Lecture 21 — March 22, 2012

Quarks & hadrons: quantum No. & conservations in strong interaction

Quarks & quantum No.

	Charges (e)	iso spin T_3	Baryon B	Flavors S'	C	B'	T'
u	$+2/3$	$+1/2$	$+\frac{1}{3}$	0	0	0	0
d	$-1/3$	$-1/2$	$+\frac{1}{3}$	0	0	0	0
s	$-1/3$	0	$+\frac{1}{3}$	-1	0	0	0
c	$+2/3$	0	$+\frac{1}{3}$	0	$+1$	0	0
b	$-1/3$	0	$+\frac{1}{3}$	0	0	-1	0
t	$+2/3$	0	$+\frac{1}{3}$	0	0	0	$+1$

All the quarks have spin-½, and have 3-colors (red, green and blue). All the anti-quarks ~~have~~ are anti-particles of quarks.

A baryon consists of 3 quarks with a total charge ±1 or 0.

and a meson consists of one quark and one anti quark.

Start with mesons

$|u\bar{d}\rangle$, charge $+1$, $B=0$, $T_3 = 1$,

What about spin? $S=0$ or 1.

What about orbital angular momentum L?

What about the total angular momentum $\vec{J} = \vec{L} + \vec{S}$

What about the parity? $P = (-1)^{L+1}$.

The ground state of $|u\bar{d}\rangle$ has $S=0$, $L=0$, hence $J=0$, $P=-1$.

that is π^+.

We can construct $\pi^- = |\bar{u}\, d\rangle$, $Q = $ charge $= -1$, $T_3 = -1$

Question, $S=1$ state of $|u\bar{d}\rangle$? that is ρ^+.

Question $T=1$, $T_3=0$, $S=0$ meson?

$$\frac{1}{\sqrt{2}}\left(|u\bar{u} - d\bar{d}\rangle\right)$$

We now discuss Kaons.

$|u\bar{s}\rangle$, $Q=1$, $B=0$, $T_3 = +\frac{1}{2}$, $S' = +1$

Consider spin $S=0$, $L=0$.

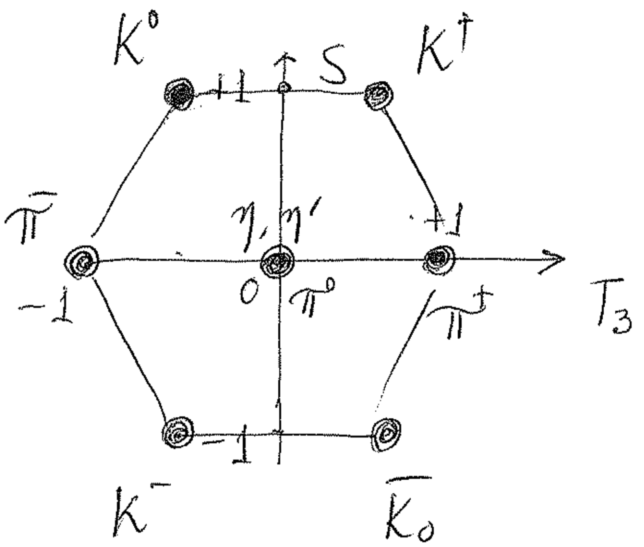
that is K^+

The high spin state of $|u\bar{s}\rangle$ with $S=1$ is

called K^{*+}

parity of baryon. $P = (-1)^L$. L = orbital angular momentum.

proton, $S=\frac{1}{2}$, $L=0$, $J=\frac{1}{2}$, $P=+$



Gell-Mann-Nishijima formula for hadron

$$Q = T_3 + \frac{B + \Sigma(\text{flavor})}{2}$$

Check for quarks

u-quark $Q = \frac{2}{3}$, $T_3 = \frac{1}{2}$, $B = \frac{1}{3}$, $\Sigma = 0$.
the formula is satisfied.

d-quark $Q = -\frac{1}{3}$, $T_3 = -\frac{1}{2}$, $B = \frac{1}{3}$, $\Sigma = 0$ OK.

s-quark, $Q = -\frac{1}{3}$, $T_3 = 0$, $B = \frac{1}{3}$, $\Sigma = -1$, OK

...

Now we consider 3 quark states, or baryons.

$|uud\rangle$, total spin can be $S=\frac{1}{2}$ or $\frac{3}{2}$.

total isospin $T=\frac{1}{2}$, $T_3=+\frac{1}{2}$, $Q=+1$

The $S=\frac{1}{2}$ state is proton.

the $S=\frac{3}{2}$ states is Δ^+.

$|udd\rangle$, the total spin $S=\frac{1}{2}$ states is neutron n.

$Q=0$, $T_3=-\frac{1}{2}$

$|uuu\rangle$? $Q=+2$, Δ^{++}

how 3 identical fermions with the same flavors together? Since u has spin $\frac{1}{2}$ with $S_z=\pm\frac{1}{2}$.

Resolution: 3 colors.

$$\Psi = \psi_{space} \cdot \psi_{spin} \cdot \psi_{flavor} \cdot \psi_{color}$$

ψ_{color}: antisymmetric for exchange of any 2 out of 3 quarks in a baryon. Any baryon is colorless.