OVERVIEW OF ERROR FIELD SCALING STUDIES IN EAST AND IMPLICATIONS FOR ITER

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Error field is a potential threat for future fusion reactors. The error field source is mainly from poloidal field/toroidal field coils misalignment, coil feeds, MHD instabilities, etc. The estimated error field in future reactors is very small, about $br/B_T \sim 10^{-5}$. In spite of this, it may result in locked mode, degradating the plasma confinement and even leading to disruption. Therefore, it has been one of the high priorities in MHD topical group. One of the main aims is to extrapolate the error field tolerance for future reactors using solid scalings obtained from theoretical analysis as well as experimental results. However, the empirical scalings from different devices can derive large difference when extrapolating to future reactors. By the same time, the proposed theories seldom can answer the difference among different devices. To clarify these doubts, we carried out a series of investigations in EAST and gave some answers for the doubts between theory and experiment [1-5].

The primary concern is the large difference on density scaling of error field penetration between theory and experiment. We first tried to clarify the difference of density scaling between theory and experiment [5, 6]. It was concluded that there is no density dependence in classical error field penetration theory [7], whereas there is strong density dependence in experimental observations. From theoretical analysis, we noticed that viscosity diffusion time (~momentum confinement time ~ energy confinement time) is crucial for density scaling of error field penetration. However, there is no direct evidence given in experiment. To clarify this doubt, we carried out two groups of experiments in ohmically heated plasmas in EAST [5]. It is shown that the error field penetration lies in saturated ohmic confinement (SOC) region (Fig. 1), therefore there is density dependence for error field penetration threshold. On the other aspect, when error field penetration lies in linear ohmic confinement (LOC) region, then there is nearly no density dependence for error field penetration threshold. Good agreement has been derived by detailed analysis considering the relevant parameter scalings which have also changed with the density scanning. This analysis was verified by experiments in KSTAR and DIII-D, as well as by TM1 simulation in DIII-D [8]. Further verification was extended to lower hybrid wave heated plasmas in EAST [3]. Moreover, good agreement between theoretical analysis and experiment has been obtained in toroidal field and q_{95} scalings in EAST [4].

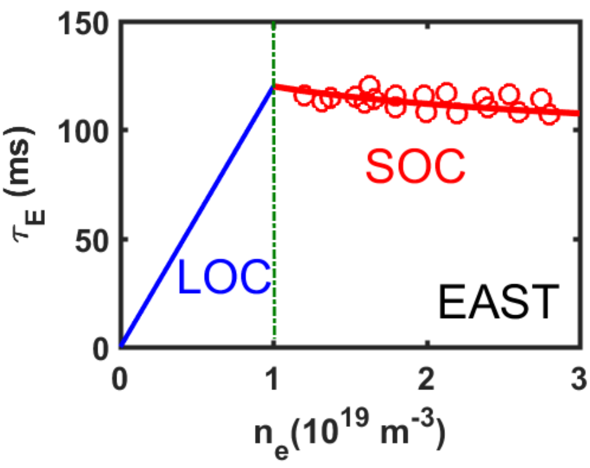

Fig 1. *Energy confinement time of error field penetration in ohmically heated plasmas in EAST.*

To further make clear the scalings of error field penetration in higher parameters. The auxiliary heating power scan is carried out in EAST [1, 2]. To clarify the contribution of plasma beta in error field penetration, purely radio-frequency (RF) wave heated discharges were carried out in EAST. The experimental results show that the dependence of the threshold RMP coil current for field penetration, on the total absorbed power P tot scales as approximately , indicating that the error-field tolerance is improved with increasing RF power. This is benefited by the increased electron perpendicular flow dominated by a counter-current electron diamagnetic flow with increasing RF power. However, theoretical scaling in cylindrical geometry overestimates the power index. Assuming an additional term for the normalized beta in the scaling, it is shown that the fitted from the experimental observation is around −1, indicating a degradation effect of plasma beta. To clarify the underlying physics of the plasma-beta effect that was not included in the theoretical scaling in cylindrical geometry, the MARS-Q code with full toroidal geometry is employed for simulation of nonlinear field penetration. The MARS-Q simulation results reproduce the dependence well, and hence the P tot scaling of the threshold current in experimental observations. The main reason for this is that the net total torque, which is mainly contributed by the neoclassical toroidal viscosity (NTV), increases with increasing plasma. The results demonstrate that the nonlinear toroidal coupling effect via NTV torque plays an important role in determining field penetration, even in cases with relatively low , which is far less than the no-wall beta limit. Furthermore, the rotation effect on error field penetration in EAST under low neutral beam injection torque in the co-current direction (Co-NBI) and counter-current direction (Ctr-NBI) has been investigated with similar technique [1]. We further give some implications for ITER.

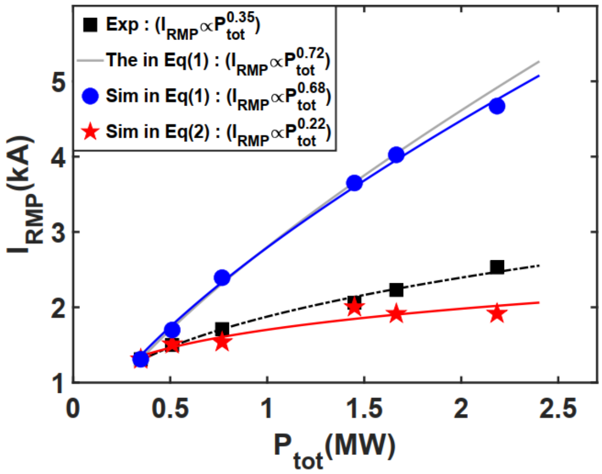

Fig 2. *Comparisons among experiment, theory and simulation in power scan of error field penetration experiment in EAST.*

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