Erosion/deposition modelling with ERO2.0
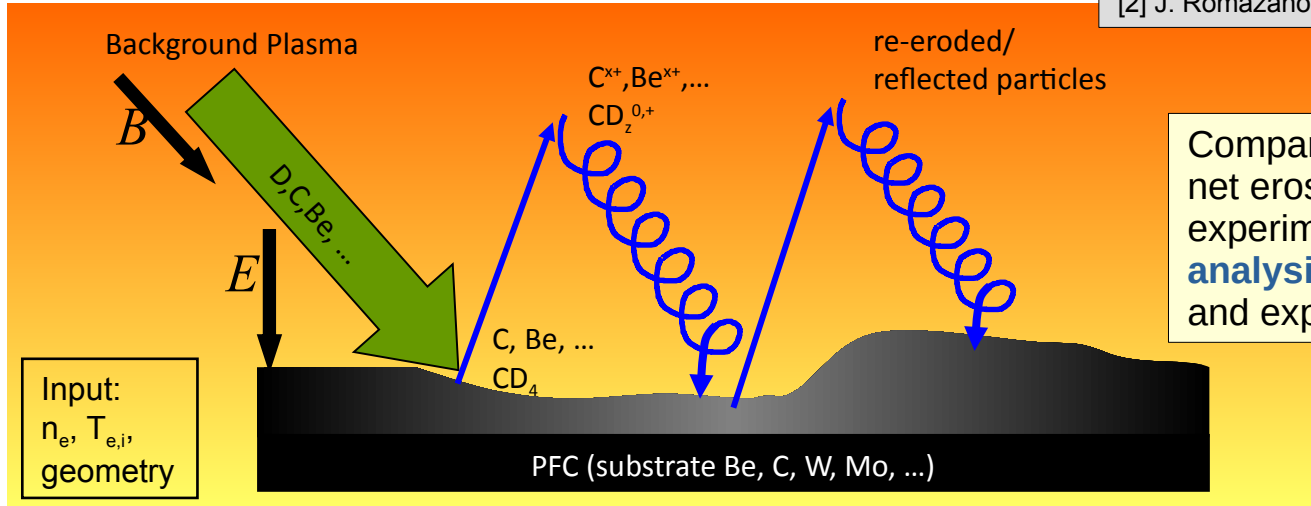
J. Romazanov, S. Rode, S. Brezinsek, M. Groth, A. Kirschner, et al.

JÜLICH
Forschungszentrum

The 3D simulation code ERO2.0

[1] A. Kirschner et al., Nuclear Fusion (2000)
[2] J. Romazanov et al., Physica Scripta (2017)

Background Plasma

B

E

D,C,Be, ...

Input:
n_e, $T_{e,i}$,
geometry

C, Be, ...
CD_4

$C^{x+}, Be^{x+}, ...$
$CD_z^{0,+}$

re-eroded/
reflected particles

Compare simulated steady-state net erosion/deposition to experimental **post-mortem analysis data** for code validation and experiment interpretation

PFC (substrate Be, C, W, Mo, ...)

A. Kirschner

Plasma-surface interaction:

- physical sputtering/reflection
- chemical erosion (CD_4, BeD)
- (re-)erosion and (re-)deposition
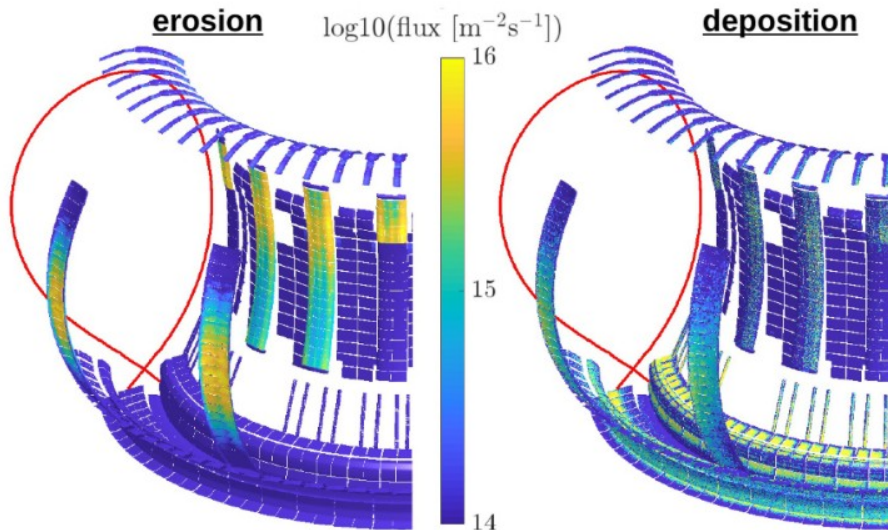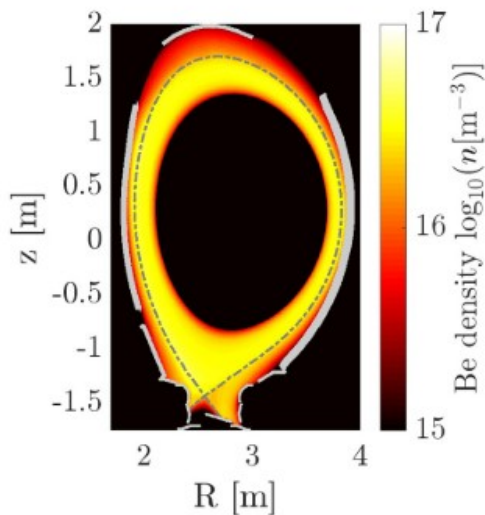- material mixing

Impurity transport:

- Lorentz force (including E x B)
- ionisation, dissociation
- friction (Fokker-Planck), thermal force
- cross-field diffusion

Example of ERO2.0 application to JET-ILW

Modelling of Be erosion and redeposition in the V5-C configuration in ohmic, L and H-mode ("Be Monitoring Pulse") with EDGE2D-EIRENE solutions
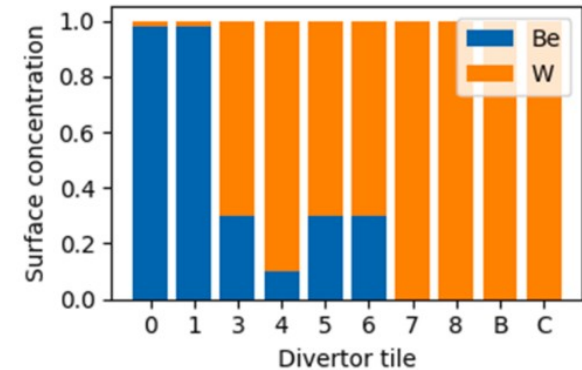
At that time, experimental benchmark focussed on spectroscopy → no direct comparison with post-mortem data benchmark yet for these simulations

Recent, ongoing or planned efforts for JET (Aalto-FZJ collaboration)

[1] H. Kumpulainen et al., PSI/NME 2022
[2] R. Mäenpää et al., EPS 2019
[3] R. Mäenpää et al., PSI/NME 2022
[4] D. Matveev et al., PSI 2022
[5] D. Matveev et al., AAPPS-DPP 2022
[6] P. Virtanen, B.Sc. thesis, 2022

- **Mirror assemblies** (see next slides)

- **W erosion** in H-mode plasmas [1]

  - Inter- and Intra-ELM, different scenarios, fuelling rate + power scans, D vs T plasma

  - Be erosion included; **Be concentration on divertor tiles was analysed**

  - Connection to e.g. **louvre clip post-mortem data**?

- **Nitrogen seeding** [2, 3]

  - Influence of N_2 molecular physics on the N transport; ammonia reactions planned.

  - Connection to **[15]N tracer experiment post-mortem data**?

- **Beryllium erosion** and redeposition

  - Revisit the simulations with...

    - ...upgraded code (e.g. mixing model)

    - ...recent experimental data from H, D, T experiments

    - ...recent EDGE2D-EIRENE plasma backgrounds (BeMP)

    - ...updated Be sputtering yields for H, D, T projectiles.

  - Compare to **post-mortem data for Be main chamber and Be layer growth in the divertor.**

- **Isotope removal** experiment [4, 5]

  - modelling of Be co-deposited layers in inner divertor in raised ISP discharge.

- **Nickel erosion** by CX neutrals impact from recessed Inconel components [6]

  - first comparison available to core spectroscopy.

Starting point: analyse existing simulations w.r.t. post-mortem data

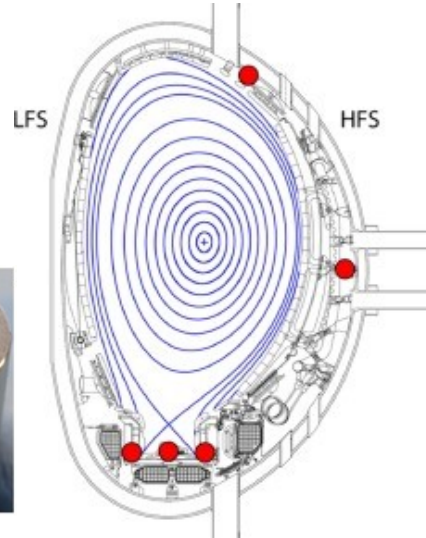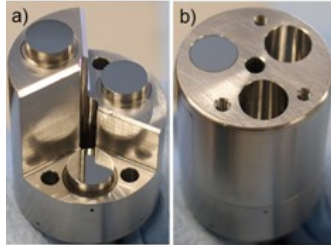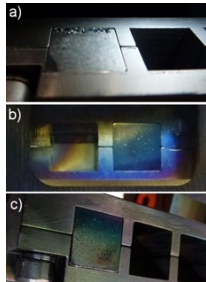# Erosion and deposition of First Mirrors

Experiments at JET

Verification of models (EIRENE+ERO2.0)

Predictions for ITER First Mirrors

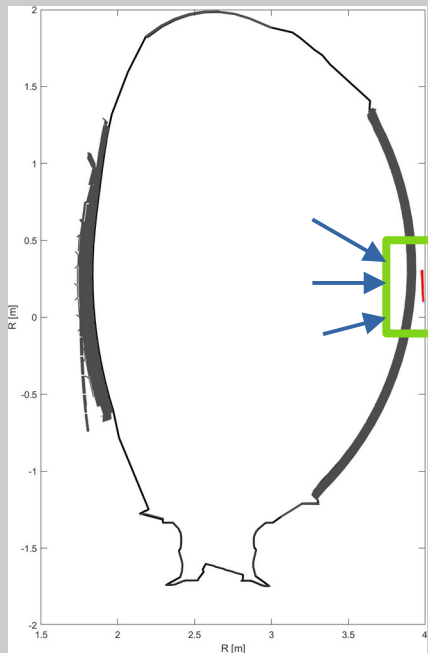ITER-like Mirror Test Assembly (ILMTA)

First Mirror Test (FMT) programme

FZJ-ITER contract 2021/22

WP PWIE

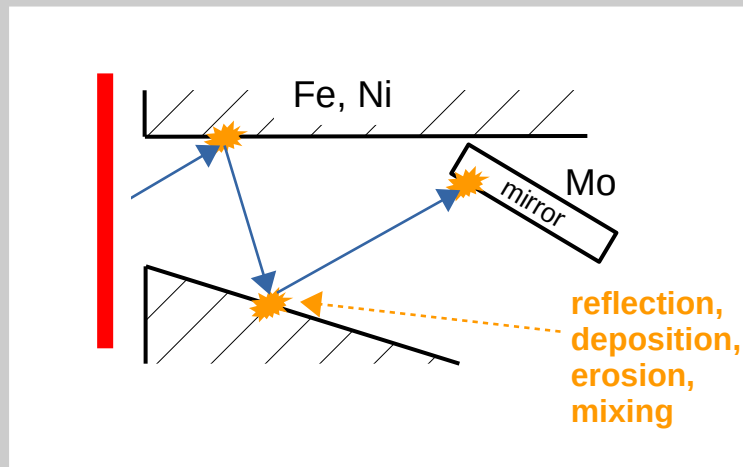# Modelling workflow – multi-stage approach

global modelling

incoming particles distribution function f (flux, energy, angle)
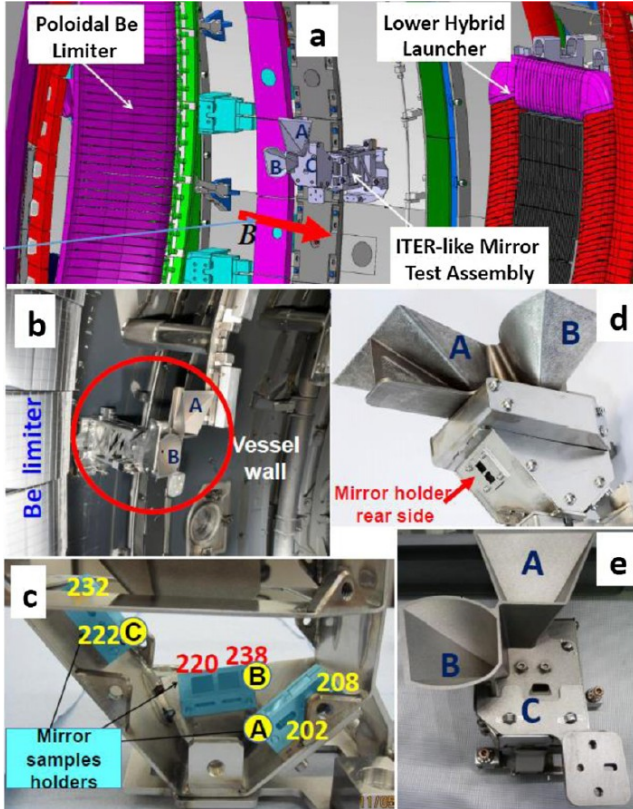
for H, D, Be

local modelling

re-sample particles at catcher surface with increased statistics and continue tracing inside small volume

Fe, Ni

Mo

mirror

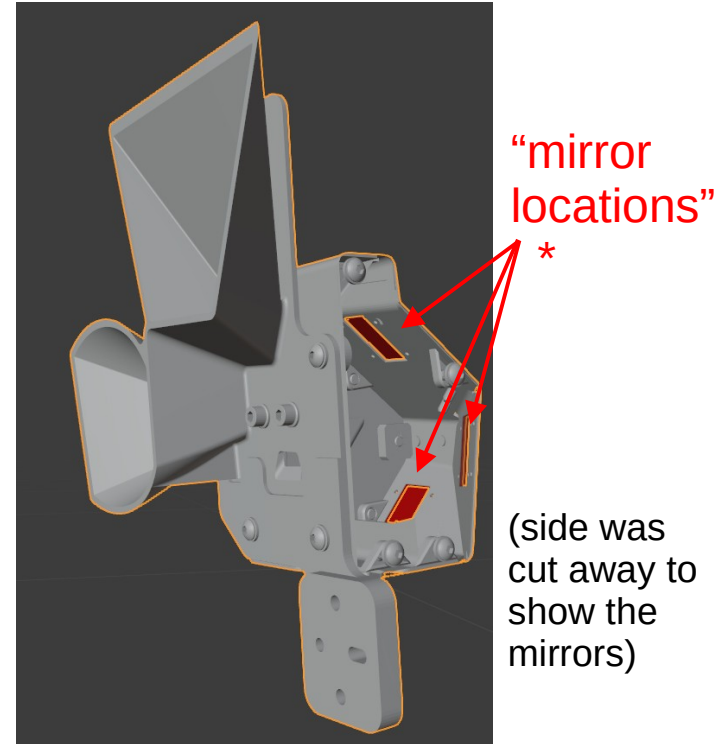reflection, deposition, erosion, mixing

JET ITER-like Mirror Test Assembly (ILMTA)

3D model cut

M. Rubel et al (2021)

exposed in JET ILW-3 campaign (2015-2016), 23.4 h tokamak plasma exposure + 1027 h glow discharge cleaning

"mirror locations" *
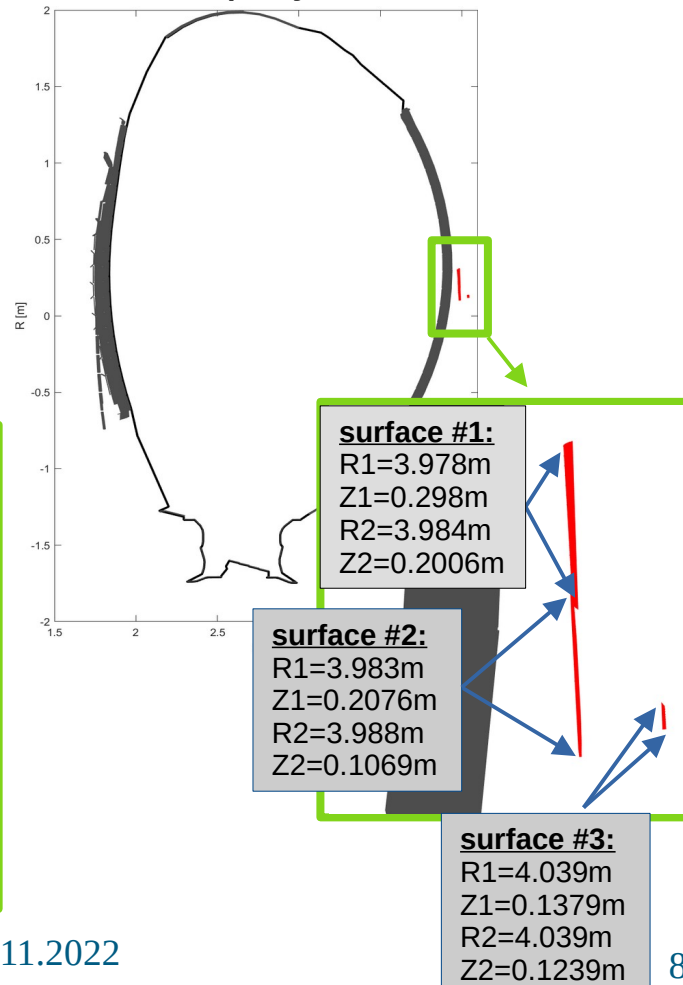
(side was cut away to show the mirrors)

* Actually these are just sample holders. In reality, each sample holder should have two mirror samples on it, but this is not included in the present 3D geometric model.
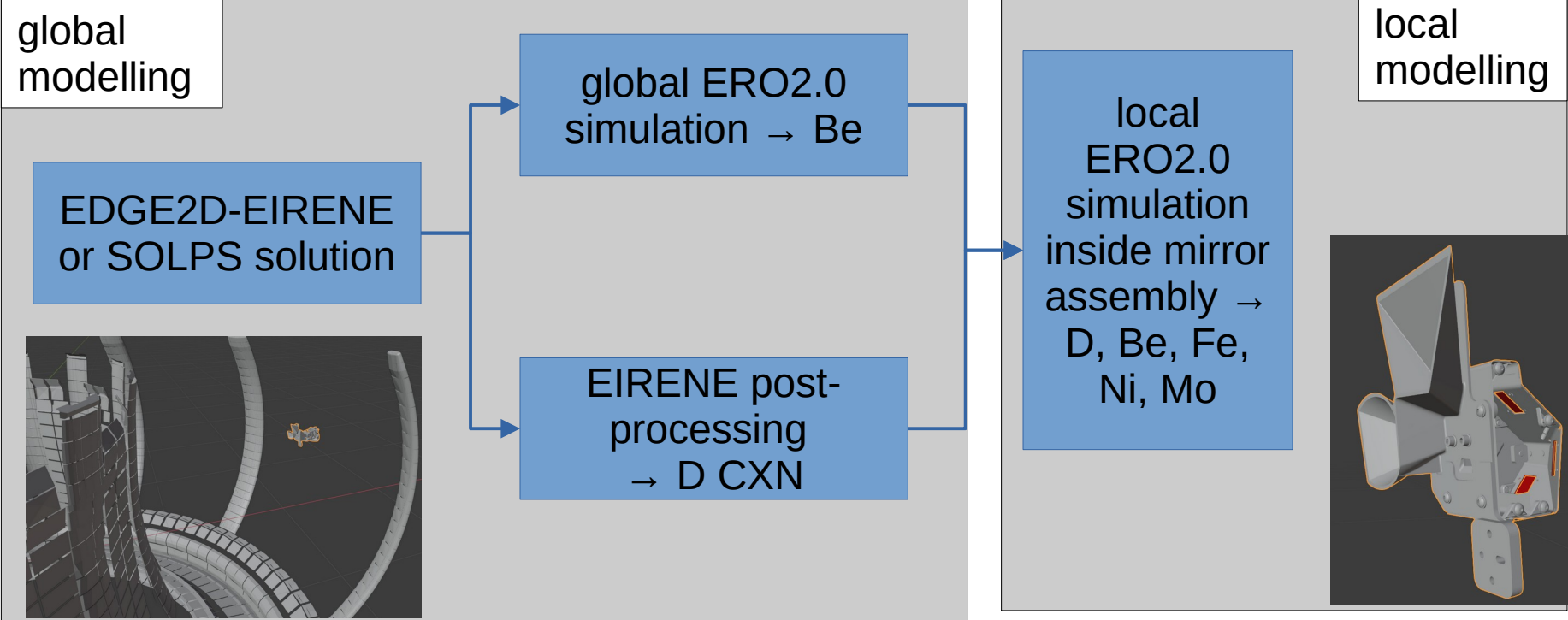
ILMTA location

3D view
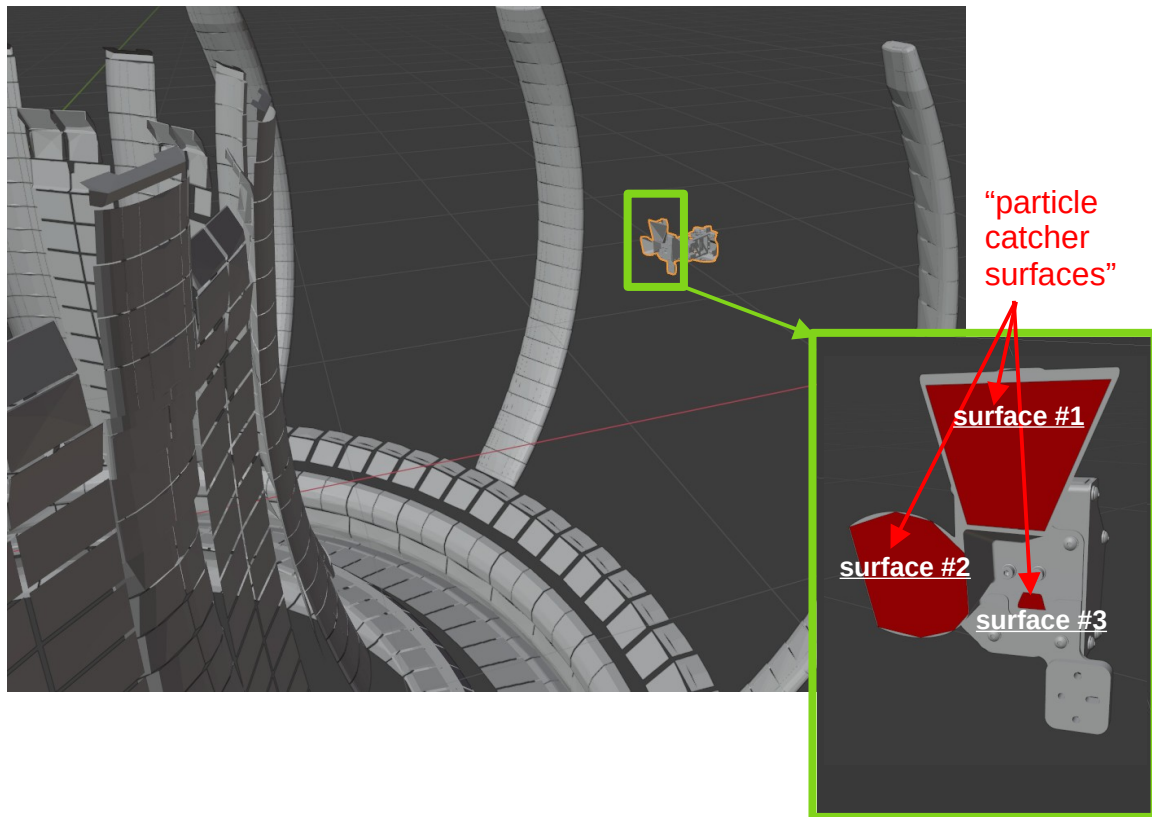
2D projection

"particle catcher surfaces"

surface #1

surface #2

surface #3

surface #1:
R1=3.978m
Z1=0.298m
R2=3.984m
Z2=0.2006m

surface #2:
R1=3.983m
Z1=0.2076m
R2=3.988m
Z2=0.1069m

surface #3:
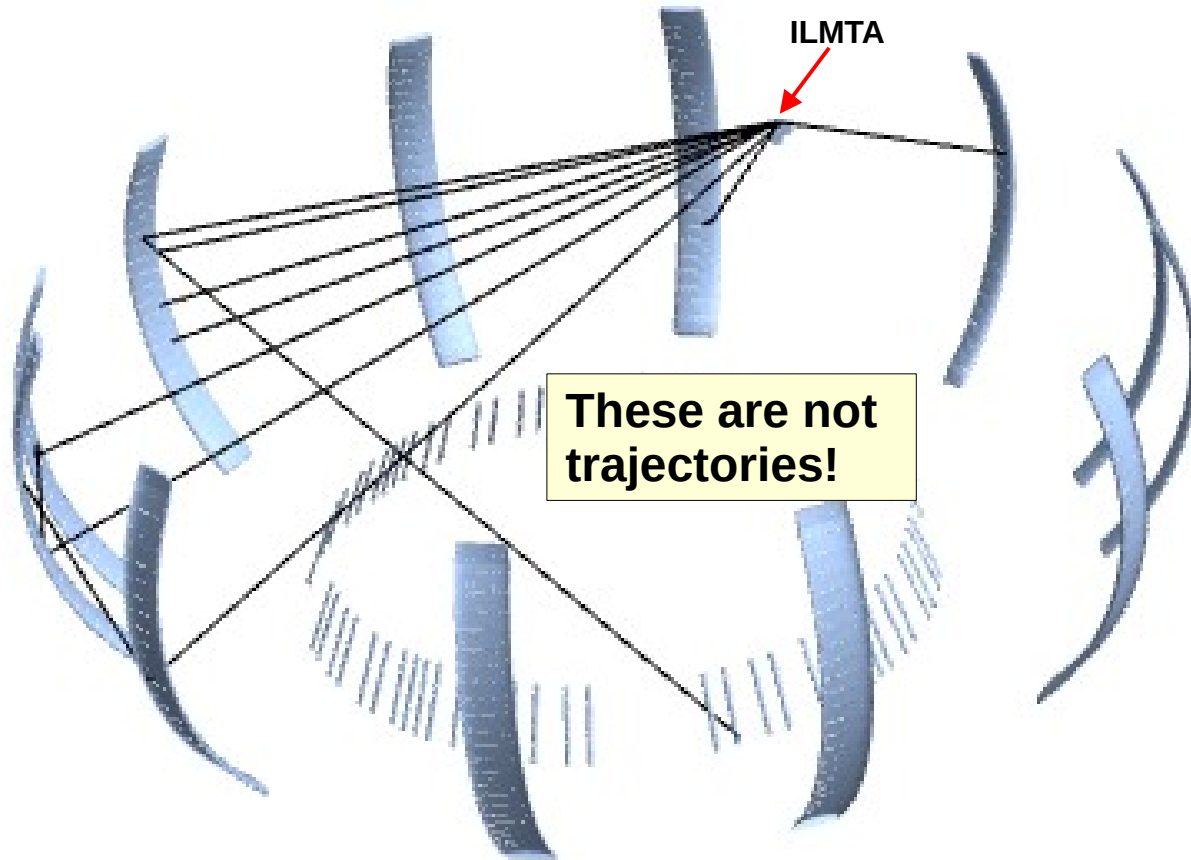R1=4.039m
Z1=0.1379m
R2=4.039m
Z2=0.1239m

Modelling workflow – multi-stage approach

Two-level approach needed to account for differences in the level of geometric detail and plasma parameters. Also, to have sufficient statistics in local modelling (low fluxes to ILMTA!).

global modelling

EDGE2D-EIRENE or SOLPS solution

global ERO2.0 simulation → Be

EIRENE post-processing → D CXN

local modelling

local ERO2.0 simulation inside mirror assembly → D, Be, Fe, Ni, Mo

Global Be transport to ILMTA (ERO2.0) – first test run

ILMTA

These are not trajectories!

Of 1 Mio Be test particles starting from limiters, only a few reach the ILMTA entrance → statistics problem.

Where do these few particles originate? → Mostly from outer poloidal limiters, only one from inner limiter.

Need to repeat simulation many times to gather better statistics, before proceeding to local run.

EIRENE-standalone simulations to obtain D CXN fluxes

"Grid notch" with diagnostic surface was introduced in EIRENE to collect CXN distributions at ILMTA entrance

provided by M. Groth

EIRENE CXN energy distributions at ILMTA entrance

grid notch

diagnostic surface
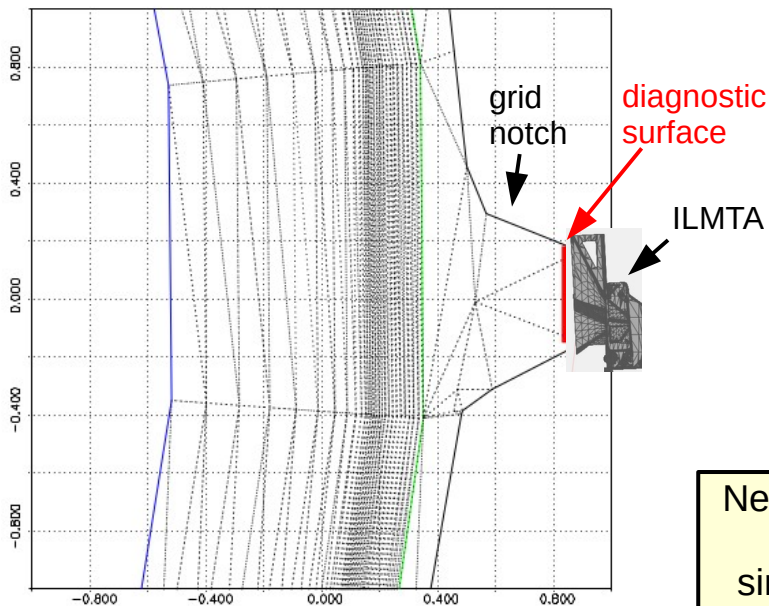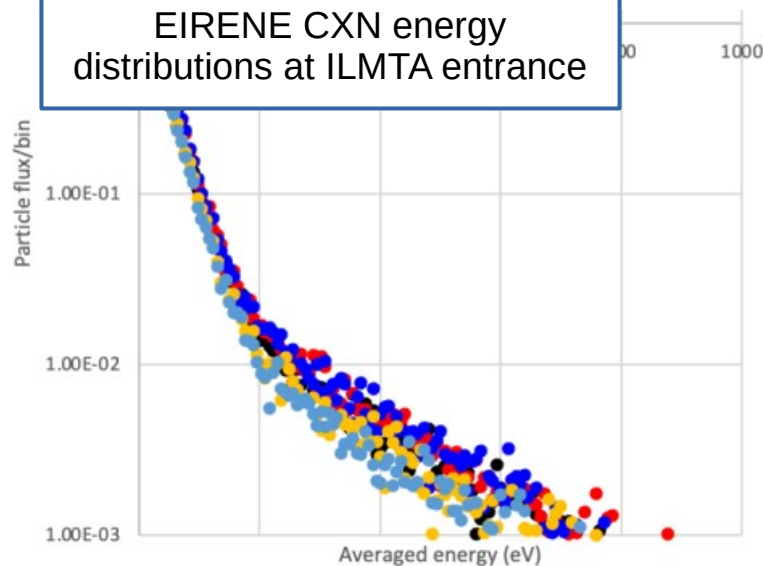
ILMTA

Next step: include CXN distribution from EIRENE into ERO2.0 to simulate subsequent erosion and deposition inside ILMTA

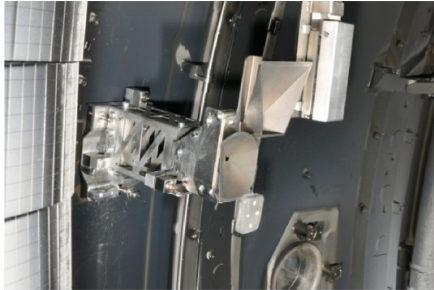Refinement: obtain also CXN angular distribution from EIRENE

Erosion and deposition of First Mirrors

Experiments at JET → **ITER-like Mirror Test Assembly (ILMTA)**

FZJ-ITER contract 2021/22

Verification of models (EIRENE+ERO2.0) → **First Mirror Test (FMT) programme**

Predictions for ITER First Mirrors

WP PWIE

JET First Mirror Test

S. Moon et al (2019)

JÜLICH Forschungszentrum

cassettes in main chamber and divertor:
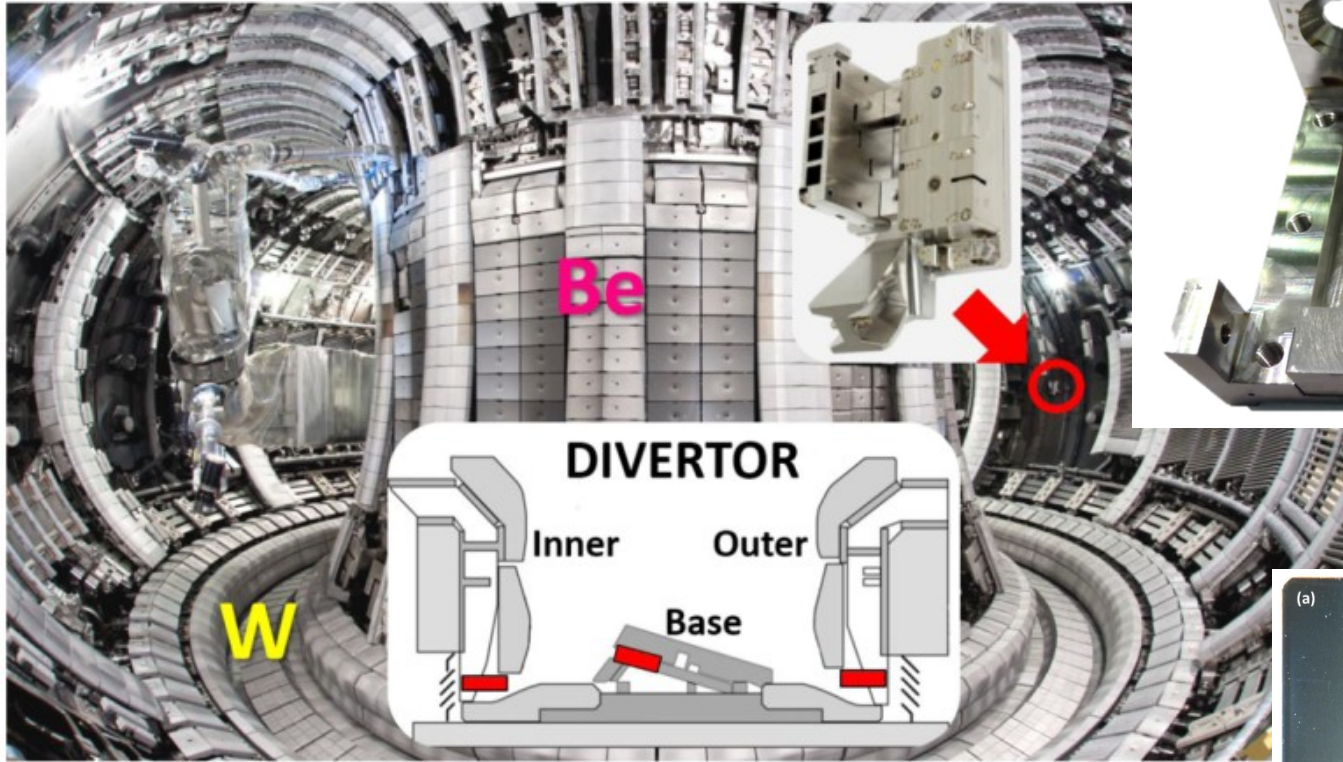
five-way cassette in main chamber:

DIVERTOR

Inner   Outer

Base

Be

W
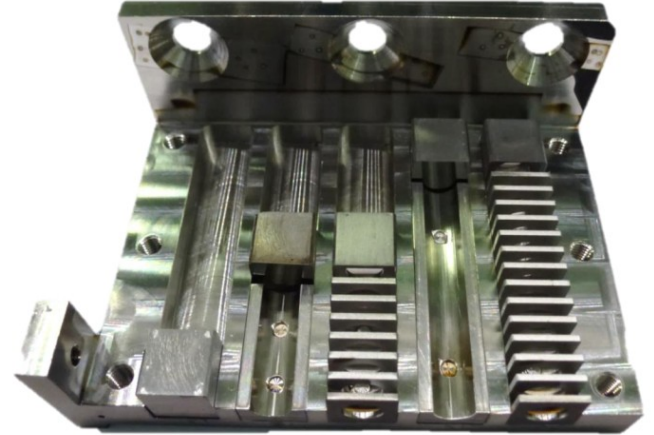
mirror samples after exposition:

(a) (b)
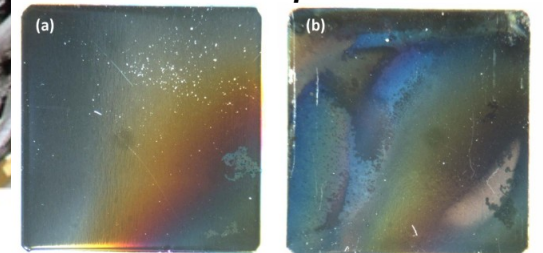
JET First Mirror Test – what is needed?

- Once established, similar modelling workflow as for ILMTA could be applied.

- Locations and geometries (ideally 3D model) of mirror cassettes needed.

- CXN data (fluxes, energy+angle distributions) needed from EIRENE.

Summary and outlook

- **Modelling for ILMTA:**

  - Ongoing with EDGE2D-EIRENE + standalone EIRENE (Aalto) + ERO2.0 (FZJ).

  - Current status: refinement of global-scale modelling (better Be statistics from ERO2.0, angular D CXN distributions from EIRENE), before going to local-scale modelling.

  - Results can be expected in a few months from now.

- **Modelling of First Mirror Tests:**

  - No work started on this. But can be done more easily after experience with ILMTA.

  - Question of manpower (EIRENE, ERO2.0)?