



Filamentary transport in high-power H-mode conditions and in no/small-ELM regimes  
to predict heat and particle loads on PFCs for future devices

---

N. Vianello, V. Naulin for Topic-21 Scientific Team

14 November 2017



This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

**Include scientific team and logos**



Deliverables listed during the call for manning of last December

1. Provide cross-machine L-Mode shoulder dependence on current both at constant  $B_t$  and at constant  $q_{95}$
2. Establish robust scenario for density shoulder profile in H-Mode and establish dependence on fuelling/neutral profiles/divertor condition
3. Use the new HHF probe on AUG to study filamentary transport under high-power H-Mode conditions and under different plasma configurations (SN, DN)
4. Study the role of ELM regimes, neutral compression and particle density in filamentary transport and related shoulder formation
5. Identify the contribution of collisionality and seeding on filamentary transport and related shoulder formation
6. Determine the effect of filaments and shoulder formation on target heat loads in different H-mode plasmas

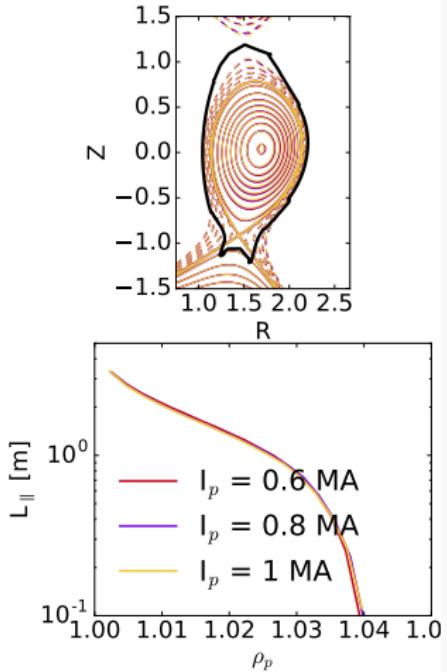


Deliverables listed during the call for manning of last December

1. Provide cross-machine L-Mode shoulder dependence on current both at constant  $B_t$  and at constant  $q_{95}$
2. Establish robust scenario for density shoulder profile in H-Mode and establish dependence on fuelling/neutral profiles/divertor condition
3. Use the new HHF probe on AUG to study filamentary transport under high-power H-Mode conditions and under different plasma configurations (SN, DN)
4. Study the role of ELM regimes, neutral compression and particle density in filamentary transport and related shoulder formation
5. Identify the contribution of collisionality and seeding on filamentary transport and related shoulder formation
6. Determine the effect of filaments and shoulder formation on target heat loads in different H-mode plasmas

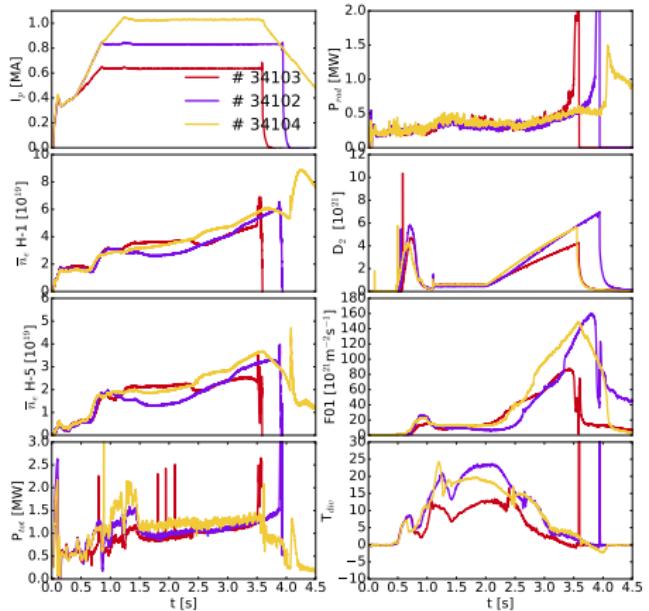
So far H-Mode operation has been limited to AUG since no operational scenario in high-density NBH heated plasma on TCV has been established

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



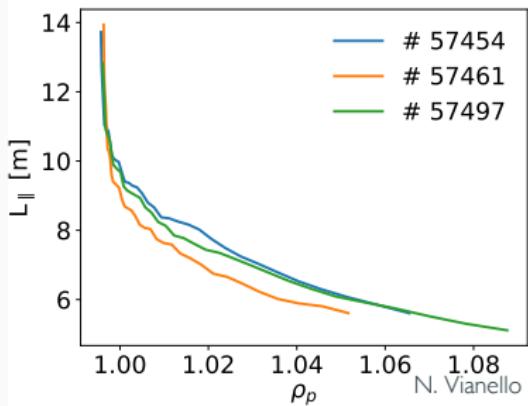
- ✓ AUG: All the shots were performed in the so-called Edge Optimized Configuration (EOC) shape
- ✓ AUG: We matched correctly the shape and the  $L_{\parallel}$  here shown from outer divertor plate up to X-point

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



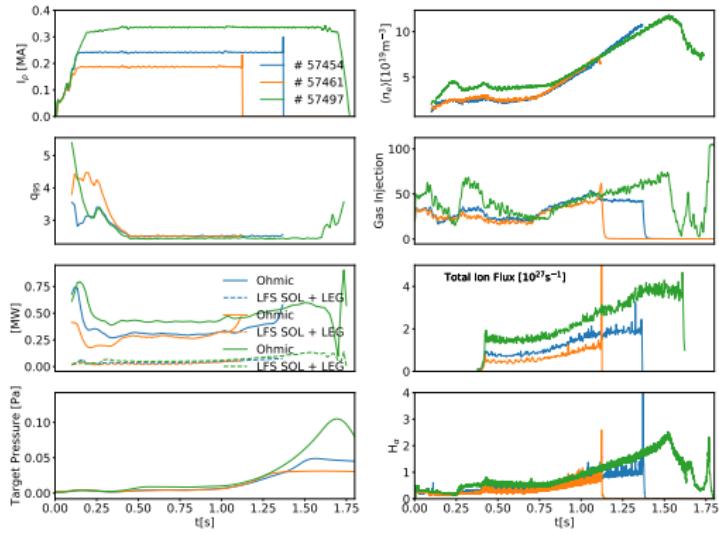
- ✓ AUG: The scan was performed with similar puffing rate (0.8-1 MA) whereas we reduced it at lower current to avoid early disruption
- ✓ AUG: The total power (Ohmic plus NBI) was kept constant throughout the scan
- ✓ AUG: We have comparable edge density, divertor neutral pressure and divertor temperature

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



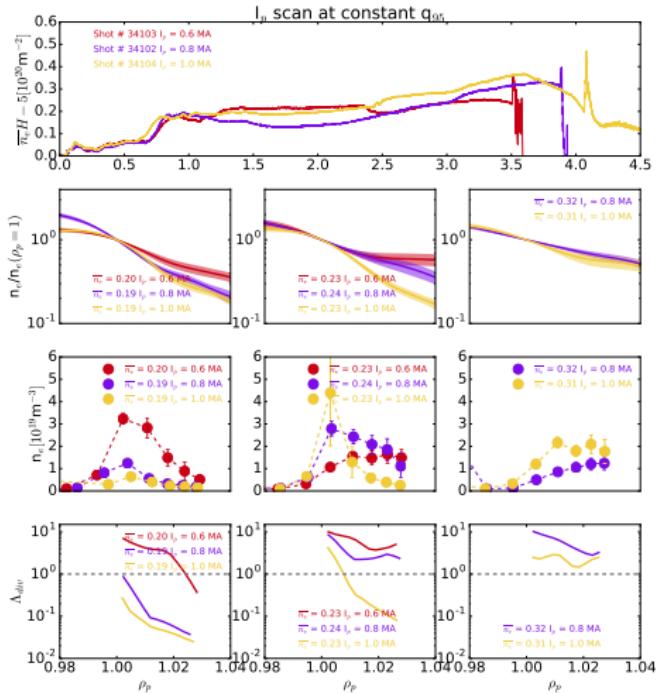
- ✓ TCV: We repeat the same exercise at TCV with a slight difference in the profile of parallel connection length. This required operation at unusual low toroidal field (up to 0.8T)

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



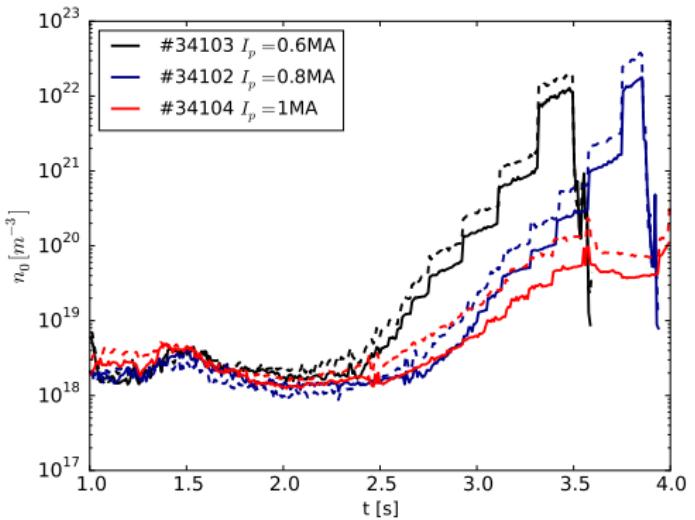
- ✓ TCV: no additional heating used. Nevertheless the difference in power crossing the separatrix is small
- ✓ TCV: The difference in target pressure similar to AUG behavior

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



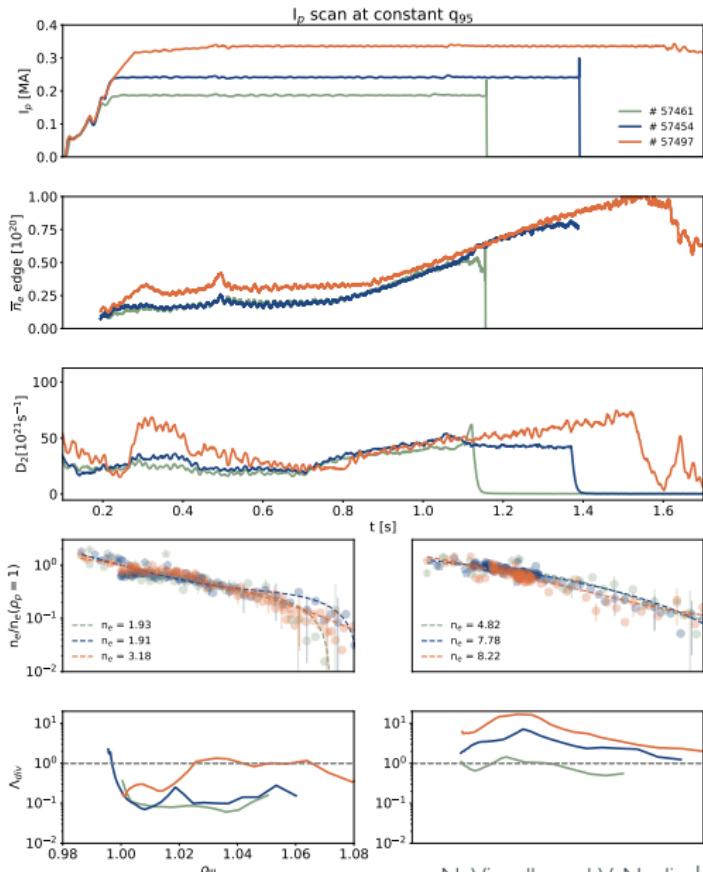
✓ AUG: At comparable edge density Upstream profiles are different with the tendency to develop shoulder easier at lower current. We have flattening of the upstream profiles only when  $\Lambda_{div}$  is well above one on all the profile

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



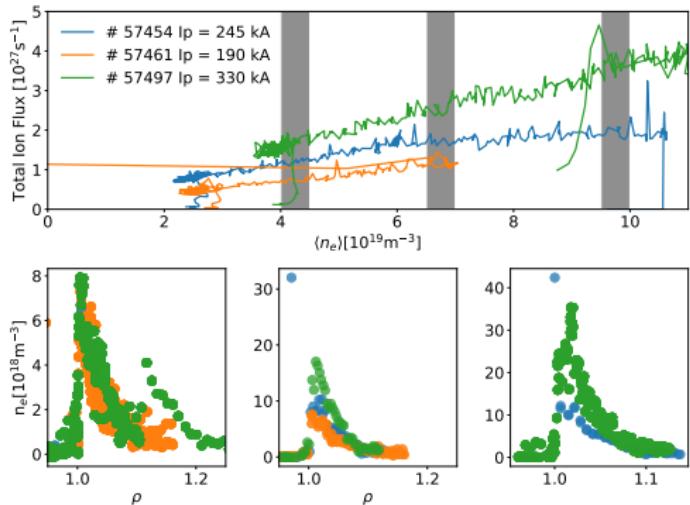
- ✓ Neutrals estimated using calibrated  $D_\alpha$  images coupled with values of density and temperature at the target suggest a larger

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



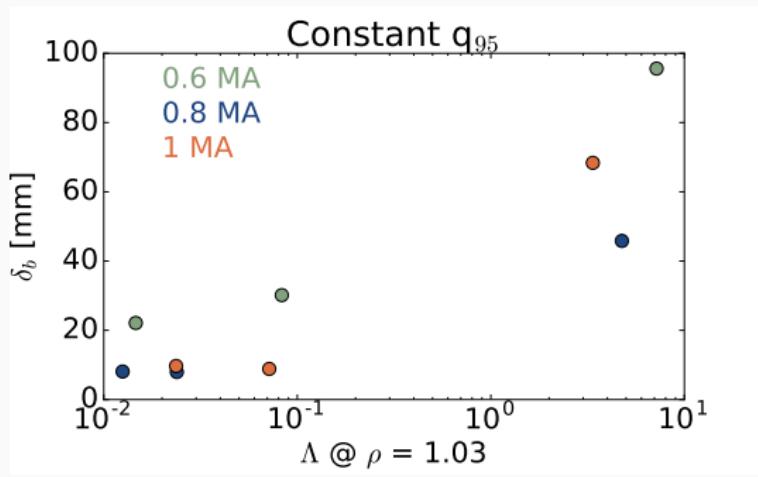
✓ TCV: This tendency is not observed for TCV where profiles seem resilient to modification of  $B_t$  even though we reached pretty high value of  $\Lambda_{div}$  all along the profile.

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



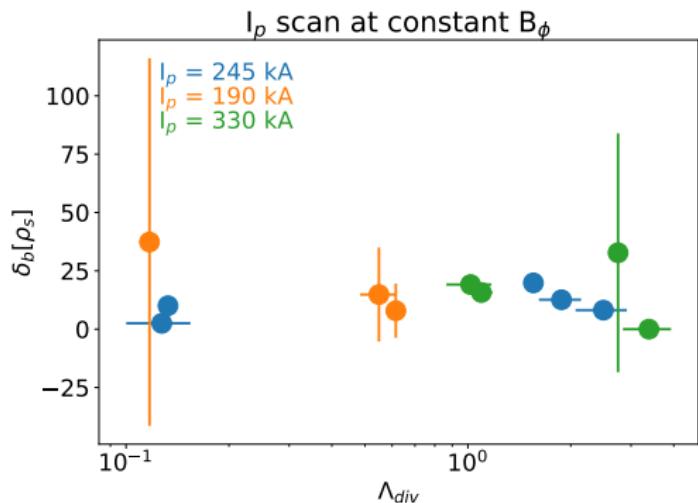
- ✓ TCV: This is due to the fact that we can't observe during the density ramp any signature of rollover or detachment, whereas upstream profile modification at TCV are only observed well after rollover

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



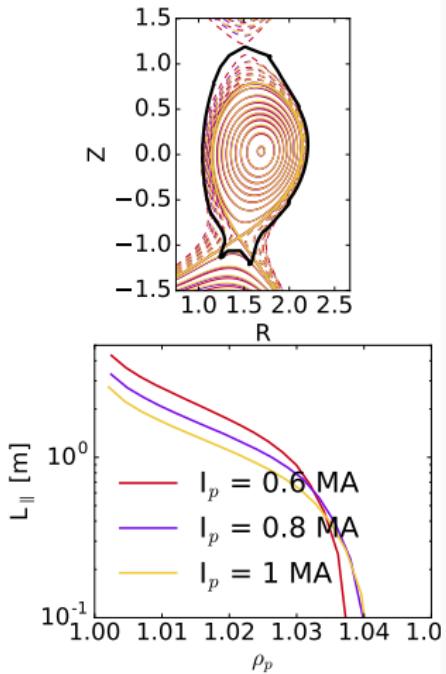
✓ AUG: There is the tendency towards larger blobs at lower current

# L-Mode analysis: $I_p$ scan at constant $q_{95}$



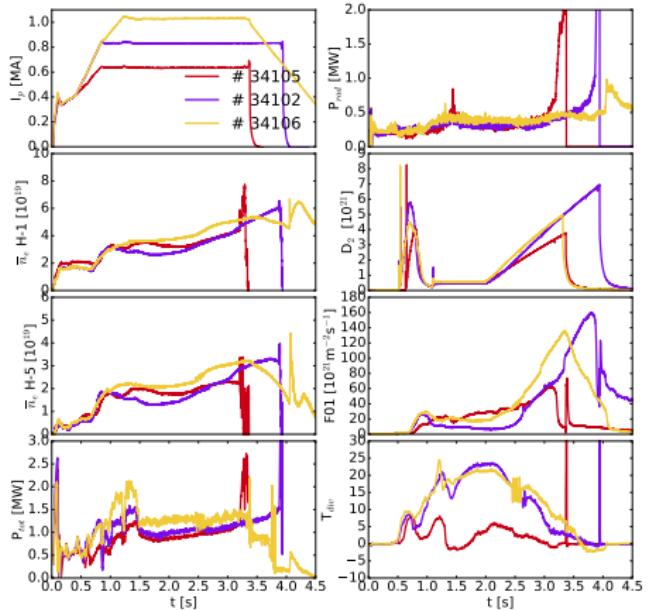
- ✓ TCV: this is not confirmed for TCV but in line with the lack of shoulder and detachment

# L-Mode analysis: $I_p$ scan at constant $B_t$



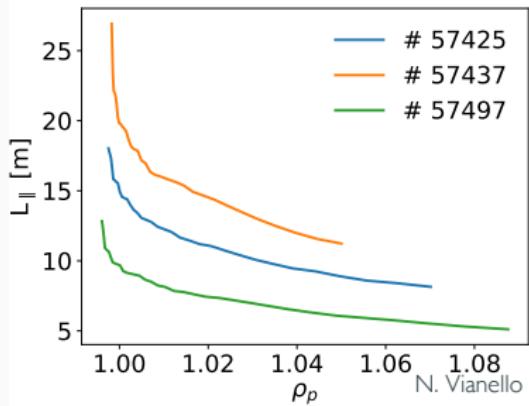
- ✓ AUG: We matched correctly the shape the parallel connection length  $L_{\parallel}$  is modified consistently
- ✓ AUG: The scan was performed with similar puffing rate (0.8-l MA) whereas we reduced it at lower current to avoid early disruption

# L-Mode analysis: $I_p$ scan at constant $B_t$



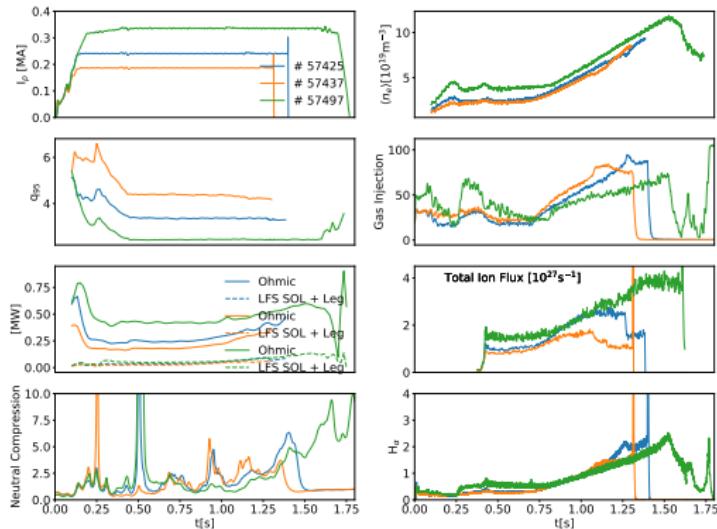
- ✓ AUG: We have comparable edge density and divertor neutral pressure even though pressure increase earlier at higher current
- ✓ AUG: The total power (Ohmic plus NBI) was kept constant throughout the scan

# L-Mode analysis: $I_p$ scan at constant $B_t$



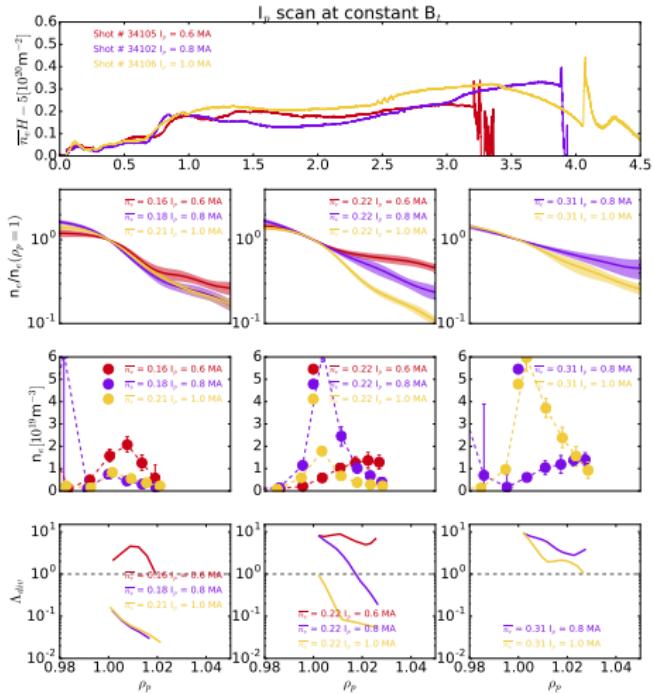
- ✓ TCV: We repeat the same exercise at TCV with a consistent variation of parallel connection length

# L-Mode analysis: $I_p$ scan at constant $B_t$



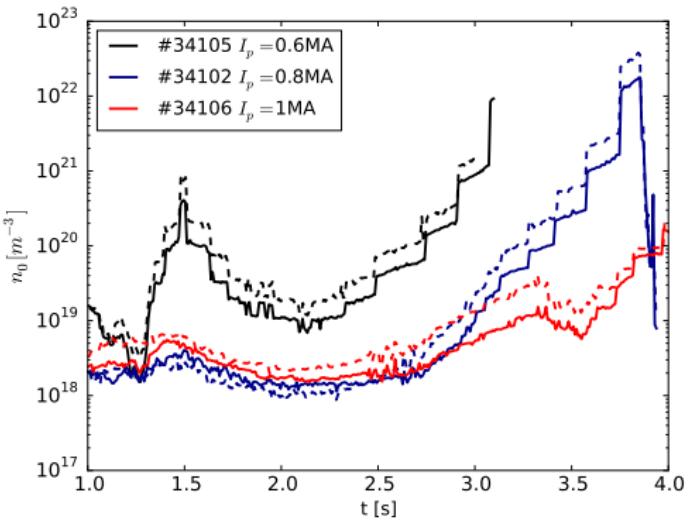
- ✓ TCV: no additional heating used. Nevertheless the difference in power crossing the separatrix is small
- ✓ TCV: Neutral compression is roughly constant between

# L-Mode analysis: $I_p$ scan at constant $B_t$



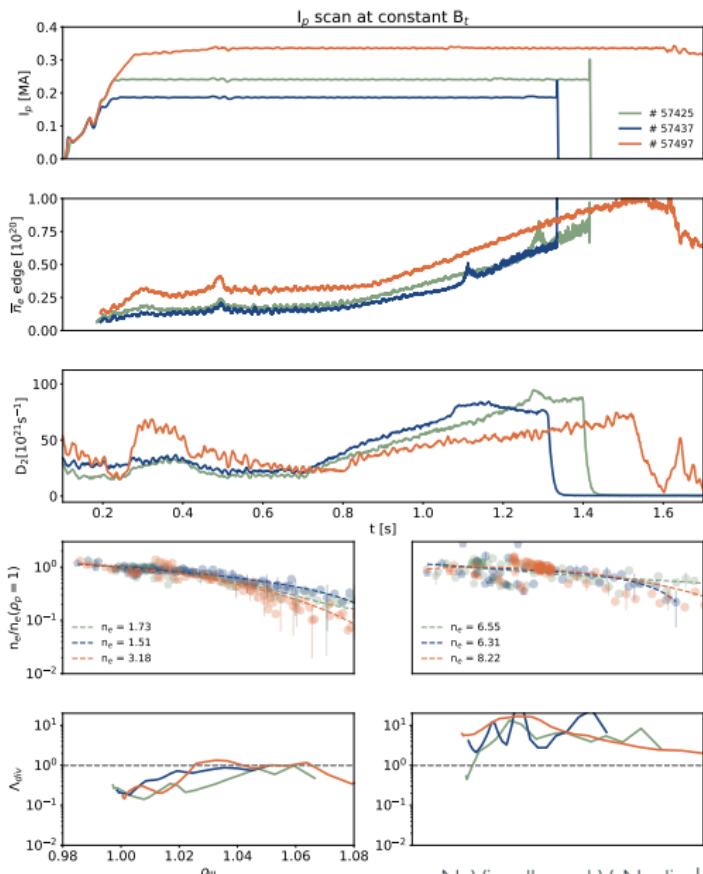
✓ AUG: At comparable edge density Upstream profiles are different with the tendency to develop shoulder easier at lower current. **We have flattening of the upstream profiles only when  $\Lambda_{\text{div}}$  is well above one on all the profile**

# L-Mode analysis: $I_p$ scan at constant $B_t$



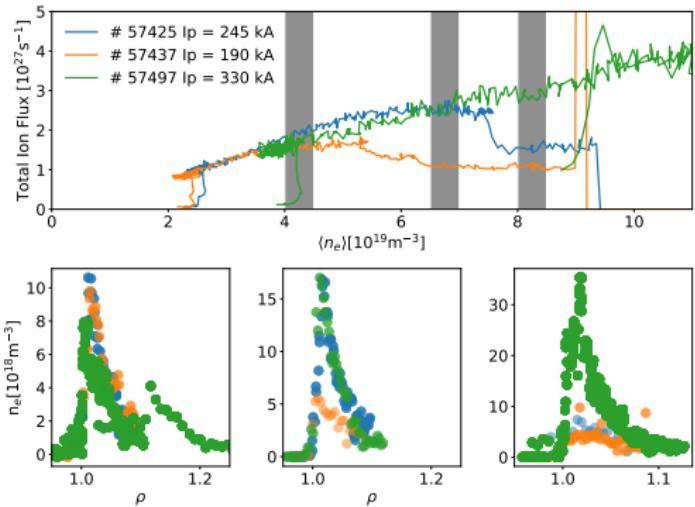
- ✓ Neutrals at lower current are substantially higher even with similar edge density profiles.

# L-Mode analysis: $I_p$ scan at constant $B_t$



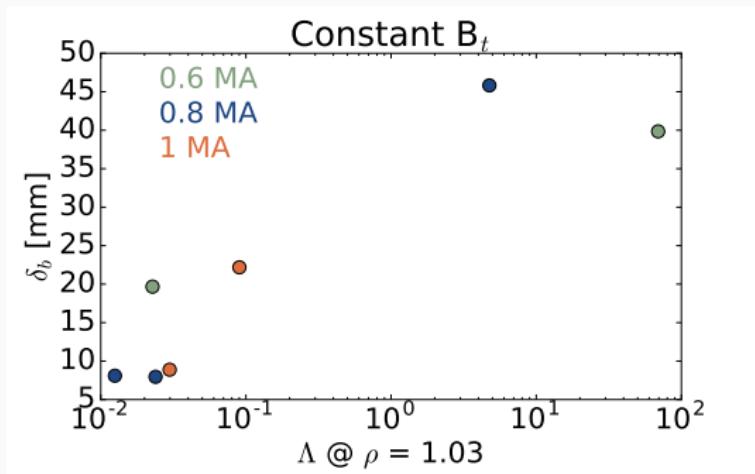
✓ TCV: This tendency is substantially confirmed at TCV where profiles

# L-Mode analysis: $I_p$ scan at constant $B_t$



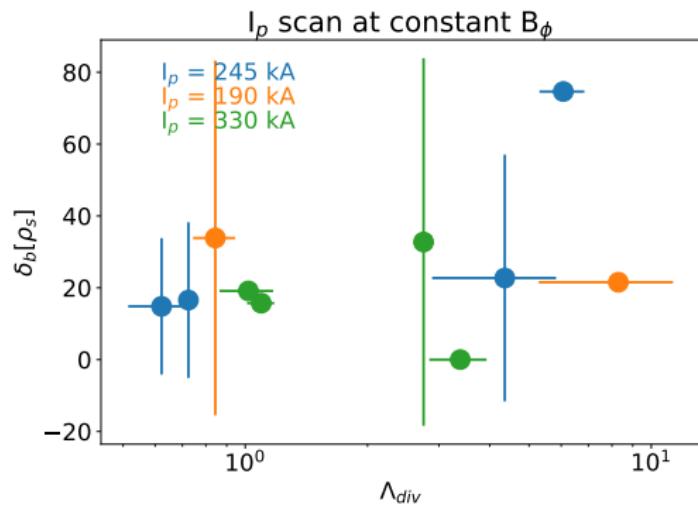
- ✓ TCV: This is consistent with onset of detachment (at least in intermediate and lower current)

# L-Mode analysis: $I_p$ scan at constant $B_t$



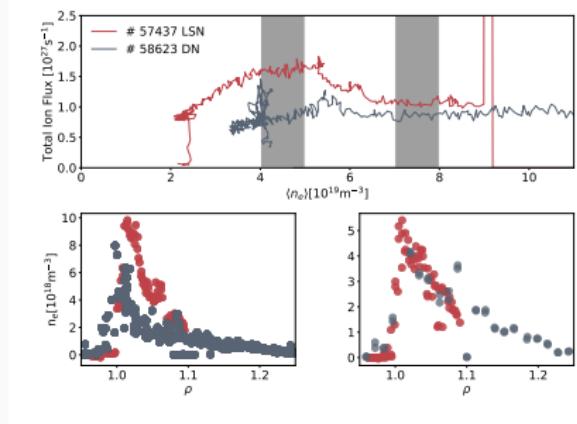
- ✓ AUG: While the general observation of increasing blob size with  $\Lambda_{div}$  is confirmed there are no differences between the current

# L-Mode analysis: $I_p$ scan at constant $B_t$

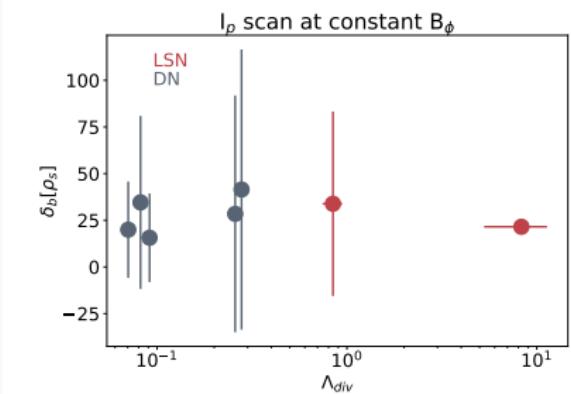
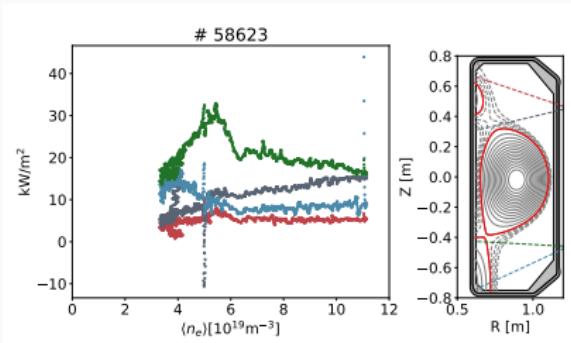


✓ TCV: confirm the observation of AUG.

# LSN vs Double null on TCV



# LSN vs Double null on TCV



# H-Mode effect of puffing location



# H-Mode effect of cryopumps



plored



# Program for 2018: AUG



# Program for 2018: TCV



# Program for 2018: MAST-U

