Investigation of pellet-driven plasma perturbations for ELM triggering studies

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Motivation

ELMs caused transient power load on plasma facing components can be critically high for large size toroidal machines like ITER. Pellet ELM pacemaking has been found to be a promising mitigation technique. To predict the capability of the pellet ELM triggering in future tokamaks and to optimise the ELM pacemaking tool the understanding of the trigger mechanism is indispensable.

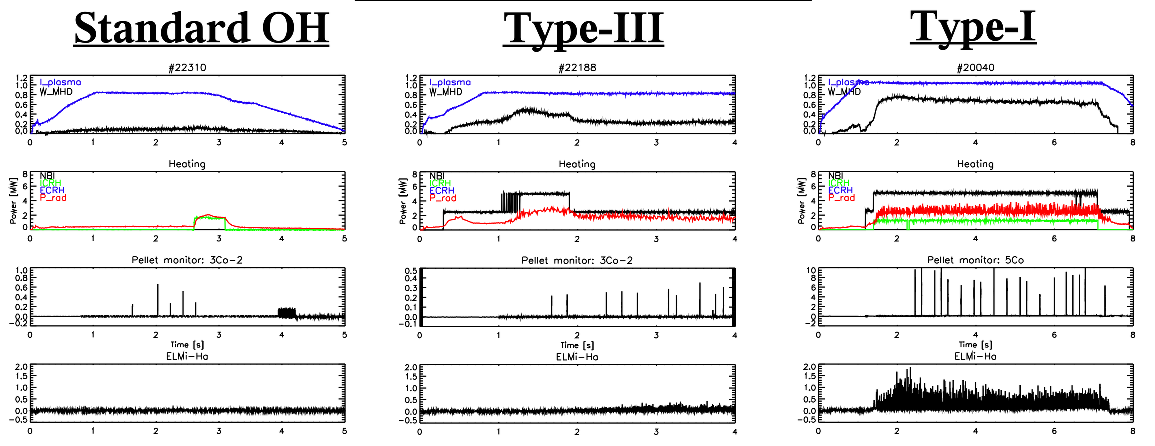
Pellet ELM triggering mechanism can be:

- the high pressure non-axisymmetric pellet cloud
- the cooling of the pedestal region causing a sudden increase of the pedestal plasma pressure gradient driving the plasma to the unstable region of the ballooning instability
- the strong MHD perturbation generated by the high beta pellet cloud

Aim is to investigate these pellet caused plasma perturbations in view of the understanding of the ELM triggering mechanism.

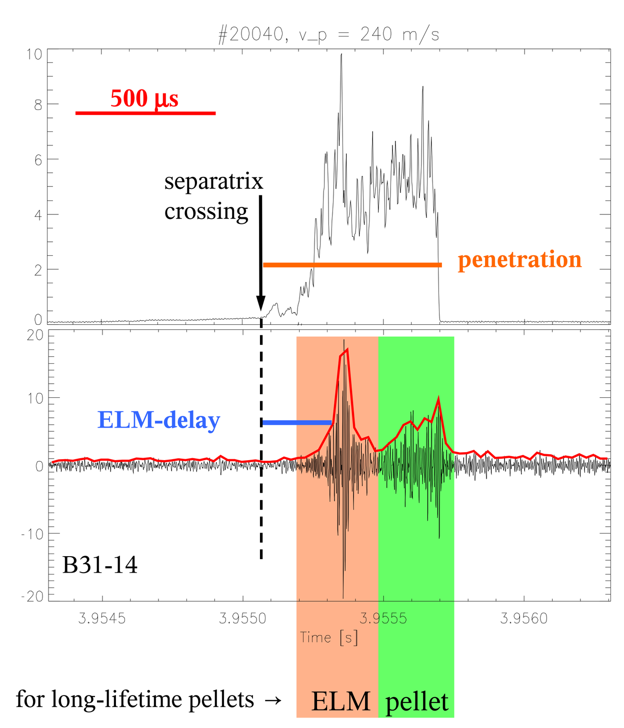
Scenarios

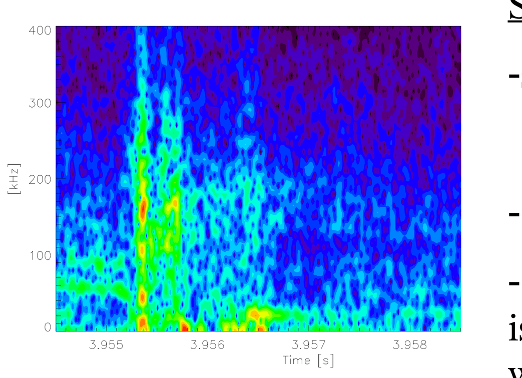
Standard OH | Type-III | Type-I

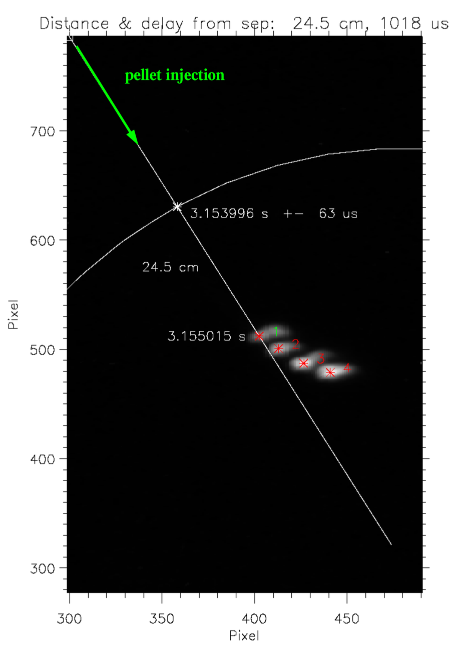


Experimental setup

Processing of the pickup coil signals







Pellet localization (space, time):

- fast CCD cameras + spatial calibration

→ def: **penetration = distance from separatrix**

Pickup coil signal analysis:

- eliminate LF component by moving-box average (5µs)

-calculate the envelope of the remaining HF component

(25µs box)

- **assume: envelope ~ MHD perturbation**

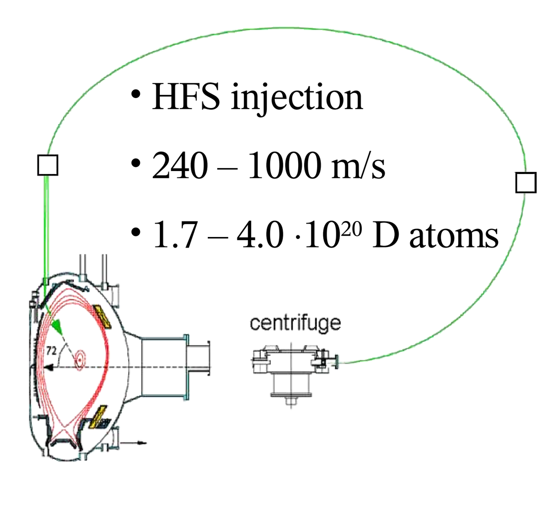
Spectral analysis:

-short time Fourier transform (STFT) with Gauss window

- Morlet wavelet scalograms

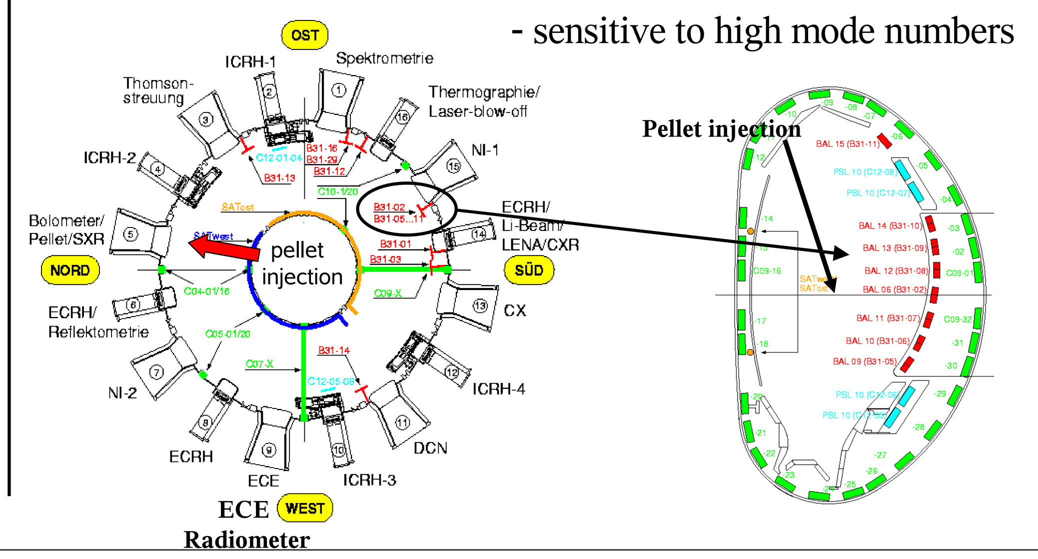
- Toroidal mode number determination is based on the phase of continuous wavelet transform

The centrifuge pellet injector



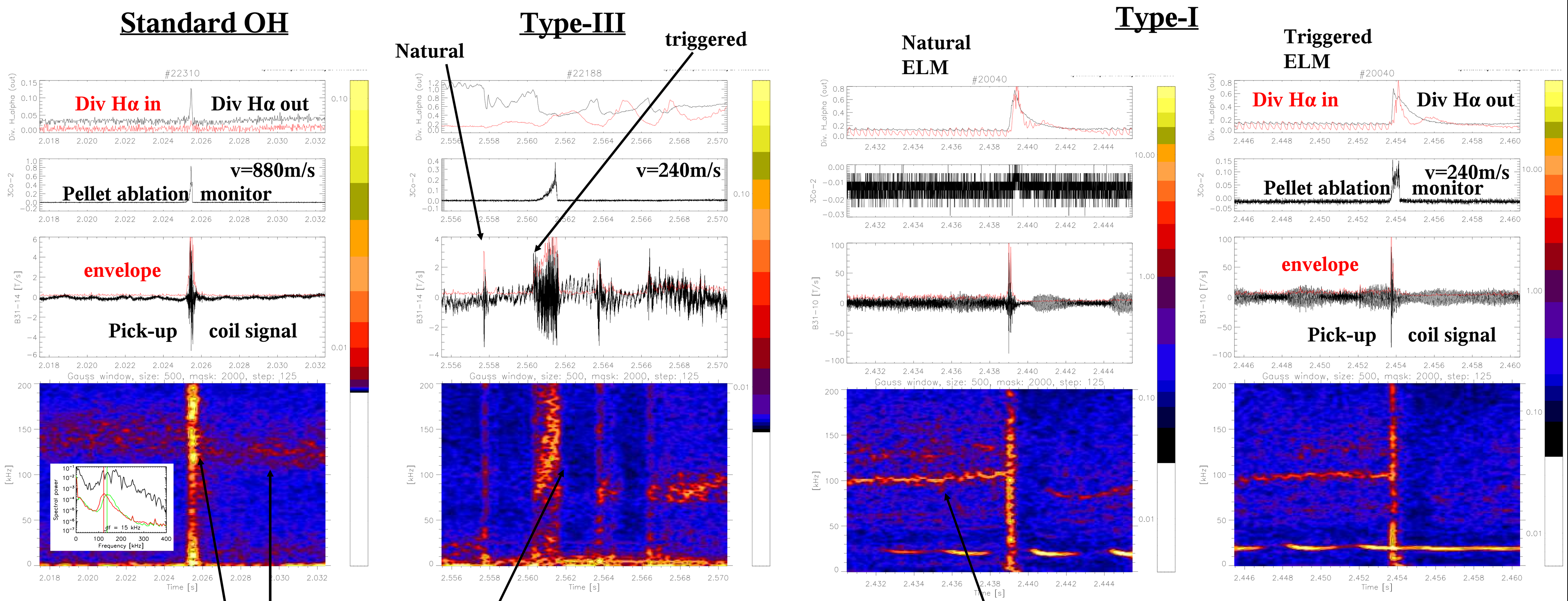
The pickup coil system

- 2 MHz sampling
- close to plasma
- sensitive to high mode numbers



Analysis of pick-up coil signals

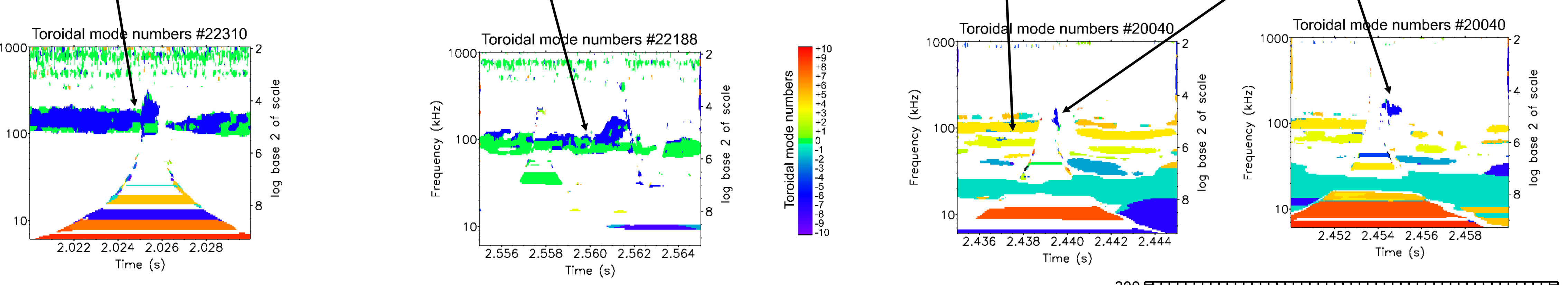
Standard OH | Type-III | Type-I

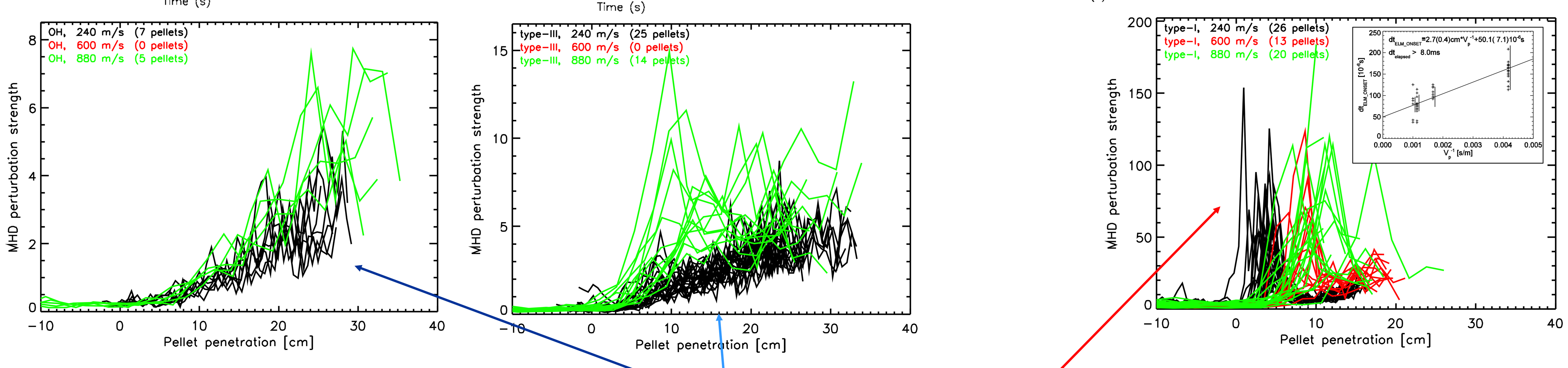


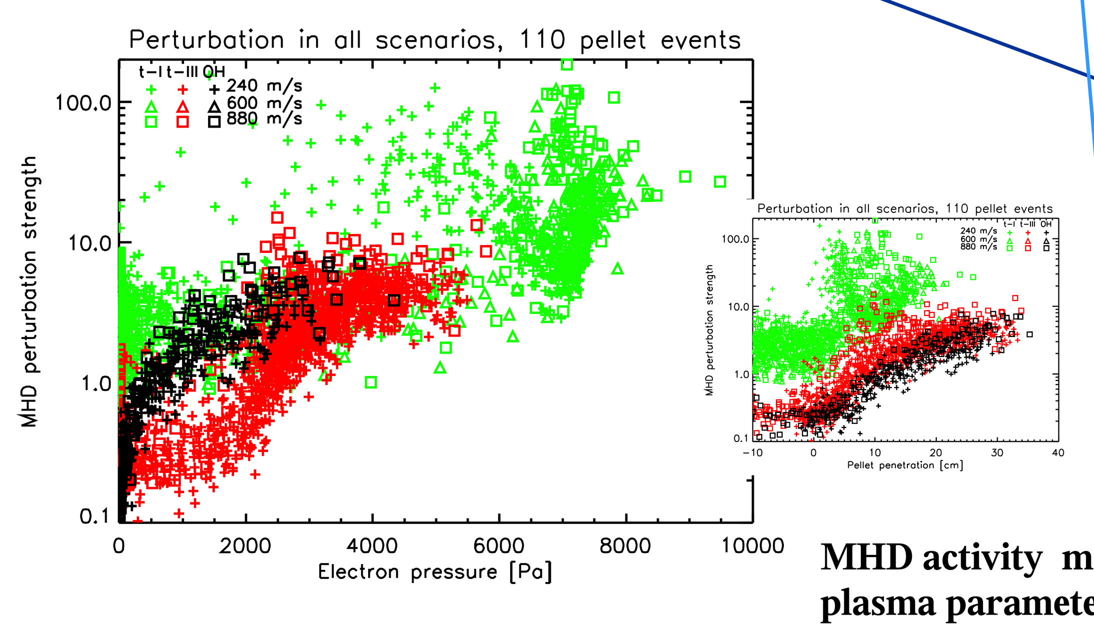
Ohmic case:
TAE: frequency is reduced by fuelling
amplitude enhanced by the polarised pellet cloud
Toroidal mode number n=-6
(ion diamagnetic drift dir.?)

Type-III case:
frequency chirp during pellet ablation
more resembles to ohmic?

Type-I case:
washboard modes: n=3,4
(electron diamagnetic drift dir.)
the same mode as in ohmic n=-6, but only for short time after the ELM termination
which is extended during pellet ablation







MHD activity magnitude during pellet ablation:

ELM-free ohmic plasma: the induced MHD perturbation rises gradually with pellet penetration independently of the pellet velocity

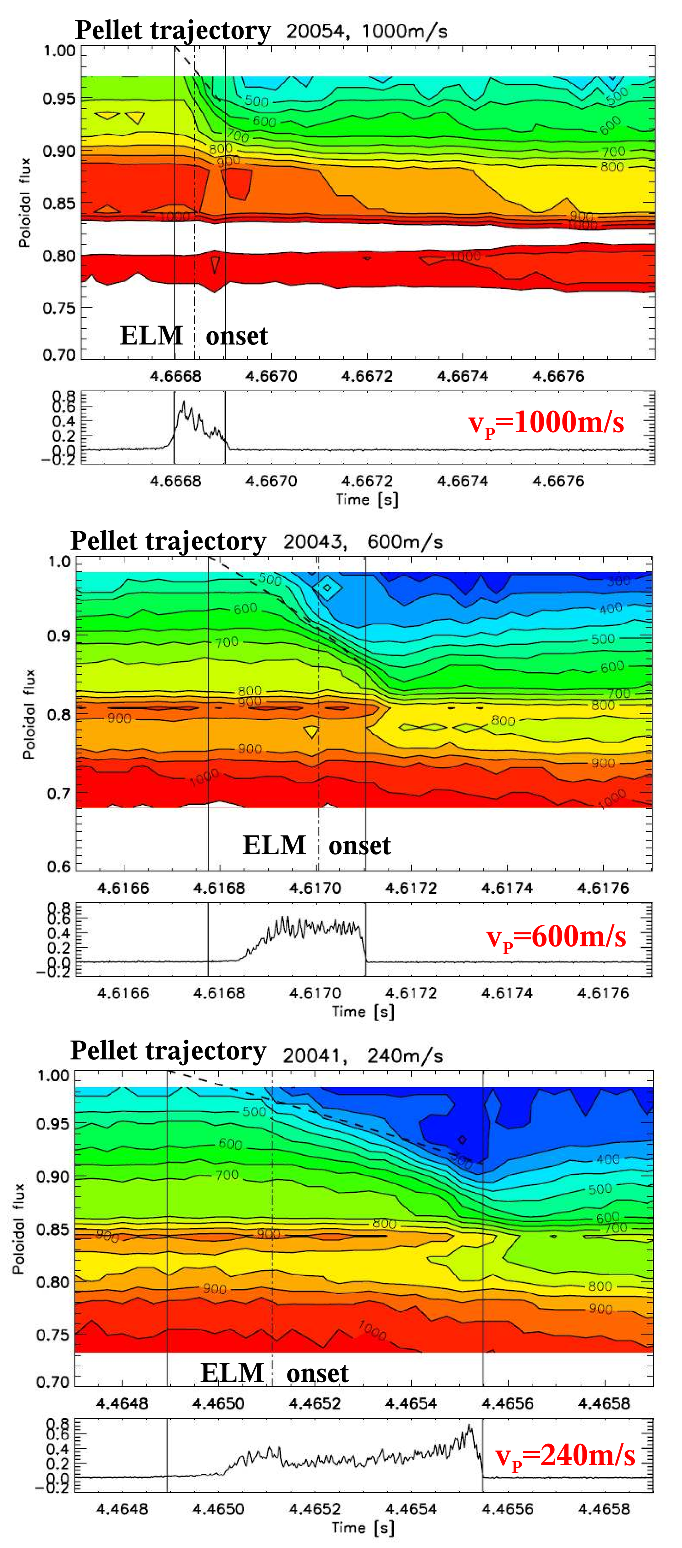
type-I ELMy H-mode: an additional explosive growth after the pellet has reached a certain position in the H-mode pedestal triggering an ELM → pellet time of flight method allowed to determine the most probable location of the seed perturbation

type-III ELMy H-mode: more resembles to the ohmic case, the magnitude of ELM related MHD activity is usually smaller than that of the directly pellet driven

MHD activity magnitude probably depends on the plasma parameters but not on the pellet parameters

Cooling in type-I H-mode

Pellet caused local cooling is homogeneously distributed on the magnetic surface on a few 10µs timescale because the fast electron cooling wave travels with electron thermal speed (10^7m/s).
The local cooling appears on fast ECE electron temperature measurement located toroidally 90° from the location of the pellet injection on a few 10µs timescale.



Pellet caused cooling

appears immediately after the pellet reached the according magnetic surface

causing remarkable temperature drop on a short timescale

the cooling front moves together with the pellet for all pellet velocities.

The pellet plasma cooling lasts until the pellet is completely ablated and the plasma starts to recover but on a ms timescale.

The relative temperature drop is in the range of few 10% seems to depend on the pellet velocity.

The temperature decrease caused by the triggered ELM is slower than direct pellet one, therefore they can be discriminated.

Conclusions

The ablating pellet intensifies the inter-pellet TAE mode in ohmic discharges.

For type-I ELMy H-mode the inter ELM washboard mode dominates the magnetic spectra at high frequencies and the direct pellet driven mode can be detected only after the termination of the ELM

The type-III ELMy H-mode more resembles to the ohmic case than to the type-I.

The pellet caused cooling appears immediately after the pellet reached the according magnetic surface causing remarkable temperature drop on a short timescale and the cooling front moves together with the pellet.

But ELM triggering mechanism is still an open question.

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