EUROfusion

High density, high confinement, power exhaust compatible H-mode regime in TCV and ASDEX Upgrade

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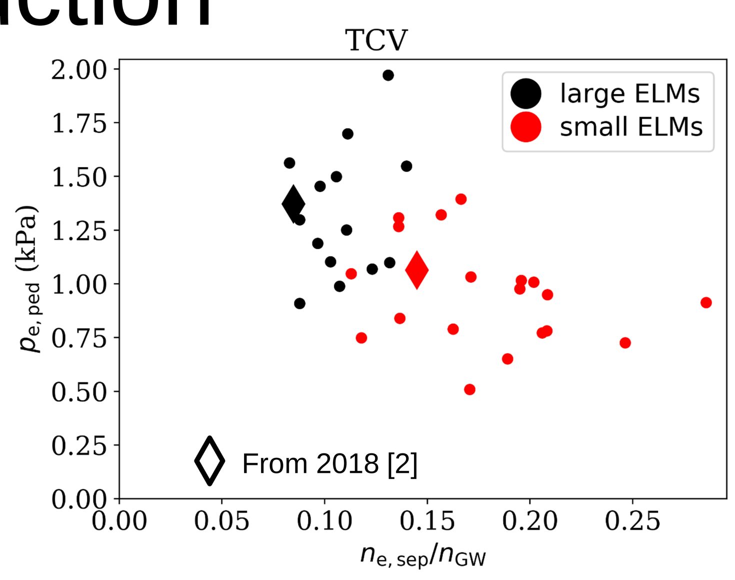
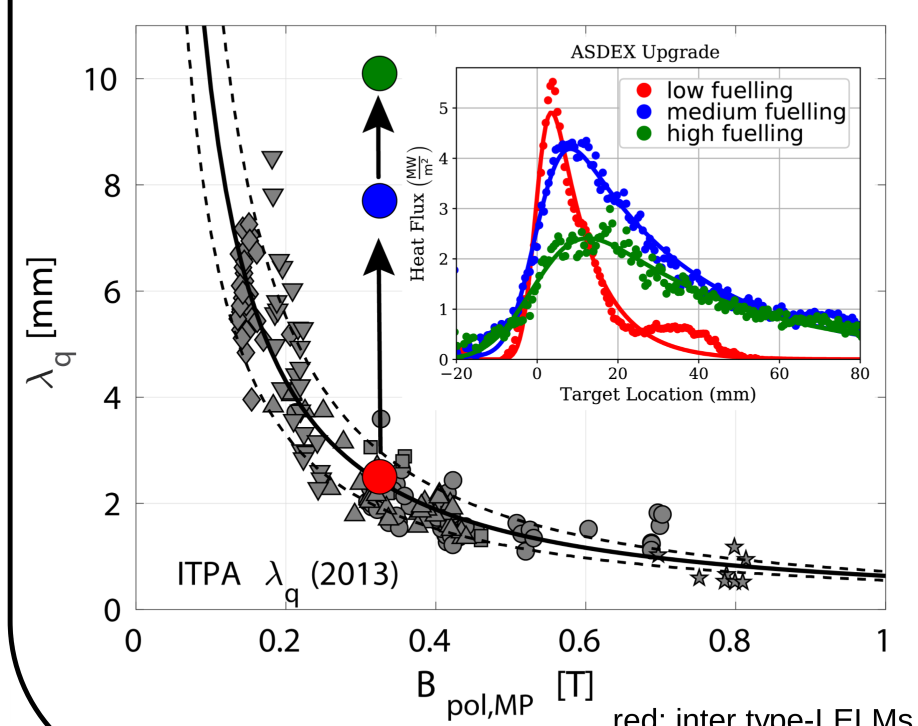
[7]See author list of ''LABIT, B. et al., Nucl. Fusion 59 (2019) 086020"

1.Introduction

- **High density H-mode regime without ELMs named quasi-continuous exhaust (QCE) regime, former small ELMs [1,2] or type-II ELMs [3,4].**
- **Accessed conditions:**
  - strong shaping (high triangularity and close-to-double-null).
  - high pressure/density at the pedestal bottom, close to the separatrix.



2.Scrape-off layer transport



red: inter type-I ELMs
blue and green: QCE

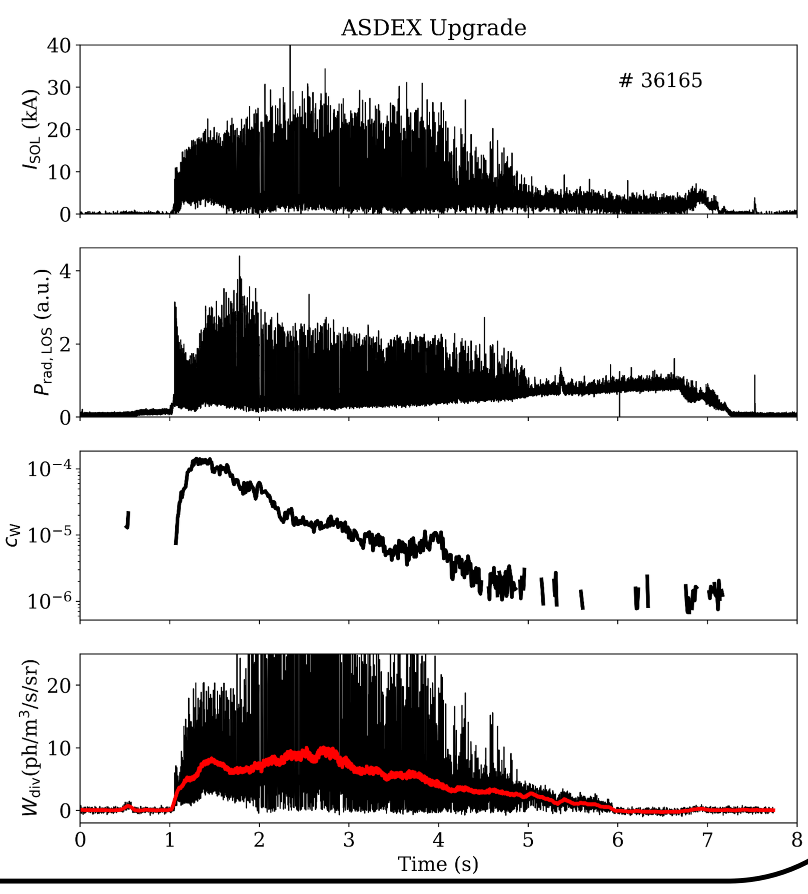
QCE regime characterized by enhanced filamentary transport.

- **Filaments occur with a high frequency and are observed to have a high radial propagation velocity [5].**
- **Density shoulder routinely observed [6].**
- **Power fall-off length broadens significantly in ASDEX Upgrade [7].**

3.Tungsten control

Low W core concentration and no impurity accumulation in the QCE regime.

- **With absence of ELMs the W source significantly reduces, QCE filaments do not cause significant W influx.**
- **Core concentration reduces in line with reduced second despite the missing ELM flushing contribution.**



4.Nitrogen seeding

Nitrogen seeding is used to alter radiation distribution and reduce the heat and particle flux onto the divertor target.

ASDEX Upgrade

- **Re-appearance of ELMs simultaneous to decrease in pedestal density and to increase in pedestal temperature [4].**

TCV

- **Low level of nitrogen does not show a change in density, stored energy and ELM behavior.**

Conclusions and Outlook

A regime with quasi-continuous exhaust in strongly shaped plasmas with high separatrix density at ASDEX Upgrade and TCV is investigated.

- **Hypothesis is that small ELMs are ballooning modes close to the separatrix.**
  - Modes modify the shape of the pedestal profile by increased transport until the stability boundary of type-I ELMs is not reached anymore.
  - Increased transport is manifested in filaments, a density shoulder and a wider power foot print in the divertor.
- **Integrating all studied elements led to a discharge with double feed-back in β_{pol} and T_{div} without any large ELMs, reaching a flat-top with $\beta_N = 2.1$ and $H_{98,y2} = 0.9$ with a partially detached divertor.**
- **Future studies will focus on:**
  - A better understanding of the underlying Physics mechanism and the extrapolation towards larger tokamaks, including an extrapolation of the observed broadening of the power fall-off length.
  - Reducing the influence of the filaments onto the divertor detachment by introducing the so called X-point radiator [8].
  - A potential route to avoid ELMs after the L-H transition either by N seeding already in the L-mode phase or by a start-up from L-mode to EDA H-mode reaching the QCE regime.

5.Increasing the operational window

In both machines the edge safety factor was successfully lowered to 3.7.

TCV

- **Achieved by reducing B_{tor} from -1.4 T to -1.16 T (I_p =-170 kA).**
- **Increasing plasma current leads to core MHD modes, not linked to the edge effects leading to the QCE.**

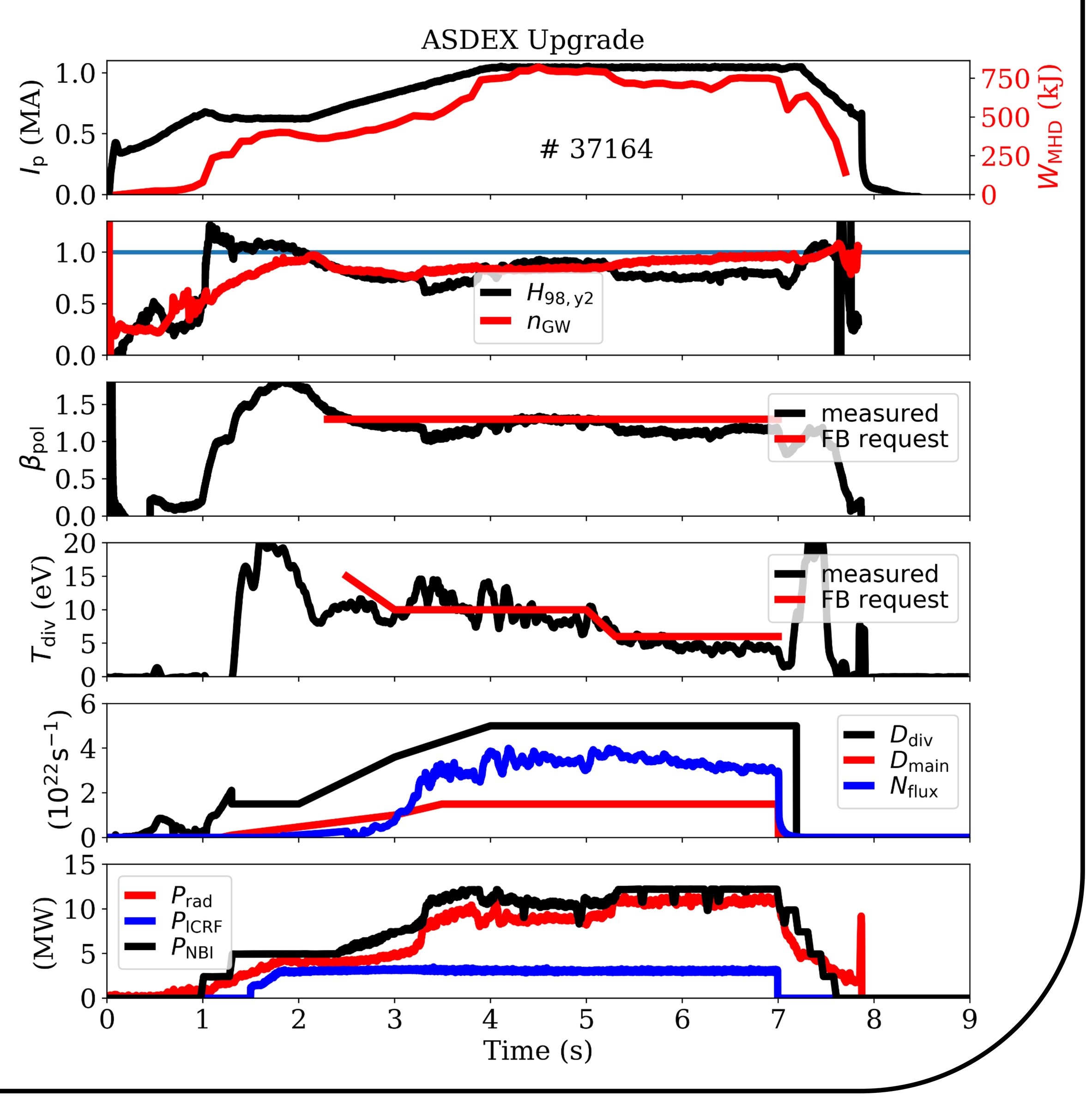
ASDEX Upgrade

- **Achieved at B_{tor} = -1.83 T (I_p = 940 kA) with central X3 ECRH.**
- **Increasing plasma current is limited by X3 absorption at elevated core density and by shaping coil current limits.**

6.Integrated scenario from start-up into partial detachment

For the first time double feed-back controlled discharge achieved using neutral beam injection for β_{pol} control and nitrogen seeding for divertor electron temperature (detachment state) control.

- **H-mode entry**
  - At elevated edge safety factor for easier access to the QCE regime.
  - A few low amplitude ELMs remain at the L-H transition.
  - Plasma current ramp to achieve $q_{95} = 4.6$.
- **Detachment**
  - Feed-back N seeding achieving two levels of T_{div}.
  - Filaments/ELMs lead to high ion saturation current, in between filaments detachment achieved.



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ASDEX Upgrade

EPFL SWISS PLASMA CENTER

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