Post-ablation evolution of the tungsten VUV/XUV spectra in JET

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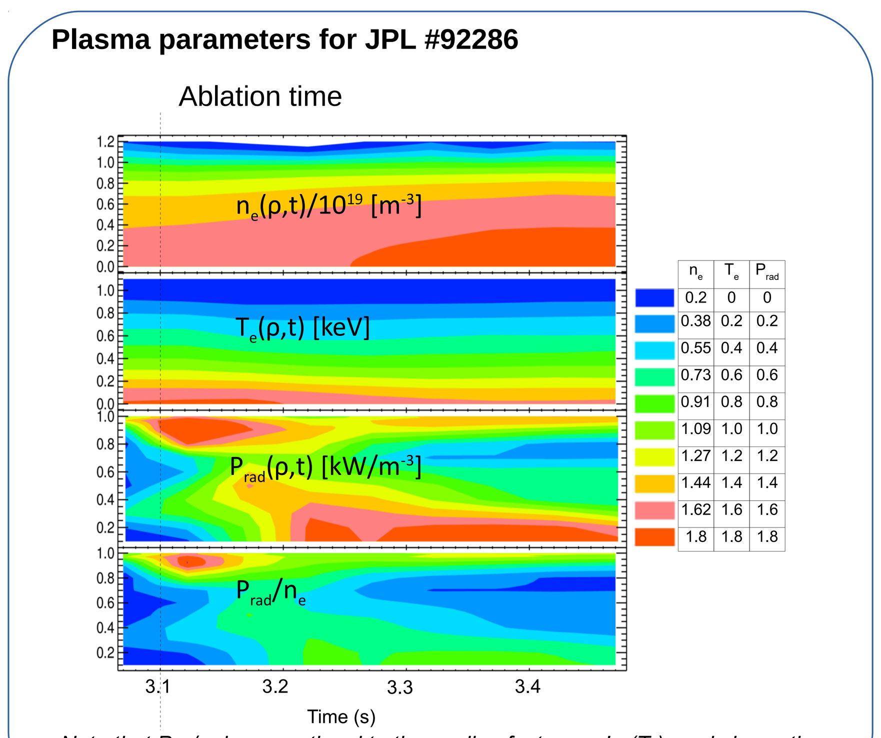
Introduction

We suggest that the introduction of tungsten into fusion plasmas significantly changes their behaviour due to considerable cooling of the pedestal. Study of this hypothesis depends on understanding both the transport of tungsten in the fusion plasma and its radiative properties.

Experiment overview

The presence of sawteeth can dominate the transport and introduce non-local T_e effects [1], so in this experiment tungsten is ablated into JET L-mode, low temperature (T_e < 2 keV), non-sawtoothing plasmas.

- Four JET pulses: #92284, #92285, #92286, #92293, ablation at 3.1 s in octant 6
- #92286 pulse data:
  - B = 3T, I = 1.55 MA at 3.1 s, 1.7 MA from 3.5 s.
  - NBI 1 MW, Z_{eff} ~1.3 (no visible change due to ablation)

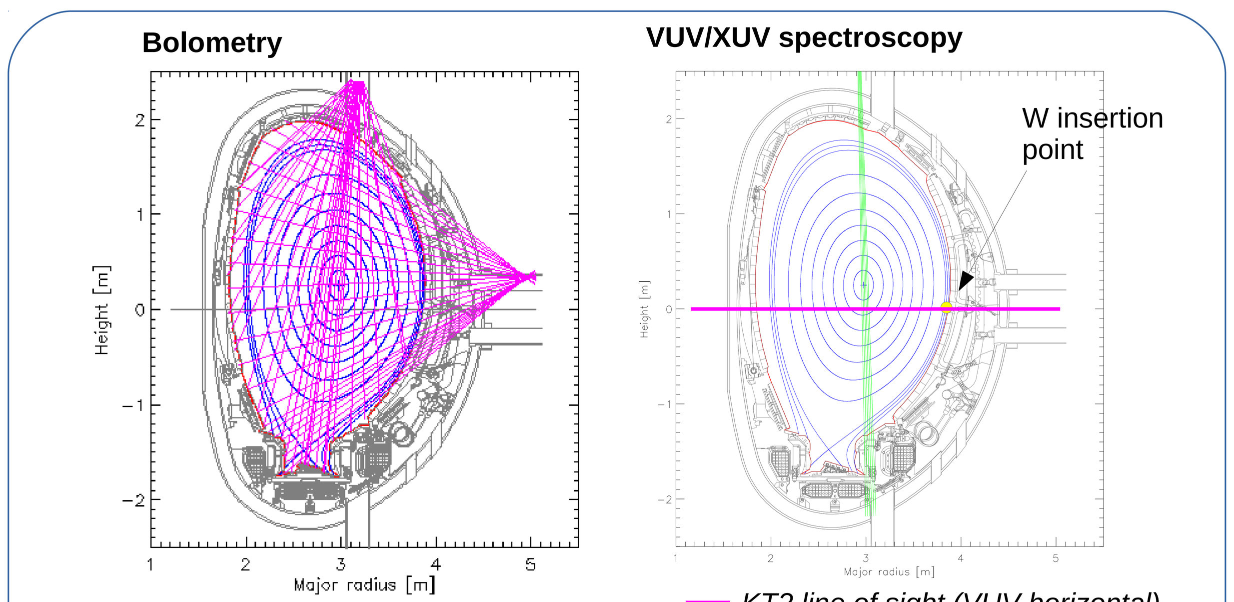


Note that P_{rad}/n_e is proportional to the cooling factor, $n_W L_W(T_e)$, and shows the penetration of tungsten to the plasma

Measurement setup

Four spectrometers used:

- Vertical l-o-s
  - 15–140 nm KT7/1
  - 14–45 nm KT7/2
  - 4–7 nm, KT7/3
- Horizontal l-o-s
  - 10–104 nm, KT2



Horizontal bolometer, all spectrometers and ablation insert in octant 6, vertical bolometer in octant 3

KT2 line of sight (VUV horizontal)

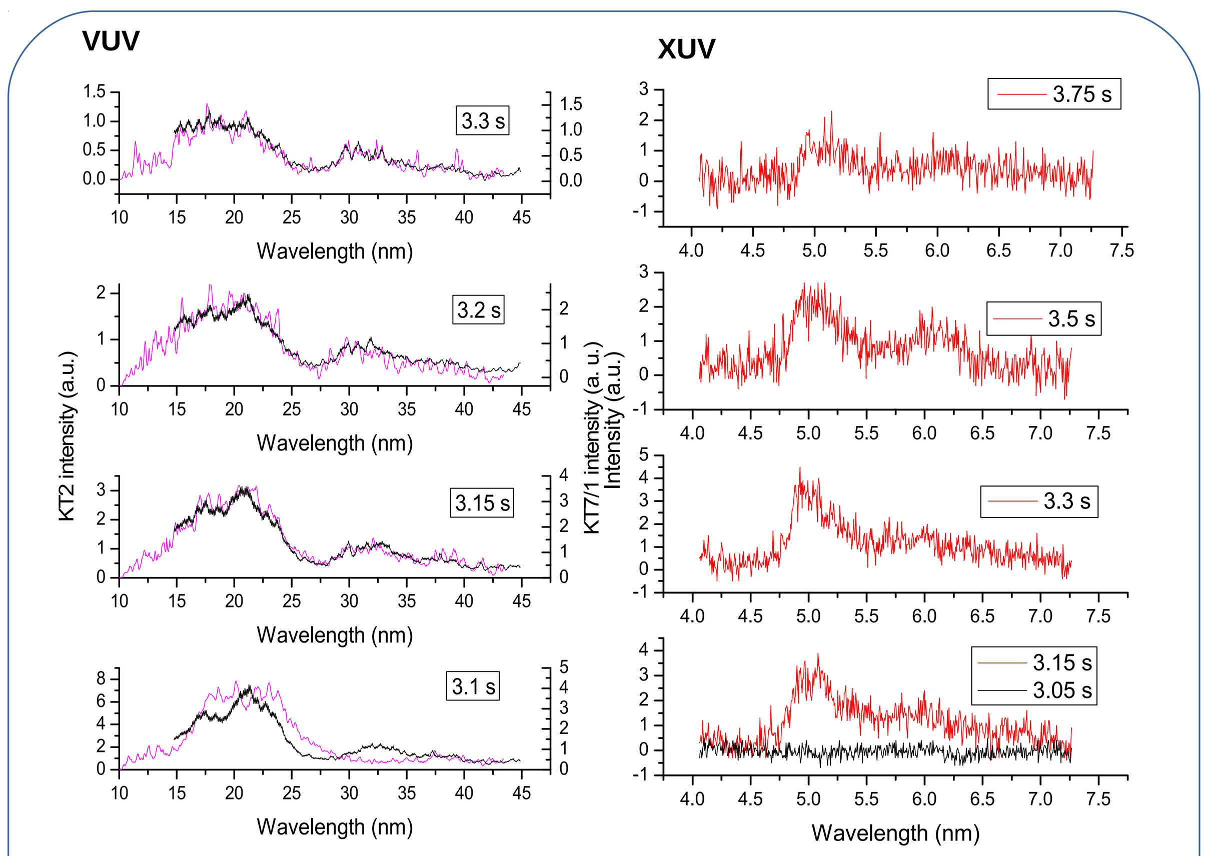
KT7 lines of sight (VUV and XUV vertical)

Results – spectroscopy

- Spectra preparation - average of five frames before ablation subtracted to show only ablated tungsten features

Evolution:

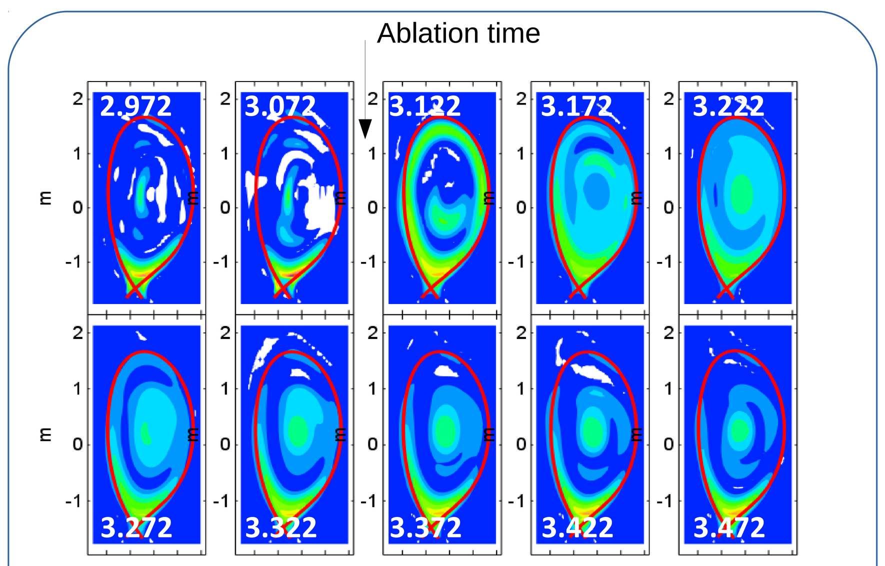
- VUV – maximum amplitude just after ablation, decay:
  - horizontal – time constant 160 ms
  - vertical – t_c 200 ms
- XUV features:
  - increase – first 100 ms
  - decay – t_c 470 ms



Temporal evolution of VUV and XUV spectra. Left – VUV spectra from vertical (black) and horizontal (magenta) line of sight. Wavelength dependent calibration sensitivities have been applied to each spectrometer. Right – XUV spectra from vertical line of sight. The sensitivity response is expected to be flat as a function of wavelength for this instrument.

Results – bolometry reconstruction

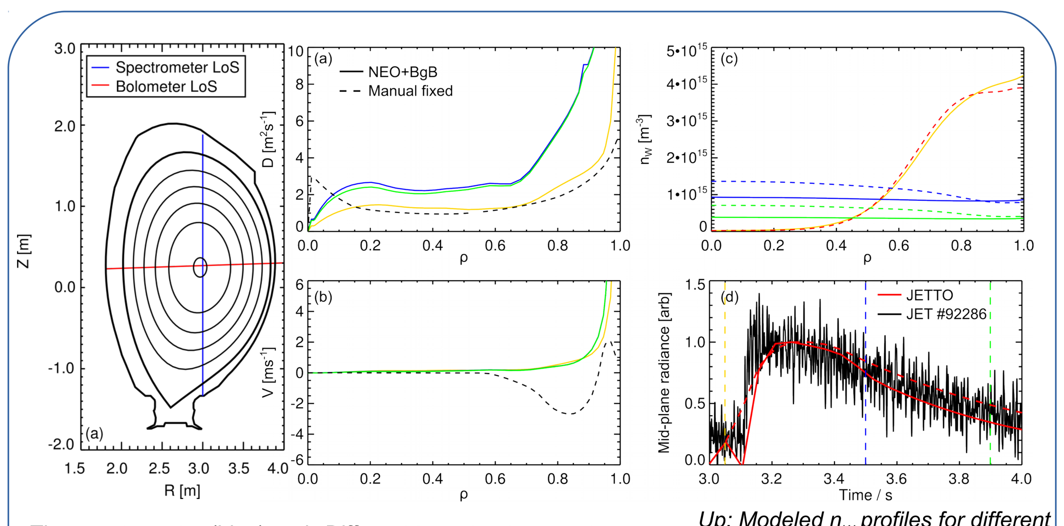
- Just after ablation radiation localised along the separatrix, originates from many species, esp. deuterium
- after ~100 ms (time of increase of the XUV feature) maximum radiation in the plasma core (apart from divertor) and then start of the decay, t_c ~500 ms



Reconstruction of the radiated power from the bolometer, averaged over 50 ms time frames. The ablation is at 3.1s

Modelling- overview

- Transport is modelled with neoclassical edge convection and turbulent core diffusion (resulting core n_W insensitive to model selection)
- Measurement of line-integrated radiation is used to constrain the transport model
- Synthetic modelling of the total radiated power and spectral radiance can be used to assess the W cooling function L_W



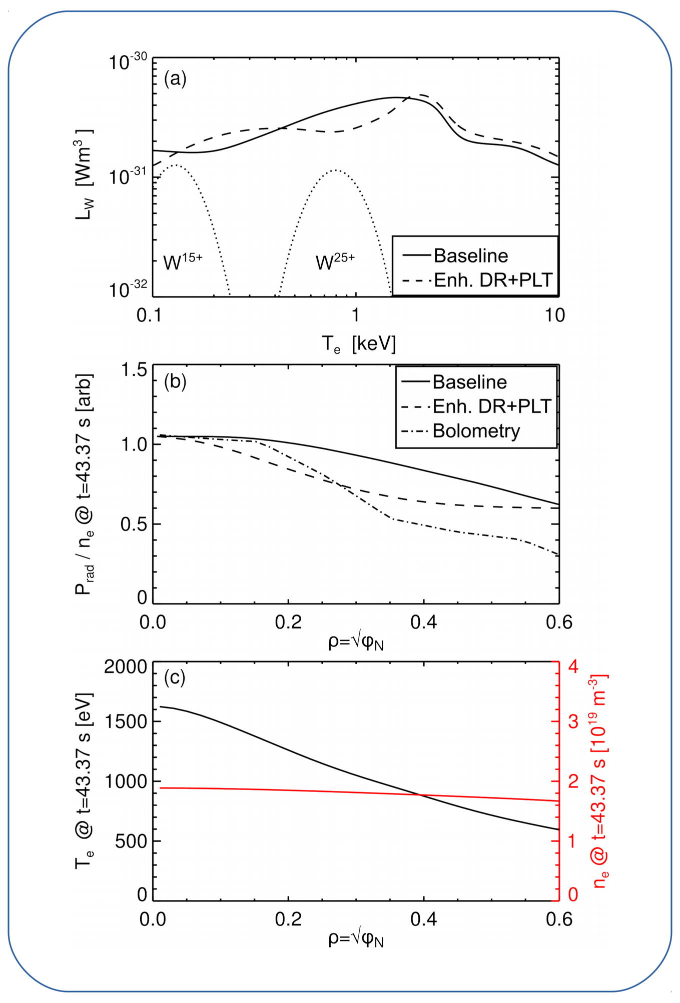
The spectrometer (blue) and bolometer (red) line-of-sight used for synthetic diagnostic measurements

Different tungsten transport coefficients used in JETTO simulations

Up: Modeled n_W profiles for different transport coefficients
Down: comparison of the synthetic and experiment radiation along the bolometer LoS

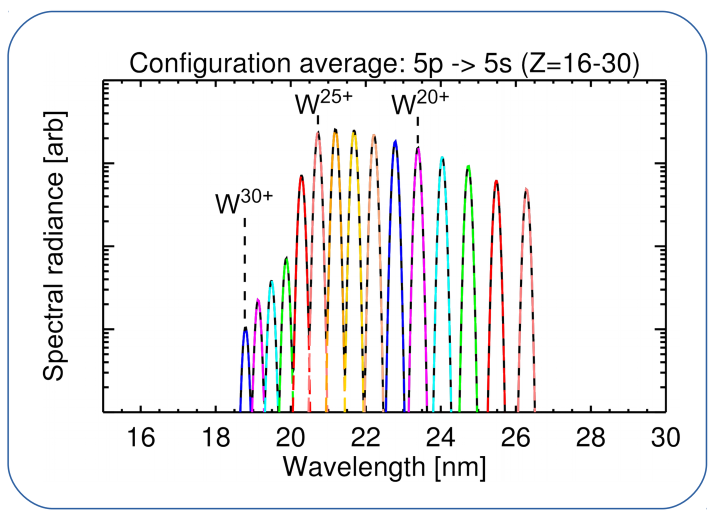
Radiation modelling

- W cooling function between 0.8 – 2 keV from baseline (Pütterich [2]) atomic data is smoothly increasing with temperature
- With updates to the total line power (PLT) coefficients [3] and an (over-)estimate of the dielectronic rate (DR) coefficient enhancements [4], the cooling function can feature structure within this temperature region
- By using inverted bolometry measurements to determine P_{rad}/n_e across the plasma radius, $L_W n_W$ can be assessed as a function of temperature
- n_W is modelled using JETTO [5] to understand the contribution of n_W to the P_{rad}/n_e measurement



Spectroscopic features – discussion

- XUV feature comes from $W^{27+ - 35+}$ [2]
- VUV features are emitted by $W^{16+ - 30+}$ ions and are sensitive to the configurations included in the collisional radiative population model and to the ionization balance
- Modelling of W ion emission between Z=23-26 has been calculated previously [2, 6]
- Work is ongoing to assess the contribution to the emission feature from $W^{18+ - 22+}$



Summary

- We have introduced tungsten by ablation in a L-mode low temperature (<2 keV) plasma without sawteeth and performed measurements and data treatment to obtain VUV and XUV spectra of ablated tungsten and reconstruction of the spatial distribution of the radiated power
- Modelling results of P_{rad}/n_e suggest that the current baseline set of ionisation, recombination, and line power coefficients do not recover the experimental results between T_e=0.6 - 1.3 keV
- An enhanced baseline data set better recovers the flatter radiation profile at lower temperature but work is ongoing to deliver new dielectronic rate coefficients
- Spectral fitting is an ongoing work for $W^{18+ - 22+}$ with data already available for $W^{23+ - 26+}$
- A finalised set of atomic data producing L_w should provide consistency over both the total radiation and VUV emission profile.

References

[1] E. R. Solano et al, 43rd EPS Conference on Plasma Physics, P2.005 (2016); [2] T. Pütterich et al, Plasma Physics and Controlled Fusion **50**, 085016 (2008); [3] S. Henderson et al., Plasma Physics and Controlled Fusion **59**, 055010 (2017); [4] N R Badnell et al, Phys. Rev. A, **85**, 052716 (2012); ; [5] G. Cenacchi and A. Taroni, Rapporto ENEA RT/TIB 88(5), (1988) [6] T. Pütterich et al, AIP Conf. Proc. **1545**, 132 (2013).

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