Negative triangularity studies in view of DTT operations

P.Mantica[1], A.Mariani[1], L.Aucone[1,2], A.Balestri[3], J.Hobirk[4], G.Merlo[4], A.O.Nelson[5], O.Sauter[3]

[1]*Institute of Plasma Science and Technology, CNR, Milano, Italy*

[2]*Department of Physics 'G. Occhialini', University of Milano-Bicocca, Milano, Italy*

[3]*Ecole Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), Lausanne, Switzerland*

[4]*Max-Planck-Institut für Plasmaphysik, Garching, Germany*

[5]*Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY 10027, USA*

Plasmas with negative triangularity (NT) shape have recently attracted interest as possible fusion reactor scenarios featuring an ELM-free L-mode edge with improved core performance compensating the H-mode pedestal loss. Within this framework, an NT option is under investigation for the Divertor Tokamak Test (DTT) facility, under construction in Italy, both for the DTT full performance scenario (5.85T/4 MA/45 MW coupled power) and for the early operational phases at reduced current and power.

The study has been articulated both along an experimental line of investigation, with experiments on AUG and TCV using the same NT shapes foreseen in DTT, and along a modelling effort using integrated modelling with ASTRA/TGLF or gyrokinetic GENE simulations. In both approaches, a comparison between NT and PT geometries has been pursued, with two NT geometries considered, with lower (LD) and higher (HD) δ values, as shown in Fig.1.

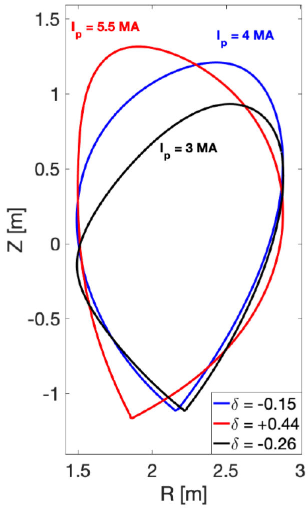

Fig.1: LCFS for DTT PT/NT scenarios

TCV shows a significantly higher effect of NT geometry than AUG, mainly because of a significant density increase in TCV that is not observed in AUG. In TCV a large beneficial effect of NT comes from the plasma edge and SOL, allowing NT L-modes to outperform PT L-modes with the same power input, reaching the same central pressures as PT H-modes with twice as much applied heating power. The HD shape enhances the effects already seen with the LD shape. For AUG, NT plasmas go into H-mode more easily than for TCV, but always present much smaller pedestals compared with PT plasmas with the same input power, showing a much weaker or absent ELM activity. The AUG NT pulses outperform PT pulses with the same input power only at low ECRH power. In general, for higher power or with NBI, the NT core pressure can reach ~80% of the PT values, which is still a good result for a scenario with reduced ELM activity. Both experiments therefore look promising for DTT, although the origin of the different behaviour between TCV and AUG has not yet been identified, with experiments planned to study the role of neutral penetration, which is higher in TCV.

The ASTRA/TGLF simulations reproduce well the AUG results while they systematically underpredict the ion temperature for TCV. For DTT they indicate an enhancement of the edge pressure gradient due to NT geometry, particularly in the HD configuration, when the real geometry is used instead of the Miller approximation. The DTT modelling results are more similar to the AUG results, predicting an NT scenario that has core pressure values around 80-90% of the PT H-modes, but without ELMs, since access to the 2nd stability region is prevented in DTT, unlike in AUG. This makes the NT scenario promising for DTT operations.

GENE local linear and non-linear simulations indicate a very strong direct stabilizing effect of changing the shape to NT LD in the TCV case at ρ_{tor}=0.95, while a non-negligible stabilization was observed in DTT simulations at ρ_{tor}=0.85 only when the PT kinetic profiles were kept fixed and the triangularity was varied. An even larger stabilizing effect is found with TCV NT HD, compared with LD, justifying the adoption of the new shape. The effect is found in both ITG- or TEM-dominant regimes. Global non-linear GENE-TANGO simulations of the DTT HD case are ongoing. These runs will give a high-fidelity prediction of the kinetic profiles for the DTT NT case, to compare with the estimates based on the quasi-linear TGLF model, coupled with ASTRA.