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MHD and energetic ions instabilities related to the formation of ITBs in EAST reversed shear plasmas with $q_{min} \simeq 2$

Ming Xu[1], on the behalf of EAST team
[1] Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP)
e-mail (speaker): mxu@ipp.ac.cn

The formation of internal transport barriers (ITBs) has been investigated in EAST weak/reversed shear plasmas with minimum safety factor $q_{min} \leq 2$. The so-called "off-axis" sawteeth (OAS) is frequently excited for the reversed shear magnetic configuration, which triggered by the magnetic reconnection of m/n=2/1 double tearing modes (DTMs) [1], where m, n are the poloidal and toroidal mode numbers respectively. Abundant of phenomena are easily excited during the oscillation of OAS, e.g., two kinds of Alfven Eigenmodes (BAEs and RSAEs) are excited by the beam ions generated from NBI [2-3], and two kinds of low-frequency modes (LFMs) are excited by thermal pressure gradient [4-5], et al. The suppression of OAS or DTM is one important step to establish the structure of ITBs. All those results listed above are summarized in Fig.1.

One example for the suppression of OAS or DTM is demonstrated in Fig. 2. The reversed magnetic configuration is established by LHCD and ECRH, and the oscillation period of OAS is $\tau_O \approx 100ms$ for the EAST shot #61959. In shot #61962, the $\tau_O \approx 260ms$ for the perpendicular injection of NBI (NBI1R), which is fully suppressed for the tangential injection of NBI (NBI1L), as marked by the yellow shaded region.

The establishment (or sustainment) of ITBs is often accompanied by the Alfven eigenmodes. Similarly, several different instabilities can be observed during the formation of ITBs in EAST, e.g., Alfven ion temperature gradient (AITG) mode is excited by thermal pressure gradient, BAEs and RSAEs are excited by energetic ions, GAM instability is related to the poloidal flow, et al. One typical example of the formation of ITBs are selected as given in Fig. 3. The two similar discharge conditions for the case without and with OAS are given by the blue and red lines respectively. The existence of OAS is an important excitation condition for the establishment of ITBs, and the structure of ITBs forms gradually when the power of NBI with $P_{NB} \approx 4MW$ is injected. Interestingly, the fast ions density decreased by 3% for the excitation of the pairs of BAEs-RSAEs instabilities. The redistributed distribution of fast ions is beneficial for the formation of ITBs, and some possible physics are discussed.

References
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[2] Ming Xu, et al. Nucl. Fusion 59 (2019) 084005.
[3] Ming Xu, et al. Chin. Phys. Lett. 38 (2021) 085201.
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Figure 1. The ITBs can be excited by suppression of DTMs, and fast ions or pressure gradient induced instabilities are observed for the condition of $q_{min} \leq 2$ in EAST.

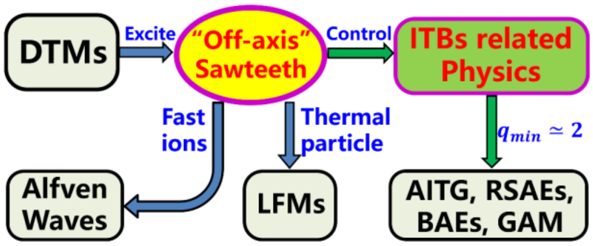

Figure 2. The oscillation period of OAS is suppressed dramatically by the tangential injection of NBI.

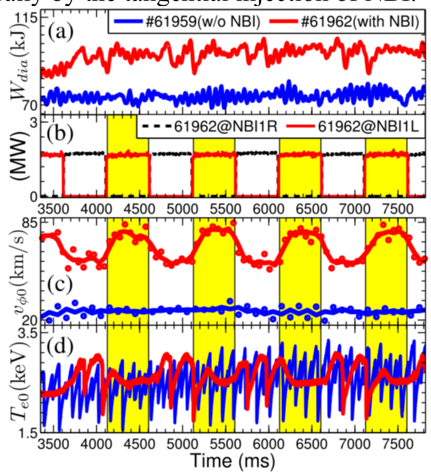

Figure 3. One typical example for the formation of ITBs together with the excitation of the pairs of BAEs-RSAEs instabilities. (a) plasma stored energy for two similar cases, (b) neutron yield S_n, (c) spectrogram of ECE signal at R=2.06 m ($0.4 \leq \rho < 0.5$).