MF1-I9 AAPPS-DPP2020

4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Experimental and modeling development at JET for DT preparation and ITER risk mitigation

J. Garcia[1], D. Douai[1], L. Frassineti[2], J. Hillesheim[3], A. Huber[4], C.F. Maggi[3], J. Mailloux[3]. E de la Luna[5], H. Weisen[6] and JET contributors*
1 CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.
2 Division of Fusion Plasma Physics, KTH, Stockholm SE
3 CCFE, Culham Science Centre, Abingdon, OX14 3DB, UK
4 Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung - Plasmaphysik, 52425
Jülich, Germany
5 Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain
6 EPFL, Swiss Plasma Center, Lausanne, Switzerland
*See the author list of E. Joffrin et al. 2019 Nucl. Fusion 59 112021
e-mail (speaker):Jeronimo.garcia@cea.fr

Nuclear fusion is a promising way of producing commercially and environmentally sustainable energy by means of the fusion of Deuterium (D) and Tritium (T) nuclei. An important international effort has been carried out since the mid XX century in order to study nuclear fusion by means of magnetically confined plasmas. Such effort, mostly done using the tokamak concept, has led to a deep understanding of the physics by which plasmas can be confined and the conditions required to successfully provide fusion energy. However, one key element is still not well understood; whereas most of the experiments have been performed using D as a main gas, the DT mixture is the one envisaged to produce fusion energy in burning plasmas. The inherent radioactive nature of the DT reaction, which in addition to alpha particles produces non-confined neutrons, is the reason for the scarce knowledge of DT plasmas as specific nuclear safety measures are required to operate. Such limited knowledge is indeed a risk for the safe DT operation at ITER, which will work with plasmas mainly heated by the alpha particles generated by the DT reactions.

The tokamak JET, able to operate with DT plasmas, has developed a scientific program in H, D, T and DT with the aim of supporting and minimizing the risks of the transition from DD to DT plasma operation in ITER [1]. Such program helps to understand and document the physics differences between D and H, T and DT plasmas but also to provide scenario solutions integrating several key aspects such as core transport, impurity accumulation avoidance, power exhaust and potential difficulties for operation.

The JET scientific program has two equally important aspects; a strong experimental activity covering all the H isotopes and their mixtures, and a modelling/theory side that contributes to validate models and helps to understand further the experimental results. On this basis, JET has also started a 'predict first' activity aiming at predicting how DT plasmas will behave. Such effort is essential for evaluating whether JET DT plasmas can safely provide the expected scientific outcome but it is also important for guiding experimental proposals towards key specific physics involving DT plasmas. Some of the main results obtained in this program involve both core and edge plasma regions.

Experimentally, the change of isotope from H to D leads to significant differences in the energy confinement [2] due to inherent dependences of turbulence or MagnetoHydroDynamics (MHD) on the isotope mass. This is clearly seen at the plasma edge, where the density increase with the mass whereas the frequency of the so-called Edge Localized Modes (ELMs) decreases [2]. Analyses performed with the nonlinear MHD code JOREK [3] show that diamagnetic effects are important and a higher isotope mass leads to the destabilization of low toroidal modes and the stabilization of high modes [4]. Regarding turbulent transport in the core, some physical mechanisms such as electromagnetic fluctuations, zonal flows, ExB shearing or collisionallity can efficiently reduce transport in increasing isotope mass plasmas [5,6].

DT extrapolations to the maximum available power at JET, performed with a large variety of sophisticated codes and validated models with different isotopes, show that 11-16MW of fusion power are possible [7]. Favorable core isotope effects are found in conditions of low turbulent transport, such as strong rotating and high core thermal and fast ion energy plasmas. In these conditions, clear alpha particle effects, e.g. resonant with Alfvén waves [8], could be seen. However, the improved confinement could also lead to undesirable effects such as stronger core impurity accumulation [9].

These results have played a key role in defining the DT campaign at JET, which will take place in 2021, and they are a crucial step in the challenging task of predicting and understanding ITER DT plasmas.

References

1 E. Joffrin et al 2019 Nucl. Fusion 59 112021
2 C.F. Maggi et al., PPCF 60, 014045 (2018)
3 Huysmans G T A et al 2007 Nucl. Fusion 47 659
4 Fil and S. Pamela in preparation
5 J. Garcia et al 2017 Nucl. Fusion 57 014007
6 H. Weisen et al accepted in Journal of Plasma Physics
7 J. Garcia et al 2019 Nucl. Fusion 59 086047
8 R. J. Dumont et al 2018 Nucl. Fusion 58 082005