Novel Effects of Edge-localized RMPs and Plasma Density on the L-H Transitions and Transport

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ABSTRACT

- Establish L–H / H–L access maps in KSTAR with the new tungsten LSN and carbon USN divertors, including threshold power vs density and configuration.
- Determine how power-ramping history and ERMPs [1] drive scatter in the L–H threshold and impact transition stability.
- Characterise magnetic fluctuations across density and configuration.
- Evaluate n = 1 ERMP impacts: L–H avoidance, H–L triggering, transient ELM suppression, spectral reshaping, hysteresis.

BACKGROUND

- Understanding the low-to-high (L–H) confinement transition is essential for achieving H-mode access in ITER and advanced scenarios [2].
- Key challenge: large scatter in the L–H threshold due to hidden variables (e.g., power-ramping history, impurities), which complicates prediction and real-time control [3,4].
- Stable, predictable high-performance operation reduces unplanned plasma terminations and mitigates transient heat/particle loads—supporting high-performance pathways.
- Understanding and controlling ELMs and edge transport lowers plasma facing component erosion and the risk of discharge termination and hardware stress.

METHODS

L-H TRANSITION STUDY

KSTAR 2024, tungsten LSN and carbon USN divertors; B_T = 1.9 T, Ip = 0.6 MA, n_e = 1.5–3.5×10^{19} m^{-3}; NBI heating with programmed power ramps (step and linear). Calculate power thresholds P_{net}

$$P_{net} = P_{ohm} + P_{NBI} - \frac{dW_{mhd}}{dt} - P_{rad}$$

CONTROL AND FEEDBACK

Density feedback in L-mode; targeted ramp-rate and density scans; ERMP (n=1) applied conventionally (in H-mode) and pre-emptively (in L-mode).

DIAGNOSTICS

CES for Ti and toroidal rotation V_T; BES for n_e; ECE/CECE/ECEI for Te; Mirnov coils for δB spectra and mode numbers; Dα for ELM timing.

OUTCOME

L-H TRANSITION POWER THRESHOLD (Fig 1)

- Left panel shows the power threshold against density (scatters in power threshold due to different ramping)
- Right panel compares the USN and LSN plasmas at similar density: repeated L-H/H-L transitions in tungsten LSN plasmas

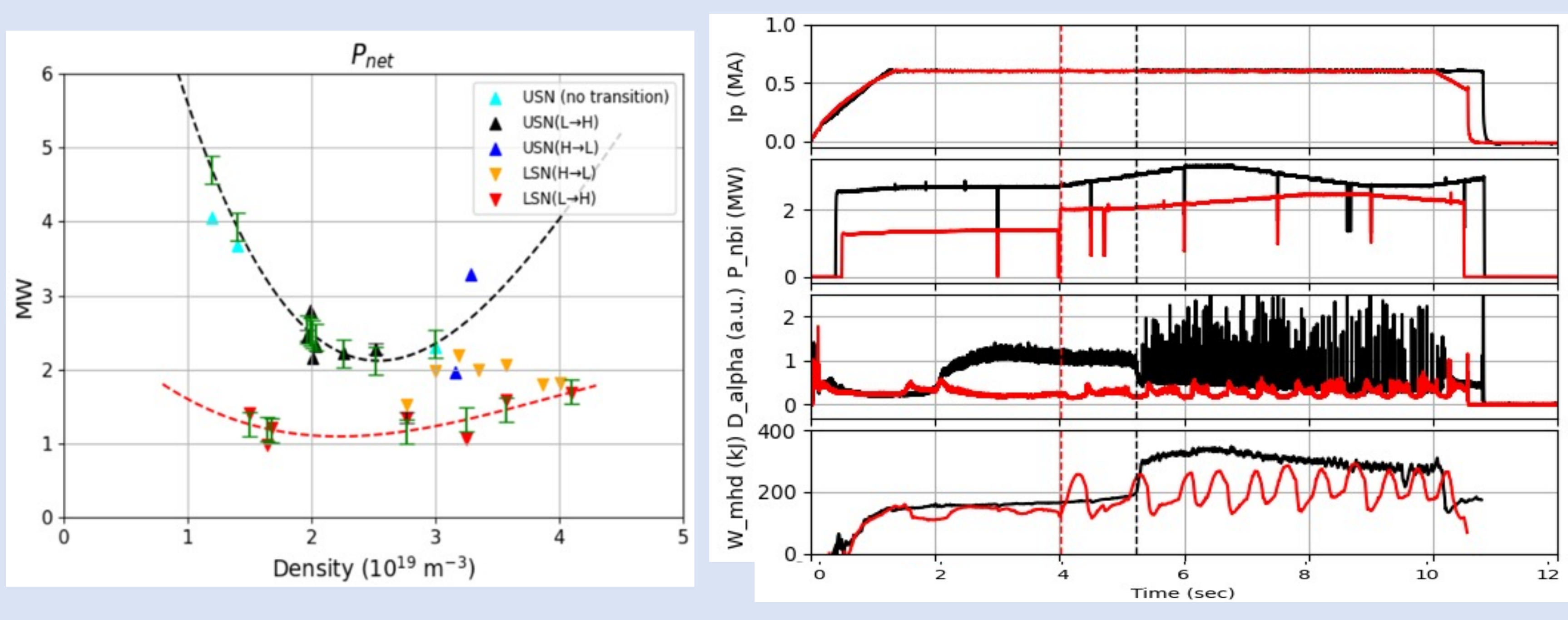


Fig. 1 (left) P_{net} against density for multiple L-H and H-L transitions; (right) Time traces of Ip, P_{NBI}, Dα, W_{mhd}. Red and black are for #35645 and #35641, respectively. Dotted vertical lines denote the L-H transitions.

OUTCOME - CONT.

FLUCTUATIONS AND DEPENDENCE ON DENSITY (Fig 2)

Magnetic fluctuations are ubiquitous but shift with density/configuration—low-density cases show suppression of broadband δB at L–H with persistent 10–20 kHz lines; higher density shows stronger δB–δn- δTEe coherence; EP-driven chirping appears.

TOROIDAL ROTATION AND Er SHEAR (Fig 3)

At the L–H transition, the toroidal velocity develops a strong pedestal—stronger than that of T_i—while Er forms a deep negative well. With increasing density, both the toroidal velocity and the Er shear decrease.

ERMP IMPACT (Fig 4)

ERMPs can delay/avoid L–H, trigger H–L, transiently suppress ELMs, change spectra, and imprint hysteresis (Fig 4); pre-emptive ERMPs briefly raise peak W_{MHD} and n_e but lead to a shorter-lived, more unstable H-mode.

Fig 2. Magnetic spectra: 35645 (left), 35636 (middle), 35647 (right). The first L–H transition is marked by the red dashed vertical line.

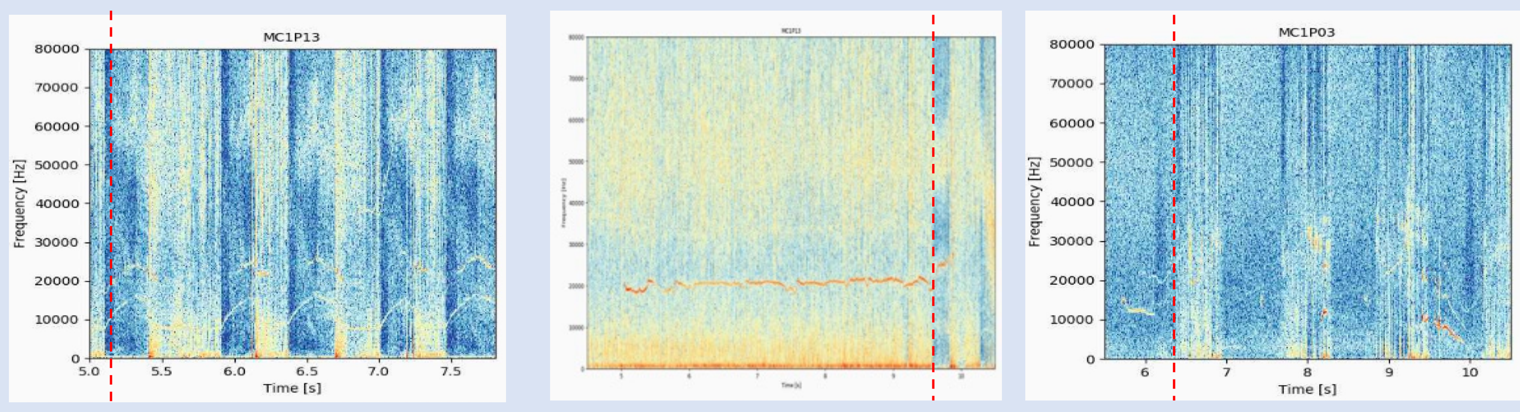


Fig 3. V_T-profiles for 35645 (left) and 35647 (middle); Er profiles (right).

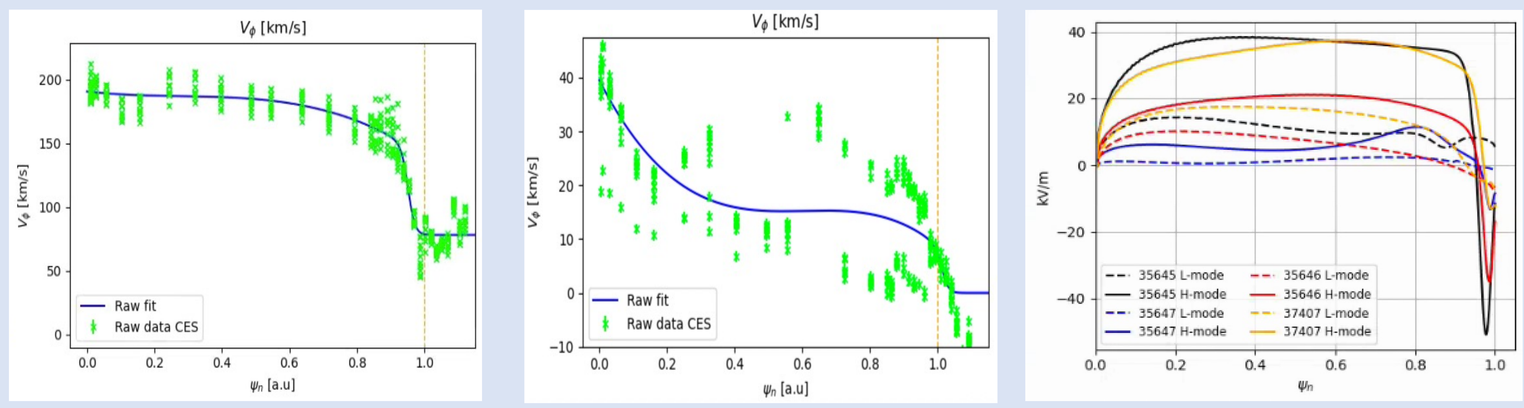
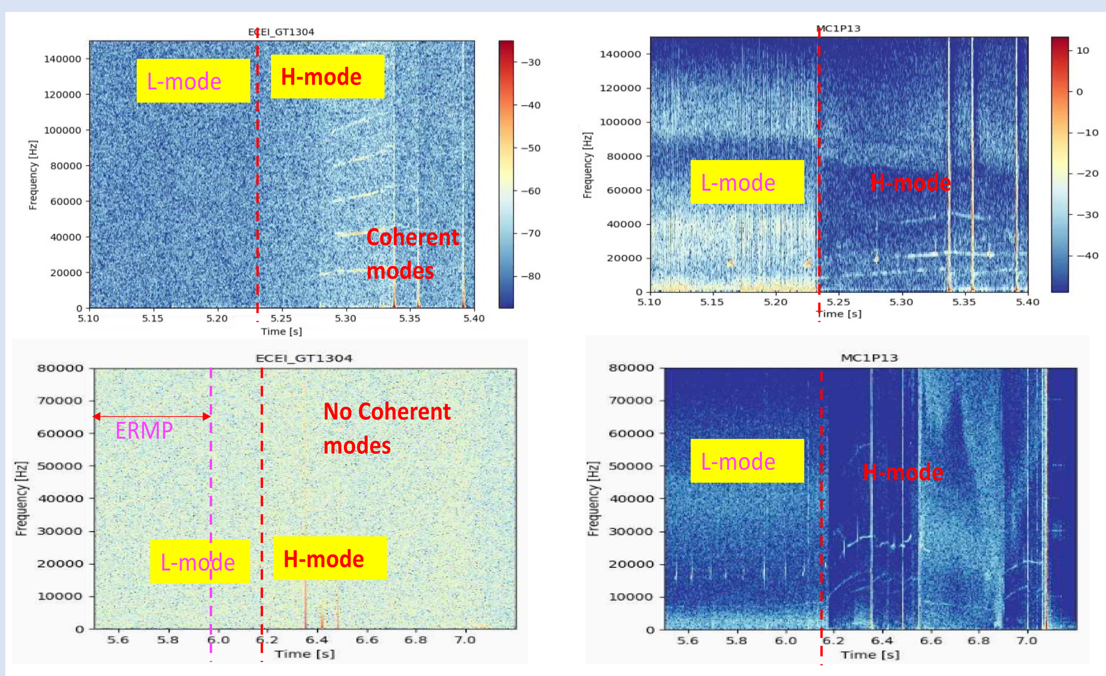


Fig 4. Spectra of Te (left) and magnetic fluctuations (right). Top and bottom are for #35641 (black) and #37404 (red) discharges, respectively



CONCLUSION

- Power-ramp history (hidden variable) causes scatter in L–H threshold.
- Magnetic fluctuations crucial to L–H access and subsequent evolution.
- The transient, non-equilibrium nature of the plasma strongly impacts transition (L–H, H–L) and ELM dynamics (with detailed analysis ongoing).

ACKNOWLEDGEMENTS / REFERENCES

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