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Radiation shielding analysis for the IFMIF-DONES secondary beam duct

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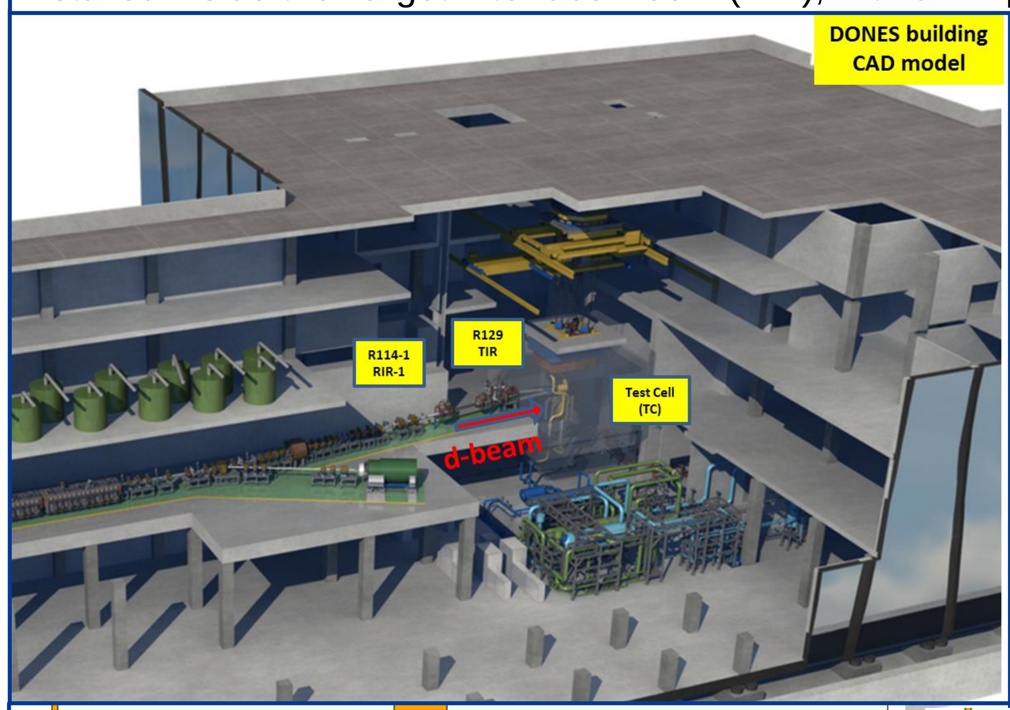
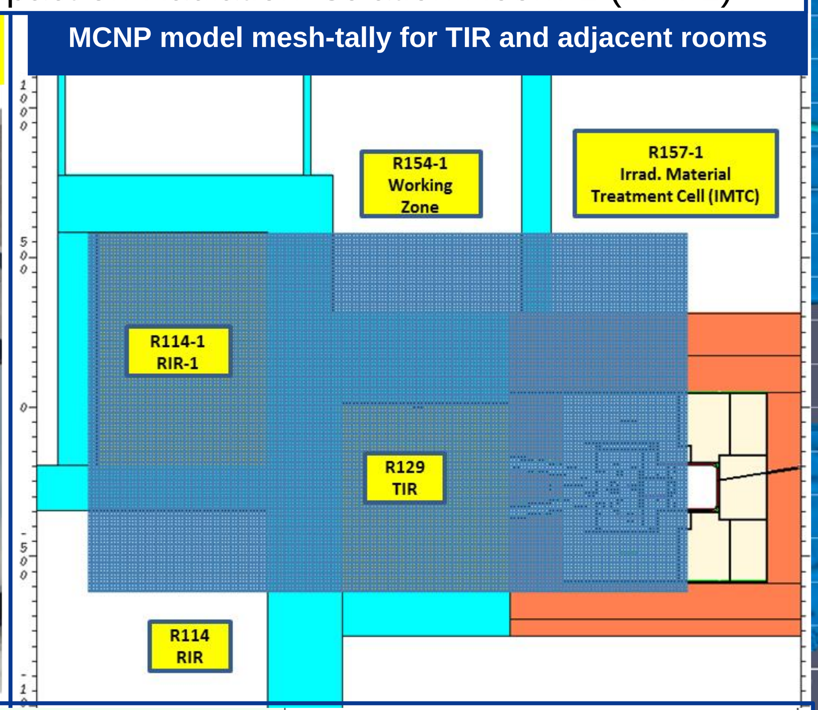
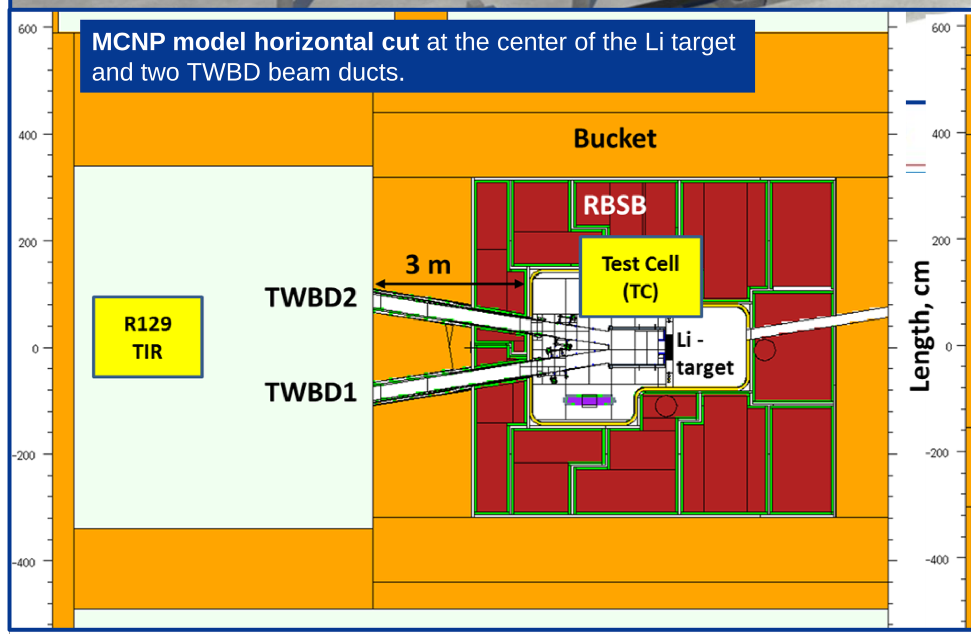
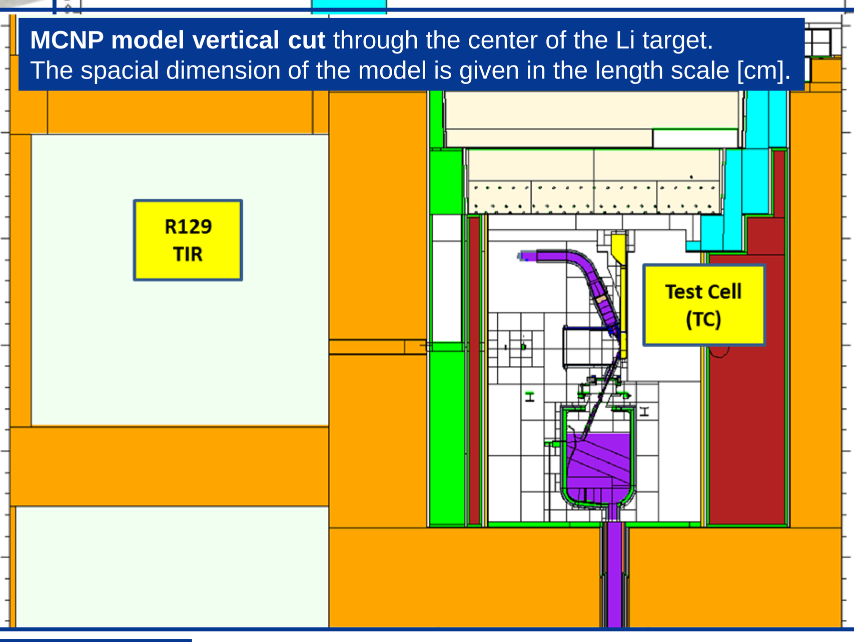
Motivation of this work:

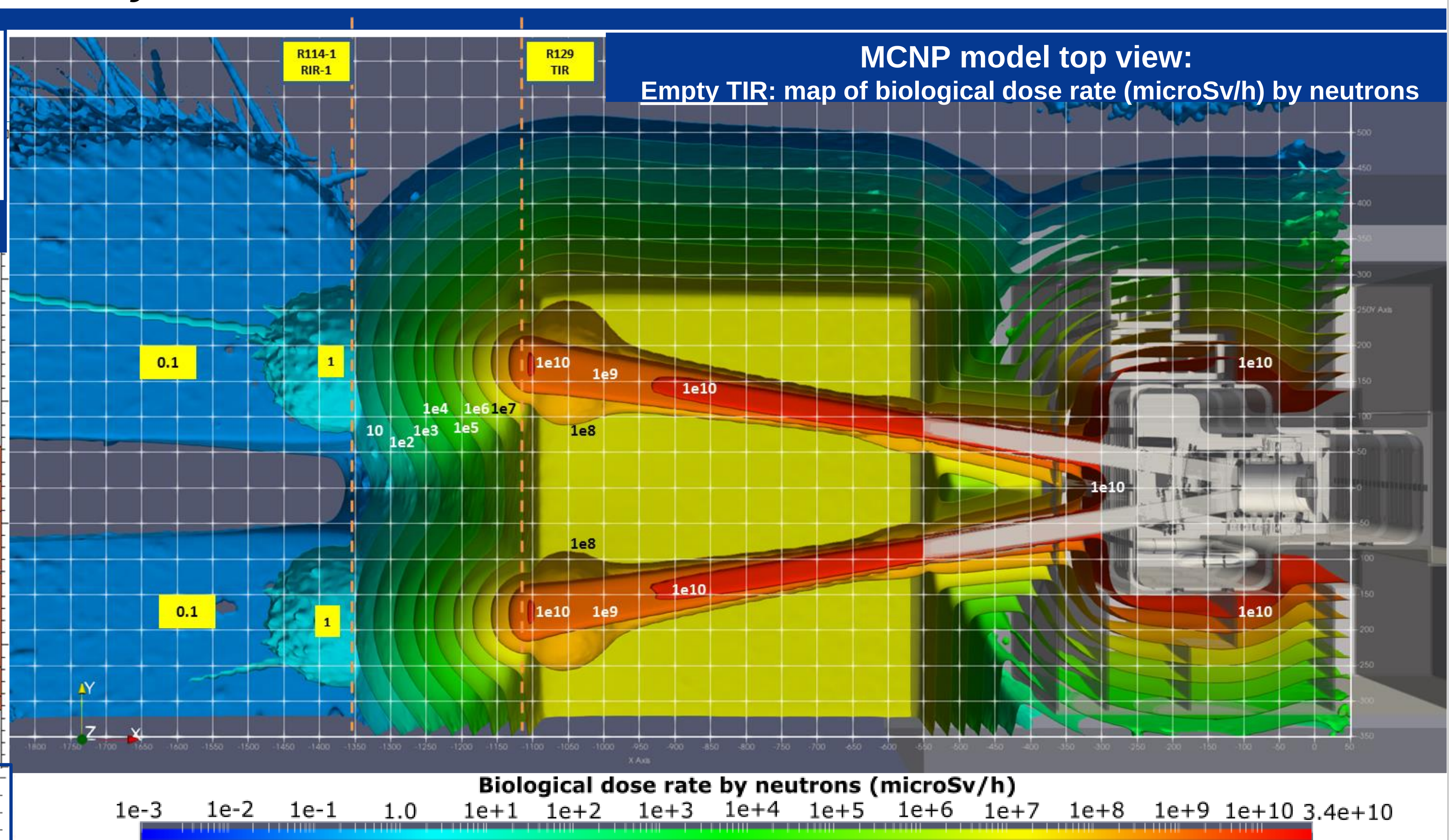
The purpose of this research work consists in performing neutronics analysis for the **IFMIF-DONES Through Wall Beam Duct #2 (TWBD2)** and proposing the radiation shielding for the TWBD2 diagnostics installed inside the Target Interface Room (TIR), with an impact on Radiation Isolation Room-1 (RIR-1).





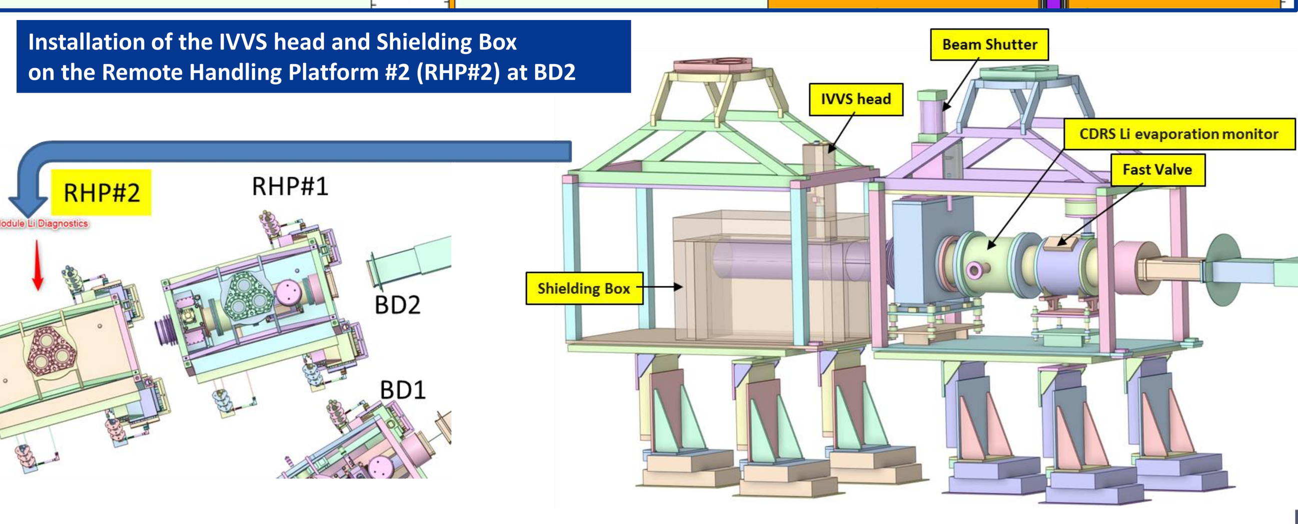


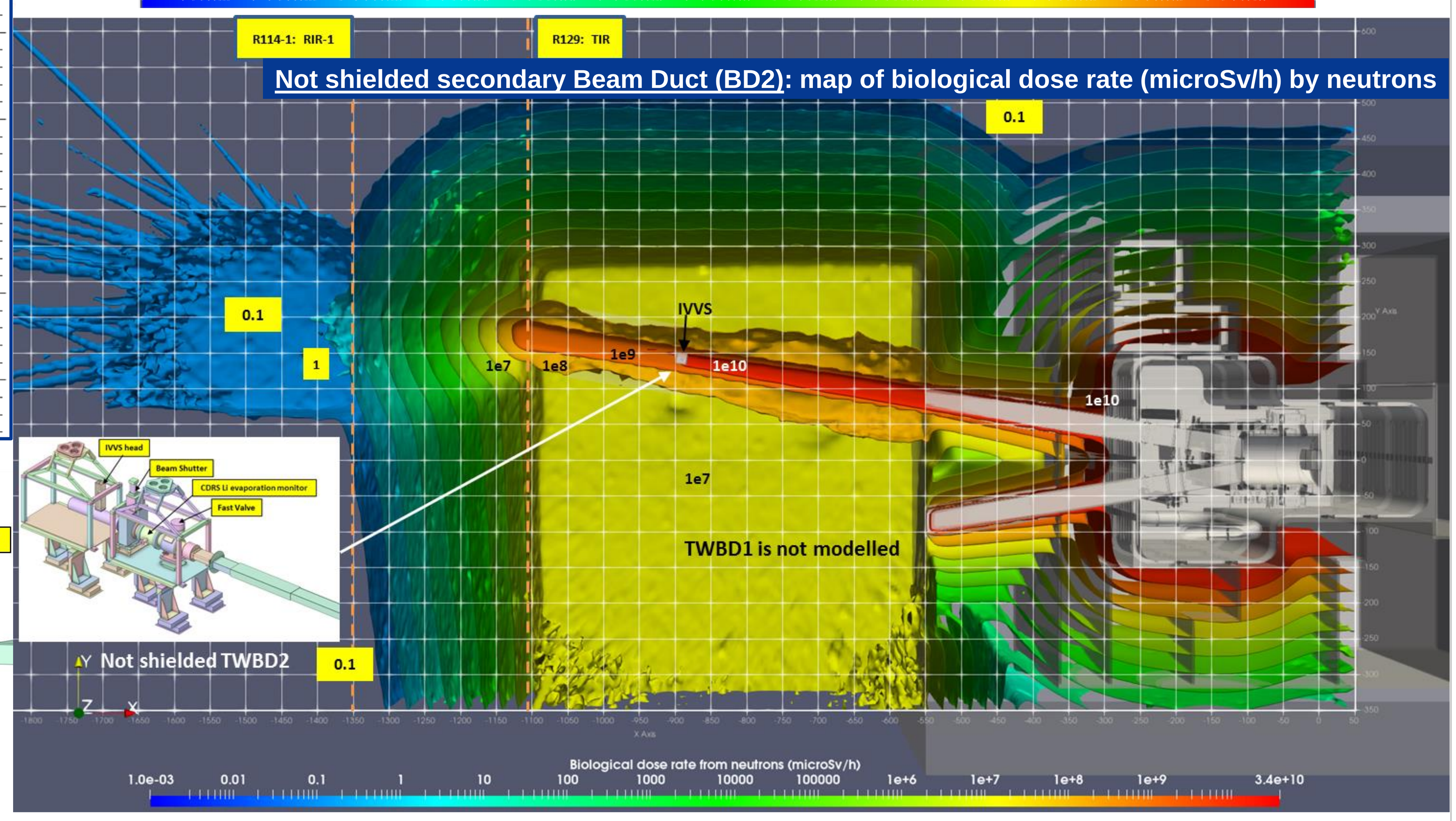


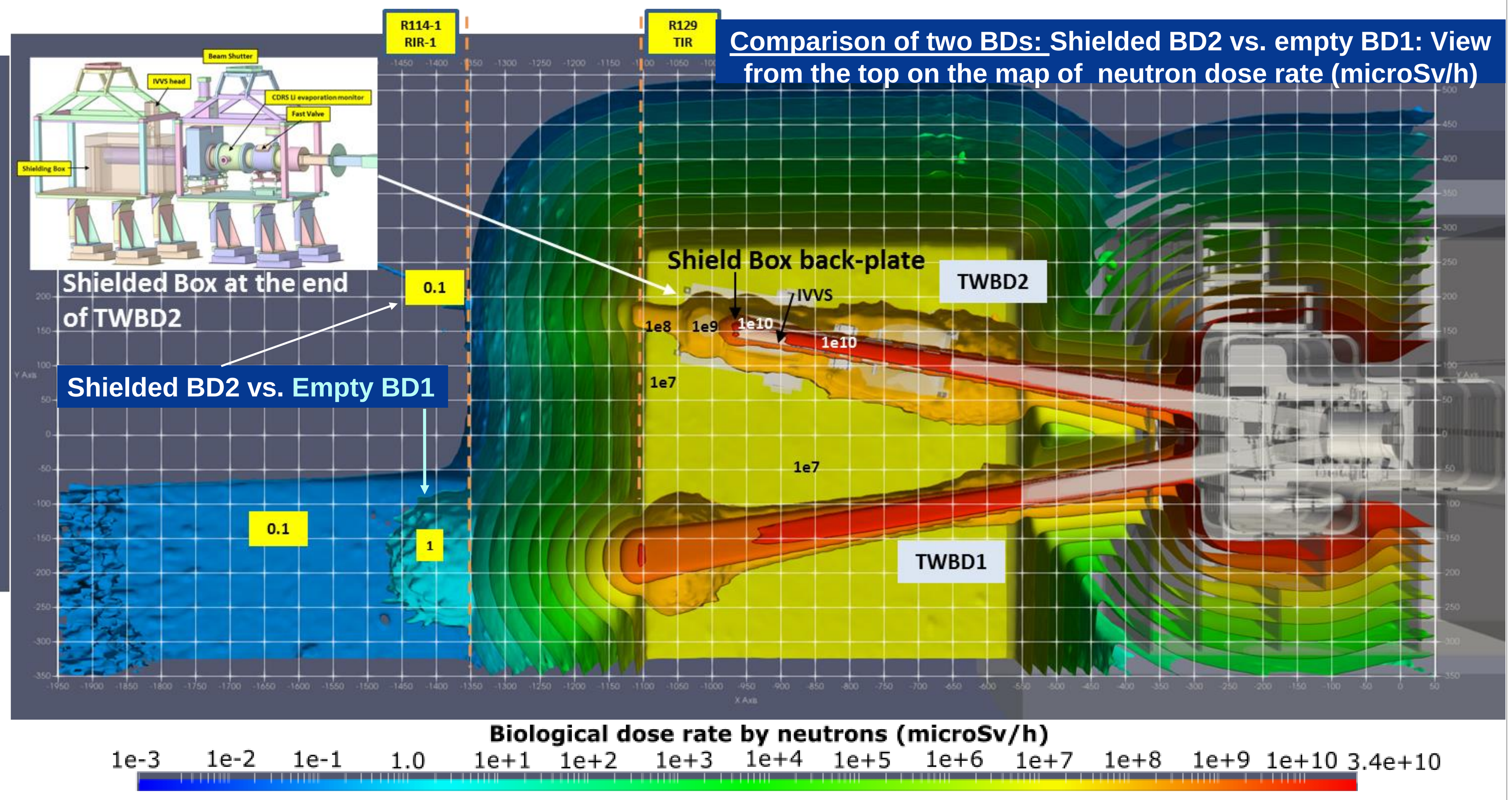


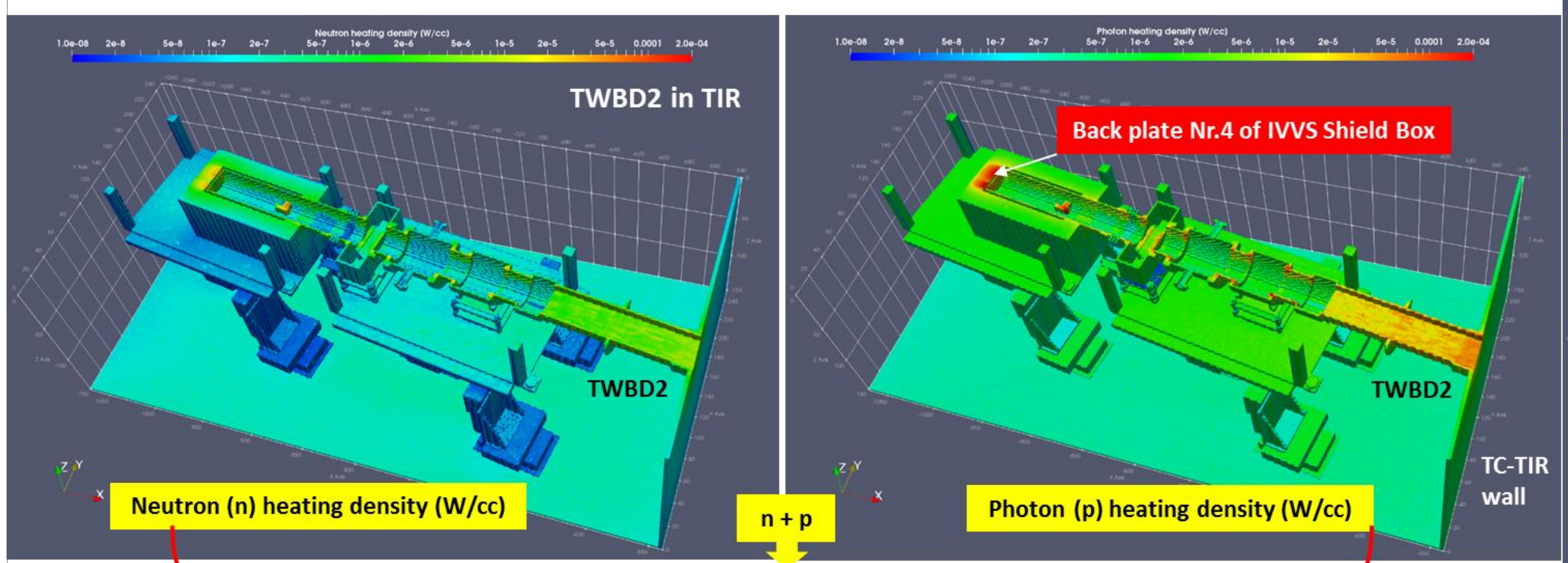
The In-Vessel Viewing System (IVVS) will withstand very severe radiation environment conditions.
The gamma irradiation test of the IVVS actuating components reached a total dose of 4.88 MGy [1], without any evident and significant damages and degradation of the piezo-motor functionality.

Reference:
[1] P. Rossi et al., "IVVS actuating system compatibility test to ITER gamma radiation conditions," Fusion Engineering and Design, 88 (2013) 2084 – 2087.

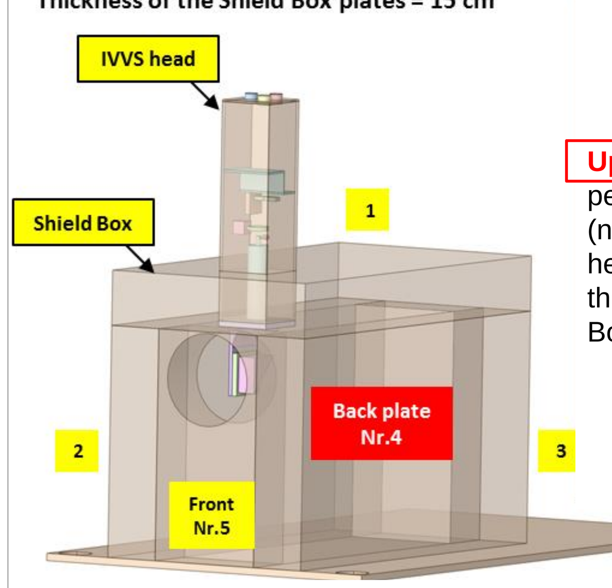




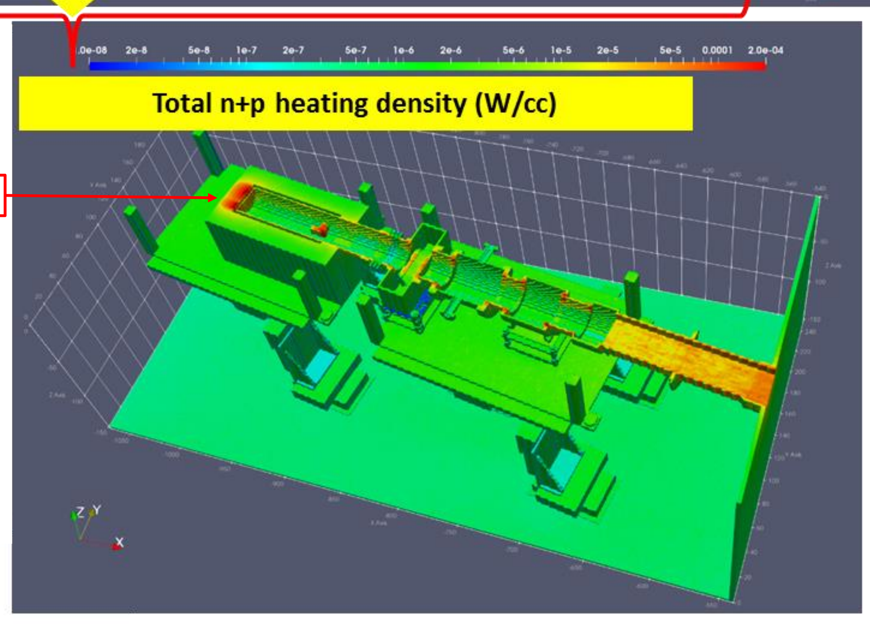


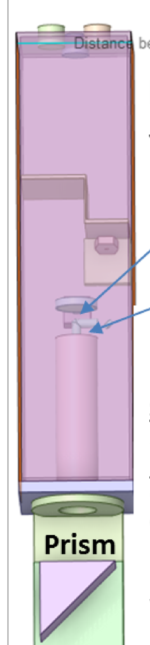


Thickness of the Shield Box plates = 15 cm



Up to 2.0e-4 W/cc peak value of total (neutron + photon) heating density at the IVVS Shield Box back plate Nr.4





IVVS optical head based on the concept design Ref. [2]

IVVS optical head materials:

Silica: (Lenses, Mirrors, Prism) density 2.32 g/cc; **O** 66.67% at, **Si** 33.33% at.
Lead Zirconate Titanate: ($Pb[Zr_xTi_{1-x}]O_3$) (Both actuators and linear stages) with density 7.75 g/cc; **O** 60% at, **Pb** 20% at, **Zr** 10.4% at, **Ti** 9.6% at.
SS316L: Rest of the IVVS components, with density 7.9 g/cc.

Reference:
[2] P. Rossi et al., "IVVS probe mechanical concept design," Fusion Engineering and Design, 98–99 (2015) 1597–1600.

Shield Plate Nr.	Volume [cc]	Plate side in Shield Box. Plate thickness = 15 cm	Photon heat [W]	Neutron heat [W]	Total (neutron+photon) nuclear heat, [W]
1	1.03E+05	Upper plate of shield box (steel SS316L)	1.94E-01	3.12E-02	2.25E-01
2	1.09E+05	Left plate of shield box (steel SS316L)	2.16E-01	3.38E-02	2.50E-01
3	1.09E+05	Right plate of shield box (steel SS316L)	2.09E-01	3.30E-02	2.42E-01
4	2.95E+04	Back plate of shield box (steel SS316L)	5.56E-01	1.02E-01	6.58E-01
5	2.20E+04	Front plate of shield box (steel SS316L)	5.51E-02	9.13E-03	6.42E-02
Total:	3.73E+05	Integral heating for Shield Box	1.23E+00	2.09E-01	1.44E+00

Conclusion:

- The proposed **Shield Box** around the IVVS Diagnostics at the end of the secondary **Through Wall Beam Duct #2 (TWBD2)** inside the room TIR allows reducing the biological dose rate at least by one order of magnitude inside the next room RIR-1.
- The Shield Box is made of steel SS316L plates with a thickness of 15 cm, the box's whole weight is 2.96 tons.
- The total (neutron + photon) nuclear heating in steel plates integrated over the Shield Box volume is 1.44 W.
- Performed neutronics analysis provided supporting results for the proposed design of the IVVS Diagnostic system.
- Neutronics results indicated the possibility to implement the IVVS Shield Box design in TWBD2 inside the TIR of IFMIF-DONES.
- Neutronics results for TWBD2 in TIR of DONES:
  - Photon absorbed dose rate 70 Gy/h in the IVVS prism is less than the 5 kGy/hr limit of the IVVS operability.
  - Sum of photon and neutron radiations rises absorbed dose in the IVVS prism to 130 Gy/hr, still less than 5 kGy/hr limit.
  - The IVVS actuator worked at 4.88 MGy, the limit for the life-time integrated photon dose is 10 MGy.
  - Maximum absorbed dose in IVVS prism is 0.6 MGy/FPY (photon), total (n+p) dose is 1.13 MGy/FPY. Taking into account the reference data 4.88 Mgy for photons and 10 MGy for total absorbed doses, the actual lifespan of IVVS operation will be found.
- Performed neutronics analysis provided supporting results for the proposed designs of Shield Box and IVVS. Neutronics results indicated possibility to implement this shielding designs in TWBD2 of the IFMIF-DONES Target Interface Room (TIR).

IVVS Shield Box effectively mitigates the biological dose rate inside the Radiation Isolation Room-1 (RIR-1), reducing the contribution of TWBD2 to 0.1 microSv/h.

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