

PEELING LIMITED PEDESTALS IN JET-ILW, MAST-U AND TCV: EFFECT OF DENSITY AND ISOTOPE MASS IN DEUTERIUM AND TRITIUM-RICH PLASMA ON PEDESTAL STRUCTURE AND STABILITY AND VALIDATION OF PEDESTAL PREDICTIONS FOR ITER.

L. Frassinetti

KTH Royal Institute of Technology



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MOTIVATION

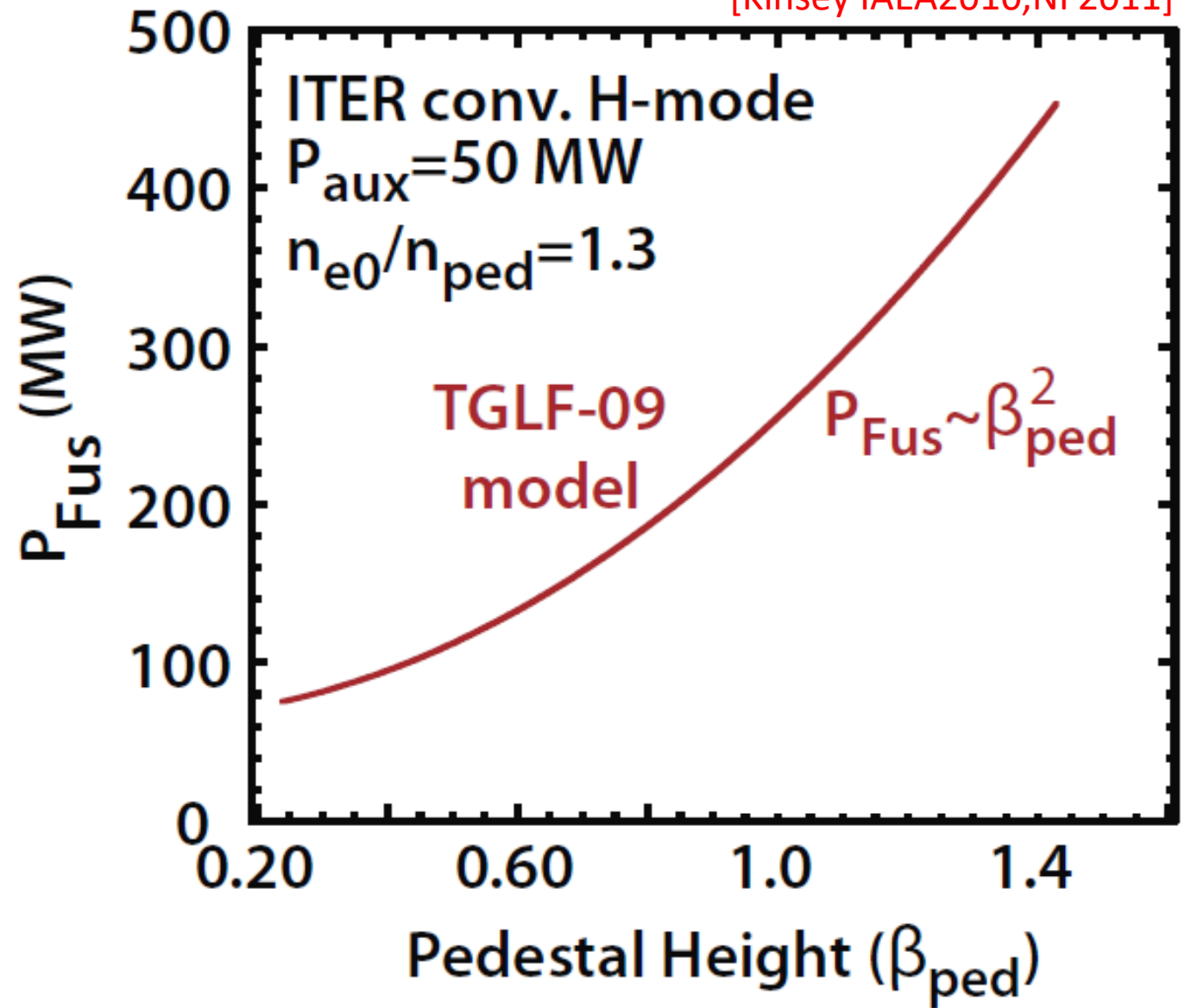
- The pedestal plays a major role for ITER:

- fusion power will scale as

$$P_{fus} \sim (p^{ped})^2$$

- Assessing and predicting the pedestal behavior in ITER-relevant conditions is essential

[Kinsey IAEA2010,NF2011]





MOTIVATION AND GOALS

- ITER will operate:
 - relatively high n^{ped} [Garzotti NF2019]
 - high n^{sep}/n^{ped} [Garzotti NF2019]
 - in mixed deuterium/tritium plasmas
 - with a metal wall



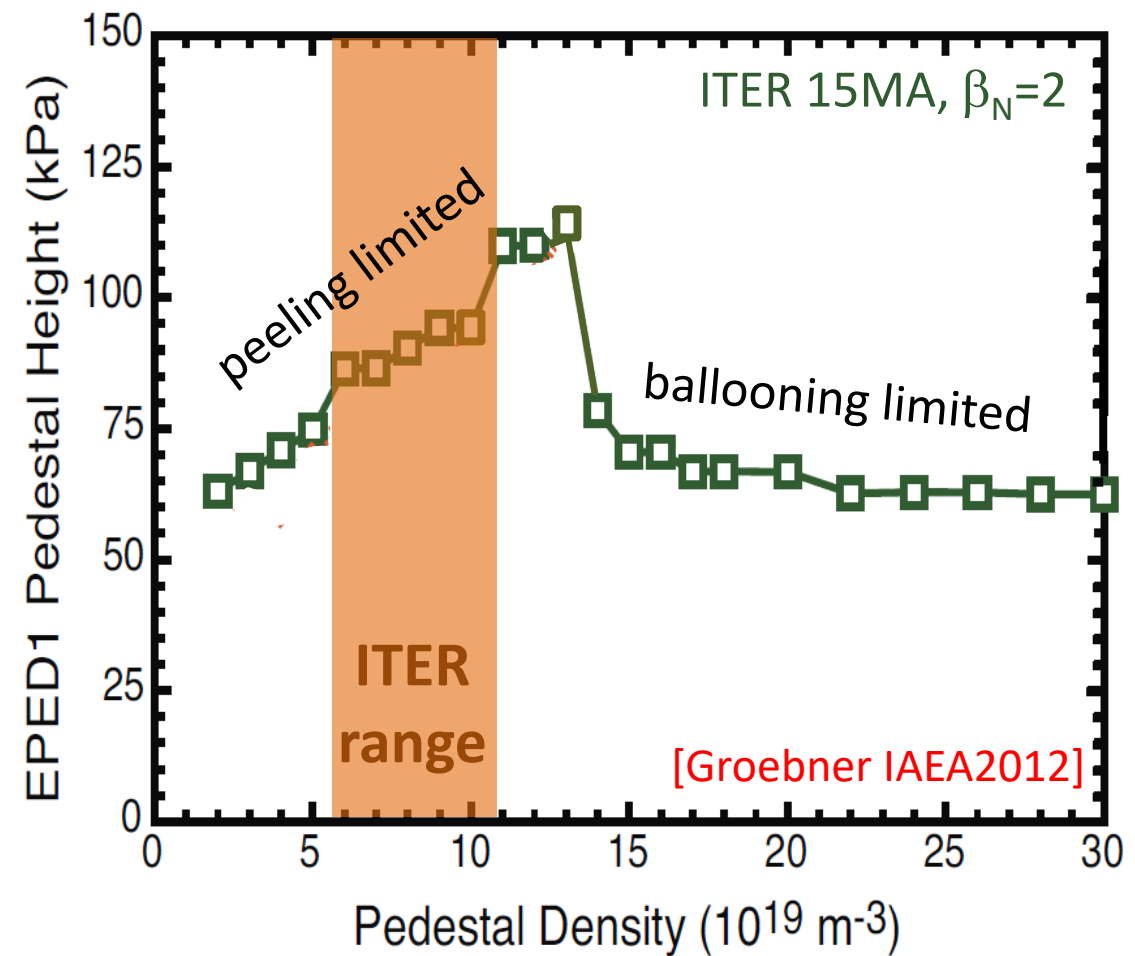
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 - relatively high n^{ped} [Garzotti NF2019] } $\Rightarrow$ mainly from DIII-D in peeling limited pedestals
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- Earlier modelling suggests that ITER will be limited by peeling instabilities
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- **Goals:**
 - reach peeling limited plasmas
 - assess the role of density, isotope and wall material in the peeling limited pedestals
 - validate the European pedestal predictions at ITER relevant $v_{ee}^{*ped}, \rho_i^{*ped}, n^{sep}/n^{ped}$
 - understand if ITER will be limited by peeling or ballooning instabilities



OUTLINE

1. Reaching peeling limited pedestals in JET-ILW, MAST-U and TCV
2. The datasets
3. Effect in peeling limited pedestals of
 - n_e^{ped} on p_e^{ped} in JET-ILW, MAST-U and TCV
 - n_e^{sep}/n_e^{ped} on p_e^{ped} in JET-ILW, MAST-U and TCV
 - the isotope mass in peeling limited pedestals in JET-ILWplus corresponding pedestal predictions validation
4. Pedestal predictions in ITER
 - will ITER be limited by peeling or ballooning instabilities?
 - Is a transition from peeling to ballooning limited pedestals a problem?Type I ELMs are assumed → the predictions are an upper bound of ITER pedestals.



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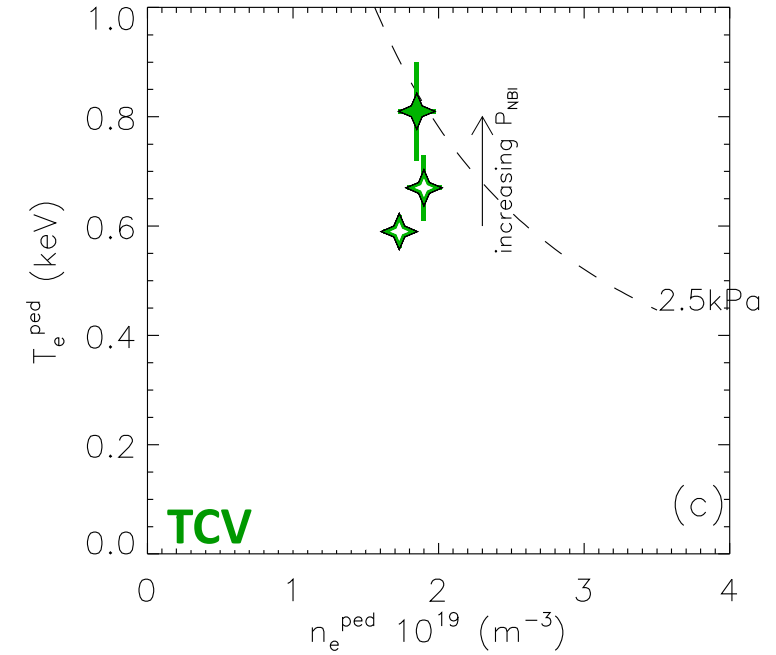
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- Key ingredient: low $\nu^{*ped} \rightarrow$ low n^{ped} and high T^{ped}



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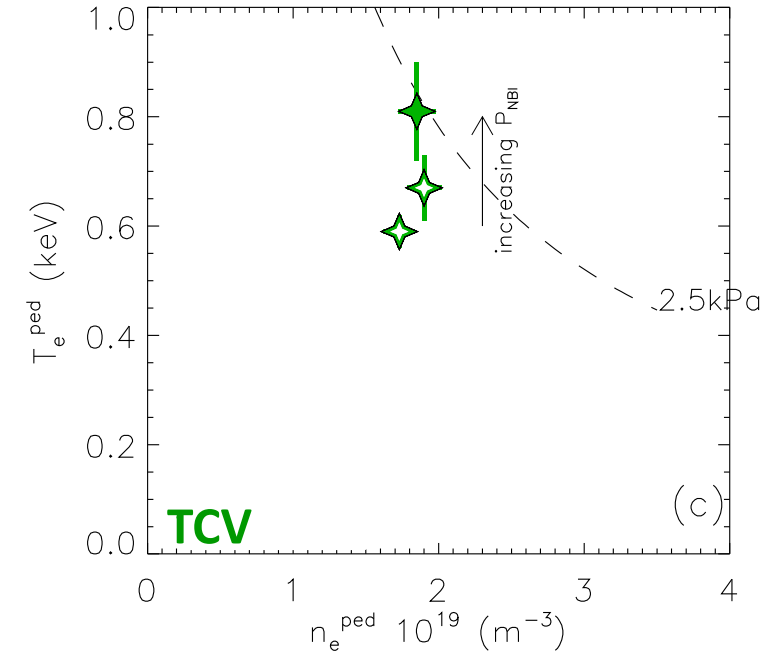


TCV:

- high- δ (ITER relevant)
- 155kA/1.4T
- Increase power for high T^{ped}



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JET-ILW:

MAST-U:

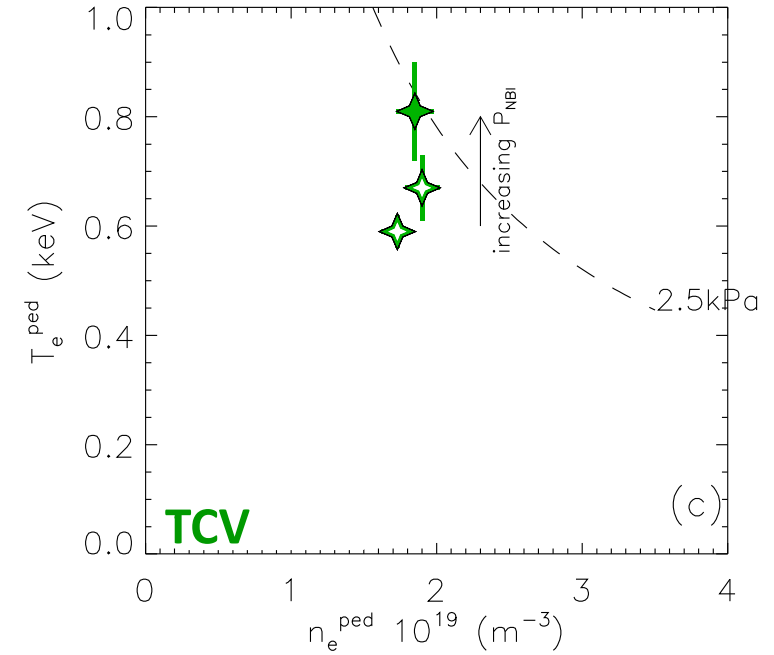
TCV:

- Extra ingredient:
 - Increase q_{95} via B_t increase
 - Optimized elongation [Imada NF2024]

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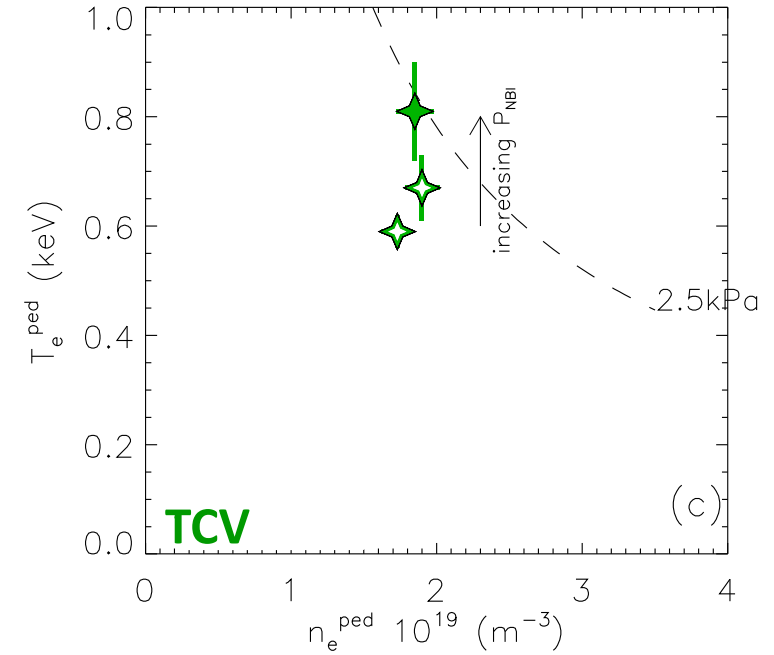
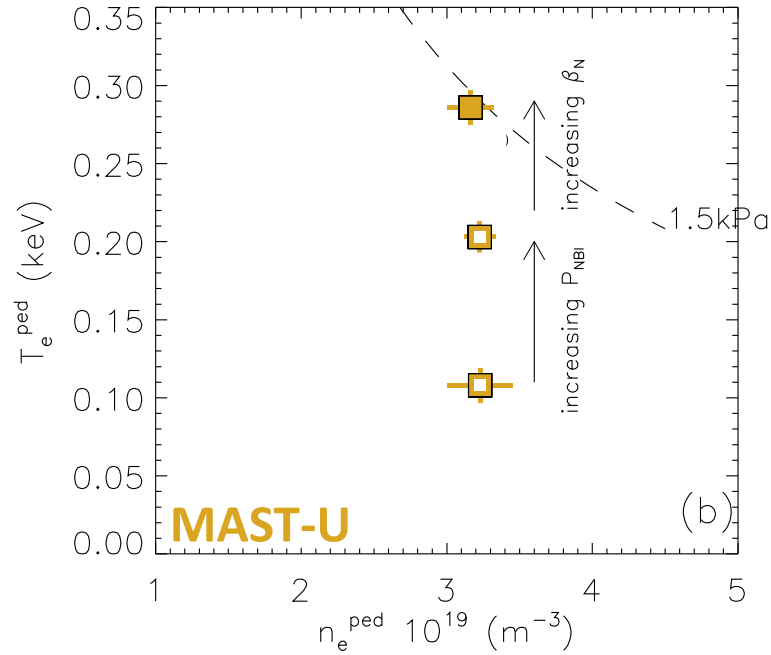
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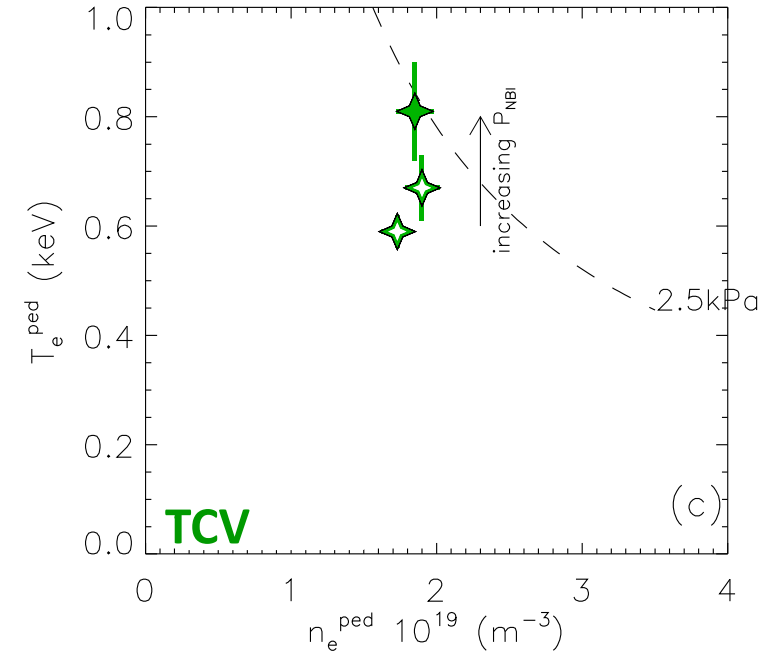
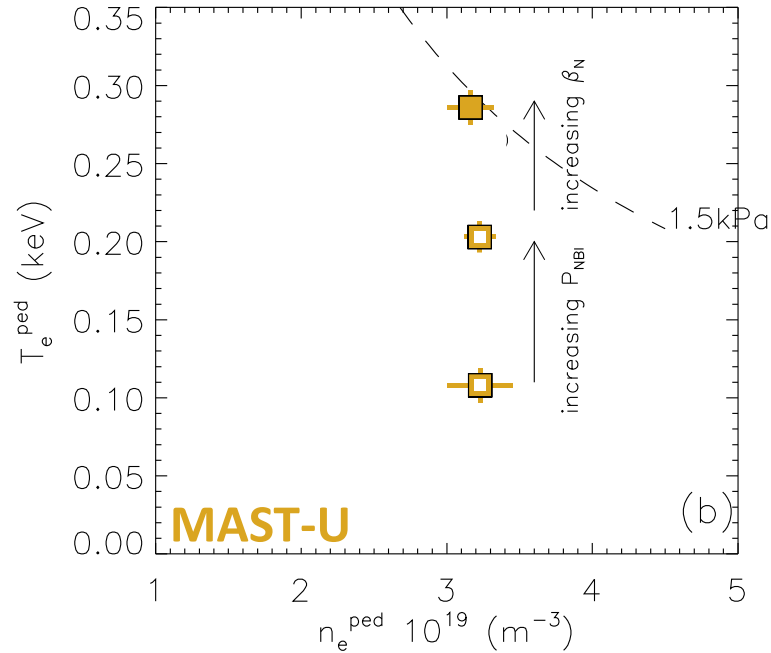
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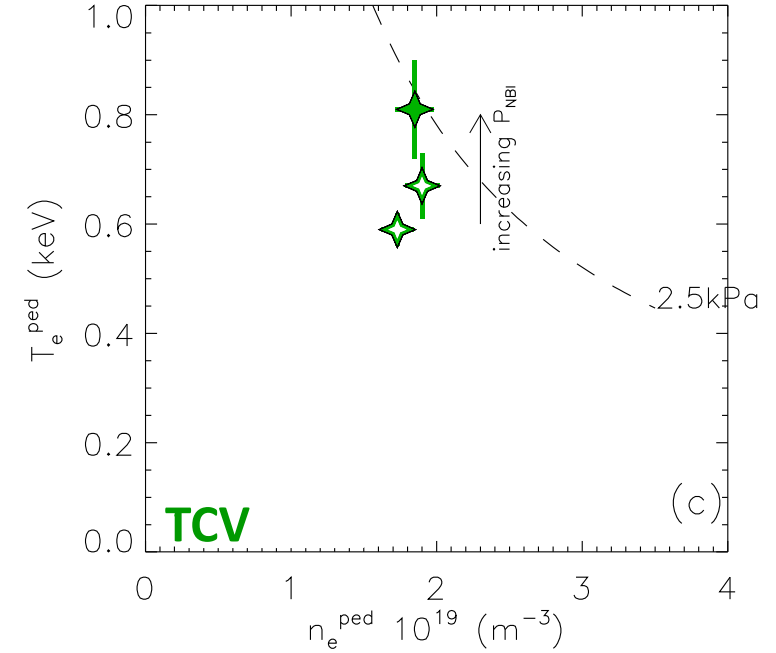
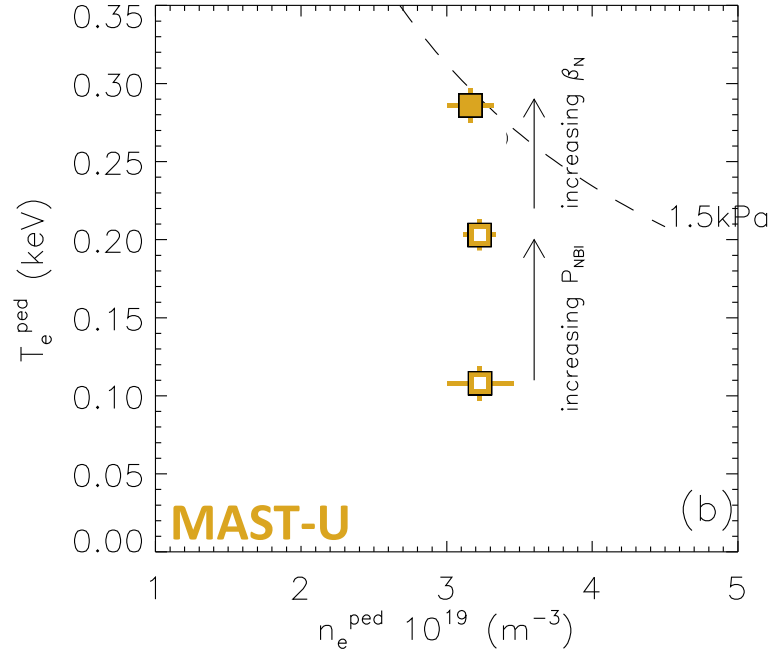
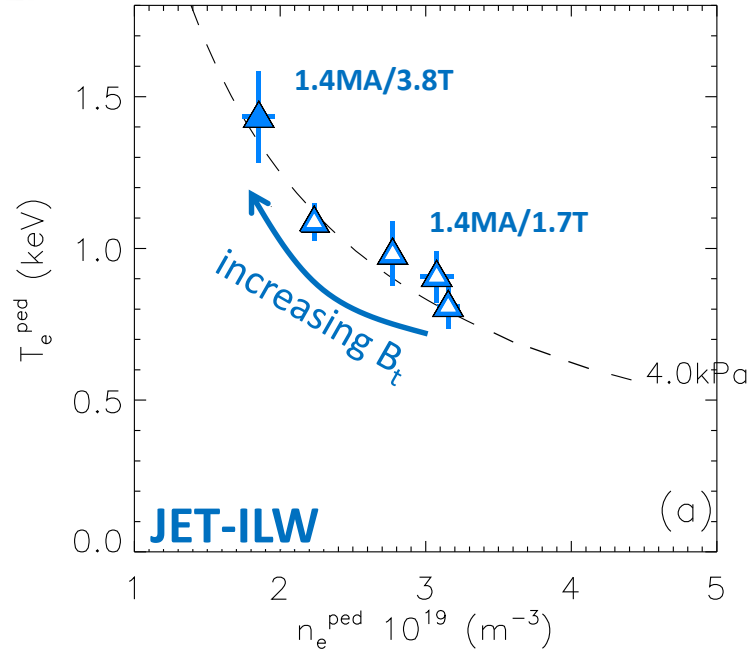
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JET-ILW:

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- $P_{tot} = 25 \text{ MW}$ (max possible power in this scenario)

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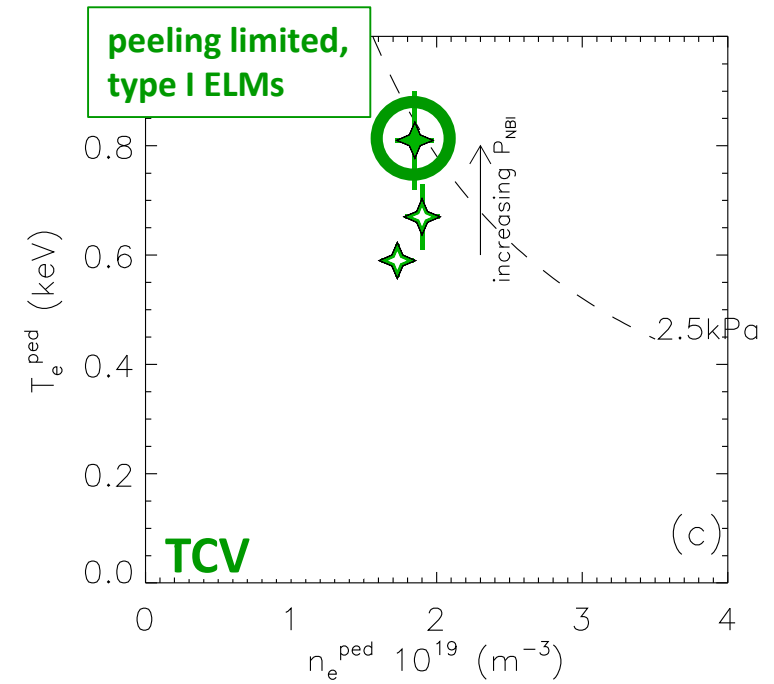
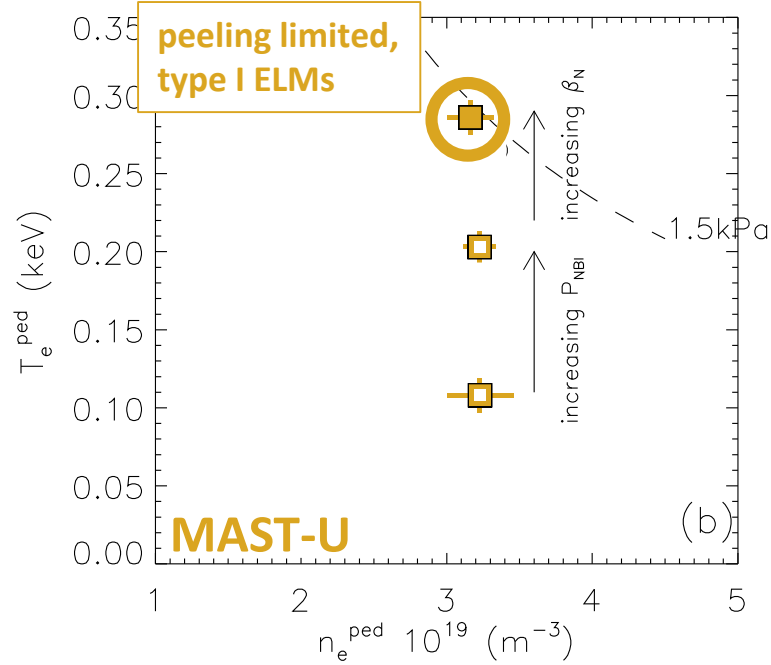
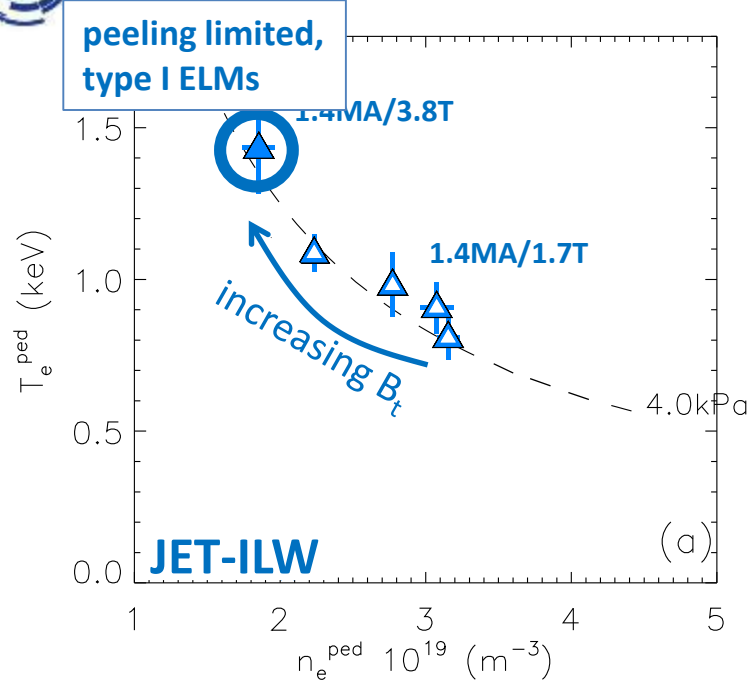
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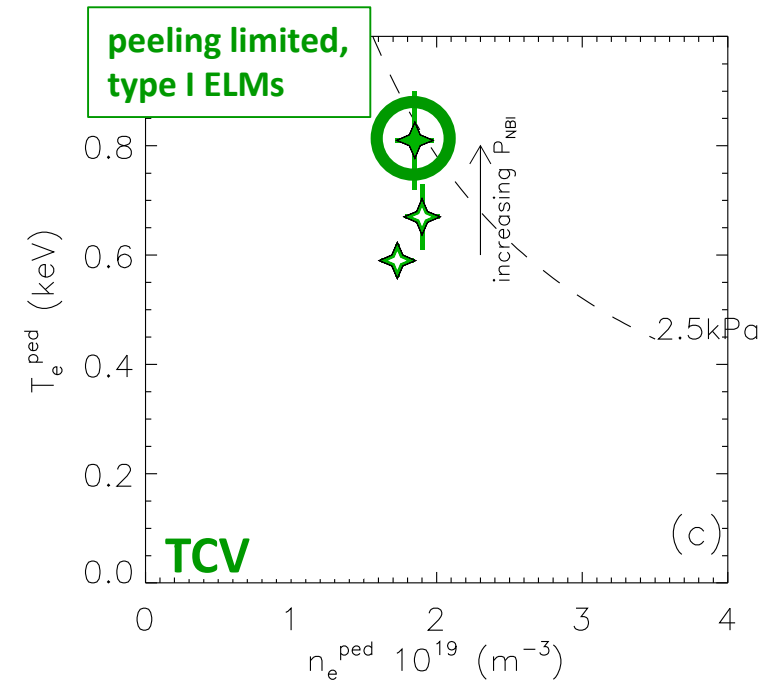
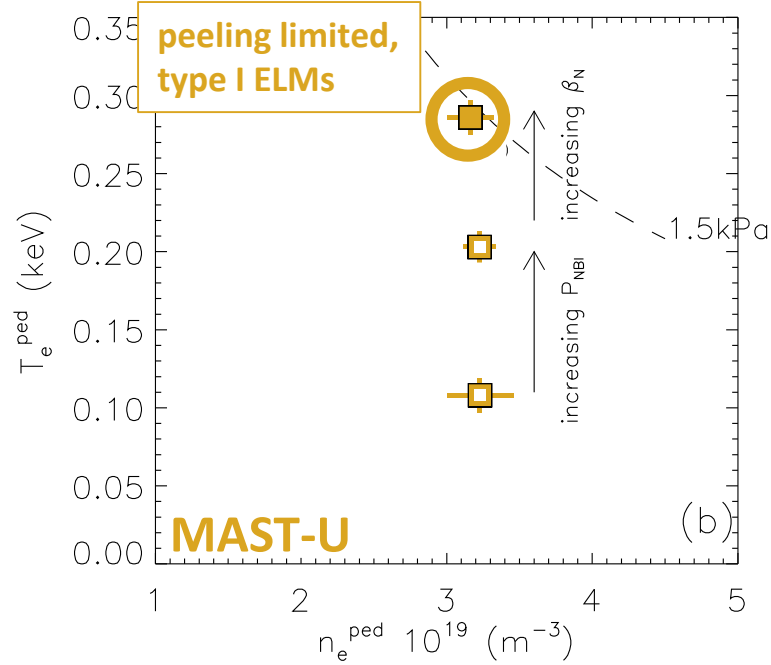
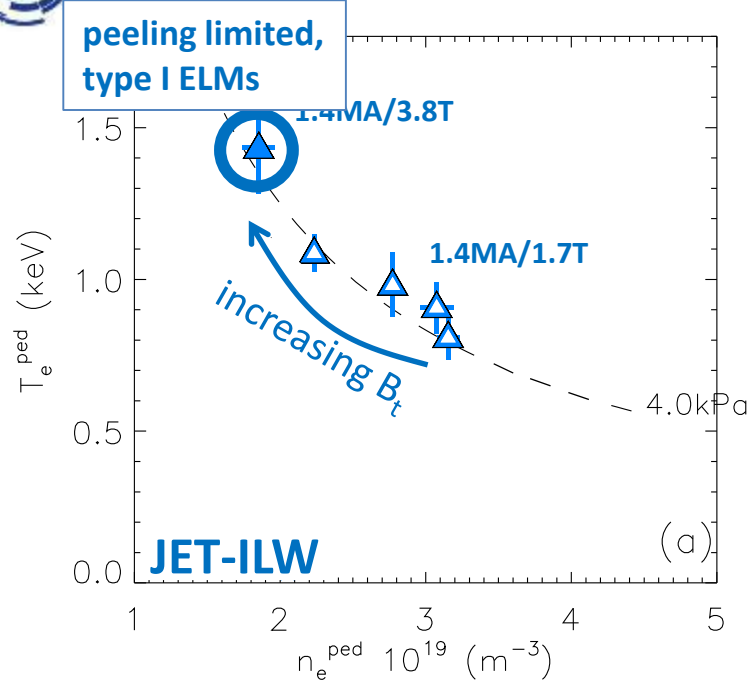
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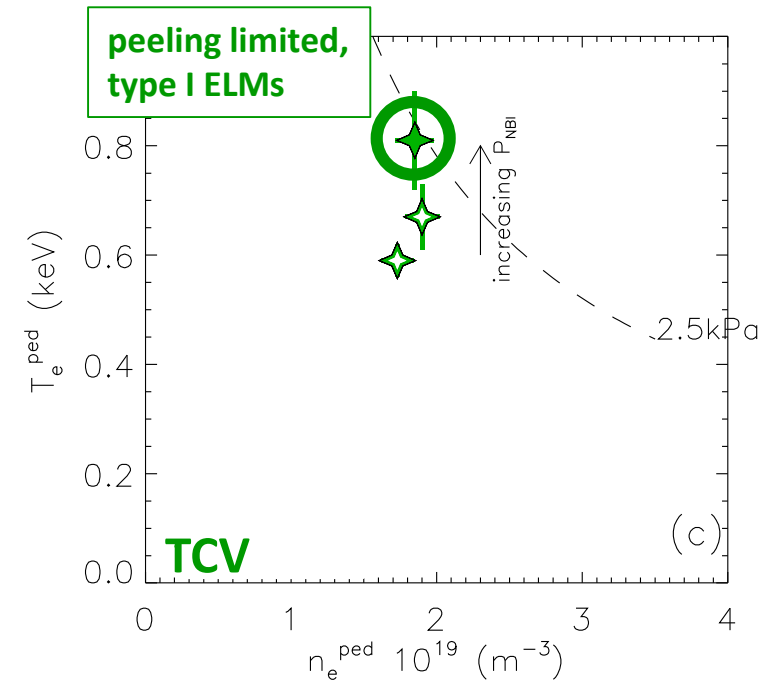
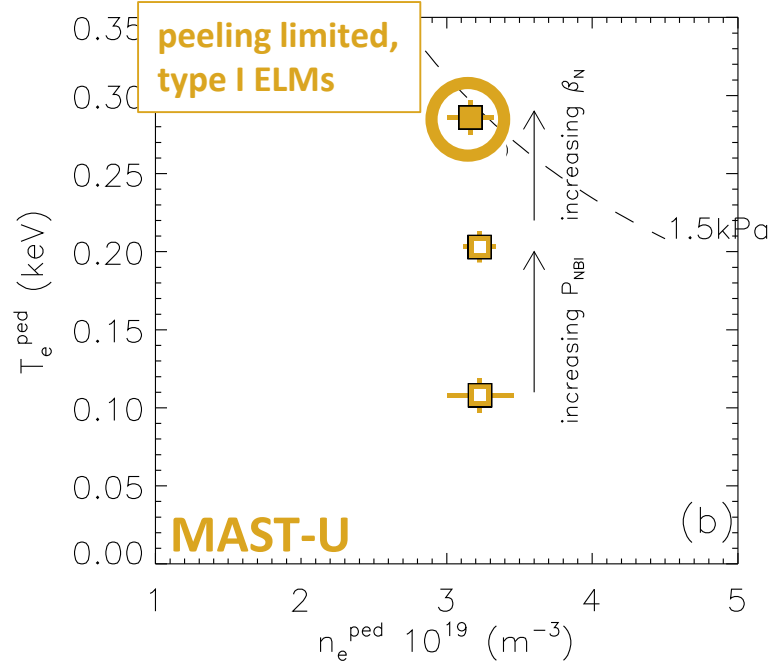
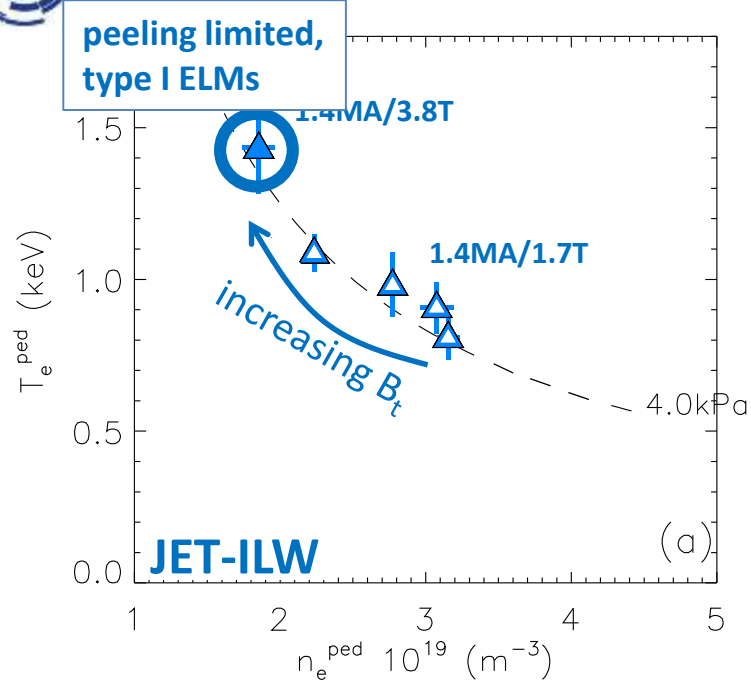
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JET-ILW:

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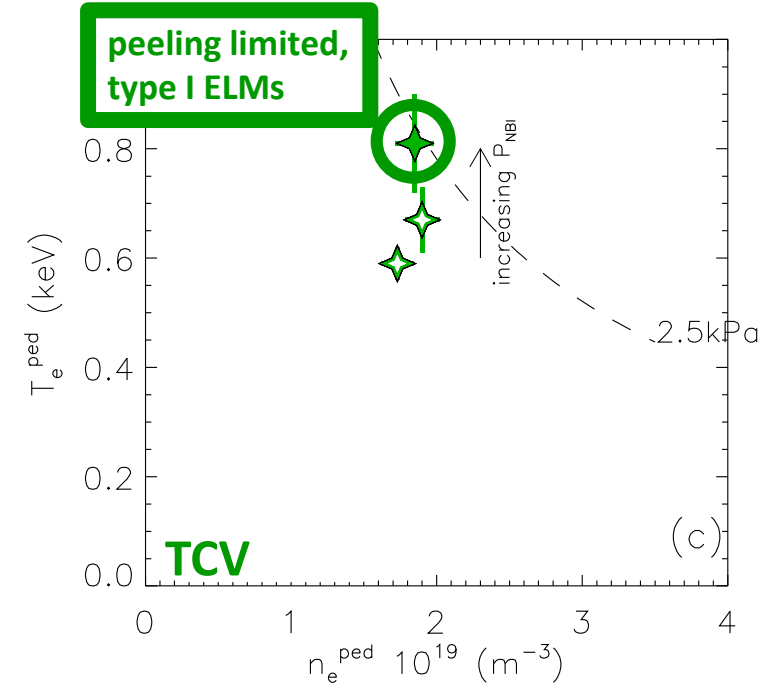
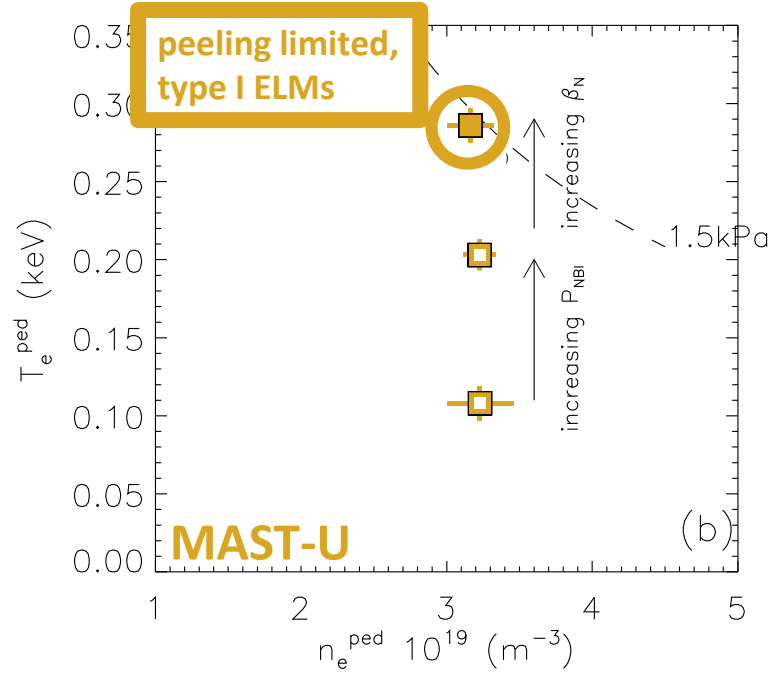
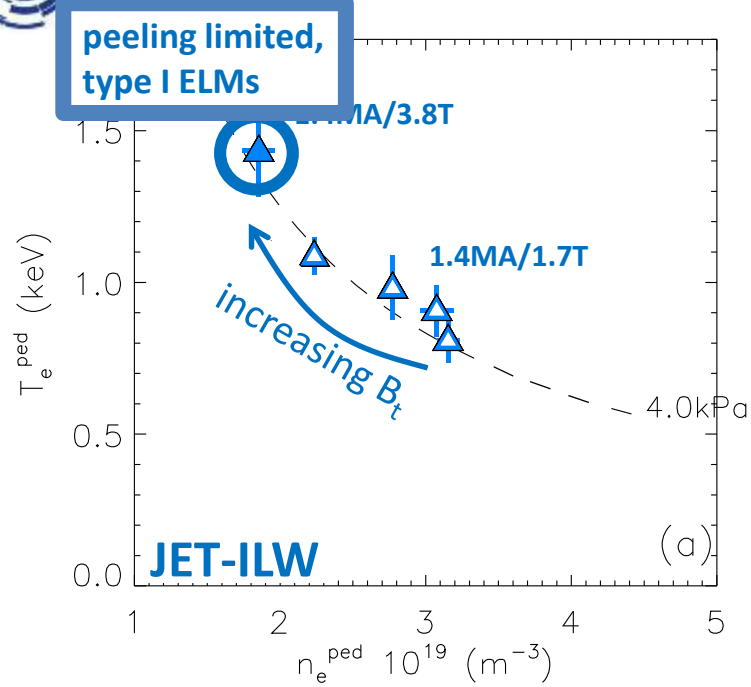
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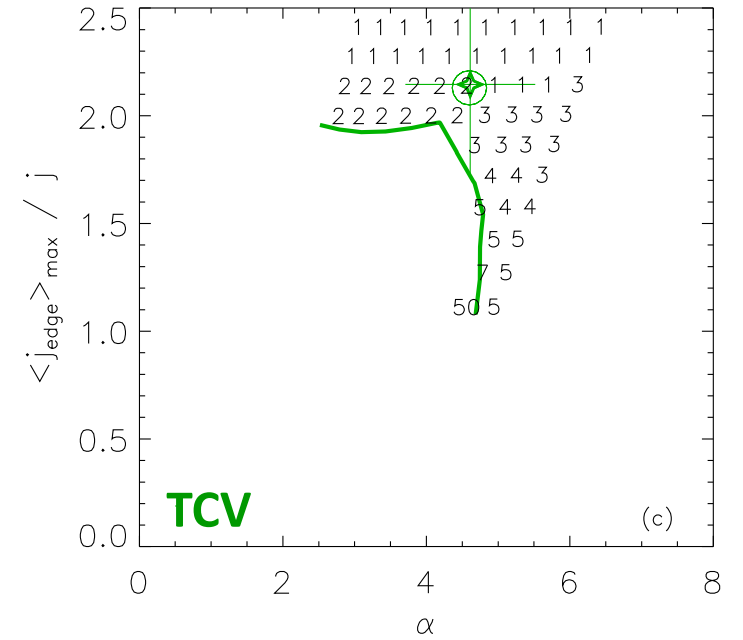
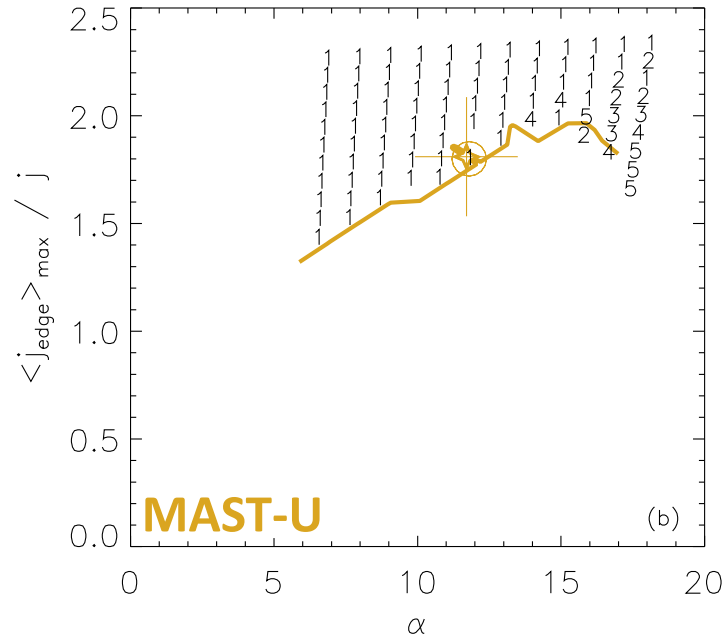
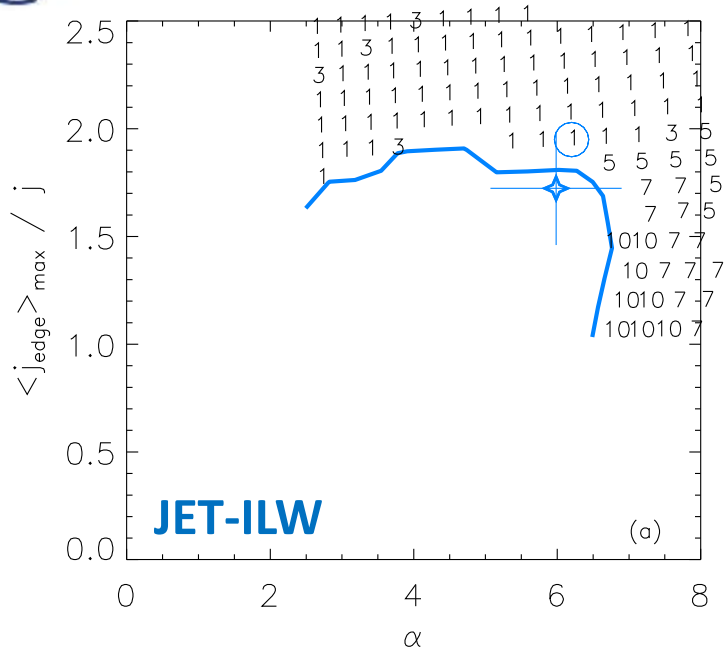
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PEELING LIMITED PEDESTALS REACHED IN JET-ILW, MAST-U AND TCV



JET-ILW:

- Pedestal:
 - near the peeling boundary
 - limited by low- n modes

MAST-U:

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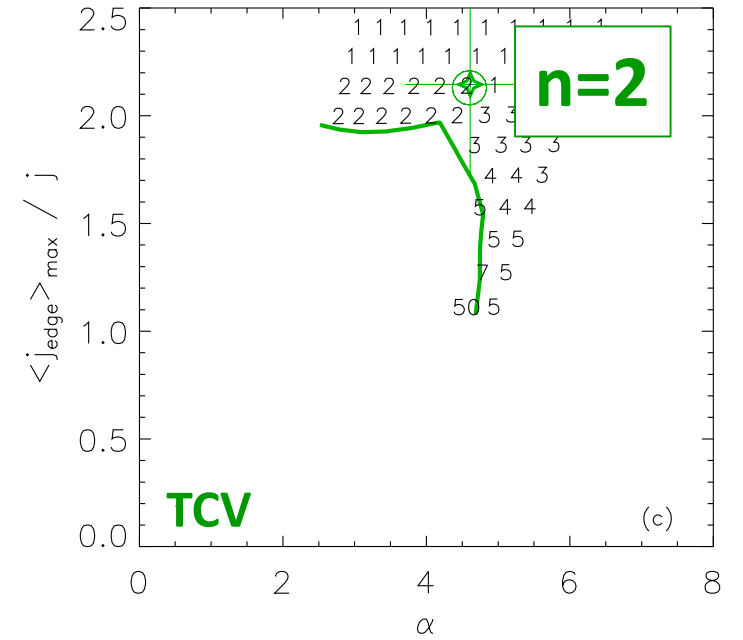
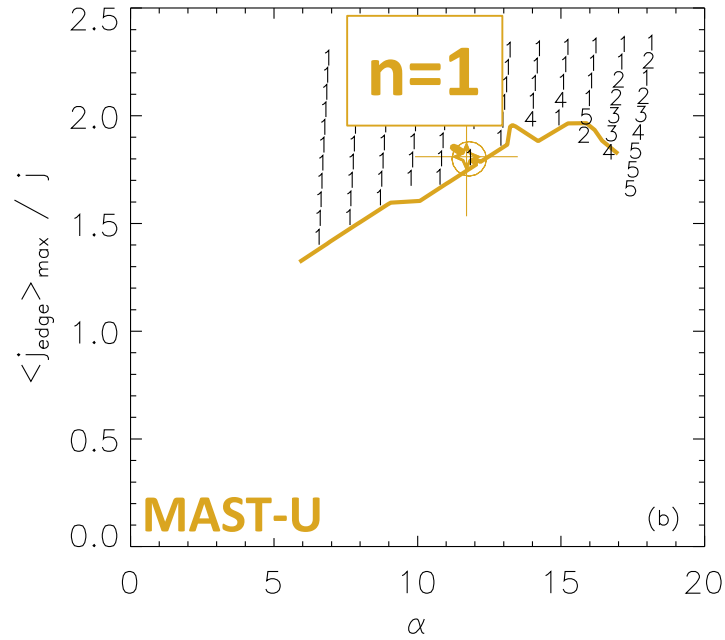
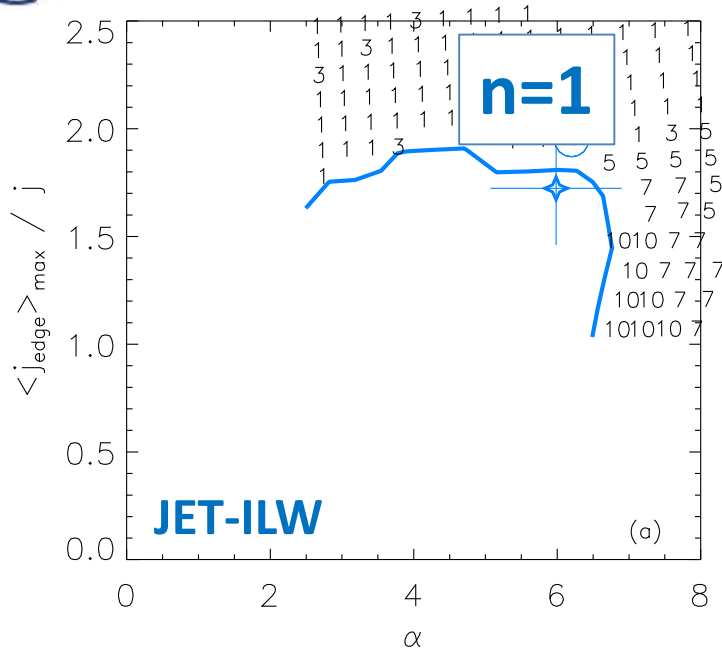
TCV:

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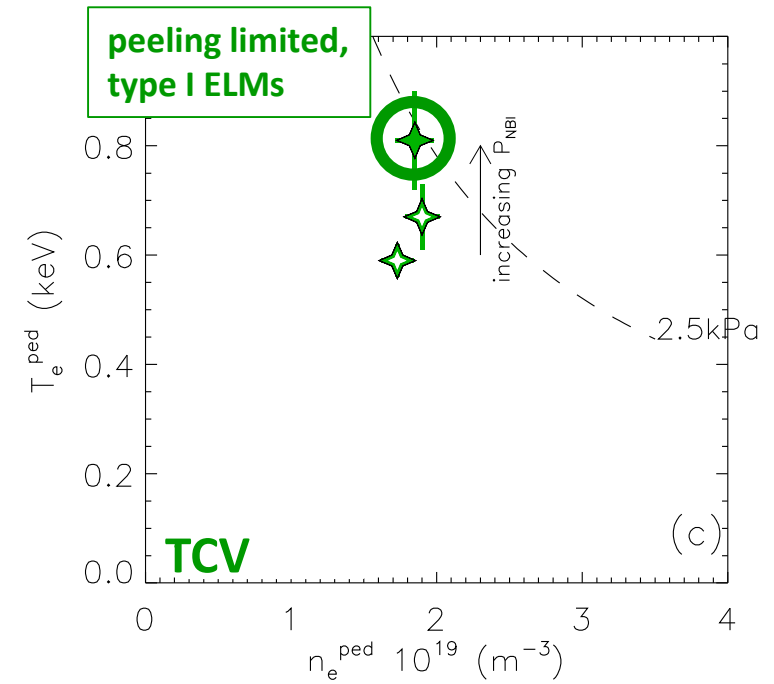
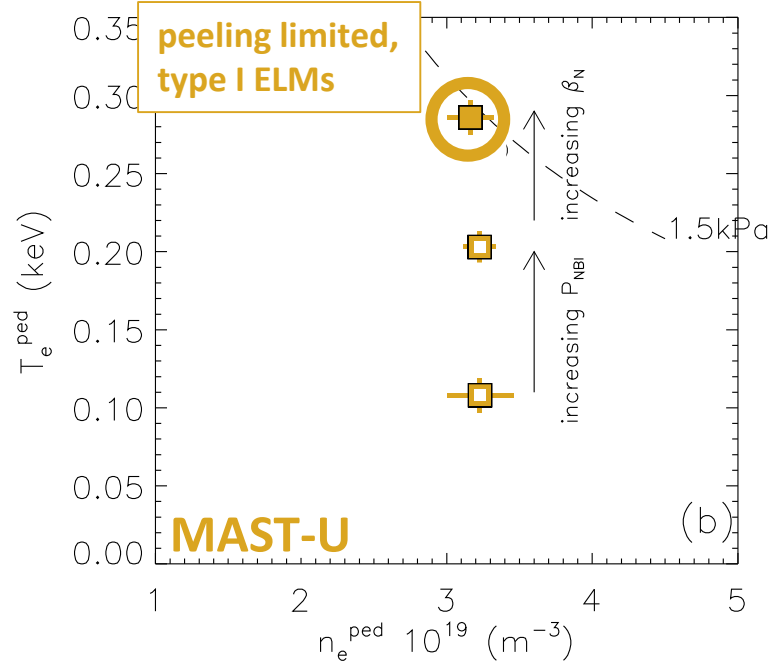
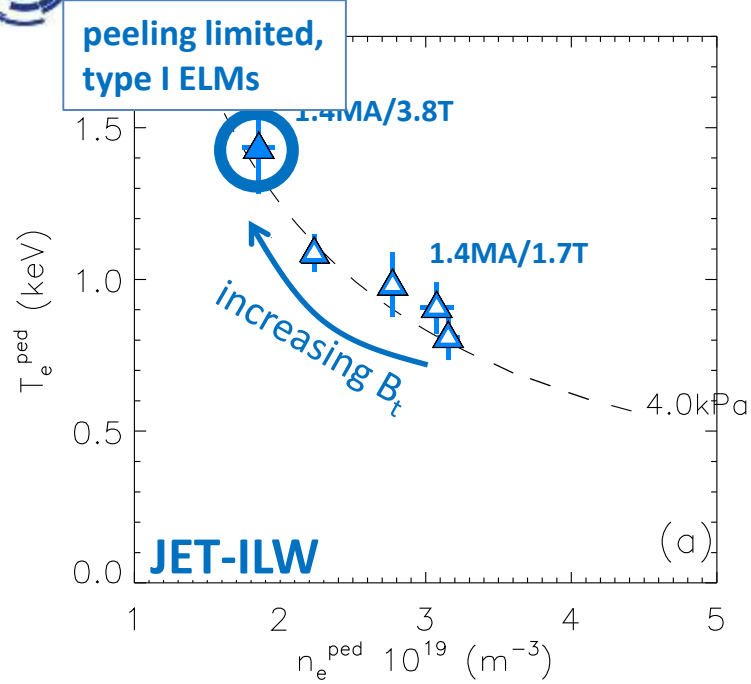
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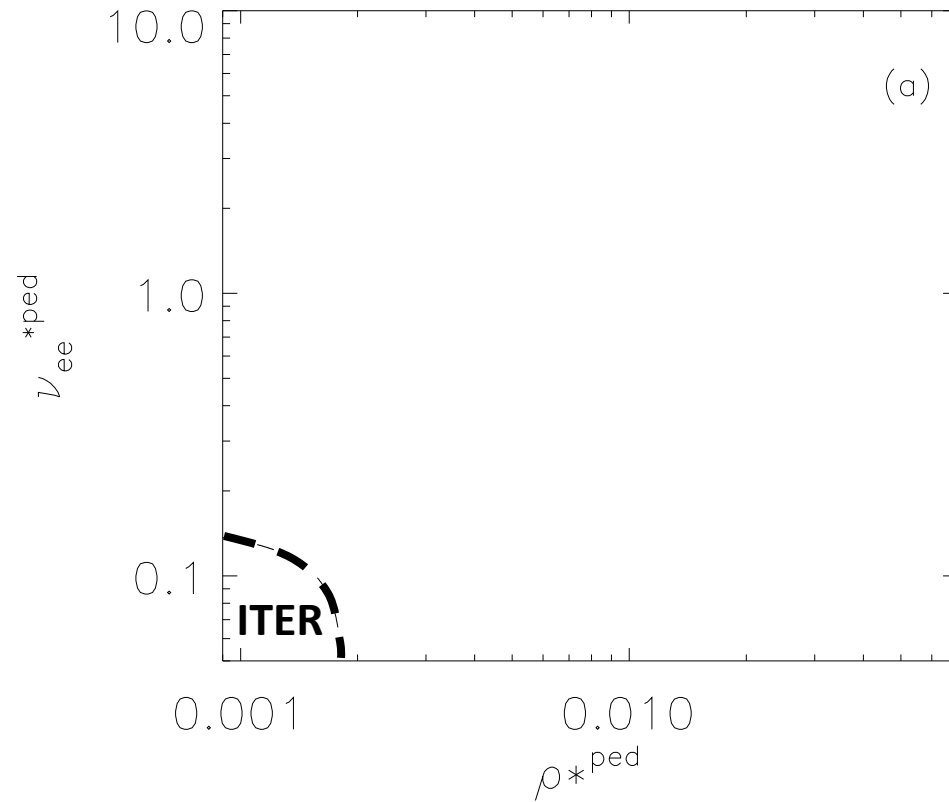


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3. Effect of
 - n_e^{ped} on p_e^{ped} in peeling limited pedestals in JET-ILW, MAST-U and TCV
 - n_e^{sep}/n_e^{ped} on p_e^{ped} in peeling limited pedestals in JET-ILW, MAST-U and TCV
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 - will ITER be limited by peeling or ballooning instabilities?
 - Is a transition from peeling to ballooning limited pedestals a problem?



THE DATASETS

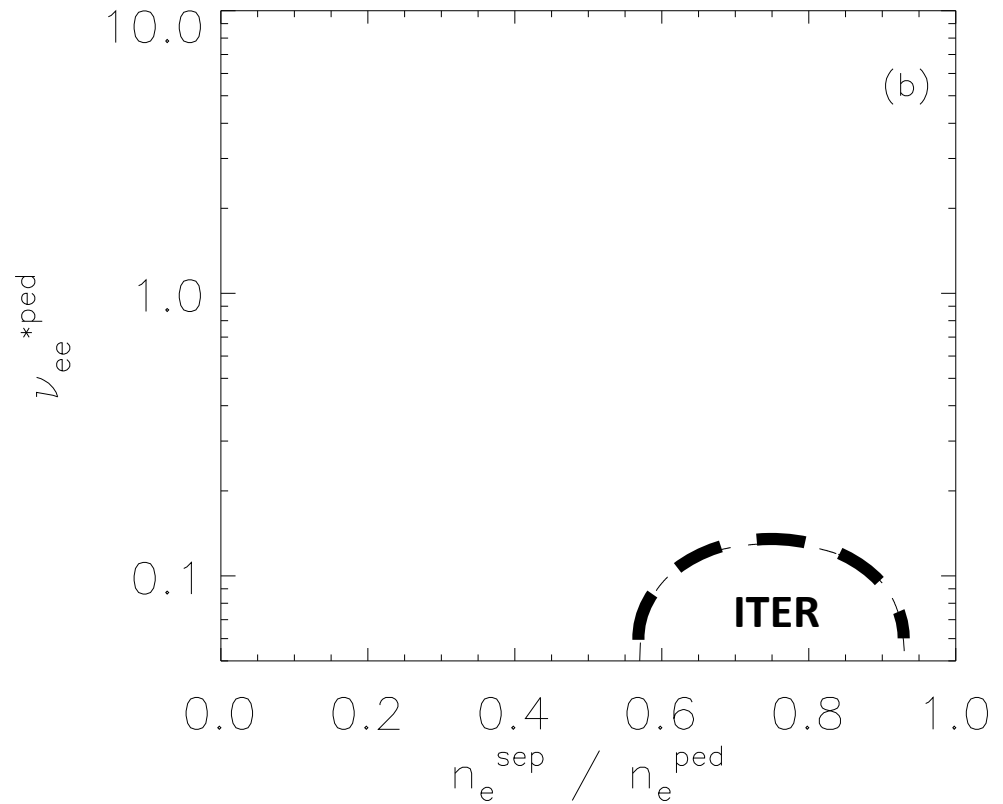


JET-ILW:

- $\langle \delta \rangle = 0.4$
- $1.4\text{MA}/3.8\text{T}, q_{95} = 8.5$
- $P_{NBI} = 25\text{MW}$

MAST-U:

- $\langle \delta \rangle = 0.5$
- $750\text{kA}/0.5\text{T}, q_{95} = 6.7$
- $P_{NBI} = 3.2\text{MW}$

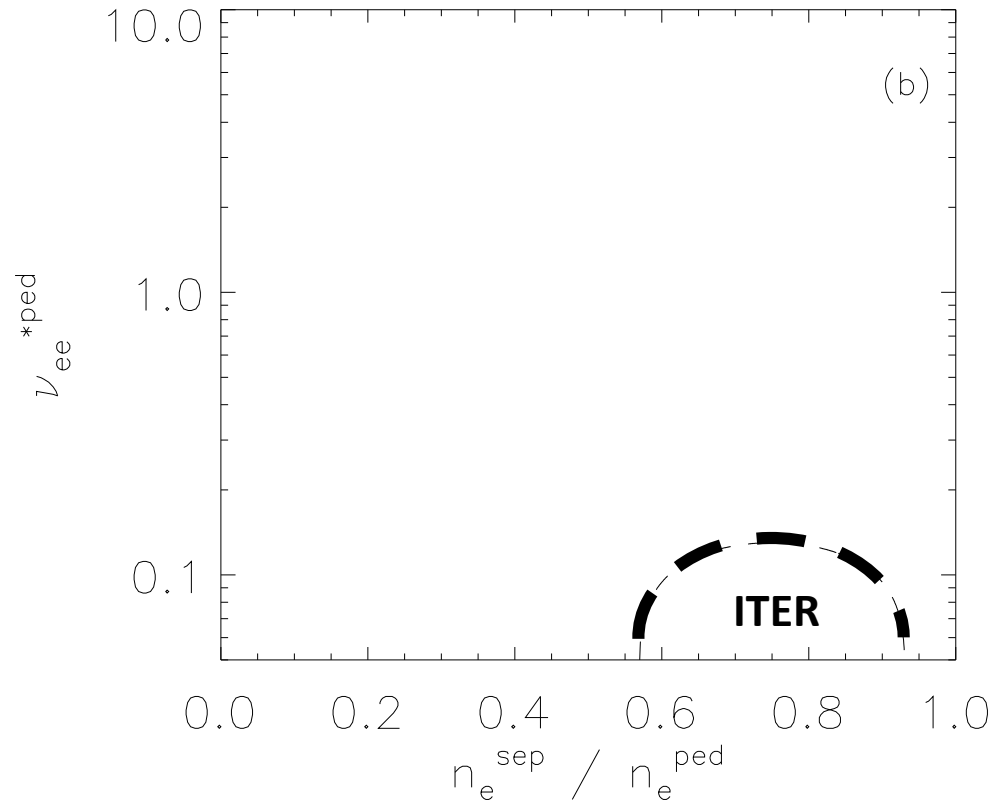
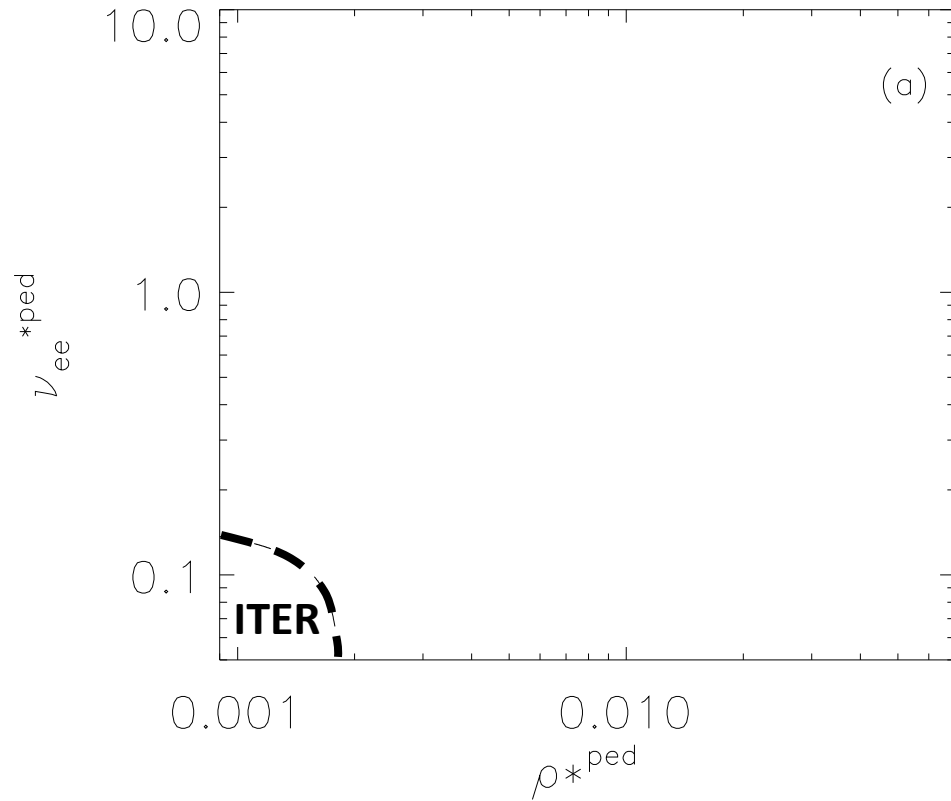


TCV:

- $\langle \delta \rangle = 0.5$
- $155\text{kA}/1.4\text{T}, q_{95} = 5.0$
- $P_{NBI} + P_{ECRH} = 1.0 + 1.1\text{MW}$



THE DATASETS



JET-ILW:

- $\langle \delta \rangle = 0.4$
- $1.4\text{MA}/3.8\text{T}, q_{95} = 8.5$
- $P_{NBI} = 25\text{MW}$
- **Gas scan**

MAST-U:

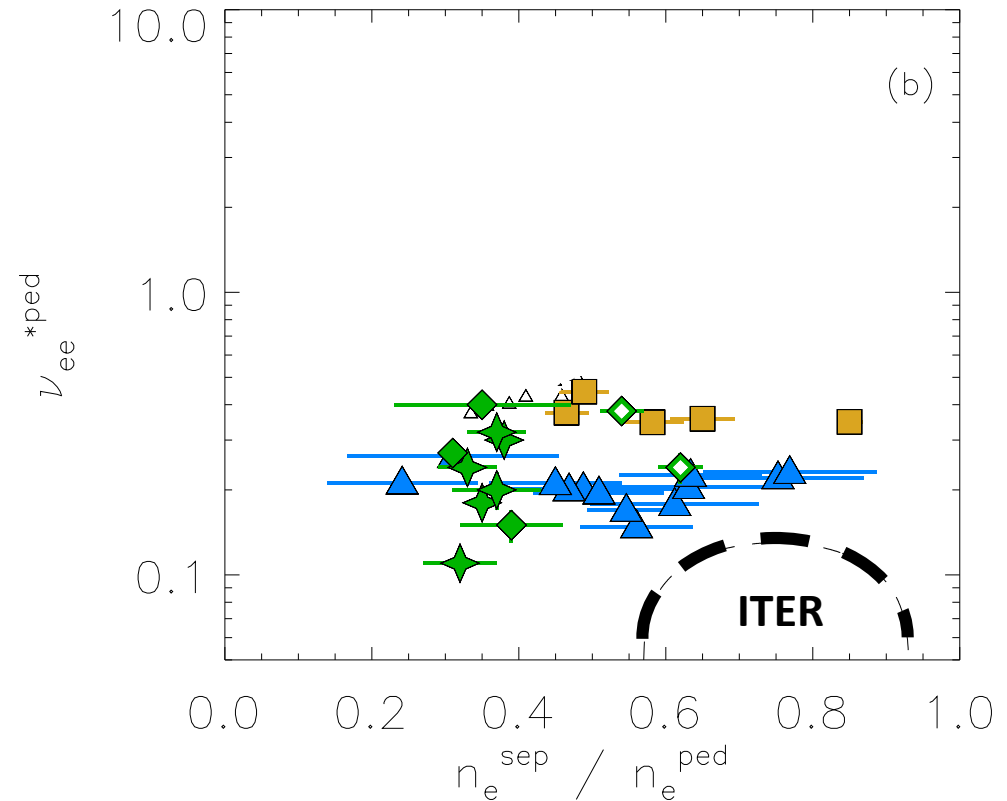
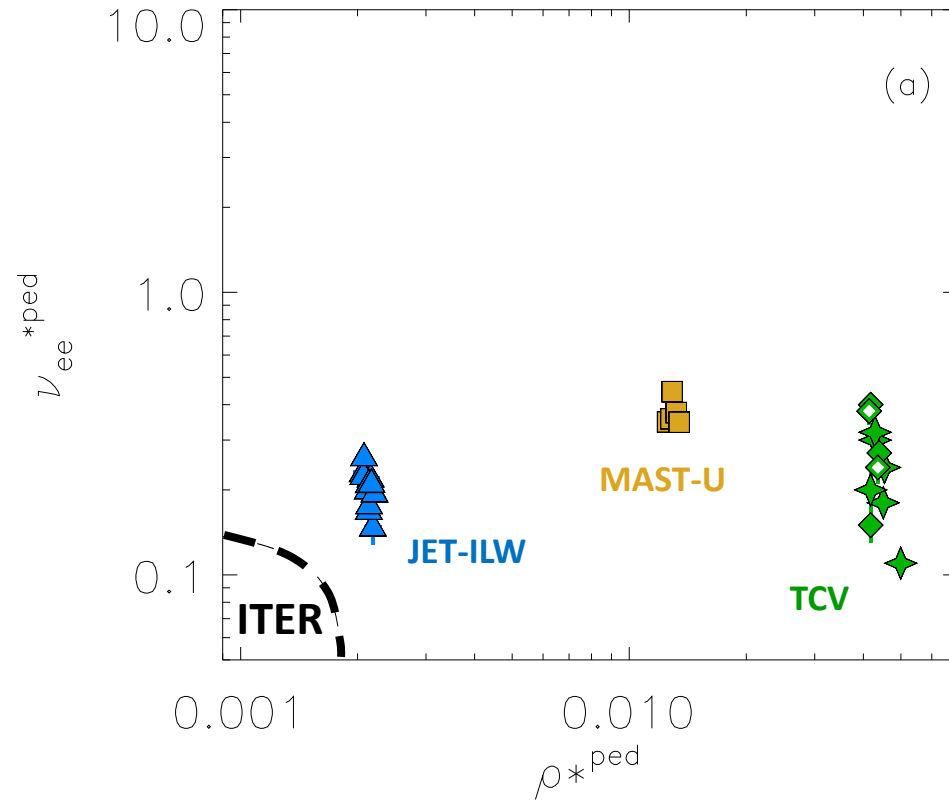
- $\langle \delta \rangle = 0.5$
- $750\text{kA}/0.5\text{T}, q_{95} = 6.7$
- $P_{NBI} = 3.2\text{MW}$
- **Gas scan**

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- **Gas scan**



THE DATASETS: ITER ranges approached for JET-ILW



JET-ILW:

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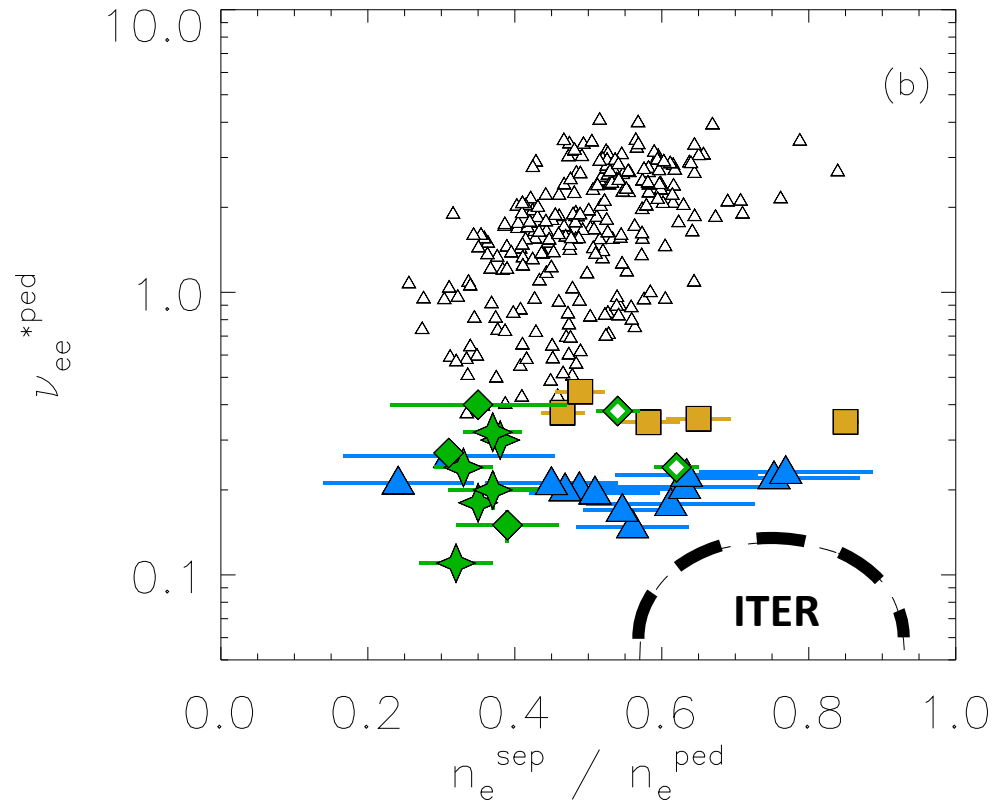
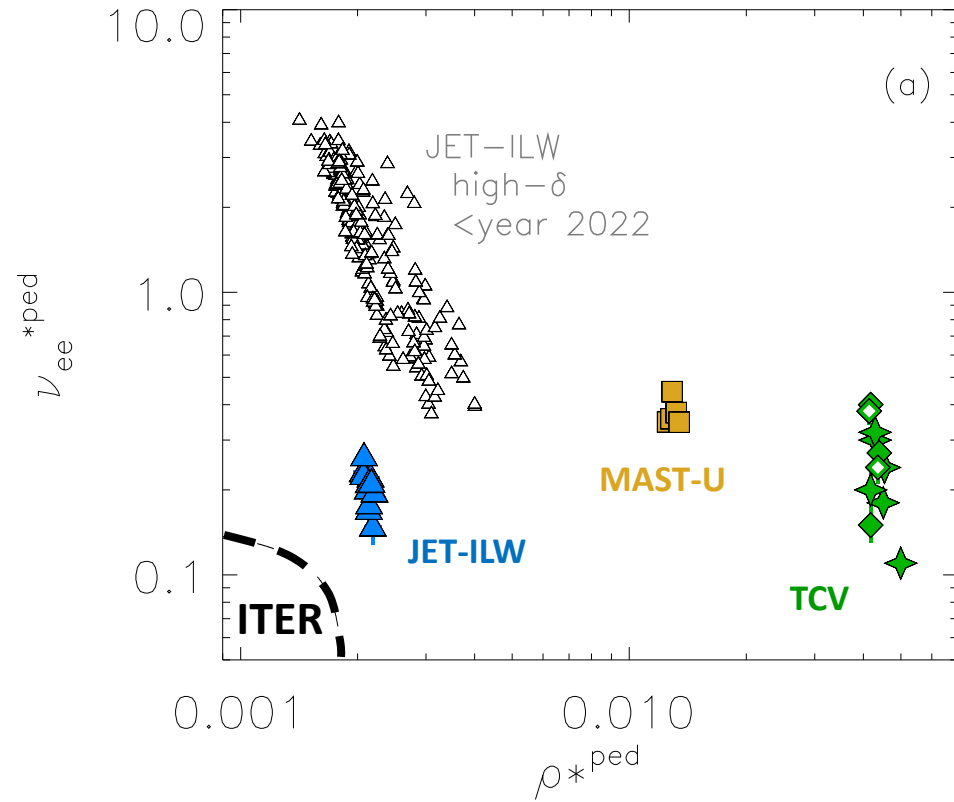
TCV:

- $\langle \delta \rangle = 0.5$
- $155\text{kA}/1.4\text{T}$
- $P_{NBI} + P_{ECRH} = 1.0 + 1.1\text{MW}$
- Gas scan

→ approached ITER $\nu_{ee}^{*ped}, \rho_i^{*ped}, n_e^{sep}/n_e^{ped}$



THE DATASETS: ITER ranges approached for JET-ILW



JET-ILW:

- $\langle \delta \rangle = 0.4$
- $1.4\text{MA}/3.8\text{T}$, $q_{95} = 8.5$
- $P_{NBI} = 25\text{MW}$
- Gas scan

→ approached ITER v_{ee}^{*ped} , ρ_i^{*ped} , n_e^{sep} / n_e^{ped}

MAST-U:

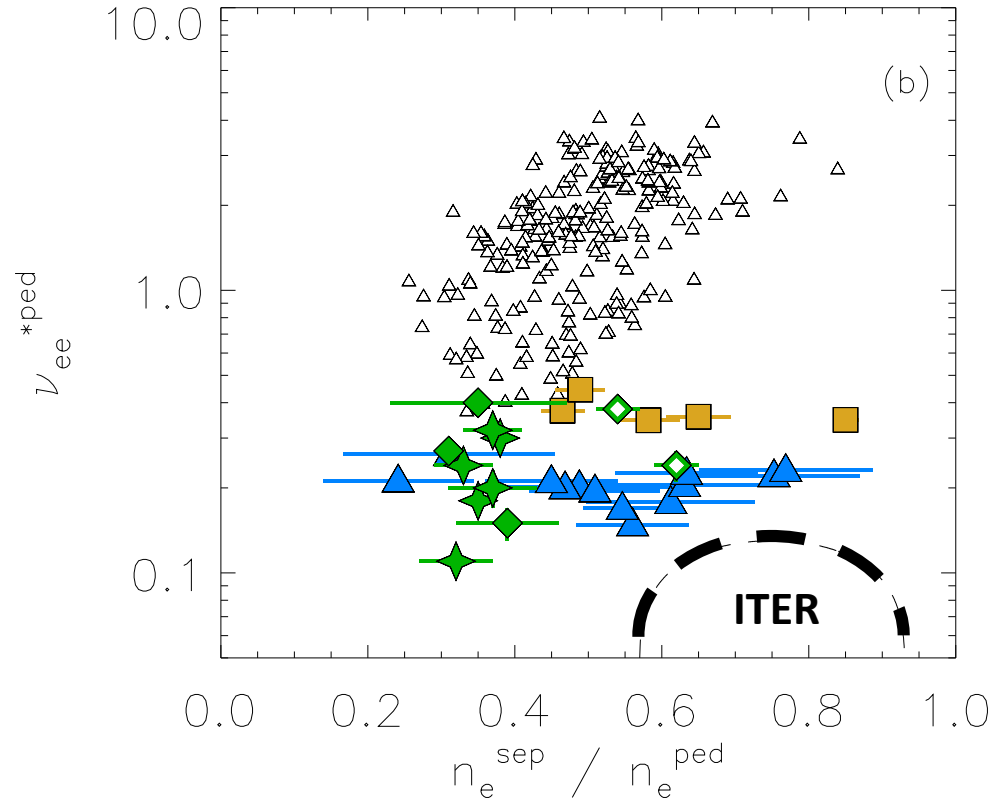
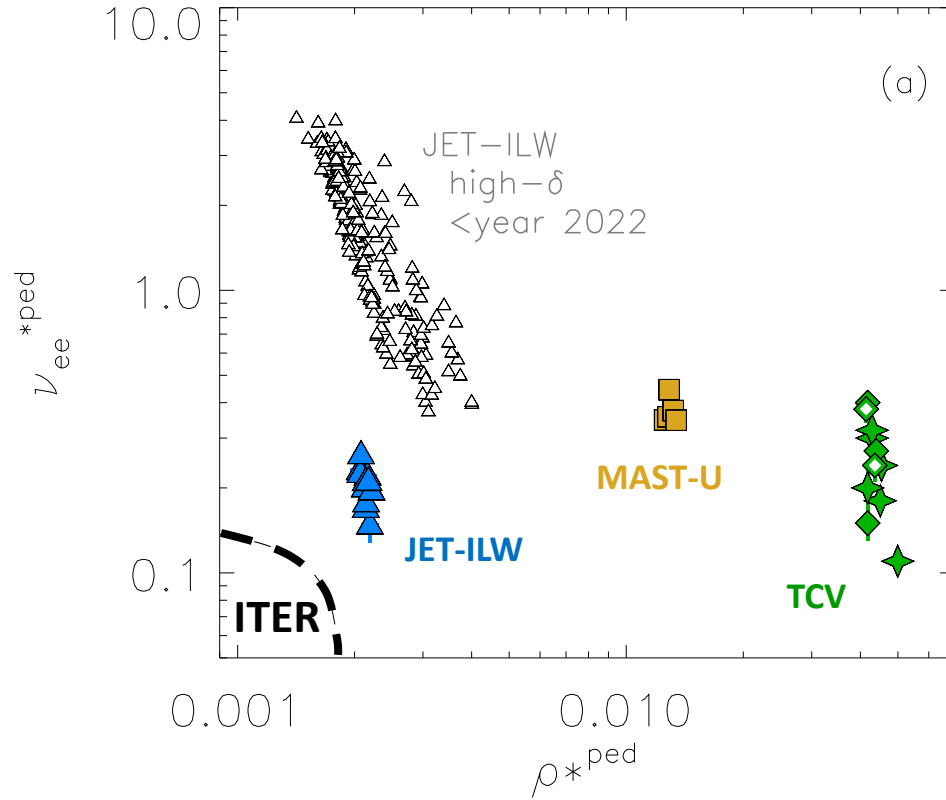
- $\langle \delta \rangle = 0.5$
- $750\text{kA}/0.5\text{T}$, $q_{95} = 6.7$
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- Gas scan

TCV:

- $\langle \delta \rangle = 0.5$
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THE DATASETS: ITER ranges approached for JET-ILW



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TCV:

- $\langle \delta \rangle = 0.5$
- 155kA/1.4T
- $P_{NBI} + P_{ECRH} = 1.0 + 1.1MW$
- Gas scan

approaching ITER ν_{ee}^{*ped} , ρ_i^{*ped}

→ approached ITER ν_{ee}^{*ped} , ρ_i^{*ped} , n_e^{sep} / n_e^{ped}

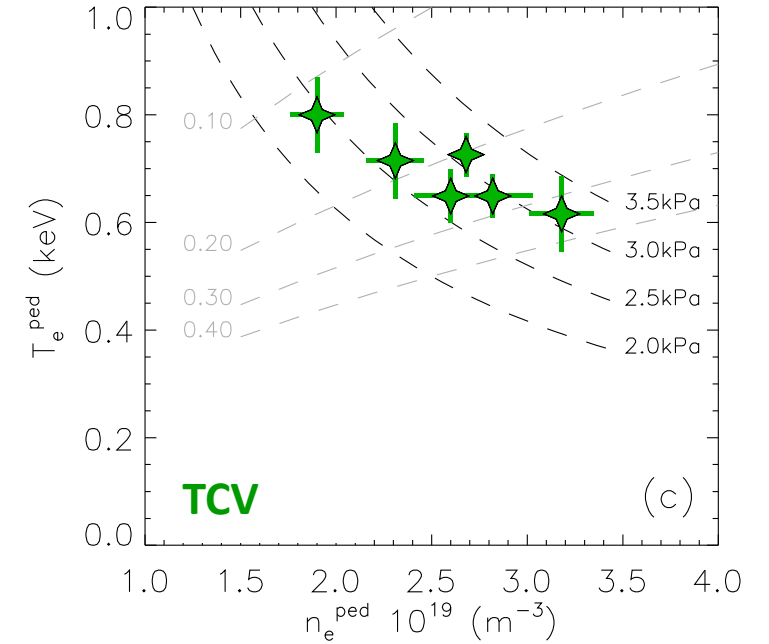
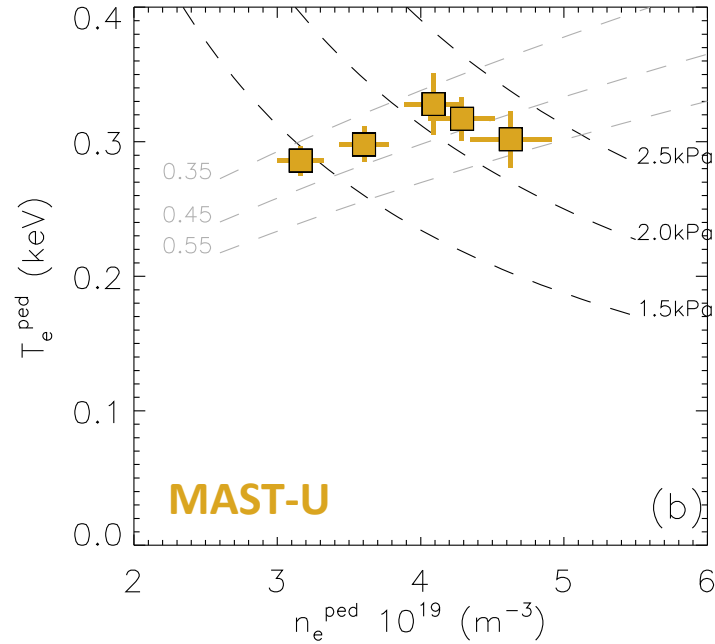
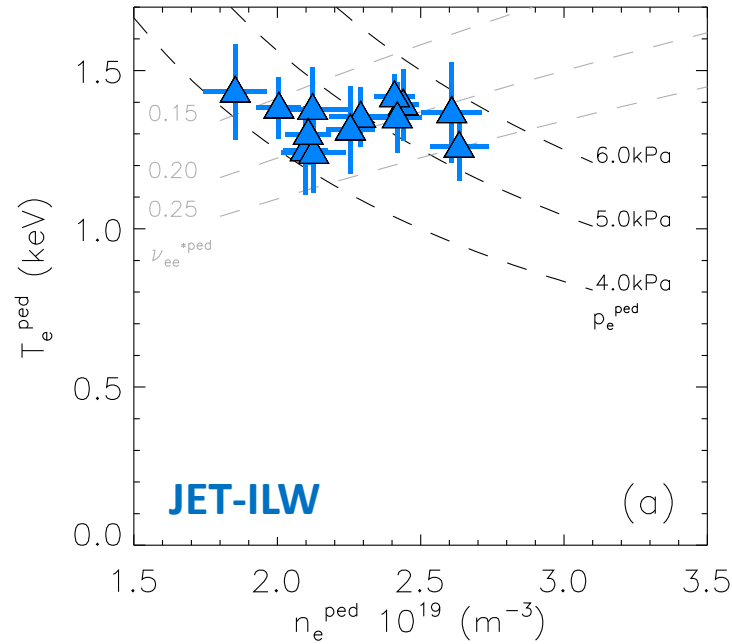


OUTLINE

1. Reaching peeling limited pedestals in JET-ILW, MAST-U and TCV
2. The datasets
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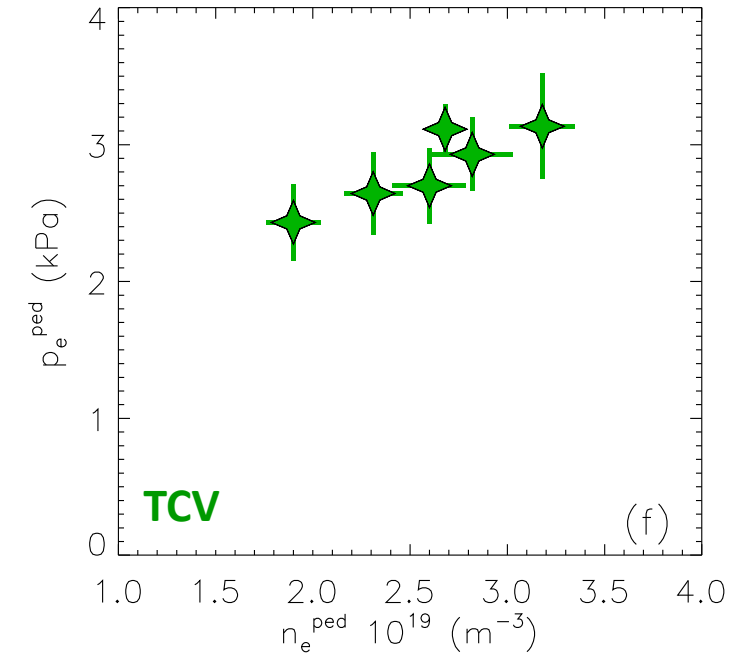
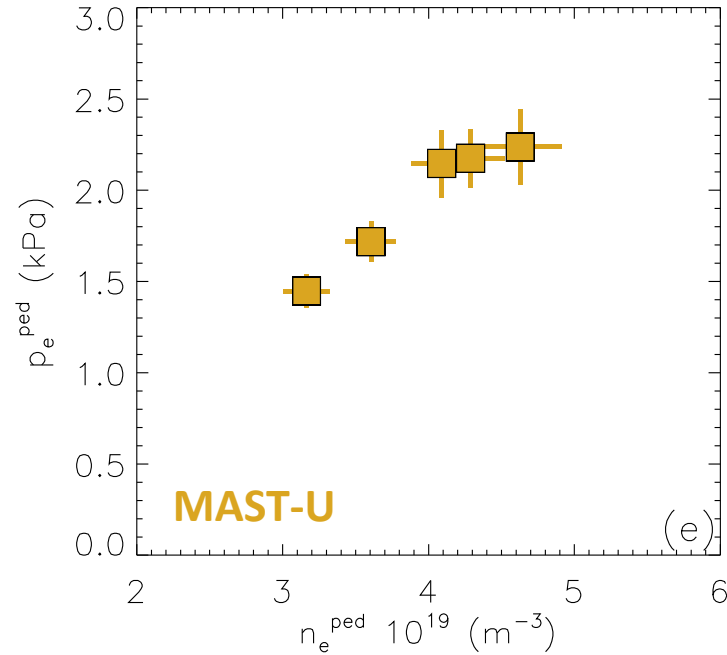
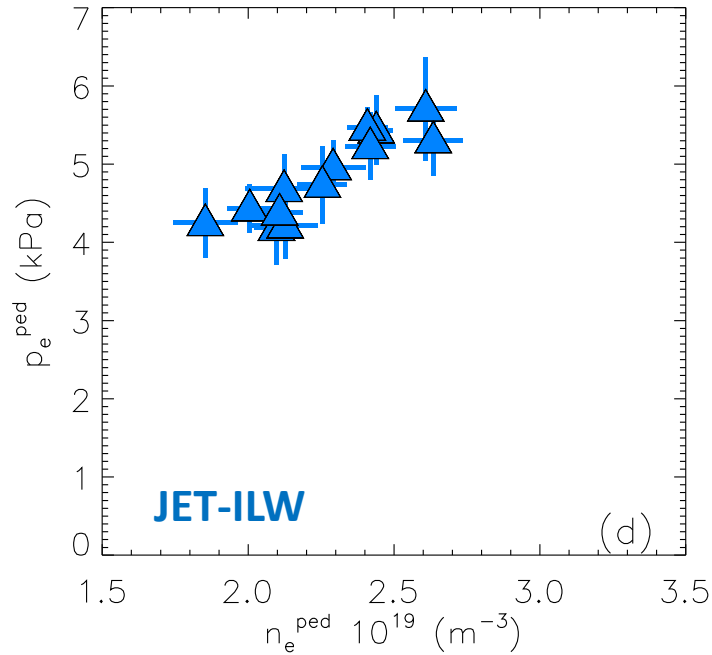
Pedestal pressure increases with increasing n_e^{ped}



- With increasing n_e^{ped} :
 - T_e^{ped} is not strongly affected (same for T_i^{ped})



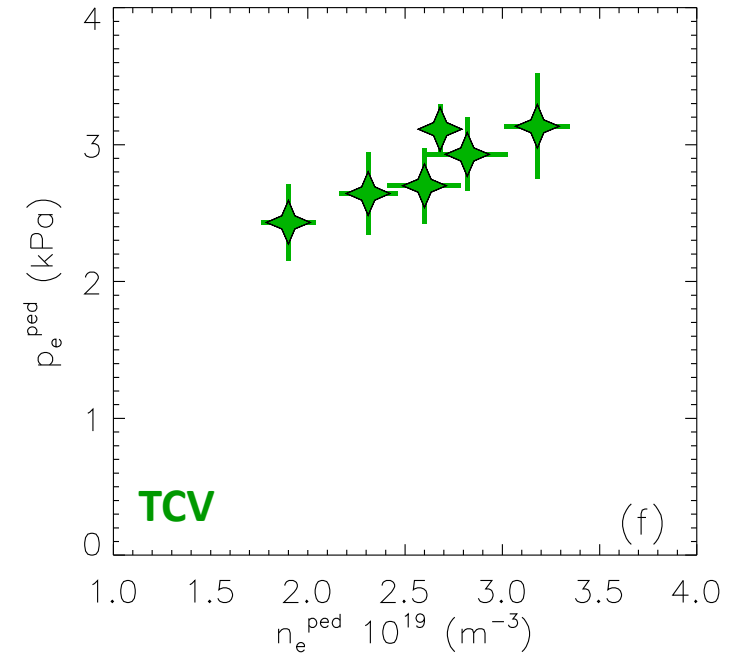
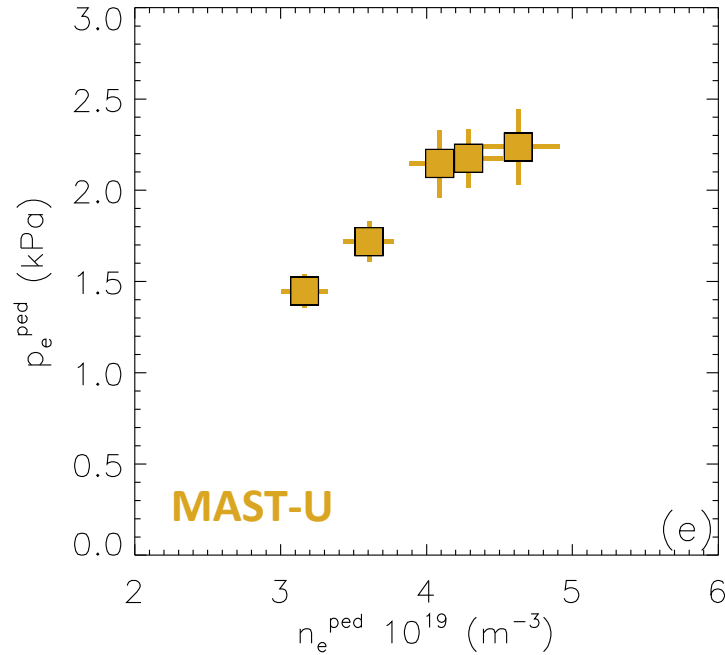
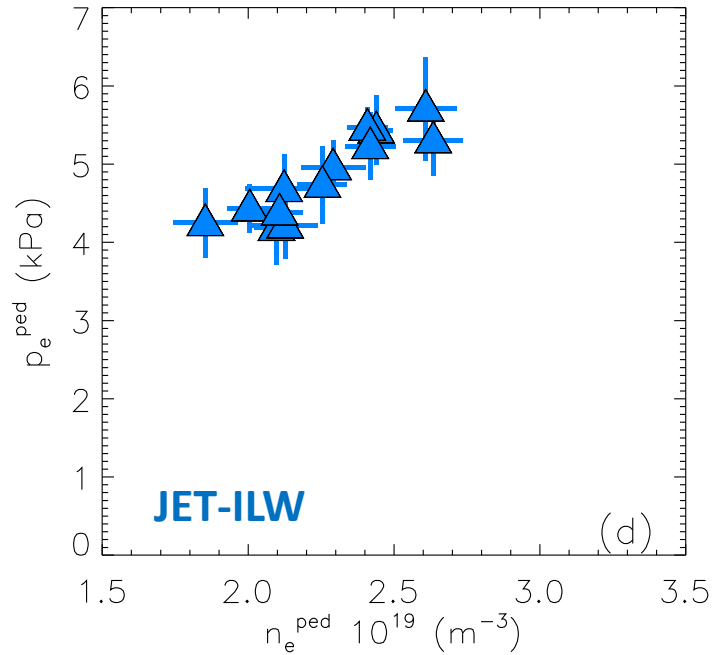
Pedestal pressure increases with increasing n_e^{ped}



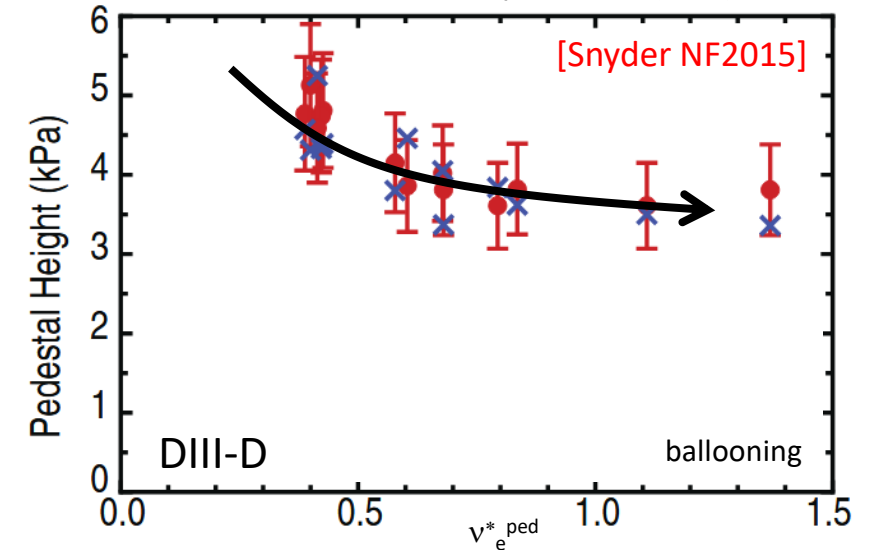
- With increasing n_e^{ped} :
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} increases (same for p_{tot}^{ped})



Pedestal pressure increases with increasing n_e^{ped}

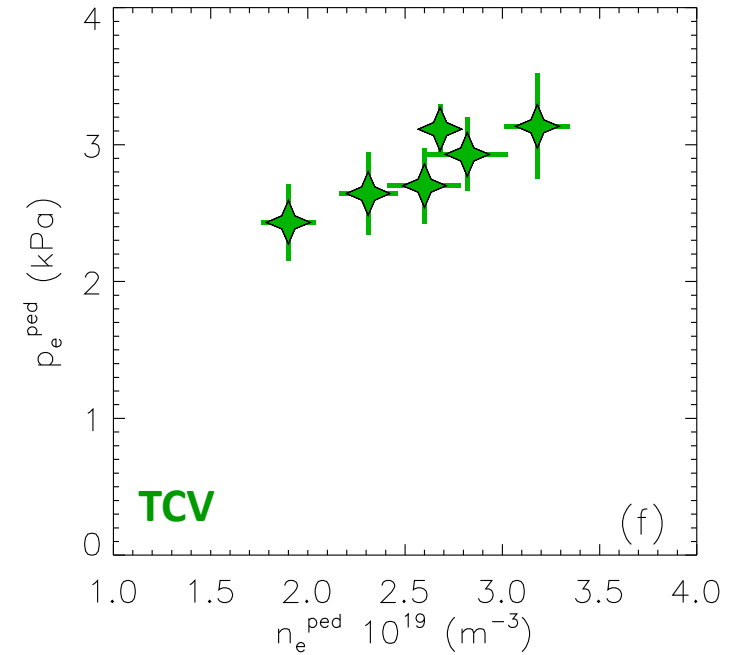
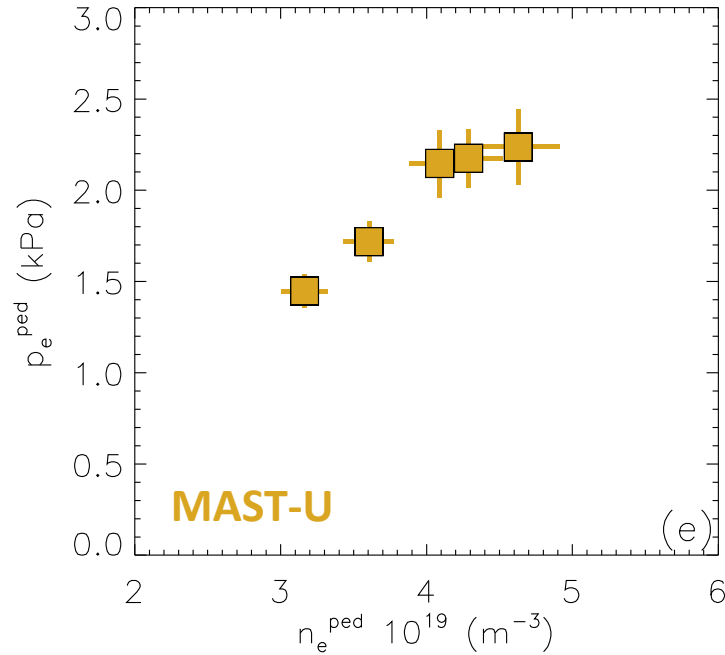
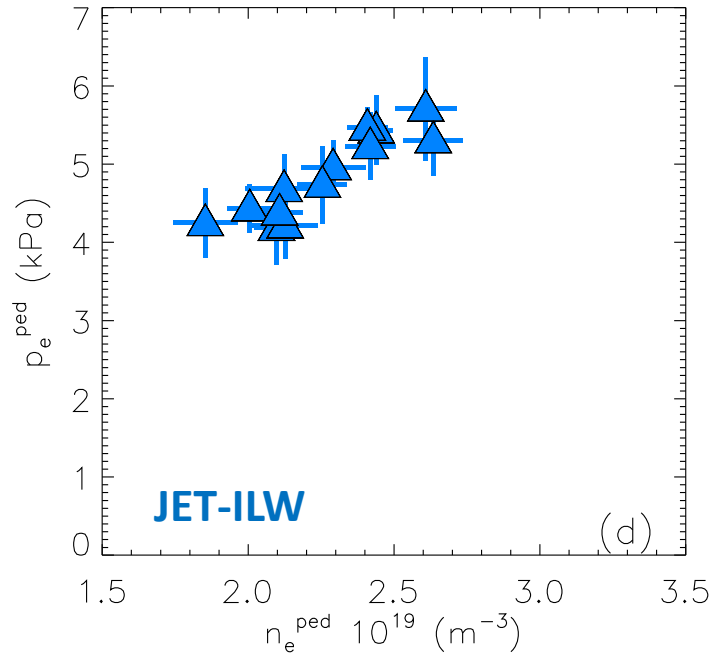


- With increasing n_e^{ped} :
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} increases (same for p_{tot}^{ped})
 - behavior opposite to what observed in ballooning limited pedestals





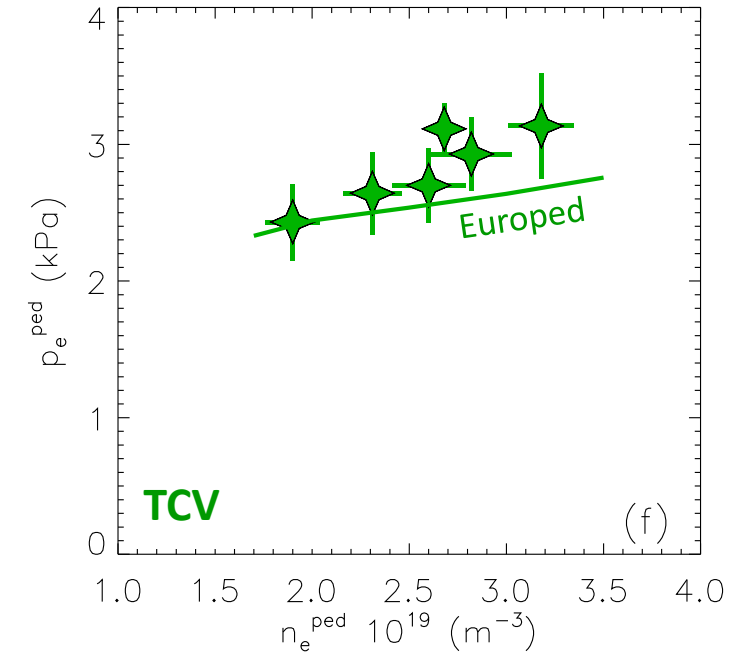
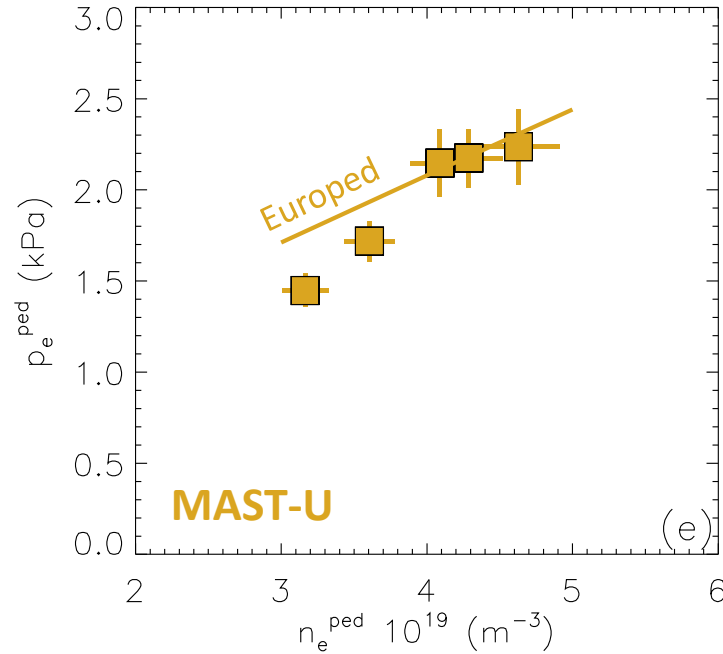
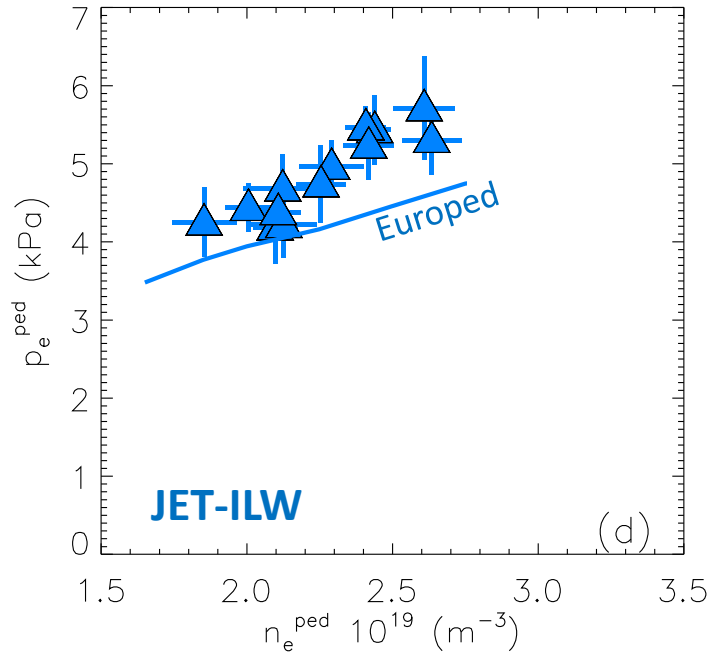
Pedestal pressure increases with increasing n_e^{ped}



- With increasing n_e^{ped} :
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
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 - behavior opposite to what observed in ballooning limited pedestals
- Pedestal predictions:
 - Europed [Saarelma PPCF2018] implementing the EPED1 width scaling $w_p = k \sqrt{\beta_\theta^{ped}}$ (with $k = 0.076$ for JET-ILW, $k = 0.11$ for MAST-U, $k = 0.15$ for TCV)



Pedestal pressure increases with increasing n_e^{ped}



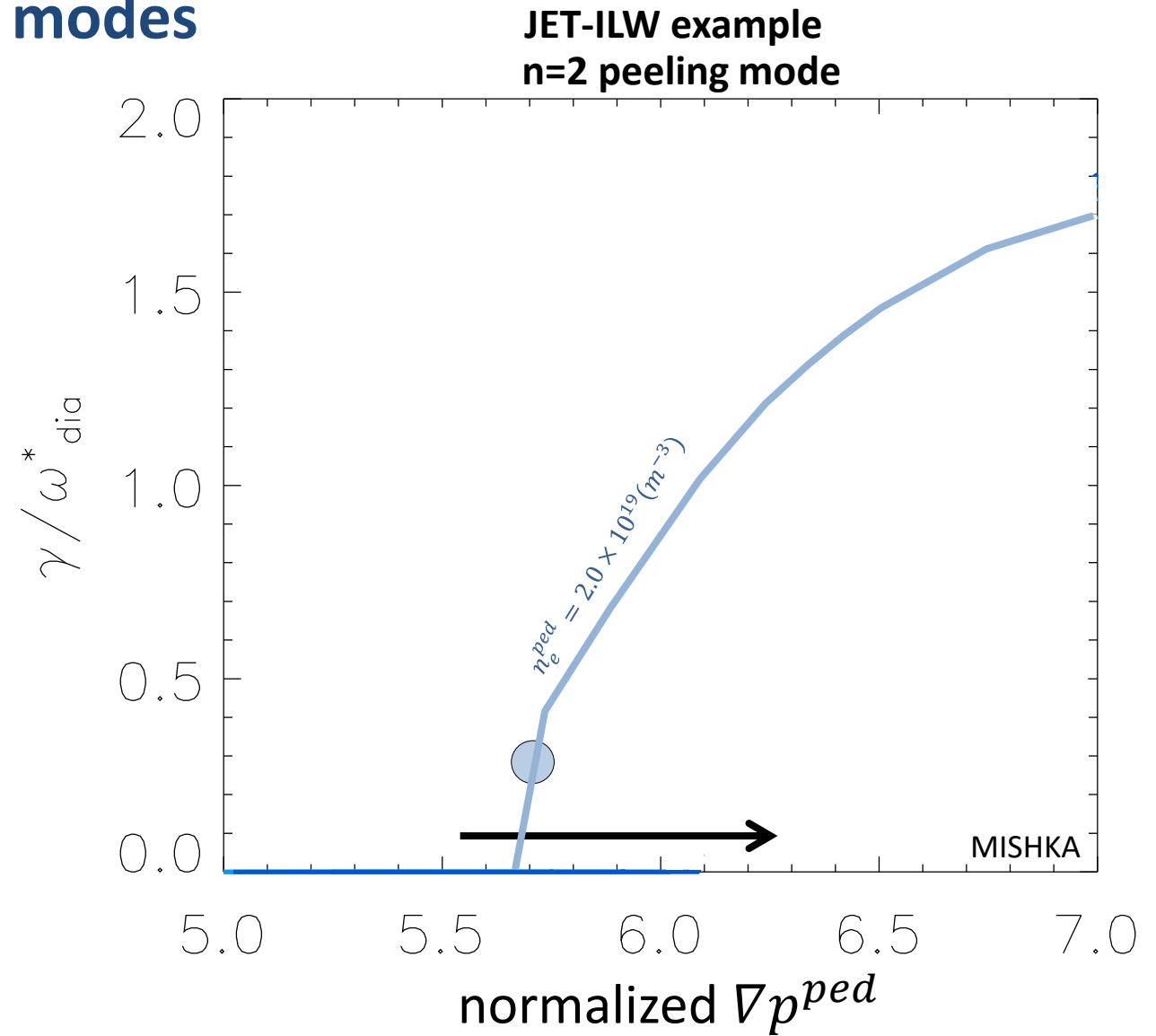
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 - Good qualitative agreement in all three machines



Increasing n_e^{ped} stabilizes peeling modes

- The increase of density stabilizes peeling modes

[Snyder PPCF2004], [Frassinetti NF2025]



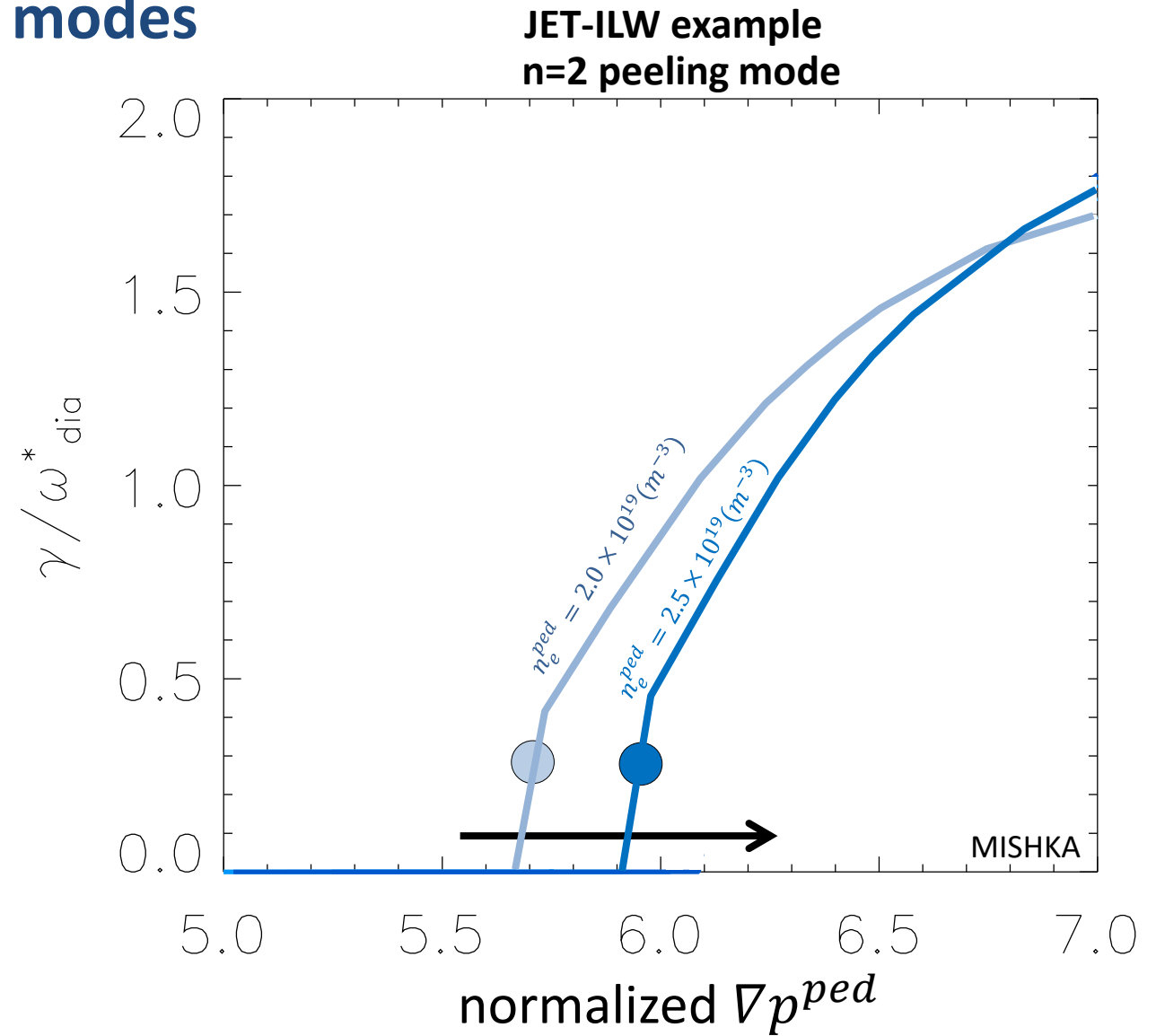


Increasing n_e^{ped} stabilizes peeling modes

- The increase of density stabilizes peeling modes

[Snyder PPCF2004], [Frassinetti NF2025]

→ ∇p^{ped} that triggers the peeling instability increases with increasing n_e^{ped}



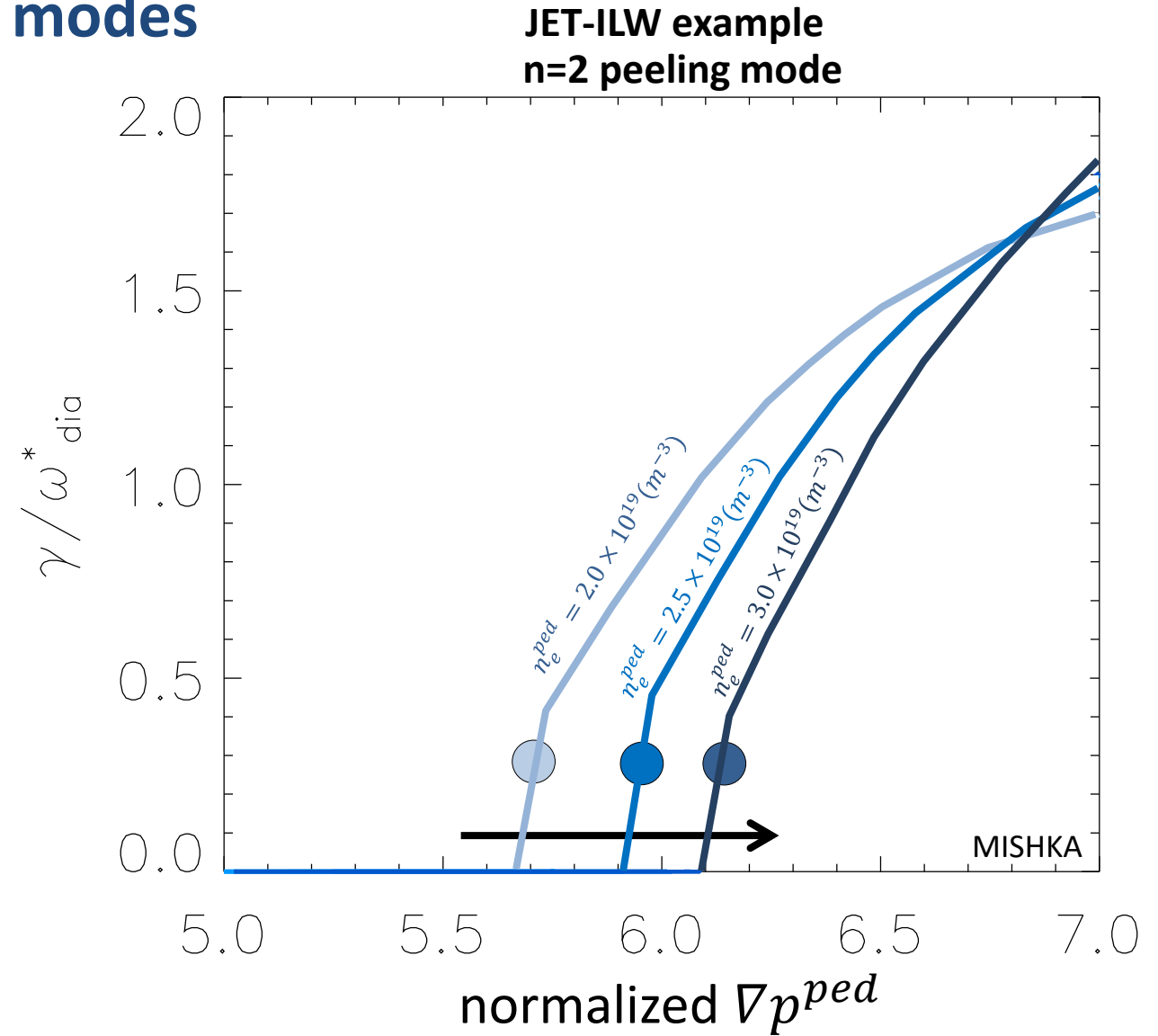


Increasing n_e^{ped} stabilizes peeling modes

- The increase of density stabilizes peeling modes

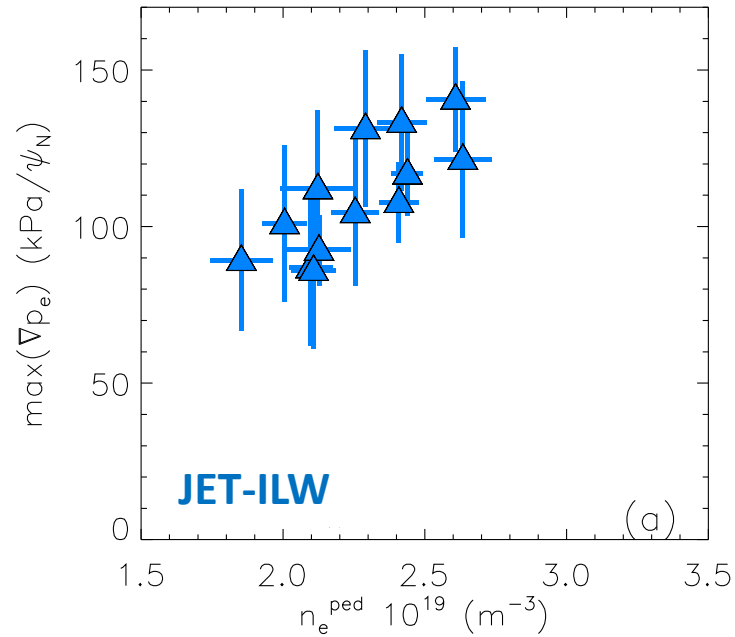
[Snyder PPCF2004], [Frassinetti NF2025]

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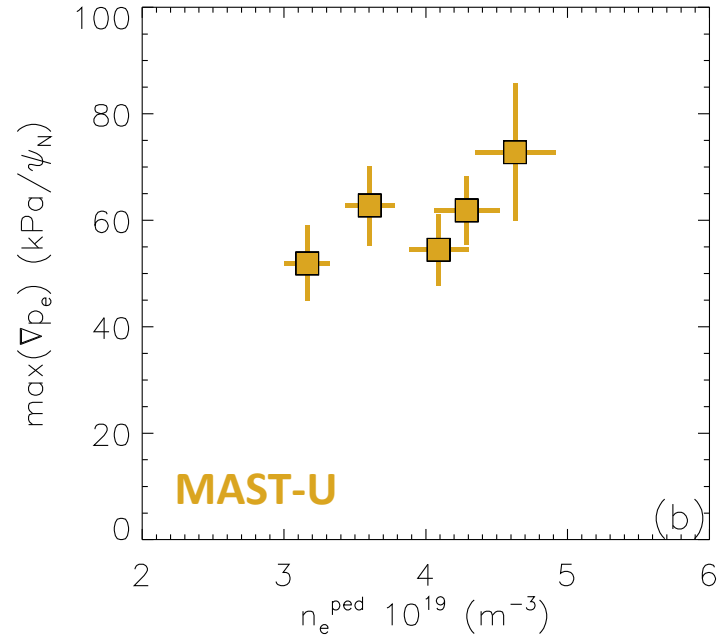
Reasonable predictions approaching ITER ν^{*ped}, ρ^{*ped}



JET-ILW:

The increase in p_e^{ped} is due to:

- the increase in the gradient



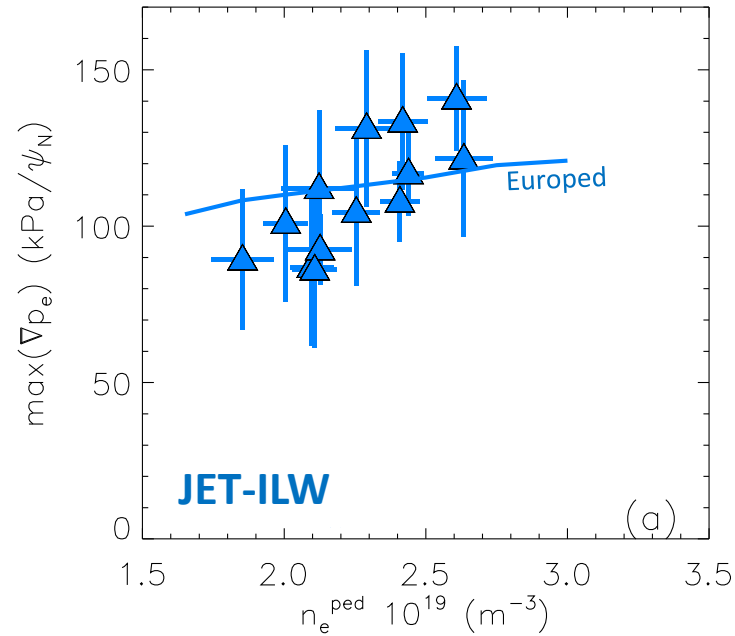
MAST-U:

The increase in p_e^{ped} is due to:

- the increase in the gradient



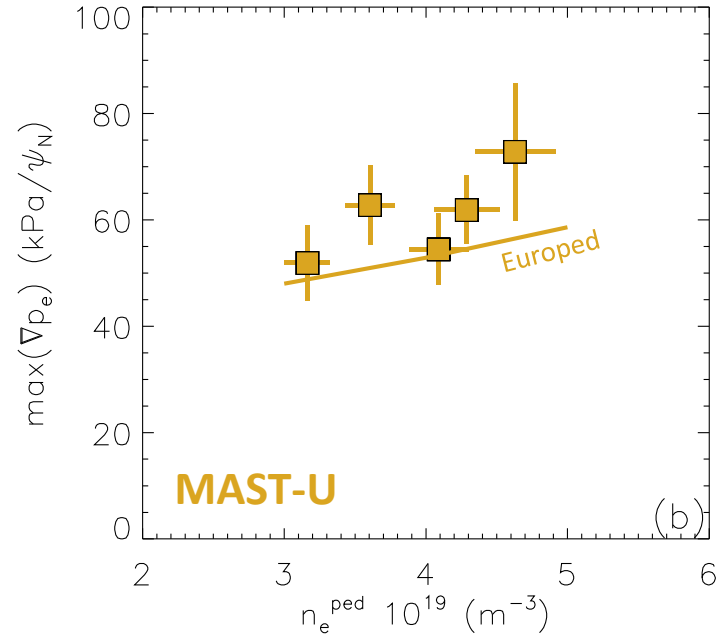
Reasonable predictions approaching ITER ν^{*ped}, ρ^{*ped}



JET-ILW:

The increase in p_e^{ped} is due to:

- the increase in the gradient
 - effect due to the stabilization of peeling modes



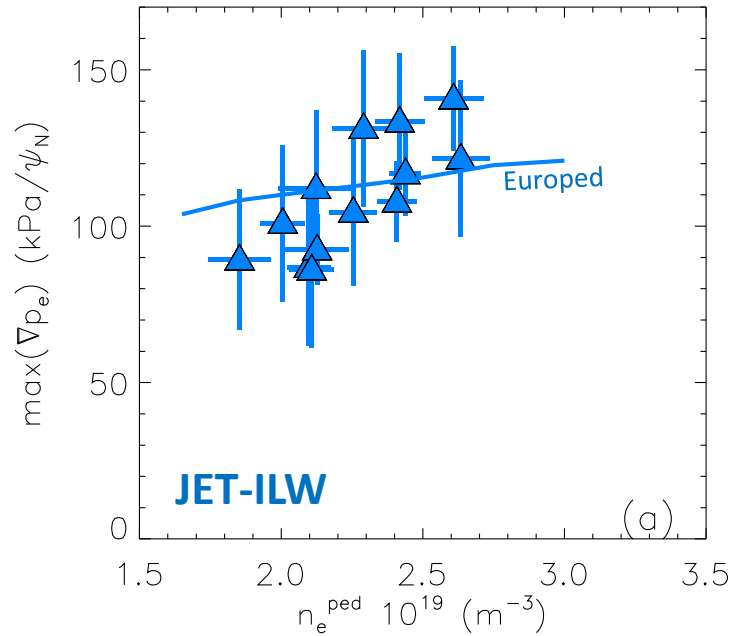
MAST-U:

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 - effect due to the stabilization of peeling modes



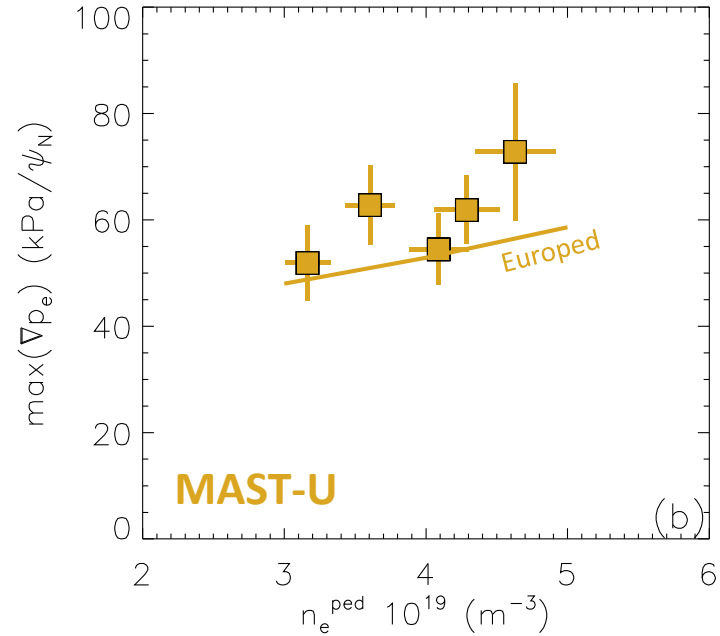
Reasonable predictions approaching ITER ν^{*ped}, ρ^{*ped}



JET-ILW:

The increase in p_e^{ped} is due to:

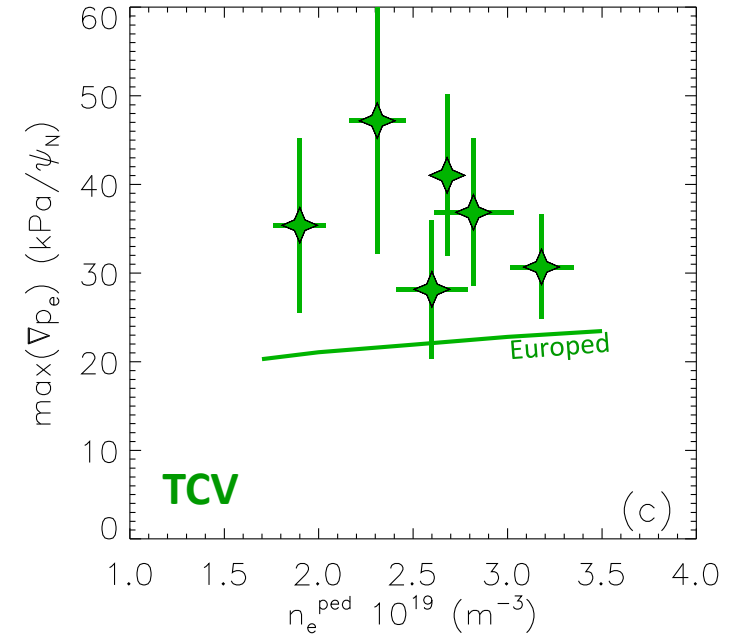
- the increase in the gradient
 - effect due to the stabilization of peeling modes



MAST-U:

The increase in p_e^{ped} is due to:

- the increase in the gradient
 - effect due to the stabilization of peeling modes



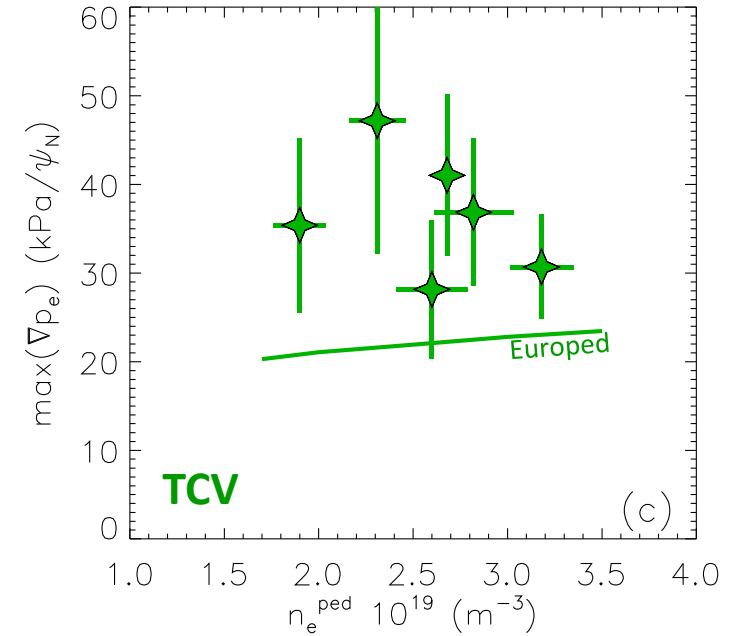
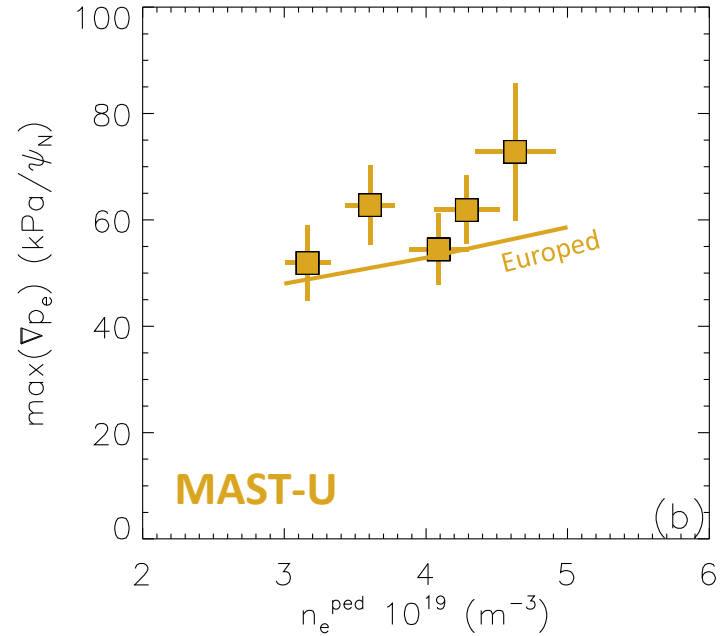
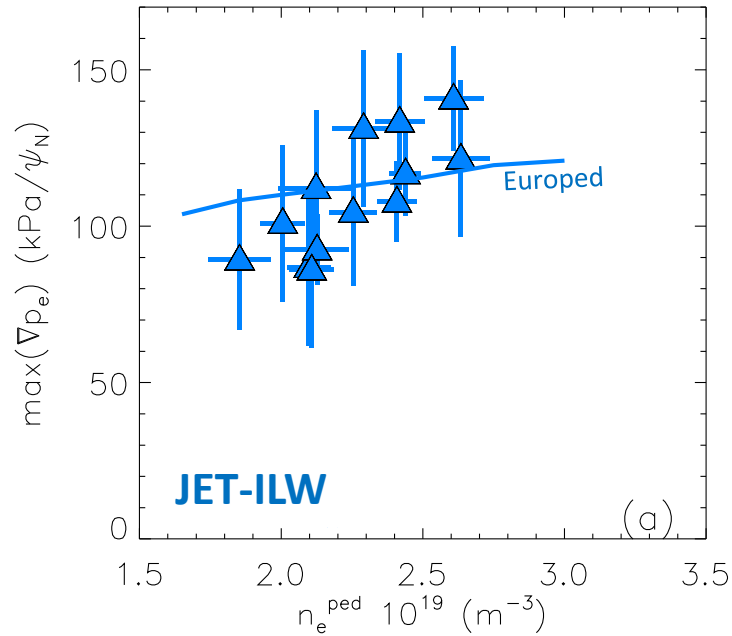
TCV:

The increase in p_e^{ped} is due to:

- NOT the increase in the gradient
 - effect NOT due to the stabilization, but to pedestal widening



Reasonable predictions approaching ITER ν^{*ped}, ρ^{*ped}



JET-ILW:

The increase in p_e^{ped} is due to:

- the increase in the gradient

➤ effect due to the stabilization of peeling modes

- Good qualitative agreement with Europed
- Good understanding

MAST-U:

The increase in p_e^{ped} is due to:

- the increase in the gradient

approaching ITER $\nu_{ee}^{*ped}, \rho_i^{*ped}$

➤ effect due to the stabilization of peeling modes

- Good qualitative agreement with Europed
- Good understanding

TCV:

The increase in p_e^{ped} is due to:

- NOT the increase in the gradient

➤ effect NOT due to the stabilization, but to pedestal widening

- No reasonable agreement with Europed
- No good understanding yet



OUTLINE

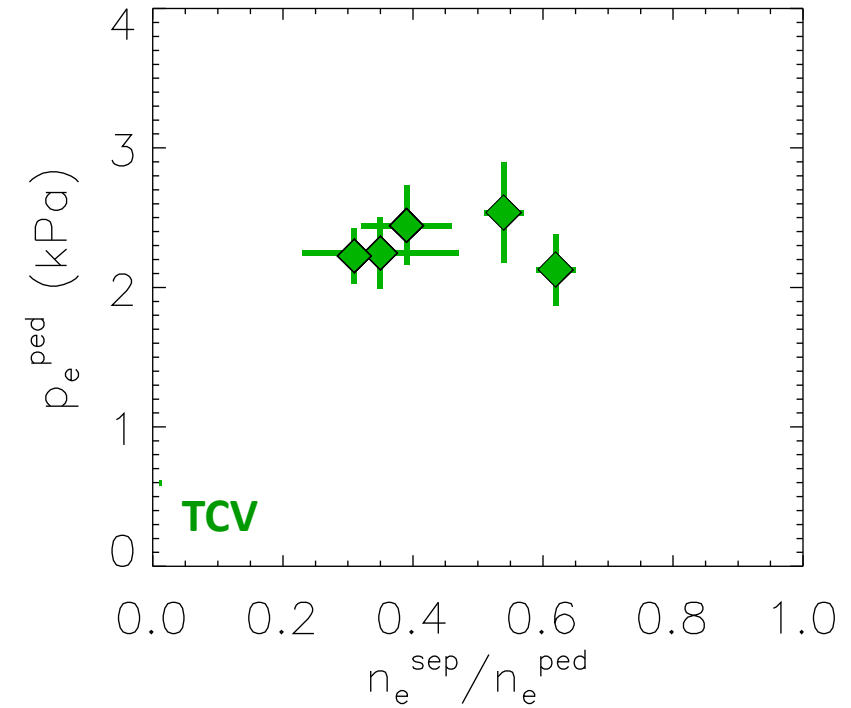
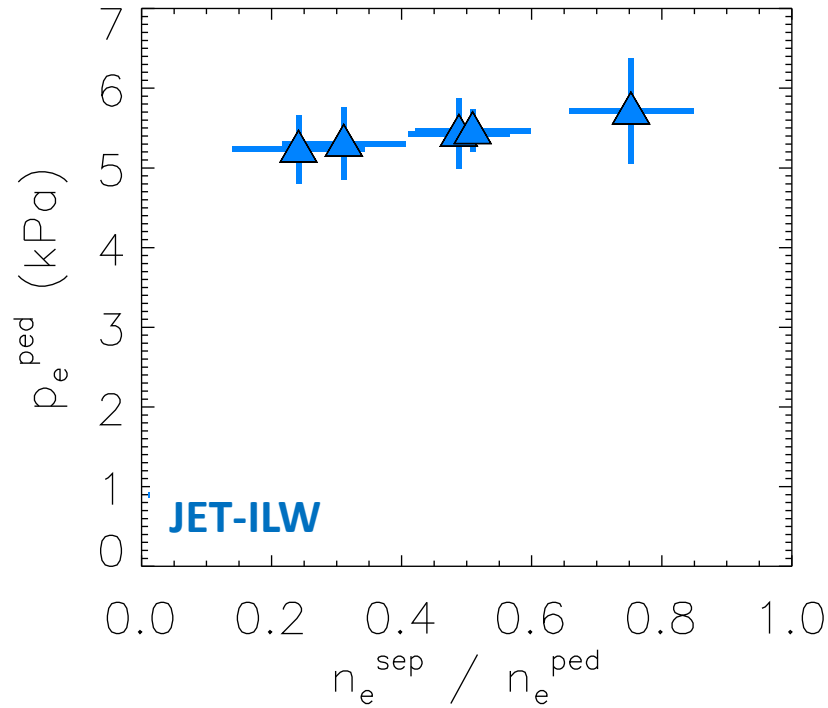
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Effect of n_e^{sep}/n_e^{ped} on pedestal pressure

MAST-U dataset:

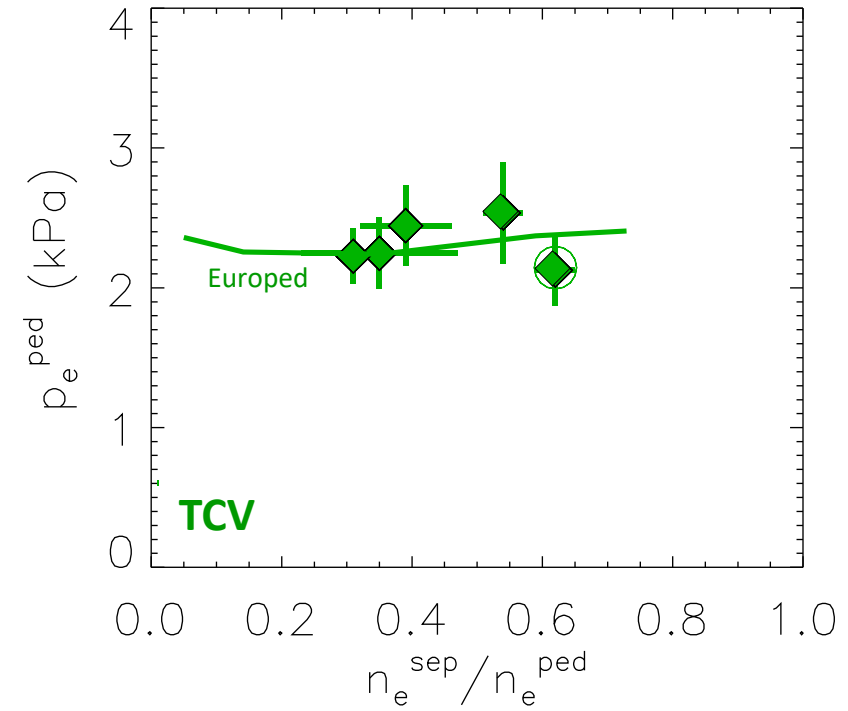
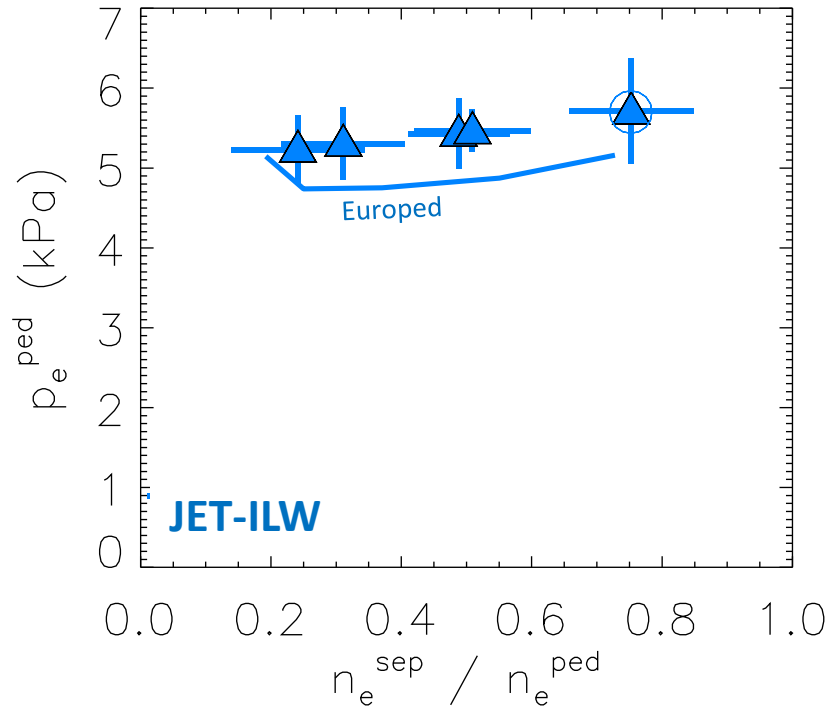
n_e^{sep}/n_e^{ped} variation achieved only via
 n_e^{ped} variation → not discussed here



- With increasing n_e^{sep}/n_e^{ped} (at constant n_e^{ped})
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} is rather constant (same for p_{tot}^{ped})



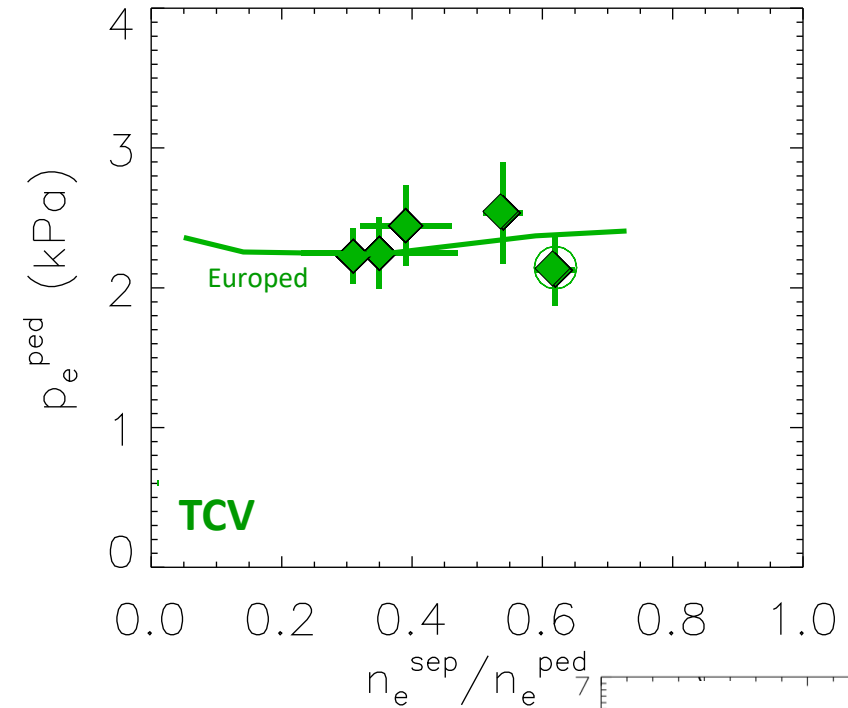
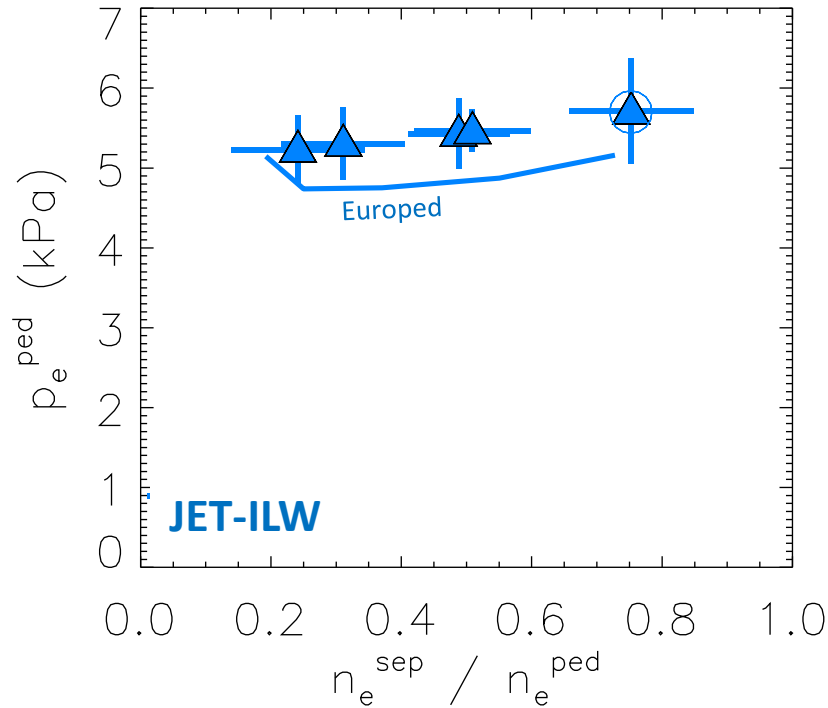
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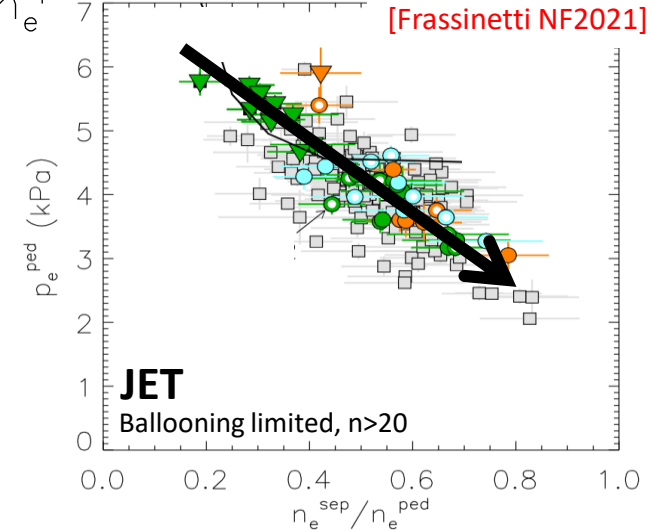
- With increasing n_e^{sep}/n_e^{ped} (at constant n_e^{ped})
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} is rather constant (same for p_{tot}^{ped})
- Pedestal predictions:
 - Good qualitative agreement in both JET-ILW and TCV



Effect of n_e^{sep}/n_e^{ped} on pedestal pressure

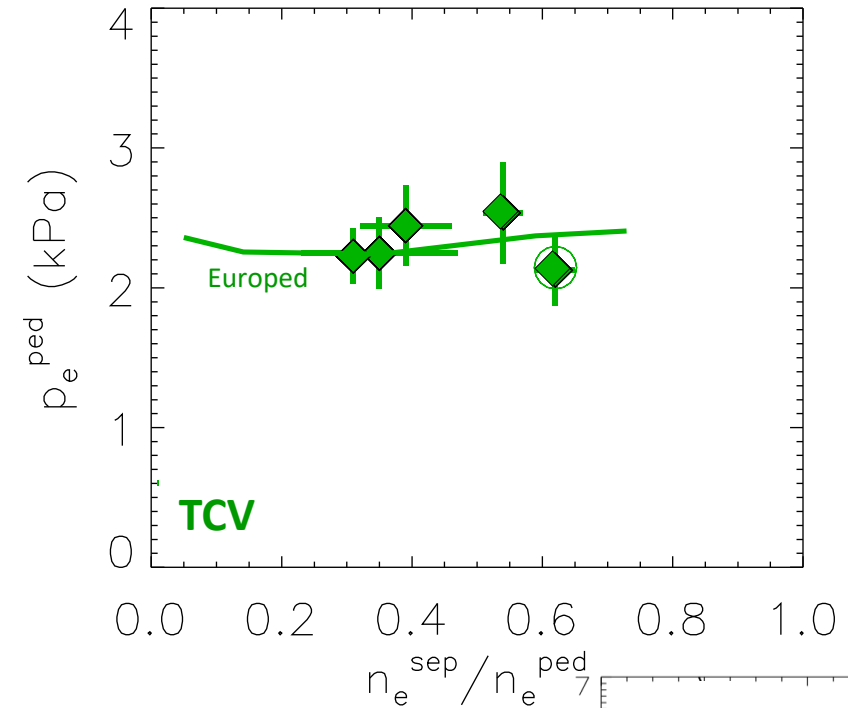
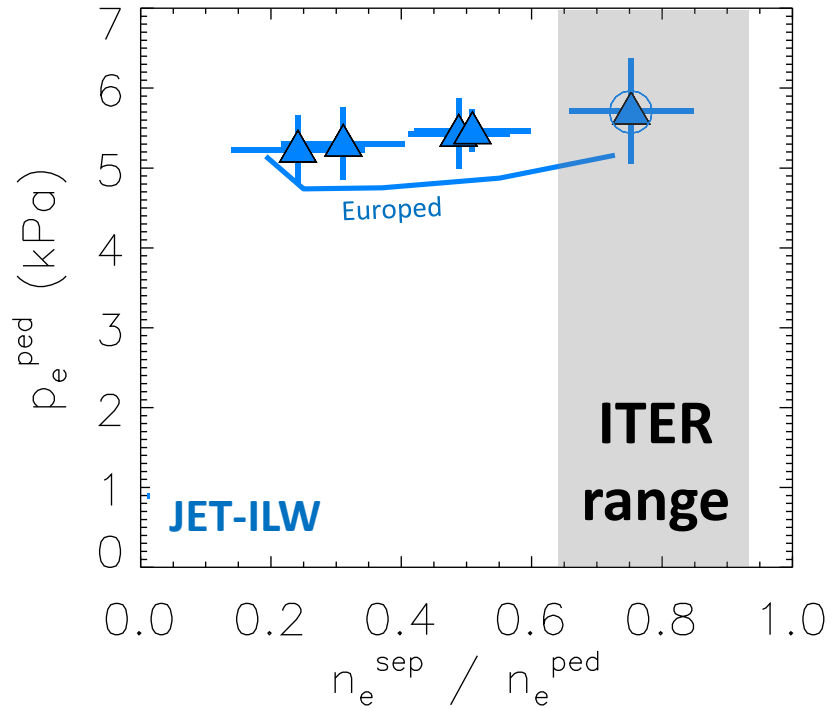


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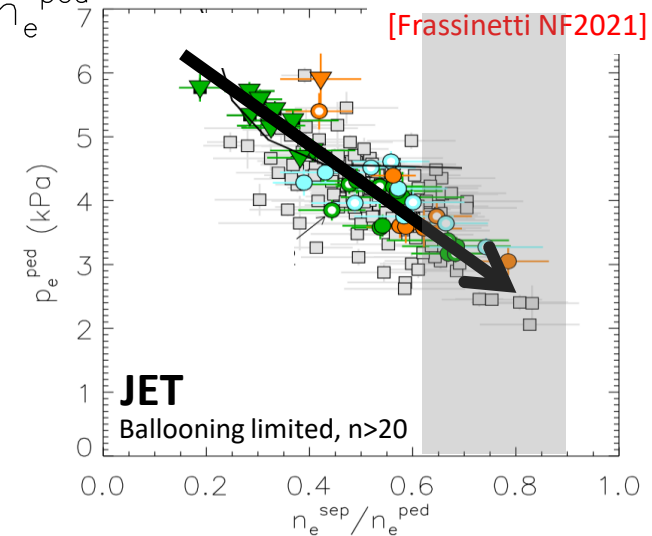




Effect of n_e^{sep}/n_e^{ped} on pedestal pressure



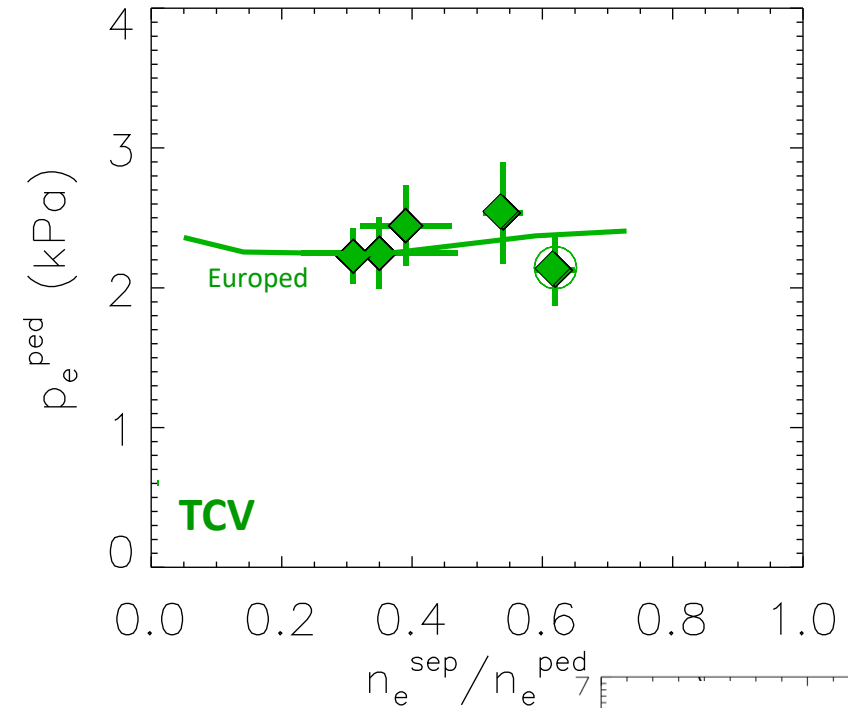
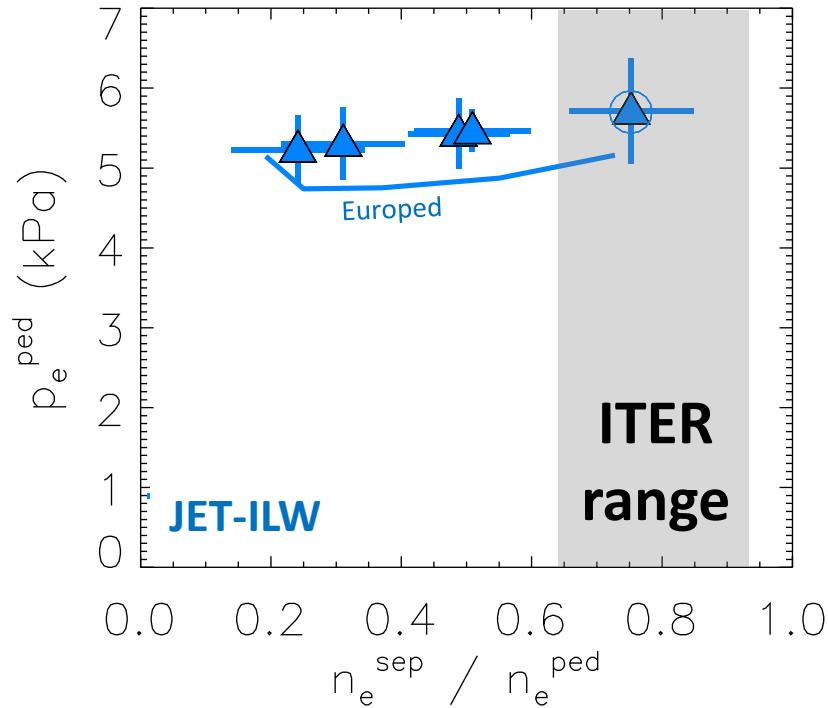
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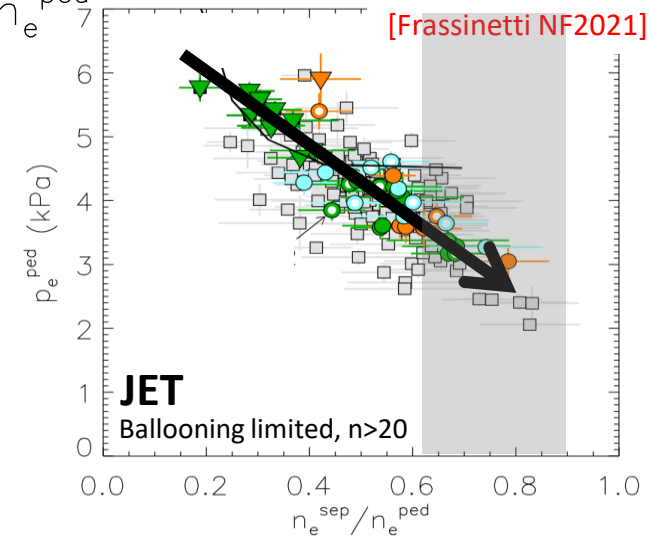


Effect of n_e^{sep}/n_e^{ped} on pedestal pressure

Good news for ITER



- With increasing n_e^{sep}/n_e^{ped} (at constant n_e^{ped})
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} is rather constant (same for p_{tot}^{ped})
 - behavior opposite to what observed in ballooning limited pedestals
- Pedestal predictions:
 - Good qualitative agreement in both JET-ILW and TCV





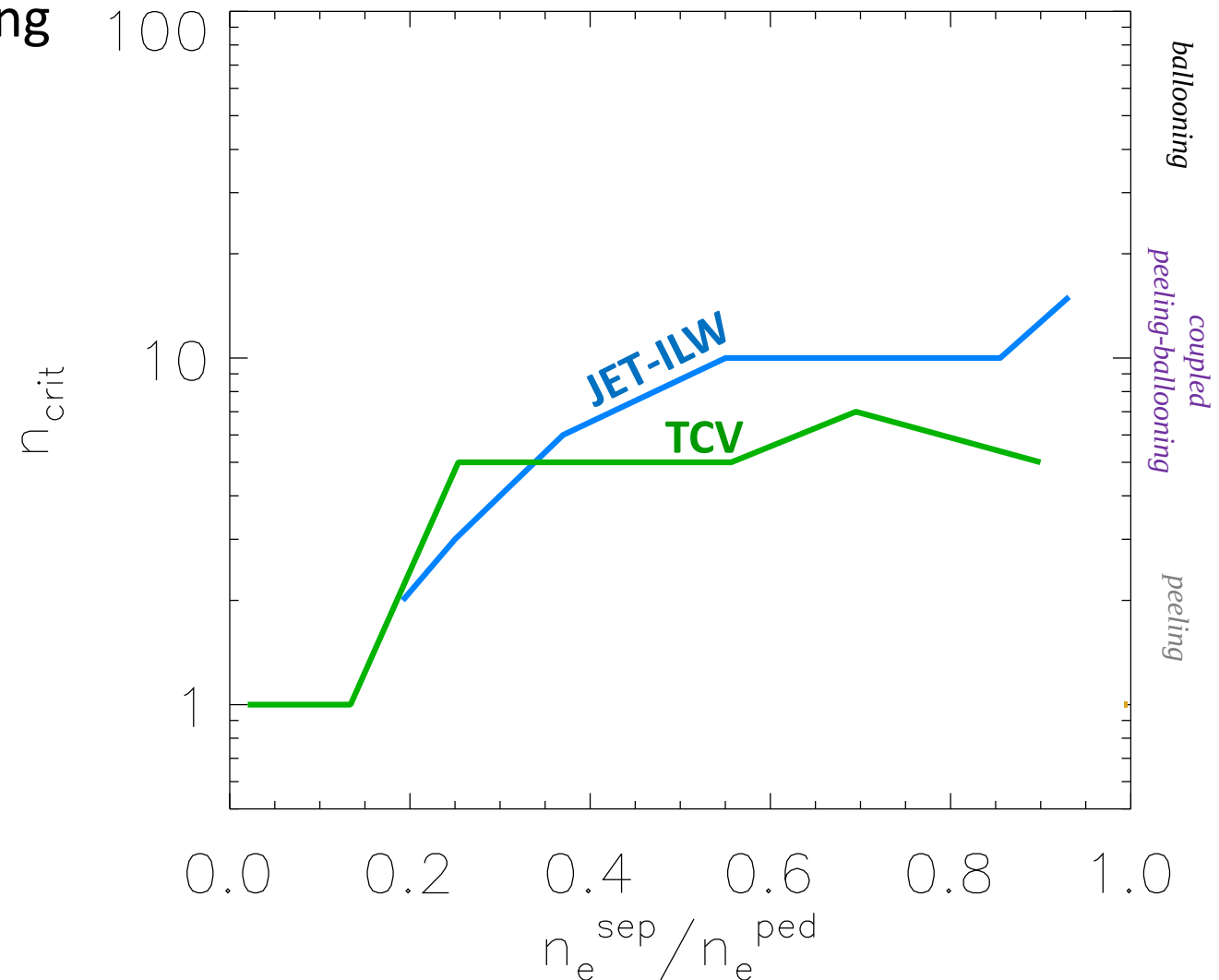
Increasing n_e^{sep}/n_e^{ped} can effects on the global pedestal stability

- Increasing n_e^{sep}/n_e^{ped} destabilizes ballooning modes [Dunne PPCF2017, Frassinetti NF2021]



Increasing n_e^{sep}/n_e^{ped} can effects on the global pedestal stability

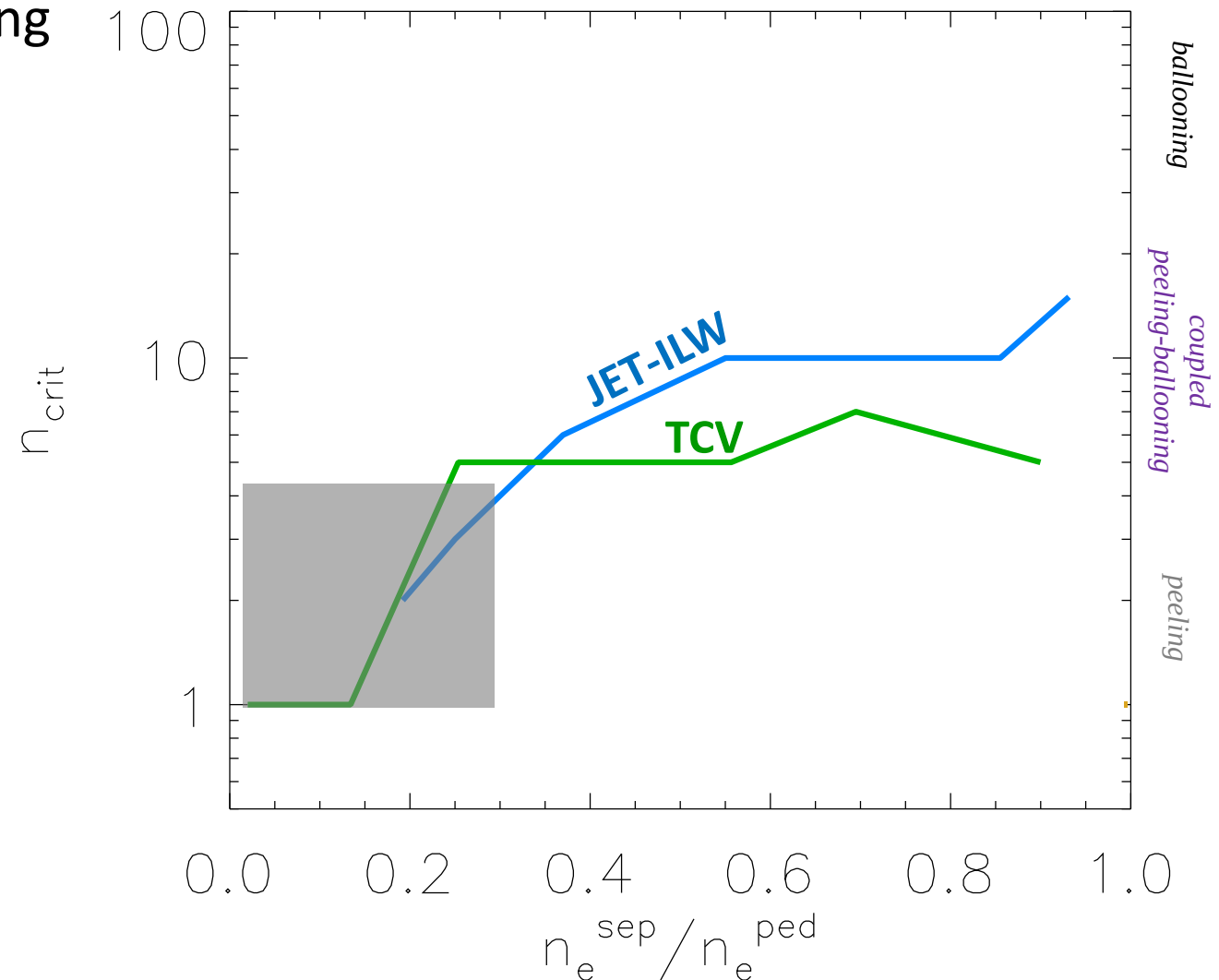
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 - The pedestal moves from being **peeling limited** to **ballooning limited**
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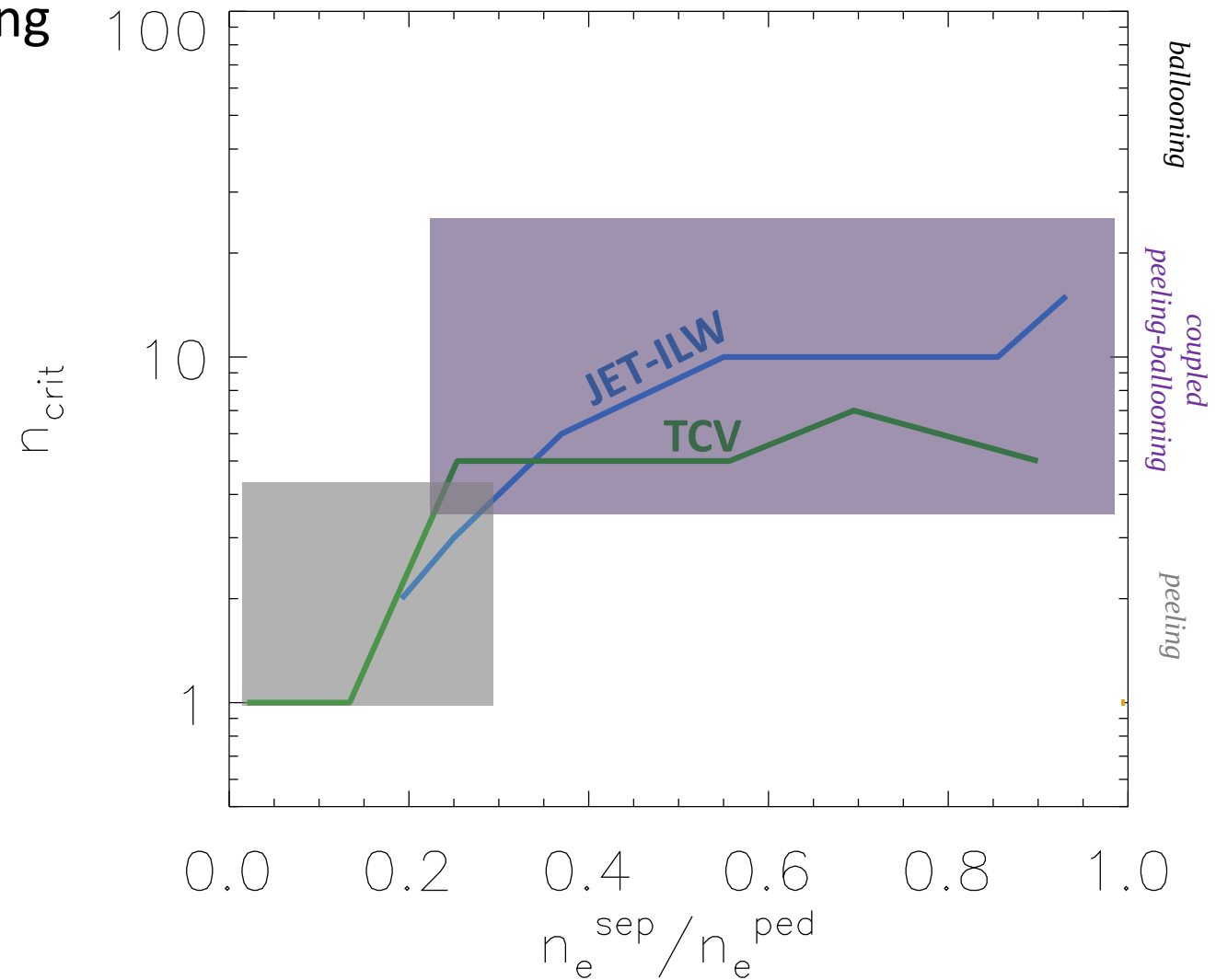
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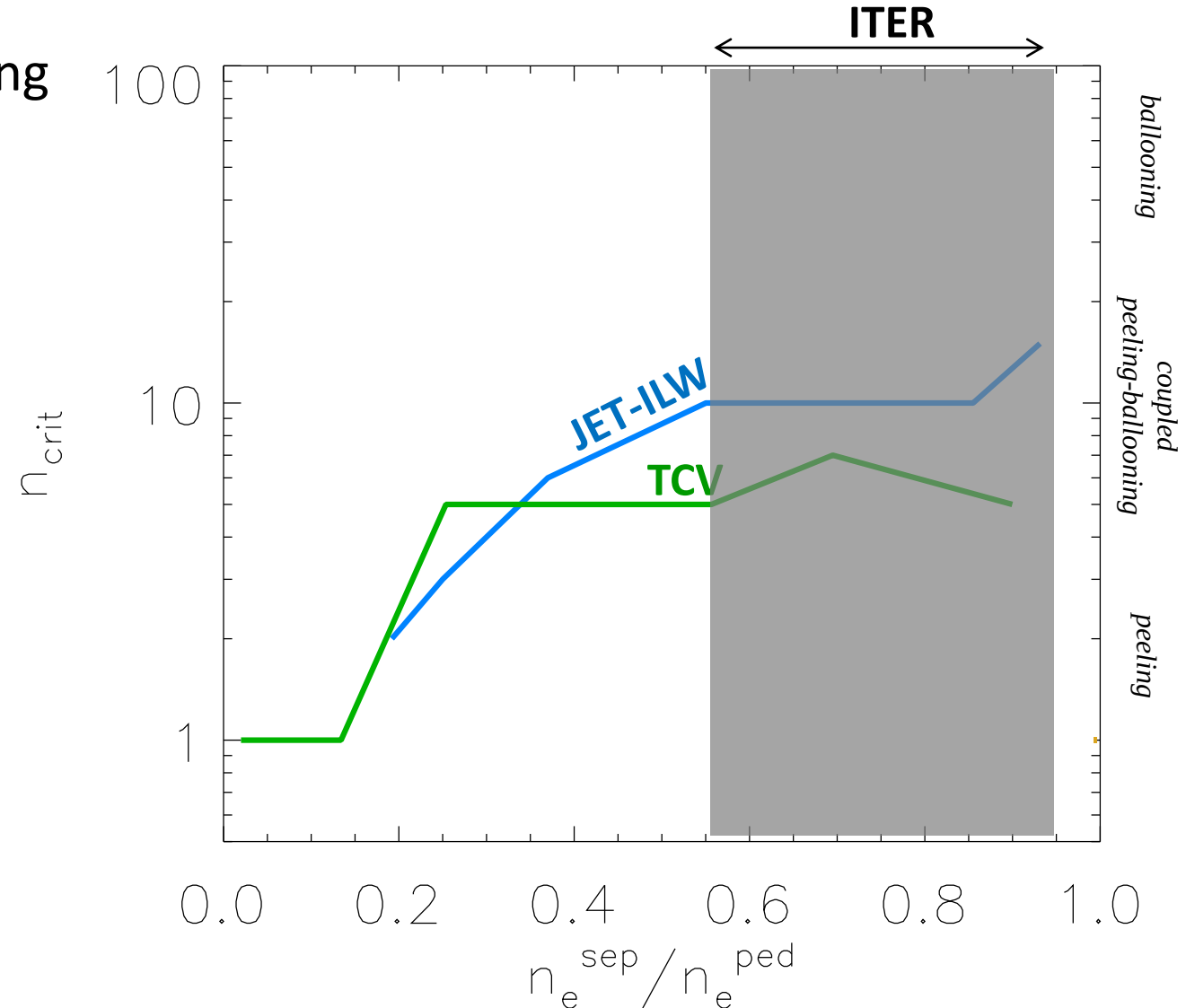
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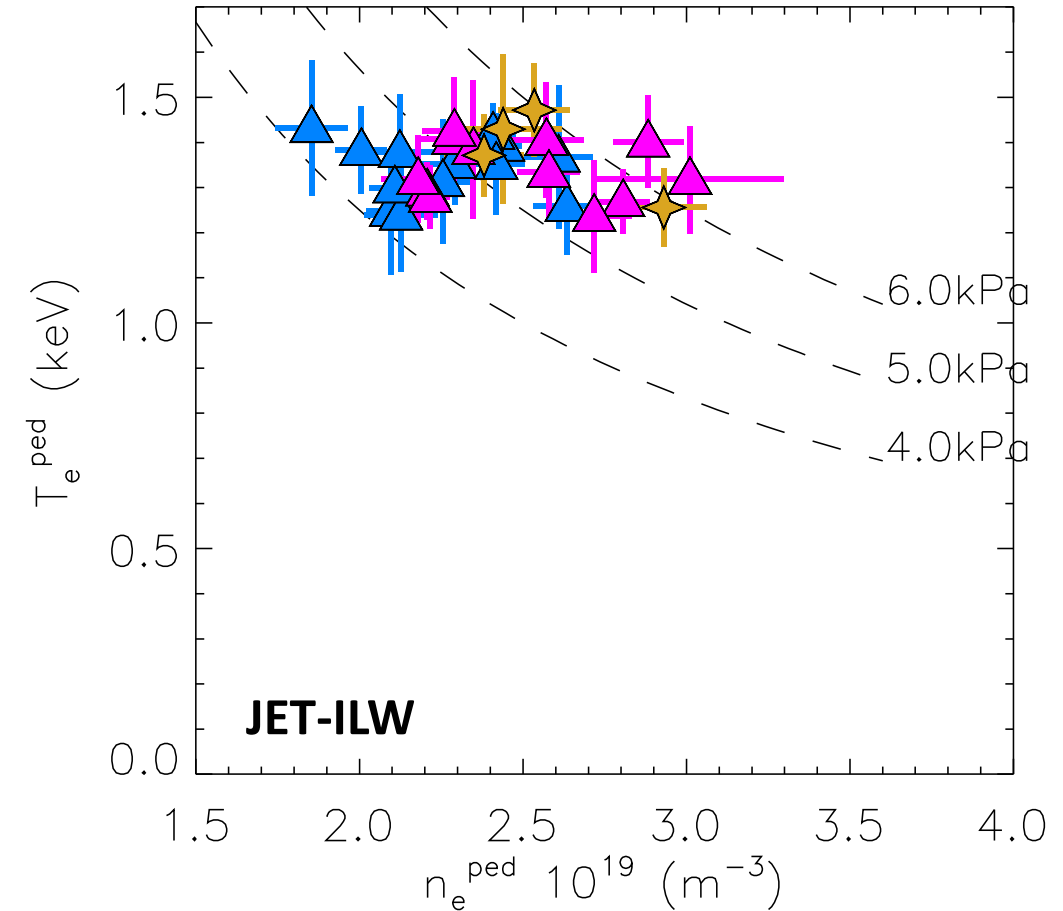
OUTLINE

1. Reaching peeling limited pedestals in JET-ILW, MAST-U and TCV
2. The datasets
3. Effect of
 - n_e^{ped} on p_e^{ped} in peeling limited pedestals in JET-ILW, MAST-U and TCV
 - n_e^{sep}/n_e^{ped} on p_e^{ped} in peeling limited pedestals in JET-ILW, MAST-U and TCV
 - **the isotope mass in peeling limited pedestals in JET-ILW and corresponding pedestal predictions with Europed**
4. Pedestal predictions in ITER
 - will ITER be limited by peeling or ballooning instabilities?
 - Is a transition from peeling to ballooning limited pedestals a problem?



INCREASING THE ISOTOPE MASS INCREASES THE PEDESTAL PRESSURE

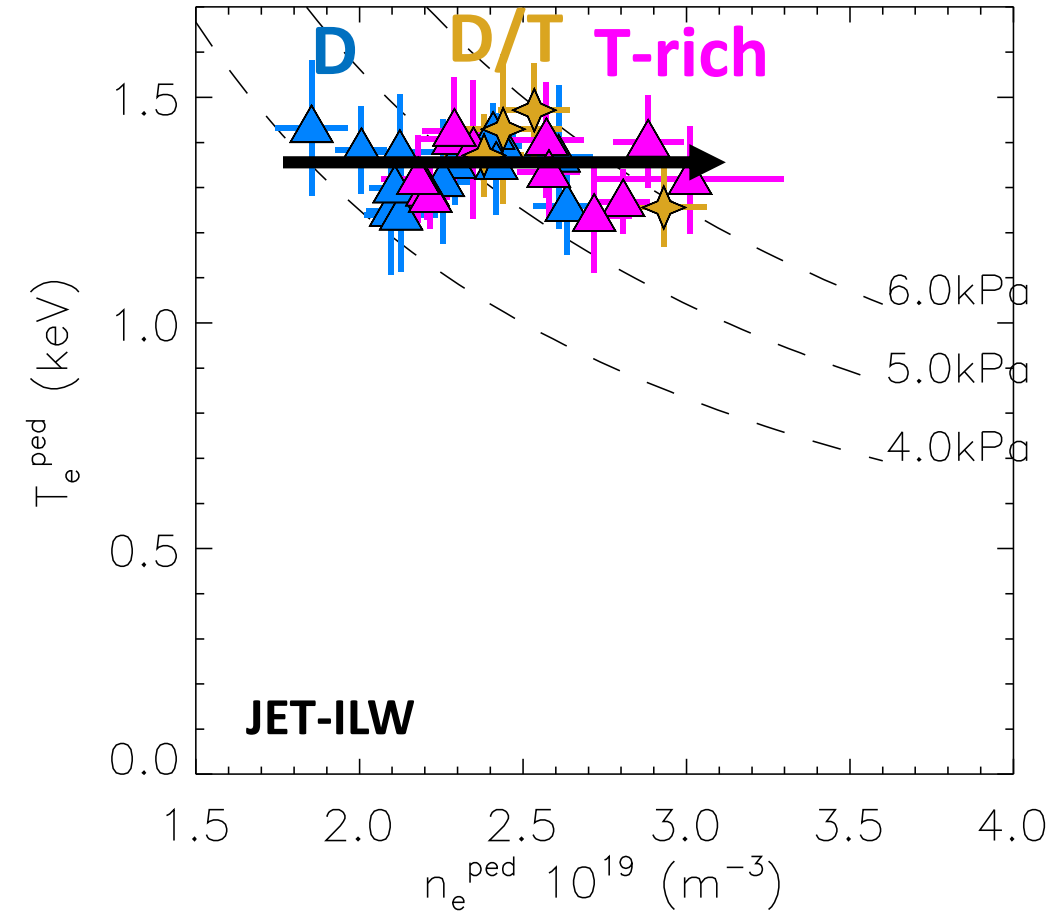
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 - pure deuterium, $A_{eff} = 2.0$
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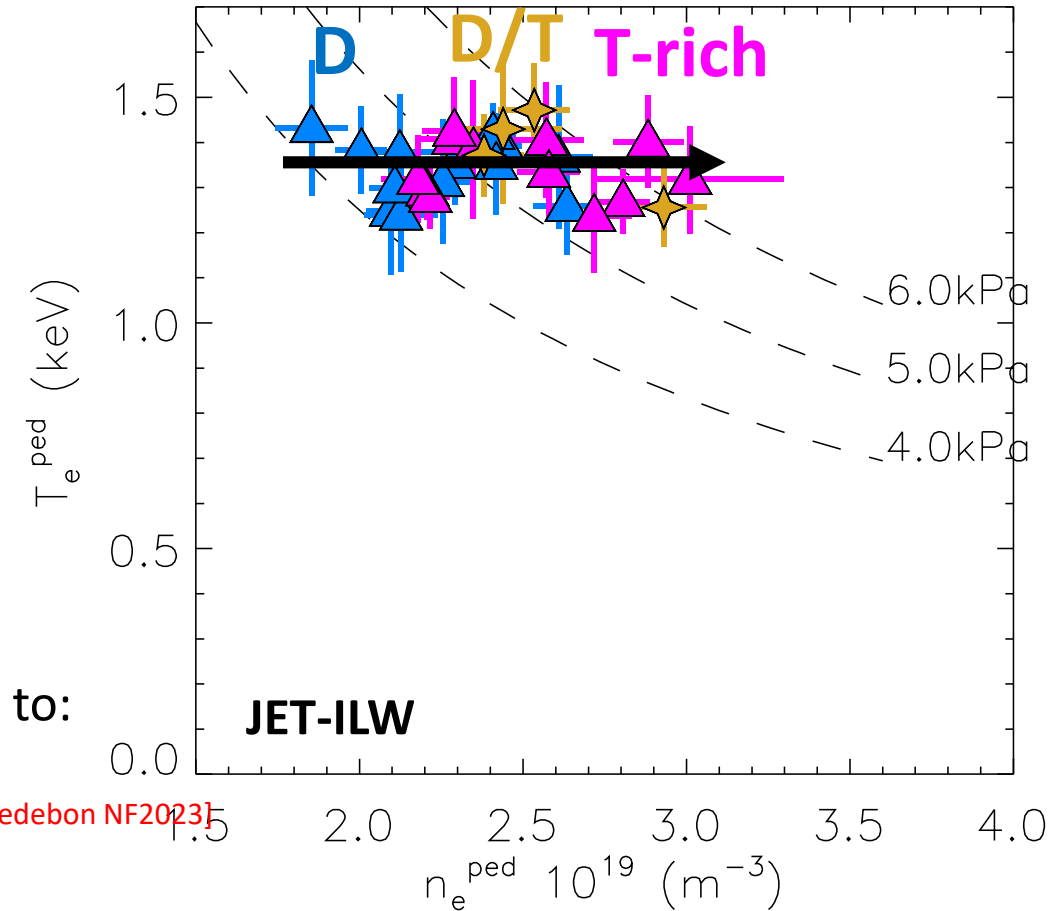
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↳ 2. n_e^{ped} increases with increasing A_{eff} , possibly due to:

- reduction of inter-ELM pedestal particle transport
- and/or increase in n_e^{sep}

[Predebon NF2023]

[Saarelma NF2024]





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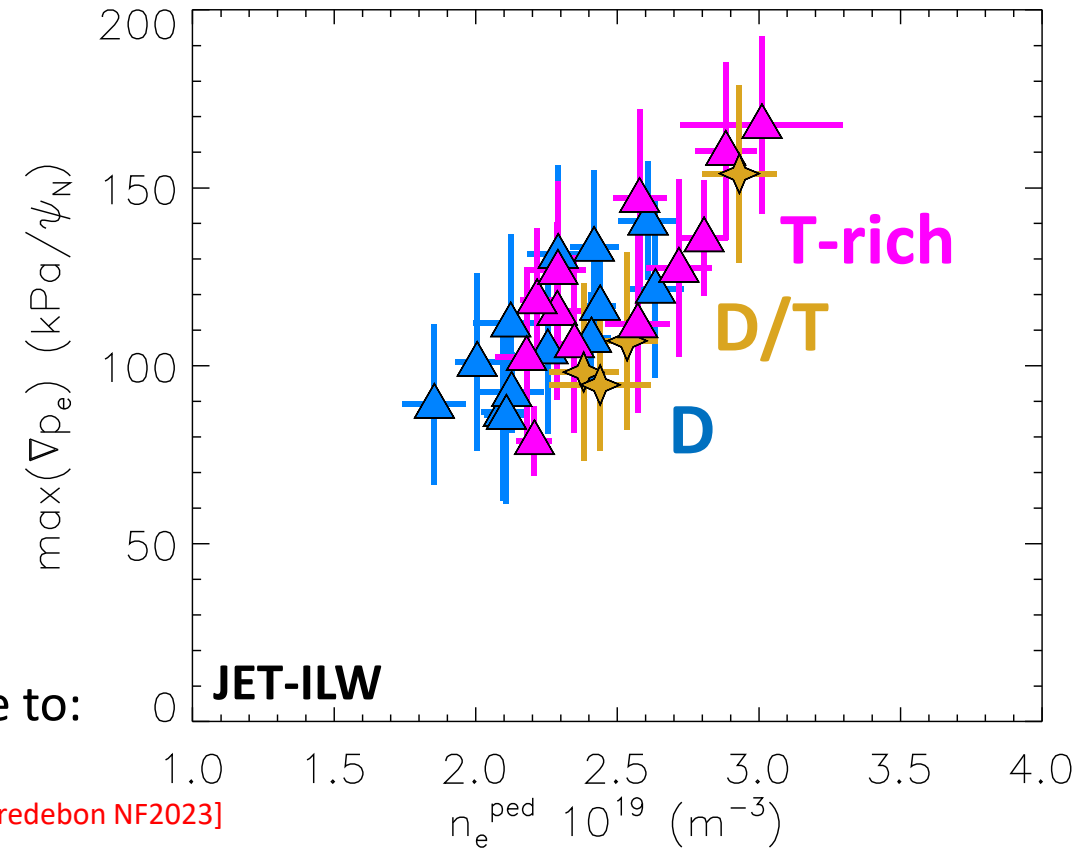
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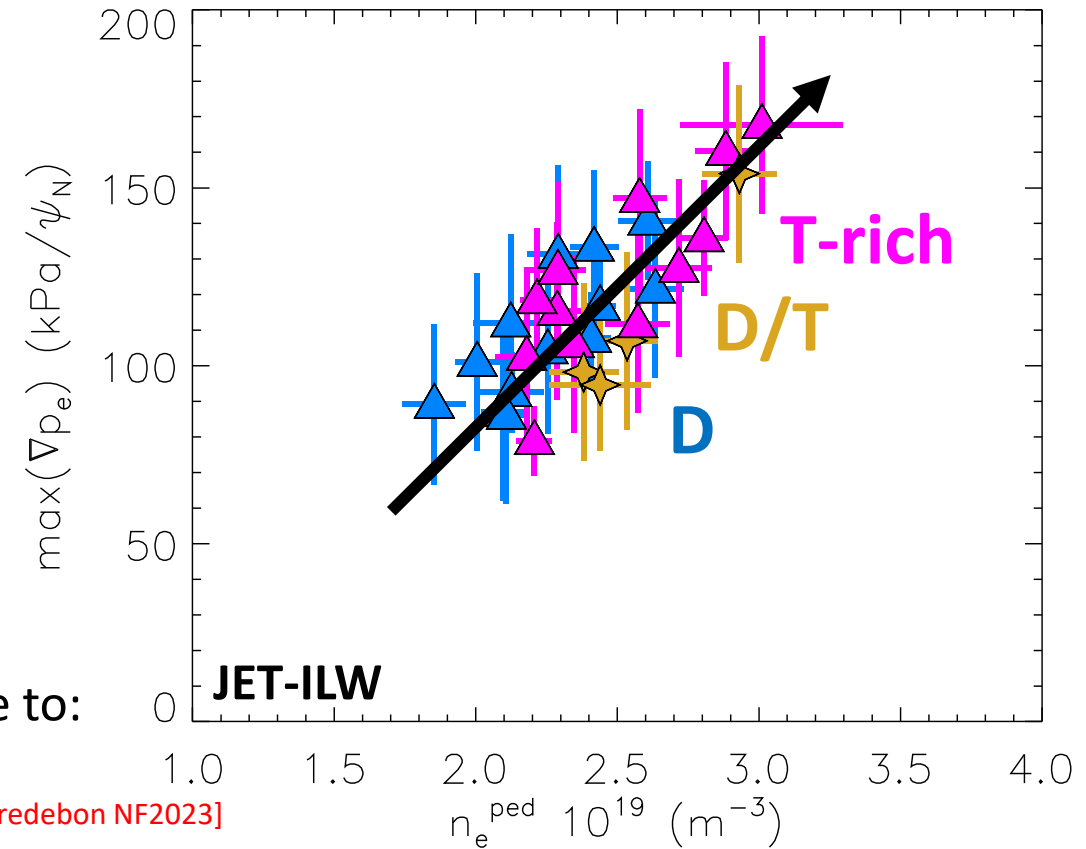
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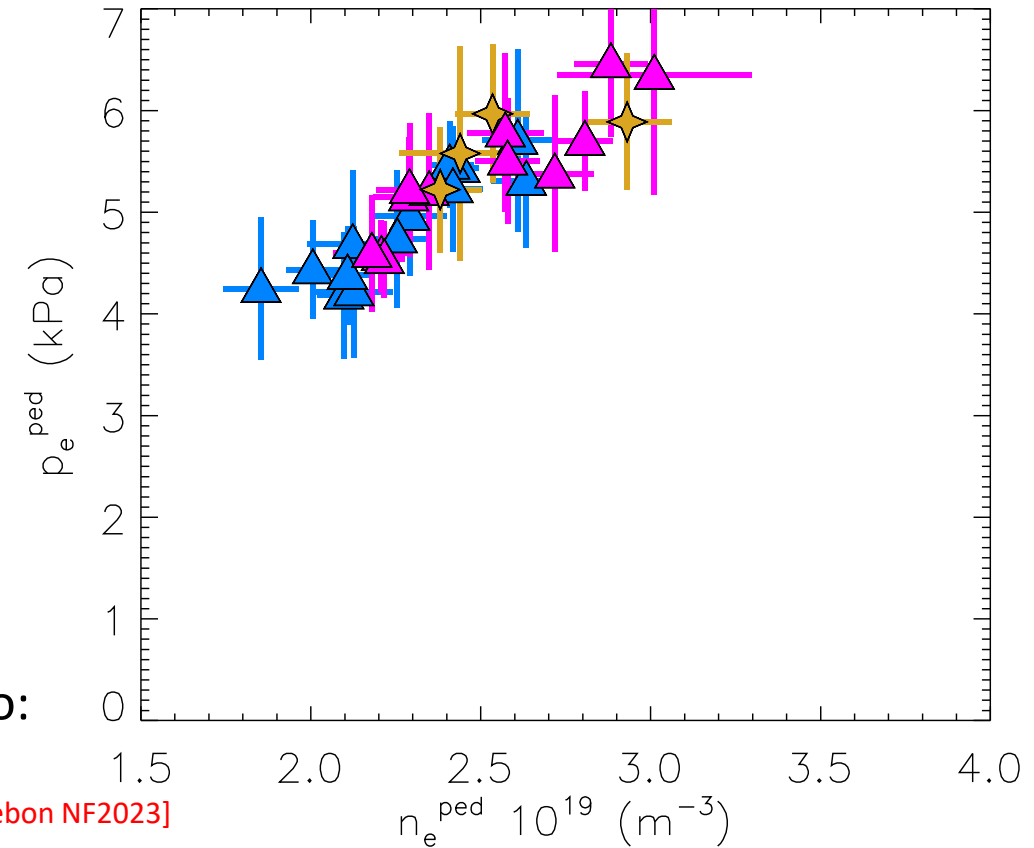
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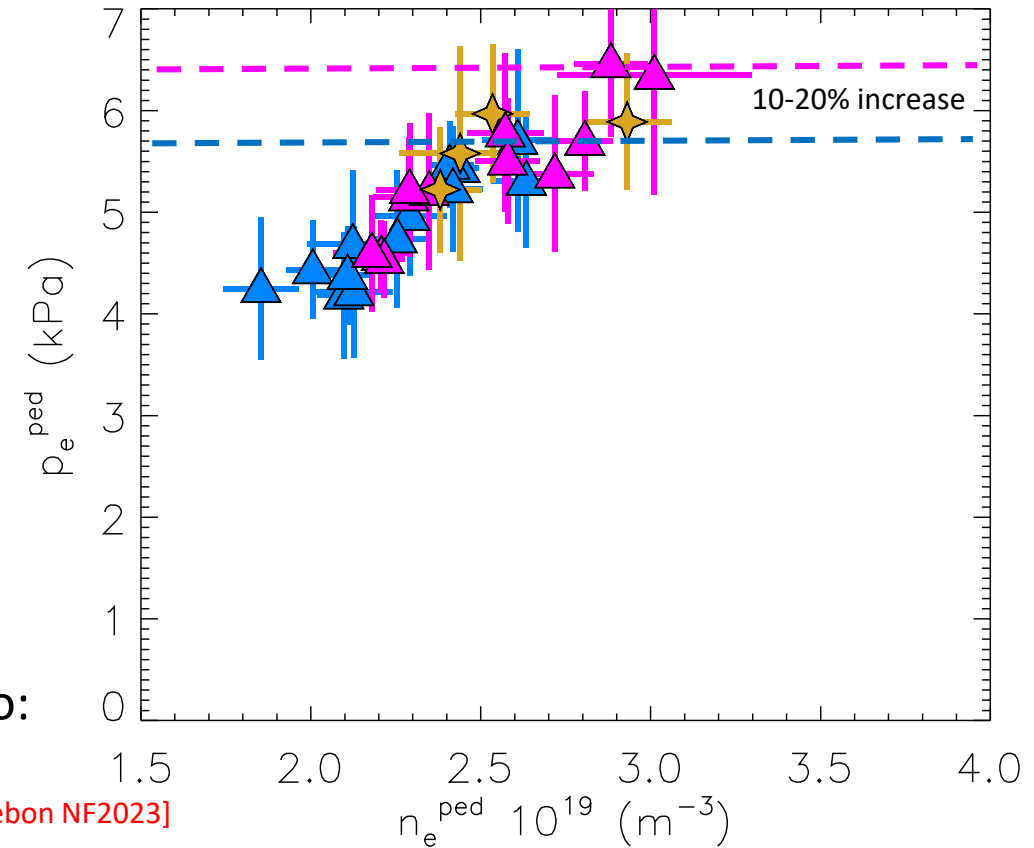
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**Positive result in view of
future ITER D/T operation**



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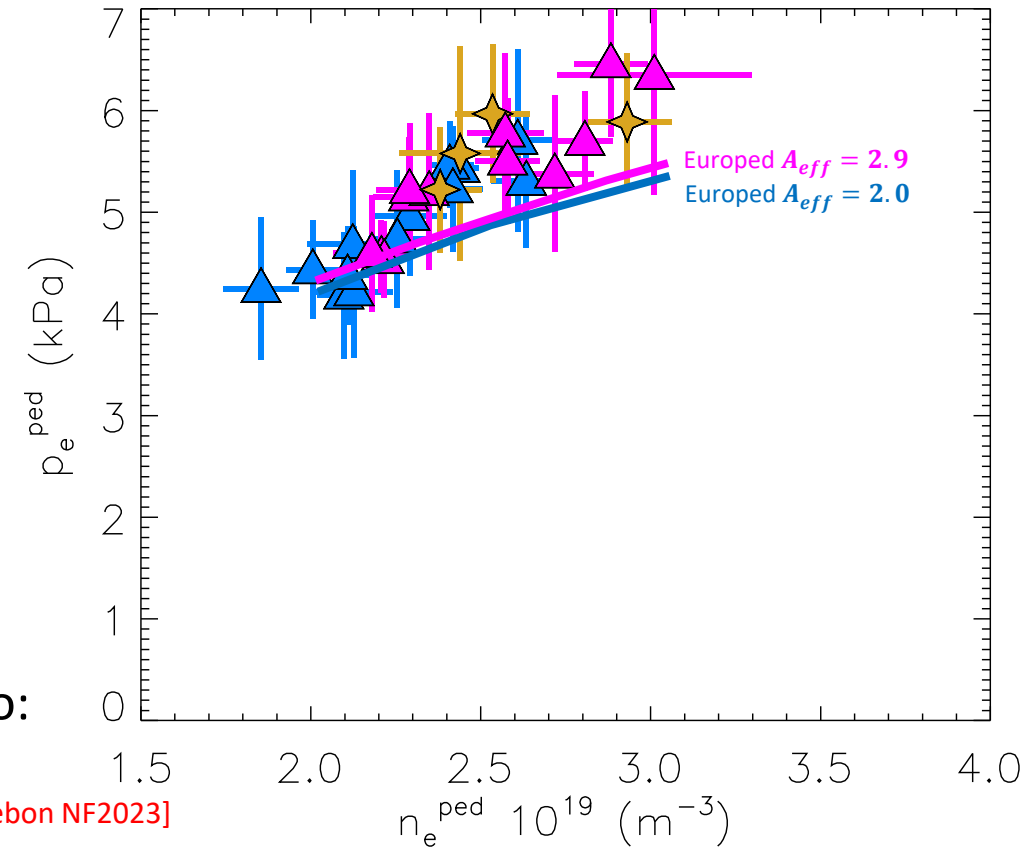
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- Pedestal predictions:

- Reasonable qualitative agreement
- No direct effect of the isotope mass in this scenario



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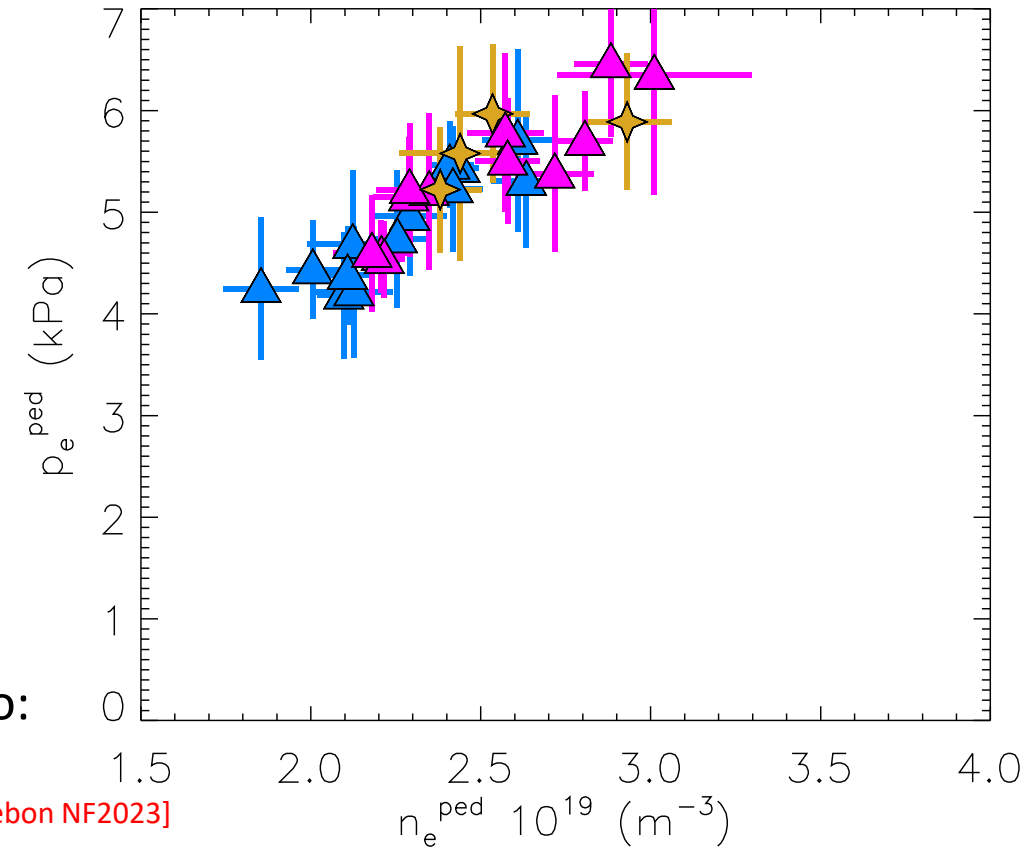
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similar to ballooning
limited pedestal in JET-ILW
[Schneider NF2023, Frassinetti NF2023]





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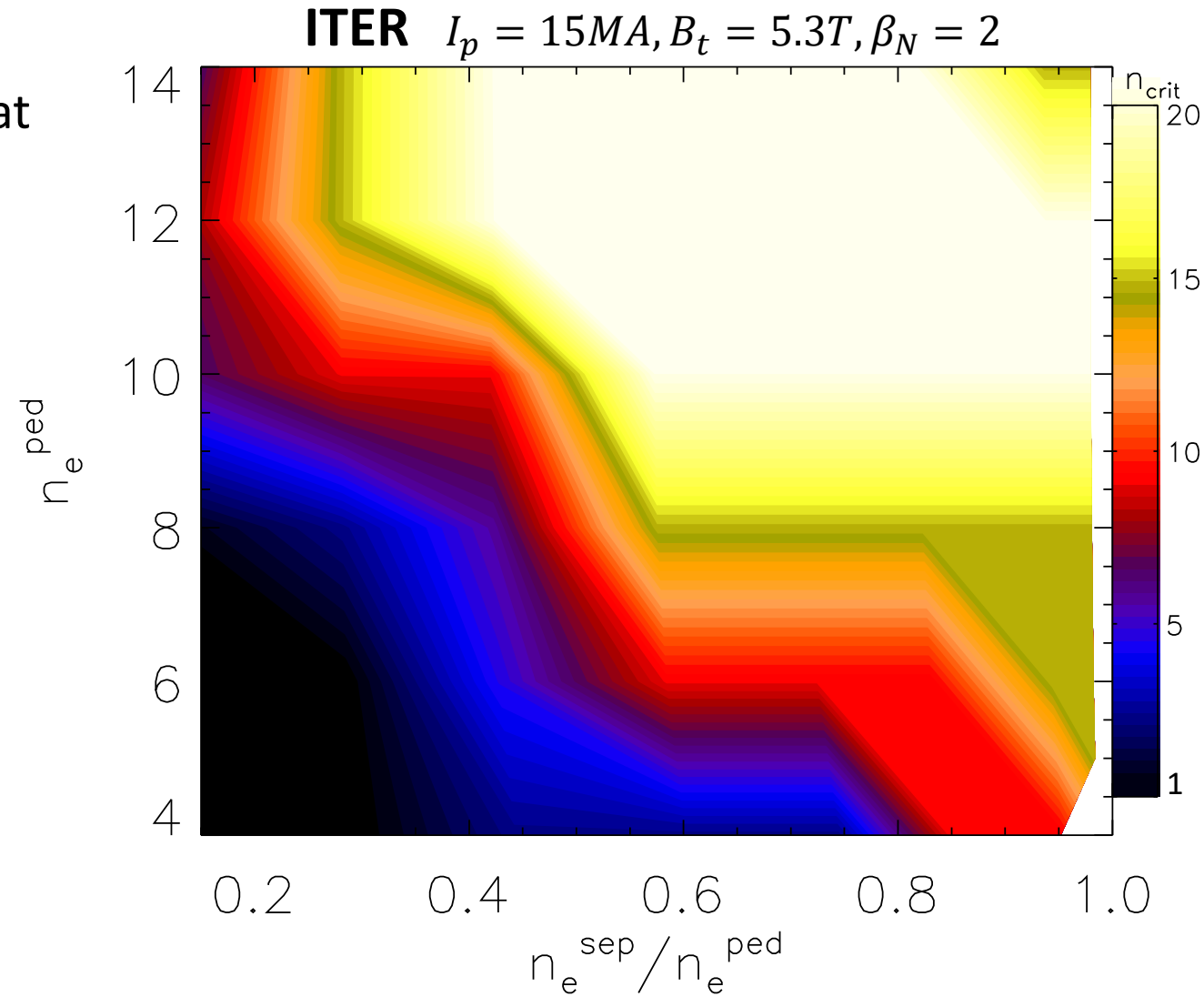
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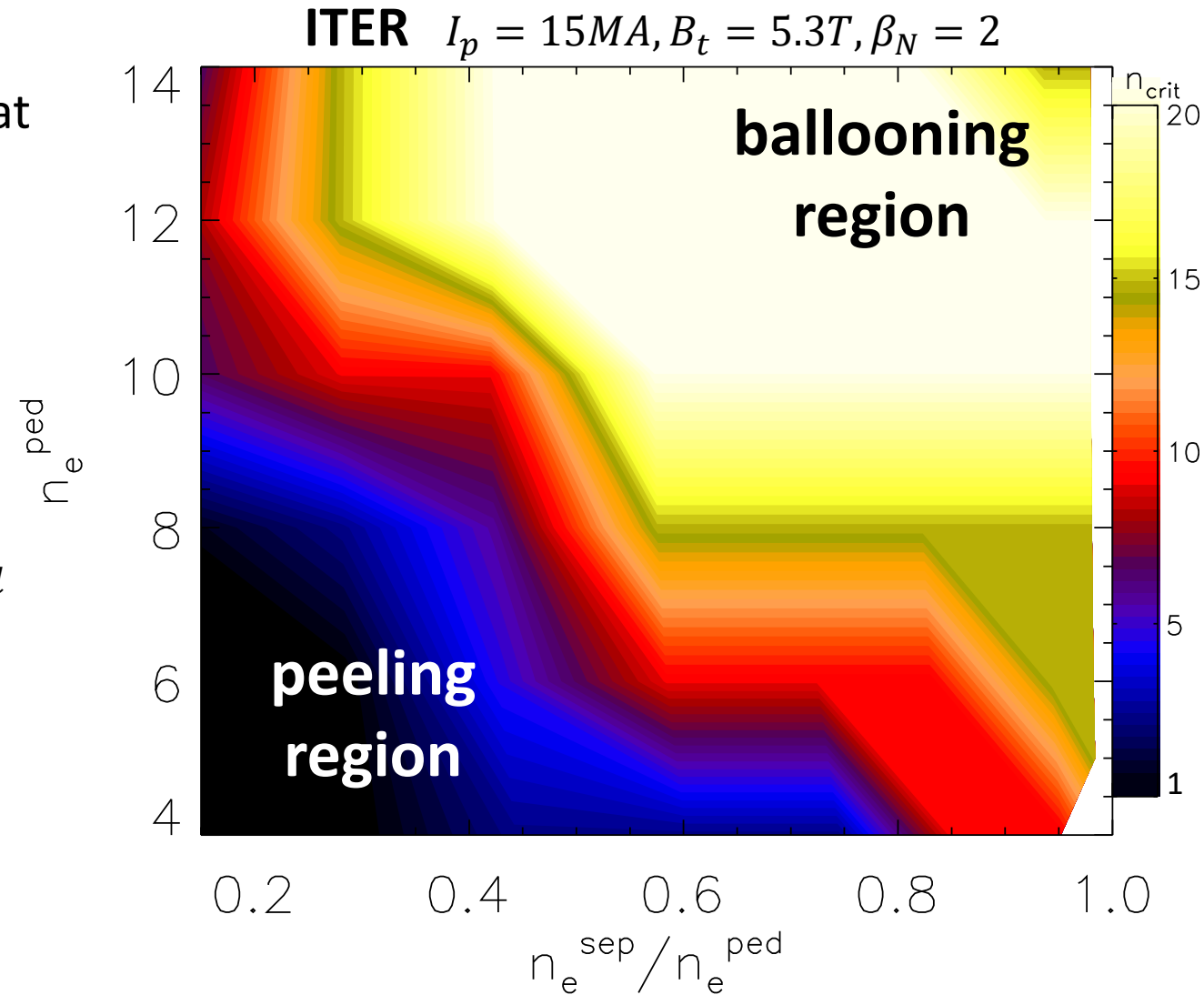
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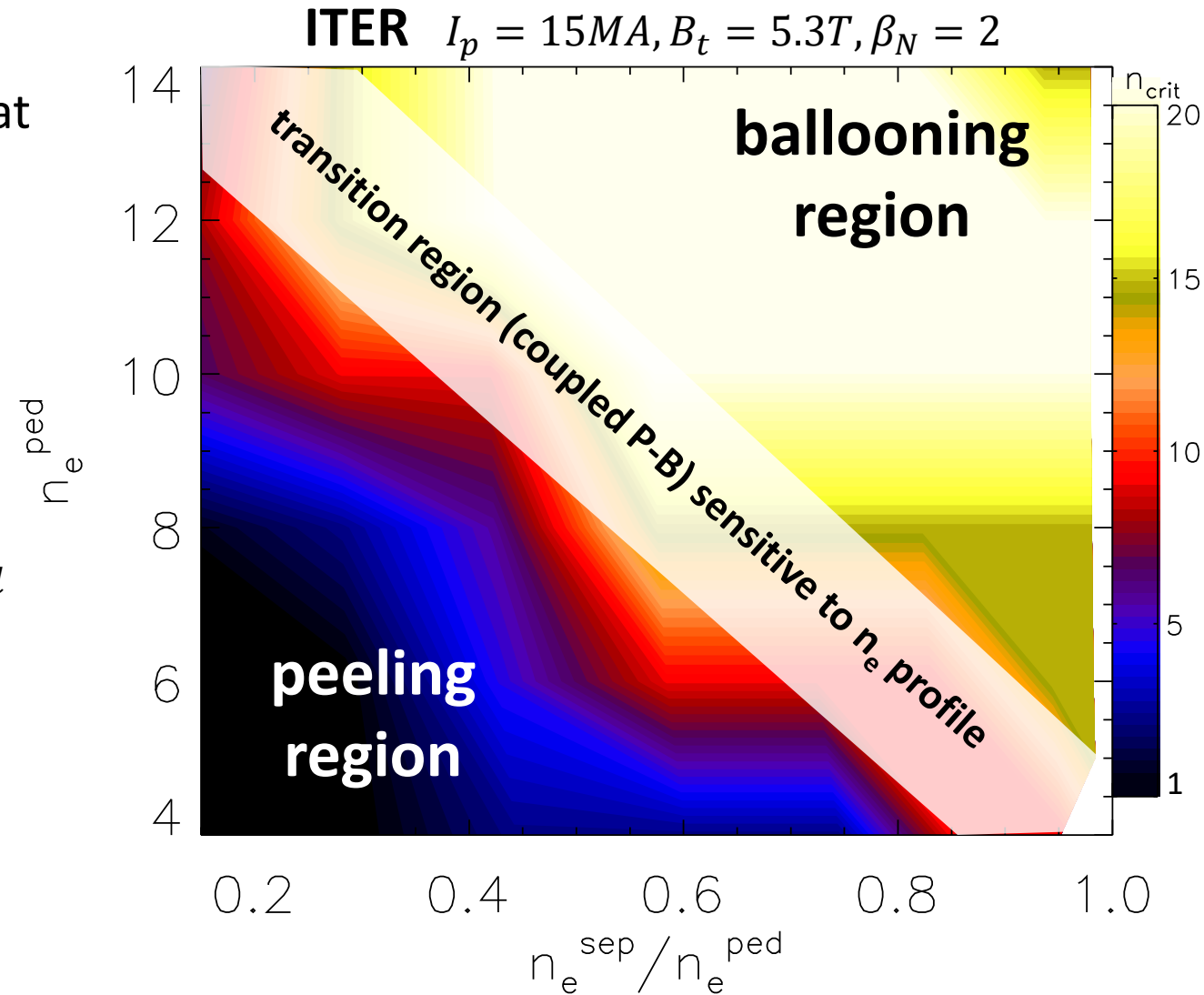
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ITER predictions: pedestal instabilities very sensitive to n_e profile

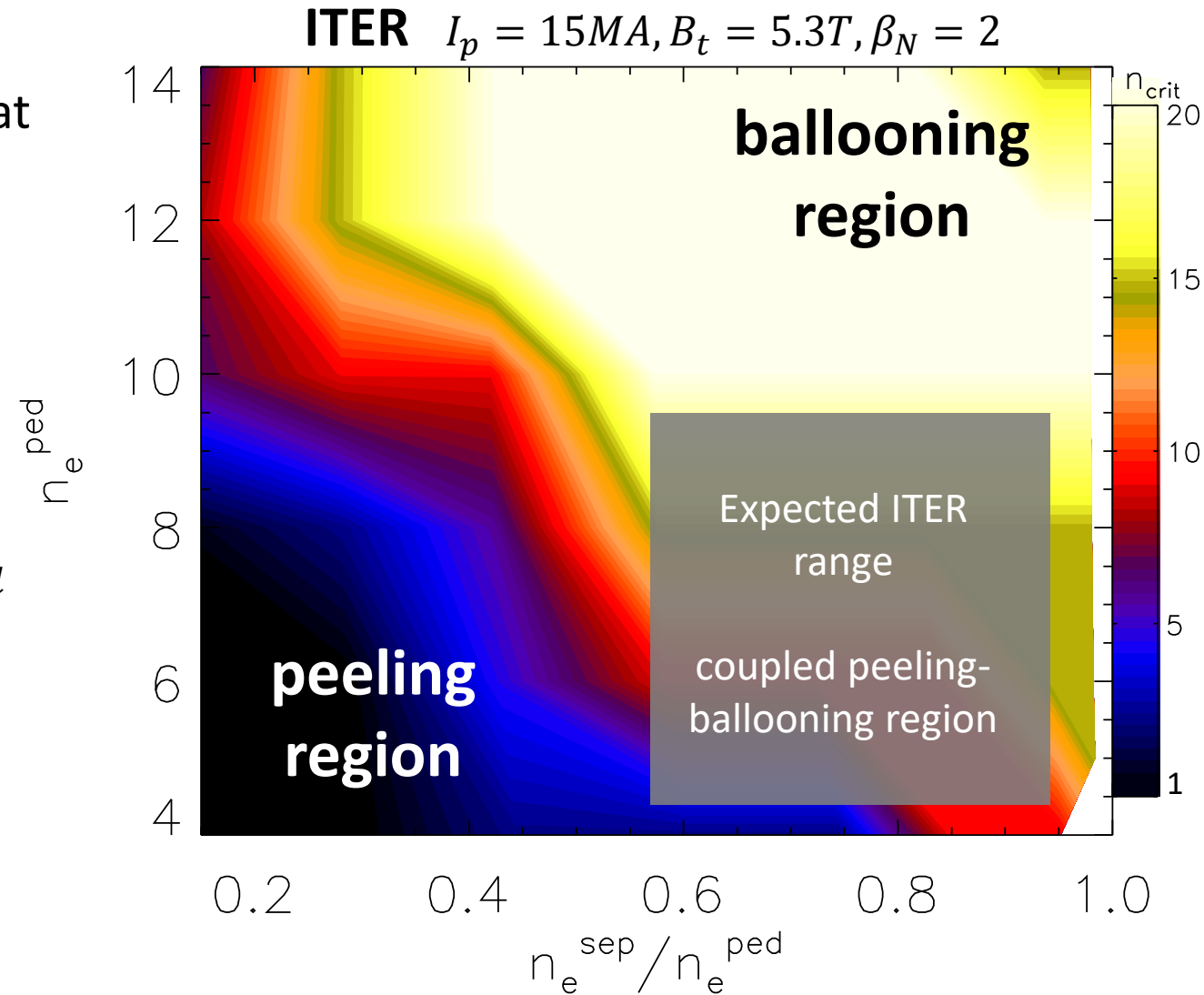
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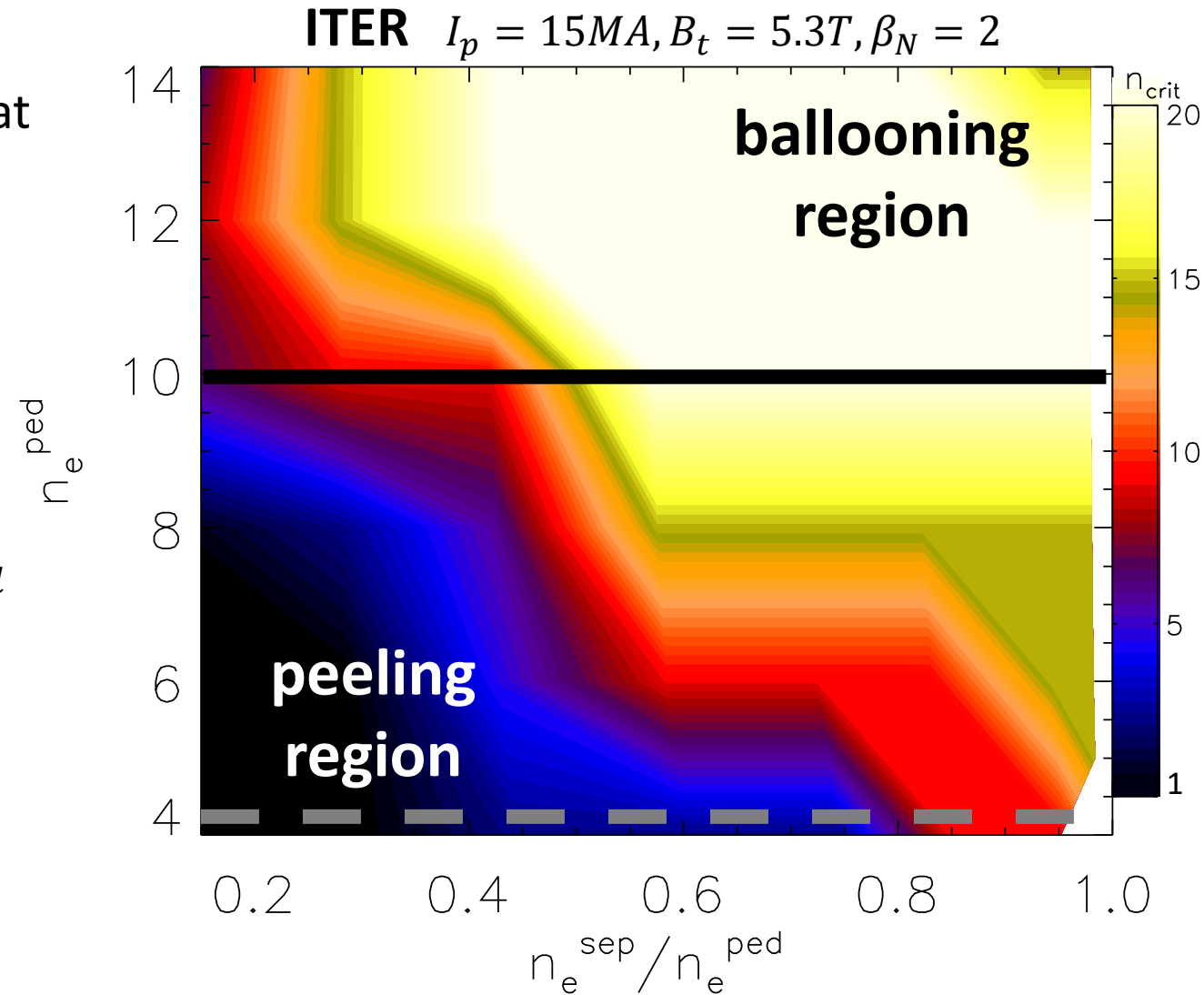
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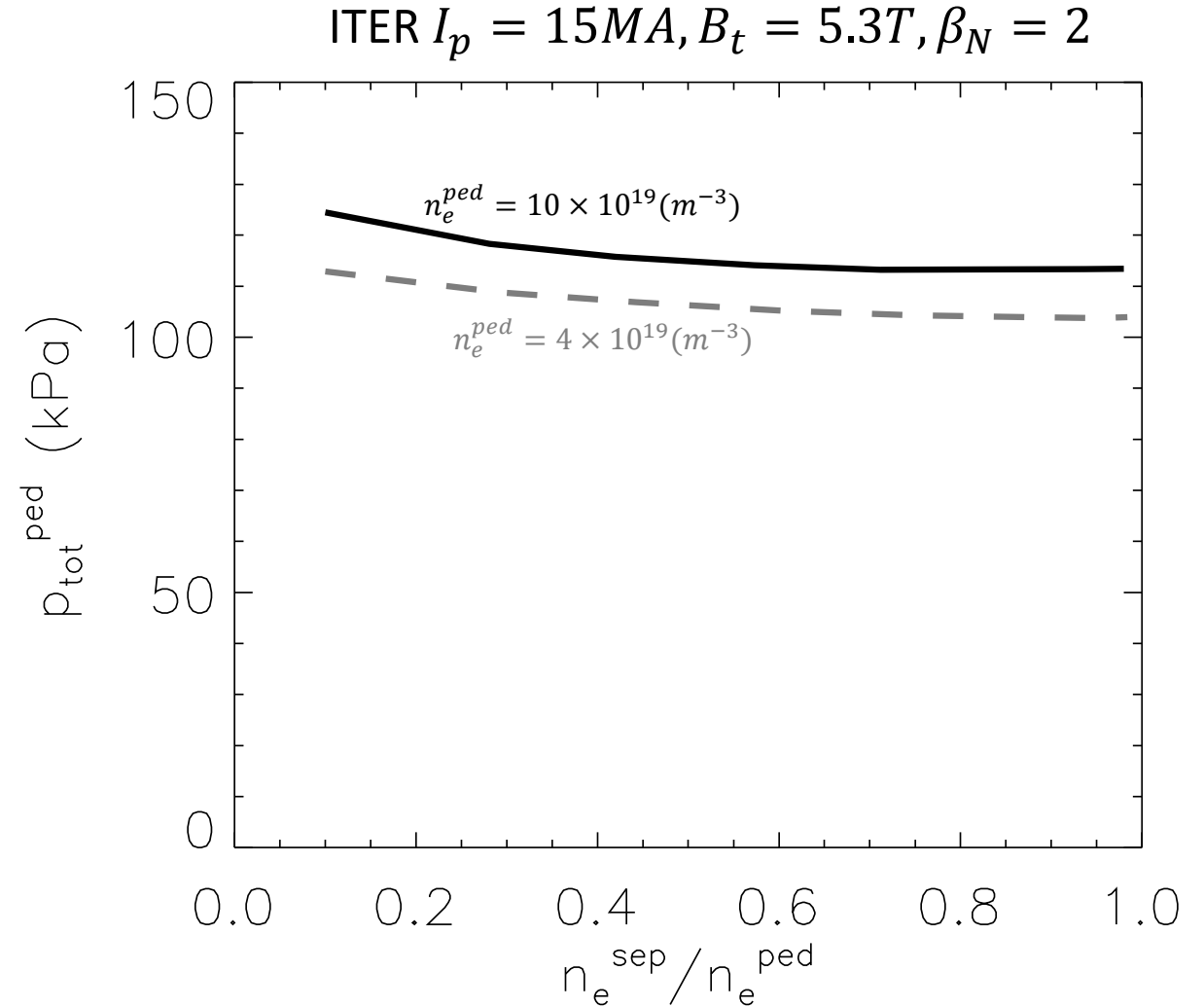
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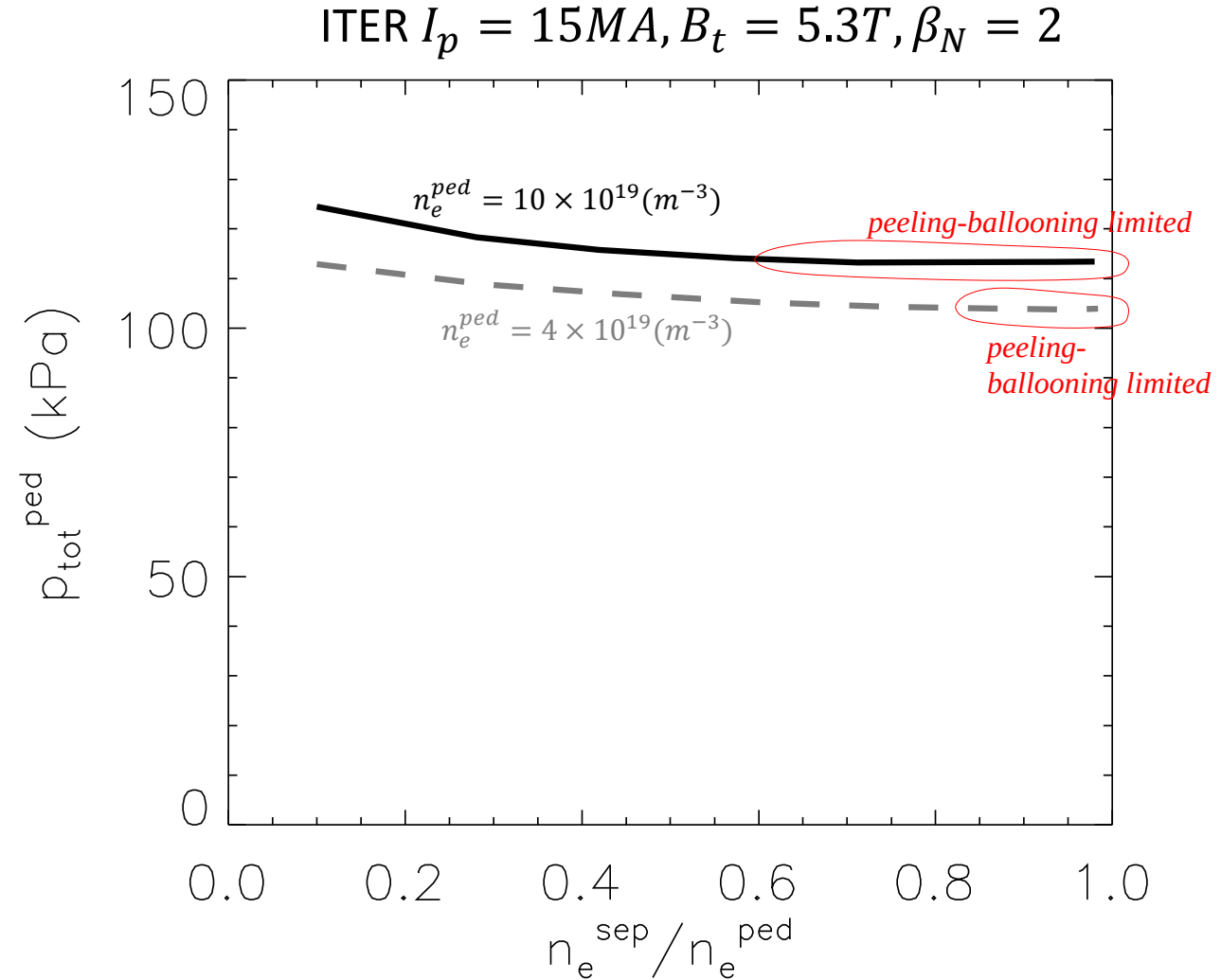
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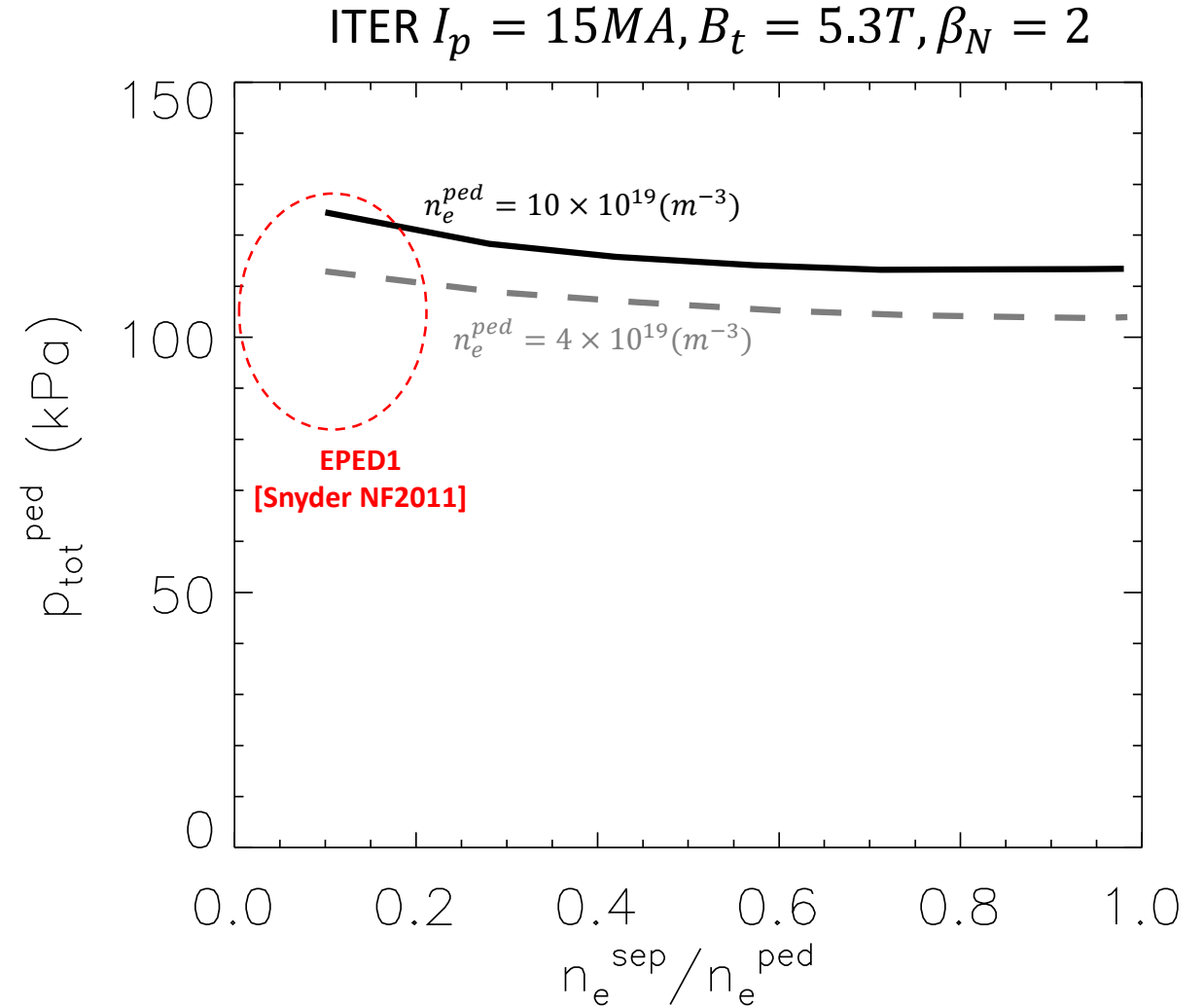
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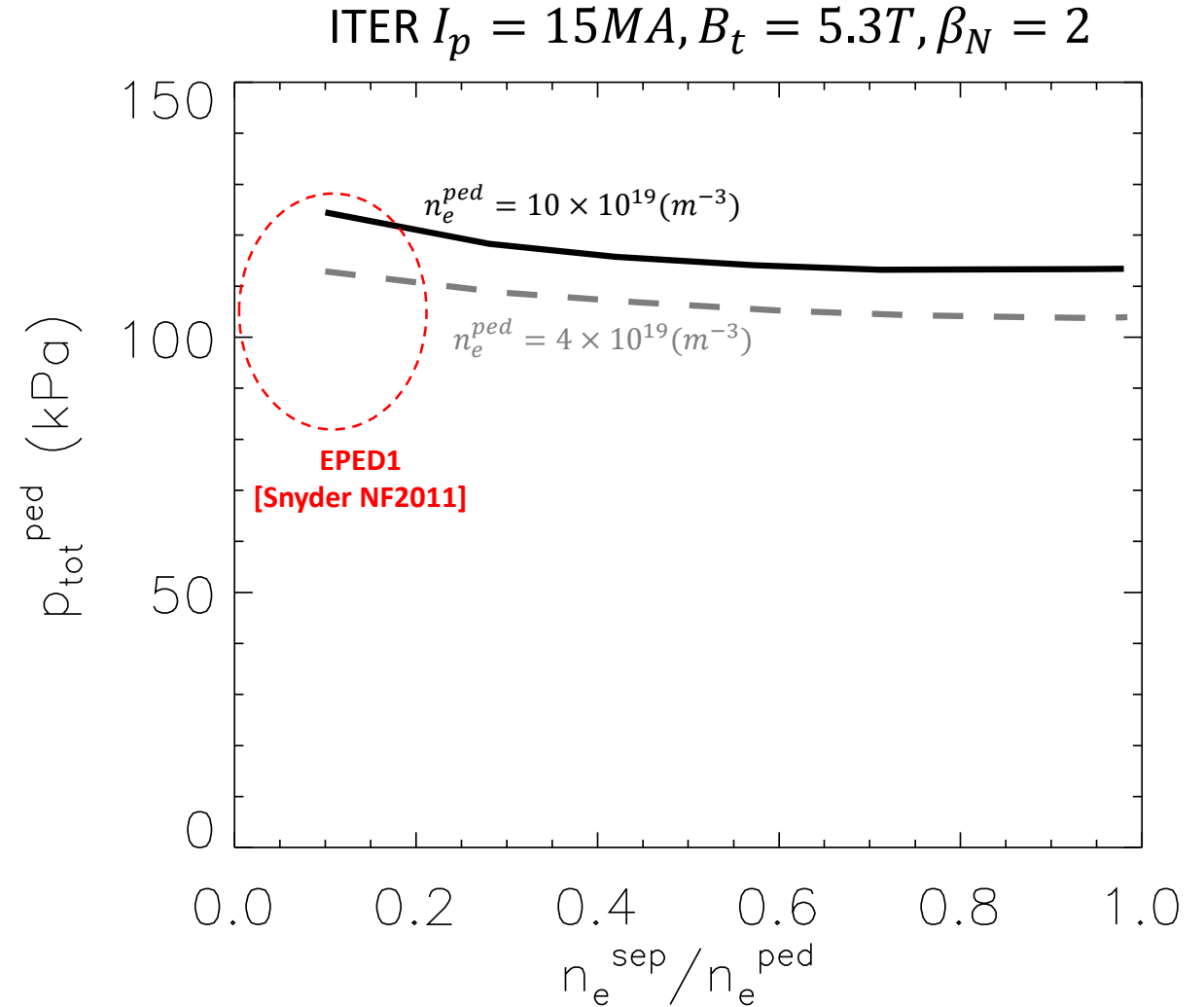




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Positive result for ITER





CONCLUSIONS

- Low v_{ee}^{*ped} /peeling limited pedestals reached in JET-ILW, MAST-U, TCV
- No major qualitative difference observed between metal wall and carbon wall machines
- Some promising results in view of ITER:
 - p^{ped} does not degrade with increasing n_e^{sep}/n_e^{ped}
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- Reasonable European predictions in the ITER range of v_{ee}^{*ped} , ρ_i^{*ped} , n_e^{sep}/n_e^{ped}
- ITER pedestal predictions:
 - Q=10 scenario will have coupled peeling-ballooning instabilities
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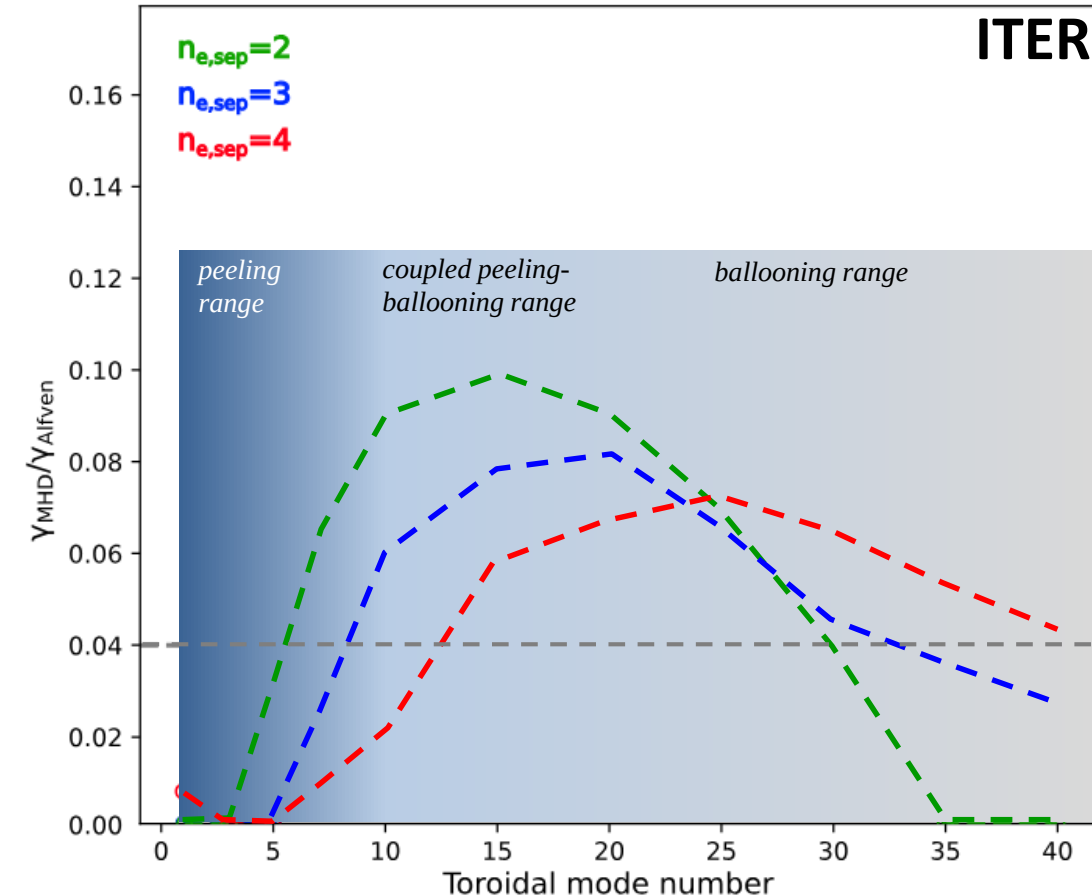




INTRODUCTION

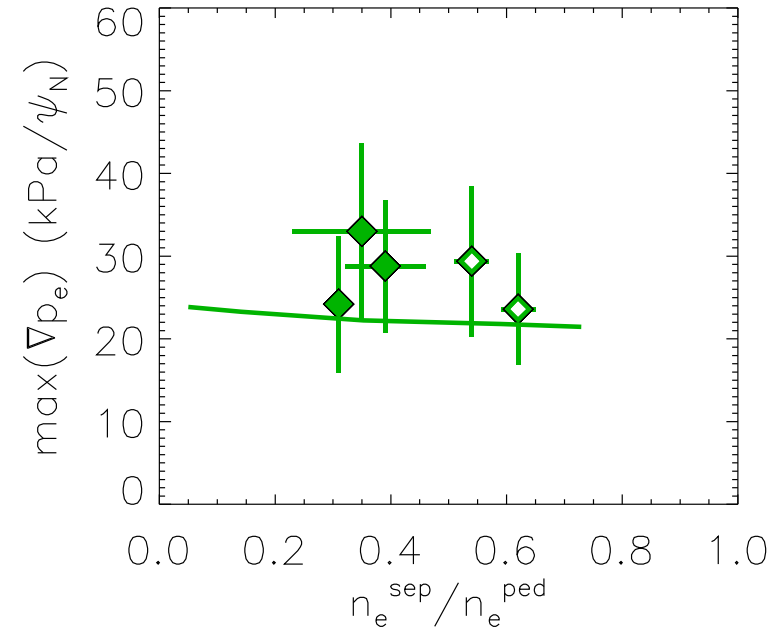
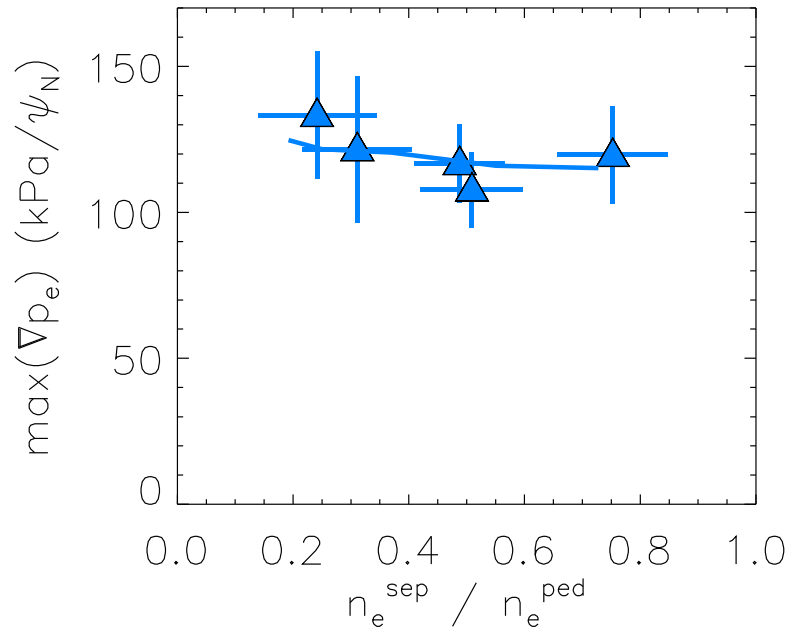
[Luda NF2025]

- Fusion power in ITER will scale as $P_{fus} \sim (p^{ped})^2$ [Kinsey IAEA2010,NF2011]
 - It is crucial to:
 - understand the pedestal behavior in present days machines.
 - validate our pedestal predictive codes
 - improve ITER pedestal predictions
- Pedestal predictions for ITER have been done already for many years. Some examples:
 - EPED model
 - ITER pedestal is likely limited by peeling instabilities → p^{ped} increases with increasing n^{ped} [Snyder NF2011]
 - Pedestal stability
 - ITER pedestal might be close to the transition between peeling and ballooning instabilities [Saarelma NF2012]
 - The result is very sensitive to the exact J_{bs} in the pedestal [Maget NF2013]
 - IMEP model
 - ITER pedestal might be limited by ballooning instabilities [Luda NF2025]





Effect of n_e^{sep}/n_e^{ped} on pedestal pressure

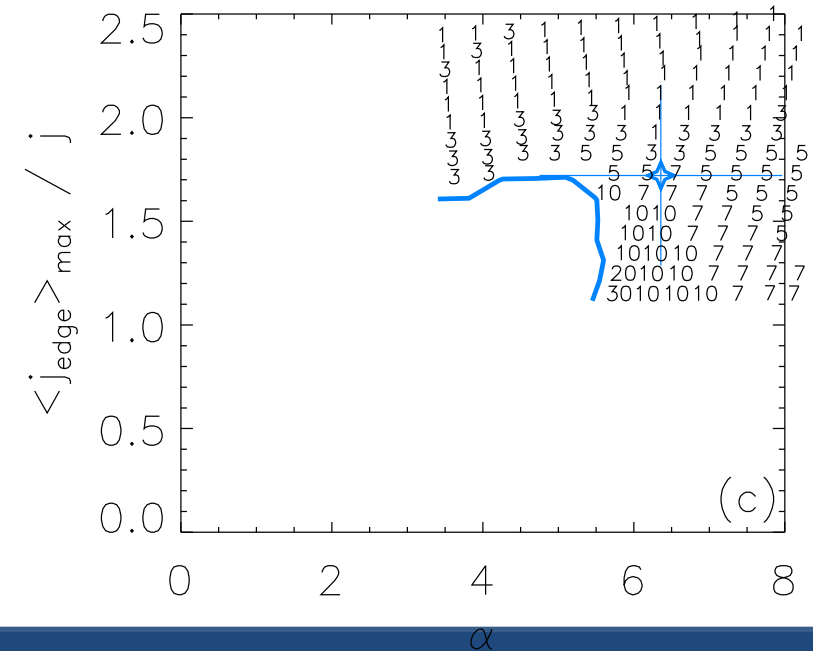
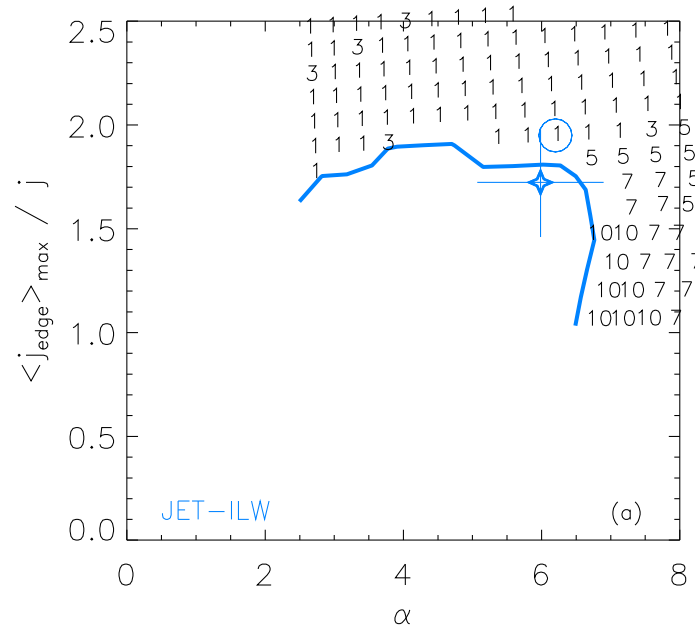
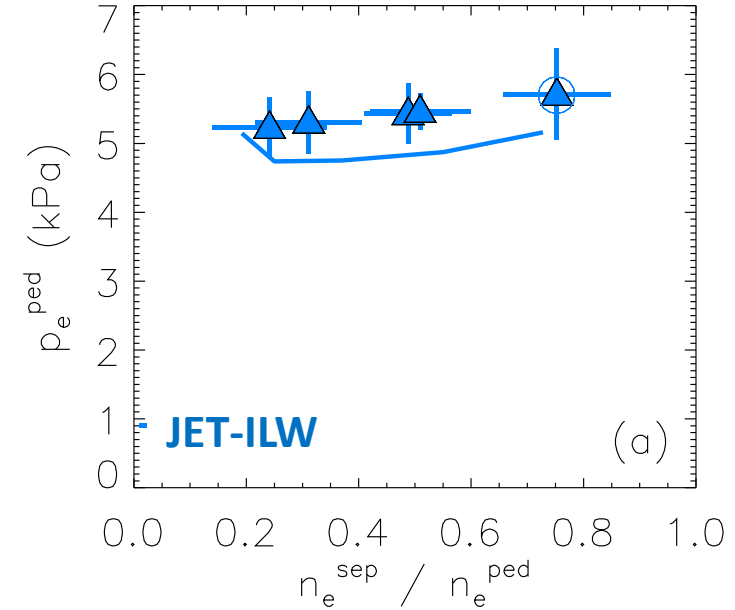


- With increasing n_e^{sep}/n_e^{ped} (at constant n_e^{ped})
 - T_e^{ped} is not strongly affected (same for T_i^{ped})
 - p_e^{ped} is rather constant (same for p_{tot}^{ped})
 - behavior opposite to what observed in ballooning limited pedestals
- Pedestal predictions:
 - Good qualitative agreement in both JET-ILW and TCV



Increasing n_e^{sep}/n_e^{ped} can effects on the global pedestal stability

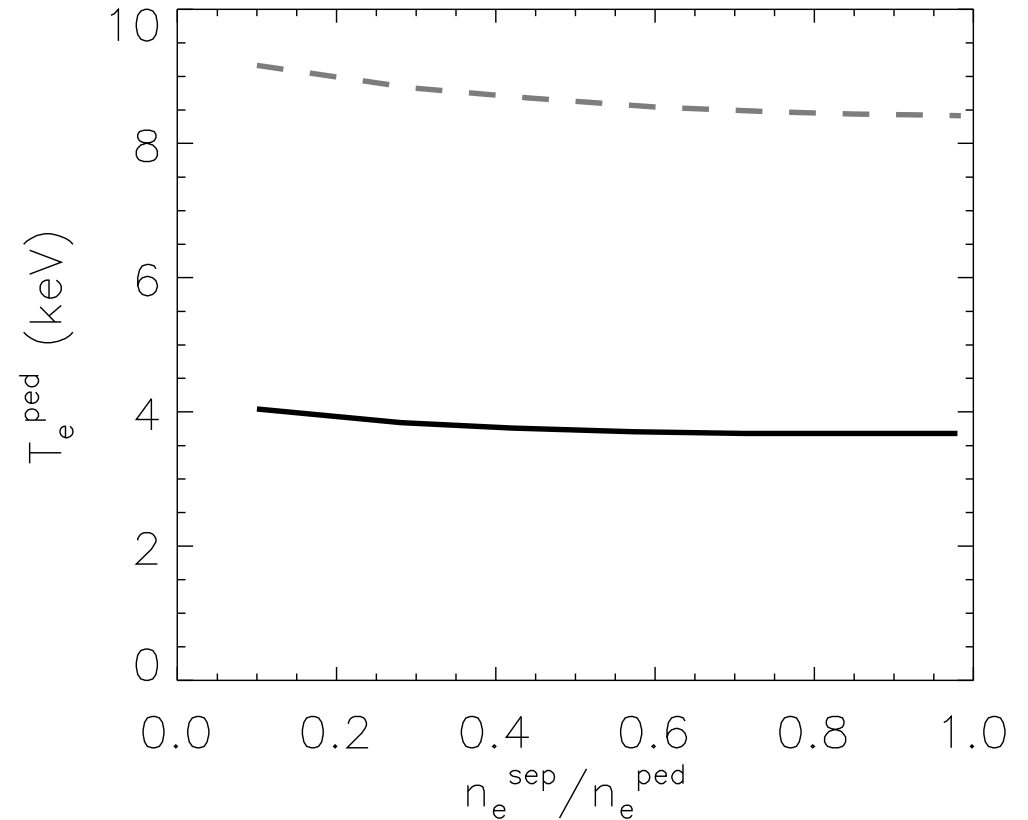
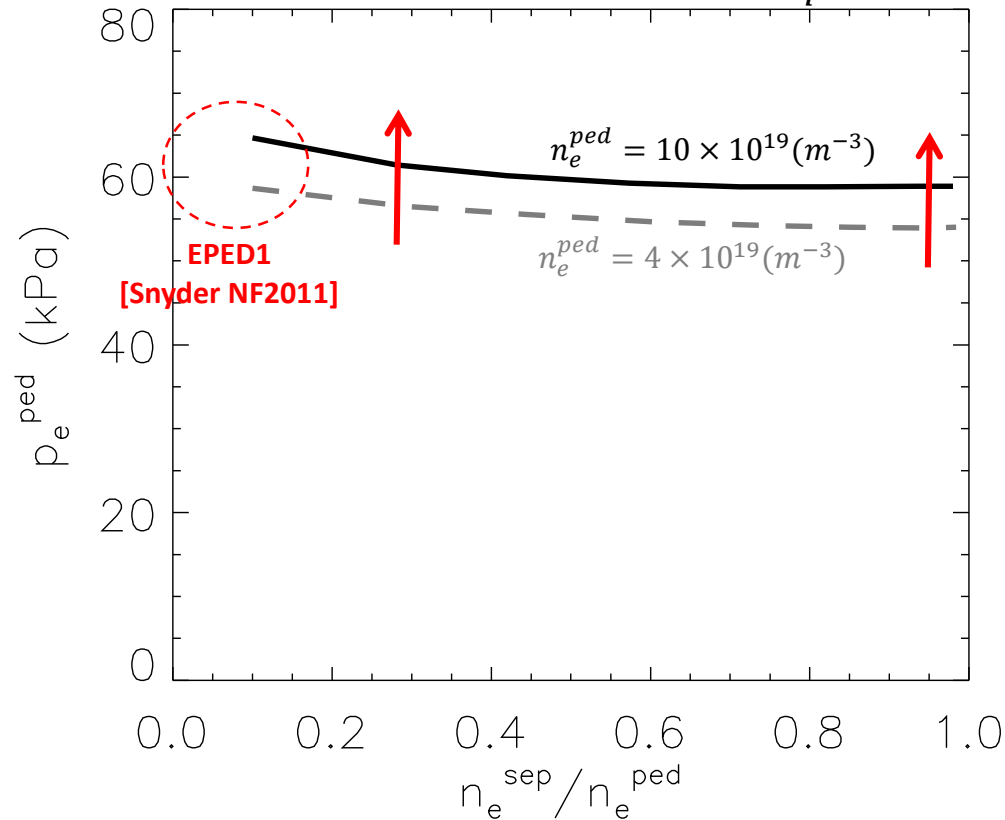
- Increasing n_e^{sep}/n_e^{ped} destabilizes ballooning modes
 - increasing n_e^{sep}/n_e^{ped} can shift the pedestal from peeling limited to ballooning limited





ITER predictions: no major degradation expected if ballooning limited

ITER $I_p = 15\text{MA}$, $B_t = 5.3\text{T}$, $\beta_N = 2$



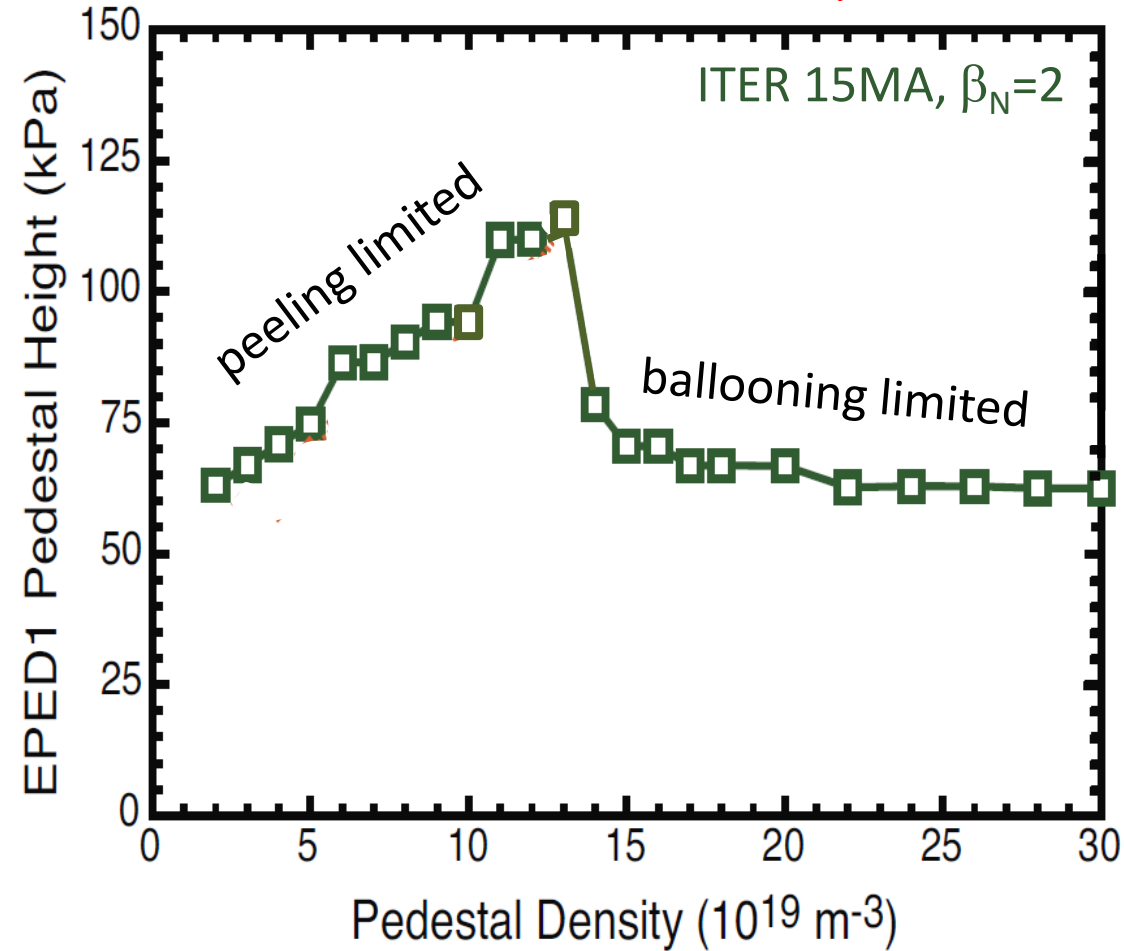
- The transition to ballooning limited pedestals occurs at already high $n_e^{\text{sep}}/n_e^{\text{ped}}$ and high n_e^{ped}
 - the degrading effects of $n_e^{\text{sep}}/n_e^{\text{ped}}$ is negligible.
 - p_e^{ped} still increases with increasing n_e^{ped}
- Results consistent with earlier predictions



INTRODUCTION

- The pedestal plays a major role for ITER:
 - fusion power will scale as $P_{fus} \sim (p^{ped})^2$
- ITER pedestal predictions have been done already for many years. Examples:
 - EPED model

[Snyder NF2011]

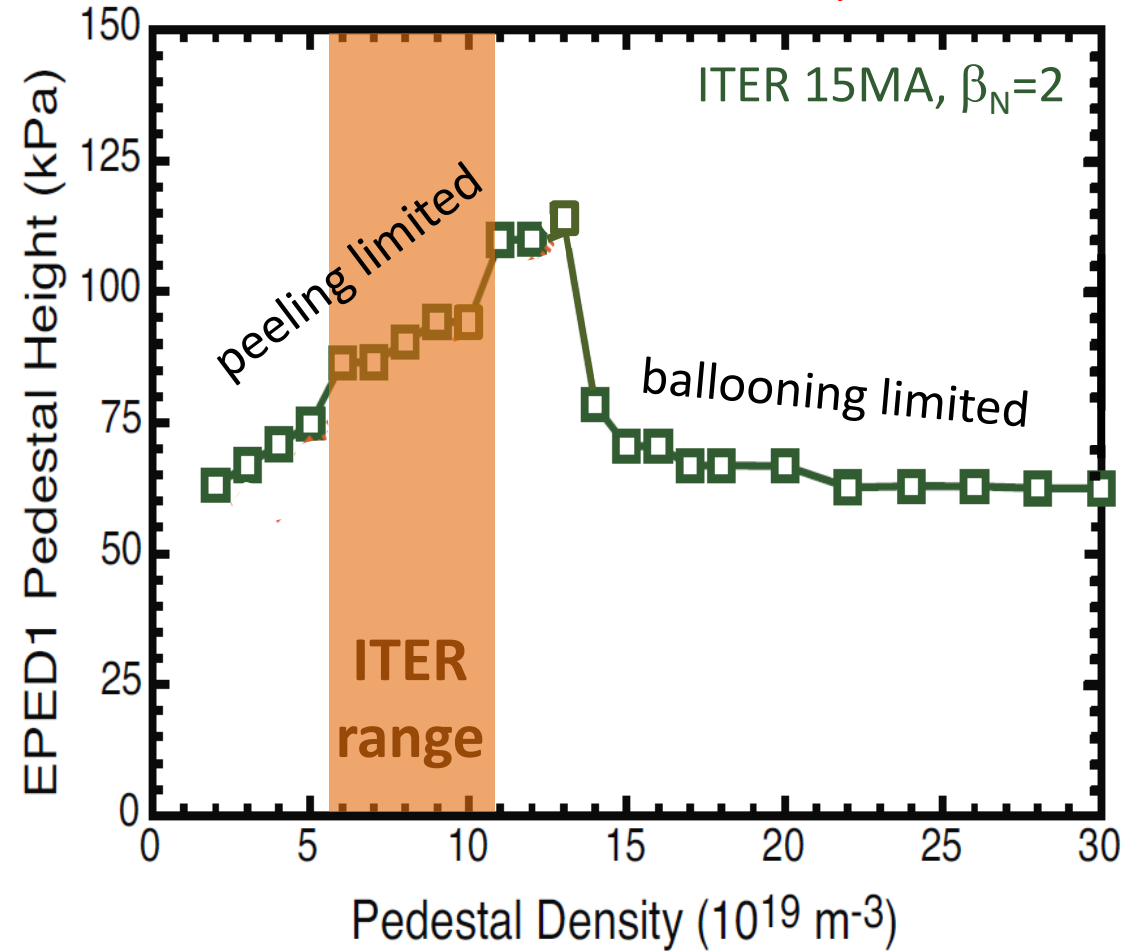




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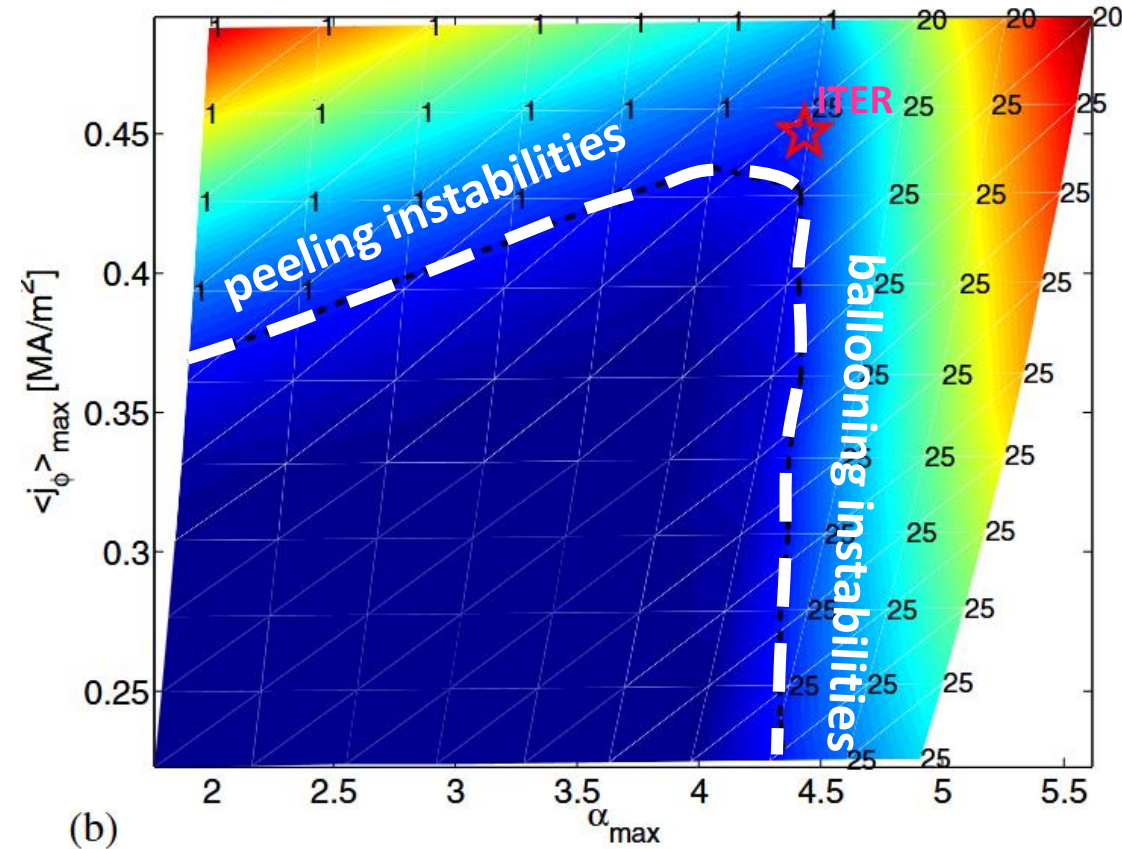




INTRODUCTION

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 - EPED model
 - ITER pedestal is likely limited by peeling instabilities [Snyder NF2011]
 - Pedestal stability
 - ITER pedestal might be close to the transition between peeling and ballooning instabilities [Saarelma NF2012]
 - The result is very sensitive to the pedestal J_{bs} [Maget NF2013]

[Saarelma NF2012]





INTRODUCTION

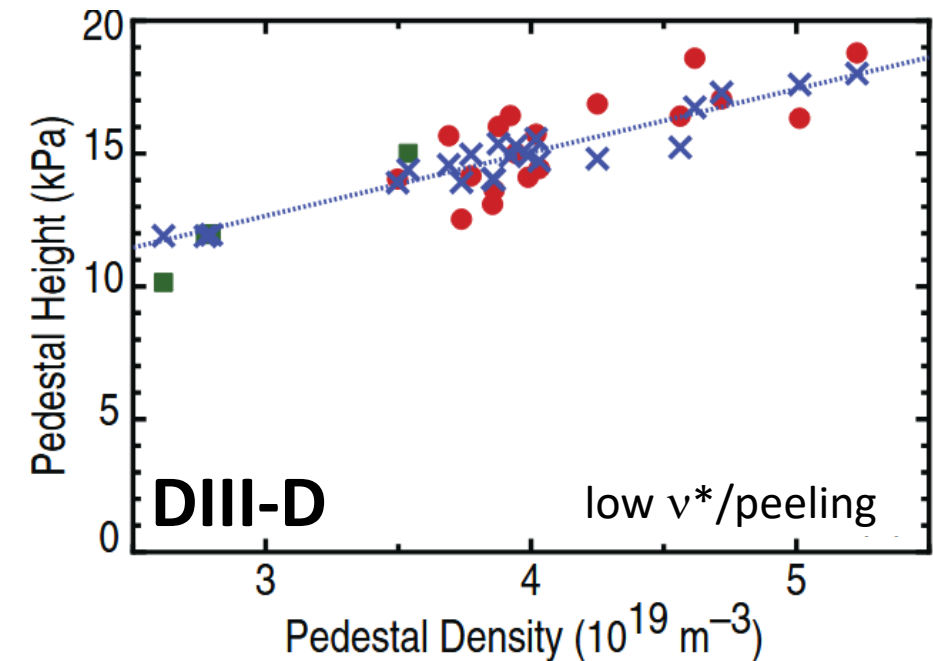
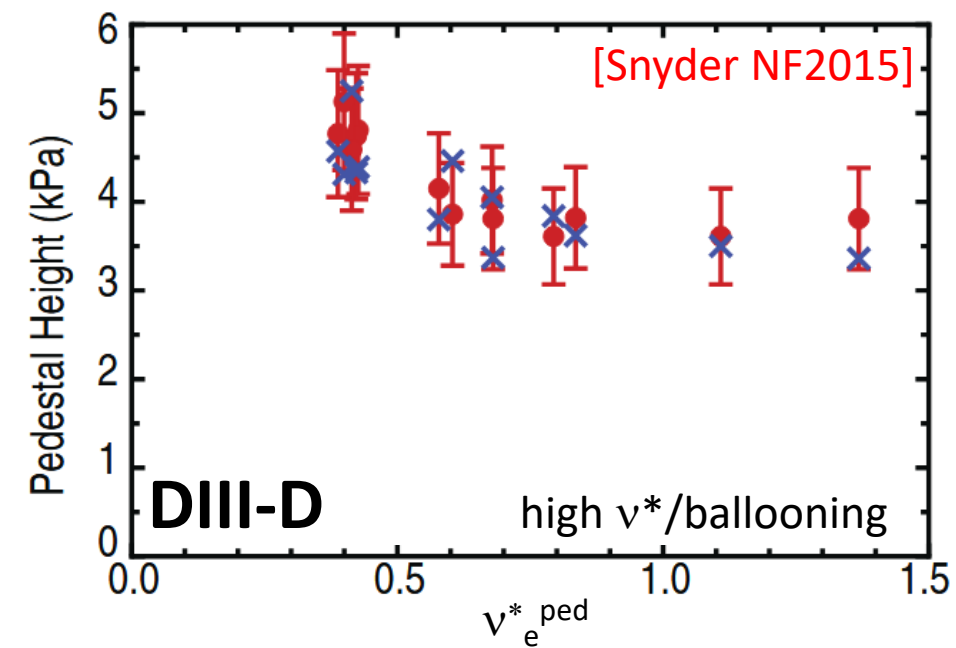
- Different pedestal behavior expected depending on the limiting instability:

- **ballooning instabilities:**

- p^{ped} decreases with increasing n^{ped}

- **peeling instabilities:**

- p^{ped} increases with increasing n^{ped}





INTRODUCTION

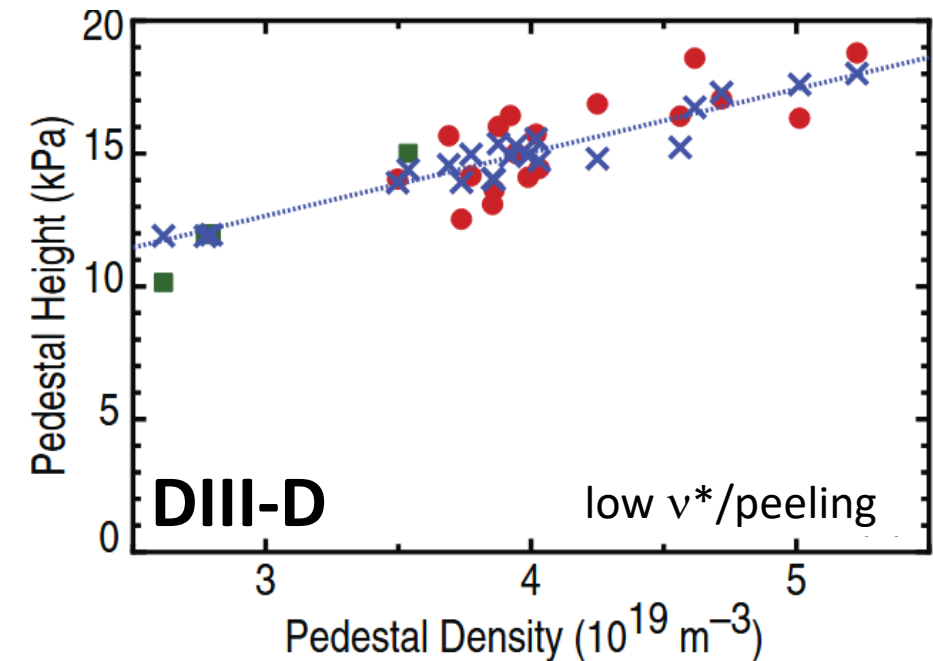
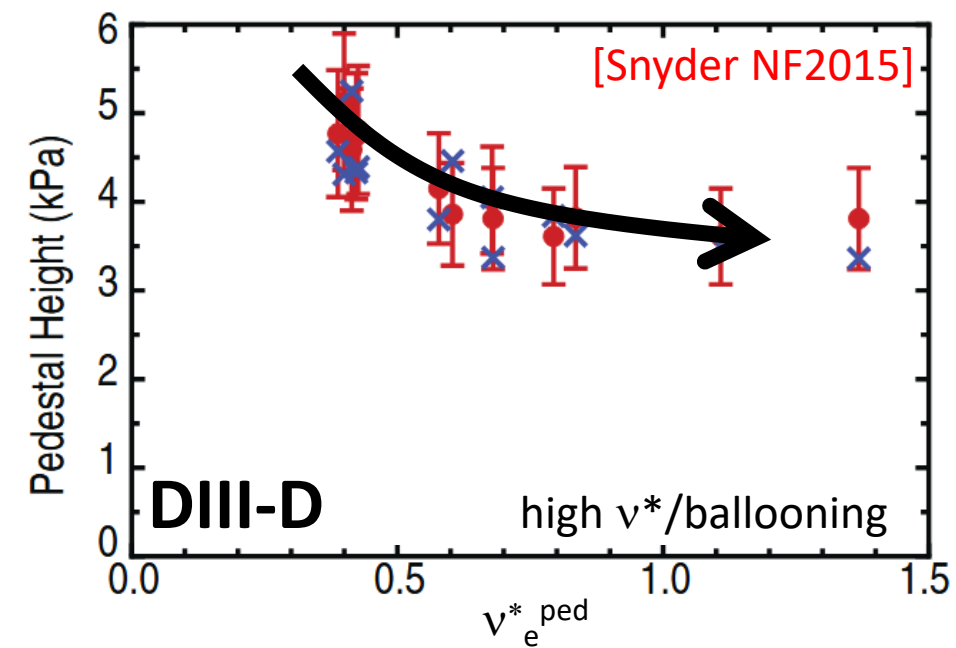
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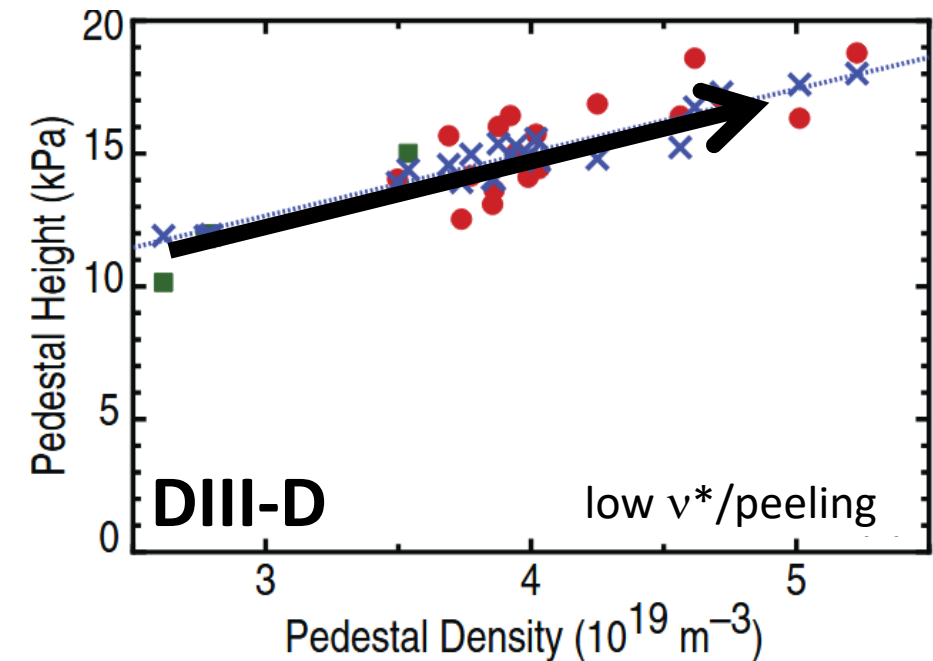
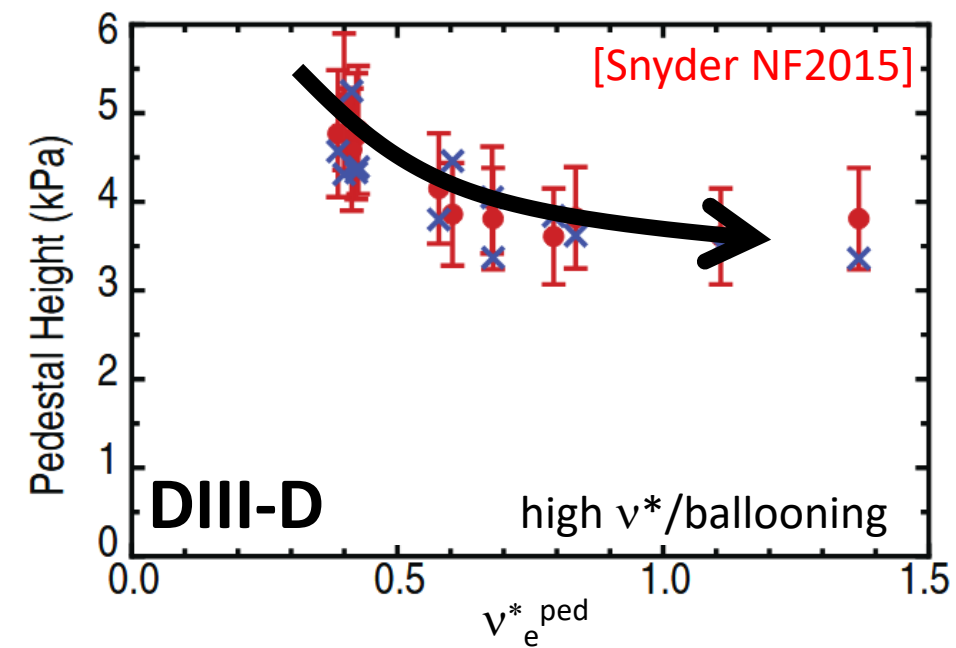
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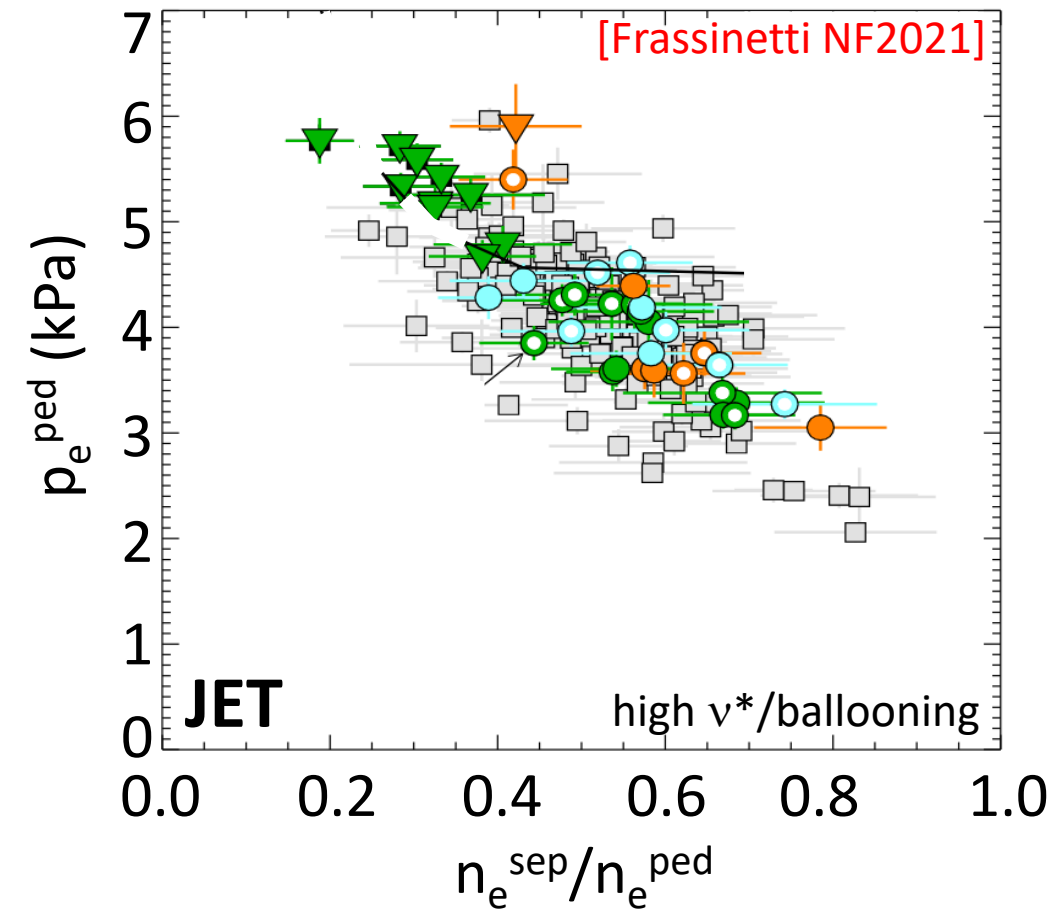
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INTRODUCTION

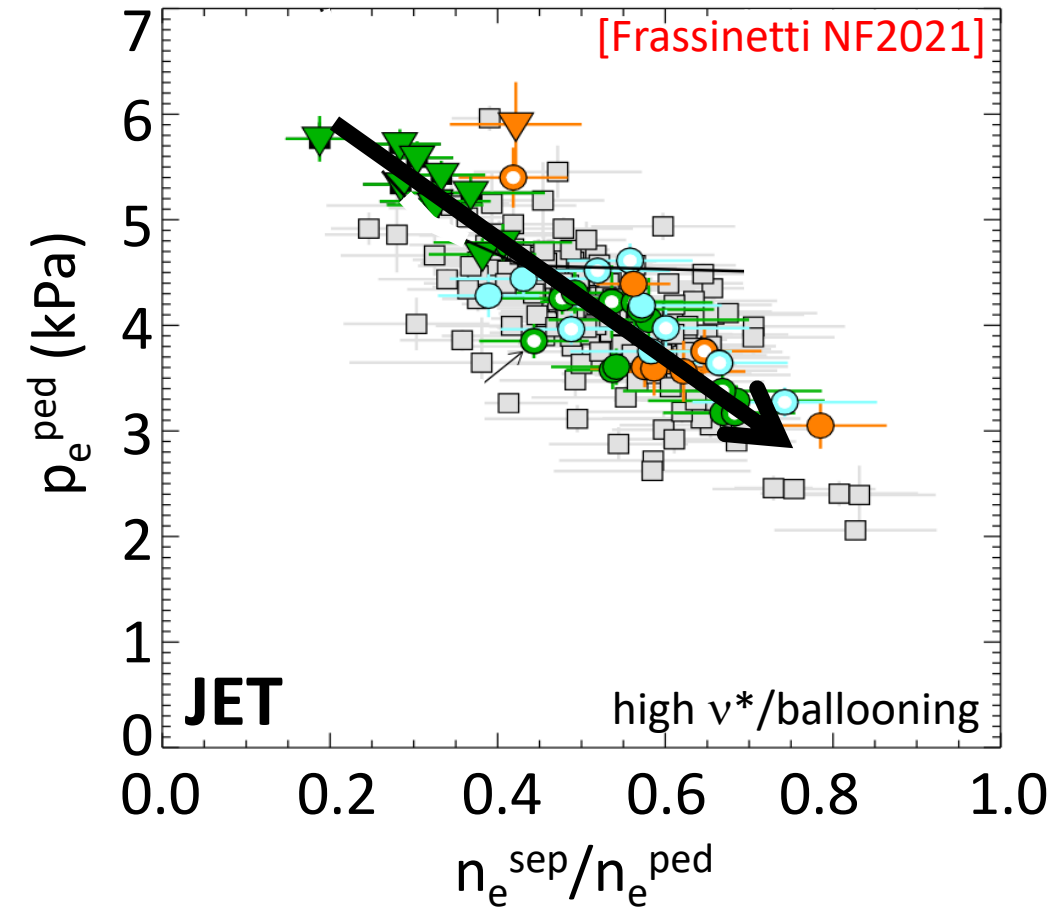
- Different pedestal behavior expected depending on the limiting instability:
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 - **peeling instabilities:**
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 - p^{ped} versus n^{sep}/n^{ped} ?





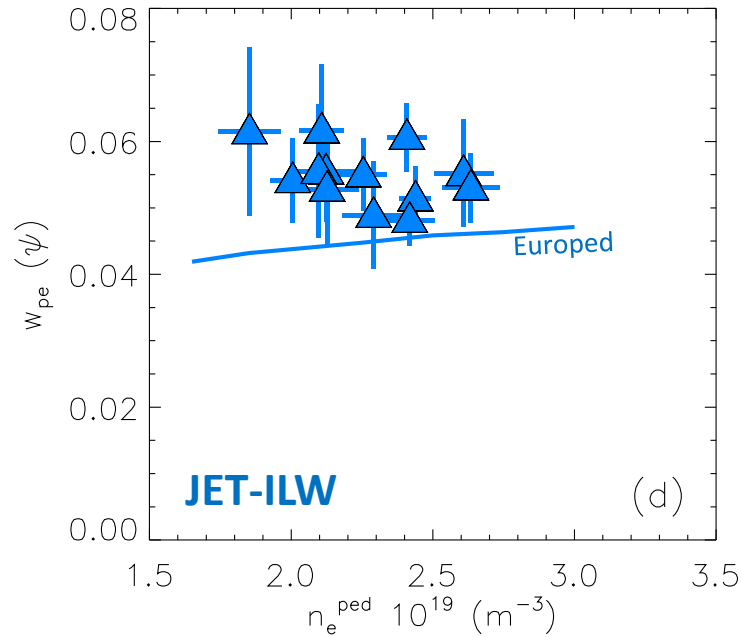
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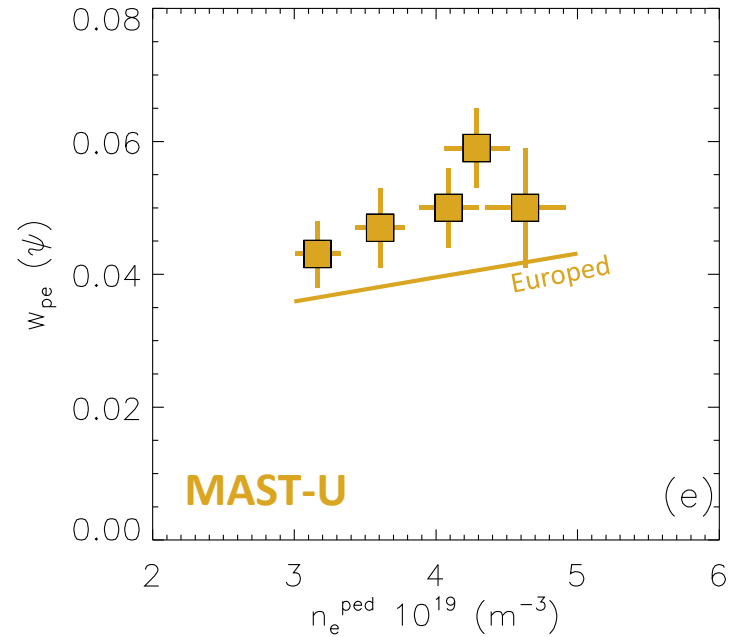
Different mechanisms explain the increase in p_e^{ped}



JET-ILW:

The increase in p_e^{ped} is due to:

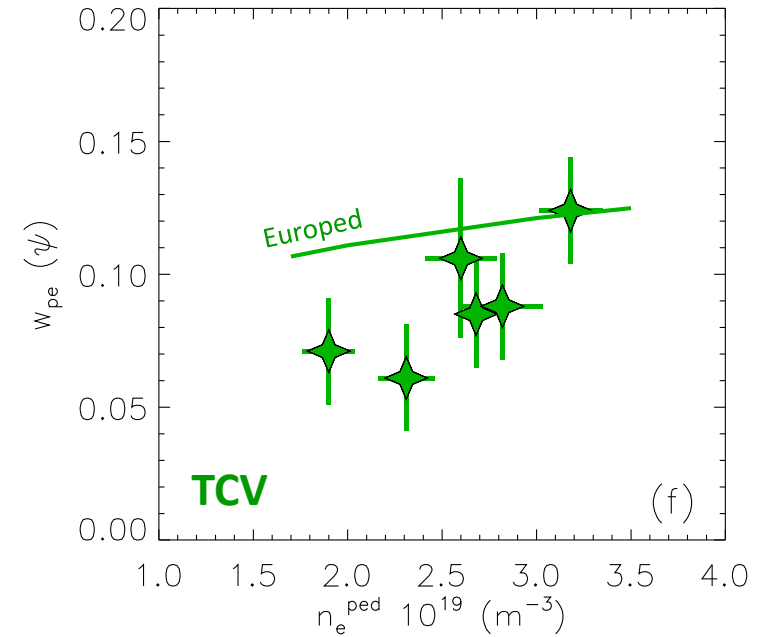
- the increase in the gradient
 - effect due to the stabilization of peeling modes
- NOT an increase in the pedestal width



MAST-U:

The increase in p_e^{ped} is due to:

- the increase in the gradient
 - effect due to the stabilization of peeling modes
- the increase in the pedestal width



TCV:

The increase in p_e^{ped} is due to:

- NOT the increase in the gradient
 - effect NOT due to the stabilization
- the increase in the pedestal width

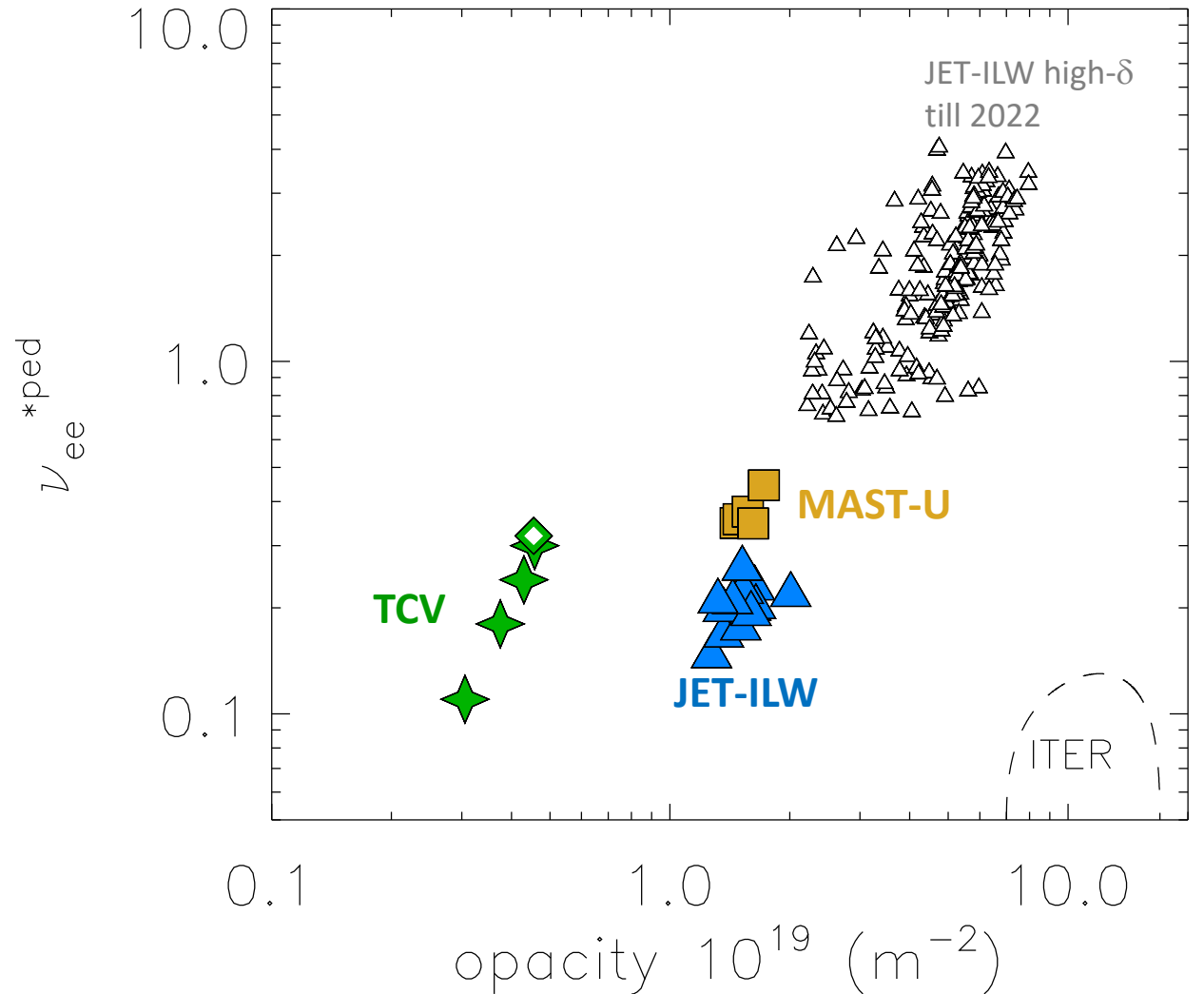


Opacity

- Opacity defined as in [Mordijc NF2020]:

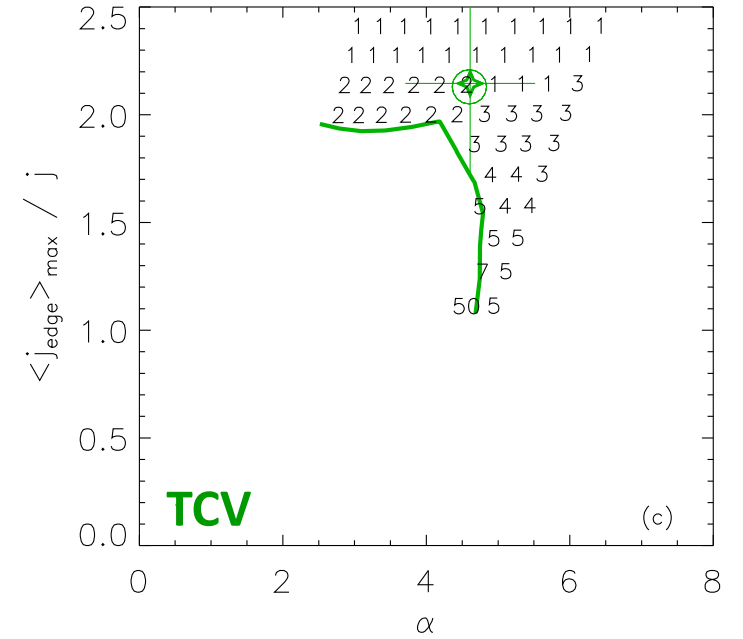
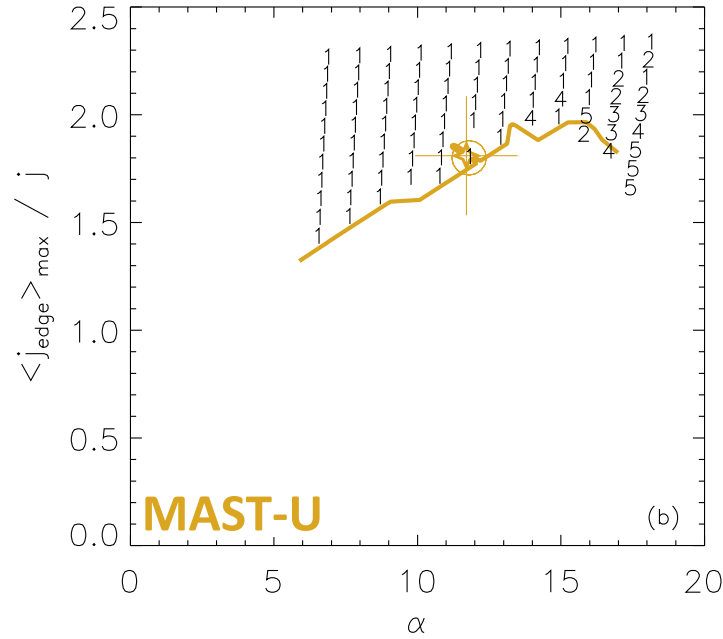
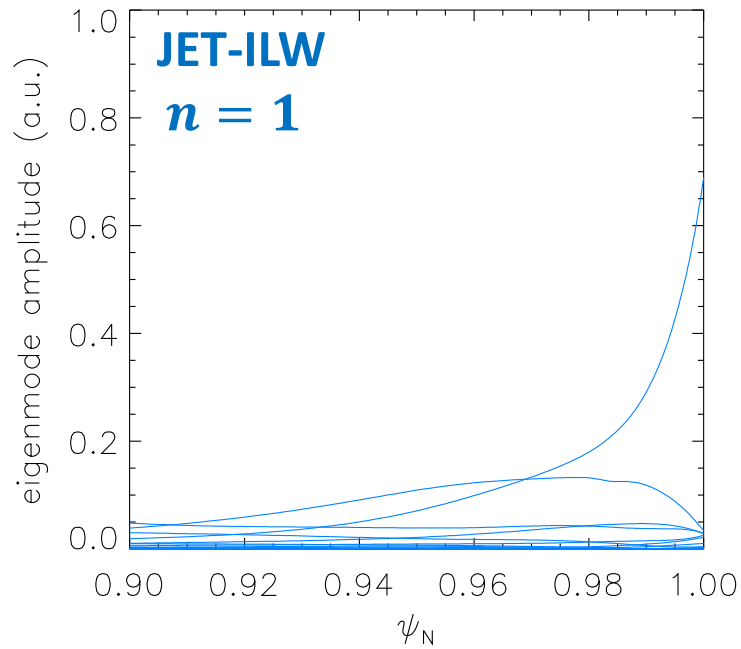
$$\frac{(n_e^{ped} + n_e^{sep})}{2} \times a$$

- The TCV dataset has opacity much lower than JET-ILW and MAST-U, mainly due to the lower size





PEELING LIMITED PEDESTALS REACHED IN JET-ILW, MAST-U AND TCV



JET-ILW:

- Pedestal:
 - near the peeling boundary
 - limited by low- n modes
- Clear dominant peeling component

MAST-U:

- Pedestal:
 - at the peeling boundary
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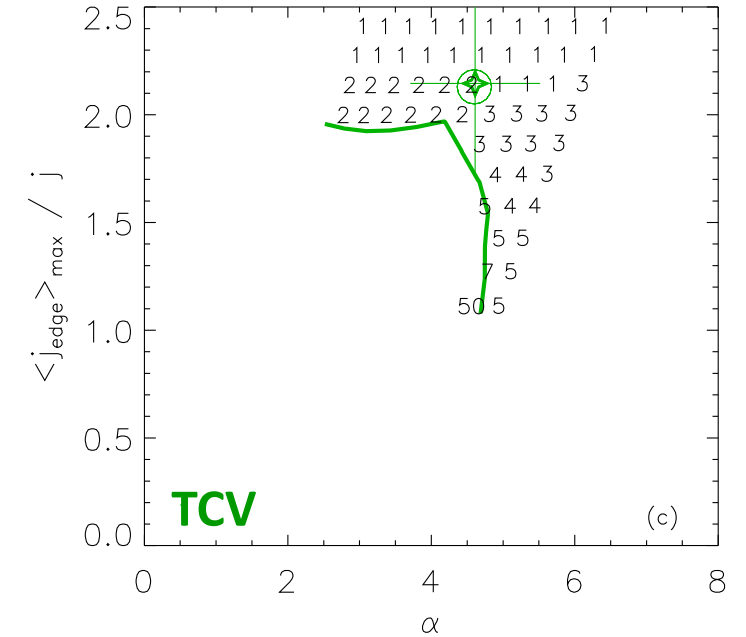
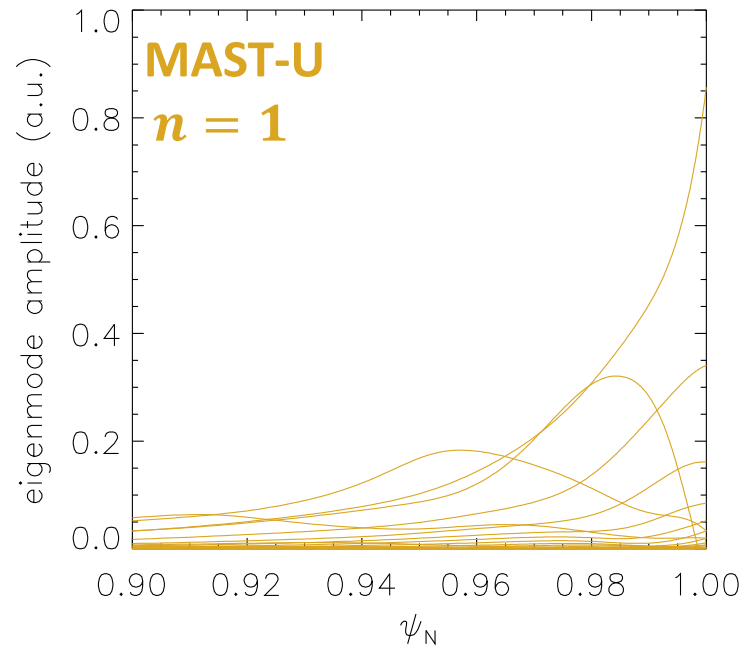
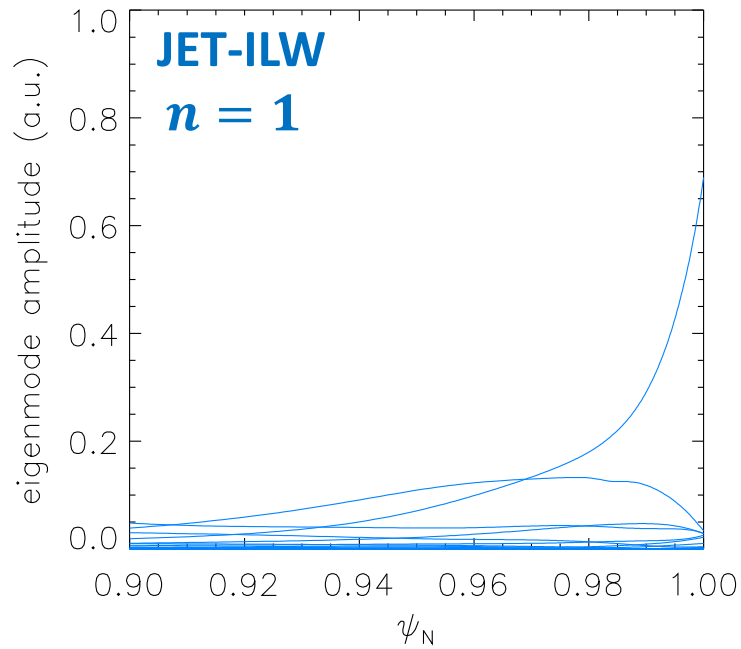
TCV:

- Pedestal:
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HELENA for equilibrium and MISHKA for the stability (with diamagnetic criterion)



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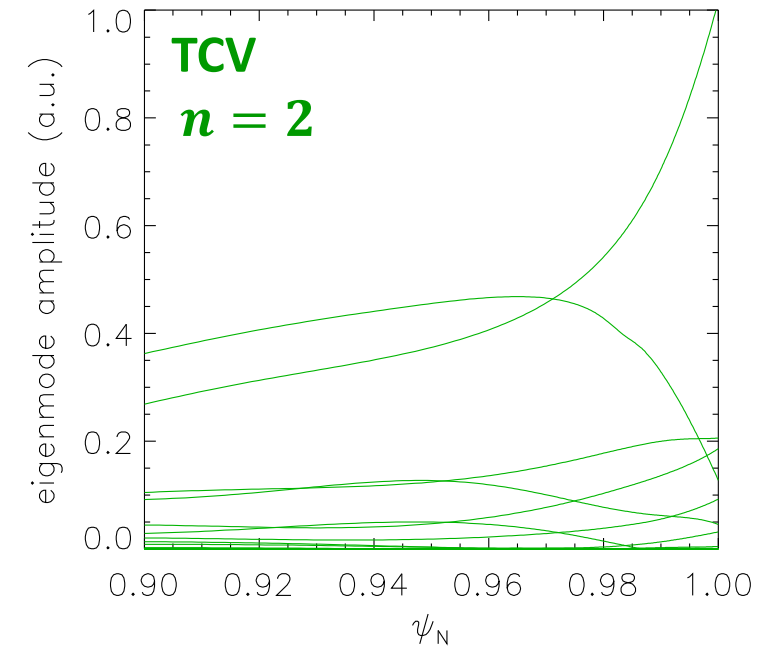
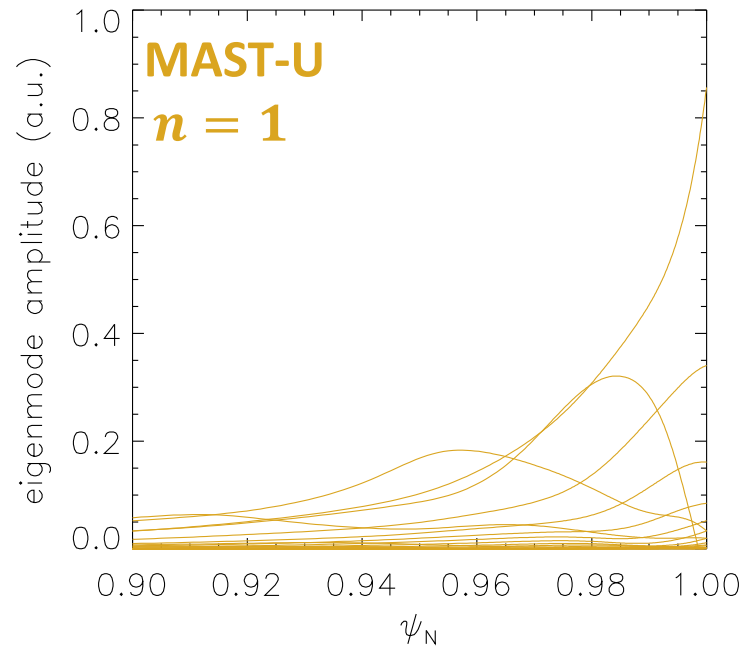
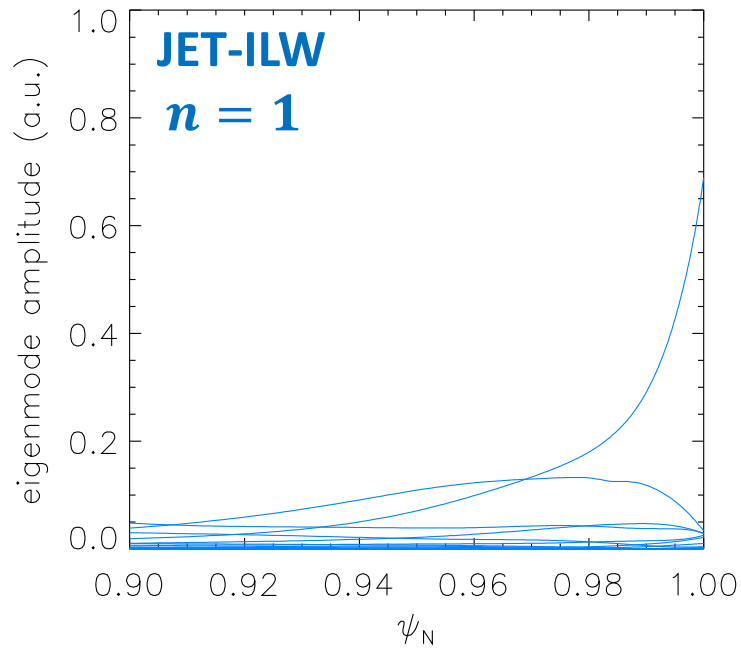
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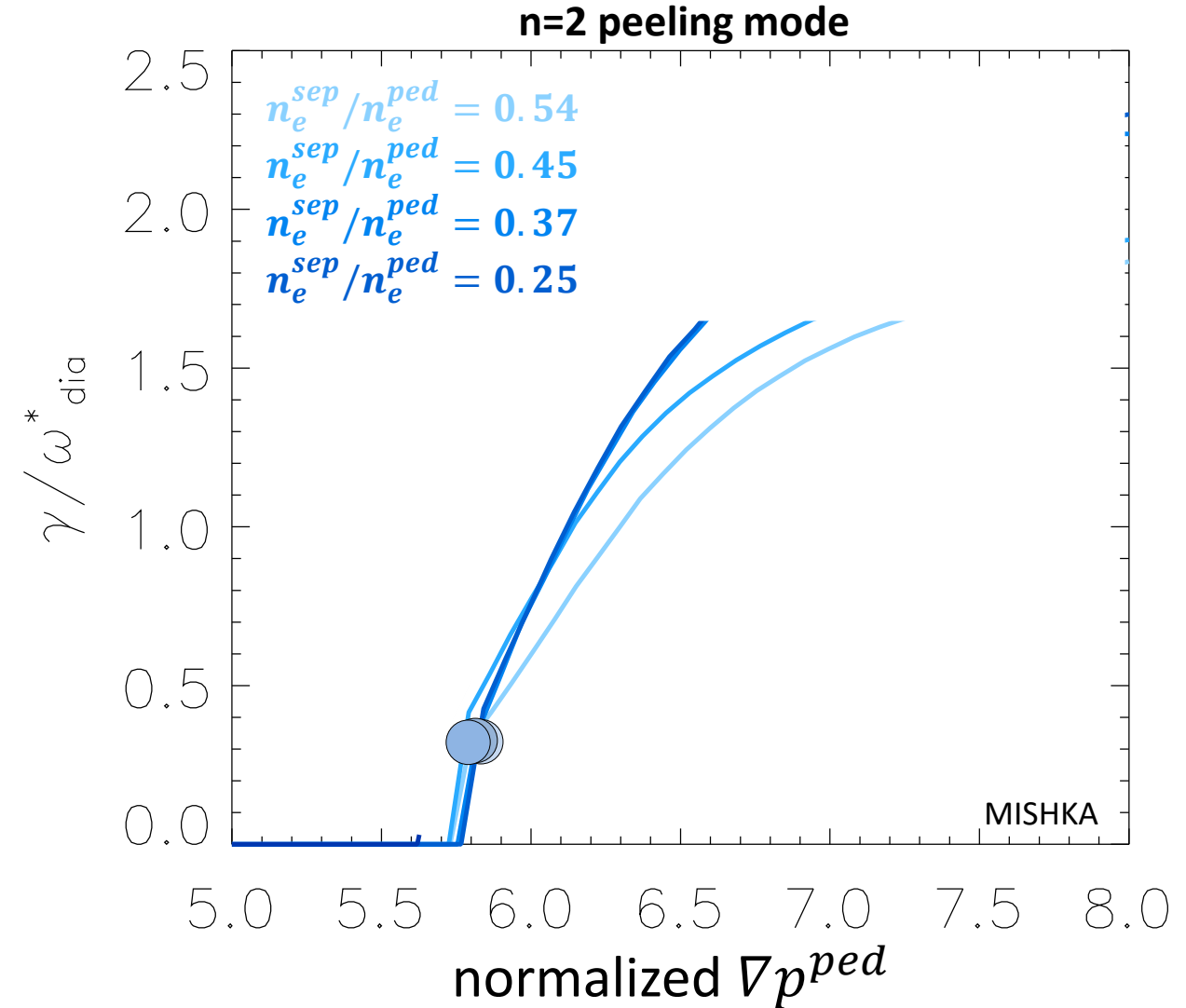
Increasing n_e^{sep}/n_e^{ped} has minor effects on peeling mode stability

- Zero-order explanation:

- The increase of n_e^{sep}/n_e^{ped} does not have a major effect on peeling modes

[Frassinetti NF2025]

→ No variation is expected in ∇p^{ped}



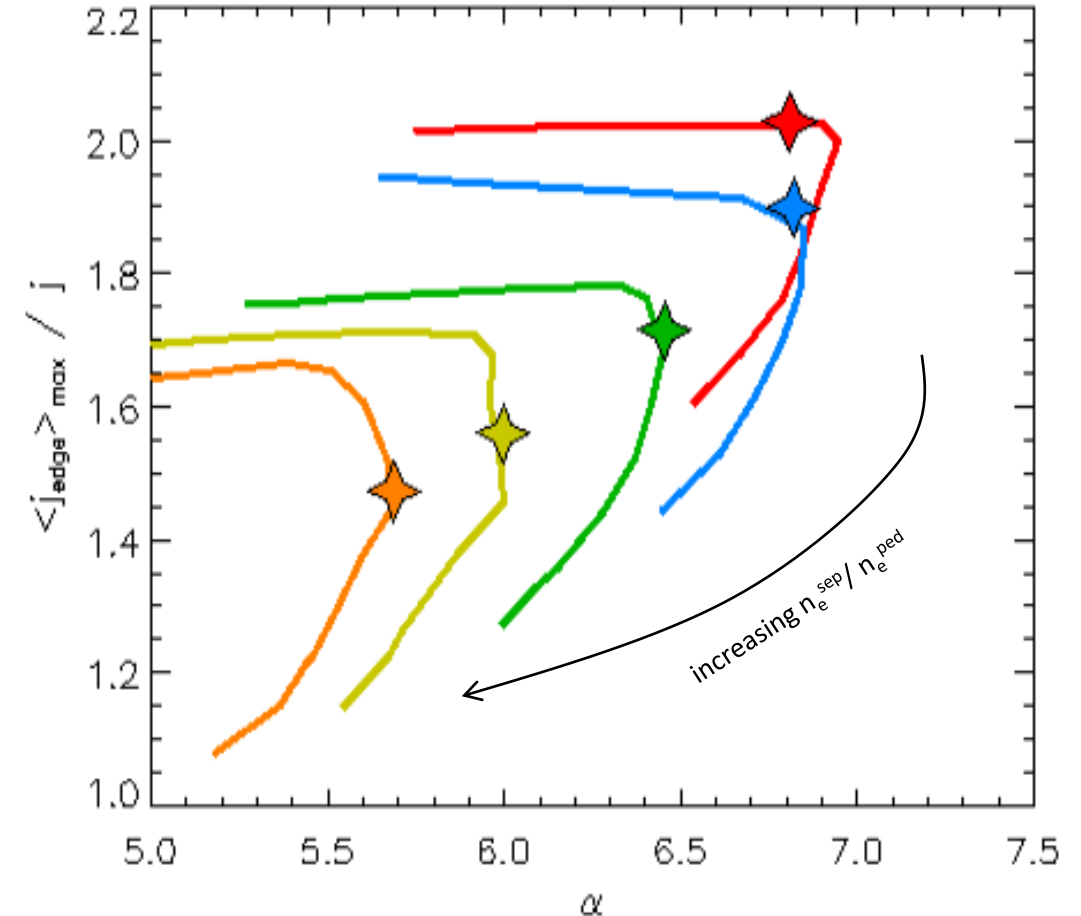
- A more accurate explanation can be found in [Frassinetti NF2025]



ITER Peeling ballooning stability in the n_e^{sep}/n_e^{ped} scan

- $I_p=15\text{MA}$
- $B_t=5.4\text{T}$
- $\beta_N=2.03$
- $n_e^{ped}=12\times 10^{19}\text{ (m}^{-3}\text{)}$
- $n_e^{core}=13.9\times 10^{19}\text{ (m}^{-3}\text{)}$
- $T_i=T_e$
- Old shape

- Starting point:
 - predicted Europed profiles from a n_e^{sep}/n_e^{ped} scan
- Using HELENA+MISHKA, the 2D pedestal stability digram has been created for the predicted profiles
- The increase of n_e^{sep}/n_e^{ped} scan destabilizes the ballooning modes [Dunne PPCF2017, Frassinetti NF2021]
- The ITER pedestal is near the transition from peeling to ballooning → the destabilization of ballooning modes moves the pedestal to the ballooning boundary

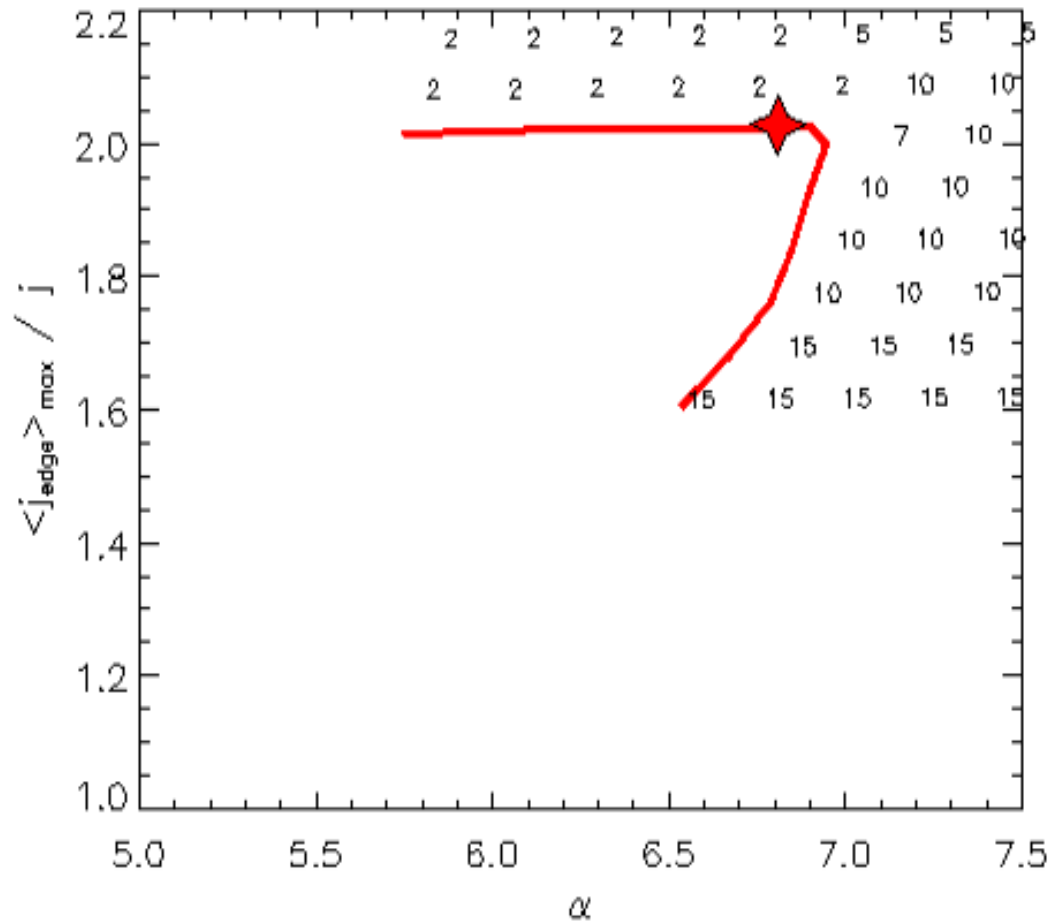




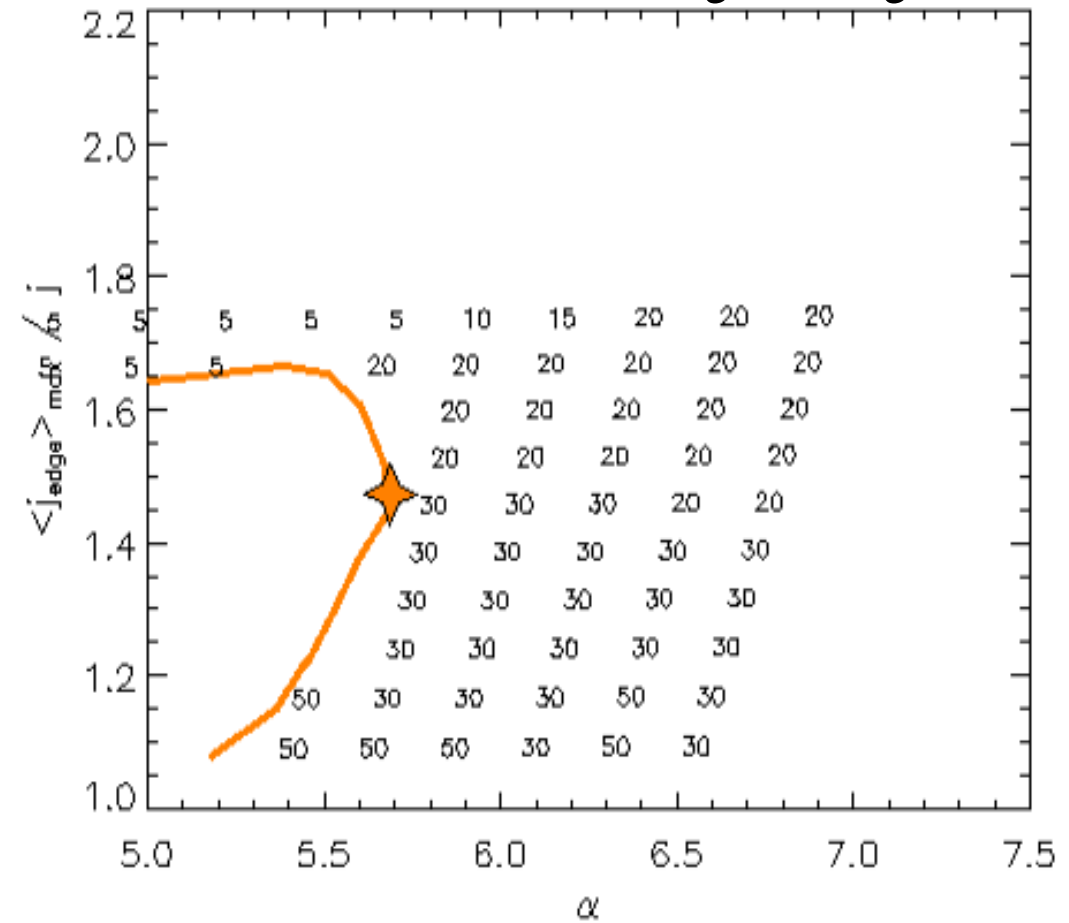
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ITER with low n_e^{sep}/n_e^{ped}

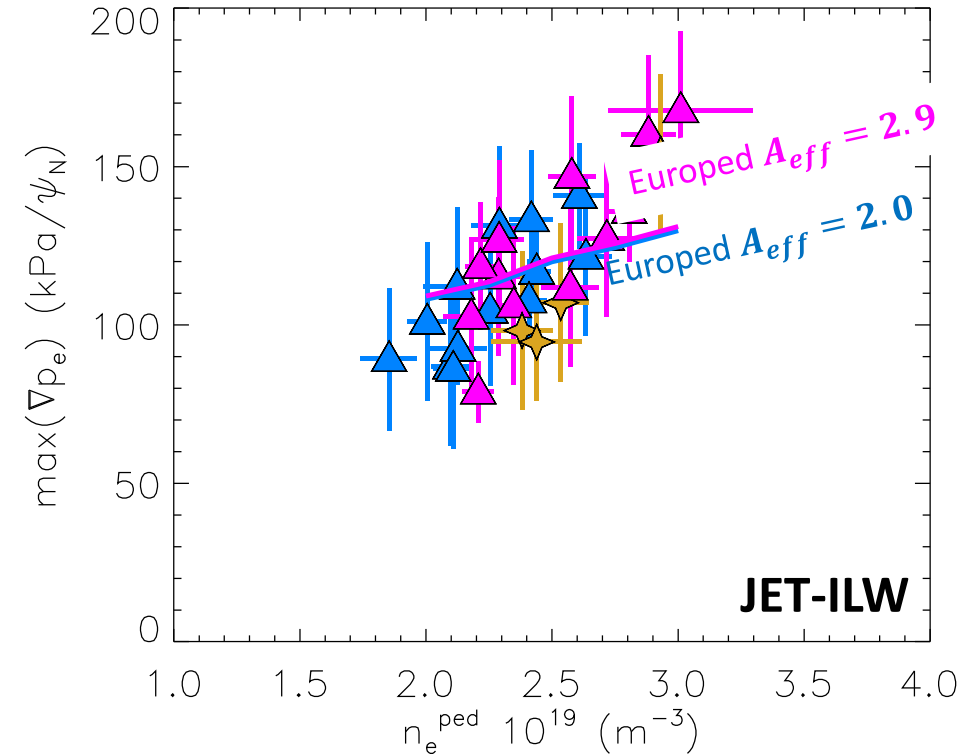
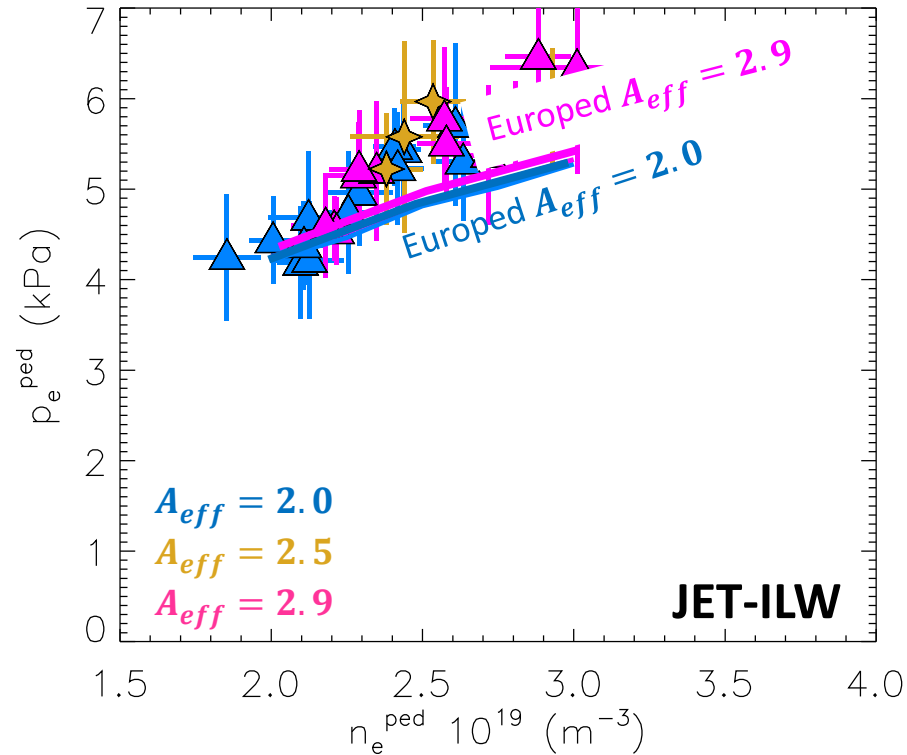


ITER with high n_e^{sep}/n_e^{ped}

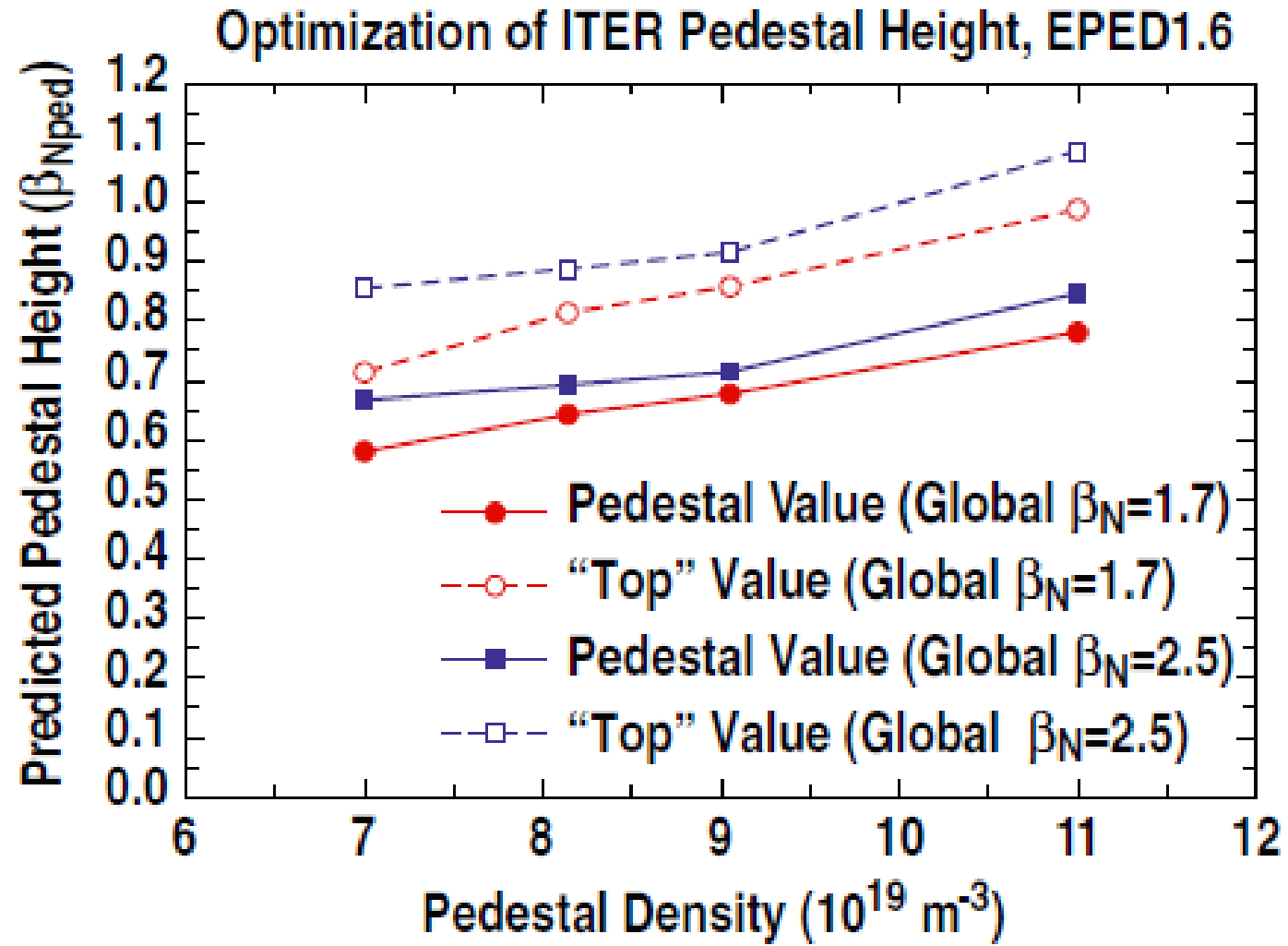


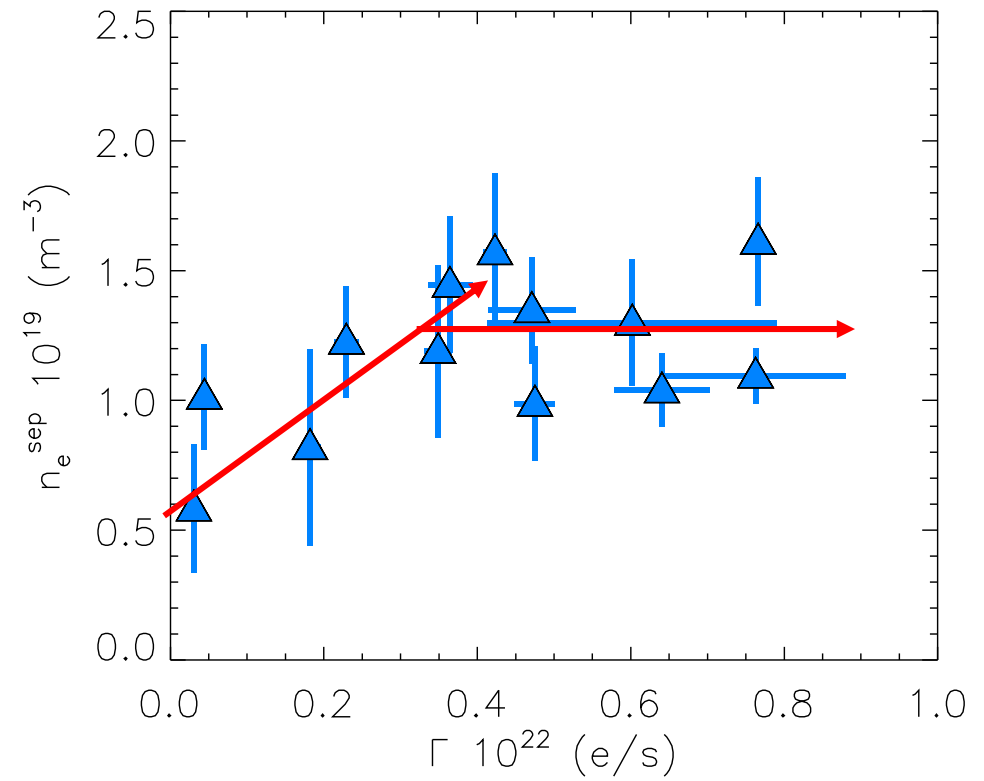
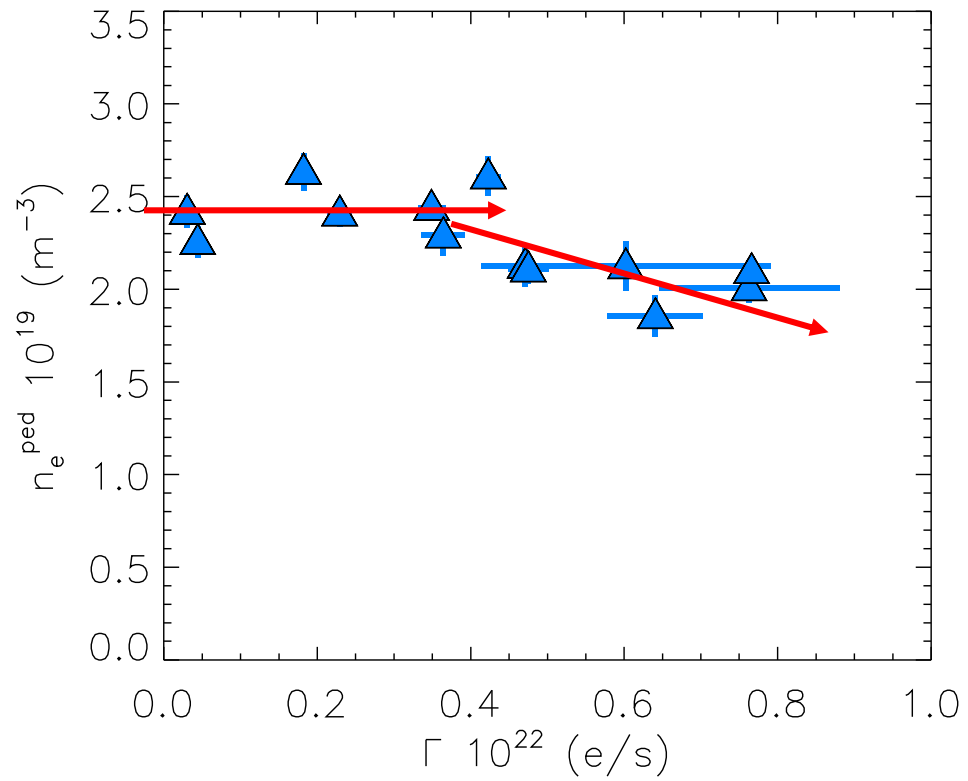


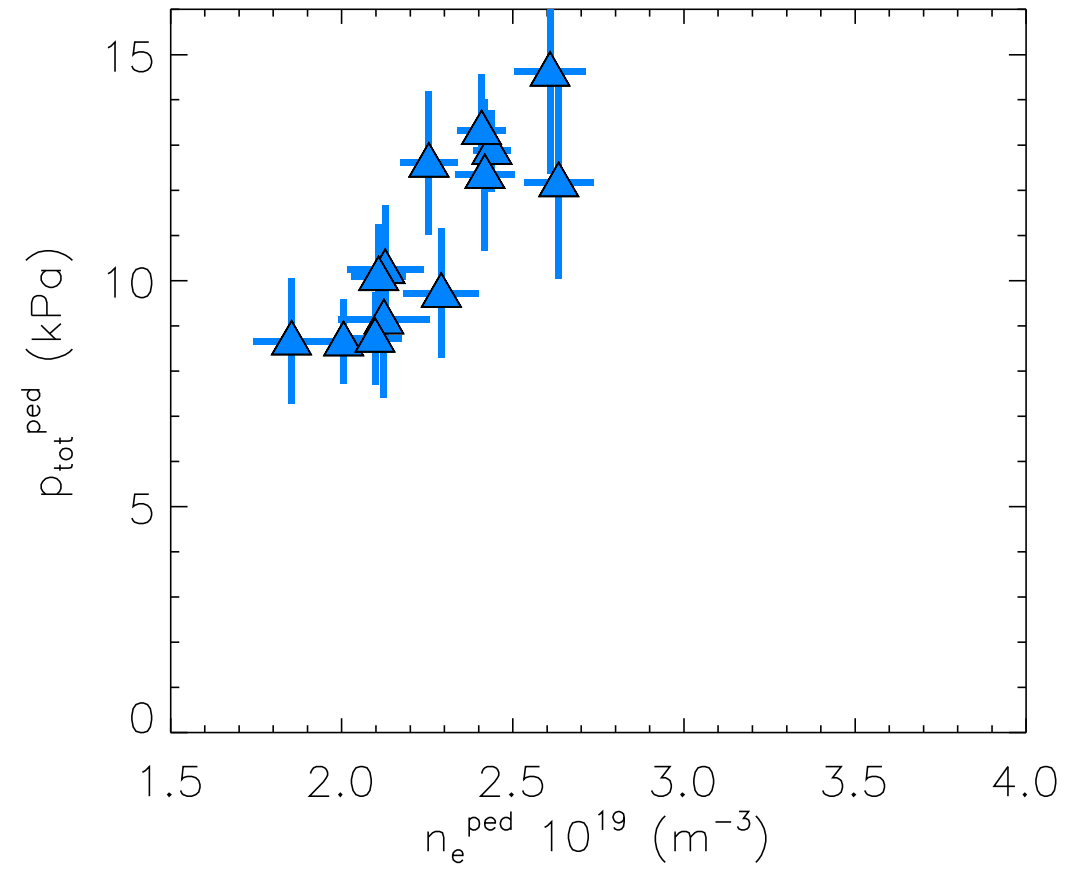
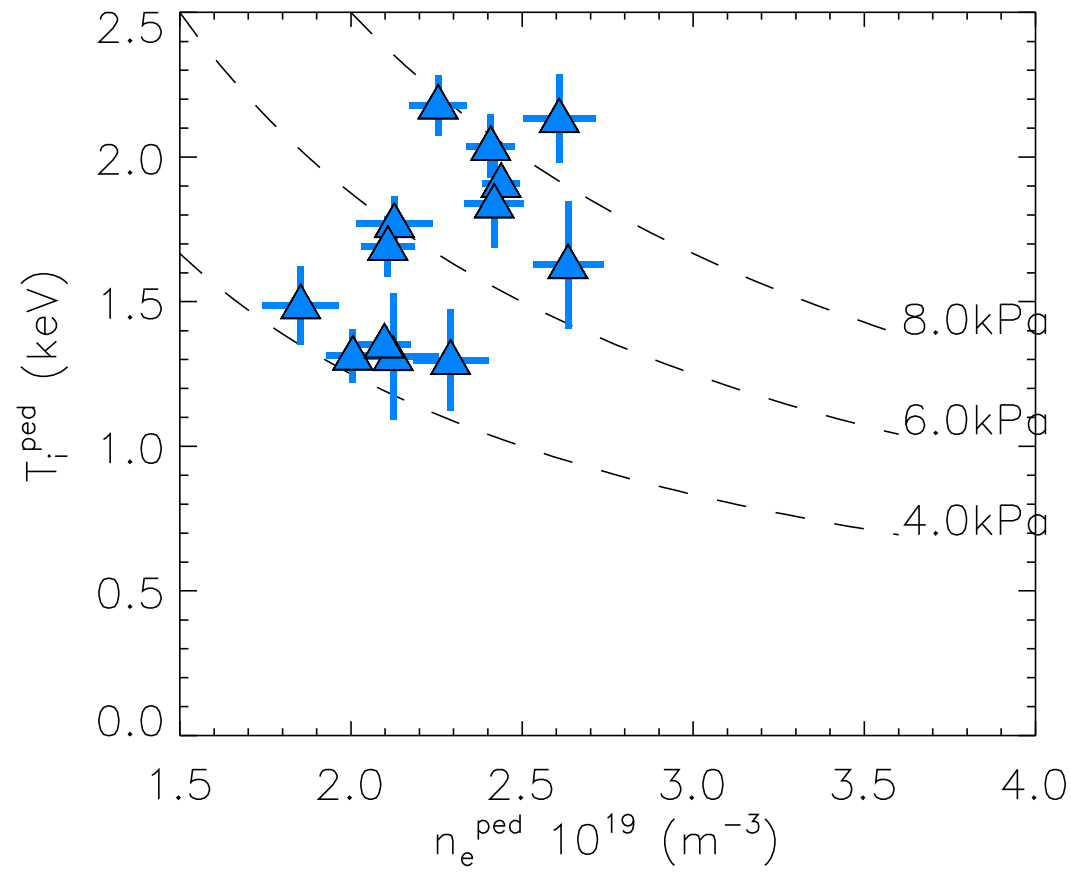
INCREASING THE ISOTOPE MASS INCREASES THE PEDESTAL PRESSURE



- The improvement is due to an increase in ∇p_e^{ped} (no major effect on the width)
- Pedestal predictions with Europed:
 - Good qualitative agreement
 - No direct effect of the isotope mass on the pedestal stability
 - Improvement due to the stabilizing effect of the increased density on peeling modes









CONCLUSIONS

- Low v_{ee}^{*ped} /peeling limited pedestals reached both in metal wall and carbon wall machines
- In peeling limited pedestals:
 - p^{ped} increases with increasing n_e^{ped} (degradation observed in ballooning limited)
 - p^{ped} does not degrade with increasing n_e^{sep}/n_e^{ped} (degradation observed in ballooning limited)
 - p^{ped} increases with increasing isotope mass (similar to ballooning limited, but partially different mechanism)
- Very positive information for ITER (assuming type I ELMy H-modes)
- Reasonable European predictions in the ITER range of v_{ee}^{*ped} , ρ_i^{*ped} , n_e^{sep}/n_e^{ped}
- ITER pedestal predictions:
 - transition peeling vs ballooning strongly sensitive on the density (and B_t , not shown here)
 - Ballooning pedestal recently predicted also in [Luda NF2025]
 - No pedestal degradation expected despite a possible transition to ballooning limited plasmas
- The work increases the relevance for ITER of small/ELMs regimes [Giroud IAEA2025, Dunne IAEA2025] which have been achieved in ballooning limited regimes