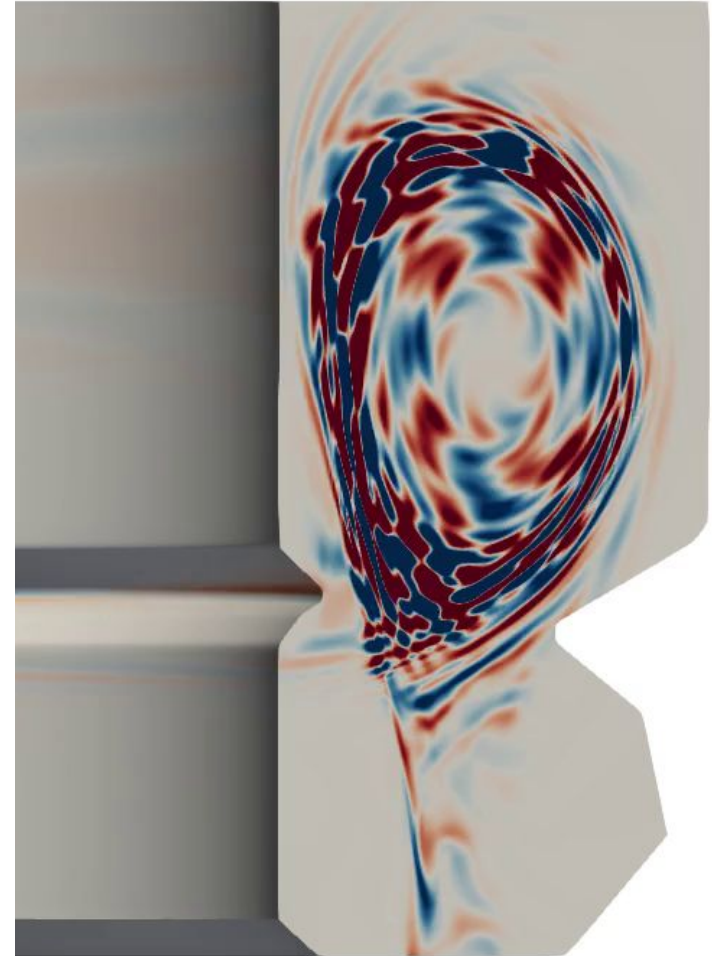


GBS simulations with flexible wall geometry - Overview

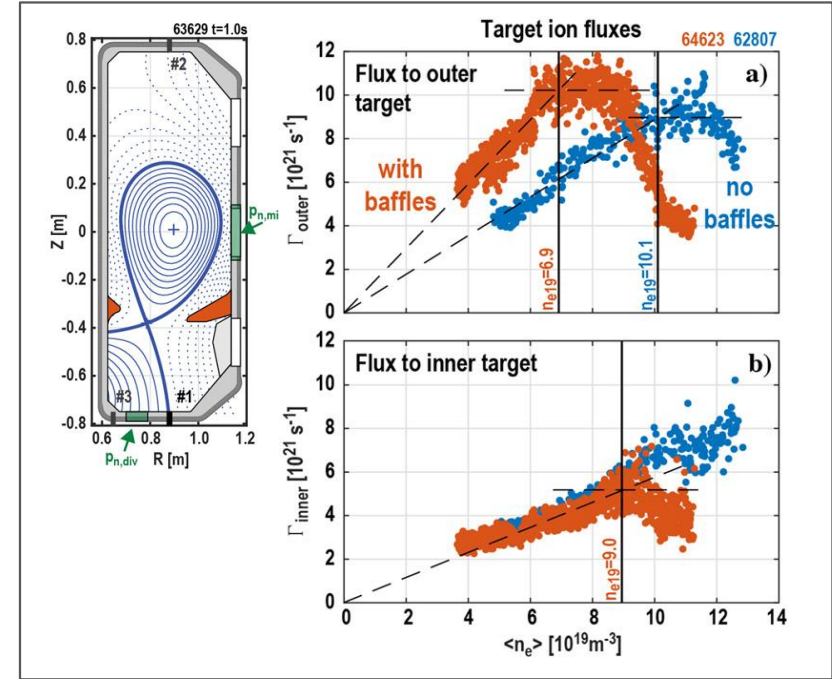
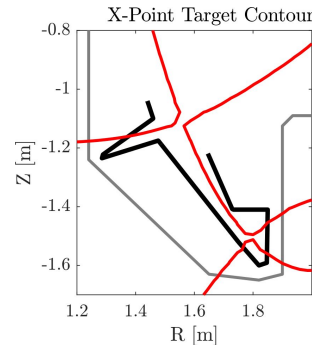
D. Mancini on behalf of L. Stenger and the GBS team



Wall geometry fundamental to capture exhaust dynamics

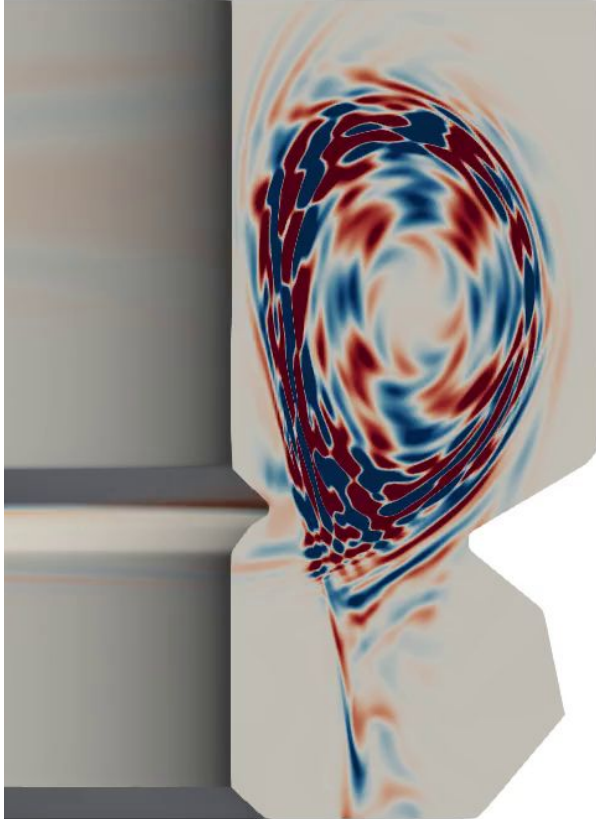
Present and future experiments relies on particular wall geometries, e.g.:

- TCV with baffles demonstrates early roll-over of target particle flux
[H. Reimerdes et al, NF 2021]
- SPARC empirical scalings suggest the need for XPT *[A.Q. Kuang et al, JPP 2020]*



Idea: extend GBS coordinate system to **simulate flexible wall geometries**, starting from TCV with baffles

GBS is a fluid turbulence code developed on a Cartesian grid



Main version of GBS [M. Giacomini et al, 2022 JCP] implements:

- Drift-reduced, two-fluid Braginskii equations for n , $v_{\parallel e,i}$, $T_{e,i}$, Ω , ϕ
- Coupled to neutral code KINDNES
- **Non-field aligned structured Cartesian** discretization in cylindrical coordinates (before this work)
- Bohm-Chodura boundary conditions at first wall

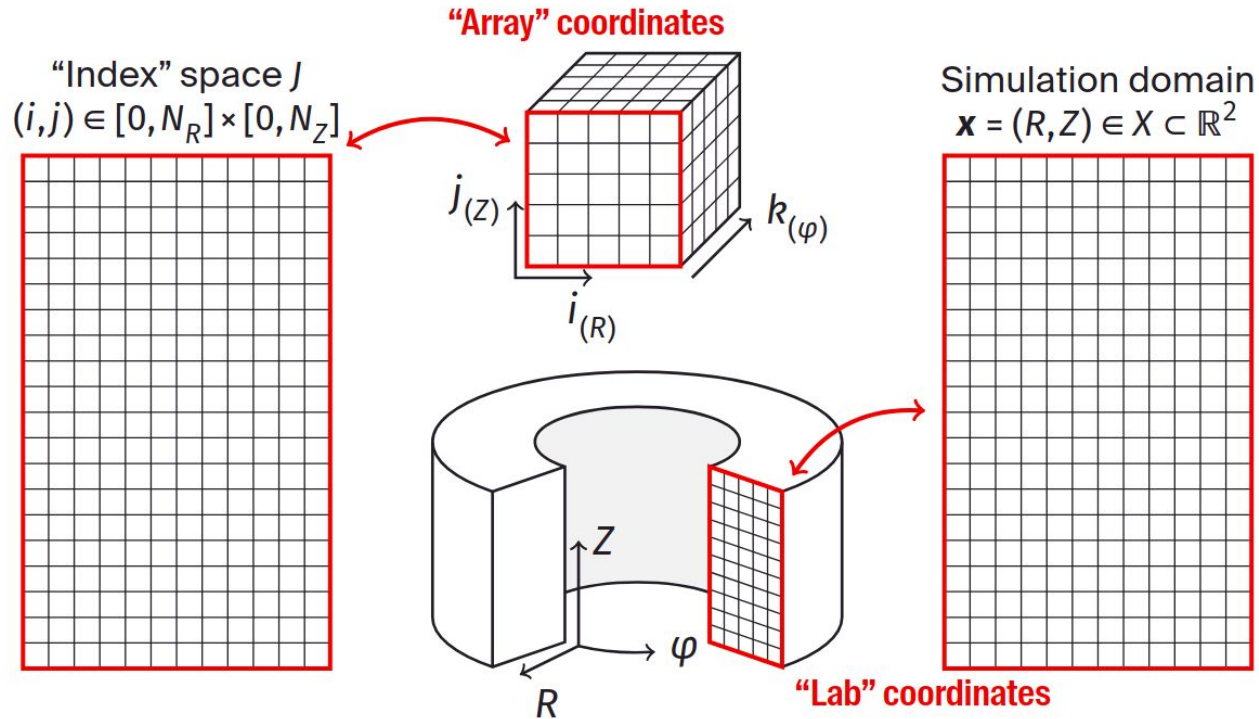
Index

- The curvilinear grid in GBS
- First turbulence simulations of TCV with baffles (no neutrals)
- First turbulence simulation of TCV with baffles with neutrals

D7.6	Evaluation of impact of baffle on edge turbulence in TCV with at least on turbulence code (GBS, SOLEDGE3X or GRILLIX)	Report / presentation / paper	EPFL, CEA, IPPG	12/2025
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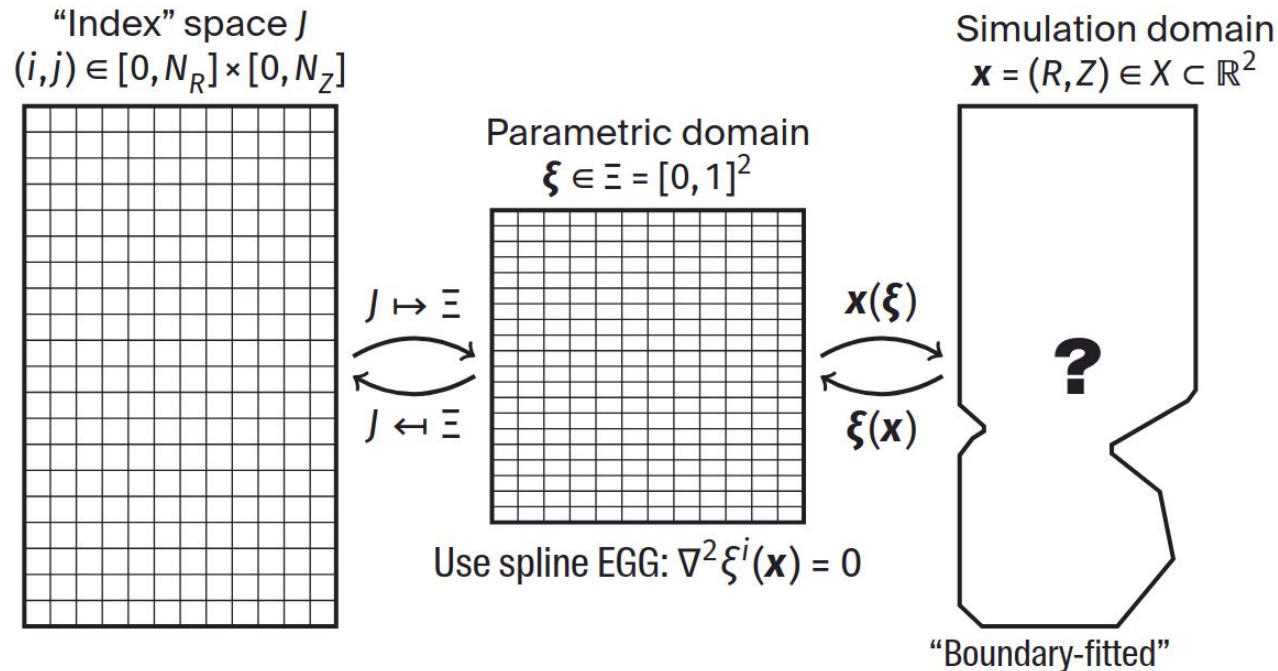
D6.3	KINDNES kinetic neutrals module compatible with flexible wall geometry (EPFL)	Code
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For GBS Louis chose the curvilinear mesh approach



For GBS Louis chose the curvilinear mesh approach

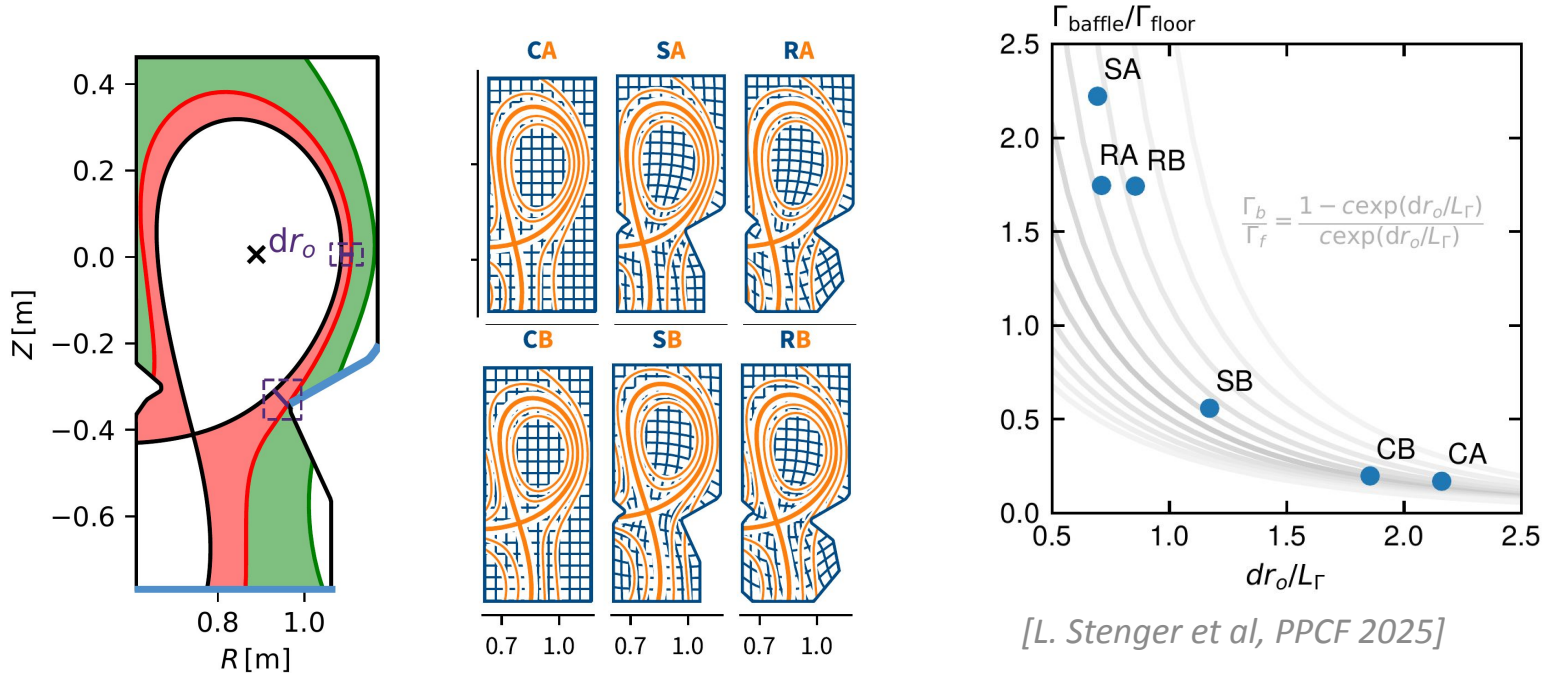
Index space mapped to a domain defined by splines



[J. Hinz et al, Computer Aided Geometric Design 2018]

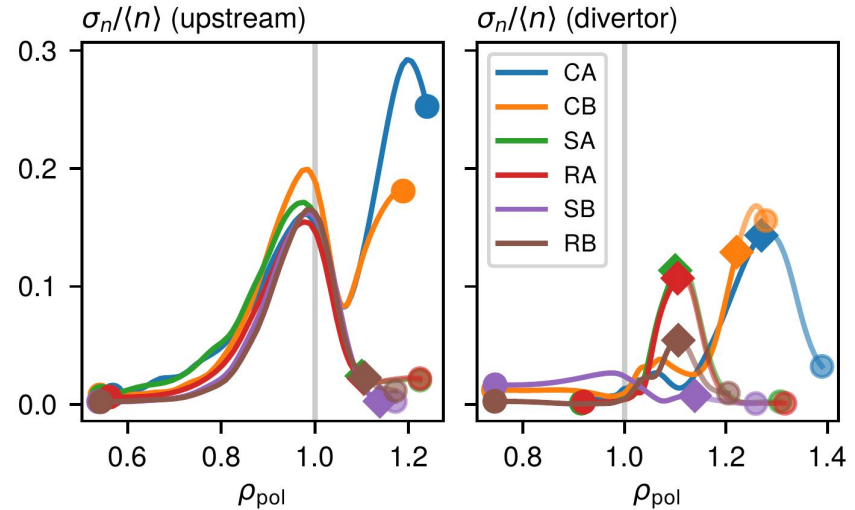
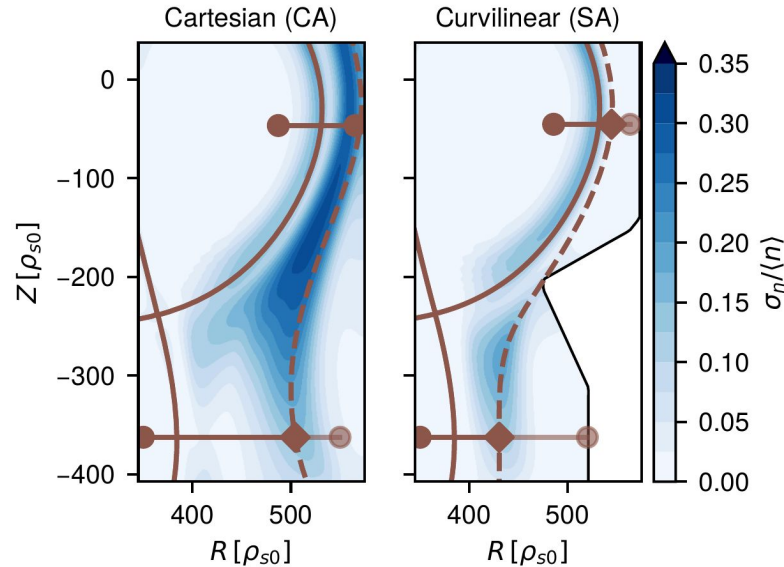
First simulations of TCV with baffles with turbulence shows the fraction of particle flux impacting on the baffle

Several simulations comparing simple rectangular box with TCV with baffles, modifying the distance between LCFS and the baffle tip



First simulations of TCV with baffles with turbulence shows that baffle can act as “limiter”

Strong reduction of density fluctuations in the far SOL of baffled cases



The reduction of connection length when impacting the baffle decreases the parallel transport time

[L. Stenger et al, PPCF 2025]

Index

- The curvilinear grid in GBS
- First turbulence simulations of TCV with baffles (no neutrals)
- **First turbulence simulation of TCV with baffles with neutrals**

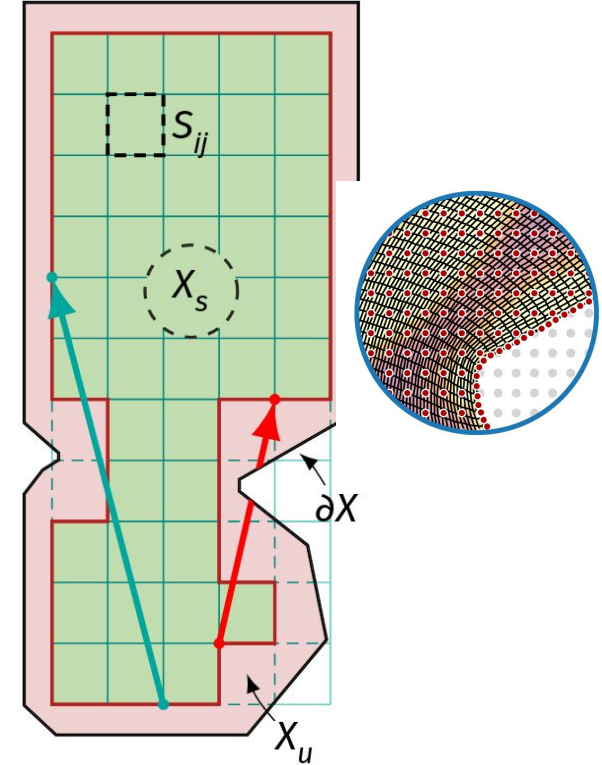
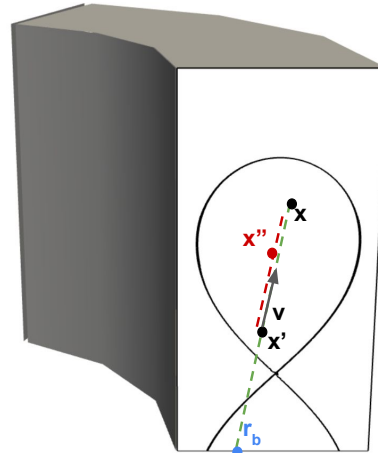
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D6.3	KINDNES kinetic neutrals module compatible with flexible wall geometry (<i>EPFL</i>)	Code
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KINDNES code adapted to flexible grid to have simulations with baffles and neutrals

Fundamental idea of KINDNES is to solve neutral dynamics along their straight trajectories:

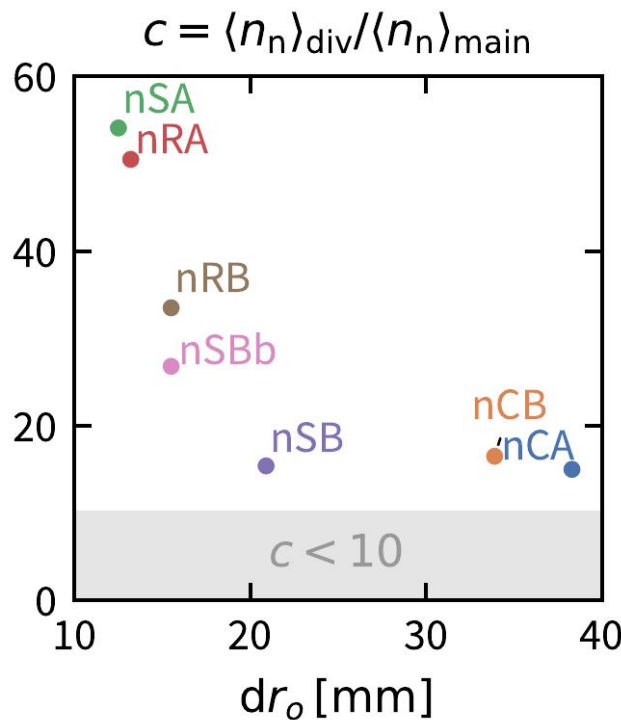
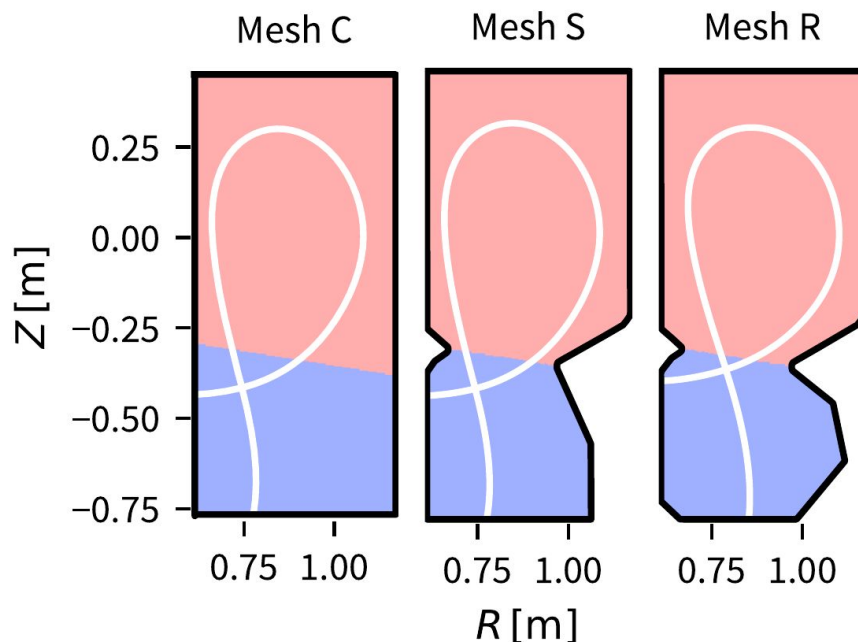
- System solved on unstructured grid, natural extension to curvilinear mesh
- Need for interpolation between curvilinear (plasma) and cartesian (neutrals)
- Need to distinguish between possible and not possible trajectories



[L. Stenger, PhD thesis 2026]

First turbulence simulations of TCV + neutrals shows increased neutrals compression in the divertor volume

Increasing baffle closure leads to increased neutrals compression

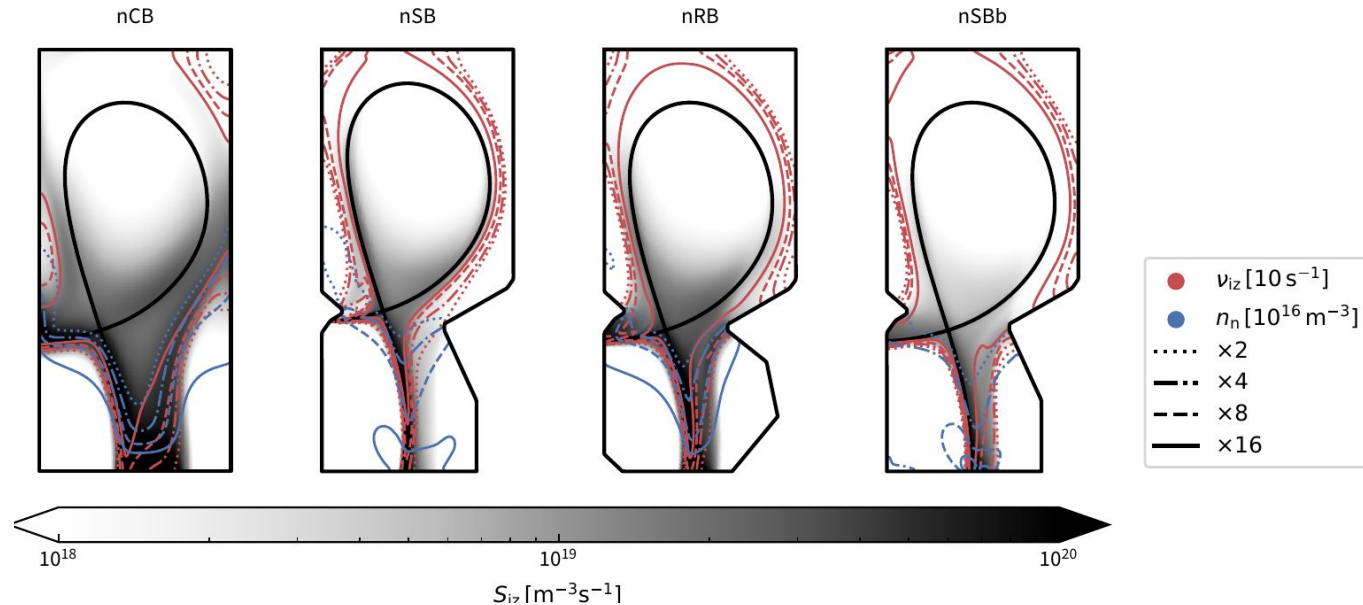


[L. Stenger, PhD thesis 2026]

First turbulence simulations of TCV + neutrals shows evidence of plasma plugging

Increasing baffle closure increases baffle tip temperature and local ionization

Decreased neutrals in the main chamber



[L. Stenger, PhD thesis 2026]

Conclusions

GBS model is now implemented **on a curvilinear grid**, created with a spline mesh generator, together with the **KINDNES** solver:

- The first simulations of turbulence with **TCV baffles** shows the **reduction of plasma fluctuations** at the OMP for radial positions above the outer baffle length
- In case of **wide outer baffles**, it is possible to observe **strong parallel flow above it**
- The implementation of **KINDNES** model on the curvilinear grid showed the **flexibility** of the method, extending it to **unstructured grids**
- Simulations with **self-consistent neutral dynamics** retrieve the **increase in divertor neutral compression** for increasing baffle length
- **Longer outer baffle lead to** increased plasma temperature and density, **plugging** the neutrals in the divertor volume
- Simulations with **baffle** shows **reduced particle and heat fluxes**, especially in the divertor volume **far from the LCFS**

For GBS Louis chose the curvilinear mesh approach

... and how they are introduced in GBS

