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Investigation of a Possibility of Chromium-51 Accumulation in the SM-3 Reactor to Fabricate a Neutrino Source

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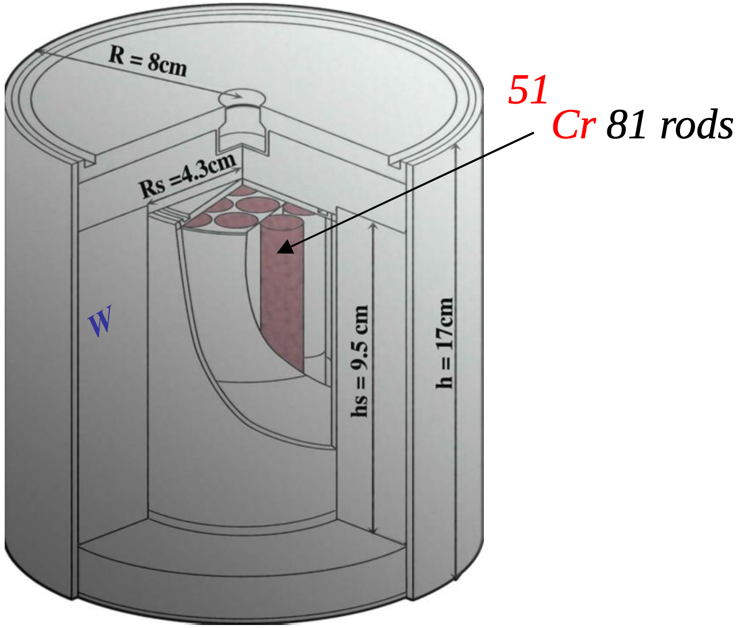
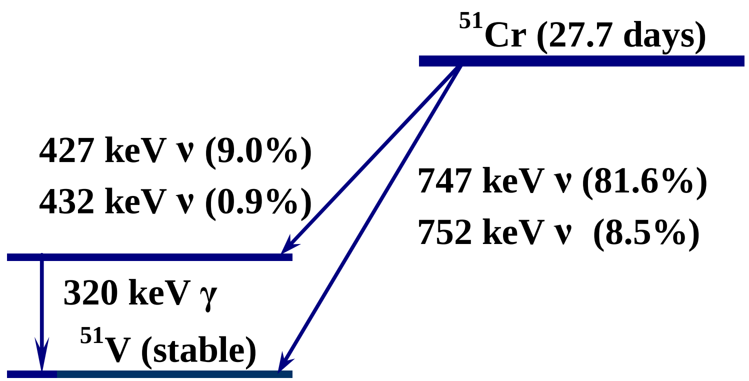
^{51}Cr Neutrino Source

$${}_{24}Cr^{51} + e \longrightarrow {}_{23}V^{51} + n + g$$

$${}_{31}Ga^{71} + n \longrightarrow {}_{32}Ge^{71} + e$$



Decay scheme of ^{51}Cr

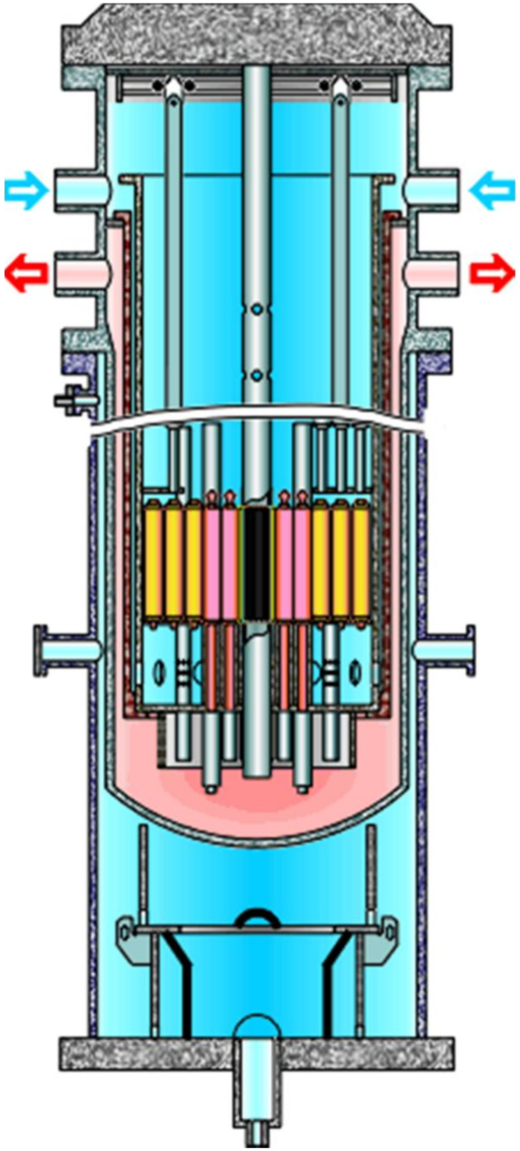


3 MCi ^{51}***Cr***

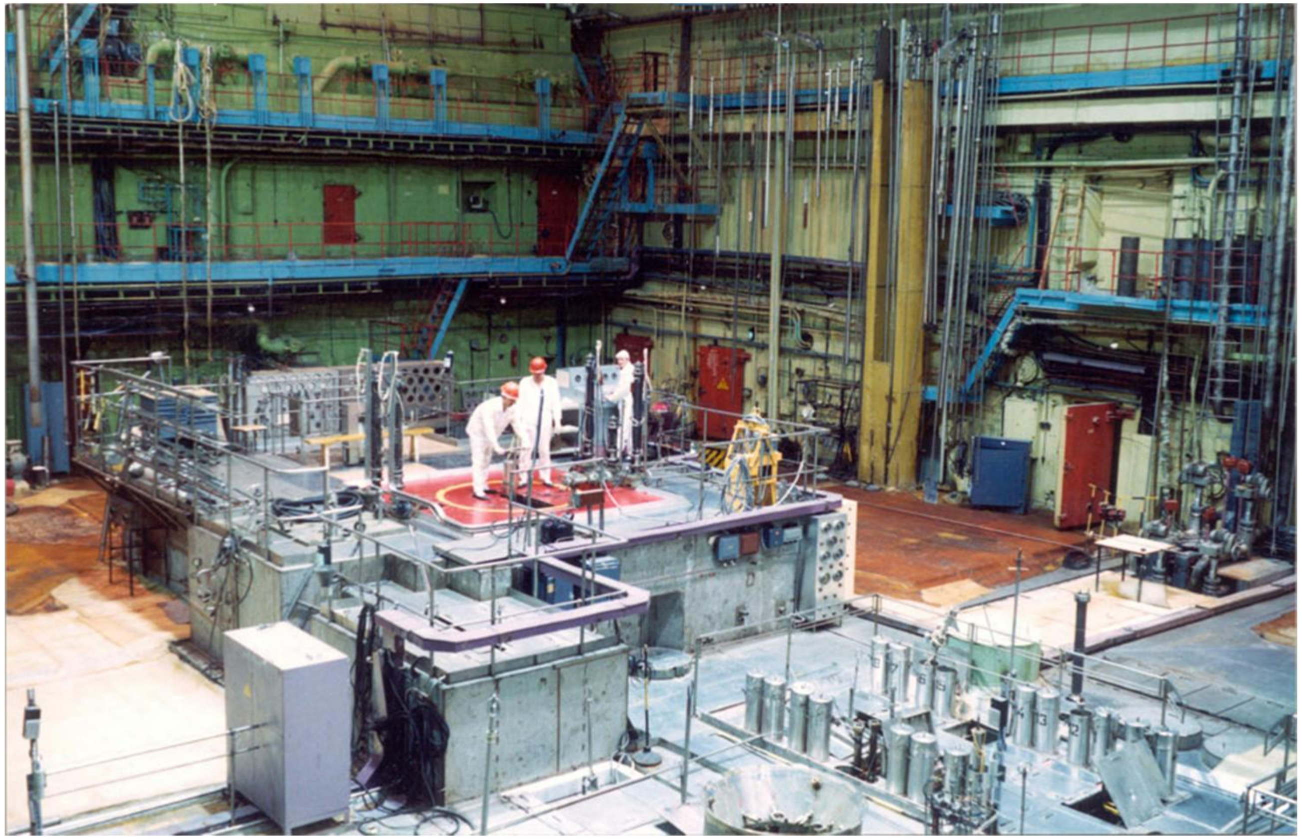
3 kg of ^{50}*Cr with 97% enrichment*

By each ^{51}*Cr decay there is emitted*
an average of 36 keV of thermal energy.
The source heat emission ~650 W

High Flux "Super Power" Reactor SM-3



The unique high-flux reactor SM-3 is operated by RIAR (this is one of two reactors with the highest thermfl neutron flux available in the world. The second one is located in the USA, ORNL)



The Reactor Hall

Main Parameters of SM-3 Reactor

- Thermal power output – 100MW
- Max thermal neutron flux ~$5 \cdot 10^{15}$ cm^{-2} s^{-1}
- Max fast neutron flux ~ $2 \cdot 10^{15}$ cm^{-2} s^{-1}
- Irradiation positions are

  27 neutron trap cells (∅12 mm),

  30 beryllium reflector channels (∅69 mm),

  24 in core cells (∅12 mm)
- Typical working schedule:

  10 days -1.5 days - 10 days - 5 days
- Number of the effective days per year ~220

Radionuclides Produced by RIAR

Trans-plutonium elements

$^{241-243}Am$, $^{244-248}Cm$, ^{249}Bk, $^{249,252}Cf$, ^{254}Es

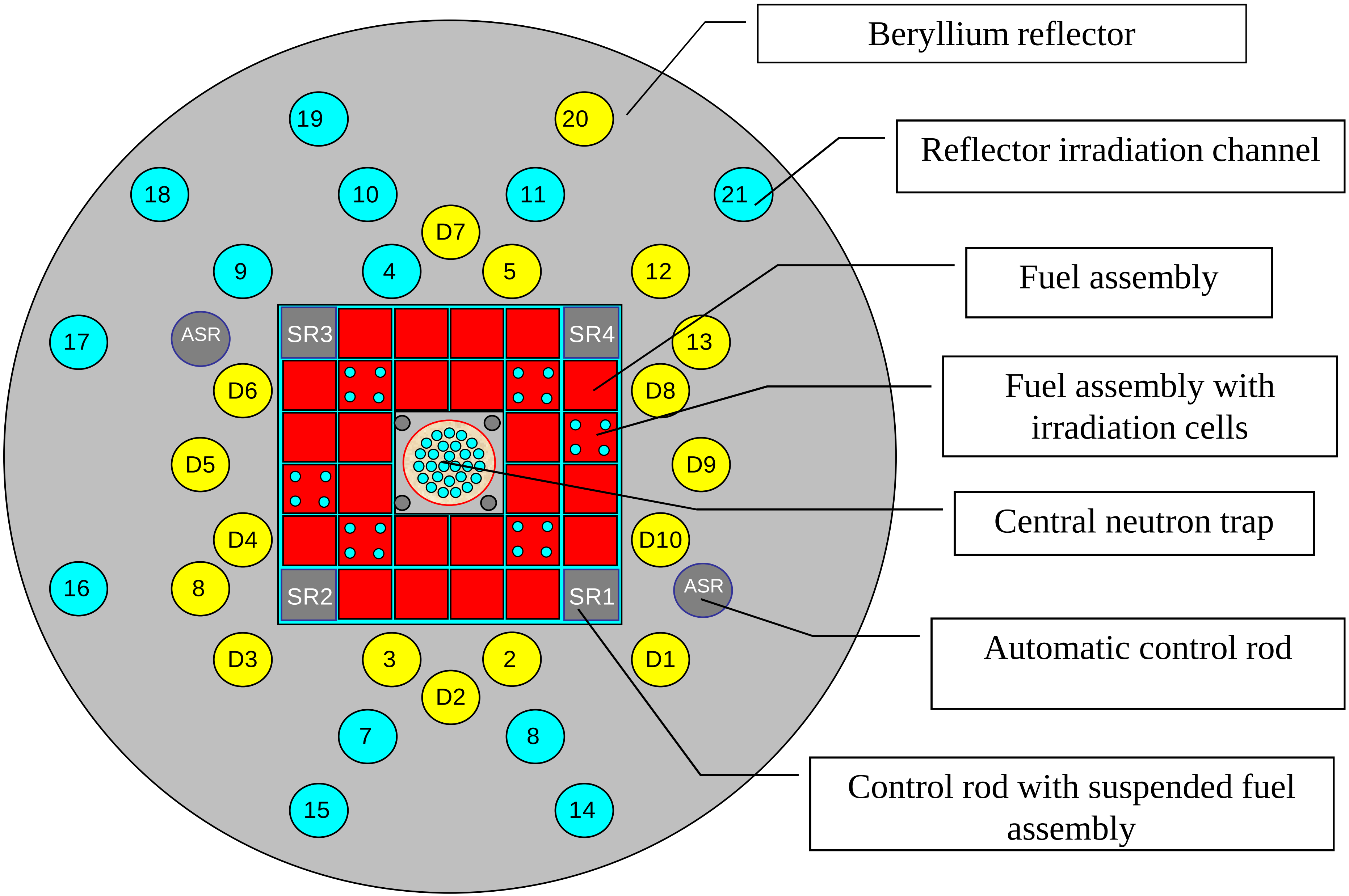
Industry/Medical radionuclides

^{60}Co, ^{192}Ir, ^{75}Se, ^{125}I, ^{103}Pd, ^{131}Cs, ^{169}Yb, ^{99}Mo, ^{121}Sn, ^{131}I, $^{32-33}P$, ^{51}Cr, ^{89}Sr, ^{188}W, ^{212}Bi, ^{106}Rh, ^{90}Y, ^{121}Sn, ^{59}Fe, ^{177}Lu, ^{153}Gd

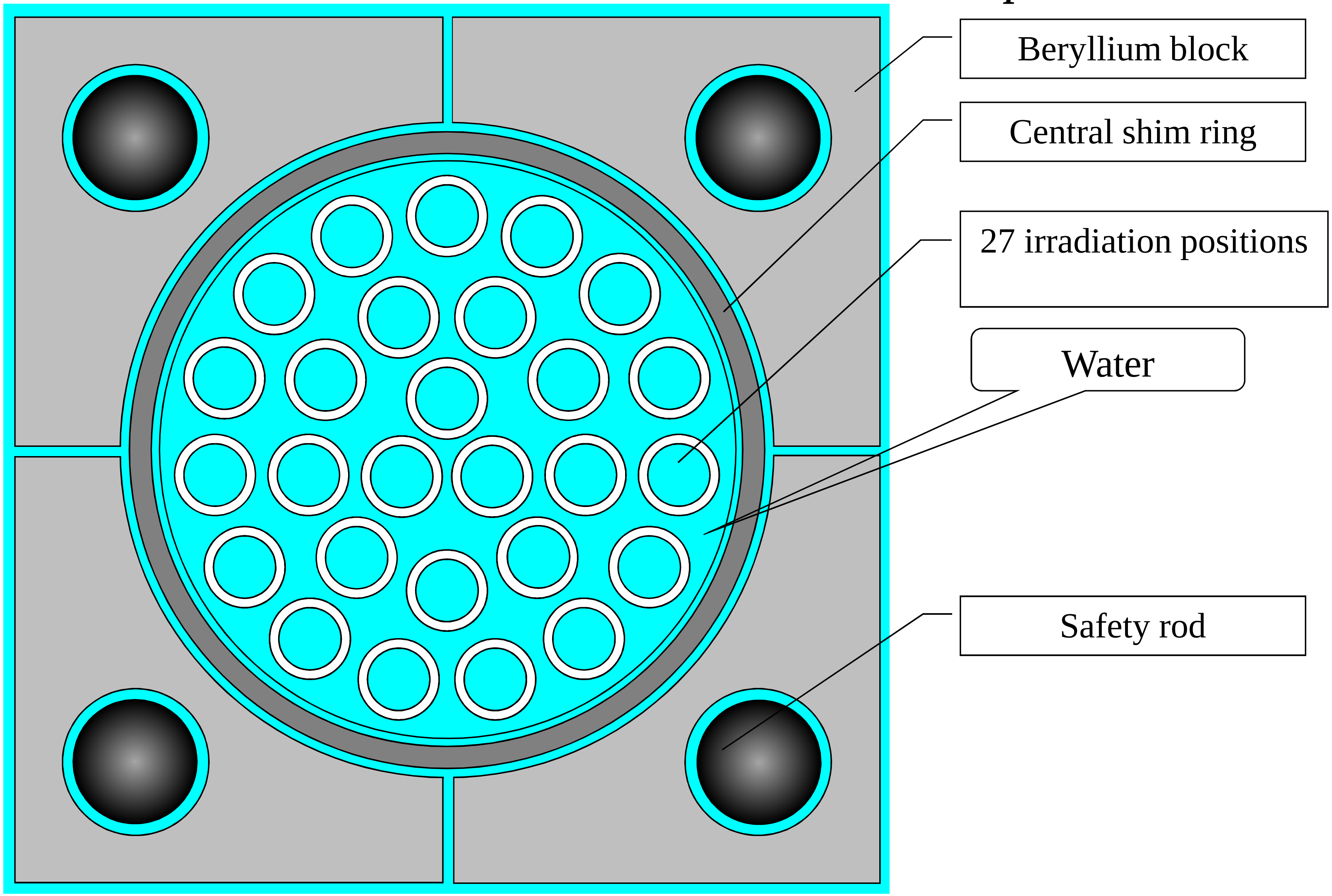
Other isotopes

^{54}Mn, ^{55}Fe, ^{63}Ni, ^{109}Cd, $^{113,117m,119m}Sn$, ^{204}Tl …

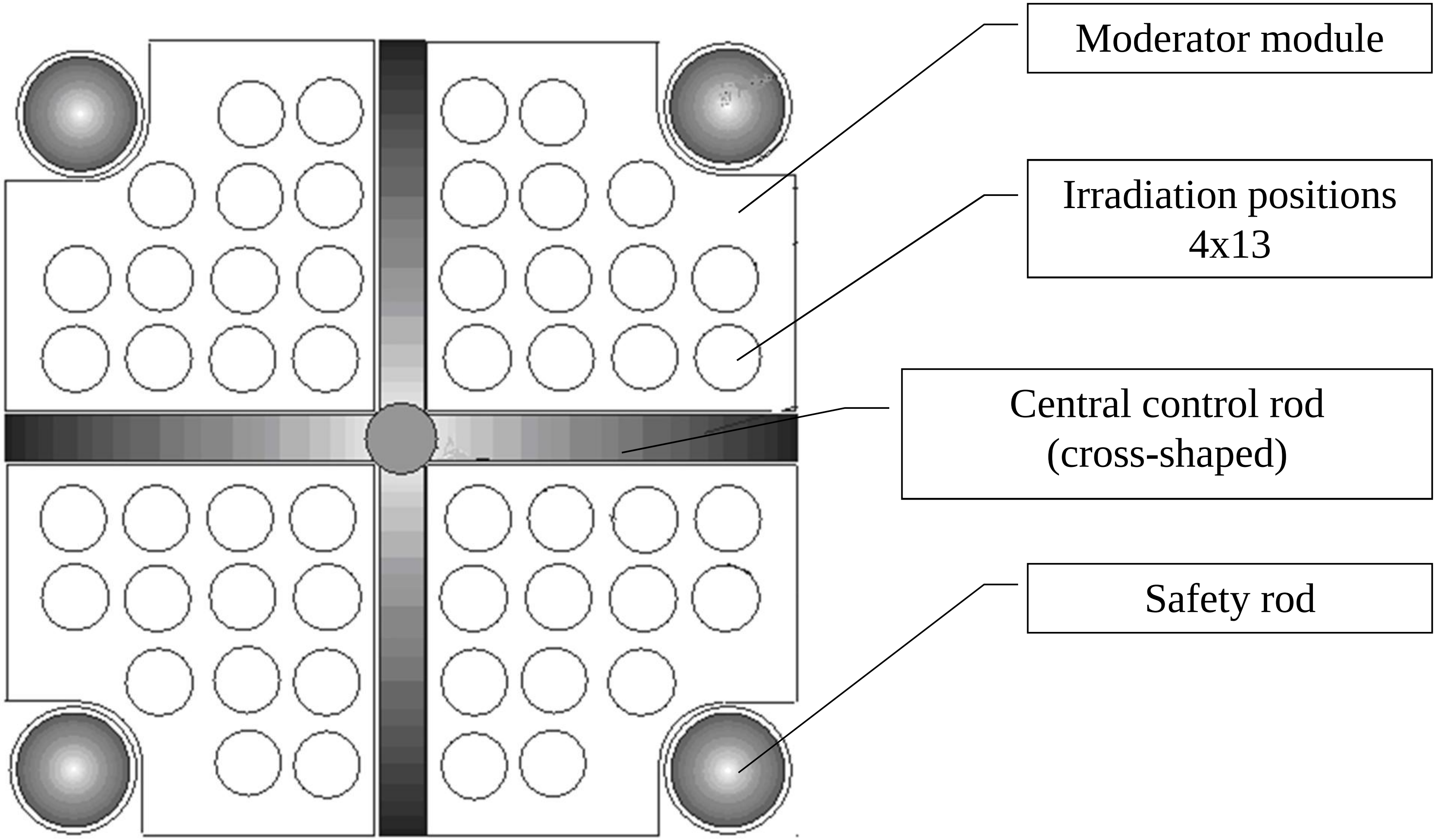
Reactor SM-3 Cross-section



Reactor SM-3 Central Neutron Trap



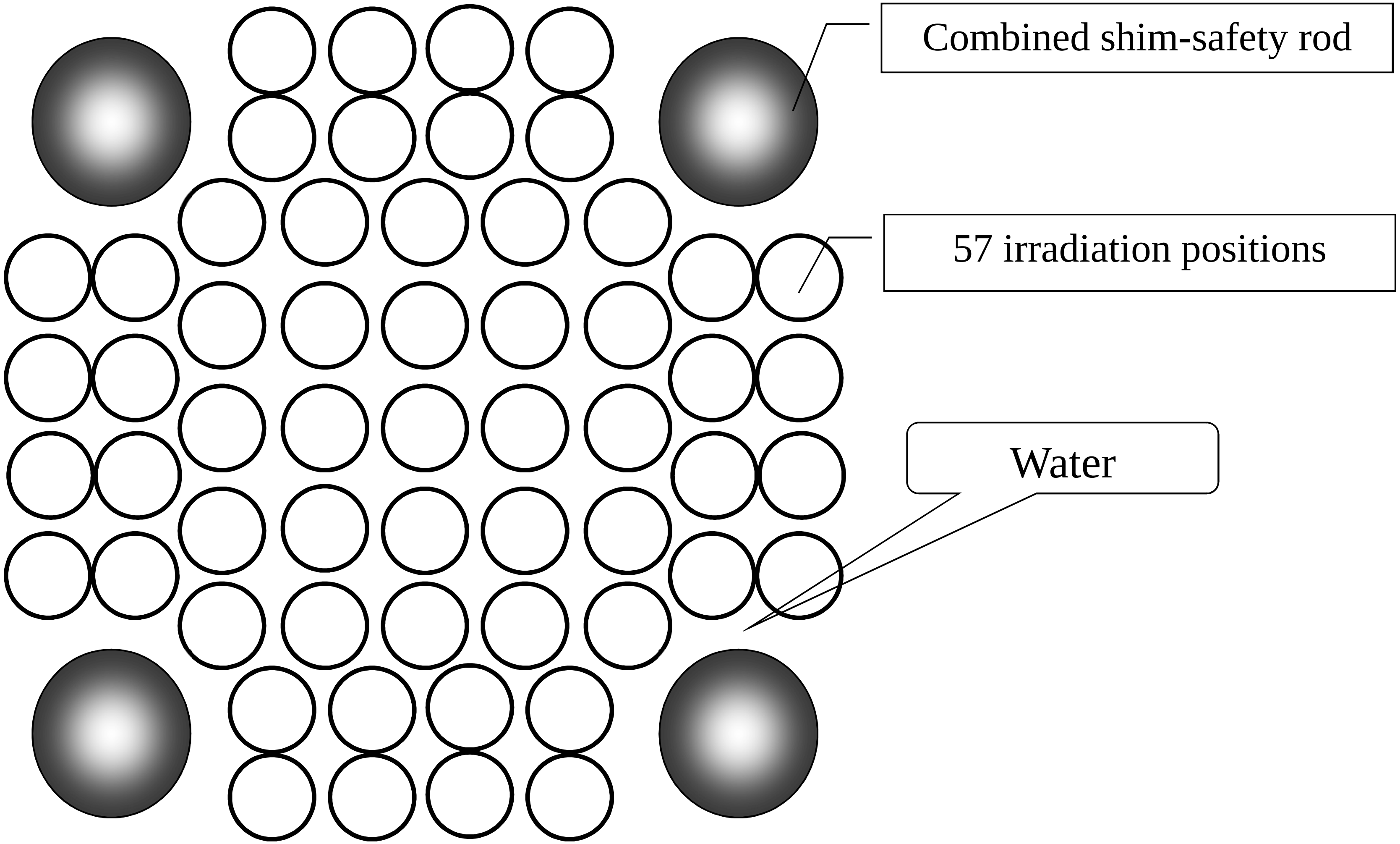
Modular – composite Neutron Trap



Any moderator's module could be filled/flooded with water, beryllium, (heavy) hydride…

Water flooded for Chromium-51

Neutron Trap
without a Central Shim Rod

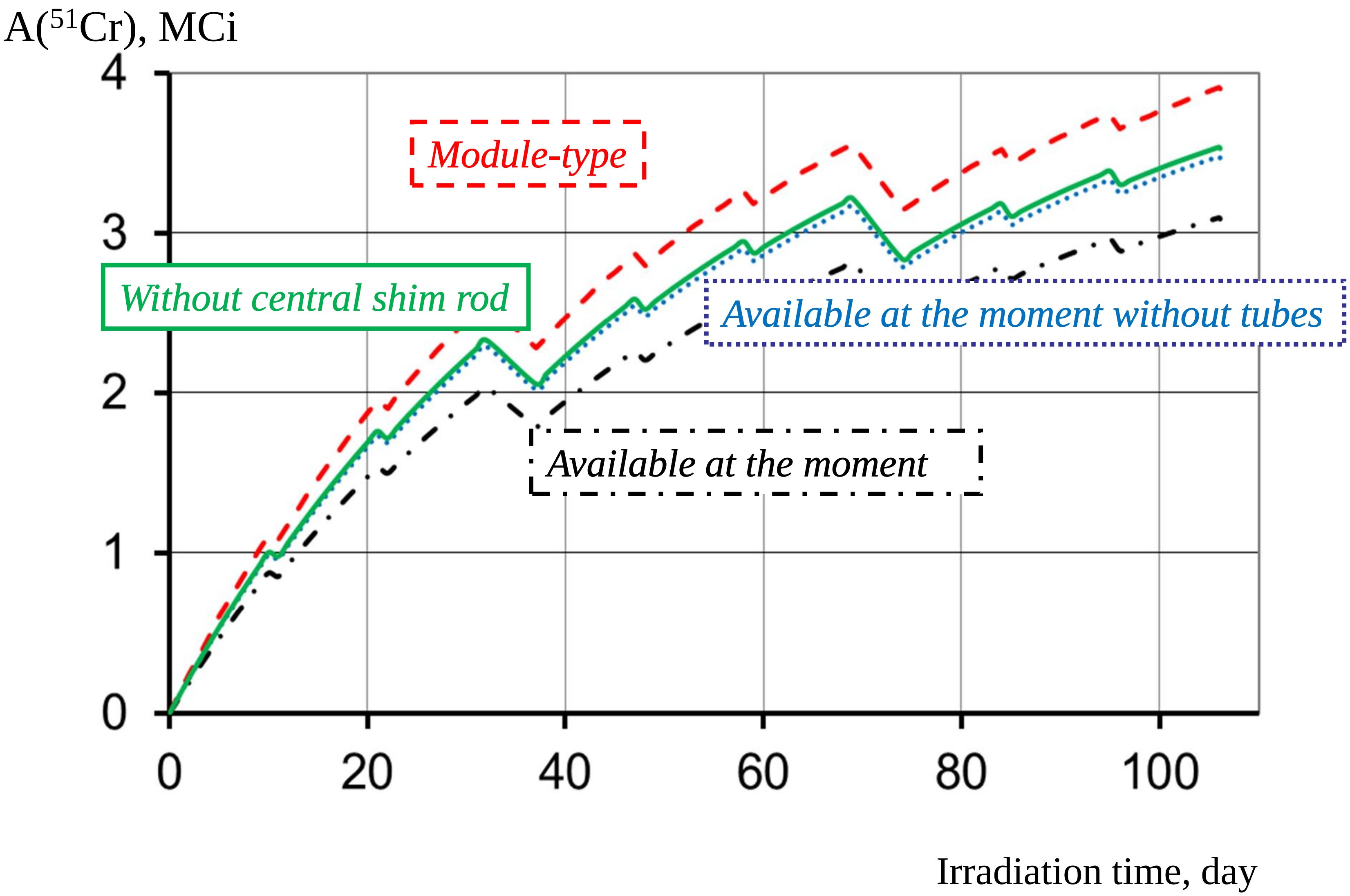


Neutron Physics Parameters

Neutron trap modification	**Neutron flux, cm^{-2} c^{-1}**				**T_{ng}, K**
	0 ÷ 0.5 eV	0.5 ÷ 100 eV*	0.1 ÷ 100 keV	0.1 ÷ 100 MeV	
“Separator-type”	3.76E+14	1.00E+14	7.77E+14	1.04E+15	720
“Separator-free”	4.29E+14	9.28E+13	6.86E+14	9.23E+14	680
“Module-type”	4.87E+14	8.80E+13	6.59E+14	1.01E+15	650
Neutron trap without the central shim rod	4.41E+14	8.75E+13	6.38E+14	9.39E+14	676

* - per unit lethargy

Simulation Results



Conclusion

- Numerical simulations show the principal possibility to produce material for ^{51}Cr neutrino source via irradiation in the SM-3 nuclear reactor

- Future tasks to be fulfilled are
  - the source geometry justification;
  - more precise simulations on the base of available rod/source geometries;
  - analysis of impurities activation during irradiation;
  - analysis of source radiation due to impurities, shielding design;
  - irradiation planning with consideration of lack in other isotope’s availability during chromium irradiation.

“If at sometime a heavenly angel should ask what the laboratory in the hills of East Tennessee did to enlarge mans life and make it better, I daresay the production of radioisotopes for scientific research and medical treatment will surely rate as a candidate for the very first place”

Alvin Martin Weinberg

Thank you