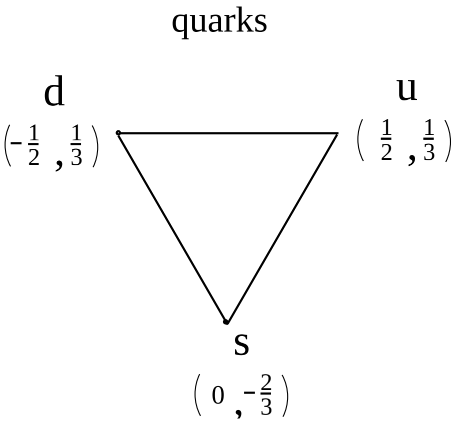
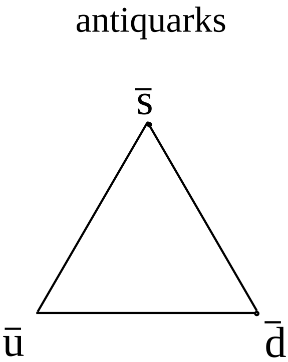
from the previous lectures ...

Physical	Unphysical
$3 \times \bar{3} = 8 + 1$	$3 \times 3 = 6 + \bar{3}$
$3 \times 3 \times 3 = 10 + 8 + 8 + 1$	
$\bar{3} \times \bar{3} \times \bar{3} = \overline{10} + 8 + 8 + 1$	

Questions: Is there a physical meaning to the 3, $\bar{3}$?

Gellmann & Zweig: baryons & mesons are made of quarks.



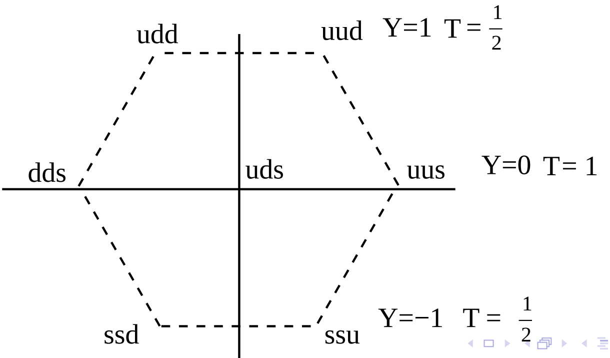


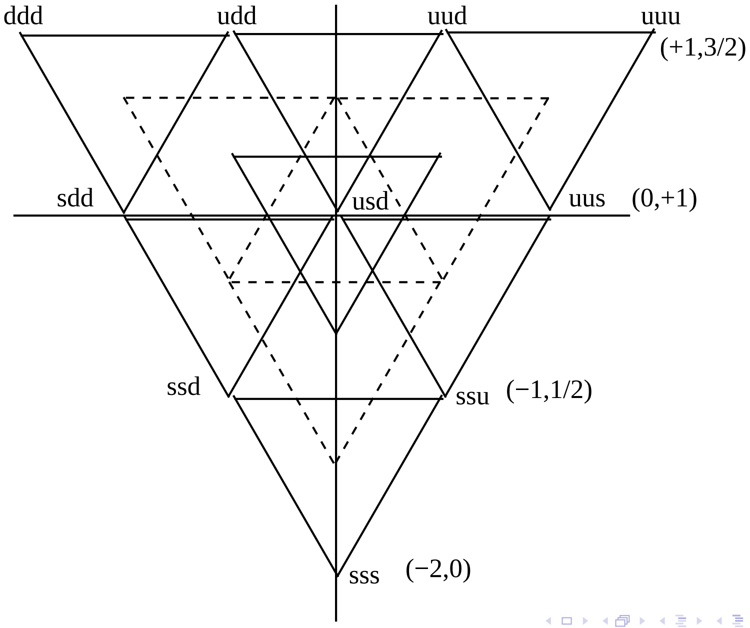
$$
\begin{aligned}
Q(\text{ up }) &= \tfrac{2}{3} & \qquad Q(\text{ antiup }) &= -\tfrac{2}{3}\\
Q(\text{down}) &= -\tfrac{1}{3} & \qquad Q(\text{antidown}) &= \tfrac{1}{3}\\
Q(\text{strange}) &= -\tfrac{1}{3} & \qquad Q(\text{antistrange}) &= \tfrac{1}{3}
\end{aligned}
$$

We can now see how the proton & neutron and all the other slew of hadron resonances fit in the quark model.

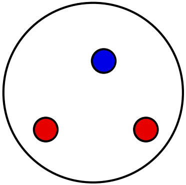
$3 \times 3 \times 3 = (6 + \bar{3}) \times 3 = 6 \times 3 + \bar{3} \times 3 = 10 + 8 + 8 + 1$

baryons

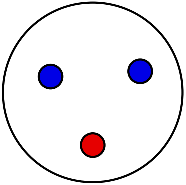



ddd
udd
uud
uuu
(+1,3/2)
sdd
usd
uus
(0,+1)
ssd
ssu
(−1,1/2)
sss
(−2,0)

The 10 is the symmetric representation $\mathrm{uuu} \quad \rightarrow \quad \mathrm{spin} = \frac{3}{2}$

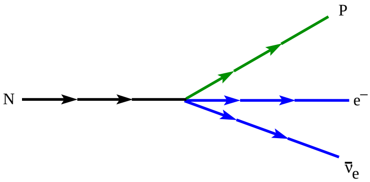


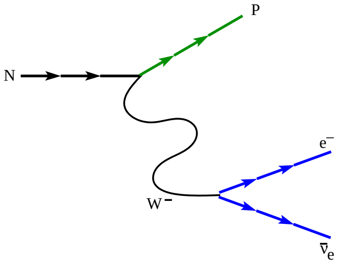
P = uud

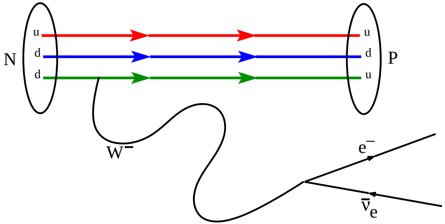


N = udd

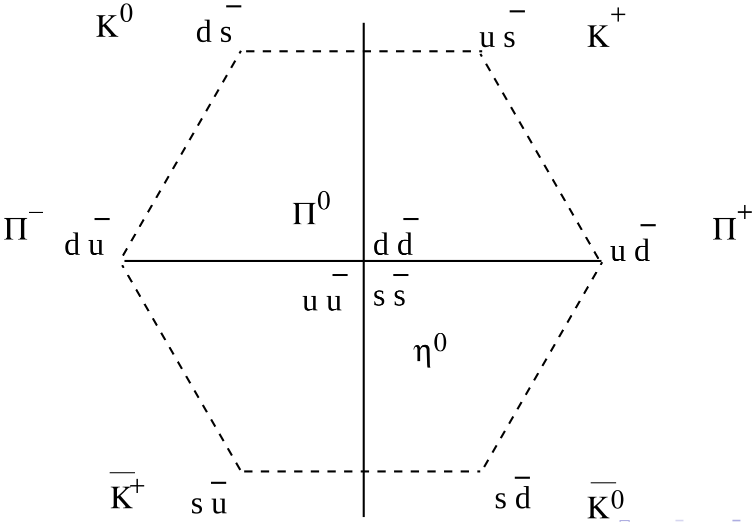
β–beta decay from the quark point of view







mesons $3 \times \bar{3} = 8 + 1$



$$\begin{aligned}
\pi^0 &= \frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d}) \\
\eta &= \frac{1}{\sqrt{6}}(u\bar{u} + d\bar{d} - 2s\bar{s}) \\
\eta' &= \frac{1}{\sqrt{3}}(u\bar{u} + d\bar{d} + s\bar{s})
\end{aligned}$$

where $\pi^0,\ \eta\ \in 8$ and $\eta' \in 1$.

The decaplet is a fully symmetric representation of $SU(3)$ and spin.

$$\begin{aligned}
\Delta^{++} &= u^\uparrow u^\uparrow u^\uparrow \qquad \leftarrow : \ \frac{1}{\sqrt{2}}(\lambda_1 - i\lambda_2) \\
\Delta^{+} &= \frac{1}{\sqrt{3}}(u^\uparrow u^\uparrow d^\uparrow + u^\uparrow d^\uparrow u^\uparrow + d^\uparrow u^\uparrow u^\uparrow) \\
\Delta^{0} &= \frac{1}{\sqrt{3}}(u^\uparrow d^\uparrow d^\uparrow + d^\uparrow u^\uparrow d^\uparrow + d^\uparrow d^\uparrow u^\uparrow) \\
\Delta^{-} &= d^\uparrow d^\uparrow d^\uparrow
\end{aligned}$$

to go down the aile we operate with a lowering operator $\swarrow = \frac{1}{\sqrt{2}}(\lambda_4 - i\lambda_5)$, etc.

$$
\begin{aligned}
y^{*+} &= \frac{1}{\sqrt{3}}(u^\uparrow u^\uparrow s^\uparrow + u^\uparrow s^\uparrow u^\uparrow + s^\uparrow u^\uparrow u^\uparrow) \\
Y^{*0} &= \frac{1}{\sqrt{6}}(u^\uparrow d^\uparrow s^\uparrow + u^\uparrow s^\uparrow d^\uparrow + d^\uparrow u^\uparrow s^\uparrow + d^\uparrow s^\uparrow u^\uparrow + s^\uparrow u^\uparrow d^\uparrow + s^\uparrow d^\uparrow u^\uparrow) \\
\Omega^- &= s^\uparrow s^\uparrow s^\uparrow
\end{aligned}
$$

What is the wave function of the Proton?

The Proton is orthogonal to Δ^+. Both are combinations of uud.

$$\mathrm{P} = (\alpha uud + \beta udu + \gamma duu)$$

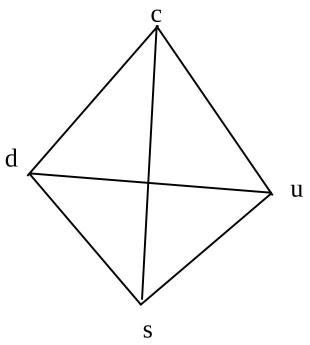
$$\mathrm{P} \cdot \Delta^+ = 0 \ \Rightarrow \quad \alpha + \beta + \gamma = 0 \Rightarrow \quad 2 \text{ solutions}$$

$$
\begin{aligned}
\mathrm{P_A} &= \frac{1}{\sqrt{2}}(ud - du)u && \text{asymmetric under } 1 \leftrightarrow 2 \\
\mathrm{P_S} &= \frac{1}{\sqrt{6}}[(ud + du)u - uud] && \text{symmetric under } 1 \leftrightarrow 2
\end{aligned}
$$

Nice ... But ...

<u>Problems</u>:

1) $\Delta^{++} = u^{\uparrow}u^{\uparrow}u^{\uparrow}$ fully symmetric $\rightarrow$ conflict with Pauli's spin–statistics
2) charm was discovered $su(3)_{\mathrm{flavour}}$ $\rightarrow$ not enough. $SU(4)_f$ $\quad 4 \; =$



In 1974 J/Ψ particle was discovered with $m \sim 3.1\mathrm{GeV}$. spin $= 0$. $c\bar{c}$.
bottom was discovered in 1978 $m(B - \mathrm{meson}) \approx 10\mathrm{GeV}$. Spin $= 0$. $b\bar{b}$.
top was discovered in 1994 $m_t \sim 175\mathrm{GeV}$.