Study of the loss cone feature using neutral particle analyzer in large helical device

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It is very important to control the trapped particle by the helical ripple to realize the helical type plasma fusion device. High-energy particles generated by the ion cyclotron resonance heating and the neutral beam injection (NBI) heating have a wide pitch angle distribution by the initial heating mechanism and the atomic process in plasma. The particle with large pitch angle has a complicated orbit, sometimes the loss orbit at certain energy and pitch angle, although the particle with large parallel component against magnetic field line is well confined along the magnetic surface. The loss region in the phase space, so call a loss cone, can be clarified by measuring the pitch angle distribution of the high-energy particle. To this purpose, the lost ion has been directly measured near the plasma. Here the charge exchange neutral particle between the high-energy ion and the background neutral is measured to obtain the pitch angle of the high-energy ion in the plasma. In the large helical device (LHD), we have used two different neutral particle analyzers, the time-of-flight (TOF-NPA) and the silicon detector (SD-NPA) neutral particle analyzer. NBI heating in long discharge is suitable for this purpose in LHD. Three NBIs are tangentially injected to minimize the particle number toward the loss cone region in LHD. The energy of the high-energy ion supplied from NBI decreases by the plasma electron. The pitch angle scattering is occurred by the plasma ion at the energy of the several times of the electron temperature. Therefore we can easily compare the experimental pitch angle distribution with the simulation result, which is obtained by considering the initial pitch angle distribution and the atomic process. The pitch angle distribution from 40 to 100 degrees can be obtained by horizontal scanning the TOF-NPA during the long discharge over 100 seconds sustained by the NBI#2 (co-injection) at the magnetic axis (R_{ax}) of 3.6 m. The trapped particle by the helical ripple can be clearly observed around the pitch angle of 90 degrees. The loss cone feature is agreed with the result. It is interesting to investigate the dependence of R_{ax} of the loss cone feature. However it is not suitable to use the scanning of TOF-NPA during NBI plasma discharge although it can provide the precise structure of the loss cone because it is very difficult to sustain the long discharge at different magnetic axis. We use SD-NPA, which has ability of 6 different pitch angle measurement at R_{ax} =3.5, 3.6 and 3.75 m. The much trapped particle can be observed at Rax=3.5 m because the large helical ripple can be expected at inner magnetic axis. The electric field is often utilized to minimize the loss cone in the helical system. The electric field can be obtained by the charge exchange recombination spectroscopy in LHD. The effect of the electric field against the loss cone feature will be described.