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# Experimental observation of local reduction of gradient in energy spectrum of energetic particles interacting with MHD bursts

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Alpha particles produced by D-T reactions play a crucial role in heating thermal plasma in fusion reactors, and they must be confined to keep fusion plasmas burning. However, energetic particles (EPs) such as alpha particles interact with Alfven Eigenmodes (AEs), leading to anomalous transport [1]. Thus, the understanding and external control of nonlinear interactions between EPs and AEs are essential for the realization of controlled nuclear fusion.

Transport of EPs depends on the saturation amplitudes of AEs. Saturation is determined by the balance of destabilization and stabilization. For the excitation of AEs, the radial gradient of the EP distribution function plays a dominant role. The relationships between the excitation of AEs and radial gradient of the distribution function of EPs and the resulting transport have been investigated [2,3]. In contrast, various mechanisms contribute to the damping of AEs. One of the possible mechanisms is Landau damping by EPs. Since the gradient of distribution function in energy is basically negative because of the slowing down, EPs can receive energy from AEs. Experimental investigation of the relationship between AE damping and EPs has been limited.

Utilizing the Large Helical Device (LHD) in NIFS, we have investigated the interaction between AEs and EPs produced by tangential neutral beam injection (NBI). EPs become neutrals by charge exchange, being detected by the Si-based Neutral Particle Analyzer (Si-NPA).

Toroidicity-induced AE (TAE) bursts with the toroidal mode of n=1 was observed (Fig. 1). We divided the duration of TAE bursts into two phases based on the slope of power spectrum: (1) the growth phase characterized by a positive slope and (2) the decay phase characterized by a negative slope (Fig 1: bottom). The energy spectrum of EPs during the two phases were compared to the reference with no MHD activities (Fig. 2: top). In both phases, the gradient in energy reduced at the energy where resonance condition of $v_{\mathrm{EP}} \sim v_{\mathrm{A}}$ is satisfied (Fig. 2: bottom). This response suggests that Landau damping of TAE by EPs has been directly observed. It is also indicated that the Landau damping is more significant in the decay phase of the TAE bursts.

References

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[2]Collins, et. al, Phys. Rev. Lett. 116, 095001 (2016)
[3]Todo, Nucl. Fusion, 59, 0960487 (2019)

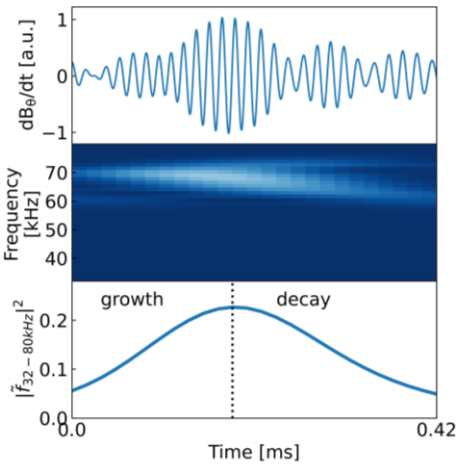


Figure 1: Typical structure of TAE bursts. These bursts are divided into two phases based on the slope of power spectrum (bottom panel). The duration with positive slope is set as growth, whereas the duration with negative slope is set as decay.

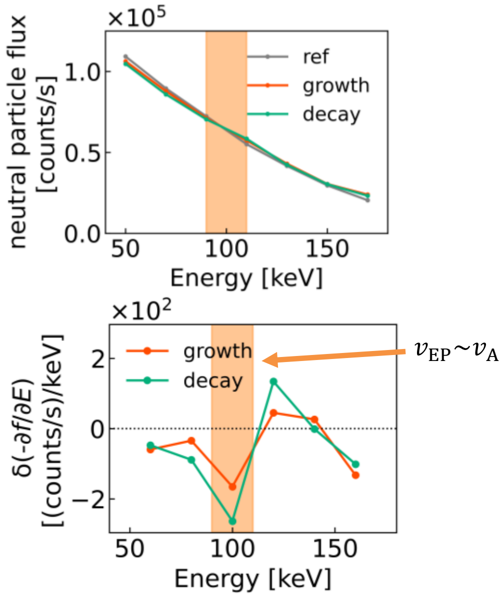


Figure 2: (Top) Energy spectrum of EPs measured by Si-NPA. The results of growth and decay phase of TAE, and reference with no MHD activities are compared. (Bottom) Difference in the gradient of energy spectrum from that of the reference. Orange-shaded area shows the energy where resonance condition of $v_{\mathrm{EP}} \sim v_{\mathrm{A}}$ is satisfied.