§58. Perpendicular Angular Resolved Multi-Sightline Neutral Particle Analyzer

Ozaki, T.

ARMS is the 20 channel Angular Resolved Multi-Sightline neutral particle analyzer (ARMS) [1]. This analyzer is prepared for investigating the loss region by measurement of the spatial (=pitch angle) resolved energetic ion distribution. According to N.Watanabe's calculation [2], there is a transit region around the pitch angle of 80 degrees. The ARMS in the perpendicular direction (P-ARMA) has been installed at 12^{th} cycle. The automatic operation of P-ARMS has started from the last cycle. By the improvement of the analytic program, the energy resolved pitch angle distribution with time evolution can be obtained just after the discharge.

Figure 1 shows the pitch angle distribution when the magnetic strength is varied. P-ARMS, which is installed perpendicularly against the magnetic axis, is settled at the torus position of 140 degrees from the NBI#4, which is injected to the perpendicular direction against the magnetic axis. Even at the weak magnetic field, much particle with the pitch angle of 90 degrees can be observed. The fact is relevant to the result that the high-energy particle over 1 MeV can be obtained at the ion cyclotron heating which accelerates the ion perpendicularly. The perpendicular particle is well confined in the helical plasma. At 80 degrees, there is a loss region. However the loss region becomes reduced by the strong magnetic field. Although NBI#4 is injected with the pitch angle over 80 degrees, the pitch angle of the ion becomes small by the pitch angle scattering with the plasma ion. The similar tendency can be obtained by the measurement of the tangential injected NBI using the tangential ARMS. At the tangential NBI, the pitch angle changes from the small angle to the large angle. However a few amount particles with the pitch angles over 80 degrees can be observed because there is the loss region around 80 degrees.

Fortunately the loss region appears near the plasma outer radius. We have compared the pitch angle distributions in the different plasma densities. In the high-density, the ion flux at the outer plasma radius can be observed, although the ion flux at the inner plasma radius can be obtained in the low density because the background neutral cannot invade the plasma in the high-density. The loss region at the high density is reduced at the low density. This means that the confinement at the plasma center is improved. Actually perpendicular NBI#4 can heat the plasma ion effectively.

Figure 2 shows the pitch angle distribution when there is none or extremely low-density plasma. In this condition, we can observe the loss particle directly because the pitch angle scattering is very rare. At the weak magnetic field, very weak signal around perpendicular direction can be observed. At the strong magnetic field, the particle signal appears at 80 degrees, where there is the loss region. We cannot find the strong signals at the tangential NBI plasmas. This means that the lost particle may be observed at the strong magnetic field, although the injected NBI hits the armor directly at the weak magnetic field. The analysis of the phenomena is still continued. One of the explanations is as follows. If there is plasma, we can observe the ion, which exists in the plasma because the charge exchange with the background neutral occurs. At no plasma, it is very difficult to observe the signal because the charge-exchange cross-section with the gas is less than one tenth. However enough signal of the direct lost particle can be expected because the direct lost particle toward the detector has much interaction length with the gas. At the tangential injection NBIs, the strong signal is observed because the particle is not injected with the pitch angle of the loss region.

In the summary, the energetic ion with the perpendicular pitch angle is well confined in LHD. This means that the effective heating by NBI#4 can be explained. However the loss region around the pitch angle of 80 degrees at the outer minor radius still exists. The loss region can be reduced by the strong magnetic field. The positive electric field created by a strong electron cyclotron resonance heating can also reduce the loss region.

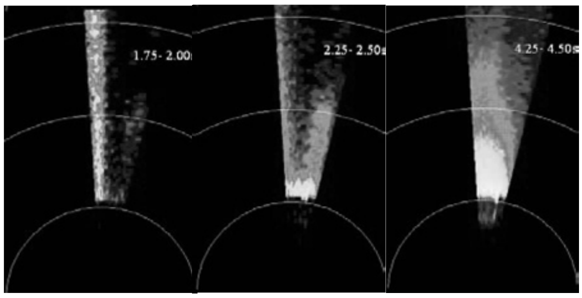

Fig.1. The pitch angle distribution with plasma (left) B=-0.43T, (center) B=-1.2T, (right) V=-2.7T.

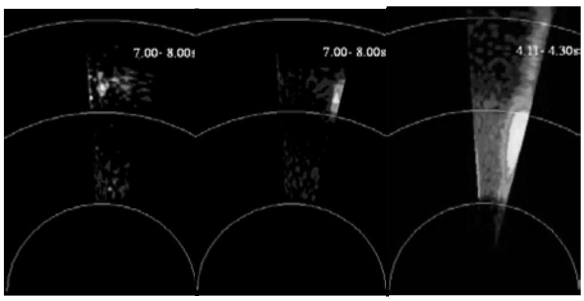

Fig.2. The pitch angle distribution without plasma (left) B=-0.43T, (center) B=-1.2T, (right) V=-2.7T.

[1] E. Veshchev et. al, RSI 79, 10E310(2008).
[2] T. Watanabe, et al., Nucl. Fusion 46 (2006) 291–305.