Overview of KSTAR research towards DEMO

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As a superconducting device, KSTAR is solving the physical and technical issues towards future fusion reactors by demonstrating long-pulse operation of high-performance discharge that conventional normal conducting devices could not sufficiently handle. The key to achieving high-performance is basically an operation mode with improved confinement. To this end, high Ti mode with fast ion roling transport barrier [1] and high li mode with high no wall beta limit, which have inherently stable characteristics were implemented in KSTAR along with several advanced operation modes such as hybrid and I-modes. Furthermore, active controls of possible instabilities are also progressing across the core and the edge-pedestal regions. Through electron cyclotron heating, it was performed to suppress Alfven eigen mode that will inevitably appear in reactor-level devices. Edge-localized mode (ELM) control using unique 3D field capability of KSTAR, goes beyond just ELM control and is being advanced with field spectrum optimization and adaptive control to minimize performance degradation. It was demonstrated that AI-based ELM control even enables to control 1st ELM. Eventually, the optimization of 3D field techniques made long-pulse operation of ELM suppressed discharge possible [2]. As a last resort, research on disruption mitigation using symmetric multiple shattered pellet injections is being conducted in order to mitigate the increased possibility and damage of disruption accompanying high performance. Real-time characterization and forecasting of disruption precursors were demonstrated by introducing DECAF (Disruption Event Characterization and Forecasting) to the KSTAR plasma control system for activating the disruption avoidance and mitigation actions asynchronously. By studying the multi-scale interaction between micro-scale turbulence, meso-scale shear flow, and macro-scale magnetic island using advanced diagnostics such as ECEI, we improved the understanding of the underlying physics. This kind of understanding is an important physical basis for high performance and stable long-pulse operation that KSTAR pursues. To support these studies, KSTAR is steadily progressing the upgrade of heating power and transition to full metallic wall.

References

[1] H. Han et al., Nature **609**, 269–275 (2022).

[2] J.-K. Park et al.,Nature Physics **14**, 1223–1228 (2018).

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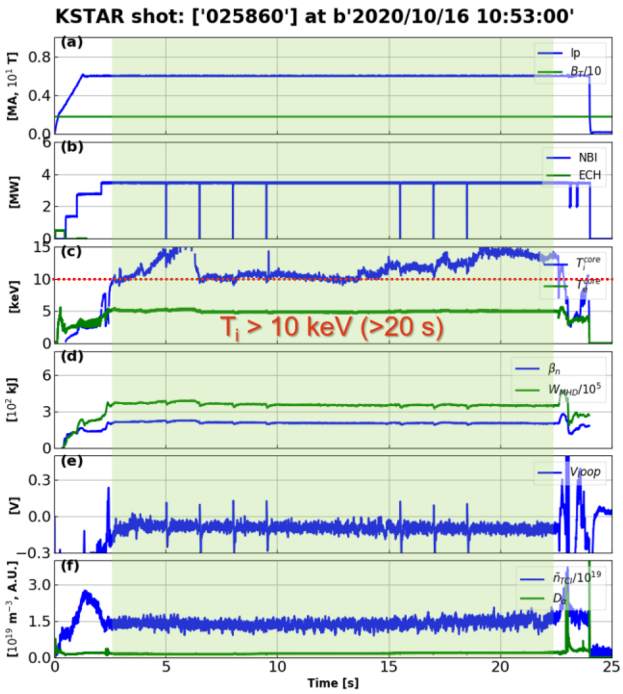

Figure 1. Fast Ion Rolling Enhanced (FIRE) mode in KSTAR.

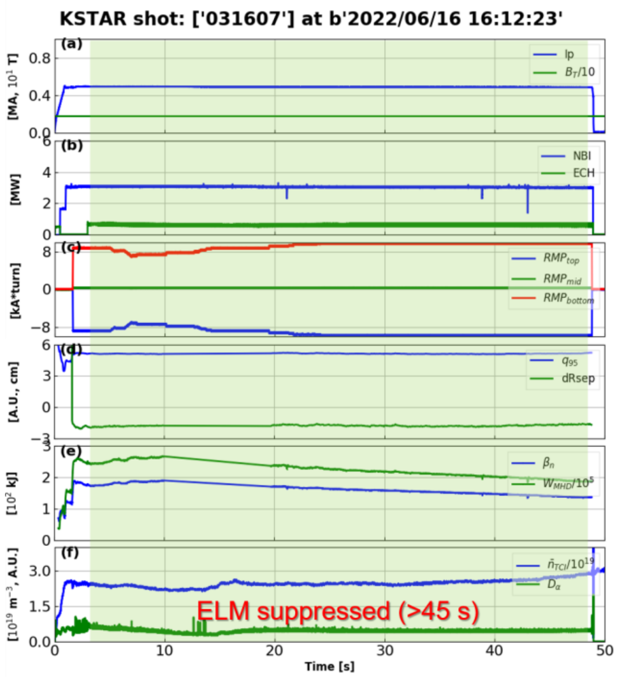

Figure 2. Long (>45 s) ELM suppression through 3D field optimization in KSTAR