

## §26. Neutral Particle Signals during Electron Cyclotron Resonance Heating

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In the experiment, an additional heating using an electron cyclotron resonance heating (ECH) to a plasma produced by an ion cyclotron resonance heating has been performed in hydrogen and helium mixture gas. An Ion temperature measured by X-ray crystal spectroscopy has been increased remarkably during ECH phase as shown in Fig. 1. This phenomenon has not been observed in hydrogen plasmas. The reason will be mentioned elsewhere. Here we focus on the difference between the X-ray spectroscopy and a compact neutral particle analyzer (CNPA) in the observed ion temperature. The X-ray spectroscopy is installed tangentially at the equatorial plane on 3-O port in LHD. The ion temperature is estimated from a Doppler broadening of highly ionized titanium. Central ion temperature can be observed since highly ionized titanium is localized near the plasma center. CNPA is also arranged perpendicularly almost at the equatorial plane on 3-O port. In the neutral particle measurement, the energy spectra of the charge exchange neutral particles can be observed. Each energy flux is determined by ion amounts with a velocity vector of a sight line direction and back ground neutrals, considering the energy depending cross section. The position where CNPA is located, is the end of the longitudinal axis in the ellipse cross section of LHD plasma. Therefore the measurement is strongly depended on the back ground neutral addition to the neutral particle flux reduction due to the plasma interaction. This is the difference between large device as LHD and small devices in neutral particle measurement.

When the ECH is applied in the plasma, plasma electrons are heated and expanded toward the out of the plasma. Plasma ions are also expanded by following the electrons. As the result, the plasma density is remarkably decreased as shown in Fig. 1. Back ground neutrals (mainly hydrogen atom) emit almost constantly from the wall of the vacuum vessel. Hydrogen atoms invade to the plasma center with a finite time by a chain reaction of charge exchange with proton in the plasma. At the low plasma density, the neutral particle flux increases since much hydrogen atoms reach the plasma center as shown in Fig. 2. The increase of the neutral particle flux in CNPA is due to the increase of the back ground neutrals because the shape of the energy spectrum was not changed. It takes time for reaching the plasma center because the invading speed of the back ground neutrals is limited. At a certain time in the ECH phase, a back ground neutral density still keep low temporary near the plasma center although there are much back ground neutrals around a peripheral region. There are much energetic ions in the plasma center and much lower energy ions in the peripheral region since the central temperature becomes higher than peripheral one. Therefore in CNPA measurement, much low energy neutral particles can be observed due much back ground neutrals near the edge region at the beginning of ECH application. However the energetic neutral particles are detected not so much. When the ion temperature is estimated by the slope of the energy spectrum in CNPA, the slope temperature decreases first. When the back ground neutrals reach the plasma center, the slope temperature increases.

Figure 3 shows the slope temperatures in different energy ranges. Here suffixes of 0, 3, 6, 9, 12, 15 and 18 correspond to 0.82, 3.75, 8.03, 13.5, 20.3, 27.8 and 36.6 keV, respectively. In the slope temperatures at low energy ranges, the slope temperature was not changed during ECH phase. However in those in higher energy ranges, the slope temperature becomes high a by the ECH application. The start time of a temperature rising depends on the energy range. The delay of the start time corresponds to the invading speed of the back ground neutrals. To observe high slope

temperature in the higher energy range suggests that the higher temperature region is localized in the plasma center.

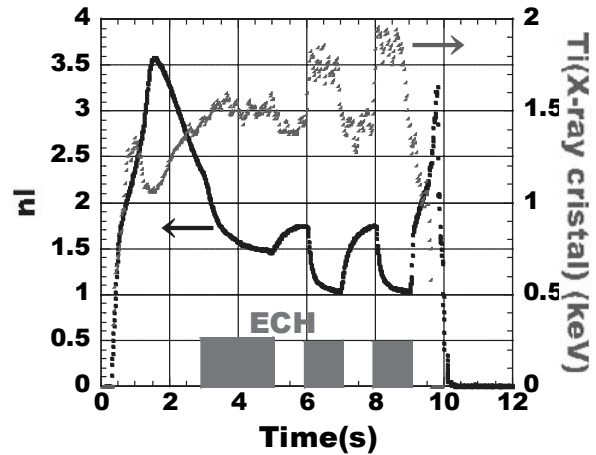


Fig. 1. ECH,  $T_i$ (X-ray) and  $n_e$ .

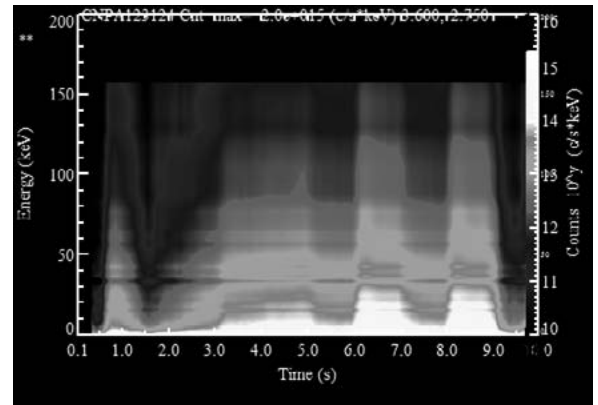


Fig. 2. Time history of neutral particle flux in CNPA.

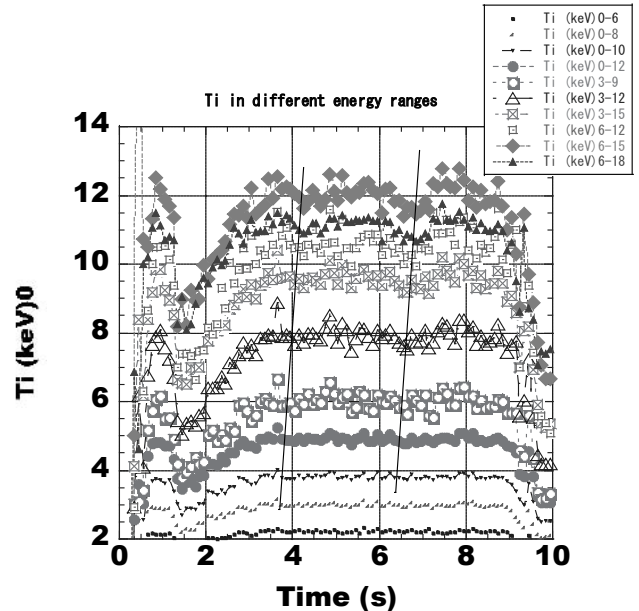


Fig. 3. Slope temperatures in different energy ranges in CNPA.