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Karlsruhe Institute of Technology

Institute for Neutron Physics and Reactor Technology (INR)
P.O. Box 3640, D-76021 Karlsruhe, Germany

Neutronic Analyses for the IFMIF-DONES Test Cell and Adjacent Rooms

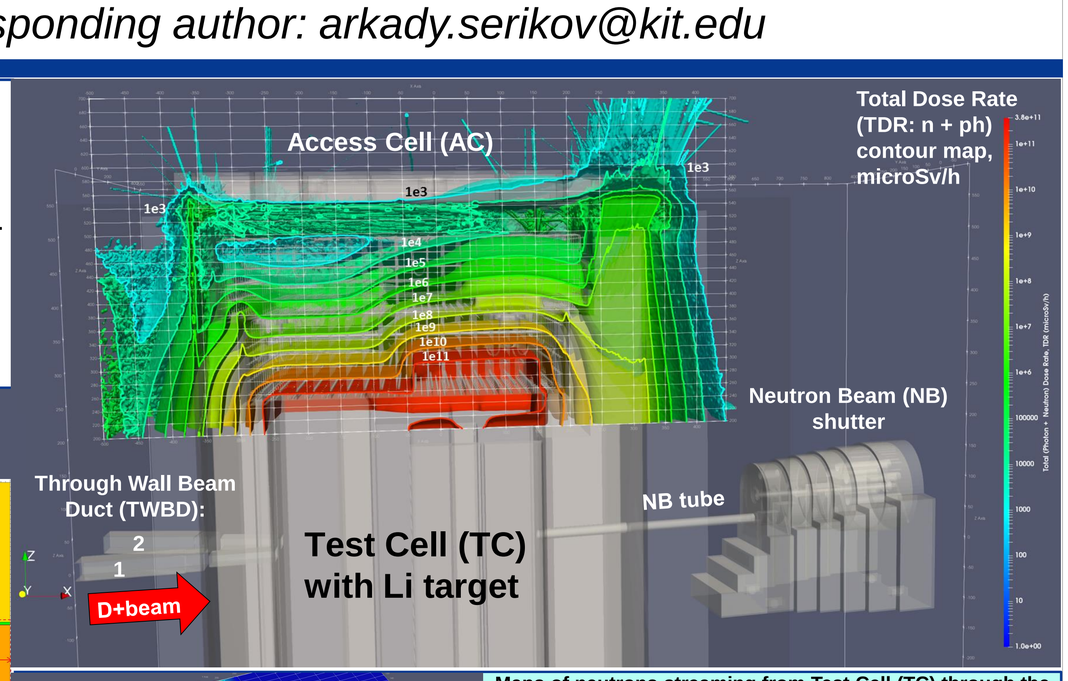
Arkady Serikov[a*], Davide Bernardi[b], Barbara Bienkowska[c], Björn Brenneis[a], Daniel Sánchez-Herranz[d], Carlos Meléndez[e], Ivan Podadera[f, g], Yuefeng Qiu[a], Anna Talarowska[h]

[a]Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[b]ENEA Brasimone, Italy; [c]Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland; [d]Universidad de Granada, C/Gran Vía de Colón 48, 18010, Granada, Spain;
[e]ESTEYCO, Avda. Burgos, 12B-Bajo I 28036, Madrid, Spain; [f]IFMIF-DONES España, Granada, Spain; [g]CIEMAT, Departamento de Tecnología, Madrid, Spain;
[h]National Centre for Nuclear Research (NCBJ), Otwock-Swierk, Poland **Corresponding author: arkady.serikov@kit.edu*

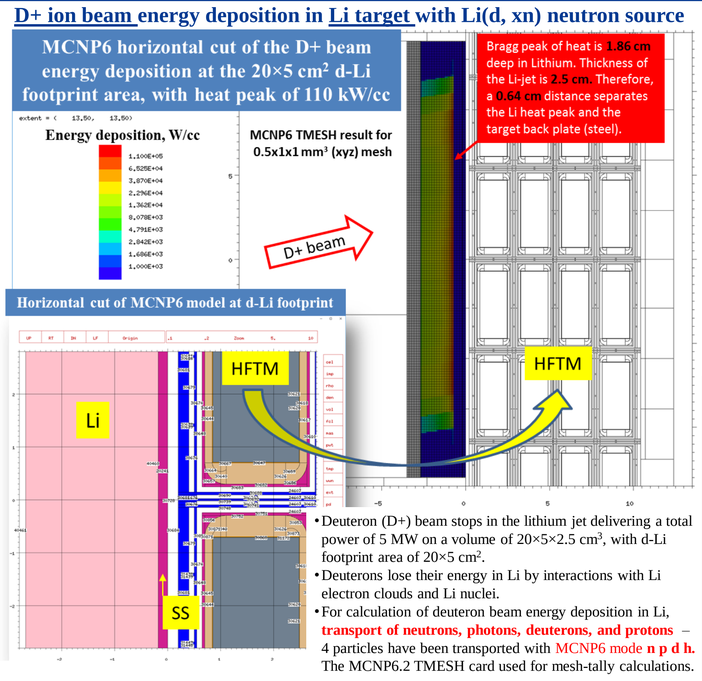
Motivation of this computational research work:

The purpose of this research is to perform neutronics analysis for the **IFMIF-DONES Test Cell (TC) and the rooms around: Complementary Experiments Room (CER), Target Interface Room (TIR), Radiation Isolation Room-1 (RIR-1), Access Cell (AC).** The maps of operational dose rate have been assessed for these rooms and correspondence to the irradiation areas classification has been established. Nuclear heating calculations are used in thermo-analyses for reliable operation of the systems.

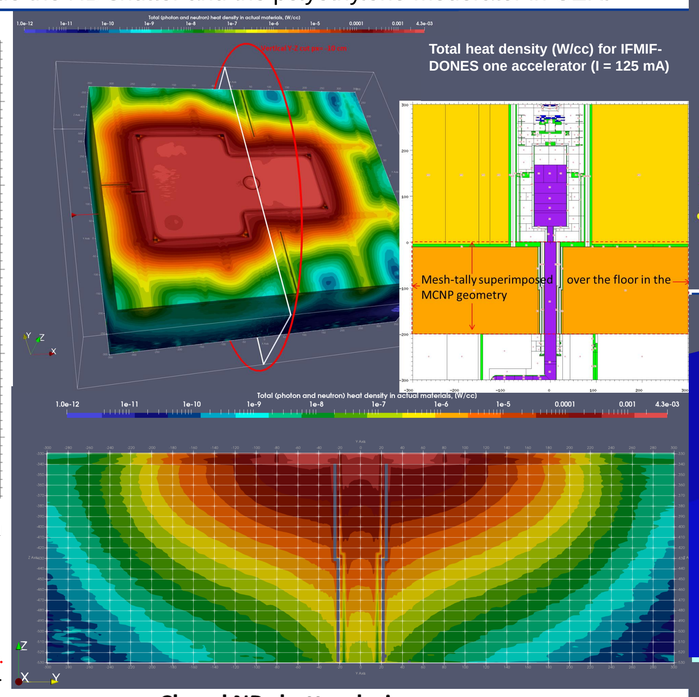
Neutron streaming from TC to CER through the Neutron Beam (NB) tube and shutter has been studied to characterize the neutron energy spectra and space distributions. Determining the neutron spectra in CER is important for the IFMIF-DONES users for conducting a variety of complementary neutron experiments. Fast spectrum will be used for irradiation of the radiation-resistant electronics, devices, and samples. Thermal neutrons will be used for activation and neutron scattering experiments. The neutron spectrum thermalization is planned with the n-spectrum filters inside the NB shutter and the polyethylene moderator in CER.



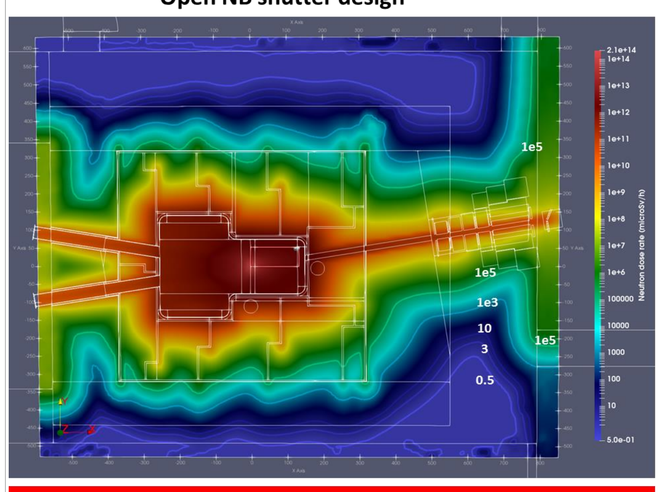
D+ ion beam energy deposition in Li target with Li(d, xn) neutron source



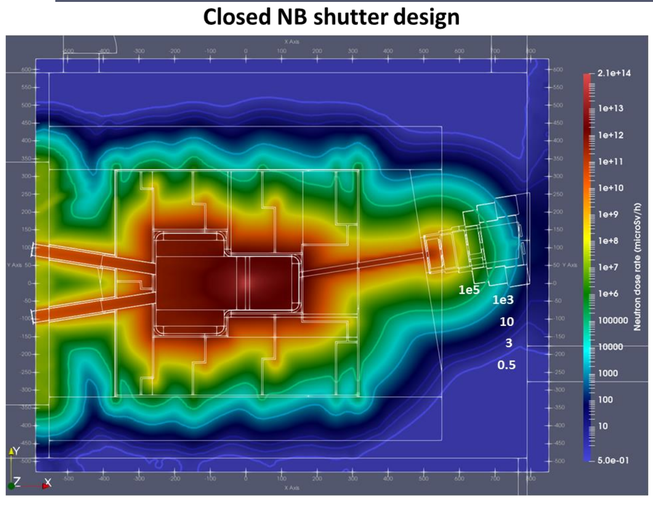
- Deuteron (D+) beam stops in the lithium jet delivering a total power of 5 MW on a volume of 20×5×2.5 cm³, with d-Li footprint area of 20×5 cm².
- Deuterons lose their energy in Li by interactions with Li electron clouds and Li nuclei.
- For calculation of deuteron beam energy deposition in Li, **transport of neutrons, photons, deuterons, and protons** – 4 particles have been transported with MCNP6 mode **n p d h.** The MCNP6.2 TMESH card used for mesh-tally calculations.



Open NB shutter design

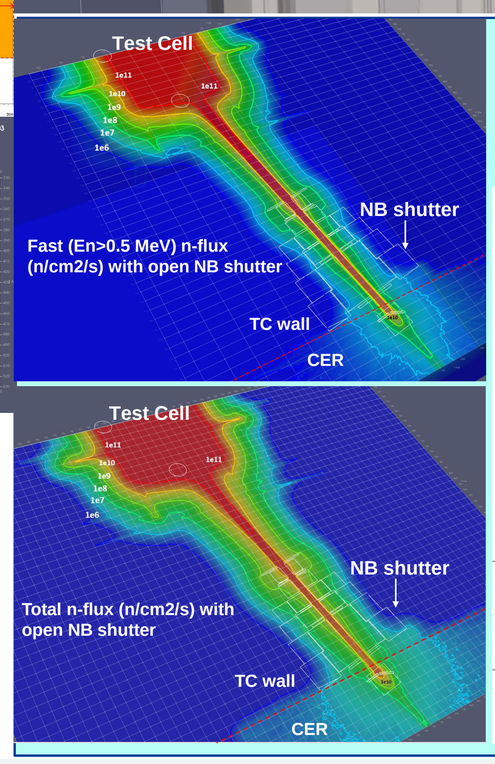


Closed NB shutter design

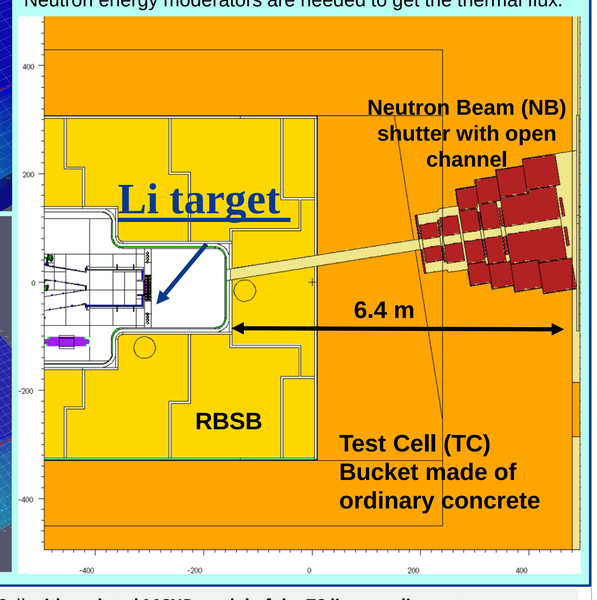


CER is Red (forbidden) radiation zone: DR>1e5 microSv/h

CER is Yellow (limited regulated) rad. zone: (10<DR<1e3) microSv/h

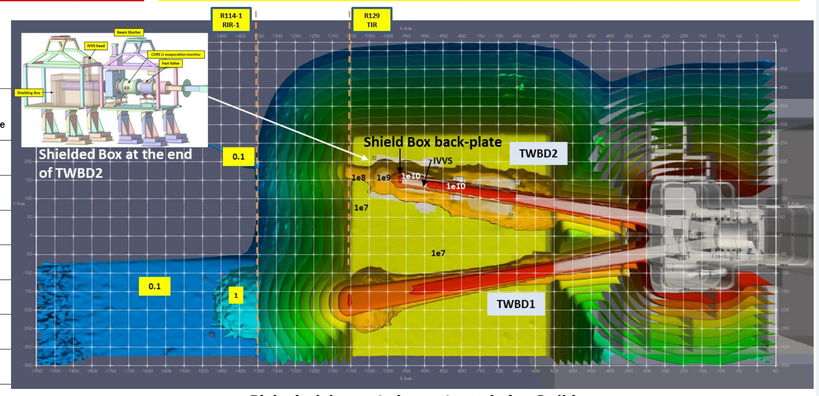


Maps of neutrons streaming from Test Cell (TC) through the Neutron Beam (NB) tube and NB shutter to Complementary Experiments Room (CER). The collimated neutrons will be supplied to conduct variety neutronics experiments inside CER. The MCNP mesh-tally reveled the dominancy of fast neutrons in the total neutron flux at the exit from NB shutter to CER. Neutron energy moderators are needed to get the thermal flux.

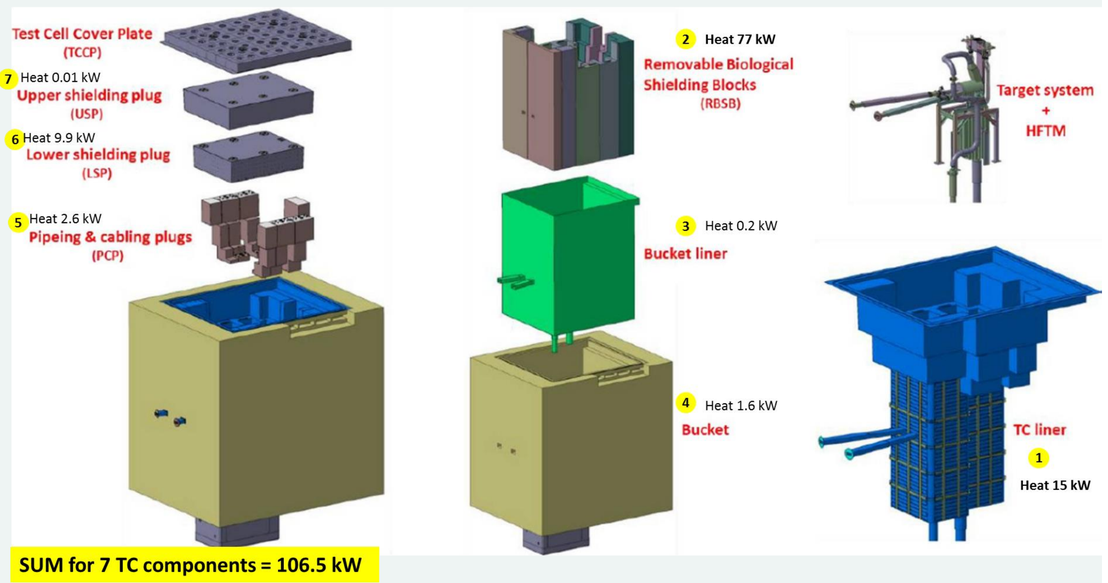


IRRADIATION AREA CLASSIFICATION

Area		Colour	Total dose rate Effective dose rate external & internal exposure
Unrestricted area within the facility			
Unrestricted area		White	< 0.5 μSv/h
Controlled and Supervised areas			
Supervised area		Blue	< 3 μSv/h
Controlled area	Free Permanenced	Green	< 10 μSv/h
	Limited Regulated	Yellow	< 1 mSv/h
	Specially Regulated	Orange	< 100 mSv/h
	Forbiden	Red	≥ 100 mSv/h

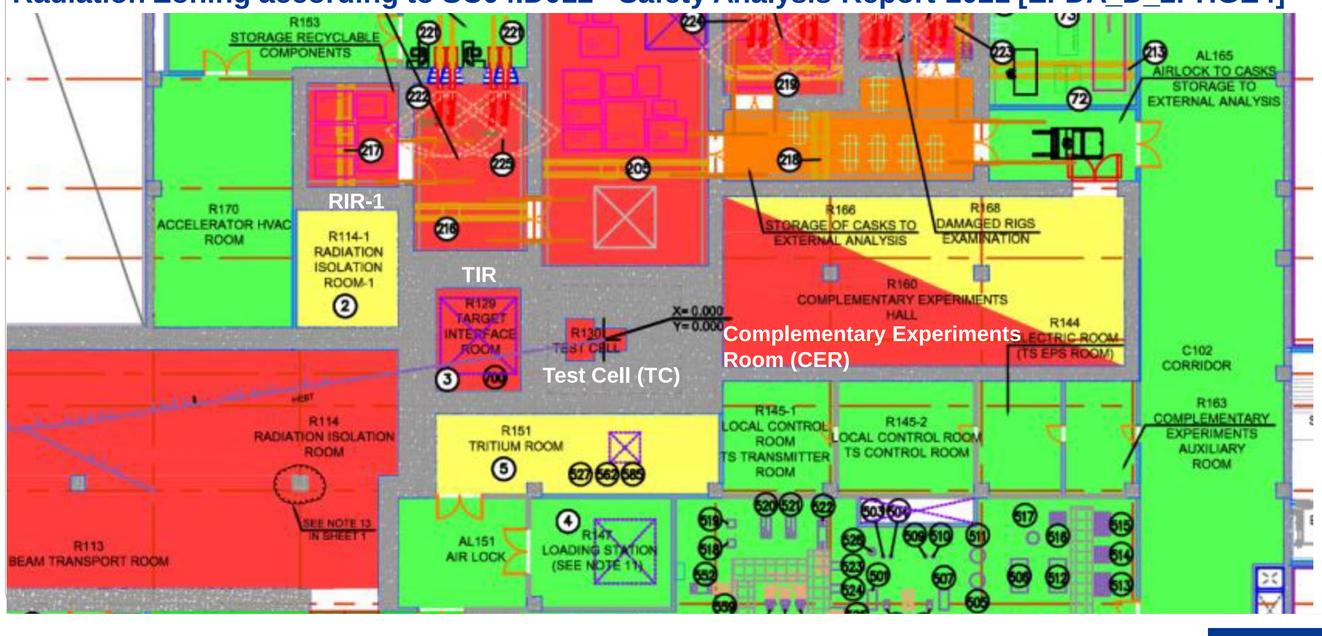


Integral nuclear heat (kW) in IFMIF-DONES Test Cell **with updated MCNP model of the TC liner cooling system**



SUM for 7 TC components = 106.5 kW

Radiation Zoning according to SC04.D012 - Safety Analysis Report-2021 [EFDA_D_2PHGE4]



Conclusions:

1. Neutron and photon fluxes, nuclear heating, neutron damage, and biological dose rates have been calculated with the McDeLicious (MCNP6 modification) code with the Deuteron-Lithium (D-Li) source. Deuteron ions (D+) accelerated up to 40 MeV with I=125 mA current impinged on the liquid Li target. D+ beam delivers 5 MW of stopping energy to the liquid Li jet. Much lower heat is transferred by neutrons and photons, depositing energy to the surrounding components, such as Target Assembly (7 kW), and Test Cell seven components (107 kW).
2. For the forthcoming IFMIF-DONES users, neutron spectra characteristics have been analyzed in CER at the exit of the open NB shutter. High total neutron flux ($2 \cdot 10^{10}$ n/cm²/s) can be achieved in CER, with the majority of fast neutrons (~88%), part of epithermal ($1.8 \cdot 10^{9}$ n/cm²/s), and thermal neutrons ($7 \cdot 10^{8}$ n/cm²/s). With an open NB shutter, the fast neutrons could be used directly in irradiation tests on electronics, devices, and materials. For the users of thermal and epithermal fluxes, spectrum tailoring is required by the installation of the neutron energy filters inside the channels of the shutter and neutron energy moderators (e.g. Polyethylene).
3. The radiological protection requirements for CER (Room R160) are fulfilled. For the open NB shutter design, the neutron Dose Rate (DR) exceeds **1e5 microSv/h** in CER – it is a **Red** (forbidden) radiation zone. By closing the NB shutter, DR in CER drops down to **1e3 microSv/h**, allowing set CER to the **Yellow** (limited regulated) radiation zone: (10<DR<1e3) microSv/h.
4. Inside TIR, the IVVS Shield Box effectively mitigates the dose rate inside the Radiation Isolation Room-1 (RIR-1), reducing by 10 times the contribution of TWBD2 from 1.0 to 0.1 microSv/h. The dose rate in RIR-1 should be less than 1 mSv/h and, as following ALARA the TWBD2 contribution is very small, all the dose will be formed by the primary TWBD1 – the subject of a separate task.
5. The Access Cell (AC) is classified as a Yellow zone, where the dose rate should be limited by 1 mSv/h. The performed analyses revealed the radiation hot spots on the AC floor due to the leakages through the gaps. Following the outcomes of this analysis, the design improvements are introduced to block the radiation leakages.

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