A model to explain certain L-H transition power threshold differences

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On a given device, and for similar discharge parameters such as B_T, I_p, and n_e, the L-H transition power threshold P_{TH} shows significant differences depending on magnetic topology, plasma cross-section shape, and momentum input. In particular,

- In a single-null diverter, P_{TH} is typically more than a factor of two higher when the ion ∇B-drift is away from the X-point.
- Similarly, in double-null configurations, P_{TH} depends very sensitively on the balance between the two diverters. In an L-mode discharge near the threshold, a transition can be induced by shifting the balance towards the X-point in the direction of the ion ∇B drift.
- Higher triangularity δ implies a correspondingly higher P_{TH}. Thus, with the ion-drift in the favorable direction, sweeping the X-point radially outward, towards larger R at constant Z, lowers the power threshold.
- Lowering the X-point, thus decreasing the distance to the diverter plates, also lowers P_{TH}.
- With fixed magnetic topology, external momentum input, e.g., through unbalanced neutral beam injection (NBI), also plays a significant role. Regardless of the direction of the ion ∇B-drift, co-current NBI increases P_{TH} significantly, while counter-current NBI has the opposite effect.

Various and differing explanations have been offered for these observations in the literature. We demonstrate here that they all can be explained, although only qualitatively at this point, by a model of edge electric fields that can be attributed at a fundamental level to unneutralized charge separation due to ∇B and curvature drifts in the collisional edge plasma just inside the separatrix[1]. More quantitatively, they are driven by the Pfirsch-Schlüter component of the parallel "return current," $J_{\parallel}^{PS} \sim p'(\psi)(1 - B^2/ <B^2>)$; thus, they are a robust feature of tokamak plasmas. Their dependence on the edge pressure gradients also dynamically couples them to the transition process itself, reinforcing or opposing it with an increasing magnitude as the pedestal pressure gradient starts to build up, depending on the relative direction of the ion drifts.

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[1] A. Y. Aydemir, Nucl. Fusion **49**, 065001 (2009).