§6. Space and Energy Distributions of High Energy Electrons in LHD Plasmas Heated by ECH

Muto, S., Morita, S., Kubo, S., Igami, H., Yoshimura, Y., Takahashi, H., Shimozuma, T., LHD Experimental Group

Hard x-ray measurements have been carried out in Large Helical Device (LHD). In LHD hard x-rays have been measured by a germanium-semiconductor detector in the case of low density plasmas heated by Electron Cyclotron Heating (ECH). Especially, maximum counting rate is obtained at an electron density of 2.0×10^{18} m^{-3} [1].

It is important to investigate suprathermal electrons which mean the high energy electrons produced by ECH. In order to confirm the existence of the suprathermal electrons, however, it is necessary to prove its non-maxwellian energy-distribution function in a local position of the plasmas. Accordingly, it is also important to observe the radial profile of the suprathermal electrons. In LHD an assembly of x-ray Pulse Height Analyzer (PHA) makes it possible to measure the x-ray energy spectra with multiple sight lines [2].

Figure 1 shows x-ray energy spectra obtained with the PHA assembly. The spectra are measured from the ECH plasmas. The spectra are quantitatively corrected by the transmission rate of a 1-mm-thick beryllium window and the quantum efficiency of Si(Li) semiconductor detectors. This assembly does not directly see divertor plates from which strong x-rays are emitted due to the bombardment of energetic electrons. Therefore, it is available to obtain the local emission from the plasmas through the Abel inversion [3].

The energy spectra obtained in the present study seem to be explained by two components of continuum x-ray emissions, as shown in Fig.1. One component is the x-ray emissions from the bulk electrons. The other is the x-ray emission from the high energy electrons driven by ECH. Here, the emissions are analyzed assuming thermal component and high energy tail. At a normalized radius of ρ = 0.1 the electron densities of the bulk and suprathermal electrons are estimated to be 1.25×10^{18} and 7.50×10^{17} m^{-3}, respectively. The total electron density is 2.00×10^{18} m^{-3}. Then, the density ratio between the bulk and suprathermal electrons is 0.62:0.38. The electron temperature of the bulk plasma is estimated to be 5.4 keV from the x-ray energy spectrum. The average energy of the suprathermal electrons is 40 keV.

Figure 2 shows the estimated radial profile of the average energy for the suprathermal electrons. The electron temperature of the bulk plasmas is of course a function of the normalized radius. However, the radial profile of the average energy is approximately constant against the normalized radius. Accordingly, the low-density ECH discharge in LHD is confirmed to be non-equilibrium plasma.

The radial profiles of the total electron density and the density of the suprathermal electrons are also shown in Fig.2. The high energy component becomes small with the normalized radius. It is less than 10 % at $\rho \geq 0.6$. The bulk electrons dominantly exist in $\rho \geq 0.2$. The density of the suprathermal electrons rapidly increases at $\rho \leq 0.2$. Particularly, the suprathermal electron density is comparable to the bulk electrons at $\rho \leq 0.1$ indicating ECH power deposition focused on the plasma center.

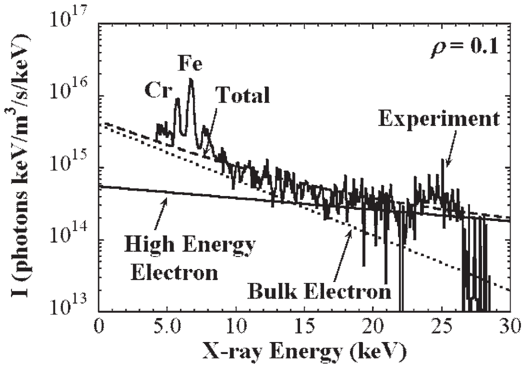

Fig. 1 Abel inverted x-ray energy spectra obtained from the experimental and calculated results. X-ray energy spectra calculated for the bulk component (dotted line) and the high energy component (solid line) are plotted with the total spectrum of two components (dashed line).

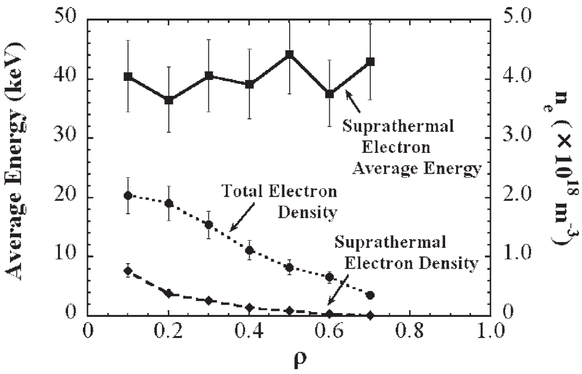

Fig. 2 Radial profiles of average energy for suprethermal electron (solid line), density of suprathermal electrons (dashed line), and total electron density (dashed line), respectively.

1) Muto, S. *et al.*, Rev. Sci. Instrum. **74** (2003) 1993.
2) Muto, S. *et al.*, Rev. Sci. Instrum. **72** (2001) 1206.
3) Muto, S. *et al.*, Plasma and Fusion research **2** (2007) (S1069),1-4.