Karlsruhe Institute of Technology

EUROfusion

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Neutronics analyses for a stellarator reactor based on the HELIAS concept

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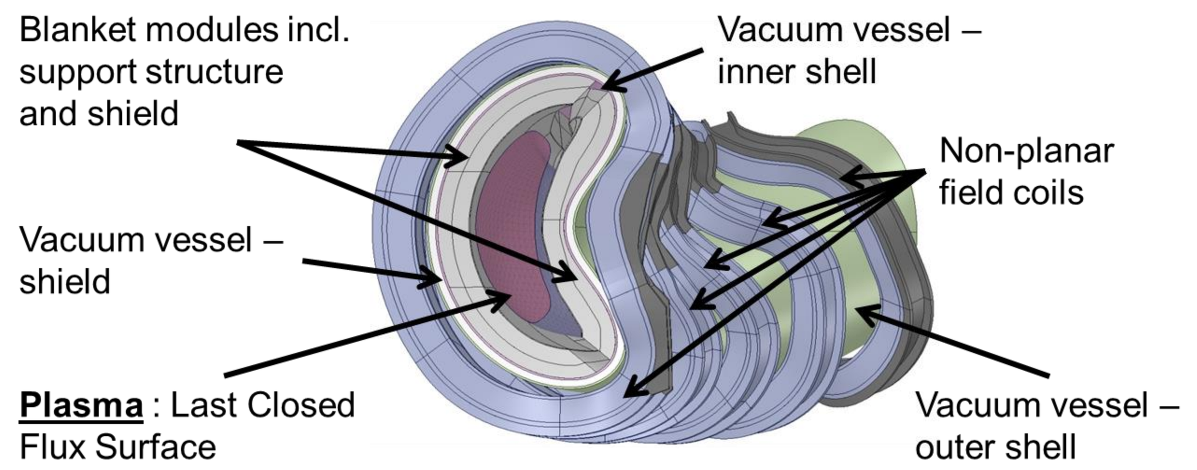
Objective

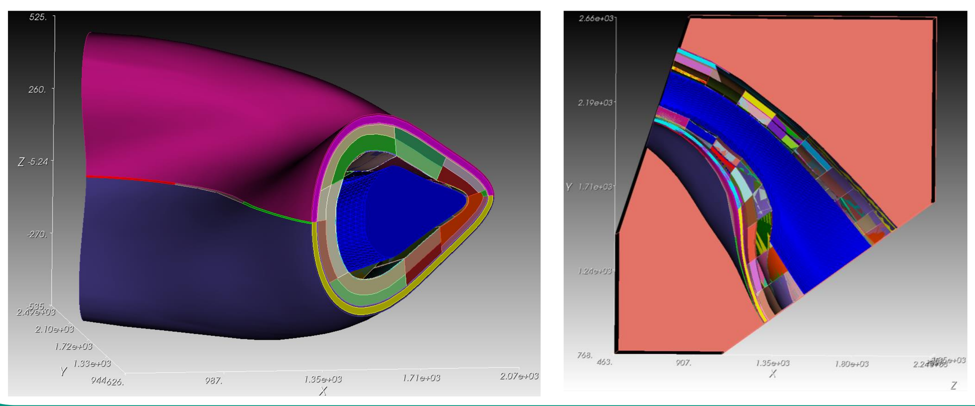
The Helical-Axis Advanced Stellarator (HELIAS) is a demonstration power reactor with 3000 MW D-T fusion power. The objective of this work is to perform first neutronics analyses of a stellarator, based on the Monte Carlo (MC) particle transport simulation technique with MCNP, to assess its nuclear performance in terms of breeding and shielding capability. The results will be applied to a first design analysis of HELIAS.

CAD to MC Geometry

Conversion of the layered CAD geometry into MC representation with Faceted Solids: Direct tracking of particles in CAD geometry by using DAGMC (DAG = Direct Accelerated Geometry) of UW-Madison, USA.

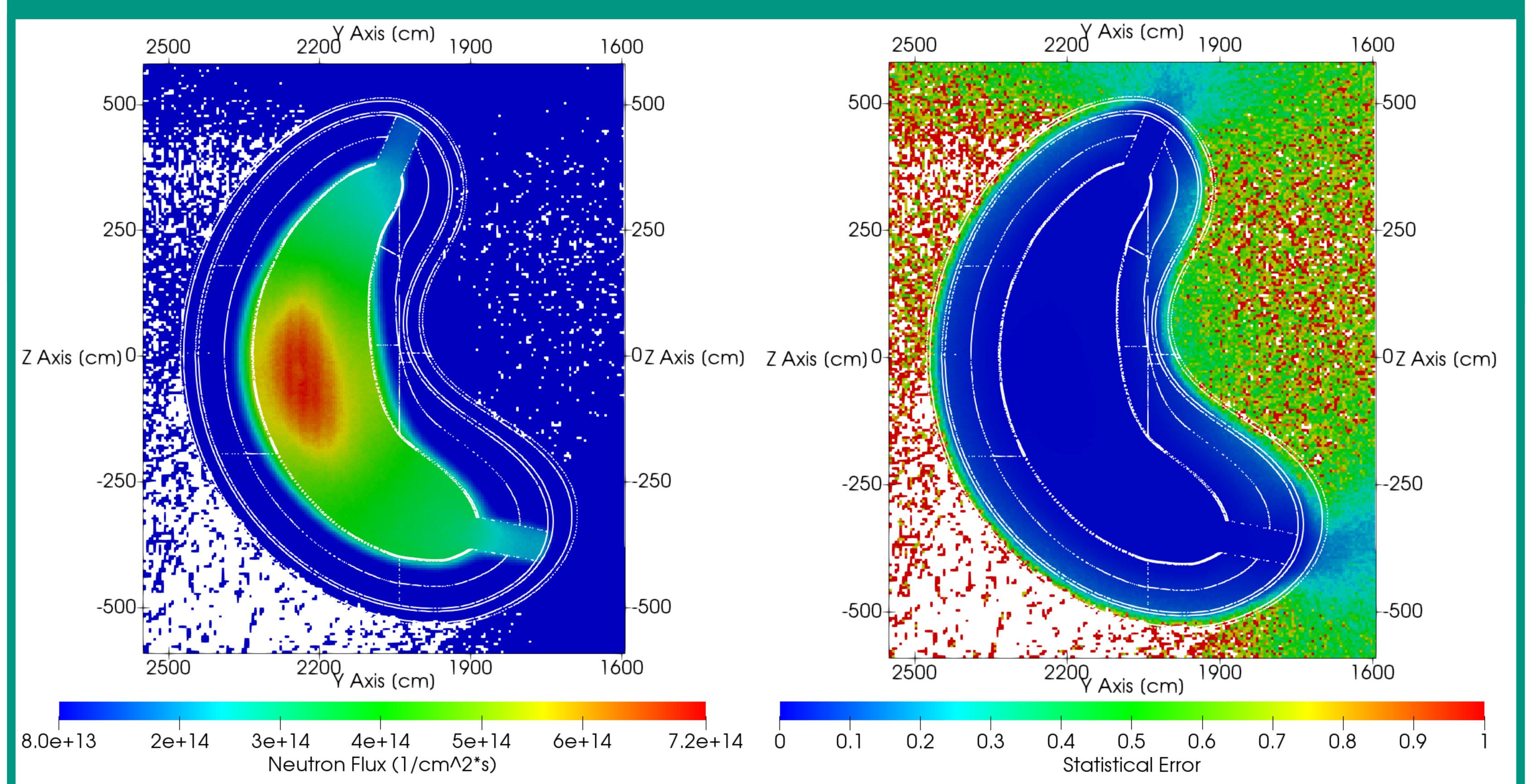


HELIAS CAD model including material layers and plasma distribution



Converted HELIAS model in DAGMC representation including material layers, last closed flux surface (blue) and bounding box (orange)

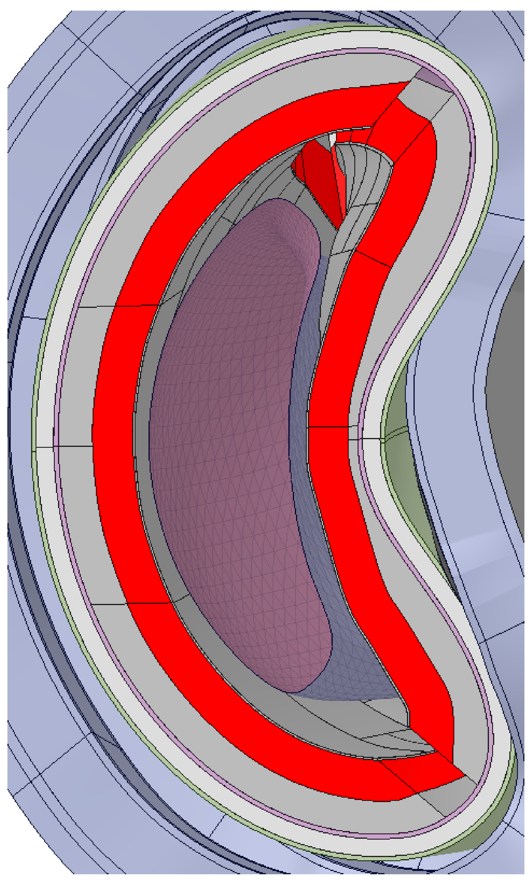
Neutron Flux Distribution



Neutron flux distribution, and corresponding statistical error, with associated geometry in the beanshape side of the HELIAS reactor. Calculations performed without variance reduction and areas without any statistics are displayed in white color.

Tritium Breeding Ratio (TBR)

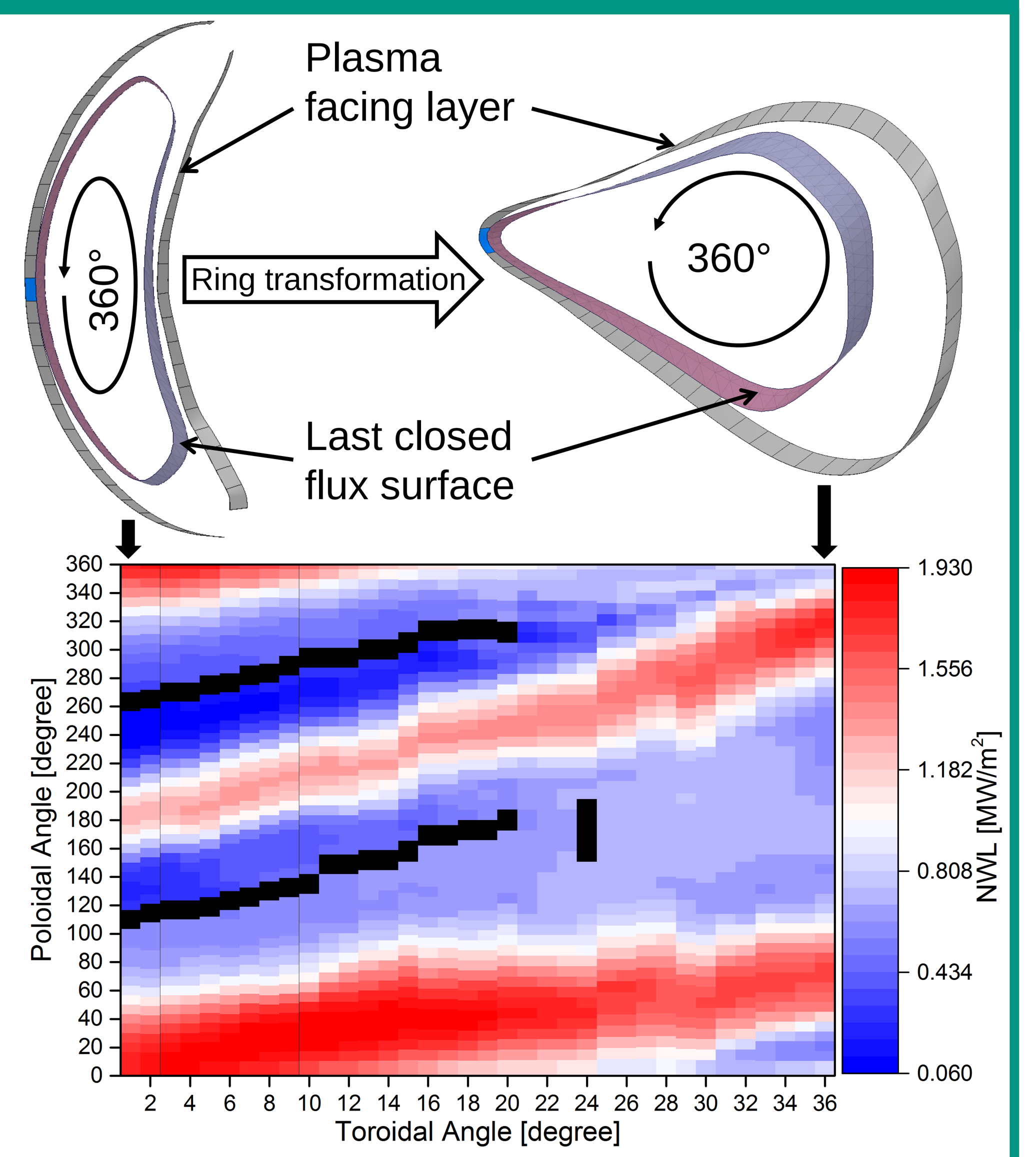
- Tritium self-sufficiency is a pre-condition for any D-T fusion power reactor.
- Helium Cooled Pebble Bed (HCPB) Breeder Blanket (BB) is assumed as a suitable option for the HELIAS power reactor.
- Homogenized breeder material mixture with a Lithium-6 enrichment of 60 % in the 50 cm thick breeder layer.
- Very high TBR value of 1.387±0.001 is obtained → very idealistic assumption of homogenized breeder zone which covers nearly the entire plasma chamber.
- Result is a good starting point for the stellarator BB development.



Breeder Zone indicated in red and filled with homogenized HCPB material mixture

Neutron Wall Loading (NWL)

- NWL is the fusion power loaded to the first wall per unit area.
- Two approaches by KIT (*DAGMC*) and IPP (*nflux*), results show agreement within the statistical uncertainties.
- Average NWL of ~1 MW/m^2 over the whole surface area.



Neutron wall load distribution of HELIAS

Conclusion and Outlook

- *CAD to MC geometry conversion:* DAGMC conversion approach successfully applied for this stellarator geometry.
- *Neutron Flux Distribution:* Reliable results from plasma to breeder zone.
- *Tritium Breeding Ratio:* Very high TBR for the idealistic configuration, good start for HELIAS BB development.
- *Neutron Wall Loading:* Results of two different approaches are comparable within statistical uncertainties.
- *Nuclear design analyses:* Apply variance reduction techniques, and calculate shielding efficiency, nuclear heating.