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Deuteron Beam Energy Deposition in Liquid Lithium Target and Heating in the IFMIF-DONES Target Assembly

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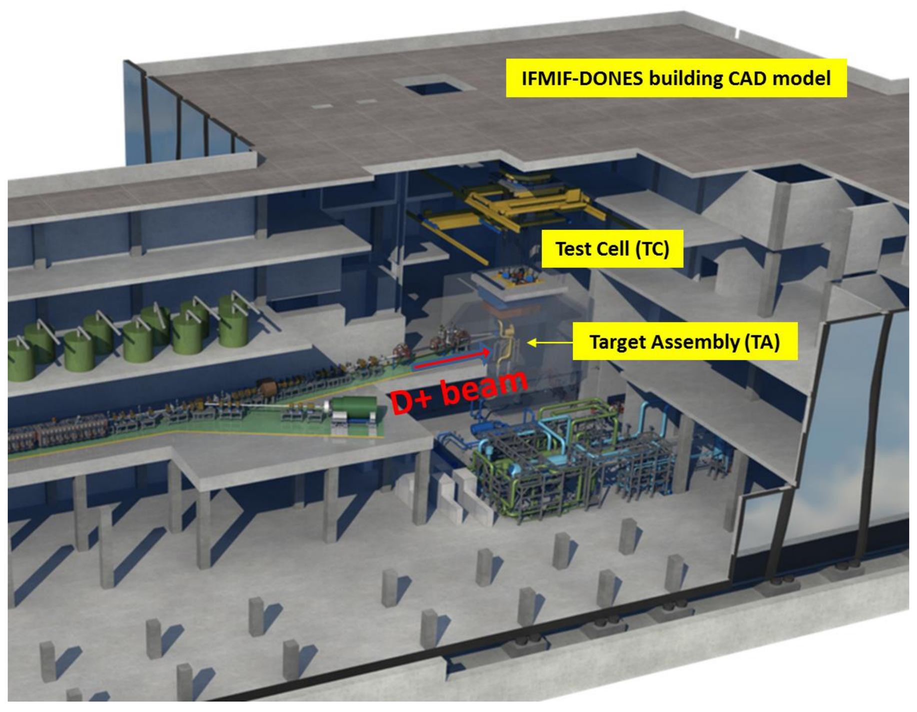
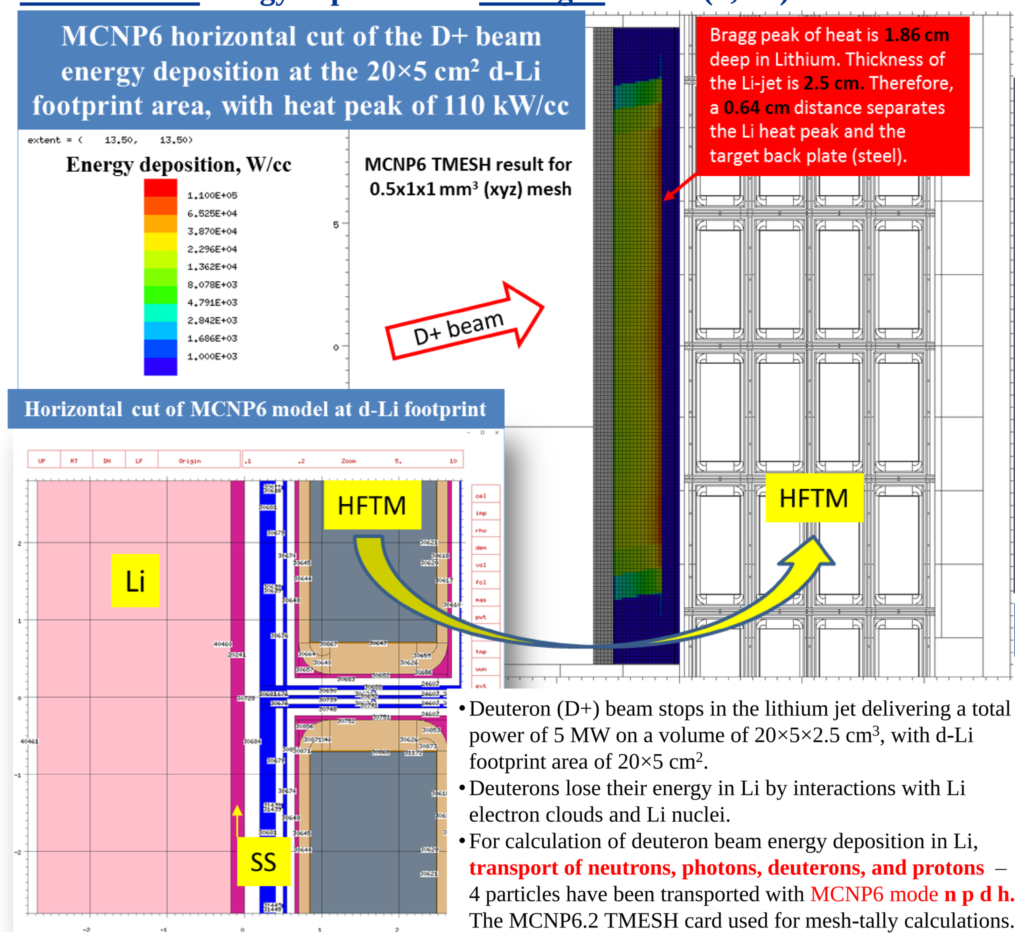
Motivation of this computational research work:

One of the major aims of the IFMIF-DONES (International Fusion Materials Irradiation Facility – Demo Oriented NEutron Source) is **the neutron irradiation of the materials placed behind a lithium target bombarded by the accelerated deuteron beam.** This paper presents the detailed computational neutronic analysis of deuteron beam ions (d+) interaction with lithium atomic electrons and nuclei. Neutronics calculations have been performed with the MCNP6.2 code. The transport of four particles (deuteron, neutron, photon, and proton) has been used for energy deposition in lithium target. **The dominant contribution to heating in lithium** is caused by the interaction of deuteron ions with electrons and nuclei of lithium. Among the deuteron-produced secondary particles, the particular importance constitutes neutrons and photons because they penetrate much deeper outside the target.



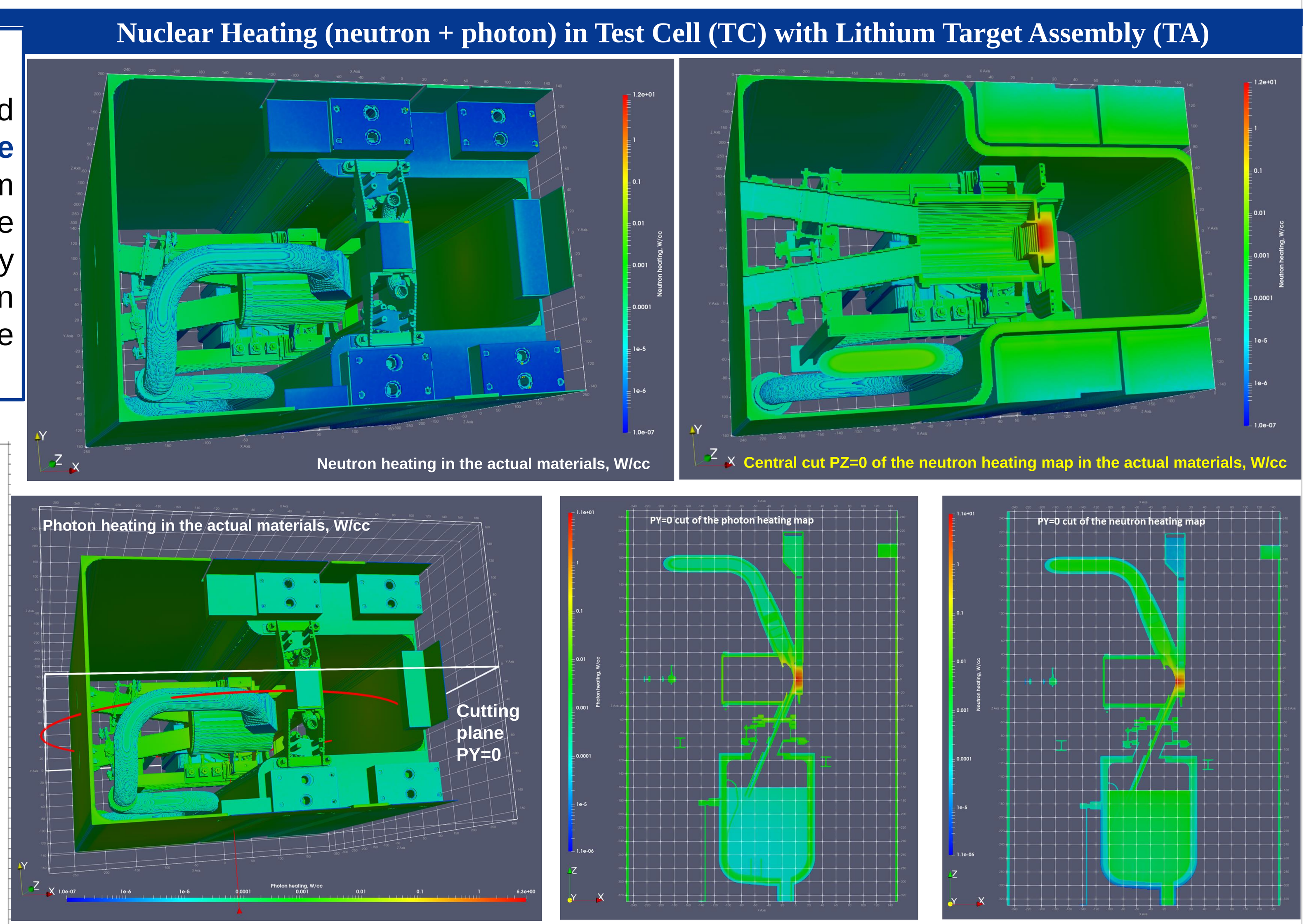
- The CAD model of IFMIF-DONES building is properly prepared for the **McDeLicious-17 code package** – an MCNP6 code modification.
- The geometry of each component of the building was simplified and decomposed into a number of simple primitive elements.
- The CAD model is converted into MCNP model and fill into the separate envelope using the MCNP universe card. The CAD-to-MCNP conversion is performed using **McCad and SuperMC codes.**

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

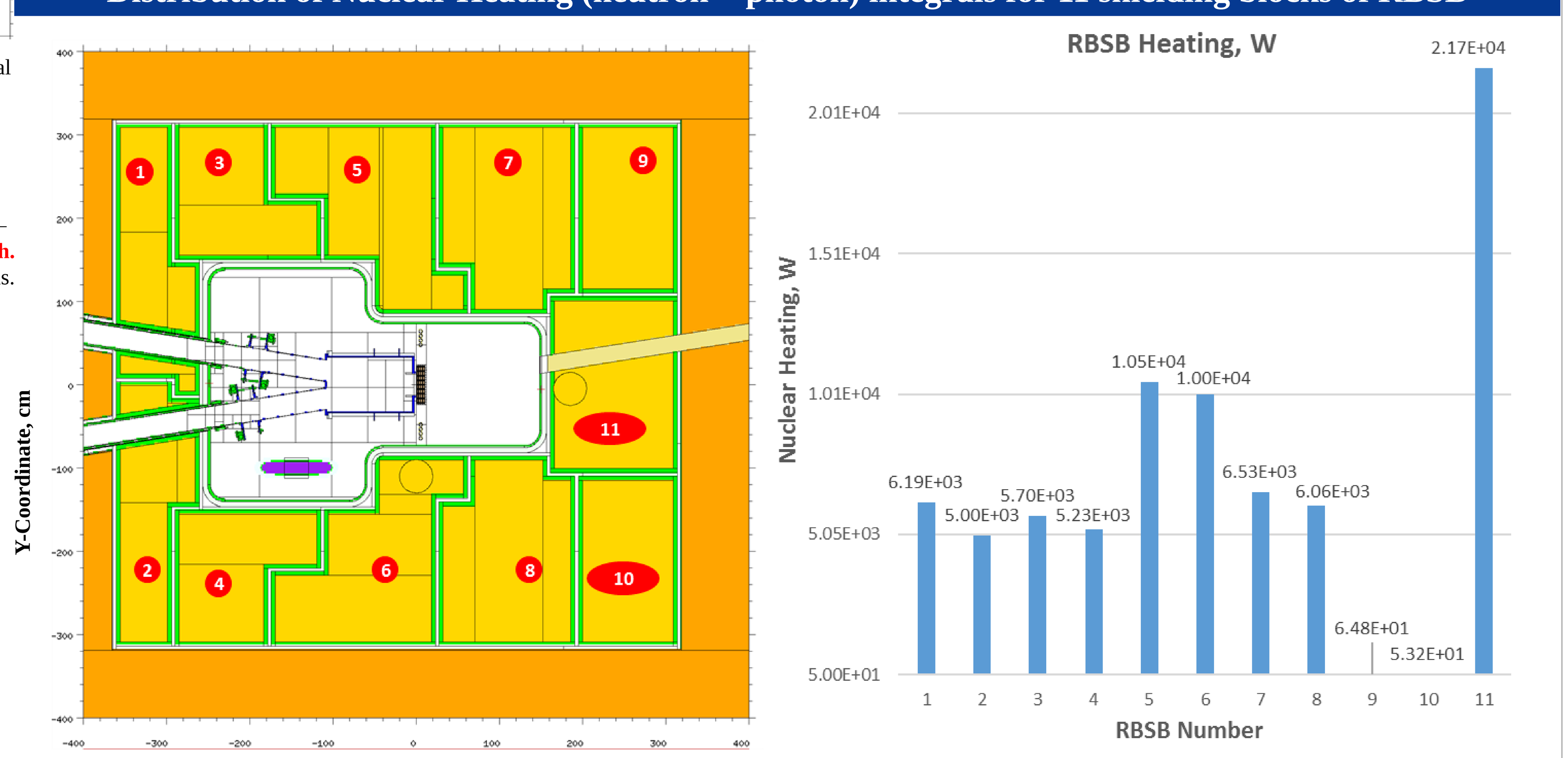


- Deuteron (D+) beam stops in the lithium jet delivering a total power of 5 MW on a volume of 20×5×2.5 cm³, with d-Li footprint area of 20×5 cm².
- Deuterons lose their energy in Li by interactions with Li electron clouds and Li nuclei.
- For calculation of deuteron beam energy deposition in Li, transport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

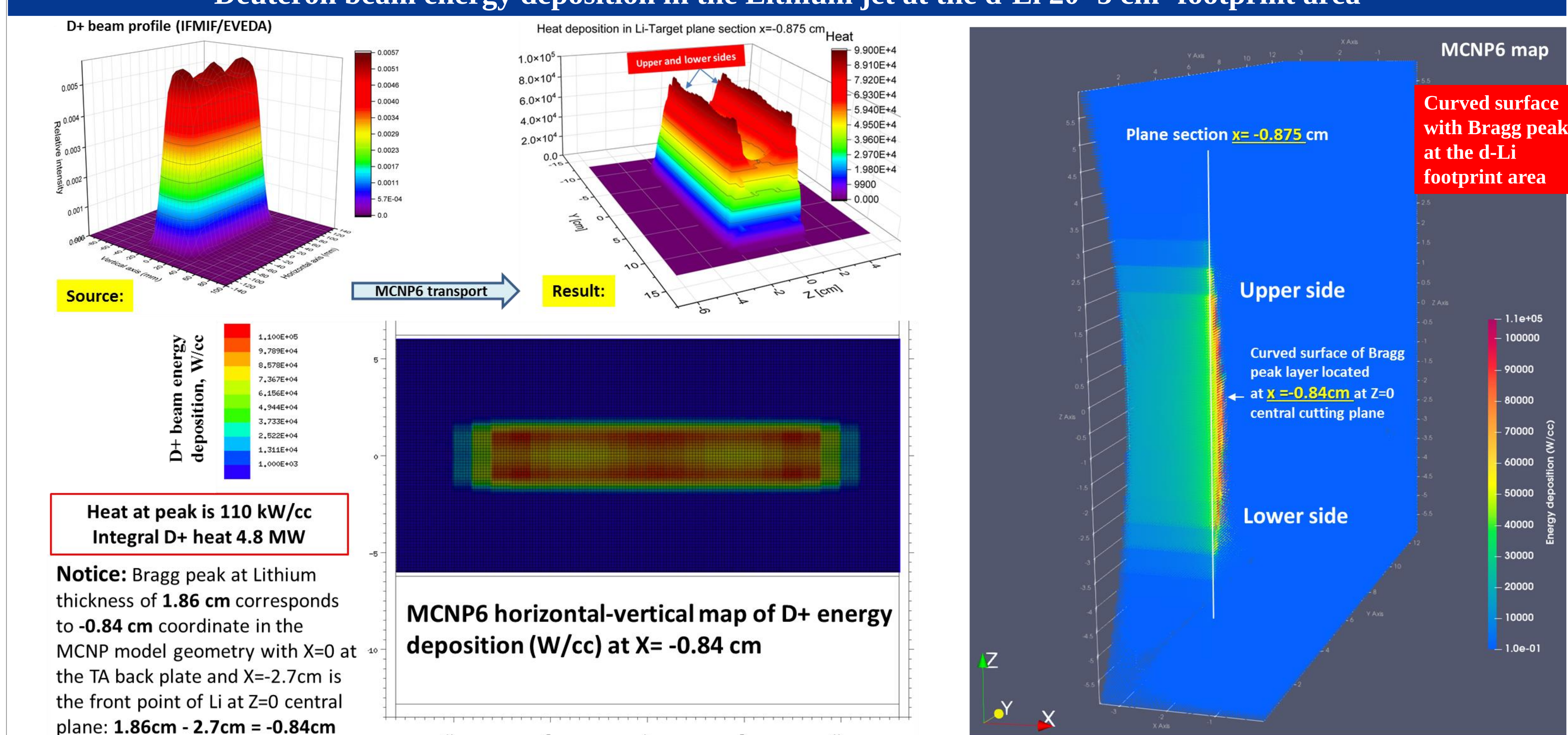
Nuclear Heating (neutron + photon) in Test Cell (TC) with Lithium Target Assembly (TA)



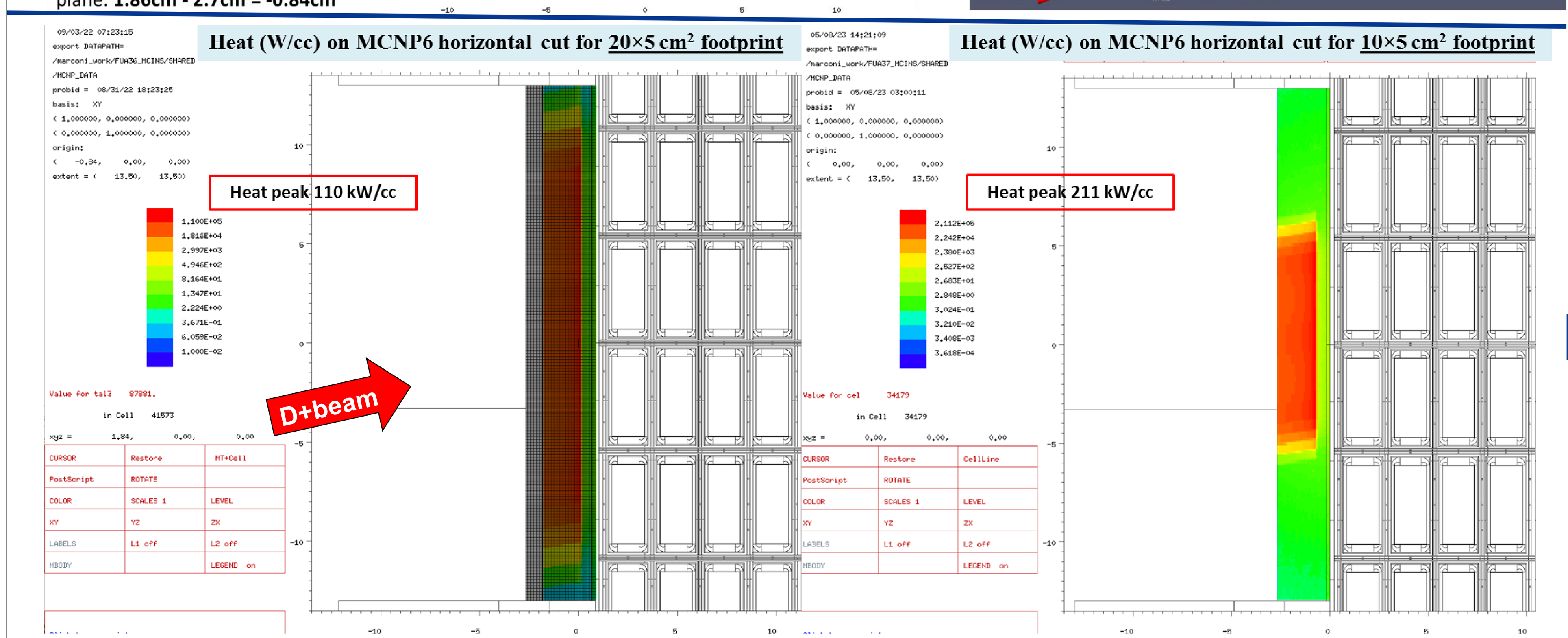
Distribution of Nuclear Heating (neutron + photon) integrals for 11 shielding blocks of RBSB



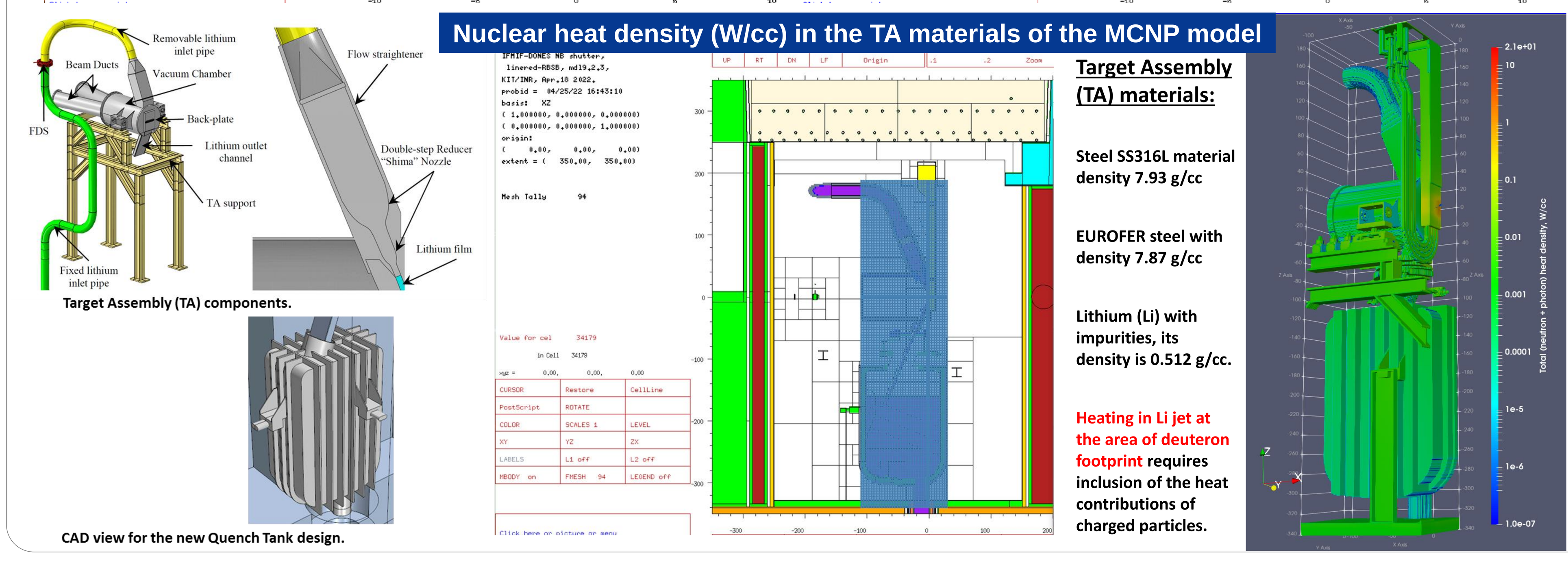
Deuteron beam energy deposition in the Lithium jet at the d-Li 20×5 cm² footprint area



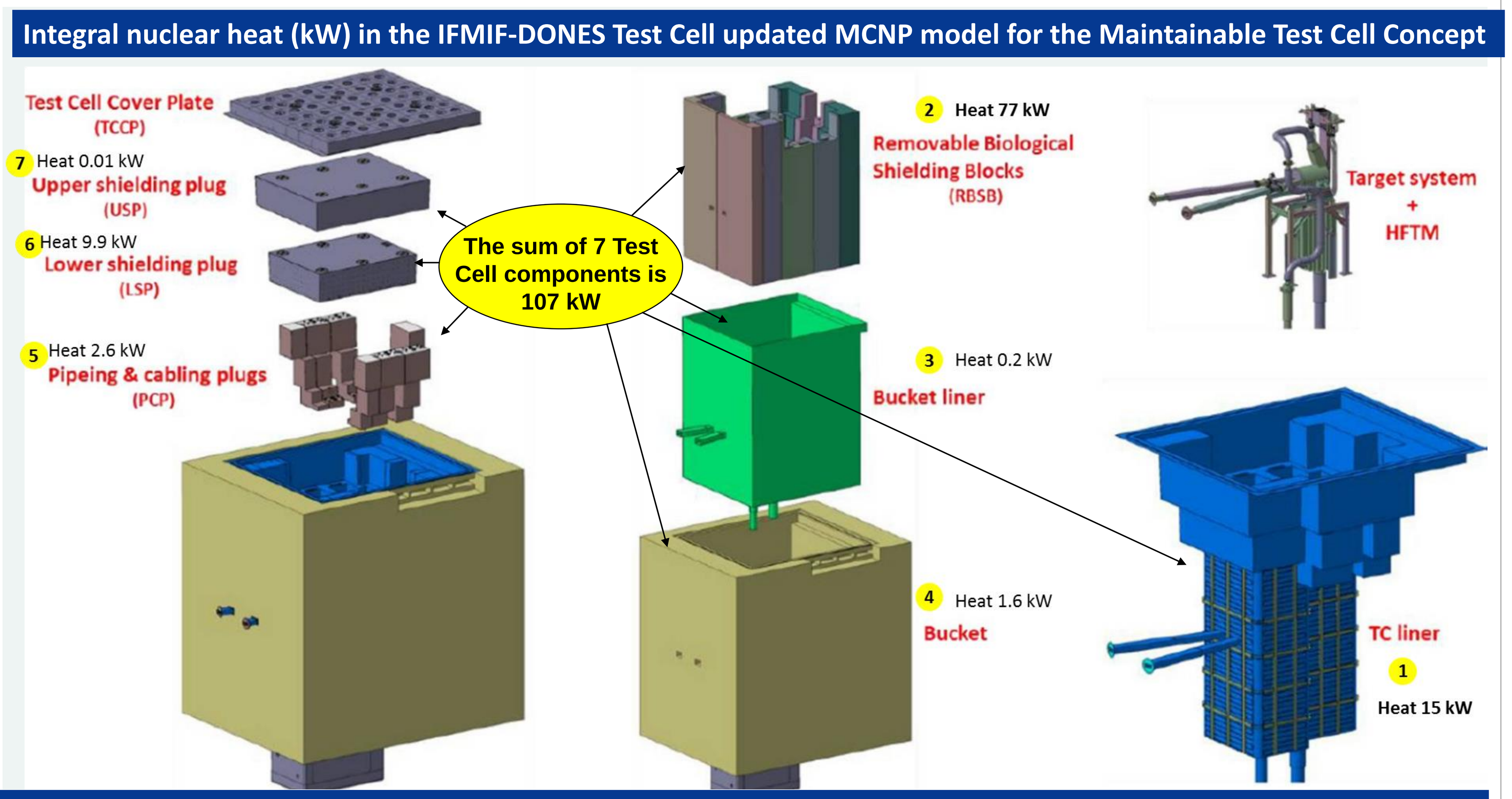
Notice: Bragg peak at Lithium thickness of **1.86 cm** corresponds to **-0.84 cm** coordinate in the MCNP model geometry with X=0 at the TA back plate and X=-2.7cm is the front point of Li at Z=0 central plane: 1.86cm - 2.7cm = -0.84cm



Nuclear heat density (W/cc) in the TA materials of the MCNP model



Integral nuclear heat (kW) in the IFMIF-DONES Test Cell updated MCNP model for the Maintainable Test Cell Concept



Conclusions *

- Deuteron energy deposition in Liquid Lithium Target, nuclear heating in the IFMIF-DONES Target Assembly and Test Cell have been presented, examining variants of high heat loads due to:
  - A more focused deuteron beam with a 10x5 cm² Li footprint caused a factor of 2 increase in heat deposition in Li (peak of 211 kW/cc vs. 110 kW/cc). Taking into account that the initial temperature of Li entering the target is 300 C, for 20x5 cm² footprint the temperature increases to 428.8 C by delta-t 128.8 C, while for 10x5 cm² it rises up to 552.2 C by 252.2 C. That means a more concentrated beam of 10x5 cm2 resulted in a similar ratio of temperature heating up as the heat deposition, delta temperature increased due to the halved beam by the same factor of 2.
  - Operation of two accelerators with double D+ current of 250 mA with IFMIF parameters caused double heating of the TC materials.
- An extremely high heat load of 110 kW/cc or 211 kW/cc on a speedy Li-jet flowing at 15 m/s does not leave time to heat up the Target Assembly surrounding components.
- Distributions of the monolithic materials should be used to supply volumetric nuclear heat sources (W/m³) for the CFD/FEM thermo-hydrodynamic calculations the the STAR-CCM+ code. Otherwise, substantial errors could be introduced due to two reasons:
  - Heat averaging in different materials per mesh elements,
  - Results approximations for different types of meshes use in neutronics and thermo-hydrodynamic calculations.
- Nuclear heat distributions in the Target System of the standard IFMIF-DONES with 20x5 cm² footprint are presented for four materials (EUROFER, lithium, steel SS316L, and thermal isolation).

*** Reference: Temperature calculations are presented in the ICFRM-21 Poster P3-356 "Thermal hydraulic and structural analysis of the IFMIF-DONES Liquid-Lithium Target System" by Sergej Gordeev, Arkady Serikov.**

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