# Global effects in gyrokinetic simulations

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# ORB5 - Code, equations and approximations

- ORB5 is a full $f^1$, EM, flux-driven, global, PIC GK code

- ORB5 solves a full-f Vlasov equation, in spite of $\delta f$ splitting used as control variate. The total distribution function is represented as $f = f_0(\psi, t) + \delta f$ and only $\delta f$ is discretized using markers
  - It leads to noise reduction (under PIC-Monte Carlo considerations)

- The initial phase space is sampled with markers. Such markers are evolved and their orbits are followed during the simulation in the 5D phase space

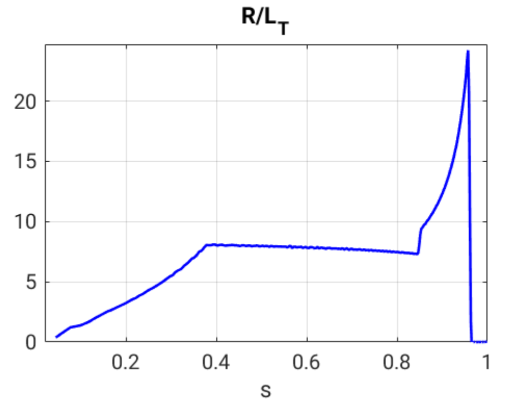
- Fields solved with 2nd and 3th order B-splines
  - For the two angular coordinates the solver works in Fourier space. Assuming that the perturbations are almost field aligned it solves the fields for few modes per radial location

[1] except for the polarization term

# Non linear analysis

- 2 TCV equilibria have been taken, #60797 for positive triangularity (PT), #58499 for negative triangularity (NT), $\delta \pm 0.5$
- Model includes: gradient driven electrostatic turbulence, kinetic trapped electrons, long wavelength approximation for the polarization term, limiter
- Limiter contributes twice:
  - it damps fluctuations in the Vlasov equation
  - it changes the QNE: it removes the flux surface average from the electron adiabatic response and it introduces a RHS term (not included in our simulations)
    - This model may work with adiabatic electrons, but with kinetic electrons we should re-compute continuously the matrices of the QNE since the additional term depends on electrons temperature

$$\rho^{lim} = \rho + \frac{n_{e_0}}{Z_0^2 T_e} \Lambda\left(M^{SOL} - M^{lim}\right)(T_e - T_e^{bc})$$

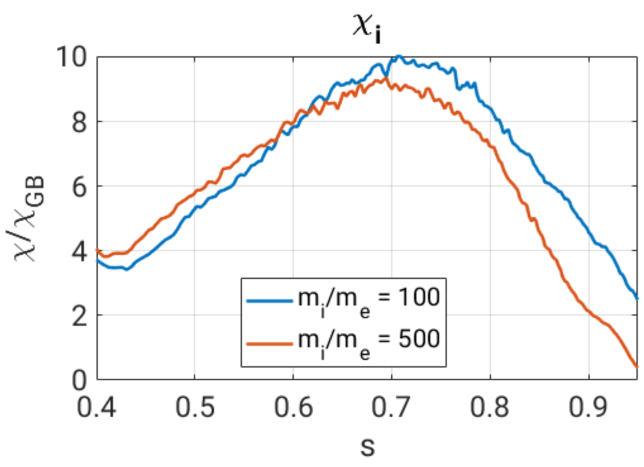


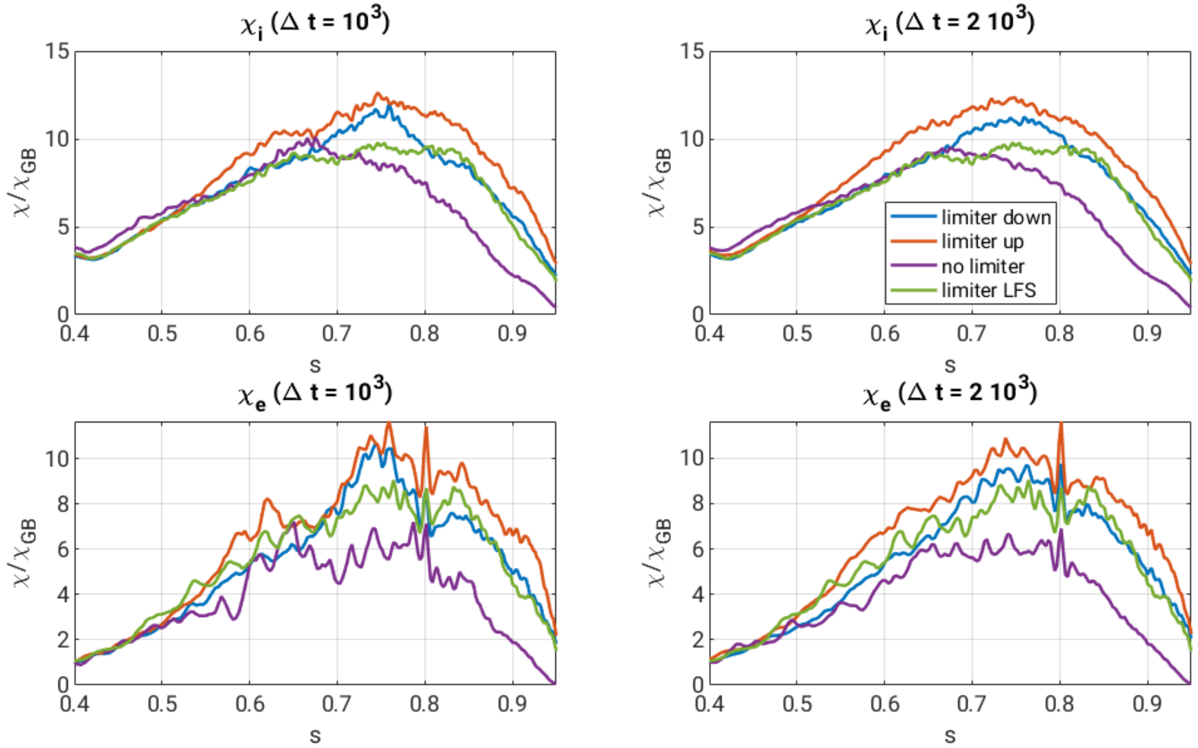

    - Done to match the Bohm condition but electron temperature itself changes with such b.c.

We can think to insert it when the adaptive background scheme will be available, otherwise the feedback of the Bohm condition on the electrons is not self-consistent

# Limiter scan - PT

- Limiter position has been scanned: no limiter configuration, limiter UP, DOWN, LFS
  - Limiter UP configuration (direction of e-gradB drift) has systematically more transport than the limiter DOWN configuration

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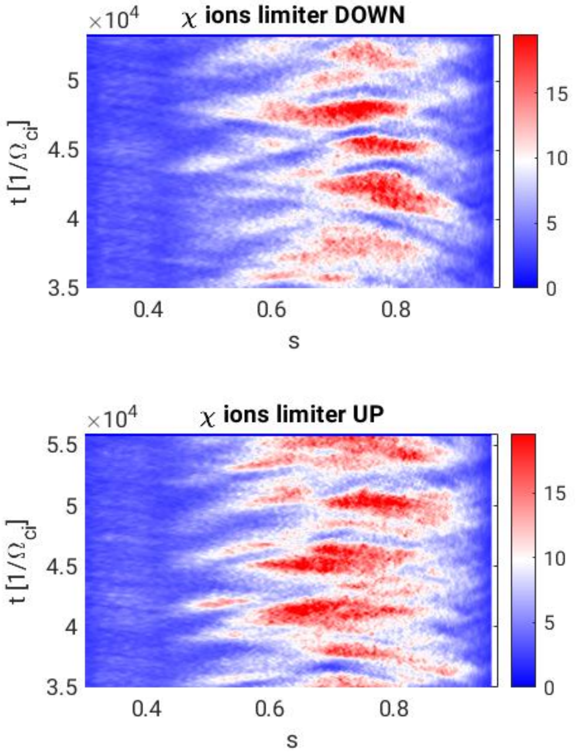


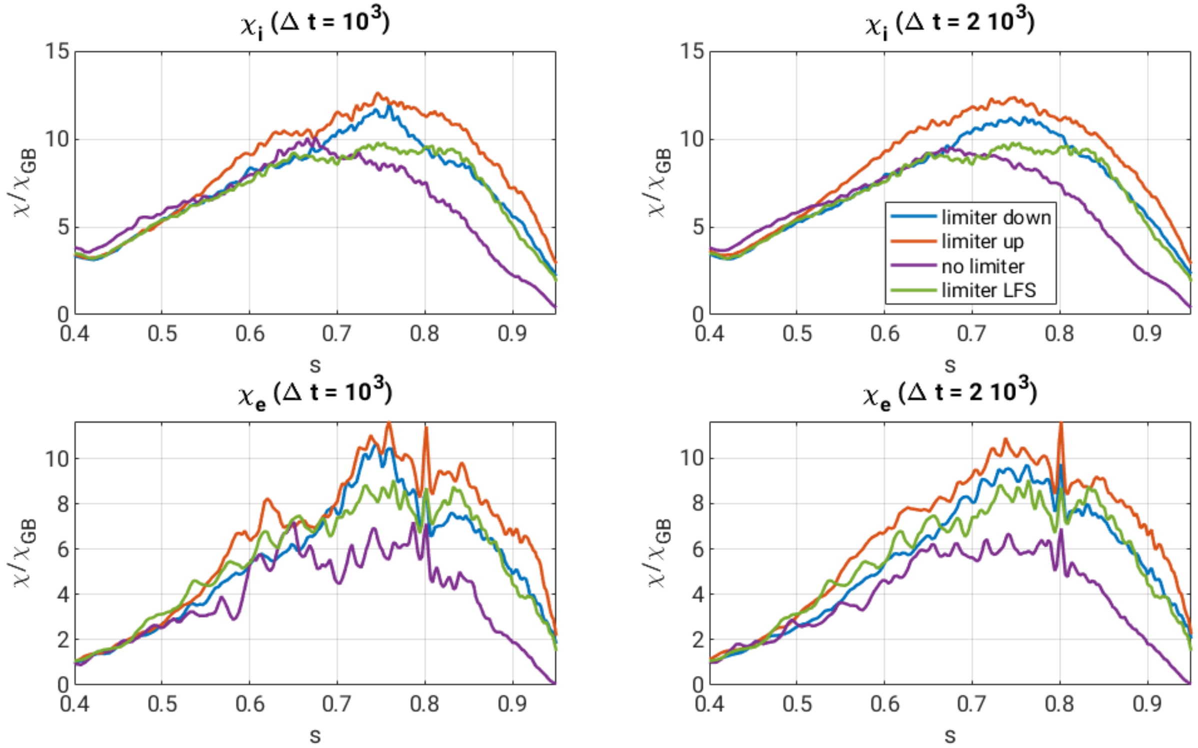


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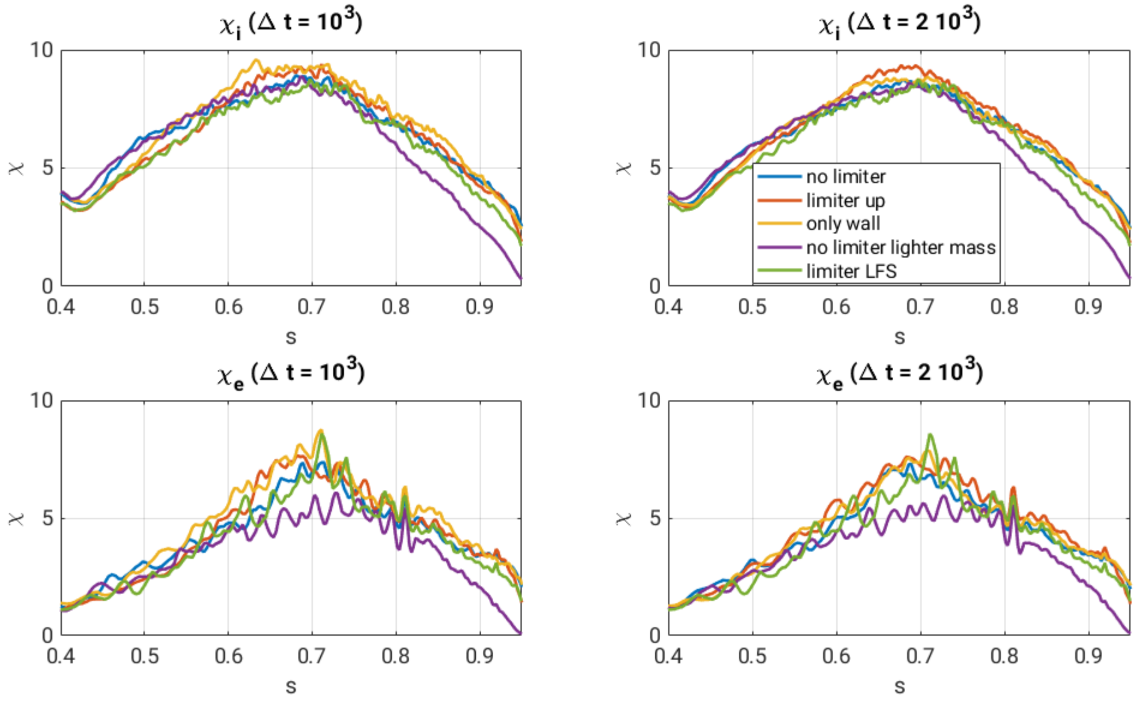
# Limiter scan - NT

- For the NT configuration there is not a huge difference between limiter UP and limiter free configuration
  - This may be due to the fact that the fluctuations are more in the core and thus less sensible to boundary conditions (we will see)

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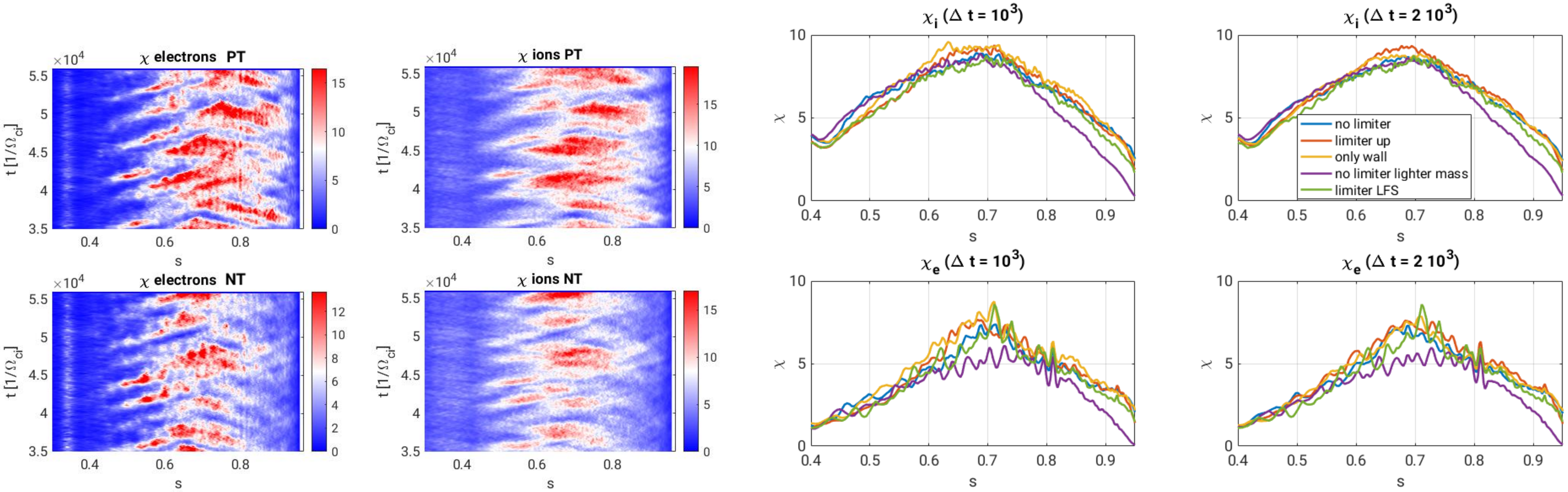
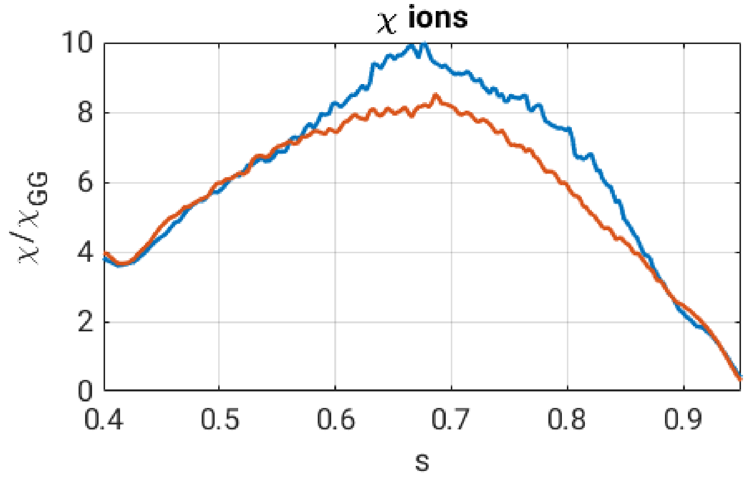
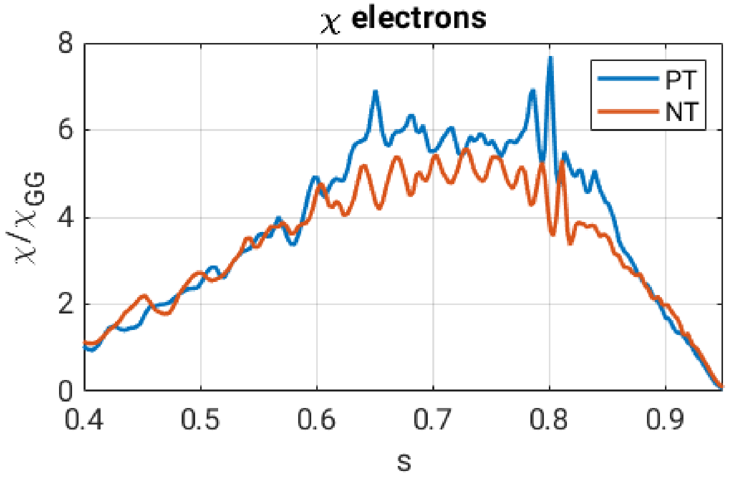


# Positive versus negative triangularity

- Without limiter, positive and negative triangularity do not feature huge differences
  - NT is performing better but the improvement is not the same as the experiment. This may strongly depends on the initial profiles

  - For other profiles with smoother R/LT there is always an improvement of NT (see next TSVV2 meeting) with respect to PT

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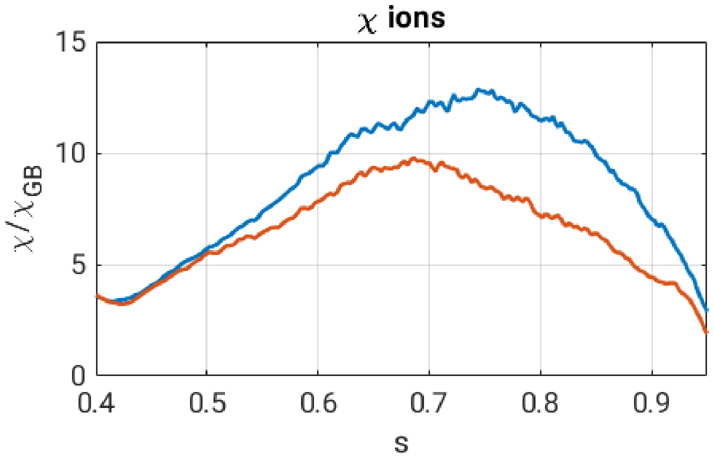
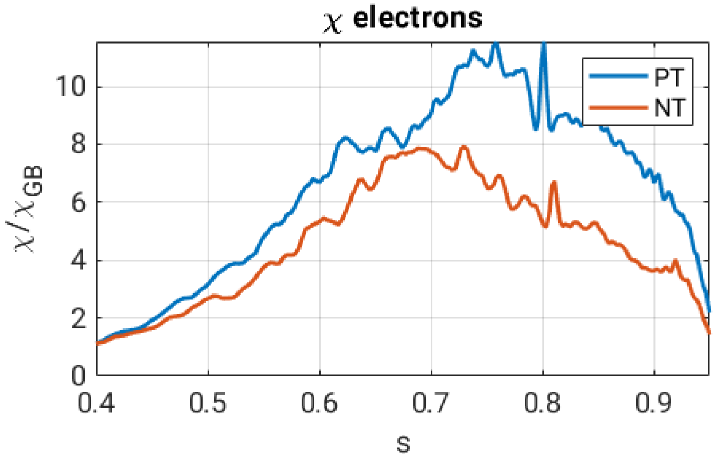
# Positive versus negative triangularity

- With limiter, positive and negative triangularity feature larger differences
  - NT is performing a lot better than PT
  - Limiter does not bring any reduction of $\chi$ for NT(when compared to the no-limiter case), it just increases $\chi$ PT (again, as compared to no-limiter case)
  - Again, this difference can be due to higher edge-core communication for PT
  - NT does not see much effect of the limiter, tentatively because of weaker non-local effects (as compared to PT)
    - We still need to investigate the physical origin of this behavior (if any)

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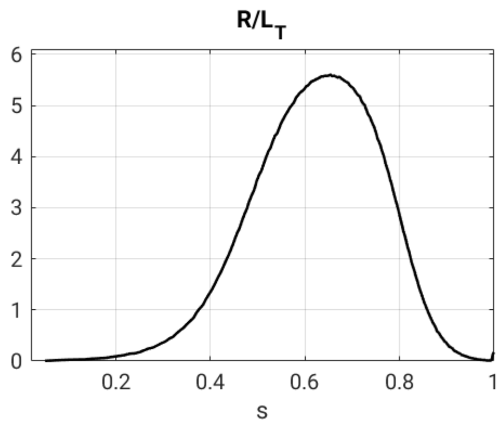
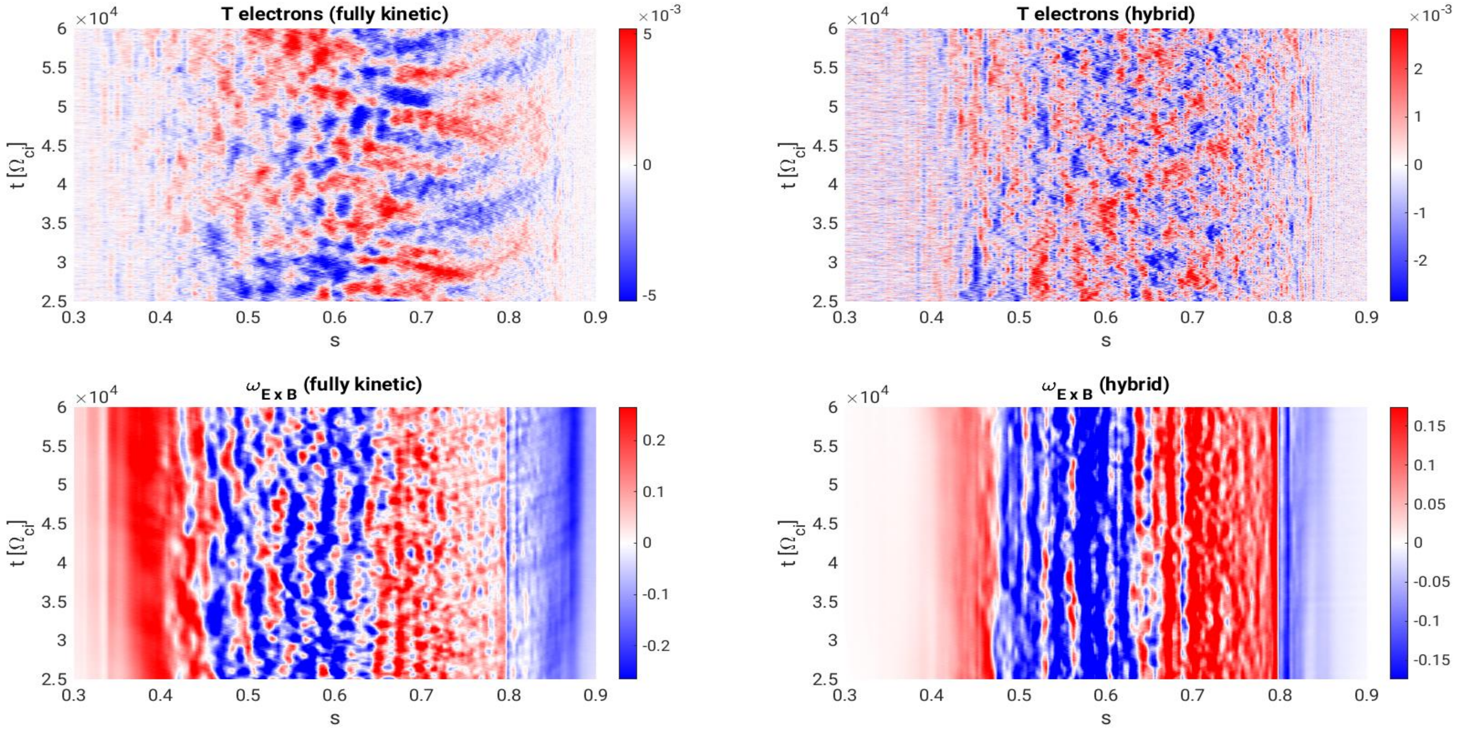
# Toward fully kinetic electrons

- Boundary conditions on the potential have to be changed
  - Only the polarization term contains the electrostatic potential
- Fully kinetic electrons appear to insert more non-locality in the system: boundary conditions have to be chosen carefully..



# Another global effect: minimum of safety factor

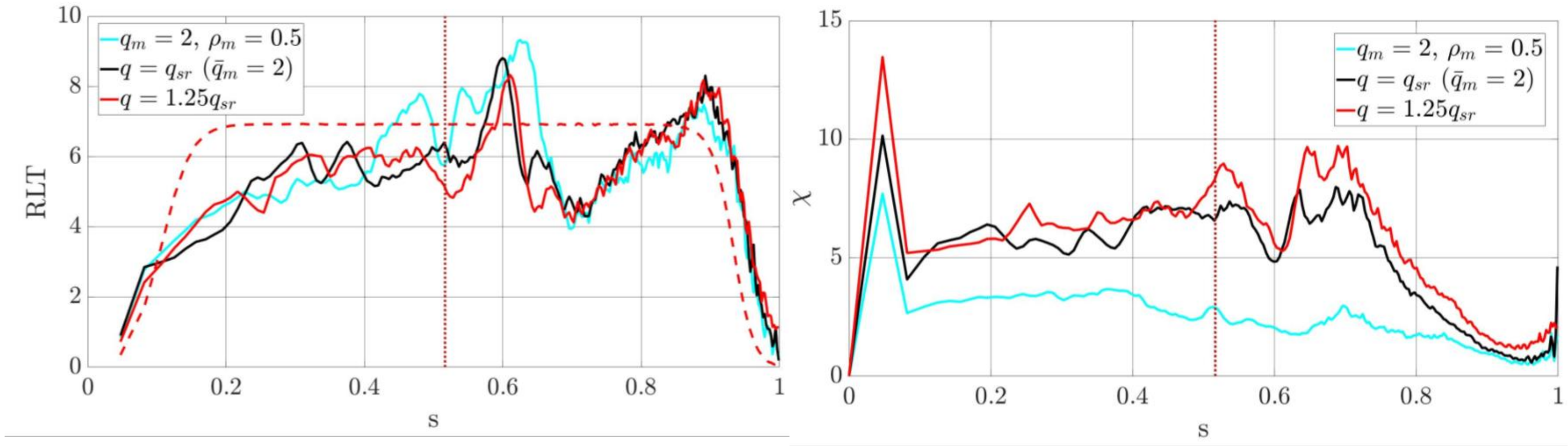
- A master student (Philippe Griveaux) studied the effects of a reversed shear q profile
  - Adiabatic case: not a big effect of a rational value of $q_{min}$
  - Hybrid case: using $q_{min}$ = 2 has a huge effect on transport all over the radius
    - Looking at the radial location s=0.7 , after the evolution the three cases share the same logarithmic gradient: but heat fluxes are completely different! There is no local closure that can be adopted

Cyan curve:
$q_{min}$ exactly 2

**Black** curve:
$q_{min}$ slightly above 2

Red curve:
$q_{min}$ well above 2

Pure ITG CBC parameters

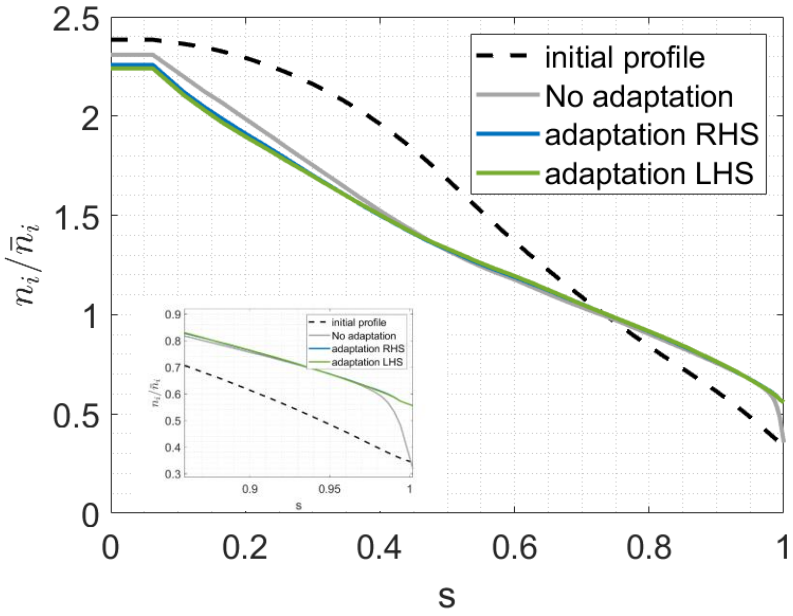


# Towards background adaptation..

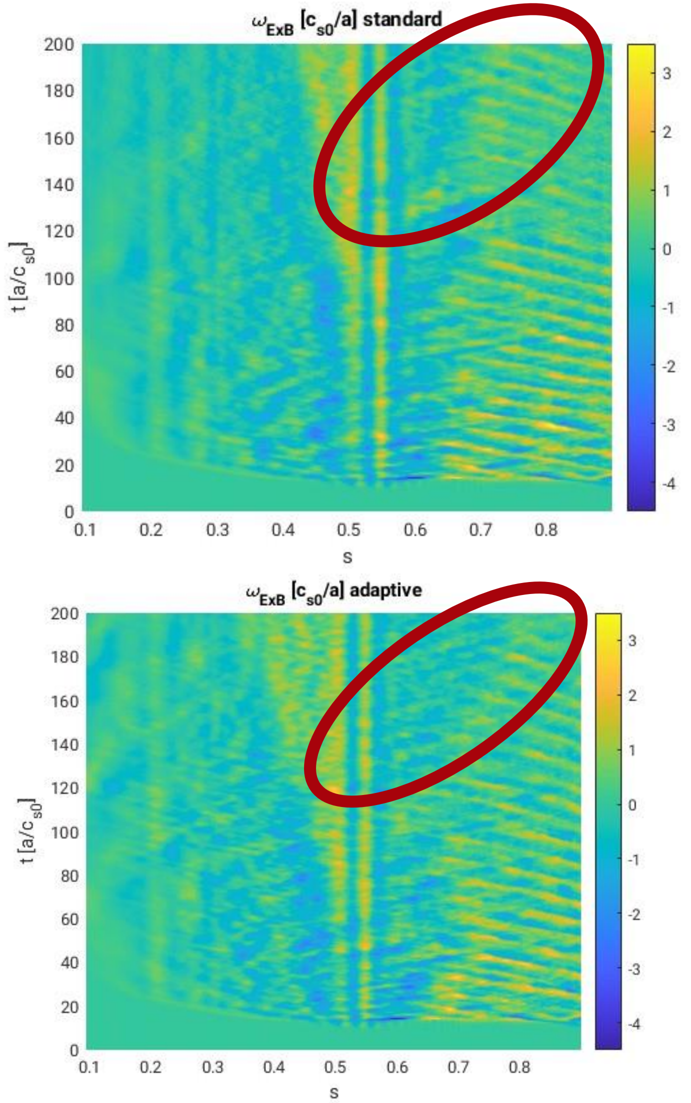
- The background adaptation (M. Murugappan) allows to deviate consistently from the initial profile maintaining a correct GK ordering

- It will be extremely useful for solving the edge region correctly

- The adaptation is 1D




Courtesy M. Murugappan



# Summary

- Boundary condition on the potential to mimic Bohm condition not mature enough
  - When the hybrid electrons model is adopted the self-consistency is lost
  - When the fully kinetic electrons model is adopted the model cannot be used
- Damping the fluctuations in different poloidally localized regions leads to differences
  - Positive triangularity seems to react more than negative triangularity to the limiter position
- First numerical experiments on reversed shear safety factor is providing insightful results
  - Huge impact of the minimum located on the rational surface on the whole plasma domain
- Deliverable of the 2D equilibrium
  - This approach is not compatible with the background adaptation scheme (at least for the moment)
- Other information on ORB5
  - A simpler collisional operator has been inserted (linearized, no ions-electrons operator, but requires much less markers)
  - Coarse graining noise control has been inserted as well for controlling noise in a more transparent way
  - The background adaptation scheme has been implemented and it is currently under test