Beam slowing-down time measurement using beam blip in KSTAR

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The confinement of the energetic particle would be the key issue in success of realizing energy production using fusion plasma because a 3.5 MeV energetic alpha particle sustains the burning plasma after the ignition. As the main mission of Korea Superconducting Tokamak Advanced Research program is exploring the physics and technologies of high performance steady state tokamak operation that are essential for the fusion reactor, its performance has been extended over the current tokamak operation boundary year by year, and recently showed high performance plasma(betap~3). In addition, the confinement of the energetic particle is also important key point in neutral beam driven plasma at KSTAR. The measured absolute value of the neutron intensity is generally used for estimating the confinement time of energetic particle by comparing it with the theoretical value based on transport calculation, but for the calculation process, the many accurate diagnostic data of plasma parameters such as thermal and incident fast ion density are essential. In this paper, the time evolution of the neutron signal from He3 counter during the beam blank has permitted to estimate slowing down time of energetic particle and the method is applied to investigate the fast ion effect on various discharge cases in KSTAR plasma which is heated by high energy deuterium neutral beams.

1. Introduction

The high beta operation on NBI heating at KSTAR shows the high performance plasma depending on injection of ECH power and considered the enhanced confinement of fast ion as the key role in formation of high performance plasma[1,2]. It was also reported that confinement degradation is observed by Alfven-eigenmode induced instability in steady state high q_{min} operation.[3] Therefore the accurate measurement of beam slowing down time is very important to characterize the steady state plasma discharges at beam driven plasmas. There are several direct diagnostic method to see the fast ion transport behaviour such as FILD, neutral particle analyser, and FIDA. However, they need highly elaborate efforts to deduce the confinement time from the experimental raw data. So, the indirect method such as the neutron measurement is generally used for estimating the fast ion behaviour because the neutron production is proportional to the intensity of fast ion intensity in beam driven plasma.[4] In this paper, we applied the He3 and FC 4 proportional counter with a field programmable gate array (FPGA), and a fast digital signal processor (DSP) with a good time resolution to the time response of neutron signal. In addition, decay time of beam blank period is used, where blank beam time should be done for other diagnostics CES, MSE for background noise subtraction.

2. Neutron measurement and slowing down time analysis

Firstly, the conventional blip beam method is used for estimating slowing down time of ohmic plasma. As shown in Figure 1(# 18355), a deuterium probe beam was injected into steady state diverted plasmas with Te=0.5-1.5 keV and ne=1-2*10^{19}/m^3. The KSTAR NB line is consists of three line probe is consists of three beams and typically tangentially beam A whose energy of 100 keV is used for blip experiment. The beam rise in less than 5msec and falls in 1 msec. The beam width of 10 msec is injected. The neutron emission rate rises linearly until the end of the beam pulse and then decay exponentially. As the plasma density is increased, slowing down time is decreased as expected. The line integrated density is used for estimating theoretical value due to unavailable Thomson data for this discharge. So only qualitative description is valid for this discharge. The classical slowing down expression using neutron decay time at beam heated plasmas is given by many references[5]. By comparing the measured with calculated one, we can see how much of the abnormal MHD activity. Beam blank is used for CES(charge exchange spectroscopy) measurement or happened due to fault mode of NBI beam. Nominal blank period of beam for diagnostic is about 10 msec and retrigger time for NBI interlock is set to 10-20 msec.

Figure 2 shows the typical high betap discharge where the decay time constant measured by new diagnostic method is given by solid circle at (g). No noticeable change of MHD activity is observed around transition period of high betap to normal discharge around 14s except 100 kHz range AE mode. The beam energy voltage is 100, 65 and 70 keV. Note that there are arc event around 10 and 13s at the ion source so that those are omitted for data analysis. The rato of measured to theoretical slowing down time does not change during the transition. Considering that beam line B and C consists of half energy beam is nearly same as the primary beam so that its effect reduce the theoretical calculated on by 16%. So as far as the error bar or detection ambiguity, it seems to be difficult to judge whether anormalous diffusion of fast ion is shown at the slowing down time measurements, but more study is required to clarify this. Shot# 18483 show three different discharges of ITB, L-mode and H-mode discharge in a single shot. Firstly, ITB is formed at inboard limited plasma and the ion temperature increases up to 6 keV in weakly reverse shear q profile but it comes back transited to H-mode around 5.8s with detaching from the inboard limiter to diverted plasma. Note that during ITB-mode, AE activity with frequency ranging of 100 kHz was observed as shown in Figure 3. The ratio of measured to theoretical slowing down time is about 80-90 % in L-mode and drops to 50 % at H-mode. Another interesting point is that during 3-6s, mode amplitude decrease corresponding to increase of neutron signal. But no significant change is observed at slowing down time from neutron signal. Therefore, in order to judge the beam transport loss, two evidences should be correlated. The first one is change of slowing down time and second one is corresponding mode amplitude change.

3. Summary

An experiment to measure the slowing down time of fast ions in KSTAR plasmas has been performed for various discharge cases by using neutron diagnostics. The beam slowing down time measurement is done during beam blank period for plasma diagnostics based on pulse mode He3 neutron counter and the feasibility study shows that the blank beam method would be useful to estimate the beam confinement time for three different discharge.

References:

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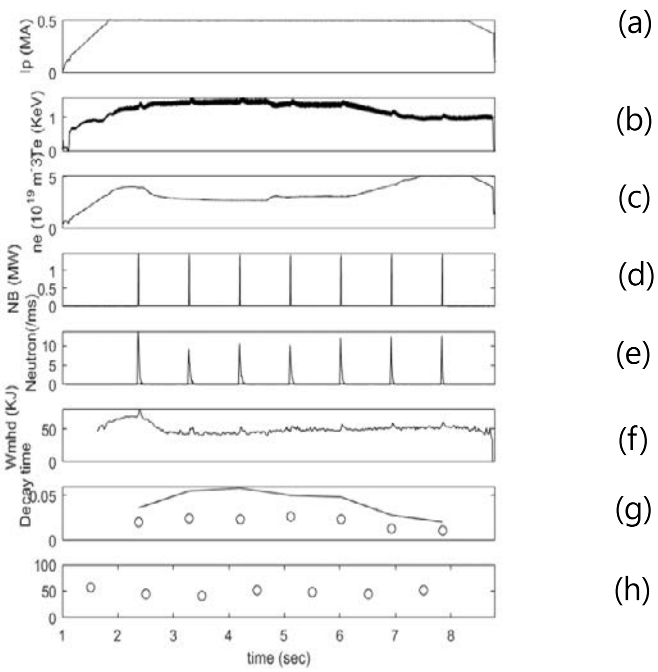
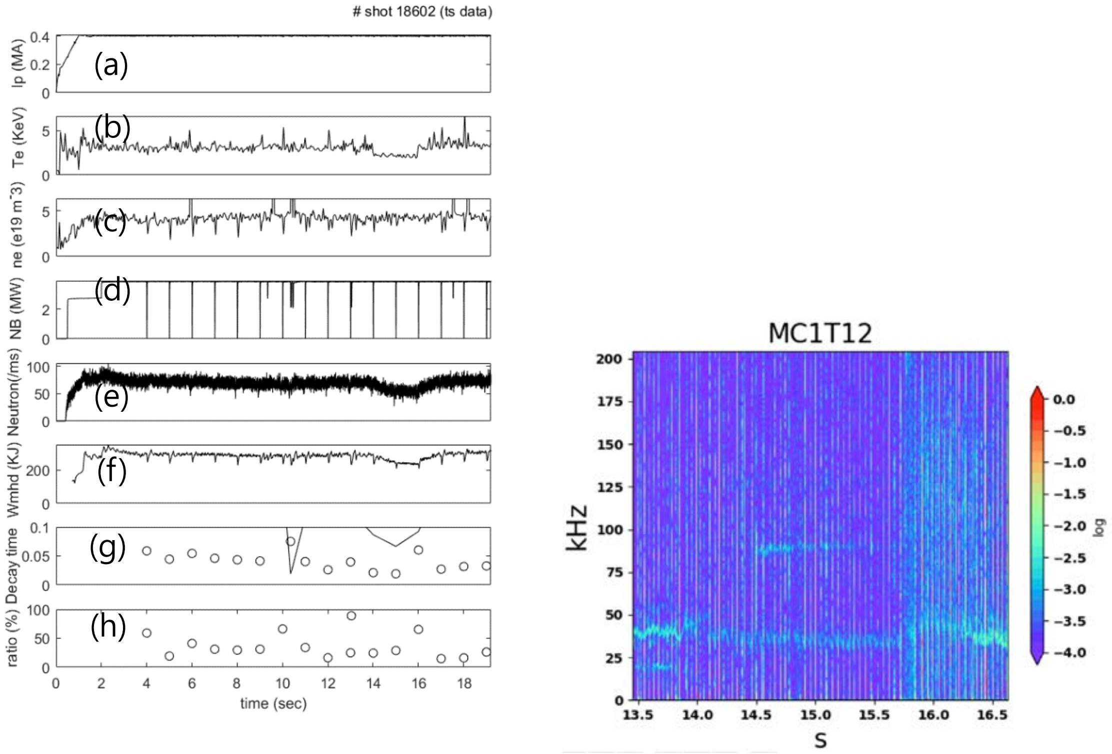
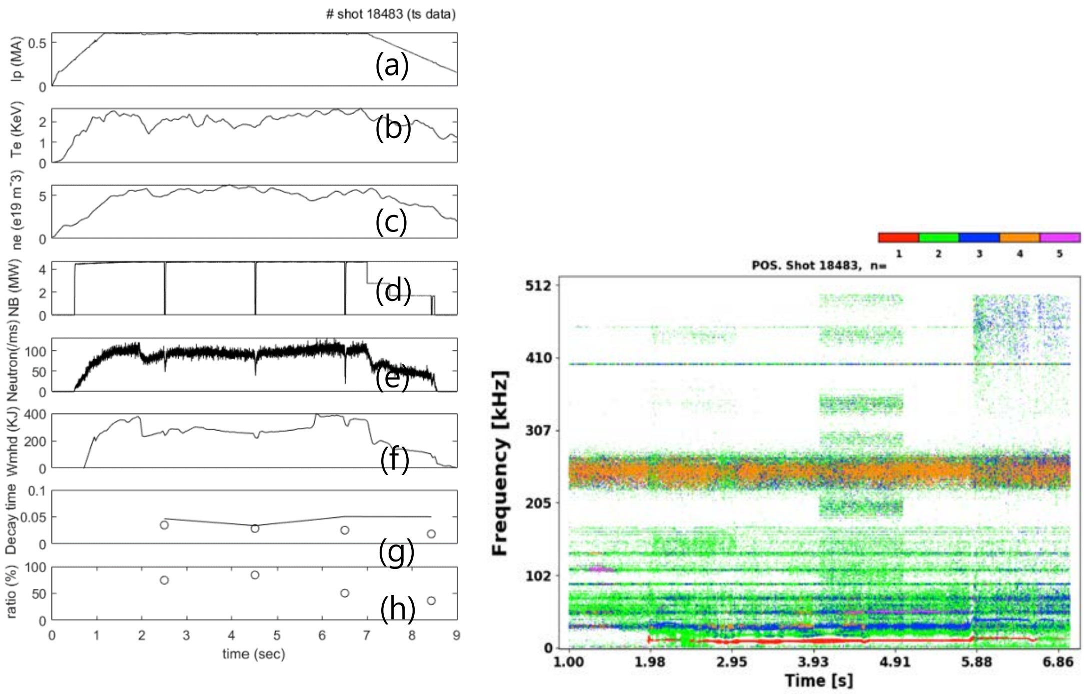


Fig. 1. Time evolution of the plasma discharge of shot #18355: (a) plasma current (b) electron temperature, (c) density, (d) blip NB power, (e) neutron, (f)stored energy, (g)slowing down time, (h) ratio of measured to theoretical one.



[a] [b]

Fig. 2. Time evolution of the plasma discharge of shot #18602: (a) plasma current (b) electron temperature, (c) density, (d) NB power, (e) neutron, (f) stored energy, (g) slowing down time, (h) ratio of measured to theoretical one. [b] Spectrogram from Mirnov coil.



[a] [b]

Fig. 3. Time evolution of the plasma discharge of shot #18483: (a) plasma current (b) electron temperature, (c) density, (d) NB power, (e) neutron, (f) stored energy, (g) slowing down time, (h) ratio of measured to theoretical one. [b] Spectrogram from Mirnov coil.