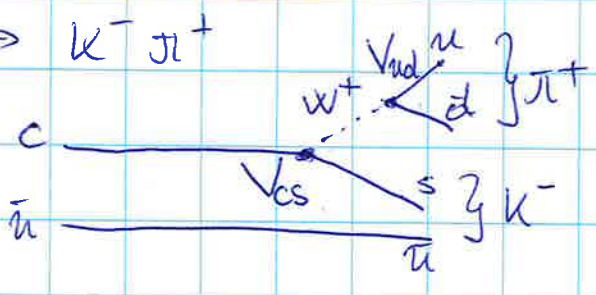
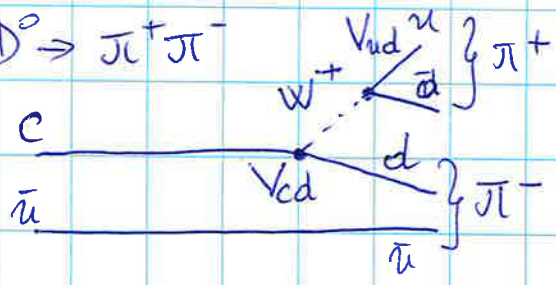
18.5. ŠIBKI RAZPADI MEZONOV – NADALJEVANJE

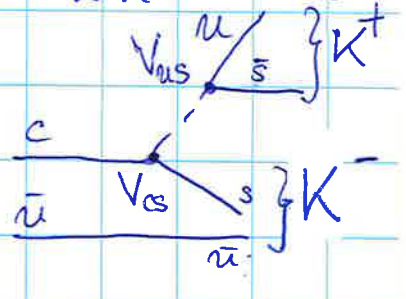
$D^0 \to K^- \pi^+$



$D^0 \to \pi^+ \pi^-$



$D^0 \to K^+ K^-$



$V_{cs}, V_{ud}, V_{cd}, V_{cs}$: ELEMENTI NEKE 3×3 MATRIKE: MATRIKA CABIBBA; KOBAYASHIJA IN MASKAWE, MATRIKA CKM – KOMPLEKSNA MATRIKA

$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} \quad \text{PO VELIKOSTI} \quad \begin{bmatrix} |V_{ud}| & |V_{us}| & |V_{ub}| \\ |V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}| & |V_{ts}| & |V_{tb}| \end{bmatrix} = \begin{bmatrix} \square & \square & \cdot \\ \square & \square & \square \\ \cdot & \square & \square \end{bmatrix}$$

$$\Gamma(D^0 \to K^- \pi^+) \propto |V_{cs}|^2 |V_{ud}|^2 \qquad \Gamma(D^0 \to \pi^- \pi^+) \propto |V_{cd}|^2 |V_{ud}|^2 \qquad \Gamma(D^0 \to K^- K^+) \propto |V_{cs}|^2 |V_{us}|^2$$

$$\Gamma(D^0 \to \pi^- \pi^+) / \Gamma(D^0 \to K^- \pi^+) = |V_{cd}|^2 / |V_{cs}|^2$$

$V_{ud} \sim V_{cs} \sim V_{tb} \sim 1 \qquad |V_{us}| = |V_{cd}| = 0.22$

$$\begin{bmatrix} 1-\lambda^2 & \lambda & A\lambda^3(\rho+i\eta) \\ -\lambda & 1-\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & A\lambda^2 & 1 \end{bmatrix}$$

VOLFENSTEINOVA PARAMETRIZACIJA MATRIKE CKM

$A = 0.836, \rho = 0.122, \eta = 0.355 \qquad \lambda = 0.22 = \sin\Theta_c$ CABIBBOV KOT

MATRIKA 3x3 CKM JE UNITARNA. $U^+U = I$

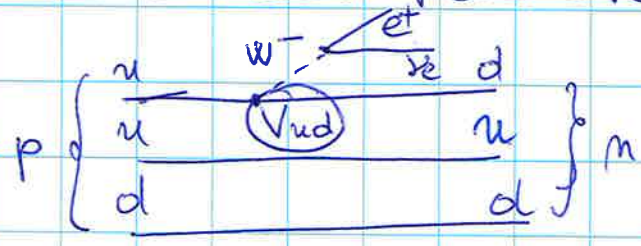
⇒ SKALARNI PRODUKT STOLPCEV MED SABO JE 1 ALI 0

$V_{ud}V_{ud}^* + V_{cd}V_{cd}^* + V_{td}V_{td}^* = 1$ (VRTIC) $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

$|V_{cd}|^2 + |V_{cs}|^2 + |V_{cb}|^2 = 1$

KAKO DO VREDNOSTI ELEMENTOV MATRICNIH CKM: PREKO MERITEV

V_{ud}

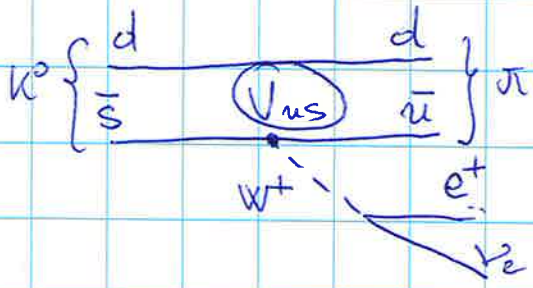


BETA RAZPADI: SUPERDOVOLJENI $0^+ \to 0^+$

$\frac{1}{\tau} = \frac{\Gamma}{\hbar} \propto |V_{ud}|^2$

V_{us} RAZPAD $K^0 \to \pi^- e^+ \nu_e$

(SEMILEPTONSKI)

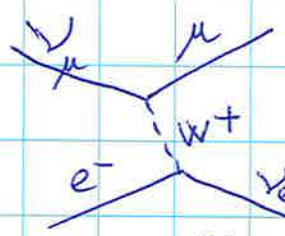


$\Gamma_{K^0 \to \pi e \nu} \propto |V_{us}|^2$

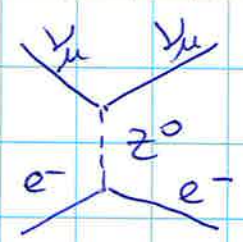
V_{cd} RAZPAD $D^0 \to \pi^- e^+ \nu_e$

$\Gamma_{D^0 \to \pi e \nu} \propto |V_{cd}|^2$

NEVTRALNI ŠIBKI TOK



NABITI ŠIBKI TOK



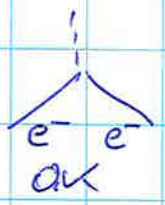
NEVTRALNI ŠIBKI TOK

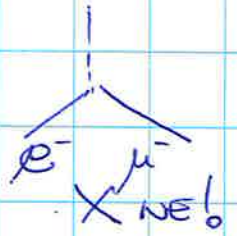
V INVARIANTNI AMPLITUDI NASTOPA

$$J_\mu^{NC} = \bar{u}_e \gamma_\mu (C_V - C_A \gamma^5) u$$

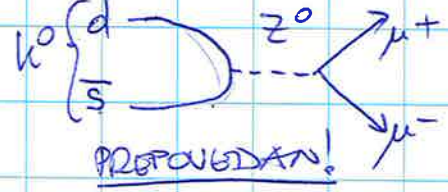
[ZA NABITI TOK $C_V = 1$, $C_A = 1$]

NEVTRALNI ŠIBKI TOK NE SPREMINJA OKUSA DELCEV





$K^0 \to \mu^+ \mu^-$

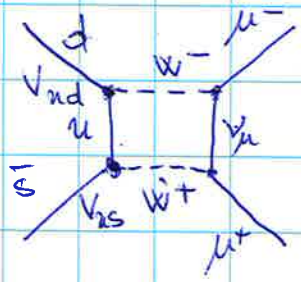


PREPOVEDAN!

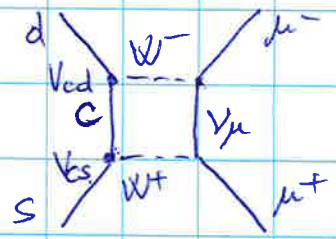
EKSPERIMENT
TA RAZPAD ZELO MALO VERJETEN
(ZELO REDEK)

TA RAZPAD PA NI NUJNO ČE:

ŠKATLAST DIAGRAM



$\mathcal{M}_1$



$\mathcal{M}_2$

$$\Gamma(K^0 \to \mu^+ \mu^-) \propto |\mathcal{M}_1 + \mathcal{M}_2|^2 \sim 0$$

(KER NE MOREM VZETI OBEH DIAGRAMOV)

$$\mathcal{M}_1 \propto V_{ud} V_{us} \sim 1 \cdot \lambda \qquad \mathcal{M}_2 \propto V_{cd} V_{cs} \sim 1 \cdot (-\lambda)$$

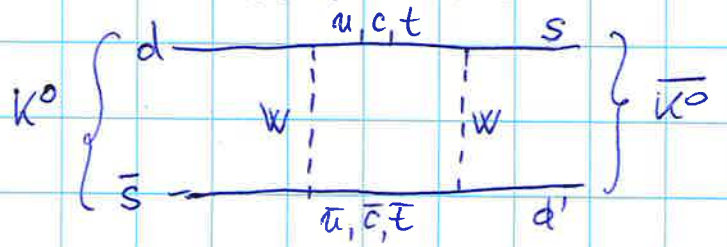
KER $m_c \gg m_u$ SLEDI $\mathcal{M}_1 \neq -\mathcal{M}_2 \Rightarrow \Gamma(K^0 \to \mu^+ \mu^-) \neq 0$

MEHANIZEM GIM GLASHOW, ILIOPOULOS, MAIANI

MEŠANJE PRI NEVTRALNIH MEZONIH : DELEC ⇔ ANTIDELEC

K^0, D^0, B^0, B_s^0 — so-ta — BELLE, BABAR 2007 — ARGUS 1987 — CDF 2005

$K^0 \leftrightarrow \bar{K}^0$, $D^0 \leftrightarrow \bar{D}^0$, $B^0 \leftrightarrow \bar{B}^0$, $B_s \leftrightarrow \bar{B}_s$



KER JE MOŽEN PREHOD $K^0 \leftrightarrow \bar{K}^0$, K^0 in $\bar{K}^0$ NISTA LASTNI FUNKCIJI ČASOVNEGA HAMILTONIANA

$$\Rightarrow \psi_{K^0} \neq A \cdot e^{-iE_k t} \cdot e^{-t/\tau}$$

SPLOŠNO STANJE: $\psi = a_1 |K^0\rangle + a_2 |\bar{K}^0\rangle$

IZKAŽE SE, DA STA LASTNI STANJI

$$|K_1\rangle = \frac{1}{\sqrt{2}}(|K^0\rangle + |\bar{K}^0\rangle) \quad m_1, \tau_1$$

$$|K_2\rangle = \frac{1}{\sqrt{2}}(|K^0\rangle - |\bar{K}^0\rangle) \quad m_2, \tau_2$$

$CP|K_1\rangle = \frac{1}{\sqrt{2}}(|\bar{K}^0\rangle + |K^0\rangle) = |K_1\rangle$

$CP|K_2\rangle = \frac{1}{\sqrt{2}}(|\bar{K}^0\rangle - |K^0\rangle) = -|K_2\rangle$

$CP|K^0\rangle = |\bar{K}^0\rangle$, $CP|\bar{K}^0\rangle = |K^0\rangle$

$CP = +1$

$CP = -1$

$$|K^0\rangle = \frac{1}{\sqrt{2}}(|K_1\rangle + |K_2\rangle)$$

$$|\bar{K}^0\rangle = \frac{1}{\sqrt{2}}(|K_1\rangle - |K_2\rangle)$$

$$|K^0(t)\rangle = \frac{1}{\sqrt{2}}\left(|K_1\rangle e^{-im_1 t} e^{-\frac{t}{\tau_1}} + |K_2\rangle e^{-im_2 t} e^{-\frac{t}{\tau_2}}\right) = a_1(t)|K^0\rangle + a_2(t)|\bar{K}^0\rangle$$

$K \to \pi\pi$, $\pi\pi\pi$

$CP(\pi\pi) = +1$

$CP(\pi\pi\pi) = -1$

$P(\pi\pi) = P(\pi)P(\pi) = (-1)^2 = +1$

$P(\pi\pi\pi) = (P(\pi))^3 = (-1)^3 = -1$

$C(\pi) = +1$ SE VIDI IZ $\pi^0 \to \gamma\gamma$

$CP(\pi\pi)=+1$ $CP(\pi\pi\pi)=-1$

$CP(K_1)=+1$ $CP(K_2)=-1$

$K_1 \to \pi\pi$

$K_2 \to \pi\pi\pi$

CE SE OHRANJA CP PARNOST PRI TEH RAZPADIH

RAZPADNA ČASA τ_1, τ_2 $\quad d\Gamma = \frac{|M|^2}{2M_K} dQ \leftarrow \cdots \left(\frac{d^3p}{(2\pi)^3}\right)$

NIZKE GIBALNE KOLIČINE

→ MAJHEN FAZ. PROSTOR → MAJHEN Γ, VELIK τ

$M_{K_0} \doteq 0.5$ GeV $\quad M_\pi \approx 0.14$ GeV $\quad M_{2\pi} \sim 0.28$ GeV $\quad M_{3\pi} \sim 0.42$ GeV

$\Rightarrow$ P_π ZA 2π-RAZPAD DOSTI VEČJE KOT P_π PRI 3π

$\rightarrow \quad \Gamma_{\pi\pi} \gg \Gamma_{\pi\pi\pi} \Rightarrow \tau_1 \ll \tau_2$

$$|K^0(t)\rangle = \frac{1}{\sqrt{2}}\left(|K_1\rangle \underbrace{e^{-im_1 t} e^{-t/\tau_1}}_{\text{HITREJE PROTI } 0} + |K_2\rangle e^{-im_2 t} e^{-t/\tau_2}\right)$$

ČE POČAKAMO DOVOLJ DOLGO, BODO OSTALI SAMO $|K_2\rangle$, K_1 BODO RAZPADLI NA $\pi\pi\pi$

FITCH, CRONIN IN SODELAVCI:

$|K_2\rangle$ RAZPADA TUDI V $\pi\pi$! $\Rightarrow$ CP SE NE OHRANJA $\rightarrow$ NOBELOVA NAGRADA

SAHAROV: RAZVOJ VESOLJA

ZGODNJE VESOLJE: DELCEV ENAKO KOT ANTIDELCEV

DANES: ANTIDELCEV SKORAJ NIČ

POGOJI SAHAROVA
1. DELCI SE RAZLIKUJEJO OD ANTIDELCEV
   $\equiv$ KRŠENA SIMETRIJA CP
   (PARNOST CP SE NE OHRANJA)
2. BARIONSKO ŠTEVILO SE NE OHRANJA
3. RAZVOJ VESOLJA JE SEL SKOZI FAZO DALEČ OD RAVNOVESNEGA STANJA