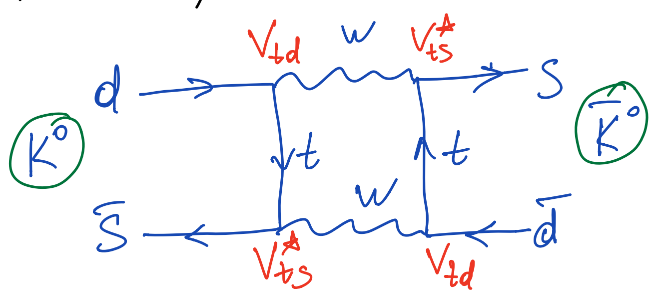
Why in K oscillations top quark does not matter and in B systems it plays a dominant role?

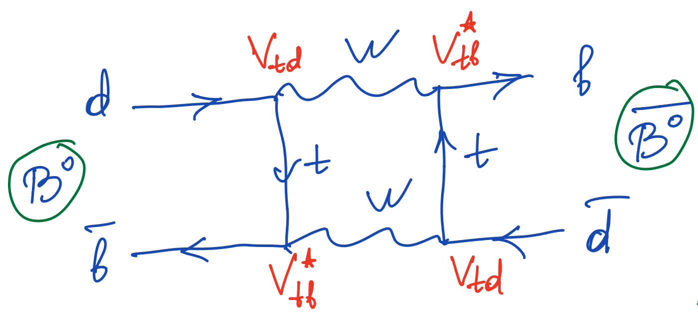
$$V_{CKM}: \quad \begin{array}{c|ccc} & d & s & b \\ \hline u & & & \\ c & & & \\ t & & & \end{array} \qquad \begin{array}{c} u \\ c \\ t \end{array} \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

$\lambda \approx 0.23$; $A \approx 0.8$; $\rho \approx 0.13$; $\eta \approx 0.35$



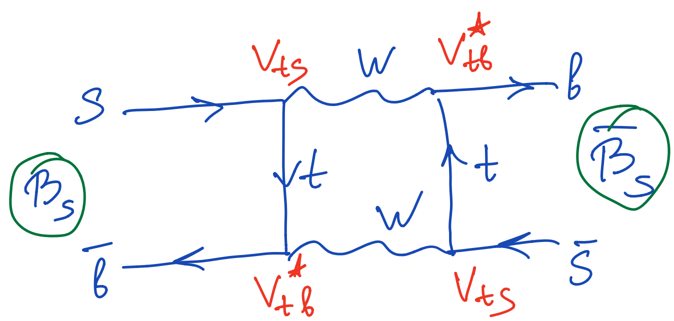
$V_{td}\, V_{ts}^* \sim A^2\lambda^5 \leftarrow$ can neglect

$\left.\begin{array}{l} V_{cd}\, V_{cs}^* \sim \lambda \\ V_{ud}\, V_{us}^* \sim \lambda \end{array}\right\}$ define oscillations



$\left.\begin{array}{l} V_{td}\, V_{tb}^* \sim A\lambda^3 \\ V_{cd}\, V_{cb}^* \sim A\lambda^3 \\ V_{ud}\, V_{ub}^* \sim A\lambda^3 \end{array}\right\}$ same order

full expression: $\sim |V_{td} V_{tb}^*|^2 m_t^2$ dominates



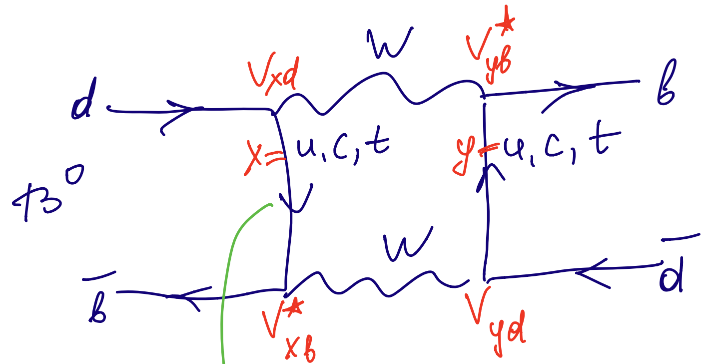
$V_{ts}\, V_{tb}^* \sim A\lambda^2 \longrightarrow$ dominates

$V_{cs}\, V_{cb}^* \sim A\lambda^2$

$V_{us}\, V_{ub}^* \sim A\lambda^4$

In b-system top quark defines oscillation parameters!

Why in the last expression we have squared top quark mass?



$$\mathcal{M}(x, y) \sim G_F^2 \frac{V_{xd} V_{xb}^* V_{yd} V_{yb}^*}{(k^2 - m_x^2)(k^2 - m_y^2)}$$

below show why:

(for one line only)

① $$(1-\gamma^5)\left[\underbrace{\frac{V_{ud} V_{ub}^*}{\hat k - m_u}}_{\text{fermion propagator}} + \frac{V_{cd} V_{cb}^*}{\hat k - m_c} + \frac{V_{td} V_{tb}^*}{\hat k - m_t}\right](1+\gamma_5)$$

$\hat k = \gamma^\mu k_\mu$ $(= \not{k})$

② using $(1-\gamma^5)(1+\gamma^5) = 0$, get (multiply each by $\frac{\hat k - m_x^{\nearrow 0}}{\hat k + m_x}$)

$$2\hat k (1+\gamma^5)\left[\frac{V_{ud} V_{ub}^*}{k^2 - m_u^2} + \frac{V_{cd} V_{cb}^*}{k^2 - m_c^2} + \frac{V_{td} V_{tb}^*}{k^2 - m_t^2}\right]$$

③ using V unitarity, i.e. $V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0$:

$$2\hat k (1+\gamma^5)\left[V_{cd} V_{cb}^* \left(\frac{1}{k^2 - m_c^2} - \frac{1}{k^2 - m_u^2}\right) + V_{td} V_{tb}^* \left(\frac{1}{k^2 - m_t^2} - \frac{1}{k^2 - m_u^2}\right)\right]$$

(we subtracted $\frac{0}{k^2 - m_u^2}$)

$$\approx 2\hat k (1+\gamma^5)\left[V_{cd} V_{cb}^* \cdot \frac{m_c^2}{k^2(k^2 - m_c^2)} + V_{td} V_{tb}^* \cdot \frac{m_t^2}{k^2(k^2 - m_t^2)}\right]$$

④ then need to multiply it by the same expression for the second fermion line in the box

$\Rightarrow$ get $V_{xd} V_{xb}^* V_{yd} V_{yb}^* m_y^2 m_x^2$

⑤ and take integral over k:

$$\frac{1}{i}\int \frac{k_\mu k_\nu \, d^4k}{k^4 (k^2 - m_t^2)^2 (2\pi)^4} = -\frac{g_{\mu\nu}}{64\pi^2 m_t^2}$$ ← removes m^2

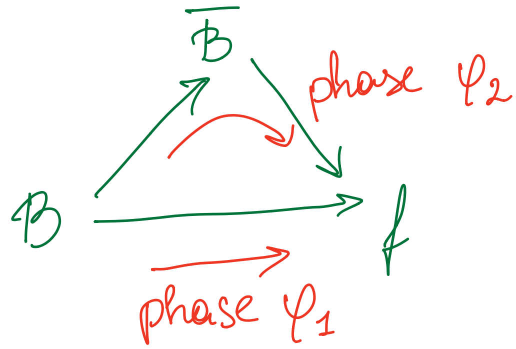
⑥ we had $m_t^2 \cdot m_t^2$ in the numerator, so in total:

$$\sim (m_t^2)^2 \cdot \frac{1}{m_t^2} = m_t^2$$

⑦ this is true for each quark contribution

Bottom line: amplitude is proportional to m_q^2 and to the product of CKM matrix elements

Why we need interference in B system to observe CP-violation?



Interference between two amplitudes gives access to measure phase difference $\Delta\varphi$

This phase is non-0 due to CP-violating effects (decays of particles and anti-particles differ)