Back to $K^0-\overline{K}^0$ CP violation

Chapter 2

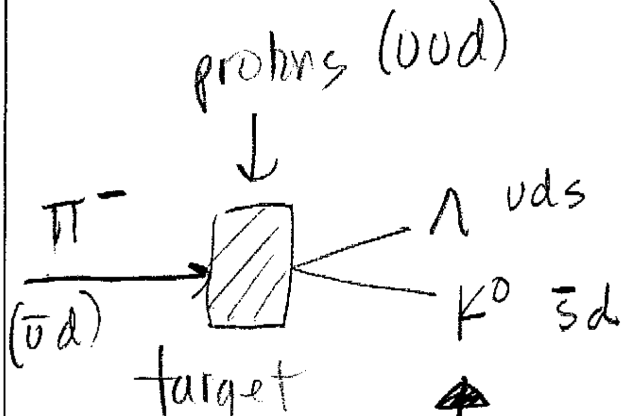
$K^0_1 \to \pi^+\pi^-$ $\quad |\vec{p}^*| = 206$ MeV/c

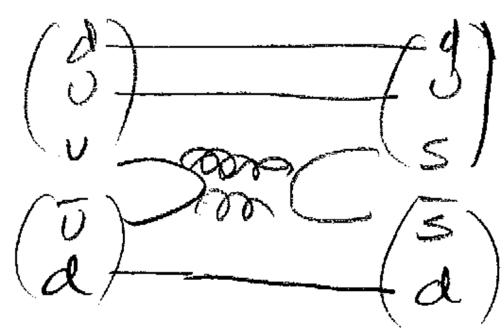
$K^0_2 \to \pi^+\pi^-\pi^0$ $\quad \underbrace{|p^*_{max}| = 133 \text{ MeV/c}}_{\text{often less (3-body)}}$

have definite lifetimes

expect $\tau_1 < \tau_2$

τ_1: $0.9\cdot10^{-10}$ s $\qquad$ τ_2: $5.1\cdot10^{-8}$ s





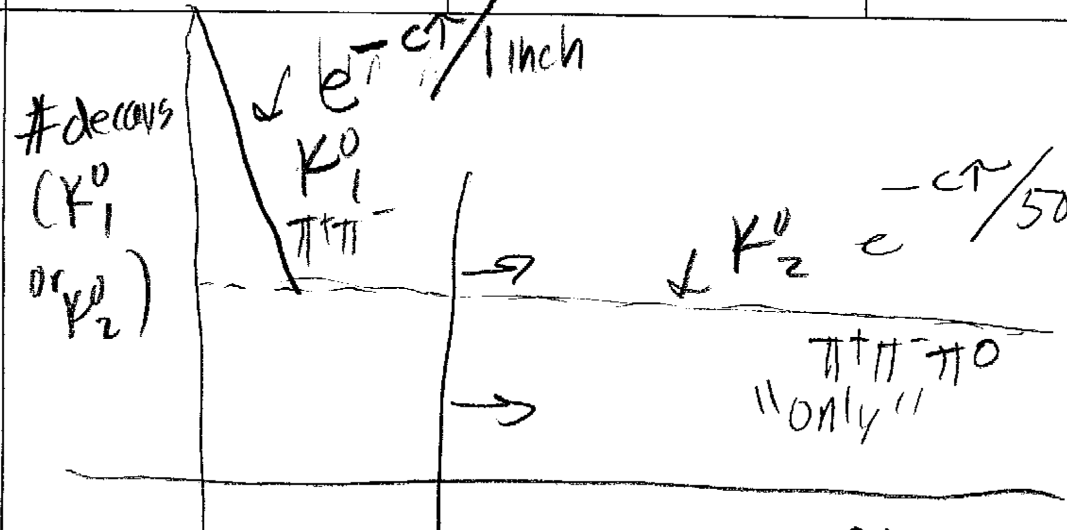
$$K^0_1 = \frac{1}{\sqrt{2}}(K^0 - \overline{K}^0)$$

$$K^0_2 = \frac{1}{\sqrt{2}}(K^0 + \overline{K}^0)$$

$$\frac{1}{\sqrt{2}}(K^0_1 + K^0_2) = K^0$$

K^0_1: lifetime $0.9\cdot10^{-10}$ s

$c\tau \cong 1$ inch $\qquad$ $c\tau \approx 51$ feet.



$c\tau$ measured

Like piano.. "prompt" tone

"persistent" tone

$\rightarrow$ look here for

$K_2^0 \rightarrow \pi^+\pi^-$

Chapter 4

Done in 1964... $K_2^0 \rightarrow \pi^+\pi^-$

(Cronin and Fitch, Nobel 1978)

Idea:

$$K^0 \rightleftarrows \overline{K^0}$$

When Rates equal

eigenstates

$|K_1^0\rangle, |K_2^0\rangle$

Turns out..

$$\begin{tikzcd} K^0 \arrow[r, bend left, "\text{smaller rate}"] & \overline{K}^0 \arrow[l, bend left, "\text{Larger Rate}"] \end{tikzcd}$$

"Matter Accumulates" d quarks.

<u>How</u>: must include <u>decay</u> aspect of Hamiltonian.

$\underset{\sim}{H}$ in K^0-$\overline{K}^0$ basis.

$$\begin{pmatrix} m_{K^0}c^2 - \frac{i}{2}\Gamma_{K^0} & \alpha F^2 - \frac{i}{4}\Delta\Gamma_{+} - i\underset{\text{top quark}}{t} \\ \alpha F^2 - \frac{i}{4}\Delta\Gamma_{+} + i\underset{\text{top quark}}{t} & m_{K^0}c^2 - \frac{i}{2}\Gamma_{K^0} \end{pmatrix}$$

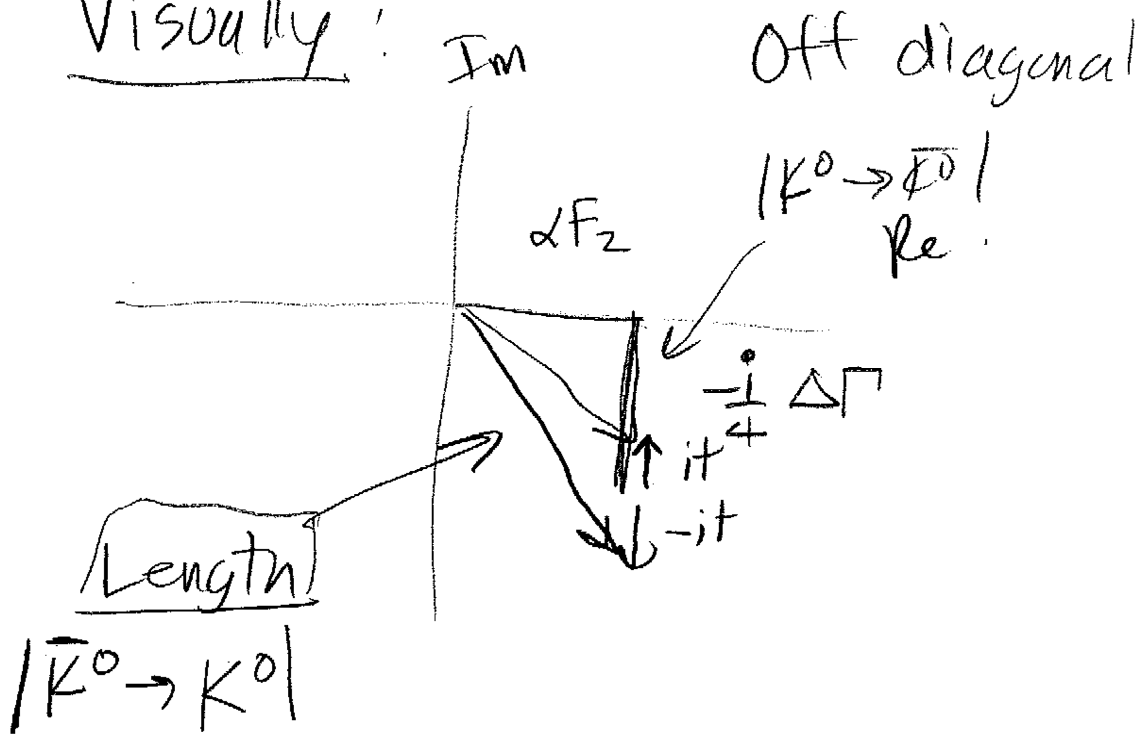
"probability $\overline{K}^0$ stays a $\overset{(-)}{K^0}$"

Lossless $K^0 \to \overline{K}^0 \to K^0$

K^0 unstable, its amplitude leaks away!

makes $\tau_1 \neq \tau_2$

Visually:



Rate of $\bar{K}^0 \to K^0$ exceeds that of $K^0 \to \bar{K}^0$

"matter accumulates"

→ GOOD FOR THE UNIVERSE

→ CONNECTION TO MATTER-DOMINATE UNIVERSE NOT YET PROVEN.

→ Basic idea supported by studies of $B^0 \to \bar{B}^0 \to B^0$
$b\bar{d}$

→ Now B^0_s, ($D^0 = c\bar{u}$) studied too!

Bound States (1 Lecture, Chap 5)

Assume you know hydrogen

Hydrogen : tiny effects

Fig 5.2

① $T \neq \frac{p^2}{2m}$

$$= \sqrt{(cp)^2 + (mc^2)^2} - (mc^2)$$

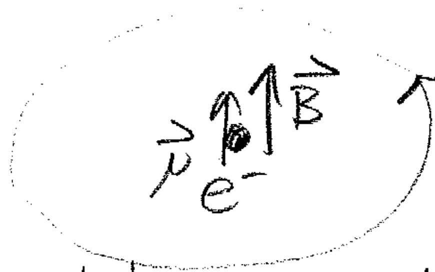
$$= mc^2\left(1 + \frac{(cp)^2}{(mc^2)^2}\right)^{1/2} - mc^2$$

$$\simeq \cancel{mc^2} + \frac{mc^2 c^2 p^2}{2(mc^2)^2} + \frac{1}{2}\left(\frac{1}{2}\right)\left(-\frac{1}{2}\right)\frac{mc^2 (c^2p^2)^2}{(mc^2)^4} \cancel{- mc^2}$$

$$= \underset{\uparrow}{\frac{p^2}{2m}} - \underset{\uparrow}{\frac{p^4}{8m^3c^4}}$$

overestimates — pushes down, independent of L, s

② $\vec{L} \cdot \vec{s}$



$\vec{J} = (\vec{L} + \vec{s})$

makes eigenstates out of $\vec{J}$ eigenstates