Progress in studies of the negative triangularity reactor option in TCV

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Negative-triangularity (NT) tokamak configurations are well known to feature enhanced confinement, from experiments performed in TCV in the 1990's and 2000's. This work has spurred proposals and studies of a NT DEMO that would operate in L-mode with confinement comparable to conventional H-mode but remaining intrinsically free of ELMs. Further confirmation of the good qualities of NT has been provided recently by DIII-D and ASDEX Upgrade.

The addition of ion heating - using NBI - to TCV, formerly only heated through ECRH, has motivated an extensive new campaign to broaden the exploration of NT in what remains a device uniquely suited for shaping studies. This work aimed not only to reach $T_i \sim T_e$ and higher β_N, but also to perform more systematic scans of detailed shape characteristics and up-down asymmetry and of confinement regimes, and to investigate stability limits, turbulence, and fast-ion physics, as well as the properties of the edge and the accessibility of detachment. In particular, stable, fully diverted NT plasmas were developed for the first time. A similarity study with DIII-D was also conducted using similar, rescaled shapes.

Analysis of this extensive data set is in progress and this contribution will report on the results to date. Peak performance with $\beta_N \sim 3$ and L-mode confinement up to 70% better than H-mode has been obtained transiently, and $\beta_N \sim 2$ has been achieved in steady state. The L-mode existence domain appears to be remarkably broad, with only anecdotal transitions to H-mode even at peak NBI power (1.3 MW) and with the grad-B drift pointed towards the X-point. Among the main findings we shall report the strong dependence of confinement on triangularity (δ), continuing to the most negative attainable values without plateauing; the equally strong dependence of core and edge turbulence on δ; and the seemingly weak variation of macroscopic density and current limits upon δ sign reversal.

This contribution will also touch on the first global gyrokinetic study of positive vs negative δ plasmas, performed for TCV cases and rewarded by remarkably good agreement with core turbulence measurements. This has highlighted in particular the importance of retaining global effects to properly model NT configurations.