§3. Development of Neutron Diagnostic Systems Leading to Extended Physics of Energetic Particle Confinement in LHD

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We have developed the following neutron measurement systems and related items for D-D burning plasma experiments, especially for study of high-energy particle physics.

1) The combined neutron transport code consisting of MCNP, FIT3D-DD and GNET.
2) The neutron flux monitor and the signal processing unit for neutron counters.
3) The artificial diamond neutron energy spectrometer.
4) The neutron profile monitor using scintillating fibers and the digital signal processing unit for discrimination of neutrons and gamma rays.
5) The neutron profile monitor using nuclear emulsions.
6) The neutron energy spectrometer using recoil proton detector.

In this report, we briefly describe the results of 1), 4) and 5) among the above items because of the limitation of writing space given.

Confinement of energetic tritons for the LHD deuterium plasma is investigated using the GNET (Global NEoclassical Transport) code, in which the drift kinetic equation (DKE) of energetic particles is solved in five-dimensional phase space. GNET is also applied to evaluate the source profile of the tritons solving the DKE for NBI beam ions. The velocity distributions of energetic tritons are evaluated over a range of minor radii, and we present the characteristics of the triton distribution in velocity space. Next, we calculate D-T nuclear reaction rates using the obtained velocity distribution of tritons. Figure 1 shows the radial profiles of the neutron production rate and the total production of 14MeV neutron is evaluated as 9.0 x 10^{10} s^{-1} in the typical LHD plasma.

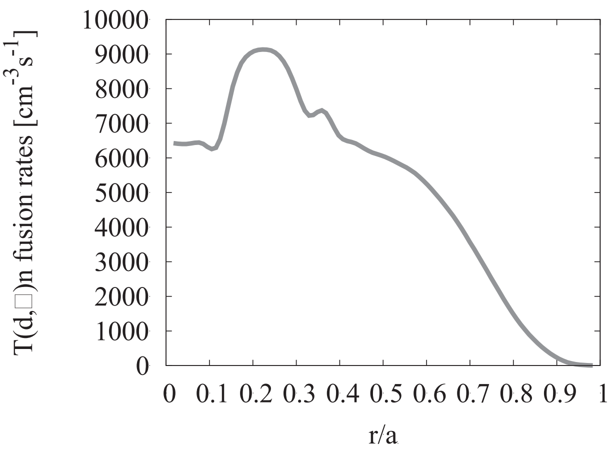

Fig. 1 Radial profile of D-T fusion reaction rate in the typical plasma.

In order to measure the incident directions of 14 MeV neutrons, a direction sensitive detector composed of scintillating fibers (Sci. Fi.) has been used. In that system, the signals from the scintillating fibers were measured with a photomultiplier tube (PMT) where the penetration of recoil proton from one fiber to the other was prevented with the shielding region between the fibers. In the present study, we are trying to optimize the design of the detector to use at LHD. We calculated the angular dependence of counts over a threshold energy for the case of 1mm-diameter Sci. Fi. The lengths were set to 10 cm and 5cm. Also, experiments were carried out at Fusion Neutron Source (FNS) facility of Japan Atomic Energy Agency. It can be recognized that the measured angular distribution is broader than calculated results. As Sci. Fi. is sensitive to gamma rays, the difference should be due to the background gammas. To reduce the gamma sensitivity, it is effective to adopt smaller core Sci. Fi. Also from the calculated results for different core size, we can conclude that, by using smaller core Sci. Fi., higher angular resolution can also be achieved.

We have developed a compact pinhole camera based on nuclear emulsion technique for neutron emission profile measurement. Figure 2 shows the point spread functions of the pinhole camera obtained by experiments with an accelerator-based DD neutron point source and by simulations. Using the camera installed at a fusion experimental device KSTAR, the pinhole images of DD neutron from the plasma integrated over several plasma shots were successfully obtained.

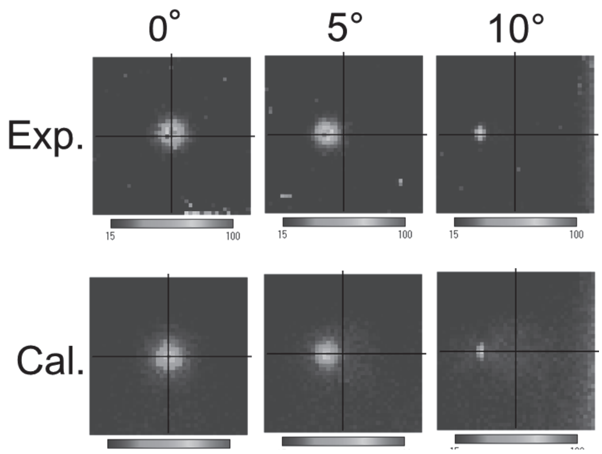

Fig. 2 Distributions of recoil proton-track density. Upper plots are the distributions obtained by experiments using a mono-energetic 2.5 MeV neutron point source and lower ones are Monte Carlo simulations based on PHITS.