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ASSESSMENT OF THE PUMPING EFFICIENCY IN DEMO CONVENTIONAL AND ALTERNATIVE DIVERTOR CONFIGURATIONS

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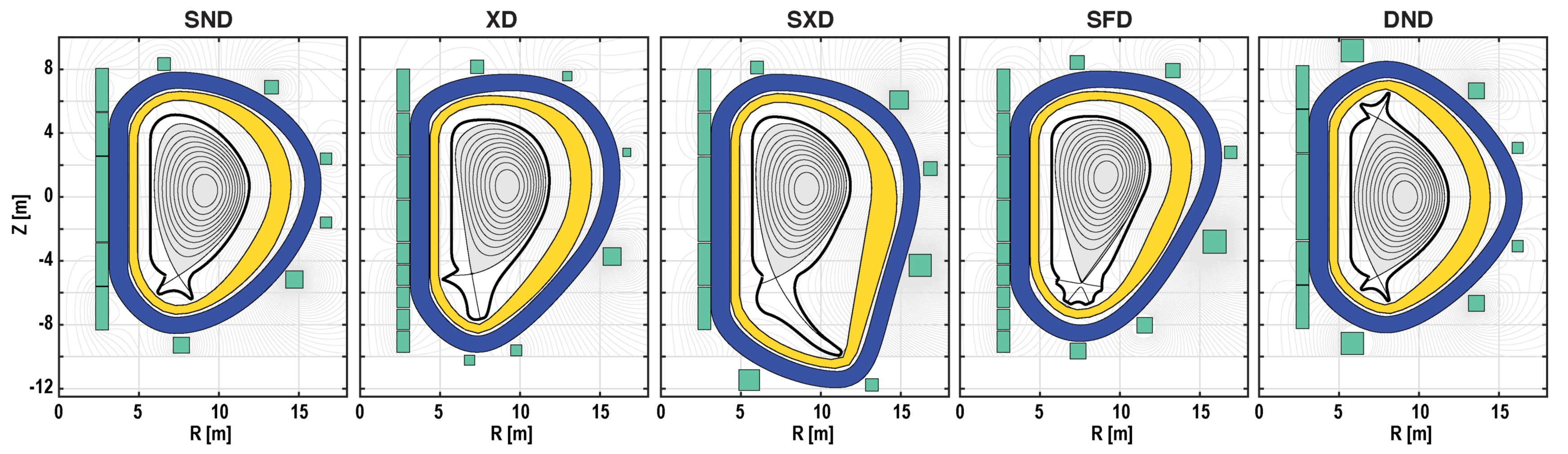
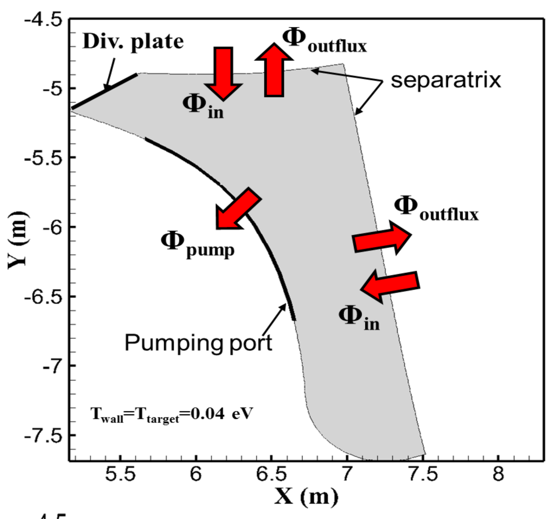
- **Alternative configurations for the DEMO divertor aiming to mitigate the heat loads at the plasma-material interface.**
- **This work studies the pumping efficiencies of proposed alternative divertor configurations and compares against SN as reference.**
- **The effect of location and the size of the pumping ports as well as the neutral flow behavior in the PFR are analyzed.**
- **Plasma scenarios are based on a highly dissipative divertor relying on a partially or even full detached divertor operating regime.**

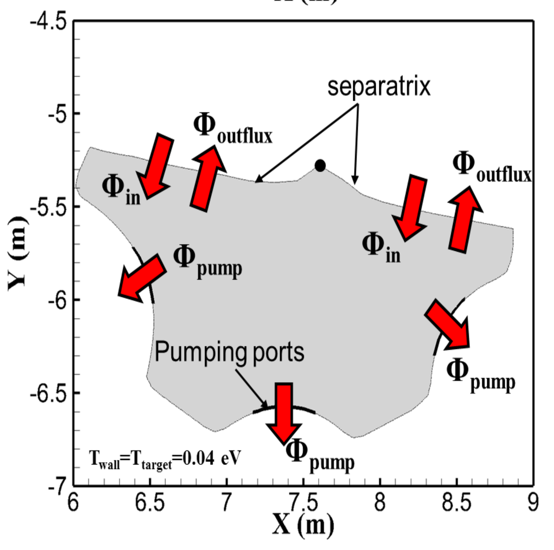
DEMO divertor configurations



- **The 2017 reference plasma configurations** [R. Ambrosino et al., FED,doi:10.1016/j.fusengdes.2019.04.095.]
- **16 ports with 3 cassettes each**
- **SOL EDGE2D-EIRENE code provides all input data for: P_{SOL}=50 MW, n_{sep}=2.4e19 m^{-3}**
- **Imput data: pressure for electrons and atomic/molecular deuterium along the seperatrix.**

DIVGAS [2,3] generic model



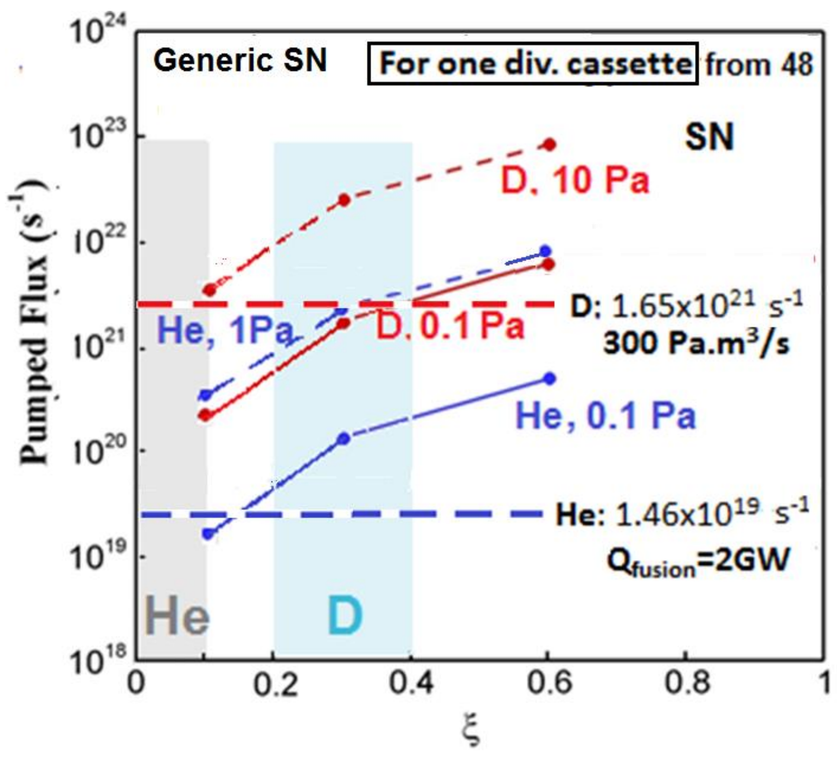


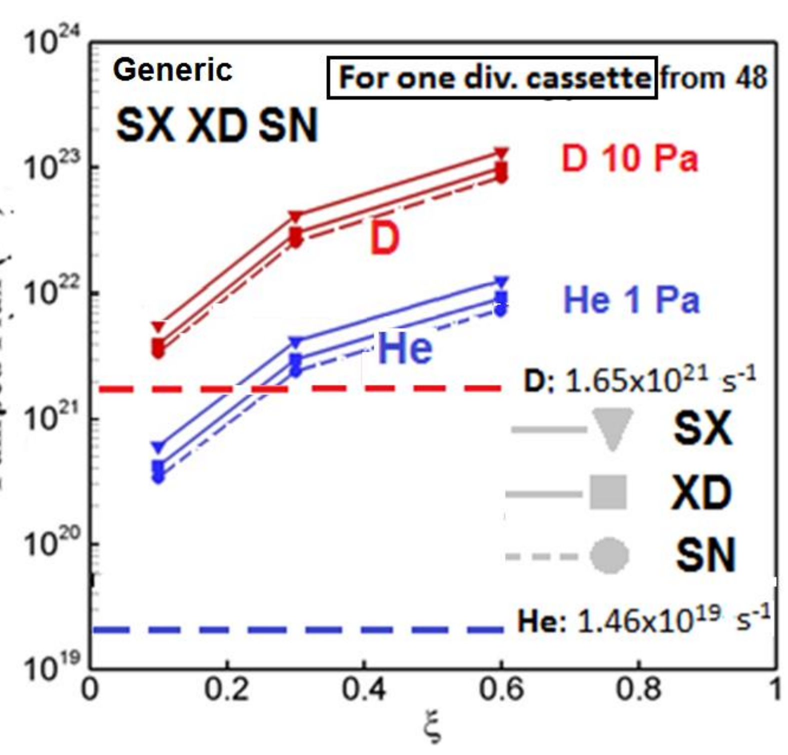
- **Particle balance:** $\Phi_{pump} = \Phi_{in} - \Phi_{ouflux}$
- **Effective pumping speed:** $S_{eff} = \frac{1}{4} \times A \times \xi \times v_t$
- **Pumping efficiency:** Φ_{pump} / Φ_{in}
- **Divertor „closure“:** $\Phi_{outflux} / \Phi_{in}$

- **A capture coefficient ξ (0≤ξ≤1) is assumed on the entrance to the pumping port**
- **The particle flux Φ_{in} depends on the imposed plasma BCs.**
- **Wall recombination included - Volumetric A&M processes are excluded.**
- **Perfect sealed divertor is assumed – No leakages.**

[2] S. Varoutis et al., FED, vol. 136, (2018),
[3] S. Varoutis et al., Nucl. Mat.Energy, vol. 19, (2019),

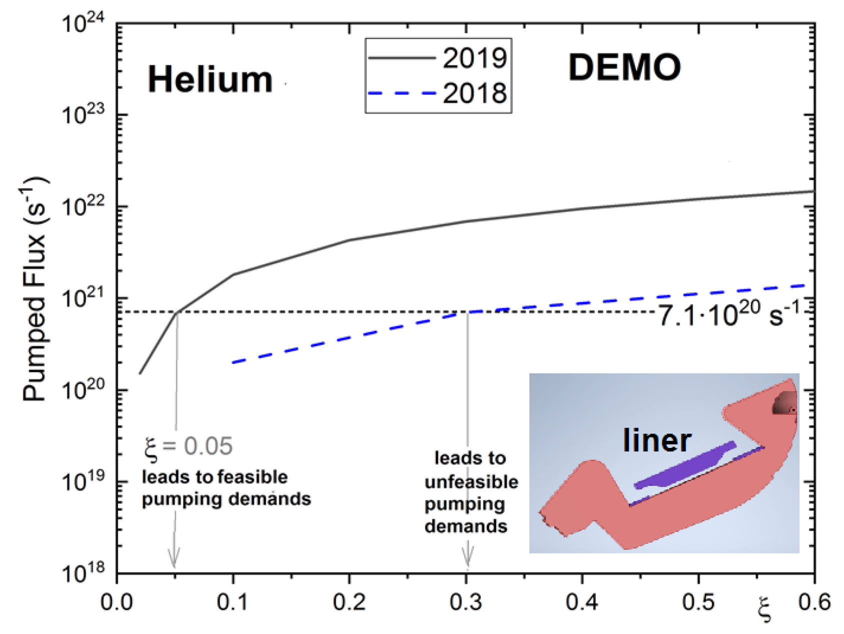
Generic SN - results of DIVGAS simulations





- Parametric variation of the divertor pressure; generic divertor design
- **Higher neutral pressure and gas collisionality at PFR, allow for a required helium removal within a realistic range of capture coefficients ξ below 0.05 for separatrix He pressure both 1 and 0.1 Pa. Whereas the fuel gas pumping can be realized in the range 0.2 – 0.3 for the high pressure at the separatrix ~ 10 Pa. The fuel particle throughput is taken as 300 Pa.m³/s.**
- **The XD divertor compared with the reference SN case allows for higher neutral compression in the PFR, thus facilitating pumping. For the case of SX divertor this effect is even more pronounced.**

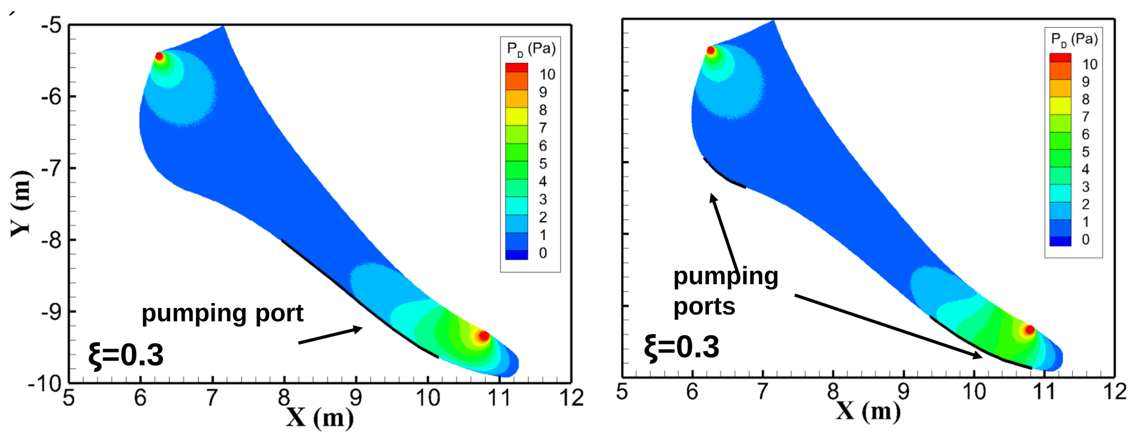
DEMO SN divertor- He pumped flux vs ξ for different BC



- **Specific divertor design with liner**
- **Helium pumped flux vs ξ for low He pressure at the separatrix (blue dashed line , 2018 year case) and a new 2019 design with higher He pressure as a BC for DIVGAS.**
- **Two cases with different He pressure at the separatrix. Corresponding pumping speeds are of about 214 m²/s for ξ ~ 0.3 and about 36 m³/s for ξ ~ 0.05 is estimated, which will require about 20 and 4 pumps, respectively.**

Alternative divertors

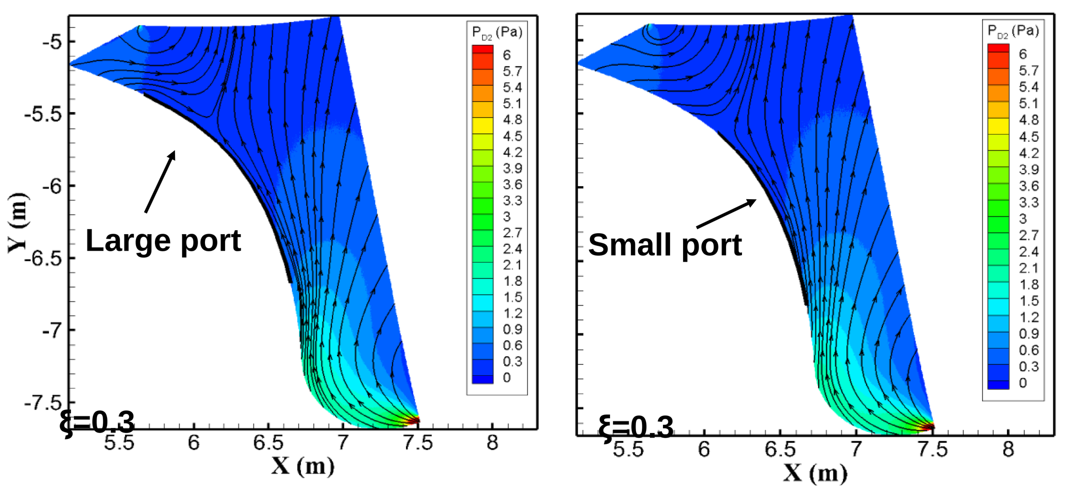
1. Influence of pumping port location



# Ports	Φ_{pump} / Φ_{in}	$\Phi_{outflux}$ / Φ_{in}
1	0.134	0.866
2	0.144	0.856

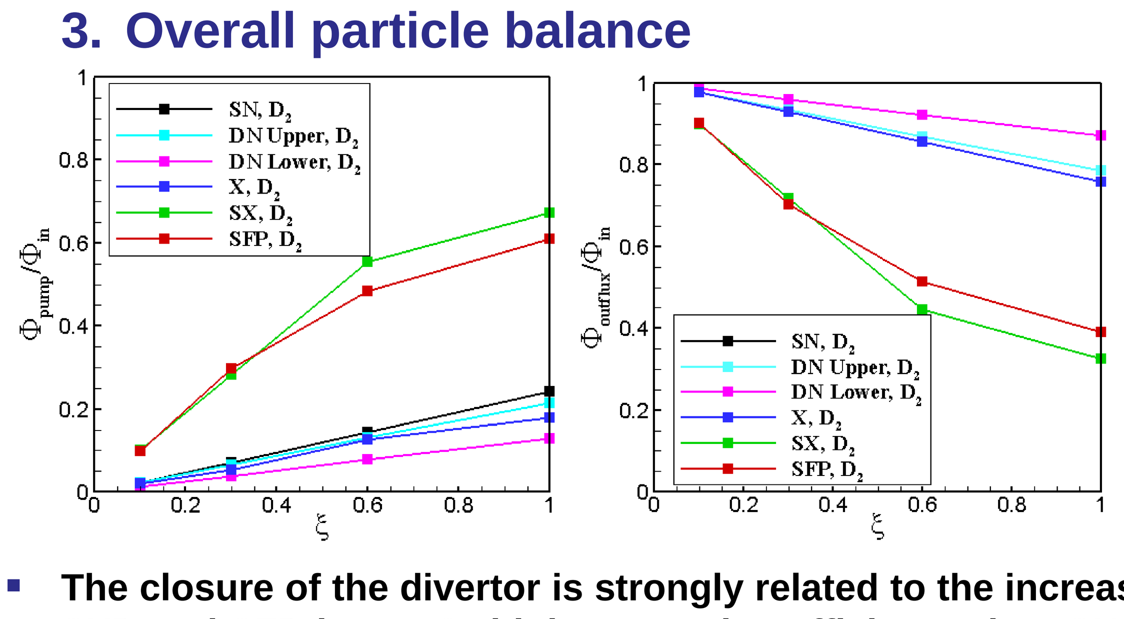
- **The position of the pumping port within high pressure areas (i.e close to strike points) significantly increases the pumping efficiency.**
- **Due to large separatrix surfaces the outflux is not influenced by the position of the pumping port. Typical behaviour for all „open“ divertors.**

2. Influence of pumping port size



- **Linear dependence of the pumping efficiency on the port size is observed (due to moderate gas collisionality in PFR).**
- **30% decrease in port size → 30% decrease in pumping efficiency.**

3. Overall particle balance



- **For “open divertor” configurations a linear dependence of pumped flux and outflux on ξ is obtained.**
- **The closure of the divertor is strongly related to the increase of pumping efficiency. For ξ=0.3, SXD and SFD have ~6x higher pumping efficiency than SN, DN and X divertors. The outflux is reduced by a factor of ~1.4.**

Conclusions

- **For „open divertors“ due to large outflux, high pumping efficiency cannot be ensured.**
- **High pressure areas are favorable for positioning the pumping ports → engineering constraints limit the design space.**
- **There is a clear trend towards higher pumping efficiency with divertor „closure“. For ξ=0.3, SX and SFP have ~6x higher pumping efficiency than SN, DN and X divertors. The outlux is reduced by a factor of ~1.4.**
- **A more „geometrically closed“ divertor allows for higher neutral compression and gas collisionality in the PFR, thus facilitating pumping → Dome structure will result in even higher neutral compression → Plugging of neutral outflux.**
- **He pumping seems to be feasible in configuration of a new SN divertor with higer He recycling**

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