



## Pedestal structure and stability of ECRH-only heated plasmas in TCV, comparison with NBI-only heated plasmas

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### Introduction

- ITER will start research operation using RF heating only [1].
- In DIII-D, a comparison of NBI vs. ECRH heating showed a difference in the post-ELM recovery and in the peeling-ballooning (PB) boundary [2, 3].
- In ASDEX-U, little difference was found in pedestal structure and transport between ECRH and NBI heated plasmas [4].
- In this work, experimental dataset of TCV, at  $B_t = 1.4\text{T}$ ,  $I_p = 170\text{kA}$ , high triangularity, without baffles and without seeding.

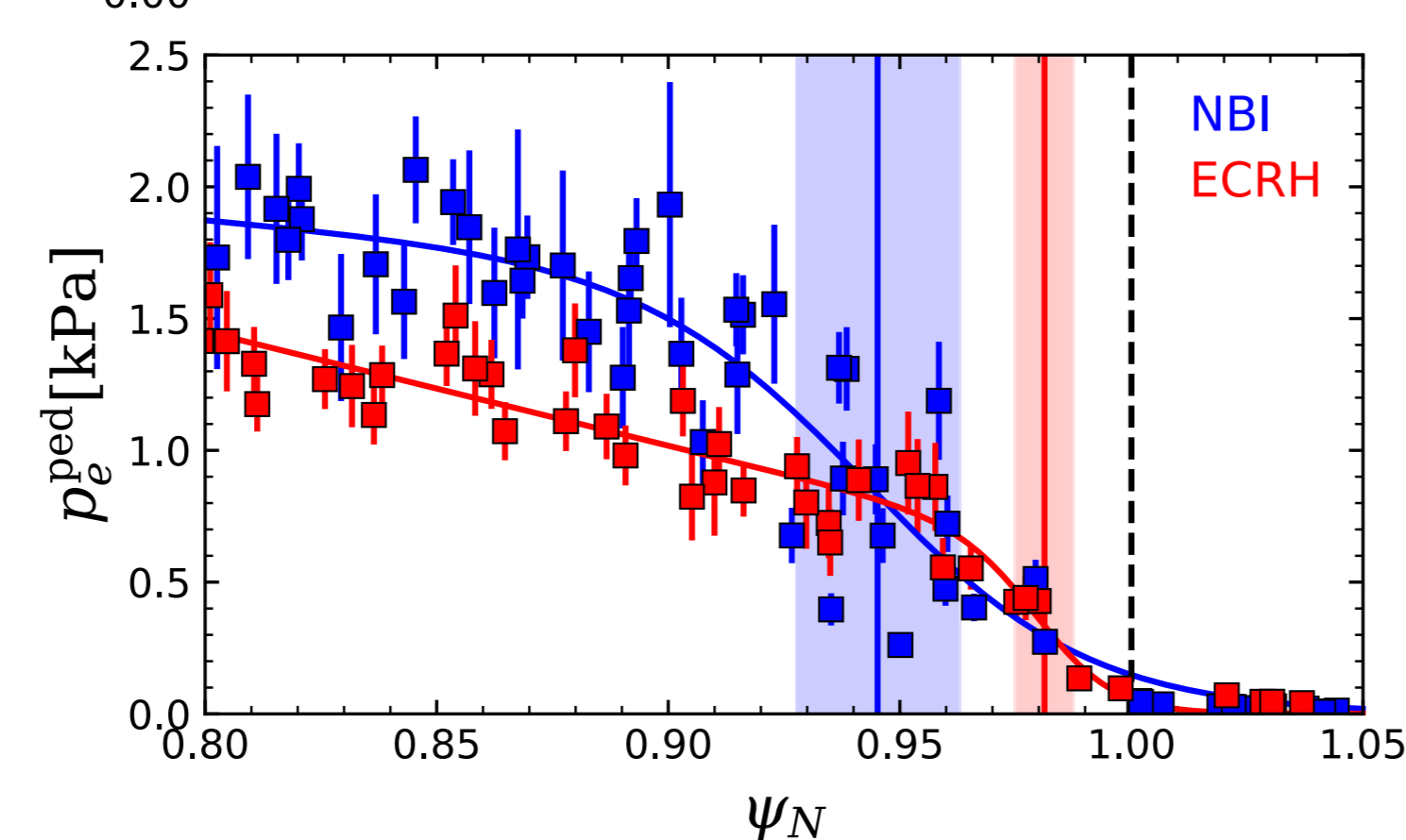
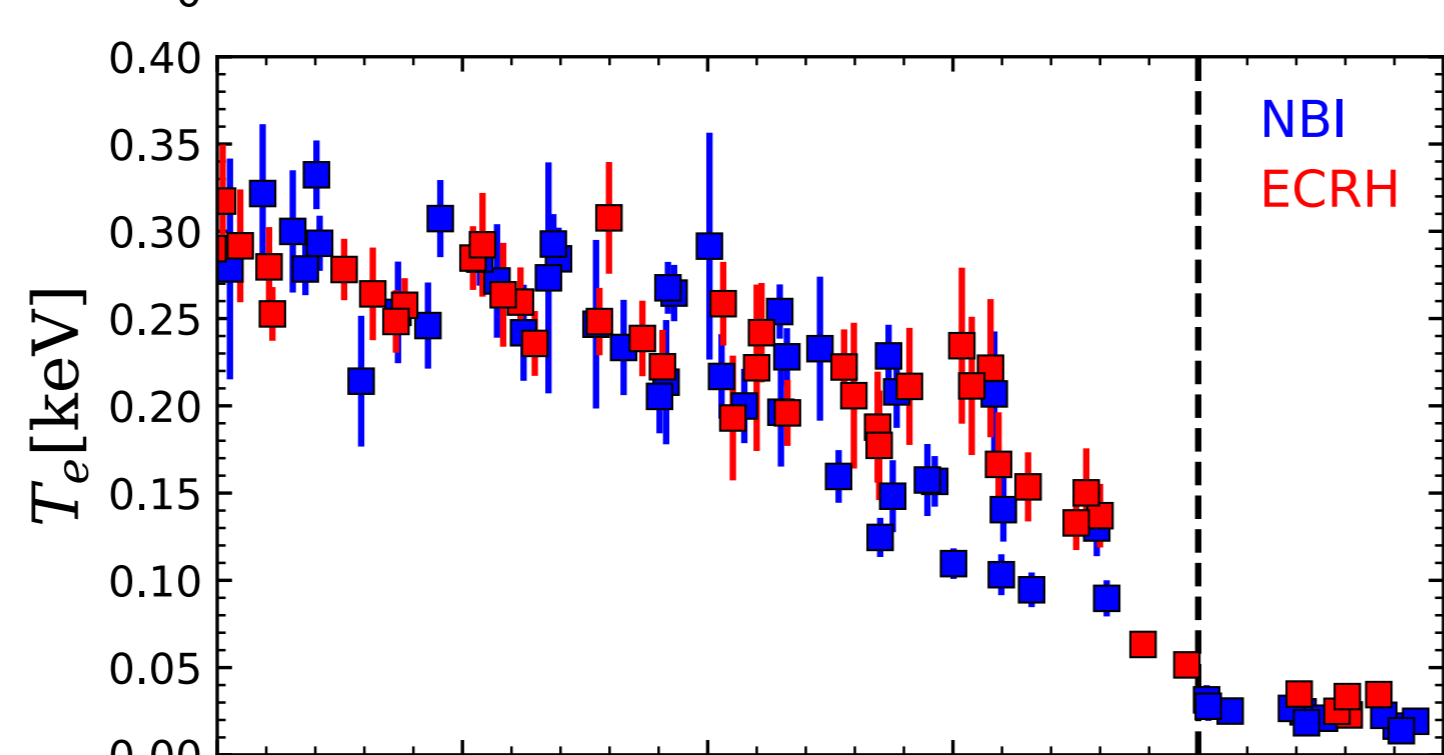
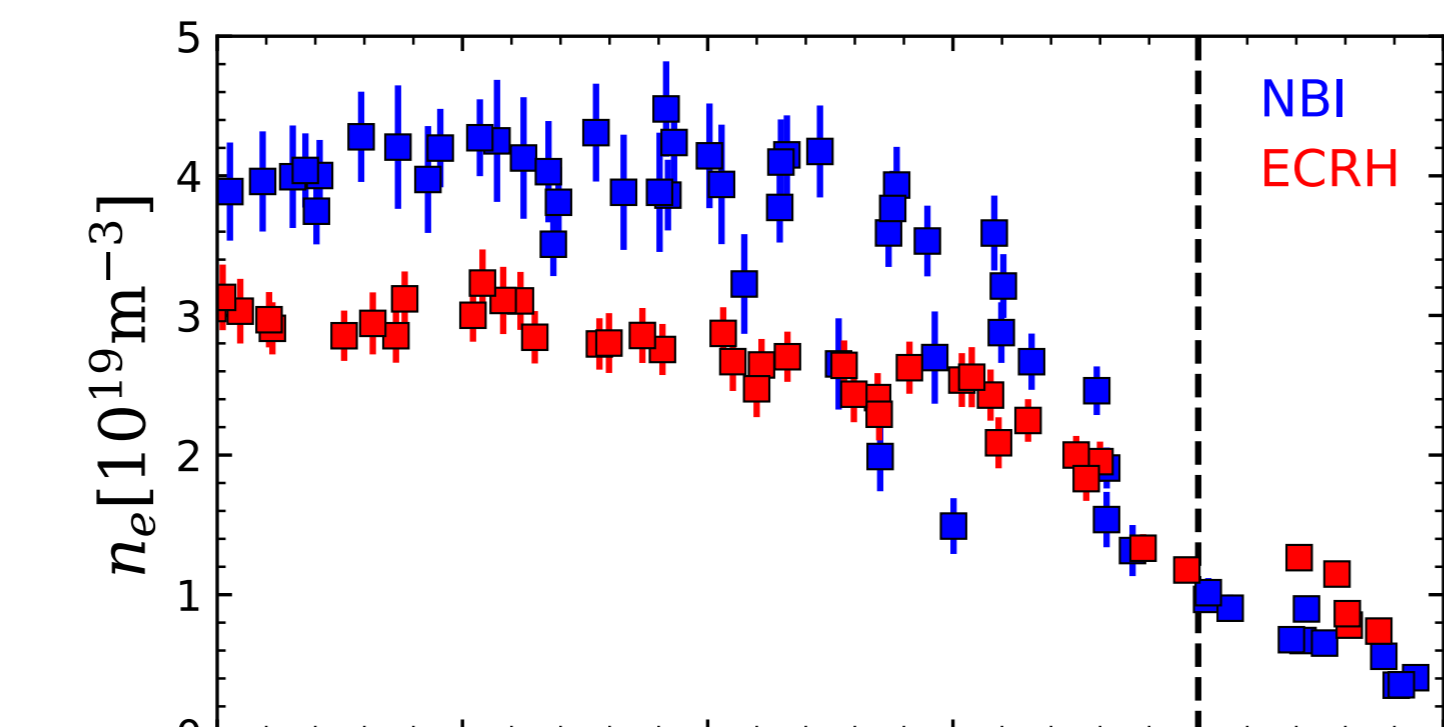
### Comparison of two pulses at similar engineering parameters

- Selection of two pulses, #66294 (NBI-only) and #86226 (ECRH-only), matching engineering parameters, and important physics parameters.

	$B_t/I_p$	Shape	$P_{\text{abs}}[\text{MW}]$	$\Gamma_{\text{valve}}$	$\beta_N$	$n_e^{\text{sep}}[10^{19}\text{m}^{-3}]$
#66294	1.4T/170kA	High $\delta$ - LSN	$\approx 0.4$	0	1.39	$1.25 \pm 0.22$
#86226	1.4T/170kA	High $\delta$ - LSN	0.45	0	1.33	$1.42 \pm 0.07$

### Characterization of the pedestal:

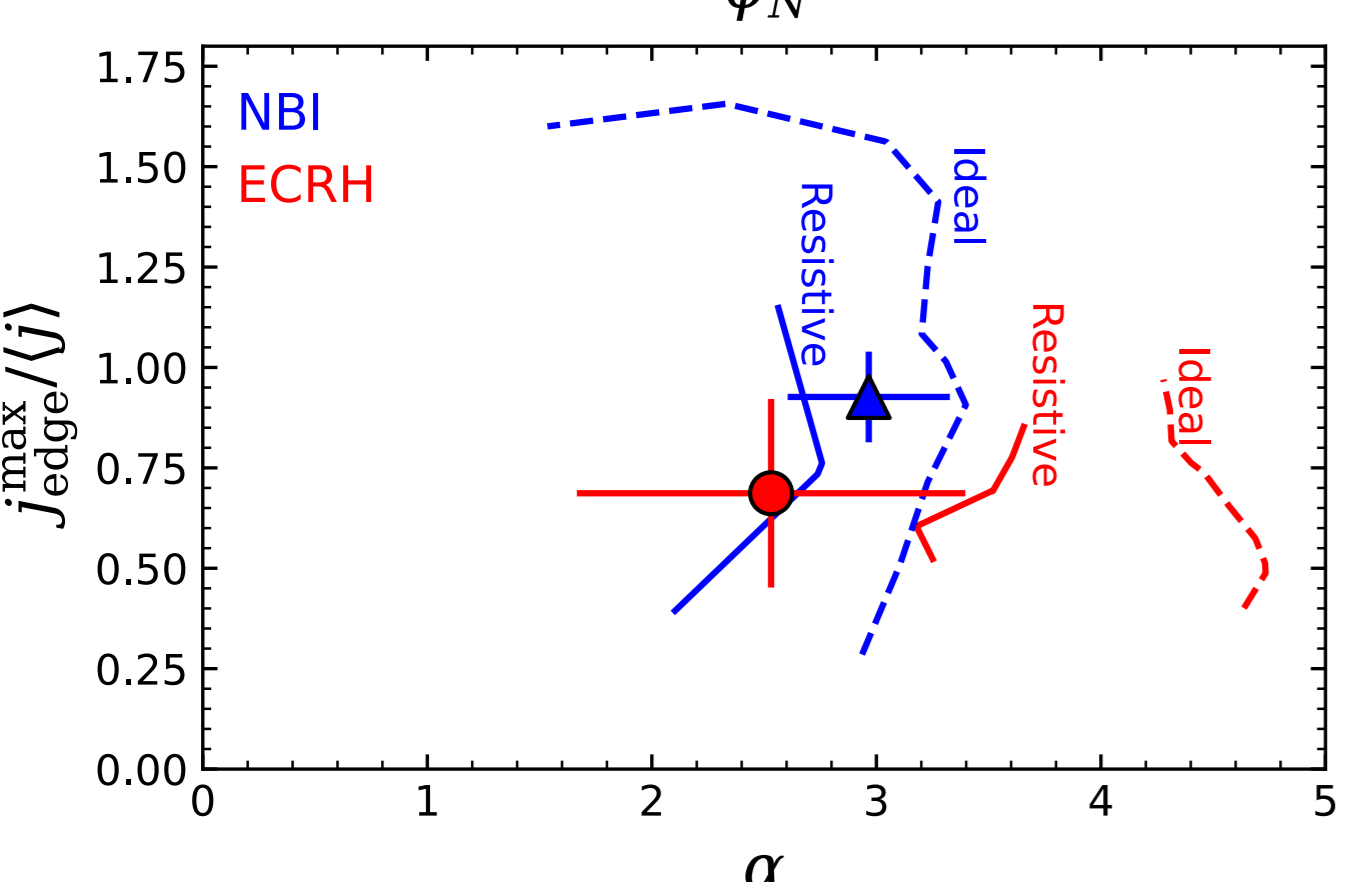
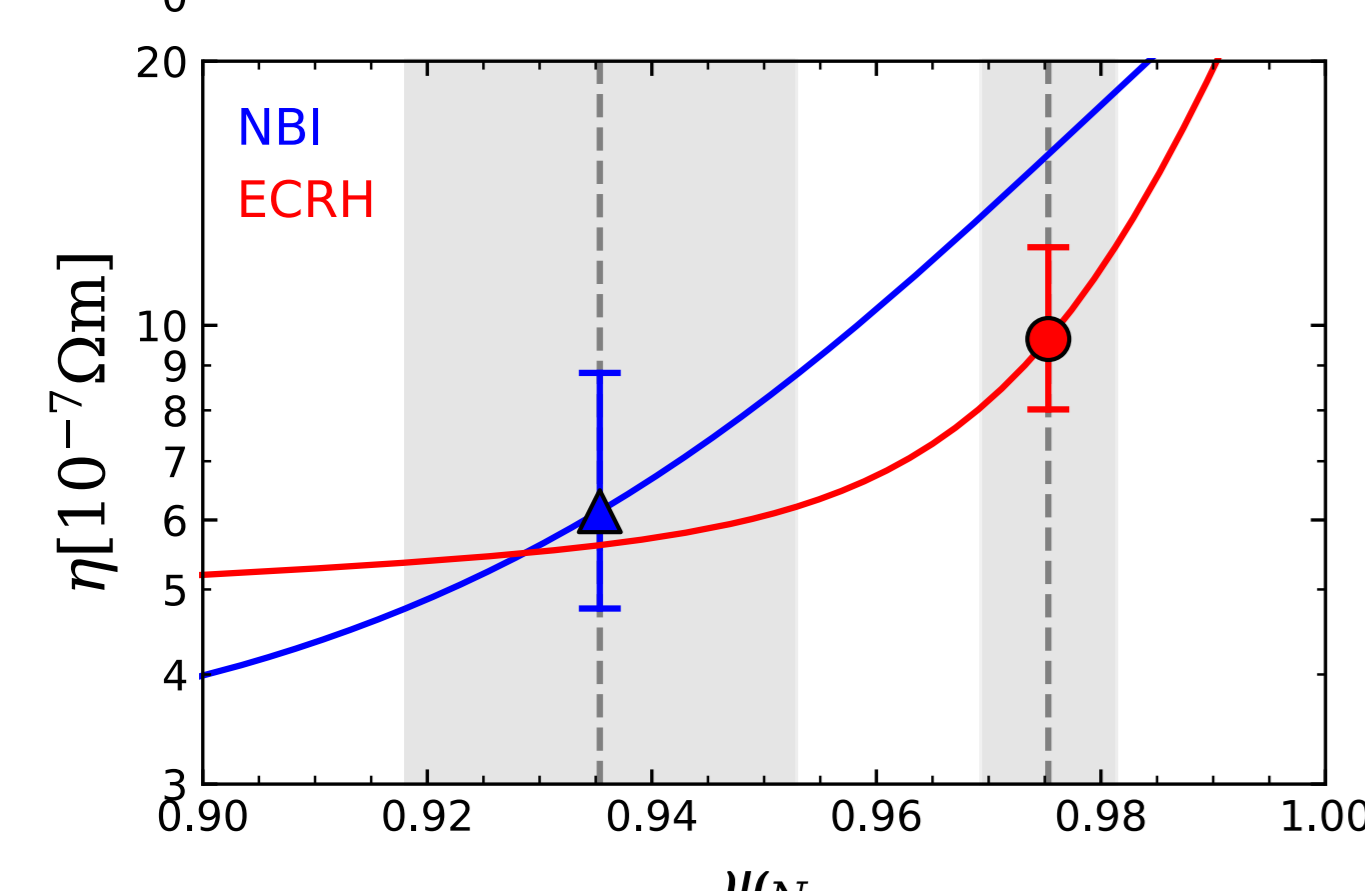
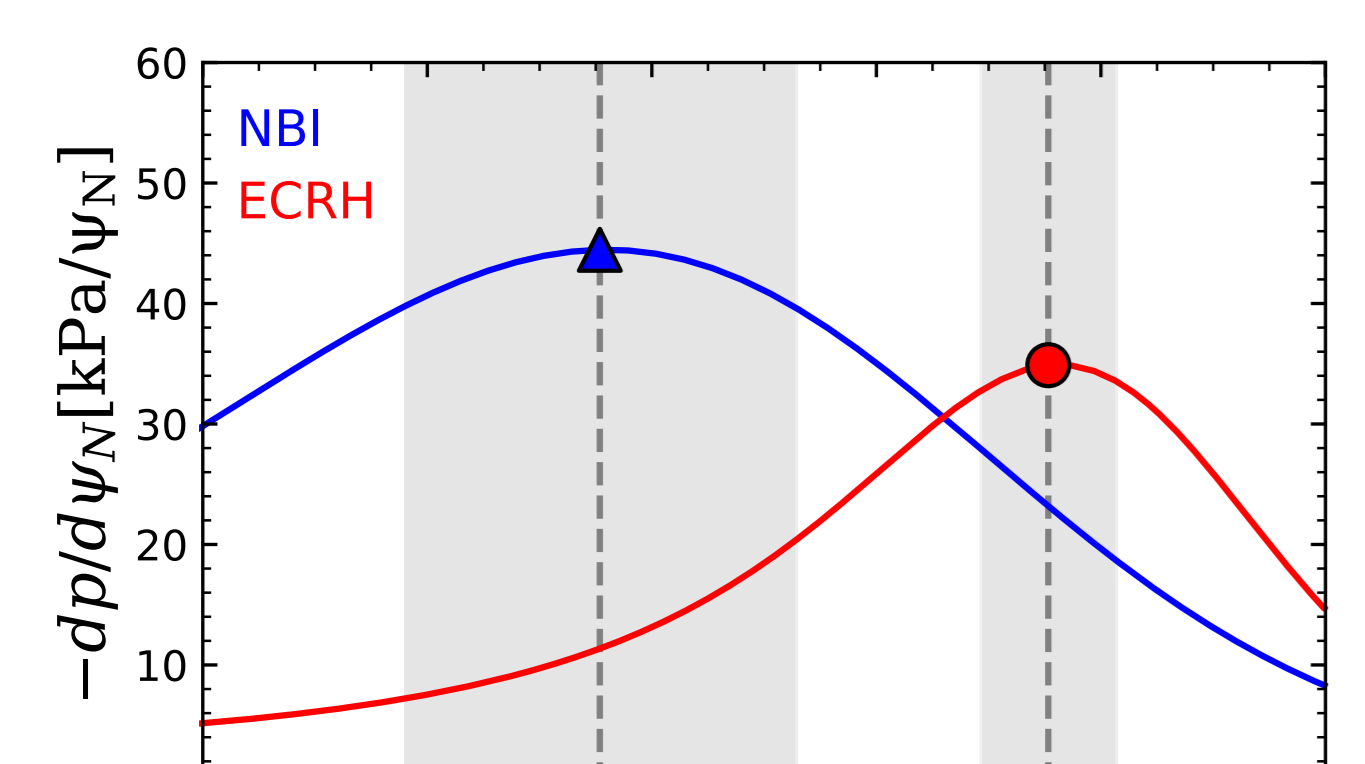
- NBI pulse has larger  $n_e^{\text{ped}}$ .
  - NBI fuelling  $\Gamma_{\text{NBI}} \approx 1.5e20 \text{ e/s}$ ,
  - Pedestal transport may be different.
- NBI and ECRH pulses have:
  - Similar  $n_e^{\text{sep}}$ ,
  - Similar  $T_e^{\text{sep}}$  from the two-point model [5],
  - Similar  $T_e^{\text{ped}}$ .
- NBI pulse has larger  $p_e^{\text{ped}}$ ,  $\nabla p_e$ , and  $\alpha$  compared to ECRH pulse. **→ NBI pulse has better pedestal stability than ECRH pulse → Why?**



- ECRH has lower  $n_e^{\text{ped}}$ , and similar  $n_e^{\text{sep}} \rightarrow$  larger  $n_e^{\text{sep}}/n_e^{\text{ped}}$ .
- $n_e^{\text{pos}}$  and  $p_e^{\text{pos}}$  are outward for ECRH.
- At  $p_e^{\text{pos}}$ , lower temperature and larger resistivity for ECRH.

### Ideal and resistive MHD stability boundaries

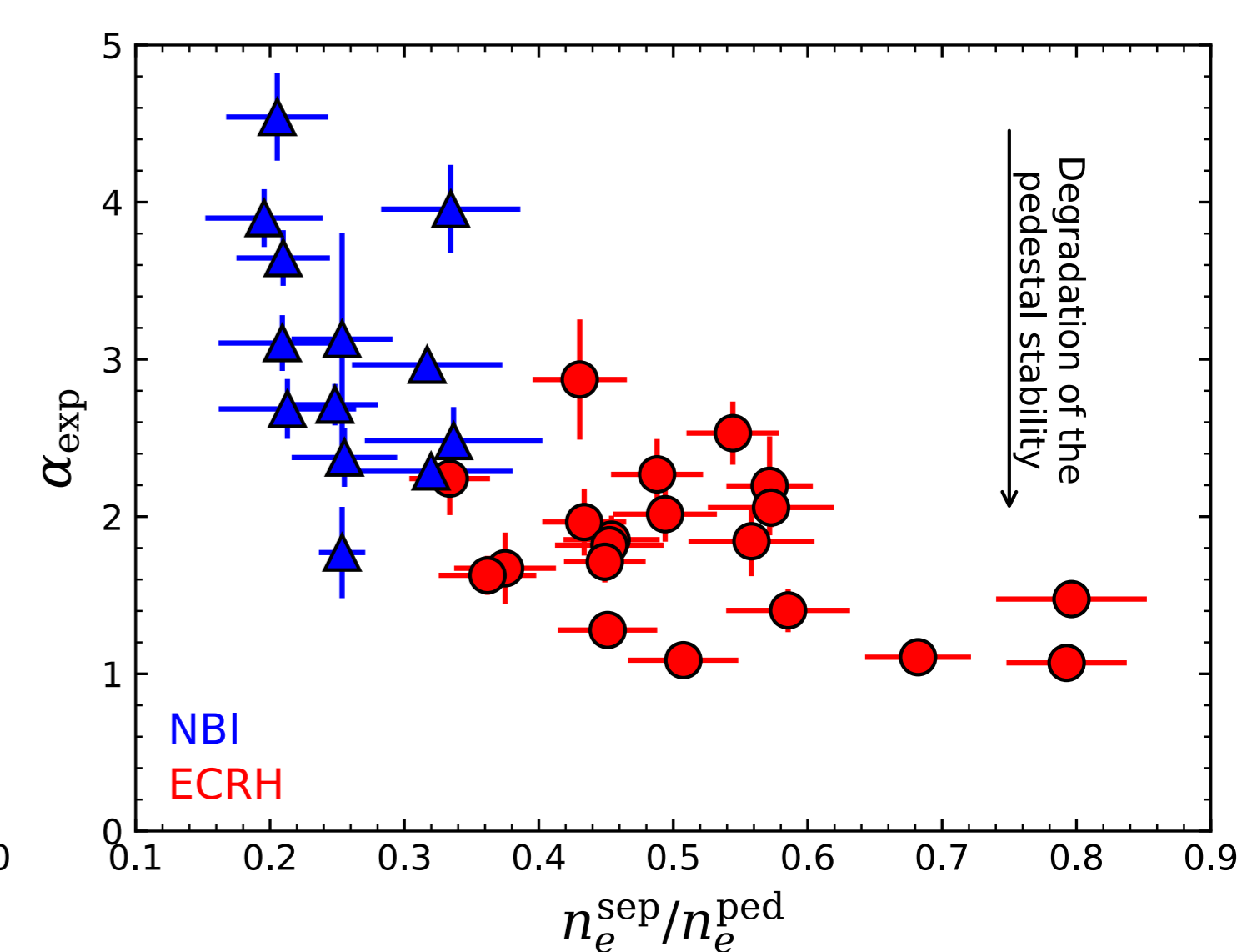
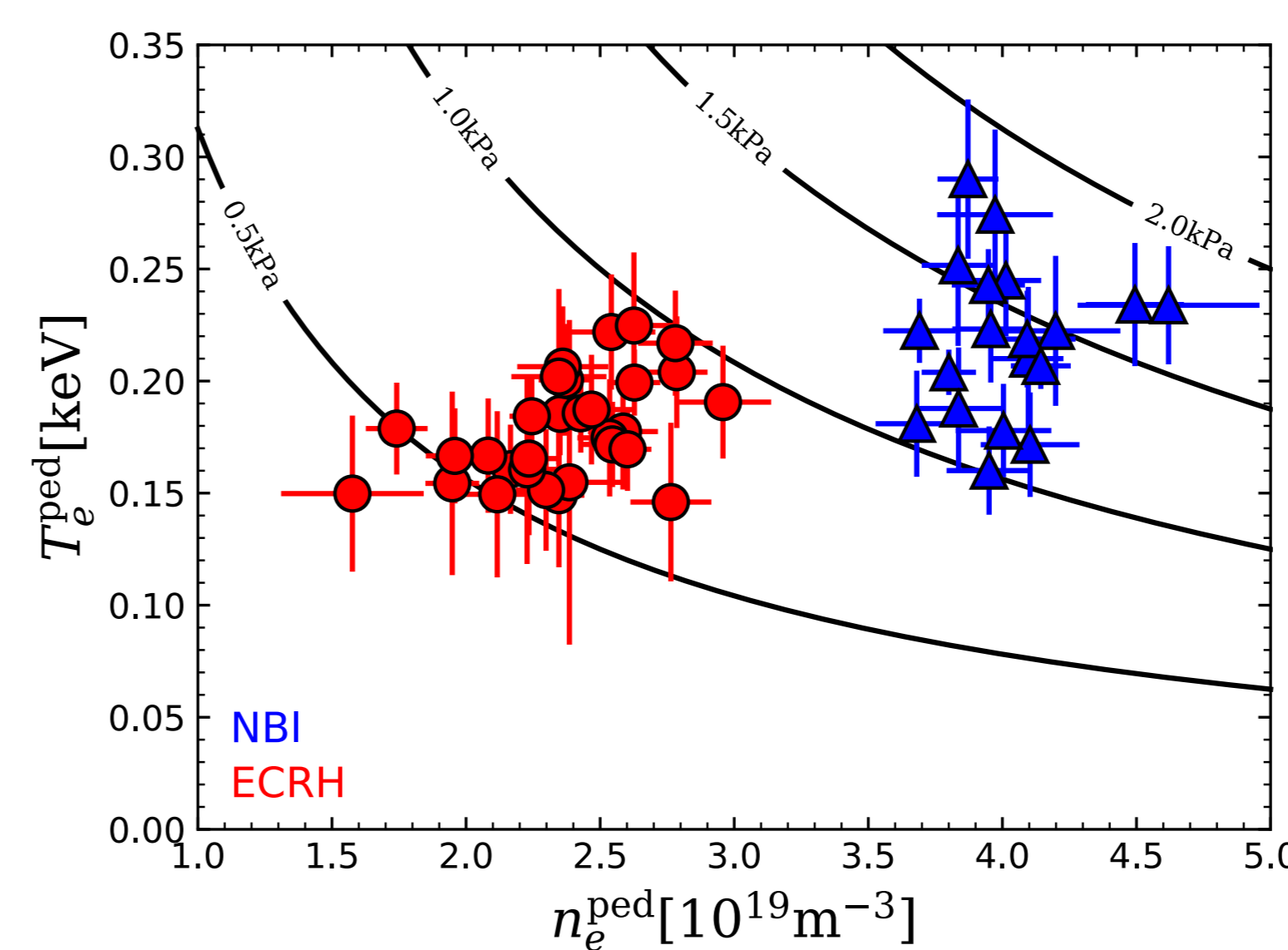
- For **NBI**, the resistivity at the maximum pressure gradient is low. Small difference between ideal and resistive boundaries, both are close to the experimental point.
- For **ECRH**, larger resistivity, and larger resistive effects compared to NBI. Resistive MHD is necessary to describe the pedestal stability.



### Effect of normalized separatrix density on the pedestal stability

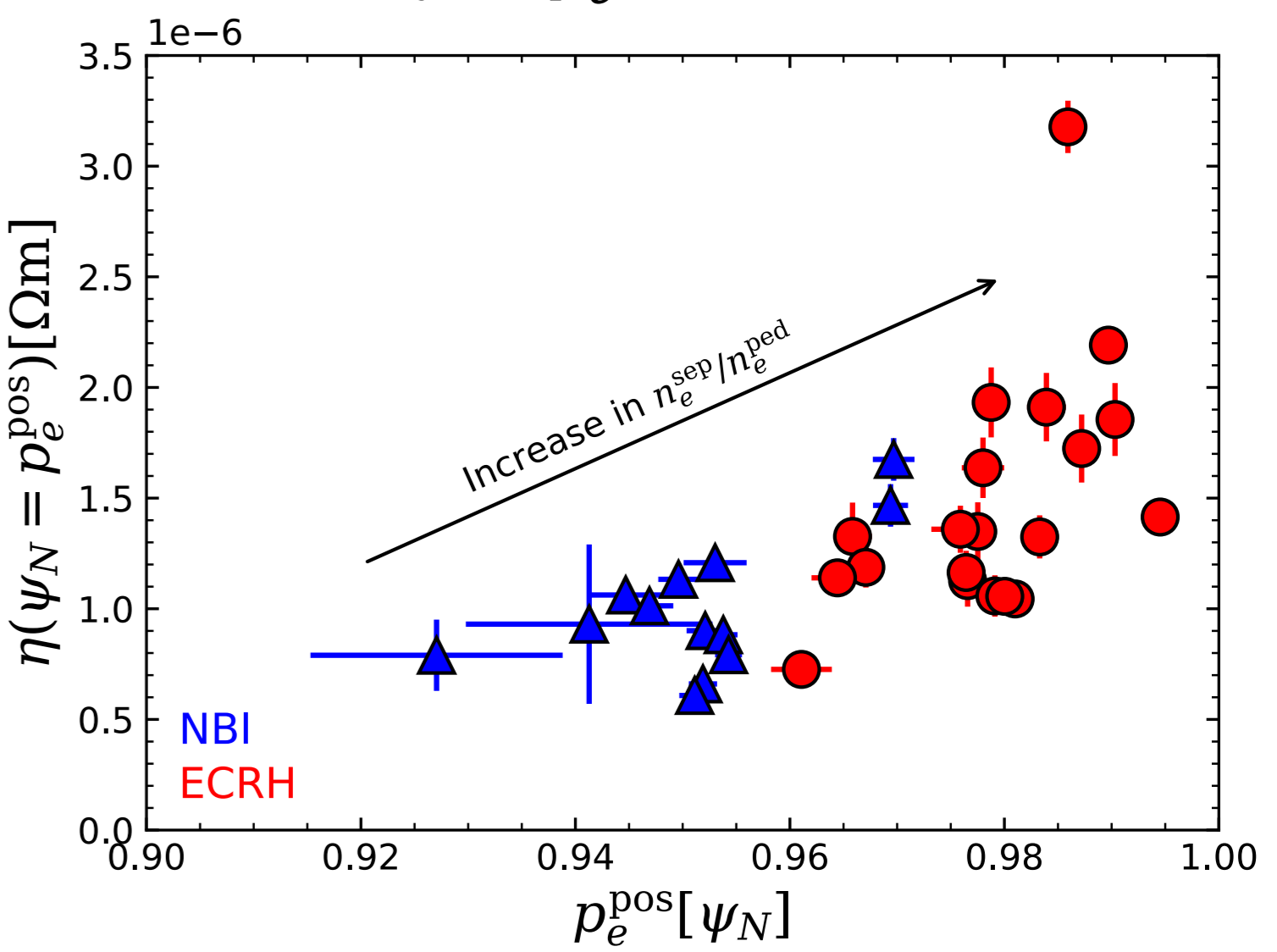
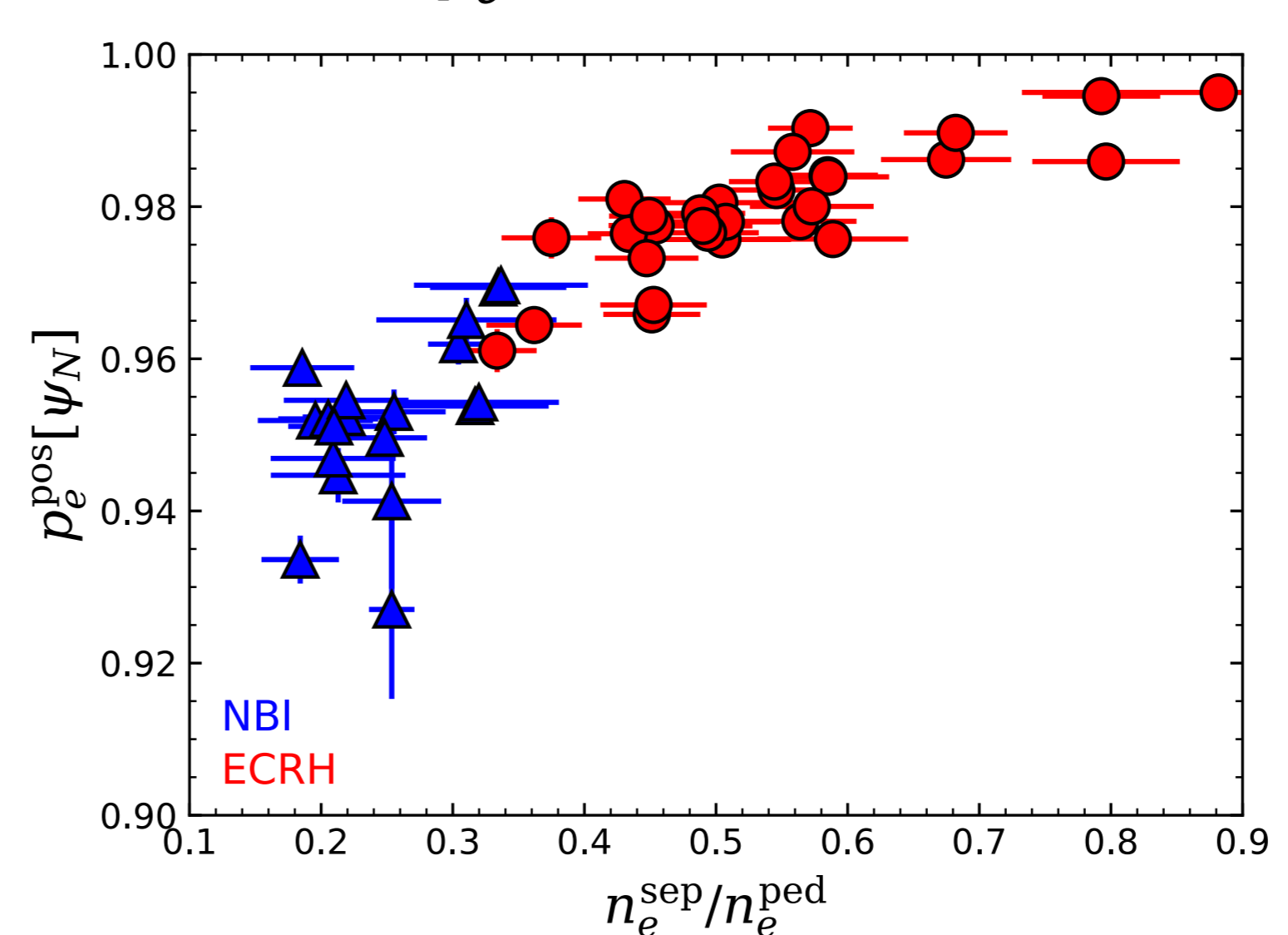
#### Over the dataset

- $n_e^{\text{ped}}(\text{NBI}) > n_e^{\text{ped}}(\text{ECRH})$ ,  $T_e^{\text{ped}}(\text{NBI}) \approx T_e^{\text{ped}}(\text{ECRH})$ ,  $p_e^{\text{ped}}(\text{NBI}) > p_e^{\text{ped}}(\text{ECRH})$ .
- NBI pulses have higher normalized pressure gradient  $\alpha$ , and better stability.
- Degradation of the pedestal stability is correlated with an increase in  $n_e^{\text{sep}}/n_e^{\text{ped}}$ , similar to previous JET-ILW results [6, 7, 8]

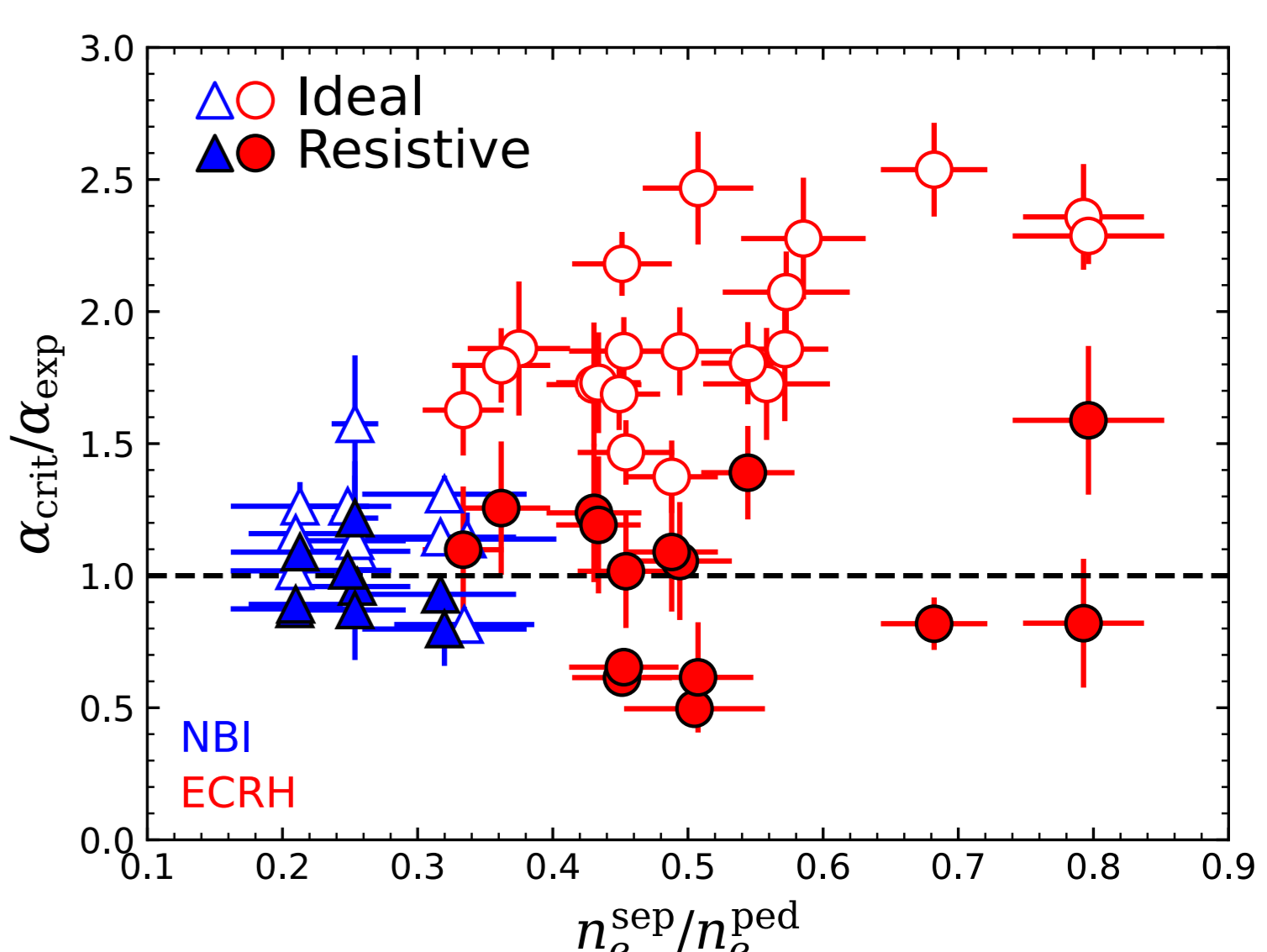


#### From NBI to ECRH pulses,

- Comparable  $T_e$  profile in the pedestal.
- Increase in  $n_e^{\text{sep}}/n_e^{\text{ped}}$  leads to an outward shift of the pressure pedestal.
- Increase in  $p_e^{\text{pos}}$  leads to an increase in the resistivity at  $p_e^{\text{pos}}$ .



- With ideal MHD, ECRH pulses are far from the PB boundary ( $\alpha_c/\alpha_e > 2$ ).
- ECRH pulses have high  $n_e^{\text{sep}}/n_e^{\text{ped}}$  and high  $\eta(p_e^{\text{pos}})$ , and are better described by resistive MHD.
- NBI pulses are well described by both ideal and resistive MHD.
- Larger resistive effects for ECRH pulses give explanation for lower  $p_e^{\text{ped}}$  compared to NBI pulses.



### Conclusion

- ECRH have lower  $n_e^{\text{ped}}$  (due to NBI fuelling and/or different transport) and similar  $n_e^{\text{sep}}$ ,
- ECRH have higher  $n_e^{\text{sep}}/n_e^{\text{ped}}$ ,
- pressure pedestal is shifted outward,
- larger resistivity at  $p_e^{\text{pos}}$ ,
- larger resistive effects,
- lower  $\alpha$ ,  $\nabla p_e$  and  $p_e^{\text{ped}}$  for ECRH.

### Future work

- Europe with ideal and resistive MHD for ECRH and NBI pulses.
- Inter-ELM pedestal transport study, with experimental observation and gyro-kinetics.
- Test of the Saarelma-Connor model for the density prediction.

### References

- [1] Loarte et al, PPCF 2025 [4] Sommer et al, NF 2012 [6] Stefanikova et al, NF 2018  
 [2] Banerjee et al, NF 2021 [5] Stangeby, 2000, The Plasma Boundary of M.F.D. [7] Frassinetti et al, NF 2021  
 [3] Banerjee et al, NF 2024 [8] Nyström et al, NF 2022