§49. Pellet Charge Exchange Helium Measurement Using Neutral Particle Analyzer in Large Helical Device

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High-energy particles including α particles are emitted not only by charge exchange but also by MHD instabilities such as the Alfven eigen mode in ITER or a fusion reactor. Their particles damage the plasma wall in addition to creating poor plasma confinement. Decelerated α particles (or helium ions) with an energy over 1 keV makes a bubble and causes serious damage to the wall surface unlike hydrogen. Actually in LHD, where helium plasmas are often used, the helium flux over 10^{19} $m^{-2}s$ can be observed by the microscopic measurement of the irradiated materials. Therefore, the suitable method for measuring α particle/helium ion distribution should be established immediately. In the Large Helical Device (LHD), it is easily possible to do a simulation experiment of α particle heating by using ion cyclotron resonance heating (ICH).

To confirm the extended feasibility of PCX, we have tried to measure the radial profile of the high-energy particle spectra by perpendicular injection of TESPEL to the NBI plasmas. PCX has been done in NBI plasmas with different magnetic axes in order to compare those spectra. It is well known that the inner shift of the magnetic axis provides better confinement of energetic particles in helical devices from computer simulation results.

In the experiment, TESPEL is injected to the plasma produced by two tangential NBIs, NBI#1 (counter injection against the magnetic field) and NBI#2 (co-injection), and the perpendicular NBI#4. Therefore, the initial angular distribution is roughly uniform. The flux intensity is colored so we can easily compare those discrepancies. TESPEL reaches ρ=0.6. The time behavior of each energy flux during TESPEL injection can be obtained. The radial energy profile can be obtained by comparing the pellet traveling time with the signal as shown. Better confinement of energetic particles can be obtained by the inner shift of the magnetic axis in helical devices because the plasma region overlaps the particle orbit. Therefore, the increase of flux from the PCX can be expected at the inner axis shift. The maximum flux over a wide energy region can be obtained at the inner magnetic axis shift, especially at the plasma edge. We conclude that PCX is a useful technique to observe the radial energy spectrum of the energetic particles.

By using ICH with a higher harmonic fast wave, helium ion acceleration can be expected. This heating is utilized mainly for electron heating using Landau damping. We choose the suitable combination between the magnetic field and the frequency of the ICH so that there is no ion cyclotron resonance layer for the hydrogen in the plasma core region. One of their combinations realizes the resonance layer for the He^4 positioned in the plasma core region.

In the measurement of helium ion by the PCX, hydrogen still gets mixed in the detector because the charge and mass of hydrogen is close to that of helium. However the accelerated hydrogen ions are few because there is no resonance layer for hydrogen if the combination of the magnetic field of 1.86 T and the ion cyclotron frequency of 38.47 MHz is used. The He^4 resonance layer appears at ρ=1/3 in the 3rd harmonic of the ICH frequency. On the other hand, there are hydrogen resonance layers only at the peripheral region of the plasma.

In the experiment, the plasma is produced by the two tangential NBIs, NBI#1 and NBI#3. The ICH is intermittently applied. The TESPEL is injected into the plasma after NBI injection in order to minimize the effect of protons generated from NBI. Four similar discharges with TESPEL injection are shown. In two discharges, we measure the helium and hydrogen, respectively. In the next two discharges, the same procedure is performed without ICH.

The line averaged plasma density of $2x10^{19}$ m^{-3} and the central plasma temperature of 2 keV can be observed. To confirm the helium acceleration, we compare the spectra of the helium and hydrogen by using a CNPA with different plate voltages. We must remember that most signals are hydrogen even if we set the plate voltage for helium. TESPELs reach ρ=0.6 in all discharges. As mentioned above, the hydrogen component is mixed even if we set the helium channel. Therefore, we use the ratio of He/H. Figure 1 shows the energy resolved He/H ratio profiles with and without ICH. The acceleration can be observed at the wide area between ρ=0.7-0.85. We can confirm the acceleration of the helium ion by the HHFW heating from the ratio profiles. This means that PCX is a useful technique for the profile measurement of helium ions or α-particles.

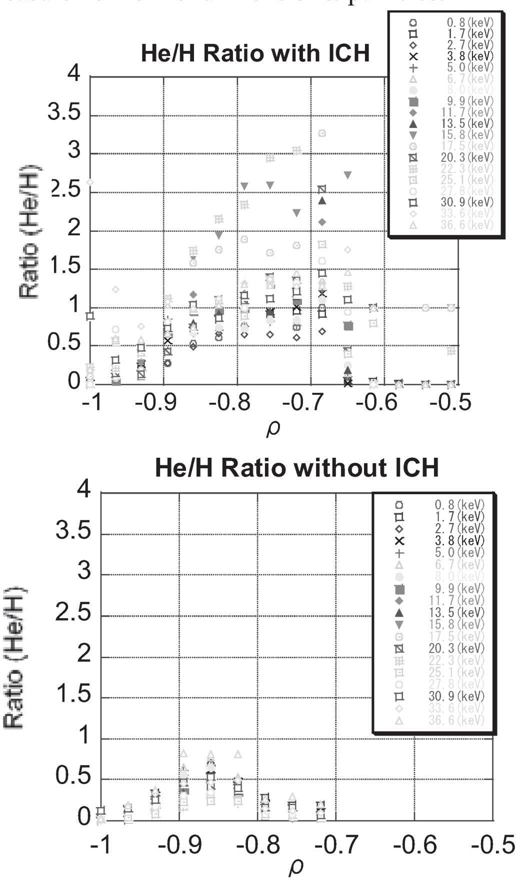

Fig.1 Helium Profile