Time Independent Two Neutrino Oscillations

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1 Abstract

It is our goal to study MSW effect of Solar Neutrinos Oscillations, particularly time independent two neutrino oscillations. We want to study the survival probability of solar neutrinos as a function of certain parameters. To this end we aim to write programs to describe the simulation methods, analysis and input parameters and try to reconstruct neutrino energy and eventually try to fit more advanced fits using both the recoil electron energy and reconstructed neutrino energy. We also aim to write programs to look through previous Monte Carlo data and try to run on actual data.

2 Introduction

Neutrinos are weakly interacting particles which travel at the speed of light. Because of their weakly interacting property they can reach us from inaccesible regions where photons might get trapped, so we get to examine the interior of the sun and other stars. we all know that the sune shines by burning four protons giving an alpha particle,a positron and solar neutrinos as shown: $4p \rightarrow \alpha + 2e^{+} + 2\nu_e$
These solar neutrinos travel from the Sun to the Earth. For many years the Scientists were confused as for the large discrepancy between their predicted rate and observed rate, when they reached the earth.It was eventually found out that actually the Neutrinos were not massless as the physicist assumed, but they do have mass and they actually oscillate from one kind to the other.The Neutrinos created in the solar interior ν_e convert in to $\nu_x(x = \mu, \tau)$ on their way to the Earth to the Sun. This effect of Solar Neutrino oscillation is know as the MSW affect. Most solar neutrinos are produces below 2Mev. Sun is a high intensity solar neutrino source which produces pure ν_e and also provide high senstivity to neutrino mixing parameters and sensitivity to neutrinos masses down to $10^{-11}eV^2$.we give particular attention to the LMA and SMA solutions ,which are characterized by a lack of time-dependent phenomena (either summer-winter or day-night asymmetries). We study dependence of the electron neutrino survival probability, $P_e(E)$ as a function neutrino energy.

3 The Method

The methods to which we reslove to our experiment is scattering of a sola r neutrino off of a target electron($\nu e \rightarrow \nu e$) which results in a complete reconstructed electron track(Fig.1). From the reconstruction of the electron recoil energy (T_e) and its angle with respect to the solar axis ($\theta_\odot$), the neutrino energy for each event is given by

$$E_\nu = \frac{mT_e}{p\cos\theta_\odot - T_e} \ . \tag{1}$$

Then the results can be compared with solar models and solar mixing models. we can count four neutrino species below 2 MeV; pp, ^{7}Be, pep and NO, where the CNO spectra are counted as one. For each species there is a ν_e flux Φ_e, a ν_x flux Φ_x ($x = \mu, \tau$).

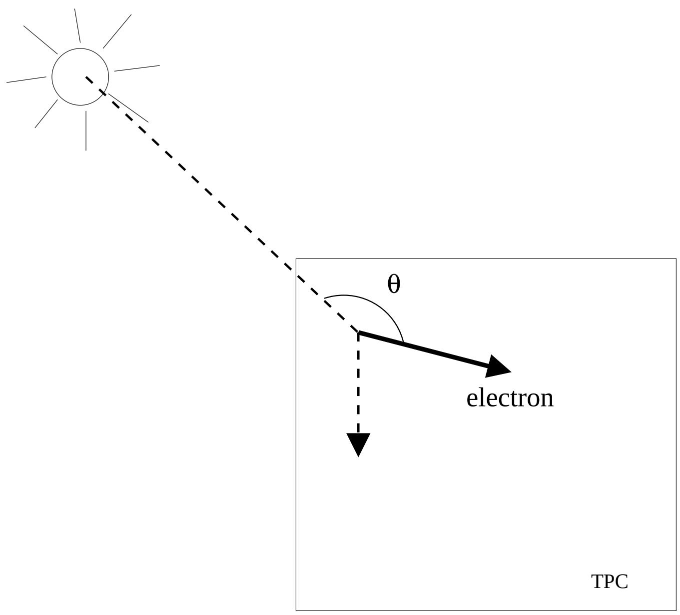

Figure 1: The solar neutrino detection scheme. The recoiling electron energy and direction are measured, and the neutrino energy is reconstructed according to Eq. 1. Only a small fraction of the solid angle around the solar axis is considered at any given time. The angle θ shown should be labelled $\pi - \theta$ to correspond with Eq. 1.

The lowest electron reconstructed energy track is 100 keV tracks which travel several cm before stopping, providing adequate track lever arm for better measurement of T_e The neutrino survival probabilities were computed. The MSW-SMA region is, generally speaking, characterized by a strongly varying $P_e(E)$. The MSW-LMA region has a slow, continuous spectral distortion across the 0-2 MeV region. Fig. 2 shows $P_e(E)$ for a conveniently chosen central point in the SMA region, and for four points nearby corresponding to a 21% variation up and down in both mass and $\sin^2 2\theta$. Fig. 3 does the same for the LMA region. Because no time-dependent effects are expected in this

Table 1: Parameters used in the simulations described in the text.

Parameter	Value
Exposure	7 & 70 ton-years
σ_T/T	0.05 at 100 keV
σ_θ	15° at 100 keV
^{238}U	0.5 μg
$^{14}C/^{12}C$	5×10^{-20}g/g

region, the most general analysis is done by studying the E_ν vs. x scatter plot, where $x = T_e/T_e^{max}$. Monte Carlo events were generated using the parameters listed in Table 1. Results are presented for exposures of 7 and 70 Ton-years, roughly corresponding to one and ten years of data taking.

we use the following detector resolutions:

$$\frac{\sigma_T}{T}(T) = \frac{0.016}{\sqrt{T}} \qquad \sigma_\theta(T) = \frac{4.7^\circ}{T^{0.6}} \tag{2}$$

where T is the electron kinetic energy in MeV. At the lowest track energy of 100 keV, this corresponds to resolutions of 5% for energy and 15° for angle. The backgrounds were simulated were found to be neglible. Figure 4 compares the SMA and LMA solutions; there is some distinction with 7 ton-years and a very clear distinction with 70 ton-years.

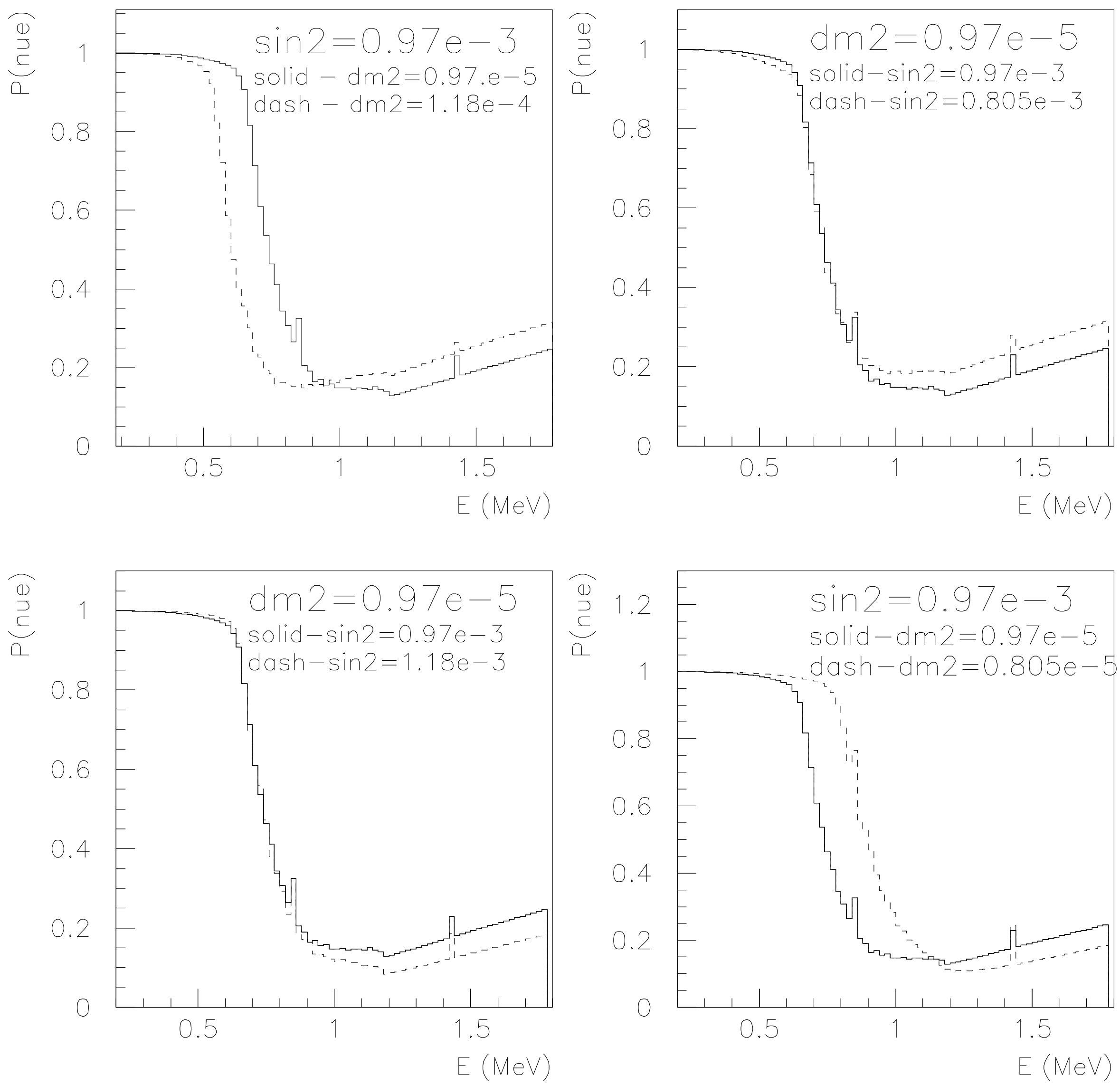

Figure 2: The neutrino survival probability in the SMA region, as a function of neutrino energy. The solid line is always the same, and represents the calculation for the nominal point at ($\Delta m^2 = 0.97 \times 10^{-5}, \sin^2 2\theta = 0.97 \times 10^{-3}$). The dashed lines represent points displaced from the nominal point by 21%, respectively above, to the left, to the right, and below the nominal point.

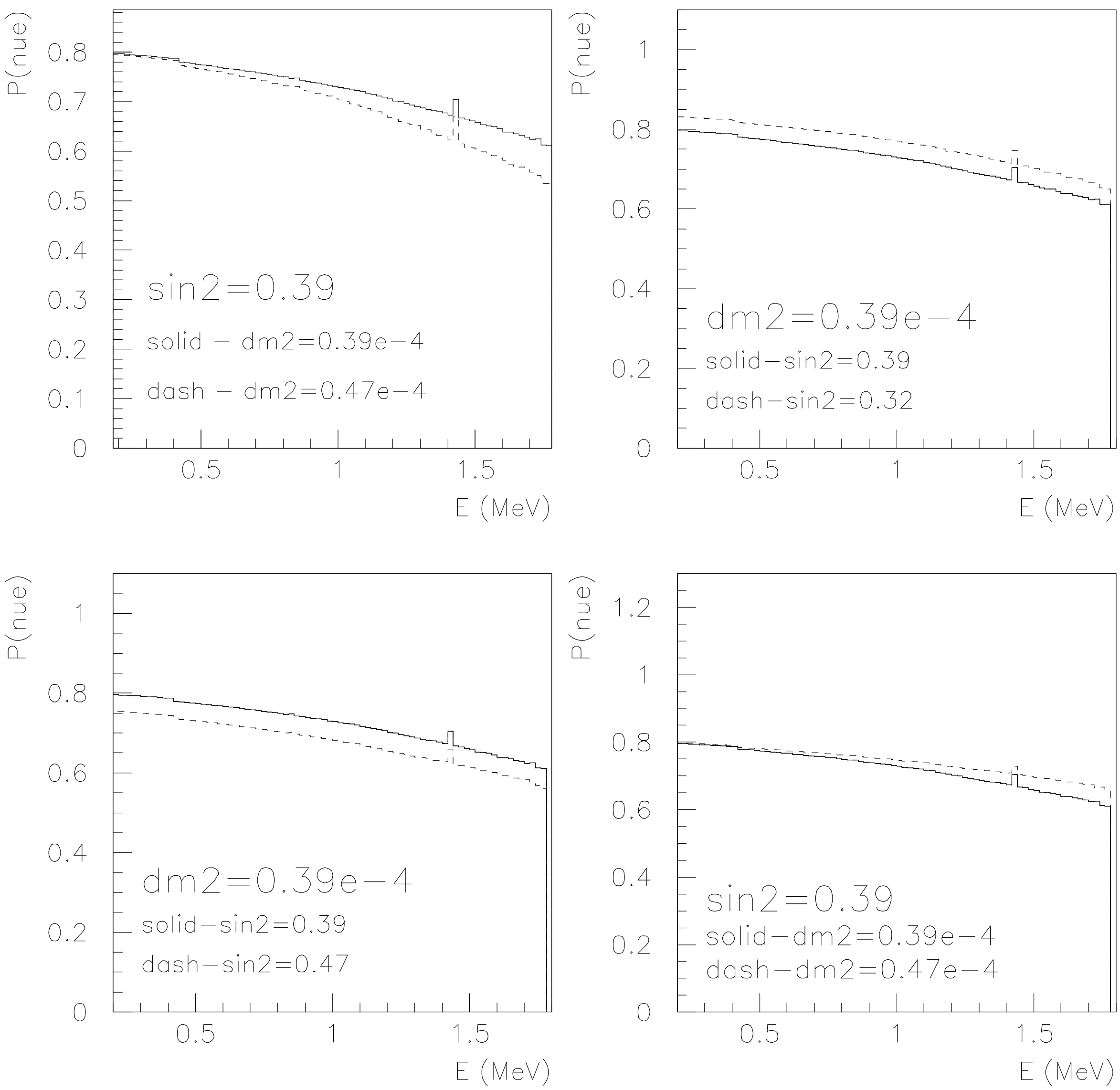

Figure 3: The neutrino survival probability in the LMA region, as a function of neutrino energy. The solid line is always the same, and represents the calculation for the nominal point at ($\Delta m^2 = 3.9 \times 10^{-5}, \sin^2 2\theta = 0.39$). The dashed lines represent points displaced from the nominal point by 21%, respectively above, to the left, to the right, and below the nominal point.

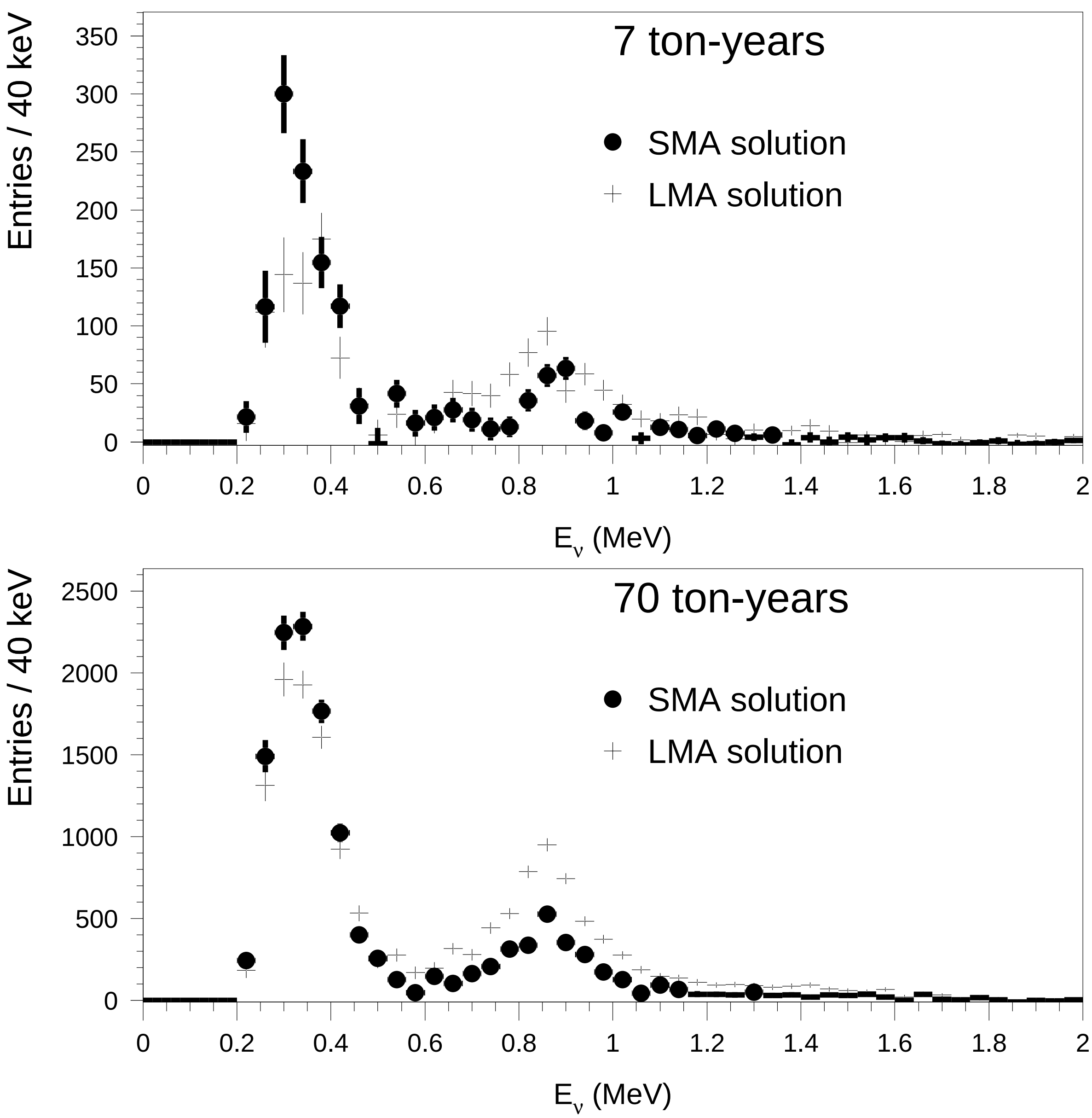

Figure 4: MC prediction of experimental neutrino energy spectrum for LMA (dots) and SMA (crosses) solutions. The top (bottom) plot corresponds to 7 (70) ton-years.

4 Conclusions

It is nice to be able to say that with strong evidence for long distance neutrino mixing the next generation of experiments should aim for precision measurements of neutrino mixing parameters.The uncertainty in the mixing parameters could be reduced by a factor of twenty;in some cases, the mixing parameters can be determined at the several percent level.There is a lot to be done on this project particularly the time dependent oscillations, considering the day-night effect and the summer-winter effect, which Professor Bonvicini is working on and I will continue to assist him.

5 Acknowledgment

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