University of Stuttgart
Institute of Nuclear Technology
and Energy Systems

Generation of an Activation Map for Decommissioning Planning of the Berlin Experimental Reactor II

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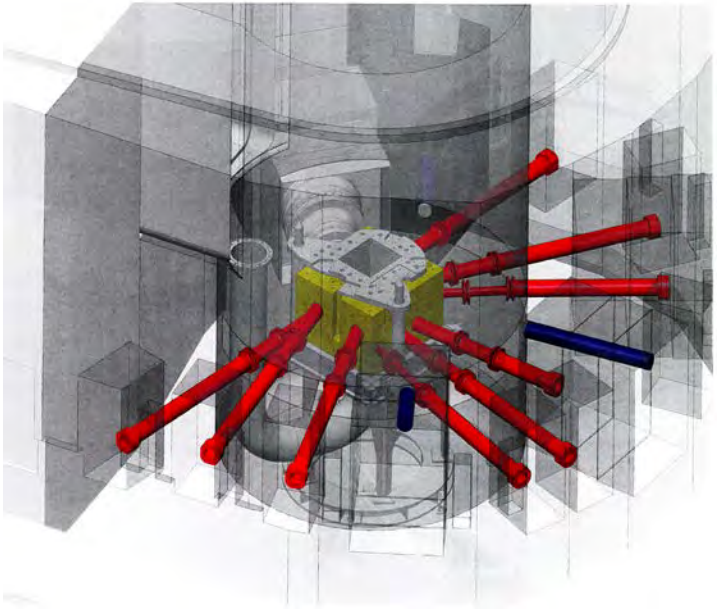
Outline

- Introduction Berlin Experimental Reactor BER-II
- Principal calculation method (combination of MCNP6, PARTISN, FISPACT)
- Model of the reactor in MCNP6 and PARTISN
- Assumptions for activation calculations and power history
- Validation of methodology for activation calculation by comparison with measured data for selected points and flux distributions
- Results: - neutron flux distribution
  - Examples of activation maps for several isotopes
- Summary and outlook

Berlin Experimental Reactor BER-II

- Research reactor (since 1991: 10 MW)
- Operation started in 1971 (5 MW)
- Planned decommissioning in 2019
- Water cooled pool-type reactor
- Core height: 60cm
- 30 fuel elements: - 24 FE with 23 plates
  - 6 FE with control rods and 17 plates



- **Task:** generation of activation map to support decommissioning planning
  - → challenging geometry due to numerous beam tubes and cold neutron source
  - → no use of cylindrical symmetry possible
  - → no use of Monte Carlo for neutron flux determination of the whole reactor due to poor statistics in outer concrete regions

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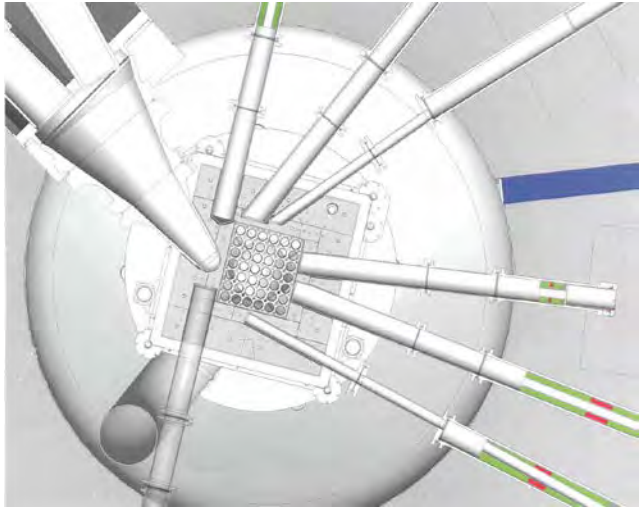

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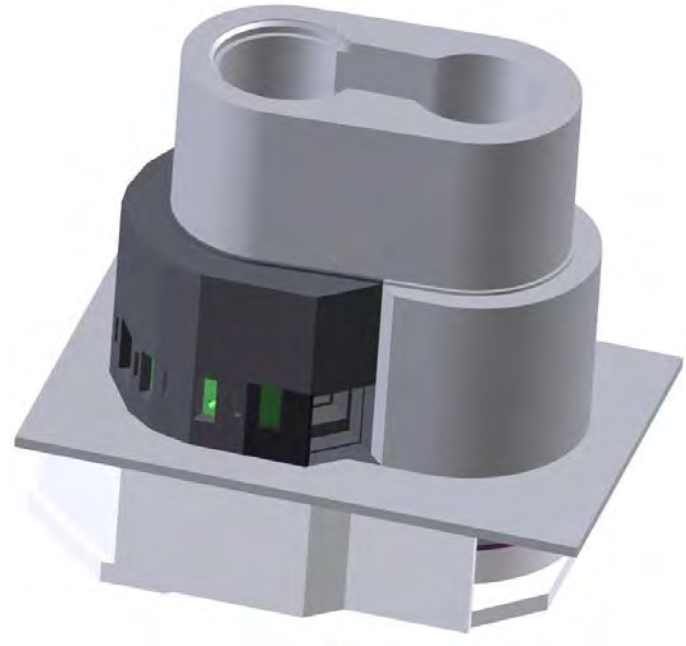

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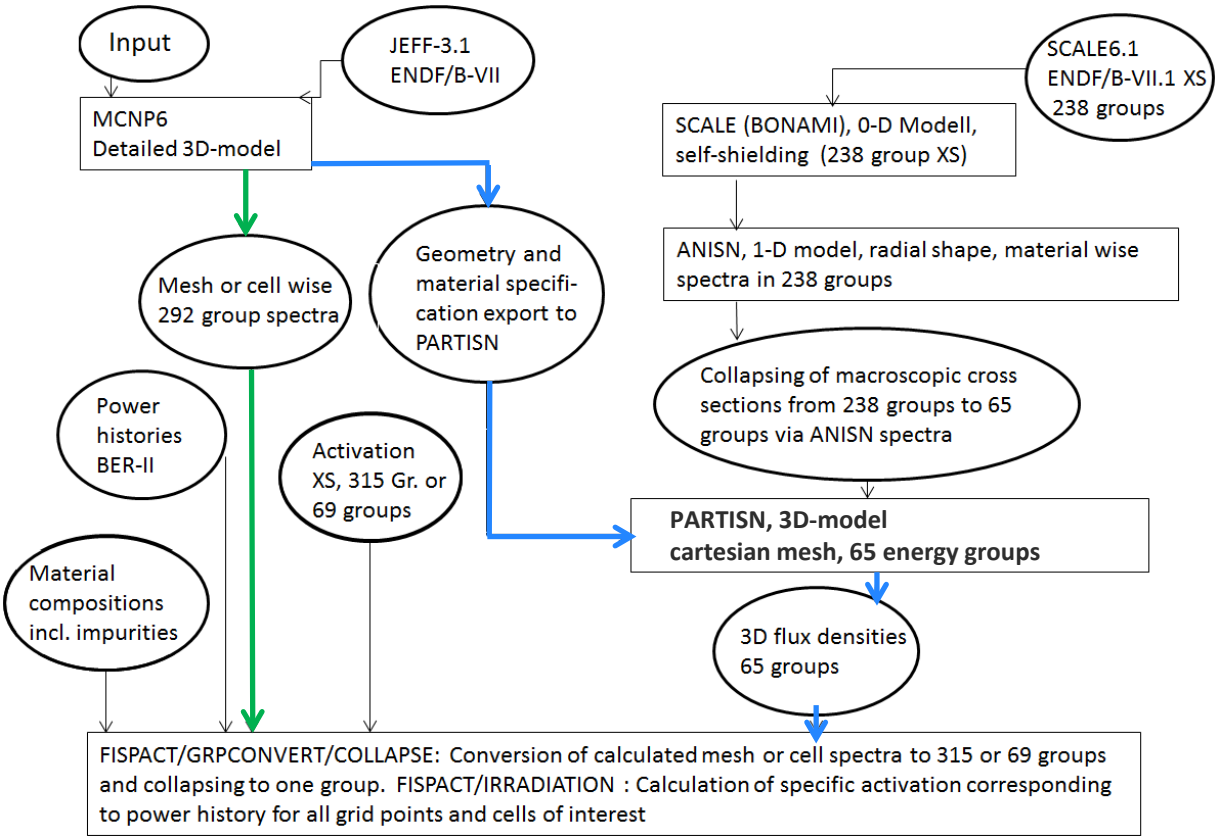
Method of calculation

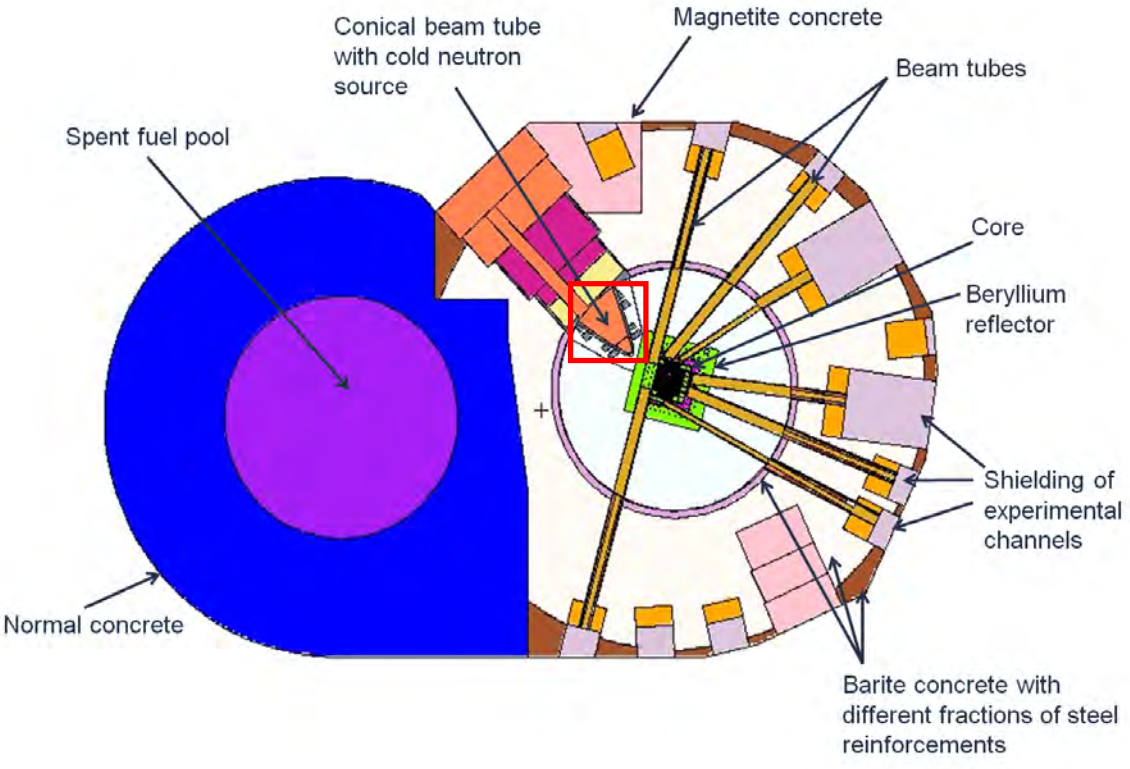
- MCNP6 and deterministic models in combination with FISPACT

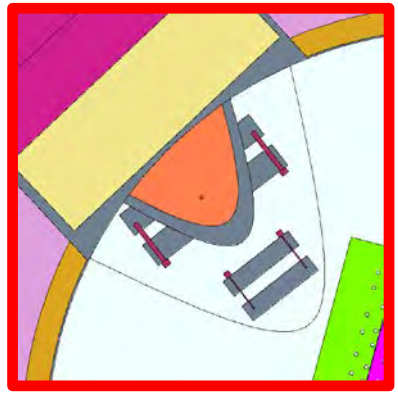


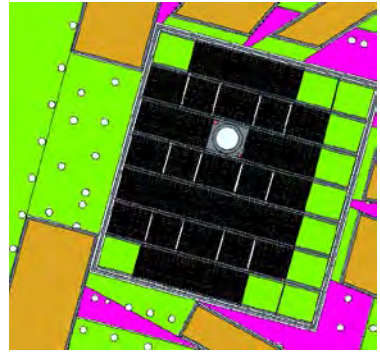
Validation and regions of interest

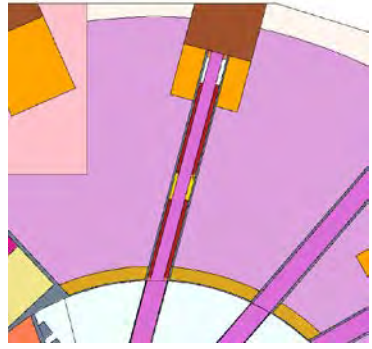
Full reactor calculation

Model of the reactor BER-II in MCNP6

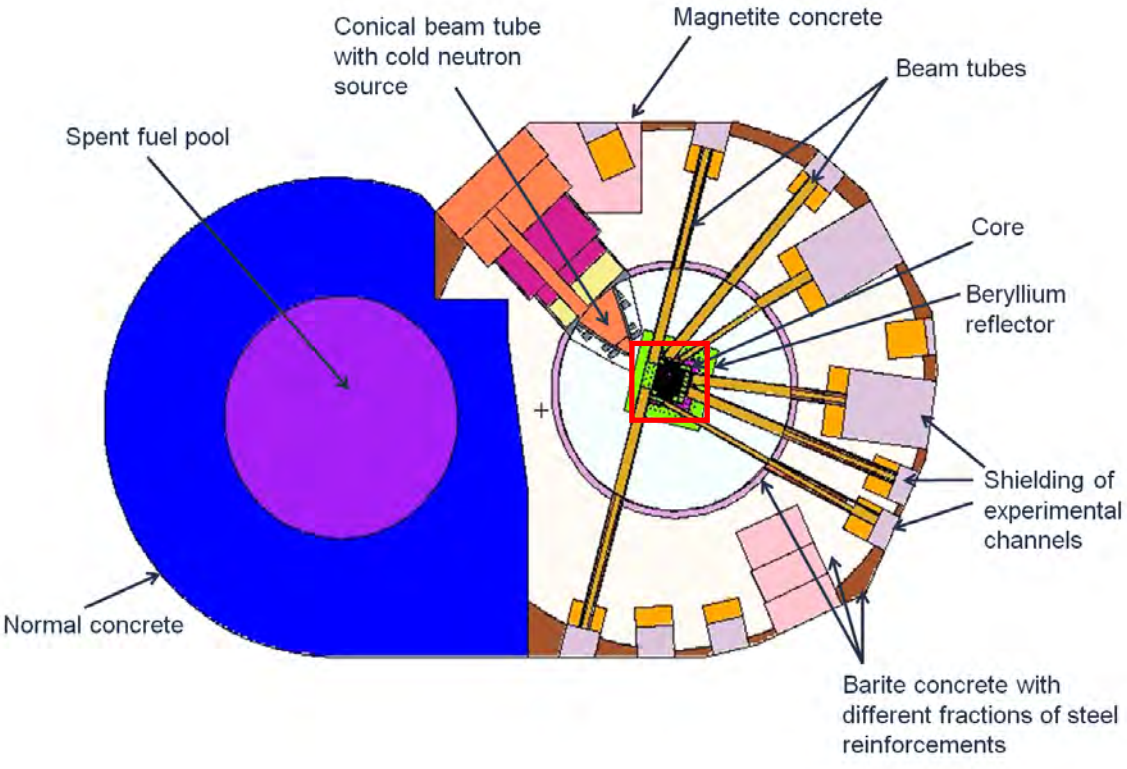


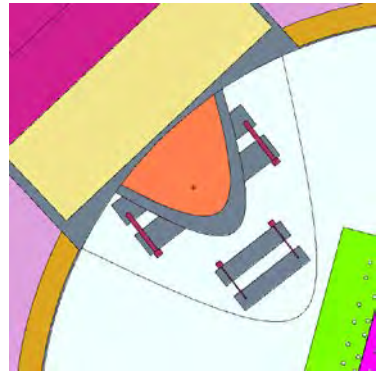


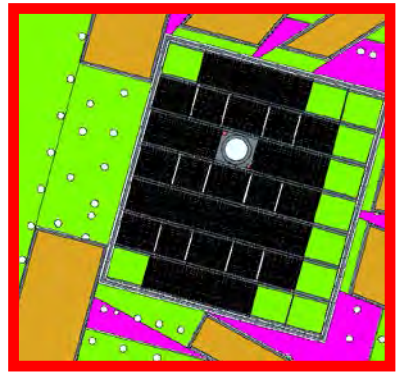


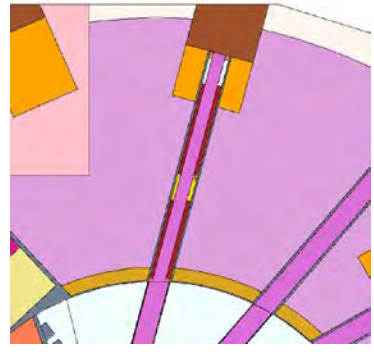


Model of the reactor BER-II in MCNP6









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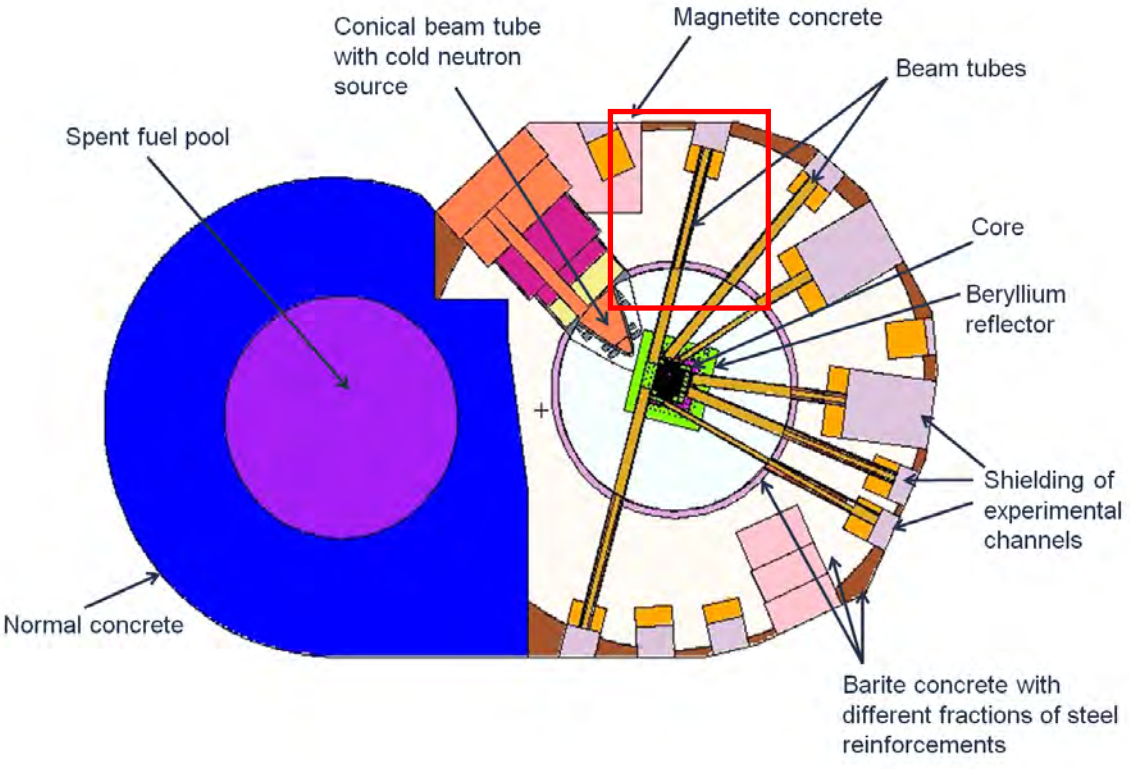
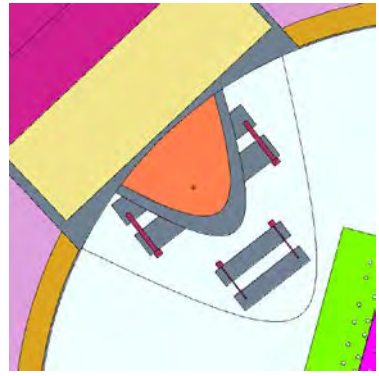
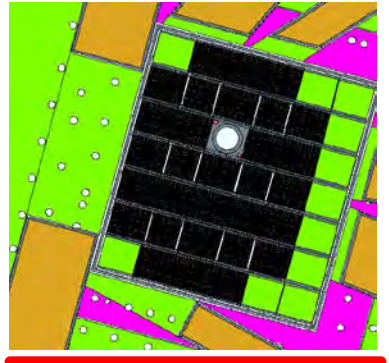
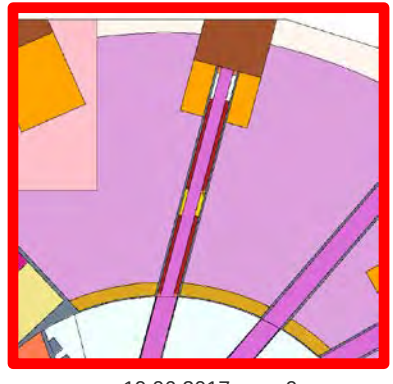


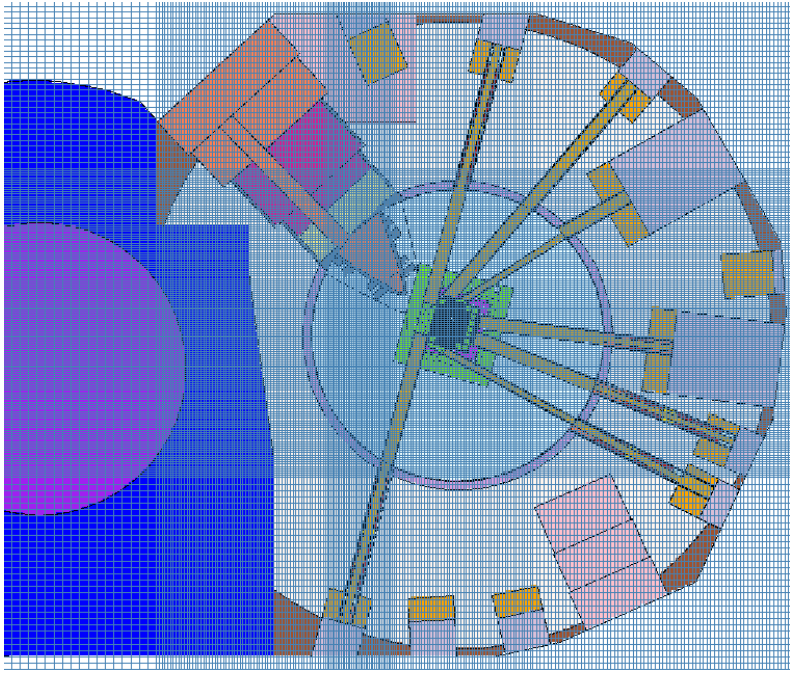




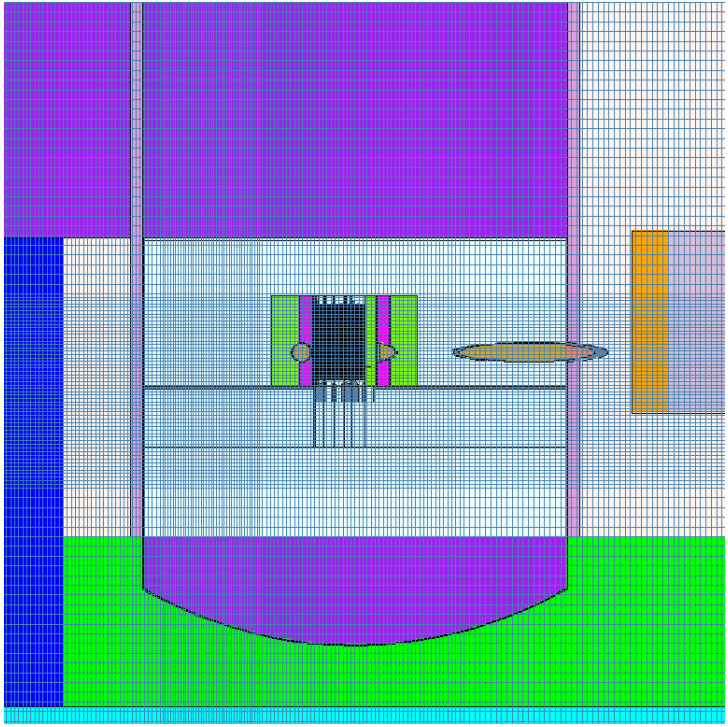


Model in PARTISN

- Mesh with 270 x 220 x 178 = 10 573 200 cells to generate PARTISN input
- S_N order of 32 for angular resolution
- 65 energy groups in macroscopic XS



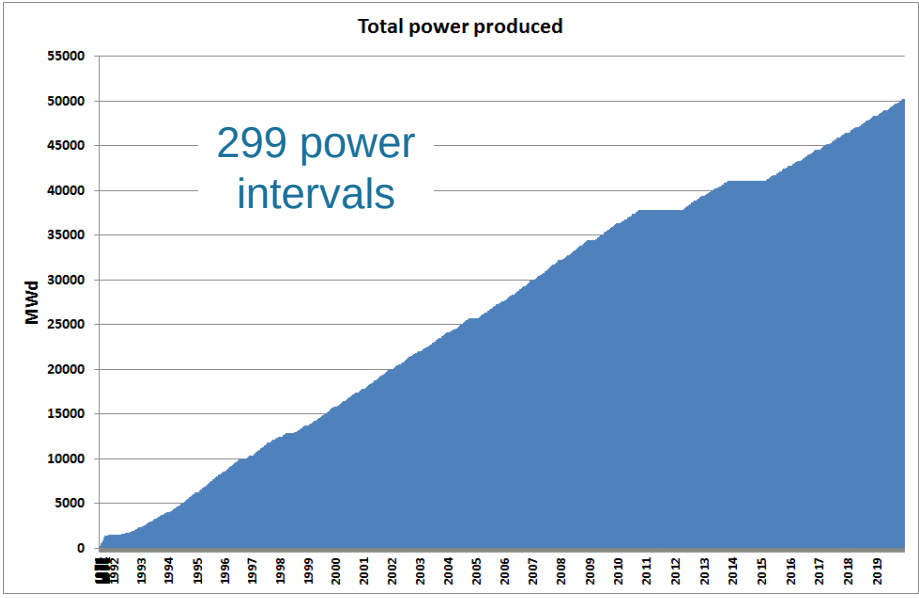
xy plane at core level



yz plane with cold neutron source

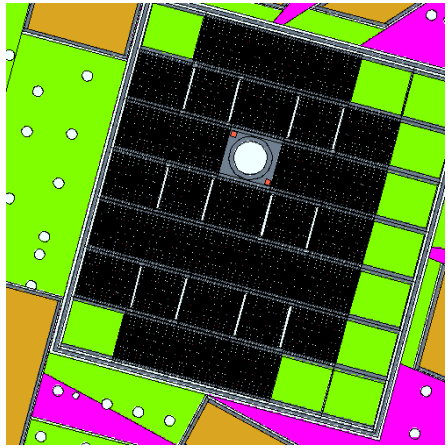
Power history

- 1974 – 1985: 5 MW power, annual intervals
- 1985 – 1991: Refurbishment to 10 MW, installation of conical beam tube
- 1991 – 2019: 10 MW power, weekly intervals
- Assumptions for activation calculation:
  - average burn-up
  - no rod movement
  - constant flux shape, just adoption of amplitude
  - 2017, 2018, 2019 operation periods like in 2016



Validation of activation calculation

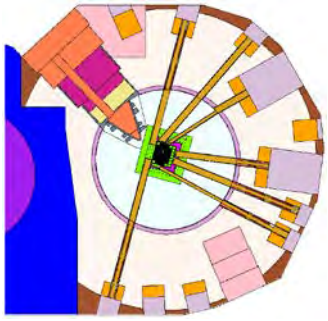
- Flux from MCNP6 cell tallies
- Uncertainties in material impurities influences results
- Exact position of screws unknown



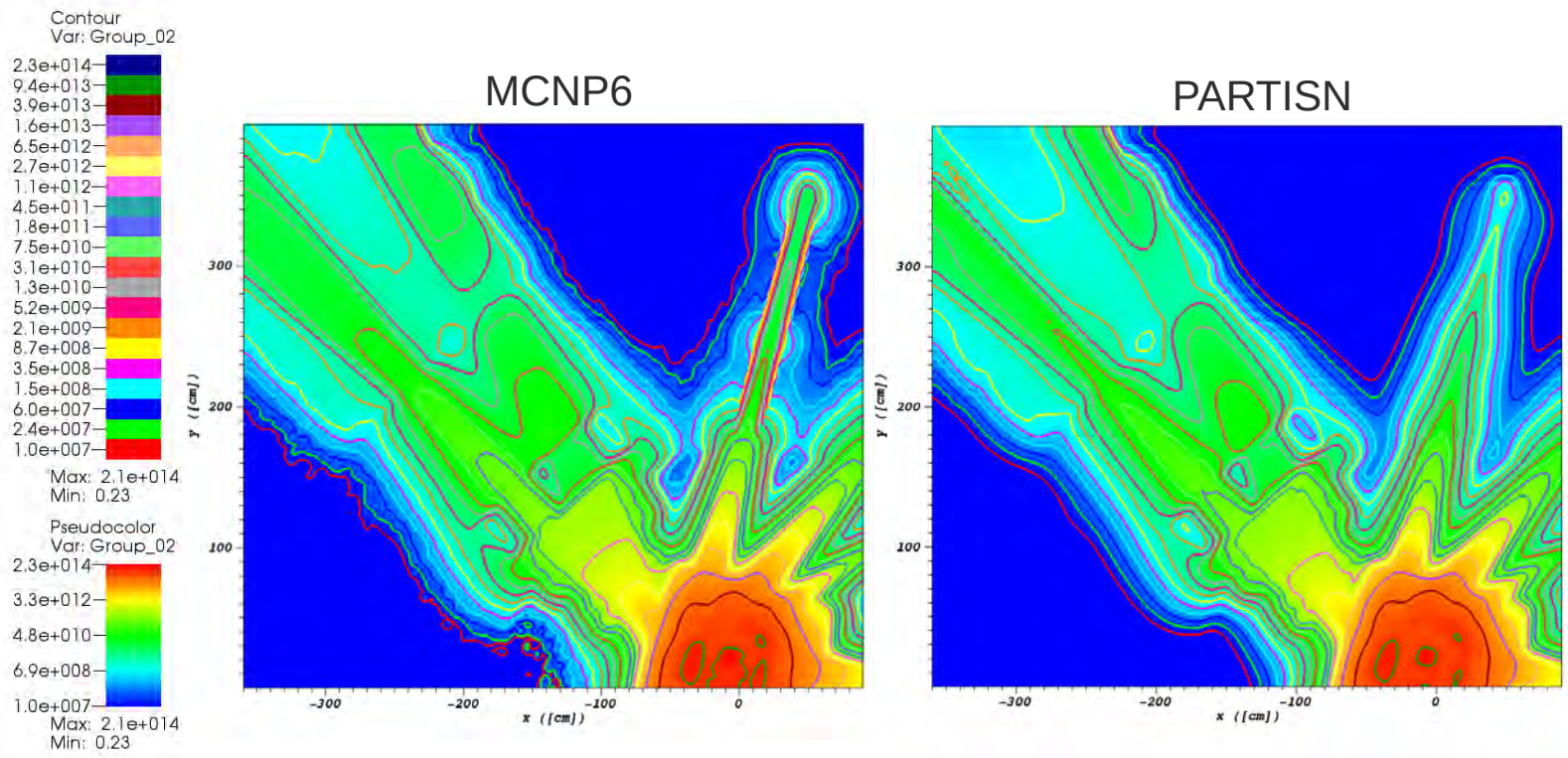
Activity of Co-60

Component	Position	Measured [Bq/g]	Calculated [Bq/g]
Screw nut (stainless steel)	Front flange	5.84E+07	3.81E+07
Screw nut (stainless steel)	Back flange	9.9E+06	1.12E+07
In-core irradiation tube (AlMg3)	In the core (C3)	2.4E+06	4.12E+06

Validation of PARTISN flux distribution

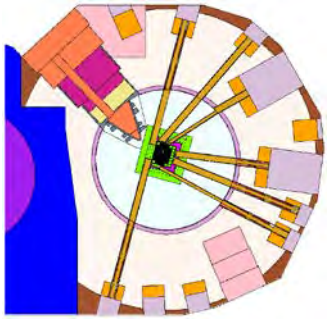


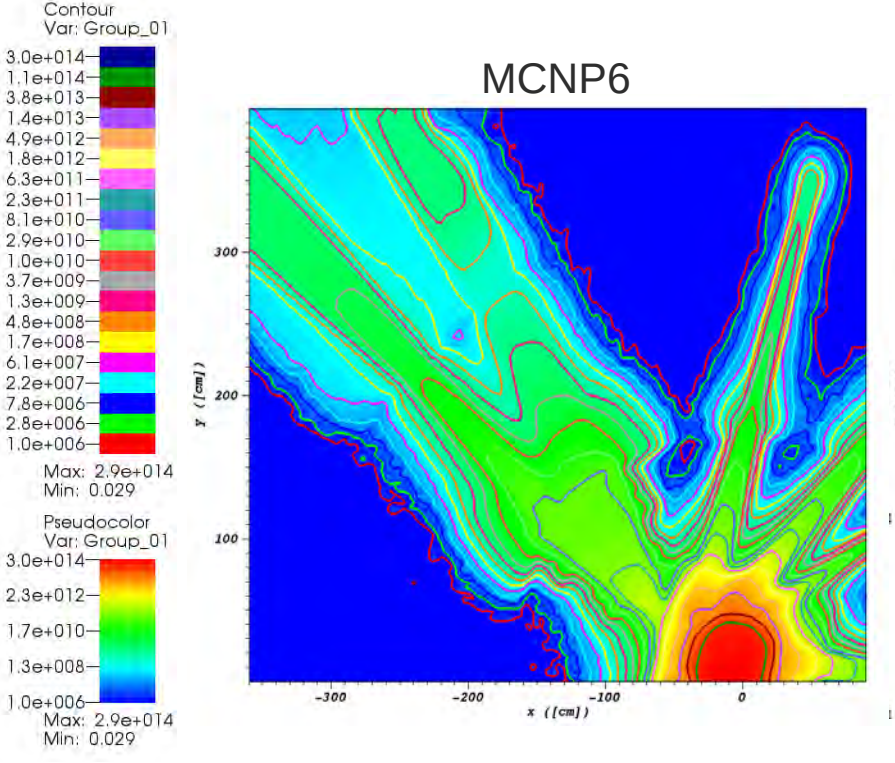
- Thermal flux calculated with MCNP6 and PARTISN at position of the cold neutron source



Validation of PARTISN flux distribution

- Fast flux calculated with MCNP6 and PARTISN at position of the cold neutron source





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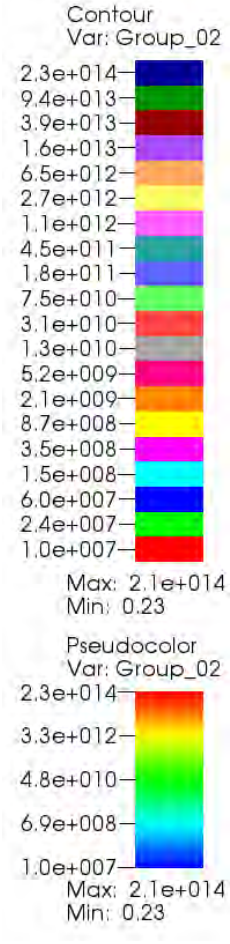

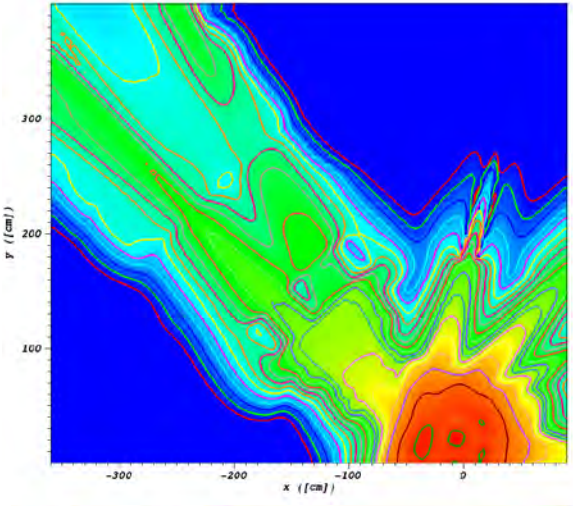

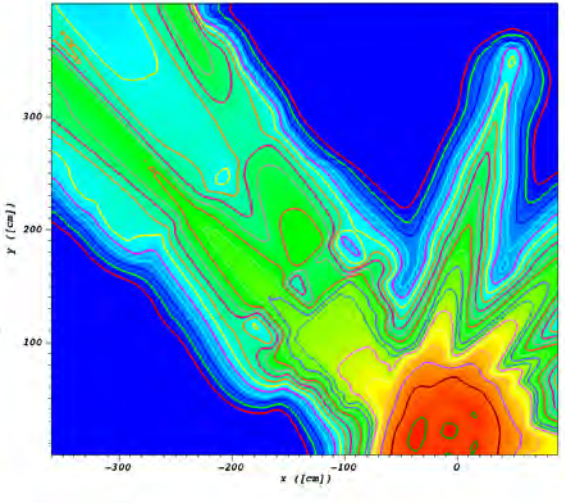

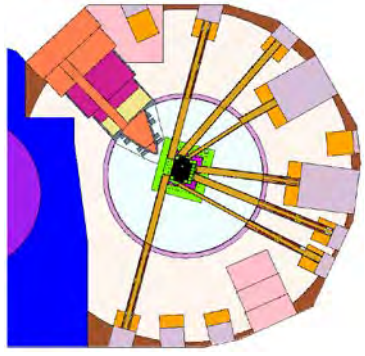

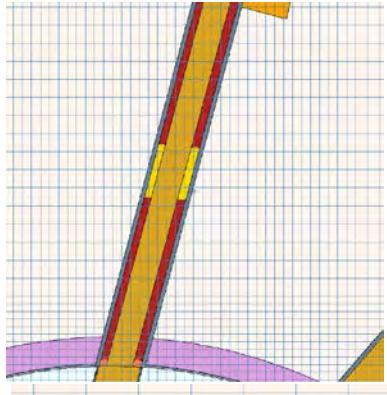

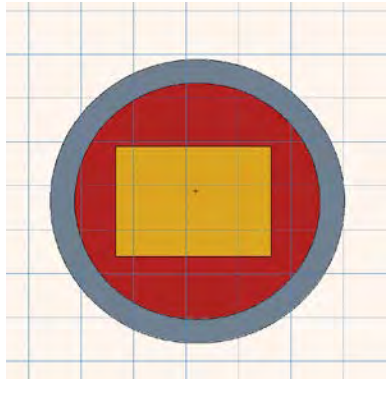

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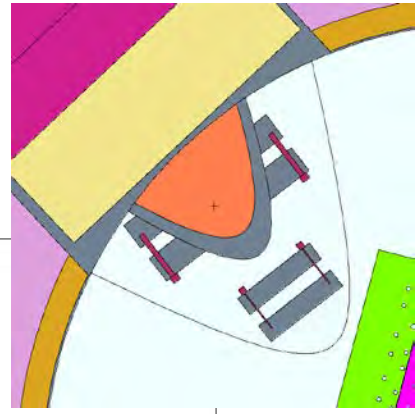
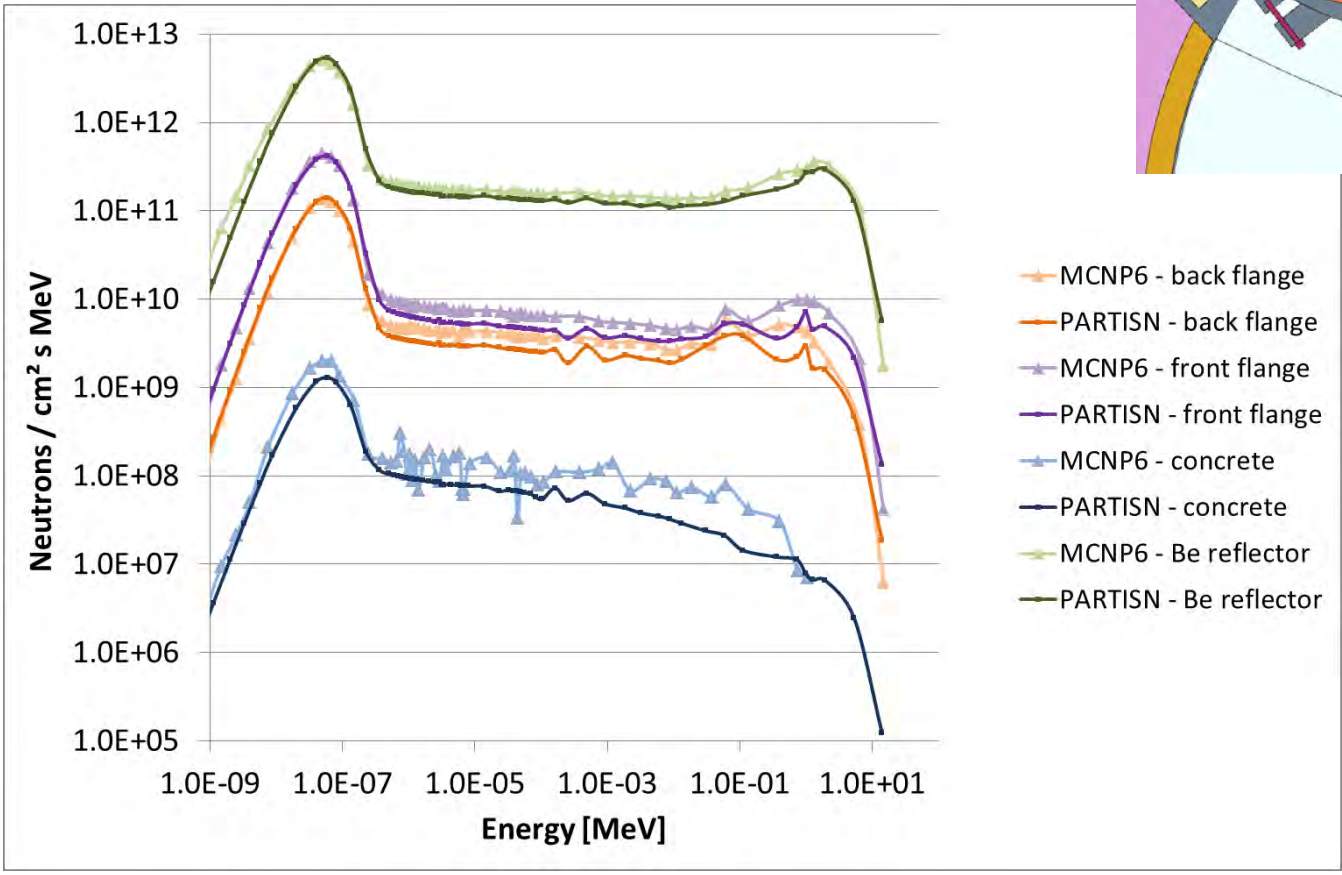
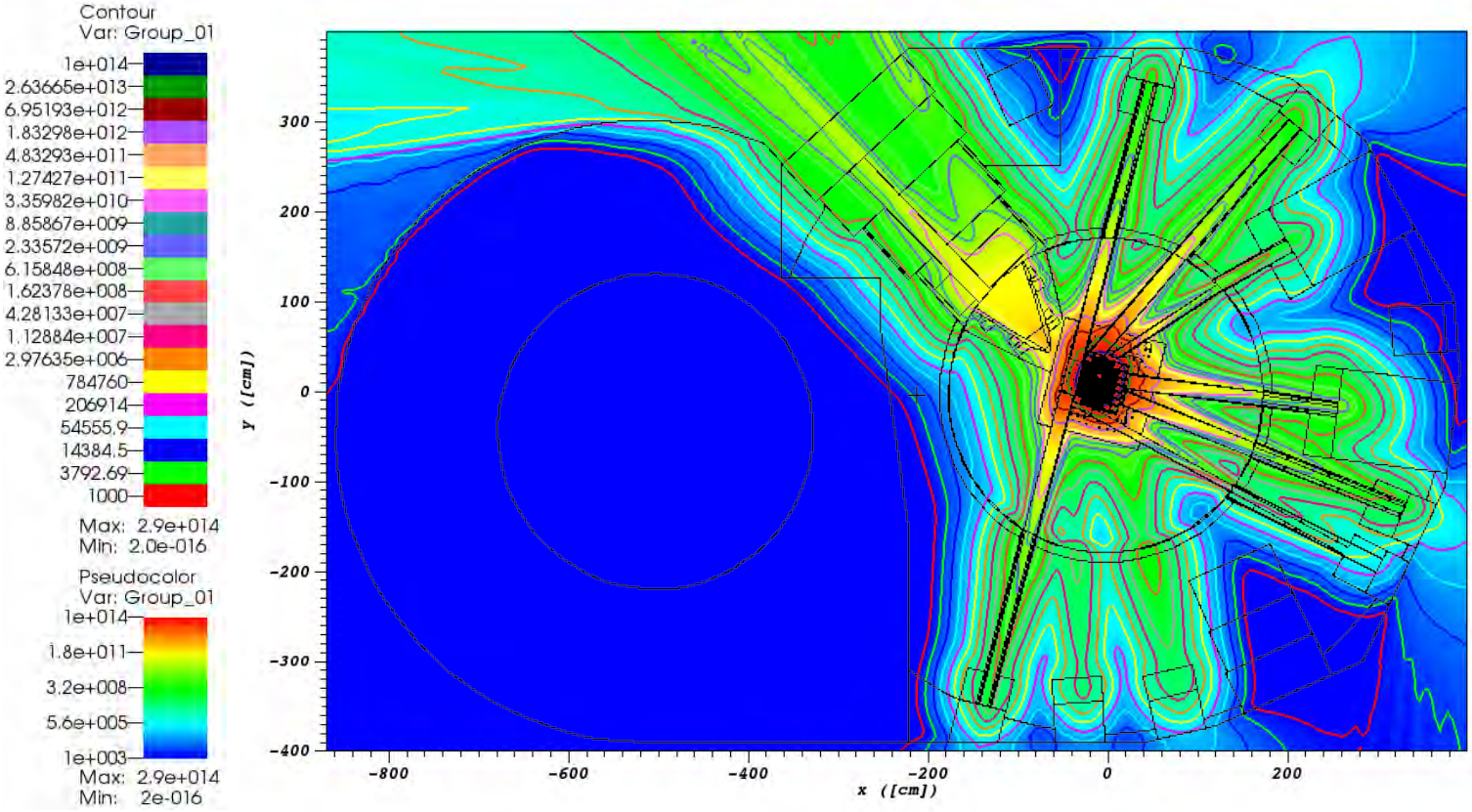




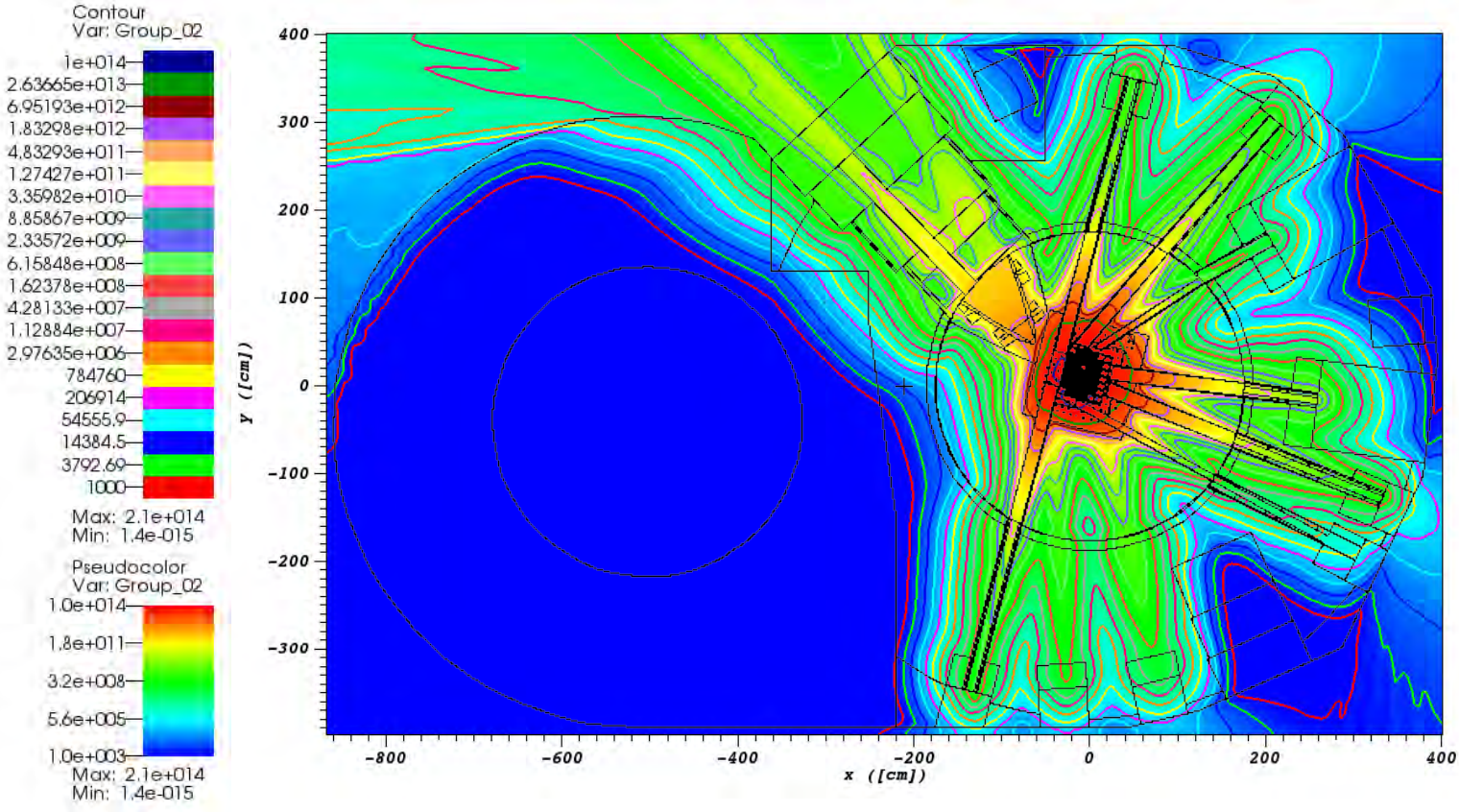
Results of neutron flux distribution with PARTISN

- Fast flux at the height of the 7 beam tubes

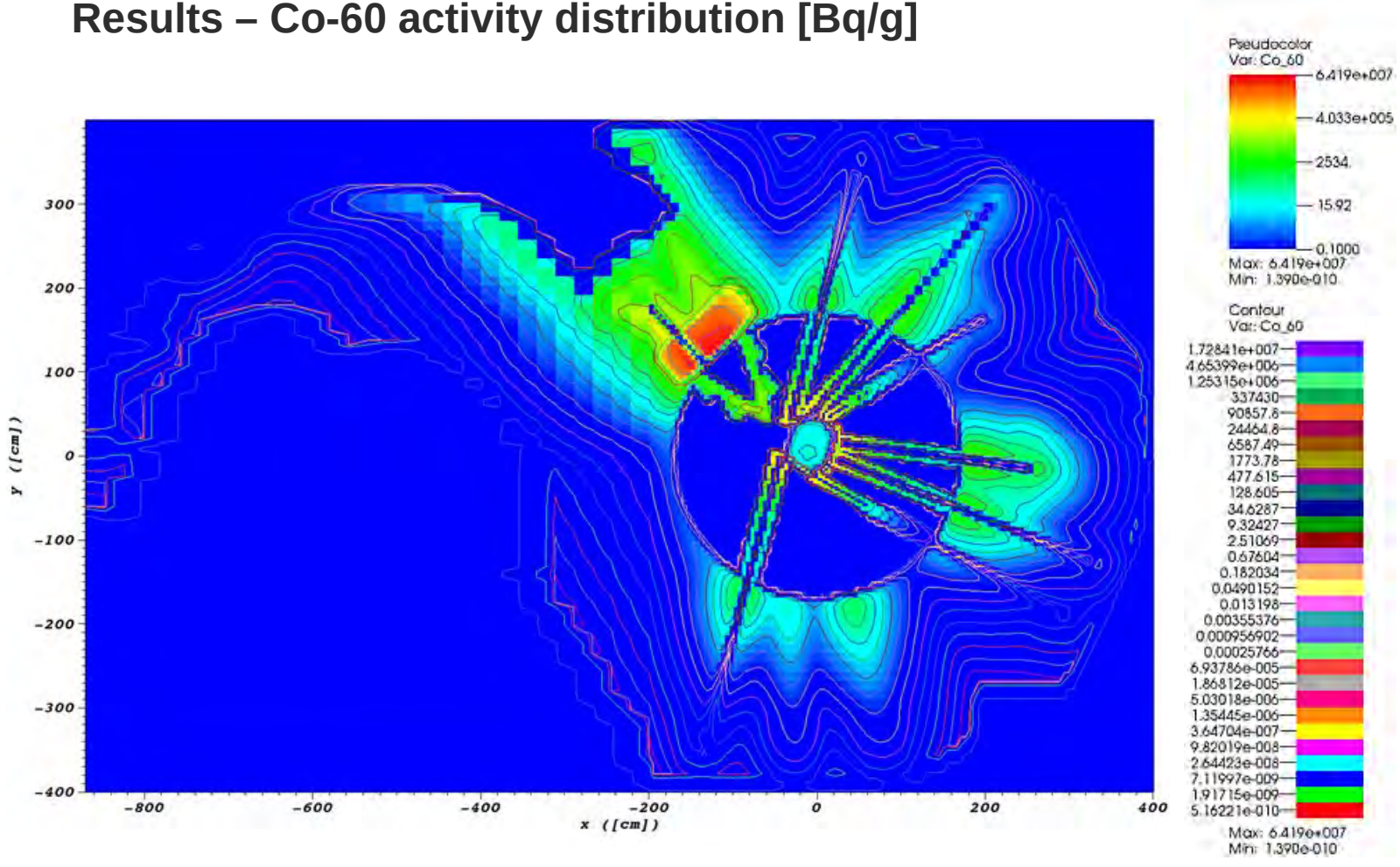


Results of neutron flux distribution with PARTISN

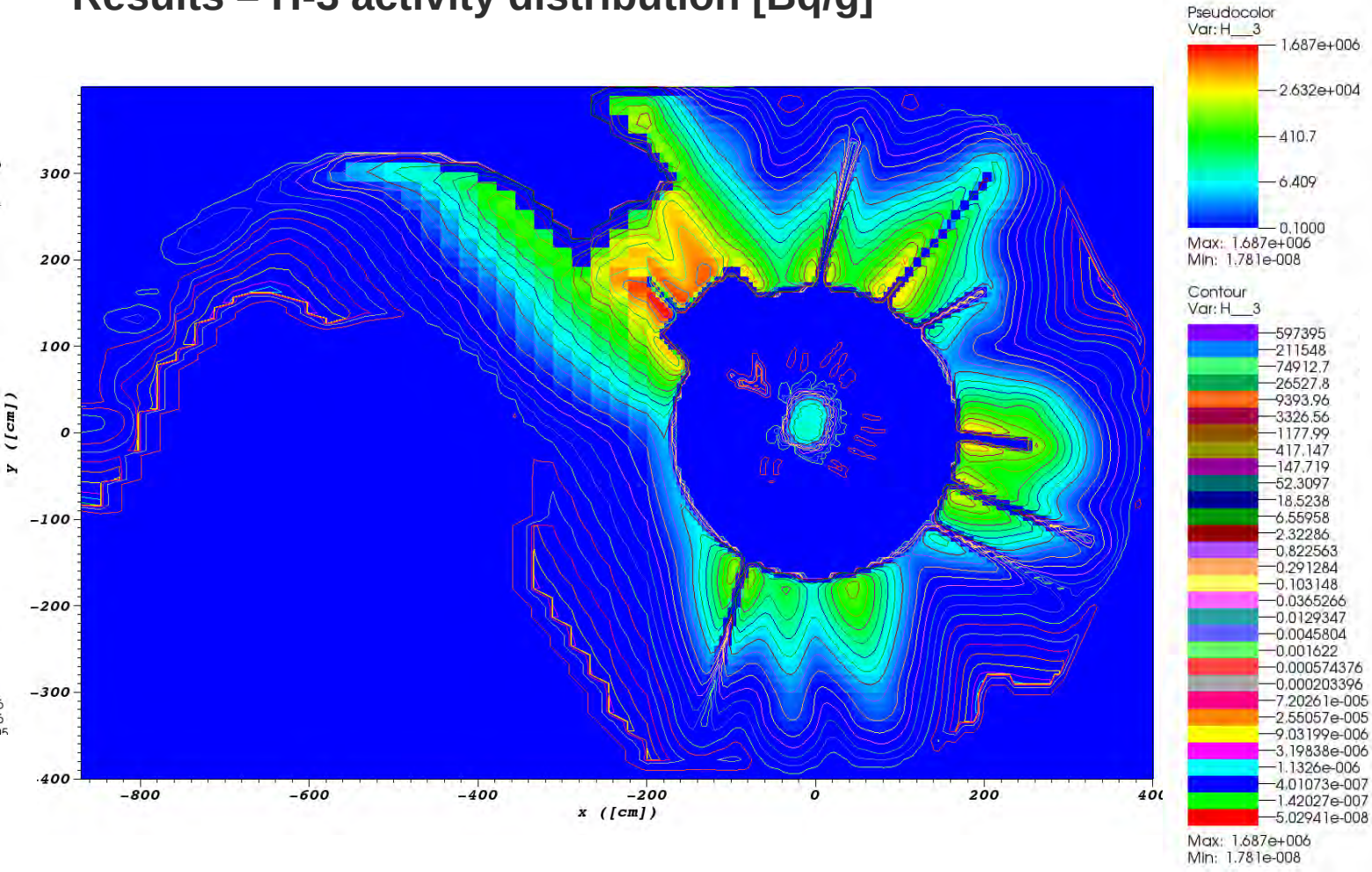
- Thermal flux at the height of the 7 beam tubes



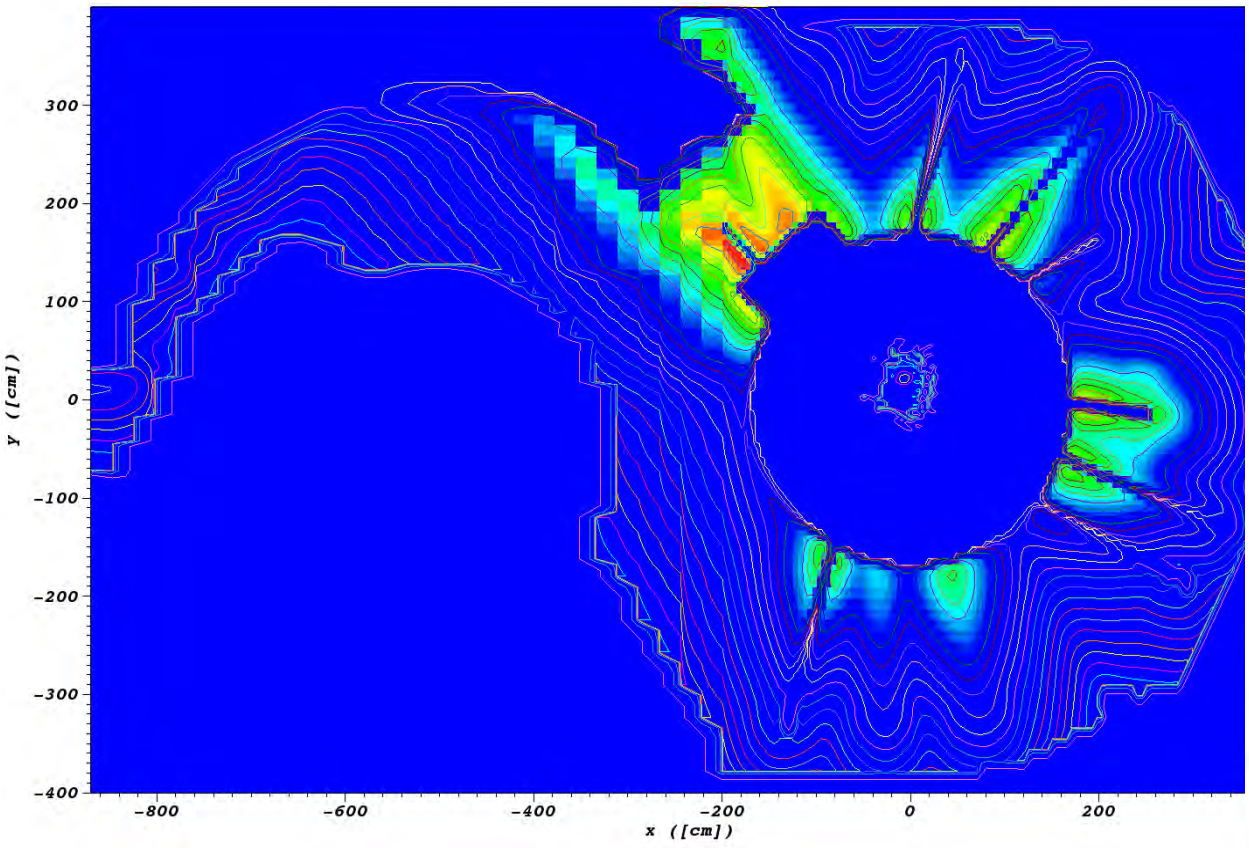
Results – Co-60 activity distribution [Bq/g]

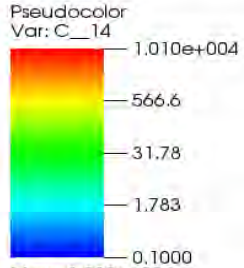


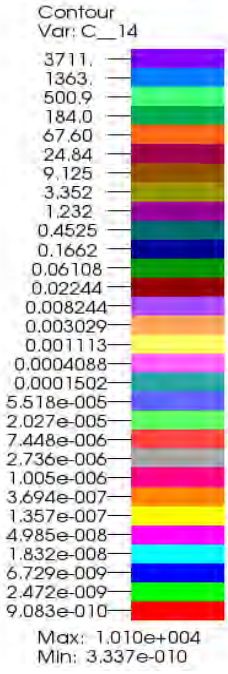
Results – H-3 activity distribution [Bq/g]



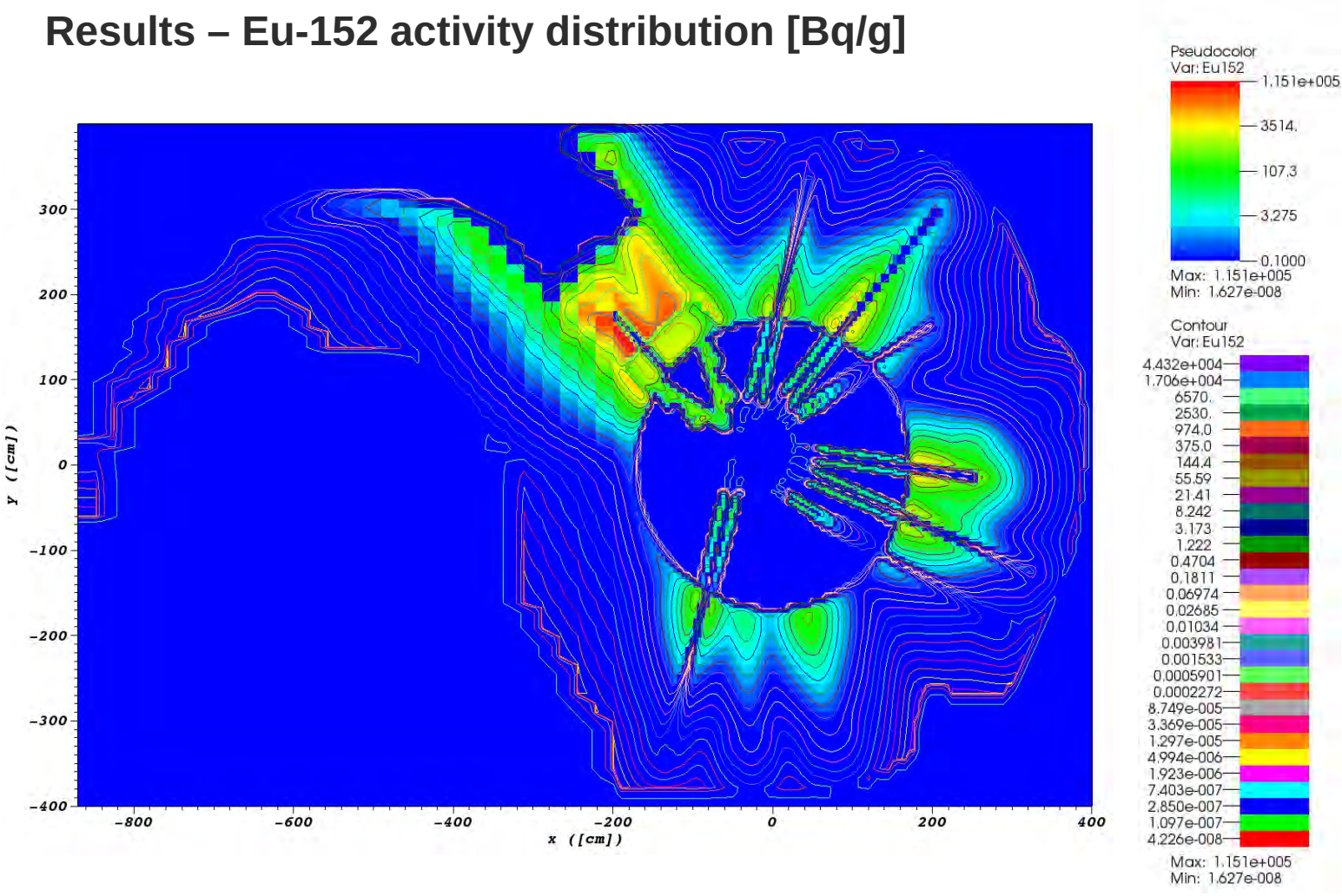
Results – C-14 activity distribution [Bq/g]





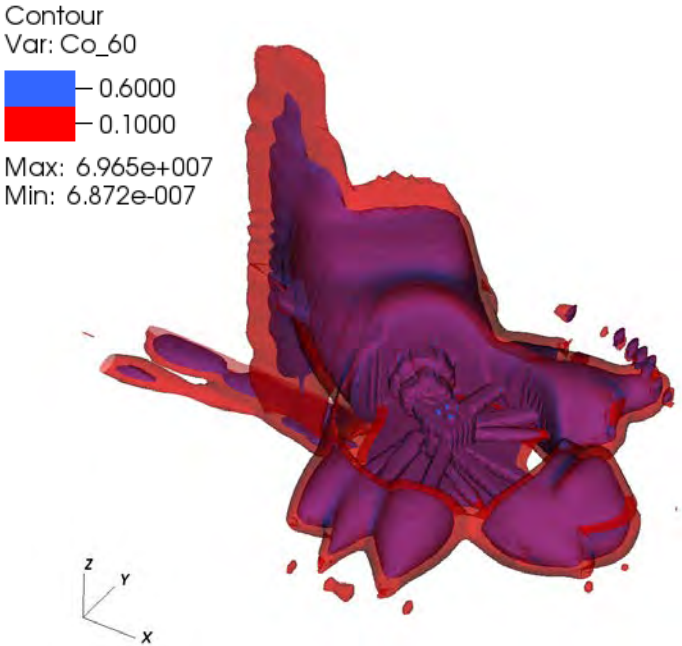


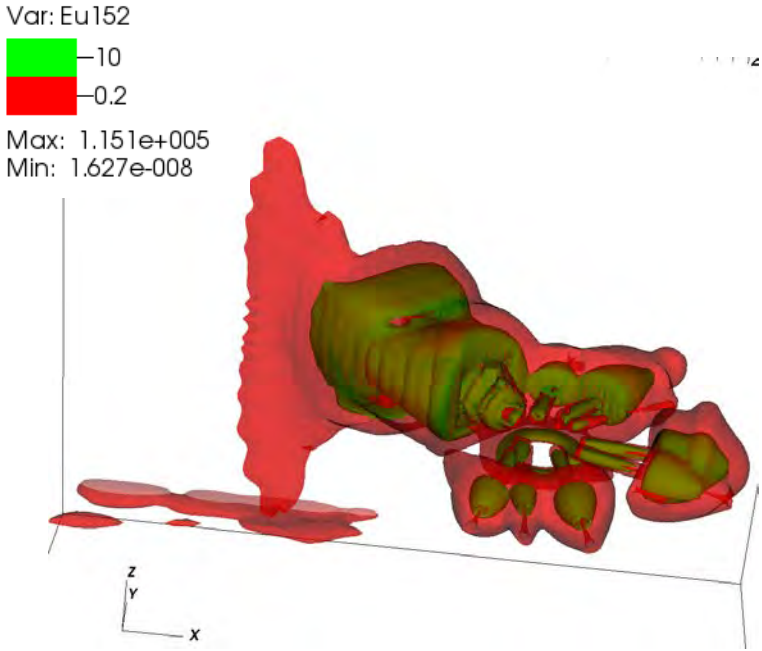
Results – Eu-152 activity distribution [Bq/g]



Results of activation calculations

- Generation of zone models showing regions with restricted waste disposal or regions with defined waste disposal paths for certain isotopes (from the German radiation safety regulations)





Summary and Outlook

- Coupled method of MCNP6 and PARTISN proves efficient to calculate neutron flux in remote regions of the reactor
- Activation calculation of probes in agreement with measurements
- Generation of activity maps covering the whole reactor for 11 nuclides in the concrete shielding (only four shown)

Ongoing work and planned activities:

> activation calculation for cold neutron source

> activation calculations for Beryllium reflector (recycling possible?)

> extend FISPACT-II to use it in parallel mode

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Thank you!

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