Unlocking the Mysteries of the Top Quark

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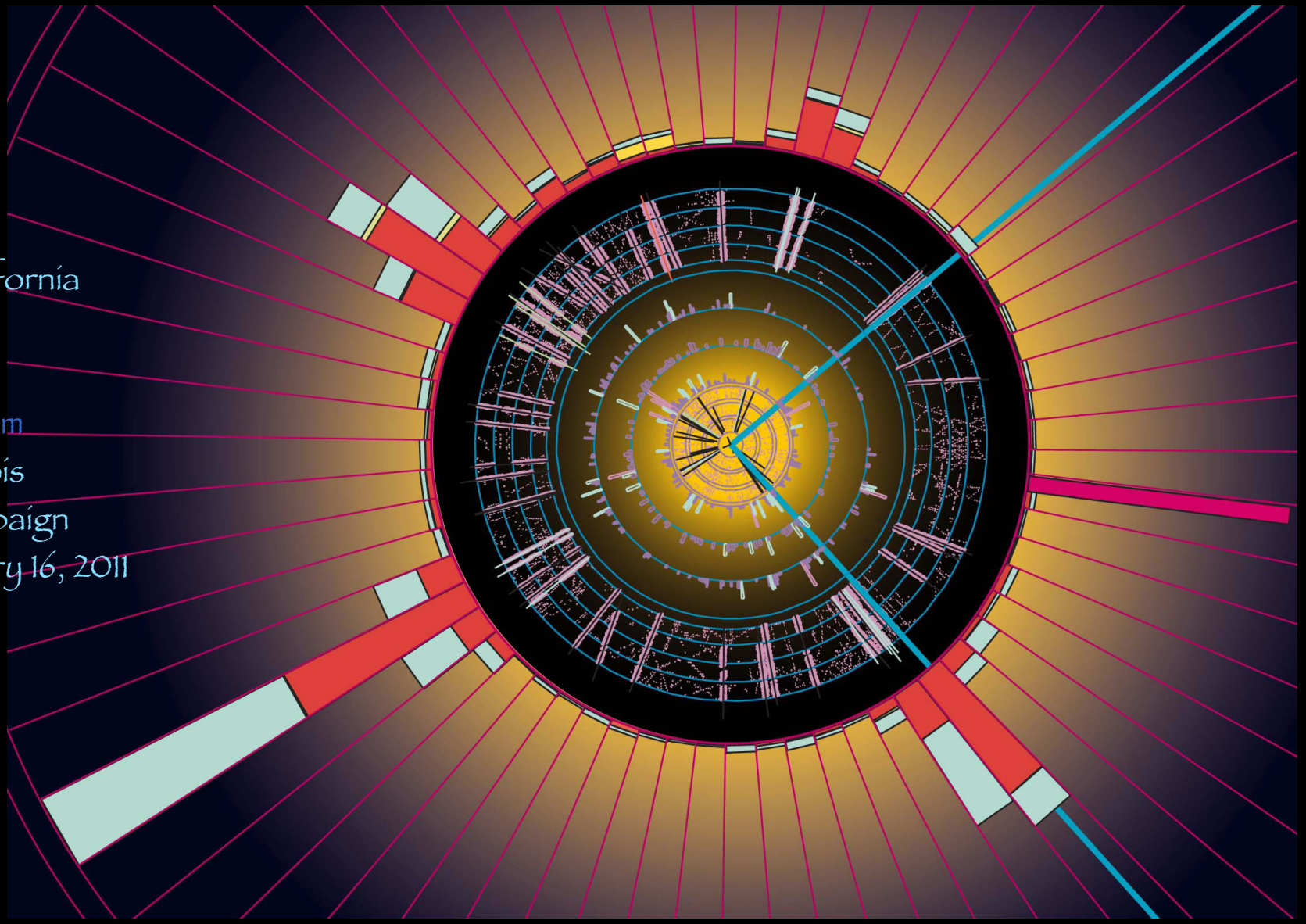


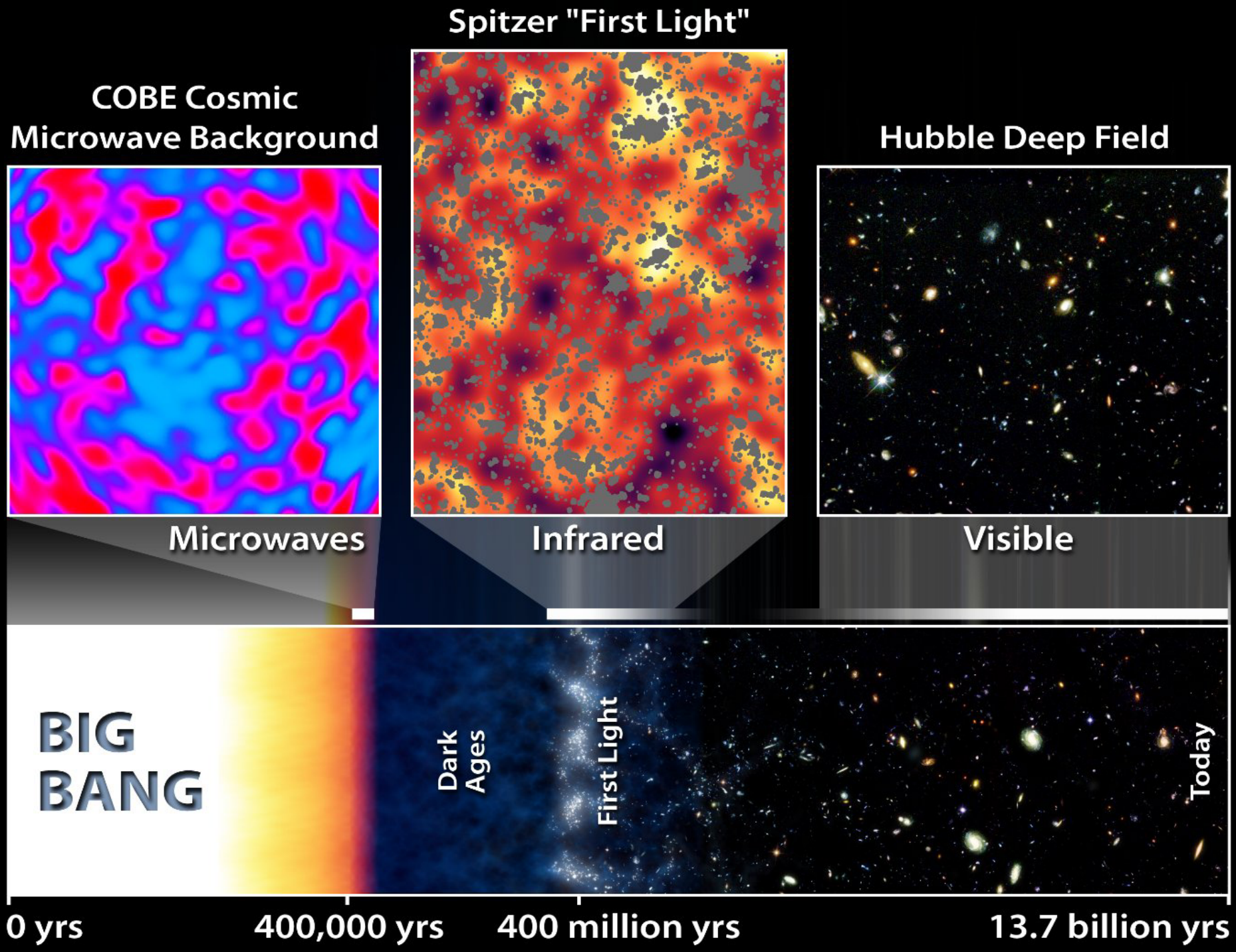
Talk Outline

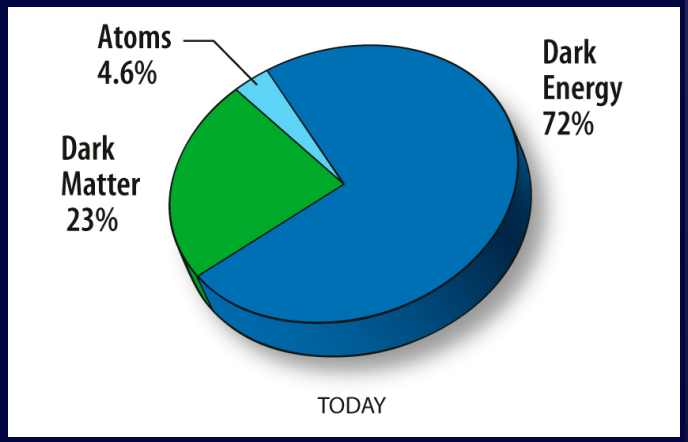
- The Big Questions
- Distance and Time Scales
- The Standard Model

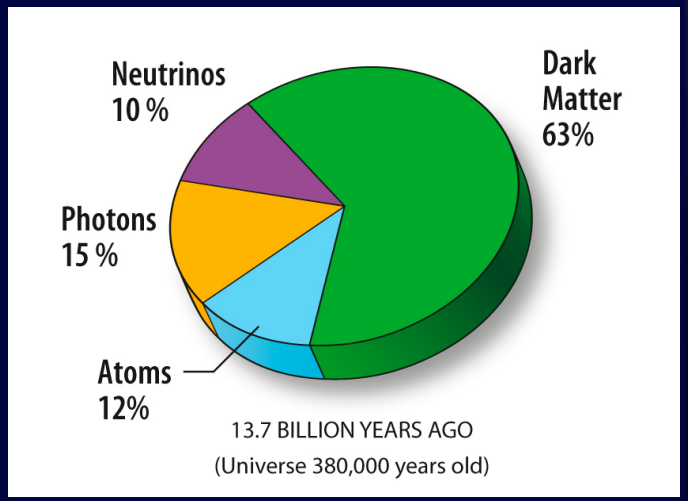
What are the Big Questions in Particle Physics?

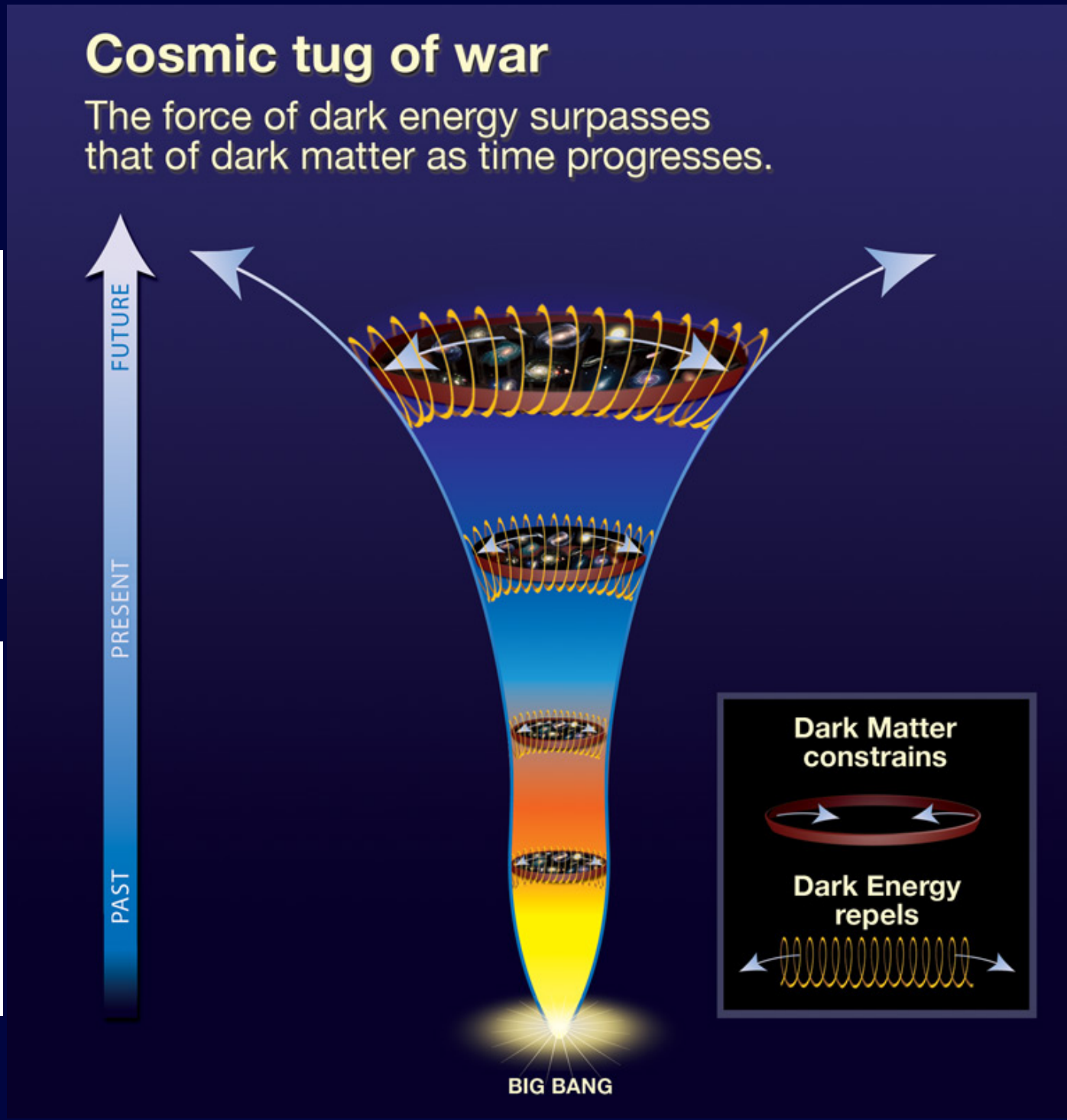
- How did the universe begin?
- How will it end?
- What is it made of?

Particle physicists work with astrophysicists and cosmologists to discover the answers


Spitzer "First Light"
COBE Cosmic Microwave Background
Hubble Deep Field
Microwaves
Infrared
Visible
BIG BANG
Dark Ages
First Light
Today
0 yrs
400,000 yrs
400 million yrs
13.7 billion yrs


Atoms
4.6%
Dark
Energy
72%
Dark
Matter
23%
TODAY


Neutrinos
10 %
Dark
Matter
63%
Photons
15 %
Atoms
12%
13.7 BILLION YEARS AGO
(Universe 380,000 years old)


Cosmic tug of war
The force of dark energy surpasses
that of dark matter as time progresses.
FUTURE
PRESENT
PAST
BIG BANG
Dark Matter
constrains
Dark Energy
repels

Distance Scales

Universe	930 Yotta-meters	10^{27} m
Milky Way galaxy	1 Zetta-meter	10^{21} m
Solar system	2.7 Exa-meters	10^{18} m
Jupiter's orbit	1.6 Tera-meters	10^{12} m
Sun	1.4 Giga-meters	10^{9} m
USA	4.5 Mega-meters	10^{6} m
Tevatron collider	1.9 kilo-meters	10^{3} m
Person	1.7 meters	10^{0} m
Infra-red light	10 micro-meters	10^{-5} m
Ultra-violet light	100 nano-meters	10^{-7} m
Carbon nanotube	1 nano-meter	10^{-9} m
Hydrogen atom	25 pico-meters	10^{-11} m
Proton	1 femto-meter	10^{-15} m
Top quark	<1 atto-meter	10^{-18} m

High energy physics

is

nano nano physics

Time Scales

Universe	4.3 Peta-seconds	10^{17} s
Earth	1.4 Peta-seconds	10^{17} s
Homo sapiens	2 Tera-seconds	10^{15} s
USA	7.4 Giga-seconds	10^{9} s
Tevatron collider	0.8 Giga-seconds	10^{8} s
"Fame"	900 seconds	10^{3} s
Eye blink	80 milli-seconds	10^{-1} s
Light travels 1 km	3.3 micro-seconds	10^{-6} s
K_L meson lifetime	0.5 nano-seconds	10^{-9} s
B^0 meson lifetime	1.5 pico-seconds	10^{-12} s
Ultraviolet light	1 femto-second	10^{-15} s
Shortest laser pulse	80 atto-seconds	10^{-16} s
X-rays	300 zepto-seconds	10^{-19} s
Top quark lifetime	0.5 yocto-seconds	10^{-24} s

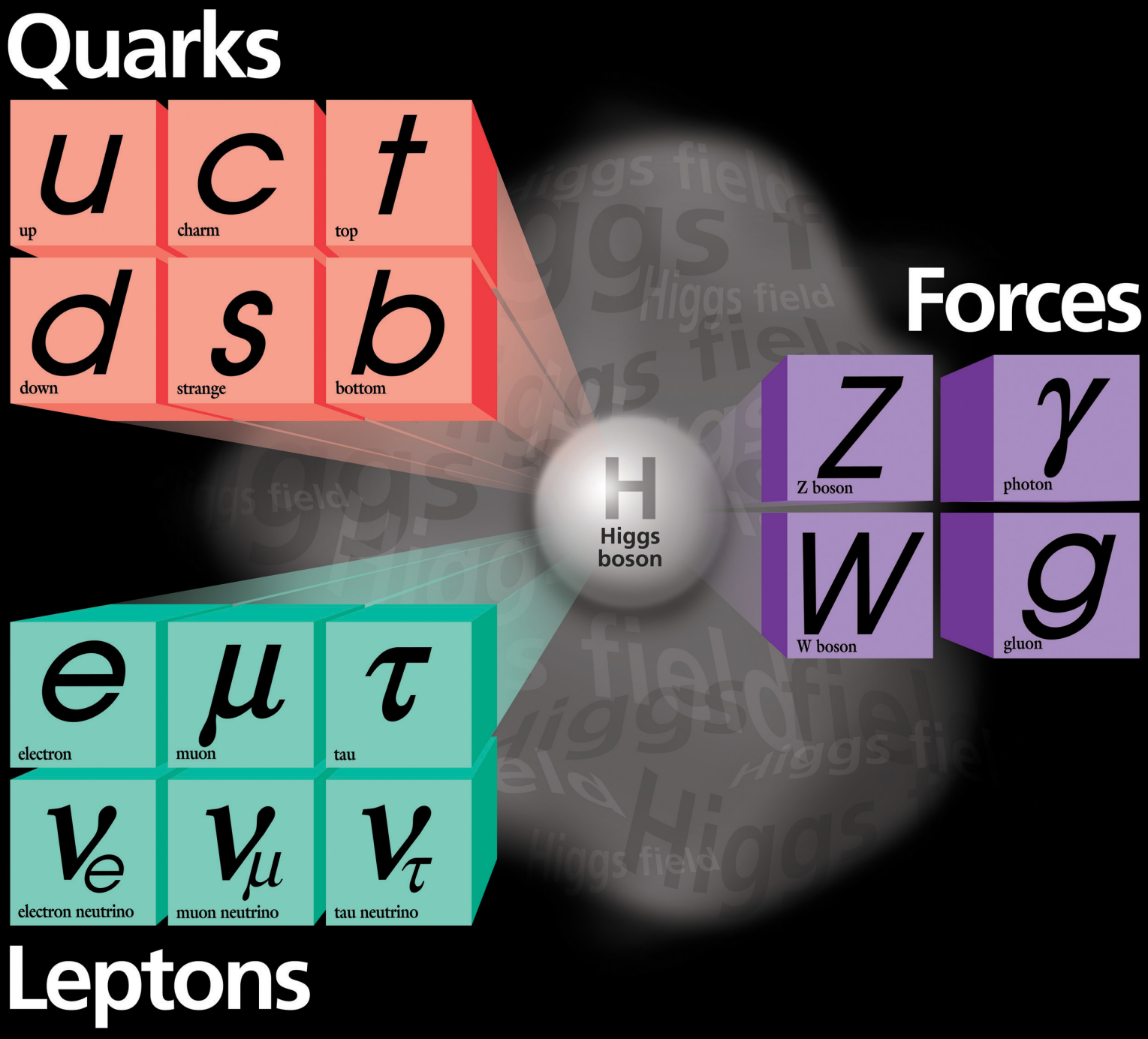
In high energy physics,

B^0 mesons are considered to have a very long lifetime (1.5 ps).

We measure their decay length to identify them in top quark decays.

The Standard Model of Particle Physics

- Describes the majority of phenomena in Nature
- Builds everything from quarks and leptons
- Forces are carried by
  - Photons – electromagnetic force
  - W and Z bosons – weak force
  - Gluons – strong force
- Higgs boson predicted to give mass to everything
- SM is accurate to 1 in 10^{10} precision


Quarks
u
up
c
charm
t
top
d
down
s
strange
b
bottom
Forces
Z
Z boson
γ
photon
H
Higgs boson
W
W boson
g
gluon
e
electron
μ
muon
τ
tau
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
Leptons

More Big Questions

- Why is there matter–antimatter asymmetry?
- Do quarks have substructure?
- Why are there three quark and lepton generations?
- How do particles acquire mass?
- Do supersymmetric particles exist?
- What is dark matter?
- What is dark energy?
- What is the space-time structure? (more dimensions?)

Much work to do!

The Tevatron collider at Fermilab has been running for 25 years trying to answer these questions.

Credits for Images

p.1 Fermilab
p.4 NASA / JPL Caltech / A. Kashlinsky (Goddard Space Flight Center)
p.5 NASA/WMAP, NASA/Space Telescope
p.8 Fermilab