

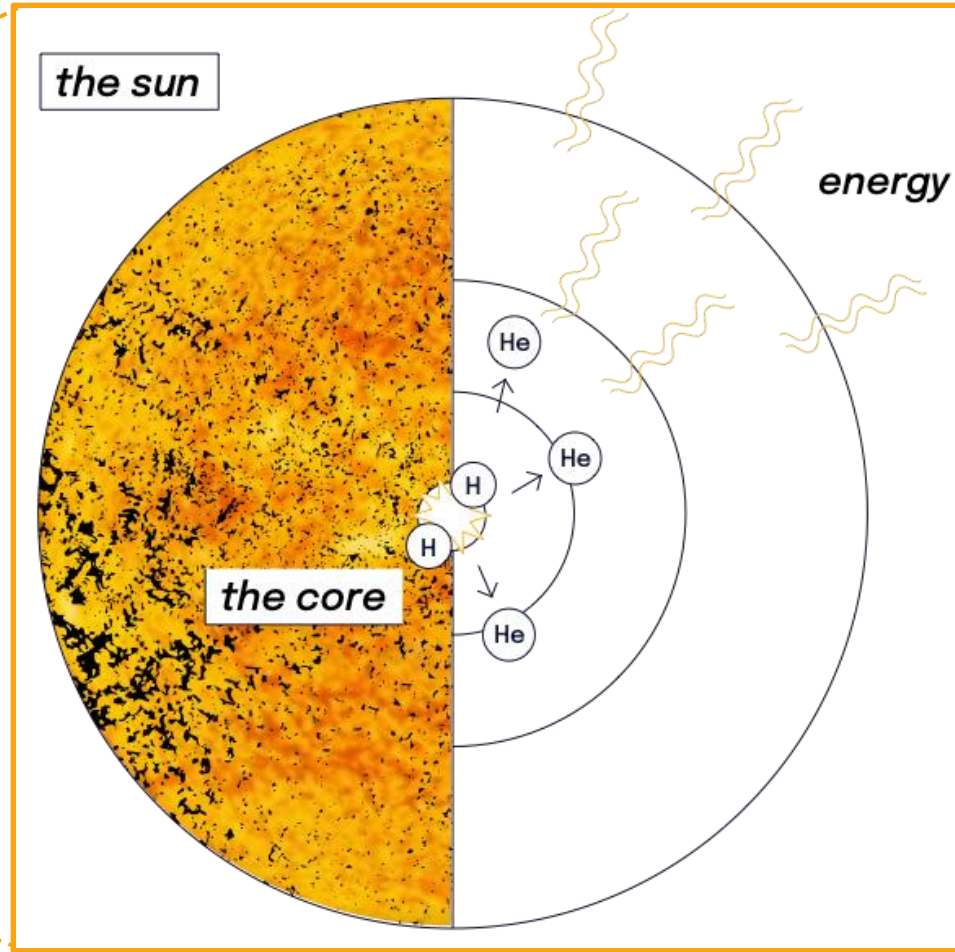
From Collision Cascades to Long-term Defect Dynamics: A computational study of irradiation effects in fusion relevant materials

Jintong Wu

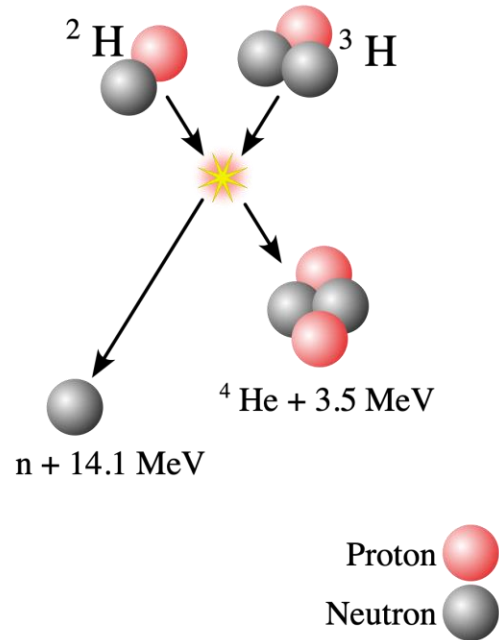
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What is Fusion?

What we see as light and feel as warmth is the result of a fusion reaction in the core of our Sun: hydrogen nuclei collide, fuse into heavier helium atoms and release tremendous amounts of energy in the process.

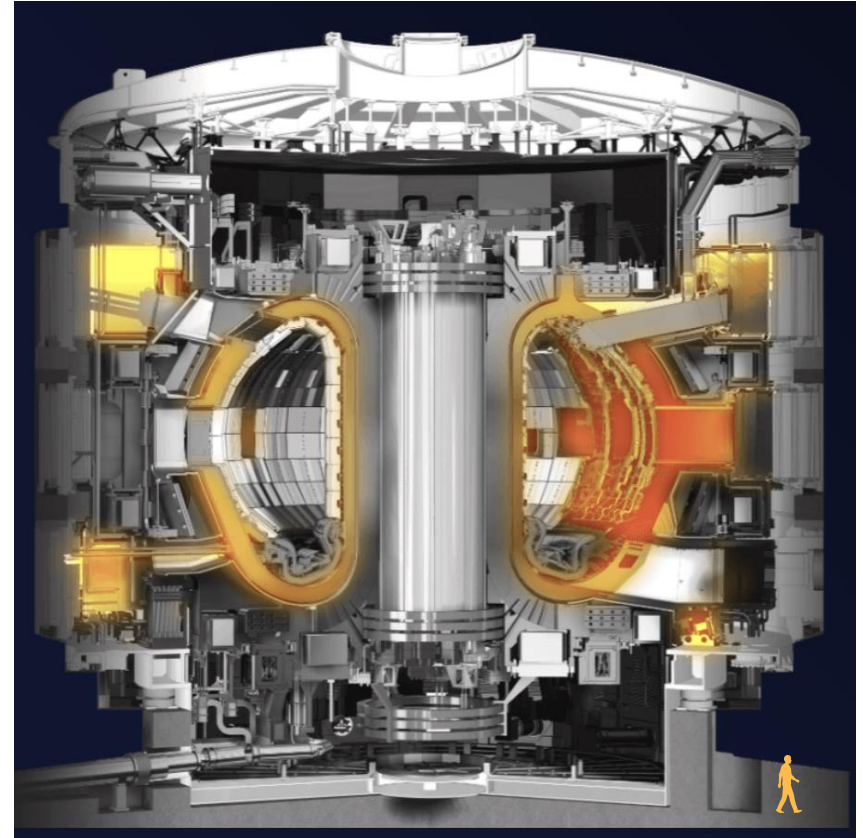


Making it work



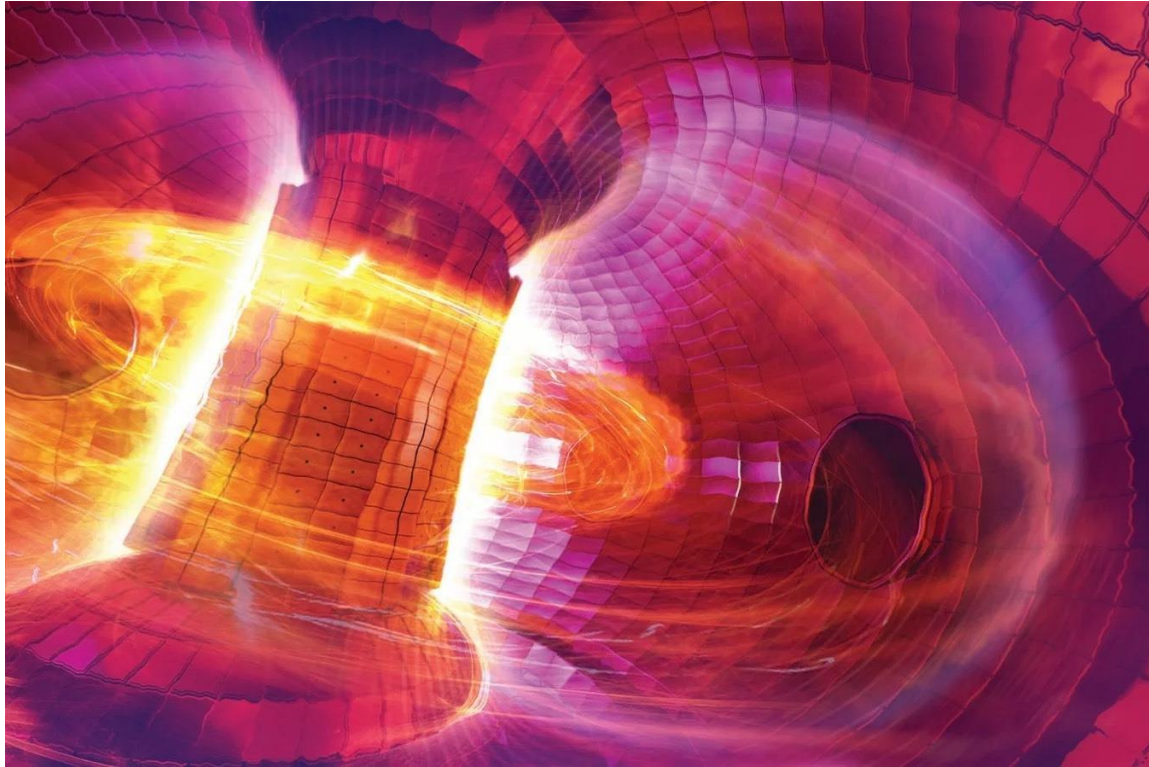
Although different isotopes of light elements can be paired to achieve fusion, the deuterium-tritium (D-T) reaction has been identified as the most achievable and the most efficient.

Temp $\approx 150,000,000$ °C is required to achieve D-T fusion in the laboratory



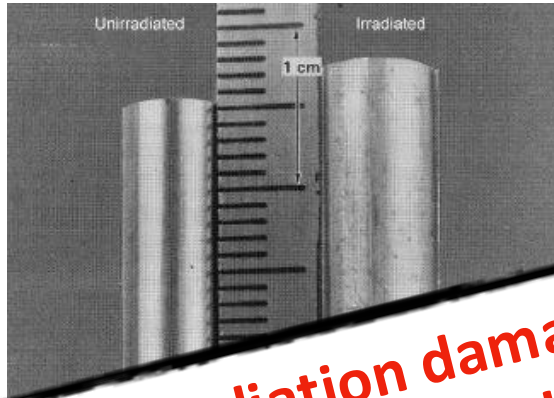
Commonly, be achieved in a Tokamak device that uses magnetic fields to contain and control the hot plasma

Making it work



The intense flux of high-energy neutrons and other particles generated during fusion reactions

Making it work



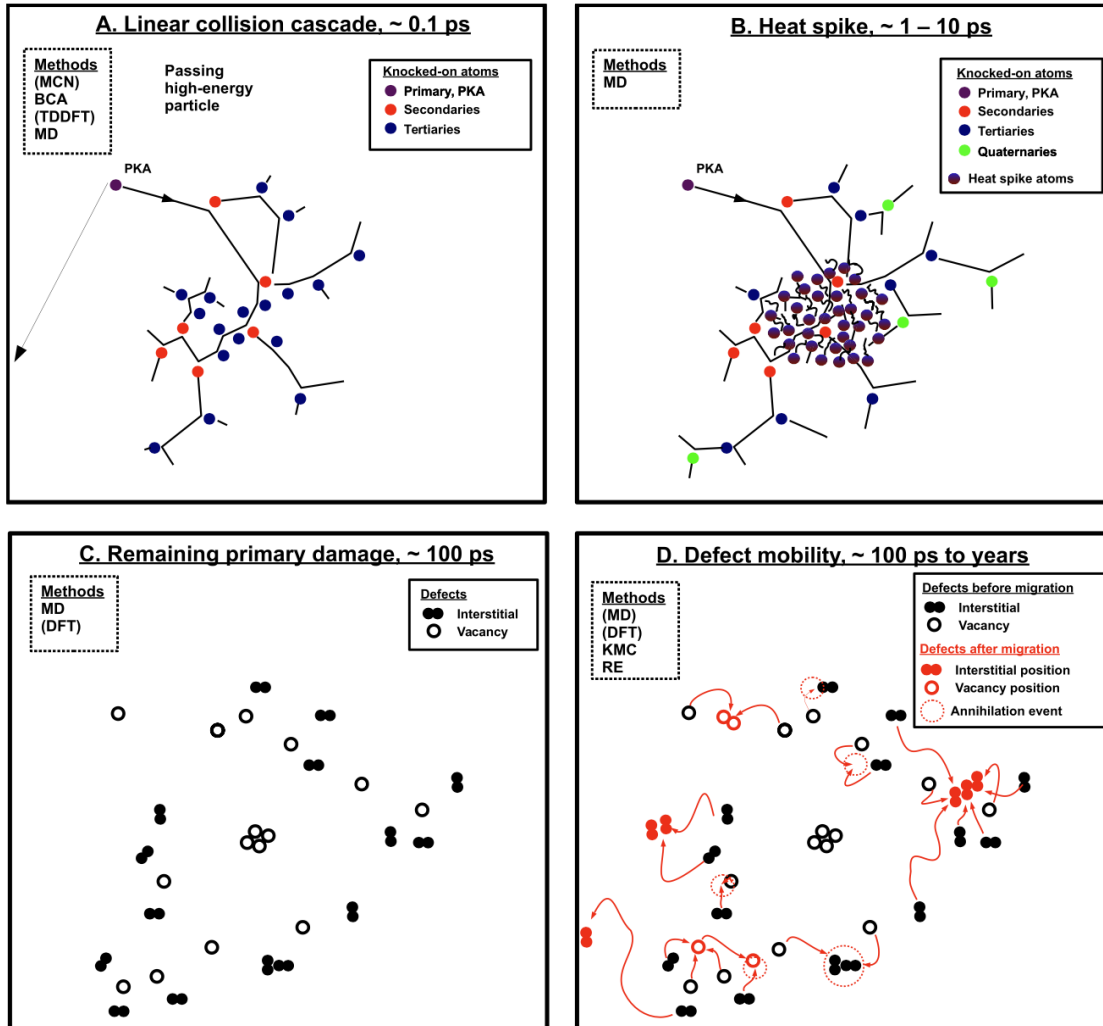
FFTF fuel pin bundles

Studying irradiation damage in fusion plasma-facing materials is essential because their long-term performance under extreme neutron exposure directly determine the safety, efficiency, and viability of future fusion reactors.

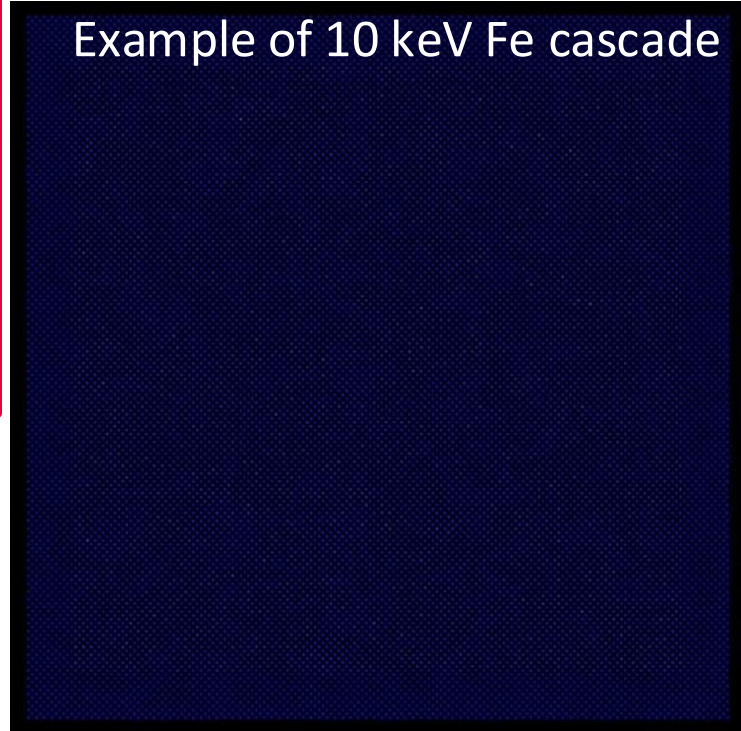
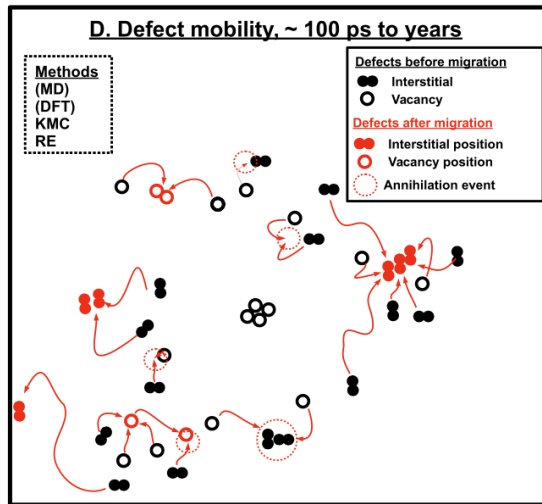
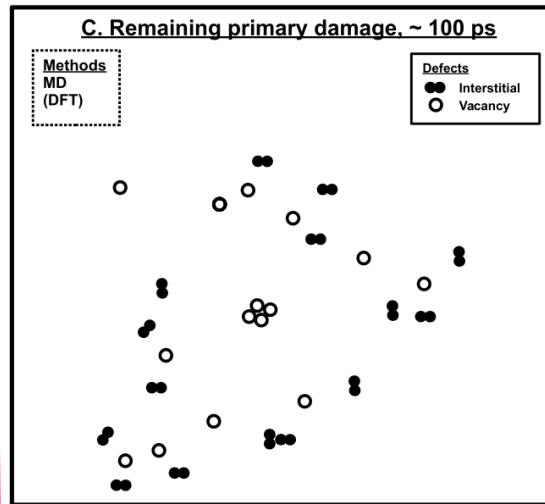
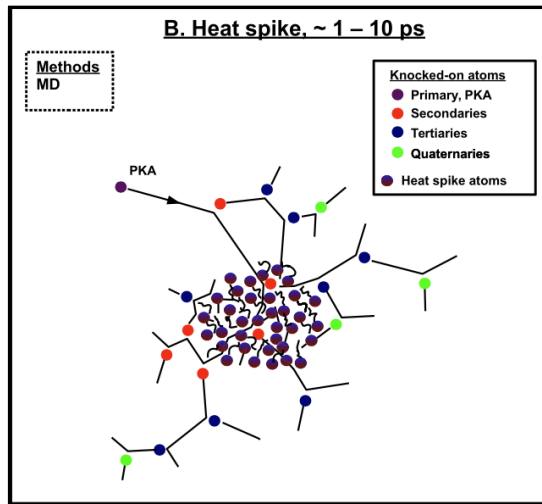
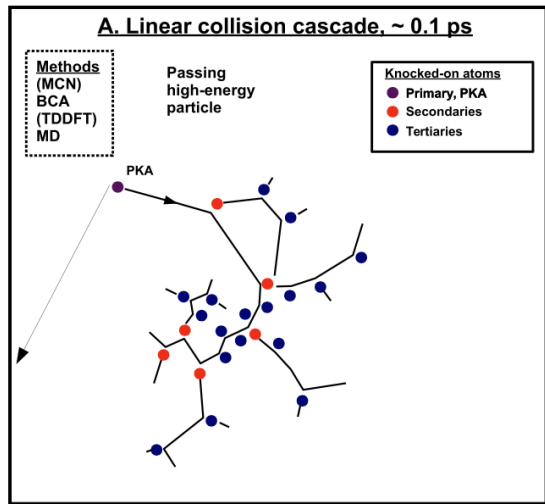
Key Properties of Plasma-Facing Materials (PFMs)

- **Thermal resilience:** High melting point and thermal conductivity to endure rapid heat
- **Plasma compatibility:** Low sputtering yield to reduce erosion and impurity generation.
- **Structural stability:** Low thermal expansion to limit stress from temperature gradients and radiation damage.

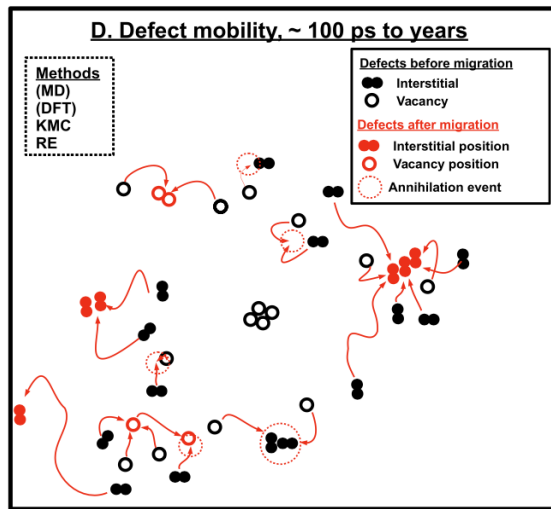
Background of this study



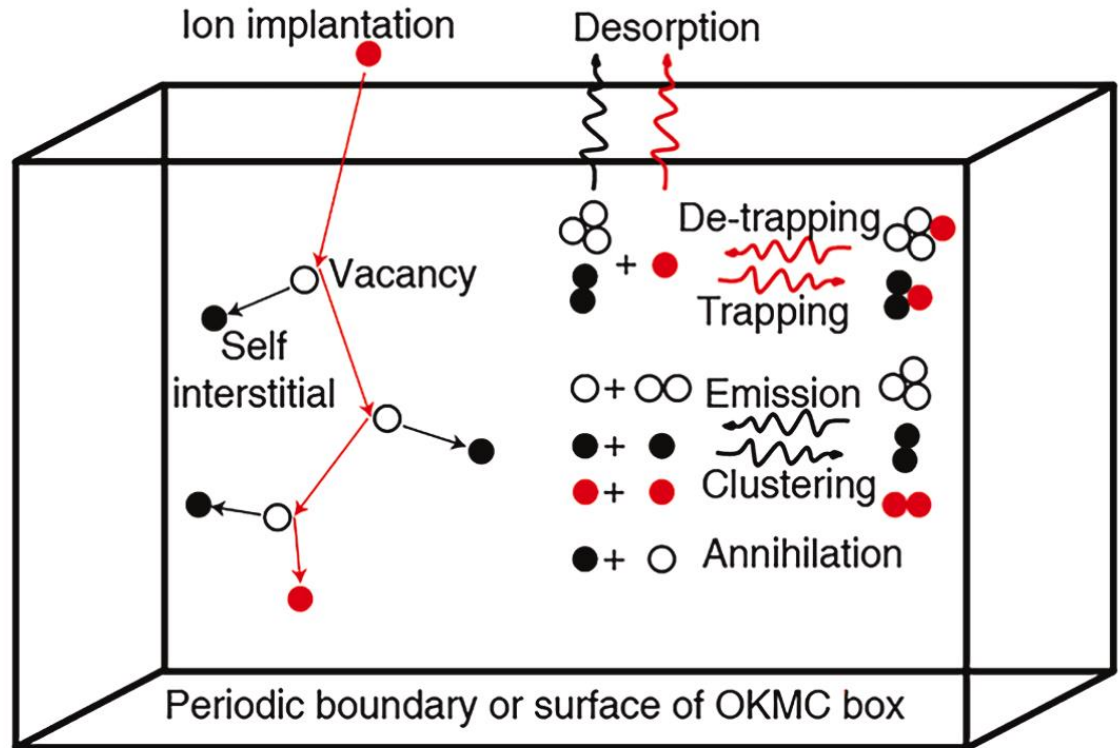
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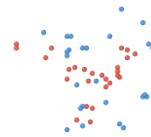
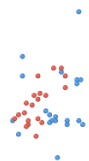
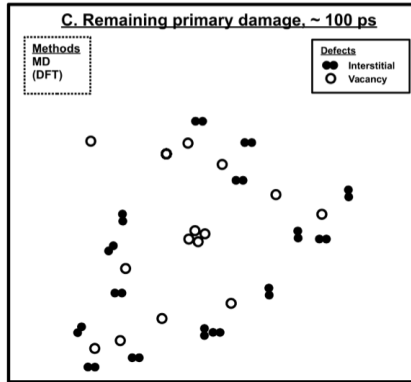
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Unsolved questions

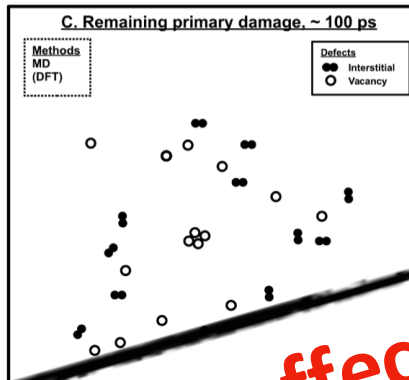
PKA database



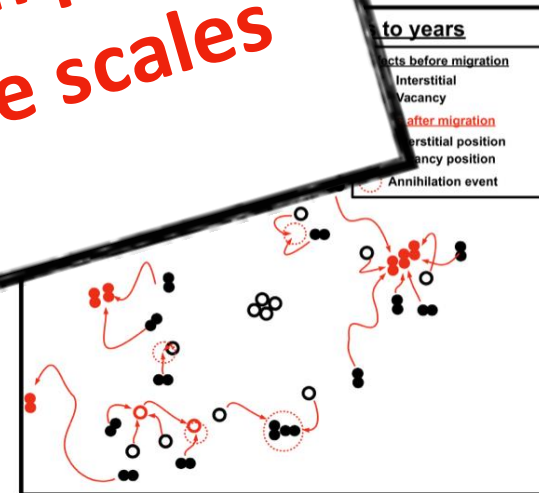
Unsolved questions

PKA
database

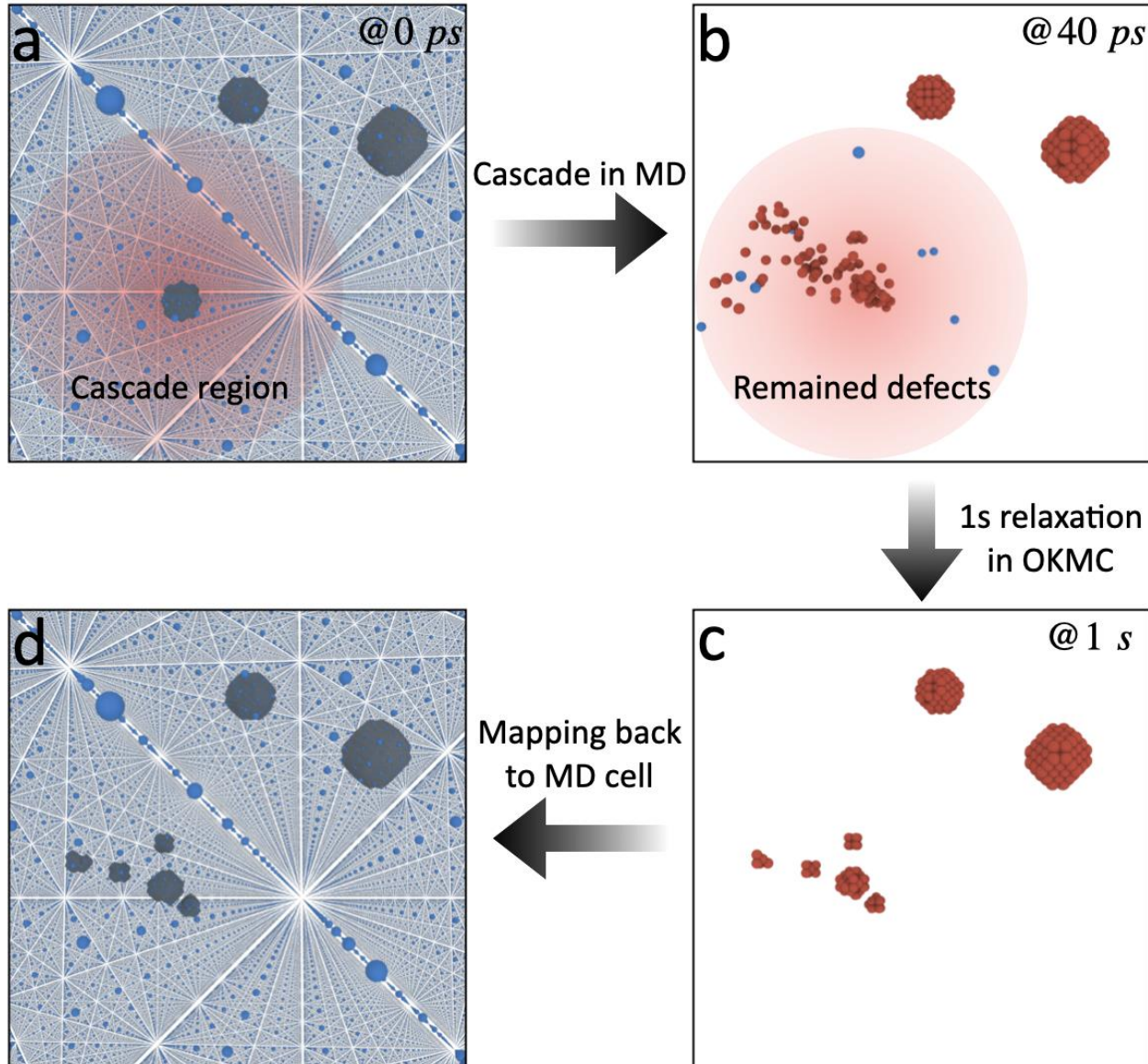
Cascade in OKMC
(Overlapping insertion)



The true effect of cascades on pre-existing defects over long time scales remains unknown!

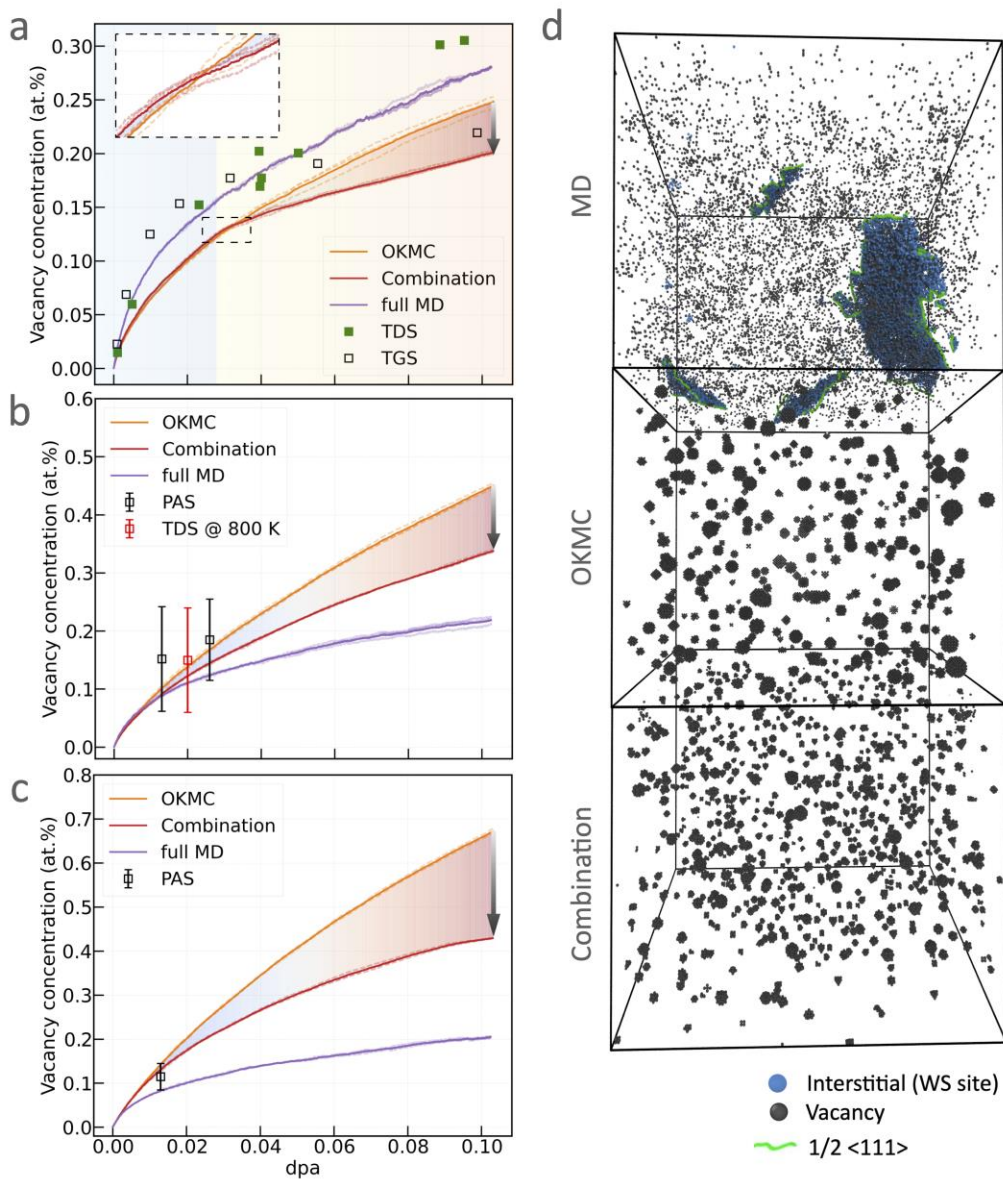


Methodology



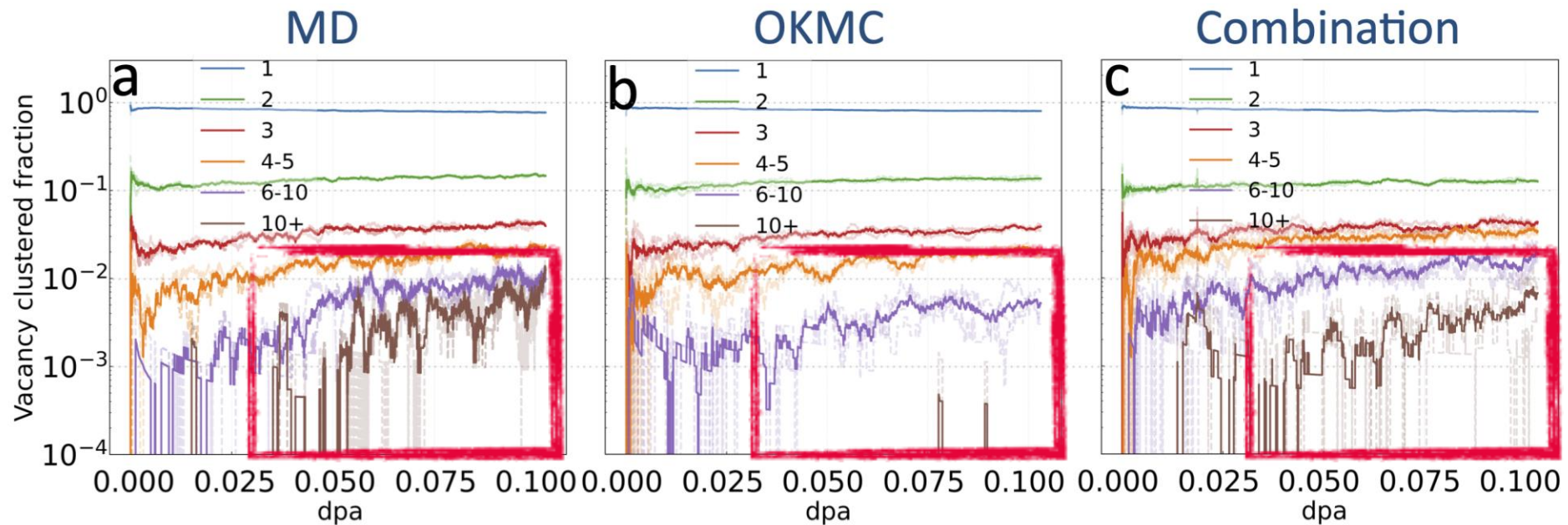
Results

Results (W case)



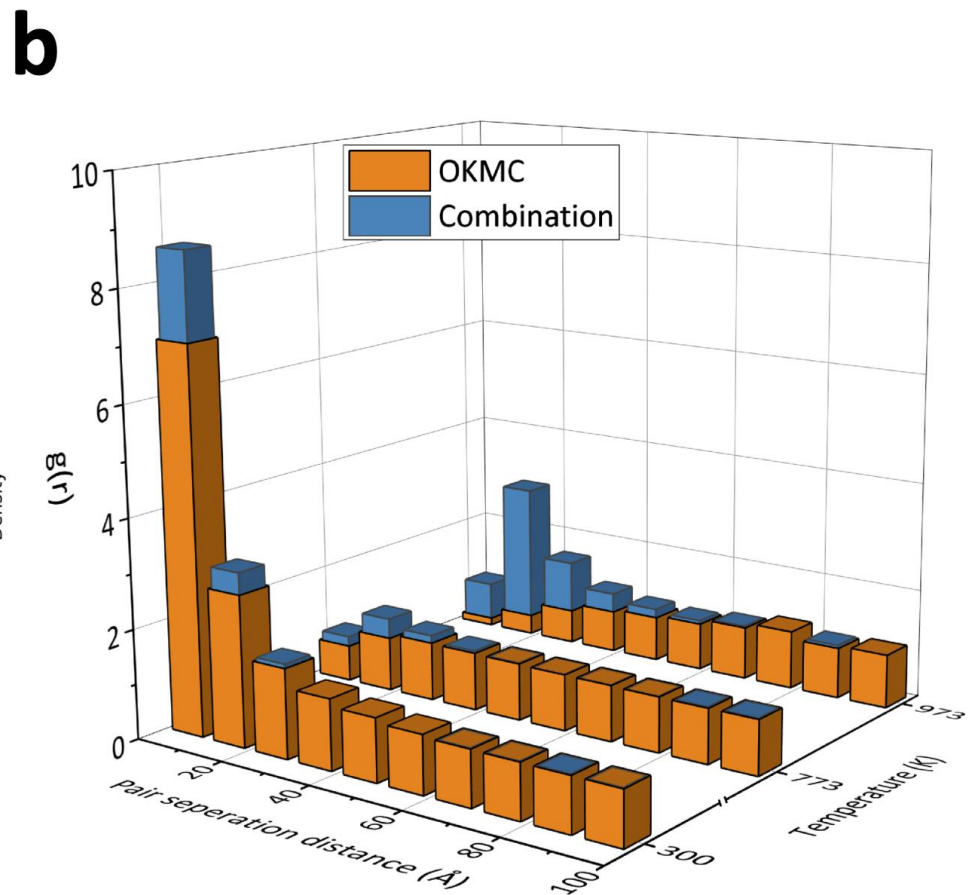
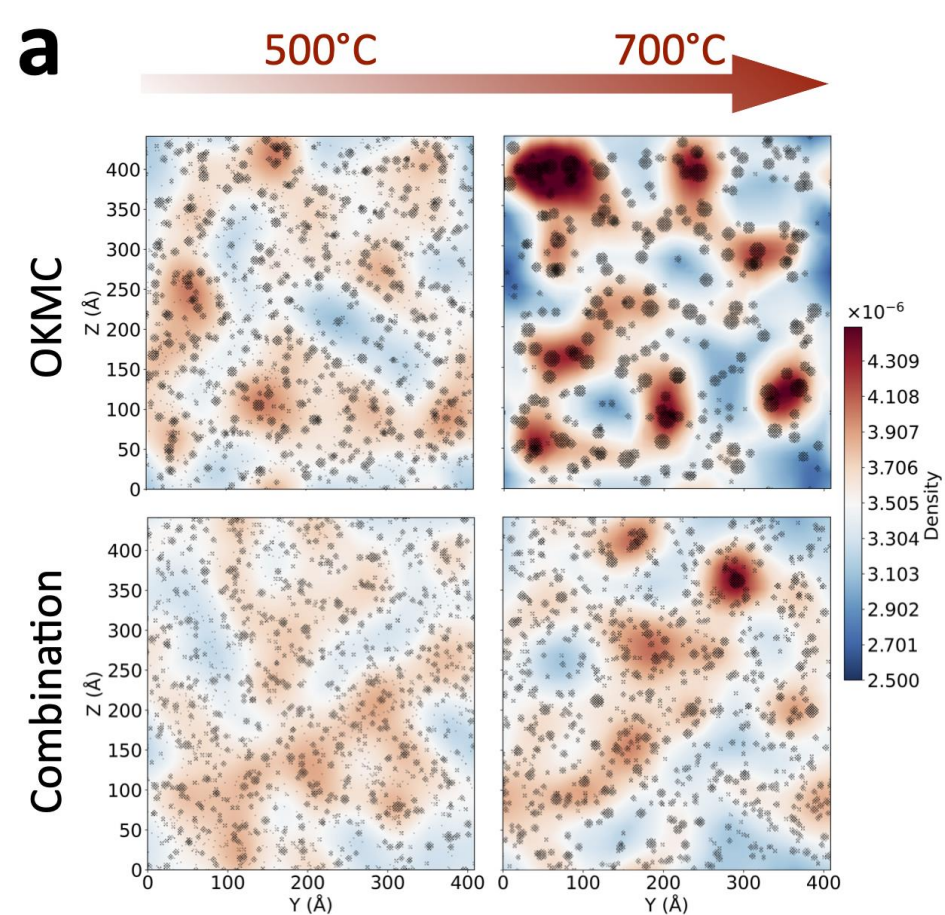
Results (W case)

Clustering behavior @RT



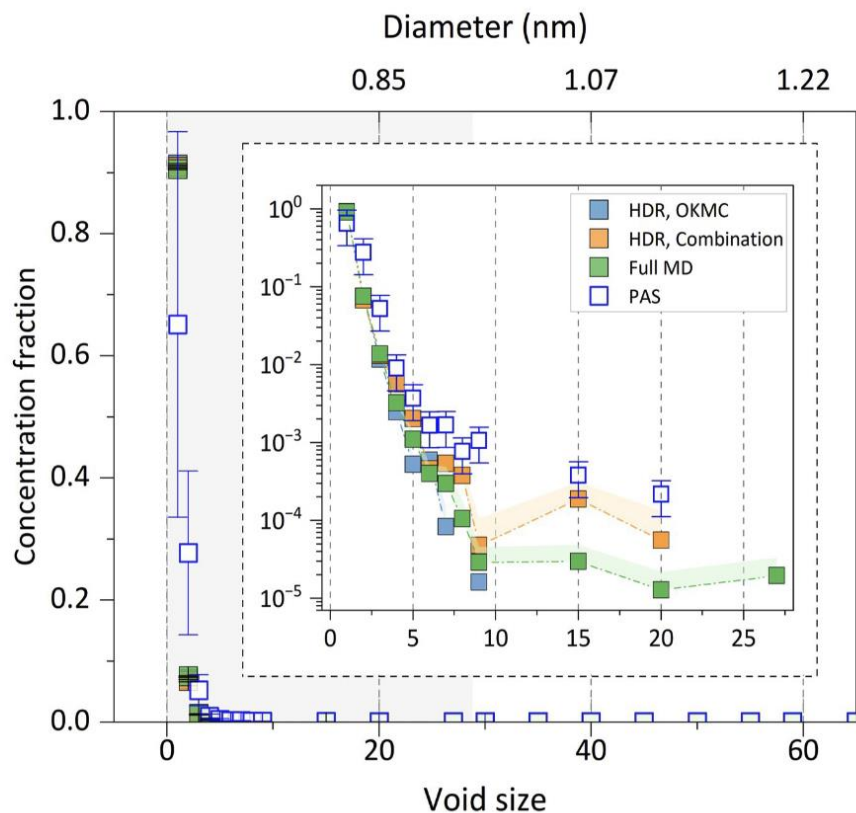
Results (W case)

@0.1 dpa

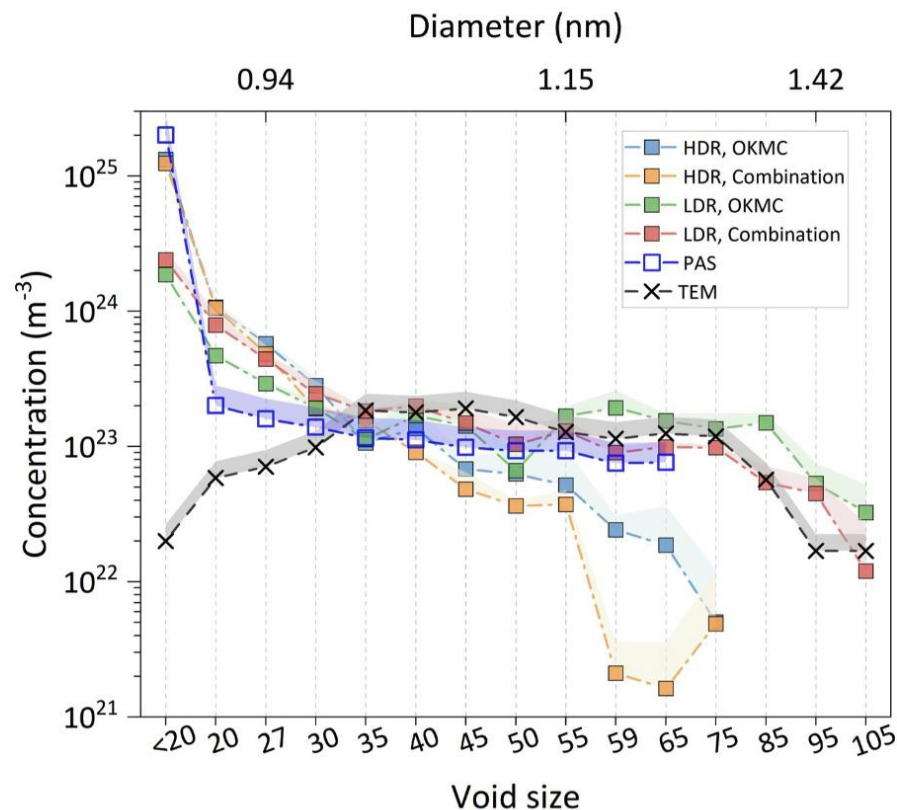


Experimental comparison (W case)

@RT, 0.085 dpa



@500 °C, 0.02 dpa



Conclusions & Outlook

- Integration of full MD cascades into the OKMC model significantly impacts atomistic evolution under reactor-relevant conditions
- In tungsten, full MD cascades dramatically alter void distribution by splitting and destroying existing voids at HT, but provoke the clustering at RT
- The full MD automatically handles all cascade parametrizations, capturing every possible irradiation event
- **The approach is transferable to various materials, enhancing atom-level insights into irradiation effects when paired with experimental investigations**



Thank you

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