PROFILE MODIFICATIONS IN TdeV DURING ELECTRON CYCLOTRON HEATING

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Introduction

TdeV (R=.83m, a=.21m, B_T=1.96T) is now operating with 600 kW of electron cyclotron heating at 110 GHz [1]. The wave is launched perpendicular to the magnetic field via a steering mirror from the low-field side in the 2X-mode. With the $v_{\nabla B}$ drift towards the X-point, H-mode discharges are routinely obtained at any deposition radii below r/a=0.75. Profile modifications resulting from ECRH are studied using as primary diagnostics a 9-channel submillimeter wave interferometer/polarimeter, an 8-channel infrared Thomson scattering, a 33-75 GHz AM-reflectometer and a CX analyser.

ECRH experiment

Based on the observation that H-mode in TdeV is linked to the separatrix density rather than to the average density, we obtain stationary H-modes by controlling the edge density [2]. This is done by fuelling the discharge so as to make the edge interferometer chord signal follow a reference waveform (r/a=.65) allowing the central density to vary freely. Figure 1 compares stationary H-modes obtained with central and off-axis deposition in single-null TdeV discharges. As seen from the peaking factor curves, $n_0/\bar{n}_e$, on-axis and off-axis (r/a=.65) deposition of EC heating modifies the density profiles in a different fashion. On-axis power deposition flattens the density

Fig. 1 On and off-axis ECRH H-modes in TdeV

profiles whereas during off-axis deposition the density profiles start off flat and peak progressively. The peaking factor $n_0/\bar{n}_e$ reaches 1.5. In all cases, the temperature profiles exhibit a complementary behaviour such that the local pressure is approximately constant. The central safety factor q_0, is close to unity during on-axis deposition and increases continuously from 0.9 to 1.3 during off-axis heating in agreement with the observed sawtooth stabilisation at around 700 ms. Calculations with a neoclassical resistivity distribution shows that for all these
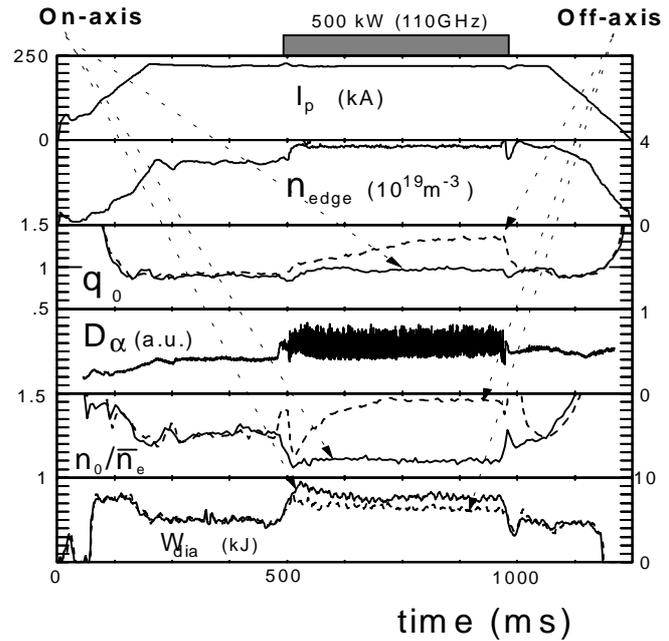
situations, the current profiles remain consistent with the temperature profiles, namely that flat temperature profiles correspond to wide current J_p profiles and peaked T_e profiles to narrow ones. The fact that the density profile for the off-axis case evolves slowly over a characteristic resistive time suggests that the current penetration plays an important role in the slowing down of the peaking of the density. Figure 2 illustrates this density and temperature profile
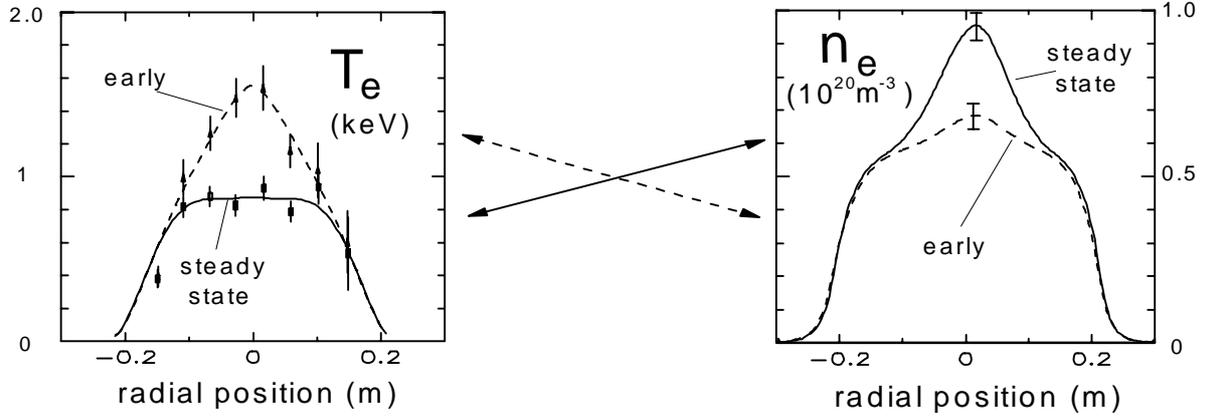

Fig. 2 H-mode T_e and n_e profiles during off-axis ECRH

complementarity during off-axis heating in stationary H-mode. Accordingly, during this evolution from flat to peaked $n_e(r)$, the measured diamagnetic energy remains constant. Density peaking is also observed in L-mode with off-axis heating, it is significant at large densities and disappears completely below $\bar{n}_e \approx 3 \times 10^{19} \text{m}^{-3}$.

Transport

To better understand particle transport in off-axis ECH plasmas and to discriminate between diffusion and convection, we have conducted a density modulation experiment [3]. The particle transport was analysed both in the early (flat density profile in Fig. 2) and late phase (peaked profile of Fig. 2) of the EC heating period. It is clearly seen in these experiments that the gas pulse penetrates more slowly for peaked n_e profiles than for flat ones. The D and V results, averaged over 20 D_2 puffs during a stationary H-mode, are presented in Fig. 3 for these two types of profiles. Consistent with the observed temporal
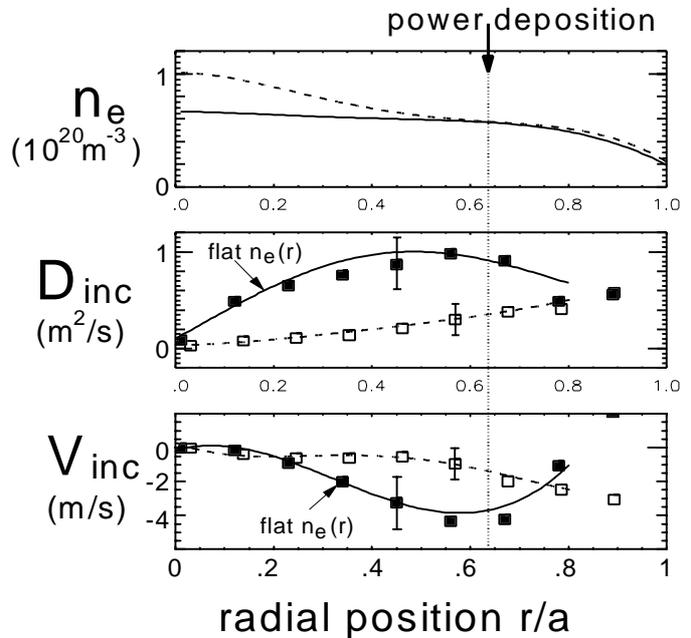

Fig. 3 Measured incremental D and V coefficients

penetration, both coefficients are significantly larger for flat $n_e(r)$ than for peaked $n_e(r)$ inside the deposition radius. The fact that the edge density profile measured by the reflectometer remains the same for both profiles suggests that a particle transport barrier exists near the deposition

region for the peaked density profile. An ASTRA [4] heat transport analysis of these two cases is summarised in Fig. 4. For these calculations, we used the experimental T_e and n_e profiles and assumed neoclassical ion transport profiles adjusted to fit the measured axial values. The current distributions are simulated with neoclassical resistivity and the electron power sources are determined from beam waist measurements and ray tracing. The code is run for the two types of density profiles obtained with off-axis heating (500 kW) using the particle transport coefficients of Fig. 3. As seen on other machines (DIII-D, RTP), a negative electron heat flux inside the deposition

Fig.4 Heat transport analysis for the two ne profiles.

radius is observed opposing the temperature gradient in both cases. Heat transport is improved in the confinement zone with respect to on-axis heating but, contrary to particle transport, does not seem to differ for these two types of off-axis heating. The fact that the heat flows are very similar for both density profiles is not surprising since the pressure profiles are comparable. The error bars on q_e include density and temperature uncertainties. Reducing the particle heat flux from $5/2\Gamma_n kT_e$ to $3/2\Gamma_n kT_e$ does not reverse the sign of the assumed diffusive flow. Accordingly, non-diffusive heat transport such as non local transport or heat pinch which could result from superthermals or trapped electrons must be invoked.
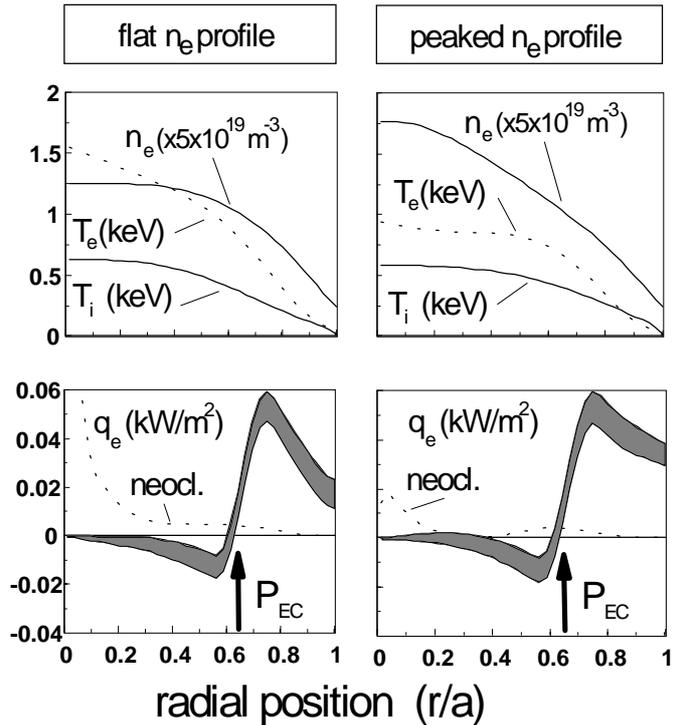
Biasing effects

Divertor plate biasing [5] has no significant effect on central profile modifications. In fact we observed that it mainly influences the edge of the discharge making it a useful tool to control H/L mode transitions. As illustrated in Fig. 5, negative biasing is seen to be detrimental to H-mode (left). With 500 kW of ECRH and no biasing, a stationary H-mode is obtained. When -250 V is applied to the outer plate with respect to the vessel, the discharge turns into L-mode. On the contrary, positive biasing is favourable (right). In this case, the discharge is operated just below the threshold with 200 kW of ECRH and no biasing. Applying +250 V induces a stationary H-mode during the whole EC period. Consequently, the resulting stored energy is reduced by ~15% for negative biasing and improved by as much for positive polarity. Reversing the toroidal field and plasma current polarity, does not reverse this effect; negative biasing is detrimental to H-mode and positive biasing favours it regardless of B_T direction. Our results on biasing polarity, contrary to those of JFT-2M [6], confirm the theory that H/L
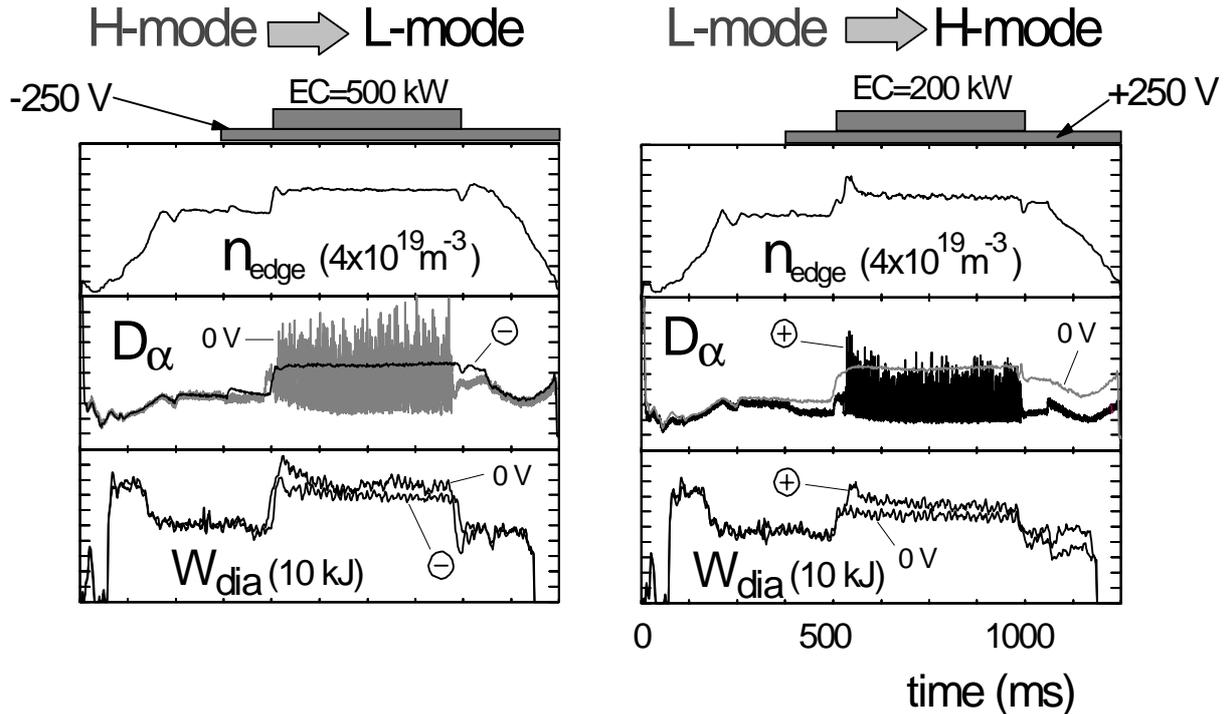
Fig. 5   H-mode control with divertor plate biasing

transitions are governed by the radial electric field gradients and not its polarity.

Summary

EC heating during stationary H-mode in single-null TdeV can produce flat or peaked density profiles. Transport experiments in off-axis heated plasmas indicate that both the diffusive and convective processes are significantly larger in flat $n_e(r)$ than in peaked $n_e(r)$. Heat transport analysis (ASTRA) shows that an inward heat flux exists inside the deposition radius which cannot be explained by diffusion processes. Biasing is seen to have very little influence on the central profiles while efficiently controlling edge profiles; negative biasing induces H to L transitions and positive biasing reduces the H-mode power threshold.

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