16th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems - Theory of Plasma Instabilities

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Impact of Suprathermal Ions on Neutron Yield at Pre-DT Phase of ITER Operation

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The neutron and tritium production at pre-DT phase of ITER operation need to be quantified in view of the plans for commissioning and operation of the heating systems, as discussed in the ITER Research Plan (IRP) [1]. An assessment of neutron production has been carried out for the whole set of scenarios foreseen by the IRP for the pre-DT phase, Pre-Fusion Plasma Operation, (PFPO-1 and PFPO-2) with the application of H0-NBI, ECRH and ICRH H and He3 minority and 3-ion heating schemes. Fast ions originated from NBI and minority ICRH react with intrinsic Be impurities producing neutrons and fast deuterons. For protons, the reaction rate is affected by the synergistic acceleration of H0-NBI ions by ICRH when both systems are applied simultaneously. This deuteron source produces secondary neutrons and tritium from interaction of the thermal deuterium ions with fast and thermalized deuterons. To address the neutron production by fast particles, simulations have been performed for L-mode and H-mode scenarios in hydrogen and helium plasmas for a range of toroidal field values (1.8-5.3 T) as foreseen in these phases in the IRP. The simulations include nonlinear effects, such as synergy of H0-NBI and IC waves in a hydrogen minority heating scheme, as well as the 3-ion ICRH scheme. The ICRH power absorption and distribution function of ICRH-generated suprathermal ions for plasma scenarios are calculated with the SSFPQL-TORIC suite of codes [2]. The ECR wave absorption, heating and current drive is calculated with the OGRAY code [3]. Profiles of plasma parameters are calculated self-consistently with heating and current-drive by 1.5D transport simulations in the ASTRA framework [4]. The beam energy and NBI power are adjusted to fulfil the shine- through power load limits in ITER. It is shown that the main source of neutrons for the plasma parameters expected in PFPO is due to the interaction of Be impurity with suprathermal ions produced by NBI and ICRH, fast deuterium from the Be(p,d)2⍰ reaction and further secondary fusion reactions. Local fractions of the NBI and ICRH fast ion pressures and their gradients at PFPO are higher than those of fast alphas in the ITER Q = 10 baseline scenario, making AEs unstable. The AE stability analysis of PFPO plasmas is performed using the perturbative NOVA suite of codes with rich kinetic physics [5, 6]. It is shown that sawtooth oscillations and excitation of AEs can noticeably reduce the neutron rate. The total upper estimate of the integrated neutron emission for the two PFPO phases will be provided.

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