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# Energetic-particle Transport and Loss Induced by Helically-trapped Energetic-ion-driven Resistive Interchange Mode in the Large Helical Device

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Understanding of interplay between energetic particle (EP) and EP-driven magnetohydrodynamic mode is of the greatest importance in order to reduce the anomalous transport and/or loss of EPs in current fusion machines and in a fusion reactor. In high-ion-temperature discharges performed in relatively low-density plasma on the Large Helical Device (LHD), helically-trapped energetic-ion-driven resistive interchange mode (EIC) is often excited due to the intensive injection of positive-ion based perpendicular neutral beams (P-NBs) [1]. Study of EIC mode-induced EP transport/loss has progressed by starting the deuterium operation of LHD by using neutron diagnostics because neutrons emitted from NB-heated LHD deuterium plasma are produced mainly from so-called beam-thermal reactions. The effect of EIC mode on beam ion confinement has been studied by total neutron emission rate ($S_n$) measured with the neutron flux monitor and by the neutron emission profile obtained with first vertical neutron camera (VNC) based on stilbene detectors with automated pulse-shape discrimination capability[2]. Loss of helically-trapped beam ion due to EIC mode was reported by comparing $S_n$ and the radial neutron emission profile before and after the EIC mode excitation [3]. The second VNC based on fast-neutron scintillator EJ410 characterized by high-detection efficiency operated with current mode is newly installed in order to obtain neutron emission profile with high-time resolution. By using second VNC, it is found that decay time of neutron signal due to EIC mode in central and edge cords is almost the same, whereas rise time of neutron signal after EIC event is different in central and edge cords. The decrements of $S_n$ and neutron signal in the central cord linearly increase with EIC amplitude suggesting that the convective process is dominant. Orbit following simulation using guiding center orbit following code in the Boozer coordinates (DELTA5D) including magnetic fluctuation [4] is performed to understand the effect of EIC fluctuation on beam ion confinement. In this simulation, EIC perturbations are taken into account as the form $\delta B=\nabla\times(\alpha B)$ including the frequency sweeping from 10 kHz to 5 kHz within 2 ms as observed in experiments. The width and the location of the magnetic fluctuation are decided to be r˜0.06 m and r/a˜0.87, respectively, based on the experimental observation [1]. Time evolution of $S_n$ obtained by DELTA5D simulation shows that $S_n$ decreases significantly within ˜5 ms by including the magnetic fluctuation. In addition, it is found that the drop rate of $S_n$ increases with the increase of EIC amplitude, as observed in the experiment. Detailed comparison of time evolution of neutron emission profile and transport/loss process of beam ion due to EIC mode will be presented.
[1] X. D. Du et al 2015 Nucl. Fusion 56 016002. [2] M. Isobe et al 2018 Nucl. Fusion 58 082004. [3] K. Ogawa et al 2018 Plasma Phys. Control Fusion 60 044005. [4] D. A. Spong 2011 Phys. Plasmas 18 056109.

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