PARTICLE TRANSPORT OF OHMIC DISCHARGES WITH DIFFERENT PLASMA CURRENT IN EAST TOKAMAK

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Whether for L-mode or H-mode, the energy confinement time is directly proportional to the plasma current. For ohmic discharges, the higher the current, the better the heating effect, resulting in higher plasma temperature and improved energy confinement. However, the study of particle transport is more complex due to the uncertainties associated with particle sources. This paper utilizes density modulation methods to investigate the effects of different current levels on particle diffusion and convective velocity under ohmic discharge conditions. The choice of ohmic discharge is made to avoid the limitations imposed by auxiliary heating and to neglect the core particle source.

This study investigates the underlying mechanisms of current-dependent particle transport in ohmic plasmas through density modulation experiments [1] conducted on the EAST tokamak. Under carefully controlled conditions (fixed line-averaged density $\bar{n}_e \approx 2.0\times10^{19}$ m^{-3}; toroidal field B_t = 2.2 T, and identical magnetic configuration), three distinct plasma current levels (I_p = 300 kA, 400 kA, 500 kA) were systematically compared. Experimental results reveal that higher plasma currents lead to elevated electron temperatures (T_e increases by ~25% at ρ=0) and improved global energy confinement, despite nearly identical density profiles across all cases. To resolve the paradoxical observation of similar density gradients with varying transport coefficients, a novel methodology combining experimental analysis and multi-scale simulations was developed. The BOUT++ framework was employed to model particle sources localized at ρ~0.9, aligning with the modulation phase minimum. Through Genetic Algorithm-based transport coefficient analysis [2,3], it was found that both diffusion coefficient D and inward convection velocity V decrease significantly with increasing I_p (e.g., D reduced by ~60% at I_p = 500 kA compared to 300 kA), as shown in Fig. 1. The derived transport coefficients exceed neoclassical predictions by 1-2 orders of magnitude, unequivocally demonstrating turbulence-dominated transport dynamics. Further GS2 gyrokinetic simulations identify ion-temperature-gradient (ITG) modes as the primary turbulence driver, with linear growth rates inversely correlated to plasma current, shown in Fig. 2. This current-induced suppression of ITG instability provides a unified explanation for the observed reduction in transport coefficients and enhanced confinement at higher I_p.

Systematic density modulation experiments on EAST tokamak reveal that increasing plasma current significantly reduces particle transport coefficients while maintaining identical density profiles. The study advances fusion plasma physics by establishing a quantitative link between plasma current, turbulent transport, and global confinement. Its integrated approach—combining precision experiments, advanced diagnostics (DBS, BES), and multi-scale simulations (BOUT++, GS2)—sets a new standard for transport analysis. The results are particularly impactful for ITER and CFETR, validating ITG-dominated transport models in low-q scenarios and demonstrating plasma current as a key actuator for turbulence control.

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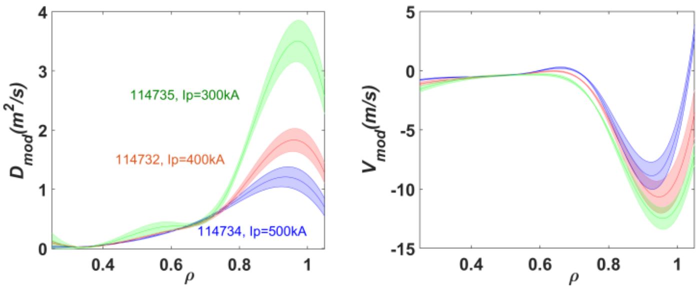

Fig. 1. Diffusion coefficients and convective velocity of different plasma current from density modulation experiments.

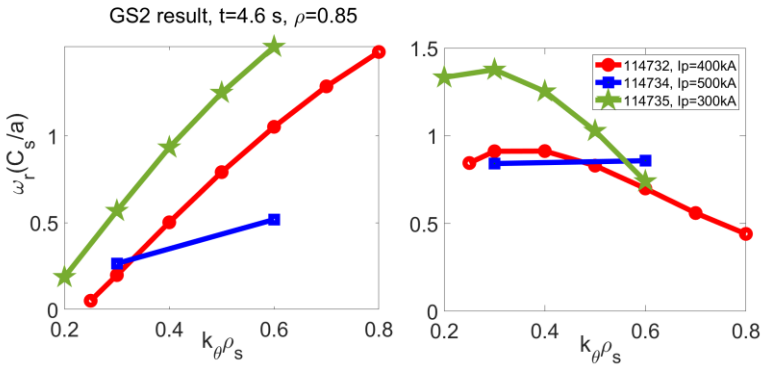

Fig.2. Results of turbulence simulation using GS2 code.

REFERENCES

[1] K.W. Gentle *et al*, Determination of particle transport coefficients in ASDEX by gas modulation, **32** 217, *Nucl. Fusion* (1992)

[2] Yoshiaki Ohtani *et al*, Particle transport of electron cyclotron resonant heating plasma in Large Helical Device, **62** 025029, *Plasma Phys. Control. Fusion* (2020)

[3] K Tanaka *et al*, Extended investigations of isotope effects on ECRH plasma in LHD, **62** 024006, *Plasma Phys. Control. Fusion* (2020)