Yukawa & the False Meson!

In 1934 Hideki Yukawa predicted the existence and the approximate mass of a particle call the "meson" as the carrier of the strong force that holds the atom together. Yukawa called his carrier particle the meson, from *mesos*, the Greek word for *intermediate*, because its predicted mass was between that of the **electron** and that of the **proton**, which has about 1,836 times the mass of the electron.

Muon Discovery

Carl Anderson found the mu meson had about the right mass to be Yukawa's carrier of the strong nuclear force, but over the course of the next decade, it became evident that it was not the right particle.
It behaved like a heavy version of the electron, and is in fact a lepton rather than a meson. They had found the **muon**!

Particle Accelerator

Particle accelerators are areas of space where there are strong magnetic and electric fields. Particles can be made to move very fast in circular or straight paths. Then they are collided into each other smashing into pieces. These pieces or "showers" contain other particles made from the original particles and their kinetic energy.

Feynman Diagram Skills….

Charge is conserved bottom to top.

Muon converts to muon neutrino of same type (or antiparticle version).

Electron & anti neutrino pair produced. (or reversed with e^+ and v_e)

Pions or Pi-mesons

Pion (short for pi meson) is the collective name for three subatomic particles: π^0, π^+ and π^-. Pions are the lightest mesons and play an important role in explaining low-energy properties of the strong nuclear force.
Pions are made of a quark and antiquark a down or up combination.
Decay via weak interaction

Kaons or K-mesons

A Kaon also called K-meson is any one of a group of four mesons distinguished by the fact that they carry a quantum number called strangeness.
In the quark model they are understood to contain a single strange quark (or anti strange quark) and either an up or down or anti up or anti down.

Muon Facts

The muon (mu μ is an elementary particle similar to the electron, with a -1.6×10^{-19}C negative charge and mass 200x that of the electron.
It is a fundamental particle.
The muon is unstable with a mean lifetime of 2.2 μs.
This comparatively long decay life time (the second longest known) is due to being mediated by the weak interaction.

Muon Decay

All muons decay to **three particles** (an electron plus two neutrinos of different types)

But the daughter particles are believed to originate newly in the decay.

You need to learn and remember the decay!

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Matter & Antimatter

The universe is consists of matter which splits into hadrons (have quarks inside) and leptons (which are empty).

Hadrons then split into baryons (3 quarks or 3 antiquarks) and mesons (1 quark and 1 antiquark. All have fractional charges which add to up to whole numbers.

Hadrons

Are unstable with the exception being the proton- the only stable Hadron.
Are composed of smaller fundamental particles called Quarks.
Meson have 2 Quarks and Baryons 3. Hence mesons don't decay to protons or neutrons.
Masses much larger than that of leptons.

Bosons

Bosons for em forces and gravity are without mass.
These forces have infinite range.
Bosons for the strong and weak interactions have mass.
These forces are short range.
The strong interaction only acts between hadrons (particles made of quarks)
The weak interaction acts on all particles.

Leptons

Leptons are just points of charge so don't interact through strong interaction.

They are also lightweight compared to hadrons as they have quarks inside which are quite massive!

Lepton & Collisions

Each of the charged leptons has an antiparticle with identical mass but whose other properties are opposite.

Each lepton has an associated neutrino, and antineutrino

Leptons can be accelerated and then collide with each other or other particles to produce hadrons.

Neutrino Facts

Neutrinos are elementary particles that travel close to the speed of light, lack an electric charge, are able to pass through ordinary matter almost undisturbed and are thus extremely difficult to detect.
Neutrinos have a minuscule, but nonzero mass. They are usually denoted by the Greek letter (nu) ν.

Neutrino Creation

Created as a result of certain types of radioactive decay or nuclear reactions such as those that take place in the Sun, in nuclear reactors, or when cosmic rays hit atoms.
Also when neutrons change into protons or vice versa, the two forms of beta decay.

Lepton Decay

When leptons decay we can check to see if it will happen by looking at the conservation of charge, lepton electron number, lepton muon numbers.
The system is simple. If you are it then you get a “1” if you are not you get a “0” and if you are an anti you get a “-1”

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Basic Quarks

Up (u) / down (d) / strange (s)

Learn combinations of quarks and antiquarks required to make;

- for baryons (proton and neutron only),
- antibaryons (antiproton and antineutron only)
- mesons (pion and kaon)

Quark Facts

We don't know exactly how small quarks and electrons are; they are definitely smaller than 10^{-18} meters, and they might literally be points, but we do not know.
Quarks have a fractional charge

u=2/3, d=-1/3, s=-1/3

Meson Wheel

The Pi-meson and K-mesons can be placed in what is called the 8-fold way. This is confusing at AS as there are six corners and 1 particle to learn in the middle (Pi-Zero). However, if can help to think about the particle anti-particle symmetry. You need a diagram for this one!

Evidence of Quarks

Scientists created very high energy electrons and fired them at protons or neutrons.

They found that they were scattered around three main points. This led to the concept of three quarks in hadrons.

Conservation of Charge

Any particle interaction must conserve charge. This works from start to end and cannot occur if they don’t add up.

If we have +1 at the start we must end up with +1!

Conservation of Baryon Number

This must be conserved with interactions between Baryons (as anything that is not a Baryon has a Baryon Number =0.

All Baryons have a B Number=1 and all Anti-baryons have a B Number=-1).

Conservation of Strangeness

Any Hadron that is made up a Strange quark has a Strangeness = -1. Any made up an Anti-strange quark has S=1. Therefore anything that is not a Hadron has a S=0. This is the opposite of all the other numbers as the “strange” is negative which seems “strange”.

Conservation of Lepton Number

There are however two types of Lepton Number each associated with the Electron and Muon. Any Electron or Electron-neutrino has an Le Number =1 with their anti-particles having -1. This pattern also continues with the Lepton-muon number (Lμ) and the Lepton-tau number (Lt). **(tau not required at AS)**

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