Effect of fuelling location on pedestal and ELMs in JET

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MOTIVATION

- With the JET ITER-like wall (W divertor, Be wall) strong fuelling is normally used to increase ELM frequency (and reduce ELM size) to avoid W contamination of the plasma. Strong fuelling often reduces confinement [1,2,3]. JET operation (in C and ILW) typically uses divertor fuelling.
- *Is the colder pedestal and lower confinement in ILW affected by fuelling location & pumping?*
- We report here on plasmas with lower puffing than usual. Some of them achieved steady good confinement. Additionally we describe transient W events observed and their effect on the pedestal.

EXPERIMENTAL SETUP AND RESULTS

- Vary poloidal fuelling location in JET ILW plasmas with 2 MA, 2.3 T, $n_e/n_{e,Greenwald}$~0.65, and 12-14 MW of NBI heating (shapes shown below).
- ELM frequency achieved for different fuelling levels varies with fuelling location and plasma shape (injection locations shown below).
- When sufficient f_{ELM} obtained, plasma can recover from transient W events & healthy steady state can be reached.
- In this series of pulses, when f_{ELM} < 40 Hz, sudden W influxes can lead to hollow T_e profiles or loss of H mode. In those cases f_{ELM} shown is measured 0.5 ms before initial W detection.
- For each fuelling location we study the lowest value at which W was controlled, marked with dashed circles in the figure. We only saw differences in the **blue** shape.

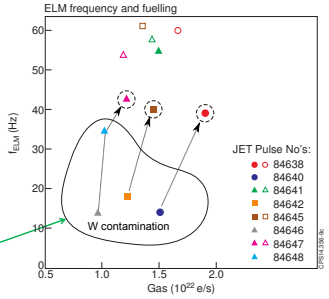
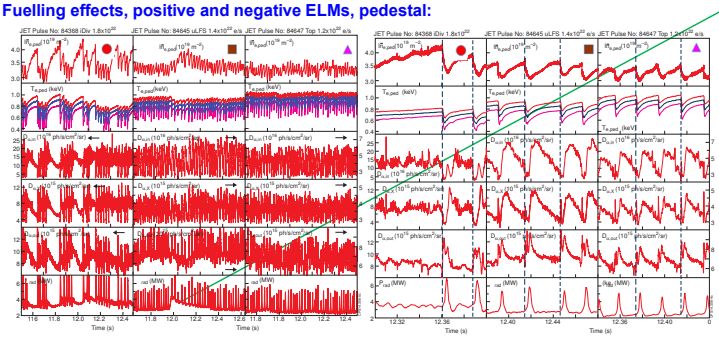


Fig. 2 ELM frequency for different fuelling levels.. Circles for Divertor fuelling, Squares for upperLFS, triangles for top fuelling. Solid symbols for **blue** shape, open symbols for **red** shape (see below)

Fuelling effects, positive and negative ELMs, pedestal:



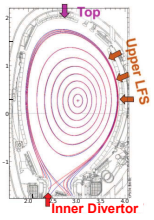
- Langmuir probe analysis shows that in all cases studied the inner strike line is partially detached, outer is attached.
- "Negative ELMs" are drops in D_α, instead of spikes. They are present when a dense (>10^{20} m-3) cold plasma (T_e<1-3 eV) is viewed: D_α is dominated by recombination [5]. When ELM deposits energy in plasma T_e rises and recombination rate drops, leading to reduced D_α. Later D_α may increase again as plasma cools back down, or as n_e and T_e rise (possibly elsewhere along the line of sight) in between ELM
- Divertor fuelling ● has negative ELMs at inner strike line and X-point.
- Upper LFS ■ fuelling has negative ELMs at inner strike, positive ELMs at X-point and outer strike
- Top fuelling ▲ has positive ELMs in all locations
- Situations with negative D_α ELMs and cooler pedestals (denser divertor) are correlated, in this experiment and in hybrid/baseline comparison.
- In most baseline JET ILW plasmas divertor fuelling is used and ELMs are negative at least at inner strike and X-point.

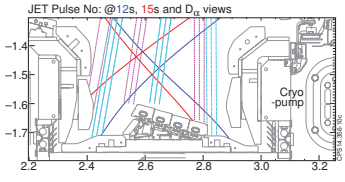
FUELLING LOCATIONS AND PLASMA SHAPES EXPLORED

Fuelling locations: inner divertor source (iDIV ●) is toroidally distributed, upper low field side (uLFS ■) and Top ▲ are toroidally localized.

Plasmas had 2 different shapes for 3 s each in each pulse (1st **blue**, then **red**), shown below

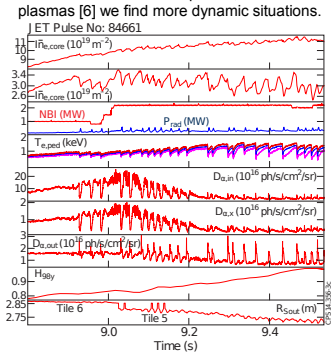
- **Blue**: with strike points near cryo-pump duct, better pumping and poorer diagnostics. Fuelling location made a difference to SOL and pedestal (see above). This configuration has H_{98}~ 0.8-0.9, medium density $n_{e,ped}$ ~ 3.3-4.2 10^{19} m^{-2} , hotter pedestals, $T_{e,ped}$ ~ 0.8-1. 0 keV.
- **Red**: conventional shape with higher triangularity, outer strike on solid W target, lower pumping and better diagnostic coverage. Fuelling location made little or no difference for this shape. H_{98}~0.75, density $n_{e,ped}$ ~ 4-5 10^{19} m^{-2}, pedestals colder $T_{e,ped}$ ~ 0.6 keV





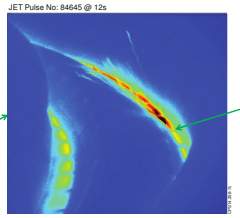
DYNAMIC EVOLUTION OF ELM BEHAVIOUR AND NEGATIVE ELMS

- In a different series of pulses, meant to study the difference between hybrid and baseline plasmas [6] we find more dynamic situations.



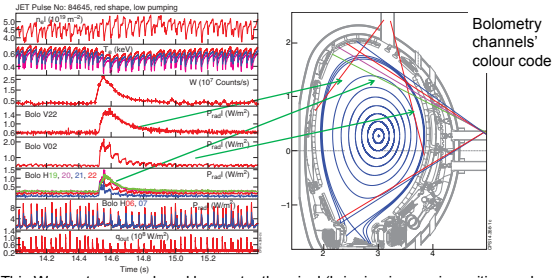
- as power increases inner strike and X-point ELMs change from negative to positive. At the same time pedestal temperatures increase.
- It is not clear yet if the X-point is hot because the pedestal is hot and the ELM burns through the cold plasma, or if a hot X-point enables $T_{e,ped}$ to rise further and produce a larger ELM.
- Correlation between hot X-point and hot pedestal observed to hold in many cases.
- Inner strike and X-point together

TRANSIENT W EVENTS AND THEIR CONSEQUENCES



- In various cases of the gas puff location study W events were detected, and we see their influence on pedestal and ELMs
- initial W event that triggered the radiation spike and drop in $T_{e,ped}$ in uLFS case shown earlier is captured by a spectroscopic camera as a flash of W I light (400.8 nm)

Different event, during low pumping **red** shape, with better outer strike diagnostics.



- This W event was produced by sawtooth arrival (bringing in core impurities and energetic ions), in the red shape, when IR measurements are available. Note low pumping and correspondingly lower $T_{e,ped}$.
- note reduction in ELM power density while pedestal radiation is high.
- Pedestal bolometry channels show transient increase in radiation. Pedestal density rises, pedestal temperature drops, ELM size decreases, ELM duration increases from 3 to 7 ms.
- Eventually ELMs flush the W out, pedestal returns to previous state.

SUMMARY

- Fuelling location affects SOL behaviour and achievable pedestal temperature before ELMs, but only when fuelling is sufficiently low and/or pumping sufficiently strong, and/or power high.
- The clearest difference is in the presence of "negative ELMs" at the X-point viewing line, more prevalent with divertor fuelling.
- There is a correlation between the presence of negative ELMs at the X-point and the temperature of the pedestal top. Negative ELMs correlate with cold pedestals, low confinement.
- Transient W events show direct effects of W on pedestal and ELMs: pedestal radiation increase leads to weaker ELMs, colder pedestal. The plasma may or may not recover from such events, depending on ELM frequency.

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