

A Bayesian approach for the selection of predictor variables in the L-H power threshold scaling in metal-wall machines

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Understanding the scaling of the L-H transition power threshold P_{LH} is crucial for the operation of future tokamaks such as ITER and SPARC[1-3]. However, multicollinearity of the predictor variables in the scaling makes it difficult to disentangle the effect on the power threshold of the individual plasma variables. In this study, we analyze the scaling of P_{LH} in a database with experimental data from three metal-wall tokamaks: JET-ILW (W divertor, Be wall), ASDEX Upgrade (tungsten wall) and Alcator C-Mod (molybdenum wall)[4]. Power-law regression is carried out using a hierarchical Bayesian model with a Dirichlet process prior and a variable selection prior [5]. This method simultaneously allows identifying redundant predictor variables, as well as grouping highly correlated predictors. The analysis provides strong statistical evidence that, in the database studied, the poloidal magnetic field B_p is a better predictor of the threshold power than the toroidal field B_t or plasma current I_p . Furthermore, the method systematically evaluates the impact of ten different divertor configurations for the three tokamaks. For ITER, the new model predicts that under the standard H-mode line-averaged density of $n_e = 1.0 \times 10^{20} \text{ m}^{-3}$, the threshold power for deuterium plasmas can vary between 100 and 200 MW, with the large uncertainty mainly influenced by the divertor geometry. This work provides a systematic, statistically sound analysis of LH threshold data in a multi-machine database, potentially offering additional insight into the physics of the L-H transition.

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