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(N)TM Onset by Central EC Power Deposition in FTU and TCV Tokamaks

S. Nowak[1], P. Buratti[2], O. Sauter[3], E. Lazzaro[1], G. Pucella[2], D. Testa[3], W. Bin[1], G. Calabro' [2], G. Canal[3], B. Duval[3], L. Federspiel[3], C. Galperti[1], S. Garavaglia[1], G. Granucci[1], A.N Karpushov[3], D. Kim[3], A. Moro[1], H. Reimerdes[3], J. Rossel[3], C. Sozzi[1], A.A. Tuccillo[2], O. Tudisco[2], D. Wagner[3] and FTU and TCV Teams

[1]IFP-CNR, Milano, Italy, [2]CR ENEA, Frascati, Italy , [3]CRPP – EPFL, Lausanne, Switzerland

INTRODUCTION

- Investigation of (N)TM onset / amplification in triggerless conditions / weak MHD activity in rotating plasmas is still an open issue to avoid plasma degradation and possible disruptions at high β [1-4]
- Mode destabilization by on-axis or nearly central EC power is a field still not well understood: response from devices with different shape and comparable size and operation parameters can give more information
- Action of central co-ECCD on mode destabilization is associated to ***direct effects***: 1) change of mode stability paramter Δ'_0 for current density modification far from resonant location, 2) increased bootstrap and to ***concomitant effects***: 1) change of plasma rotation profile for an ECCD torque, 2) change of the local difference between plasma and mode velocity allowing the destabilizing action of the ion polarization current

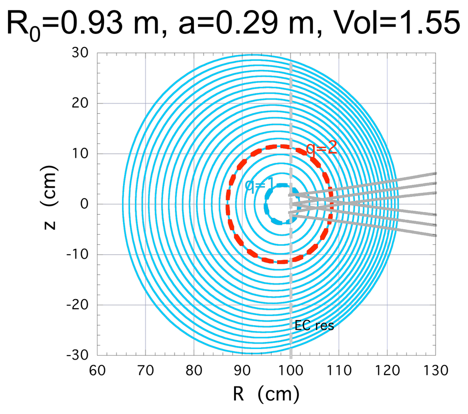
EXPERIMENTAL CONDITIONS

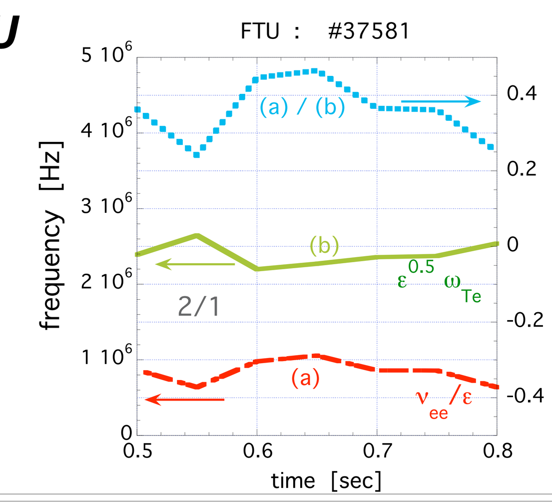
- L-mode scenario, low plasma rotation, collisionless regimes $\nu_{ee}/\varepsilon < \sqrt{\varepsilon}\,\omega_{Te}$
- **FTU (circular):** 360 -500 kA, 5.3 T, 4-6 10^{19} m^{-3}, k=1.02
- **TCV (D-shaped):** -115 kA, -1.44 T, 1.6 10^{19} m^{-3}, k=1.4
- **ECRH systems** [5-6] **:**

FTU : 4 gyrotrons, 140 GHz, 0.5 MW each (2 gyrs. used) – O1 heating
TCV : 6 gyrotrons, 82.7 GHz, 0.4 MW each (3 gyrs. used) – X2 heating

FTU

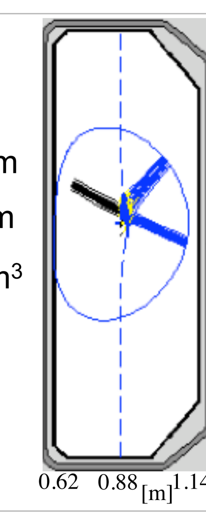
R_0=0.93 m, a=0.29 m, Vol=1.55 m^3

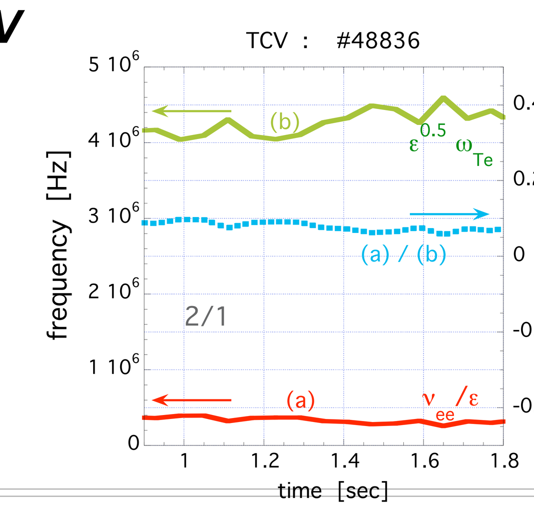




TCV

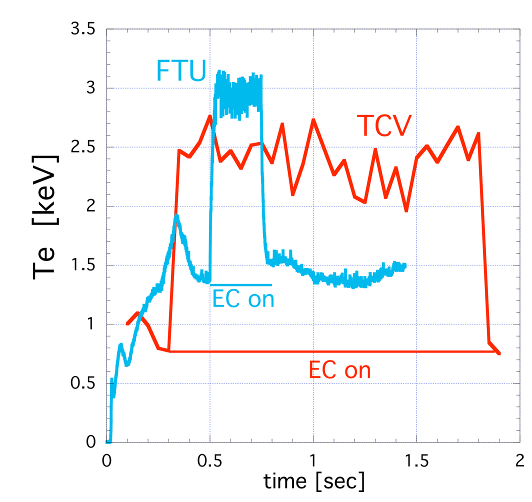
R_0=0.88 m
a=0.25 m
Vol=1.4 m^3

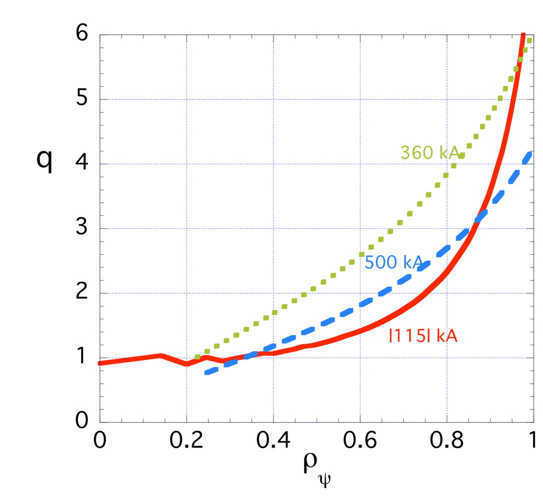


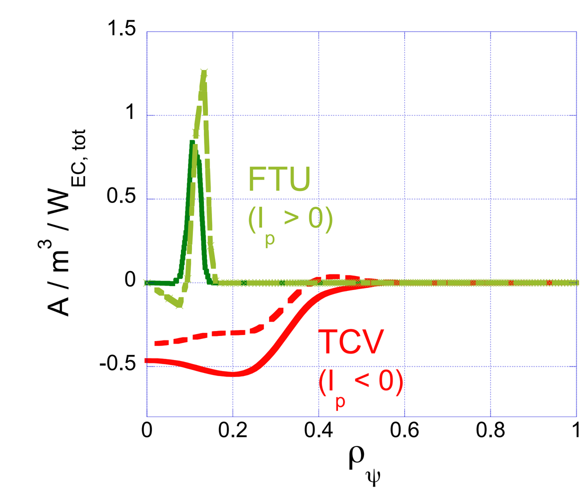


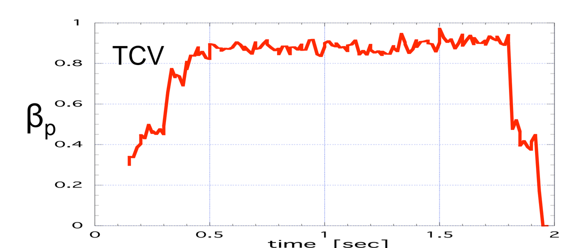
MODE DESTABILIZATION

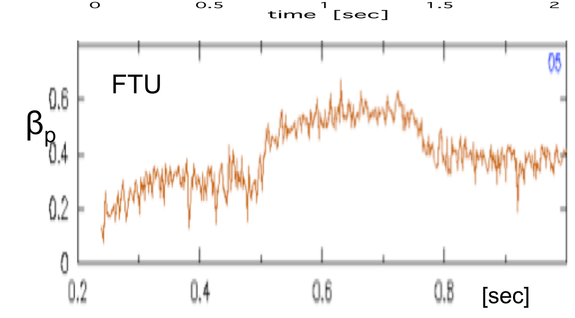
- on-axis or nearly central EC power deposition can destabilize the 3/2 and 2/1 modes
- destabilization is seen to appear operating with different plasma current : 360-500 kA in FTU and -115 kA in TCV and with narrow (FTU) and wider (TCV) widths of the EC current density profiles
- tearing modes onset appear by central EC in triggerless conditions w/o sawteeth , ELMs (TCV), while the modes are amplified in plasmas with very weak pre-EC MHD activity (FTU)
- in both machines same level of EC power (> 0.5 MW) seems to be necessary for the destabilization with similar increase of the central electron temperature
- the modes are triggerred / amplified when the poloidal beta β_p reaches its stationary value larger than the crtitical one suggesting the classification of tearing as neoclassical
- at the EC on the mode amplification is prompt (FTU), while the mode early/late onset depends on strength of ECCD: 3 gyrs. co/ 2 gyrs. co+1 gyr. cnt (TCV)



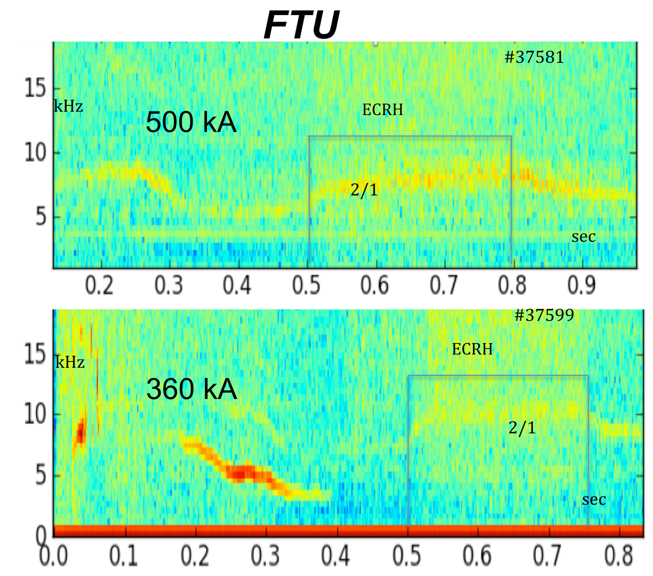




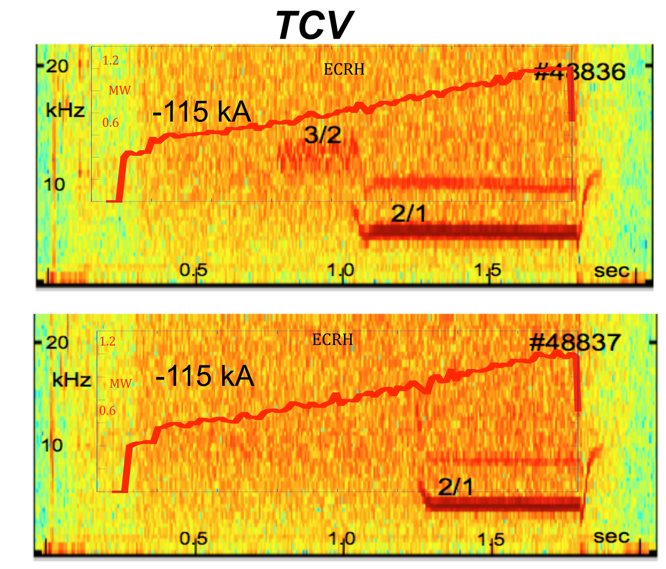




FTU

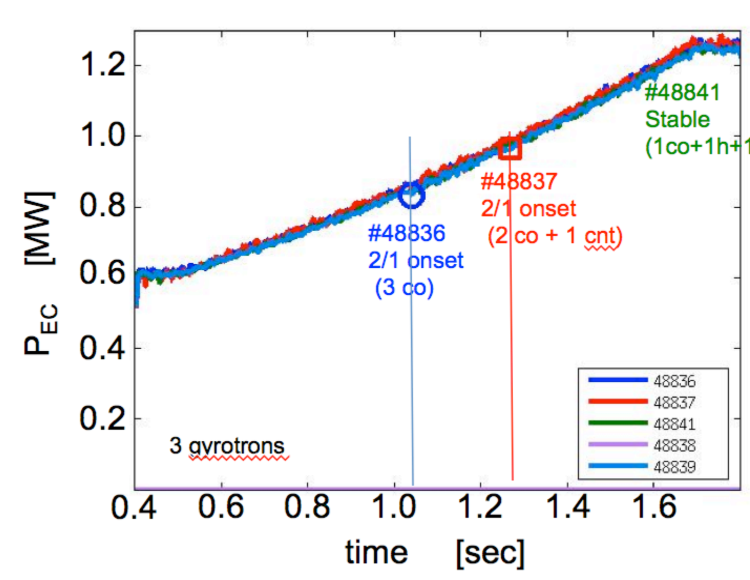


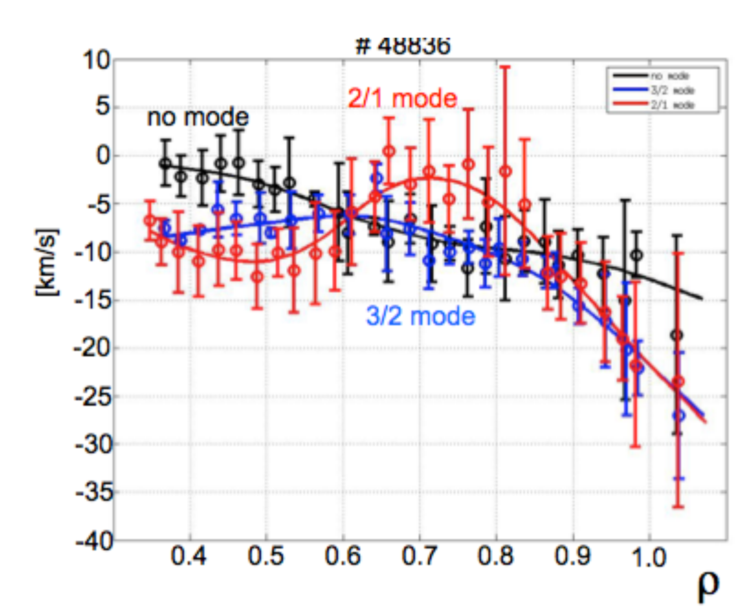
TCV

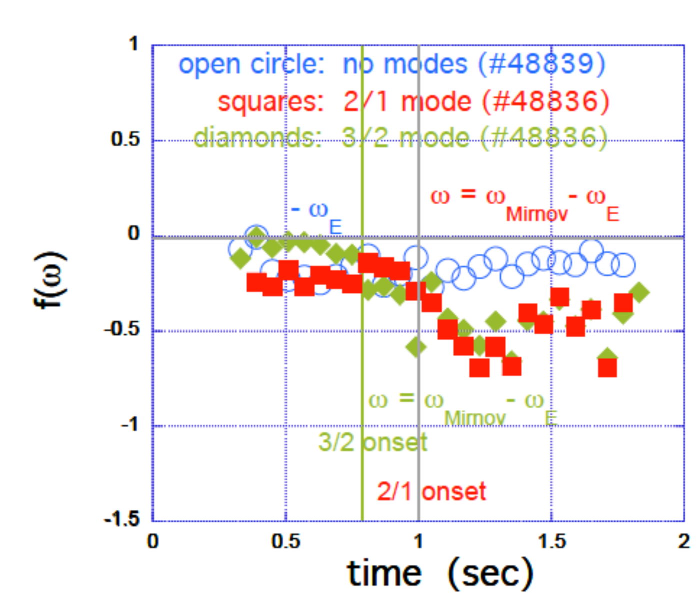


TCV ANALYSIS

- experiments show that the ***main driving mechanism*** for the mode destabilization is associated to the change of the current density profile due to the strength of the generated co-ECCD : for the same EC power level and different co-/cnt-ECCD combinations the modes do not appear
- in the L-mode scenario the spontaneous plasma rotation is in cnt-I_p direction (positive) in ohmic phase; the co-ECCD seems to affect the rotation acting through a torque responsible of the acceleration in co-I_p
- consequently, the difference between plasma and mode velocity can change in sign allowing the destabilizing effect of the ion polarization current through term: $f(\omega)=(\omega\omega_{pi}-\omega^2)/\omega^2_{pe} < 0$, being ω the mode freq. in cnt-I_p ; it is observed that the mode starts when $f(\omega)<0$, thus considering the ion pol. current as a ***concomitant necessary driving mechanism***



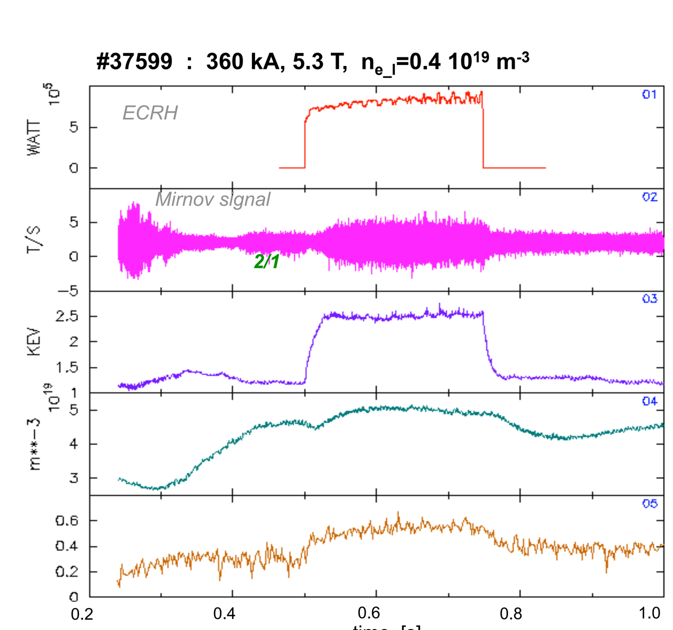


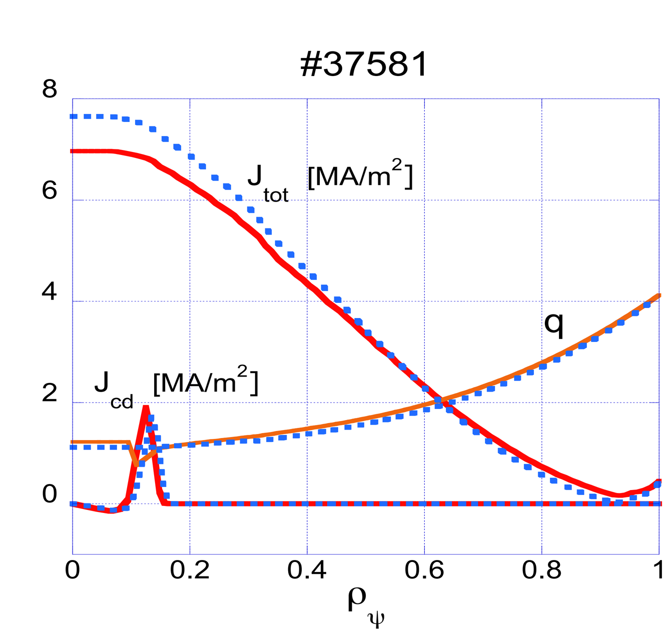


- ASTRA [7] simulations have shown that at the mode onset the changes of magnetic shear are small and it is difficult to predict the exact Δ'_0 dependencies.

FTU ANALYSIS

- the ohmic plasmas at 360 kA and 500 kA are characterized by small MHD instability with also sawteeth
- with respect the TCV triggerless conditions we investigate not really the mode onset, but the ***amplification*** of latent modes by nearly central co-ECCD
- in heating phase a common trend is characterized by a growing up in amplitude of the mode (Mirnov) with the concomitant increase of β_p
- these evidences in the low collisionality regimes suggest to consider the 2/1 mode as a NTM once saturated
- JETTO [8] calculations show: 1) a slightly increasing of the shear due to small modifications of the q profile for co-ECCD generation inside the q=1 , 2) a little bit outwards deplacement of the 2/1 location
- no significant increase of Δ'_0 at this resonant surface is found using a simplified analytic expression which embodies cyclindrical and toroidal effects [9-10]





JETTO simulations

- no effect on mode amplification due to modification of rotation through the ion polarization term

CONCLUSIONS

- (N)TM destabilization by central EC power deposition has been investigated for FTU and TCV tokamaks of comparable size in similar plasma conditions
- the **purpose** was the understanding of the ***main driving mechanisms*** leading to the mode onset (TCV) and amplification (FTU)
- the mode appearance can be related in both machines to the modification of the plasma current density and the mode stability parameter Δ'_0 , but ASTRA and JETTO calculations did not give a clear response about the role of this probably main mechanism
- however, experimental results in TCV with different ECCD components have shown that the mode appearance depends on the co-ECCD strength consistent with a change of the current density profile
- co-ECCD torque seems to affect the plasma rotation (TCV) and the mode frequency increase (FTU)
- concomitant effect on the destabilization seems to be related to the ion polarization current (TCV), negligible for amplification (FTU)
- the triggering/amplification of the modes follows the β_p increase and the modes could be classified as neoclassical

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