EUROfusion

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

presented by N. Vianello on behalf of MST1-Topic 21 scientific team

23 May 2018

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.

Scientific team

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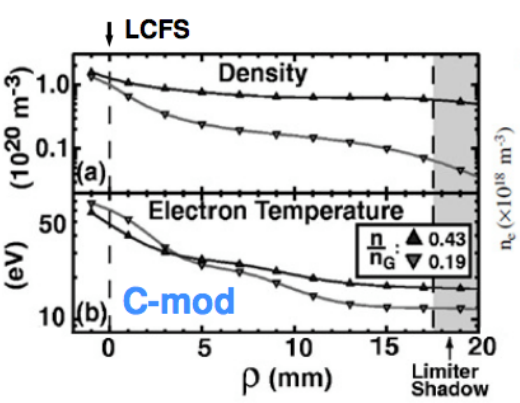
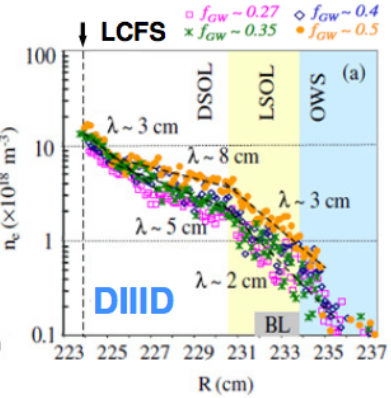
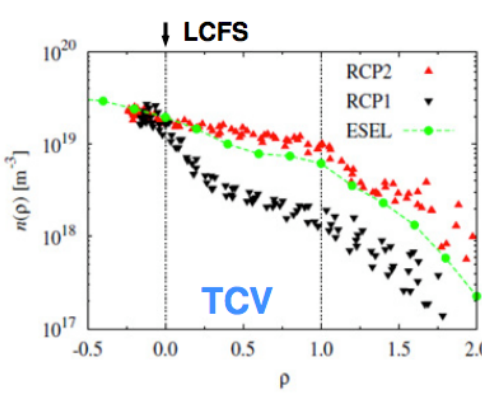
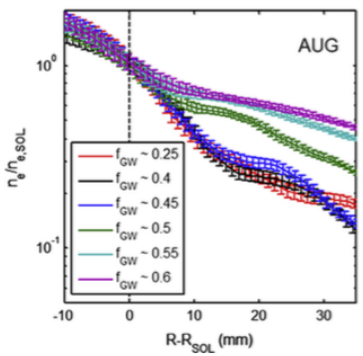
Background

✓ Role of turbulence transport in the SOL saturation is a well know feature (Carralero *et al.* 2014; Garcia *et al.* 2007; LaBombard *et al.* 2001; Rudakov *et al.* 2005). Increasing density, even without reaching detachment SOL profile tend to flatten



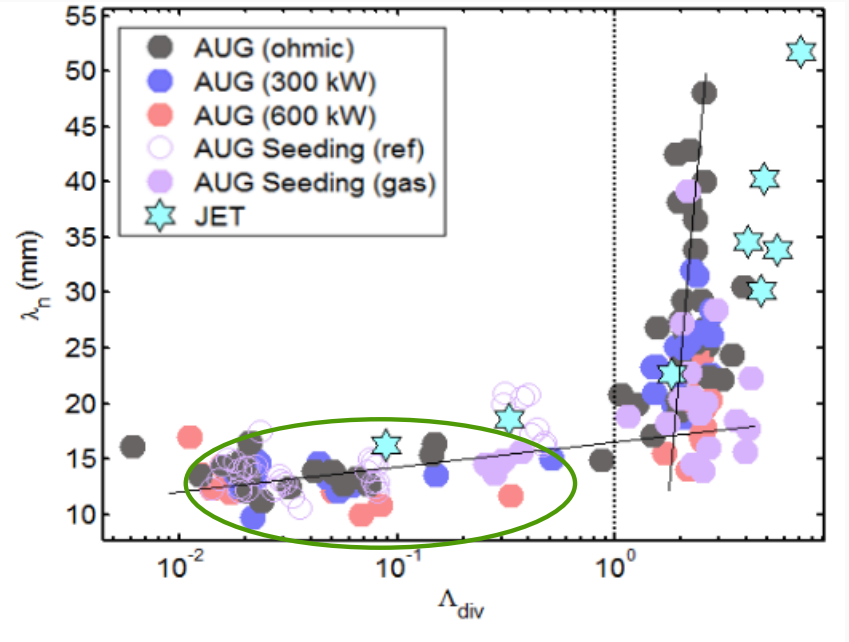






Background

- ✓ AUG and JET (HT) (Carralero *et al.* 2015) suggest that $\Lambda_{div} = \frac{L_{\parallel}/c_s}{1/\nu_{ei}} \frac{\Omega_i}{\Omega_e}$ dominates this process and a transition from sheath-limited



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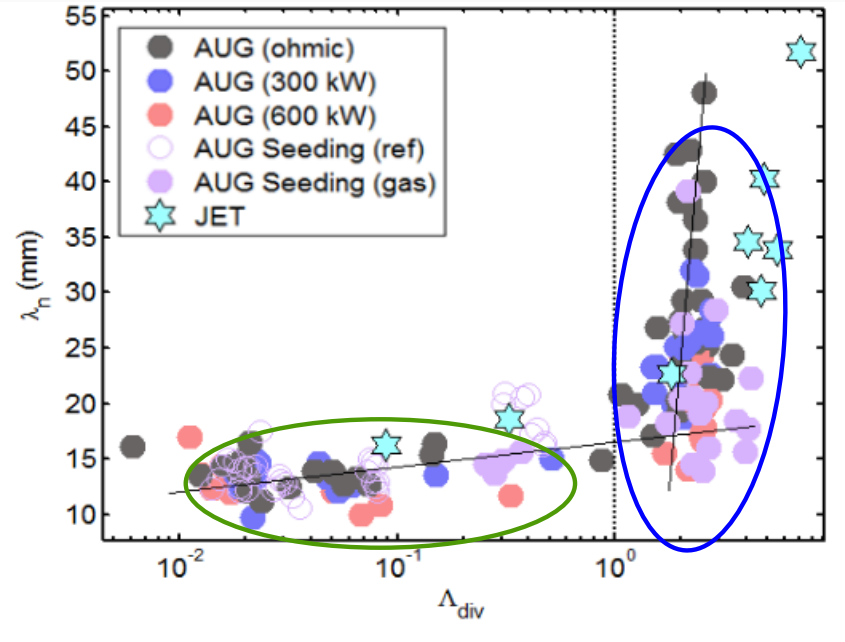

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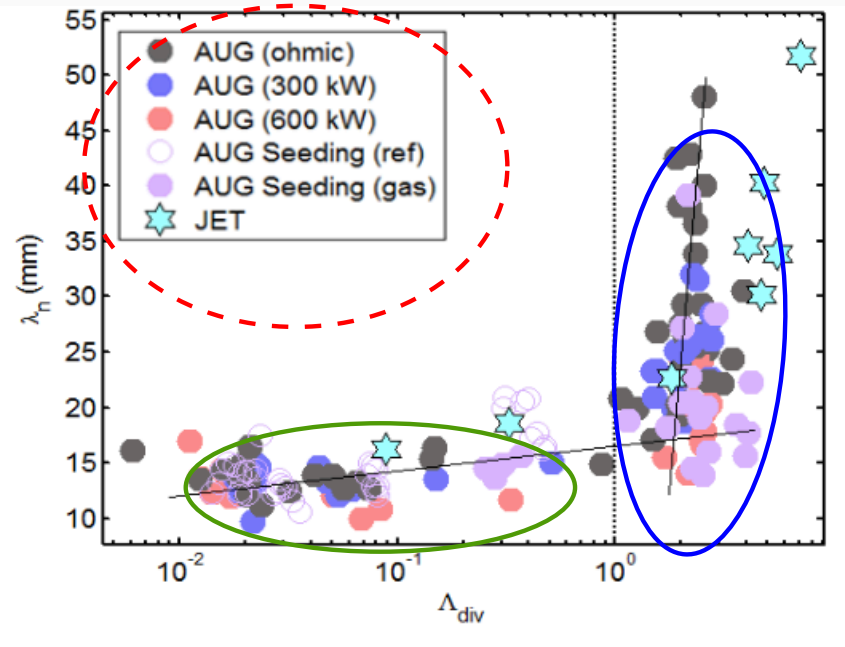
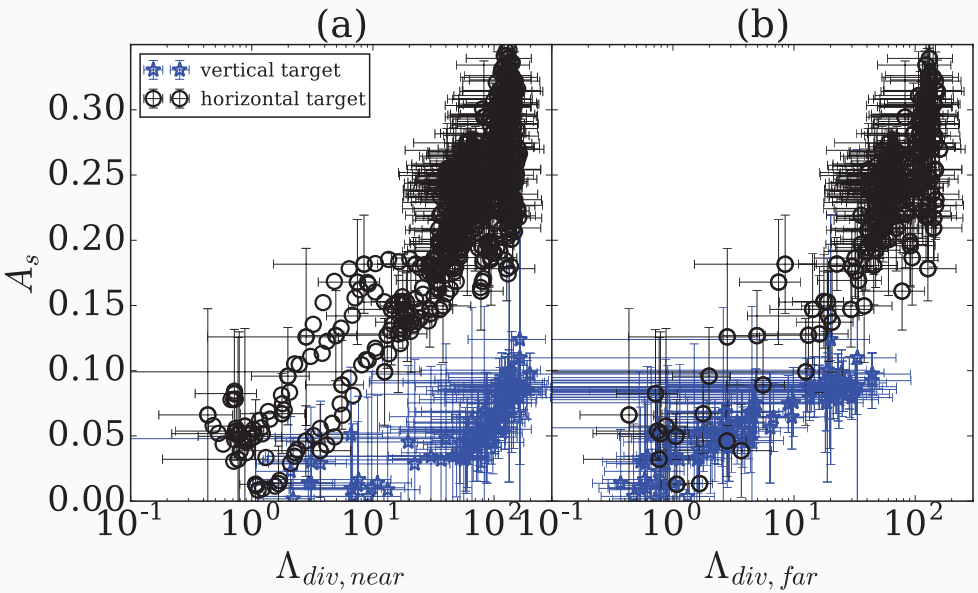
- ✓ Tested by changing n_e and T_e through fueling/seeding/heating



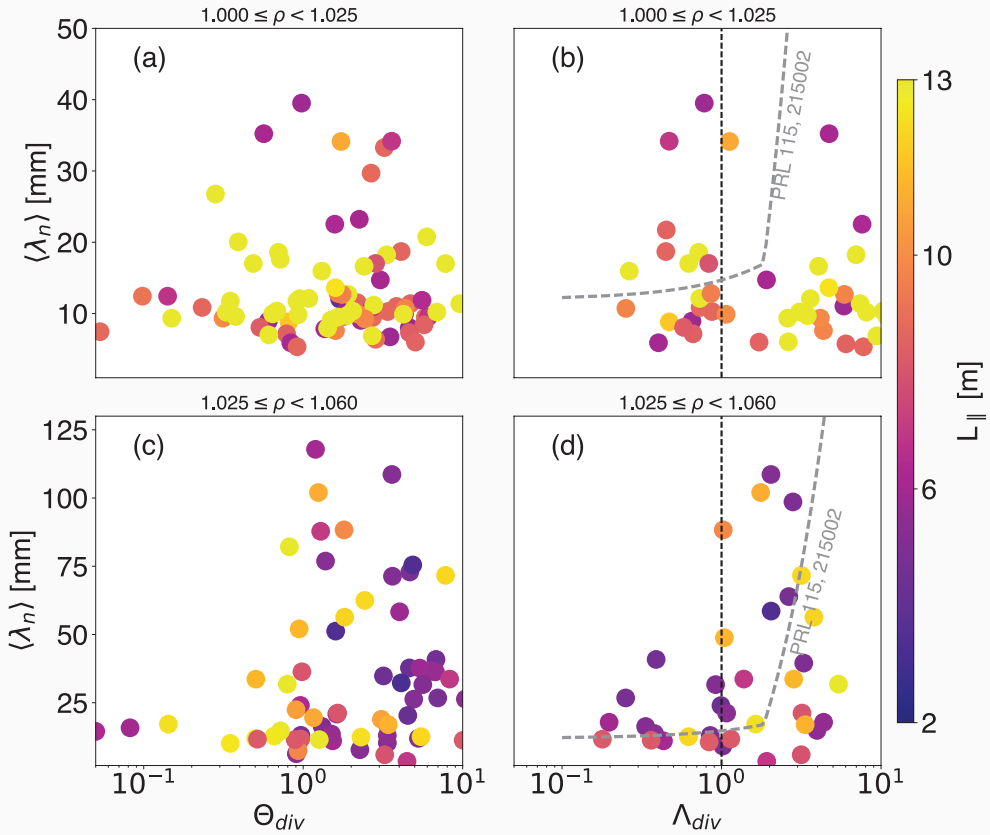
Background

- ✓ Λ_{div} does not describe properly evolution of upstream profile in JET-VT (Wynn *et al.* 2018)



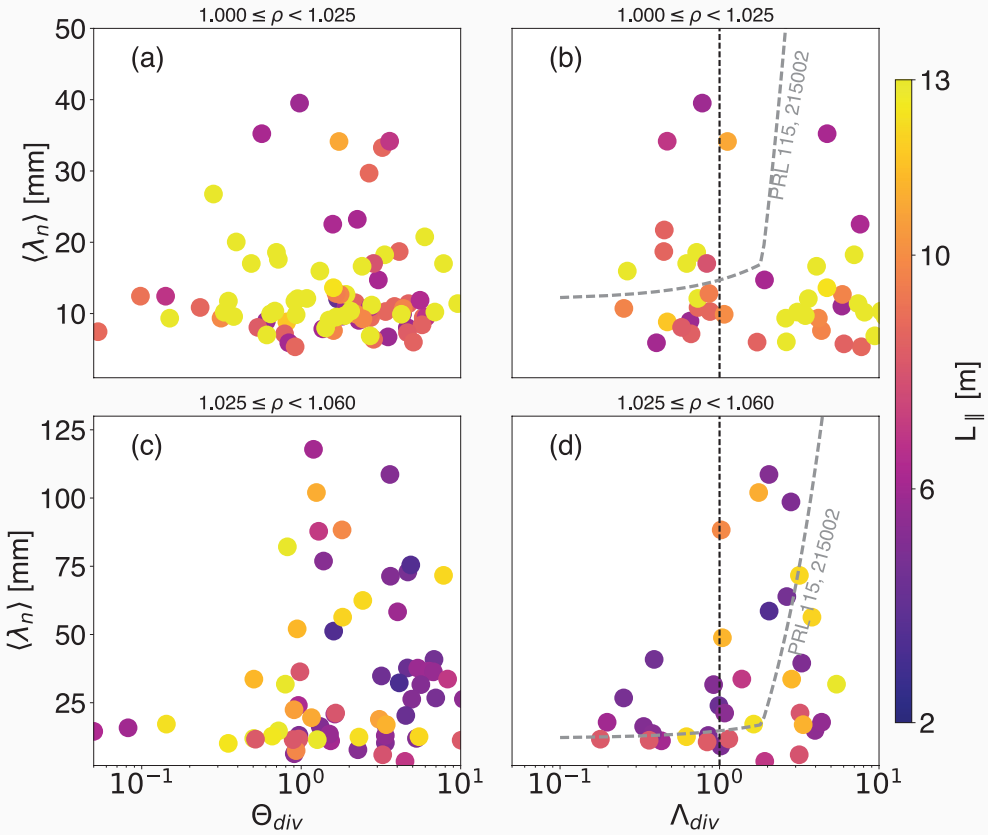
Background

- ✓ On TCV (Vianello *et al.* 2017) Λ_{div} necessary but not sufficient to guarantee increase λ_n in the far SOL



Background

- ✓ On TCV (Vianello *et al.* 2017) Λ_{div} necessary but not sufficient to guarantee increase λ_n in the far SOL
- ✓ Additional mechanism suggested among which neutral clogging



Motivation and deliverables

- ✓ Relation between downstream divertor conditions and up-stream SOL profiles is not well understood. Influence of SOL blob structures on shoulder formation and divertor conditions is key element towards predictive capabilities. Joint effort within the EUROfusion framework to address this issue on all the MST1 devices (AUG, TCV and MAST-U)

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A series of deliverables were foreseen by 2017 program

1. Cross-machine L-Mode shoulder dependence on current both at constant B_t and at constant q_{95}. Rationale: disentangle the effect of current and parallel connection length
2. Establish robust scenario for density shoulder profile in H-Mode and establish dependence on fuelling/neutral profiles/divertor condition
3. Fluctuations mesurement 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

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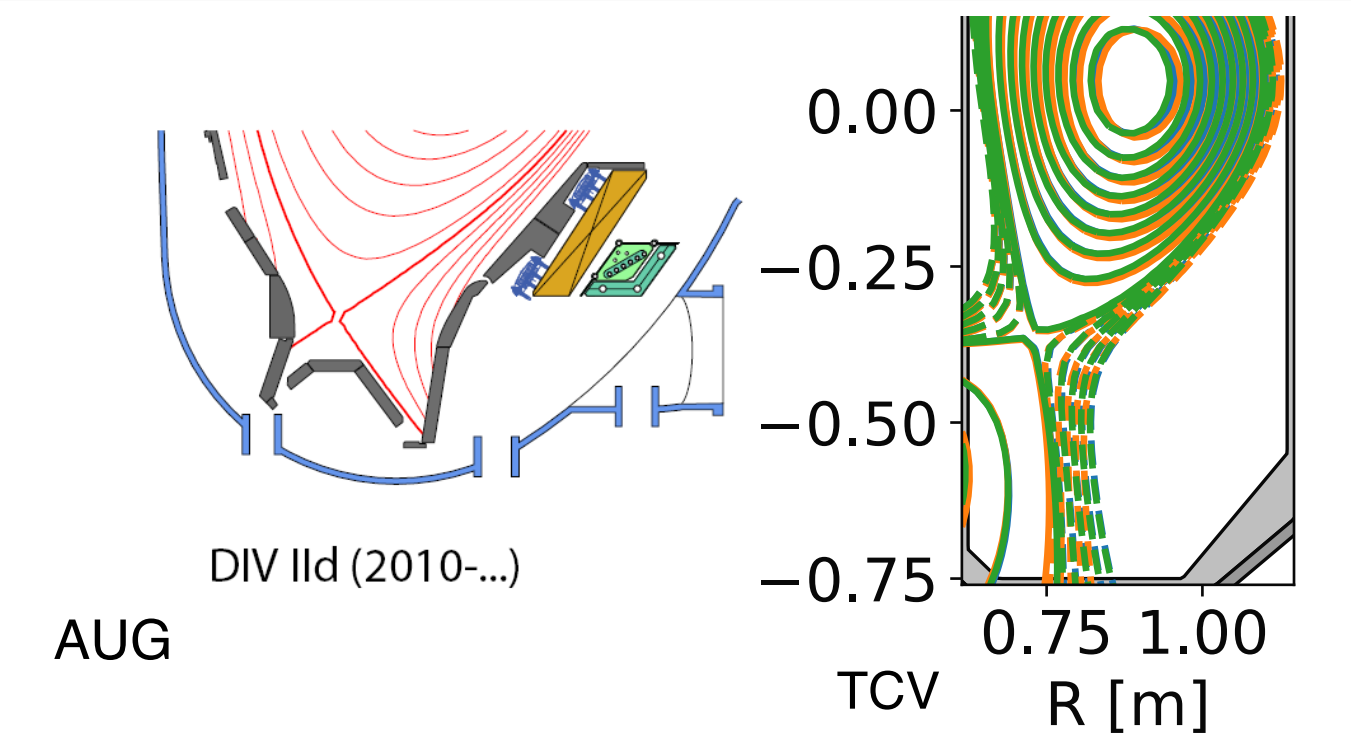
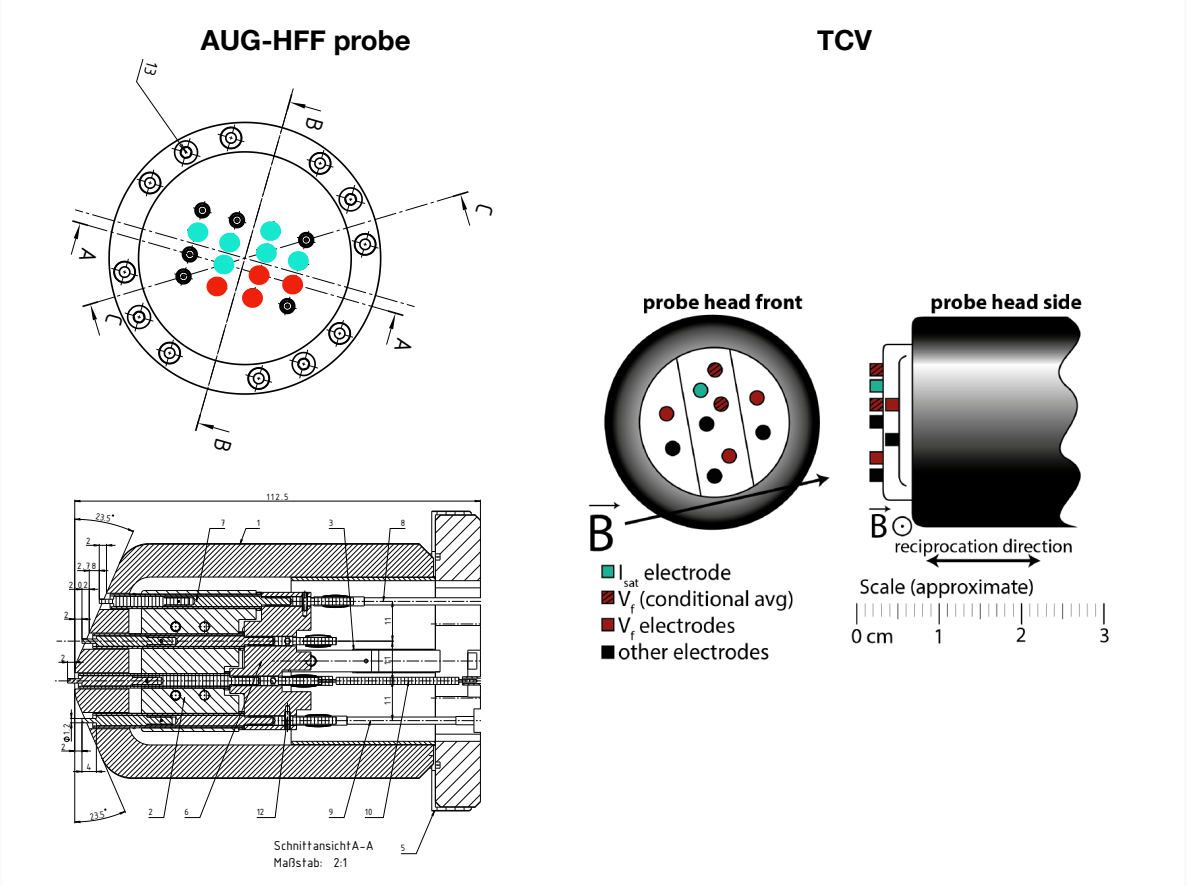
Remember this is still a work in progress

Devices, diagnostics and methods



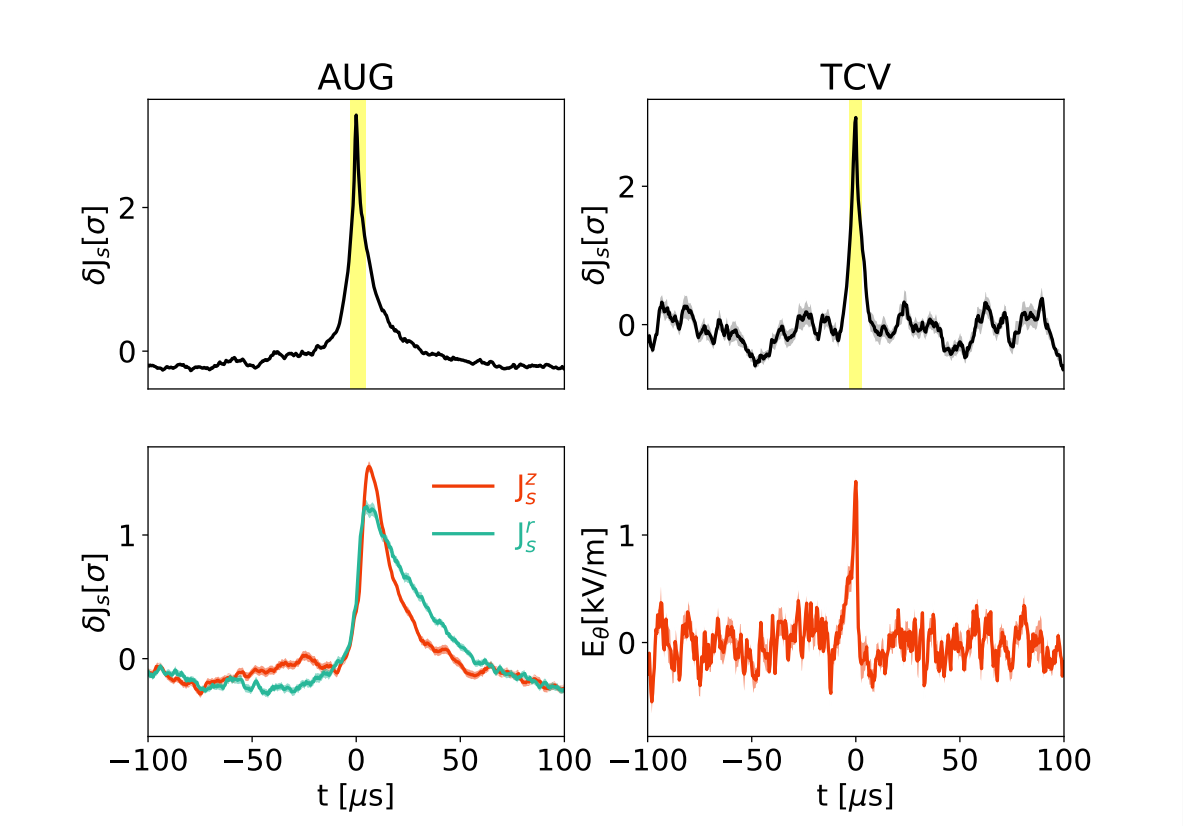
- ✓ **AUG:** Metallic wall, cryopumps, closed divertor with SP on vertical target, short divertor leg
- ✓ **TCV:** Carbon wall, completely open divertor, operated with relative long divertor leg, no cryopump

Devices, diagnostics and methods



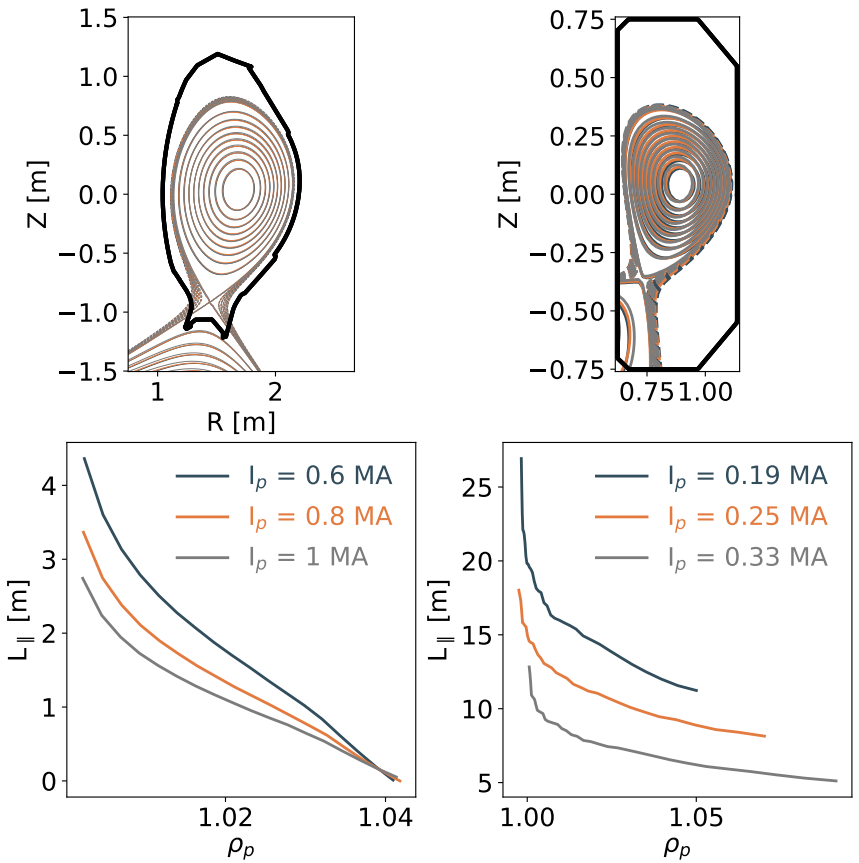
- ✓ **AUG:** Ion saturation current measured at different radial/poloidal position to get velocity from 2D cross-correlation
- ✓ **TCV:** Only 1 j_{sat} measurement available, different velocity estimate. v_r from **E** × **B** evaluation from floating potentials on CAS, v_z from 2D cross-correlation analysis

Devices, diagnostics and methods



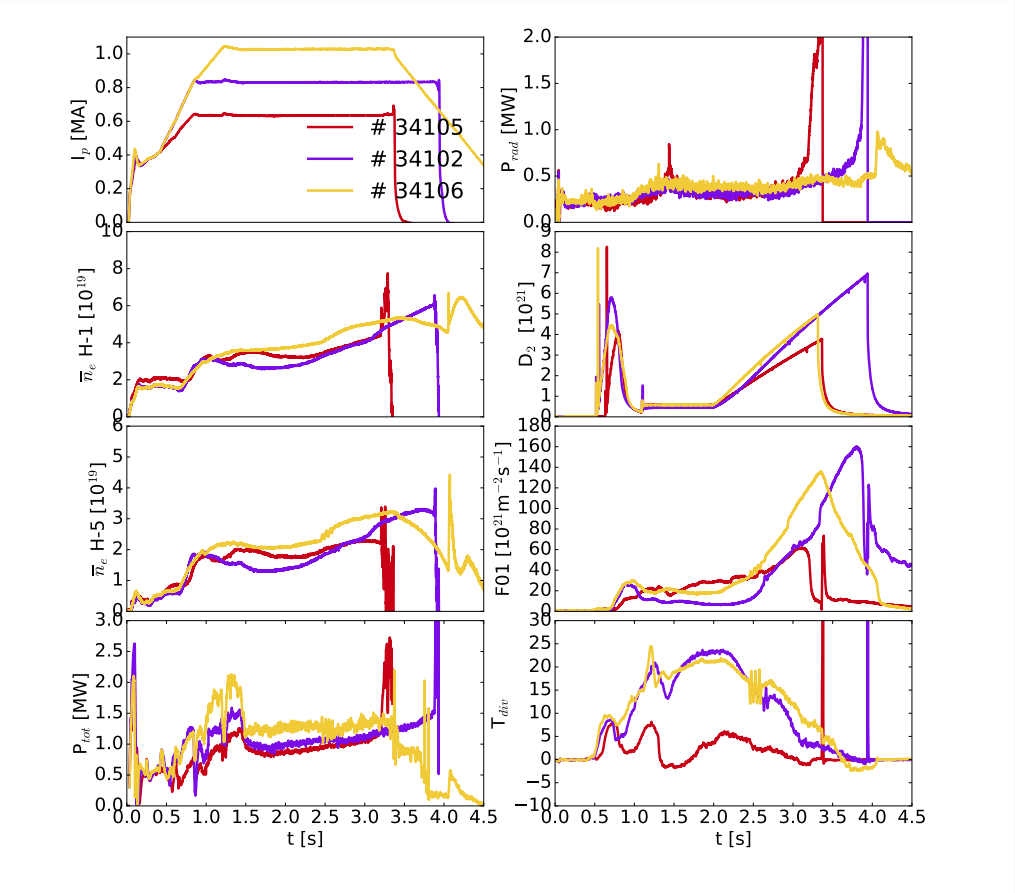
- ✓ Blob-size is $\delta_b = 0.5 * \tau_b * v_\perp$
- ✓ τ_b estimated from FWHM of Conditional Avearage binormal blob velocity estimated (although differently in the two devices)

Current scan at constant B_t in L-Mode plasma



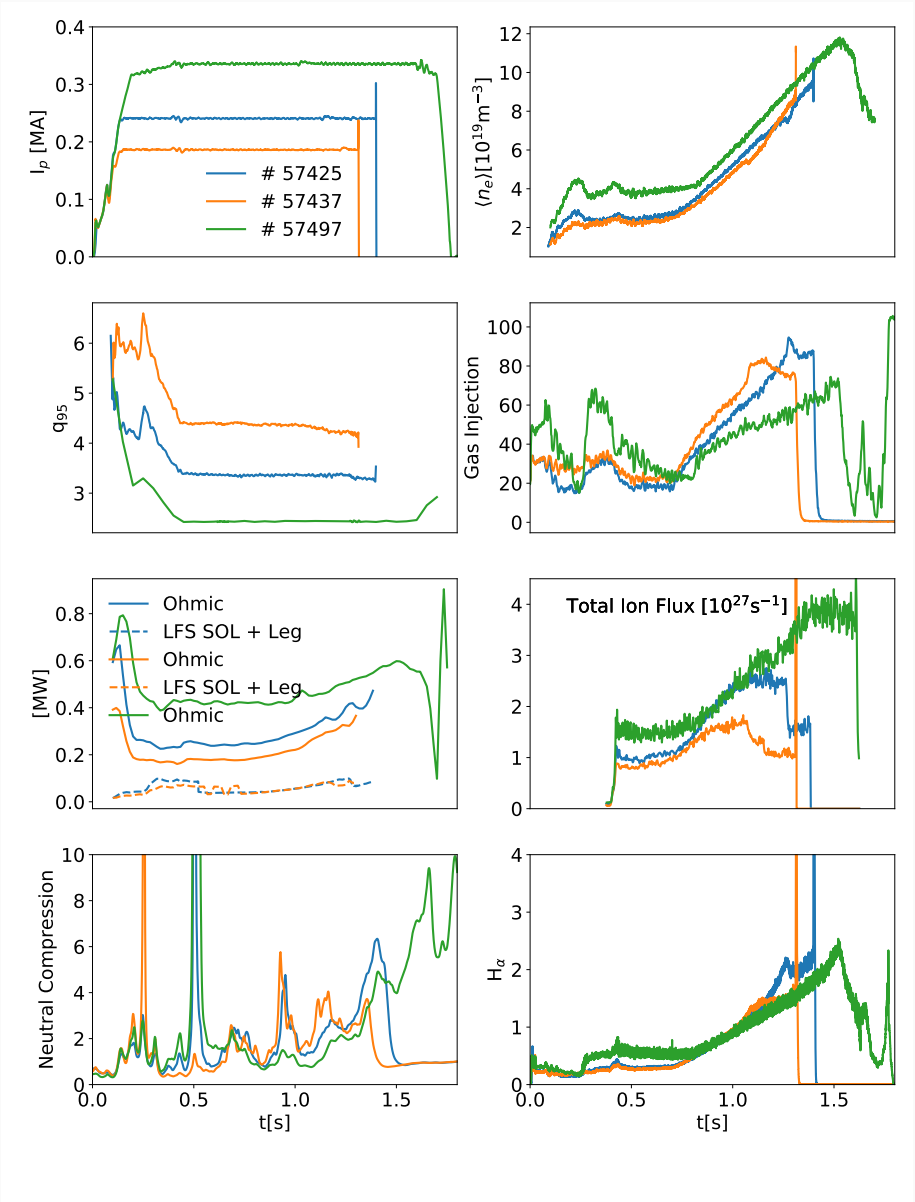
- ✓ Shape matched in within the single scan done for each of the machine
- ✓ The scan implies a modification of the $L_{||}$ (shown from the X-point height to the outer target). There is a factor of 5 difference between the two machines due to the very long outer divertor leg of TCV

Current scan at constant B_t in L-Mode plasma



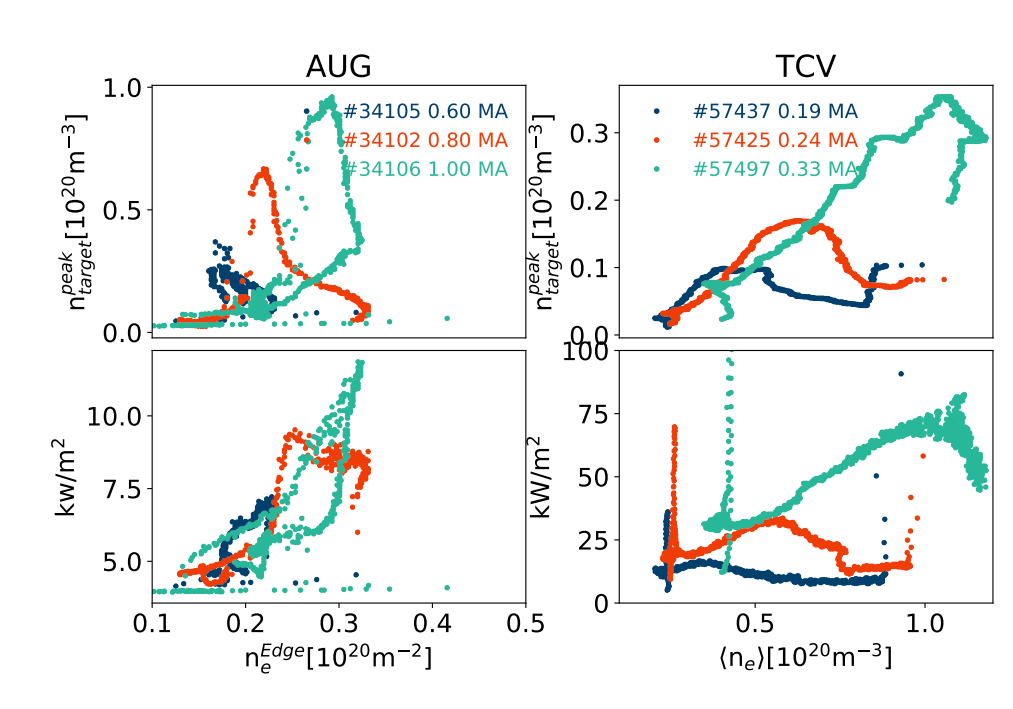
- ✓ AUG: Fueling reduced only at lower I_p to avoid earlier disruption. Similar neutral pressure in the subdivertor region reached. 0.5 MW NBI additional power added to keep power in the SOL approximately constant

Current scan at constant B_t in L-Mode plasma



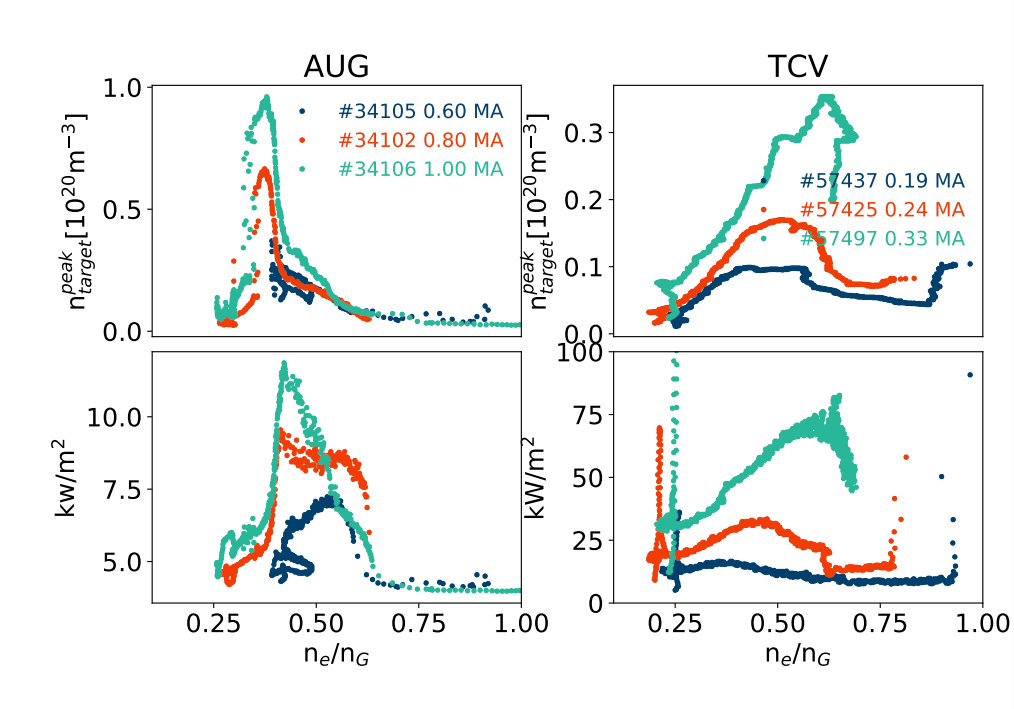
✓ TCV: Ohmic heating only. Similar neutral compression reached and D_α radiation from the floor. Ion flux rollover reached in all the three current, although marginally at 330 kA

Current scan at constant B_t in L-Mode plasma



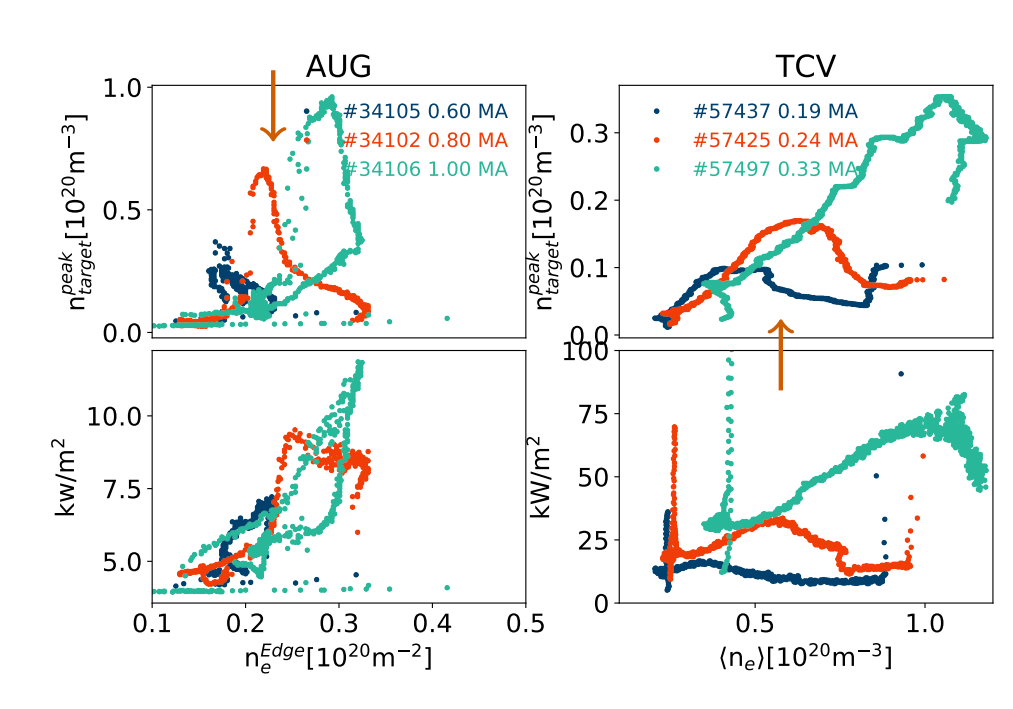
- ✓ In both the machines both the peak target density and the radiation close to divertor target exhibit rollover at increasing density with increasing current

Current scan at constant B_t in L-Mode plasma



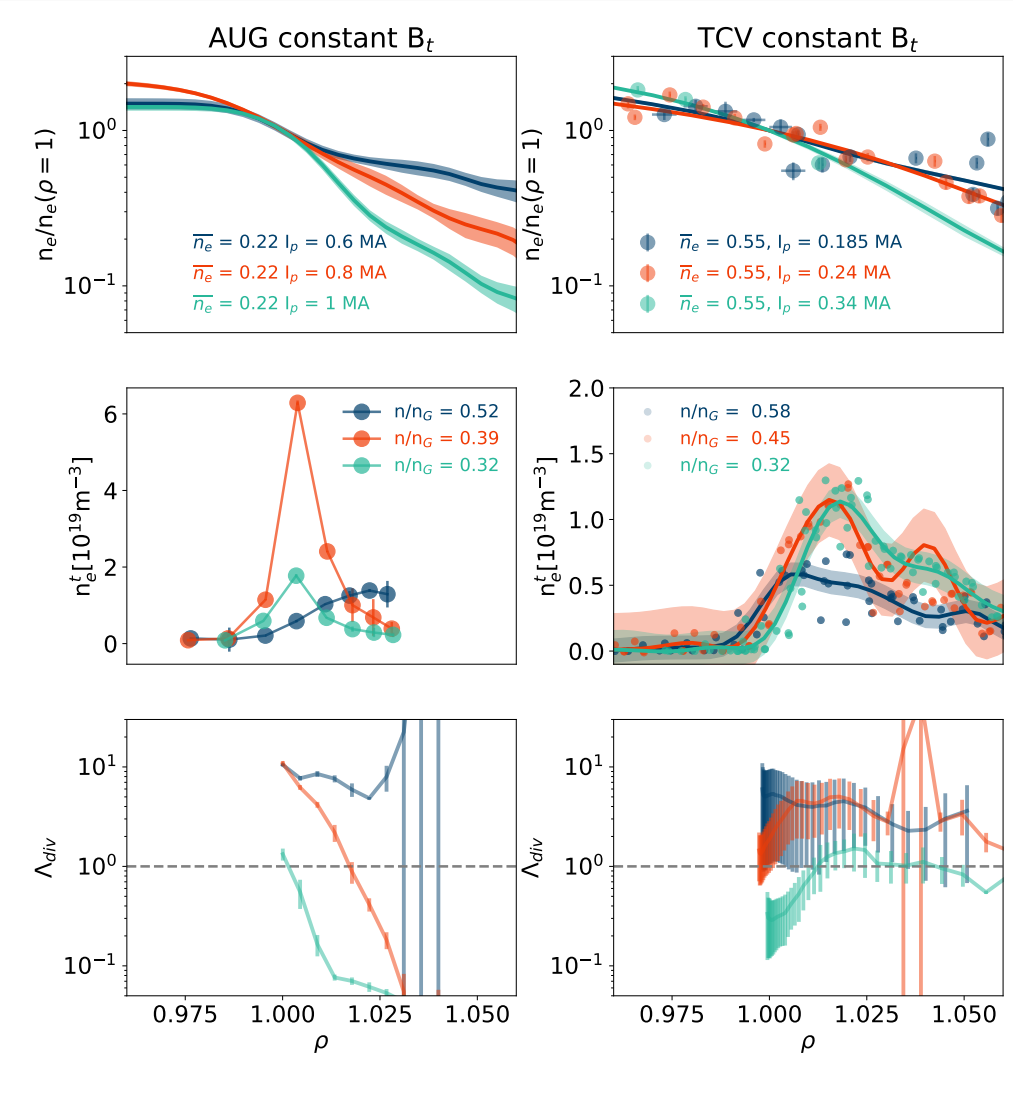
- ✓ Whenever considered as a function of Greenwald fraction the behaviors at different currents almost reconciled for AUG but not for TCV and at 0.6 MA for AUG

Current scan at constant B_t in L-Mode plasma



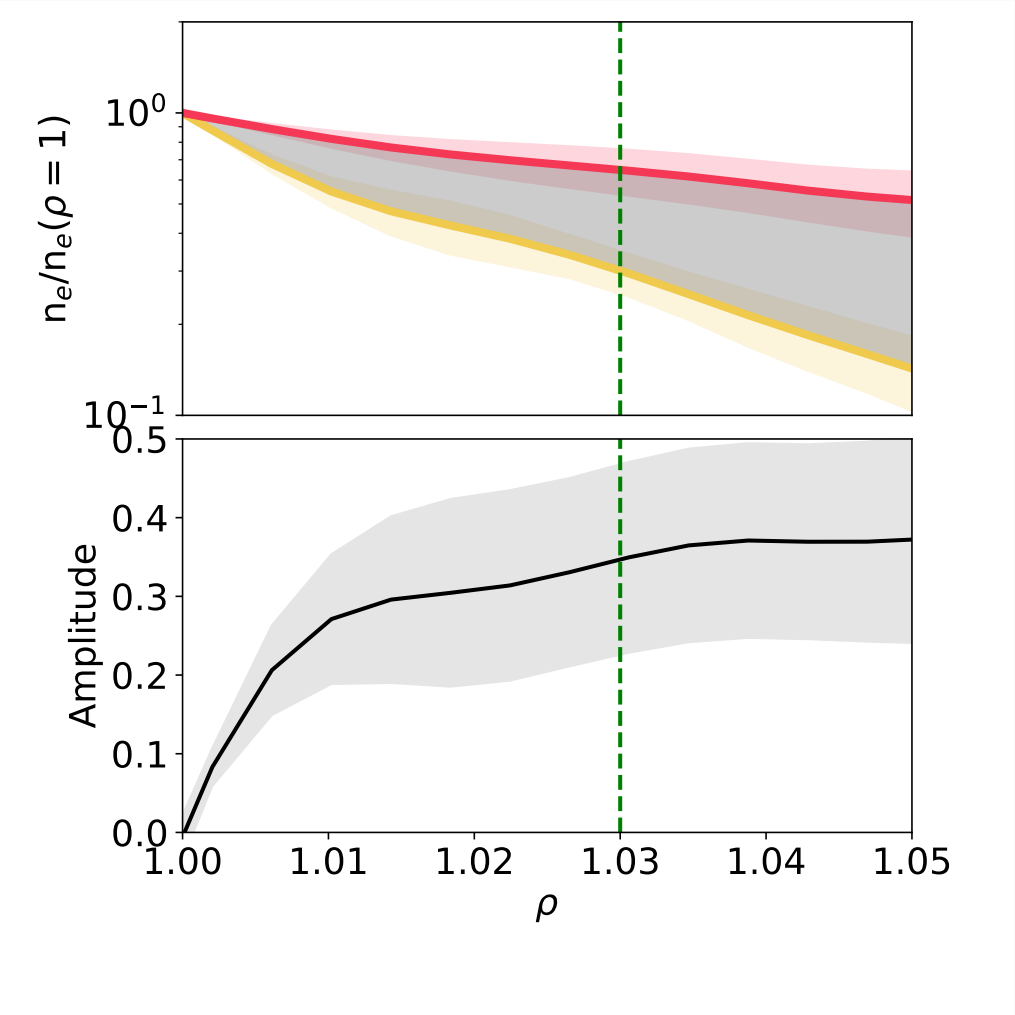
✓ We now consider the Target and upstream profiles at the same level of densities

Current scan at constant B_t in L-Mode plasma



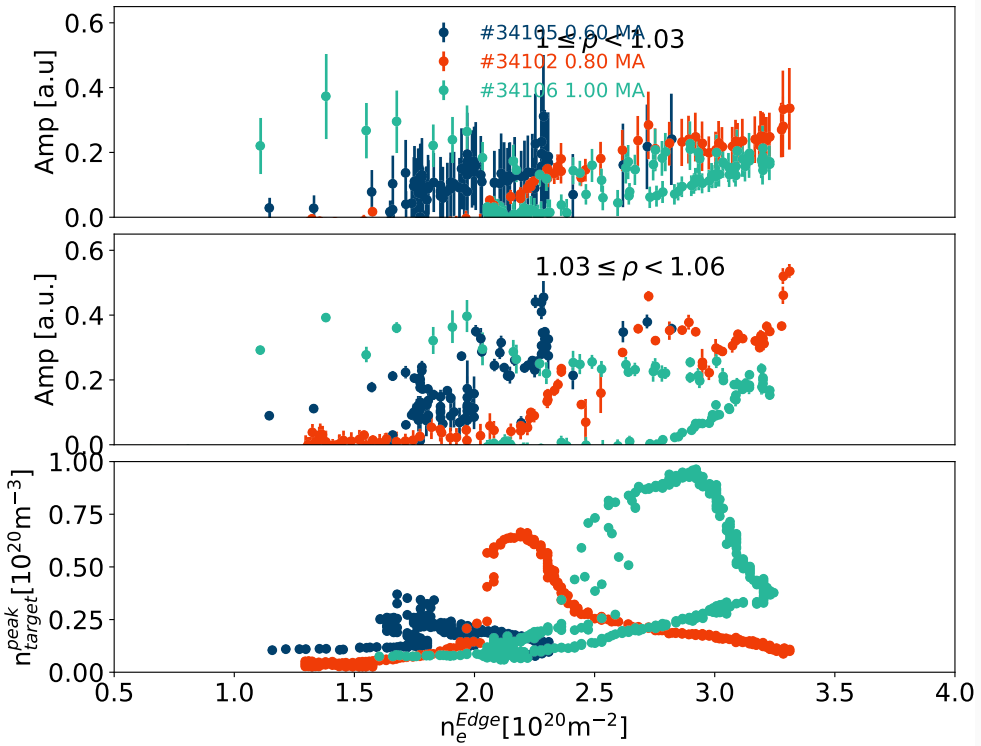
- ✓ We now consider the Target and upstream profiles at the same level of densities
- ✓ For both AUG and TCV flattening of normalized upstream profile reached earlier in density at lower current. For both the machine the increase of λ_n reached for larger values of Λ_{div}

Current scan at constant B_t in L-Mode plasma



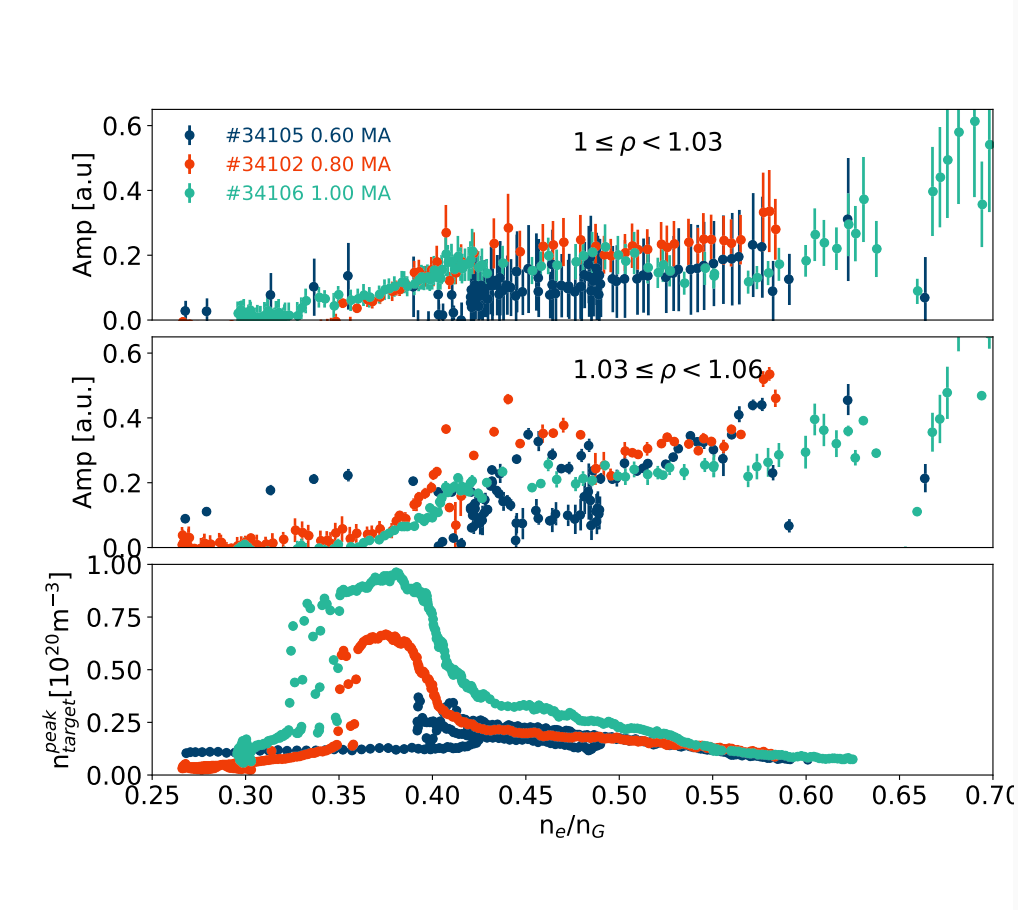
- ✓ Quantifying profile evolution using the shoulder amplitude metric introduce by Wynn and Lipschultz for JET (Wynn *et al.* 2018).
- ✓ Amplitude is the difference between normalized upstream density profiles
- ✓ Distinguishing behavior on the near and far SOL

Current scan at constant B_t in L-Mode plasma



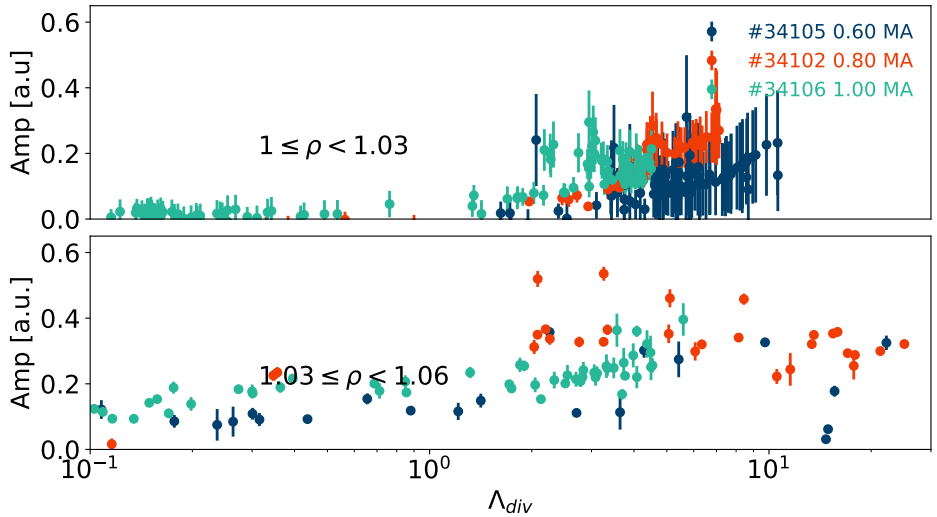
- ✓ Amplitude evolve faster in density at lower current in the far SOL. Amplitude starts increasing close to the transition to highly-recycling regime in analogy to JET HT (Wynn *et al.* 2018)

Current scan at constant B_t in L-Mode plasma



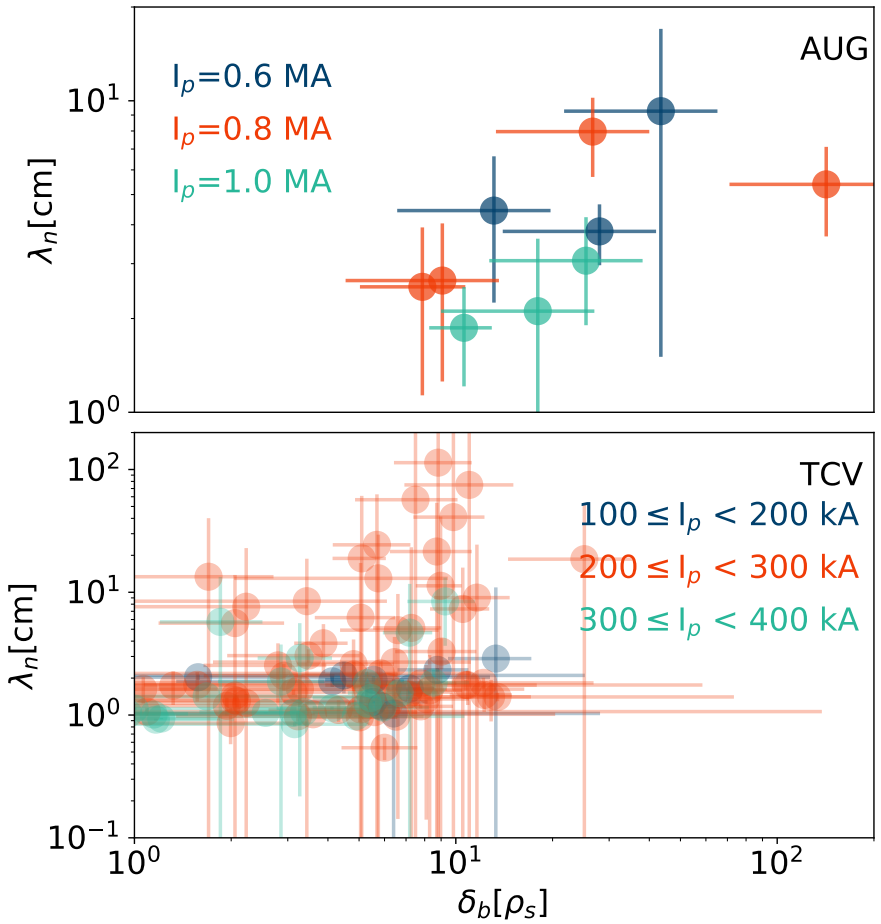
- ✓ Amplitude evolve faster in density at lower current in the far SOL. Amplitude starts increasing close to the transition to highly-recycling regime in analogy to JET HT (Wynn *et al.* 2018) but once evolution *vs* greenwald fraction is considered the evolution is equivalent between different current.
- ✓ Still some inconsistency at lower current in agreement with different detachment evolution

Current scan at constant B_t in L-Mode plasma



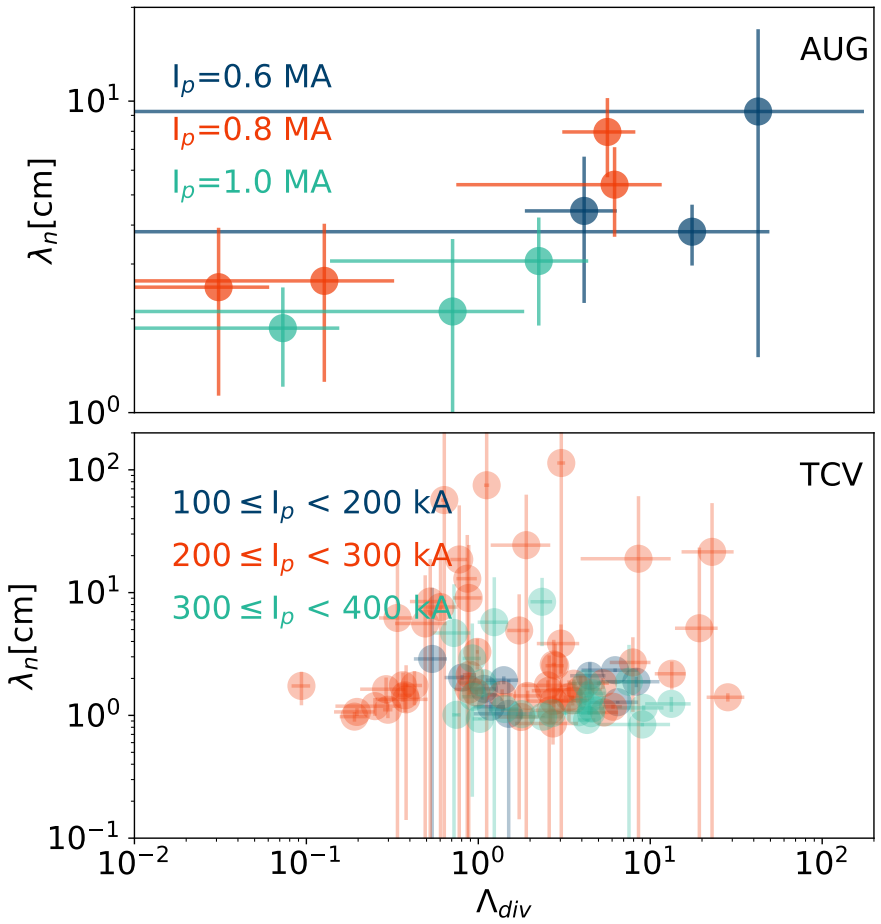
- ✓ Amplitude evolution reconciled in AUG if considered as a function of local evolution of Λ_{div}

Current scan at constant B_t in L-Mode plasma



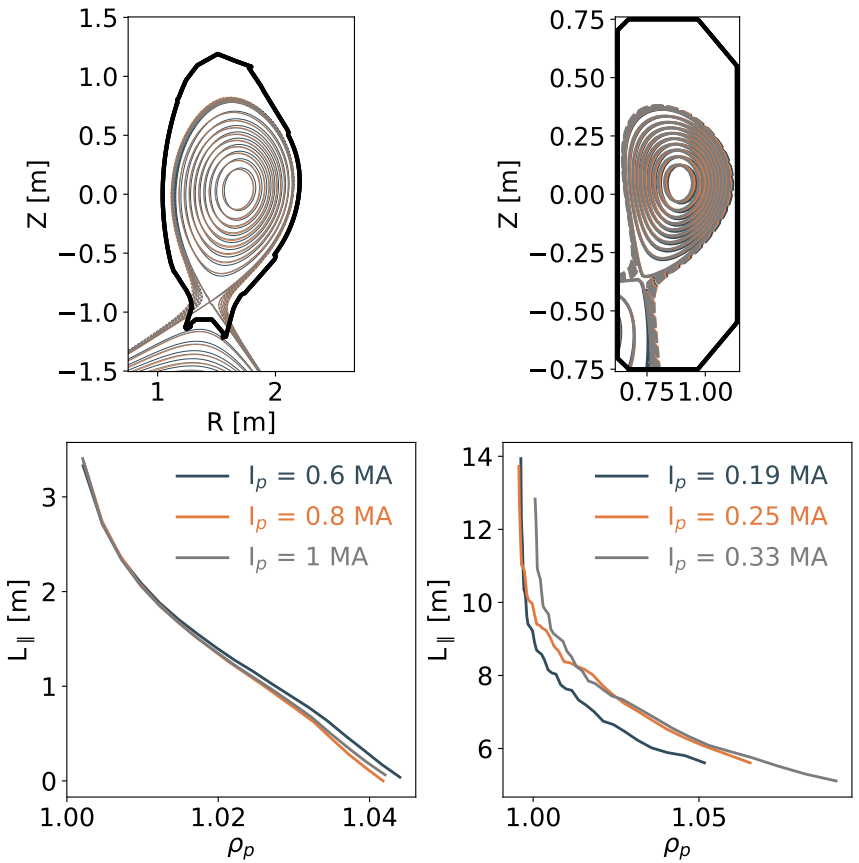
✓ For both AUG and TCV λ_n increases with blob size without significant difference within the current explored

Current scan at constant B_t in L-Mode plasma



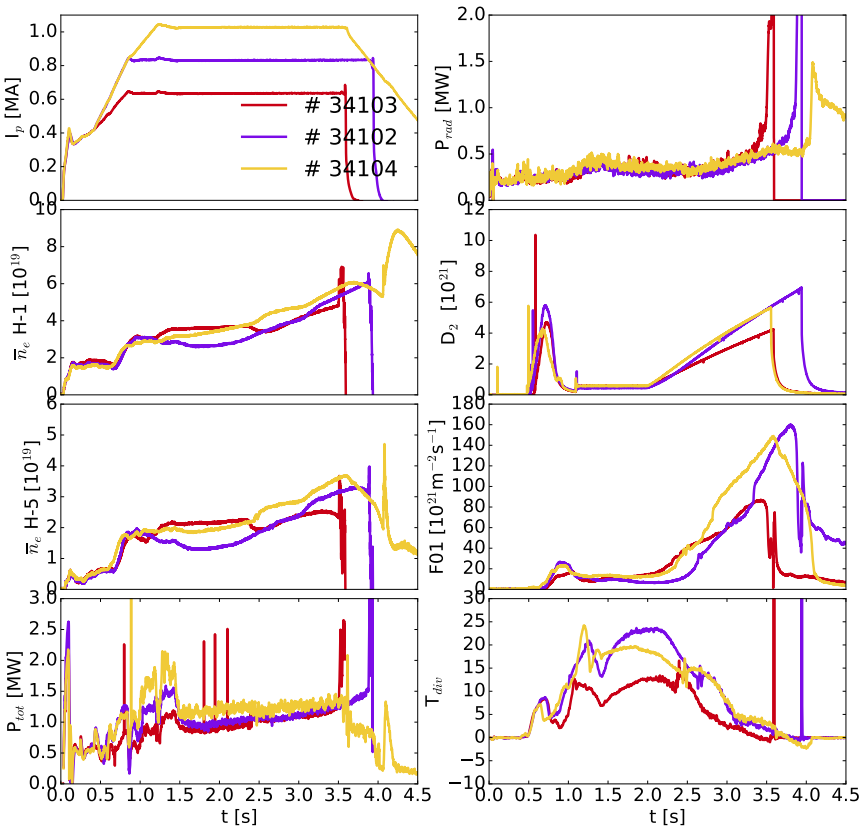
✓ The evaluation of λ_n as a function of Λ_{div} confirms that this variable is insufficient to completely reconcile AUG and TCV

Current scan at constant q_{95}



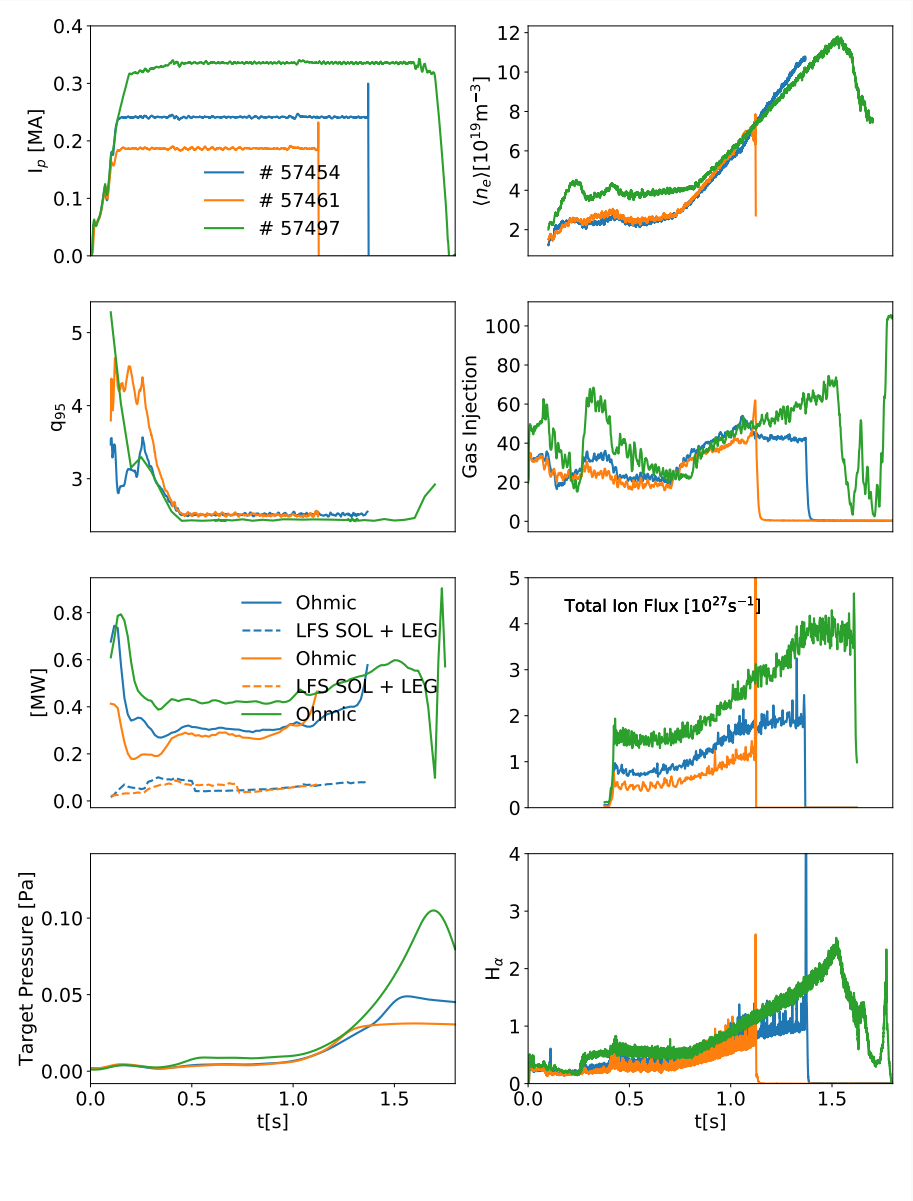
- ✓ Shape matched in within the single scan even though this required for TCV operation with very low toroidal field (0.8T)
- ✓ The parallel connection length remains almost unchanged

Current scan at constant q_{95}



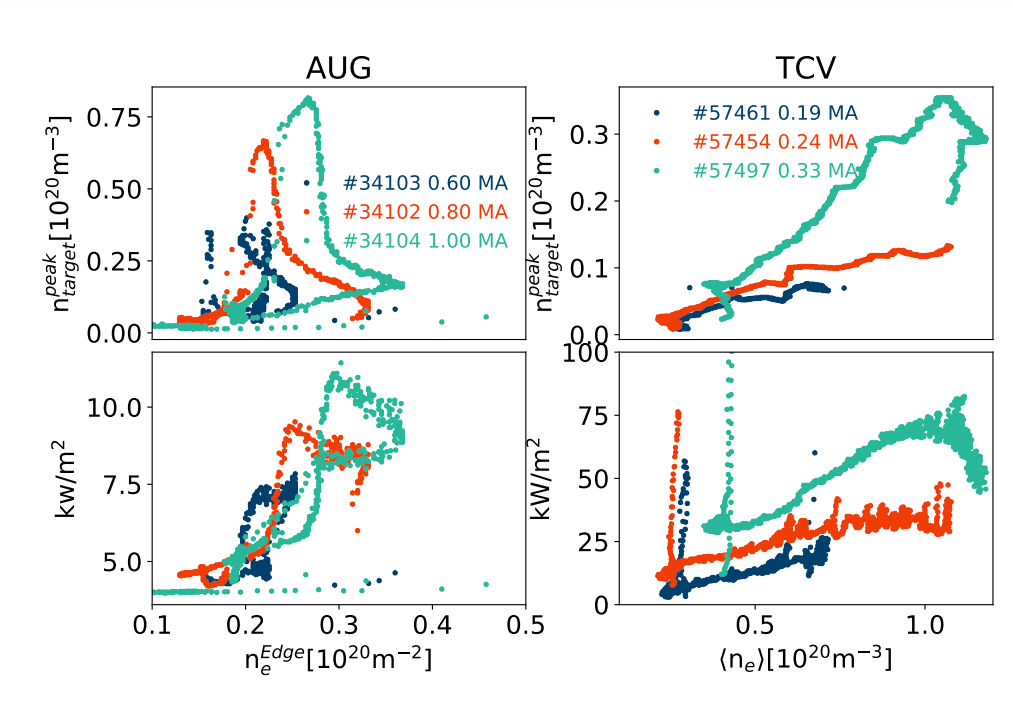
- ✓ AUG: As for the case of constant B_t we have pretty reproducible behavior matching basically the plasma condition in within the current scan

Current scan at constant q_{95}



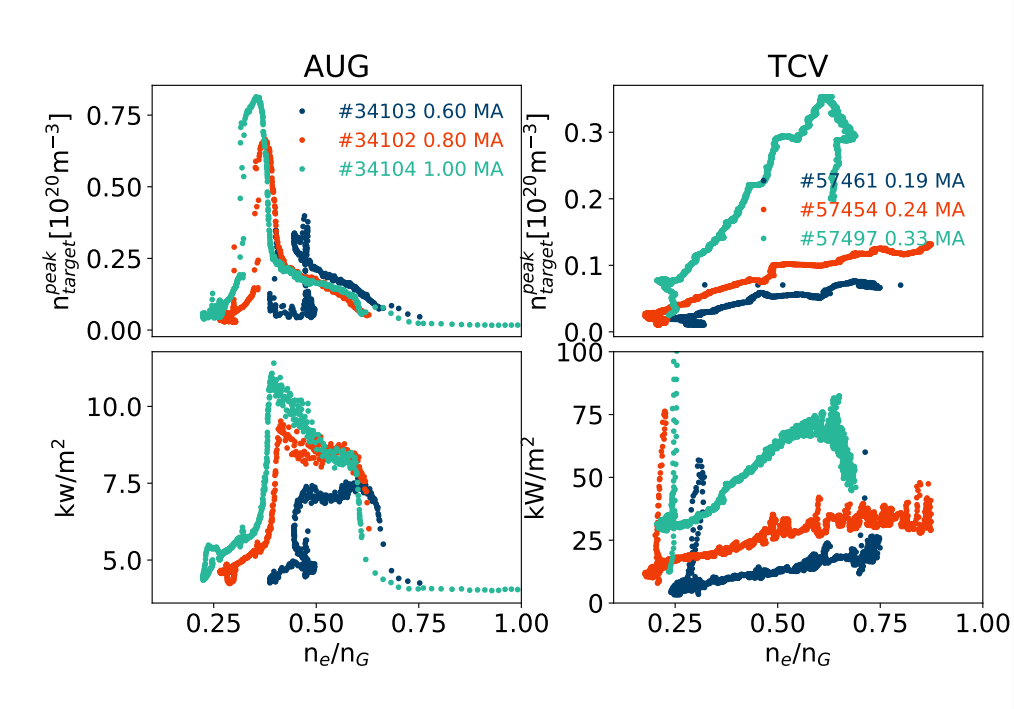
✓ TCV: Even at such an high density at lower current (and lower B_t) no sign of target ion flux rollover/detachment

Current scan at constant q_{95}



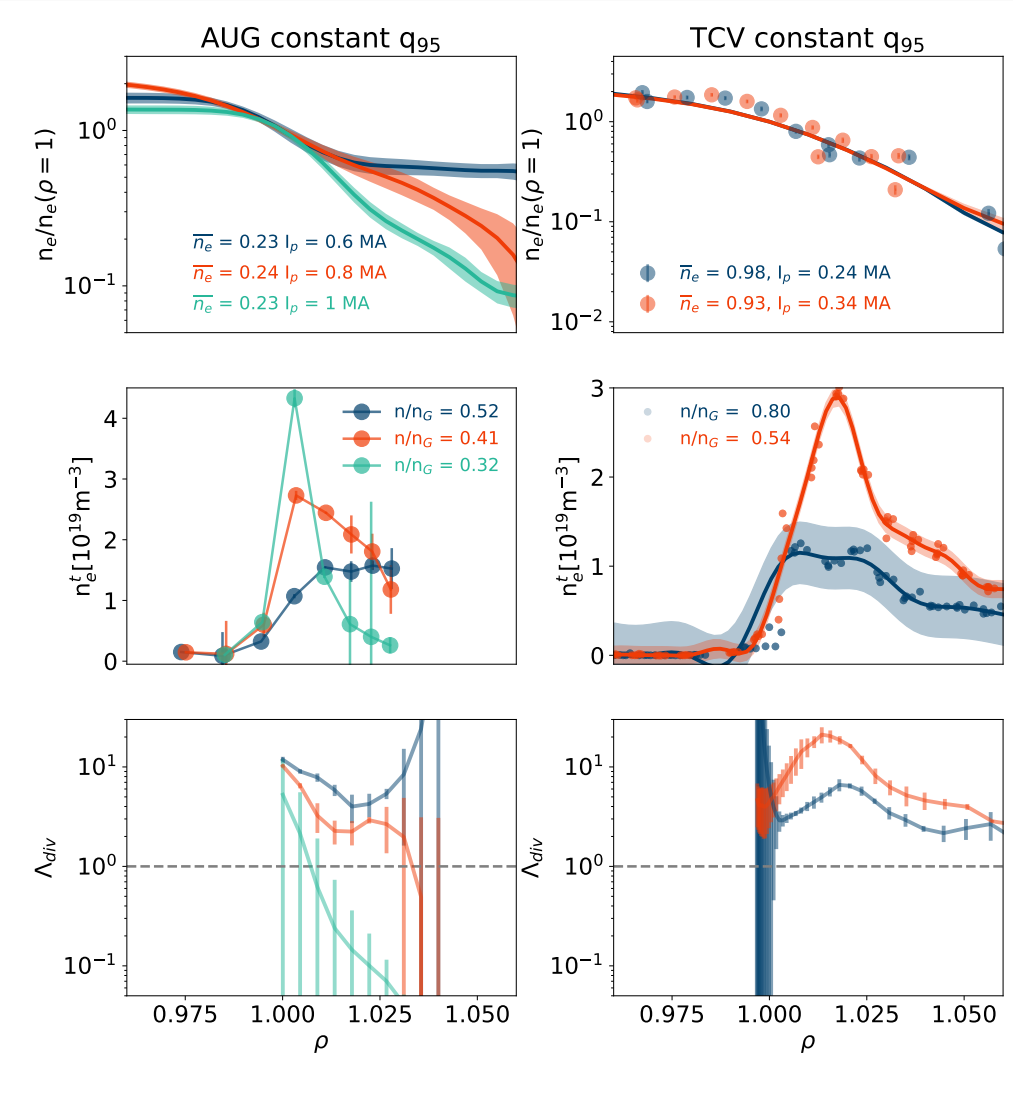
- ✓ AUG peak target density rollover occurs at lower density for lower current as well as radiation front movement. For TCV rollover achieved only at higher current: lower I_p does not exhibit sign of detachment even if high density is achieved. Consistent with lower volumetric recombination from DSS

Current scan at constant q_{95}



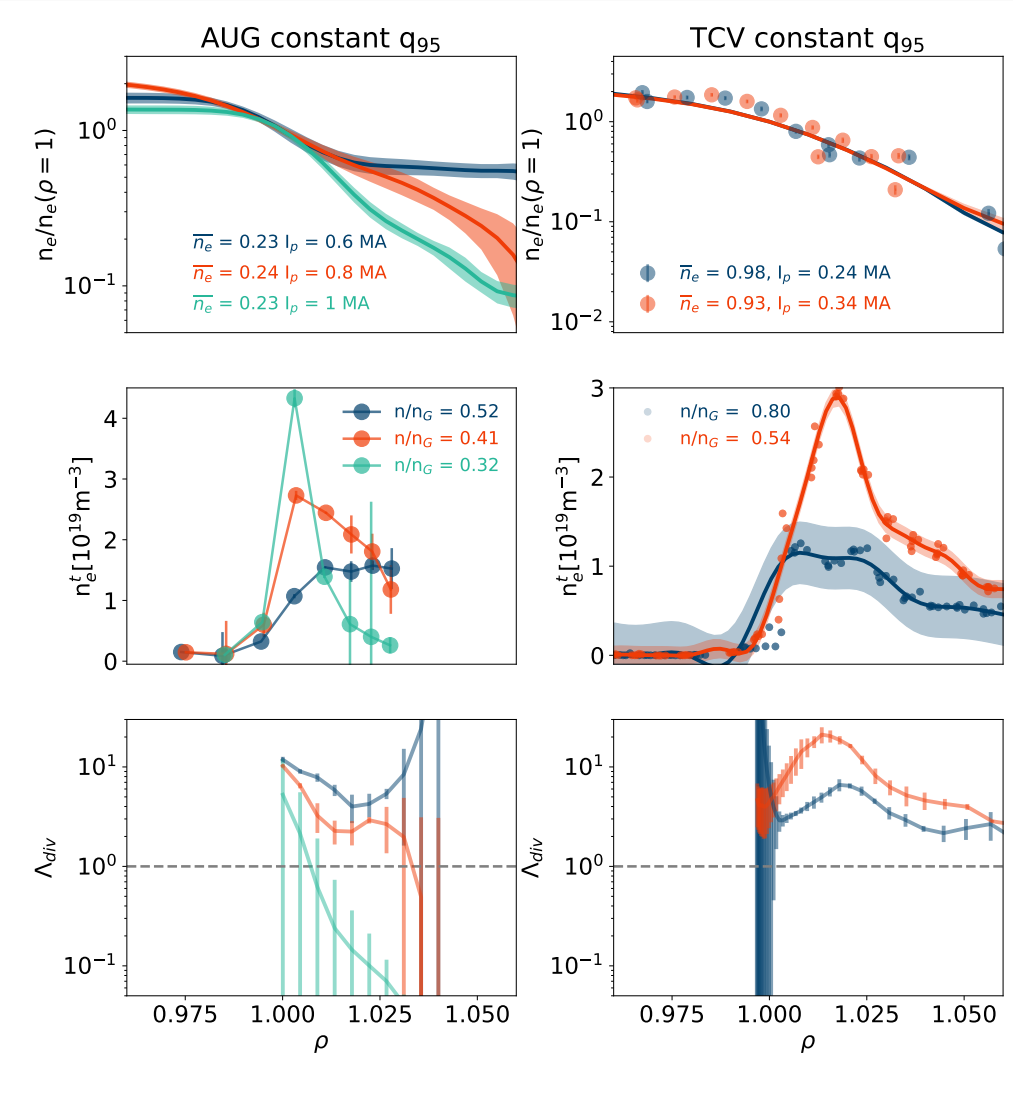
- ✓ Interestingly considering the behavior as a function of greenwald fraction does not reconcile the different current neither on AUG.

Current scan at constant q_{95}



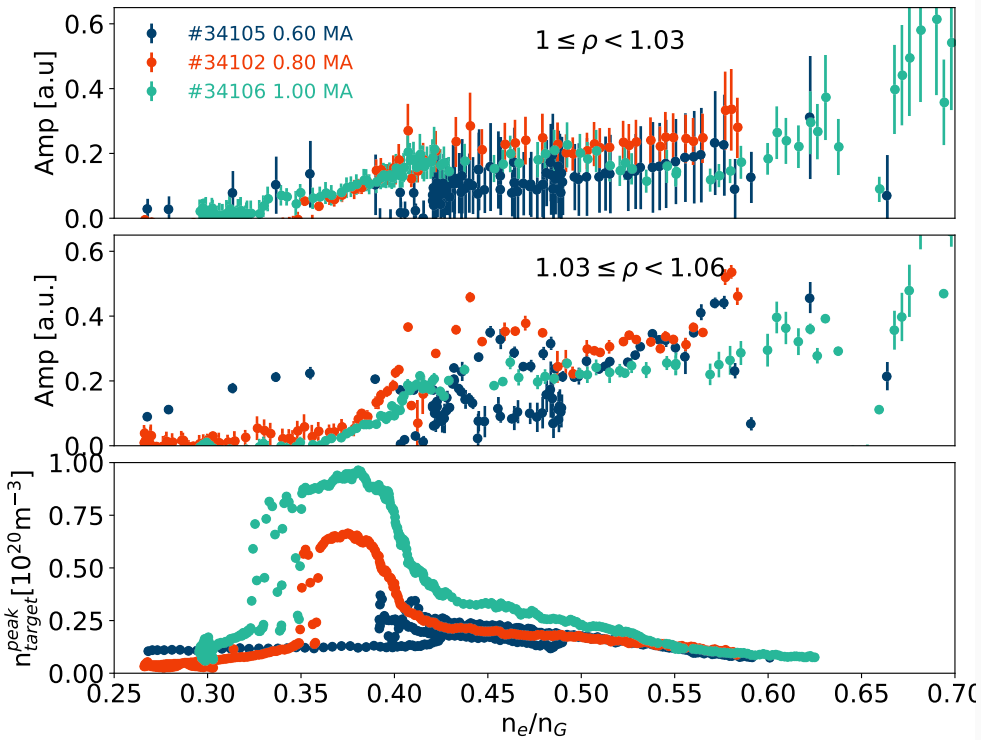
✓ For AUG upstream and target profiles still exhibit flattening earlier in density at lower current but always at large values of Λ_{div}. For TCV no sign of upstream profile flattening even at very large values of Λ_{div}

Current scan at constant q_{95}



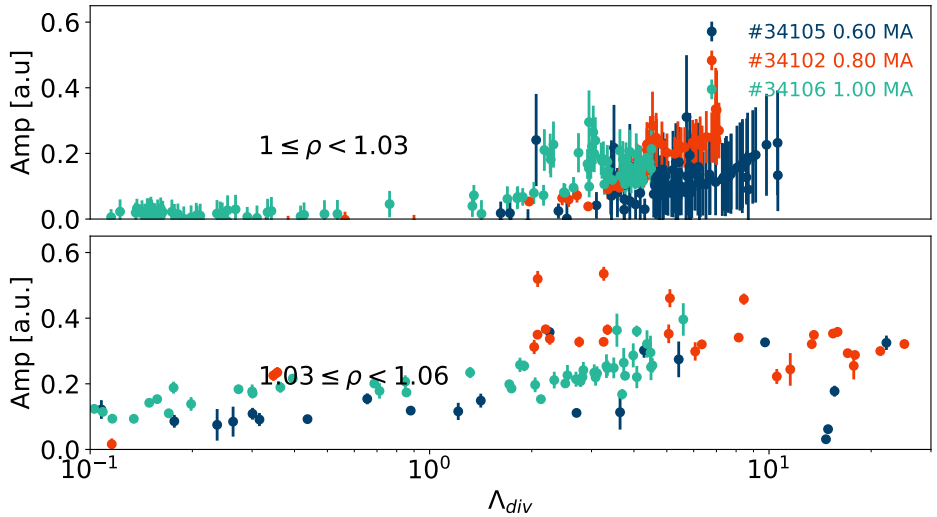
- ✓ For AUG upstream and target profiles still exhibit flattening earlier in density at lower current but always at large values of Λ_{div}. For TCV no sign of upstream profile flattening even at very large values of Λ_{div}
- ✓ This is due to the fact we did not reach divertor detachment which seems mandatory for upstream profile modification

Current scan at constant q_{95}



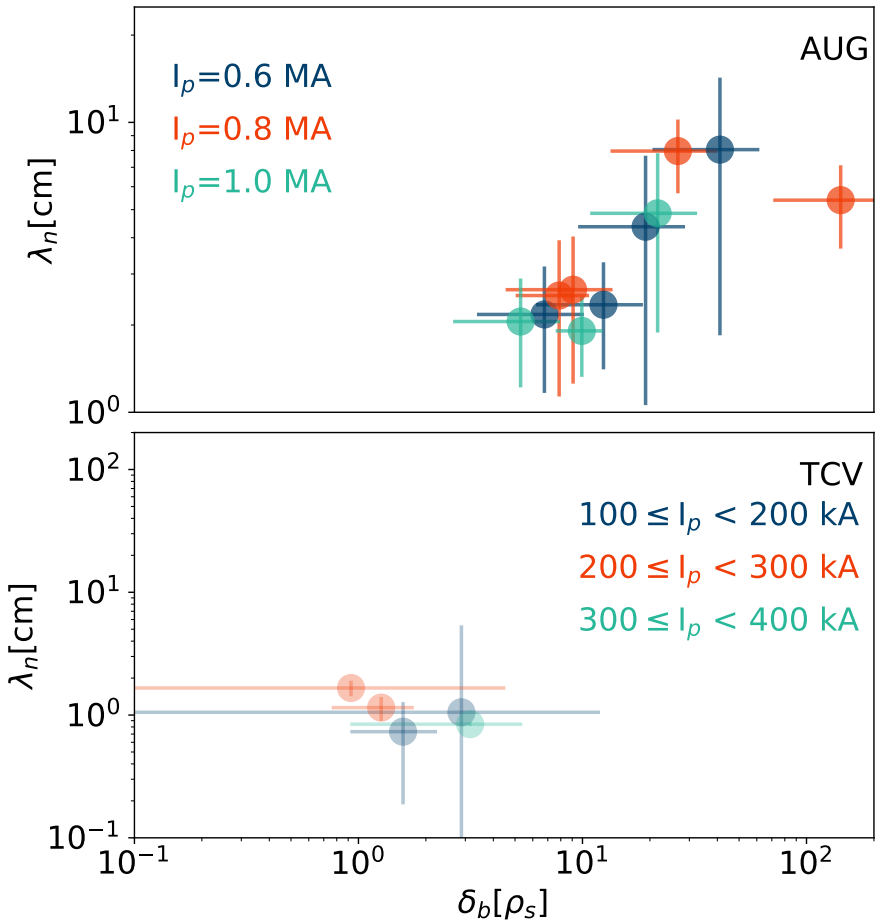
- ✓ AUG: Amplitude evolution as a function of greenwald fraction confirms that shoulder starts appearing at the onset of highly recycling regime

Current scan at constant q_{95}



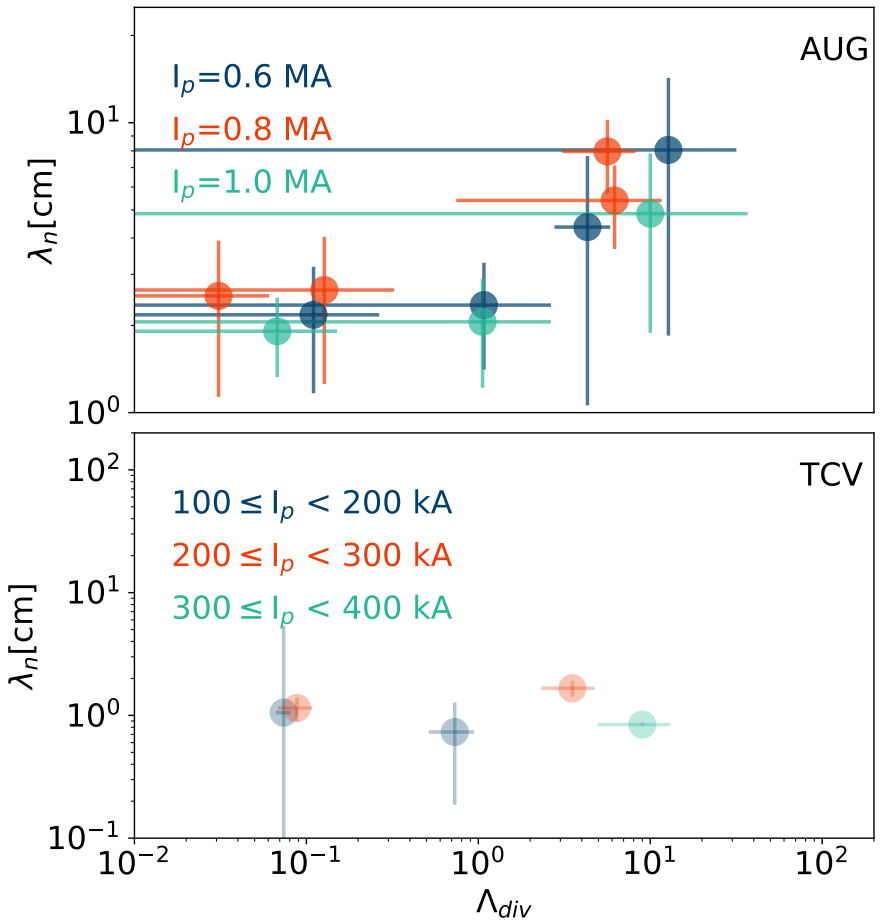
✓ AUG: Amplitude evolution as a function of Λ_{div} still reconcile the explored current scan

Current scan at constant q_{95}



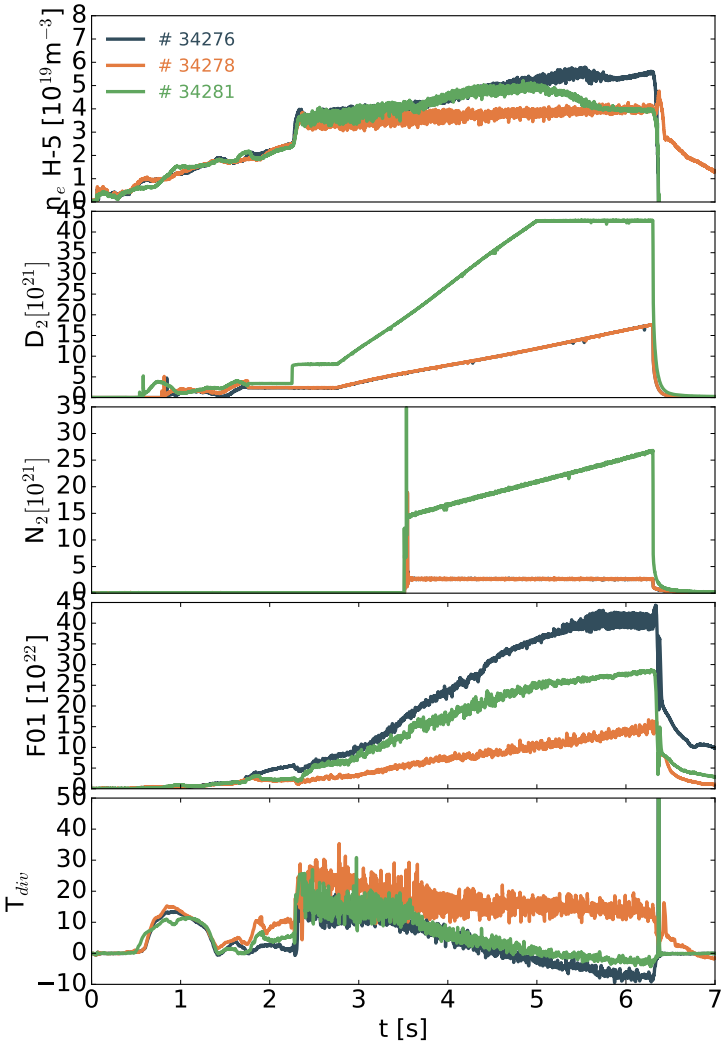
✓ AUG exhibit consistently an increase of λ_n with blob-size whereas for TCV the profile remains flat consistently with a small variation of δ_b

Current scan at constant q_{95}



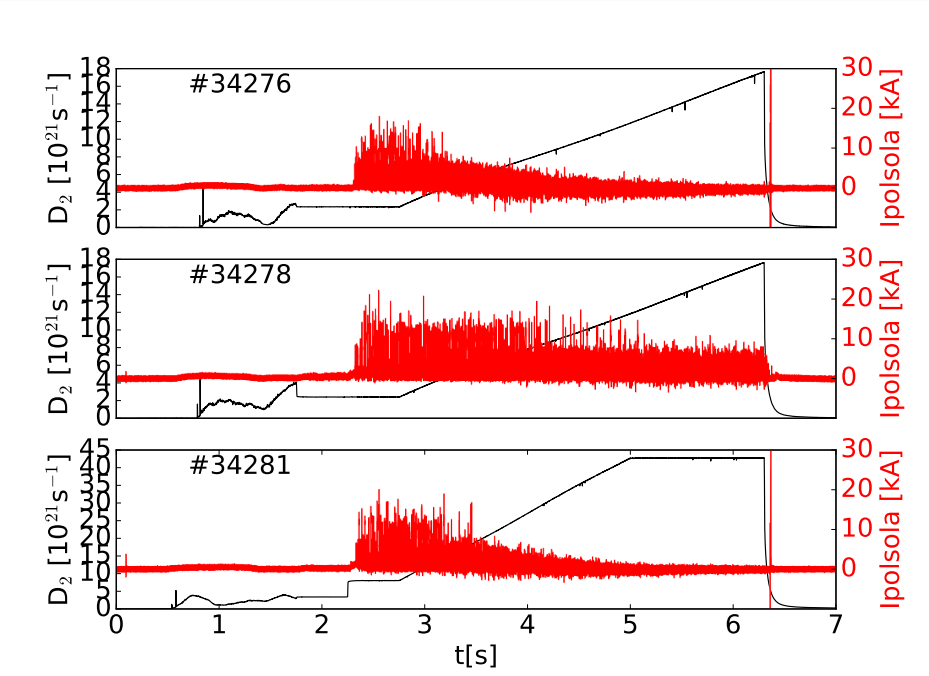
✓ And for TCV this is true even at high value of Λ_{div}. Λ_{div} is not sufficient to guarantee flat profiles on TCV.

H-Mode analysis on AUG



- ✓ We perform a series of shots in H-Mode with 6.5 total heating power where we changed the fueling and the efficiency of cryopumps. Specifically we have
  - ✓ # 34276 without the cryompumps
  - ✓ # 34278 with the same fueling as # 34276 but with the cryompump
  - ✓ #34281 where we increase fueling and seeding trying to mimic the same subdivertor pressure as # 34276
- ✓ Keeping the same fueling with the cryopump clearly reduce the pressure in the the sub-divertor area, we don't reach clear detachment and the edge density is constant even during the fueling ramp. Degraded H-mode reached later without the cryopump

H-Mode analysis on AUG



✓ Different behavior of ELM during the fueling ramp. ELM size and frequency changes strongly without the cryopump or during extreme fueling case

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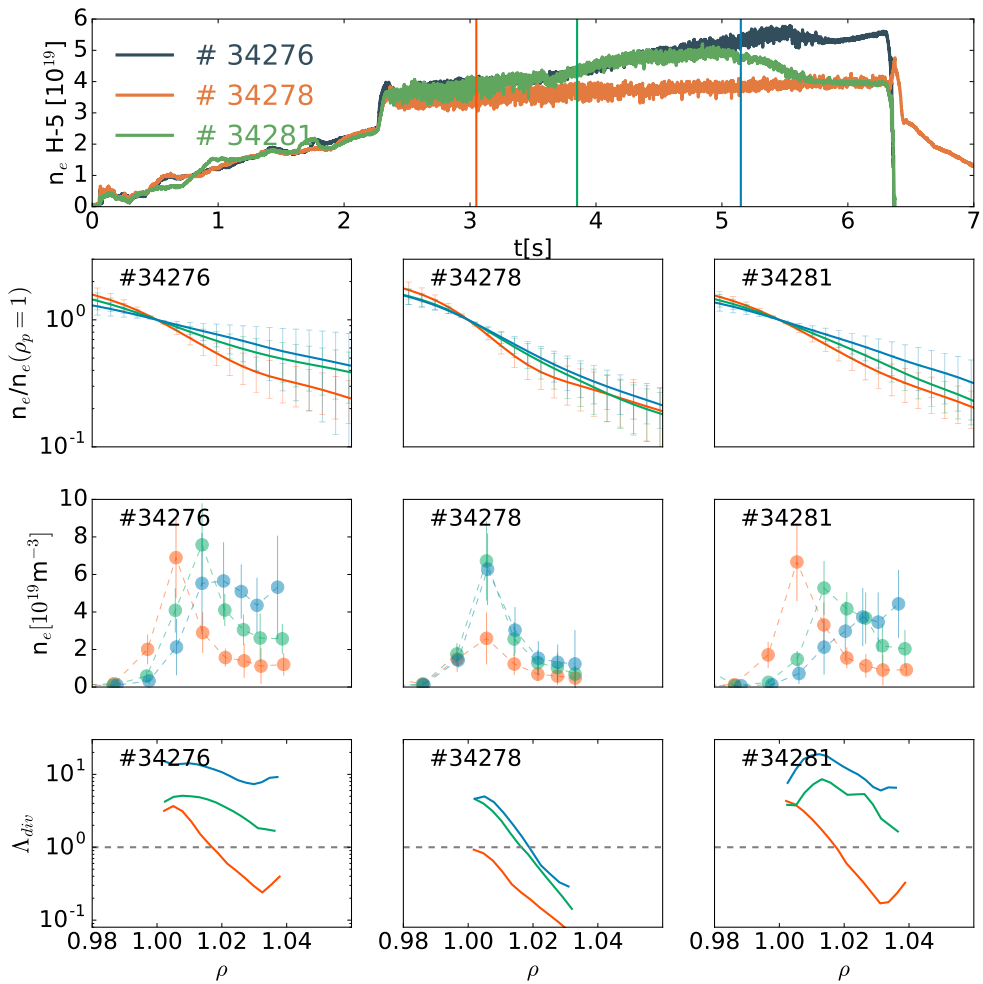

✓ The profiles for shot # 34278 with the cryopum and lower fueling remains more steep in all the three timing wind and the plasma is still attached. Interestingly for shot # 34281 with the cryopumps and higher fueling the detachment is more pronounced

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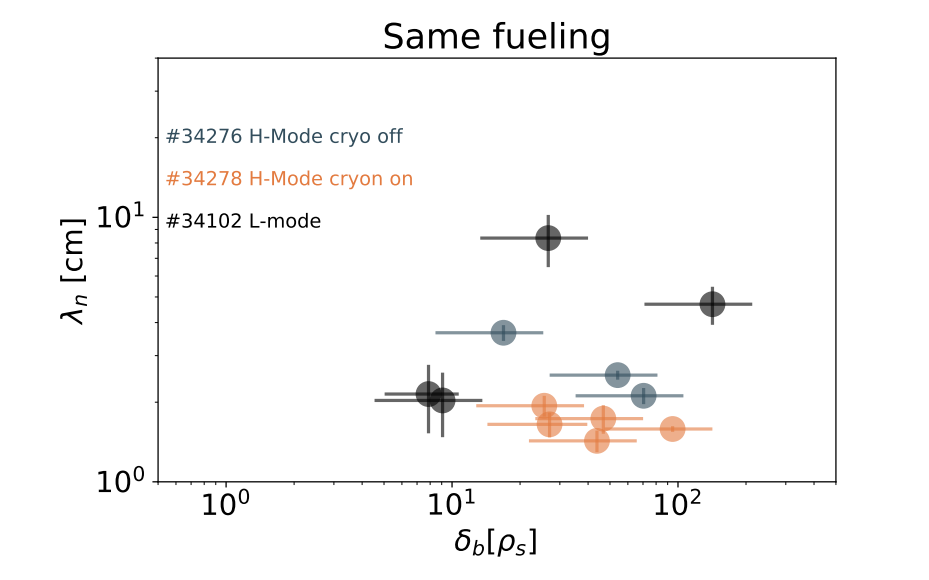
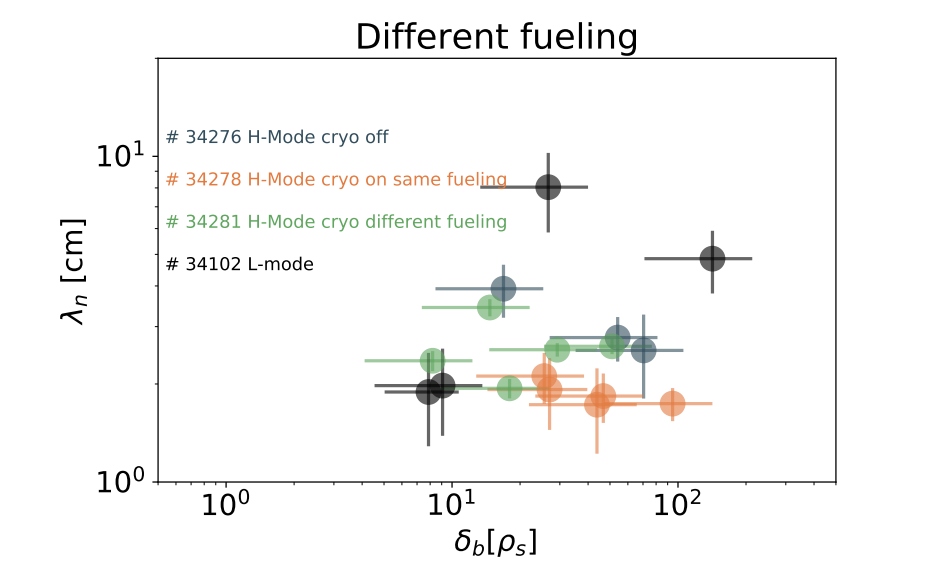


✓ Without the cryopumps, we reached flatter profiles with comparable inter-ELM resolved blob-size. This indicates strong neutral pressure effects in determining upstream profiles

H-Mode analysis on AUG



✓ Increasing the fueling and correspondingly the divertor neutral pressure move towards a situation similar to # 34276 without the cryopump

Conclusion

- ✓ Current scan at constant B_t and at constant q_{95} performed during density ramps L-Mode experiments both at AUG and TCV
- ✓ In both the case shoulder appear earlier in density at lower current but AUG shows reconciliation of behavior if considered as a function of greenwald fraction and Λ_{div} for constant B_t but not for constant q_{95}. AUG still well represented by Λ_{div}. Shoulder starts developing at the onset of highly recycling regime
- ✓ Both the experiments exhibit at constant B_t flattening of the profile as blob size is increasing, independently from the current. The same behavior is observed during current scan at constant q_{95} only on AUG
- ✓ On TCV during the current scan at constant q_{95} detachment not reached and this prevents upstream profile flattening
- ✓ H-Mode experiments performed on AUG where fueling and pumping have been varied. Proved inter-ELM profile flattening also in H-Mode but high neutral pressure (not only edge density) is needed

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- ✓ **Can we find a different parameter to reconcile the experimental observation?**

On going work

A series of works are still on-going or yet to be started

✓ Neutral density estimate from light emission **M. Agostini**

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