Fluctuation Measurements with Li-beam and CO$_2$ laser scattering at the "iota edge"

Sándor Zoletnik

KFKI-RMKI, EURATOM Association

Nils Basse

RISO National Lab. EURATOM Association

Outline:

Types of discharges

Diagnostics used

Overview of main experimental results

Understanding of phenomena

Remaining questions and ways to analyse them

# Measurements performed

All discharges with

" 400 kW ECRH heating

" Close to iota=0.35

" line density 0.5-3 10^{13} cm^{-3}

" Measurements with and without divertor

Discharge types

" Good confinement (iota<0.35)

" Bad confinement (iota>0.35)

" Good confinement with fast current ramp (2kA in 100ms)

(The current moves the plasma from good to bad confinement)

" Bad confinement with fast current ramp

(Comparison with good confinement +current ramp)

" Good confinement with slow current ramp (2 kA in 700 ms)

(Slowly moves from good to bad confinement)

Good confinement with fast current ramp
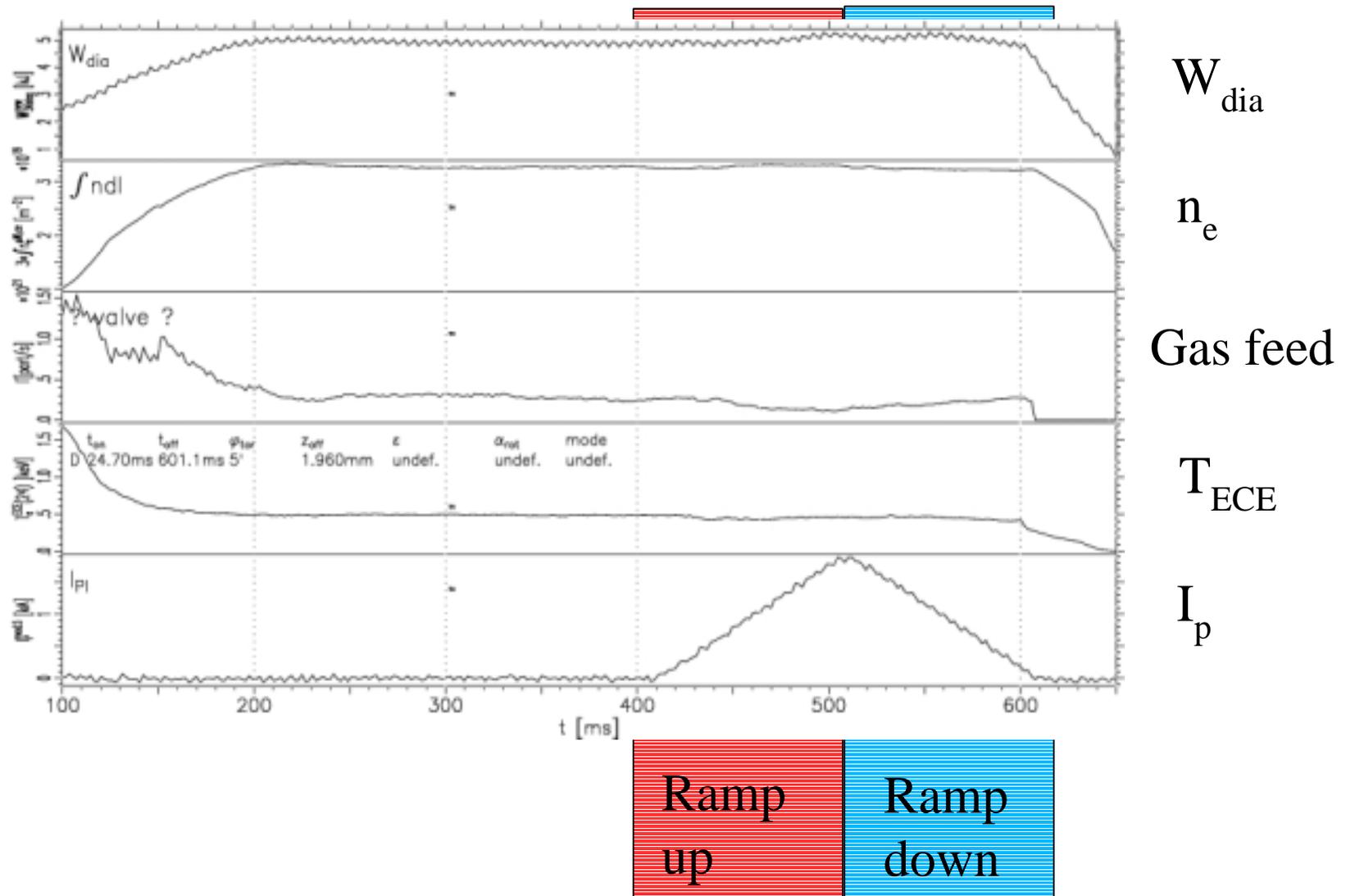## (Bt=2.5T, iota=0.344, Bz=22mT, ECRH 400kW)
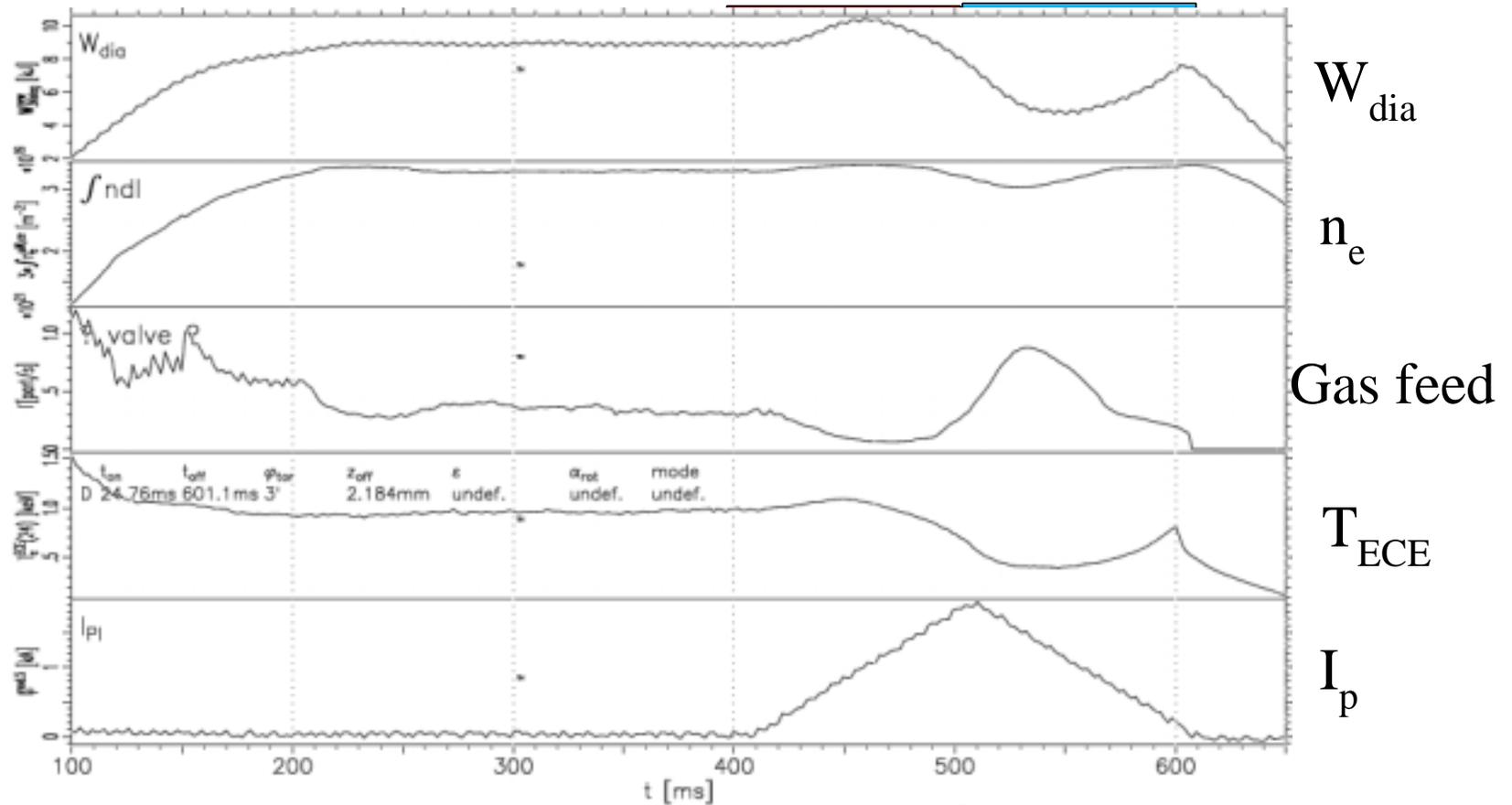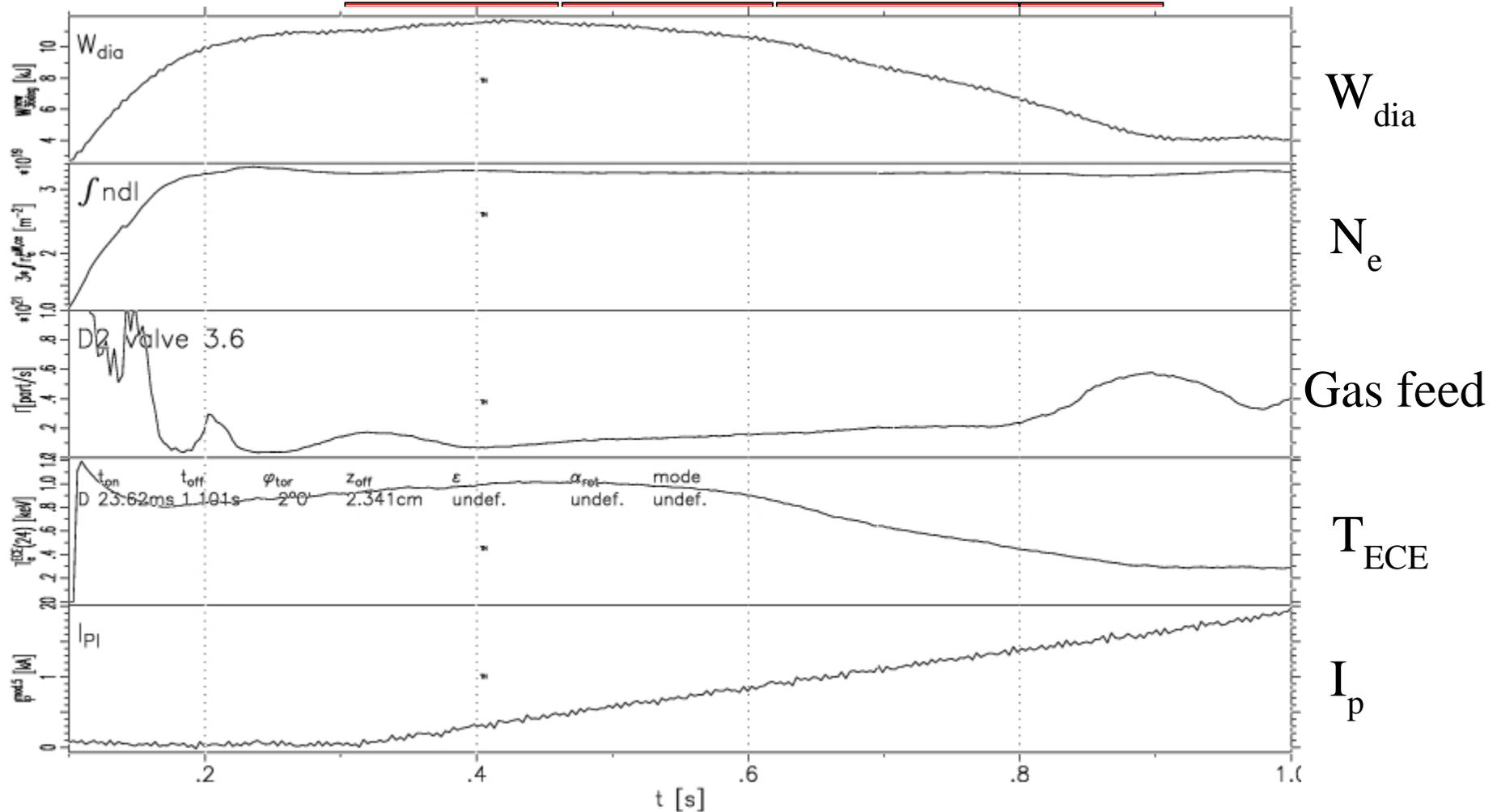

| Ramp up | Ramp down |

Bad confinement with fast current ramp
(Bt=2.5T, iota=0.362, Bz=22mT, ECRH 400kW)

W_{dia}

n_e

Gas feed

T_{ECE}

I_p

Ramp up	Ramp down

Good confinement with slow current ramp
(Bt=2.5T, iota=0.344, Bz=22mT, ECRH 400kW)

Slow current ramp minimizes current penetration effects

Slow degradation with several phases

General observations during the confinement degradation

"Discharges are reproducible

but

"Very sensitive to heating mode

"Transition has no internal time constant

"Degradation details are controllable by plasma current

"Transition is roughly the same with divertor as before it

These features indicate that no bifurcation is involved. If the transition is caused by turbulence, there is no feedback from the profile changes to the turbulence.

This is in clear contrast to the L-H mode transition.

Diagnostics used in the analysis

CO2 laser scattering

Line integrated relative density fluctuation frequency and k spectrum. Flow velocity direction resolved. Some localisation is provided using the changing direction of the magnetic field.
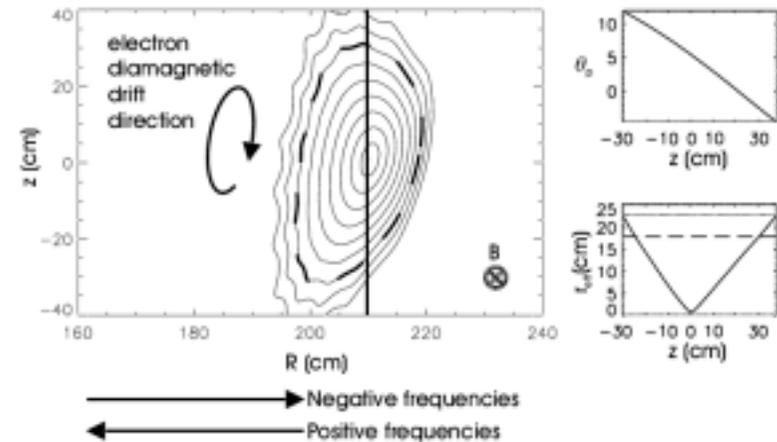
Li-beam Beam Emission Spectroscopy

Determines absolute fluctuation amplitude profile, temporal, radial and poloidal correlation in SOL and edge. Limited to structures larger than about 1 cm. Spatial resolution is limited to 1 cm.
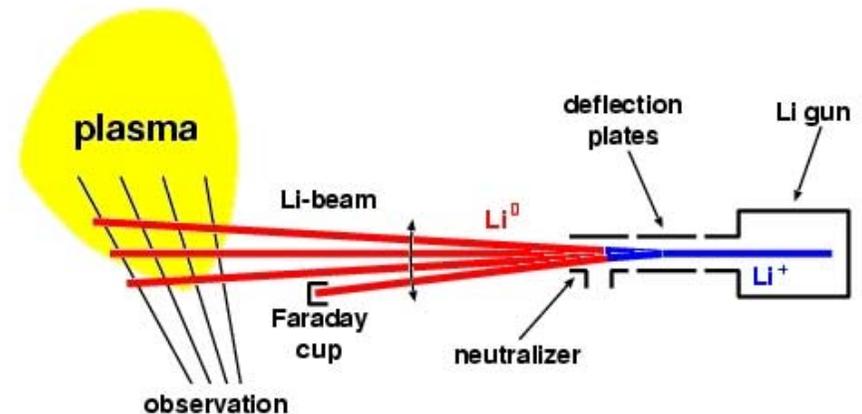
Mirnov coils

Reflectometry

General observations with the fluctuation diagnostics during confinement transition

"There are reproducible changes in fluctuation properties (amplitude, k-spectrum, power-spectrum, flow velocity)

"Fluctuation change with iota modification is identical to fluctuation change with current ramp

"The changes are gradual when degradation is gradual

"The fluctuation amplitude itself is not correlated with confinement (not everyl k)

"Large difference in SOL/egde turbulence change with/without divertor is seen with the Li-beam! (Local measurement)

Turbulence phenomena analysed

" Core turbulence (electron d.d., CO2 laser scattering)

" SOL turbulence (ion d.d., Li-beam)

" Mode-like core phenomena (Li-beam, Mirnov coils)

Major changes in fluctuations during confinement degradation
Relative weight of large structures (≈1cm) increases

"Seen by CO_2 laser scattering as change in slope of the k-spectrum

"Exponent correlates with confinement even

temporally
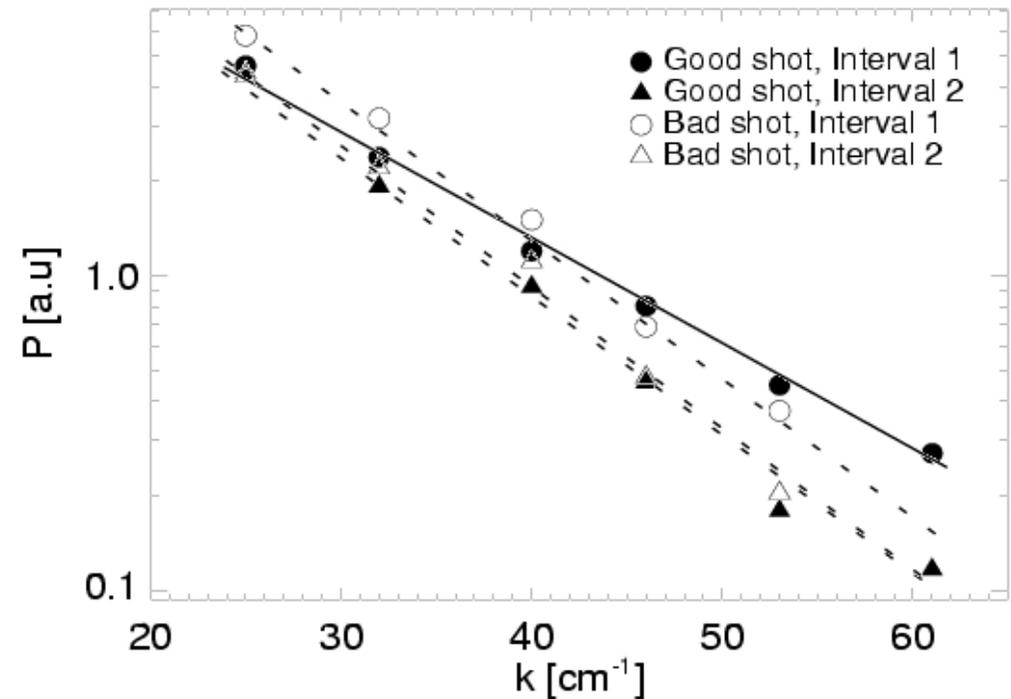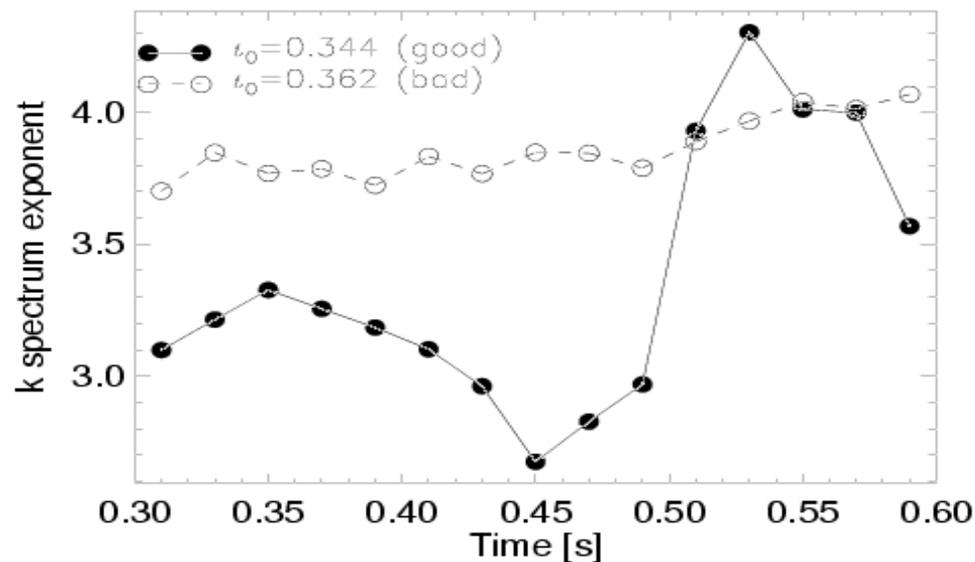
Major changes in fluctuations during confinement degradation (cont'd)
Long wavelength (k=15cm^{-1}) Density fluctuations extend from edge to core

The CO2 laser scattering diagnostics has seen in fast current
ramp discharges that turbulence extends to the core.
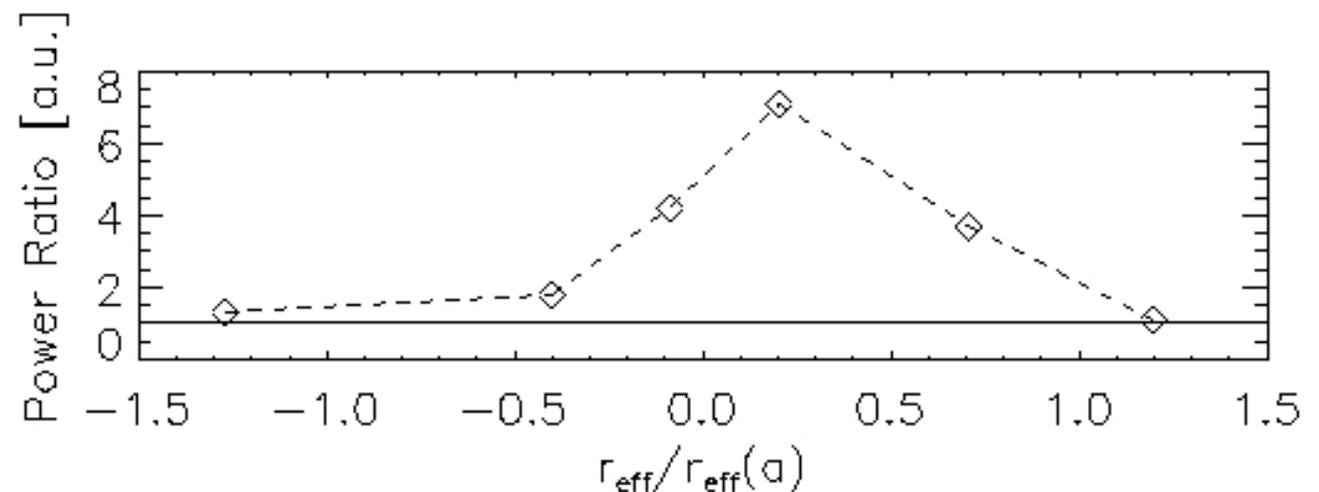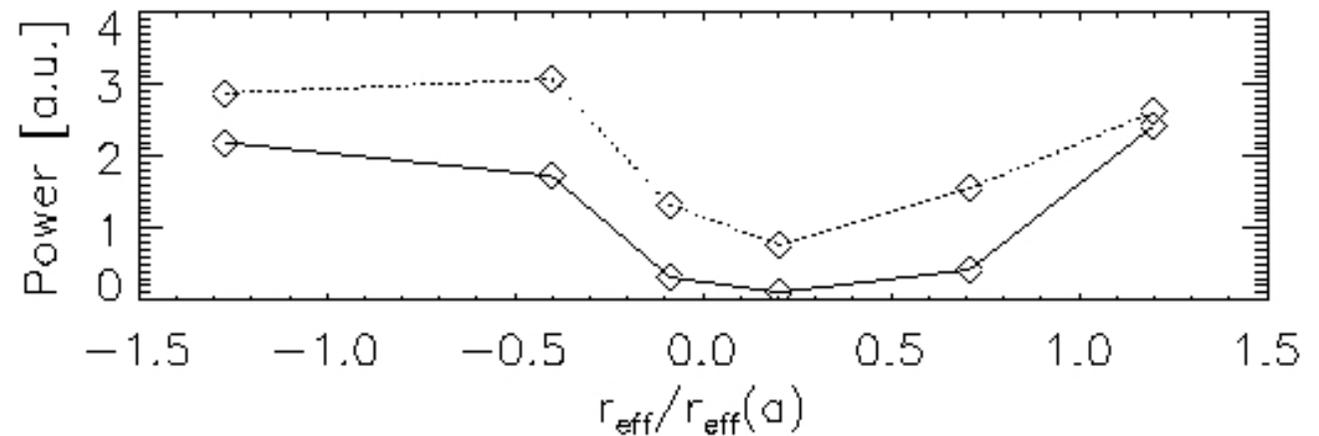
Major changes in fluctuations during confinement degradation (cont'd)
Poloidal flow velocity decreases in degraded confinement

The CO2 laser scattering, reflectometry and Er field measurement see a drop in poloidal flow velocity in the confinement region.

Power spectrum at the bottom of the plasma in good and bad confinement
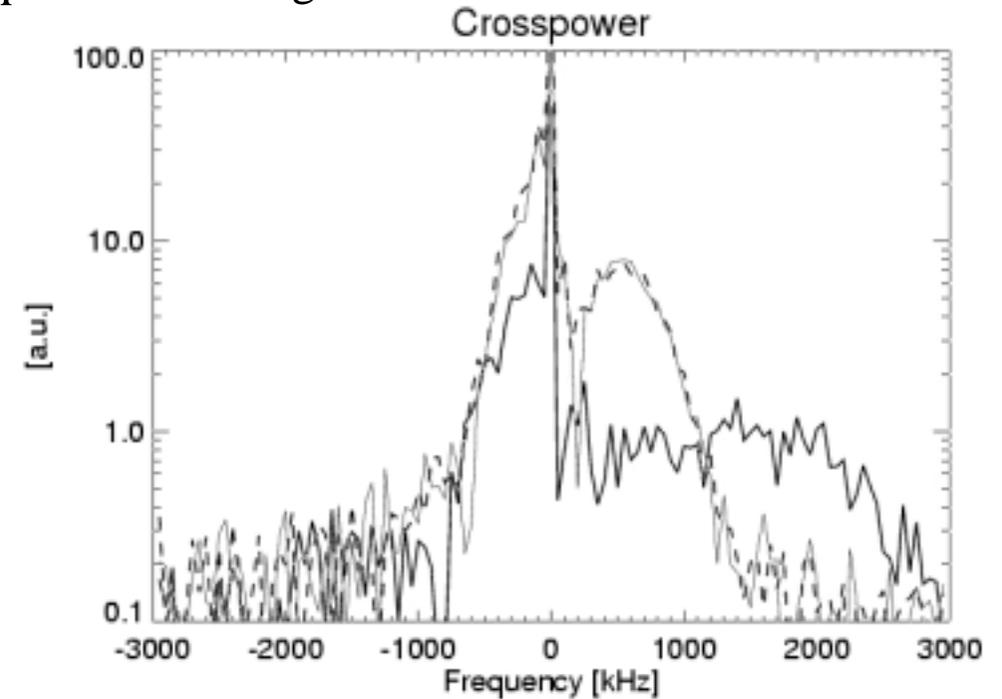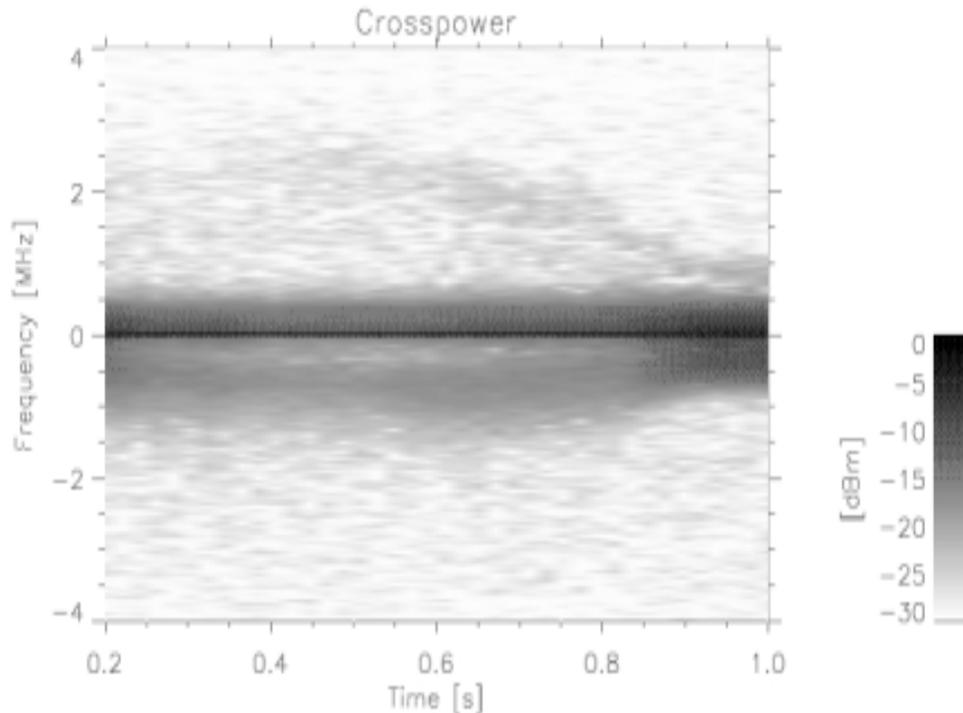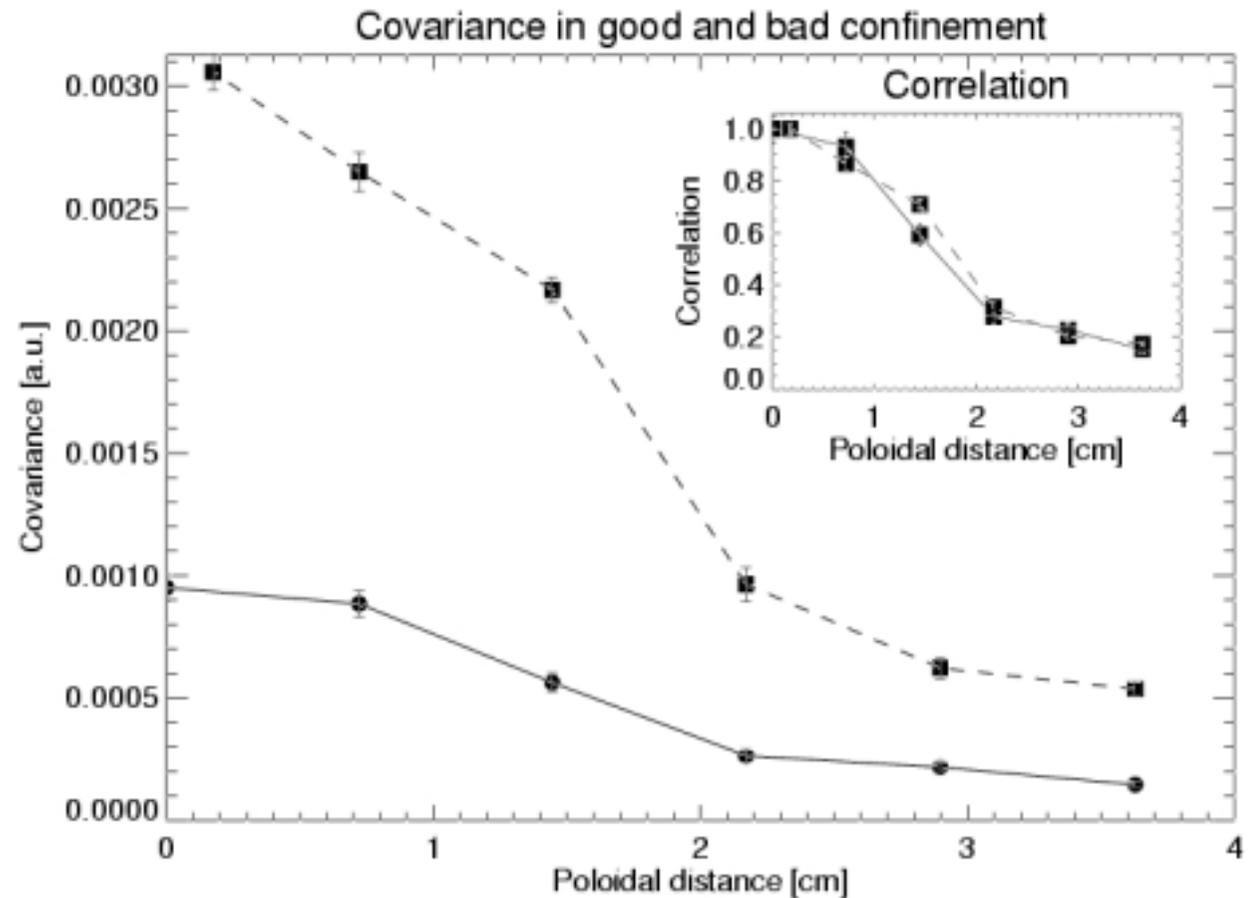

Ion diamag. Direction

Electron diamag. Direction

In measurements before the divertor the Li-beam did not detect much change in SOL turbulence during confinement degradation.

In new measurement with the divertor there is a large increase in amplitude but no change in poloidal correlation length.
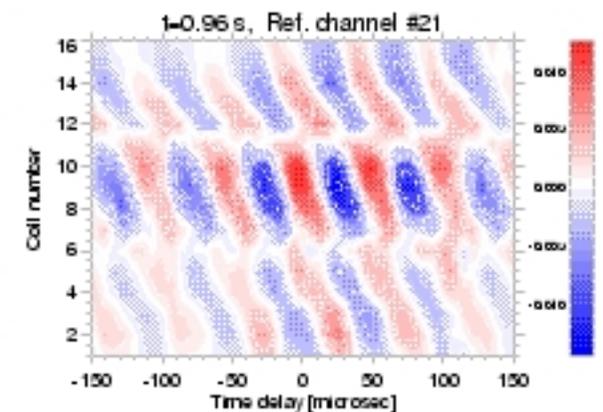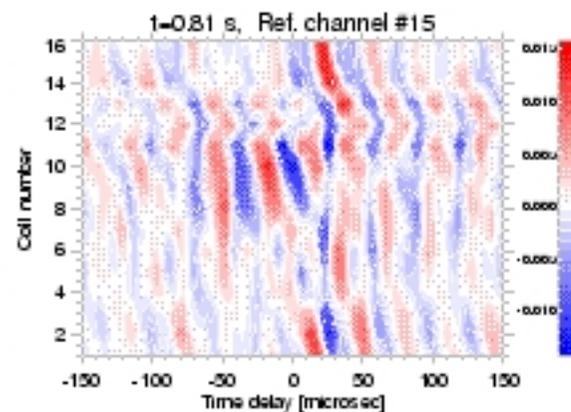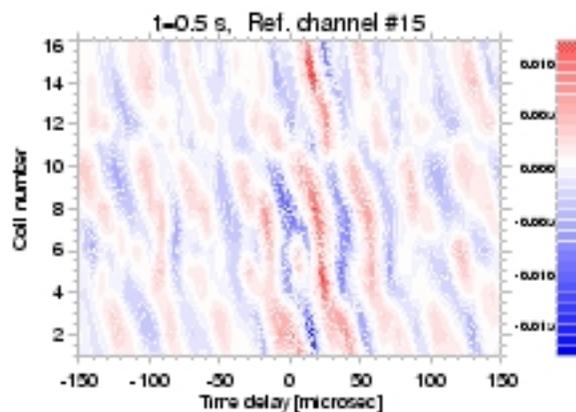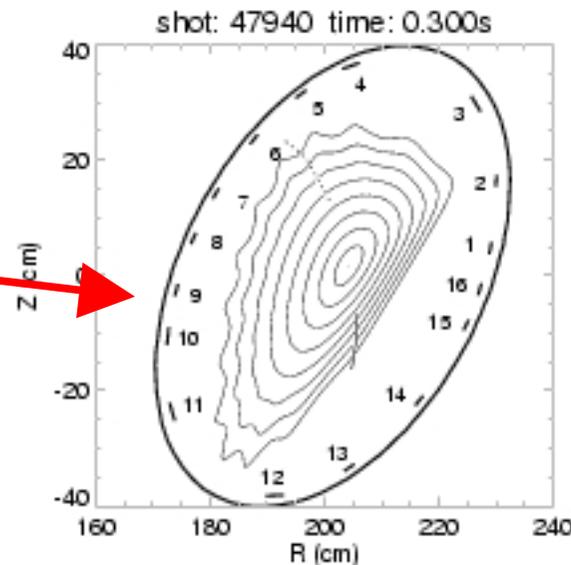

Covariance in good and bad confinement

Major changes in fluctuations during confinement degradation (cont'd)
Poloidal distribution of edge fluctuations

The poloidal distribution is measured by the crosscorrelation of all Mirnov signals with one edge Li-beam channel.

" Without divertor fluctuations get localised to the inboard limiter during confinement degradation
" With divertor no localisation happens

shot: 47940 time: 0.300s

t=0.5 s, Ref. channel #15

t=0.81 s, Ref. channel #15

t=0.96 s, Ref. channel #21

S. Zoletnik

Major changes in fluctuations during confinement degradation (cont'd)
Mode-like fluctuations

Short correlation time (few cycles) mode-like fluctuations with different frequency show interesting changes during confinement degradation.
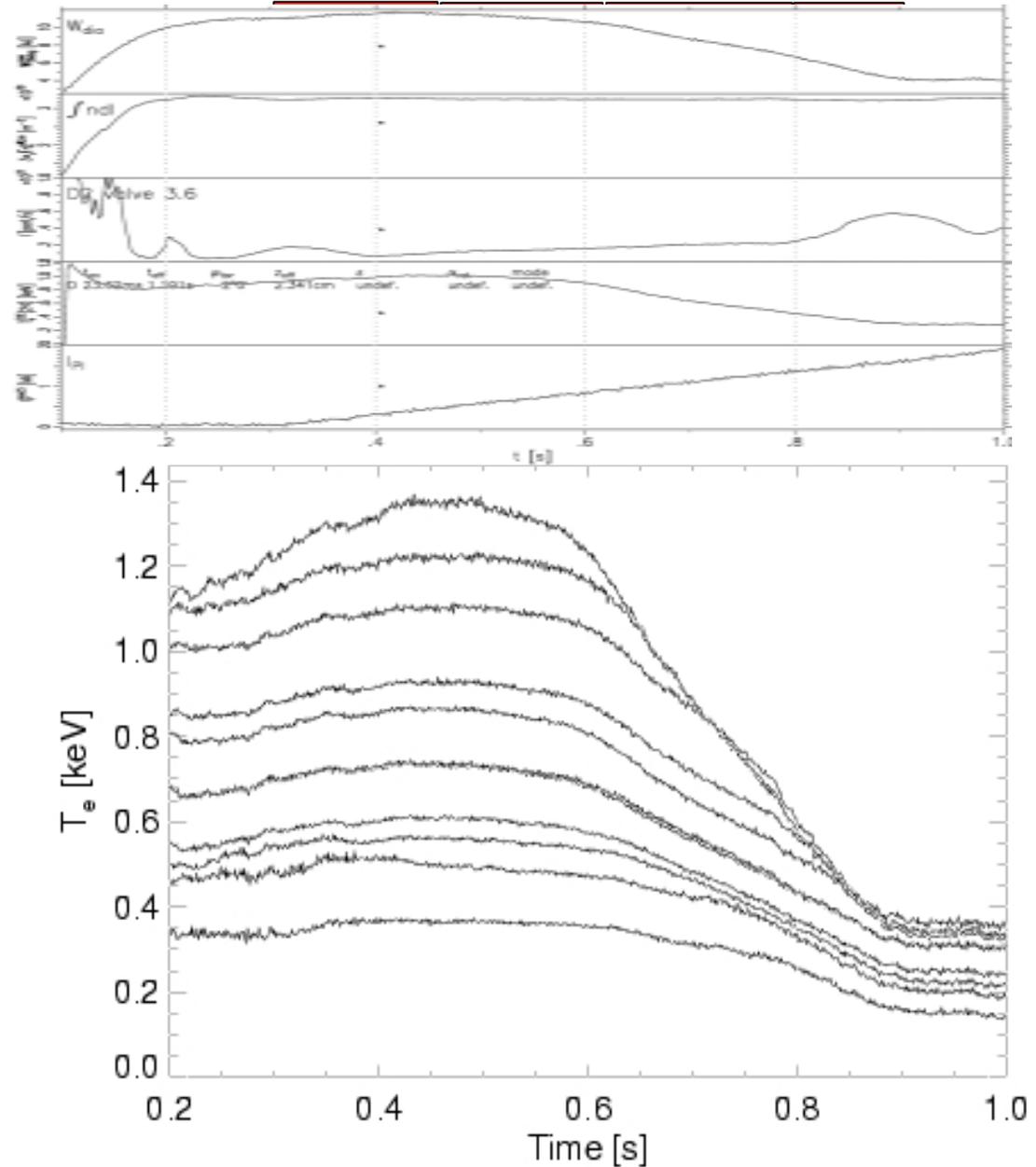
Modes seem to merge when tendencies change.

These modes are probably localised to some surfaces (rationals?) and merging might be connected to plateau formation.
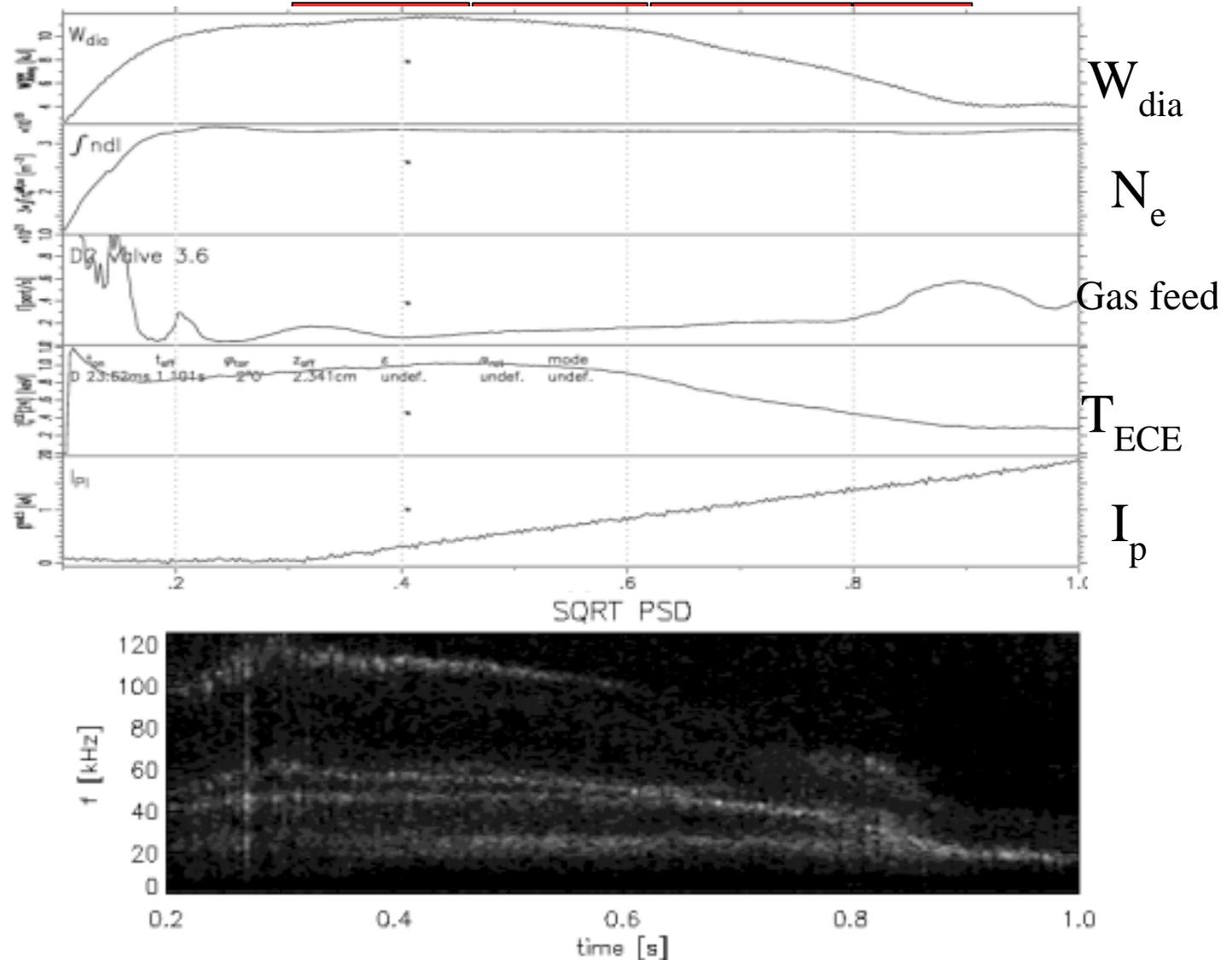
Plateaus seem to form at the same timepoints where mode-like frequencies merge.

Picture of confinement degradation

"Good and bad confinement radial regions are present in plasma

"These regions move radially with iota and merge

"Lowest confinement is reached when bad confinement region reaches to the limiter/divertor

"Mode-like phenomena are probabaly localised to good or bad confinement regions.

"Poloidal flow velocity changes as a result of transport change (different flow velocities with/without divertor.

Remaining questions and ways to analyse them

"Localisation of mode-like phenomena → ECEI+Mirnov

"What are the mode-like phenomea? (GAE?)

"Is poloidal flow velocity change a consequence? → modify flow velociy (by NBI?)

"Location of good/bad confinement regions → radial ECRH heating scan, LBO for particle transport measurement

"Relation between good/bad regions and iota → iota profile modification by ECCD?

"Is SOL turbulence localised around limiter/divertor strike point in degraded confinement? → Langmuir probes

"Turbulence behaviour at other iota-edge?

Ongoing work

Calculation of 2D density fluctuation correlation functions

Modeling of fluctuation signals from fluctuation structures
(simple eddy, streamer, zonal flow...)

Analysis of some CO_2 scattering measurements

Calculation of correlations along flux surfaces