6. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS

NIFS Bilateral Collaboration Research Program on Heliotron J

The Heliotron J group at IAE, Kyoto University has joined the Bilateral Collaboration Research Program managed by National Institute for Fusion Science (NIFS) since FY2004. This unique collaboration program promotes joint research bilaterally between NIFS and research institutes or research centers of universities that have facilities for nuclear fusion research. Under this collaboration scheme, the facilities operated in the different universities are open to all fusion researchers just as joint-use facilities of NIFS.

The main objective of the research in our Heliotron J group under this joint research program is to investigate experimentally/theoretically the transport and stability of fusion plasma in the advanced helical magnetic field and to improve the plasma performance through advanced helical-field control in Heliotron J. Picked up in FY2021 are the following seven key-topics; (1) transport study concerning field configuration control and relating plasma structure formation control, (2) control of plasma profile, plasma flows, plasma current for confinement improvement, (3) investigation of structure formation of plasma fluctuations in the core and peripheral region, (4) enhancement of operation region of high-density plasmas using novel fueling methods, (5) optimization of particle supply and heating scenario, (6) development of new technology in experiment and analysis.

Two results from this collaboration research in FY2021 are shortly reported below. The annual report for all the collaboration subjects in this program will be published by NIFS.

Magnetic configuration effect on energy confinement properties and profile structure formation: In the Heliotron J device, which has extensive and precise magnetic field controllability, the bumpiness component (toroidal mirror ratio) in the magnetic field spectrum is a characteristic control knob for neoclassical transport, MHD, and fast ion confinement to verify the effectiveness of the configuration optimization. We have recently expanded the magnetic field configuration range in the experiments and have focused on rotational transform control experiments. Controlling the rotational transform makes it possible to investigate the dependence of the confinement properties on the rotational transform and its physical mechanism that appears in the scaling laws. In addition, it is possible to control the rational surfaces, which determine the structure of the peripheral magnetic field by changing the rotational transform, thereby significantly changing the topology of the peripheral magnetic field. Experiments were performed by varying the central rotation transform from 0.46 to 0.63 while keeping the line-averaged density at about 1×10^{19} m^{-3}. The ECH injection conditions and magnetic field strength are adjusted to achieve central heating. The overall trend is that the confinement energy decreases with increasing rotational transform. To investigate the effect of rotational transform control on neoclassical transport, we compared the confinement time with the effective helical ripple, $\varepsilon_{\mathrm{eff}}$. The effective helical ripple scan shows a gradually increasing trend with increasing rotational transform. However, the correlation with Wp is unclear. This suggests that rotational transform may affect turbulent transport as well as neoclassical transport. In the future, we plan to conduct neoclassical analysis and turbulence simulation analysis, including the effect of geodesic curvature.

Formation of electron internal transport barrier (e-ITB) in NBI only plasmas Role of preionization in NBI plasma start-up and stochastic acceleration phenomena: Producing plasmas using NBI only has never been successful in medium-sized helical devices. We have used non-resonant microwaves for pre-ionization and have successfully produced NBI plasmas. Pre-ionization generates a plasma of $n_e = 4\times10^{18}$ m^{-3}, and the carbon ion emission (OV) peak is observed at 3 ms after NBI injection. The dependence of the OV peak delay time on the density of the pre-ionized plasma is investigated. A numerical code for 0-dimensional NBI production has been developed. The simulation results agree with the experimental plasma evolution. The radiation barrier temperature of light impurities such as carbon and oxygen, and the threshold value for the density of pre-ionized plasma reproduces the measurement. The simulation results clearly show that the pre-ionizing plasma (1) produces enough NBI fast ions, which in turn (2) heats the background plasma and (3) ionizes the background gas to promote fast ion production, which contributes to the positive feedback. On the other hand, high-energy electrons exceeding 2 MeV are observed in the pre-ionized plasma from synchrotron radiation measurements. Since no resonance layer for microwaves of 2.45 GHz is located in the vacuum vessel, stochastic interaction between the microwave electric field and electrons (statistical acceleration) may be the mechanism of energetic electron generation. In Heliotron J, plasma production is usually performed by second harmonic ECH heating at 70 GHz, but in this case, the magnetic field strength must be fixed around 1.25T. The technique using pre-ionization enables NBI discharges at 0.6 T to 1.4 T, which can be combined with novel fueling methods such as pellet injection and high-intense gas puffing to perform operational scenarios for high-beta experiments.