31st International Seminar on Interaction of Neutrons with Nuclei:
Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold
Neutrons, Related Topics (ISINN-31)

Analysis of Physical Parameters of the New High-Flux Pulse Reactor

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Outline

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- Benchmark for determining the critical mass of neptunium
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- Key characteristics of the reactor
- Optimization of research reactor parameters
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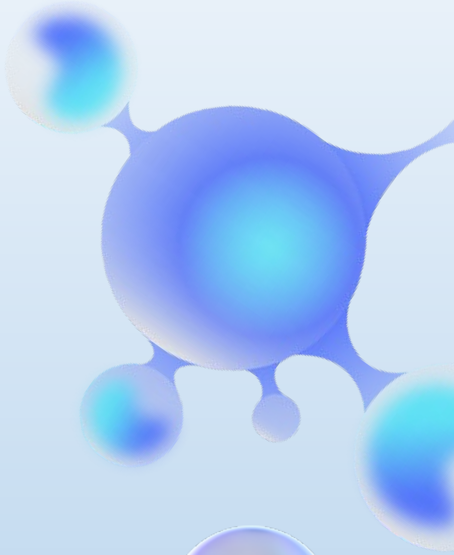
Aim and objectives

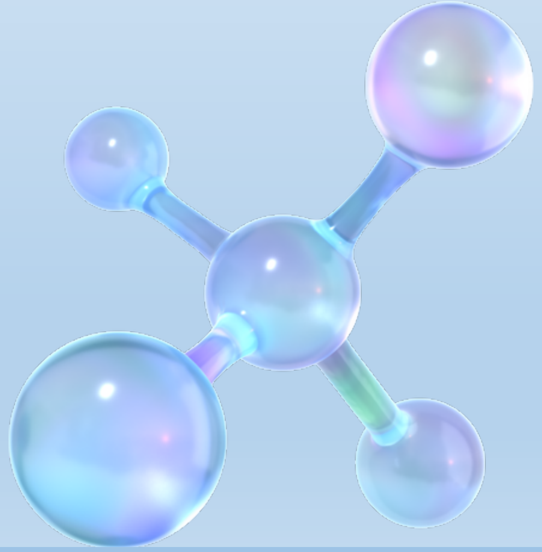


Aim:

Justification of NEPTUNE relevance
for neutron studies.

Objectives:

1. Evaluation of the parameters of the neptunium reactor.
2. Analysis of different types of fuels.
3. Optimization of the parameters of the reactor.



Pulse reactor NEPTUNE

Main aims of NEPTUNE development:

- Successful continuation of the neutron research program following the end of the operational life of the IBR-2M.
- Adhering to the new standards set by the homeland and the global legislation.

Fuel composition

Advantages

The effective threshold of ^{237}Np (0,4 MeV) is noticeably lower than the fission threshold of ^{238}U

The lifetime of the fast neutron generation (τ) in the neptunium zone is significantly lower than in the plutonium one

The effective delayed neutron fraction $\beta_{эф}$ is noticeably lower than the same value for ^{239}Pu

Disadvantages

Little-studied properties of nitride fuel in reactor conditions

Insignificant experience of the neptunium as a fuel fraction

Lack of infrastructure for the production of fuel compositions

Benchmark for determining the critical mass of neptunium

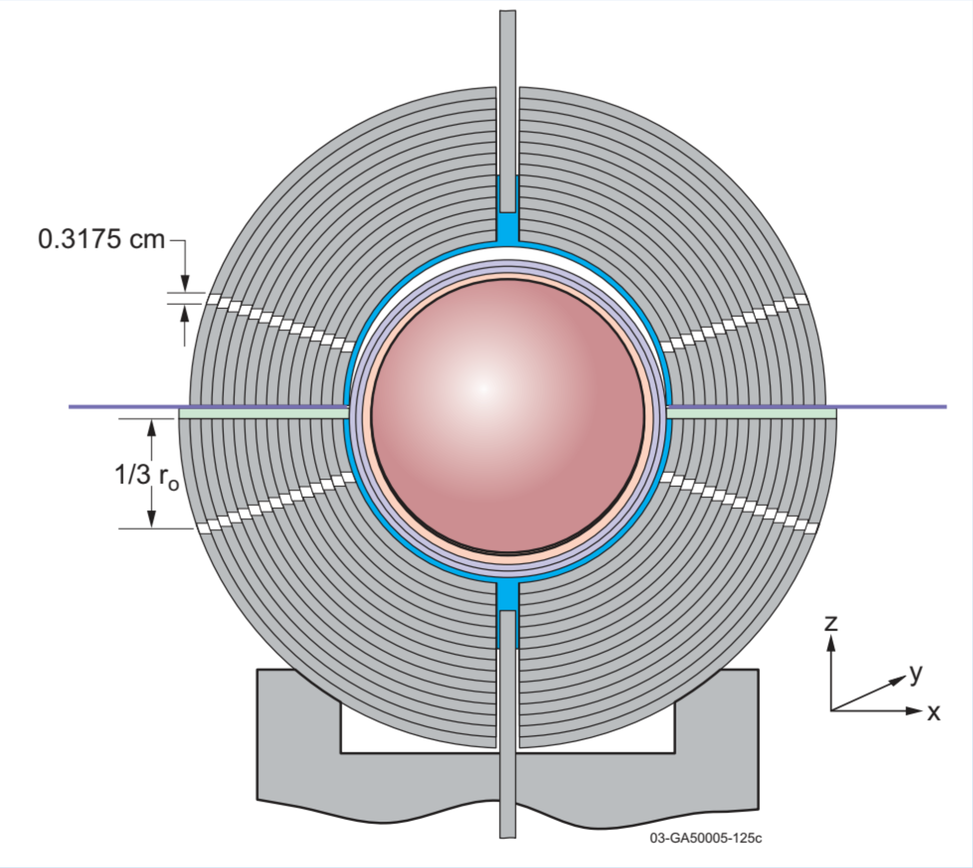


Fig. 1: Experiment scheme

Fig. 2:
Neptunium sphere

The neptunium sphere weight – 6,0704 kg.

This experiment was performed in an effort to decrease the uncertainty in the critical mass of ^{237}Np.

Comparison of benchmark models with experiment

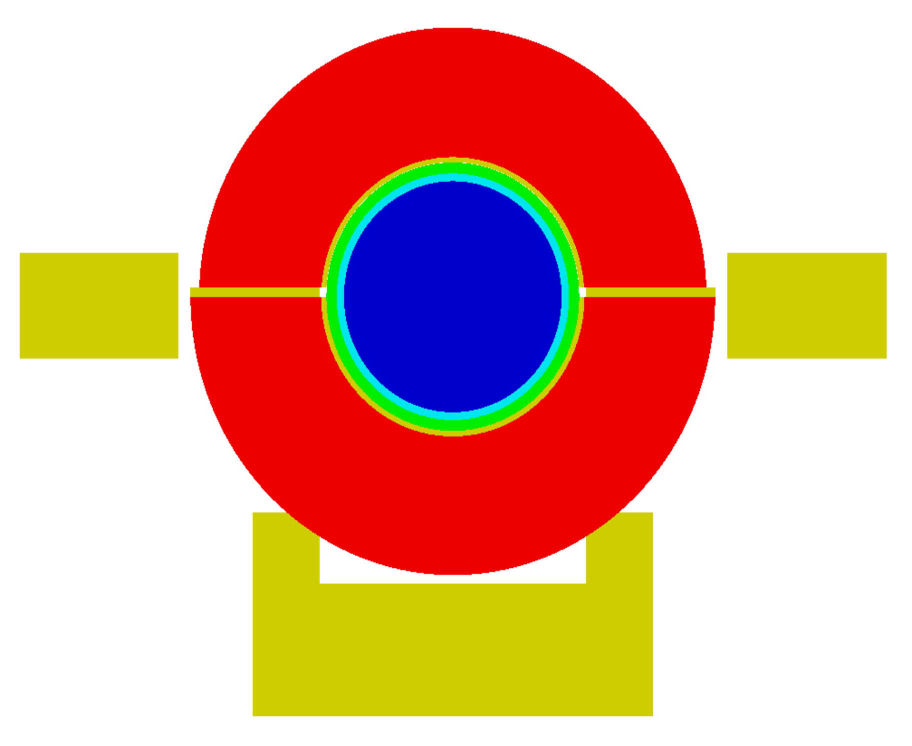


Fig. 3: Benchmark model

Table 2: Comparison of effective multiplication factors

Parameter	Los Alamos	JINR	Experiment
k_{eff}	0,9978 ± 0,0002	0,99612 ± 0,0001	1,0026 ± 0,0001
Δk, pcm	480	648	-

We can assume that our calculations are close to the calculations at Los Alamos and the result of the experiment.

Comparison of different fuel-loaded reactor models

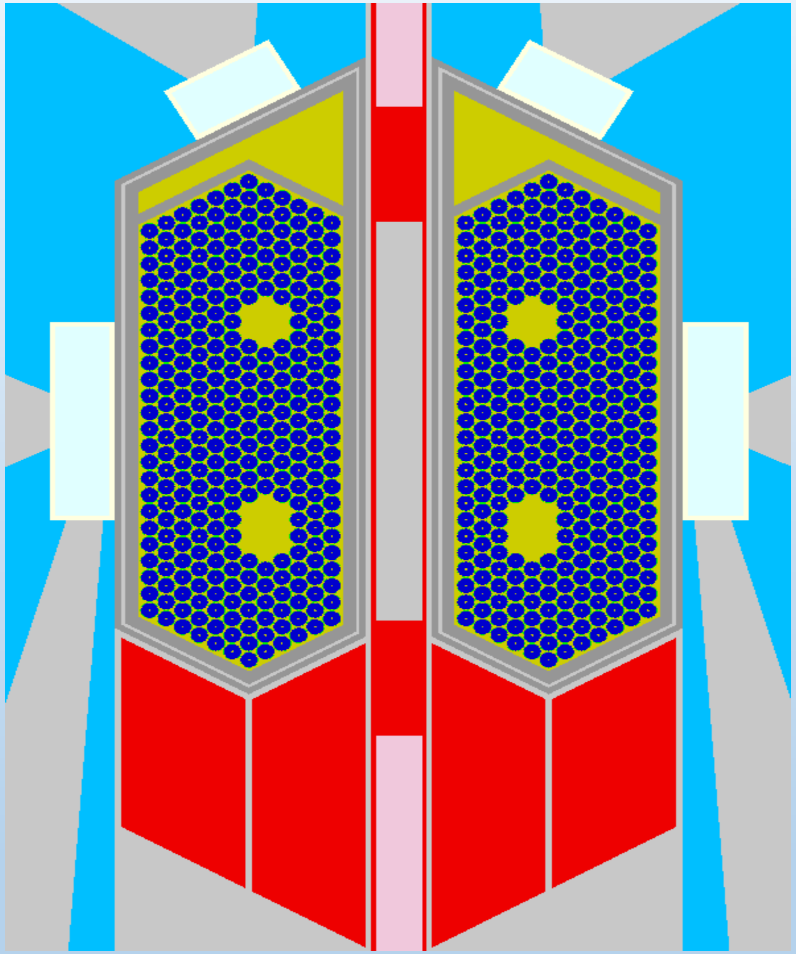


Fig. 4: Reactor model of NEPTUNE

Table 3: Comparison of parameters of different fuel-loaded reactors

Parameter	NpN	UO_2	PuO_2
Prompt neutron lifetime, s	$1{,}0.10^{-8}$	$4{,}9.10^{-7}$	$1{,}7.10^{-7}$
Effective delayed neutron fraction, %	0,140	0,730	0,220
Max. neutron flux, $n/cm^2.s$	$1{,}22.10^{14}$	$1{,}1.10^{13}$	$2{,}5.10^{13}$

Key characteristics of the reactor

Pulse length:

$$\theta_{eff} \cong \left(\frac{\tau}{\alpha V^2}\right)^{\frac{1}{3}}$$

Pulse delayed neutron fraction:

$$\beta_p \cong 0.5\,(\alpha V^2 \tau^2)^{\frac{1}{3}}$$

Pulse energy Q:

$$Q \cong S\pi B \frac{\tau}{\varepsilon_m} \exp\left(\frac{4B}{3}\right)$$

Power spread of pulse energy Q:

$$Q \cong Q_{nom} \exp\left(\frac{\Delta\rho}{\beta_p}\right)$$

where:

τ – average neutron lifetime;

V – linear velocity of the reactivity modulator;

α – reactivity modulator parabola coefficient.

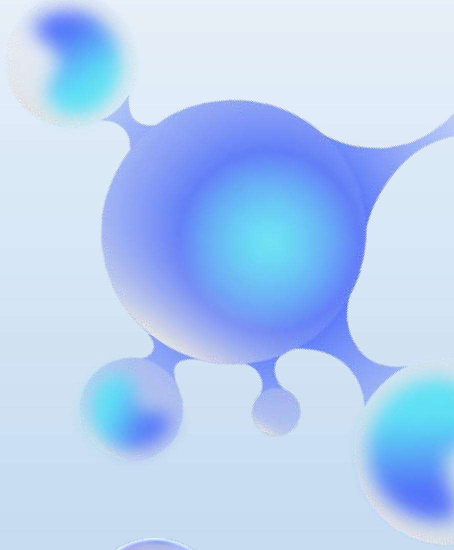
Optimization of research reactor parameters

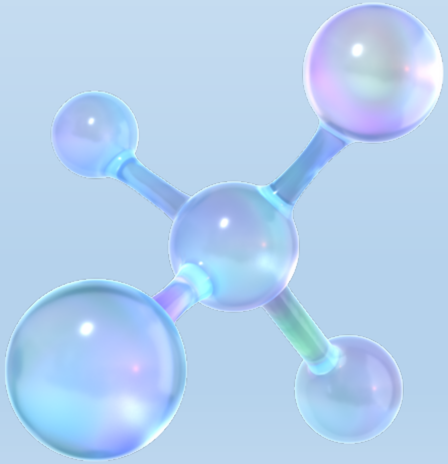
Further possible changes:

① Reactor and fuel element designs

② Fuel composition by adding other isotopes

With a change in the isotopic composition of the fuel in the core, it is possible to achieve an increase in the average neutron lifetime by 2-3 times.





Conclusions

- The possibility of obtaining shorter bursts while maintaining the neutron flux.
- Reduction of background power in the intervals between pulses in comparison with other options.
- Lack of infrastructure for the production of fuel compositions.
- Reactor parameter optimization work is performed for criticality safety and nonproliferation issues.

References

1. *E. P. Shabalin.* Fast pulsed reactors. Moscow: Atomizdat, 1976. 248 p.

2. *V.L. Aksenov, M.V. Rzyanin & E.P. Shabalin.* Research Reactors at JINR: Looking into the Future. Phys. Part. Nuclei 52, 1019–1032 (2021).

3. *E. P. Shabalin, V. L. Aksenov.* Conception of Dubna Neutron Source of the Fourth Generation. Poverhnost`. Rengenovskie, sinhotronnyie i neytronnyie issledovaniya 7, 13—19 (2018).

4. *E. P. Shabalin, V. L. Aksenov, G. G. Komyshev, A. D. Rogov.* Neptunium-Based High-Flux Pulsed Research Reactor. Atomic Energy 124 (6), 364-370 (2018).

Thank you for your attention!

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