NEUTRONICS ANALYSES AND ADVANCES IN RADIATION TRANSPORT AND ACTIVATION SIMULATION TOOLS FOR ITER

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1. Group TECF3IR @ UNED

WORK
applications:
- neutronic analyses and design
- analyses of ITER diagnostics
- analyses of HCLL and HCPB TBS components of PI of ITER
- quality analysis of relevant activation cross-sections for SDR

development:
- R2S-UNED, D1S-UNED, MCUNED, ACAB
- scripts to convert mesh results to VTK format, weight-window generators, RSSA source manipulation scripts, etc.

various other projects in the framework of:

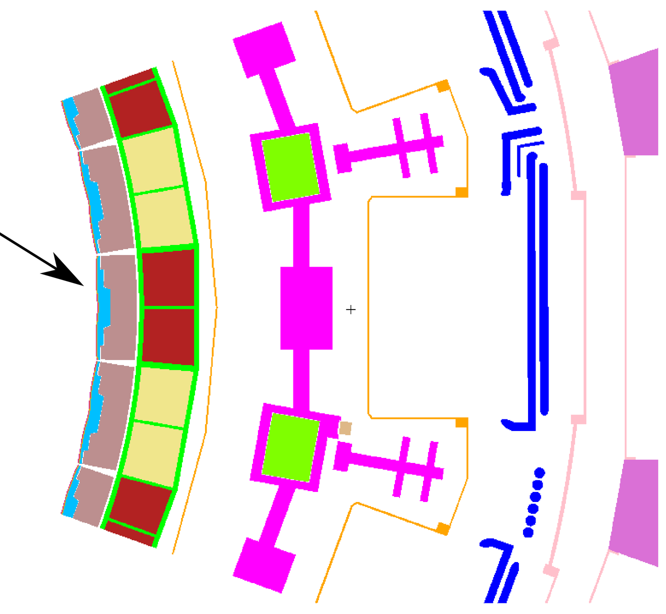
TechnoFusión and EUROfusion (IFMIF, ENS, DEMO)

EDUCATION
- distance-learning approach of UNED offers established capabilities to distribute knowledge of fusion engineering on-line

COMPUTATIONAL RESOURCES
- IFERC Helios users
- dedicated *homemade* cluster with over 600 cores

3. Methodology

CAD geometry
↓
translation to computational geometry
↓
neutron transport calculations
↓
activation calculations
↓
transport calculation using the decay gamma source



XY cut of the MCNP model of ITER (C-lite [3]) and the inserted water cooling system (translated from CAD to computational geometry).

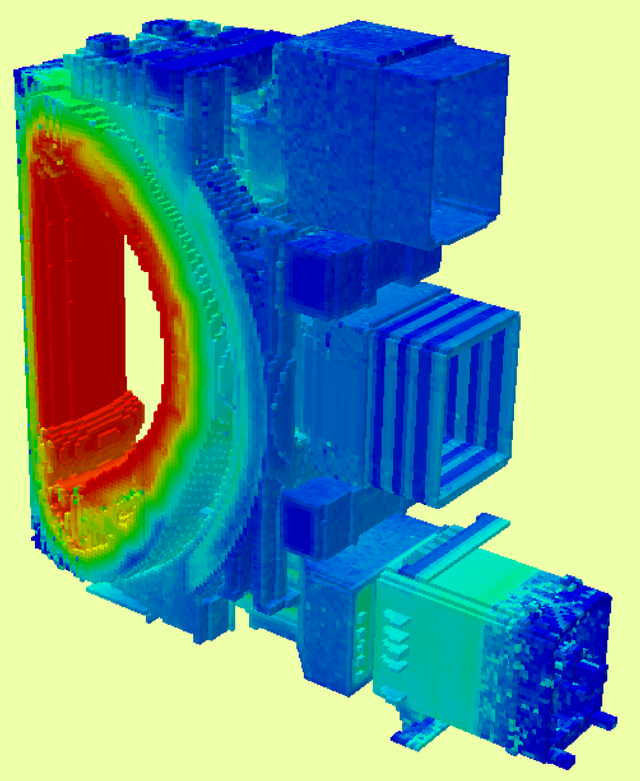
- in the process of carrying out the PhD thesis, various tools are used:
  SpaceClaim (geometry preparation),
  SuperMC/MCAM [2] (CAD-to-MCNP geometry translation),
  MCNP5/6 (particle transport calculations),
  ACAB (activation and transmutation calculations),
  D1S-UNED (1-step method for shutdown dose rate calc.),
  R2S-UNED (2-step mesh method for shutdown dose rate calc.)
  and scripts for weight-window generation, mesh-to-VTK, etc.

2. Goals of the PhD thesis

MOTIVATION
The field of neutronics is one of the most important tools in the design of ITER.

Neutronics analyses are usually carried out by using the state-of-the-art computer codes (e.g. MCNP6, R2S-UNED (figure right), etc.) in order to investigate the design of different components and, if necessary, to propose an improved and optimised design or to add a supplementary radiation shielding.

The aim of this PhD thesis is to solve different challenges in the design of ITER that arise due to neutron transport and activation during the operation or the maintenance of the device. A great emphasis is also placed on computational tools used for neutronics analyses, and for this reason additional capabilities will be incorporated into already existing codes.



Decay gamma source after 10^6 seconds of cooling time. The source was produced using the R2S-UNED code. [1]

Goals:

- ***to develop a computational methodology for analysis and design*** of nuclear components for ITER and ***to apply it in applications***

- selection of relevant neutronics applications in the design of ITER:
  + *transport calculations* (power deposition calculations, identifying streaming issues
  + *activation calculations* using D1S and R2S methodologies
  + *radiation shielding design*

  ↳ ***to present various neutronics challenges*** met in the design of the world´s largest tokamak

- identification of limitations in computational tools and incorporation of additional capabilities into already existing tools for activation calculations

  ↳ ***to improve the performance of 3D coupled transport-activation calculations*** for high-resolution decay gamma dose mapping and its uncertainty propagation

4. Currently Done Work for the PhD

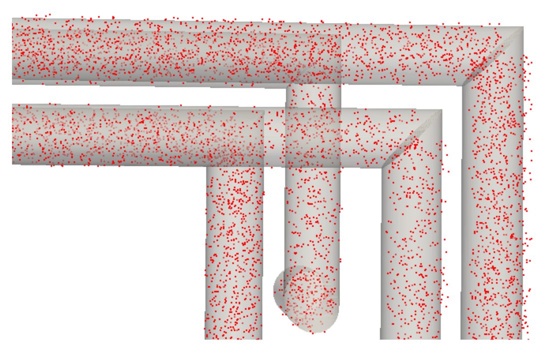
- **Radiation from Divertor/EqPort/BSM Cooling Pipes:**

water used for cooling in-vessel components becomes highly activated due to $^{16}O(n,p)^{16}N$ threshold reactions - ^{16}N (having a half-life of 7s) emits 6 MeV gamma rays - the cooling water flows close to the superconducting toroidal field (TF) and poloidal field (PF) coils = ***additional heating of the coils and increased gamma flux above the bio-shield lid***

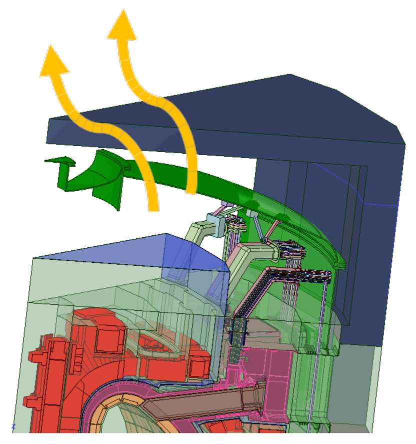
Impact: in case of high (above specified limits) power deposition in coils or excessive gamma streaming through the bio-shield lid, the position or the design of the water cooling system has to be adapted

1. Water in the cooling system becomes activated and ^{16}N emits high energy gamma rays.

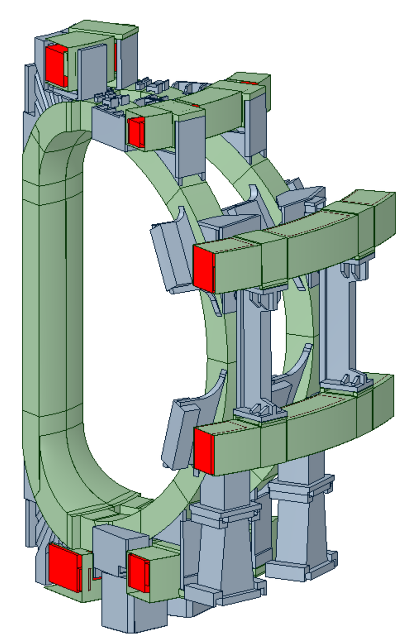
$$^{16}O(n,p)^{16}N$$



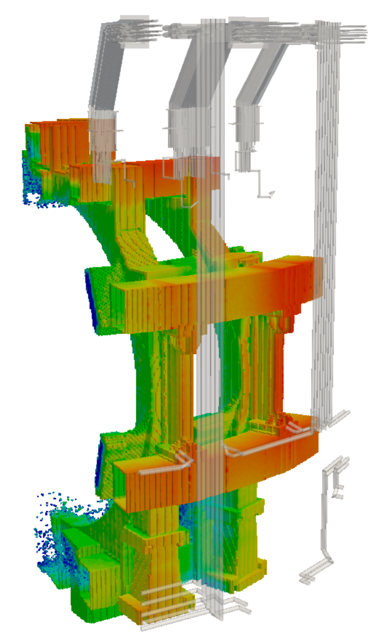
2. Gamma flux, dose rate in silicon and biological dose are calculated above the concrete bio-shield lid in order to study the possibility of gamma streaming.



3. Due to proximity of superconducting coils, produced gammas also deposit power in coils and support structures inside the cryostat. For this reason, the total heating of the components was studied.



4. Additionally, the specific power deposition was calculated (using the R2S-UNED code) in order to investigate "hot-spots".



References
[1] R. Juárez, R. Pampin, B. Levesy, F. Moro, A. Suarez, J. Sanz, *Shutdown dose rates at ITER equatorial ports considering radiation cross-talk from torus cryopump lower port*, Fusion Engineering and Design, Volume 100, November 2015, Pages 501-506
[2] Wu, Y. and FDS Team, *CAD-based interface programs for fusion neutron transport simulation*, Fusion Engineering and Design, 2009. pp. 1987-1992. Vol. 84.
[3] C-LITE VERSION 1 RELEASE 131031 ISSUED 31/10/2013 - Halloween edition