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Verification of different Monte Carlo approaches for the neutronic analysis of a stellarator

[1]A. Häußler, [1]U. Fischer, [2]F. Warmer   andre.haeussler@kit.edu

[1]Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR), 76344 Eggenstein-Leopoldshafen, Germany
[2]Max Planck Institute for Plasma Physics (IPP), 17491 Greifswald, Germany

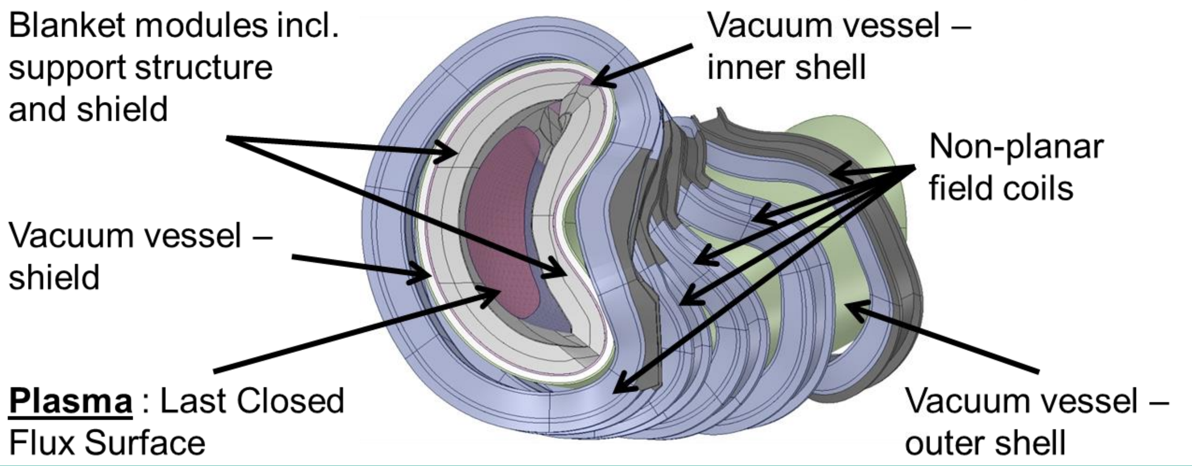
Objective

The Helical-Axis Advanced Stellarator (HELIAS) is a demonstration power reactor based on D-T fusion with 3000 MW of fusion power. The objective of this work is to check the suitability of three different approaches for neutronic design analyses of HELIAS based on the Monte Carlo (MC) particle transport simulation technique with the code MCNP.

CAD Geometry

Three different approaches to generate a CAD based MCNP geometry:

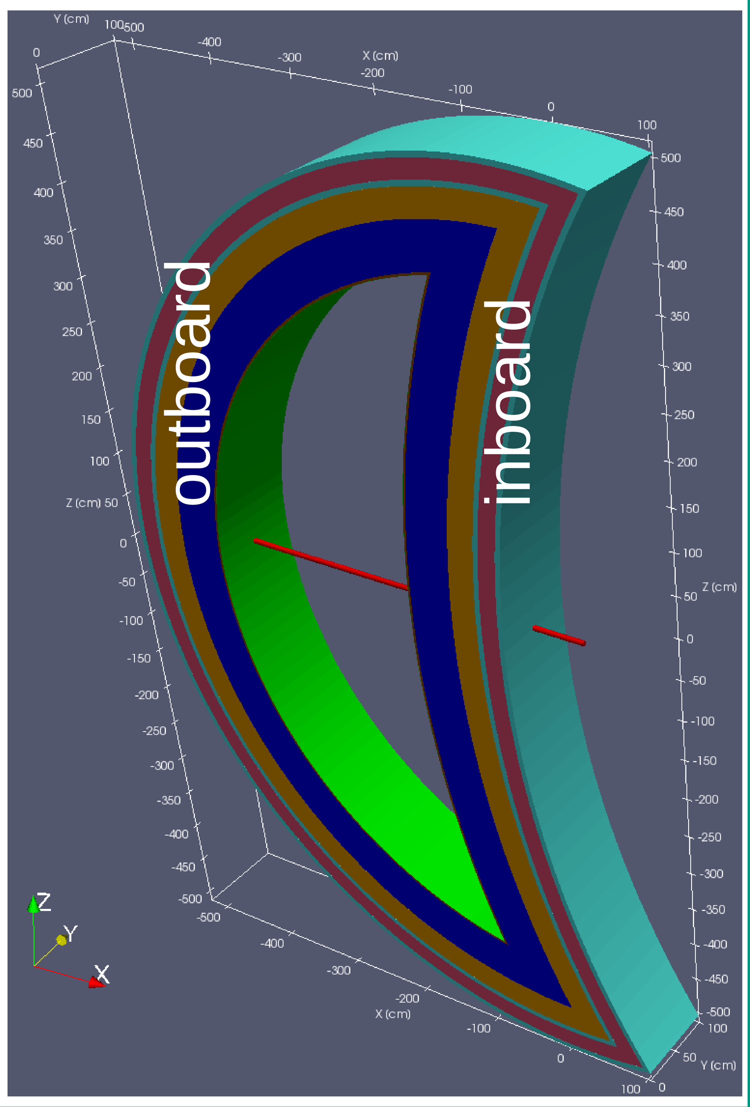
1. Traditional CSG: “Geometry translation approach” with KIT’s CAD to MCNP conversion tool McCad
2. Faceted Solid: Direct tracking of particles in CAD geometry by using DAG-MCNP (DAG = Direct Accelerated Geometry)
3. Unstructured Mesh: Tracking of particles on unstructured mesh geometry using MCNP6



HELIAS CAD model including material layers and plasma distribution

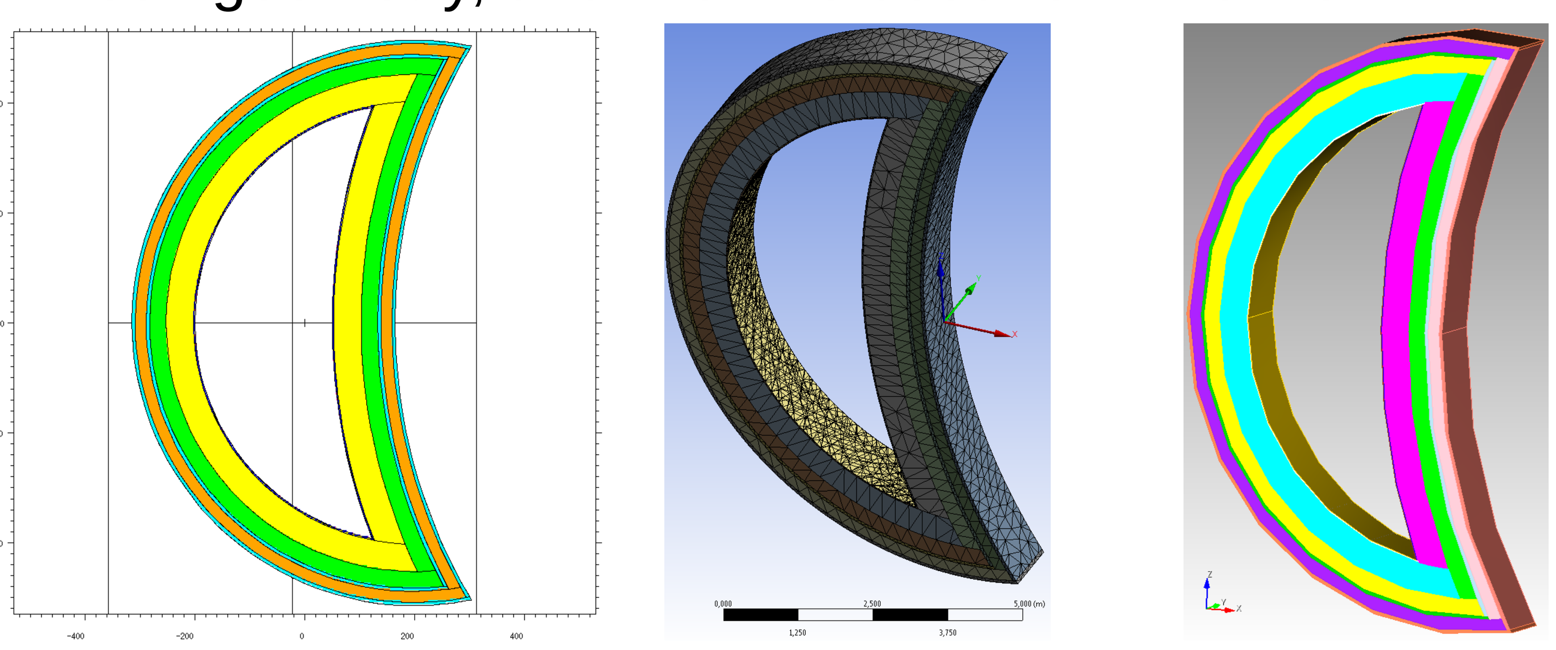
CAD Verification Geometry

- Simplified geometry model to check and verify the three investigated methods.
- Volumetric 14 MeV neutron source in plasma chamber and reflecting boundary conditions.
- Homogeneous material layers to represent breeder blanket, back support structure and vacuum vessel plus shielding at inboard and outboard.
- Red line indicates region of mesh tally used for verification calculations.



Methodology

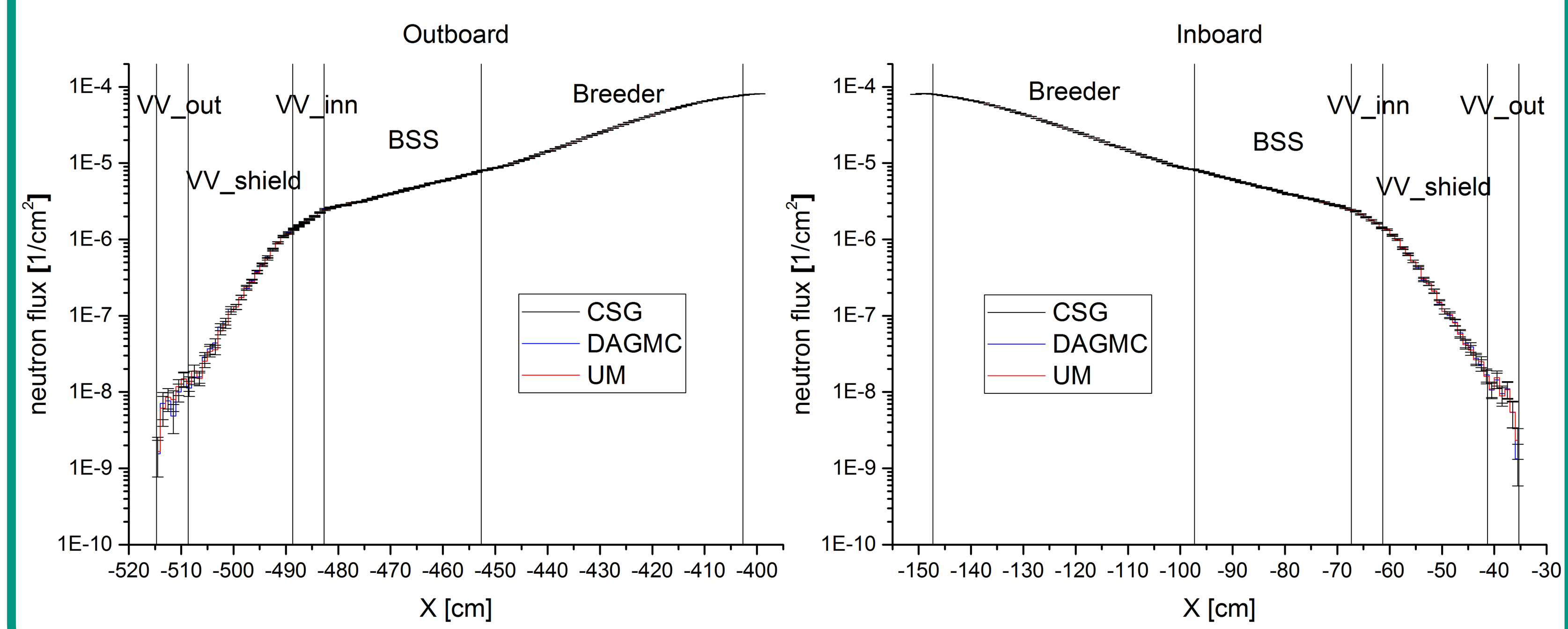
- CAD geometry processed differently for the three investigated approaches.
- Mesh tally for neutron flux in 1 x 1 x 1 cm^3 resolution along the x-axis.
- MCNP 6 used for traditional CSG and Unstructured Mesh geometry, and MCNP5 used for DAGMC.



Geometry shown in CSG, in Unstructured Mesh and in DAGMC representation.

Results

- Results show the neutron flux profile over the inboard and outboard regions.
- All three investigated methods give identical results within the statistical uncertainty.



Conclusion and Outlook

- Three different approaches for MC based nuclear analyses successfully tested on a simplified geometry model.
- The three approaches give comparable results despite the differences in geometry set-up.
- Methods can be used for neutronic design analyses of HELIAS based on a suitable CAD model.