Evolution of the electric potential and turbulence in OH and ECRH low-density plasmas at the T-10 tokamak

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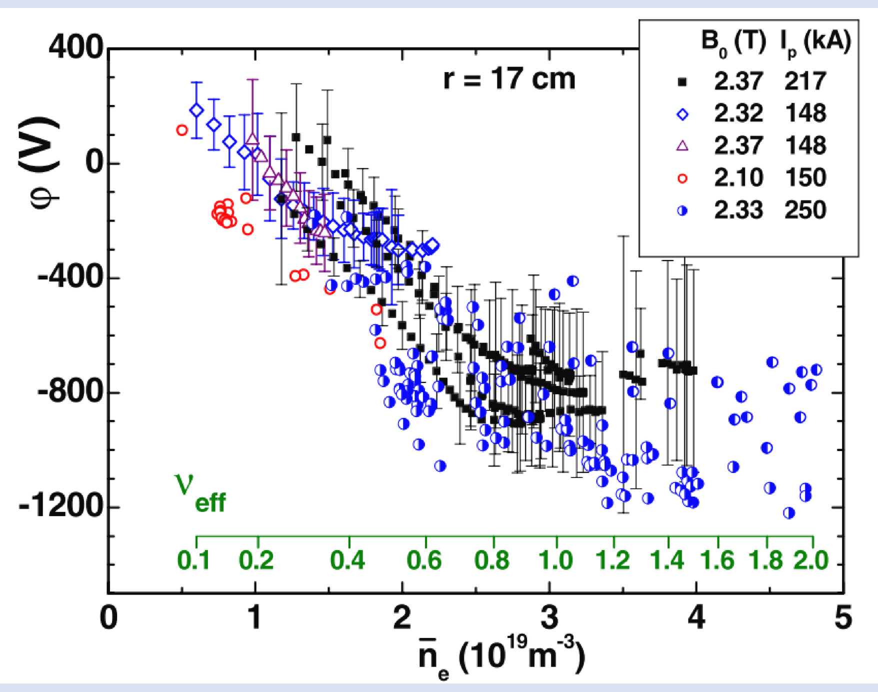
ABSTRACT

- Plasma regime with a positive core electric potential (positive electric field) was obtained for the first time in a tokamak. This low-collisionality regime was reached by strong electron-cyclotron resonance heating (P_{EC} = 2.2 MW) of the low-density ($\bar{n}_e \approx 1.0 \cdot 10^{19}$ m^{-3}) plasmas in the T-10 circular tokamak (B_0=2.2 T, R=1.5 m, a=0.3 m, I_{pl} = 230 kA).
- The obtained positive electric field is not consistent with NC approach and suggests turbulence origins. The coupling of plasma potential and collisionality was extended towards the 'banana' collisional regime predicted for ITER, so the positive plasma potential is expected for ITER

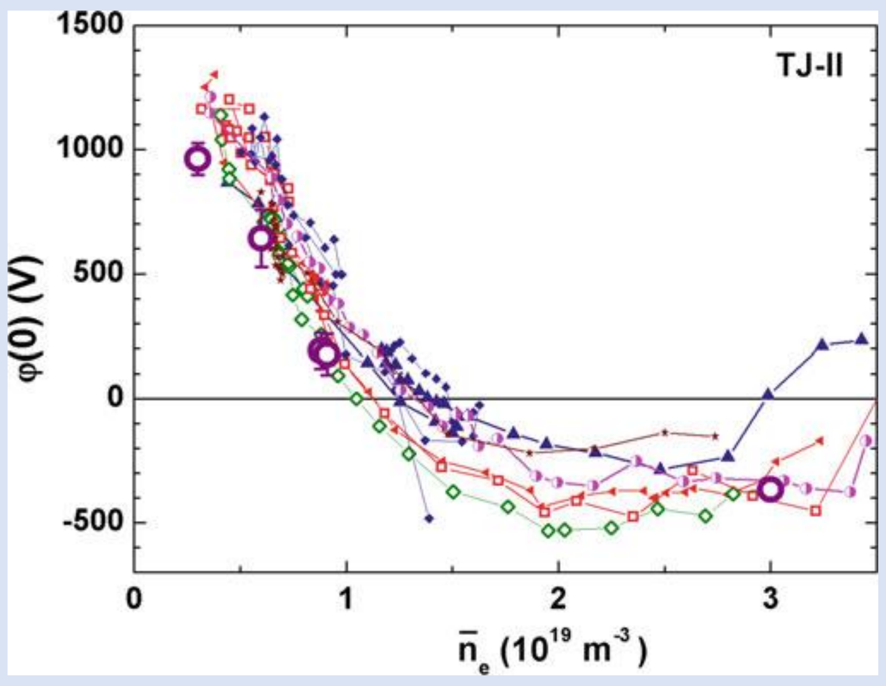
BACKGROUND

Experiments show the link of plasma potential to plasma effective collisionality, $\nu_{eff} \propto n_e/T_e^2$: the higher is the collisionality, the lower is plasma potential, or the stronger is the negative radial electric field. In stellarators the similar tendency also takes place: the higher density (collisionality) plasmas are characterized by stronger negative plasma potential. On top of that, in low-density (collisionality) stellarator plasmas the core plasma potential has a positive sign, which have never been observed in a tokamak.

T-10 tokamak



TJ-II stellarator

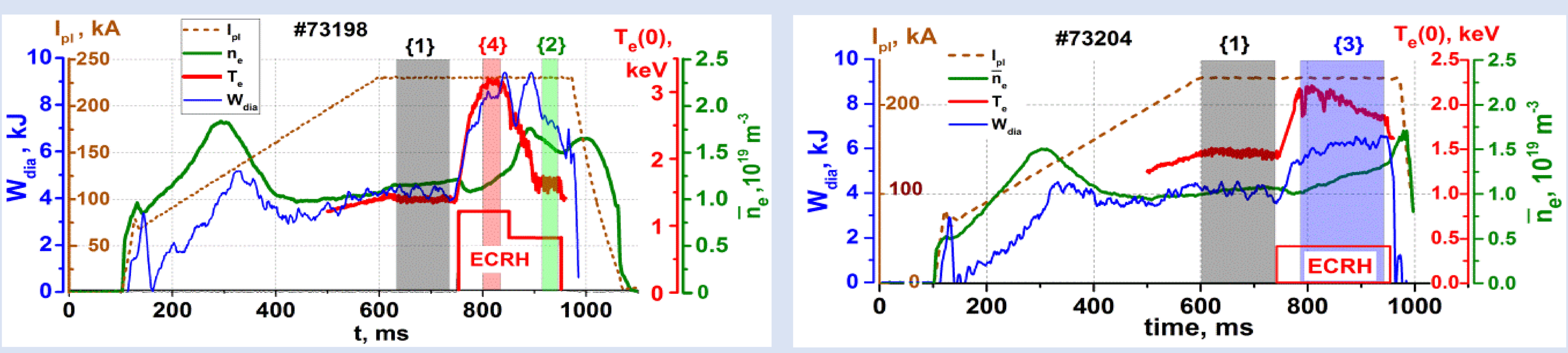


EXPERIMENTAL RESULTS

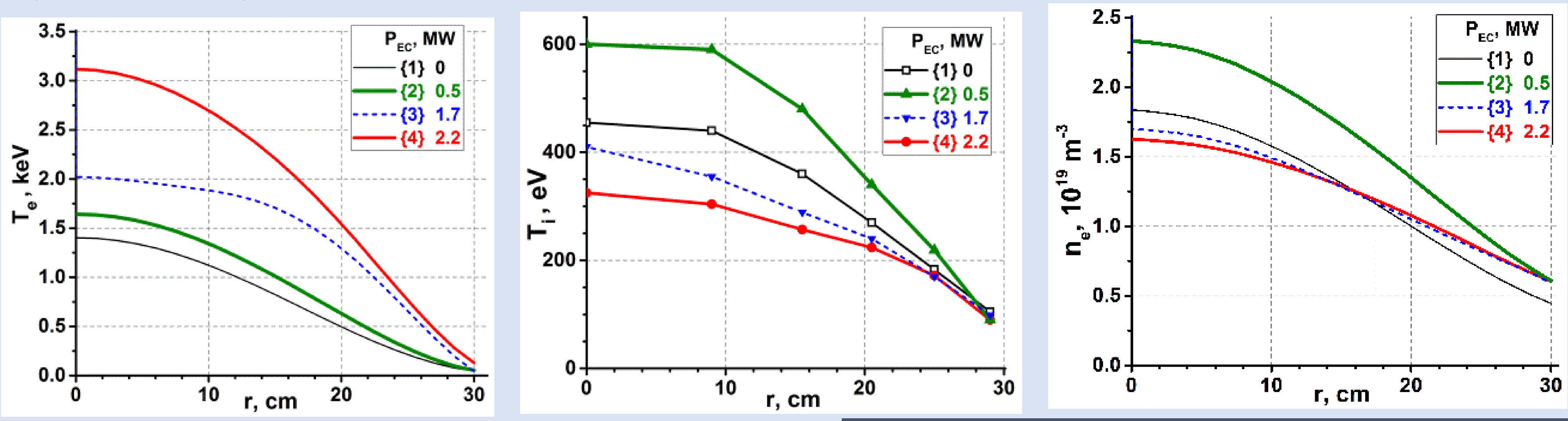
The discharges under study (B_{tor} = 2.2 T, I_{pl} = 230 kA) contained up to four stages, differing in the level of ECRH power P_{EC} and localization of the EC-resonance zone in the plasma:

{1} – ohmic discharge, OH;
{2} – on-axis EC-heating (0.5 MW), gyrotron B;
{3} – off-axis EC heating (1.7 MW), gyrotrons A+C;
{4} – combined EC heating (2.2 MW), gyrotrons A+B+C.

Time evolution of current I_{pl}, line averaged density $\bar{n}_e$, central electron temperature $T_e(0)$ and stored energy W_{dia} in discharge with powerful combined ECRH. Scenario with P_{EC} = 0.5 MW, 2.2 MW (left), scenario with P_{EC} = 1.7 MW (right).



T_e , T_i and n_e profiles as measured by 2-ω ECE-, CXRS and interferometer.

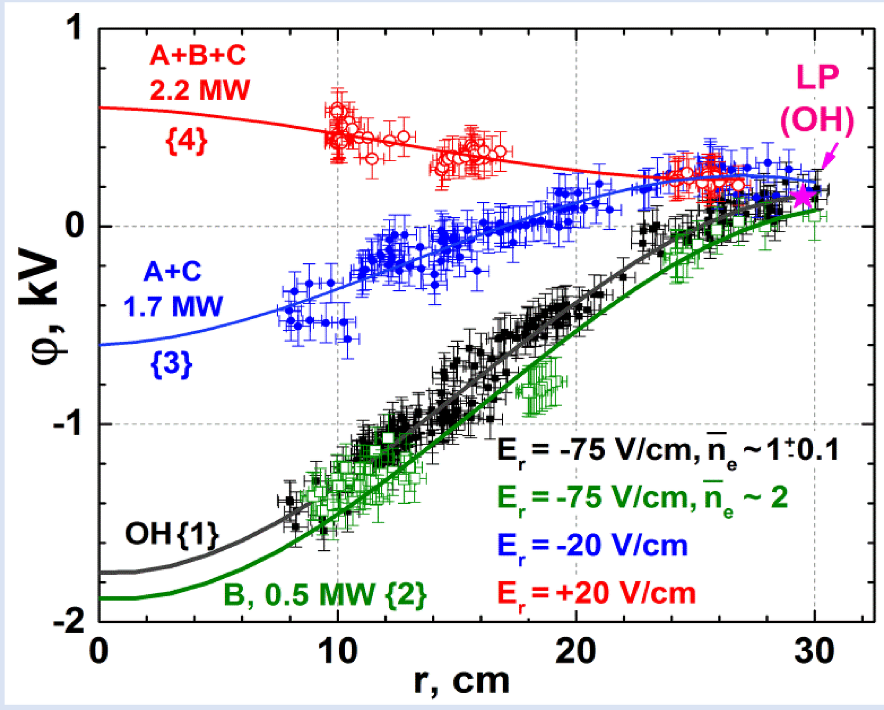


OUTCOME

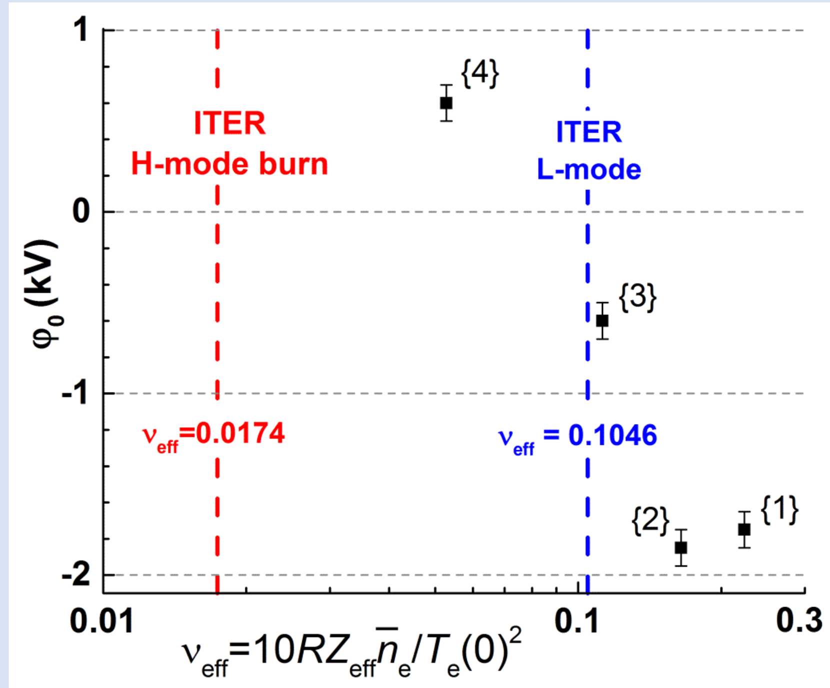
Obtaining the positive potential in a tokamak fills the existed gap and completes the general observations: the higher is the plasma collisionality, the higher is the negative potential in toroidal plasmas; the lower is the plasma collisionality, the higher is the positive potential in toroidal plasmas. Therefore, the obtained low-collisionality regime with positive potential in the core plasmas allows us to predict the positive plasma potential in the future fusion reactor like ITER.

Neoclassical theory is invalid for positive Er explanation, while the turbulence may give the positive contribution to the electric field E_{turb}

Profiles of potential in the Ohmic phase (OH) D plasma $\bar{n}_e$=1.0×10^{19} m^{-3},T_e < 1.3 keV, T_i < 0.6 keV) and with switch on various groups of gyrotrons A, B and C, T_e < 3.2 keV.

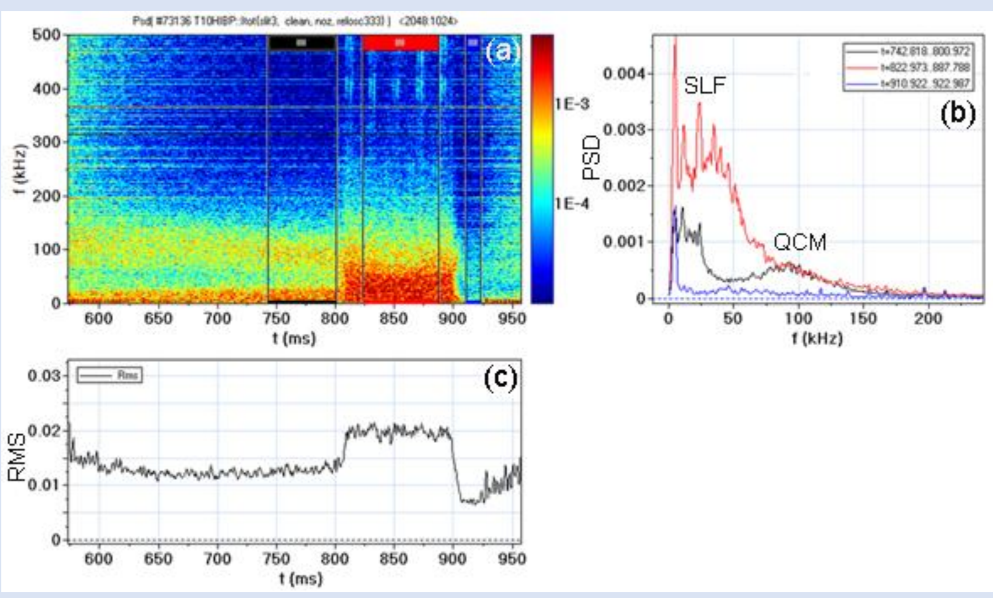


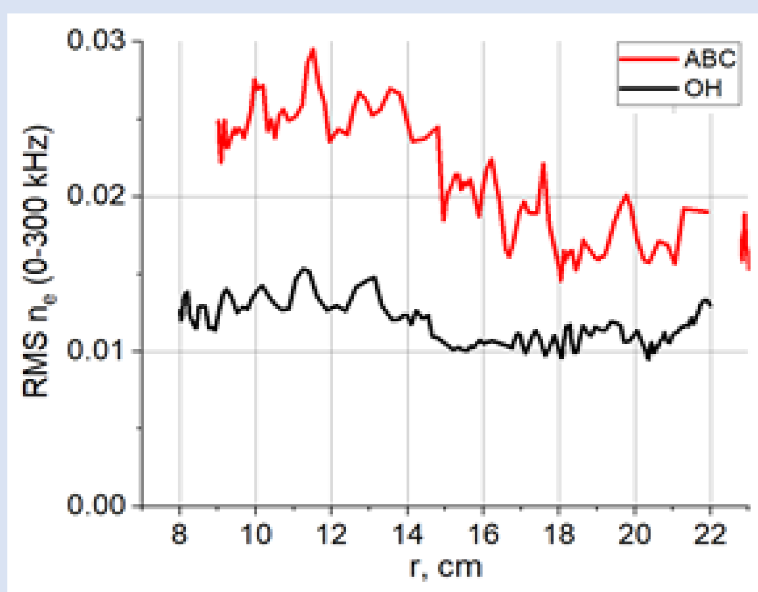
The potential vs collisionality in T-10 plasmas with OH and ECRH, and estimations for ITER.

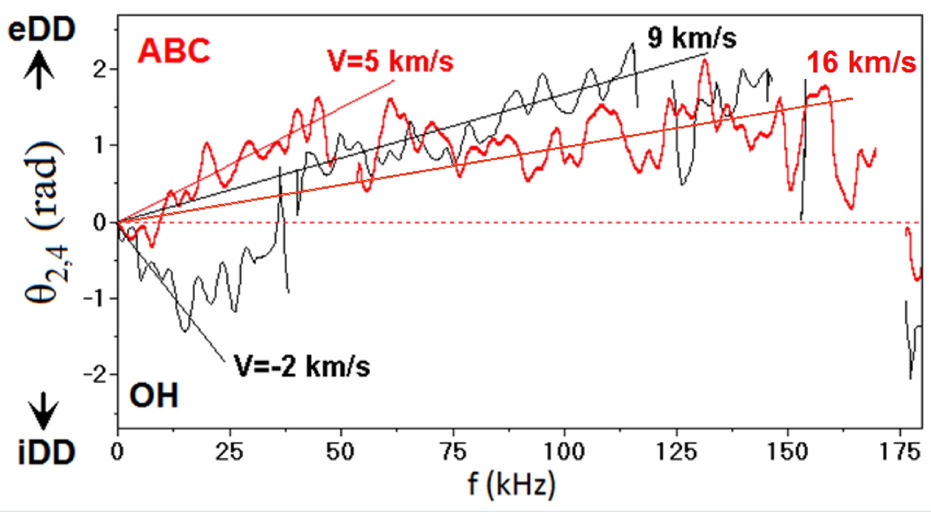


Plasma density turbulence evolution in the shot #73136 with scenarios {1, 3}, P_{EC} < 1.7 MW. (a) Power spectrogram of the density fluctuations, (b) power spectra in OH (blue and black) and ECRH (red) phases of the discharge, (c) time trace of the density RMS; r_{HIBP}=0.12 m.

The RMS of the core plasma density fluctuations increases up to a factor 2 of in the core area for P_{EC} =1.7 MW (right figure).







The cross-phase of density fluctuations vs frequency for OH (black curve) and ABC (red curve) stages of the shot with changes of the potential sign #73197; B_t = 2.2 T, I_{pl} = 230 kA, E_b = 320 keV, r_{HIBP} = 0.09-0.11 m.

CONCLUSION

- The first observation of the positive electric potential φ = +500 V near the center and a positive electric field E_r ≈ +20 V/cm in a core tokamak plasma was done. This observation is consistent not with NC expectations, rather with turbulence effects, that is supported by an increase of the electrostatic fluctuations with powerful ECRH.
- The coupling of core plasma potential and collisionality was experimentally established in a wide range of plasma parameters. Based on that, the positive plasma potential for ITER collisionless plasmas is predicted.

ACKNOWLEDGEMENTS / REFERENCES

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