§17. Vertical Distribution Measurement of Energetic Particle Using ARMS

Ozaki, T.

ARMS (Angular Resolved Multi-Sight line neutral particle detector) [1] is the time and angular resolved neutral particle analyzer with 20 channels. We prepare two ARMSs, which are installed at the tangential and perpendicular directions against LHD plasma. In this cycle, vertical energetic distribution can be obtained by rotating the detector.

A helical plasma has various merits for example, about plasma stability compared with a tokamak plasma. However there is a loss cone which is a loss region of the energetic particles. Although the loss cone is minimized by the device design in LHD, it is not clear experimentally. The energetic spatial distribution (=pitch angle distribution) in mid-plane has been mainly observed. However there is no information about the vertical direction. On the ICH plasma in LHD, extremely high energetic ions over 1 MeV can be confined. Two dimensional information including vertical one about energetic ion distribution is important for investigating this mechanism. On the steady state operation in ICH mode, the pulse duration is determined by the drop of flake from the wall. Although the flake is a part of wall materials, it is produced by the collision between the energetic particles and the wall components. Therefore it is very important to observe the orbits of the energetic particle.

We have developed ARMS as shown in Fig. 1. In this cycle, we can succeed to observe the vertical pitch angle distribution of energetic particle. The silicon surface barrier diode (20 channels), which is usually used as X-ray detector, is utilized for ion measurement. The detector is covered with 0.1 micron Al film to shield soft-x rays. The pre-amplifier circuit is very compact and mounted in the small vacuum chamber. The detector and the pre-amplifier are cooled by the liquid nitrogen in order to reduce the electrical noise. We can measure the ion energy with 15 keV by the noise reduction. Maximum observable energy is determined to be 1 MeV by the particle penetration to the sensitive layer in the detector. ARMS was calibrated by using gamma-ray from Am 241. The time resolution is set to be 5 ms in the pulse height analyzer. Different 20 sight lines with different pitch angles can be observed. Therefore the loss cone behaviors in various plasma condition can easily investigated.

Typical behaviors in NBI plasma are as follows. In perpendicular NBI injection mode, the different signals could be observed when the magnetic axes are varied. The loss cone was obviously reduced when the magnetic axis was shifted to inward rather than outward. When the magnetic axis was moved to outward, the particle flux has been reduced in all pitch angles because the particles have been lost in the loss region before the pitch angle scattering. By shifting inward, the particle loss was reduced since the particle orbit is closed to the magnetic surface. Loss cone which was observed around 85 degrees, was disappeared by applying the strong ECH in the plasma center. According to the potential measurement by using HIBP, the positive potential was created in this situation. The positive potential improved the confinement of the particles.

The vertical energetic particle distribution can be obtained by rotating the detector which is settled on the rotating stage as shown in Fig. 2. In principle, two dimensional profile of neutral particles can be obtained because any rotation angle can be selected. In current status, we cannot access the rotator by a remote control during the discharge. Therefore we set the rotation angle to be 90 degrees at the beginning of every day. Typical experimental result overlapped ICH (4.5-5.0 seconds) on NBI plasma is shown in Fig. 3. Each 500 ms accumulated profiles are shown. The vertical and horizontal axes show the middle plane and upper sightline. Particle flux is expressed by the density of the color. Much signals had been expected during ICH application period. However the flux slightly decreases in this period. The detail analysis will be proceeded soon.

[1] E.Veschev et al., Rev. Sci. Instrum., 77, 10F129 (2006)

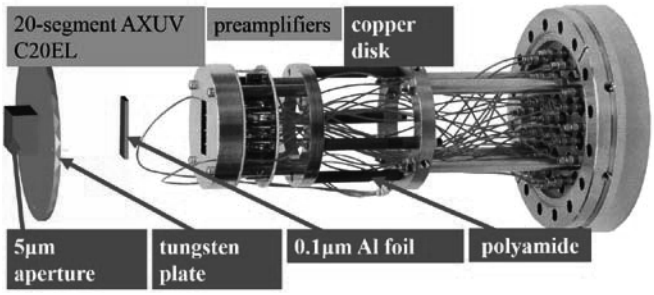

Fig. 1 Inside structure of ARMS

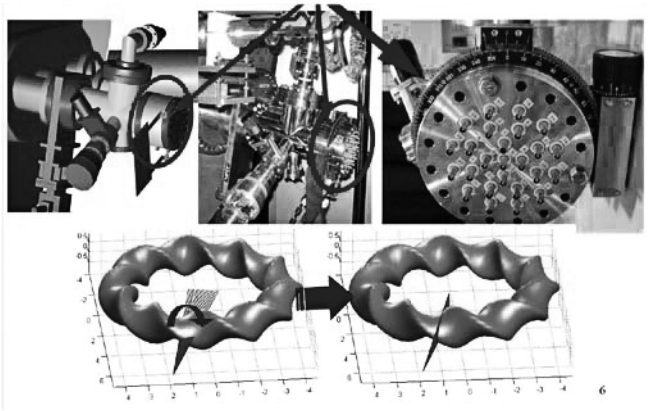

Fig. 2 Rotation mechanism of ARMS

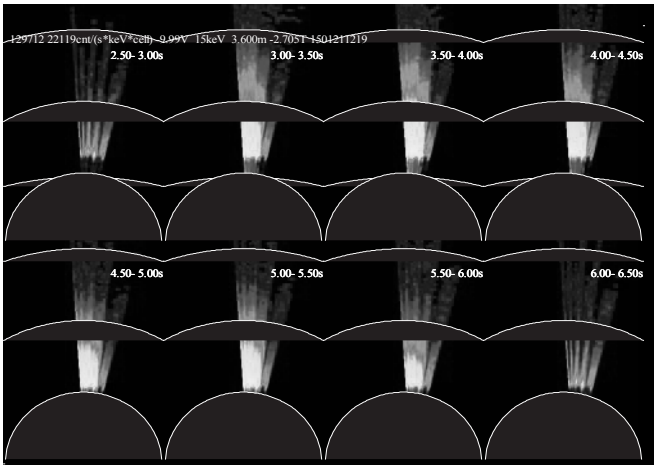

Fig. 3 Typical result in vertical direction during NBI and ICH phases