# Pedestal width and turbulence spreading

Acknowledgements : Festival de Théorie 2005 (P. Diamond & D. Hughes)

P. Beyer, X. Garbet, V. Grandgirard, S. Benkadda,

G. Ciraolo, G. Darmet, Y. Sarazin, P. Tamain & Ph. Ghendrih

Association Euratom-CEA, CEA Cadarache

& CNRS / Université de Provence

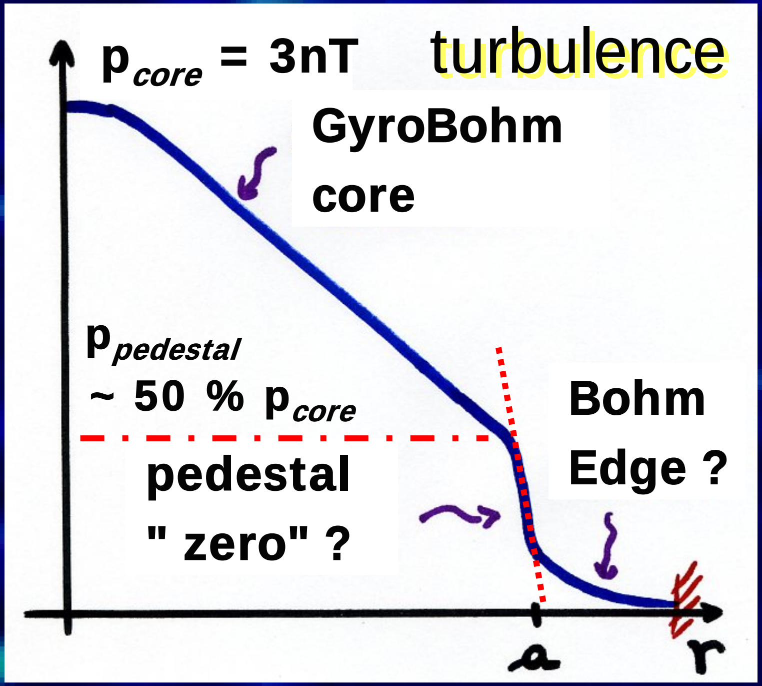
Euratom cea

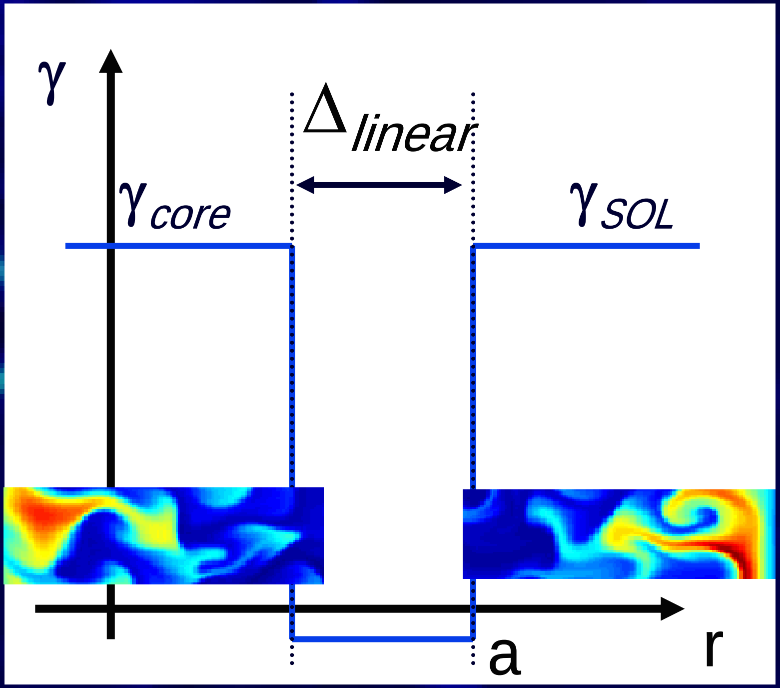
TORE SUPRA

# in H-mode reference scenario
# ITER performance
# = Pedestal width

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

# Turbulence spreading & $\Delta_{pedestal}$




## Turbulence spreading into pedestal

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

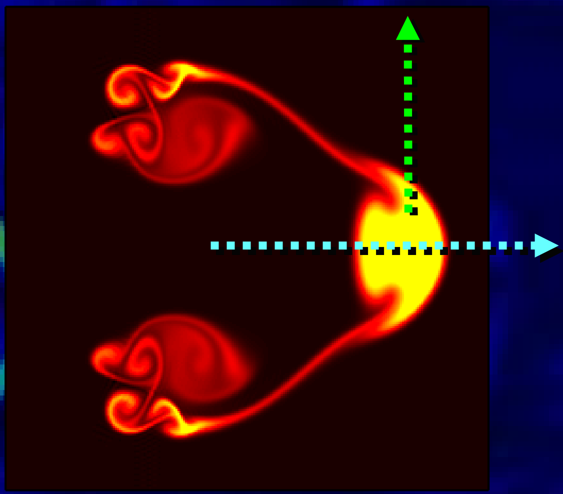
# a "simple" turbulence model

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



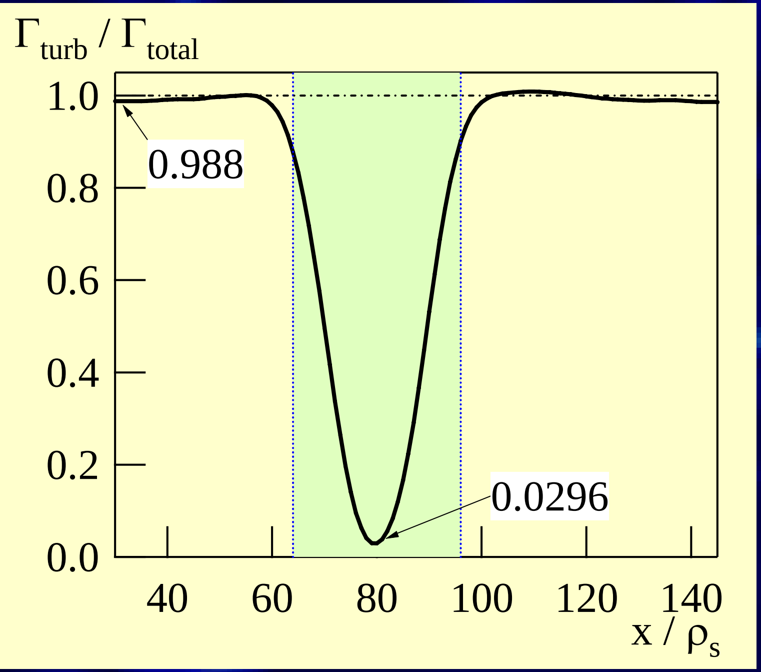
$$\partial_t N + \nabla\Gamma_\perp = -N/\tau_{//}$$

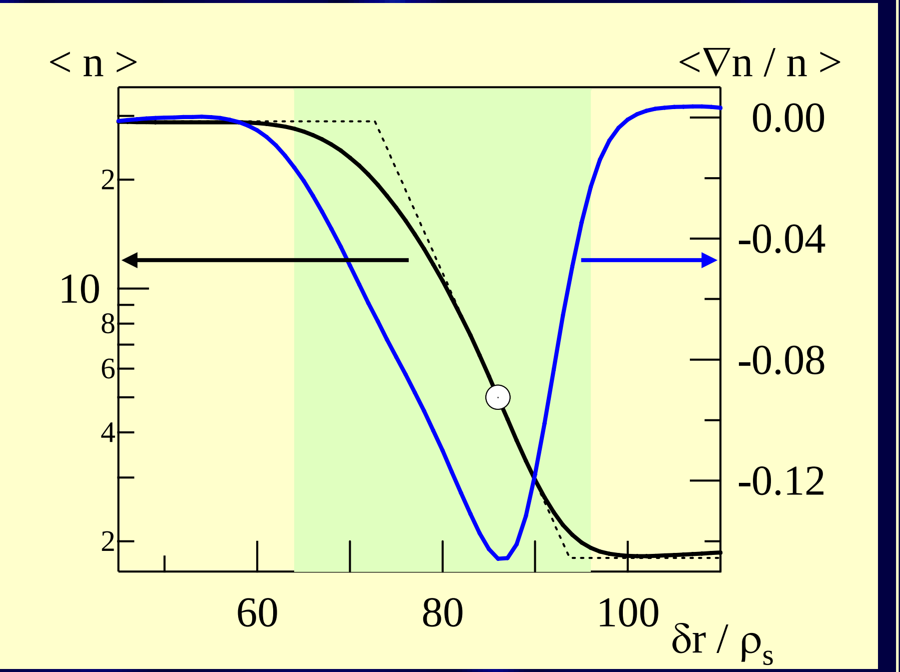
$$\Gamma_\perp = -D\nabla N + \Gamma_{tur}$$

linear analysis :

$$\exists\Gamma_{tur} \Rightarrow g \neq 0$$

# Pedestal width < region g=0



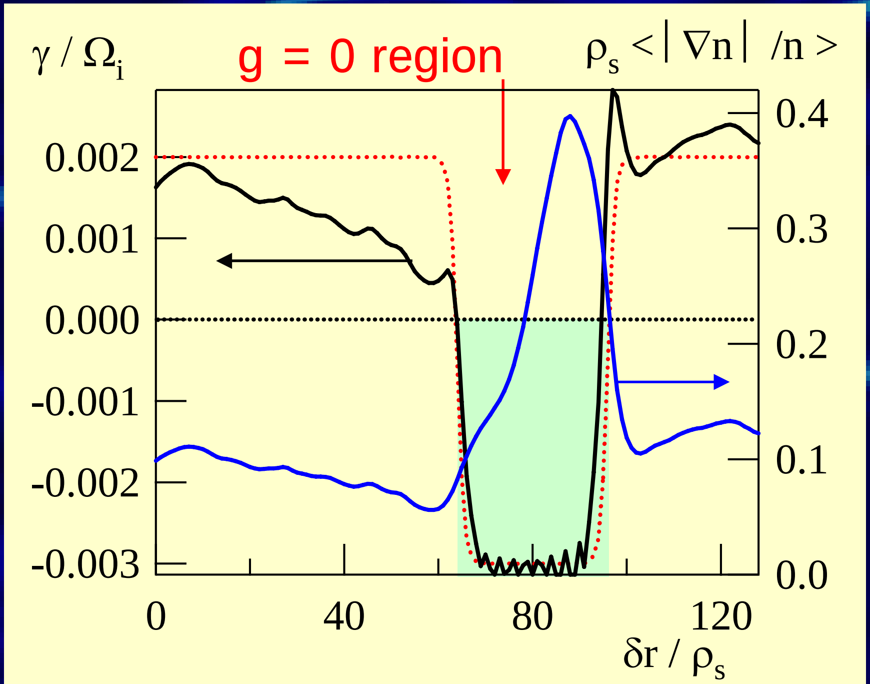

Standard features of Transport Barriers

drop in turbulent transport

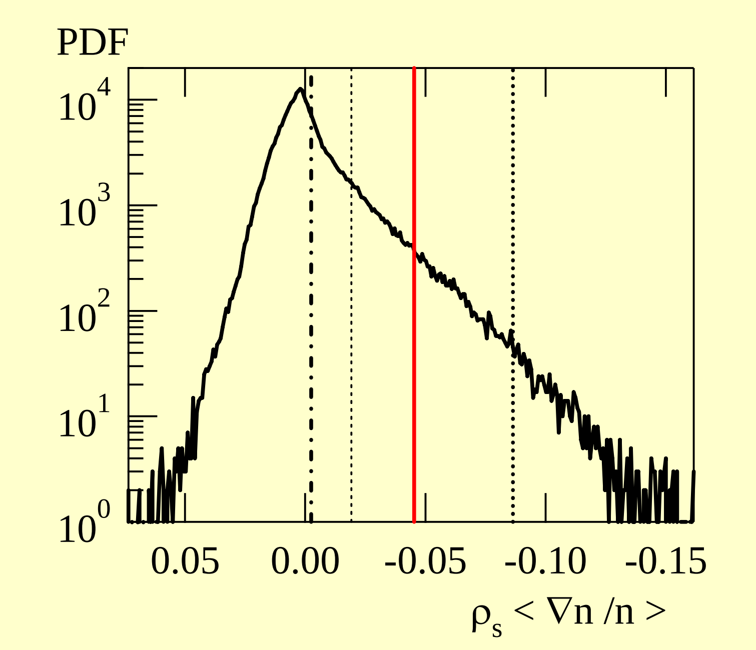
tanh like fit of pedestal

Spreading : inward and outward

# g=0 region = linearly stable

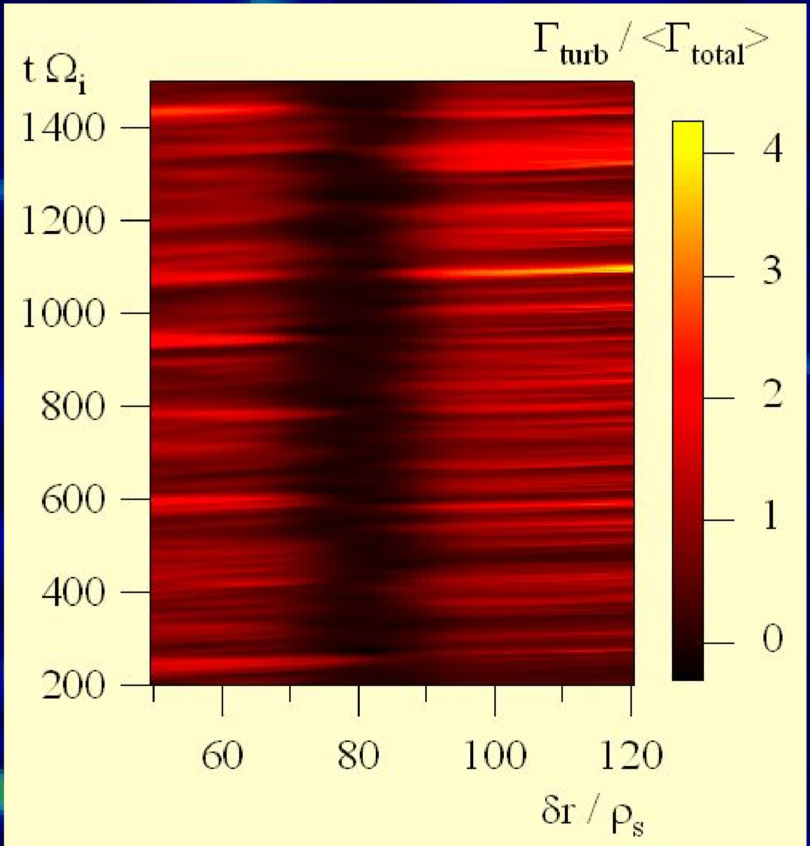


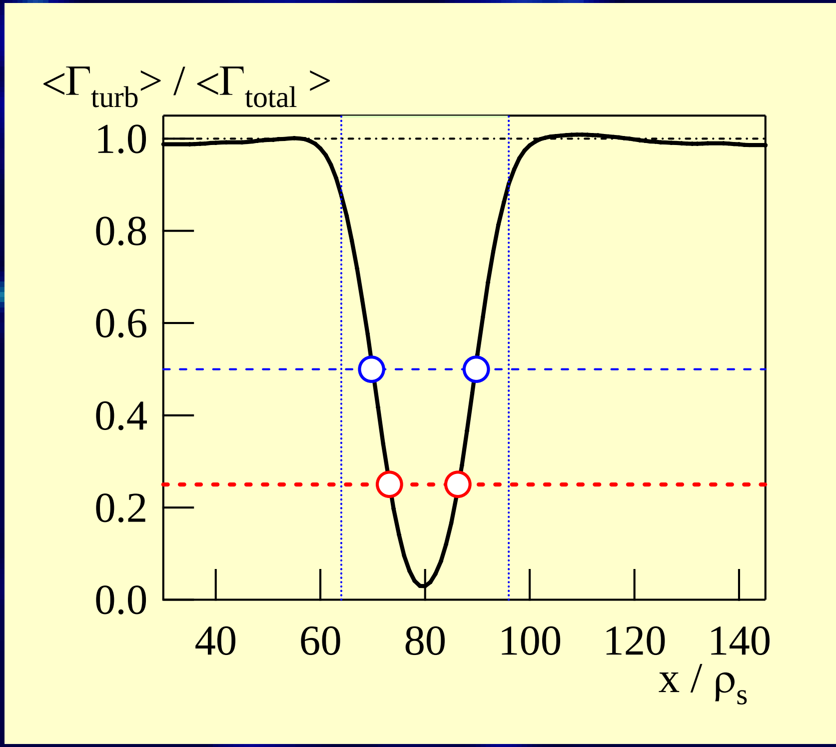

In g = 0 region
linearly damped
turbulence




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

# Barrier fluctuates

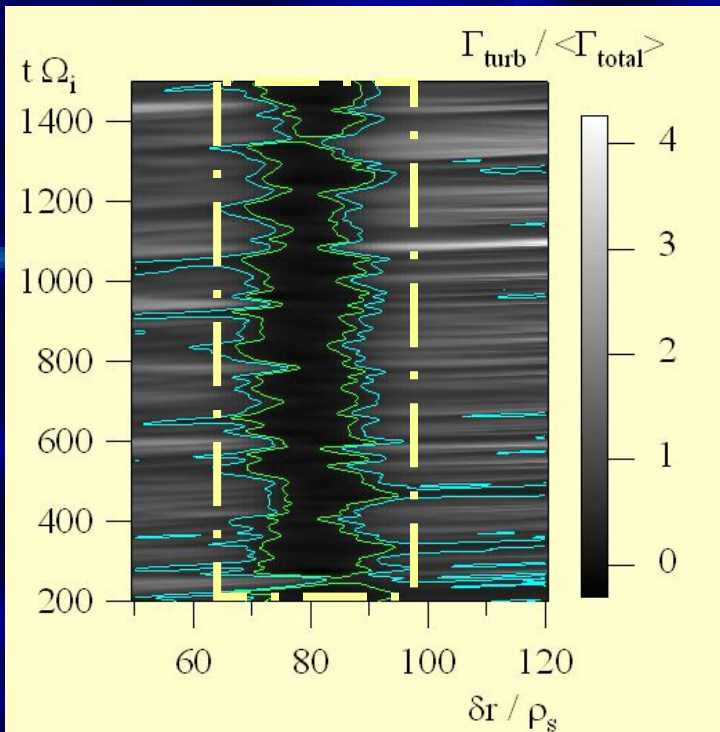


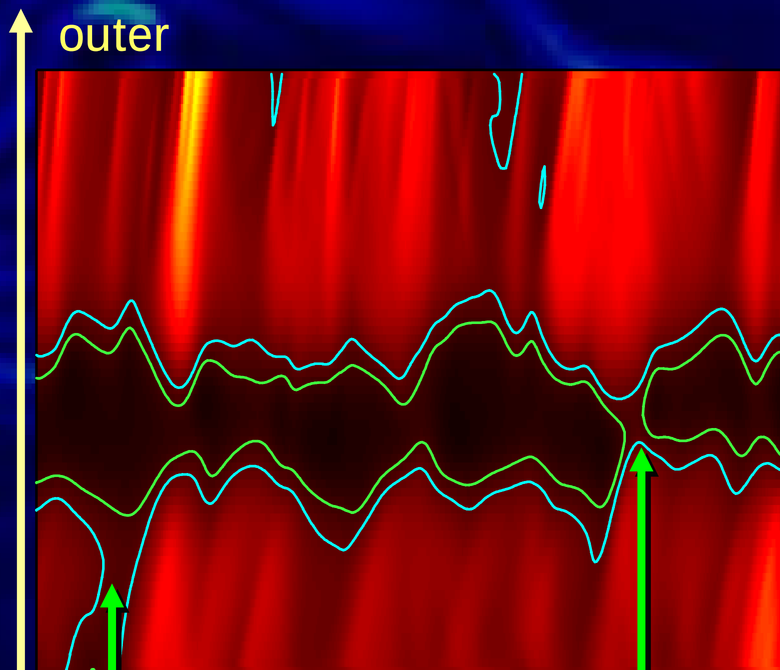




< > = average = time + poloidal

else poloidal average only

# Time dependent spreading into the barrier



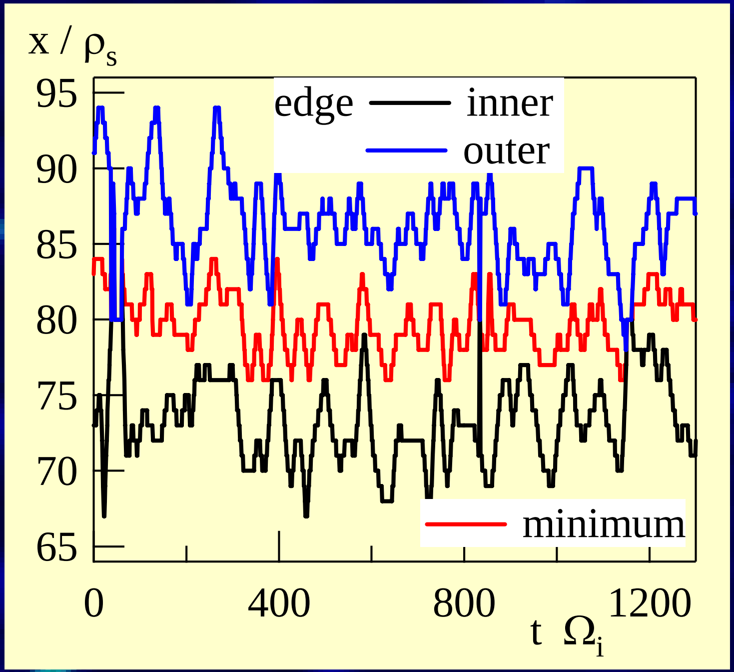

transient barrier suppression

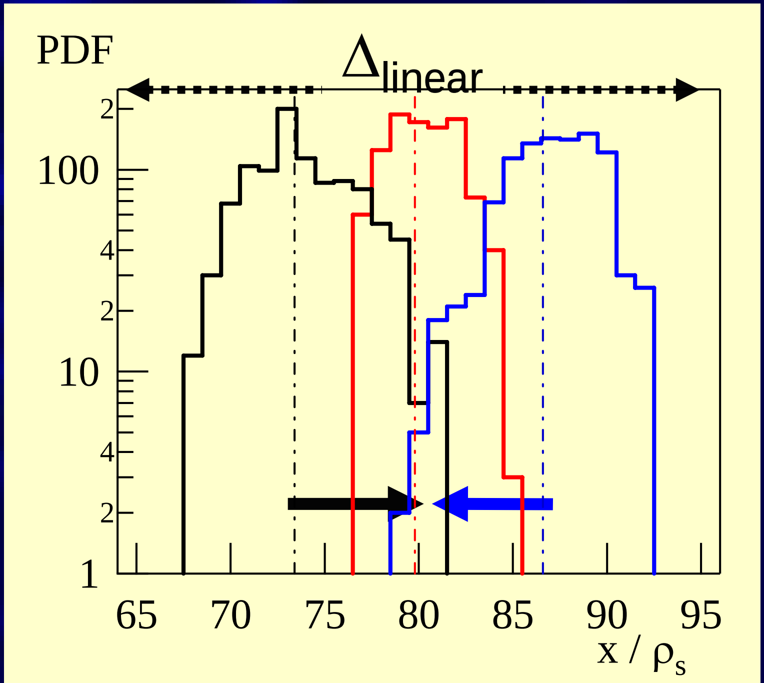
Edge slide away

correlation between the 2 sides of the barrier

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

# Statistics of barrier (skewed)



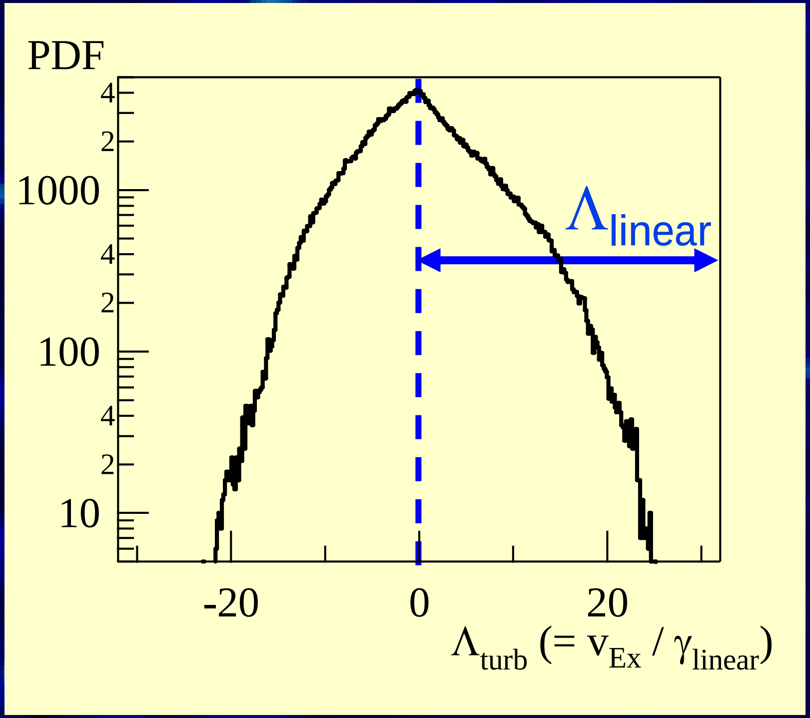

inward shift of barrier > 25 %

mean value = 10 $\rho_s$ inward shift

skewness : inner ≈ 0.3 outer ≈ -0.3

spreading ⇒ shrinking feature of pedestal

# Reduced pedestal width




PDF of radial velocity : $v_{Ex}$

turbulence decay rate : $\gamma_{linear}$

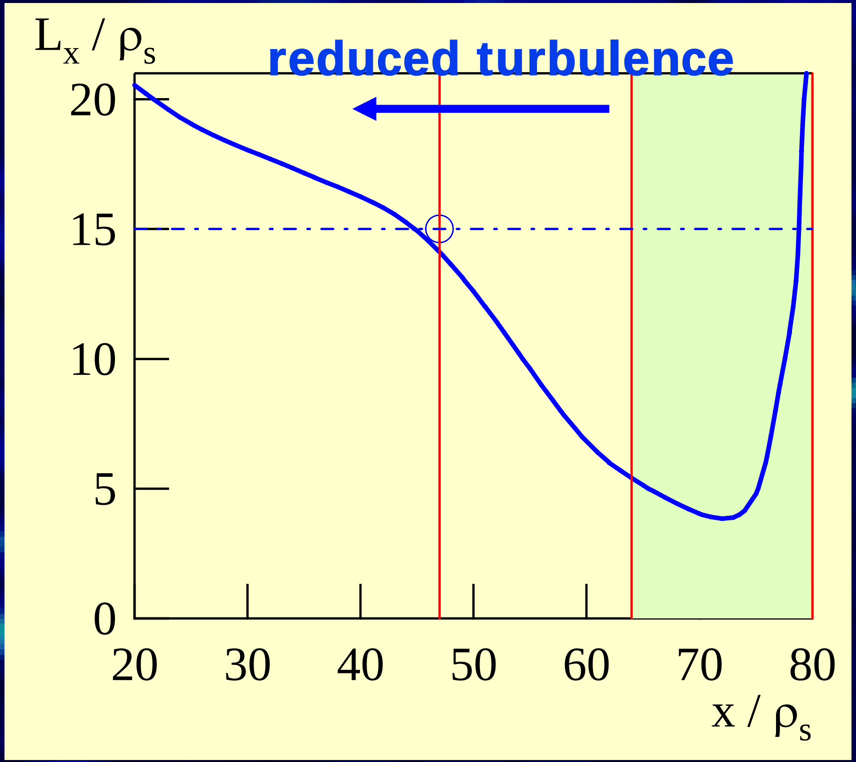
$\Rightarrow$ turbulence penetration

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

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

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

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

# Summary

Pedestal linear width reduced by spreading

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

spreading of stabilsation

turbulence reduction in vicinty of pedestal

when interplay ETB formation & physics

$\Rightarrow$ more complex situation

$\Rightarrow$ modification of drive of the ETB