Contribution ID: **991** Type: **Regular Poster**

Recent key contributions of ICRF heating in support of plasma scenario development and fast ion studies on JET and ASDEX Upgrade

Wednesday, 12 May 2021 12:10 (20 minutes)

Ion Cyclotron Resonance Frequency (ICRF) heating plays an important role in many present day experiments and it is one of the auxiliary heating methods that will be used in ITER. In this contribution, we will review the recent key ICRF results from the JET and ASDEX Upgrade (AUG) tokamaks in preparation of ITER.

In the recent JET campaigns, the focus has been in the preparation of integrated scenarios for high fusion performance with long duration (Pfus=15MW for 5s) (1) and alpha physics (2) in the forthcoming campaign with deuterium-tritium (D-T) fuel mixture. Following the successful earlier characterization and optimization of hydrogen minority heating for the use in JET scenario plasmas (3), the new developments include the integration of He-3 minority heating in high-performance D plasmas for improved bulk ion heating compatible with the control of central high-Z impurity accumulation in the presence of the ITER-like metallic wall. With He-3 minority heating, the best plasma performance in terms of the neutron rate and plasma energy content was obtained at a low He-3 concentration of ˜2%. The resulting modest He-3 consumption is advantageous in light of lower operational cost when using He-3 minority heating in ITER. It is also well in line with earlier computational multi-code work (4) for ITER where good absorption performance with a He-3 concentration of ˜3% was found. In the coming JET campaigns, which will include a campaign with tritium and D-T plasmas, these experiments will be extended to the studies of He-3 minority heating and second harmonic heating of tritium, which are the two main ICRF heating schemes planned for ITER full-field operation in 50%-50% D-T plasmas. Further ICRF options for JET D-T campaign are discussed following a recent review (5).

On AUG, novel applications of ICRF waves for plasma heating have become possible through the improved operating space of ICRF system and, in particular, its extended frequency range (6). It has allowed the application of second harmonic heating of hydrogen on AUG for improved core electron heating in the ITER-baseline-like plasmas with pure wave heating (i.e. without NBI-induced torque to simulate ITER burning plasma conditions) (7). The extended frequency range has also been instrumental for the experiments using third harmonic ICRF heating of NBI-injected deuterons for fast ion studies and for further development of fast ion and neutron diagnostics. Figure 1 shows a typical discharge with a more than two-fold increase of the D-D fusion rate due to ICRF-accelerated deuterons achieved with this scheme in AUG. As a continuation of the very successful earlier experiments with this scheme on JET (8), this ICRF development on AUG has provided for the first time a means for simultaneous controlled variations and measurements of both the confined and the non-confined parts of ICRF-driven fast deuterium distribution. Furthermore, analysis and modeling of JET and AUG experiments in D, H-D, H-He-4 and D-He-4 plasmas heated with He-3 minority heating and the so-called three-ion ICRF schemes (9) have provided improved insights on core ICRF physics as well as nonlinear electromagnetic stabilization of ion temperature gradient (ITG) modes by fast ions (10,11).

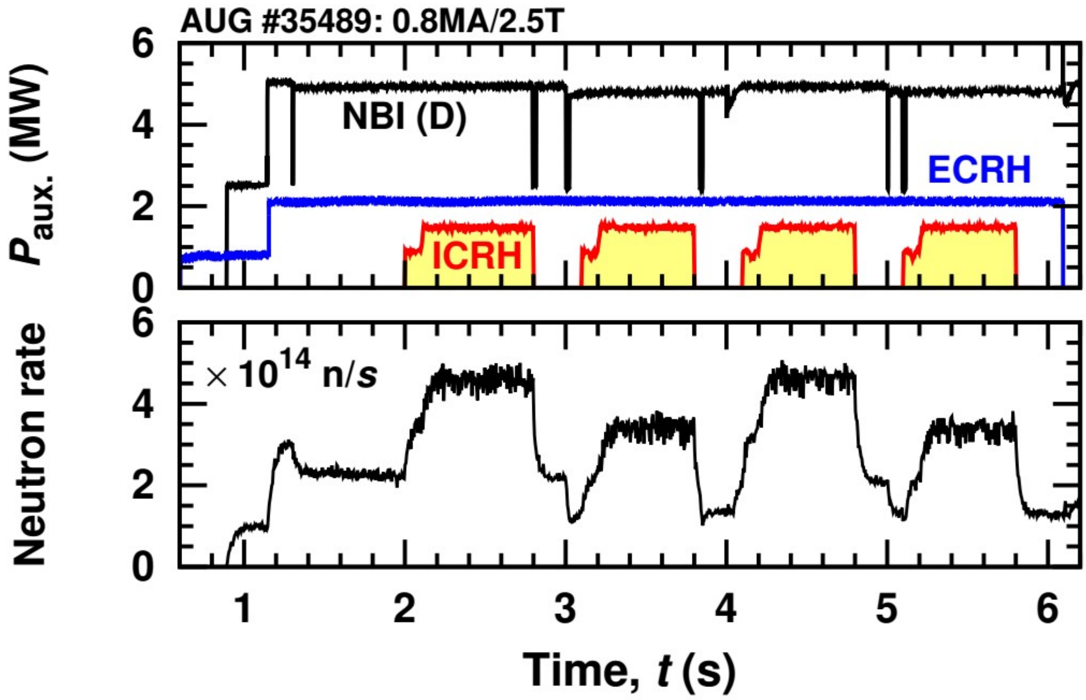

Figure 1: Time evolution of the neutron rate in 2.5T/800kA AUG discharge 35489 with pulses of ICRF power (red) tuned to central third harmonic resonance of D-NBI ions. ECRF power (blue) and NBI power (black) are virtually constant while NBI injectors with different injection energies (93keV and 60keV) are used.

The rich variety of new ICRF scenarios in various plasma scenarios (H-mode and improved confinement regimes) in the two devices of different sizes has formed a challenging test bed for the validation of numerous modelling tools. We will discuss some representative examples from the comparisons of experimental results with the ICRF modelling code PION (12). PION computes the ICRF power absorption and the distribution functions of the resonant ions in a self-consistent way. Thanks to its speed, it forms a part of the automated data processing chain at JET, and has recently been installed in the ITER Integrated Modelling and Analysis Suite (IMAS) for integrated predictive modelling of ITER.

Despite its relatively simple physics model, we find that PION reproduces successfully many features observed in the recent ICRF experiments on JET and AUG. For example, in the case of modelling the novel three-ion-schemes, it reproduces the strong ion cyclotron damping by third ion species despite its low concentration, strong ICRF acceleration of resonant ions into the MeV range, and the dependence of confined and lost resonant ions distribution functions on experimental parameters (13). Our results increase our confidence in the applications of PION such as those reported in (14, 15) for predictive simulations of future experiments planned in the JET D-T campaign and ITER.

Acknowledgements *This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.*

References

1. L. Garzotti et al. 2019, Nucl. Fusion 59, 076037
2. R. Dumont et al. 2018, Nucl. Fusion 58, 082005
3. M.J. Mantsinen et al. 2017, EPJ Web of Conferences 157, 03032.
4. R. Bilato et al., 2014, AIP Conference Proceedings 1580, 291.
5. E. Lerche et al., RFPPC 2019.
6. Vl. Bobkov et al., RFPPC 2019.
7. T. Pütterich et al., 27th IAEA Fusion Energy Conference (FEC2018), EX/P8-4; T. Pütterich et al, EPS2020.
8. S.E. Sharapov et al. 2016, Nucl. Fusion 56 112021 and references therein.
9. Ye.O. Kazakov et al., this conference and references therein.
10. N. deOliveira et al., 2020, submitted to Nuclear Fusion.
11. A. Di Siena et al 2019 Nucl. Fusion 59, 124001.

10. L.-G. Eriksson, T. Hellsten and U. Willén 1993, Nucl. Fusion 33, 1037.
11. M.J. Mantsinen et al., 2019 Europhysics Conference Abstracts, vol. 43C, O5.102.
12. D. Gallart et al., RFPPC 2019.
13. I.L. Arbina et al., 2019 Europhysics Conference Abstracts, vol. 43C, P4.1079.

Affiliation

ICREA and Barcelona Supercomputing Center

Country or International Organization

Spain

Primary author: Prof. MANTSINEN, Mervi J. (ICREA and Barcelona Supercomputing Center)

Co-authors: Dr BILATO, Roberto (Max-Planck Institut für Plasmaphysik); BOBKOV, Volodymyr (Max-Planck--Institute for Plasma Physics); GALDON-QUIROGA, Joaquin (Max-Planck-Institut fur Plasmaphysik, Garching, Germany); Dr GALLART, Daniel (Barcelona Supercomputing Center); GARCIA-MUNOZ, Manuel (University of Seville); GONZALEZ-MARTIN, Javier (University of Seville); JACQUET, Philippe (CCFE); KAPPATOU, Athina (Max-Planck-Institut für Plasmaphysik); KAZAKOV, Yevgen (Laboratory for Plasma Physics, LPP-ERM/KMS); KIPTILY, Vasily (United Kingdom Atomic Energy Authority); Dr LERCHE, Ernesto (LPP-ERM/KMS, Association EUROFUSION-Belgian State, TEC partner, Brussels, Belgium;); Dr MANTICA, Paola (Istituto Di Fisica Del Plasma, Consiglio Nazionale delle Ricerche (CNR), 20125 Milan, Italy); Mr MANYER, Jordi (Barcelona Supercomputing Center); NOCENTE, Massimo (Dipartimento di Fisica, Università di Milano-Bicocca); Dr OCHOUKOV, Roman (Max--Planck-Institut fur Plasmaphysik, Garching, Germany); PÜTTERICH, Thomas (Max-Planck-Institut für Plasmaphysik); Dr SAUTER, O. (Swiss Plasma Center (SPC), Ecole Polytechnique Fédérale de Lausanne (EPFL)); SCHNEIDER, Philip A. (Max-Planck-Institiut für Plasmaphysik); Dr TARDINI, Giovanni (IPP, Garching, Germany); VAN EESTER, Dirk (LPP-ERM/KMS); Dr SHARAPOV, Sergei (Culham Centre for Fusion Energy, UK); Dr WEILAND, Markus (Max-Planck-Institut für Plasmaphysik); JET CONTRIBUTORS (CCFE Culham Science Center); EUROFUSION MST1 TEAM; ASDEX UPGRADE TEAM (IPP Garching)

Presenter: Prof. MANTSINEN, Mervi J. (ICREA and Barcelona Supercomputing Center)

Session Classification: P3 Posters 3

Track Classification: Magnetic Fusion Experiments