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Neutronic characteristics of the ITER Diagnostic Equatorial Port #8

e-poster #249

31ST SYMPOSIUM ON FUSION TECHNOLOGY

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Scope of neutronics analysis

The neutronics analysis scope includes the following characteristics:

1) Neutron flux distributions in **Equatorial Port #8 (EP8)** Port Plug and ISS.

2) Nuclear heating loads:
- EP8 Port Plug Mirrors of 5 Diagnostic systems in the following materials:
  - Molybdenum; Aluminum; Steel; Rhodium.

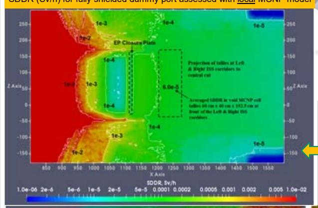
3) Neutron damage (DPA) in EP8 Port Plug mirrors and structural materials.

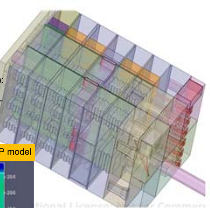
4) Neutron thermalization inside NFM graphite with Fission Chamber (FC).

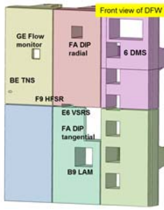
5) Shut-Down Dose Rate (SDDR) mesh-tally for dose mapping at the following locations of maintenance at ~12 days after ITER shutdown:
- 30 cm to the EP8 Closure Flange (CP): 9.5e-5 to 5.7e-2 (Sv/h);
- 30 cm to the EP8 Back Flange (BF): 7.2e-5 to 3.6e-2 (Sv/h);
- 30 cm to Disruption Mitigation System (DMS) Optical Unit: 7.8e-5 to 1.9e-4 (Sv/h).
- EP8 Inter-Space Structure (ISS) maintenance corridors: 102 microSv/h
- Assessment of the EP8 Diagnostics impact on SDDR inside of EP8 ISS.

State-of-the-art codes and data for ITER applications:
- SpaceClaim software for CAD processing;
- SuperMC (FDS, China) for CAD-to-MCNP conversion;
- Shut-Down Dose Rate (SDDR) calculations:
  - D1S-UNED v.3.1.2 for transport and activation.
- Radiation transport calculations (neutron and gamma fluxes):
  - ITER C-MODEL R181031 (Rev.190110), MCNP6.20 code, EPRDATA14 Electron-Photon-Relaxation data (E<1keV)
  - FENDL-3.1d neutron cross-sections.

SDDR (Sv/h) for fully shielded dummy port assessed with local MCNP model

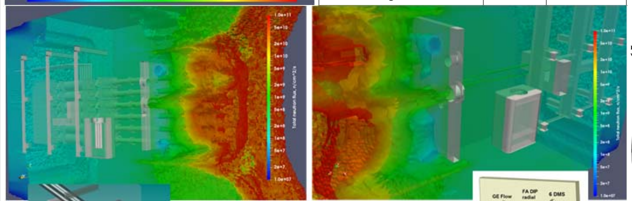






SDDR increment is observed for the EP model of EP8 with Diagnostic systems inside ISS due to additional decay gamma sources produced in steel materials of DMS and NFM.

EP model	LC SDDR, microSv/h	RC SDDR, microSv/h
DGEPP with fully shielded dummy Port Plug and empty ISS	60	60
EP8 without Diagnostics inside ISS	77	86
EP8 with Diagnostics inside ISS	100	102



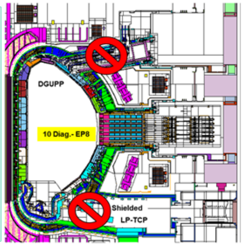
N-streaming assessment on maps of **total neutron flux**

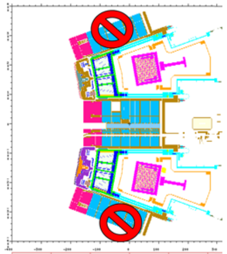
Analysis conclusion: 5 systems of EP8 contributing to SDDR inside the empty ISS: **DMS, LAM, GE, FA DIP Radial, and VSRS.**

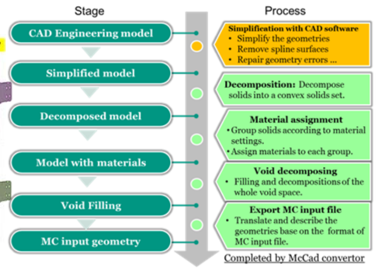
Front view of CP from plasma

Local modeling assumption for SDDR calculations in EP8 inside C-MODEL 181031 (R190110) and D1S-UNED transport and activation code

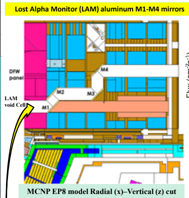
- **Local MCNP model of EP8** includes the following 10 Diagnostics:
  - 55.B9 Lost Alpha Monitor (**LAM**)
  - 55.BE Tangential Neutron Spectrometer (**TNS**)
  - 55.F9 High Field Side Reflectometer (**HFSR**)
  - 55.FA Density Interferometer Polarimeter – (**DIP**) Radial
  - 55.FA Density Interferometer Polarimeter – (**DIP**) Tangential
  - 55.B4 Neutron Flux Monitor (**NFM**)
  - 55.E6 Visible Spectroscope Reference System (**VSRS**)
  - 55.GE Flow Monitor
  - 18.GC Glow Discharge Conditioning (**GDC**)
  - 18.DM Disruption Mitigation System (**DMS**)

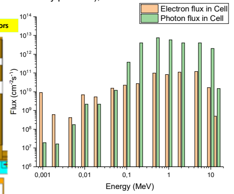


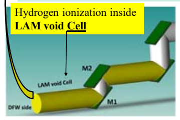


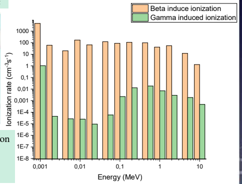


At the last stage of CAD-to-MCNP conversion, **MC input geometry** has been produced with 10 Diagnostics of EP8 is sufficient for the following calculations:
- neutron and photon fluxes;
- nuclear heating (neutron and secondary photons);
- neutron damage (dpa).



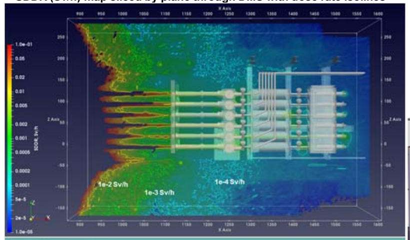


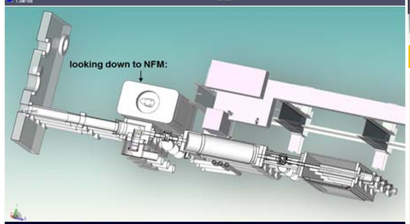


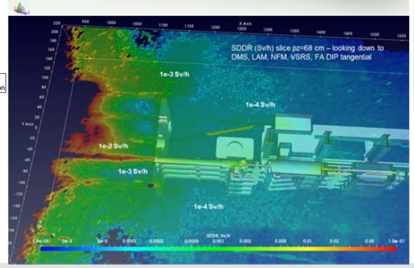


Photon and electron emission energy distribution spectra in LAM void Cell calculated in energy range of 10 eV - 20 MeV, with particular consideration of its **low-energy (E<1 keV)** part.

SDDR (Sv/h) map sliced by plane through DMS with dose rate isolines







Neutron thermalization inside the NFM graphite with Fission Chamber (FC) of NFM.

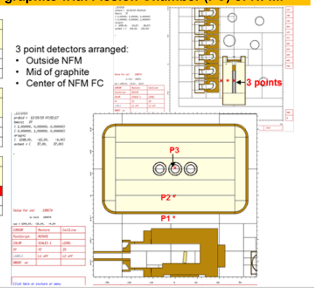
P1 - Point Detector Outside NFM (outside NFM cylinder Y=-22 cm)		
Neutron energy group	Group neutron flux, n/cm^2/s	Thermal/Fast Ratio
Thermal (En<0.1 MeV)	1.54E+08	1.81E+00
Fast (En>0.1 MeV)	8.46E+07	
Total	2.38E+08	

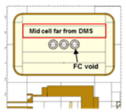
P2 - Point Detector Inside NFM graphite moderator (Y=-12 cm)		
Neutron energy group	Group neutron flux, n/cm^2/s	Thermal/Fast Ratio
Thermal (En<0.1 MeV)	2.20E+08	1.07E+01
Fast (En>0.1 MeV)	2.05E+07	
Total	2.40E+08	

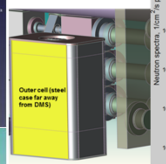
P3 - Point Detector Inside NFM Fission Chamber void (Y=0)		
Neutron energy group	Group neutron flux, n/cm^2/s	Thermal/Fast Ratio
Thermal (En<0.1 MeV)	1.57E+08	3.08E+01
Fast (En>0.1 MeV)	5.10E+06	
Total	1.62E+08	

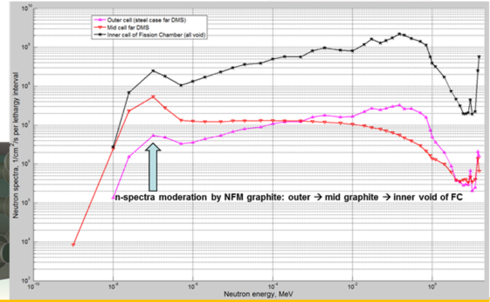
3 point detectors arranged:
- Outside NFM
- Mid of graphite
- Center of NFM FC

Substantial neutron flux thermalization is important for neutron detection by fission reaction rate counting on U-235 deposited inside the thin (1.07e-4 cm) layer inside the void of FC cylinders. U-235 mass in 1 FC is 1 g, there are 3 FC inside graphite moderator covered by steel case of NFM.









Conclusions and future work

- **Presented scoping neutronics** results have been obtained with newly developed EP8 local model integrated into the ITER tokamak C-MODEL R181031 (Revision 190110) and the results have a relative character.
- **Shielding performance** of the EP8 Diagnostic systems has been estimated with nuclear heating and neutron damage loads on mirrors (ITER_D_2NAEN8) and local SDDR inside ISS (ITER_D_2NAFZ3).
- **Streaming analysis** indicated suitability of the doglegs in most Diagnostic channels and sufficiency of their shielding performance, with a recommendation to increase the length of M1-M2 shift of B9 LAM.
- **Among studied mirror materials** (rhodium, molybdenum, steel, aluminum), rhodium demonstrated significant beta decay heating comparable with prompt (neutron + photon) heating. Maximum nuclear heating in rhodium is 11.3 W/cc for the m1-small front mirror of 55.GE Flow Monitor located close to DFW.
- **Maximum neutron damage** of 1.56 dpa/0.54fpy in steel substrate of the m2-small mirror at front of 55.GE Flow Monitor.
- **Local SDDR** in the EP8 ISS corridors is ~102 microSv/h with Diagnostics inside ISS.
- **Designing work on EP8 Diagnostics systems is in progress.** The updated designs of the systems will be assessed later with neutronics analyses in the course of preparations for Final Design Review. Following the ALARA, task of arranging additional shielding in ISS is ongoing to reduce the SDDR values.

Acknowledgment & Disclaimer

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