Why is Search for CP violation in τ decay so important?
why do we want longitudinally polarized e^-
or $e^\pm$ beam(s)?

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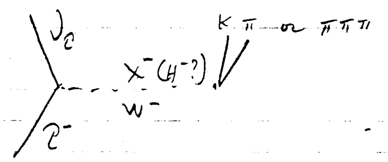
Why is Search for CP violation in τ decay so important?

1. If CP violation is found in τ decay it implies the existance of a charged spin 0 particle (charged Higgs?) interfering with W exchange mechanism.



2. If X^- exists, it implies that leptons participate fully in CP violations. CP violation is needed to have matter-antimatter asymmetry in the universe.
3. It will trigger a systematic study of X^- coupling to all other particles using semileptonic decay of hadrons

4 Neutrino oscillation and existence of $X^{\pm}$.

Solar neutrino and atomospheric neutrino experimats

$\Longrightarrow$ neutrinos have mass

$\Longrightarrow$ Origin of neutrino mass $\Rightarrow$ Charged and neutral Higgs coupled to leptons.

5 Range of m_x

a. τ decay agrees with Standard model to 2 %

$$\frac{m_W^2}{m_X^2} < 0.02 \qquad \therefore \quad m_X \gtrsim \frac{m_W}{\sqrt{0.02}} \sim .57 \text{ TeV}$$

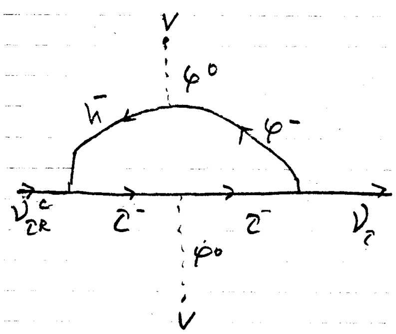
b. If CP violation in τ decay is about the same order of magnitude as $K_L \to 2\pi$ $|\epsilon| < 2.2 \times 10^{-3}$ then

$$m_X \sim \frac{m_W}{\sqrt{2.2\times10^{-3}}} = 1.7 \text{ TeV}$$

This is amazing, we can do 1.7 TeV physics using 4 GeV machine, if we can do 0.22 % experiment!

6 Some people insist that we should build 2 TeV machine to produce 1.7 TeV particle, rather than wasting time building a 4 GeV machine to do 1.7 TeV physics. If 1.7 TeV X particle is produced by 2 TeV machine there is no way we can measure the imaginary part of the coupling constant, whereas TCF can do this!

7 Maybe the τ neutrino mass is produced by



φ^0 neutral Higgs
φ^-, h^- } charged Higgs
V vac. exp. value of φ^0

This may explain 90 % of matter in the universe "Dark matter" that keeps the universe from expanding too fast.

3. Why do we want longitudinally polarized e^- or $e^\pm$ beam(s)?

1. We need polarization to see whether $\tau^- \to \nu_\tau + \bar{\nu}_\mu + \mu^-$ (YST 1995) violates CP.

$$\vec{W}_\tau \cdot (\vec{P}_\mu \times \vec{W}_\mu) \rightarrow \vec{W}_\tau \cdot (\vec{P}_\mu \times \vec{P}_e)$$ ↙ decay electron mom

No final state interaction ∴ we need T odd term

Can test T, TCP, CP for pure leptonic system complex coupling constants for leptonic vertices.

2. For semileptonic decay of τ such as

$\tau \to K + \pi + \nu_\tau$ (YST 1996) (unpol + pol) Kühn + Mirkes 1996 (unpol) wrong → 1998 Choi, Lee Song (pol,

$\tau^\pm \to \pi^\pm \pi^+ \pi^- + \nu_\tau$ (YST 1997) (unpol + pol) Choi, Hagiwara, Tanabashi (1995) unpolarized.

we need $\vec{W}_\tau$ to obtain $\vec{W}_\tau \cdot \vec{P}_\pi$, $\vec{W}_\tau \cdot \vec{P}_K$ ← T even

$\vec{W}_\tau \cdot (\vec{P}_\pi \times \vec{P}_K)$ ← T odd

For τ^- decay (S wave ↓, P wave ↓, T violating phase ↓)

$$\cos(\delta_0 - \delta_1 + \delta_t) \left[C_0 \vec{P}_\tau \cdot (\overline{P_K - P_\pi}) + C_1 \vec{W}_\tau \cdot \vec{P}_K + C_2 \vec{W}_\tau \cdot \vec{P}_\pi \right]$$

(in Rest frame of $\vec{P}_K + \vec{P}_\pi$)

$$+ \sin(\delta_0 - \delta_1 + \delta_t) \; C_3 \vec{W} \cdot (\vec{P}_K \times \vec{P}_\pi)$$

For τ^+ decay

$$\cos(\delta_0-\delta_1-\delta_t)\left[c_0\,\vec{p}_\tau\cdot(\vec{p}_K-\vec{p}_\pi)-c_1\,\vec{w}_\tau\cdot\vec{p}_K-c_2\,\vec{w}_\tau\cdot\vec{p}_\pi\right]$$
$$+\sin(\delta_0-\delta_1-\delta_t)\;c_3\,\vec{w}\cdot(\vec{p}_K\times\vec{p}_\pi)$$

c_0, c_1, c_2 and c_3 are simple known functions. The objective is to obtain δ_t by comparing τ^- and τ^+ decays.

From T even part:

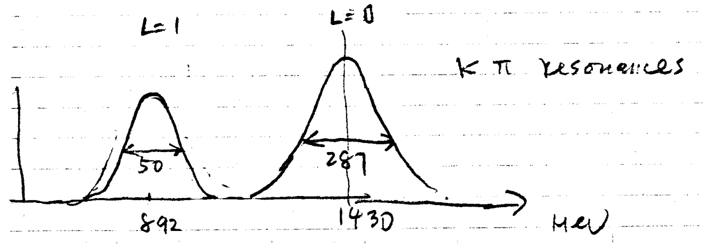
$$\cos(\delta_0-\delta_1+\delta_t)-\cos(\delta_0-\delta_1-\delta_t)=-2\sin(\delta_0-\delta_1)\sin\delta$$

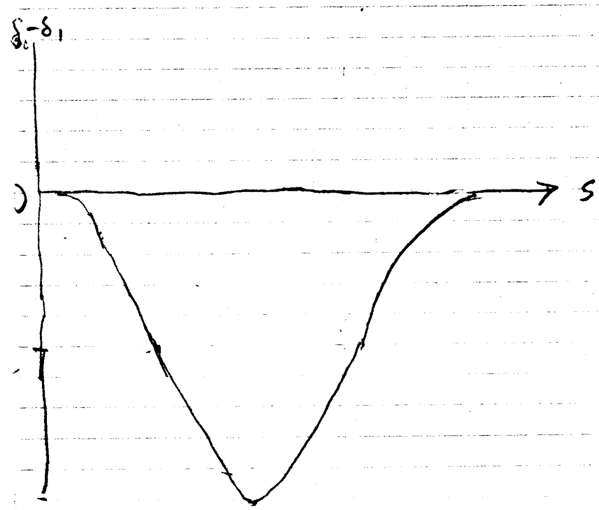
From T odd part:

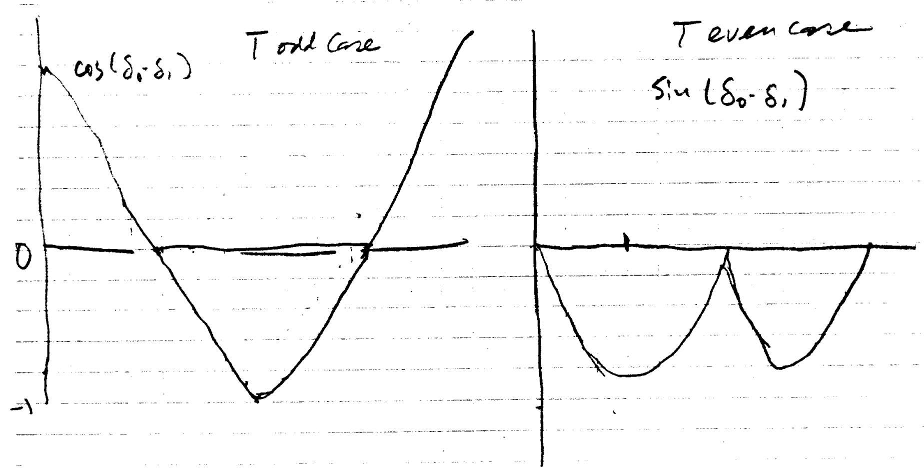
$$\sin(\delta_0-\delta_1+\delta_t)-\sin(\delta_0-\delta_1-\delta_t)=2\cos(\delta_0-\delta_1)\sin\delta_t$$

δ_0, δ_1 and δ_t are all functions of $(p_K+p_\pi)^2=s$

δ_0 and δ_1 vary rapidly but δ_t not expected to vary much


L=1
L=0
K π resonances
50
287
892
1430
MeV


δ0-δ1
0
s


cos(δ0-δ1)
T odd case
0
-1
T even case
sin(δ0-δ1)

Characteristics of τ polarization in τcf and B factory
YST, Phys. Rev 51D, 3172 (1995)

τcf 99 % s wave production 1 % d wave

B factory 75 % s wave production 25 % d wave

If CP is conserved in the production

$$\vec{W}_{\tau^-} = \vec{W}_{\tau^+} \equiv \vec{W}_\tau \quad \text{parallel to } e^- \text{ or } e^+ \text{ if s wave}$$

$$= \left| \frac{w_{e^-} + w_{e^+}}{1 + w_{e^-} w_{e^+}} \right| \hat{e}_z \leftarrow \text{beam direction}$$

From $\vec{W}_\tau \cdot \vec{P}_\pi$ term to obtain δ_t

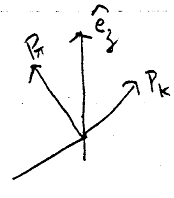
compare $(\vec{P}_\pi)_z$ distributions from τ^+ and τ^-.

Difference indicates ~~CP~~.

Check the result with reversed $\vec{W}_\tau$.

Similarly for $\vec{W}_\tau \cdot \vec{P}_K$ term

$$\vec{W}_\tau \cdot (\vec{P}_K \times \vec{P}_\pi) = \vec{P}_K \cdot (\vec{P}_\pi \times \hat{e}_z) |W_\tau|$$



$$= P_{Ky} P_{\pi x} |W_\tau|$$

plot $P_{Ky} P_{\pi x}$ distribution from τ^+ and τ^- decay

difference is ~~CP~~.

τ/charm Factory vers B Factory for CP in τ
(pol.) (unpol)

cross section factor of 6
pol " " 5

30

If B factory can do 0.8 % exp.
τ charm can do $\frac{0.8}{\sqrt{30}}$ % = 1.4×10^{-3} experiment.