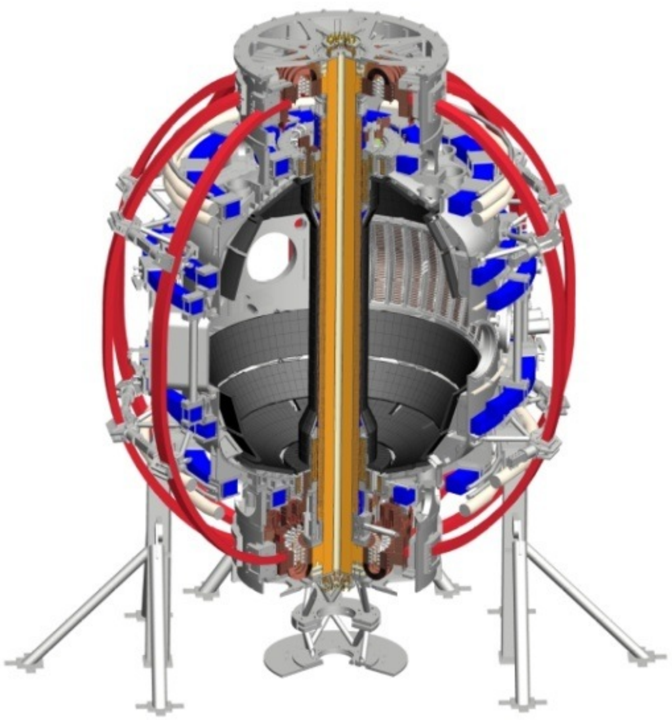
NSTX-U Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Pedestal Structure Evolution between ELMs on NSTX with Different Lithium Conditioning and Plasma Current

Q. Teng, A. Diallo,
T. K. Gray, R. Maingi and B. LeBlanc

56th Annual Meeting of the APS Division of Plasma Physics
October 27-31, 2014
New Orleans, Louisiana



Objective: Understanding the Dynamics of Pedestal Structure Is Crucial to Accurately Predict and Improve Fusion Performance of Future Devices like ITER

- Core plasma performance is **correlated** with pedestal parameters[1]
- Large ELMs can induce huge heat and particle load on plasma-facing components, which could be disastrous in large tokamaks
- ELMs expel impurities out of core plasma, which is favorable and necessary for steady state operation
- Lithium conditioning has been proved to improve energy confinement with a broad pedestal structure[2]

Here we study the effects of lithium and plasma current between ELMs on the pedestal dynamics

Summary of Result

- During ELM cycle, P_{NBI}, I_p and Lithium conditioning are held constant
  - P_e^{ped}, and P_e^{width} increase during an ELM cycle, at constant P_e^{grad}; This is consistent with previous experimental result by Ahmed *et al*[5] and theory model EPED[6]
  - There is a small increase in n_e^{ped} compared with T_e^{ped}'s growth
  - Both P_i^{ped} and T_i^{ped} grow

- Larger plasma current increases n_e^{ped}, with a smaller increasing impact on T_e^{ped}

- More lithium conditioning
  - has no effect on P_e^{grad}
  - increases P_e^{ped},and P_e^{width}
  - More parameters other than I_p and P_{NBI} need to be considered to clarify this effect

Profile Analysis Method

- Fit electron profiles using modified tanh function[3]

$$\frac{\alpha - \alpha_0}{2}\frac{(1 - \mathrm{a}_1\zeta)e^{\zeta} - e^{-\zeta}}{e^{\zeta} + e^{-\zeta}} + \frac{\alpha + \alpha_0}{2}$$

where α is the pedestal height, α_0 is the offset, $\zeta=2(x^{sym}-x)/\Delta$, x^{sym} is the symmetry point of x axis, and Δ is the pedestal width.

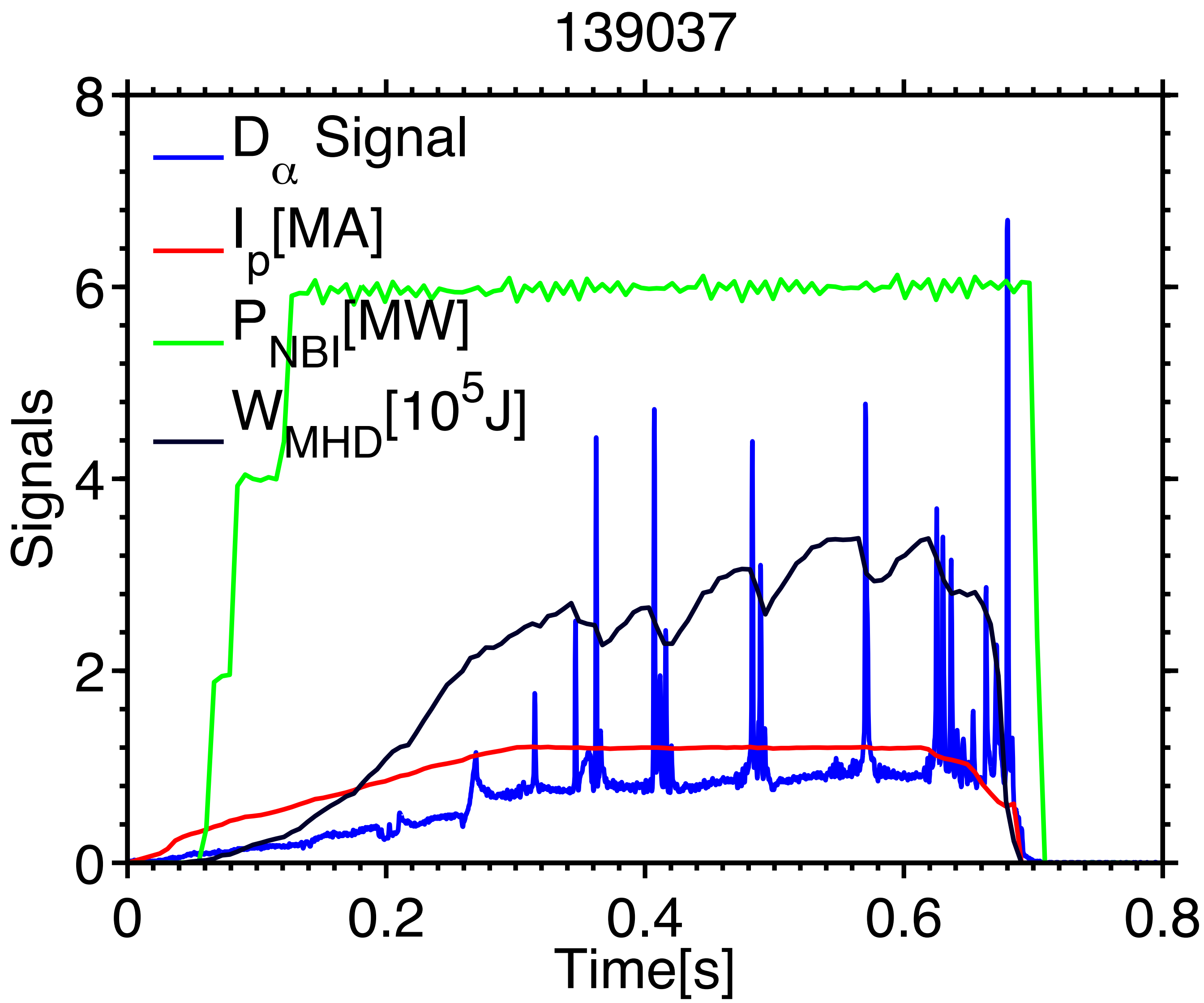
- Implement a Monte Carlo method to calculate error bars of pedestal parameters

- Ion profiles do not exhibit tanh-like pedestal structure, thus its pedestal height parameters is taken from the same location as electron pedestal height

Three Groups of Discharges Are Used in Analysis

Discharge Number	I_P(MA)	Lithium(mg)	P_{NBI}(MW)
139027	0.7	50	6
139047	1	50	6
139049	1.1	50	6
139037	1.2	50	6
141248	0.7	150	3.8
141241	0.9	150	3.9
141243	1.2	150	3.9
141247	1.3	150	3.8
132540	1	0	6
132556	1	156.7	5
132560	1	238.3	5

Time history of D_α and W_{MHD} Between ELMs

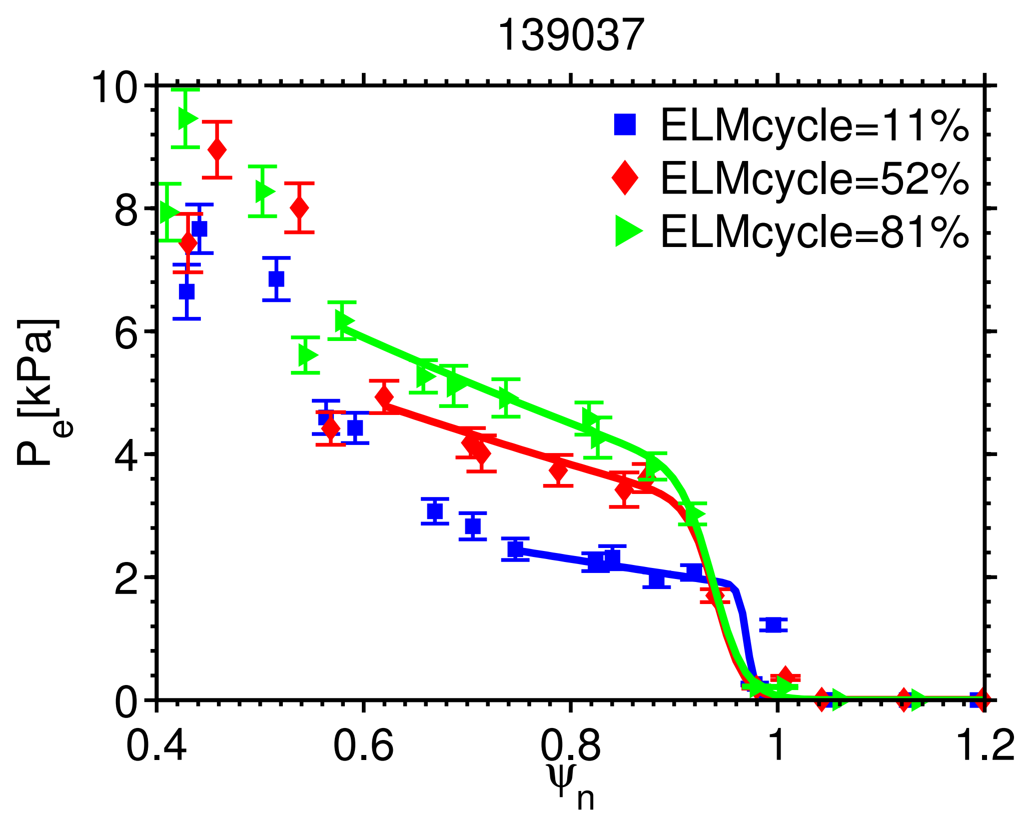


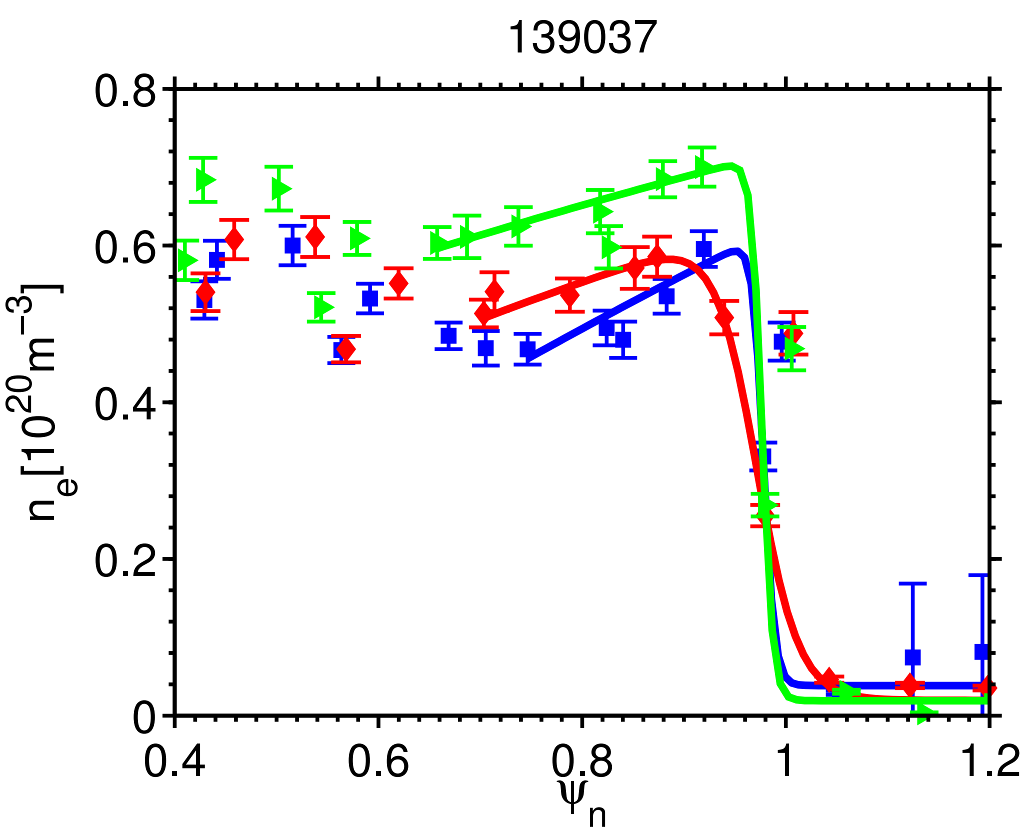
- Plasma current(I_p) and neutral beaming injection power(P_{NBI}) are kept constant during each discharge

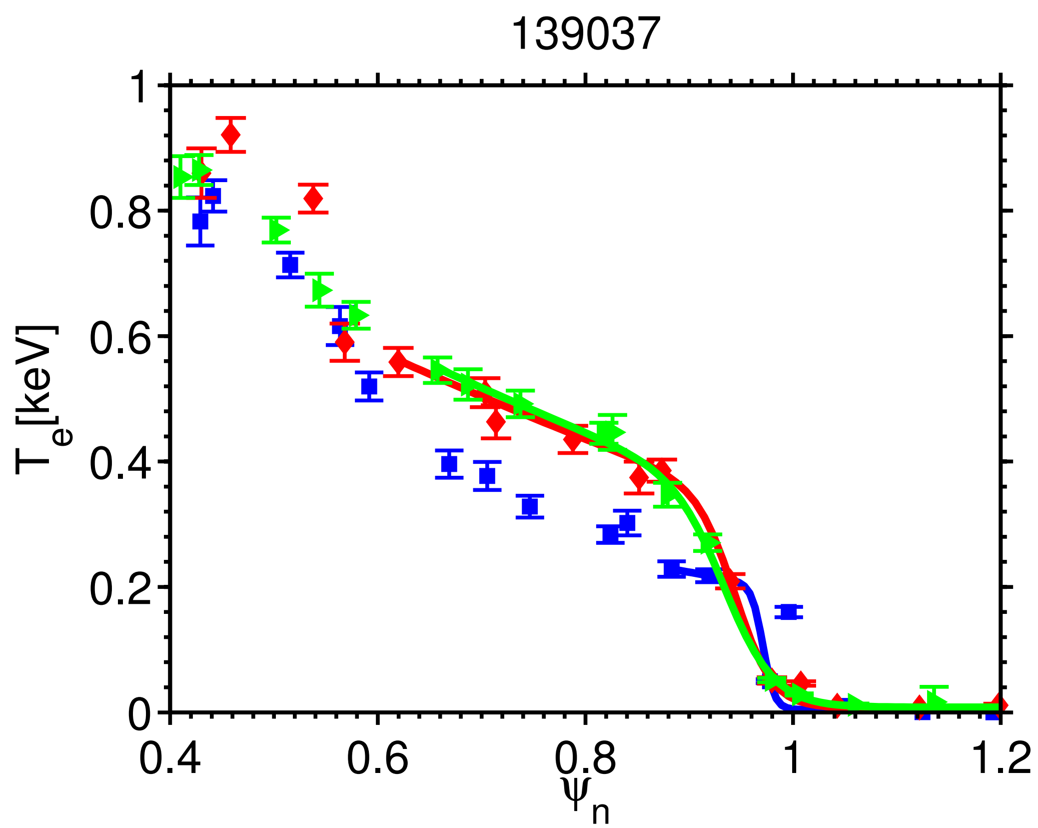
- Total plasma stored energy(W_{MHD}) shows a considerable drop at each ELM burst

Pedestal Dynamics of Discharges with 50mg of Lithium Conditioning

Electron Pedestal Profiles Increase Between ELMs

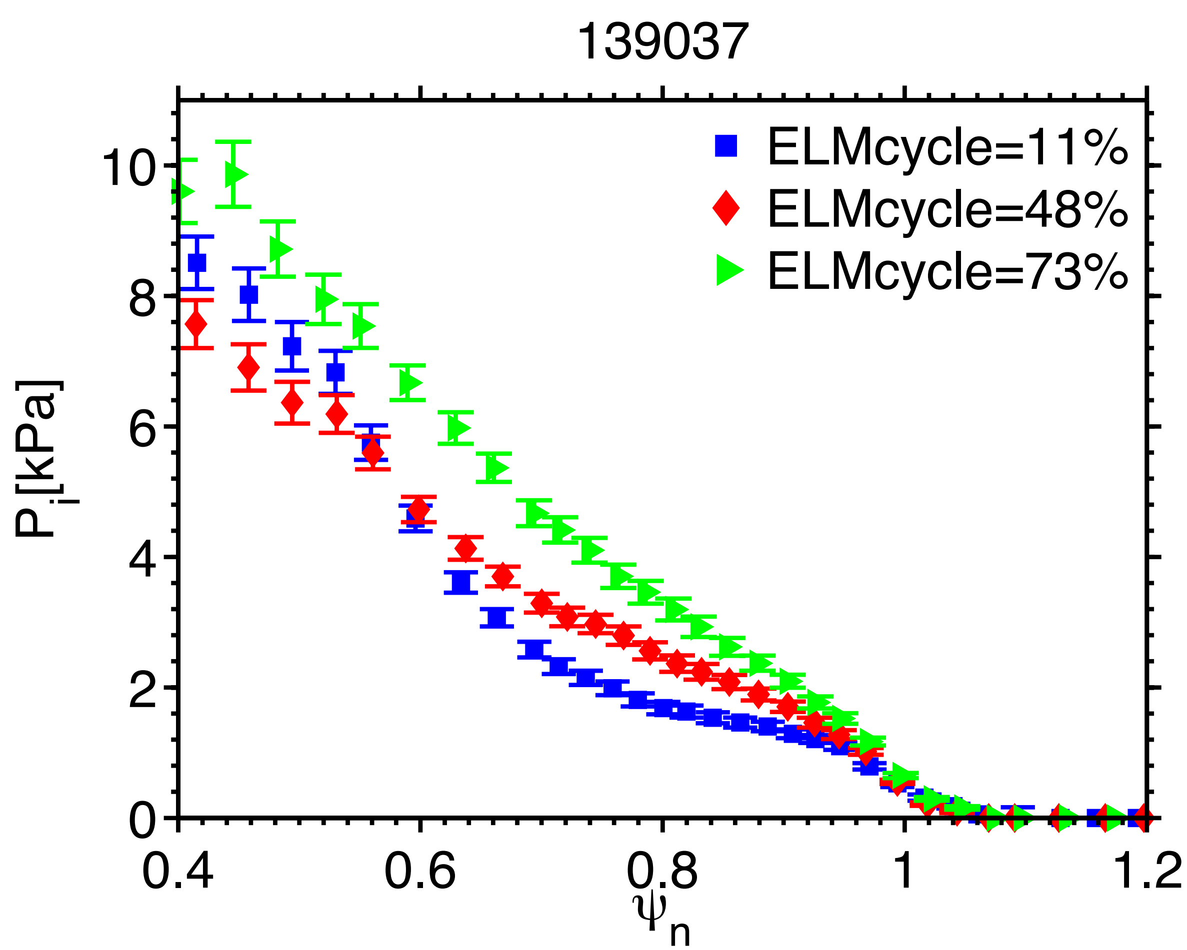


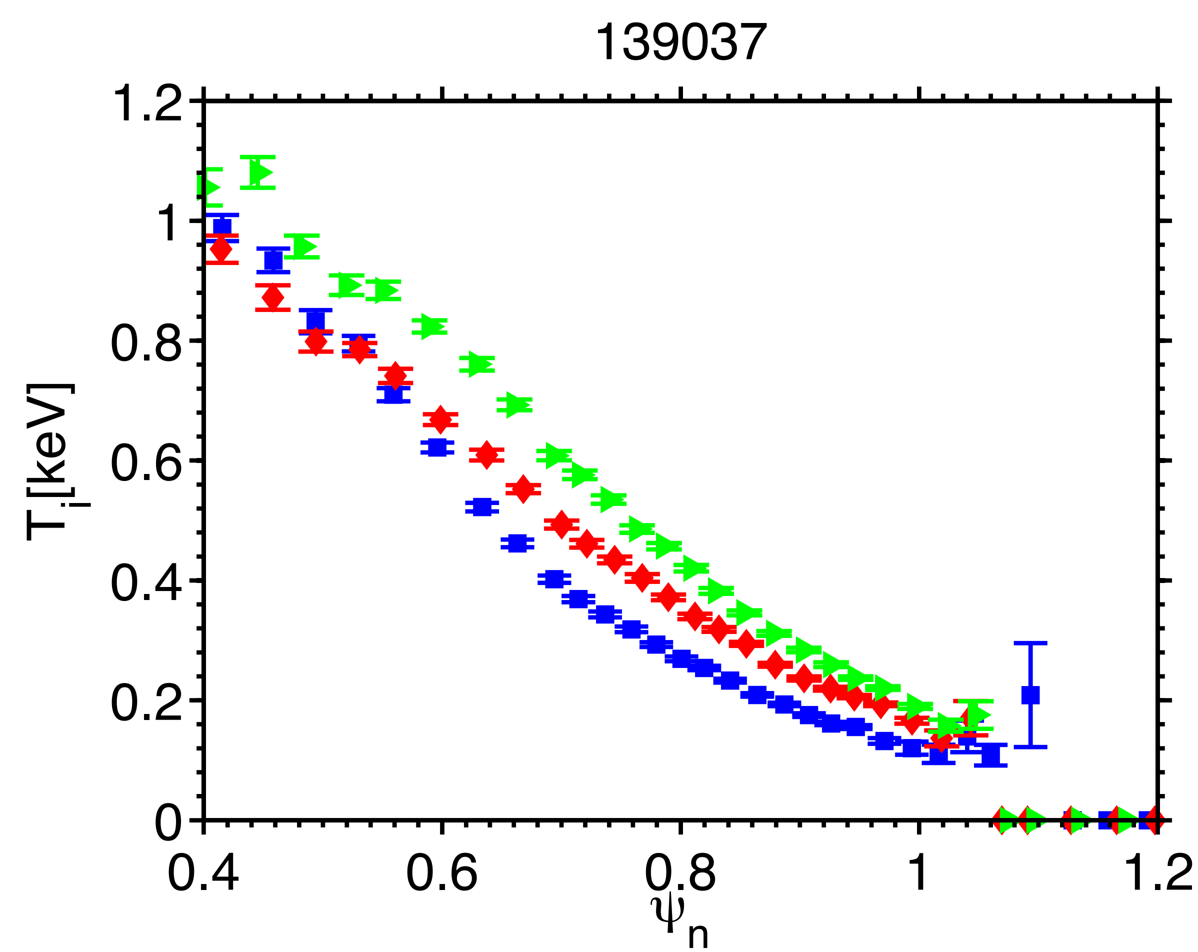




Electron pressure, density and temperature profiles grow during an ELM cycle

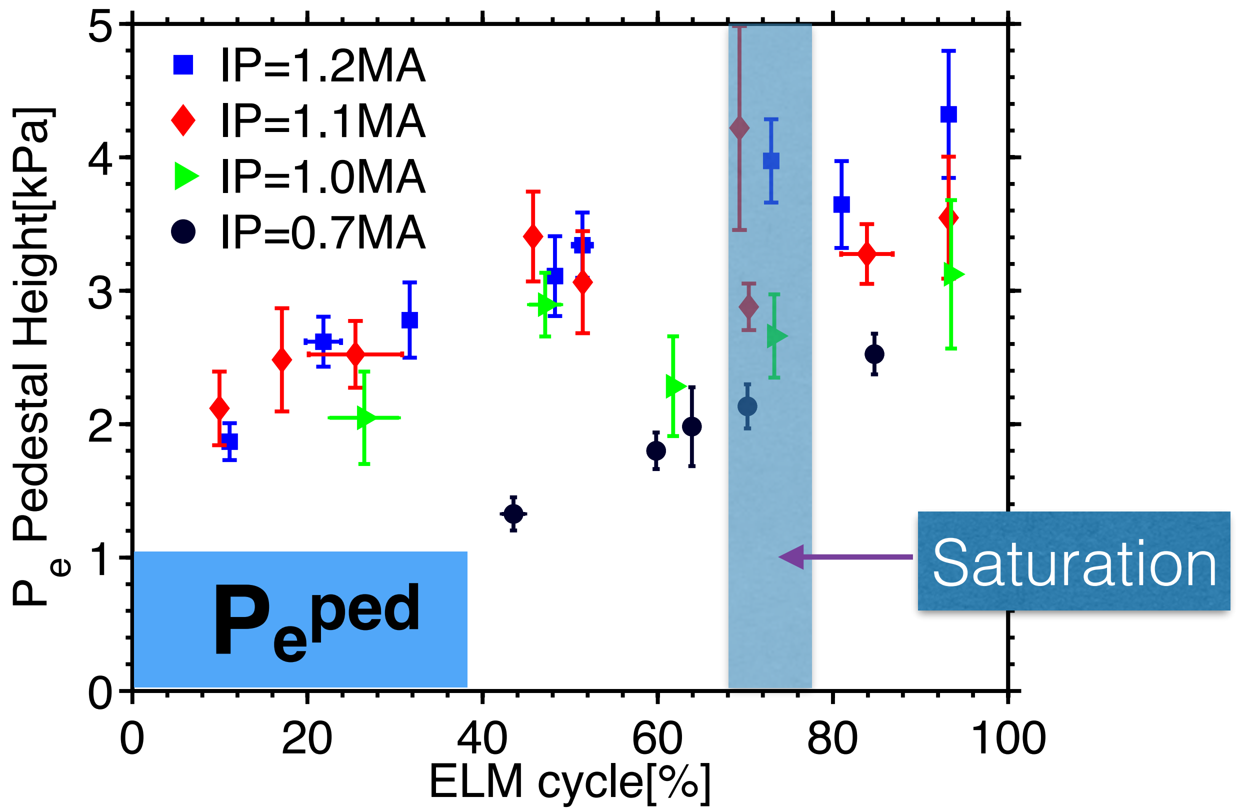
Ion Pedestal Profiles Increase Between ELMs

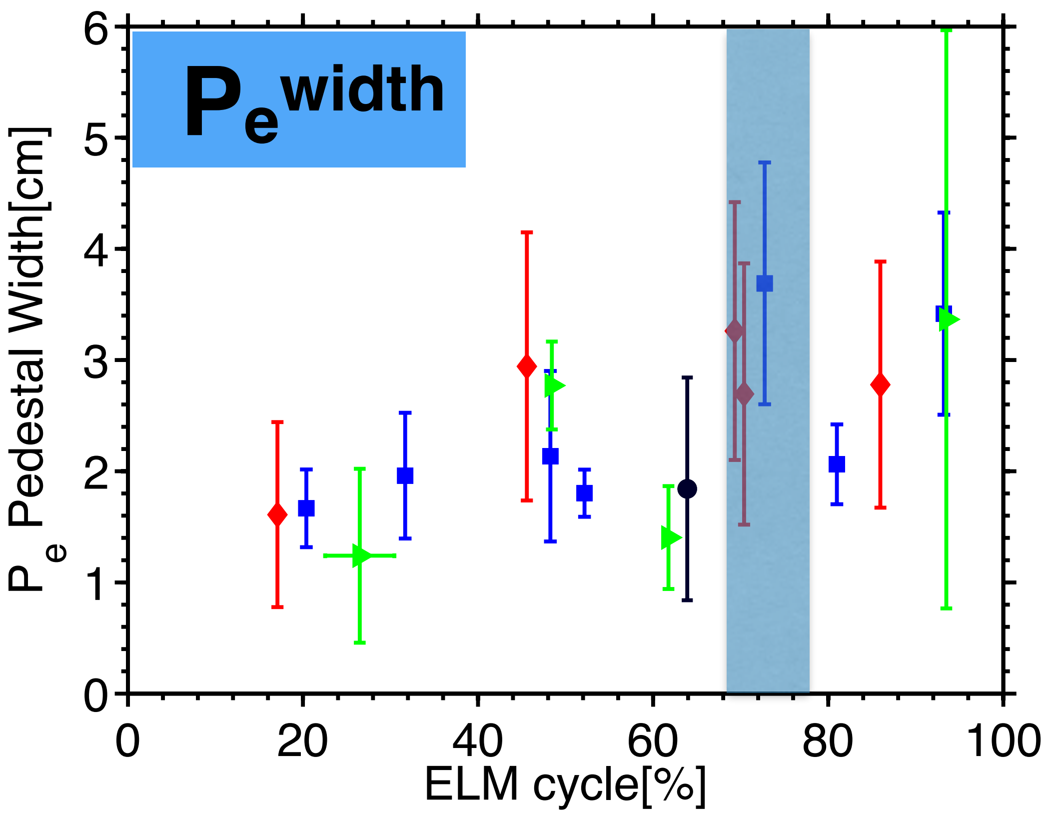


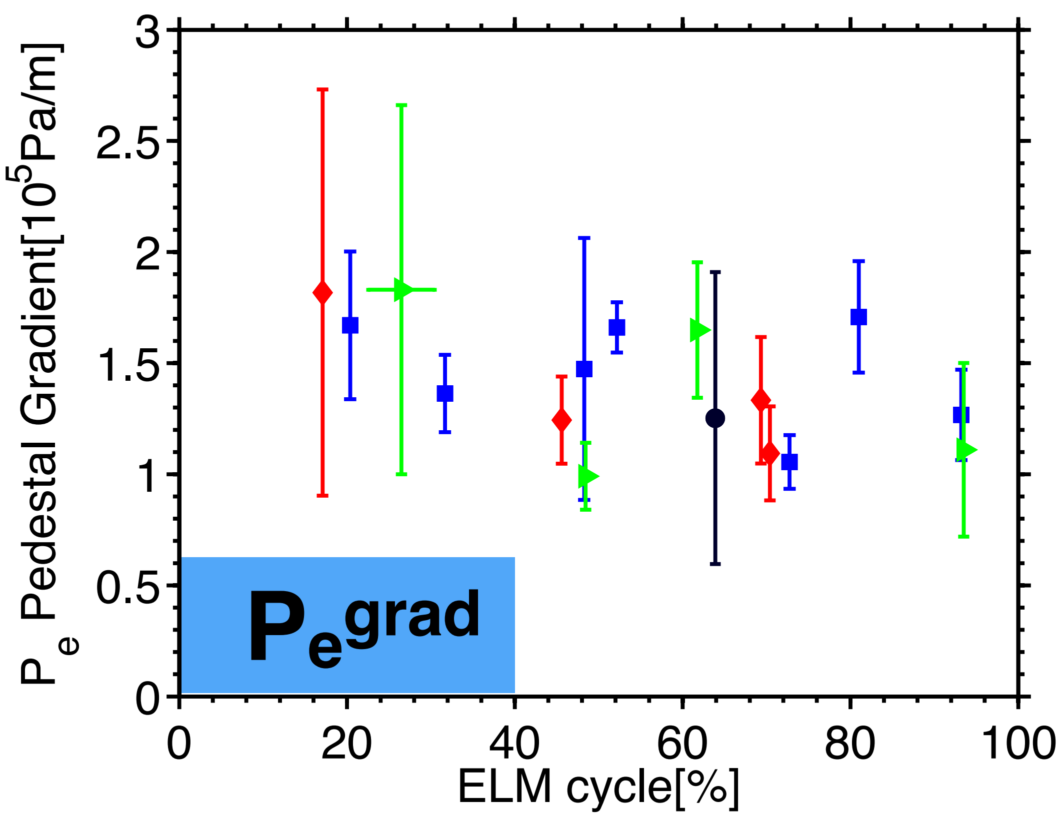


- Ion pressure profiles grow during an ELM cycle
  - For detailed analysis of impurities, please read F. Scotti's poster on APSDPP 2013
- Ion temperature profiles grow during an ELM cycle

Electron Pressure Pedestal Height and Width Increase, with Gradient Clamped

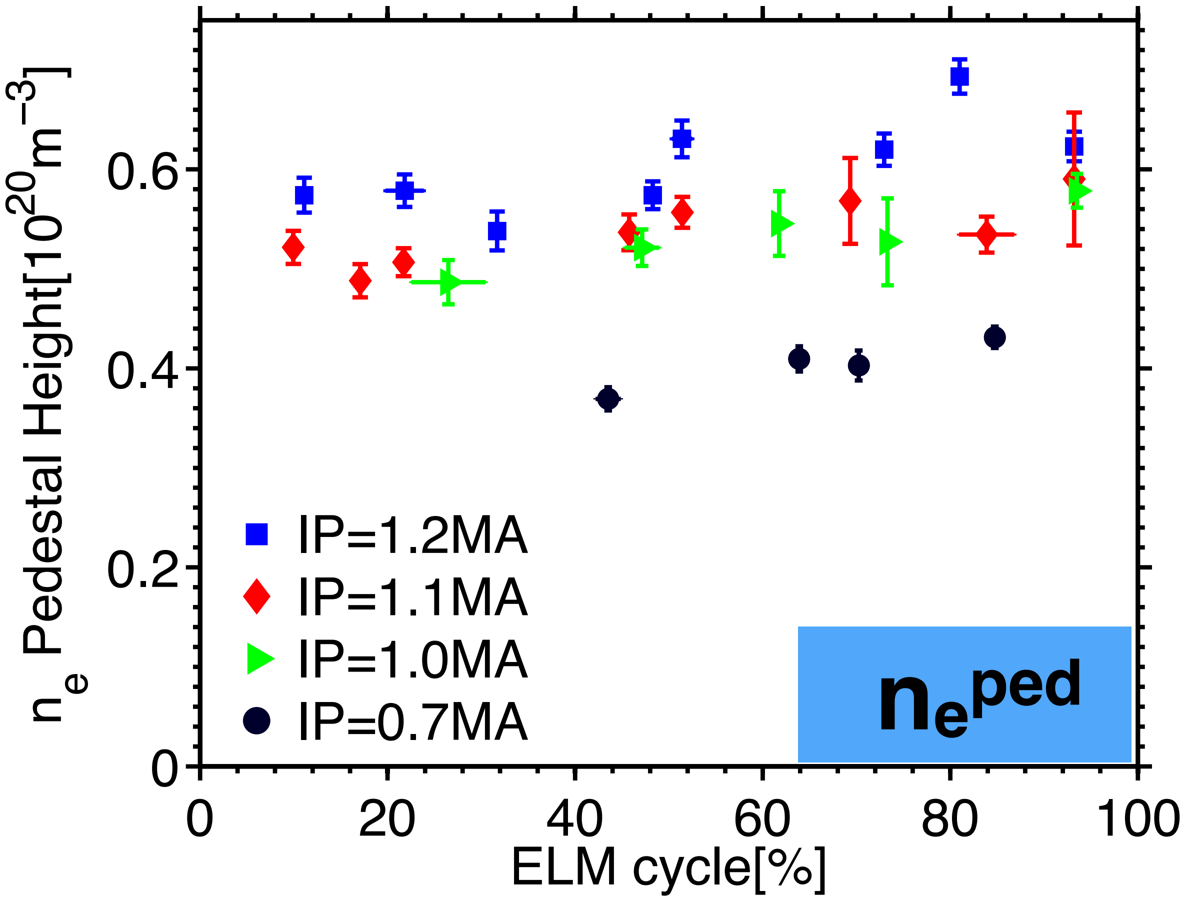


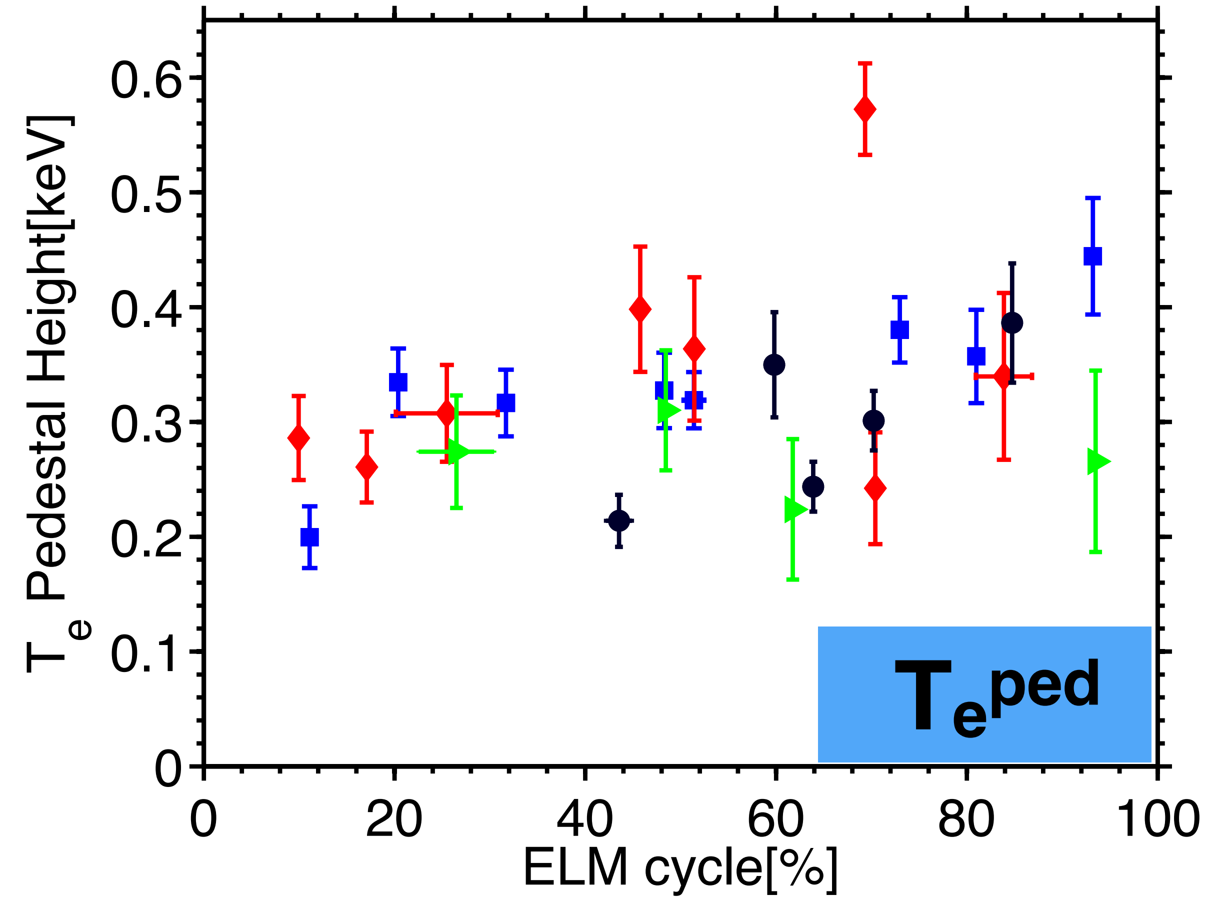




- P_e^{ped} grows by a factor of 2 and saturates at about 70% of the ELM cycle
- P_e^{width} grows by a factor of 2 and saturates at about 70% of the ELM cycle
- P_e^{grad} is roughly constant within the error bar

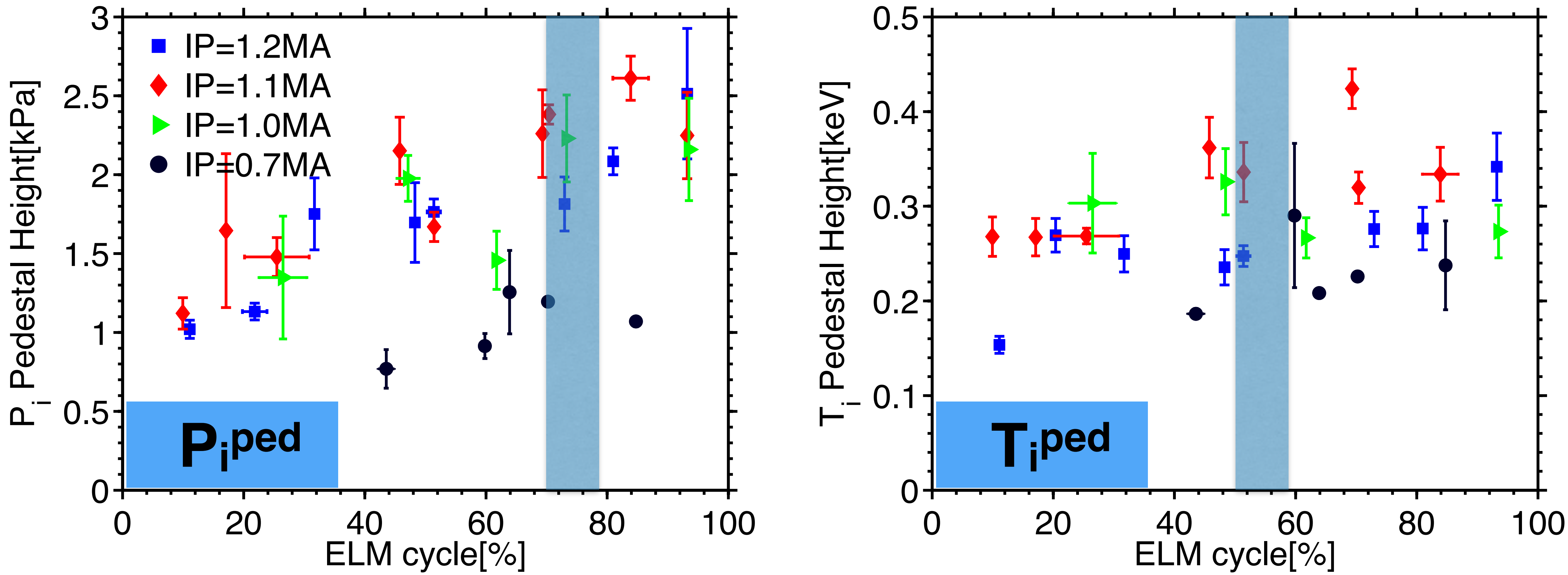
Electron Density Pedestal Height Remains Constant while Temperature Pedestal Height Increases





- n_e^{ped} is almost constant during ELM cycles, increasing by no more than 15%. This could be explained as electron density recovers soon after an ELM crash, within the first 10% of an ELM cycle.
- T_e^{ped} appears to grow by a factor of less than 2, exhibiting more scattering.

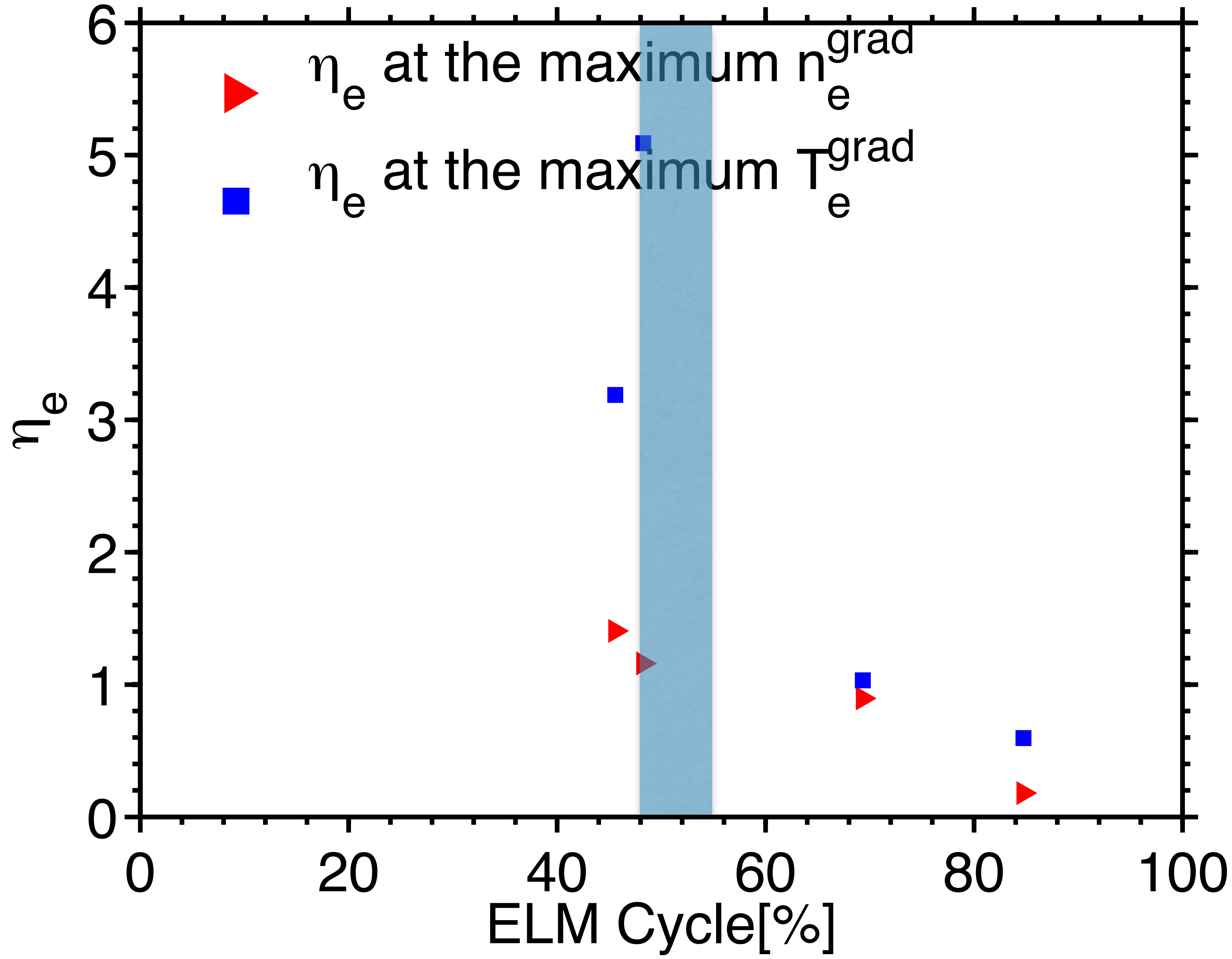
Ion Pressure and Temperature Pedestal Height Increase



- P_i^{ped} grows by a factor of around 2.5, saturating at about 70% of the ELM cycle.
- T_i^{ped} grows by a factor of less than 2, saturating at 50% of the ELM cycle.

η_e Decreases after 50% of an ELM Cycle

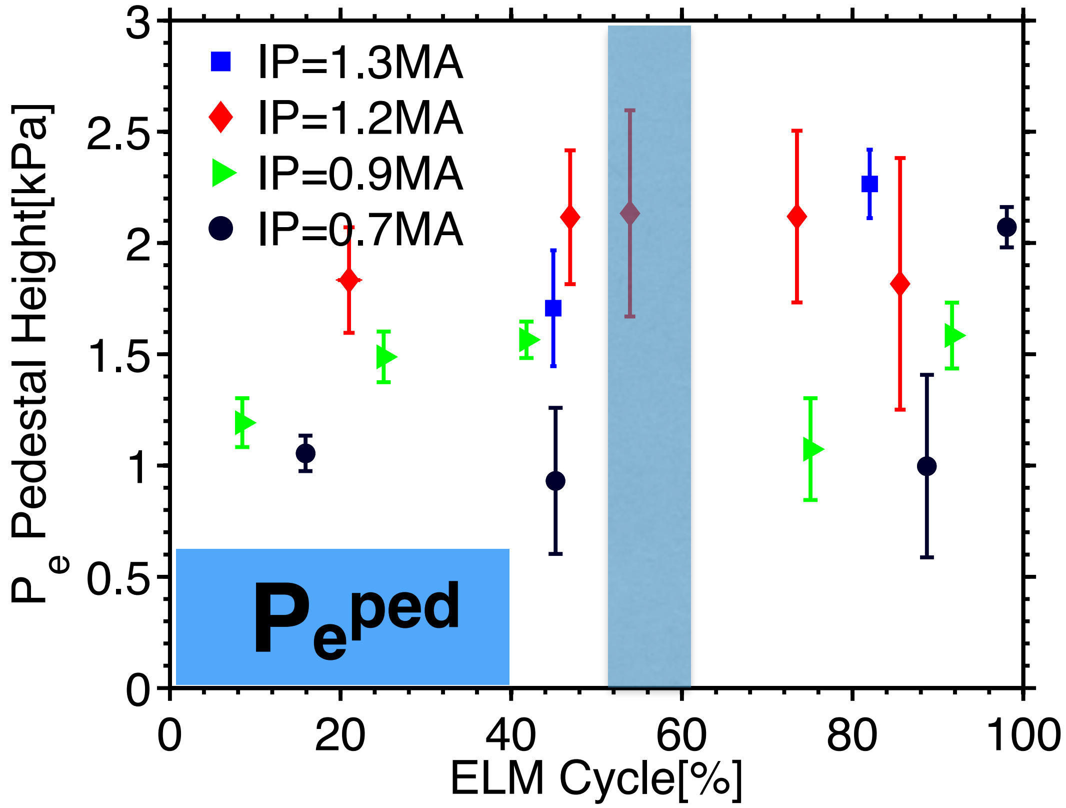
$$\eta_e = \frac{d\ln T_e}{d\ln n_e}$$

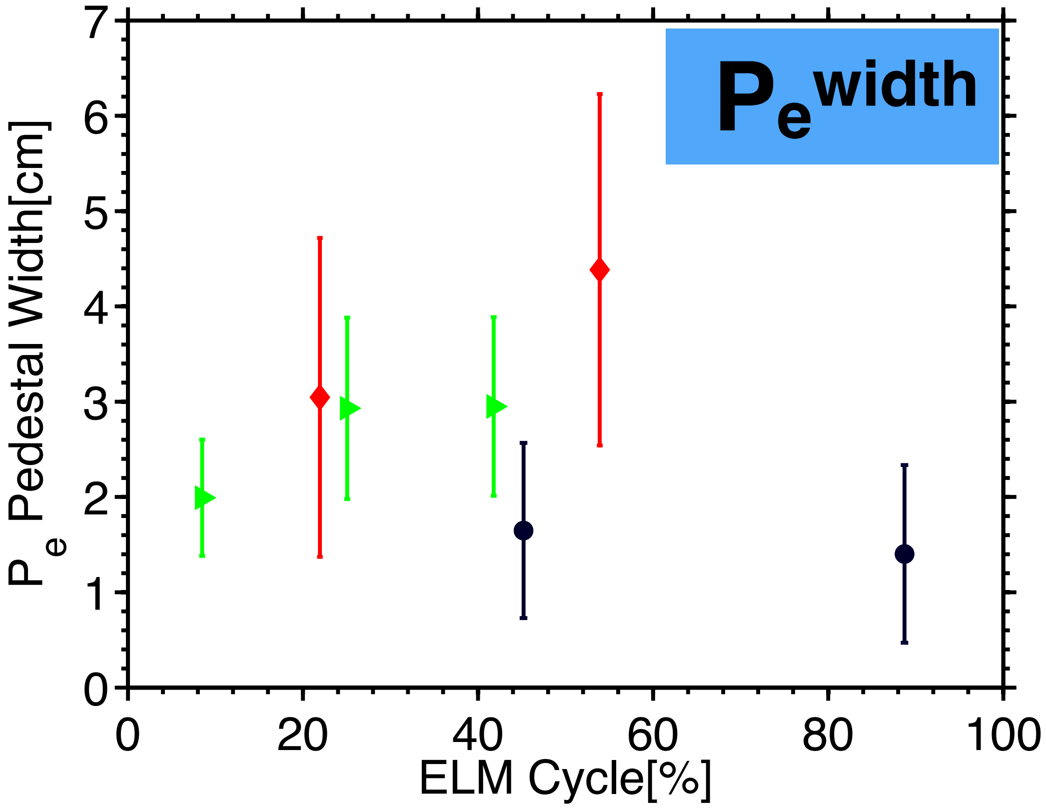


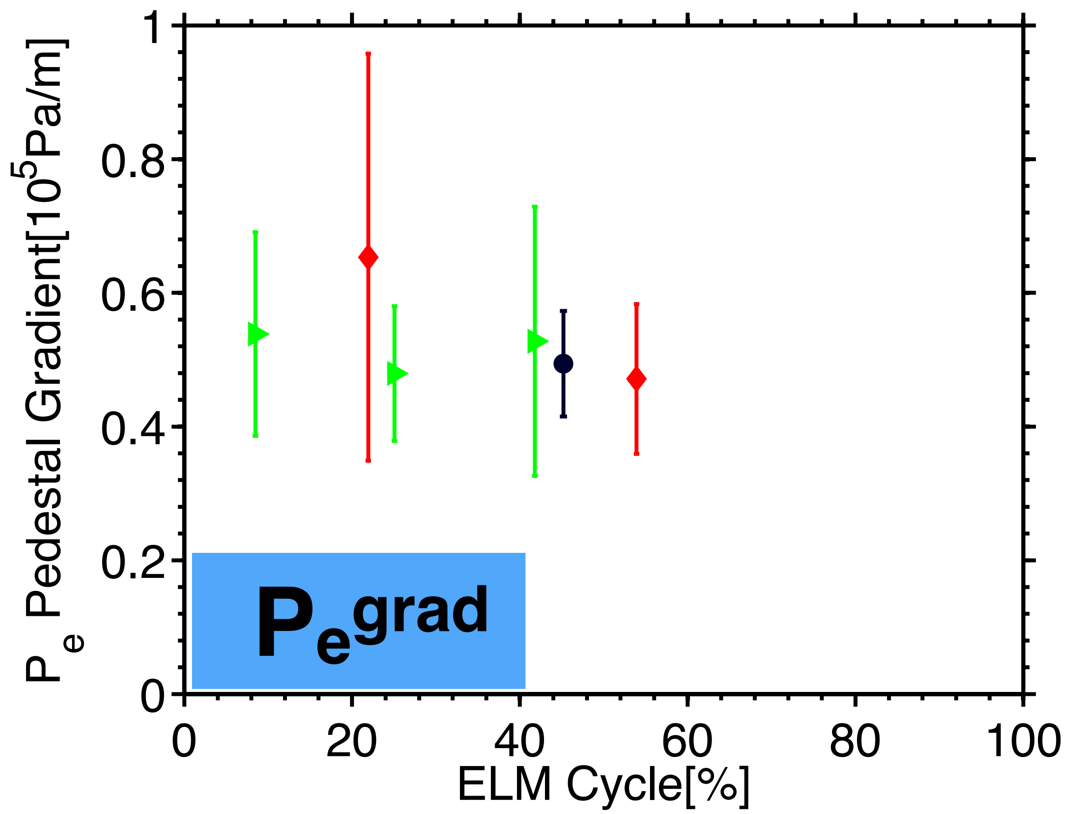
- η_e is calculated at the maximum n_e^{grad} and at the maximum T_e^{grad}. The values are quite different, while they both yield a decreasing trend toward smaller than 1.5
- When η_e is smaller than $\eta_{e,crit}$ ($\eta_{e,crit} \gtrsim 1.5$ in ASDEX-U), ETG mode would decrease[4]

Pedestal Dynamics of Discharges with 150mg of Lithium Conditioning

Electron Pressure Pedestal Height and Width Increase, with Gradient Clamped

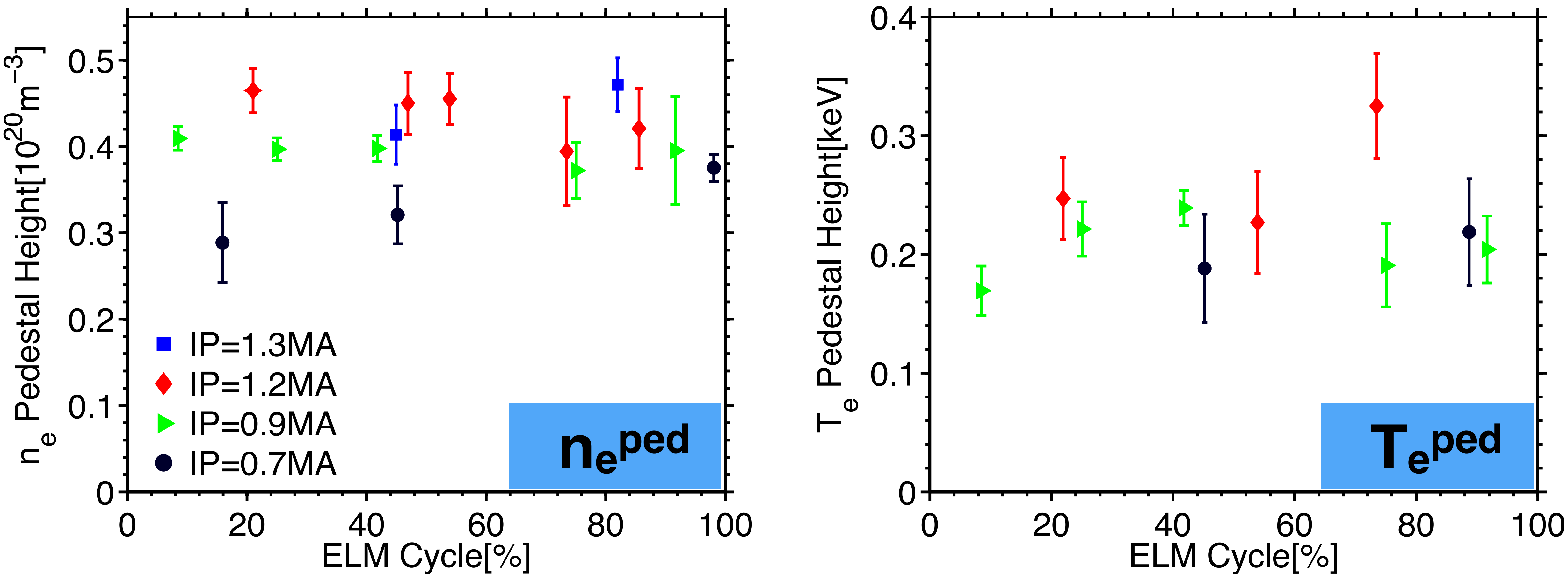






- P_e^{ped} grows by a factor of 1.3 and saturates at about 50% of the ELM cycle.
- P_e^{width} grows by a factor of 1.5 during the ELM cycle.
- P_e^{grad} is roughly constant within the error bar.

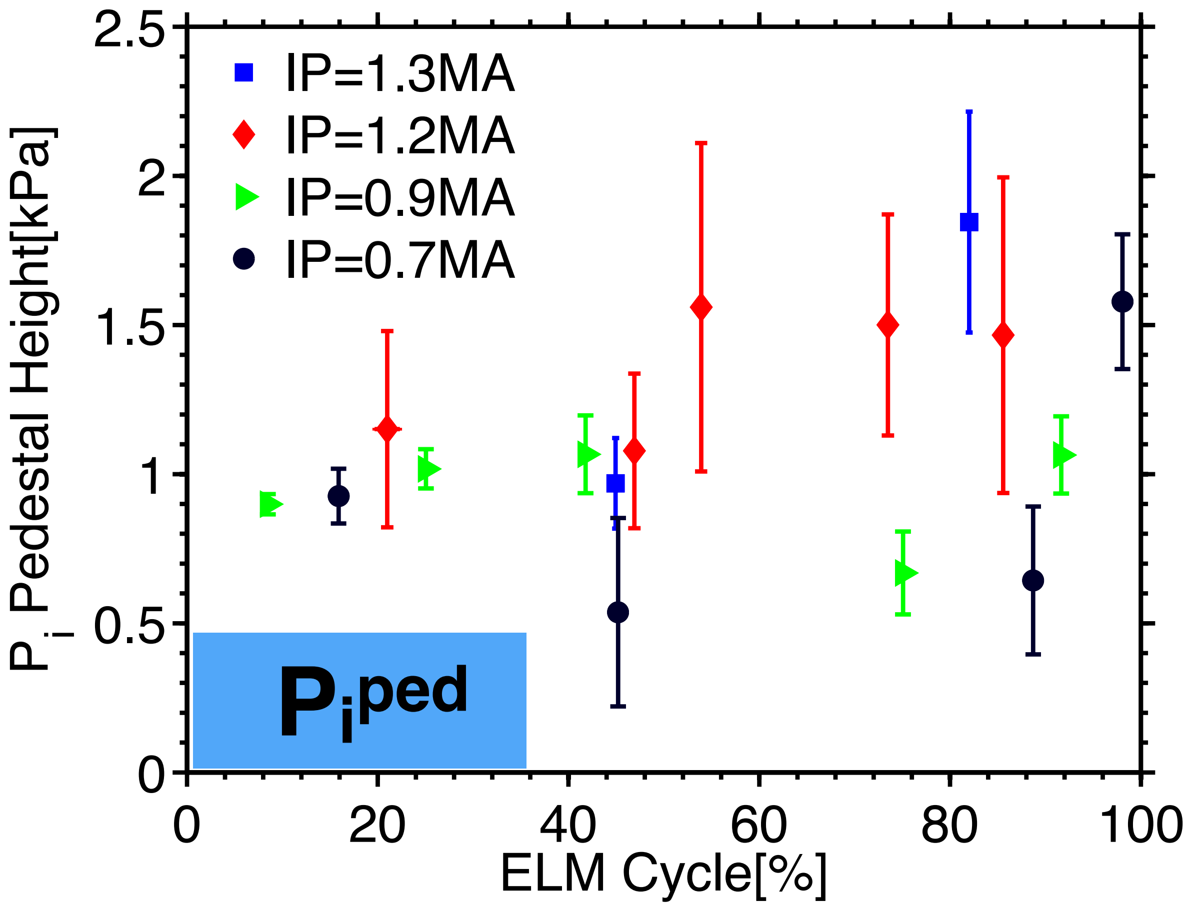
Electron Density Pedestal Height Keeps Constant, Temperature Pedestal Height Increases by 20%

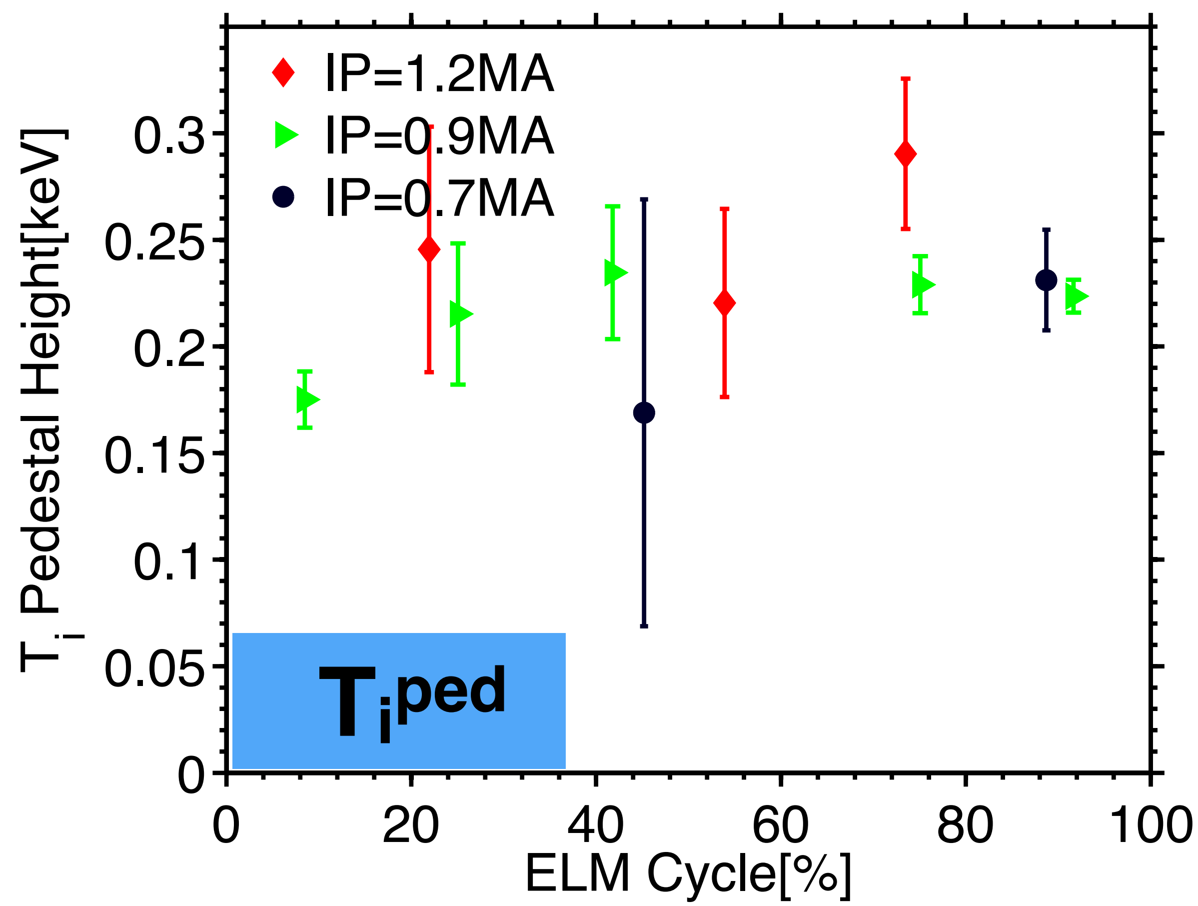


- n_e^{ped} is roughly constant during ELM cycles

- T_e^{ped} grows by less than 20%

Ion Pressure and Temperature Pedestal Height Increase

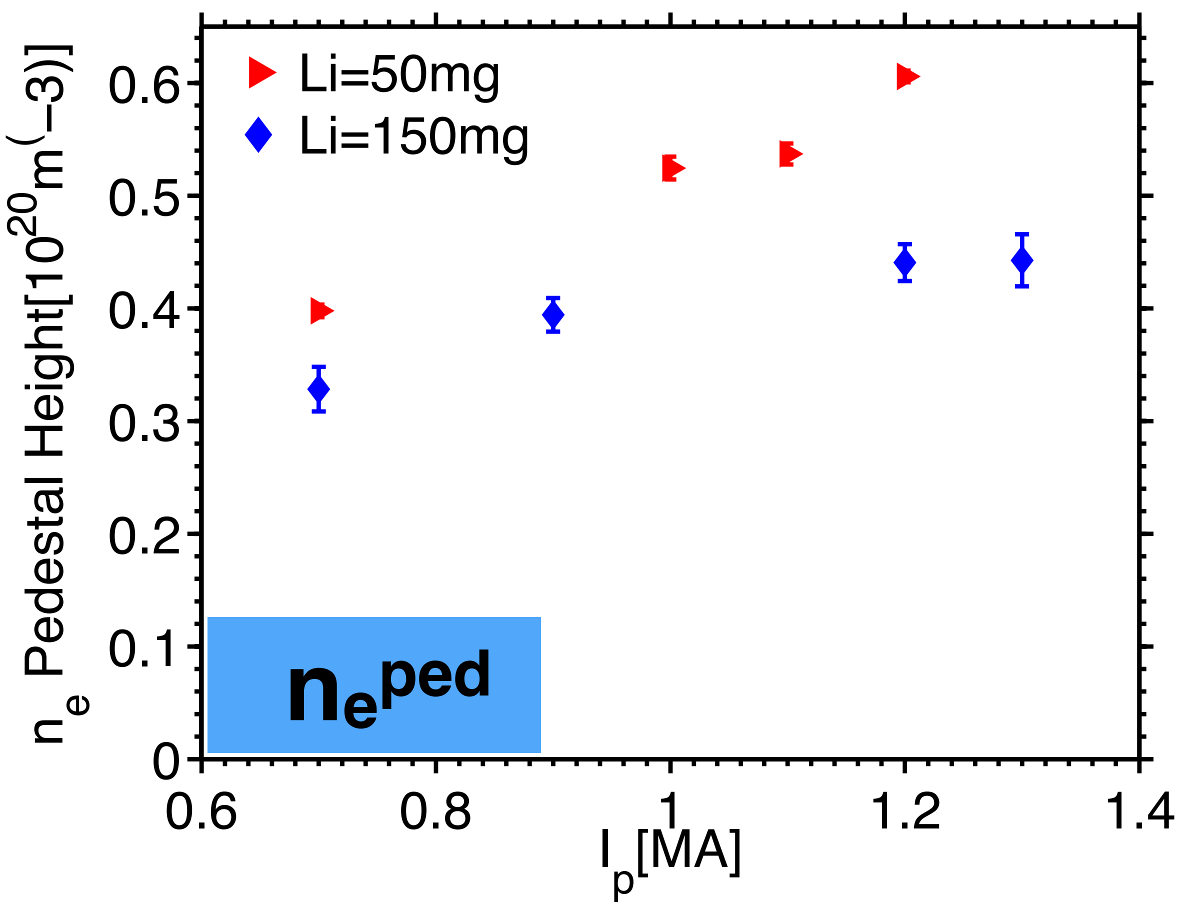


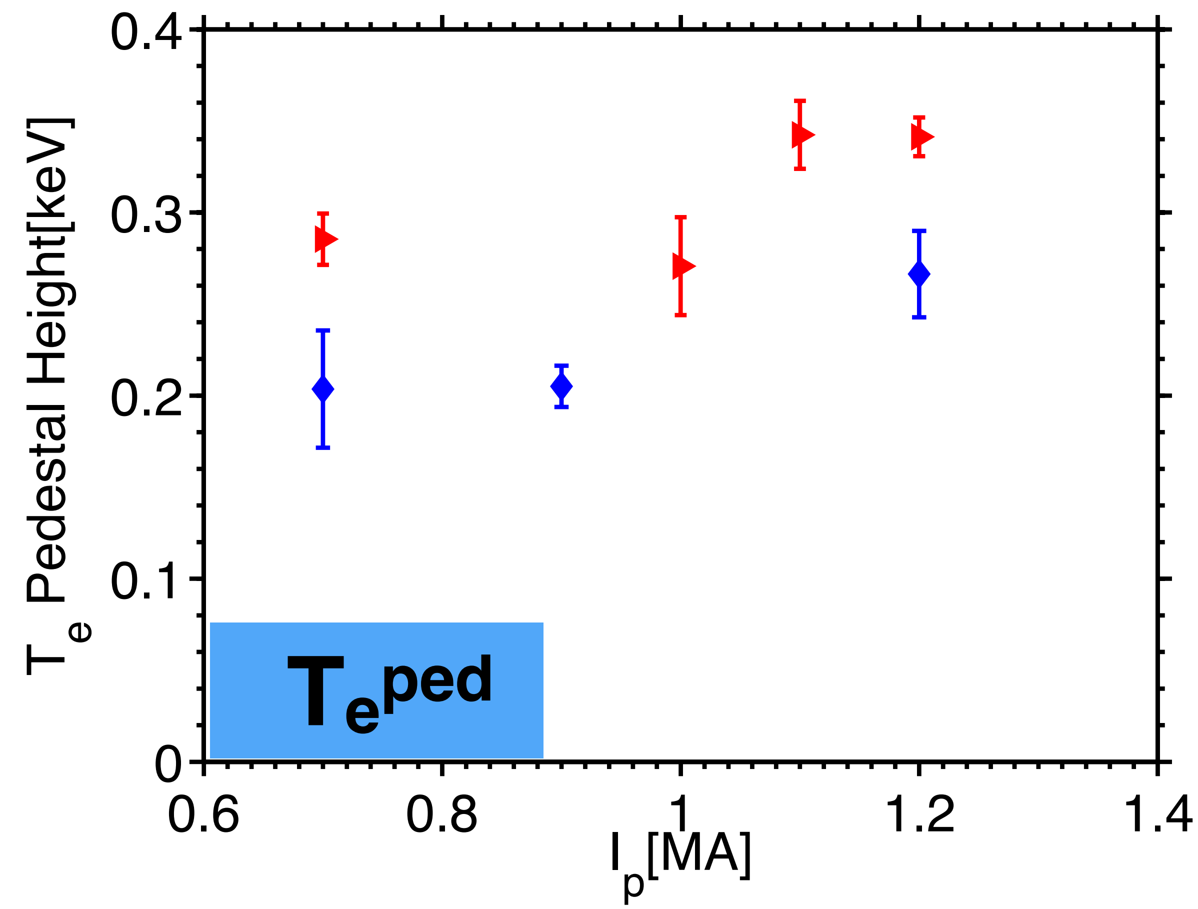


- Growth of P_i^{ped} is unclear though some show growing trend
- T_i^{ped} grows by a factor of 1.3 during the ELM cycle

Impact of Plasma Current and Lithium Conditioning on Pedestal Dynamics

Plasma Current Increases n_e^{ped} More than Increasing T_e^{ped}

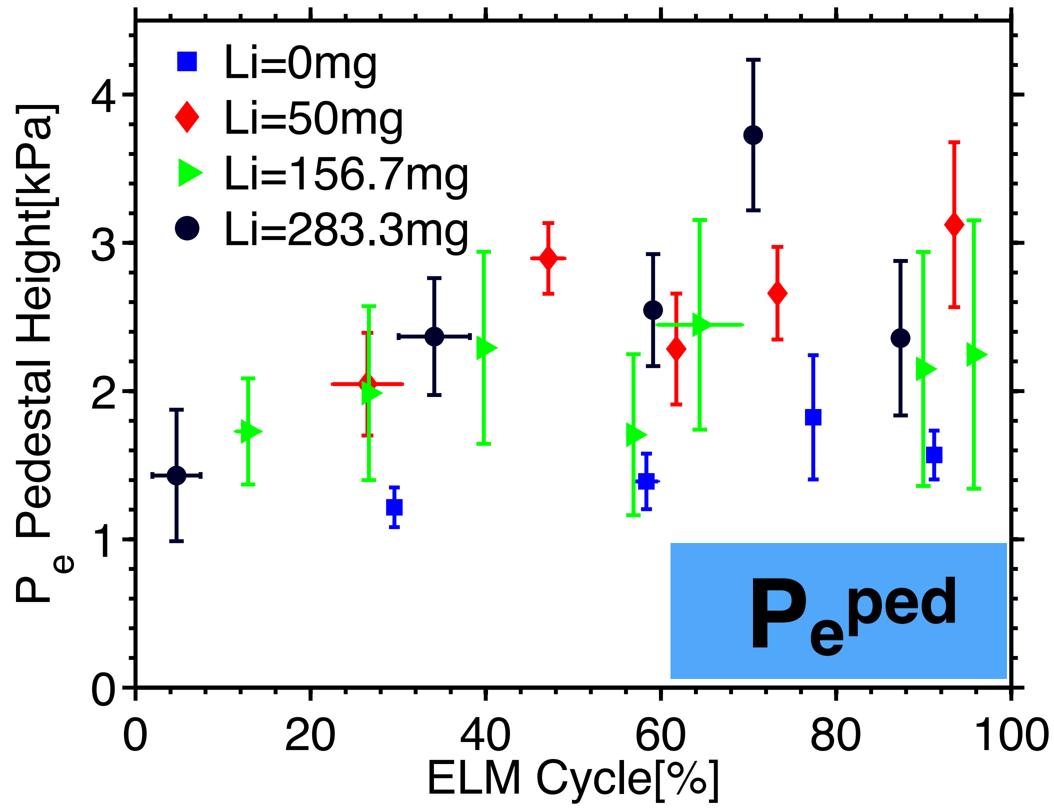


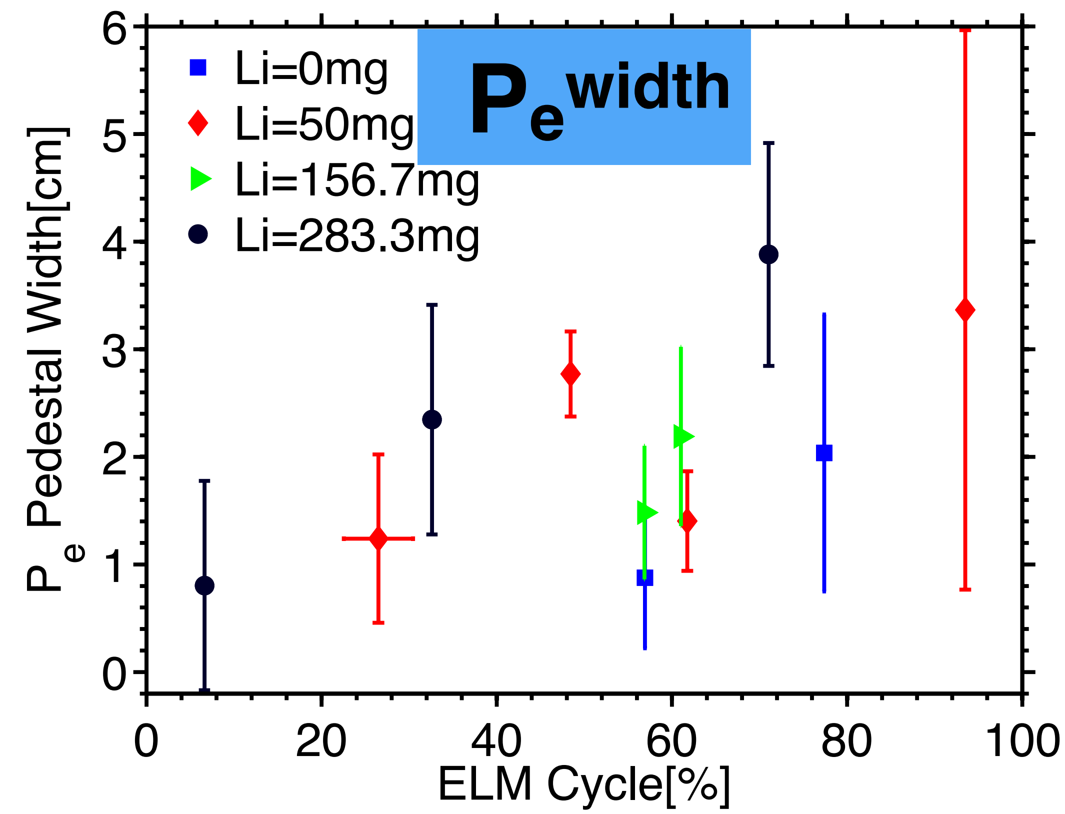


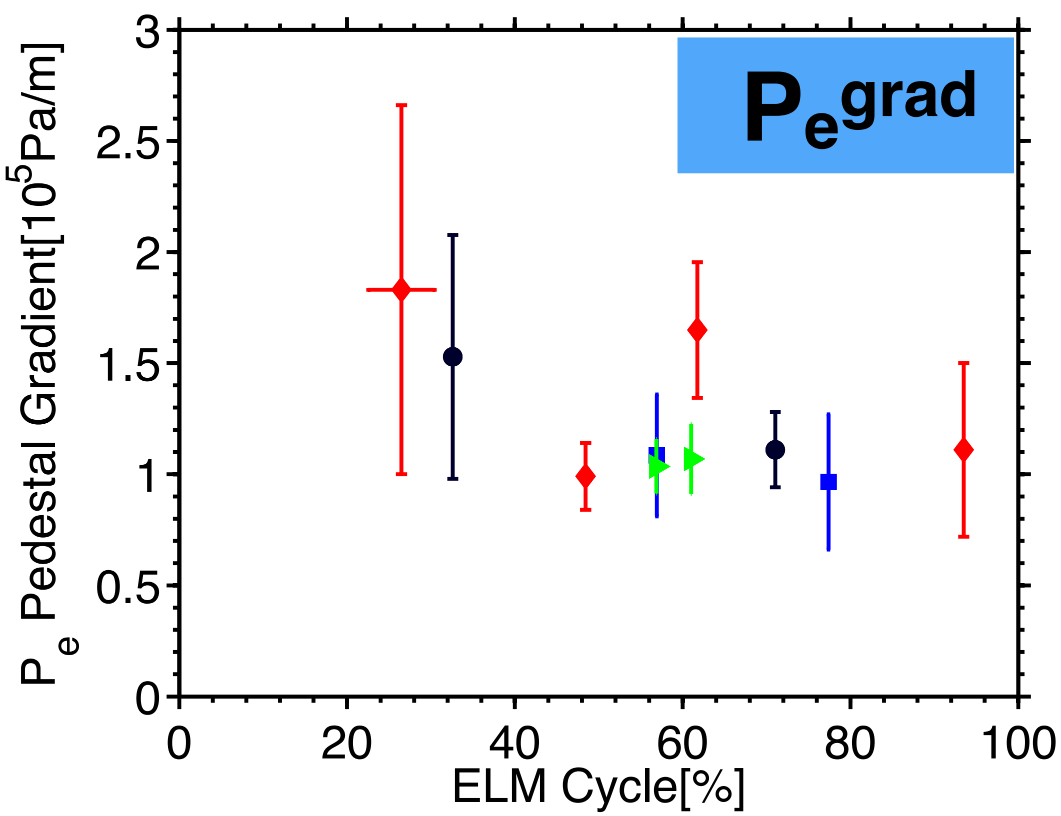
By taking the average of pedestal parameters over the entire ELM cycle, we get the impact of I_p on electron pedestal parameters. I_p rises by a factor of 1.9(from 0.7MA to 1.3 MA) increases,

- n_e^{ped} by a factor of 1.4
- T_e^{ped} by a factor of 1.2

Lithium Conditioning Shows Overall Increasing Impact on Electron Pressure Pedestal Structure

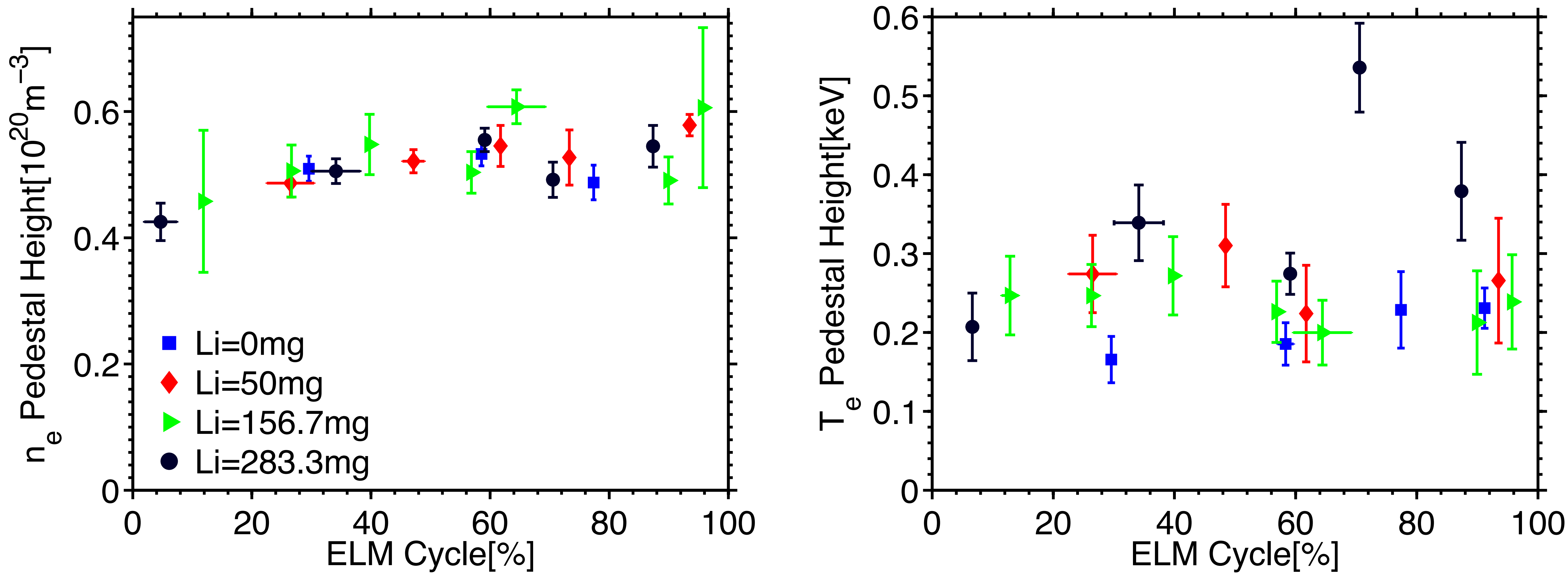






- Generally speaking, larger lithium conditioning would increase P_e^{ped} and P_e^{width}
- Lithium conditioning doesn't affect P_e^{grad}
- Some exceptions exist, like when lithium conditioning is increased from 50mg to 156.7mg, P_e^{ped} is reduced. This implies other factors besides I_p and P_{NBI} need to be considered.

Lithium Conditioning Changes n_e^{ped} More than Changing T_e^{ped}



- Lithium conditioning doesn't effect n_e^{ped}
- Lithium conditioning increases T_e^{ped} overall. But this effect doesn't have a consistent trend either

Summary and Future Work

- During ELM cycle, P_{NBI}, I_p and Lithium conditioning are held constant
  - P_e^{ped}, and P_e^{width} increase during an ELM cycle, at constant P_e^{grad}; This is consistent with previous experimental result by Ahmed *et al*[5] and theory model EPED[6]
  - There is a small increase in n_e^{ped} compared with T_e^{ped}'s growth
  - Both P_i^{ped} and T_i^{ped} grow

- Larger plasma current increases n_e^{ped}, with a smaller increasing impact on T_e^{ped}

- More lithium conditioning
  - has no effect on P_e^{grad}
  - increases P_e^{ped},and P_e^{width}
  - More parameters other than I_p and P_{NBI} need to be considered to clarify this effect
- Future work could be focused on adding lithium conditioning's effect into EPED model and/or improving the measurement of pedestal width.

References

- [1] Osborne, T. H., et al. Plasma physics and controlled fusion 40.5 (1998): 845.
- [2] Krasheninnikov, S. I., L. E. Zakharov, and G. V. Pereverzev. *Physics of Plasmas (1994-present)* 10.5 (2003): 1678-1682.
- [3] Groebner, R. J., and T. H. Osborne. Physics of Plasmas (1994-present) 5.5 (1998): 1800-1806.
- [4] Jenko, Frank, et al. Physics of Plasmas (1994-present) 16.5 (2009): 055901.
- [5] Diallo, A., et al. Nuclear Fusion 51.10 (2011): 103031.
- [6] Snyder, P. B., et al, Nuclear Fusion 51.10 (2011): 103016.