SOLPS-ITER Simulation Study for Power Exhaust in JA-DEMO Divertor

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Outline

- Introduction to JA-DEMO divertor and SOLPS-ITER

- Effects of different Ar seeding rates on SOL and divertor plasma

  - Density, temperature and impurities concentration at outer middle plane

  - Heat load, impurities on inner and outer divertor targets

- Summary

QST

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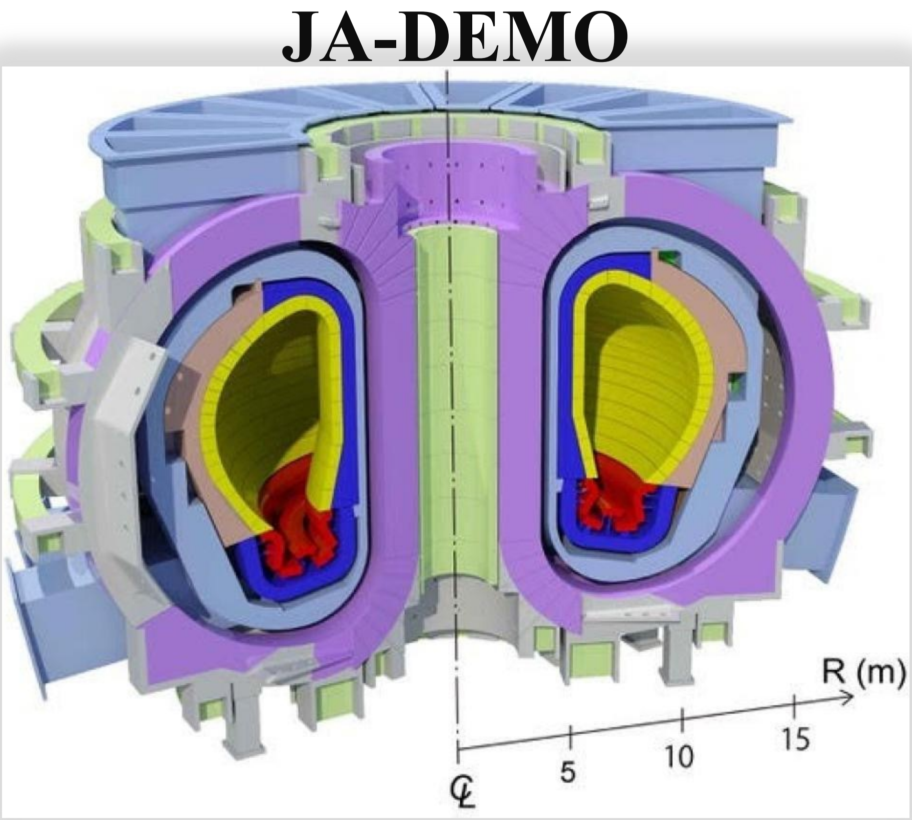
JA-DEMO Divertor



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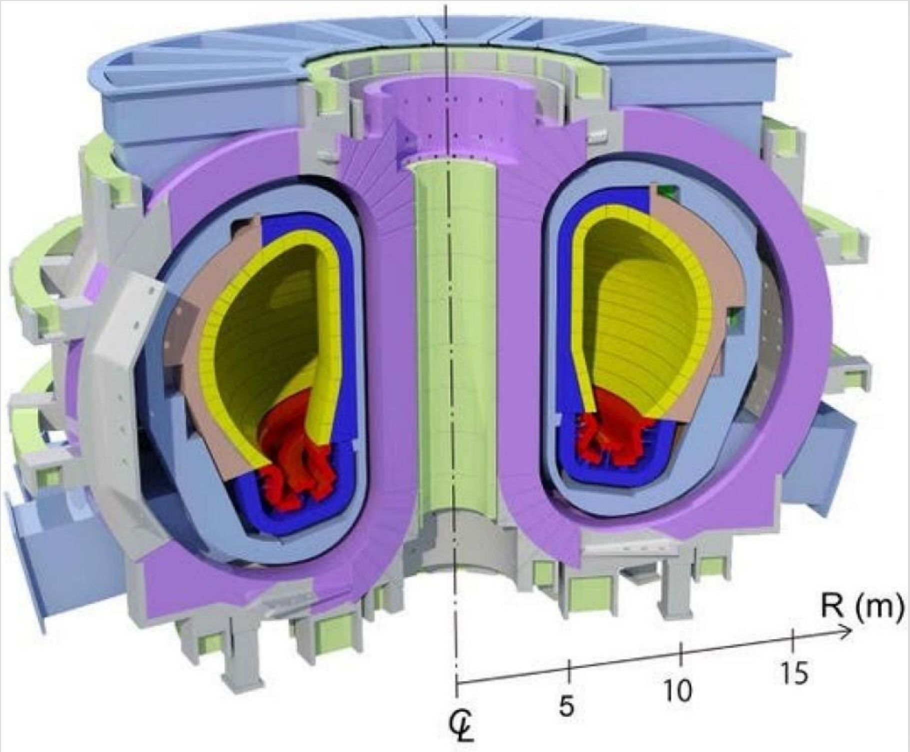
Parameters	JA-DEMO	ITER(Q=10)
Major radius, *R* (m)	8.5	6.2
P_{fus} (GW)	1.5	0.5
P_{sep} (MW)	235 ~ 300	100
P_{sep}/R (MW/m)	28 ~ 36	16

JA-DEMO Divertor

JA-DEMO



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JA-DEMO: Q_{DIV} > 50 MW/m^2

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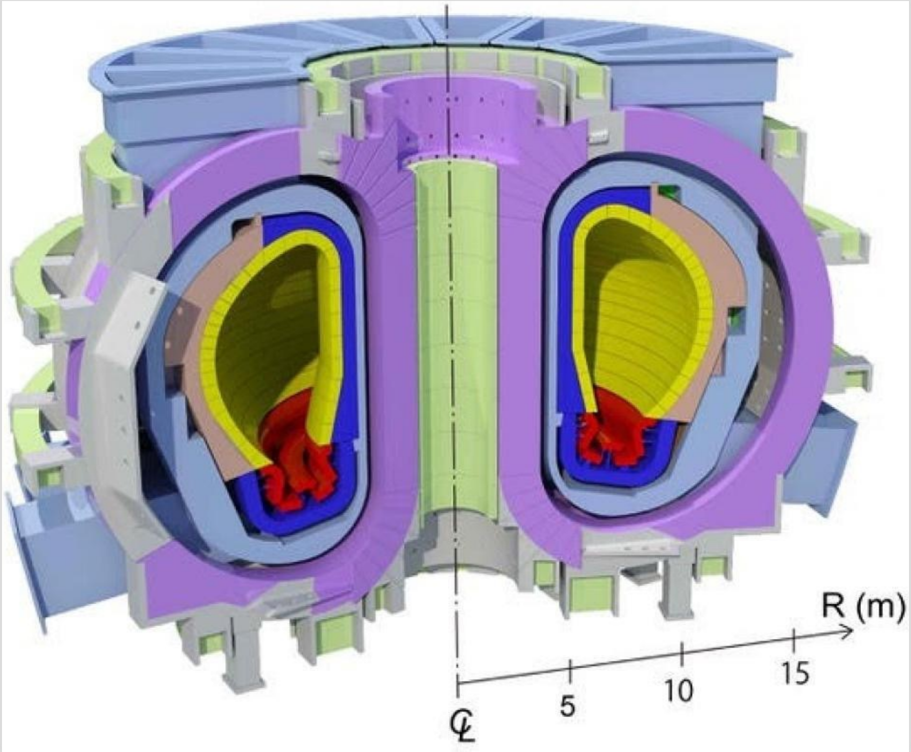

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- **Requirements for divertor plasma**

  Steady heat load, $q \leq$ 10 MW/m^2

  Negligible erosion rate, $T_e \leq 10$ eV

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JA-DEMO Divertor

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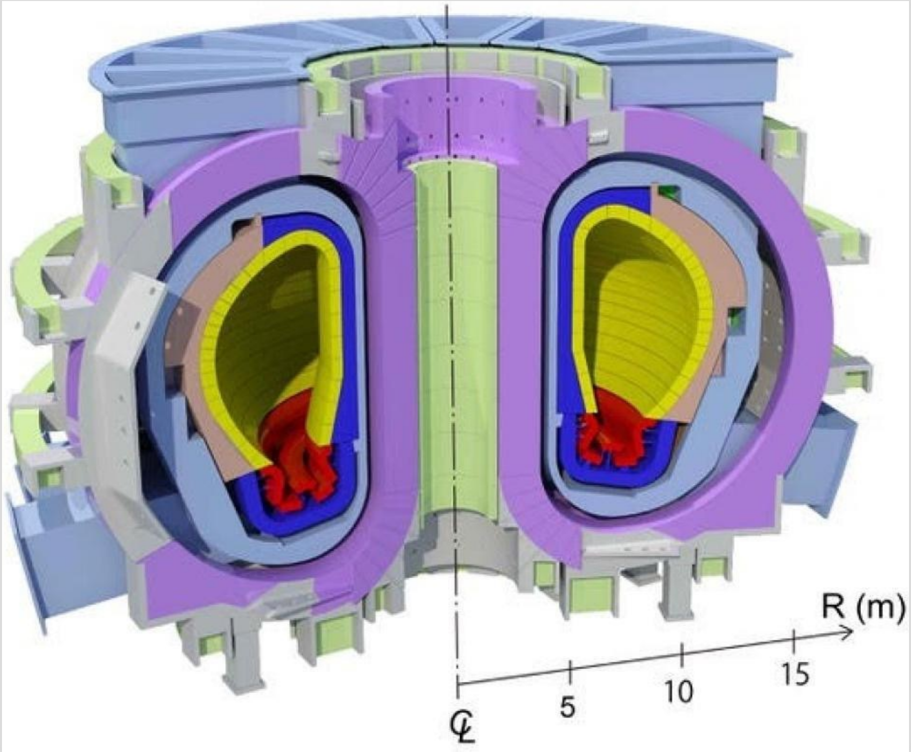

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Power exhaust solutions for JA-DEMO divertor must meet the requirements beyond that of ITER. ⇒ A Huge Challenge! ☹

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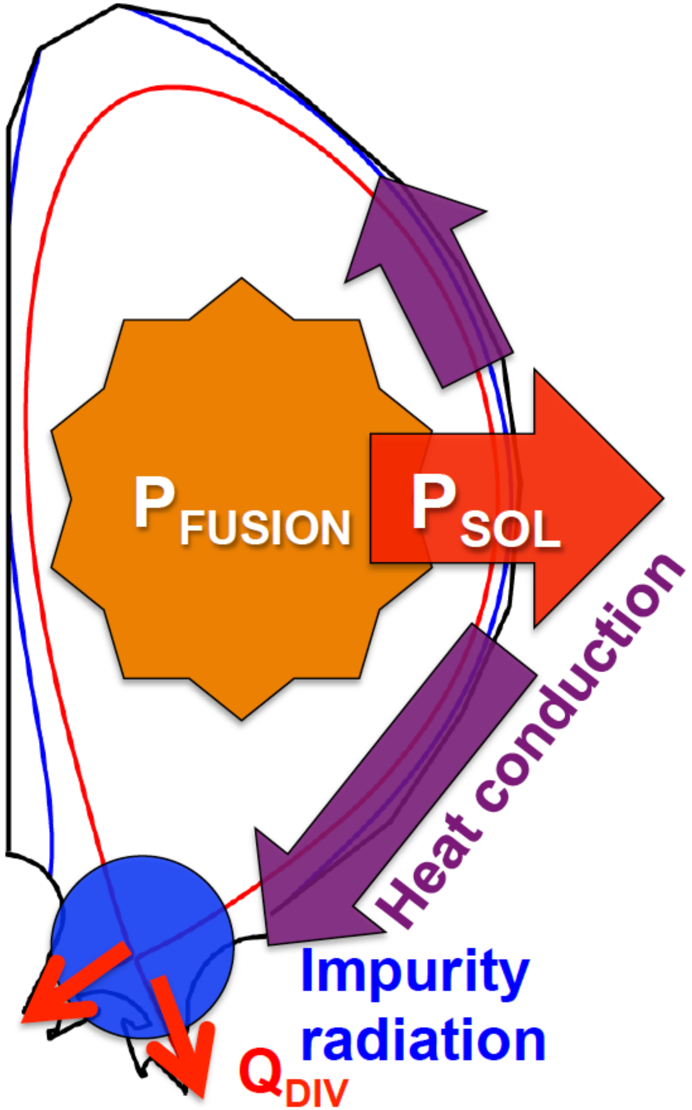
Divertor heat load control with impurity radiation will be necessary in JA-DEMO



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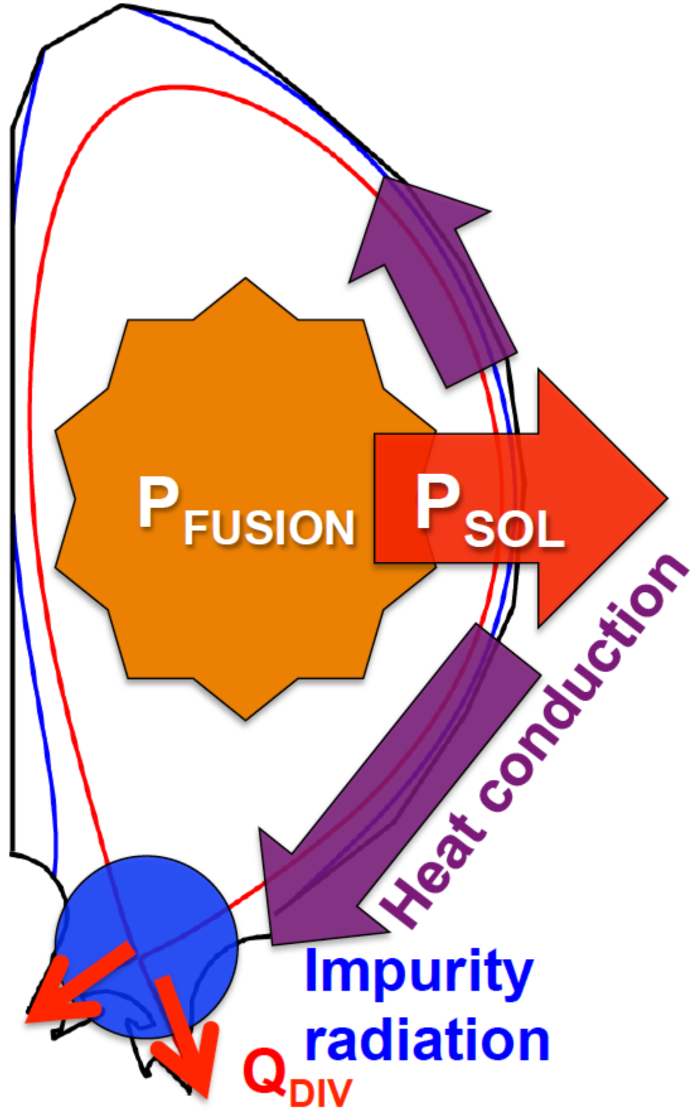

Q_{DIV} **control with radiation (Ne, Ar and Kr)**

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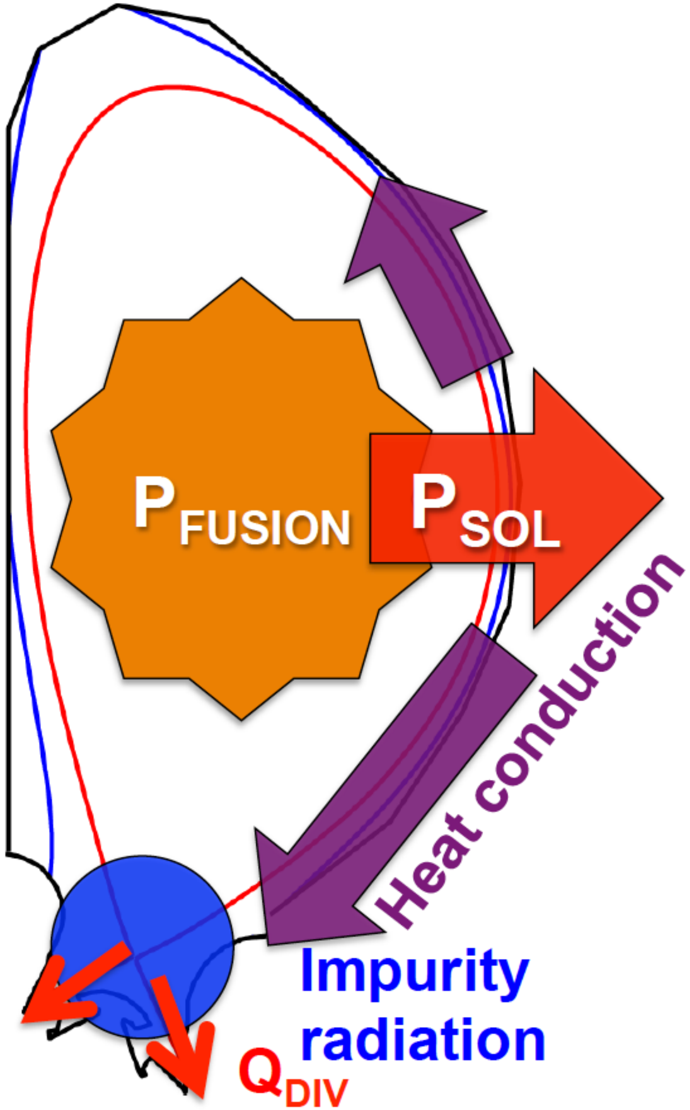

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Divertor/SOL plasma:
More radiation impurities needed to increase radiation loss. Z_{eff} ↑

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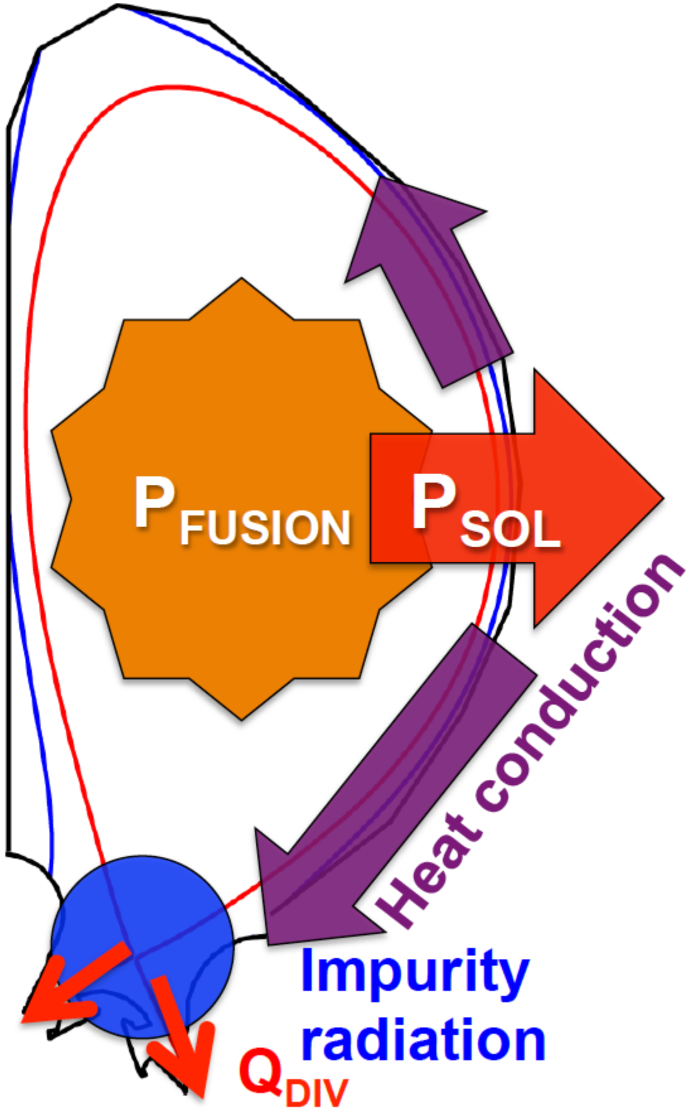

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Divertor/SOL plasma:
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Less radiation impurities needed to avoid fuel dilution. Z_{eff} ↓

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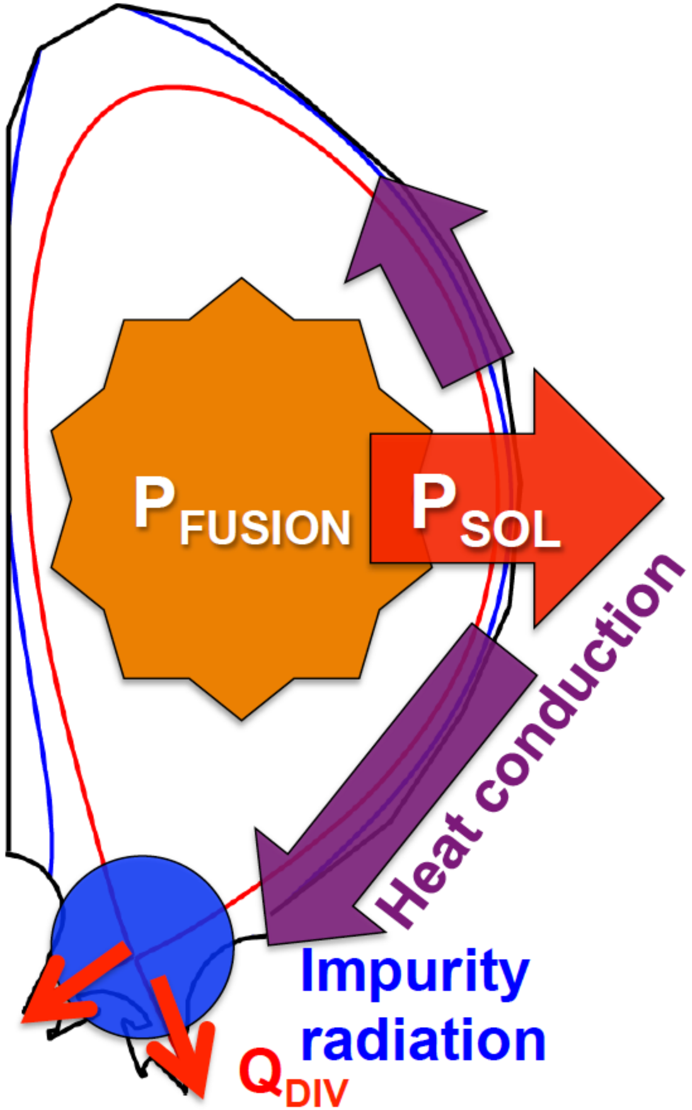

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Impurity control for JA-DEMO divertor

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What is SOLPS

Scrape-Off Layer Plasma Simulation

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B2.5
2D fluid plasma solver
(rectangular grid)

EIRENE
3D Monte-Carlo neutral code
(grid-independent)

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What is SOLPS

Scrape-Off Layer Plasma Simulation

Particle, energy sources and sinks

B2.5
2D fluid plasma solver
(rectangular grid)

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3D Monte-Carlo neutral code
(grid-independent)

Plasma background

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A multiplicity of SOLPS versions

	EIRENE96/99	EIRENE_facelift	EIRENE_2010
B2			
B2.5 + drifts			
B2.5+improved drifts model			

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A multiplicity of SOLPS versions

	EIRENE96/99	EIRENE_facelift	EIRENE_2010
B2	SOLPS4.0	SOLPS4.2	SOLPS4.3 (ITER divertor design)
B2.5 + drifts	SOLPS5.0 (most widely distributed version)	SOLPS5.1	
B2.5+improved drifts model	SOLPS5.2		SOLPS-ITER

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- **Effects of different Ar seeding rates on SOL and divertor plasma**

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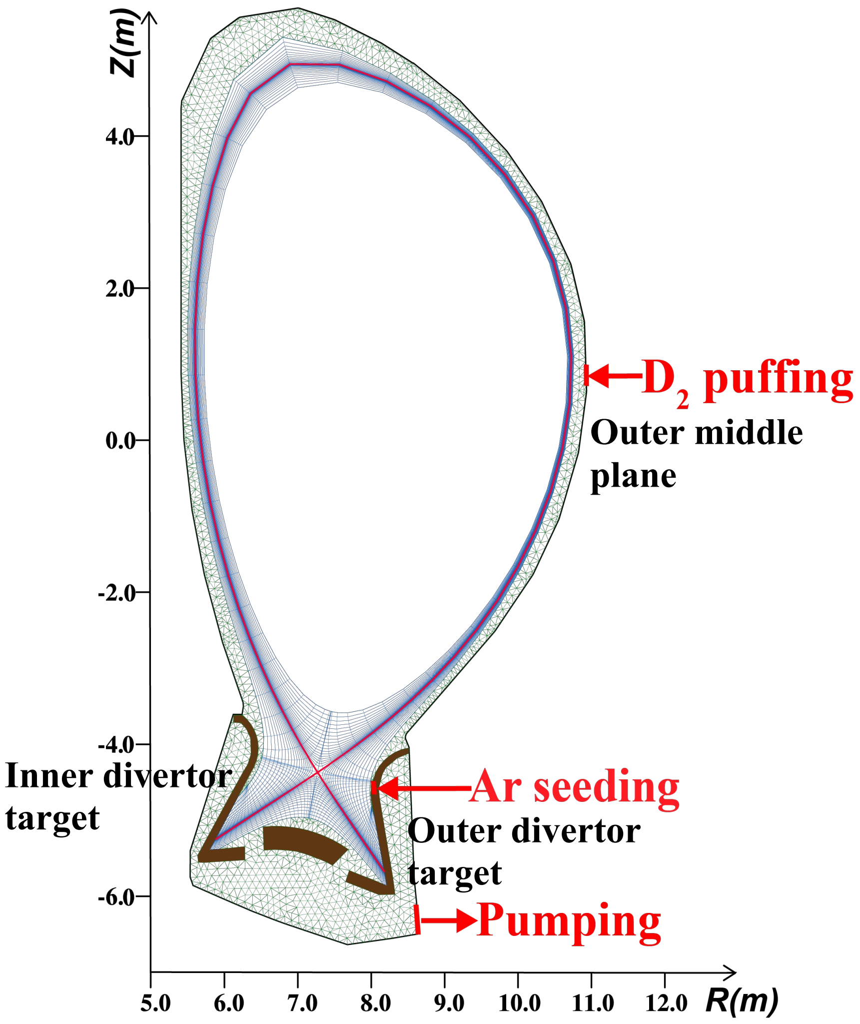
Basic input settings in SOLPS-ITER(Version 3.0.9) for JA-DEMO divertor

JA-DEMO



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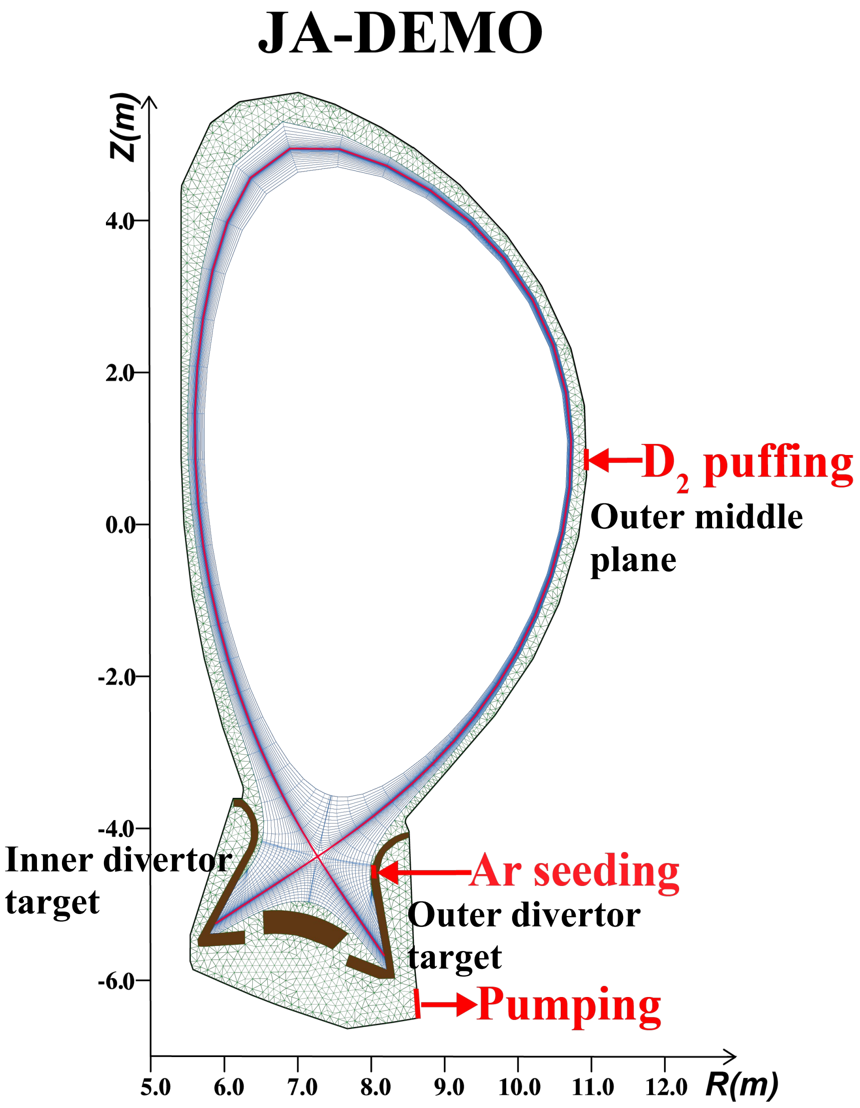

- $P_{core/edge}$ = 250 and 300 MW
- Plasma species: D, He and Ar
- D_2 puffing rate = 7.0×10^{22}atoms/s
- Ar seeding rate = 1.0×10^{19}, 5.0×10^{19} and 1.0×10^{20} atoms/s
- Recycling coefficient at the pumping surface = 0.99
- D = 0.3 m^2/s, $X_e = X_i$ = 1.0 m^2/s
- Without drift model

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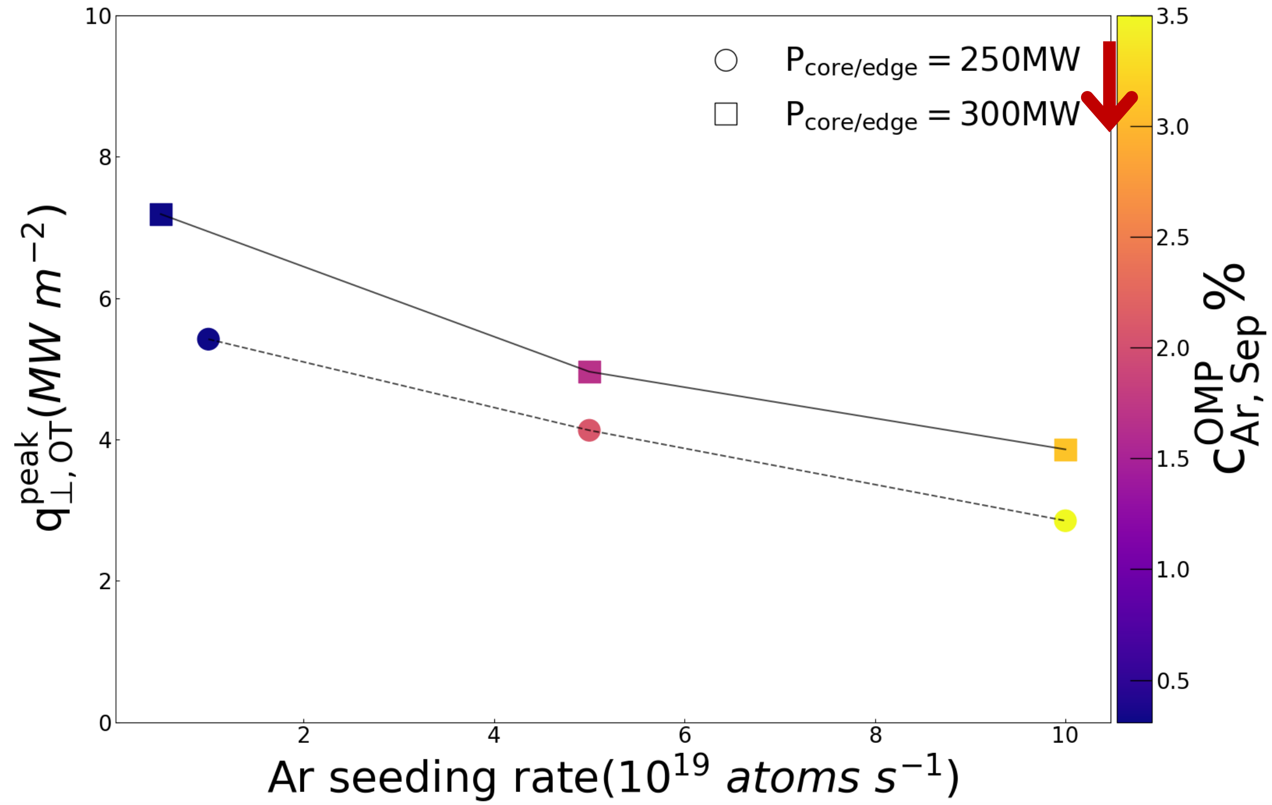
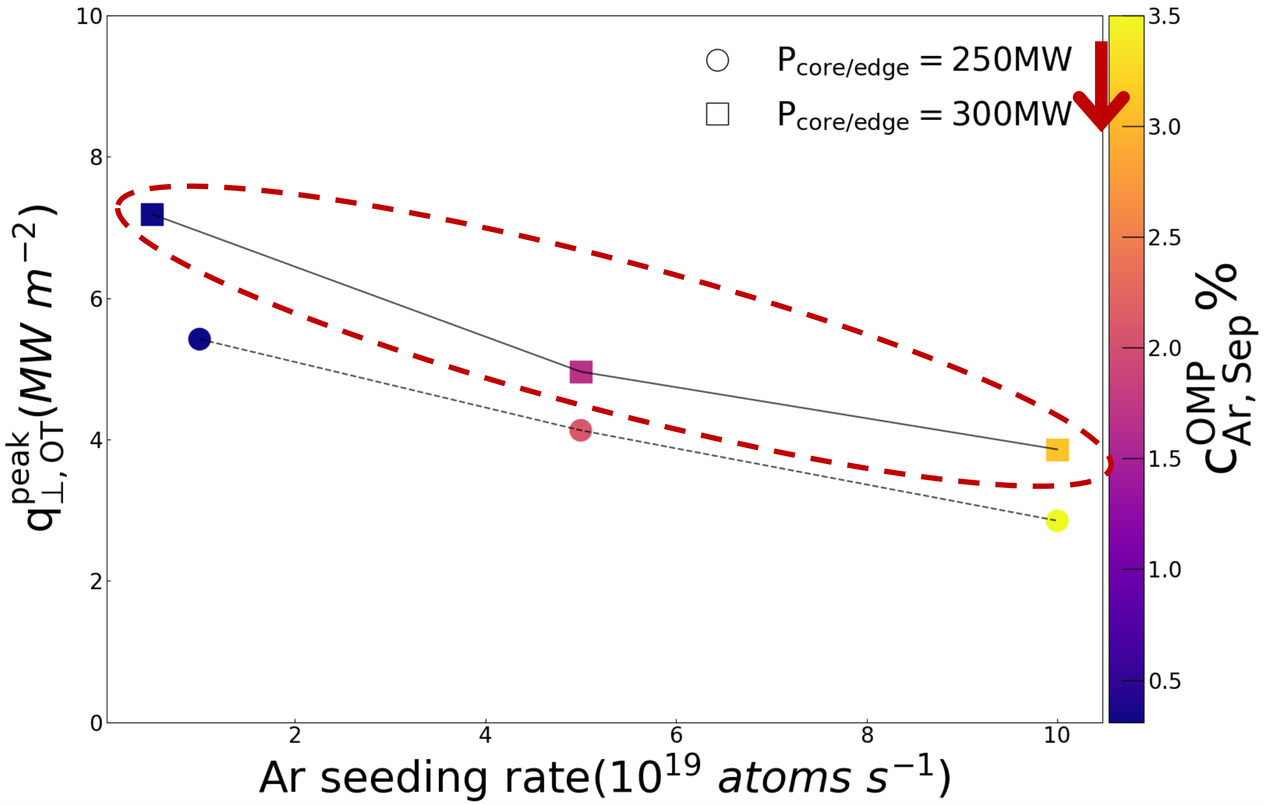
The peak heat flux density on the outer divertor target (Scan of Ar seeding rate and $P_{core/edge}$)



- ✓ As Ar seeding rate is increased gradually from 1.0e19 atom/s to 1.0e20 atom/s, the corresponding peak heat load on the outer divertor target are reduced gradually.
- ✓ Under the condition of higher power entering SOL($P_{core/edge}$ = 300MW), the heat load on the outer divertor target will be also controlled well under 10 MW/m^2.

QST

The peak heat flux density on the outer divertor target (Scan of Ar seeding rate and $P_{core/edge}$)



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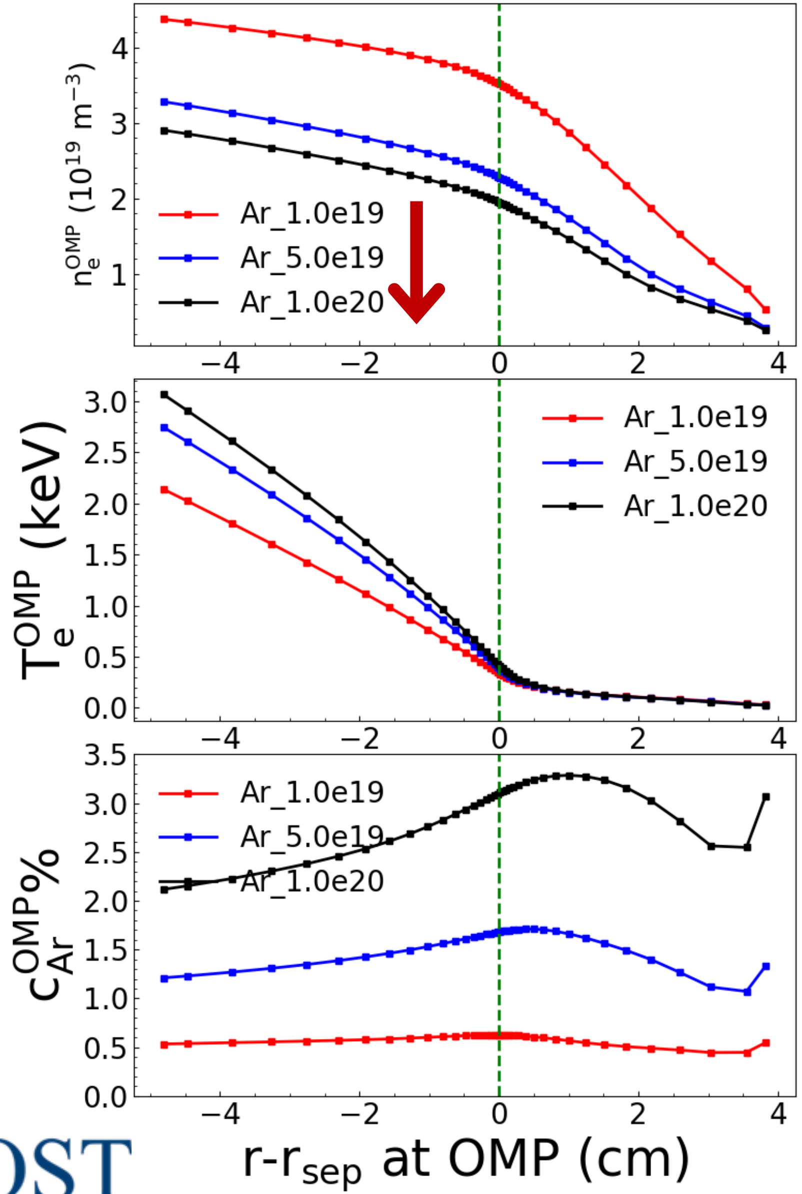
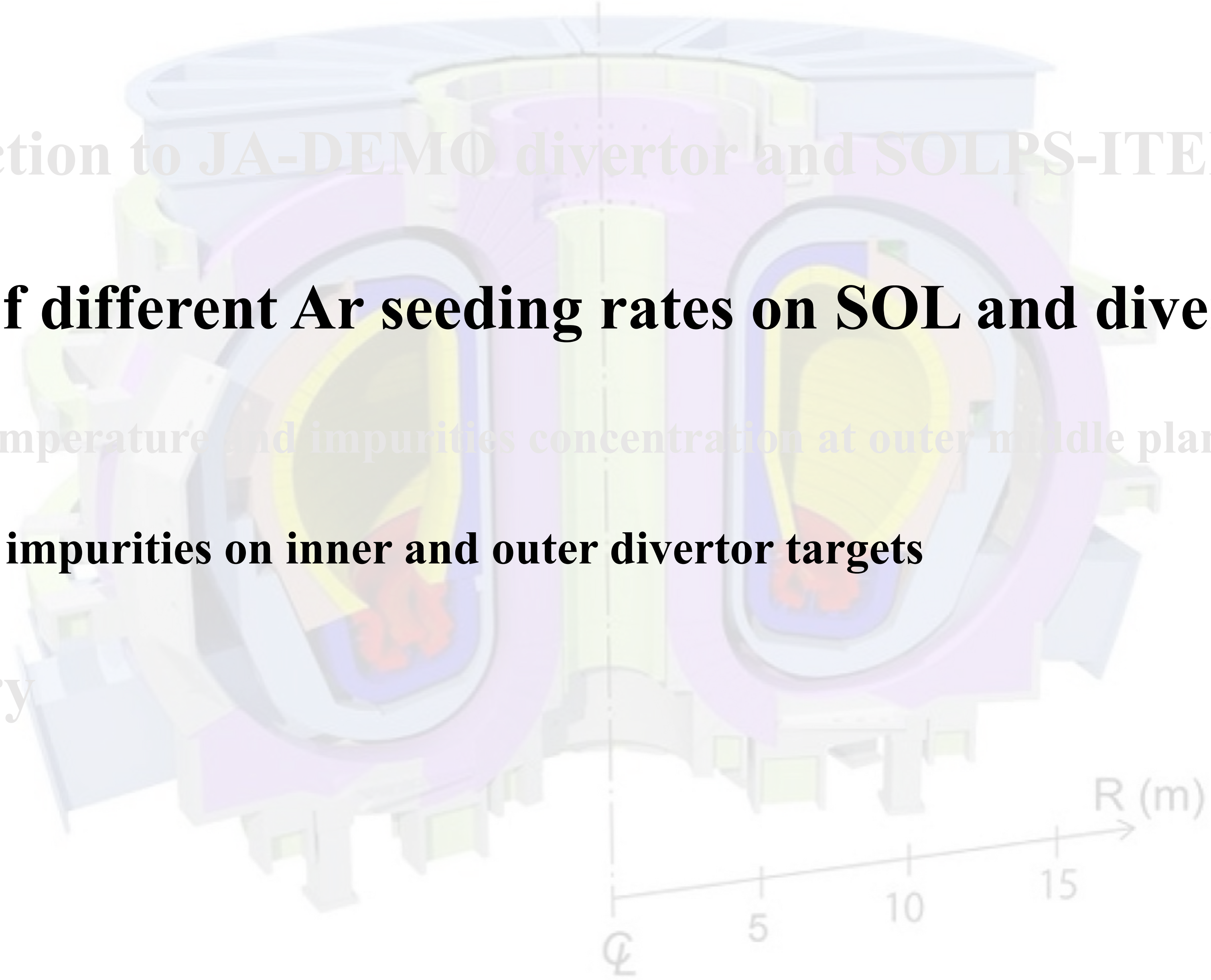
Upstream profiles of electron density, electron temperature, He/Ar ions concentration, He/Ar ion density at the outer mid-plane for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



- ✓ **As Ar seeding rate is increased, the separatrix electron density at outer middle plane is reduced.**
- ✓ **Owing to more and more Ar seeded from outer divertor region, Ar ion density at outer middle plane is also increased.**

Outline



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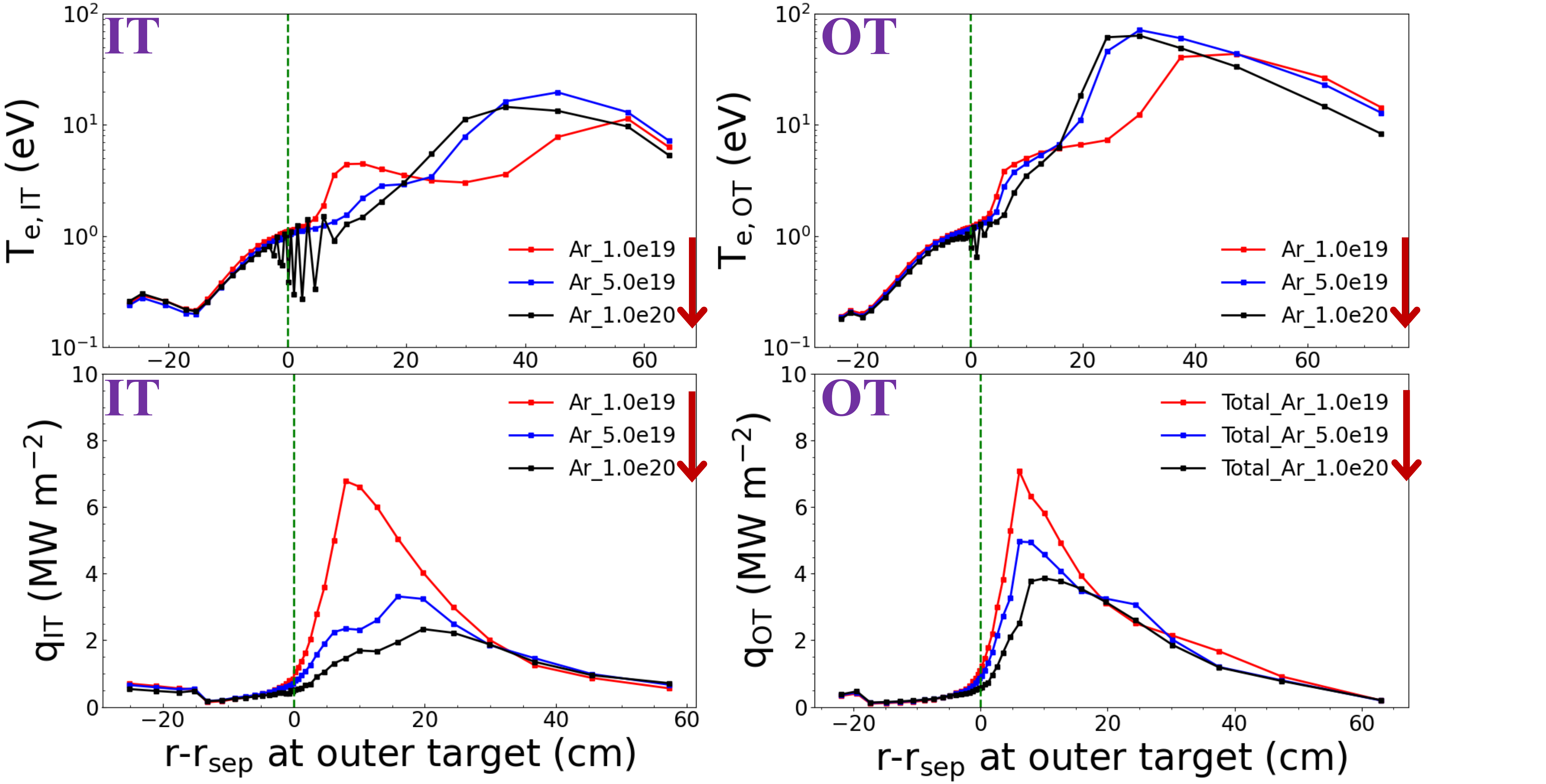
Electron temperature and heat flux density on the inner and outer divertor targets for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



✓ **As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s with increasing divertor radiation, the peak heat load at inner and outer divertor target are reduced separately.**

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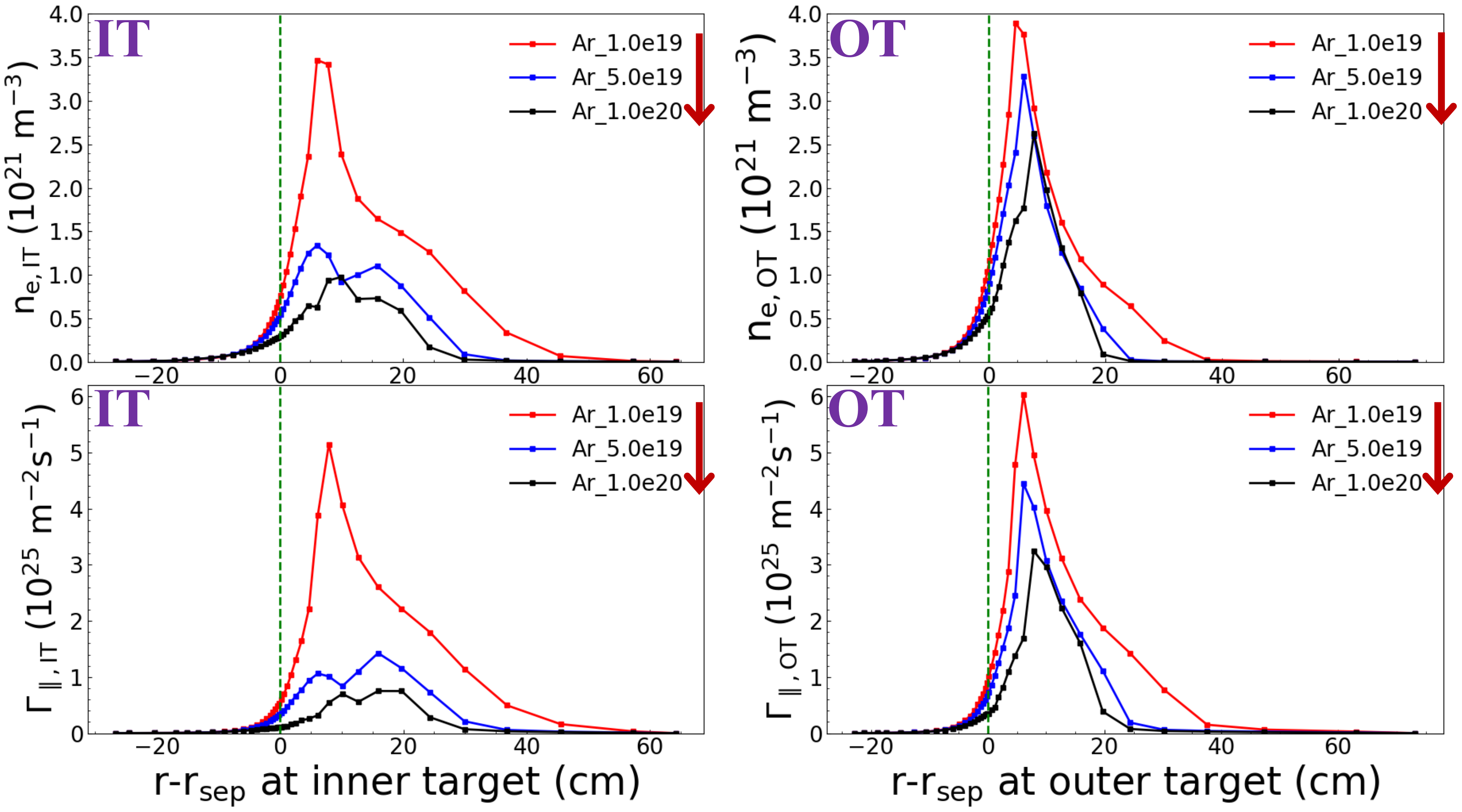
Electron density and parallel particle flux density on the inner and outer divertor targets for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



- ✓ As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s, the electron density and particle flux density at the divertor targets reduced, which shows that divertor enters detachment.

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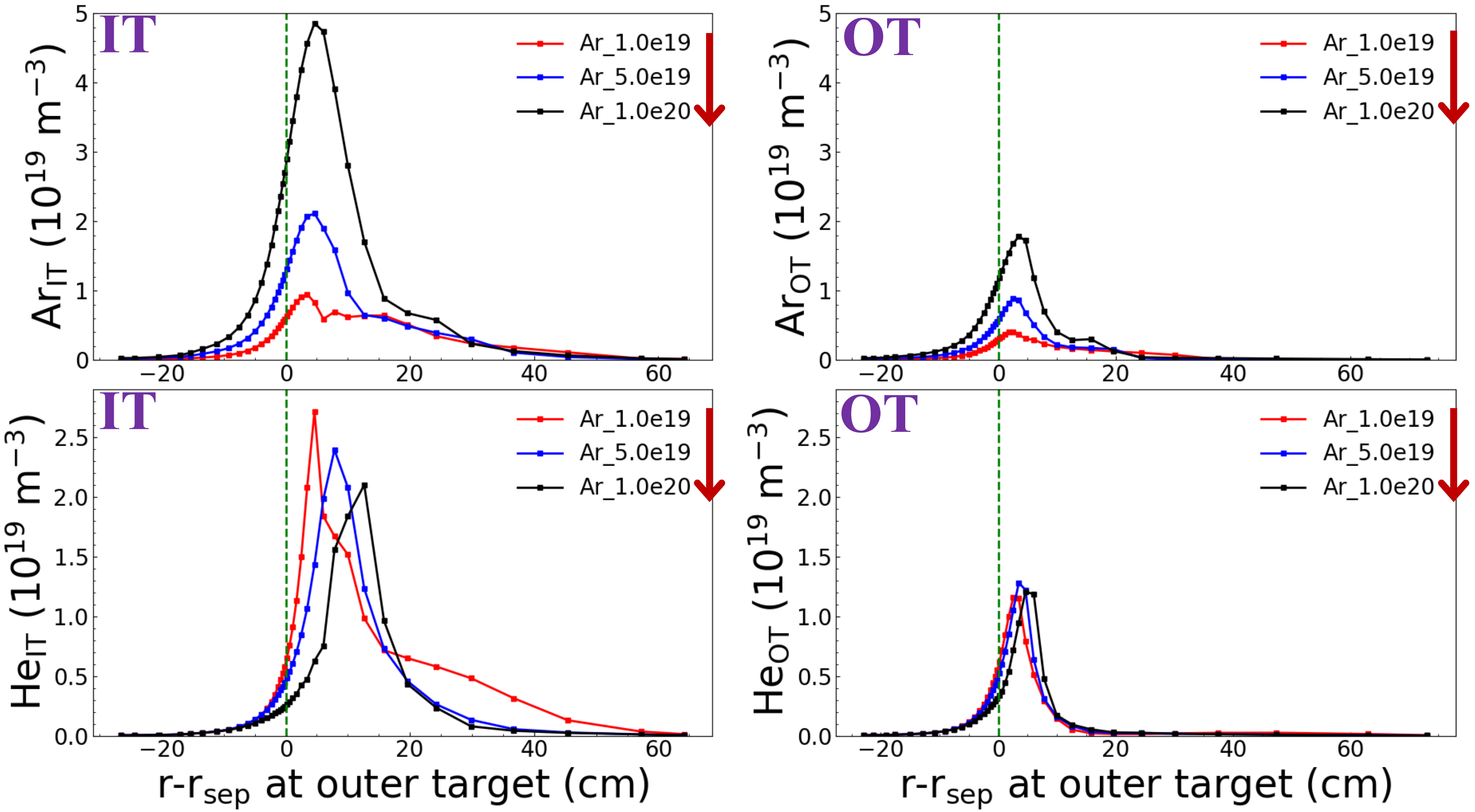
Ar ion density and He ions density on the inner and outer divertor targets for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



✓ **As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s, Ar density are increased at the inner and outer divertor target.**

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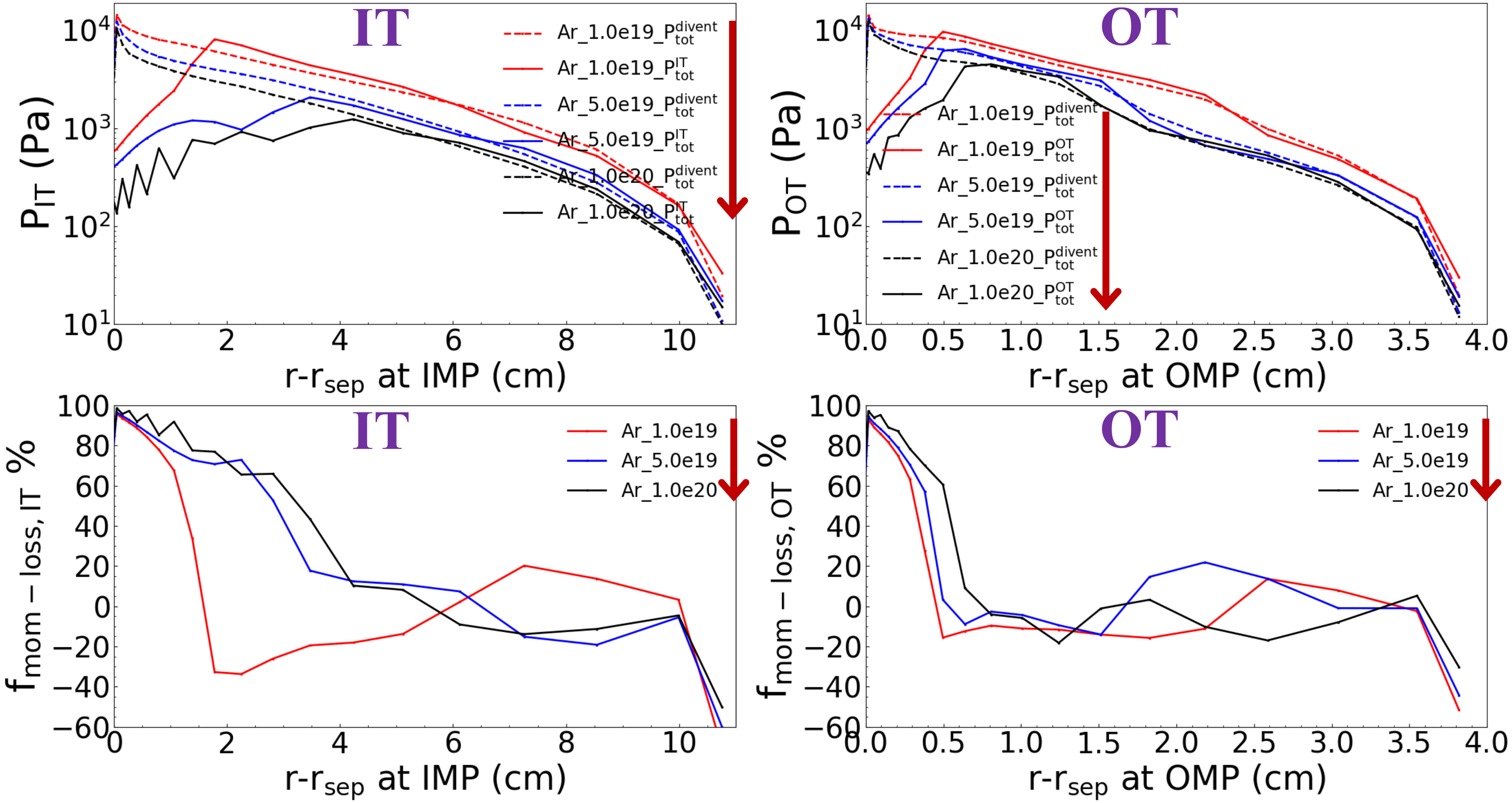
Momentum loss for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



✓ **As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s, the momentum loss is extended to outer flux surface.**

$f_{mom\text{-}loss} = 1 - P_{target} / P_{div\_entrance}$

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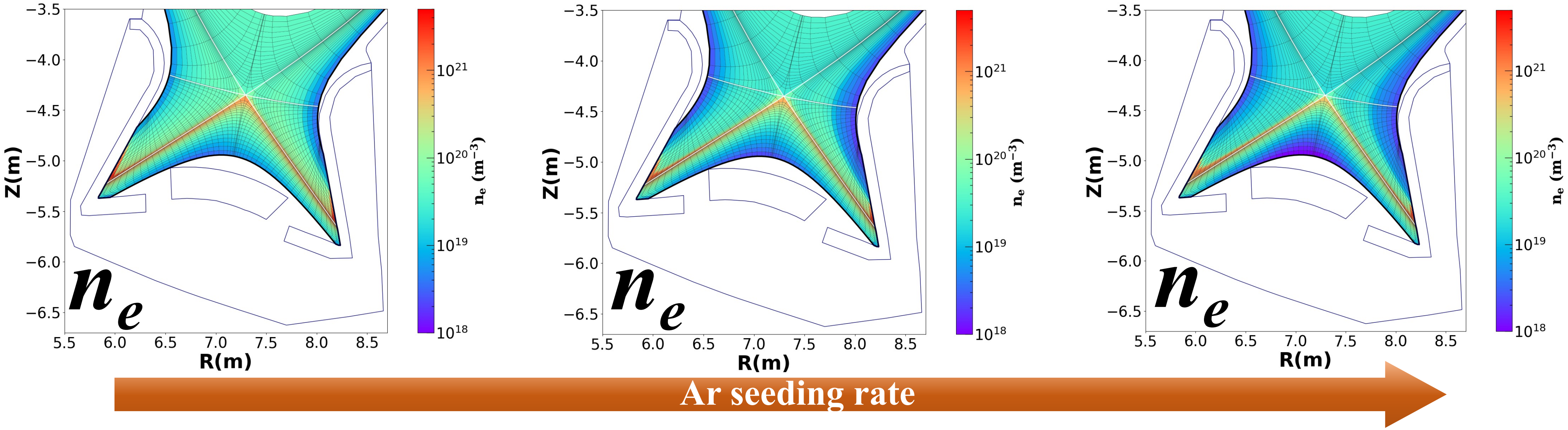
2D distributions of electron density and Ar density for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



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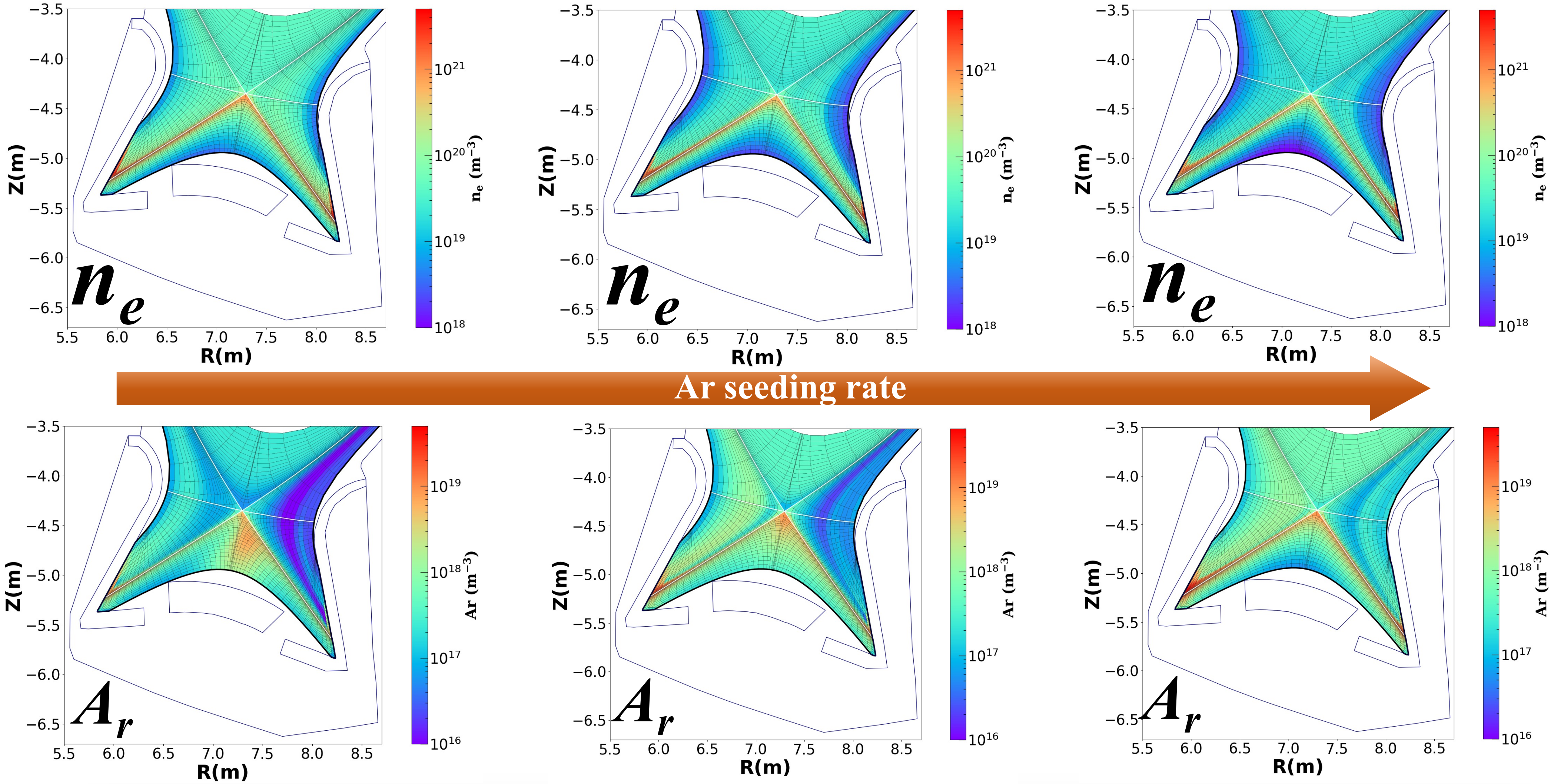
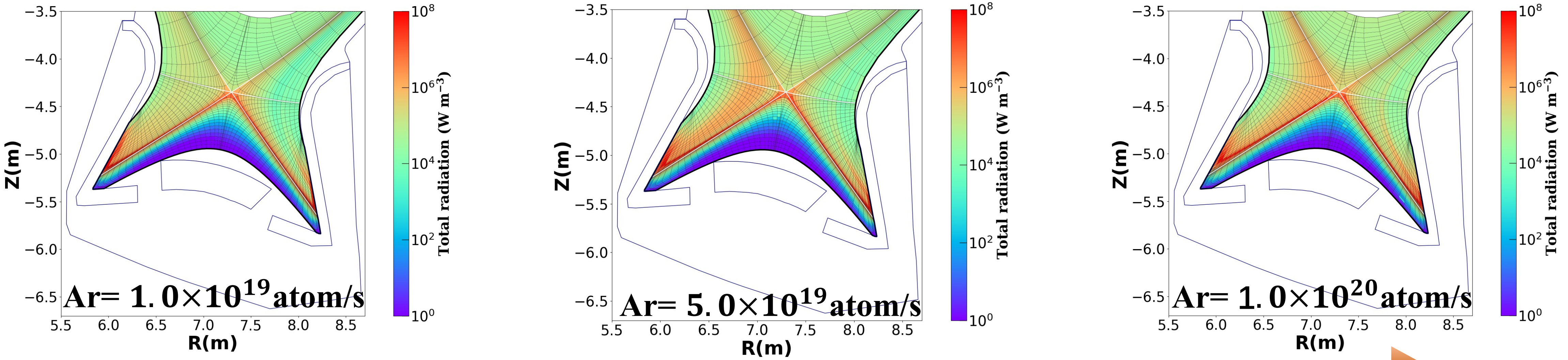


✓ **As Ar seeding rate is increased, Ar density is increased while electron density is reduced.**

2D distributions of total radiation for cases with different Ar seeding rates($P_{core/edge}$ = 300MW)



Ar seeding rate

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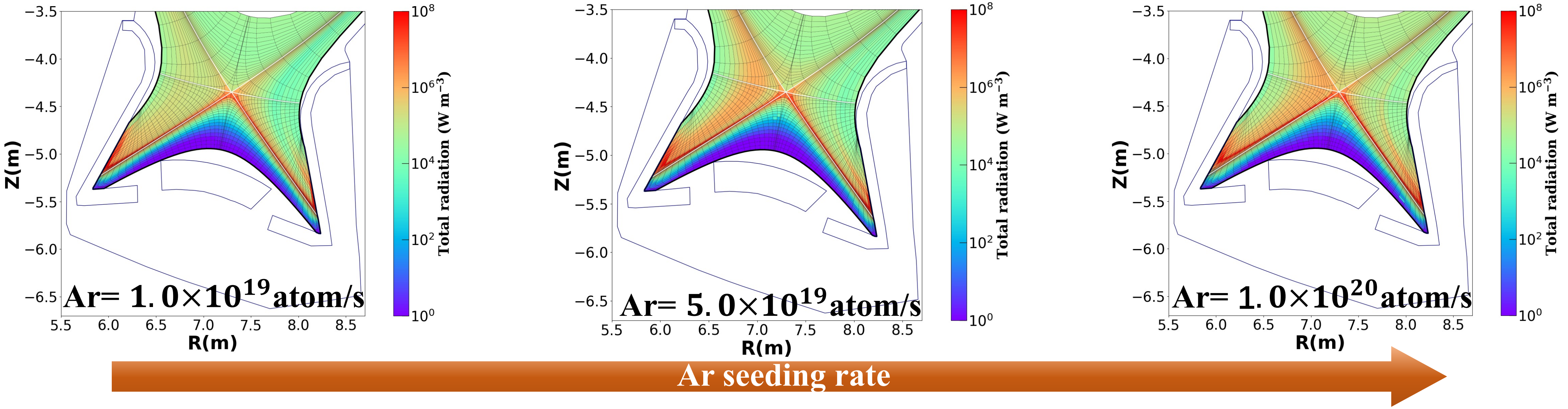

	$P_{core/edge}$ (MW)	P_{sep} (MW)	Total radiation (MW)	Total radiation for IT (MW)	Total radiation for OT (MW)	Total radiation for SOL (MW)	f_{rad}^{div}
Ar=1.0e19/s	300	284.3	170.5(Ar=147.1)	72.9	70.9	16.6	56.4%
Ar=5.0e19/s	300	273.2	194.1(Ar=175.2)	84.2	78.1	18.4	66.1%
Ar=1.0e20/s	300	266.3	206.5(Ar=190.3)	78.9	88.9	20.9	70.9%

✓ As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s, the radiation power is increased significantly.

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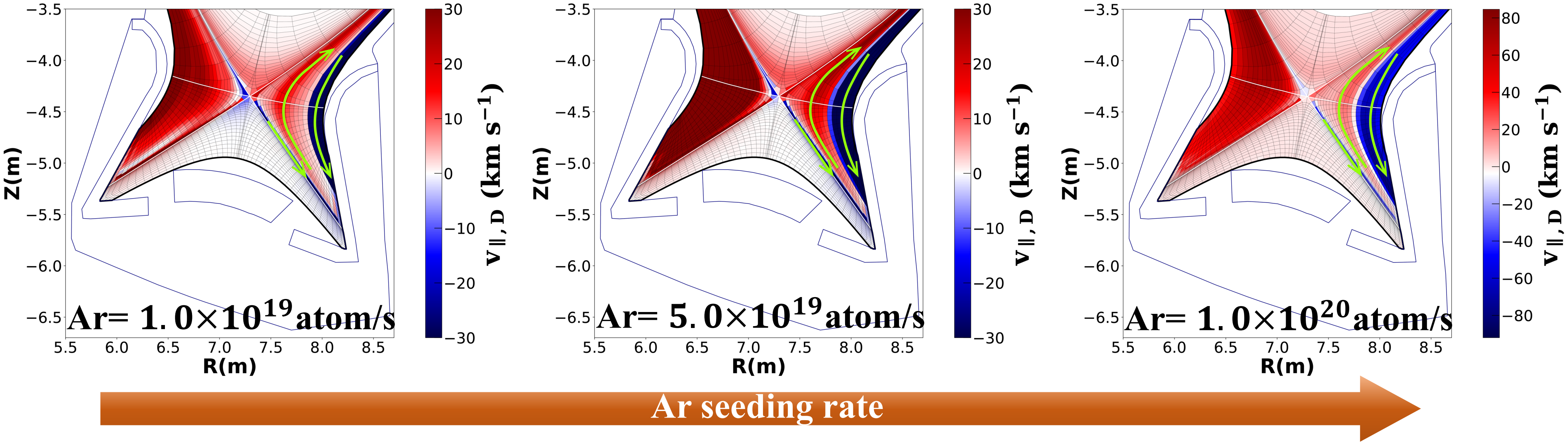
2D distributions of parallel velocity(D) for cases with different Ar seeding rates($P_{core/edge}$ = 300MW) (Flow reversal)



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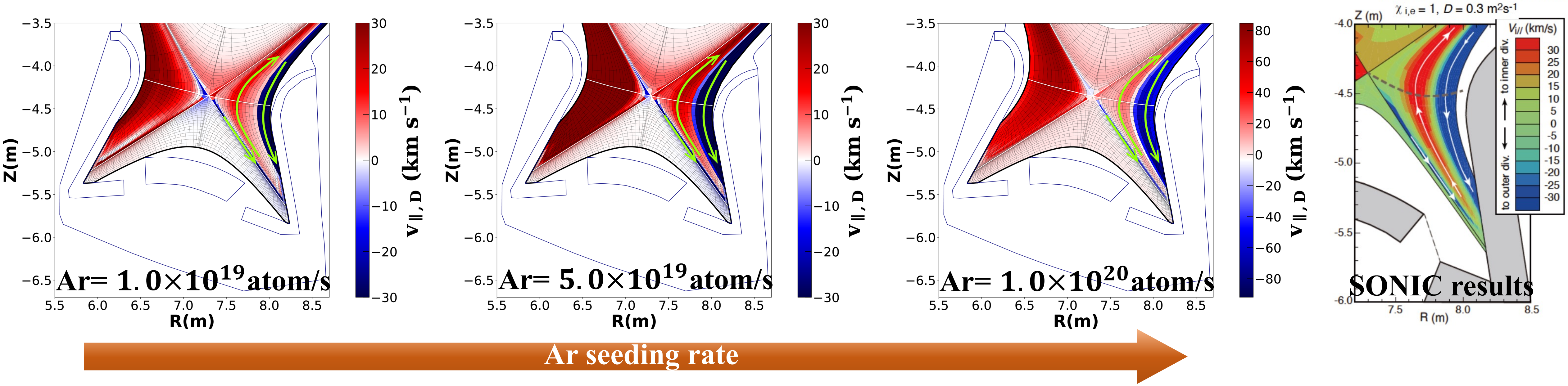
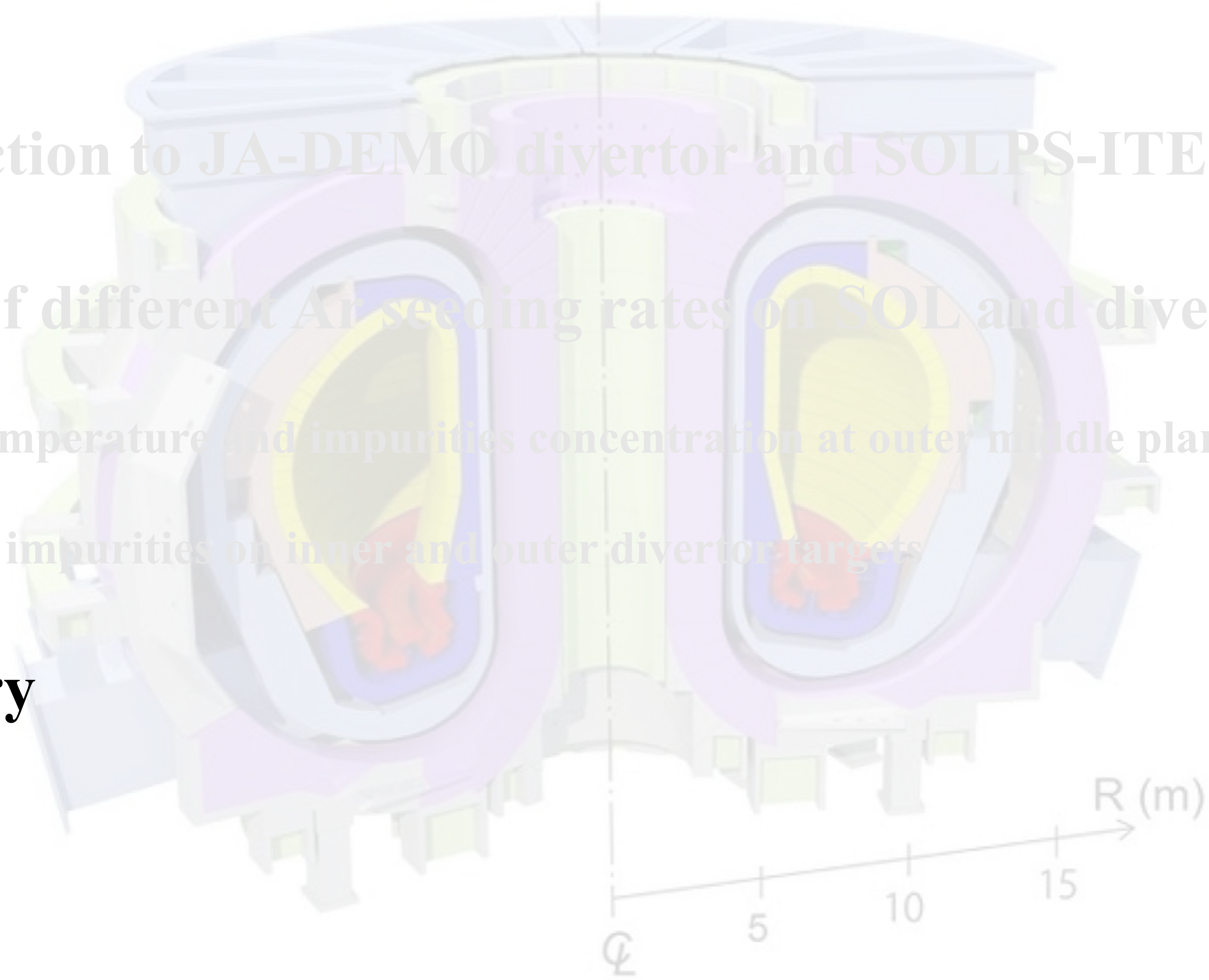


- ✓ In the outer divertor region there is the flow reversal, which is consistent with SONIC results.
- ✓ As Ar seeding rate is increased from 1.0e19 atom/s to 1.0e20 atom/s, the region for the flow reversal in SOL is reduced.

Outline



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Thank you for your attention!

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