Assessing Alternative Divertor Configurations for Power Exhaust in EU-DEMO

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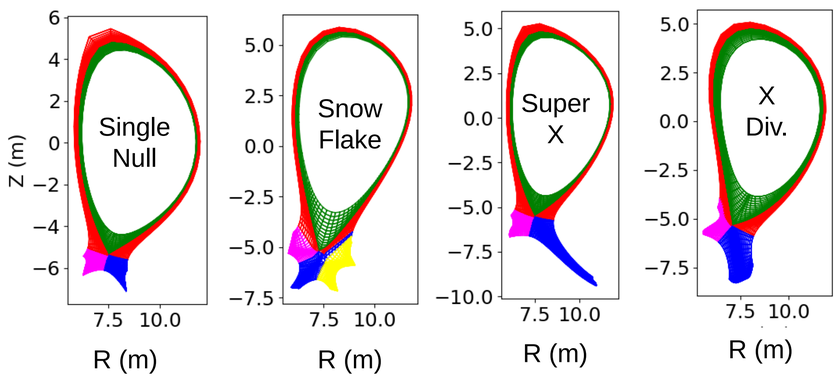
INTRODUCTION

- Aiming to deliver net electrical power ~ 2050, DEMO will produce ~ 450 MW of α power.
- Duplicating the ITER power exhaust strategy (high-radiating regime) requires probably f_{rad}~0.9
  - Considered likely to be obtained but cannot be completely positive.
  - Very little margin for plasma control is left.
- Alternative Divertor Configurations (ADC) may put weaker constraints in terms of, e.g., impurity fraction required.
- However, they are known to be challenging from an engineering perspective

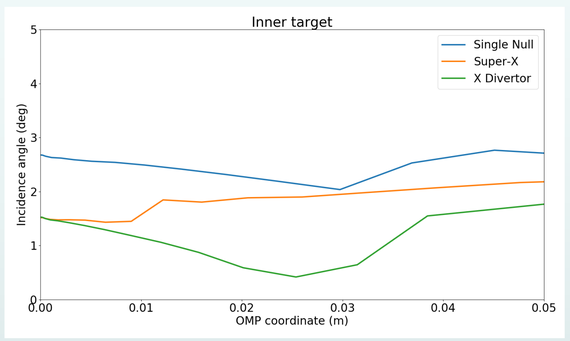
Need to carefully quantify the expected advantages

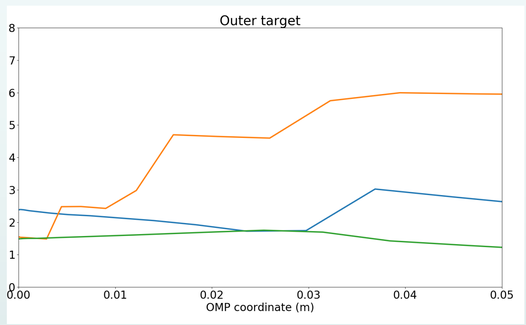


- Concentrate on three possible ADCs.
- First stage: run a large number of SOLPS-ITER simulations to perform a gross comparison.
- No quantitative results expected, but assess relative pro's / con's

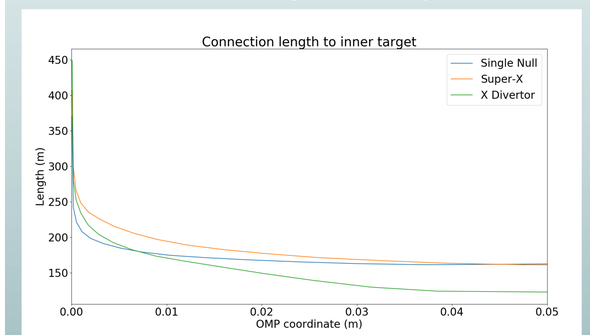
Most complete data for SN, SX and XD. Focus on them.

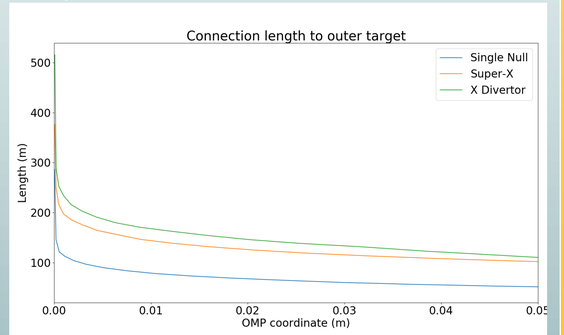
GEOMETRY MATTERS



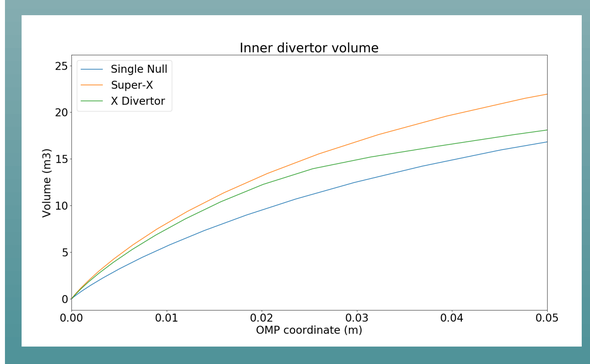


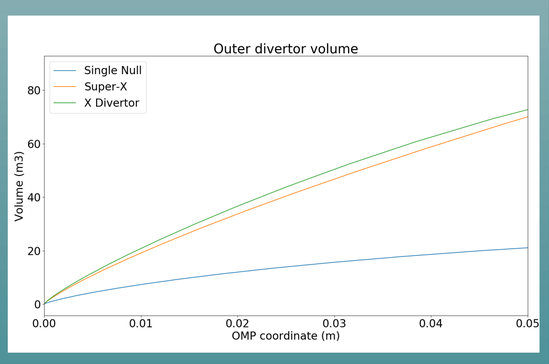
- Low magnetic incidence angle can help decreasing the power density deposition on the targets, leading to longer lifetime
- Both the considered XD and SX design show an advantage over SN on the inner target. On the outer one, the gain is less pronounced, especially for SX





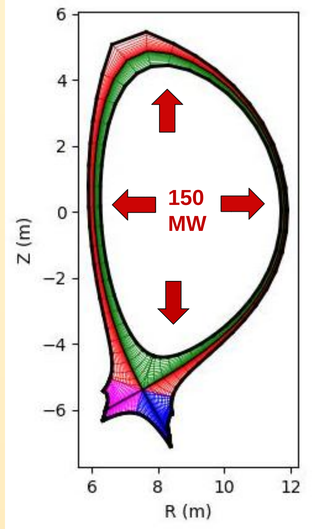
- All alternative configurations show an increased connection length close to the separatrix, especially on the (usually most critical) low-field-side
- Expected effects: (i) Lower the target temperature and heat flux (2-Point model gives $T_{tar} \propto L^{-4/7}$ and $q_{tar} \propto L^{0}$), (ii) Increase the chance to enter the high radiating region with a low impurity concentration (using Ar as divertor radiator $T_e \leq 30$ eV is required), (iii) Enhance the role of radial transport





- Alternative configurations also present a divertor volume radially increasing faster than SN, once again especially at the LFS.
- This, combined with radial transport, is expected to provide a larger radiation volume, contributing to enhance the divertor performance.

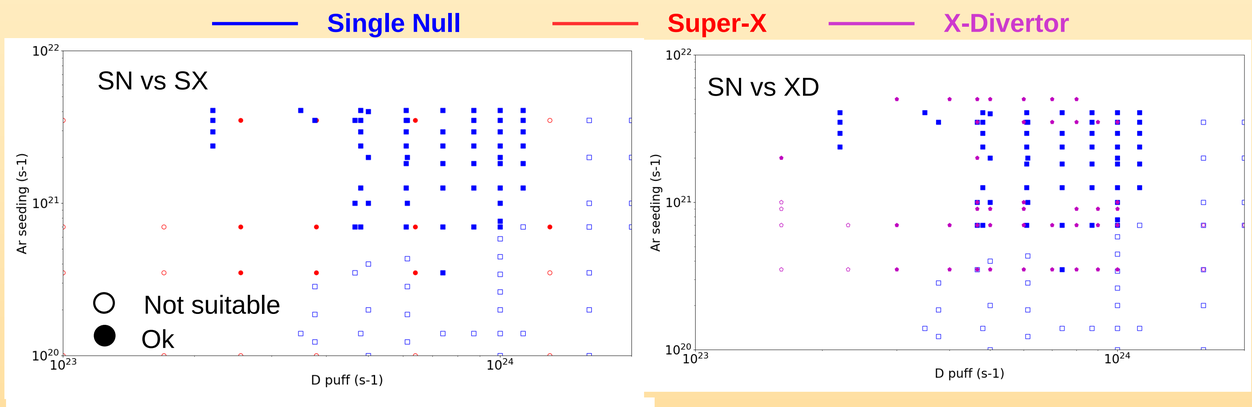
MODELLING SETUP

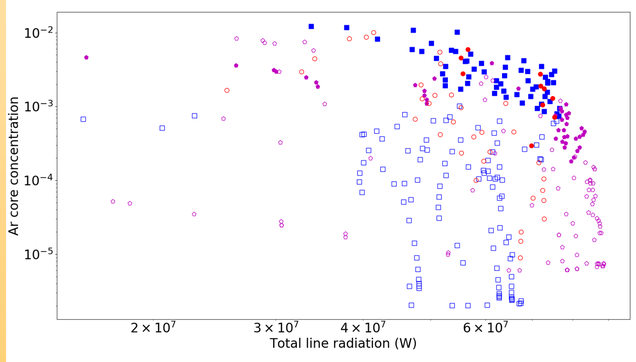


- SOLPS-ITER code (version 3.0.6)
- Main input parameters:
  - Core power: 150 MW (ions = electrons)
  - $D = 0.1$ m²/s (flat), $\chi = 0.1$ m²/s (core), 0.3 m²/s (SOL)
  - D+He+Ar plasma
  - D fueled from the core, Ar seeded from the wall

COMPARISON CONDITIONS

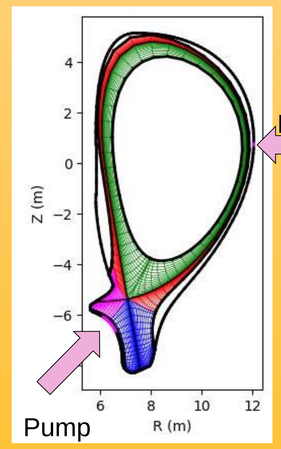
- Too many uncertainties to provide a quantitative analysis, but a qualitative comparison is still possible.
- Scan a large range of Ar seeding and D puff, define acceptable divertor condition as T_e < 5 eV, $n_{e,omp}$ < 4.2e19 m-3 (An alternative condition on low q_{tar} instead of T_e was also examined, but proved to be less restrictive)
- Try highlighting which configurations present a larger operational space (and how much)





- Both Super X and X-Divertor show a larger acceptable parameter space as compared to SN.
- In particular, Ar seeding can be as low as 0.5 the corresponding SN value, for acceptable divertor conditions
- As a further advantage, XD can access a region of large line radiation (taken in the first 5 cm distance from the separatrix at OMP) corresponding to relatively low Ar core concentration (measured as $C_{Ar} = n_{Ar}/n_e$

SWITCHING TO KINETIC NEUTRALS MODEL



- As a next step, we want to perform XD analysis including kinetic neutrals.
- A first case was selected to convert from fluid to kinetic neutrals:
  - Ar puff = $9 \times 10^{20}\ s-1$
  - D puff = $4.66 \times 10^{23}\ s-1$
- This is known to introduce a better neutral description, but is not straightforward:
  - D2 and Ar puff become localized (at OMP)
  - Pump is localized. Moreover, pumping speed is not under direct user control.
- We calibrated our kinetic case with a scan over the pump albedo
- Target: match as closely as possible the neutral pressure in the PFR reported by the selected fluid case: 2.33 Pa
- We will then use the same setup to repeat with kinetic neutrals a subset of the previous fluid study

Albedo (Pa)	D_0 pressure (Pa)	D_2 pressure (Pa)	D_{total} pressure (Pa)
0.85	2.60	4.64	7.04
0.75	1.48	2.35	3.83
0.65	0.93	2.11	3.04
0.55	**0.72**	**1.66**	**2.38**
0.45	0.59	1.38	1.96
0.35	0.56	1.24	1.80

CONCLUSIONS/PERSPECTIVES

- We presented the results of a a comparison among a few alternative divertor configurations, based on a scan on possible levels of D fueling and divertor radiator (Ar) seeding.
- ADC can take advantage of the longer connection length and larger divertor volume, accessing acceptable divertor conditions for lower Ar seeding (roughly as low as 0.5 the level needed by standard Single Null.
- XD seems capable to access a region of stronger divertor radiation level then SN or SX. In such region the core Ar concentration drops, with possibly favorable effect on core plasma performance.
- **Ongoing work:**
  - A preliminary scan is ongoing to determine an "equivalent" set of input parameters, if a kinetic model for neutrals is introduced
  - Estimates for the severity of possible W sputtering are being performed

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