§31. Detection of Particles with Energy of up to 2.5 MeV in LHD

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In the large helical device (LHD), the tail temperature of high-energy particles accelerated by ICRF heating estimated in the energy region lower than 300keV tends to saturate with regard to the tail temperature deduced from slowing down time and ICRF power [1]. Therefore, it is difficult to detect high-energy particles with the energy of MeV level by increasing power. However, it is possible to detect these particles by exposing for a long time. Figure 1 shows silicon-diode-based fast neutral analyzer at 6I port (6I-SiFNA), which detects the particles with the perpendicular pitch angle at an inner port of LHD. Line of sight is directed to points where resonance layer and flux surface contact tangentially each other in order to detect particles, which are in resonance condition for a long time. Energy was calibrated using radioisotopes.

Figure 2 shows a long-pulse discharge sustained with ICRF heating and ECH. Mode of ICRF heating was minority ion heating using helium as majority ions and hydrogen as minority ions. The applied ICRF frequency was 38.47MHz and the magnetic strength at major radius on the mid plane of 3.6m was 2.85T. The major radius of magnetic axis was scanned from 3.62m to 3.67m. In this discharge, line averaged electron density was kept low at 0.5×10^{19}m^{-3}. Injected ICRF power was approximately 1MW. Duration time was 362 seconds. Figure 3 shows the relation between the energy and the detected particle counts during the long-pulse discharge. Energy resolution is 4.1keV. It was clarified that the high-energy particles with the energy of 2.5MeV can exist. Larmor radius of 2.5MeV proton at resonance layer reaches 9cm. Long exposure time made it possible to detect MeV level particles. The calculation of orbit of particles predicts that the particles can be confined up to 3MeV in LHD [2]. At the energy of 2.5MeV, $k_\perp \rho_i$ at resonance layer is approximately 1, where $k_\perp$ is perpendicular wave number estimated from dispersion relation, ρ_i is Larmor radius of resonant ions. Therefore the acceleration of particles by left hand polarized field depending on $J_0(k_\perp \rho_i)E_+$ still possible and the acceleration by strong right hand polarized field depending on $J_2(k_\perp \rho_i)E_-$ is also expected. Figure 4 shows energy spectra during low and high power injections. It was found that in the low-energy region, slope of energy spectrum is almost saturated with ICRF power, however, in the high-energy region, the slope changes with the power.

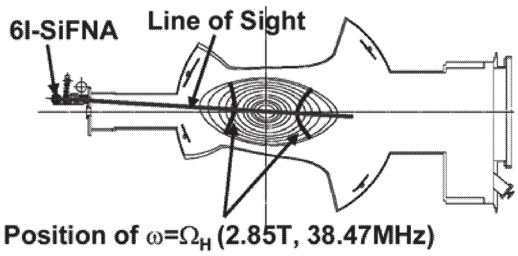


Fig.1 Fast neutral analyzer (6I-SiFNA) and the line of sight.

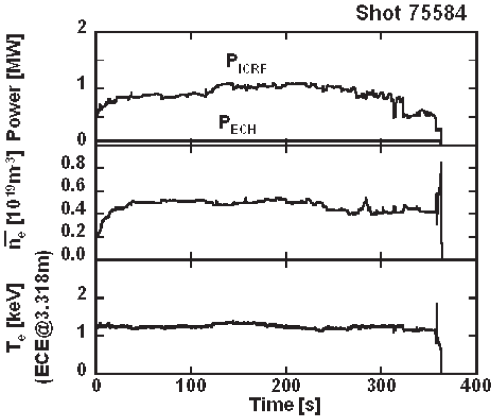


Fig.2 Long-pulse discharge sustained with ICRF heating and ECH.

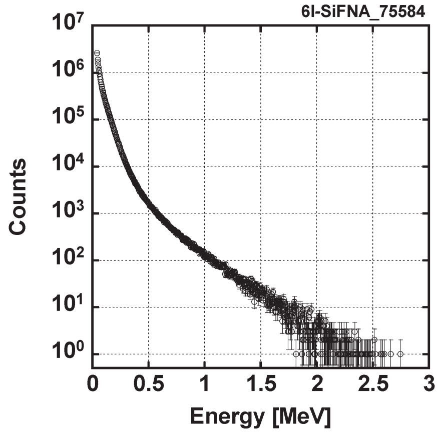
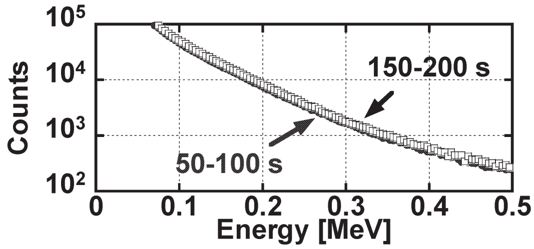


Fig.3 The relation between the energy and the detected particle counts measured with 6I-SiFNA.

(a)



(b)

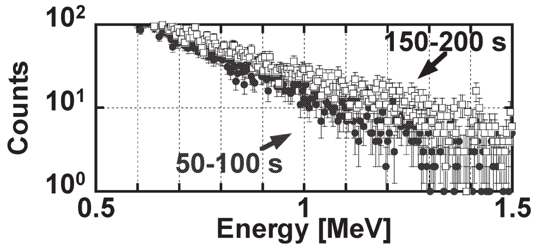


Fig.4 Energy spectra during the low-power injection (50-100s) and the high-power injection (150-200s) in (a) low-energy region and (b) high-energy region.

Reference
1) Krashilnikov, A.V., et al. Nucl. Fusion **42**, (2002) 759
2) Mutoh, T., et al. Proceeding of 21st IAEA Fusion Energy Conference, EX/P1-14