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High Performance FTU Multiple Pellet Injection with no High-Z Impurity Accumulation

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Introduction

High field pellet fuelled discharges, with peak densities close to $n_e(0) \sim 10^{21}$ m^{-3}, have achieved in FTU good density and particle confinement properties in a quasi-steady regime [1]. This regime, obtained in a clean plasma, at low q and high density with a good electron-ion coupling and no direct ion heating, simulates, in many regards, burning plasma conditions to be attained in future experiments. The main features of these discharges are the reduction of the electron thermal diffusivity, the ion channel drop to the neo-classical level, the confinement improvement with respect to ITER-89P, the neutron yield that, at 8 T, reaches a value of 1.3 10^{13} neutrons s^{-1}. The improvement is associated with the stabilisation or total suppression of the sawtooth activity, probably due to the effect of pellets on the current profile. When the sawtooth is completely suppressed, central impurity accumulation takes place which might lead to a confinement deterioration or to a major disruption. If the sawtooth period is only increased, but crashes are still present, this phenomenon can be avoided while reaching good performances as well. The role of impurities in the evolution of these discharges is investigated using the technique of impurity emission analysis by an impurity transport code.

2. Experimental set-up

FTU is a circular tokamak (R=0.93m ; a=0.3m) with a molybdenum toroidal limiter. Up to 8 pellets can be injected with a typical velocity of 1.3 km/s and a mass of the order of 10^{20} D atoms. Plasma electron density is measured by a five chord DCN interferometer, a two chord CO_2/HeNe interferometer and the Thomson scattering (TSC) system. The electron temperature profile is measured by an ECE interferometer, a fast ECE polychromator and by the TSC which can now provide a profile every 17 ms. The radiation losses are measured by a 16 channels bolometer array. Impurity lines are analysed by visible and UV spectrometers. The average value of the ion effective charge (Z_{eff}), is derived from the visible bremsstrahlung emission along a central chord.

In this paper we analyse the impurity transport in two discharges having I_p = 0.8 MA B_T = 7.1 T (12744) with 3 pellets injected and I_p = 1.2 MA B_T = 8.0 T (18598) with 5 pellets injected. The time evolution of the electron density, of the central electron temperature and of the central soft X-ray emission are shown in fig. 1 and fig. 2.

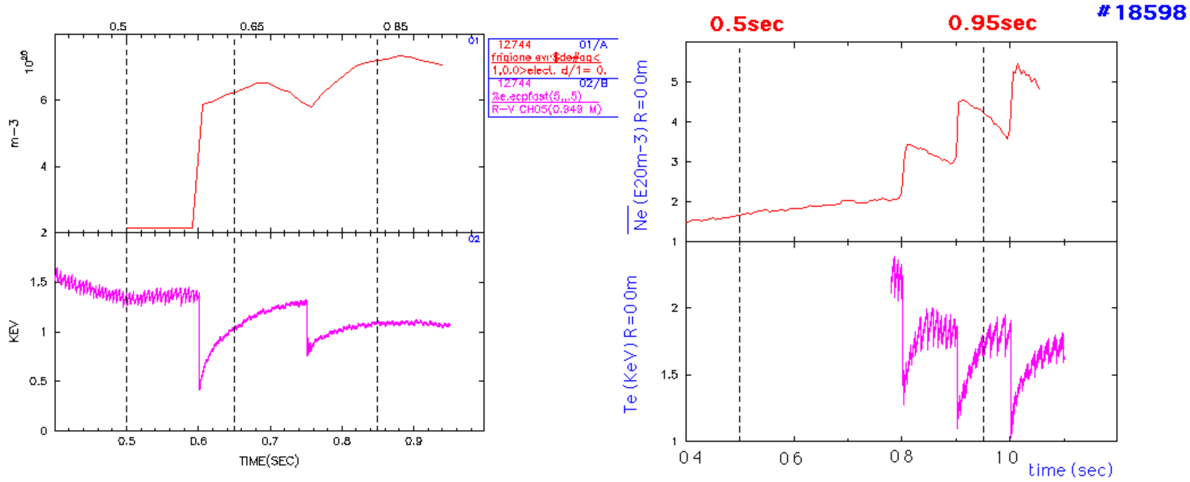

Fig. 1. Left: central electron density and central electron temperature of discharge 12744. Right: line averaged electron density and central electron temperature of discharge 18598. Vertical lines: times where simulations have been performed.

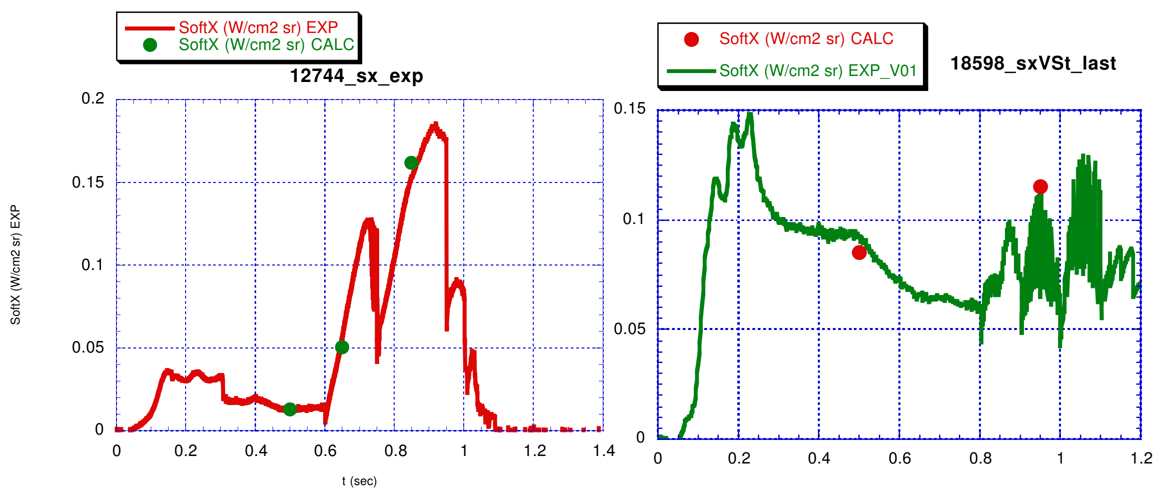

Fig. 2: soft X-ray emission (central chord). Left: discharge 12744. Right: discharge 18598. Dots: times where simulations have been performed.

3. Impurity emission analysis

The average Z_{eff} measured by visible Bremsstrahlung, the UV spectra obtained by a SPRED spectrometer, the radiated power and soft X-ray emission profiles (fig. 3) are simulated by an impurity transport code [2], assuming before injection, as usual for FTU [3], a diffusion coefficient $D_{\perp} = 0.5\ m^2 s^{-1}$ and a peaking factor S = aV(r)/2D, where V(a) = 5 m/s. The density and the relative importance of the intrinsic impurities is estimated by simulating the experimental UV line brightnesses and the global soft X-ray emission, and by comparison with the visible Bremsstrahlung Z_{eff} before injection (since afterwards the signal saturates).

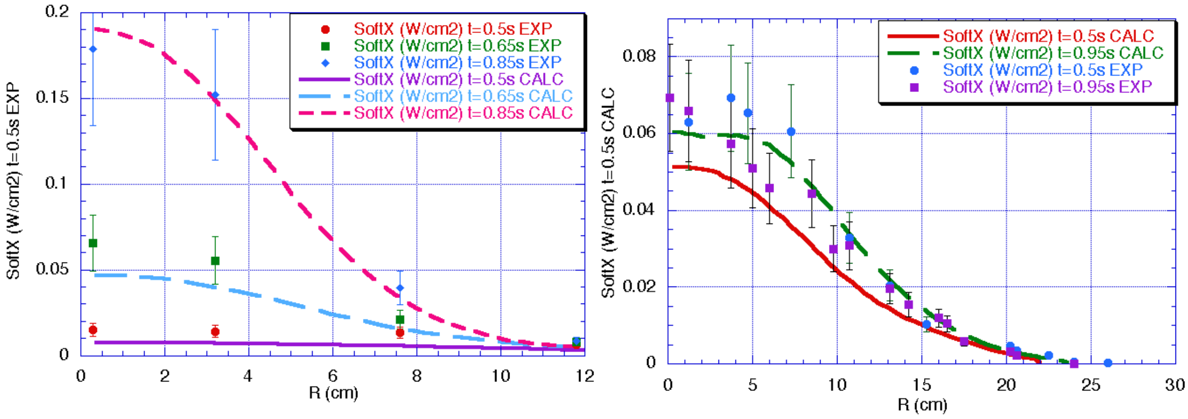

Fig. 3: soft X-ray emission profiles according to the simulation in the discharge 12744 (left) and 18598 (right)

If sawtooth activity is absent (discharge 12744), though the post-pellet electron temperature decreases, a strong increase of soft X-ray emission with no variation of profile width is found. A plasma disruption is then caused by the negative central balance between ohmic input and radiation losses which are enhanced by the high central electron density achieved.

On the contrary, a very clean plasma before injection together with a moderate sawtooth activity that persists after injection provide a good confinement phase, where soft X-ray emission intensity does not change, and the emission profile becomes broader (discharge 18598).

In the first discharge, the simulated impurity profiles after pellets are consistent with an impurity accumulation scenario, typical of a convective transport regime, but with an inward convection velocity in the plasma core (0<r<10 cm) two orders of magnitude higher than the one expected in a neoclassical regime (fig. 4). The impurity densities are one order of magnitude higher after pellet injection.

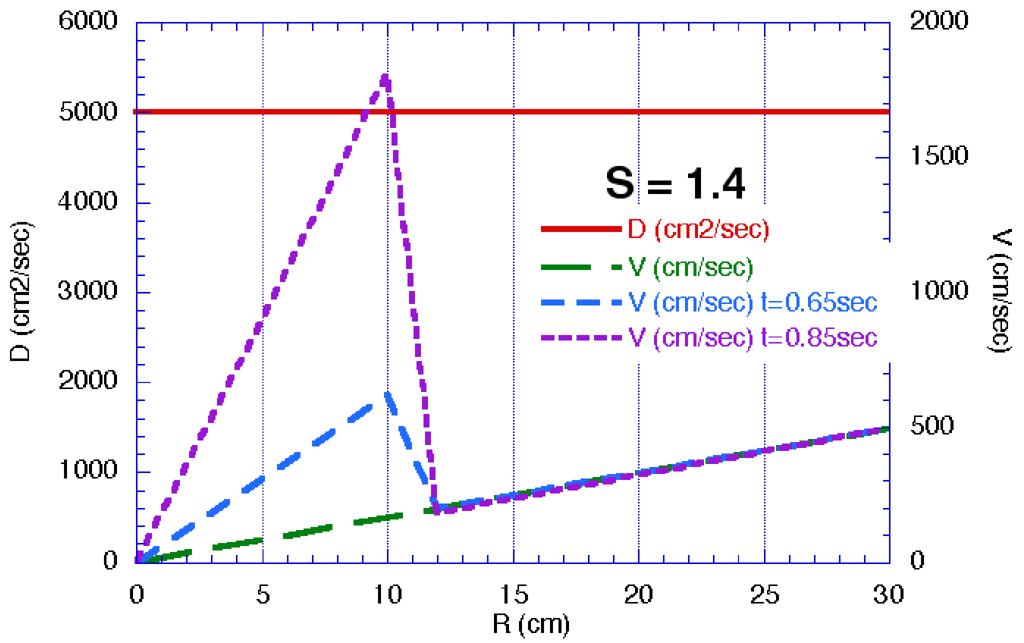

Fig. 4: perpendicular diffusion and inward convection velocity assumed to reproduce the discharge 12744.

In the second discharge, the impurity profiles before and after pellets are reproduced by the same diffusion parameters, and no disruption takes place. The impurity densities are almost constant after pellet injection.

Conclusion

In pellet injection experiments on FTU, a regime characterized by impurity accumulation and high inward convection, deleterious for the discharge, can be prevented by a moderate sawtooth activity and a reduced initial impurity content.

X-ray and UV spectroscopy together with an impurity transport code is a useful tool to understand the plasma behaviour in this kind of experiments.

References

1. D. Frigione et al., Proc.18th IAEA, Sorrento 2000, IAEA-CN-77/ICP/0

2. D. Pacella, M. Leigheb, M. Mattioli, Physica Scripta, 57 (1998) 265

3. M.J.May et al., Phys. Rev. E. Vol. 64, 036406 (Sept 2001)