Losses of fusion products due to fishbones on JET and predictions for burning plasmas.

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Fishbones are ubiquitous in high performance JET plasma and are typically considered benign. However, in recent high-performance hybrid experiments, sporadic and explosive fishbones have been observed which correlate with decreases in performance and main chamber hotspots. Additionally, recent unambiguous measurements obtained with a 2D scintillator probe and fast acquisition show coherent losses of fusion product protons and tritons due to these explosive fishbones [1]. This is particularly of note due to the velocities of fusion products being much too large to resonate with the fishbone.

Using careful MHD marker constrained EFIT reconstructions, we can show that the orbits of the lost fast fusion products are due to barely trapped/confined particles being ejected by the mode. Modelling the fishbone as a conventional n=1 MHD internal kink oscillation we use HAGIS and the newly developed HALO (HAgis LOcust) code to confirm the non-resonant losses of fusion products. In the HAGIS drift calculations, the energy content of those losses is insufficient to explain the observed hotspots, however full-orbit HALO calculations show that a combination of magnetic-moment scattering, and wall proximity cause fishbones to produce a 25% loss of D-D fusion products at the experimentally observed location of the hotspot (Figure 1). A breakdown in magnetic moment conservation leads to a rapid diffusion in pitch-angle space.

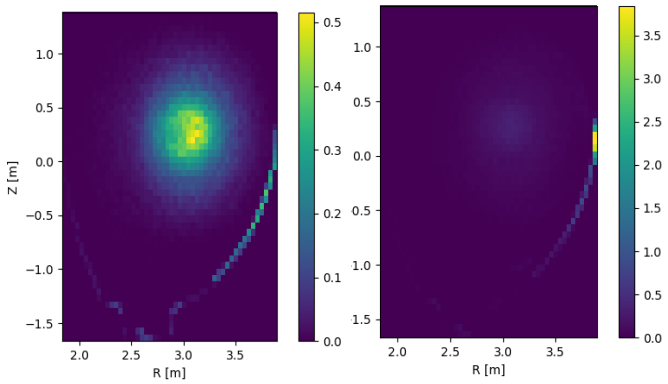

Figure 1: HALO predictions of TRANSP fusion product numbers in equilibrium (left) and with the fishbone (right). Calculated losses are completely due to FLR

Extrapolations to JET DT and ITER will be presented that show the implications for alpha particle losses due to this previously neglected FLR mechanism for fishbone induced losses. Losses of this type on ITER are expected to be substantially less than 1%

[1] V. G. Kiptily *et al. Nucl. Fusion*, vol. 58, no. 1, p. 14003, Jan. 2018.

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