Negative triangularity tokamak plasmas: history and potential for a reactor solution

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Plasmas with a polodal cross-sectional shape featuring negative triangularity (NT) are emerging as a potential candidate for operation in nuclear fusion reactors.

While standard H-mode regimes follow a standard "core-first" approach which maximizes the core stored energy by optimizing the overall magneto-hydro-dynamic (MHD) stability of the plasma, the NT configuration adopts a "wall-first" approach which prioritizes power handling provided that the core stored energy reaches a minimum target [1].

A reactor with NT shape would benefit from three distinct characteristics that simplify its construction, operation and maintenance: high confinement despite the absence of an edge pedestal, robust L-mode edge operation and optimal placement of divertor legs on the low field side of the machine. The first two features allow inherent ELM-free operation with low impurity confinement and a passive safety system against undesired transitions to H-mode, respectively; the most prominent advantage of the last property is that, for a given flux expansion, the scrape-off-layer wetted area is maximized by having strike points impinge on the divertor at large radii.

Research on NT plasmas, although sporadic, spanned five decades of theoretical and experimental work on various machines worldwide [2]. While NT plasmas were dismissed early on poor MHD stability grounds, recent experimental and computational work demonstrated that reactor relevant pressure levels can be obtained. Therefore, as core-edge integrated solutions need to simultaneously optimize all aspects of a reactor, from pressure levels sustained in the core to wall exhaust, the improved core confinement properties and the relaxed constraints on the first wall featured by NT plasmas spurred renovated interest in this concept as a viable reactor solution.

The history of NT plasmas is reviewed before examining in greater detail the most recent results, from experiments to MHD and non-linear gyro-kinetic modelling.

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References

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