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Vision of the Korean fusion energy development program and Role of the KSTAR*

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International thermonuclear Experimental Reactor (ITER) program with the goal of ~0.5 GW fusion power is going to demonstrate the role of α-particle physics and capability of the tritium breeding system. Based on successful validation of these critical physics and technical issues in ITER, a prototype reactor (DEMO) that can produce plasma energy more than ~1GW is envisaged. However, building a DEMO device that would become larger than the ITER may be a challenging engineering task. Then the limited volume of the plasma translates to an increased confined energy density of a stable plasma to make the reactor economical. An alternative mode of operation that can have enhanced energy confinement and improved stability has to be pursued in parallel with the effort in improving the present H-mode operation, along with a simpler control of harmful MHD instabilities.

The Korean Superconducting Tokamak Advanced Research (KSTAR), the first fully superconducting tokamak device, is an integral part of the Korean fusion energy development program which is mandated by law in Korea. During a decade of relentless effort toward a high beta steady state operation since 2008, the KSTAR has explored the tokamak plasma operation regime that has not been accessible before such as a long pulse operation of H-mode up to ~70 s, Internal Transport Barrier (ITB) mode up to ~7s, long sustainment of ELM-crash free operation up to ~10s, etc. In order to support the Korean DEMO (K-DEMO) program, research has focused on developing an operation regime that can exclude harmful instabilities such as the NTM and ELM-crash. This includes an innovative mode of operation with less pedestal height at a low edge safety factor (q_{95}~2.05) so that the number of rational surfaces inside the plasma can be minimized and complex control tools for the ELM-crash and NTM can be avoided.

Notable new exciting physics results have been achieved through the unique capabilities of KSTAR. The KSTAR with the magnetic field alignment close to perfect axisymmetry is equipped with sophisticated In-Vessel Control Coil (IVCC) as a magnetic perturbation tool used to study the neo-classical toroidal viscosity (NTV) physics and to suppress the ELM-crash with the predictive model. The state of the art 2D/3D microwave imaging diagnostics have revealed new and comprehensive physics that were not feasible with the conventional diagnostic tools. This includes measurement of turbulence induced by Resonant Magnetic Perturbation (RMP) responsible for suppression of the ELMs, development of a solitary perturbation for possible mechanism for the ELM-crash and validation of the long disputed q_0 issue in sawtooth physics. The upgrade plan of the KSTAR in ~2021 including new divertor system and current drive system will provide an opportunity to test the integrated steady state operation of the plasmas with the ion temperature well over ~10keV to support the K-DEMO program.

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