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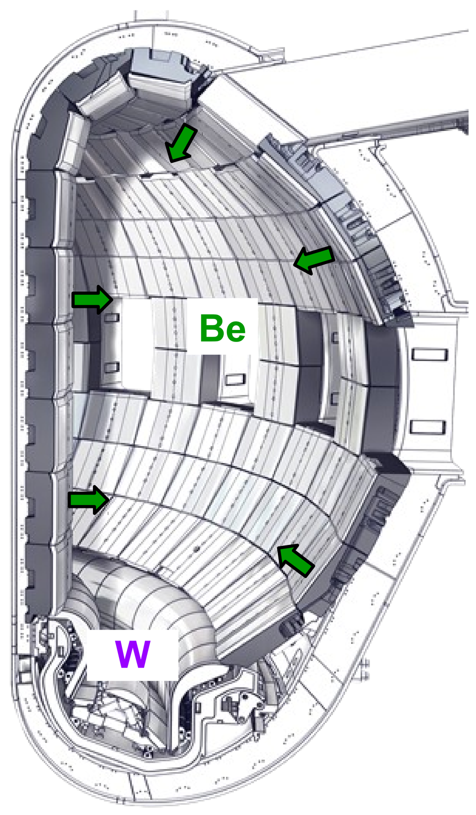
ERO2.0, a massively parallel Monte-Carlo code for plasma-wall interaction and global impurity transport modeling in fusion devices

Motivation: making predictions for future fusion devices like ITER

Effects of plasma-wall interaction (PWI):

- Erosion of the wall by sputtering limits lifetime
- Erosion is a source of impurities in the plasma
- Impurities contribute to fuel retention (co-deposition)
- Impurities can lead to radiative collapse of the plasma

→ (Predictive) modelling of PWI is indispensable for design of future fusion reactors.
→ Also: useful input for design or positioning of diagnostics.

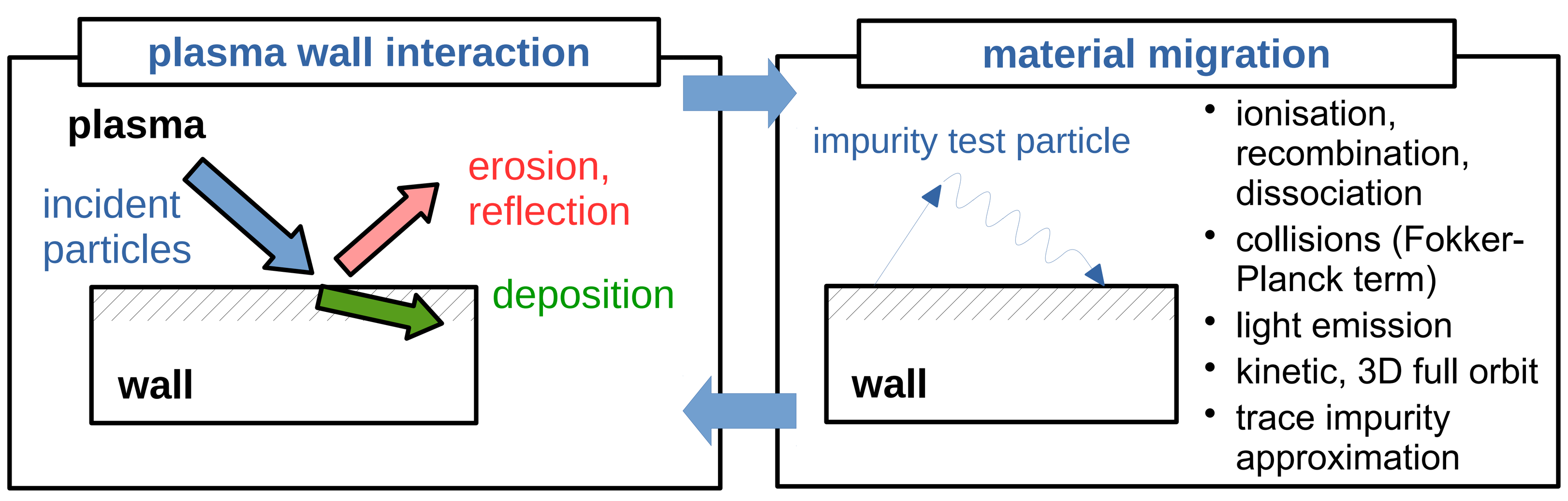


ITER tokamak cross-section.

ERO2.0: a 3D massively-parallel code for global PWI studies

Illustration of the code concept:

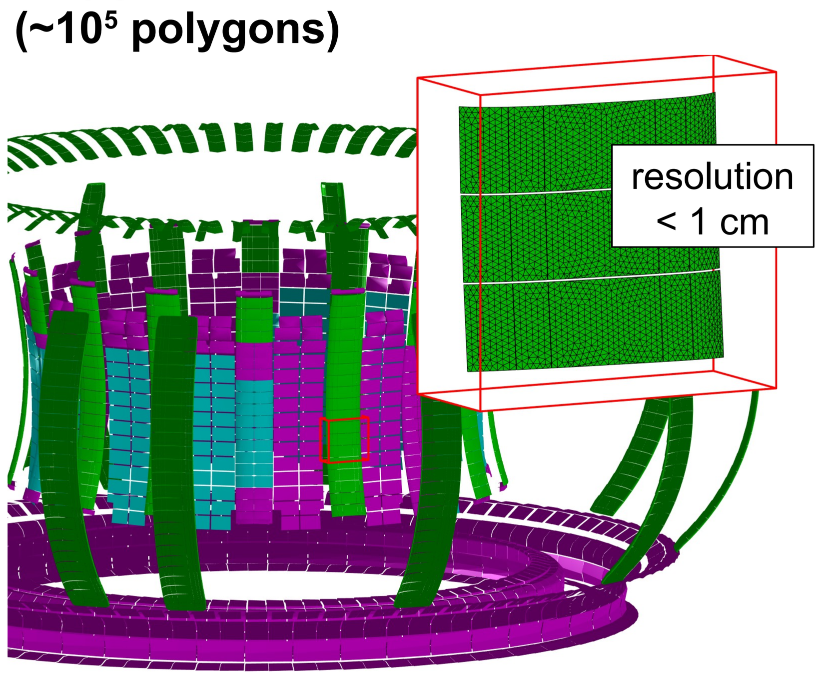
See Ref. [1-3].



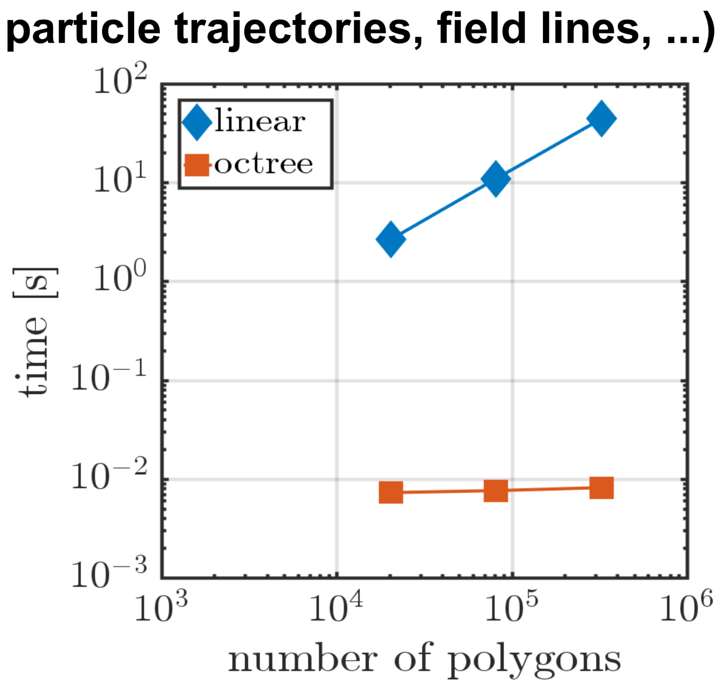
Main code features:

- polygon meshes: flexible and detailed description of large and complex 3D wall components
- optimization of polygon mesh algorithms (intersection, distance queries) lead to a code speedup of factor ~10^2-10^4
- massive parallelisation shows good scaling, giving another speedup factor proportional to the number of CPU cores

Polygon mesh example: JET-ILW (~10^5 polygons)



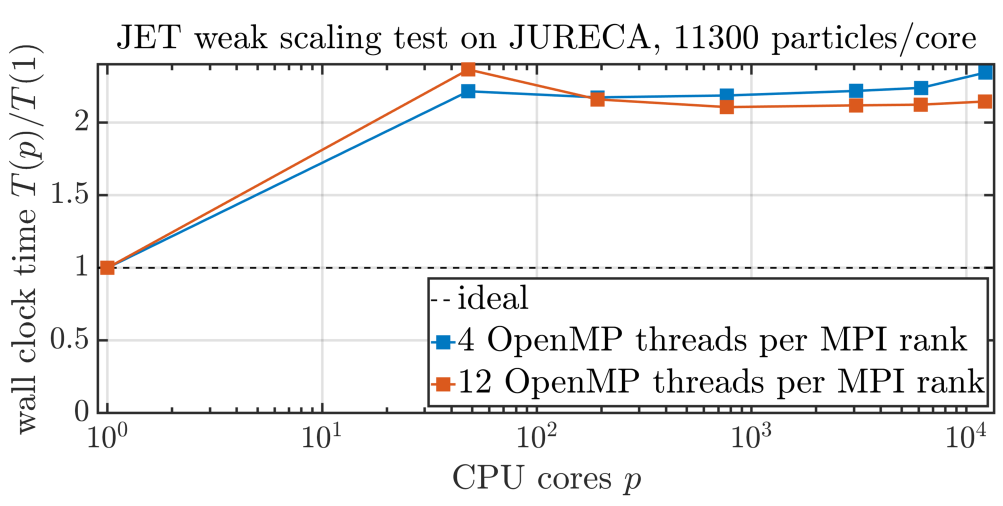
Optimization of polygon mesh intersection queries (e.g. with particle trajectories, field lines, ...)



Massive parallelization using hybrid MPI/OpenMP approach

ERO2.0 was developed and tested on JURECA with support by JSC SLPP.

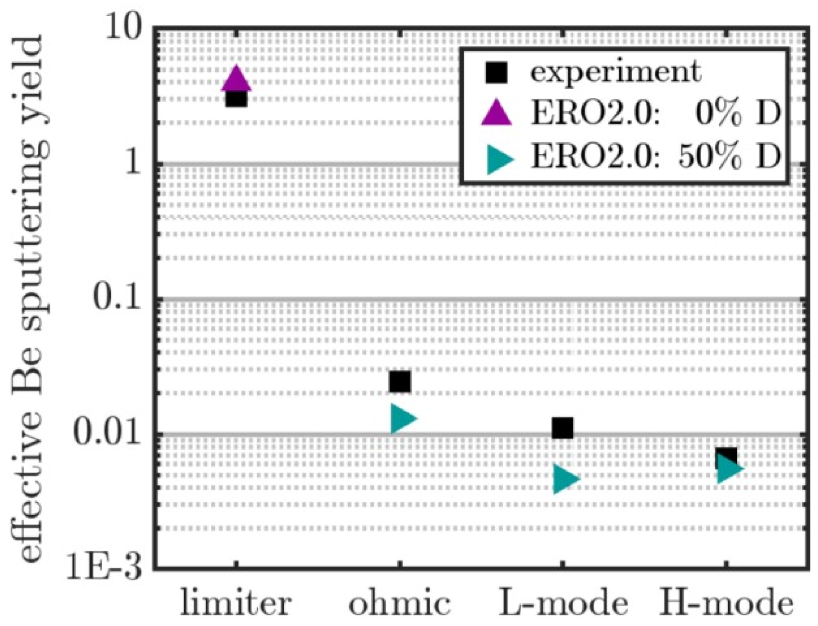
JURECA JARA-HPC computing project ID jiek43



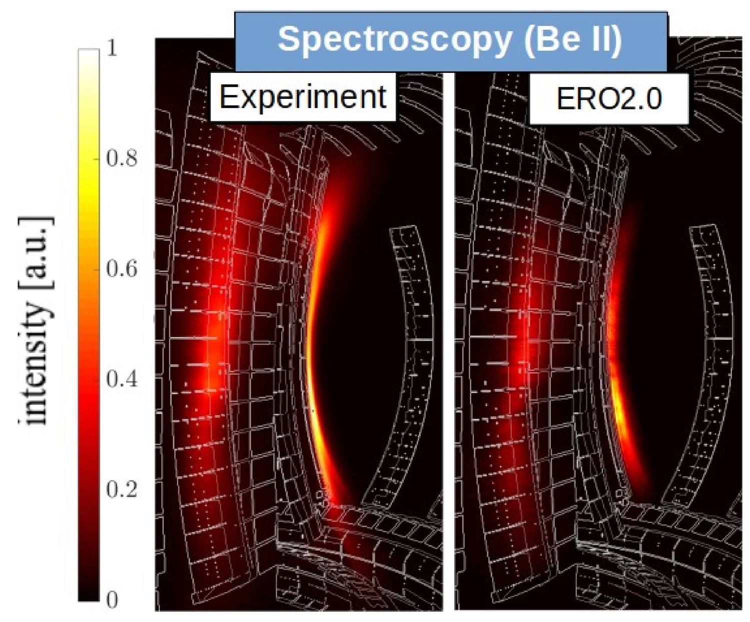
Application example 1: Be erosion in JET and ITER

Good agreement between JET simulations and experimental spectroscopy measurements:

See Ref. [2-3].



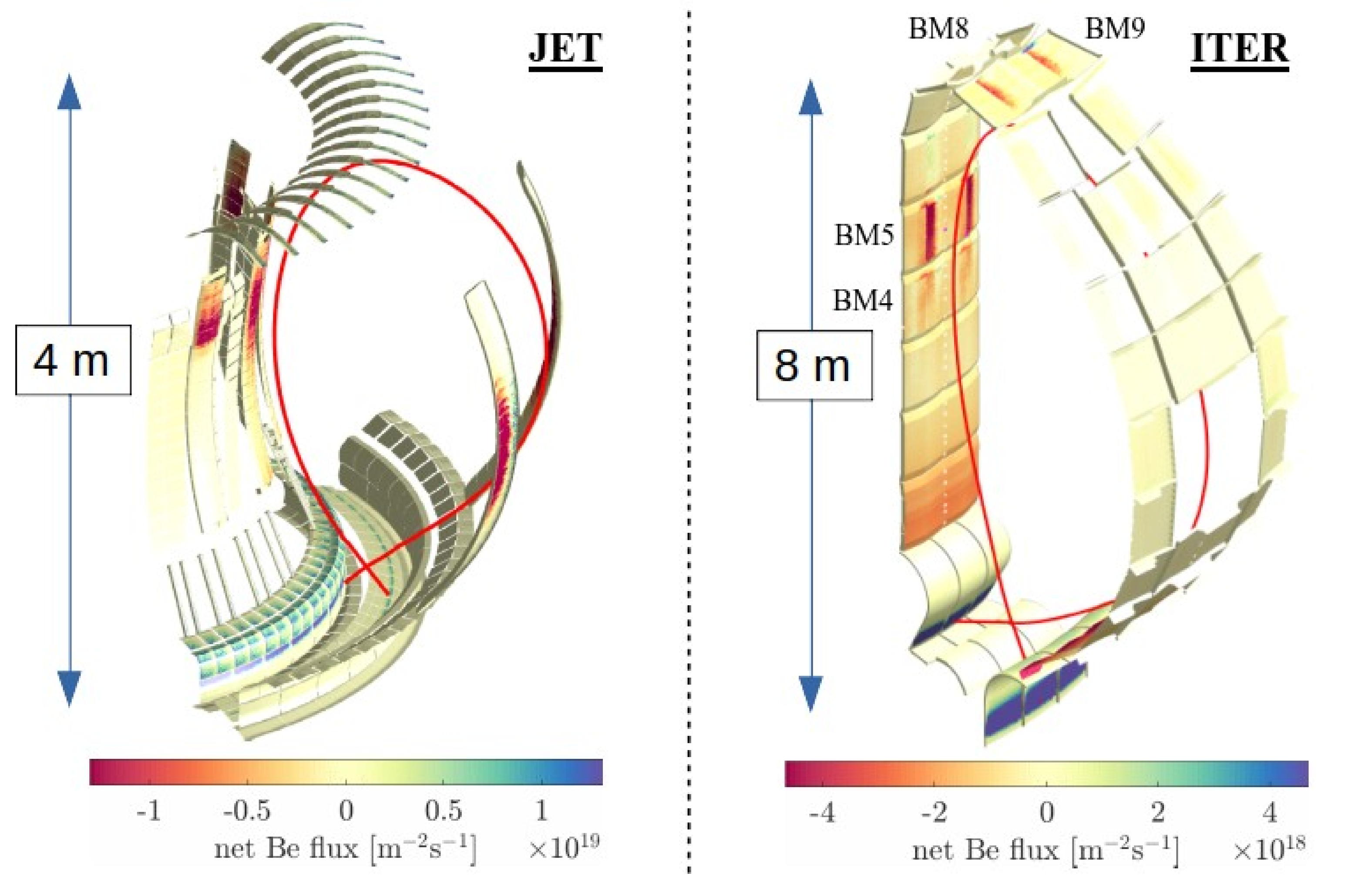
Be erosion deduced from spectroscopy at the inner wall, during different operational phases.



Wide-angle camera images of Be II emission in limiter configuration.

Comparison of Be net erosion/deposition flux in JET and ITER:

See Ref. [3-5].



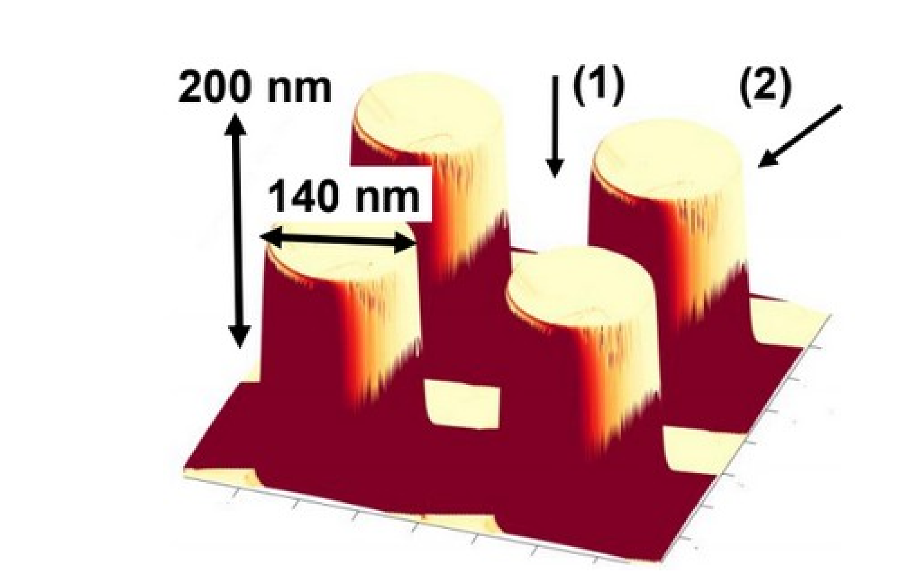
Inter-ELM H-mode phase at JET.

Hydrogen L-mode phase at ITER.

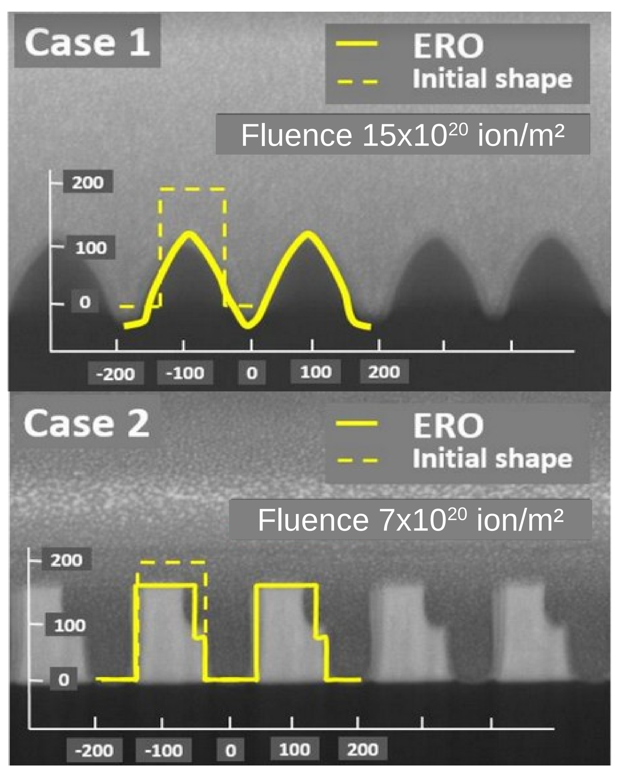
Application example 2: study of surface roughness effects (micro-scale)

See Ref. [6].

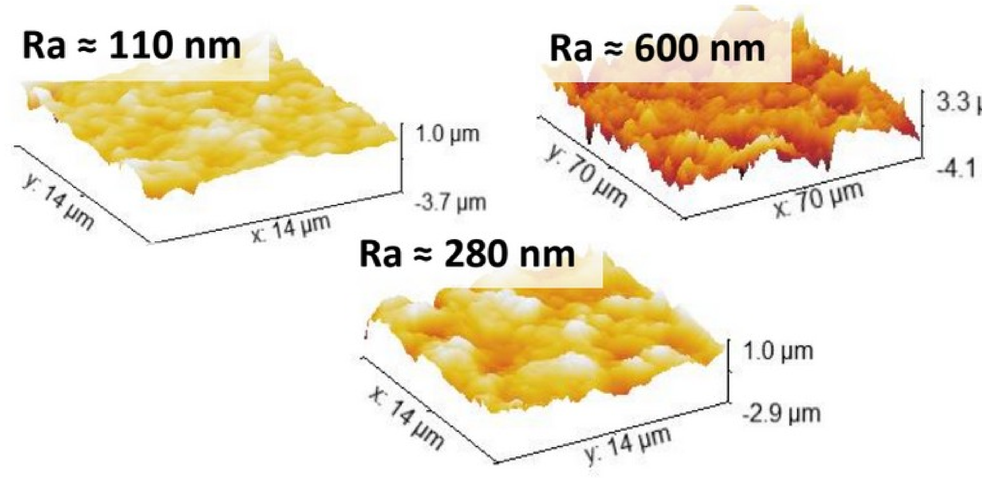
Validation of surface modification algorithm using ion beam experiments:



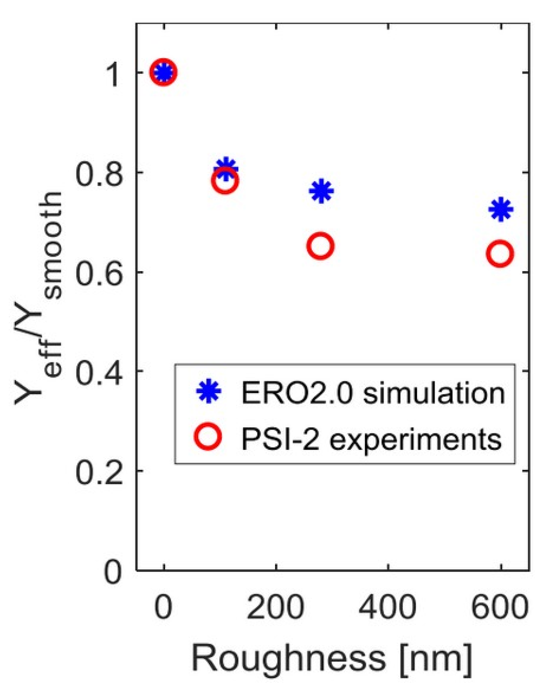
Si/Ta cylindrical structures exposed to a 5 keV Ar+ beam.



Erosion is decreased by roughness:



Molybdenum samples with pre-defined roughness, exposed in the PSI-2 linear plasma device.



References

[1] A. Kirschner, V. Philipps, J. Winter, Nucl. Fusion 40, 989 (2000).
[2] J. Romazanov *et al.*, Phys. Scr. T170 (2017) 014018.
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