Exploration of the physics and viability of a negative-triangularity reactor in the TCV tokamak

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The TCV tokamak has pioneered negative triangularity since the mid-1990's, proving its superior confinement properties and establishing its comfortable stable operational range in spite of concerns over increased MHD activity. This work ushered in the tantalizing prospect of a naturally ELM-free, L-mode reactor regime with confinement as good as or better than the H-mode on which ITER operation is primarily predicated: i.e., ultimately, a quiescent energy-producing reactor potentially no larger than an H-mode DEMO. Very recently, DIII-D has joined the effort and confirmed the main TCV findings.

A large, multi-faceted campaign is underway on TCV with the goal of documenting virtually every aspect of the negative-triangularity concept, taking full advantage of the device's shaping flexibility to explore a broad range of shapes, both diverted and limited, in particular by varying the upper and lower triangularities independently. The study aims to map out the detailed dependence of transport and confinement on the shape, the macroscopic stability limits, and the exhaust properties and particularly access to divertor detachment. The associated physics, pertaining especially to turbulence, fast-ion dynamics, and scrape-off layer (SOL) properties, is being investigated in parallel.

This work has been motivated at once by a renewed worldwide interest in this concept and by the recent addition of ion heating (by neutral-beam injection) to the device's existing electron heating capabilities (second- and third-harmonic electron cyclotron resonance heating). This allows us to extend our work to truly reactor-relevant ion to electron temperature ratios and plasma pressures.

This talk will report on L-mode performance with β_N in excess of 2 and confinement up to 70% better than H-mode. It will describe the stable parameter range and the optimal compromises reached in TCV to optimize the integrated tokamak performance from core to edge. There will also be an emphasis on the underlying physics, illustrating in particular the core and edge turbulence suppression that accompanies negative triangularity and the properties of the SOL heat-flux profile, with direct comparisons with numerical modeling. The result will be a solid case for the scientific viability of negative triangularity.