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Progress in energetic particle confinement research in the Large Helical Device deuterium experiments using integrated neutron diagnostics

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In a magnetic confinement deuterium-tritium (D-T) fusion reactor, energetic alpha particles produced by DT fusion reactions will be the primary heating source for steady state sustainment of ignition conditions. Therefore, energetic particles should be well-confined for the realization of fusion power generation. To understand the energetic particle confinement in fusion burning plasmas, studies of energetic ion confinement have been intensively performed in existing fusion devices. We have performed energetic particle confinement study in stellarator/heliotron named the Large Helical Device (LHD). In LHD deuterium plasma experiments, the neutrons generated from the plasma are dominated by beam-plasma deuterium-deuterium (D-D) reactions. Therefore, significant progress in energetic particle confinement research using neutron diagnostics is expected [1].

The study of energetic particle confinement in helical systems has been enhanced using a novel neutron diagnostic developed based on the latest technology in LHD [2, 3]. The neutron flux monitor [4], which measures the total neutron emission rate, plays an essential role in providing many new insights, including a deeper understanding of ripple transport in the helical system. Information on the spatial distribution of energetic particles is essential for understanding the interaction between energetic particles and magnetohydrodynamic (MHD) instabilities exited by energetic particles. Three neutron cameras [5, 6] were installed to obtain the neutron emission profile, which gives information on the radial profile of energetic particles. The visualization of helically-trapped energetic particles has been successfully achieved, and energetic particle transport due to energetic-particle-driven MHD instabilities, which prevent the preservation of high ion temperature states, was clarified (Figure 1 left) [7]. Furthermore, the study of MeV ion confinement was conducted. In deuterium plasmas, 1 MeV tritons are produced due to D-D fusion reactions, and a small number of D-T neutrons are produced by secondary reactions during the deceleration of triton. 1 MeV tritons are regarded as the mimic of D-T fusion-born alpha particles because initial velocity distribution and kinetic parameters of tritons are close to those of alpha particles. To selectively measure the small number of D-T neutrons among many D-D neutrons, we have developed, and installed detectors using many scintillating fibers [8] and demonstrated alpha particle confinement ability in a helical device for the first time in the world (Figure 1 right) [9].

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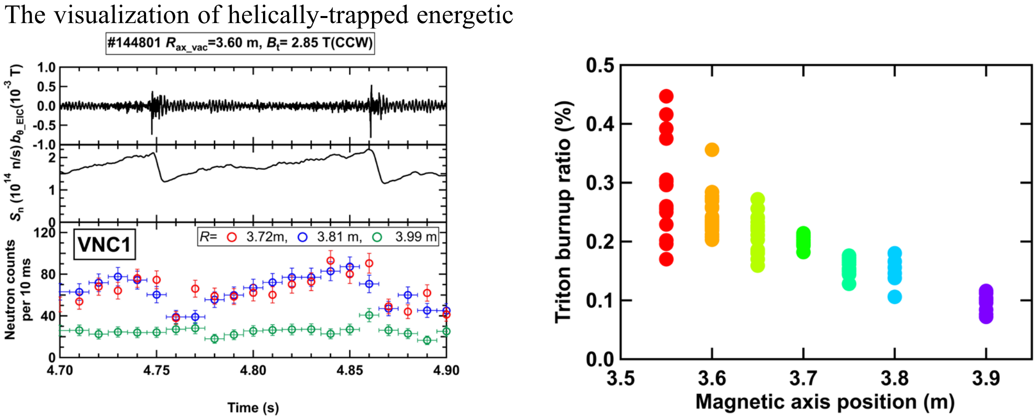

Figure 1. (left) Time evolution of magnetic fluctuation amplitude (b_{θ_EIC}), total neutron emission rate (S_n), and line-integrated neutron counts by vertical neutron cameras [7]. Due to the strong bursting magnetohydrodynamic instability, drop of S_n as well as neutron emission profile changes due to the transport of beam ions. (right) Magnetic configuration dependence of triton burnup ratio [9]. The triton burnup ratio increases with inward shift of the magnetic axis position (R_{ax}). The obtained maximum triton burnup ratio (0.45%) is comparable that obtained in KSTAR [10] whose minor radius is comparable with LHD.