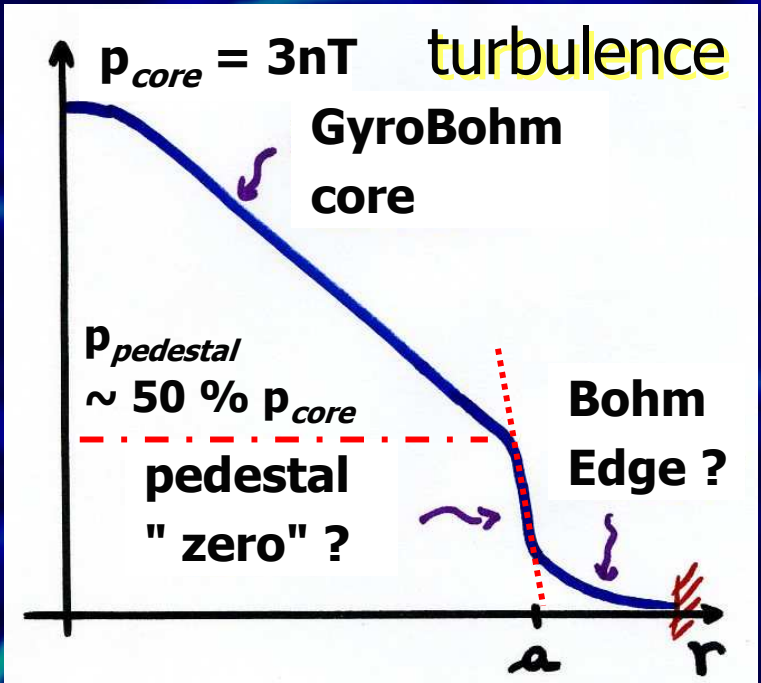
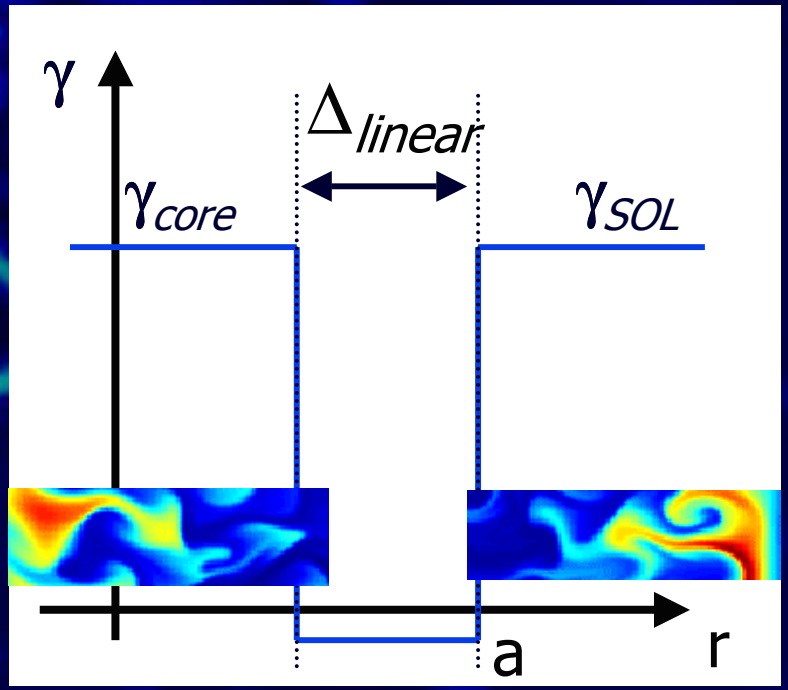
Pedestal width and turbulence spreading

- ITER reference scenario
  = Hmode & 5 keV pedestal
- Pedestal scaling (threshold, etc.) ~ open issue
- Free parameter = $\Delta_{pedestal}$

Turbulence spreading & $\Delta_{pedestal}$





Turbulence spreading into pedestal

$\Delta_{pedestal} > \Delta_{linear}$?????? $\Delta_{pedestal} < \Delta_{linear}$

a "simple" turbulence model

Equation 2D interchange ~ Rayleigh-Bénard

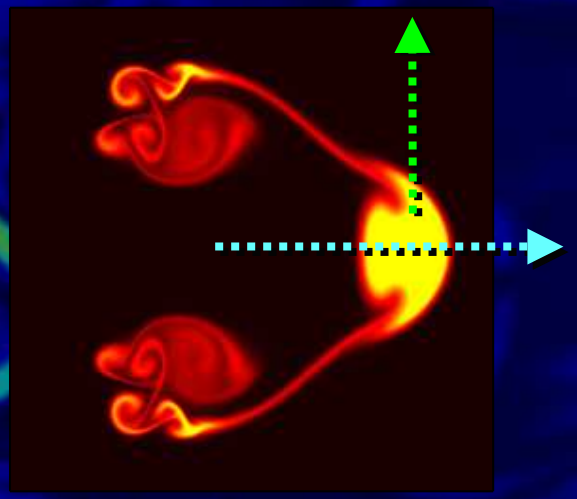
$$(\partial_t - D\Delta_\perp)N + [\phi, N] = -\sigma N \exp(\Lambda - \phi) + S$$

$$(\partial_t - \nu\Delta_\perp)\Delta_\perp\phi + [\phi, \Delta_\perp\phi] - g\partial_\theta N = \sigma (1 - \exp(\Lambda - \phi))$$

convection

g term

// sink

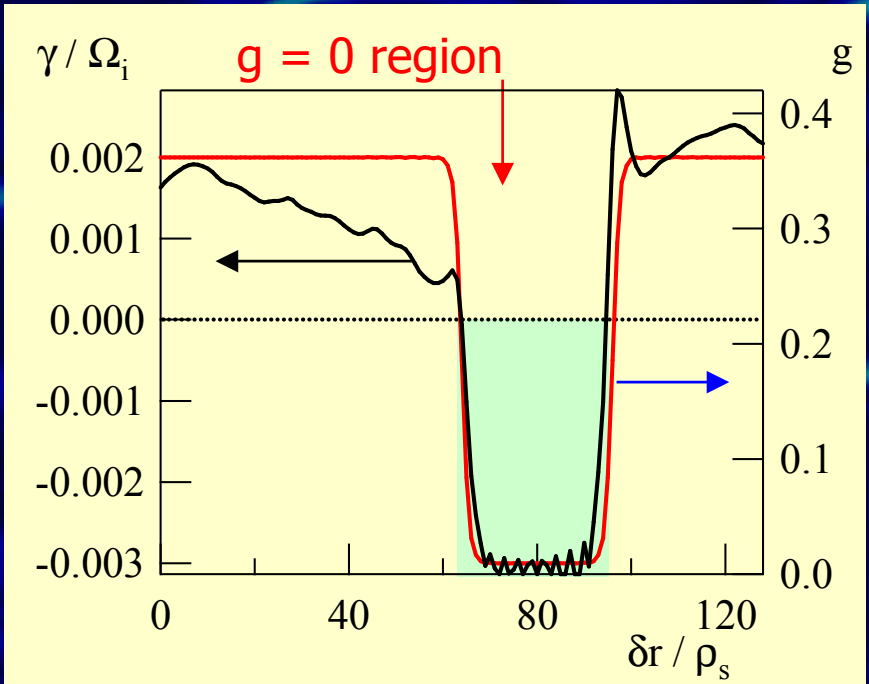


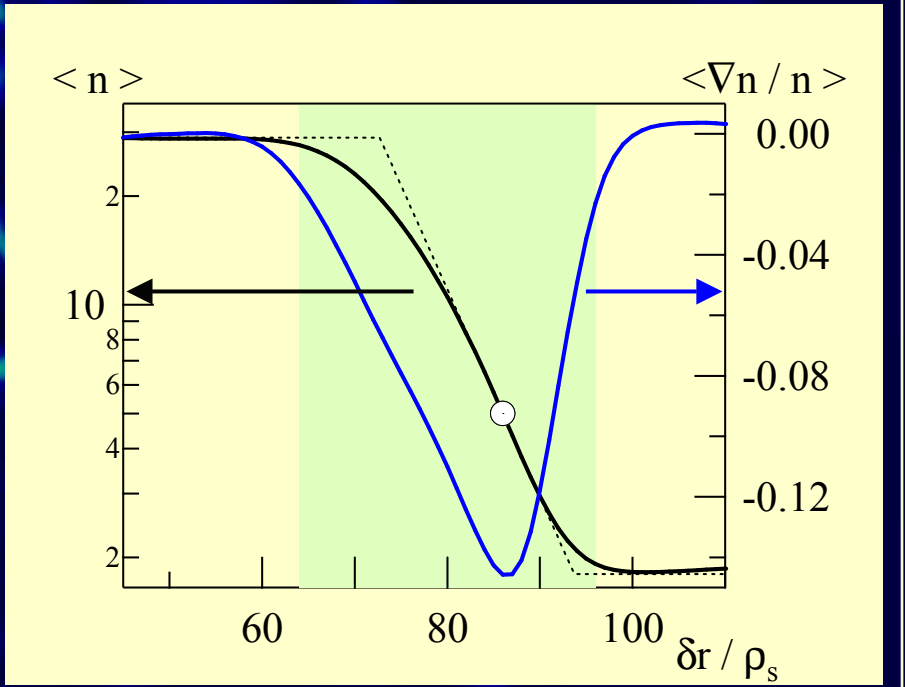
$$\partial_t N + \nabla\Gamma_\perp = -N/\tau_{//}$$

$$\Gamma_\perp = -D\nabla N + \Gamma_{tur}$$

linear analysis :
$\exists \Gamma_{tur} \Rightarrow g \neq 0$

Artificial Transport Barrier



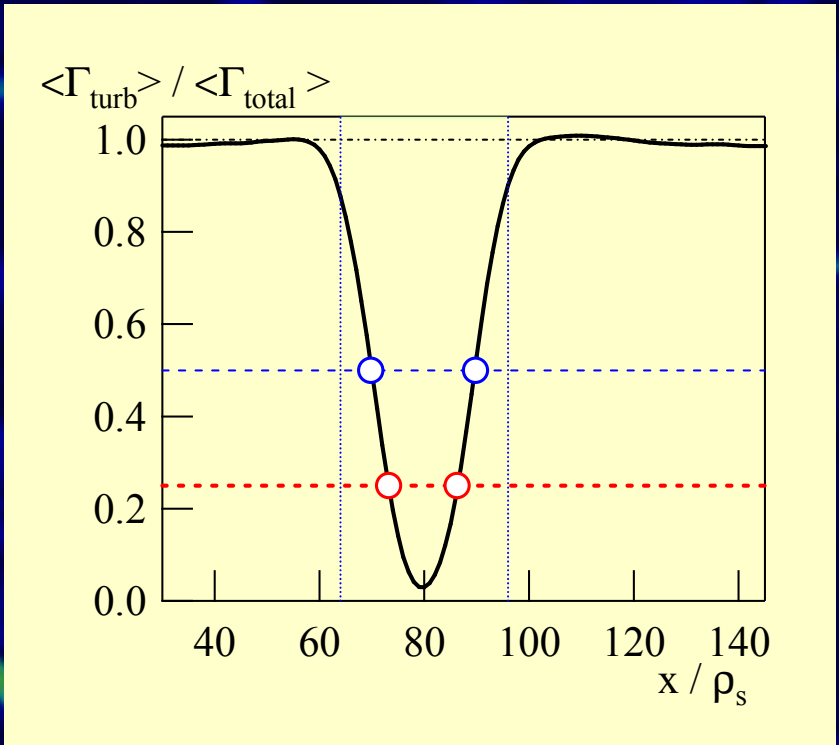


Standard features of Transport Barriers

strong increase of ∇n / n

tanh like fit of pedestal

Pedestal width < region g=0



Turbulence drop

< linear stable region

smooth shape

∃ turbulent transport

"Linear" barrier

= complex signature

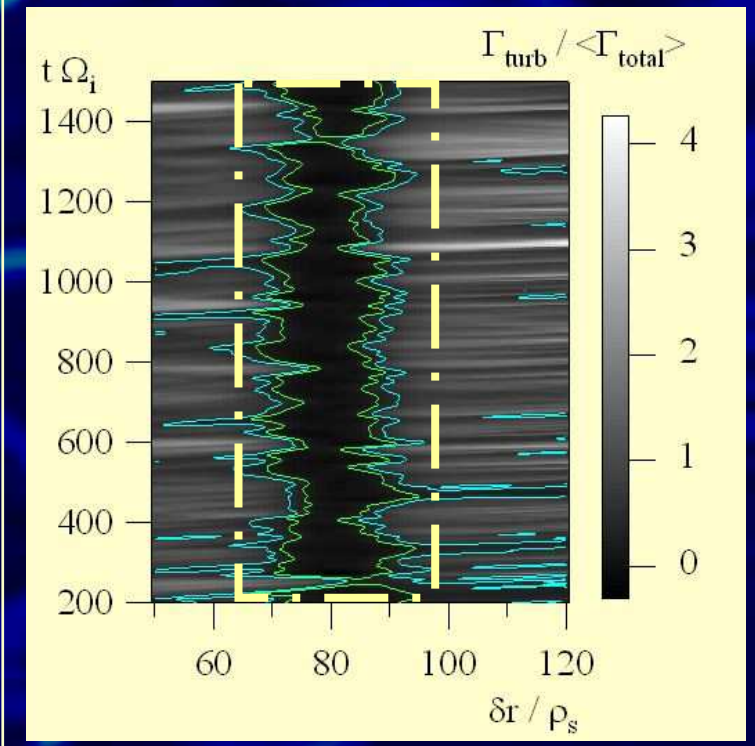
width ?

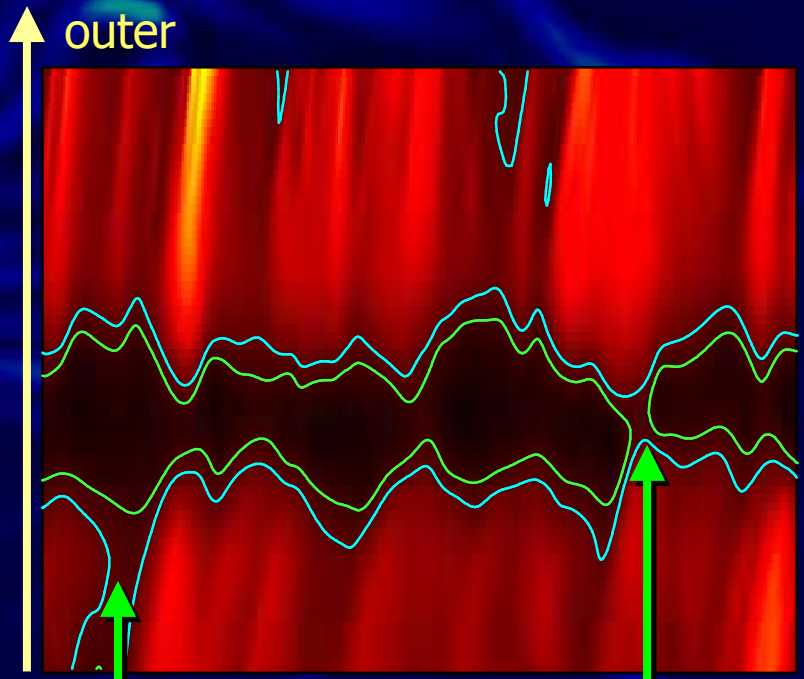
transport ?

<> = average = time + poloidal

else poloidal average only

Time dependent spreading into the barrier





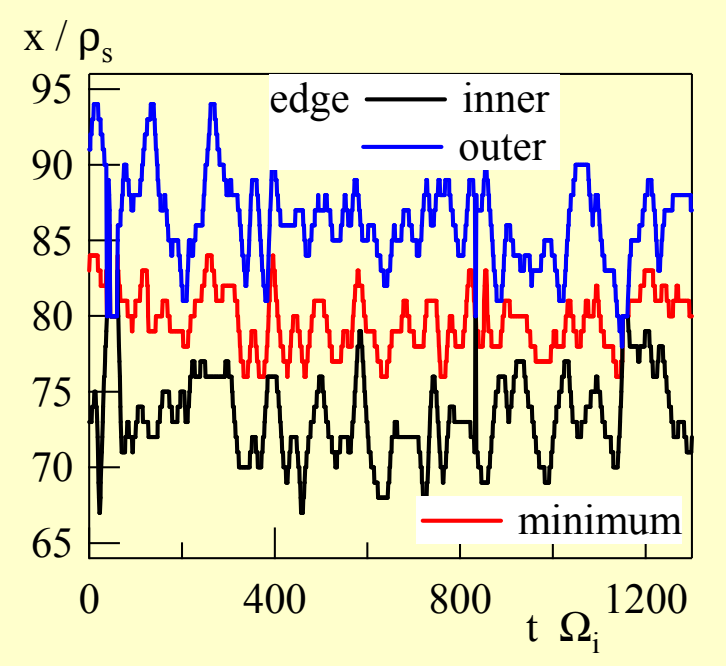
Edge slide away

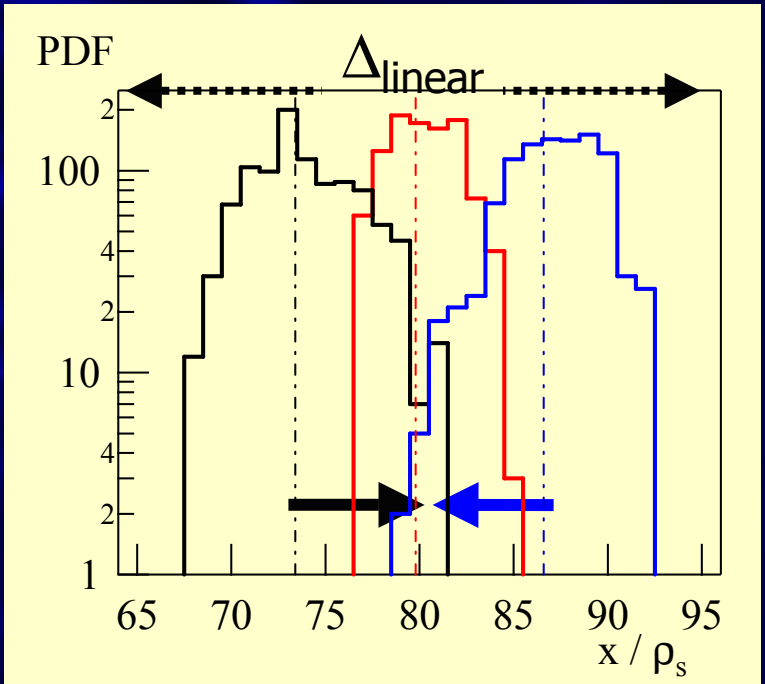
transient barrier suppression

correlation between the 2 sides of the barrier

propagation $M_{\perp} \approx \pm 0.015$

Statistics of barrier (skewed)





inward shift of barrier > 25 %

mean value = 10 ρ_s inward shift

skewness : inner ≈ 0.3 outer ≈ -0.3

spreading ⇒ shrinking feature of pedestal

Summary

Pedestal linear width $\Rightarrow$ reduced by spreading

spreading into ETB $\approx$ $v_{Ex}\ \gamma_{linear}$

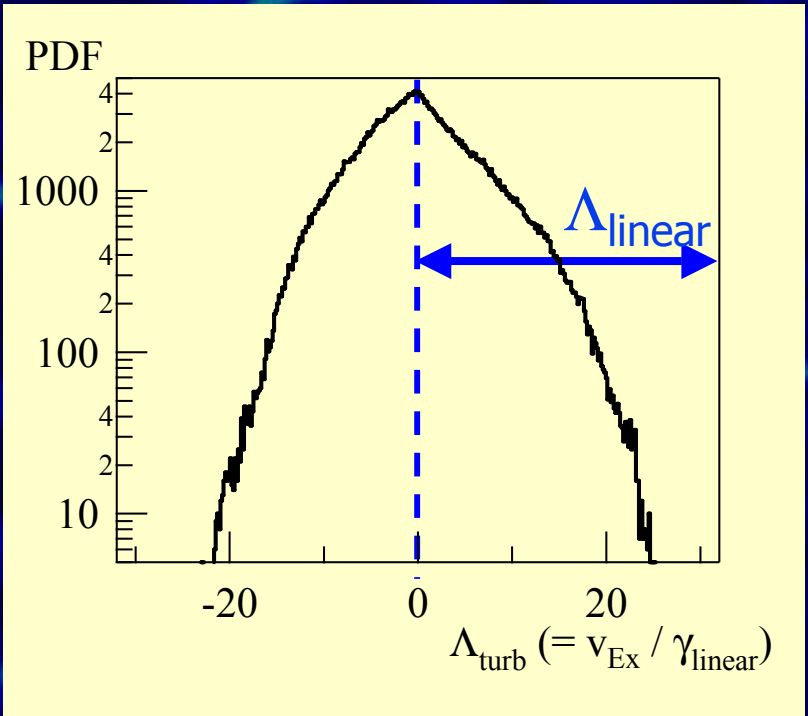
spreading of stabilisation

vicinty of pedestal = reduced turbulence

Pedestal properties

depend on SOL & core turbulence

Reduced pedestal width



PDF of radial velocity : v_{Ex}

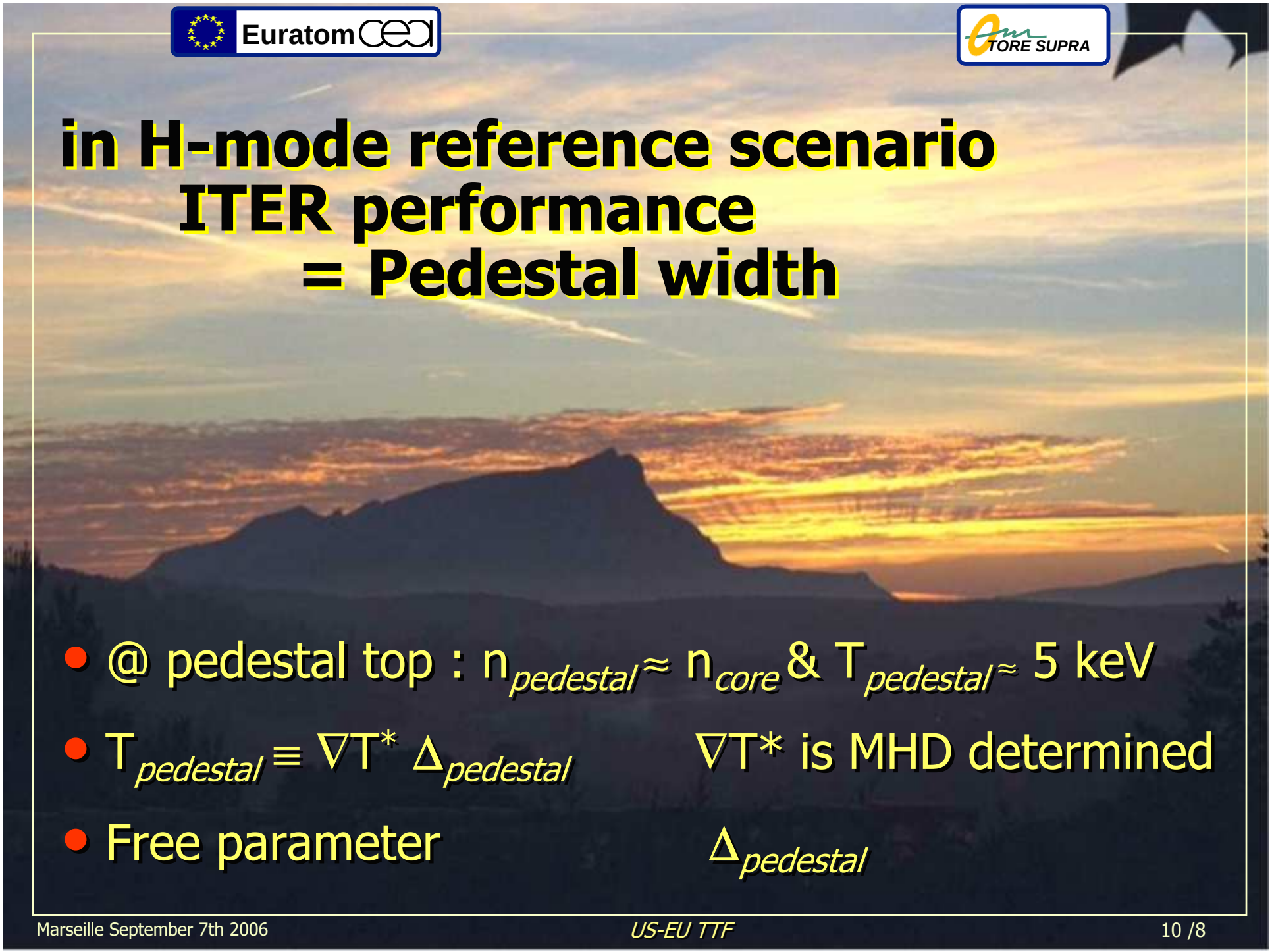
turbulence decay rate : γ_{linear}

$\Rightarrow$ turbulence penetration

$$\Lambda_{turb} \approx v_{Ex}\ \gamma_{linear}$$

$$\Delta_{ETB} \approx \Delta_{linear} - \Lambda_{core} - \Lambda_{SOL}$$

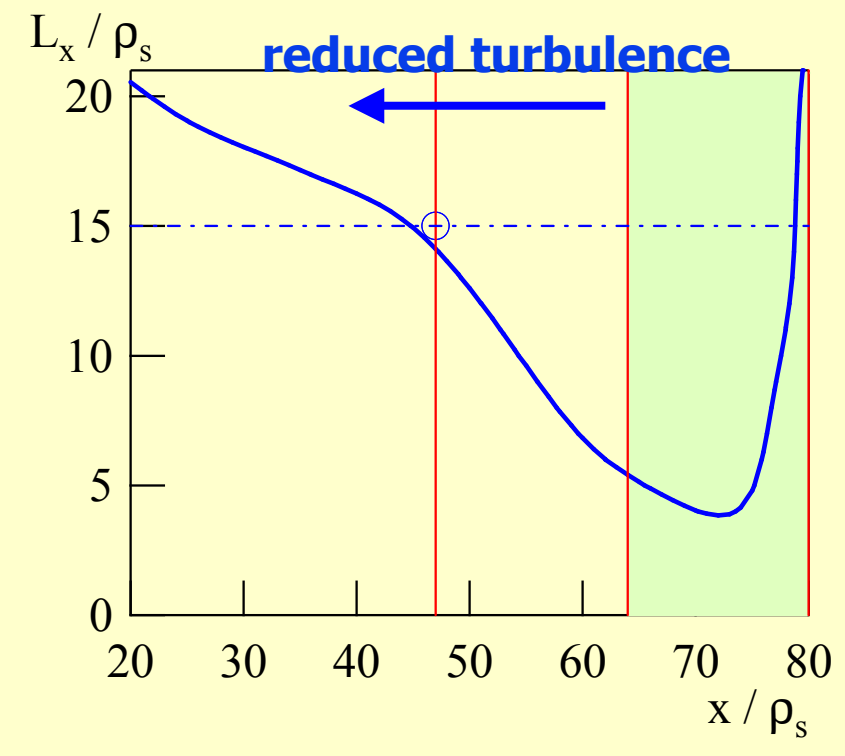
burn-through $\Rightarrow$ correlation of inner & outer shift



in H-mode reference scenario ITER performance = Pedestal width

- @ pedestal top : $n_{pedestal} \approx n_{core}$ & $T_{pedestal} \approx$ 5 keV
- $T_{pedestal} \equiv \nabla T^* \, \Delta_{pedestal}$ ∇T^* is MHD determined
- Free parameter $\Delta_{pedestal}$

ETB = reduced turbulence in edge



Correlation length

radial $L_x \approx 15\ \rho_s$

With barrier

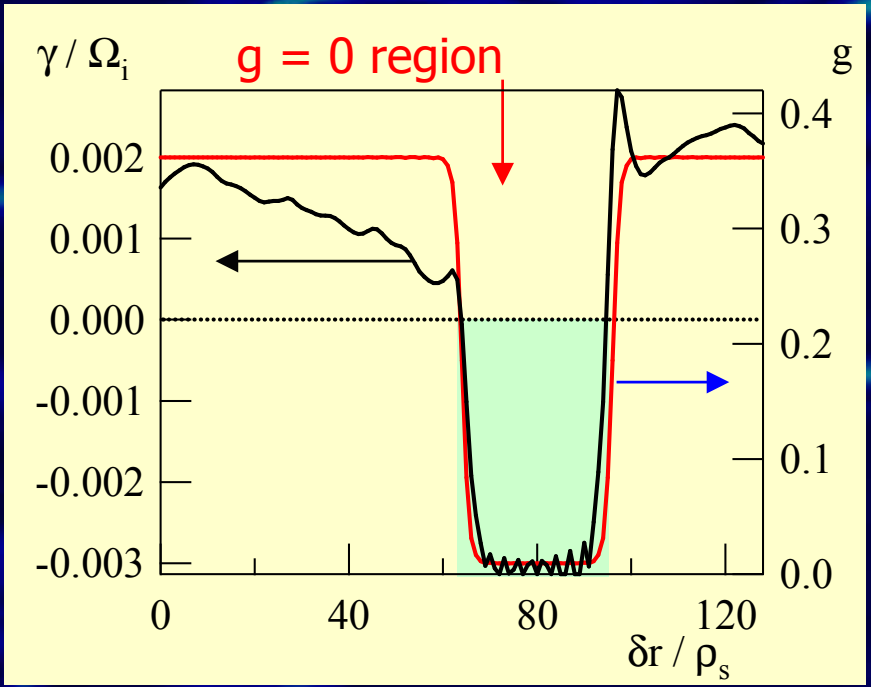
$L_x < 5\ \rho_s$

drop uphill (spreading)

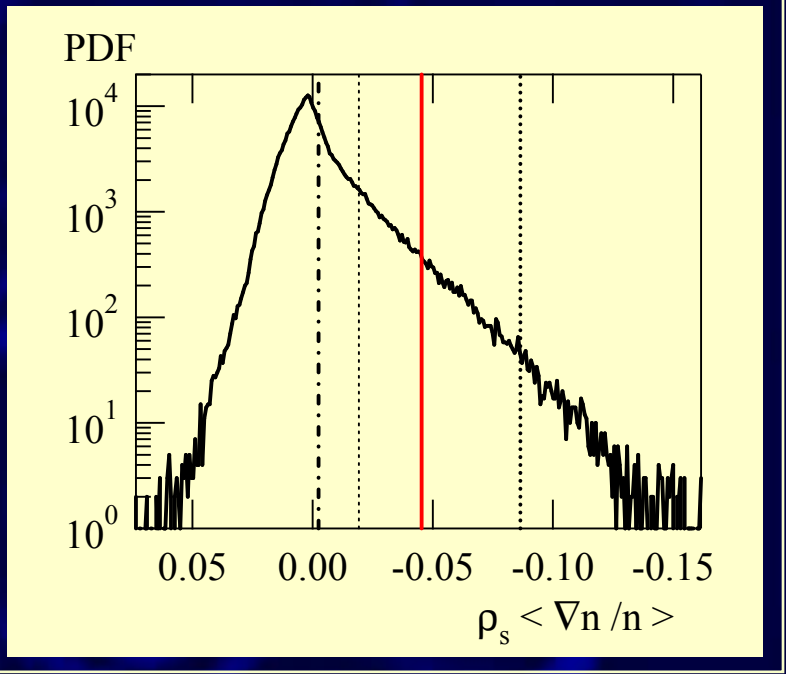
LH transition positive feedback loop

transition $\Rightarrow \Lambda_{SOL} \searrow \Rightarrow \Delta_{ETB} \nearrow$

g=0 region = linearly stable



In g = 0 region
linearly damped
turbulence



In NL regime
most of data = linearly stable
> 2.55 r.m.s. = unstable