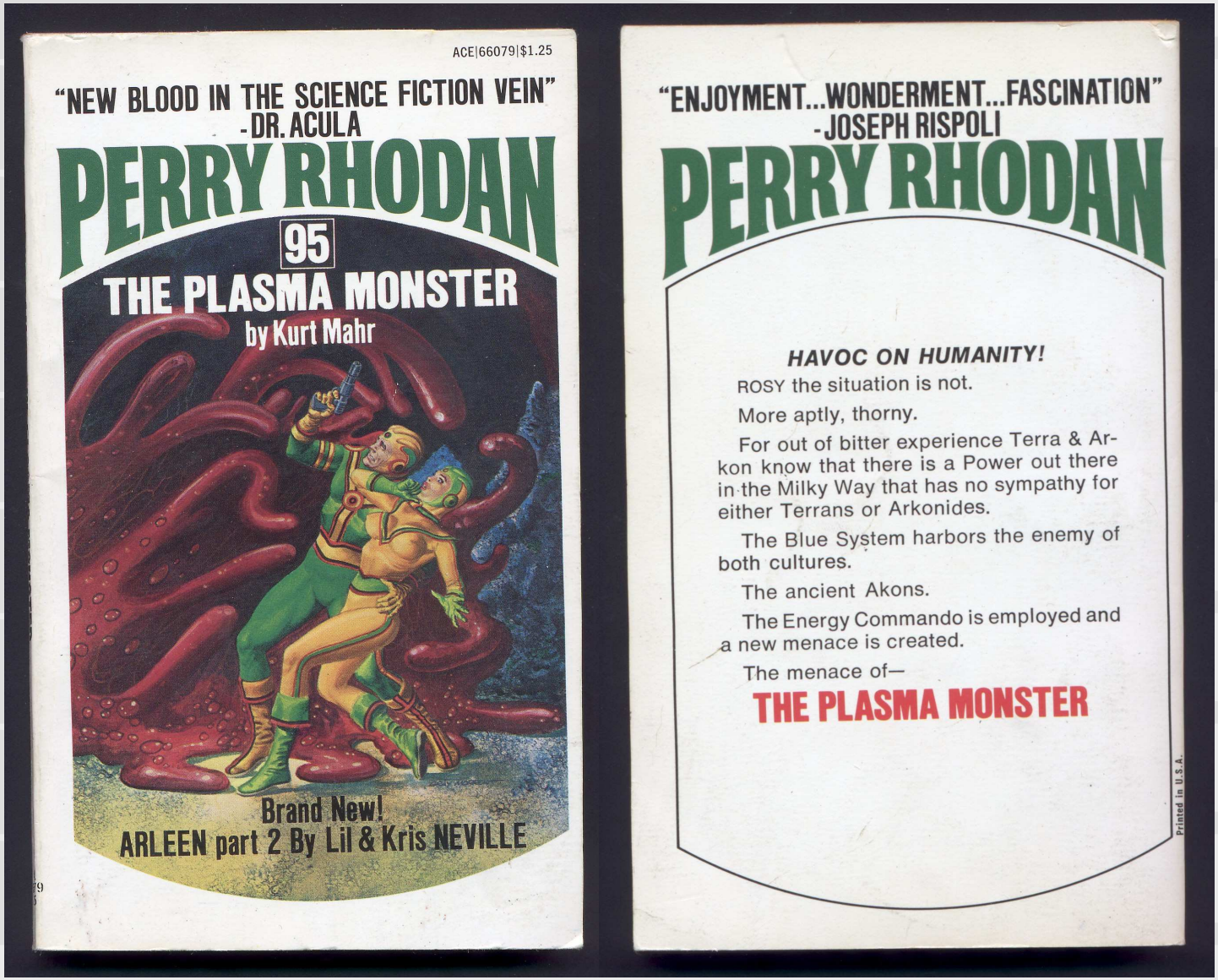
Turbulence in high density H-mode plasmas



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Wendelstein 7-AS

RISØ

Turbulence in high density H-mode plasmas

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1. W7-AS and the density fluctuation diagnostic
2. The high density high confinement (HDH) mode
3. Turbulence in the HDH-mode

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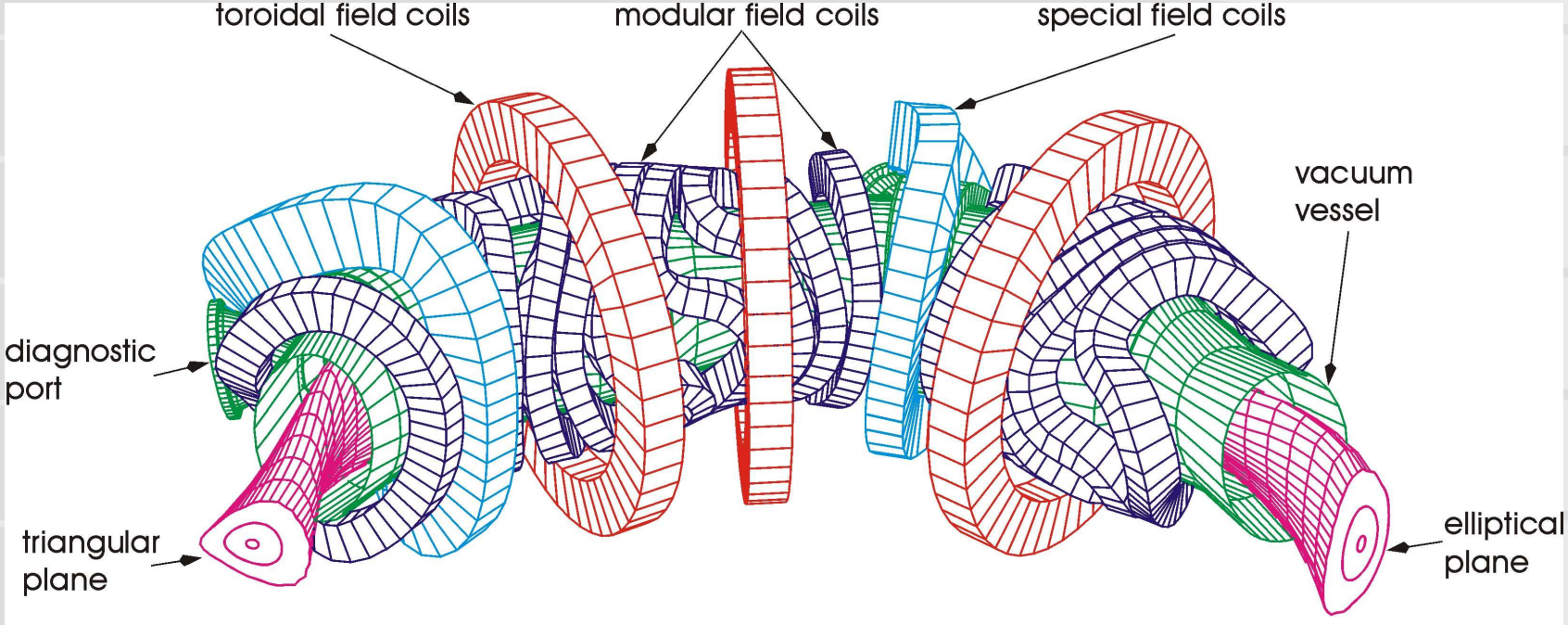
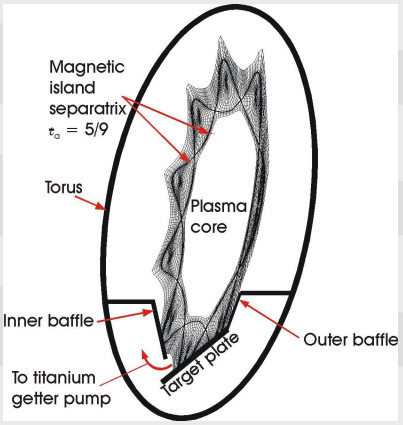
Workshop on turbulence and anomalous transport, 6-8 May 2002, Risø, Denmark

The Wendelstein 7-AS (W7-AS) stellarator





Major radius R = 2 m

Minor radius a ≤ 16 cm

$B_\varphi \leq 2.5$ T

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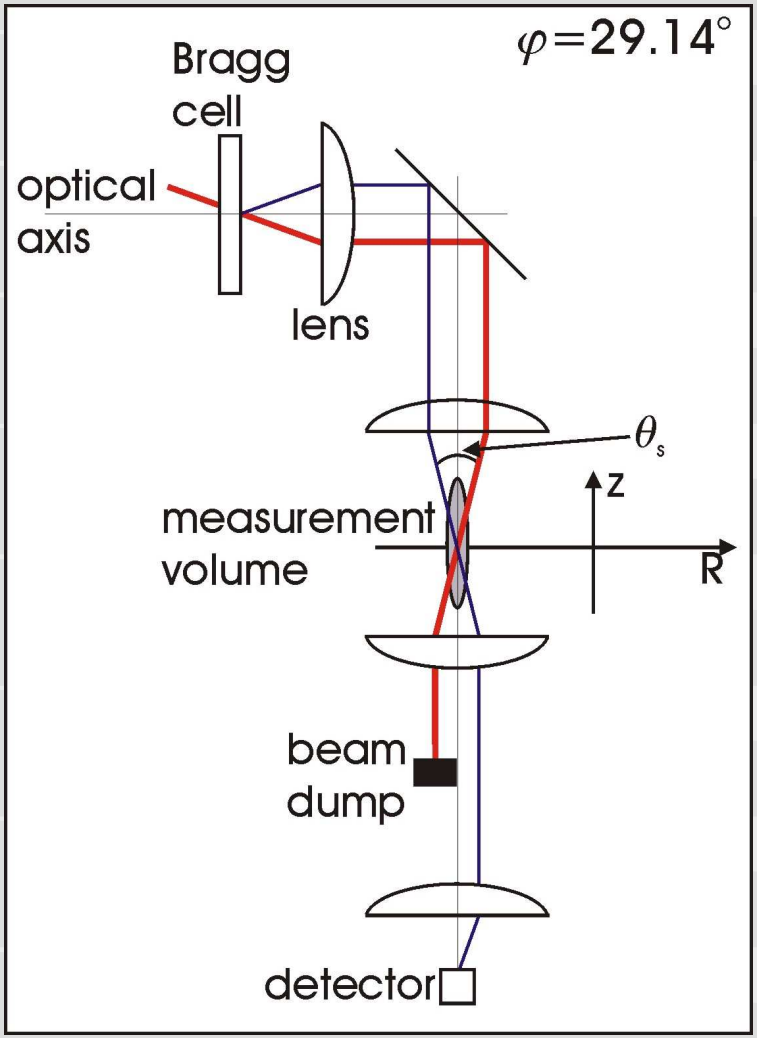
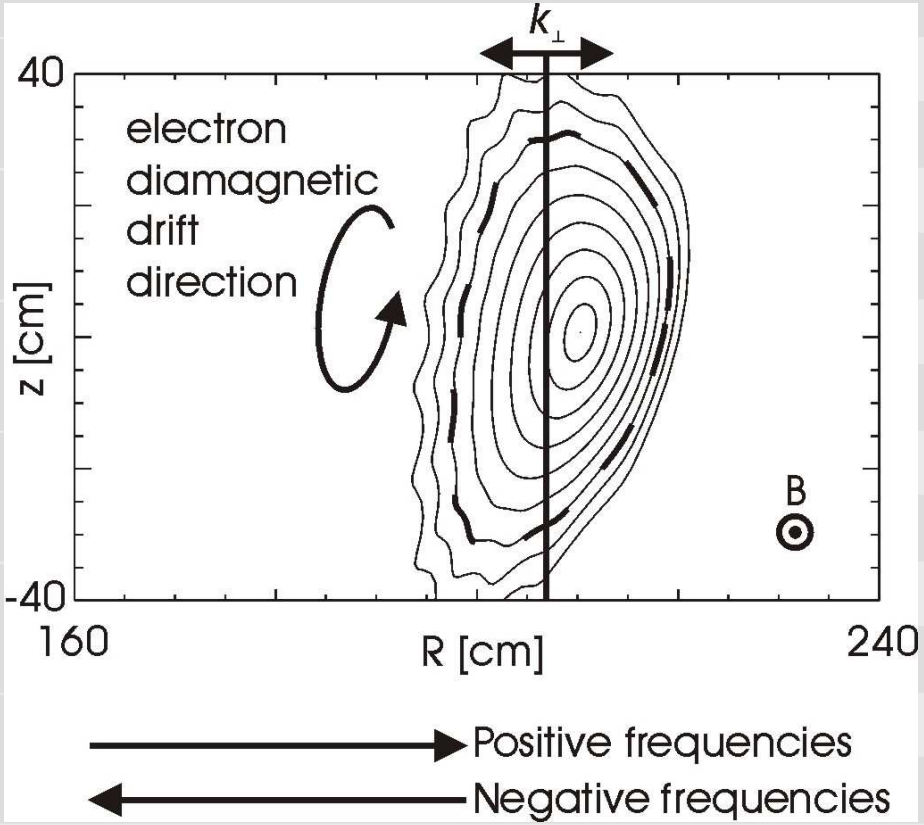
The density fluctuation diagnostic



- Diagnostic installed on the Wendelstein 7-AS (W7-AS) stellarator
- Small angle collective scattering of infrared light (radiation source is a CO_2 laser)
- Heterodyne, dual volume system (only 1 volume shown for clarity)
- Wavenumber analysed here is 20 cm^{-1} (range is from 14 to 62 cm^{-1})
- M. Saffman et al., Rev. Sci. Instrum. 72 (2001) 2579

The density fluctuation diagnostic



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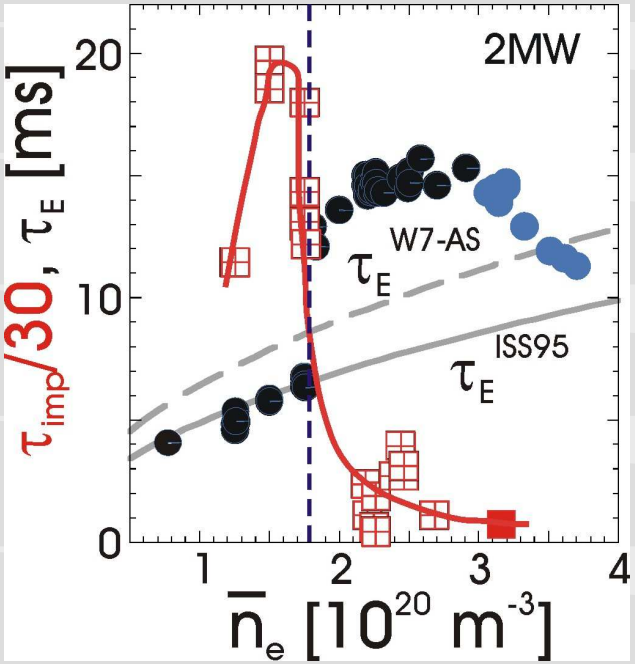
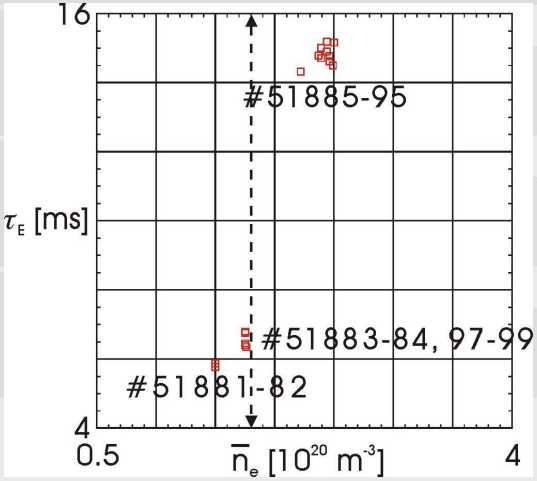
The high density high confinement (HDH) mode





Main characteristics of the HDH-mode compared to the normal confinement (NC) mode:

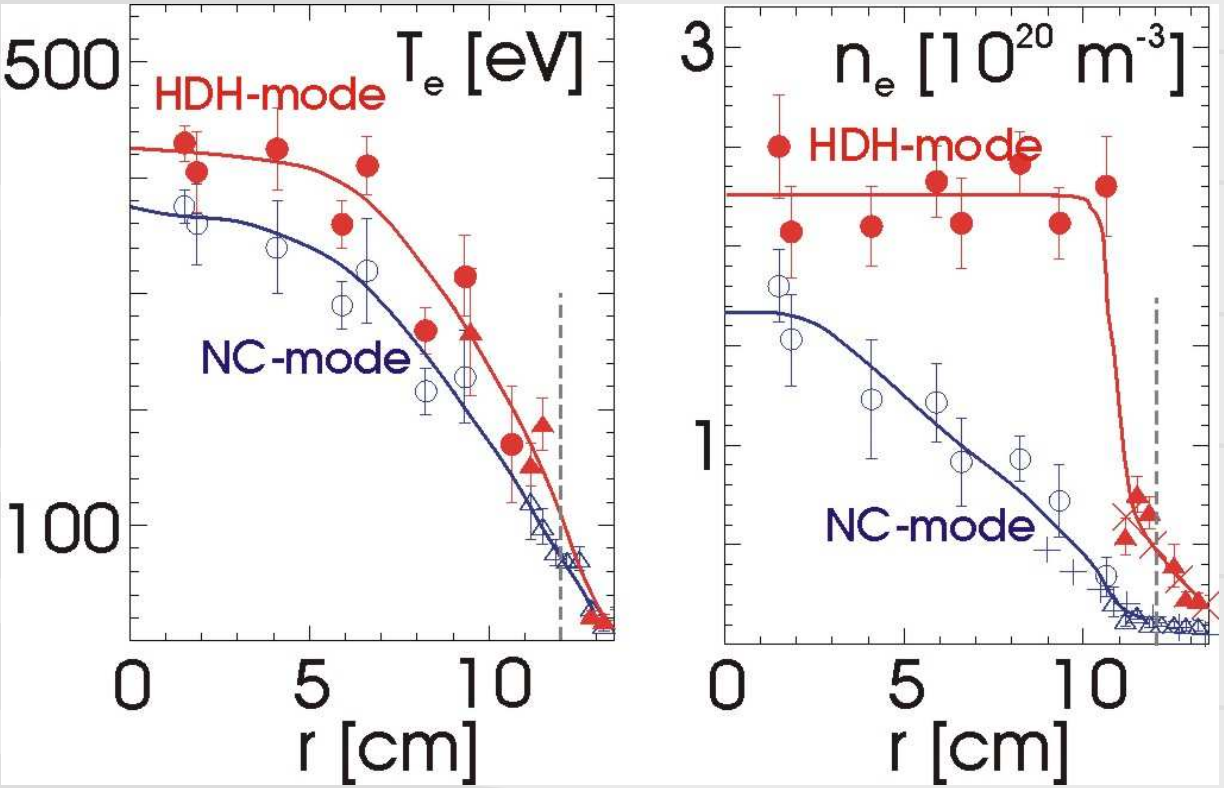
- Increased τ_E
- Decreased τ_{imp}
- Enhanced D_α-emission, cf. the Alcator C-Mod enhanced D_α (EDA) H-mode
- Radiation from the edge
- No ELMy activity

The above features enable the attainment of high power, high density, steady-state operation

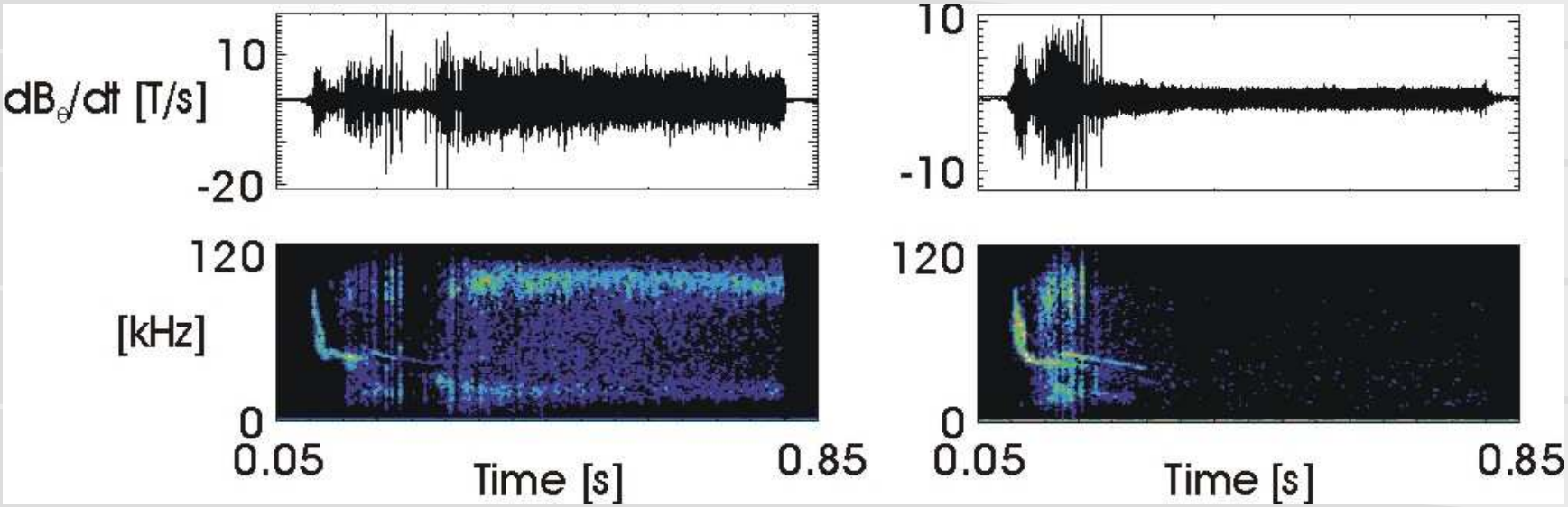
The high density high confinement (HDH) mode

Associated with the NC-→ HDH-mode transition, changes in the temperature and density profiles are observed:

- The temperature profile retains its shape, but increases somewhat in magnitude
- The density profile develops from having a constant gradient to a flat central profile accompanied by an extremely steep edge gradient



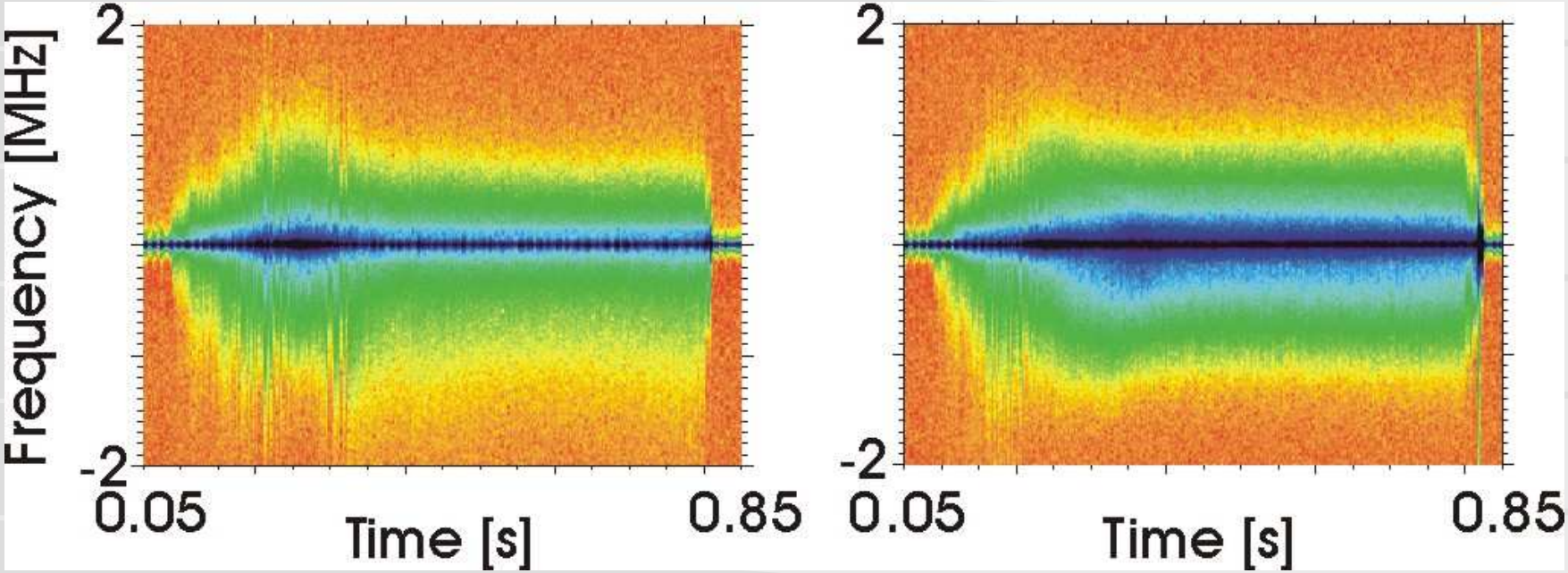
Magnetic fluctuations

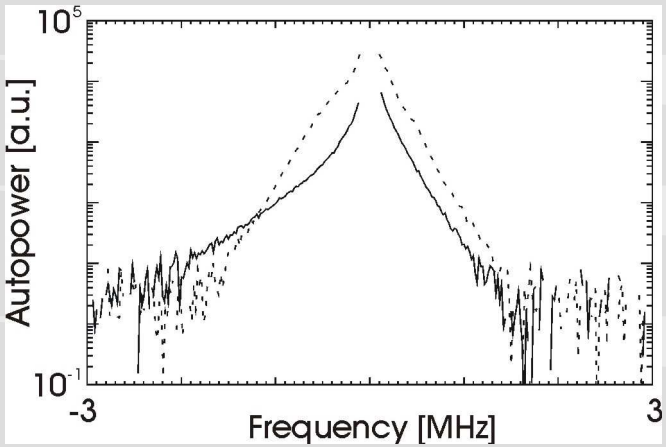


Fluctuations in the poloidal magnetic field are measured by Mirnov coil arrays placed around the vacuum vessel. The above figures show the time derivative (top row) and spectrogram (bottom row) for NC-mode (left) and HDH-mode (right) discharges:

- ELMs occur from 150 to 250 ms in both discharges
- Two features at 20 and 100 kHz rotating in the electron diamagnetic drift direction are observed in NC-mode
- Magnetic fluctuations almost disappear in the HDH-mode

Density fluctuations





- Top left: Spectrogram of density fluctuations in the NC-mode
- Top right: HDH-mode
- Left: Overlayed autopower spectra (500 to 600 ms), solid line NC-mode, dotted line HDH-mode

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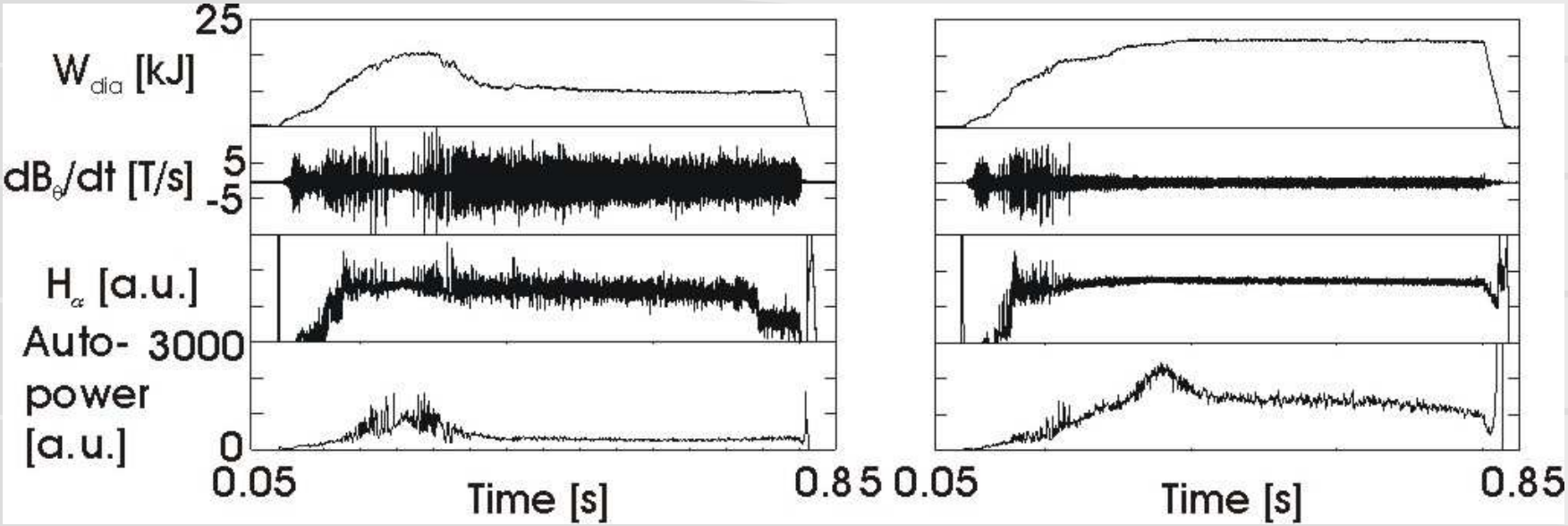
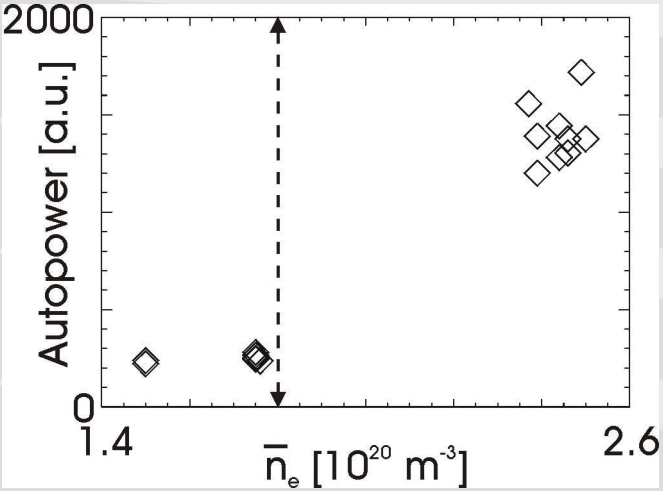
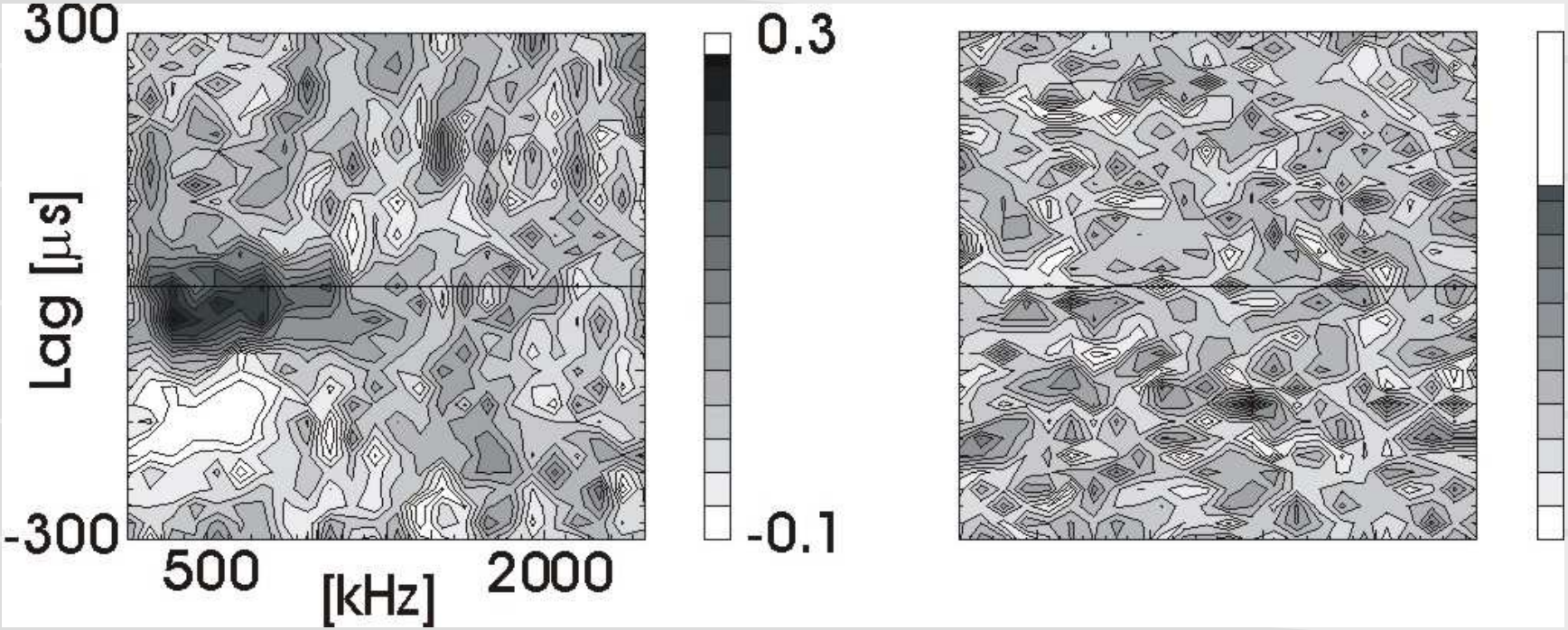
Stored energy and fluctuation waveforms





- Top left, top to bottom: Stored energy, magnetic fluctuations, H_α-light and density fluctuations integrated over all frequencies in NC-mode
- Top right: HDH-mode
- Left: Density fluctuation power versus line density

Magnetic and density fluctuation correlation

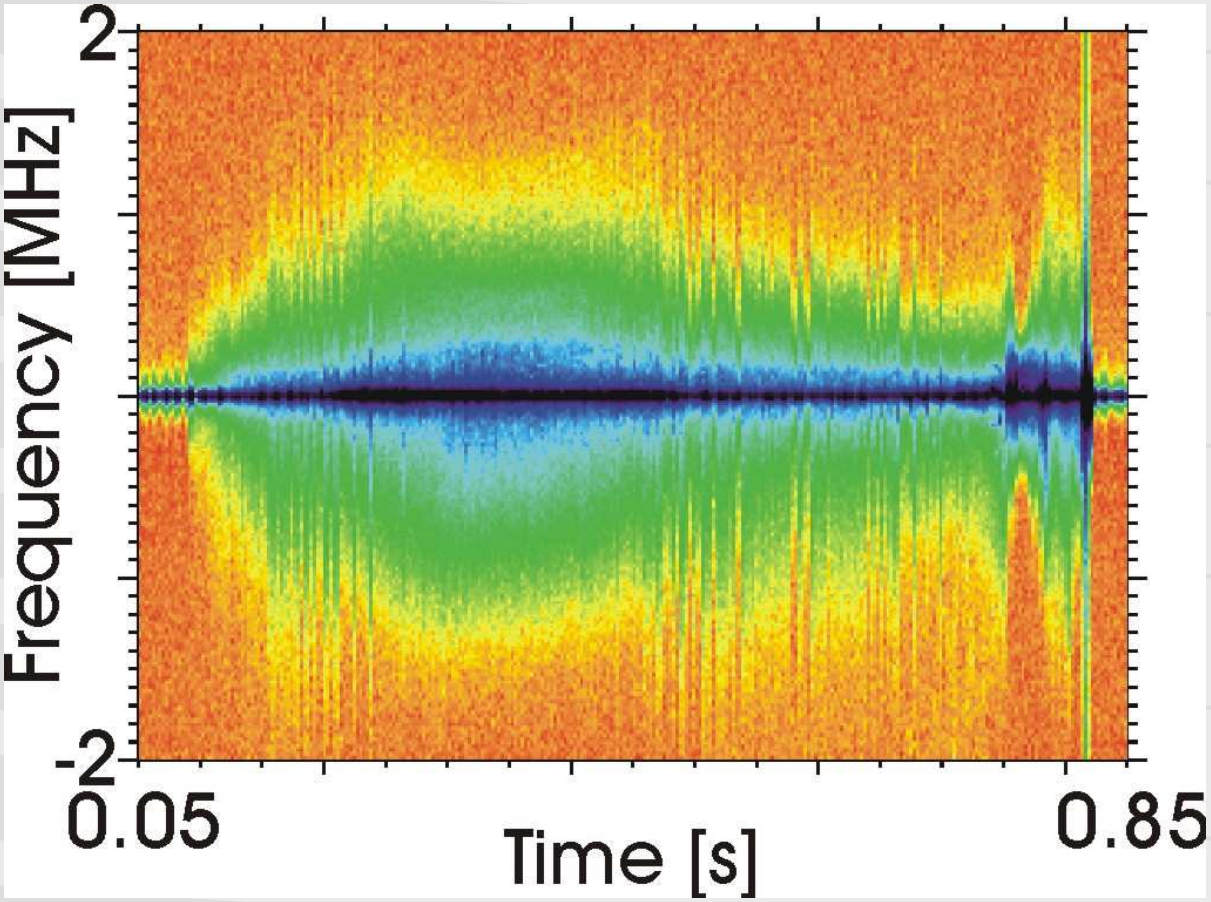


Correlations between the RMS Mirnov coil power and the autopower for density fluctuations in different frequency bands is shown above for NC-mode (left) and HDH-mode (right). Time time lag step is 20 μs:

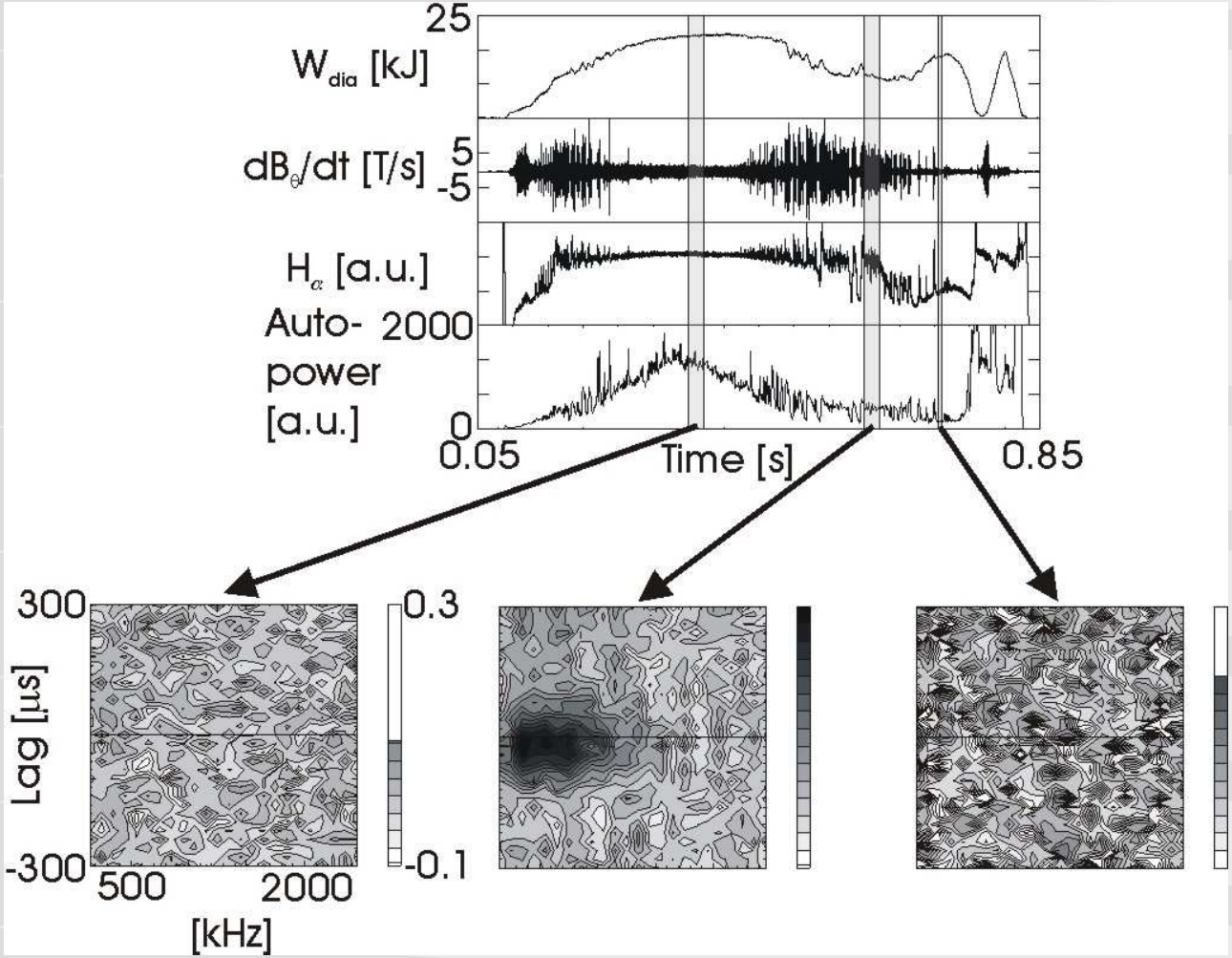
- Correlations between magnetic and density fluctuations exist in NC-mode but not in HDH-mode

Density fluctuations

To compare fluctuations in HDH-, NC- and the ELM-free H-mode, we study a discharge that underwent several confinement transitions. The density fluctuation spectrogram is shown in the right-hand figure.



Magnetic and density fluctuation correlation



- Top: Traces as shown previously

Bottom: Correlation between magnetic and density fluctuations:

- Left: HDH-mode
- Center: NC-mode
- Right: ELM-free H-mode

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Conclusions and outlook

A new improved confinement regime, the high density high confinement (HDH) mode, was discovered in W7-AS in 2001. In this talk we have presented turbulence measurements made during this confinement state and have compared them to measurements in the normal confinement (NC) mode:

- A significant increase of the density fluctuation level from NC- to HDH-mode
- Magnetic and density fluctuations are correlated in the NC-mode but not in the HDH-mode, corresponding to the distinction between the low confinement (L) mode and the ELM-free H-mode.
- In the EDA H-mode a quasi-coherent (QC) mode is observed; so far, no QC mode has been observed in W7-AS.

Completed work and ongoing studies: www.npb.dk