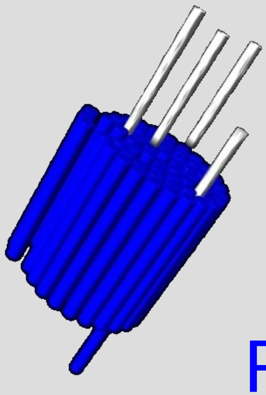
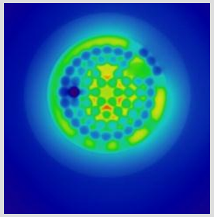
PRESENT SERVICES AT THE TRIGA MARK II REACTOR OF THE JSI





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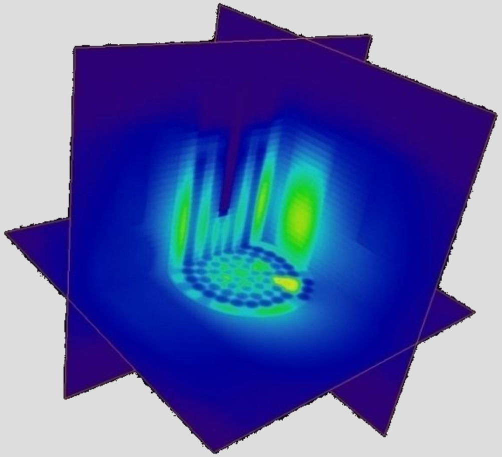
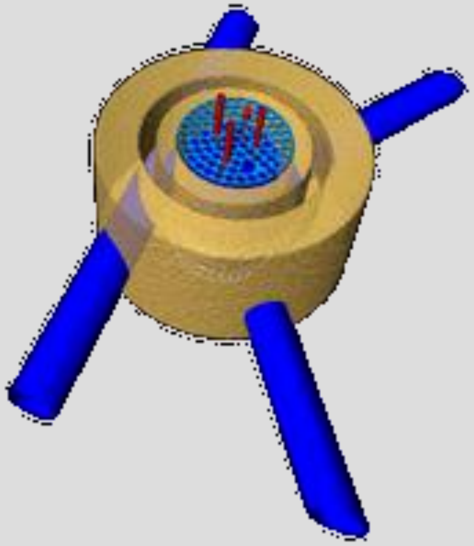




IAEA TM 38728
Vienna, June - July 2010

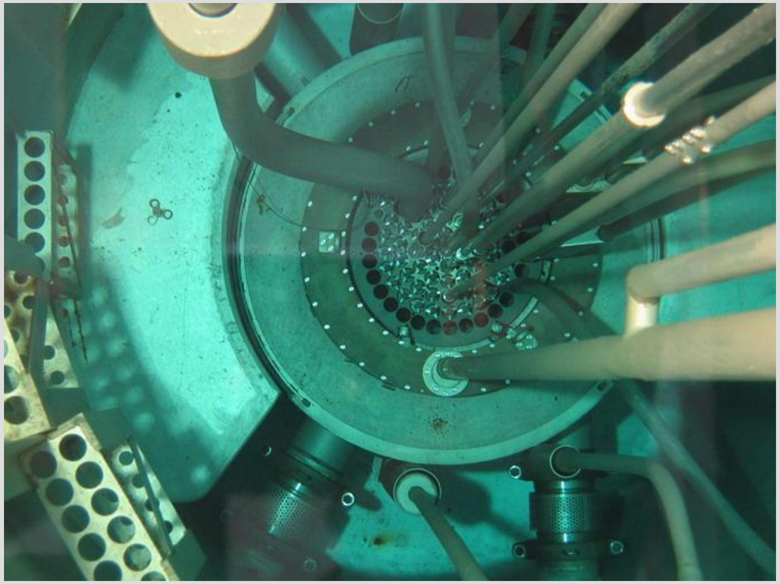
Outline

- Neutron activation analysis
- Irradiation of various samples
- Training and education
- Verification and validation of nuclear data and computer codes
- Testing and development of experimental equipment used for core physics tests at the Krško Nuclear Power Plant (digital reactivity meter)
- Conclusions

JSI TRIGA reactor

- Research reactor used for:
  - **T**raining
  - **R**esearch
  - **I**sotope production
- Manufactured by
  - **G**eneral **A**tomics
- Main advantages:
  - simple design
  - inherently safe
  - easy to operate
  - reletively cheap

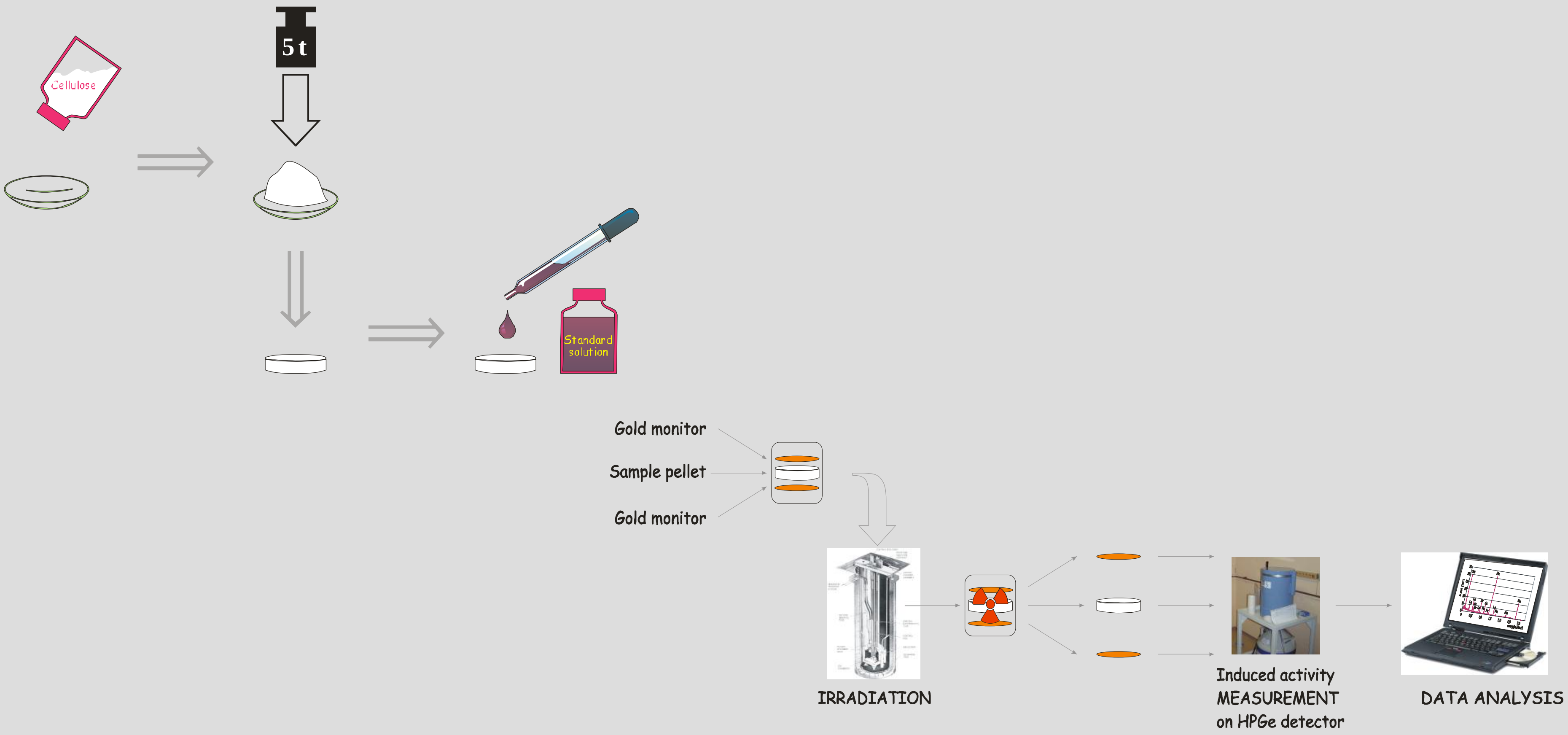
TRIGA Mark II at Jozef Stefan Institute, Ljubljana, Slovenia (max. power ≈ 250 kW)



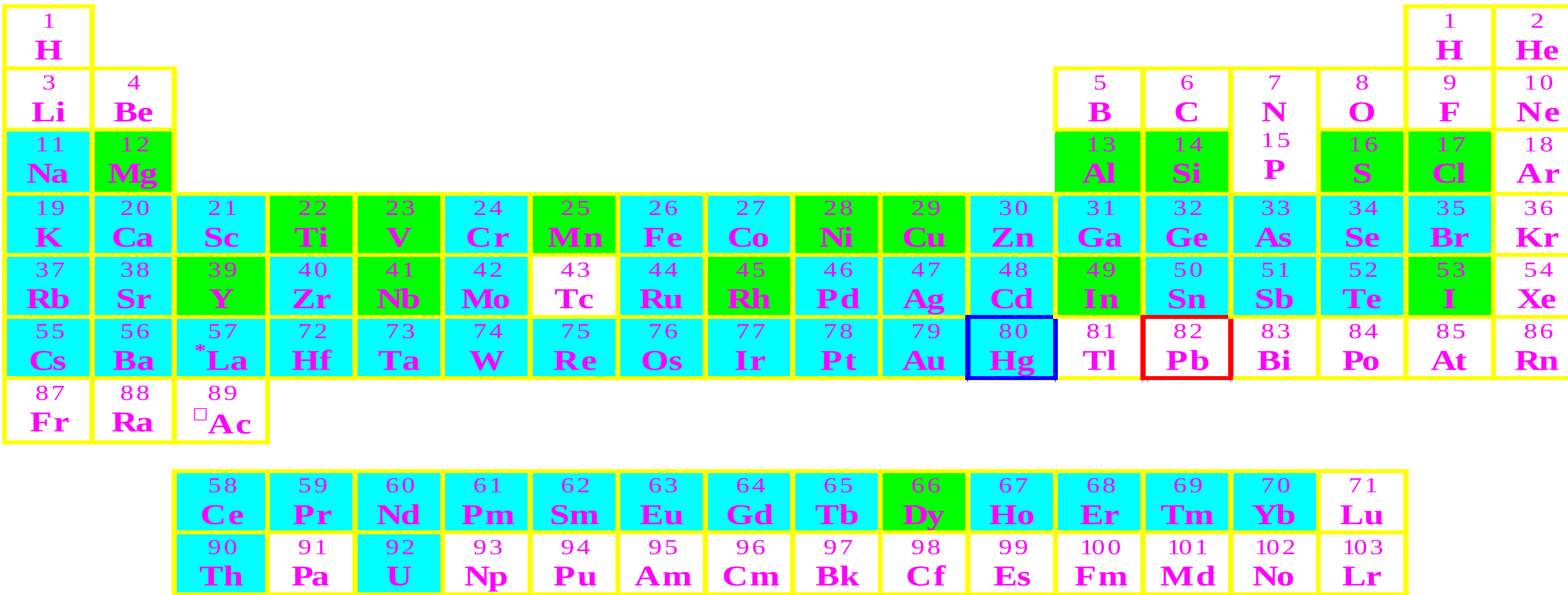
Neutron activation analysis

- Standardization
  - Relative
  - k_0 - based
- Mode
  - Radiochemical NAA
  - Instrumental NAA

Neutron activation analysis



Neutron activation analysis

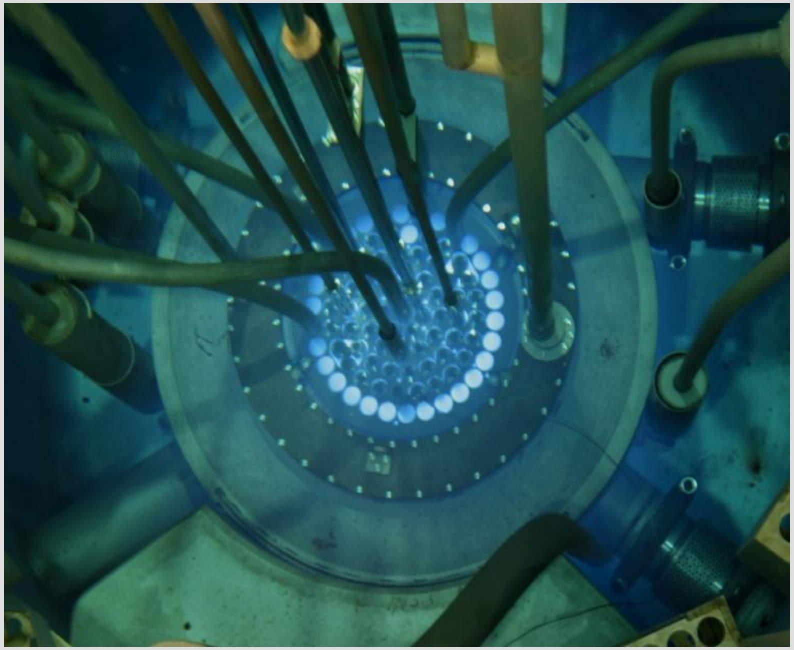


Short irradiation (1-5 min)

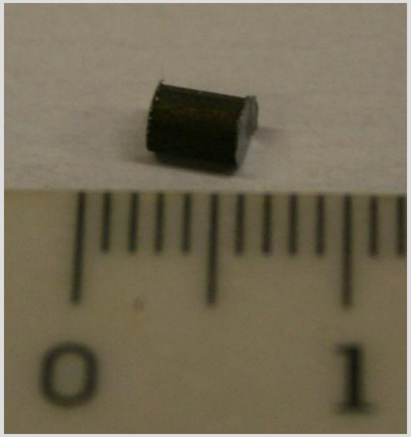
Long irradiation (up to 20 h)

Irradiation of samples

- Neutrons
  - Irradiation of various materials (eurofer, SiC composites, teeth, detectors, electronic components)
- Photons (γ-rays)
  - Irradiation of semiconducting dosimeters and human and animal teeth

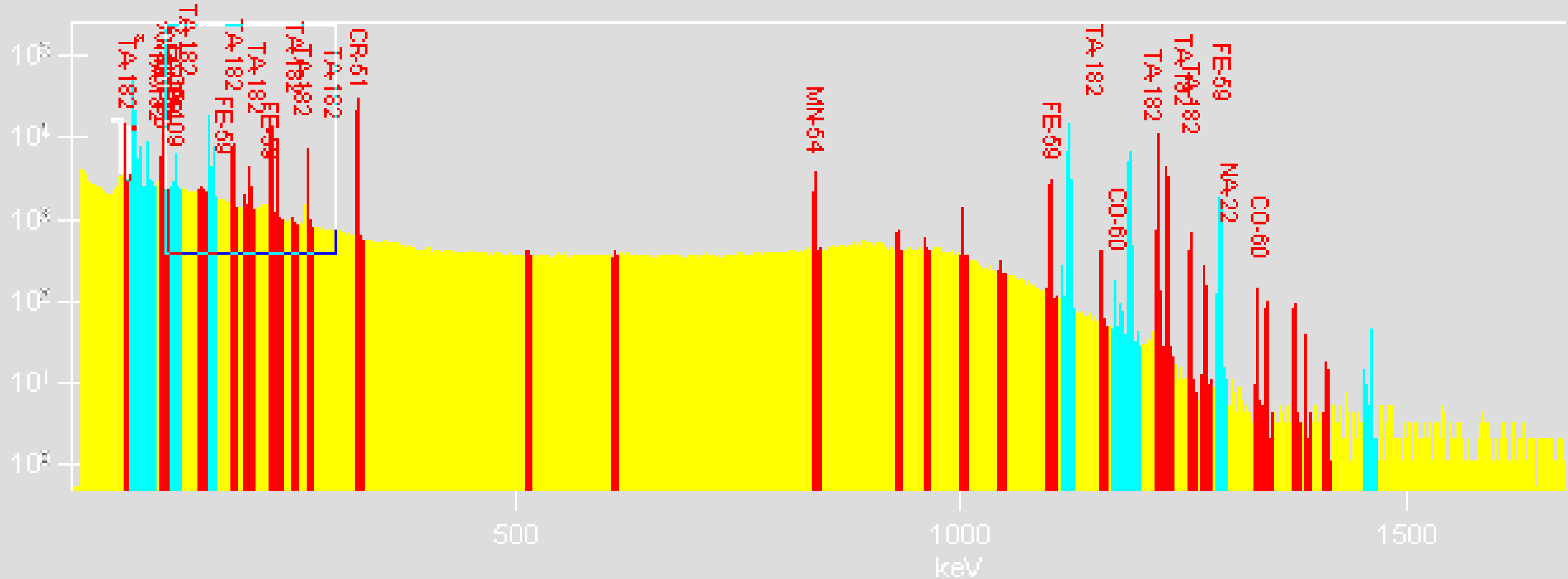


Irradiation of Eurofer



irradiation time ~ 200 h

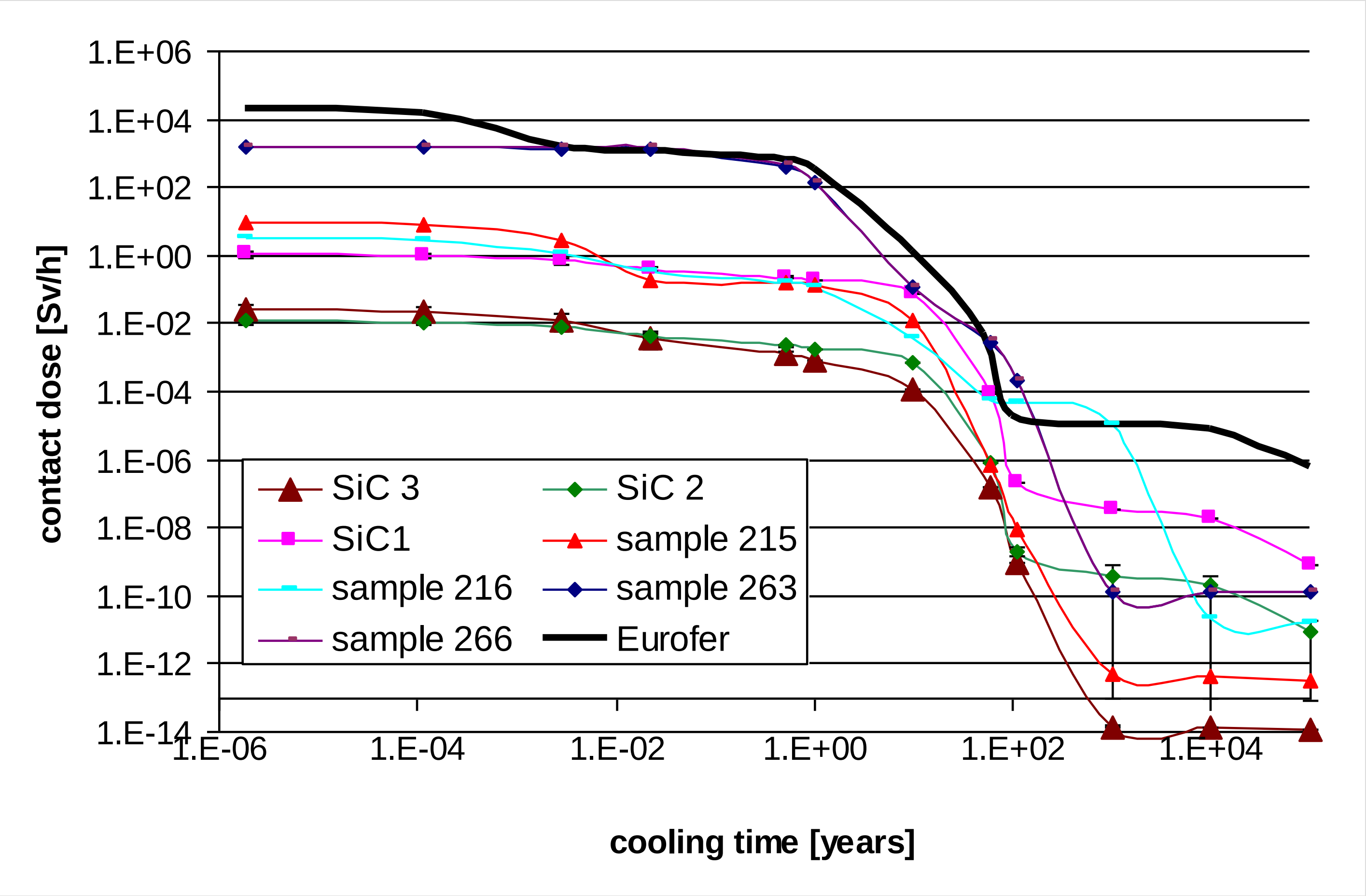
	no Cd	under Cd	main contributor
specific activity (Bq/g)	2×10^8	7×10^7	^{51}Cr ^{182}Ta
dose rate at 1 m (μSv/h)	3.8	3.2	^{182}Ta



Irradiation of SiC

- irradiation time ~ 20 – 60 min
- contact dose rate 10 mSv/h two hours after irradiation and 5µSv/h one week after irradiation
- activation mostly due to impurities
- impurities determined with NAA
- calculations with FISPACT software

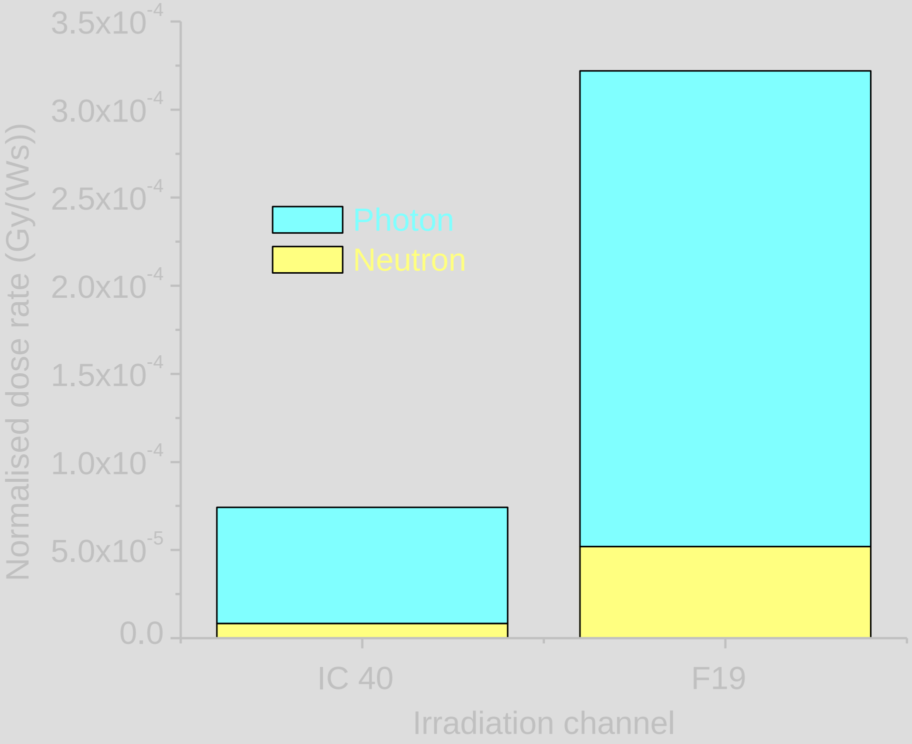
Results – FISPACT calculation



- Contribution of impurities in SiC very important
- Eurofer activity much higher than SiC

Irradiation of teeth

- Human and animal teeth irradiated in two irradiation channels for 10 to 400 seconds
- The activation was negligible
- After irradiation the EPR measurements were performed

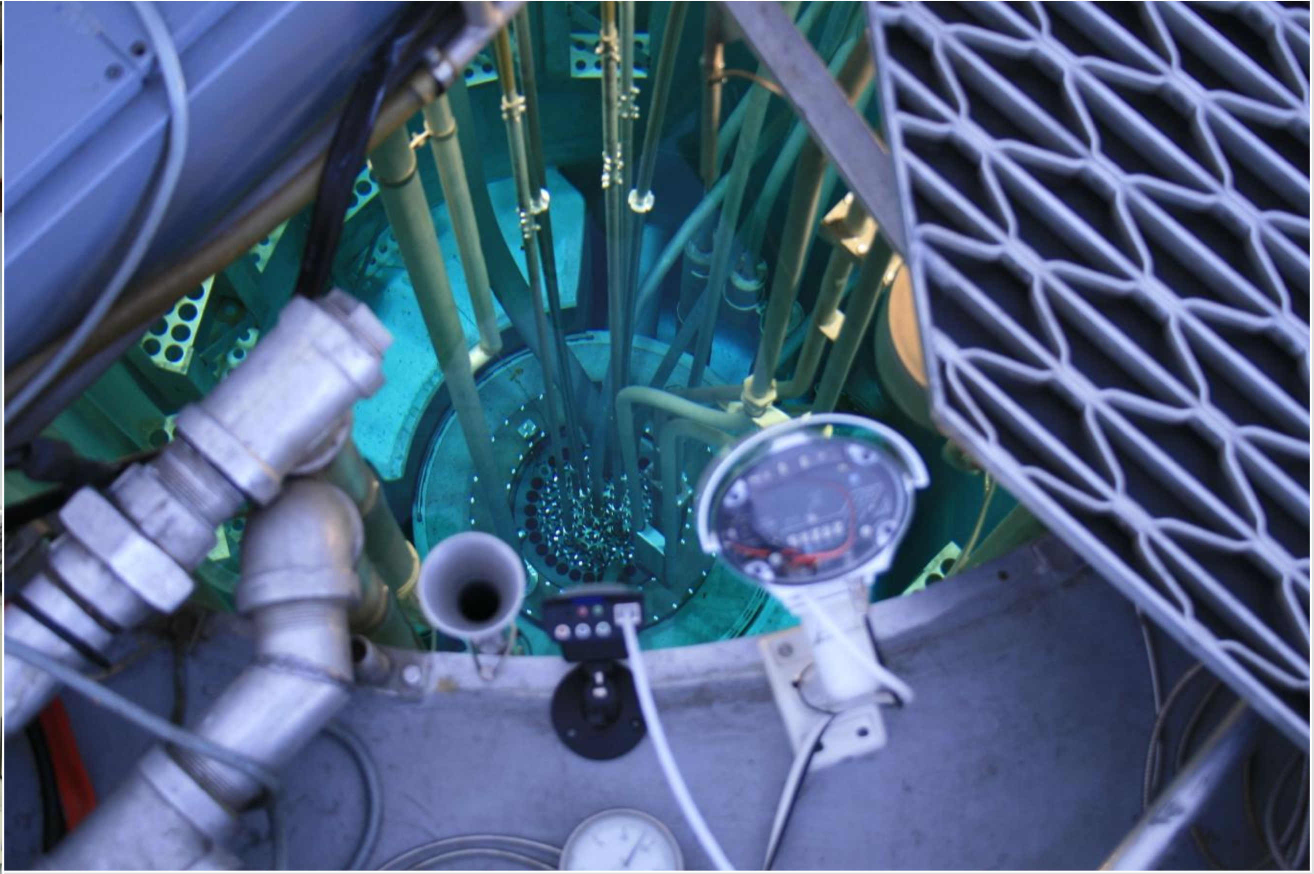
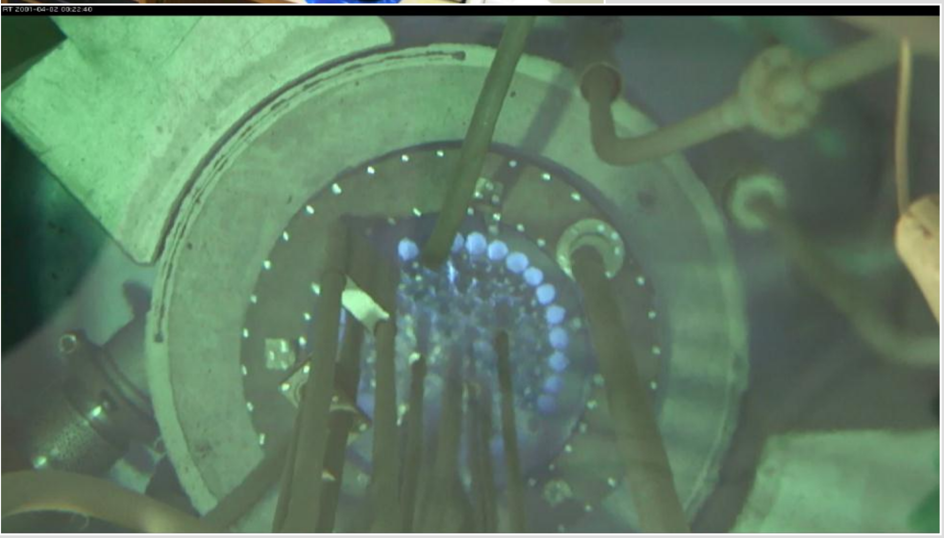
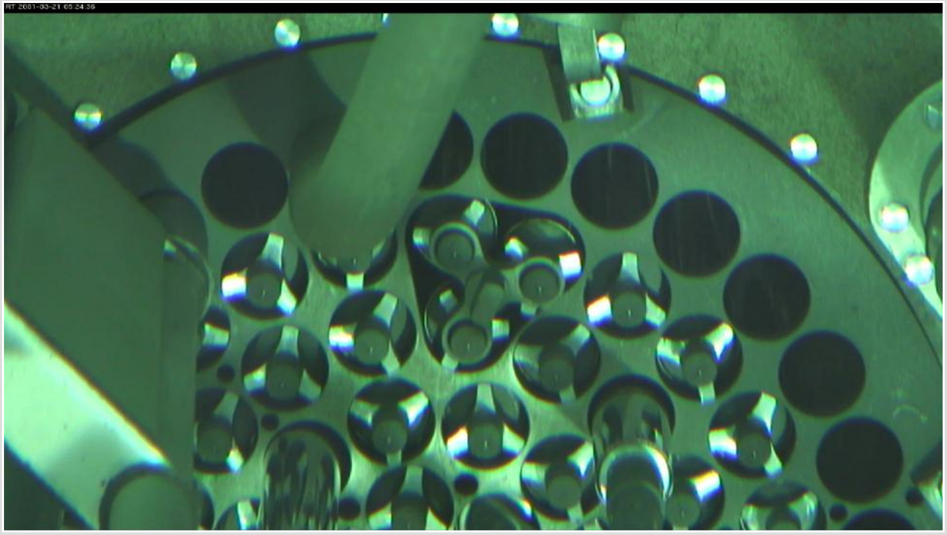


Conclusions

- Impurities in SiC are very important (large contribution to activity) → development of methods for impurity determination
- SiC less active than Eurofer up to 1000 years
- EPR biodosimetry good for relatively high doses (need to improve accuracy at lower doses)

Training and Education

- All nuclear professionals in Slovenia started their career or attended practical training courses at the TRIGA reactor:
  - professors of nuclear engineering and reactor physics at Ljubljana and Maribor Universities,
  - directors and key personnel of the Nuclear Power Plant (NPP) Krško,
  - the Slovenian Nuclear Safety Administration
  - The Agency for Radioactive Waste].
  - All NPP Krško reactor operators and other technical staff
- The reactor is used in regular laboratory exercises for
  - graduate and post graduate students of physics and nuclear engineering at the Faculty of Mathematics and Physics, Ljubljana University.
- The reactor has been used in several international training courses, the latest one being organised by the Eastern Europe Research Reactor Initiative (www.eerri.org) in March 2010

Verification and validation of nuclear data and computer codes

- Calculation of multiplication factor, k_{eff}
- Calculation of neutron spectra and neutron flux distributions
- Calculation of self-shielding factors – improvement of dosimetry nuclear data

Multiplication factor, k_{eff}

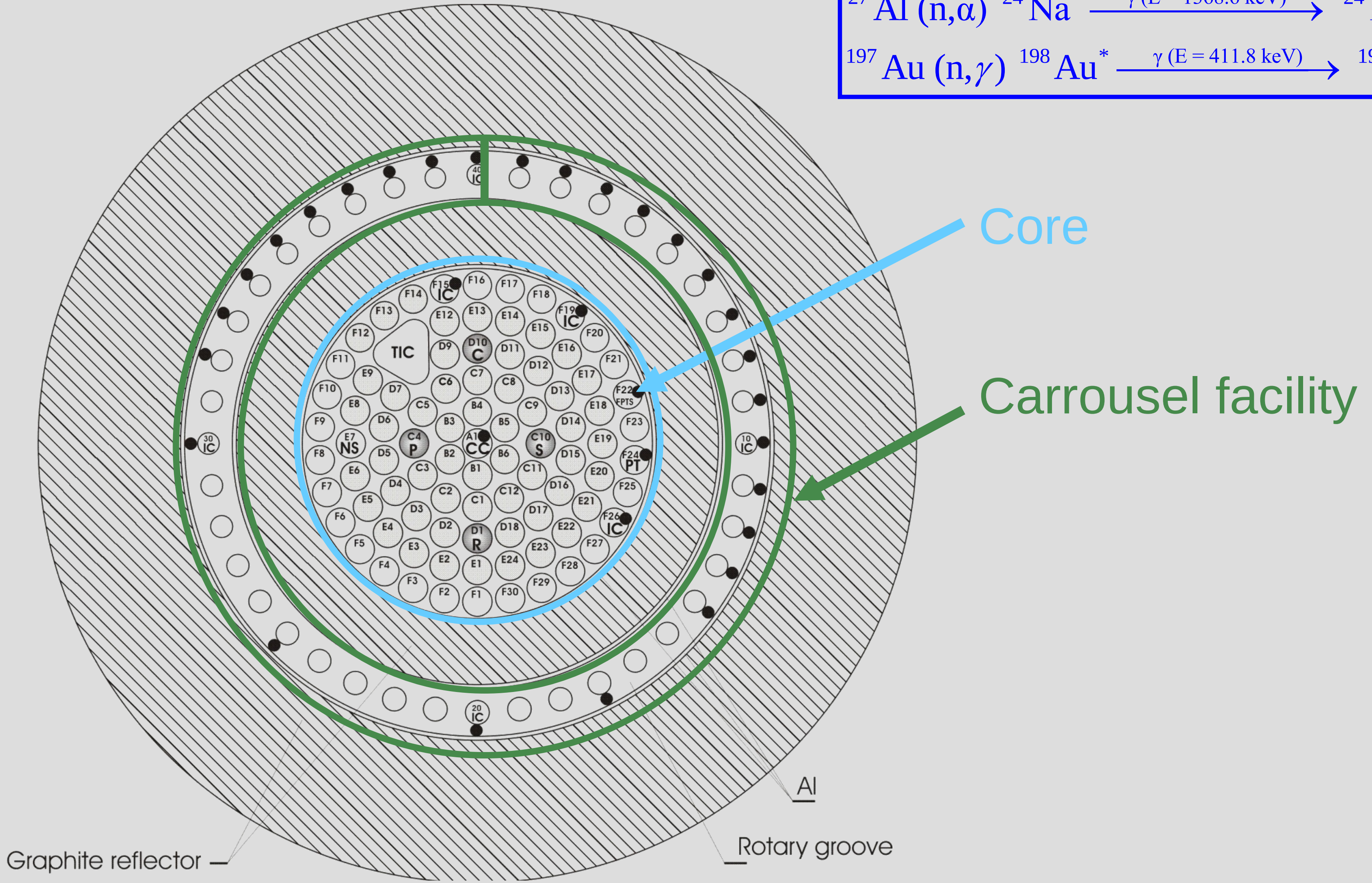
Cross section set → Case ↓	Benchmark-model k_{eff}	ENDF/B-VI.8	ENDF/B-VII	JEFF 3.1
Core 132	**1.0006 ± 0.0056**	1.0001 ± 0.0001	1.0059 ± 0.0001	1.0019 ± 0.0001
Core 133	**1.0046 ± 0.0056**	1.0048 ± 0.0001	1.0107 ± 0.0001	1.0063 ± 0.0001

- Very good agreement betwen calculations and experiment
- Highest differences in k_{eff} due to Zr cross section (~ 400 pcm) and thermal scattering cross sections on H in ZrH (~ 200 pcm)

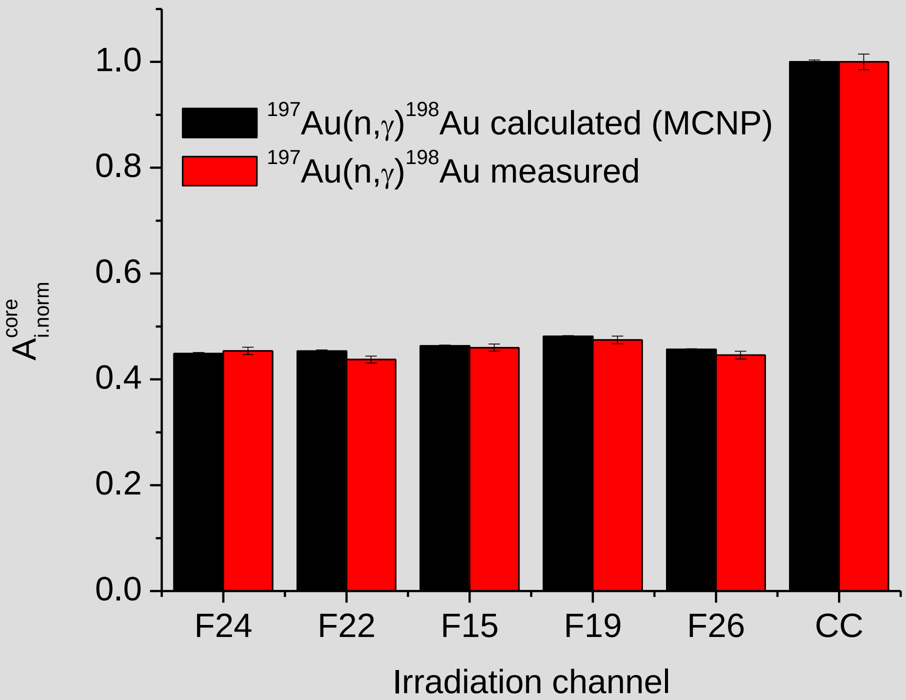
Neutron flux distribution

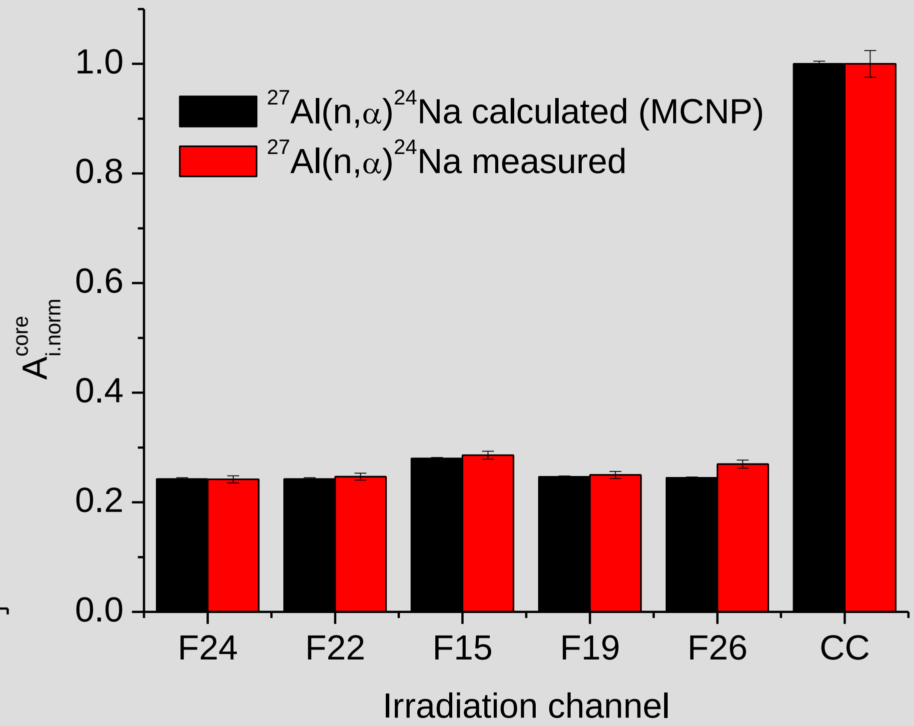
$$^{27}Al\,(n,\alpha)\;^{24}Na^{*}\xrightarrow{\gamma\,(E\,=\,1368.6\,keV)}\;^{24}Na$$

$$^{197}Au\,(n,\gamma)\;^{198}Au^{*}\xrightarrow{\gamma\,(E\,=\,411.8\,keV)}\;^{198}Au$$

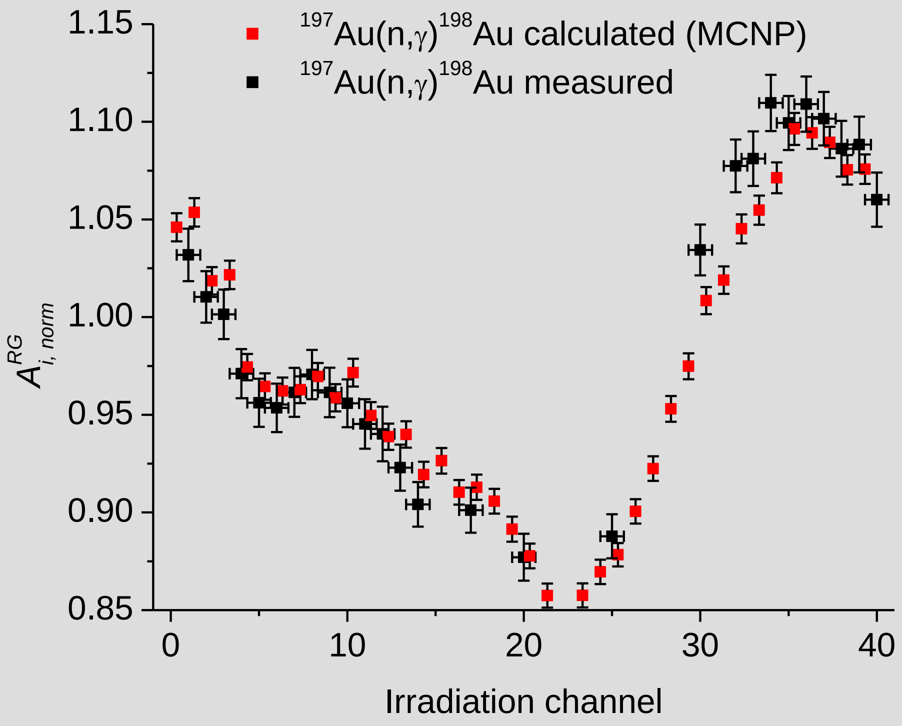


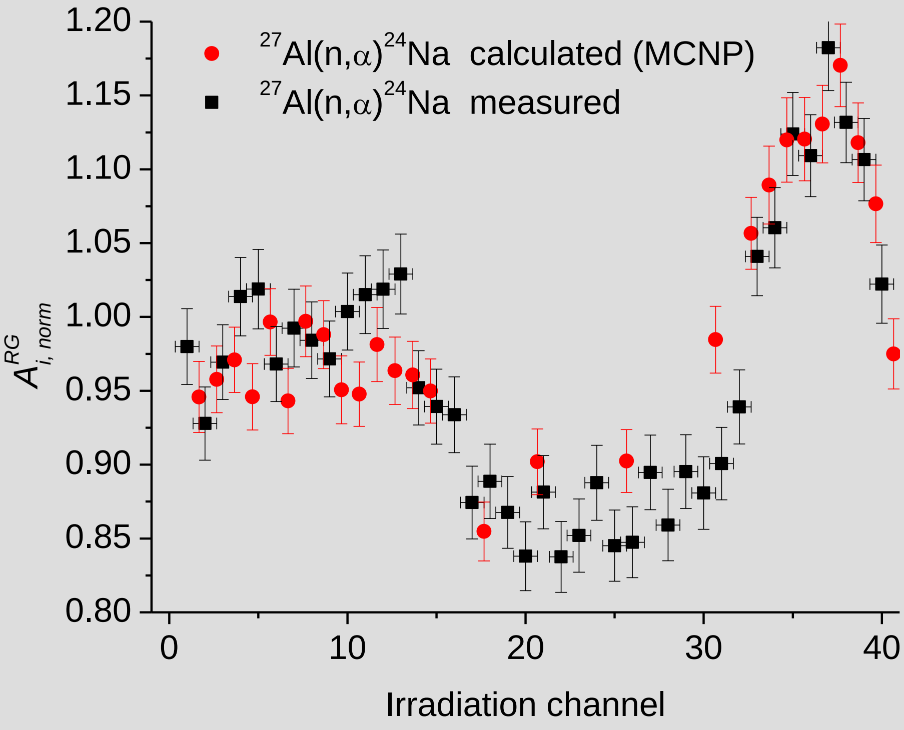
Neutron flux distribution - core





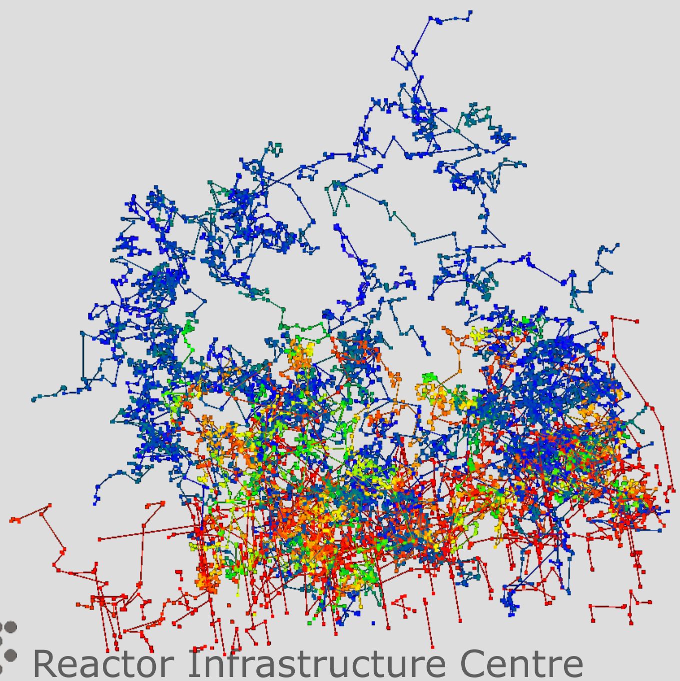
Neutron flux distribution – carrousel facility

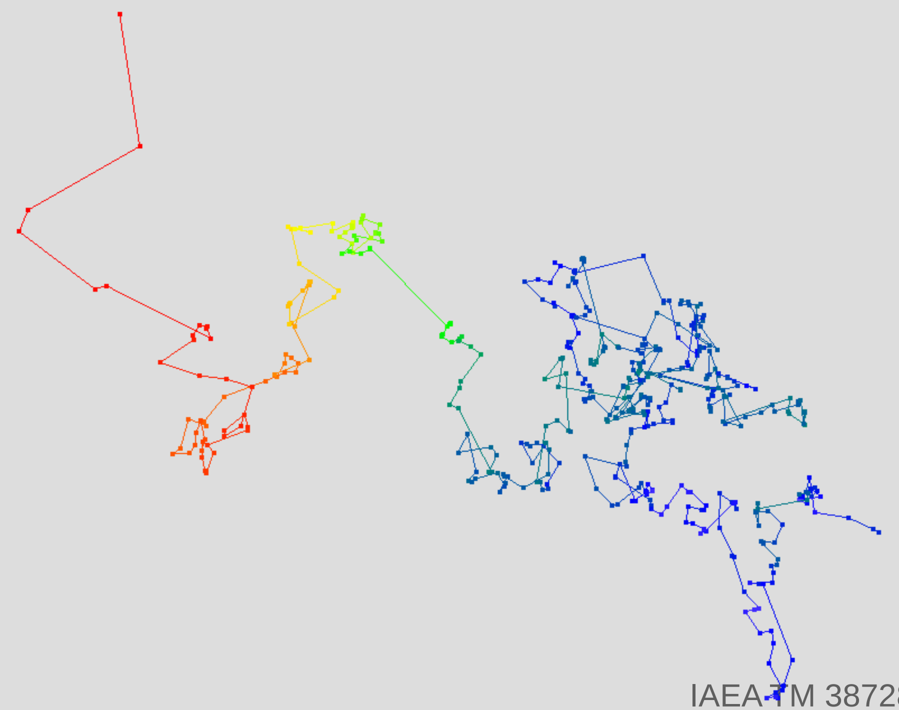




Monte Carlo method

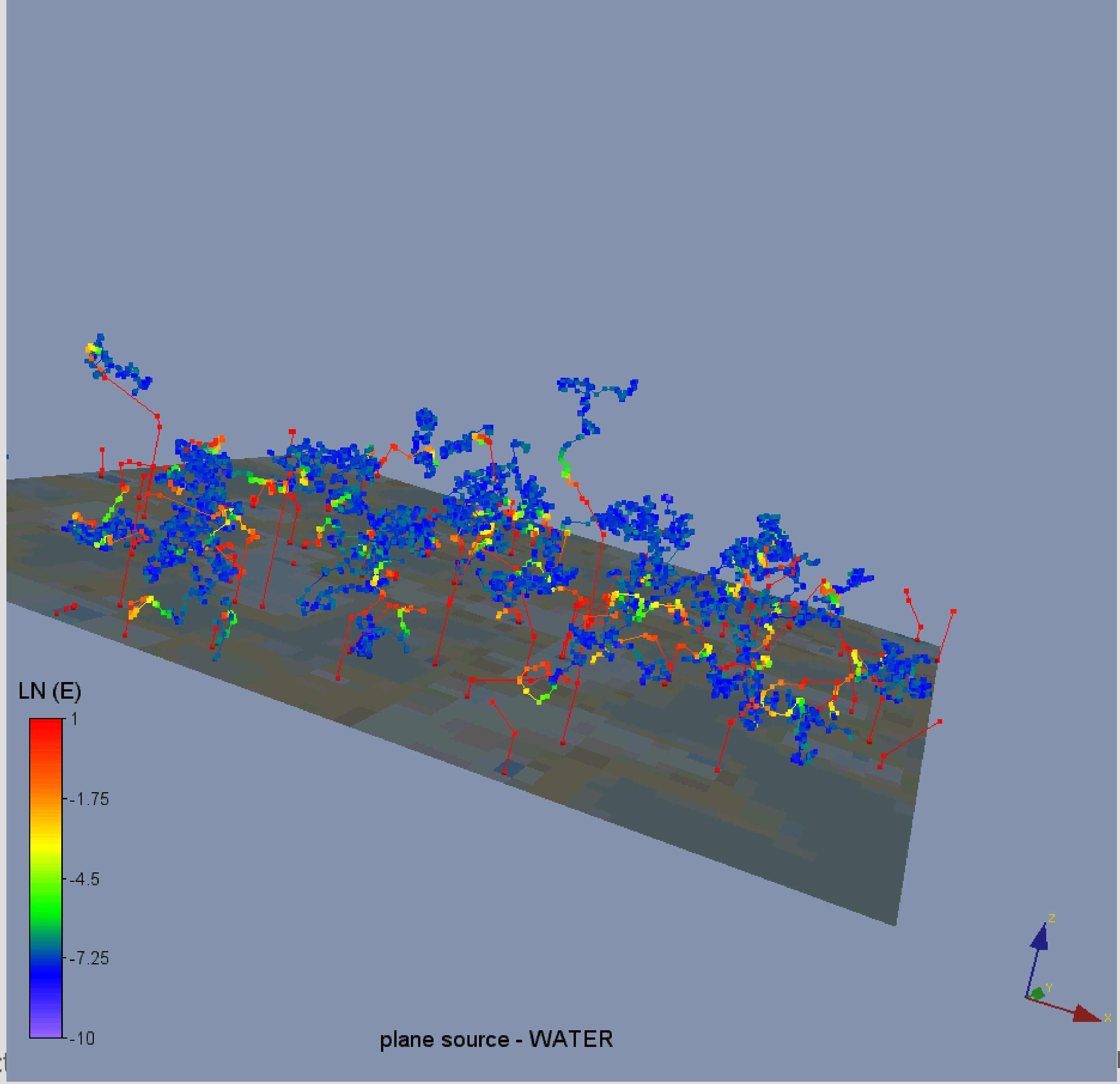
- Calculations performed with MCNP – Monte Carlo computer code for neutron and photon transport
- Transport of individual particles

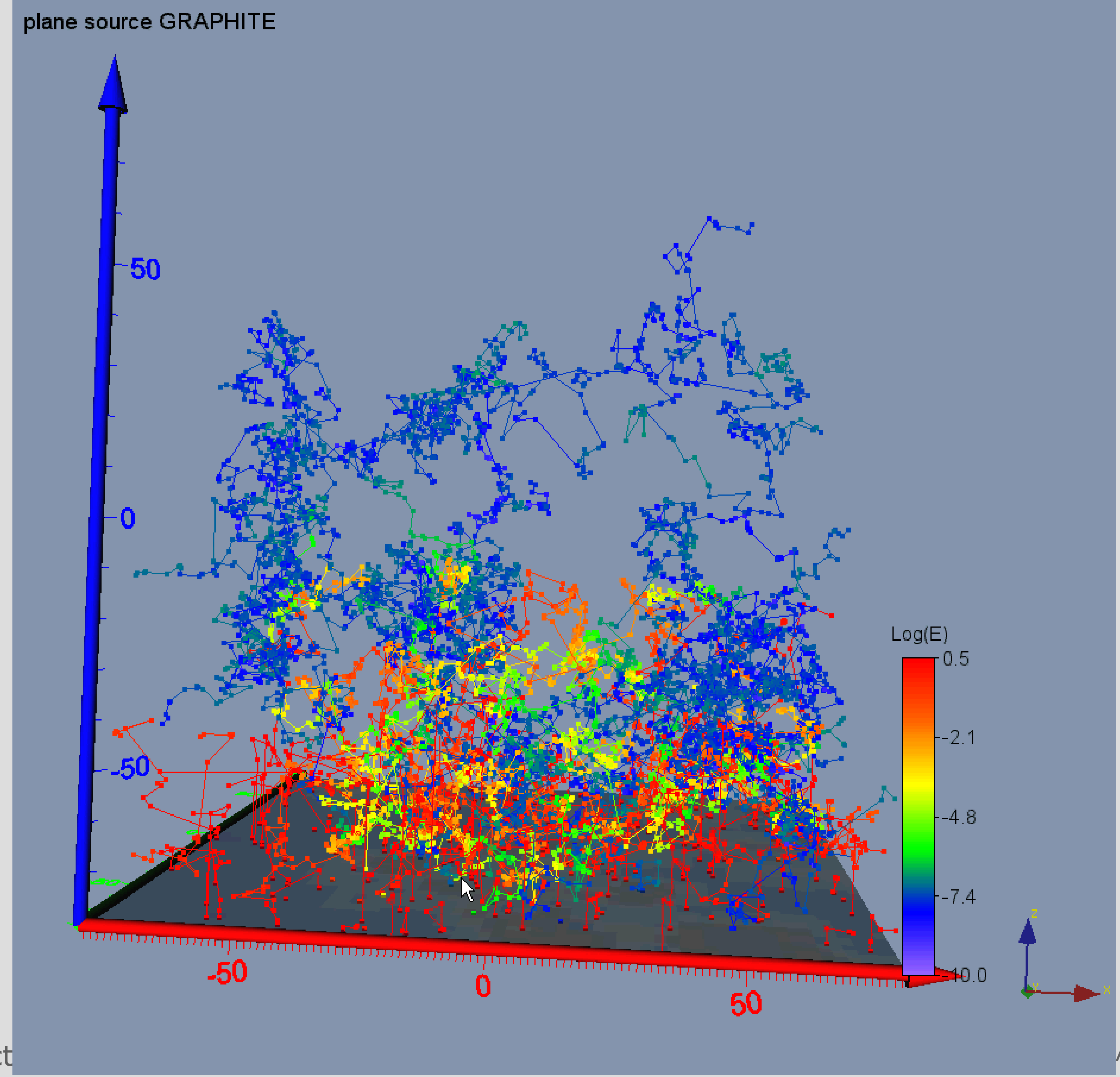




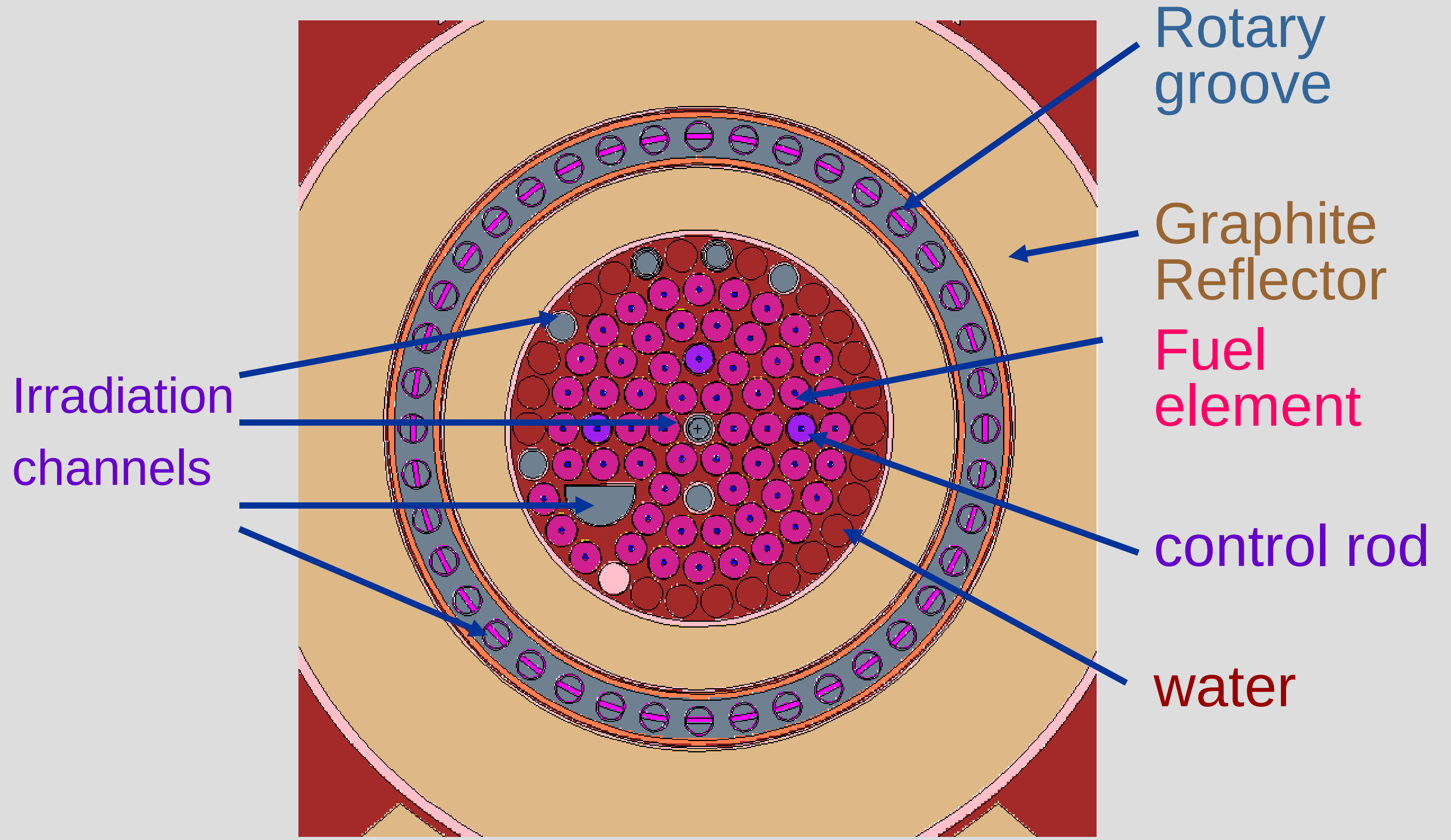
Visualisation

- Visualization enhances the understanding of neutron transport
- Important in:
  - education (students of reactor physisc)
  - training (nuclear reactor operators)

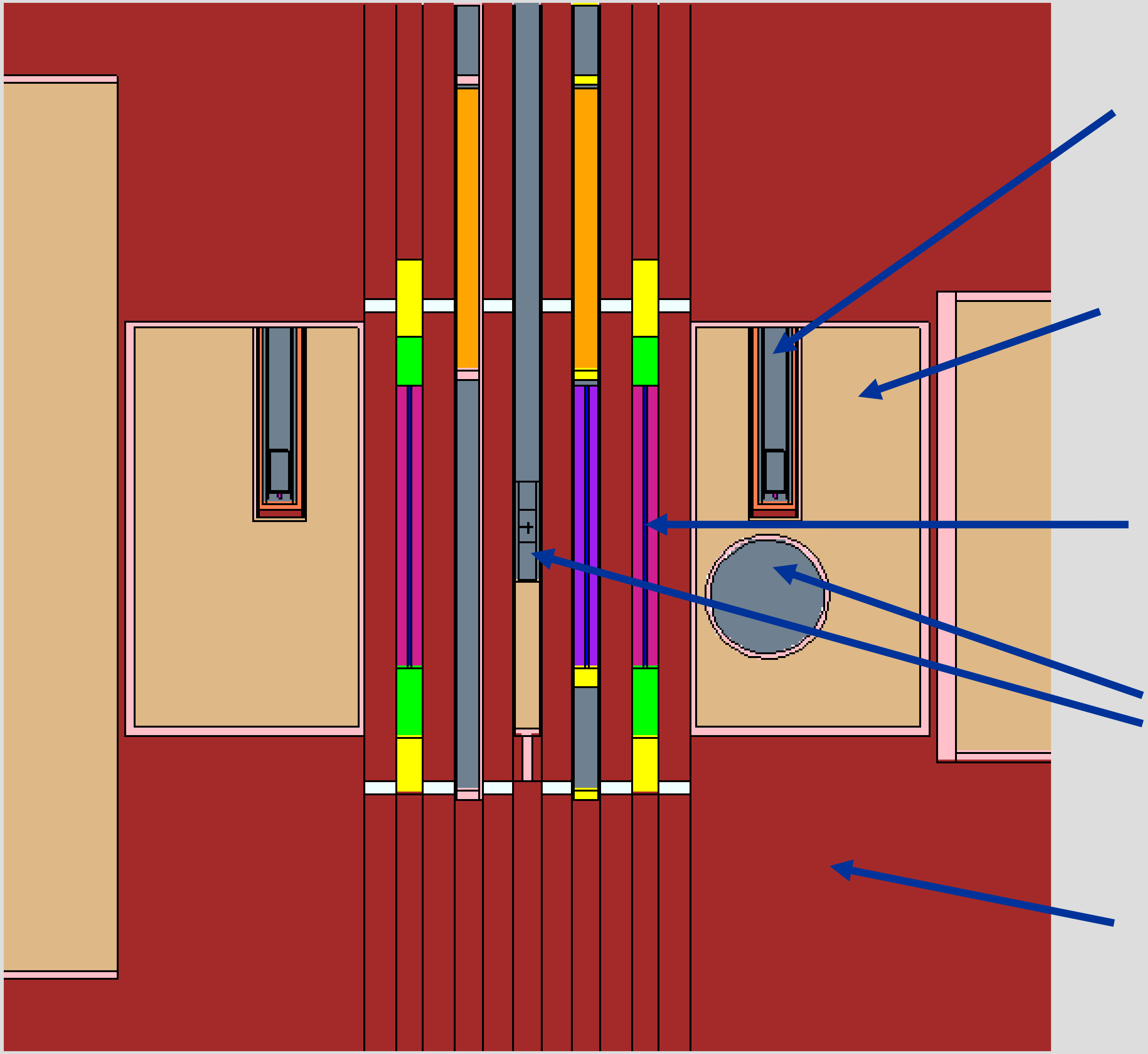

LN (E)
1
-1.75
-4.5
-7.25
-10
plane source - WATER
Z
Y
X


plane source GRAPHITE
50
0
-50
-50
0
50
Log(E)
0.5
-2.1
-4.8
-7.4
-10.0

Computational model- top view

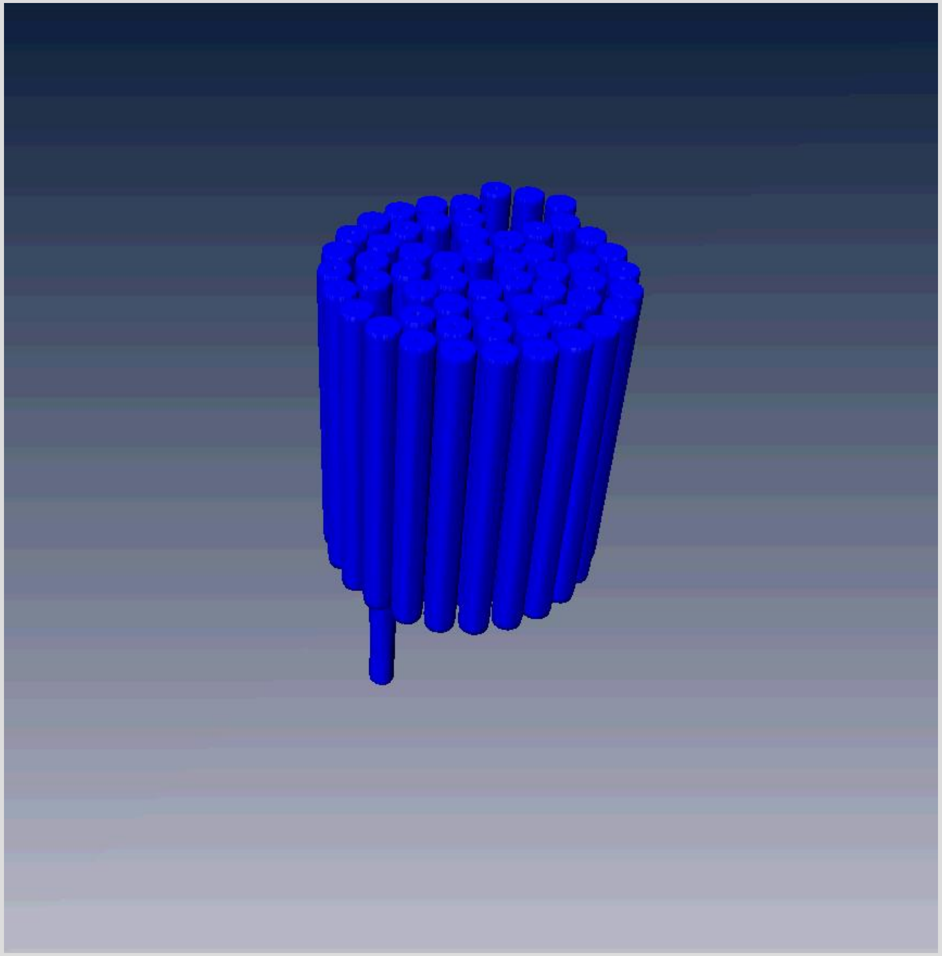


Computational model- side view

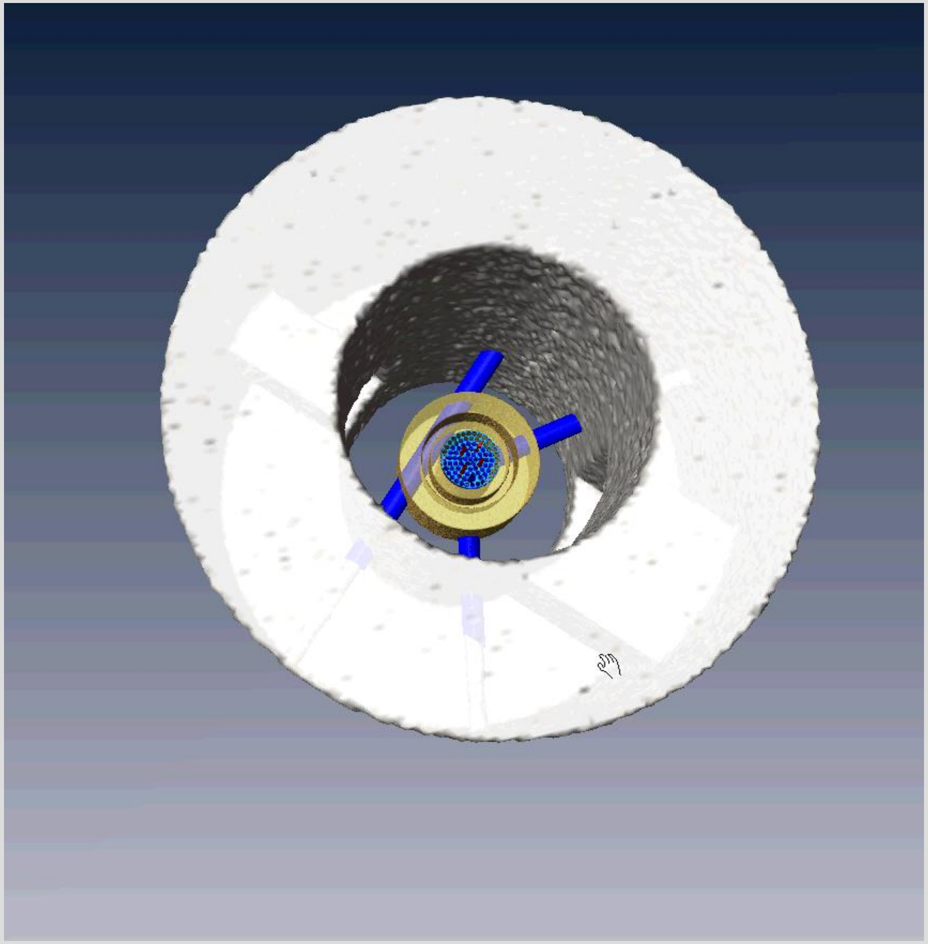


- Rotary groove
- Graphite Reflector
- Fuel element
- Irradiation channels
- water

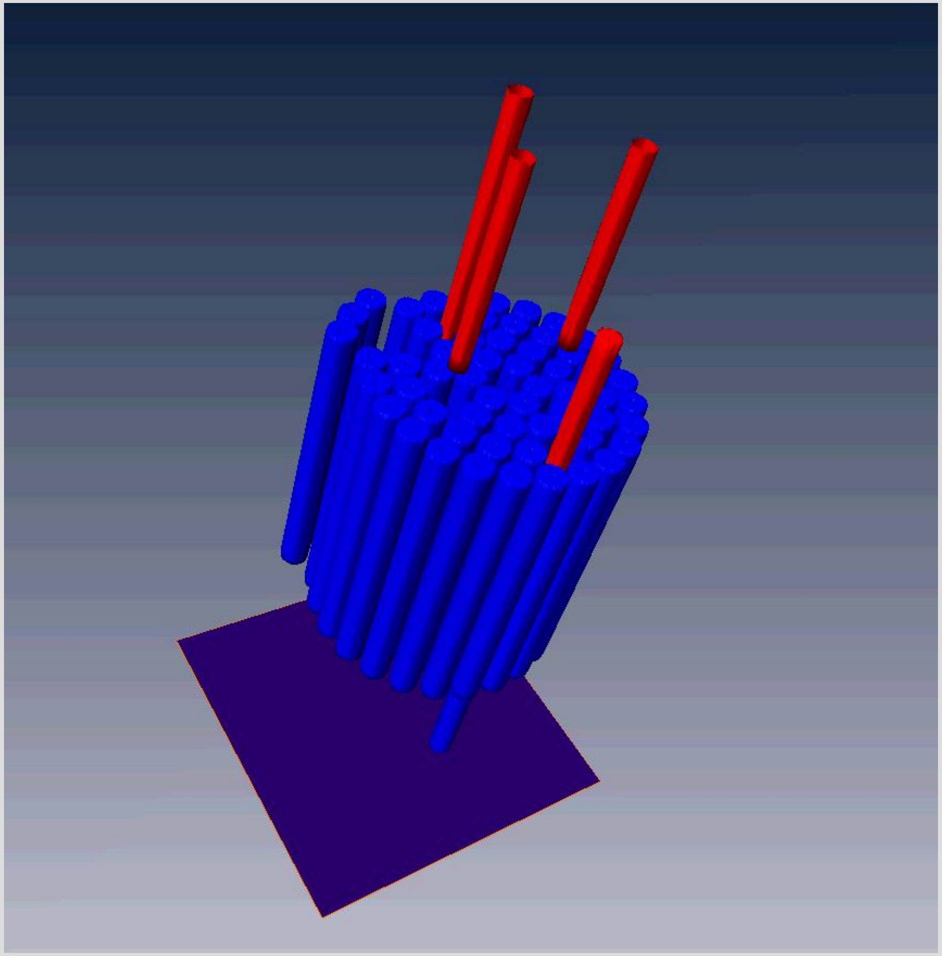
TRIGA Mark II components



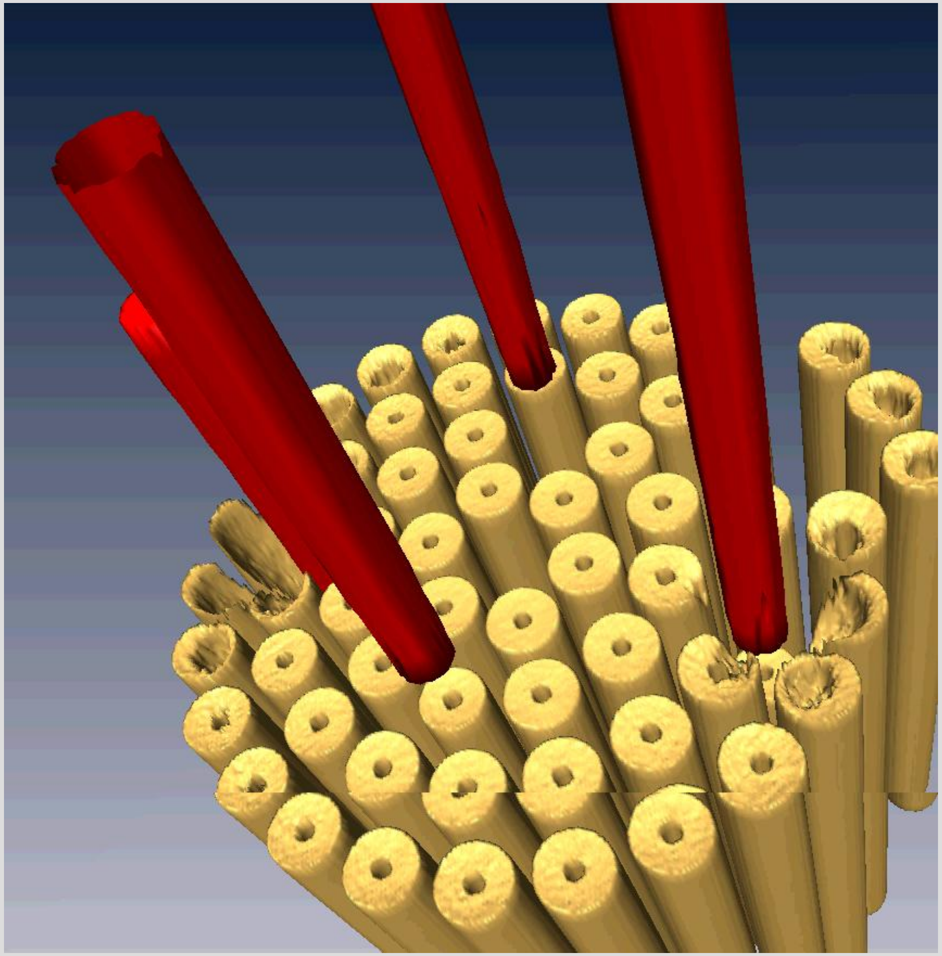
TRIGA Mark II shield



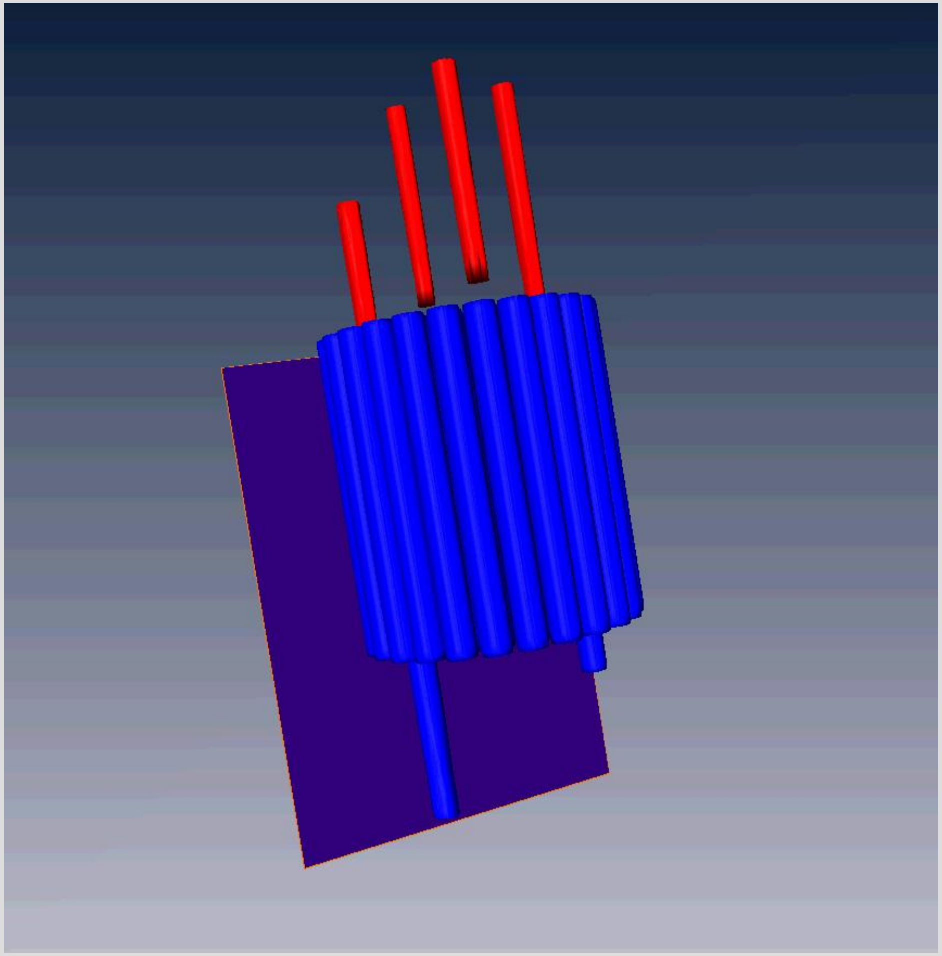
Power distribution I



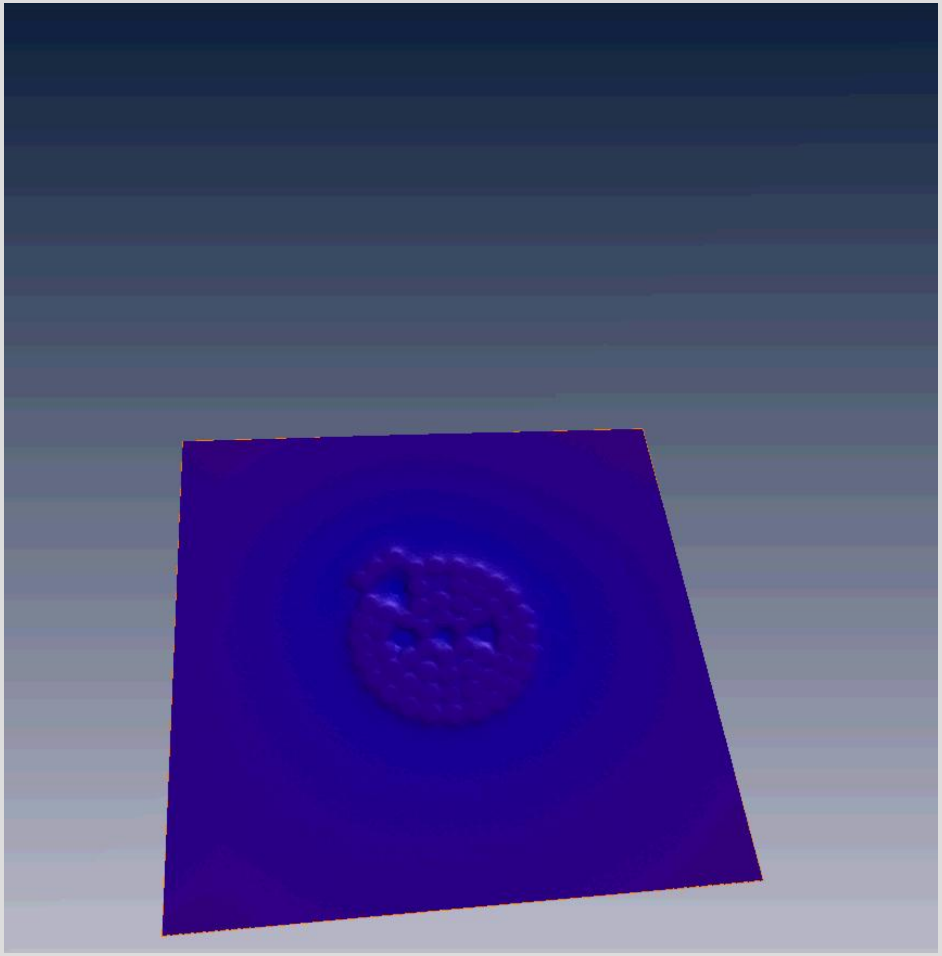
Power distribution II



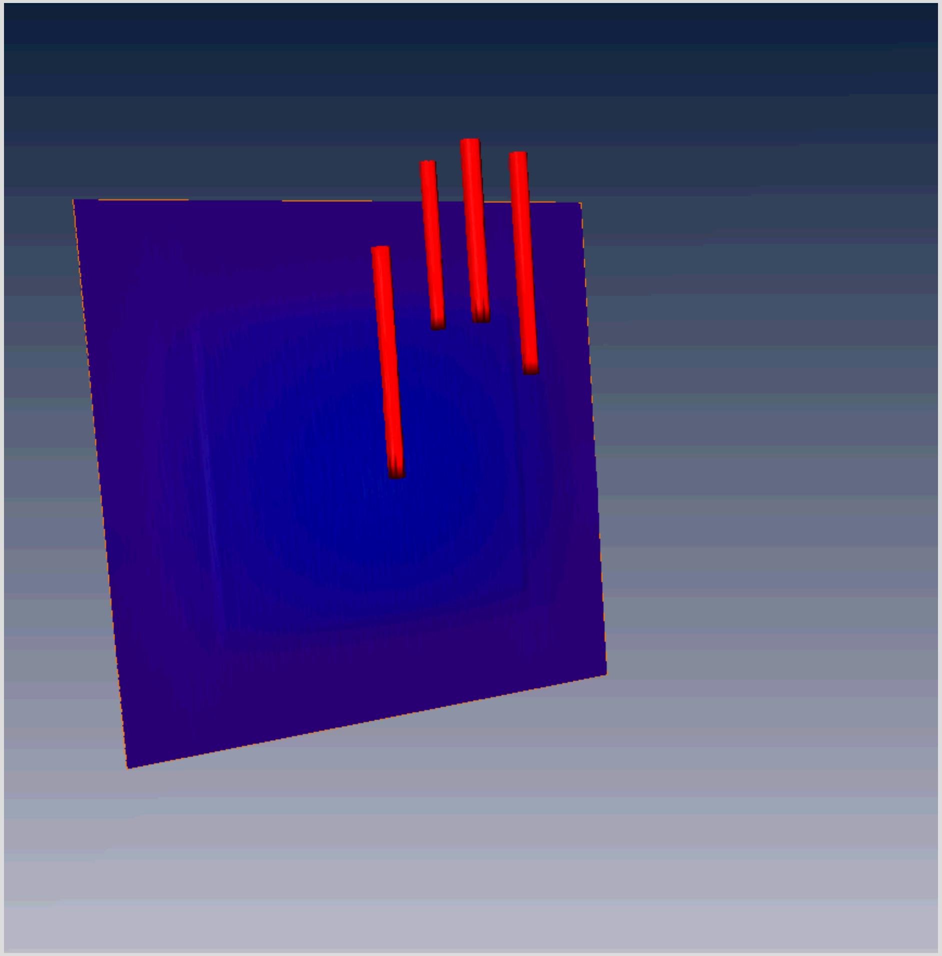
Power distribution III



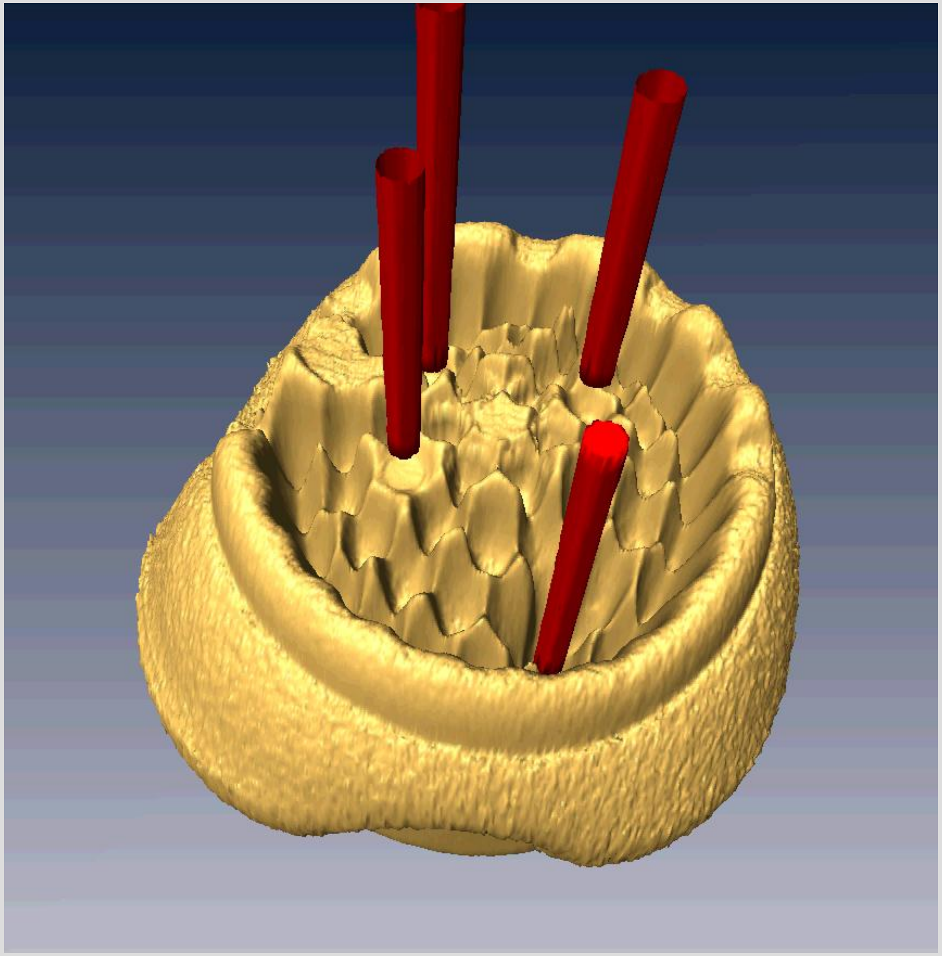
Thermal flux distribution I



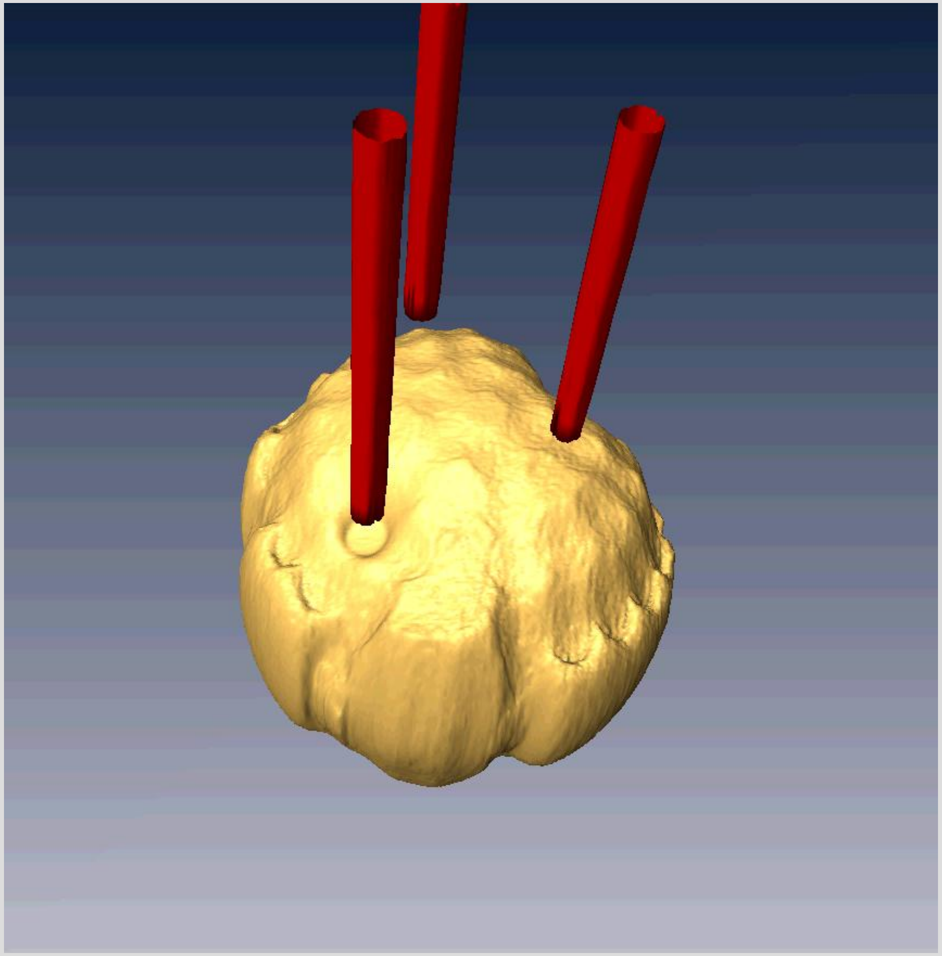
Thermal flux distribution II



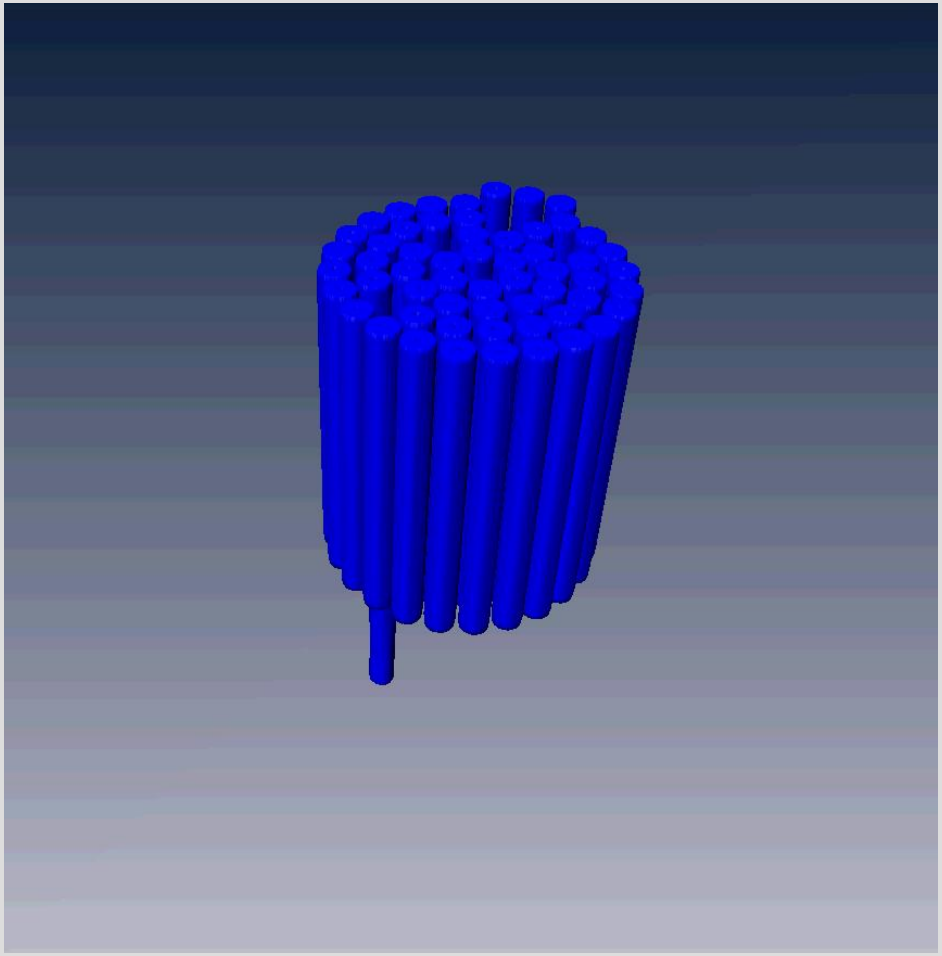
Thermal flux distribution III



Total flux distribution



TRIGA Mark II components



Start-up test at Krško NPP

- New methods and equipment developed at TRIGA reactor in Slovenia
- Reducing test duration from 10 days to 14 hours
- Methods and equipment still being teseted and improved with great help of our TRIGA Mark II research reactor

Part of our time during start-up tests.
At 3 am in Krško NPP

Conclusions

- Major activities were presented, being carried out at the TRIGA Mark II reactor of the Jožef Stefan Institute
- Although being over 40 years old, the reactor still significantly contributes to new scientific achievements in nuclear science and to preservation of knowledge on nuclear energy in Slovenia and broader