

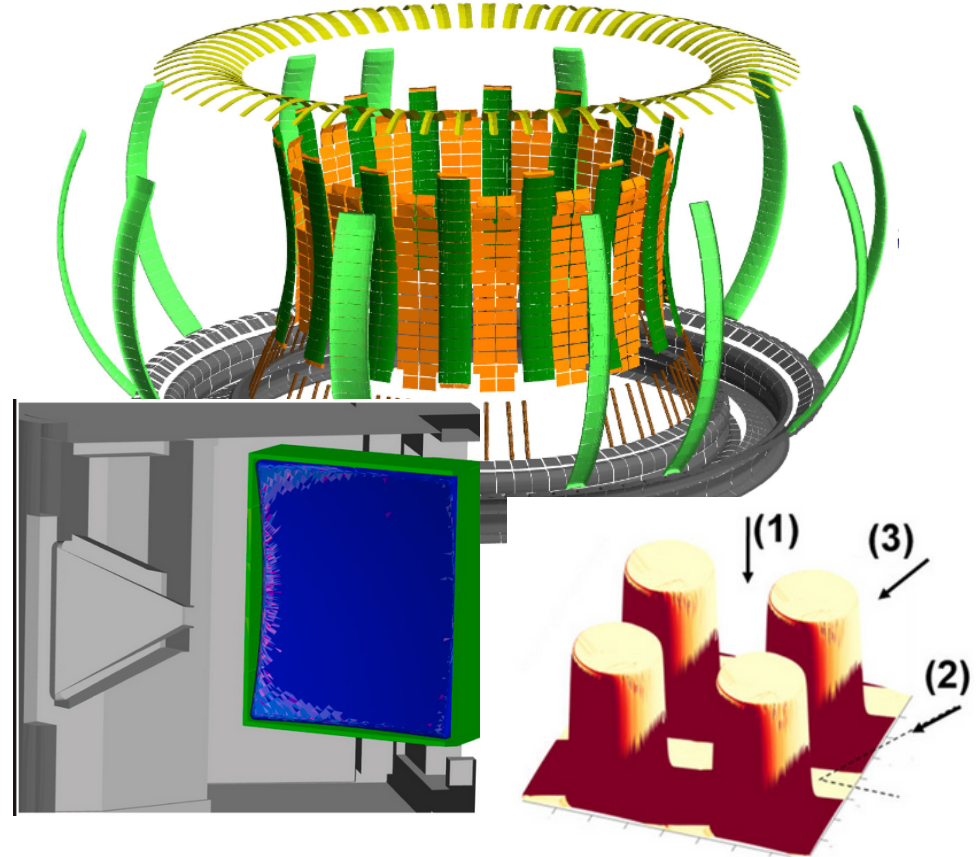
## Overview of ERO2.0 and interactions with EIRENE

J. Romazanov on behalf of the ERO Developer Team

Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics (IFN-1), 52425 Jülich, Germany

## Key facts

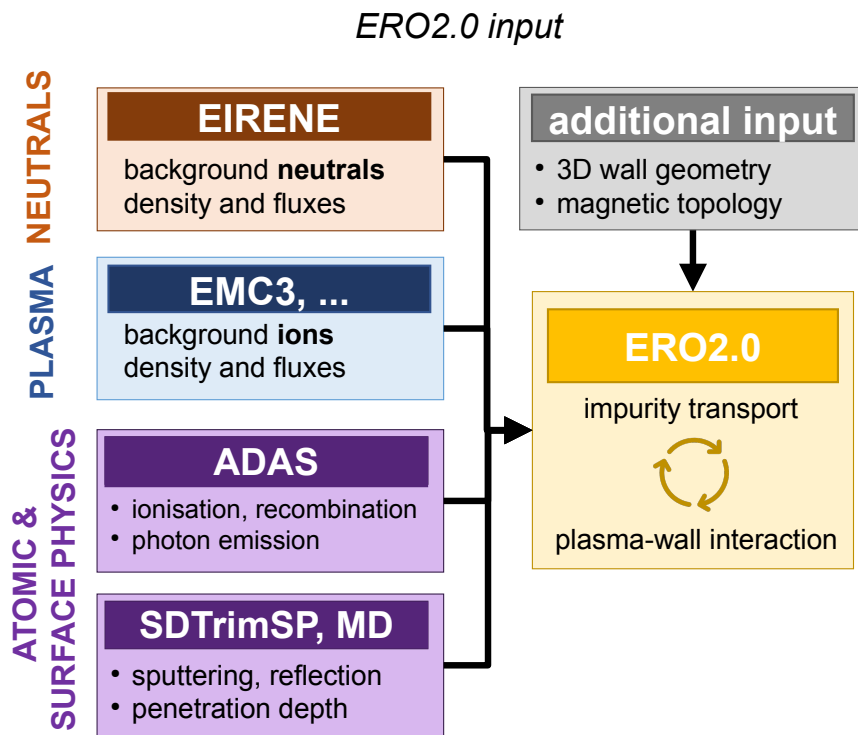
- Core developer team at FZJ + international collaborations
- Monte-Carlo code for PWI (erosion, deposition) and impurity transport code
- Detailed, fully 3D (CAD-based) wall geometry
- Possibility of Larmor-resolved ion orbits
- Written in C++ (modular, object-oriented)
- MPI + OpenMP parallelization, GPU acceleration in work
- Interfaces to other codes



# Overview of the code

## Key facts

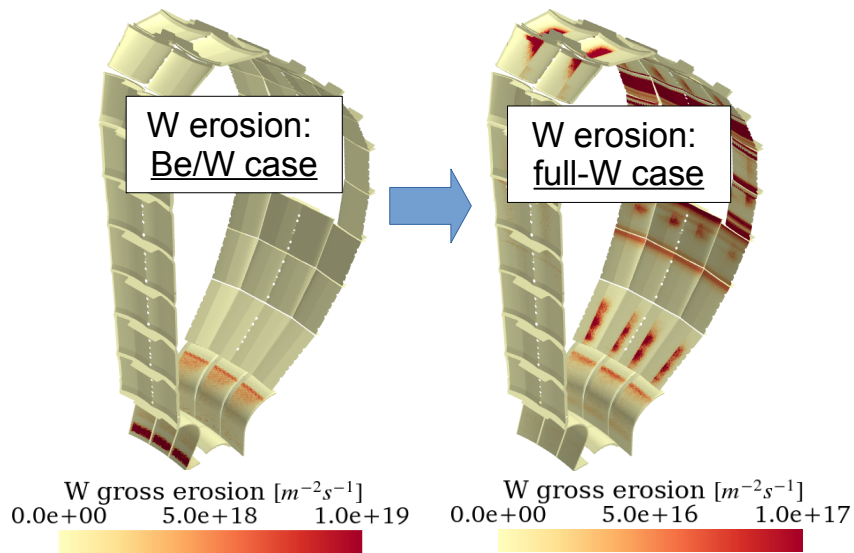
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# Examples of ERO2.0 applications

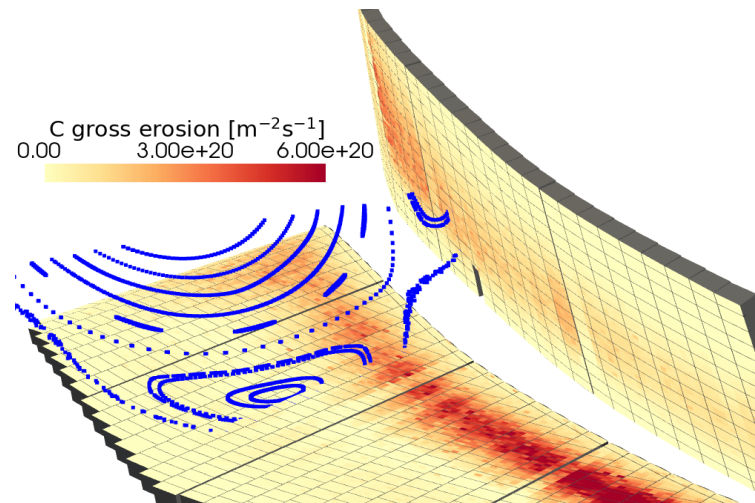
## ITER tokamak

- Be wall lifetime considering 3D shaping
- diagnostic first mirrors lifetime
- transition from Be to W first wall

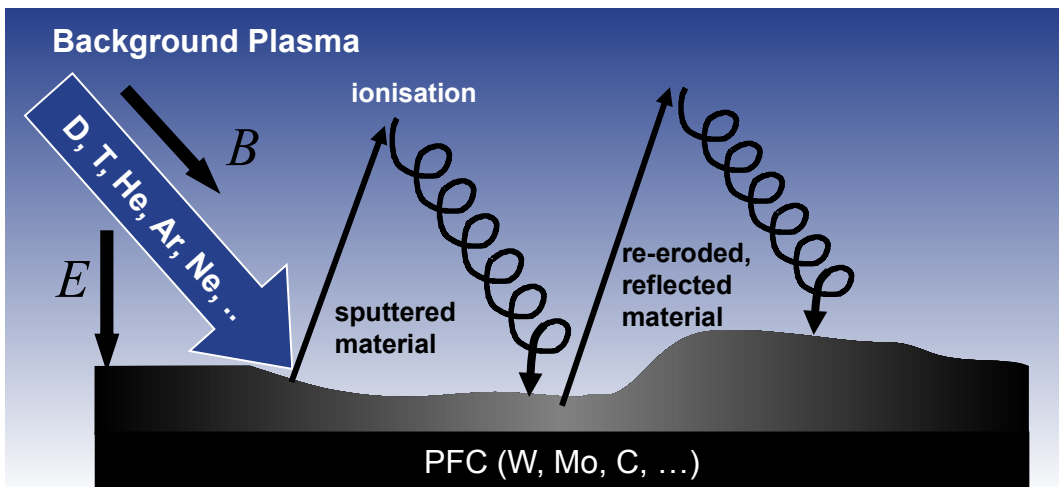


## W7-X stellarator

- graphite (carbon) erosion
- impurity transport in 3D environment
- long-pulse operation, upgrade to metallic wall



# Key physics included



## Basic output:

- Erosion/deposition patterns on the wall
- Distribution of impurities in the plasma

### Plasma-wall interaction

- physical and chemical sputtering
- reflection
- material mixing
- re-erosion, re-deposition

### Impurity transport

- ionisation, recombination, dissociation of molecules
- Full Orbit or Guiding Center
- collisions (Fokker-Planck) in trace impurity approximation

[1] Kirschner et al., NF (2000)  
 [2] Romazanov et al., Phys. Scr. (2017)

# Overview of ERO2.0 ↔ EIRENE interaction topics

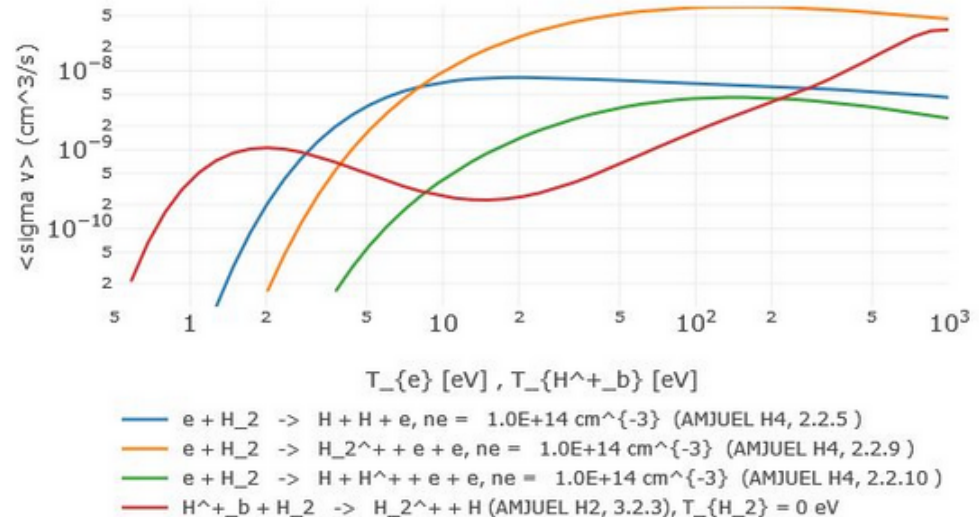
- Databases (A&M, PWI)
- Simulation data exchange
- Kinetic ion transport model
- Software engineering
- Others (e.g. code coupling)

- **ADAS data**
  - ionisation/recombination, photon emissivities
- **Molecular data**
  - ERO2.0: focus on impurities (hydrocarbons, N<sub>2</sub>, ammonia, ..)
  - EIRENE has much more comprehensive model & data incl. hydrogen molecules
- **Possible actions:**
  - Build common curated database
  - Coupling to ModCR

Linked projects:  
TSVV-5, ...

from EIRENE  
webpage

H2 dissociation rate coefficients



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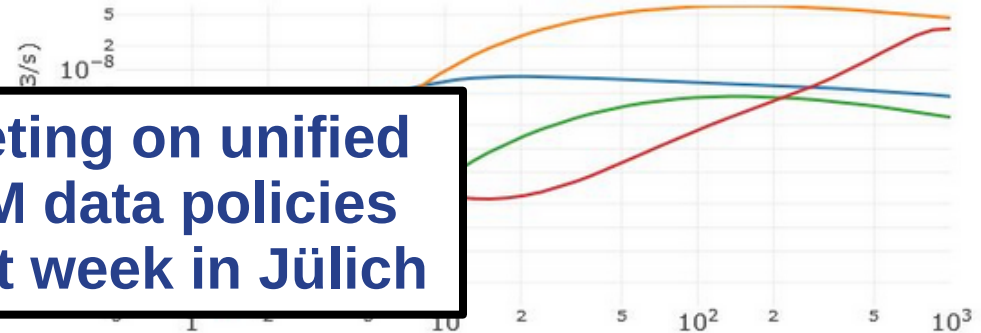
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H2 dissociation rate coefficients



**Meeting on unified  
A&M data policies  
next week in Jülich**

- **Possible actions:**

- Build common curated database
- Coupling to ModCR

$T_{\{e\}}$  [eV],  $T_{\{H^+_b\}}$  [eV]

- e + H<sub>2</sub> → H + H + e, ne = 1.0E+14 cm<sup>-3</sup> (AMJUEL H4, 2.2.5)
- e + H<sub>2</sub> → H<sub>2</sub><sup>++</sup> + e + e, ne = 1.0E+14 cm<sup>-3</sup> (AMJUEL H4, 2.2.9)
- e + H<sub>2</sub> → H + H<sup>++</sup> + e + e, ne = 1.0E+14 cm<sup>-3</sup> (AMJUEL H4, 2.2.10)
- H<sup>+\_b</sup> + H<sub>2</sub> → H<sub>2</sub><sup>++</sup> + H (AMJUEL H2, 3.2.3), T<sub>{H<sub>2</sub>}</sub> = 0 eV



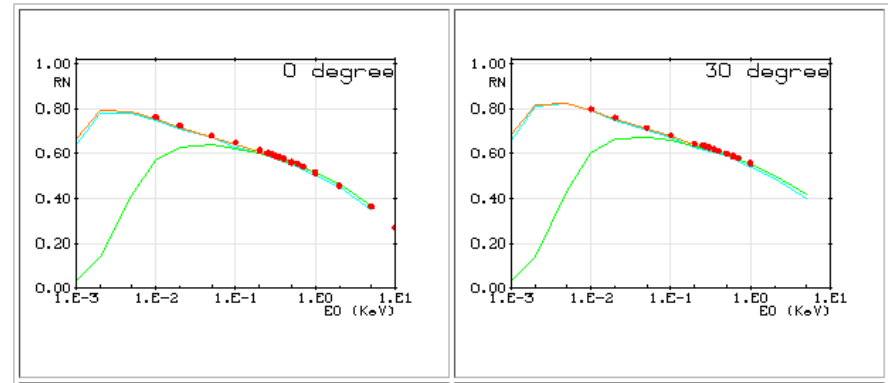
- **Reflection coefficients**
  - typically from TRIM (SDTrimSP)
  - same data layout needed (function of e.g. impact energy and angle)
  - ERO2.0 also uses sputtering coefficients (from same simulations)
- **Possible actions:**
  - Build common curated database
  - Requires streamlining of formats and review of input parameters / assumptions
  - Integrate MD data?

Linked projects:  
TSVV-7, ...

D on W

from EIRENE  
webpage

**Particle Reflection Coefficient**

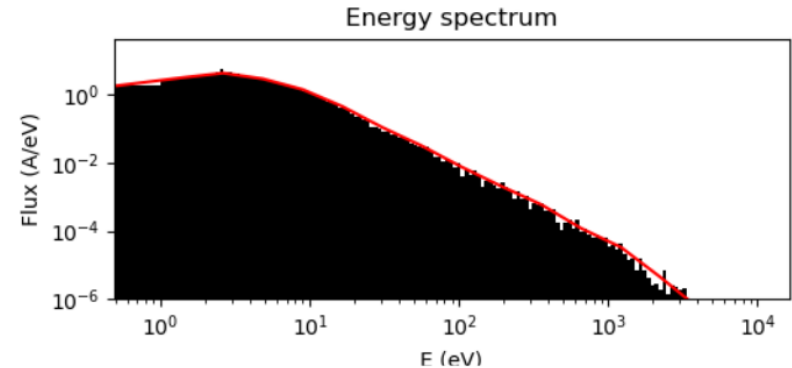


- **X-EIRENE input to ERO2.0:**
  - charge-exchange neutrals: energy and angular resolved fluxes for calculation of erosion
  - volumetric data: neutral densities and temperatures for impurity collisions
- **Possible actions:**
  - Define prioritised “common interest” plasma cases. Ensure plasma backgrounds are suitable for ERO2.0.
    - Example: SOLPS-ITER cases for ITER, DEMO: often outdated or wrong wall geometry/equilibrium, no wide-grid, no CXN data, ...
  - Streamline exchange on common grids (ERO2.0 M.Sc. thesis in progress)

\*(EIRENE coupled to B2, EMC3, SOLEDGE, ..)

Linked projects:  
TSVV-6, TSVV-7

H. Kumpulainen,  
TSVV-5 meeting  
24.05.2024



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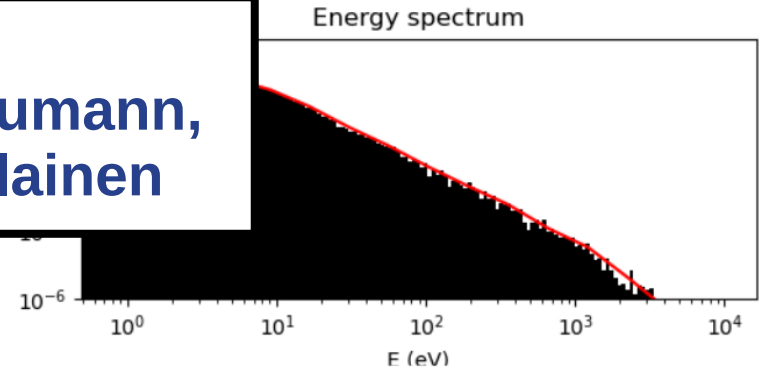
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H. Kumpulainen,  
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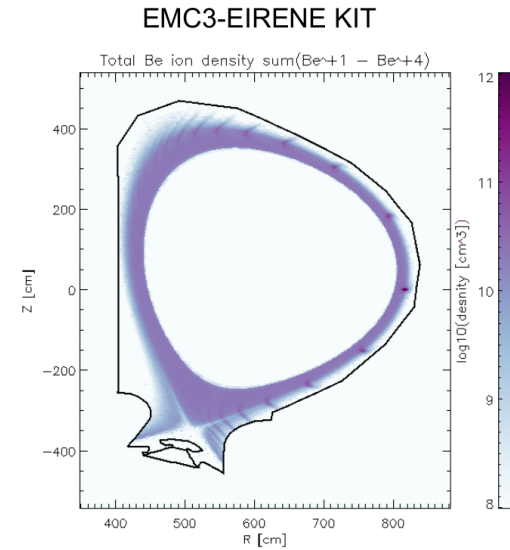
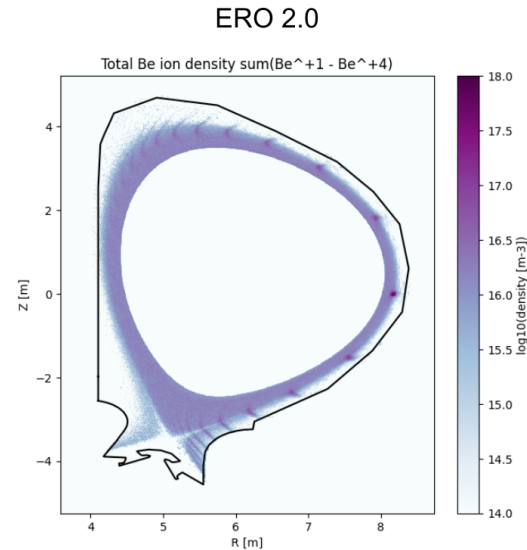
See talks by  
Christoph Baumann,  
Henri Kumpulainen



- **EIRENE Kinetic Ion Transport (KIT)**
  - same equations as for ion transport in ERO2.0
- **Possible actions:**
  - Code-code benchmark
  - Streamline and improve technical implementation (e.g. adaptive stepping)
  - Comparison *Guiding Center vs Full-Orbit*
  - Implement higher-order corrections (thermoforce, ...)
  - Non-linear effects?

Linked projects:  
TSVV-6, ...

D. Harting, PSI-26



- **EUROfusion Standard Software recommendations:**
  - IMAS interfaces
  - software engineering best practises (CI/CD, documentation, issue tracker, code webpage, ...)
  - licensing
  - training
  - validation & verification
- **Possible actions:**
  - Share know-how, streamline as much as possible (shared infrastructure etc.)

Linked projects:  
TSVV-5, TSVV-6,  
TSVV-7



Annex-2 Guidelines for EUROfusion standard software

Gitlab server @FZJ:



EIRENE / EIRENE  Developer

A Monte Carlo transport solver: multi species, nonlinear and time dependent. See also <http://www.eirene.de>

Monte Carlo neutral gas ... plasma physics



ero / ero2  Owner

ERO2.0 source code + master config file.

- **Parallelisation**
  - Both codes use MPI + OpenMP -> exchange on ideas for profiling, optimisation, GPU acceleration, ...?
- **Data storage**
  - SimDB being built for X-EIRENE simulation data -> co-usage by ERO2.0?
- **Code-code coupling**
  - Implement “real coupling” between ERO2.0 and X-EIRENE? (ERO2.0 providing impurities)

Linked projects:  
TSVV-5, TSVV-6,  
TSVV-7

