§4. Optimization of Helical System Concept

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The collaboration research between the Heliotron J group and the CHS group has started since this fiscal year, which is aimed at understanding the common confinement physics independent of the device characteristics through joining the plasma experiment mutually and discussing the experimental results. Especially we have been exploring the control of the confinement and transport of helical plasmas by investigating the confinement improved modes [1], which is closely related to the optimization of advanced helical configuration. The collaboration research will continue three years, and the following five themes are chosen; (1) the construction for confinement database, (2) the structure formation accompanying with the confinement transition, (3) ECCD, EBWH and EBCD, (4) the production and confinement of high energy particles and (5) the theoretical analysis of helical configuration optimization. Each group joined the plasma experiment for one week in the first and second term year, and we have been using internet for data analysis. This fiscal year we put emphasis on the themes, ECCD and production and confinement of high energy particles. The results are as follows:

i) Electron Cyclotron Current Drive

The main purpose of the ECCD experiment in CHS is to understand the control of toroidal current and the physics of current drive in helical systems. The dependence of non-inductive EC current on the injection angle and the electron density has been studied experimentally [2]. The 53.2GHz power of 170 kW is injected from the top of the torus. Since the ohmic current does not exist, the toroidal current can be measured accurately compared to tokamaks. The experimental results shows that the toroidal current at the perpendicular injection is less than 0.5 kA, which is mainly the bootstrap current. When the magnetic field is reversed at the perpendicular injection, the direction of the toroidal current changes with keeping the absolute value. On the other hand, the toroidal current changes its flowing direction depending on the injection toroidal angle, while it does not when the magnetic field is reversed. Thus we conclude that the oblique EC injection drives the non-inductive EC current. The maximum current is 6 kA at the low density, $n_e < 0.6\times10^{19} m^{-3}$. No clear change of global confinement due the toroidal current has been observed. Although the flow direction agrees with the linear theory, the absolute value is rather low. The EC current tends to be suppressed with an increase of the electron density. In the future, we will study the off-axis ECCD, B scan and configuration effect in order to study the effect of the helical ripple which produces trapped electrons. The polarization optimization of injection beam and the current drive at the high density (high collisional regime) will also be required. The current drive by electron Bernstein waves is under investigation.

ii) Production and confinement of high energy particles

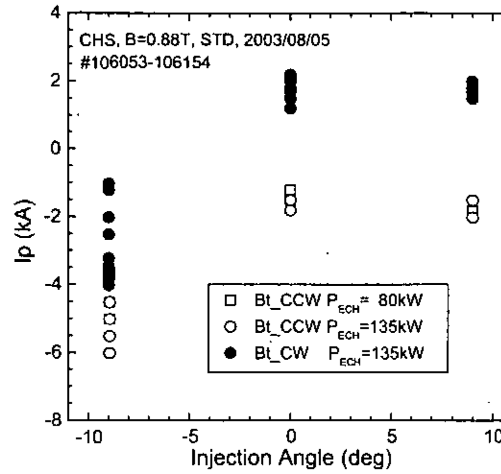

Fig. 1 Dependence of EC driven current on injection angle in CHS.

In Heliotron J ECH plasmas, a high energy tail of more than 6×Ti was observed at low density of $n_e < 1\times10^{19} m^{-3}$ similarly as in the TCV, FT and W7-A devices. The physics of the high energy ion production is not yet clear, although some explanations are proposed such as the mode conversion of EC waves to the lower hybrid waves and the effect of non-isotropic Maxwell profile. We have measured the high energy ions in ECH/ECCD plasmas on the CHS devices, and compared with the experimental results on the Heliotron J device [3]. The high energy ions are observed in ECH plasmas only when the ECCD is applied at the low density. High energy electrons are increased under this condition, which are measured with a photon counting X-ray CCD camera. The magnetic fluctuation of 50-250 kHz is also observed, while such a magnetic fluctuation was not observed in Heliotron J. The modes are n=1 and n=2, whose propagation is in the ion diamagnetic drift direction, opposite to the toroidal magnetic field. The propagating direction is reversed as the magnetic field direction is changed. From these results, it is found that the high energy production in the ECH plasma is common in Heliotron J and CHS, but the production regime is different. The production of the high energy electrons is closely associated with the MHD phenomena and the high energy ion production. On the other hand, the time evolution of neutral particle flux after the NBI turn-off has been measured with a NPA system in Heliotron J. The inner vertical coil current is scanned. The decay time of the neutral particle flux is getting shorter as the magnetic field is changed from the standard configuration to the weak bumpiness one.

References

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3) S. Kobayashi, M. Isobe, et al., JSPF Annual Meeting , 25aA40P, Mito, Nov. 25-28, 2003