Energy matters

The Large Hadron Collider is a ring-shaped accelerator that boosts the kinetic energy of the charged particles in the ring at several places round it. Fixed magnets all the way round the ring bend the path of the particles to keep them in the ring. When they collide with other particles:

- The total energy of the particles and antiparticles before the collision = their rest energy + their kinetic energy.
- The total energy of the new particles and antiparticles after the collision = their rest energy + their kinetic energy

Using conservation of energy,

$$\begin{matrix}\text{the rest energy of}\\ \text{the products}\end{matrix} = \begin{matrix}\text{total energy}\\ \text{before}\end{matrix} - \begin{matrix}\text{the kinetic energy}\\ \text{of the products}\end{matrix}$$

For example, if a proton and an antiproton each with kinetic energy of 2 GeV collide, their total energy before the collision is 6 GeV (as each particle has 2 GeV of kinetic energy and approximately 1 GeV of rest energy – see Table 1). The result could be a range of products, as long as their total energy does not exceed 6 GeV, provided the conservation rules (e.g. charge) are obeyed.

Note:

1 GeV = 1000MeV

Baryons and mesons

When K mesons are created, short-lived particles with greater rest masses than protons may also be produced. These particles are created through the strong interaction, so they are hadrons. However, in comparison with K mesons, they decay into protons as well as into π mesons (whereas protons are never among the decay products of K mesons). Consequently, we can divide hadrons into two groups:

1 **Baryons** are protons and all other hadrons (including neutrons) that decay into protons, either directly or indirectly.
2 **Mesons** are hadrons that do **not** include protons in their decay products. In other words, K mesons and π mesons are not baryons.

We shall see in Topic 2.4 that baryons and mesons are composed of smaller particles called **quarks** and **antiquarks**.

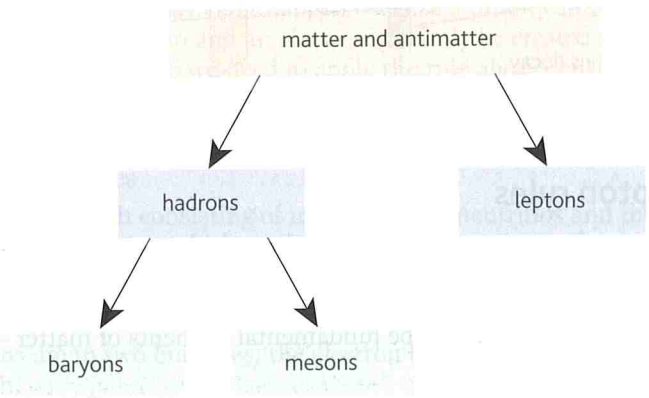

Figure 2 *Particle sorts*

Figure 1 *The Large Hadron Collider*

Summary questions

1 a What is i a hadron? ii a lepton?

b State whether each of the following particles or antiparticles is a baryon, a meson or a lepton:

i an electron, ii a neutron,

iii a K meson.

2 State one similarity and one difference between

a a muon and a π^- meson,

b a π^+ meson and a K^+ meson,

c a K^0 meson and a neutron.

3 Complete the following sentences:

a A particle that is not a hadron is a _____.

b Hadrons are divided into _____ and _____.

c _____ do not include protons in their decay products.

4 A K^+ meson can decay into 3 charged mesons.

a Complete the following equation for this decay:
$K^+ \longrightarrow \quad + \pi^+ +$

b Use the rest energy values in Table 1 to calculate the maximum kinetic energy of the π mesons, assuming the K meson is at rest before it decays.