Relaxation & Transport in Fusion Plasmas

- Large scale flows, fronts & zonal
  - Relaxation dynamics
    - Scaling parameters & control
- Global, flux driven,
  2D & 3D fluid, non-linear
  simulations of plasma transport

Relaxation & Transport in Fusion Plasmas

- **Collision Frequency Effect on Turbulent Transport**
  Gloria Falchetto et al. poster TH/1-3Rd
- **SOL scaling with density front propagation**
  Philippe Ghendrih et al. poster TH/1-3Ra
- **Dynamics of Barrier Relaxation**
  Sadri Benkadda et al. poster TH/1-3Rb
- **ELM control with stochastic transport**
  Marina Bécoulet et al. poster TH/1-3Rc

Zonal Flow Enhancement at low ν_{ii}

Global, fluid, non-linear

3D ITG turbulence

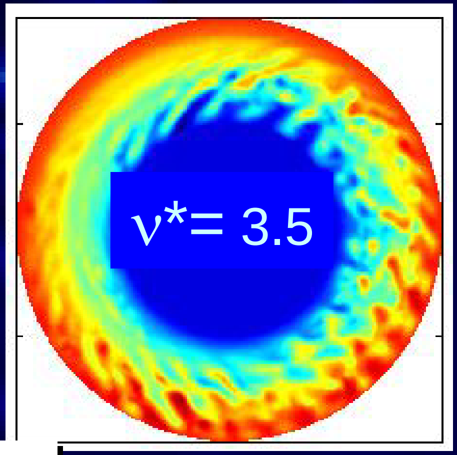
// Landau damping

flux driven F_{inj}

Electrostatic potential

ν_{ii} damped zonal flows

➔ radial transport

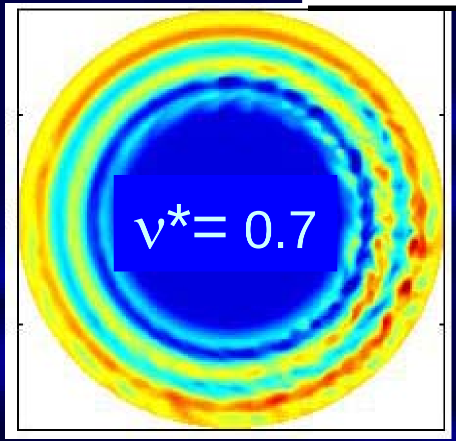


Poloidal section

weak damping of zonal flows

➔ shearing = upshift of threshold ∇T_i

➔ reduced transport



Control parameters

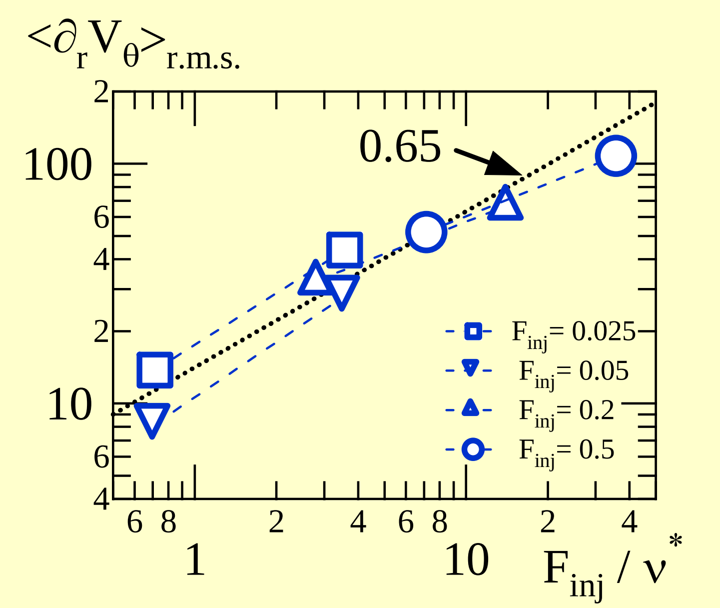
F_{inj} & ν^*

G. FalchettoTH/1-3Rd

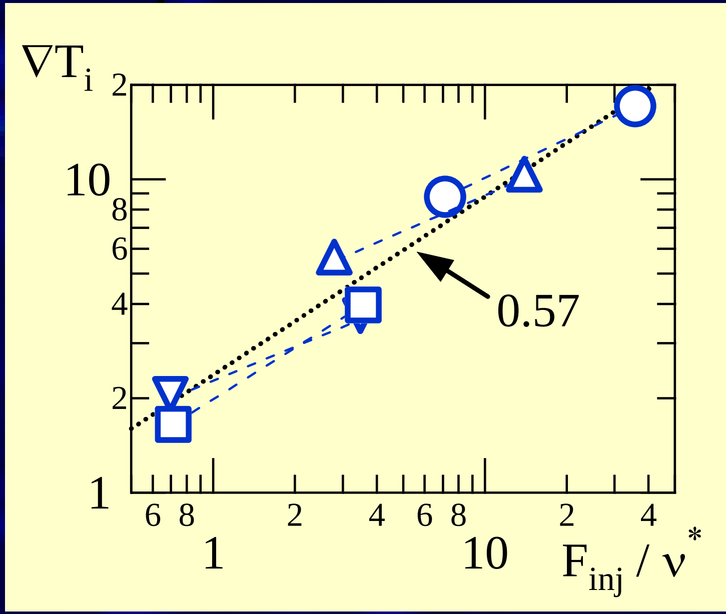
Lower collisionality ν^* = reduced turbulent transport

Steady state simulation : ∃ trend with F_{inj} / ν^*

Mean shearing rate



∇T_i gradient increase

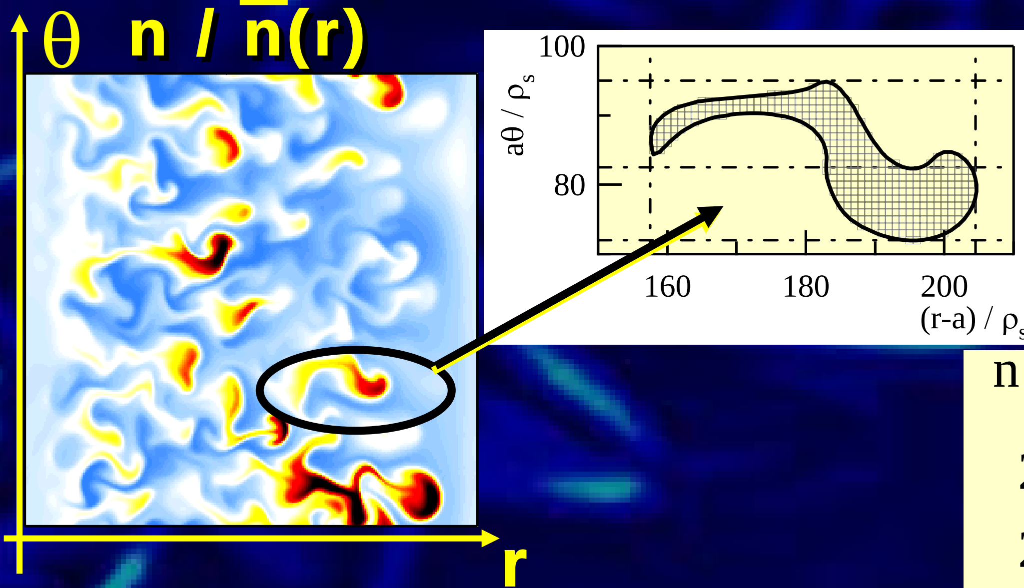


Similar ν^* effect in SOL turbulent transport

Zonal flows versus front propagation

G. Falchetto TH/1-3Rd

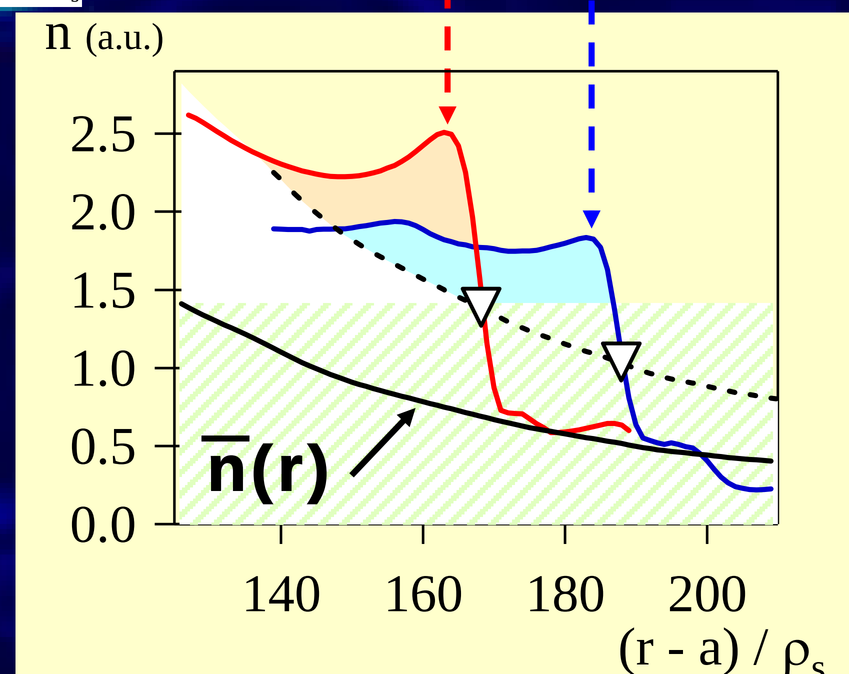
Front transport in SOL



2D SOL interchange

Δ x = 19.72 ρ_s

Δ t = 600 / Ω_i



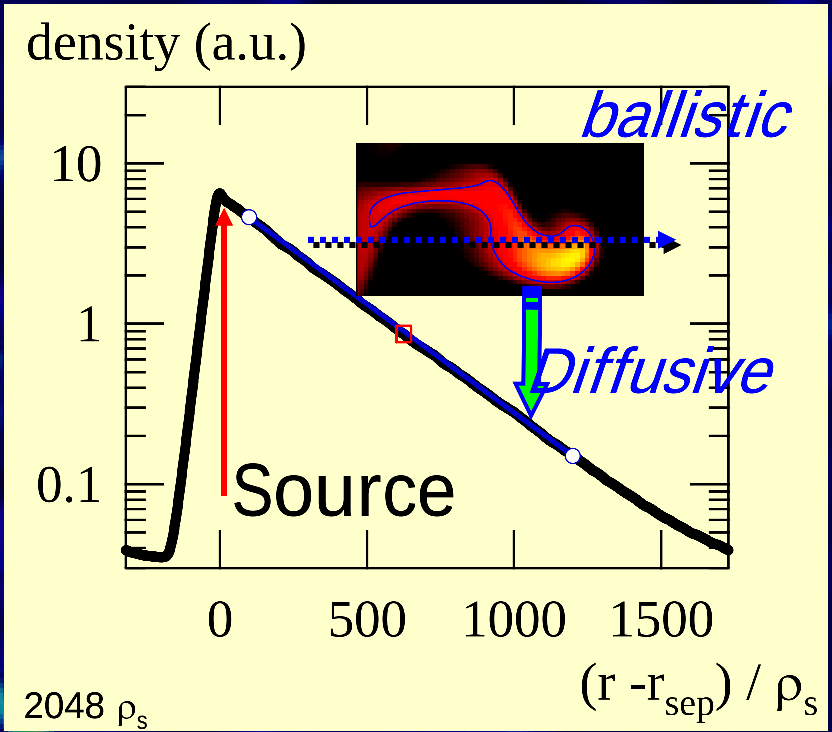
Defining a Density Front

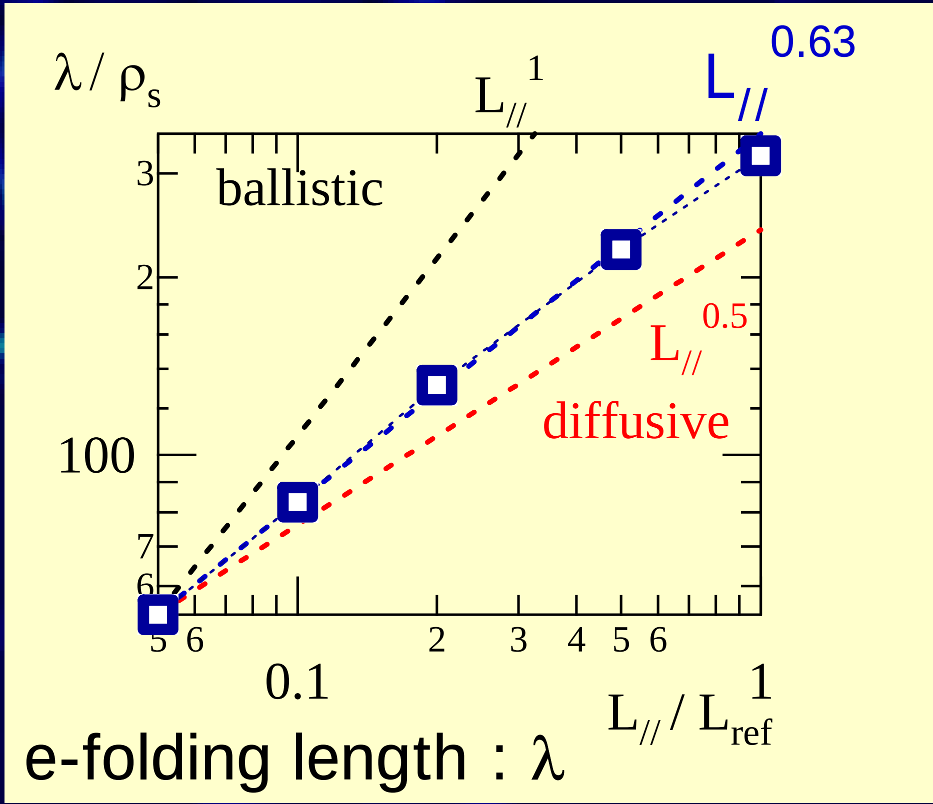
Ballistic motion $M_\perp \sim 0.04$

$\Rightarrow \lambda \sim 4\ \%\ L_{//}$? ($\lambda \sim 2.4$ m !)

Ph. Ghendrih TH/1-3Ra

SOL width scaling
= balance of diffusive and ballistic



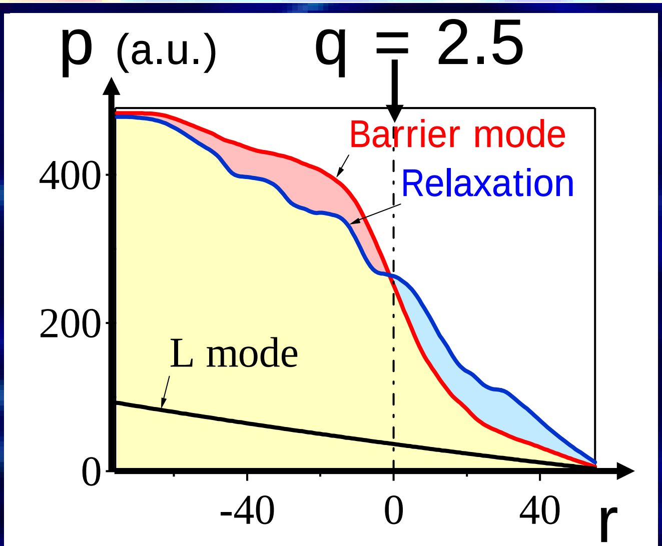


Intermittency :
Ballistic over-density transport

Analytical scaling $L_{//}^{5/8}$

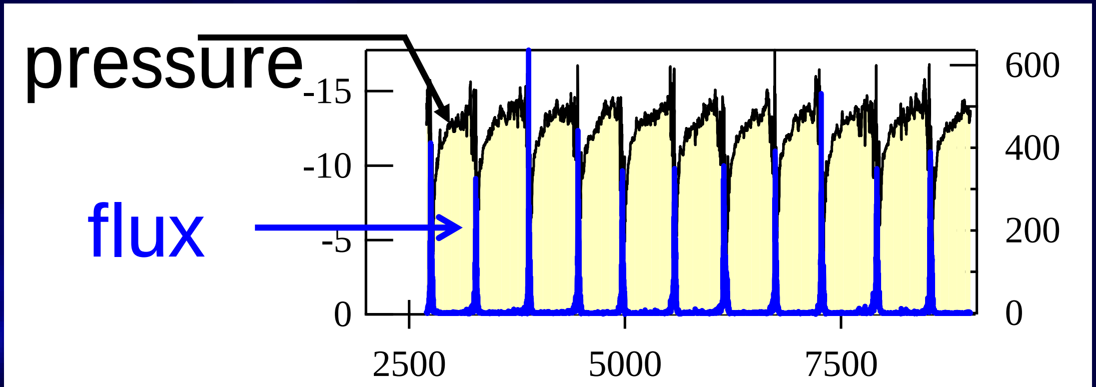
Ph. Ghendrih TH/1-3Ra

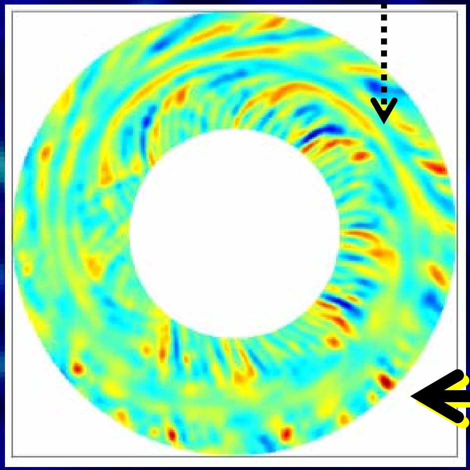
Transport Barrier & Relaxations



3D turbulence
Resistive ballooning
barriers = shear ExB flow driven
without zonal flows ≠ prey / predator

Relaxation events

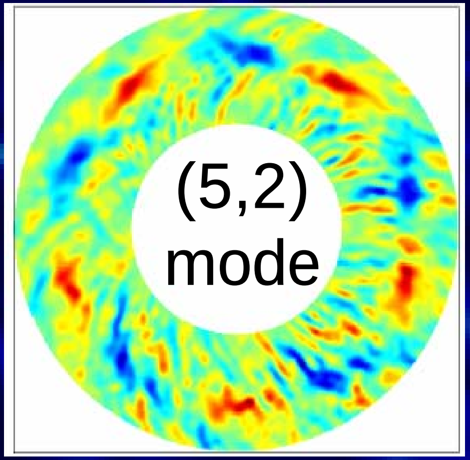




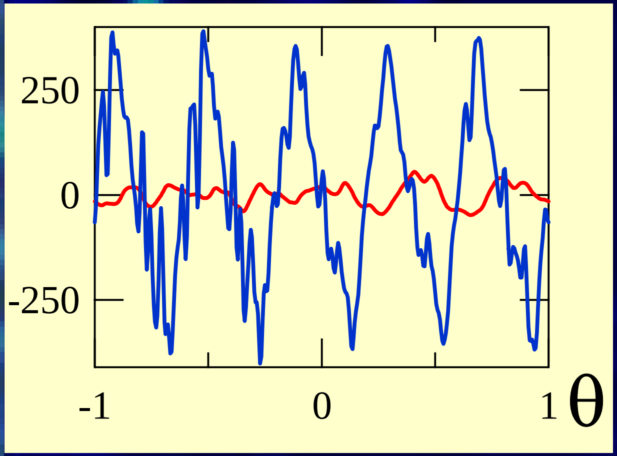
potential
fluctuations

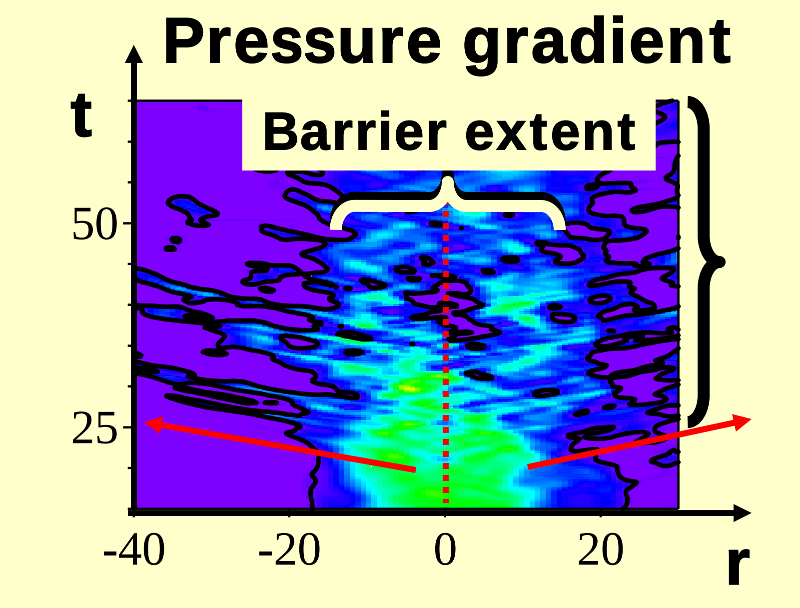
S.Benkadda TH/1-3Rb

Electrostatic Mode at Barrier Location



potential fluctuations





multiple structures

Radial ballistic propagation inward & outward

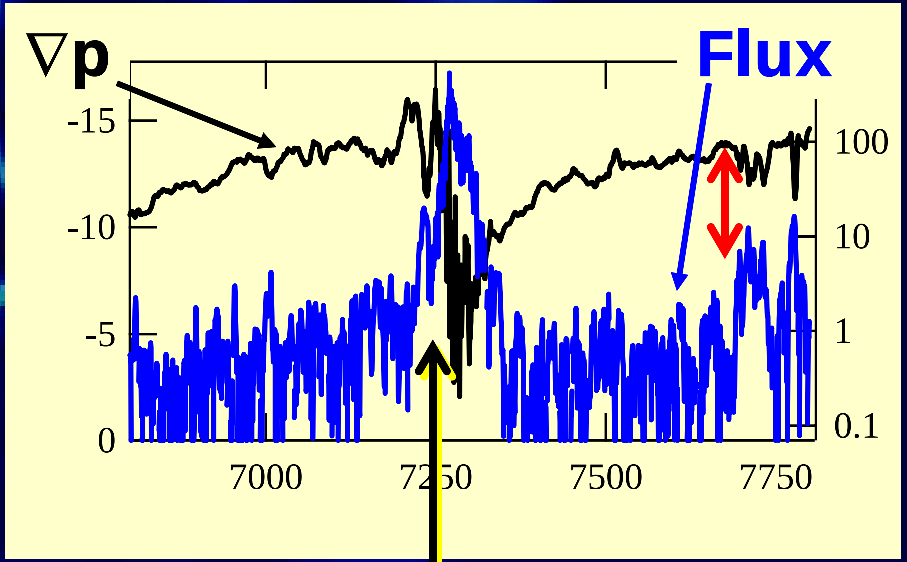
S.Benkadda TH/1-3Rb

linear growth + shearing out à la Dupree

$$\tilde{p} \approx \tilde{p}_0 \exp(\gamma t + i\,\omega_E t)$$

Linear growth

Doppler effect



shear $\omega_E \approx \omega'_E x$

collisional diffusion D_{coll}

$$\langle\tilde{p}\rangle \approx \tilde{p}_0 \exp(\gamma t - t^3/\tau_D^3)$$

$\tilde{p}_0$ effect

collisional effect

t^3 shearing out : Dupree time

$$\tau_D \approx 1 / (D_{coll}\,\omega'^2_E)^{1/3}$$

Transitory growth
& stabilization by shear flow

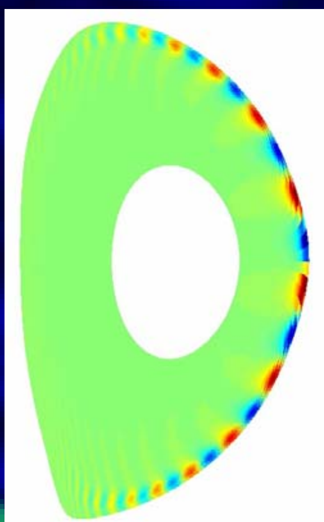
S.Benkadda TH/1-3Rb

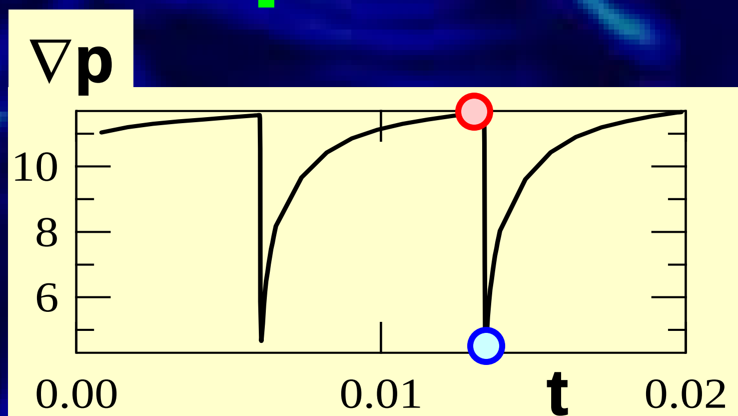
Modelling ELM activity

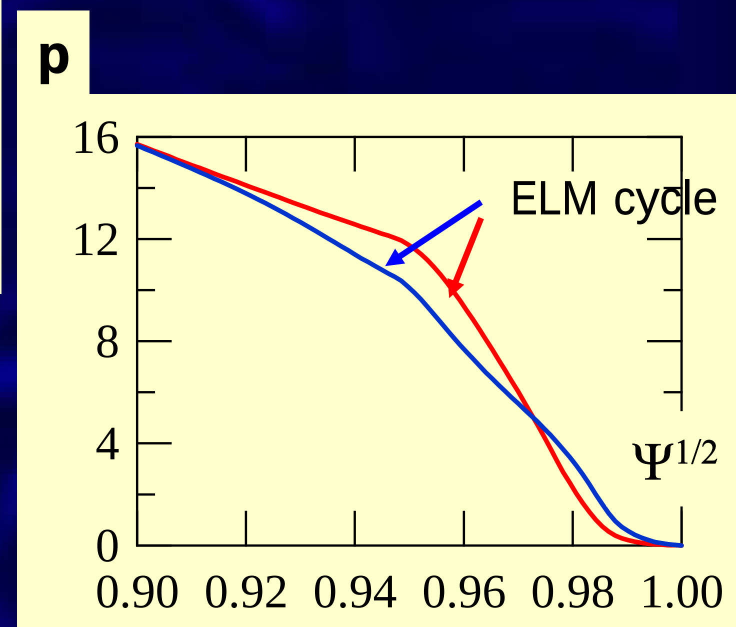
DIII-D:# 115467
1.6T/1.13MA
q_{95}=3.8

Ballooning linear growth + 2D transport : SOL = sink

M. Bécoulet TH/1-3Rc



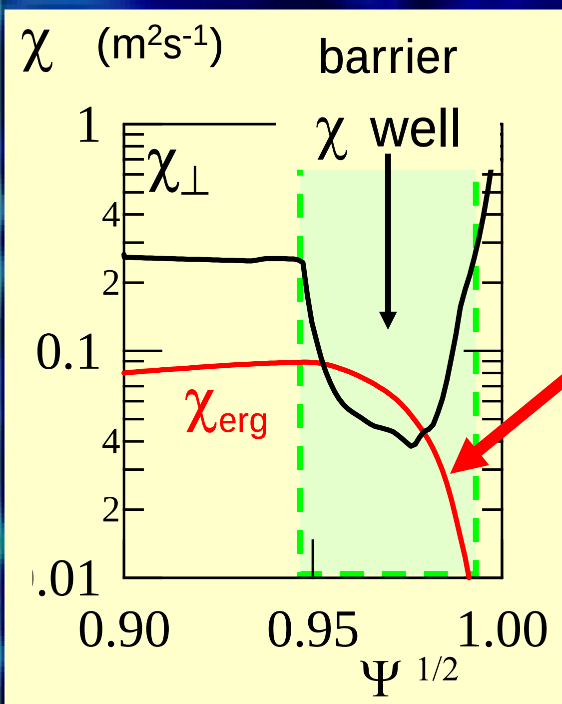




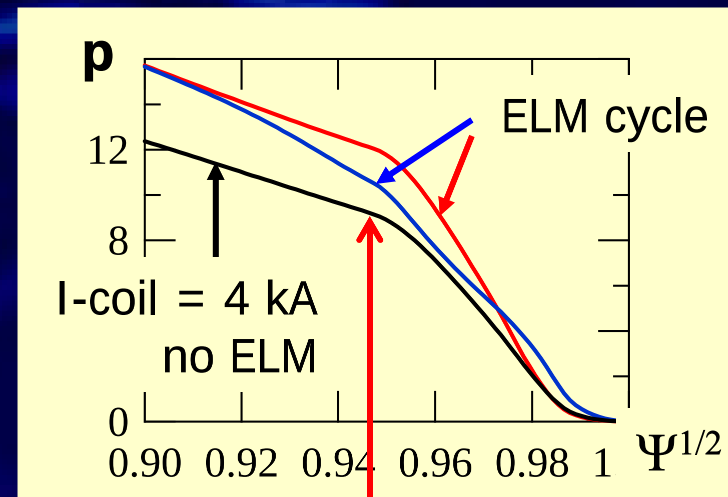
ELM : δB_r / B ~10^{-2} (n=-10)

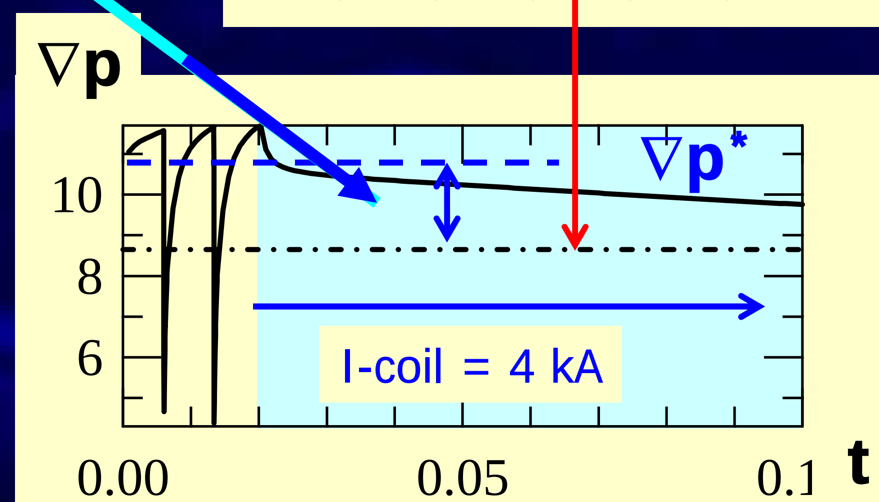
Controlled confinement degradation

External ~δB_r / B ~10^{-4} (n=-3)



Confinement loss
χ_{erg} controlled





M. Bécoulet TH/1-3Rc

Association EURATOM-CEA

ELMs, Zonal Flows, Fronts
Control of Large Scale Structures

Posters P3 / P4

Large scale flows and Front propagation

TH / 1-3Rd

Zonal Flows : **lower $\nu^* \Rightarrow$ larger ∇T_i**

TH / 1-3Ra

Fronts : **SOL width $\lambda \propto R^{0.63}$**

TH / 1-3Rb

Dynamics of Barrier Relaxation = time delay
growth rate γ^{-1} and velocity shearing-out

TH / 1-3Rc

ELM control by external magnetic perturbation
can be made robust
confinement penalty is controlled

TH / P6-7

More on Zonal flows : gyrokinetics