Core radiative collapse in WEST LHCD plasmas: characterisation and integrated modelling

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Tokamaks devices characterised by metallic walls, such as tungsten, are prone to a core radiation due to heavy impurities. This leads to a radiative collapse during a discharge that causes the plasma to enter a central low-temperature degraded state where q profile reversal can trigger tearing modes. This happens mainly during the plasma current or the power ramp up due to the maximum cooling rate of tungsten at 1.5keV. This phenomena is observed in JET during Ip ramp up [1], WEST [2] and FTU [3].

In WEST tokamak, during the 1st phase of operation [4] mostly heated by LHCD, we observed that two different confinement states coexist at a given ratio of additional power over plasma electron density, we call them cold branch ($T_e(0)$ higher than 2keV) and hot branch ($T_e(0)$ values around 1.5 keV). Moreover, 25% of the hot branch is effected by a rapid collapse of the central electron temperature. This means that from 3keV, a slow decrease of central temperature is followed by a fast collapse occurring in less than 0.1s. At the end, the plasma goes on the cold branch and MHD is triggered. Experimentally we observed that prior to the collapse, electron density slightly increases, while the tungsten central density (from the bolometry inversion) is constant. Then, it increases very quickly until it reaches a peak. Meanwhile, the signal of the hard X-ray central channel for the energy band 60-80 keV decreases indicating that LHCD absorption decreases in the plasma center.

In order to disentangle the causality chain, integrated modelling is performed. The framework is composed of RAPTOR [5] coupled with QuaLiKiz 10D neural network [6] (QLKNN) for the transport coefficients and LUKE code [7] used to compute the LHCD power deposition profile. It is found that the initial slow reduction of the $T_e(0)$ due to the density raise is captured when QLKNN is used. The rapid collapse is captured when both the tungsten accumulation and the decrease of LHCD central value deposition are taken into account.

Furthermore, we find that the reduction of central LHCD power deposition can explain the tungsten accumulation. In fact, when the central LHCD power deposition decreases, the core $T_e(0)$ gradient is reduced as well as the core T_i due to a reduction of the equipartition. This reduces the W neoclassical temperature screening and leads to W core peaking as observed experimentally.

References

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