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Plasma Disruption Mitigation Features Using MGI and SPI on the EAST Device

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This study systematically compares the effects of shattered pellet injection (SPI) and massive gas injection (MGI) on plasma disruption mitigation in the EAST device. The results indicate that SPI has significant advantages over MGI, as it predominantly deposits impurities in the plasma core, leading to faster thermal radiation release and a shorter overall disruption duration. In contrast, MGI primarily deposits impurities at the plasma edge, resulting in a longer impurity penetration time. During the current quench (CQ) phase, MGI experiments observed a distinct radiation tail extending from the plasma core to the edge, accompanied by a second current spike. This phenomenon is primarily attributed to cold vertical displacement events (VDEs), which cause premature plasma contact with the first wall, generating halo currents and emitting hard X-rays. Furthermore, experiments revealed that both SPI and MGI induce MHD mode switching, where the inherent n = 1 and n = 2 modes transition into a new n = 1 mode with a larger amplitude and shorter period. This new mode also exhibits a reversed rotation direction and is accompanied by bursts of soft X-rays. These findings suggest that MHD mode switching is primarily driven by impurity–plasma interactions rather than the injection method. Additionally, under current EAST experimental conditions, SPI at velocities between 150 and 250 m/s did not trigger cold VDEs, further supporting its suitability for disruption mitigation in the EAST device.

The study also highlights that the timescales of thermal quench (TQ) and CQ phases depend on the device size and plasma performance parameters. For example, the TQ duration is less than 1 ms in EAST, approximately 0.7 ms in DIII-D[1], and about 0.2 ms in J-TEXT[2]. Given such short TQ durations, the underlying physical mechanisms remain poorly understood and require further investigation. Moreover, the m/n = 2/1 mode, commonly observed in the J-TEXT device and known to transition into the m/n = 3/1 mode, has also been detected in both MGI and SPI experiments in EAST. This further supports the idea that impurity–plasma interactions are the fundamental driver of MHD behavior, rather than the specific injection technique.

Overall, this study confirms the advantages of SPI over MGI in disruption mitigation, particularly in terms of impurity penetration depth, disruption duration, and thermal energy dissipation rate. Additionally, the findings emphasize the importance of understanding MHD mode evolution for optimizing disruption mitigation strategies. Future research should focus on high-time-resolution diagnostics, numerical simulations, and further comparative experiments under different parameter conditions to uncover the underlying mechanisms of MHD mode transitions and provide theoretical and experimental support for disruption mitigation strategies in ITER and future fusion reactors.

References：

[1] Eidietis N.W., Izzo V.A., Commaux N., Hollmann E.M. and Shiraki D. 2017 Phys. Plasmas 24 102504
[2] Li Y. et al 2021 Nucl. Fusion 61 126025

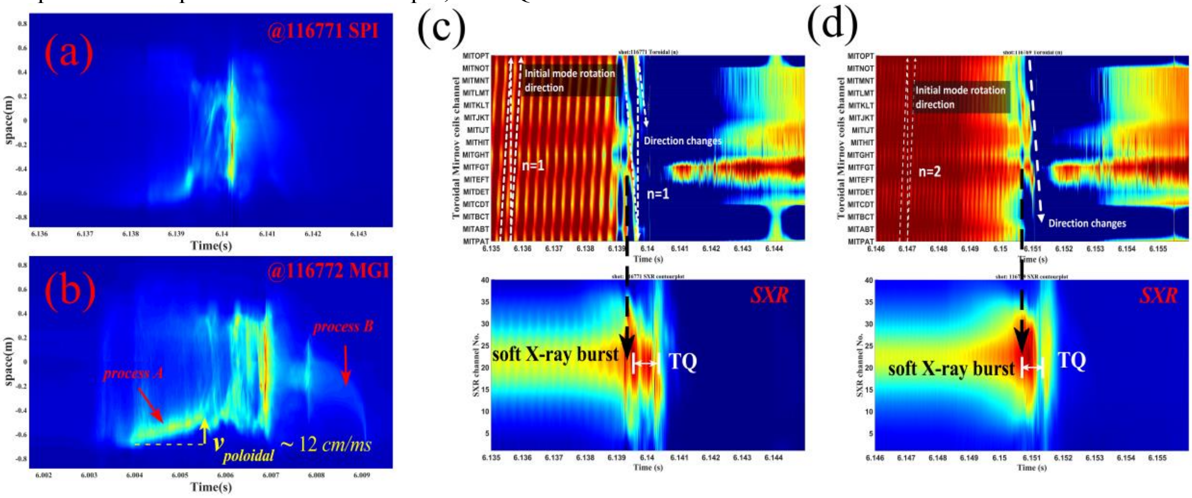

Fig. 1. (a) Comparison of radiation distribution between (a) MGI and (b) SPI injection, and the evolution of inherent (c) n=1 and (d) n=2 MHD instabilities into a new n=1 instability under SPI.