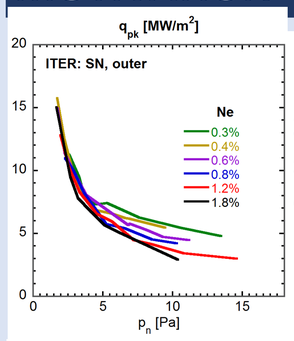
ID: 7

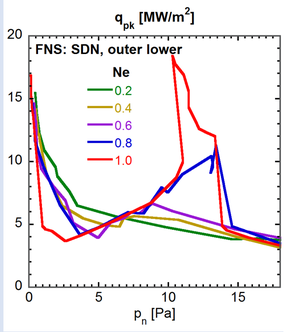
Radiation-condensation instability: a driver for up-down or in-out asymmetry of divertor plasma

A.S. Kukushkin[1,2], A.A. Kozhurin[1,3]
[1]NRC Kurchatov Institute, Moscow, Russia
[2]NRNU MEPhI, Moscow, Russia; [3]Lomonosov MSU, Moscow, Russia
ank755@gmail.com

MOTIVATION



Single-null: smooth, monotonic evolution of $q_{pk}(p_n)$ → easy control

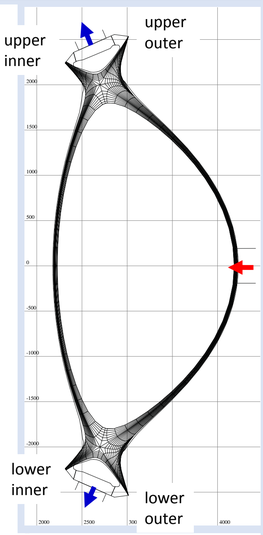


Double-null: bifurcations with symmetry break, counter-intuitive evolution with $dq_{pk}/dp_n > 0$ → divertor control can be a problem

DOUBLE NULL

Pro:
Core plasma stability with high elongation
Power load spread over two divertors

Contra:
Difficult to reach up-down symmetry
Feedback?
Inner targets receive a tiny fraction of power
Power load gain marginal
More expensive
Assumed in FNS project [B.V. Kuteev et al., NF 2017]



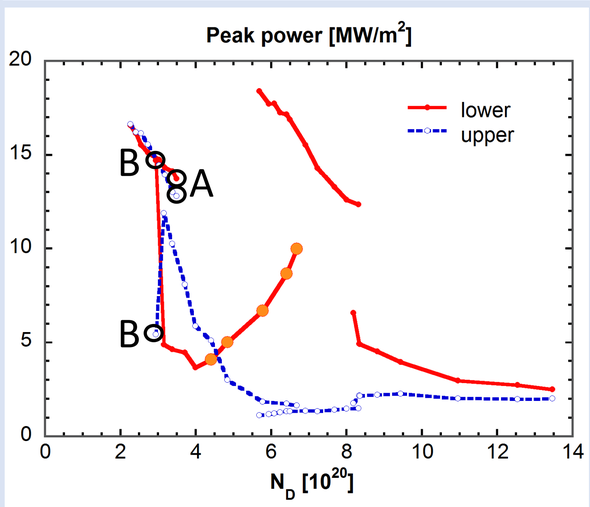
SOLPS4.3 code

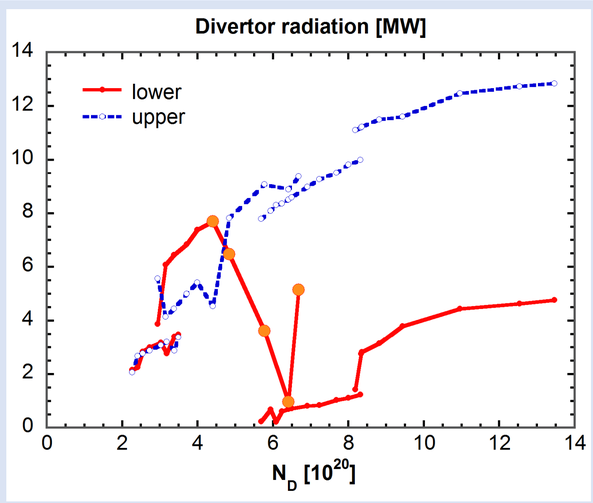
Pumping top and bottom, D and Ne puff from OMP
P_{SOL} in-out split 1:3

SUMMARY

- Radiation-condensation instability causes significant up-down asymmetry of power loading q_{pk} in a symmetric double-null divertor configuration
- This makes the dependence of q_{pk} on neutral pressure p_n non-monotonic, thus making divertor control difficult and reducing operational window
- The same instability may be responsible for change in the in-out asymmetry often seen in calculations for single-null divertors

SYMMETRY BREAK –outer divertors, P_{SOL}= 30 MW, N_{Ne} = 10^{19}





Strong asymmetry in q_{pk}, irregular, correlates with Q_{div_rad} → radiation driven?

RADIATION-CONDENSATION INSTABILITY

Very roughly:

$Q_{rad} \sim n_e n_Z L_R(T) \sim p_e p_Z L_R(T) / T^2$

$p \sim Const \rightarrow dQ_{rad}/dT < 0$
possible In a flux tube

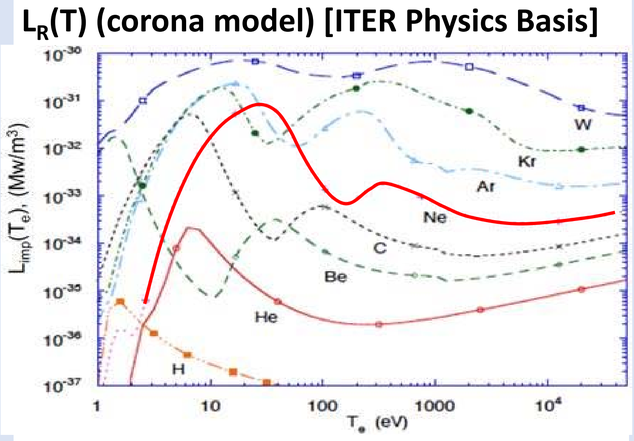
"hot": $T^{\uparrow} \rightarrow n_{\downarrow} \rightarrow Q_{rad\downarrow} \rightarrow T^{\uparrow}$

$N_{D,Ne} \sim Const$

→ "cold": $n^{\uparrow} \rightarrow Q_{rad}{}^{\uparrow} \rightarrow T_{\downarrow} \rightarrow n^{\uparrow}$

Negative curvature of $\log L_R(\log T)$
→ $T^{\uparrow}$ more unstable

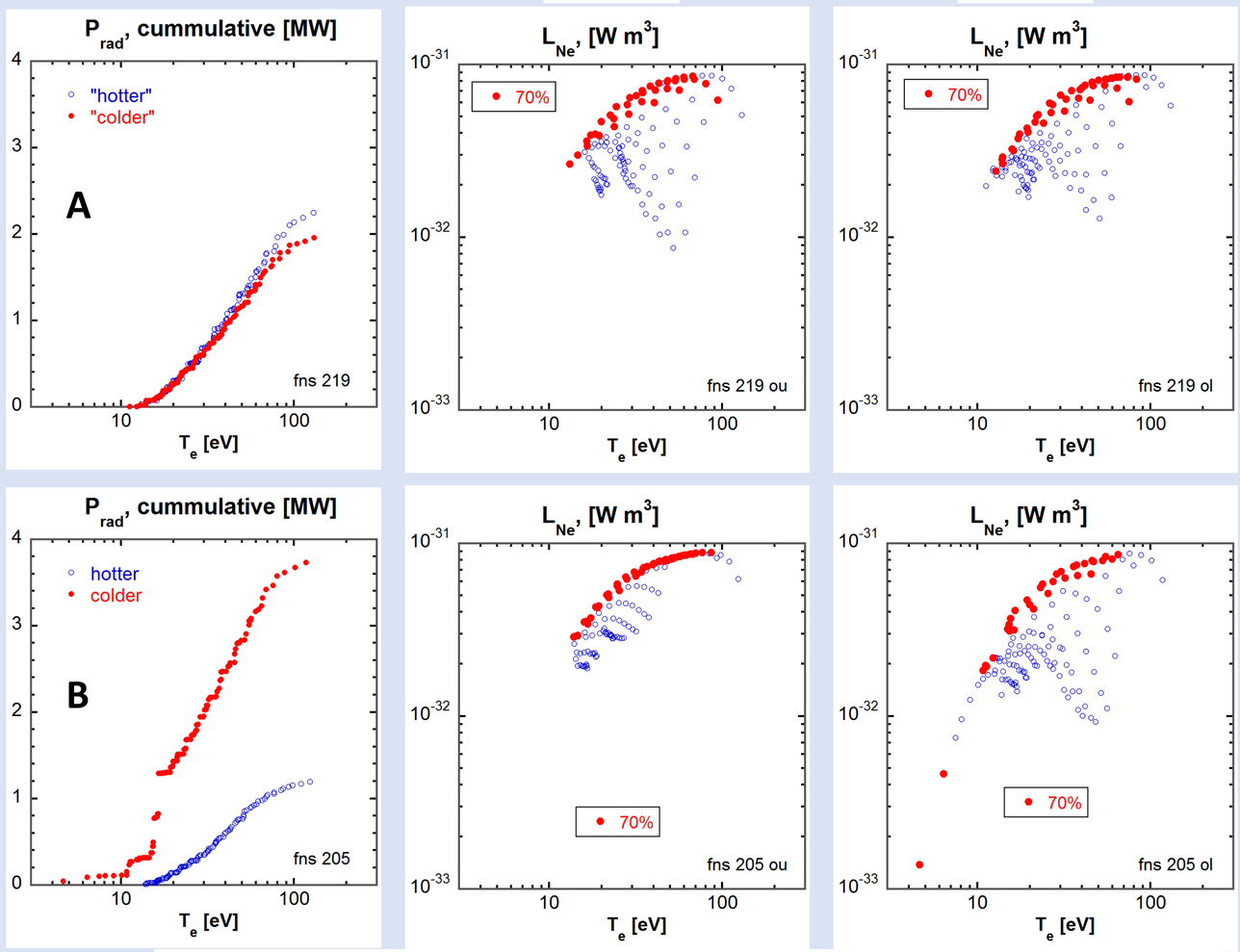
$L_R(T)$ (corona model) [ITER Physics Basis]

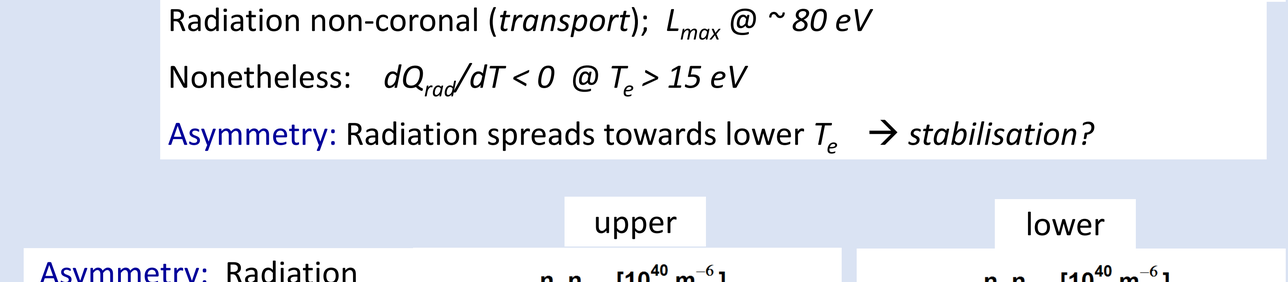


Ne: *$dQ_{rad}/dT < 0$ @ $T_e > 15$ eV*
L_{max} @ ~ 30 eV

EFFECTIVE L_R FROM SOLPS4.3 CALCULATIONS

upper | lower





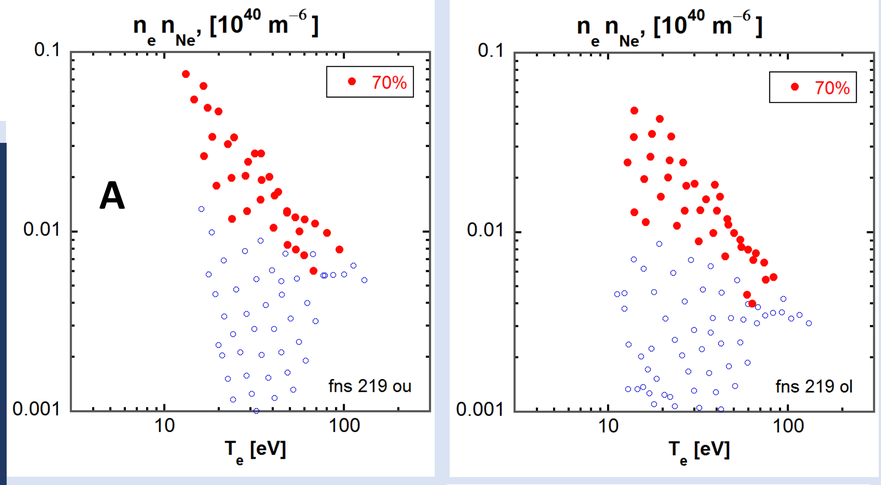
Radiation non-coronal (*transport*); L_{max} @ ~ *80 eV*

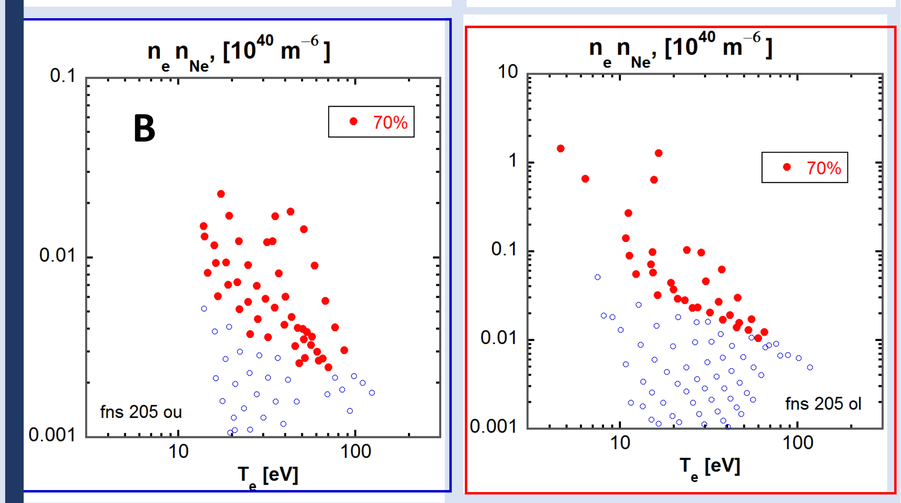
Nonetheless: $dQ_{rad}/dT < 0$ @ $T_e > 15$ eV

Asymmetry: Radiation spreads towards lower T_e → *stabilisation?*

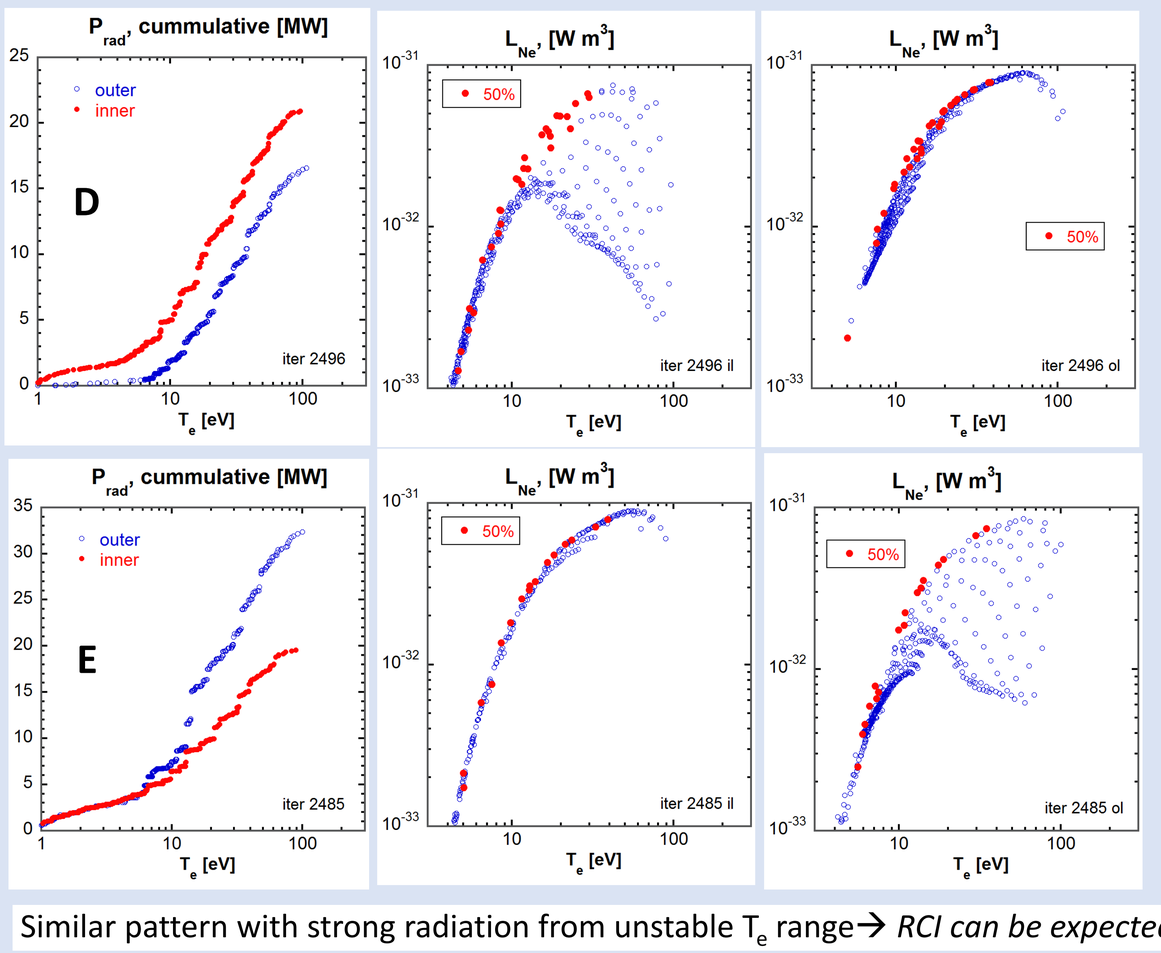
Asymmetry: Radiation spreads towards higher *n* → *Consistent with RCI*

upper | lower

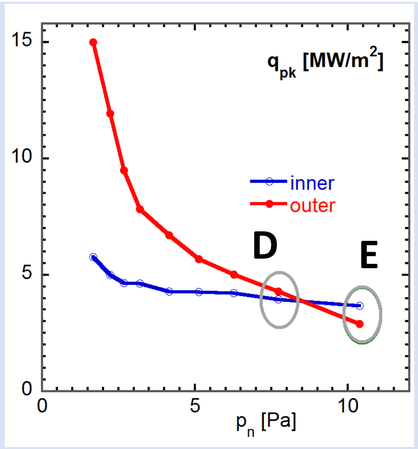




PROJECTIONS FOR SINGLE NULL



ITER [Pacher JNM 2015]
P_{SOL} = 100 MW, c_{Ne_sep} = 1.8%
Ne migrates to outer divertor



Similar pattern with strong radiation from unstable T_e range → *RCI can be expected*

REFERENCES

- A. S. Kukushkin, *Plasma Phys. Reports* **45** (2019) 637
- A.S. Kukushkin, S.I. Krasheninnikov, *Plasma Phys. Control. Fusion* **61** (2019) 074001