Empirical scaling of the n = 2 error field penetration threshold in tokamaks

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Abstract:
This paper presents a multi-machine, multi-parameter scaling law for then=2 core resonant error field threshold that leads to field penetration, locked modes, and disruptions. Here, is the toroidal harmonic of the non-axisymmetric error field (EF). While density scalings have been reported by individual tokamaks in the past, this work performs a regression across a comprehensive range of densities, toroidal fields, and pressures accessible across three devices using a common metric to quantify the EF in each device. The metric used is the amount o overlap between an EF and the spectrum that drives the largest linear ideal MHD resonance, known as the ''dominant mode overlap''. This metric, which takes into account both the external field and plasma response, is scaled against experimental parameters known to be important for the inner layer physics. These scalings validate non-linear MHD simulation scalings, which are used to elucidate the dominant inner layer physics. Both experiments and simulations show that core penetration thresholds for EFs with toroidal mode number n=2 are of the same order as then=1 thresholds that are considered most dangerous on current devices. Both n=1 and n=2 thresholds scale to values within the ITER design tolerances, but data from additional devices with a range of sizes are needed in order to increase confidence in quantitative extrapolations of n=2 thresholds to ITER.