Zonal field generation in ELMy H-mode discharges

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While pedestal plasma density, temperature and flow profiles have been extensively studied, the behavior of the edge current is less well known. MAST MSE measurements show that toroidal current j_ϕ is not affected by the occurrence of a type-I ELM. The DIII-D LIBEAM diagnostics indicate a rapid decay of the edge toroidal current J_ϕ within ~5% of the ELM cycle and a slow recovery/increase of current throughout the remainder of the cycle.

In this work, nonlinear simulations of plasma edge pedestal collapse in the tokamak configuration are carried out in the BOUT++ two-fluid framework, which allows studies of nonlinear dynamics of ELMs with extensions beyond ideal MHD physics. It is found from simulations that the peeling-ballooning modes trigger magnetic reconnection, which drives the collapse of the pedestal pressure. When heating source and bootstrap current added, simulations show that pedestal pressure collapses and recoveries. Consistent with the picture of the rapid magnetic flux change driven current, strong edge currents are observed after an ELM event, as can be seen from Fig. 1 showing the comparison between $J_{||}$ calculated from Ampere's law due to zonal magnetic field as shown in Fig.2 and J_b based on the neoclassical calculation of the bootstrap current. It is clear that the neoclassical calculation predicts less edge current than the total current calculated from Ampere's law. The peak of total radial current profile is shifted inward relative to that of bootstrap current J_b. The current diffusion time after an ELM event can be estimated using a cylindrical geometry with a shell current model of thickness Δ_J: $\tau_{L/R} \approx 2.39\times10^{-6} a^2 T_e^{3/2} (\Delta_J (r_w - a)/a^2)/\ln\Lambda$. For $\Delta_J/a \sim 2\%$, $(r_w-a)/a \sim 20\%$, $\tau_{L/R}^{ITER} \approx 5.8$s with Te=4.5keV, and $\tau_{L/R}^{DIII\text{-}D} \approx 74$ms-0.707s depending on pedestal T_e.

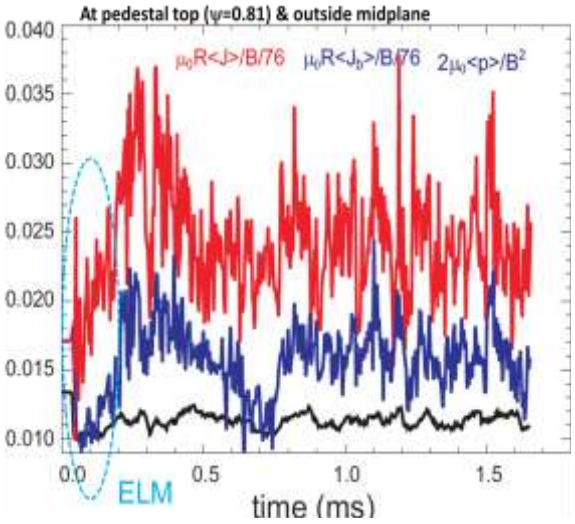

Fig.1 Time history of pressure p, bootstrap current J_b, and total parallel current $J_{||}$ during an ELM event.

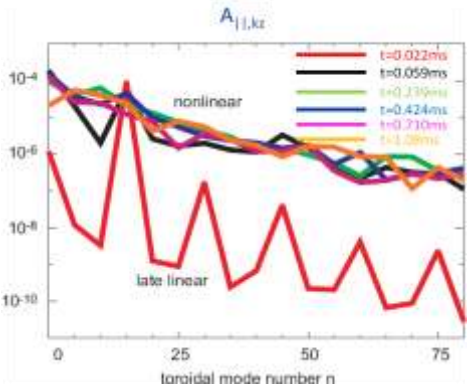

Fig.2 Spectrum of $A_{||}$ vs mode number n

The theory of zonal magentic field generation due to an ELM event can be validated by measuring pedestal toroidal/parallel current profiles of H-modes using Li-BEAM and MSE, which will test the pedestal inductive current model vs neoclassical bootstrap current model.

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