FY3403 Particle physics
Problemset 1 fall 2024

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Background material: mainly Griffiths chapter 1 + online resources.

Problem 1. The particle adventure

For questions that we have not covered in the lectures, consult textbooks or scientifically solid resources online to find the answer.

a) Do you agree with the statements below? Give additional comments where needed.

1. There exist subatomic particles with no mass and no charge.
2. There exist some particles which can go through billions of kilometers of matter without slowing down or being stopped.
3. Antimatter only exists in *science fiction*, not as a scientific fact.
4. Particle accelerators are used for treatment of cancer.
5. The smallest constituents of the atomic core are protons and electrons.
6. Particles and antiparticles can materialize from energy.
7. Particle physicists need larger accelerators in order to study larger objects.
8. Magnets are used in circular-accelerators in order to make the particles move faster.
9. The work done by particle physicists at accelerators helps us understand how the universe were developing during its very early history.
10. Gravitation is the strongest fundamental force in nature.
11. There exist more than one hundred subatomic particles.
12. All known matter is made of leptons and quarks.
13. The protons in *the Large Hadron Collider* (LHC) at the CERN laboratory in Geneva, Switzerland cross the French-Swiss border 11 000 times per second (without visa or passport!).
14. Frition is one of the fundamental forces of nature.
15. The largest magnet in the world (situated in a particle physics laboratorium) weighs more than half of the Eiffel Tower.

b) Who said first that the fundamental building blocks of nature are earth, air, fire and water?

c) Why is the expression *atom* misleading?

d) How large part of an atom is just empty space?

e) About how large is (i) an atom, (ii) an atomic nucleus, (iii) a proton, (iv) an electron.

f) How many types of leptons are there in *the Standard Model of Elementary Particle Physics*? How many types of quarks? What do we call these particles?

g) In about how many years have physicists known that there are more types of particles than protons, neutrons, electrons and photons?

h) Which quark were discovered last? When and where?

i) Why are there not equal amounts of matter and anti-matter in the universe?

j) The word *lepton* originates from greek and means "small mass", which is misleading. Why?

k) Which lepton decays are possible? Why (or why not)?

$$\tau^- \to e^- + \bar{\nu}_e + \nu_\tau,$$
$$\tau^- \to \mu^- + \nu_\tau,$$
$$e^- \to \mu^- + \bar{\nu}_\mu + \nu_e$$

l) What are protons made of?

m) What are electrons made of?

n) Which of the following are made of quarks? (a) Baryons, (b) Mesons, (c) Barons, (d) Hadrons, (e) Leptons

o) How many generations (also called families) of matter particles do we have? Why?

p) How many types of fundamental interactions exist in nature? What are they called?

q) What is a color charge?

r) What keeps the atomic nucleus together?

s) How is gravitation described in the *Standard Model of Elementary Particle Physics*?

t) What is a bubble chamber? Why is it not much used today?

u) Is it true that "*Diamonds are forever*"?

v) What is a *squark*?

w) What is *dark matter*?

x) What is the advantage of particle accelerators with colliding beams?

y) What are *linacs*?