Warwick particle physics masterclass 19th March 2014

- 13.00-13.20   Introduction and Welcome: Prof. Tim Gershon
- 13.20-13.50   Hunting the Higgs: Dr. Michel Janus

- 13.50-14.20   Refreshments/chat with Particle Physics Group members

- 14.20-15.50   Neutrino Physics Data Analysis Challenge: Andrew Furmanski, Steve Dennis, Eddy Larkin
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- 16.30 End

Introduction to Particle Physics

Tim Gershon
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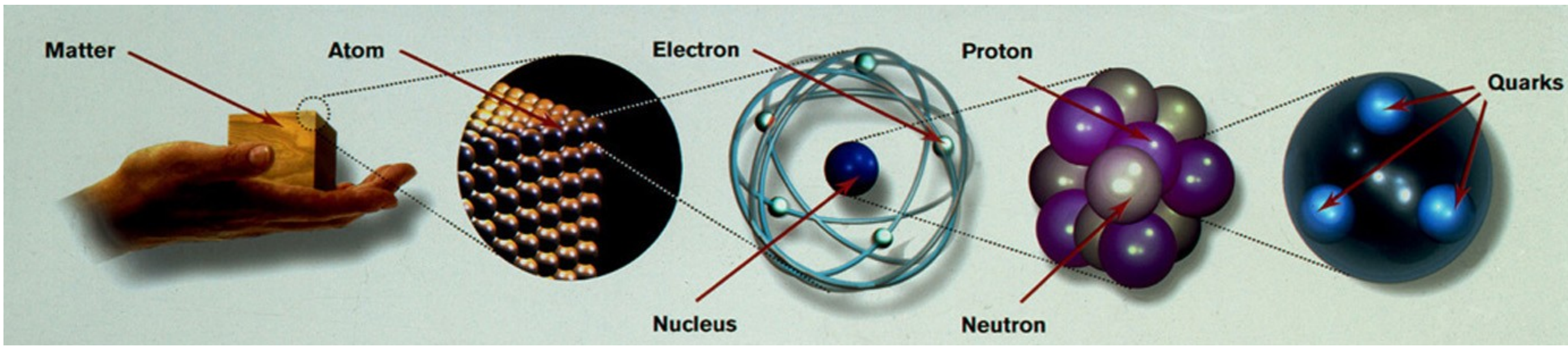
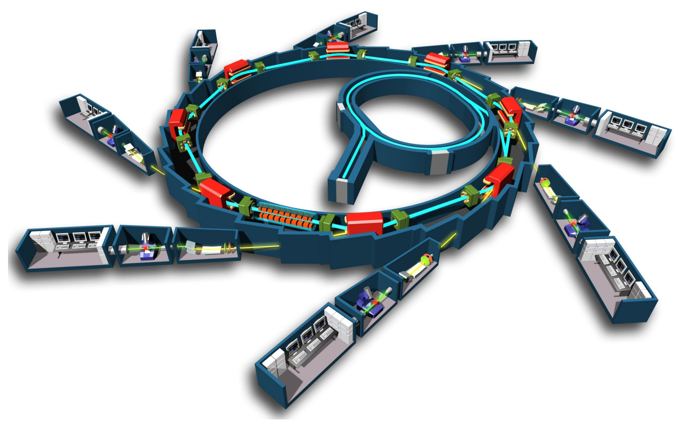
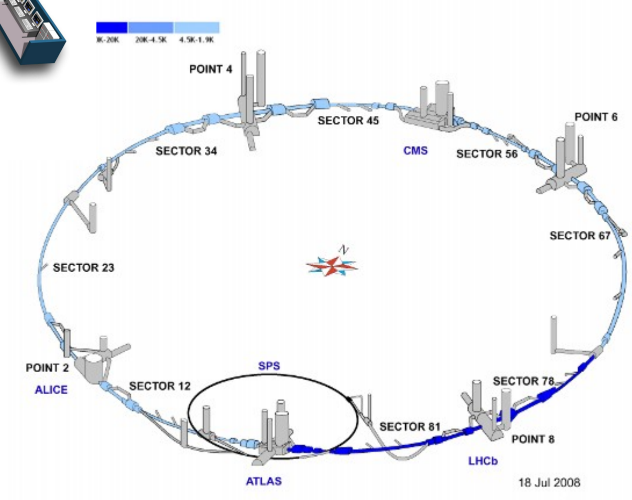
Masterclass 19th March 2014

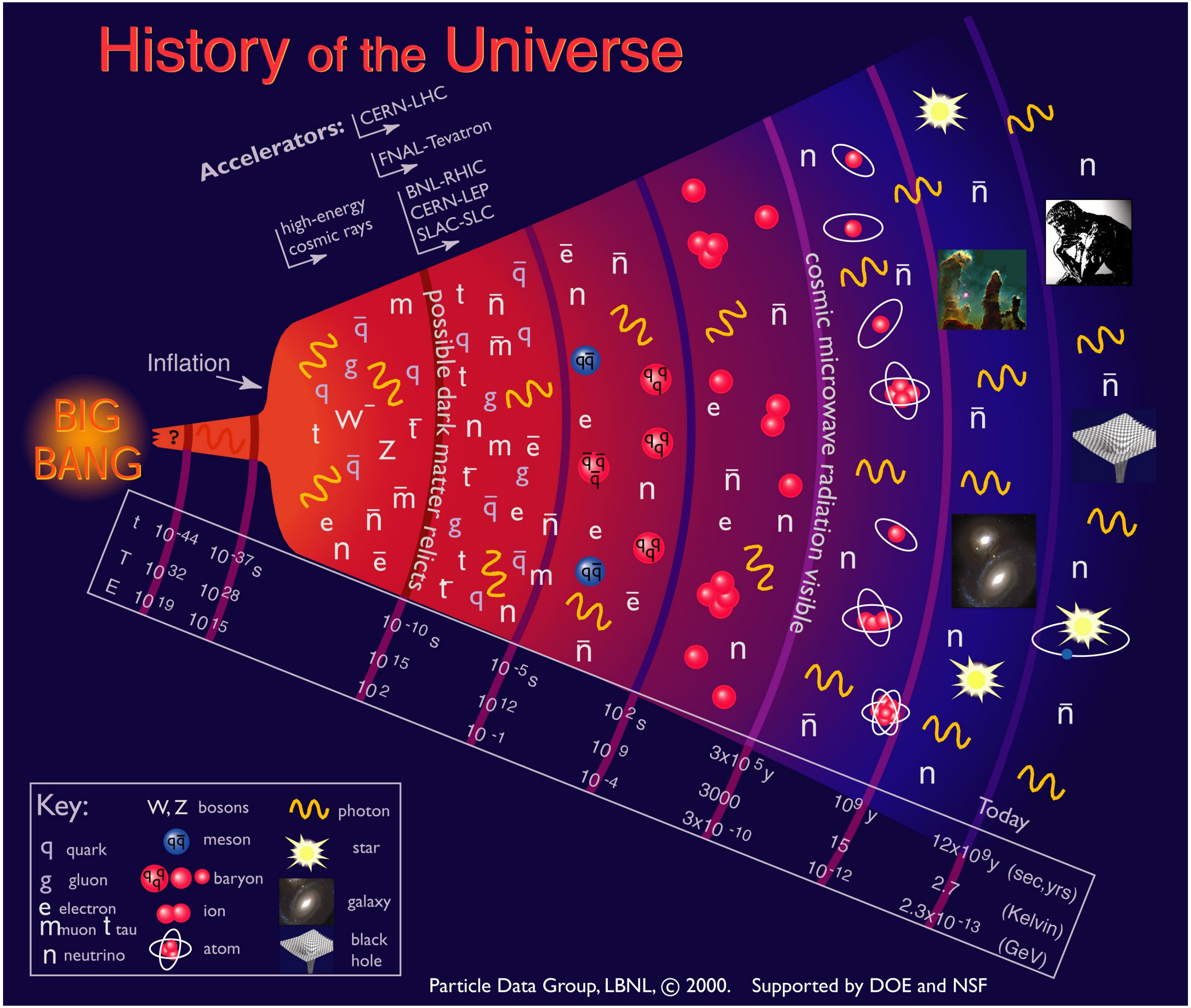
To understand what matter is made of on the smallest scales we need powerful microscopes







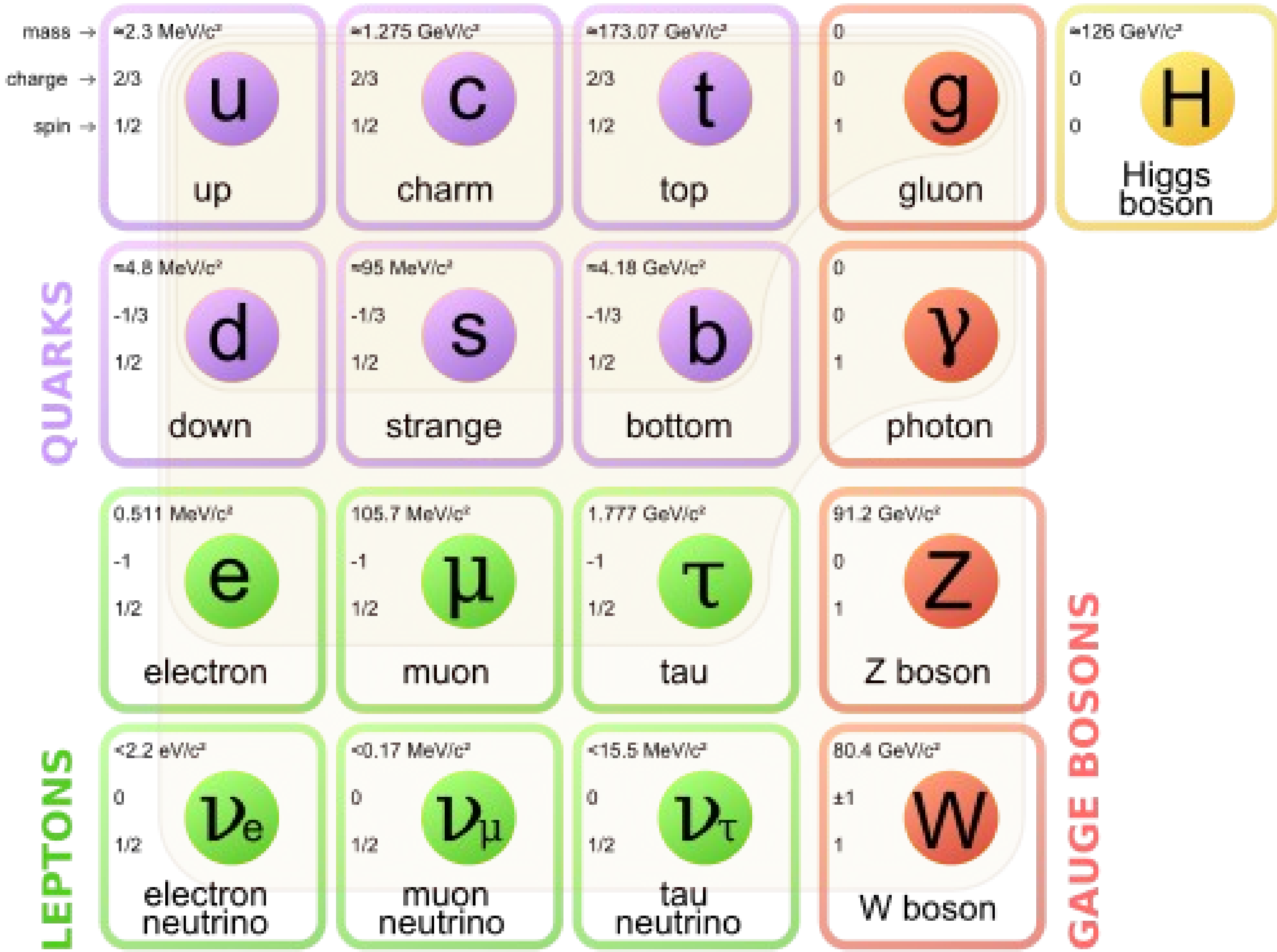
Higher energies correspond to earlier times



Particle physics is …

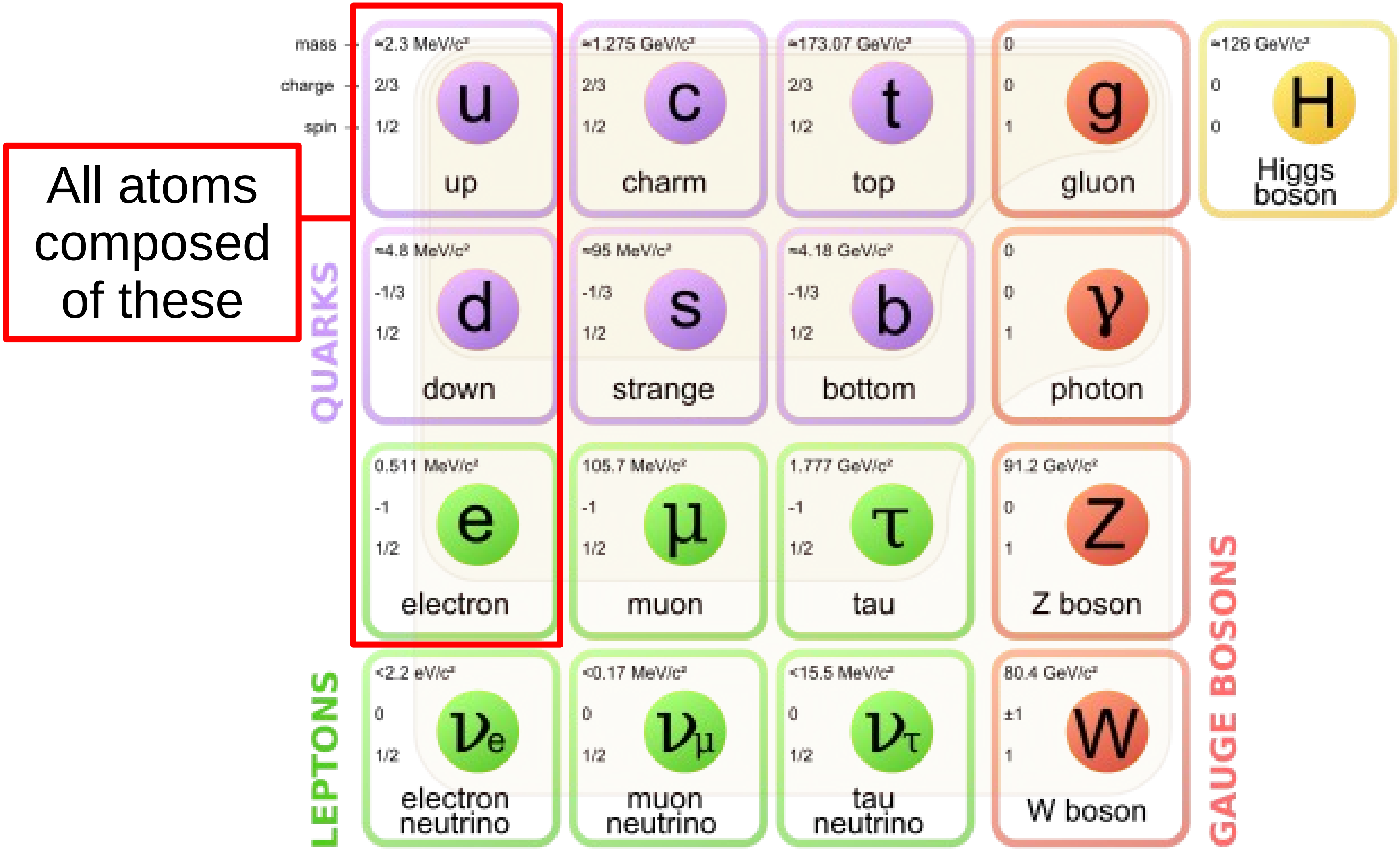
- … the study of the fundamental particles
- … both those that make up matter and those that describe interactions (forces)
- … the search for an ever more fundamental theory of nature
- … part of the quest to understand the origin of the Universe

The Standard Model



Theoretical framework for the Standard Model is based on gauge invariance of relativistic quantum field theory

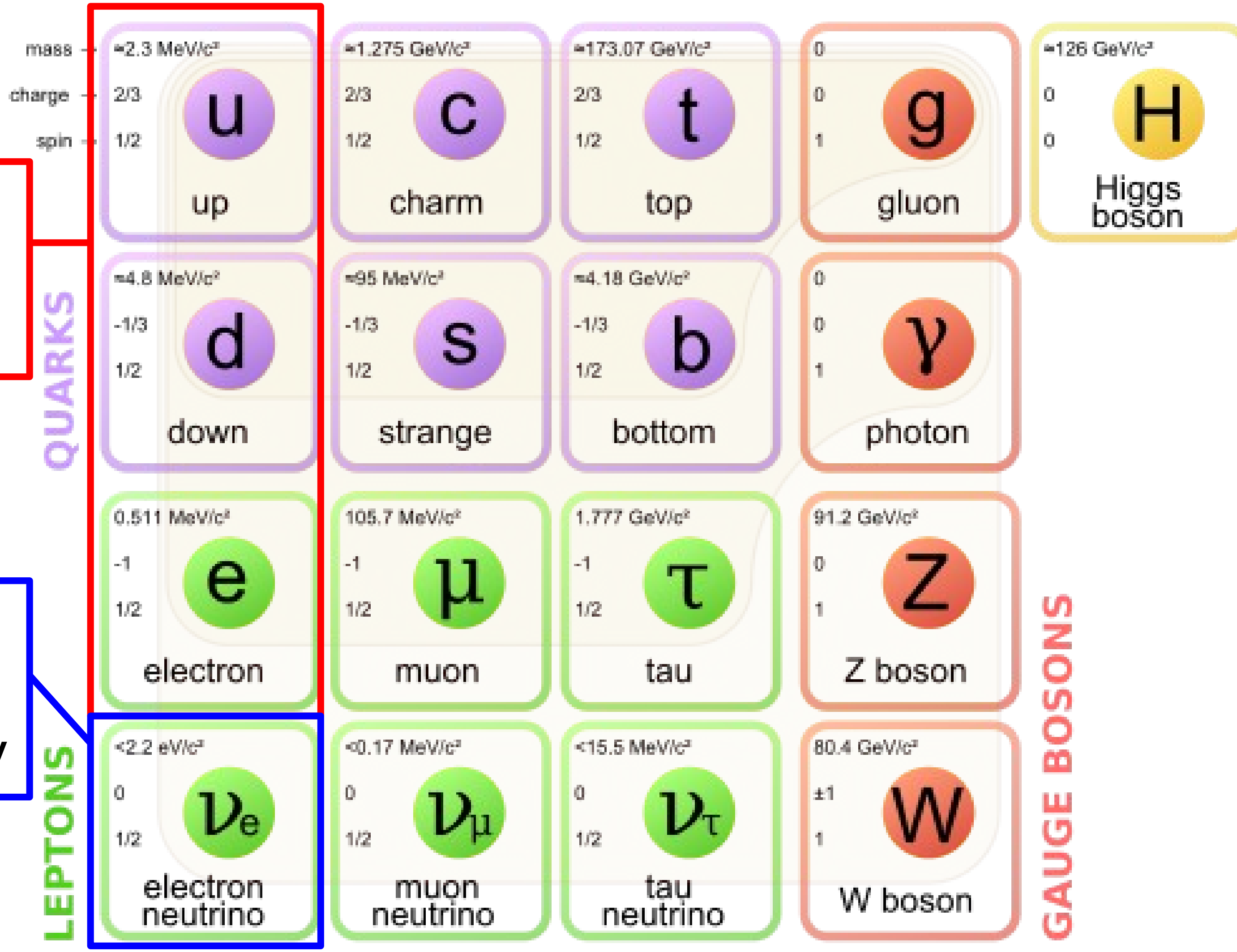
The Standard Model



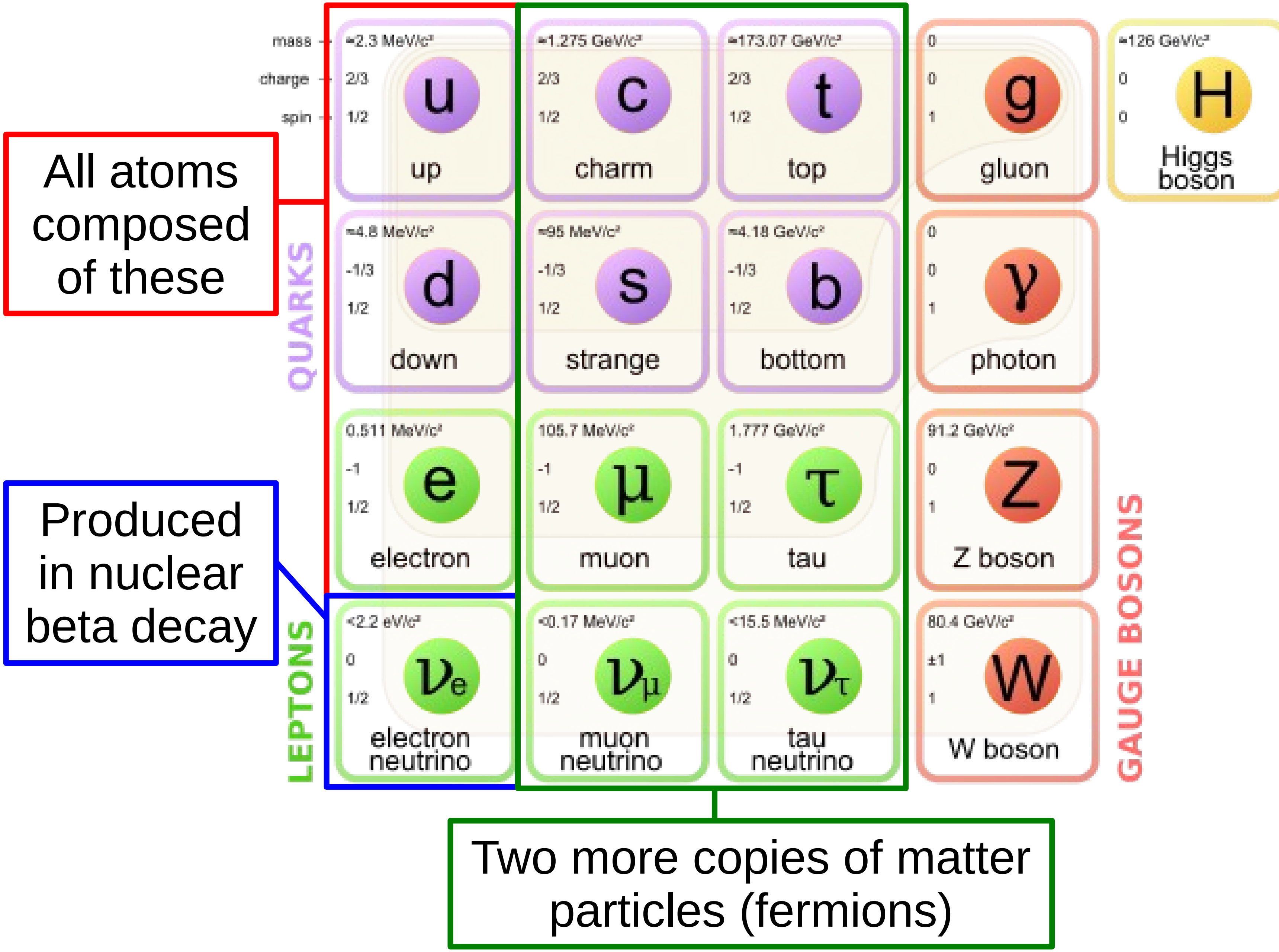
The Standard Model

All atoms composed of these

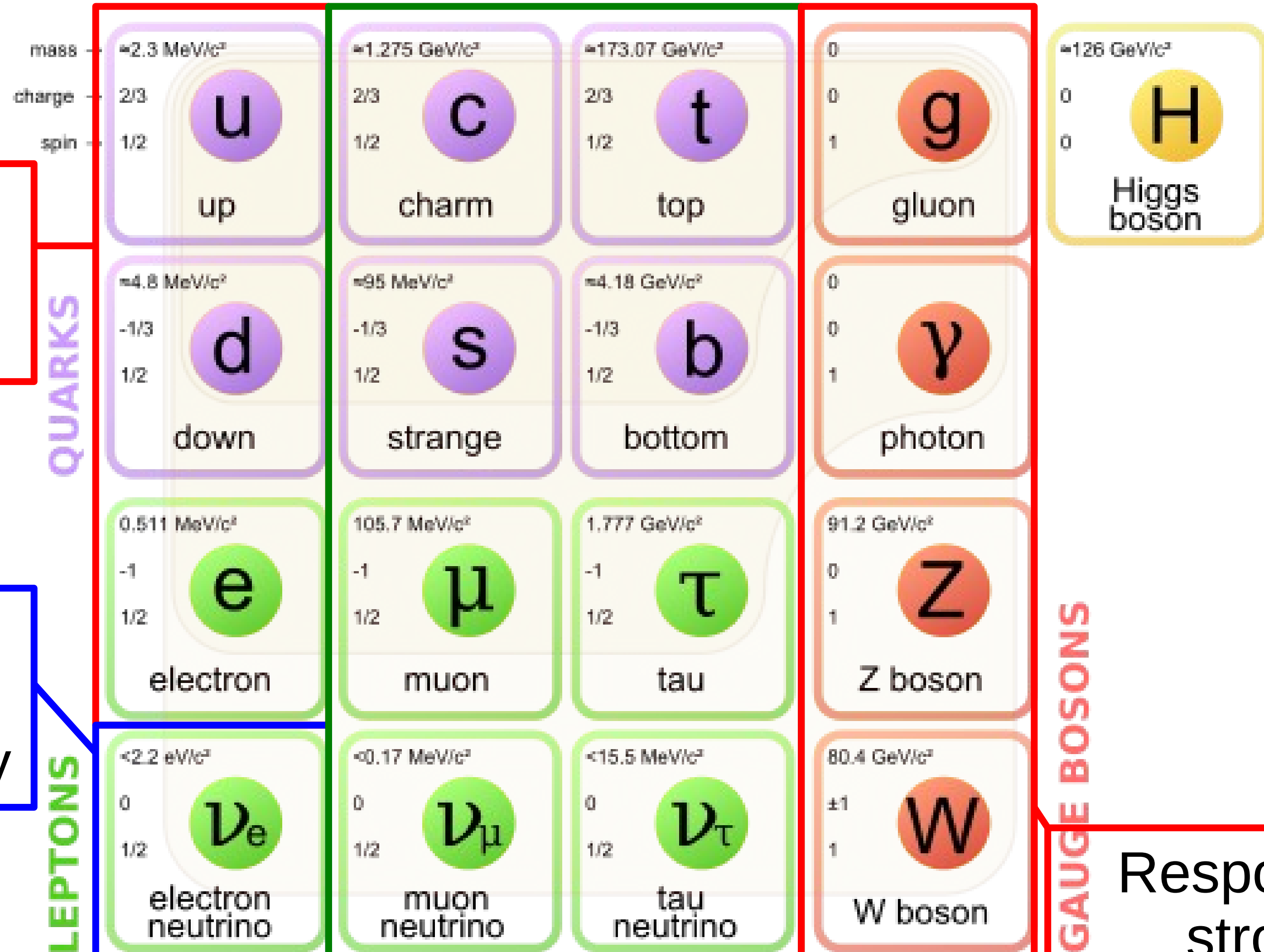
Produced in nuclear beta decay



The Standard Model



The Standard Model



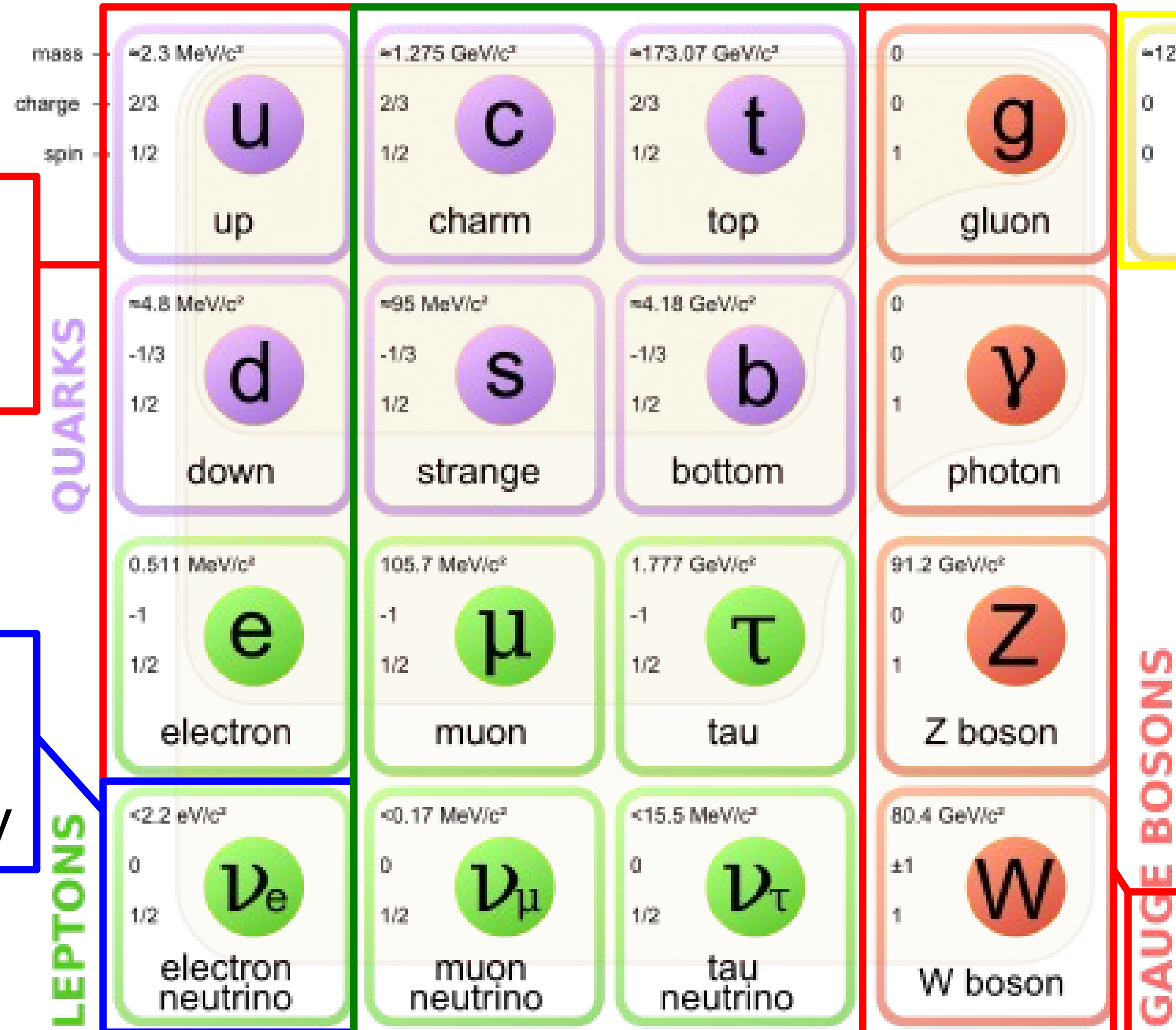
All atoms composed of these

Produced in nuclear beta decay

Two more copies of matter particles (fermions)

Responsible for strong (g), electromagnetic (γ) and weak (Z, W) interactions

The Standard Model



All atoms composed of these

Produced in nuclear beta decay

Added “by hand” to explain mass

Two more copies of matter particles (fermions)

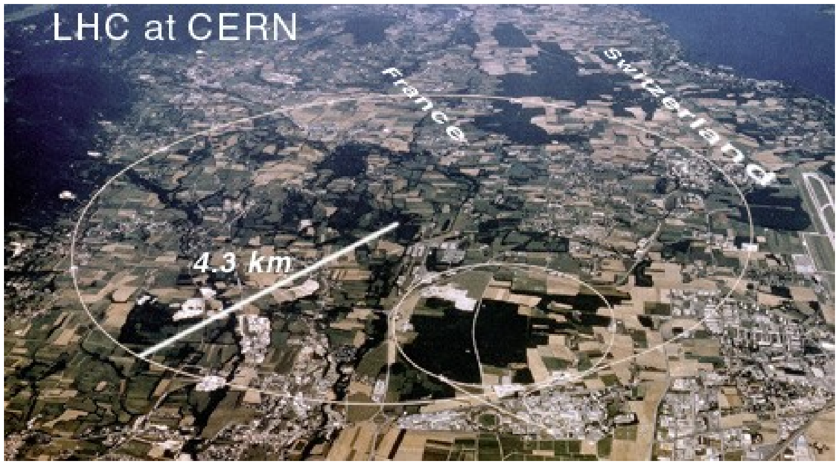
Responsible for strong (g), electromagnetic (γ) and weak (Z, W) interactions

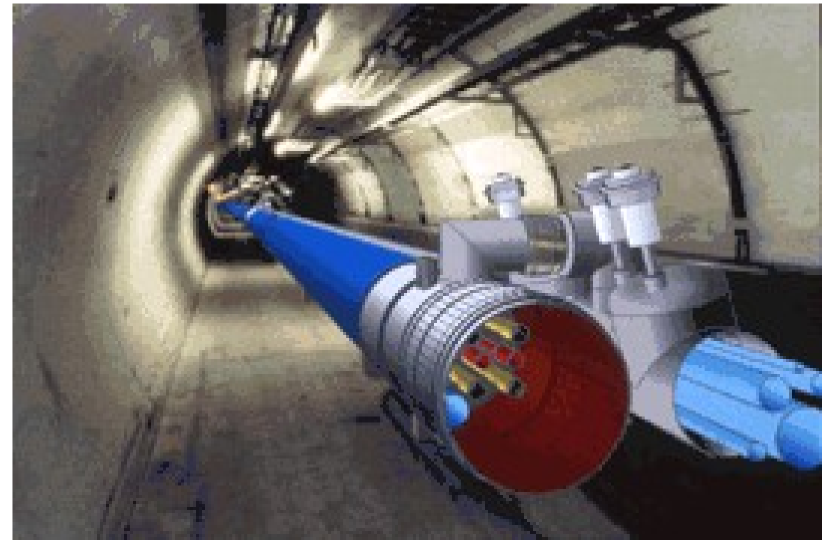
Mysteries of the Standard Model

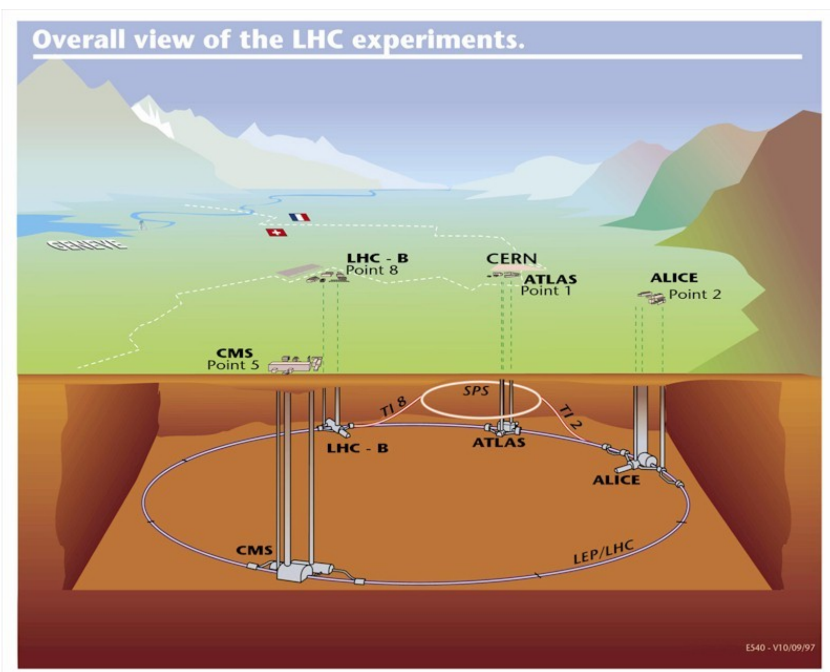
- Why are there so many particles?
- Do the forces unify at high energy?
- Does the Higgs' mechanism explain fully the origin of mass?
- Why are neutrinos special?
- What is the cause of the asymmetry between matter and antimatter in the Universe?
- What is dark matter? What is dark energy?
- What is the fundamental theory of nature (including gravity)?

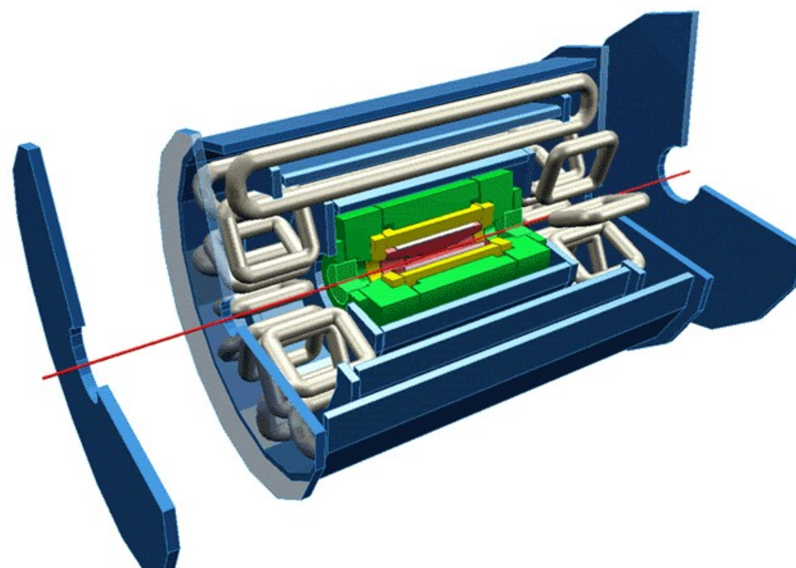
These are big, difficult, questions
But they (mostly) can be, and are being, addressed experimentally

The Large Hadron Collider









The Large Hadron Collider

- Aims of the LHC include:
  - to discover the Higgs boson (✓)
  - to find hints of a more fundamental theory, that may
    - provide better understanding of the Higgs mechanism
    - allow unification of the forces (strong, EM & weak)
    - explain the origin of dark matter
  - to improve understanding of matter-antimatter asymmetry

The Large Hadron Collider

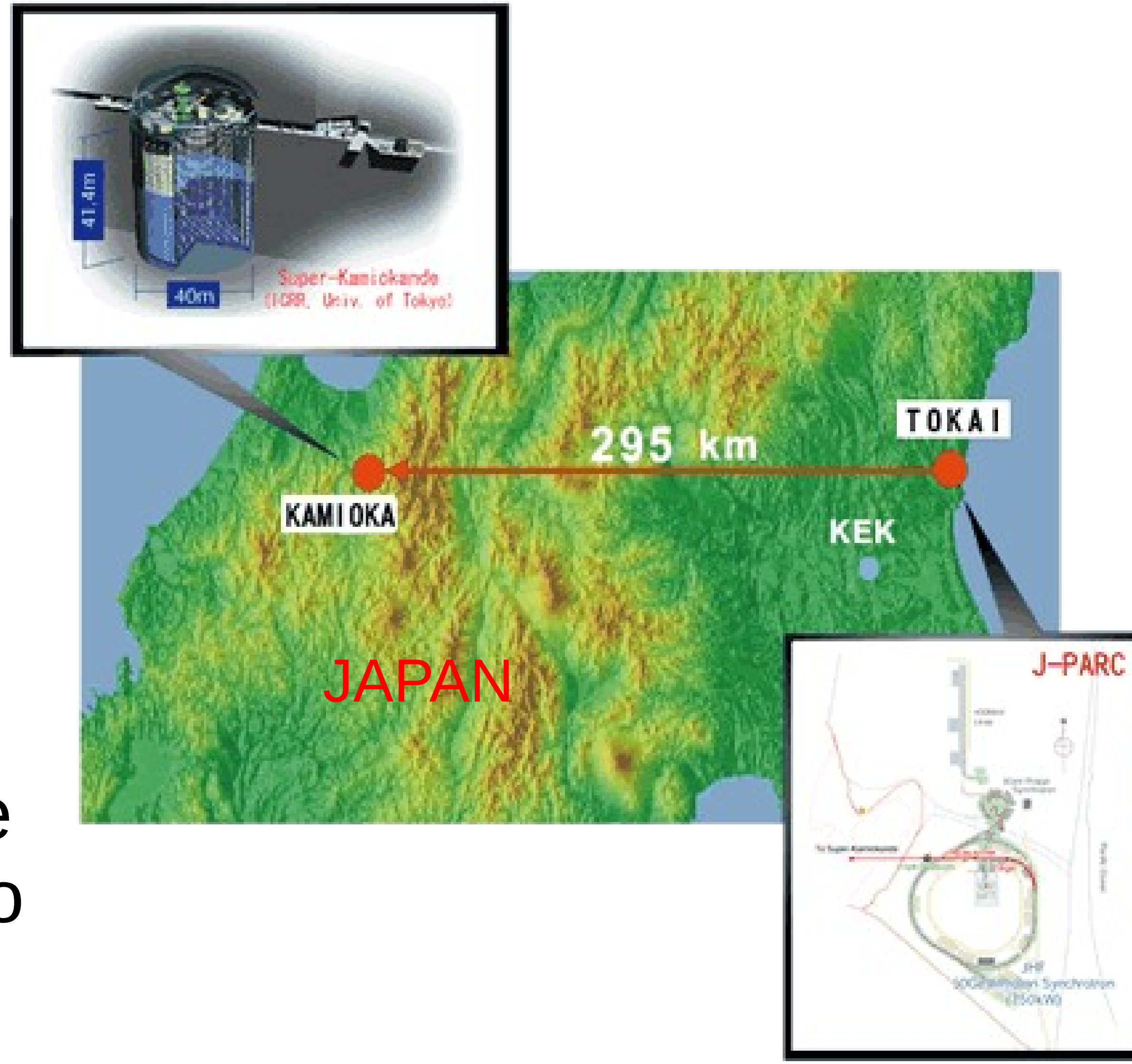
- Goals achieved by colliding protons at very high energies
  - acceleration with superconducting magnets (cooler than outer space)
  - protons travel at 99.9999991% of the speed of light – over 10,000 laps of the 27 km circumference ring per second – through a vacuum that is more empty than interplanetary space
  - collisions are (much) hotter than the sun
  - detectors the size of cathedrals packed with advanced technologies examine the debris of the collisions
- It is a triumph of science, technology, engineering and international collaboration

Matter & antimatter & neutrinos

- A "big bang" must produce equal amounts of matter and antimatter
- But, as far as we can tell, all our Universe is made of matter
  - where did the antimatter go?
  - study differences between matter and antimatter (called "CP violation") to try to find a solution
- Neutrinos seem special because
  - they are much lighter than all other matter particles
  - they have no charge, so might be their own antiparticles
  - very interesting to study CP violation in neutrinos

The T2K experiment

- T2K is a “long baseline neutrino oscillation” experiment
- Produce neutrinos (or antineutrinos) by colliding protons with a fixed target
- See if they change type as they travel 280 km to the detector



Summary

- We have an excellent understanding of the fundamental particles, but know there is even more to be learned
- Some experiments use the highest energy collisions (LHC) but other important approaches also being used
- Astonishing and unforeseeable new technologies “spin-off” from fundamental research
- This is a very exciting era in particle physics

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