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NEUTRINO OSCILLATIONS I.L.L EXPERIMENT REANALYSIS

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In the spring of 1990, it was announced that the operating power of the high-flux reactor of Institute Laue Langevin (ILL), Grenoble, had been incorrectly reported since its earliest days of operation. One impact of this is that the ILL reactor was operated at **1.095** times it's rated full power (**57 MW thermal**). It also affects the results of experiment conducted by a collaboration from Caltech, Munich, and ISN-GRENOBLE which searched for neutrino oscillations at ILL reactor in early 1980. The possible implications of neutrino oscillations resulting from the wrong normalisation applied in the earlier analysis, stimulated the present reanalysis of that experiment.

In addition, other constants which are used to normalise the inverse beta decay spectrum one measures near a fissioning reactor, have changed since 1980.

-First, there have been refinements in the determination of the antineutrino $\overline{\nu_e}$ source spectrum that one expects from a reactor. In the case of the I.L.L reactor, the fuel element consists of 8.5kg of 93% enriched ^{235}U in the form of UAl3. This almost pure ^{235}U core has the advantage of lending itself to a well defined prediction of the electron-antineutrino spectrum. The $\overline{\nu_e}$ spectrum of ^{235}U used to find the expected yield in ref.1 was that measured by schrekenbach et al. in 1980. An improved spectrum done by the same authors in 1984 which, if applied to I.L.L neutrino oscillations analysis, enhances the normalisation by nearly **5%.**

-Other corrections are connected with the inverse beta decay cross section. The neutron lifetime used in the earlier work was **926s** and now is **889±4s** which boosts the cross section by **4%**. In addition, in the previous analysis there was no attempt to correct for neutron recoil, weak magnetism and radiatives corrections, all these effects were account for in subsequent neutrino oscillations experiments. These corrections lower the normalisation yield by nearly **2%**.

All the changes above result in an estimated net increase in the normalisation of the ILL experiment of about **18%.** What is the source of this difference between experiment and theory ? One plausible reason for the difference is that, there was mistakes or wrong assumptions made when calculating the predicted yield or limitations in the monte carlo code employed. The purpose of the present work is to repeat the simulation studies of the ILL detector response to positrons using a completely different Monte carlo code. The resulting response functions are then used to calculate the expected yield from the I.L.L experiment taking into account the local neutron efficiencies at each point of the detector. This yield is then normalised to solide angle and the reactor power in order to compare to the experimental data. This is done first assuming no oscillations taking place and then again with a two-state neutrino oscillations probability function incorporated. This probability function is parameterised by the mixing angle θ and the difference of the square of the masses Δm^2 associated with two mass eigenstates. The expected positron yield $Y(E_e+,l,\Delta m^2,\theta)$ per MeV and hour is given by:

$$Y(E_{e^+},L,\Delta m^2,\theta)=N_p\varepsilon_n(t_c)N_F A(PSD)\iint\Phi(E_{\overline{\nu_e}},L',\Delta m^2,\theta)R(E_{e^+},E'_{e^+})h(L,L')\sigma(E_{\overline{\nu_e}})dL'dE'_{e^+}$$

$R(E_{e^+},E'_{e^+})$: response function for a positron energy E_e+

h(L,L') : Distribution of distances traveled by $\overline{\nu_e}$.

where : $\Phi(E_{\overline{\nu_e}},L,\Delta m^2,\theta)=\dfrac{S(E_{\overline{\nu_e}})}{4\pi L^2}\left[1-\sin^2 2\theta\sin^2\left(1.27\dfrac{\Delta m^2 L}{E_{\overline{\nu_e}}}\right)\right]$ and $E_{e^+}=E_{\overline{\nu_e}}-1.804$

with $N_F=6.48.10^{21}$Number of fission/hour, $N_p=2.96.10^{28}$ Number of protpns, ε_n =19.4% neutron efficiency in the time window t_c=200µs , A(PSD) =0.98 PSD acceptance and L=8.76m.

The ratio of the experimental to expected integral positron yield assuming the no-oscillations

case is found to be : $\mathbf{R}=\dfrac{\int Y_{\exp}(E_{e^+})dE_{e^+}}{\int Y_{th}(E_{e^+},L,0,0)dE_{e^+}}$ = **0.832 ± 3.5% (stat) ± 8.87% (syst)**

In order to test the compatibility of a certain oscillations hypothesis ($\Delta m^2,\theta$) with the measurement, the following χ^2 expressions are defined :

$$\chi_F^2=\frac{1}{16}\sum_{i=1}^{16}\frac{(R^{-1}Y_{\exp}(E_{e^+})-Y_{th}(E_{e^+},L,\Delta m^2,\theta))^2}{\sigma_i^2(stat)} \quad \text{and} \quad \chi_N^2=\frac{(R-1)^2}{\sigma^2(stat)+\sigma^2(syst)}$$

$$\chi_S^2=\chi_N^2+\chi_F^2 \qquad \text{with} \quad R=\frac{\int Y_{\exp}(E_{e^+})dE_{e^+}}{\int Y_{th}(E_{e^+},L,\Delta m^2,\theta)dE_{e^+}}$$

A comparison of the new theoretical and the experimental spectra of the ILL experiment with the spectra calculated and measured for the Bugey and the Gösgen experiments is performed.

In conclusion, the reanalysis of ILL experiment shows a depletion of **18%** in the neutrino flux. An interpretation of this integrated counting difference between the experimental and the expected spectra , by simple two neutrinos oscillations scheme exclude the no oscillations case at 2σ level. The parameters of neutrino oscillations deduced from this reanalysis i.e coresponding to the minimum of χ_S^2 are: **$\sin^2 2\theta$ = 0.31, Δm^2 = 2.23ev²**. The mixing parameter found in our study is in good aggreement with the one found by **G.Conforto** deduced from an analysis of neutrinos accelerators experiments, which is **$\sin^2 2\theta$ = 0.48 ± 0.1.±0.05**

Ref.1 H.Kwon et al. Phys.Rev D 24, N° 5 ,1097(1981)