Effect of launched LH wave spectrum on current profile and MHD activity in Tore Supra

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1. Introduction. Long pulse operation with high Lower Hybrid (LH) power (~ 5MW), in near full current drive conditions, were performed in Tore Supra (TS) in the 2011 experimental campaign [1]. The LH waves for heating and current drive are coupled to the plasma using two launchers: a Fully Active Multijunction (FAM, denoted C3) launcher and a Passive Active Multijunction (PAM, denoted C4) launcher, the latter being an ITER-relevant design [2,3]. In the experimental conditions studied here, i.e. with vanishing loop voltage ($V_{Loop} < 0.05V$), MHD-activity is prone to occur, being quite sensitive to small variations in LH power or phasing. Indeed, previous experiments in TS have shown that the two LH launchers can produce different current profiles, even though peak $n_{//}$-value is the same [4], indicating that the details of the launched $n_{//}$-spectrum, in particular the negative lobes, play a role for the current profile. Here, the effect of the LH launchers (FAM versus PAM) on the current profile and MHD-activity is further investigated in high LH power discharges.

2. Experimental results. In the experiments analyzed in this paper, both LH launchers were powered simultaneously, using the same peak $n_{//}$ value ($n_{//}$ = 1.7). The time evolution of two discharges is shown in Fig.1 (toroidal magnetic field B_T = 3.4T). The total LH power waveform is the same in both discharges, only the power fraction between the FAM and PAM varies (#47435: f_{FAM} = 60%, f_{PAM} = 40%; #47436: f_{FAM} = 75%, f_{PAM} = 25%). The peak value of the launched spectrum is the same on both launchers in both pulses ($n_{//}$ = 1.7). Fig. 1 shows that the MHD-activity appears 1s earlier in #47435 than in the following pulse. Since the MHD is mainly related to the current profile, the results suggest that the change in power division between FAM and PAM can lead to different current profile. The electron temperature perturbations using the fast ECE diagnostic for the two discharges at t ~ 15s are plotted in Fig. 2. Analysis of the q-profile for the two discharges show that the electron temperature perturbation corresponds to the m/n = 3/2 mode, which is located at a normalized radius r/a ~ 0.37. Fig. 2 reveals that the m/n = 3/2 rational surface is located slightly further off-axis in #47436, i.e. when using a large power fraction on FAM, suggesting a broader current profile in this case.

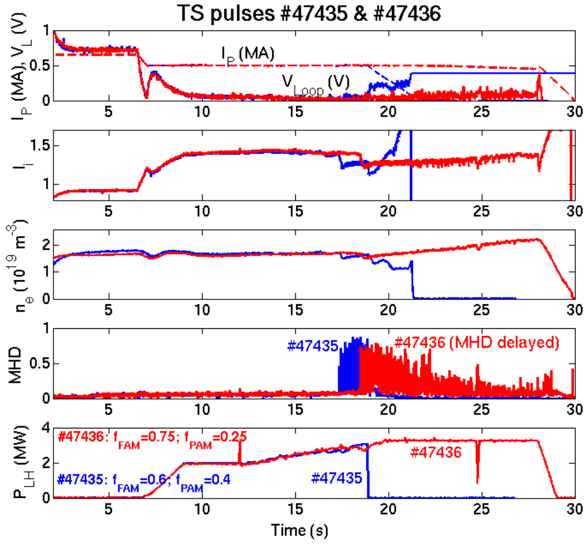

Fig. 1: Two TS pulses with same total LH power, but different power division between FAM and PAM.

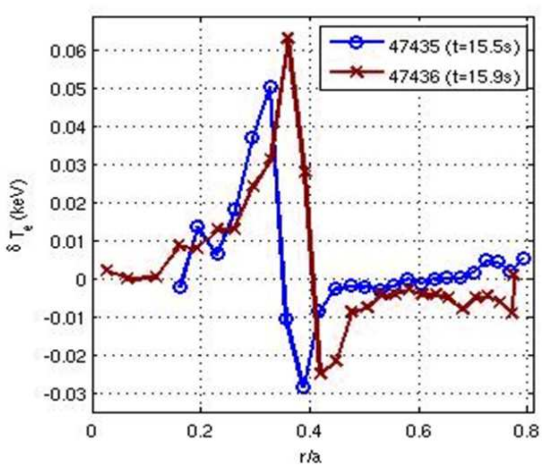

Fig. 2: Temperature perturbation measured by fast ECE diagnostic at t~15s. The m/n=3/2 surface is located further off-axis in #47436.

3. Modelling. To interpret the experimental results, C3PO/LUKE simulations [5] combined with METIS and ALOHA, are performed to calculate power deposition and LH driven current profile, where METIS calculates the equilibrium and ALOHA [6] is utilized to model the LH spectrum to be used as input in C3PO/LUKE. In order to clarify it further, two time slices are analyzed (t = 10s and t = 15s), for which the plasma current, loop voltage, plasma density, impurity concentration (Z_{eff}), central electron temperature are almost the same. The power on the two launchers (P_{FAM}, P_{PAM}) is (1.45MW, 1MW) at t = 10s and (1.7MW, 1.15MW) at t = 15s for #47435. The corresponding values for (P_{FAM}, P_{PAM}) in #47436 are (1.85MW, 0.6MW) at t = 10s and (2.1MW, 0.75MW) at t = 15s. Although the waveform for the total LH power (i.e. P_{FAM}+P_{PAM}) is the same at every time slice for the two discharges, the power fraction on FAM is larger in #47436 (f_{FAM} = 75%) than in #47435 (f_{FAM} = 60%). The C3PO/LUKE calculations, for the experimental parameters of #47435 and #47436, are shown in Fig. 3. To be sure that the simulations are reliable, the experimental values of the Hard

X-ray signal from fast electron bremsstrahlung diagnostics in energy range 50-110 keV were compared with the simulated ones, including shape and absolute amplitude. It is seen from Fig. 3(b) that the power deposition moves slightly outward in #47436, i.e. with larger power fraction on the FAM launcher. As a result, a slightly broader driven current profile is obtained in #47436, as seen in Fig. 3(d). The different driven current profiles could be due to different power spectra of FAM (C3) and PAM (C4), which is shown in Fig. 4. The spectra are calculated by ALOHA, using the experimental values of waveguide power and phasing between waveguides, as well as experimental value of the density near the grill mouth.

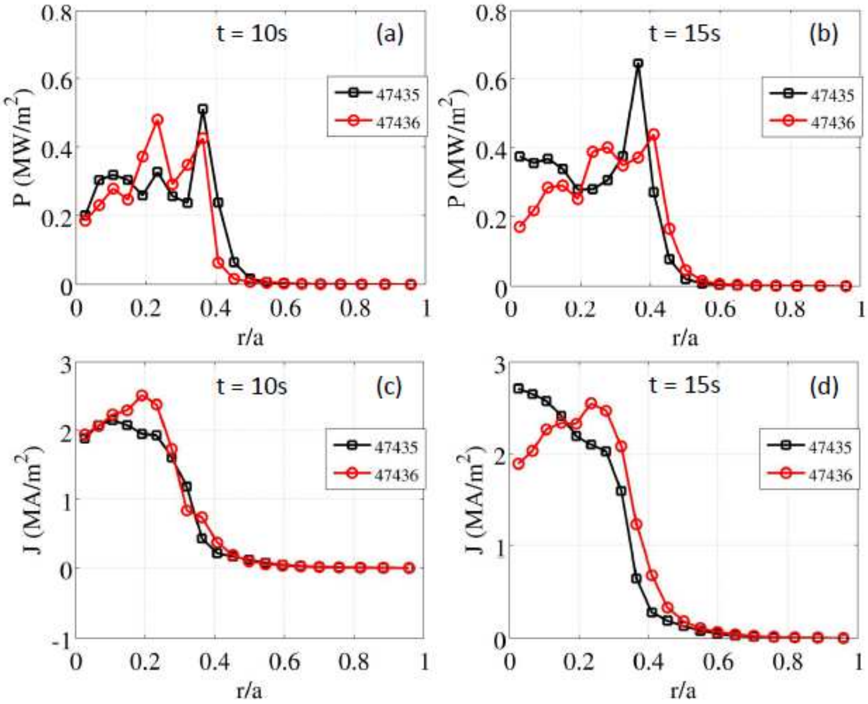

Fig. 3: Simulated power deposition and LH driven current profile for #47435 and #47436.

Usually, the driven current, $J_{LH,}$ mainly comes from the main lobe. It is seen in Fig. 4 that the main lobe is located at the same value ($n_{//} = 1.7$) for FAM (C3) and PAM (C4), meaning that the power deposition from positive lobe should be the same. However, the negative lobes are different for the two launchers. For FAM, the main negative lobe and main positive lobe are located at the same absolute value of $n_{//}$, meaning that they are nearly deposited at the same radial location [4]. Therefore, the negative lobe thus simply reduces the driven current without changing the profile shape. In the case of the PAM, the main negative lobe is located at $n_{//} = -2.9$, which is deposited at a different radius, compared to the main positive lobe, thus modifying the driven current profile.

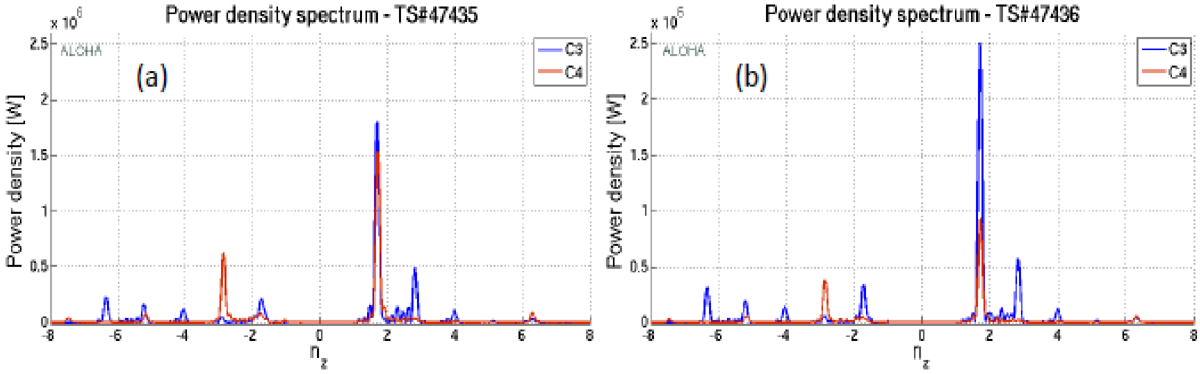

Fig. 4: Calculated power spectra for #47435 (a) and #47436 (b), using the ALOHA code.

4. Conclusion. The onset of MHD-activity in high LH power discharges, at vanishing loop voltage, is found to be sensitive to small variations in LH power or $n_{//}$-spectrum. In the experimental scenario studied here, broader current profile, and delayed MHD-onset, appears to occur when using larger power fraction on FAM, with respect to PAM. This is agreement with C3PO/LUKE simulations, using detailed LH spectra from the ALOHA code.

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