# Particle Physics 2 : Exercise 6

**1) Kaon decays**

Draw the lowest-order Feynman diagrams for the decays

$$K^0 \to \pi^+\pi^-, \quad K^0 \to \pi^0\pi^0, \quad \bar{K}^0 \to \pi^+\pi^-, \quad \text{and} \quad \bar{K}^0 \to \pi^0\pi^0$$

and state how the corresponding matrix elements depend on the Cabibbo angle $\theta_C$.

**2) $B^0$ decays**

Draw the lowest-order Feynman diagrams for the decays

$$B^0(d\bar{b}) \to D^-(d\bar{c})\,\pi^+(u\bar{d}), \quad B^0(d\bar{b}) \to \pi^+(u\bar{d})\,\pi^-(d\bar{u}) \quad \text{and} \quad B^0(d\bar{b}) \to J/\psi(c\bar{c})\,K^0(d\bar{s}),$$

and place them in order of decreasing decay rate.

**3) $D^0$ decays**

Draw the lowest-order Feynman diagrams for the decays

$$D^0(c\bar{u}) \to K^-(s\bar{u})\,\pi^+(u\bar{d}) \quad \text{and} \quad D^0(c\bar{u}) \to K^+(u\bar{s})\,\pi^-(d\bar{u})$$

and explain the observation that

$$\frac{\Gamma(D^0 \to K^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} \approx 3 \times 10^{-3}.$$

**4) T meson**

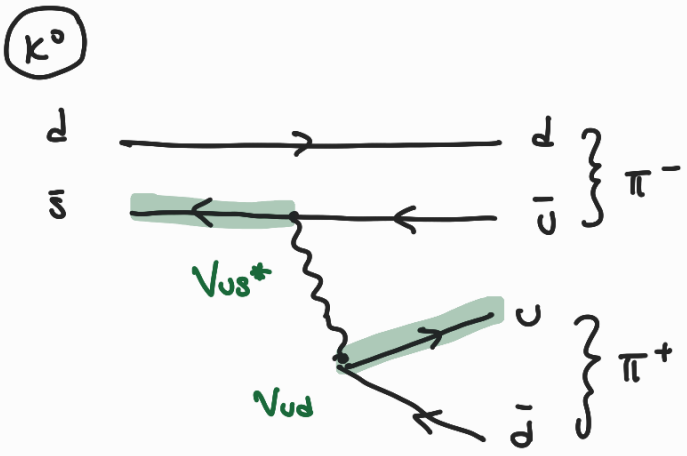
A hypothetical $\bar{T}^0(t\bar{u})$ meson decays by the weak charged-current decay chain,

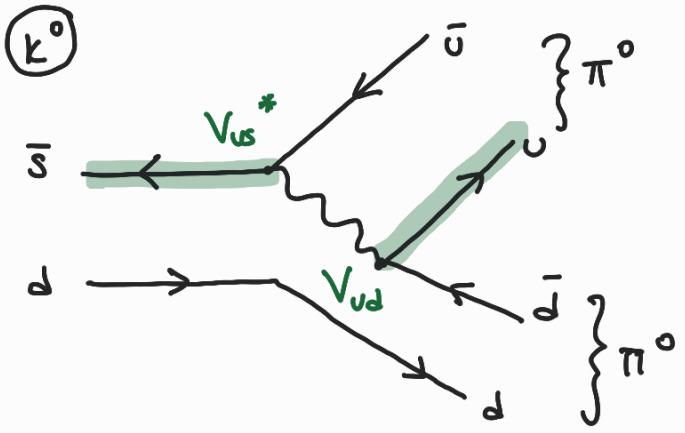
$$\bar{T}^0 \to W\pi \to (X\pi)\pi \to (Y\pi)\pi\pi \to (Z\pi)\pi\pi\pi.$$

Suggest the most likely identification of the $W, X, Y$ and $Z$ mesons and state why this decay chain would be preferred over the direct decay $\bar{T}^0 \to Z\pi$.



Updated: 29 mars 2023

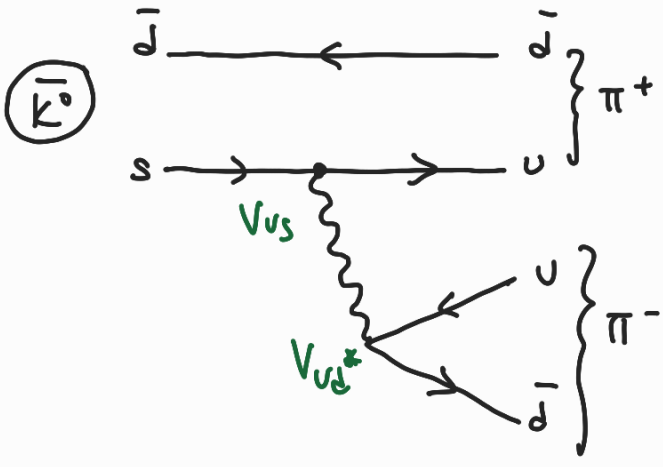


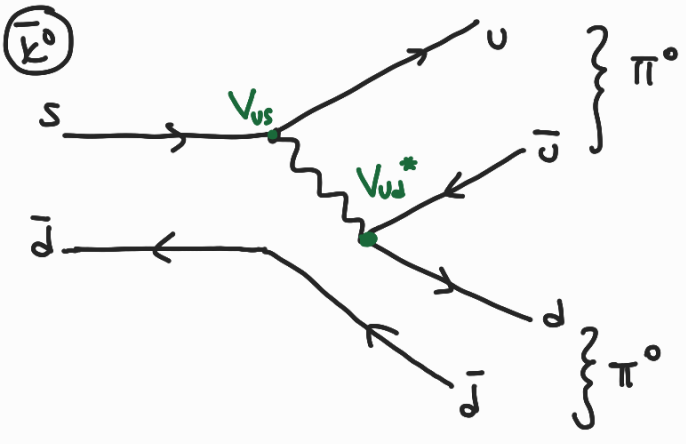




In two flavour approximation, $M \propto |V_{us}||V_{ud}| \approx \sin\theta_c \cos\theta_c$

$$\begin{pmatrix} d' \\ s' \end{pmatrix} = \begin{pmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{pmatrix} \begin{pmatrix} d \\ s \end{pmatrix}$$

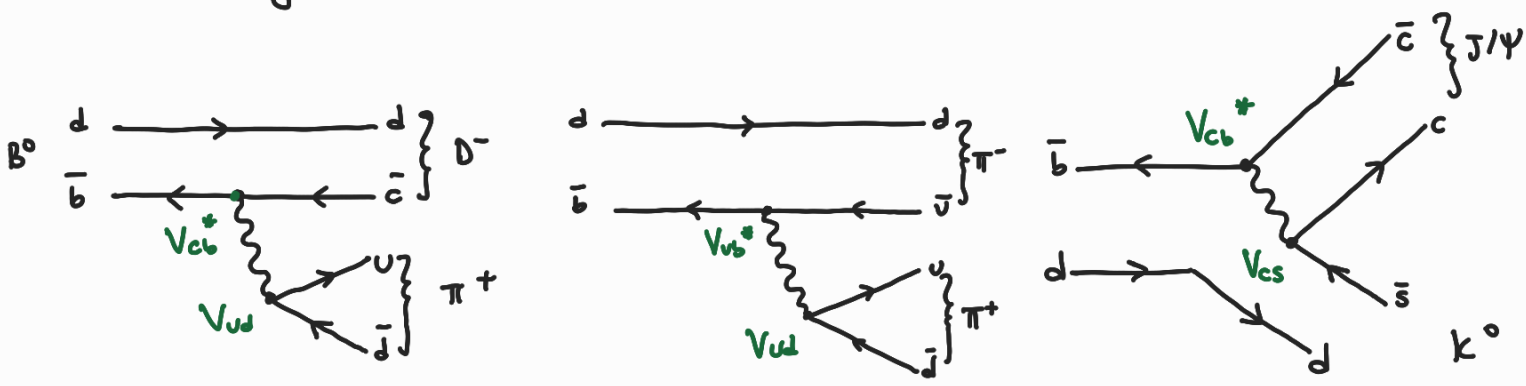
($V_{ud}$, $V_{us}$ above the matrix; $V_{cd}$, $V_{cs}$ below)




$$M \propto |V_{us}||V_{ud}| \approx \sin\theta_c \cos\theta_c$$

## 2) $B^0$ Decays

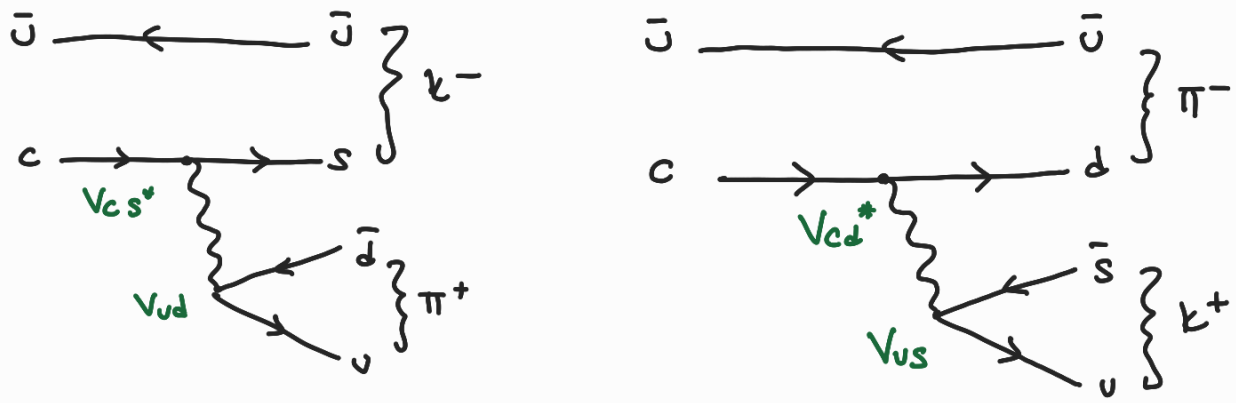



$$\underset{Br}{\mathcal{M}(B^0 \to D^- \pi^+)} : \underset{Br}{\mathcal{M}(B^0 \to \pi^+\pi^-)} : \underset{Br}{\mathcal{M}(B^0 \to J/\psi K^0)}$$

$$|V_{cb}|^2 |V_{ud}|^2 : |V_{ub}|^2 |V_{ud}|^2 : |V_{cb}|^2 |V_{cs}|^2$$

$$1.1 \times 10^{-3} : 1.5 \times 10^{-5} : 1.6 \times 10^{-3}$$

## 3) $D^0$ decays




$$\frac{\Gamma(D^0 \to K^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} \approx \frac{|V_{cd}|^2 |V_{us}|^2}{|V_{ud}|^2 |V_{cs}|^2} = \frac{0.225^2 \cdot 0.225^2}{0.974^2 \cdot 0.973^2} = 3 \times 10^{-3}$$

4) T Meson

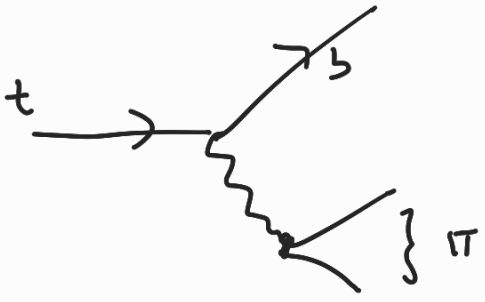
$t \to b \to c \to s \to u$

$T^0 = t\bar{u} \to W\pi \to (X\pi)\pi \to (Y\pi)\pi\pi \to (Z\pi)\pi\pi\pi$

In each case quark paired with the $\bar{u}$ decays according to the LARGEST CKM element

Thus

$W = B^-(b\bar{u})$, $X = \bar{D}^0(c\bar{u})$, $Y = K^-(s\bar{u})$, $Z = \pi^0(u\bar{u})$




HOW CAN WE KNOW

For the direct decay → $\pi^0\pi^0$ would involve $t \to d$ with CKM element $|V_{td}|^2 \sim 10^{-4}$ (too small)

$t\bar{u} \to u\bar{u}$

$\bar{u} \to \bar{u}$