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Experimental verification of X-point potential well formation in unfavorable magnetic field direction

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Recent TCV measurements confirm, for the first time, the predicted formation of an electric potential well below the X-point in the unfavorable B_t direction, substantially reshaping the divertor $E \times B$ flow pattern [1]. Such a potential well may strongly influence the divertor performance for reactor operation with unfavorable H-mode access (e.g. reverse triangularity, I-mode). The local charge balance in the private flux region (PFR) of diverted tokamak plasmas is argued (JET [2], DIII-D [3], AUG [4]) to be established by parallel currents and ∇B currents. This hypothesis is verified herein for TCV configurations using SOLPS-ITER simulations accounting for drifts and currents. Simulated parallel currents reproduce the characteristic features of TCV target currents measured by wall-mounted Langmuir probes whereas simulations without drifts fail. For low temperature (detached divertor) conditions, the parallel electric field is dictated by these parallel currents. This work demonstrates, for the first time, that the electric potential in the PFR becomes negative with respect to both target plates for detached operation for unfavorable H-mode access (ion ∇B away from the PFR). This implies: a reversal of the parallel electric field in the PFR, a significant enhancement of the radial electric field close to the separatrix and a substantially altered $E \times B$ drift pattern with much stronger poloidal flows. The reported experimental validation follows the installation of a reciprocating divertor probe array on TCV providing unprecedented insights into 2D plasma profiles in the divertor [5]. A simple analytical model, based on electron momentum balance and the leading order terms in the current continuity equation, highlights the underlying physics and generates a scaling of the potential well depth with divertor conditions and machine size.

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