§29. Development of Neutron Diagnostic Systems for LHD Deuterium Experiment

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Deuterium plasma experiments are now being planned in Large Helical Device (LHD). In the deuterium experiment, neutrons with the energy of 2.5 MeV (DD neutron) are emitted as a result of DD fusion reaction in deuterium plasmas. Because most of neutrons will be produced by beam-plasma reactions in LHD, DD neutron diagnostics play an important role not only in measuring fusion output but also in assessing global confinement property of beam ions. In our research collaboration, we study suitable arrangement of neutron detectors and development of neutron diagnostics system including 1) ex-vessel neutron yield monitor, 2) neutron profile monitor, 3) neutron spectrometer.

Toward the detailed design of the ex-vessel neutron yield monitor, we have studied the neutron transport in LHD by using Monte Carlo code MCNP [1]. In this annual year, we evaluated an influence of additional components to 3D sector model of LHD such as several diagnostics ports (I-ports) and a mount for a laser interferometer. Figure 1 shows (a) the cross-sectional view of the 3D-model with I-ports along the equatorial plane, and (b) the calculated neutron spectra with/without the I-ports. It was found that fraction of 2.5 MeV neutrons in the spectrum with the I-ports was larger than that without I-ports.

As the DD neutron spectrometer, we have proposed a spectrometer based on coincident detection of the scattered neutron and recoiled proton from a plastic scintillator as the incident neutron target, or a radiator. To investigate the requirements for the proposed spectrometer, we calculated the expected neutron spectra emitted from DD reaction in deuterium plasma on LHD by using a first approximation model [2]. Since DD neutrons without scattering before incident into the spectrometer should be separated from a background of scattered neutrons, an energy resolution of less than 7%, which is corresponding to an energy broadening of the calculated spectra, is required. In addition, the detection efficiency would be reach 10^{-6} counts/neutron in the proposed spectrometer to keep the statistical uncertainly of the detected neutron intensity less than 10%, by assembling the 4 set of three detectors as a whole spectrometer system (see Fig. 2).

As the neutron profile monitor, we are developing a neutron camera with nuclear emulsion [3]. Recoiled proton due to elastic scattering of incident neutron make track in the nuclear emulsion. In the case of the incident neutron into the nuclear emulsion are well collimated, the 2D image of DD neutron could be re-constructed by pair of the scattering angle and track length of each recoiled proton. We proposed an algorithm for the readout of recoil proton tracks with latent image analysis. For the mono-energetic 2.5 MeV neutron beam at FNS at JAEA, the incident neutron energy was estimated to be 2.5 MeV with uncertainty of 36% by the proposed readout-algorithm. The algorithm would be helpful for suppressing of the background by the scattered neutron in re-constructed profile.

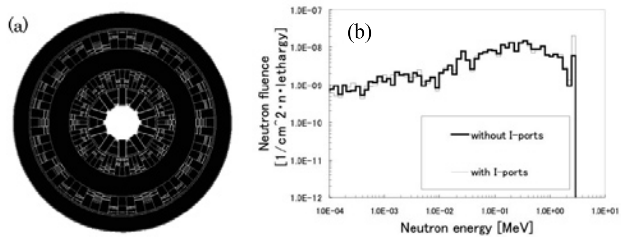

Fig. 1 (a) the cross-sectional view of LHD 3D-model with I-ports along the equatorial plane, and (b) the calculated neutron spectrum with/without the I-ports.

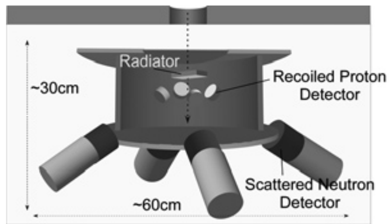

Fig. 2 Conceptual drawing of the proposed spectrometer with 4 set of three detectors *i.e.* the radiator, the recoiled proton detector, and the scattered neutron detector.

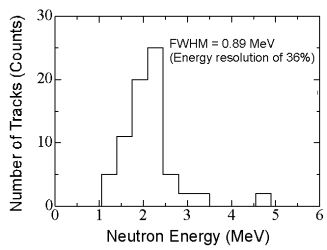

Fig. 3 The estimated neutron spectrum with nuclear emulsion OPERA.

1) Nishio, N. *et al.*: "A study on neutron monitoring system of LHD based on Monte Carlo Simulations", Proceedings of 18th Topical Conference on High-Temperature Plasma Diagnostic 2010 in Rev. Sci. Instrum. (submitted).
2) Tomita, H. *et al.*: "Development of neutron spectrometer toward deuterium plasma diagnostics in LHD" Proceedings of 18th Topical Conference on High-Temperature Plasma Diagnostic 2010 in Rev. Sci. Instrum. (accepted).
3) Nomura, Y. *et al.*: "Neutron Measurement in Fusion Reaction Experiments Based on State-of-the-art Nuclear Emulsion Technique" Proceedings of JSPF Annual meeting, Dec. 2009, 2aD18P.