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Observation of improved confinement by non-axisymmetric magnetic field driven rotation braking in KSTAR

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Toroidal plasma rotation and rotational shear flow are the key mechanism of the high performance operation regime in the magnetic confinement fusion devices [1, 2]. It has been widely demonstrated that non-axisymmetric (3D) magnetic field has the capability for control of kinetic and magnetohydrodynamic (MHD) plasma properties [3, 4, 5]. In this presentation, we report the observation of improved confinement discharges achieved in the magnetic braking experiment in KSTAR tokamak. The observed improved confinement was achieved with reduced toroidal plasma rotation by 3D magnetic field induced toroidal rotation braking.

A series of experiments has been conducted for control of toroidal plasma rotation utilizing 3D magnetic field and electron cyclotron heating (ECH). Plasma parameters are in the range of B_T =1.6 T - 1.8 T, I_P = 500 kA – 700 kA, and q_{95} = 3.7 - 5.4. Neutral beam heating of 4 MW is injected using 3 beam sources, supplying strong toroidal torque to generate fast rotating plasmas in the H-mode confinement. The n = 1 3D magnetic field and ECH are applied to reduce the rotation and modify the rotational shear. In those discharges, as shown in Fig. 1, toroidal rotation is significantly reduced along with density-pump out by 3D magnetic braking. Mitigation of the ELMs are also observed. Total stored energy is increased by up to 15 – 20 % in spite of density decreases. Neutron rate shows fast ion confinement is improved during the 3D field period.

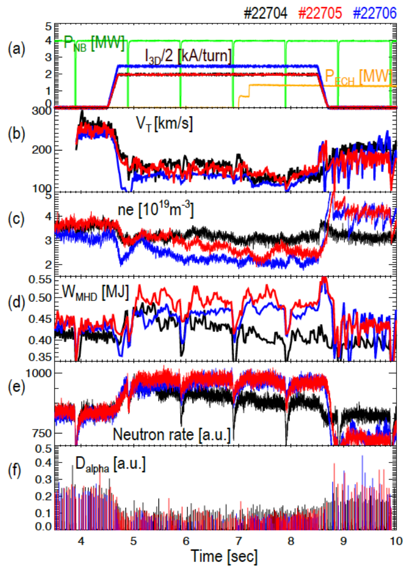

Figure 1. History of improved confinement discharges.

Detailed transport process is presented in Fig. 2. It is shown that kinetic plasma responses such as density pump-out, rotation reduction, and increase of the stored energy are not promptly initiated by the 3D field application but occur in a particular sequence. First, the rotation begins to drop a bit slowly after turning-on of the 3D field coils, which occurs almost simultaneously in the whole plasma volume. The rotation shear build-up begins slightly after the rotation reduction. The plasma density is pumped out by the 3D field when the 3D field coil currents reach the near-maximum. The neutron rates slowly begin to rise around the beginning of 3D field flat-top, which coincides with the density decrease. When the rotation reaches the near-minimum level, the ion temperature is raised relatively slowly, and finally the stored energy begins to increase at the time near minimum density.

Measurement of turbulent fluctuation by ECEI and gyrokinetic analysis consistently indicate that turbulent transport is reduced in the improved confinement phase. The observed sequential process and transport analysis suggest that the rotation reduction by the 3D magnetic field and associated transport modification is the main mechanism of the improved plasma confinement.

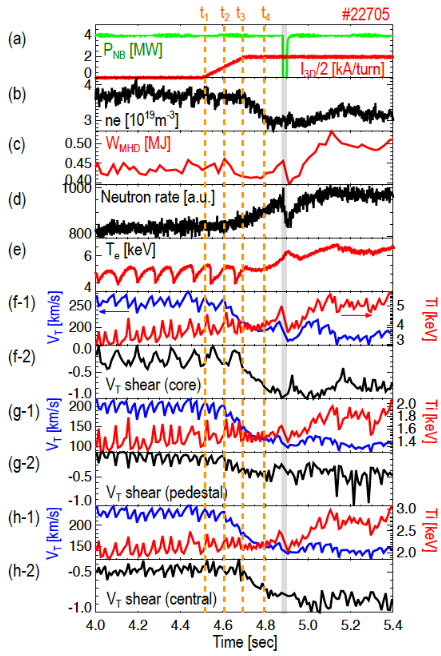

Figure 2. Detailed evolution of kinetic properties.

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