Simulation of tokamak SOL turbulence

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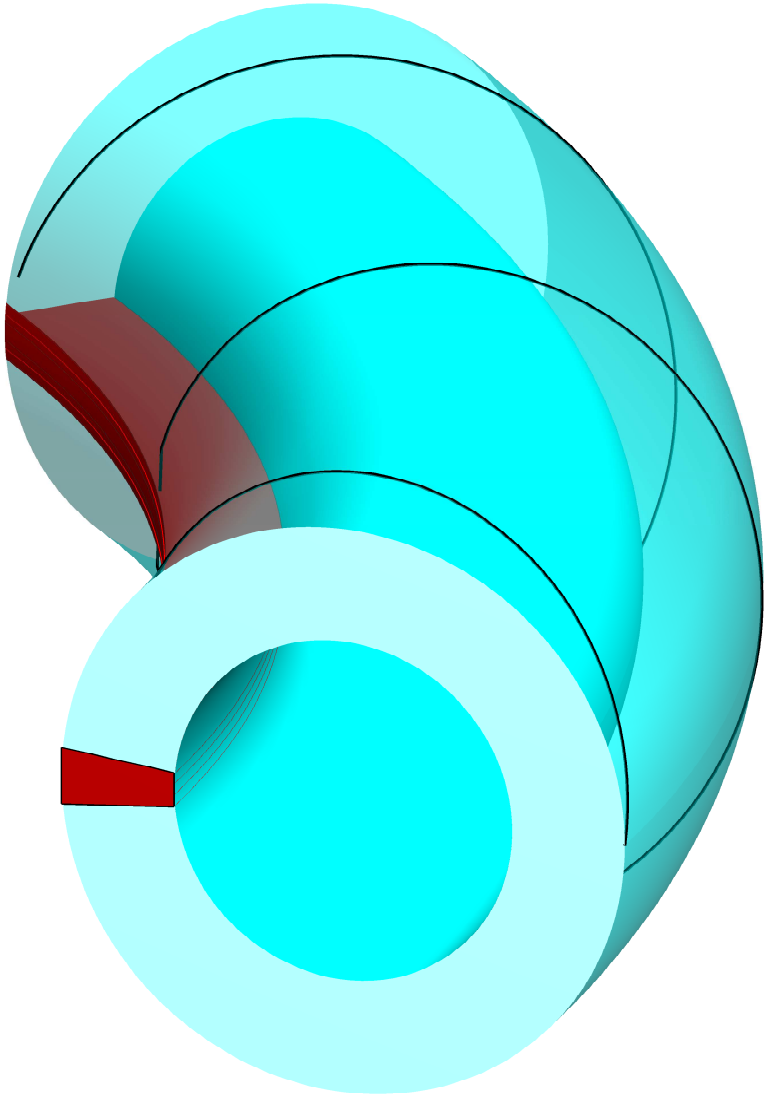
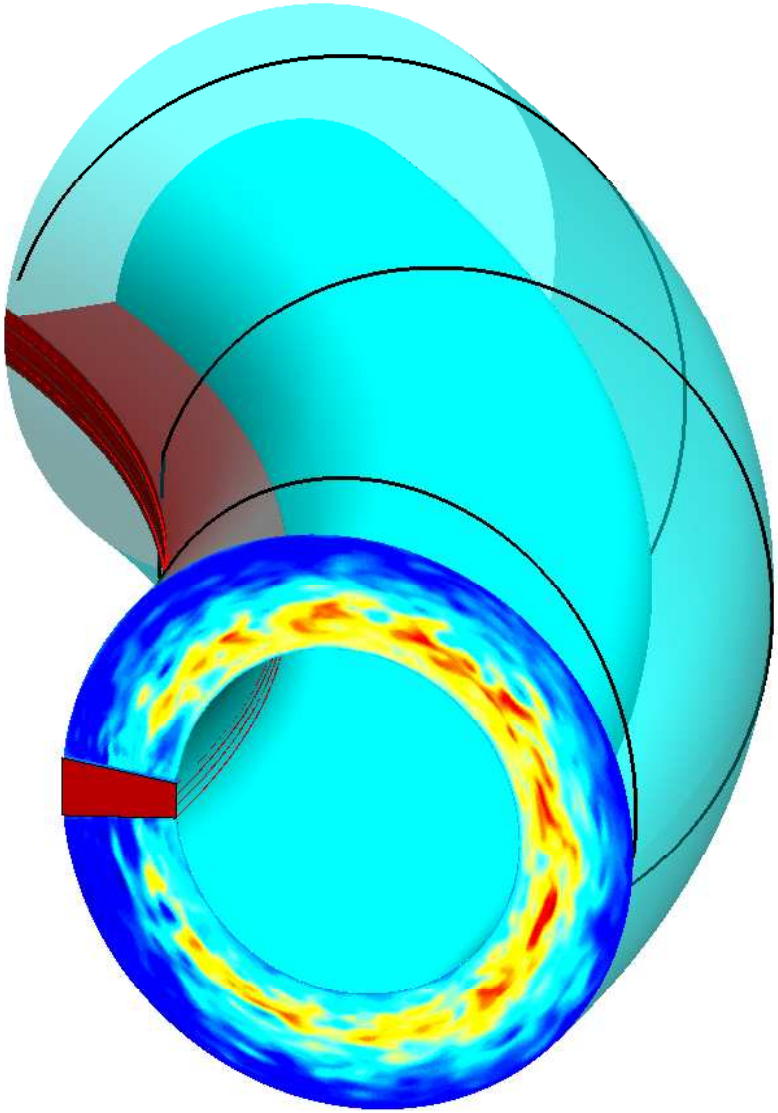
Scrape Off Layer (SOL)



- open magnetic field lines
- low temperatures
- collisional plasma
- atomic physics

Objectives



Objectives :

- properties of the SOL turbulence
- instabilities and drives
- non-linear saturation mechanism

How ?

- simple geometry : toroidal limiter
- global self-consistent code

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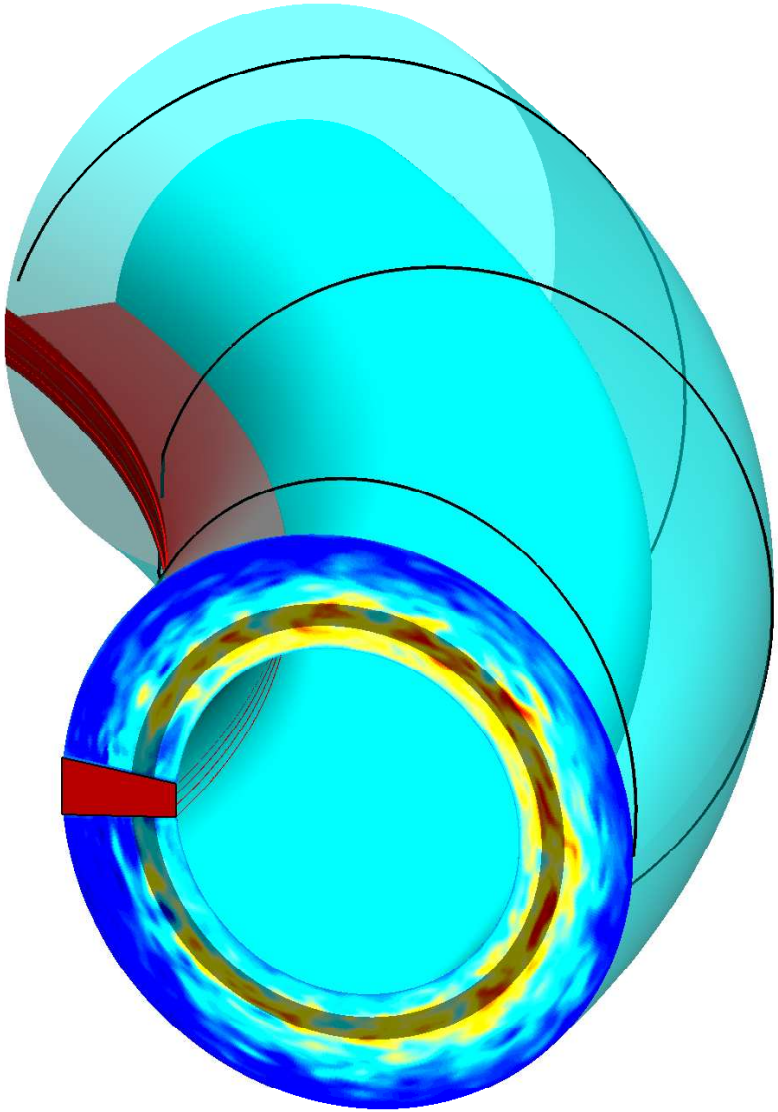

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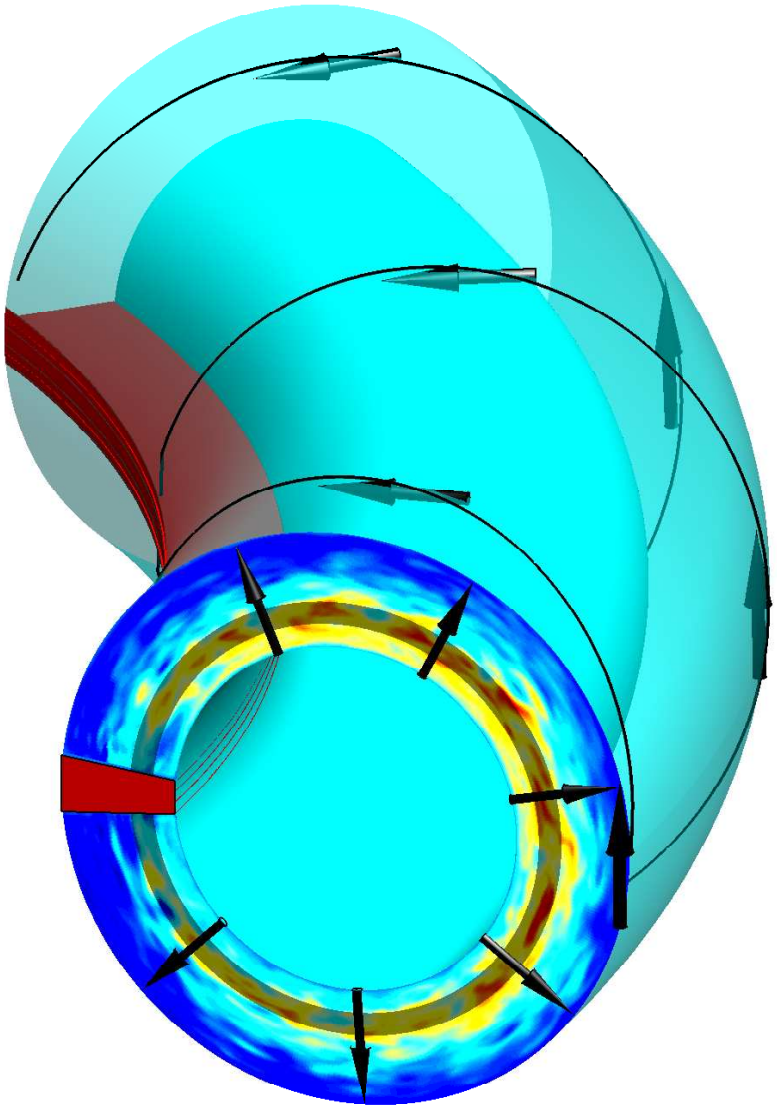

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The drift-reduced Braginkii equations

collisional plasma : Braginskii two fluid model (e-i) equations : density, velocity and temperature

+

$$\beta = \frac{p}{B^2/2\mu_0} \ll 1$$
$$\frac{\partial}{\partial t} \ll \Omega_i$$
$$n_e = n_i$$

- separation of perpendicular and parallel dynamics
- elimination of the fast gyromotion from the description
- only the drift velocities are retained

Electrostatic drift reduced Braginskii equations

Continuity equation for the electrons

$$\frac{\partial n}{\partial t} = \frac{c}{B}[\Phi, n] + \frac{2c}{eRB}\left(\frac{\partial p_e}{\partial y} - en\frac{\partial \Phi}{\partial y}\right) - \frac{\partial\left(nV_{||e}\right)}{\partial z}$$

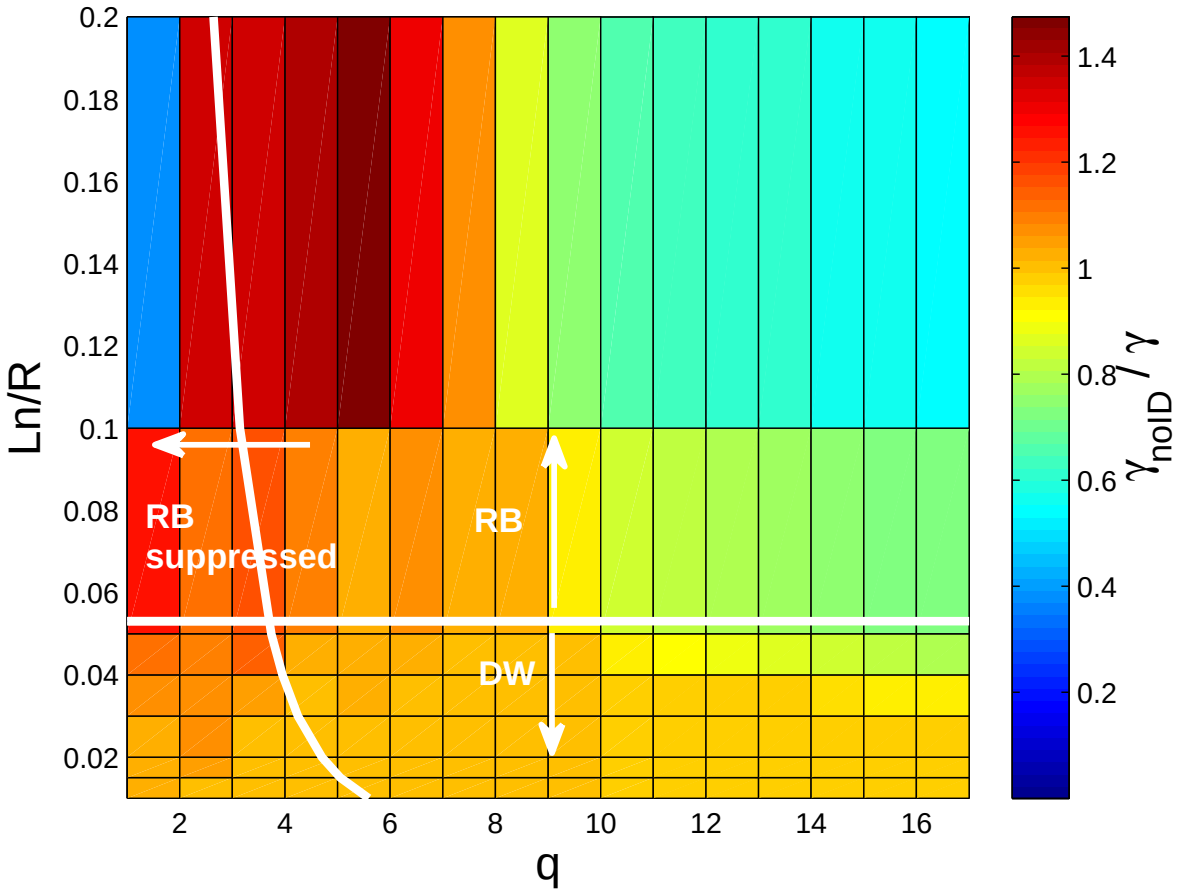
- v_{ExB} convection
- v_{de} convection
- compressibility due to curvature
- $v_{||e}$ convection

Example of turbulence movie

Main instabilities

	Resistive Ballooning (RB)	**Drift wave (DW)**
drive	V_d & ∇p & R	$\mathbf{E} \times \mathbf{B}$ & ∇p
growth rate	$\sim c_s \sqrt{\frac{2}{RL_n}}$	$\sim \frac{c_s}{L_n}$
parallel dynamics	$k_{\|\|} \sim \frac{1}{qR}$	$k_{\|\|} \neq 0$
perpendicular dynamics	$k_{min} < k_y < k_{max}$	$k_y \rho_s \approx 1$
physical properties	destabilized by resistivity (non adiabatic)	destabilized by resistivity or electron inertia (non adiabatic)

$q - L_n/R$ linear phase space



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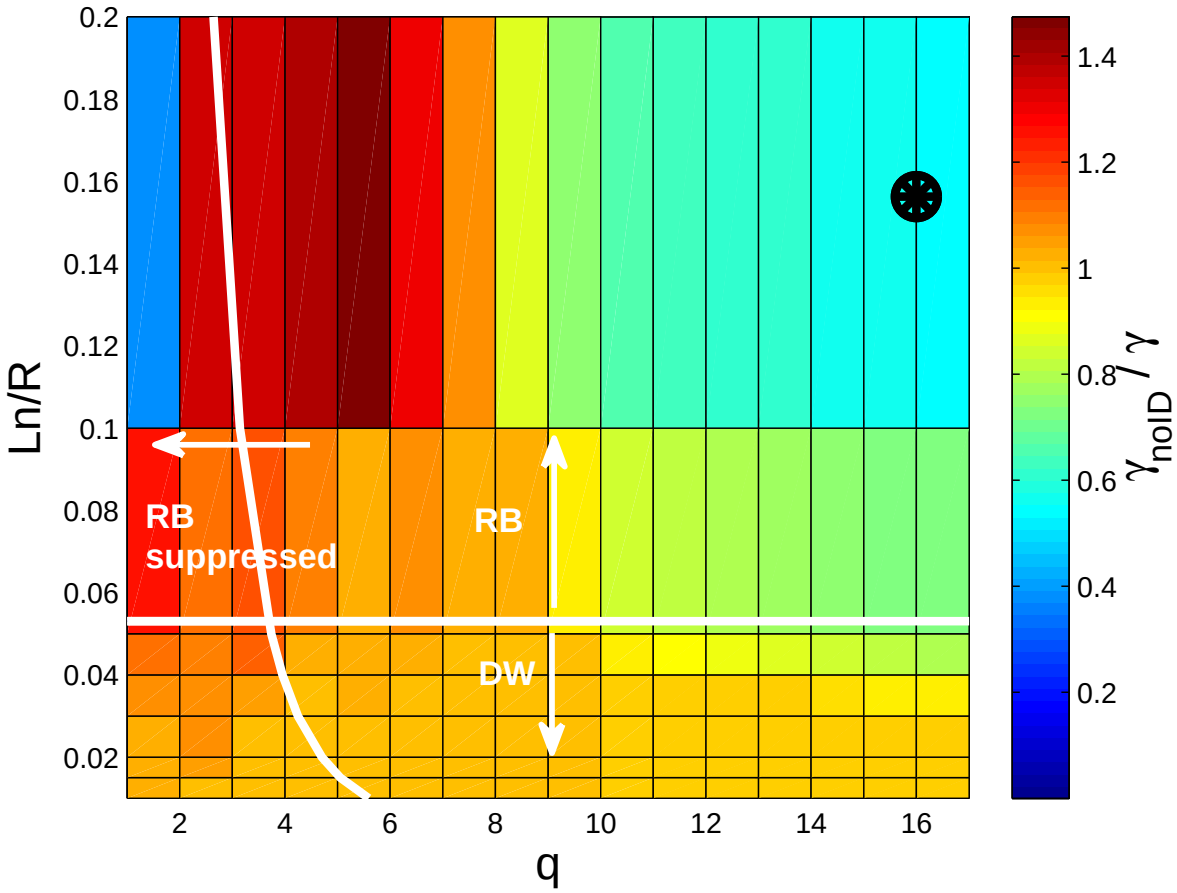

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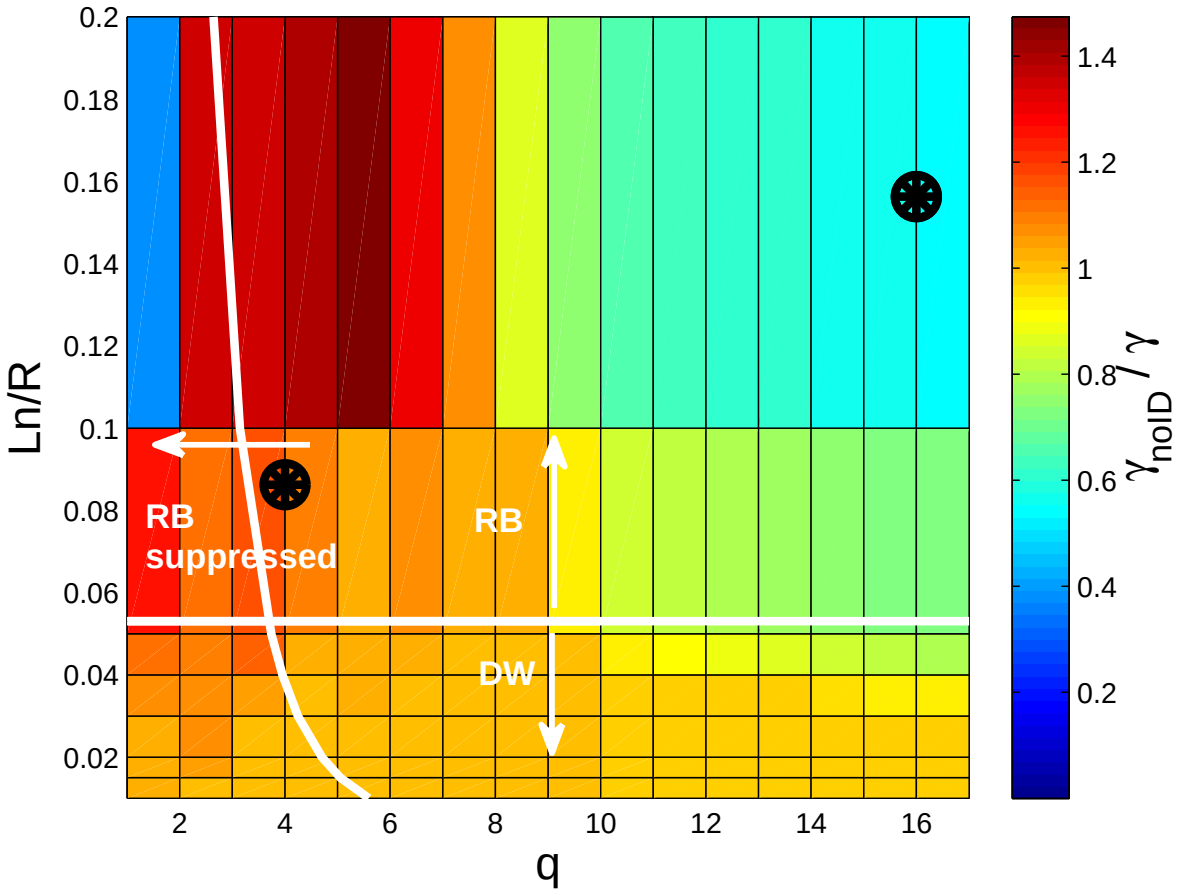
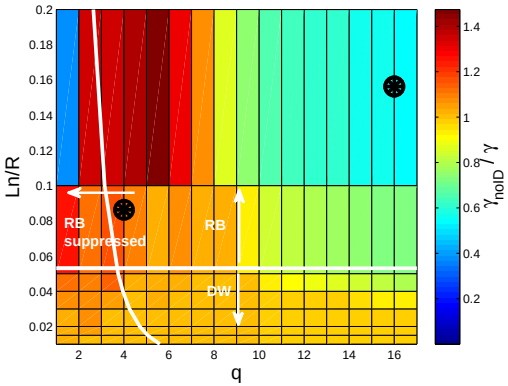
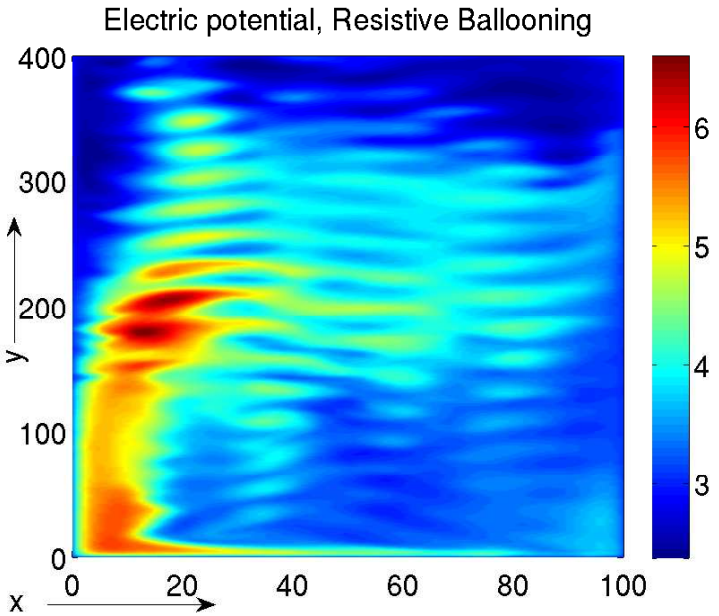


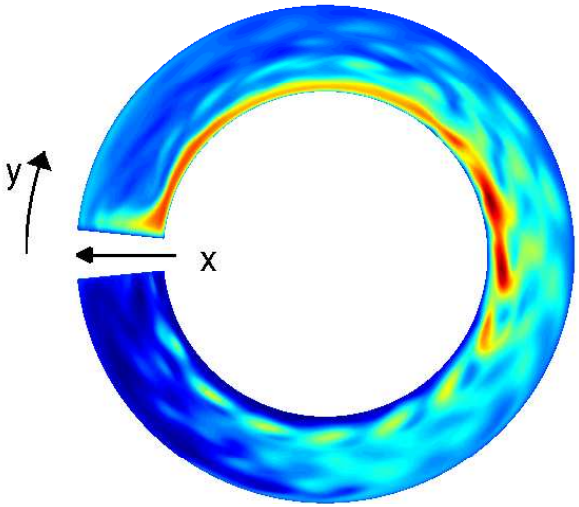
Non-linear simulation for the RB instability

- $q = 16$ (simulation parameter)
- $Ln/R \approx 0.16$ (computed parameter)



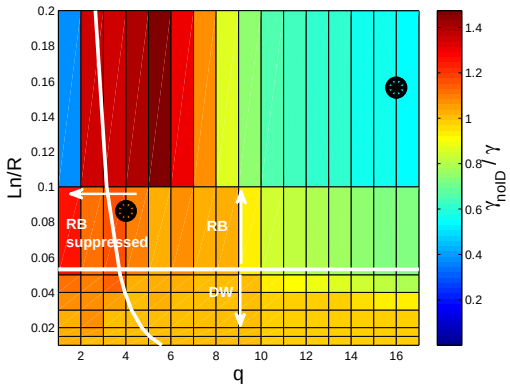


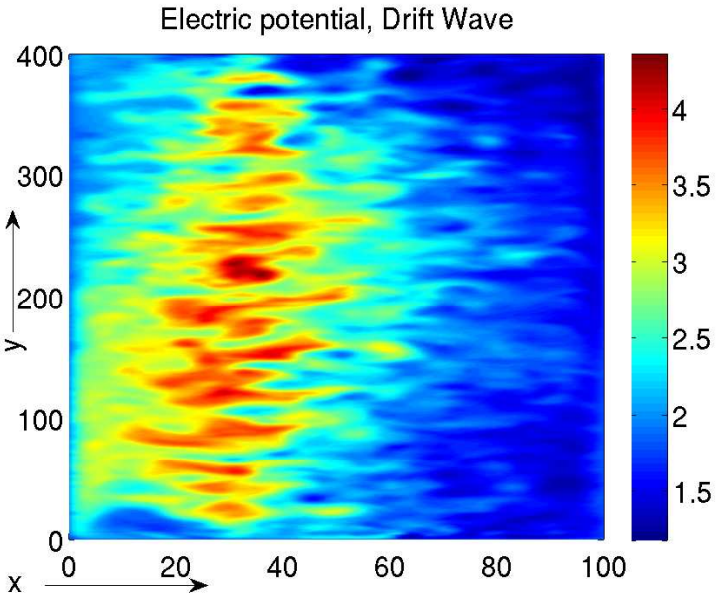
Electric potential, Resistive Ballooning

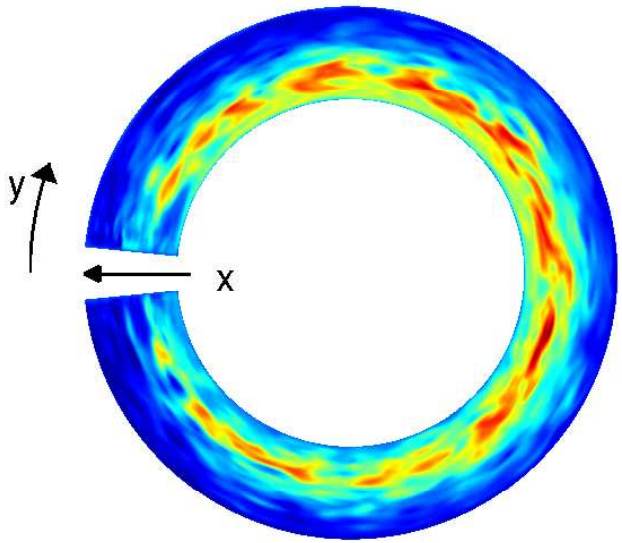


Non-linear simulation for the DW instability

- $q = 4$ (simulation parameter)
- $Ln/R \approx 0.09$ (computed parameter)







Conclusions

- simulation of the self-consistent SOL turbulence dynamics
- two instabilities regime : DW and RB. Good agreement with the linear studies
- linear study, easy-to-use method to interpret the non-linear results :
  - DW : small Ln/R ratio, small q, high toroidal mode number
  - RB : high Ln/R ratio, high q, small toroidal mode number
- Work in progress and envisaged :
  - magnetic shear
  - electromagnetic effects
  - ion temperature
  - divertor geometry