Wendelstein 7-AS

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Measurements of plasma turbulence by laser scattering in the Wendelstein 7-AS stellarator

Nils P. Basse[1,2], S. Zoletnik, M. Saffman, P. K. Michelsen and the W7-AS Team

[1]Association EURATOM – Risø National Laboratory, Denmark
[2]Ørsted Laboratory, Niels Bohr Institute for Astronomy, Physics and Geophysics, Denmark

1. The Wendelstein 7-AS (W7-AS) stellarator
2. The density fluctuation diagnostic
3. Measurements

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Student visit, 21st of November 2001, Risø, Denmark

Wendelstein

Situated in Bayern, height 1838 m

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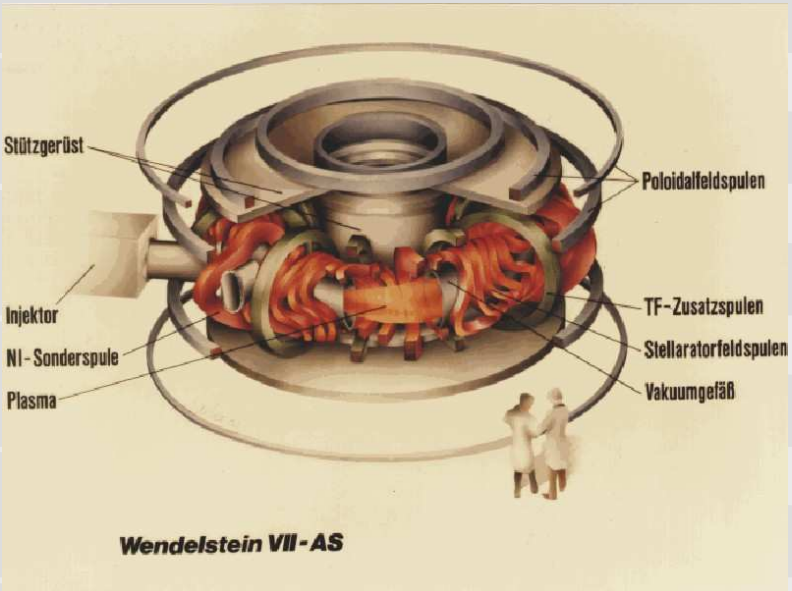
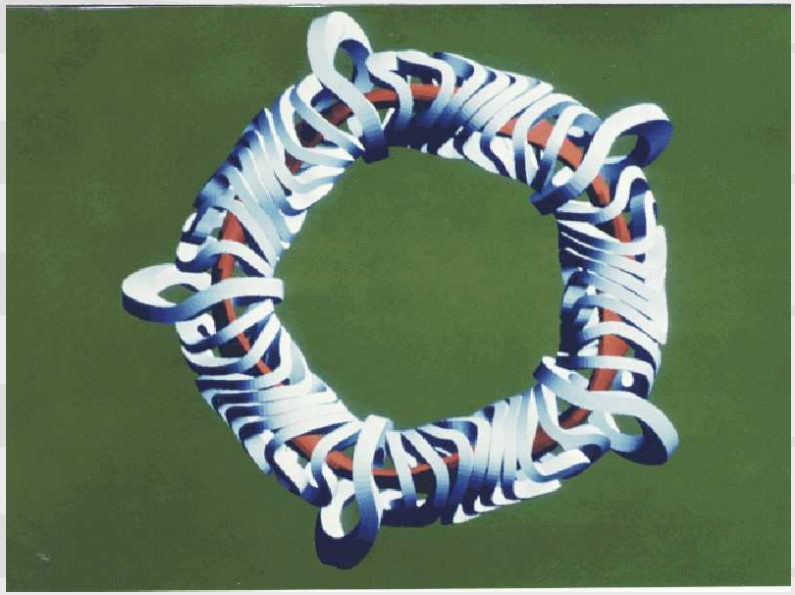
The W7-AS stellarator





The 'stellarator' was invented by Lyman Spitzer, Jr., in 1951

A fusion machine has 3 main parts:

- The vacuum vessel containing the plasma
- A system of coils (W7-AS: 45 modular coils, 10 planar coils) creating the magnetic field required
- External heating systems

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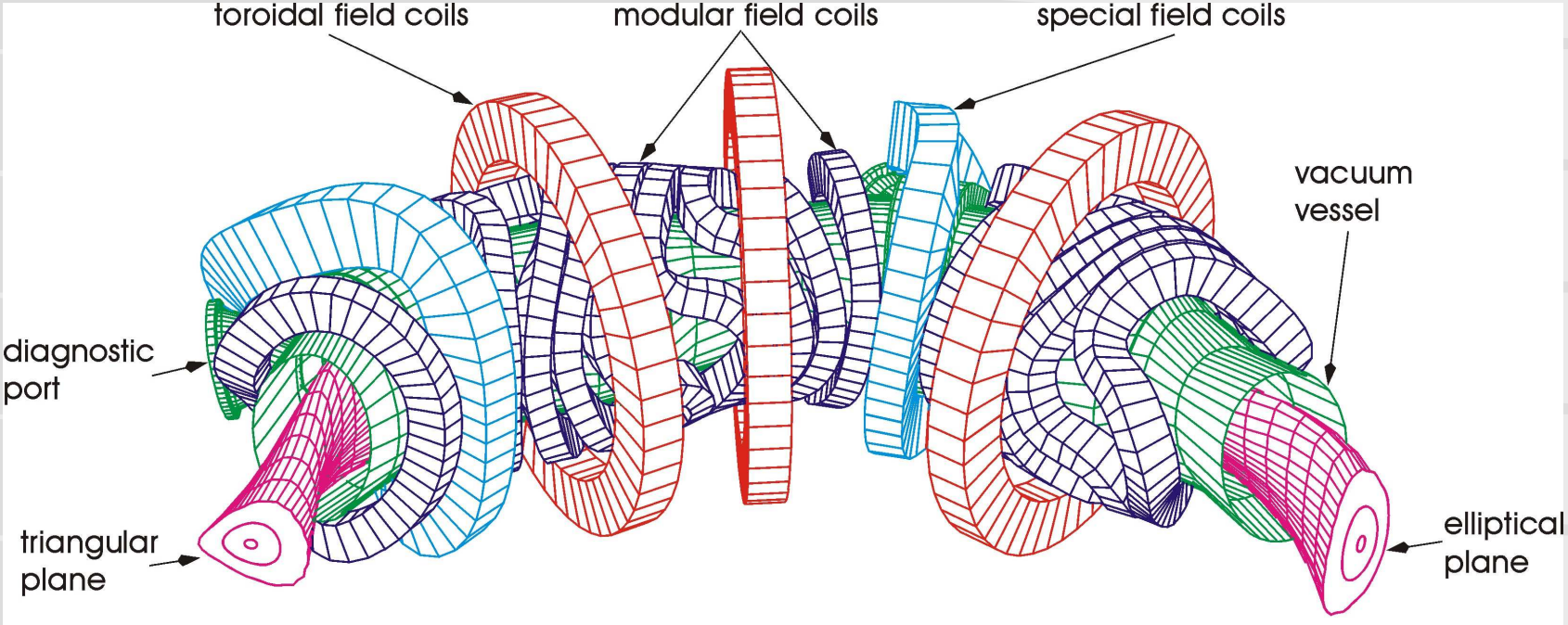
The W7-AS stellarator



- Machine size: Major radius R = 2 m, minor radius $a \leq 0.18$ m
- Rotational transform ι = n/m = poloidal/toroidal winding number is between 0.3 and 0.6 (safety factor q = $1/\iota$)
- Maximum temperatures: T_e = 7 keV, T_i = 2 keV
- Maximum density: $n_e = 4 \times 10^{20}$ m^{-3}
- Maximum normalised plasma pressure: $\beta = p/(B^2/2\mu_0)$ = 3.1 % (average value)

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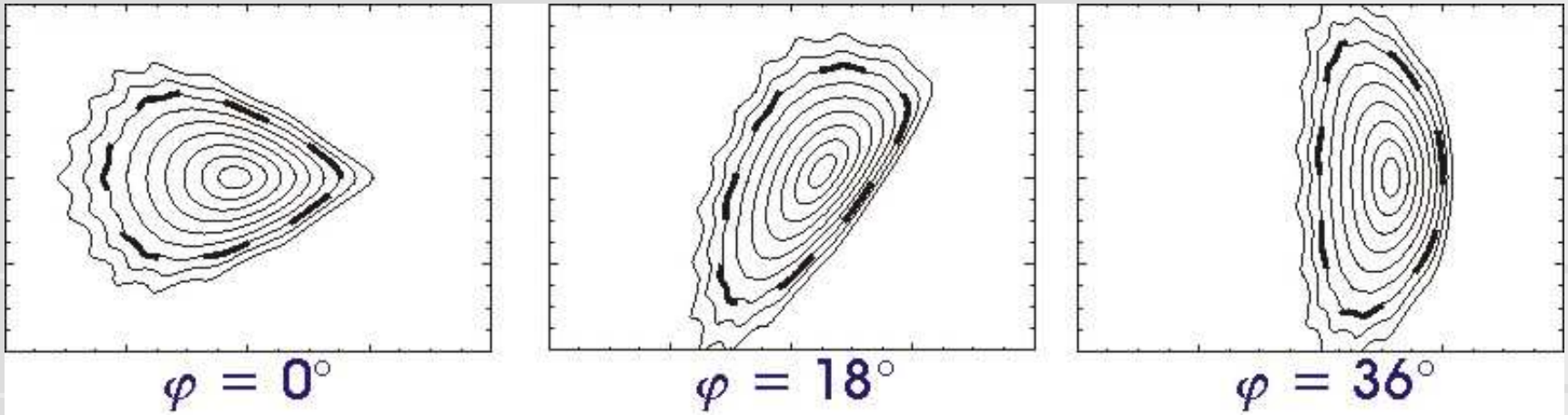
The W7-AS flux surfaces



To visualise the magnetic field structure as a function of the toroidal angle φ, one can calculate flux surfaces on which the magnetic field and plasma current wind helically (shown here for ι = 0.344)

External heating systems:

- Electron cyclotron resonance (ECR) heating: Gyrotrons at 70 and 140 GHz, total power 2.5 MW
- Neutral beam injection (NBI) heating: 4 MW

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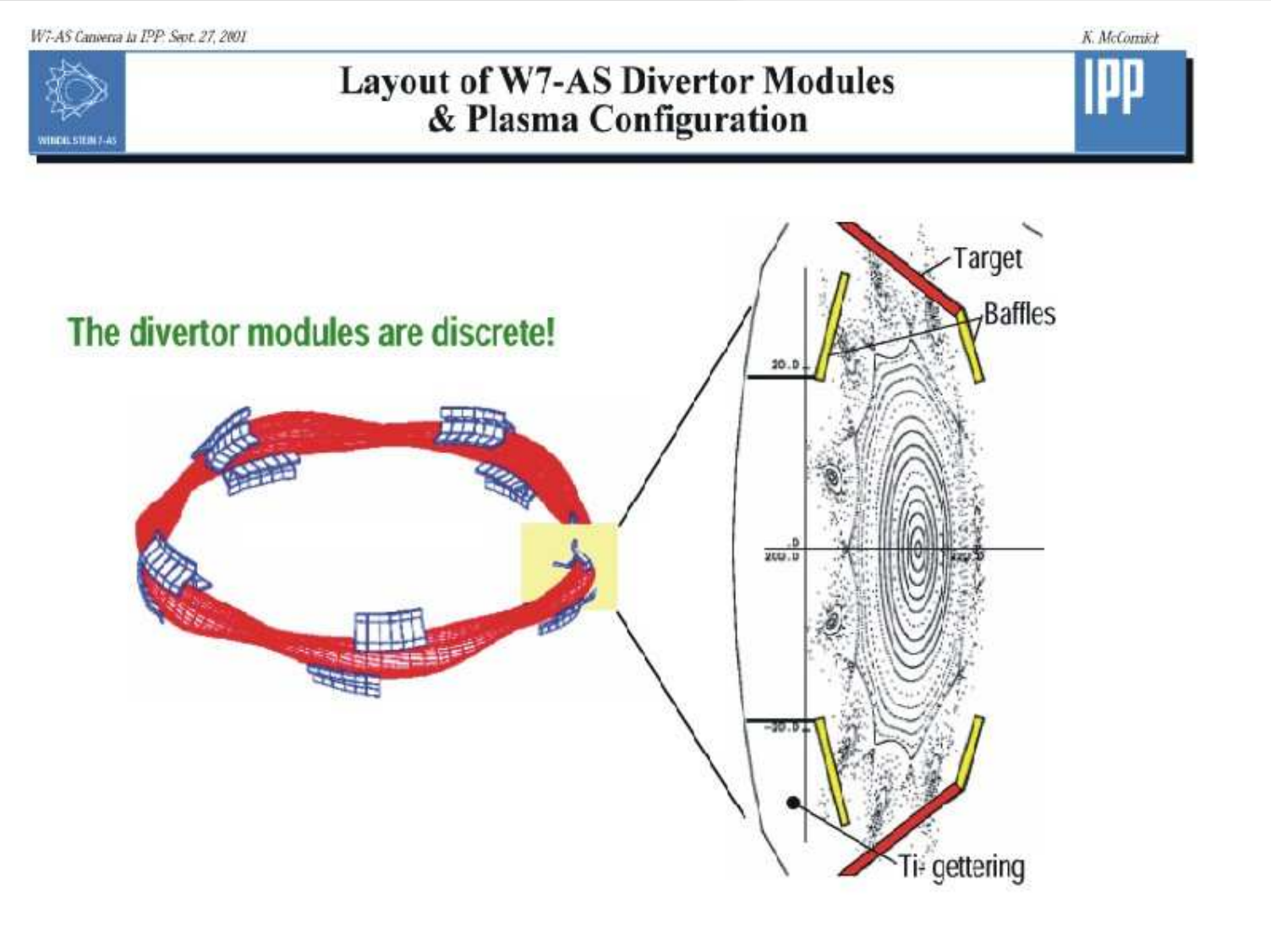
The W7-AS divertor



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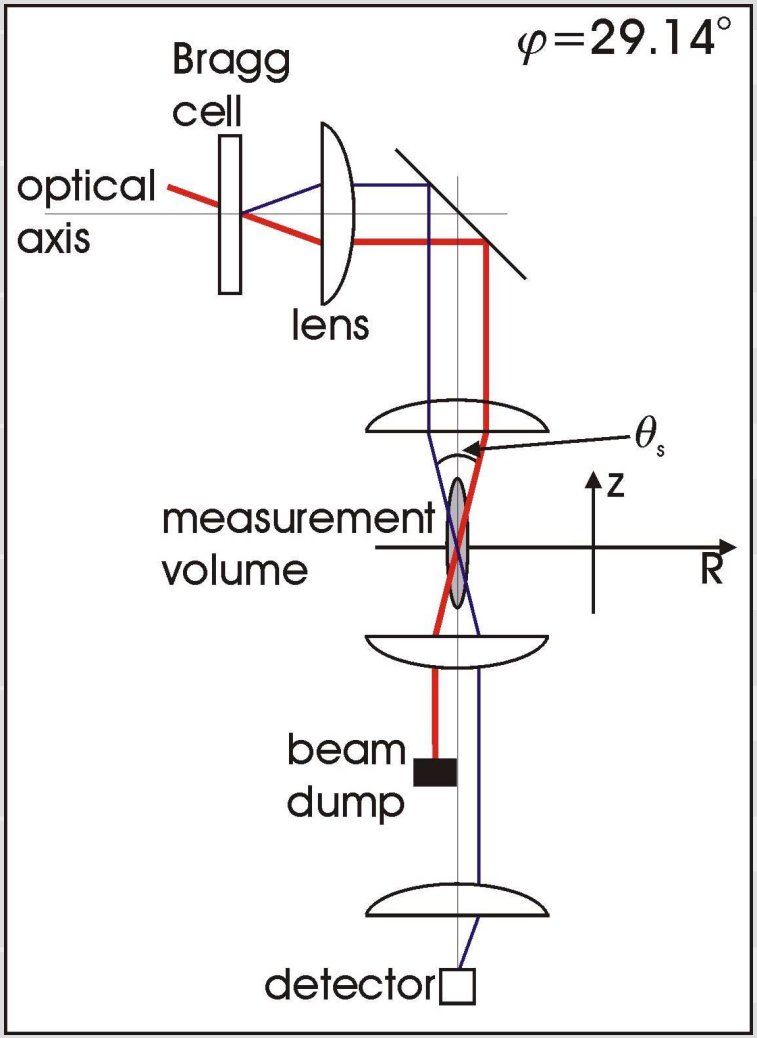
The density fluctuation diagnostic



- Diagnostic installed on the 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 range is from 14 to 62 cm^{-1}
- M. Saffman et al., Rev. Sci. Instrum. 72 (2001) 2579

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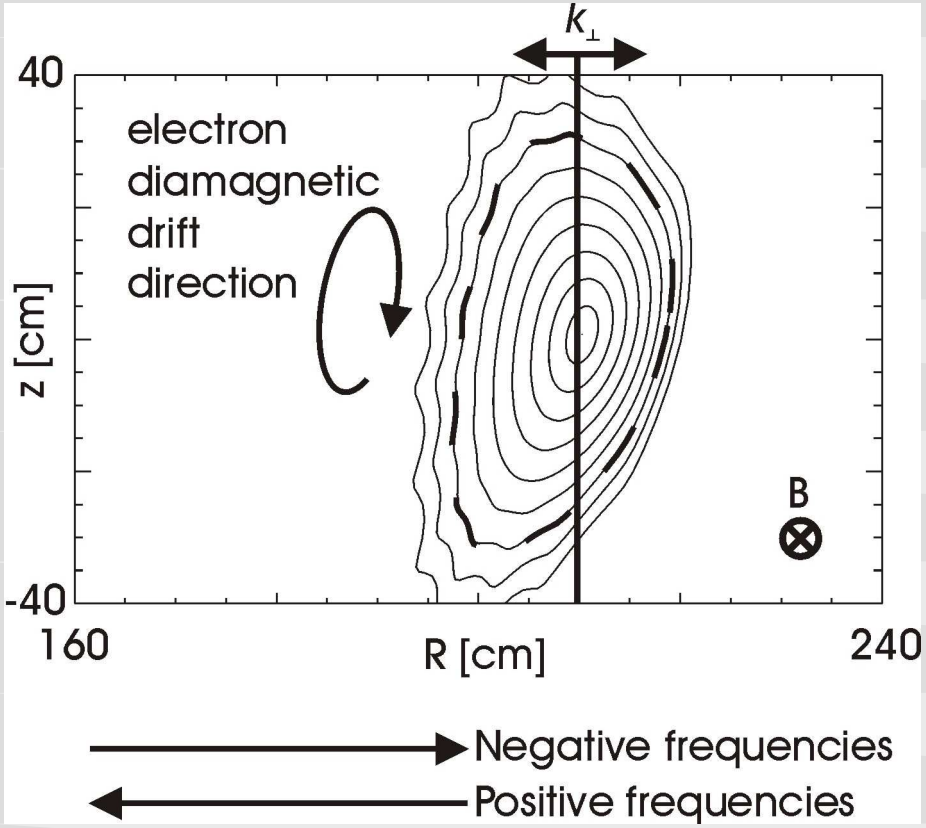
The density fluctuation diagnostic



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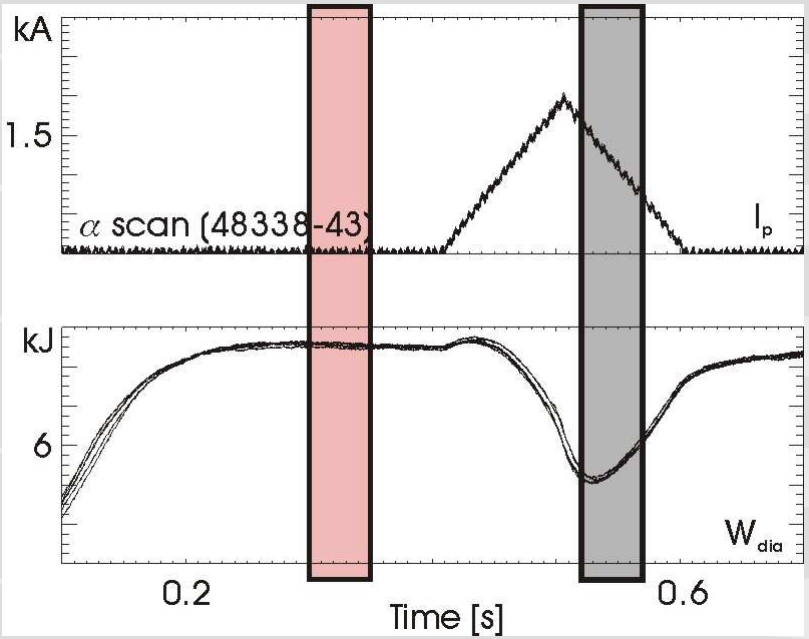
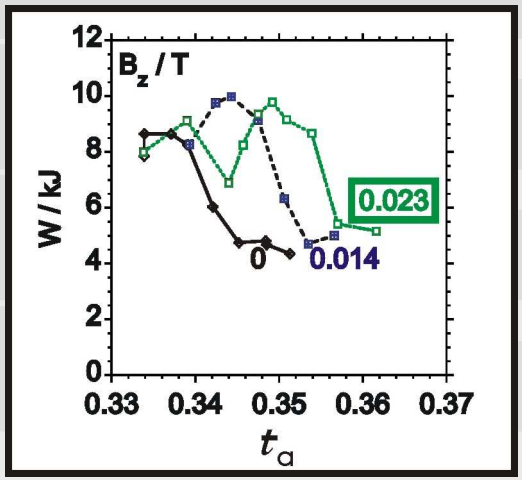
Current ramp experiments



A net plasma current can be created using an Ohmic (OH) external transformer

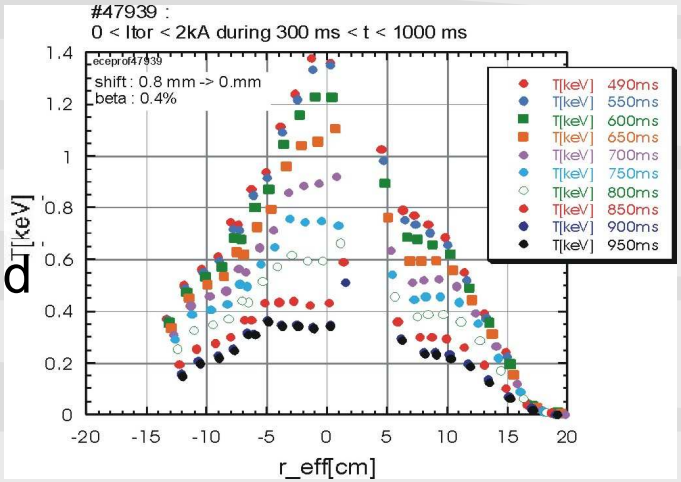
The current alters the rotational transform ι

The plasma confinement quality depends sensitively on ι



Plasma energy versus ι and the vertical magnetic field B_z

Electron temperature



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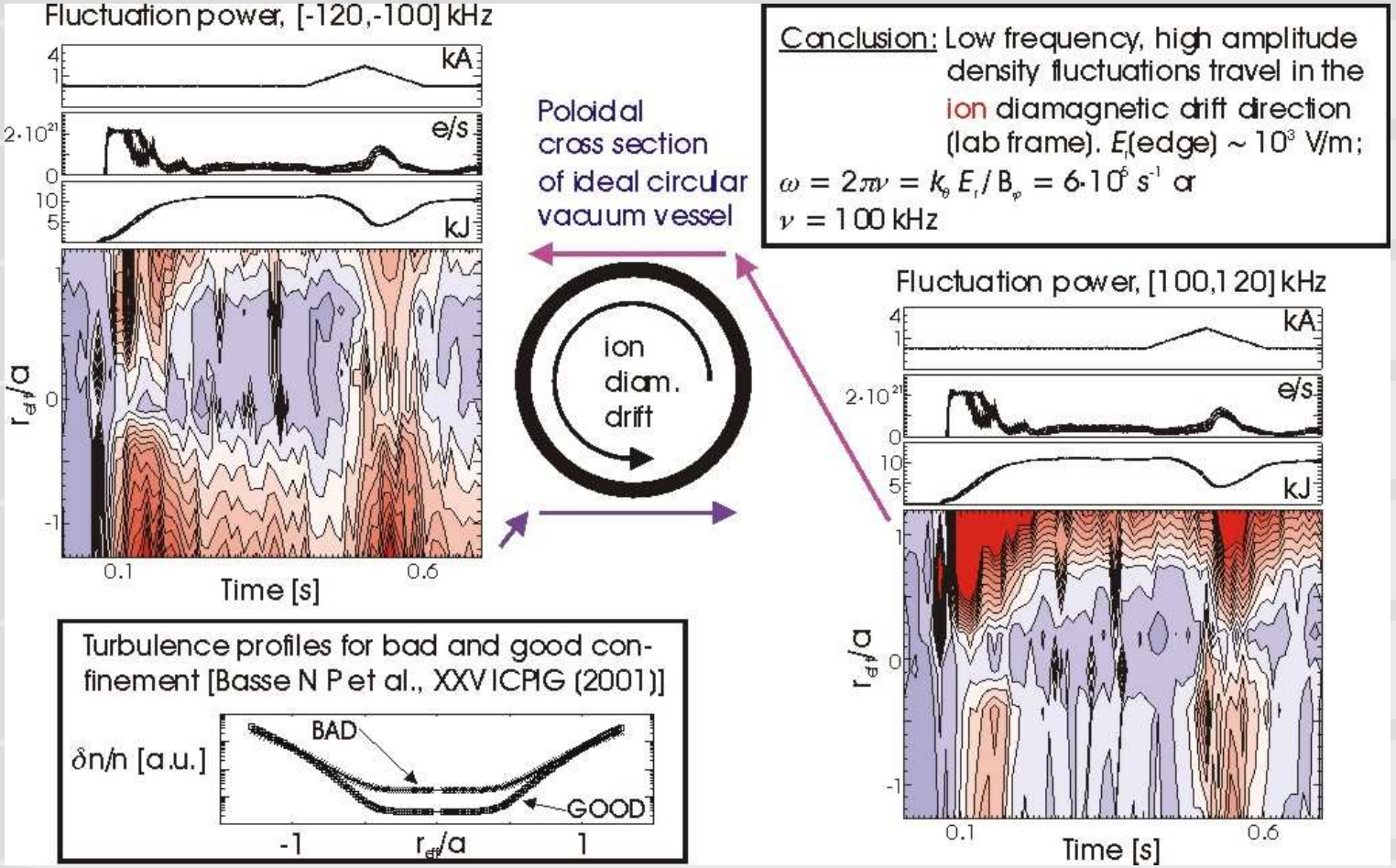
Current ramp experiments: Wide beam localisation



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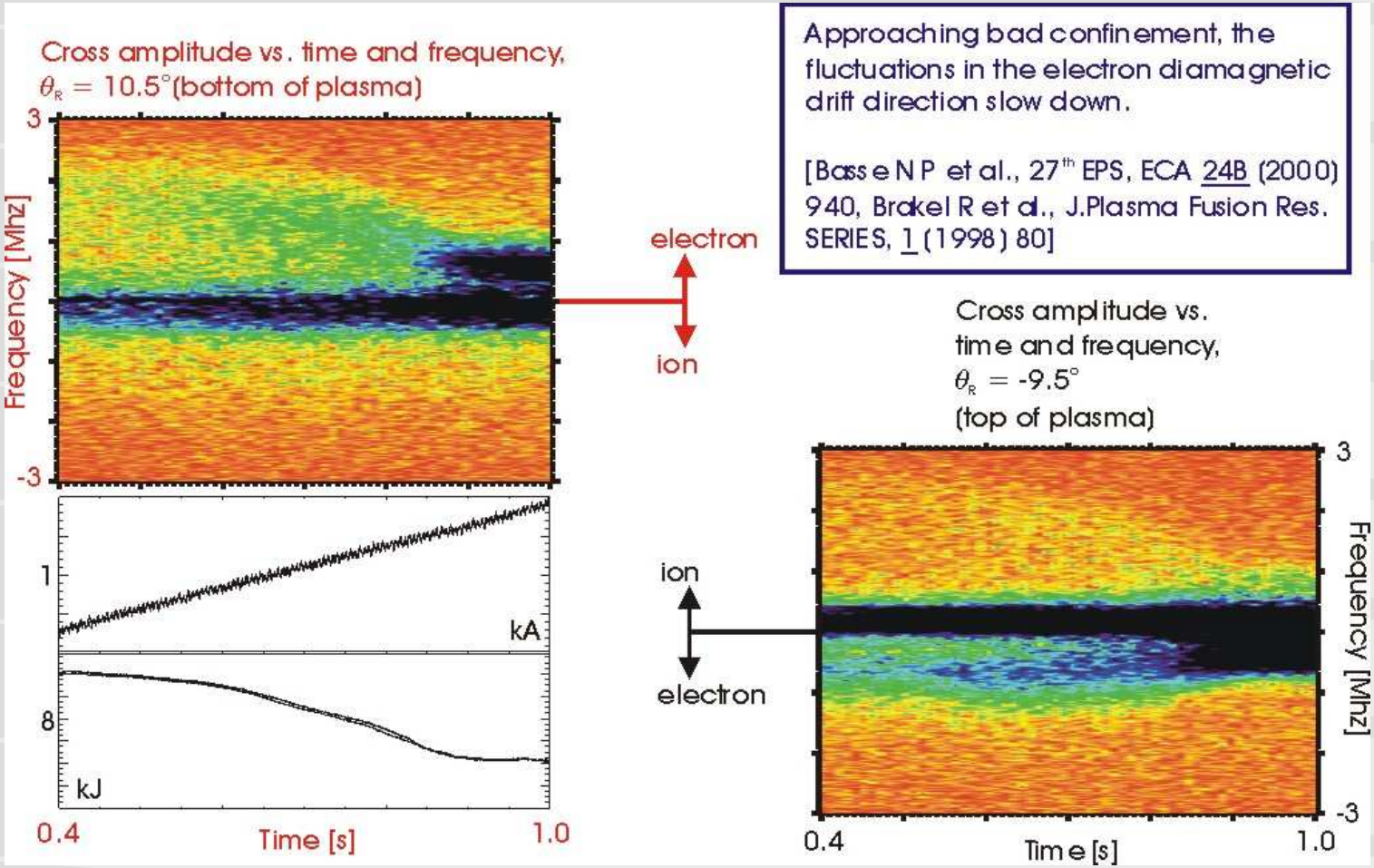
Current ramp experiments: Narrow beam localisation



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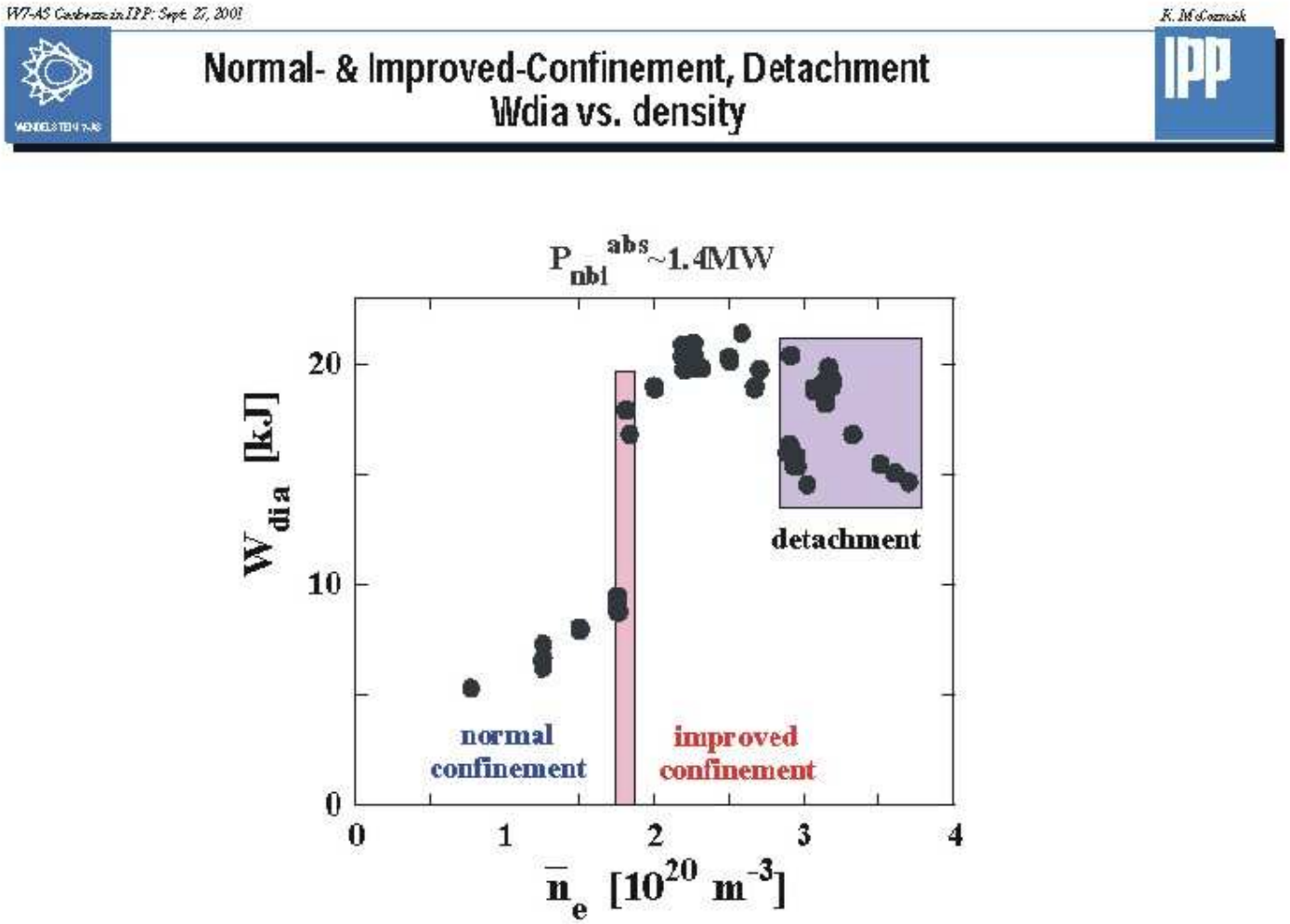
The ultra high density mode



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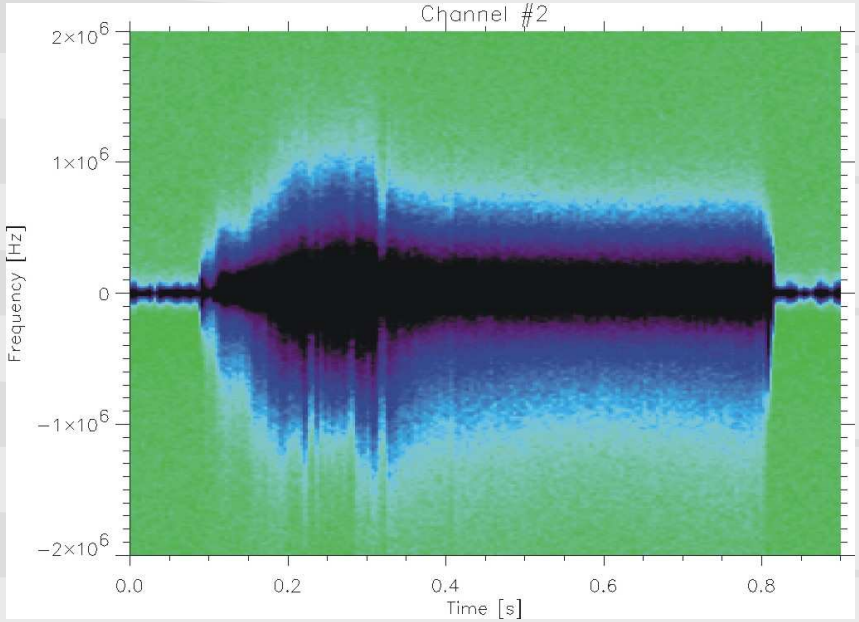
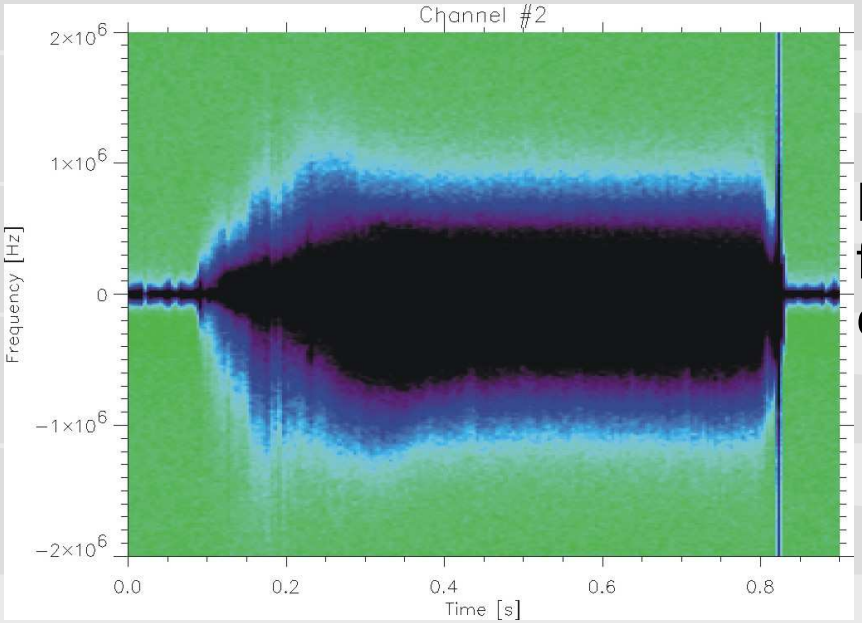
The ultra high density mode

Right: Autopower spectrum versus frequency and time, bad confinement





Left: Autopower spectrum versus frequency and time, good confinement

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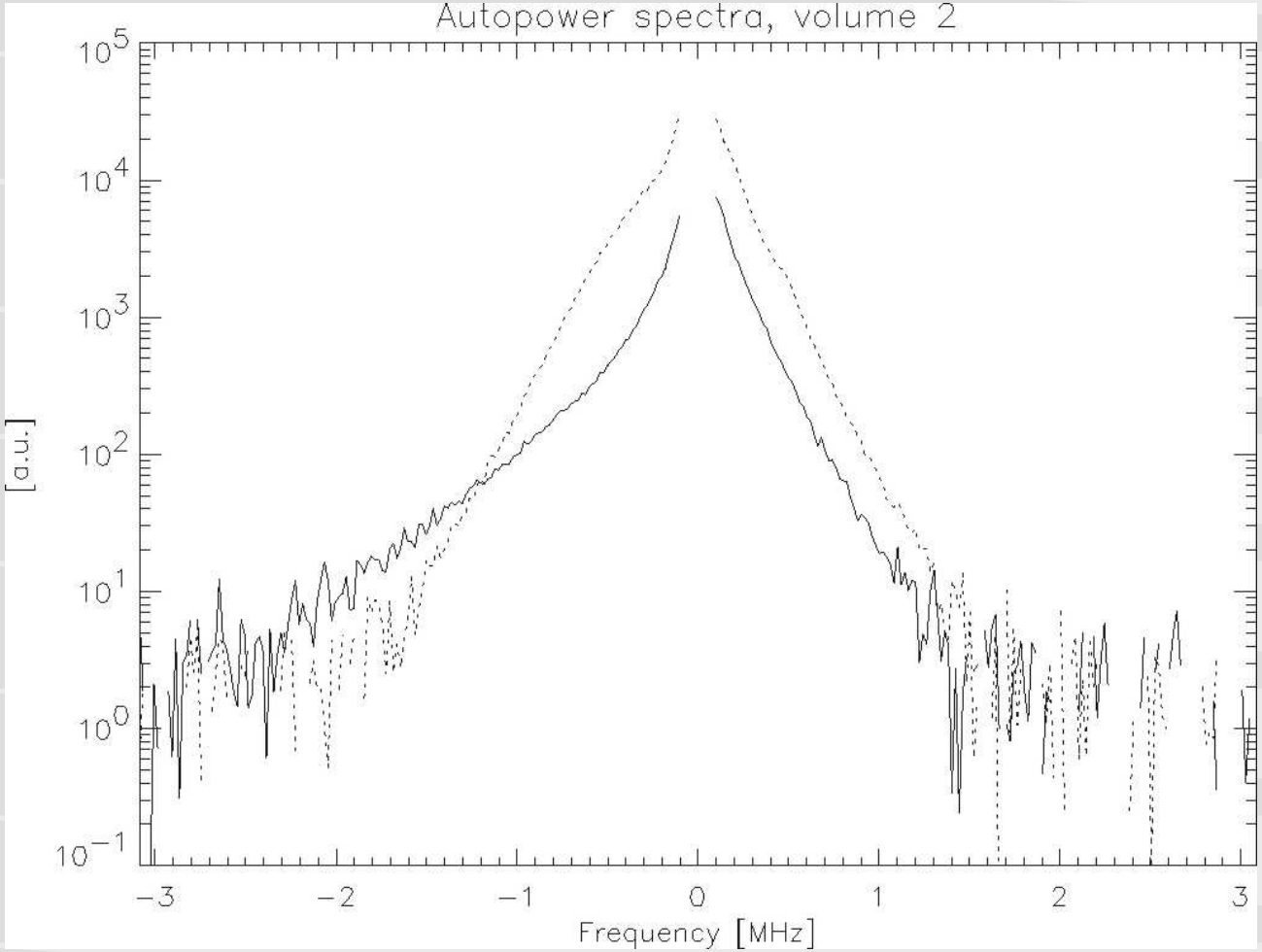
The ultra high density mode



Good confinement:
Dotted line

Bad confinement:
Solid line

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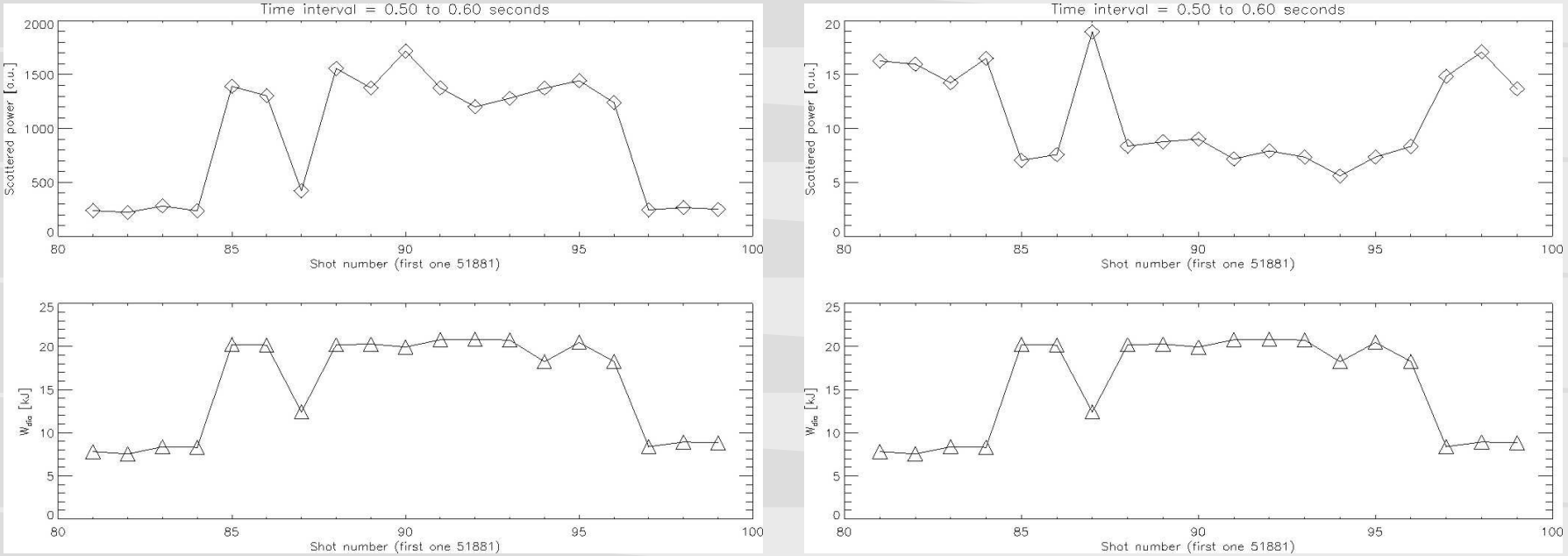
The ultra high density mode



Top rows:

- Left: Autopower integrated over all frequencies [-3,3] MHz versus shot number
- Right: Autopower integrated over [-3,-1.2] MHz versus shot number

Bottom rows (identical):

- Stored energy versus shot number

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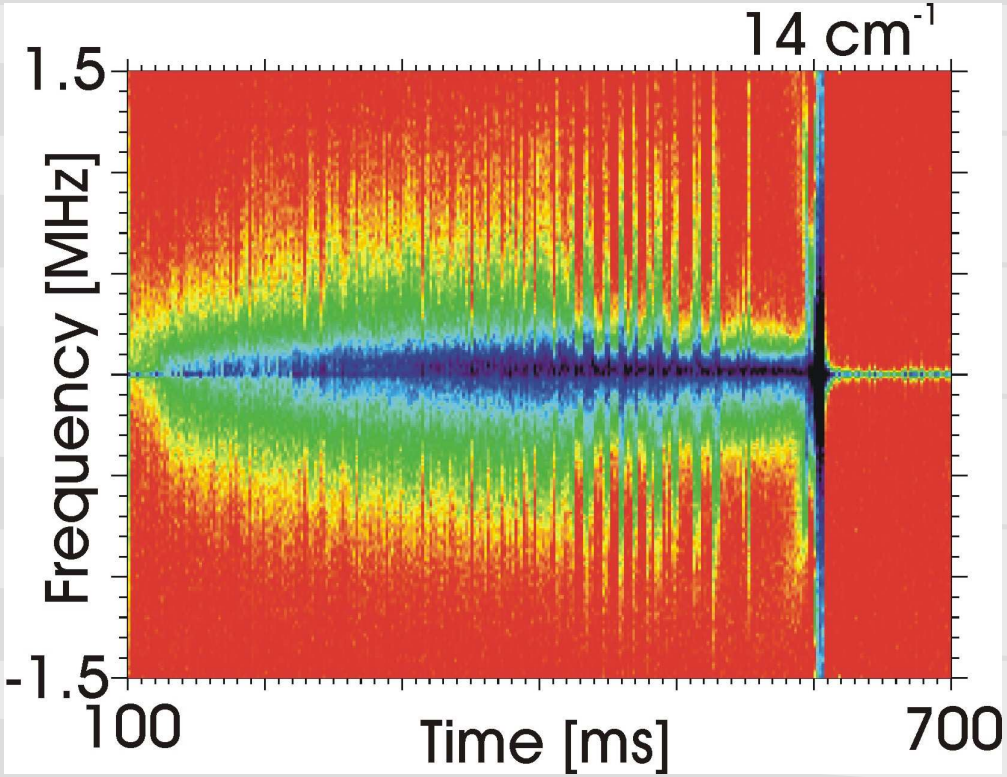
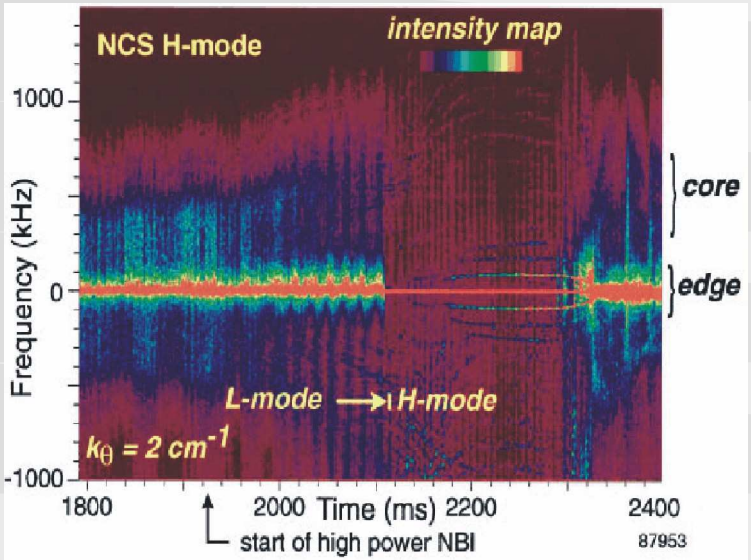
Low- and high confinement mode

Right-hand figure:

Autopower spectra from a W7-AS shot displaying three distinct phases:

1. L-mode 100-400 ms
2. Dithering H-mode 400-550 ms
3. ELM-free H-mode 550-600 ms





Left-hand figure:

Autopower spectra from a DIII-D discharge.

C. L. Rettig et al., Phys. Plasmas 4 (1997) 4009

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