Third IAEA Technical Meeting on Divertor Concepts

The physical design of EAST lower tungsten divertor by SOLPS modeling

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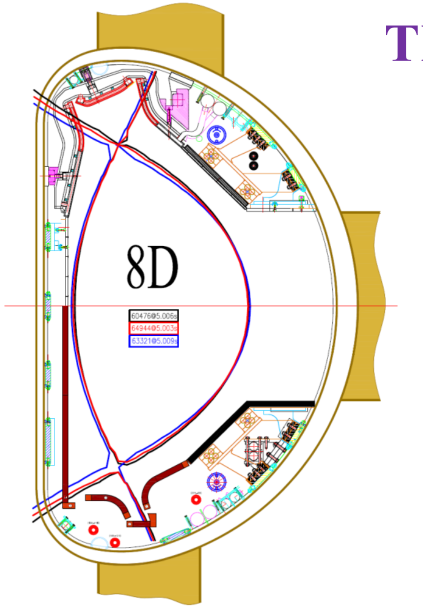
The physical design requirements for the EAST lower tungsten divertor

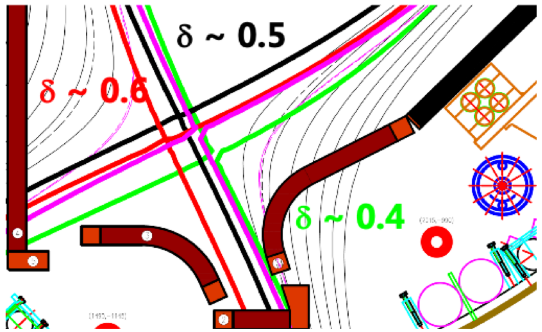
The lower graphite divertor of EAST tokamak becomes to the main limitation to the achievement of the further high power long-pulse discharge.

Divertor requirements:

- Heat flux to the target < 10 MW/m^2
- T_e< 10 eV includes the far SOL at the target
- W impurity control and efficient particle removal



The range of triangularity
δ = 0.4-0.6



The compatibility of double null and different triangularity discharges should be satisfied

The design for EAST lower divertor

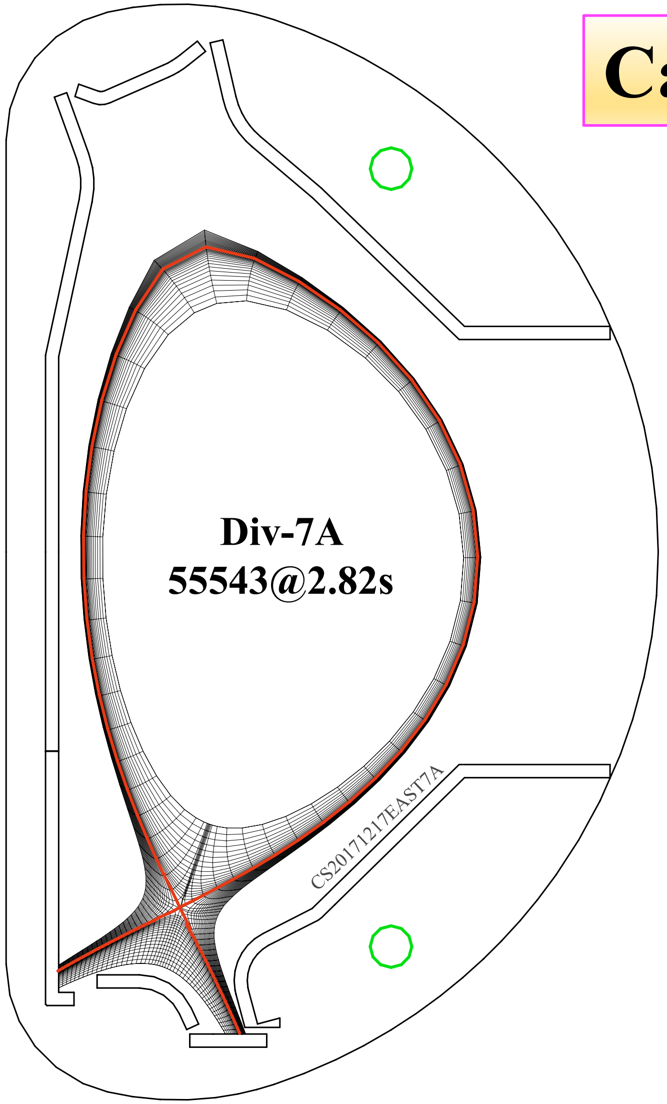
Physical design by considering the divertor shapes, external impurity seeding , W target erosion and W impurity transport.

- The divertor shape
- The target angle
- The impact of pumping
- The pump location

→ **The physical design of divertor shape**

→ **The performance during impurity seeding & application of QSFD**

The SOLPS modeling is applied for the EAST lower divertor design



Carbon PFM is assumed at the beginning of the design

SOLPS5.0/Eirene99

- P_{SOL}= 4.0MW

Simulation species:

D^0, D^+, C^0- C^{6+}

Physical and chemical sputtering are included:

Physical sputter yield: Roth formula

Chemical sputter yield: 0.01

Radial transport coefficients:

D= 0.3 m^2/s

χ = 1.0 m^2/s

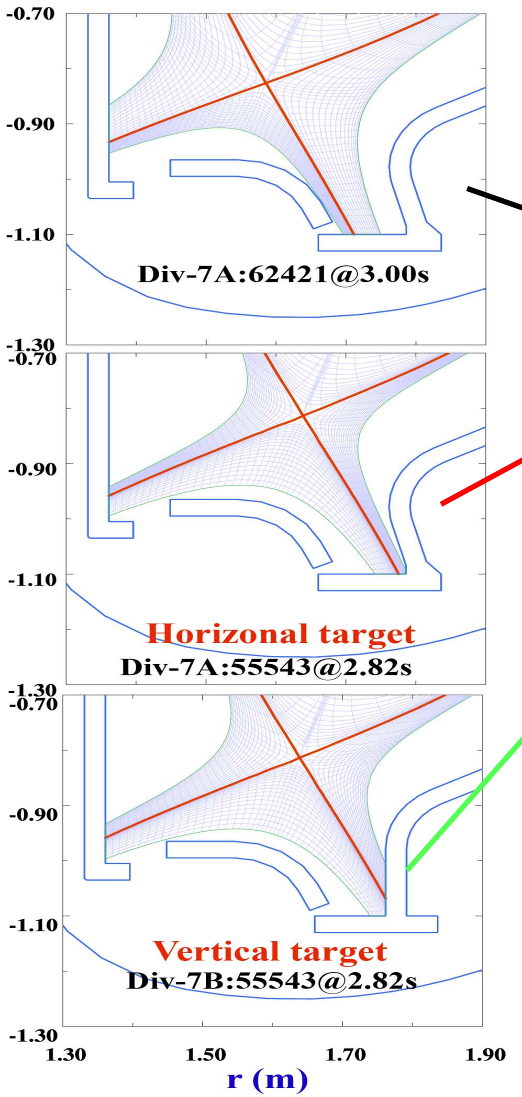
No gas puffing or drifts included.

The density scan shows the divertor shape has significantly impact on the divertor plasma

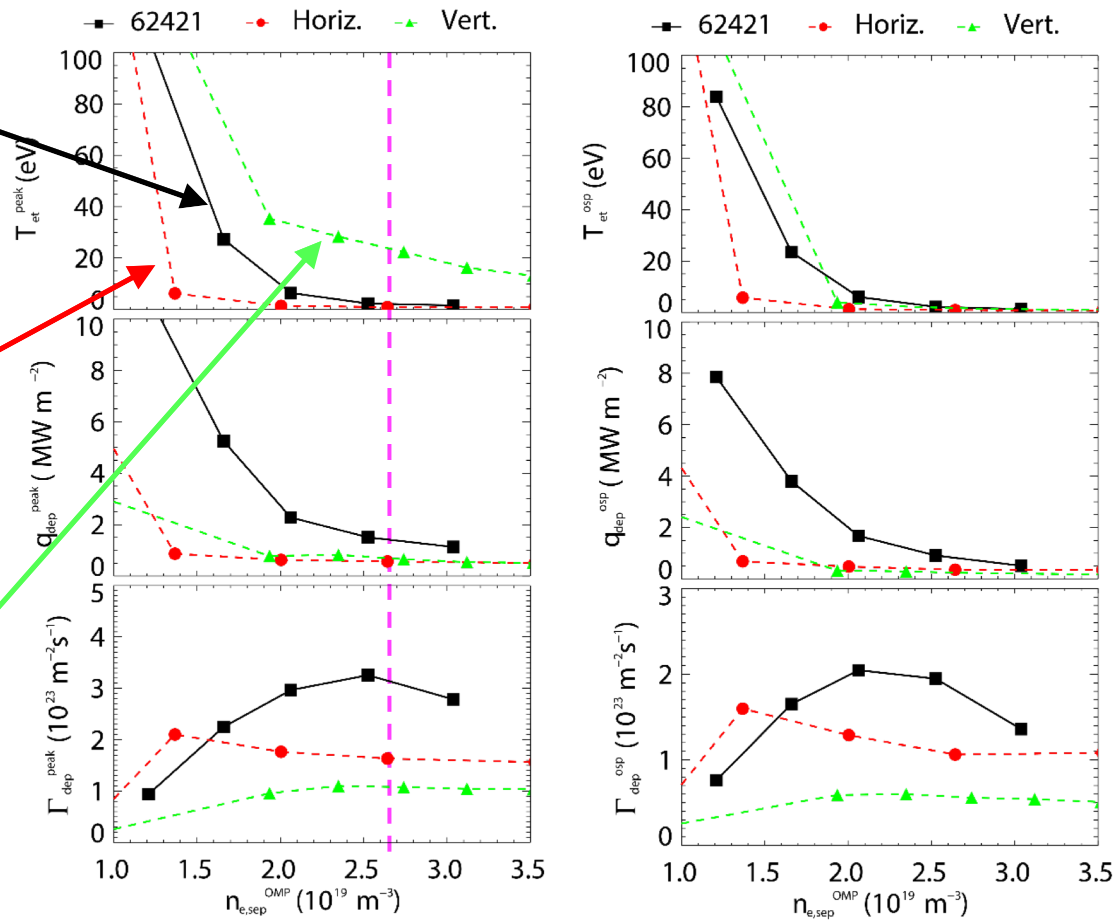
Horizontal target
(SP far from corner)

Horizontal target
(SP closed to corner)

Vertical

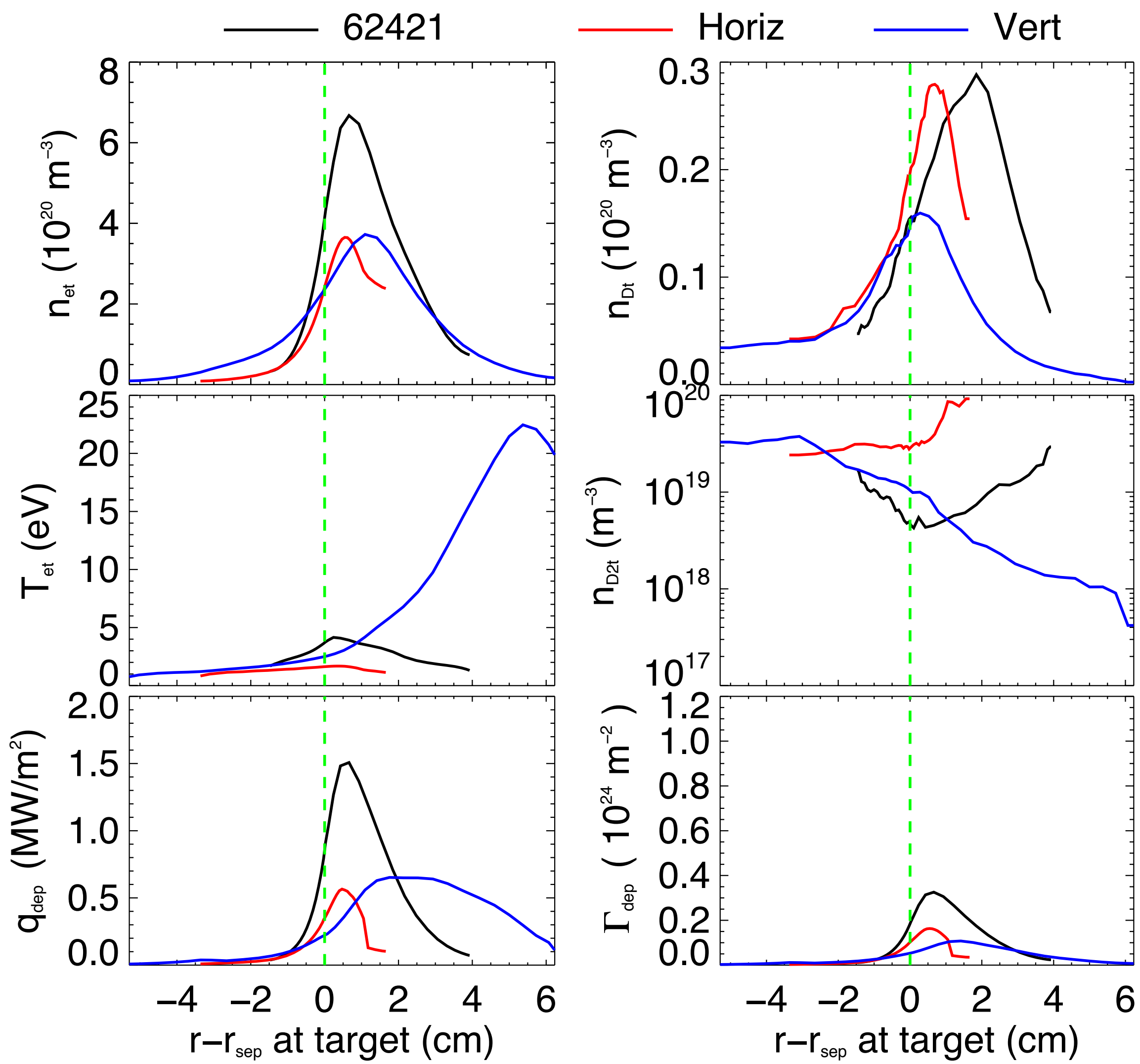


Peak values | **The values at OSP**



Horizontal target with the OSP near the corner is the best

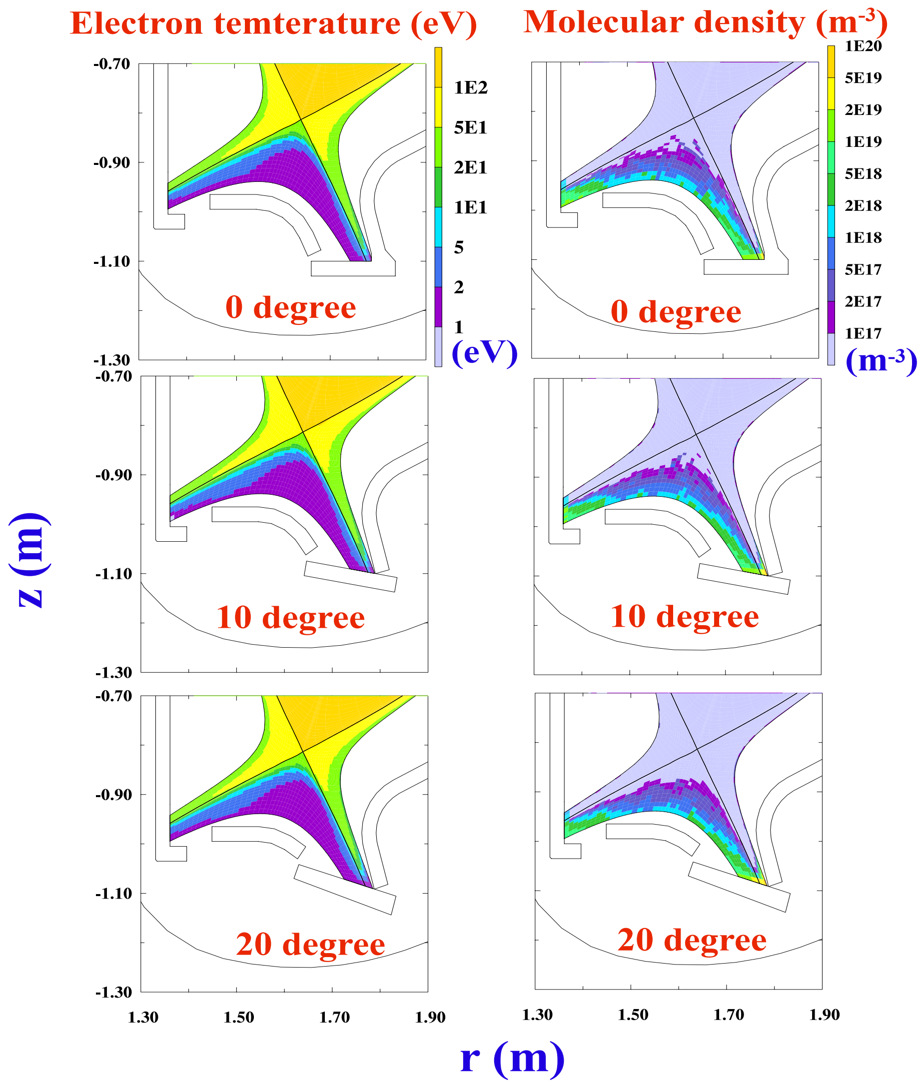
The divertor shape changes the divertor plasma profiles remarkably

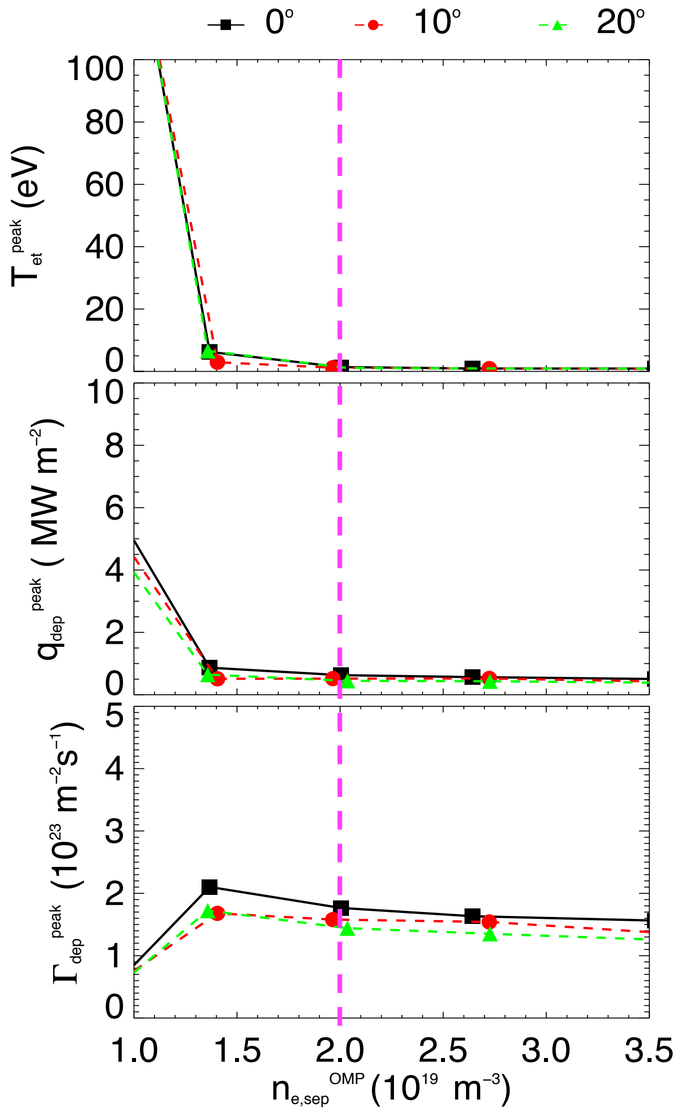


The plasma profiles along the outer divertor, the plasma density at separatrix of OMP is fixed to 2.6e19 m^{-3}.

- **The horizontal target achieves full detachment**
- **Vertical target achieves detachment at OSP, but has high temperature at far SOL.**
- **Horizontal far SP target (62421) has the highest heat flux density.**

The divertor target angle influences the divertor plasma slightly



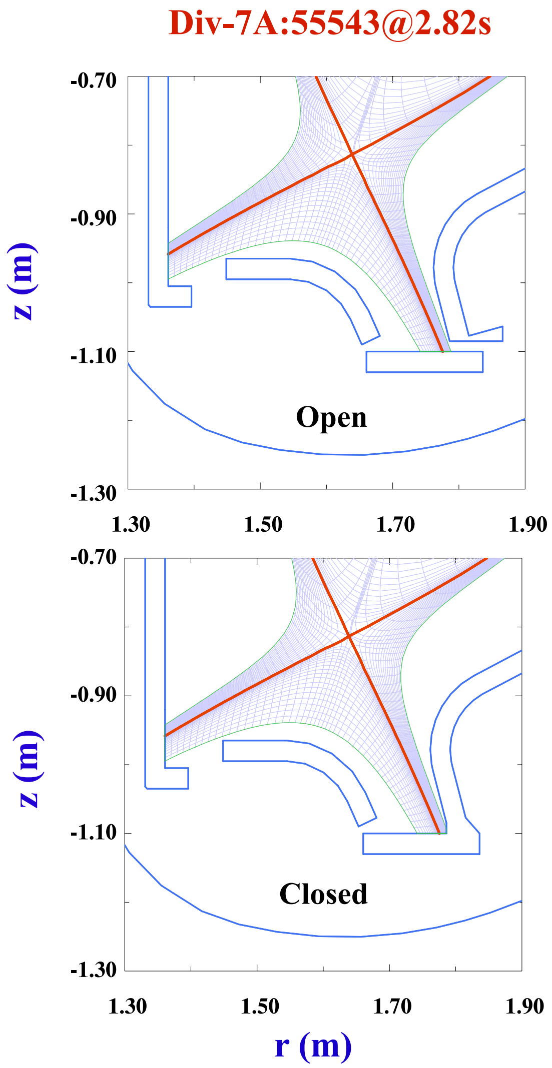


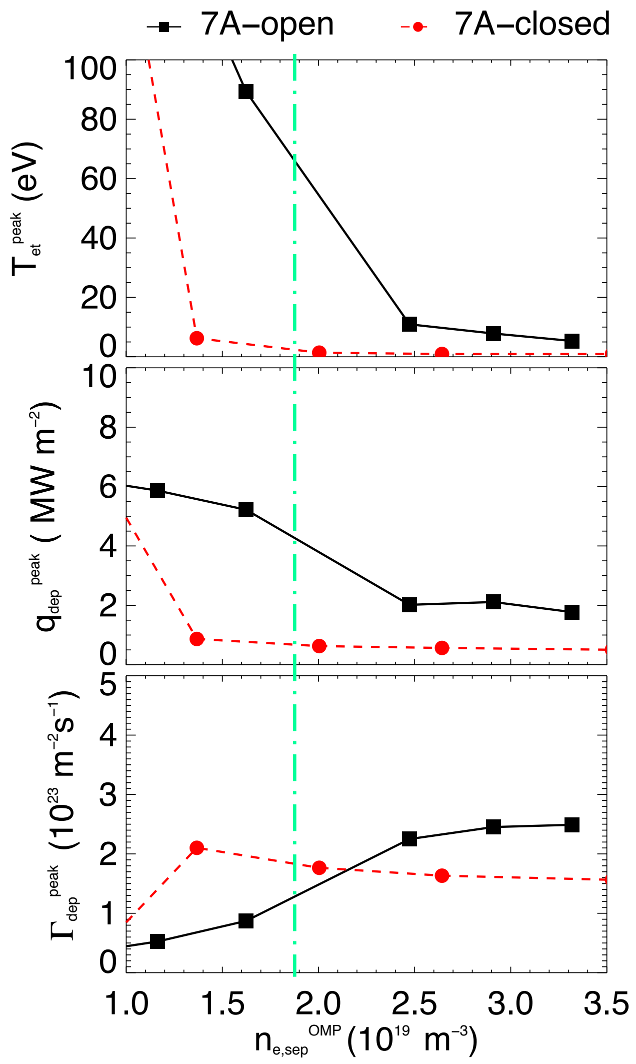
- The target angle plays slightly role in the divertor plasma, as the ploidal plasma incident angle is still large.
- The 0 angle target is preferred by considering engineering construction.

The divertor closure shows great impact on the divertor plasma (W, W/O pump)

Pump at the SOL bottom

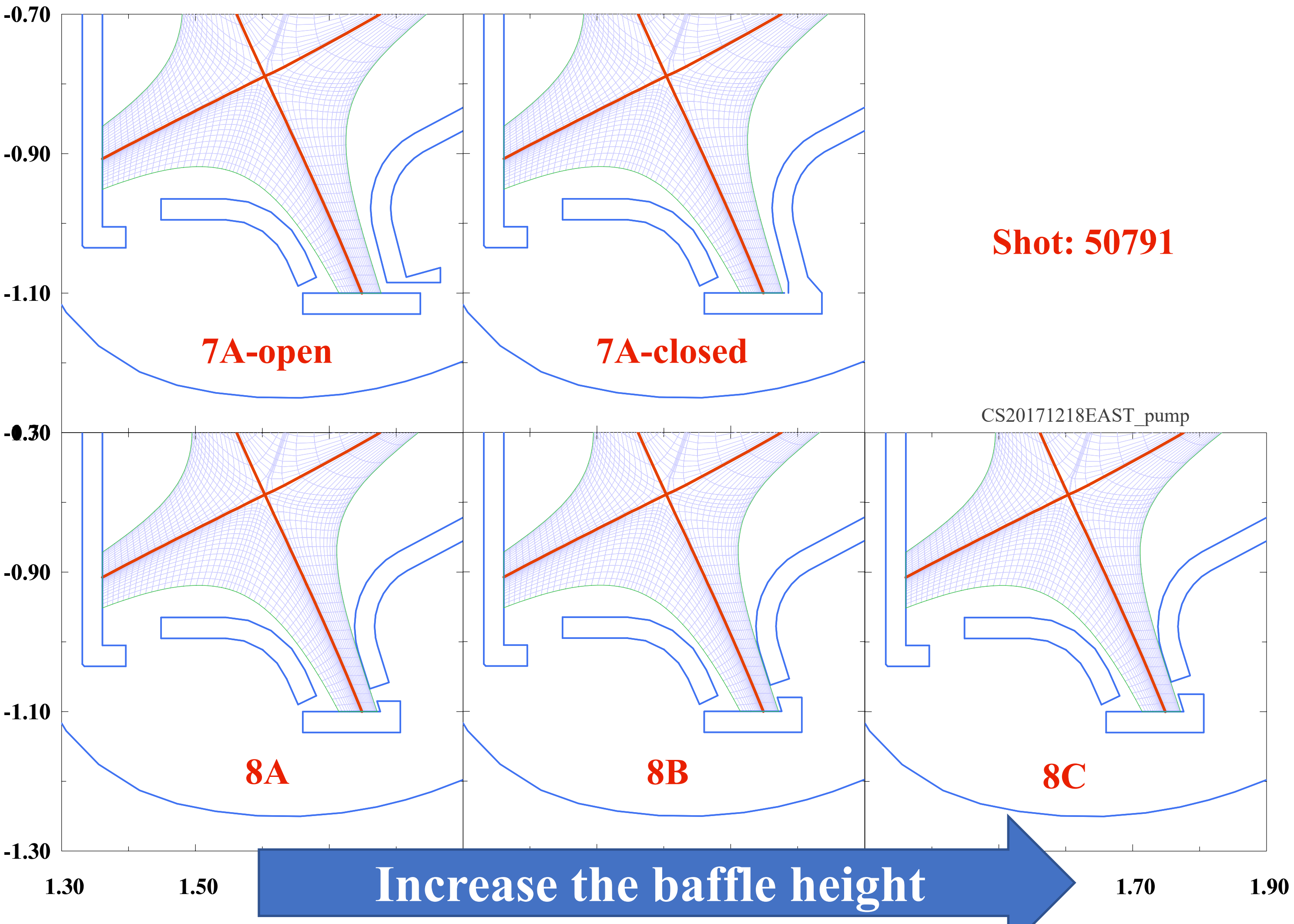
No pump at the SOL bottom

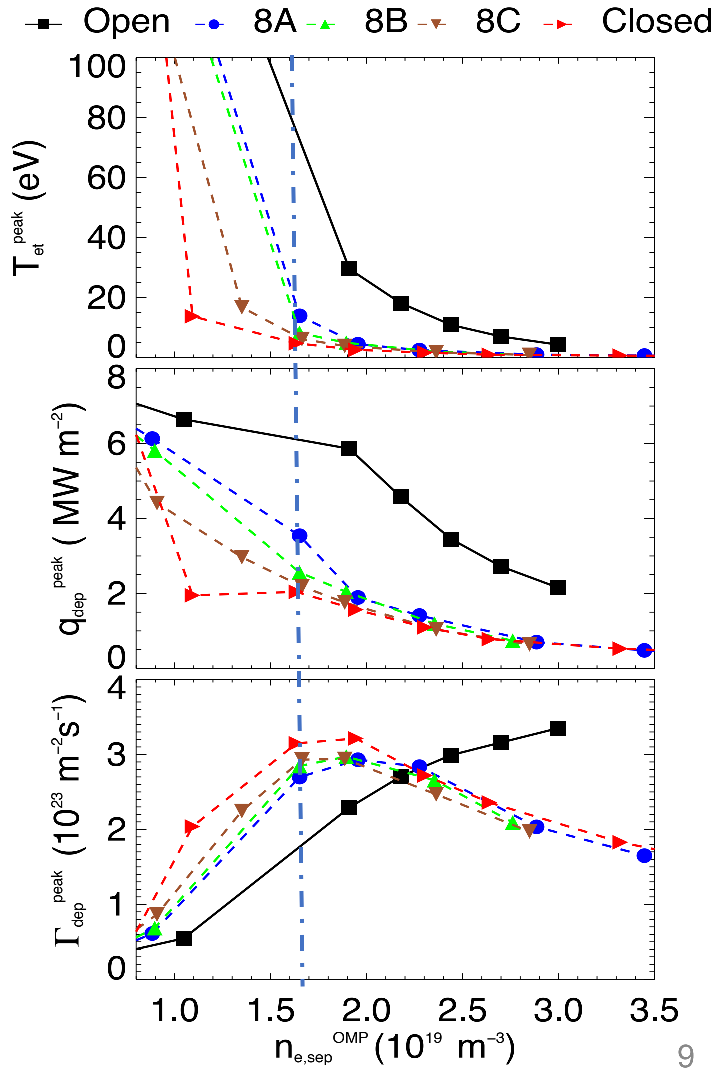




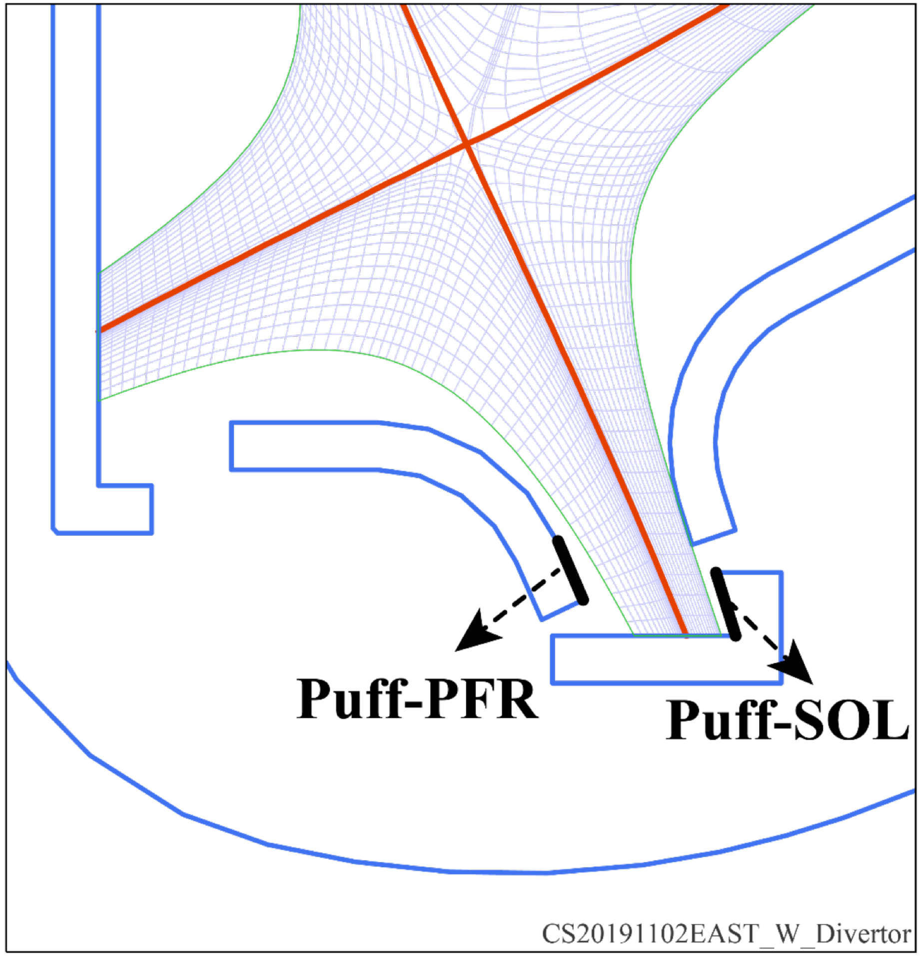
- Adding the pump at the bottom of SOL makes the divertor more open.
- The divertor plasma is changed greatly by the divertor closure.
- The open divertor is not good for the detachment

The location of the pump has significant impact on the divertor plasma





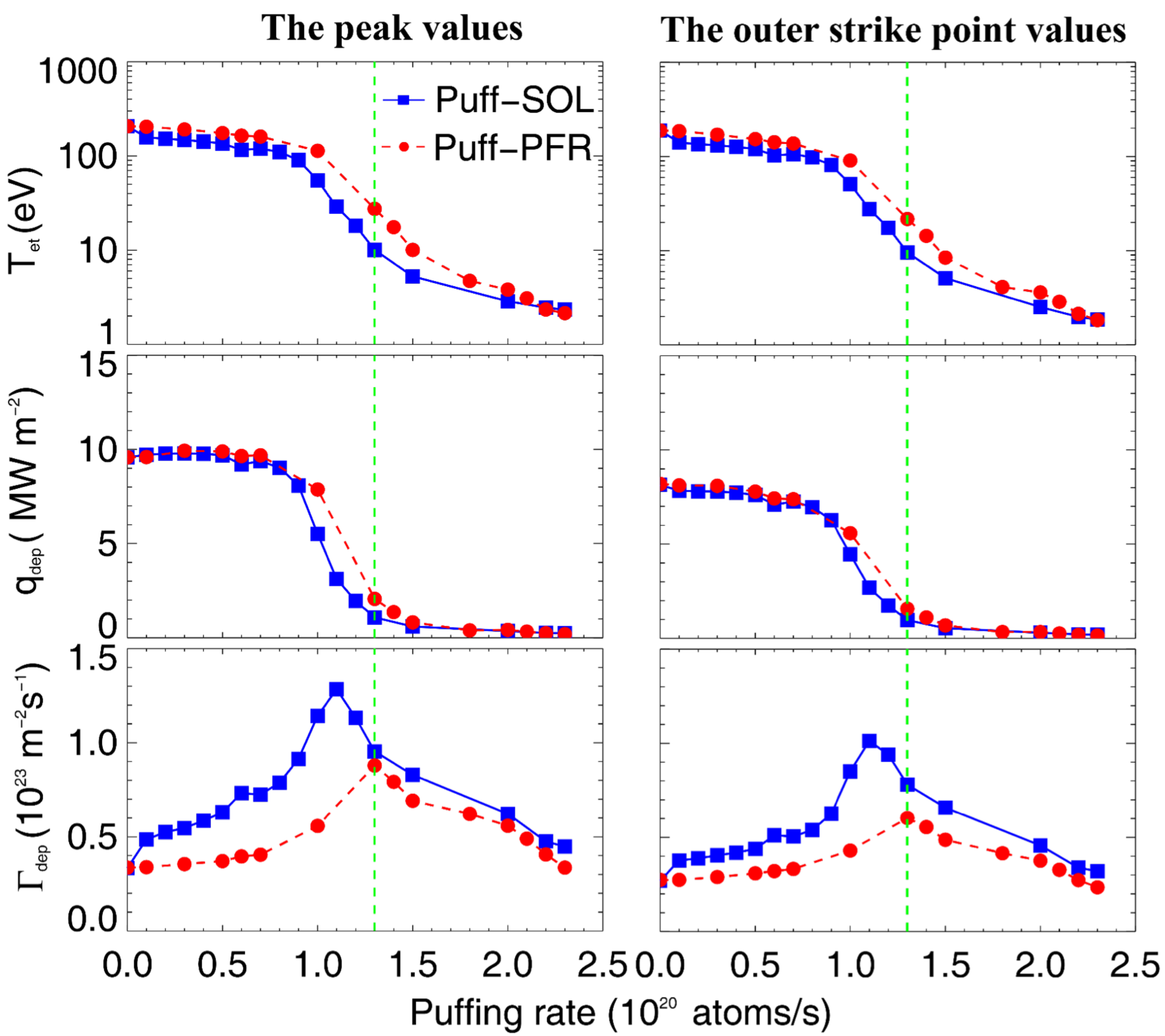
Investigation of the gas seeding position on the divertor/SOL plasma

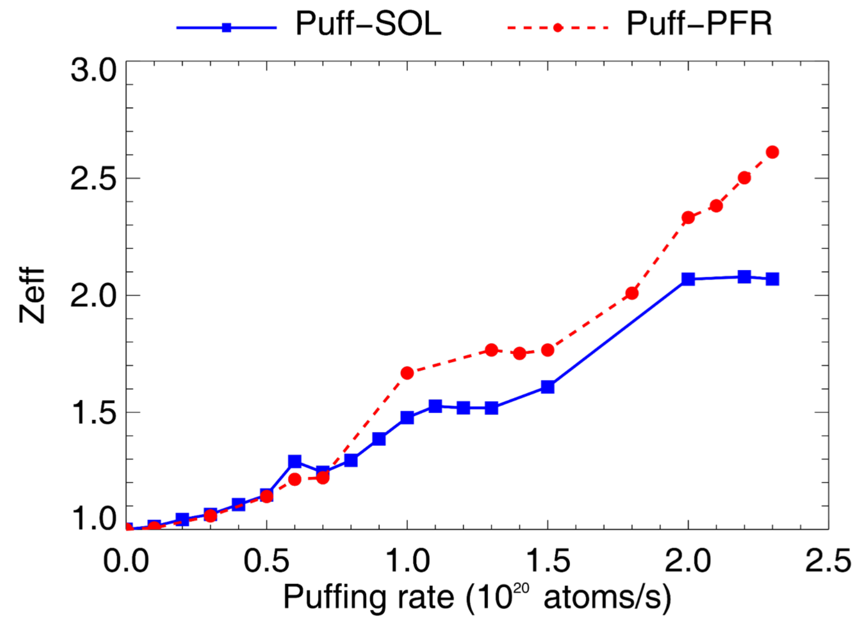


The divertor with W target material is simulated.

- **Two external impurity gas seeding positions are compared: puffing at SOL and PFR.**
- **The puffing rate scan with argon has been done.**
- **The power crossing the core-edge interface (CEI) P_{SOL} = 4 MW, n_{D+} at CEI is fixed to 4.5e19 m-3. ($ne_{sep,omp}$ ~ 1.5e19 m-e3**

The argon seeding scan shows difference between two puffing locations on the plasma

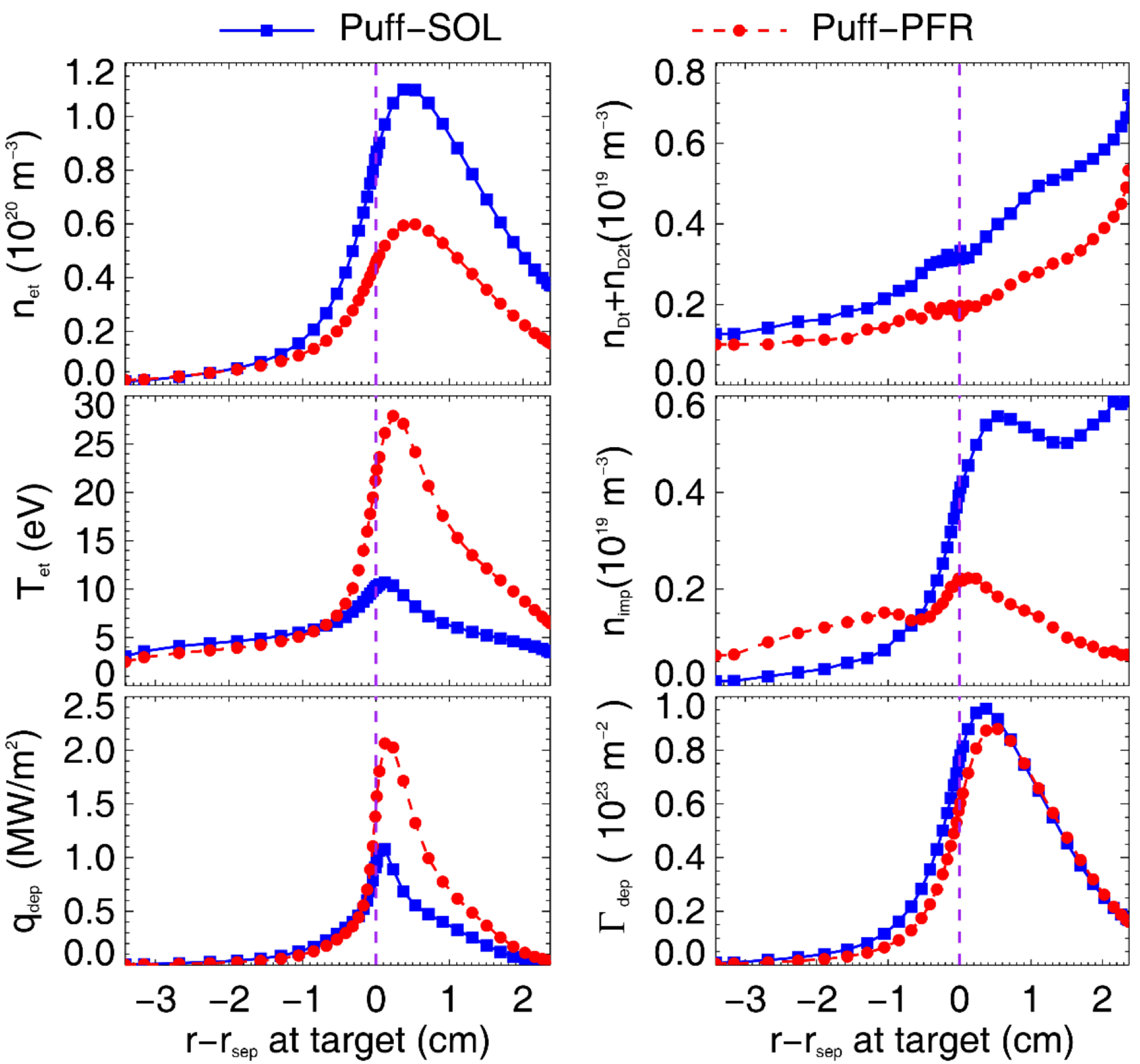


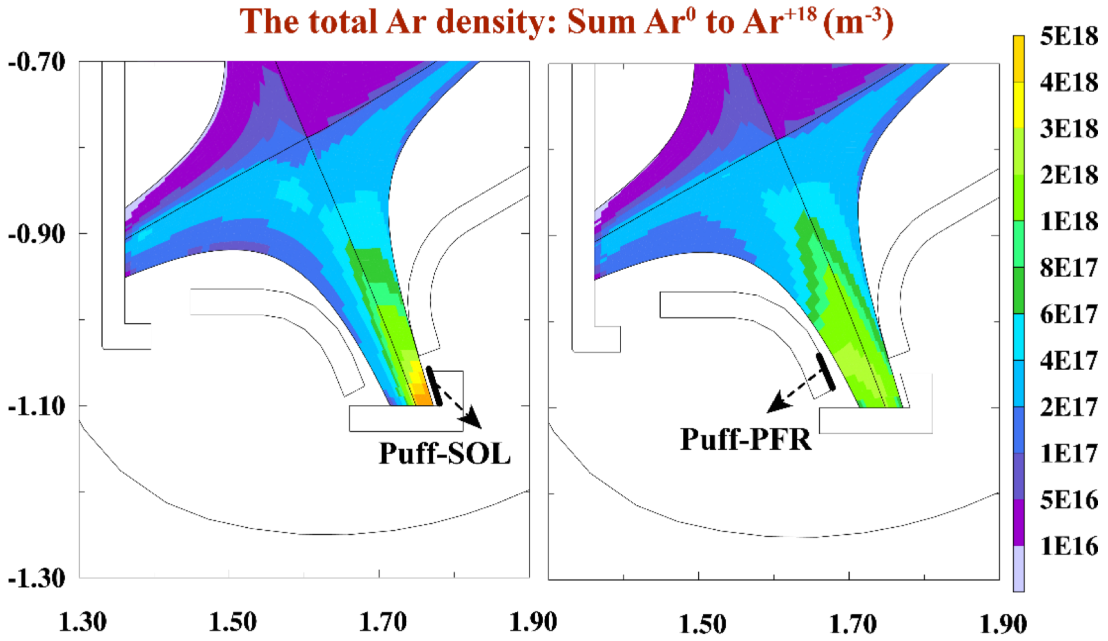


Argon seeding scan in two locations shows

- **Flux rollover: puffing at SOL achieves detachment with smaller seeding rate.**
- **Zeff at the core edge: puffing at SOL has better impurity screening.**

The profiles at the outer target shows significant differences between two seeding locations

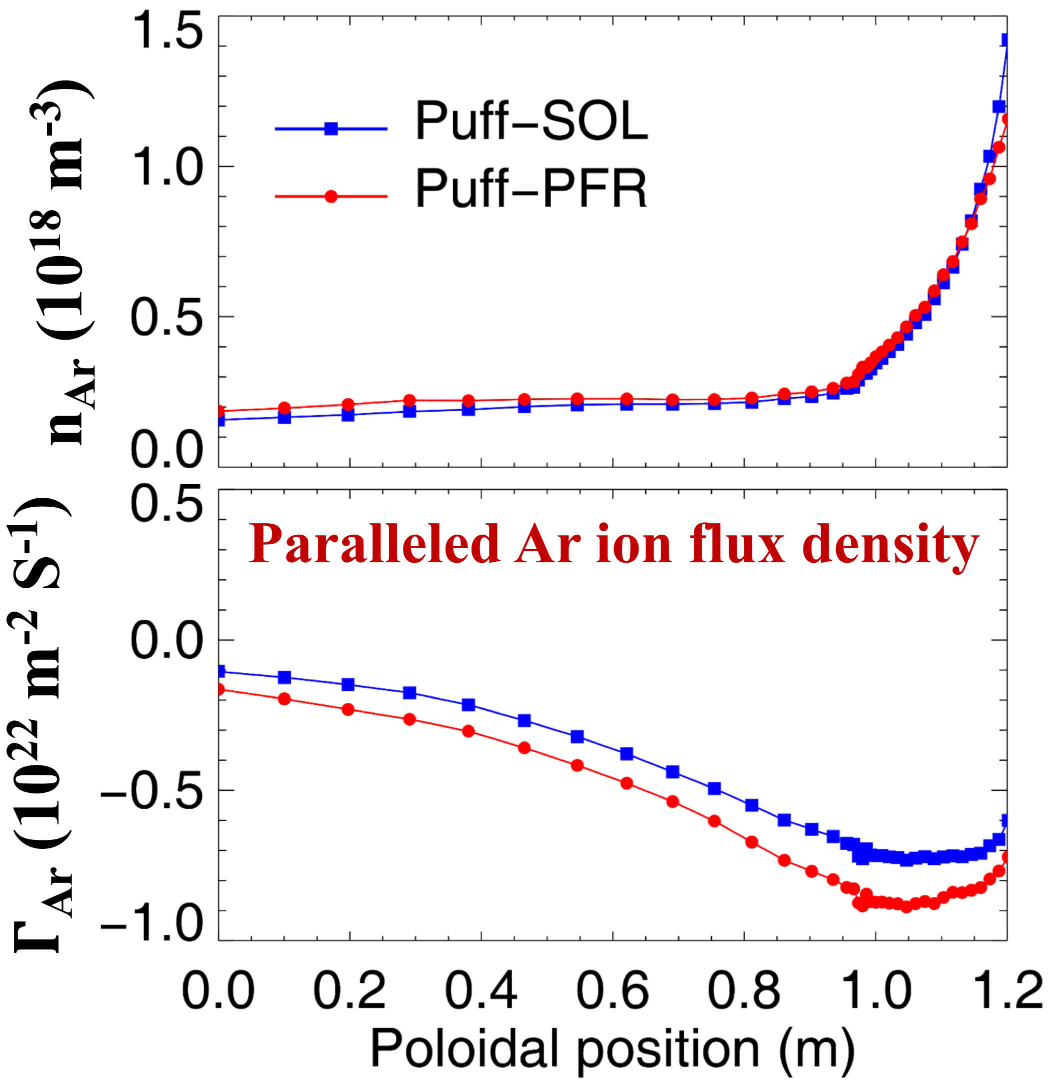


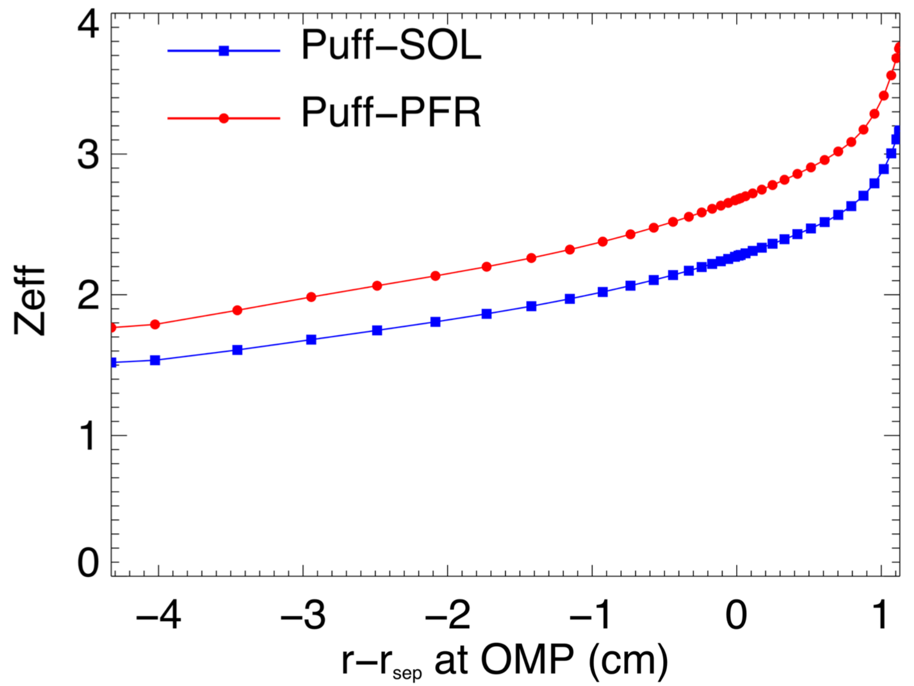


The same Ar gas seeding rate (1.3e20 atoms/s)

- Te and q of the seeding at SOL is much lower.
- The Ar impurity density are totally different.

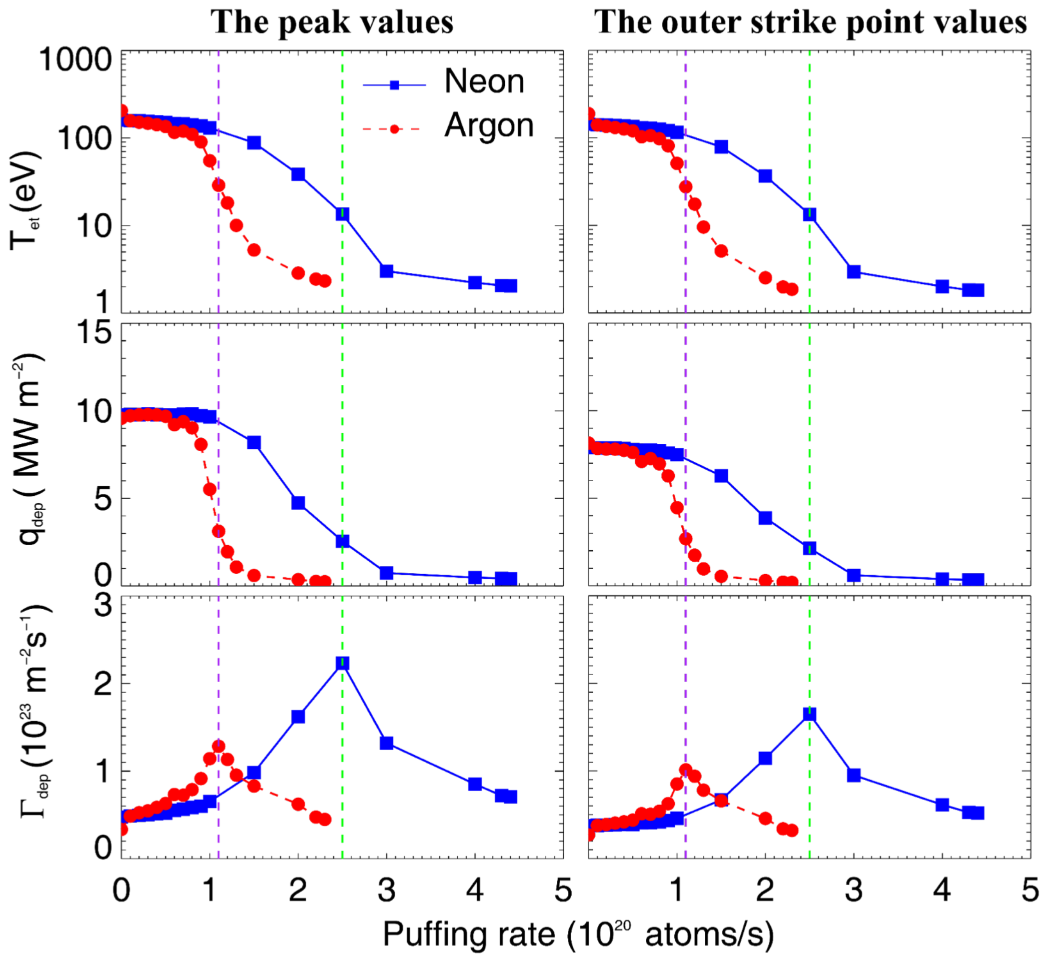
The smaller Ar ion flux from the outer target to the upstream reduces Zeff of puff-SOL case

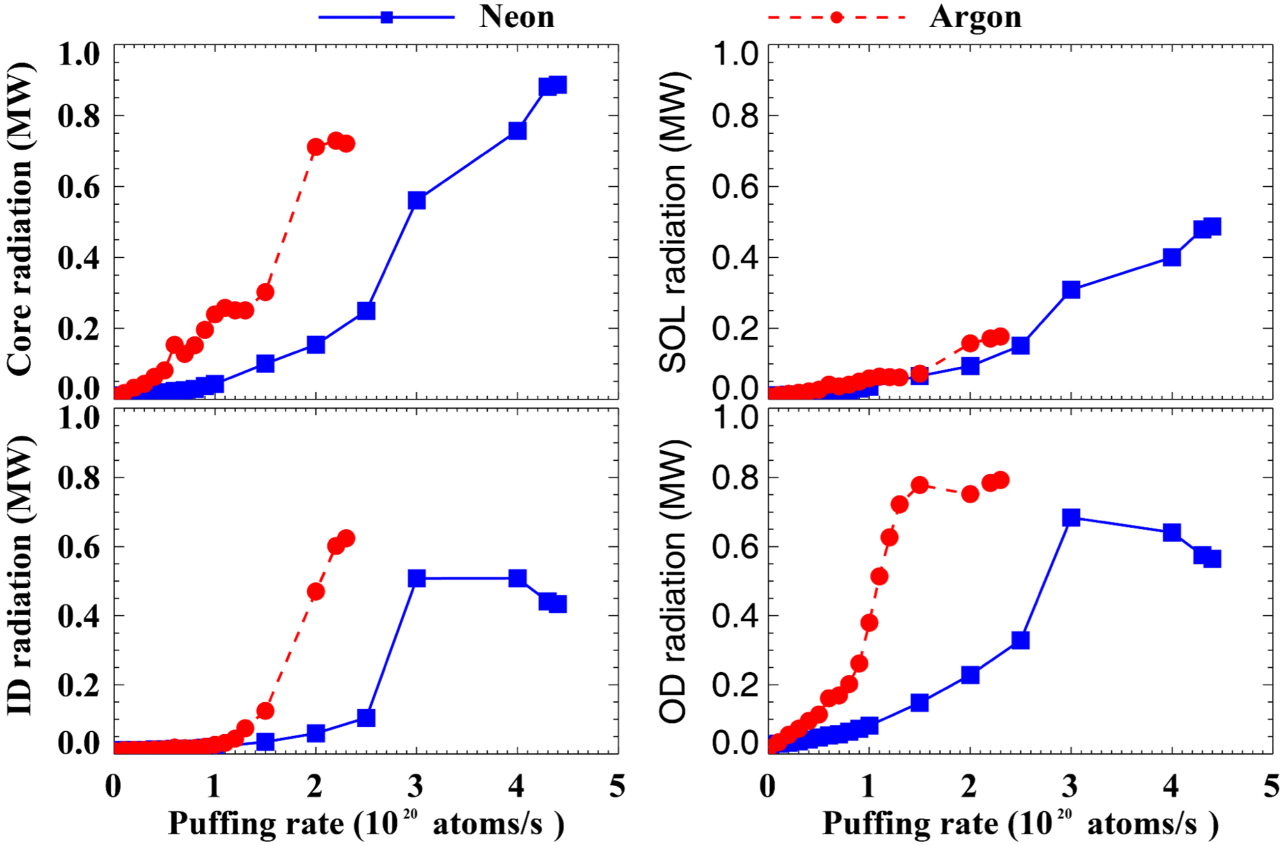




- **The direction of Ar flux at the SOL is from outer target to OMP (negative value).**
- **Puff-SOL case has smaller Ar ion flux, and better impurity screening.**

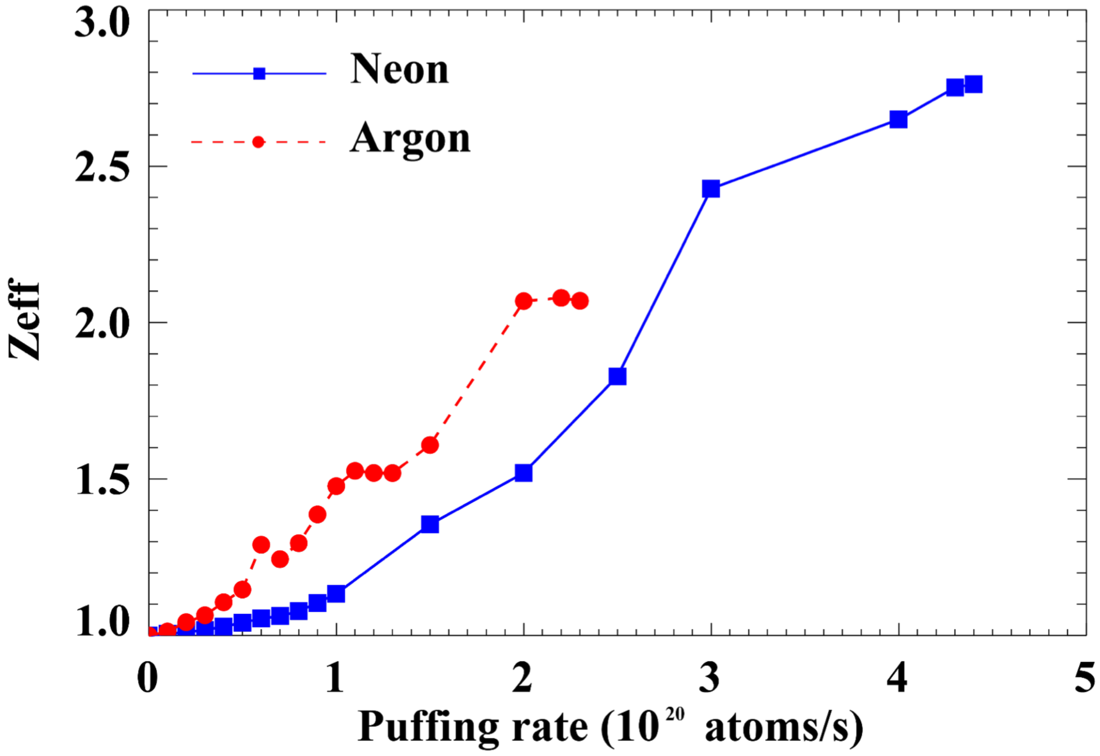
The comparison between Ne and Ar seeding rate scan shows significant difference on divertor plasma



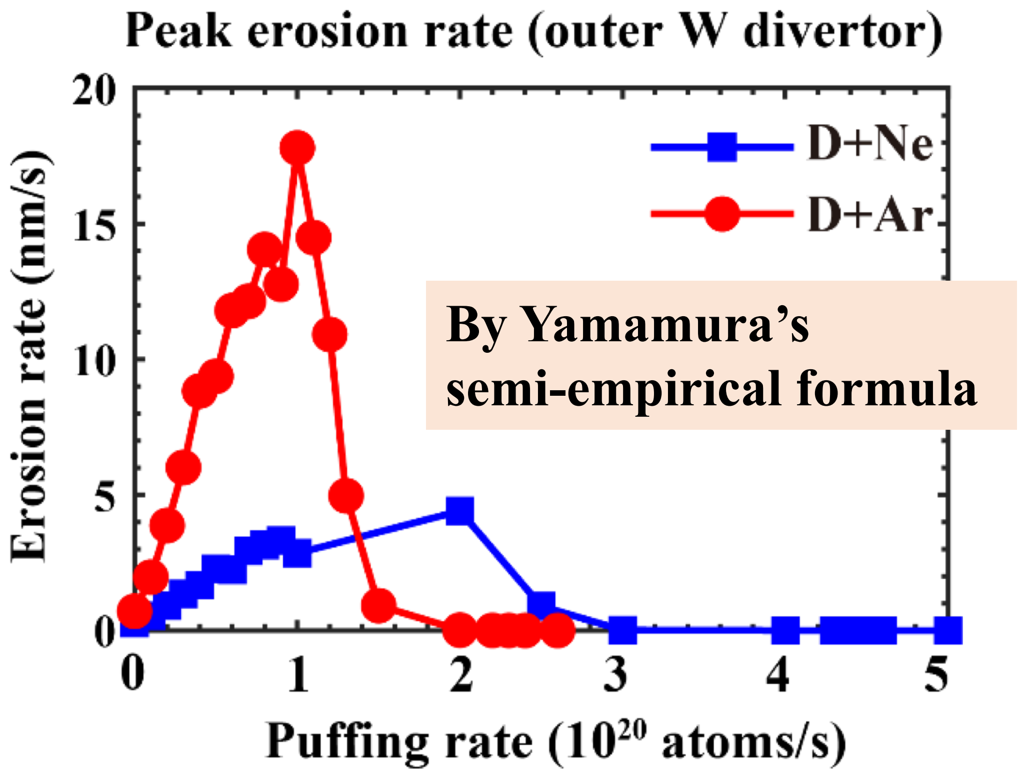


- Detachment requires much smaller Argon seeding rate than that of neon.
- Argon has more power radiation efficiency than that of neon

The Ne and Ar seeding rate scan shows big difference on the impurity screening and W target erosion

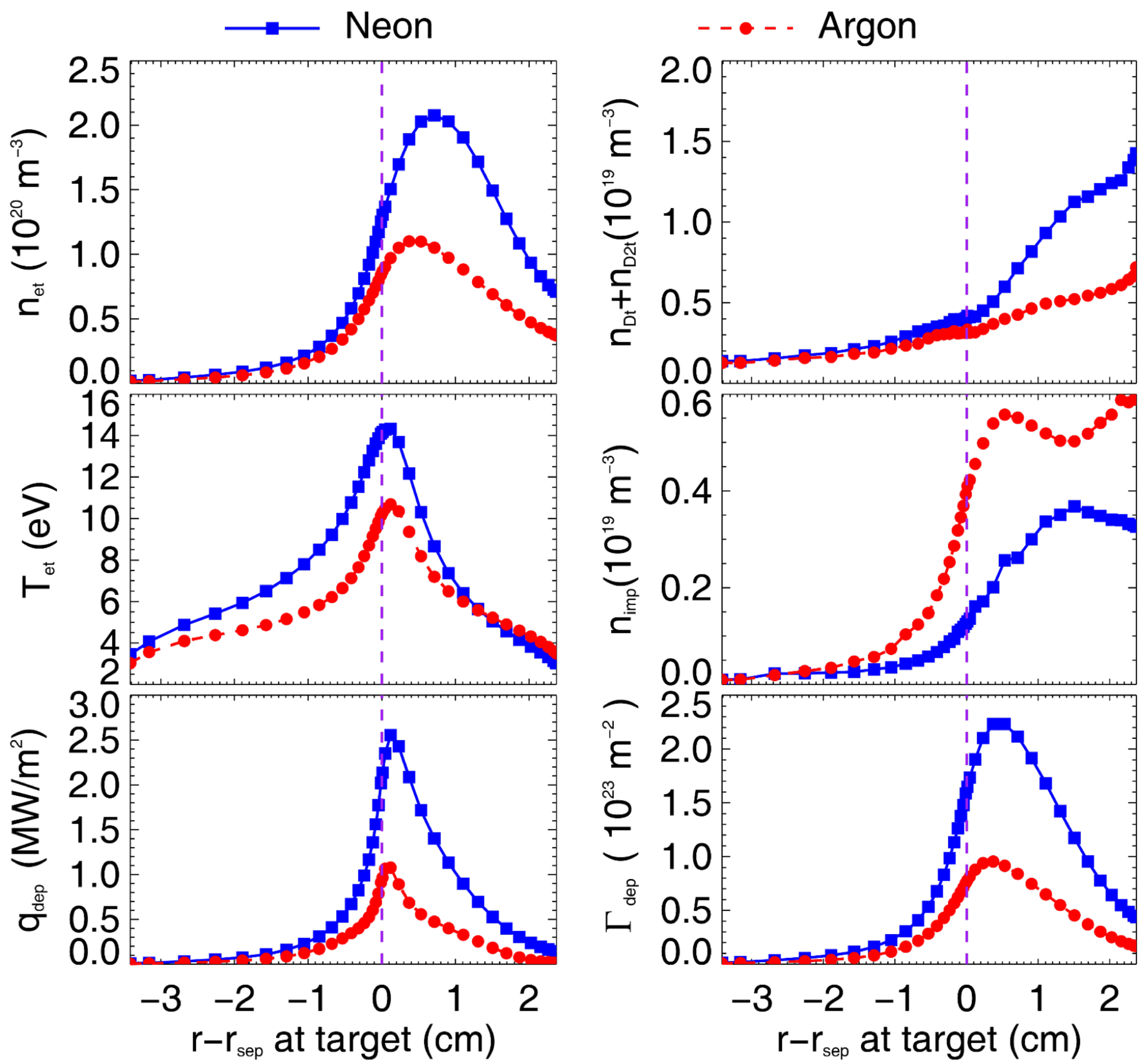


For the same seeding rate, argon seeding leads to much higher Zeff.



- W target erosion rate -> increases ->decreases, until to the full detachment.
- Ar case has the highest erosion rate.

A similar outer divertor plasma condition (T_e) is obtained by Ne and Ar seeding, respectively



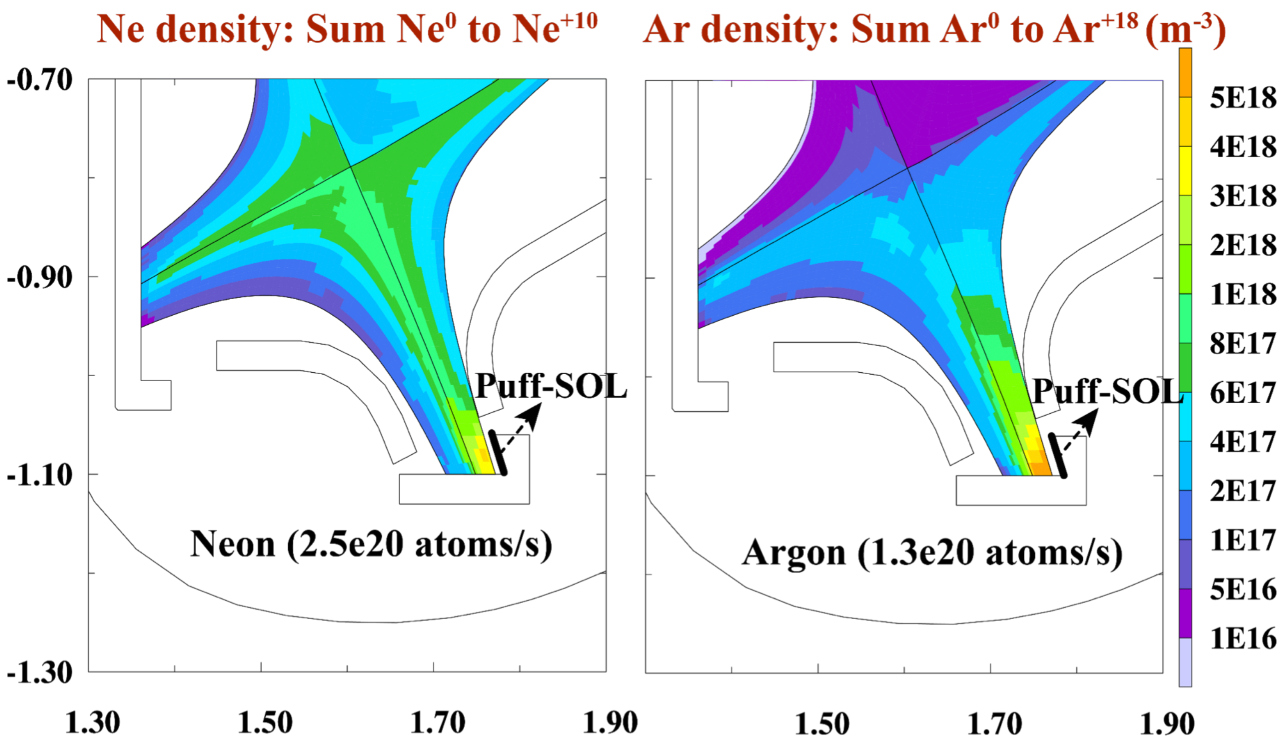
Similar divertor plasma condition obtained by seeding Neon and Argon with different rate

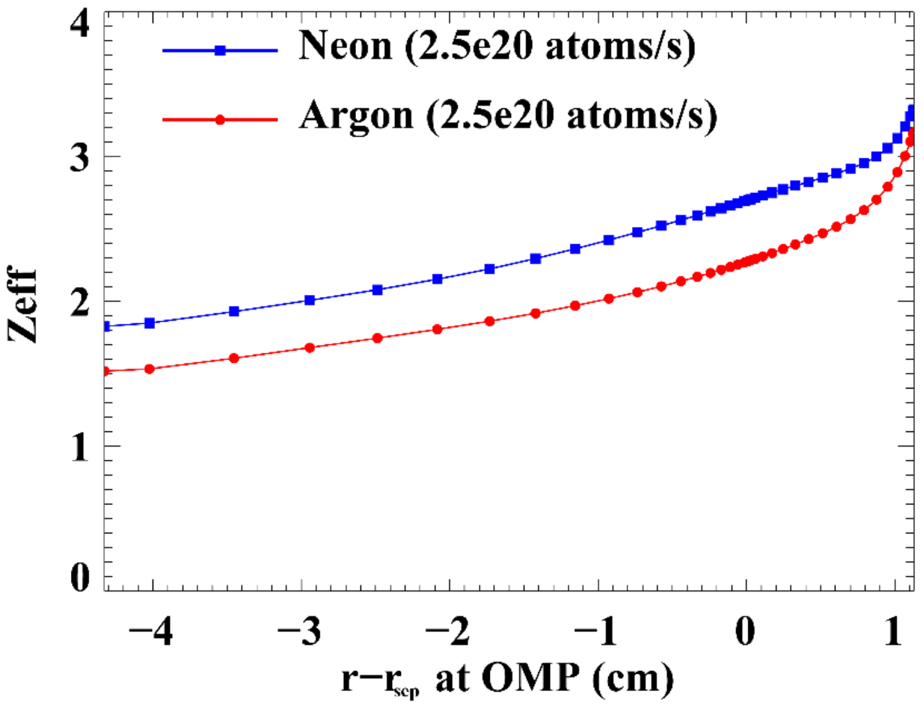
- **Neon seeding rate 2.5 atoms/s**
- **Argon seeding rate 1.3 atoms/s.**
- **T_e and q of Neon seeding case are higher**

It can be used to identify the influence of neon/argon impurity seeding on:

- **Zeff**
- **W target erosion**

For the similar divertor plasma condition, the Ar seeding has smaller Zeff in the core than that of the Ne seeding

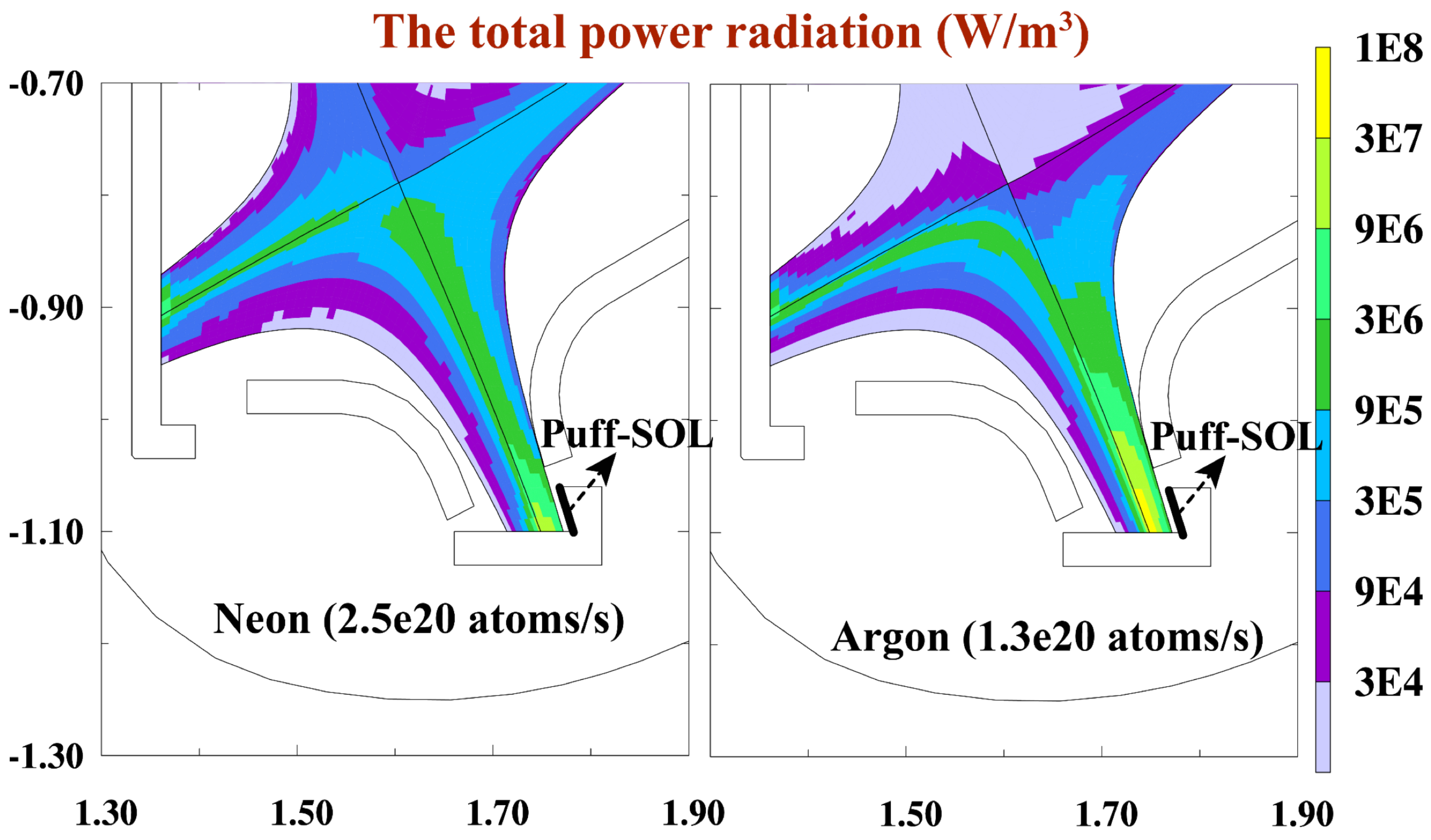


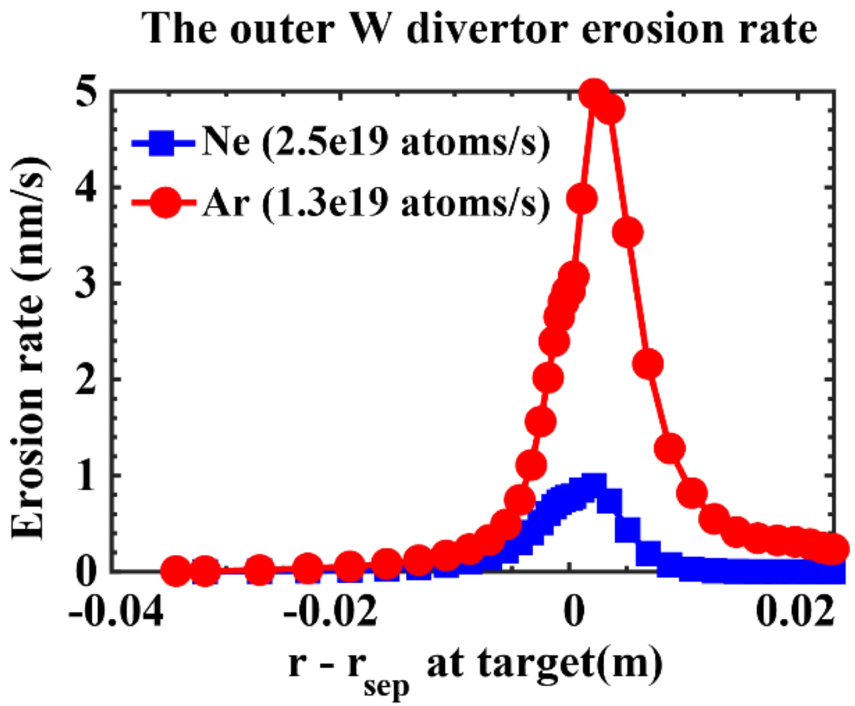


- More argon impurity accumulates in the divertor region than neon impurity.
- Zeff at OMP of the argon seeding is much lower than that of neon seeding.

The divertor has better screening of argon impurity than neon impurity

The power radiation shows the advantage, but W divertor erosion shows the disadvantage of Ar seeding

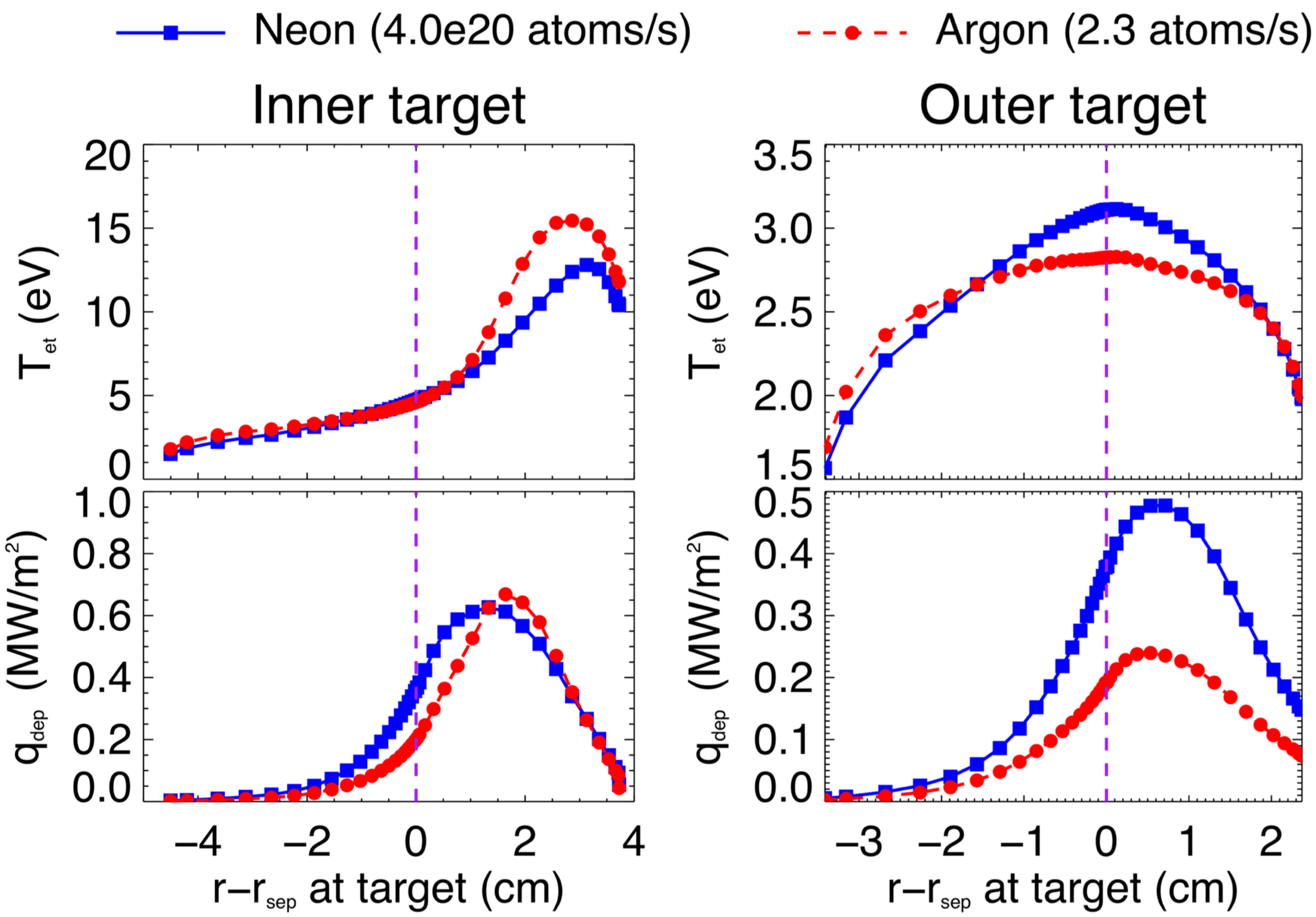


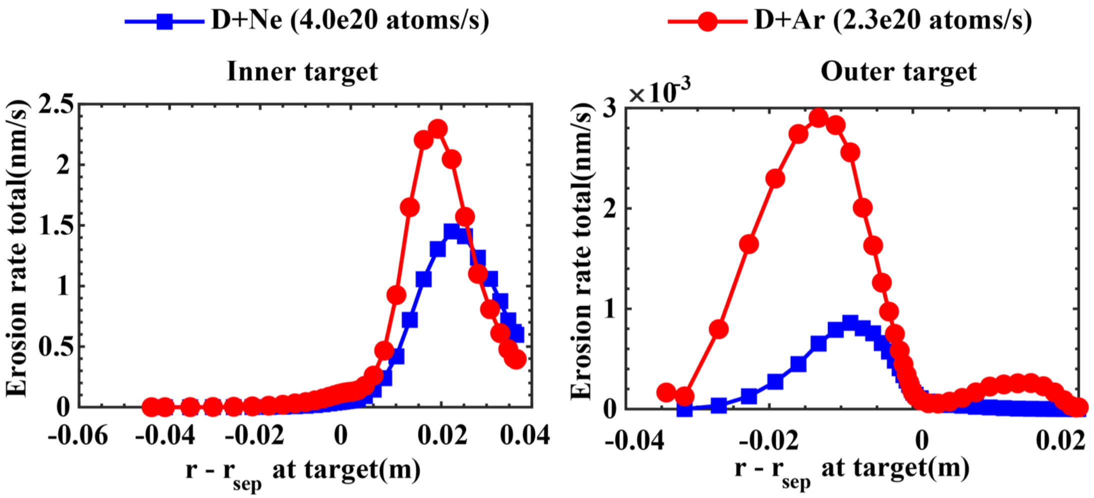


The radiated power focused more in the outer divertor region and less in the core region during Ar seeding.

Argon seeding may lead to W higher erosion rate

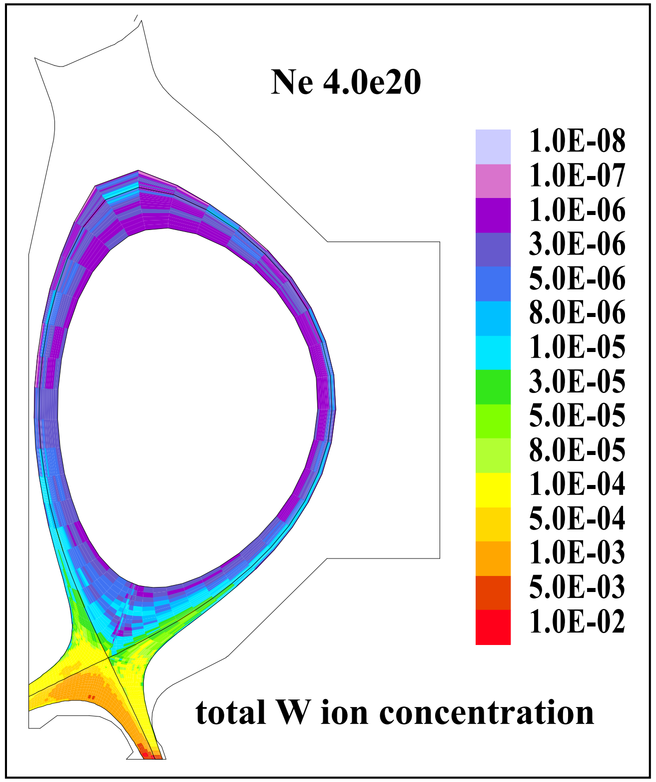
The comparison during the partial detachment shows Ar seeding leads to higher W erosion rate than Ne seeding

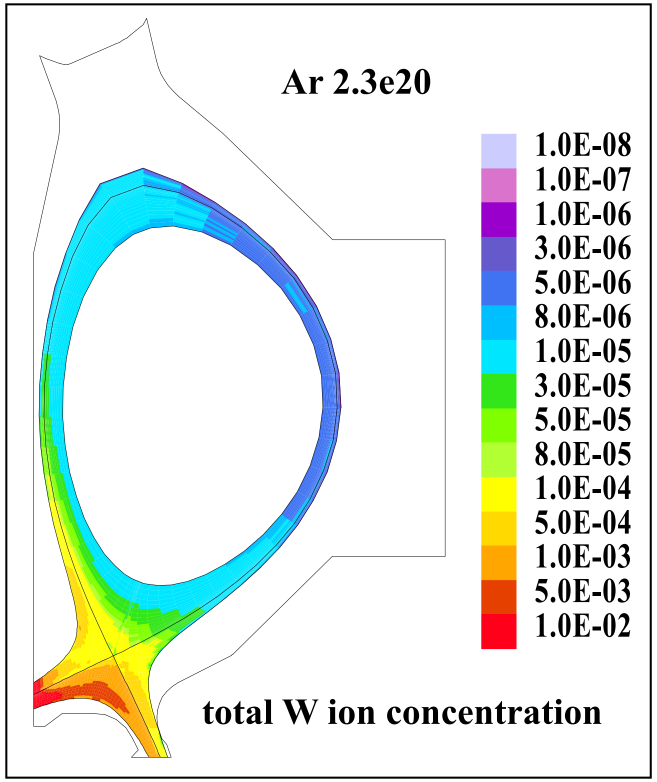


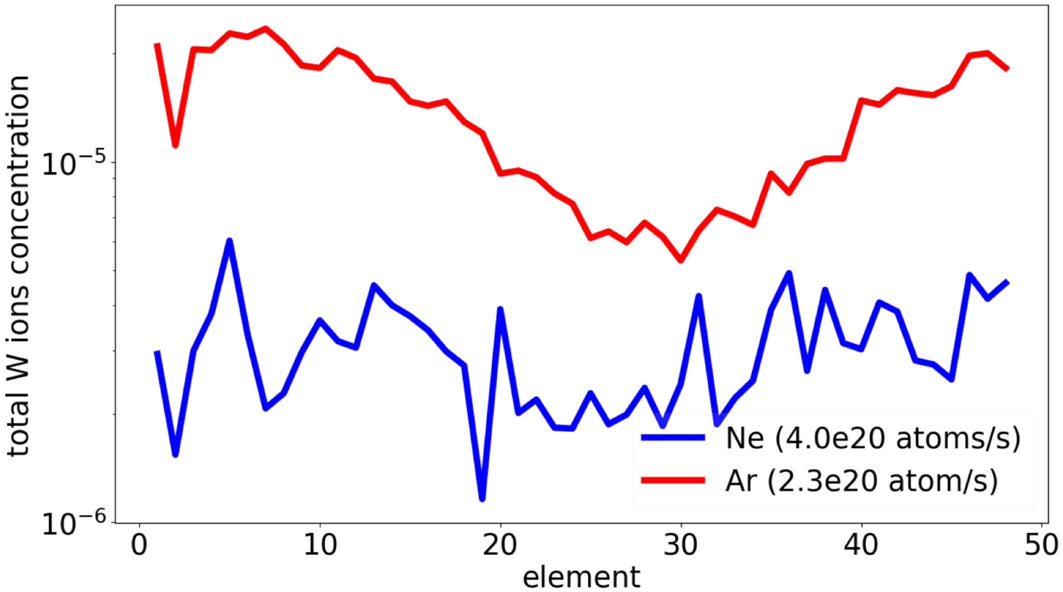


- The seeding rate of Ne and Ar is 4.0e20 and 2.3e20 atoms/s.
- Similar Te at the targets are obtained.
- Ar seeding leads to higher erosion rates.

Argon seeding leads to more W impurity accumulated in the core plasma region (DIVIMP modeling)

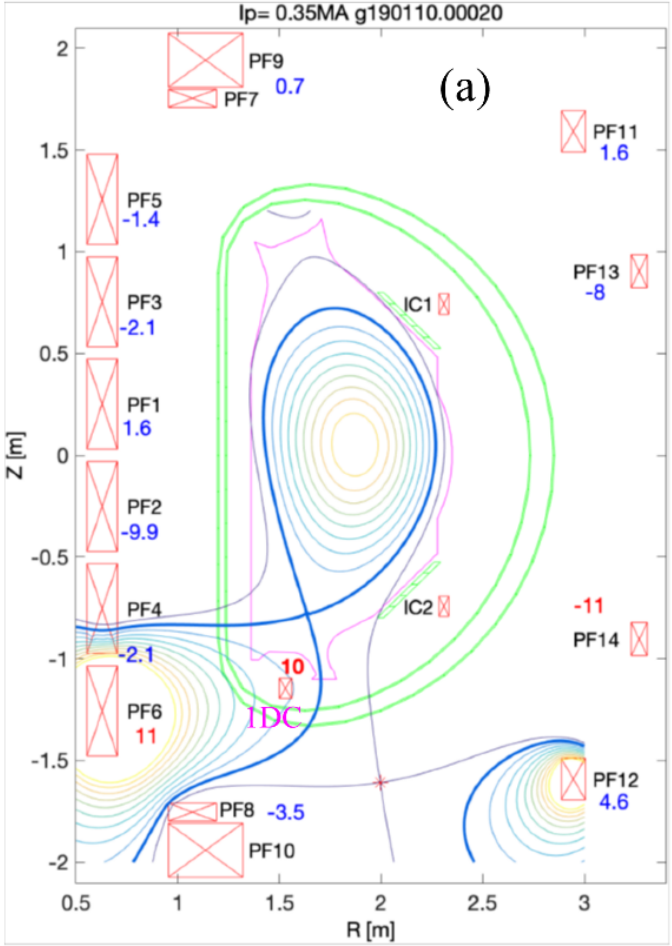


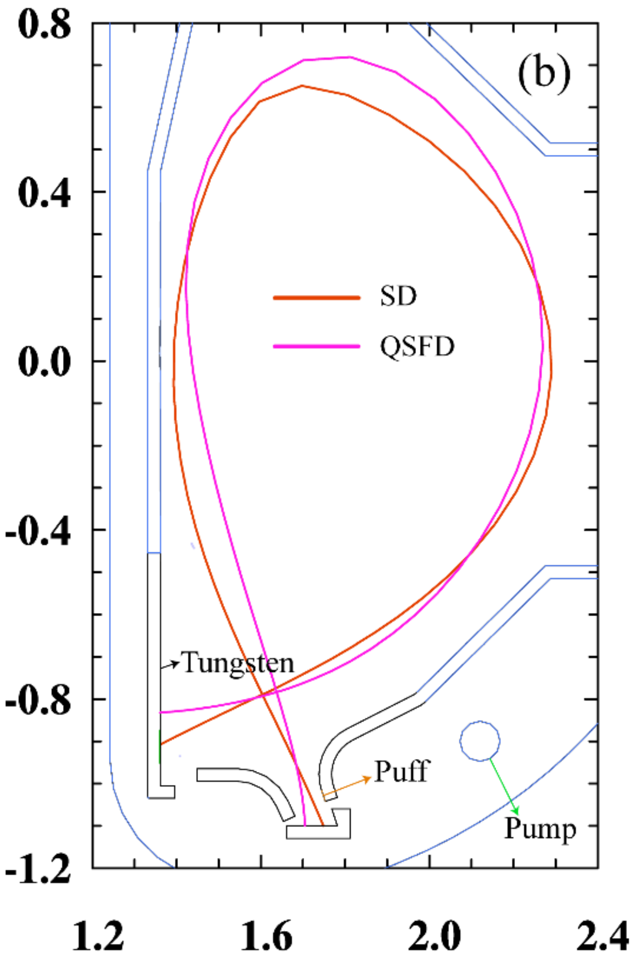




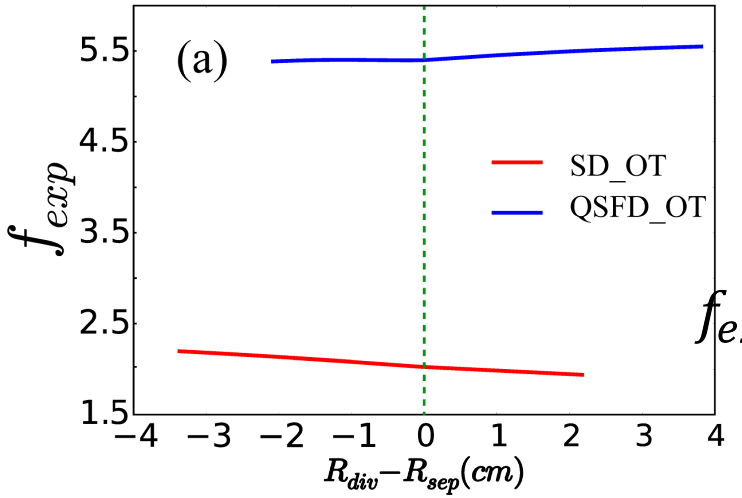
- ➢ **Argon seeding causes higher W erosion, resulting in the higher W concentration at the core edge.**

A DC coil will be added at the bottom of the lower divertor to construct the quasi-snowflake equilibrium





SOLPS-ITER modeling

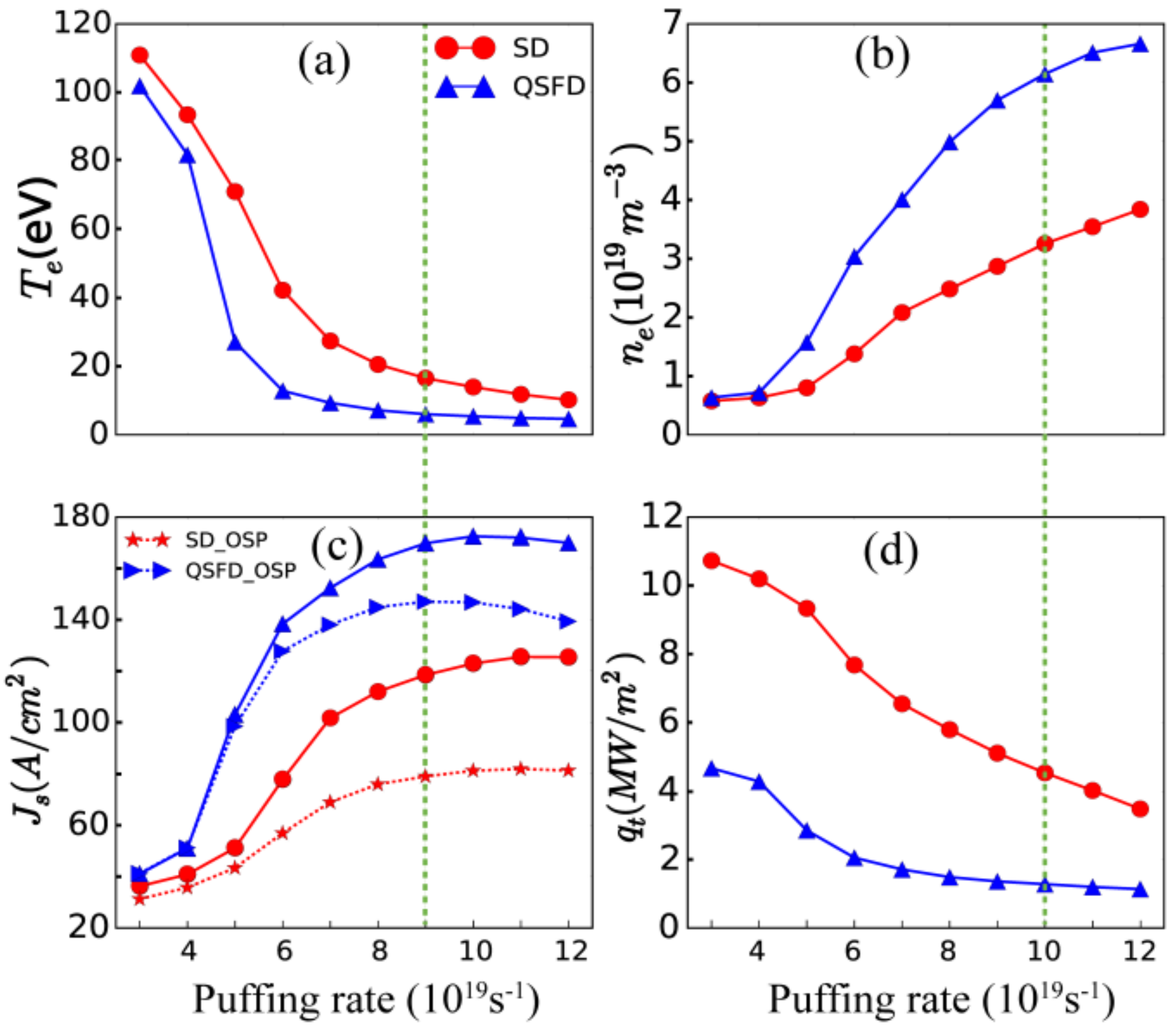


$$f_{exp} = \frac{(B_p/B)_u}{(B_p/B)_t}$$

Coil parameters

- $|I_{DC,max}|$ = 10 KA/turn
- D_{xpts} = 0.90cm
- I_p = 350KA

The comparison between SD and QSFD indicates the QSFD could significantly reduce q and Te at target

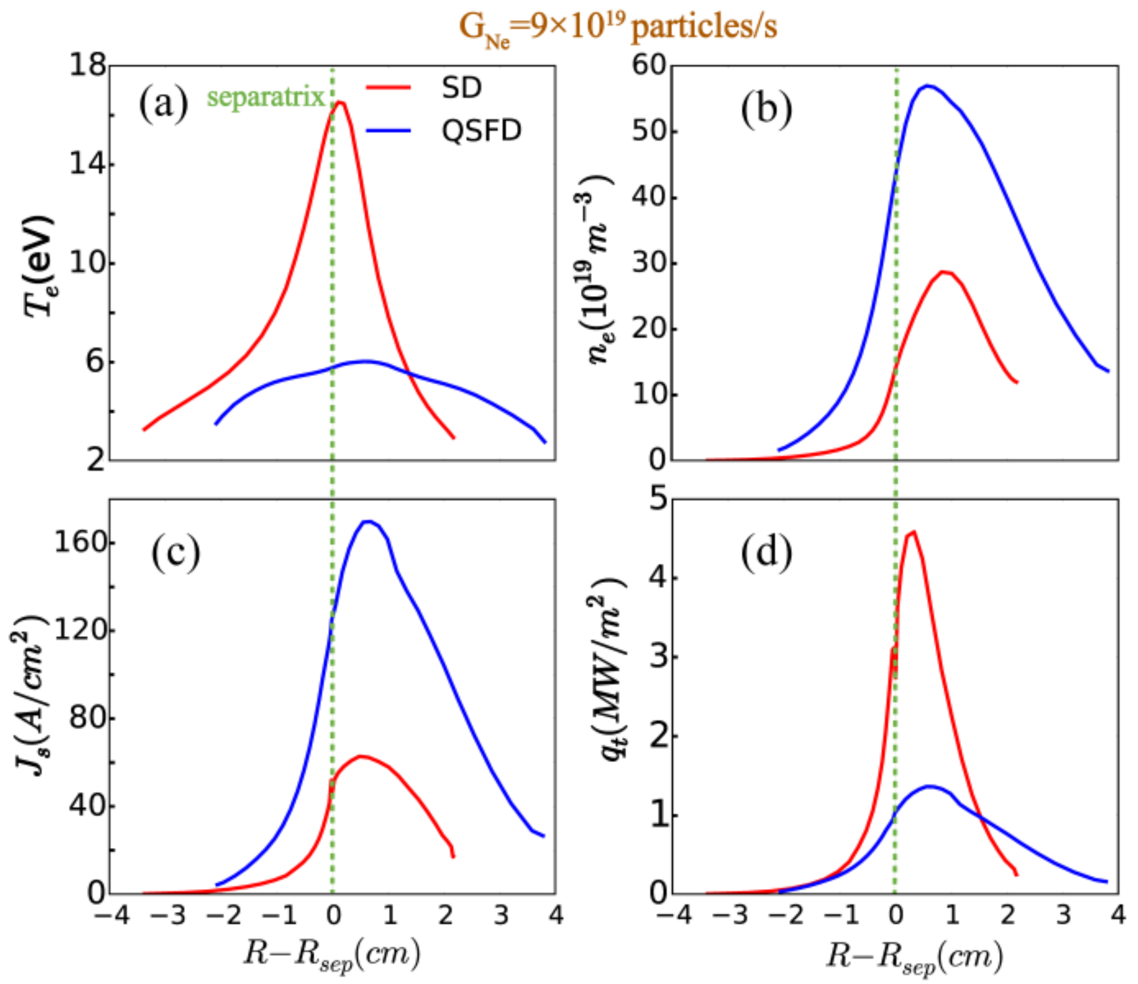


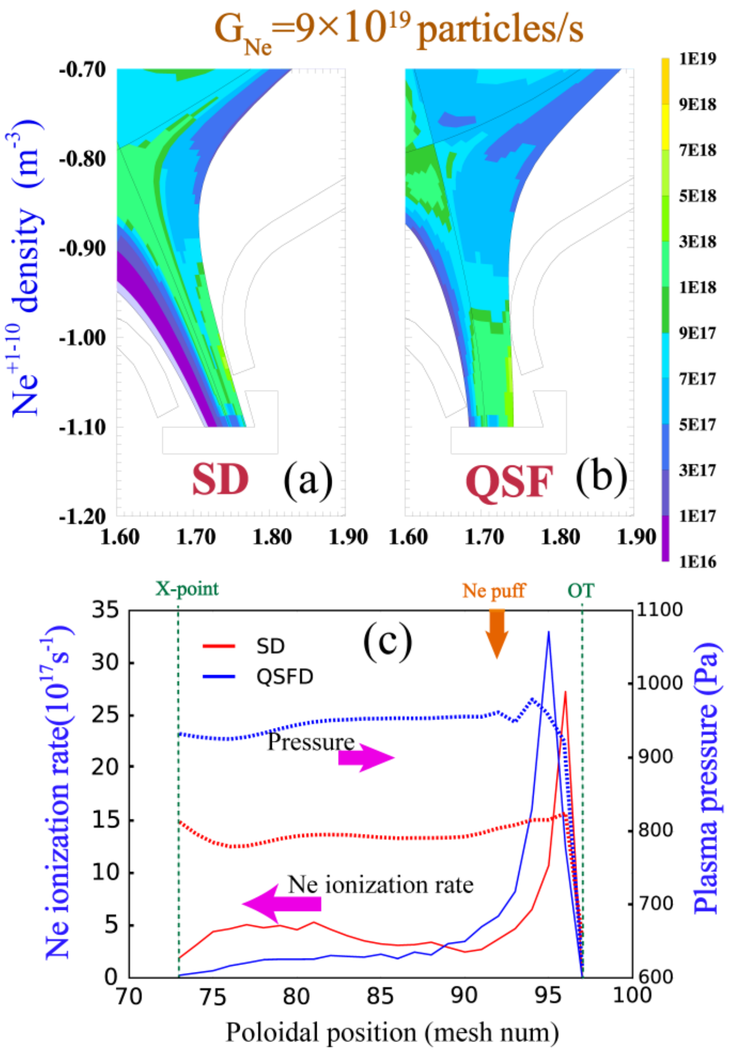
With Ne seeding rate scan:

- **The T_e and q_t of QSFD is lower.**
- **The QSFD could promote the achievement of plasma detachment with Ne seeding.**

The the neon seeding at the OSP is applied.

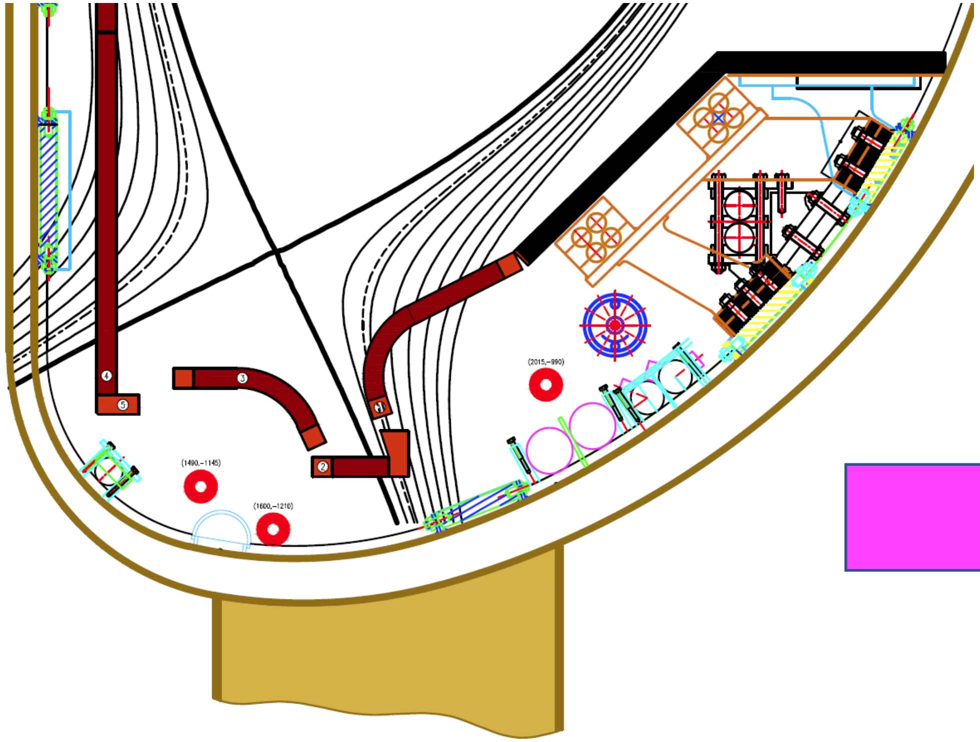
The more Ne impurity accumulation at the QSFD than at SN leads to the significant lower Te

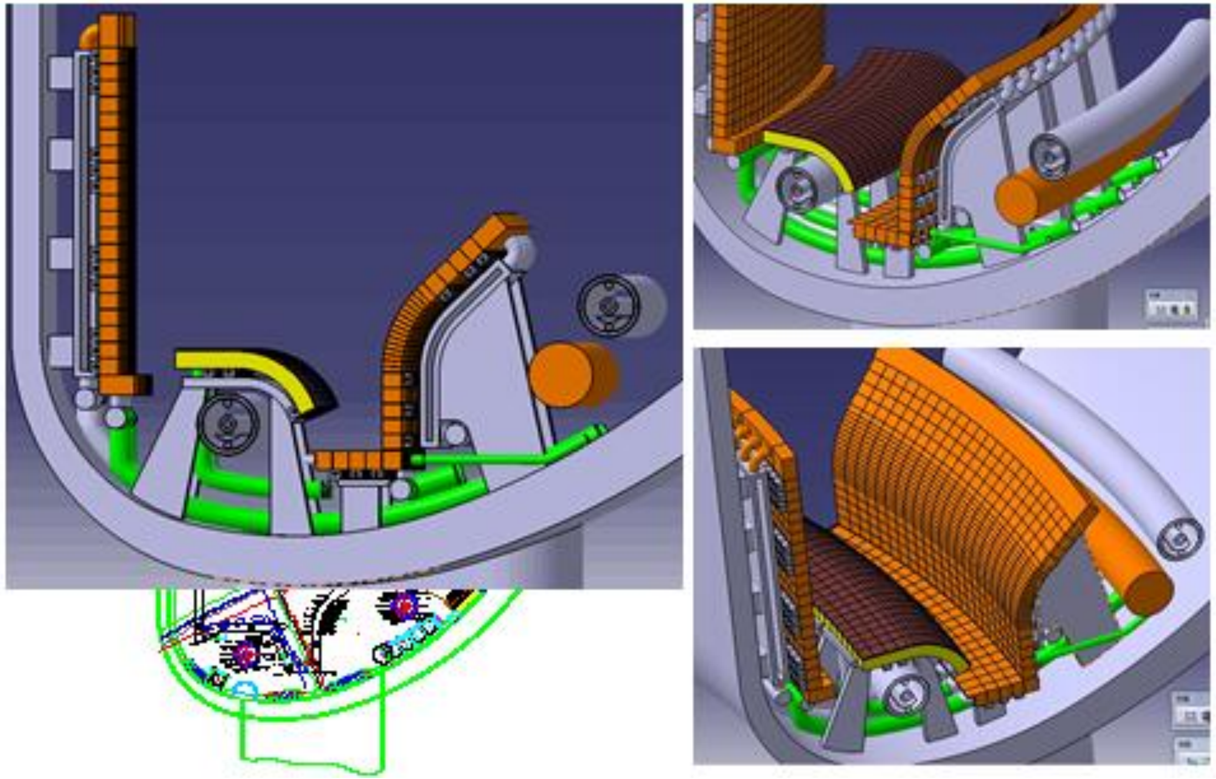




- The incident angle of the QSFD is different.
- The reflection of the incident particle in SD may be easily escape from the pump.

The designed EAST lower tungsten divertor





Better flexibility

Summary

1. The shape of EAST lower tungsten divertor is confirmed via the shape optimization.
2. The SOLPS modeling shows external impurity gas (Argon) seeding at SOL is better than seeding at PFR by considering the divertor power dissipation and impurity screening.
3. Ar seeding is better for the power radiation and divertor impurity screening, but it may cause more serious W erosion, and core contamination by W impurity.
4. By seeding the Ne gas near the outer strike point (OSP), the quasi-snowflake divertor is better in the power dissipation.

Thanks for your attention!