APPLICATIONS OF IN-SHOT CONTINUOUS NBI CONTROL SYSTEM TO FIRE MODE IN KSTAR

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The NBI [1-3] control system has been upgraded to enhance its control capabilities and improve the performance of advanced operational scenarios in KSTAR. This upgraded system incorporates in-shot continuous control and decoupling control of beam power and energy. In the 2023 KSTAR campaign, the enhanced NBI control system was successfully commissioned and applied to FIRE mode [4,5], resulting in significant performance improvements. It helps to understand FIRE mode characteristics based on beam parameters, expanded the operational window, and introduced a new approach to achieving FIRE mode with a mild MHD activity.

By implementing decoupling control, the independent effects of beam power and energy were systematically investigated. It was confirmed that beam power directly influences ion heating, affecting ion temperature and the fast ion population, while variations in beam energy modify the beam-driven current profile, potentially impacting sawtooth activity, which defines the lower operational limit of FIRE mode. The lower operational limit was successfully extended under high perveance conditions using decoupling control, with minimal impact on ion heating and the fast ion fraction, thereby preserving ion temperature.

The application of in-shot control revealed a strong correlation between MHD activity and ion temperature in FIRE mode. MHD activity, which degrades ion temperature, predominantly occurs at high beam power. It was observed that reducing beam power and energy through in-shot control effectively suppresses MHD activity, thereby maintaining high ion temperatures. Based on this observation, a novel NBI control method utilizing in-shot capability was developed and analysed. This method involves initiating the discharge with high beam power to avoid sawtooth activity and establish an ion internal transport barrier (ITB), followed by a controlled reduction in beam power to access the mild MHD FIRE mode regime.

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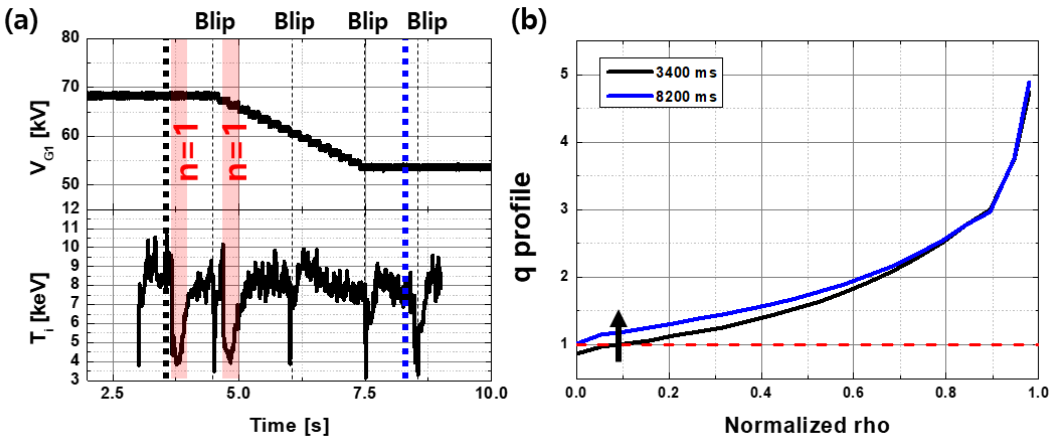

Fig 1. *Sawtooth activity can be avoided while maintaining ion temperature through decoupling control of NBI in #33906.*

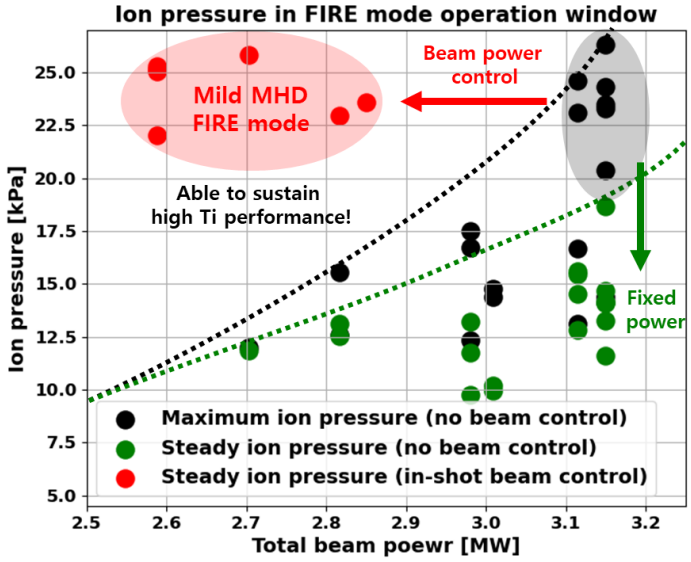

Fig 2. *Accessing a mild MHD state in FIRE mode through in-shot NBI control while sustaining high ion pressure.*