PSI-2 SIMULATIONS USING SOLPS-ITER

WP PWIE SP D

20. November 2025 | D. Reiser |

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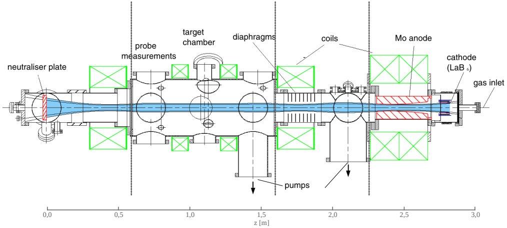
TO DO

Basic Steps to a Running System for PSI-2 Simulations

- Installation of Code Package
- Preparing Geometry Input
- Test Run B2.5 Standalone
- Preparing Visualization Tools
- Preparing Source Input Files
- Adjustment of Physics Parameters
- B2.5 Standalone Runs
- B2.5-Eirene Runs



TO DO (NOVEMBER 2024)

Basic Steps to a Running System for PSI-2 Simulations

- **Installation of Code Package ✓**
- **Preparing Geometry Input ✓**
- **Test Run B2.5 Standalone ✓**
- **Preparing Visualization Tools ✓**
- **Preparing Source Input Files !**
- **Adjustment of Physics Parameters !**
- **B2.5 Standalone Runs !**
- **B2.5-Eirene Runs !**

- At the moment Gateway is not available
- Next steps will follow the to-do list
- Goal for 2025: adjusting details and focus on molecular reactions

STATUS NOVEMBER 2025

PSI-2 Simulations

- **Installation of Code Package ✓**
- **Preparing Geometry Input ✓**
- **Test Run B2.5 Standalone ✓**
- **Preparing Visualization Tools ✓**
- **Preparing Source Input Files !**
- **Adjustment of Physics Parameters !**
- **B2.5 Standalone Runs !**
- **B2.5-Eirene Runs !**

- The code package has now been implemented in our system
- All input files have been generated and the code is actually fully executable for PSI-2 geometry
- However, results could not be obtained because various factors lead to convergence problems

Details follow

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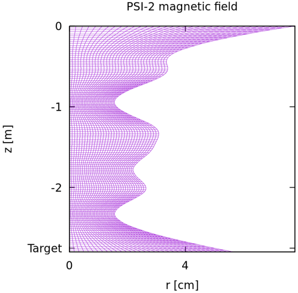
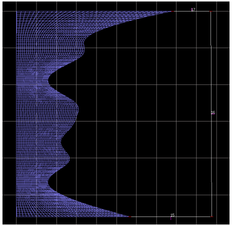
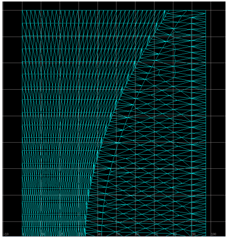
PSI-2 SIMULATION: STEP BY STEP

Magnetic field and computational grids







PSI-2 magnetic field, Biot-Savart-Solver, Input for DivGeo, B2 conventions

This is done and available and can be changed in a flexible way!

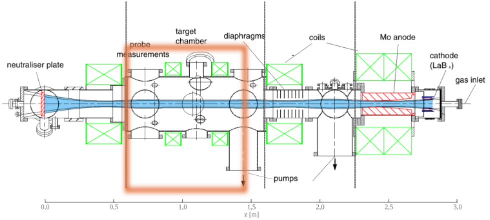
PSI-2 SIMULATION: STEP BY STEP

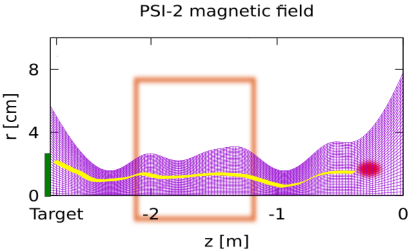
Plasma source

To avoid confusing model overload, the real source is approximated

Match experimentally accessible region

Sheath boundary conditions at both ends





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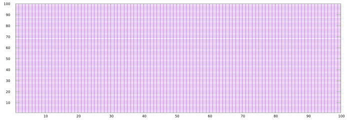
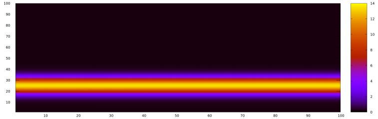
PSI-2 SIMULATION: STEP BY STEP

Volume sources and boundary conditions

Volume sources have been implemented according to needs

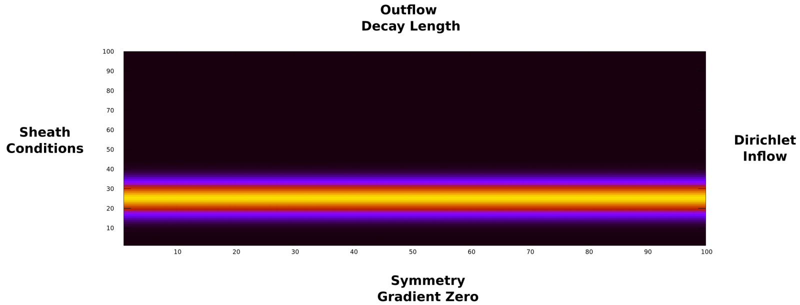
Try to start with homogeneous field in sub-domain to avoid Laval nozzle effects





PSI-2 SIMULATION: STEP BY STEP

Homogeneous Field and Inflow Scenario



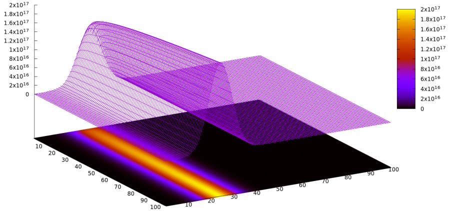
Boundary Conditions for n, $u_{||}$, T_e and T_i

PSI-2 SIMULATION: STEP BY STEP

Starting guess for iteration

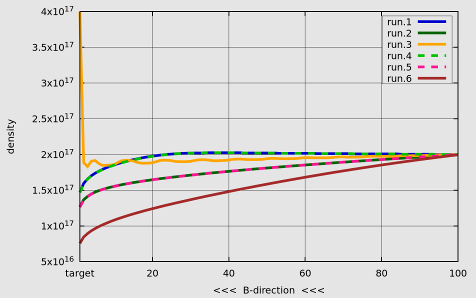
Starting SOLPS-ITER runs with profiles far from solution is extremely unstable.
Pre-processing tools have been developed to provide something reasonable

- **Dirichlet Inflow**
  Profile for n, T_e and T_i, extrapolation for $u_{||}$
- **Symmetry Gradient Zero**
  $\partial n / \partial x = 0$
- **Outflow Decay Length**
  $\partial n / \partial y = -n/\lambda$
- **Sheath Conditions**
  $u_{||} = c_s$, extrapolation for n
  Prescribe fluxes Γ_e and Γ_i



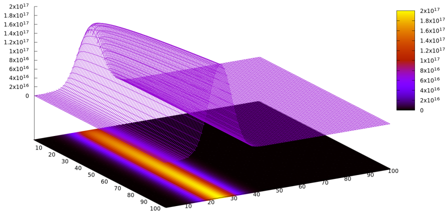
EXAMPLES FOR STARTING GUESSES

- **run 1**
  Reference with sheath bc and zero bias
- **run 2**
  No sheath bc
- **run 3**
  With sheath bc and bias = -2
- **run 4**
  With sheath bc and bias = +2
- **run 5**
  No sheath bc, T_e and T_i fixed
- **run 6**
  With sheath bc and 10 x neutrals



Densities vary only about a factor of 2, exception : run 2 with negative biasing!

GOALS



Simplified models are nice . . .

. . . but SOLPS-ITER can take into account

- Electric fields
- Currents
- Multi-species model
- Stable sheath physics
- Detailed plasma chemistry
- Kinetic neutrals

These important points raise a problem for simplified approaches!

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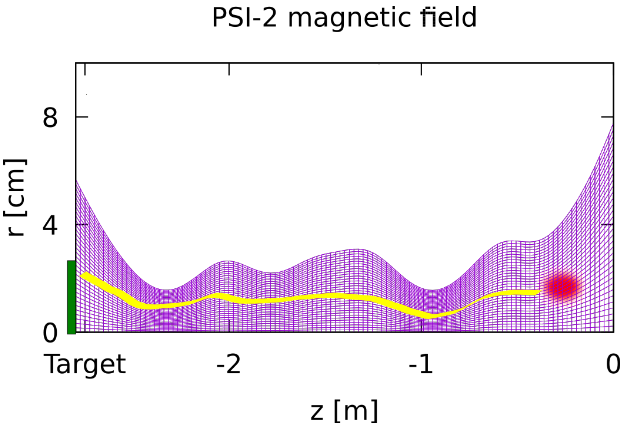
PSI-2 SIMULATION: STEP BY STEP

Current focus

Inflow conditions (profiles!) hard to realize in SOLPS-ITER

Return to source modelling



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PSI-2 SIMULATION: STEP BY STEP

Code parameters

$$\frac{\partial n}{\partial t} + \boldsymbol{\nabla} \cdot (n\mathbf{V}) = S_n$$

$$\frac{\partial}{\partial t}(mn\mathbf{V}) + \boldsymbol{\nabla} \cdot (mn\mathbf{V}\mathbf{V}) = -\boldsymbol{\nabla} p - \boldsymbol{\nabla} \cdot \mathbf{\Pi} + \mathbf{R} + Zen(\mathbf{E} + \mathbf{V} \times \mathbf{B}) + \mathbf{S}_m$$

$$\frac{\partial}{\partial t}\left(\frac{3}{2}nT + \frac{1}{2}mnV^2\right) + \boldsymbol{\nabla} \cdot \left(\frac{5}{2}nT\mathbf{V} + \frac{1}{2}mn\mathbf{V}V^2 + \mathbf{q} + \mathbf{\Pi} \cdot \mathbf{V}\right) = S_E - Q + \mathbf{R} \cdot \mathbf{V} + Zen\mathbf{E} \cdot \mathbf{V}$$

- $\mathbf{\Pi}$, $\mathbf{R}$, Q and $\mathbf{q}$ depend on closure model of fluid equations.
- $\mathbf{V}_\perp$ and $\mathbf{E}$ depend on model for electromagnetism, viscosity etc.
- S_n, $\mathbf{S}_m$ and S_E depend on physical system.

An infinite number of models can be used, but we are aiming at a multi-species standard.

PSI-2 SIMULATION: STEP BY STEP

Current work

The convergence problems require the following steps

1. **A multi-species parameter set must be aligned with successful applications**
2. **Meaningful start profiles must be prepared to stabilize the iteration**
3. **Kinetic neutral particles should eliminate uncertainties with fluid neutrals**

We are trying to build on the successes of GyM, PISCES-RF, and Magnum-PSI