Contribution ID: **815** Type: **Regular Poster**

Assessment of Neutron Production during Pre-Fusion Operation of ITER

Tuesday, 11 May 2021 18:25 (20 minutes)

The neutron and tritium production during the pre-DT, Pre-Fusion Plasma Operation, (PFPO) phase of ITER need to be quantified in view of the plans for commissioning and operation of the heating systems in hydrogen and helium plasmas, as discussed in the ITER Research Plan (IRP) 1. In the assessment presented here, we consider a number of tritium and neutron sources of different origins. In hydrogen plasmas with Ohmic and ECRH heating, neutrons and tritium appear due to the presence of residual deuterium nD/nH ˜ 1.5 10-4 caused by the finite purity of the hydrogen fuel. Application of hydrogen NBI (Ep = 500-870 keV) and ICRH H and 3He minority heating schemes in He and H plasmas respectively, creates and accelerates fast protons and 3He ions which produce neutrons interacting with Be impurities. In addition, fast protons produce fast D and alphas, which in turn produce neutrons interacting with Be impurities (figure 1). The evidence for the importance of nuclear fusion reactions of fast particles produced by auxiliary heating with Be impurities has been demonstrated in JET experiments [2]. Besides stationary plasma conditions, we also estimate the possible sources that can lead to in-vessel component activitation in this phase produced during plasma disruptions should runaway electrons be formed. This includes both bremsstrahlung emission and secondary neutrons. The impact of runaway electrons on the divertor or first wall will yield different bremsstrahlung and secondary neutron production levels.
An assessment of neutron production has been carried out for a wide range of plasma scenarios foreseen in the ITER Research Plan 1 for the PFPO phase, including the application of H0-NBI, ECRH, ICRH H and 3He minority heating, and with the 3 ion ICRH heating scheme with 3He minority as a function of Be fraction, fBe= nBe/ne. Fast deuteron, alpha and neutron production by the interaction of fast protons originating from NBI and hydrogen minority ICRH heating with Be impurity: 9Be(p,d)2a, 9Be(p,a)6Li, 9Be(p,n)X, is calculated using the ASTRA-NBI [3,4] and TORIC-SSFPQL[5] codes. On the basis of the calculated sources of fast deuterons and alphas with these codes, the neutron sources due to secondary reactions with Be impurities: 9Be(d,n)X, 9Be(a,n)X are derived. Neutron sources produced by fast 3He minority ions accelerated by ICRH in the reaction 9Be(3He,n)X (4) are calculated for the 3-ion heating scheme [6] and the 3He minority scheme. The impact of the synergy between the H0-NBI ions and hydrogen minority ICRH heating on neutron production is assessed for 7.5 MA/2.65 T Helium H-mode plasmas with 33 MW (NBI), 20 MW (ECRH) and 20 MW (ICRH) heating power levels to be performed in PFPO-2. [7]. In these plasmas, the main source of neutrons is due to the interaction of Be impurities with suprathermal protons produced by ICRH and NBI. Secondary fusion reactions occur due to the interaction with beryllium of the fast deuterium and alphas from the 9Be(p,d)2a , 9Be(p,a)6Li reactions as well but the magnitude of this neutron source is much lower. Our modelling shows that the synergy between the H0-NBI and the hydrogen minority ICRH noticeably reduces the neutron yield (Sn,ICRH + Sn,NBI > Sn,ICRH+NBI), which is due to widening of the ICRH absorption and reduction of the fast proton tails due to the preferential absorption of ICRH waves by fast NBI protons in the plasma (figure 2).
Local fractions of the NBI and ICRH fast ion pressure and their gradients during PFPO-2 are higher than those of fast alphas in the ITER Q = 10 baseline scenario, making AEs unstable over a wide range (x < 0.5) of the low magnetic shear. For instance, the injection of H0-NBI with Ep=0.87 MeV in helium plasmas is superalfvenic for the whole range of magnetic fields to be explored in ITER. The stability of TAE modes has been analysed in these plasmas which typically have both a high pressure of suprathermal particles and a Weak Reversed Shear (WRS) current profile due to the large current drive produced by the NBI [8,9]. The possible impact of saw-tooth oscillations and TAEs on neutron production in these plasma scenarios has been assessed based on a linear instability analysis and it has been found that they can noticeably reduce the local neutron density source and beam-driven current drive but have moderate impact on the integral neutron production.
Disclaimer: ITER is the Nuclear Facility INB no. 174. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization. This publication is provided for scientific purposes only. Its contents should not be considered as commitments from the ITER Organization as a nuclear operator in the frame of the licensing process.
References
1 ITER Research Plan, ITER Technical Report ITR-18-03 (1 "ITER Research Plan within the Staged Approach" (Level III –Provisional Version). ITER Technical Report ITR-18-003, 17 September 2018)
[2] A.V. Krasilnikov, et al, Nucl. Fusion 58 (2018) 026033
[3] A. Polevoi, et al "Benchmarking of the NBI block in ASTRA code versus the OFMC calculations", JAERI-DATA-Code 97-014, March 1997,
https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/052/28052091.pdf

[4] A.R. Polevoi et al, “Reassessment of Steady State Operation in ITER with NBI and EC Heating and Current Drive“, P5.1012, 46th EPS Conference on Plasma Physics, 8 - 12 July 2019, Milan, Italy, hppt://ocs.ciemat.es/EPS2019PAP/pdf/P5.1012.pdf
[5] R. Bilato, M. Brambilla, et al., Nucl. Fusion, 51 (2011) 103034
[6] Ye.O. Kazakov et al., Nature Physics 13, 973-978 (2017)
[7] R. Bilato, et al, “Synergies between H-NBI fast-ions and ICRF heating in the non-activated operational phase of ITER”, 45th EPS Conference on Plasma Physics, July 2-6, Prague, Check Republic, http://ocs.ciemat.es/EPS2018PAP/pdf/P1.1070.p
[8] G.Y. Fu, C.Z. Cheng, and K.L. Wong, Phys. Fluids B 5, 4040 (1993)
[9] N.N. Gorelenkov, C.Z. Cheng, and G.Y. Fu, Phys. Plasmas 6, 2802 (1999)

Indico rendering error

Could not include image: [404] Error fetching image

Affiliation

ITER Organization

Country or International Organization

ITER Organization

Primary authors: POLEVOI, Alexei (ITER Organization); LOARTE, Alberto (ITER Organization); Dr BILATO, Roberto (Max-Planck Institut für Plasmaphysik); GORELENKOV, Nikolai (PPPL, Princeton University); KAZAKOV, Yevgen (Laboratory for Plasma Physics, LPP-ERM/KMS); LEHNEN, Michael (ITER Organization); Dr POLUNOVSKIY, Eduard (ITER Organization); Dr TCHISTIAKOV, Andrei (ITER Organization); Dr FABLE, Emiliano (Max Planck Institute for Plasma Physics); KIPTILY, Vasily (United Kingdom Atomic Energy Authority); KRASILNIKOV, anatoli (Director Institution @Project center ITER”); Mr KUYANOV, Aleksey (NRC Kurchatov Institute); NAZIKIAN, Raffi (Princeton Plasma Physics Laboratory); PINCHES, Simon (ITER Organization)

Presenter: POLEVOI, Alexei (ITER Organization)

Session Classification: P2 Posters 2

Track Classification: Magnetic Fusion Theory and Modelling