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Review Article

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Is It Possible to Build a Simple Telescope for Solar Neutrinos Registration?

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About the problem

The question of neutrino registration is closely related to the problem of beta decay.

The question of whether the phenomenon of radioactive decay is purely accidental was actively discussed at the beginning of the last century, in particular, at Solvay congresses.

N. Bohr and other creators of quantum mechanics proved that radioactive decay is a consequence of the quantum mechanical tunneling effect.

Einstein and his supporters categorically objected to the fact that this phenomenon could be accidental.

A little later, almost the entire physical community leaned towards the point of view of N. Bohr and his colleagues. Currently, on the basis of quantum mechanical evidence, the phenomenon of nuclear decay is considered purely accidental.

Beta-decay and solar neutrinos

However, in 2001, one of Einstein's supporters, Prof. E. Falkenberg, published an article entitled "Radioactive Decay Caused by Neutrinos?". In it, he gave experimental evidence that beta-decay does not occur by chance, but under the influence of neutrinos, and the decay rate in the Earth laboratory is determined by the total neutrino flux (from cosmic sources and the Sun).

According to his data, solar neutrinos change the beta-decay rate, modulating it to a depth of about 0.4% with a period of equal to the year (Figure 1). This remarkable result was subsequently repeatedly verified and confirmed by various researchers on various beta-isotopes [2, 3].

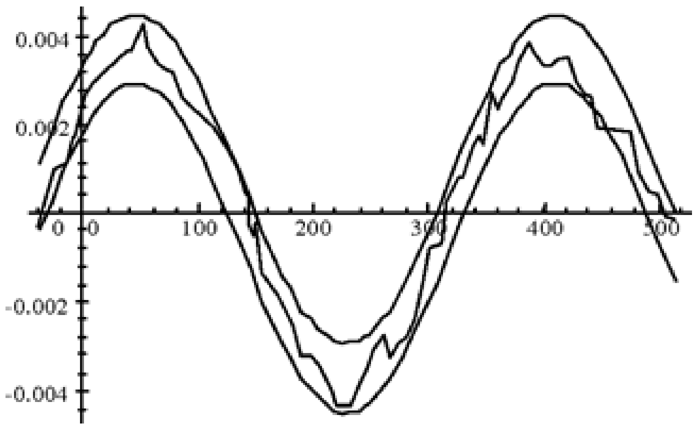

Figure 1: Modulation of the beta-decay rate induced of the solar neutrino flux, discovered by E. Falkenberg [1].

Experiments on a Nuclear Reactor

The measurements carried out by Falkenberg and his followers seem to be quite convincing evidence that beta-decay is caused by a neutrino flux. But it seems important to put such an experiment in which the rate of beta-decay could be controlled. Such an experimental approach is possible if to use the neutrino flux generated by a nuclear reactor. It gives the control of the neutrino flux and of the induced the beta-decay rate. The described experiment was carried out on the IBR-2 pulse reactor (Dubna) [5].

The result of these measurements is shown in Figure 2.

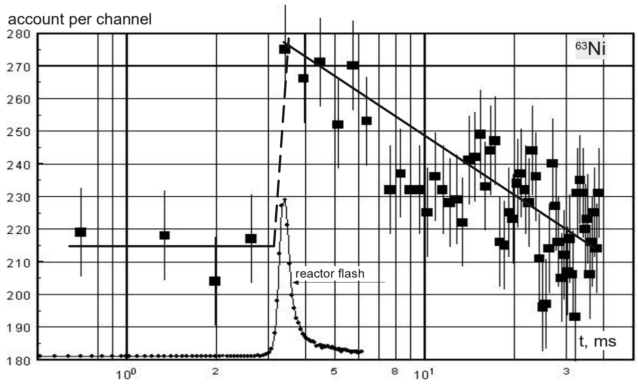

Figure 2: The result of the effect of reactor neutrinos created by a pulsed reactor on the decay rate in the beta-source 63Ni placed in the stream of these neutrinos.

At a time about 3 ms after the start of the registration process, there was a flash of reactor activity, shown in the figure. On the abscissa axis in logarithmic scale, the time is postponed in msec. This figure shows the power surge of a pulsed nuclear reactor, which occurs approximately 3 ms after the start of measurements. The black squares show the count of beta-electrons emitted by the nickel-63 source. It can be seen from the figure that beta-electrons are registered at a certain low level before the reactor flare. During the are-up, isotopes accumulate in the reactor core, during the decay of which neutrinos are emitted. At the same time, the measuring part of the installation is carefully protected from the ingress of neutrons and gamma-quanta, which they could cause a parasitic signal in the detector, so that only neutrinos pass through this protection.

Analysis of the rate of decline of the beta-electron count after the are shows that the neutrinos emitted by the reactor core are generated mainly by boron- 12 and boron-13 nuclei, which are formed as nuclear fuel fission fragments. The successful result of this experiment is due to the fact that neutrinos emitted by both isotopes-boron-12 and boron-13-have a high boundary energy (about 13 MeV) and therefore have a very noticeable effect on the beta-electrons of Ni-63, whose energy below 0.06 MeV. This makes it relatively easy to isolate from the total number of beta electrons generated by the source those that arose due to interaction with reactor neutrinos.

Measuring this effect on other isotopes which have greater energy of beta- electrons shows that this effect is much weaker and in this case it is more difficult to register [4, 5]. The cross section of the neutrino interaction in exo-energetic reaction of beta-decay is on much orders value more than it in endo-energetic reaction of reversed beta-decay. It was considered in [6].

An important argument proving the correctness of the experimental results obtained is their agreement with the values of neutrino fluxes, which are calculated independently. The cosmic neutrino flux is known from published literature data. Its intensity determines the full activity of the beta source. The flux of reactor neutrinos can also be found according to the corresponding reference books.

Thus, the ratio of the flux of reactor neutrinos to the flux of cosmic neutrinos is a priori a known quantity. The ratio of the effect of reactor neutrinos on the beta-source to the total intensity of the source should be equal to the ratio of the corresponding neutrino fluxes on which beta-decays depend. The measurements fully confirmed this theoretical position. The measurement results showed that these ratios are equal up to a factor of the order of two [6].

At the same time, this coincidence indicates the reliability of the experimental data obtained, since it can be considered absolutely improbable that some

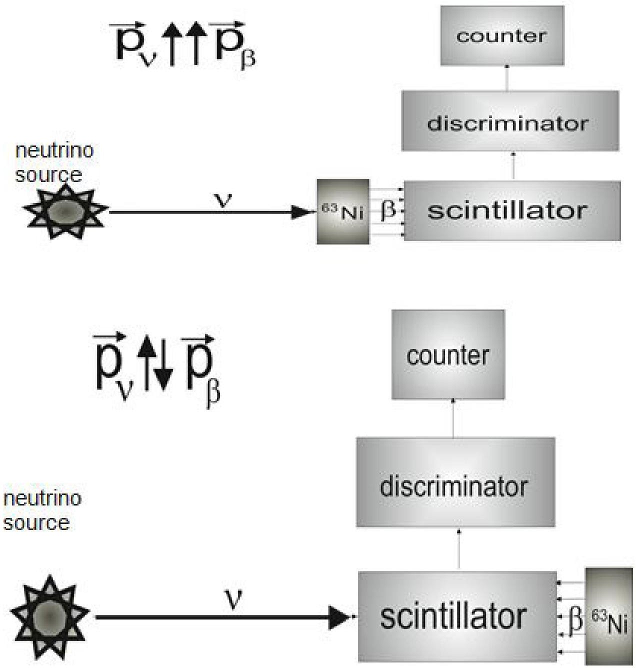

Figure 3: Illustration of the difference in the effect of neutrinos on beta-electrons in the consonant (upper picture) and counter (lower picture) direction of the fall of reactor neutrinos and beta electrons.

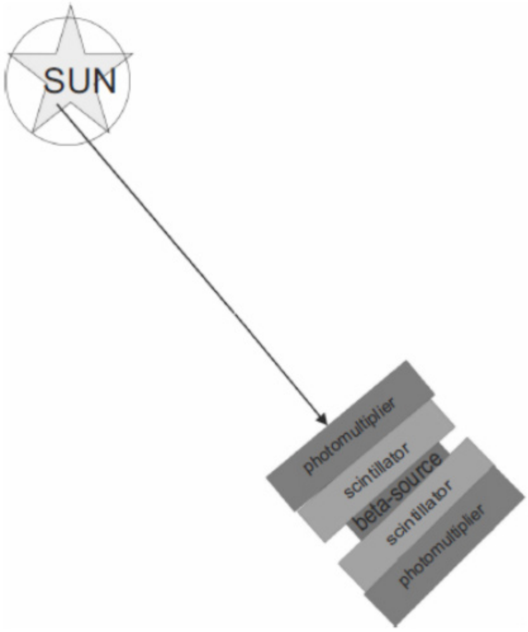

Figure 4: A technique for measuring the difference in the effect of neutrinos on the beta-spectrum in the consonant and counter direction of neutrino and beta electron pulses.

unknown effect of a different nature (not neutrinos) caused there would be an acceleration of decays in the beta source in the interval between the reactor flares, and which would be exponential in shape and would have a value corresponding to the ratio of two neutrino fluxes.

On the Principe of a Solar Neutrino Telescope

An important feature noticed when registering the effect of reactor neutrinos on beta-sources was due to the fact that the beta-electrons induced by neutrinos had an energy slightly exceeding the boundary energy of the beta-spectrum under normal conditions. The reason for this was the inelastic nature of the interaction of neutrinos with beta-decaying nuclei (in our experiment, the boundary energy of neutrinos was about 13 MeV). With an inelastic impact, some part of the neutrino energy was transferred to beta-electrons (in our case in the experiment, their boundary energy was about 63 keV).

The inelastic nature of the effect of neutrinos on beta-electrons facilitates the registration of their interaction with the difference measurement method.

Measuring the difference in the effect of neutrinos on the beta-spectrum in the consonant and counter direction of neutrino and beta-electron pulses (Figure 4) opens up the possibility to measure the flux of solar neutrinos, as well as to investigate the possible anisotropy of cosmic neutrino fluxes.

Due to the fact that the ratio of the magnitude of the solar neutrino flux to the total flux of cosmic neutrinos is known from Falkenberg's experience and is approximately equal to $4 \cdot 10^{-3}$, it is possible to estimate the amount of beta-source activity at which the solar neutrino flux can be registered. If we assume that the time of one measurement can be approximately equal to 10^3 sec, then in order to isolate solar neutrinos, the registration rate of beta-electrons must exceed 10^4 *beta/sec*.

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