Coordination de la Formation par la Recherche

Sujet de Thèse CEA
"SUJET-LABO 2018"

Référence du dossier :

Pôle : DRF ***N° :*** SL-DRF-18-0259

1 - Laboratoire d'accueil au CEA

Centre :**Cadarache**

Département/Service :**IRFM / Service Chauffage et Confinement du Plasma**

Nom du laboratoire :**SEM/Support aux Expériences et Modélisation**

2 - Titre du sujet de thèse

Current profile shaping and its impact on tokamak energy confinement: from theory to the control room

3 - Thématique de Recherche

Physique corpusculaire et cosmos / Physique des plasmas et interactions laser-

4 - Pièce jointe

Y a t-il une pièce jointe associée ? **Non**

Intitulé de la pièce jointe :

5 - Résumé

In a tokamak plasma, the current profile impacts strongly the turbulent transport, therefore the energy content. Maximizing the energy, hence the D-T fusion rate, is at the heart of research on fusion by magnetic confinement. Current profile is the easiest plasma parameter that can be shaped from the tokamak control room using external magnetic field coils as well as electromagnetic waves. To shape in real time the current profile, improved first principle based turbulent transport codes are needed. Since 2017, for the first time, a neural network regression of a quasilinear transport code is now available and integrated in a real time control suite.
The PhD student will apply these novel tools to
1) reproduce well diagnosed experimental current ramp up of the world largest tokamak, JET
2) validate the embedded turbulence code with respect to nonlinear codes over the, rarely explored, parametric domain of a current ramp up.
The iteration between first principle physics and experiment modelling will be carried out until convergence. Then, on the WEST tokamak, in Cadarache, experiments will be designed and realized in order to optimize and control the current profile shape leading to improved plasma performances.

6 - Exposé du sujet

In a tokamak plasma, the current profile impacts strongly the turbulent transport and therefore the energy content. Moreover, the achieved temperature backreacts on the current through a modified resistivity. Maximizing the energy content and hence D-T fusion rate, is at the heart of research on fusion by magnetic confinement. Current profile is the easiest plasma parameter that can be shaped from the tokamak control room. It can be shaped using either external magnetic field coils and/or electromagnetic waves. To shape in real time the current profile, improved first principle based turbulent transport codes have to be embedded in real time controllers.
Since 2017, for the first time, a 9D neural network regression of a first principle transport code, QuaLiKiz, is available [Bourdelle physics of plasmas 2007, Citrin plasma Phys. and controlled fusion 2017, VanDePlassche EPS conference2017] and integrated in a real time control suite, RAPTOR [Felici, Citrin et al submitted 2017].
On the other hand, well diagnosed JET (world's largest tokamak, UK) plasma current ramp up [Voitsekhovitch plasma Phys. and controlled fusion 2010, Mailloux EPS conference 2012] are available to test the validity of the model.
Moreover the physics embedded in the gyrokinetic quasilinear turbulent transport code, QuaLiKiz, has recently successfully reproduced heat, particle and angular momentum transport of JET high confinement mode at high plasma current [Citrin plasma Phys. and controlled fusion 2017, Breton EPS conference 2017] as well as of ohmic heated pulses up to the boundary of the confined plasma [BourdelleEPS conference 2017].

From this state of the art tools and data, the PhD student will:
1. challenge QuaLiKiz embedded physics; indeed colder plasmas with a widely varying plasma current are rarely modelled with first principle codes. To validate QuaLiKiz's turbulent fluxes, the nature of the turbulence in these regimes will be studied thanks to gyrokinetic nonlinear codes, GENE or GKW. The goal being to reproduce well diagnosed JET current ramp up experiments. This part of the PhD work might lead to the discovery of new turbulence regimes and/or might lead to the revision of the state-of-the-art plasma resistivity estimation, which might actually be affected by the turbulence.
2. use QuaLiKiz neural network regression, or a revision of it if found necessary, inside RAPTOR, and design future WEST experiments, at the CEA Cadarache. The plasma scenario design will focus on the current profile optimization in order to optimize the turbulent transport / current profile interplay, hence maximize the energy content. Such experiments will then be realized on WEST.

This PhD work will be carried in collaboration with DIFFER in the Netherlands, where the neural network regression of QuaLiKiz and RAPTOR are developed. At CEA Cadarache the expertise is on the first principle turbulent transport code QuaLiKiz and on tokamak operation with WEST on site. The nonlinear modelling will be done in collaboration with Aix Marseille University and the Max Planck Institute in Garching, Germany.

The work proposed in this PhD is at the crossroads of turbulence transport theory and tokamak operation. It will be carried in the exciting proximity of a tokamak in operation and in collaboration with world leading experts in real time control and optimized regression for faster modelling tools. The results of this PhD will allow improving ITER scenario optimization.

7 - Collaborations (éventuelles) prévues

Laboratoire :

Organisme : **Eindhoven University**

Responsable : **Felici Federico**

Raison de la collaboration :

Real time control expert, RAPTOR developer.

Duree : **36**

Laboratoire : **Dutch Institute for Fundamental Energy Research**

Organisme : **DIFFER**

Responsable : **Citrin Jonathan**

Raison de la collaboration :

QuaLiKiz co-developer with C. Bourdelle.

Duree : **36**

8 - Partenariat(s) industriels prévu(s) (éventuellement)

9 - Correspondant chargé du suivi de la thèse au CEA

Nom: **BOURDELLE** Prénom: **Clarisse**

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Habilitation à diriger des recherches : **Oui**

Organisme de rattachement : **CEA**

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Combien de doctorants encadrerez-vous durant l'année universitaire 2018/2019 ? **1**

10 - Directeur de thèse

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