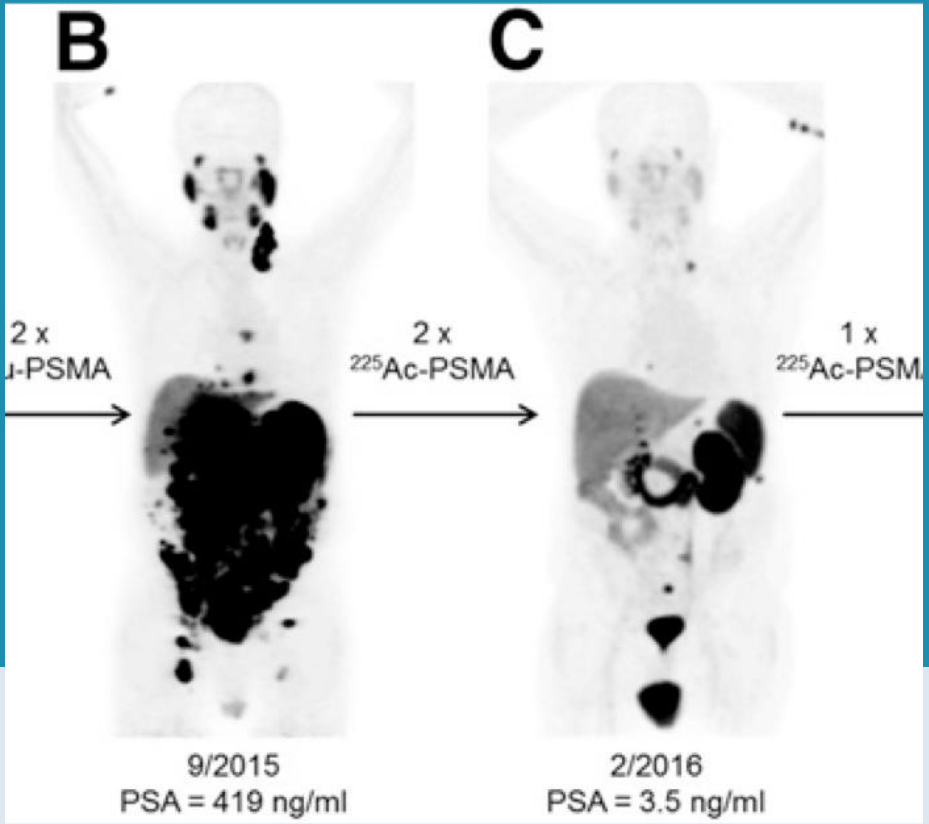
WP3: Medical & Societal Applications



RO6: Making use of the R&D progress to the benefit of society through the direct use of the actinide isotopes themselves (theranostic applications), or the application of techniques for their detection (environmental monitoring).

Societal Applications	
Medical: Many α-emitting radioisotopes have been identified for medical applications in cancer treatment[26], most of which are either very heavy isotopes (Z>82) or actinides. Of particular interest is ^{225}Ac, which can be either be used for treatment[3], or as a generator for ^{213}Bi[27]. However, these investigations are greatly hindered by the limited access to ^{225}Ac, currently only available in sufficient purity from the stockpile of ^{233}U, a highly regulated product resulting from the 20th century nuclear civil and military engineering	**Medical:** Within LISA, we will aim at investigating the production of ^{225}Ac for medical applications with laser ionisation combined with ISOL. The MEDICIS facility[29] at CERN has begun delivering radioisotopes produced with the ISOL technique for medical research since 2018. By implementing the laser technology from LISA at this facility, **high-purity samples of ^{225}Ac will be delivered to medical research facilities in Europe** while the technology will be put to the test towards the next generation ISOL facilities, where this isotope could be produced in larger quantities.
research. Alternative production routes currently suffer from high contamination levels.[28] **Radioecology:** Detection of actinides in environmental samples is routinely performed by radiometric methods and by mass spectrometry such as AMS, SF ICP MS and (most often dynamic) SIMS. However, all of these suffer from isobaric interferences and only SIMS provides spatial resolution. Isotope distributions – relevant for forensics – are measured by consuming the sample (destructive).	**Radioecology:** By **combining SIMS and resonant laser ionisation** for actinides detection isobaric interferences are avoided. The proposed static SIMS consumes only a minute amount of sample making this hyphenated technique quasi non-destructive. Element and isotope distribution of single µm sized particles can be obtained, while the particle remains intact for further investigations. Information on (a) origin and (b) **potential leach-out of actinides into the environment due to weathering can be predicted**. The proposed developments will allow fast simultaneous measurement of all major actinides, which strongly will improve the current time consuming practice of sequential measurements.

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WP3: tasks

Objectives
- Transfer the knowledge acquired in this training network program towards societal applications - Benefit society via new opportunities in cancer treatment research - Benefit society via a better understanding of radioecology and environmental radioactivity

Description of work and role of partners
WP3 - Medical & Societal Applications [Months: 4-48] **KUL** Task 1: ionization scheme developments for ruggedized use in application, such as medical radioisotope production or natural sample studies. Establish and test 2-step laser resonance ionization schemes for ease-of-use and simplicity. This work will be carried out based on the input from the other work packages. The open-access laser ionization scheme database will be further developed in the network as an essential resource for information sharing within the consortium and beyond. Task 1a: Ra and Ac schemes – KUL Task 1b: Pu schemes – LUH IRS Task 2: Demonstrate a more user-friendly, industry-ready, laser-ionization system via the optimization of the laser laboratory setup to allow fast switching between elements: quickly adjustable tuning ranges from the lasers, self-correcting pointing system for optimized beam delivery, multi-laser laboratory for quick switch between two frequently-used elements. Task 2a: Automatization of the CERN MEDICIS laser laboratory for medical radioisotope production – KUL Task 2b: Double-capacity laser system installation for radioecology studies – LUH IRS

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WP3: milestones & deliverables

Few and far enough away that we should have no problem meeting the milestones and deliverables.

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Application of fast scanning option for multi actinide detection	10 - LUH IRS	Report	Confidential, only for members of the consortium (including the Commission Services)	24
D3.2	Optimized production scheme for 225Ac	2 - KUL	Report	Public	30
D3.3	Application of narrowband excitation for 238U / 238Pu discrimination	10 - LUH IRS	Report	Confidential, only for members of the consortium (including the Commission Services)	42

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS11	Extraction of laser-ionized radium and actinium from CERN MEDICIS	2 - KUL	24	Sample identification by radioactive decay measurement with and without lasers
MS12	Development of high resolution excitation schemes for Pu	10 - LUH IRS	30	Efficiency and saturation curves

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WP3: 2 ESRs to recruit

ESR #	Host institution	PhD (Y/N)	Start date	Duration	Deliverables
ESR1	**KUL**	**Y**	**M6**	**36**	**D3.2**
Project title: Optimized production of ^{225}Ac by the ISOL method for medical applications (**WP3**: Medical & societal applications)					
Objectives: Study and optimize the extraction of ^{225}Ac using the ISOL technique, by either its direct production or the production of precursors, towards a sustainable, large-scale production of this isotope for medical applications.					
Expected results: Quantifying the properties for the production of actinium and radium ion beams by the ISOL technique; optimizing the target and ion source geometries to maximize the production and extraction of actinium; provide regular samples out of the CERN MEDICIS facility to seed medical research programs; devise a route towards the sustainable use of the ISOL technique for the production of medical-grade samples of ^{225}Ac.					
Planned secondment(s): TRIUMF (Jens Lassen) – M17-18 – production of laser-ionised actinium at ISAC; LIOP (Jürgen Lindener-Roennecke) – M25-26 – laser laboratory automation for stability and reliability with high-quality optical supports; CERN MEDICIS (Thierry Stora) – M32-37 – implementation of the research outcomes at the CERN MEDICIS facility & production of ^{225}Ac samples.					
Enrolment in Doctoral degree: KUL Arenberg Doctoral School under the supervision of Prof Thomas E. Cocolios					

ESR #	Host institution	PhD (Y/N)	Start date	Duration	Deliverables
ESR12	**LUH IRS**	**Y**	**6**	**36**	**D3.1, D3.3**
Project title: Multi-element ultra-trace detection of radionuclides in environmental samples (**WP3**: Medical and Societal Applications)					
Objectives: Though multiple element mapping is possible with the present Resonant Laser Secondary Neutral Mass Spectrometer (rL SN MS), the present apparatus suffers from a number of shortcomings. (a) Changing the laser settings from one element to another is a time-consuming process and (b) isobaric / isotopic separation is limited by the rather wide bandwidth of the present laser system. Within LISA, new laser excitation schemes will be developed by combining theoretical modelling (DFT) and high-resolution laser spectroscopy experiments on actinides for applications in trace analysis and radioecology.					
Expected results: Addressing (a) Speeding up the change from on element to another. The candidate will test two-step excitation schemes for Th, U, Np, Pu, Am, Cm (instead of the three step ones used so far). By adding one additional laser (so the system will have four in total), two elements can be resonantly ionized in a fast alteration cycle to save time and considerably lower the influence of instrumental drifts. Alternatively, closely lying excitation wavelengths might be easily accessible by simply tuning the lasers back and forth very fast, for which an additional Ti:Sa laser is required with improved scanning options. Addressing (b) Selective and highly-efficient suppression of isobars. Important examples are detection of ^{238}Pu in a ^{238}U matrix and detection of ^{241}Am in the presence of ^{241}Pu. The ^{238}Pu/U ratio might exceed 1:10^6, calling for an isobaric suppression of at least 1:10^8 or better, to be able to measure the ^{238}Pu abundance at sufficient precision. The present setup is not able to suppress ^{238}U over ^{238}Pu by more than a factor of ca. 5000. One of the reasons is a closely lying resonance of U. The candidate will test narrow bandwidth excitation in one or two steps of the excitation ladder of ^{238}Pu for further suppression of unwanted U ionization.					
Planned secondment(s): MSL (Dorian Parker) – M6-7 – Ti:Sa laser development; LLNL (Mavrik Zavarin) – M18-19 – System development; IER (Kenji Nanba) – M33-34 – Environmental sampling around the Fukushima Daiichi site and sample preparation for ultra-trace analysis.					
Enrolment in Doctoral degree: LUH IRS faculty Mathematics and Physics under the supervision of Prof Clemens Walther					

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WP3: LISA-4-Society

LISA-4-Society Action
Radioecology Field Study
A first action will be a radioecology field study, sampling the ground in Ukraine, including the **Chernobyl exclusion zone** (CEZ). Preparedness for radiological incidences and accidents, requires (a) instruments for fast trace analysis of actinides and (b) skilled personnel versed in sampling and operating the machines. To this end, we will demonstrate the **skillset** developed by our ESRs **directly in the field**. Up to 8 persons will travel to Kiev, take environmental samples in the CEZ, perform sample preparation for transport (separation of the high ^{137}Cs activity) go back to LUH IRS for detection afterwards.
^{225}Ac for medical applications
A second action will concentrate on the use of ^{225}Ac for medical applications. A team of up to 8 ESRs will oversee themselves the complete chain in the **production** of that radioisotope at the CERN MEDICIS facility and its **delivery** to a medical research facility, starting with the conception of the target unit, its irradiation, the extraction and collection of the radioisotopes, their isolation after collection, and finally the delivery to a medical research facility.

- Showcasing our success in translating our research to society;
- Producing promotional material (e.g. videos, articles, …);
- Involving all ESRs

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