§15. Spatial Resolution of the Heavy Ion Beam Probe for LHD

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Radial electric field in magnetically confined plasma changes the trajectory of charged particles in the plasma. In addition to that, it affects the behavior of plasma turbulence. Thus, it is a key parameter to determine the confinement the plasmas.

Heavy ion beam probe (HIBP) is a unique tool to measure the electrostatic potential and density fluctuation directly and simultaneously in high temperature plasmas. Thus, an HIBP has been installed on the Large Helical Device (LHD) in order to study the transport phenomena in plasmas

The probing beam of the HIBP has a finite width and the detector also has a finite area, so the detected secondary beam comes from a finite volume. Thus, the observed region has a finite volume, which is referred as a sample volume, as shown in Fig. 1. The size of the sample volume determines the spatial resolution of the HIBP. Therefore, the estimation and the optimization of the size of the sample volume are important for measuring the fine structure of the potential profile and plasma turbulence.

In order to estimate the structure of the sample volume, the beam width, the divergence of the beam, and the energy difference are taken into account. We estimated the dependence of the length of the sample volume (L_{sv}) on each of them in this fiscal year[1].

The beam-width dependence is shown in Fig. 2. The diameter of the beam is about 10 mm in experiments, so the maximum length of the sample volume is about 40mm. The diameter of the aperture in the injection-side beam line is 25 mm, so the L_{sv} can be 63 mm at most.

The dependence on the divergence of the probing beam is shown in Fig. 3. The size of the sample volume depends on the divergence strongly. Thus, the divergence should be reduced for the better spatial resolution.

The energy difference of the beam comes from the negative ion source, the stripping process in the gas cell, and the stripping by the residual neutral gas in the accelerator tube. The energy difference due to the stripping in the accelerator tube can be comparable to the accelerating voltage, and is dominant. The expansion of the sample volume due to the energy difference is 12 mm at most as show in Fig. 4. If the charge stripping in the accelerator tube can be negligible small, the expansion of the size of the sample volume is negligible. Thus, the minimization of the pressure in the accelerator tube is important.

The results indicate that the divergence expands the sample volume more than the beam width and the energy difference do. From the view point of the secondary beam current, the divergence should be as small as possible. Thus, the parallel beam is preferred for the measurement with the better spatial resolution.

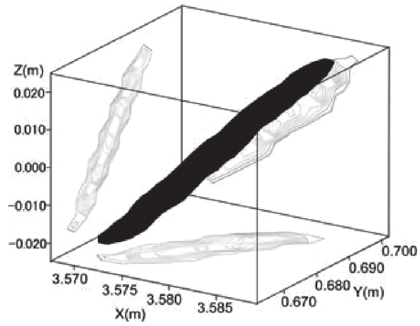

Fig. 1 A sample volume, assuming the beam with the diameter of 10 mm is injected into the designed direction. X-, Y- , and Z-axes are the major radius, toroidal displacement, and vertical axis, respectively

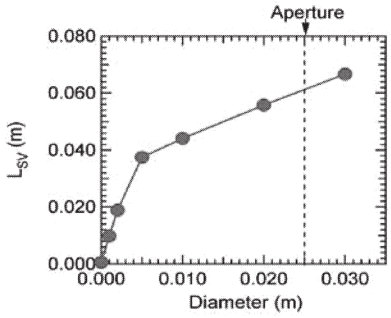

Fig. 2 Beam-width dependence. The horizontal axis is the diameter of the beam, and the vertical axis is the maximum length of the sample volume.

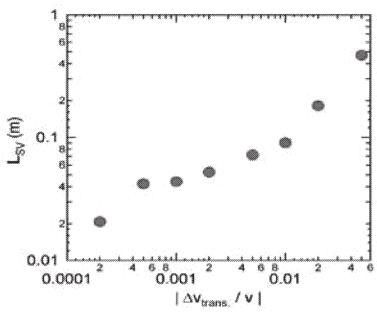

Fig. 3 Dependence on the divergence of the probing beam. The horizontal axis is the ratio of the velocity in the transverse direction to that in the traveling direction.

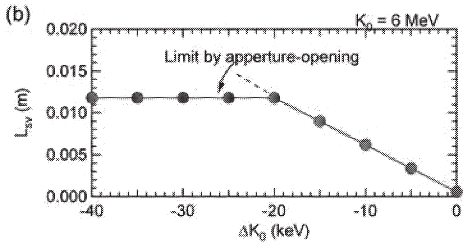

Fig. 4 Dependence on the energy difference. The beam with the energy difference of 22 keV or more can not go through the slit.

Reference

1) Ido, T., et al.: to be published in Plasma and Fusion Res. (2007)