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Analysis of large and small scale fluctuations in the plasma edge of ASDEX Upgrade

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Introduction

Large and small scale fluctuations of both electron density and temperature are accessible by the Thomson scattering system on ASDEX Upgrade [1] in the steep edge gradient region of H mode plasmas: The characteristic structures and spatial distributions of large scale fluctuations which exist during and in between Edge Localised Modes (ELMs) were investigated by 2D snapshots of the electron density and temperature in the poloidal plane [2, 3].

Small scale fluctuations between ELMs are inferred indirectly in the steep gradient region by measuring the gradient lengths L_{ne} and L_{Te} of the 1D radial electron density and temperature profiles, respectively. The deduced parameter $\eta_e = L_{ne}/L_{Te}$ was identified as a critical parameter in theoretical calculations of the fluctuations induced by electrons. Several values for η_e were found on ASDEX Upgrade for different plasma parameters [5].

The variation of the mean amplitudes of the large scale fluctuations and of the parameter η_e with plasma parameters for type I ELMy discharges is investigated in this paper.

Experimental Setup

The vertical Thomson scattering diagnostic consists of a bundle of up to six vertically launched, radially staggered Nd-YAG laser beams. The scattered light is observed from the low-field side in 16 spatial channels. The whole system was shifted radially to measure low field side edge plasma profiles and structures in the poloidal plane (Fig. 1). The data presented in this paper were obtained both with the previously used charge sensitive analog-to-digital converters resulting in data with larger error bars, and the presently used transient recorders and improved data evaluation [4] providing more accurate data.

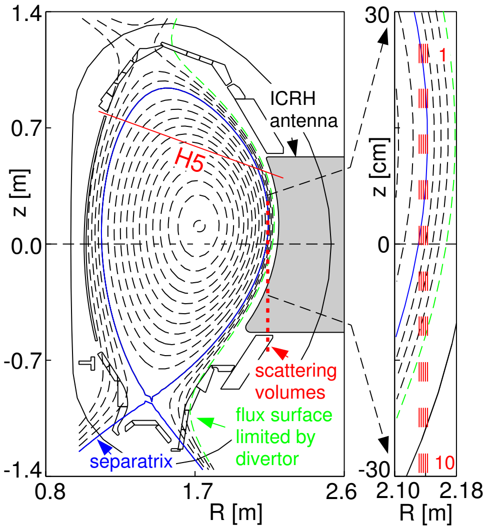

Figure 1: poloidal cross section

The line-averaged electron density at the plasma edge including the pedestal shoulder is measured by the DCN interferometer-signal H5.

Results

Discharges with heating powers from neutral beam injection (NI) and ion cyclotron resonance heating (ICRH) between $2.5\ MW \leq P_{NI} + P_{ICRH} \leq 17\ MW$ and upper and lower triangularities of $-0.08 \leq \delta_u \leq 0.50$, $0.33 \leq \delta_l \leq 0.55$, elongations $1.34 \leq \kappa \leq 1.84$, toroidal magnetic fields $-3\ T \leq B_t \leq -1.9\ T$ and plasma currents $0.8\ MA \leq I_p \leq 1.0\ MA$ were investigated.

The probability distribution functions (PDFs) of the large scale fluctuations of both the electron density and temperature between ELMs were investigated in [3] for discharge #20417, which is also included in the above mentioned ensemble: in the middle of the steep gradient region the PDFs are symmetric and asymmetric both further inwards (more minima), and further outwards (more maxima). To compare the amplitudes of the large scale fluctuations for different discharge parameters the variance of the normalized electron density, $Var(n_e/\langle n_e\rangle)$, with $\langle n_e\rangle$ as the mean value over the time interval of the evaluation, was determined at the radial position in the steep gradient region where its PDF is symmetric. In a plot of the relative amplitudes of the large scale fluctuations versus the edge line integral $H5$ normalized to the Greenwald density [6] $n_e^{GW} = I_p/(\pi a^2)$ with $a = 0.5\ m$ as the minor radius of the ASDEX Upgrade plasma, a clear increase of the fluctuation amplitudes when approaching the Greenwald density is observed (fig. 2a). For a narrow window of heating powers and triangularities a near linear increase of $Var^{0.5}(n_e/\langle n_e\rangle)$ with the normalized density $H5/n_e^{GW}$ is found (fig. 2b).

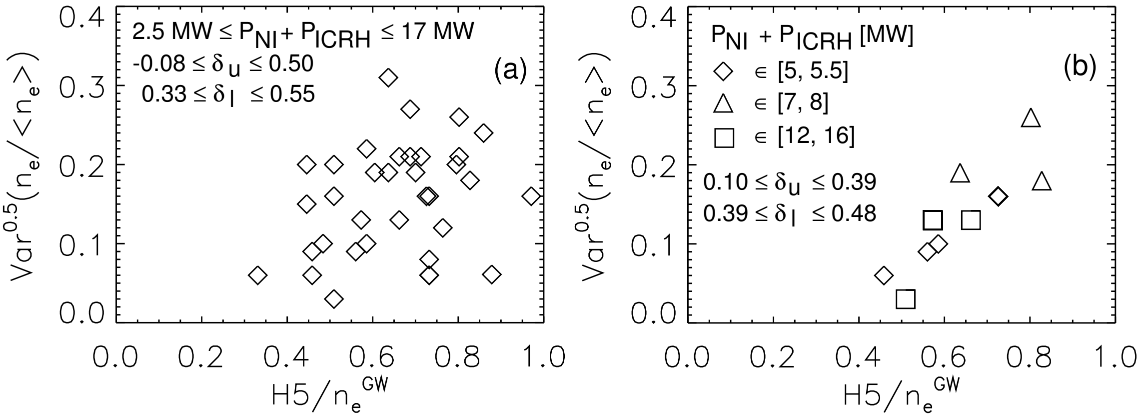

Figure 2: Relative amplitudes of the large scale fluctuations versus normalized edge density for a broad range (a) and a narrow window (b) of heating powers and triangularities.

The large scale fluctuations of electron density and temperature are in phase [3]. Thus macroscopic plasma volumes are apparently moved radially with respect to their positions in the unperturbed profile by these fluctuations. In a double logarithmic plot of the electron temperatures versus the electron densities of a plasma edge profile (fig. 3) the radial positions of the measured data are eliminated. In-phase-changes of electron density and temperature do not increase the scatter in the plot of T_e versus n_e in contrast to plots of radial profiles where large scale fluctuations clearly increase the scatter. Thus the parameter $\eta_e = L_{ne}/L_{Te}$, which characterizes the small scale turbulence, can be determined practically independently of the large scale flucatuations. The η_e parameters were determined in parallel to the amplitudes of the large scale fluctuations for the above mentioned set of plasma parameters. No correlation between the η_e data and the amplitudes $Var(n_e/\langle n_e \rangle)$ of the large scale fluctuations or the applied heating power was observed up to now. There is however a correlation of η_e with the plasma shape, which is characterized by the upper and lower triangularities δ_u and δ_l and the elongation κ. The dependence of η_e on these 3 parameters is presented here as projections of the parameter space into the 2D planes (η_e, δ_l) (fig. 4a), (η_e, δ_u) (fig. 4b) and (η_e, κ) (fig. 5). The error bars of η_e are indicated for all data points in fig. 4 and 5. The data with the larger error bars were acquired with the charge sensitive digitizers used earlier. Both with increasing lower and upper triangularities δ_l, δ_u the value of η_e is increasing. Note that for $\delta_u \approx 0$ the parameter η_e has

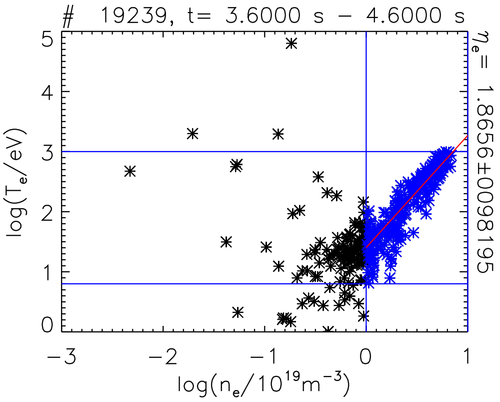

Figure 3: Determination of $\eta_e = L_{ne}/L_{Te}$.

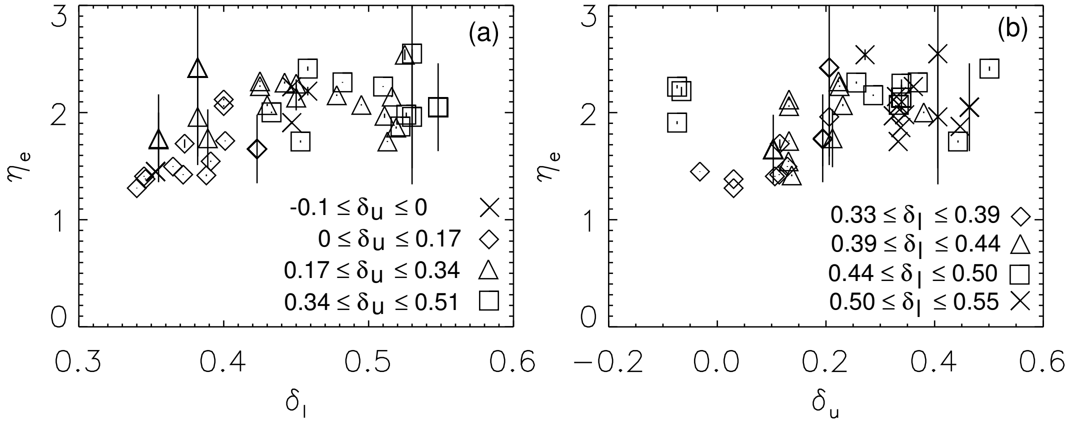

Figure 4: η_e versus δ_l for several ranges of δ_u (a), and versus δ_u for several ranges of δ_l (b).

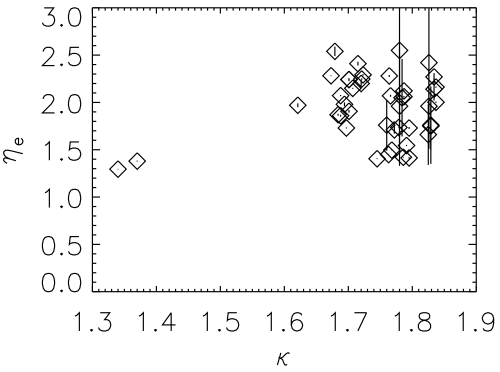

Figure 5: η_e versus κ.

a minimum, $\eta_e \approx 1.3$ (fig. 4b). At this minimum value also the elongation κ has the smallest value in this ensemble of data points (fig. 5). For decreasing negative upper triangularities δ_u the parameter η_e is increasing again (fig. 4b).

Discussion

The increase of the amplitudes of the large scale fluctuations in the steep gradient region, $Var(n_e/\langle n_e\rangle)$, with increasing edge density, normalized to the Greenwald density, $H5/n_e^{GW}$, may indicate that these fluctuations are produced when the plasma edge approaches the density limit set by the plasma current. Interestingly there is no threshold value for the first appearence of the large scale fluctuations near the density limit, $(H5/n_e^{GW})_{th} \approx 1$, but their amplitudes start to be visible at $H5/n_e^{GW} > 0.3$, which is considerably away from the density limit. The amplitudes of the fluctuations are rising when approaching the density limit.

No correlation between the amplitudes of the large scale fluctuations, $Var(n_e/\langle n_e\rangle)$, and the parameter η_e was found so far. This may indicate that the small scale fluctuations parametrized by η_e are of different origin than the large scale fluctuations. The minimum value $\eta_e = 1.3$ was observed for a plasma shape that in the ensemble of investigated plasma shapes is closest to circular ($\kappa = 1.34$, $\delta_u \approx 0$, $\delta_l \approx 0.34$). With increasing elongation κ, or absolute values of the triangularities also increased η_e values are observed. The maximum value of $\eta_e = 2.6$ is observed for an elongated triangular plasma shape ($\kappa \approx 1.71$, $\delta_l \approx 0.53$, $\delta_u \approx 0.34$). For larger values of the parameters κ, δ_l, δ_u the parameter η_e may be constant at around $\eta_e \approx 2.1 \pm 0.4$.

These results are at least qualitatively in agreement with theoretical calculations of toroidal electron temperature gradient modes [7], where also an increase of η_e with increasing elongation κ and triangularity δ, or its radial gradient $d\delta/dr$ was found, although to a smaller extent.

The data base will be extended to further investigate the trends found so far.

References

[1] H. Murmann *et al.*, Rev. Sci. Instrum. **63** 4941 (1992)

[2] B. Kurzan *et al.*, Phys. Rev. Lett. **95**, 145001 (2005)

[3] B. Kurzan *et al.*, Plasma Phys. Control. Fusion **49**, 825 (2007)

[4] B. Kurzan *et al.*, Plasma Phys. Control. Fusion **46**, 299 (2004)

[5] J. Neuhauser *et al.*, Plasma Phys. Control. Fusion **44**, 855 (2002); A. Kallenbach *et al.*, Proc. of the 19th IAEA Conference Fusion Energy, Lyon, France, October 2002, paper EX/P4-05; L. D. Horton *et al.*, Nucl. Fusion **45** 856 (2005)

[6] M. Greenwald *et al.*, Nucl. Fusion **28**, 2199 (1988)

[7] F. Jenko *et al.*, Phys. Plasmas **8**, 4096 (2001)