Evolution of the edge pressure gradient during the ELM cycle on MAST

R. Scannell[1], D. Dickinson[2], A. Kirk[1], C. M. Roach[1], S. Saarelma[1]

[1]*Euratom/CCFE Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK*

[2]*Department of Physics, University of York, Heslington, York YO10 5DD, UK*

Introduction

The height achieved at the top of the edge pedestal is one of the key factors determining the core plasma parameters and hence fusion performance in future devices. This height is determined by both the width of the region over which the transport barrier acts and the gradient sustainable within the transport barrier. The physics determining this width and gradient, as well as the extrapolation of these factors from current devices to future devices, are all active areas of research.

In this paper the evolution of the pedestal in MAST during the ELM cycle is diagnosed using a 130 point Thomson scattering (TS) system [1]. These data are then analysed by the HELENA[2], GS2[3] and ELITE[4] codes to determine the plasma stability to infinite n ballooning modes, kinetic ballooning modes and finite n ballooning modes respectively.

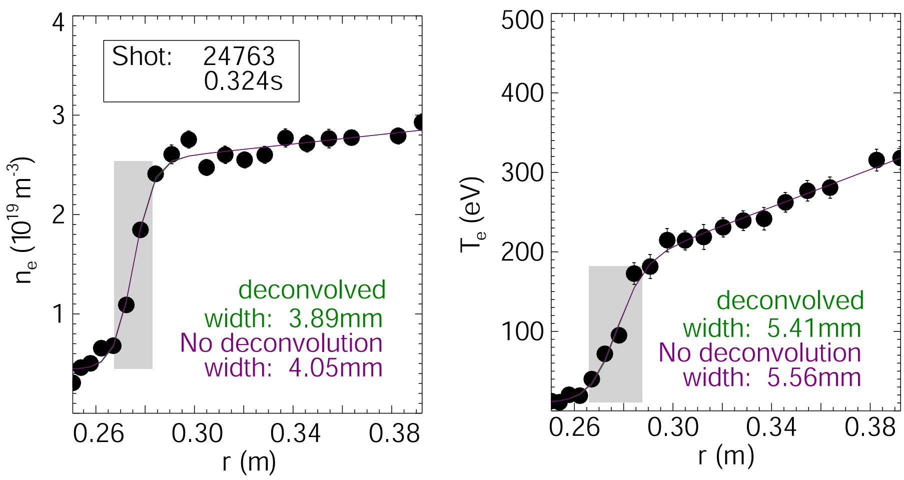

Figure 1 – Profile fits to a single set of n_e and T_e data. Multiple measurement points within the edge transport barrier indicate that the gradients in this region are well resolved.

Data Selection

The MAST TS system measures T_e and n_e profiles simultaneously on both the high field side and low field sides of the plasma. Very high resolution, 3-4mm, is obtained on the high field side due to the scattering geometry, this is smaller than typical pedestal widths observed in this region of 10-20mm. Similar pedestal widths are observed on the low field side with a diagnostic resolution of ~10mm. For this reason, data examined in this paper are taken from the high field side of the plasma. This TS system combines eight Nd:YAG lasers and measures profiles every ~4.2ms.

The data examined in this paper are obtained from a set of three similar MAST H-mode discharges in double null configuration: 24459, 24452 and 24763. The data were selected from H-mode periods where the ELM separation varied from 6-12ms. The diagnostic sampling rate is therefore insufficient to diagnose an individual ELM cycle, but arranging the profiles obtained as a function of ELM cycle allows the general ELM cycle to be diagnosed.

Measured T_e and n_e data from a single time point, together with mtanh fits [5], are shown figure 1. The determined pedestal widths with and without taking into account the instrument function are shown in the figure 1. Although the effect of deconvolution is small, ~4% on Δ_{Te} and Δ_{ne}, this combines to create a difference of ~8% in the peak pressure gradient observed, this has significant implications for MHD stability. Full deconvolution, using the method detailed in [6], is used for all the data presented here.

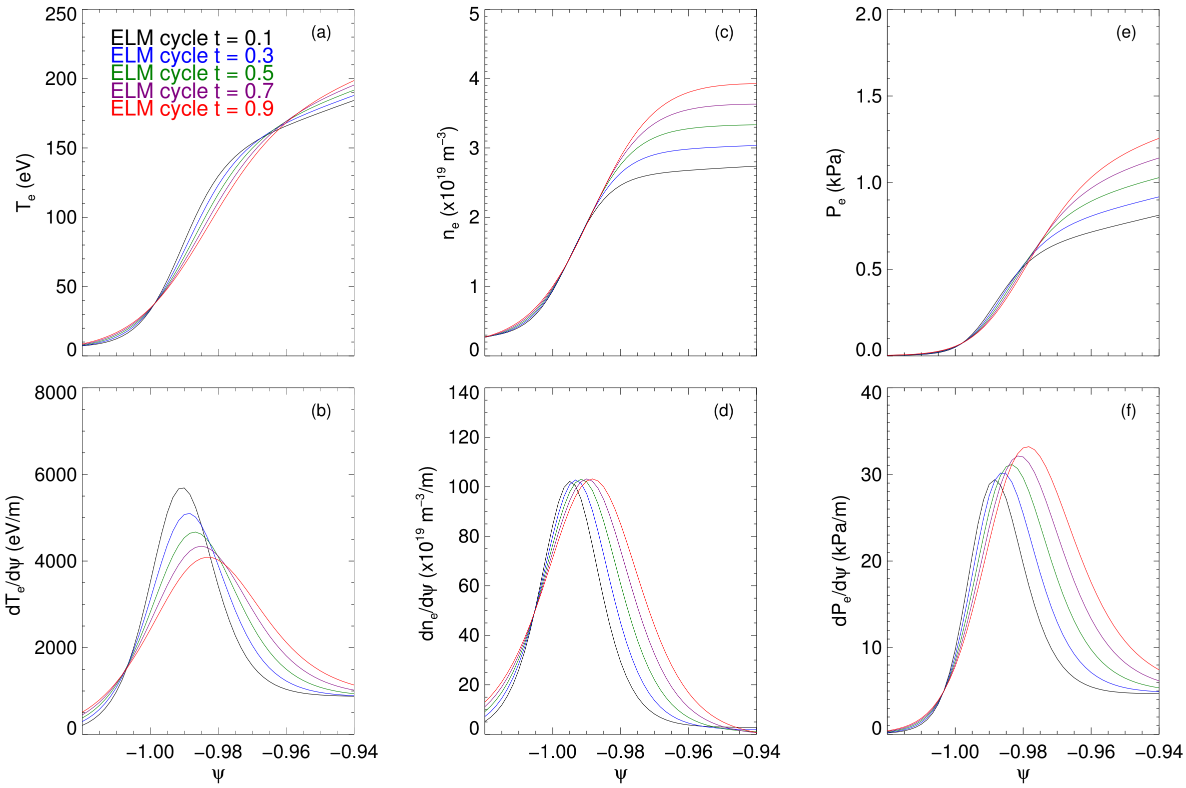

Figure 2 – Evolution of n_e, T_e and P_e profiles and their gradients during the ELM cycle.

Profiles during the ELM cycle

To obtain $P_e(\psi)$ profiles, mtanh fits are preformed on n_e and T_e in real space where the convolution may be taken into account. The $n_e(r)$ and $T_e(r)$ profiles are then used to determine

$P_e(r)$, and all three profiles were mapped to ψ space and refitted by mtanh parameters. This was performed for 50 profiles during the three MAST discharges and the ELM time 't' for each profile was computed where t is the normalised time in the ELM cycle ie t=0.01 just after an ELM and t=0.99 is just before an ELM. The evolution of the mtanh parameters with t was found to be approximately linear over the ELM cycle and linear fits were performed. From these linear fits the plasma profiles at t={0.1, 0.3, 0.5, 0.7, 0.9} are reconstructed. The results of this process are shown in figure 2. Clearly visible in $n_e(\psi)$, $T_e(\psi)$ and $P_e(\psi)$ and their gradients are the inward movement of the extent of the edge transport barrier over the course of the ELM cycle. The density pedestal height increases significantly, while the temperature pedestal height shows only a small increase. This results in little change in the peak value of $dn_e/d\psi$ over the ELM cycle and a decreasing peak $dT_e/d\psi$. While the pressure pedestal height more than doubles throughout the ELM cycle, due to the expanding Δ_{pe}, the resulting peak $dP_e/d\psi$ increases by less than 20%. It should be noted that the pedestal width expansion with t shown here in ψ space is also observed in radial space and so is not purely due to flux expansion with increasing β.

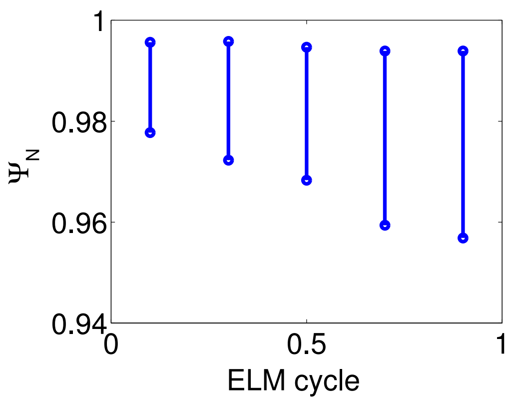

Figure 3 – Region of plasma unstable to n=∞ ballooning modes during the ELM cycle as calculated by the HELENA code.

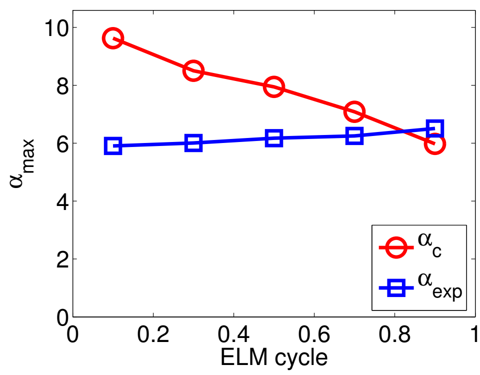

Figure 4 – Experimental peak pressure gradient evolution and stability boundary to finite n ballooning modes as calculated by the ELITE code.

Plasma Edge Stability

The experimental data from the previous section is now used to determine the plasma stability. The profiles shown in figure 2 are used in the Sauter formula [7] to calculate the edge bootstrap current. The ion temperature profile is assumed to follow the $T_e(\psi)$ profile and ion density calculated from $n_e(\psi)$ assuming a Z_{eff} of 2 in the plasma edge region. Plasma current and boundary conditions are obtained from EFIT. These experimental data were then passed to the HELENA code which computes the stability at each flux surface to infinite n ballooning modes. The results of the stability calculations from the HELENA code are shown in figure 3, where the blue line indicates the region unstable to infinite n ballooning modes. This unstable region may be seen to expand during the ELM cycle, closely following the region of high pressure gradient seen in figure 2.

An equilibrium generated by the HELENA code was passed to the local gyrokinetic code, GS2 to perform linear microstability analysis. The results of this code show that the region of plasma unstable to infinite n ballooning modes is also unstable to the kinetic ballooning modes (KBMs). It has also been shown that the fastest growing modes in the steep gradient region of the pedestal are twisting parity modes, while tearing modes are the fastest growing inside of the pedestal top.

The experimental data was also analysed by the ELITE code to determine plasma stability to intermediate n modes. The results of this analysis are shown in figure 4. It may be seen that the experimental pressure gradient (α_{exp}) observed exceeds the stability limit (α_c) just before the ELM crash. It is interesting to note that the onset of the instability is caused by the pressure gradient limit falling towards the experimental pressure gradient during the ELM cycle and not the other way around. This is caused in part by the expanding pedestal width during the ELM cycle, as narrow pedestal widths cause stabilising finite n corrections [8] increasing the stability limit α_c.

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