§25. 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.

The neutron profile monitor based on the radial collimated neutron flux array system is planned to install LHD for measurement of a line-integrated neutron emission rate. A stilbene scintillator which allow pulse shape discrimination between neutrons and γ-rays, is one of the candidates for the neutron detector in the neutron profile monitor. It was necessary to discriminate neutrons from g-rays because a stilbene crystal is sensitive not only to neutrons but also to γ-rays. To achieve high count rate operation, a digital signal processing DSP system was applied to stilbene scintillation detectors of the multichannel neutron emission profile monitor.[1)]

A charge comparison method was used to discriminate neutrons from γ-rays based on the difference in decay time of an output pulse (see the two-dimensional map in Fig. 1). The n-γ separation was occasionally unstable, depending on the counting rate, the n/γ ratio, the surrounding temperature, and so on. Thus, a new automatic n-γ discrimination method using DSP on a two-dimensional map was investigated. At first, the pulses were categorized as neutron or γ-ray using the initial line (see Fig.1 (a)), the pulses on the 2D map were categorized again with the new line and revised the slope of the line until the rate of change in the angle of rotation of the line became below 1% (see Fig.1 (b)). As one example of the result of repetition in the process, the γ-ray contamination was 3.8%, which was below the statistical error with time resolution of 10 ms.

As an additional neutron profile monitor for deuterium plasma experiment planned in LHD, we propose a compact neutron pinhole camera based on state-of-the-art nuclear emulsion technique.[2)] The proposed neutron pinhole camera is designed to provide a time integrated neutron profile. In the stable deuterium plasma in the LHD, it would be possible to compare the shot integrated neutron profile obtained by the proposed neutron pinhole camera with that obtained by the neutron profile monitor based on the scintillator.

We considered a design of the neutron pinhole camera based on Monte-Carlo simulation of neutron and recoil proton transport, by PHITS (Particle and Heavy Ion Transport code System). Figure 2 shows geometry of the neutron pinhole camera. With analysis based on model calculation, the spatial resolution of 100 mm might be achievable by a of about 100 mm with b of 5.72 m and φ of 5 degrees (type 1) or b of 4 m and φ of 8 degrees (type 2), whereas the S/N of reconstruction image should be improved by increasing efficiency (*e.g.* by using multi-pinhole collimator) for the application to emission profile imaging of DD neutron in LHD plasma.

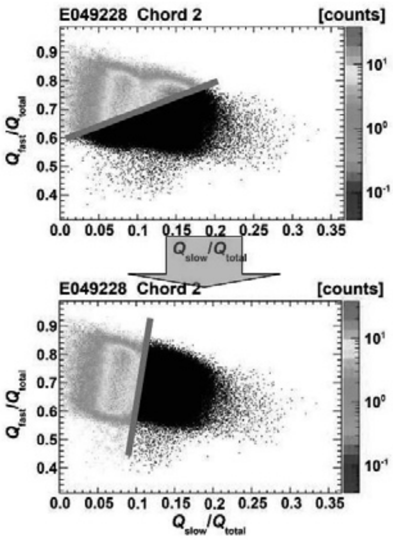

Fig. 1 The two-dimensional map in Q_{fast}/Q_{tot}–Q_{slow}/Q_{tot} space for n-γ discrimination.

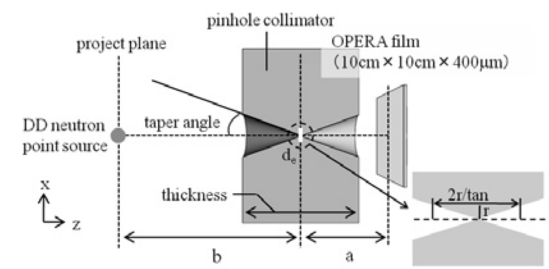

Fig. 2 Geometry of the neutron pinhole camera. The pinhole camera consists of a collimator and a nuclear emulsion.

1) K. Ishii *et al.*, Rev. Sci. Instrum. **81**, 10D334 (2010).
2) Y. Nomura *et al.*, "Design Consideration on Compact Neutron Pinhole Camera with Nuclear Emulsion for Energetic-ion Profile Diagnostics", 20th International Toki Conference (ITC-20), P2-38.