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Observation of fast ion profile stiffness due to the Alfvén eigenmode

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Fast-ion transport by Alfvén eigenmodes (AEs) is one key issue in the discussion of fast-ion confinement. In the DIII-D tokamak experiment, stiff transport of fast-ions increased with increasing neutral beam (NB) injection power when the amplitudes of multiple interacting AEs exceeded a certain threshold [1]. These experiment results are supported by simulation studies that predict monotonically degrading fast-ion confinement and profile stiffness with increasing beam power [2]. To investigate the universality of the fast-ion profile stiffness dependence on AE amplitude, an experiment was performed at the Large Helical Device (LHD) to scan the injection current of the NB and vary the AE amplitude. Since LHD uses only external field coils to generate the confinement field, the variation of the confinement field with the NB injection power is significantly smaller plasma equilibrium with the NB injection power is significantly smaller than for tokamak devices; this control of the plasma parameters while changing NB power better allows for an isolating of the fast-ion dependence on AEs. The relationship between NB injection power, $P_{t\text{-}NB}$, and AE amplitude shown in Fig. 1 (a) agrees with the trend obtained in DIII-D [3]. Under the experimental conditions, the AE amplitude increased linearly with NB injection power beyond an NB power threshold of about $P_{t\text{-}NB}$ = 1.6 MW. Fig. 1 (b) shows the neutron emission rate, S_n, with variable NB injection power for both the experiment and from a Fokker-Plank simulation [4]. The result shows S_n has a linear dependence on $P_{t\text{-}NB}$; this is expected because the fast-ion density will increase with $P_{t\text{-}NB}$, resulting in a high beam-thermal neutron emission rate. However, S_n did not increase linearly with $P_{t\text{-}NB}$ in the experiment; this suggests that large amplitude AEs degrade fast-ion confinement. Fig. 1 (c) shows the fast-ion profiles measured by fast-ion D alpha (FIDA) measurement [5]. The blue shifted FIDA intensity between 663-665 nm, corresponding to the energy range of 98-166 keV in the ctr-direction, was used for estimating the radial profile of the fast-ion density. There is direct evidence of stiffening of the fast-ion profile and degradation of the fast-ion confinement. This is consistent with the experimentally observed reduction in the expected neutron emission rate shown in Fig. 1 (b). However, it is possible that AE-induced transport is not the primary cause of the observed degradation. We will discuss an alternative fast-ion confinement degradation mechanism at high-power NB injection.

References

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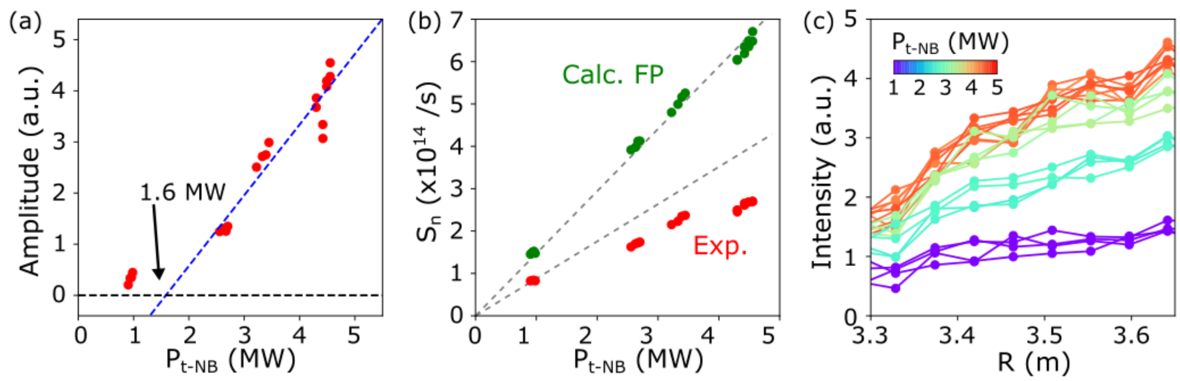

Figure 1: Injection NB power dependencies of (a) AE amplitude, (b) neutron emission rate S_n, and (c) fast-ion profiles.