ID: 851

Role of drifts, impurities and neutrals for credible predictions of radiation and power flux asymmetries in the DEMO scrape-off layer

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** See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia*

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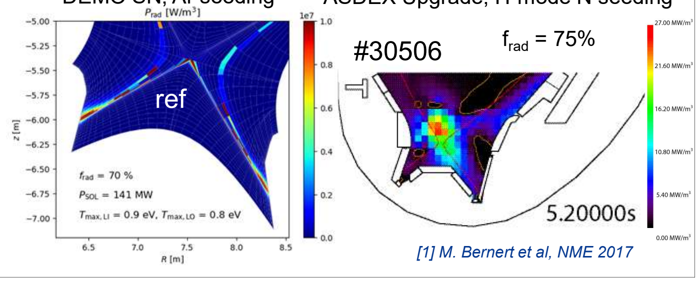
ABSTRACT

- Reduced physics SOLPS-ITER simulations are used for DEMO power exhaust scoping studies
- The radiation pattern in these **reference** simulations differs qualitatively from highly radiating solutions in present-day full-metal devices
- We've added physics (drifts, complex impurity models) in the DEMO simulations and tested the reference model on JET L-mode N-seeding experiment

BACKGROUND

- In N-seeded high-power discharges in ASDEX Upgrade and JET, strong radiation and detachment of outer divertor is associated with the radiation front moving to closed field lines above the X-point (XPR)
- XPR is observed at several power levels and also in L-mode
- The XPR is not observed in the detached edge plasma solutions obtained in DEMO and ADC scoping studies

Typical radiation pattern modelled for DEMO (left) and measured (right)



[1] M. Bernert et al, NME 2017

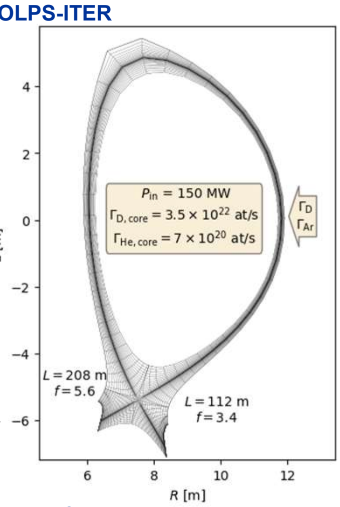
DEMO SCOPING STUDIES USING SOLPS-ITER

Setup of the reduced physics reference (**ref**) simulations presented here:

- Fluid neutrals
- D + He + Ar (bundled)
- P_{in} = 150 MW at the core boundary (150 MW assumed to be radiated by high-Z impurities)
- Currents on, no drifts
- Fixed transport coefficients, yielding $<\lambda_q> \sim 3$ mm
- 1% of neutrals absorbed at the PFR boundary

Criteria for operating points:
- $n_{sep,OMP}$ <= 4.2E19m^{-3}
- T_e < 5 eV at the targets
- q_{max} < 10 MW/m^2 at the targets

- Same model used here for the JET **ref** simulation, but with N impurities and P_{in} + transport coefficients as in [3]



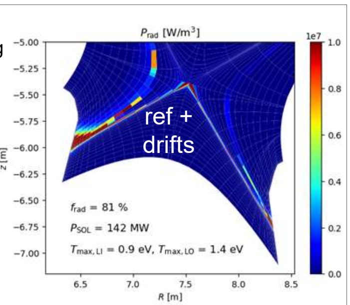
For DEMO SN simulations using kinetic neutrals, see [2] F. Subba et al, to be submitted (2021)

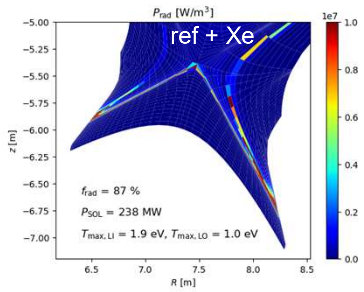
EFFECTS OF MODEL VARIATIONS

We've tested the effects of drifts, unbundling of Ar impurities, and explicit inclusion of core radiators (Xe) with P_{in} = 300 MW

Drift effects in DEMO

- Outer target T_e increases
- More seeding and higher f_{rad} required for operating points
- More radiation in the inner divertor



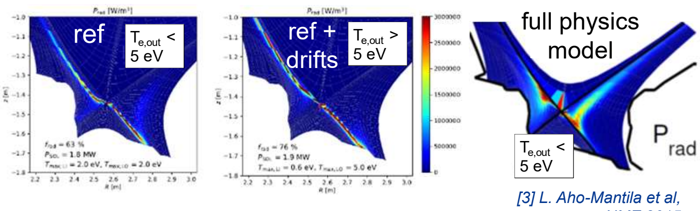


Role of impurity model for the DEMO radiation pattern

- Similar radiation pattern as in **ref** when Ar is unbundled
- Core radiation (Xe) can be kept small even when P_{in}=300 MW, no XPR is formed in mixed Xe+Ar simulations

Model variations in JET N-seeded L-mode simulation

- Reference, reduced physics model yields $T_{e,out}$ < 5 eV with radiation front in the divertor
- When drifts are activated, $T_{e,out}$ < 5 eV only when the radiation front moves to closed field lines above the X-point (unstable)
- Full physics model (incl. drifts and kinetic neutrals) yields a more stable solution with XPR and $T_{e,out}$ < 5 eV (not verified in the exp.)
- In-out asymmetries observed with all model variations



[3] L. Aho-Mantila et al, NME 2015

CONCLUSIONS

- DEMO divertor solutions obtained with SOLPS-ITER do not yield significant X-point radiation for P_{sep}/R = 16 – 26 MW/m and T_{out} < 5 eV (detached solutions)
- Adding more physics terms (in particular drifts) is seen to be important to achieve XPR in our JET L-mode simulation, but the same is not observed in DEMO simulations
- The difference in edge plasma conditions (temperatures, power fluxes) between DEMO and present-day machines may mean that DEMO will not have XPR
- More stringent requirements and input assumptions (e.g. deeper detachment, narrower λ_q) may modify the modelled DEMO conditions and should be reviewed as a next step

This work has received funding from the Academy of Finland. This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission , the Academy of Finland, or the ITER Organization.