EUROfusion

COREDIV simulations for DEMO

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PLAN 2020

COREDIV simulations for 2020 are planned to continue the activities already started in 2019 on DEMO scenario analysis for $H_{98}<1$, concentrating in particular on He accumulation, divertor protection and burn-up fraction.
More in detail, focus shall be given on the following aspects:

- Consider $H_{98}=0.6$ with strong peaking profile for density (in 2019, the $H_{98} = 0.5$ case was studied)
- Determine the necessary impurity seeding for divertor protection for all cases.
- Analyse the role of He recycling coefficient.
- Provide an estimate of the burn-up fraction for the various cases analysed.

Starting point of the present analysis will be the same DEMO QH-mode baseline considered in 2019, then a scan in R and B (with the same values as in 2019 Final Report) shall be performed.

Only the lower single null divertor configuration is considered for the present task.

INPUT PARAMETERS

Major radius R [m]	I_p [MA]			$\langle n_{e,line} \rangle$ [$x10^{20}m^{-3}$]		
	B_t = 6T	B_t = 7T	B_t = 8T	B_t = 6T	B_t = 7T	B_t = 8T
9	18	21	24	0.681	0.795	0.903
10	20	23.33	26.66	0.61	0.712	0.81
11	22	25.66	29.33	0.556	0.649	0.741
12	24	28	32	0.51	0.595	0.68

Plasma density and current for different magnetic field and major radius.

- Aspect ratio = 3.1
- H_{98} = 0.6
- P_{aux} = 50MW
- n_{GR} = constant
- $n_e^{sep} = n_{e,line}/3$
- $Ne(0)/ n_{e,line}$ = 1.2

SHORT DESCRIPTION ON THE TRANSPORT

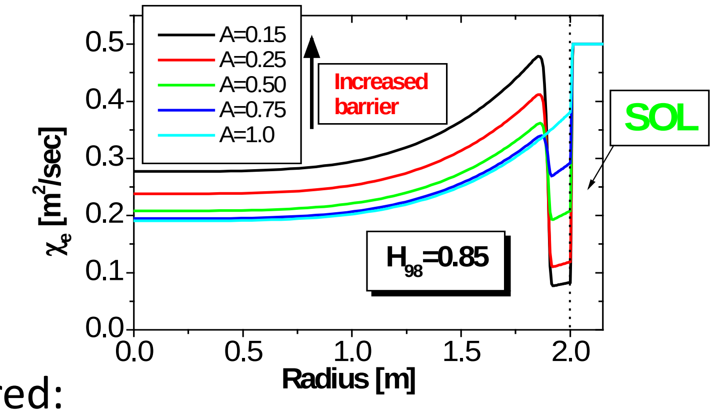
Transport model for background ions

Anomalous transport described by simple model:

τ_E from experimental ELMy H-mode scaling

$$\chi_{e,i}^{an} = C_{e,i}\frac{a^2}{\tau_E}\times\left(0.25+0.75\left(\frac{r}{a}\right)^4\right)\times F_B(r)$$

C_e – adjusted iteratively to keep prescribed confinement

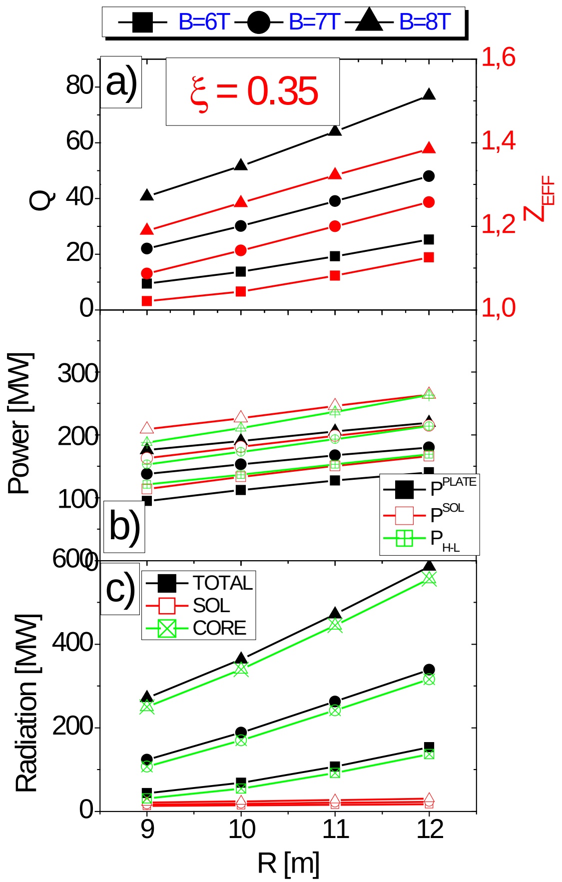


The following modelling approaches have been considered:

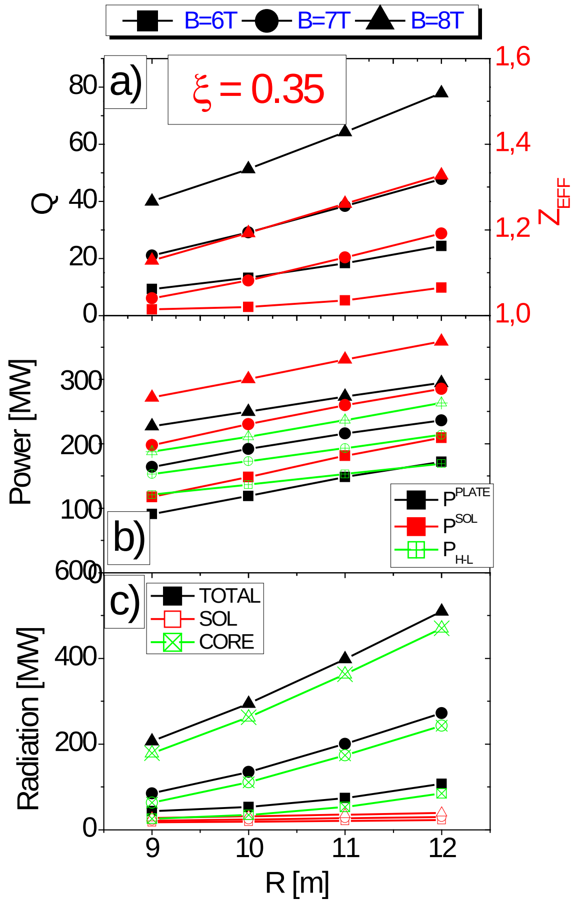
- fixed H_{98}
- assumption that 71.6% of the alpha power (Pα) heats electrons and 28.4% goes to ions in the new configuration (in the old one all Pα goes to electrons).
- no barrier (height of the barrier A = 0.85)

Influence of transport in core and SOL for different values of R and B

$D_{\perp}^{SOL} = 0.5 m^2/s$



$D_{\perp}^{SOL} = 1.0 m^2/s$



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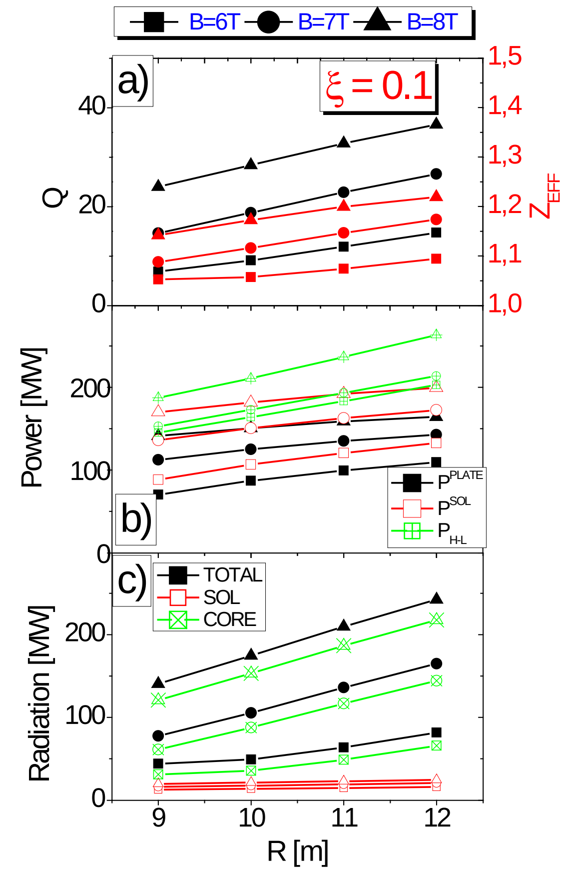

- For all cases P^{PLATE} >100MW → obligatory seeding
- For all cases $P^{SOL} > P_{LH}$ → obligatory seeding
- Diffusion in the SOL have small influence on the Q
- Different ξ coefficient: strong influence on Q, because of He accumulation (dilution effect)

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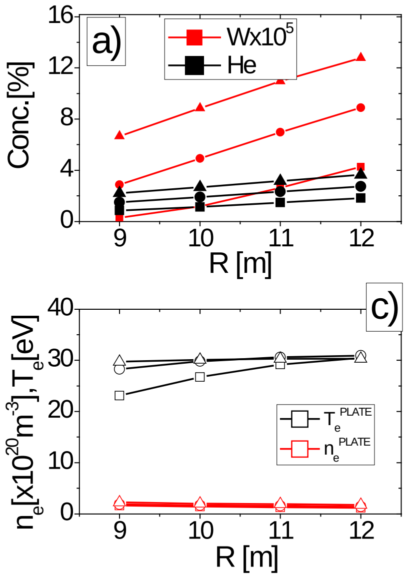
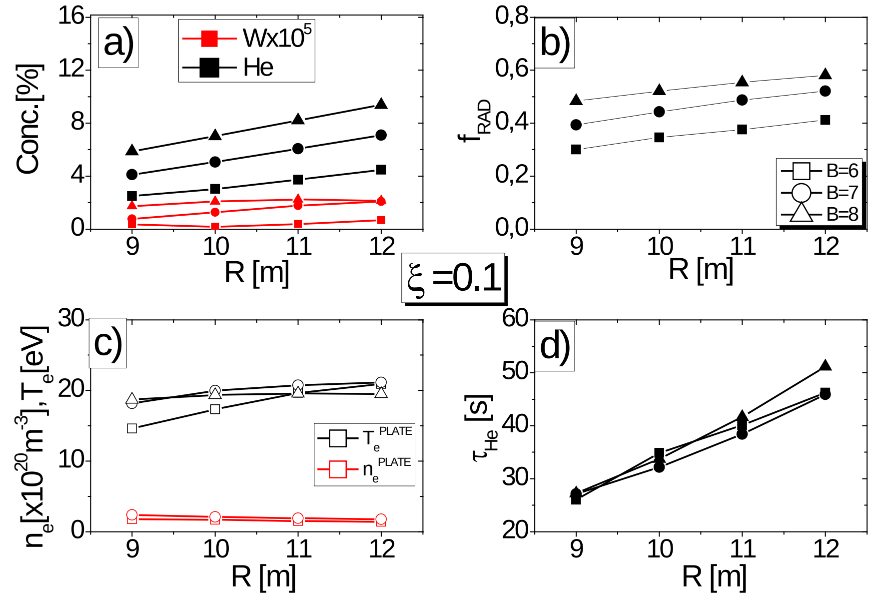
Influence of transport in core and SOL for different values of R and B

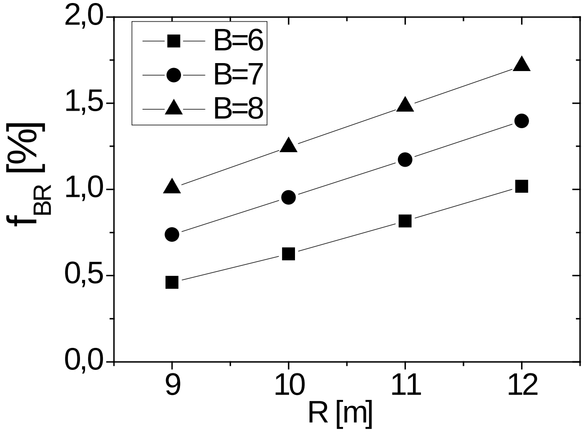


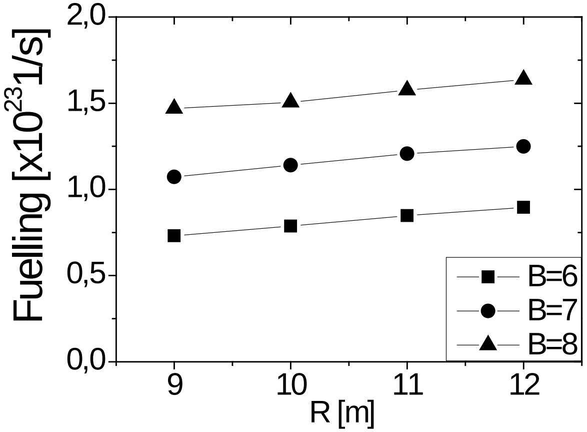


- With the increase of the magnetic field and radius, we observe increase of the He confinement time. The W concentration is lower than $12x10^{-5}$%
- For the case when B= 8T and R=12m, He concentration go to 10%.

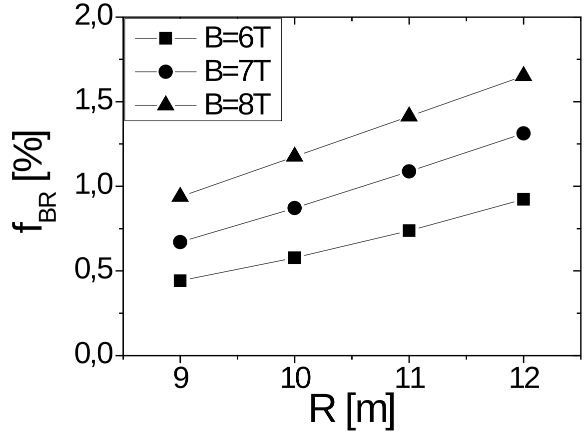
Influence of transport in core and SOL for different values of R and B

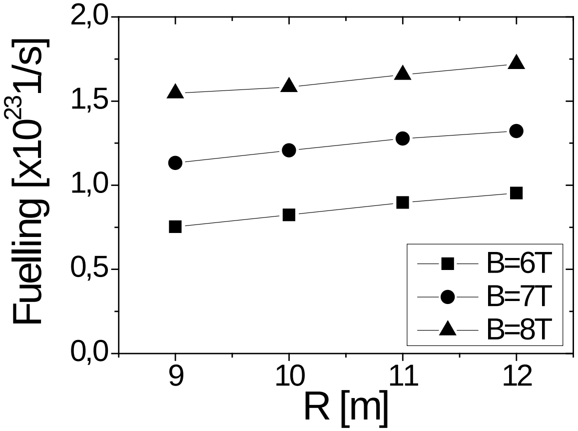
$D_{\perp}^{SOL} = 0.5 m^2/s$





$D_{\perp}^{SOL} = 1.0 m^2/s$





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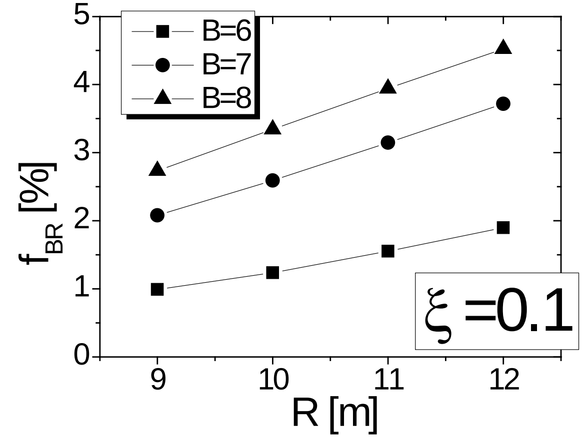
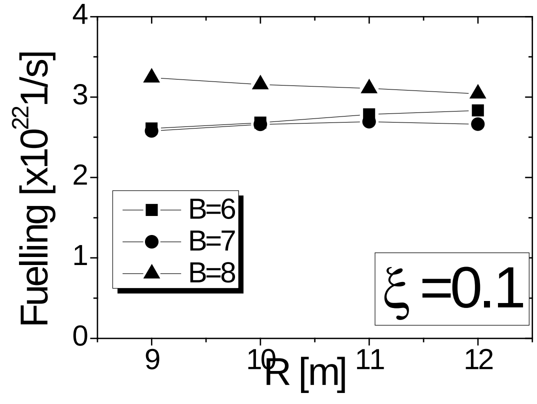




Influence of the different peaking factor

$k = n_e(0)/n_e^{LINE}$

Influence of the different peaking factor on the plasma density is analysed for the case with R = 11m and B_t = 7T.

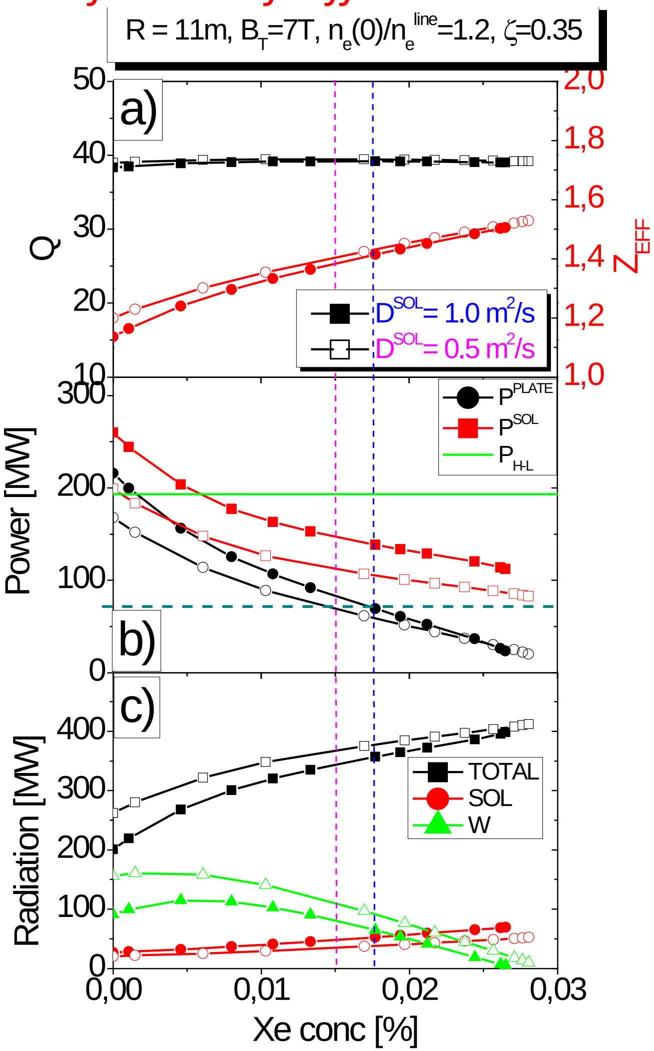
Parameter	Peaking factor			
	k = 1.35	k = 1.21	k = 1.16	k = 1.1
Q	43.2	38.96	36.86	34.75
P^{SOL} [MW]	217	199	190	182
C_{He} [%]	3.11	2.3	2.2	2.14
f_{BR} [%]	3.63	1.17	0.9	0.72
Fuelling [$x10^{23}$1/s]	0.44	1.2	1.48	1.75
$T_e(0)/\langle T_e \rangle$	2.98	3.19	3.28	3.37

Plasma parameters for different peaking factor.

Increase of the peaking factor from 1.1 to 1.35 have positive influence on alfa production, which increases by about 20%. Very strong effect of *k* is observed for the burn-up fraction (increase by 5 times) and fuelling source, which decreases by about 4 times.

Influence of the impurity seeding- Xe seeding

Influence of diffusion in the SOL



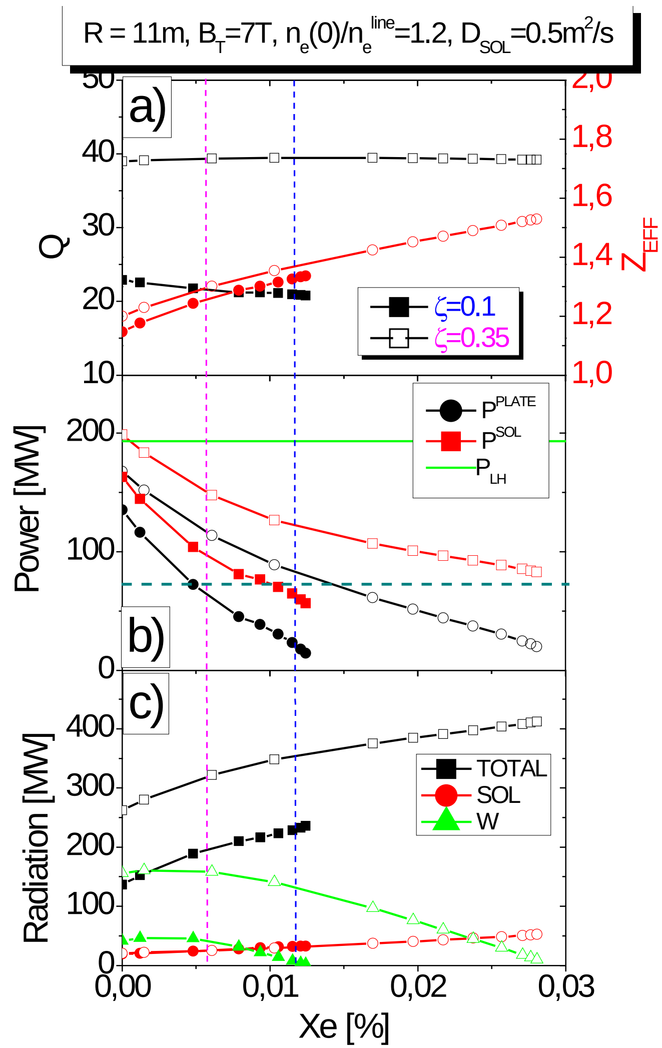
The working point for the case with higher diffusion in SOL only moves slightly towards higher Xe concentration.

The operation window in terms of the allowed seeding impurity concentration is strongly narrowed down in the case of lower ζ value.

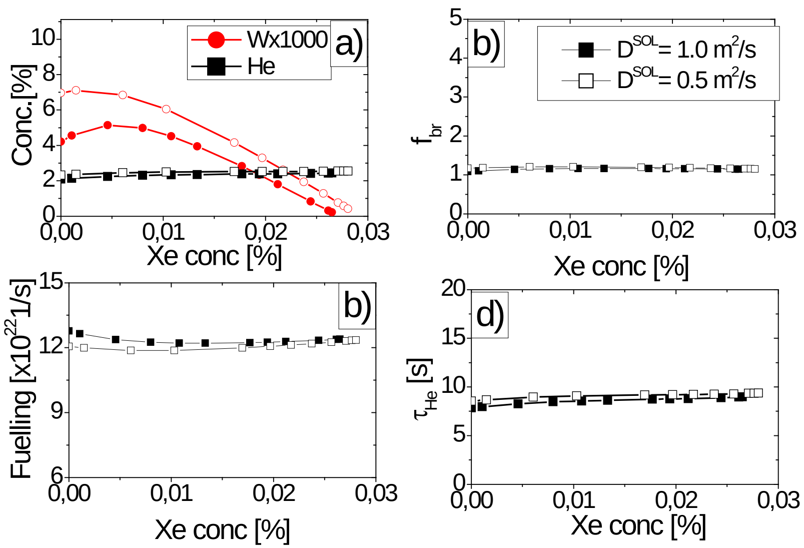
The He transport in the core have small effect on the radiation in the SOL and the Z_{EFF}, which are more effected by Xe and W impurities.

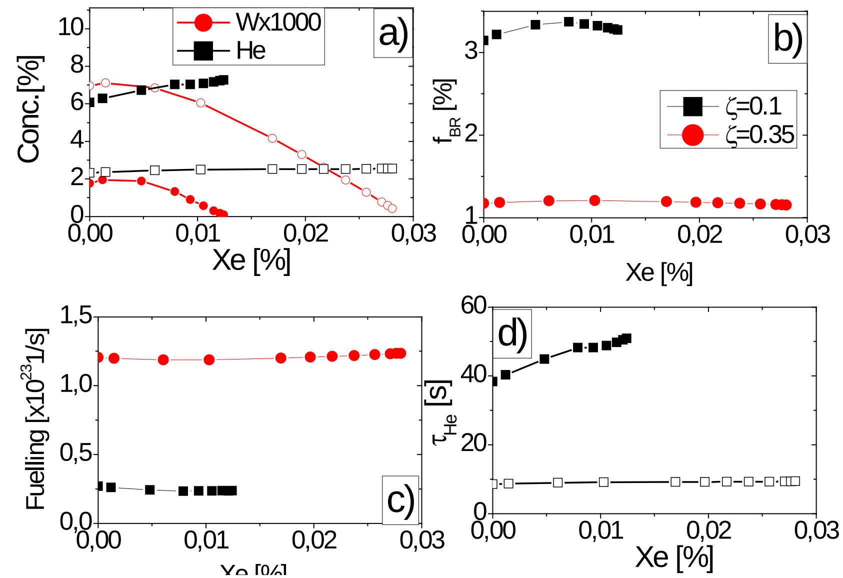
Q- factor is weakly affected by Xe puff

Influence of diffusion in the core



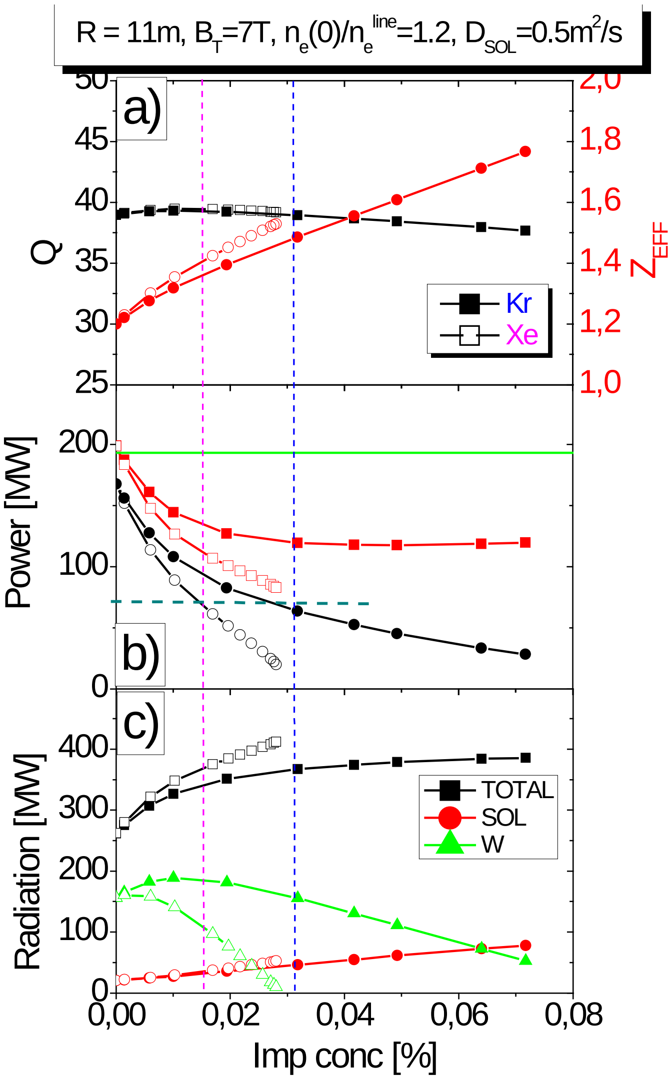
Influence of the impurity seeding- Xe seeding

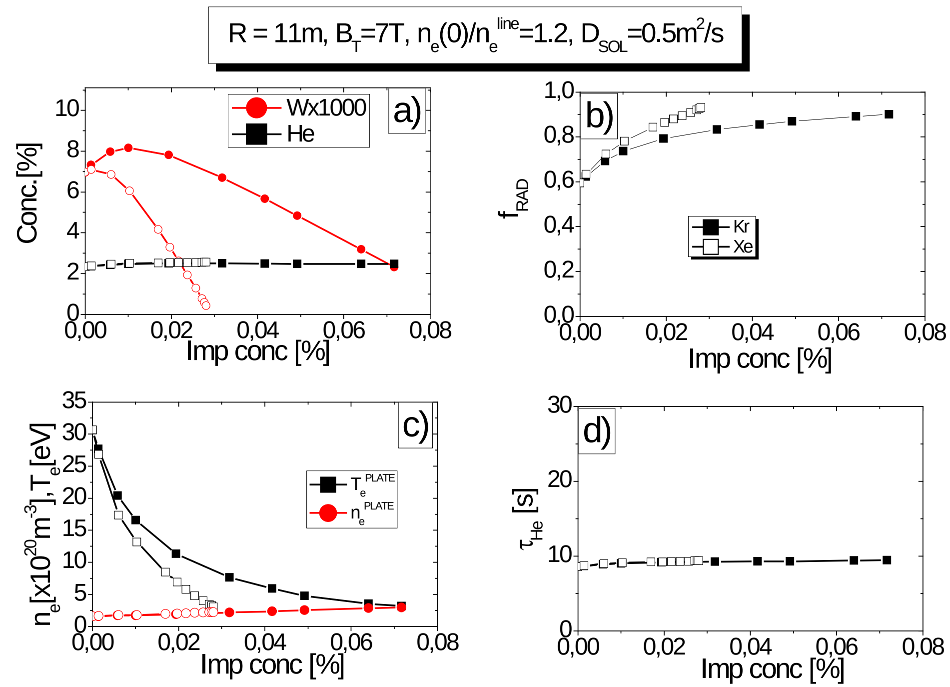




- The burn-up fraction and the fuelling source are scarcely affected by the Xe concentration as well as by the SOL transport. It appears, that the transport has small influence on the fuelling.
- For the core transport has a strong influence on both quantities.

COMPARISON: Kr & Xe

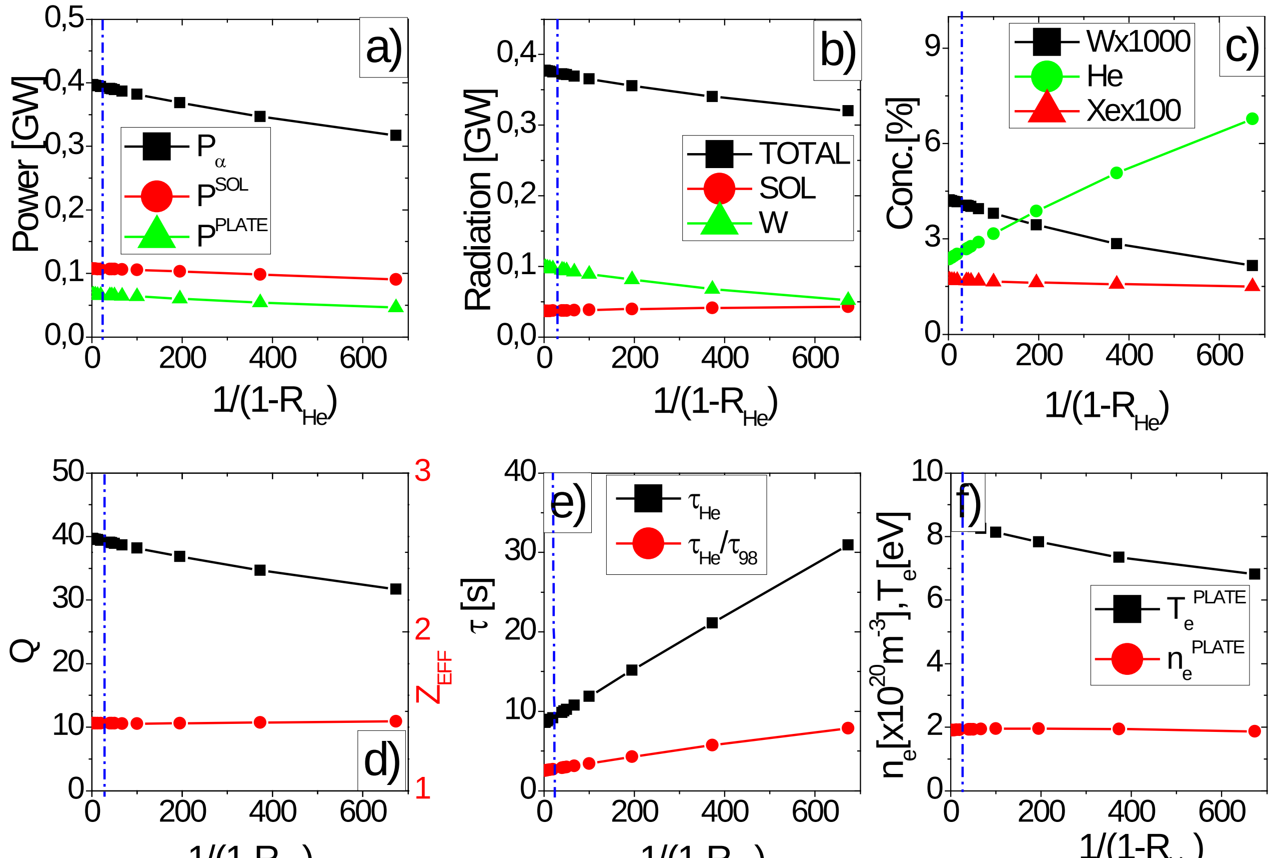




- In the case with Kr seeding working space started from 0.031%, but for Xe this value is 0.0175%.
- The Q- factor is apparently very similar for both impurities.

Influence of the He recycling coefficient

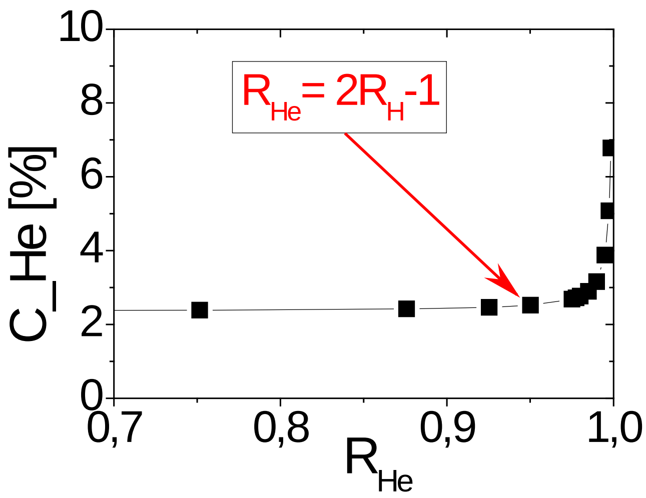
fixed Xe level
$\Gamma_{Xe} = 2.0\times10^{20}$ 1/s
R = 11m, B = 7T



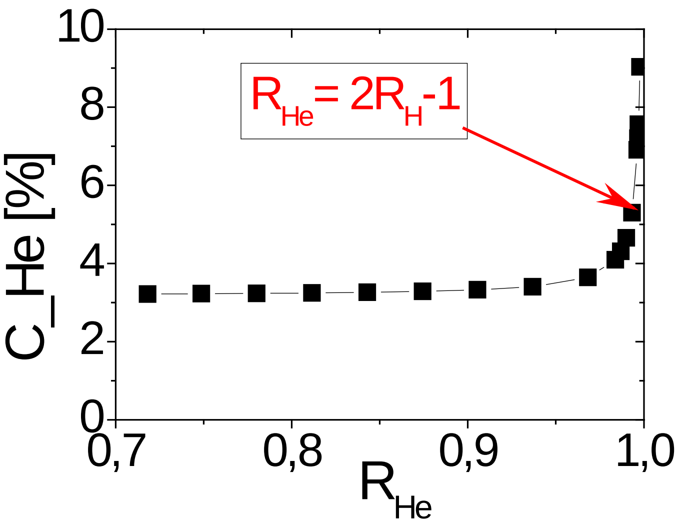
- The He confinement increases linearly from 9.0s to 31s for R_{He} values from 0.5 to 0.9979
- The ratio τ_{He}/τ_E changes only 3 times
- fusion power (Q - factor) is reduced by about 20%
- influence of R_{He} on the effective charge state , radiation in the SOL and plasma temperatures at the target strike points is rather weak.

Influence of the He recycling coefficient

fixed Xe seeding puff level $\Gamma_{Xe} = 2.0 \times 10^{20}$ 1/s
R = 11m, B = 7T



H-mode, R = 9, B=5.88T



Strong increase of the helium concentration, when its recycling coefficient is higher than 0.97

CONCLUSION

- The simulations of the DEMO L-mode carried out for 50MW auxiliary heating power, with different magnetic field, radius and plasma current, have shown that it is mandatory to apply additional impurities (Krypton and Xenon considered here) to reduce power to the plate.
- The peaking factor has strong influence on the burn-up fraction and fuelling.
- The COREDIV code has been used to simulate discharges with lower confinement with different impurity seeding with the special focus on the influence of the impurity seeding on the burn-up fraction, fuelling and plasma confinement. The simulations with constant electron density at the separatrix, it is found that impurity seeding has a small influence on the burn-up fraction, which remains around 1%.
- It appears also, that the helium core transport properties (coefficient ζ) has strong influence on DEMO performance, which is related to helium transport. If the particle transport is reduced (lower ζ), than the helium concentration increases leading to the reduction of the fusion power (Q factor).

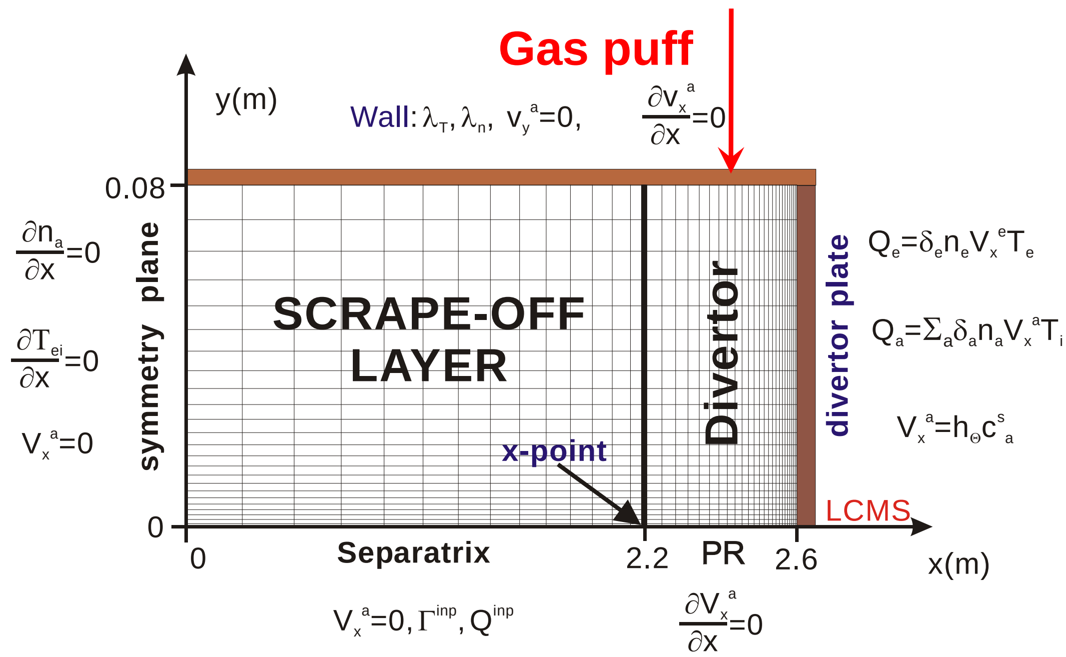
Conferences in 2020

SOFT: I.Ivanova-Stanik et al. „ *Analyses of the burn-up fraction and fueling for lower confinement discharges in DEMO reactor*"

IAEA: V. Pericoli Ridolfini„Analysis of the performances of a fusion reactor in a low confinement mode"

RECYCLING –PUMPING IN COREDIV

Scrape-off layer in COREDIV

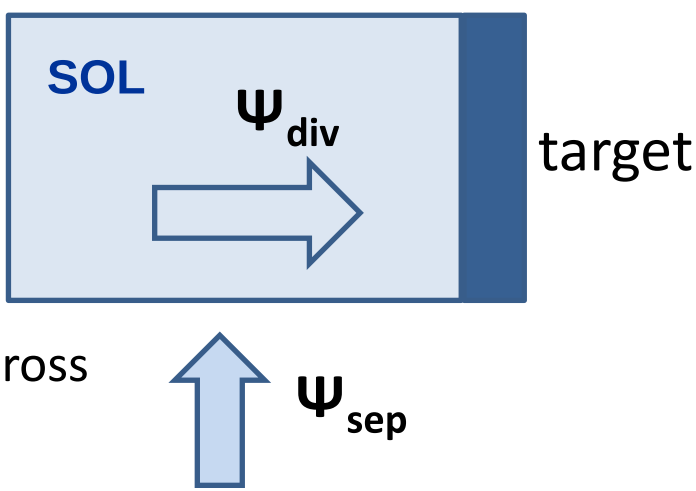


Gas puff source is situated in the divertor region (see arrow)

DEFINITION:

Recycling coefficient for main plasma/impurities:

$$R = 1-(\Psi_{div}/\Psi_{sep})$$



Ψ_{sep}- flux cross separatrix

In standard simulations:

$$R_{He} = 2R_H - 1$$

$$R_{He} = 2R_H - 1 \approx 0.99$$