Finite elements for the simulation of plasma turbulence in the Tokamak boundary

Annalisa BUFFA, EPFL, Institute of Mathematics - Lausanne
Valentin CARLIER, EPFL, Institute of Mathematics - Lausanne
Marco PICASSO, EPFL, Institute of Mathematics - Lausanne
Markus RENOLDNER, EPFL, Institute of Mathematics - Lausanne
Paolo RICCI, EPFL, Swiss Plasma Center - Lausanne

We will present a finite element approach to solve a subset of the drift reduced Braginskii equations [2], used to describe plasma turbulence in the boundary of fusion device. The studied system features different phenomena with various time scales : the typical time of interest for turbulence is around $10^5 s^{-1}$, while the fastest wave, the shear Alfven wave have a frequency of $10^8 s^{-1}$. In order to avoid a drastic CFL condition, we propose to use an IMEX time integration strategy, treating the transport explicitly and the fast wave implicitly [1]. The remaining shear Alfven wave system that needs to be solved implicitly is a constrained system and we exploit this to propose a mixed formulation that can be reduced using a Schur complement method. However, due to the strongly anisotropic nature of the system, this leads to an almost ill posed problem of type $A + \epsilon B$, where A which is a Laplacian along the magnetic field lines is not invertible due to the presence of closed field lines. Hence, one must exploit the special structure of the problem to obtain an efficient way to solve it. The aim of this presentation is therefore to present the small Braginskii system, its specific structure and our strategy to obtain a stable and efficient discretization.

[1] M. Bassanini, S. Deparis, F. Sala, R. Tenderini. *Imex-rb : a self-adaptive imex time integration scheme exploiting the rb method.* arXiv preprint arXiv :2506.16470, 2025.

[2] M. Giacomin, P. Ricci, A. Coroado, G. Fourestey, D. Galassi, E. Lanti, D. Mancini, N. Richart, L. N. Stenger, N. Varini. *The gbs code for the self-consistent simulation of plasma turbulence and kinetic neutral dynamics in the tokamak boundary.* Journal of Computational Physics, **463**, 111294, 2022.

Contact : valentin.carlier@epfl.ch