# Particle Physics 2 : Exercise 4

## 1) $\tau$ lepton branching ratios

Explain why the tau lepton branching ratios are observed to be approximately

$$Br(\tau^- \to e^- \nu_\tau \bar{\nu}_e) : Br(\tau^- \to \mu^- \nu_\tau \bar{\nu}_\mu) : Br(\tau^- \to \nu_\tau + \text{hadrons}) \approx 1 : 1 : 3.$$

## 2) Weak charged-current interaction

Assuming that the process $\nu_e e^- \to e^- \nu_e$ only occurs via the weak charged-current interaction (*e.g.* ignoring the Z-exchange neutral-current process), show that for $E_\nu \gg m_e$

$$\sigma_{CC}^{\nu_e e^-} \approx \frac{2 m_e E_\nu G_F^2}{\pi},$$

where $E_\nu$ is neutrino energy in the laboratory frame in which the struck $e^-$ is at rest.
In the derivation, the cross section results for (anti)neutrino - (anti)quark scattering shown in the lecture can be used (so there is no need to compute scattering amplitudes).

## 3) Solar neutrinos

Using the above result, estimate the probability that a 10 MeV Solar $\nu_e$ will undergo a charged-current weak interaction with an electron in the Earth if it travels along a trajectory passing through the centre of the Earth.
Take the Earth to be a sphere of radius 6400 km and uniform density $\rho = 5520$ kg m$^{-3}$, and assume that the density of protons and neutrons in the Earth is the same.



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