Toroidal rotation and low-Z impurity behaviour across sawteeth in TCV

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The local particle and heat transport increase across sawteeth (ST) crashes in a tokamak plasma is well documented. Although plasma momentum transport, often estimated from radially resolved plasma rotation, is often modelled as a continuous process that depends on the plasma parameters and their gradients, MHD has long been shown to strongly affect TCV's experimental rotation profile, and that in many other machines. On TCV, for similar conditions (plasma shape density and temperature), the average toroidal rotation profile gradient outside the ST-mixing radius was seen to be reasonably constant whereas the average profile is flattened inside, with what appeared to be a co-plasma current core-weighted additional component, and this over wide range of plasma currents.

The question remains as to whether the rotation profile varies strongly in the presence events such as ST-crashes, or only at specific parts of the event's phase. The ST is particularly interesting as it incorporates a relatively benign period, where the core pressure builds, followed by a rapid expulsion (the ST-crash) where a large increase in transport of many physical parameters is observed. In the experiments reported in this paper, the natural TCV ST period for the plasma configuration (~2ms) was lengthened by precision X2 ECCD deposition close to the q=1 surface stabilising the ST to obtain regular ST periods in the range of 8-40ms. A diagnostic neutral beam system based CXRS system measured the Carbon intrinsic impurity rotation profiles, in the absence of a perturbing external torque, with a 2ms temporal resolution. So called "ST-locking" was then employed such that the ST-crashes occurred at fixed, and pre-shot known, times during the plasma discharge. CXRS acquisition was then synchronised to the ST crashes so that conditional resampling overs several ST cycle was then particularly appropriate to decrease the measured rotation profile uncertainties.

The ST crash was found to reset the toroidal rotation profile to similar levels independently of the controlled and varied ST period with the whole rotation profile then evolving (accelerating) at similar rates following each crash so that the pre-ST profile further peaks with increasing ST period. The behaviour of the ion temperature and Carbon impurity density measured during the ST crash is also presented showing that this low-Z impurity is preferentially evacuated from the plasma core, compared to the Deuterium working gas. The strong momentum transport, here in the form of a radial expulsion, may become part of the explanation for changes in the plasma configuration (L-H transitions, Rotation reversals) that often appear correlated with the ST-crash and/or the plasma safety factor profile. These measurements underline how any description and prediction of plasma rotation and impurity transport must include the effect of ST, where present, and, most probably, all other forms of MHD activity.

a See the author list of S. Coda et al, 2017 Nucl. Fusion 57 102011