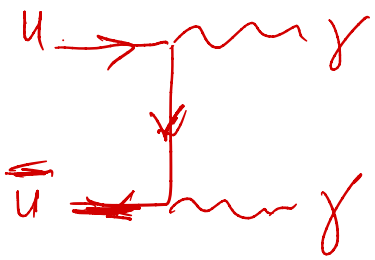
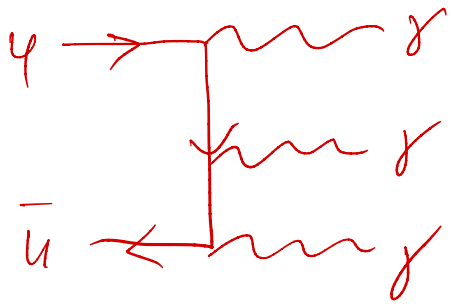
① C, P, CP – parity conservation in QED, QCD

$\pi^0 \to \gamma\gamma$: ≈100% !



$\pi^0 \to \gamma\gamma\gamma$?



?

C-parity

J^{PC}

$S=0$

$P=-1$

$C=+1$

$C(\gamma) = -1$

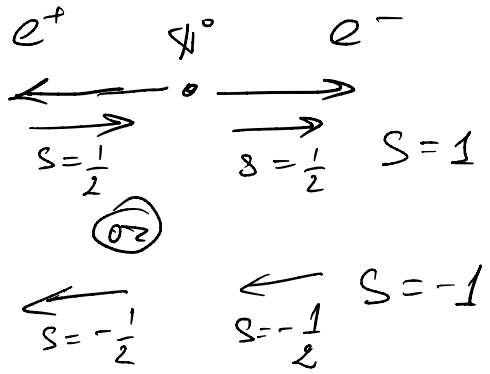
$C(\gamma\gamma) = (-1)^2 = 1$

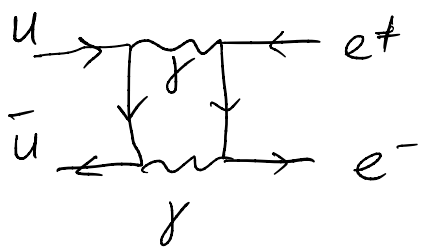
$\pi^0 \to e^+e^-$? – helicity in QED

$\pi^0 \to \gamma e^+e^-$

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

?



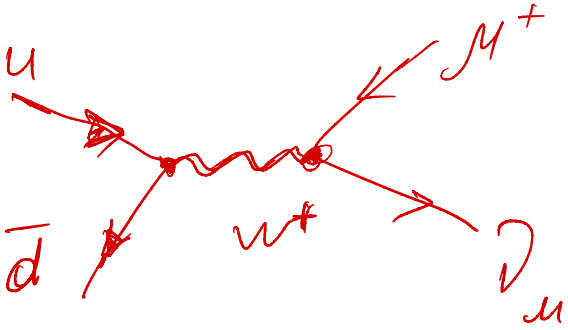


helicity-suppressed!

② weak interaction

$\pi^+ \to \mu^+ \nu_\mu$

$e^+ \nu_e$



RH: $\to$ S, $\to$ P

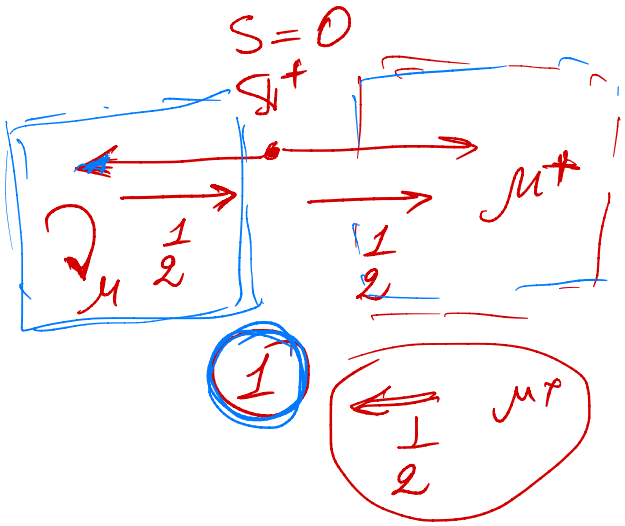
LH: $\leftarrow$ S, $\to$ P

$W^\pm$: LH particles, RH antiparticles

$\frac{B(\pi \to e\nu)}{B(\pi \to \mu\nu)} \gtrsim 10^{-4}$

$\left(\frac{0.5}{100}\right)^2 \ll 10^{-4}$

helicity $\neq$ chirality



$\sim |A|^2 \sim m_\mu^2$

① $m = 0$ $\to$ P, S

RH chiral = RH hel + $\left(\frac{m}{E+m}\right)$ LH hel

② $m \neq 0$: 1RF: $\to$ P, $\to$ S

2RF: P = 0

3RF: p' $\leftarrow$, $\to$ S

$\sim m_\mu$

$m_{\pi^+} = 139$ MeV

$m_\mu \simeq 105$ MeV ; $m_e \sim 0.511$ MeV

Lorentz transformation:

$$E' = \gamma (E - \beta p)$$

$$p' = \gamma (p - \beta E)$$

For photons (or massless particles) $E = p$:

$$E' = \gamma (E - \beta E) = \gamma E (1 - \beta)$$

$$p' = \gamma (E - \beta E) = \gamma E (1 - \beta)$$

as $\beta \leq 1$ we never can change the sign of massless particle momentum

$\Rightarrow$ helicity is Lorentz-invariant for massless particles

Exact theoretical calculation for pions:

$$R_\pi = \frac{B(\pi \to e \nu)}{B(\pi \to \mu \nu)} = \left(\frac{m_e}{m_\mu}\right)^2 \left(\frac{m_\pi^2 - m_e^2}{m_\pi^2 - m_\mu^2}\right)^2$$

↑ spin effect (helicity)

↑ phase space factor (particle masses, energy release)

K^0, $\bar{K}^0$, K_S, K_L

$\frac{1}{\sqrt{2}}(K^0 + \bar{K}^0)$:

$\frac{1}{\sqrt{2}}(K^0 - \bar{K}^0)$

$K_S \to \pi^+\pi^-$

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

$m(K) = 498$ MeV

$m(\pi^\pm) = 139$ MeV

$m(\pi^0) = 135$ MeV

$m(\pi^+\pi^-\pi^0) = 413$ MeV $\sim m(K)$

$m(\pi^+\pi^-) = 278$ MeV

(1) QED, QCD : P, C, CP $\pi^0 \to \gamma\gamma$, $\not\to \gamma\gamma\gamma$

(2) weak : W : LH P
RH $\bar{P}$
$\Rightarrow \not P, \not C, \not{CP}$ $\pi^\pm \to \mu\nu$, $e\nu$

(3) Phase space $\sim \Gamma^{-1}$ $K_S \to 2\pi$, $K_L \to 3\pi$

(4) CKM : weak inter. of quarks
GIM mech. $K^0 \to \mu^+\mu^- \Rightarrow c, m_c$

(5) $K_S, K_L \to \not{CP}$