Neutrino oscillations

Our current understanding of neutrino oscillations features some anomalies that appear at short baselines (SBL) and that we address here within the context of the 3 + 1 mixing scenario. The neutrino mixing can be written in terms of the mixing matrix $U_m$, where $\alpha$ represents an active ($\alpha = e, \mu, \tau$) or sterile ($\alpha = s$) neutrino flavour eigenstate and $\| \cdot \|$ a neutrino mass eigenstate. The scenario is labeled as $\Delta m^2 = 1.0$, because the $\alpha_s$ mostly mixed with $\nu_4$, $|U_{\alpha s}| \approx 1$, is much heavier than $\nu_1$, $\nu_2$, $\nu_3$. We also consider $|U_{ee}|^4 = |U_{\mu\mu}|^4 = |U_{\tau\tau}|^4 = |U_{es}|^4 = |U_{\mu s}|^2 = |U_{\tau s}|^2 = 10^{-3}$. Using the mixing matrix one can write the effective oscillation probabilities of flavor neutrinos at short baselines $\mathcal{P}$:

$$\mathcal{P} = \sum_{\alpha \beta} |U_{\alpha s}|^2 |U_{\beta s}|^2 P_{\alpha \beta} \left( \delta m^2_{\alpha \beta} L^2 / 2 \right), \tag{1}$$

where $\alpha, \beta = e, \mu, \tau$, $L$ is the source-detector distance, $E$ the neutrino energy and $\delta m^2_{\alpha \beta} = m_{\beta}^2 - m_{\alpha}^2$. Since we will only consider $\alpha = e, \mu$, $\beta = e, \mu$, we will be interested in $\mathcal{P}_{ee}$ and $\mathcal{P}_{\mu\mu}$, $\mathcal{P}_{e\mu}$ and $\mathcal{P}_{\mu e}$.

This method recovers the reactor properties and the detector properties are similar.

Reactor fluxes and Reactor Antineutrino Anomaly (RAA)

The RAA is a deficit of the ratio of $\alpha$, observed in several SBL experiments in comparison with the theoretical expectation as computed in [1] and [3]. The RAA has been first analyzed in [2] and a possible explanation can be the existence of (new) neutrino oscillations at $L \approx 20 \text{ m}$, corresponding to $\Delta m^2_e < 1.5 \times 10^{-3} \text{ eV}^2$.

Gallium anomaly

The Gallium radioactive-source experiments

GALLEX and SAGE observed a SBL $\nu_e$ deficit of $\alpha_s$, which was first noticed in [3]. This anomaly can be explained by neutrino oscillations generated by a squared mass difference $\Delta m^2_e < 1 \text{ eV}^2$.

How to be model independent?

Is there a way to avoid all the model dependencies and have a clean signature of the $\nu_s$ neutrino oscillations? We can measure the fluxes at different distances and use their ratios. In this way, the systematic effects related to the theoretical calculations and the flux normalizations are automatically removed from the final result. A distance-dependent effect would be the signature of SBL oscillations.

DANSS

The first release of the DANSS experiment [4] considered the ratio of the spectra measured in the "top" and "bottom" positron regions (a total of 4 SBL antineutrino events). The best fit points in the case of 3+1 and 3 neutrino mixing have a difference $\Delta \chi^2 < 1$, in favor of 3+1 oscillations ($\sim 3\sigma$).

The collaboration provides [2] an excellent plot only with the antiquark for the resonance of the sinto antineutrino will be studied with more data.

Other experiments

Other experiments that also provide model-independent measurements are [1, 2] (for the details)

- KamLAND (a ratio of spectra at 40 m and 200 m from the source)
- KAMKARGON and LSND data, at 180 m and 30 m from the source

We included all these experiments, but they play a marginal role in the analyses!

More soon?

Several experiments which aim at measuring SBL neutrino oscillations in a model-independent way are under development or already taking data. Some of them are:

- STEREOS
- SOLAR
- PROSPECT

We will possibly have new data soon!

Efficiency of GALLEX and SAGE

In the last part of our analysis we consider the possibility that theominous flavor of the principal fraction (effective neutrino) has a different normalization with respect to the predicted one. In order to do this, we multiply each spectrum by $\frac{f(\alpha)}{f(\beta)}$, $f(\alpha)$ is a free factor, $f(\gamma)$, $f(\delta)$, which is one of the theoretical calculations is correct. We also verified that the spectrum of $^{38}$Ar cannot be constrained with current data.

Free fluxes: obtaining the normalization

As for the Gallium case, we find that the best-fit for the oscillation parameters $\Delta m^2_3$ and $\sin^2 2\theta_{13}$ is almost independent of the $\alpha_e$ coefficient, as they are constrained by DANSS and SNEI alone. The fit, however, shows a $\sim 2\sigma$ deviation of $\nu_{13}$ and $\nu_{14}$ from the expected value.