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Redistribution of Energetic Particles by MHD bursts on Large Helical Device

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1. INTRODUCTION

The confinement of fast ions is one of the most important issues on helical devices since the large helical ripple plays an important role on the topology of the fast ion orbit. Concerning on the fast ion studies on LHD, (a) the confinement of Neutral Beam Injected particles during their slowing-down processes, (b) interactions between fast ions and instabilities and/or ICRF-induced-waves, and (c) the confinement property of fast ions in the presence of electric fields are the important issues to be studied.

During the high-beta experiment with the configuration of R_{ax}=3.6 [m] and Bt=0.5~0.75 [T], the fast change of energetic neutral fluxes were observed on the E//B-NPA being associated with MHD burst signals which were measured by mirnov coils. These phenomena were observed during the 4^{th}- and 5^{th}- experimental campaign of LHD. In this paper, we will focus on the behavior of fast-ions during these phenomena.

2. Experimental Set-Up

On LHD, two of high energetic neutral beam (NB) injector was in operation during the 4^{th}-experimental campaign. They are based on negative-ion sources, thus they have only single energy components. Each injector has two ion-sources. The injection energy of the beam was designed to be 180keV. The beam power was about 1.3MW per single ion-source. The Beam is injected into co- and counter- direction, respectively. From the 5^{th}-campaign, additional 3^{rd}-NB injector was installed to the counter-direction and started its operation.

The Princeton-type E//B-NPA was installed on the tangential-port of LHD to examine the confinement property of fast ions produced by NBI. The energy range of the NPA covers from 0.5[keV] to 180[keV] for Hydrogen, which is sufficient for NB-particle measurement on LHD.

3. MHD induced neutral flux increase

During the high beta campaign of LHD, the sudden increases of neutral flux being associated with the MHD burst were observed at E//B-NPA as shown in Fig.1. The magnetic filed strength was 0.5-T and the direction of the field is reversed compared to the standard configurations, thus the NPA was observing the co.-rotating particles. The high energy component (132-keV) of the neutral flux was increased at the time bin when the MHD-bursts were observed. The flux increase of lower energy components occurred simultaneously and/or after the increase of high energy components of the signals. Since the fast neutral particle measurement is the result of the product between the ion density($n_i(E)$) of interested energy and the density of low energy neutrals which is coming from the plasma periphery, we must be care full about on which components MHD-bursts had their influences. If MHD-bursts had influences on the peripheral neutral density, the effect should also appear on the H-alpha signals and the influences on NPA-signals should not have the time delay depending on the fast neutral energy. Therefore, the flux increase of the fast neutral was considered to be the result of the change of the fast ion populations in plasmas.

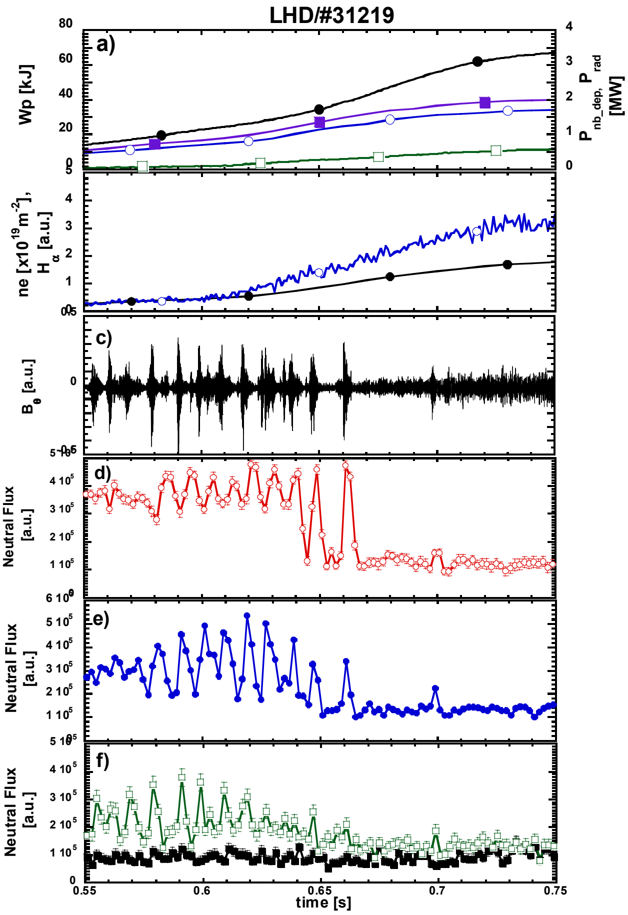

Fig.1 Typical wave forms of dischrarges where neutral flux increases associated MHD bursts were observed. a)Stored energy (black lines with closed circles), Deposition power of co.-Neutral Beam (blue lines with open circles), that of counter.-NB (purple lines with closed squares) and radiation power (green lines with open squares) are shown. b) Line averaged electron density (blue lines with open circles) and H-alpha signals are shown. c) Magetic fluctuation signals (B_θ) measured by a Mirnov-coil is shown. d)-f) Neutral Flux signals measured by E//B-NPA for 86-keV, 113-keV, 132-keV and 151-keV are shown by red lines with open circles, blue lines with closed circles, green lines with open squares, and black lines with closed squares, respectively.

The dominant component of the MHD bursts was TAE whose toroidal mode number(n) was 2 and poloidal mode number(m) was 3 or 4. The frequency of the mode was changing quickly during the bursts as shown in Fig.2(b). This mode was typically observed when the fast neutral flux increase was observed with a MHD-burst. The small deviation in plasma stored energy was also observed. This phenomena is more clearly seen in the time derivative of the plasma stored energy as shown in Fig.2(a) and might indicate that the degradation of the NB heating efficiency by the TAE[1].

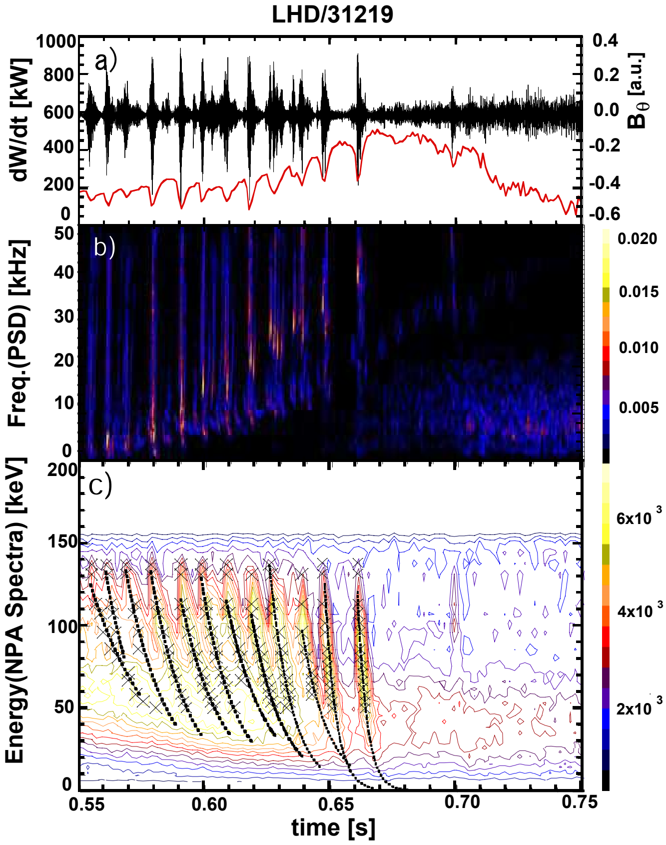

Fig.2 a) dW/dt and mirnov signals are shown in red lines and black lines, respectively. b) Power Spectrum Density of Mirnov signals are shown. c) E//B-NPA spectra are shown by contours. The x-symbols indicate peak positions of the flux increase at each energy channels. Dashed-lines show the result of exponential fitting of peak positions for each flux increase.

In Fig.2(c), the spectra of the E//B-NPA are shown by contours. The energy decay of the increased flux was more clearly seen in this figure. The energy decay time of each increased flux was evaluated by the exponential fitting of peak positions at energy channels of the NPA and was compared to the line averaged electron densities. As shown in Fig.3(a), the energy decay time is inverse proportional to line averaged electron densities. This result suggests that the energy decay itself was the result of classical slowing-down process, since the electron temperature stayed almost const during this period of the discharge. To evaluate the slowing-down time of the particle which was detected by the NPA, a series of orbit following calculation was performed by taking the launching points of the calculations on the NPA line of sight and by using the electron temperature and density profile of the discharge. In Fig.3(b), the result of the calculation were shown for the particle which are traveling at ρ_{avg} between 0.51 and 0.64, where the ρ_{avg} express the particle's location in plasma minor radius being averaged along the orbit. In this figure, the time with which the particle of 86-keV spend to lose its energy down to 54-keV are shown as slowing-down time. The slowing-down time of the particle rotating around ρ_{avg} = 0.55 seems to well express the experimental observations. By comparing the slowing-down time distribution to the energy decay time of the increased flux, the location where the fast ion population increased was evaluated and is shown in Fig.3(c). There seems to be the phenomena had a preference to occur at ρ_{avg} = 0.55.

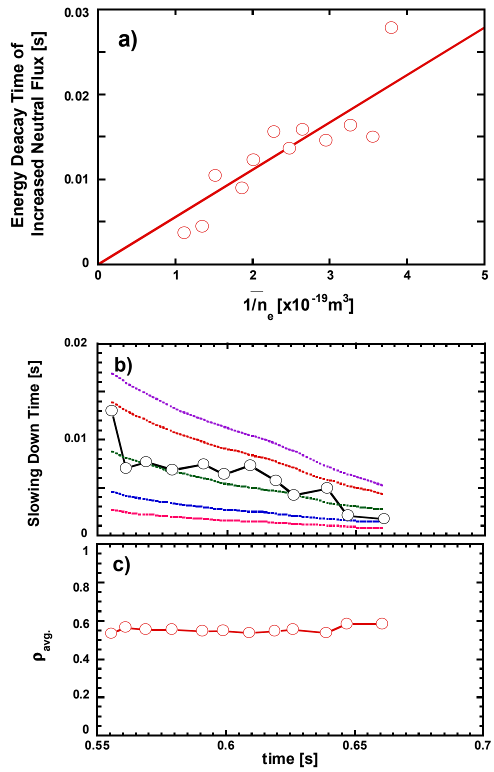

Fig3. a) Comparison of energy decay time of the flux increase to line averaged electron density. b) Evaluated slowing-down time of the particle. The slowing-down time of $\rho_{avg.}$=0.513, 0.526, 0.553, 0.594, and 0.646 are shown by purple dashed lines, red dashed lines, green dashed lines, blue dashed lines, and pink dashed lines, respectively. Black lines with open circles shows the experimental results. c) The evaluated location where the fast ion increase occurred .

4. SUMMARY

Fast Neutral Flux increases being associated with MHD bursts were observed by the tangential NPA on low field LHD-plasmas. The flux increase was caused by the increase of fast ion population on the NPA line of sight. It is turned out the increase at the high energy of around 130keV was induced by MHD-burst and the increase at the lower energy is the result of the energy slowing-down of the MHD induced increase at high energy. The MHD-induced increase of fast-ion population had a preference of being occurred at ρ_{avg} of arround 0.55.

The further analysis is necessary for the identification of the mode of MHD-bursts which induces the change of fast ion population and for the driving mechanism of the mode. The TAE of n=2 and m=3 or 4 is the most probable candidate.

References

[1] S.Yamamoto, *et.al*, presented at this conference.