Fast Ion D-D and D-\(^3\)He Fusion on JET

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*See Appendix of F. Romanelli et al., Proc. 25th IAEA FEC 2014, Saint Petersburg, Russia

Third harmonic ICRH [1,2] has been shown at JET to be an effective tool for accelerating NBI-produced beam ions to the MeV energy range, suitable for studying ITER relevant fast particle physics, as well as for preparing JET fusion product diagnostics for a future D-T campaign. By adding 3 MW of ICRH power at 3rd harmonic to 3.4 MW of D NBI in D plasma, it was possible in recent experiments to increase the yield of D-D neutrons by an order of magnitude, up to \(7 \times 10^{15}\) n/s. Neutron emission spectra measured in these experiments, both by time-of-flight analysis and using a novel diamond detector, reveal broad spectra with neutron energies up to \(
\sim 6\ MeV\) for D-D neutrons [3]. This broadening of the D-D neutron spectra results from ICRH acceleration of NBI-produced D with starting energy \(\sim 100\ \text{keV}\) into the MeV energy range. Control of the D-D neutron energy spectrum was demonstrated by varying plasma density, ICRH power, and pitch-angle of NBI, which play a key role for the coupling between the beam and ICRH. The experiment was extended to ICRH acceleration of D beams in D-\(^3\)He plasmas with amounts of \(^3\)He increasing discharge by discharge up to D-\(^3\)He \(\approx 70:30\). The aneutronic D-\(^3\)He fusion, giving birth to 15 MeV protons and 3.7 MeV alpha-particles has been studied on JET before [4]. In contrast to \(^3\)He minority ICRH [5] and \(^3\)He NBI [6], the ICRH acceleration of D beam in D-\(^3\)He plasma generates a fast D distribution function with a cut-off in energy, which is easy to control. The rate of D-\(^3\)He fusion was measured from 17 MeV \(\gamma\)-rays produced by D(\(^3\)He, \(\gamma\)) \(^5\)Li reaction and found to be \(~10\ kW\). High resolution \(\gamma\)-spectrometry, NPA, scintillator probe, and Faraday cups were all employed for measuring ICRH-accelerated D ions and charged fusion products of both D-\(^3\)He and D-D reactions. Analysis of the experiments with the suite of ICRH-modelling tools PION, SELFO, and SPOT/RFOF is found to agree with the measured neutron and \(\gamma\)-ray spectra and profiles [7,8]. Remarkably long sawtooth-free periods of up to \(~2.5\ \text{s}\) were obtained in these plasmas and Alfvén Eigenmodes were excited. These results pave the way for further experiments such as counteracting the effective, but ultimately undesirable sawtooth stabilisation by fast ions observed in the experiment using a separate ICRH source, as well as for investigating fast ion effects on AEs and other plasma instabilities.

This work has received funding from Euratom and the RCUK Energy Programme [grant number EP/I501045]. The views and opinions expressed herein do not necessarily reflect those of the European Commission.