Memoirs of the Faculty of Engineering, Kyushu University, Vol.73, No.1, June 2013

Study on Correlation between Electrochemical-Neutrino-Detector Signal and Solar Wind Velocity

by

Shouhei NAKAMURA[*], Norichika TERAO[**], Nur AIDA[*] and Kenji ISHIBASHI[***]

(Received May 7, 2013)

Abstract

We have developed an electrochemical detector which is sensitive to both reactor neutrinos and natural background neutrinos. The output current of the detector produces a peak at the first 1-3 days, as initial peak. The Initial peak shows a large variation in individual measurements for natural background neutrinos. In experiments in certain period, the initial peak had a relationship to the solar wind. Further experiments were carried out to study the correlation between the solar wind and the initial peak. From the experimental result for 21 months, it was found that the initial peak has no correlation with the solar wind. This suggests that the detector is either insensitive to electron neutrinos, or capable of detecting them but the effect of solar wind variation was too small to be measured.

Keywords: Neutrino, Electrochemical detector, Scalar auxiliary field, Solar wind velocity

1. Introduction

A neutrino is electrically neutral, and makes only a weak interaction with a range much shorter than that of electromagnetic interaction. The neutrino is capable of passing through ordinary materials almost unaffected. The quite small interaction cross section of neutrino was successfully explained by the electroweak theory.[1)] For low energy solar neutrinos, measurements were carried out by radiochemical experiments such as GALLEX[2)] and SAGE[3)], where the neutrino detection threshold of 0.23 MeV. Neutrinos with energies below this energy have not been measured so far. It is natural to consider that neutrinos below this energy should show the behavior on an extrapolation. Nevertheless, neutrinos with de-Broglie wave

* Graduate Student, Department of Applied Quantum Physics and Nuclear Engineering
** Research Associate, Department of Applied Quantum Physics and Nuclear Engineering, on leave to Japan Atomic Energy Agency
*** Professor, Department of Applied Quantum Physics and Nuclear Engineering

length comparable to atomic or molecular size may induce unexpected reaction in addition to that of extrapolation.

It is known well that determination of electromagnetic potentials requires constraint conditions like Landau and Fermi gauges.[4] Such gauges accompany a scalar auxiliary field[5] (B^0 thereafter, $B^0 \approx \sum\left(\partial / \partial x^\mu\right)A^\mu$ for four-dimensional potentials A^μ). The auxiliary field B^0 possesses an energy density like electric and magnetic fields. When considerably low energy neutrinos receive certain strength of external field such as auxiliary field B^0, the external field may disturb the mass-generation mechanism of neutrinos. Although the mechanism is not elucidated, the external auxiliary field may give rise to influence to the neutrino mass state.

Biological materials may produce a certain field like the auxiliary field B^0. If low energy neutrinos receive the field, they may readily break into fragments due to a disturbed mass-generation mechanism. Some ions combined with such fragments were considered to generate the output electric signal electrochemically. On the basis of the above consideration, we have developed an electrochemical detector[6] and performed experiments for neutrinos measurement.

From the previous experiments, it has been found that the electrochemical detector produces a considerable output signal for nuclear-reactor neutrino irradiation. Almost all of the reactor-neutrinos are comprised of antielectron neutrinos. The detector operated under environmental condition is supposed to be sensitive to some kinds of neutrinos in natural background. They may be either electron neutrinos, antielectron neutrinos or both of them. - The detector tends to make a peak current at first 1-3 days (we called “initial peak” thereafter). The initial peak has large variation in individual measurements and the variance is several times larger than that in equilibrium after a few weeks.

As one of possible reasons for the variation, we are interested in solar activity. The solar activity has a periodicity of 28 days. Among the activity, the solar wind velocity also varies on the same periodicity. The solar wind has relationship to geomagnetism. Magnetic field in the relativistic treatment has a gamma-matrix property of vector type, and neutrino momentum also owns the same property as well. The sun is the major source of electron neutrinos and it has possibilities that the solar wind affect the transportation of electron neutrinos originated in the sun. Thus, it is not denied that there exist some correlation between the solar wind and electron neutrino flux on the earth. As a result by confirming our data of the past half year, we found a positive correlation between the solar wind velocity and the initial peak current. Therefore, we continue the experiment to study the correlation between the solar wind velocity and the initial peak current.

2. Experimental apparatus

The experimental apparatus and its working principle are explained briefly. **Figure 1** illustrates the cross section of the experimental apparatus.[6] The experimental apparatus was made in a Teflon container with a volume of about 100 ml. The Teflon container had purified water of 50 ml in the lower half region, where gold and glassy carbon plates were utilized as electrodes. Both plates were 20×50 mm in dimension. The thickness was 0.1 mm for the gold plate, and 1.0 mm for the glassy carbon one. Electrodes were boiled in nitric acid for cleaning the surface, and subsequently rinsed by ultrasonic wash in purified water. Before pouring in

the apparatus, purified water was bubbled by nitrogen gas for reducing oxygen dissolved. Raw silk is the biological product that is produced from silkworms. Raw silk fibers of 0.5 g in weight were set onto both sides of the gold plate (a total of 1.0g). Silk fibers of 17 mm long were used in most cases. A voltmeter with an input impedance adjusted to 1 MΩ was connected by conducting wires (typically copper) between the two electrodes. The experimental apparatus was placed in a temperature-controlled incubator at 27˚C (300K).

This apparatus generated a considerable electric voltage of tens of mV in the environmental condition.[6)] In addition, nuclear reactor neutrino irradiation increased the output voltage.[6)] The results indicate that this apparatus is sensitive to environmental and reactor low-energy neutrinos. It was inferred that the biological material produces the scalar auxiliary field B^0, which rapidly breaks a low-energy neutrino ($\xi_Q\xi_{Qd}$) into two groups of fragments: ξ_Q and ξ_{Qd}. The fragment ξ_Q has a weak charge Q and that of ξ_{Qd}

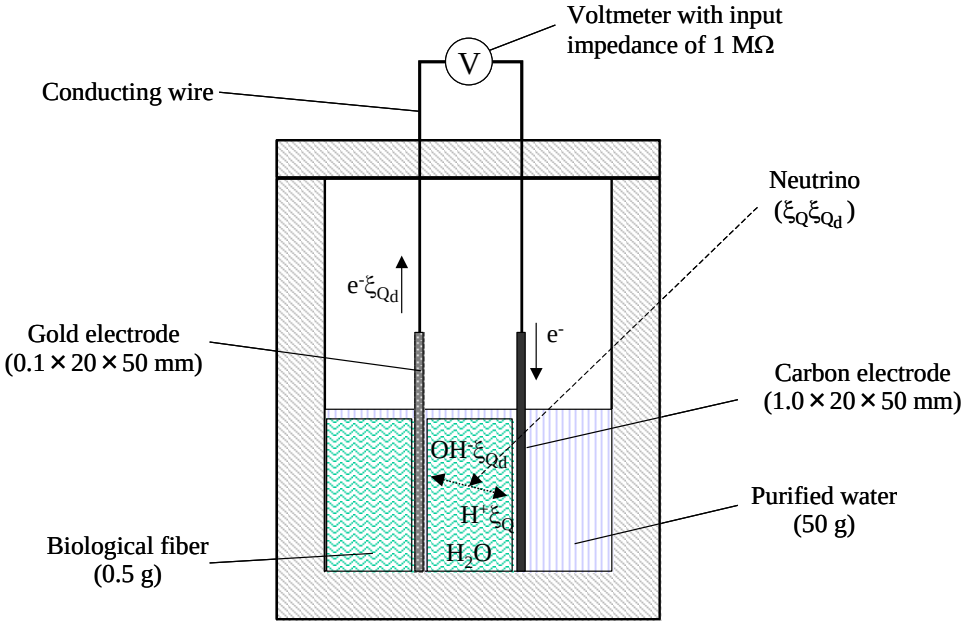

Fig. 1 Schematic view of the experimental apparatus.

owns a weak dipole moment Q_d. These fragments break up a water molecule into $OH^-\xi_{Qd}$ and $H^+\xi_Q$ ions as

$$\xi_Q\xi_{Qd} + H_2O \rightarrow OH^-\xi_{Qd} + H^+\xi_Q \ . \quad (1)$$

For simplicity, only ions were indicated in **Fig. 1**. The $OH^-\xi_{Qd}$ ions move to the gold electrode, to which electron-ξ_{Qd} pairs in spin coupling are transferred. A recombination of two $OH^-\xi_{Qd}$ may make water, oxygen and electron-ξ_{Qd} pairs as

$$2OH^-\xi_{Qd} \rightarrow H_2O + (1/2)O_2 + 2e^-\xi_{Qd} \ \text{(gold electrode)} \ . \quad (2)$$

The e-ξ_{Qd} pairs conduct through a metallic wire to arrive at the glassy-carbon electrode. Meanwhile, the $H^+\xi_Q$ ions diffuse toward the glassy-carbon electrode, combine with oxygen molecules, and absorb electrons to form water molecules as

$$2H^+\xi_Q + (1/2)O_2 + 2e^- \rightarrow 2(H\xi_Q)_2O \ \text{(carbon electrode)} \ . \quad (3)$$

A current is thus induced in the circuit between the electrodes. Consequently, the output voltage of the apparatus experimentally appears over the input impedance.

For the basic signal of this apparatus, initial peaks appeared around 2-3 days and they disappeared quickly. At first, we took the scenario as follows. It seems to take few days for $OH^{-}\xi_{Qd}$ to be accumulated by eq. (1) and to diffuse toward the gold electrode. Following the reaction of eq. (2), oxygen molecules O_2 are generated and accumulated and they should diffuse toward the carbon electrode. The accumulation and diffusion of O_2 seem to be insufficient during few days. Accordingly the output voltage appears by the reaction between initial H^+ (or some other ions) and O_2 remaining at the early stage (2 days) in the apparatus, but it disappears soon after consumption of the ions and O_2.

3. Experiments

We prepared six electrochemical detectors, that is, we obtain six signals to give more reliable tendency under environmental conditions. The experimental apparatuses were placed in the incubator at a temperature of 27 degrees centigrade. The run time was typically 20 days in each period.

As an example, the output voltages of six detectors (no. 1-6) are shown in **Fig. 2**. The wire connection method was changed to employ silver-paste bonding, instead of use of soldering in the previous experiment.[6] This promotes the output voltage almost twice, and produces the value around 100 mV. The standard deviation of output signal is 10 % in one sigma, and three times as large as the previous experiments. The signal growth to the twice magnitude is supposed to be related to the increase of B^0. The three-fold variation may be ascribed to the fluctuation in B^0 growth in the apparatus.

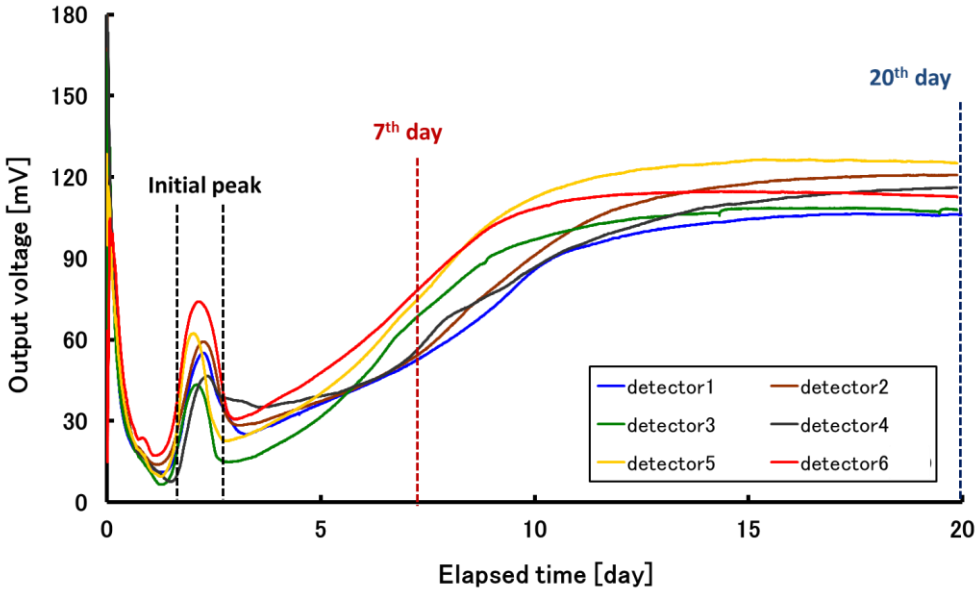

Fig.2 Example of output voltage as a function of elapsed time for individual detectors.

4. Influence by solar wind and geomagnetic indices

The environmental neutrinos may be influenced by solar activities. We searched the correlation between the output voltage and the solar characteristics data available by an artificial satellite and observatories. The solar wind is a stream of charged particles ejected from the upper atmosphere of the sun with kinetic energies usually between 10 and 100 keV. We took the Real-Time Solar Wind (RTSW) data from the spacecraft of Advanced Composition Explorer (ACE) which were available by the Space Weather Prediction Center (SWPC) as updating data lists and plots. **Figures 3-1 to -4** present the relationship between solar wind velocity and the average output voltage at three different days of elapsed time. Here, the data of solar wind velocity are referred at the instantaneous value corresponding to the time of the initial peak. For the initial peak, the time duration of output voltage reaching the maximum value varies in each measurement, so that, the horizontal error bar is specified only for the initial peak average. For the data of 7th and 20th days, the times at measurement are uniquely determined as those days. The data of solar wind velocity referred have a small variation for each detector. Thus, the plots of 7th and 20th days have horizontal error bars of a very small range.

We classified the data of output signals according to the period in measurement: Data 1 was obtained during Nov. 2010~Feb. 2011, Data 2 Apr. 2011~Jul. 2011, Data 3 Oct. 2011~Jan. 2012 and Data 4 Jan. 2012~Jul. 2012. The numbers appearing in **Figs. 3-1 to -4** stand for the measurement order in experiments. The dashed line in the figure was drawn by the least-square-fit to the output voltage at the initial peak point. The data at the initial peak tend to show some correlations. For paired data $(x_i,\ y_i)$, the Pearson correlation coefficient r is given by

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}\ , \qquad (4)$$

where $\bar{x}$ and $\bar{y}$ are the sample mean of x_i and y_i, respectively.

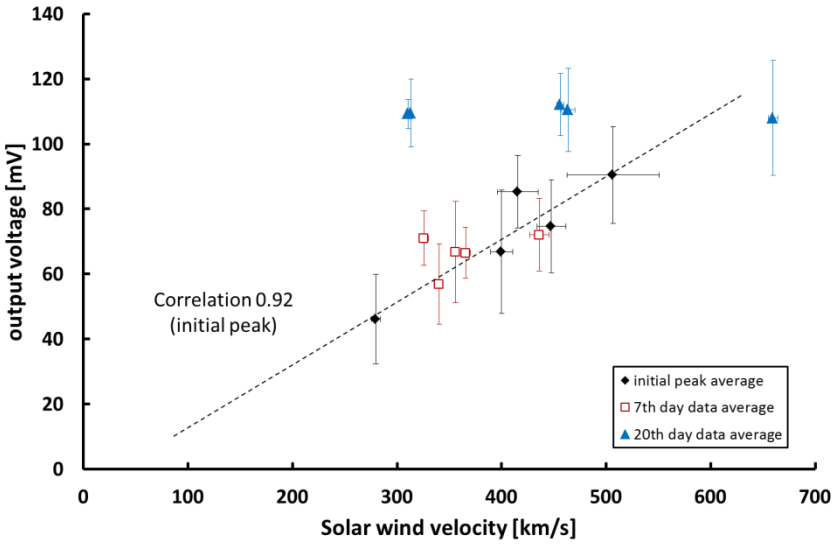

Fig. 3-1 Correlation between the output signal and solar wind velocity for Data 1 (Nov. 2010~Feb. 2011).

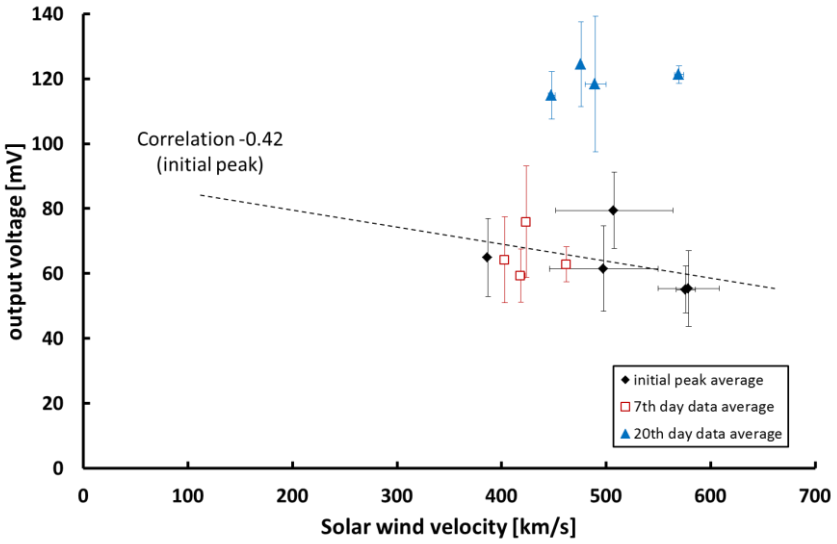

Fig. 3-2 Correlation between the output signal and solar wind velocity for Data 2 (Apr. 2011~Jul. 2011).

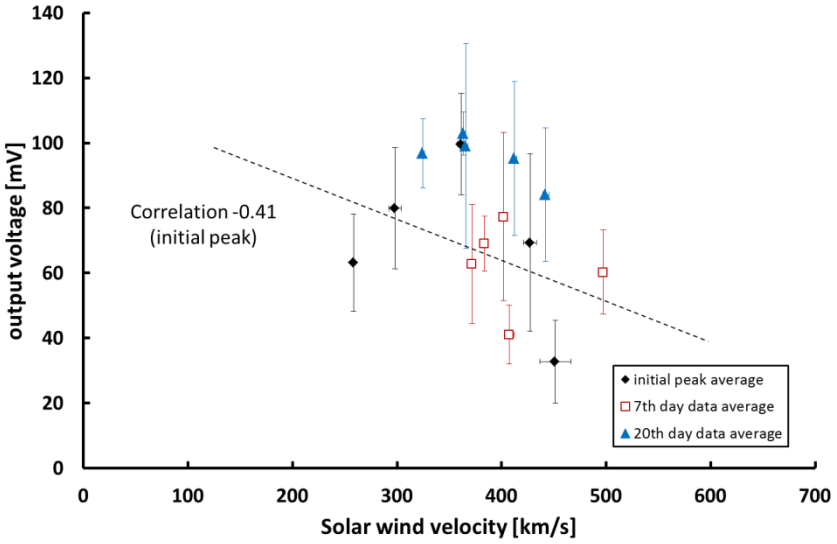

Fig. 3-3 Correlation between the output signal and solar wind velocity for Data 3 (Oct. 2011~Jan. 2012).

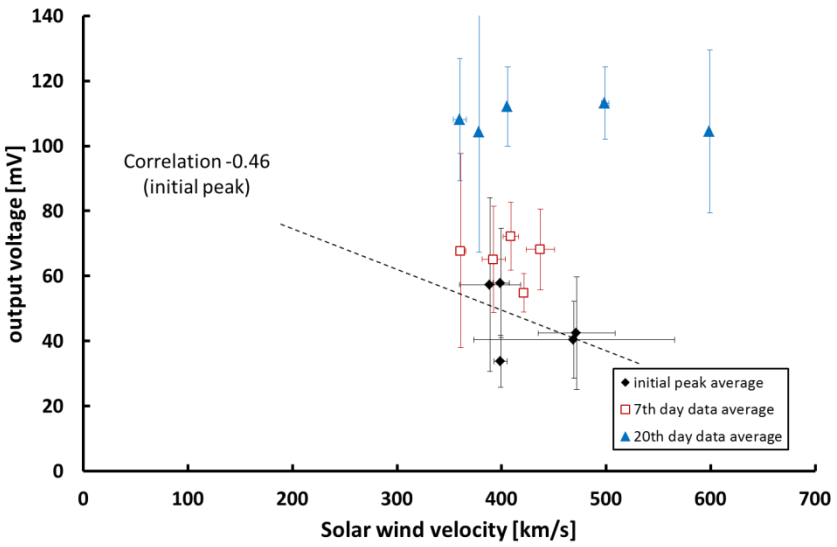

Fig. 3-4 Correlation between the output signal and solar wind velocity for Data 4 (Jan. 2012~Jul. 2012).

The dashed line in **Fig. 3-1** exhibits a good correlation (0.92). The positive correlation suggests that the apparatus may be sensitive to electron neutrinos. This is contradictory to the previous experimental result that the output signal of the apparatus was influenced by the reactor neutrinos of almost pure antielectron-type. The question in the contradiction motivated us to carry out further experiments. The further experimental data do not show appreciable correlation. These correlation coefficients are summarized in **Table 1**, where positive and negative values are scattered. As a whole, there is no tendency to imply the relationship between the solar activity and the output voltage from the solar wind velocity.

Environmental neutrinos consist mainly of electron neutrinos and antielectron neutrinos. The sun is the major source of electron neutrinos, so that, we imagine that the solar wind velocity may affect the transportation of electron neutrinos. From the experimental result, there was no correlation between the initial peak and the solar wind. The experimental results indicate that the apparatus is either insensitive to electron neutrinos, or capable of detecting them but the effect of solar wind variation was too small to be measured.

We recall that the detector produced the large experimental signal near the nuclear reactor, where antielectron neutrinos were dominant. The geoneutrinos (antielectron neutrinos) are supposed to be relatively independent of the solar activity. For these reasons, it is natural to consider that the detector is sensitive to antielectron neutrinos. As for the reason for the initial-peak variation, it is considered to be important to identify the electrochemical reaction thereof. Numerical simulation together with further experiments on the initial peak will clarify the reason for the variation.

Table 1 Correlation coefficients between the output voltage and the solar wind velocity.

	Initial peak	7^{th} day	20^{th} day
Data.1 (Nov.2010~Feb.2011)	0.92	0.44	-0.27
Data.2 (Apr.2011~July.2011)	-0.42	-0.08	0.40
Data.3 (Oct.2011~Jan.2012)	-0.41	-0.16	-0.74
Data.4 (Jan.2012~July.2012)	-0.45	-0.20	-0.12

5. Conclusion

The electrochemical apparatuses were operated in natural circumstances under different solar activity conditions. We found no appreciable correlation between the output voltage and the solar wind velocity as a whole. This suggests that the apparatus is either insensitive to electron neutrinos, or capable of detecting them but the effect of solar wind variation was too small to be measured.

Acknowledgements

The authors express their gratitude to the staff of the laboratory of radiation physics and measurement for cooperating of the experiment, and the ACE SWEPAM instrument teams and the ACE Science Center for providing the ACE data.

References

1) S.L. Glashow, “The status of the electroweak sector of the standard model,” Nucl. Phys. 22 579-588(1961), A. Salam, “Weak and Electromagnetic Interactions,” Elementary Particle Theory (ed. By N. Svartholom, Almquist and Forlag. 1968), 367-377, S. Weinberg, “A Model of Leptons,” Phys. Rev. Letters, 19 1264-1266 (1967).
2) Gallex Collaboration, W. Hampel, et al., “GALLEX solar neutrino observations: results for GALLEX IV,” Physics Letters B 447 127-133 (1999).
3) J.N. Abdurashitov, et al., “Measurement of the solar neutrino capture rate with gallium metal,” Phys. Rev. C 60 558011-5580132 (1999).
4) G. Kallen, Quantum Electrodynnamics, Springer-Verlag, Berlin (1972).
5) R. Utiyama, “Theory of Invariant Variation and the Generalized Canonical Dynamics,” Prog. Theor. Phys. Suppl. 9, 19-44 (1959).
6) K. Ishibashi, et al., “Electrochemical Neutrino Detector and Its Signal Generation Scenario in Relation to Oxygen Production,” *Prog. Nucl. Sci. Tech.* 1, 436-439 (2011).