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Neutrino Oscillation Physics

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Abstract

This Theoretical project consists in the study of neutrinos flavor oscillation phenomenon in two and three families in vacuum, uniform matter and non-uniform matter. It was presented the validity of this hypothesis as a solution of the Solar Neutrino Problem, where the experimental results of the flux of neutrinos detected on earth coming from the Sun wasn't matching the expected values from the theory. It was obtained thus the probabilities of occurring oscillation for each case and then analysed its behavior as a function of the dependent parameters.

Key words:

Neutrino, Flavor Oscillation, Solar Neutrino Problem.

Introduction

Experimental results of the neutrino flux coming from the Sun wasn't matching the expected values from the theory. Everything appointed that eletronic neutrinos were disappearing while travelling to the Earth. As a solution for this question it was proposed the neutrino flavor oscillation theory, which has a very important consequence, it requires that neutrinos have to have mass, something that wasn't predicted before. This theory is based on the concept of superposition of states, which means that neutrinos are a combination of other states, a mixture of other neutrinos known as mass states or physical neutrinos.

The purpose of this Project is to analyse the oscillation phenomenon for the simplificated two neutrinos case (two families) and then the more complex three families case. This will be done for the different medium of neutrino propagation such as vacuum (medium that neutrinos travel from the Sun to the Earth), Uniform matter and non-uniform matter (good approximation for the medium inside the Sun).

The objective is to calculate, using apropriate approximations, the probabilities of occurring oscillation for each medium case, which is the probability of a certain neutrino flavor to become another flavor, known as conversion probability, and the survival probability, which is the case that a neutrino do not suffer the oscillation phenomenon.

Results and Discussion

Developing the calculations from this theory it was obtained the survival probability for two families in vacuum, which depends on the parameters **Δm²** (neutrino's square mass difference), **E** (neutrino's energy), **L** (distance traveled by the neutrino) and **θ** (the mixture angle between the mass states):

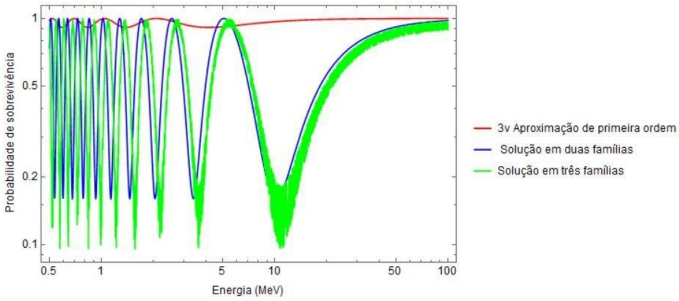
$$P_{e\to e} = |<\nu_e(t)|\nu_e>|^2 = 1 - P_{e\to\alpha} = 1 - sen^2(\frac{\Delta m^2}{4E}L)sen^2 2\theta$$

Similarly for three families in vacuum it was obtained the survival probability:

$$P_{ee} = 1 - 4cos^2(\theta_{12})cos^4(\theta_{13})sen^2(\theta_{12})sen^2\left(\frac{m_2^2 - m_1^2}{4E}\right) - 4sen^2(\theta_{12})cos^2(\theta_{13})sen^2(\theta_{13})sen^2\left(\frac{m_3^2 - m_2^2}{4E}\right) - 4cos^2(\theta_{12})cos^2(\theta_{13})sen^2(\theta_{13})sen^2\left(\frac{m_3^2 - m_1^2}{4E}\right)$$

The graph of both probabilities can be seen below:

Image 1. Survival Probability of the Eletronic Neutrino in Vacuum for two families in Blue and for three families in green.



From this plot is possible to infer that the greater the square mass difference is and the greater de distance L traveled is the greater is the frequency of the oscillation, and the greater the mixture angle is the greater is the amplitude of the oscillation.

Conclusions

In this study was possible to characterize flavor neutrinos as a superposition or mixture of mass states (physical neutrinos), which supports the oscillation theory, phenomenon induced by neutrino's mass difference. It was analysed the behavior of oscillation and the conversion and survival probabilities as function of deterministic parameters for different mediums of propagation in two and three families.

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