Study of the Impact of High Neon Radiation on Pedestal and Divertor in JET Experiments

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Impurity radiation is a major requirement to protect the divertor targets of future fusion devices, such as ITER and DEMO, from power loads beyond the material limit of $5-10\,\mathrm{MW/m^2}$ [1]. Such radiation is induced by deliberate puffing of impurity gases (e.g. N, Ne, Ar, Kr) into the plasma. In a DEMO device with an ITER-like geometry around 70% of the radiation loss power must originate from inside the separatrix[2, 3]. It is crucial to understand if and how radiative power losses within the confined plasma impact the plasma confinement and the discharge stability. Therefore, at JET dedicated neon-seeded experiments with high heating powers $(15-29\,\mathrm{MW})$, high line-averaged densities ($n_\mathrm{G} \simeq 0.8$), $B_\mathrm{T} = 2.6\,\mathrm{T}$ and $I_\mathrm{p} = 2.5\,\mathrm{MA}$ were carried out. The time trace of a typical discharge is shown in Fig. 1. After the beginning of neon seeding the radiative power fraction $f_\mathrm{rad} = P_\mathrm{rad}/P_\mathrm{heat,tot}$ (with P_rad estimated by a dedicated algorithm) increases from about 0.3 to 0.6. A slight increase of the energy confinement $H_{98(y,2)}$ of up to 10% is observed. It is observed that with increased neon content in the plasma the ELM frequency increases, while their amplitude is decreased. From about $t = 52\,\mathrm{s}$ on, periodic radiation spikes are measured. Their origin is yet to be examined.

In this discharge which is typical for neon seeded pulses with $P_\mathrm{heat} > 19\,\mathrm{MW}$ it is observed that the zone of the strongest radiation power density moves from the high-field side scrape-off layer into the confined region above the X-point (see Fig. 2). It is observed that after the end

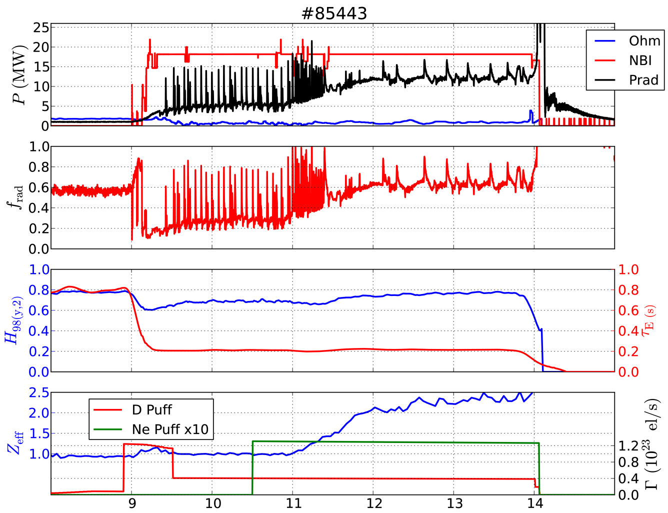

Figure 1: *Time traces of JPN 85443 (from top): heating powers and radiation power, radiative power fraction f_{rad}, $H_{98(\mathrm{y},2)}$ and energy confinement time τ_{E}, puffs, and deuterium and neon puffs and Z_{eff}.*

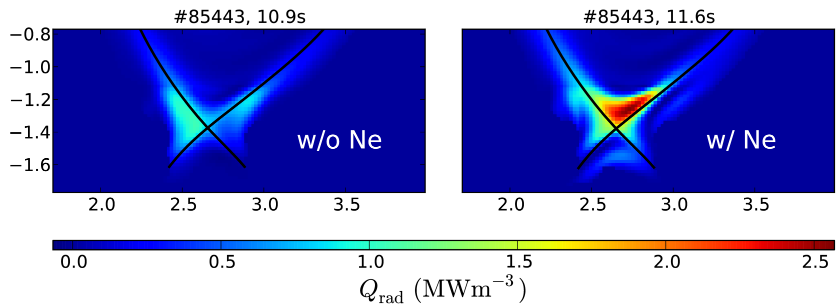

Figure 2: *Transition of the strongest radiating zone from the high-field side scrape-off layer into the confined region close to the X-point.*

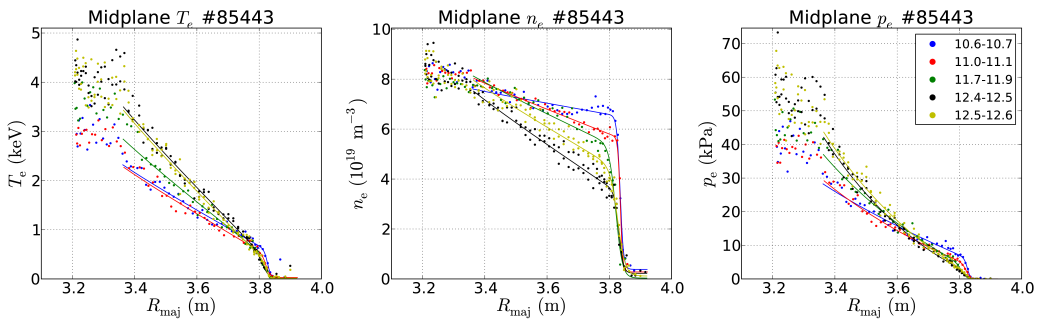

Figure 3: *Radial profiles of n_e and T_e during a neon seeded discharge, from high resolution Thomason scattering. Where ELMs occur the profile is ELM-filtered.*

of the neon puff the X point radiator vanishes and radiation from the high-field side dominates again. This vanishing can also be caused e.g. by beam blips or increased deuterium puffing, as it was observed in other neon seeded JET pulses.

About 0.3 s after the first radiation shift to the X-point it is measured that the radial n_{e} profile is degraded by about 50% at the pedestal top position but recovers to the unseeded value in the core (see Fig. 3, at $R = 3.3\,\mathrm{m}$). For the T_{e} profile pedestal top degradation is about 25%

and accompanied by an inward movement of the pedestal top position by less than 5 cm. The core T_e instead is increased with neon seeding. The decreasing pedestal pressure correlates with decreasing pressure at the divertor targets (see Fig. 4), indicating detachment. The radial profile's transition occurs (in the given and in other similar discharges) roughly 1.5 s after the onset of the neon puff and within 0.1 s.

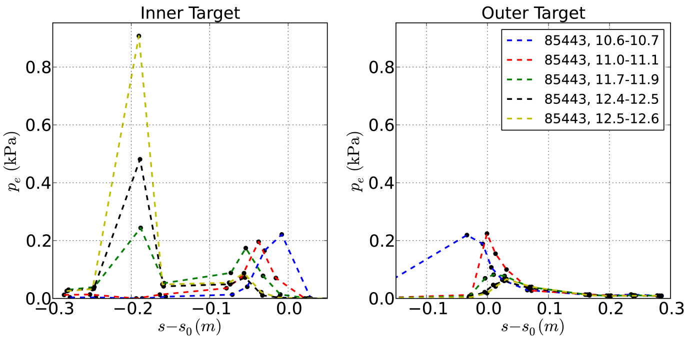

Figure 4: *Target pressure profiles during neon seeded discharge 85443.*

To examine the slight increase in confinement despite the increased radiation in the pedestal region 1D transport simulations with ASTRA-TGLF [4, 5] have been performed. An unseeded time slice (JPN 84884, $t = 13.0$ s, $f_{rad} = 0.3$), a seeded time slice (JPN 85443, $t = 12.8$ s, $f_{rad} = 0.6$), and the seeded time slice with the neon ions substitued by deuterium ions (all other input parameters were kept constant) were simulated, see Fig. 6. The simulation was carried out for $\rho_{pol} < 0.75$. The most important input parameters have been the full electron density profile, the T_e and T_i profiles ($T_e = T_i$ is assumed as CX spectroscopy data from the very similar discharge 92118 imply) for $\rho_{pol} > 0.75$, the radiation distribution profile, and the NBI heating profile (see Fig. 5).

In a comparison between the unseeded and the neon seeded case without neon it is observed that in the latter case ∇T is lower for $\rho_{pol} > 0.5$. Because the density is degraded in the pedestal but recovers towards the core, ∇n is increased, leading to an increased outward heat diffusion and a lower ∇T. However, this effect is compensated. Comparing the seeded case with neon and the seeded case without neon, is can be seen that ∇T is increased in the case with neon. This can be explained by a stabilization of the ion temperature gradient (ITG) due to the dilution of the main ion den-

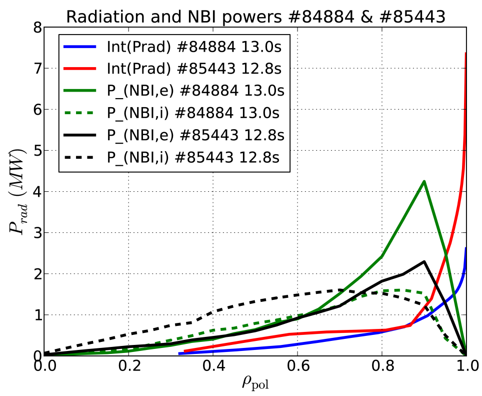

Figure 5: *Comparison of radiation power and NBI heating power profiles for unseeded and neon seeded pulse.*

sity, which leads to a higher energy confinement and higher core temperatures [6, 7].

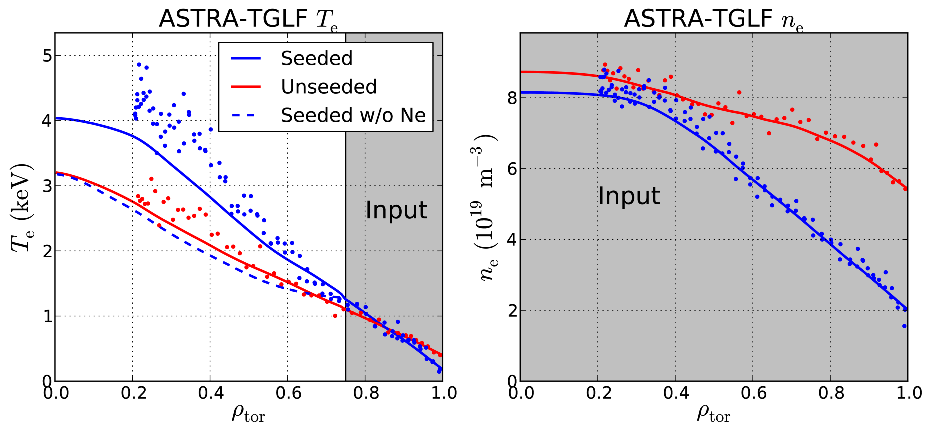

Figure 6: *Radial profiles of T_e and n_e, from experiment (dots) and ASTRA-TGLF simulations (lines).*

As shown in this contribution, in neon seeded JET discharges with $P_{heat} > 19\,MW$ a movement of the zone with the highest radiation power density from the high-field side to close to the X-point could be observed. Depending on the neon puff, a degradation of the pedestal top values of T_e and n_e and their recovery, and an increased core T_e could be measured. The stabilizing process in the core region have been identified by ASTRA simulations to be the impurity dilution effect on the ITG. The processes that lead to the degradation of the pedestal profiles and to a movement of the strongest radiating zone to the X-point are yet to investigate by ongoing numerical simulations with SOLPS-ITER[8, 9].

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.
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