Multi-code simulations of the gas baffle effects on TCV Lower Single Null edge plasmas

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Towards more reactor-relevant divertor conditions in TCV

TCV (Tokamak à Configuration Variable) is undergoing a major upgrade [1, 2]:

- **Gas Baffles inserted**→ objective: maximize

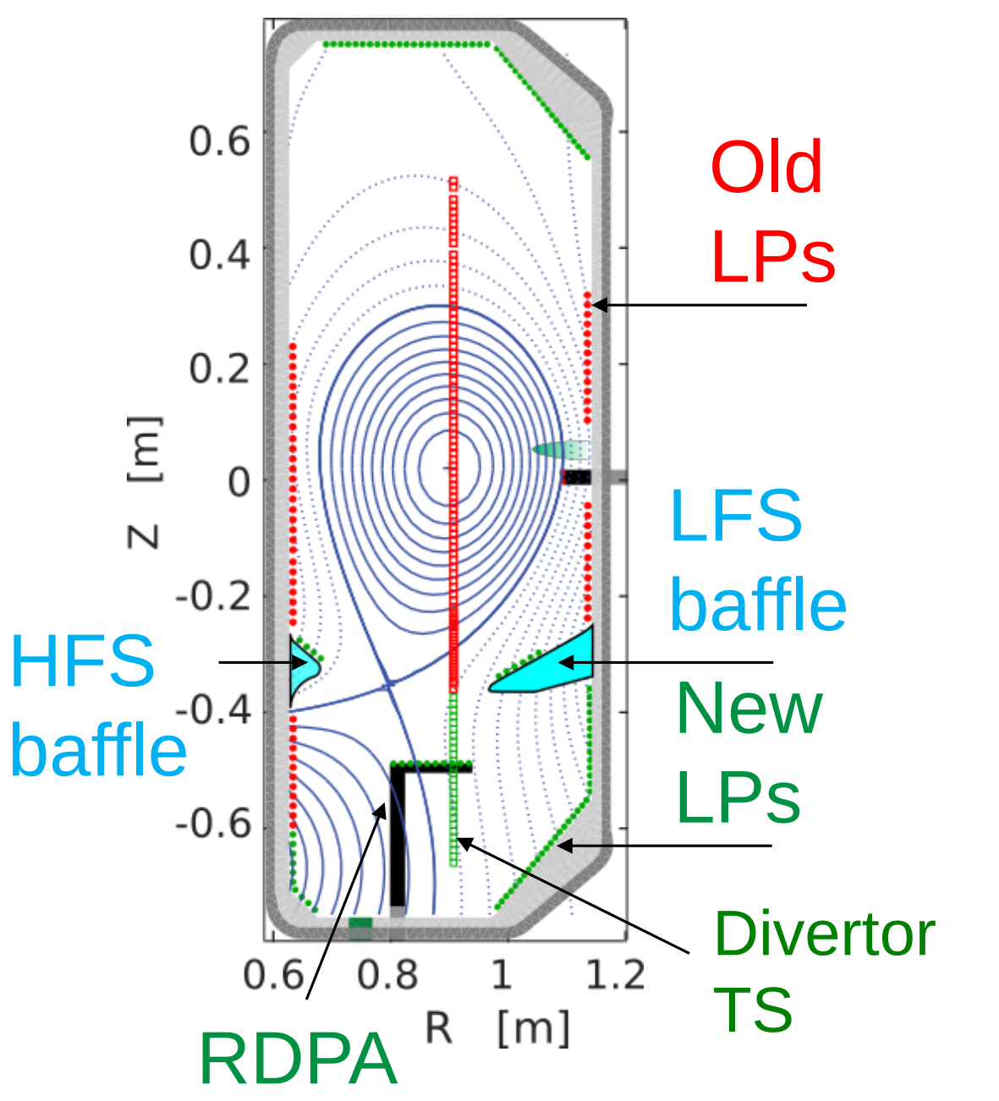
$$c_D \equiv \frac{\langle n_n \rangle_{div}}{\langle n_n \rangle_{main}} \quad ,$$

with $n_n = n_{D^0} + 2n_{D_2}$, to facilitate detachment

- Future increase in input power (~ 3x)

→ access detachment at lower plasma density

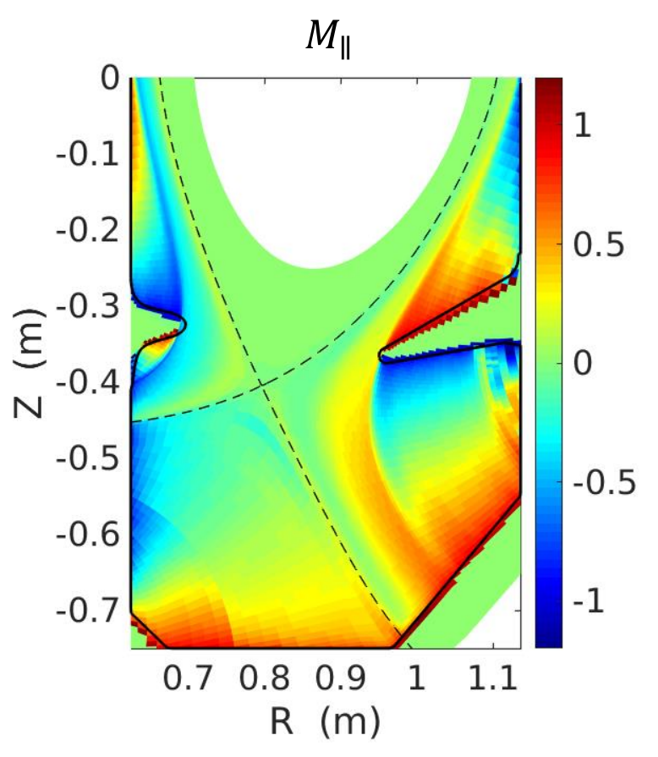
- Improved **divertor diagnostics**



Strategy of simulations of baffles performances on TCV

First version of gas baffle [3] chosen based on SOLPS-ITER [4,5] simulations. Limitations: grid can be extended only up to baffle tip.

SolEdge2D-EIRENE [6,7] 2D transport code:



- Penalization technique → grid up to first wall
- Heat flux and recycling on baffles evaluated

→ SolEdge2D: scan of baffle lengths

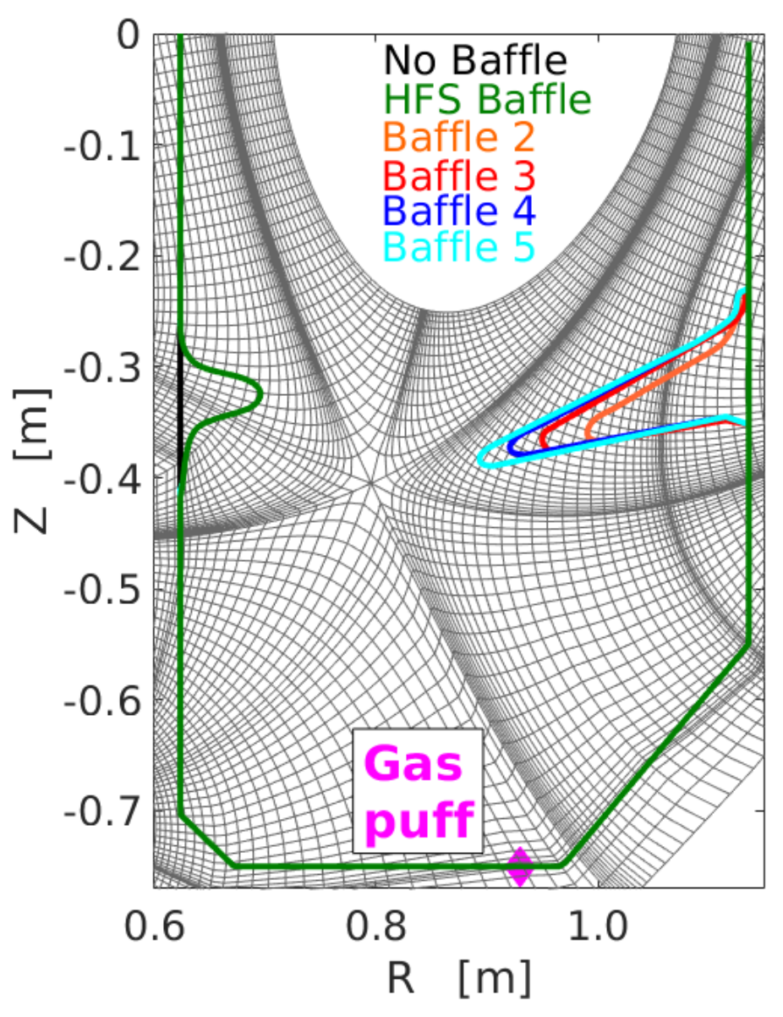
Goal: Interpretation of present experiments, guidelines for design of a new batch of baffles

SOLPS-ITER: Upstream conditions scan at fixed baffle length + drifts

Both codes: simulations baffled/unbaffled, comparison with experiments

Effect of baffle closure at fixed upstream conditions

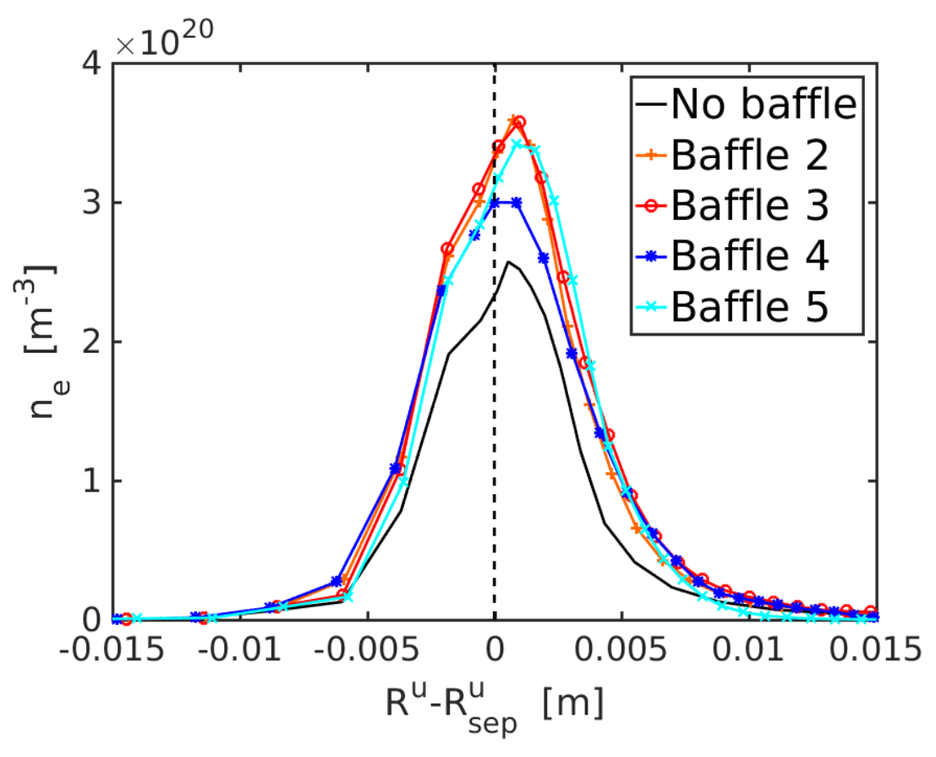
	ρ_{min}	$\Delta\rho\ [\lambda_q]$	TCV	ρ_{min}	$\Delta\rho\ [\lambda_q]$
No Baffle	1.083	5.9	Baffle 3	1.069	4.9
HFS Baffle	1.057	4.1	Baffle 4	1.043	3.1
Baffle 2	1.120	8.6	Baffle 5	1.025	1.8

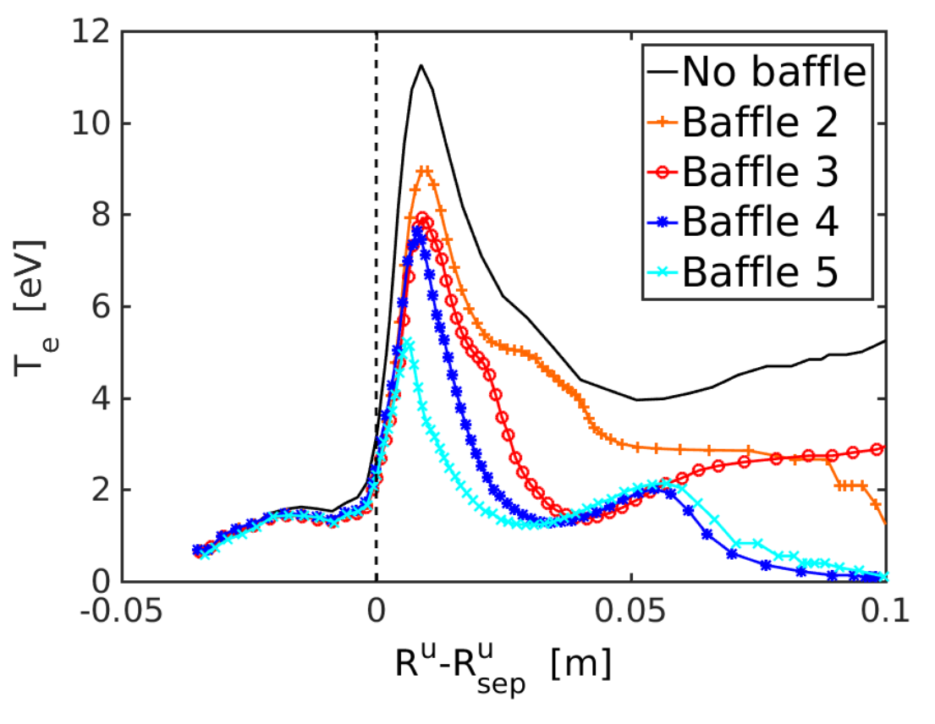


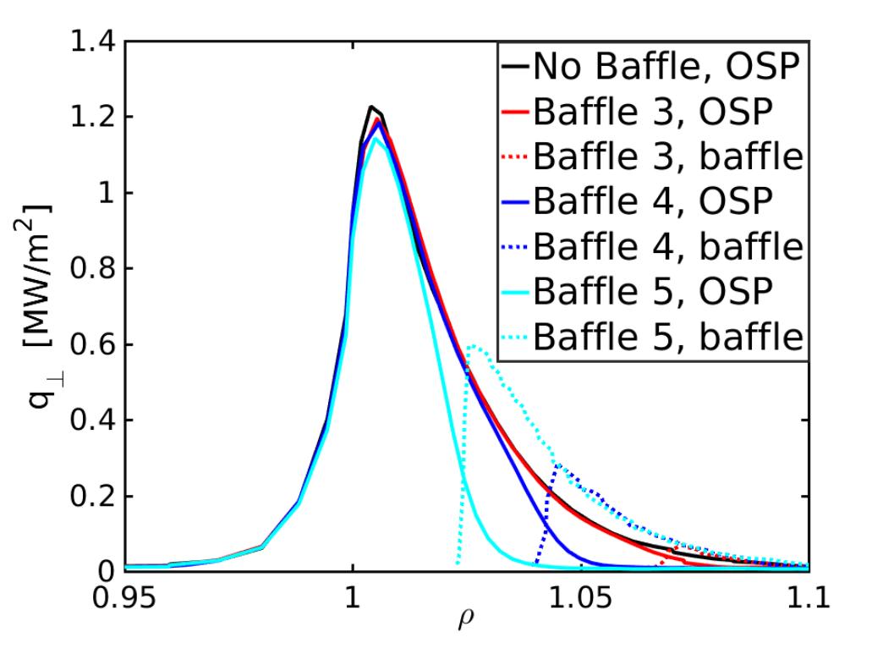
$n_u = 1.8 \cdot 10^{19}\ m^{-3}$, $P_{in} = 1.2\ MW$ (1/3 el. , 2/3 ions)

$D_0 = 0.2\ \frac{m^2}{s}$, $\chi_0 = 1.0\frac{m^2}{s}$, no drifts, $R = 0.986$

Upstream profiles in the SOL almost unaffected





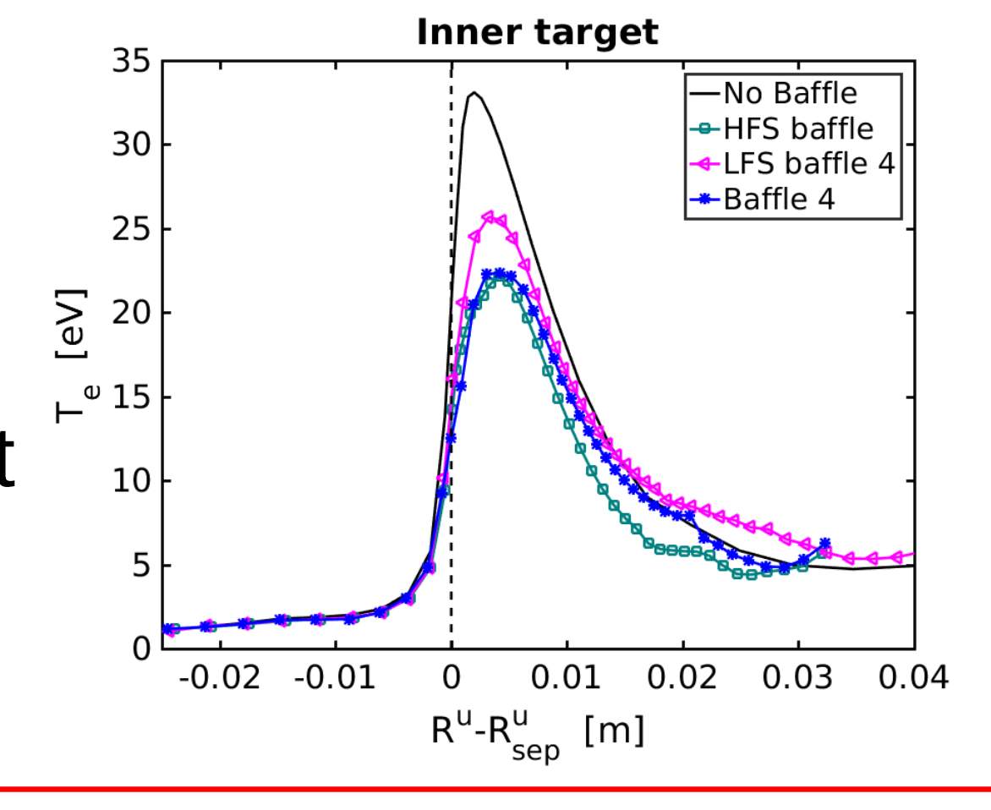


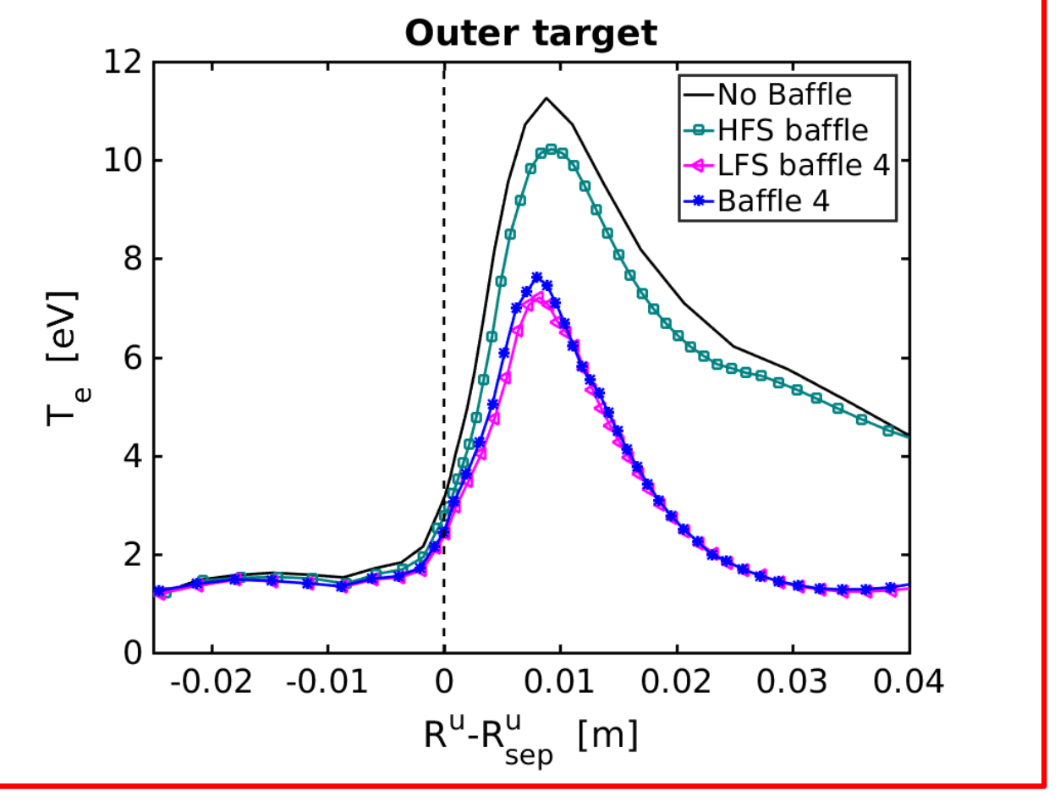
- Biggest effect on T_e^t , longer baffle intercepts more heat flux

→ $\max(q_\perp)$ on Baffle 5 comparable to outer target
→ $\max(\Gamma_\perp)$ on Baffle 5 ≪ outer target : ionization localized in the divertor

Only HFS baffle vs Only LFS baffle

HFS baffle: cools down inner target, but weaker global effect than LFS baffle



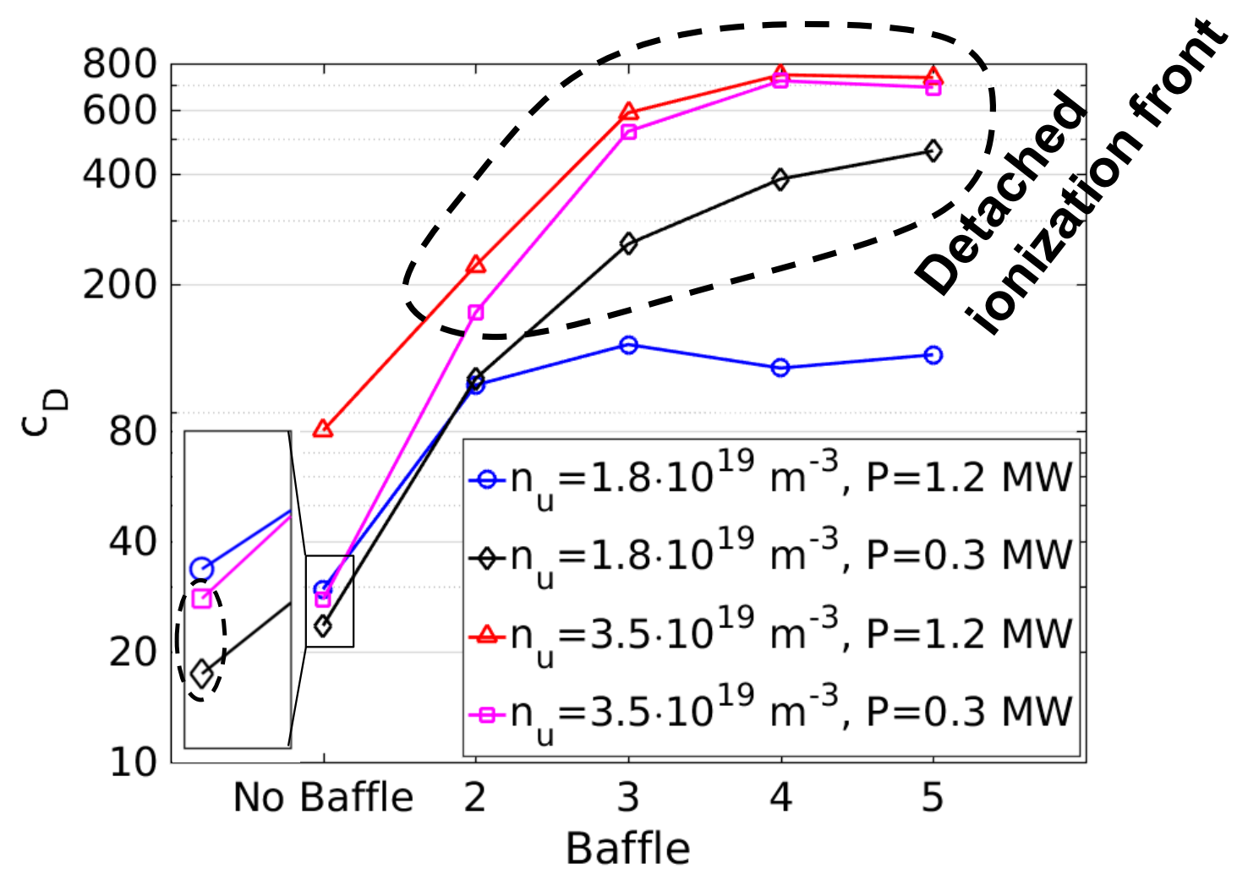


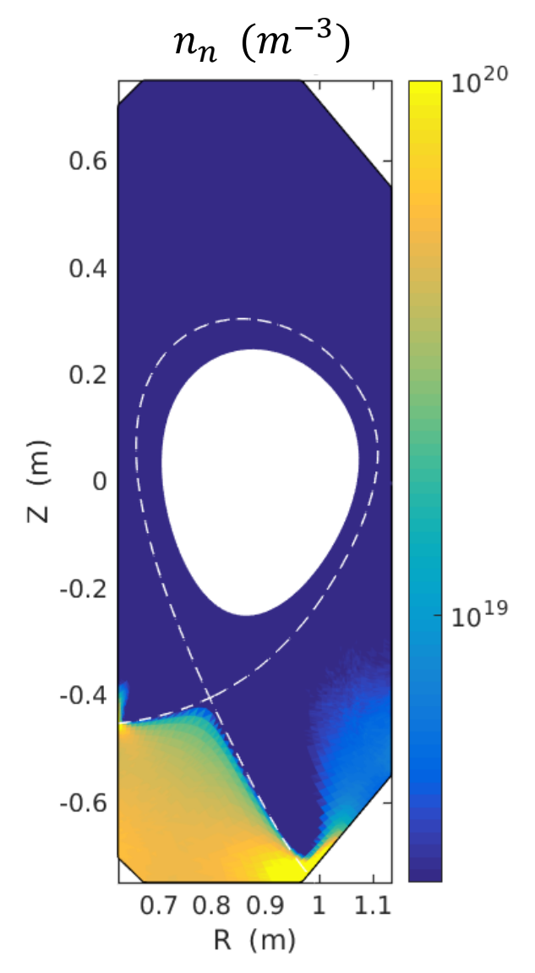
Neutral compression predictions with SolEdge and SOLPS

SolEdge2D: upstream conditions explored:

$$n_u = [1.8e19, 3.5e19]\ m^{-3}$$
$$P_{in} = [0.3\ , 1.2]\ MW$$

Increasing LFS baffle length ⇒ ionization front movement





High density, high power

Attached ionization front:

$c_D^{MAX} \sim c_D^{NoBaff.}$x4

Baffle 3 best

$n_n^{SOL} < n_n^{PFR}$

Detached ionization front:

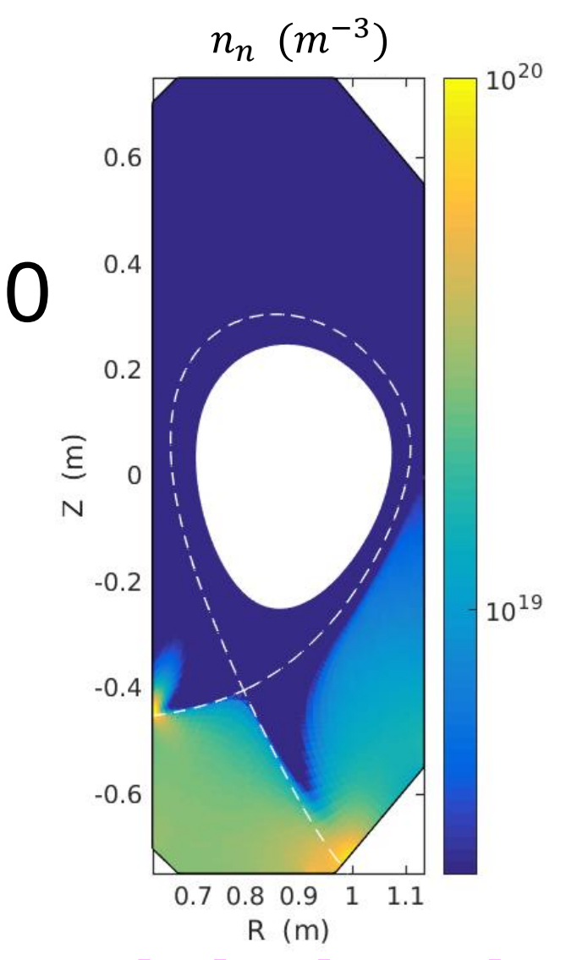
$c_D^{MAX} \sim c_D^{NoBaff.}$x20

Baffle 4 best

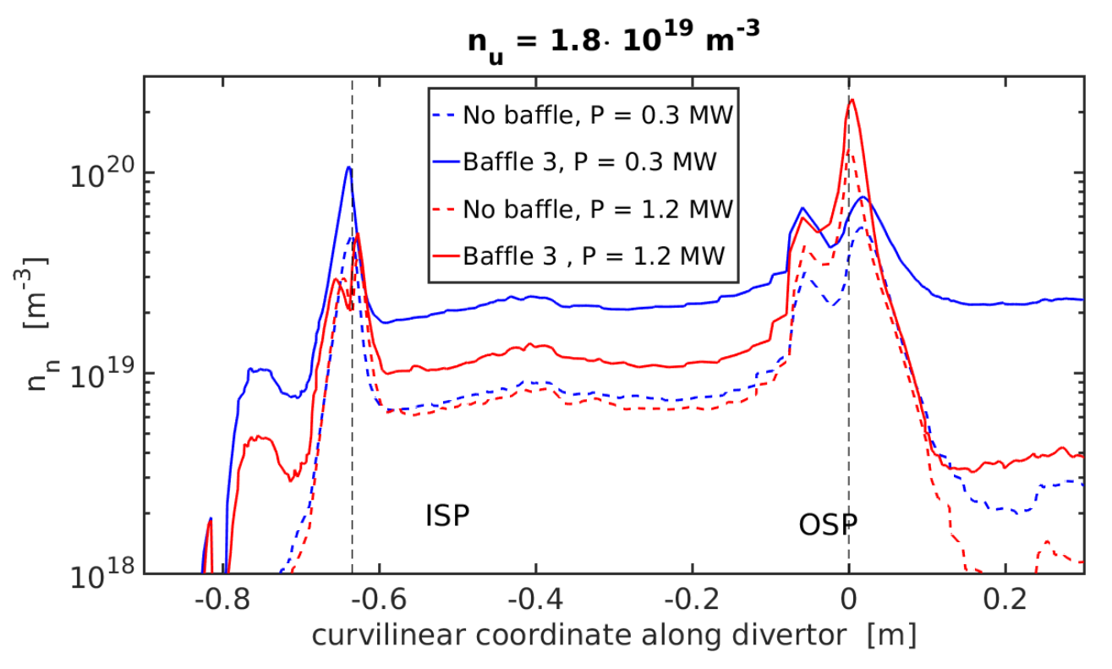
$n_n^{SOL} \simeq n_n^{PFR}$

$$n_n^{SOL}/n_n^{PFR}\ \sim \langle\lambda_{iz}\rangle^{SOL}/\langle\lambda_{iz}\rangle^{PFR} \leq 1$$

More neutrals blocked by baffles
⇒ better c_D improvement



High density, low power



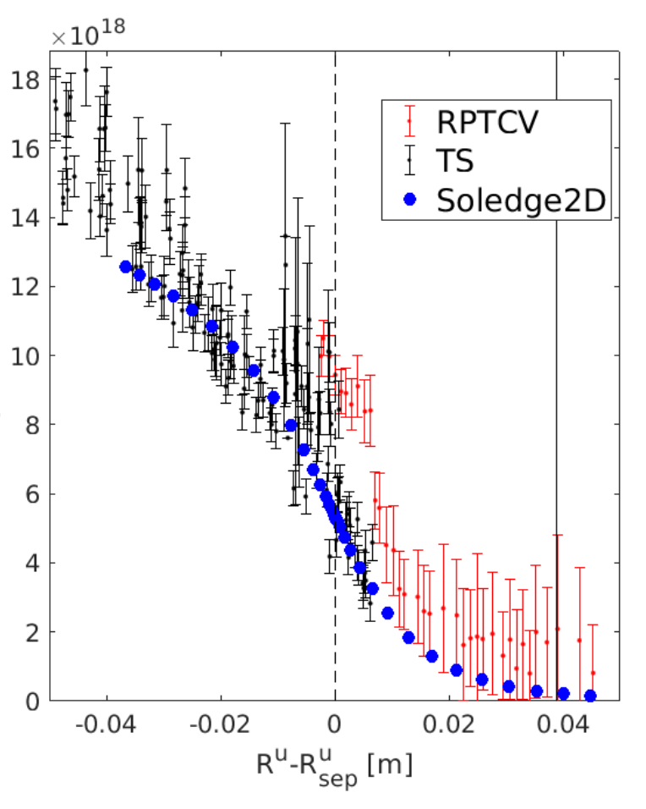
As in SOLPS-ITER simulations [3], Baffle 3 optimizes c_D in attached cases

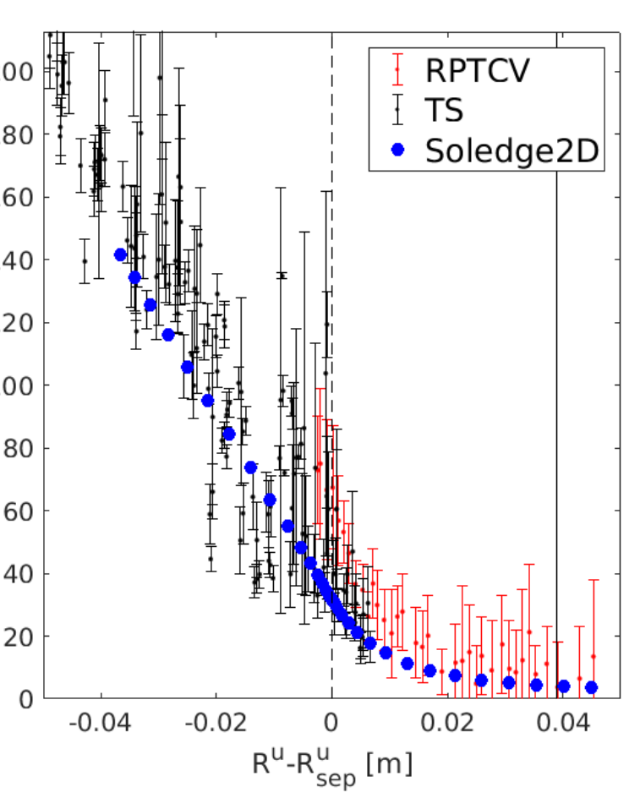
Main difference with SOLPS [8]:
→ $\langle n_n \rangle_{div}$ Baffle 3 vs No Baffle:
SolEdge ~ X 1.5 / SOLPS ~ X 5

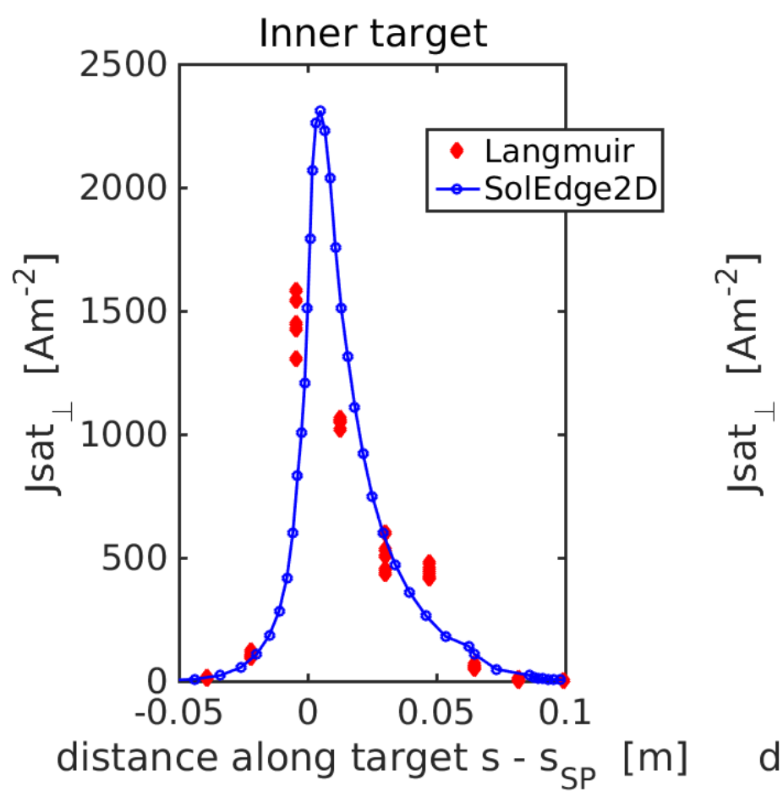
Comparison with experiments: preliminary results

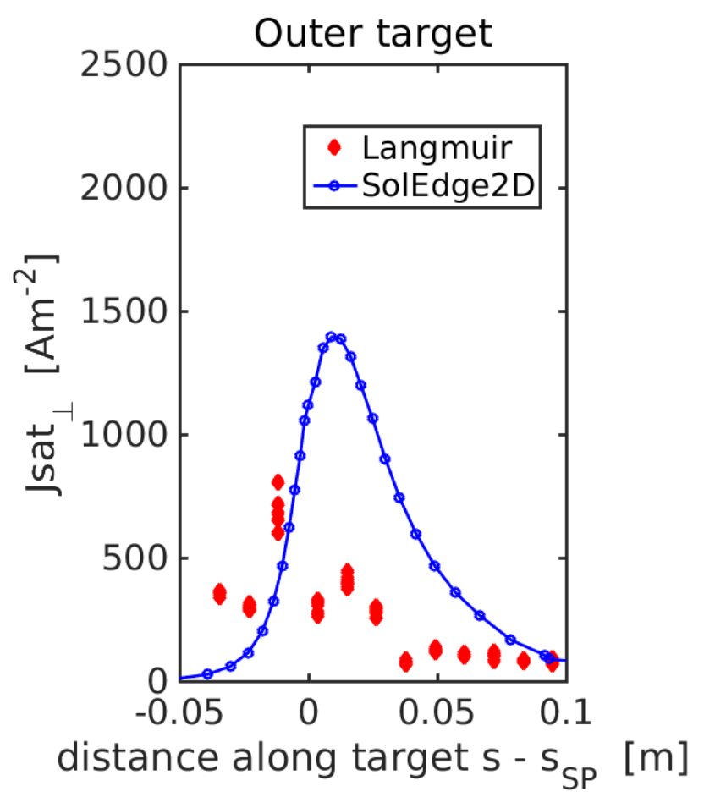
Ohmic L-mode, 140 KA, P=180kW
baffle-compatible

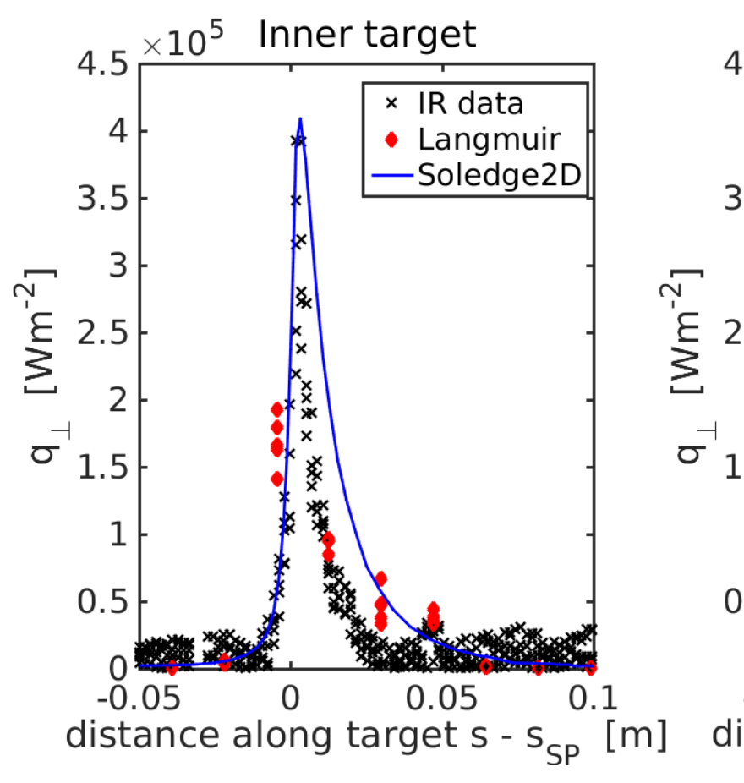
- $D, \chi \propto \exp\left(-\frac{\theta^2}{2\sigma^2}\right)$ ~ballooning, no drifts
- Carbon regulated via recycling: $R_C = 0.4 \Rightarrow P_{rad}^{SolEdge} \simeq P_{rad,edge}^{Exp}$

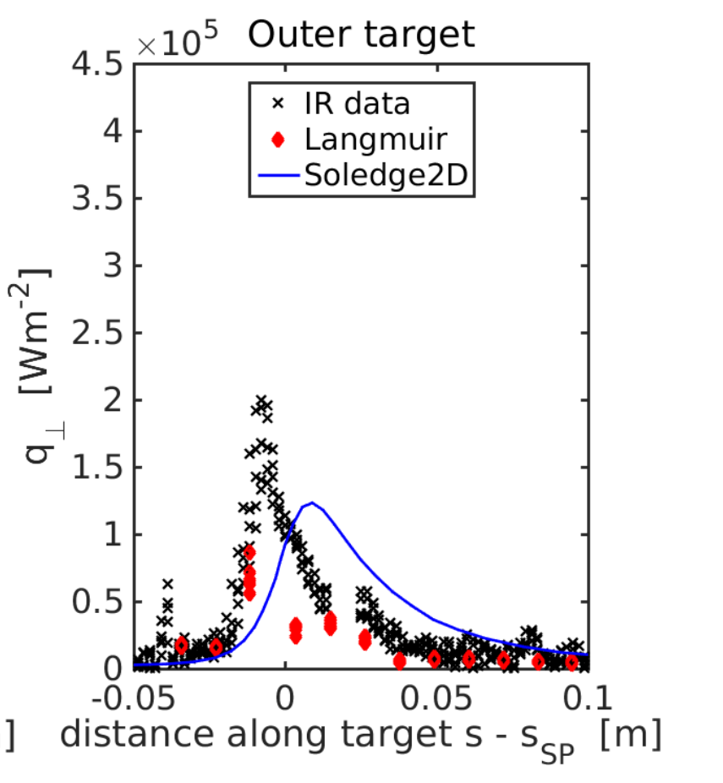












- Shape and asymmetry of target profiles in good agreement, but small shift, and $j_{sat}^{SolEdge} \simeq 2 \cdot j_{sat}^{Exp}$ $(n_{e,t}^{SolEdge} > n_{e,t}^{Exp}\ ,\ T_{e,t}^{SolEdge} < T_{e,t}^{Exp})$

Conclusions

- SolEdge2D-EIRENE simulations confirm that, in attached cases, Baffle 3 maximizes c_D. $\langle n_n \rangle_{div}$ underestimated with respect to SOLPS.
- When ionization front is detached, the baffle is more effective because more neutrals would be directed to the main chamber
- Baffle 4 optimizes most of the detached cases
- HFS baffle has globally a weaker effect than LFS baffle

Ongoing work:

- SolEdge2D-EIRENE and SOLPS-ITER comparison baffled-unbaffled
- SOLPS-ITER simulations including drifts

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