§7. Neutral Particle Signals during Long Pulse Discharge

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The long pulse discharge in LHD is maintained by the ICH using a mixed gas of H (minority) and He. In the ICH, the control of the gas ratio of H and He is essential to determine a resonance layer position and to obtain high heating efficiency. Impurities from a vacuum wall enter to the plasma because accelerated protons by ICH hit the part of the vacuum wall. To prevent this accident, we move the resonance position between the ICH and the plasma by scanning a magnetic axis. The fuel gas is supplied by a gas puffing. However the ratio is not specified by the original supplied gas content because the part of the gas is absorbed to the wall. The actual gas ratio is monitored by a Penning spectroscopic gauge. The gas ratio is strongly varied by scanning of the magnetic axis. The helium signal is varied by the scanning although the hydrogen signal is almost constant as mentioned elsewhere. This means that much amount of hydrogen is supplied from the vacuum wall. The variation of the helium amount may be due to the out gas from the divertor which is heated by accelerated ion.

The compact neutral particle analyzer (0.8-160 keV, 40 channels) measures the time history of the neutral particle as shown in Fig. 1. This can observe the charge exchange hydrogen atoms which are produced by the charge exchange reaction between the back ground hydrogen, helium neutrals or partially ionized (He^+ etc.) ions and energetic ions. During the magnetic axis scan, the neutral flux in low energy region is constant. However the neutral flux in higher energy region (energetic neutral particles), the flux is synchronized with the scanning cycle. The charge exchange cross section between H-H is higher than that between H-He at the energy range of less than 10 keV. However the cross section of H-H is similar to that of H-He at >10 keV. This means that the effect of He or He^+ background cannot be neglected in higher energy region although the effect of H background is large at the low energy. He ions can be easily accumulated to the plasma center due to the plasma electric field. The origin of the energetic neutral particle is close to the plasma center where there is also close to the resonance region. Therefore the observation of the energetic neutral particles can give the understandings of the heating mechanism. Two possibilities can be supposed about the synchronization between the energetic neutral particles and the magnetic axis scanning. One is due to the increasing of the background of He, another is that the resonance region moves to the different He concentration. The latter may be more dominant because the phase of the He signal in the Penning gauge is different from that of the energetic particle flux.

The neutral particle flux in lower energy region, which comes from H-H charge exchange reaction slightly increases during long pulse discharge. The result in the neutral particle flux corresponds to the result in the Penning measurement. This means that the hydrogen gas is exhausted from the divertor because the divertor is heated up by the accelerated ion. On the contrary, the energetic neutral particles decrease gradually with the time. Two subjects can be considered; one is decreasing of the background helium, another is the decreasing of the energetic ion. However if all conditions are same, the heating efficiency of ICH is determined by the gas ratio at the resonance region. Therefore two subjects has deep relations. From the experimental result, the earlier plasma collapse can be observed when the energetic neutral particle flux strongly decreases as shown in Fig. 2. The neutral particle at the low energy region slightly increases (Fig. 2). This means that H outgas from the divertor increases. Therefore the heating efficiency of the ICH decreases due to high H concentration. The decreasing of heating efficiency is advanced because the helium gas exhaust from the divertor also decreases (negative cycle).

We conclude that the control of the helium concentration around the resonance region may be one of the essential issues to achieve the stable long pulse discharge from the result of the neutral particle flux measurement.

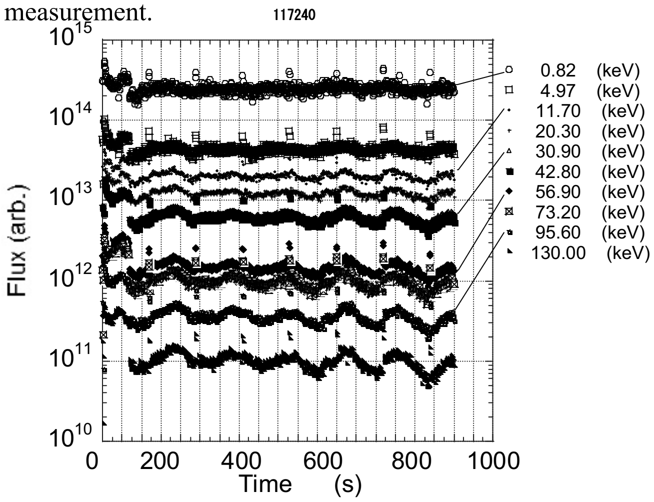

Fig. 1. The neutral particle flux (CNPA).

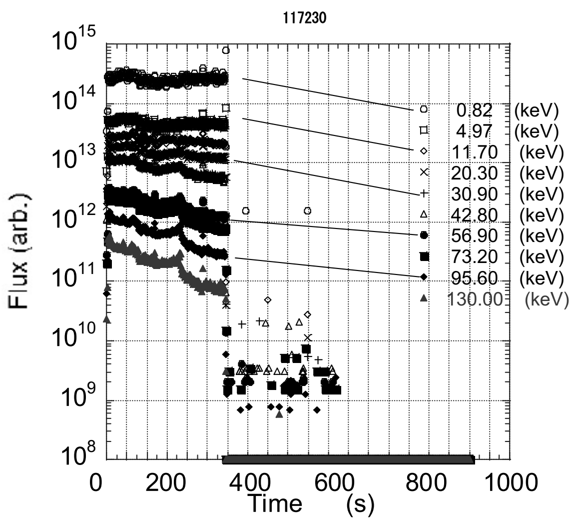

Fig. 2. The neutral particle flux in earlier collapse.