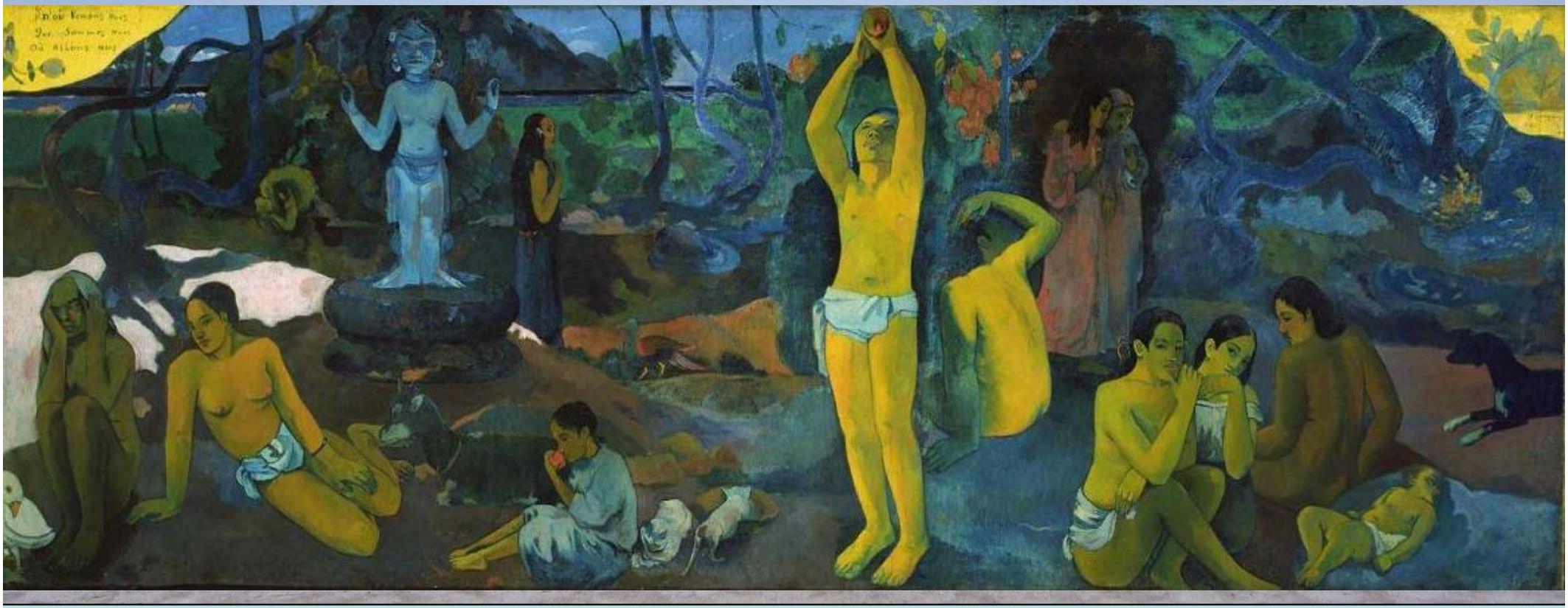
¿ Qué somos ?

¿ De dónde venimos ?

¿ Adónde vamos ?

John Ellis

KING'S College LONDON



El objetivo de la física de partículas:

¿ Cómo está hecho el Universo ?

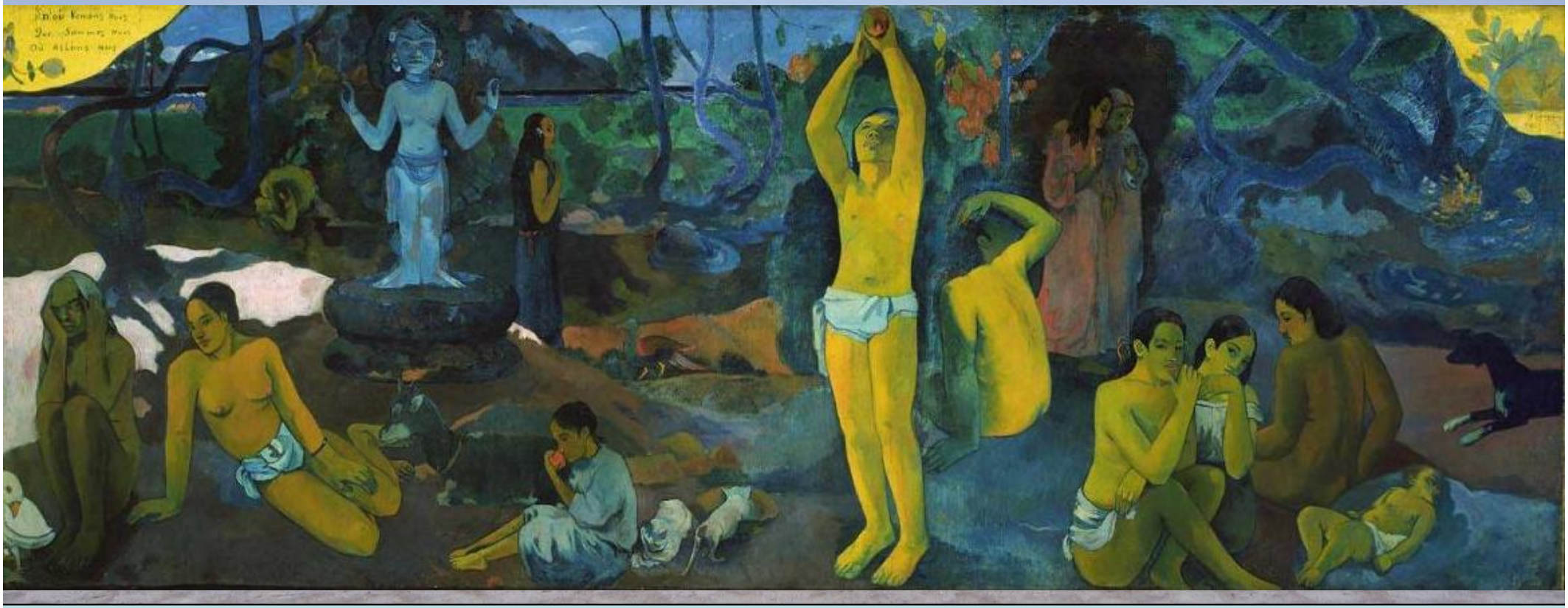
What are we?

Where do we come from?

Where are we going?

John Ellis

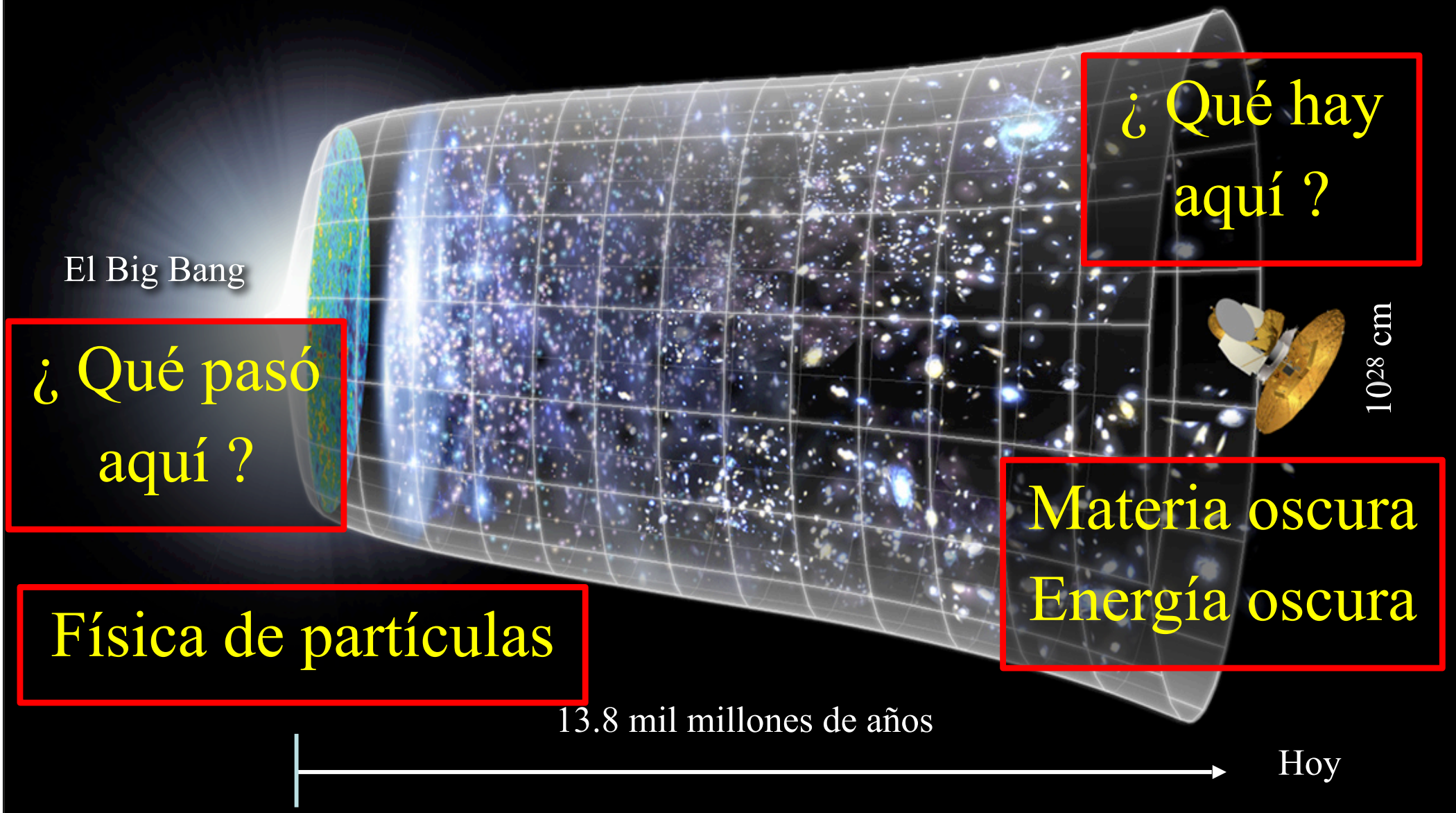
KING'S College LONDON



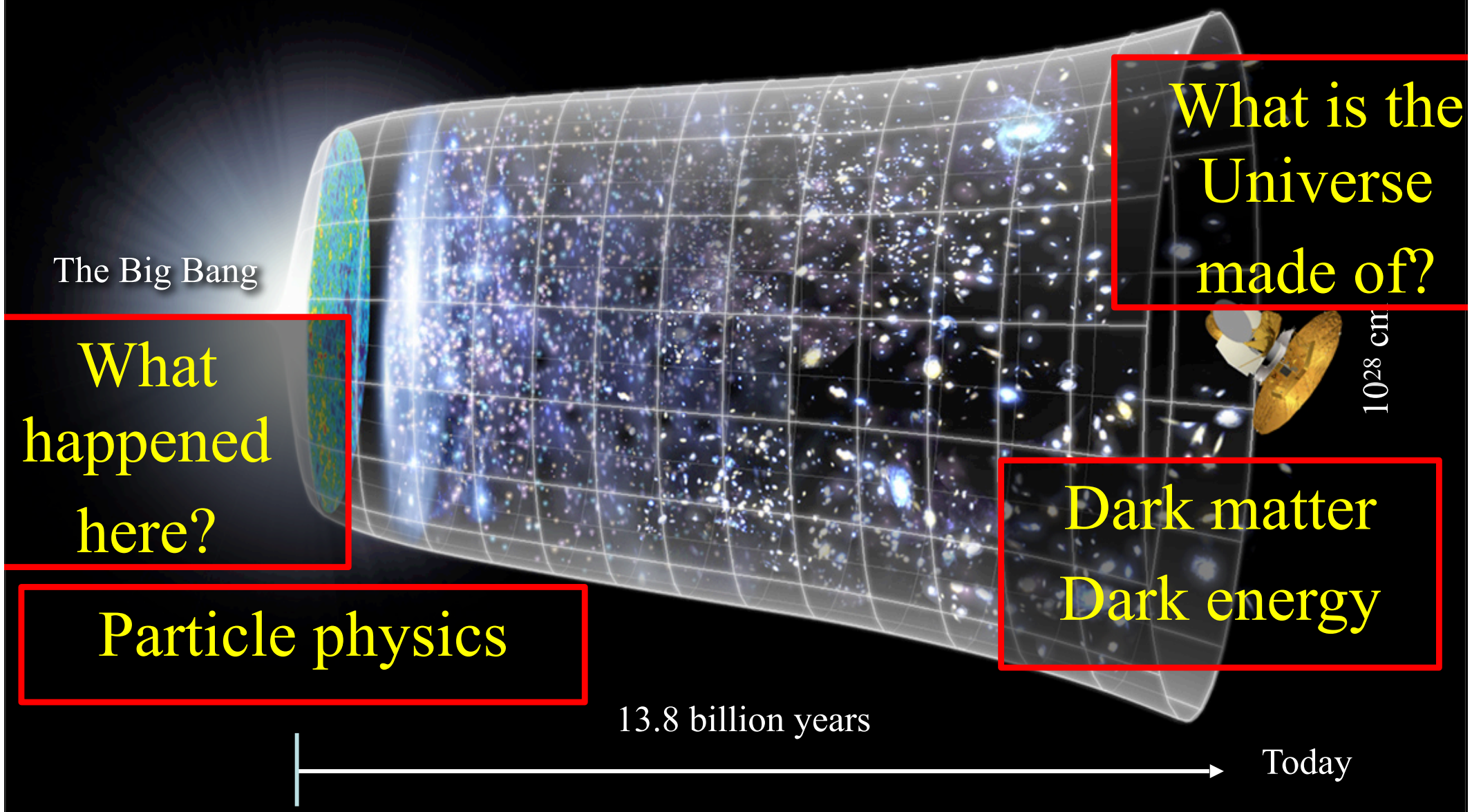
The objective of particle physics:

How to construct a Universe?

Los Secretos Oscuros del Universo



The Dark Secrets of the Universe



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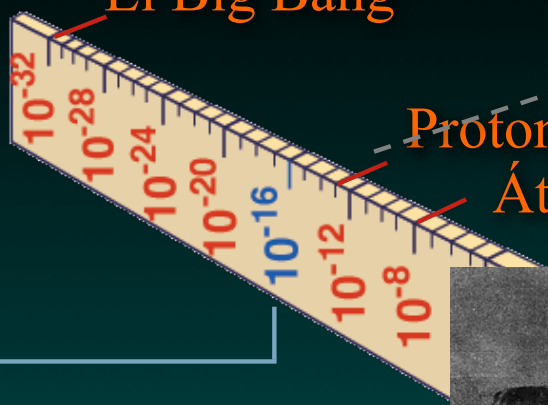
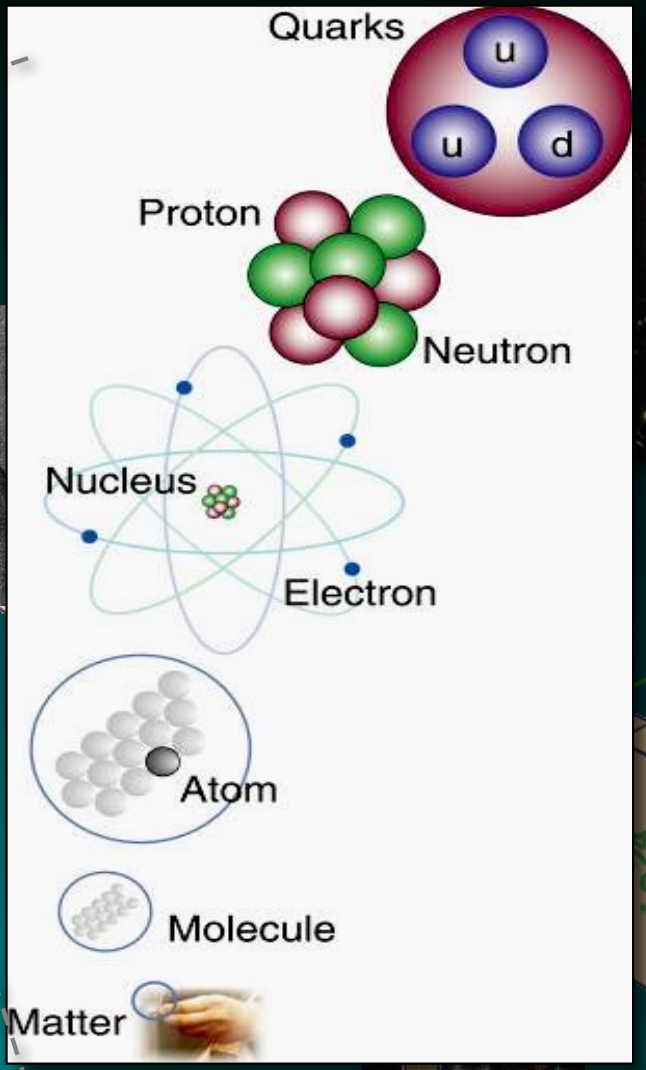
El Big Bang

Proton

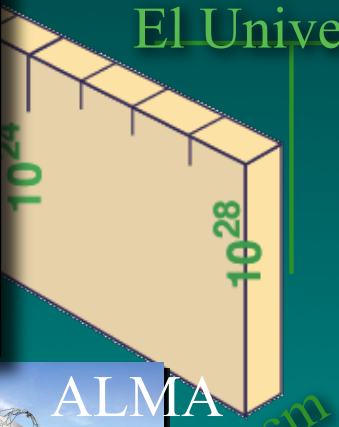
Átomo

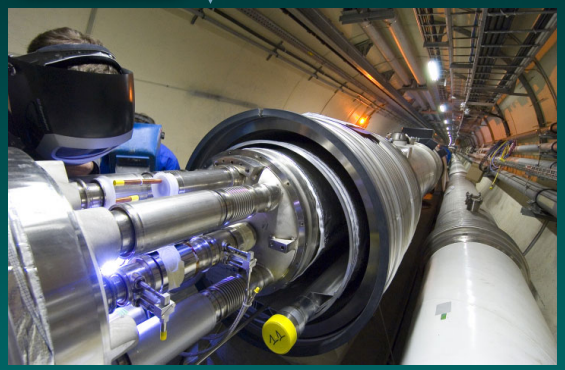




Las galaxias

El Universo





LHC

Un super-microscopio

Estudiar las leyes fundamentales de la física
para comprender mejor
los primeros momentos del Universo
Un super-telescopio también

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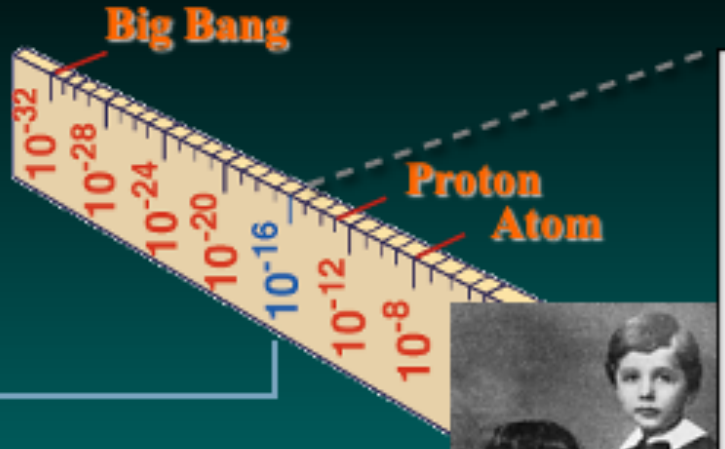
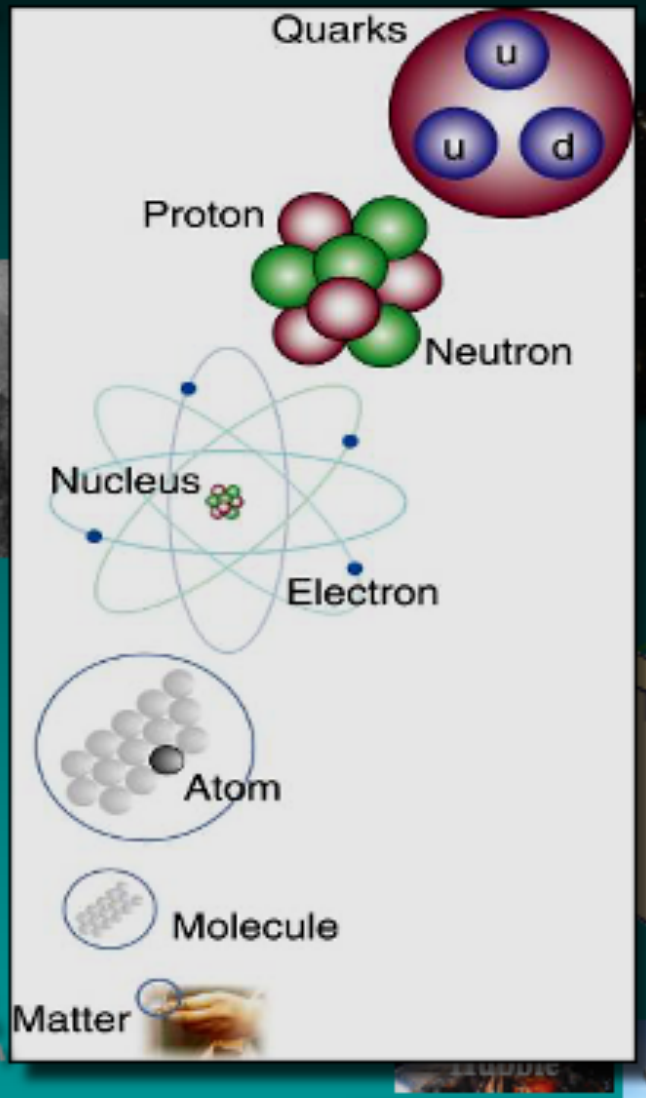
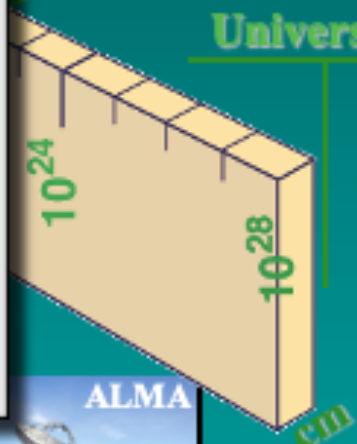




LHC

Super-Microscope



Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

El Universo está en expansión

- Edwin Hubble descubrió que la luz de las galaxias distantes parece más roja
- Este efecto crece con la distancia
- Un efecto debido a la expansión de las olas de la luz durante la expansión del Universo
- Las galaxias las más distantes:

  ~ 10,000,000,000 de años luz
- **¡ La misma física que aquí en la Tierra !**

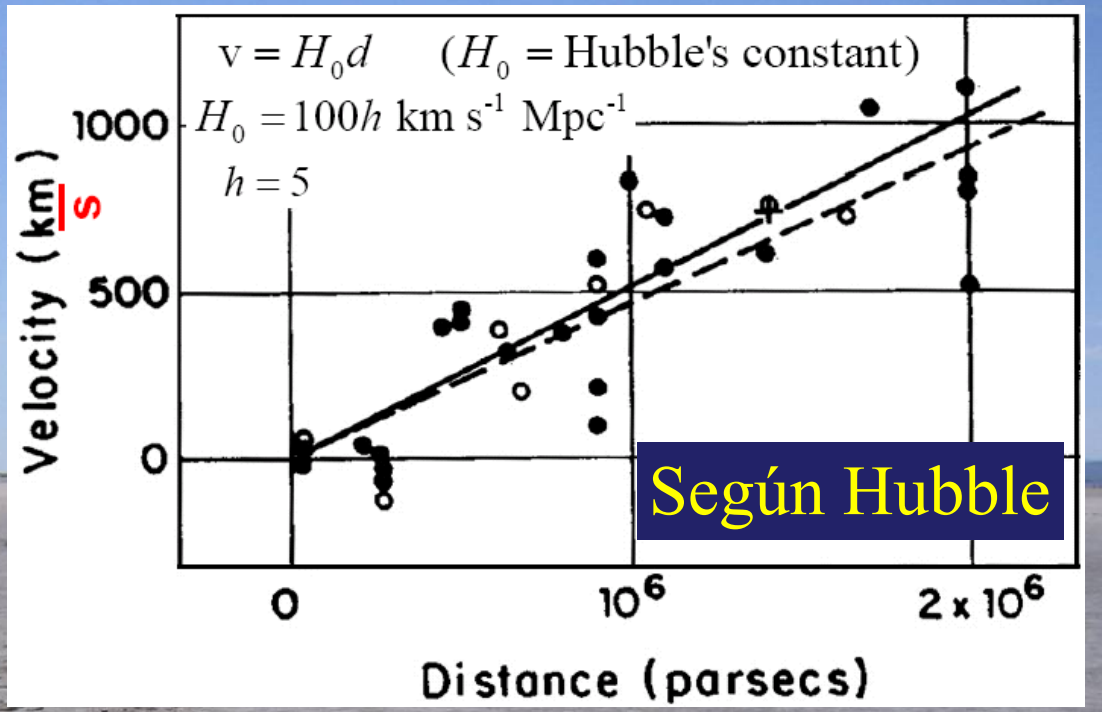
The Universe is Expanding

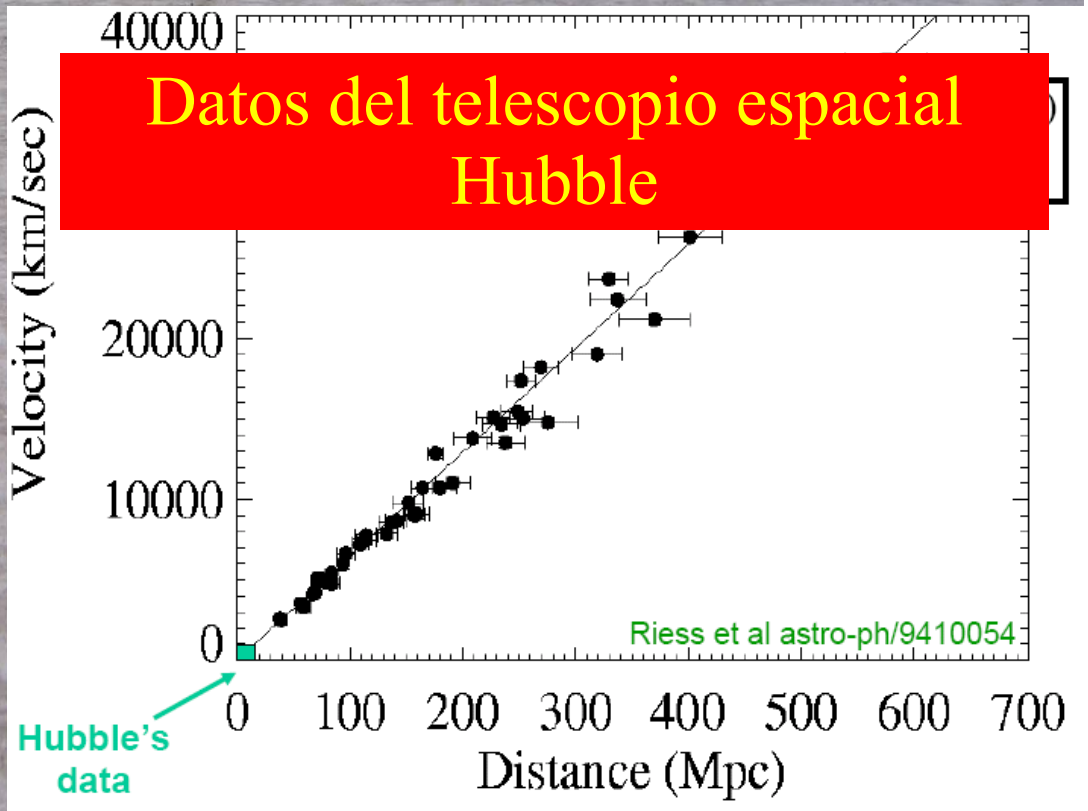
- Edwin Hubble discovered that the light from distant galaxies seems redder
- This effect grows with distance
- It is due to the expansion of light waves as the Universe expands
- The most distant galaxies are

  ~ 10,000,000,000 light-years away
- **The same light as here on Earth!**

La expansión del Universo

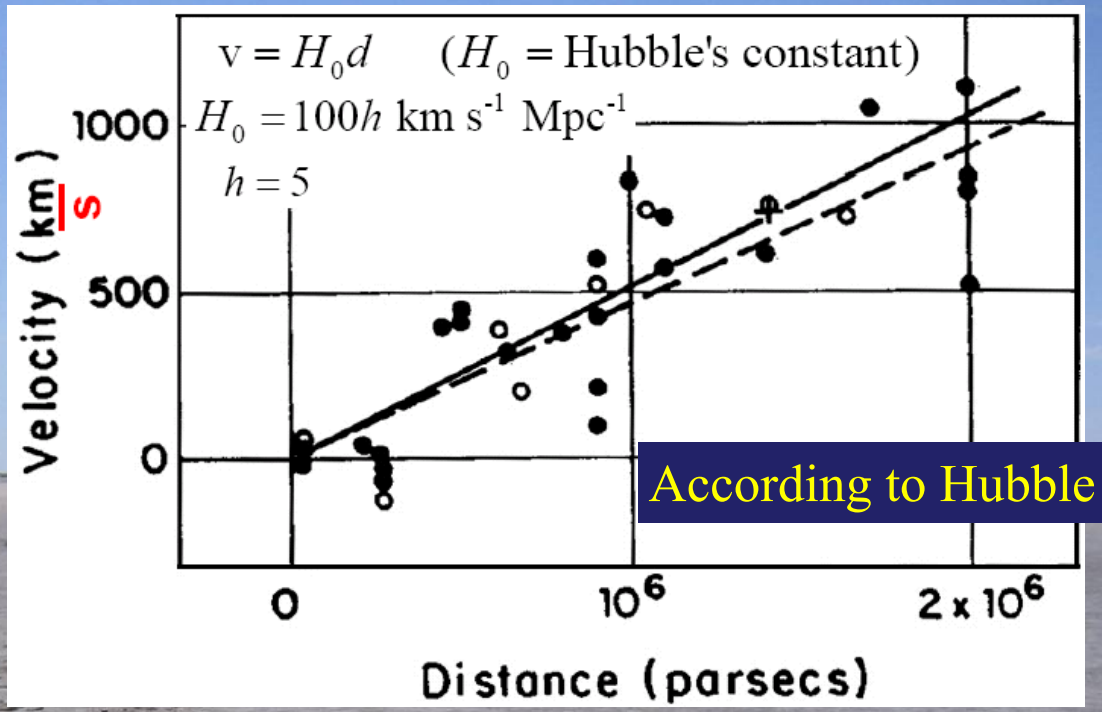
Hubble, jugador de baloncesto



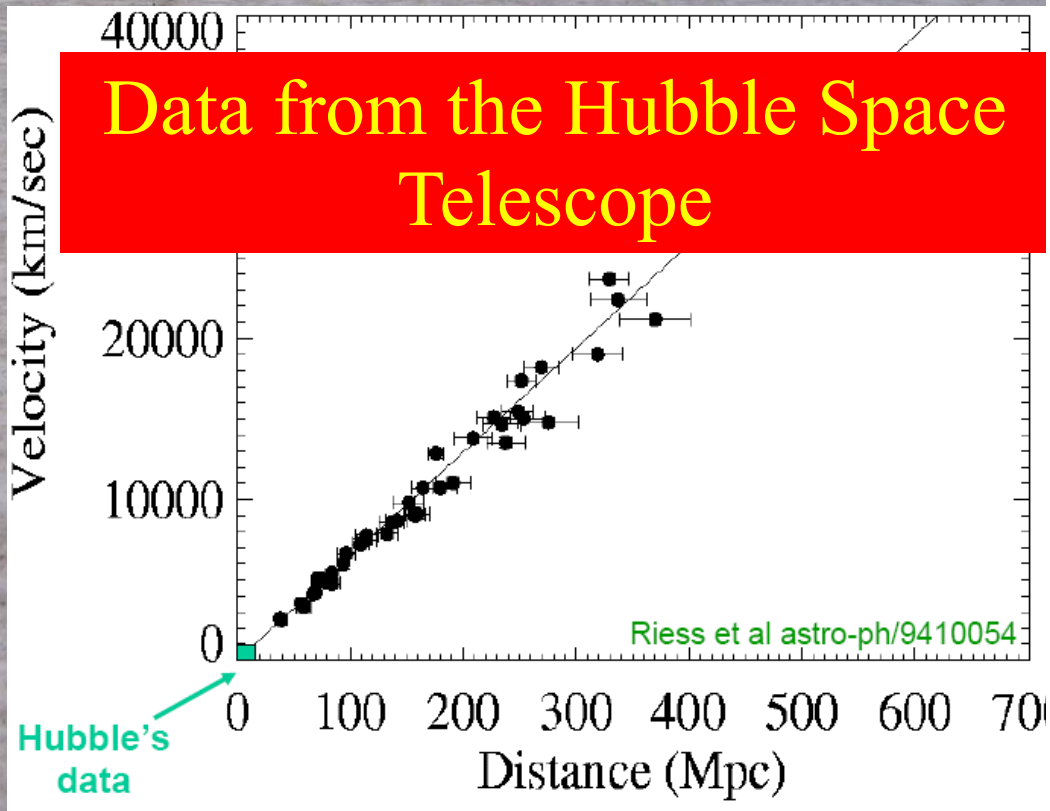


The expansion of the Universe

Hubble, basketball player



Data from the Hubble Space Telescope



El universo está en expansión

- Las galaxias se separan

  la expansión descubierta por Hubble

- Antes, el universo era 3000 veces mas pequeño y mas caliente que hoy

  el fondo cósmico de microondas emitido cuando nacieron los átomos

The Universe is Expanding

- The galaxies are moving apart

  the expansion discovered by Hubble

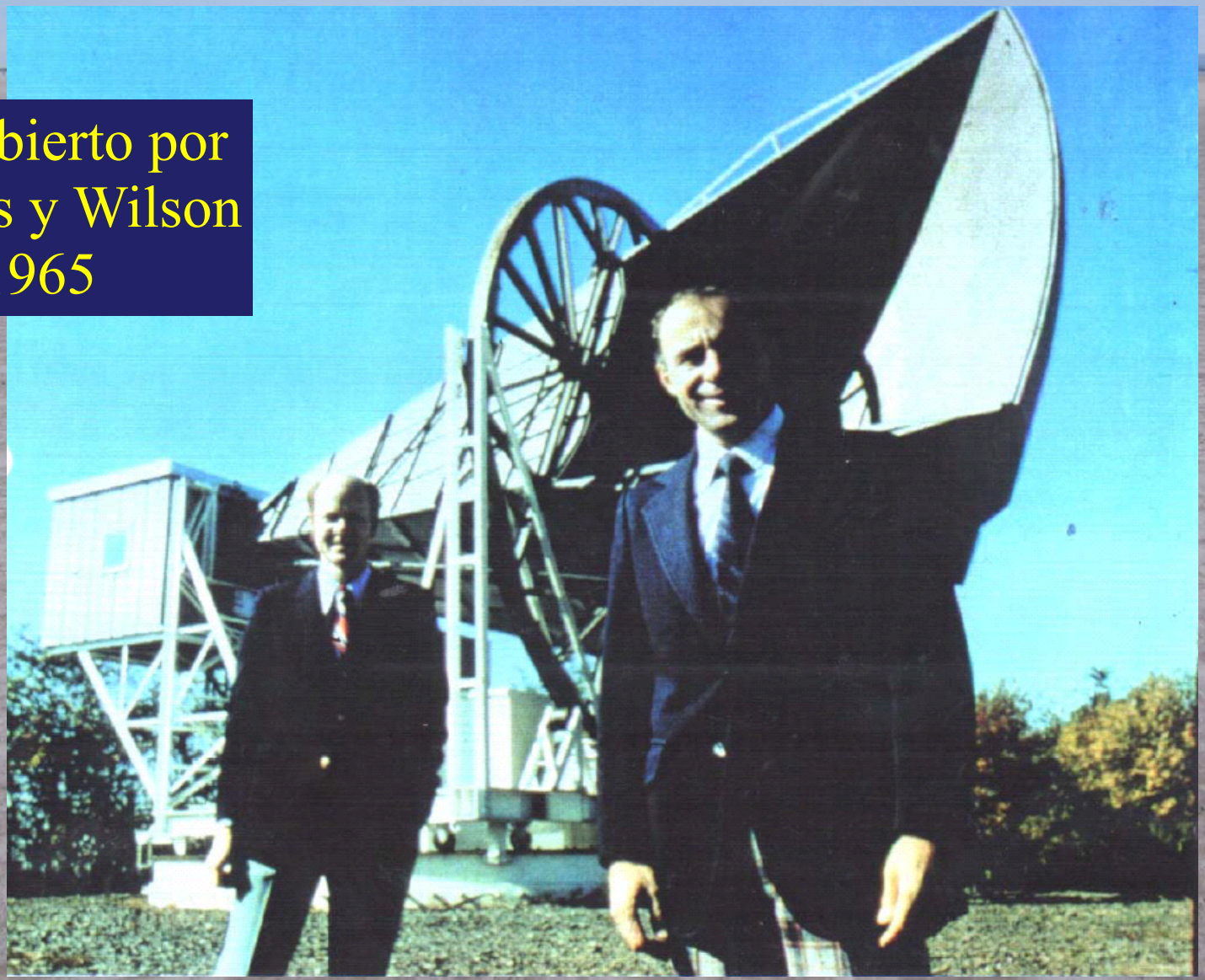
- The universe was once 3000 times smaller and hotter than today

  the cosmic microwave background

  emitted when atoms were born

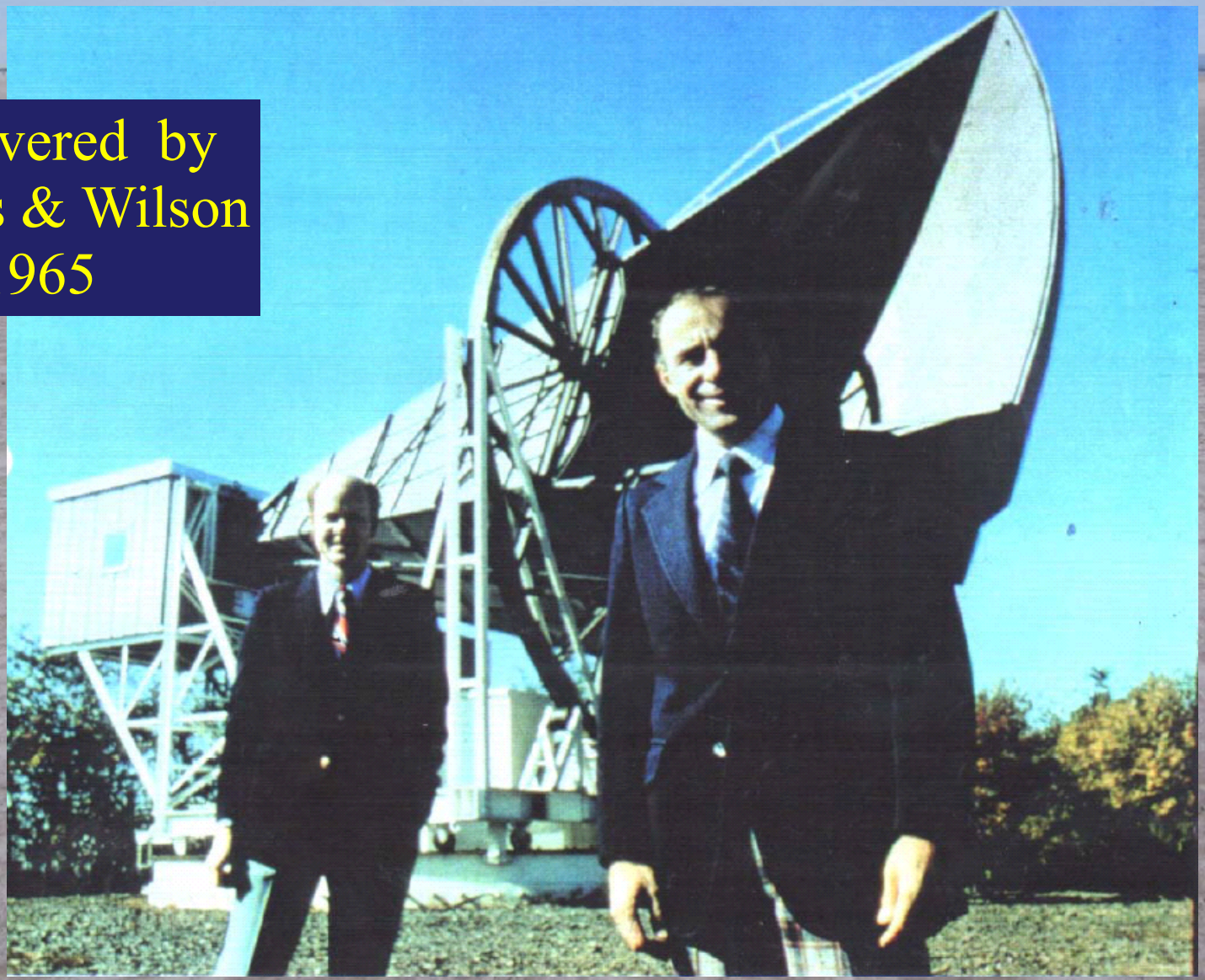
El fondo cósmico de microondas

Descubierto por Penzias y Wilson 1965



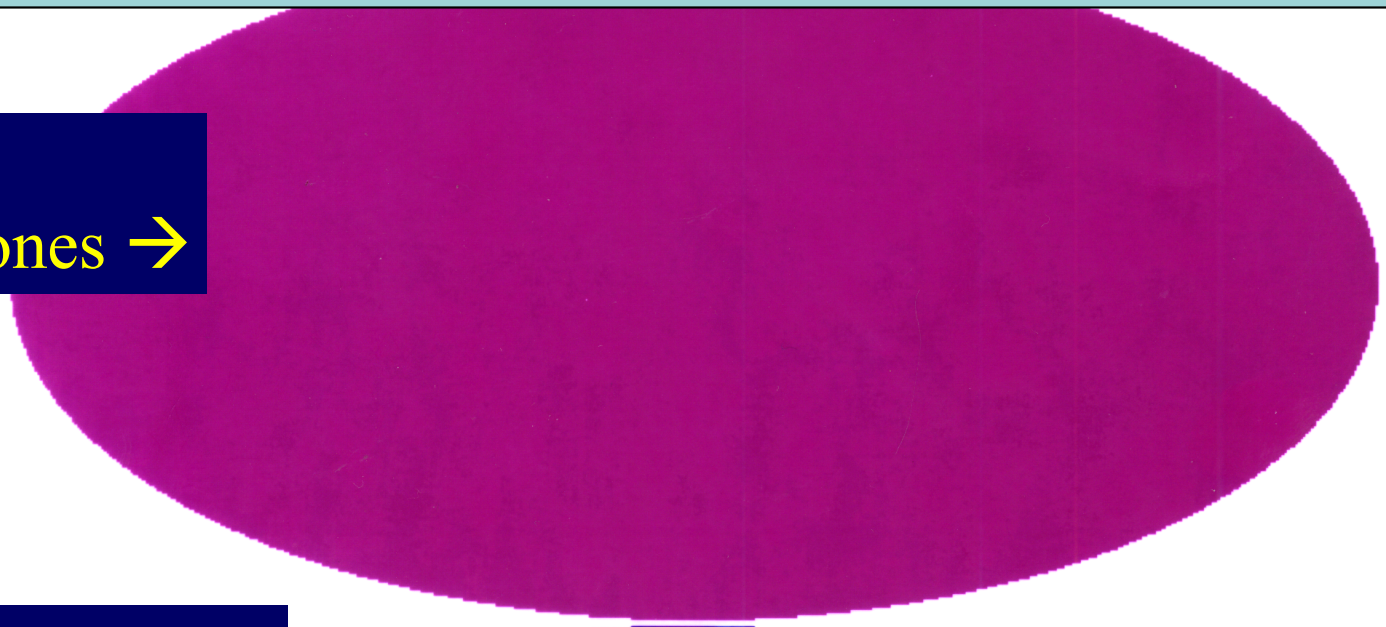
The Cosmic Microwave Background

Discovered by
Penzias & Wilson
1965

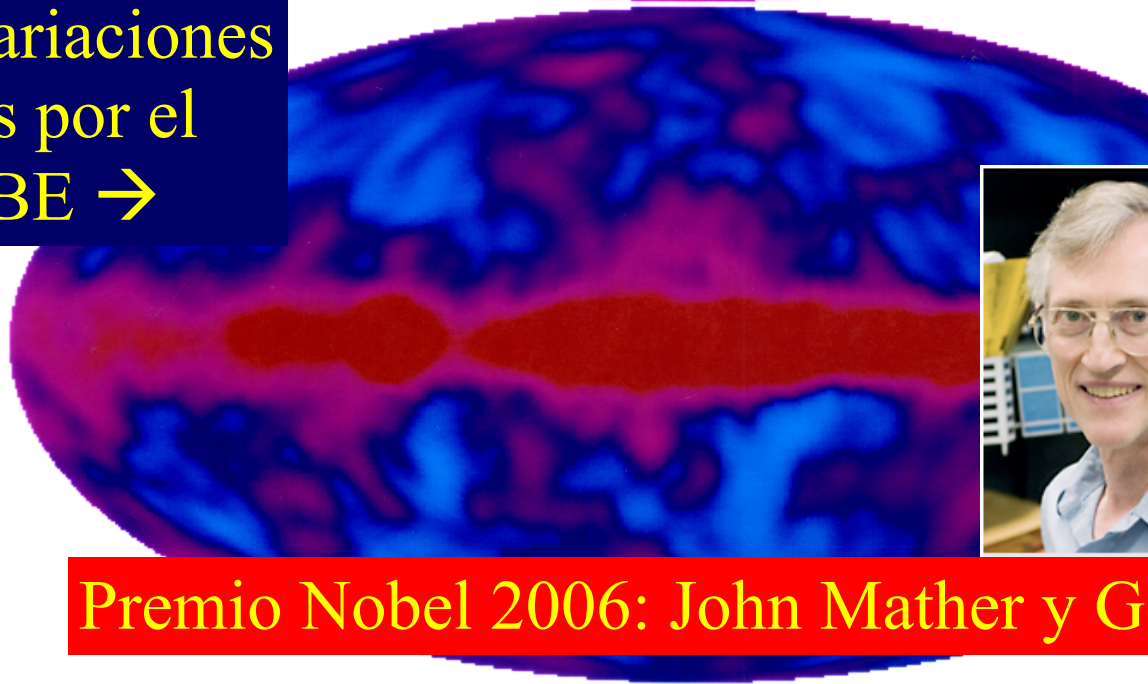


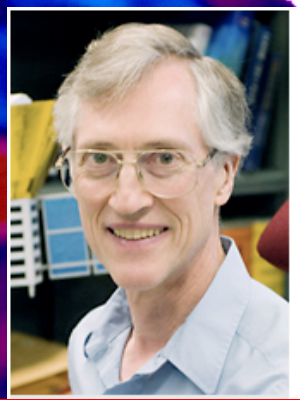
El fondo cósmico de microondas

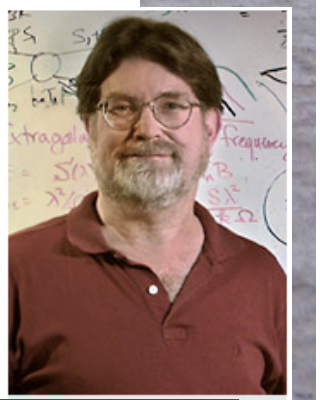
Casi identico en
todas las direcciones →



Pequeñas variaciones
descubiertas por el
satelite COBE →



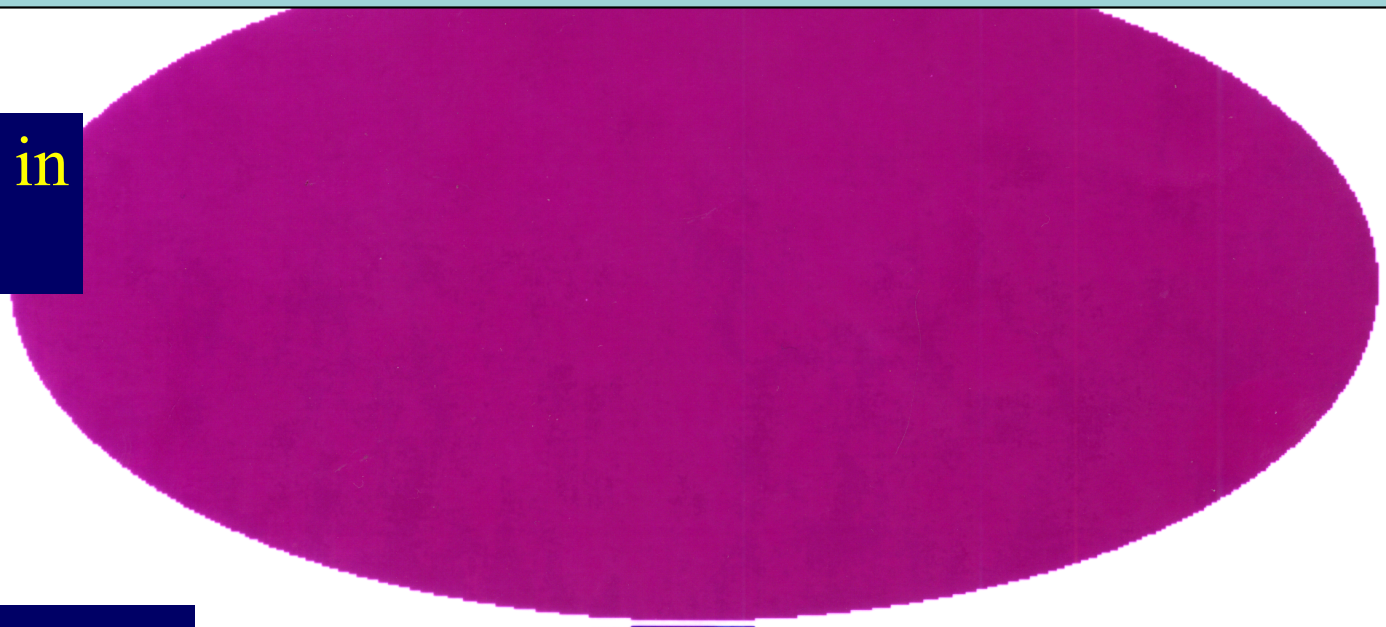




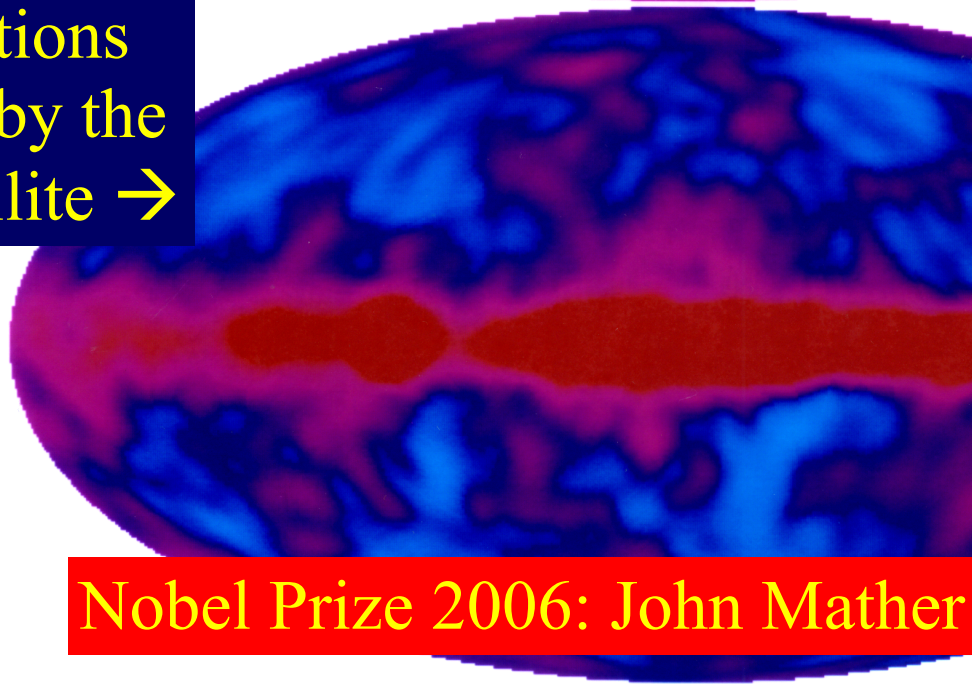
Premio Nobel 2006: John Mather y George Smoot

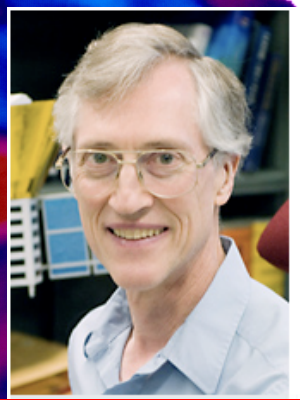
The Cosmic Microwave Background

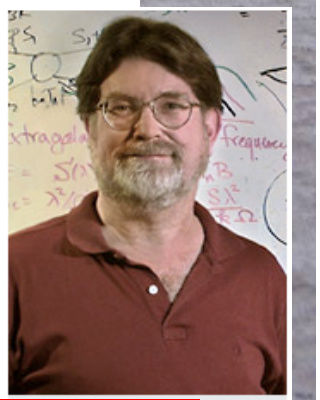
Almost the same in all directions →



Small variations discovered by the COBE satellite →

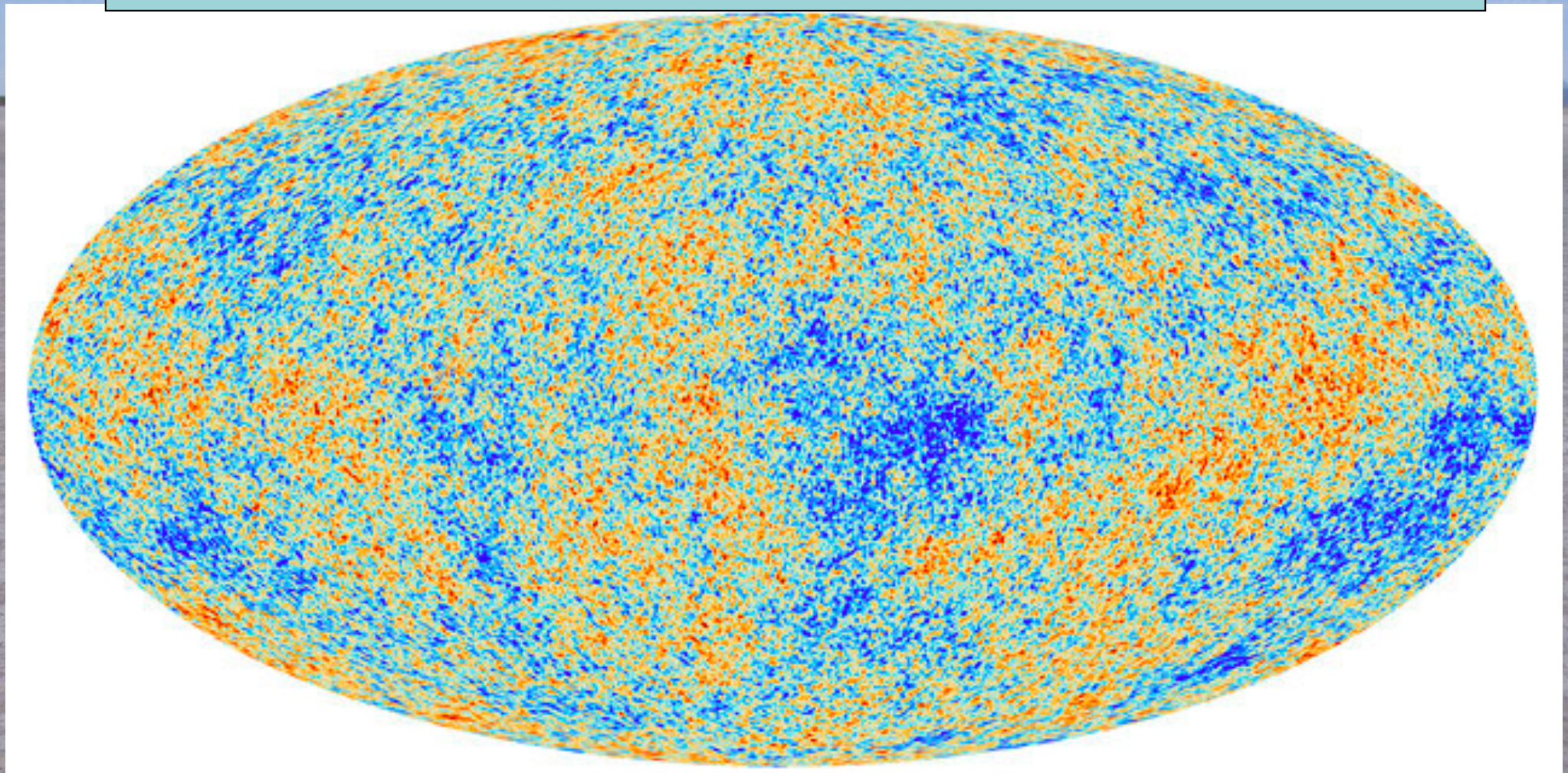






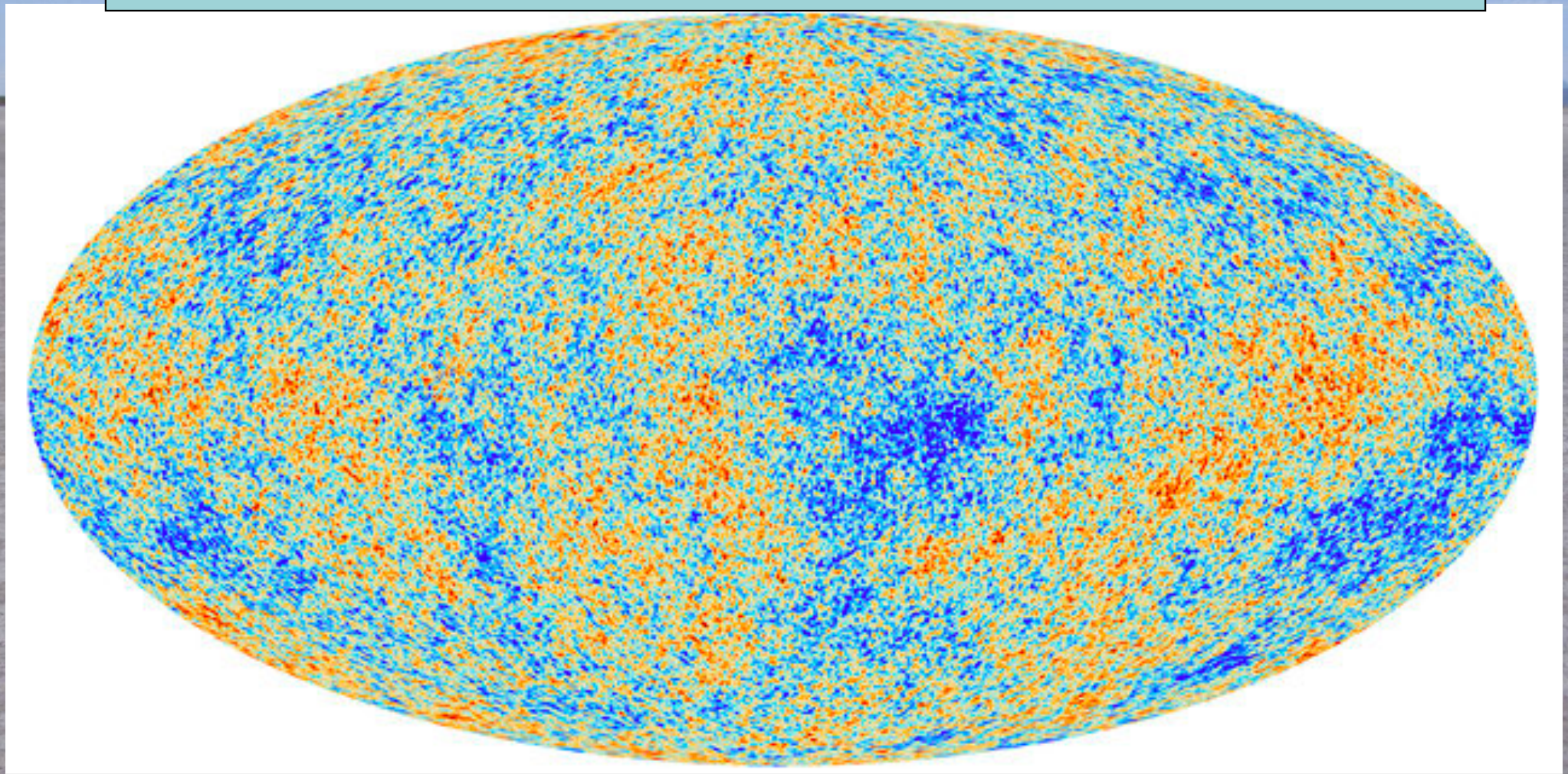
Nobel Prize 2006: John Mather & George Smoot

El fondo cósmico de microondas según el satélite Planck



Nos cuenta que contiene el Universo

The Cosmic Microwave Background according to the Planck Satellite



Tells us what the Universe is made of

El universo está en expansión

- Las galaxias se separan

  la expansión descubierta por Hubble
- Antes, el universo era 3000 veces mas pequeño y mas caliente que hoy

  el fondo cósmico de microondas
- El universo era una vez 1,000,000,000 de veces mas pequeño y mas caliente que hoy

  el origen de los elementos livianos en el Big Bang: interacciones nucleares en el jóven universo

The Universe is Expanding

- The galaxies are moving apart

  the expansion discovered by Hubble
- The universe was once 3000 times smaller and hotter than today

  the cosmico microwave background
- The universe was once 1,000,000,000 times smaller and hotter than today

  the origin of the light elements in the Big Bang:

  nuclear interactions in the young Universe

300,000 años

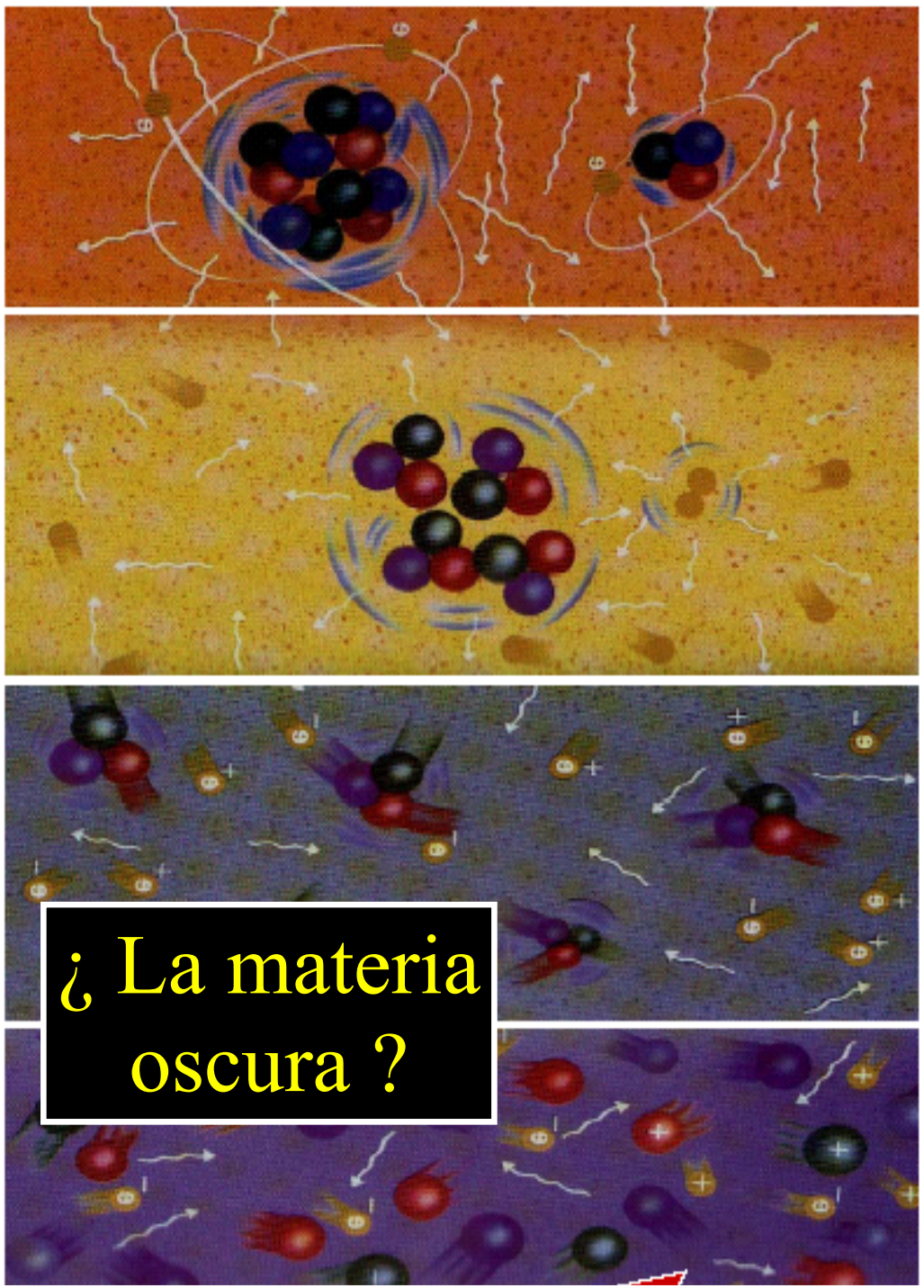
Formación de los átomos

3 minutos

Formación de los núcleos

1 micro-segundo

Formación de los protones y neutrones



¿ La materia oscura ?

1 pico-segundo

¿ El origen de la masa ?

¿ El origen de la materia ?

300,000 years

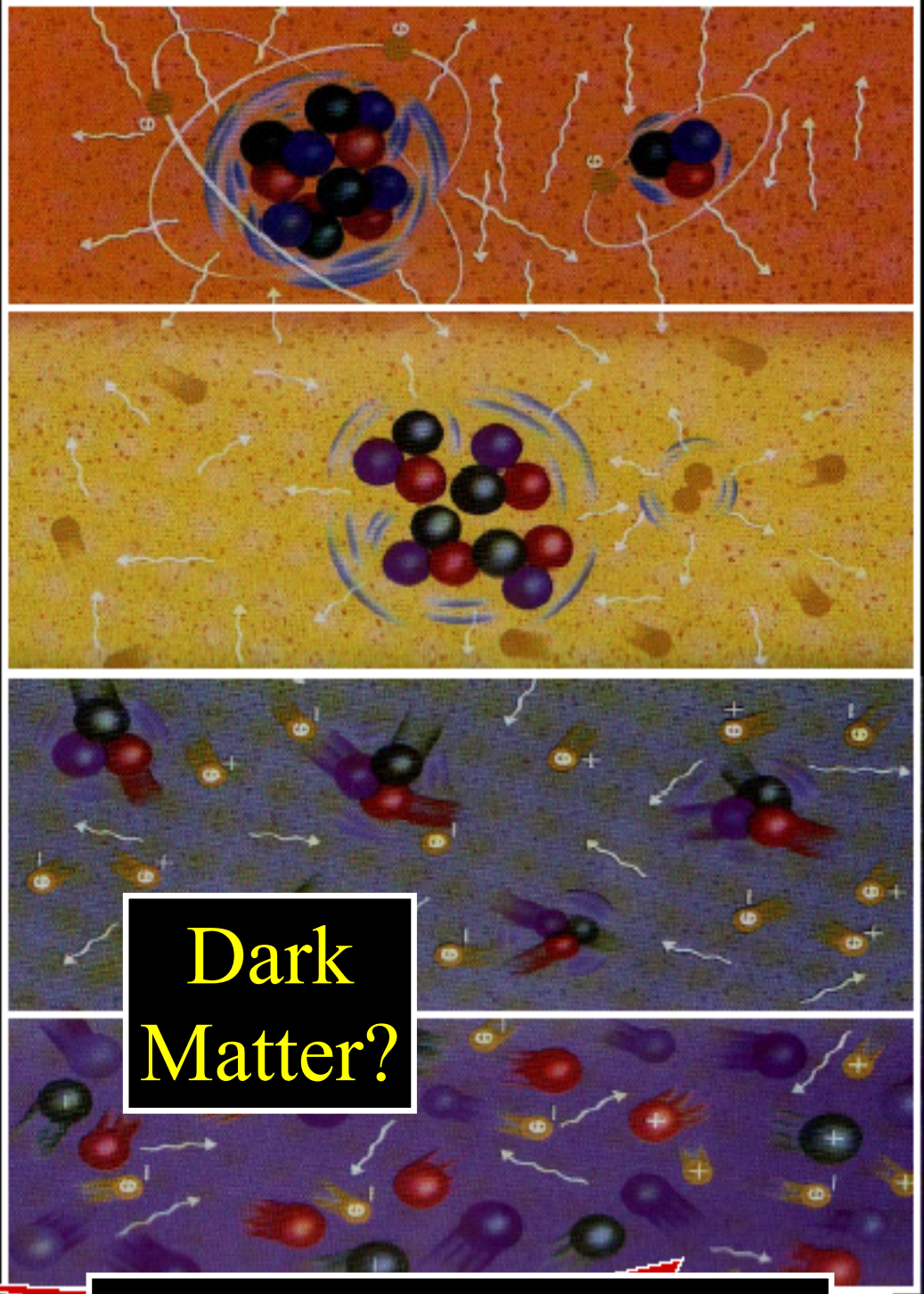
Formation of first atoms

3 minutes

Formation of first nuclei

1 micro-second

Formation of first protons & neutrons



Dark Matter?

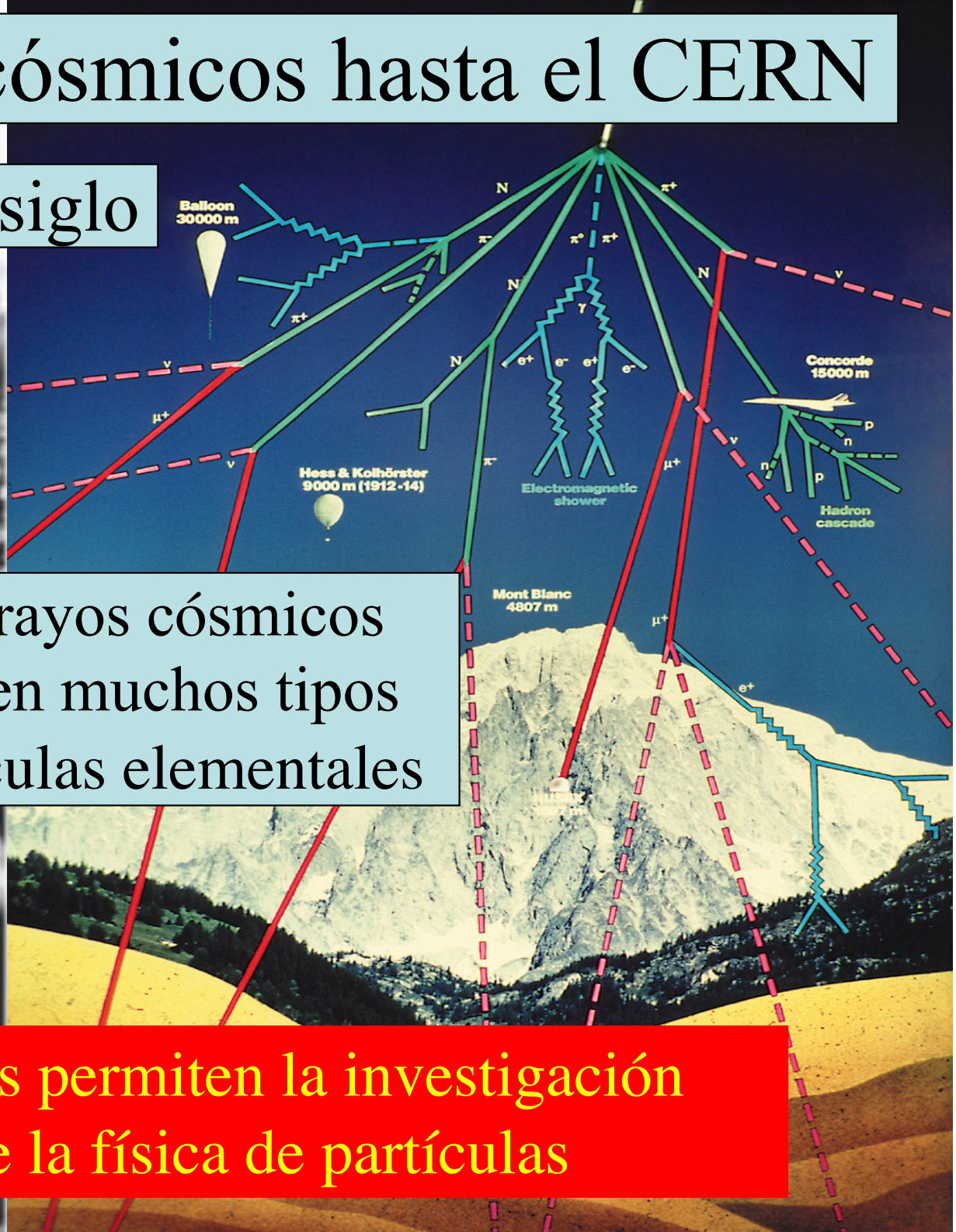
1 pico-second

The origin of mass?

The origin of matter?

Desde los rayos cósmicos hasta el CERN

Descubiertos hace un siglo



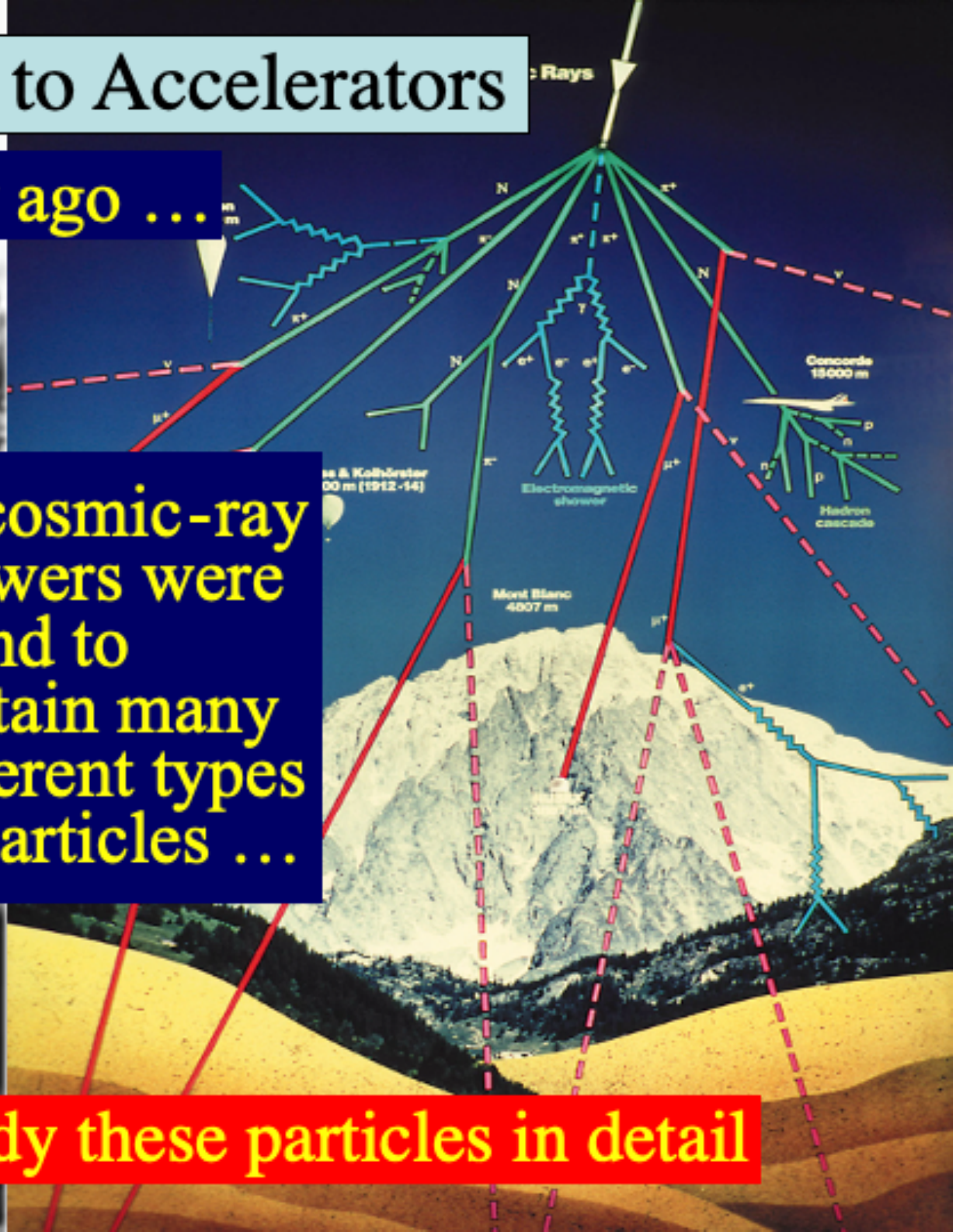
… los rayos cósmicos producen muchos tipos de partículas elementales

Los aceleradores permiten la investigación detallada de la física de partículas

From Cosmic Rays to Accelerators

Discovered a century ago …

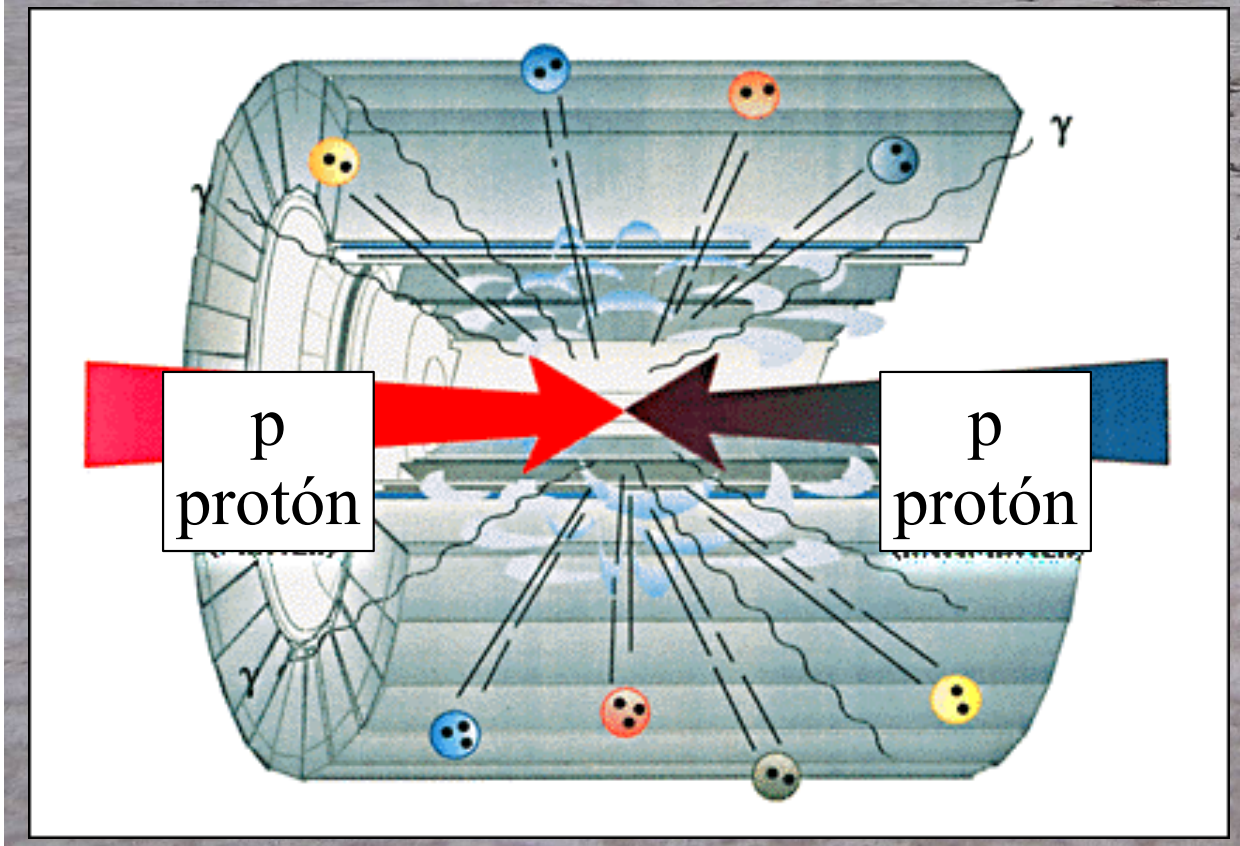
… cosmic-ray showers were found to contain many different types of particles …



Accelerators study these particles in detail

Experimentos con aceleradores

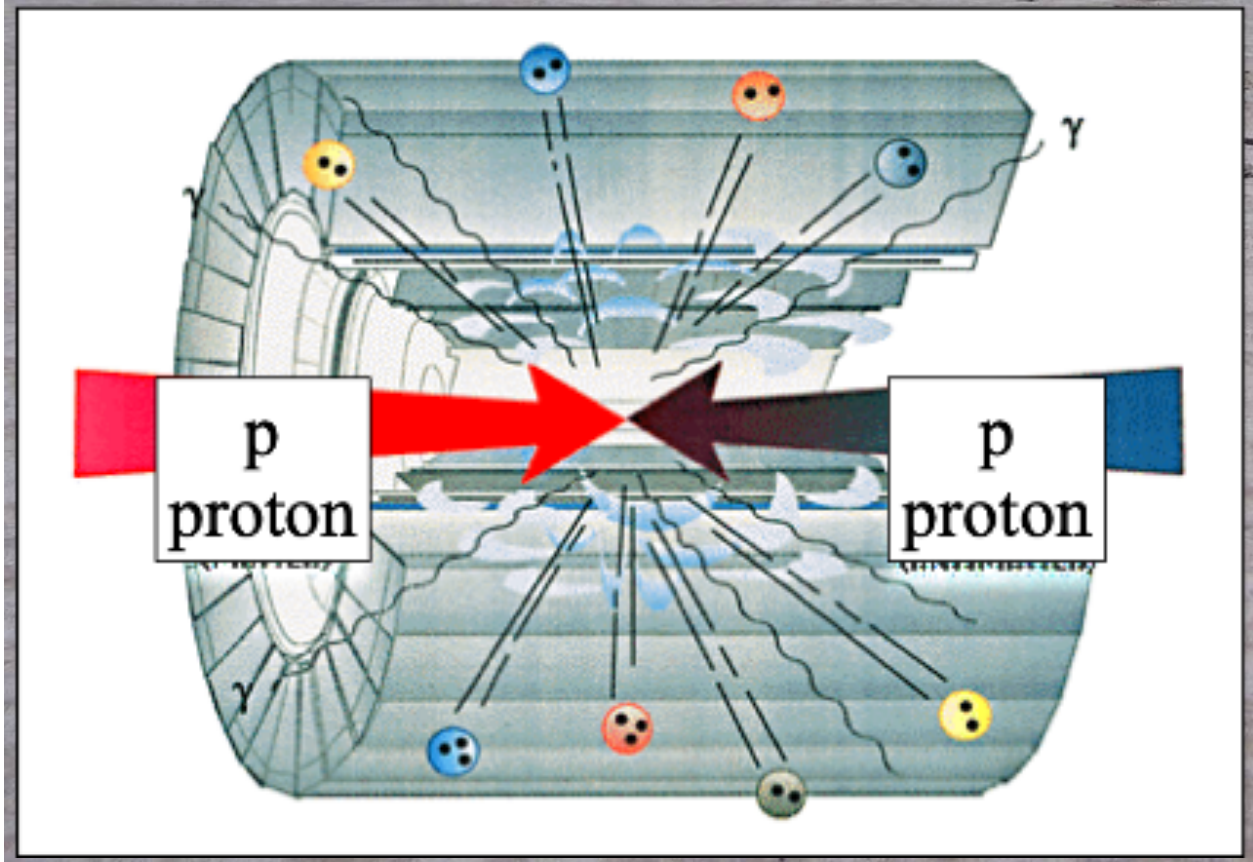
Para estudiar las partículas, necesitamos super-microscopios capaces de alcanzar energías muy altas:
Colisionadores de partículas



Los choques reproducen las condiciones al inicio del Big Bang

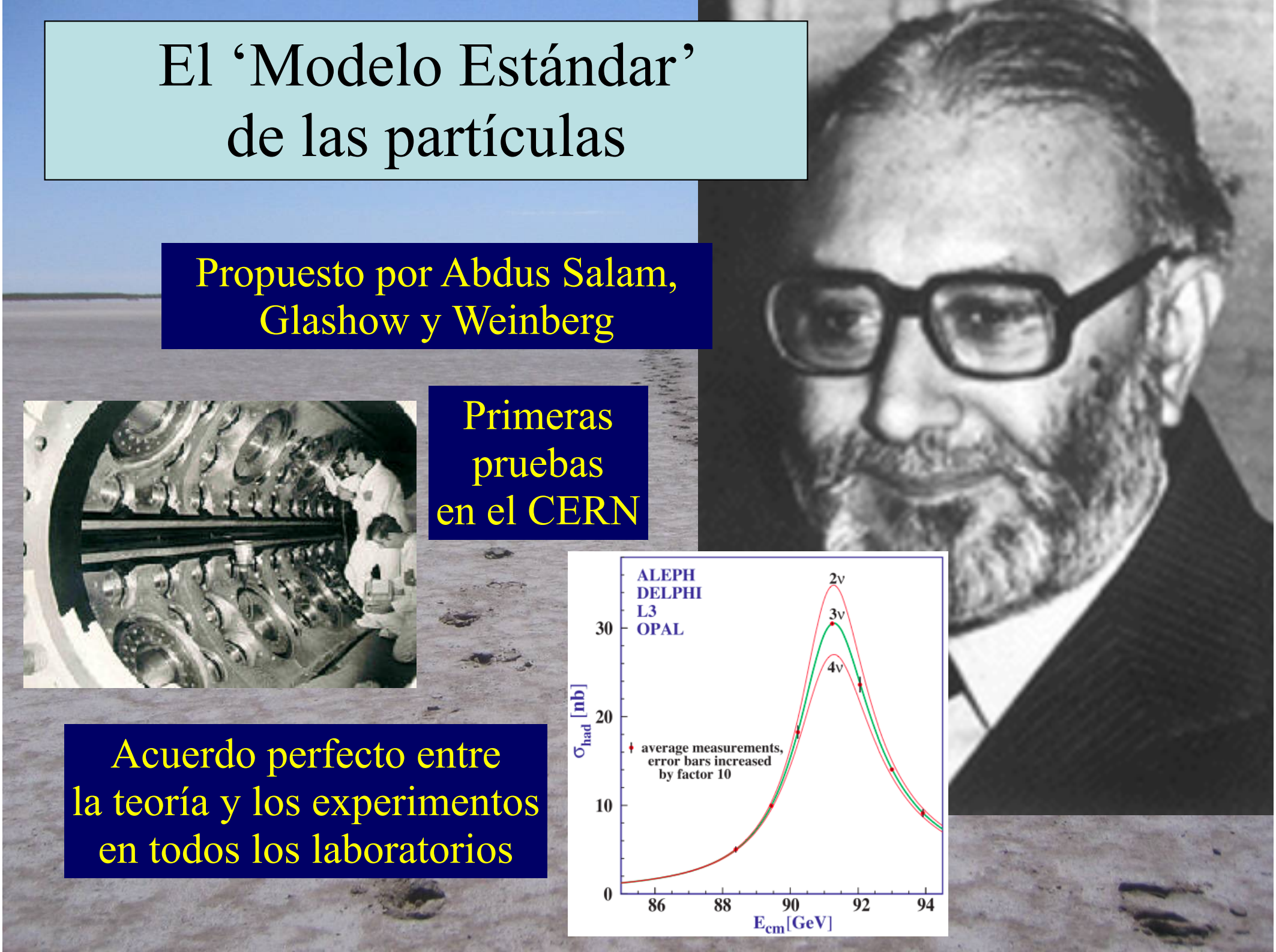
Experiments with Accelerators

In order to study particles, we need super-microscopes using high energies to probe small distances:
Particle Colliders



Collisions reproduce the conditions at beginning of Big Bang

El ‘Modelo Estándar’ de las partículas

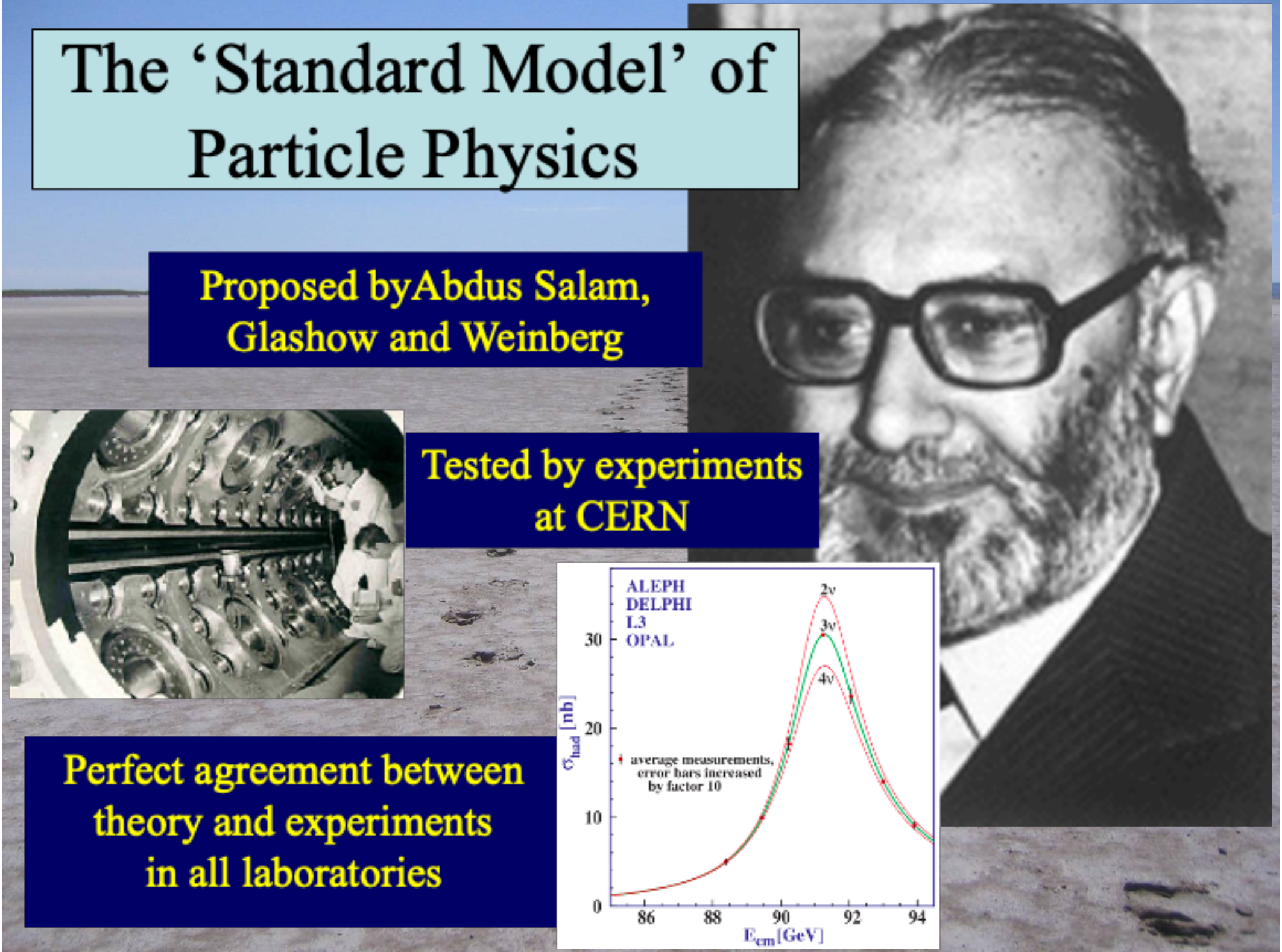


Propuesto por Abdus Salam, Glashow y Weinberg

Primeras pruebas en el CERN

Acuerdo perfecto entre la teoría y los experimentos en todos los laboratorios

The 'Standard Model' of Particle Physics

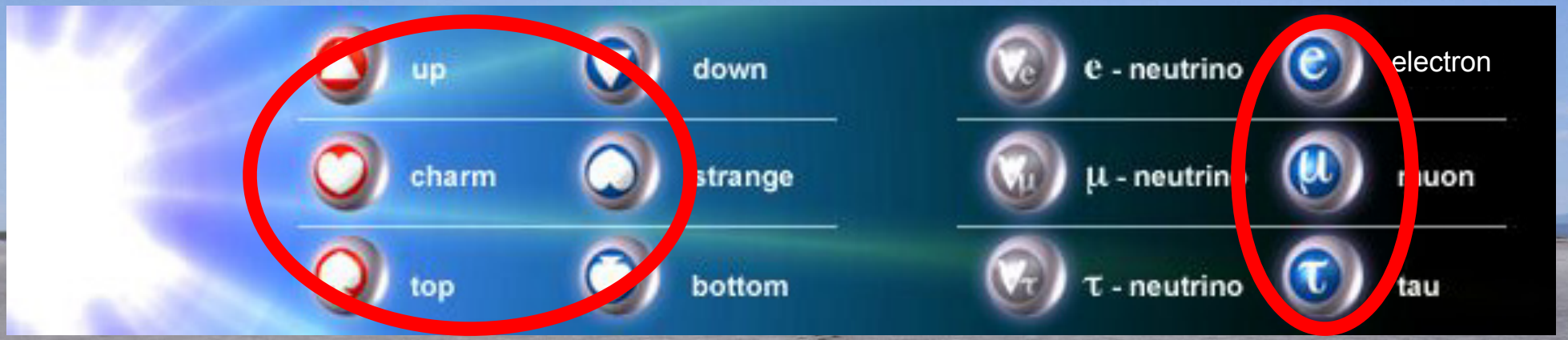


Proposed by Abdus Salam, Glashow and Weinberg

Tested by experiments at CERN

Perfect agreement between theory and experiments in all laboratories

Partículas de materia



¿ Cuál es el origen de la masa ?

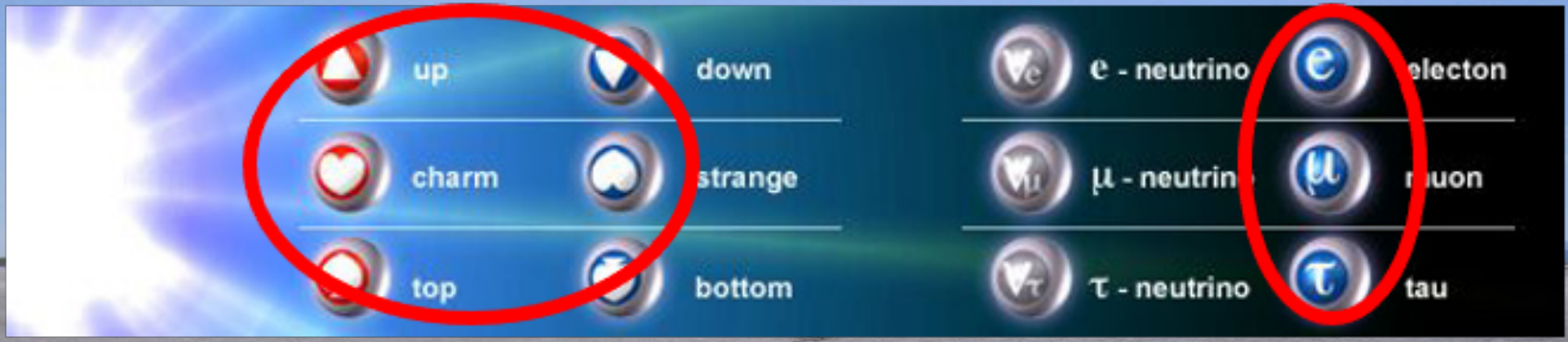
El 'Modelo Estándar'

¿ Cuál es el origen de la materia ?

Fuerzas e interacciones

Gravedad | Electromagnetismo | Fuerzas nucleares: débil y fuerte

The matter particles

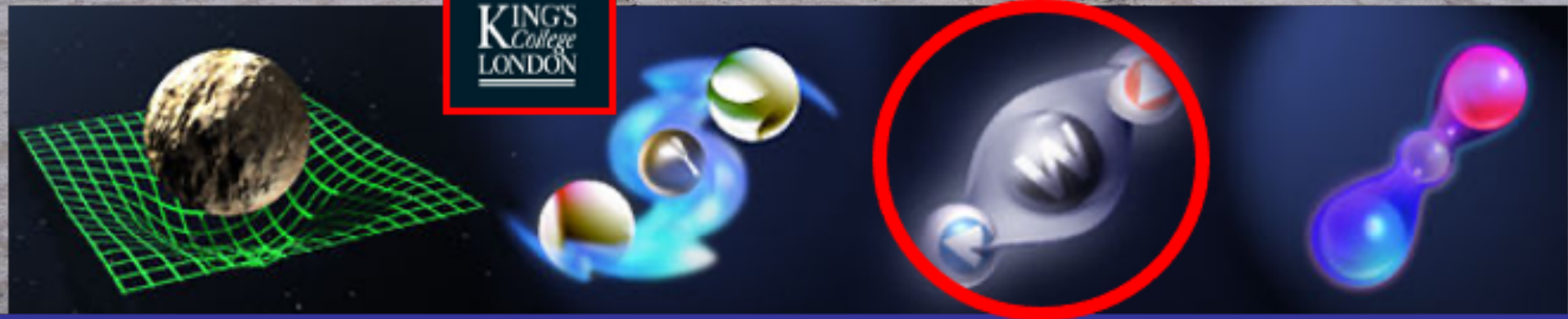


The 'Standard Model'

Where does mass come from?

What is the origin of matter?

The fundamental interactions



Gravitation electromagnetism weak nuclear force strong nuclear force

Algunas partículas tienen masas, algunas nó

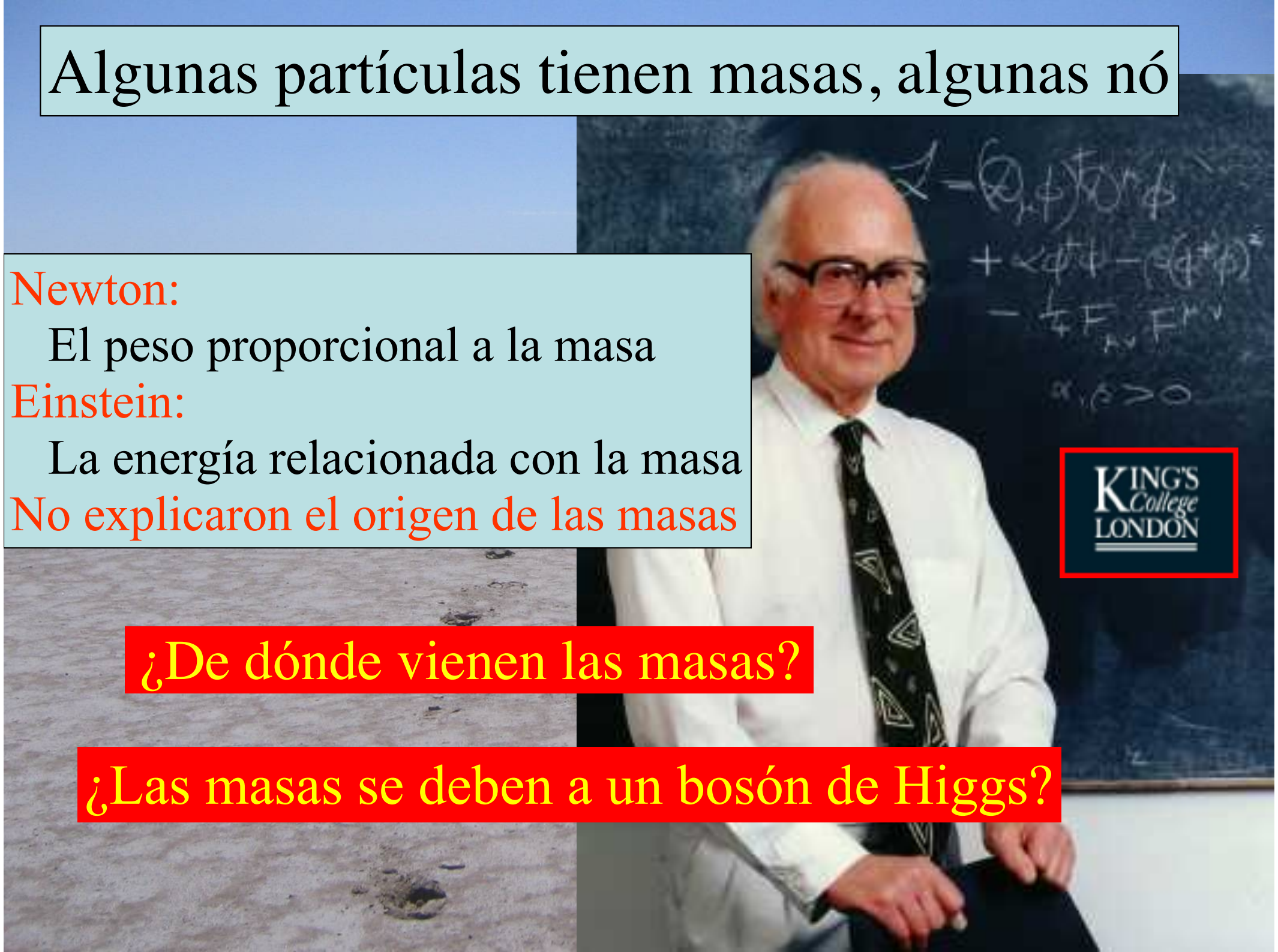
Newton:

El peso proporcional a la masa

Einstein:

La energía relacionada con la masa

No explicaron el origen de las masas



¿De dónde vienen las masas?

¿Las masas se deben a un bosón de Higgs?

Why do Things Weigh?

Newton:

Weight proportional to Mass

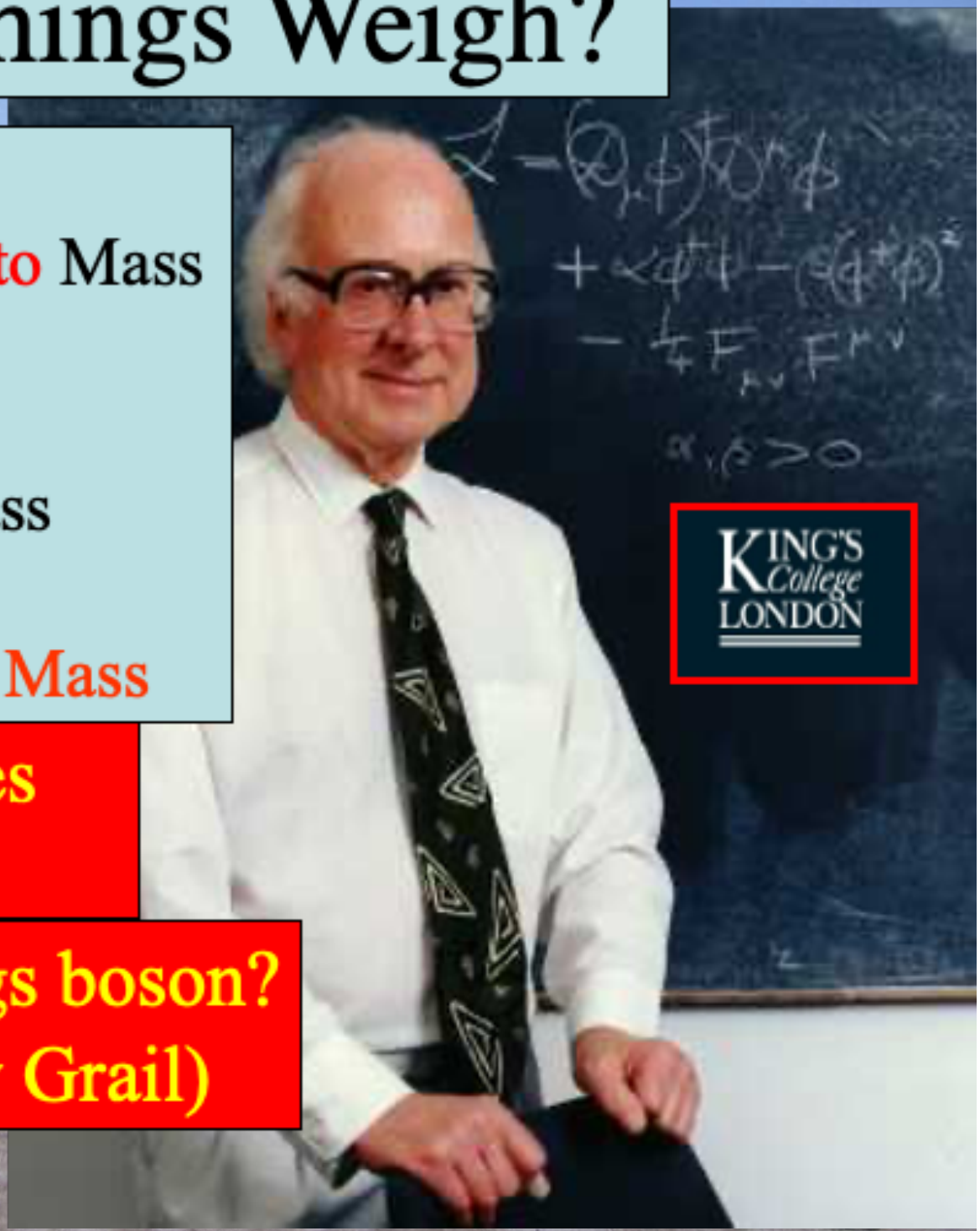
Einstein:

Energy related to Mass

Neither explained origin of Mass

Where do the masses come from?

Are masses due to Higgs boson? (the physicists' Holy Grail)



Como un campo de nieve

El esquiador anda muy rapido:
como una partícula sin masa
(el fotón = la partícula de la luz)

El LHC descubrió
el copo de nieve:
el bosón de Higgs

El raquetista anda menos
rápido: como una partícula
con una masa (el electrón)

El marchador anda muy
despacio: como una
partícula con una masa grande

Think of a Snowfield

Skier moves fast:
Like particle without mass
e.g., photon = particle of light

Snowshoer sinks into snow,
moves slower:
Like particle with mass
e.g., electron

The LHC discovered the snowflake: The Higgs Boson

Hiker sinks deep,
moves very slowly:
Particle with large mass

El primer estudio detallado del bosón de Higgs (1975)

A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John ELLIS, Mary K. GAILLARD * and D.V. NANOPOULOS **
CERN, Geneva

Received 7 November 1975

A discussion is given of the production, decay and observability of the scalar Higgs boson H expected in gauge theories of the weak and electromagnetic interactions such as the Weinberg-Salam model. After reviewing previous experimental limits on the mass of

We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

"No querríamos promover grandes búsquedas experimentales"

A Phenomenological Profile of the Higgs Boson

- First attempt at systematic survey

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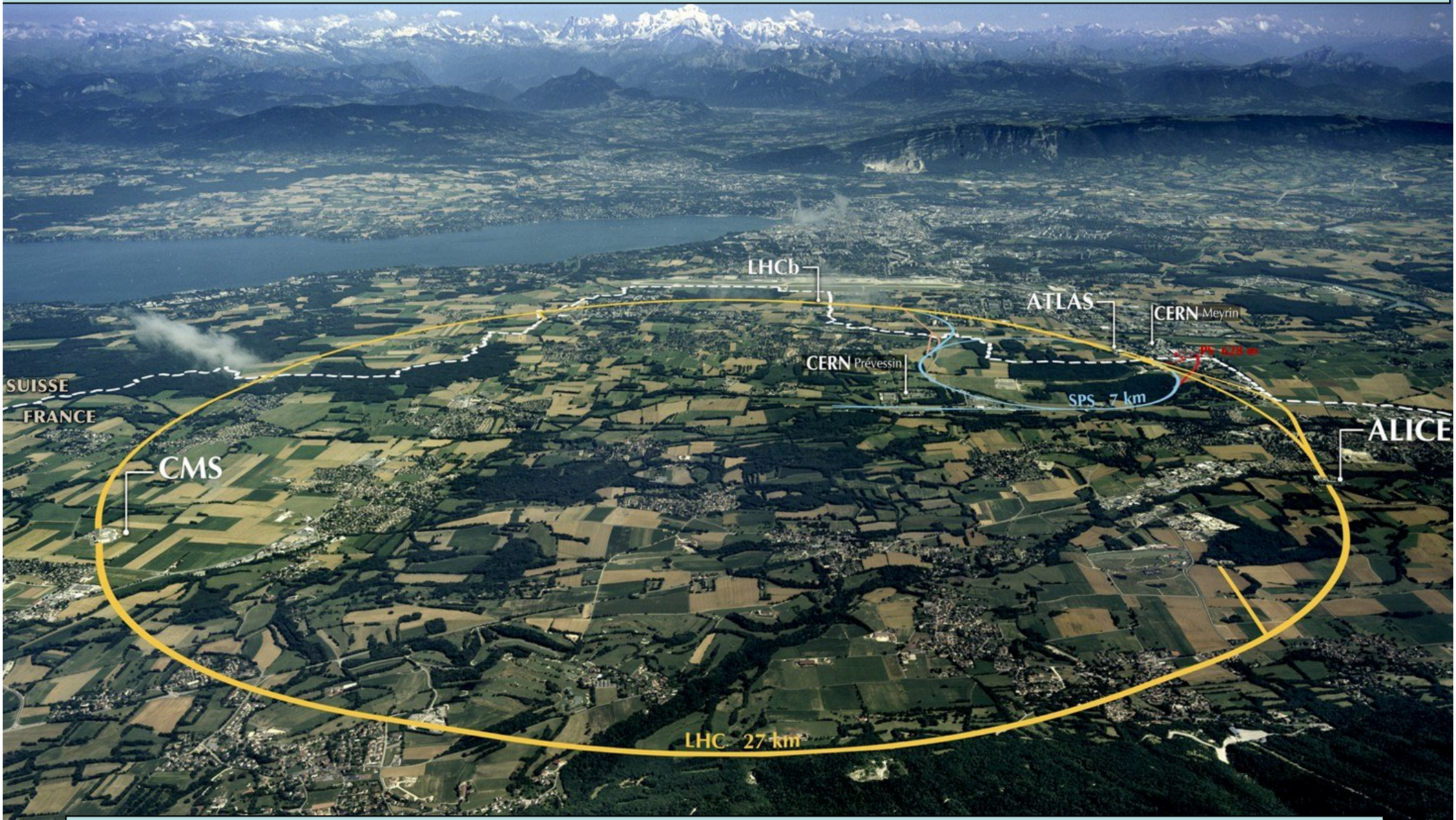
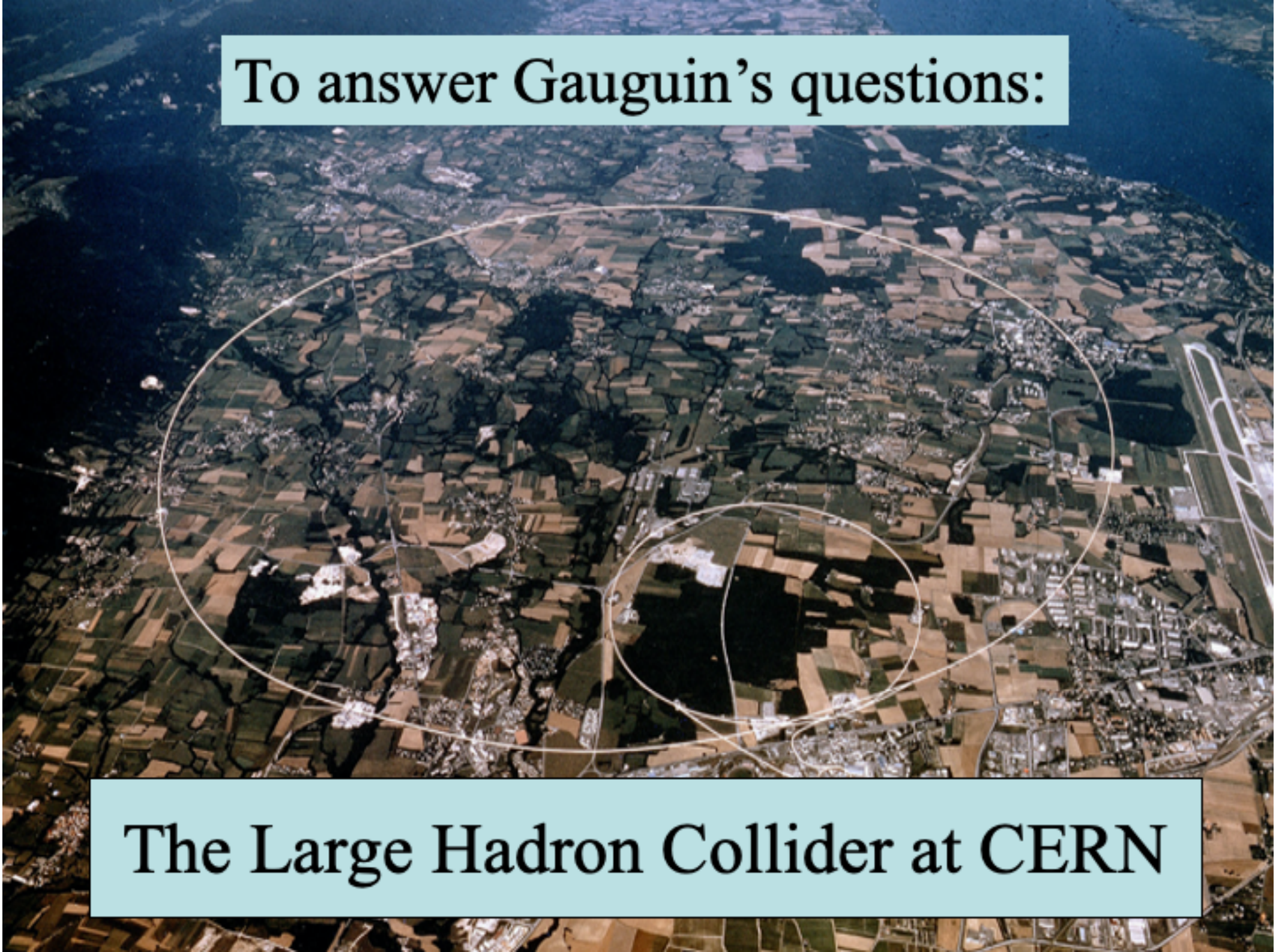
Para encontrar respuestas a las preguntas de Gauguin:



El ‘Gran Colisionador de Hadrones’ (LHC)


To answer Gauguin's questions:
The Large Hadron Collider at CERN

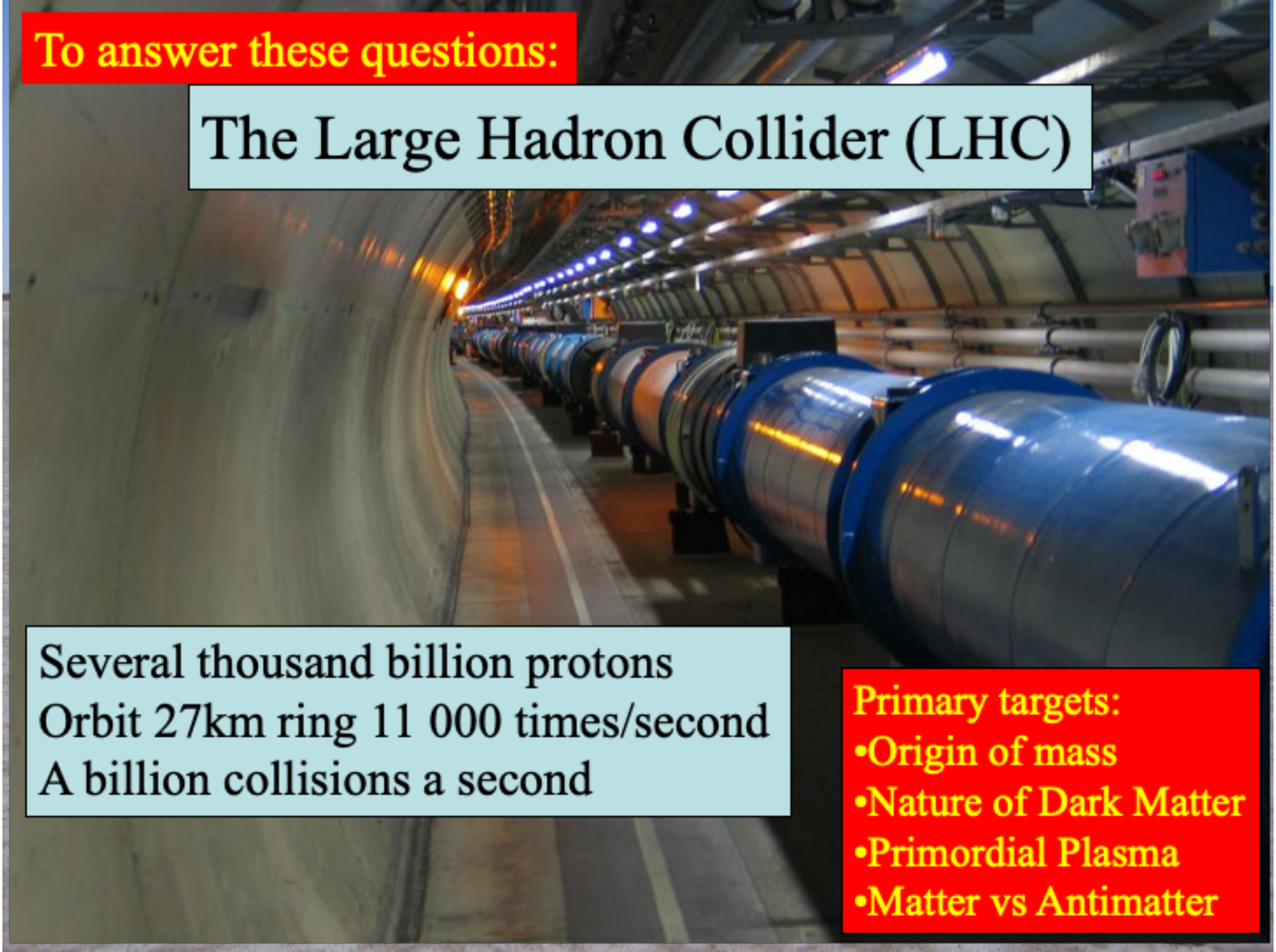
Para dar respuestas a estas preguntas:

El ‘Gran Colisionador de Hadrones’ (LHC)

Miles de millones de protones
Circulan el anillo de 27 kilómetros
de circunferencia 11,000 veces/segundo
Miles de millones de colisiones/
segundo

Objetivos primarios:

- El origen de las masas
- La materia oscura
- El plasma primordial
- Materia vs antimateria

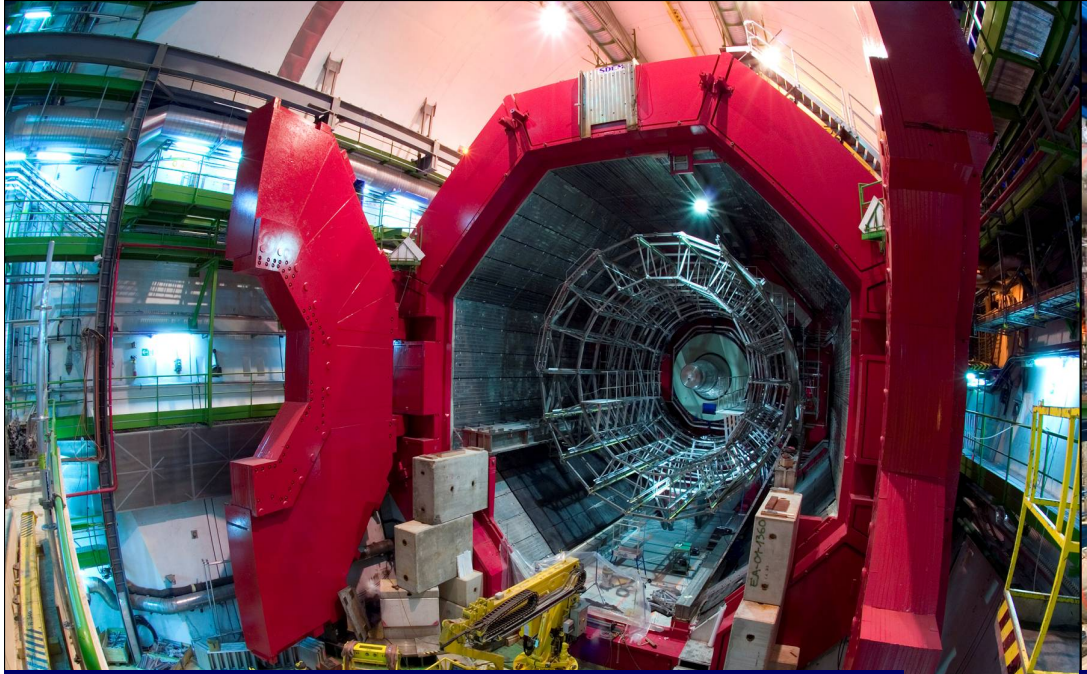


To answer these questions:

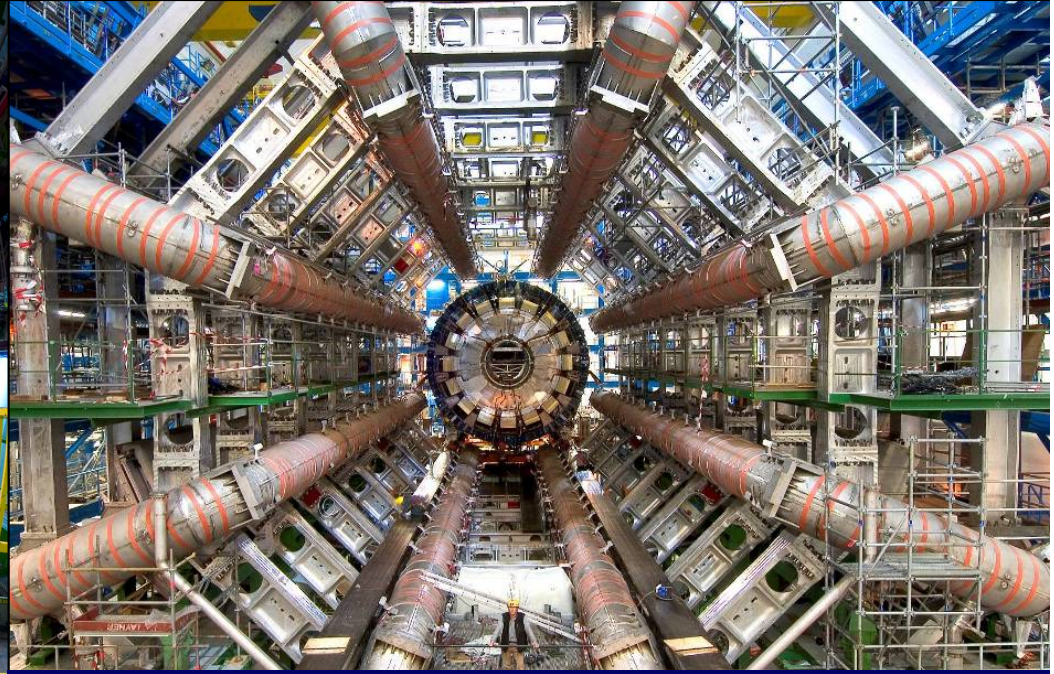
The Large Hadron Collider (LHC)

Several thousand billion protons
Orbit 27km ring 11 000 times/second
A billion collisions a second

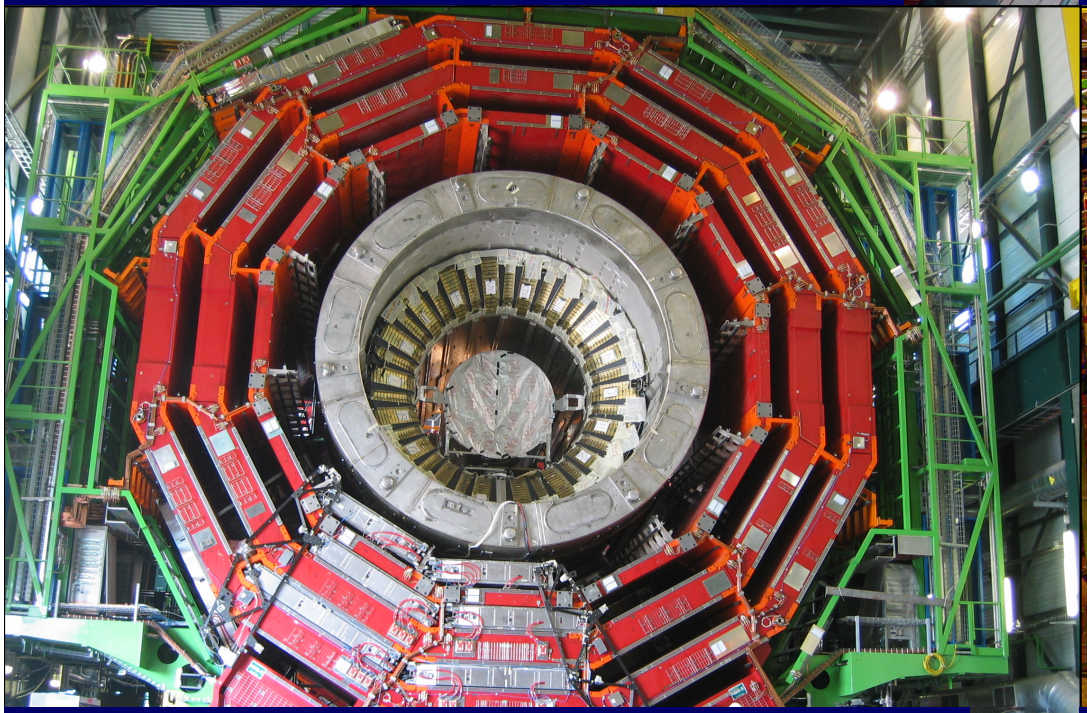
Primary targets:
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter



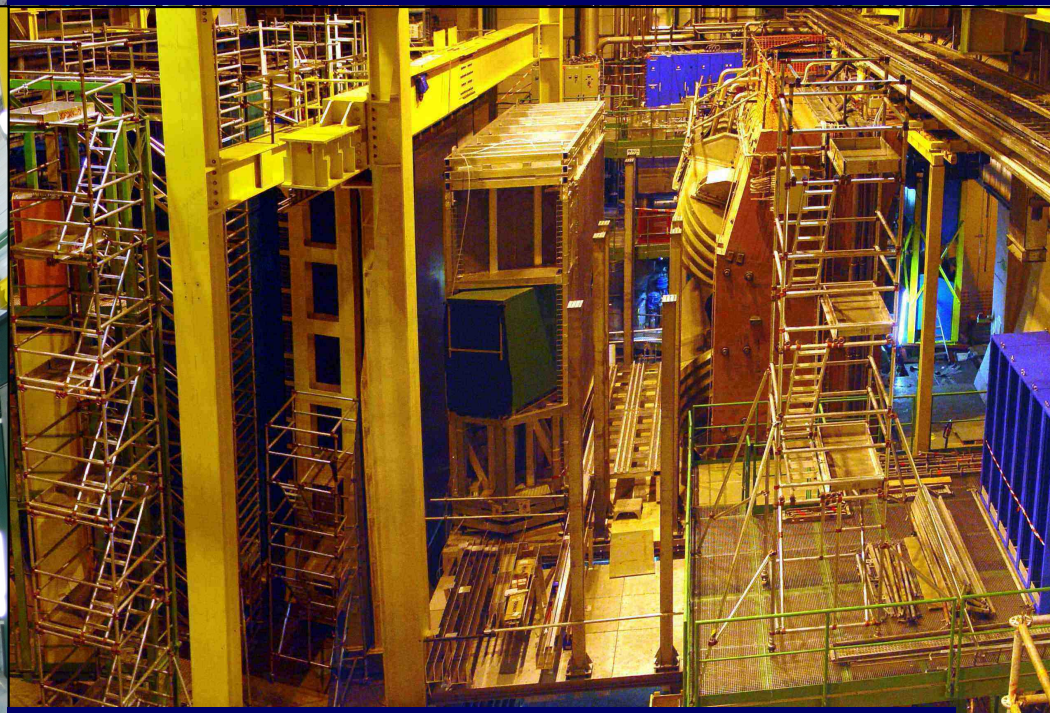
ALICE: El plasma cósmico



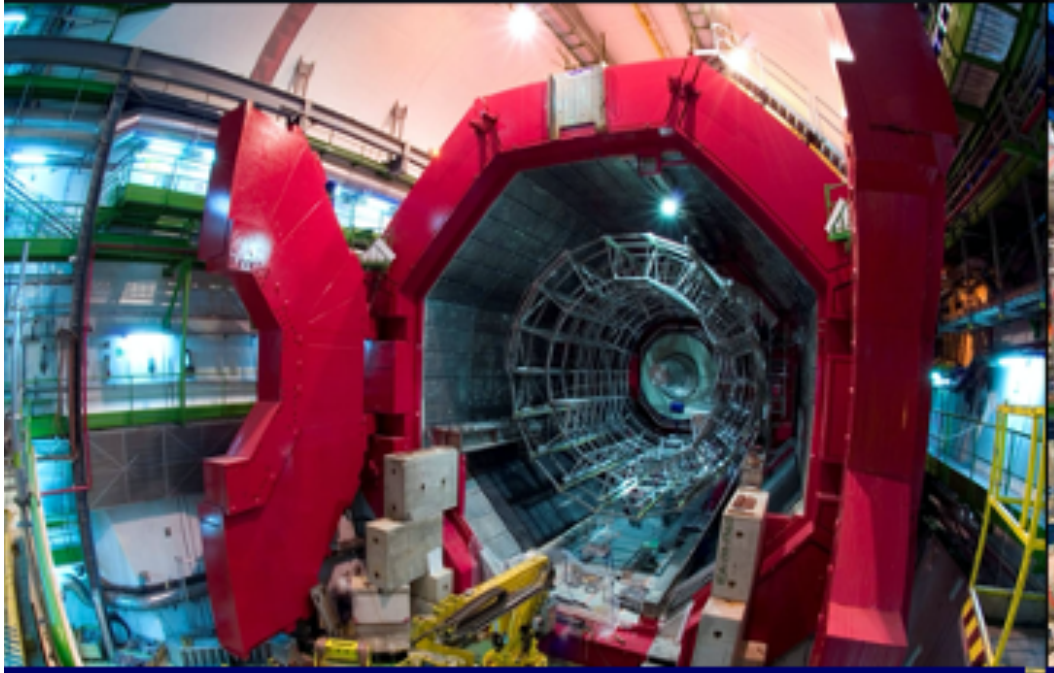
ATLAS: Higgs y materia oscura



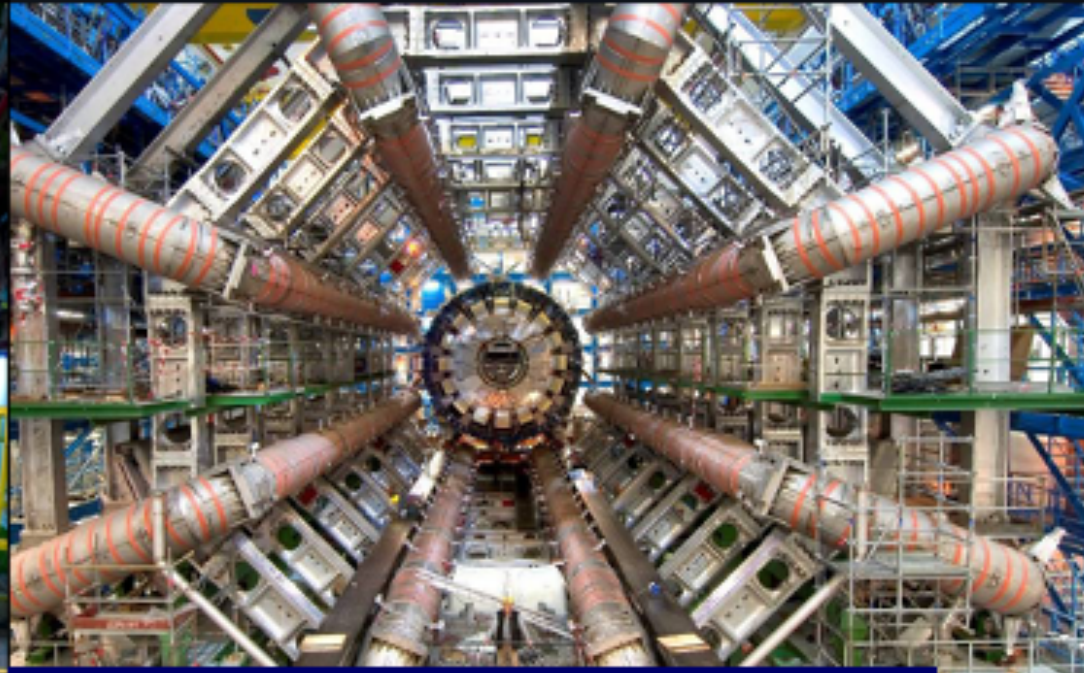
CMS: Higgs y materia oscura



LHCb: Materia y antimateria

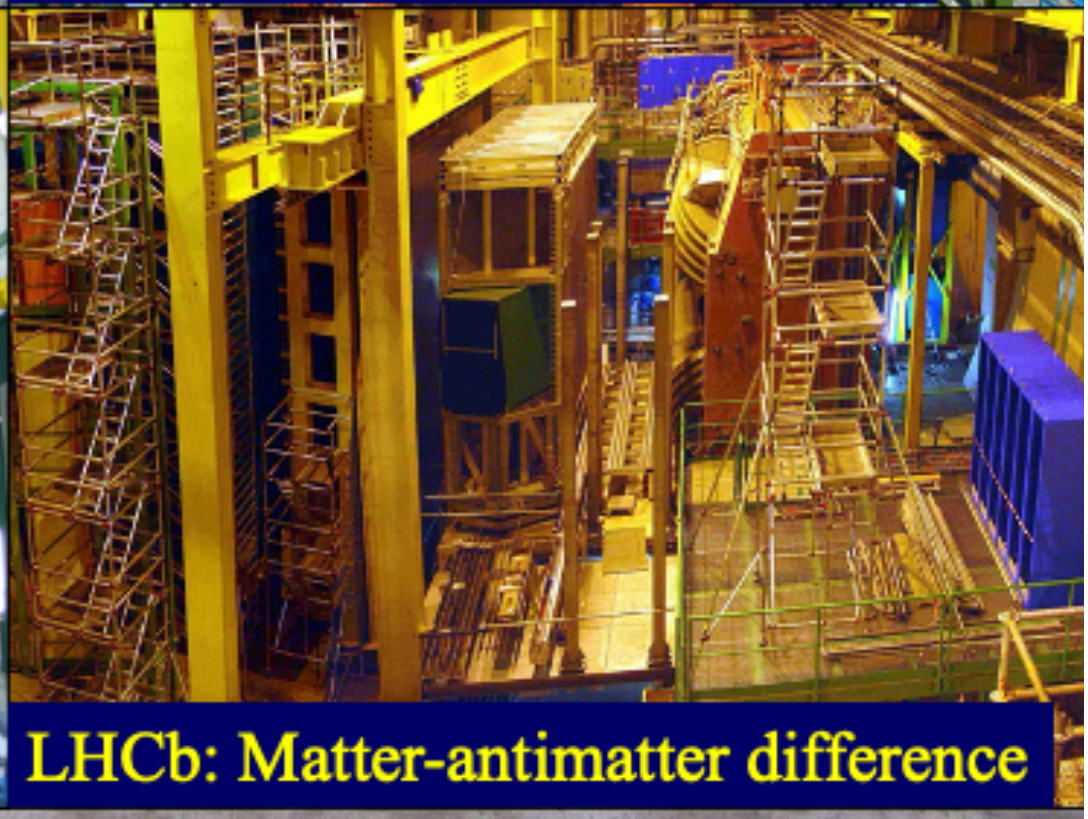


ALICE: Primordial cosmic plasma



ATLAS: Higgs and dark matter

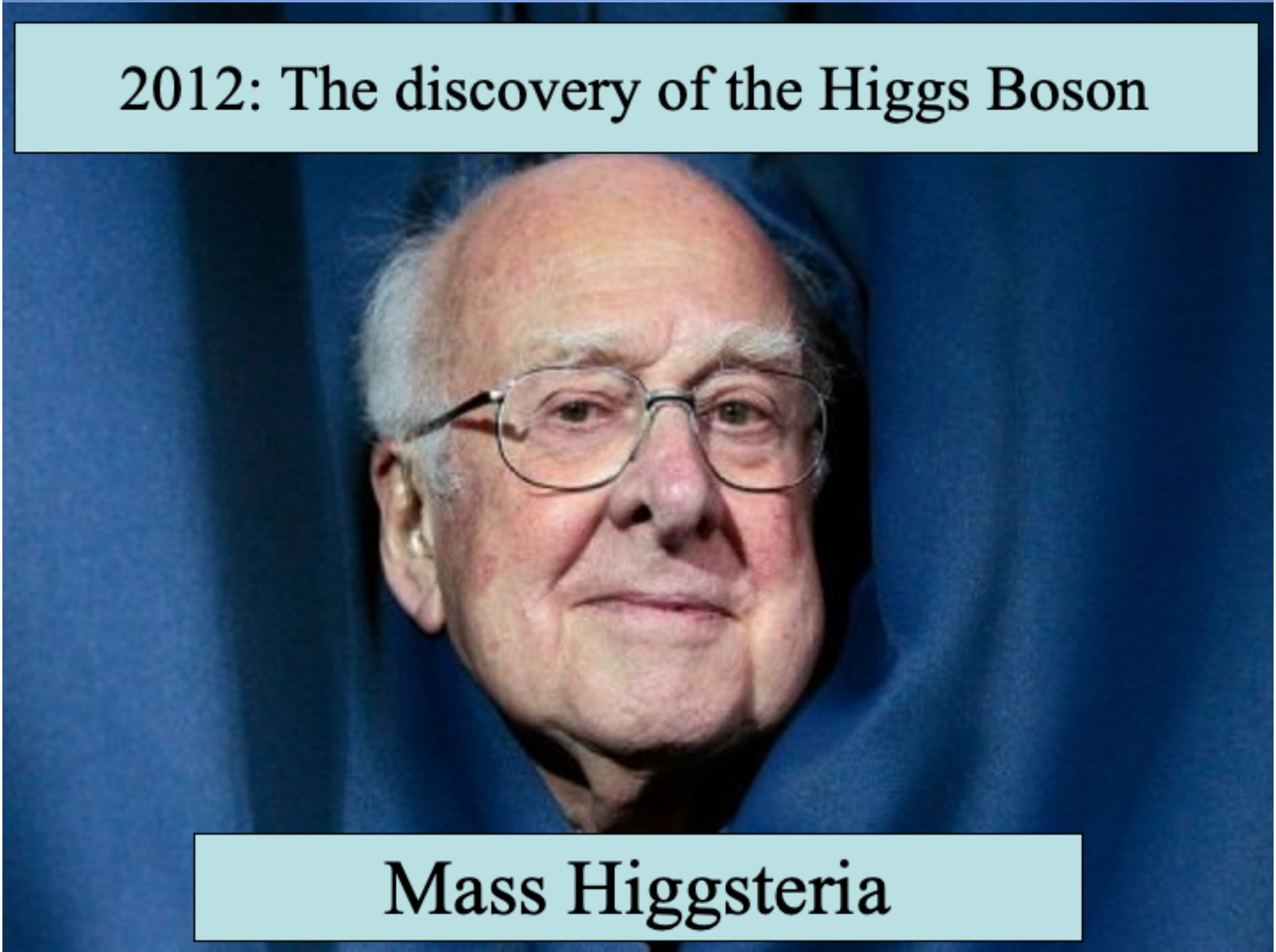
CMS: Higgs and dark matter



LHCb: Matter-antimatter difference

2012: ¡ El bosón de Higgs !

2012: The discovery of the Higgs Boson



Mass Higgsteria

Una nueva partícula

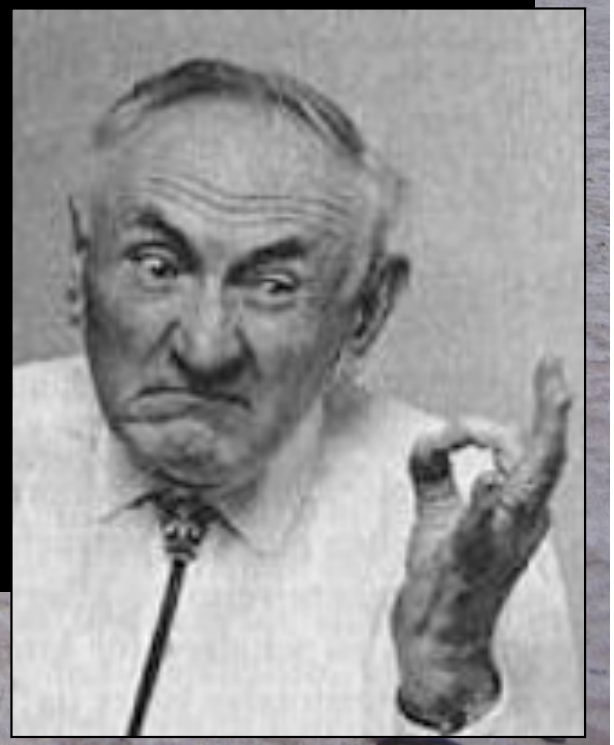
An Interesting Event

El día de la Higgsdependencia

Higgsdependence Day!

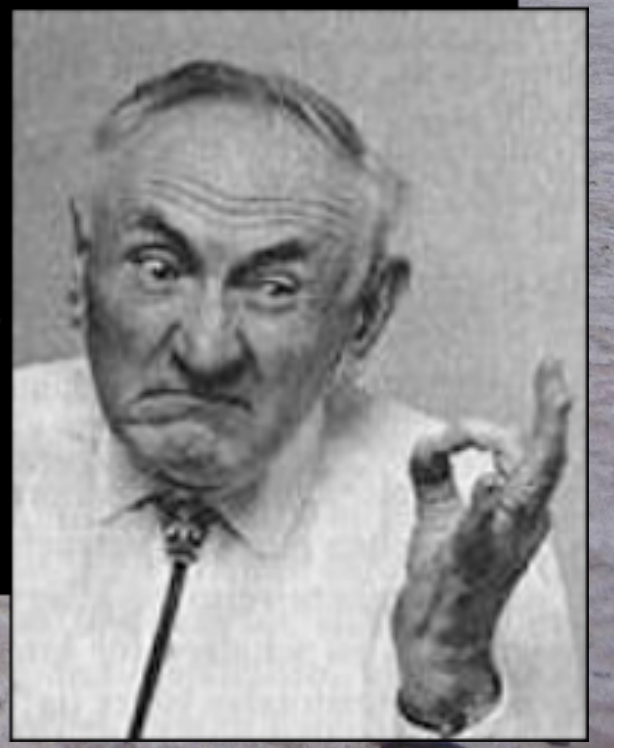
Hypótesis de la materia oscura

- Motivado por las observaciones de Fritz Zwicky del cúmulo de galaxias ‘Coma’
- Las galaxias se mueven demasiado rápido
- Las observaciones necesitan un campo gravitacional más fuerte que previsto por la materia visible
- **¿ La materia oscura ?**



The Dark Matter Hypothesis

- Proposed by Fritz Zwicky, based on observations of the Coma galaxy cluster
- The galaxies move too quickly
- The observations require a stronger gravitational field than provided by the visible matter
- **Dark matter?**



Las curvas de rotación de las galaxias

- Las observaciones de Vera Rubin
- Las estrellas también orbitan
  ‘demasiado rápido’
- Sus observaciones necesitan un campo gravitacional más fuerte que el generado por la materia visible
- **Otra prueba de la materia oscura**


Scanned at the American Institute of Physics

The Rotation Curves of Galaxies

- Measured by Vera Rubin
- The stars also orbit ‘too quickly’
- Her observations also required a stronger gravitational field than provided by the visible matter

Scanned at the American Institute of Physics

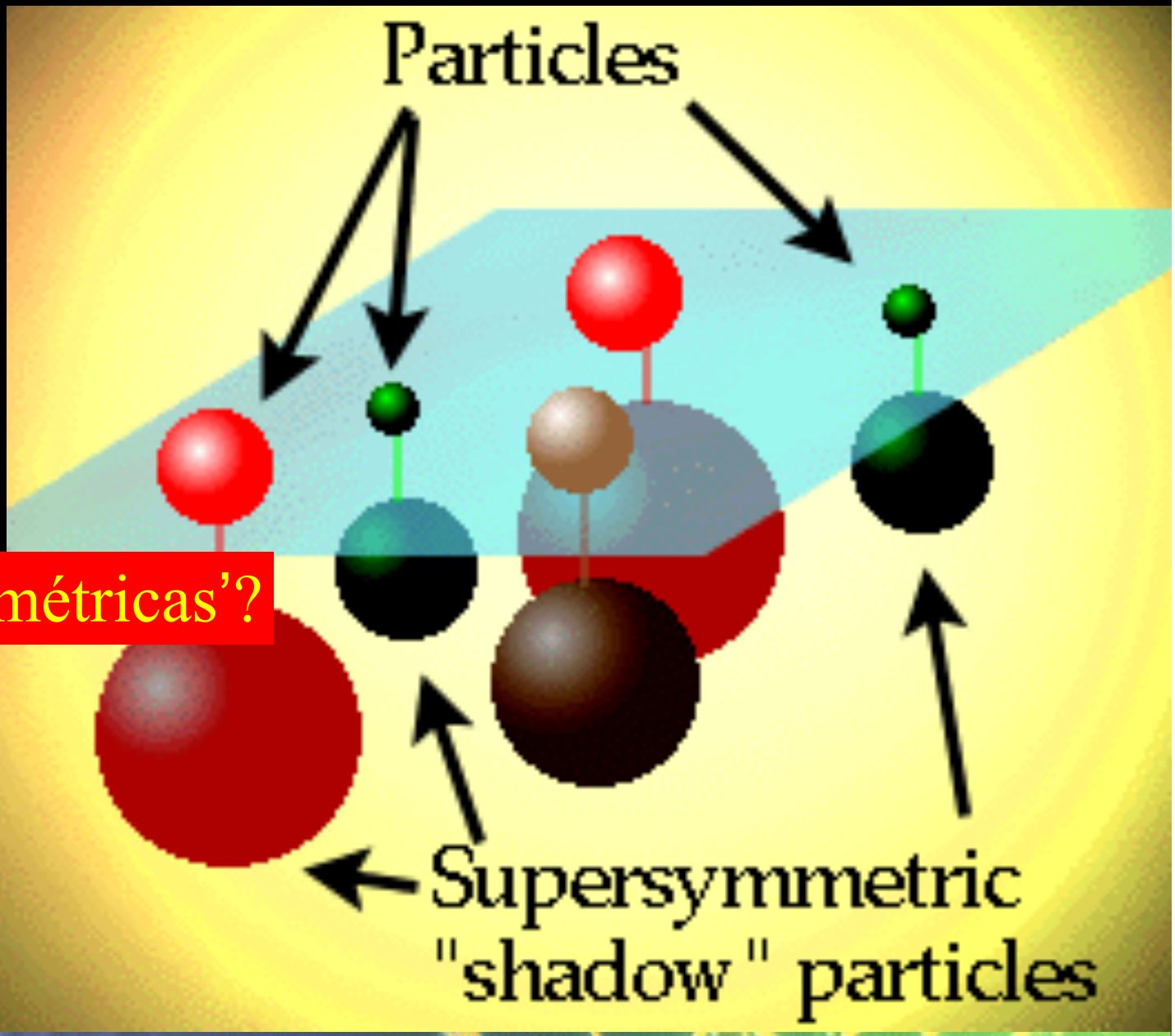
- **Further strong evidence for dark matter**

¿ La materia oscura en el Universo ?

Los astrónomos nos dicen que la mayoría de la materia en el Universo es ‘Materia oscura’ invisible

¿ Partículas ‘Supersimétricas’?

Las buscamos con los experimentos al LHC

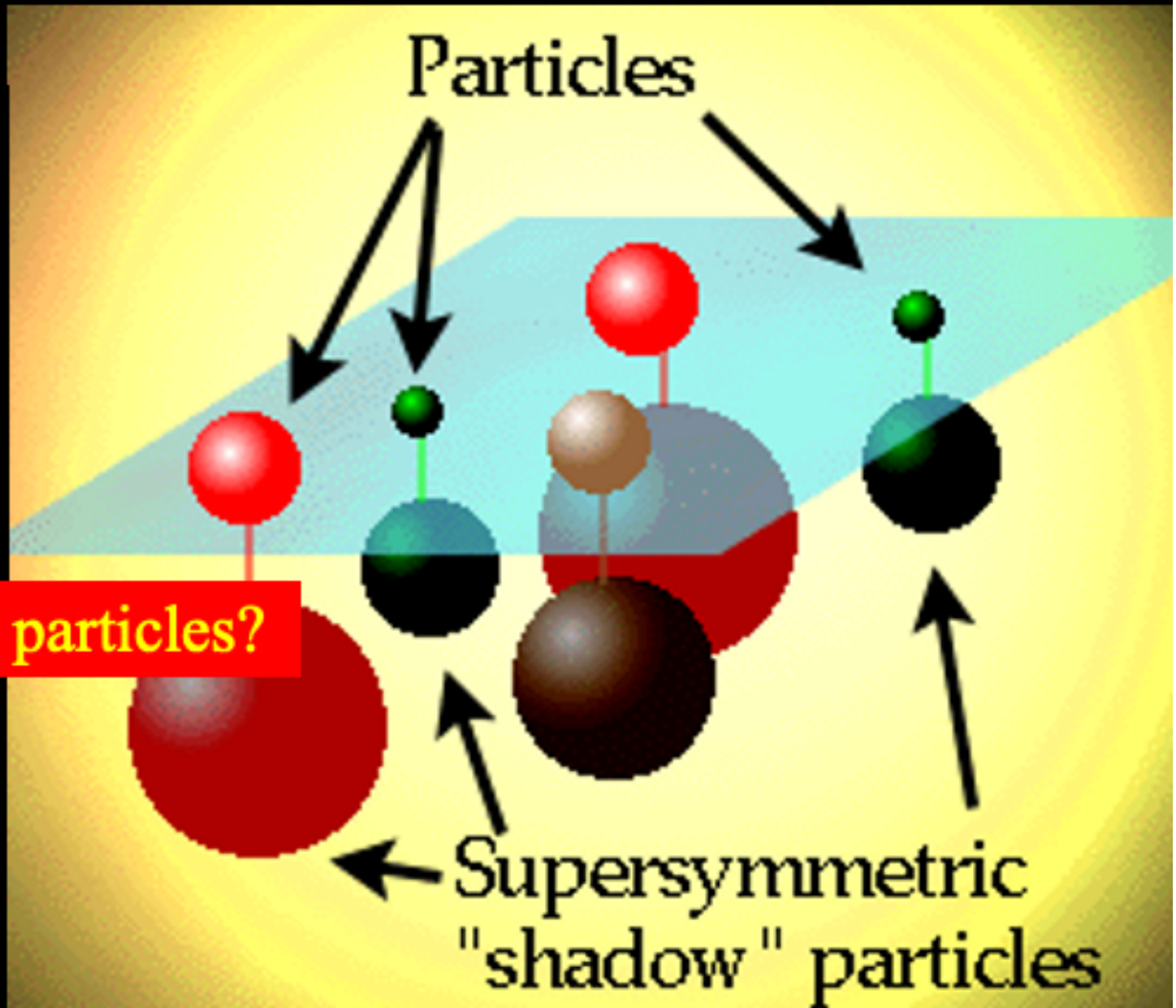


What is the Dark Matter in the Universe?

Astronomers say that most of the matter in the Universe is invisible Dark Matter

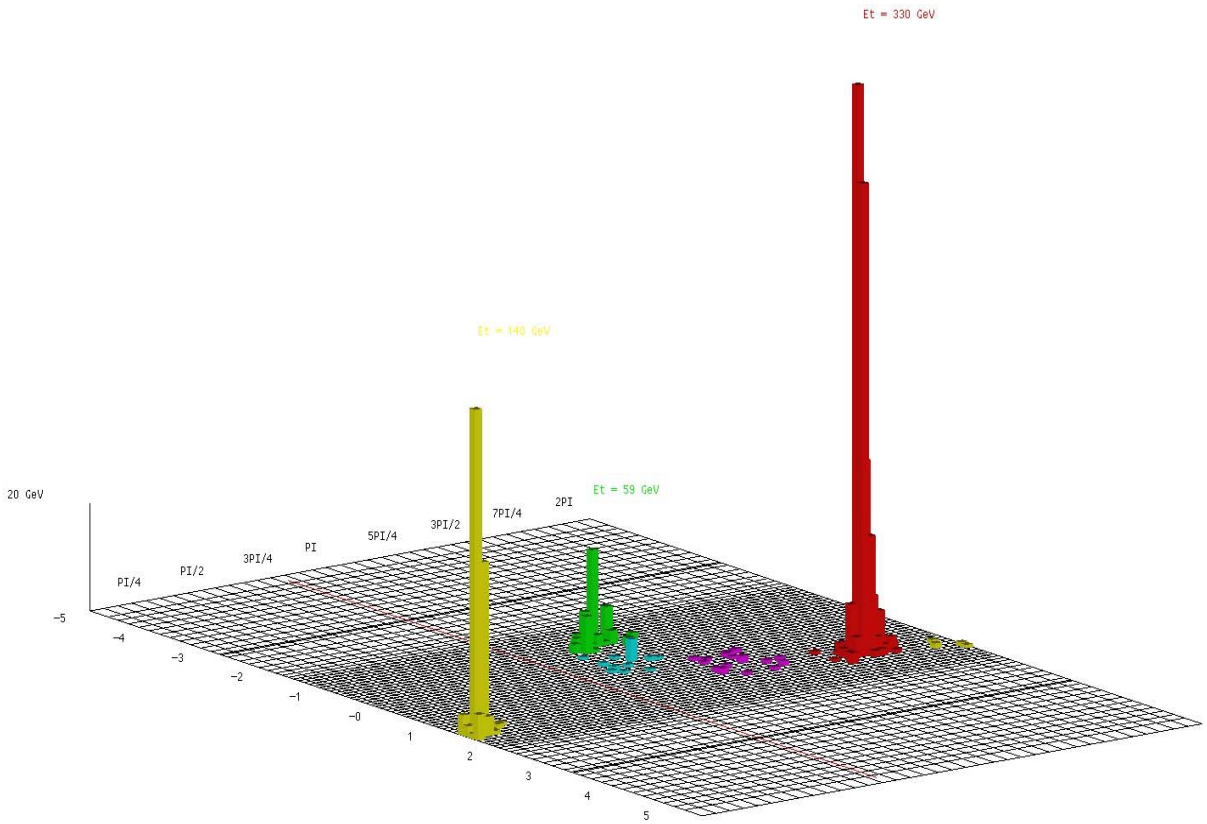
Made of unknown particles?

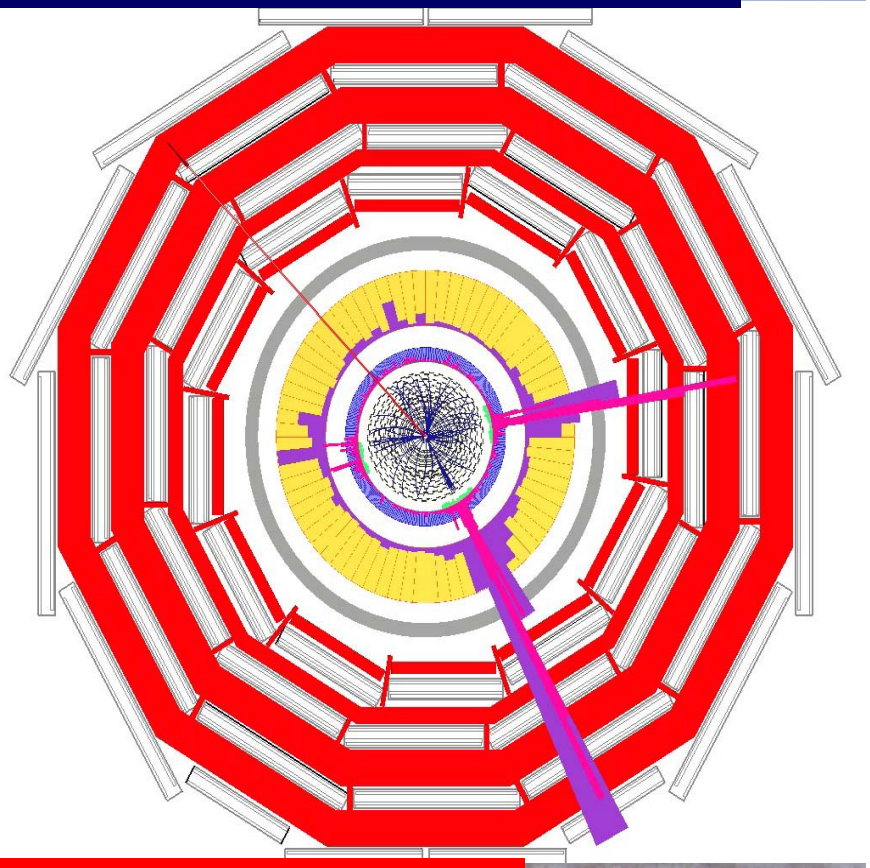
We are searching for them at the LHC



Búsquedas de la supersimetría en el LHC

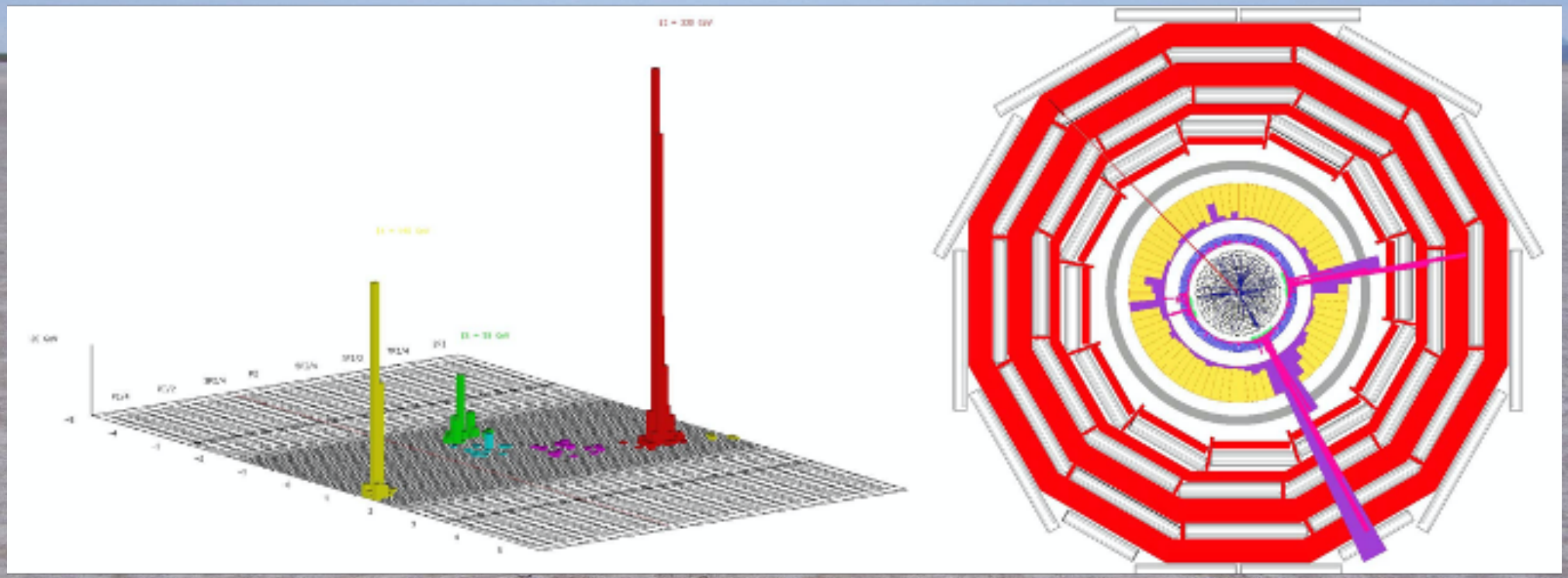
Simulación de un evento supersimétrico en el LHC





Energía faltante llevada por las partículas supersimétricas de la materia oscura

Classic Dark Matter Signature



Missing transverse energy carried away by dark matter particles

La diferencia entre la materia y la antimateria:
¿El origen de la materia?

Dirac previdió las ANTIpartículas:

Las mismas masas

Propriedades internas opuestas:

cargas eléctricas, …

Descubiertos en los rayos cósmicos

Estudiados por los aceleradores

La materia y la antimateria no son iguales: ¿POR QUÉ?

¿Por qué el Universo contiene materia, no antimateria?

El experimento LHCb está buscando las respuestas

How do Matter and Antimatter Differ?

Dirac predicted the existence of antimatter:
- same mass
- opposite internal properties:
  - electric charge, …

Discovered in cosmic rays

Studied using accelerators

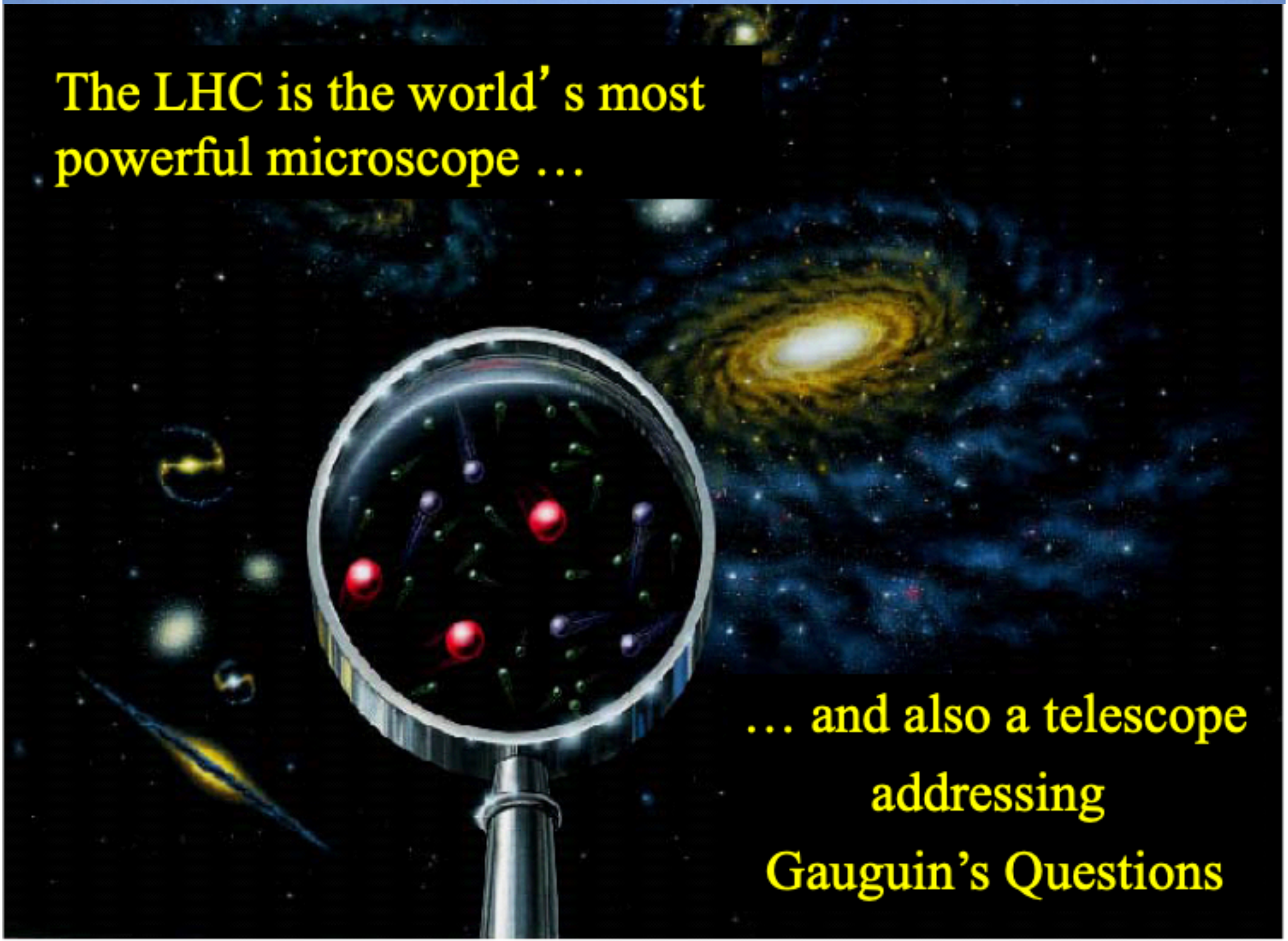
Used in PET scanners

Matter and antimatter not quite equal and opposite: WHY?

Why does the Universe mainly contain matter, not antimatter?

The LHCb experiment is looking for answers


El LHC no es sólo
un super-microscopio …
… también un super-telescopio
investigando los secretos
oscuros del Universo


The LHC is the world's most powerful microscope …
… and also a telescope addressing Gauguin's Questions