§13. Study on High Energy Particles Escaped from LHD Using Scintillator Probe

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For lost ion measurements, a scintillator probe is installed into the LHD, as shown in Fig. 1. The cylindrical shaft axis of the scintillator detector is located 12.5 degrees in a counterclockwise direction from the center of the 5-O port, where it is a horizontally long poloidal cross section, and below the mid-plane. Assuming that the collisions between protons induced by NBs at less than 150 keV and bulk plasmas can, along with the electric fields, be ignored, fast ions running toward the outer wall of the LHD are estimated numerically. The Lorenz orbit calculations indicate that the lost ions are mainly produced by the prompt loss of NBs, and that the lost particles, escaping from the last closed magnetic surface (LCMS), are found to be quite few. For effective detection of lost ions, a scintillator detector with a stroke of about 2.5 m is designed for traveling near the LCMS and across a divertor leg at the magnetic axis Rax = 3.75 m. The shaft from the tip to the end facing the air is 4.45 meters long and can slue 360 degrees around its axis to change the aperture angle. The movable system for the scintillator probe provides information on the continuous space distributions of lost ions at a poloidal cross section.

The head of the scintillator detector (ϕ37 mm, ZnS(Ag)) has an aperture of 2 mm x 0.5 mm. The head is made of molybdenum in order to overcome severe heat loads from the divertor leg. Three thermocouples are in contact with the cylindrical inner wall of the probe shaft at the positions of 80, 220, and 2100 mm from the tip of the head. These positions correspond to the head, the shaft where the heat flux flows into the divertor plate, and the sapphire view port, and should be treated carefully to protect against the heat from the plasmas and the plasma heating devices. The sapphire view port is in contact with the coaxial water pipe for cooling from the air side. The focused scintillation light is introduced into an image-intensified CCD camera unit (Hamamatsu, C4336) with a frame rate of 1/30 sec, and the 3 x 3 photomultiplier array using the optical fiber bundle is covered with the coaxial water pipe. We plan to record a camera image into the LHD storage system by using image acquisition hardware (National Instruments, NI-1409) with the ICCD camera in the 8th campaign; at present it has been recorded by video recorder. The photomultiplier signals are prepared to be stored into a CAMAC module.

The gain of the ICCD camera and the probe position are remote-controlled with RS-232C from the room next to the LHD torus hall.

Figure 2 shows the camera image on the scintillator plate with only NB#3 heating of the H^+ 105 keV 350kW beam under R_{ax} = 3.5 m, Bt = 2.829 T, and Ti = 1 keV. In this case, one of two column ion sources for the outer beam line was operated. Two bright spots are observed during the NB#3 injection on the scintillator plate, one at $\rho = 4 - 9$ cm with $\chi = 80 - 100$ degrees and another at $\rho = 1 - 3$ cm with $\chi = 90 - 110$ degrees. Given that there are differences of roughly 2 cm in ρ, the energy calibration must be carried out changing the injection energy of NB to obtain the exact values.

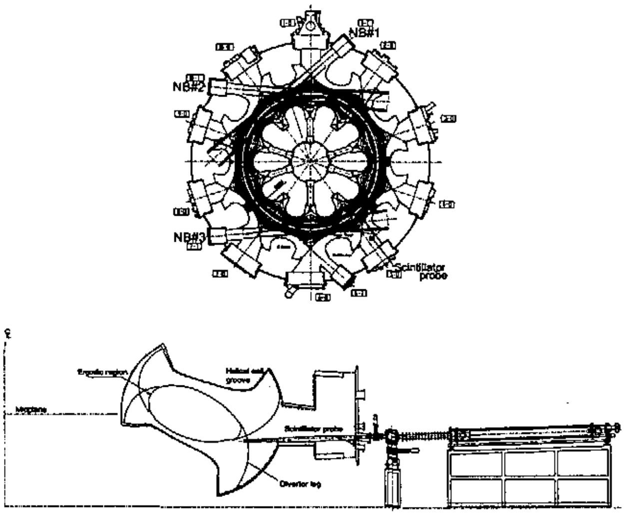

Fig. 1. Top view of the LHD midplane is shown in the upper portion of the figure. The beam lines for NB#1, 2, and 3 and the location of the scintillator probe are indicated. The lower portion of the figure shows the cross sectional view of the scintillator probe system and the LHD magnetic configuration at R_{ax} = 3.75 m.

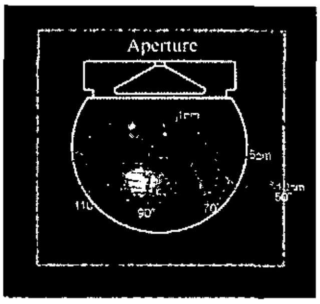

Fig. 2. Camera image of the scintillator with the calculated grid for pitch angle and gyro radius. The bright spot is due to the impact of escaping fast ions. The outline of the scintillator probe head and the rectangular boundary of the fiber bundles are drawn.