

## 2.4 Quarks and Antiquarks

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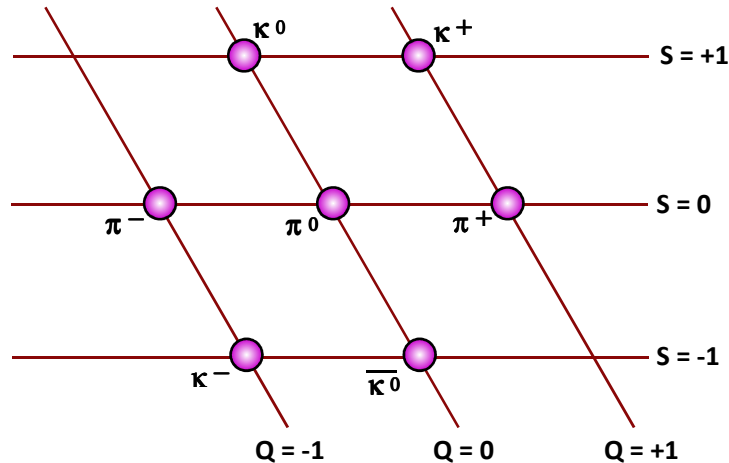
### 2.4 Quarks and Antiquarks

#### The Quark Model

By 1960, the number of known hadrons was so large that particle physicists realised they must be made up of smaller, fundamental particles.

Murray Gell-Mann proposed grouping the particles according to their strangeness and charge. When he did this, he found that they formed convincing but incomplete geometrical patterns. He used the gaps in the patterns to predict the existence of other, undiscovered particles such as the eta ( $\eta$ ) meson. When these particles were detected, physicists knew that Gell-Mann was correct.

The mesons and baryons formed similar patterns of eight particles, known originally as the **eightfold way**. Part of the meson group is shown below. (The  $\eta$  meson is omitted since we do not study this particle).



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### The Quark Model (continued)

- ❖ The name given to the fundamental particle which makes up all the hadrons, (baryons and mesons), is the **quark**. There are three basic kinds, the up quark ( $u$ ), the down quark ( $d$ ) and the strange quark ( $s$ ). There are also antiquarks,  $\bar{u}$ ,  $\bar{d}$  and  $\bar{s}$ .
- ❖ The quarks have the charge, strangeness numbers of the quarks are given in the table below.

	Quarks			Antiquarks		
	$u$	$d$	$s$	$\bar{u}$	$\bar{d}$	$\bar{s}$
Charge Q	+2/3	-1/3	-1/3	-2/3	+1/3	+1/3
Strangeness S	0	0	1-	0	0	+1

- ❖ The quark model showed that baryons are made up of three quarks and antibaryons are made up of three antiquarks. (A proton is the combination  $uud$ . A neutron is  $udd$ . The antiproton is  $\bar{u}\bar{u}\bar{d}$ . The antineutron is  $\bar{u}\bar{d}\bar{d}$ ).
- ❖ Mesons are made up of a quark and an antiquark. The antiparticle of a meson is therefore another meson, (e.g.  $\pi^-$  is the antiparticle of  $\pi^+$ ).

### Beta Decay

We can now re-draw the Feynman diagrams for  $\beta^+$  and  $\beta^-$  decay in terms of quarks:

