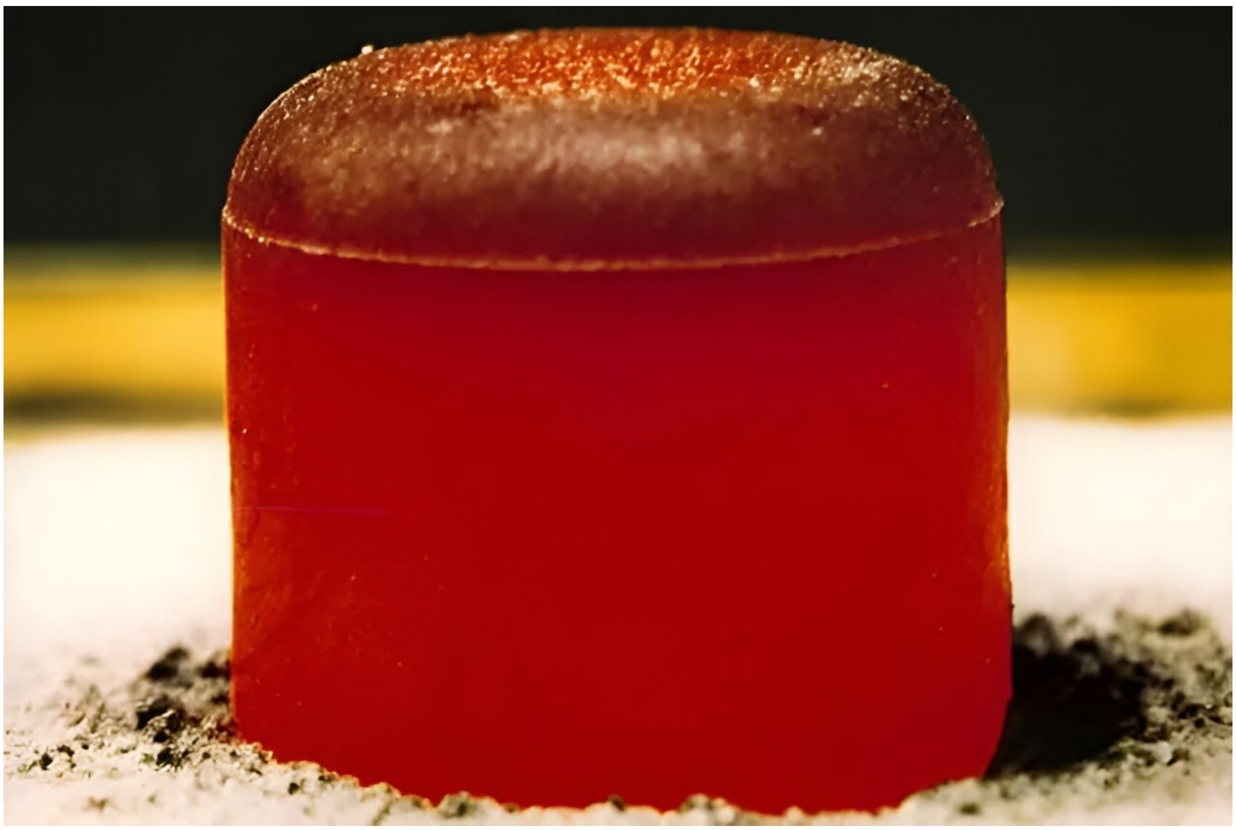
Study introduces improved plutonium production with enhanced efficiency and reduced costs

June 4 2024



Deep space exploration faces the challenge of continuous energy supply. Plutonium-238 (^{238}Pu) undergoes α- decay with a half-life of 87.7 years and an average ray energy of 5.49 MeV, which can continuously release heat and provide a heat source for this scenario. (https://doi.org/10.1007/s41365-024-01461-x). Credit: Dr. Qingquan Pan

Have you ever wondered what a spacecraft and a pacemaker have in common? Both are powered by plutonium-238 (^{238}Pu), a versatile isotope, known for its ideal heating properties.

Recent research unveils a new high-resolution neutronics model that significantly improves the production of ^{238}Pu, increasing yield by close to 20% in high-flux reactors and reducing costs. This potential breakthrough could revolutionize a wide range of technological production, from deep-space exploration to life-saving medical devices.

The findings are published in the journal *Nuclear Science and Techniques*.

Enhancing ^{238}Pu production with high-resolution modeling

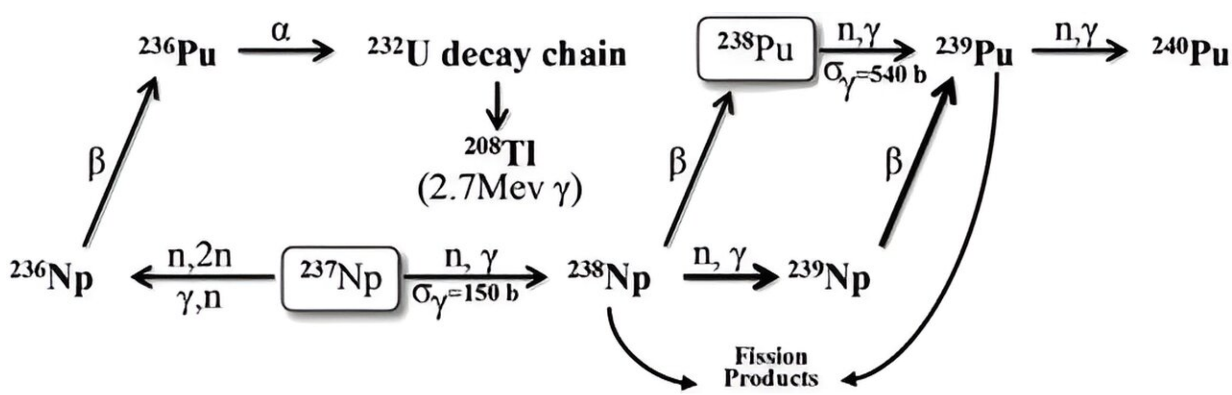
A team of nuclear scientists from Shanghai Jiao Tong University and Nuclear Power Institute of China reported that their methods—filter burnup, single-energy burnup, and burnup extremum analysis—enhance the precision of ^{238}Pu production, leading to a significant 18.81% increase in yield. This refinement eliminates theoretical approximations previously common in this field, allowing for a spectrum resolution of approximately 1 eV.

Qingquan Pan, the study's lead researcher, said, "Our work not only pushes the boundaries of isotopic production technologies but also sets a new perspective for how we approach nuclear transmutation in high-flux reactors."

The journey of neutron spectrum analysis

Plutonium-238 has a pivotal role in powering devices where traditional batteries cannot suffice, such as in deep-space missions and medical devices. Despite its importance, the production of ^{238}Pu has been plagued by inefficiencies and high costs due to a lack of precise models.

The team's approach analyzed the complex chain reactions within nuclear reactors, creating a model that not only enhances current production methods but also reduces the associated gamma radiation impact, making the process safer and more environmentally friendly.



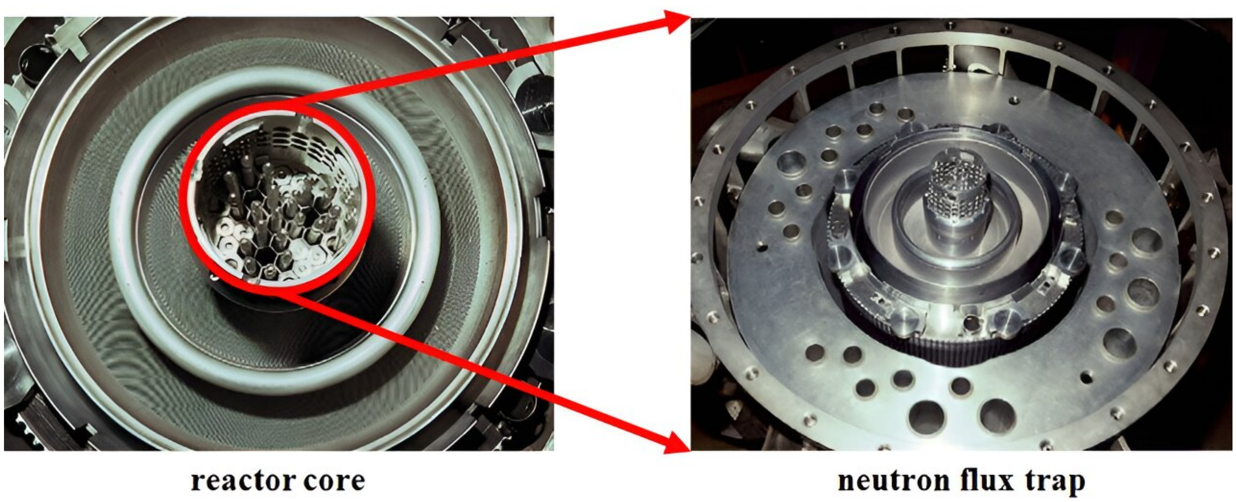
The method of producing Pu-238 through in-reactor irradiation of Np-237 has the advantage of low radioactive contamination, therefore, the production of ^{238}Pu by the in-reactor irradiation of ^{237}Np is the mainstream. During the irradiation process, various new nuclides are produced and multiple nuclear reactions occur, which are coupled with each other, forming an extremely complex nuclide transformation process. (https://doi.org/10.1007/s41365-024-01461-x). Credit: Dr. Qingquan Pan

The study compared three distinct methods. The filter burnup and single-energy burnup methods provide detailed insights into the energy spectrum's impact on nuclear reactions, while the burnup extremum analysis method evaluates how changes over irradiation time affect overall production efficiency. These techniques collectively enable precise control and optimization of neutron reactions within reactors.

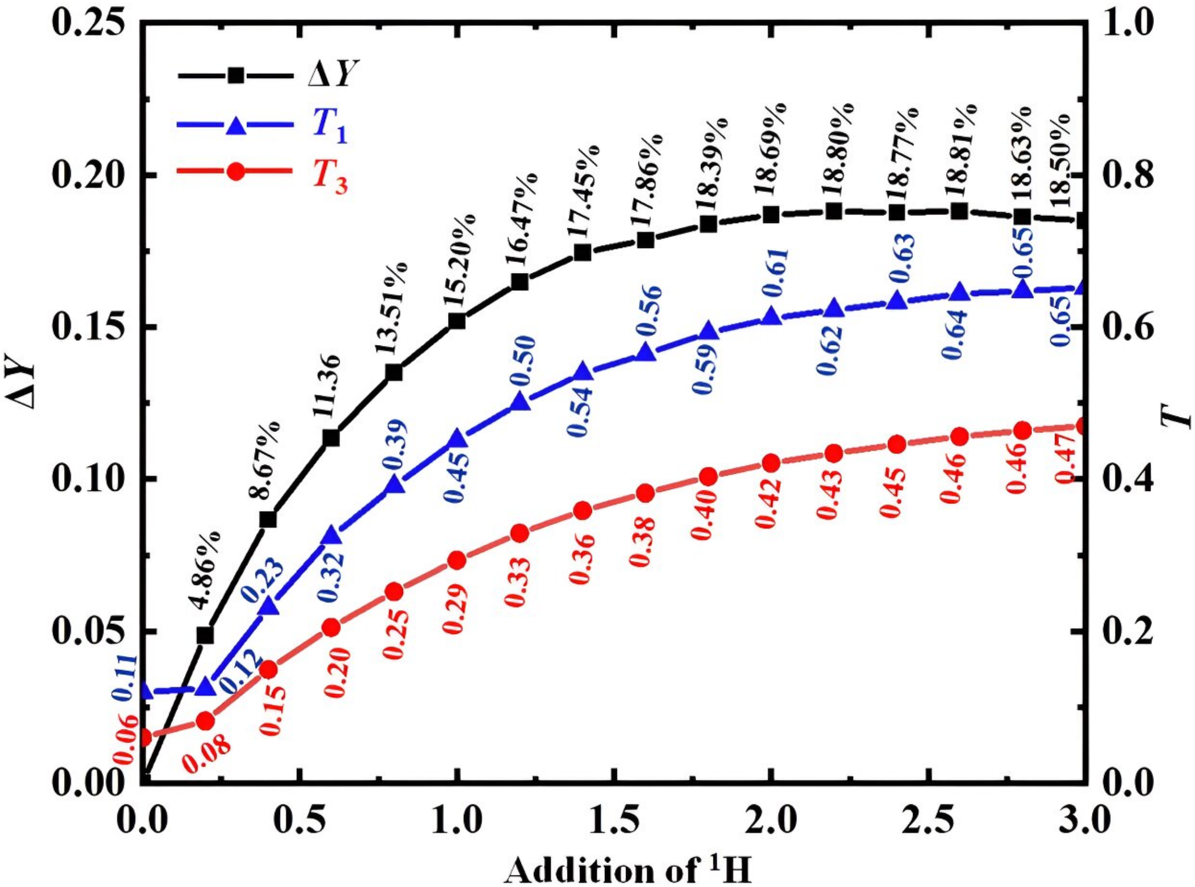
From space exploration to pacemakers

The implications of this research are vast. Enhanced ^{238}Pu production directly supports the operation of devices in harsh, inaccessible environments. "This model could significantly impact not only future space missions, ensuring longer-lasting power for spacecraft but also the reliability of medical devices like cardiac pacemakers," said Pan.

The refined production process means that more ^{238}Pu can be produced with fewer resources, and enhancing the safety of production facilities. reducing environmental impact and enhancing the safety of production facilities.



The production of Pu-238 requires a high thermal neutron flux environment. High-flux isotope reactors are currently the most well-known and stably operating high-flux thermal neutron reactors in the world, capable of providing an irradiation environment for the production of Pu-238. China is also accelerating the construction of high-flux reactors. (https://doi.org/10.1007/s41365-024-01461-x). Credit: Dr. Qingquan Pan



The Neutronics model proposed can be used for neutron spectrum optimization, which can effectively improve the production efficiency of Pu-238, improving the yield of ^{238}Pu up to 18.81%. (https://doi.org/10.1007/s41365-024-01461-x). Credit: Dr. Qingquan Pan

Looking forward, the research team plans to expand their model's applications. "Our next steps involve refining target design from an engineering perspective, optimizing the neutron spectrum used in production, and constructing dedicated irradiation channels in high-flux reactors," Pan added.

These developments will not only streamline the production of ^{238}Pu but could also be adapted for other scarce isotopes, promising widespread impacts across multiple scientific and medical fields.

A brighter, safer future in energy and medicine

The development of a high-resolution neutronics model marks a significant progress in nuclear science, with implications that extend far beyond the laboratory. When this model is applied to other scarce isotopes, its impact on both technology and industry is expected to expand, supporting significant advancements in energy, medicine, and space technology.

As the world leans more towards sophisticated energy solutions, the work of Pan and his team underscores the crucial role of innovative nuclear research in securing a sustainable and technologically advanced future.

More information: Qing-Quan Pan et al, High-resolution neutronics model for 238Pu production in high-flux reactors, *Nuclear Science and Techniques* (2024). DOI: 10.1007/s41365-024-01461-x

Provided by Nuclear Science and Techniques