EUROfusion

Use of Mesh based Variance Reduction Technique for Shielding Calculations of the Stellarator Power Reactor HELIAS

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

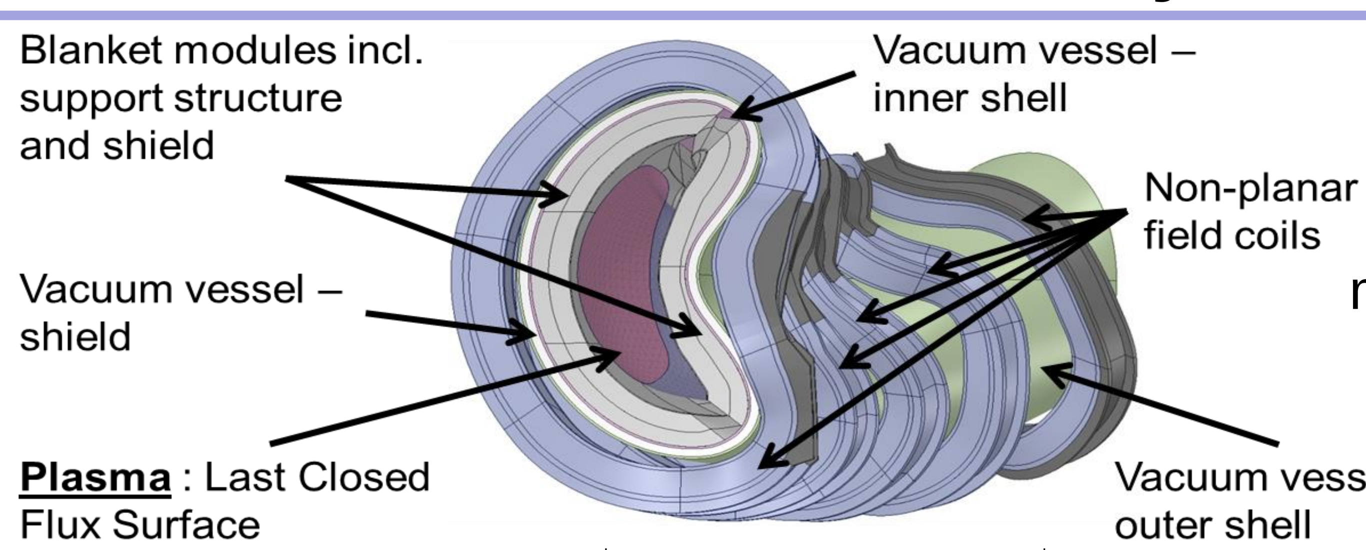
[1]Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR), 76344 Eggenstein-Leopoldshafen, Germany

[2]Max Planck Institute for Plasma Physics (IPP), 17491 Greifswald, Germany

Motivation and Objective

- Helical-Axis Advanced Stellarator (HELIAS) is a demonstration power reactor with 3000 MW D-T fusion power.
- First thorough neutronic investigation of HELIAS with DAG-MCNP (DAG = Direct Accelerated Geometry) approach.
- Shielding capability needs to be assessed for the stellarator by applying mesh based weight window variance reduction method.
- Nuclear responses in a critical area: high neutron wall load (~1.4 MW/m^2) and reduced material thickness (~103 cm).
- Evaluation of the obtained results according to the EU DEMO tokamak recommended radiation design limits.

HELIAS Geometry

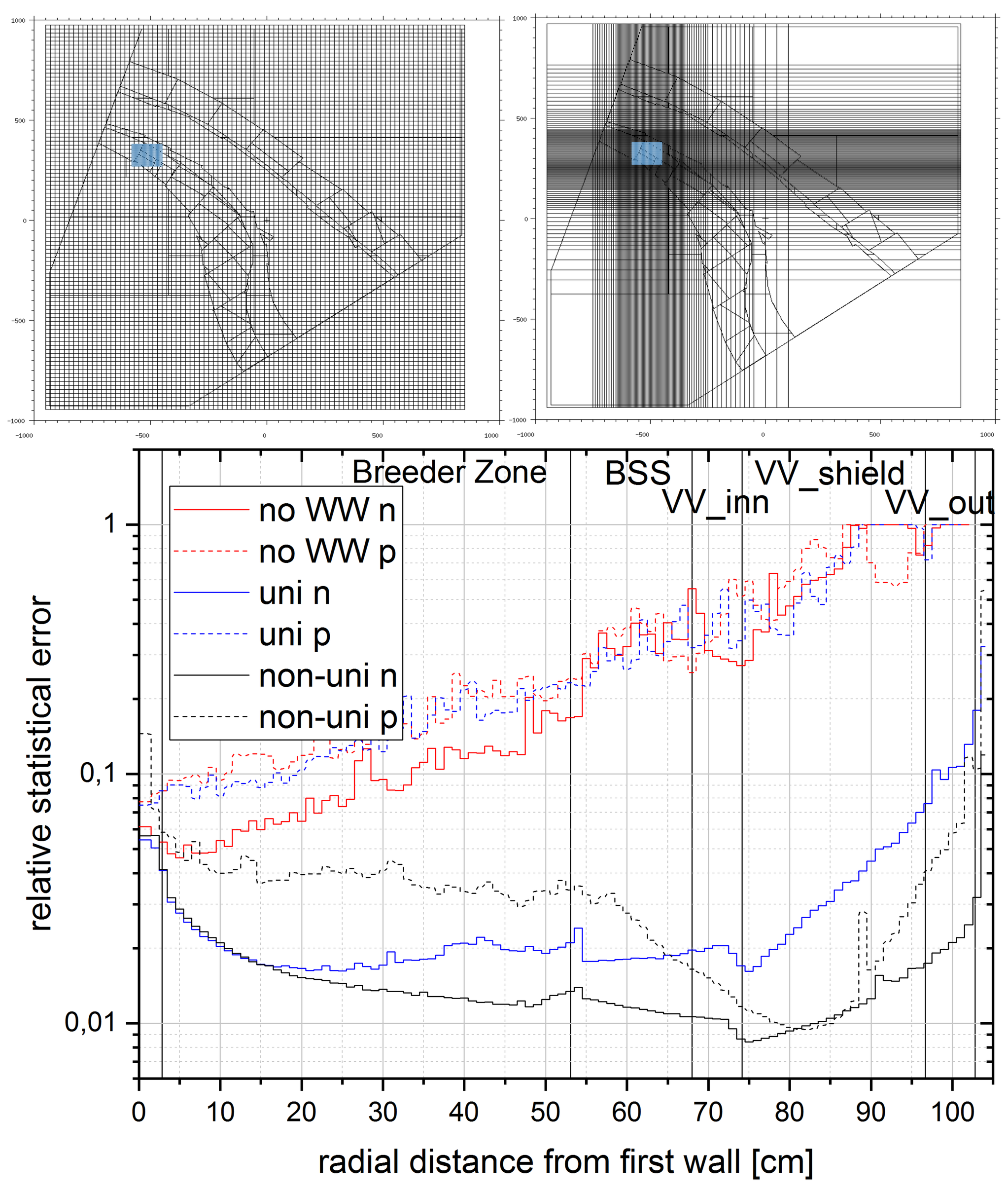


HELIAS CAD model including material layers and plasma distribution

Radial Structure	Thickness [cm]	Material Composition
Tungsten Armor	0.2	100% Tungsten
First Wall	2.5	70% Eurofer, 30% Helium
Breeder Zone	50	HCPB with 60% Li-6 enrichment
Back Support Structure (BSS)	~10 – 40	75% Eurofer, 25% Helium
Vacuum Vessel (VV) inner shell	6	100% Steel (SS-316)
VV shield	20	60% Steel (SS-316), 40% Water
VV outer shell	6	100% Steel (SS-316)

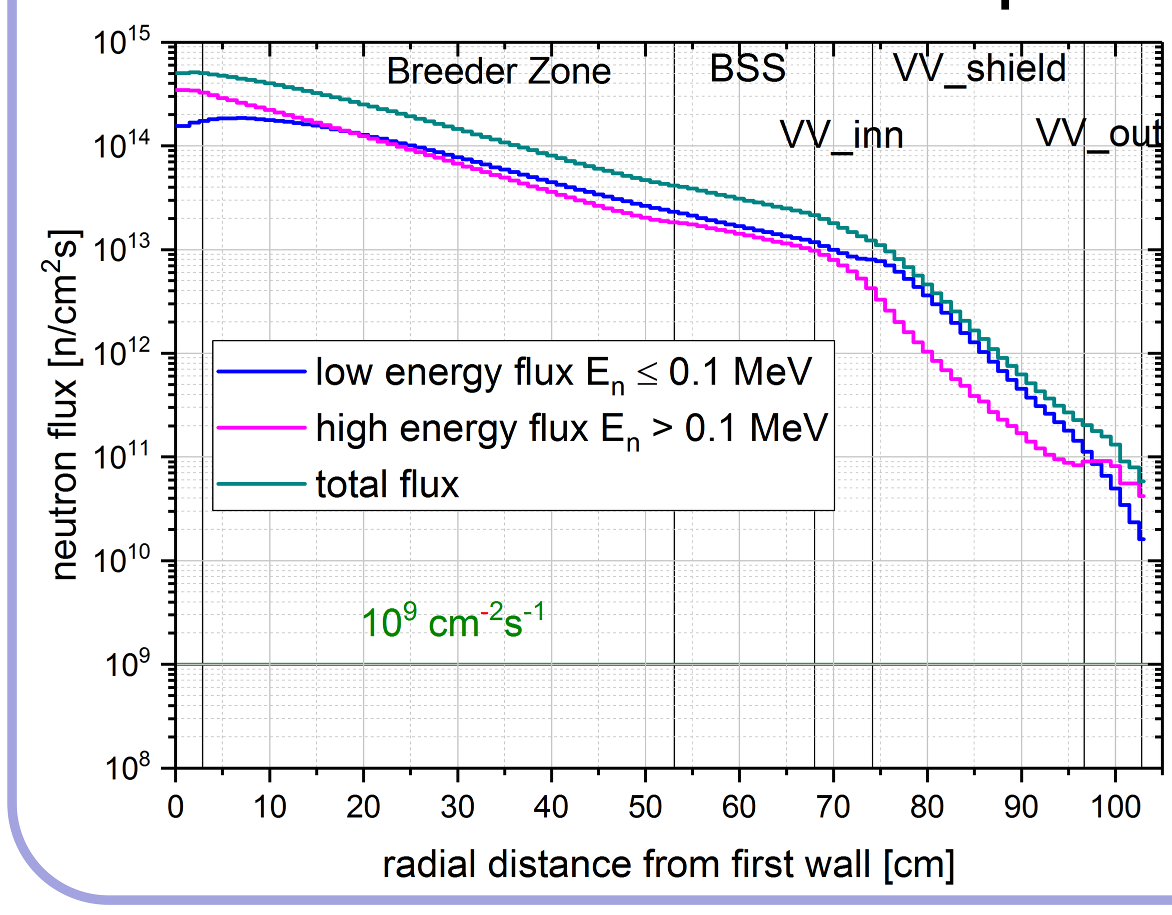
Weight Window Generation

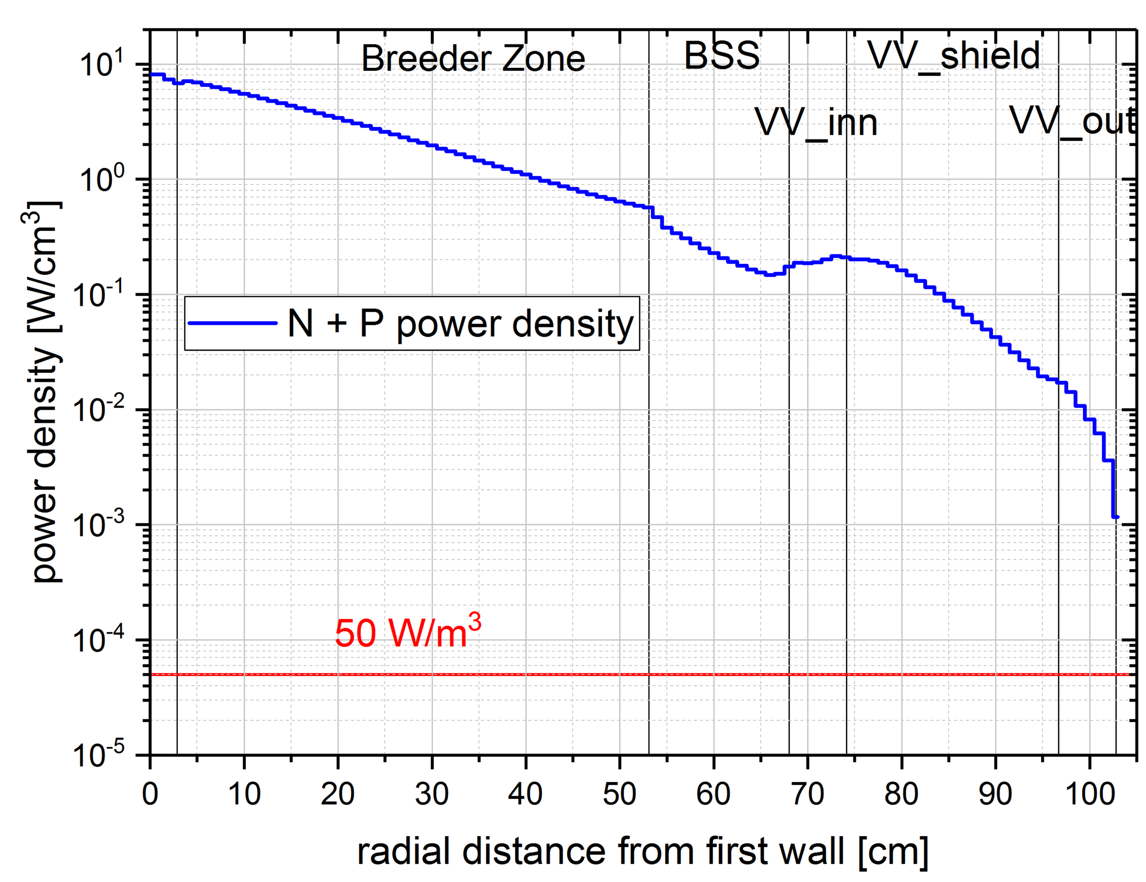
- Mesh based weight window generation with ADVANTG (ORNL).
- Two different mesh set-ups: uniform with 20x20x20 cm^3 (optimized for neutrons) and non-uniform with 5x5x5 cm^3 (optimized for neutrons and photons) in target region (blue box).
- Relative statistical error determined inside the target region, with a mesh tally, for neutrons and photons.
- Statistical error is significantly decreased → non-uniform WW mesh is used.

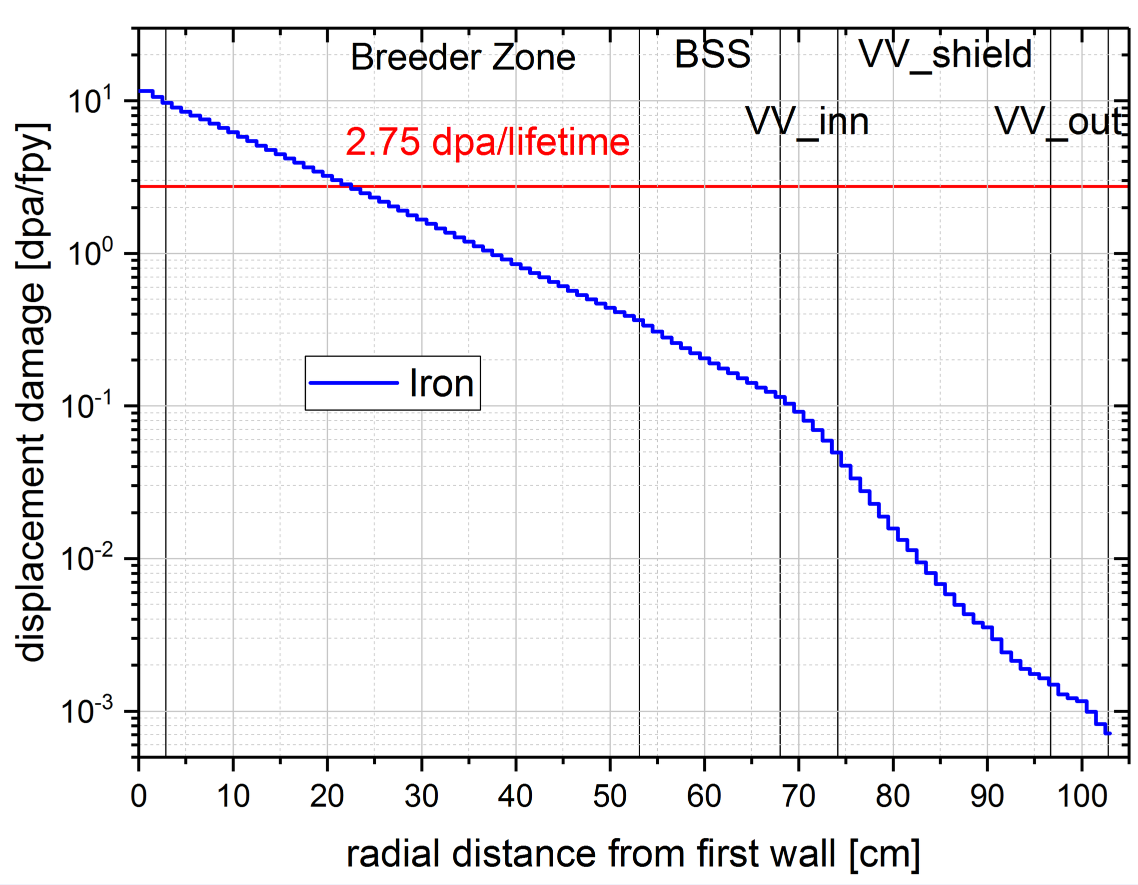


Computation and Results

- Radial profiles of nuclear responses in critical area, evaluated against radiation design requirements specified for EU DEMO tokamak.
- Nuclear responses of interest:
  - "Maximum neutron fluence to epoxy insulator" → target: **10^9 cm^{-2}s^{-1}** to coils.
  - "Peak nuclear heating in winding pack" → limit: **50 W/m^3** to coils.
  - "Lifetime criteria in order to ensure that the fracture toughness is reduced by no more than 30%" → limit: **2.75 dpa/lifetime** to VV.
- Shielding requirements for superconducting magnets not met in critical area
  → shielding performance need to be improved.
- Displacement damage at VV_inn: **~0.11 dpa/fpy**
  → lifetime of 25 years guaranteed to reach EU DEMO design limit.







Conclusion and Outlook

- *Variance reduction:* Mesh based weight window method suitable for HELIAS.
- *Calculations:* Statistical reliable radial profiles of relevant nuclear responses from first wall to magnetic field coil.
- *Shielding performance:* Requirements for superconducting magnets not fulfilled in critical area.
- *Recommended design improvements:* Larger shielding layer and/or more efficient shielding materials.

KIT Karlsruhe Institute of Technology

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.