**3D structure of the non-linear ELM phase**

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Edge localised modes (ELMs) allow sufficient purity of tokamak plasmas to be maintained and thus enable stationary H-mode. In a future device large unmitigated ELMs are believed to cause divertor power flux densities far in excess of tolerable material limits. Hence the size of energy loss per ELM and the resulting ELM frequency must be controlled. To proceed in understanding how the ELM size is determined it is necessary to characterise the non-linear evolution of pedestal erosion in 3D. In order to achieve this we compare the results of ELM simulations with the code JOREK (reduced MHD, non-linear) for ASDEX Upgrade and TCV (planned) with experimental data. This data is acquired by several fast sampling diagnostics (100kHz – 2MHz) at ASDEX Upgrade (magnetics, ECE imaging, fast framing cameras) and TCV (only magnetics) at a large number of toroidal/poloidal positions.

Key experimental findings: At the onset of type I ELMs at ASDEX Upgrade solitary magnetic perturbations (SMPs) are the dominant modes below 100kHz [1]. These are conjectured to be the signature of perpendicularly isolated and rotating current perturbation peaks (current ribbons) in the pedestal region. They clearly differ from coherent pre-cursor activity, which is observed earlier relative to the ELM crash. Interestingly we find that SMPs have characteristics of a trigger for the radial propagation of filaments and pedestal erosion. For very prominent examples the number of dominant peaks per toroidal turn is only 1 or 2. Similarly at TCV, SMPs at the onset of type I ELMs are regularly observed – often concentrated to a limited toroidal region (e.g. $\Delta \phi < 180^\circ$). Thanks to the excellent coverage of magnetic probes around the outer midplane of TCV the full dynamics of a typical SMP are captured despite rotation. The identified growth time of about 10µs is close to the inverse marginal growth rate ($2/\omega\times\iota$) often displayed in linear MHD stability diagrams.

Simulation results: Motivated by the experimentally observed structure of SMPs, JOREK simulations of ELMs in ASDEX Upgrade with significantly increased toroidal resolution are performed [2]. Notably, synthetic magnetic signals post-processed from the JOREK results resemble the magnetic signature of SMPs for the non-linear phase. Correlated to these synthetic signals is a strong edge pressure perturbation consisting of ballooning fingers ($n\sim 10$). Around the outer midplane these fingers extend both deeper inward into the pedestal region and outward into the SOL region in a given toroidal position when compared to the toroidally opposite position ($n=1$ modulation). Thus these JOREK results exhibit a 3D-asymmetric pedestal erosion during the non-linear phase that differs significantly from the classical linear ballooning picture.