Characterization of core and edge turbulence in L- and H-mode Alcator C-Mod plasmas

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Outline:

- **Alcator C-Mod tokamak**
- **Fluctuation diagnostics**
- **Low to high mode transition**
- **Enhanced neutron mode**
- **Conclusions**

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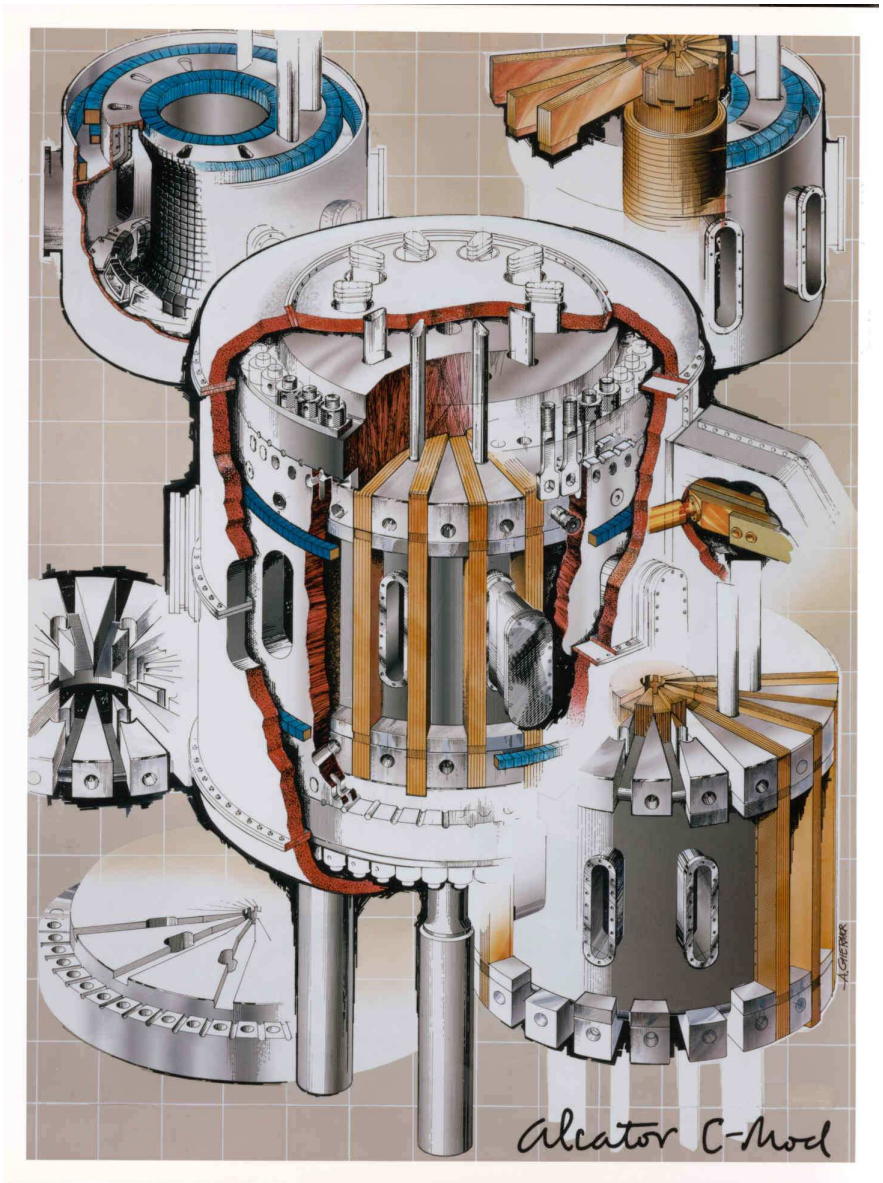
Alcator C-Mod tokamak



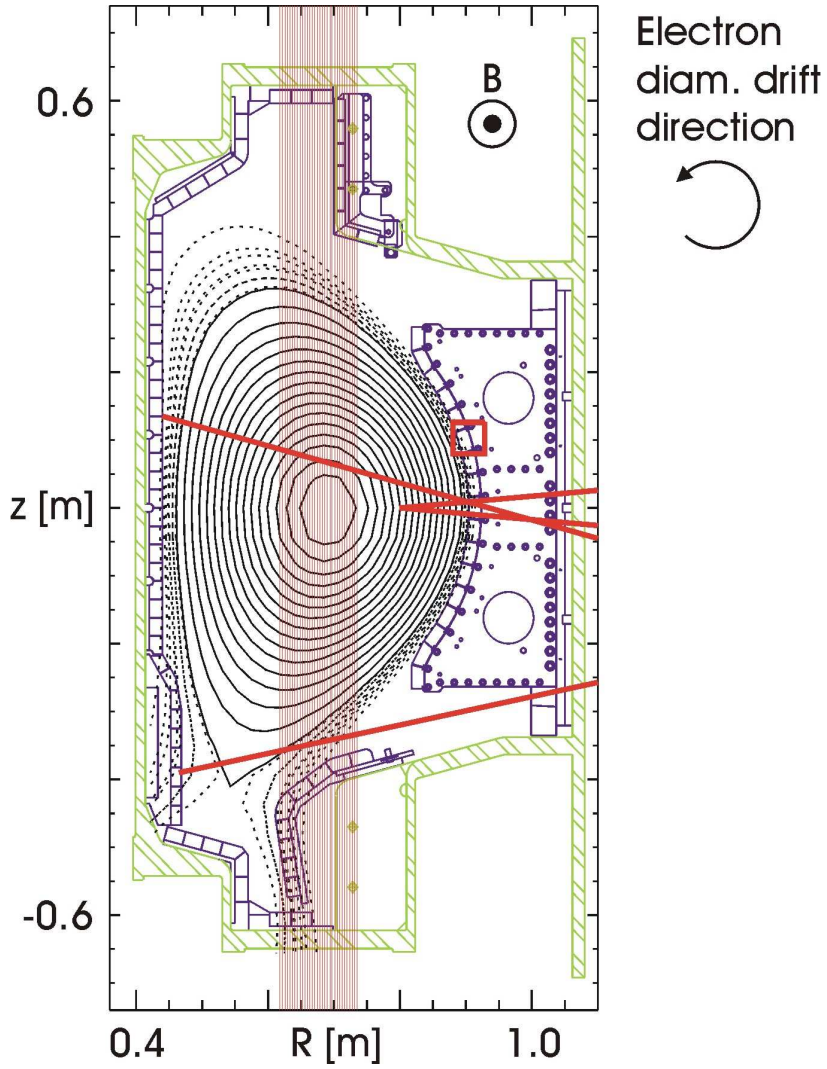
Alcator C-Mod is a divertor tokamak with high magnetic field capability ($B_t \leq 8$ T) in which quite high plasma currents ($I_p \leq 1.7$ MA) are possible in a compact geometry (R = 0.67 m, a = 0.22 m). Strong shaping options.

Plasma densities well above 1×10^{21} m^{-3} have been obtained, but more typically the average density is in the range $(1\text{-}5)\times10^{20}$ m^{-3}.

Auxiliary heating: Up to 6 MW ICRF (3 antennas, frequency between 50 and 80 MHz).

Plasma facing components are made of Molybdenum.

Fluctuation diagnostics



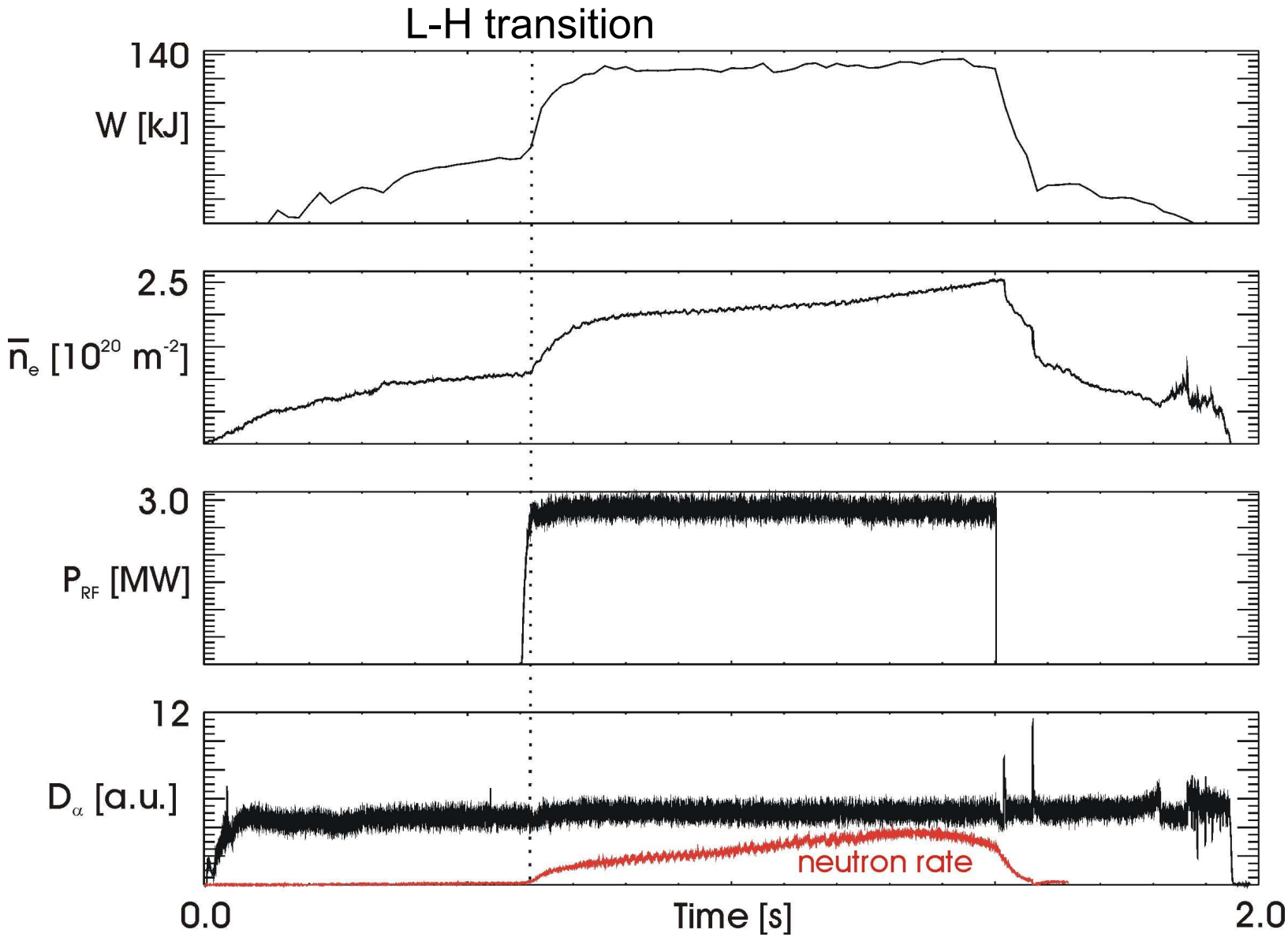
Four different diagnostics are used for turbulence studies at the L-H and H-L transitions:

- Phase-contrast imaging (PCI)
- Reflectometry
- Mirnov coil
- D-alpha light

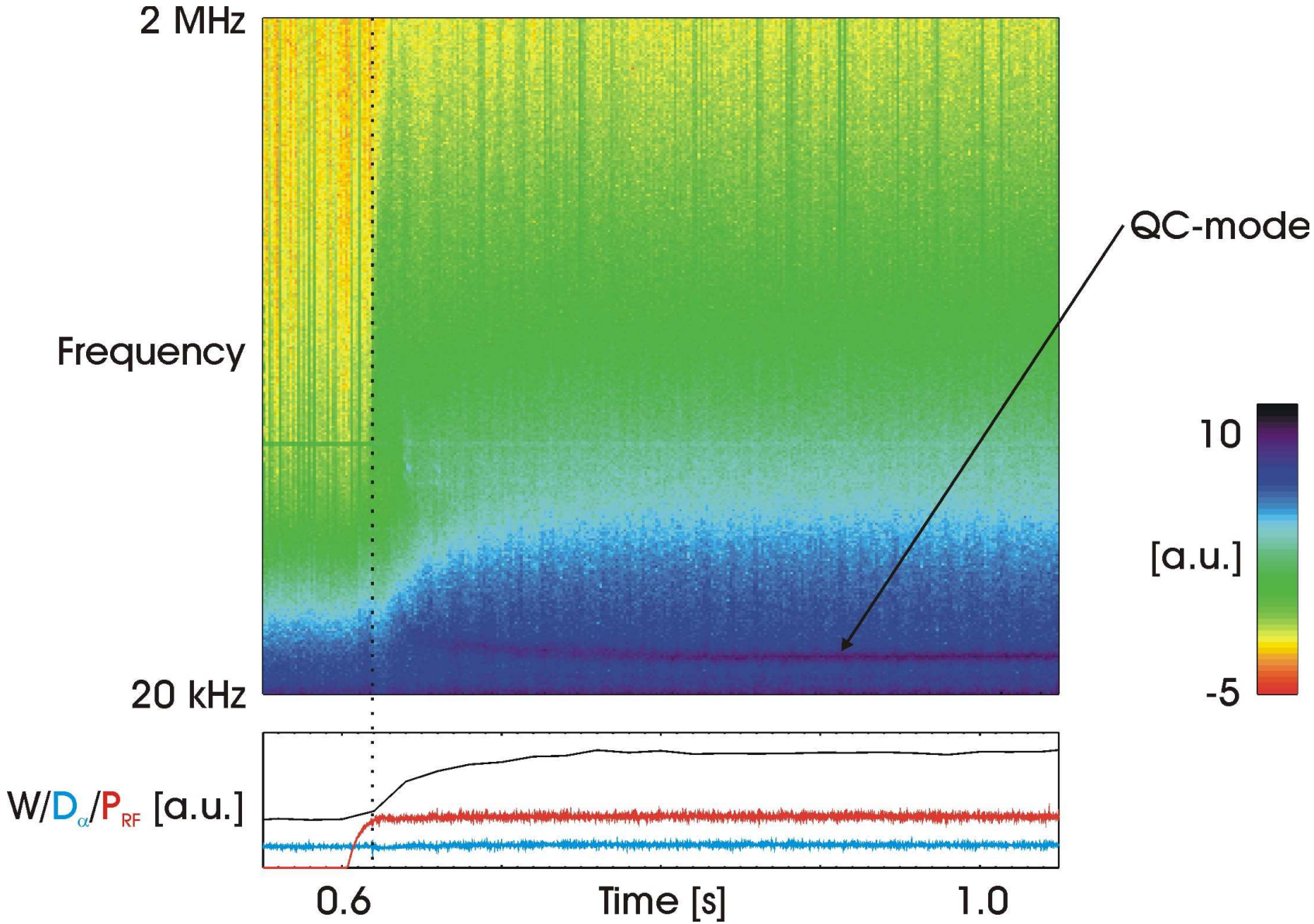
PCI: 32 vertical chords, spacing 4 mm, width of same order. Sampled 16 bit at 10 MHz, 25 W industrial CO_2 laser. Line integrated measurements. Sensitive to wavenumbers from 0.5 to 10 cm^{-1}.

Reflectometry: 7 fixed frequency channels operating in O-mode. Sampled 12 bit at 1 MHz. We show results from the 132 GHz channel, reflecting off a density of 2.2×10^{20} m^{-3}.

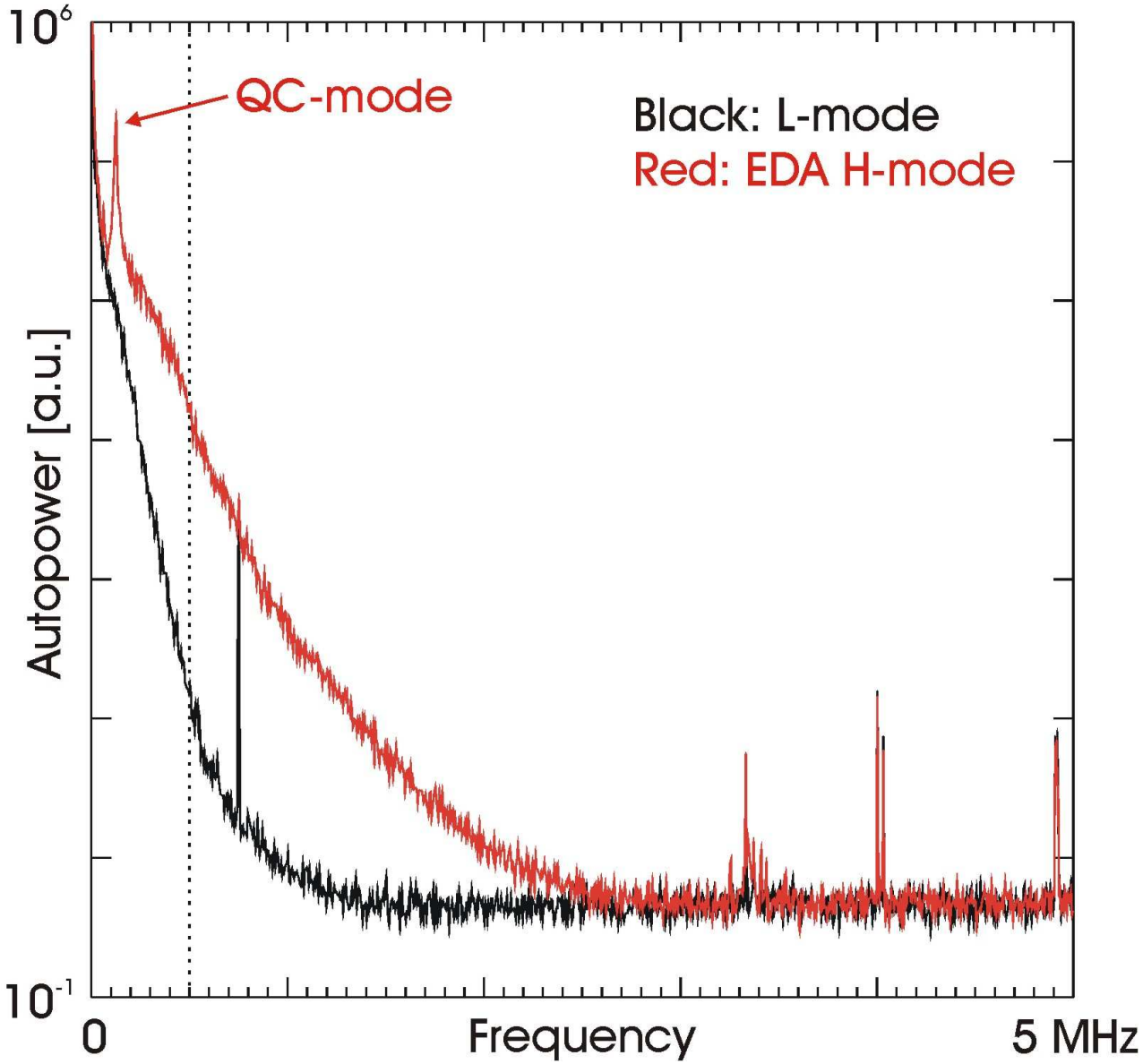
Low to high mode transition
shot 1040310012



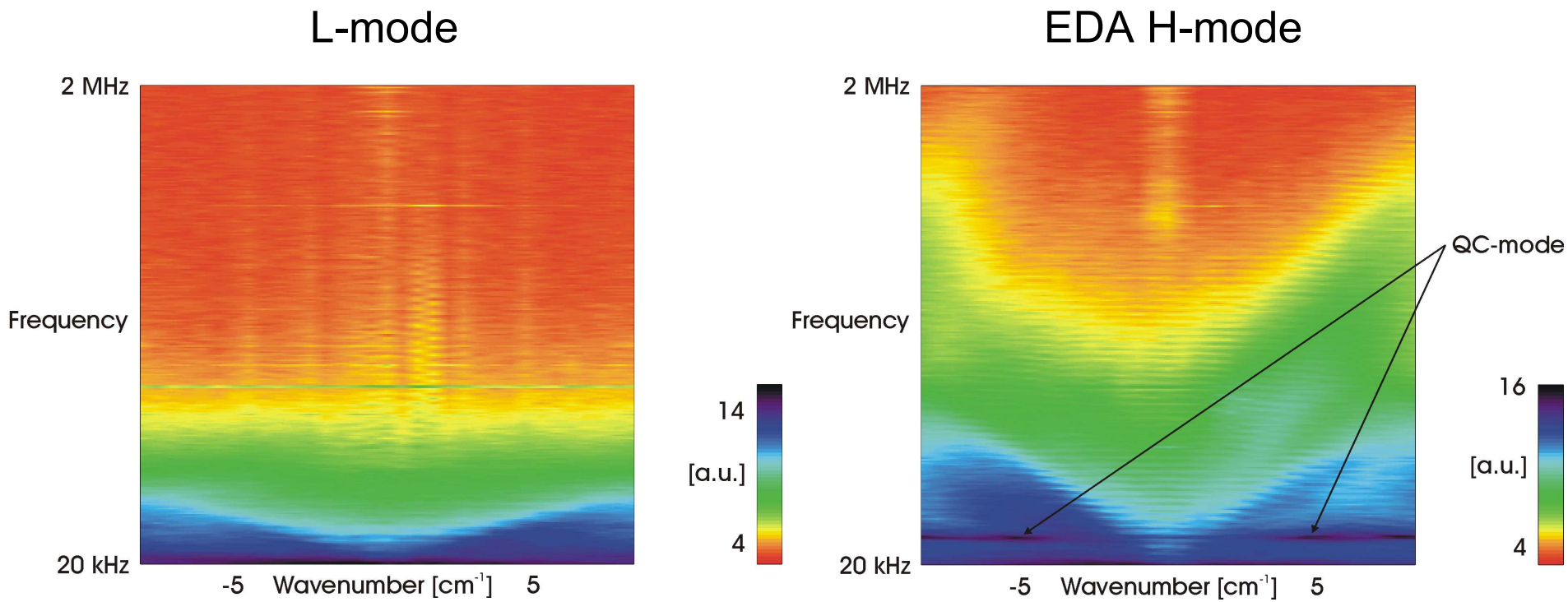
PCI spectrogram
core channel



PCI autopower spectra
core channel



PCI frequency-wavenumber spectra

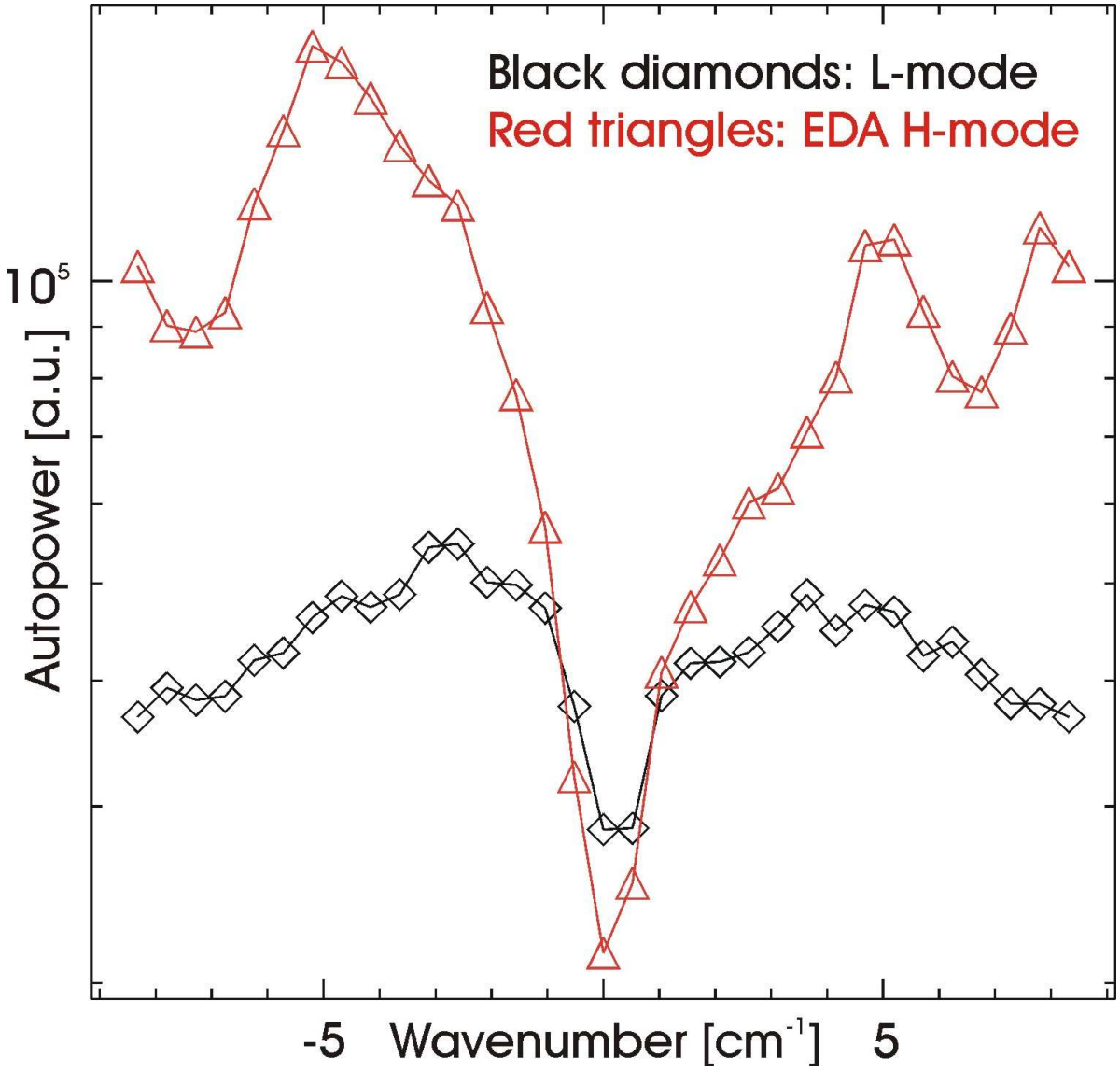


By performing 2D Fourier transforms on the PCI data from all 32 channels, we arrive at frequency-wavenumber spectra.

The largest increase in frequency coverage from L- to H-mode is at large wavenumbers.

Negative (positive) wavenumbers are due to fluctuations travelling outward (inward) parallel to the major radius.

PCI autopower-wavenumber spectra



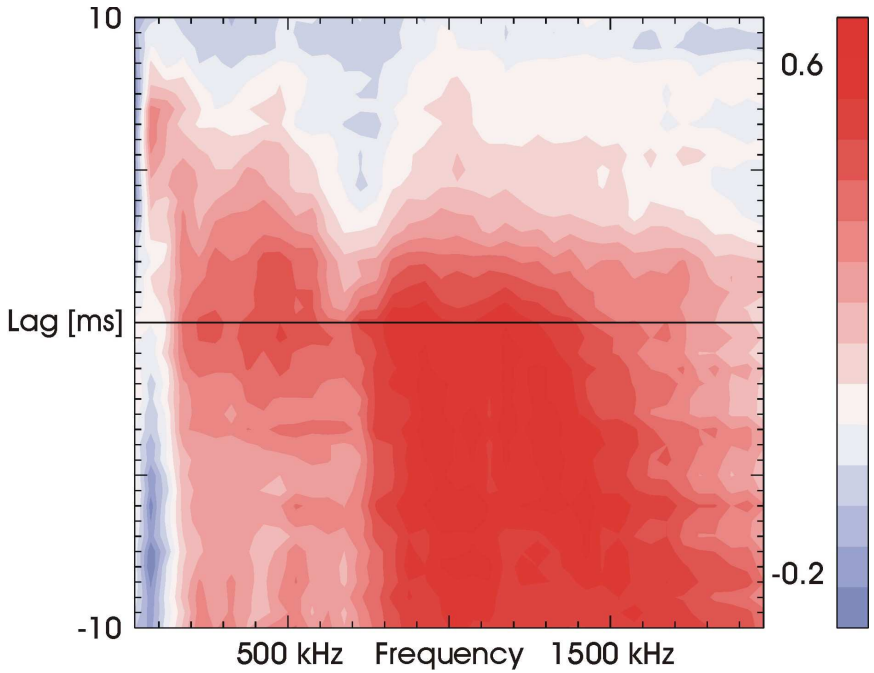
Integrating fluctuations over all frequencies we can plot wavenumber spectra for L- and H-mode.

The L-mode spectrum peaks around 3-4 cm^{-1} and only exceeds the H-mode autopower for small wavenumbers.

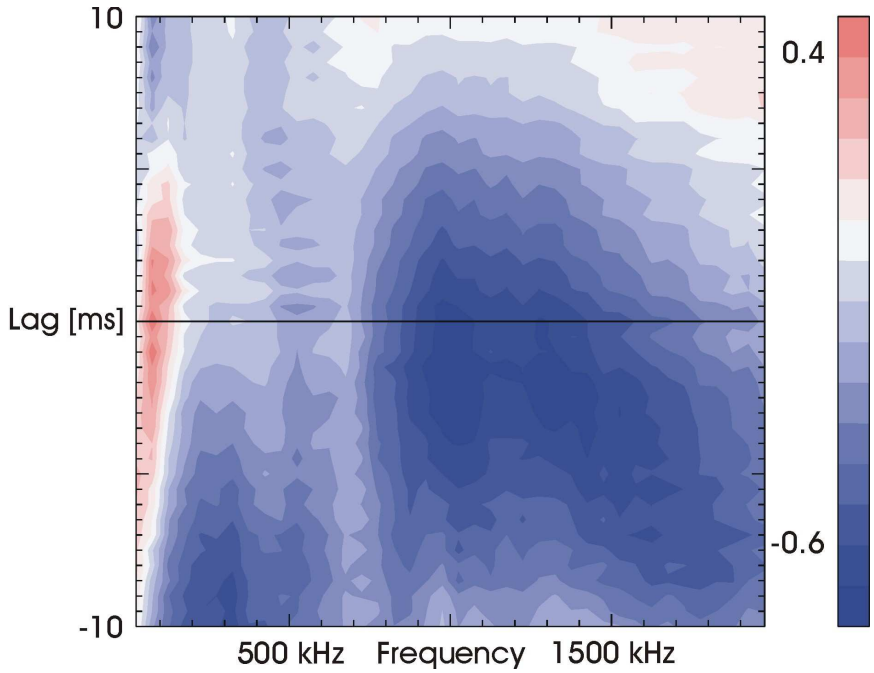
The H-mode spectrum peaks at the QC-mode wavenumber. There are indications that a second peak exists at larger wavenumbers.

Correlations
between PCI and Mirnov coil/D-alpha

Mirnov coil



D-alpha

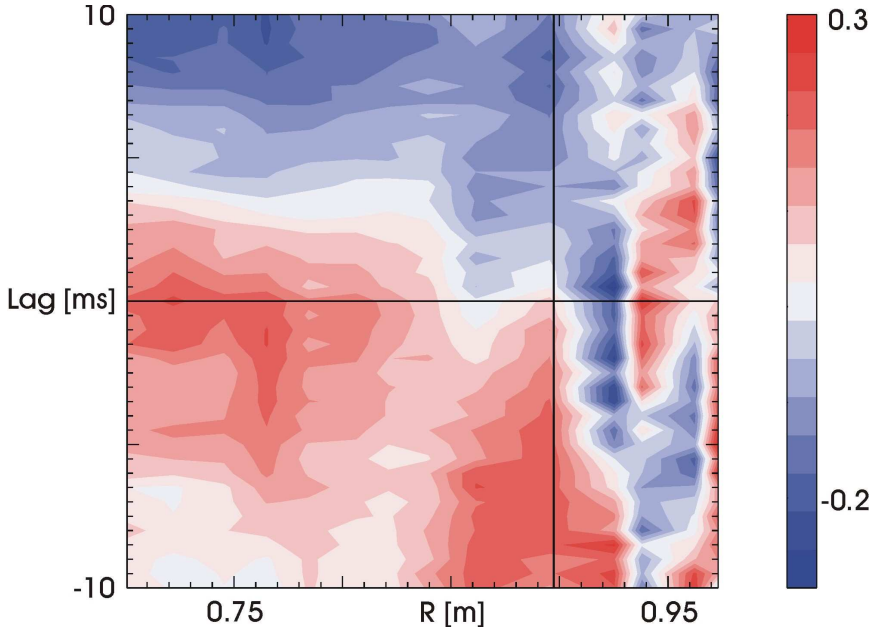


Cross correlation between rms Mirnov coil/D-alpha fluctuations and PCI band autopowers. Band autopower resolution 50 kHz, time resolution 0.5 ms.

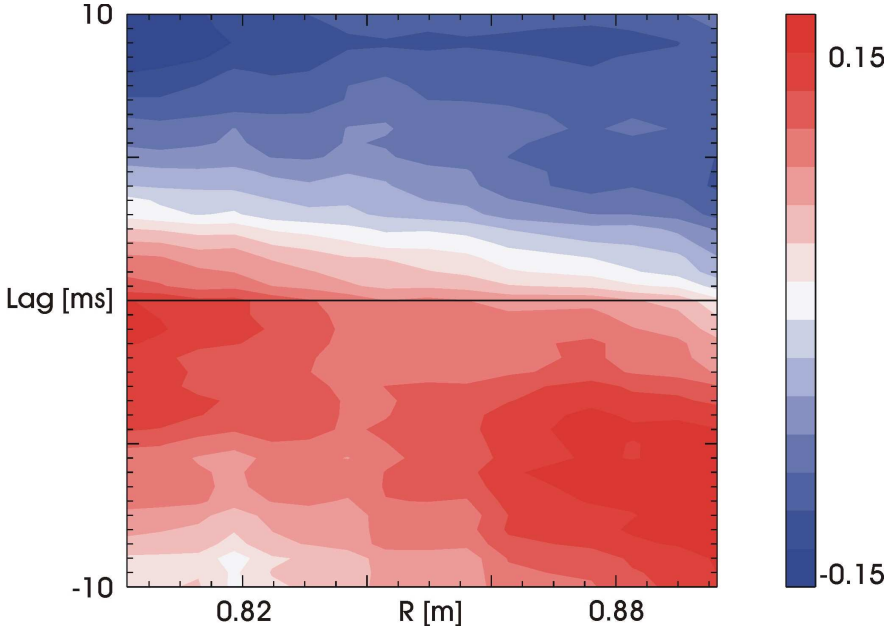
Positive (negative) time lag: PCI fluctuations occur before (after) the Mirnov coil/D-alpha fluctuations.

Correlations
between PCI and ECE

GPC2
(Grating PolyChromator 2)



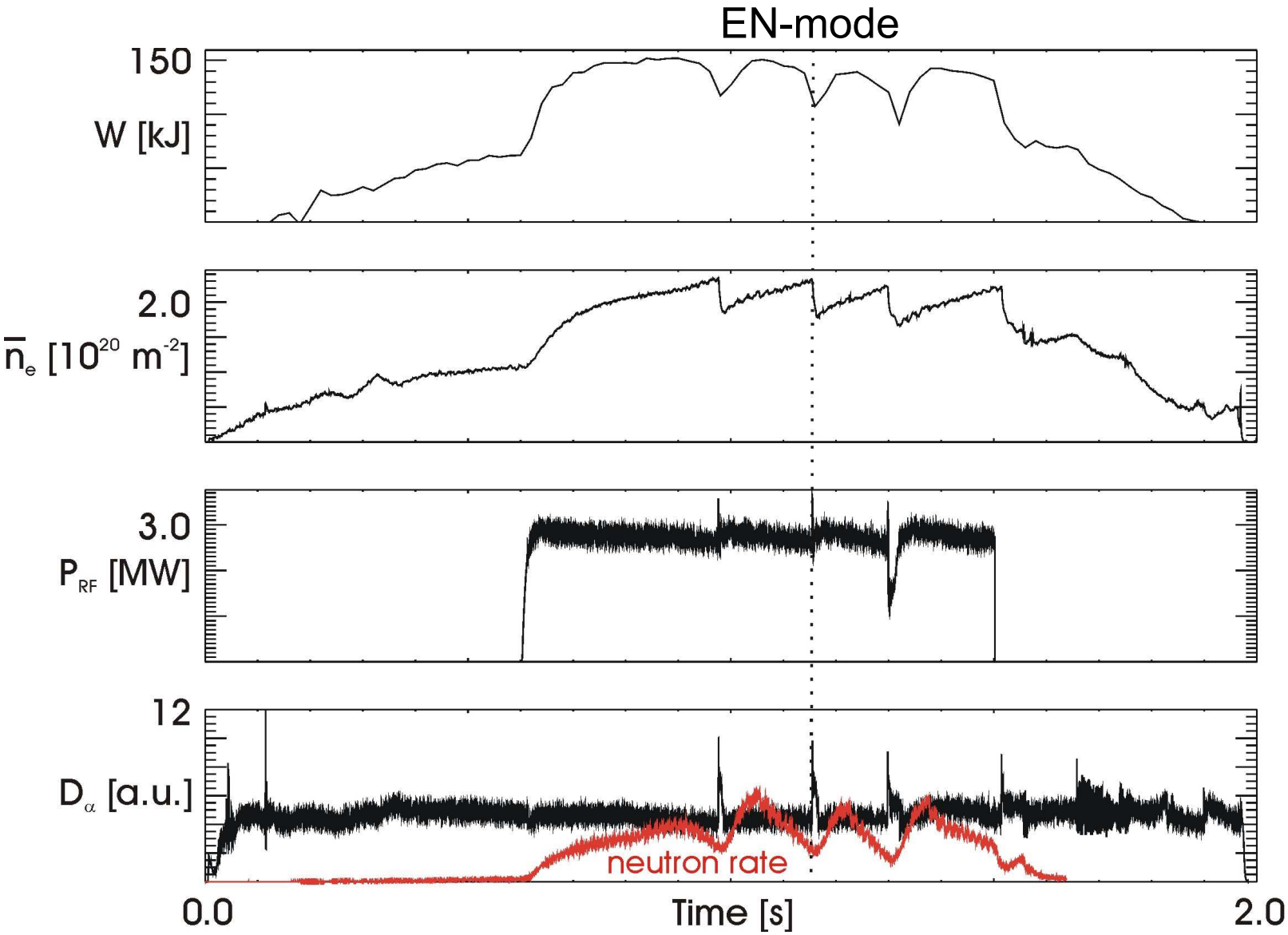
FRCECE
(Fusion Research Center ECE)



Cross correlation between rms electron cyclotron emission (ECE) temperatures and PCI band autopower from 20 kHz to 2 MHz. The time resolution is 0.5 ms.

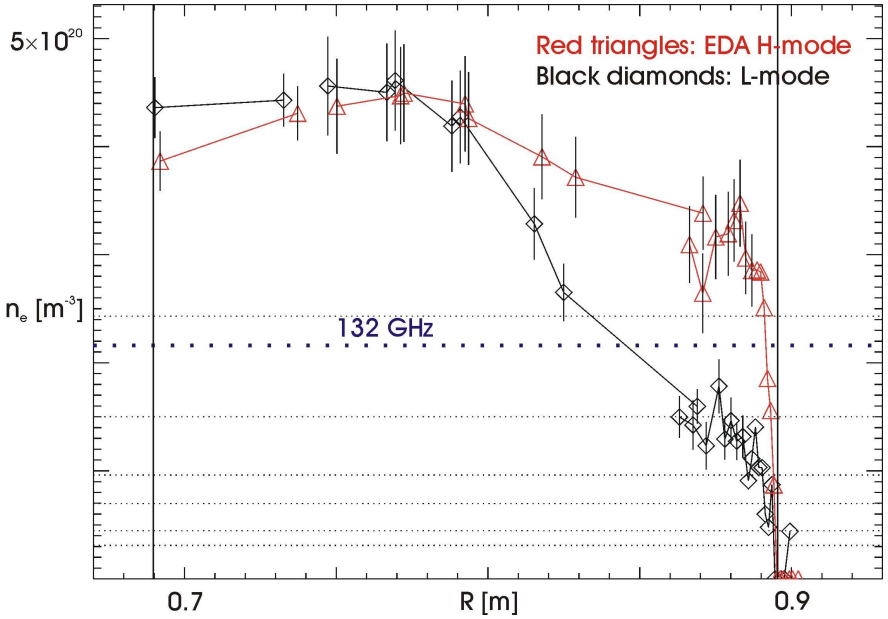
Positive (negative) time lag:
PCI fluctuations occur before (after) the ECE temperature changes.
GPC2: 14 channels, time res. 0.25 ms.
FRCECE: 15 channels, time res. 0.005 ms.

Enhanced neutron mode
shot 1040310021

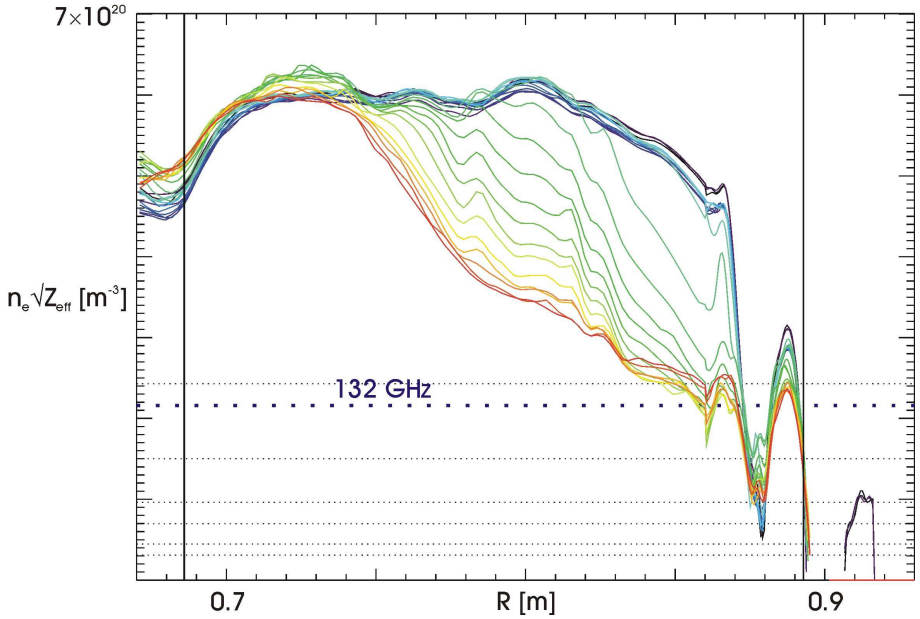


Density profiles

Thomson density profiles



Visible bremsstrahlung profiles

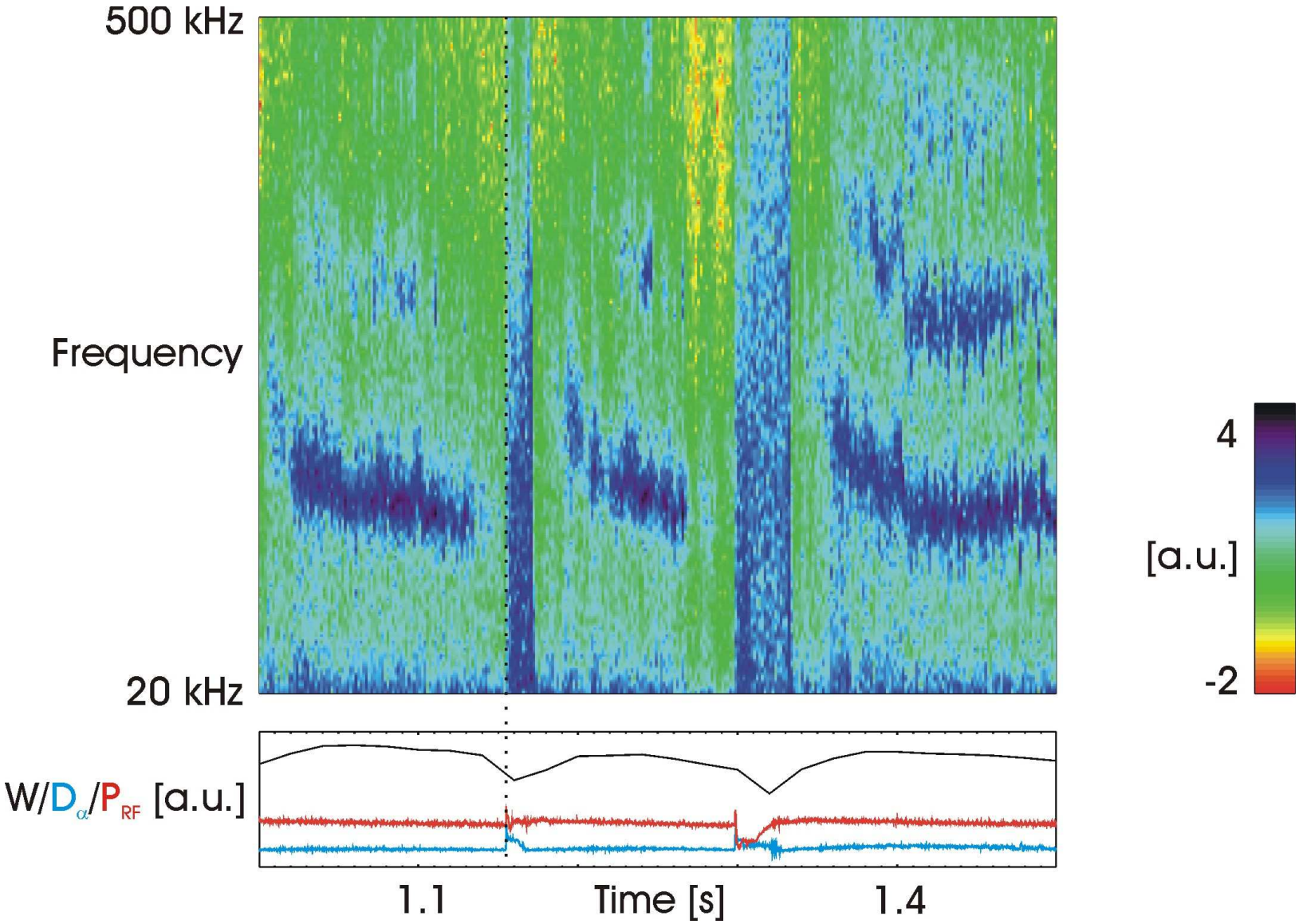


Time resolution of Thomson density profiles is 33 ms.

The EN-mode consists of a collapse of the outer density.

Time resolution of visible bremsstrahlung profiles is 0.5 ms, spatial resolution is 1 mm. A 25 ms time interval is shown.

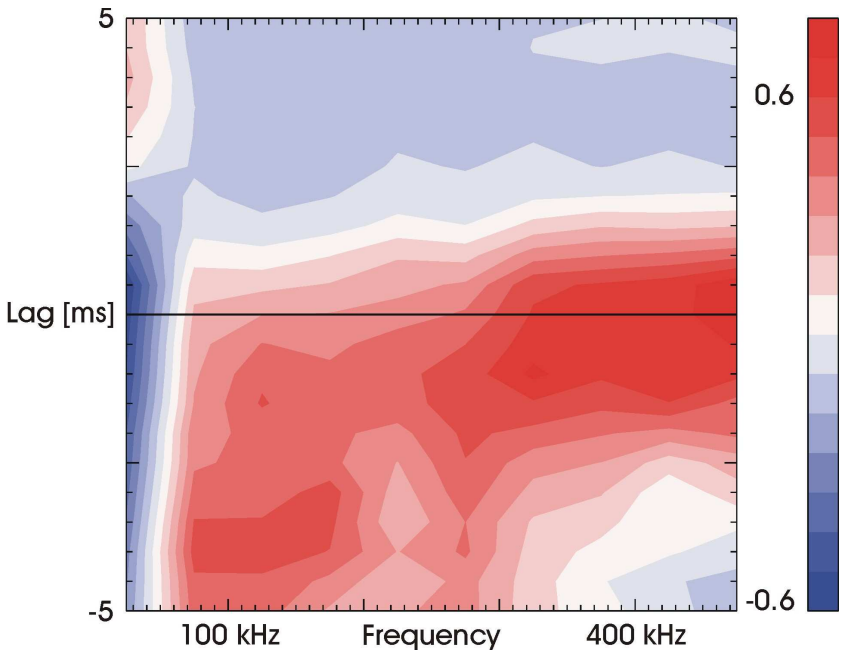
Reflectometry spectrogram
132 GHz



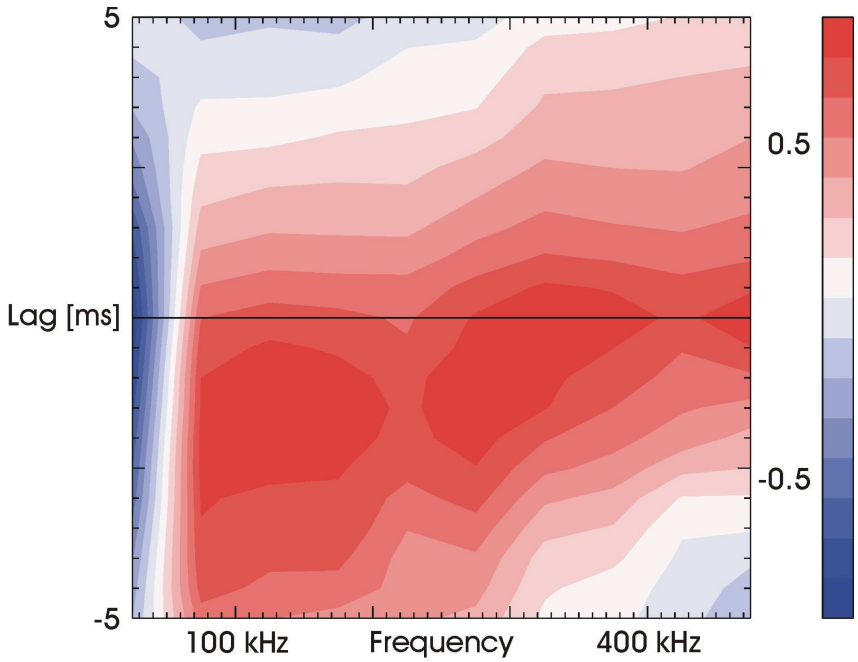
Correlations

between reflectometry and Mirnov coil/D-alpha

Mirnov coil



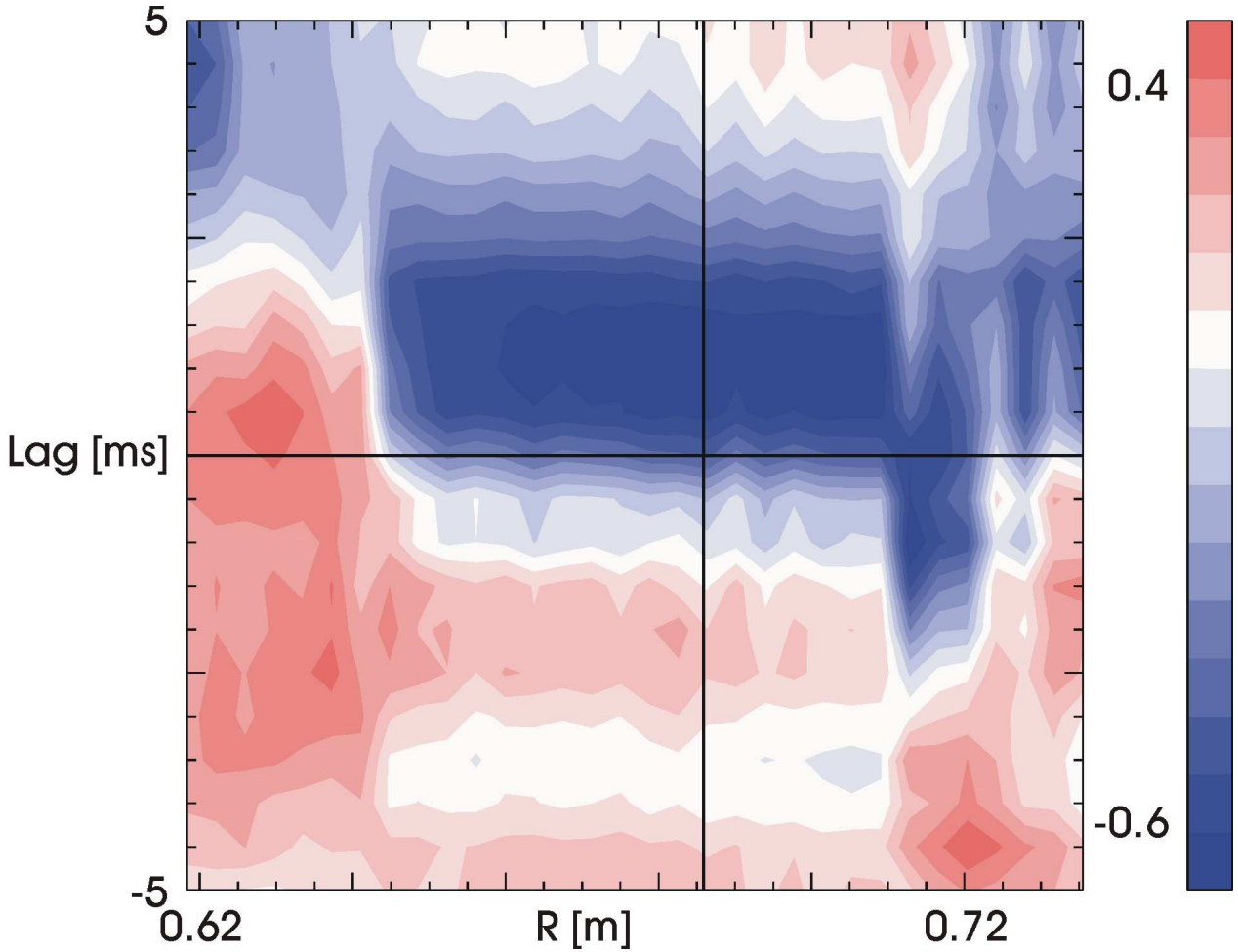
D-alpha



Cross correlation between rms Mirnov coil/D-alpha fluctuations and reflectometry band autopowers. Band autopower resolution 50 kHz, time resolution 0.5 ms.

Positive (negative) time lag: Reflectometry fluctuations occur before (after) the Mirnov coil/D-alpha fluctuations.

Correlations
between reflectometry and PCI



Positive (negative) time lag:
PCI fluctuations occur before (after) the reflectometry fluctuations.

Cross correlation between rms reflectometry fluctuations and PCI band autopower from 20 kHz to 2 MHz. The time resolution is 0.5 ms.

Conclusions

Alcator C-Mod

•We have in this talk presented an analysis of turbulence at L-H and H-L transitions in the Alcator C-Mod tokamak.
•The PCI diagnostic has been upgraded from 12 to 32 channels and fast digitization has been implemented.
•The reflectometer has been augmented by 2 high frequency (132 and 140 GHz) channels.

L-H transition:
•PCI measurements display the appearance of high frequency, large wavenumber fluctuations at the transition.
•The turbulence amplitude increases for all except very small wavenumbers.
•Strong correlations exist between PCI and Mirnov coil/D-alpha/electron temperature signals at the transition.

H-L transition:
•Reflectometer measurements show large amplitude, broadband fluctuations in the EN-mode.
•Strong correlations are found between reflectometry and Mirnov coil/D-alpha/PCI signals at the transition.