NUMERICAL ANALYSIS OF PEELING-BALLOONING STABILITY AT VARIOUS TRIANGULARITIES IN GLOBUS-M2

[1,2]V.V. SOLOKHA, [1]I.M. BALACHENKOV, [1]V.K. GUSEV, [3]A.A. KAVIN, [1]G.S. KURSKIEV, [1]E.O. KISELEV, [1]V.B. MINAEV, [1]A.N. NOVOKHATSKY, [2]V.D. PETRENKO, [1]Y. V. PETROV, [2]A.M. PONOMARENKO, [1]N.V. SAKHAROV, [1]P.B. SHCHEGOLEV, [1,2]K.D. SHULYATIEV, [1,2]A.Y. TELNOVA, [1]E.E. TKACHENKO, [1]S.Y. TOLSTYAKOV, [2]A.Y. TOKAREV, [1]V.I.VARFOLOMEEV, [1,2]A.Y. YASHIN, [1,2]N.S. ZHILTSOV

[1]Ioffe Institute, St. Petersburg, Russian Federation
[2]Peter the Great Polytechnic University, St. Petersburg, Russian Federation
[3]JSC «NIIEFA», St. Petersburg, Russian Federation

Email: vsolokha@mail.ioffe.ru

The formation of the reduced transport region during the H-mode operation implies steep density and temperature profiles, which drive the development of edge localized modes (ELMs). They are observable as periodic abrupt plasma losses to open field lines leading to increased heat loads on plasma facing components. Plasma shaping conditions were shown to have a remarkable influence on the edge plasma stability in conventional [1] as well in spherical [2] tokamaks.
ELMs behavior was investigated previously at the spherical tokamak Globus-M2 [3] at intrinsically high values of triangularity (δ=0.4) [4] and decreased triangularity [5] values around δ=0.2. The highly shaped plasmas (δ=0.4) exhibit ELMs presence with type-V traits at pedestal pressures around P_{ped}= 4 kPa in discharges using external power input provided by neutral beam injection. In low triangularity conditions (δ=0.2), ELMs were observed at the pedestal pressure around P_{ped}= 1 kPa. Recent experiments with medium triangularity values (δ=0.3) showed the presence of ELMs at P_{ped}= 2 kPa (Figure 1). The estimation of the edge gradients were performed using the Thomson scattering data [6].

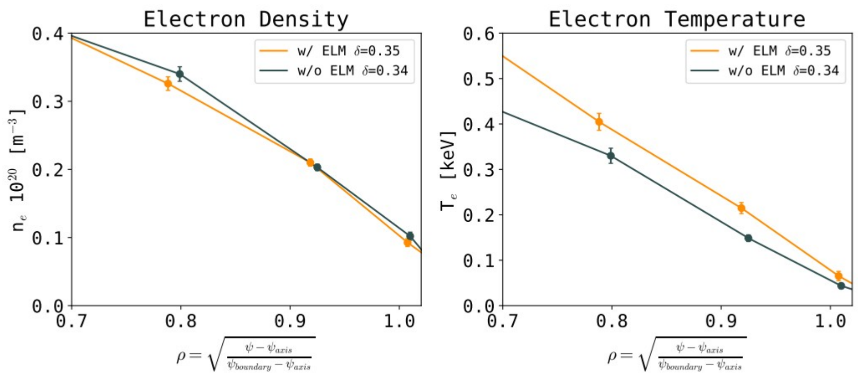

Figure 1. The electron density (left) and electron temperature (right) profiles of the Globus-M2 discharge #45936. Experimental edge data and error bars are corresponding to the Thomson scattering peripheral measurements.

The quantitative estimation of the edge plasma stability corresponding to the peeling-ballooning modes was carried out by the BOUT++ [7,8] code. The set of the single fluid magnetohydrodynamic equations was solved by the finite difference method in the 3D tokamak geometry with the diamagnetic term. In the poloidal cross section, the ψ_{norm} = 0.80-0.98 normalized flux span was covered by the mesh. The mesh with a 128×128 cell resolution in radial and poloidal directions was created based on the magnetic surfaces reconstructed by the PET code [9,10] and PyGSS code [11]. Toroidal mode numbers were limited by n<64. The initial plasma pressure profile was shaped by a hyperbolic tangent parameterized by its height and width. The current density profile consisted of Ohmic and bootstrap components. The bootstrap component was calculated by the Sauter analytical formula [12].
The stability diagram was calculated using the set of simulations for each pedestal width and height. The growth rate was calculated using the root mean square perturbation at the low-field side equatorial midplane. The estimation of the critical growth rate needed to observe the edge-localized mode burst yields 0.1 τ_A^{-1}. Discharges

with a triangularity value around δ=0.2 demonstrated unfavorable peeling-ballooning stability properties with expected destabilization at P_{ped} = 1 kPa. The increase of the triangularity up to δ=0.3 led to an increase of the pressure required to destabilize the peeling-ballooning mode up to P_{ped} = 2 kPa (Figure 2).

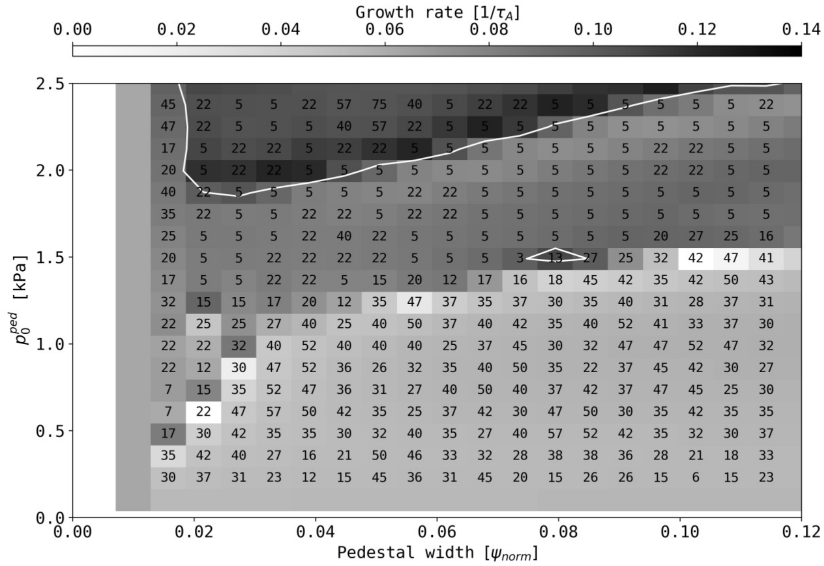

Figure 2. The stability diagram corresponding to the Globus-M2 equilibrium at δ=0.34. The white line marks the 0.1 τ_A^{-1} boundary. Toroidal mode number of the most unstable mode is shown for each simulation.

The peeling-ballooning mode with low toroidal numbers (n=5) was shown to be most unstable in the experimentally observed set of pedestal parameters for low triangularity discharges. Despite the low toroidal numbers, the unstable mode had a poloidal structure with ballooning features mostly due to the wide pedestal. For medium and high triangularity cases, the high-n modes (n=20) are expected to be observed in the experiment at high pedestal pressures. The growth rate of the peeling-ballooning mode in high triangularity discharges was shown to be sensitive to the plasma conductivity, indicating the significant contribution of the peeling mode in high triangularity conditions.

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