§55. Effect of Halo-neutrals on Fast-ion Charge Exchange Spectroscopy (FICXS) Measurement on LHD

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A fast ion charge exchange spectroscopy (FICXS) diagnostic[1] has been recently applied to Large Helical Device(LHD). As the similar diagnostic developed on DIII-D[2], FICXS diagnostic can measure both spatial and energy distribution of fast-ions from the Doppler-shifted Balmer alpha(H_α or D_α) spectra of charge exchanged fast neutrals by the injected neutral beam(NB). One of the advantages of the method is that it can provide the global confinement property of fast-ions.

On FICXS measurement, H_α lights from following three processes must be taken care of:

$$H^+_{fast} + H^0_{NB} \rightarrow H^0_{fast} + H^+_{NB} \quad (1)$$

$$H^+_{bulk} + H^0_{NB} \rightarrow H^0_{bulk} + H^+_{NB} \quad (2)$$

$$H^+_{fast} + H^0_{bulk} \rightarrow H^0_{fast} + H^+_{bulk} \quad (3)$$

The H_α lights being created through the charge exchange (CX) process between the fast ions and neutral beam particles (NB-FICX component) are of our interests (see, Eq.(1)). Simultaneously, the beam particles can also react with bulk ions and creates low energy neutrals, which are called as "halo" neutrals and are indicated as H_{bulk}^0 in Eq.(2). The H_α-lights from halo neutrals can be separated from FICX spectra by selecting a proper observation range in wavelength since its Doppler shift is smaller than the shift for H_{fast}^0. On the other hand, the halo neutral can be also a source of CX process for fast-ions, as shown in Eq.(3). The H_α light from this process (halo-FICX component) is difficult to separate from NB-FICX component, since the velocities of fast neutrals in Eq. (1) and Eq. (3) are in the same range. Therefore, it is necessary to evaluate the effect of halo-neutrals on FICX spectra, when the Doppler-shifted H_α lights are measured as the FICX spectra between perpendicular fast-ions and perpendicularly injected NBs.

Figure 1 shows a typical result of comparison between an observed spectrum for radial-FICXS measurement and its reconstructed spectra by using the result of numerical simulations, where fast-ion velocity distributions were calculated by GNET-code[3] and the intensity profile of attenuated NBs being calculated NBATTEN-code[1] using ADAS database. As shown in the figure, the calculated spectra using beam neutrals does not show the hump between 650.4nm and 652.9nm, while it was shown in the observed spectrum. The hump can be represented if we consider the halo FICX component, as shown by dashed lines in Fig.1, where the distribution of halo neutrals is estimated by a simplified particle balance model which assumes the neutral creation by charge exchange process between the NB particles and bulk ions is balanced to the loss of neutrals by ionization process with bulk-ions and electrons. In the estimation, the transport effect of neutrals is neglected. Since this model overestimates the absolute value of halo neutrals, their amount is adjusted so that the sum of evaluated halo-FICX components and the NB-FICX component well express the observed spectra. Figure 2 shows the radial distributions of n_{halo}/n_{NB} ratios on FICX Line of Sights(LOS). The ratio estimated from this method, which is indicated as "empirical", are compared to the result of EIRENE-3D Monte-Carlo neutral transport code[4]. Agreement between both of them is quite well. This confirms the hump in the radial FICXS spectra is coming from the halo-FICX components[5].

1) Osakabe, M. et al.: Rev. Sci. Instrum. **79** (2008) 10E519
2) Heidbrink, W. W. et al.: Plasma Phys. C ontrol. Fusion **46** (2004) 1855
3) Murakami, S. et al.: Fusion Sci. Technol. **46** (2004) 241
4) Reiter, D. et al.: Fusion Sci. Technol. **47** (2005) 172
5) Ito, T. et al.: Plasma Fus. Res. (to be published)

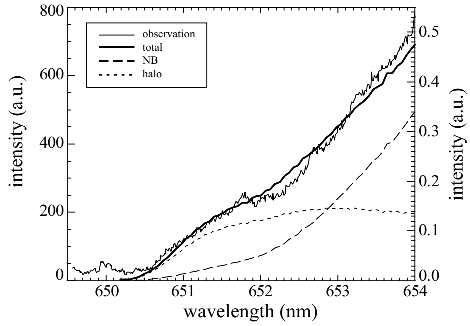

Fig.1 Comparison between the observed spectrum and the calculated spectra based on the result of the NB_ATTEN code. Thin solid, dashed and dotted curves indicate the experimental observation, the calculated spectrum with injected NB and halo neutral, respectively. Bold solid curve shows the sum of calculated spectra.

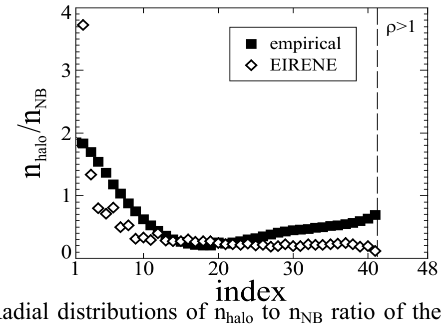

Fig.2 Radial distributions of n_{halo} to n_{NB} ratio of the empirical estimation with the experimental observation (solid squares) and the results from EIRENE-3D code (open diamonds).