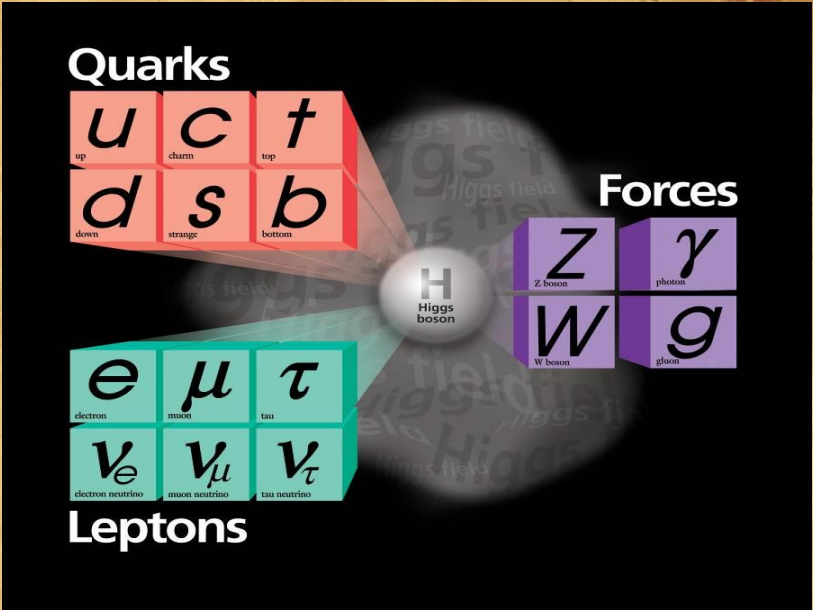


Partículas

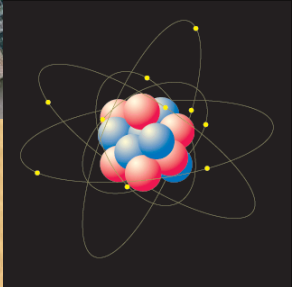
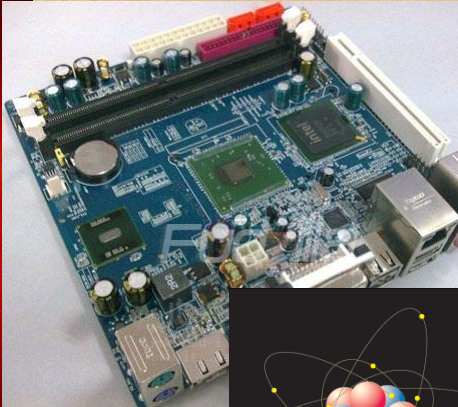
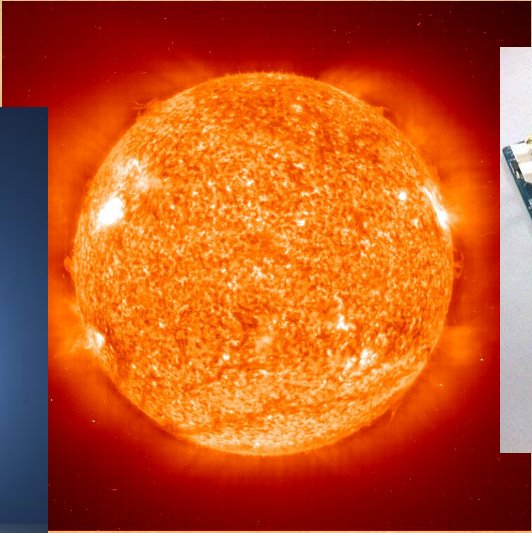
= Modelo Estándar

$$\begin{aligned}
 \mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\
 & + i\bar{\psi} \not{D} \psi + h.c. \\
 & + \chi_i Y_{ij} \chi_j \phi + h.c. \\
 & + |D_\mu \phi|^2 - V(\phi)
 \end{aligned}$$

Interacciones



Partículas





Gravedad



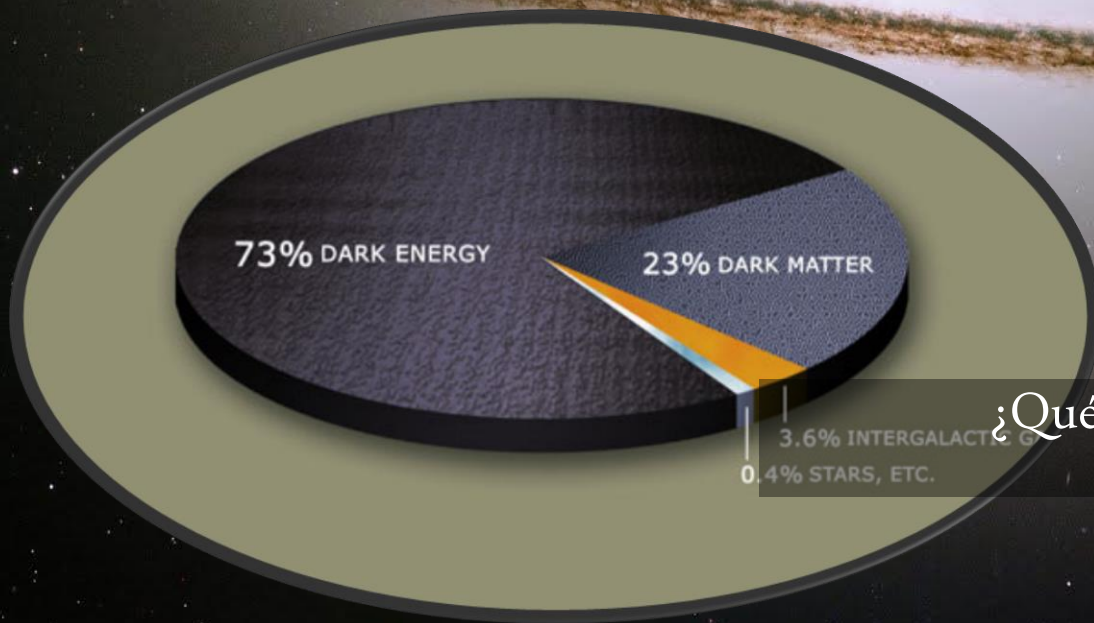
**Particulas
sin hallar**



**Demasiados
parametros**

... y sin embargo tan lejos

¡Y aún más!



¿Qué es la materia oscura?



Algunas incógnitas cosmológicas

¿Cómo conciliar gravitación y mundo subatómico?

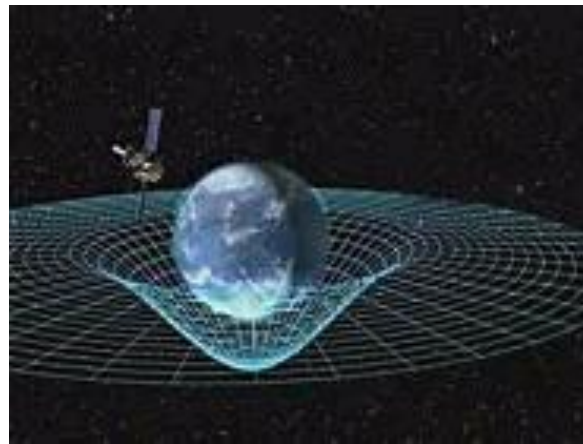


OSO



Relatividad

Planetas



Algunas incógnitas cosmológicas

¿Cómo conciliar gravitación y mundo subatómico?



OSO



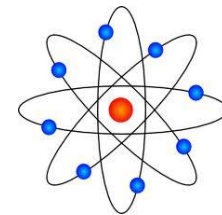
Relatividad

HORMIGA



Cuántica

Atomo



Algunas incógnitas cosmológicas

¿Cómo conciliar gravitación y mundo subatómico?



OSO



Relatividad

HORMIGA



Cuántica

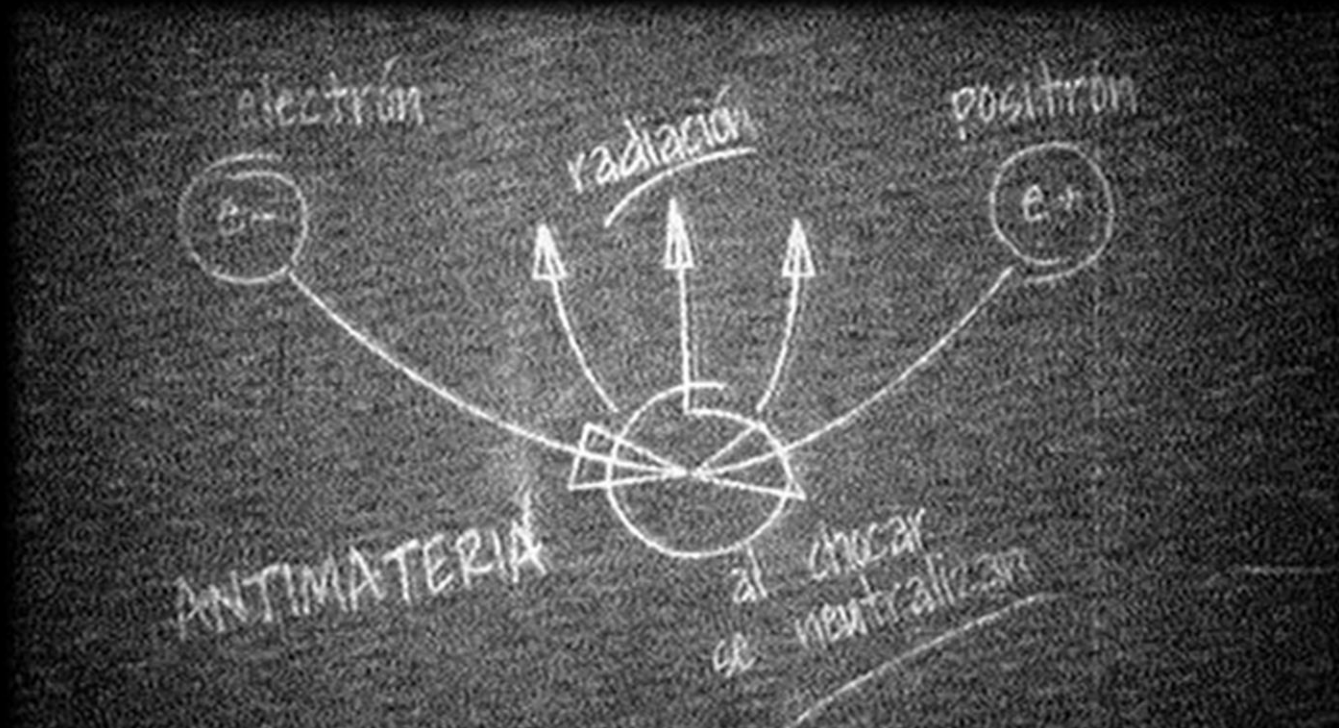
OSO

HORMIGUERO



?????

Algunas incógnitas en Física de Partículas



¿Por qué en la Naturaleza sólo vemos materia? ¿Dónde está la antimateria?



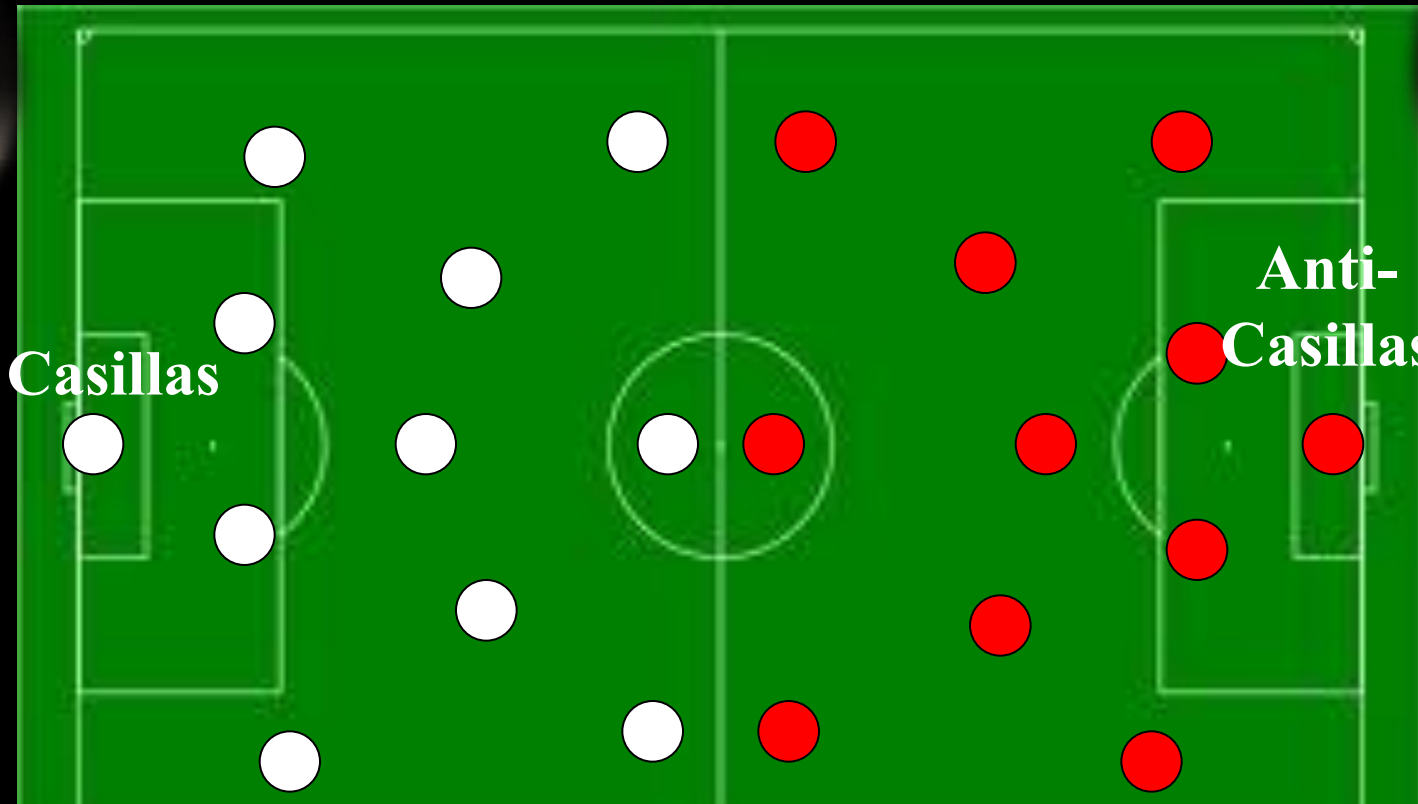
Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA



MOU



A-MOU

Anti-Casillas

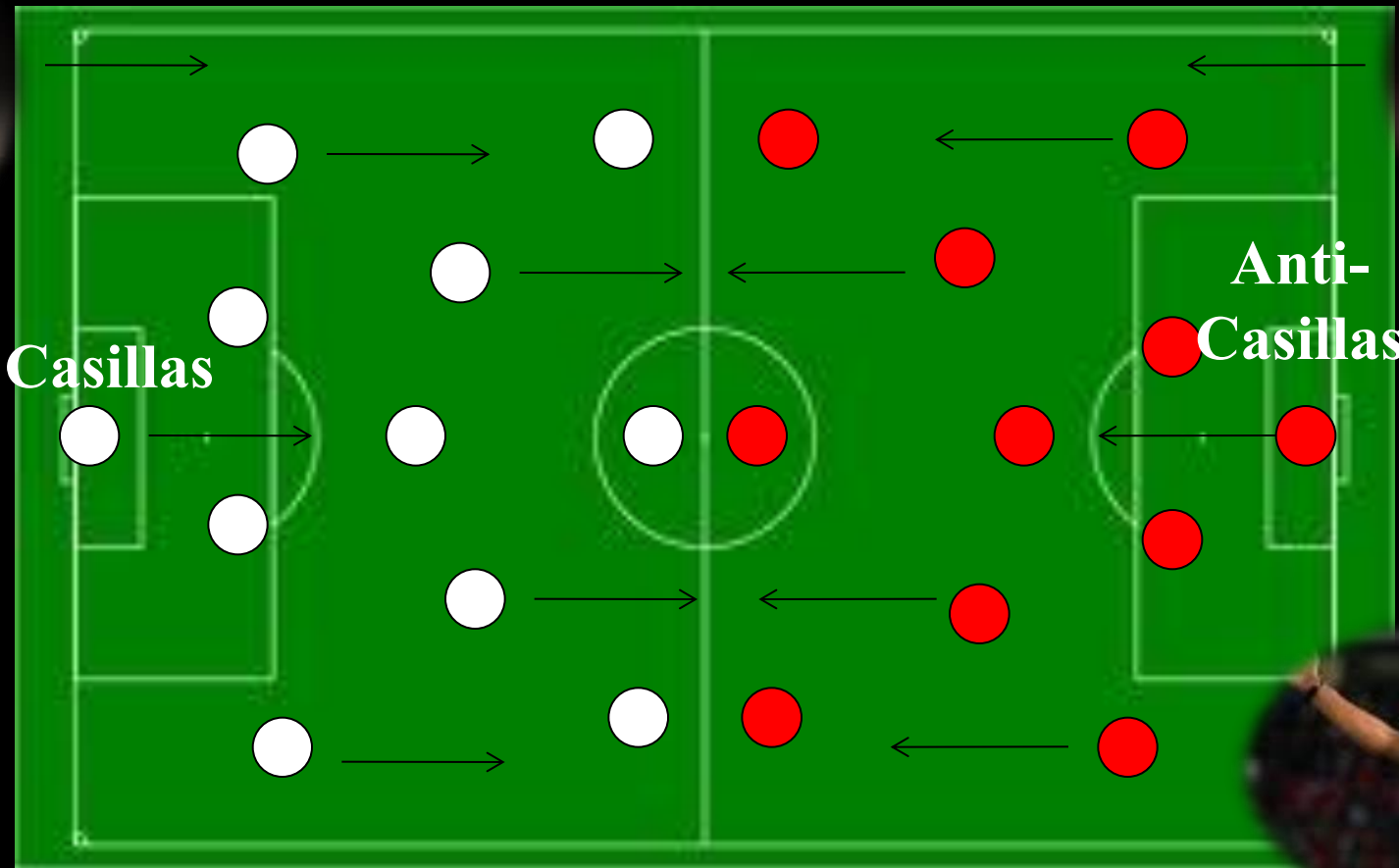
Final Universe Cup: Materia vs Antimateria

Reglas: materia en contacto con antimateria se aniquilan

Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA



MOU

A-MOU

Casillas

Anti-Casillas



Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA

Universo vacío

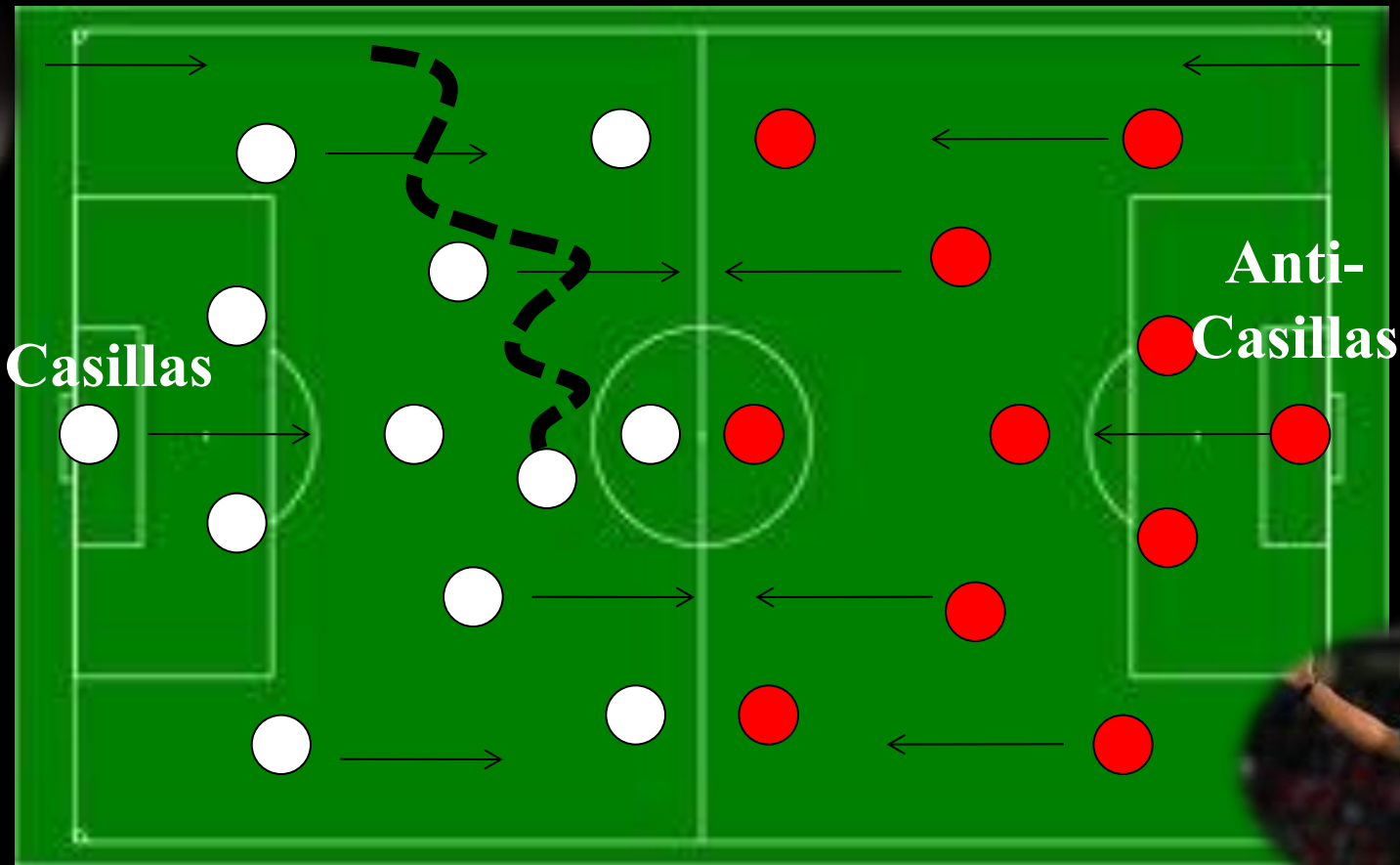
BANG



Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA



MOU

A-MOU

Casillas

Anti-Casillas



OPCION 1: exceso inicial de materia sobre a-materia

Algunas incógnitas en Física de Partículas

MATERIA

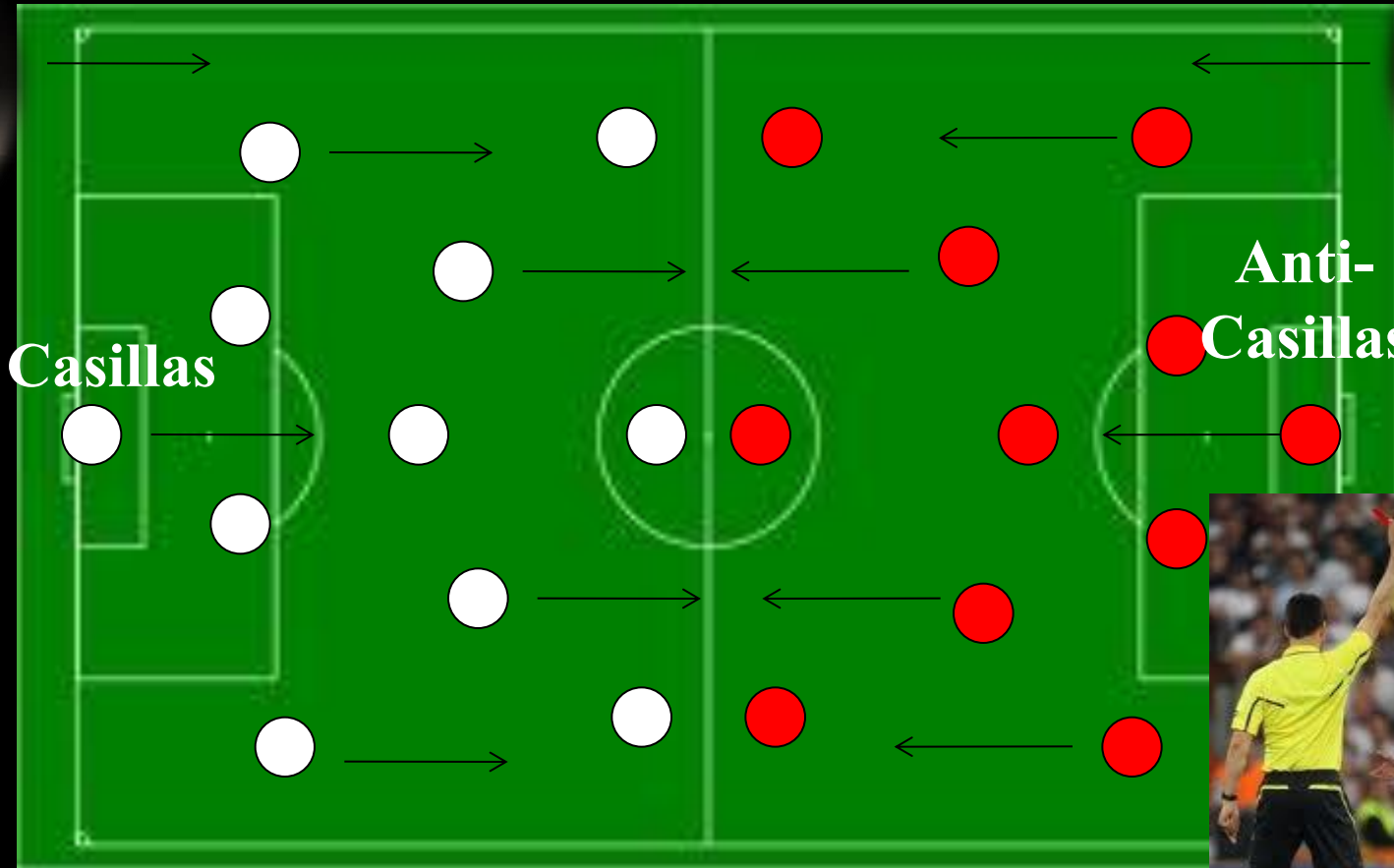
ANTIMATERIA



Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA



OPCION 2: que el arbitro este comprado (UEFA)

Algunas incógnitas en Física de Partículas

MATERIA

ANTIMATERIA



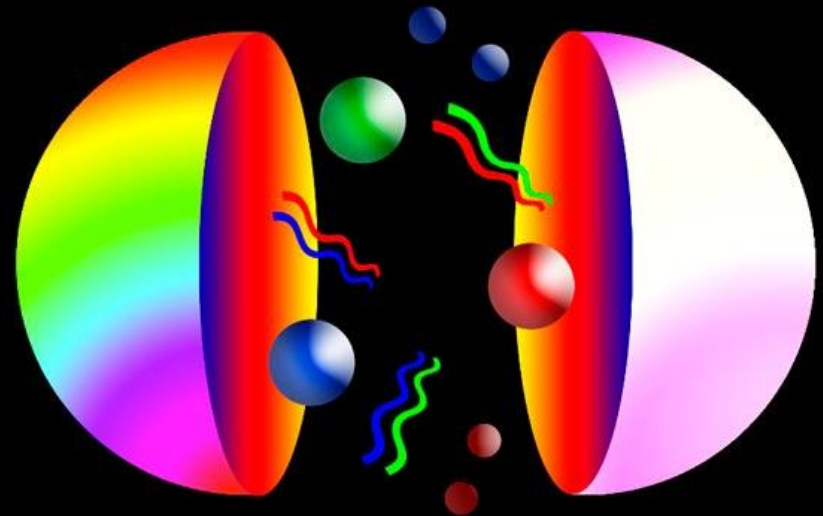
Algunas incógnitas en Física de Partículas

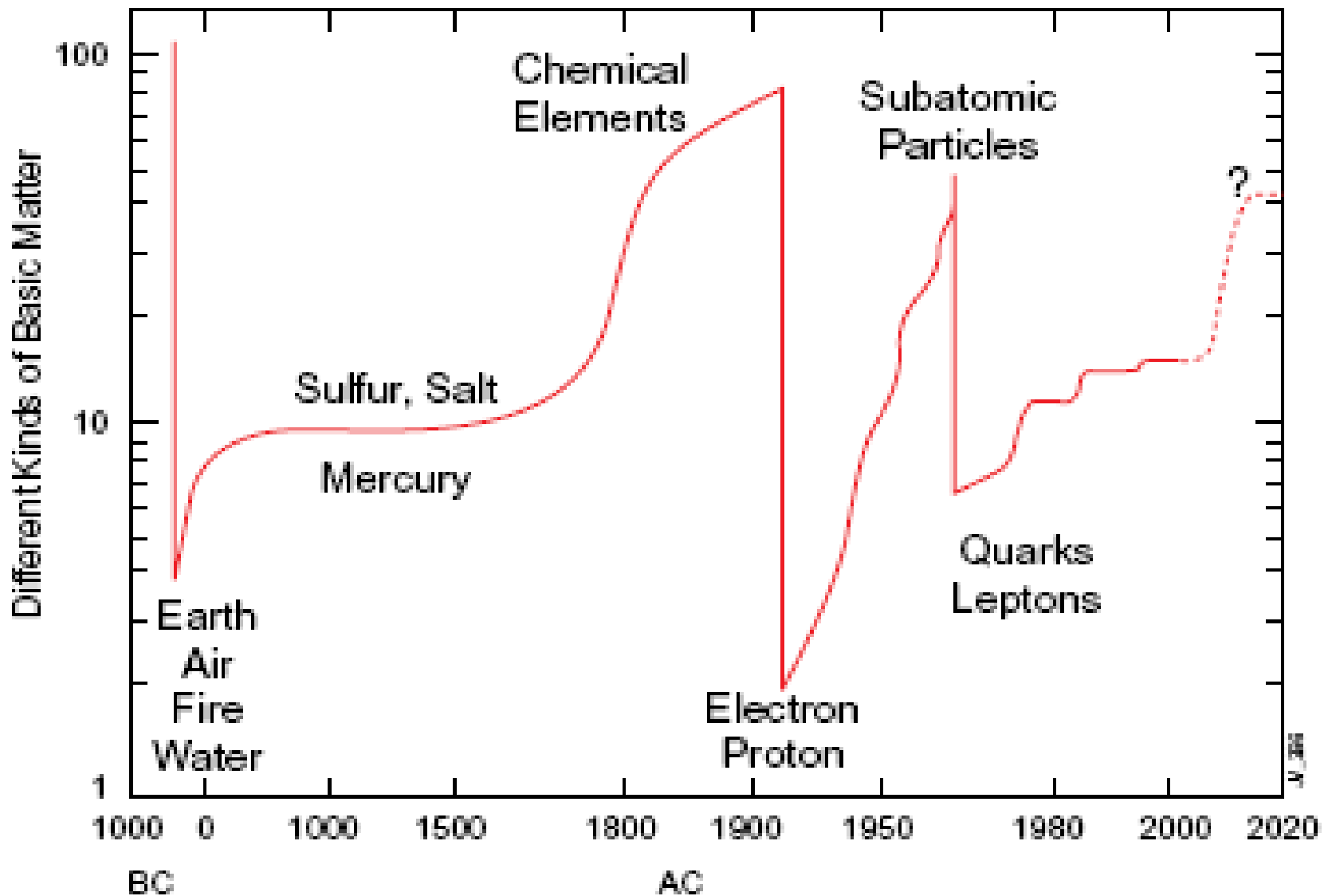


¿Por qué son tan distintas las masas de las partículas?



¿Qué mecanismo proporciona esas masas?





Guillermo de Ockham

“no hay que multiplicar los entes de la razón sin necesidad, hay que ir siempre a las hipótesis más sencillas”



Si esta es la pregunta...

New symmetries

Technicolor

Supersymmetry

Little Higgs

Extra dimensions

New forces

New particles

String Theory



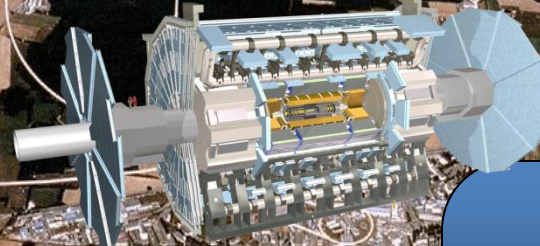
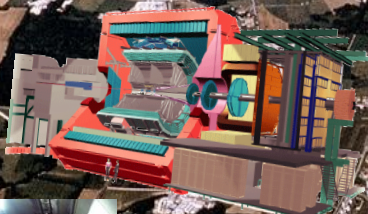
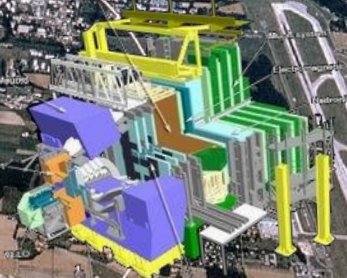
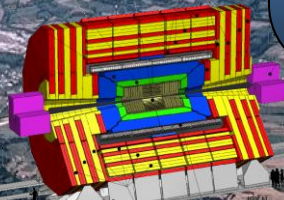
...esta es la respuesta

CMS
Propósito general

LHCb
Física del quark b
Violación CP

ALICE
Plasma de quarks
y gluones

ATLAS
Propósito general



¿CÓMO?

ENERGIA

TRABAJO



GRAVITATORIA



CINÉTICA



ELÁSTICA



ELECTR.

y...

¿CÓMO?

ENERGIA

TRABAJO



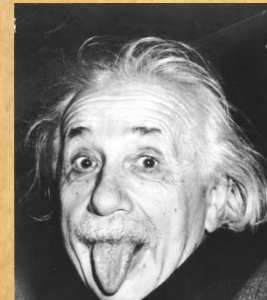
ELASTICA

CINETICA



ELECTR.

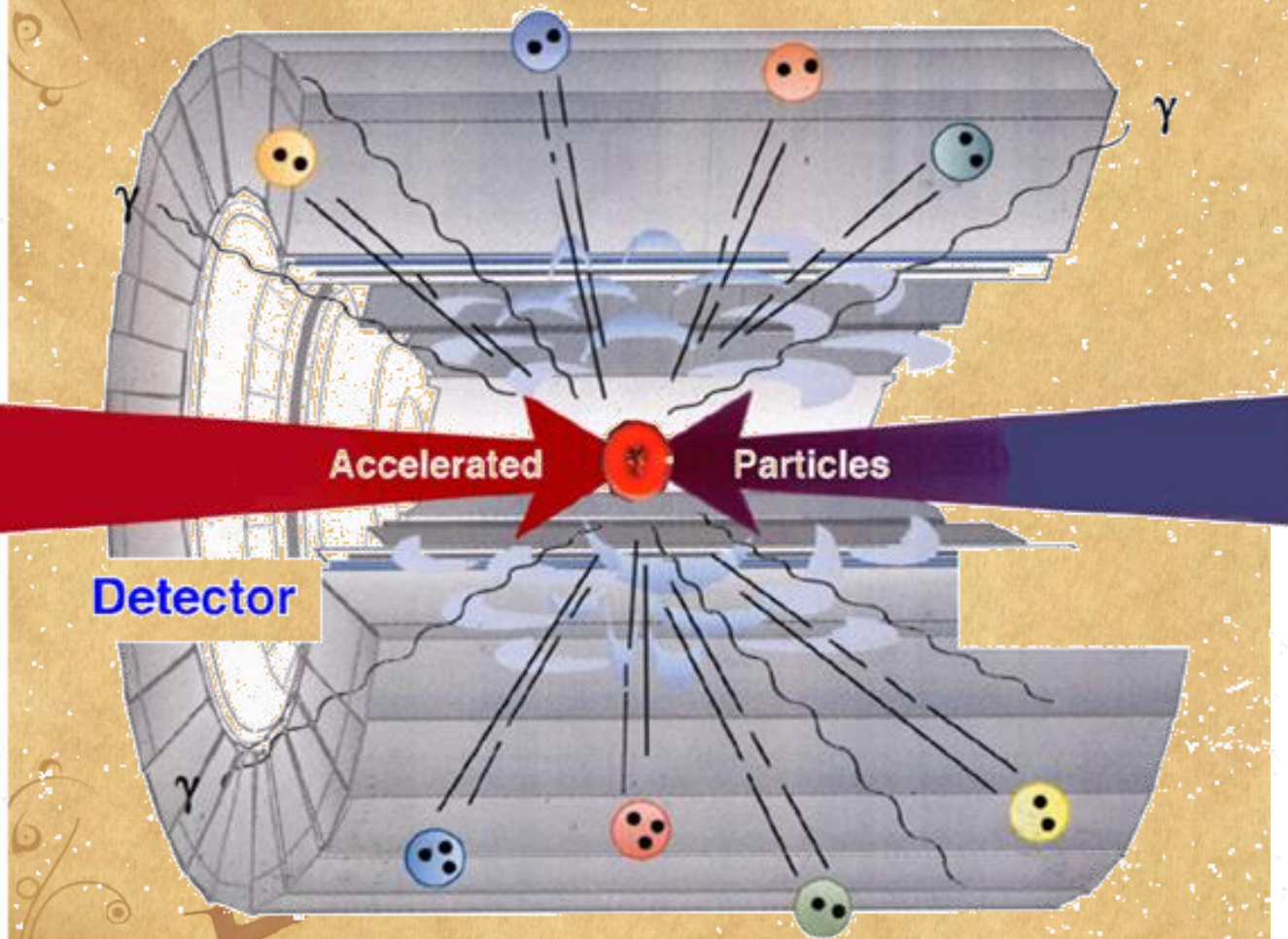
y...



$$E=mc^2$$

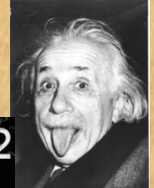
GRAVITATORIA

¿CÓMO?



MASA

CINETICA



$$E = mc^2$$

Three Generations of Matter (Fermions)

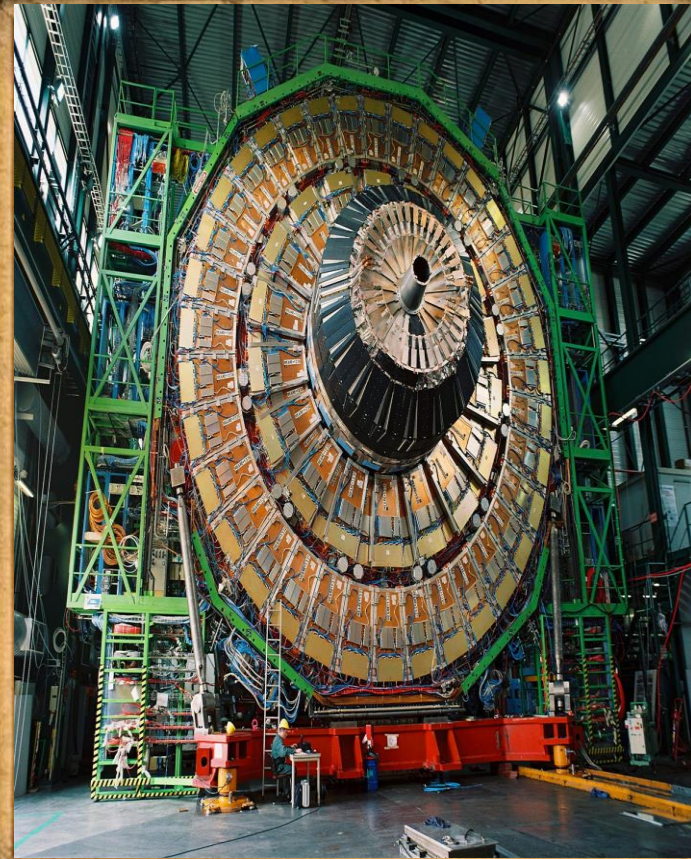
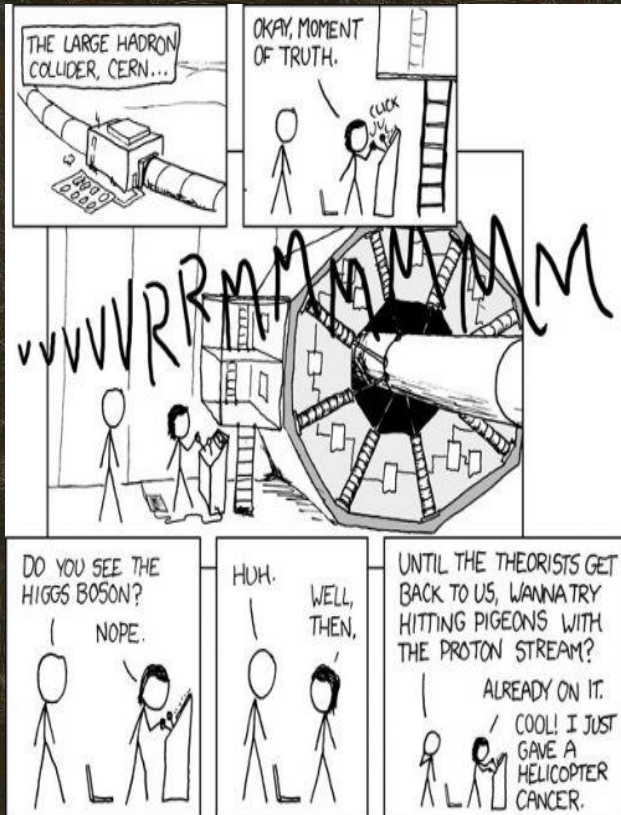
	I	II	III	
mass	3 Mev	1.24 GeV	172.5 GeV	0
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
name	u up	c charm	t top	γ photon
Quarks	6 Mev	95 Mev	4.2 GeV	0
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	d down	s strange	b bottom	g gluon
Leptons	<2 ev	<0.19 MeV	<18.2 MeV	90.2 GeV
	0	0	0	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z ⁰ weak force
	0.511 Mev	106 Mev	1.78 GeV	80.4 GeV
	-1	-1	-1	±1
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	e electron	μ muon	τ tau	W [±] weak force

Bosons (Forces)

CMS

El detector

El analisis



CMS

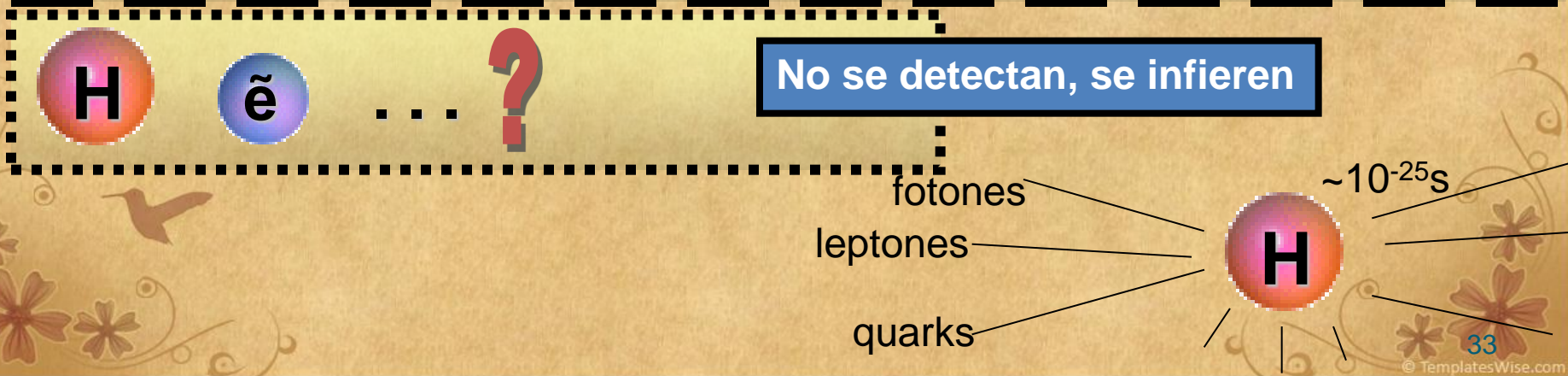
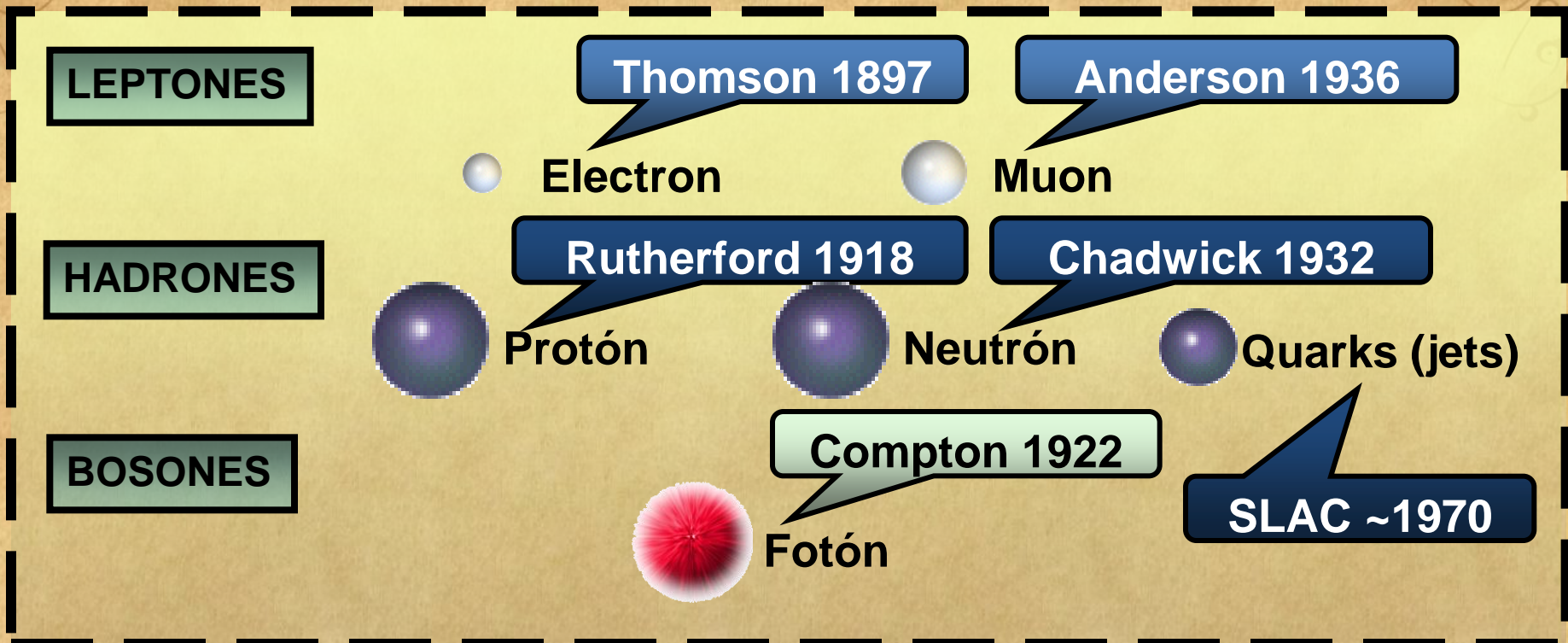
El detector

- **Objetivo:**

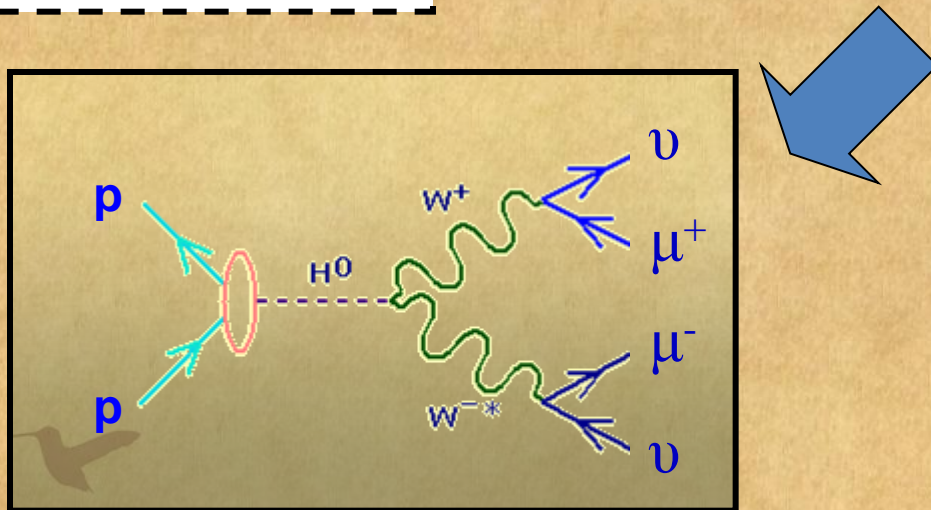
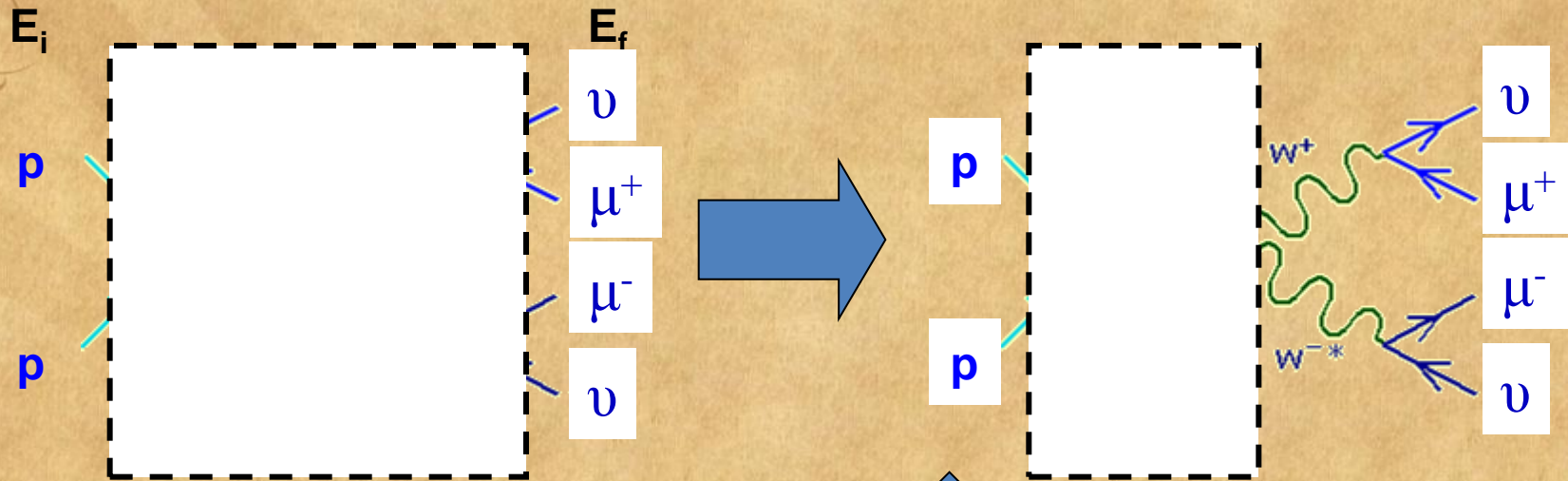
1. Detectar
2. Identificar
3. Obtener magnitudes de interés (energía, ...)



Deteccion



Deteccion



Identificación

leptones

τ^- μ^- e^- γ

τ^+ μ^+ e^+

quarks

u d s c b t

bariones



p^+ n p^- ...

mesones

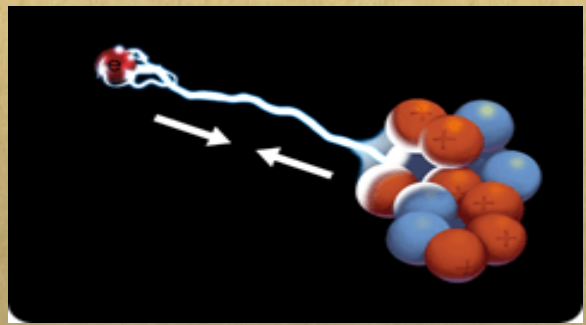
π^0 π^+ ...

Particle Zoo

¿Qué partícula es?

Carga  

Interacción



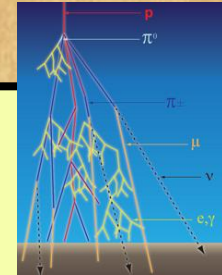
Identificación

Dos tipos de detectores

Destructivos: miden absorbiendo la partícula (calorímetros)

No Destructivos: miden la trayectoria de la partícula (sin absorción)

Atmósfera



*Calorímetro
Electromagnético*

γ e

*Calorímetro
Hadrónico*

n p ...

*Detector de
Trazas (Tracker)*

p e

*Detector de
Muones*

μ

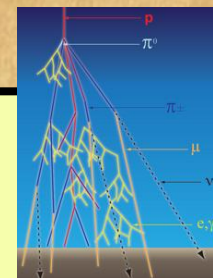
Identificación

Dos tipos de detectores

Destructivos: miden absorbiendo la partícula (calorímetros)

No Destructivos: miden la trayectoria de la partícula (sin absorción)

Atmósfera



Detector de Muones

μ					
-------	--	--	--	--	--

Calorímetro Hadrónico

n	p	...			
---	---	-----	--	--	--

Calorímetro

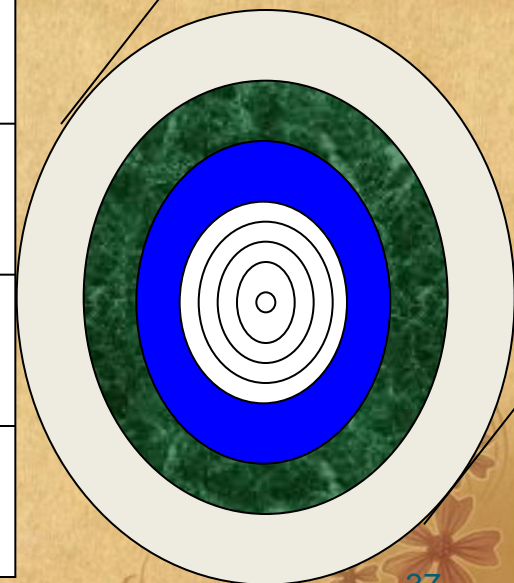
γ	e				
----------	---	--	--	--	--

Detector de

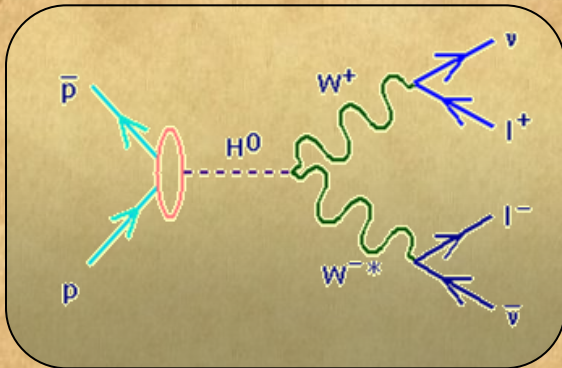
p	e				
---	---	--	--	--	--

Trazas (Tracker)

	*	*			
*	*				
γ	e	n	p	ν	μ



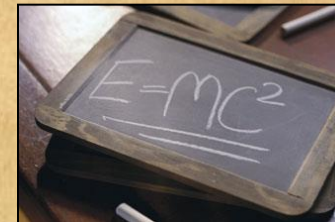
Obtencion de magnitudes de interes



1. Trayectoria de los productos

2. Energía de los productos

Conservación de la energía



1. Trayectoria

Detectores no destructivos

Tracker y cámaras muones

2. Energía

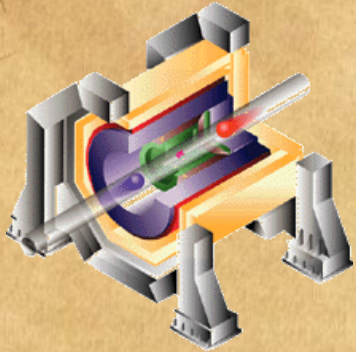
Calorímetros

Detectores no destructivos

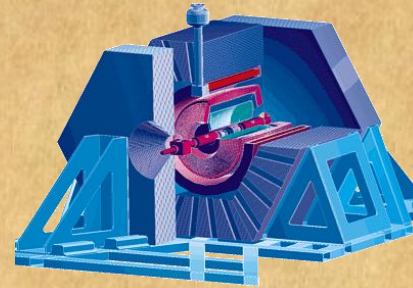
Curvatura de la trayectoria en un campo magnético

$$v = qBR / m$$

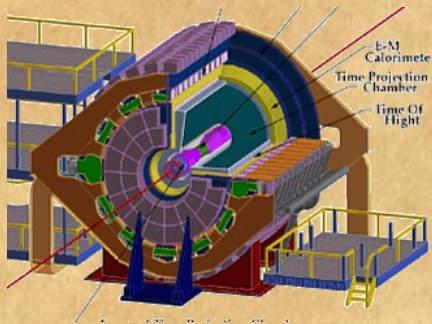
Detectores de partículas



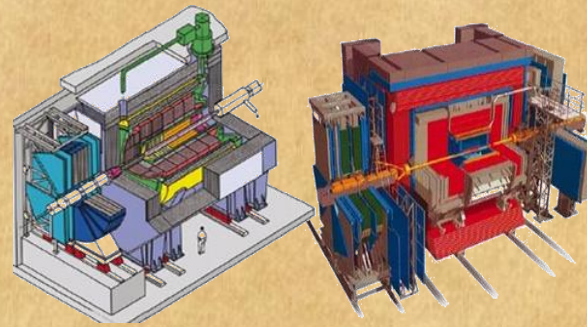
SLD del SLAC



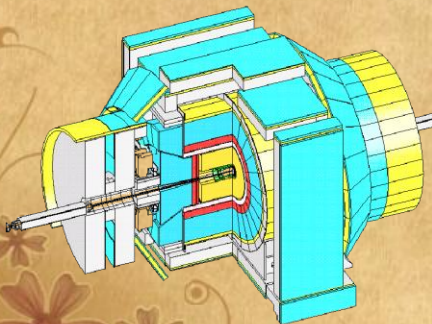
BaBar SLAc



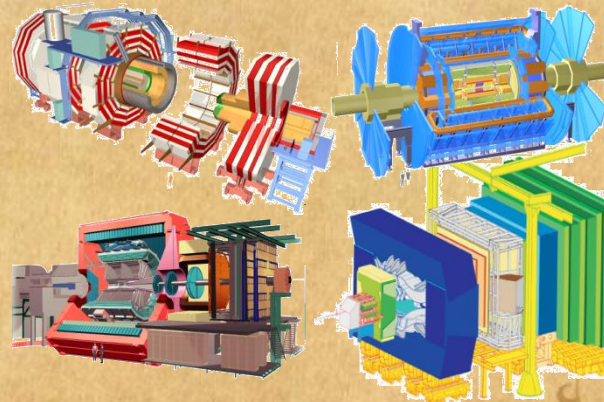
STAR BNL



H1 & zEUS
HERA

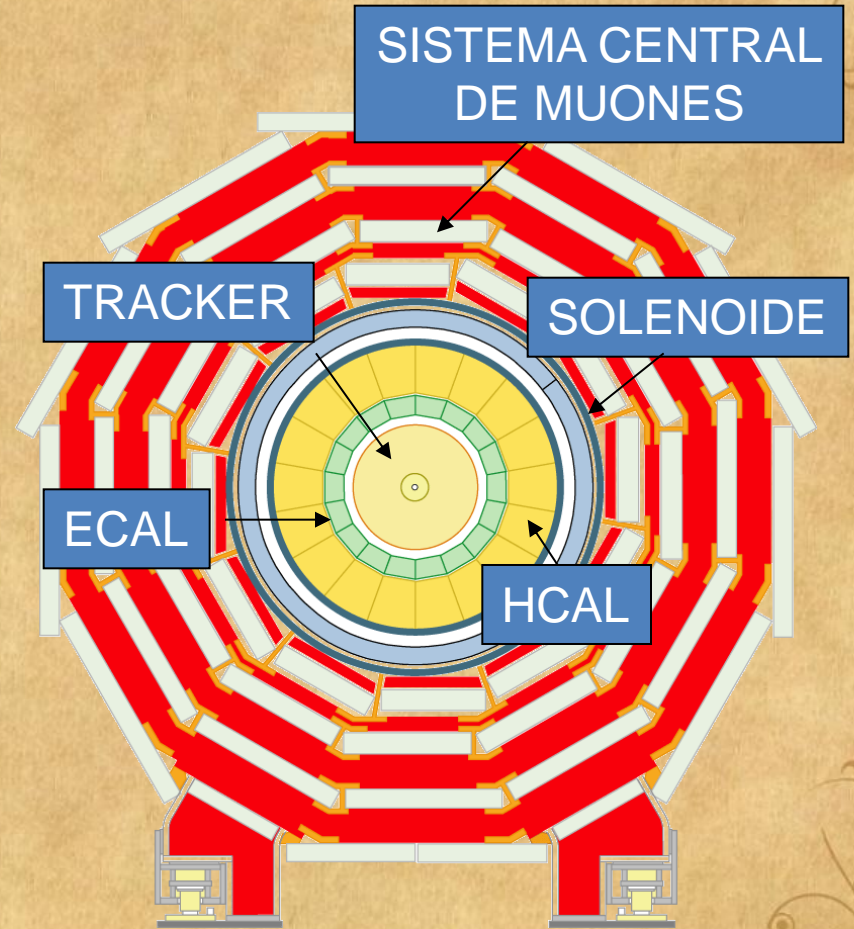
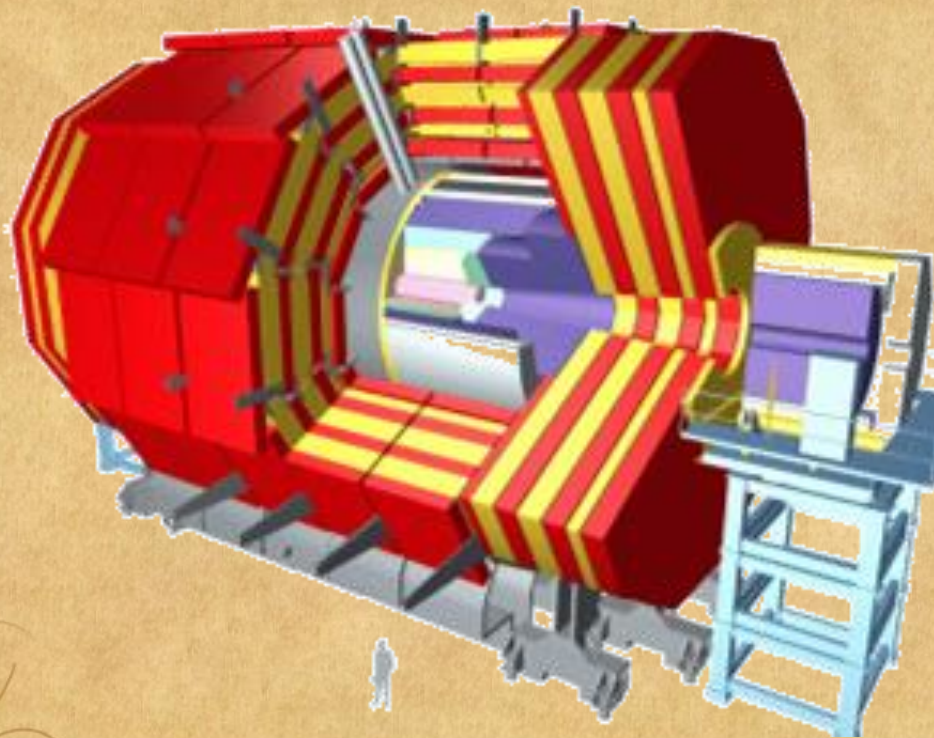


CDF TEVATRON

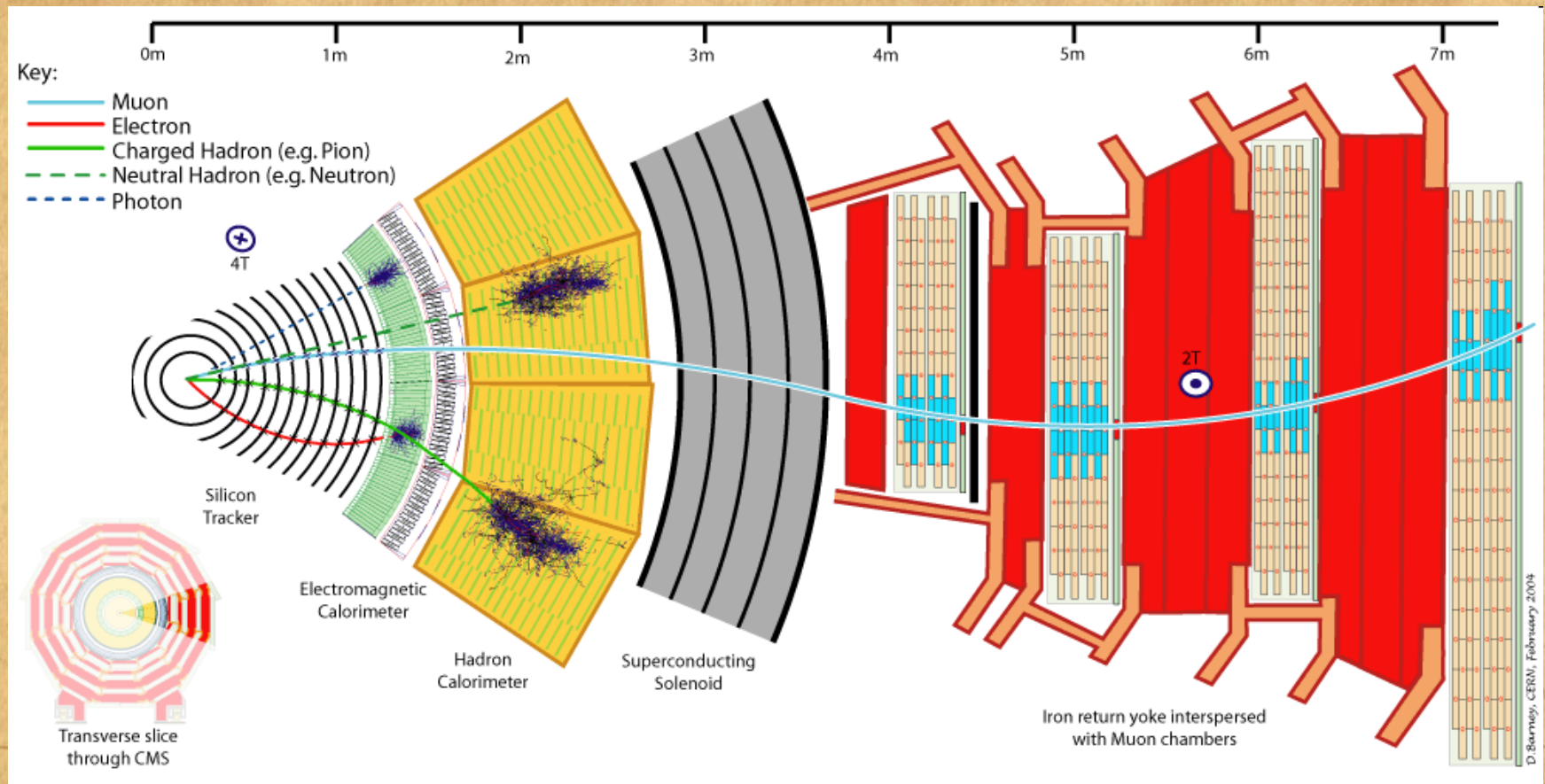


CMS, ATLAS,
LHCb y ALICE
LHC

CMS

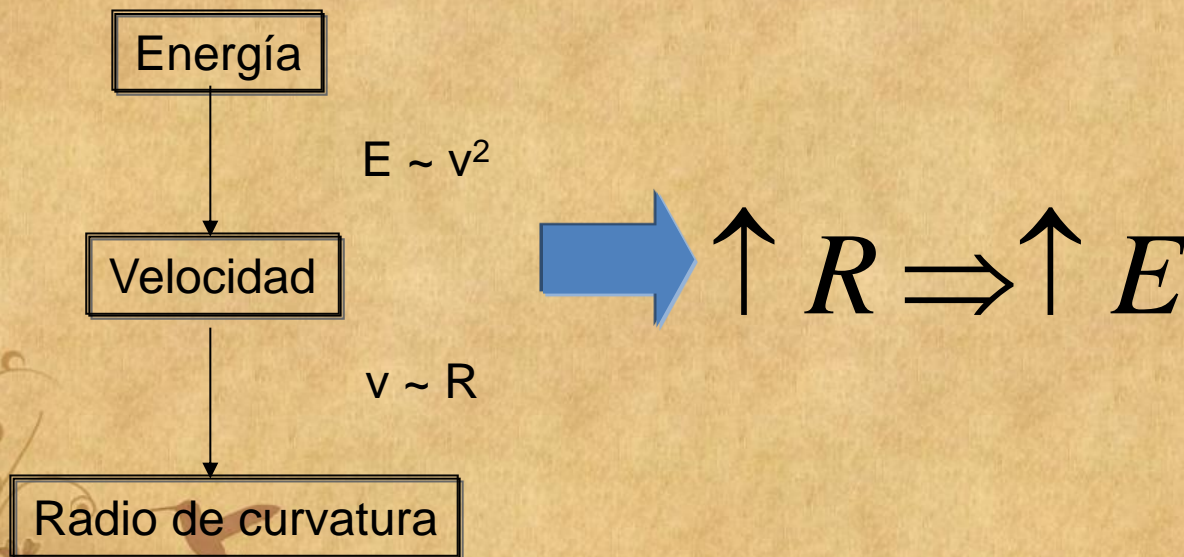


Identificacion en CMS



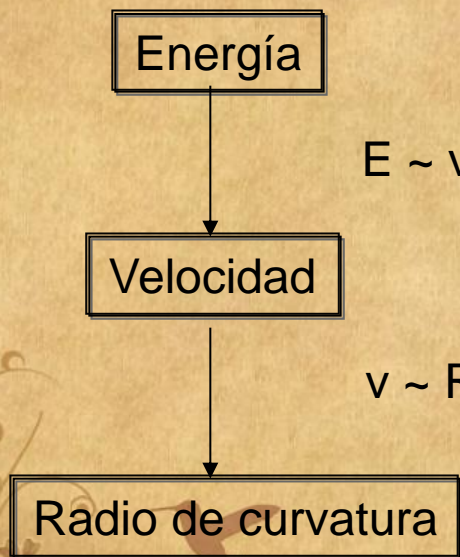
Obtención de magnitudes de interés

- Obtención de la energía de una partícula a través de la curvatura en un campo magnético

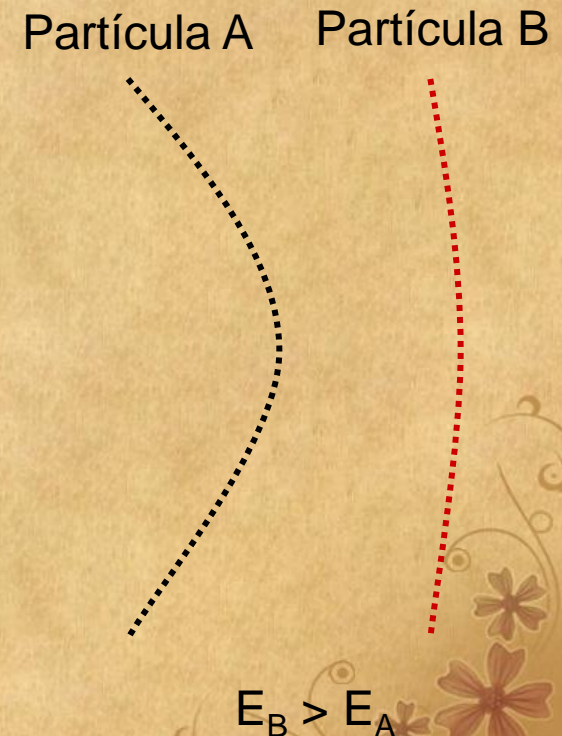


Obtención de magnitudes de interés

- Obtención de la energía de una partícula a través de la curvatura en un campo magnético

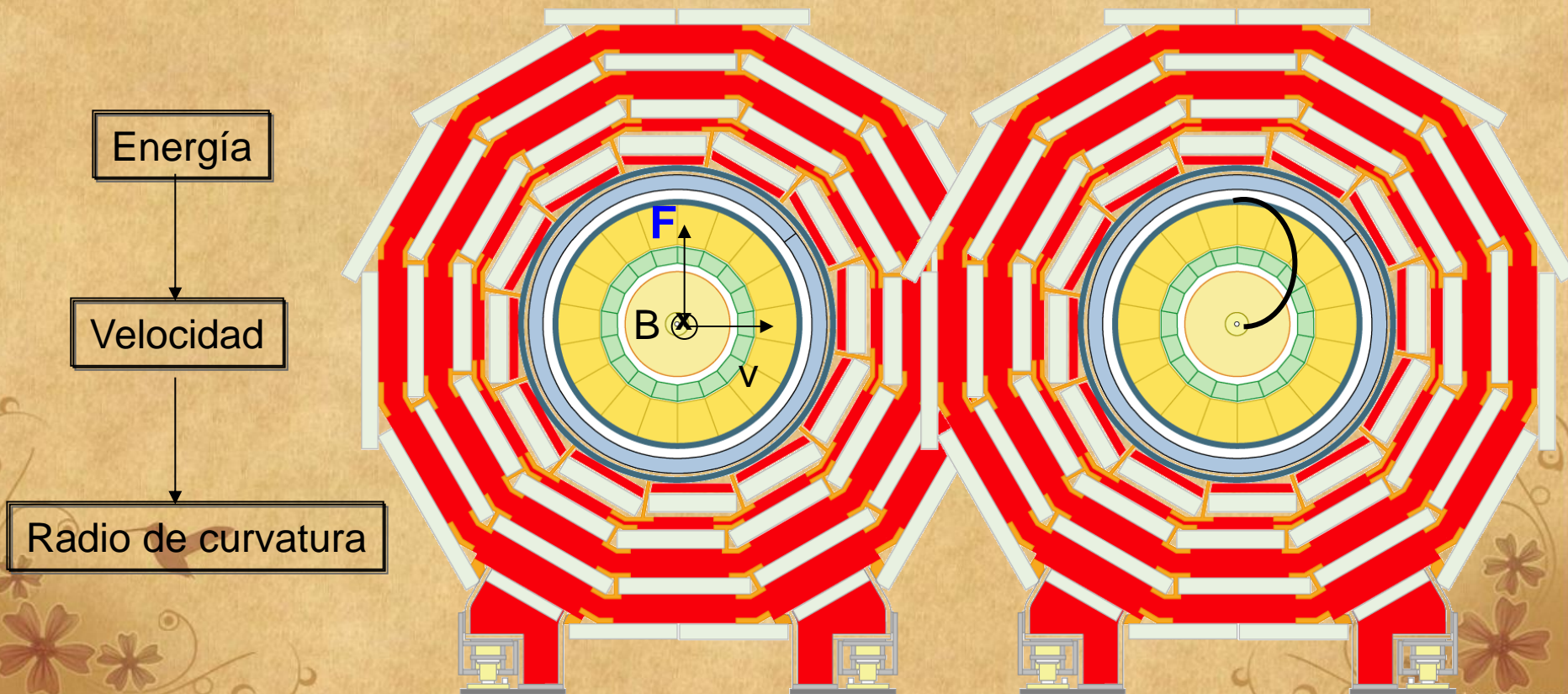


$$\uparrow R \Rightarrow \uparrow E$$



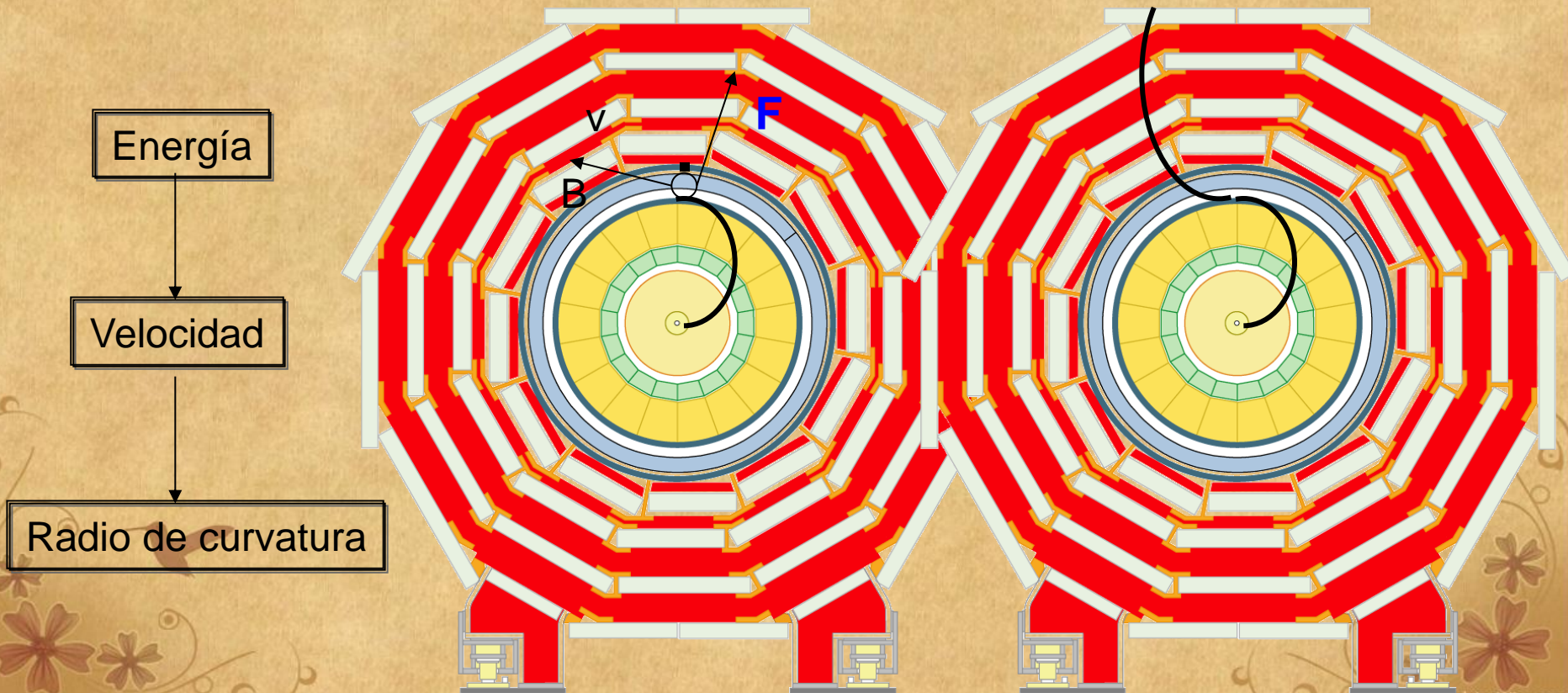
Obtención de magnitudes de interés

- Obtención de la energía de una partícula a través de la curvatura en un campo magnético



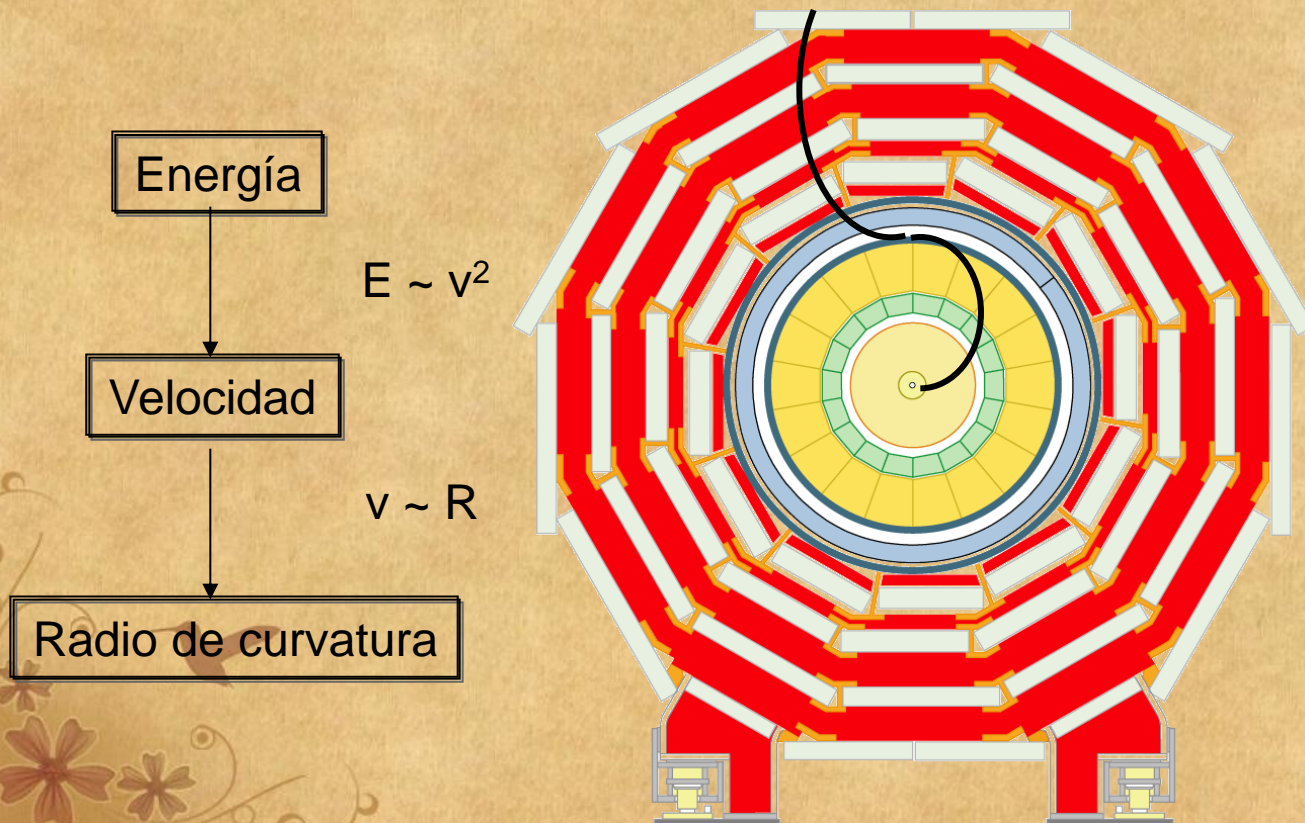
Obtención de magnitudes de interés

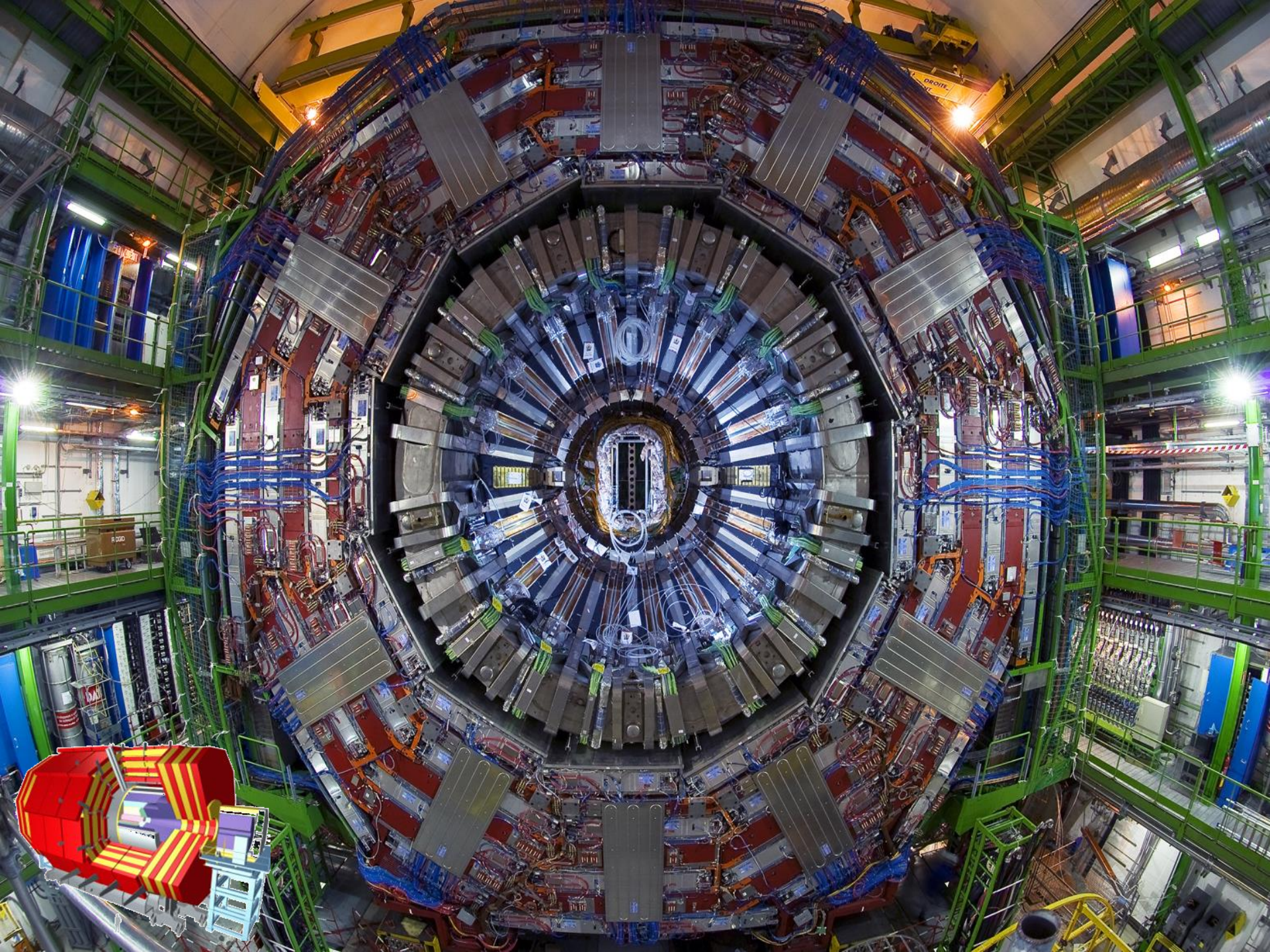
- Obtención de la energía de una partícula a través de la curvatura en un campo magnético



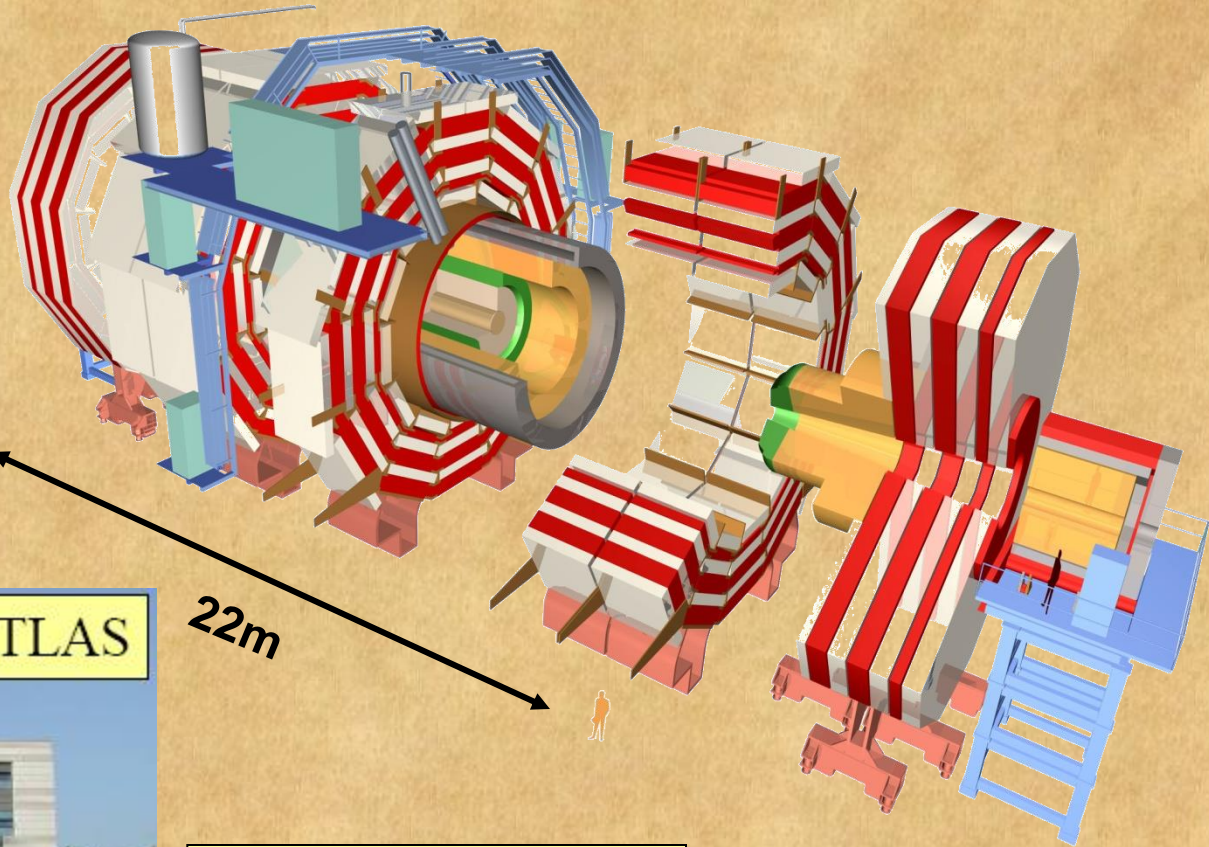
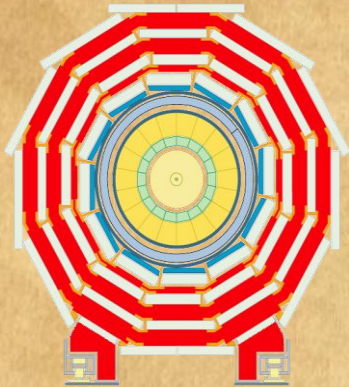
Obtención de magnitudes de interés

- Obtención de la energía de una partícula a través de la curvatura en un campo magnético





Compact Muon Solenoid



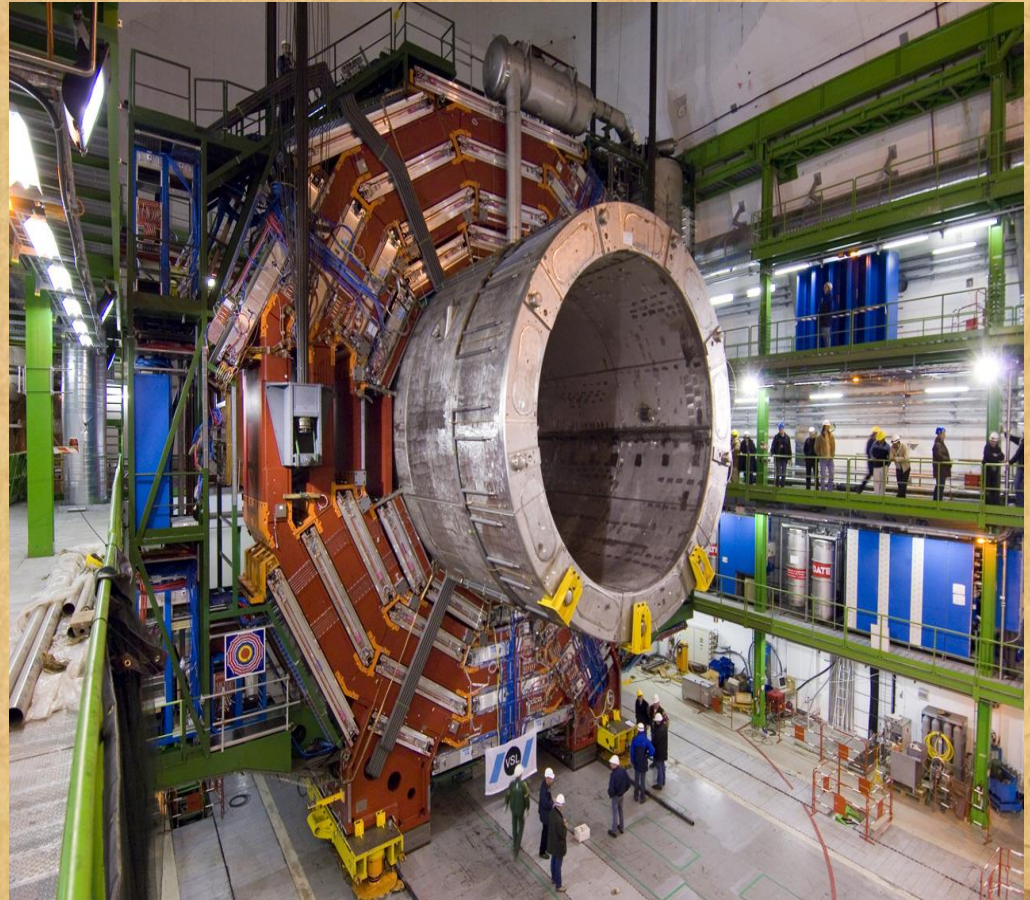
CMS 12500 toneladas
Atlas 7000 toneladas



CMS
~3000 Científicos
~200 Centros Inv.

Compact Muon Solenoid

- Fáciles de detectar (señal muy limpia)
- Muchas partículas de interés se esperan detectar a través de muones como productos finales.
- 25% de las cámaras de muones hechas en CIEMAT, testeadas y validadas, y ahora calibradas.

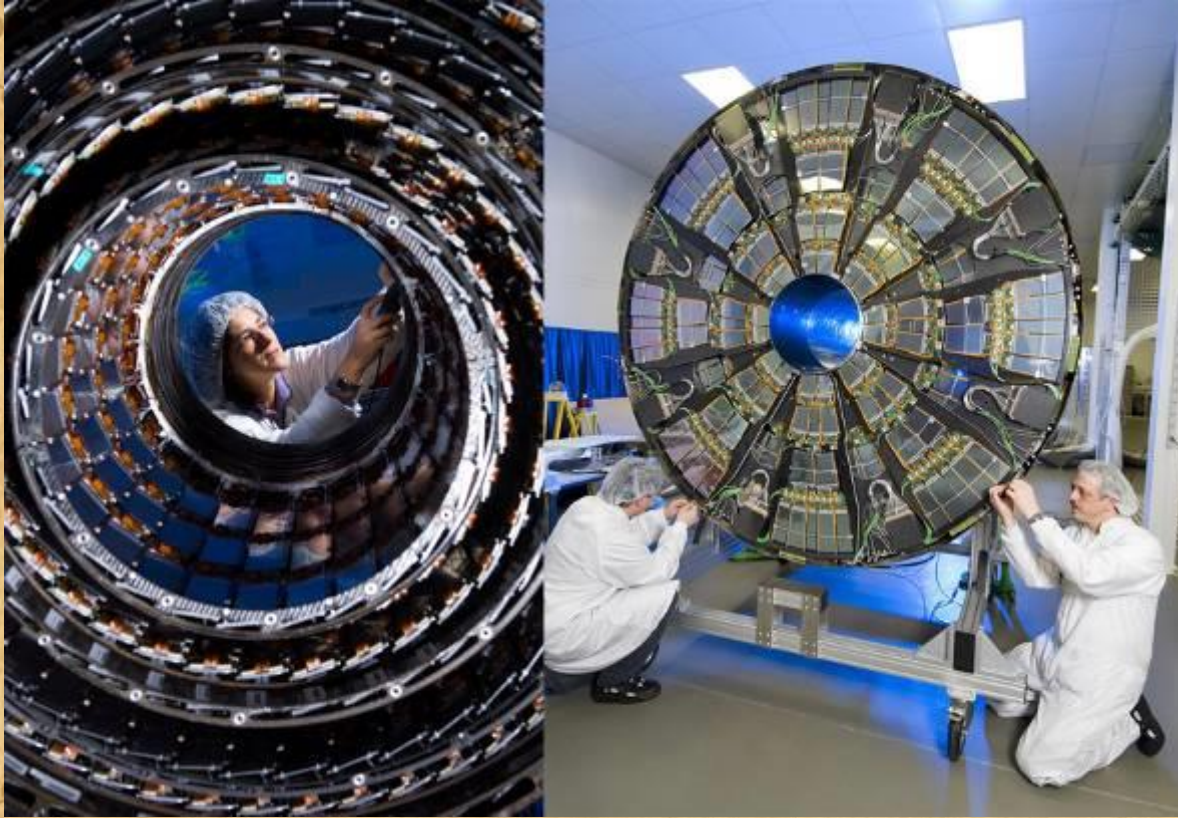


Compact Muon Solenoid



- Cilindro de 13m (largo) x 6m diámetro. Mayor solenoide superconductor jamás construído.
- Hace circular 20000 A a una temperatura de -271°C para crear un campo magnético de 4Tesla
- El campo creado es 100000 veces mayor que el de la Tierra.

Tracker



- Sensores de silicio. Miden la trayectoria de las partículas cargadas para medir su momento.
- Equivale a una cámara digital de 70Mpixels tomando 40 millones de fotos por segundo.
- Es el detector de silicio más grande jamás construido.

Objetivo: medir trayectorias de partículas cargadas (momento)

ECAL



- 80000 cristales de PbWO_4 .
- Produce luz al paso de una partícula. La cantidad de luz producida es proporcional a la energía de la partícula incidente.
- Cada cristal $\sim 10000\$$

Objetivo: mide la energía de fotones, electrones y positrones.

HCAL



- Capas de metal intercaladas con centelleadores plásticos o fibras de cuarzo.
- Latón del HCAL reciclado de la artillería rusa.



Objetivo: medir la energía de los hadrones (protones, neutrones..)

Muones

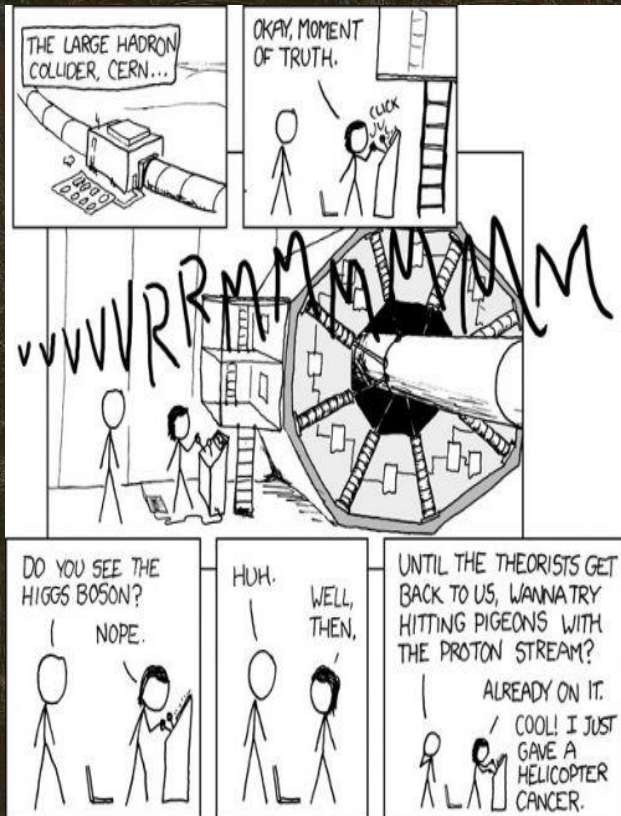


- Tres tipos distintos de detectores de muones en CMS.
- Área total area del detector es el mismo que el de un campo de fútbol (6000m²)

Objetivo: medir el momento de los muones.

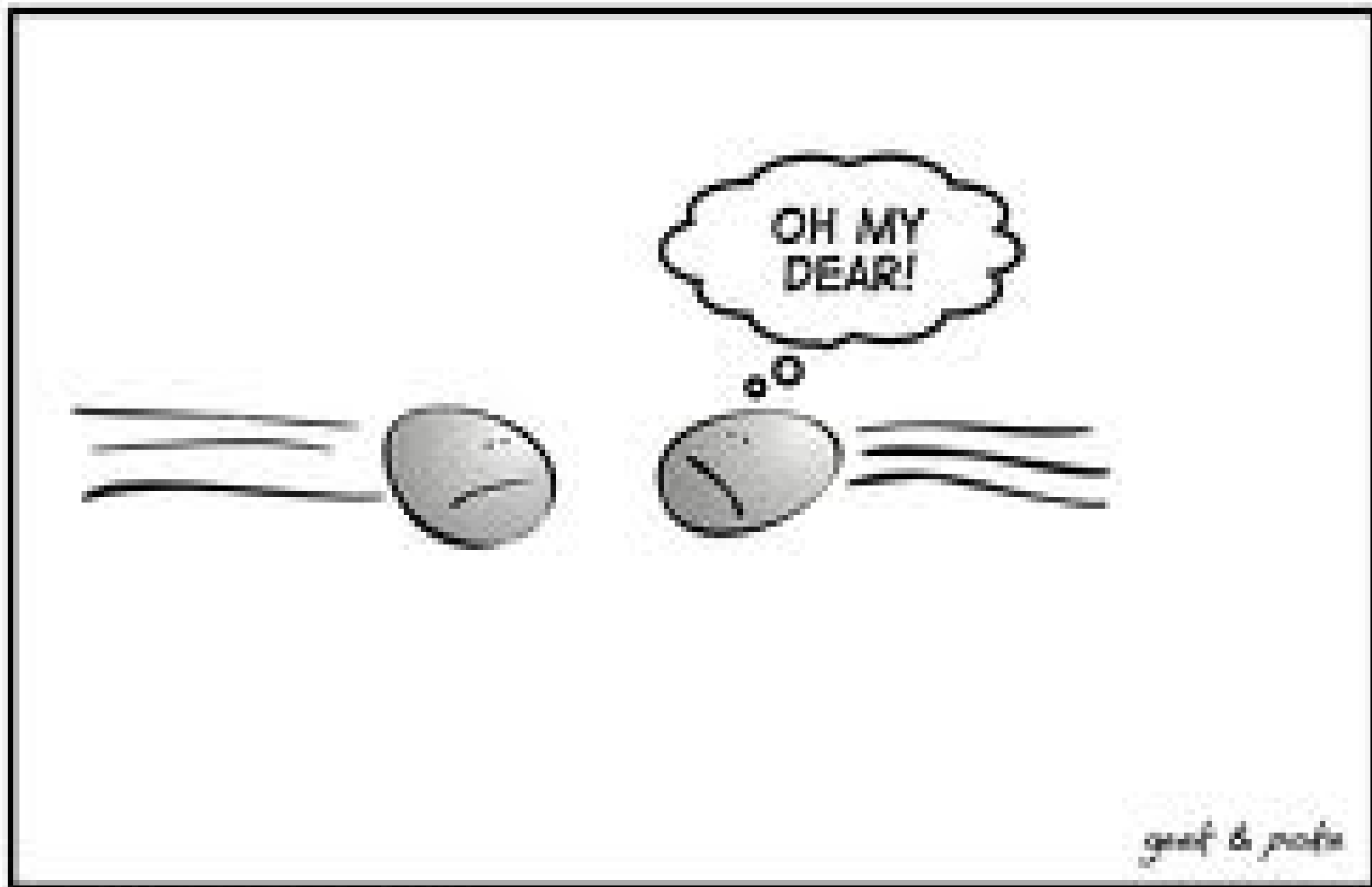
CMS

El analisis

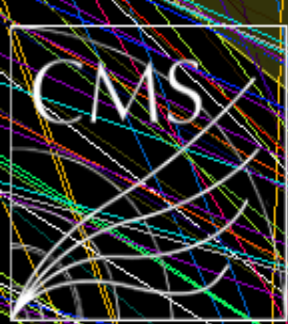


- **Indice:**

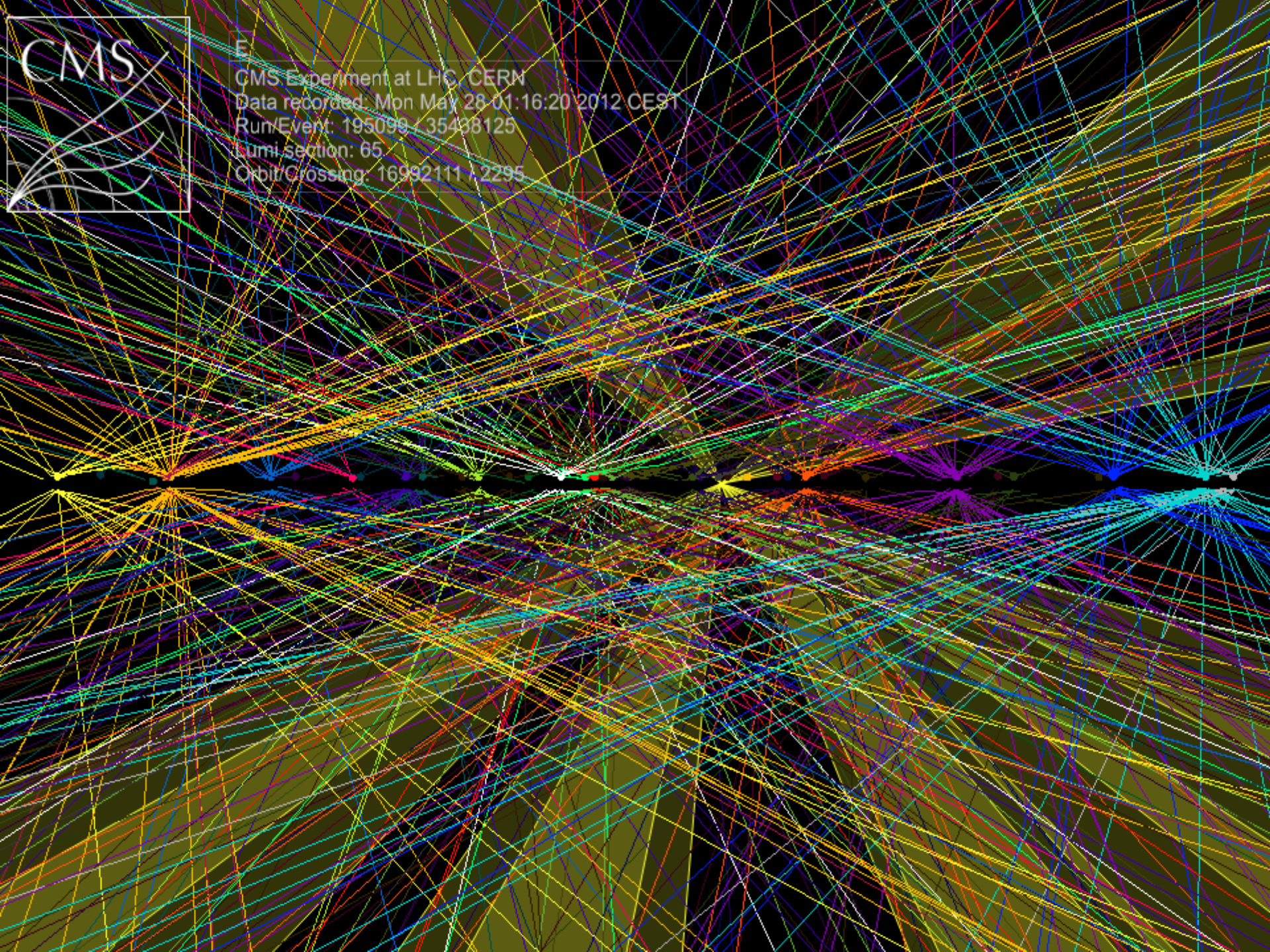
1. Reconstrucción
2. Filtrado
3. GRID

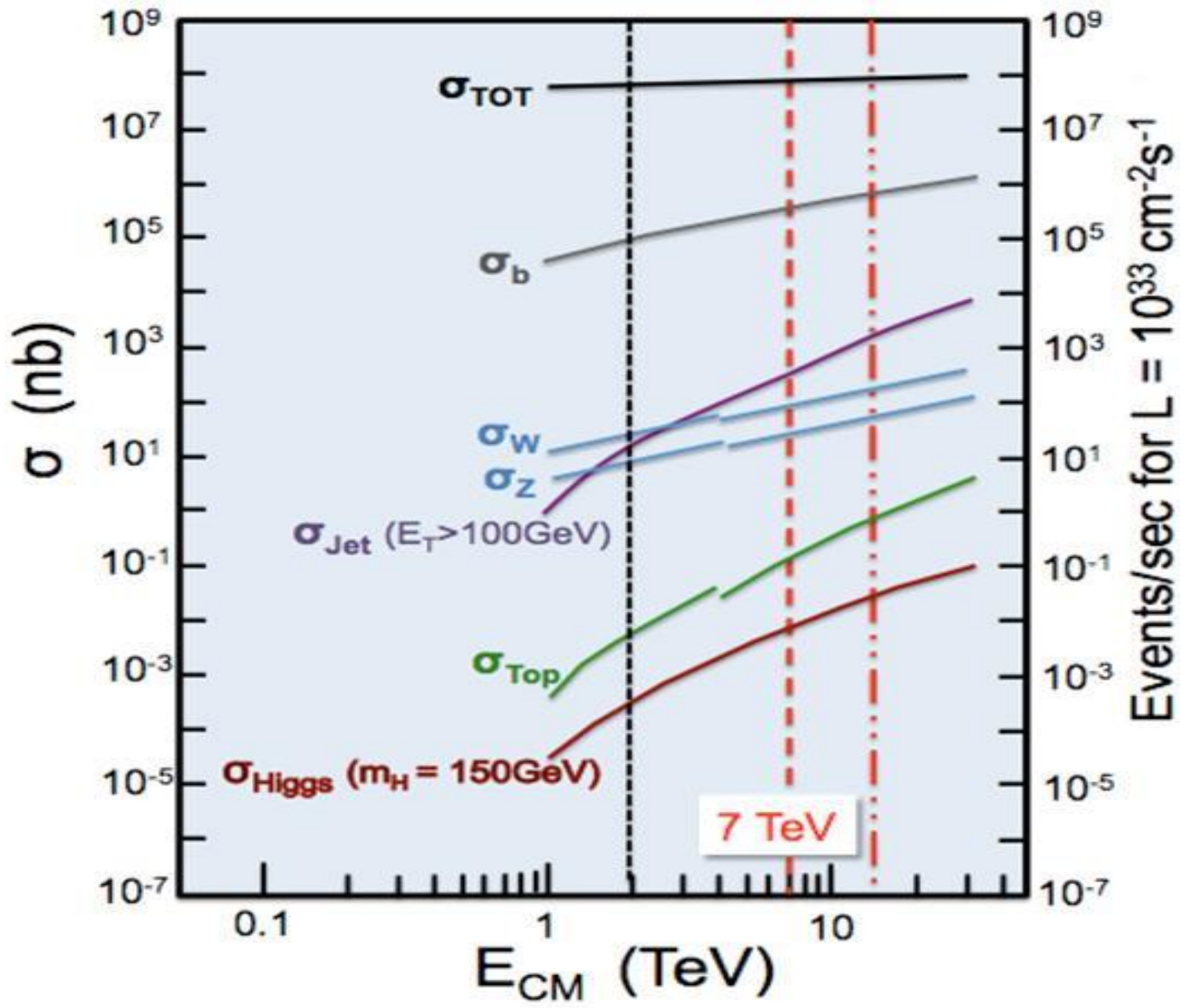


LATELY INSIDE THE LHC:
2 PROTONS 0.000000000000000000001 SEC BEFORE THE COLLISION



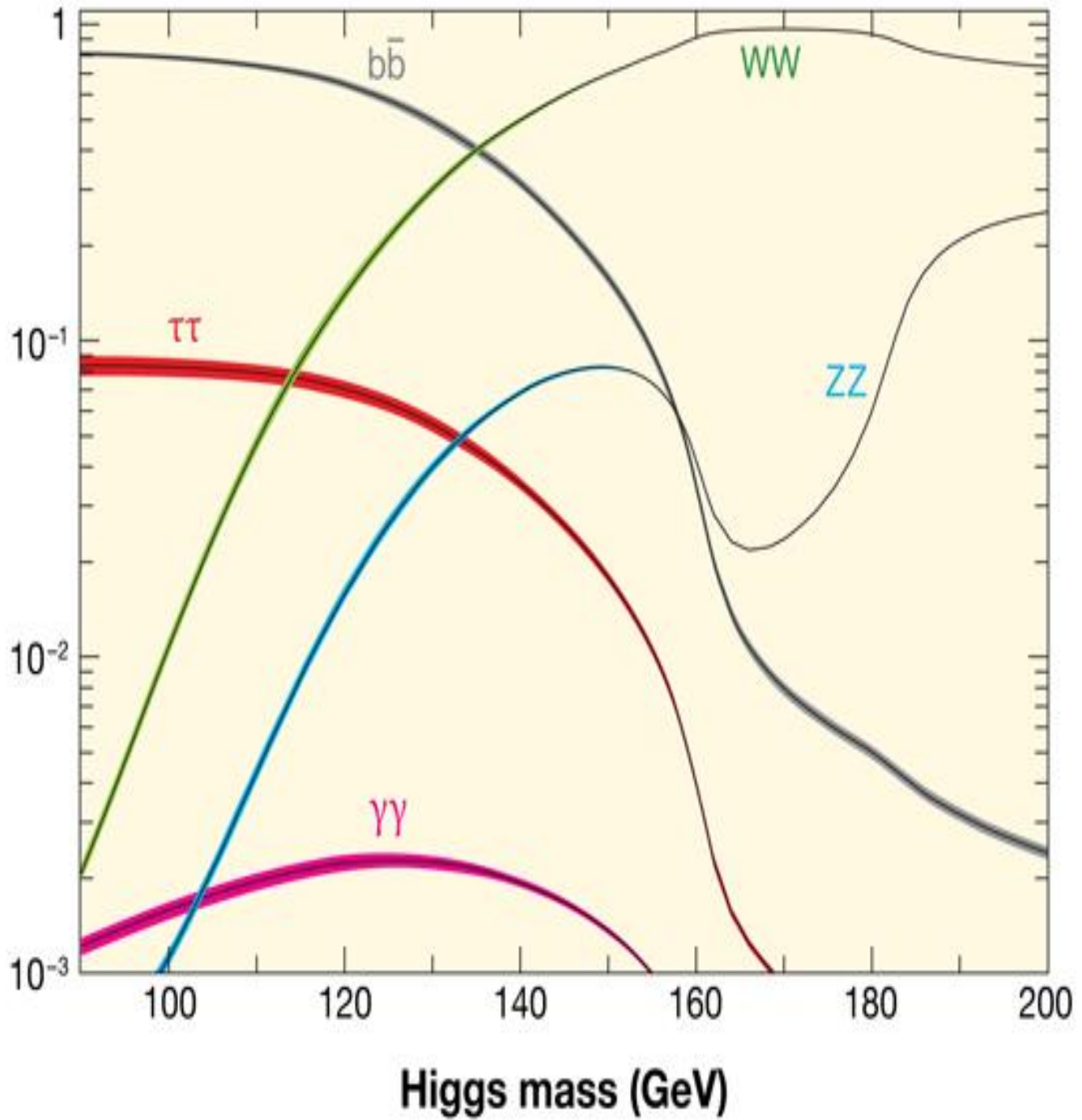
E
CMS Experiment at LHC, CERN
Data recorded: Mon May 28 01:16:20 2012 CEST
Run/Event: 195098 / 35438125
Lumi section: 65
Orbit/Crossing: 16992111 / 2295

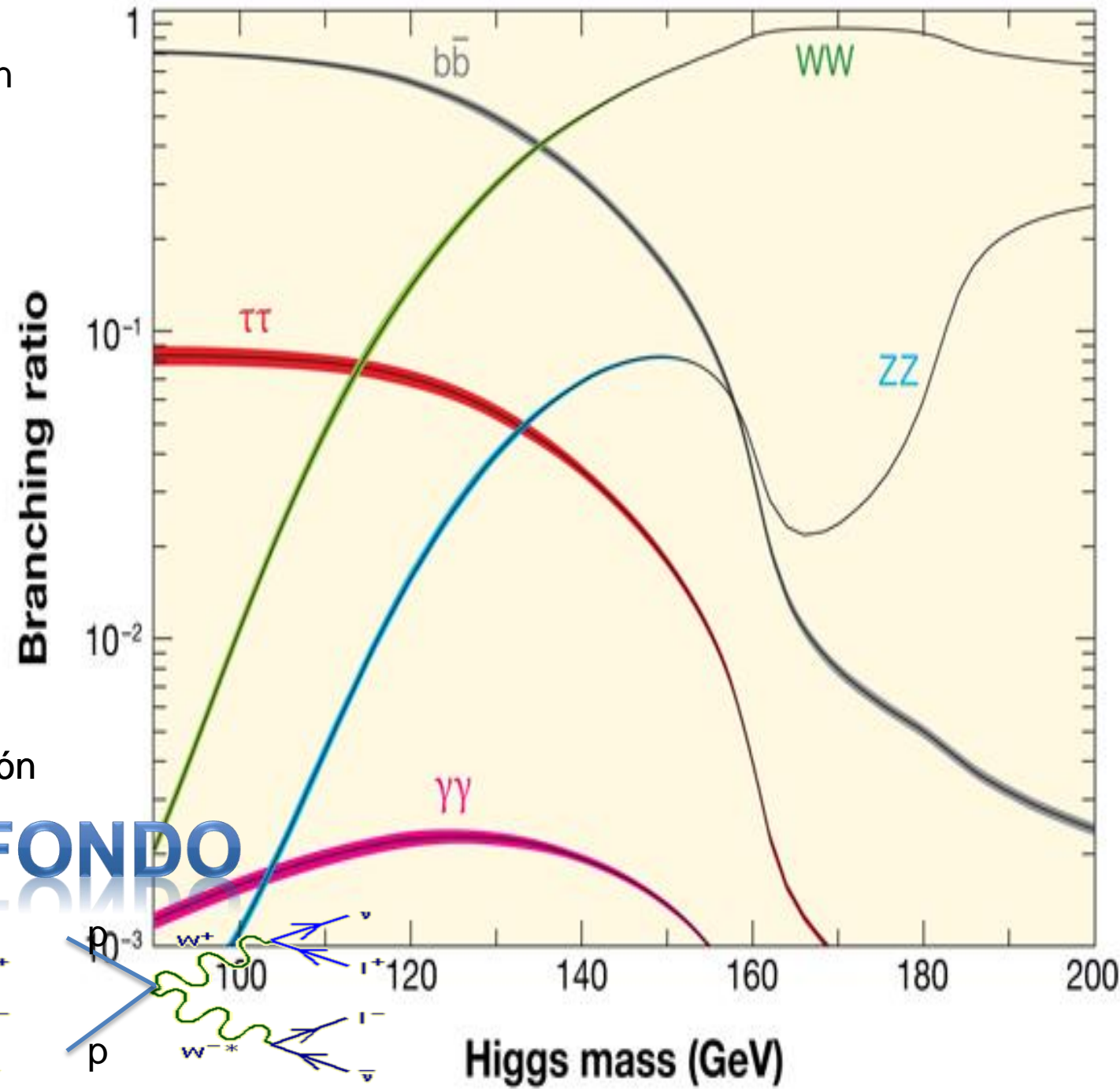




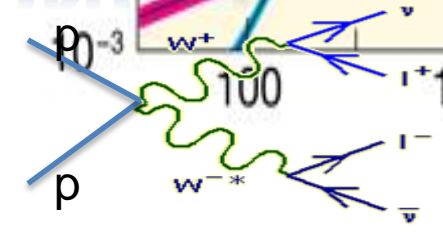
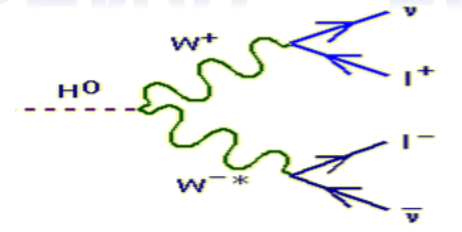


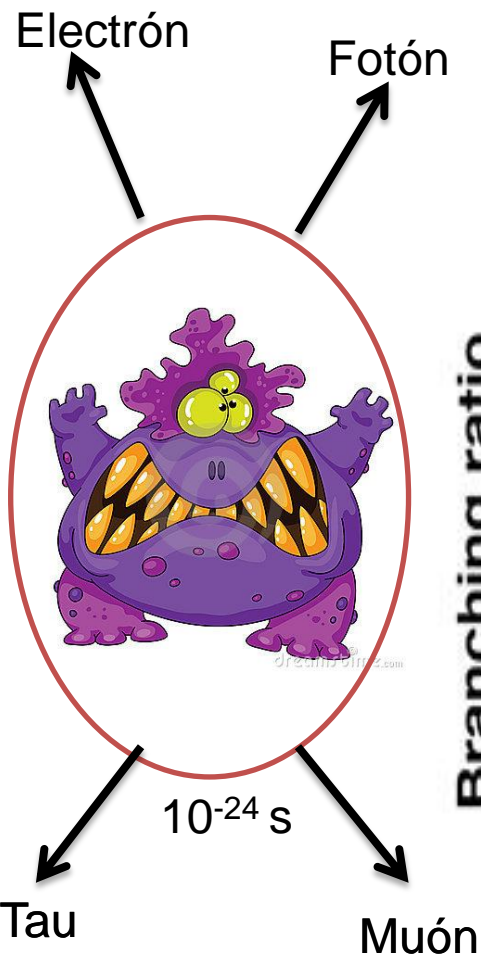
Branching ratio



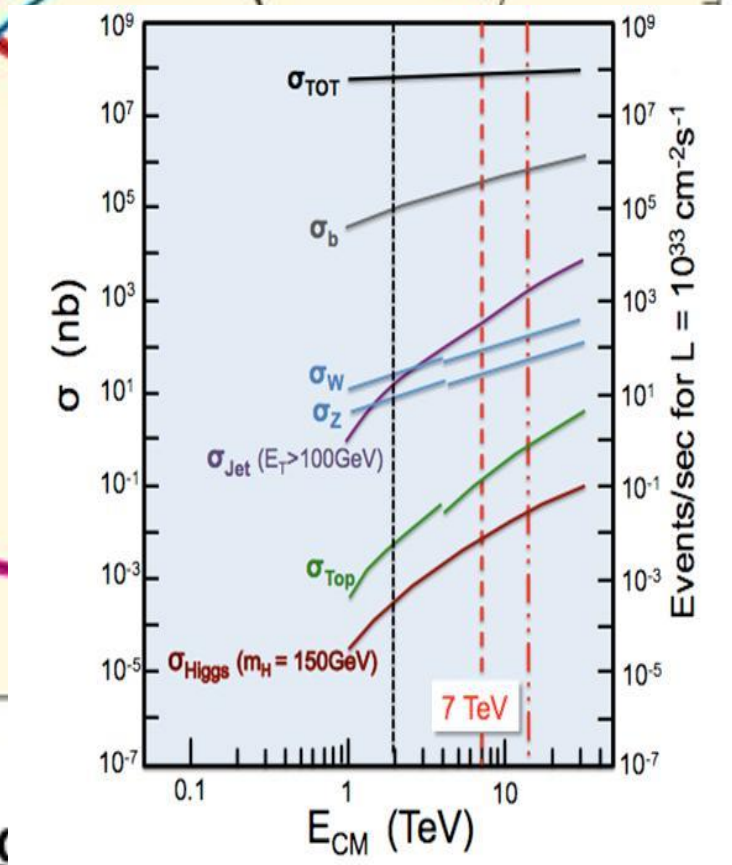
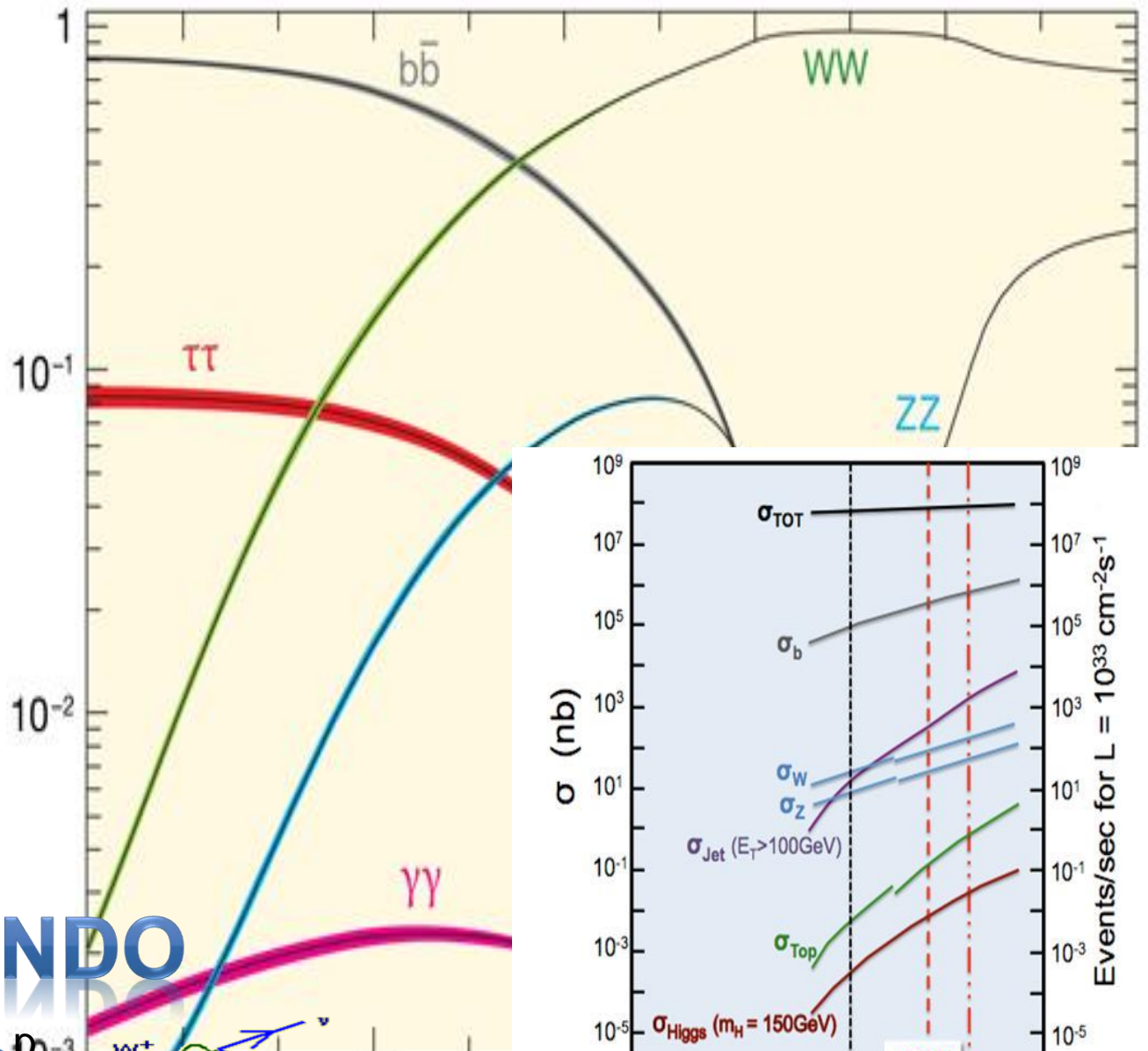


SEÑAL FONDO

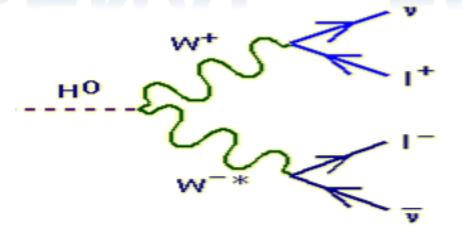




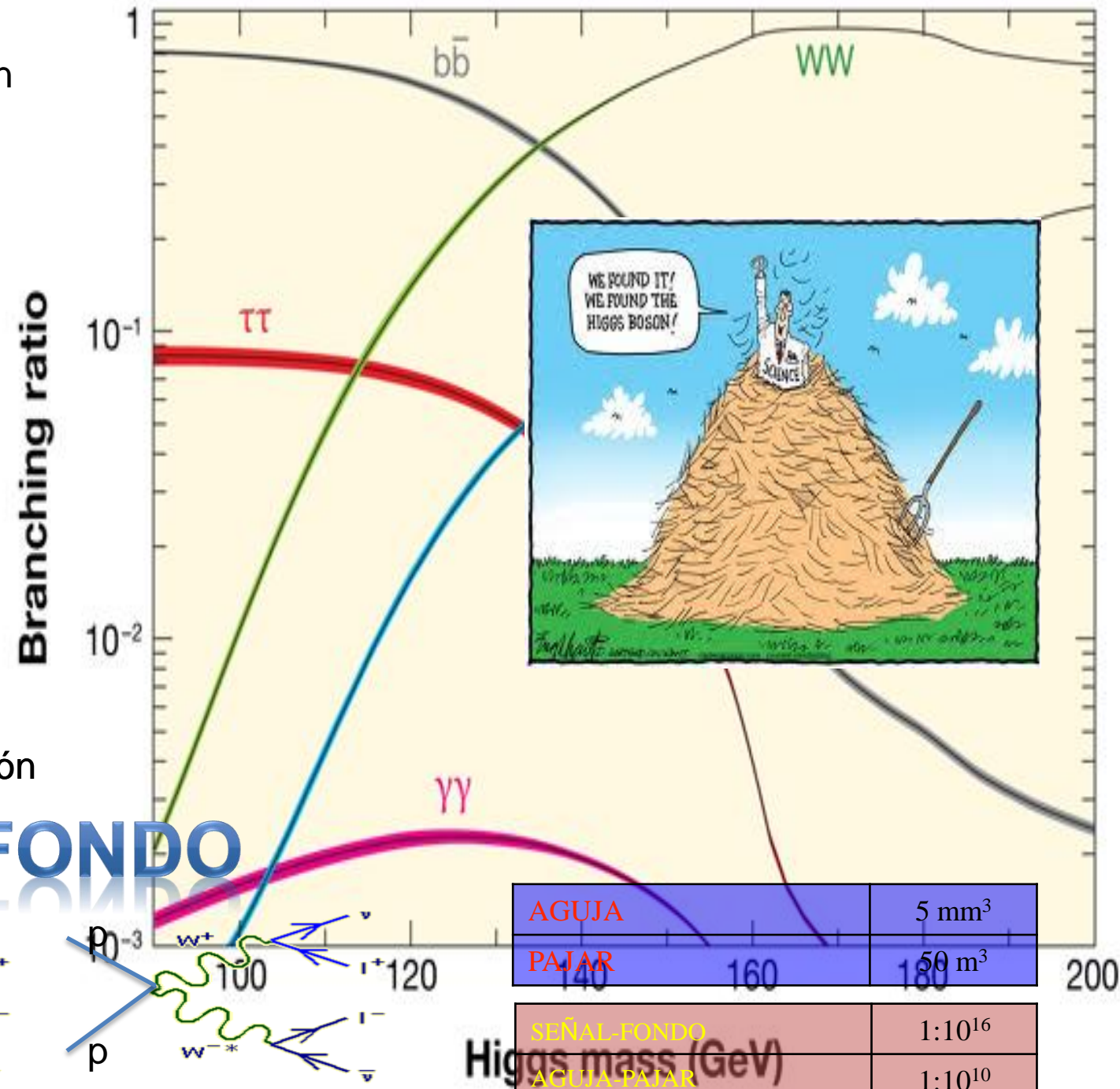
Branching ratio



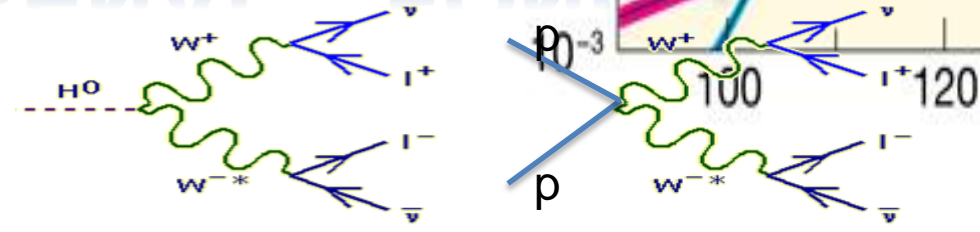
SEÑAL FONDO



Higgs



SEÑAL FONDO



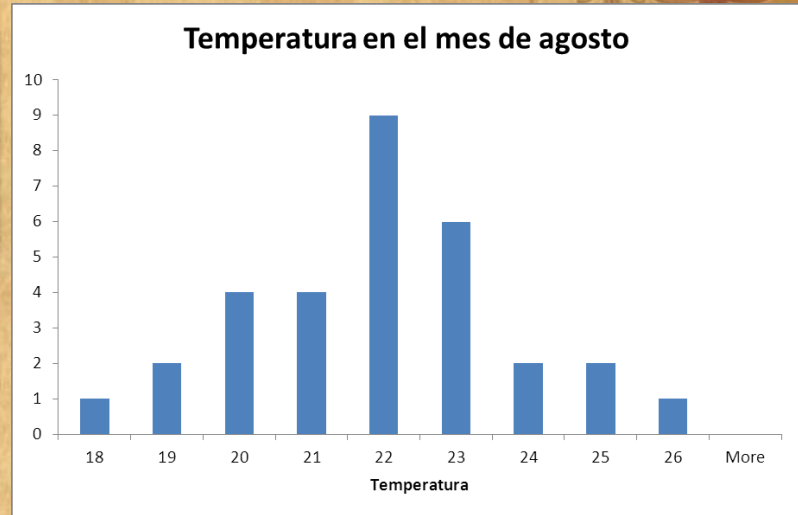
AGUJA	5 mm ³
PAJAR	50 m ³
SEÑAL-FONDO	1:10 ¹⁶
AGUJA-PAJAR	1:10 ¹⁰



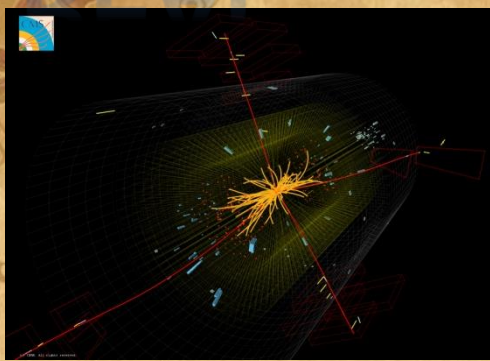
Histograma



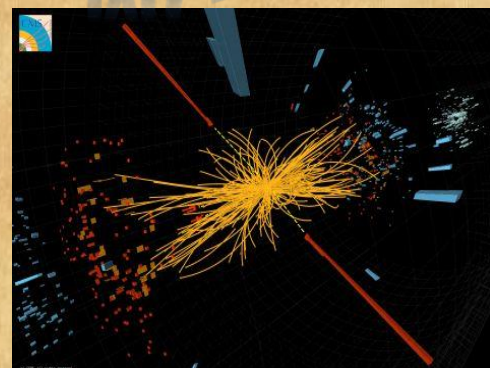
Histograma



REAL



MC



Histograma

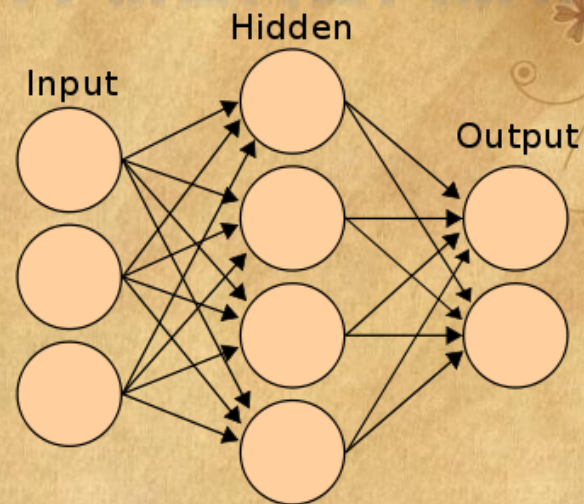


MC



RED NEURONAL

Histograma



BDT, MVA,...



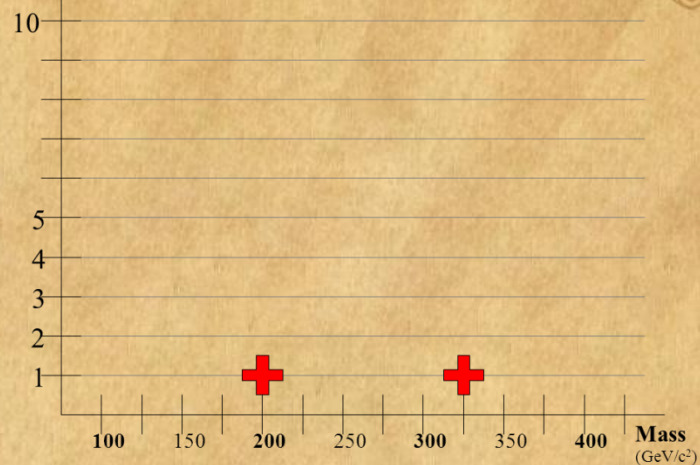
MC

Métodos
de
Análisis

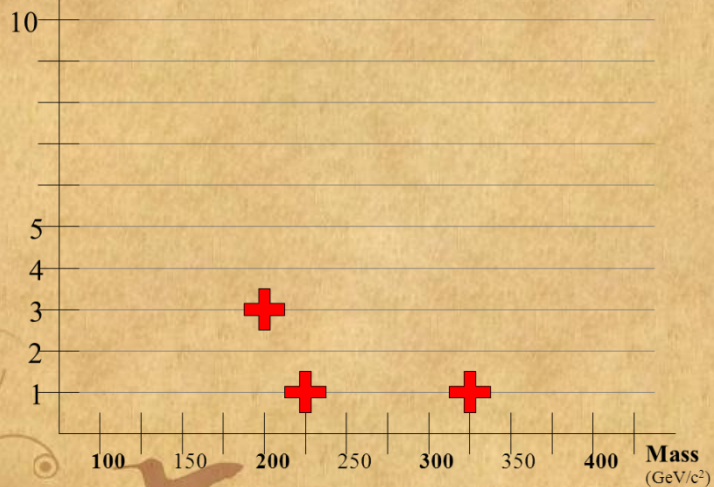
Number of events



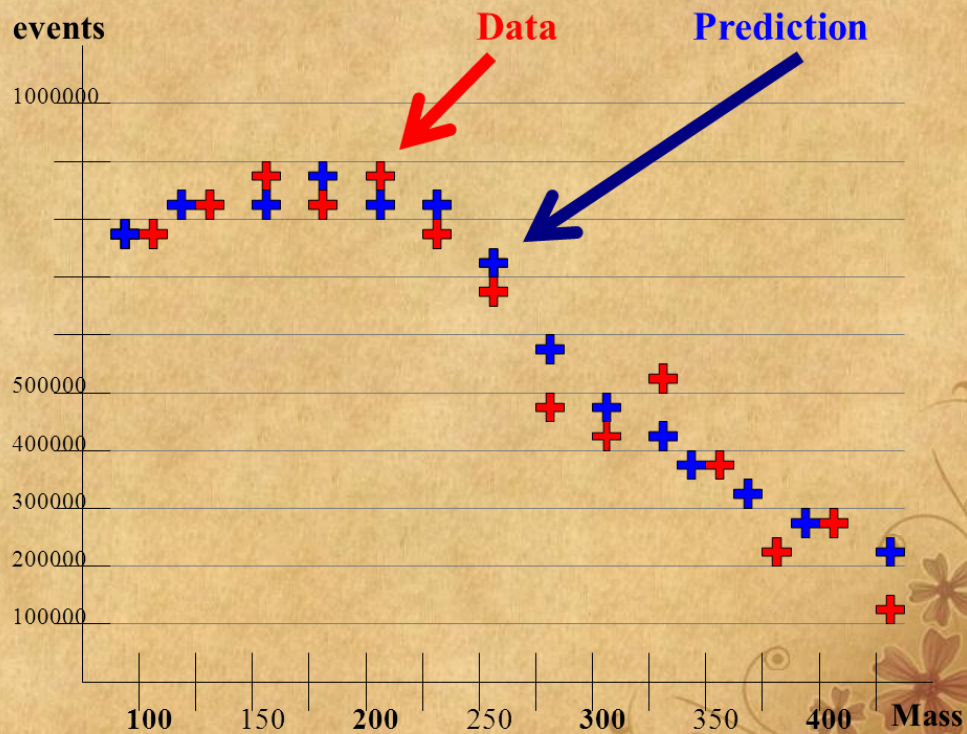
Number of events



Number of events

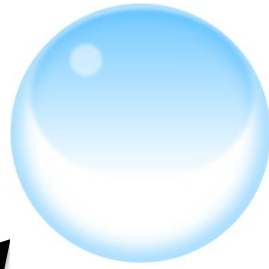
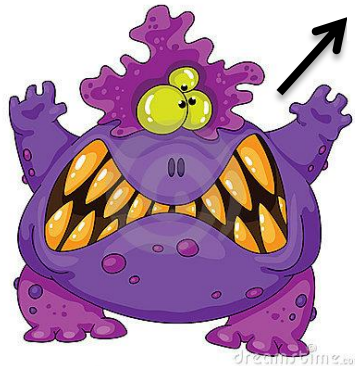


Number of events



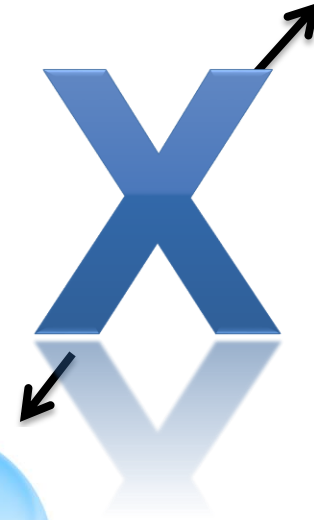
¡Gracias Daniel!

¡LA MASA!



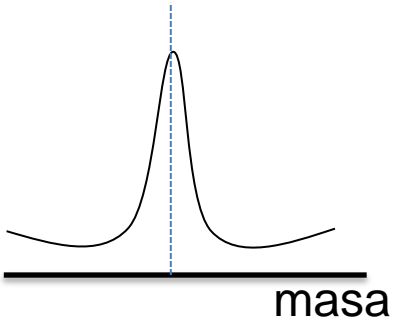
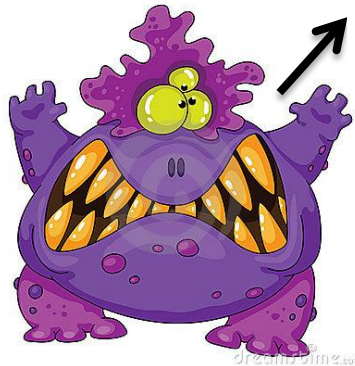
$$E = mc^2$$

¡LA MASA!

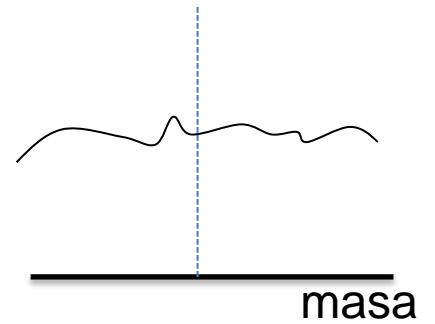


$$E=mc^2$$

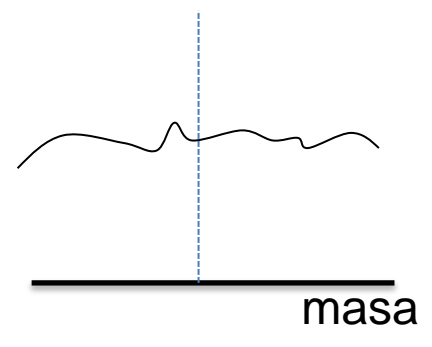
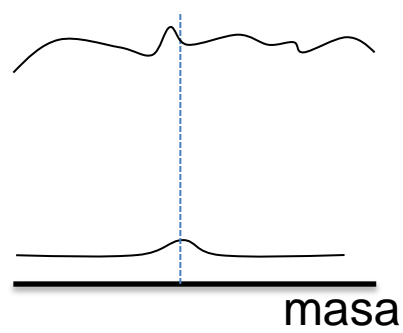
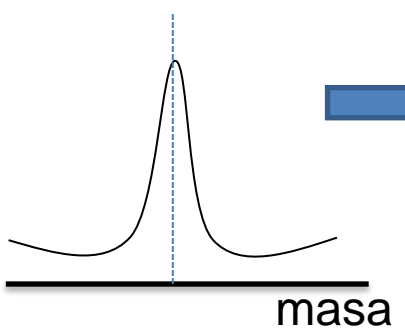
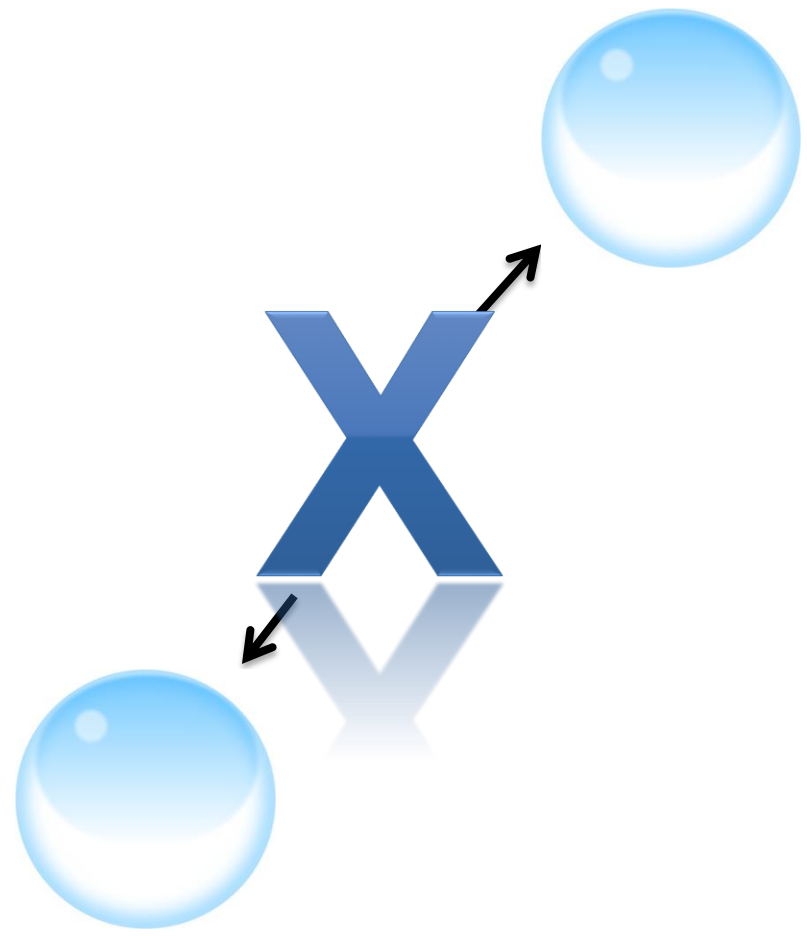
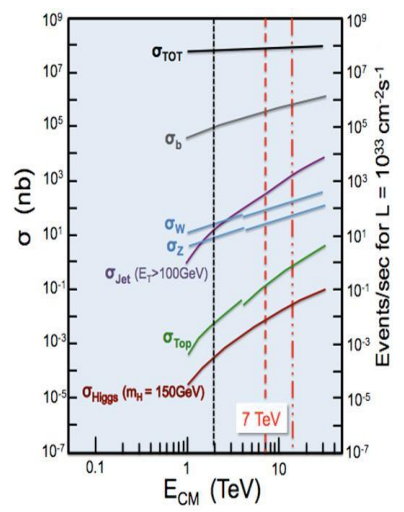
¡LA MASA!



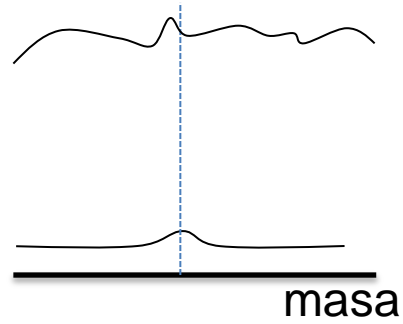
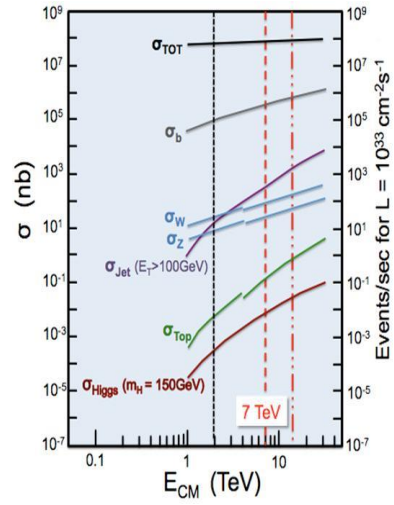
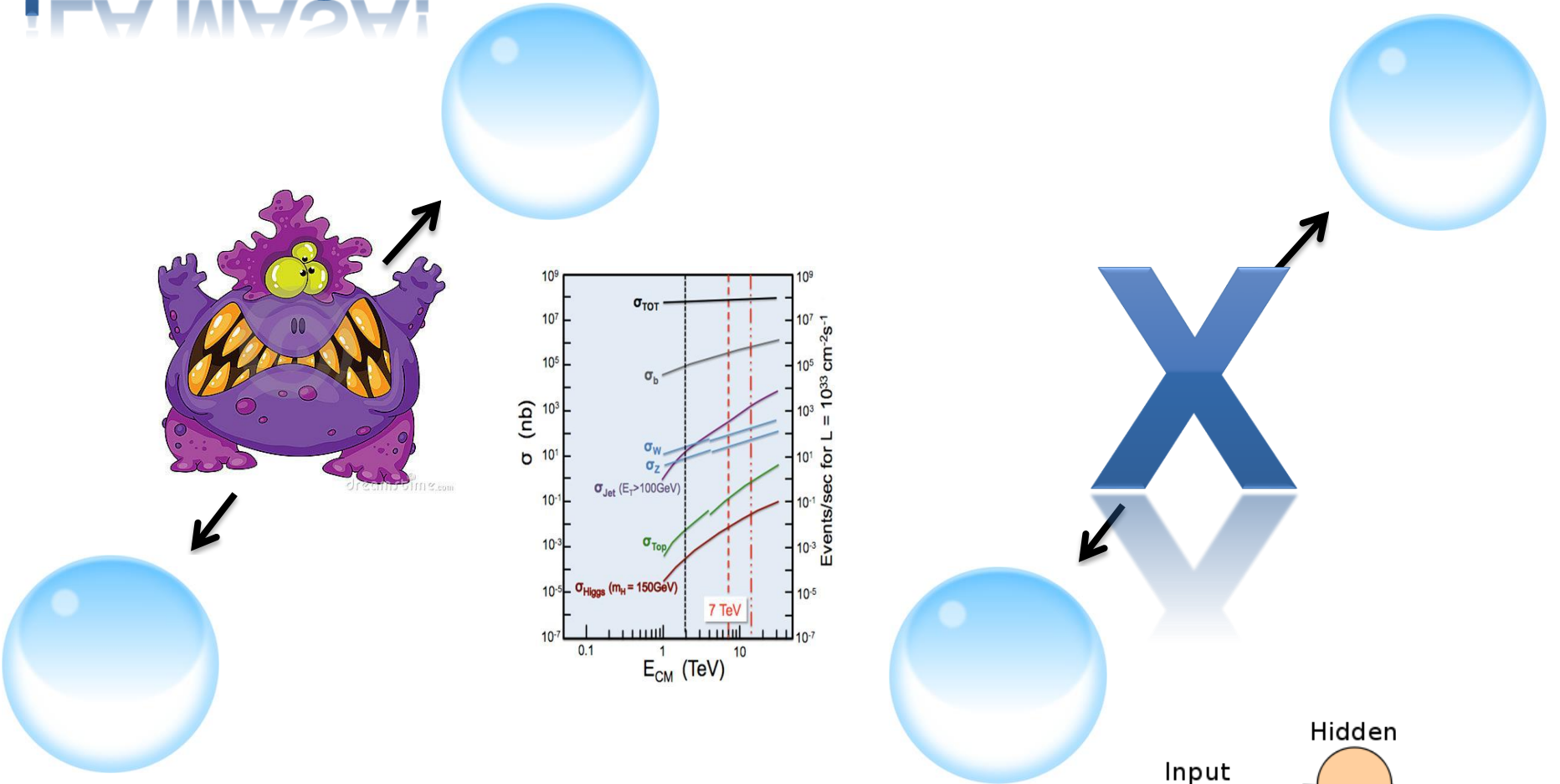
$$E = mc^2$$



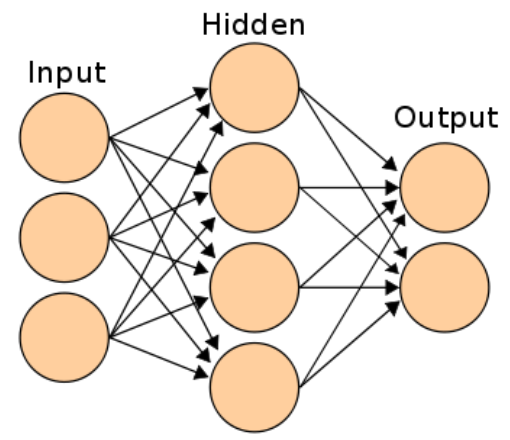
¡LA MASA!



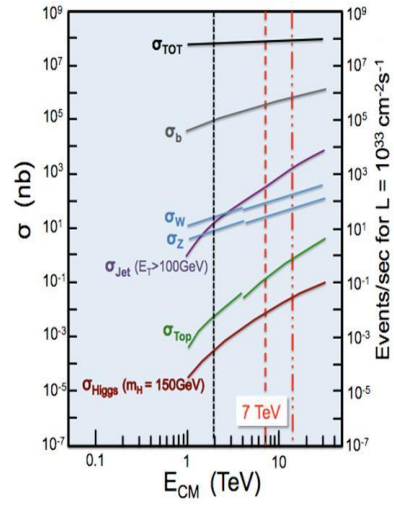
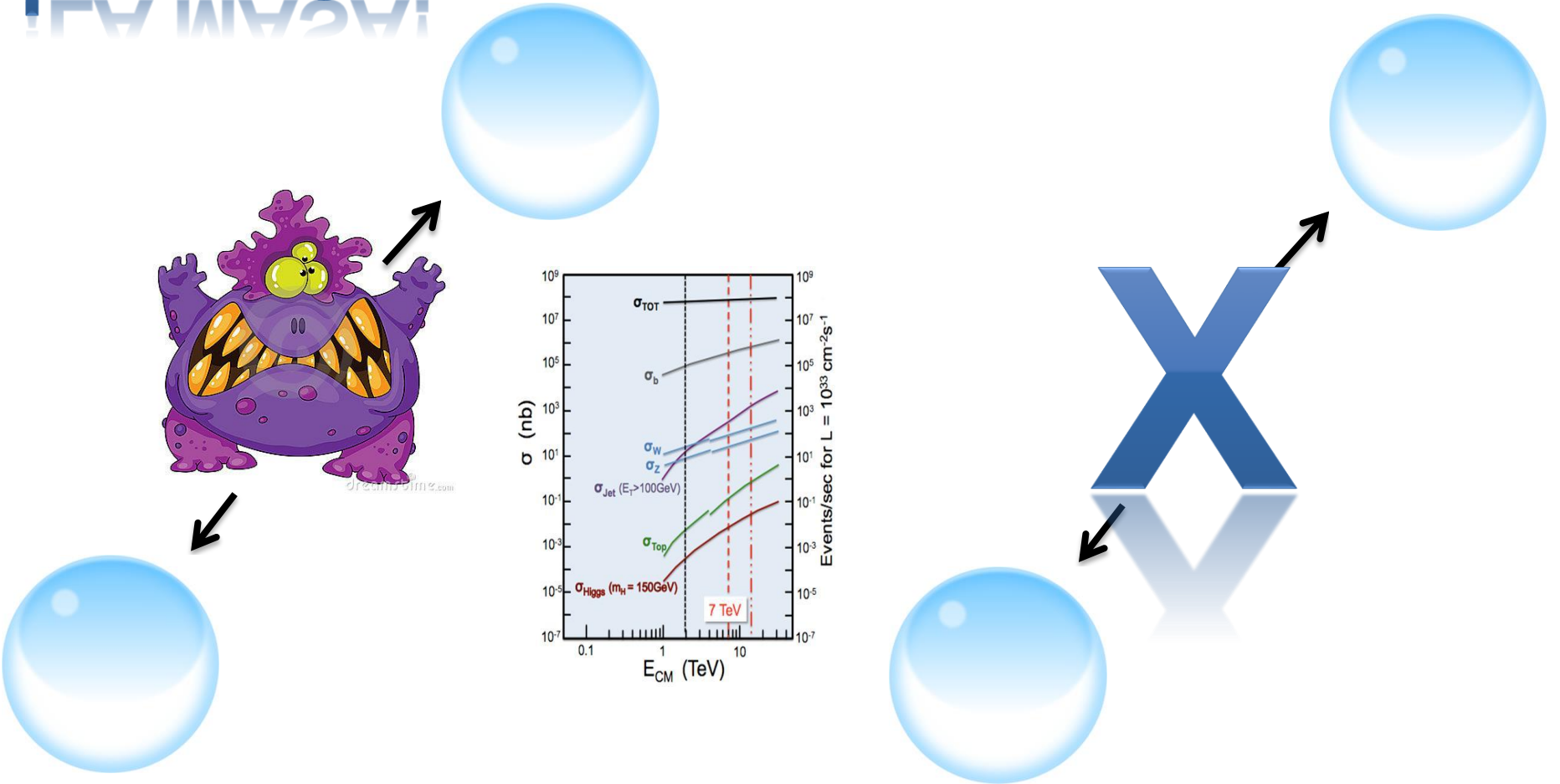
¡LA MASA!



¡HAY QUE FILTRAR!



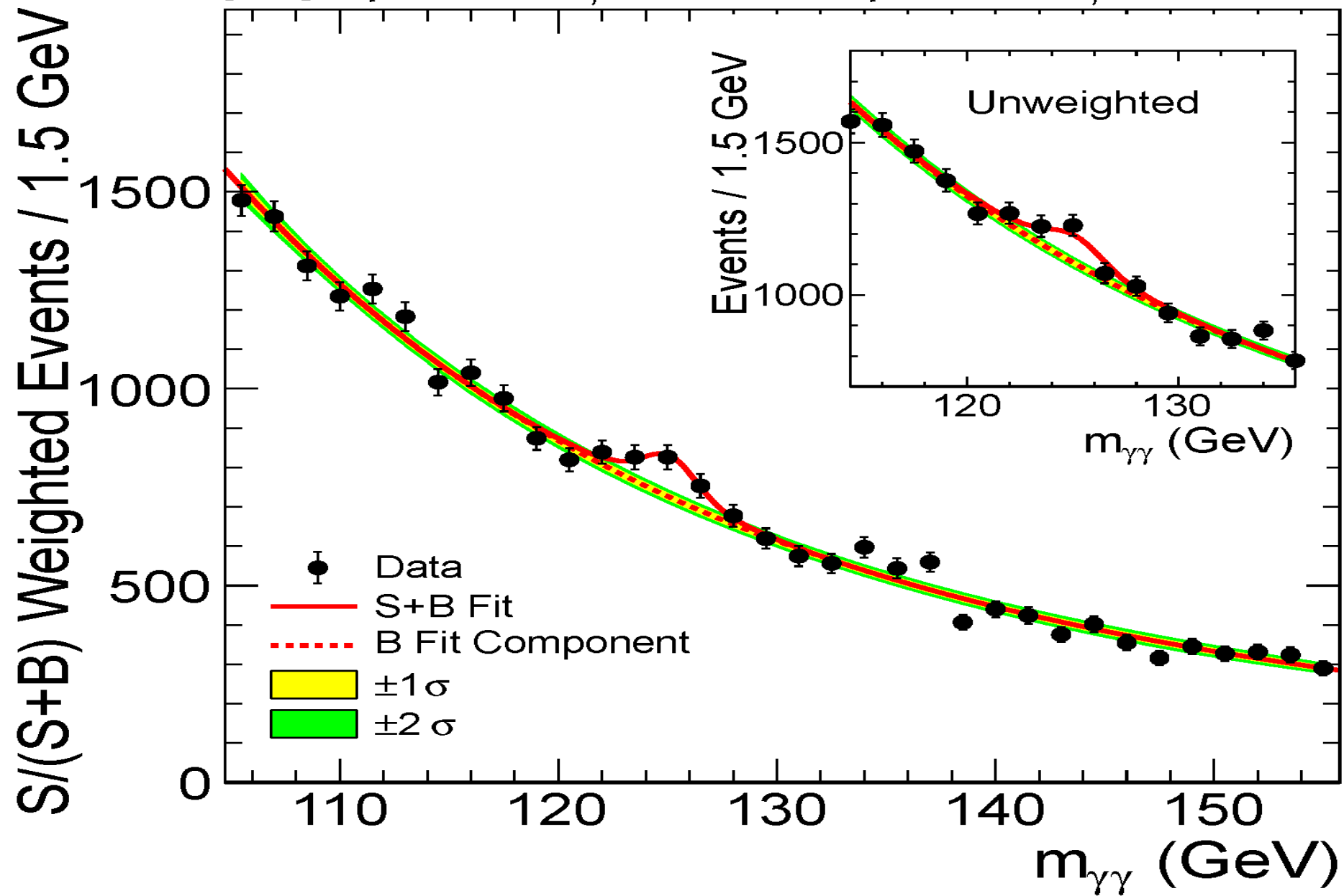
¡LA MASA!



¡HAY QUE FILTRAR!



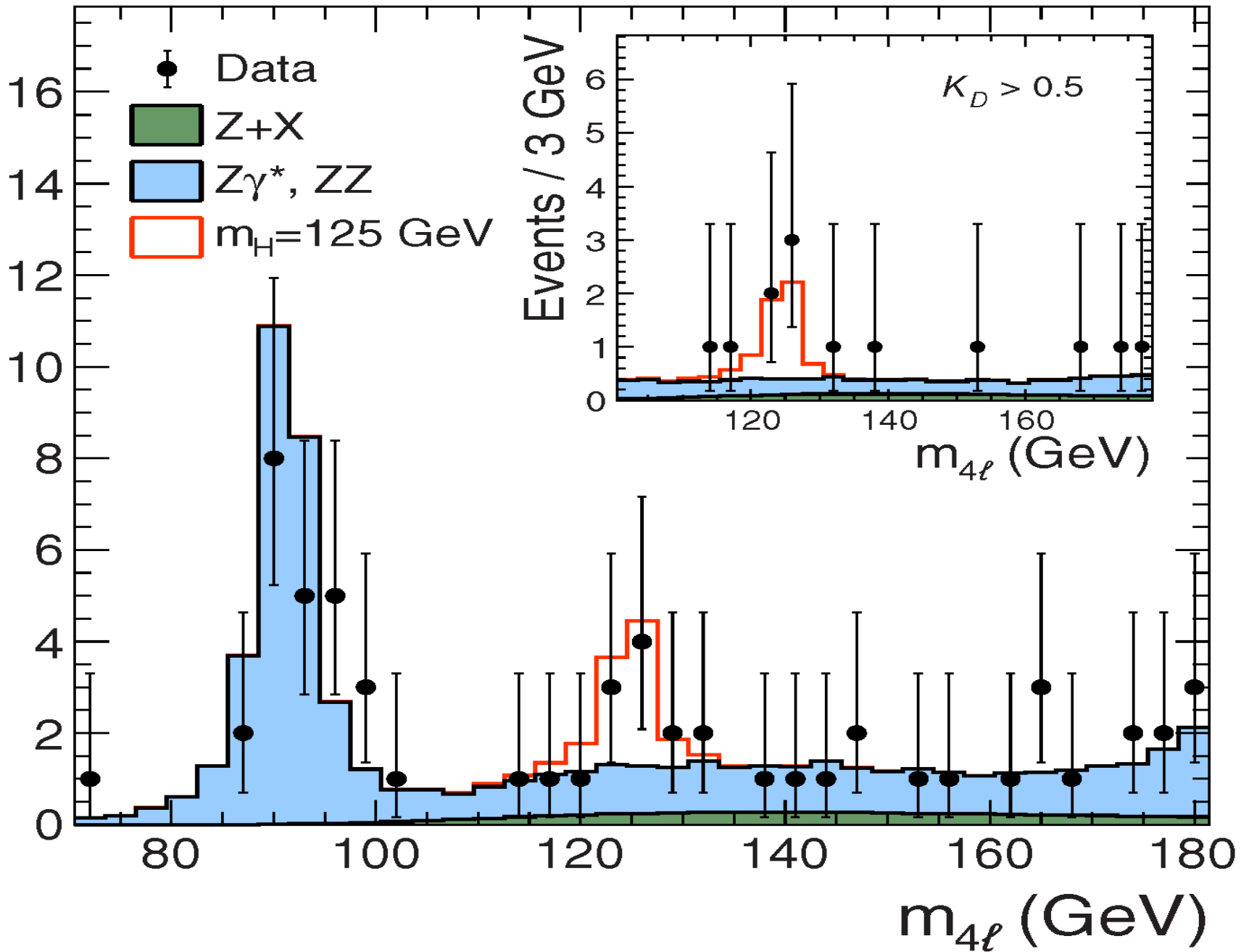
CMS $\sqrt{s} = 7 \text{ TeV}, L = 5.1 \text{ fb}^{-1}$ $\sqrt{s} = 8 \text{ TeV}, L = 5.3 \text{ fb}^{-1}$



CMS

 $\sqrt{s} = 7 \text{ TeV}, L = 5.1 \text{ fb}^{-1}$ $\sqrt{s} = 8 \text{ TeV}, L = 5.3 \text{ fb}^{-1}$

Events / 3 GeV





GRACIAS



the **BIG BANG** THEORY