Weak interactions violate C

$$C|\nu_L\rangle \rightarrow |\bar{\nu}_L\rangle$$ ← not party standard model

Parity also violated

$$P|\nu_L\rangle \rightarrow |\nu_R\rangle$$

But

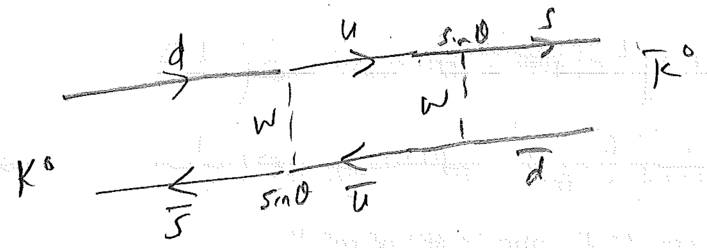
$$CP|\nu_L\rangle \rightarrow |\bar{\nu}_R\rangle$$

For 10 yrs (1951–1964) it was believed that weak interactions (as well as others) conserve CP.

$K^0 = d\bar{s}$
$\bar{K}^0 = \bar{d}s$ } are strangeness eigenstates

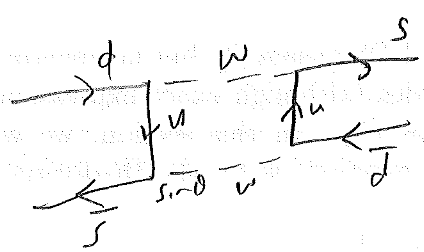
Strangeness not conserved in standard model so $K^0, \bar{K}^0$ mixing can occur

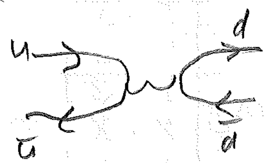
$$K^0 \underset{\Delta S = 2}{\longrightarrow} \bar{K}^0 \underset{\Delta S = -2}{\longrightarrow} K^0$$



2nd order double Cabibbo suppressed interaction

or





$\pi_0 = \frac{u\bar{u} - d\bar{d}}{\sqrt{2}}$ is an isospin eigenstate

Since $[H_{strong}, I] = 0$
energy eigenstates are isospin eigenstates

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

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

These are C eigenstates

$$C|K^0\rangle \to |\bar{K}^0\rangle$$
$$C|\bar{K}^0\rangle \to |K^0\rangle$$

also
$$C|K_1\rangle = -|K_1\rangle$$
$$C|K_2\rangle = +|K_2\rangle$$

Also
$$P|K^0\rangle = -|K^0\rangle$$
$$P|\bar{K}^0\rangle = -|\bar{K}^0\rangle$$

so
$$\begin{cases} CP|K_1\rangle = |K_1\rangle \\ CP|K_2\rangle = -|K_2\rangle \end{cases}$$

Possible decay modes of K^0:

	P	C	CP
$\rightarrow \pi^0\pi^0$	1	1	1
$\rightarrow \pi^0\pi^0\pi^0$	-1	1	-1

If CP is conserved then

$K_1 \longrightarrow \pi^0\pi^0$ but not $\pi^0\pi^0\pi^0$

$K_2 \longrightarrow \pi^0\pi^0\pi^0$ but not $\pi^0\pi^0$

Also $K_1 \rightarrow \pi^0\pi^0$ has much more phase space so decays quickly $\tau_1 \sim 1E-10s$
$c\tau = \underline{\underline{3cm}}$

$K_2 \rightarrow \pi^0\pi^0\pi^0$ $\tau_2 \sim 5E-8s$ $\sim$ $c\tau = \underline{\underline{15m}}$

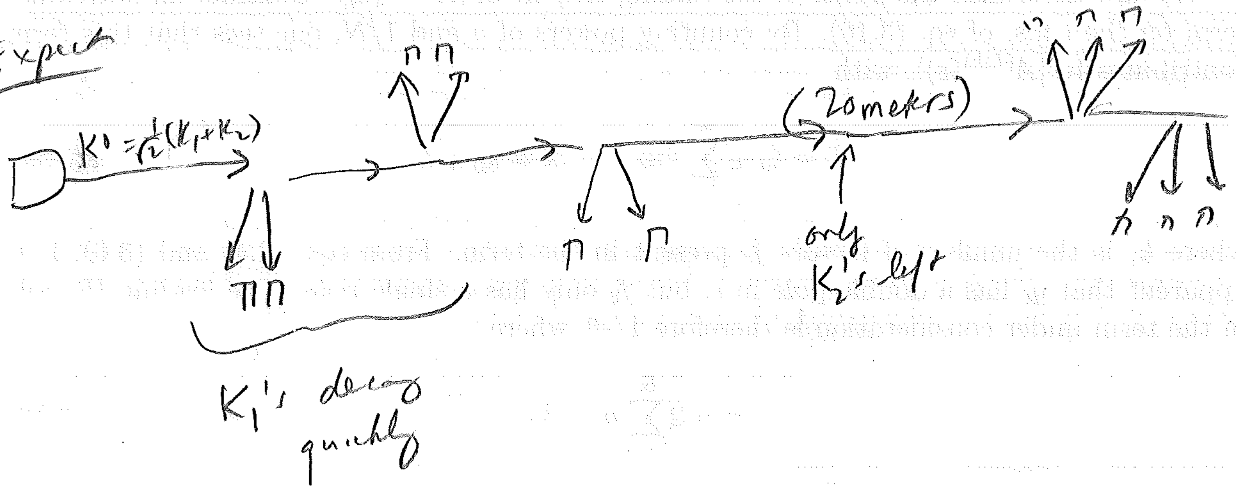
[Also $\Delta m \sim 3E-6eV$]

Consider

K^0's produced in strong interaction

$K^0 = \frac{1}{\sqrt{2}}(K_1 + K_2)$ so $\frac{1}{2}$ of each CP eigenstate

Expect



1964 Cronin + Fitch (BNL)

After 20m, still discovered $\pi\pi$ decays

CP violation

States of definite lifetimes are mass eigenstates

For K, these are called K_S w/ $\tau \sim E{-}10$ sec

K_L w/ $\tau \sim 5E{-}8$ sec

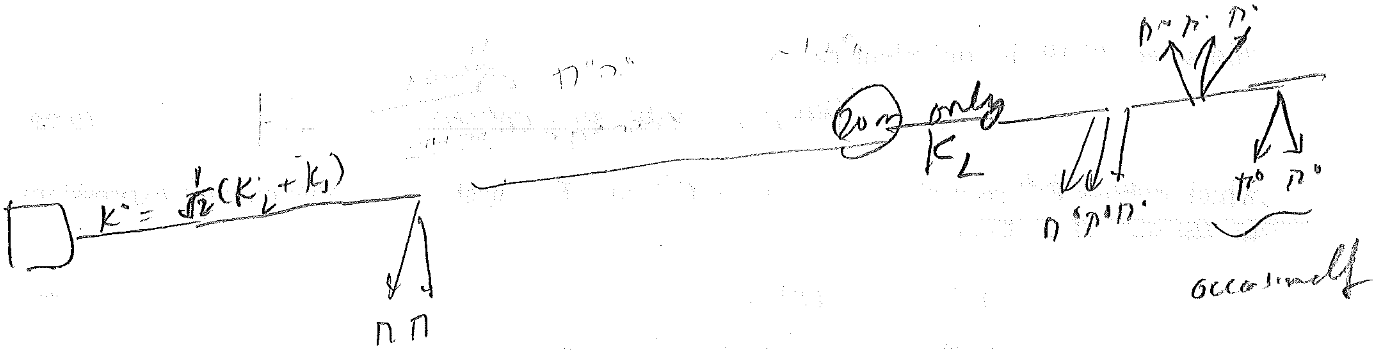
Since CP is not conserved, $[CP, H_{weak}] \neq 0$

∴ mass eigenstates & CP-eigenstates are not the same

K_S is almost K_1 $\qquad K_S \xrightarrow{\text{usually}} \pi^0\pi^0$

K_L " almost K_2 $\qquad K_L \xrightarrow{\text{usually}} \pi^0\pi^0\pi^0$ (20%)

$\qquad\qquad\qquad\qquad \xrightarrow{\text{sometimes}} \pi^0\pi^0$



CP violation apparently arises from complex phase in the CKM matrix.

Summary Conservation laws

All forces (fundamental)

energy & momentum
angular momentum
charge
CPT (qft)

Standard model

baryon #
lepton # (in each generation)

Strong + electromagnetic

flavor sym (strangeness, charm & upness)
parity
charge conjugation

Strong

isospin } broken by mass effects
$SU(3)_f$ }

G-parity

DISCRETE SYMMETRIES

85. **N8.07. N9.05.** *G-parity.* Griffiths, problem 4.36 (a). You can use the Particle Physics Booklet to check your answers, but not to arrive at them.
[Using the information in Table 4.6, determine the G parity of the following mesons: $\pi(140)$, $\rho(770)$, $\omega(783)$, $\eta(549)$, $\eta'(958)$, $\phi(1020)$, and $f(1270)$.]

86. **N8.07.** Griffiths, problem 4.37.
[The dominant decays of the η meson are $\eta \to 2\gamma$ (39%), $\eta \to 3\pi$ (56%), and $\eta \to \pi\pi\gamma$ (5%). and it's classified as a "stable" particle, so evidently none of these is a purely strong interaction. Offhand, this seems odd, since at 549 MeV, the η has plenty of mass to decay strongly into 2π or 3π.
(a) Explain why the 2π mode is forbidden, for both strong and electromagnetic interactions.
(b) Explain why the 3π mode is forbidden as strong interaction, but allowed as an electromagnetic decay.]