Main stabilization mechanisms in the edge barrier of the H-mode

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Transport simulations of temperatures, density and poloidal rotation have been made for the edge pedestal of a typical JET H-mode shot. (Data mainly from JET 69454 as obtaned from K. Crombe) However, only general features and possibilities are considered. No claims are made for conditions in this particular shot.

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New features since last meeting

- The *edge barrier* has been resolved in the simulations.
- Two mechanisms, poloidal rotation due to zonal flows and Finite Larmor Radius (FLR) effects are considered.
- These are two mechanisms found important in turbulence simulations (Rogers, Drake Zeiler, Phys. Rev. Lett. **81**, 4396 (1998).
- These results were later confirmed by analytic theory (R. Singh, V. Tangri, P. Kaw and P.N. Guzdar, Phys Plasmas **12**, 092307 2005).
- These works were both local (using local gradients) while ours are nonlocal.
- Collisions on free electrons have been replaced by an increased trapped fraction as found relevant in Moestam, Weiland Nuclear Fusion **42**, 663 (2002) (full collision dominance corresponds to trapped fraction f_t =1.).
- Collisions on trapped electrons are always included.

New features since last meeting cont.

The formation of internal transport barrier including spinup of poloidal momentum presented at EPS Dublin 2010 : (J. Weiland, T.Tala, V.Naulin, K.Crombe, P.Mantica and the JET-EFDA Contributors, *Simulations of the formation of a transport barrier in four channels including turbulent momentum sdpinup*, 37th EPS Conference, Dublin, June 21-25 2010, Paper P-1 1103) using the same model.

Model used

We use drift wave transport with *five channels*; *Ion and electron temperature*, *electron density*, *poloidal* and *toroidal momentum*. A *nonlinear frequency shift* is included giving *zonal flow*,

Features;

Electron trapping with an *enhanced trapped fraction* in order to take into account increased nonadiabatic effects on free electrons towards the edge. *Collisions on trapped electrons*, *Electromagnetic effects* (MHD ballooning branch included at drift wave correlation length). *FLR stabilization*

Comparison with previous work

As mentioned above similar systems but for local gradients were studied in a 3d turbulence code by Rogers et al (1998) and analytically by Singh et al (2005).

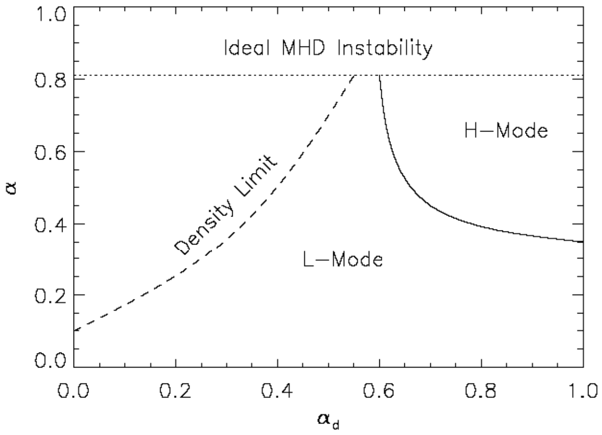


FIG. 1. Edge plasma phase space.

Here α is the usual MHD stability parameter while α_d is a parameter describing diamagnetic (FLR) stabilization. Both Rogers et al and Singh et al obtain this result. However Rogers et. al use a 3d turbulence code which automatically picks up both Zonal flows and Gam’s while Singh et al use an analytic theory that only includes Zonal flows. Thus Gam’s are not making a difference here.

L –H transition due to FLR effects

- We can combine the descriptions of drift waves and resistive ballooning modes so that

- f_t usual trapped fraction $= \mathit{Drift\ waves}$
- $f_t = 1 = \mathit{Resistive\ ballooning\ modes}$

These descriptions become identical!

H-mode transition due to FLR

- The first time we encountered an L-H transition due to FLR stabilization was in our first transport code simulations: *J. Weiland, H. Nordman Nuclear Fusion* ***31****, 390 (1991). (drift waves).*

- Later a paper on *resistive ballooning modes*: *S.V. Novakovsky, P.N. Guzdar, J.F. Drake, C.S. Liu and F. Waelbroeck Phys. Plasmas* ***2****, 3764 (1995)* where the parallel electron motion was completely prevented by collisions gave the same type of FLR stabilization for a resistive ballooning mode . This system is identical to our drift wave system when all electrons are trapped.

- A transition between drift waves and resistive ballooning modes was obtained in: *R. Moestam and J. Weiland 2002 Nuclear Fusion* ***42,*** *663****.***

Coupled modes with electron trapping, sharp density gradient and large temperature gradient

- The quartic dispersion relation separates into two quadratic dispersion relations, both depending on both ion and electron quantities. One mode with

  $\omega \sim \omega_{*e}$ High frequency mode (L-mode)

- and one mode with

  $\omega \sim \omega_{De}$ Low frequency mode (remains in H mode)

The low frequency mode is a *condensation mode* ($\delta P=0$) which gives a *particle pinch*

FLR stabilization of the High frequency mode.

The growthrate of the High frequency mode in the local limit can be written:

$$\widehat{\gamma} = \sqrt{\frac{\varepsilon_{\mathrm{n}}}{1 - f_{\mathrm{t}} + k^2\rho^2}\left(\frac{\eta_i}{\tau} + f_t\eta_e\right) - \frac{1}{4}\frac{k^4\rho_s{}^4}{\tau^2}\frac{\eta_i{}^2}{(1 - f_t + k^2\rho^2)^2}}$$

The notations are standard. We notice that the power of the FLR term is reduced for f_{t}=1, i.e. for resistive ballooning modes where electrons are 2d due to collisions. FLR stabilization here corresponds to an L – H transition

Dispersion relation with complex trapped fraction

L to H mode transition, H mode barrier in tokamak plasmas

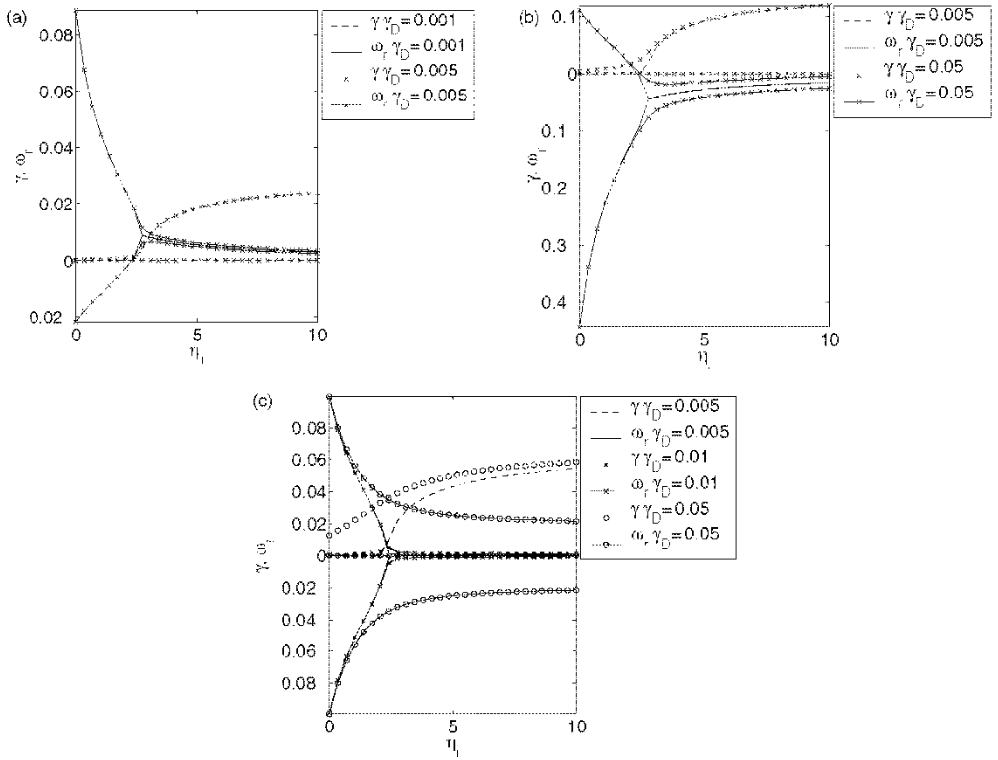
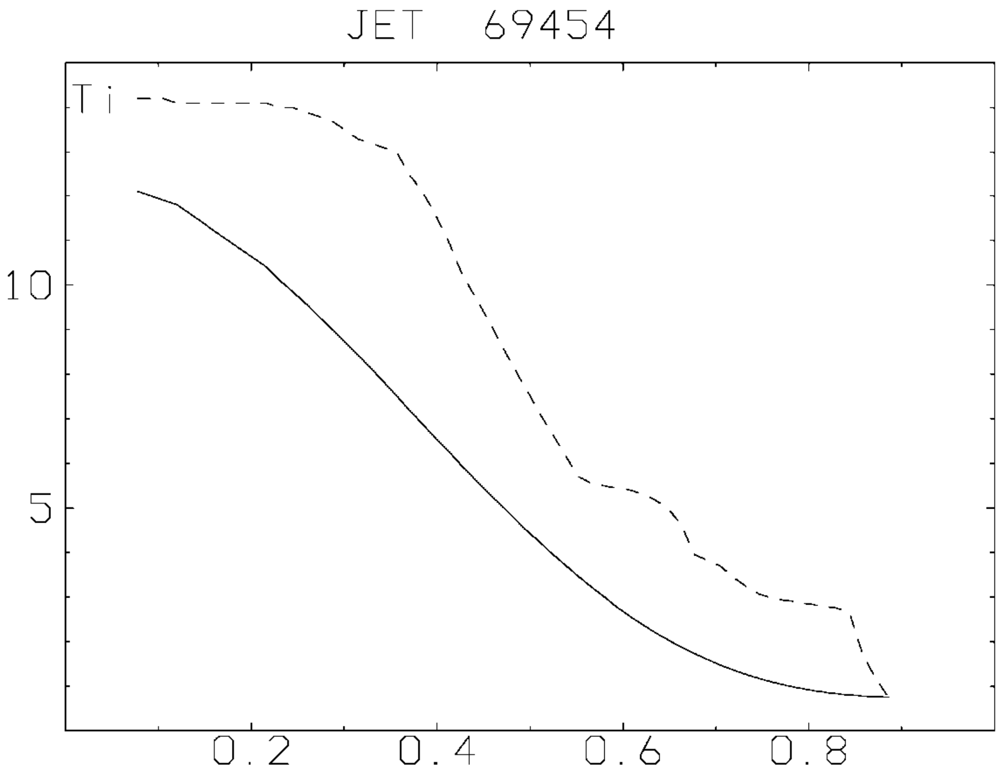


Figure 2. (*a*) $\tau = 5$, $\epsilon_n = 0.05$. (*b*) $\tau = 0.2$, $\epsilon_n = 0.05$ and (*c*) $\tau = 1$, $\epsilon_n = 0.05$. Solutions of the dispersion relation (36). γ_D represents dissipation due to parallel electron motion. (*a*) and (*b*) show that the system is more sensitive to dissipative effects for larger τ, and that τ also may alter the direction of wave propagation. An important dissipative effect is that it wipes out the instability threshold.

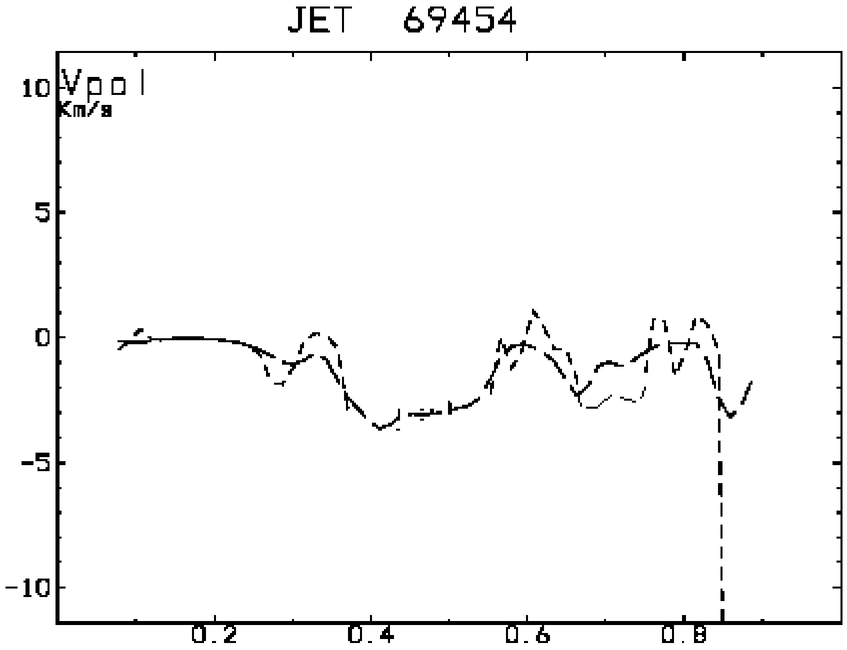
The imaginary part of the nonadiabaticity (gen. trapped fraction) reduced the stability threshold but did not change the maximum growthrate very much.

Reduced edge ion temp. Both rot. and FLR



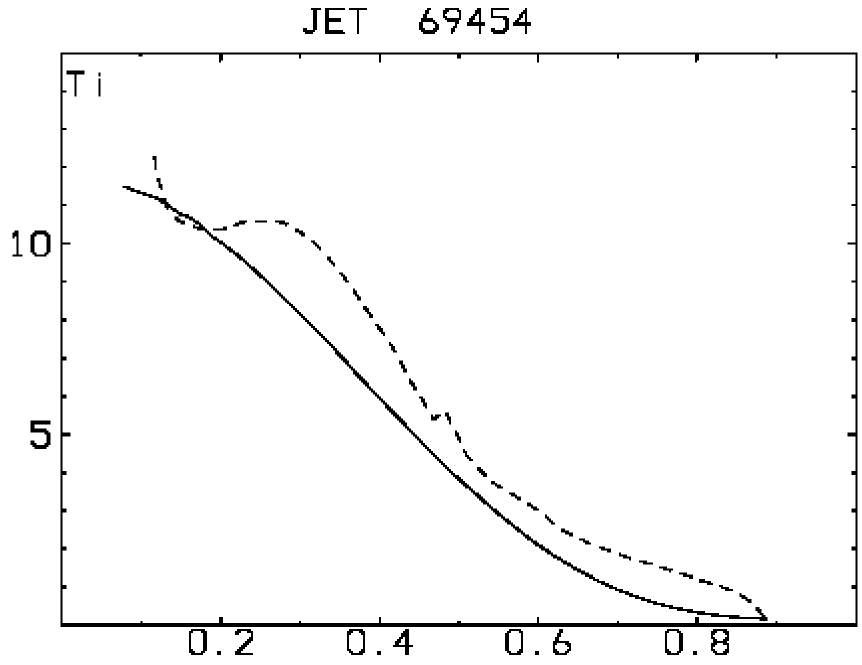
Ion edge boundary reduced by a factor 2. Dotted lines simulation

JET 69454 Vpol Both FLR and Zonal Flow

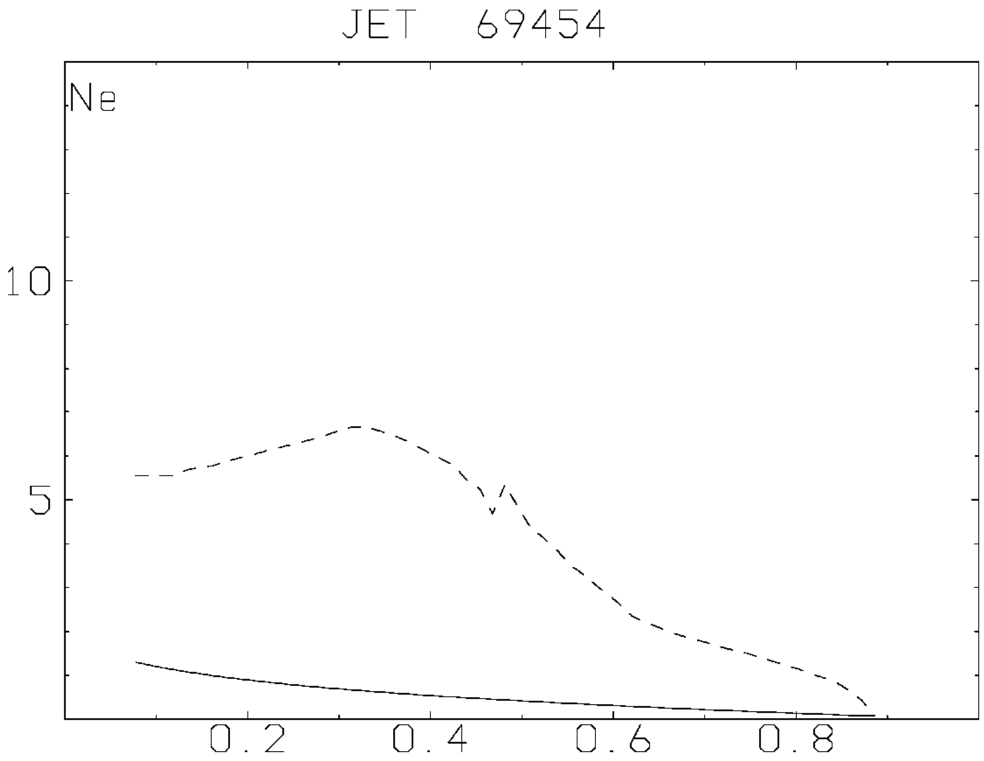


Simulation showing a strong spinup of poloidal rotation in the edge barrier .

Only FLR-stab



Only FLR stabilization



Summary

- Edge simulations were performed with a transport model which has previously obtained an H-mode due to FLR stabilization and poloidal spinup in ITB's due to zonal flows. Also the toroidal rotation is simulated.
- Data were choosen with JET69454 as starting point but were modified in several ways. Thus the results should be seen just as qualitative examples with no particular bearing on this shot.
- An increased trapped fraction was used in order to approximate varios effects that inhibit parallel electron motion.
- Thus the edge boundary could be choosen considerably lower than the top of the barrier in JET69454
- It the present simulations we could resolve the edge barrier.
- The stabilization in the edge barrier is partly due to Finite Larmor Radius effects and partly due to zonal flows (poloidal spinup).
- These two mechanisms could each give an edge barrier alone.
- However, for the data used here the poloidal spinup was most efficient