9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Observation of runaway electrons with neutron flux monitors in the initial operation phase of JT-60SA

S. Sumida[1], K. Shinohara[2,1], T. Nishitani[3], K. Ogawa[4,5], M. Isobe[4,5], S. Kono[1], M. Ishikawa[1], H. Homma[1], M. Sueoka[1], T. Yokoyama[1], S. Kojima[1], S. Inoue[1], M. Takechi[1], K. Kamiya[1], K. Kobayashi[1] and M. Yoshida[1]
[1]National Institutes for Quantum Science and Technology,
[2]Department of Complexity Science and Engineering, The University of Tokyo,
[3]Graduate School of Engineering, Nagoya University,
[4]National Institute for Fusion Science, National Institutes of Natural Sciences,
[5]Fusion Science Program, The Graduate University for Advanced Studies, SOKENDAI,
e-mail (speaker): sumida.shuhei@qst.go.jp

Local runaway electron (RE) losses are a serious problem in terms of machine protection in tokamak devices because they cause intense heat loads on plasma facing components (PFCs). Understanding of characteristics of the RE loss in a large superconducting tokamak is important to consider avoidance or mitigation methods of the local RE losses. JT-60SA is the largest superconducting tokamak in the world. In the initial operation phase of JT-60SA, safe operation scenarios were developed for the largest tokamak plasma, while many plasma disruptions occurred [1]. Even in ITER and DEMO, disruption could occur before the safe operation scenarios are developed in actual experiments. REs can be generated by the disruptions. In this study, characteristics of RE losses have been investigated in the initial operation phase of JT-60SA for contribution to development of the safe plasma operation scenarios in the initial operation phase of ITER and DEMO.

Gamma-rays are generated as bremsstrahlung when REs collide with PFCs. The gamma-rays produce photoneutrons via nuclear reaction with atoms in in-vessel components. Only hydrogen or helium gases are used for plasma production in the initial operation phase of JT-60SA. Therefore, neutrons are not produced by fusion reaction in the plasma. Thus, in this study, we used neutron flux monitors (NFMs) to indirectly detect RE losses on PFCs via measurement of the photoneutrons. The NFMs are installed at P-10 and P-18 ports (160 degrees apart at a toroidal angle). Its detector part consists of a ^{235}U fission chamber and a polyethylene moderator. Although these NFMs are designed for measurement of fusion neutrons in deuterium plasma, the NFMs are used for detection of neutrons originating from RE losses on PFCs.

There are three types of plasma disruption observed in the initial operation phase of JT-60SA: (i) vertical displacement event (VDE), (ii) radiative disruption and (iii) failure of the plasma equilibrium control scheme [1]. Based on the NFM measurement results, RE losses are found to increase rapidly when plasmas hit on the wall due to VDE or just after a rapid growth of MHD modes associated with disruption. Figure 1 shows a typical discharge of the radiative disruption case. Just after growth of MHD activities with toroidal mode number $|n|$ = 1, neutron counting rates increase rapidly, indicating that RE losses are enhanced by the MHD activity. In the control failure case, REs are also lost significantly by a MHD activity. In the previous study, these MHD activities are considered as tearing modes [1]. In conclusion, the cause of RE losses in the disruption phase are VDEs or tearing modes. Before the disruption, continuous RE losses have been also observed in spite of the low toroidal electric field. The toroidal electric field is limited low because JT-60SA is a large superconducting tokamak. This is also an important observation for future operation in large superconducting tokamaks. Since observational information on RE could be obtained by the NFM in JT-60SA, this fact indicates the potential application of the NFM to RE diagnostics in the non-activation phases of ITER and DEMO.

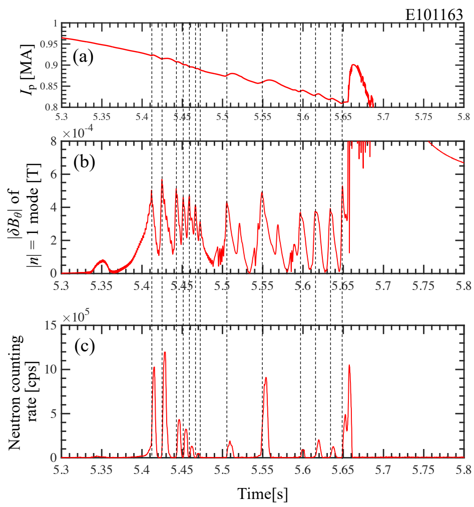

Figure 1. Time evolution of (a) I_p, (b) the magnetic fluctuation amplitude $|\delta B|$ of the toroidal mode number $|n|$ = 1 and (c) the neutron counting rates measured with the NFM at P-18 port in a typical discharge of the radiative disruption case.

References

[1] T. Yokoyama, *et al.*, Nucl. Fusion **64**, 126031 (2024)