Development of the neutron monitor onboard Space Environment Data Acquisition Equipment – Attached Payload (SEDA-AP)

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To support future space activities, it is very important to acquire space environmental data related to space radiation degradation of space parts and materials and spacecraft anomalies. Such data are useful for spacecraft design and manned space activity. A solar neutron detector will be launched in June, 2009 by the Space Shuttle and attached to the Exposed Facility (EF) on the Japanease Eperiment Module "Kibo" of the International Space Station (ISS). The detector is composed of the scintillation fiber and is called as the FIB. It has a function of tracking the recoil protons induced by neutrons and a measurement of the proton energy by the range method. We report the development status and flight data of FIB.

Key Words: Neutron monitor, "Kibo", ISS, Exposed facility, SEDA-AP

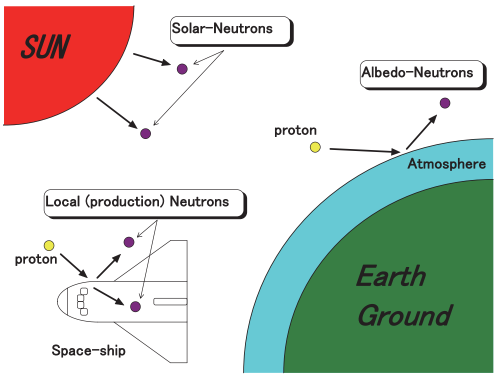
1. Introduction

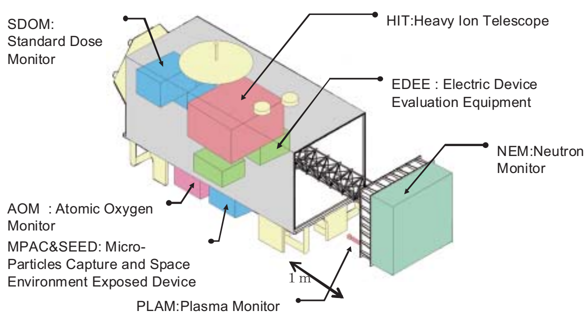
A new type of neutron detector, the FIBer neutron monitor (FIB), is developed. There are various origins of neutrons in space: solar-neutrons, albedo-neutrons, and local production neutrons (Figure 1). FIB measures high-energy neutrons, such as those of solar origin and albedo neutrons, in the energy range from 15MeV to 100MeV. One of the main purposes of this detector is to inform the cosmonauts of the arrival of strong charged particle radiation and to elucidate the ion acceleration mechanism at the solar surface. This detector will be launched in the Japanese Experimental Module (Kibo) exposed facility of the International Space Station (ISS), as one of the instruments of the Space Environment Data Acquisition Equipment (SEDA). SEDA has seven instruments to measure the space environment of the ISS orbit (Figure 2): neutron monitor, heavy ion telescope, plasma monitor, standard dose monitor, atomic oxygen monitor, electronic device evaluation equipment, micro-particle capture and space environment exposure device. The neutron monitor of SEDA has two instruments. One is the Bonner Ball Type Neutron detectors (BBND) (Matsumoto et al., 2001) and the other is FIB. Figure 3 shows the modules of the neutron instrument at SEDA. The neutron measurement module will extend to about 1 meter in order to avoid the neutrons which are produced by the collisions between the wall of SEDA, the main body and protons as shown in Figure 2.

2. Instruments

High-energy neutrons undergo elastic collisions with hydrogen atoms in the scintillator and produce recoil protons. Since the produced recoil protons penetrate two or more scintillators, the energy of an incident neutron can be determined by measuring the path length. The trajectory of the recoil proton can be determined using the 512ch outputs of the scintillation fibers which are placed in the two orthogonal directions, X and Y, only if the incident direction of neutrons is known, e.g., neutrons of solar origin. Figure 4 shows the detection principle of FIB.

Light emitted by the scintillator is transported by 15-20 cm-long optical fibers to the Photomultiplier Tube (PMT) (Takasaki et al., 1987). Hamamatsu H4140-20 photomultiplier tubes are used as the multianode (256ch) photomultiplier tubes in the X and Y directions. The signals from the two PMT's are sent to the electronic equipment





which consists of a charge amplifier, an analog memory, and a data-processing board. The circuit was designed using CMOS circuits by the High Energy Accelerator Research Organization (KEK) advanced technology group (Ikeda et al., 1993).

A detailed design of this FIB and examination results of the Bread Board Model (BBM) and the Engineering Model (EM) have already been reported (Imaida et al., 1999, Koga et al., 2001).

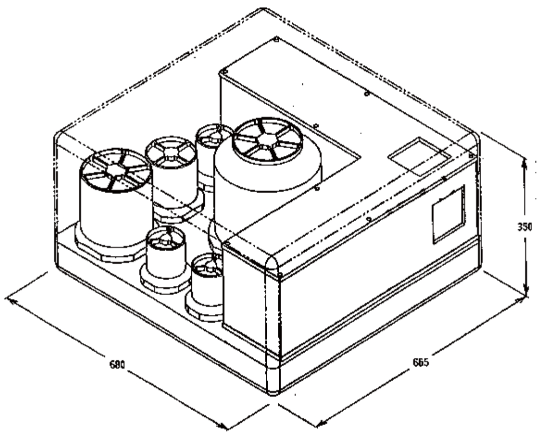


Fig. 3.　The schematic view of neutron monitor inside SEDA-AP

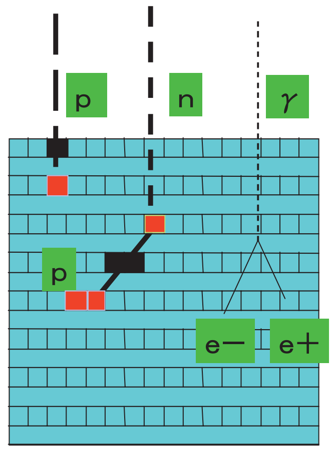


Fig. 4.　The detection mechanism of neutrons and protons by FIB

3. Irradiation Test

The flight model (FM) of this FIB was investigated using an accelerated beam at Riken. A 160MeV proton beam was bombarded in front of the FIB. The different proton energy was realized to install various thicknesses of the aluminum plates. The energy radiated on the FIB detector is equivalent to the energy of 27MeV, 44MeV, 68MeV, 102MeV respectively. The range of tracks was scanned by eye and obtained the range distribution. We have regarded that the mean value of the range corresponds to the incident proton energy, while the distribution from the mean value corresponds to the energy resolution of the detector. Thus the energy resolution has been obtained. An example of the results are plotted in Figure 5. Fitting the data to a function of 1/E, we have obtained the energy resolution of the FIB to the proton tracks as $\Delta E/E \approx 10\% /(E/50MeV)$.

However when the number of trigger events for neutrons will increase over 16 Hz, the FIB detector cannot record the pattern of the event, since the transmission rate is limited by the baud rate of the communication between the ISS and the ground based station. In this case, they can measure the number of layers, i.e., the range of charged particles. Furthermore in case the trigger rate exceeds 64Hz, the total deposited energy will be only measured with use of the mesh type dynode of the multi-anode photomultipliers. In this time, the energy resolution is not so good in comparison with the range method and it turns out as $\Delta E/E \approx 40\%$, being independently from energy.

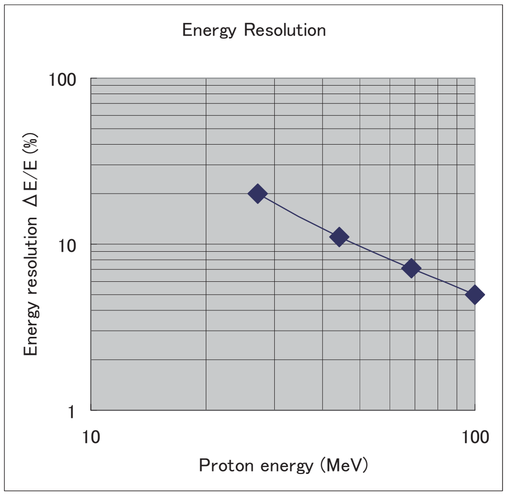


Fig. 5.　The energy resolution of the sensor

3. Initial checkout result

Development of the Flight Model (FM) of SEDA-AP has been completed and was lanced on July 16 in 2009. SEDA-AP was attached to Exposed Facility(EF) of “Kibo” on July 25 using the robot arm of “Kibo”. Initial checkout was started on August 4 and successfully ended on September 17.

4.Measurement result

Figure 6 shows the neutron tracks actually obtained from the onboard sensor. The left side is Y direction of sensor, and the right side is X direction. The both direction has 256 (16x16) squares shows each scintillation fiber (6x3mm) output. Figure 7 shows proton tracks which started from the first layer of the fiber (in the case of the neutron measurement mode was off).

5. Summary

Manufacturing of the FM of FIB was stated in 2000, and finished in 2002. From irradiation tests of the FM, performance of FIB is confirmed. Prot-flight test was done successfully and shipped to SEDA-AP system integrator.

SEDA-AP was launched by the Space Shuttle and attached to the JEM-EF. Measurement of space environment started, and will be continue for 3 years.

Space environment data in JAXA, which include data from SEDA-AP, are available to the public as data of the Space Environment and Effect System (SEES; http://sees.tksc.jaxa.jp). Those data will be used widely by academic and industrial users in laboratories, universities, JEM experiment investigators, and others in spacecraft operation, engineering fields, and scientific research. Data from SADA-AP will also be used to develop the Japanese space environment model.

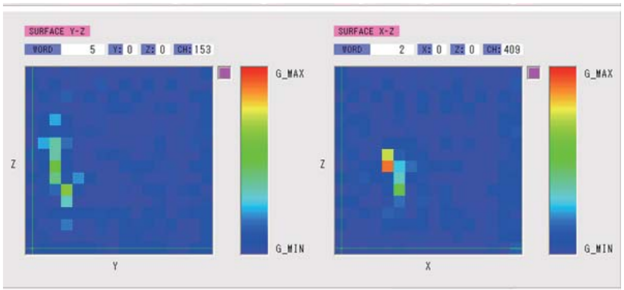


Fig. 6 a neutron track obtained on ISS

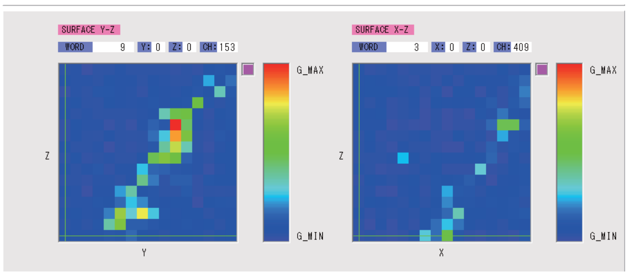


Fig. 7 a proton track obtained on ISS

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