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*andrea.mastrogirolamo@polimi.it

Impact of triangularity on edge plasma transport and detachment: a SOLPS-ITER study

A. Mastrogirolamo^{*1}, F. Mombelli¹, E. Tonello², O. Février², G. Durr-Legoupil-Nicoud², B. Labit², F. Subba³, M. Passoni¹, the TCV team^a, and the EUROfusion Tokamak Exploitation team^b

¹ Dipartimento di Energia, Politecnico di Milano, 20133 Milan, Italy

² École Polytechnique Fédérale de Lausanne (EPFL), SPC, Lausanne, Switzerland

³ NEMO Group, Dipartimento Energia, Politecnico di Torino, Turin, Italy

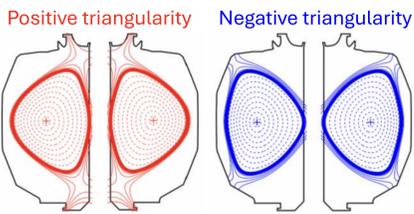
^a See the author list of Duval et al 2024 Nucl. Fusion 64 112023

^b See the author list of Joffrin et al 2024 Nucl. Fusion 64 112019

Negative triangularity

What?

Negative triangularity (NT) is a magnetic field configuration in the poloidal cross-section, reversed from the standard **positive triangularity (PT)**.

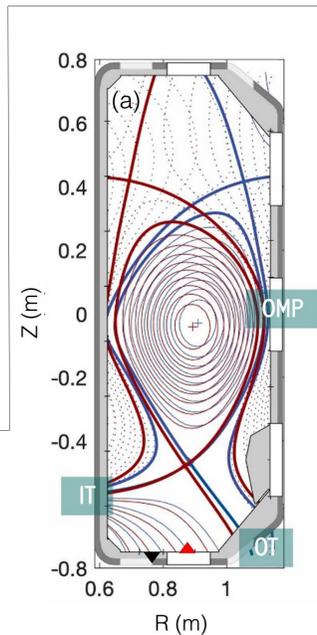


What physics underlies the distinct divertor response of NT plasmas?

Why?

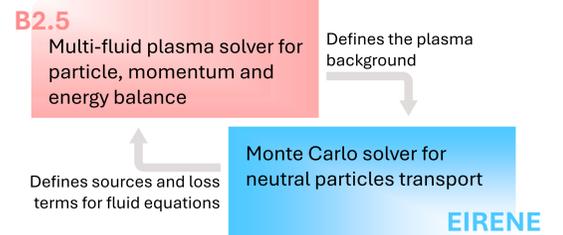
Negative triangularity plasmas achieve high-confinement-mode (**H-mode**) properties while operating in Low-confinement-mode (**L-mode**), which is inherently free from edge-localised-modes (ELMs), making them **attractive for steady-state operation**.

However, recent experiments on TCV show that NT plasmas exhibit **harder access to envisioned operating regimes** (i. e., **divertor detachment** and **reduced target cooling**) compared to positive triangularity (PT), **despite identical upstream conditions**.



The SOLPS-ITER code

... a state-of-the-art code for the **boundary plasma**, meaning the region just inside the last closed flux surface (or separatrix) and the scrape-off layer (SOL).



- 2D poloidal **mesh built on experimental magnetic equilibrium** (toroidal symmetry).
- **Self-consistent plasma-neutral coupling** through B2.5-EIRENE modules.
- **Mean-field, non-turbulent model**: cross-field transport prescribed via **anomalous diffusivities**.
- Option to include cross-field **drifts**.

Experimental scenario

This work focuses on **two Ohmic L-mode, lower-single-null discharges in TCV**, characterized by **opposite upper triangularity and identical divertor geometry**.

During a **density ramp**, experiments show that NT plasmas remain more attached, with weaker target cooling and lower divertor neutral pressure.

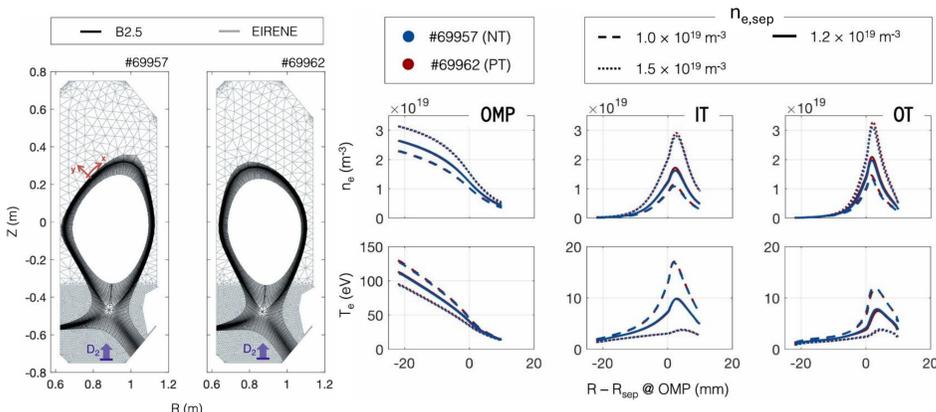
The two plasmas are compared at **matched upstream conditions**, allowing the effect of triangularity on divertor behavior to be isolated.

These observations provide the experimental basis for the **numerical investigation**.

Results and discussion

Effect of magnetic geometry

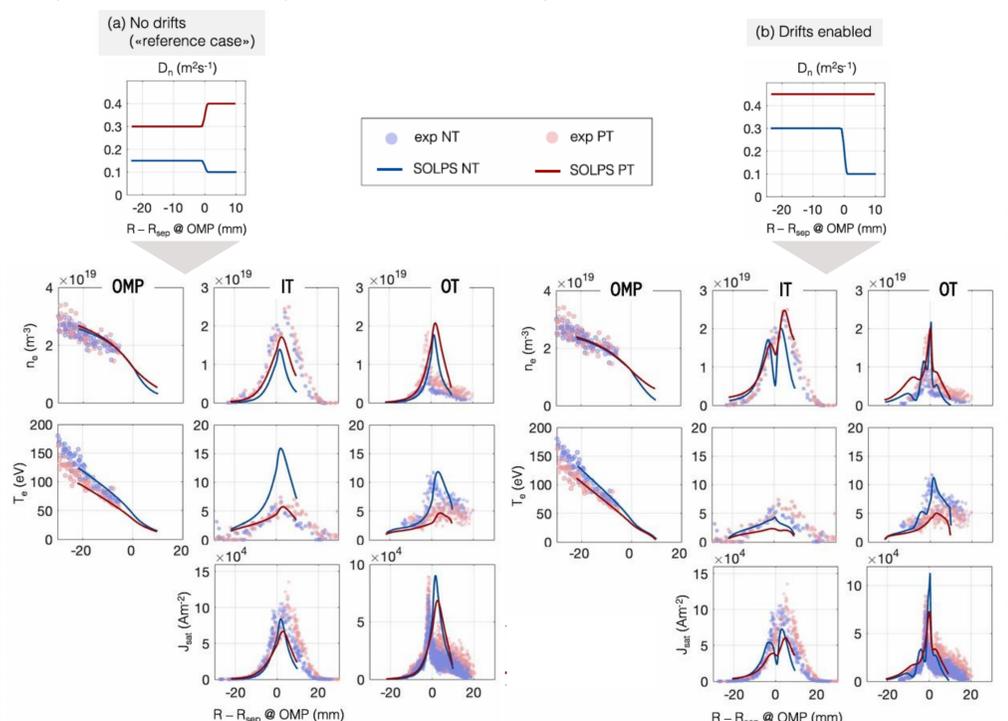
Simulations performed with **similarly constructed meshes, identical transport coefficients and identical boundary conditions** for NT and PT yield **nearly indistinguishable plasma profiles**, both upstream and at the divertor targets. This remains true even when additional physics models (e.g. drifts) are included.



Magnetic geometry alone cannot reproduce the experimentally observed behavior.

Optimization of transport coefficients

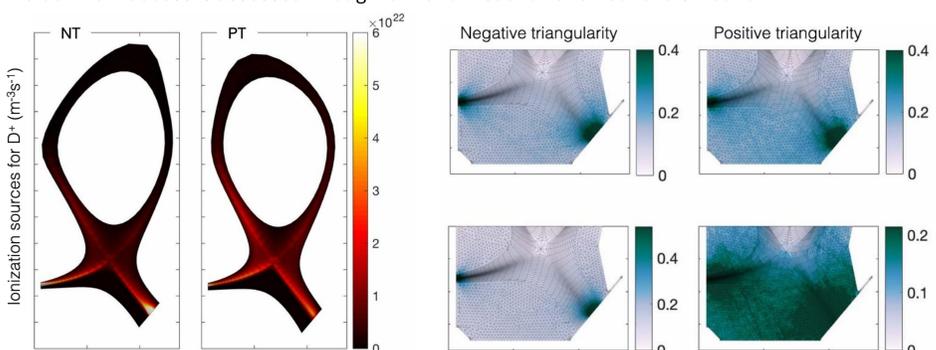
Allowing for **different anomalous transport coefficients** in NT and PT, a **parametric scan** was performed to optimize the choice of the particle anomalous diffusivity.



Agreement is met assuming reduced cross-field particle transport in NT, consistent with theoretical predictions of turbulence suppression.

Detachment access

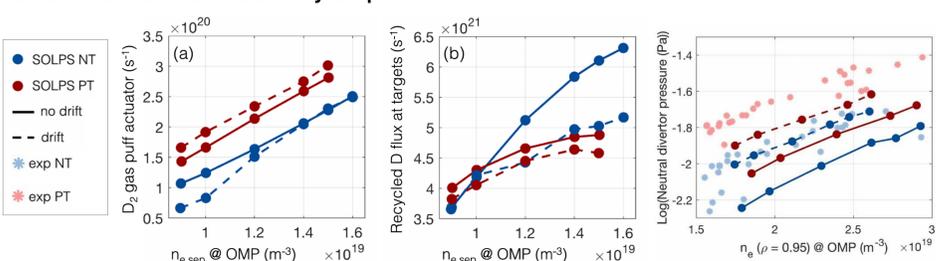
Detachment access is assessed through ionization reaction and neutral distribution.



NT simulations show more difficult access to detachment through a more attached ionization front and a narrower neutral pressure distribution.

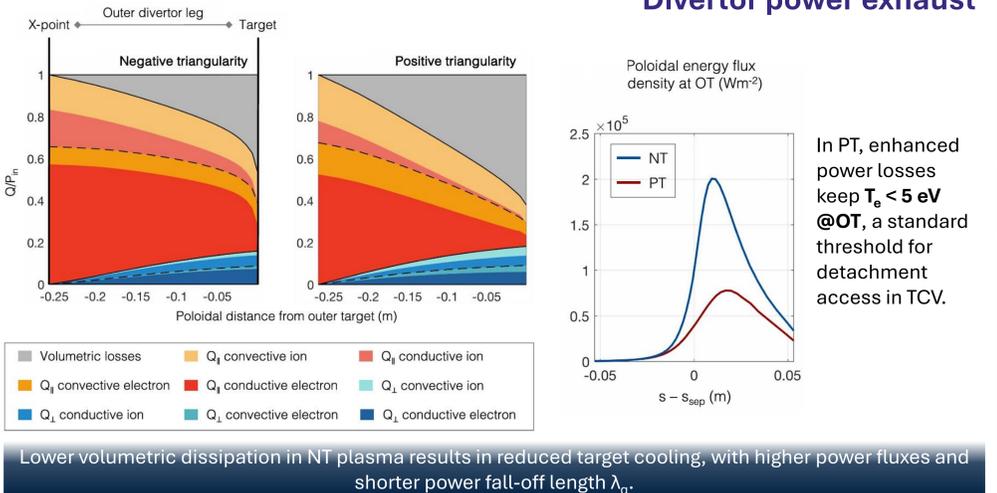
Density ramp modelling

The optimized transport coefficients were validated around the reference scenario instant, enabling to retrieve information on the **density ramp**.



The optimized transport regime captures both recycling approach to roll-over in PT and the evolution of divertor neutral pressure.

Divertor power exhaust



Lower volumetric dissipation in NT plasma results in reduced target cooling, with higher power fluxes and shorter power fall-off length λ_{q_1} .

In PT, enhanced power losses keep $T_e < 5$ eV @OT, a standard threshold for detachment access in TCV.

What's next?

Future studies will investigate power exhaust in **more heated and impurity-seeded NT plasmas**, aiming at **comparison with corresponding H-mode scenarios in PT**.

References

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