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

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ABSTRACT

- ERO2.0 is a simulation code for Plasma-Surface-Interaction and Impurity Transport modelling.
- The code was successfully validated using JET ITER-like Wall experiments.
- Predictions for the beryllium (Be) first wall erosion and transport were performed for ITER.
- The parameter study: variation of plasma species, SOL density, temperature and flow velocity, magnetic configuration, heating power.

MOTIVATION

- Steady-state erosion of plasma-facing components (PFCs) reduces wall lifetime and produces impurities.
  - Impurities may lead to enhanced retention, radiative collapse, core plasma dilution, dust formation.
- Simulation tools for erosion and impurity transport are required → ERO2.0 (Fig. 1) is a massively-parallel, 3D Monte-Carlo code designed for such tasks.

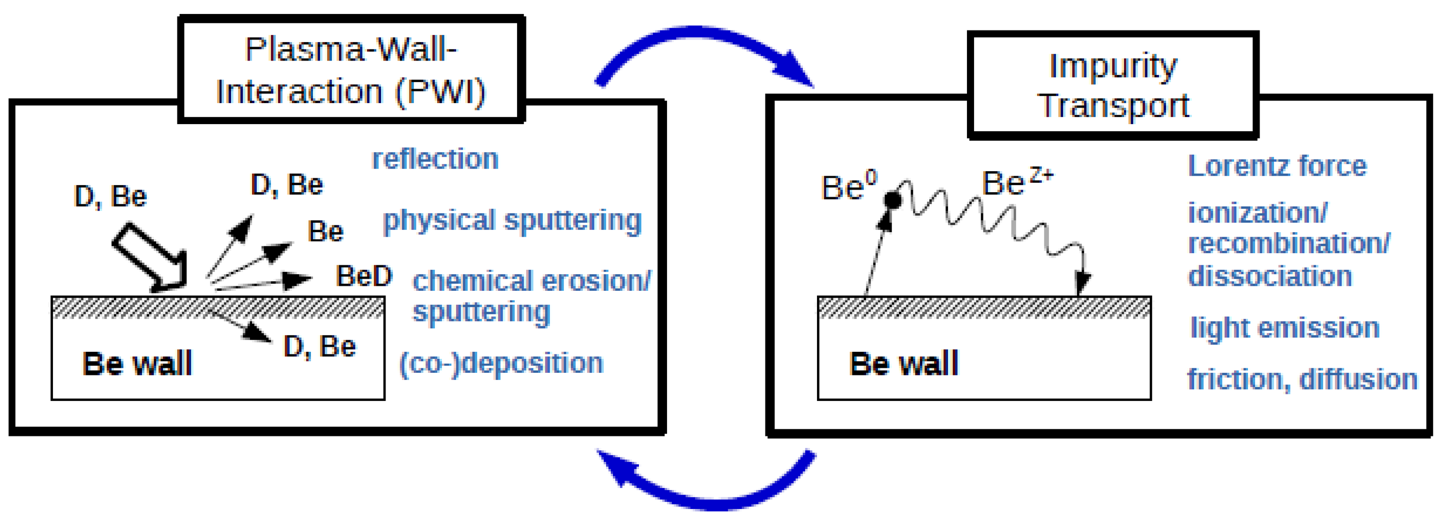

FIG. 1. Illustration of the general workflow of the ERO2.0 code, based on the example of a beryllium surface exposed to a deuterium plasma.

VALIDATION OF ERO2.0 AT JET ITER-LIKE WALL

- JET ITER-like Wall (ILW): same Be/W environment as in ITER → ideal test bed for PSI and impurity transport codes.
- First ERO2.0 application: JET limiter plasma (contact point on inner limiter) leading to strong Be erosion.
  - Good agreement between synthetic and experimental spectroscopic images from wide-view cameras (Fig. 2a), including shadowing patterns.
  - Parameter study: fuelling scan (leading to local Te variation between ~5-35 eV) showed that the so-called "ERO-max" assumption (clean Be surface) gives good results at ~35 eV, while "ERO-min" assumption (50% D inside Be surface) gives good results at ~5-10 eV (→ less D outgassing).
- Extension to diverted plasmas: at different NBI power (Fig. 2b), reasonable agreement achieved with "ERO-min" due to the lower temperatures (~5 eV).

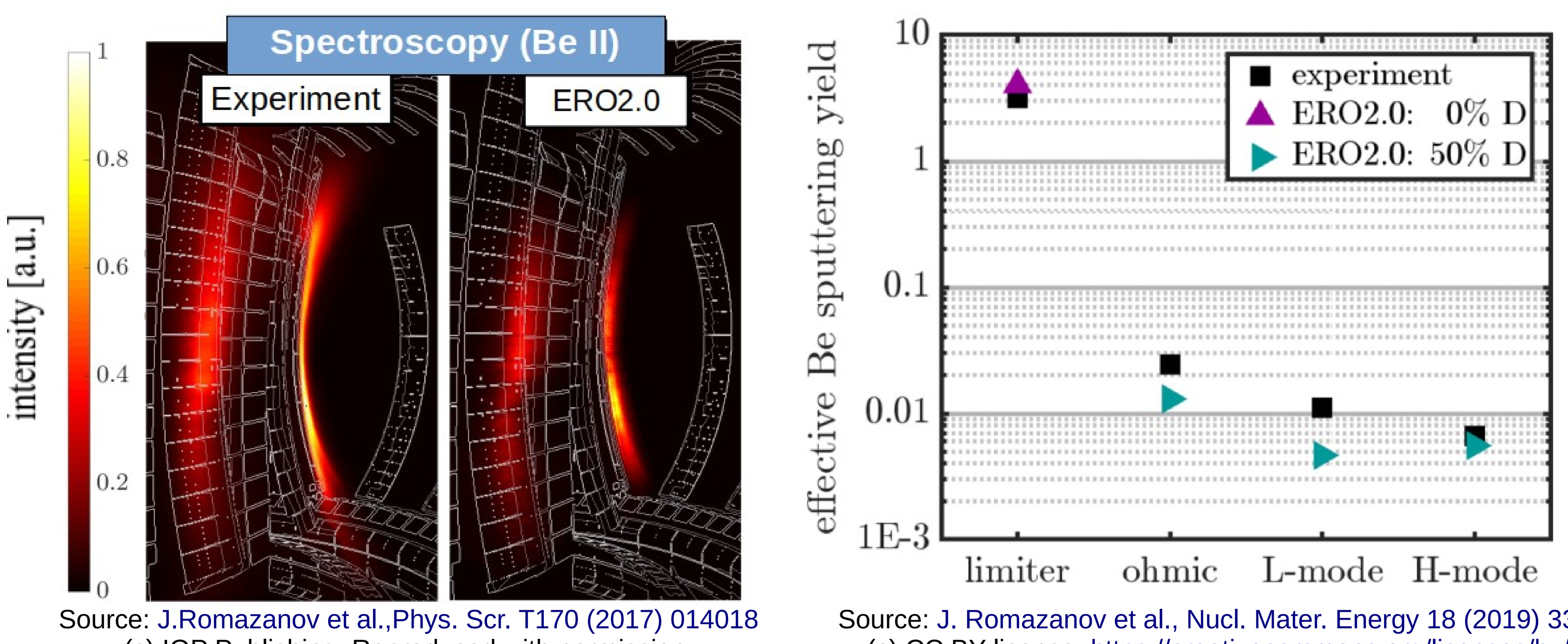

FIG. 2. Experimental validation of ERO2.0 at JET ILW. a) Experimental and synthetic wide-angle camera images of Be II 467 nm emission (limiter configuration). b) Simulated effective Be sputtering yields at the inner midplane and experimental ones determined via the S/XB method, in different discharge phases (limiter, ohmic, L-mode, H-mode).

ITER PREDICTIONS: BERYLLIUM FIRST WALL EROSION

- ITER Be first-wall erosion predictions performed for all panels 1-18 (Fig. 3):
  - Case #1: reference burning plasma scenario (Q=10)
  - Case #2: increased flow velocity (M=0.5 at inner midplane)
  - Case #3: high Te, low ne in the far-SOL (non-convective assumption)
  - Case #4: minimum dr_sep → higher triangularity
  - Case #5: same, but with non-convective assumption
  - Case #6: low-power hydrogen L-mode scenario
  - Case #7: same, but with non-convective assumption
  - Case #8: same, but helium plasma

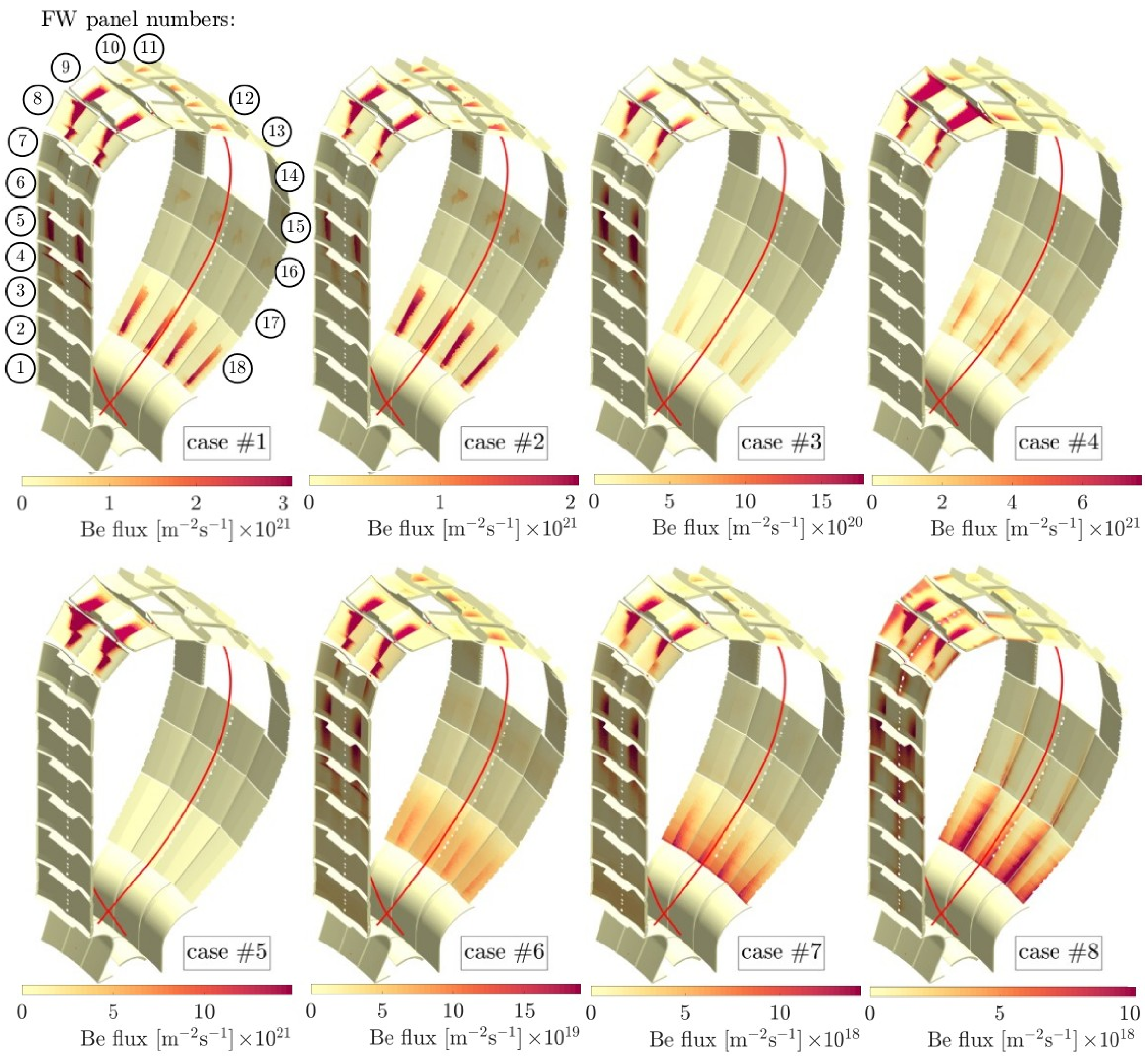

FIG. 3. Be gross erosion flux in the eight ITER simulation cases. For better visibility, each color map is cropped at the 99th percentile of main chamber flux.

TABLE. 1. Summary of the ITER simulation cases and results.

case no.	case #1	case #2	case #3	case #4	case #5	case #6	case #7	case #8
Fuel	D	D	D	D	D	H	H	He
PSOL [MW]	100	100	100	100	100	20	20	20
Confinement	H-mode	H-mode	H-mode	H-mode	H-mode	L-mode	L-mode	L-mode
Imposed SOL flow	None	M=0.5	None	None	None	None	None	None
Far-SOL density	High	High	Low	High	Low	High	Low	Low
ne at OMP FW [m^{-3}]	1.8×10^{18}	1.8×10^{18}	1.5×10^{15}	4.3×10^{17}	5.9×10^{13}	4.4×10^{17}	1.5×10^{15}	1.5×10^{15}
Te at OMP FW [eV]	10	10	20	10	20	5	10	10
Δr_{sep}	Broad	Broad	Broad	Minimum	Minimum	Broad	Broad	Broad
Be FW gross erosion [Be/s]	1.5×10^{23}	1.1×10^{23}	4.8×10^{22}	3.3×10^{23}	1.6×10^{24}	1.9×10^{22}	1.3×10^{21}	1.1×10^{21}
Be deposition on FW [%]	90.0	78.5	74.2	95.0	99.6	66.5	43.7	56.2
Be deposition in divertor [%]	9.8	21.3	25.4	4.3	0.1	31.7	53.2	41.4
Be deposition in gaps [%]	0.2	0.2	0.5	0.6	0.3	1.9	3.0	2.5

CONCLUSIONS

- The ERO2.0 code is a valuable tool for 3D simulations of global erosion and redeposition, successfully validated at JET ILW
- ITER simulations show high Be erosion at the apex → can be improved by lower triangularity

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