NEUTRINOS IN PION AND MUON DECAYS AT NEUTRINO FACTORIES AND LSND EXCESS

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Abstract

The proper and precise determination of neutrino properties in neutrino beams produced in pion and muon decays may lead to the new physics i.e.,either neutrino oscillation mechanism or neutrino is a mixture of electron neutrinos,muon neutrinos and tau neutrinos.The neutrino factory, LAMPF and accelerators facilities may be the ideal place to look for the lepton flavour violating decays of the kind $\pi^+ \to \mu^+ + \nu_e$, $\pi^+ \to \mu^+ + \nu_\tau$ and $\mu^+ \to e^+ + \nu_e^- + \nu_\mu$, $\mu^+ \to e^+ + \nu_e^- + \nu_\mu^-$ etc.The detector must be made in such a way so that the detector can be capable of electron, muon, and tauon identification with charge discrimination.An alternative solution of LSND excess, solar neutrino problem and atmospheric neutrino anomaly etc. has been suggested by the lepton number violation scheme apart from neutrino oscillation mechanism.

1. INTRODUCTION

Neutrinos and its oscillation happens to be one of most exciting topics in the high energy physics over the years.The standard model of weak interactions has been tested with experimental precision, it does not address the question of the origin of generations and their mixing, neutrino oscillation may imply that neutrinos are massive and that lepton flavours are not conserved quantum numbers. Neutrino physics has entered a very exciting period as there is a possibility to observe lepton- family number violation due to neutrino oscillation.At present there are several viable region of oscillation parameter space that are consistent with the observed solar neutrino deficit, but all of these region requires $\Delta m^2_{sol} \leq 10^{-4} eV^2$, $\Delta m^2_{atmosphere} \approx 3 \times 10^{-3} eV^2$.We know only 3 neutrino flavours but three flavours mixing can only accommodate two Δm^2 scales(i.e.,$\Delta m_1^2 - \Delta m_2^2, \Delta m_2^2 - \Delta m_3^2$). Hence either there are more sterile flavours to be discovered or else the solar neutrino deficit is not due to oscillation/or the LSND result is not due to neutrino oscillations.Before we can understand the framework within which lepton family number violation is taking place we must first confirm (or otherwise) the $\nu_\mu \to \nu_\tau$ interpretation of the atmospheric neutrino anomaly and clarify that whether the LSND and solar neutrino results due to neutrino oscillation. We expect that the

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data from SNO,KAMLAND together with further Super-Kamiokande(SK) measurements, will very likely leave us with either one region of viable parameter space for solar neutrino oscillations or perhaps rule out all regions of parameters space. In this paper, we will try to explain:(1)solar neutrino problem, (2)LSND results,(3)atmospheric neutrino deficit in a coherent manner by the lepton-family number violation scheme suggested by Raychaudhuri[5].

2. LEPTON FAMILY NUMBER VIOLATION

Within the standard model of weak interactions neutrino oscillation raised the possible prospect that there might exist observable processes that violate the charged lepton number. In an extension of the standard model the existence of lepton number violation could open a new modes of decays i.e., $n \rightarrow p + e^- + \nu_e^-(\nu_\mu^-)$ (1)
$\mu^+ \rightarrow e^+ + \nu_e(\nu_\mu) + \nu_\mu(\nu_e^-)$ (2)
$\rightarrow e^+ + \nu_e^-(\nu_\mu) + \nu_\mu^-(\nu_e)$ (2a)
Actually the process (2) is $\mu^+ \rightarrow e^+ + \nu + \nu^-$ (3)
indicating $\mu^+ \rightarrow e^+ + \gamma$ (3a)
only the process $\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu^-$ and $n \rightarrow p + e^- + \nu_e^-$ etc. do not violate lepton number.Now $\pi^+ \rightarrow \mu^+ + \nu_\mu(\nu_e, \nu_\tau)$ (4) $\pi^+ \rightarrow e^+ + \nu_e(\nu_\mu, \nu_\tau)$ (4a) in the high energy region where $E_\nu \geq 1GeV$, the electron neutrino flux will be much lower than that of muon neutrino and tau neutrino flux in (4).In fact pair's of the type $e^+\nu_\mu$,$\mu^+ + \nu_e$,$\nu_e + \nu_\mu^-$,$\nu_\mu + \nu_e^-$, $\nu_e + \nu_\mu$,$\nu_e^- \nu_\mu^-$ etc.has been suggested by Raychaudhuri[5,6]. To explain the parity violation Raychaudhuri[7,8]suggested that in any decay process neutrino appears as either ν_e and ν_μ in the low energy or ν_μ, ν_τ, ν_e in the high energy and due to asymmetry of $e^-\nu_e^-(e^+\nu_e)$ and $e^-\nu_\mu^-(e^+ + \nu_\mu)$ pairs in decay process we see parity violation.Considering these type pairs it may be possible to explain the solar neutrino problems that were persisted since the solar neutrino flux observed by Davis [3].In all cases neutrino flux can be written as $\phi(\nu) = \phi(\nu_e) + \phi(\nu_\mu)$ (5) for $E_\nu \leq 20$ MeV and $\phi(\nu) = \phi(\nu_e) + \phi(\nu_\mu) + \phi(\nu_\tau)$ (6) for $E_\nu \geq 1$ GeV.We can study the above mentioned types of pairs produced in pion and muon decay and these studies could directly relevent complimentary investigations to those for neutrino oscillation.It must be pointed out that we have also $\mu^+ + \nu_\tau$,$e^+ + \nu_\tau$,$\nu_\mu\nu_\tau$ etc.pairs in the decay processes which violates lepton number flavour but these type of process can occur in the high energy region.

3. SEARCHES OF PION AND MUON AT NEUTRINO FACTORY, LAMPF AND ACCELERATORS

In a neutrino factory, LAMPF and Accelerators we can study neutrino flux from exotic pion and muon decays and the flux of neutrinos are sufficiently high to obtain large statistics of neutrino interaction events.The flavour of interacting neutrinos can be tested via their charged current processes.In case of purely lepton flavour conserving decays $\mu^+ \to e^+ + \nu_e + \nu_\mu^-$ we expect to detect only $\nu_e + N \to e^- + X$, $\nu_\mu^- + N \to \mu^+ + X$ (7) If $\mu^+ \to e^+ \nu_e^-$,$\mu^+ \to e^+ + \nu_e^- + \nu_\mu^-$, $\mu^+ \to e^+ \nu_\mu + \nu_e$ occurs,then it is possible to identify the exotic decays by various process $\nu_e + N \to e^+ + X$, $\nu_\mu + N \to \mu^- + X$, $\nu_\mu^- + N \to \mu^+ + X$ (8) where the number of events is less than the number of events in (7). If $\pi^+ \to \mu^+ + \nu_e$ is possible then we can detect $\nu_e + N \to e^- + X$ (9) We can address the search for LFV, using (8) sign of muons which can experimentally simpler to detect.In order to gain for the enhancement cross section of neutrinos vs.antineutrinos, it is better to detect μ^+ in the storage ring, since in this case LFV decays produce ν_μ's. If we consider $\mu^- \to e^- + \nu_e + \nu_\mu$ for which $\Delta L = 2$, we should look for wrong sign of electron.We select μ^- in the storage ring since signal searched for in this case has two neutrinos final,therefore we can gain for the enhanced cross section.

4. SOLAR NEUTRINO DISCREPANCY

If we consider that neutrino flux can be written as $\phi(\nu) = \phi(\nu_e) + \phi(\nu_\mu)$ (10) in the case of low energy i.e., E_ν from 0.233 MeV to 20 MeV and if we consider the cross section is the same as electroweak theory, then if $[\phi(\nu_\mu)/\phi(\nu_e)] = 5/2$ for $E_\nu \geq 0.5$ MeV and $[\phi(\nu_\mu)/\phi(\nu_e)] = 1/3$ for $E_\nu < 0.5$ MeV (11) then the observed solar neutrino flux data from Homestake, SK, SAGE, GALLEX-GNO and SNO can be explained.

5. LSND EXCESS

(a)Results from $\pi^+ \to \mu^+ + \nu_e$ LSND excess in $\nu_e + C \to e^- + X$. A search for $\nu_\mu \to \nu_e$ oscillation has been detected by LSND group observed a total of 40 beam on high energy (60-200) MeV electron events with the $\nu_e + C \to e^- + X$ (12) inclusive reaction. This number is significantly above 21$\pm$ 2.1 events expected from ν_e contamination in the beam and the beam off background. If the result is interpreted by neutrino signal, the observed oscillation probability of $(2.6 \pm 1.0 \pm 0.5) \times 10^{-3}$ consistent with reported $\nu_\mu \to \nu_e$ oscillation evidence from LSND. Here we suggest that $\pi^+ \to \mu^+ + \nu_e$ exotic decay can explain the LSND excess in (12). Let $[\phi(\nu_e)/\phi(\nu_\mu)] = 2.6 \times 10^{-3}$ then the excess event N $= \int \phi_{LFV}(\nu_e)\sigma^{cc}(\nu_e, E_\nu)dE_\nu$=45 events which is almost the same excess event observed by LSND, where we have used $\phi(\nu_\mu)$ and σ^{cc} from Athanassopoulos [1,2]. (b)results from $\mu^+ \to e^+ + \nu_e^- + \nu_\mu$, $\mu^+ \to e^+ + \nu_e^- + \nu_\mu^-$ for LSND excess in $\nu_e^- + p \to n + e^+$. A search for $\nu_\mu^- \to \nu_e^-$ oscillation has been conducted by LSND experiment using ν_μ^- from $\mu^+ \to e^+ + \nu_e + \nu_\mu^-$ at rest (DAR). The LSND group observe a total of 51 +20.2/-19.5$\pm$ 8.0 events,which if due to oscillation corresponds to an oscillation probability of (0.31$\pm$ 0.12$\pm$0.05)Here we suggest that $\mu^+ \to e^+ + \nu_e^- + \nu_\mu^-$ decays may contribute to LSND excess. Although it appears that $\mu^+ \rightarrow e^+ + \nu_e^- + \nu_\mu$ decay may not explain the LSND excess but the flux of ν_e^- for both the decay may contribute so that the LSND excess can be explained. If $[\phi(\nu_e)/\phi(\nu_\mu)] = 3.1\times10^{-3}$ (13) using the similar procedure as in previous section, we get the observed LSND excess. According to us some of the excess may come from $\mu^+ \rightarrow e^+ + \nu_e^- + \nu_\mu$ decay. We note also that the excess ν_e^- event may also come from $\pi^- \rightarrow \mu^- + \nu_e^-$.

6. ATMOSPHERIC NEUTRINO ANOMALY

The lepton number violation process ($\pi^+ \rightarrow \mu^+\nu_\mu$, $\mu^+ + \nu_\tau$, $\mu^+ + \nu_e$ and $\mu^+ \rightarrow e^+ + \nu_e(\nu_e^-) + \nu_\mu^-(\nu_\mu)$ as described in earlier section can explain the atmospheric neutrino anomaly [4] if we consider $\pi^\pm \rightarrow \mu^\pm + \nu^\pm$, where $\nu^\pm$ flux can be written as $\phi(\nu) = \phi(\nu_\mu) + \phi(\nu_\tau) + \phi(\nu_e)$ (14). In the high energy region i.e.,$E_\nu \geq 1$ Gev, $[\frac{\phi(\nu_e)}{\phi(\nu_\mu)}] \approx (2-3) \times 10^{-3}$ (15) so we can write $\phi(\nu) \approx \phi(\nu_\mu) + \phi(\nu_\tau)$, since the experimental result suggests that R'=$R_{Data}/R_{Mc} \approx 0.7$ and if $[\phi(\nu_\mu)/\phi(\nu_\tau)]$= 7/3 , $[\phi(\nu_\tau)/\phi(\nu)]$= 3/10 and $[\phi(\nu_\mu)/\phi(\nu)$=7/10 then the atmospheric neutrino anomaly and also K2K experimental result can be explained.If there is ν_e disappearance we cannot explain the atmospheric neutrino anomaly.

7. DISCUSSION

The lepton number violation scheme mentioned above do not need neutrino oscillation mechanism.It may be mentioned that we do not need different neutrino masses to determine the different observational data in order to prefer neutrino oscillation scheme for the solution of the above mentioned problems. By observing τ lepton from high energy pion decay in the accelerators we can have information for the indication of possible lepton number violation scheme.The neutrino factory,LAMPF and high energy accelerators will be ideal place for such anomalous decay of pion and muon to prove or disprove our suggestion.A new experiment, Mini-Boone,will confront the flavour oscillation hypothesis. In the case of negative results we will be able to conclude that LSND excess was not due to neutrino oscillation.

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