NATIONAL NUCLEAR LABORATORY

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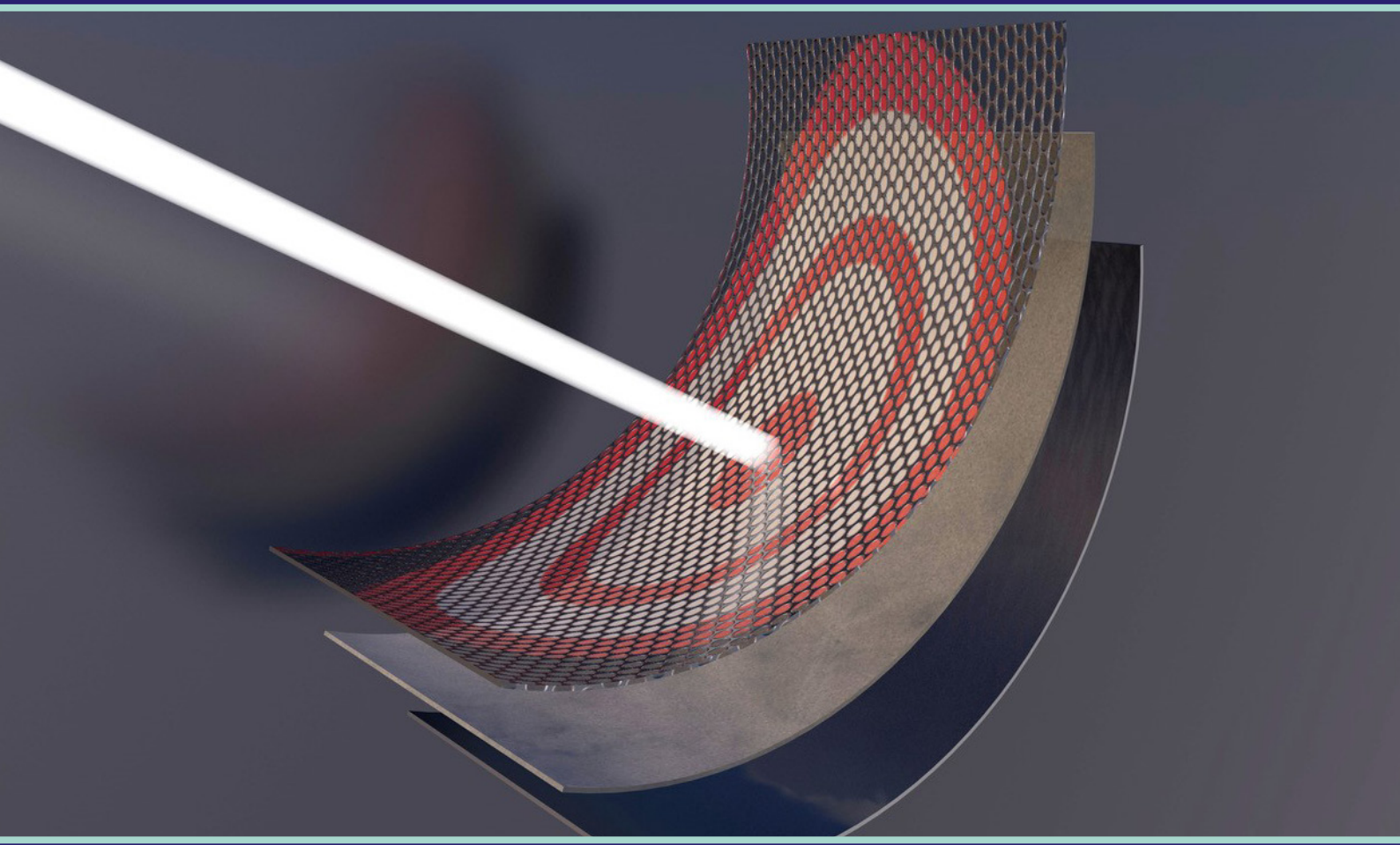

Challenge: Flexible method of production for thin film targets used in nuclear physics and nuclear medicine experiments

The National Nuclear Laboratory (NNL) are inviting proposals to explore innovative processes or methods to put down thin, metal-based films onto a low atomic mass backing material in a flexible and reproducible manner. These thin films are to be used in a particle accelerator to help study fundamental nuclear physics and to identify and produce novel radioisotopes for research and use in the medical field.

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Introduction

STELLAR is the name given to an ambitious NNL-led project to provide neutron irradiation facilities in the North West of England. Located at NNL's Central Laboratory, STELLAR will define the requirements and establish a route to providing a unique UK and international capability for access to a high energy, high-flux neutron source.

The provision of such a neutron capability in the UK has been identified as an enabling capability for future nuclear research and development across fission, fusion and medical theranostics. The nuclear data, and products that could be generated through the use of this technology, will underpin the research of real world applications across the nuclear sector. This will include research into closed-loop fuel cycles, nuclear fusion and the production of novel medical radionuclides.

One of the variables in a neutron irradiation experiments is the targets required. That is, more specifically, the target which the generated neutrons interact with to produce a changed material. The proposed STELLAR system at Central Laboratory is intended to have a range of flexible applications that would require the synthesis of a diverse range of target materials, including the production of novel radionuclides for the improvement of radiation based medical treatments.

A reproducible method of making comparable, characterisable thin film targets with different source feeds (for example different metals) is required to enable the production of comparable data sets across different projects, which may use different materials as the targets.

Developing a method of manufacturing these targets in-house would unlock the ability to utilise the full range of materials that NNL can handle, which in turn will unlock the full value of the STELLAR system.

The targets of interest are described further in the 'functional requirements' section of this challenge statement.

The key challenge associated with this target manufacture is to ensure that employing a specific system or method generates reproducible results whilst using different metal-based materials. For example, metals and metal oxides, including actinides. For the initial demonstration or development of manufacturing processes, non-radioactive materials can, and should be used. However, to ensure non-limiting manufacture, the properties of active materials should be considered, including the ability to reduce the possibility of contamination between samples (for example, proposed manufacturing methods could include a reliable decontamination process, or the use of a modular assembly).

The material feed to make the target could either be solid or solution based, and we would like to invite consideration of either (or ideally both).

Characterisation of the target is important and the ability to characterise, and troubleshoot issues, is desirable. The process or method needs to enable high predictability of sample composition in order to ensure simpler sanctioning in facilities. This includes isotopic composition as well as mass measurements and uniformity of the target surface.

There is also a need for early identification of methods that could potentially lead to subsequent scale up, depending on the demonstration of viable production routes.

Current practice

Typically, medical isotopes such as molybdenum-99 are produced by creating a mm-thick alloy, for example of uranium and aluminium/silicon, for use in nuclear reactor systems. Being dependent on reactors for radionuclide generation constrains production capability (through reactor cycles, the species that can be generated and radionuclide half-lives).

An example of a reactor production route for a proposed novel radionuclide in nuclear medicine is shown below (Figure 1). The relatively short half-life of lutetium-177 (Lu-177) and its emission of low energy β- and γ rays makes it an attractive isotope for use in imaging and radionuclide therapy.

Lu-177 is proposed for production by direct and indirect production routes. The direct production route involves the neutron irradiation of Lu-176 to form Lu-177. The indirect production route involves the neutron irradiation of ytterbium-176 to form ytterbium-177 (1.91 hour half-life) which then decays via β- to Lu-177. The direct production route is the simplest, with no intermediate products necessary, however this also results in the production of the long-lived impurity Lu-177m.

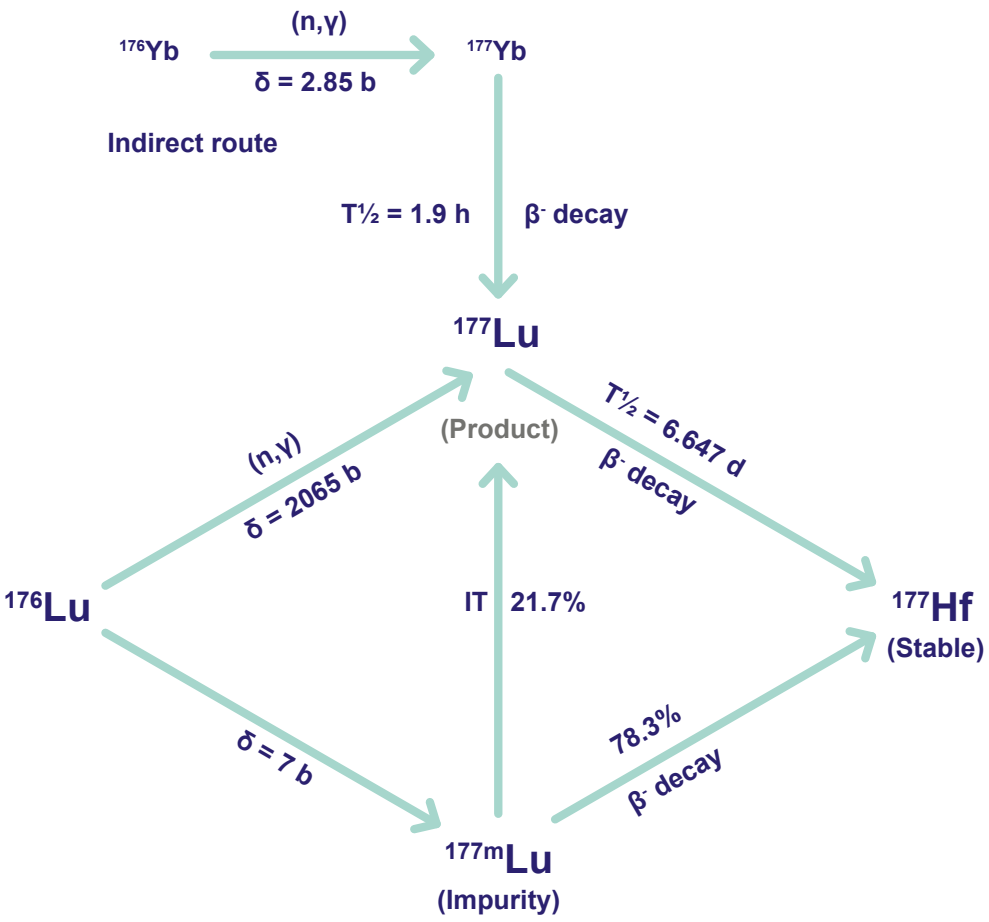

Figure 1: Indirect and direct routes to producing Lu-177

Current research targets have been made globally on an ad-hoc basis and, as such,often have limited repeatability and isotopic contamination issues, leading to less-than-desirable comparability. Many different approaches to target development are used. These often involving niche solutions that produce a target of variable quality for individual experiments.

Known laboratories with relevant experience include the Paul Scherrer Institut and the GSI Helmholtz Centre for Heavy Ion Research.

Challenge aims

The flux levels of accelerator systems have in the past been too low to generate isotopes of medical interest. It is hoped that the development of a high energy, high-flux neutron source at STELLAR will enable the exploitation of accelerator-based production routes for medical applications. The lower cost of production using accelerators is of interest, but it necessitates the production of thin film targets to ensure that neutron self-shielding effects don't dominate (i.e. the whole depth of a target needs to be irradiated).

NNL would therefore like to explore reproducible methods of producing thin films. These methods could potentially be in use in different industries already and could be adapted for nuclear use. Of particular interest are the ability to predict the formation of material in the thin-film and the ability to thoroughly clean production equipment when it is being used with different materials or on different runs.

Technological solutions could initially be demonstrated with non-radioactive targets. The ability to characterise targets, including the precise measurement of the mass of the material deposited, is a key requirement.

Benefits to the NNL's health and nuclear medicine focus area

By creating a route to reproducible metal-based targets NNL would have increased in-house capability, leading to a simpler route to fabrication as well as the ability to adapt production methods to research more challenging feeds (ie. actinide feeds with specific isotropic compositions and limited half-lives that can't be transported easily).

Reproducible production methods could lead to the generation of data which could be comparable between materials and targets. If successful, this could increase applications in the production of medical radionuclides for theranostic use, which currently has very limited capacity (if any) within the UK.

Successful solutions will lead to improved measurement performance and will enable the testing of more input streams. Production capability which is co-located with an irradiation source will enable diverse target development. This could also provide a potential route to the commercialisation of radionuclide production.

It is hoped that the ability to generate multiple thin films on a regular basis could enable regular irradiation cycles.

Constraints

Current constraints include the need for a flexible process and for the process to be easily decontaminated or cleaned. The use of radiation resistant materials is preferred but the replacement of non-radiation resistant materials could be part of the development process.

It is envisaged that the process will be based on a laboratory scale, and batch processed (i.e. not a production line). Volumes of feed are likely to be in the millilitre, rather than the litre range and the efficient use (minimal waste) of feed material is strongly desired.

The route to target production is not constrained. Targets could consist of multiple thin layers or one monolayer depending on the production method used.

Functional Requirements

Full or partial solutions to this challenge are welcome. Solutions must take into consideration the following functional requirements:

- It is desired that the targets are composed of a thin film in the range of microns to hundreds of microns thick, applied to defined backing materials. A typical example of a backing material in use would be carbon.
- The typical dimensions of a target are 50mm x 50mm, but ideally the system should be flexible, with a capability between 10mm diameter (min) and 100mm diameter (max).
- The system or process should be capable of handling different metal-based feeds, ideally actinide-based metals, oxides and nitrides.
- The ability to control the feed stock is desired, both in terms of application to the target and in the production of waste to limit environmental effects from material release.
- Predictable and measurable performance is important.
- Contamination must be minimised to minimise the time between use of the system or process.
- The solution must be able to handle corrosive materials.
- The system needs to be capable of integration with a venting system.
- Solutions should ideally be easy to use to minimise the amount of operator training required. Automated systems may be of interest.
- Systems must be capable of operation in low oxygen atmospheres (to prevent target oxidation)

What Next?

Game Changers are hosting an online briefing webinar for this challenge. Details of the webinar are available on the Game Changers website www.gamechangers.technology. If you have new ideas or innovations which can be applied to address this challenge we invite you to join us.

Please visit our FAQs on the Game Changers website for answers to some commonly asked questions, or contact us on apply@gamechangers.technology if you have further queries about this challenge.

Applications must be submitted using the Game Changers online application portal. This includes a short application form and a requirement for a poster outlining the proposed solution.

The deadline for applications for this challenge is **12 noon on Friday 18th November 2021.**

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