§28. Neutron Spectrometer for Deuterium Plasma Diagnostics

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Toward deuterium plasma diagnostics in LHD, we are developing a neutron spectrometer based on coincident detection of the scattered neutron and recoiled proton from a plastic scintillator as the incident neutron target, *i.e.* a radiator.[1)] As a result from an elastic scattering of neutron in the radiator, the neutron energy is derived from sum of the deposit energies in the radiator and the recoiled proton detector and the scattered neutron energy measured by a time-of-flight technique. To evaluate the applicability of the spectrometer, neutron energy spectrum should be estimated precisely.

We developed a detailed Monte Carlo simulation model for the neutron energy spectrum based on FIT code. The FIT code, which was developed by S. Murakami *et al.*[2)], analyzes an energy deposition and a slowing down process of a high energy ion based on its birth profile and plasma temperature and density profiles. Here, the slowing down process is treated by the steady state solution of Fokker-Plank equation. On each position in the plasma, the velocity vector of high energy deuteron is calculated by its energy distribution and the pitch angle averaged over magnetic surface obtained from FIT code. The energy of neutron caused by DD reaction and emitted to the spectrometer is calculated by

$$E_n = \frac{1}{2} m_n u_n^2$$
$$= \frac{1}{2} m_n V^2 + \frac{m_{3He}}{m_{3He} + m_n}(Q+K) + \cos\theta\, V \sqrt{\frac{2 m_n m_{3He}}{(m_n + m_{3He})}(Q+K)} \qquad (1)$$

where m_i is the mass of ion *i*, *V* is the relative velocity of ion and *K* is the energy of ion before reaction.

Figure 2 shows arrangement of neutral beam injectors in LHD and a position of the spectrometer considered in this paper. Figure 3 shows the typical calculated spectrum on the tangentially viewing spectrometer at 6-T port. In this calculation, deuterium plasma (the ion density of 1.7×10^{19} m^{-3}) was heated by one neutral beam injection (NB#2) with an acceleration voltage of 150 keV and a port-through injection power of 2.75 MW. The maximum neutron yield was roughly estimated to be about 10^8 neutrons/s at the position of the spectrometer. Thus, a counting efficiency of the spectrometer should be above 10^{-6} counts/neutron to obtain the spectrum with statistical precision of less than 10% in the integration time of 1 s, *i.e.* counting rate of more than 10^2 counts/s. We will consider the detailed neutron spectrum for each experimental condition and show the applicability of the proposed spectrometer.

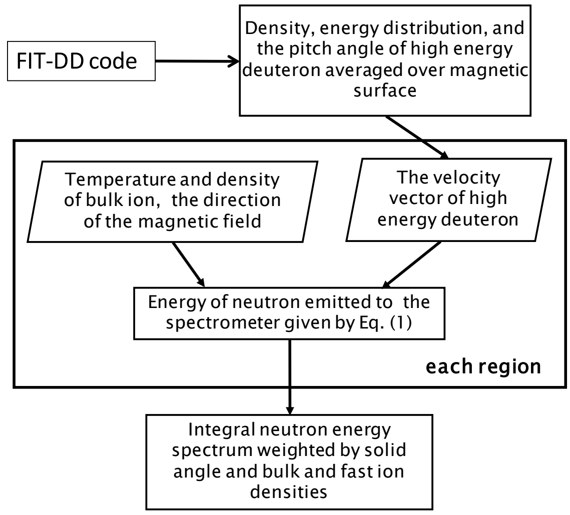

Fig. 1. Flowchart of Monte Carlo simulation model for the neutron energy spectrum based on FIT code.

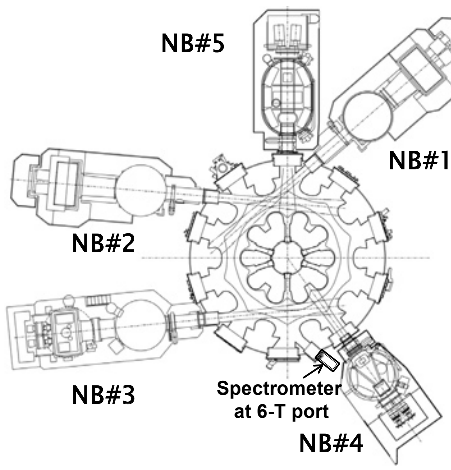

Fig. 2. Arrangement of neutral beam injectors in LHD and a position of the spectrometer considered in this paper.

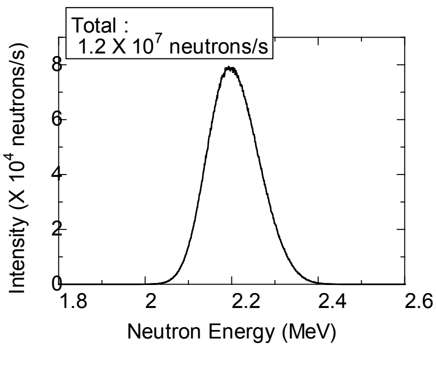

Fig. 3. Typical calculated spectrum on the tangentially viewing spectrometer at 6-T port with the neutral beam injection heating of NB#2.

1) H. Tomita, H. Iwai, T. Iguchi, M. Isobe, J. Kawarabayashi, and C. Konno, “Development of neutron spectrometer toward deuterium plasma diagnostics in LHD” Rev. Sci. Instrum. **81**, 10D309 (2010).
2) S. Murakami, N. Nakajima, M. Okamoto, "Finite beta Effects on the ICRF and NBI Heating in the Large Helical Device", Fusion Technology, **27** Suppl. S, 256-259, (1995).