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THE EXPERIMENTAL POSSIBILITY OF MEASURING THE MAGNETIC MOMENT OF NEUTRINO UP TO 10^{-11} OF BOHR MAGNETON WITH A NEUTRINO SOURCE

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It is shown that neutrino magnetic moment can be sensitively investigated by neutrino-electron scattering using high intensity artificial neutrino source.

The investigation has been performed at the Particle Physics Laboratory, JINR.

Экспериментальные возможности измерения магнитного момента нейтрино до 10^{-11} магнетонов Бора от нейтринного источника

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Исследования нейтрино-электронного рассеяния очень чувствительны к вкладу рассеяния, обусловленного магнитным моментом нейтрино. Показано, что магнитный момент нейтрино может быть измерен на подземной установке Бориксино с помощью высокоинтенсивного искусственного источника нейтрино.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

The existence of magnetic moment of neutrino is already beyond the Standard Model (SM is QCD + electroweak theory). The leptons in SM are left-handed chirality. The alternative way to the SM is the generalisation of SM in a way to include a right-handed chirality states [1]. This leads for neutrino to have a magnetic moments and it does not depend on the neutrino having or having not a mass. Also there are the sensitivity to the type of neutrino:

— Dirac neutrino has a right-handed singlets and magnetic moment is proportional to the mass of neutrino;

— Majorana type of neutrino has no singlets and magnetic moment is equal to zero.

There are two experimental facts which are in the favour of the existence of magnetic moment of neutrino.

— Deficit of neutrino flux from the Sun.

— Anticorrelation of neutrino flux with the Sun activity.

If the solar neutrino flux is correlated with the solar cycle, the most viable scenarios advanced so far have built upon a large neutrino magnetic moment. The Standard Model predicts $\mu_\nu \sim 10^{-19} \mu_B$. For solar scenarios, values of the order of 10^{-11} μ_B are desired. The discovery of such a moment would thus clearly compel new physics beyond the SM. Serious theoretical efforts are being made to explore new concepts leading to a large magnetic moment combined with a small neutrino mass [2,3,4]. At present, laboratory measurements limit the value of μ_ν less than 4×10^{-10} μ_B.

The key points for the explanation of the experimental facts are the following. The passage of Dirac neutrinos with (diagonal) neutrino magnetic moment through distances of the order of the convection zone of the Sun in the presence of a magnetic field can induce a spin precession resulting in a right-handed neutrino. Since this object is normally considered sterile, hence undetectable at Homestake, a change in the neutrino flux would result. With a magnetic field correlated with the solar cycle, the neutrino flux could follow suit via this mechanism. A Majorana neutrino transition magnetic moment, with only off-diagonal elements, interacting with a solar magnetic field, converts both spin and flavor. This effect must therefore be considered in a coupled fashion with the MSW effect.

The implications of such a scenario are: a moment $\sim 10^{-11}$ μ_B together with a magnetic field of $\sim 10^4$ gauss in the convection zone of the Sun and a field $\sim 10^6$ to 10^7 gauss in the center of Sun are necessary. This scenario is valid for $\Delta m^2 < 10^{-9}$ eV^2, thus, neutrino mass/mixing parameters or the MSW effect play no role.

Neutrino magnetic moments can be sensitively investigated by neutrino-electron scattering using a strong radioactive sources of antineutrinos and neutrinos. The presence of a magnetic moment adds a new component to the scattering cross-section.

Weak elastic antineutrino-electron scattering is

$$\frac{d\delta}{dT}(q) = \delta_0 \left[Q_i^2 + Q_r^2 \left(1 - \frac{T}{q}\right)^2 - Q_i Q_r \frac{m_e T}{q^2} \right],$$

where $\delta_0 = 88.3 \times 10^{-46}$ cm^2; $Q_i = \sin^2\theta_w$; $Q_r = \frac{1}{2} + \sin^2\theta_w$; m_e, mass of electron; T, recoil energy of electron; q, energy or antineutrino; θ_w, angle of Weinberg. For νe-scattering $Q_i = \frac{1}{2} + \sin^2\theta_w$ and $Q_r = \sin^2\theta_w$.

The electromagnetic cross-section is:

$$\frac{d\delta}{dT}(q) = \frac{\pi\alpha^2}{m_e^2}\mu_\nu^2\left(\frac{1}{T} - \frac{1}{q}\right),$$

where α is a fine structure constant.

The recoil electron spectrum rises rapidly at low energies unlike the flat profile of weak ν-e scattering, consequently, the cross-section is larger, the smaller the lower cut-off on the recoil energy. Furthermore, the recoil spectral profile in scattering provides a diagnostic magnetic signature by the $1/T$ dependence.

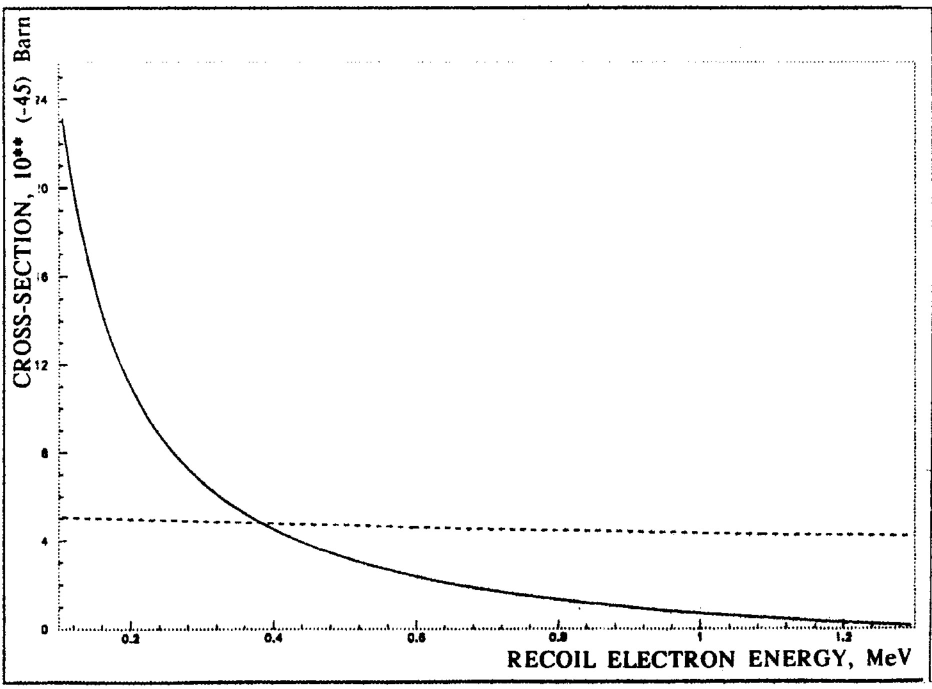

Fig.1. Electromagnetic and weak cross-section as a function of recoil electron energy

In Fig.1 the comparison of the weak and magnetic ν-e scattering cross-section with $\mu_\nu = 1.5 \times 10^{-10} \mu_B$ as a function of the electron recoil kinetic energy T is presented.

To detect such low energy recoil energy of electron we are going to use the Borexino detector at the Gran Sasso Underground Laboratories in Italy [5]. The Borexino will provide a high quality low-energy neutrino spectrometry with a low threshold ($\geq$ 0.2 MeV). We plan to investigate antineutrino-electron scattering using a laboratory radioactive source of $Sr^{90} - Y^{90}$, which emits antineutrino. The proposal to use a neutrino source to measure a magnetic moment of neutrino was presented in Singapore XXY Conference on High Energy Physics by R.Raghavanm P.Raghavan and the author [6]. With such a source the low energy scattering signal in Borexino also can be calibrated. A 1 *Mci* Sr^{90} source placed just outside the fiducial volume of detector will induce a signal of the same order as a Sun. Besides that an important advantage of the source measurement is its differential nature (source «on» — source «of») so that the background concerns are peripheral.

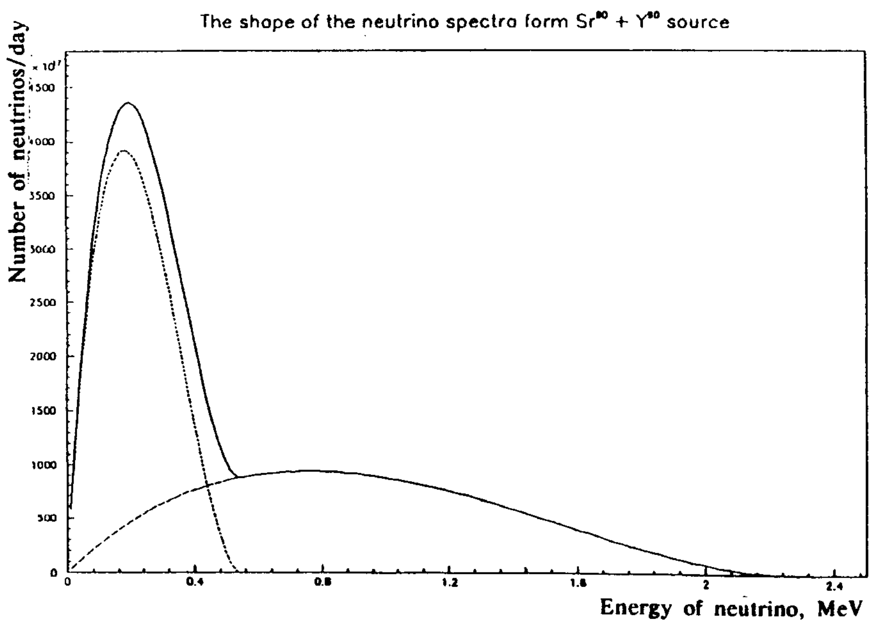

Fig.2. The neutrino spectrum from the $Sr^{90} - Y^{90}$ source. Dashed line is the activity after 1000 days

Sr^{90} ($T_{1/2} = 28\,y$, $E_{max} = 0.56$ MeV) and Y^{90} ($T_{1/2} \equiv 64\,h$, E_{max} + + 2.27 MeV) emit 2 $\tilde{\nu}e$'s/Sr decay at equilibrium. Both β^--decays are unique forbidden types with precisely calculable shapes. The $\tilde{\nu}$-spectrum from this source of 1 *Mci* is shown in Fig.2. The scattering cross-section averaged in the energy region 0.2 to 0.8 MeV (the usual low energy signal window in Borexino) is calculated to be equal to $21 \times 10^{-46}\,cm^2$. 1 *Mci* source ($10^{16}\,\tilde{\nu}$/sec) placed near fiducial volume (3.5 m from center of Borexino) can produce a $\tilde{\nu}e$ — signal of 72 events/day due to a weak interaction. With a half year's exposure, the $\tilde{\nu}e$ — cross-section can be measured to a precision of a few percent.

The presence of a magnetic moment of the order $\sim 10^{-10}$ can be easily detected in Borexino.

The signal enhancement due to magnetic neutrino scattering as a function of μ_ν is shown in Fig.3. This curve indicates that with a precision of a few percent of the scattering cross section, an upper limit

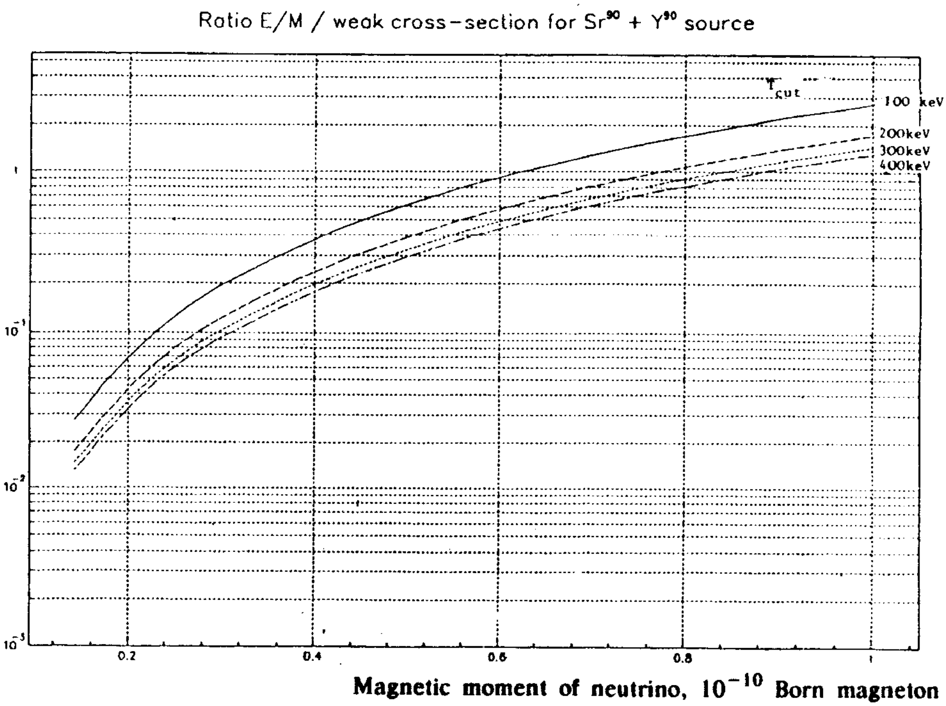

Fig.3. Enhancement of $\tilde{\nu}e$-scattering signal as a function of neutrino magnetic moment

of 2×10^{-11} can be set in Borexino. This value is by a factor of ten below the present limits.

So, in conclusion, using a neutrino source we will be able to estimate an electromagnetic scattering in $\tilde{\nu}e$-scattering, to put a limit for right-handed helicity states of neutrino.

From the detector's point of view the $\tilde{\nu}$-source would allow one to evaluate a background, to prove a convolution method of pattern recognition of ν-e events and to study a possible systematic errors.

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