

Analysis of metallic impurity density profiles in low collisionality JET H-mode plasmas

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Introduction: general issue and its relevance to ITER

A critical issue for the ITER performance is the understanding of the heavy impurity behaviour.

- Is the heavy impurity accumulation a problem in the ITER perspective?
- When does impurity accumulation occur? What are the plasma parameters governing the heavy impurity profiles? Are the impurity density profiles governed by neoclassical or turbulent transport?
- Are we able to control the impurity peaking?

Objective of this work

□ Experimental observation: in JET, different metallic impurity peakings are observed in H-mode NBI heated low collisionality discharges depending on the RF power deposition profiles



ICRH in ^3He **Minority Heating**



Ni peaked profiles



ICRH in **Mode Conversion**



Ni flat profiles

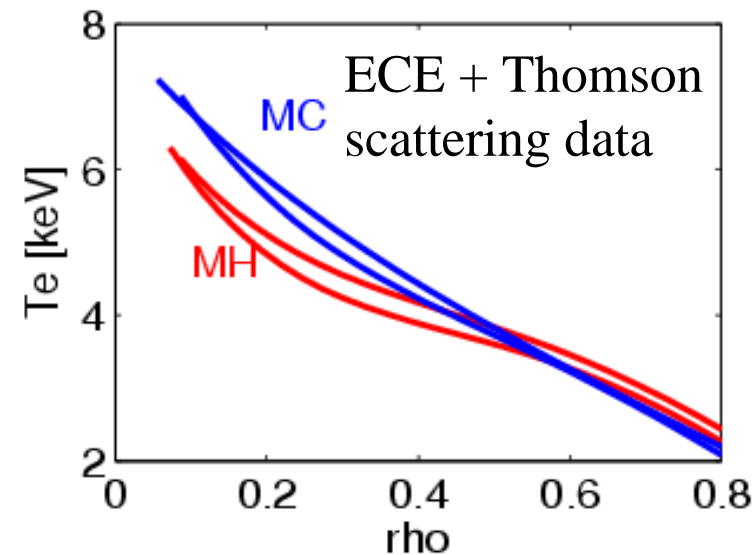
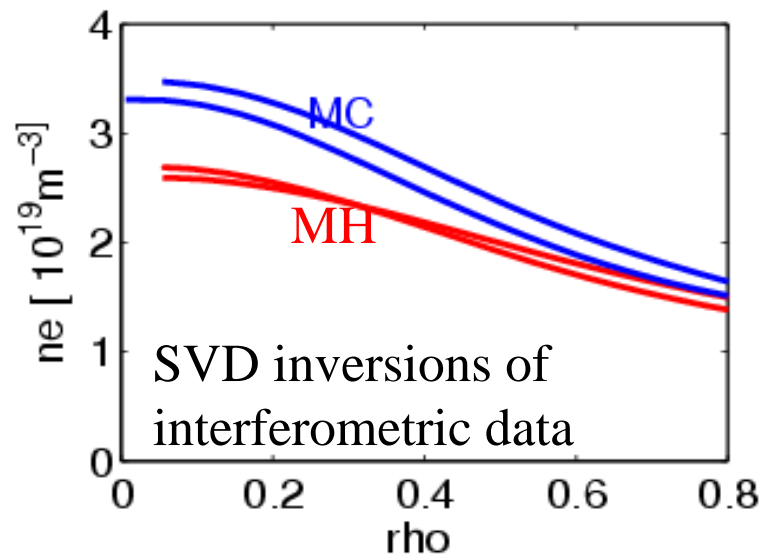
□ We aim to study this difference in impurity behaviour.
Can the transition in impurity transport be interpreted within the ITG/TEM stability theory ?

The experiments

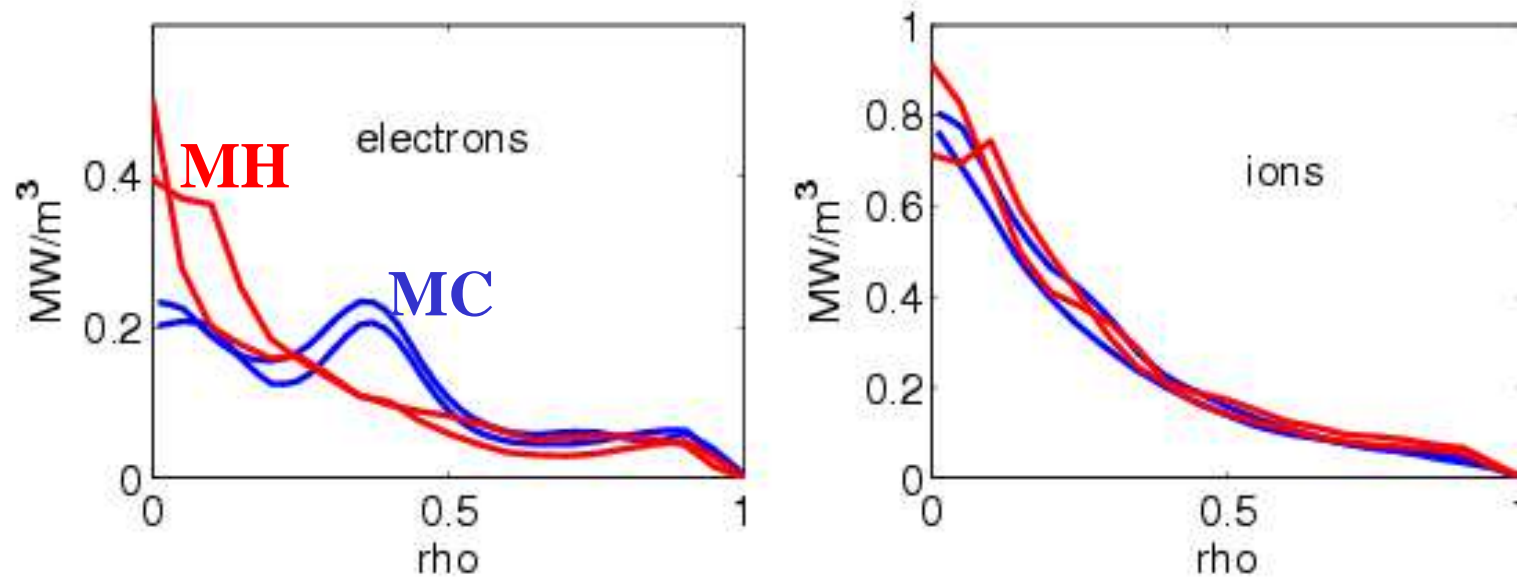
H-mode discharges at low collisionality $0.1 \leq \nu_{\text{eff}} \leq 0.2$ @ $\rho=0.5$

No sawtoothing (for ITER $\nu_{\text{eff}} \approx 0.1$)

Four discharges analysed: 2 with ICRH in Mode Conversion (MC)
+ 2 with ICRH in Minority Heating (MH)



The experiments: power deposition profiles



MH, with ~ 8% ³He, power to thermal ions $\rho_{ICRH}=0.1$

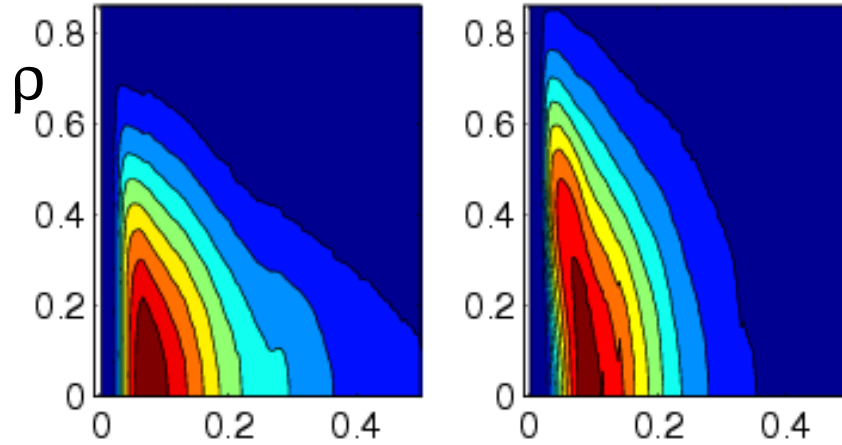
MC with ~ 20% ³He, power to electrons $\rho_{ICRH}=0.37$

Perturbative experiments: LBO

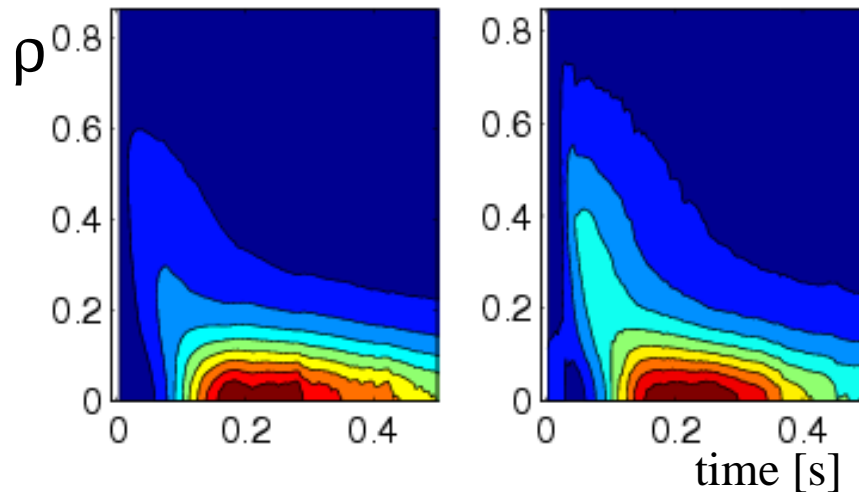
Time-dependent experiments allow the discrimination between the diffusive and convective term in the flux equations

Transients have been produced by nickel Laser Blow Off Pulses.

LBO Data : inverted SXR emissivity profiles.



MC

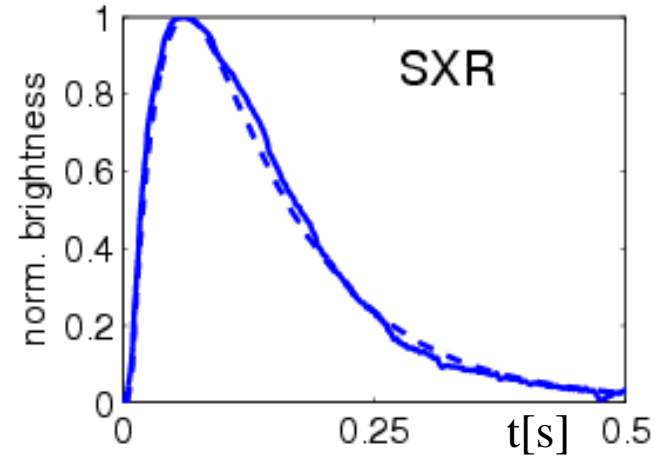
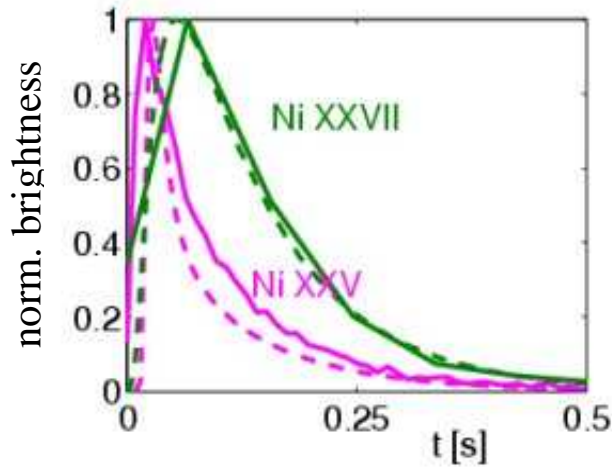


MH

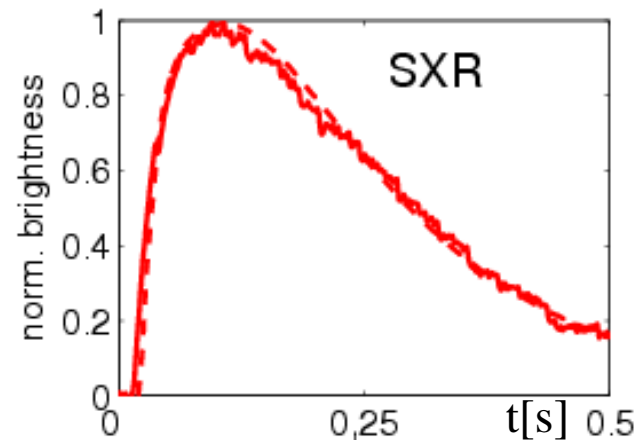
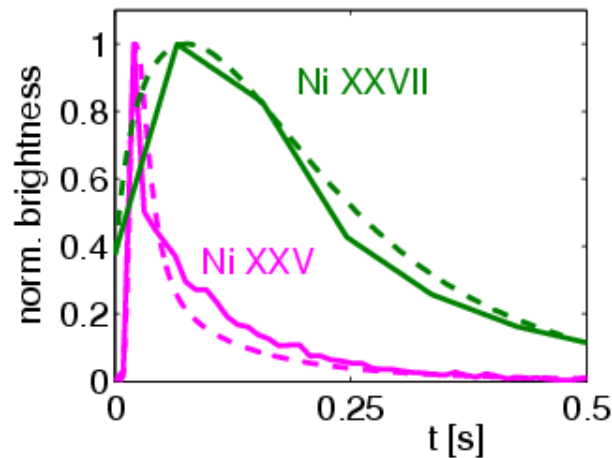
**slower penetration and
more peaked profiles**

Simulation: line & SXR brightnesses

MC →



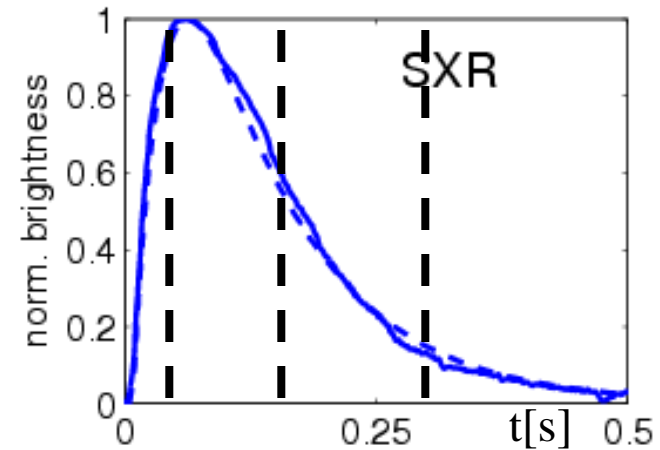
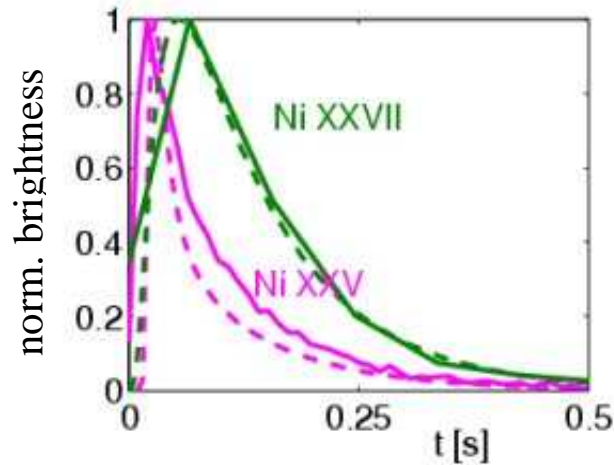
MH →



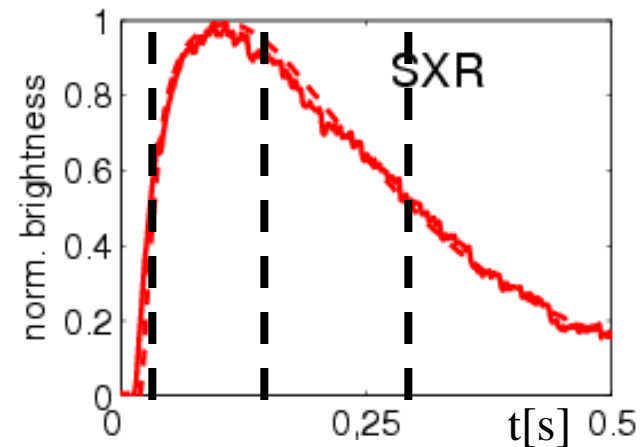
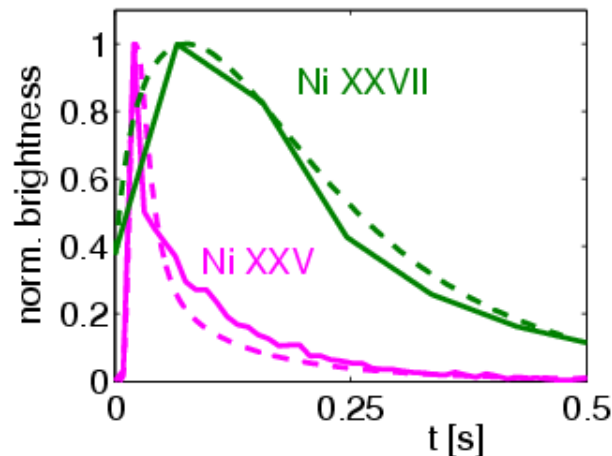
Solid: experimental; dashed: simulation

Simulation: line & SXR brightnesses

MC →



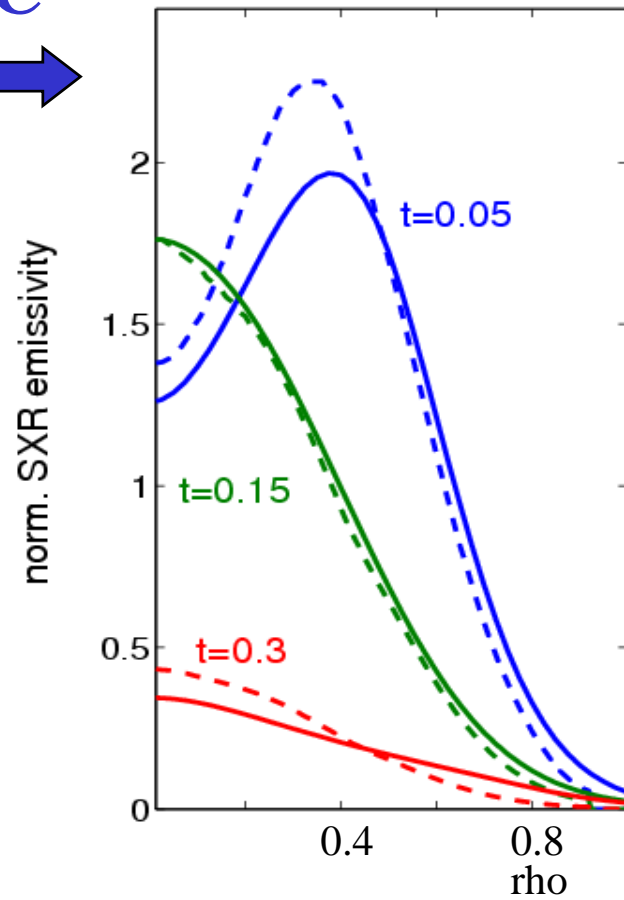
MH →



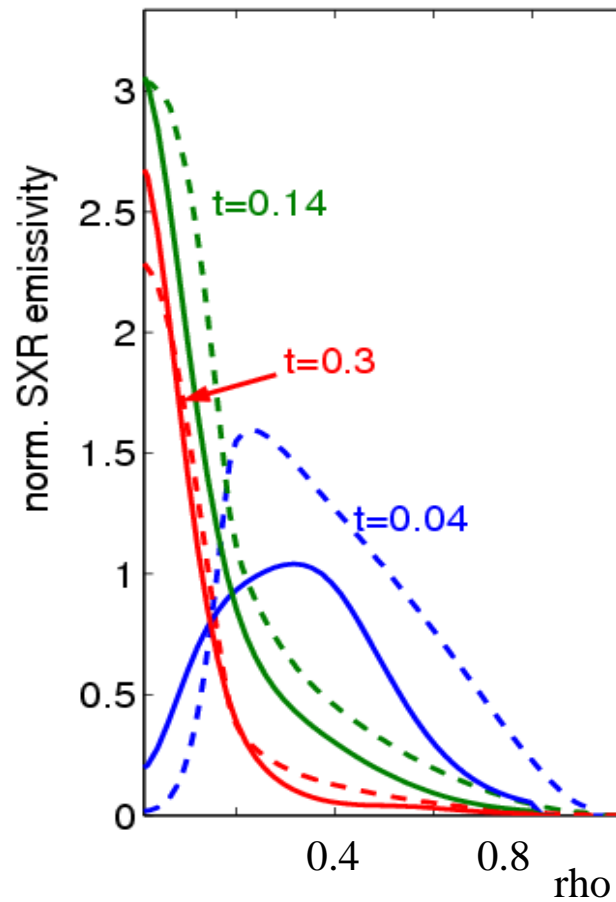
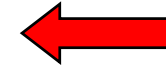
Solid: experimental; dashed: simulation

Simulation: SXR emissivity profiles

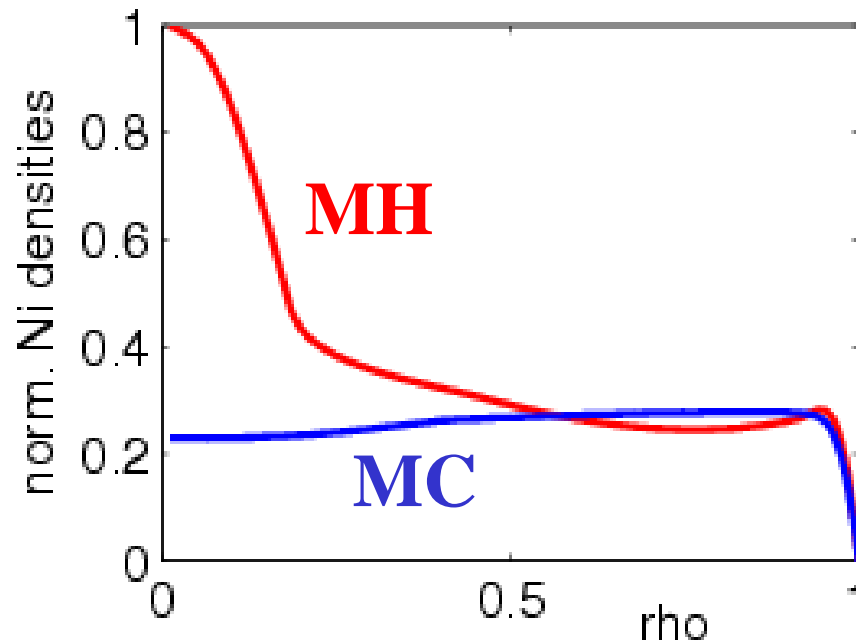
MC



MH



Simulation: extrapolation to the steady state.



MC  flat density

MH  peaked density

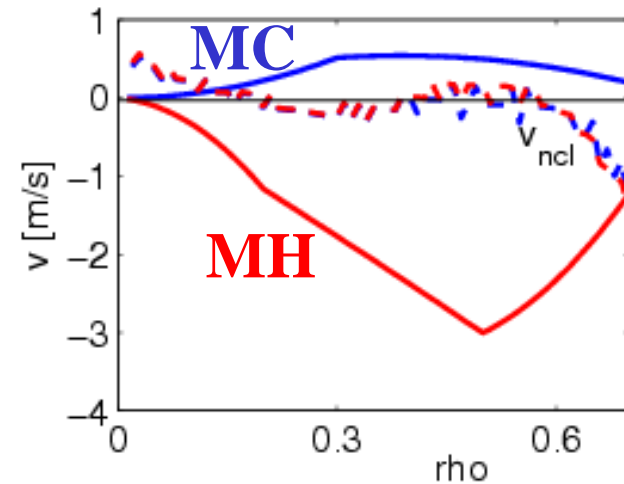
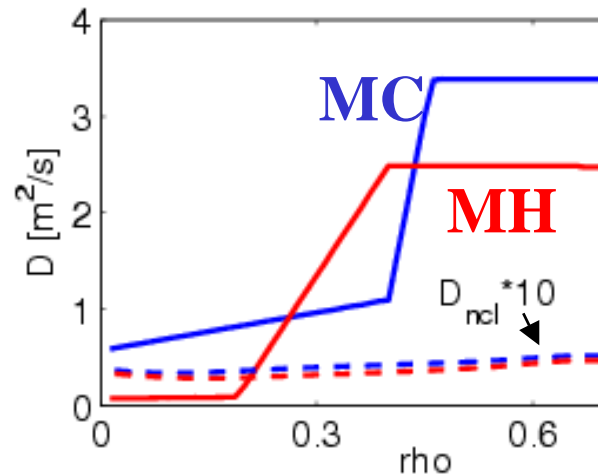
Simulation: transport parameters

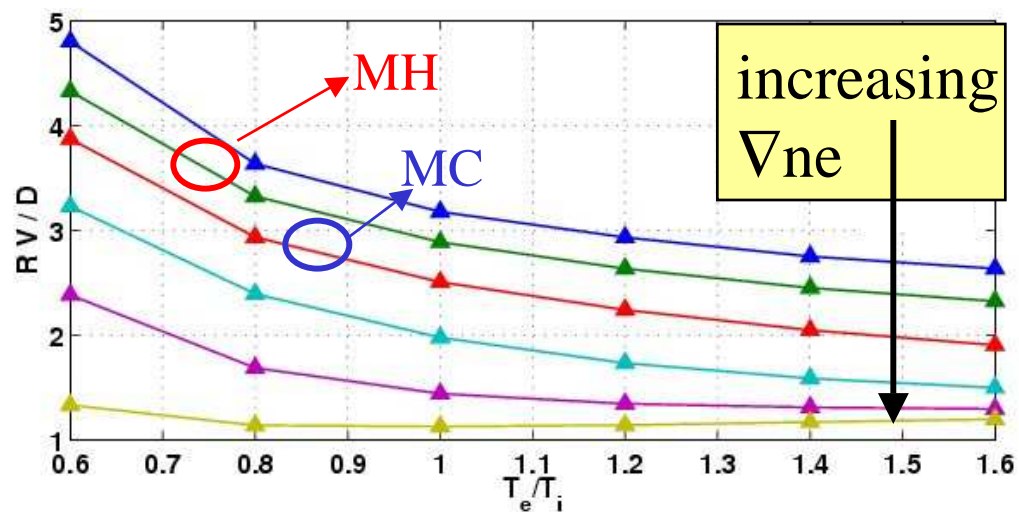
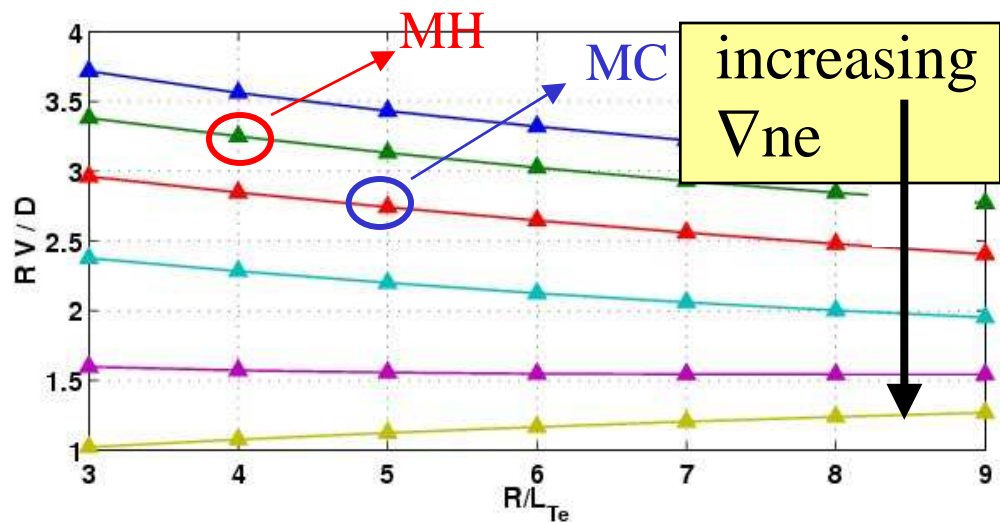
MH shots(Ni peaked) \rightarrow for $\rho < 0.2$ D about neoclassical

Inward pinch

MC shots(Ni flat) \rightarrow for $\rho < 0.2$ $D \gg D(\text{MH})$

Outward pinch





Interpretation by the gyrokinetic code GS2

Scan on the parameters R/L_{ne} ($L_{ne}=n_e/\nabla n_e$), R/L_{Te} and T_e/T_i

Density gradient increases \rightarrow

Ni peaking decreases

T_e/T_i increases \rightarrow

Ni peaking decreases

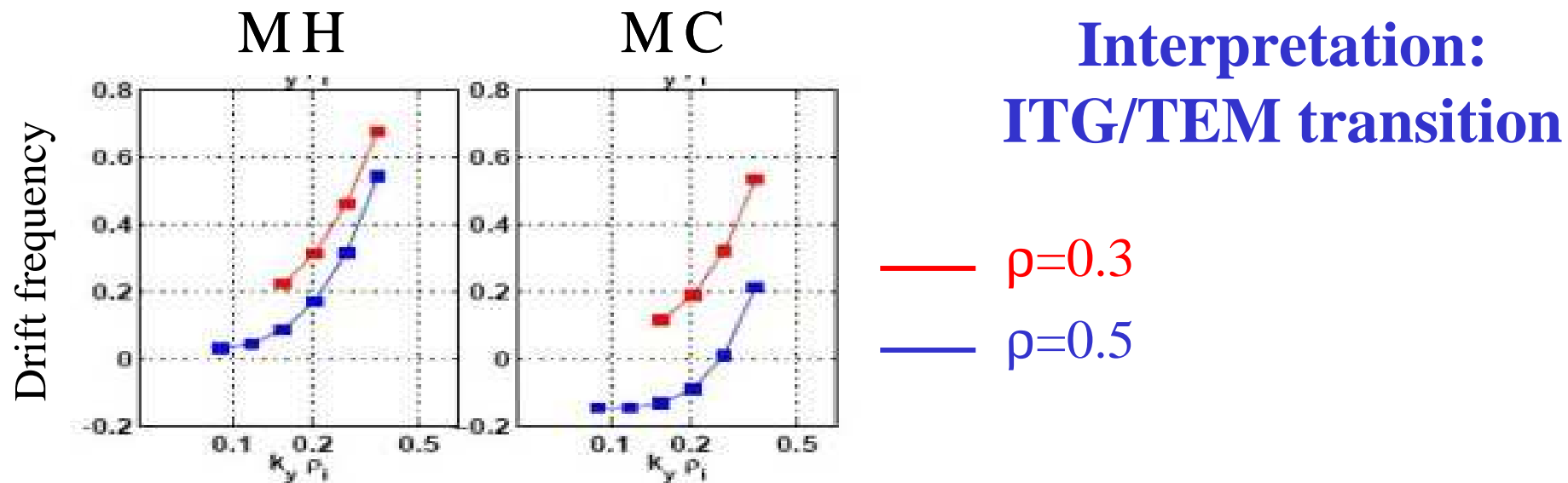
See P4.041 by C. Angioni et al.

Interpretation by GS2 : is the transition in Ni transport related to a transition from dominant ITG to dominant TEM ?

Thermodiffusive flux related to the dominant mode frequency

Rotation in the electron drift direction \longrightarrow Trapped
 Electron Modes (TEM) \longrightarrow outward thermodiffusion

Rotation in the ion drift direction \longrightarrow Ion Temperature
 Gradient Modes (ITG) \longrightarrow inward thermodiffusion



MH ITG always & Ni peaked

MC TEM for $\rho > 0.4$ only & Ni flat



Region of highest pinch values (inward or outward) where an outward flux component contributes to flatten the Ni profile in the centre

Final remarks

□ At low collisionality:

ICRH in MH \Rightarrow peaked Ni density \Rightarrow inward pinch & $D \sim D_{ncl}$ on the axis

ICRH in MC \Rightarrow flat Ni density \Rightarrow outward pinch & $D \gg D(MH)$ on the axis

□ Qualitative agreement with GS2: TEM dominating (outward thermodiffusion) at $\rho > 0.4$ in MC discharges

□ ITER perspective: specific experiments planned to confirm the importance of the electron power deposition profile as a control tool for heavy impurity profiles

Future plans

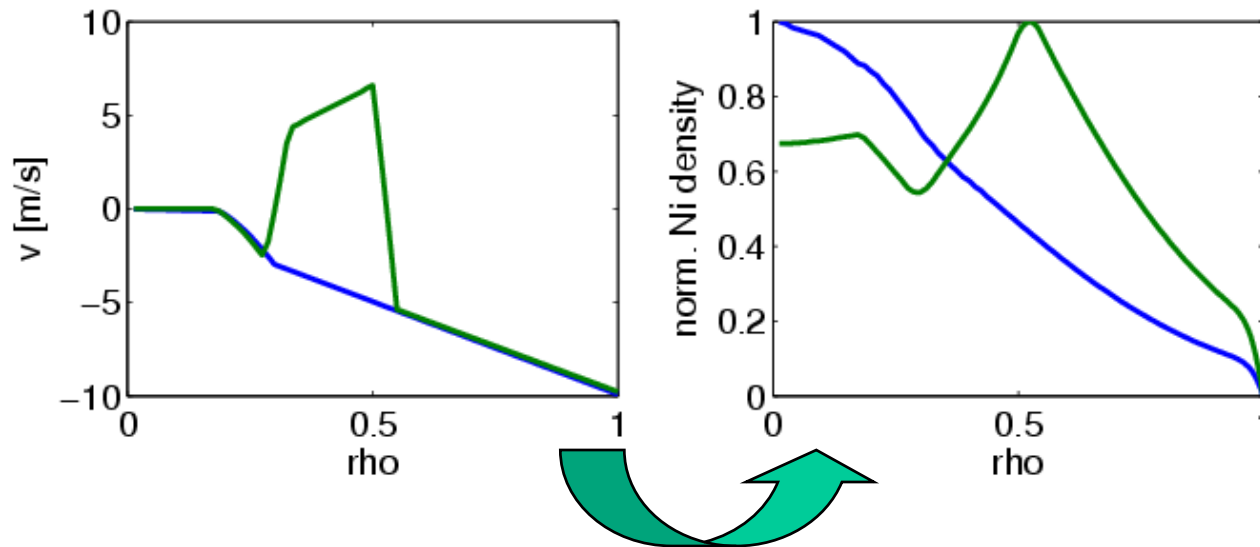
Specific time-dependent experiments in the next experimental campaigns aiming to:

- confirm the **dependence of impurity peaking on the predominant heating channel**
- verify the **importance of the shape of electron power deposition profile** as a control tool for heavy impurity profiles
- confirm the **dependence of impurity peaking on ITG/TEM transition**
- analyse the **effect of different collisionalities**

The problem of LBO: is the pulse itself a perturbation influencing the determination of the transport parameters? The answer in the following examples is **no**, because:

- diffusion and convection do not need to be changed during the pulse
- the extrapolation to the steady state (outside LBO) is compatible with the unperturbed SXR emission (taking into account the contribution from carbon)

Example of the effect of an outward flux component localized around $\rho=0.4$ (same diffusion in the two cases)



The core profile is influenced by a flux variation in the middle radius