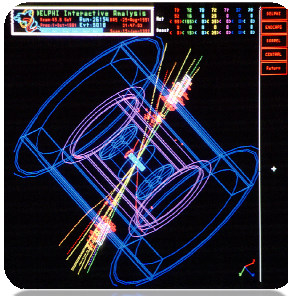
2.2 Particle Sorting

The particles that make up matter and antimatter can be divided into two groups: leptons and hadrons.

- **Hadrons** can interact via the strong interaction (strong nuclear force) and, if charged, via the electromagnetic interaction. Hadrons decay through the weak interaction – except for the proton, which is stable when free. (Protons in a nucleus can decay into a neutron and a positron)
- **Leptons** do not feel the strong force but interact via the weak interaction, (weak nuclear force) and, if charged, via the electromagnetic interaction.
- The picture opposite shows particle tracks from an electron-positron collision in the former Large Electron-Positron Collider (LEP) at CERN in Geneva. Here a Z_0 particle is produced in the collision, which then decays into a quark-antiquark pair. The quark pair is seen as a pair of hadron jets in the detector.



In a particle collision, the rest energy of the products is given by the equation:

Baryons and Mesons

The hadrons are not fundamental particles. They are composed of either two or three quarks or antiquarks. Hadrons are of two types:

- **Baryons** are either protons or other hadrons that decay into protons directly or indirectly.
- **Mesons** are hadrons that do not include protons in their decay products.

2.3 Leptons at Work

- **Types of Lepton:** electron (e-), positron (e+), muon (μ-), antimuon (μ+), electron neutrino (ν_e), electron antineutrino ($\bar{\nu}_e$), muon neutrino ((ν_μ), muon antineutrino ($\bar{\nu}_\mu$).

- **Interactions:** leptons do not feel the strong nuclear force. They interact via the weak nuclear force and, if they are charged, via the electromagnetic force.

- **Interaction Rules:** leptons can decay into other leptons via the weak nuclear interaction. They can be created or annihilated during particle collisions. They never decay into non-leptons.

- **Lepton Number:** L = +1 for any lepton and -1 for any antilepton. Lepton number is conserved during any interaction.
  NOTE: the muon branch of the lepton family and the electron branch have their own lepton numbers and **L must be conserved for both branches**. (Lepton numbers are supplied on the Data Sheet).

Example: This decay* cannot *happen $\mu^- \longrightarrow e^- + \bar{\nu}_e + \bar{\nu}_\mu$

For the electron branch:	0	=	(+1) + (-1) + 0	which is correct
For the muon branch:	+1	=	0 + 0 + (-1)	which is wrong

Muons are sometimes referred to as “heavy electrons”. They have the same charge as an electron but are more than 200 times more massive.
Neutrinos have rest masses about a million times smaller than an electron. They have no charge and they interact so weakly that billions of them pass straight through the Earth every second. Electron neutrinos do **not** interact with muons. Muon neutrinos do **not** interact with electrons.