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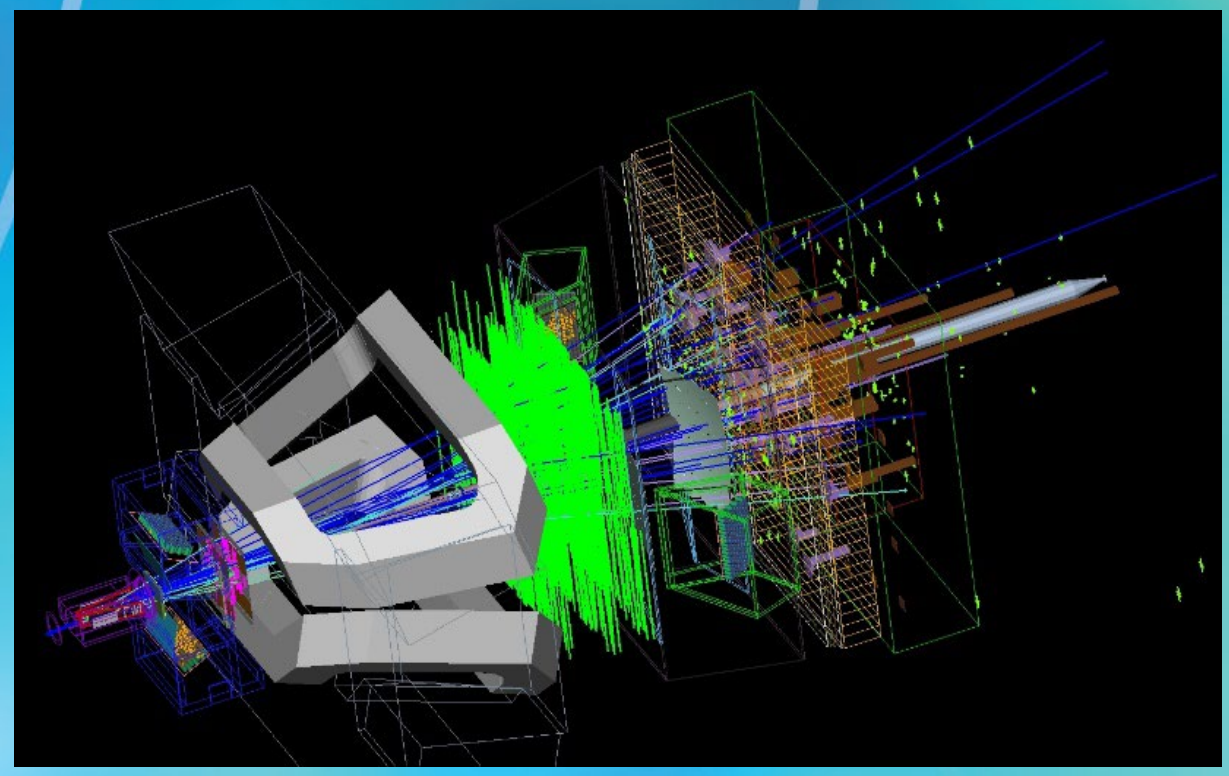
# INTERNATIONAL MASTERCLASSES

# HANDS ON PARTICLE PHYSICS

## 2024



# HISTORY OF THE UNIVERSE

Dark energy accelerated expansion

Structure formation

Cosmic Microwave Background radiation is visible

RHIC & LHC heavy ions

Accelerators

LHC protons

High-energy cosmic rays

Size of visible universe

Inflation

TODAY

POSSIBLE DARK MATTER RELICS

NUCLEONS FORM

NUCLEI FORM

Big Bang

$t = 10^{-36}$ s
$E = 10^{16}$ GeV

$t = 10^{-10}$ s
$E = 10^{2}$ GeV

$t = 10^{-4}$ s
$E = 10^{-1}$ GeV

$t = 10^{2}$ s
$E = 10^{-4}$ GeV

$t = 3 \times 10^{5}$ y
$E = 3 \times 10^{-10}$ GeV

$t = 10^{9}$ y
$E = 10^{-12}$ GeV

$t = 13.8 \times 10^{9}$ y
$E = 2.3 \times 10^{-13}$ GeV

t = Time (seconds, years)

E = Energy of photons (units GeV = 1.6 x $10^{-10}$ joules)

**Key**

quark, gluon, electron, muon, tau

neutrino, bosons, meson, baryon

ion, atom, photon

star, galaxy, black hole

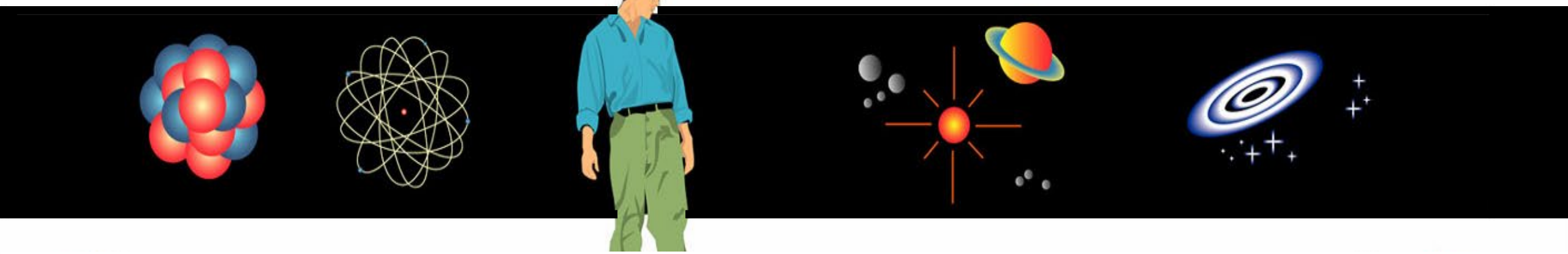
The concept for the above figure originated in a 1986 paper by Michael Turner.



Supported by DOE

Particle physics looks at matter in its smallest dimensions.

Astrophysics looks at matter in its largest dimensions.



$10^{-18}$ $10^{-15}$ $10^{-12}$ $10^{-9}$ $10^{-6}$ $10^{-3}$ $10^{0}$ $10^{3}$ $10^{6}$ $10^{9}$ $10^{12}$ $10^{15}$ $10^{18}$ $10^{21}$ $10^{24}$ m

**Microscopes**

**Binoculars**

**Optical & radio telescopes**

**Accelerators and detectors**

**Naked eye**

$\lambda = h/p$

# THE TWO FRONTIERS OF PHYSICS

**To study the Universe at small distances we need high energies:**
**Particle Physics ≡ High Energy Physics**

**Parámetros (protones)**

- Energía: **7 TeV**
- Campo magnético: **8.3 T**
- **$3\times10^{14}$ protones / haz** (en 3000 paquetes)
- Corriente: 0.56 A

**Energía almacenada**

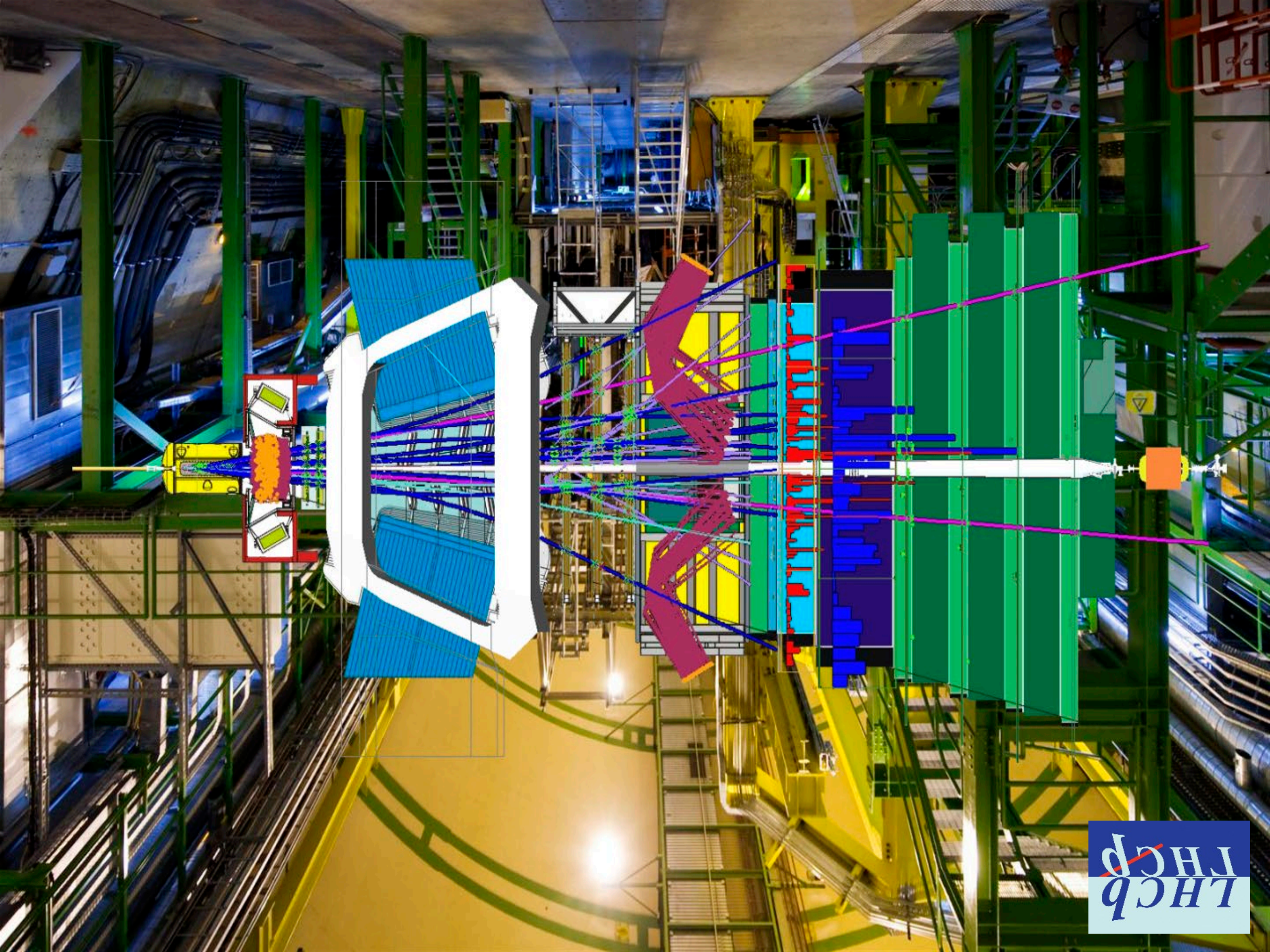
Energía en los dos haces: 0.7 GJ

Energía en los imanes: 10.4 GJ

50 toneladas a 600 km/h


CMS
LHCb
ALICE
ATLAS

- 21 m de longitud
- 10 m de alto
- 13 m de ancho
- 5600 toneladas

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NOW, HAVE FUN