SECTION 12

Slide 8

\[ \{ \begin{align*} u & \rightarrow u^+ \\ d & \rightarrow d^+ \\ u & \rightarrow \nu \mu^+ \\ \nu & \rightarrow \mu^+ \\ \end{align*} \] 

Speed of light in water \( \approx 0.75c \) for \( \varepsilon / \mu = 0.75c \)

As charged particle travels, it polarizes the water, travels so fast it leaves a disturbance, and radiated photons are contained within the electric field of the disturbance = cone

\[ \Psi(\vec{p}, t=0) = \nu_1(\vec{p}) \cos \theta - \nu_2(\vec{p}) \sin \theta \]

If masses of \( \nu, d, \nu_2 \) are different, then they must evolve differently with time

\[ \nu_x(\vec{p}, t) = \nu(\vec{p}) e^{-iEt} \]

contains mass term \( m^2 c^2 \beta^2 \)

so at a late time

\[ \Psi(\vec{p}) = \nu_1(\vec{p}) e^{-iEt} \cos \theta - \nu_2(\vec{p}) e^{-iEt} \sin \theta \]

\[ \nu_1(\vec{p}) \sin \theta + \nu_2(\vec{p}) \cos \theta \]

\[ \nu_1(\vec{p}) \cos \theta - \nu_2(\vec{p}) \sin \theta \]

Express as weak eigenstates

\[ = \nu_1(\vec{p}) \left[ \sin \theta \cos \theta (e^{-iT} - e^{-iG}) \right] + \nu_2(\vec{p}) \left[ \cos^2 \theta e^{-iT} + \sin^2 \theta e^{-iG} \right] \]

\[ G = \frac{c_0}{c_0} \]

\[ P(\text{u}) = 1c_0 \]

\[ P(\text{m}) = 1c_0 \]

\( \vec{c_0} \)

\( \vec{m} \)
\[ P(\nu_e) = |C_{\nu_e}|^2 = \left[ \sin^2 2\theta \cos \theta (e^{-i(E_\nu - E_{\nu_e})} - e^{i(E_\nu - E_{\nu_e})}) \right]^2 \]

\[ = \sin^2 2\theta \sin^2 \left( \frac{(E_\nu - E_{\nu_e})t}{2} \right) \]

\[ E^2 = p^2 + m^2 \]
\[ E = \frac{p^2 + m^2}{2p} \]
\[ \text{if } p \text{ is small, } E \approx \frac{m^2}{2p} \]
\[ \text{if } p \text{ is large, } E \approx \sqrt{p^2 + m^2} \approx 1 + \frac{m^2}{2p^2} \]

\[ E_\nu - E_{\nu_e} = \frac{p^2}{2p} + \frac{m^2}{2p} - \frac{m_1^2}{2p^2} - \frac{m_2^2}{2p_2} \]
\[ \text{since } m \text{ is small} \]

\[ \frac{m_2^2 - m_1^2}{2E} = \frac{m^2 - m_1^2}{2E} \]

\[ P(\nu_e) = \sin^2 2\theta \sin^2 \left( \frac{(m^2 - m_1^2)t}{4E} \right) \sim \sin^2 2\theta \sin^2 \left( \frac{\Delta m^2 L}{4E} \right) \]

\[ \text{Probability oscillation depends on} \]
\[ \circ \text{ energy} \]
\[ \circ \text{ mixing angle} \]
\[ \circ \text{ mass differences} \]
\[ \circ \text{ time from production} \]