Divertor heat-loads and pumping requirements for ACT-1 configuration

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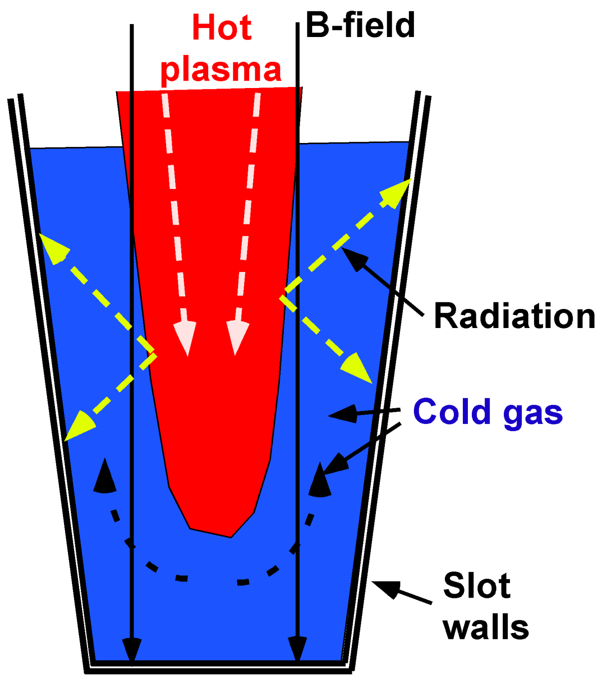
Central questions addressed

1. What divertor configuration can yield acceptable heat loads?
2. What are the DT pumping requirements – particle throughput?
3. Is helium rate pumping acceptable?

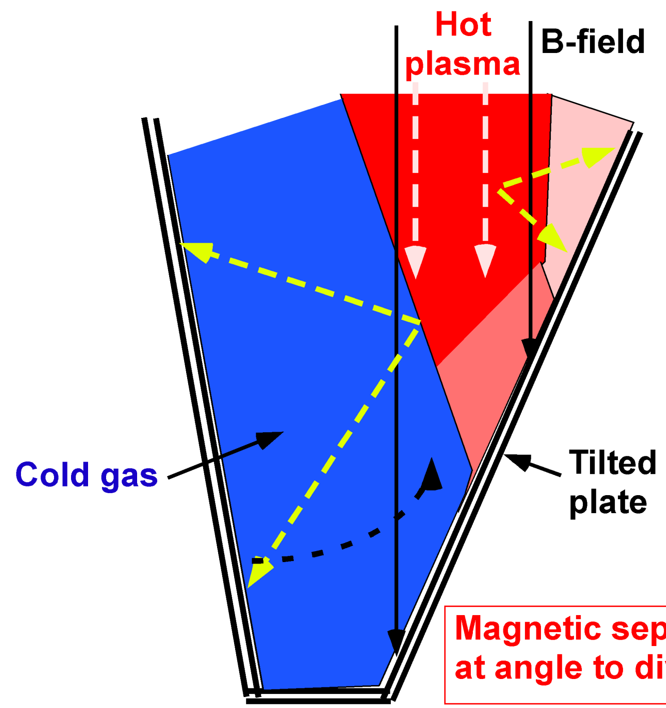
Two types of divertor configurations possible (hot plasma refers to plasma pressure)

Fully-detached divertor plasma



Magnetic separatrix
normal to divertor plate

Partially-detached divertor plasma



Magnetic separatrix
at angle to divertor plate

High-level conclusions for ACT-1

Detached divertor plasma

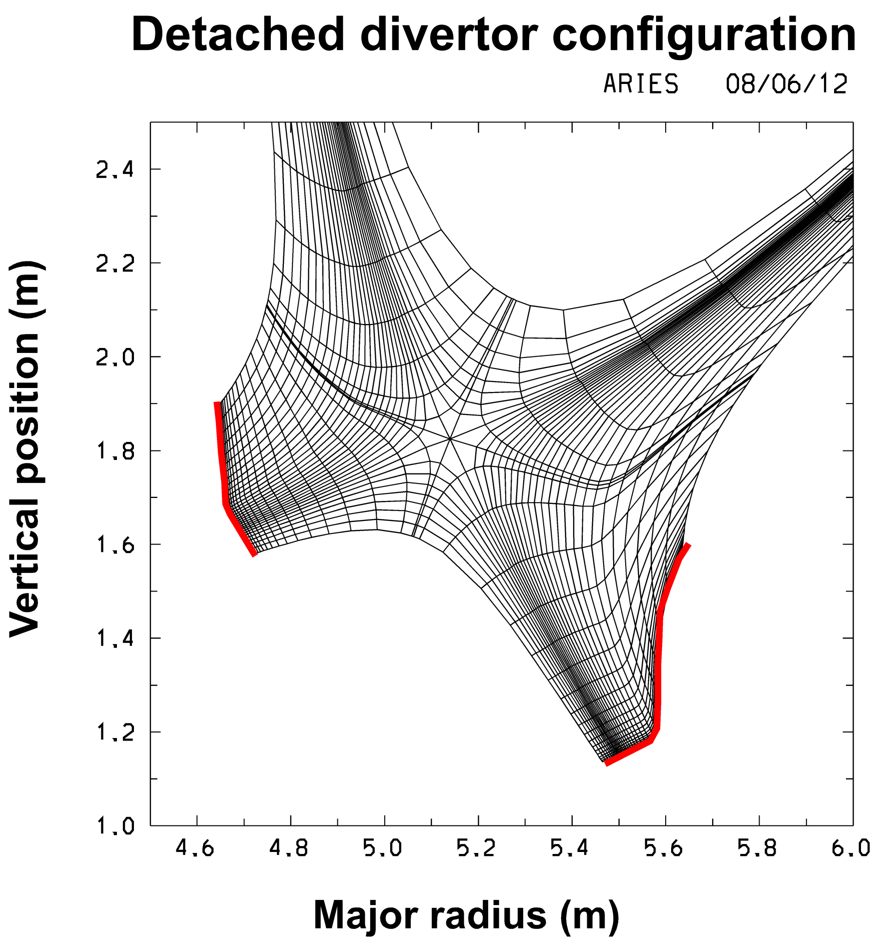
1. Divertor & wall heat loads < 5 MW/m^2 but sensitive to plate detail; divertor leg length (0.5 m & 0.76 m) close to being satisfied
2. Particle throughput is mostly controlled by pedestal transport; but divertor requires ~10^{22} particles/s (~2 kg-T/day)
3. Helium pumping rate is problematic; more work (?)
4. Neutral pressure required is ~100 times published ITER simulation

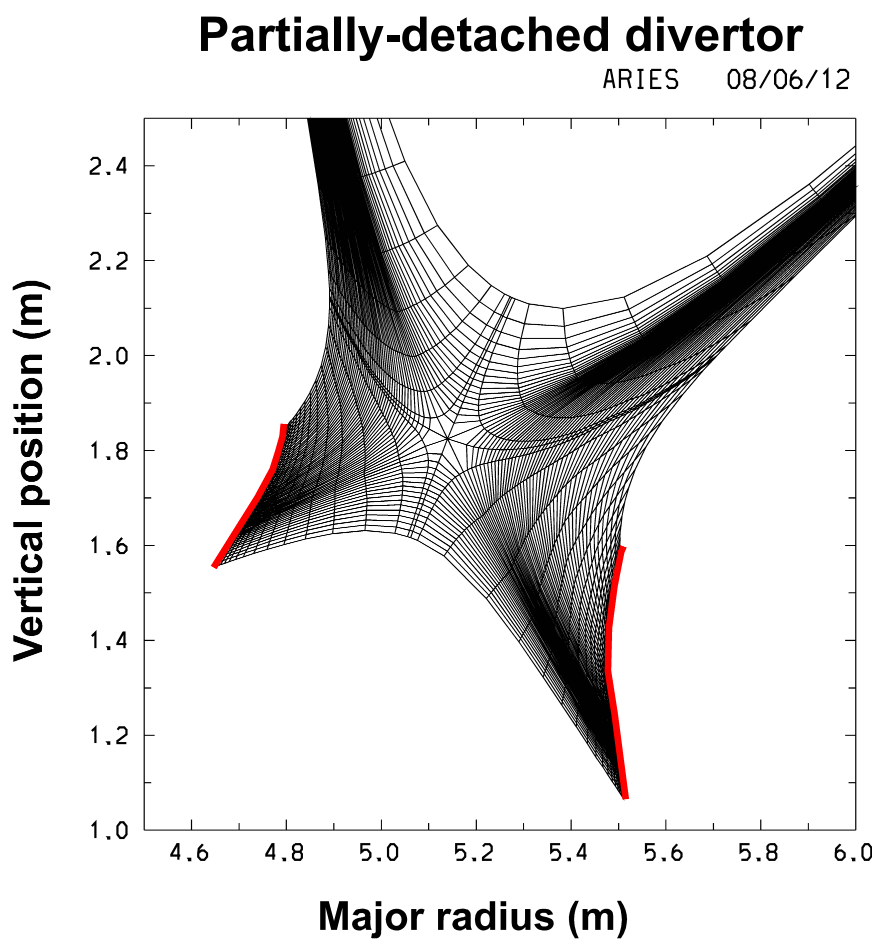
Partially-detached divertor plasma

1. Divertor & wall heat loads < 13 MW/m^2 but requires strong gas-flow under private-flux "dome"
2. Limited particle throughput calculations; still must balance reduced separatrix flux and reduced PF pumping
3. Helium pumping rate is problematic; more work (?)
4. Neutral pressure required is ~200 times ITER

Slow evolution of plasma also invites feedback control (previous mtg)

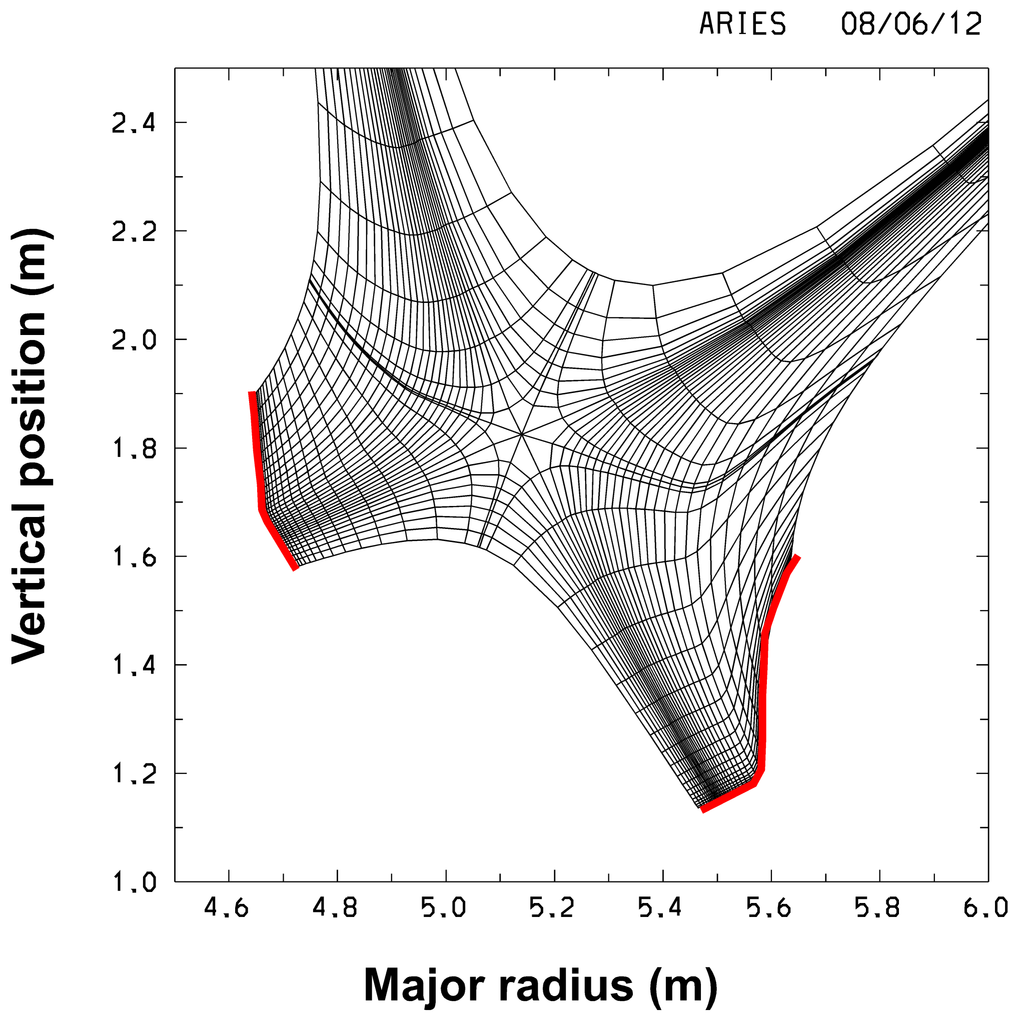
For new Aug. 2012 magnetic equilibrium, we have found both detached and partially-detached divertor solutions



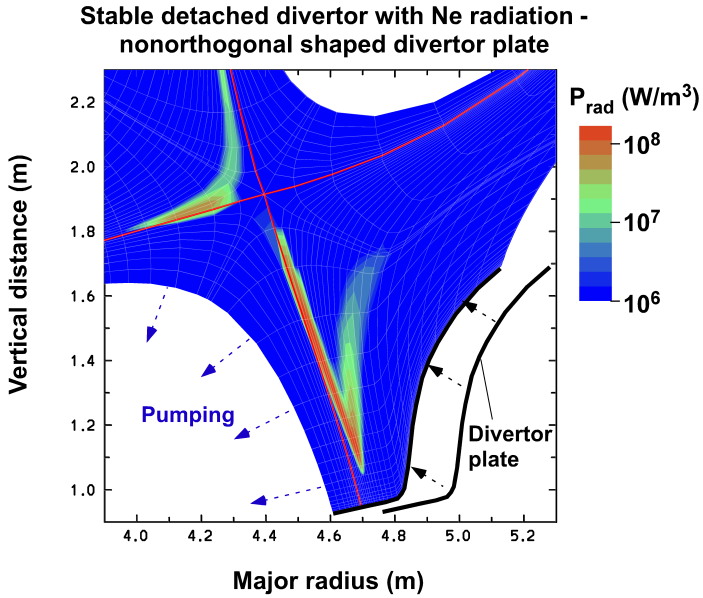


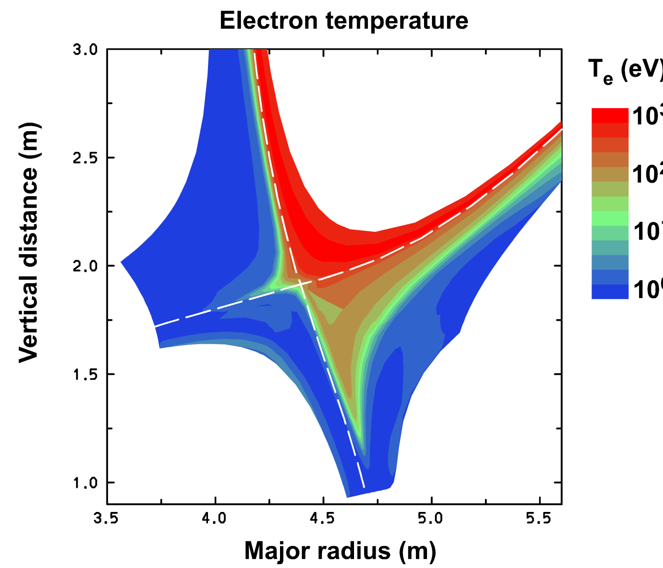
(Need a finer mesh here)

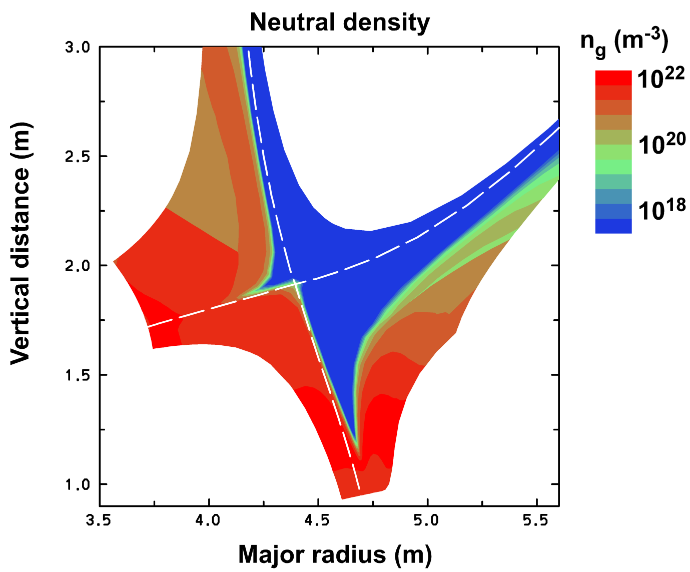
First consider the detached-like plasma solutions; divertor leg lengths are 0.5 m (inner) and 0.76 m (outer)

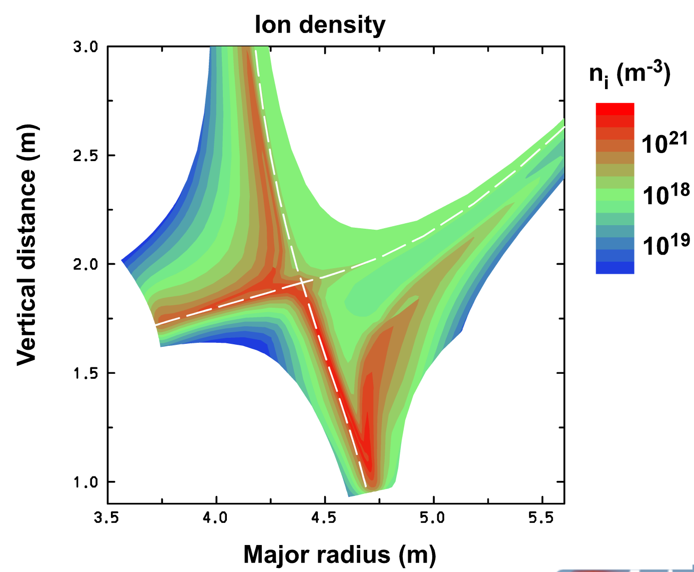


For previous Aug. 2011 case, magnetic equilibrium, a detached divertor solution was illustrated





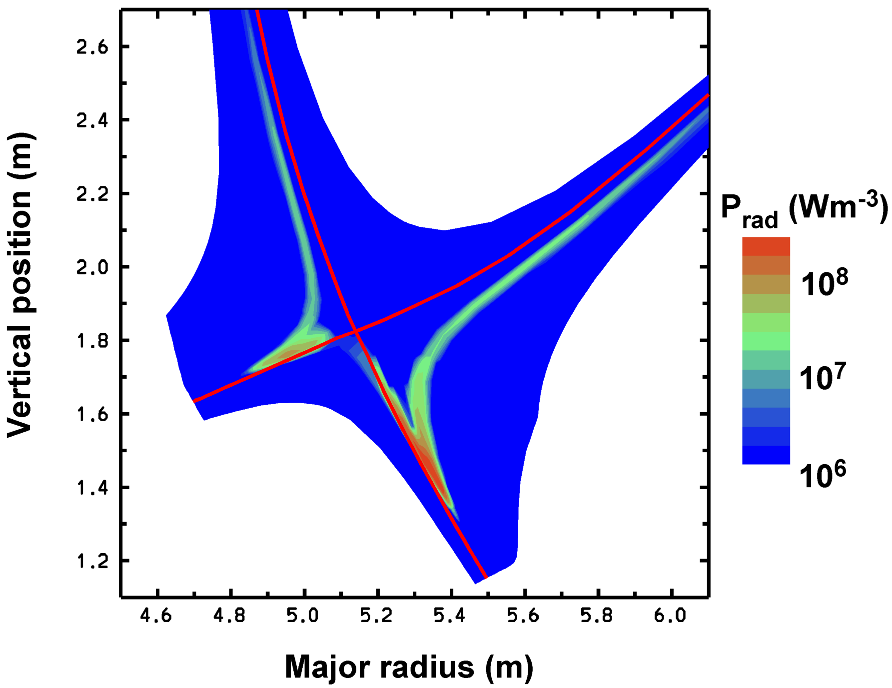




Detached plasma solutions requires a sufficiently wide slot with a "flat" bottom (separatrix perpendicular to plate)

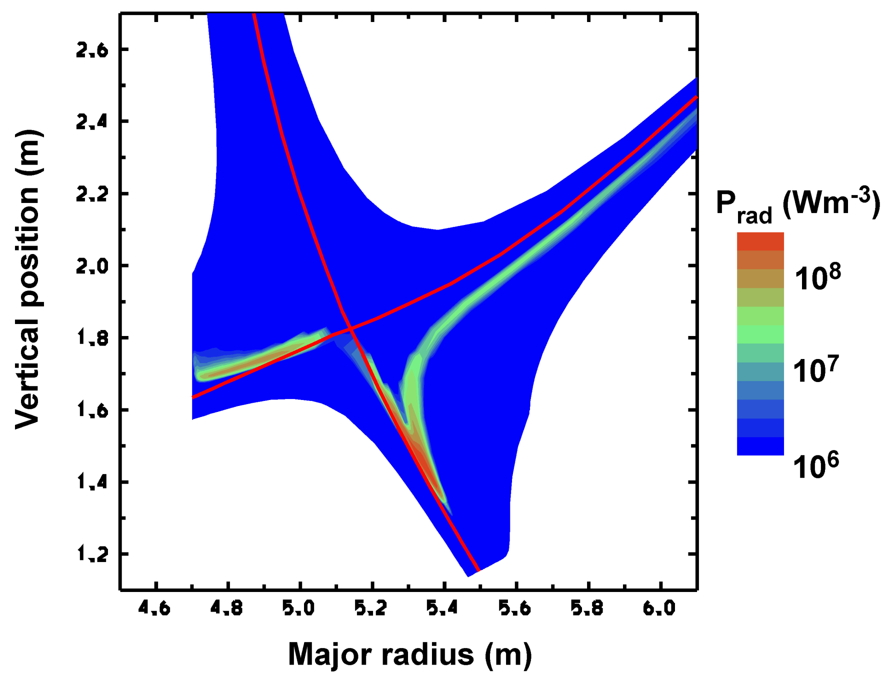
Modestly "shaped" inner plate yields a detached plasmas

Neon radiation (0.6% concentration)

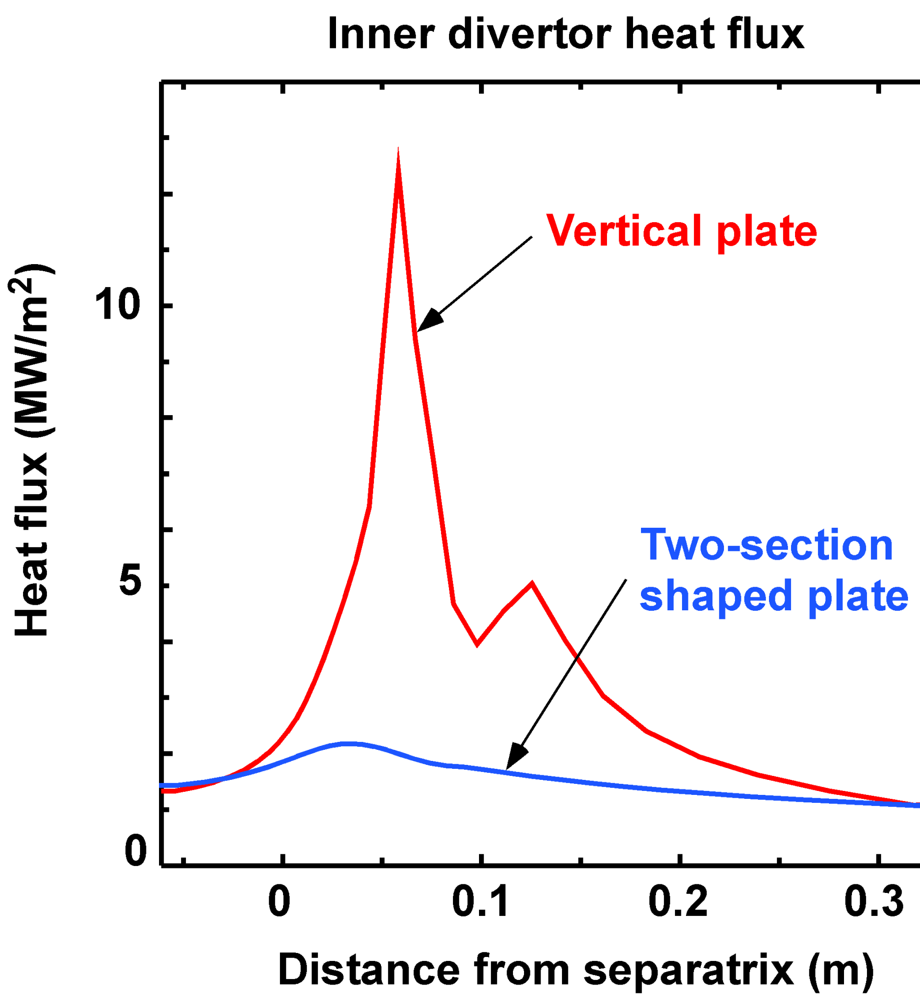


Simple vertical inner plate yields much different inner div. radiation

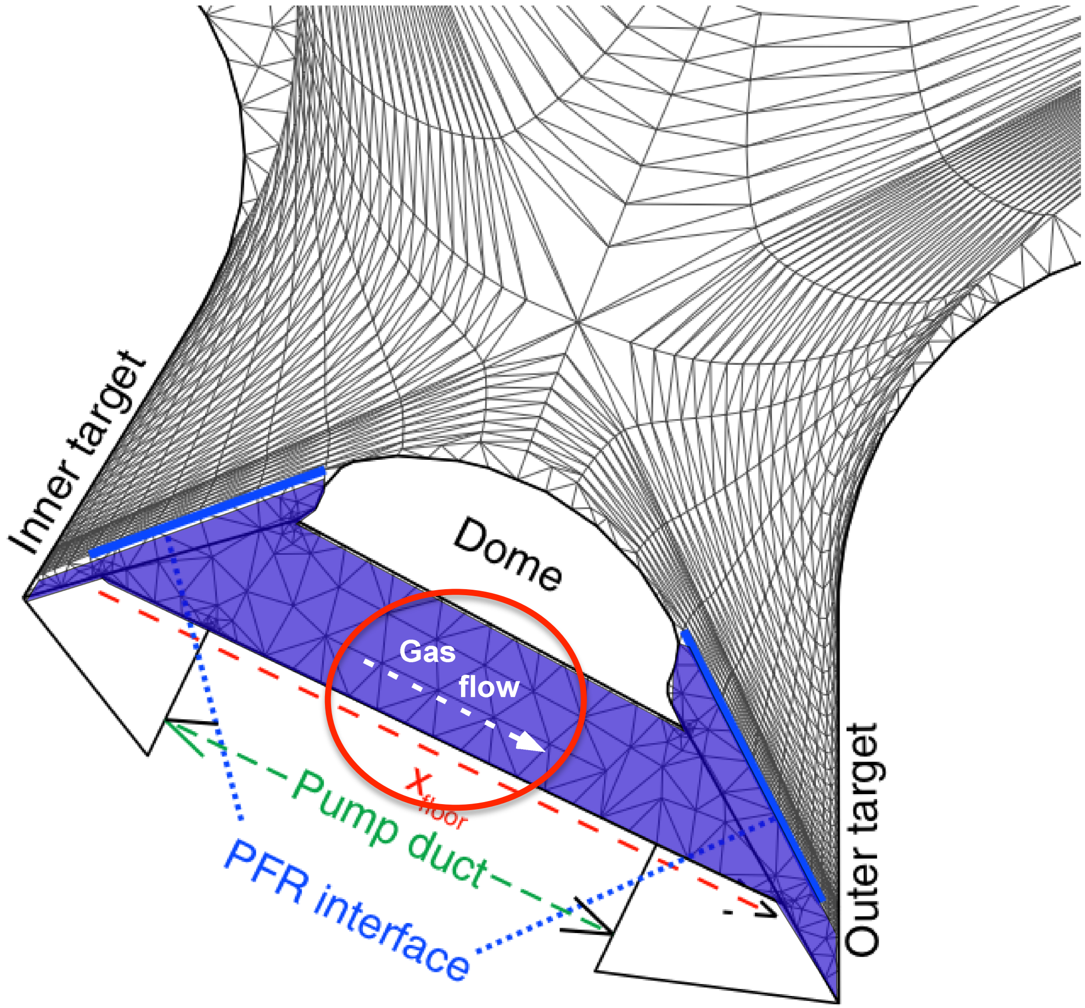
Neon radiation (0.6% concentration)



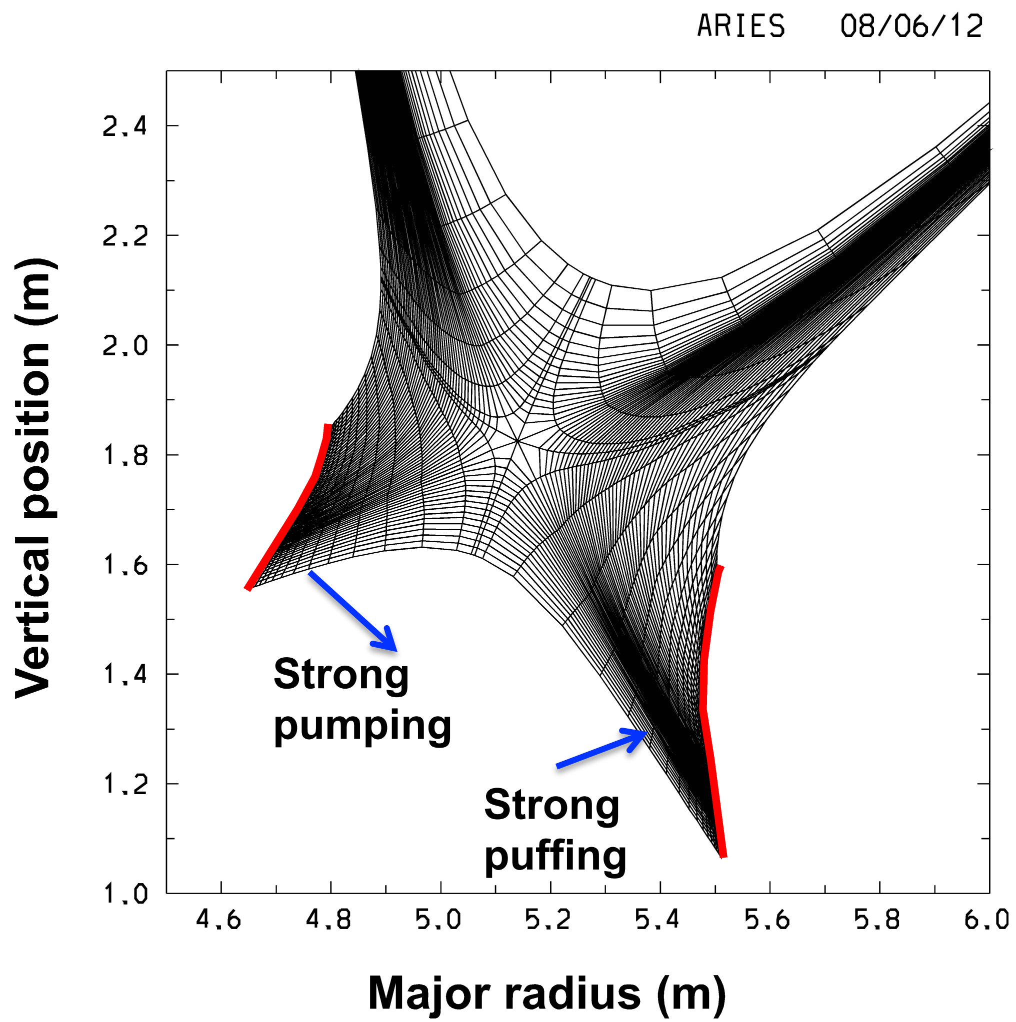
Inner-plate heat flux shows the impact of the different plate shapes – plate normal to separatrix very important



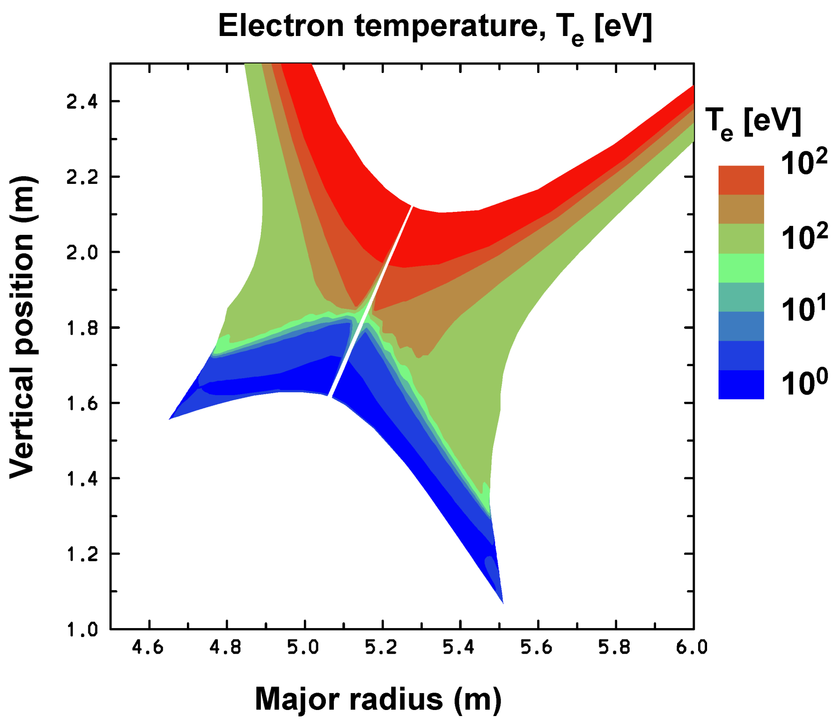
ITER is using strongly-tilted divertor plates; gas flow under dome is key to partially detached plasma

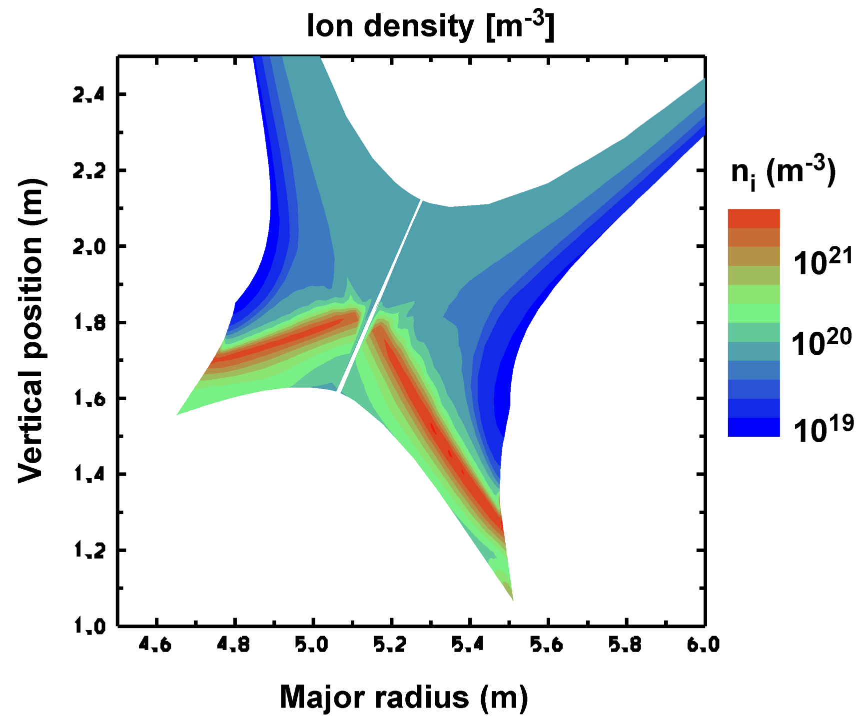


Second, consider the new partially-detached, tilt-plate solutions for ACT-1 (2012)

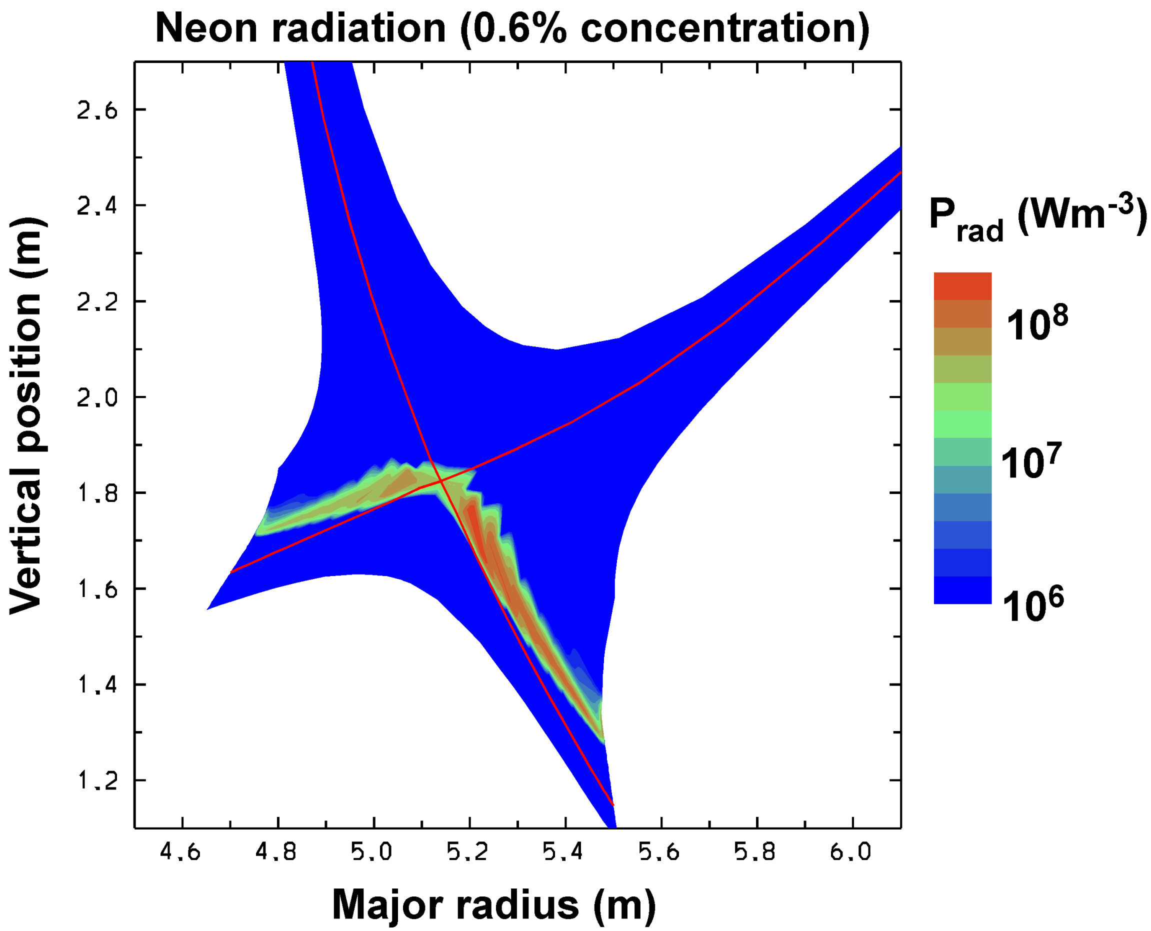


Plasma profiles for tilted-plate case shows expected structure (see earlier comparison sketch)

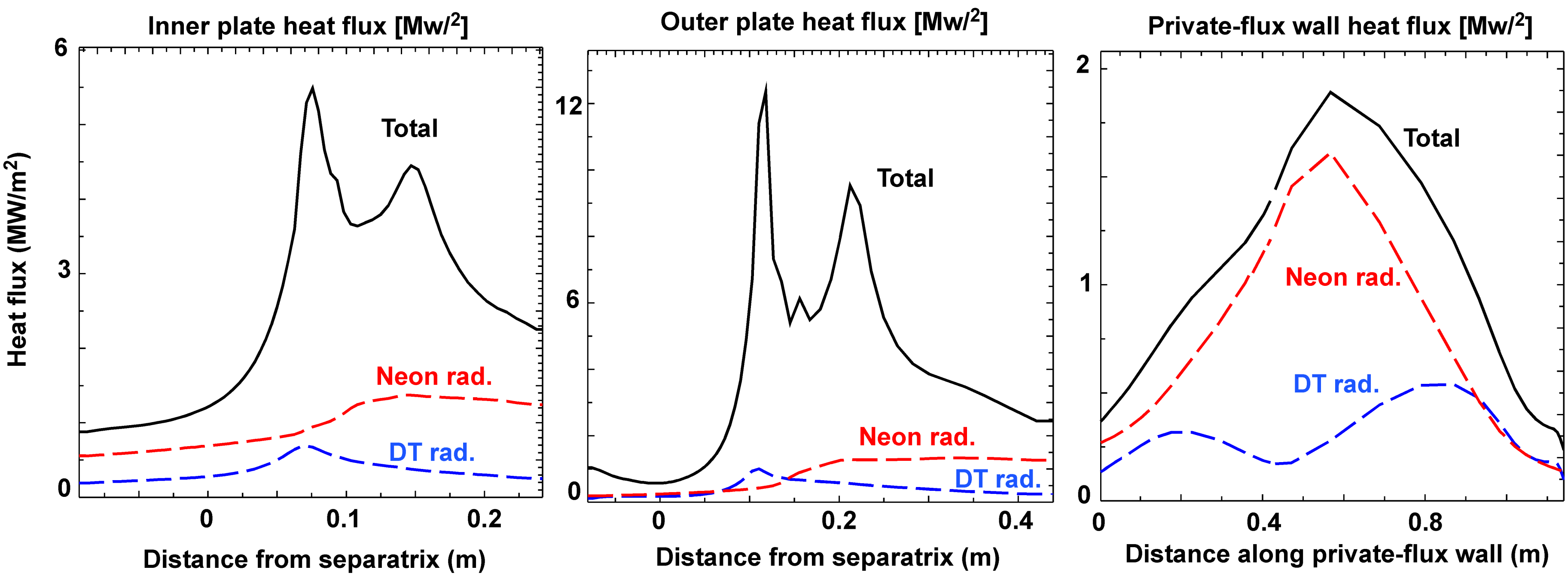




Using tilted plates on both inner/outer divertors leads to a partially detached plasma with broad neon radiation



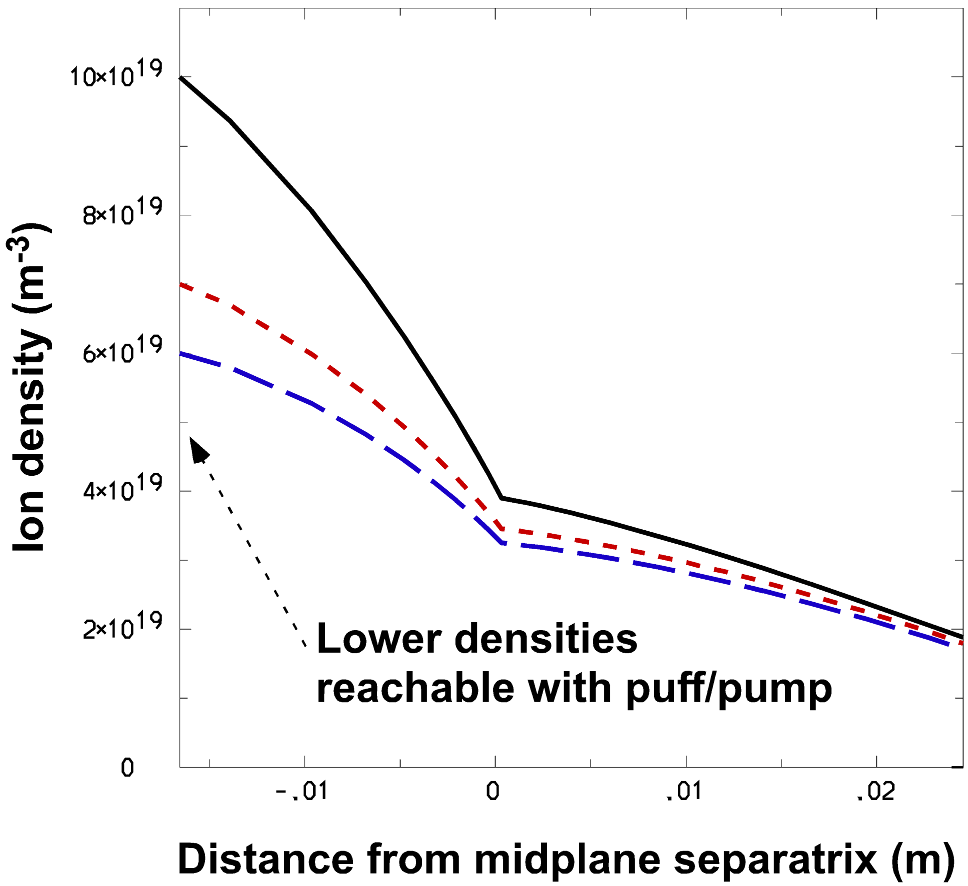
Divertor and side-wall heat loads are in the "acceptable"(?) range for tilted-plate case



Not shown: outer-wall heat flux < 2 MW/m^2, peaking near plates

Now for the DT throughput and associated pumping requirements

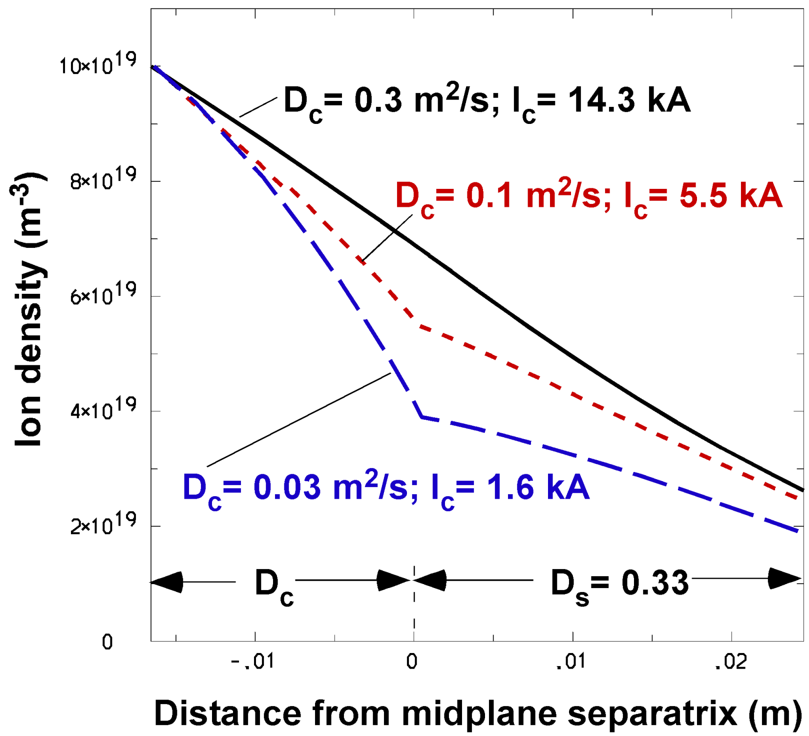
- **Separatrix density can be less than 1/2 the core-edge value**
- **Detached plasma state maintained with separatrix ion density < 4×10^{19} m^{-3}**
- **Midplane puffing allows going to lower density**

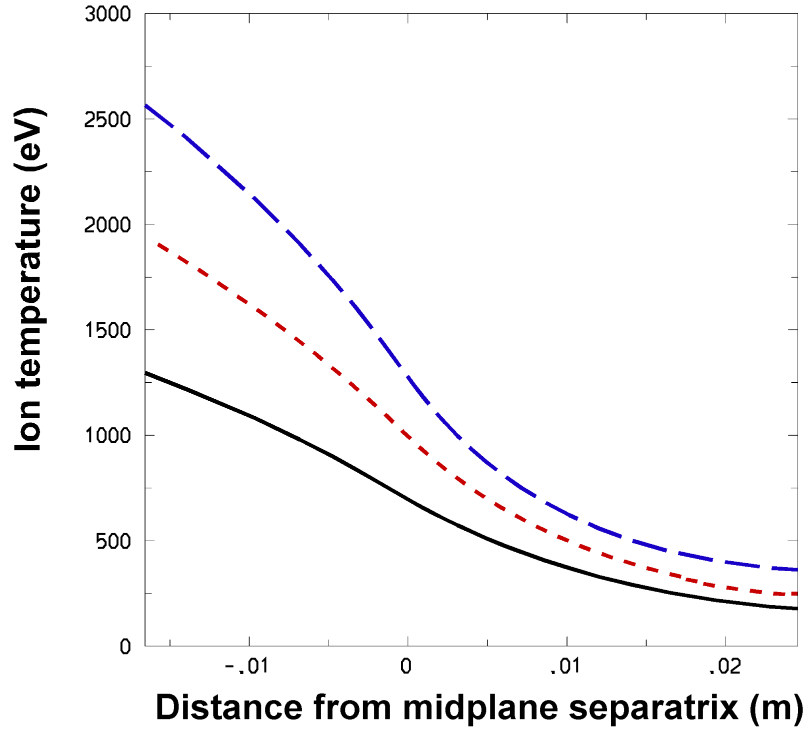


Core particle throughput controlled by pedestal-region particle diffusivity low for detached case (2011 ACT-1)

- **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; adding edge thermal transport barrier by reduced $\chi_{e,i}$ increases T_i further**





Core particle throughput can be ~16 kA for tilted-plate partially detached cases (preliminary)

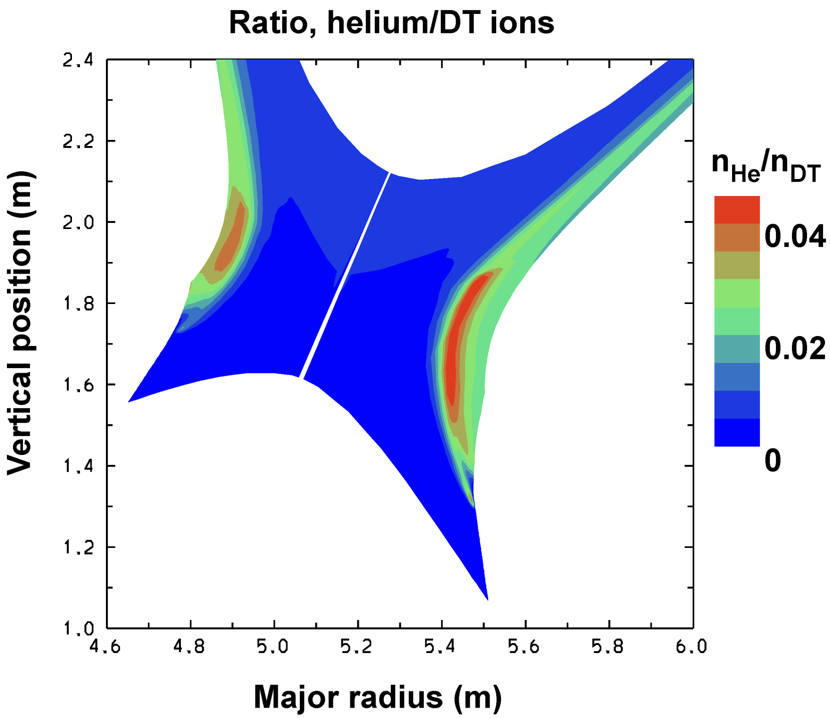
Here pedestal/SOL D is constant, but core flux reduced by decreased separatrix density; <u>still need to reduce PF pumping</u>

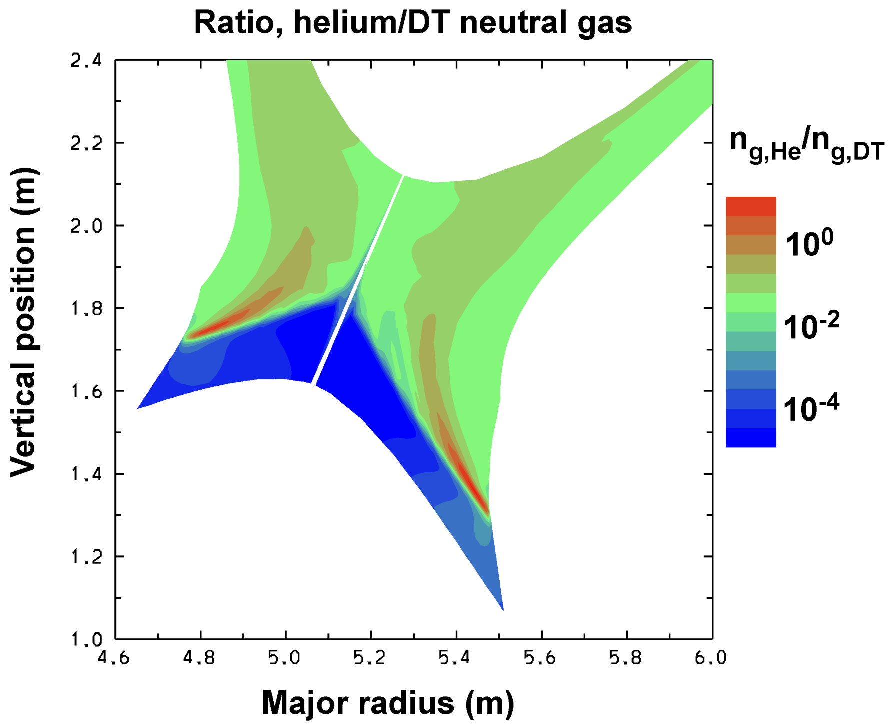
I_pump (kA)	ni_sepx (10^{20} m^{-3})	Te_sepx (eV)	Ti_sepx (eV)	peak heat-flux (MW/m^2)
19.5	0.628	334	607	15.3
19.0	0.614	337	620	14.8
18.0	0.583	345	650	13.5
16.0	0.527	362	720	12.6
10.0	0.372	436	1043	27.2 <- doesn't follow trend

Jump in solution indicative that nearby multiple are possible

Lastly, helium concentrations of ions and neutrals vary strongly and degrade He pumping

Results are similar for detached and partially-detached cases; here, tilted-plate partially detached case





Why is He low in PF-region?
Because of parallel thermal forces ($\sim dT_{e,i}/ds_{||}$) across sharp $T_{e,I}$ drop

Present ratios of He_pump / He_pedestal are much lower than DT_pump / DT_pedestal

Both detached and partially detached case give

$$n_{He,pump} / n_{He,pedestal} \sim 0.02\text{-}0.05 \text{ (spatial variation)}$$

whereas published ITER simulations by Kukushkin show

$$n_{He,pump} / n_{He,pedestal} \sim 0.2$$

Why? - different parameters (higher density), kinetic neutral analysis?

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