EXPERIMENTAL ESTIMATE OF INTERACTION OF ANTINEUTRINO WITH MATTER AT LOW ENERGY TRANSFERS

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We have obtained experimentally the upper bound of the specific energy loss of reactor antineutrino ($\tilde{\nu}$) in matter, $j \leq (0.4 \pm 0.9)\times 10^{-15}$ MeV-cm^2/g, and the upper bound of the ionization cross section, $\sigma \leq (0.5 \pm 0.5)\times 10^{-36}$ cm^2/electron. The results exclude the possibility of explaining the problem of observation of solar neutrinos by using the anomalous energy loss with an energy transfer $\mathcal{E} \gtrsim 10$ eV in each interaction act, assuming that the ν and $\tilde{\nu}$ interactions with electrons are equivalent.

The absence of an observable effect from solar neutrinos [1] has given rise to several hypotheses [2 - 6]. In one of them [6], attention was called to the fact that the available facts do not exclude the possibility of absorption of the neutrino (ν) energy in solar matter via small energy transfers ($\mathcal{E}$ < 100 keV). It is indicated there also that in the case of the spectrum of reactor antineutrinos ($\tilde{\nu}$), the specific energy loss (j) region of interest from this point of view begins with $j \gtrsim 5\times 10^{-13}$ MeV-cm^2/g. The earlier direct measurements of the specific losses yield for j the very rough estimate [7]

$$j \lesssim 10^{-3}\ \text{MeV-cm}^2/\text{g}$$

The specific loss can also be determined by measuring the ionization cross section with the aid of a Geiger counter. Using the best results obtained by this method [8], with an Ra beta source ($E_{max} \sim 1.2$ MeV), $\sigma \leq 10^{-31}$ cm^2/electron$^{1)}$, we can conclude that $j \leq (6\times 10^{-13} - 3\times 10^{-9})$ MeV-cm^2/g for an energy transfer $\mathcal{E}$ = 20 eV - 100 keV per ionization act.

We present here the result of an experiment in which we obtained lower bounds on j and σ. The experiment was performed with a reactor, in an antineutrino flux $\Phi = 2.5\times 10^{11}$ $\tilde{\nu}$/cm^{2}sec, by two methods: a current method for direct determination of j, and with a Geiger counter. In both cases, the detector was placed in a special shield consisting of 10 cm steel on the outside, 10 cm borated paraffin, 15 cm lead, and 10 cm cast iron on the inside.

In the measurement by the current method we used a low-background NaI crystal (70 mm diam × 300 mm) with an FEU-52M photomultiplier. The correspondence between the value of the current and the intensity of the light scintillations was established with the aid of an optical diode. To increase the sensitivity we subtracted from the total photomultiplier current the current corresponding to the spectral region above 70 keV. The measurements were performed with the reactor turned on and off, and the current difference was used as the upper limit of the effect due to energy loss in the crystal. As a result of several measurements, we obtained the upper bound of the neutrino energy in matter:

$$j \leqslant (0{,}6 \pm 0{,}9)\cdot 10^{-15}\ \text{MeV-cm}^2/\text{g} \quad \text{for} \quad \mathcal{E} \lesssim 70\ \text{keV}.$$

The detector used to measure the ionization cross section was a type SI-5G Geiger counter surrounded by a blanket of like counters connected for anticoincidence with the main counter to eliminate the cosmic-ray background. The difference between the counts obtained with the reactor on and off was ascribed to the antineutrino effect. Under this assumption, the obtained upper bound of the cross section for the interaction between reactor antineutrinos and the electrons of the argon gas filling the counter is

$$\sigma \leqslant (0{,}5 \pm 0{,}5)\cdot 10^{-36}\ \text{cm}^2/\text{electron}$$

corresponding to $j \leq 6\times 10^{-18} - 3\times 10^{-14}$ MeV-cm^2/g for the energy-transfer interval $\mathcal{E}$ = 20 - 100 keV, with one standard deviation.

Thus, the results exclude, with a margin amounting to several orders of magnitude, the possibility of explaining the problem of the solar neutrinos by anomalous energy losses in matter with transfer of an energy $\mathcal{E} \gtrsim 10 - 20$ eV to the electron in each interaction act.

In conclusion, we thank A. I. Afonin for help with the experiment.

[1] A lower cross section limit was obtained in [9] by using a tritium source. This limit is not considered here, in view of the much lower antineutrino energies.

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MECHANISMS OF NEUTRON GENERATION IN A LASER PLASMA

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The mechanisms whereby neutrons are generated in a plasma are discussed on the basis of the experimental data for different heating regimes. It is established that in the case of sharp focusing of the radiation (10 - 20 GW power and 2 nsec duration) the bulk of the neutron yield is due to gasdynamic acceleration of the expanding plasma, and is nonthermal in character. In the case of spherical irradiation (power 300 GW, duration 1.5 nsec), the neutrons produced in a dense CD_2 plasma (10^7/pulse) are thermal.

1. Various mechanisms of nonlinear interaction between high-power laser radiation and a dense plasma and the possible particle-acceleration mechanisms, which may in particular be the cause of neutron generation in a laser plasma, have been under discussion of late [1 - 3]. We present here results that allow us to state that, depending on the conditions, both thermal and nonthermal neutrons are produced in experiments with laser plasma. The measurements were performed both with sharp focusing of the emission of a single-channel laser on a massive CD_2 target and with spherically-symmetrical irradiation of a CD_2 particle of ~ 100 μ diameter by emission from a multichannel laser setup [5].

2. Sharp focusing on a massive target. The laser power was 10 GW, the light pulse duration 2 nsec, and the neutron yield 10^4 neut/pulse. Oscillograms of the neutron pulses obtained with the scintillation detector placed ~ 10 cm from the target, are shown in Fig. 1. The neutron pulse delay relative to the instant of plasma heating greatly exceeds the ~ 5 nsec neutron flight time, and a second neutron pulse of smaller amplitude appears after 40 nsec. When a screen of CD_2 is placed inside the chamber, the delay time decreases and an increase in the signal amplitude is observed (Fig. 1b). This allows us to conclude that in the case of sharp focusing the neutrons are produced as a result of the beam deuterons emitted from the plasma with the deuterium absorbed either on the chamber walls or in the screen.

Two successive neutron pulses obviously correspond to different deuteron groups accelerated to different velocities. Recognizing that there is no direct neutron generation in the plasma itself, we can assume that the deuterons are accelerated mainly outside the dense core of the plasma, in a rarefied envelope. The slower deuterons with energy $E_d \sim 5 - 10$ keV are in all probability due to gasdynamic expansion of the plasma [6]. With respect to the fast deuterons ($E_d \sim 40$ keV), it can be assumed that they are accelerated by the electric field produced by emission of the high-energy electrons responsible for the hard x-rays [4].