DSD-TSVV Jour Fixe – January 14, 2025

TSVV6 Impurity Sources, Transport, and Screening

G. Ciraolo on behalf of TSVV 6 team

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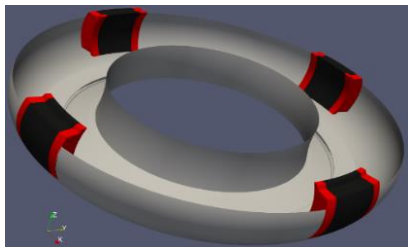
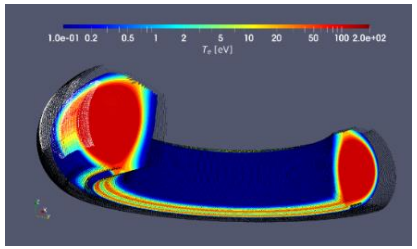
TSVV-6: code development and validation of SOLEDGE3X-ERO2.0 on WEST experiments

INVESTIGATION OF **W CORE CONTAMINATION IN WEST GEOMETRY DUE TO ANTENNA LIMITER** WITH **3D TRANSPORT SOLEDGE3X-ERO2.0 SIMULATIONS**

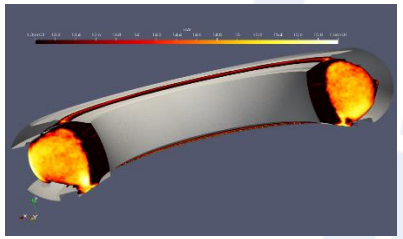
3D non-axsymmetric wall :
Radial Outer Gap: 1.5 cm

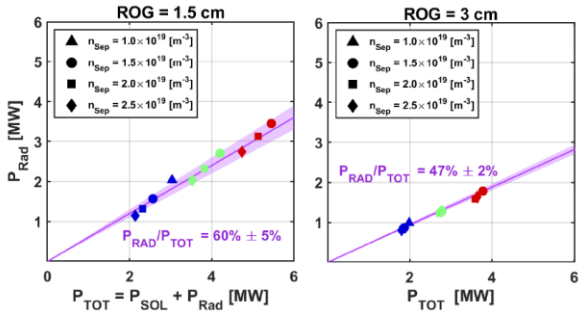


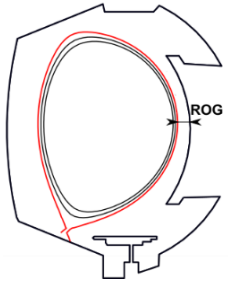
SOLEDGE3X plasma background



3D density map of W obtained with ERO2.0 using SOLEDGE3X backrgound





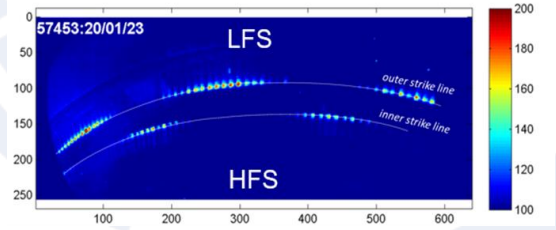


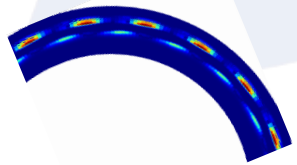
S. Di Genova et al Nuc. Fus. 2024,
G. Ciraolo et al PSI 2024

- Simulations results indicate the **role of the antenna limiter in the tungsten contamination of core plasma** depending on the distance from the plasma (ROG parameter)

Ongoing: impact of **3D non axisymmetric magnetic geometry** on power load patterns on divertor and impact on sources and transport of W

Top view toroidal IR measurements of divertor heat fluxes





SOLEDGE3X simulations

Work performed in interaction with WP TE, WP PWIE

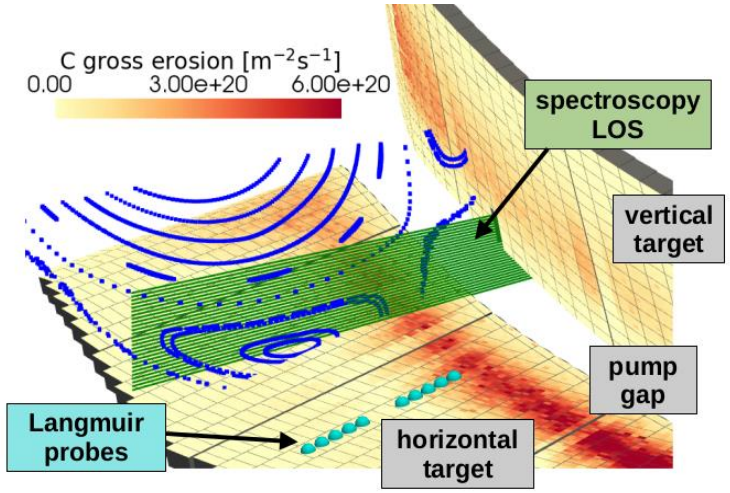
EMC3-EIRENE - ERO2.0 SIMULATIONS OF W7-X EXPERIMENTS

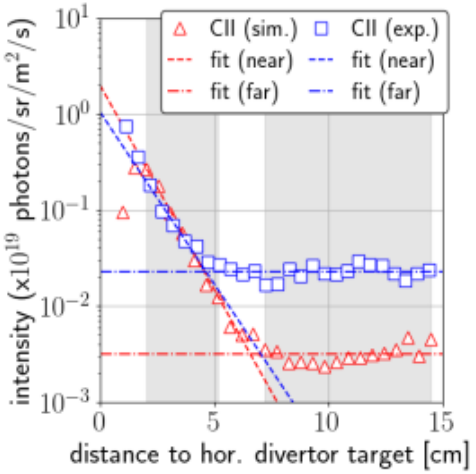
- **Simulations of carbon migration in W7-X OP1.2 campaign standard configuration plasmas were performed**, including chemical erosion and hydrocarbon molecule dissociation chain. **Successful validation using post-mortem analysis from divertor marker fingers and carbon spectroscopy.**
- **Simulations of ^{13}C tracer experiment in OP1.2 were performed,** with parameter studies on the influence of various effects (local vs global transport, re-erosion, transport coefficients, hydrocarbons, sticking coefficients, ExB drifts, parallel flow velocity). Successful validation using ion beam post-mortem analysis on divertor targets.

- **Next steps: simulation of W tiles and analysis with OP2 results**; **predictions for full-W wall W7-X.**

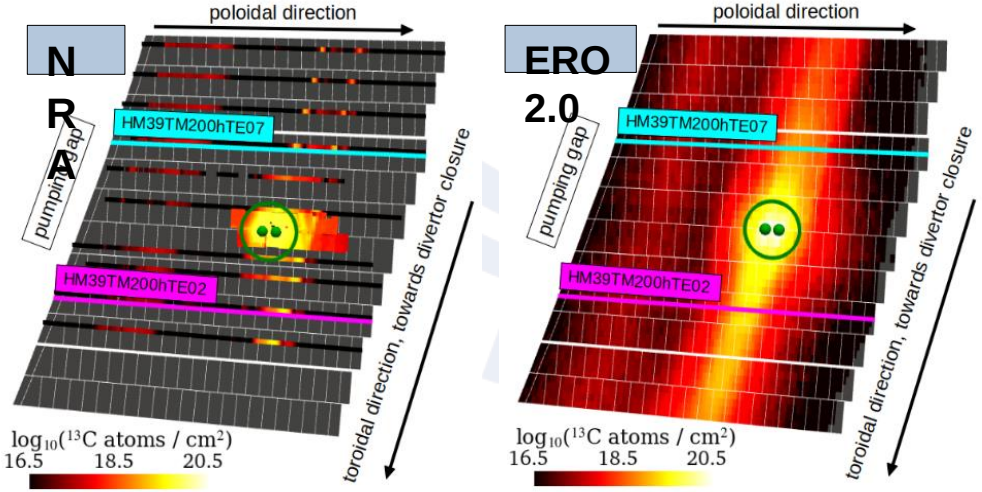
[J. Romazanov, Nucl. Fusion 2024] [J. Romazanov, Nucl. Fusion (submitted)]

12C erosion simulation and spectroscopy comparison





13C injection simulation and post-mortem analysis comparison

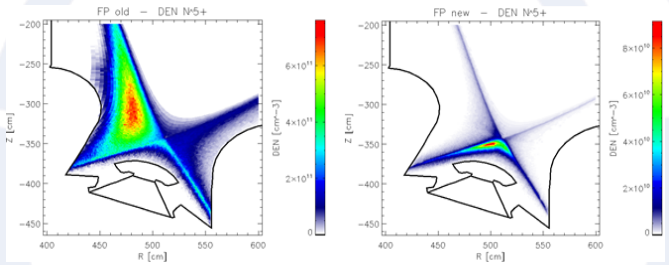


Work performed in interaction with WP W7X, WP PWIE, TSVV7

EIRENE KINETIC ION TRANSPORT MODULE

- Another important part of the project focuses on the **development of a 3D kinetic description of heavy impurity transport in edge and SOL plasmas**, necessary both for taking into account the finite Larmor radius effects on prompt redeposition and the short lifetimes of lower ionization stages of such impurities. **The Kinetic Ion Transport (KIT) module of EIRENE** has been chosen as one of the possible solutions for such a description.
- Major improvements have been obtained during these years. For example, the **correct description of grad-B drift and the formation of banana orbits** in the magnetic mirror. A test case with test particle motion in the magnetic mirror at the outer mid-plane of an ITER background plasma has been extensively used for verifying the new version of the module
- **A new Fokker-Planck collision operator has been implemented** which now properly treats the scattering of ions out of the magnetic mirror regions, which takes into account friction with background species.

*Example of **computation with KIT module on N^{5+} Density in the divertor region using an ITER plasma background from EMC3-EIRENE.** One can observe that with the old version of the Fokker-Planck operator (left panel) there was an unphysical accumulation of particles on the high field side region, now solved with the new Fokker-Planck operator (right panel)*



- First **W simulations** with **EMC3-EIRENE-KIT** achieved
  - **indication that a large fraction of the lower ionisation stages of W is NOT thermalized with the ion background plasma temperature and thus needs a kinetic treatment.**

Next steps: Include missing **thermal force** (inline with ERO2.0)
Continue Benchmark with ERO2.0 including **recycling Impurities** and **high Z impurities** (e.g. W, Ar)
Compare kinetic low Z impurity simulation to **fluid solution**

[D. Harting et al, Nucl Mat Ener. 2022]
[D. Harting et al , Nucl Mat Ener. 2024 (accepted)]

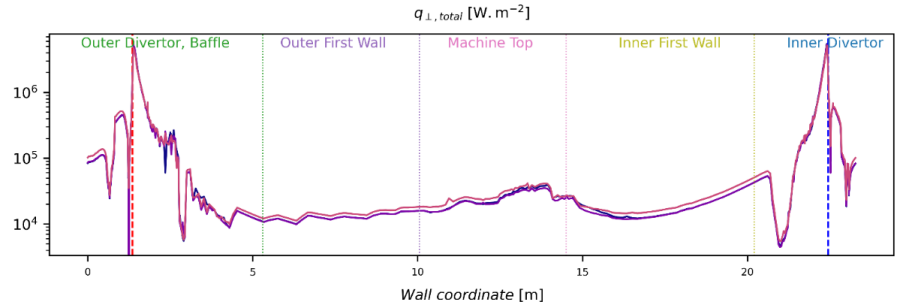
Work in interaction with TSVV 5

APPLICATION TO ITER SCENARIOS

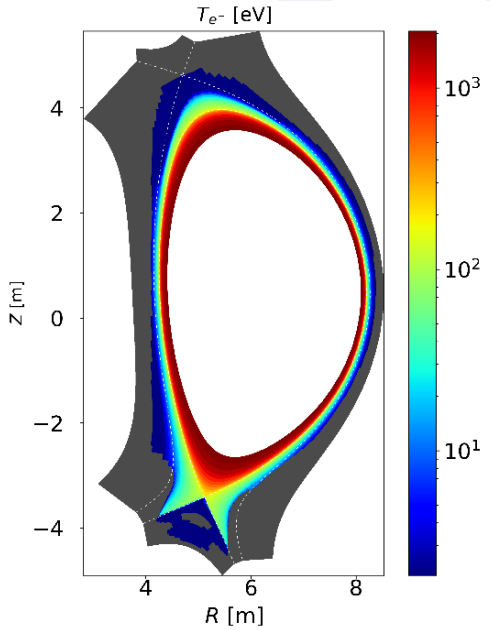
- With the change to **W wall**, we have started (in collaboration with **TSVV 3 and IO**) new SOLEDGE3X simulations for **new ITER full power scenarios with W wall and Ne seeding**

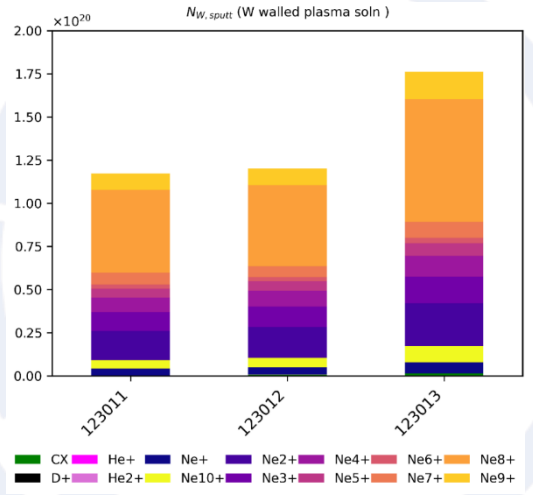
Input conditions:

- $P_{sol} = 100\ MW$
- Species: D, Ne – injected from upper gas puff; He fusion product as a flux from core
- H mode – transport barrier with $D_{\perp}^{Far\ SOL} = 0.3 m^2 s^{-1}$ (no balooning or enhanced far SOL transport)
- Scan performed over Ne seeding



Perpendicular heat flux along the wall





Ne^{8+} largest sputtering source across Ne seeding scan (excl. self sputtering)

Next step: computation of W sources and migration with ERO2.0

PLANS FOR 2025 AND ACTION ITEMS IDENTIFIED FOR 2026-2027

- **Validation steps**:
  - Application of SOLEDGE3X-ERO2.0 workflow to **WEST experiments** taking into account **3D non axisymmetric features**
    - **wall geometry** (toroidally localized antenna limiter) and 3D non-axysimmetric magnetic equilibria (with magnetic ripple)
  - Application of EMC3-EIRENE plus ERO2.0 modeling on **W7X**: simulations of **W tiles and analysis with OP2 results**; **predictions for full-W wall W7-X**

  - **AUG simulations both with SOLEDGE3X-ERO2.0 and EMC3-EIRENE ERO2.0** of a common case related to **WPTE** experimental proposal on W sources and migration (interaction with **TSVV 7, WP TE, WP PWIE**)

- Focus on the determination of the **impact of energetic particles coming from the pedestal region on divertor power load** improving the modeling of parallel heat transport (for ex. considering non-local approach and/or coupling with other appropriate numerical tools)

- Apply EIRENE KIT module for kinetic treatment of impurity transport on ITER cases and comparison with fluid approach

- **Application to ITER scenarios**
  - Complete **SOLEDGE3X plasma background for ITER scenarios with W wall** and investigation of W sources, transport and screening using ERO2.0 (as done for WEST previously)
  - Perform 3D SOLEDGE3X-ERO2.0 simulations for **start-up phase (after validation on WEST experiments):**