§26. DD Neutron Spectrometer for LHD Plasma Diagnostics

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In a deuterium plasma, neutrons with energy of around 2.5 MeV (DD Neutron) are emitted as accompanying products of DD fusion reactions. This neutron spectrum has a lot of information about plasma heating process such as ion velocity distribution, energy transfer loss in neutral beam injection (NBI), etc. Basic neutron energy spectrum was calculated by Isobe[1] in some NBI heating conditions. Figure 1 shows the neutron spectrum when the plasma is heated by NBI without any heating loss. If there will be any differences between observed spectrum and this calculated one, the energy transfer loss will be expected and the important information of plasma heating process will be provided.

For the measurement of neutron energy spectra in helical confinement deuterium plasmas, we are developing a new type of high functional neutron spectrometer.

Figure 2 shows the schematic diagram of the proposed spectrometer, which consists of a thin plastic scintillator as a radiator to scatter incident neutrons by its hydrogen atoms, a silicon surface barrier detector (Si SBD) and a plastic scintillator. Energy of recoiled proton E_{rp} is measured by the thin plastic scintillator (ΔE detector) and the Si SBD (E detector) based on a recoil proton telescope, whereas energy of scattered neutron E_{sn} is measured with a time of flight of neutron between two plastic scintillators. The energy of the incident neutron E_{in} is, therefore, derived as follows:

$$E_{in} = E_{rp} + E_{sn} = (E_{rad} + E_{pd}) + E_{sn}$$

where E_{rad} and E_{rp} are the energy deposition of the recoiled proton in the radiator and the Si SBD, respectively.

We made the prototype detector, and measured the detector response by using the accelerator DD neutrons at Fusion Neutron Source facility, Japan Atomic Energy Agency. Figure 3 shows an example of measured neutron spectra with the energy resolution of 10.4% in FWHM. The detection efficiency was estimated to be 1.3×10^{-6} counts/neutron. Because of this poor energy resolution, it is difficult for the prototype itself to diagnose the plasma heating process. To achieve a better energy resolution around several % for DD neutron, the energy deposit in the radiator should be reduced, because the energy resolution of the plastic scintillator is lower than that of the Si SBD.

We adopted to pick up only a part of measured data corresponding to events occurred near the surface of the radiator, *i.e.* the case that the pulse heights of the radiator scintillator is less than a certain discrimination level, to obtain the energy spectrum. The dependence of the energy resolution and the detection efficiency on the discrimination level is shown in Table 1. The energy resolution of 6.7% for DD neutron was demonstrated by setting the discrimination level of the radiator deposit energy of 0.25 MeV, although the detection efficiency was decreased by a factor of 3. However, through the system design sutdy, it has been found that the detection efficiency could be improved up to ~10^{-5} counts/neutron.[2,3]

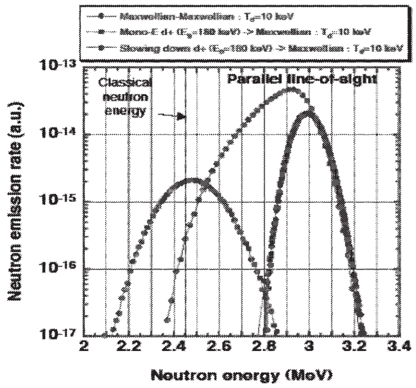

Fig. 1 The expected neutron spectrum in Deuterium Plasma

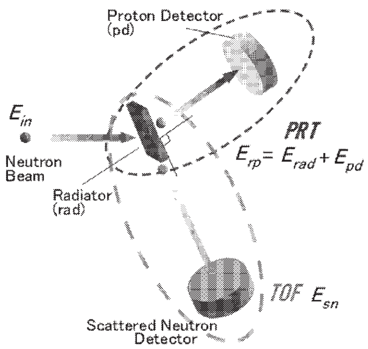

Fig. 2 Schematic diagram of the proposed neutron spectrometer.

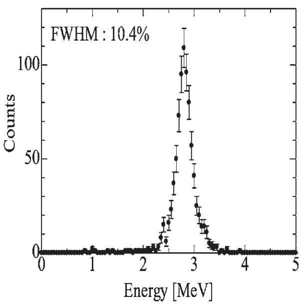

Fig.3 Measured DD Neutron Spectrum

Table 1 Energy resolution and detection efficiency of the prototype spectrometer for DD neutron.

Discrimination Level* [MeV]	Energy Resolution [%]	Detection Efficiency [Counts/Neutron]
∞	10.4%	$(1.3\pm0.1)\times10^{-6}$
1	8.9%	$(9.4\pm0.4)\times10^{-7}$
0.5	7.7%	$(4.6\pm0.3)\times10^{-7}$
0.25	6.7%	$(3.3\pm0.2)\times10^{-7}$

*Discrimination level of the pulse height energy of the radiator scintillator

[1] M. Isobe "Energy spectra of neutrons emitted from deuterium discharges", 4ac34p, The25th JSPF (2008)
[2] H. Iwai, T. Iguchi, et al. , KEK "The 23th Workshop on Radiation Detectors and Their Uses" 33 (2009)
[3] H. Iwai, T. Iguchi, et al. , 2aZC6, The 56th JSAP (2009) Spring