Systematic study of broadband turbulence properties in Ohmic, ICRH and LH plasmas

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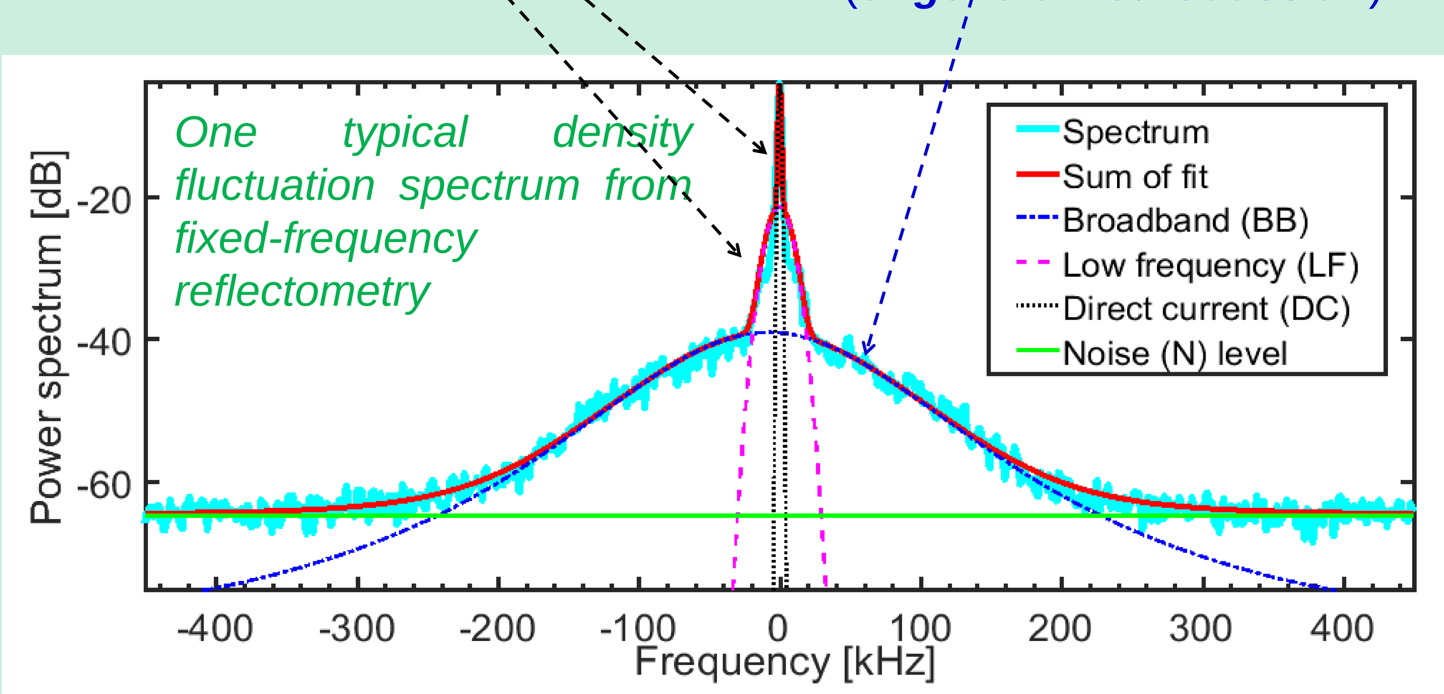
INTRODUCTION

The reflectometry spectra can be decomposed in several components [1]. To perform systematic studies, a parametrization method was developed to fit each component [2]:

Spectrum = Direct current + Low frequency + *Broadband* + Noise level

Two Gaussians + ***Taylor function*** [3] + Const.
(***or generalized Gaussian***)



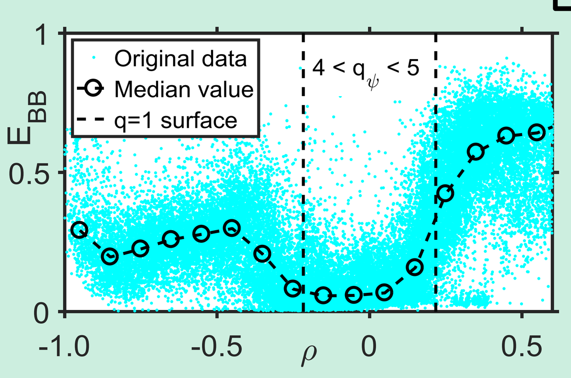
- A turbulence database contains 350,000 acquisitions from 6,000 Tore Supra shots, excluding the spectra with strong (>50 kHz) Doppler effect or low (<25 dB) SNR.
- The spectrum characteristics pave the way to extract general trends from the database.

Radial profiles of spectrum characteristics

To systematically investigate the evolution of spectrum characteristics, the normalized broadband contribution is defined as:

$$E_{BB} = \frac{\int BB\,dF}{\text{Total power of spectrum}} \approx \frac{\int BB\,dF}{\int BB\,dF + \int LF\,dF} \quad (0 < E_{BB} < 1)$$

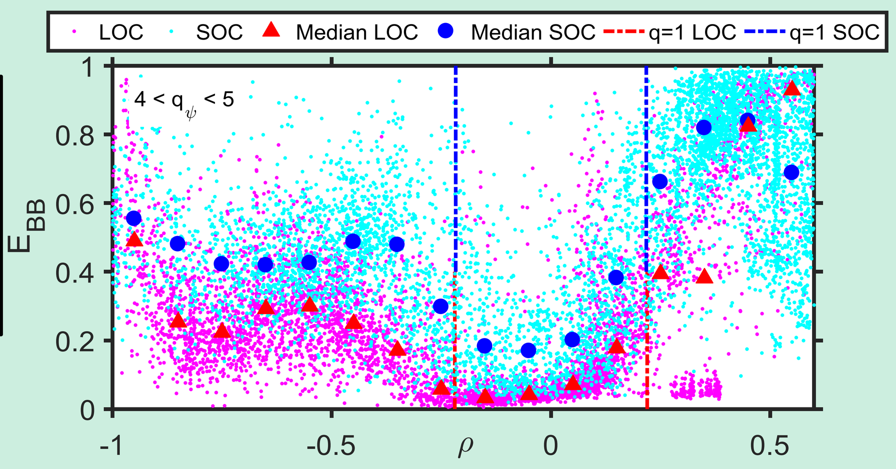
Radial profiles of E_{BB} in Ohmic

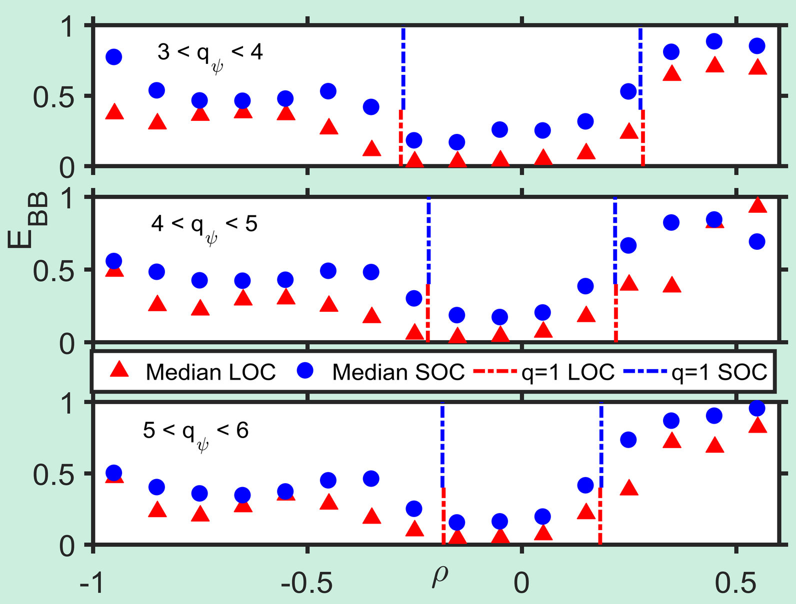


- A drop *"basin"* appears inside the q=1 surface.
- The width of this basin scales with the q=1 position
- This extends results obtained on dedicated shots in [4]
- The radial profiles of the E_{BB} median value is obtained by averaging over $d\rho = \pm 0.05$.

To study the difference between LOC & SOC regimes, a LOC/SOC empirical threshold was obtained from Tore Supra (N_l, τ_E) database:

$$N_{LOS/SOC}\ (10^{19}\mathrm{m}^{-2}) \approx 2.6 \times I_p\ (\mathrm{MA}).$$





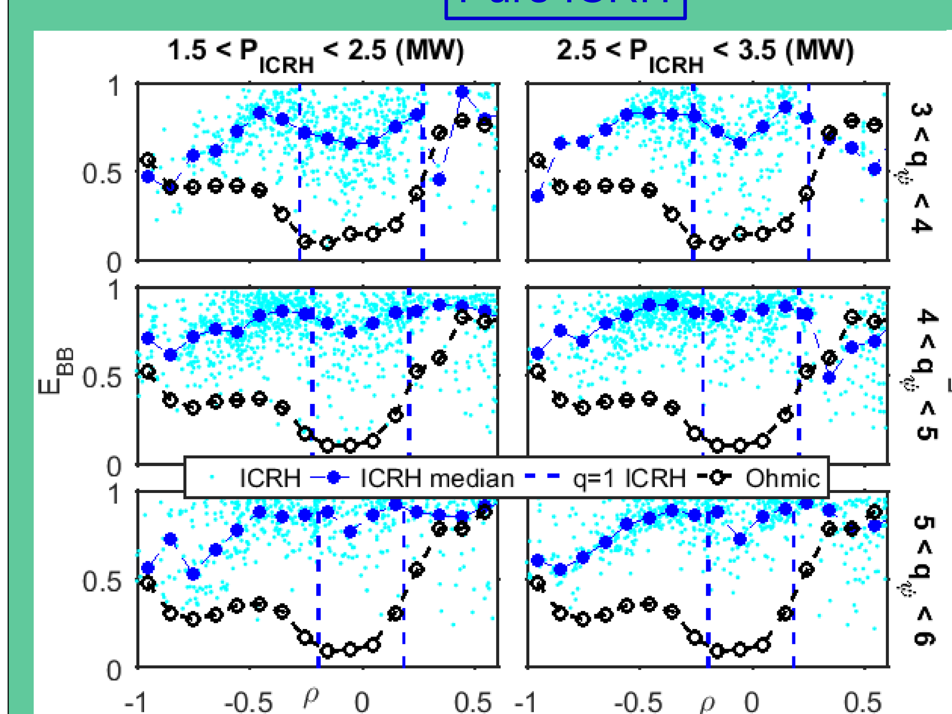
- The basin is observed in LOC and SOC regimes in all q_ψ range.
- In the basin, but also at all positions

$$E_{BB}{}^{SOC} > E_{BB}{}^{LOC}$$

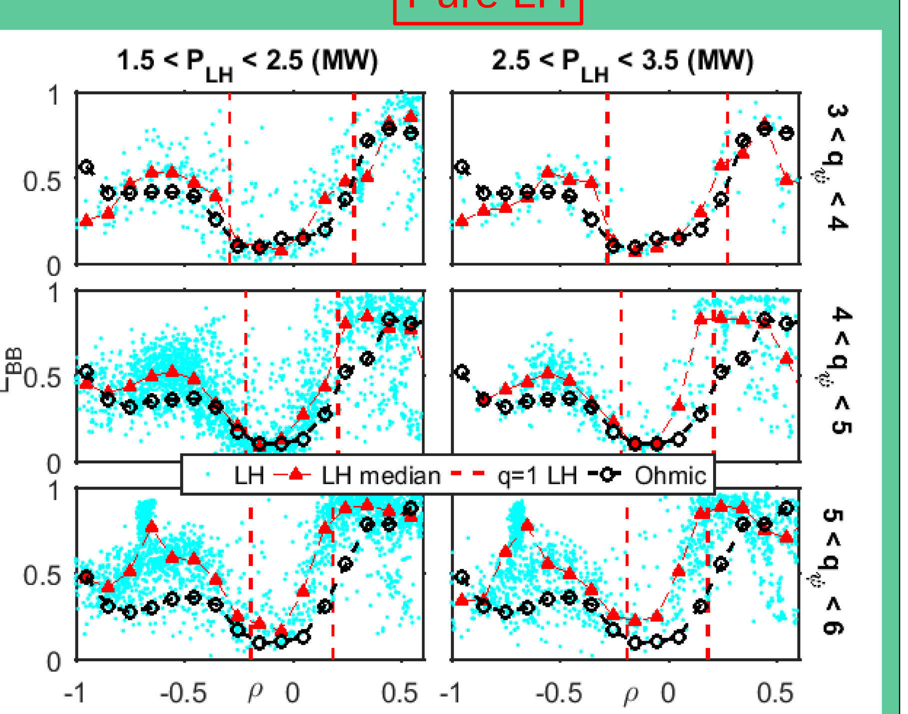
➔ higher fluctuations in SOC than in LOC

Radial profiles of E_{BB} in L-mode with additional heating

Pure ICRH



Pure LH



- For ICRH, E_{BB} reaches high level (>0.5) even at low P_{ICRH} and the basin disappears at high P_{ICRH}, whereas the basin remains for LH even at high Power.
- The huge differences on BB component (>5 times in the basin) between ICRH and LH are difficult to explain by a different fluctuation level in the two heating methods

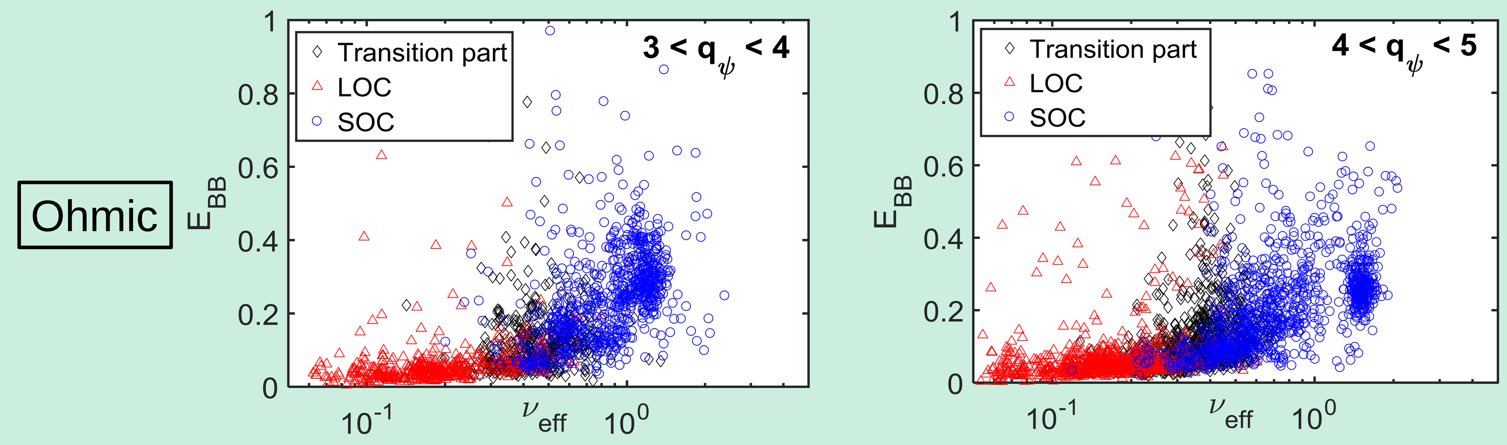
Are spectra evolutions related to a change of turbulence regime?

Transition from TEM to ITG has been shown to induce the disappearance of the Quasi-Coherent component in the reflectometry spectra [5].

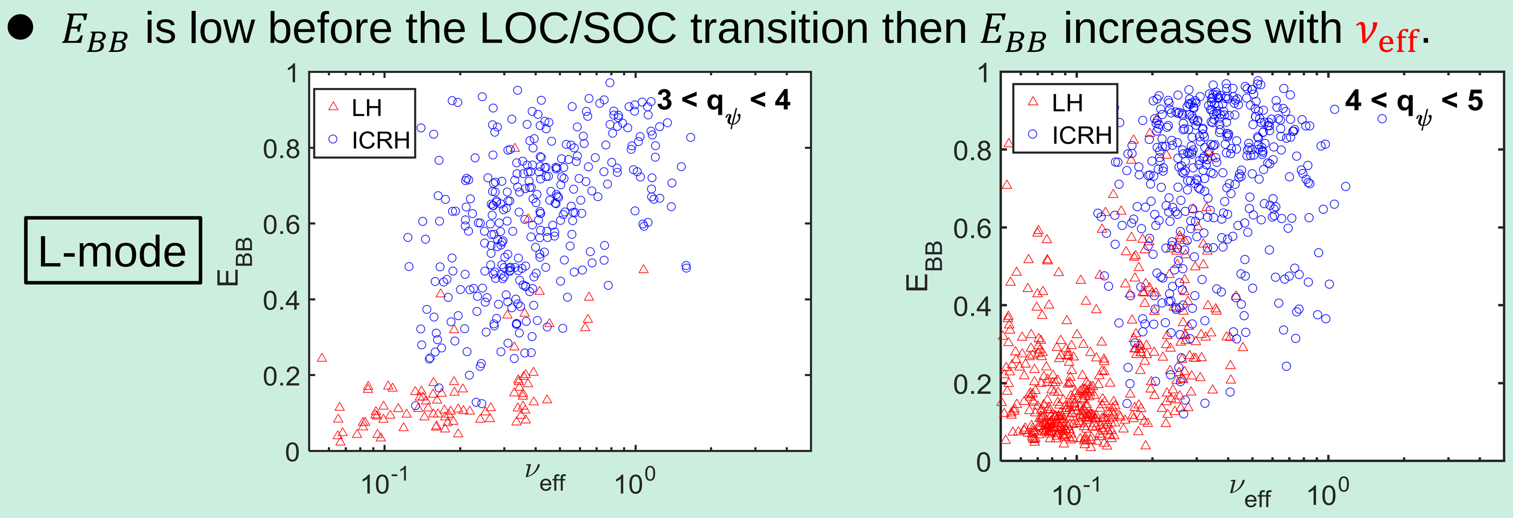
Could this transition induce a change of the spectra in other components ?

- The TEM/ITG stability regime can be related to the effective collisionality $\nu_{eff} = \nu_{ei}/\omega_{De}$, where ν_{ei} is the electron-ion collision frequency and ω_{De} the curvature drift frequency [6].
- For TEM/ITG, a approximation of ν_{eff} is expressed as [6]:

$$\nu_{eff} \sim 0.1\,RZ_{eff} n_e T_e^{-2}\ (n_e \text{ in } 10^{19}m^{-3},\ T_e \text{ in keV})$$



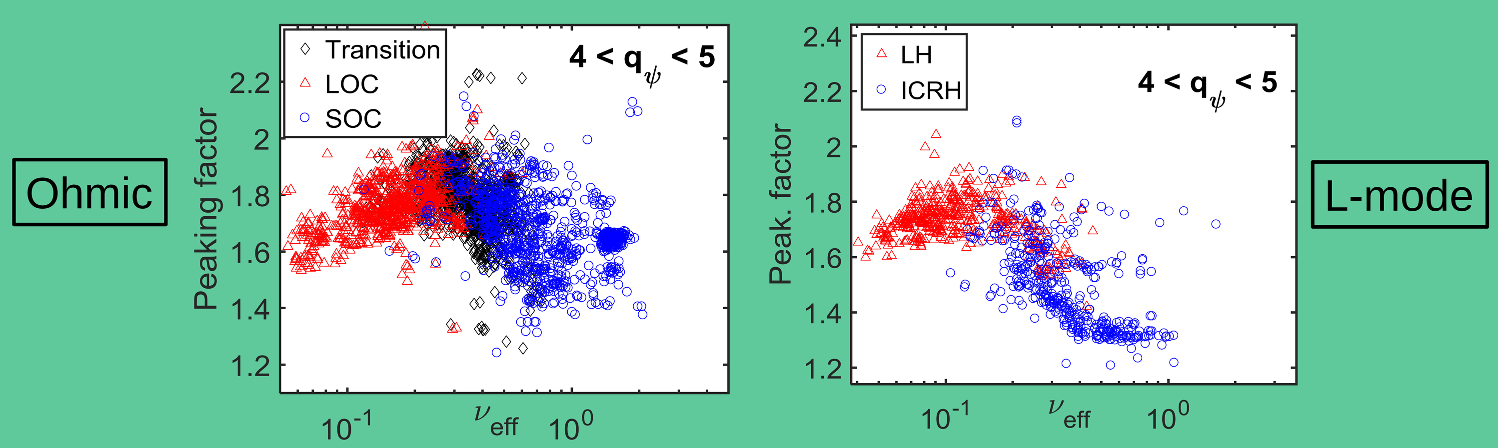
- The LOC/SOC transition (0.9~1.1 $N_{LOS/SOC}$) occurs when $\nu_{eff} \sim 0.4$ for the all q_ψ.
- E_{BB} is low before the LOC/SOC transition then E_{BB} increases with ν_{eff}.



- The similar transition occurs in L-mode with ICRH/LH, reflecting the TEM/ITG transition.

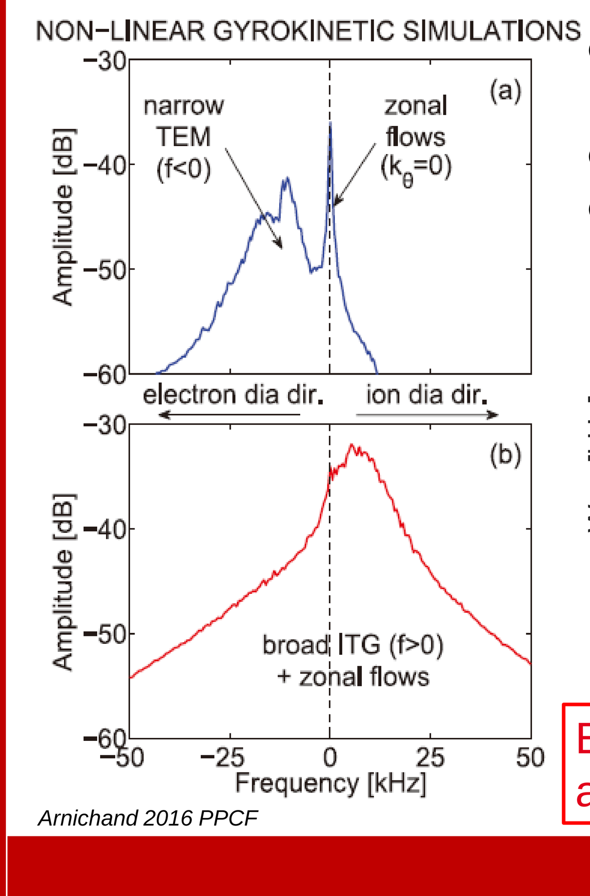
➔ Spectrum evolutions seem to be related to TEM/ITG transition

The *peaking factor* has been connected to the TEM/ITG transition through the turbulent pinch velocity. The *thermodiffusion* term is directed outwards when TEM dominates and inwards when ITG dominates [7].

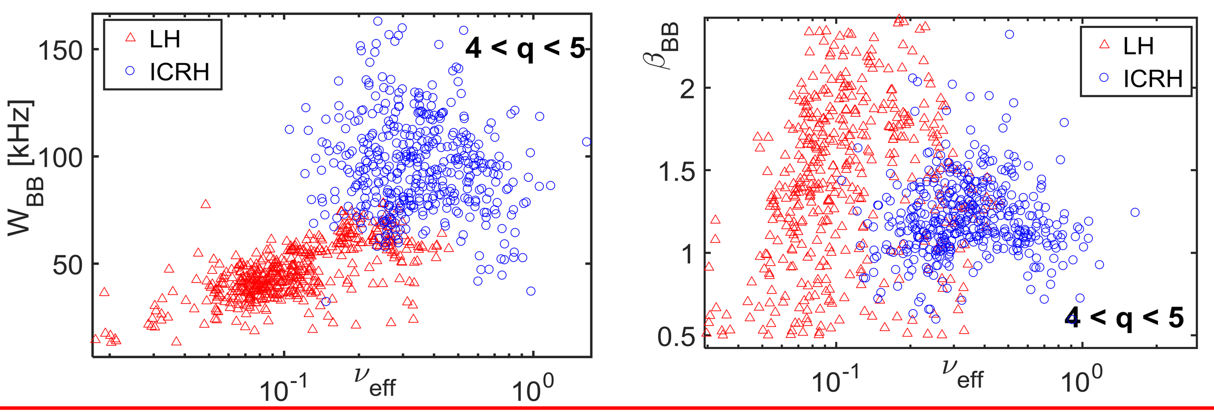


- Peaking factor evolution with ν_{eff} supports the interpretation of a fluctuation spectrum evolution related to a transition from TEM to ITG dominated turbulence.

Explanation



- Simulations [8] have shown that density fluctuation spectra are narrower in TEM than in ITG.
- Moreover in TEM, the spectra exhibits a LF component
- In ITG, this LF component is integrated in the wide BB component.



Evolution of spectrum characteristics (E_{BB}, width W_{BB}, shape β_{BB}) agrees with the change of the spectra observed in the simulation.

Conclusion

✓ Modification of the reflectometry spectra is induced by a change of the turbulent regimes.
✓ The spectrum characteristics (magnitude, width, shape) could thus be used as a new tool to determine the dominating micro-instabilities in the transport study.

References

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