

# **Why are we here?**

## **Origin of the Universe and Life**

**Prof. Katsushi Arisaka**

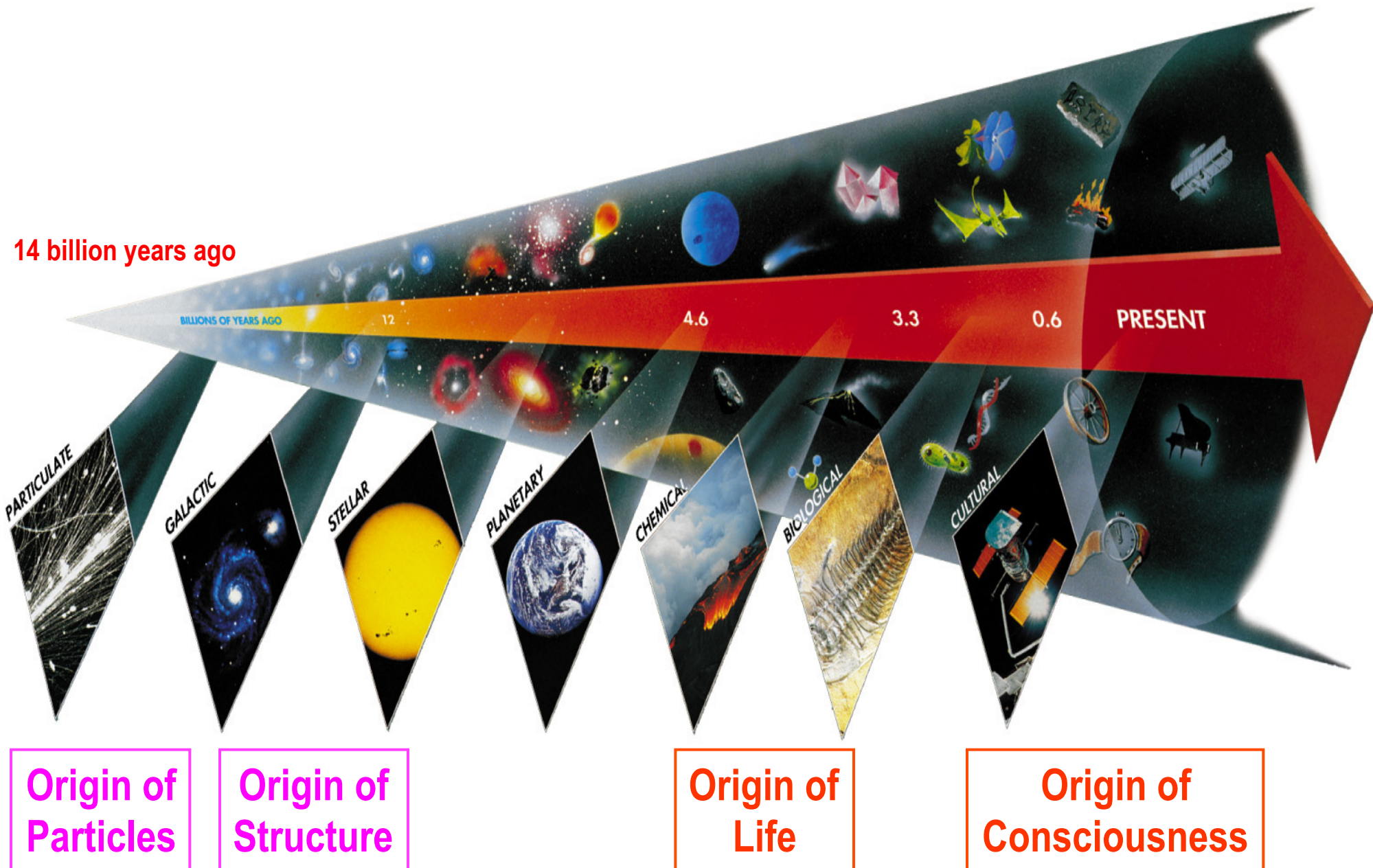
***University of California, Los Angeles  
Department of Physics and Astronomy***

[arisaka@physics.ucla.edu](mailto:arisaka@physics.ucla.edu)



**Why are we here?**

# Seven Phases of Cosmic Evolution



# Talk Outline

## ➤ Prof. Katsushi Arisaka

- Origin of Universe
- Origin of Particles
- Evolution of Universe

2:00 – 3:20

- *Cosmology*
- *Particle Physics*
- *Astronomy*

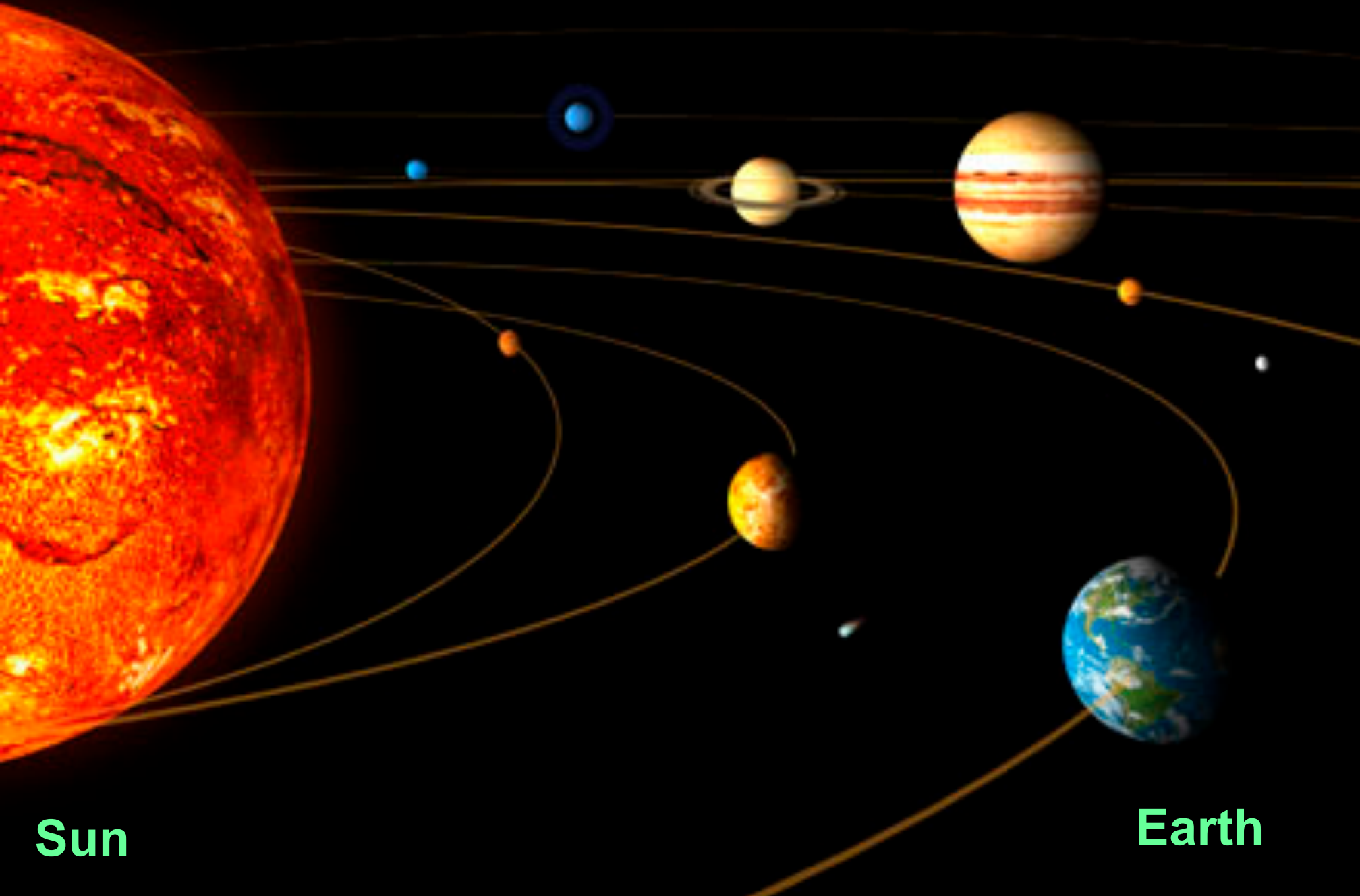
## ➤ Daniel Aharoni

- Origin of Life
- Origin of Consciousness

3:30 – 5:00

- *Molecular Biology*
- *Neuroscience*

# Solar System



Sun

Earth

# Andromeda



**~100 Billions Stars in a Galaxy**



Keck Telescope

Subaru Telescope

Mauna Kea at Hawaii  
(4200m)

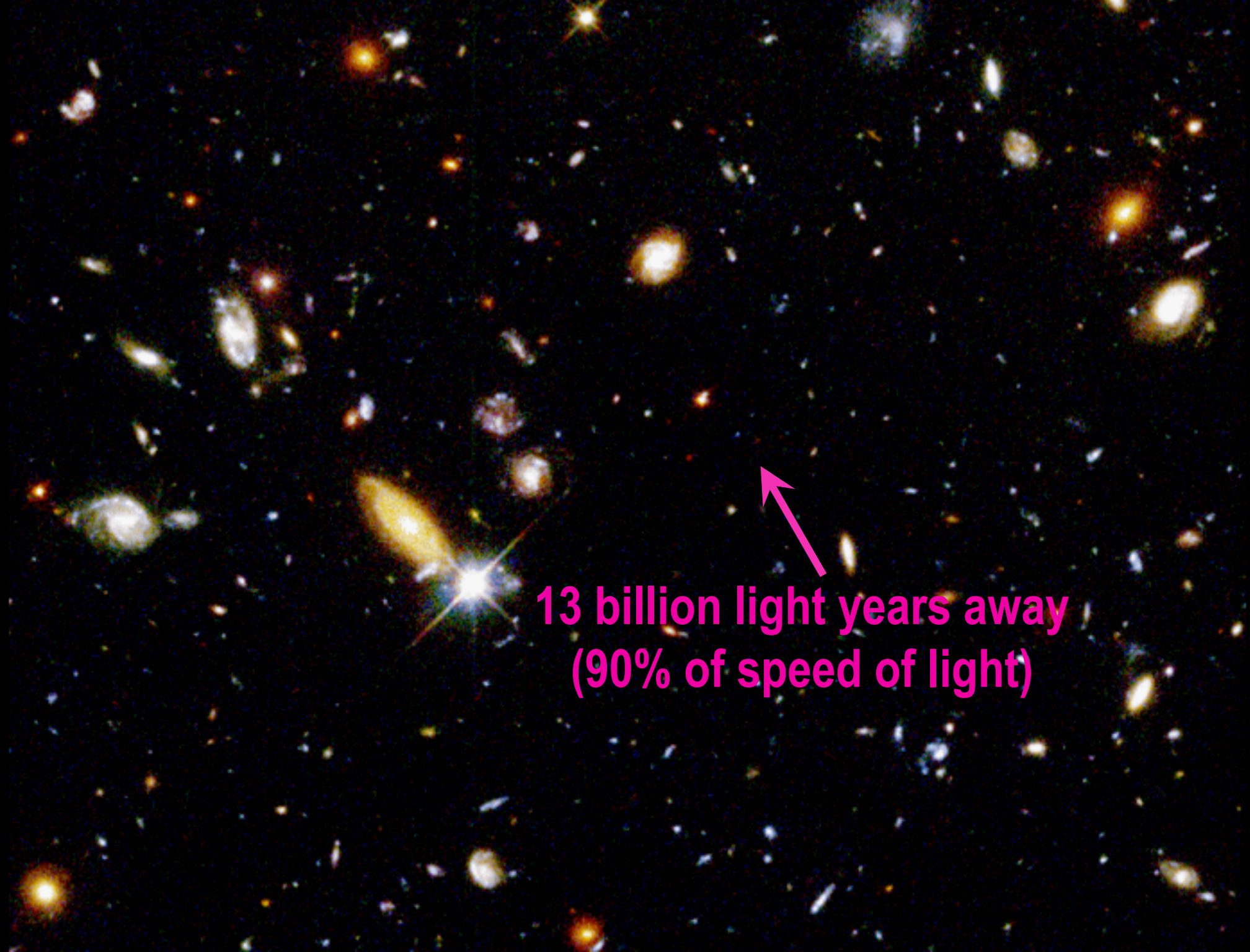
# Hubble Telescope



# Hubble Deep Field

The image displays a dense field of galaxies, including various types such as spiral, elliptical, and irregular galaxies, as well as numerous individual stars. The galaxies are scattered across the field, with some appearing as bright, distinct objects and others as faint, distant points of light. The overall appearance is a rich, multi-colored collection of celestial bodies against a dark background.

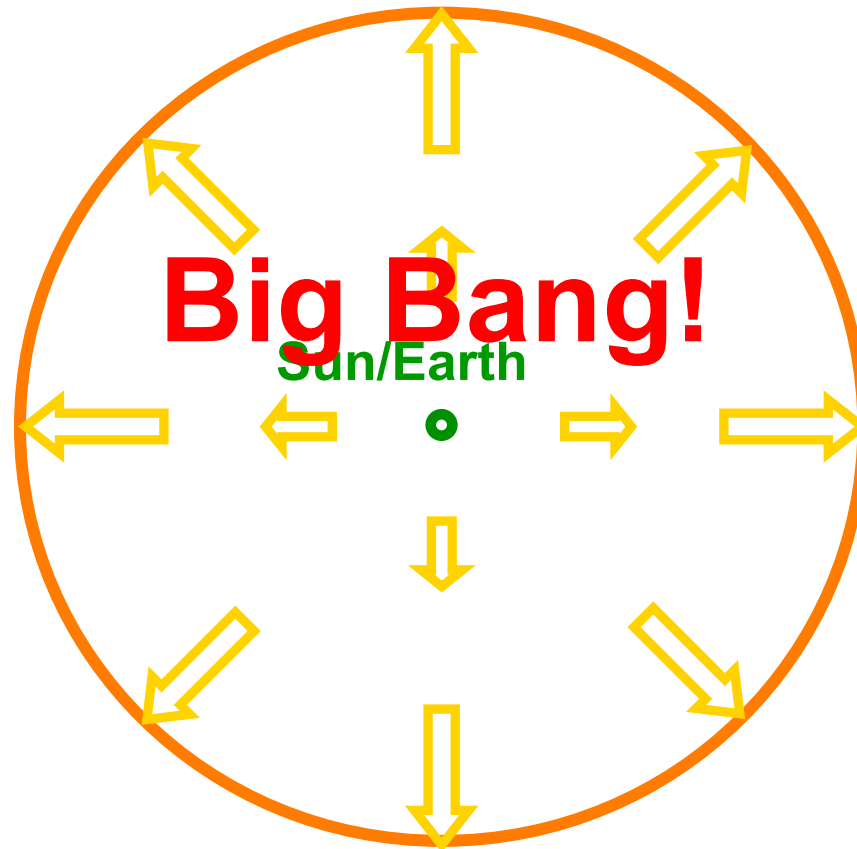
**~100 Billion Galaxies**



**13 billion light years away  
(90% of speed of light)**

# Hubble's Law: Expansion of the Universe

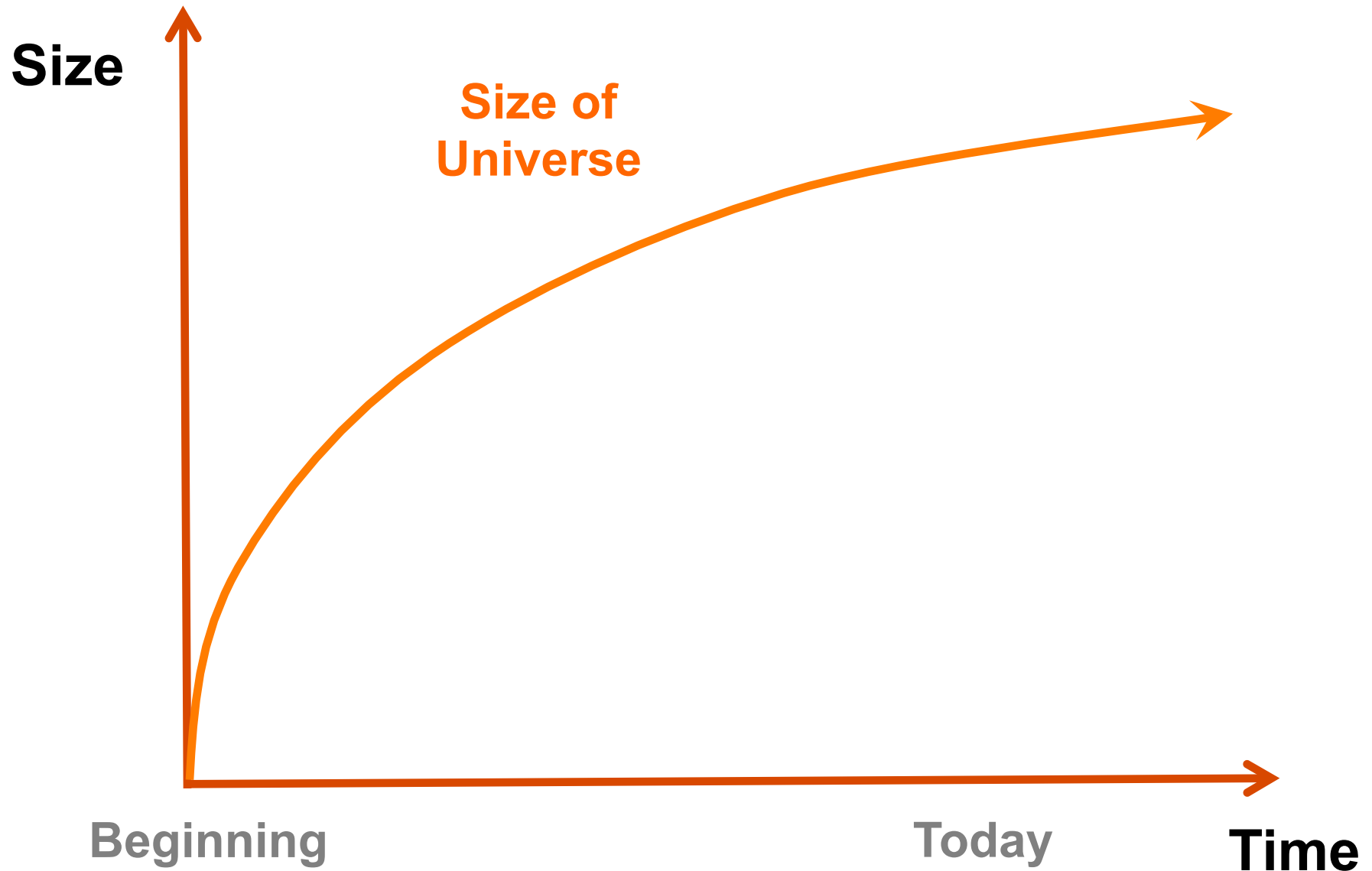
Horizon  
of Universe



14 Billion  
Light Years

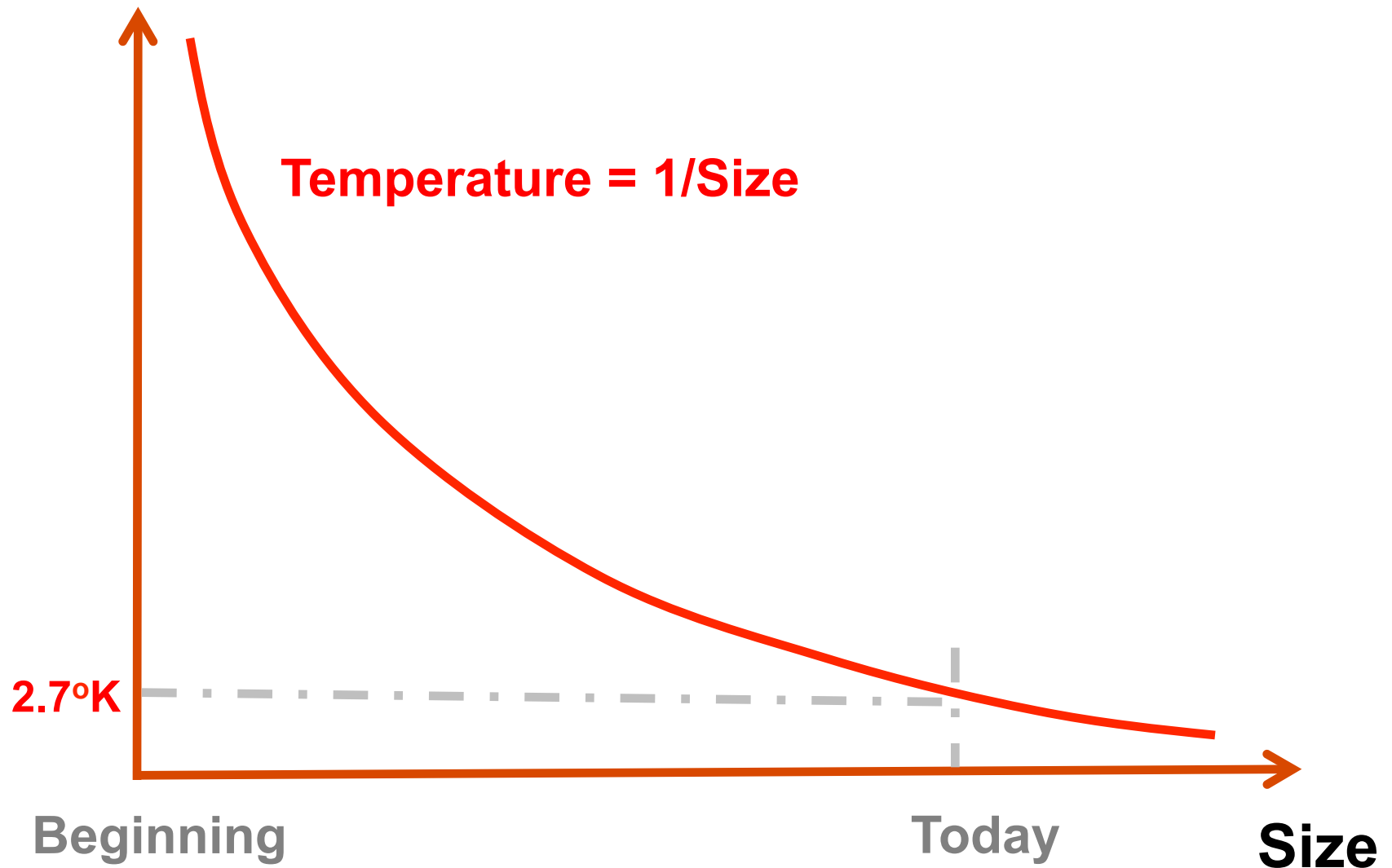
Moving Away  
at Speed of Light

# Expansion of Universe



# Temperature of Universe

Temperature



# Particle Physics

## ➤ Purpose:

- To understand the most elementary particles in nature.
- To understand the most fundamental physics laws = interaction among elementary particles.



## ➤ How?

- Study the shortest distance = The highest energy (= the highest temperature)



➤ **The best way to understand the earliest stage of the Universe**

# Periodic Table of Elements (1900)

	IA																			0		
1	1 H																				2 He	
2	3 Li	IIA	4 Be																			10 Ne
3	11 Na		12 Mg	IIIB	IVB	VB	VIB	VII B	VIII	VII	IB	IB										18 Ar
4	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			
5	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			
6	55 Cs		56 Ba	*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			
7	87 Fr		88 Ra	+Ac	104 Rf	105 Ha	106	107	108	109	110											

\* 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
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H - gas

Li - solid

Br - liquid

Tc - synthetic



Non-Metals



Transition Metals



Rare Earth Metals



Halogens



Alkali Metals



Alkali Earth Metals

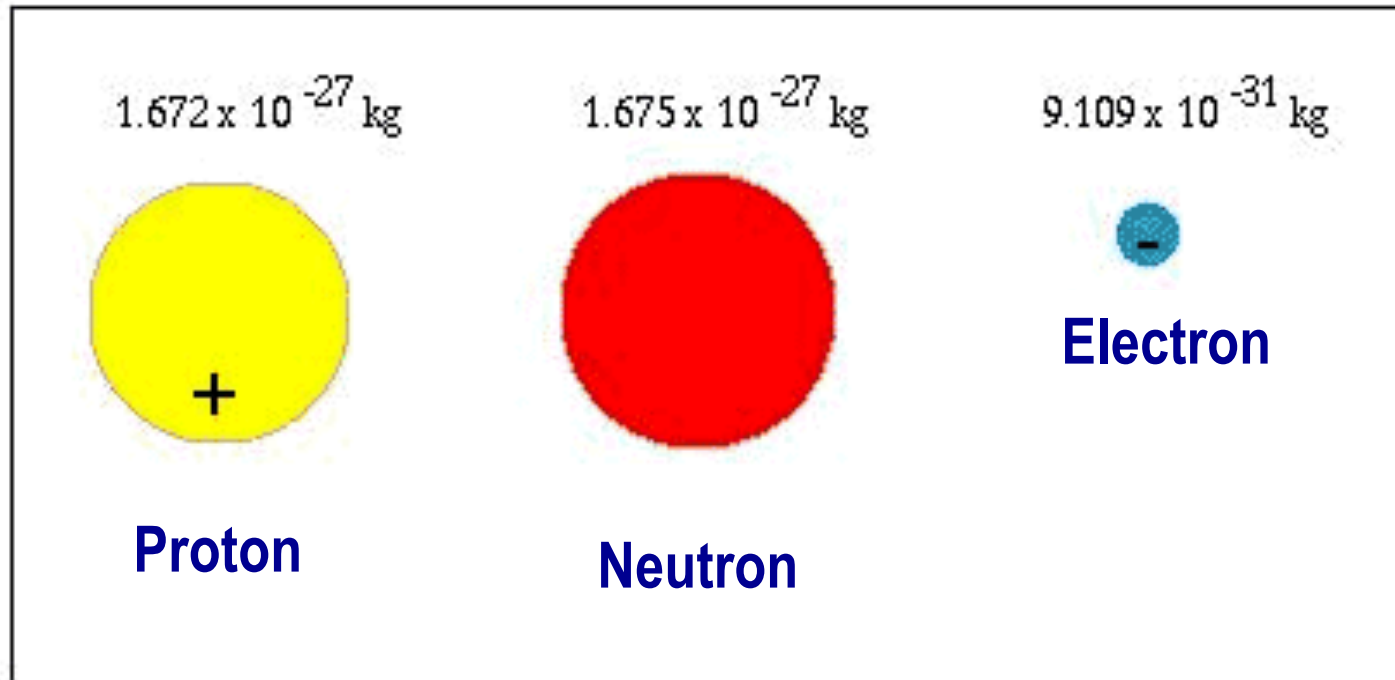


Other Metals



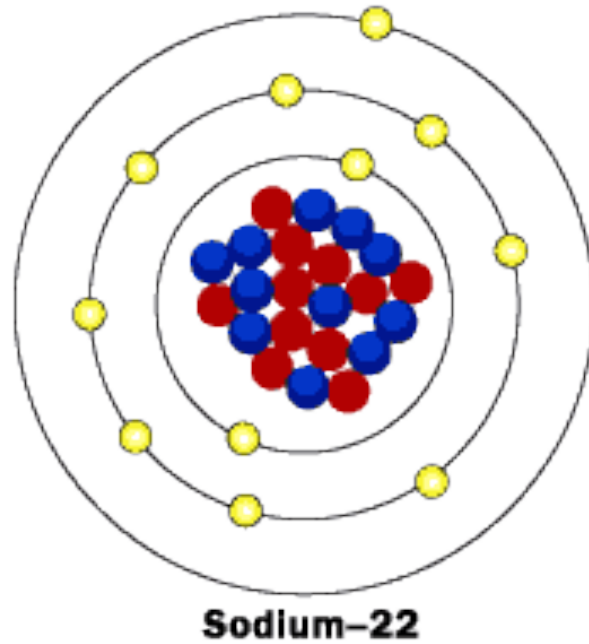
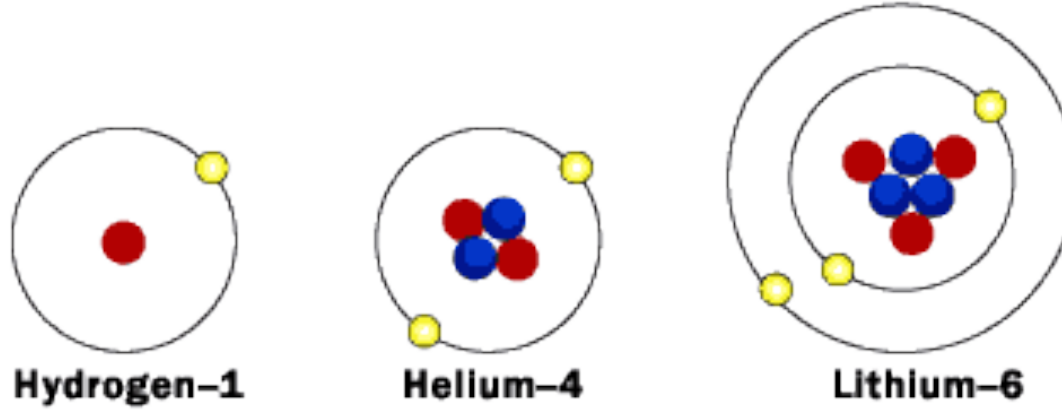
Inert Elements

# Elementary Particles (1930)



$$\text{Avogadro Number} = 1 \text{ g} / 1.762 \times 10^{-27} \text{ kg} = 6 \times 10^{23}$$

# Atoms



● Neutron      ● Proton      ● Electron

# SLAC (Stanford Linear Accelerator Center)

1 mile long

$e^+ + e^-$



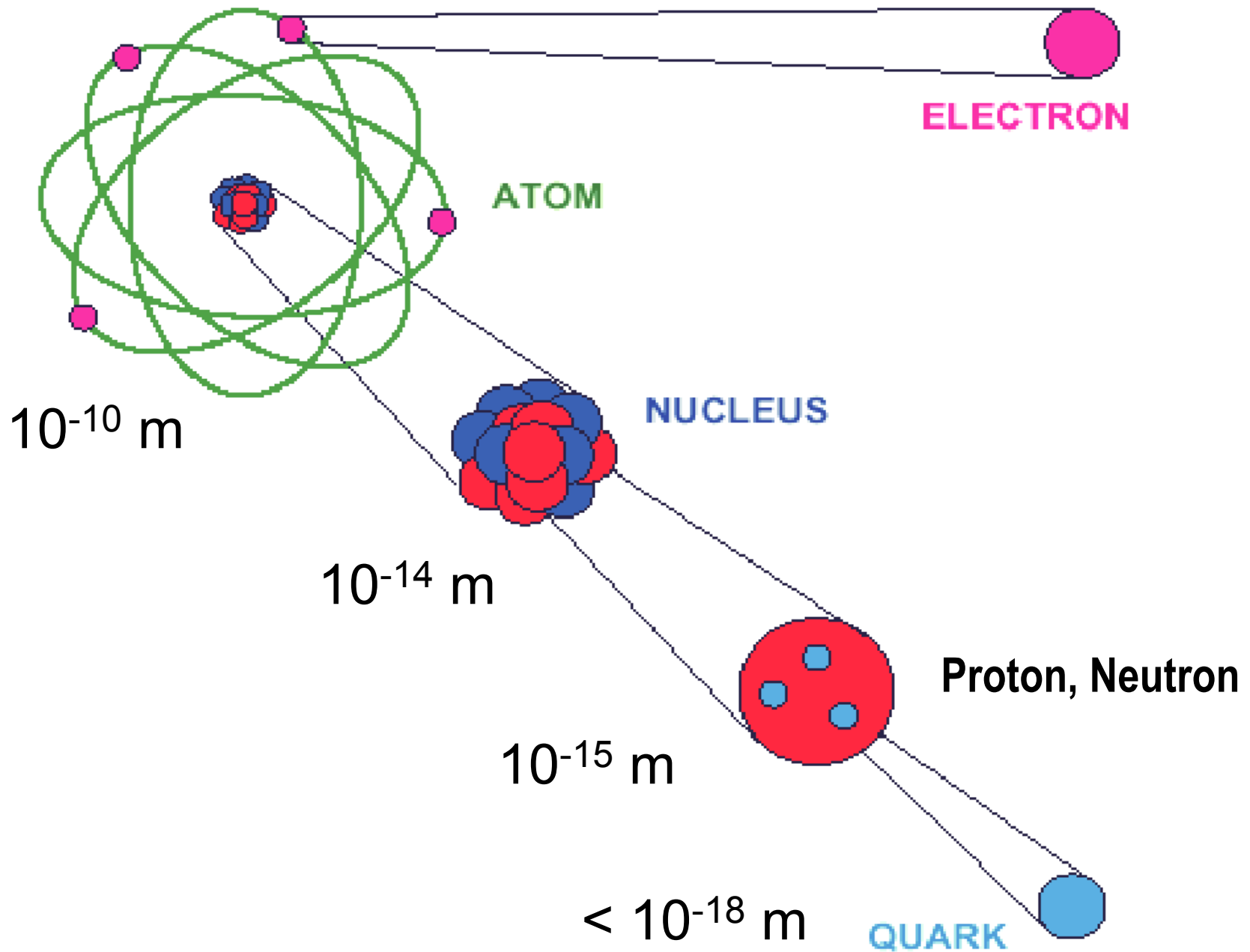
# Fermi Lab near Chicago

6km Circumference  
 $1+1=2$  TeV

$p + p^-$

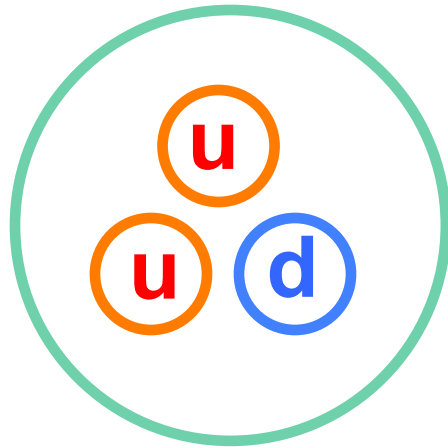


# Elementary Particles (1970)



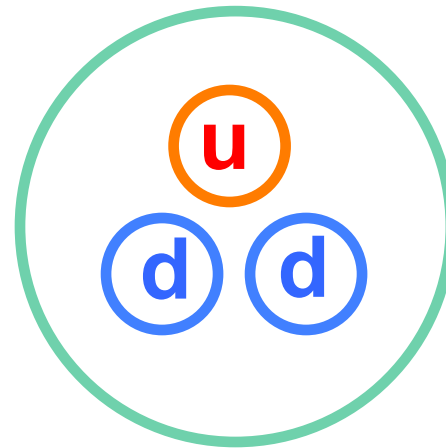
# Quark Model

**Proton**



$$+ 2/3 + 2/3 - 1/3 = 1$$

**Neutron**



$$+ 2/3 - 1/3 - 1/3 = 0$$

# Elementary Particles (2000)

		Fermion			Boson		
Charge						Charge	
+2/3	Quarks	$u$ up	$c$ charm	$t$ top	Force Carriers	$\gamma$ photon	0
		$d$ down	$s$ strange	$b$ bottom		$g$ gluon	0
-1/3	Leptons	$\nu_e$ electron neutrino	$\nu_\mu$ muon neutrino	$\nu_\tau$ tau neutrino		$Z$ Z boson	0
		$e$ electron	$\mu$ muon	$\tau$ tau		$W$ W boson	$\pm 1$
0							
-1							
		I	II	III			
Three Families of Matter							

+ Anti-particles

# Elementary Particles and Forces

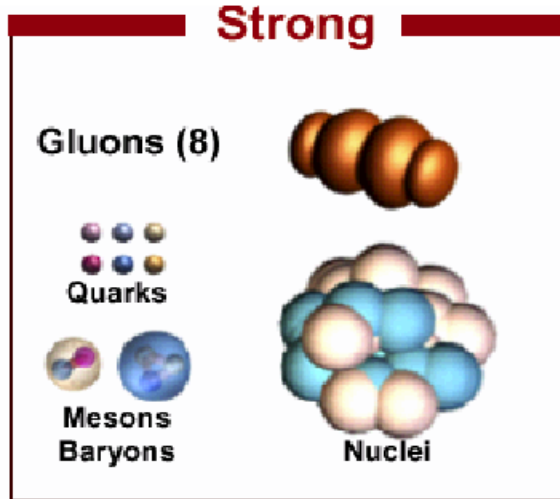
**Strong**

Gluons (8)

Quarks

Mesons  
Baryons

Nuclei

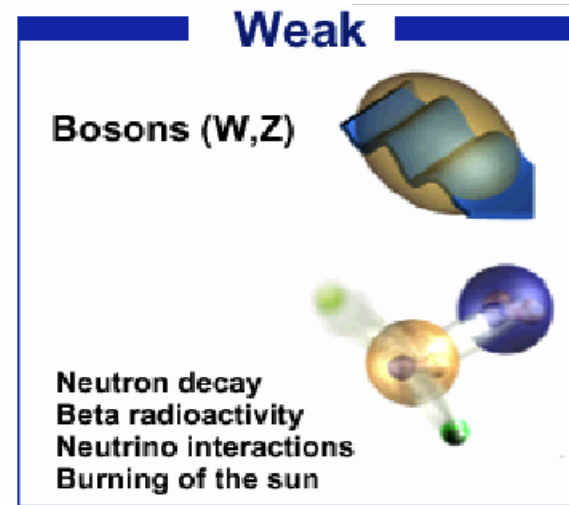
The diagram for the strong force shows various components. At the top, there are eight orange spheres representing gluons. Below them are six small colored spheres representing quarks. Further down are two pairs of quarks representing mesons and two groups of three quarks representing baryons. At the bottom is a large cluster of quarks representing a nucleus.

1

**Weak**

Bosons (W,Z)

Neutron decay  
Beta radioactivity  
Neutrino interactions  
Burning of the sun

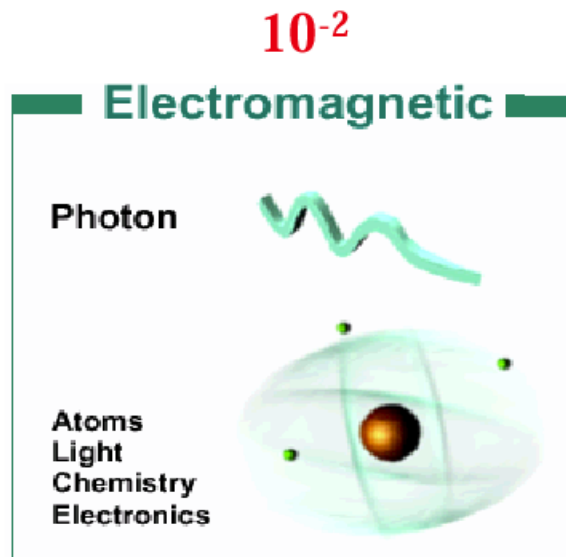
The diagram for the weak force shows two bosons (W and Z) at the top. Below them are three examples of weak interactions: a neutron decaying into a proton and an electron, a beta particle being emitted from a nucleus, and a neutrino interacting with a nucleus.

$10^{-13}$

**Electromagnetic**

Photon

Atoms  
Light  
Chemistry  
Electronics

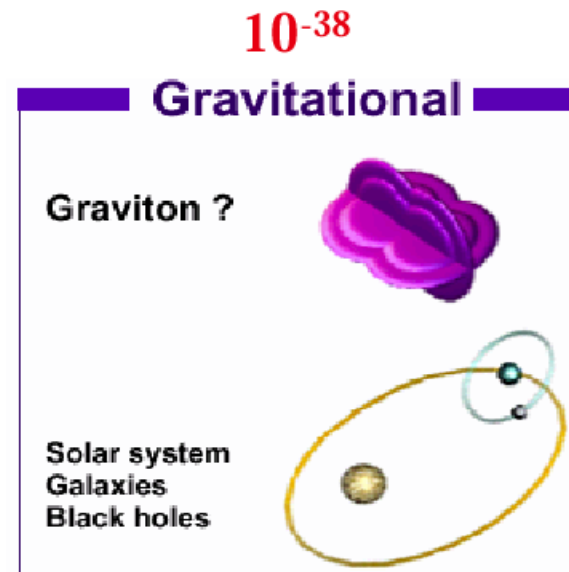
The diagram for the electromagnetic force shows a green wavy line representing a photon at the top. Below it is a model of an atom with a central nucleus and orbiting electrons.

$10^{-2}$

**Gravitational**

Graviton ?

Solar system  
Galaxies  
Black holes

The diagram for the gravitational force shows a purple cloud-like shape representing a graviton at the top. Below it are three examples of gravitational interactions: a planet orbiting a star in a solar system, a galaxy, and a black hole.

$10^{-38}$

# Power of Electric Force

## ➤ Electric Force is responsible for

- Electrons' trajectory around a nuclei
- Molecular structure
- Structure of any life (like your body), building, bridge etc...
  - Structure of anything larger than a nuclei but smaller than the mountain.
- How your brain works
- Mechanism behind computer, TV, car etc...
- ...

# Power of Gravity

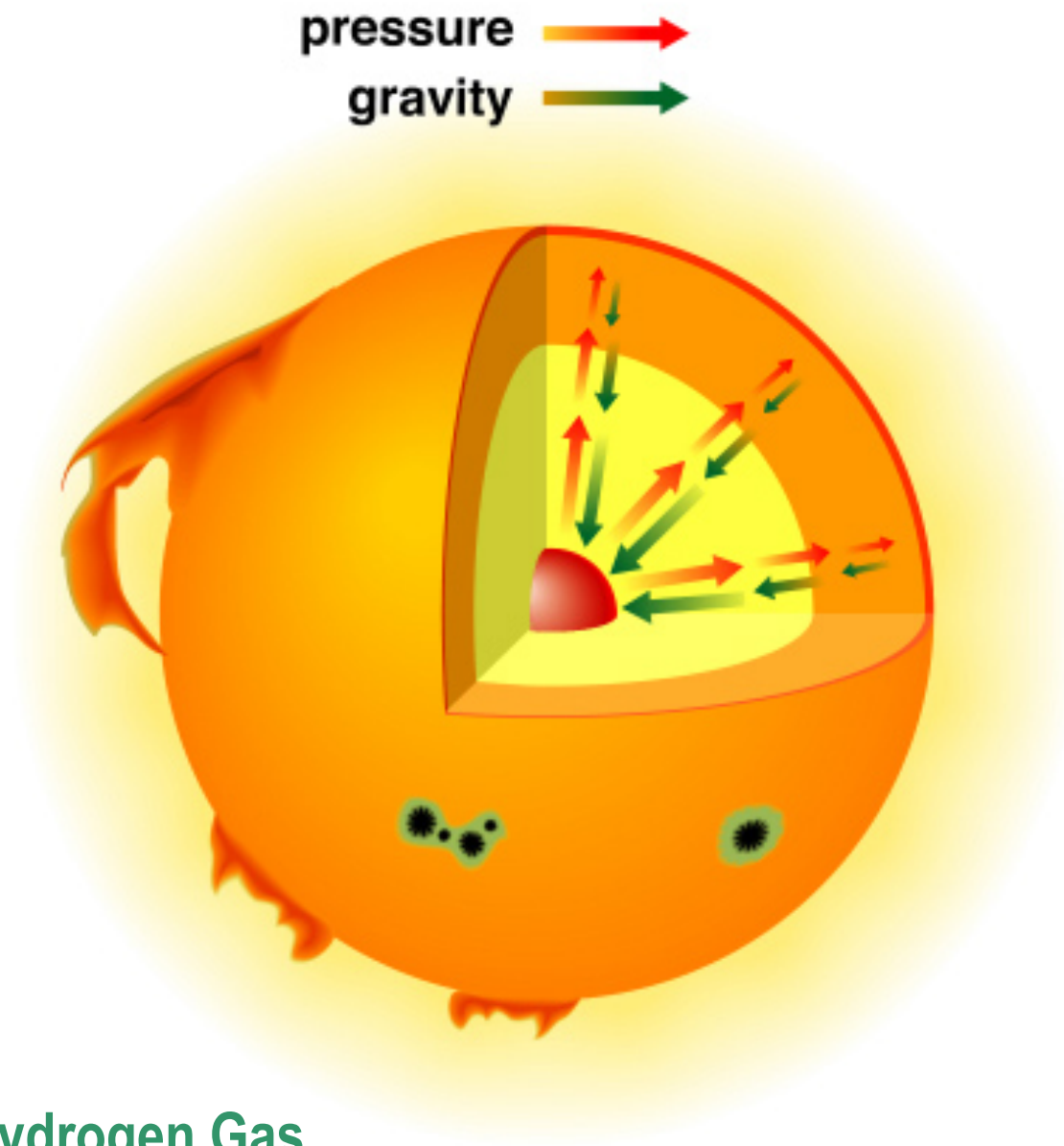
- **Gravity is responsible for**
  - Your staying on the ground
  - Trajectory of a ball
  - Orbit of Satellite, moon...
  - Formation of the solar system
  - Formation of the Galaxy
  - ...
- **Gravity is very, very weak compared to Electric Force.**
  - $N = (\text{Electric force}) / (\text{Gravity}) = 10^{39}$

# Power of Strong Force

## ➤ Strong Force is responsible for

- **Structure of the nuclei**
  - How protons and neutrons are bound together
- **Nuclear fission**
  - Nuclear power plant
  - Atomic bomb
- **Nuclear fusion**
  - Sun's energy

# The Solar Interior

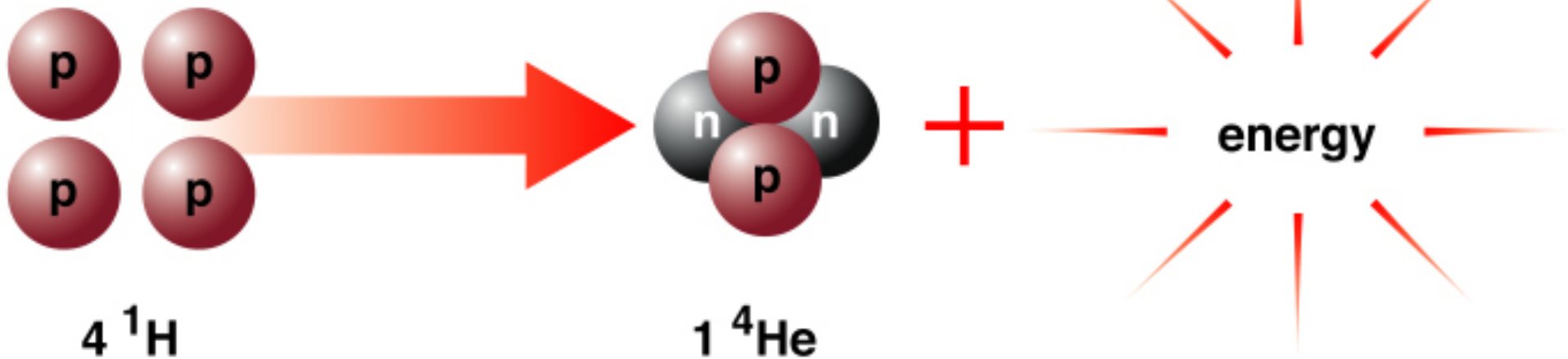


Hydrogen Gas

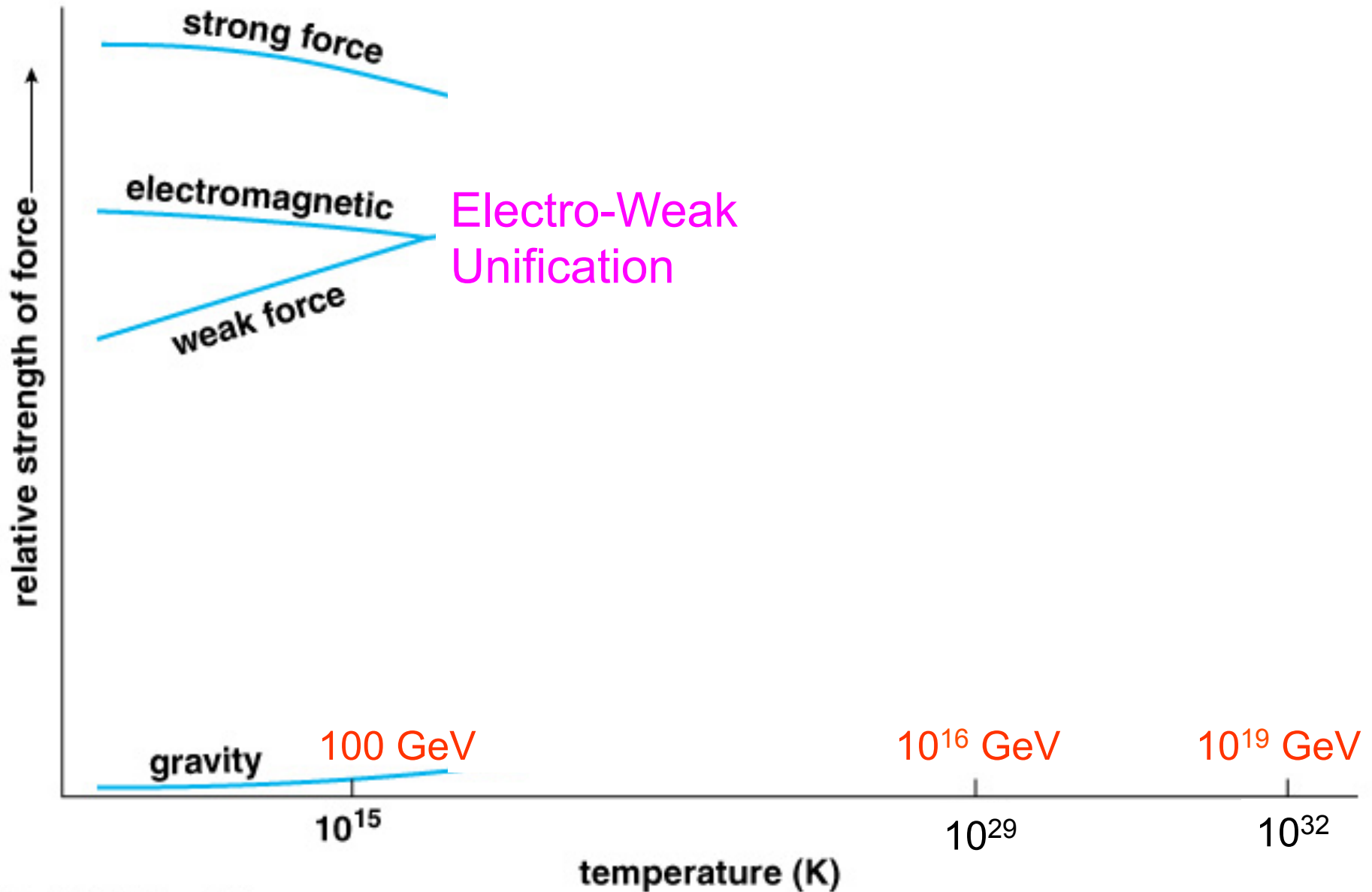
# Solar Energy

$$E = mc^2$$

$$m_{4p} > m_{He}$$

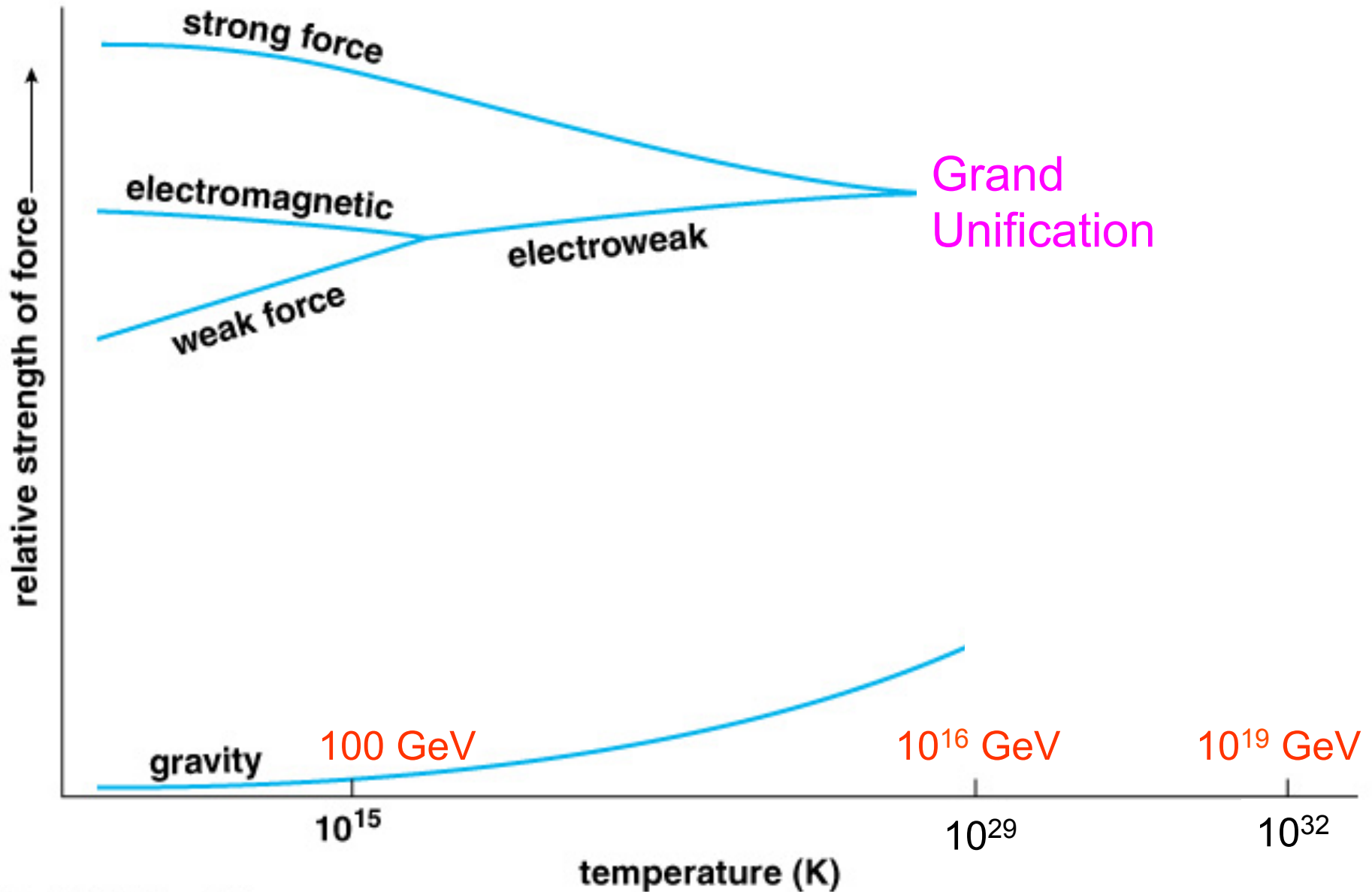


# Unification of Forces



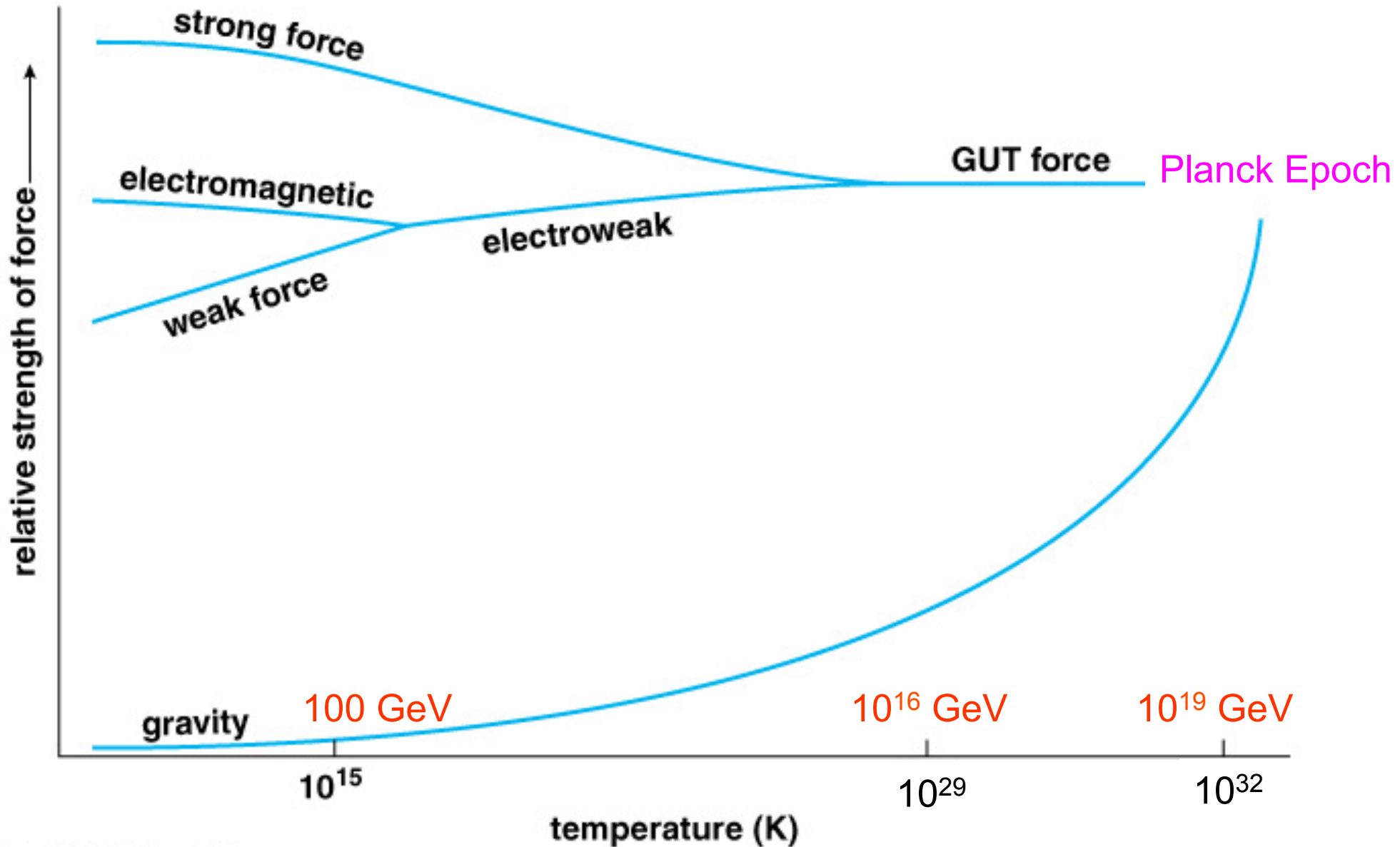
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# Unification of Forces



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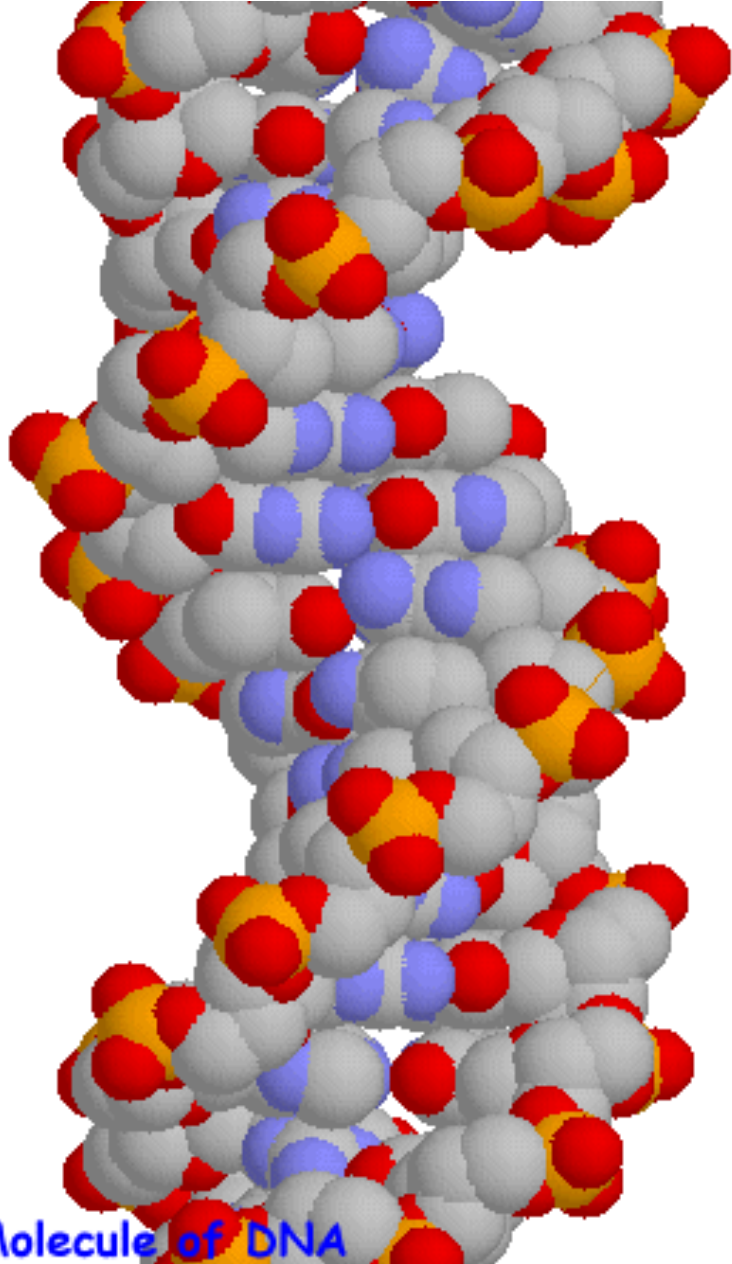
# Unification of Forces



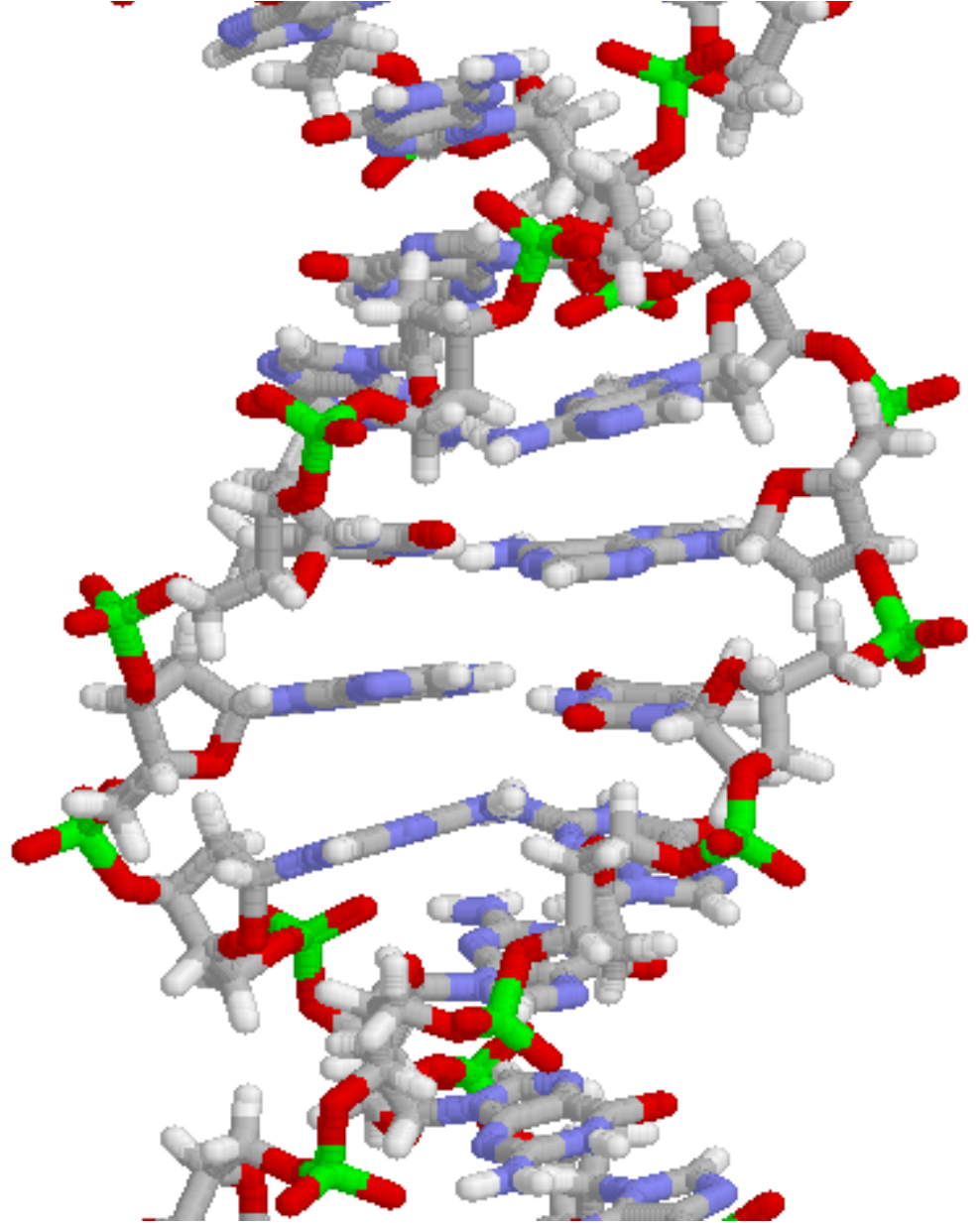
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# Structure of DNA

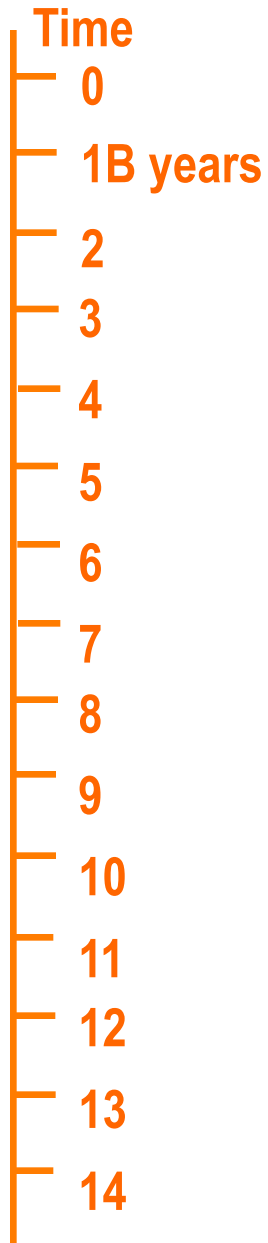


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Molecule of DNA

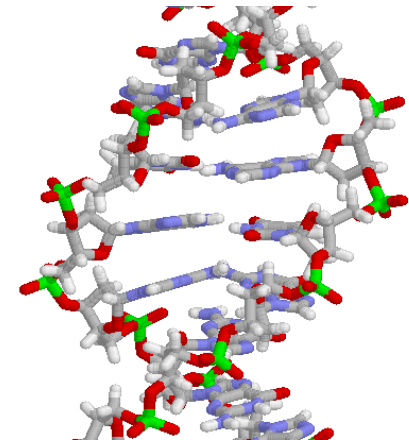
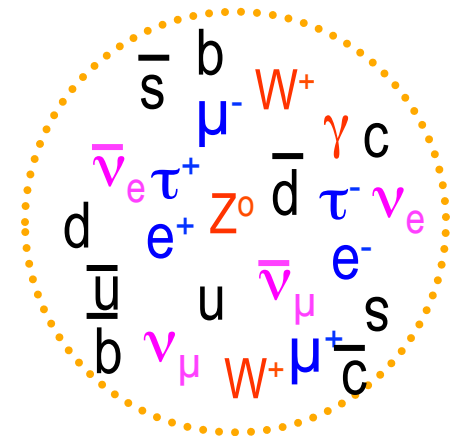
# Symmetry Breaking



*Simple*

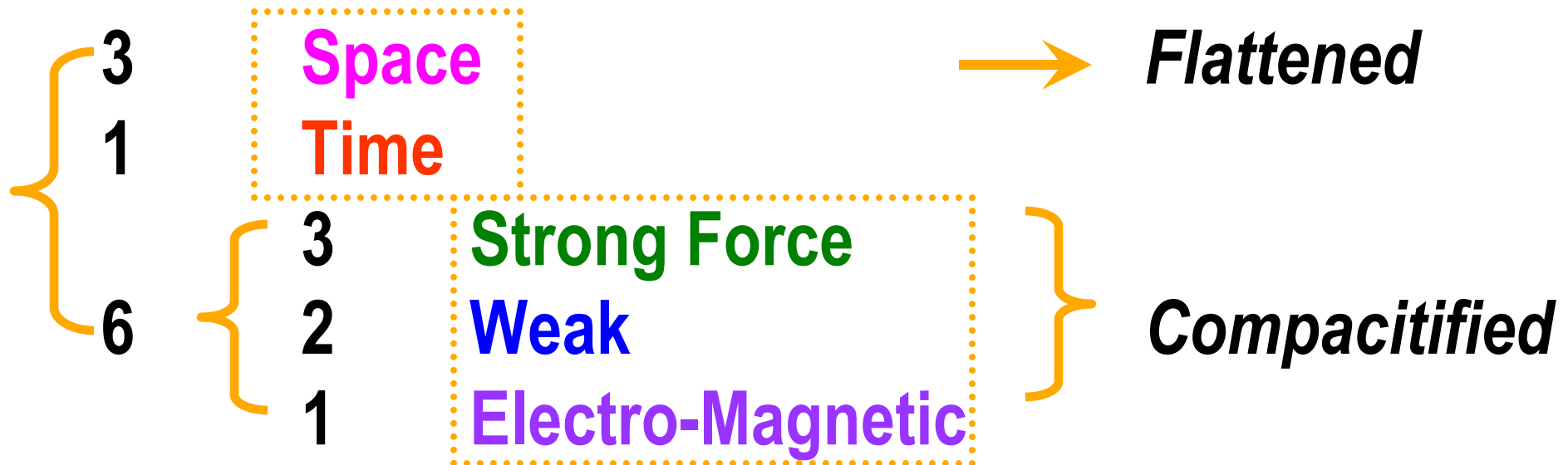
*Symmetry  
Break Down*

*Complex*

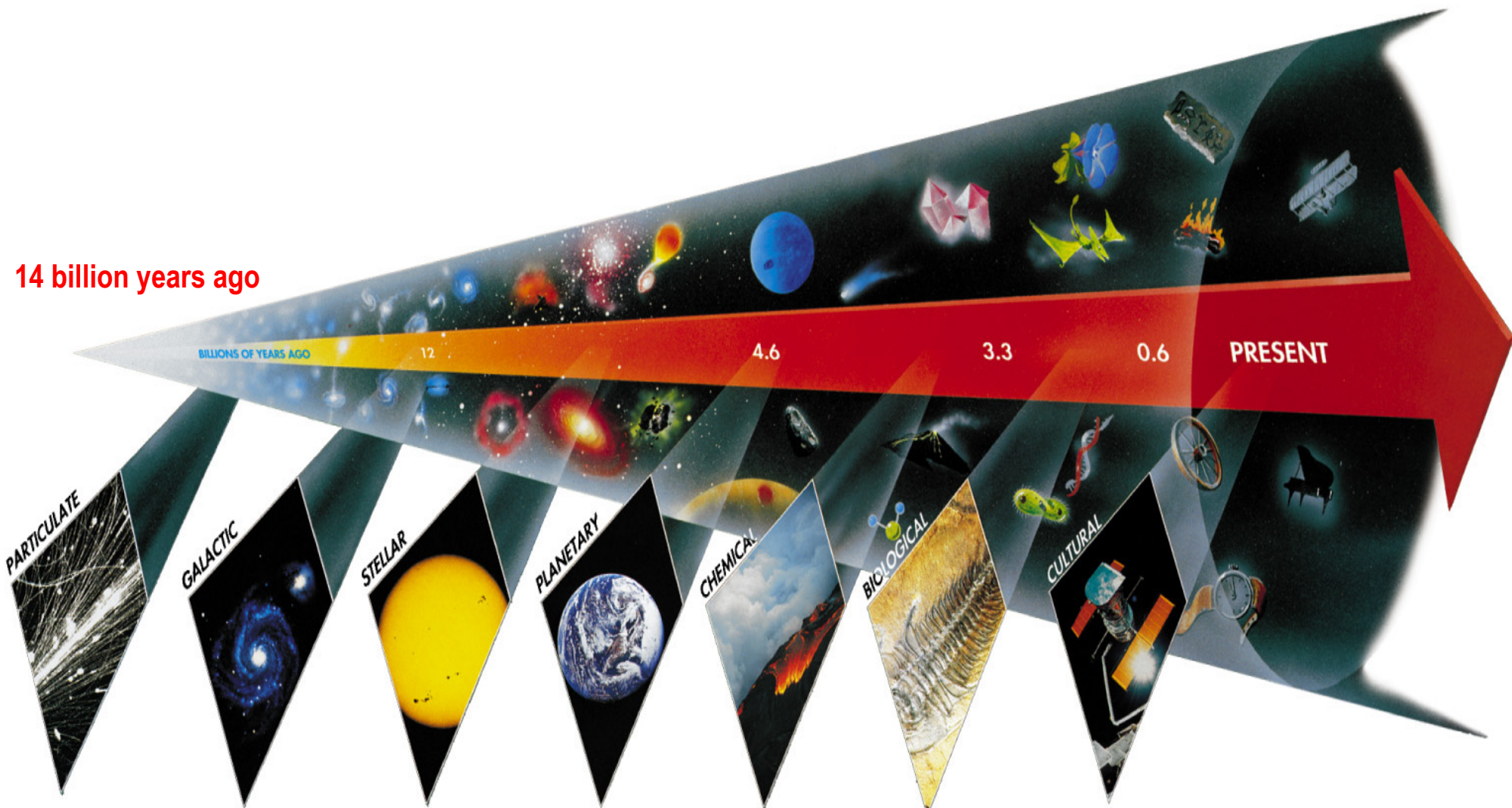


# The Beginning

- Everything was the same  $\leftrightarrow$  Perfect symmetry.
  - All the particles are the same as photons.
  - All four forces are the same.
- The Universe was 10 dimension.

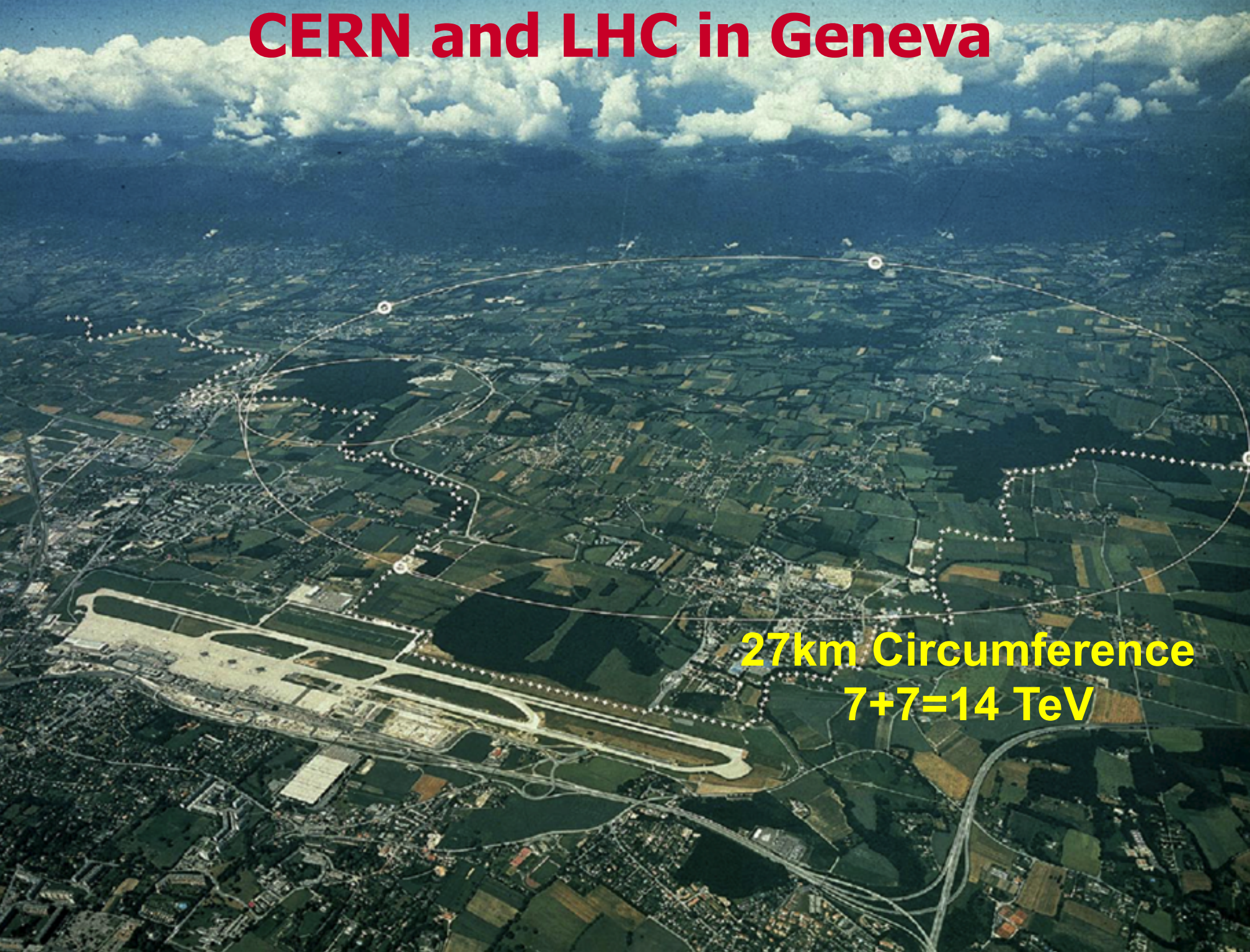


# Seven Phases of Cosmic Evolution



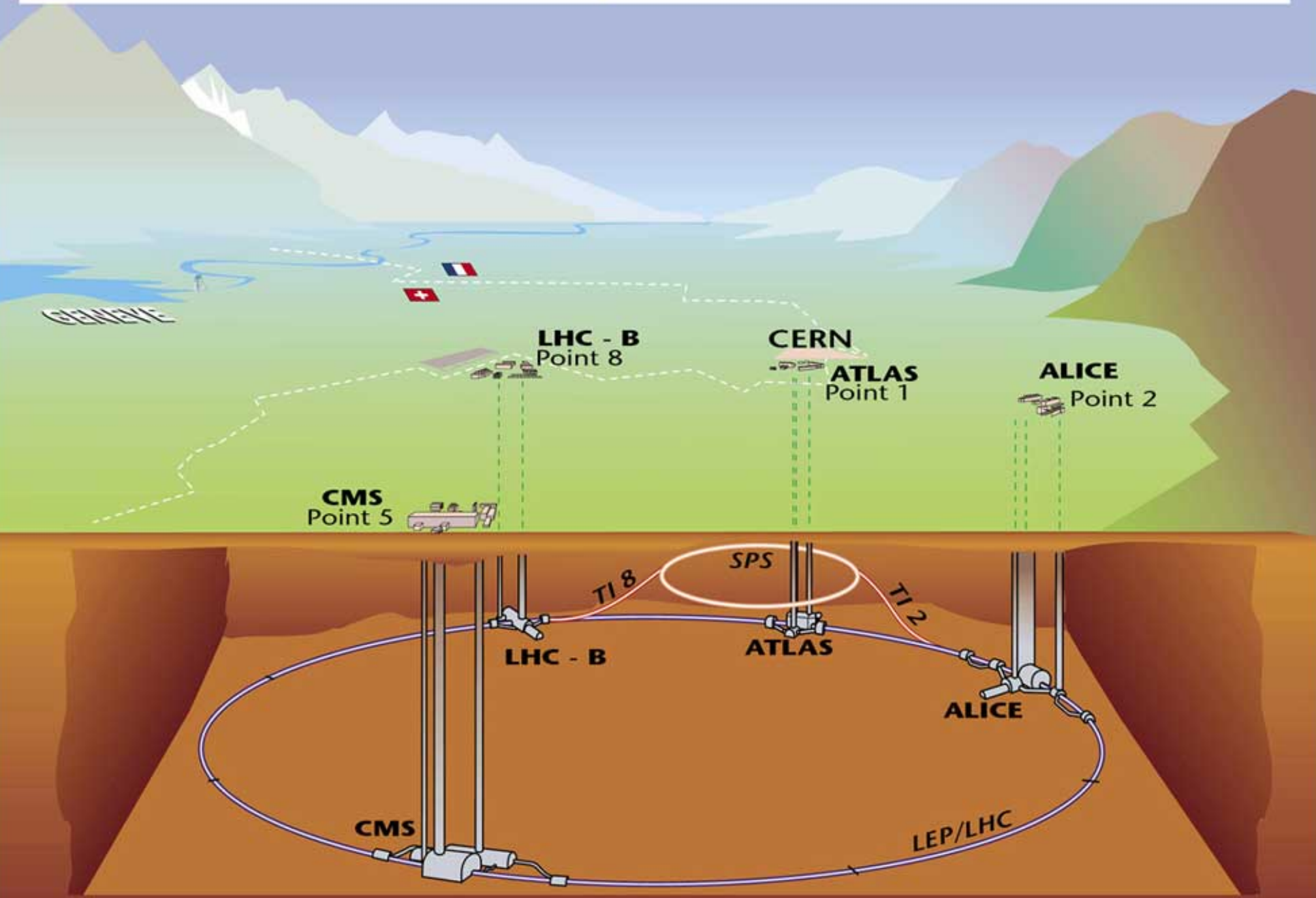
Origin of  
Particles

# CERN and LHC in Geneva

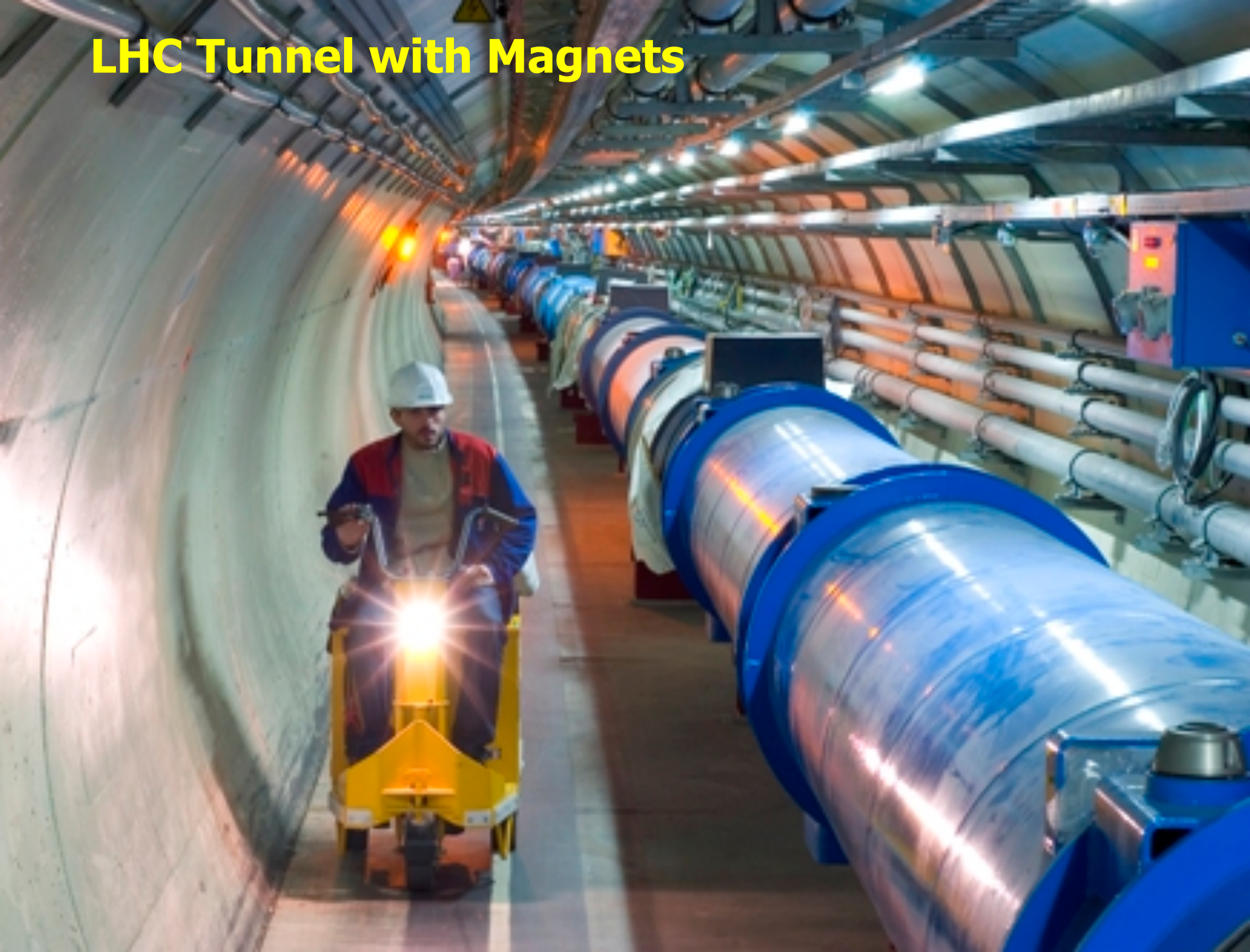


27km Circumference  
7+7=14 TeV

# Overall view of the LHC experiments.



# LHC Tunnel with Magnets



# CMS Collaboration (1993 ~)

(144 Institutions with about 1700 scientists)



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- Yerevan Physics Inst., Yerevan



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- HEPHY, Wien



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- Res. Inst. of Applied Physical Probl., Minsk
- Byelorussian State Univ., Minsk



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- Inst. für Teilchenphysik, ETH, Zürich
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- RAL, Didcot



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- Univ. of Illinois at Chicago, Chicago
- Fairfield Univ., Fairfield
- Fermi National Accelerator Lab., Batavia
- Florida State Univ. - HEPG, Tallahassee
- Florida State Univ. - SCRI, Tallahassee
- Univ. of Florida, Gainesville
- The Univ. of Iowa, Iowa City
- Johns Hopkins Univ., Baltimore
- LLNL, Livermore
- Los Alamos Nat. Lab., Los Alamos
- Univ. of Maryland, College Park
- Univ. of Minnesota, Minneapolis
- Univ. of Mississippi, Oxford
- Massachusetts Inst. of Tech., Cambridge
- Univ. of Nebraska-Lincoln, Lincoln
- Northeastern Univ., Boston
- Northwestern Univ., Evanston
- Univ. of Notre Dame, Notre Dame
- The Ohio State Univ., Columbus
- Princeton Univ., Princeton
- Purdue Univ., West Lafayette
- Rice Univ., Houston
- Univ. of California, Riverside
- Univ. of Rochester, Rochester
- Rutgers, the State Univ. of New Jersey, Piscataway
- Texas Tech Univ., Lubbock
- Univ. of Texas at Dallas, Richardson
- Univ. of California at Davis, Davis
- UCLA, Los Angeles
- Univ. of California San Diego, La Jolla
- Virginia Polytech. Inst. and State Univ., Blacksburg
- Univ. of Wisconsin, Madison



## UZBEKISTAN

- Inst. of Nucl. Phys. of the Uzbekistan Acad. of Sciences, Tashkent

electromagnetic calorimeter

solenoid

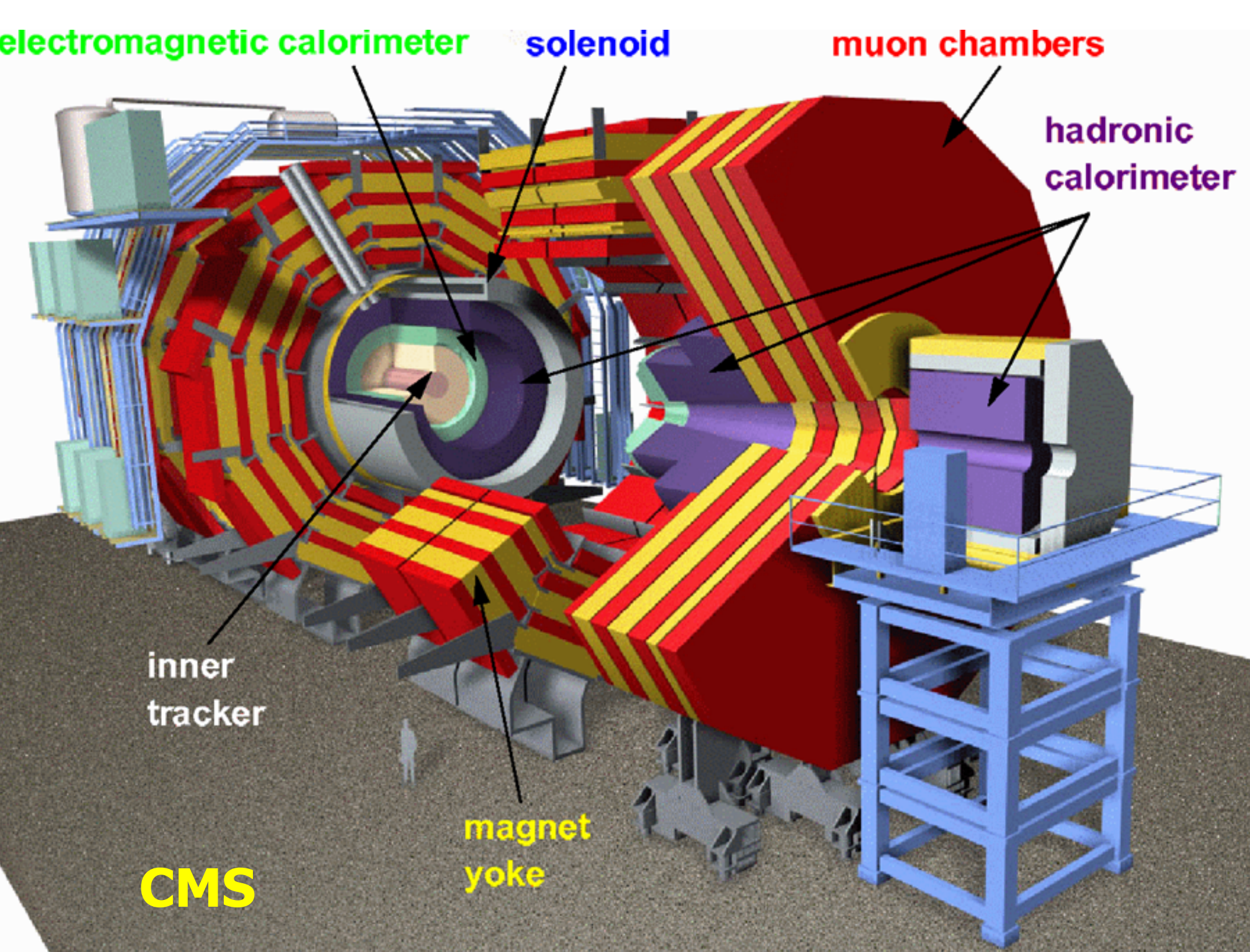
muon chambers

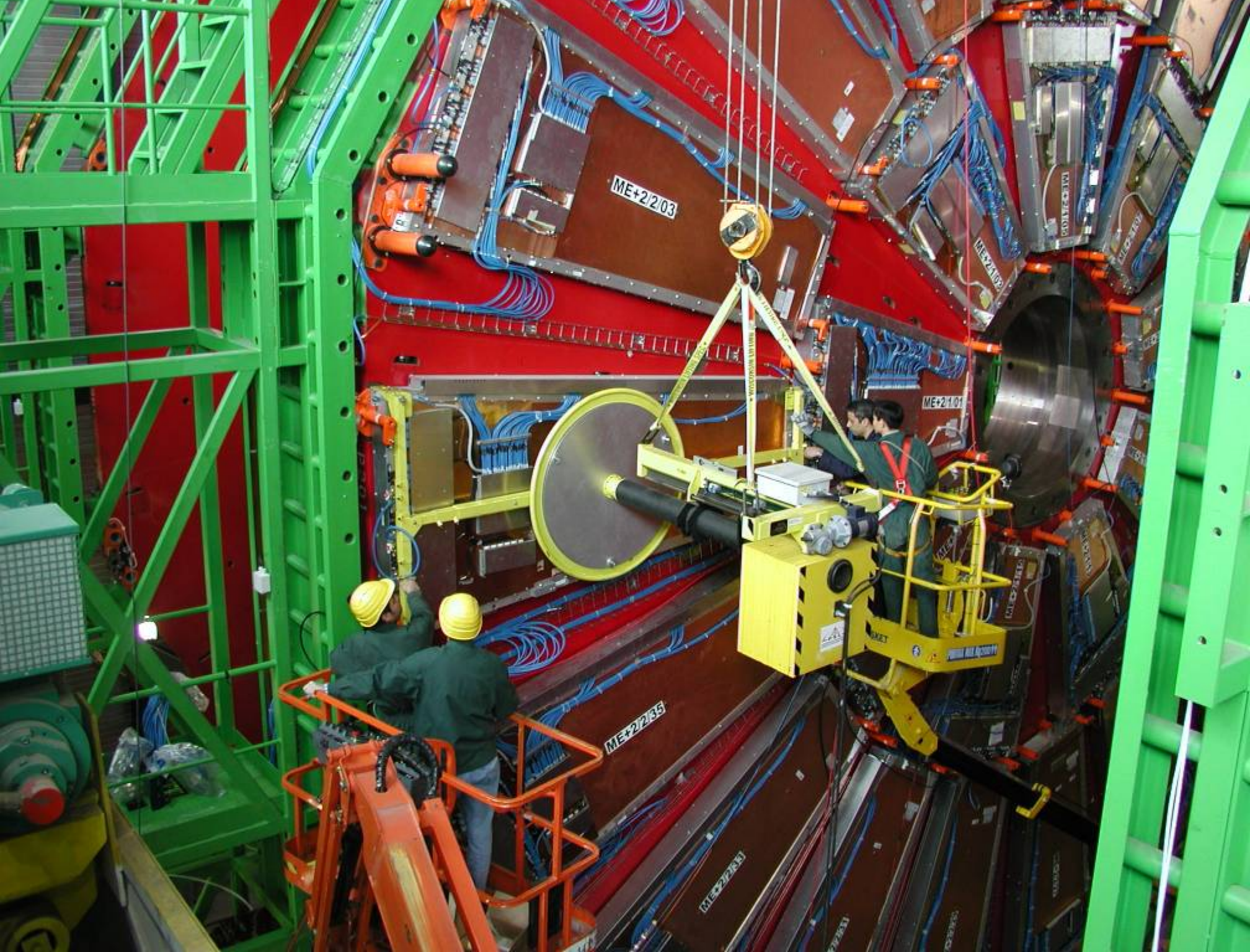
hadronic calorimeter

inner tracker

magnet yoke

CMS

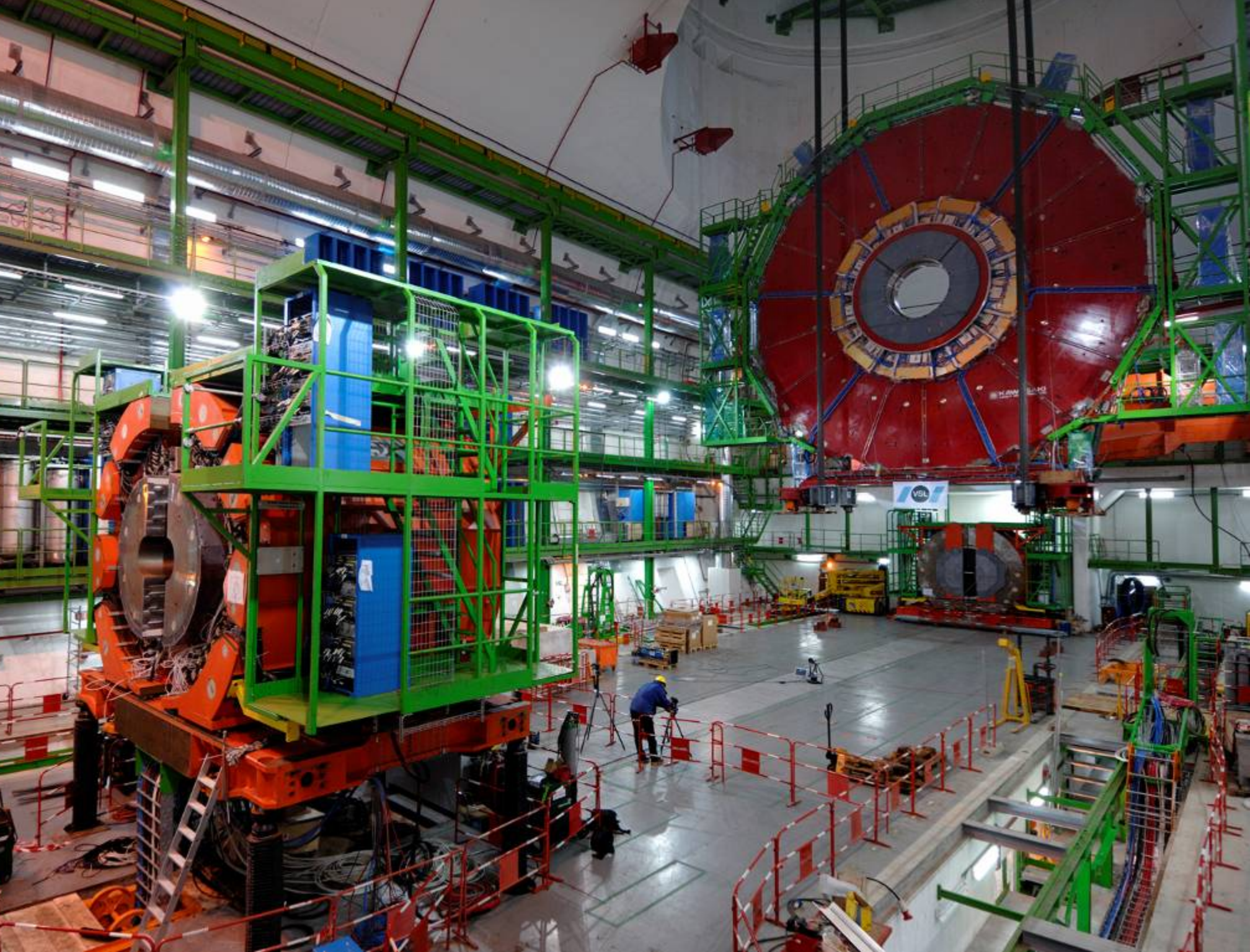


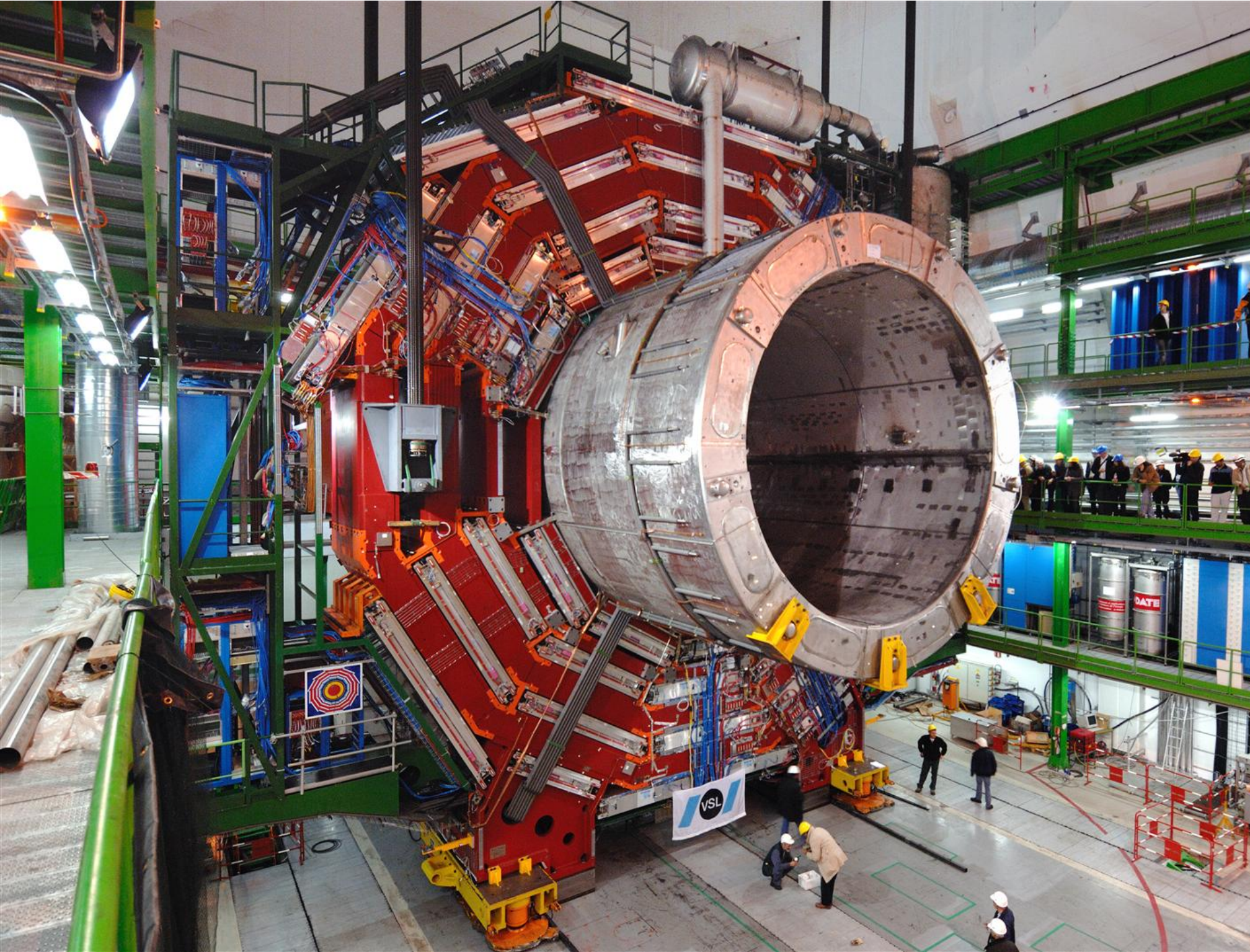


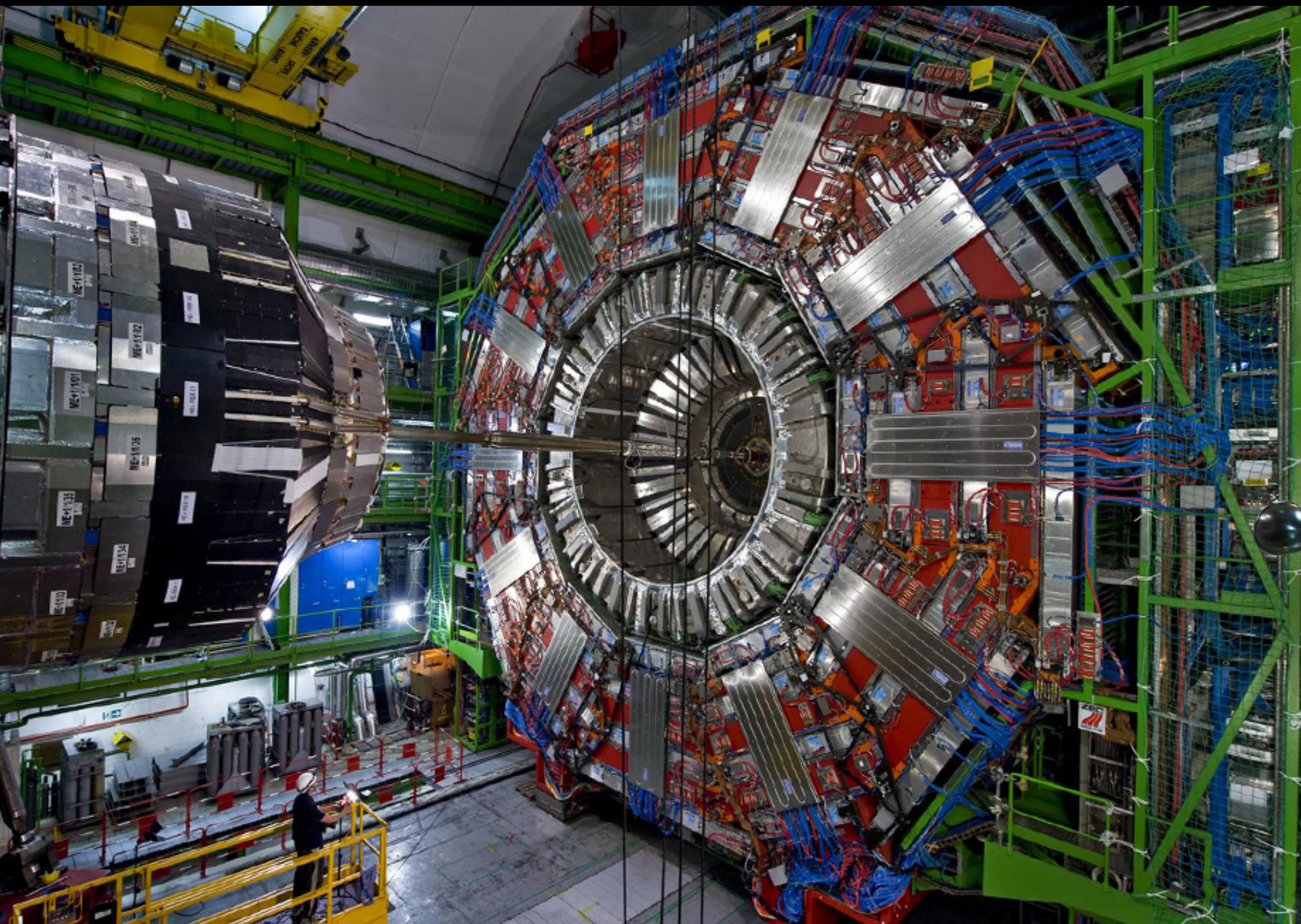












1/29/2011

Katsushi Arisaka

48

CMS Experiment, CERN

Data\_taken 2009-Nov-07 19:12:36.880368 GMT

Run\_no 120015

Event\_no 8

Lumi\_sec 1

Orbit 584946

Crossing 2603

<http://iguana.cern.ch/iss/>

L1 Triggers:

-----  
L1\_DoubleHEBitCountsRing1\_P1N1

L1\_DoubleHEBitCountsRing2\_P1N1

L1\_ETM20

L1\_ETM30

L1\_MinBias\_HTT10

L1\_Mu3QE8\_Jet6

L1\_SingleEG1

L1\_SingleEG10

L1\_SingleEG12

L1\_SingleEG15

L1\_SingleEG20

L1\_SingleEG25

L1\_SingleEG30

L1\_SingleEG35

L1\_SingleEG40

L1\_SingleEG45

L1\_SingleEG50

L1\_SingleEG55

L1\_SingleEG60

L1\_SingleEG65

L1\_SingleEG70

L1\_SingleEG75

L1\_SingleEG80

L1\_SingleEG85

L1\_SingleEG90

L1\_SingleEG95

L1\_SingleEG100

L1\_SingleEG105

L1\_SingleEG110

L1\_SingleEG115

L1\_SingleEG120

L1\_SingleEG125

L1\_SingleEG130

L1\_SingleEG135

L1\_SingleEG140

L1\_SingleEG145

L1\_SingleEG150

L1\_SingleEG155

L1\_SingleEG160

L1\_SingleEG165

L1\_SingleEG170

L1\_SingleEG175

L1\_SingleEG180

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L1\_SingleEG210

L1\_SingleEG215

L1\_SingleEG220

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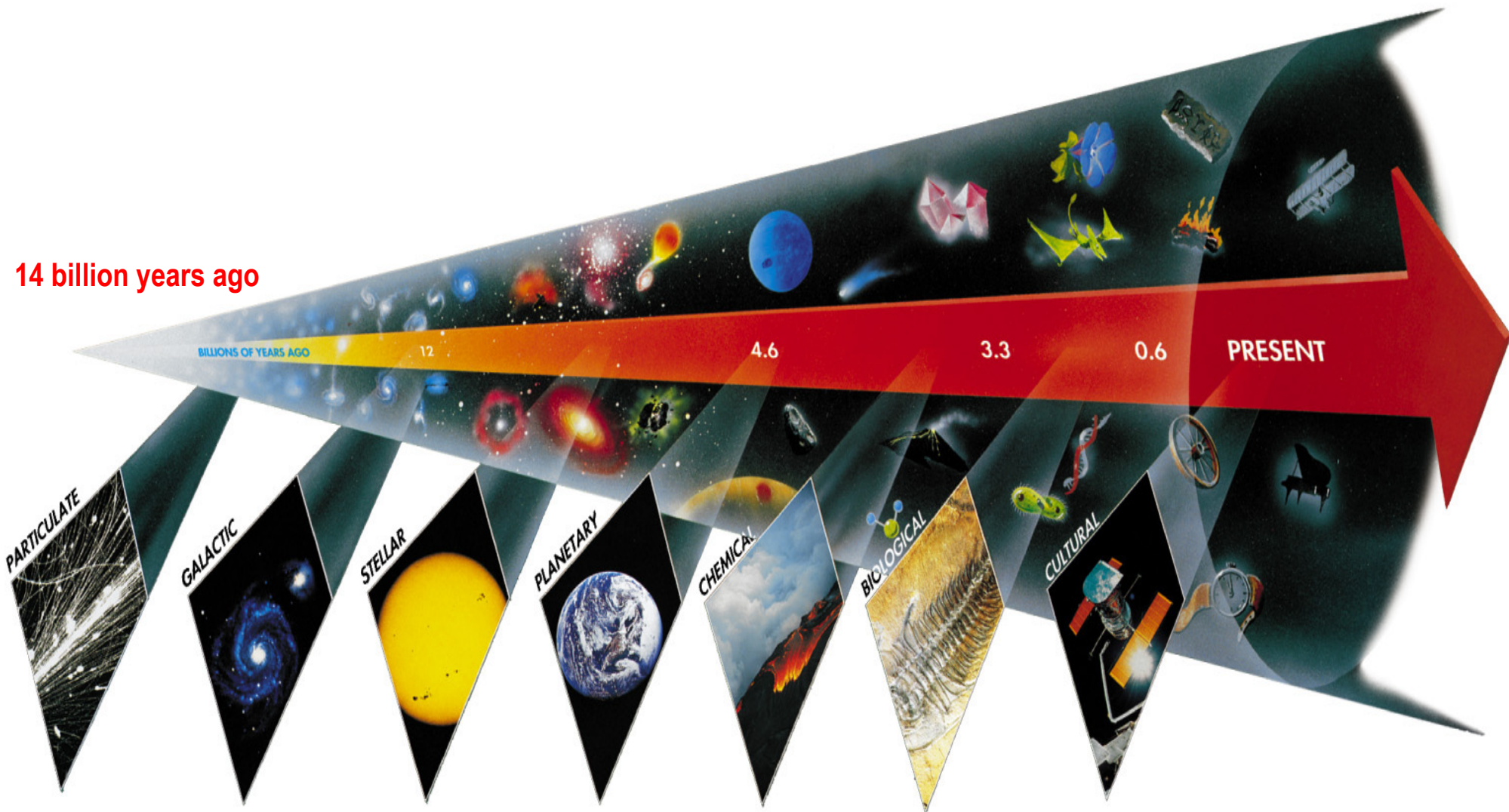
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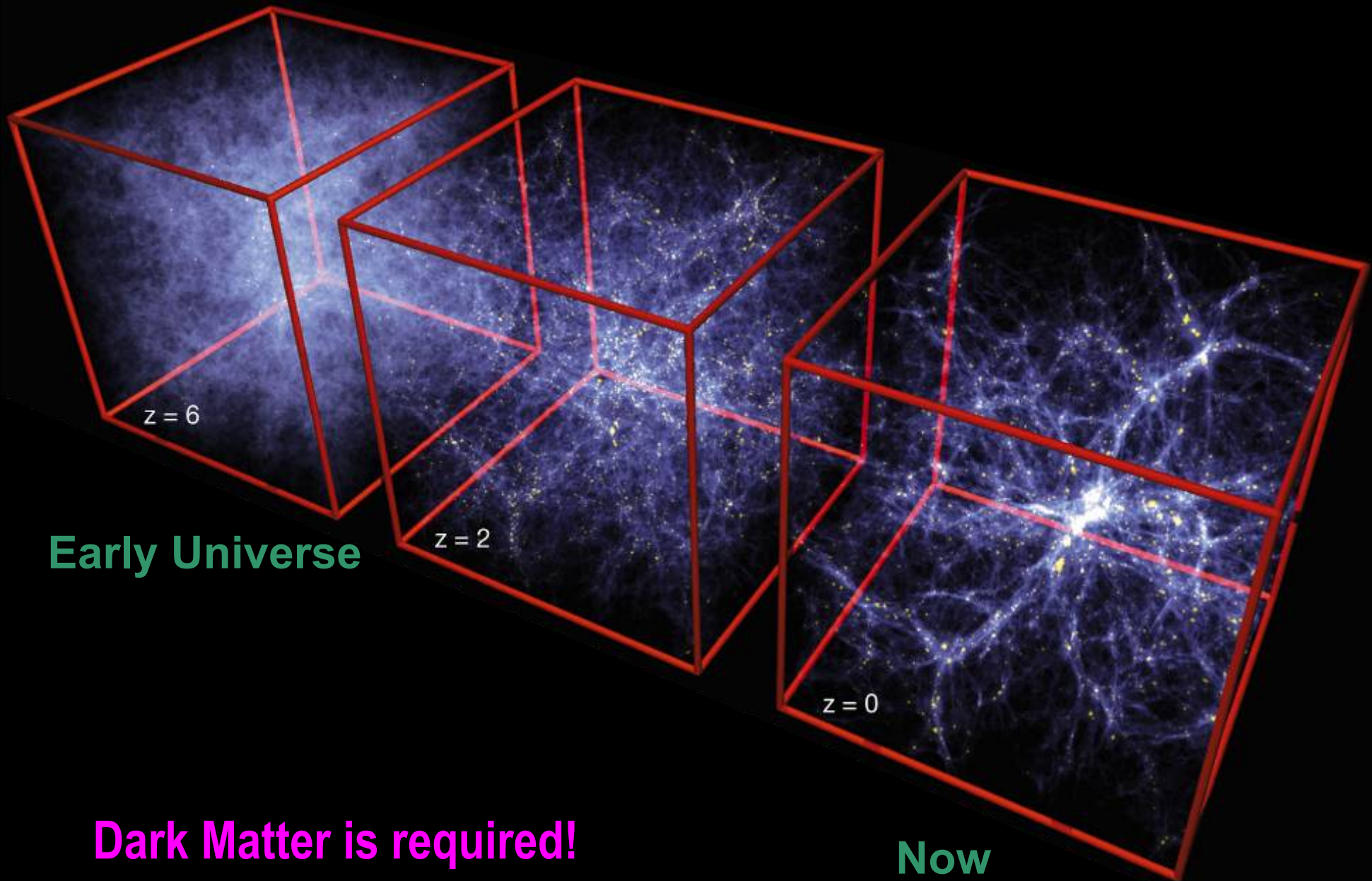
# Seven Phases of Cosmic Evolution



Origin of  
Particles

Origin of  
Structure

# Formation of Structure in the Universe



**Dark Matter is required!**

**Now**



**Dark Matter is required!**

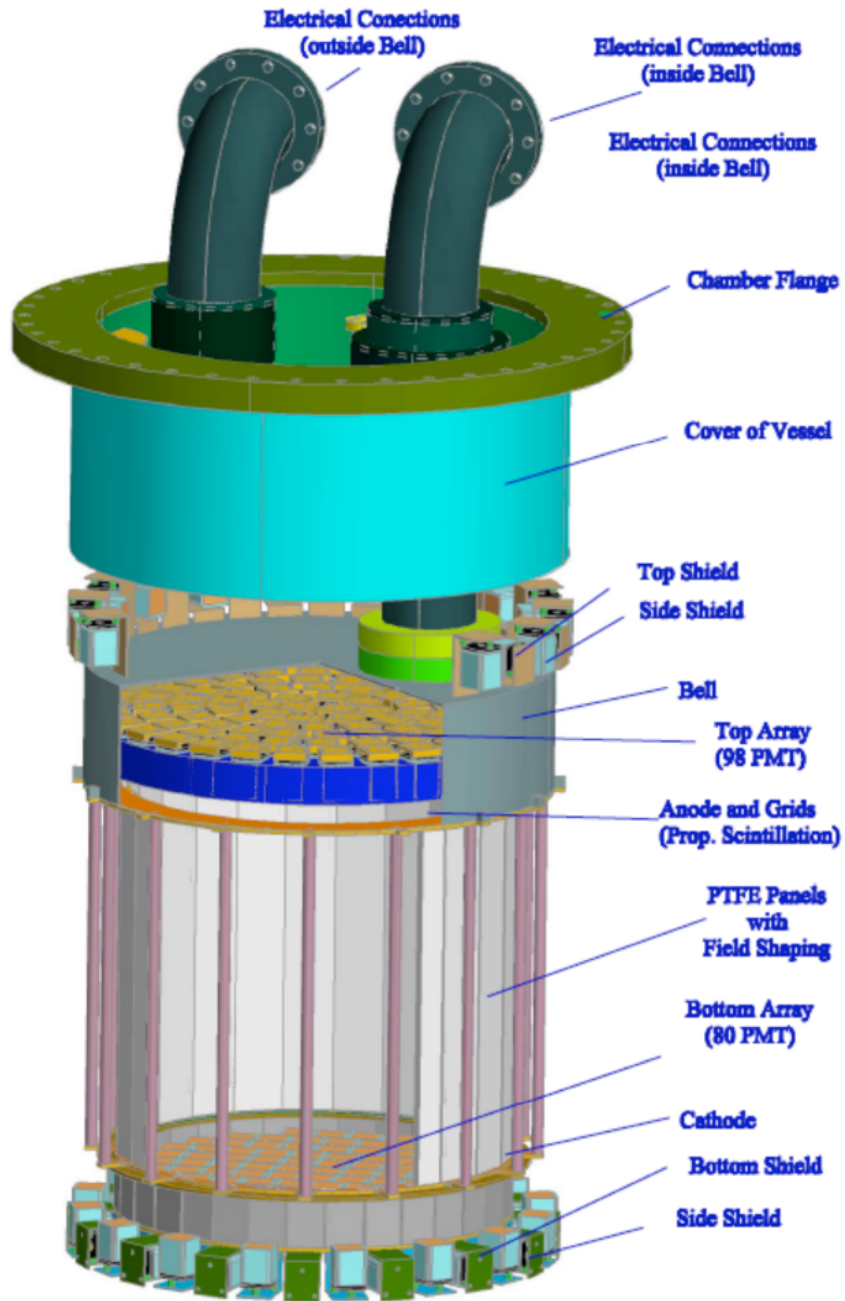
**ANDROMEDA  
GALAXY.**

# Laboratori Nazionali del Gran Sasso, Italy

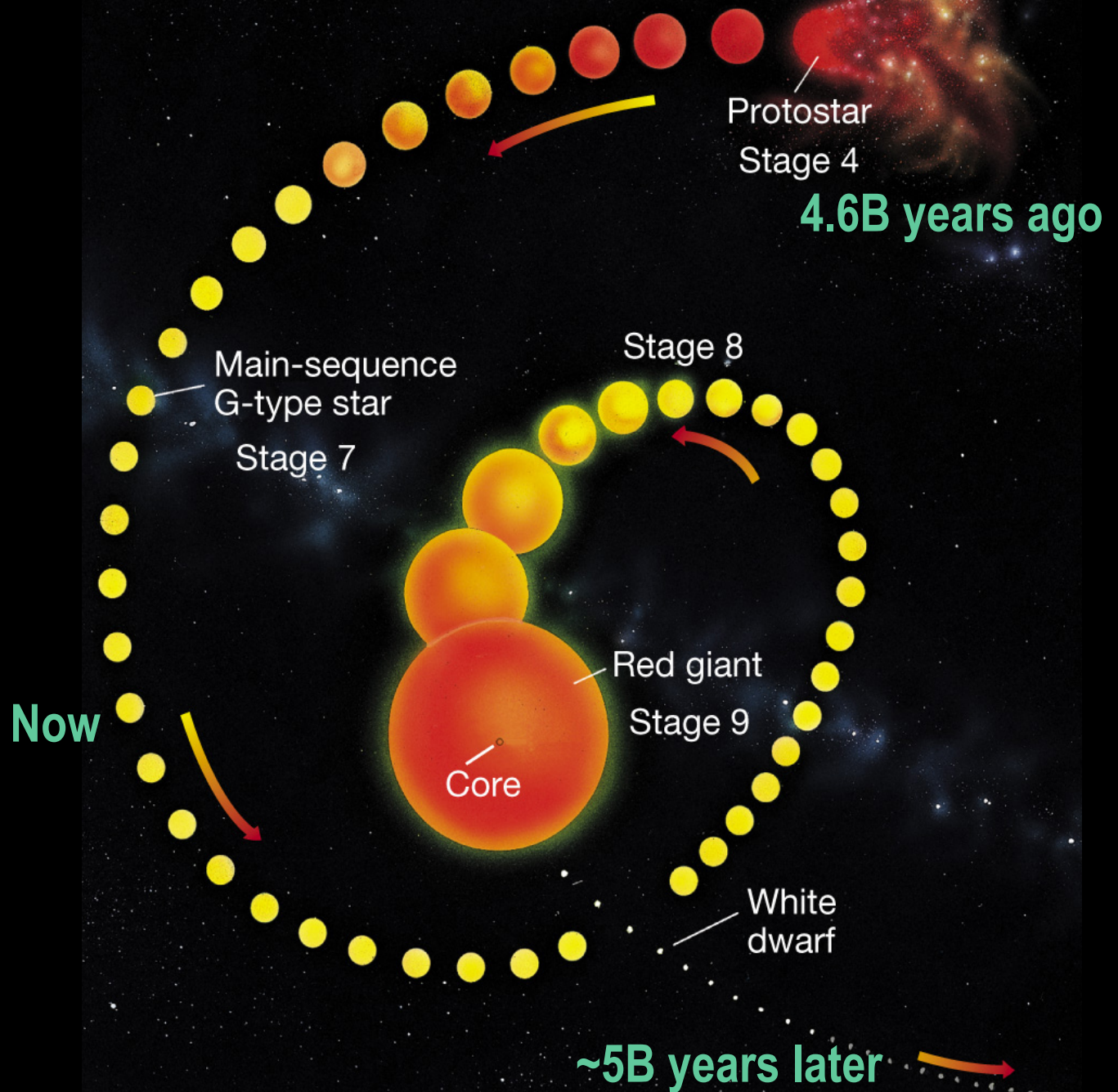
LNGS 1400 m Rock (3100 w.m.e)



# XENON100 Detector



# Evolution of a Star like Sun



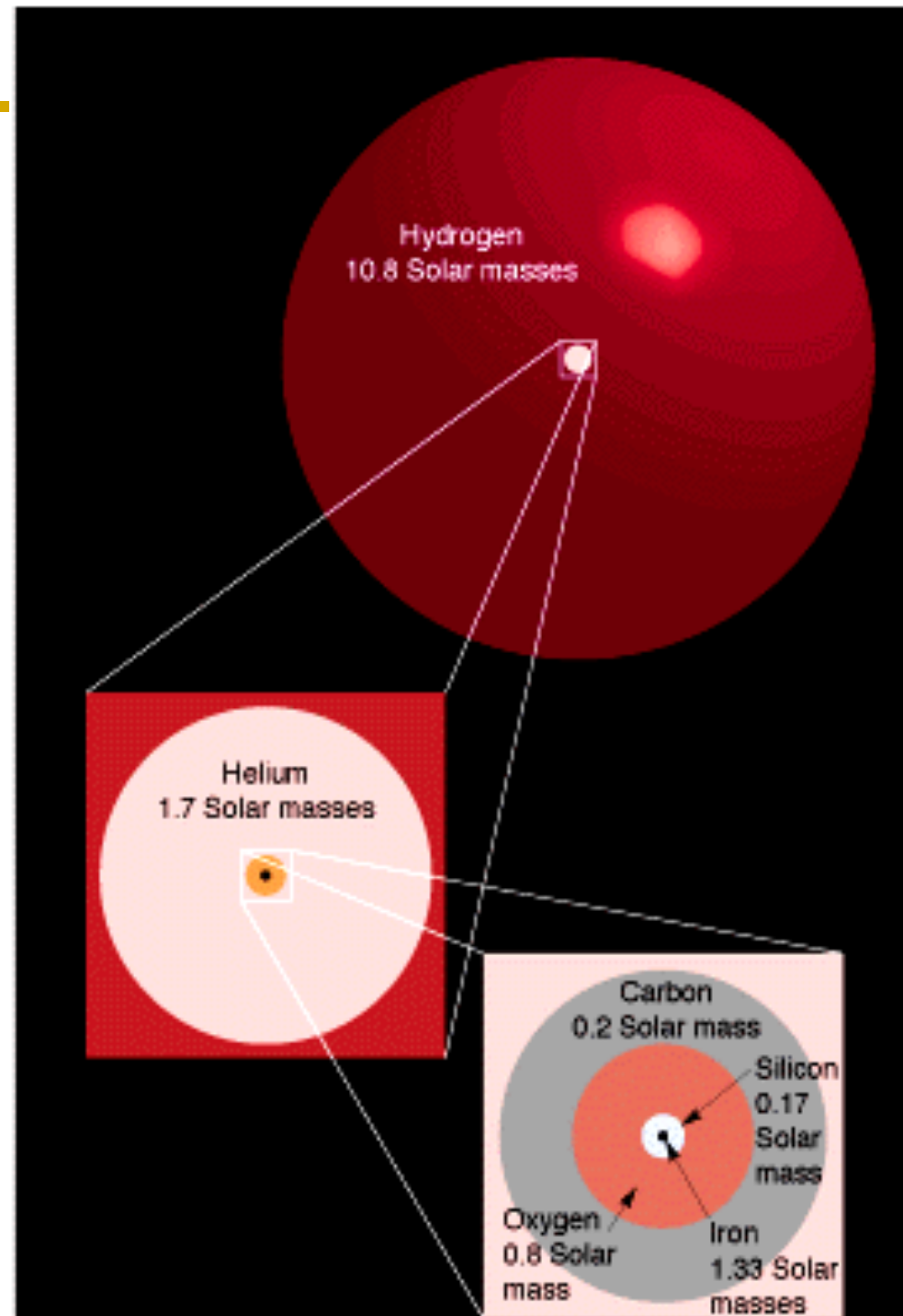
# Nuclear Burning in High Mass Stars

(20 times solar mass star)

Hydrogen	$10^7$ year
Helium	$10^6$ year
Carbon	$10^3$ year
Oxygen	1 year
Neon	
Magnesium	
Silicon	1 week
Iron	< 1 day



**Supernova explosion!**



# Origin of Elements

## ➤ Hydrogen, Helium

- From “**Big Bang**”

## ➤ Carbon – Oxygen – Iron

- From “**Nuclear fusion**” at massive stars  
( $> 8 M_{\text{sun}}$ )

## ➤ Heavier than Iron (Cu, Au, Pt, Pb...)

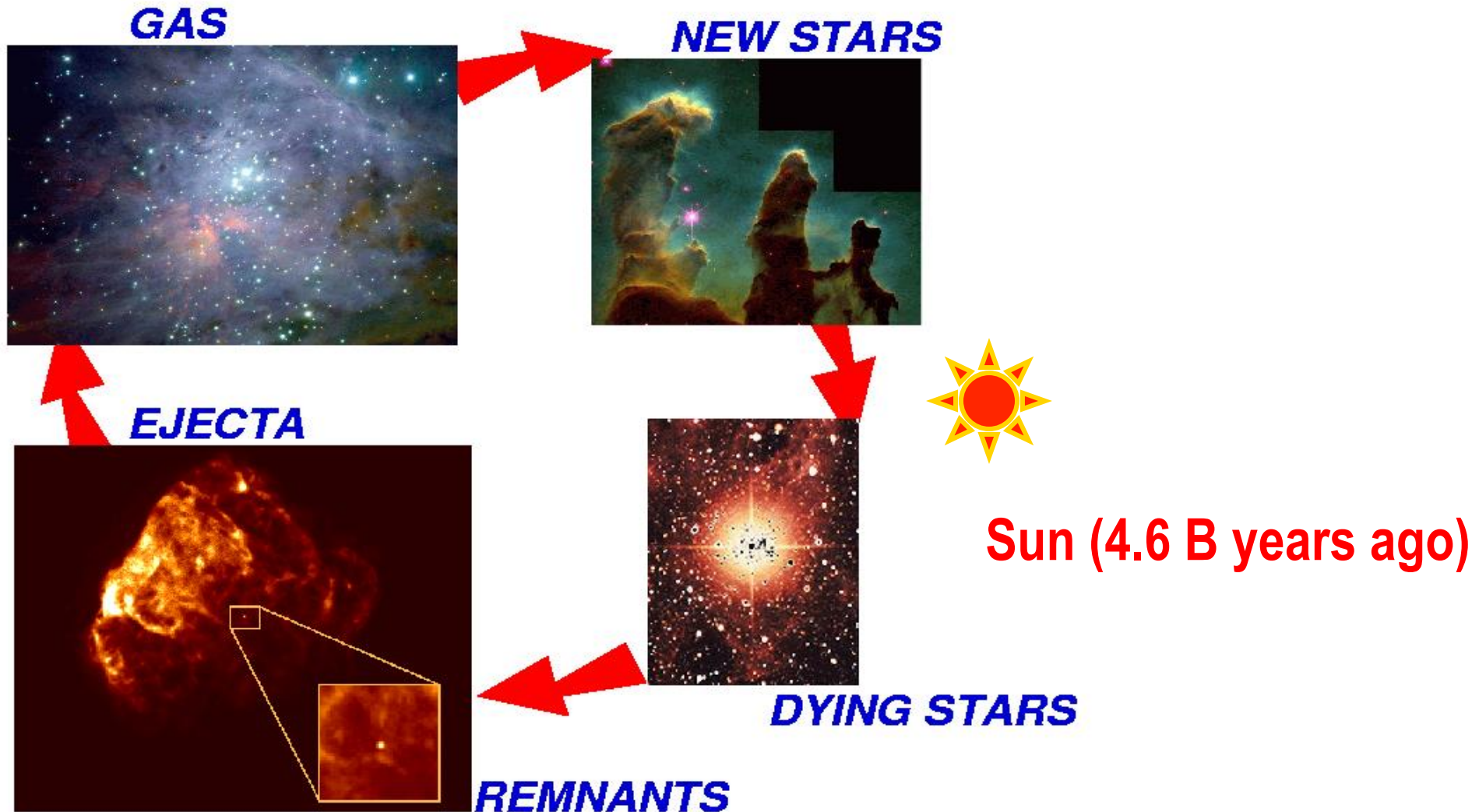
- From “**Supernova**”

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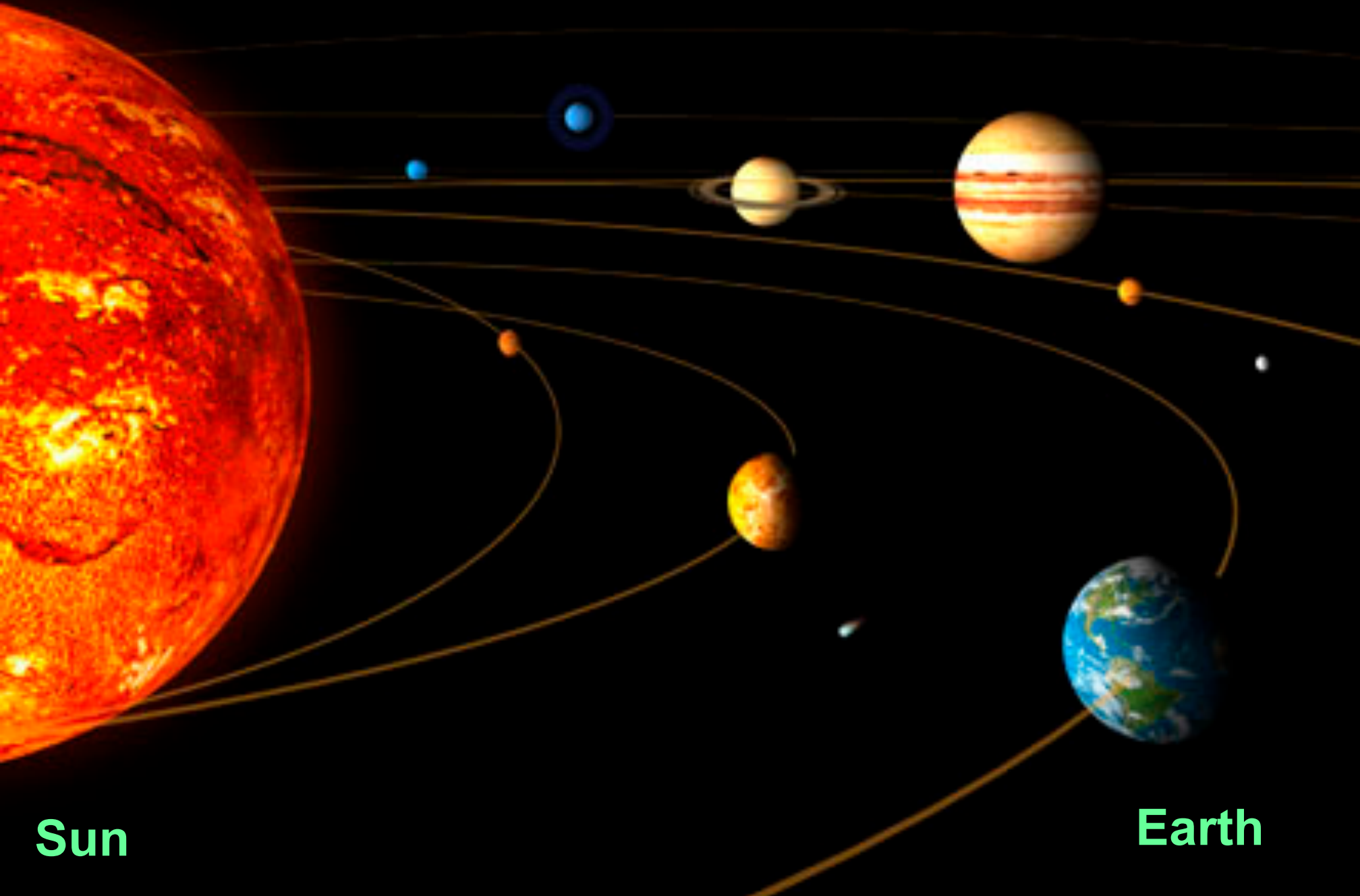
**We are made  
from “stardust”**

# Star's Life Cycle

Big Bang! (14 B years ago)



# Solar System (4.6 B years ago)



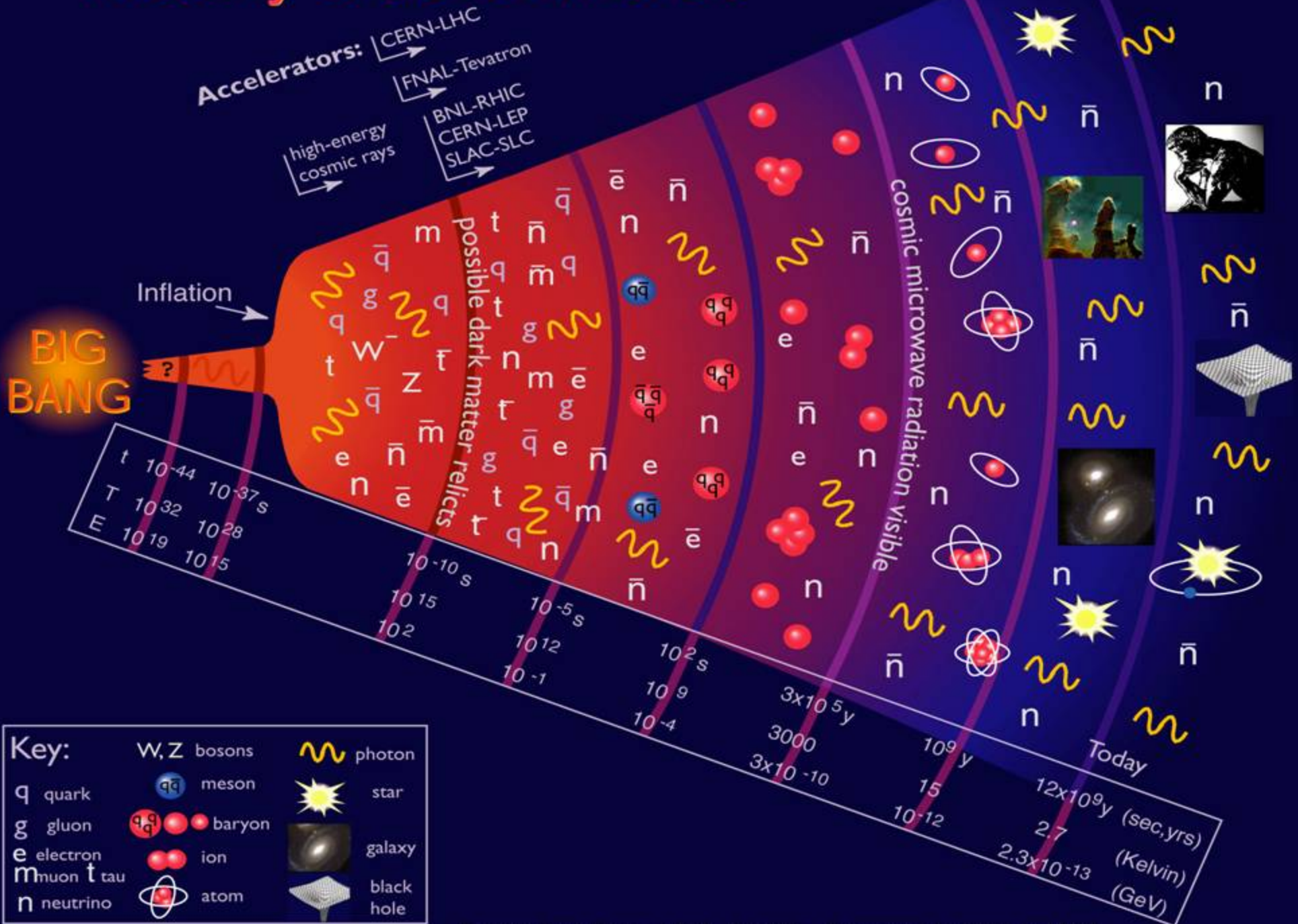
Sun

Earth



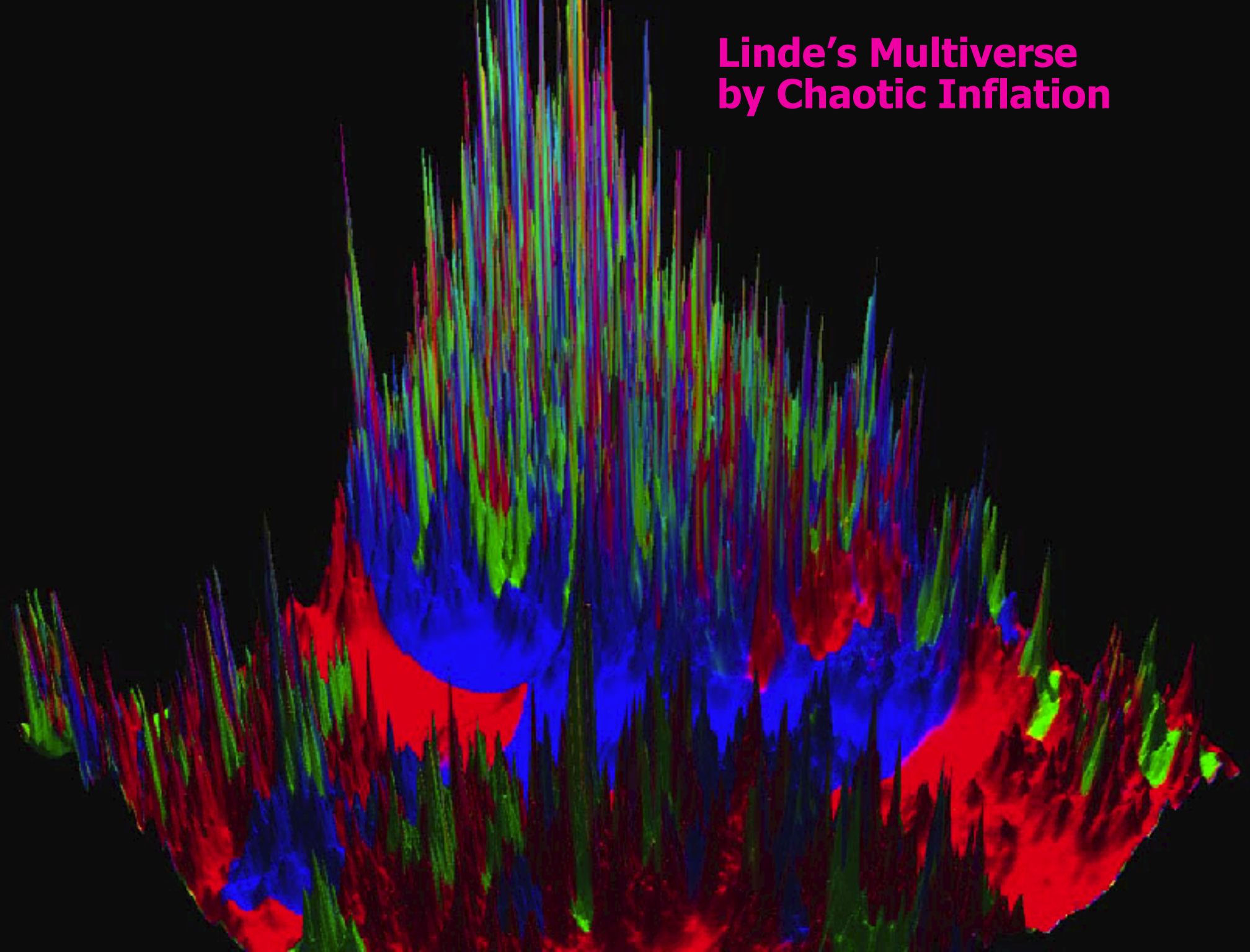
**Now we are here!**

# History of the Universe



**Are there more than  
one Universe?**

# Linde's Multiverse by Chaotic Inflation

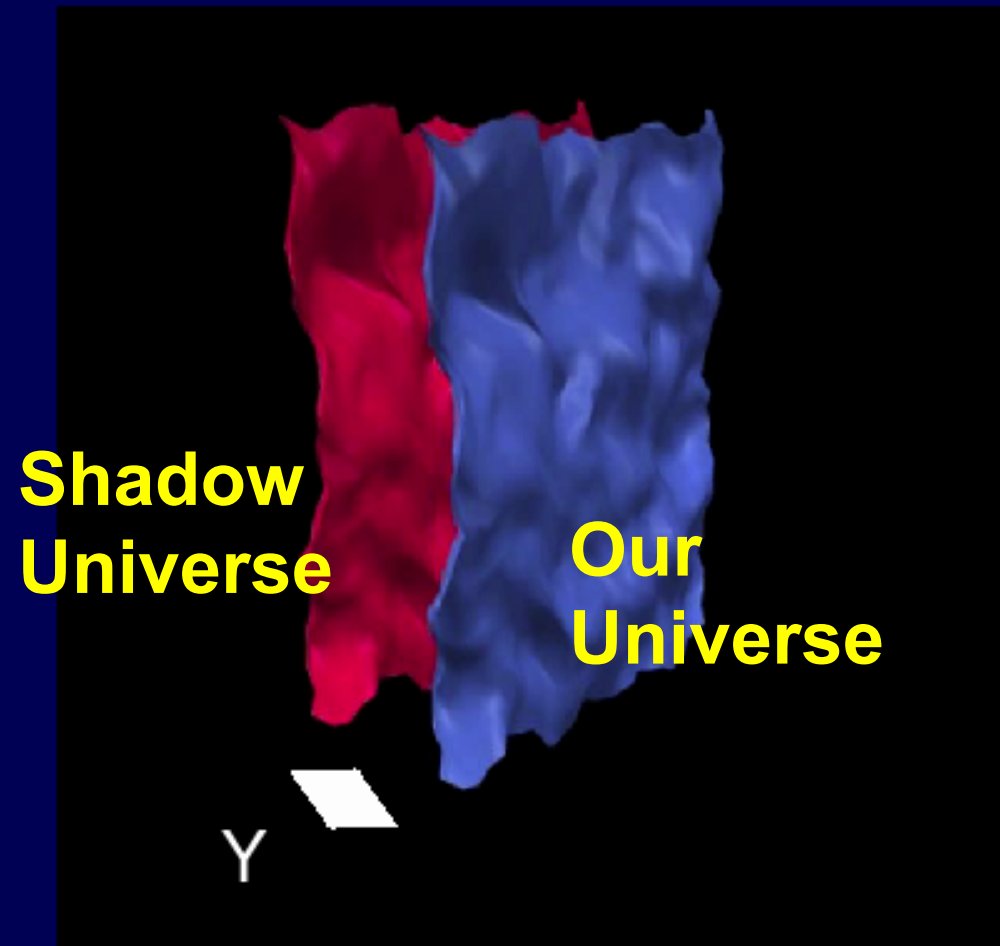
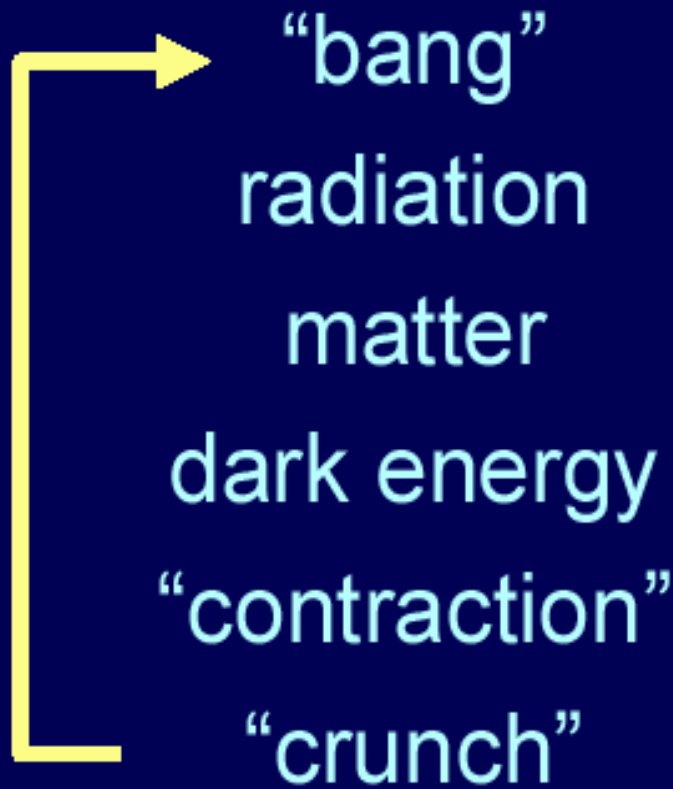




**There may be ~100 Billion Universes.**

# Cyclic Model

M theory



# Seven Phases of Cosmic Evolution

