§22. Development of Compact Neutron Camera with Nuclear Emulsion for Energetic-ion Profile Diagnostics

Iguchi, T., Tomita, H., Minato, H., Morishima, K., Kawarabayashi, J., Nakamura, M., Nakano, T., Yamamoto, Y., Takagi, K., Ishihara, K. (Nagoya Univ.),
Murakami, S. (Kyoto Univ.),
Isobe, M., Yamanishi, H.

In deuterium plasmas, neutrons around energy of 2.5 MeV (DD neutron) are emitted as accompanying products of DD fusion reaction. The measurement of DD neutron emission profile plays an important role for diagnostics of energetic deuterium ion in DD plasma because the neutrons are mainly produced by beam-plasma interactions during neutral beam injection heating. In LHD, the neutron profile monitor consisted of array of organic or stilbene crystal scintillators with a multi-channel collimator is planned to be installed toward deuterium plasma experiment. Although these neutron profile monitors based on the scintillator have provided a temporal evaluation of neutron profile, more compact neutron profile monitor is required toward stable operation of DD fusion plasma in next generation reactor because of the limited space given to the monitor.

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. 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.

Figure 1 shows a conceptual drawing of the proposed neutron pinhole camera. The camera consists of a pinhole collimator for fast neutron and a nuclear emulsion which is a solid state track detector with spatial resolution of a few micrometers for charged particles. After passing through the pinhole, neutron from deuterium plasma is incident into the nuclear emulsion. Incident neutron is scattered by a hydrogen atom and then a recoiled proton due to its elastic scattering of neutron make a track in the emulsion. After image development of the emulsion, the tracks of recoiled protons are acquired by an optical microscope.

The energy of the recoiled proton E_{rp} is obtained by the track length of the recoiled proton. In the case of neutron pinhole camera, incident direction of neutrons can be derived from a line extending from a starting point of the track of the recoiled proton to the center of the pinhole. Thus, the scattering angle θ would be derived from the angle between the track and the line, *i.e.* the energy of incident neutron E_{n} can be estimated as $E_{\mathrm{n}}=E_{\mathrm{rp}}/\cos^2\theta$. It leads to lower background events in DD neutron imaging due to gamma-rays and/or slow neutrons that are scattered at least once before reaching the emulsion. Therefore, 2D image of DD neutron could be re-constructed by the estimated incident directions of DD neutron.

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)[1]. Figure 2 shows the calculated energy spectrum of mono-energetic 2.5 MeV neutron source by using the neutron pinhole camera. The incident neutron energy was estimated to be 2.5 MeV with FWHM of 0.7 MeV. The energy resolution of the estimated spectrum was rather poor because of uncertainty in measurement of recoiled-proton track length, however it was enough to pick out the tracks of recoiled proton caused by neutrons directly incident into the emulsion. On the other hand, large background in the spectrum was caused by scattered neutron due to scattering in the pinhole collimator.

We will optimize the design of the neutron pinhole camera and demonstrate DD neutron imaging using the prototype of the proposed neutron pinhole camera.

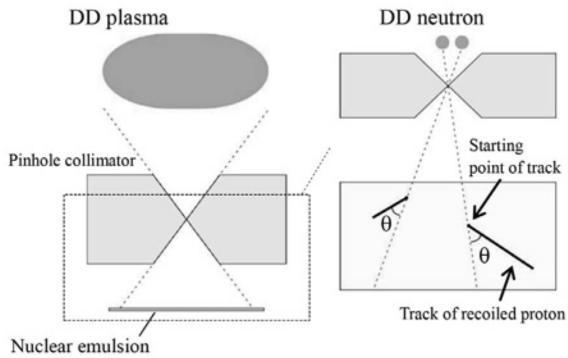

Fig. 1 Conceptual drawing of the proposed neutron pinhole camera

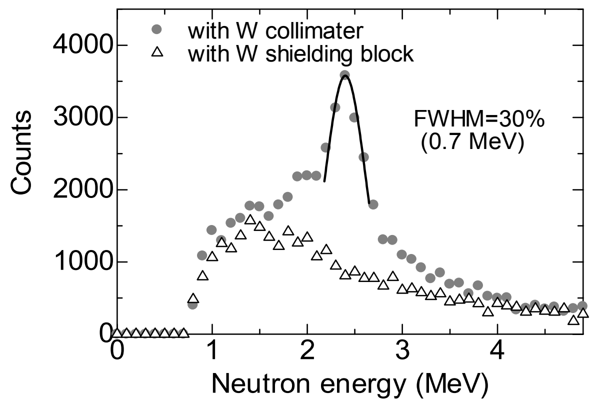

Fig. 2 Calculated energy spectrum of mono-energetic 2.5 MeV neutron source by using the neutron pinhole camera.

1) Y. Nomura, H. Tomita, J. Kawarabayashi, T. Iguchi, M. Isobe, K. Morishima, T. Nakano, M. Nakamura, S. Ohnishi, "Design Consideration on Compact Neutron Pinhole Camera with Nuclear Emulsion for Energetic-ion Profile Diagnostics" Plasma Fusion Res. **6**, 2402148 (2011).