Observation of plasma performance Improvement by edge ECCD power deposition on Experimental Advanced Superconducting Tokamak

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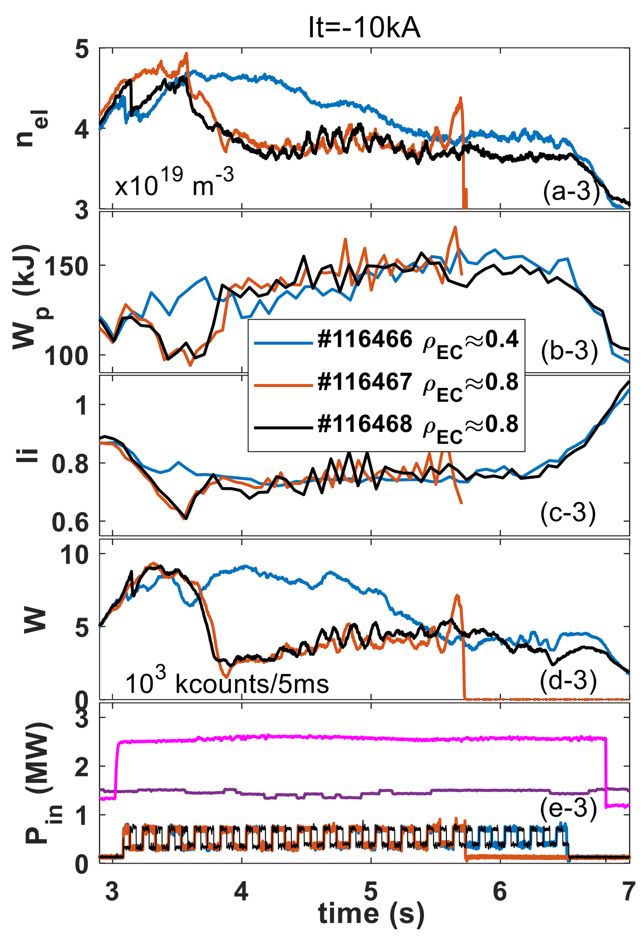
Outlook

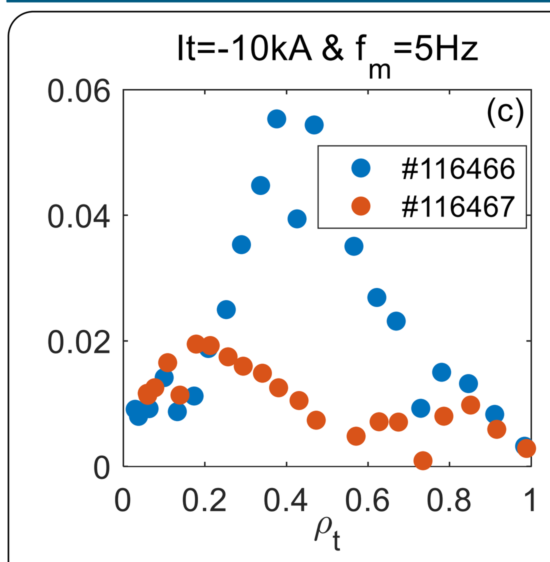
- ECRH heating system plays a dominant role in ITER and future fusion devices;
- Higher toroidal magnetic field devices requires larger ECRH gyrotron frequency, which would be much more expensive;
- Edge ECRH deposition experiments in AUG, TCV, DIII-D were observed to reduce the plasma performance;
- In EAST, we found ECCD edge power deposition improve plasma performance and reduce tungsten central accumulation;

Edge ECCD deposition experiment: experimental setup

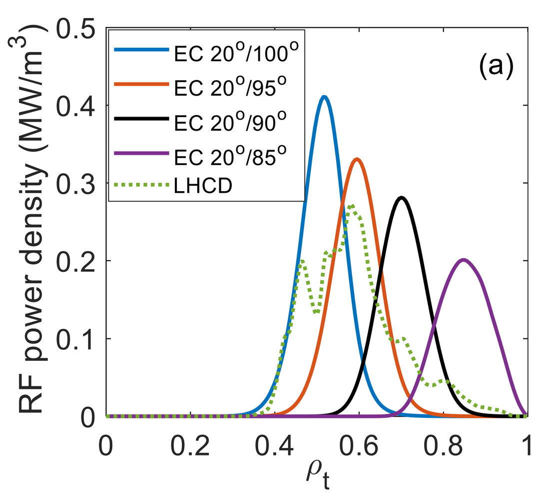
- Key Parameters:
  - Plasma current: 500 kA; Bt=-2.2T
  - LHCD power: 1.5 MW
  - NBI source power: 2.6 MW
  - ECCD power: 0.6 MW (modulated)
  - ECCD toroidal angle: 20°
  - Varying ECCD deposition location by adjusting mirror poloidal angle and Bt
  - Internal induction gradually decreased after ECCD injection;
  - plasma stored energy significantly enhanced
  - tungsten impurity reduced to a lower level



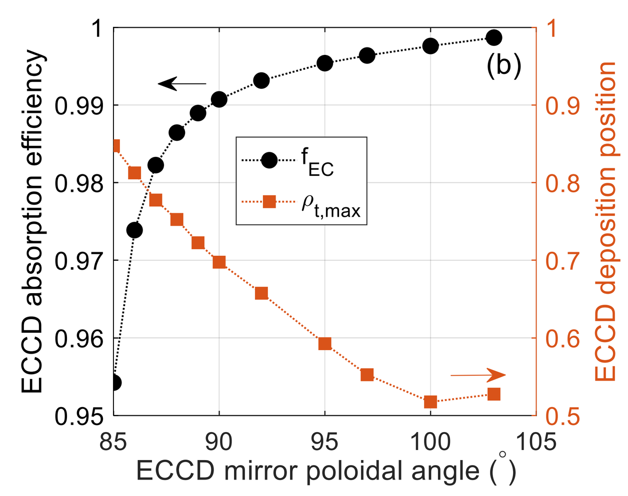
ECCD deposition position



ECE measurement



LHCD deposition: GENRAY
ECCD deposition: TORAY

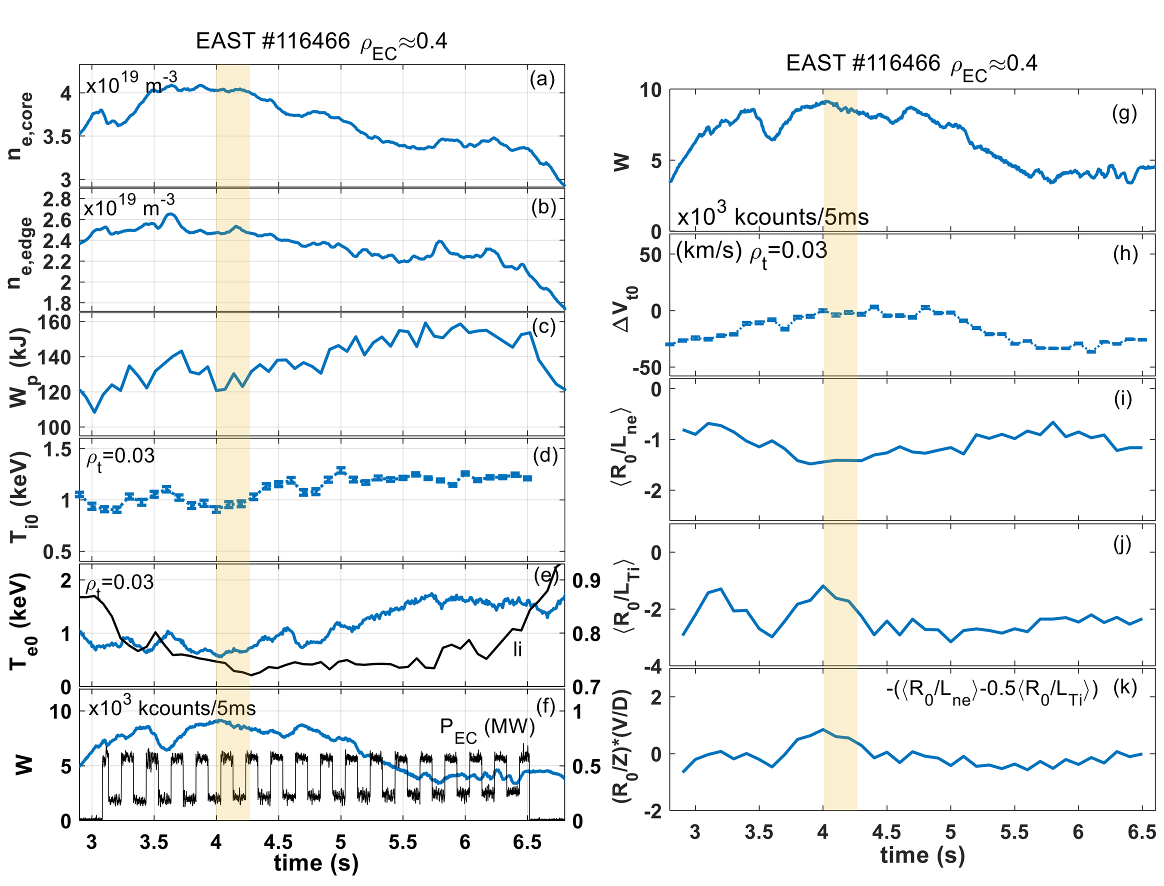


ECCD mirror angle scan

Increase of core Te and Ti prior to decrease of ne

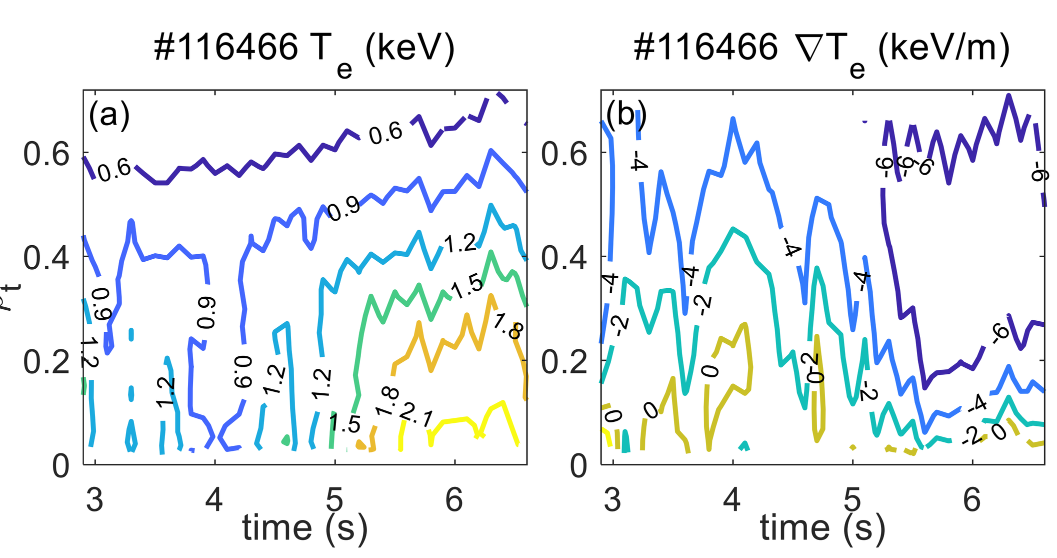
- Increase of core T_e, T_i, Wp is prior to decrease of n_e;
- Increase of T_i gradient results in a decrease of W;
- The slightly laggy decrease of ne contributes strongly to the improved plasma confinement;
- Decrease of W content strongly related to increase of $\langle R_0/L_{Ti}\rangle$ and decrease of $\langle R_0/L_{ne}\rangle$;

- $\frac{1}{n_Z}\frac{dn_Z}{dr} \approx \frac{V_{Z,neo}}{D_{Z,neo}}\frac{D_{Z,neo}}{D_{Z,neo}+D_{Z,tur}}$
- $\frac{R_0 V_{Z,neo}}{D_{Z,neo}} = -Z\left(\left\langle\frac{R_0}{L_n}\right\rangle - 0.5\left\langle\frac{R_0}{L_{Ti}}\right\rangle\right)$



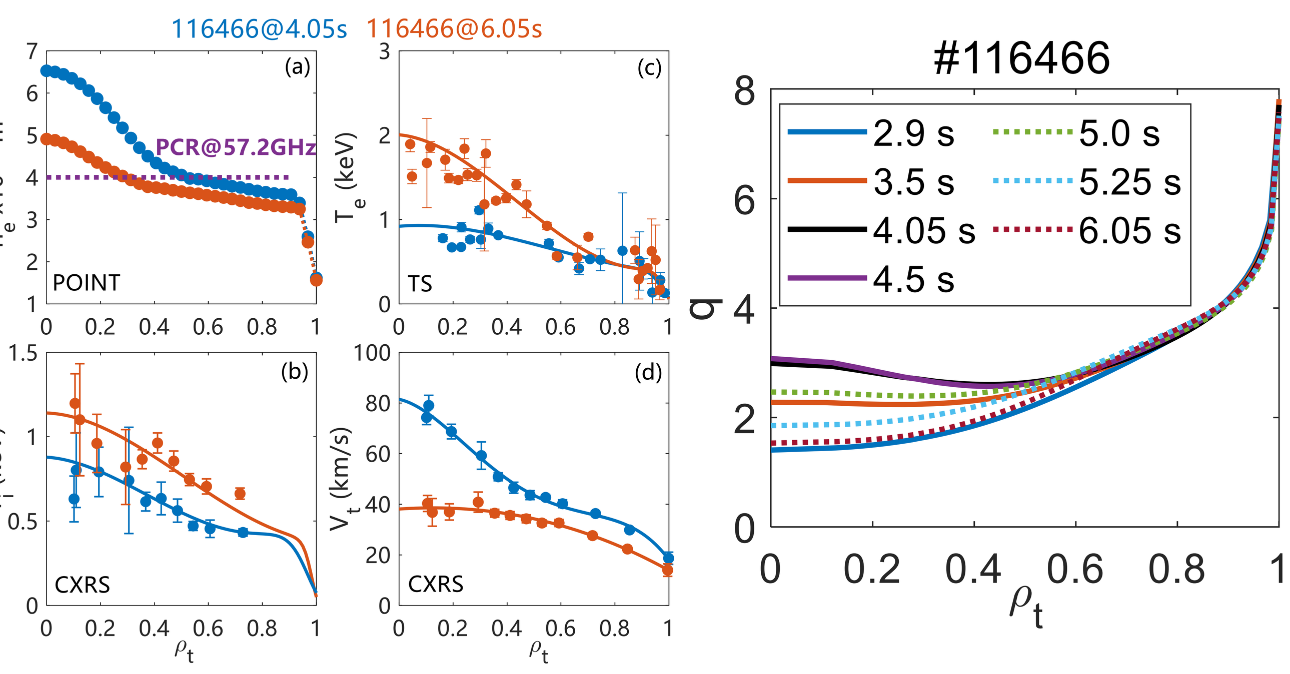
Enhancement of Te gradient propagate from edge to core

- During improved phase, both T_e and its gradient substantially enhanced.
- Core T_e nearly double in improved confinement stage
- Maximum T_e gradient near $\rho_t\sim0.4$ close to ECCD power deposition location



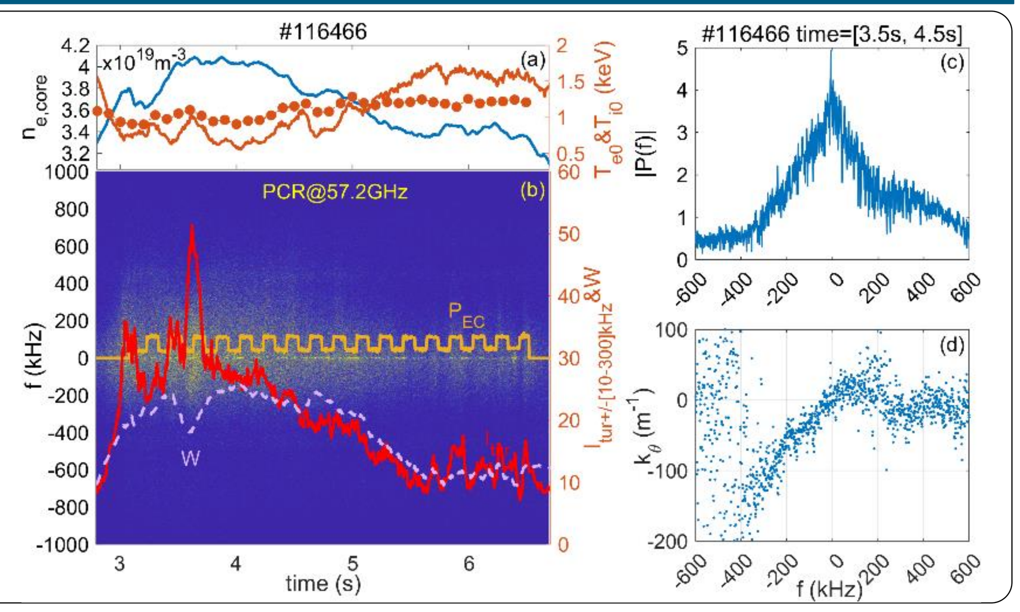
Evolution of plasma profiles

- Edge ECCD power deposition:
  - Flatter plasma density profile;
  - Higher ion and electron temperature;
  - Smaller toroidal rotation;



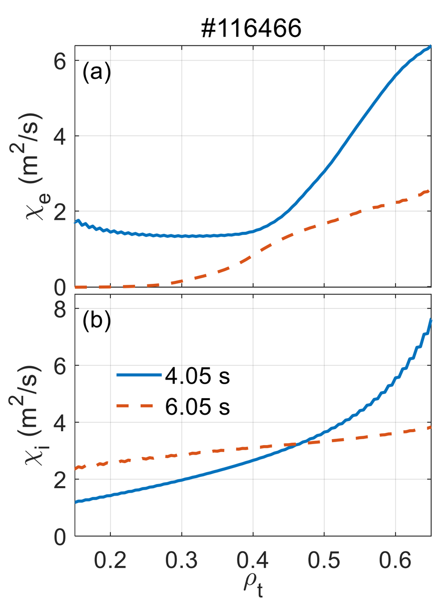
Measurement of turbulence evolution

- Turbulence position: $\rho_t\sim0.3–0.5$
- Turbulence characteristic:
  - propagating in the ion diamagnetic direction
  - Electrostatic
  - peaked near zero frequency

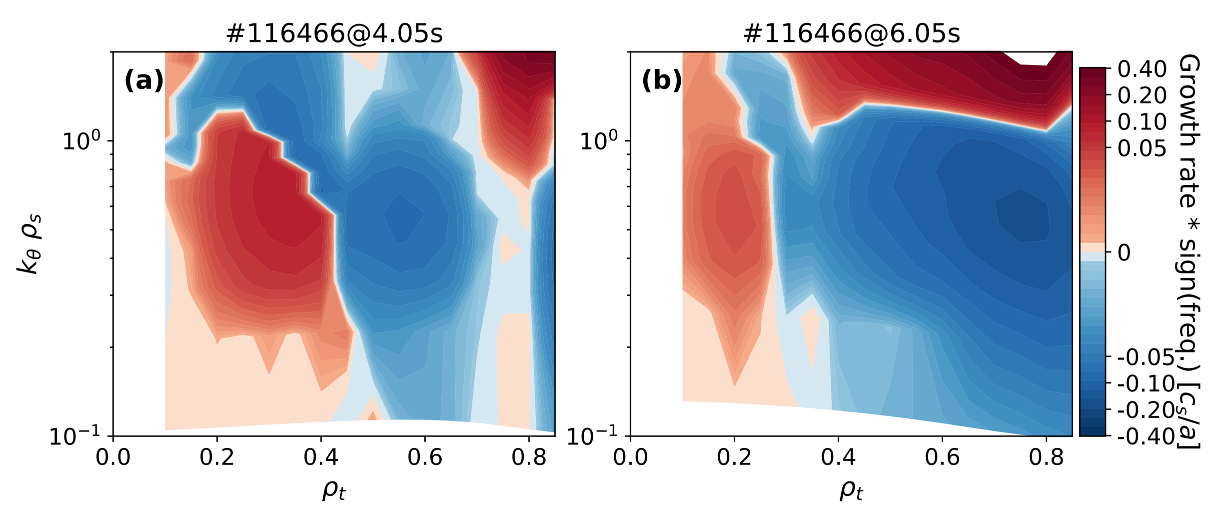


Theoretical simulation

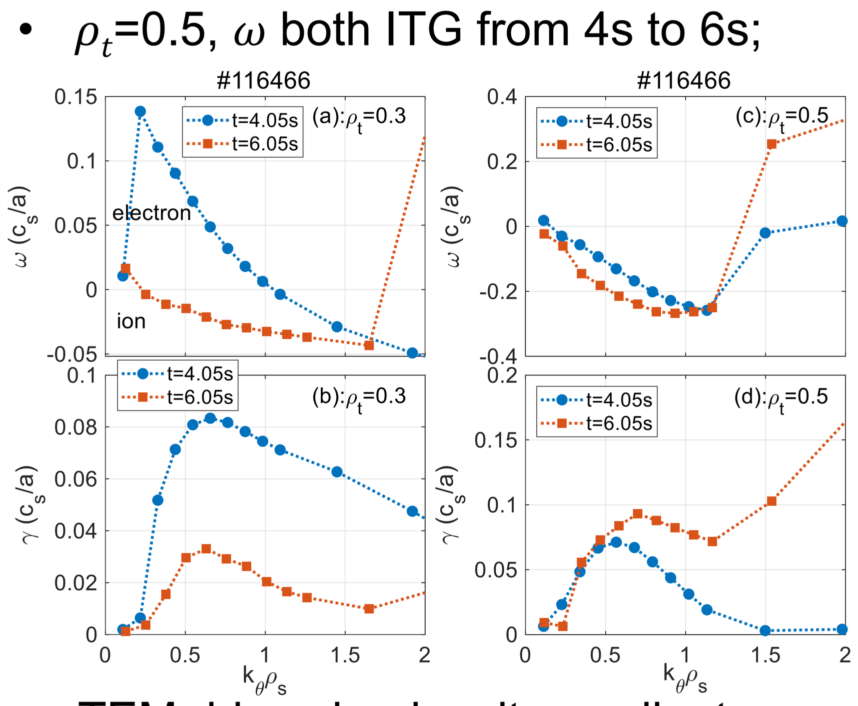
- thermal diffusivity by ONETWO



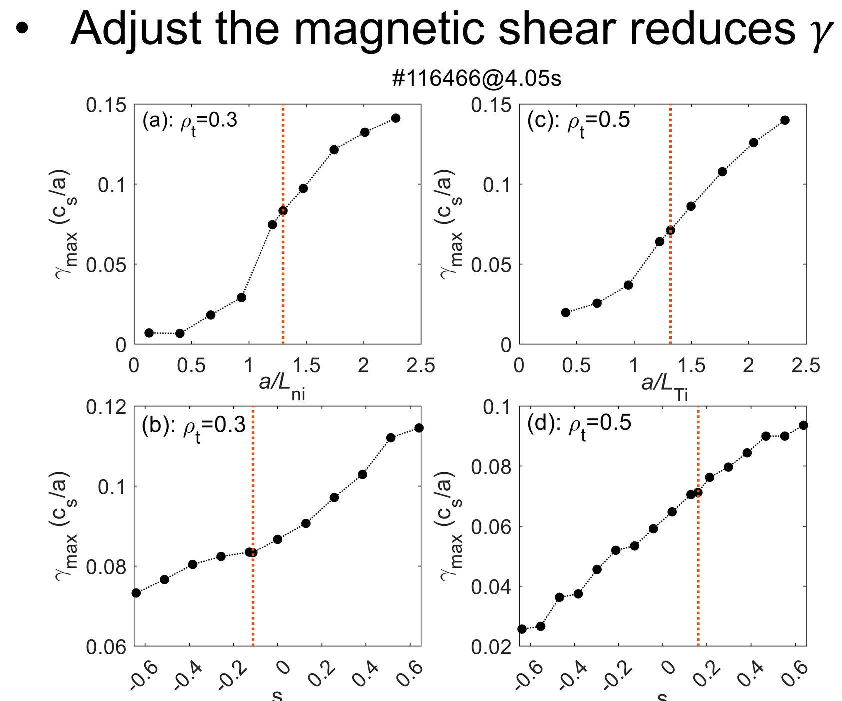
- turbulence characteristic by TGLF-SAT1
- TEM in the core region (ρ_t<0.45)
- ITG in the edge region (0.45<ρ_t<0.7)



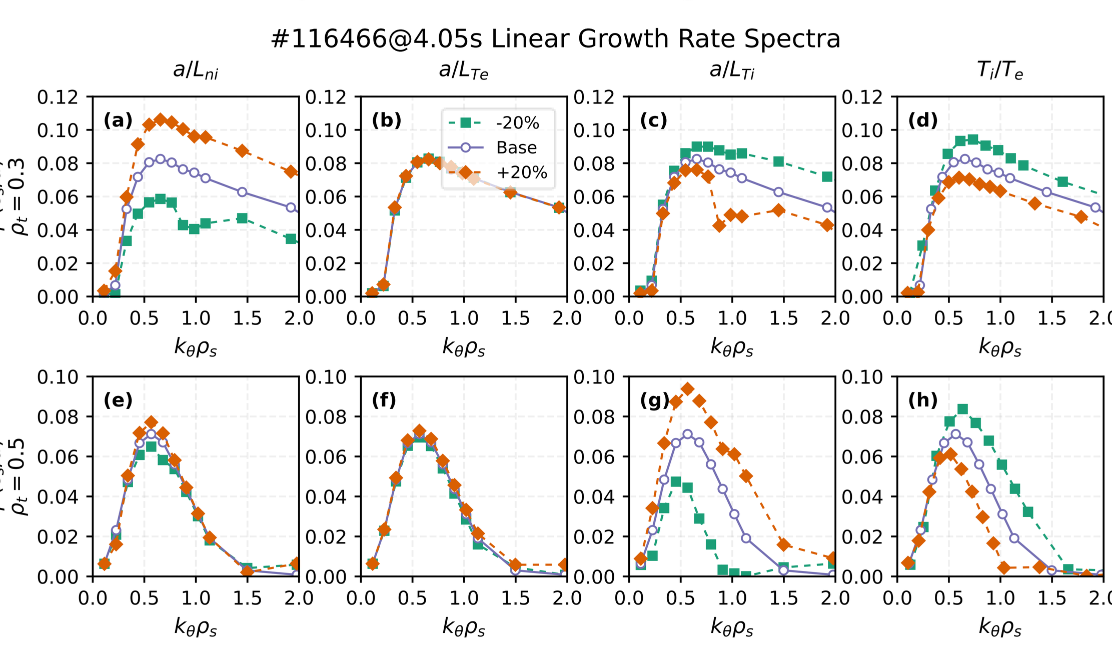
- ρ_t=0.3, ω changes from TEM to ITG;
- ρ_t=0.5, ω both ITG from 4s to 6s;



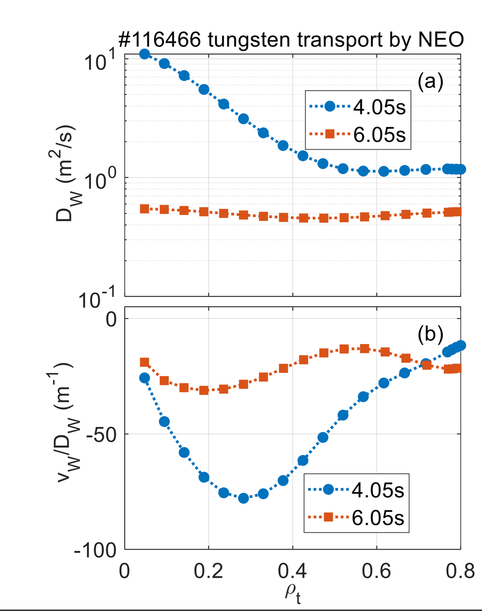
- Critical gradient ~1 a/L_ni and a/L_Ti
- Adjust the magnetic shear reduces γ



- TEM driven by density gradient;
- ITG driven by ion temperature gradient



- Tungsten neo-classical transport: NEO



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