PROCEEDINGS OF SCIENCE

PoS(NuFACT2018)046

Constraining neutrino transition magnetic moments

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The article report a preliminary result of neutrino transition magnetic moments using DUNE LAr, HK and JUNO detectors. Neutrinos, if Majorana particles, because of the combined effect of magnetic field and matter effect in core-collapse supernova can transform some of ν_e to $\bar{\nu}_e$ due to spin flavour conversions. As a result of this conversions the inverse beta decay signal will have an increment indicating evidence of transition magnetic moments. The DUNE LAr is sensitive to ν_e, so will observe a deficiency of ν_e due to this conversion whereas both HK and JUNO which are sensitive to $\bar{\nu}_e$ will see excess of $\bar{\nu}_e$. The DUNE LAr and JUNO are more or less sensitive to other type of neutrinos due to use of ^{40}Ar and ^{12}C. So can estimate the event ratio using both neutrinos and hence sensitivity on transition magnetic moments. Even an non observation of such conversion put a restrictive bound on the neutrino transition magnetic moments.

The 20th International Workshop on Neutrinos (NuFact2018)
12-18 August 2018
Blacksburg, Virginia

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1. Introduction

As a result of oscillation neutrinos have mass leading to a possibility of having magnetic moments. Hence neutrino flip to anti-neutrino [1] in the presence of transverse magnetic field. Astrophysical environment with high magnetic field can produce the signal of this flip and can be observed by detectors. We have used DUNE LAr, JUNO and HK detectors which are sensitive enough to detect the astrophysical neutrinos from supernova. In this article we present the detectability of such a signal in the detectors for typical supernova environment.

2. Neutrino magnetic moments

The theoretical predictions of neutrino magnetic moments [1] are given by Eqs. (2.1 & 2.2) for Dirac and Majorana neutrinos respectively. Dirac neutrinos has both diagonal and transition

$$\mu^D_{kj} \simeq \frac{3eG_F}{16\sqrt{2}\pi^2}(m_k+m_j)\times\left(\delta_{kj}-\frac{1}{2}\sum_{l=e,\mu,\tau}U^\star_{lk}U_{lj}\frac{m_l^2}{m_w^2}\right) \tag{2.1}$$

$$\mu^M_{kj} \simeq -\frac{3ieG_F}{16\sqrt{2}\pi^2}(m_k+m_j)\times\sum_{l=e,\mu,\tau}Im\left[U^\star_{lk}U_{lj}\right]\frac{m_l^2}{m_w^2} \tag{2.2}$$

elements whereas there is only transition components for Majorana neutrinos. Each element of magnetic moment is proportional to the corresponding neutrino mass and vanishes in the massless limit. So for non-zero magnetic moments, the spin can precess in a transverse magnetic field [1].

3. Analysis & Results

For the analysis we have used neutrinos from core-collapse supernova [2] as shown in the left panel of Fig.1. These spectrums (ν_e & $\bar{\nu}_e$) are used for detection by DUNE LAr, JUNO & HK dectors using relevant charged-current neutrino interactions [2] with their targets and detector energy resolution in the energy range of $2-100$ MeV. In order to find the event rate due to spin flavour precission we have shown a correlation between transverse magnetic field ($B_\perp$:10^5-10^{15} G) and transition magnetic moments in two neutrino mixing. This shows that for higher field it will be able to probe the smaller values of magnetic moments and is shown in the right panel of Fig.1. For this work the matter interaction parameter ($\lambda(R)$) [3] has been taken in the range of $10-200$ km.

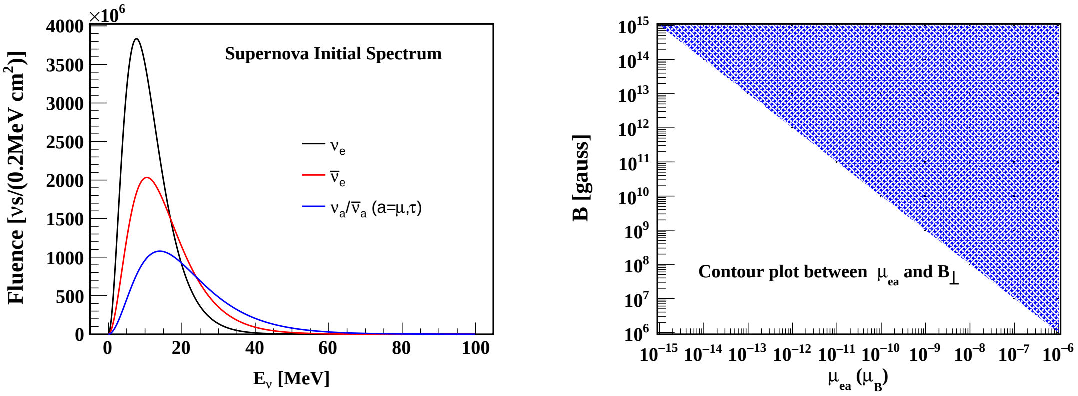

Figure 1: The initial core-collapse supernova spectrum (left panel) and the allowed region for transition magnetic moments vs transverse magnetic field (right panel).

The possible detection channels separately for ν_e and $\bar{\nu}_e$ by the three detectors before and after oscillations are listed in Table 1 for normal ordering (NO). Here we have used transverse magnetic field of the order of 10^{12} G and transition magnetic moments of the order of 10^{-12} μ_B.

Table 1: Event rates for ν_e and $\bar{\nu}_e$ channels before and after oscillation in three detectors.

Experiment	Channel	NO $\mu_{ea} = B = 0$	Ratio	NO $\mu_{ea} = 10^{-12}\mu_B$ $\mathbf{B} = 10^{12}$ **G**	Ratio
DUNE LAr (17 kton)	$\nu_e + ^{40}Ar \rightarrow e^- + ^{40}K$	10104.5	27.5	20201.1	19.2
	$\bar{\nu}_e + ^{40}Ar \rightarrow e^+ + ^{40}Cl$	367.503		1052.42	
	IBD	7705.57		16911.3	
JUNO	$\nu_e + ^{12}C \rightarrow e^- + ^{12}N$	914.165	8.9	1827.205	9.83
(20 kton)	$\bar{\nu}_e + ^{12}C \rightarrow e^+ + ^{12}B$	384.1985		1045.805	
	IBD	293850		648642	
HK	$\nu_e + ^{16}O \rightarrow e^- + ^{16}F$	300037.2	1.0	60034	11.39
(100 kton)	$\bar{\nu}_e + ^{16}O \rightarrow e^+ + ^{16}N$	11985.9		35144.5	

4. Summary & Future work

The probability of neutrino oscillation in the presence of high magnetic field can be affected if neutrinos have electromagnetic properties. So for systematic studies we have used the flux of supernova neutrinos with fixed values of μ_{ea} and B to see its effect on spin flip. In the Table.1 we have shown the number of events expected as a function of detected energy in DUNE, JUNO and HK detectors. The observed ratios between $(\nu_e, \bar{\nu}_e)$ for DUNE, $(\bar{\nu}_e, \nu_e)$ for JUNO and HK are increased by measurable order while comparing in presence and absence of magnetic field. A further study will be carried out by taking care of three body oscillation with colletive effects and the effect of backgrounds on signal for above three detectors [4].

References

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