

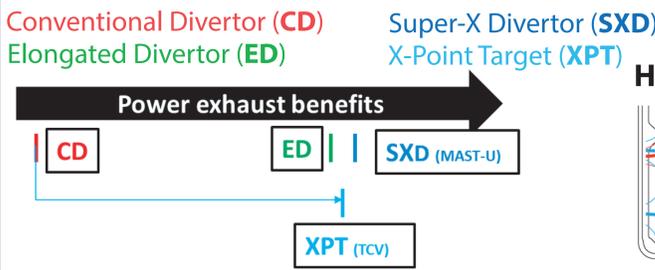
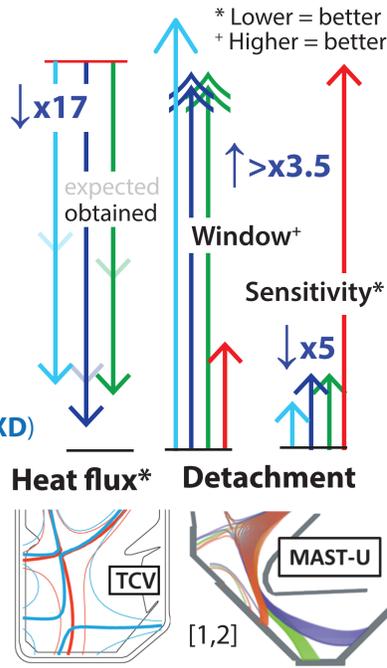
The physics basis for implementing alternative divertor configurations on reactors

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Takeaway message: ADCs can tackle power exhaust

- 1) Tangible power exhaust benefits**
 - Not only limited to lower heat loads
 - > More flexibility for reactor ops. & control
- 2) We understand their physics**
 - Continuum of ADCs provides benefits
 - Balance engineering & exhaust performance
- 3) Improve physics basis for ITER & beyond and optimise next-gen reactors**



Tangible power exhaust benefits for reactors



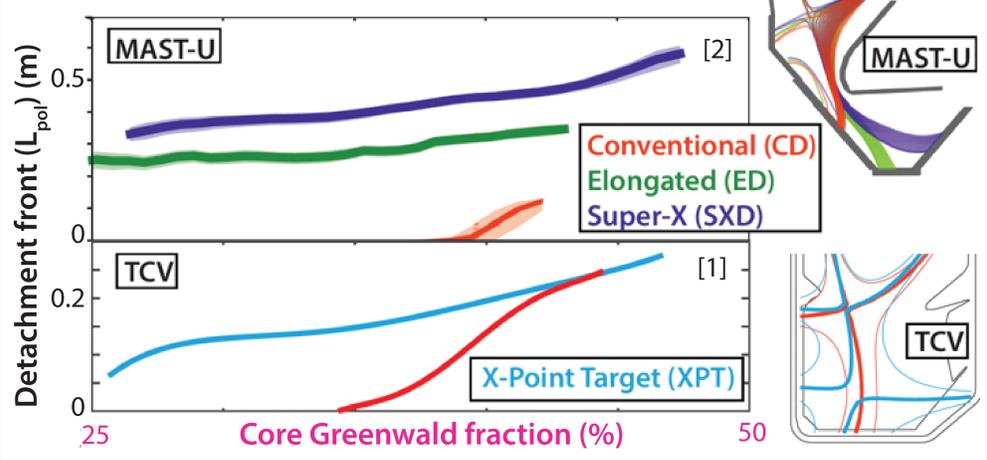
- ### Quasi-steady-state benefits [1,2]
1. Detachment onset reduction
 2. Detachment window increase (> x3.5)
 3. Reduced heat loads
 4. Reduced detachment sensitivity (x5)
 5. Benefits without core degradation

Extends to imp. seeding!

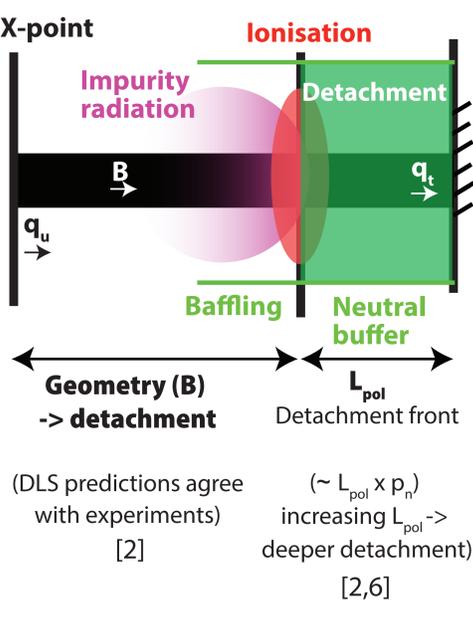
$$\text{Detachment} \propto \frac{n_{\text{neu}} \sqrt{f_z}}{q_u^{5/7}}$$

High power XPT detached where CD attached at:

- x 2.2 ↓ seeding
- x 3.0 ↑ heating



Why do the XPT and MAST-U SXD & ED work so well?



Validated tools for ADC!

-> Agrees with sims.

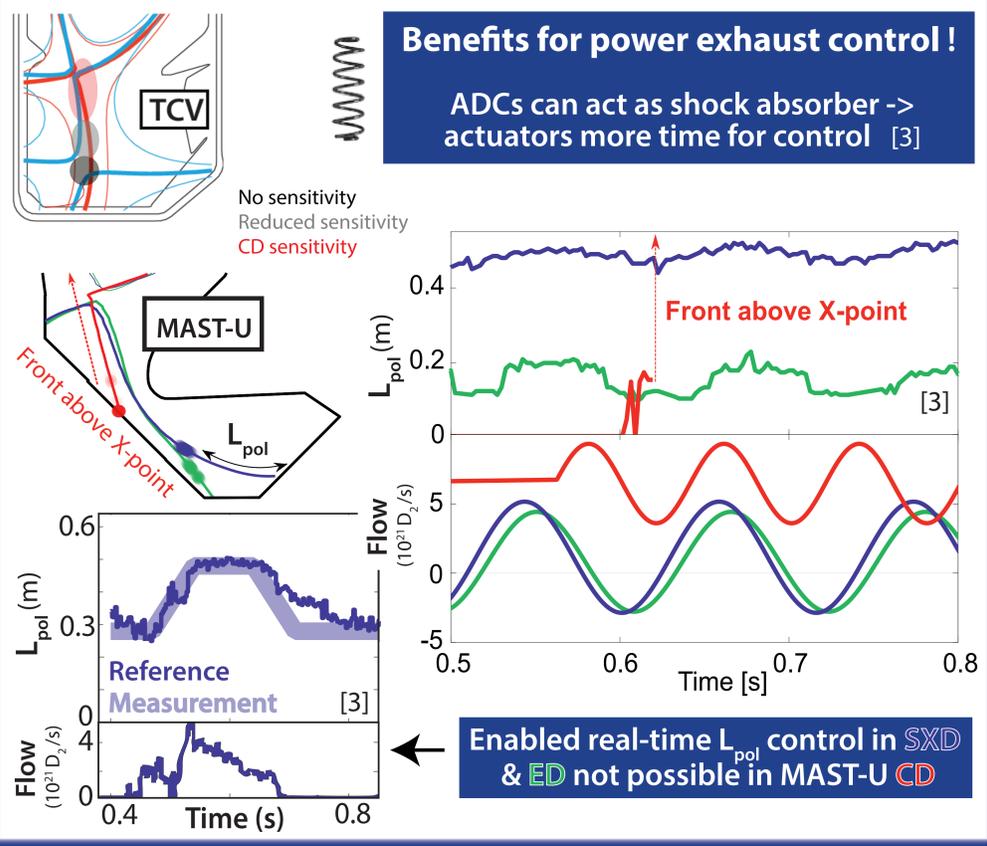
We understand why

- The most successful cases work [1,2]
- Other configs. less benefits [7-9]

What works? Synergy of optimisation routes!

- 1) Magnetic topology (B)** [2]
 - > Detachment access & redu. sensitivity
- 2) Divertor leg length (L_{pol})** [2,6]
 - > Detached power/particle losses
- 3) Neutral baffling** [9]
 - > Decouples divertors from core
 - > Enables shaping benefits

Modest shaping (can [2]) -> big benefits: MAST-U ED & SXD similar

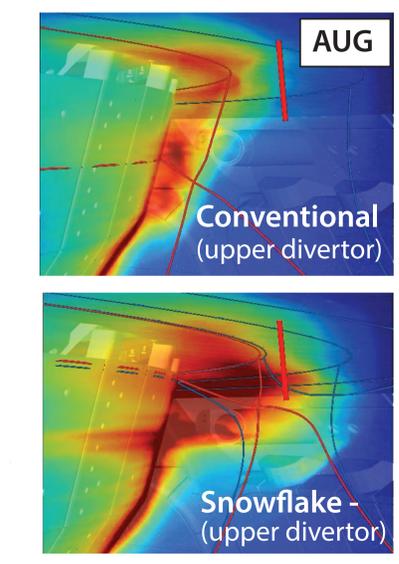
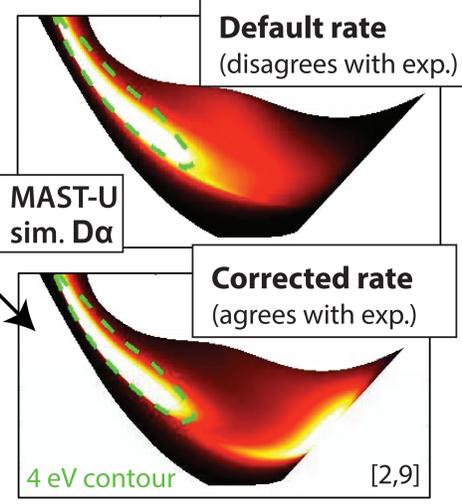


Next steps: ADC research for ITER and beyond

ADC research -> general detachment & exhaust physics

Examples:

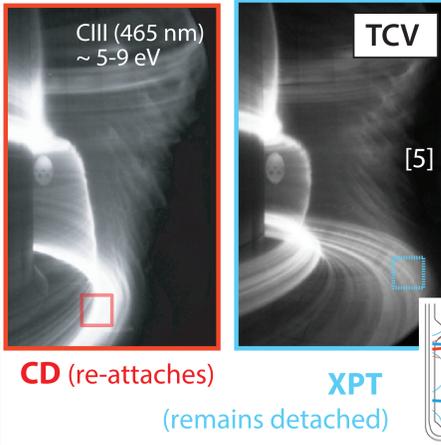
- 1) Validation of drift simulations [7-8]
- 2) Plasma-neutral interactions [2,10]



Towards reactor-relevant P_{sol}

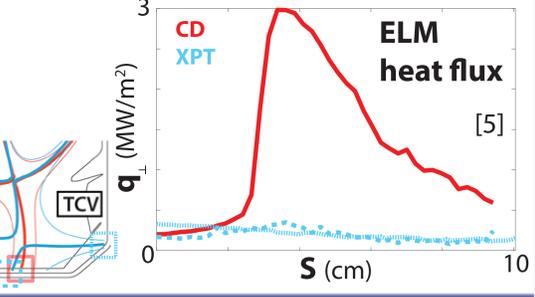
First AUG ADC experiments -> 20+ MW in SF-configuration!

Magnetics & cameras shows SF-configuration established! [11-12]



Improved handling of transients

Detached ADCs can mitigate transients where CD is attached [4,5]



[1] K. Lee, et al. Phys. Rev. Lett., 2025
 [2] K. Verhaegh, et al. Commun. Phys. 2025
 [3] B. Kool, et al. Nat. Energy, 2025
 [4] J. Flanagan, et al. NF, 2025
 [5] M. Zurita, et al. APS-DPP, 2025
 [6] N. Osborne, et al. NF, 2025
 [7] E. Tonello, et al. This conference
 [8] M. Carpita, et al. AAPS-DPP, 2025
 [9] M. Carpita, et al. NF, 2025
 [10] K. Verhaegh, et al. NF, 2024
 [11] B. Sieglin, et al. EPS-DPP, 2025
 [12] D. Brida, et al. APS-DPP, 2025