Edge plasma/neutral modeling results for ACT-1divertor*

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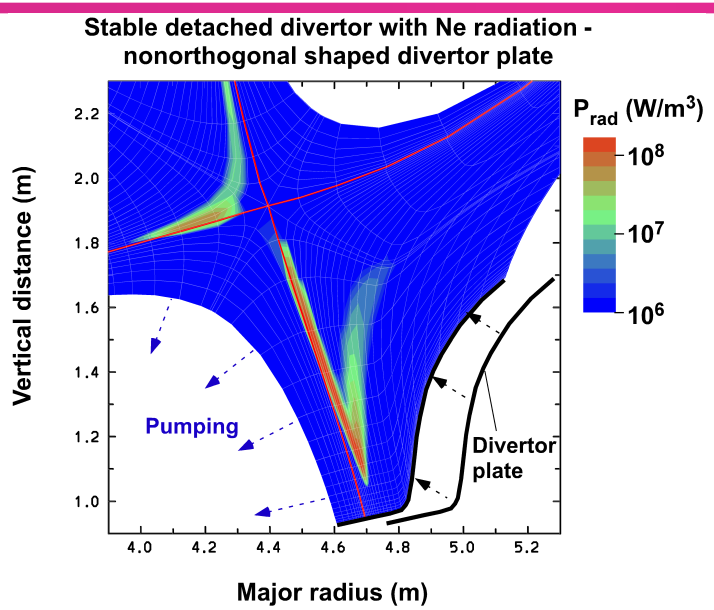
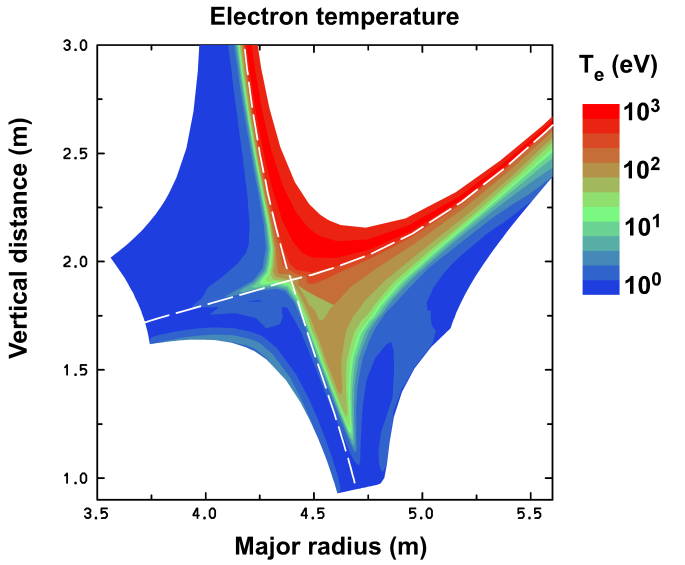
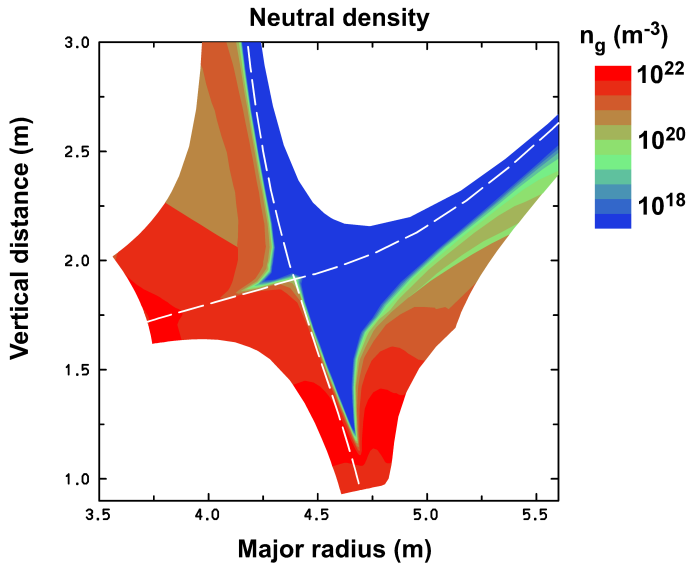
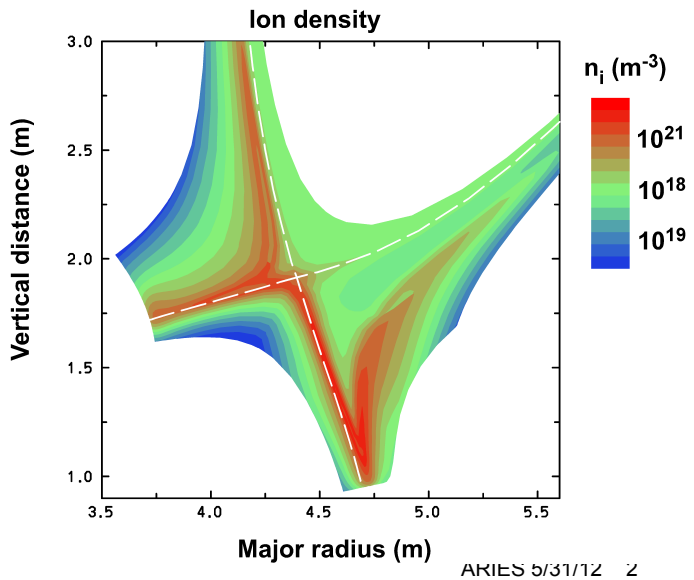
Shaped divertor-plate with detached plasma is taken as the base-case design









We provide some answers to recent important questions concerning the divertor

1. How sensitive is the detached plasma to geometry?

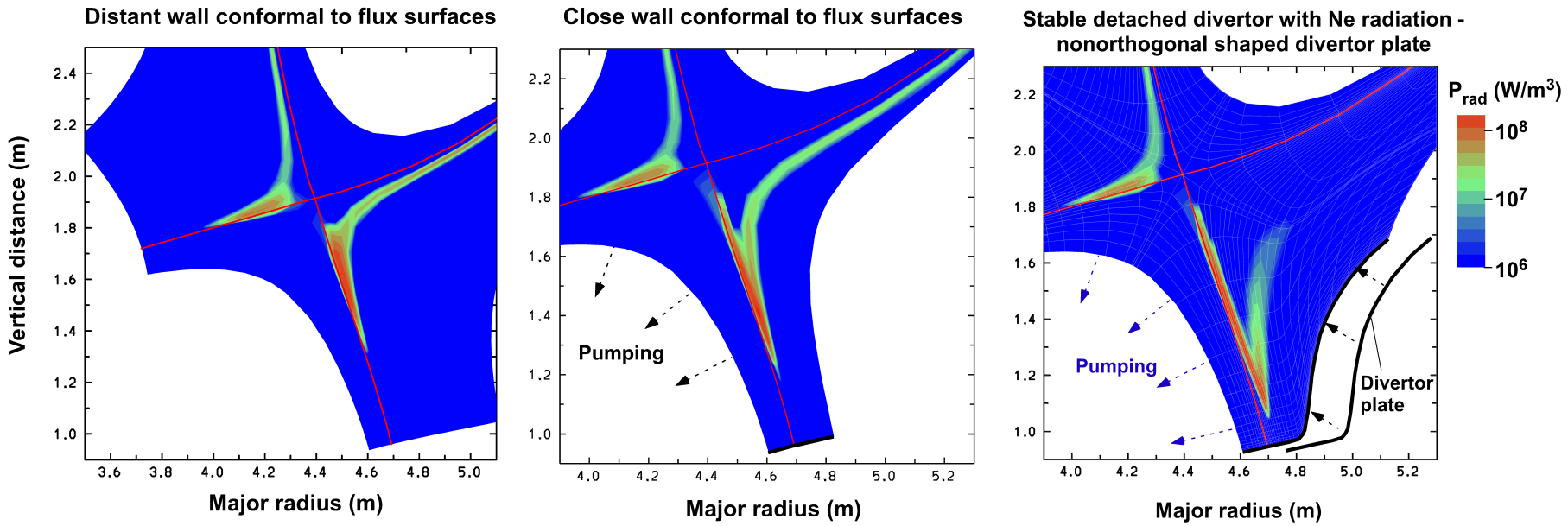
2. How can the configuration be controlled against radiative collapse?

3. What core particle throughput is needed?

We provide some answers to recent important questions concerning the divertor

1. How sensitive is the detached plasma to geometry?
2. How can the configuration be controlled against radiative collapse?
3. What core particle throughput is needed?
4. **What range of edge plasma is density allowed?**
5. **Can the divertor leg be shortened?**
6. **How does the configuration relate to the ITER divertor; is it an option?**

1. Various divertor configurations allow stable detached plasma; but not yet a simple tilted plate

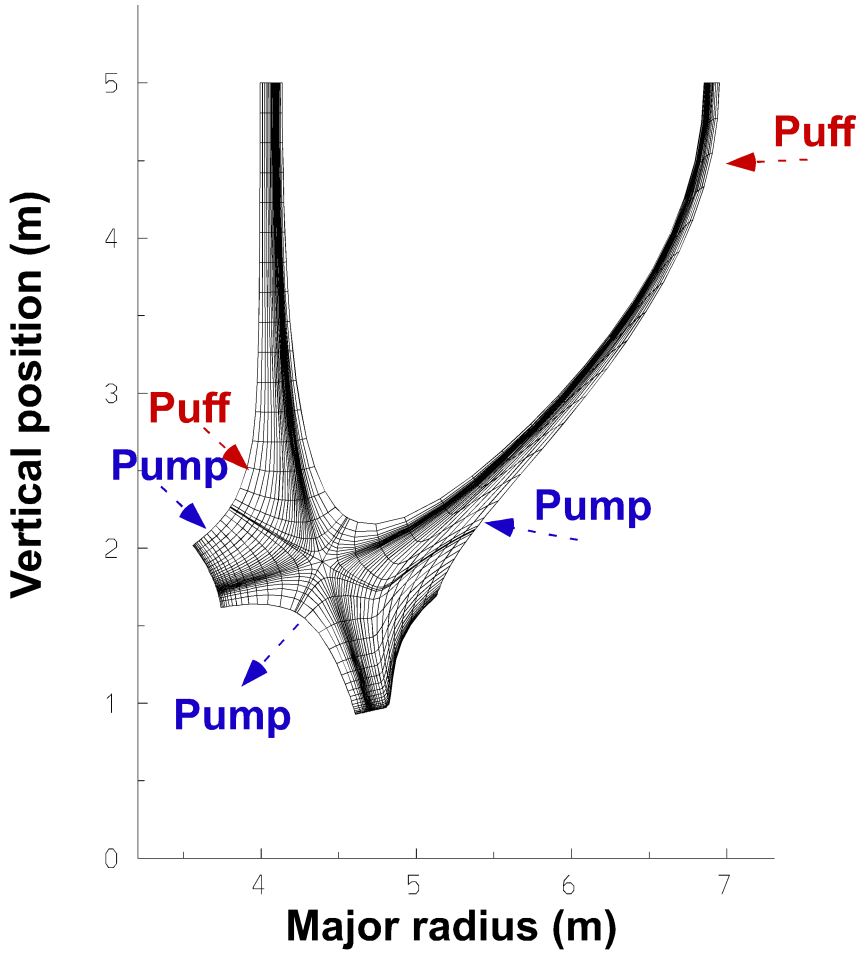


All these geometries appear to exhibit similar operating windows in terms of pumping, puffing, and core parameters

2. Stable plasma operation can be controlled by neutral pumping and puffing

- Key controlling parameter appears to be neutral pressure near the divertor plate – similar to ITER divertor*
- Pressure determined by pumping at the walls and/or gas puffing; location often of secondary importance
- Required pressure increases with power exhausted; need

$$P_{neutral} > P_{plasma}$$



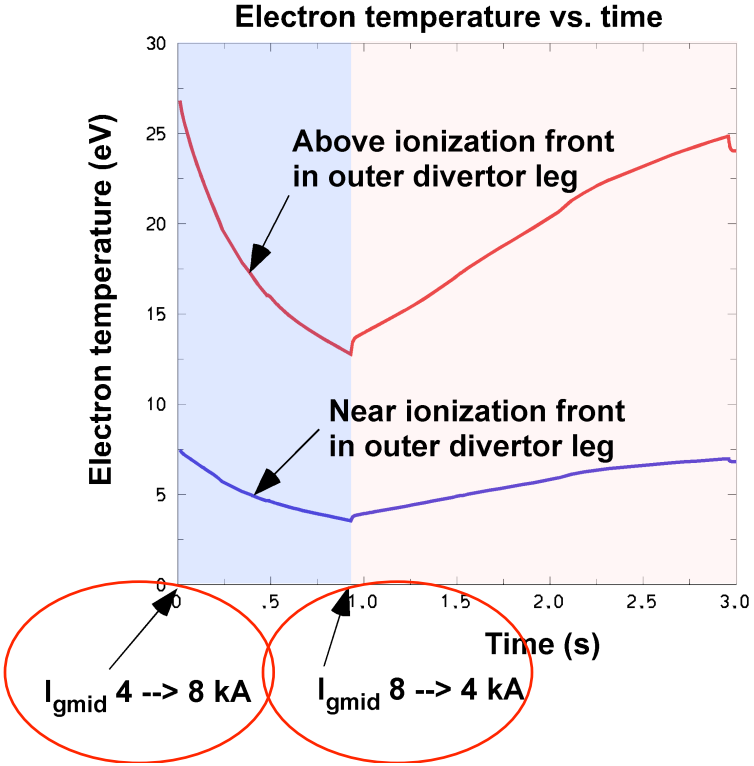
*A. Kukushkin, H. Pacher et al.

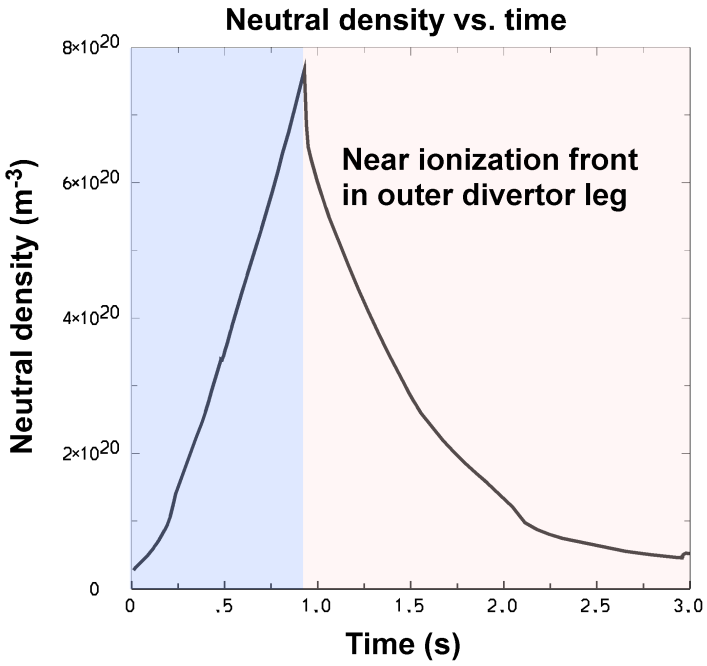
2. Time-scale of response from puff/pumping is ~seconds; suggests feedback control possible

- Net particle pumping/puffing in range of 1-10 kAmp-equiv can control position of radiating layer
- Time-scale, τ_D, is that to replace the total neutral inventory, N_g

$$\tau_D \sim N_g / I_{puff} \sim 5\times10^{22} / (5\times10^{3}/1.6\times10^{-19}) \sim 2 \text{ sec}$$

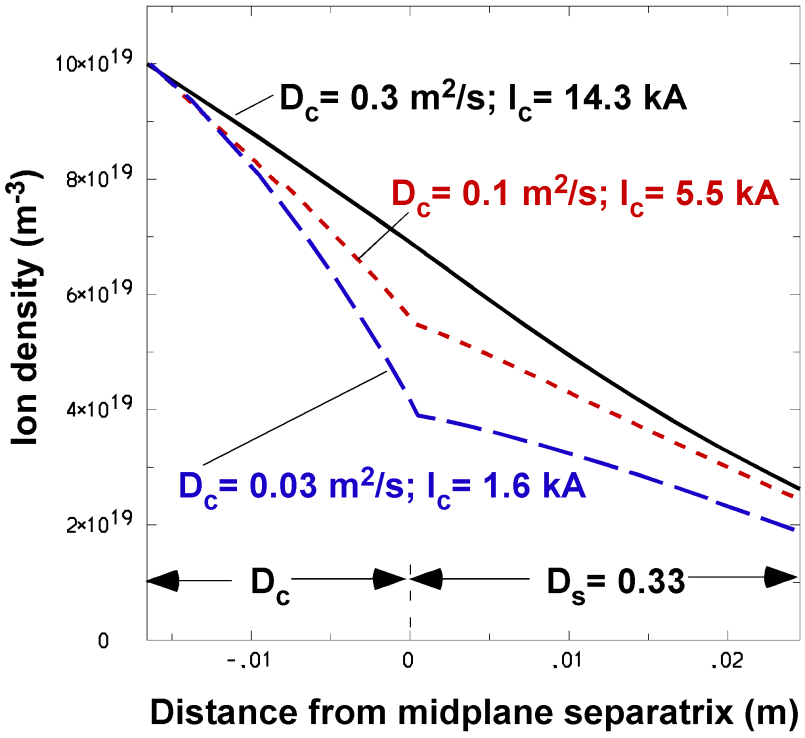
An illustration from UEDGE narrow slot case by perturbing a steady-state

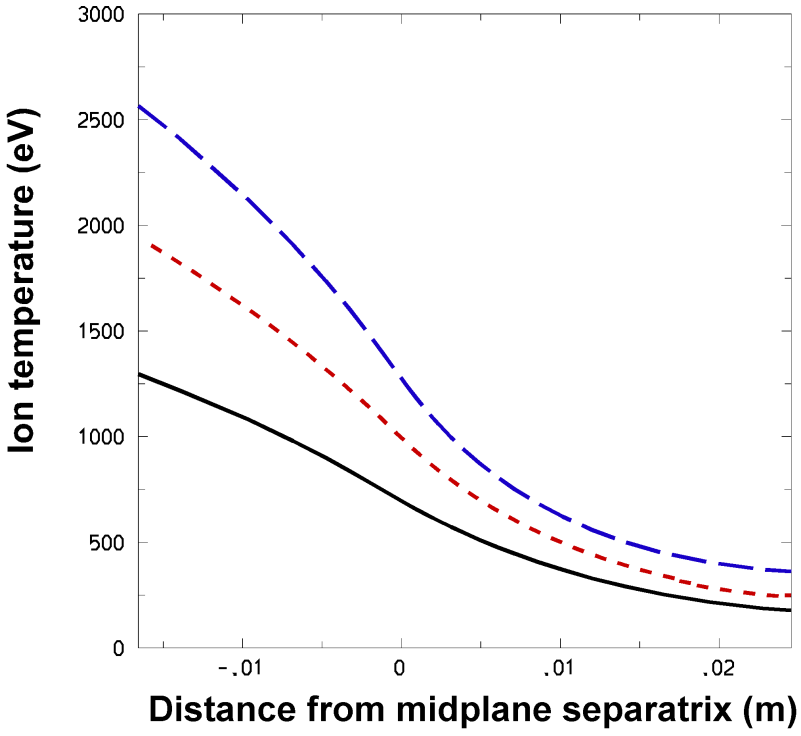




3. Core particle throughput can be ~1 kA if pedestal-region plasma particle diffusivity low

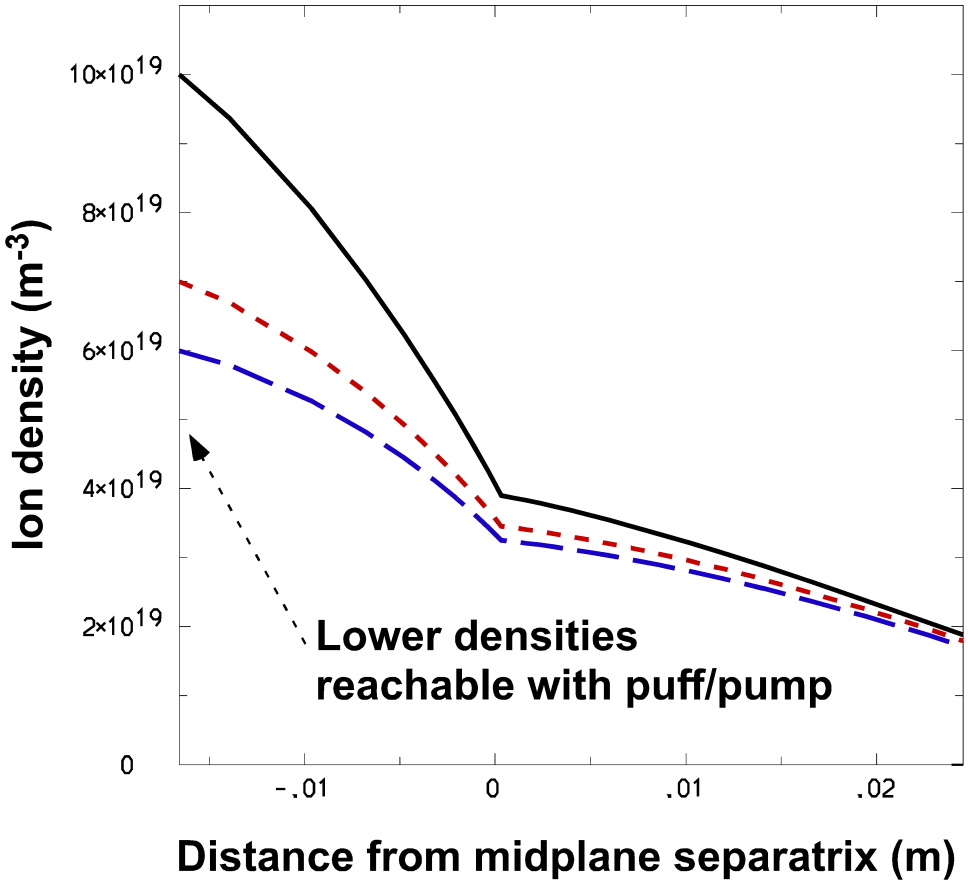
- For narrow slot case, reducing particle diffusivity in core reduces throughput; low D inferred from present experiments
- Detached plasma state maintained and core T_i rises





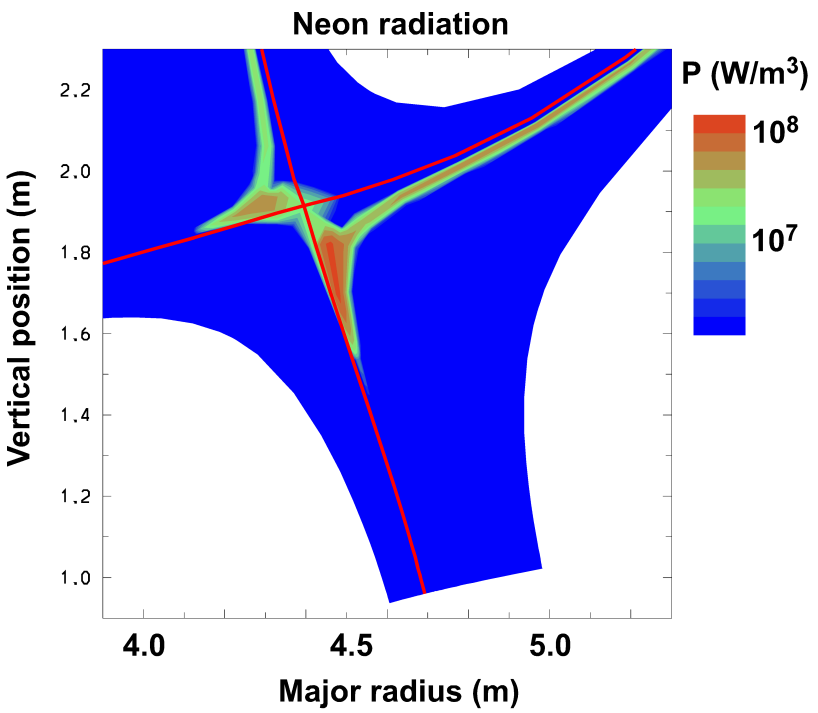
4. Core edge density can be reduced to ~5x10^{19} m^{-3}

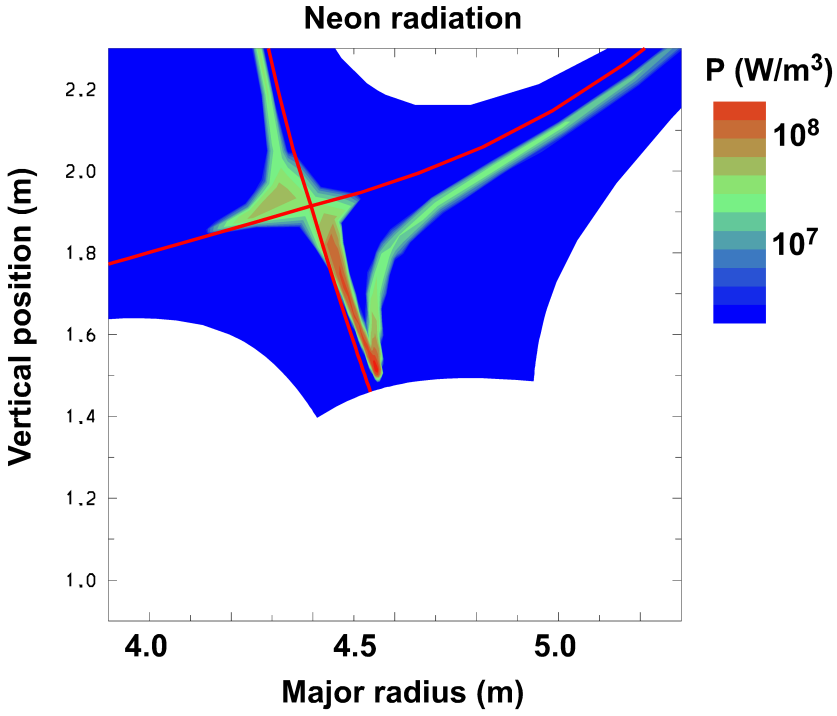
- Separatrix density can be less than 1/2 the core-edge value
- Detached plasma state maintained with separatrix ion density < 4x10^{19} m^{-3}
- Midplane puffing allows going to lower density



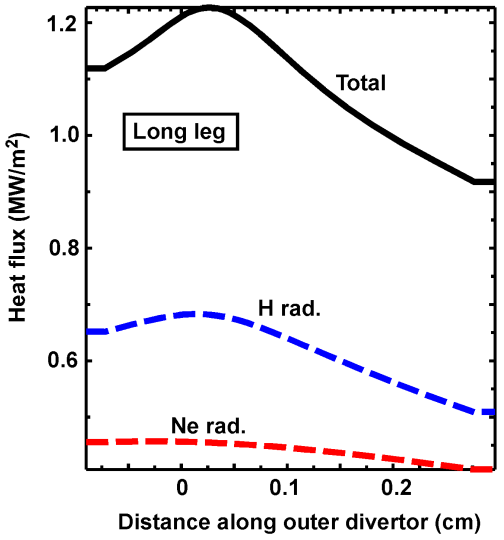
5. Shorter divertor legs are possible, but likely limit operating window

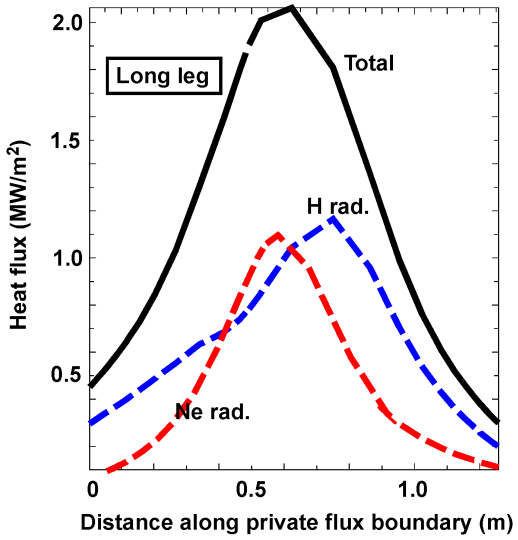
- **Outer leg length reduced by 2; still stable detachment**

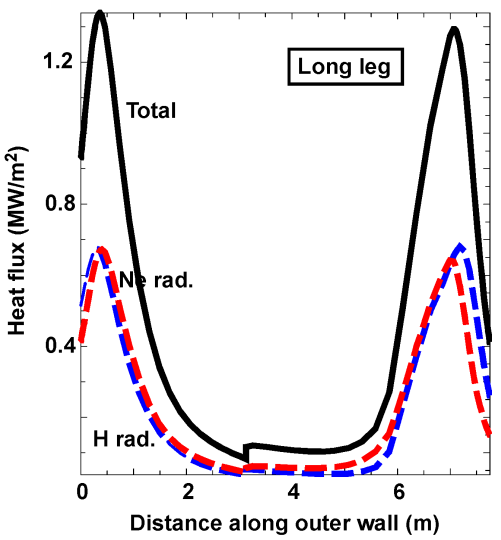


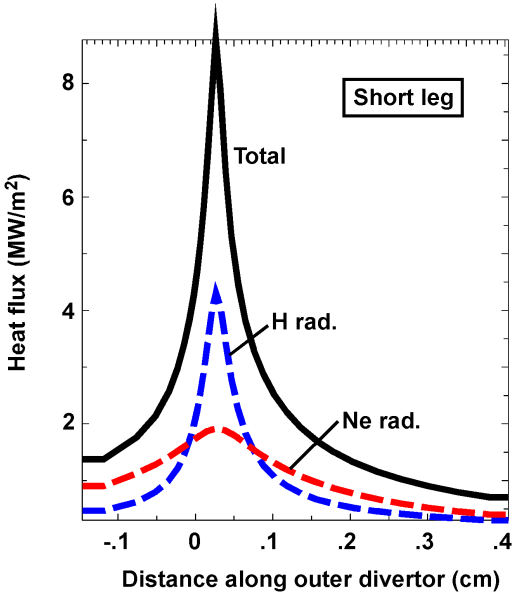


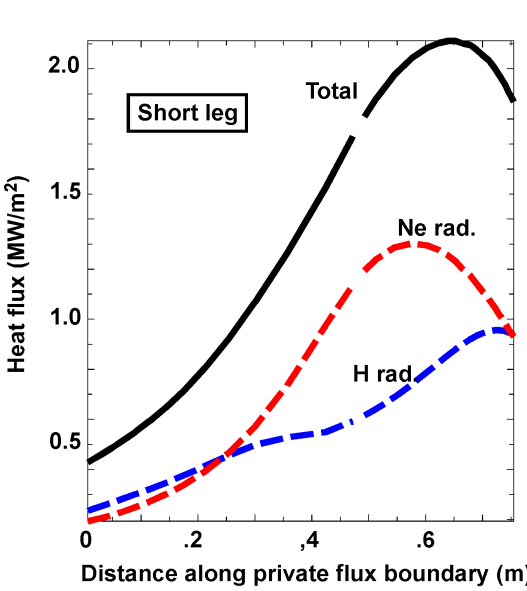
5. Shorter divertor legs have higher divertor heat flux, but ~ same on walls

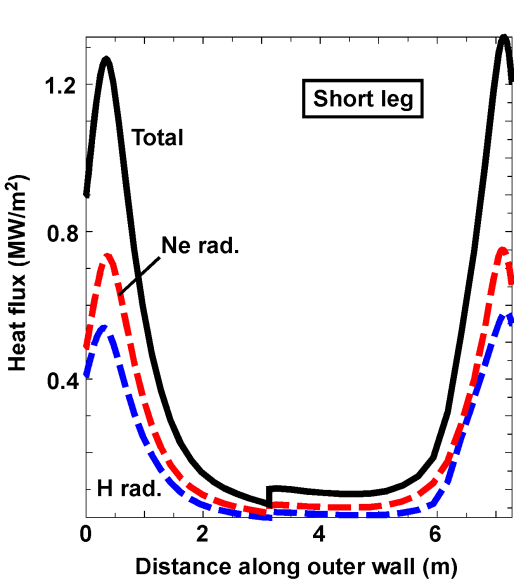






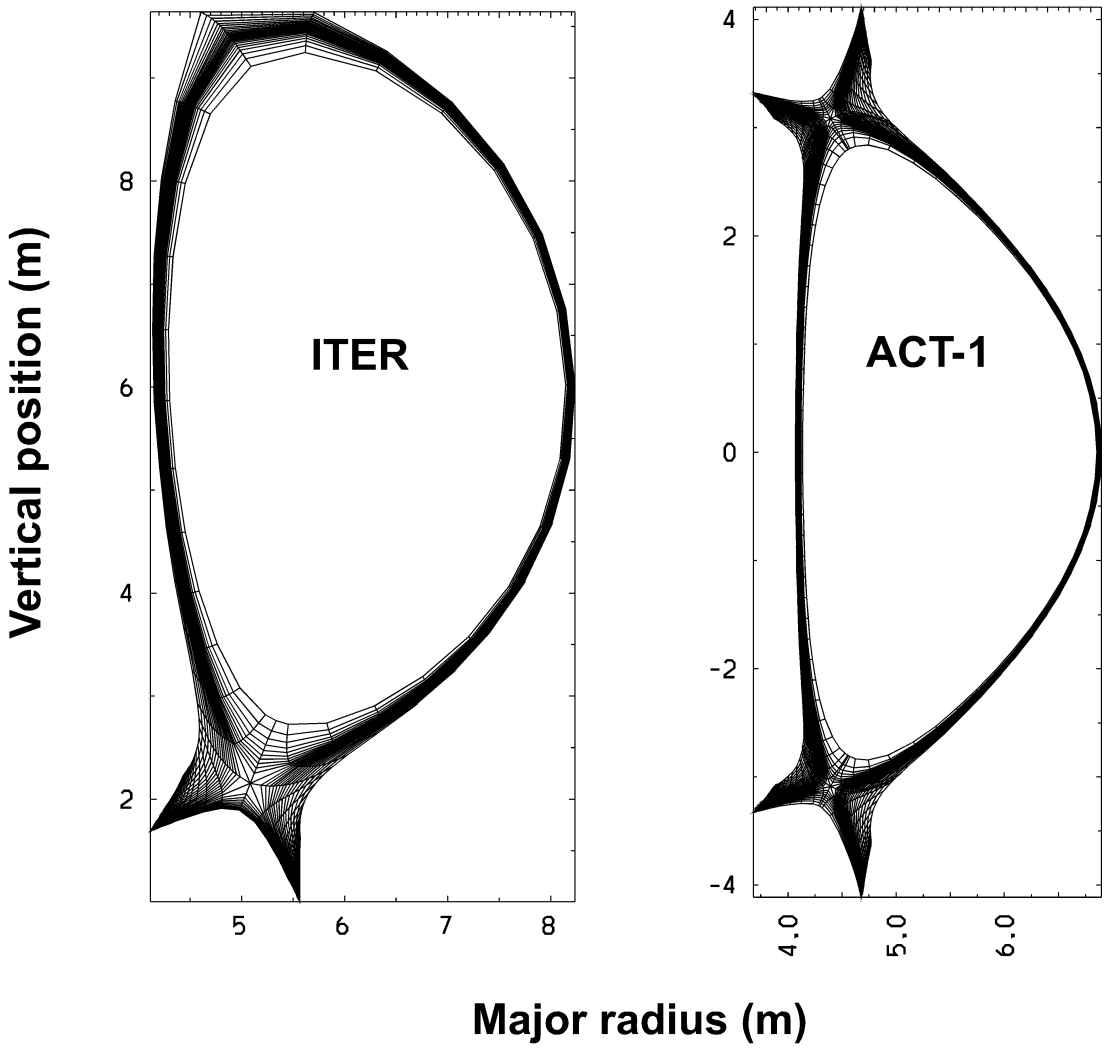




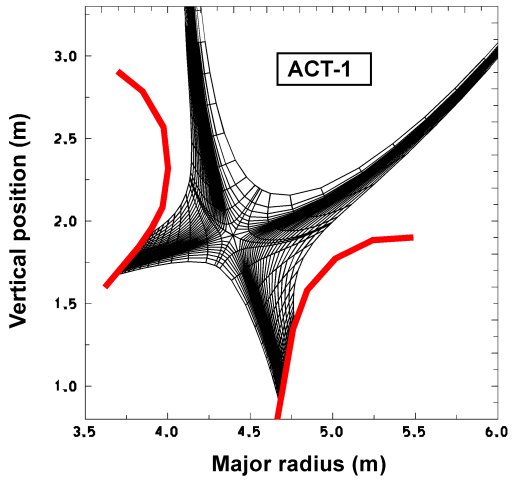


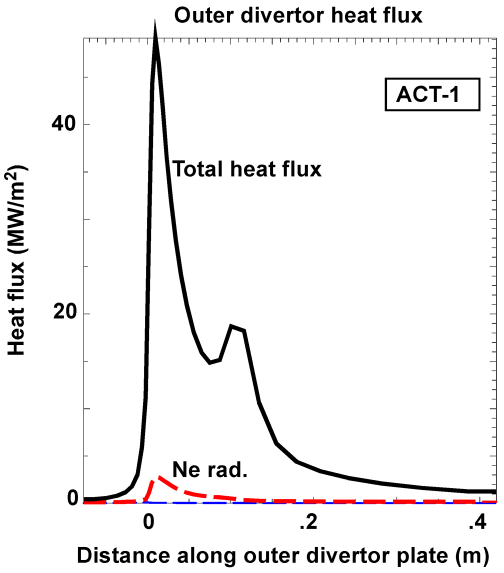
6. ITER is larger than ACT-1 and parameters are quite different

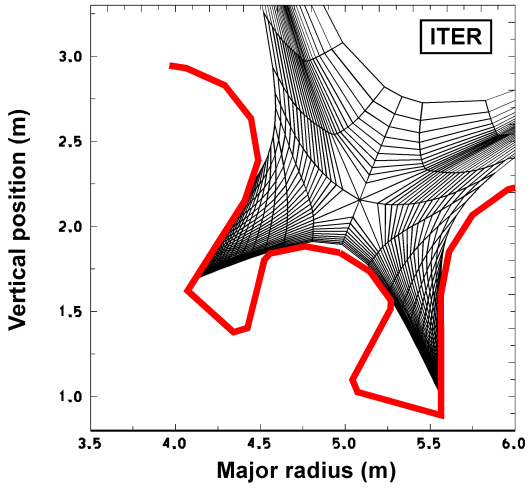
- ITER is larger in all dimensions: major radius, minor radius, and slightly in height
- ACT-1 SOL power is ~3-4x that in ITER
- ITER is a single-null that uses a tilted divertor with partial plasma detachment

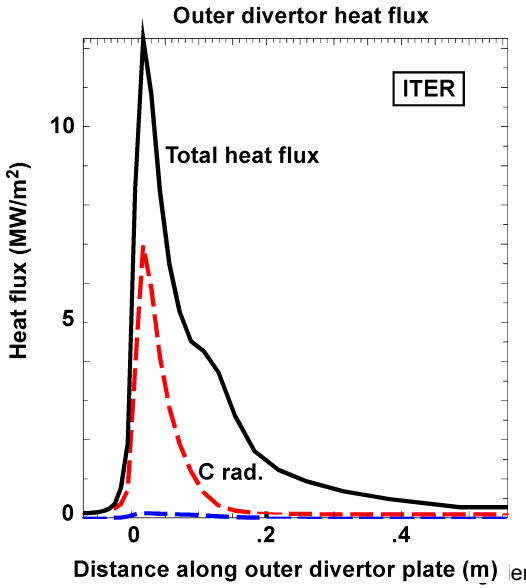


6. ACT-1 does not yet attain partial detachment; investigating puff/pump









Summary

- **Detached, radiating divertor is still best option for ARIES ACT-1**
  - Acceptable divertor/wall heat flux, though PF wall needs attention
  - Stable for a range of densities and pump/puff combinations
  - Slow time-response suggests feedback control
  - Shorter divertor leg possible, though may limit flexibility
  - Stable detachment may require an orthogonal plate region near the strike point; working to show smooth transition from partial to full detachment

- **Issues to be resolved**
  - High neutral density near separatrix – impact on T_i in core, but still reasonably high in simulations
  - Detection diagnostics for feedback control
  - Startup
  - Sufficiently closed-divertor to maintain neutral pressure
  - Helium pumping

Weakly pumped, high density SOLs yield stable, highly-radiating edge plasmas

- Fluorine from the flinabe wall can provide an effective radiatorfor core alpha-particle power
- High core-edge density is helpful, but may not be essential
- An operating window in power and core-edge density is identified
- Stability of the radiating zone and sufficient core-edge temperature for good core confinement are key issues