Divertor conditions in Non-Linear MHD ELM Simulations

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Project Objective

To accurately predict the energy loads on the wall of the reactor, in particular the divertor region, after an ELM discharge.

Improvement of modelling of divertor region

- At the edge of the plasma exists a relatively low temperature (~1eV)
- Neutrals have a significant influence on the physics in the region which will show up in a.o. temperature, density and radiation profiles.
- Charged particles flowing out of the plasma at the edges are absorbed and recombine on solid surfaces. The resulting neutrals are weakly bound to the surface and desorb back into the plasma.

Extensions to be made to JOREK

- Addition of Neutral Fluid Equation:

$$\frac{\partial \rho_n}{\partial t} = \nabla \cdot \left(D_n \nabla \rho_n \right) - \rho \rho_n S_{ni}$$

- Modeling of S_{ni}

$$S_{ni} = <\sigma v>_{ion} = \frac{0.291 \cdot 10^{-13}}{m_D} \frac{\left(\frac{13.6eV}{T(eV)} \right)^{0.39}}{0.232 + \frac{13.6eV}{T(eV)}} e^{-\frac{13.6eV}{T(eV)}}$$

- Plasma particles at boundary reflected as neutrals:

Open field lines: $\rho \vec{v}_{||} \cdot \vec{n} = D_n \nabla \rho_n \cdot \vec{n}$

Walls aligned with flux surface: $\left(D_n \nabla \rho_n \right) \cdot \vec{n} = -\left(D_\perp \nabla \rho \right) \cdot \vec{n}$

Weak form of neutral fluid equation

- Weak Form:

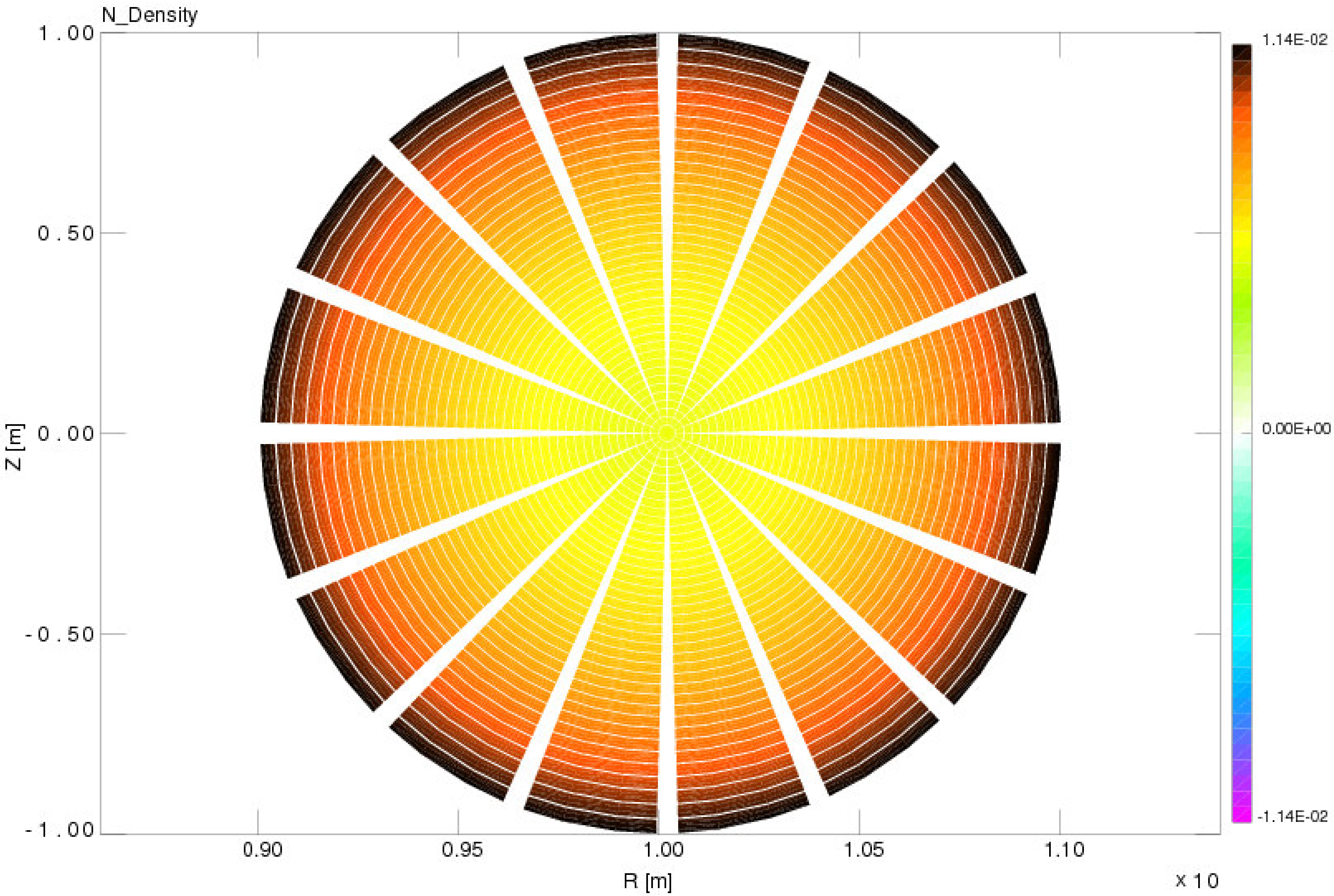
$$\oiiint \rho_n^* \frac{\partial \rho_n}{\partial t} dV = \oiint \rho_n^* D_n \nabla \rho_n \cdot \vec{n} - \oiiint D_n \nabla \rho_n^* \cdot \nabla \rho_n dV - \oiiint \rho_n^* \rho \rho_n S_i dV$$

- In first tests surface term is being neglected. This will be included in a later stage.

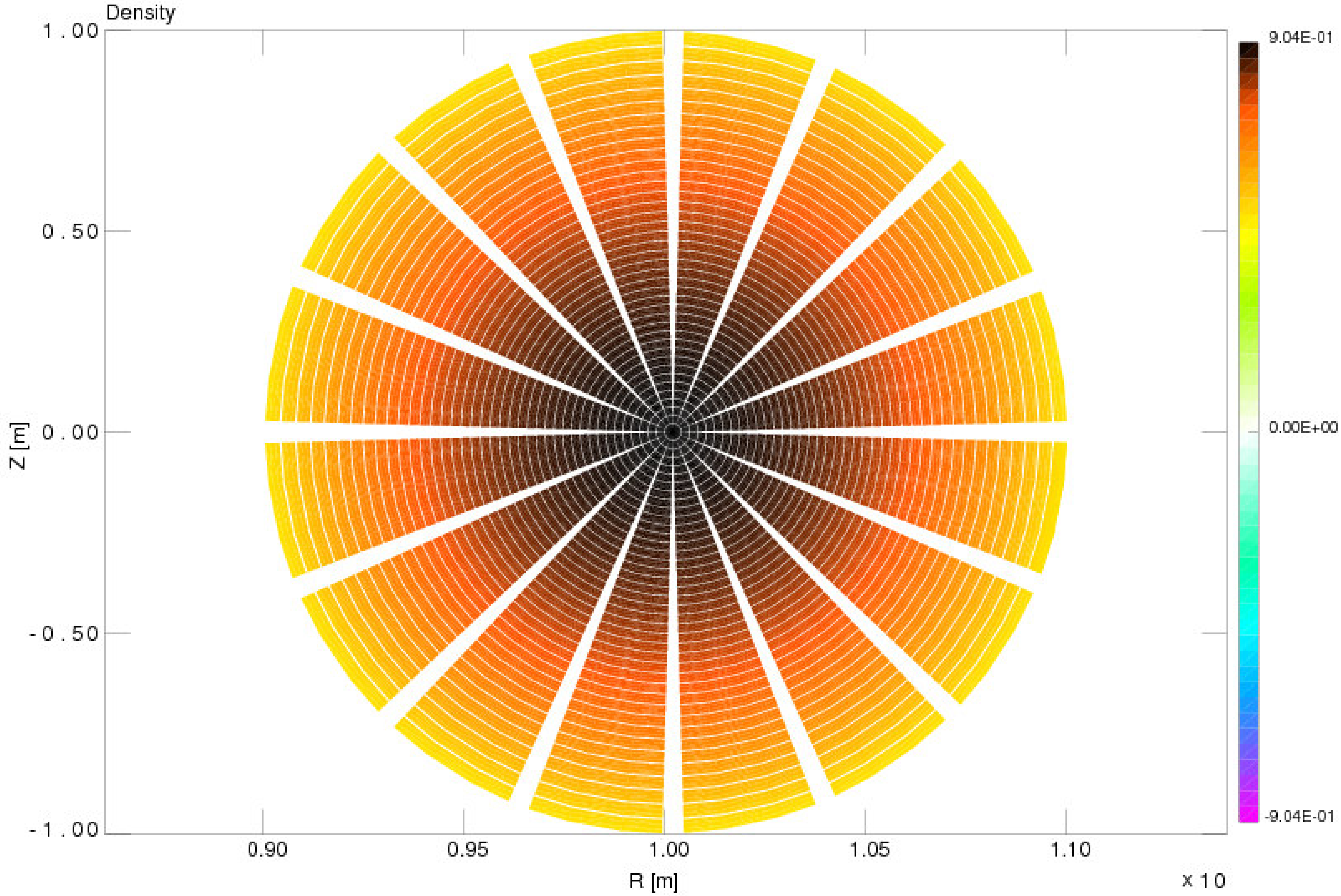
Current State of project

- Neutral fluid equation implemented
- Boundary condition at walls aligned with flux surface successfully implemented and tested. Total amount of particles is conserved.
- Boundary condition at divertor region implemented. Particles flowing out with Mach 1 boundary condition (sound speed). Reflected as neutrals. Seems to work, needs to be affirmed.
- Source term implemented. Qualitative effect seems to be correct. A strong neutral density gradient from the edges to the axis. Yet to be thoroughly tested and compared with quantitative expectations.

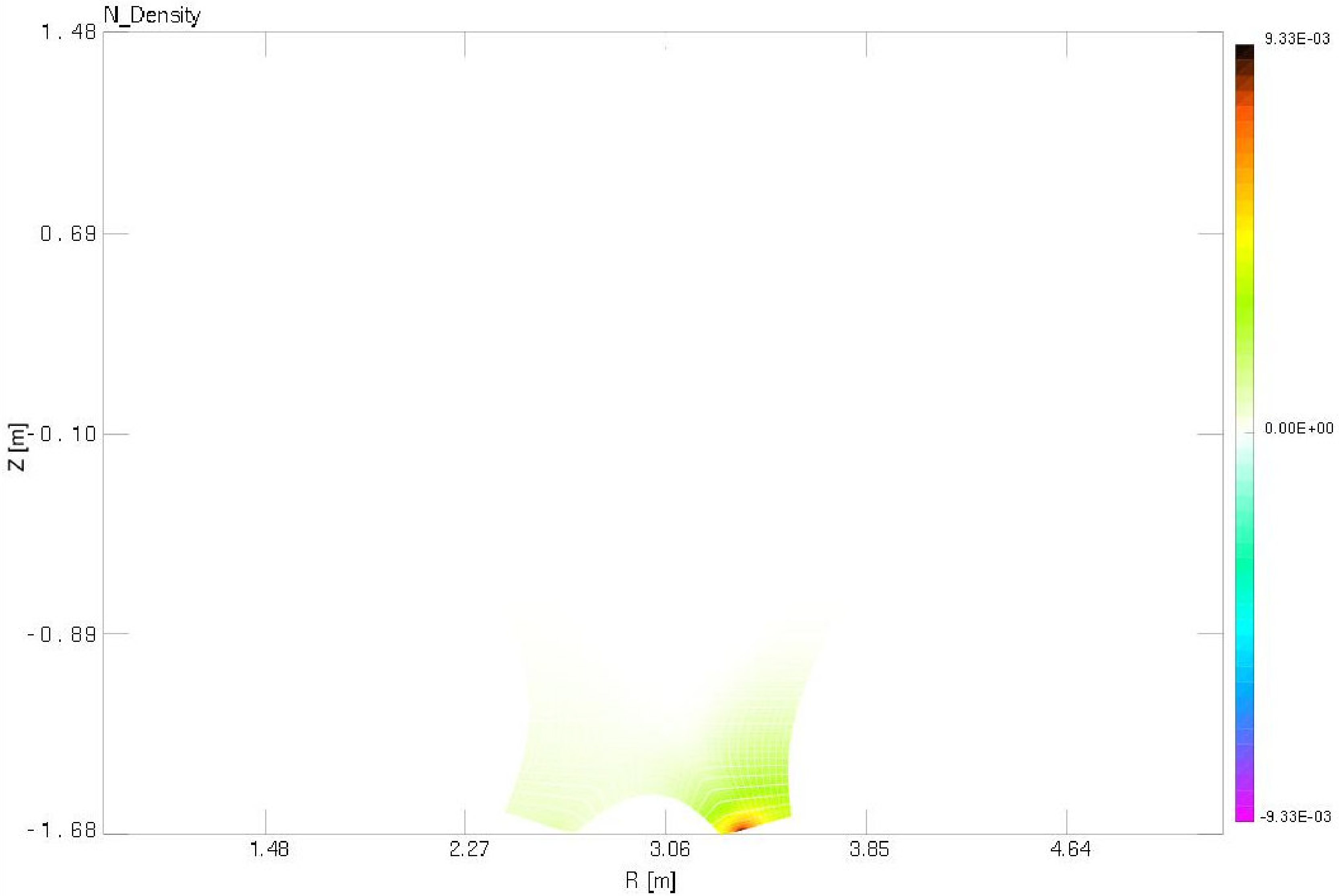
Neutral Density Plot



Density Plot



X-point plasma: Neutral density plot



Next Steps

- Testing results with quantitative expectations. Rechecking implementation.
- Implementation of density and temperature dependent neutral diffusion coefficient.
- Testing code further with X-point plasma. Obtaining agreement with quantitative expectations. Checking particle conservation.
- Comparison of temperature, density and radiation profiles with expected profiles obtained from experiment and specialized 2D divertor codes.
- Account for energy sink at the surface of the plasma and include surface term in energy equation.
- Include boundary term in neutral fluid equation.
- Making corrections until satisfactory agreement is obtained.
- Large scale numerical simulations.
- Making predictions of the energy loads at the divertor target after an ELM discharge.