MCNP calculations of the high-power LIEBE molten target at CERN for the production of radioisotopes

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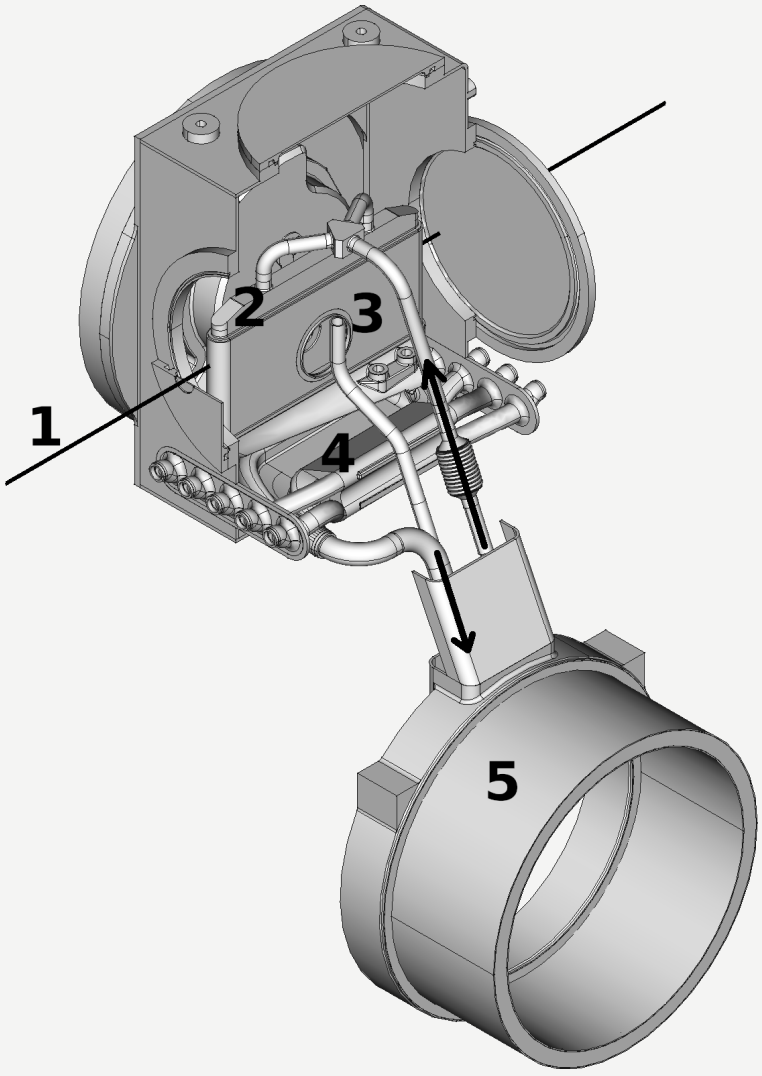
The LIEBE target



LIEBE - LIquid Eutectic lead Bismuth for Eurisol

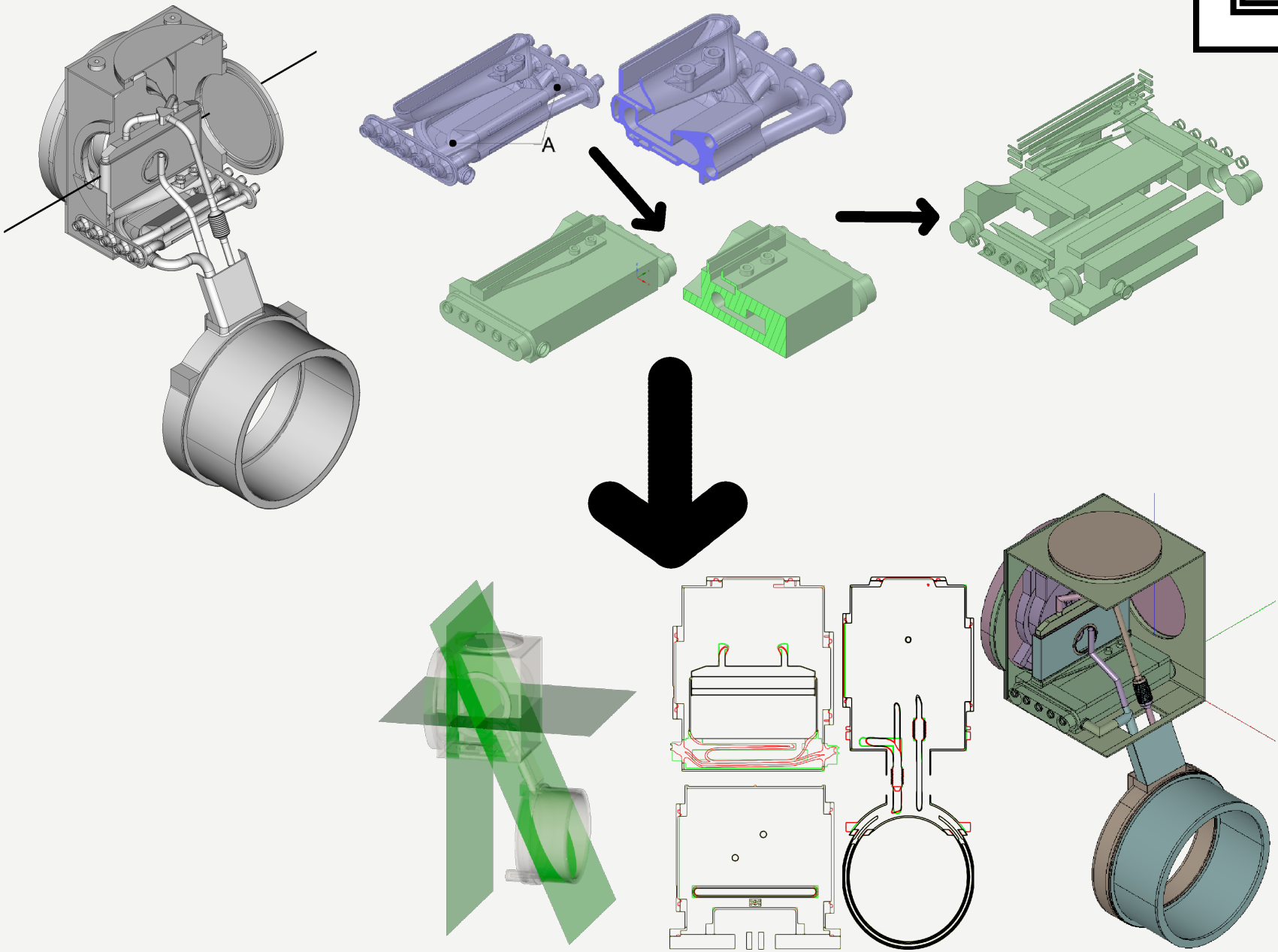
1 – Proton beam (1) hits the irradiation chamber (2).

2 – Irradiated liquid lead-bismuth eutectic (LBE) falls through a grid fragmenting it into 0.4 mm diameter droplets, which fall along the height of diffusion chamber (3).

3 – Heat, deposited to the LBE by the proton beam, is removed in the water-cooled heat-exchanger (4).

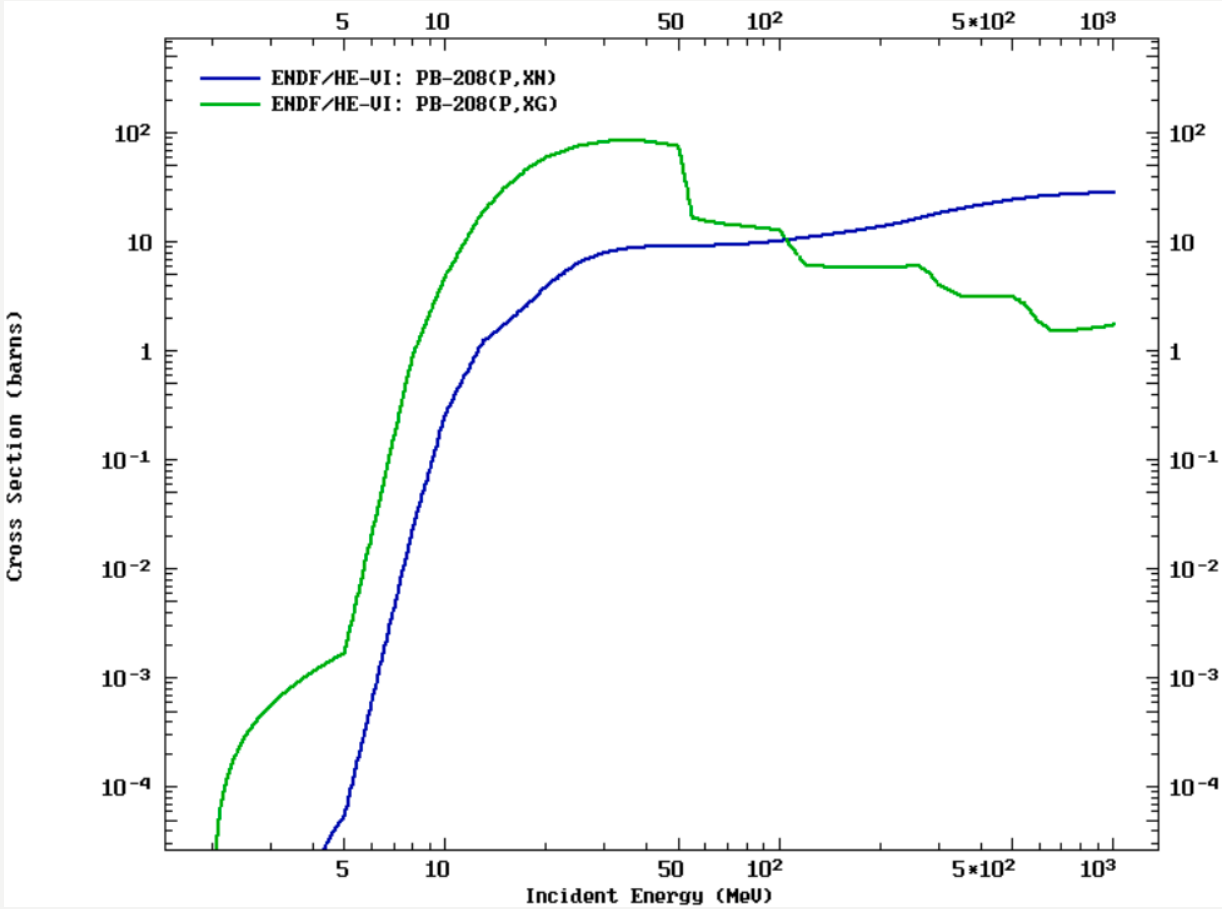
4 – LBE goes through the EM pump channel (5) back to the irradiation chamber (2).

CAD to MCNP input conversion



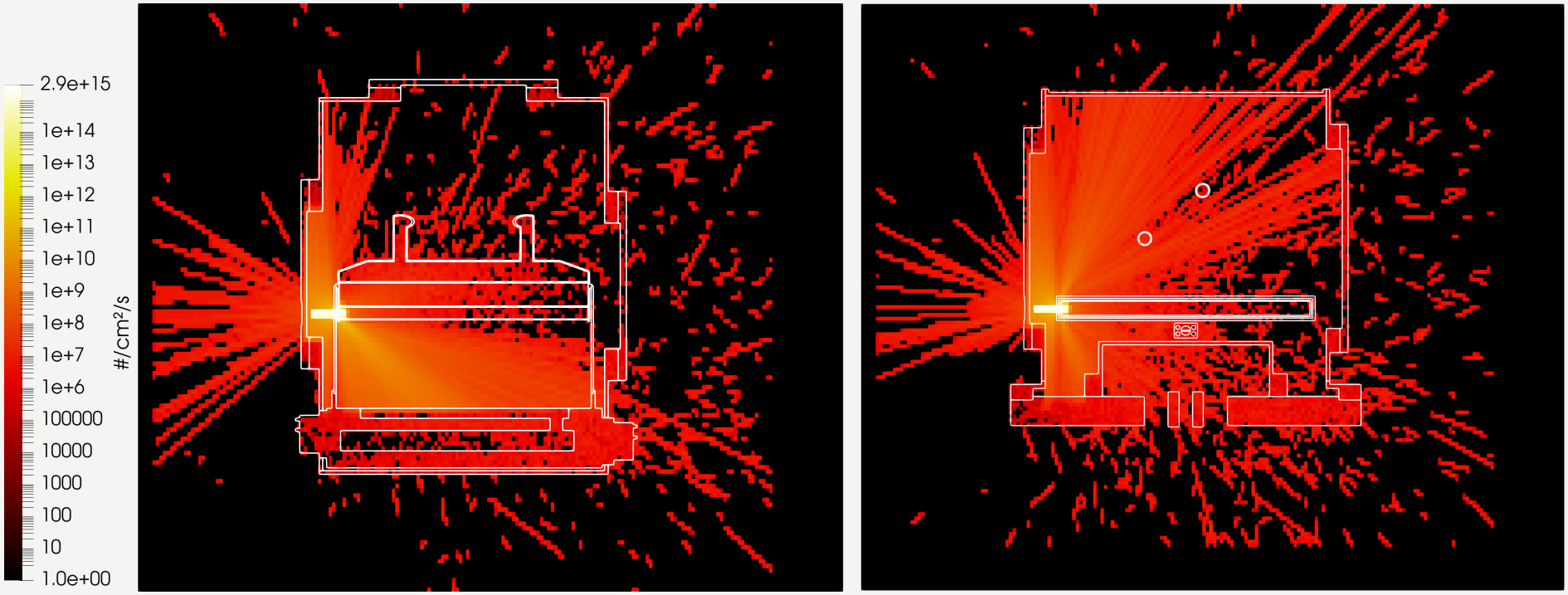
Cross sections

Nuclear reactions such as ^{208}Pb(p,n) or ^{208}Pb(p,gamma) have cross sections above 10 barns, so the reaction produces a broad spectrum of neutrons and gamma rays.

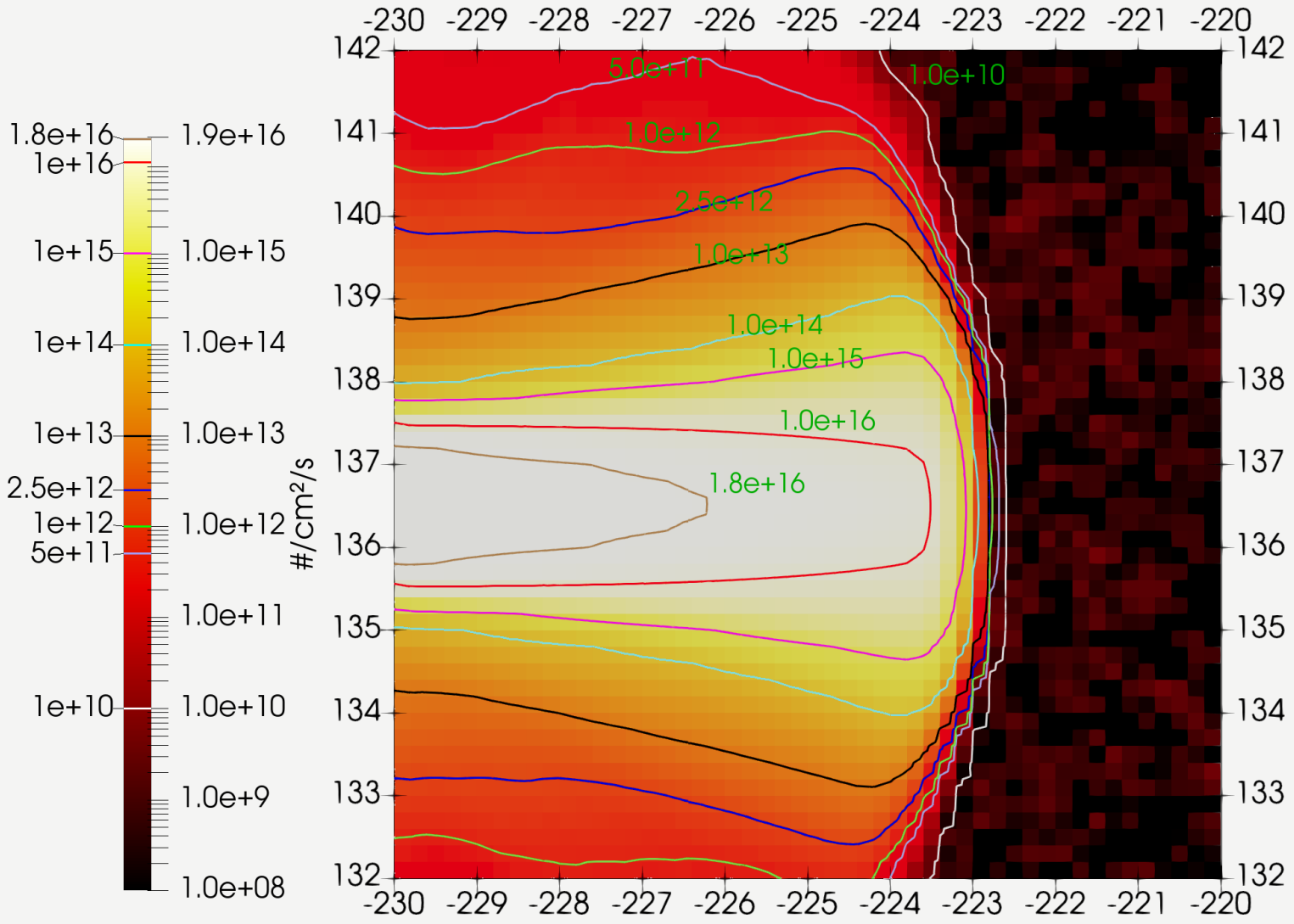


Proton flux in the target

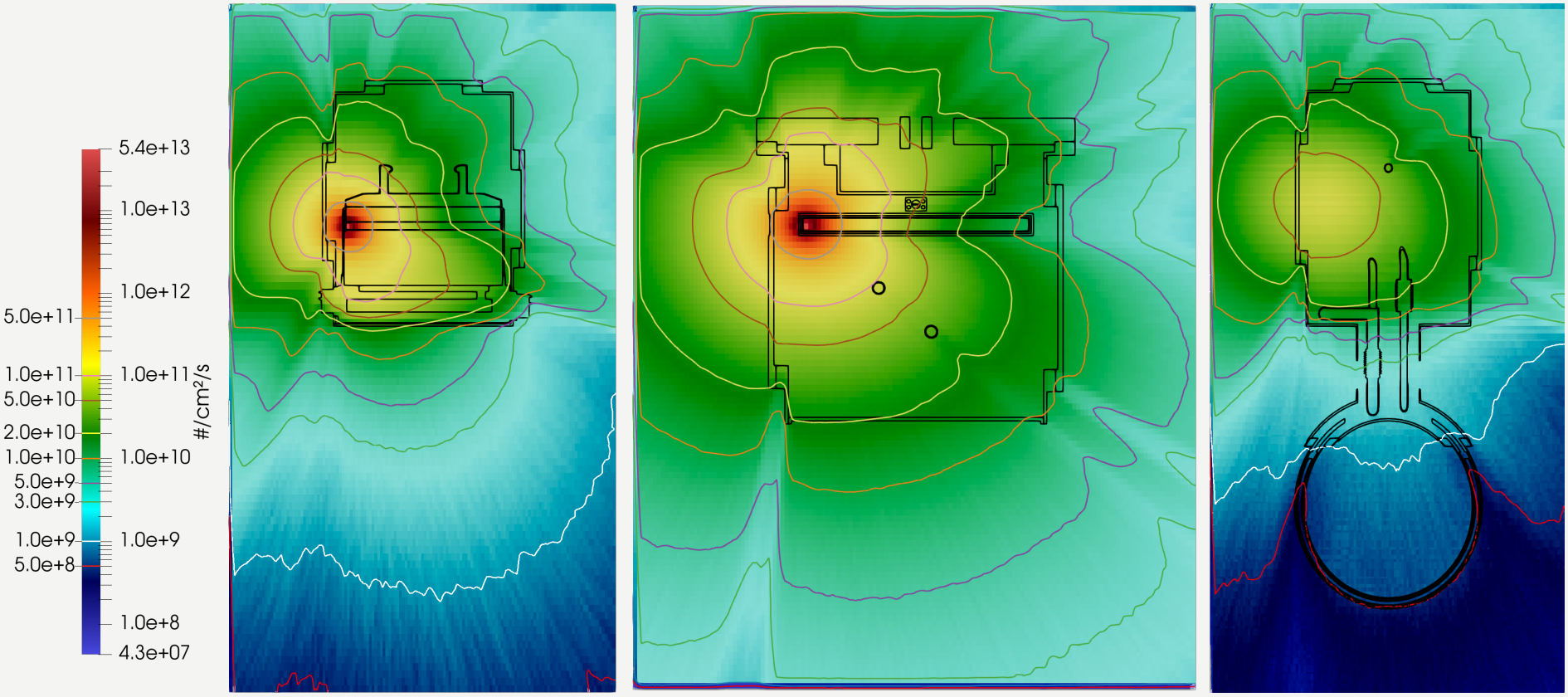
- MCNP Monte Carlo code, FENDL-3.1 cross-section data library, 10^9 number of histories
- $1\ \mathrm{mm}$ radii $70\ \mathrm{MeV}$ – $100\ \mu\mathrm{A}$ proton beam.



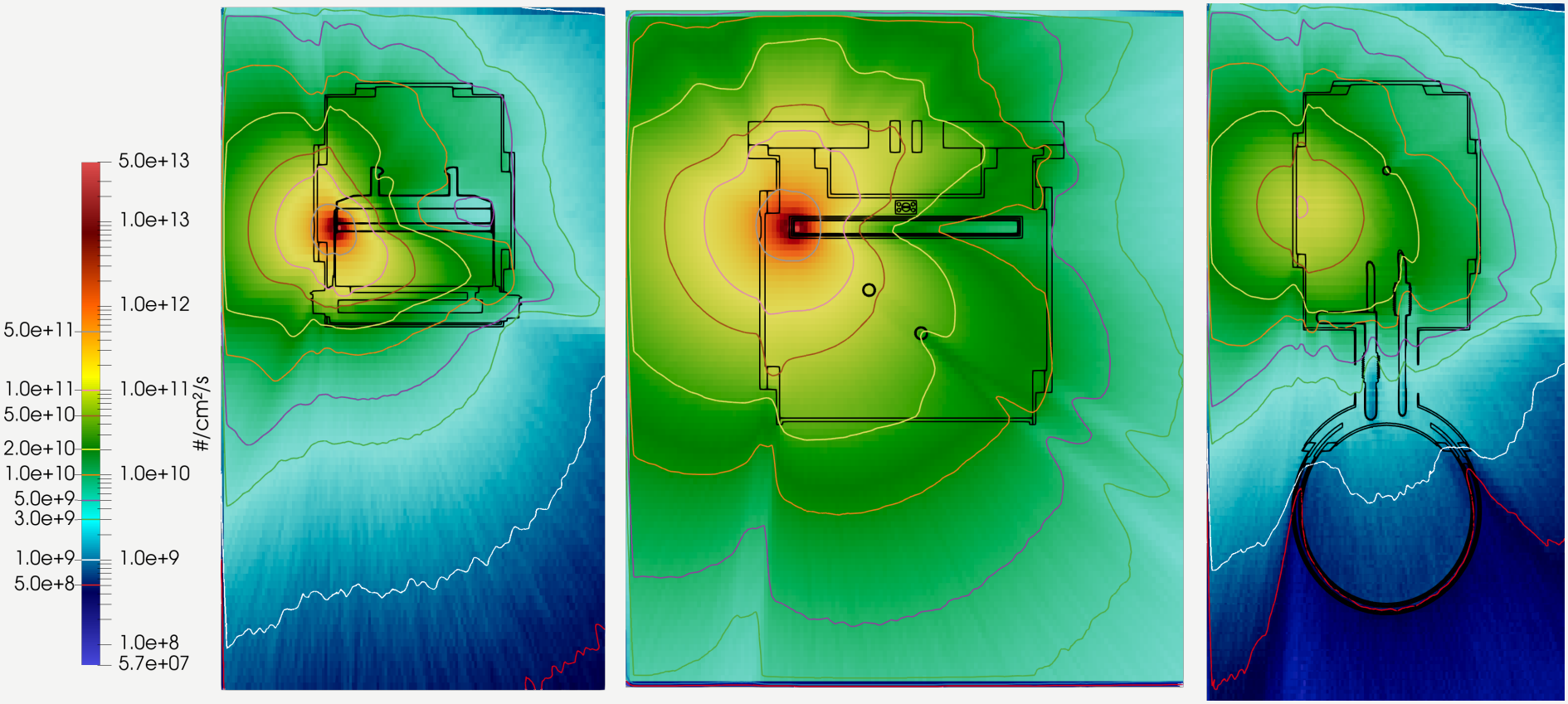
Proton flux in the target



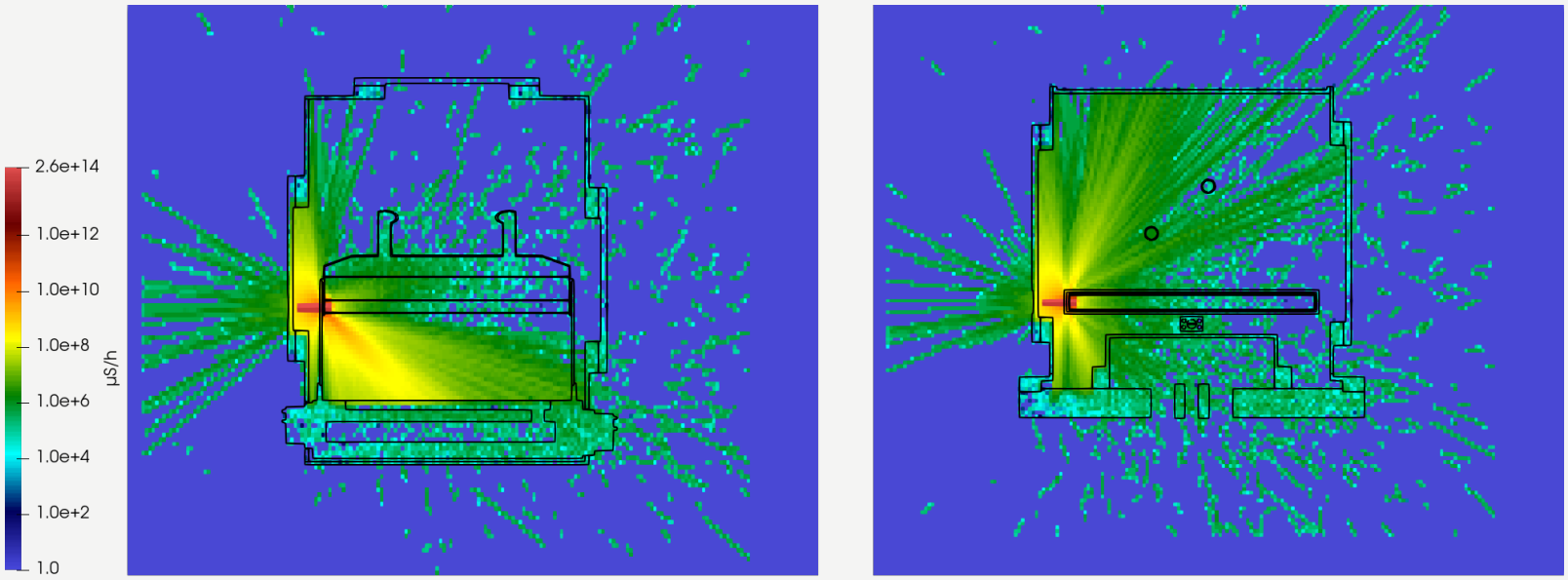
Neutron flux

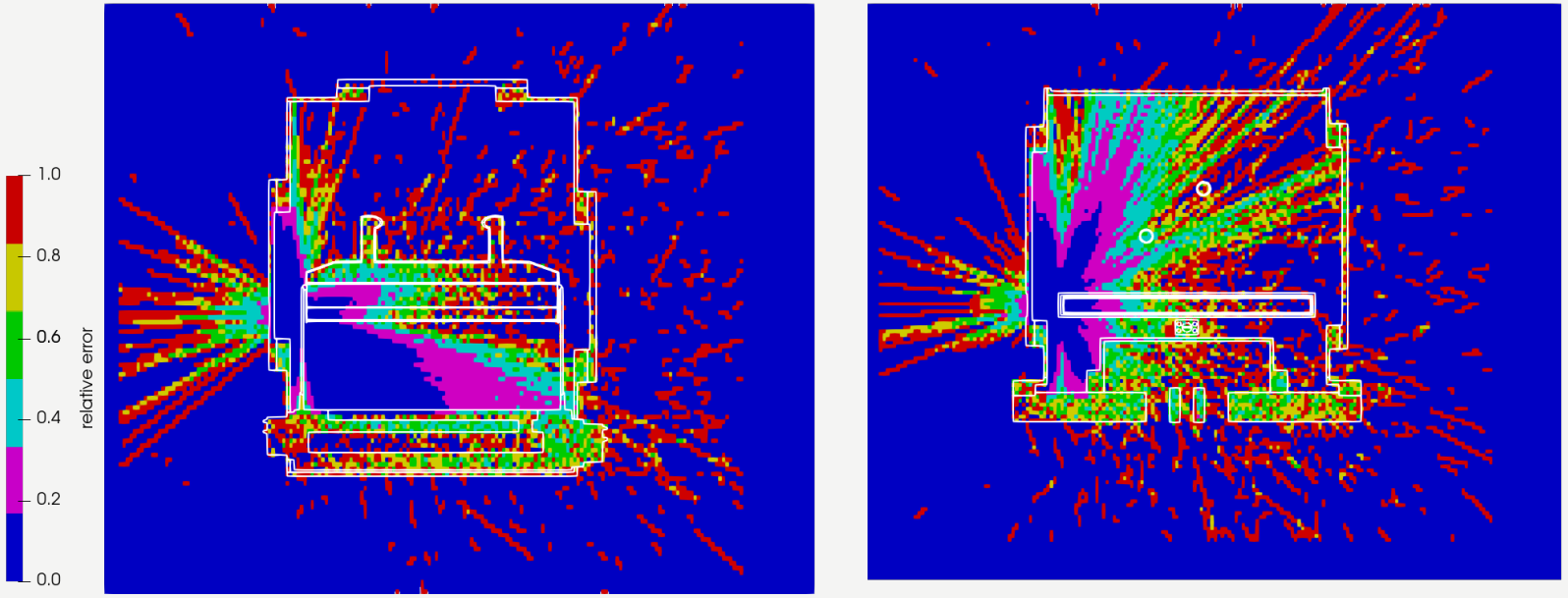


Gamma flux


5.0e+13
1.0e+13
1.0e+12
5.0e+11
1.0e+11
1.0e+11
5.0e+10
2.0e+10
1.0e+10
1.0e+10
5.0e+9
3.0e+9
1.0e+9
1.0e+9
5.0e+8
1.0e+8
5.7e+07
#/cm²/s

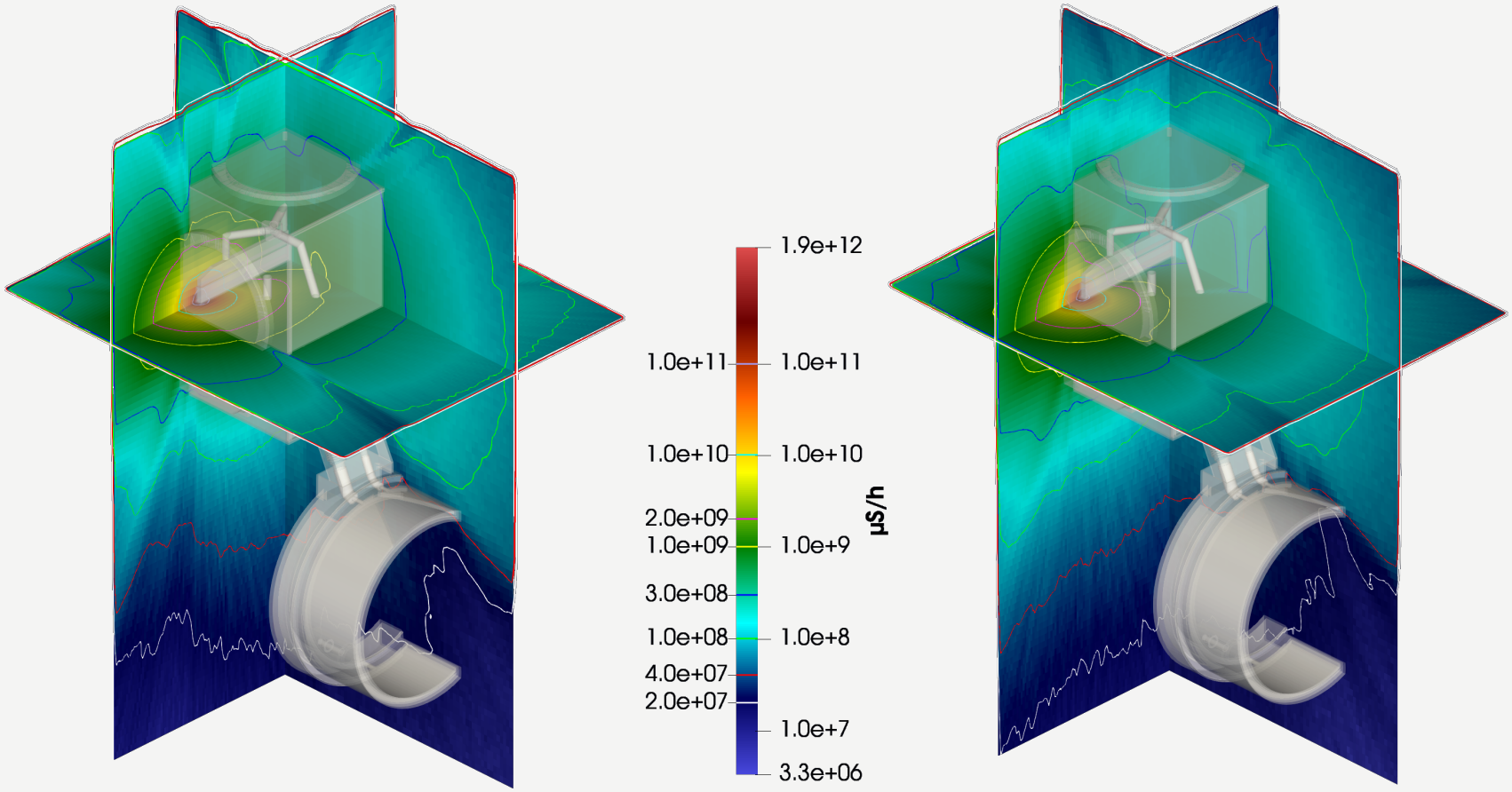
Proton induced dose rate map





Neutron and gamma induced dose rate distribution

Gamma and neutron dose rates there reach almost 2 MSv/h each. However, around the target dose rates are much lower, around 361 Sv/h for gamma rays and 214 Sv/h for neutrons.

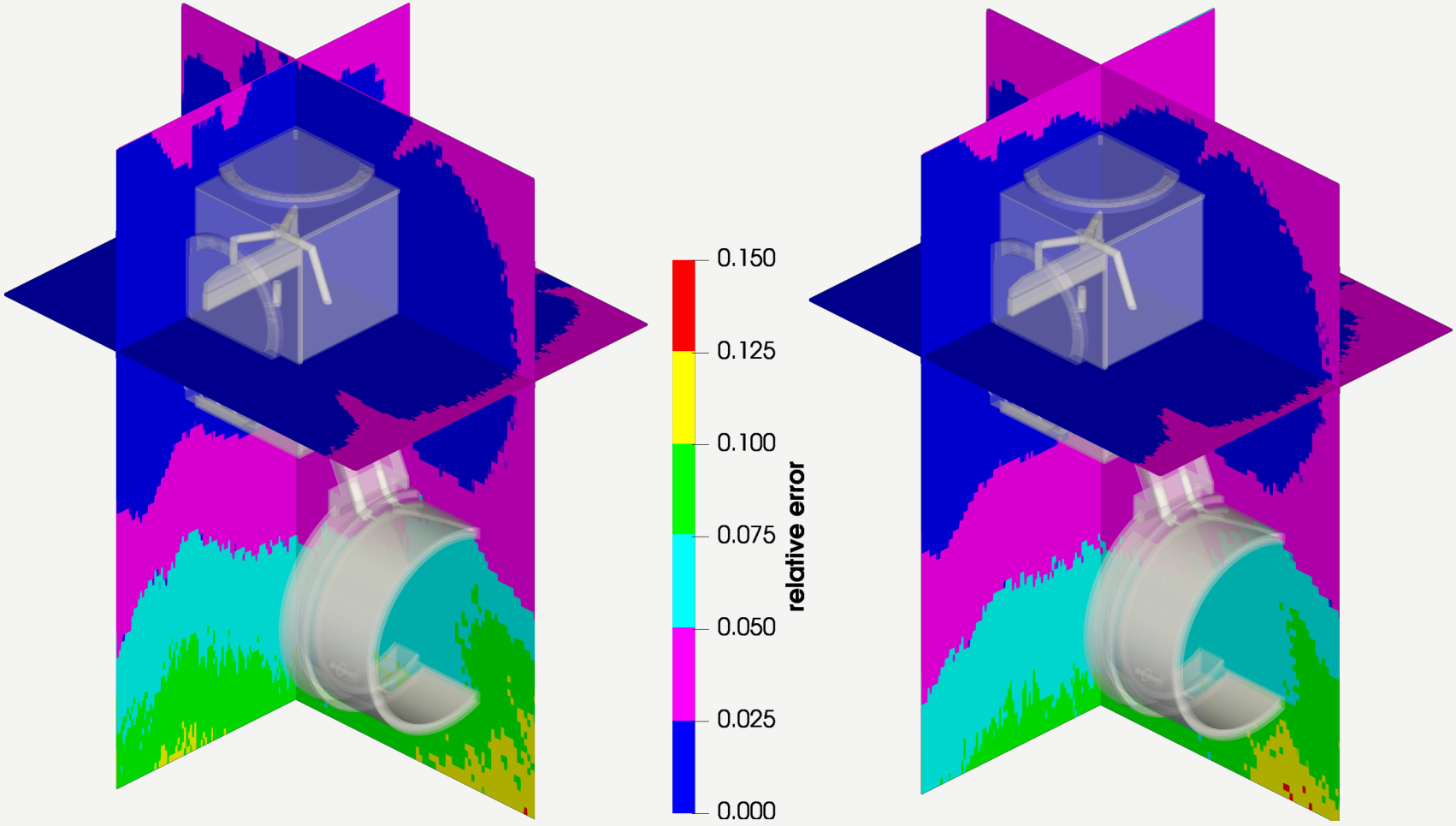


Neutron

Gamma

Neutron and gamma induced dose rate relative error

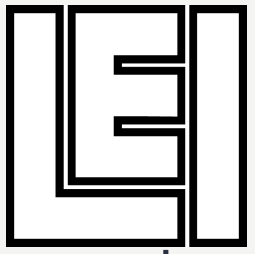
The maximum error for the dose rates reaches approximately 22 %.



Neutron

Gamma

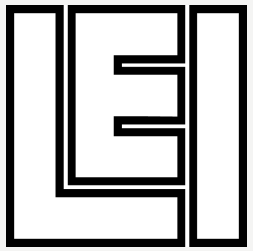
Conclusions



- The successful conversion of the LIEBE target to an accurate MCNP model.
- Successful MCNP simulations of the proton induced neutron and gamma flux around the target.
- From the distributions the maximum dose around the target is roughly 361 Sv/h for gamma rays and 214 Sv/h for neutrons. The monoenergetic 70 MeV – 100 µA proton beam penetrates roughly 7 mm deep in to the liquid eutectic lead bismuth.
- Obtained neutron distributions allow us to obtain the induced activities in the LIEBE target.
- Based on the obtained fluxes and dose rate maps further changes to the LIEBE target can be evaluated.

Future work

- Corrections to the MCNP input.
- Distributions at different proton beam energies and different target materials.



Thank you for your attention
Questions?