§56. Measurement of Re-Entering Fast Ion Flux at Outboard Side of LHD Plasmas

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Estimation of energetic ion population is very important to evaluate accurate heating power in neutral beam injection (NBI) heated plasmas and for construction of MHD equilibrium. Averaged orbit of co-directed fast ions shifts outwardly in major radial direction and deviates from flux surface of magnetic field line. Due to the orbit deviation, a part of co-directed fast ions travel outside of the outboard-side last closed flux surface (LCFS) and re-enters into the LCFS, which are called as re-entering fast ions. The numerical calculation of fast ion population in the plasma region including the re-entering fast ions is not so simple because it is required the full-orbit calculation and an adequate loss boundary. In order to experimentally estimate the re-entering fast ions, a hybrid directional probe (HDLP) has been installed in LHD, and the measurement of absolute fast ion power flux has been carried out[1)]. The power flux was evaluated from temperature increase of each probe channel, which has a thermocouple, and the calibration was carried out using laser injection onto the surface of probe channel[1)]. In 11th and 12th campaign of LHD experiments, the fast ion profiles were observed at the outside of the LCFS, and the effect of ICRF antenna on the re-entering fast ion profile was revealed.

In the 13th campaign of LHD experiment, the HDLP was reconstructed to improve signal noise ratio for fast ion measurement. The probe head shape was modified and a pair of probe channels were arranged along the magnetic field line for construct a directional probe and located near a corner of the probe head where the maximum heat flux deposits the probe surface. The fast ion measurement was carried out with the same condition as that in the 11th and 12th campaign, and the comparison between their results was summarized in Fig.1, in which the HDLP position was aligned to coincide each other. The difference between 11th and 12th is the effect of ICRF antenna. In 13th campaign, the scan of magnetic field strength from $B_\mathrm{t} = -0.6$ T to -2.0 T was carried out with the condition of $R_\mathrm{ax} = 3.6$ m, which is shown in Fig. 2. The profile of fast ions at the outside of the LCFS is wider for lower magnetic field strength. The difference of fast ion profile is estimated at the 6 cm far from the LCFS and it is almost 14 mm between $B_\mathrm{t} = -0.6$ T and -0.75 T, and is almost 50 mm between $B_\mathrm{t} = -0.6$ T and -2.0 T, where the fast ion profile with $B_\mathrm{t} = -2.0$ T is extrapolated. Here the comparison with Larmor radius is discussed. The Larmor radius of the typical fast ion with the energy of 180 keV and pitch angle of 40 degree is 64 mm for $B_\mathrm{t} = -0.6$ T, 50 mm for $B_\mathrm{t} = -0.75$ T and 10 mm for $B_\mathrm{t} = -2.0$ T. The scale length of difference of fast ion profiles on the scan of magnetic field strength is almost same scale with the Larmor radius of fast ions with the energy of 180 keV and pitch angle of 40 degree. For the further understanding of fast ion profile at the outside of the LCFS, the comparison with full-orbit numerical simulation with real coordinates is required, which is now in progress and will be reported in near future.

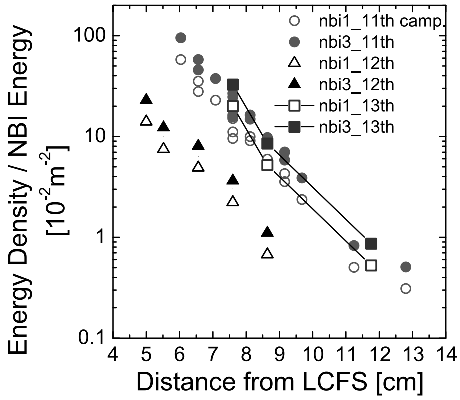

Fig. 1: The profile of fast ion power flux normalized by the deposition power of NBI measured by HDLP at the outboard side of the LCFS. In the 11th campaign, the ICRF anntenas exist, while it did not in 12th and 13th campaigns.

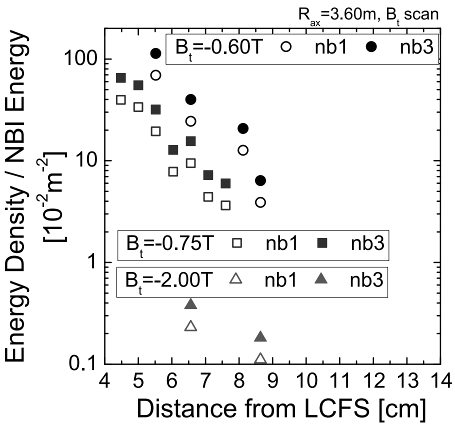

Fig. 2: The profile of fast ion power flux normalized by the deposition power of NBI. The results with the magnetic field strength of $B_\mathrm{t} = -0.6$ T, $B_\mathrm{t} = -0.75$ T and $B_\mathrm{t} = -2.0$ T are compared in the magnetic axis position of $R_\mathrm{ax} = 3.60$ m.

1) K. Nagaoka, K.Y. Watanabe, M. Osakabe, et al., Rev. Sci. Instrum. **79**, (2008) 10E523.