EUROfusion

IPPLM: COREDIV and TECXY modelling

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Outline

1. COREDIV and TECXY modeling in 2020
    - Tin and lithium
2. COREDIV and TECXY modeling and 2021
    - Divertor design params
    - Sn thermal sputtering
3. Summary
4. Prospectives for 2021

COREDIV

COREDIV = 1D transport in the core self-consistently coupled to 2D model in the SOL

Aims at steady state description of plasmas with impurities

Advantages:

- Self-consistent modeling core and SOL

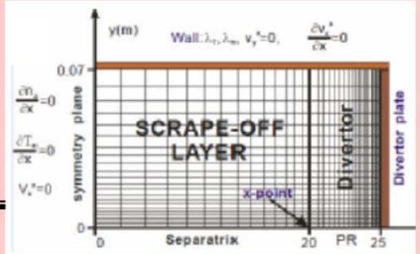
  Important for simulation of the impurities either intrinsic sources: C, W, Sn, Li, or gas puffed: Ne, Ar, Kr, Li…

Simplified core-SOL-divertor simulator (COREDIV):

Core: simplified ($H_{98(y,2)}$) heat and particle (impurity+ main ions) transport and sources, no equilibrium

Fluxes →

← Boundary

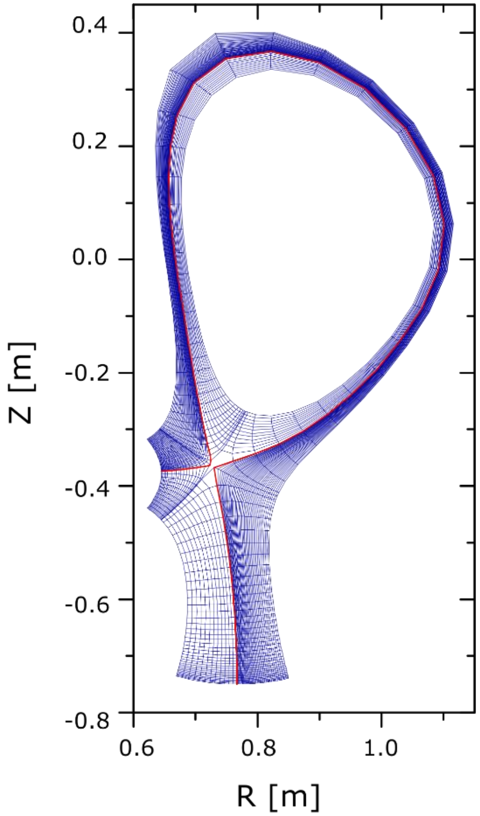


- Included atomic processes: ionization, recombination, excitation, charge exchange
- Solved each ionization stage of the impurities
- Intrinsic and seeded impurities – gas puff at different positions
- Faster code: 1case - 12h

Drawbacks:

- SOL slab geometry –profiles do not always correspond to the observed ones. One should rely on volumetric entities.
- Semianalytical model of neutrals -> not valid in detached conditions

TECXY



Modelling of the plasma transport in the SOL region with use of a numerical model based on multifluid Braginskii-like equations of the plasma transport in two-dimensional geometry with classical transport along field lines and diffusive transport across field lines. Simulations of plasma for any number of impurity species and all associated ionization stages. The TECXY code applies atomic processes like ionization, recombination, excitation, charge exchange, prompt re-deposition, sputtering, recycling or the liquid targets evaporation.

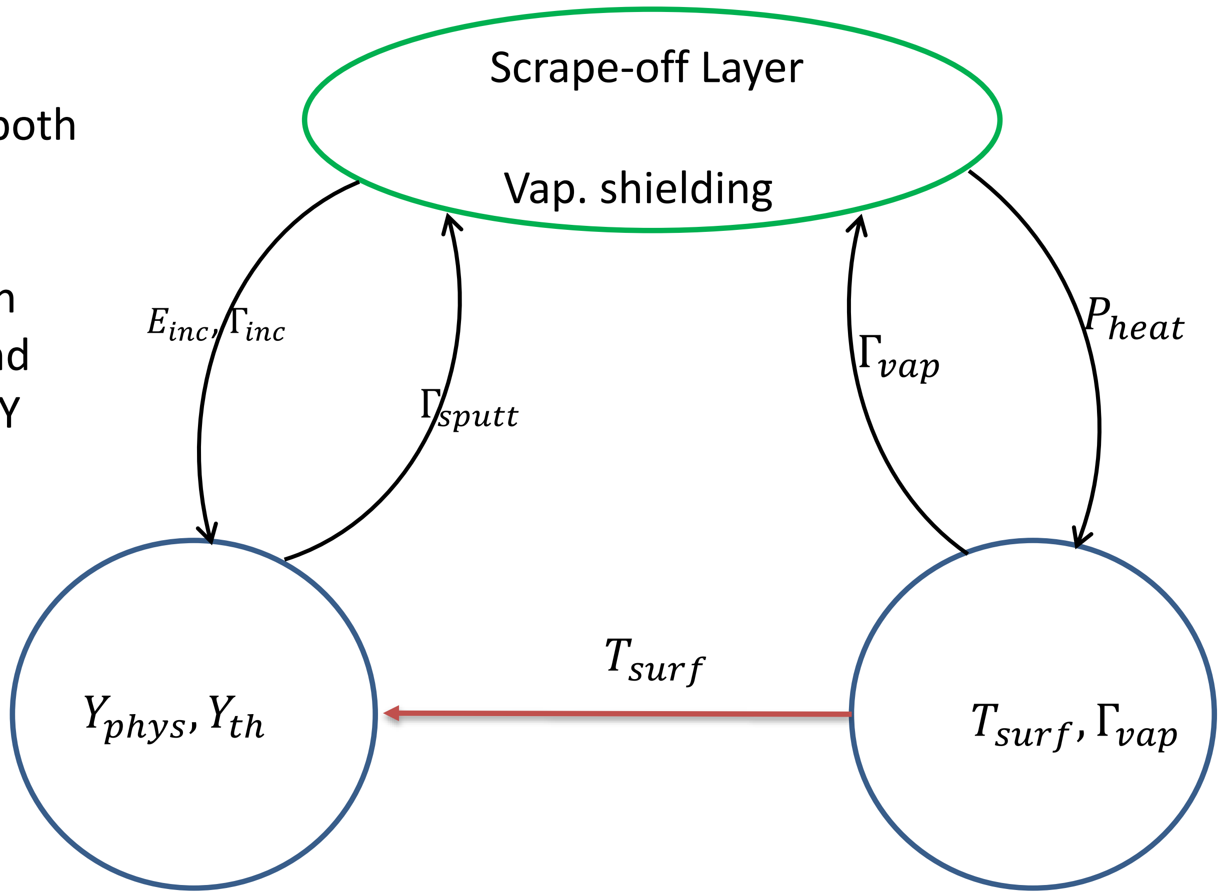
Simulations with the TECXY code could be applied for:

- Investigations of divertor plasma physics: estimation of the particle and heat fluxes to the divertor plates, plate temperatures, or.
- Modelling of the power mitigation for advanced divertor configurations (ADCs).
- Simulations of the liquid metal divertor impact on the SOL plasma.
- Study of the onset of the plasma detachment.
- Determination of the radiation spatial distribution for main plasma and plasma impurities for spectral analysis.
- Exploration of a tokamak operation parameter space related to geometry, impurities, estimation of radiative power exhaust by certain impurity mixtures and their concentration and required seeding rates.

Liquid metal impurity source model

The same impurity source model is implemented in both codes.

Upgrades are first tested in COREDIV (more robust) and then impemented in TECXY

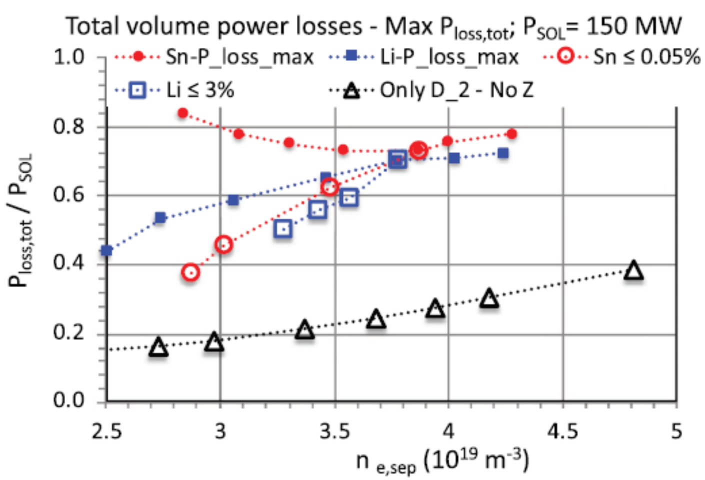


Sputtering model
Collisional and thermal component

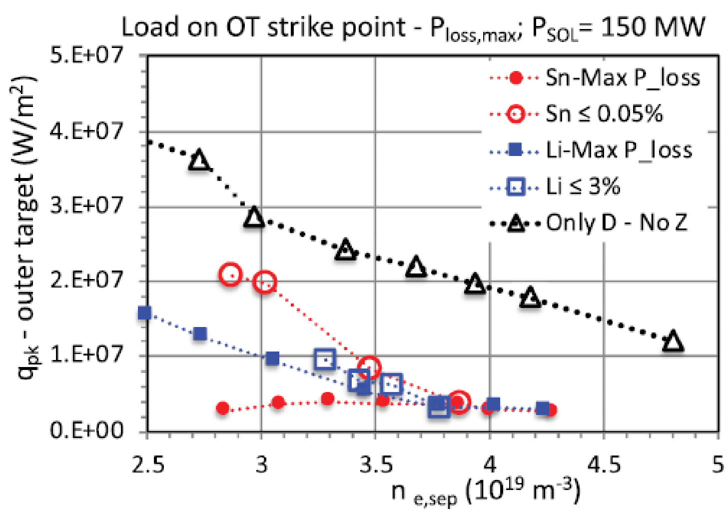
Evaporation model

2020/2021 modelling

- In 2020 TECXY modeling was focused on comparing lithium and tin divertors
- Scans of the key plasma parameters (e.g. $n_{e,sep}$ below)



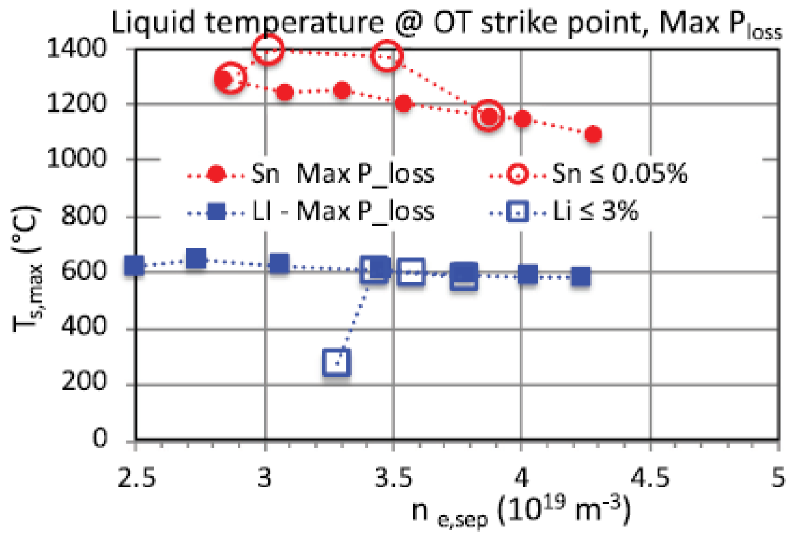
Fraction of the total power losses for Li, Sn and pure plasma



Power load on the outer target liquid vs the outer midplane separatric density in the case of maximized volume power losses.

The cross field heat and particle transport is here fixed in order to give an e-folding decay length of the power flow on the outer equatorial plane $\lambda_q \simeq 3mm$. ($\lambda_q = 1mm$ from scaling laws). Both d_W and T_0 are kept inside limits, 0.2–12 cm and 0–700 C.
Each point required tuning of all the paramteres on both targets to maximize the volume power losses, compatible with the code steadiness (i.e. avoding too strong evaporation and $T_{e,str.pt}$ $>$ 2.5eV)

2022/2021 modelling



When maximizing the volume radiation losses:

- Tin max temp. stays above 1000C
- Lithium stays around 600C.

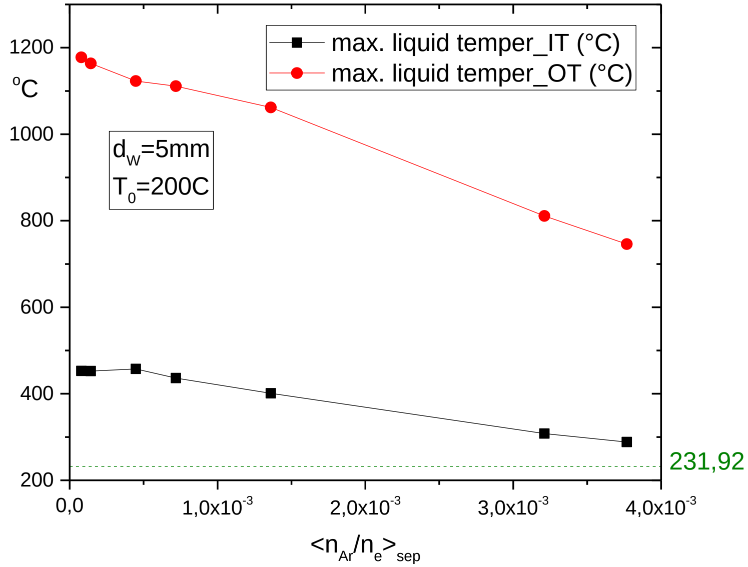
Publications

- M. Poradziński, I. Ivanova-Stanik, G. Pełka, V. Pericoli-Ridolfini and R. Zagórski, *Influence of krypton seeding on EU DEMO operation with lithium divertor*, J. Fusion Energy **39**, p. 469–476 (2020)
- V. Pericoli Ridolfini, P. Chmielewski, I. Ivanova-Stanik, M. Poradziński, R. Zagórski, R. Ambrosino, and F. Crisanti, *Comparison between liquid lithium and liquid tin targets in reactor relevant conditions for DEMO and I-DTT*, Phys. Plasmas **27**, 112506 (2020); doi: 10.1063/5.0012743
- V. Pericoli Ridolfini, I. Ivanova-Stanik, M. Poradziński, et al., *Analysis of the performances of a fusion reactor in a reduced H-mode confinement*, Nuclear Fusion **60**, 126041, 1-9 (2020); doi: 10.1088/1741-4326/abb79d

Divertor design params

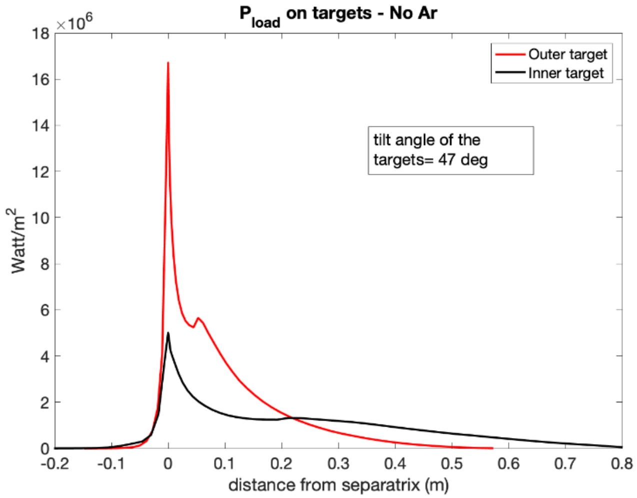
TECXY, P_{SOL}=190MW

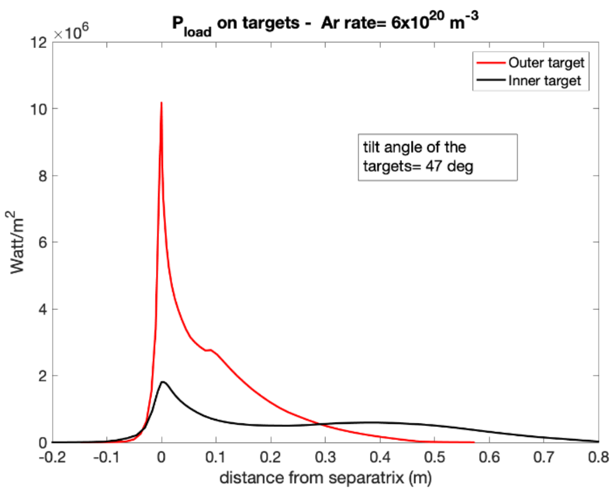
$$d_W = 5mm,\ T_0 = 200°C$$



Max surface temp. stays above the melting point. (no thermal sputtering included)

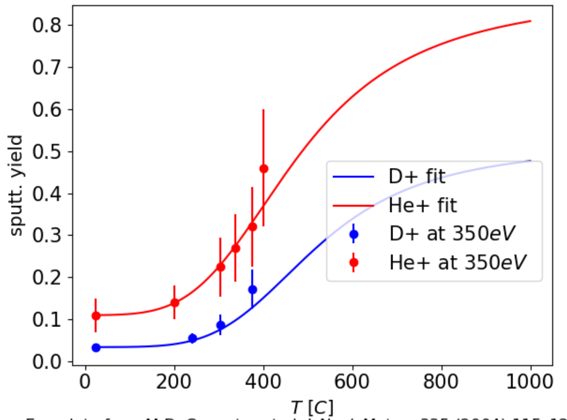
Ar puffing significantly reduces the peak power load on both targets and the Surface temperaturę.





Divertor design: tin thermal sputtering

d_W=1.5mm
d_{Sn}=2mm
T_0=150C

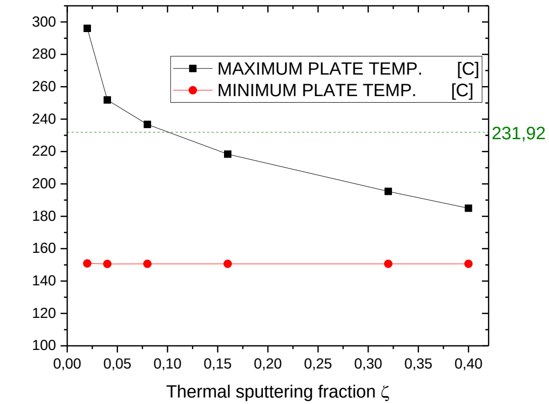


Exp. data from M.D. Coventry et al. *J. Nucl. Mater.* 335 (2004) 115–120

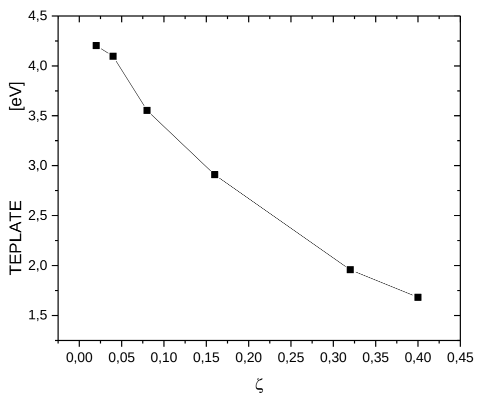
Tin thermal sputtering data only for light particles D and He. Only available to 400C.

$$Y = Y_{col} + \zeta Y_{th}$$

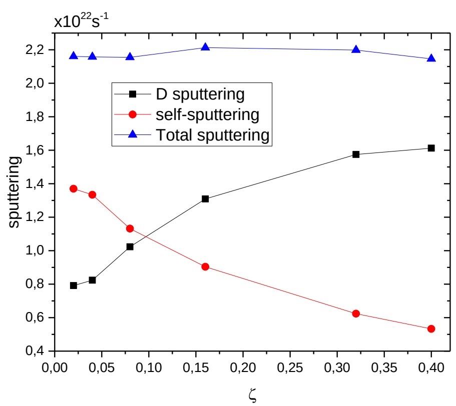
Thermal sputtering contribution is gradually increased with parameter ζ



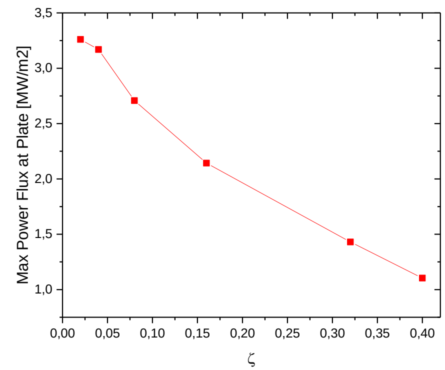
Thermal sputtering strongly influence the divertor surface temperature. T_{surf}^{max} drops below the melting point



Electron temp. at the divertor drops below 2eV



Total sputtering stays at the same level



Max Power load drops from 3.3MW/m² to 1MW/m²

Tin thermal sputtering has siginificant influence on the divertor conditions such as T_e, P_{load}, T_{surf}

Conclusions

- For given ENEA design parameters the LM surface temperature is significantly reduced.
- COREDIV and TECXY modeling is ongoing. Inclusion of tin thermal sputtering may affect the limits imposed on the LMD divertor design and needs further investigation. Electron temperatures reached at the plate indicate semi-detached and detached conditions -> need for SOLPS modelling

Prospectives for 2021

- Modelling of DEMO with the divertor design.
- Analysis of the DEMO parameter space in which tin remains liquid and evaporation stays negligible.
- Investigation of the influence of sputtering on the conditions in the divertor region.

Thank you!