Turbulence associated with the control of internal transport barriers in Alcator C-Mod plasmas

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Motivation: Nonlinear GS2 simulations suggest that trapped electron modes (TEMs) are more unstable during on- than off-axis ICRF heating of ITB plasmas. TEMs limit the density gradient. [D.R.Ernst et al., 20th IAEA Fusion Energy Conference, 2004]

Method: Measure turbulence before and during on-axis heating.

Result: Qualitative agreement between GS2 simulations and turbulence measurements.

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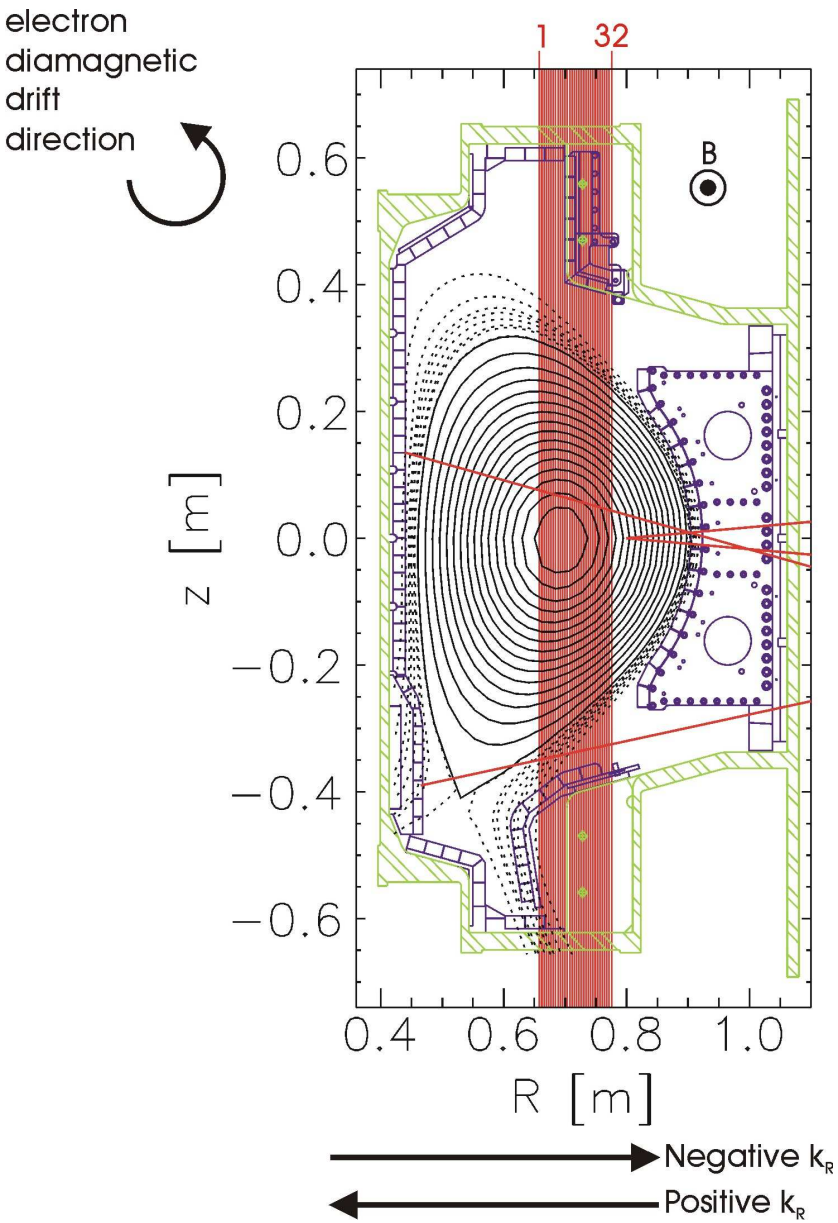
Fluctuation diagnostics



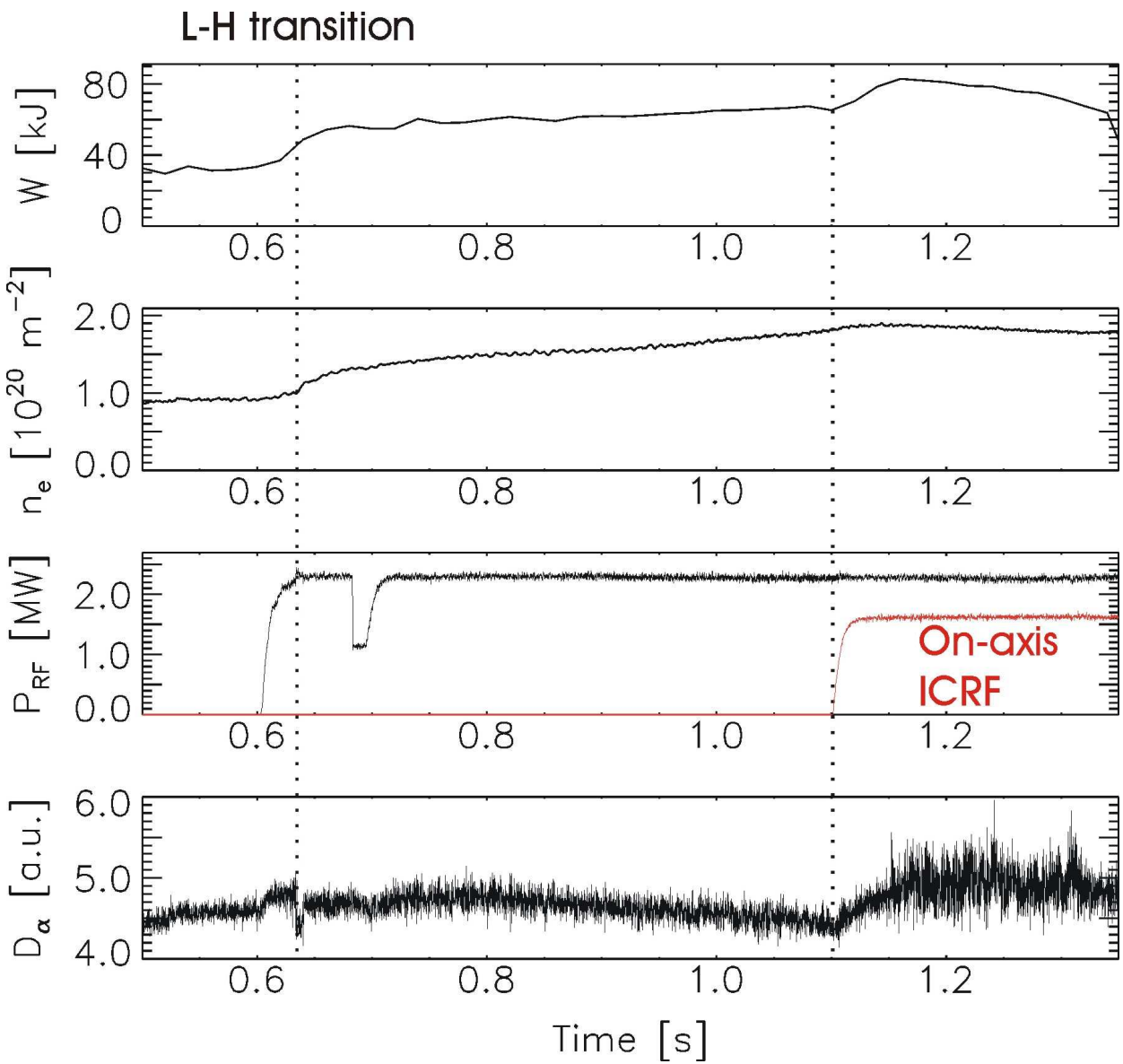
<u>Phase-contrast imaging (PCI):</u>

- Measures line integrated electron density fluctuations along 32 vertical chords.
- Sensitive to turbulence from 0.5 to 8 cm^{-1}.

<u>Reflectometry:</u>

- Measures localized electron density fluctuations.
- 132 GHz channel has cutoff at 2.2×10^{20} m^{-3}.

ITB discharge waveforms

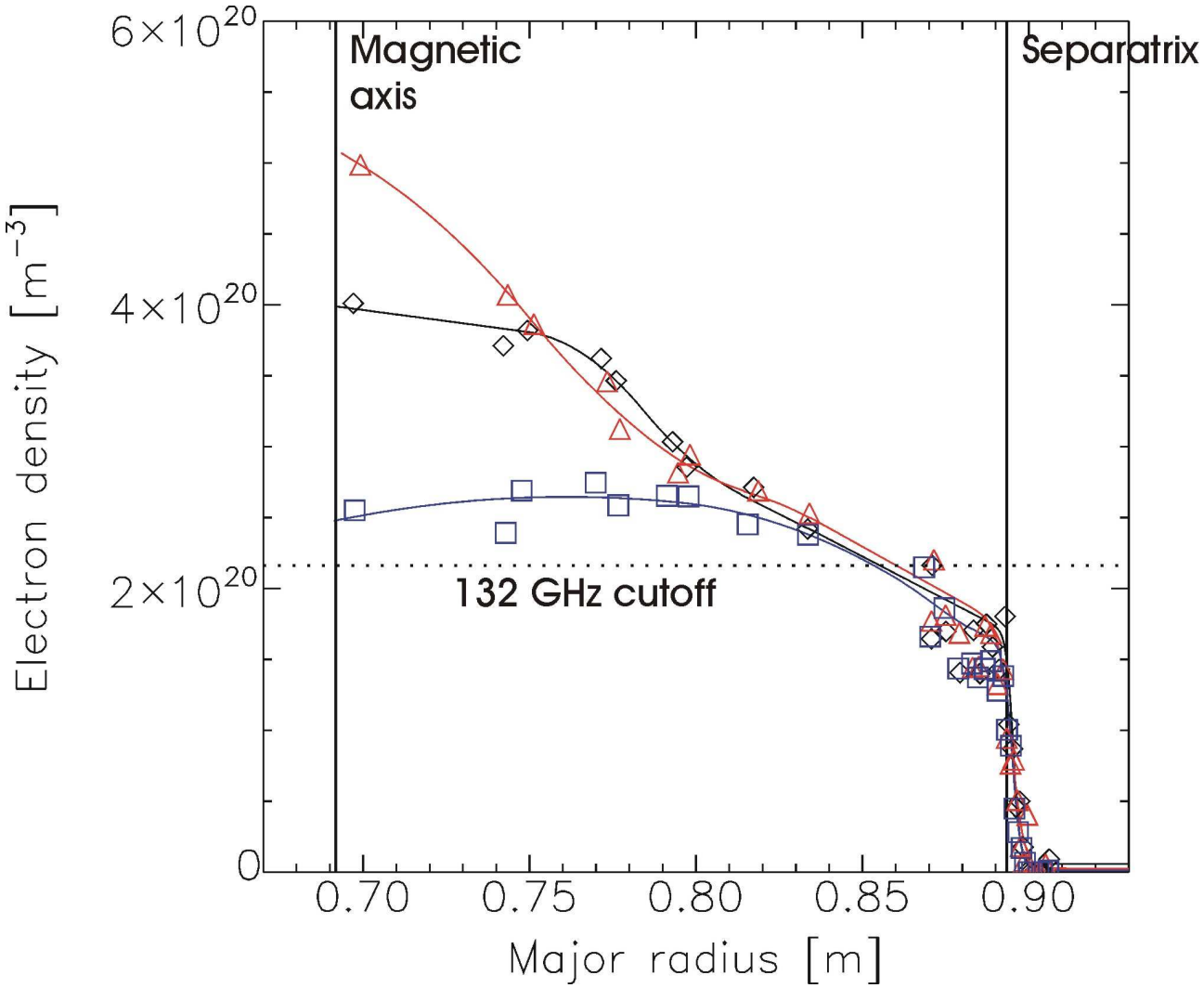


Shot:
1040323033

Toroidal field:
4.5 T

Plasma current:
0.8 MA

Density profiles



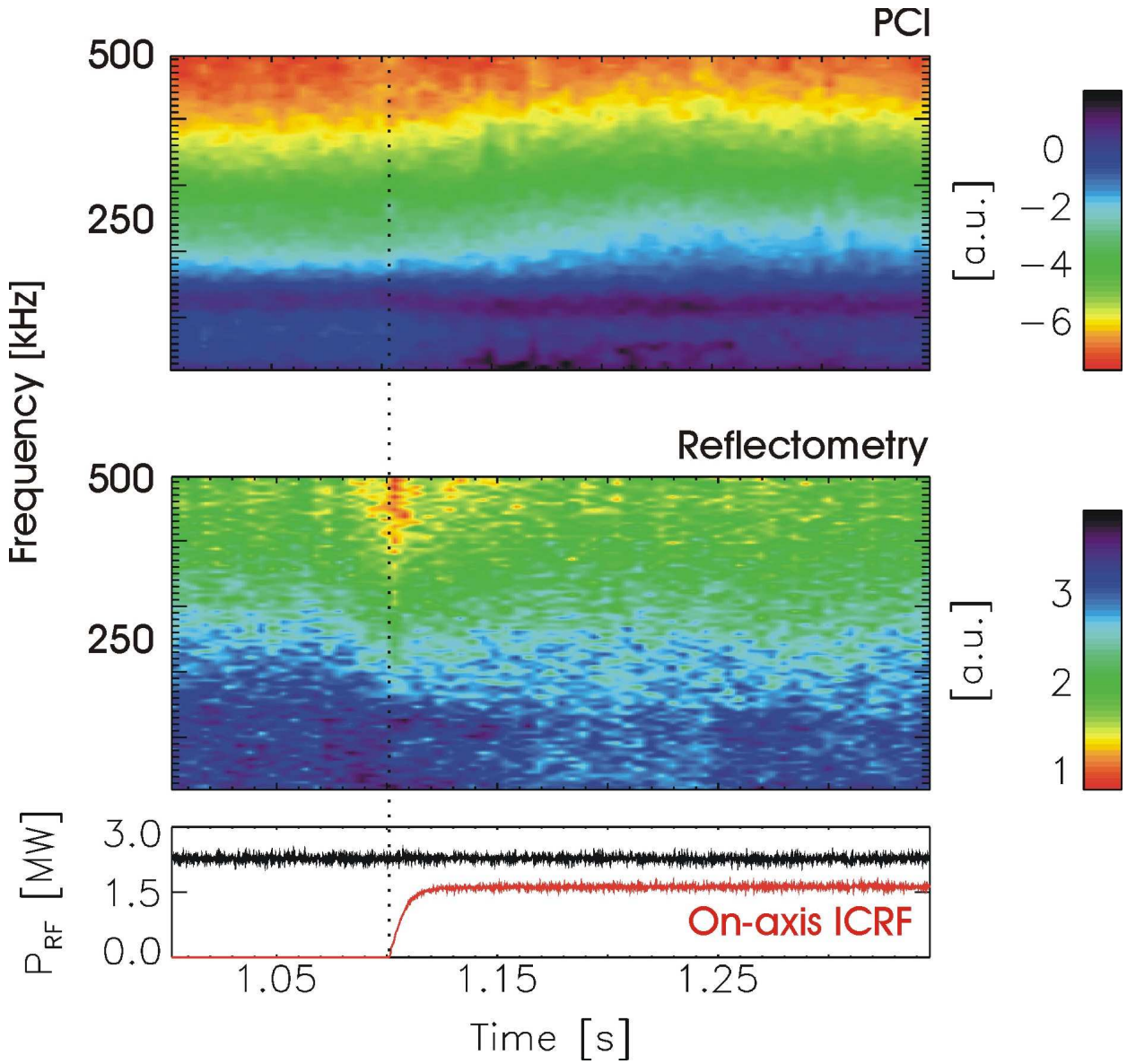
Thomson scattering profiles fitted to measurements.

Blue line/squares:
H-mode at 0.761 seconds,
off-axis ICRF heating only.

Black line/diamonds:
ITB at 1.027 seconds,
off-axis heating only.

Red line/triangles:
ITB at 1.227 seconds,
off- and on-axis heating.

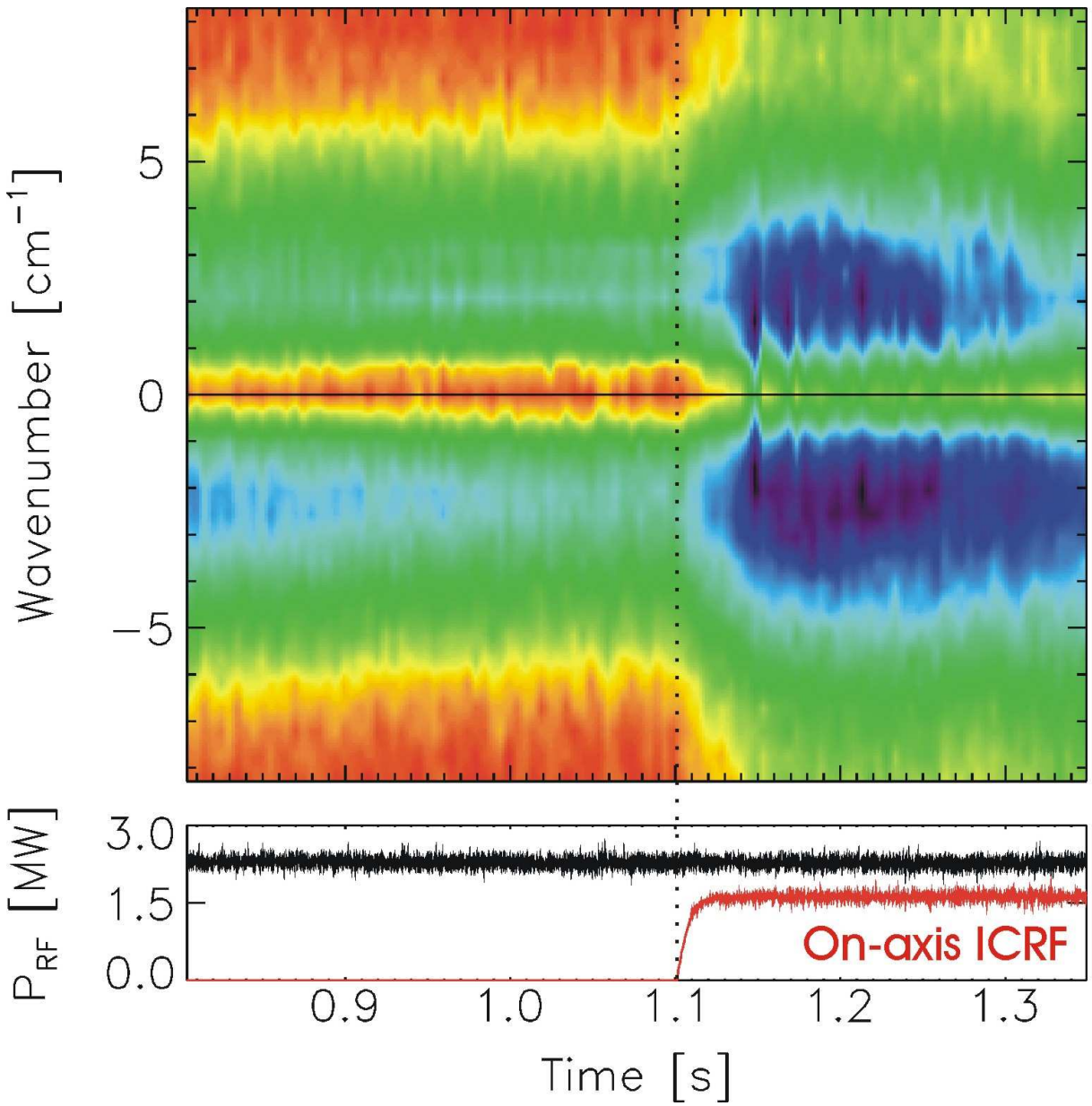
PCI and reflectometry spectra



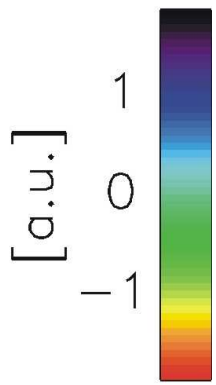
- Increase of low frequency turbulence and stronger edge quasi-coherent (QC) mode seen by PCI in response to on-axis ICRF heating.

- Small overall decrease of fluctuations visible in reflectometry (localized above the pedestal).

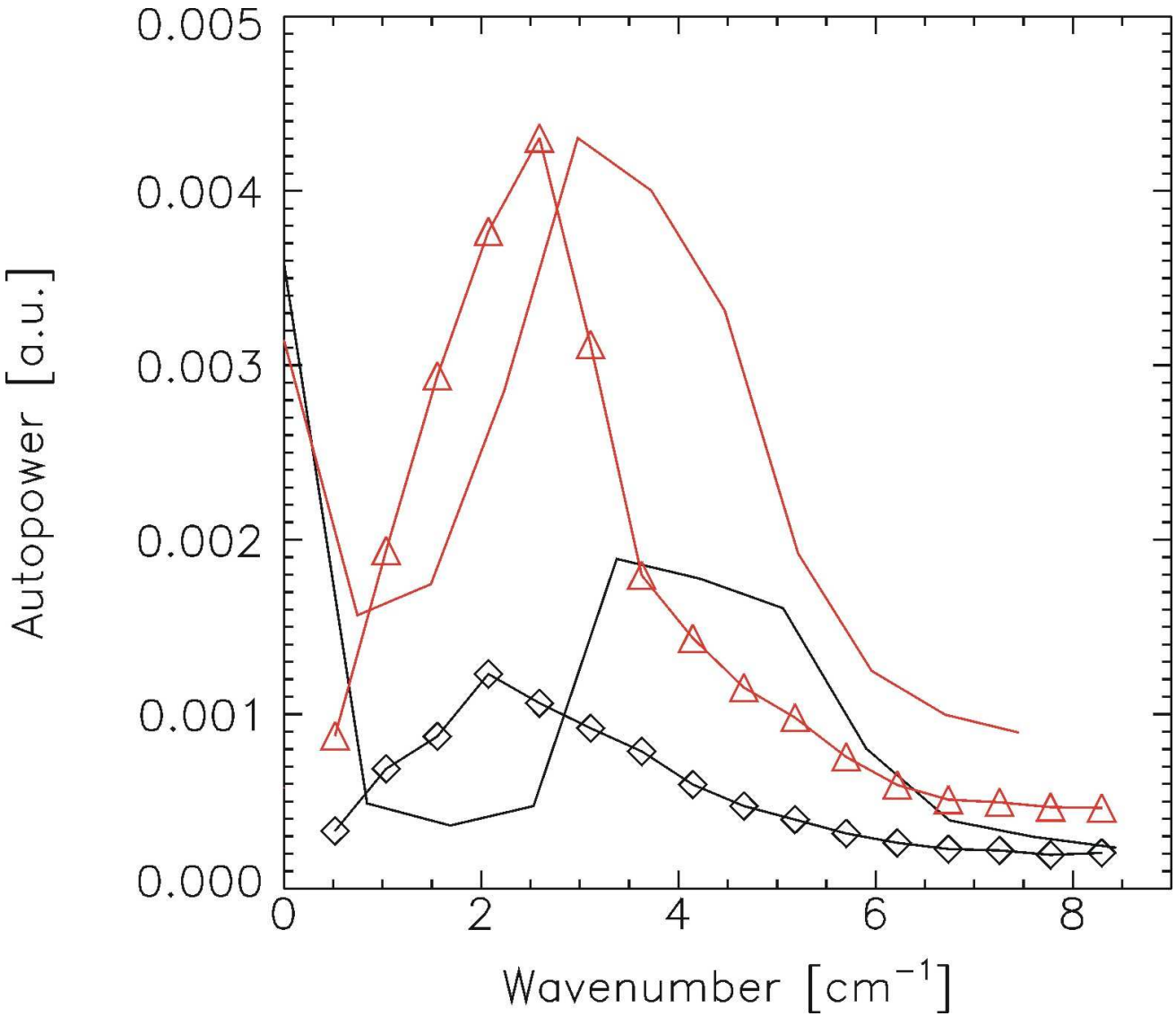
PCI wavenumber spectra



Wavenumber spectra vs time integrated over [20,80] kHz.



PCI and simulated spectra



Red triangles:
PCI wavenumber spectrum during off- and on-axis ICRF heating.
Red line:
TEM turbulence from nonlinear GS2 simulation.

Black diamonds:
PCI wavenumber spectrum during off-axis heating only.
Black line:
TEM turbulence from nonlinear GS2 simulation.

Conclusions

Alcator C-Mod

- ITBs are created using off-axis ICRF heating.
- Additional on-axis heating controls the density gradient.
- Increased transport during on-axis heating due to trapped electron mode (TEM) turbulence is found in nonlinear GS2 simulations. Ion temperature gradient driven modes do not change.
- GS2 simulations agree with TRANSP effective thermal and particle diffusivities in the ITB.
- Low frequency ([20, 80] kHz) fluctuations at medium wavenumbers (2-3 cm^{-1}) measured by PCI grow stronger as on-axis heating is added.
- Initial quantitative comparisons between GS2 and PCI wavenumber spectra are promising.
- http://www.psfc.mit.edu/people/basse/