§13. Helium Measurements Using the Pellet Charge Exchange

Ozaki, T., Goncharov, P.R., Veshchev, E.A. (Graduate Univ.), Tamura, N., Sudo, S.

It is very important to measure the helium ion profile for two different reasons. One is to measure the helium hydrogen ratio because the minority heating in ion cyclotron resonance frequency heating strongly depends on the ratio. Another is to investigate the α particle heating mechanism in future fusion reactor.

We introduce the pellet charge exchange system (PCX) in order to measure the helium ion profile[1]. One of the advantages of PCX is the ability to obtain the spatial information. When the compact neutral particle analyzer (CNPA) for measurement of the charge exchanged particle is installed just behind Tracer Encapsulated Solid Pellet (TESPEL) trajectory, the time trace of the signal can be transferred to the information of the pellet position.

The high-energy neutral particles, which are produced by the charge exchange between the injected TESPEL and the energetic ions, are observed in PCX. TESPEL is the impurity pellet as the polystyrene or the titanium etc. with the velocity of 400-500 m/s. TESPEL is ablated and produces the ablation cloud with several layers of different charge states around the traveling pellet in plasma. The pellet ablation cloud remains either the neutral or partially ionized surrounding the pellet until fully ionization of the pellet. Parts of injected particles into the pellet ablation cloud are escaped from the plasma due to the charge exchange reaction. It is neutral density of 10^8 times larger than the background neutrals because the cloud density is enough high (10^{16} cm^{-3}). Therefore the measurement in the plasma is available because the double charge exchange for He^{2+} can be expected if the high-Z material as the carbon or the lithium is used. The neutralization factor is very important in order to obtain energy spectrum in plasma. It is determined by the ratio of the recombination to the ionization. The precise calculation have been done under the LHD plasma parameter by Sergeev[2]. The neutralization factors for the hydrogen and the helium are 0.9 and 0.07, respectively if the polystyrene is used.

If the plate voltage is changed, particles of a different mass such as helium can be observed in principle. According to simple orbit calculation in CNPA, the beam spot of the helium is different from the channeltron array, which is adjusted to the hydrogen even if the plate voltage is tuned. Figure 1 shows the energy dependence of the position of the beam spots in hydrogen, deuteron and helium. Here we assume the single ionized helium ion after translation of the carbon film of helium. The spot size is assumed to be determined by the aperture size (2 mm) and the geometric configuration of the plasma and the detector. In low energy region, the spot size may be enlarged due to the scattering in the foil.

According to Fig. 1, the helium beam spots do not correspond to the detector array in higher energy channels when the plate voltage is adjusted to a low energy channel because the detector array position is adjusted to the proton. The helium atom is observed by decreasing the plate voltage of the CNPA. The helium atom is generated by the charge exchange between the fully ionized helium and the partially ionized carbon ion in the TESPEL. In LHD, the hydrogen concentration is not small due to the hydrogen NBI in helium plasma. When the TESPEL is injected to the hydrogen plasma, the ratio is almost 0.1. If detected helium signal in the hydrogen plasma comes from the scattering of the hydrogen in the detector, the contribution of the scattering of the hydrogen can be estimated to be 0.11. We assume there is the similar contamination of the hydrogen in helium plasma experiment. According to simple model, the real He/(He+H) ratio in helium plasma is estimated to be 0.12. To take account the difference of neutralization factor of H and He in the pellet ablation cloud, the helium-hydrogen ratio profile in plasma can be shown in Fig.2. The low concentration of helium may be due to the hydrogen inward flow from the wall.

References

1) T. Ozaki, et al., Rev. Sci. Instrum. 77, 10E917 (2006)
2) V. Sergeev, private communication.

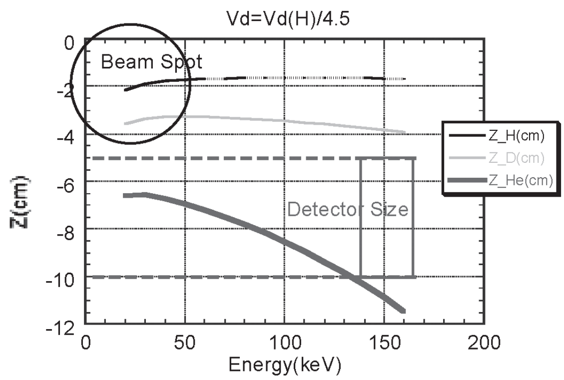

Fig.1 Beam spots in various plate voltages

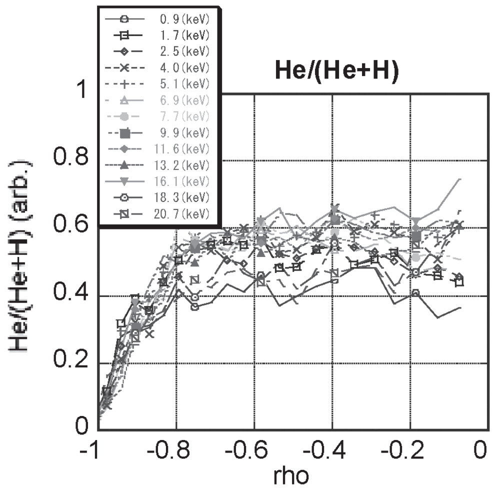

Fig.2 Helium Profile