EUROfusion

ERO2.0, A CODE FOR THREE-DIMENSIONAL MODELLING OF GLOBAL MATERIAL EROSION, TRANSPORT AND DEPOSITION IN FUSION DEVICES

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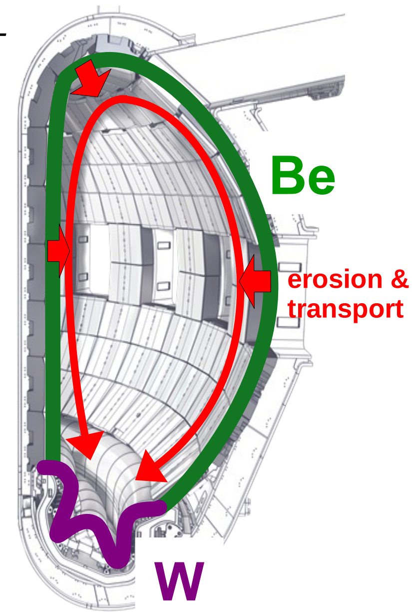
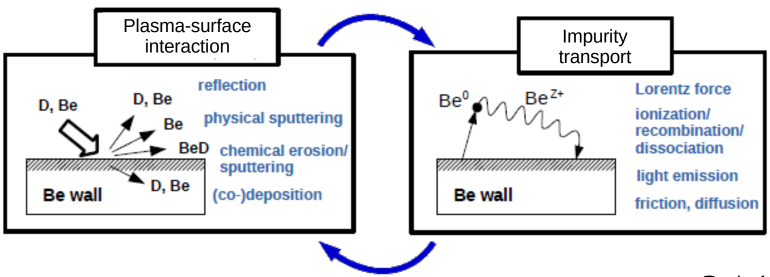
Introduction: erosion and impurity transport

- Steady-state erosion of plasma-facing components (PFCs) has significant consequences for the availability of fusion reactors:
  - Reduction of PFC lifetime.
  - Source of impurities (e.g. Be and W in ITER):
    - Enhance tritium retention (e.g. via co-deposition with Be).
    - Possibility of radiative collapse.
    - Dust formation → safety concern.
- ERO2.0 is a simulation code to predict such plasma-surface interactions (PSI):
  - Provides erosion and redeposition fluxes for all relevant PFCs.
  - Fully 3D, massively parallel.

Schematic of ITER plasma-facing materials



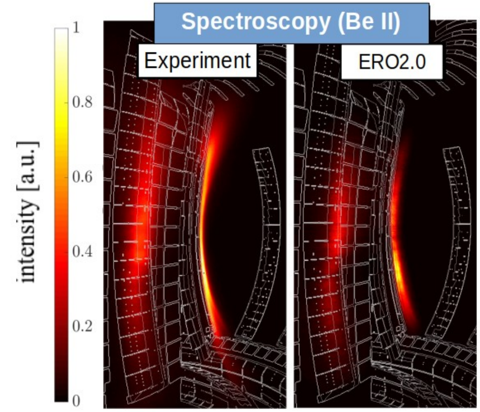
Schematic of the ERO2.0 workflow



ERO2.0 validation at JET

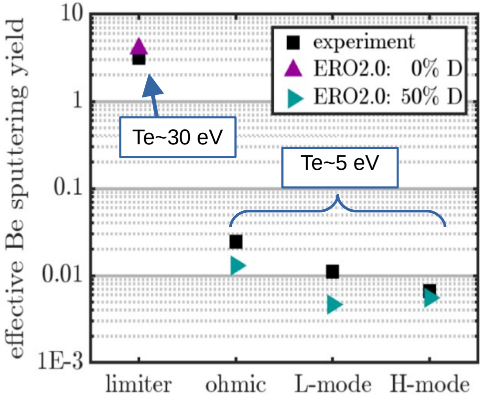
- JET ITER-like Wall (ILW): same Be/W environment as in ITER → ideal test bed for PSI and impurity transport codes.
- First test case: JET limiter plasma (contact point on inner limiter) leading to strong Be erosion.
  - Good qualitative agreement between synthetic and experimental spectroscopic images from wide-view cameras, including shadowing patterns.
  - Good quantitative agreement with effective sputtering yields measured near the contact point.
- Extension to diverted plasmas:
  - Diverted plasmas with different NBI power tested.
  - Assumption of 50% D content leads to a good agreement in the diverted phase → this assumption was also used for subsequent ITER modelling in diverted configuration.

Be II 467 nm emission



Source: J.Romazanov et al.,Phys. Scr. T170 (2017) 014018

Effective Be sputtering yields (inner midplane)

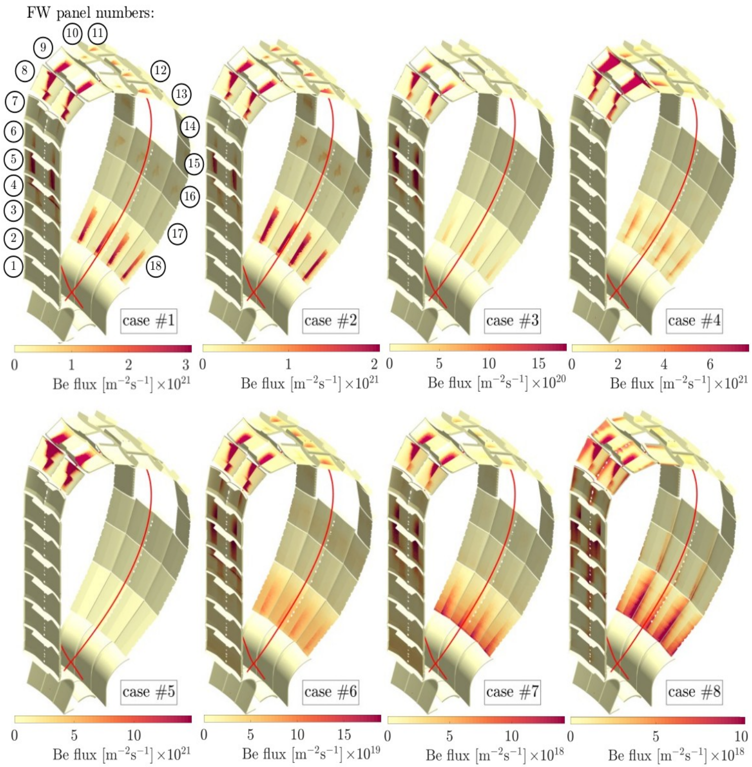


Source: J. Romazanov et al., Nucl. Mater. Energy 18 (2019) 331–338

ERO2.0 predictions for ITER

- ITER Be first-wall (FW) erosion predictions with variations of far-SOL density/temperature/flow, magnetic configuration, species (H, D, He).
- Examples:
  - Case #1: (burning plasma Q=10):
    - Total gross erosion of 1.5e23 Be/s.
    - 10% go into divertor, 90% redeposited again on FW → FW net erosion is around factor 10 lower than gross erosion.
  - Case #3: (non-convective far-SOL assumptions leading to higher T_e and lower n_e):
    - Gross erosion reduced by factor ~3.
    - Increased Be long-range transport → 25% of the Be goes into divertor.
  - Case #8: (low-power helium plasma):
    - Erosion lower by two orders.
    - 41% of the Be goes into divertor.

Be gross erosion flux



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Examples of ITER simulations

case no.	case #1	case #3	case #8
Fuel	D	D	He
PSOL [MW]	100	100	20
Confinement	H-mode	H-mode	L-mode
Far-SOL density	High	Low	Low
ne at OMP FW [m^{-3}]	1.8×10^{18}	1.5×10^{15}	1.5×10^{15}
Te at OMP FW [eV]	10	20	10
Be FW gross erosion [Be/s]	1.5×10^{23}	4.8×10^{22}	1.1×10^{21}
Be deposition on FW [%]	90.0	74.2	56.2
Be deposition in divertor [%]	9.8	25.4	41.4
Be deposition in gaps [%]	0.2	0.5	2.5