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Experimental evaluation of fast ion confinement by fast ion charge exchange spectroscopy in LHD

LHDにおける荷電交換分光計測による高速イオン閉じ込めの実験的評価

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Spectroscopic investigation for H-alpha lights from reneutralized fast ions via charge exchange process is an useful method to identify spatial density profile of fast ions for each energy range. Tangential viewing geometry is suitable to observe properties of circulating fast ions in the scheme because the line of sight has quite large sensitivity and resolution for the fast ion velocity component parallel to the magnetic field line. We have successfully identified spatial profile of circulating fast ions on two energy ranges in Large Helical Device(LHD) plasmas which is sustained by the tangential negative-ion based neutral beam. The slowing down process of the fast ions has been examined by the evaluation of time evolution of the Doppler-shifted H-alpha emission.

1. Introduction

For sustaining fusion reaction and heating plasma, fast ions including the fusion-born alpha particles and the externally-injected particles are required to be confined because their loss might degrade the performance of fusion plasmas and might damage the fast wall of the fusion reactor[1]. In particularly, circulating fast ions are important because they can give their energy and momentum to the fusion plasma for heating and current drive(CD). However, the degradation of fast ion confinement might occur by collective instabilities depending on the fast ion distribution in real or phase space. Therefore, monitoring motion of supra-thermal ions is one of the key issue for understanding fast ion confinement and fast-ion-driven instabilities in high performance fusion devices.

Fast ion charge exchange spectroscopy(FICXS)[2] is applicable to investigate fast ion profiles because of its energy- and spatial-resolved measurement in Large Helical Device(LHD). This diagnostic is one of the active beam spectroscopy based on the analysis of Doppler-shifted spectrum from reneutralized fast ions via charge exchange(CX) processes between the probe beam and the fast ion[3]. This kind of diagnostic can measure the local properties of fast ions for each line of sight(LOS) because the measurement area can be determined by the spatial profile of probe beam and the observation LOS. An arrangement of observation geometry is important if focusing on the specific velocity component of fast ion is required.

On LHD, various types of Alfvénic phenomena driven by circulating fast ions have been observed[4]. To study these modes, we have added the tangential viewing geometry to the FICXS diagnostic and the initial observation of fast ion signal in LHD plasma has been obtained[5]. In this report, the validation of the observed fast ion charge exchange(FICX) spectrum compared with the calculation will be presented. Moreover, the evaluation of slowing down process of fast ions in the quiet LHD plasma will also be shown.

2. Experimental setup

The lines of sights(LOSs) for tangential FICXS diagnostic on LHD are arranged as shown in Fig. 1. The LOSs are horizontally aligned for the spatial measurement of passing-particles at a horizontally-elongated poloidal cross section where the diagnostic NB is injected. The measurement direction is set counter clockwise(CCW) of the torus. Thus, the particle which moves to the clockwise direction in the tourus emits blue shifted H_{α}-lights, while that moves to the counter-clockwise direction does the red-shifted lights. The observation areas on the LOS depends on the choice of NBs for diagnostic usage. When the radial-NB is used as a diagnostic-NB, t the area covers between R~2.8m to ~3.8m in major radii. A modulation of the probe beam is necessary to estimate the background spectra because the tangential FICXS diagnostic does not have any background LOS.

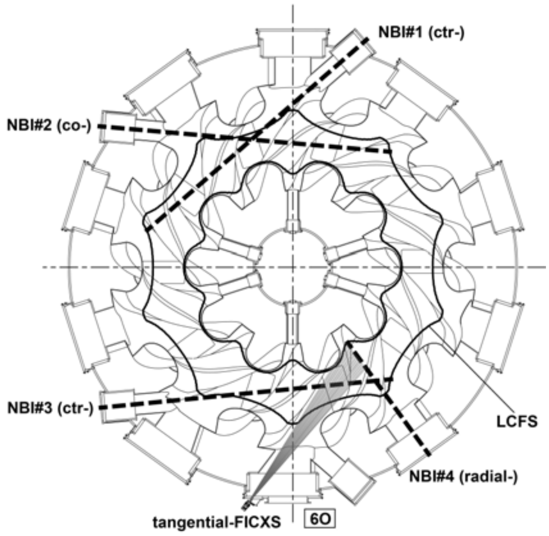

Fig. 1 Hardware apparatus of tangential FICXS diagnostic on the midplane of LHD.

3. Experimental results

The FICX spectrum is obtained where no significant instabilities are observed, so that the observed spectrum can be compared to the calculated spectra which is evaluated from the neoclassical transport simulation code for fast-ions. The calculated FICX-spectrum and the experimental observation are well agreed for the shape of spectrum. This agreement satisfies that the assumption of the fast ion velocity distribution and its spatial profile based on the realistic equilibrium used for the simulation is reasonable.

The time evolution of FICX signal derived by the integration of the observed spectrum on the limited wavelength range has also been examined. The intensity of FICX component in the specific wavelength range projects an window due to its intensity onto the phase space of fast ion. This profile on the phase space can be considered as a sensitivity of measuring fast ion density for each LOS. Therefore, it can be considered that a spatial profile of intensities of FICX component in the limited wavelengths indicates a density profile of fast ion with the specific energy range. By using this scheme, the slowing down time is evaluated by the time-evolved FICX signal. On the LOS faced the core region, the evaluated slowing down time and the calculation is well agreed as shown in Fig.2. This result indicates that the anomalous transport of fast ion for the slowing down time scale scarcely appeared in the experiment. More details will be shown in the presentation.

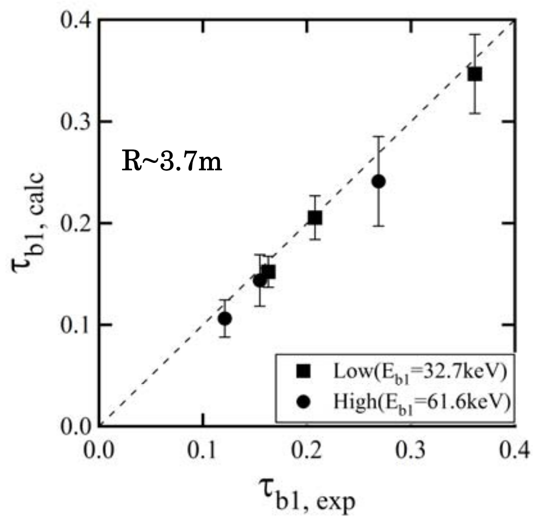

Fig. 2 Comparison between slowing down time obtained by calculation and observed FICX signal.

Acknowledgments

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