ISOLDE NEWSLETTER 2025

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Introduction

Sean J Freeman

Welcome to the 2025 ISOLDE Newsletter!

It is always a relatively easy task when CERN management ask me for highlights from ISOLDE to show at CERN Council or Science Policy Committee meetings. Over the past few years these have included radioactive molecules; transfer reactions on ^{132}Sn; nuclear clocks; colour centres in diamond; lithium diffusion in solid-state batteries; laser spectroscopy of neutron-rich calcium isotopes at a few ions per second; back-to-back PRL's from ISOLTrap and IDS on very neutron-deficient and very neutron-rich indium isotopes; and other exciting results. The scientific programme at ISOLDE continues to impress in terms of both the quality and the breadth, and the articles in this newsletter gives a glimpse into some of the science done at the facility recently. As always, life has been busy since the last newsletter and there are many other things to report.

We completed the preparations and funding requests for the series of improvements that will be implemented during Long-Shut Down 3 (LS3). I've reported in other newsletters that we have been very successful in previous years with requests to both the CERN Medium Term Plan (MTP) and CERN Consolidation Budgets, particularly securing a significant resource in last year's MTP exercise for the replacement of the proton beam dumps to allow delivery of higher energy and intensity protons. During the past year a lot of work was done by many people in preparing a request for the remaining items: magnets for the BTY line along with vacuum and civil engineering for 2-GeV proton delivery; beam switching through the central beam line; some improvements to REXTRAP, EBIS and ISCOOL; plus other smaller items. In addition, we also needed to ask for resources to follow up on the ideas from the task force looking into ways to recover and maintain the performance of the accelerating cavities of HIE-ISOLDE.

A co-fund programme was proposed by the ISOLDE Collaboration Committee and colleagues in the Accelerator and Technology Sector, which has been successful in obtaining 3.0 MCHF from this year's MTP to add to 3.7 MCHF from the collaboration to complete these activities. For HIE-ISOLDE, this includes refurbishment of Cryomodule 1 during LS3 and construction of Cryomodule 5, which will be used as a spare to gradually switch out the other cryomodules for refurbishment; this switch can be done in a Year End Technical Stop without disturbing the HIE-ISOLDE physics programme after LS3. We also heard this year that 1 MCHF was allocated from Consolidation budgets for RILIS activities at ISOLDE. All great news and thank you to everyone involved.

Over the past few years, the total investment in the improvement programme for LS3 (and a little beyond) is just shy of 29 MCHF, with around 12% supported by the ISOLDE Collaboration for items that are close to physics delivery or for items where there has been previous collaboration investment. This demonstrates a significant commitment by CERN in the ISOLDE scientific programme and now a lot of work needs to be done to implement these projects. But we should not pause, it would be wise to start thinking now about what ideas there are that might be implemented in LS4. Indeed, a brainstorming session by the Collaboration Committee last year produced a huge spreadsheet that went from new PC's for the data room (already actioned!) through to a new proton driver. I suspect even this list does not cover all the possibilities, so let your ISCC representative know if you think of something!

Since the beam dump replacement is expected to take two years and the long-shutdown for the PSB is scheduled for around eighteen months from September 2026 when the LHC LS3 starts, there was a choice to make about ISOLDE running: whether to align the beginning or the end of these two activities? There is

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an influence on the physics programme because HIE-ISOLDE operation is fixed to the second half of the calendar year. After long discussions with all stakeholders, starting the beam dump work at the end of 2025 made sense in terms of the amount of high-energy running. But it also presents advantages for ISOLDE to be down outside of the LHC LS3 as technical resources may to be easier to find. The current aim is for ISOLDE to be operational again in the second quarter of 2028, ready for the return of protons from the PSB.

We are benefitting from the ideas generated by the HIE-ISOLDE task force already in the 2025 running period. They were able to find several efficiencies in bringing the linac back on line after the annual cryoplant maintenance and so this year we were able to start using post-accelerated beams about a month earlier than in previous years. This is an excellent result and I'm grateful to all our technical colleagues in operations, cryo and rf groups who worked on this.

This is my last ISOLDE Newsletter as Physics Section Leader and Collaboration Spokesperson. As I write this, Luis Fraile has just arrived and we have a month overlap to hand things over. Another change is that in June the ISCC selected Janne Pakarinen to replace Luis as ISCC Chair. ISOLDE will therefere be in very safe hands for the next few years!

As I prepare to leave, I have been reflecting on my time at CERN and wanted to share a few thoughts with you. ISOLDE does a fantastic job, has done it for a very long time, and will continue to do so for many more decades. There are a few brand new billion-dollar radioactive beam facilities using ISOL or reaccelerated fragmentation products that have just arrived, but ISOLDE is still world-leading, competes effectively with them and will do so for the foreseeable future.

How does such an old facility keep up with the newcomers? ISOLDE stays at the forefront of science by innovative developments in beam production, instruments and physics ideas that build on years of experience. Part of this is due to the vibrant, energetic and talented ISOLDE community that uses the facility in clever ways and builds state-of-the-art instrumentation. However, ISOLDE is also unique in using GeV protons for production, which generate the widest range of isotopes, with spallation, fragmentation and fission all contributing, and this is key to ISOLDE's competitiveness. We are assisted by very talented experts in many different technical areas. Being based at CERN gives us both of these advantages, GeV protons and a huge technical skills base. However, CERN as a large organisation has very many rules and regulations that apply uniformly across the entire operation. It might be helpful to remember the advantages of CERN for ISOLDE science when you are frustrated by some bureaucracy or have to satisfy a new CERN rule or requirement!

CERN is a laboratory for particle physics, but the organisation clearly appreciates the high quality science in nuclear physics, done at ISOLDE and other CERN facilities, that diversifies the overall scientific output. CERN management value the work we do and have recently stated the importance of continuing experiments using the proton injector chain into the era of a future collider, such as FCC. On our side, we should continue to make the case for ISOLDE, calmly and collaboratively, reminding CERN of the value of its unique nuclear physics facilities. Together we can ensure that ISOLDE has a long and healthy life ahead of it.

I would like to end by thanking everyone who supports ISOLDE and by doing so have made my job easier over the past four years: the large and vibrant physics community responsible for the exciting science programme; the local group and especially Jenny, Hanne and Karl; the target group, RILIS colleagues and machine supervisors who run the facility for us; the ISOLDE Collaboration Committee for supporting me with many initiatives; the wider technical and safety teams who help ISOLDE in so many different ways; and EP, SY and BE management for their support and collaboration, especially concerning the improvements programme.

So I will say goodbye to you in my current role, although I will see many of you as I continue with experiments at ISS. I am sure that you will all join me in wishing Luis the best of luck over the next few years and I hope he finds the job as rewarding and fun as I have.

News for users 2025

ISOLDE schedule 2025

In 2025, delivery of protons to ISOLDE for physics started on 28 March and will continue until 8 December. Unlike recent years, there will be no period of physics with pre-irradiated targets after the end of proton delivery (the so-called "winter physics" mode). This marks the end of Run 3 for ISOLDE, as we then enter the Long Shutdown 3 (LS3), which will last until summer 2028. During LS3, no ISOLDE beam will be available, but normal services will remain operational. Occasional interruptions may still be necessary for maintenance etc. similar to what is typically experienced during the Year-End Technical Stop. If you plan to perform offline measurements in the ISOLDE hall during the long shutdown, please let us know.

The published schedule for 2025 can be found online here, and the weekly schedules here. EURO-LABS TNA support will be available and spokespeople of scheduled experiments will be contacted by Jenny in advance of their experiments running.

Upcoming INTC meetings

The 80th INTC meeting, scheduled for 11-12 November 2025, will only accept documents related to the n_TOF facility. Submissions concerning ISOLDE will not be considered at this meeting. Details regarding the INTC meetings in 2026 will be shared in due course. The current plan is to dedicate the February 2026 meeting to a review of Run 3. This will also be the final meeting chaired by Marek Pfützner. The incoming chairperson will define the programme for the subsequent meetings. For reporting purposes to funding agencies and other stakeholders, existing experiments will remain formally active until the end of LS3, at which point they will be officially closed. Any experiment wishing to run after LS3 will need to submit a new proposal.

User registration and access to the ISOLDE facility

A full description of the procedure for registering at CERN is given on the ISOLDE website. Note that the teamleader and deputy teamleader who submits the information *must* have a valid CERN registration. This also applies to paper forms which have been signed at the visiting institute. Please register under **"ISOLDE"** as your experiment and **"USER"** as status.

All information for getting access to the ISOLDE facility is outlined on this page on the ISOLDE website. There are a variety of training courses, managed via the CERN training hub, required before access to the ISOLDE hall can be granted. These are divided into classroom courses, which take place at the CERN training centre in Prevessin, and online courses which can be taken via the CERN online training. Enrollment for the classroom courses should take place before coming to CERN (at least 2 weeks before the course takes place, otherwise, they might be cancelled). If a user is not yet registered, an email can be sent to safety training: safety-training@cern.ch. However, once registered it will be still necessary to register for the hands-on courses in the CERN training hub in order to validate the training.

Safety in the ISOLDE hall

To access ISOLDE, you must wear, at a minimum: a dosimeter, safety helmet, safety shoes, and clothing that completely covers your legs, typically long trousers. Before leaving the facility, always check yourself on the hand-foot monitor.

No radioactive or stable beam may be sent to an experimental station without EP Safety Clearance. To obtain this Clearance, the Safety File must be fully up to date, including a general and electrical safety inspection of the installation on site. This inspection must be planned in advance to allow sufficient time to address any remarks. All participants of the experiment must be familiar with the procedures relevant to their tasks, as described in the Safety File, including the necessary

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personal protective equipment (PPE) and training. It is the responsibility of the spokesperson, in collaboration with the local team, to ensure these requirements are met.

All equipment in the hall must be clearly labelled with contact information, setup details, and the period it will be there. If any items need to remain at CERN after the run, please contact the physics coordinator to arrange suitable storage. All items must be checked by RP before being removed from ISOLDE or when opening the beamline or experimental chamber. Please note that radioactive items must be added to TREC and stored in the designated cupboard.

In case of doubt, please don't hesitate to contact the local responsible person for your setup, the physics coordinator or the EP safety office (Letizia Di Giulio and James Devine). The list of contacts for safety both for local experiments and visiting setups can be found via https://isolde.cern/safety.

ISOLDE Publications, open access and CERN EP preprints

ISOLDE should be mentioned in the abstract of articles related to experiments performed at the facility and, if possible, the ISOLDE team should be mentioned in the acknowledgements. Experiments which have benefited from previous **ENSAR2** funding at ISOLDE should also mention this in the acknowledgements of any articles which emerge and which should echo the following: *This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654002.*

For **Eurolabs** support, publications should acknowledge in the following way: *"The research leading to these results has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101057511."*

Please note that under CERN's general conditions, all publications originating from a CERN experiment or featuring a CERN author must be published as open access. Detailed information on open access publishing can be found on this dedicated website, supported by the CERN Scientific Information Service. New agreements have been signed with numerous publishers which facilitate OA publishing with a CERN author. In many cases publication costs will be covered centrally at CERN if there is at least one CERN-affiliated author in the author list. For IOP and the APS publications, costs can be covered even without a CERN author as long as the ISOLDE collaboration and IS number are mentioned e.g. "CERN, ISOLDE Collaboration, ISXXX" in the collaboration field of the submission form, and this should be added to the paper itself.

In case of any further questions, authors can ask the experts in the CERN library questions via email: open-access-questions@cern.ch.

ISOLDE papers can also be uploaded to the CERN EP preprint server, which will allow them to receive a CERN-EP number as is done for many other experiments at CERN. Details on the submission process can be found here. If there are any questions about this process, please contact the physics coordinator.

Publications on CDS

There is a specific area of the CERN Document Server from which all ISOLDE spokespeople and contacts will be able to upload DOI links (and extra information if required). Once you have signed in with your CERN credentials, you should be able to upload any new articles or theses. The link to use is here. If there are any problems with uploading, please contact the physics coordinator.

Open data

Please note that having an open data management programme is a requirement for the receipt of EUROLABS support. ISOLDE has also recently published an open data policy, following approval by the ISCC, and this can be found here.

ISOLDE facility

ISOLDE Improvement and Consolidation Program and plans for LS3

Joachim Vollaire, Erwin Siesling,
Jose Alberto Rodriguez Rodriguez, Sebastian Rothe
on behalf of BE-OP-ISO, SY-STI-RBS and SY-STI-LP

Since LHC operations began, CERN's periodic Long Shutdowns (LS) have provided opportunities to upgrade and consolidate the ISOLDE infrastructure. During LS1 (from 2013 to mid-2014 for ISOLDE), major civil engineering work was carried out with the demolition of obsolete buildings for the construction of the Building 508 (hosting the new control room and many laboratories), the extension of the Building 179 for the MEDICIS laboratory and the finalization of the technical buildings for the HIE ISOLDE project. In the target area, one of the main activities was the replacement of the 20-year-old target handling robots with modern robotic systems to improve the facility reliability. The LS2 (2019–2020) period similarly enabled major modifications as the extension of Building 179 (again!) to host the nano-laboratory dedicated to target material production and the replacement of the two Frontends (target stations). For the post-accelerator, several improvements were carried out, including the refurbishment of a cryomodule (CM), which allowed for the recovery of the nominal accelerating gradient and the installation of new diagnostic systems and two steerers integrated into the REX Linac to improve beam control. An upgrade of the electron gun in REXEBIS also improved the stripping of electrons from isotopes before injection into the Linac.

For LS3, an ambitious set of upgrades and consolidations is planned to enhance ISOLDE's performances in terms of flexibility, reliability and physics outputs ensuring the facility remains at the forefront in nuclear physics well into the next decade [1]. One of the key projects is the replacement of the two beam dumps (installed in the early 1990s) behind the ISOLDE target stations. The current dumps have been operating at the edge of their thermal and mechanical design limits. Installing modern, higher-capacity dumps is essential for safe long-term operation and will remove the bottleneck that today caps the beam intensity and energy.

Figure 1: The ISOLDE facility during construction in 1992 [2].

This consolidation will enable ISOLDE to exploit higher proton energies and currents in the future without compromising radiation safety or dump integrity. The replacement of the dumps presents a significant challenge requiring meticulous planning and execution to ensure safe removal and disposal. Unlike modern engineered beam dumps, the existing ones are simple iron blocks surrounded by concrete shielding which were covered with soil during the facility's construction (see Fig. 1). This design, while effective at the time, complicates their extraction, as access is limited, and radiation protection measures must be carefully imple-

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mented to minimize exposure during decommissioning and installation of the new dumps.

The project team responsible for the ISOLDE Beam Dump Replacement Study (IBDRS) has carefully evaluated these aspects and has proposed a new dump design incorporating proper instrumentation and the capability to safely absorb the proton beam (even considering future increases in energy and intensity). In addition, a new technical building will be constructed above the target area, providing a controlled environment for handling the dumps and shielding elements while also housing critical equipment related to the targets and dump systems (see Fig. 2).

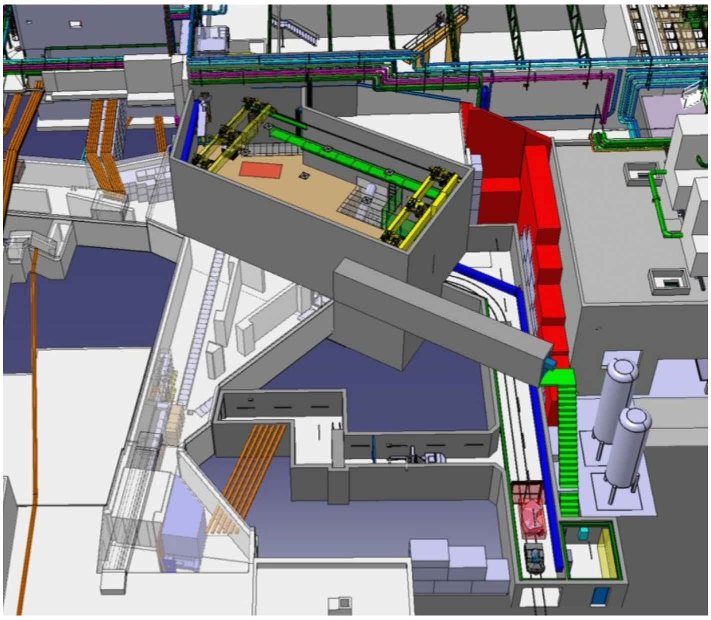

Figure 2: 3D rendering of the new building constructed in the frame of the IBDRS project.

This new infrastructure will also enable the creation of new access galleries to the target area and HRS separator zone, significantly improving accessibility to the separator magnets to facilitate their replacement in case of failure or upgrade.

Besides the IBDRS project which is fully funded, additional improvements and upgrades have been proposed for approval in 2025. One of the most major proposals is the 2 GeV BTY line upgrade, which aims to significantly increase isotope production yields by leveraging the higher proton energy available from the PS Booster. FLUKA simulations predict a 2 times increase in fragmentation product yields at 2 GeV, with gains of up to a factor of 6 for certain exotic spallation products. A detailed study has been conducted to identify the most cost-effective approach for upgrading the BTY line to operate at 2 GeV while maintaining the flexibility to run at 1.4 GeV [3]. The proposed modifications include a geometric reconfiguration of the vertical dogleg, along with an optics redesign (see Fig. 3).

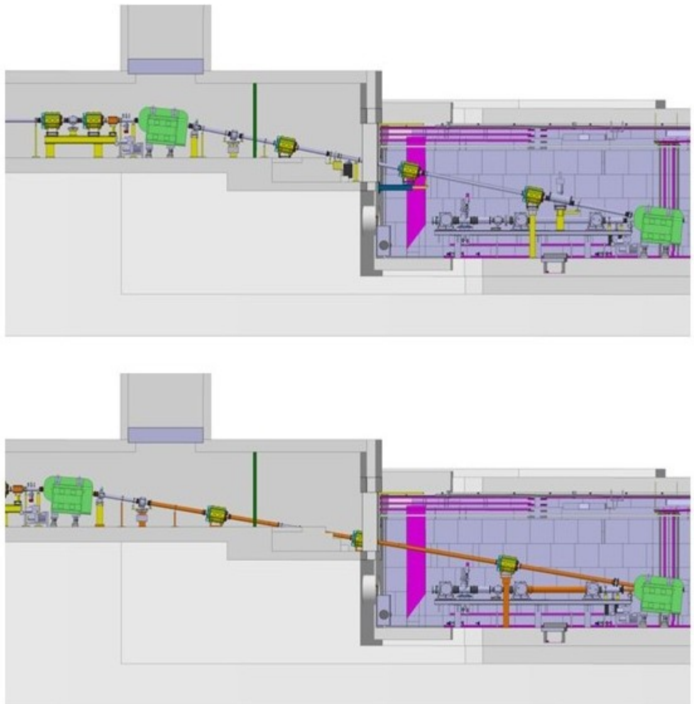

Figure 3: 3D rendering of the vertical dogleg in its current configuration (top) and in its upgraded version [4].

Additionally, two new dipole magnets will be installed in the target area to provide the necessary deflection toward the HRS target station, and new quadrupole focusing magnets will be implemented to ensure proper beam focusing at higher energy. Furthermore, the already planned consolidation of power supplies has been integrated into the proposal, ensuring that the powering requirements align with the upgrade of the BTY line.

Over the years, the Resonance Ionization Laser Ion Source (RILIS) has become the primary tool for producing Radioactive Ion Beams (RIBs) at ISOLDE, supporting more than 50% of experiments. Given its critical role, the current RILIS laboratory infrastructure is not optimally equipped or configured to meet the growing demands of the experimental program. To address these limitations, a comprehensive upgrade is planned for LS3. The consolidation of the RILIS laser laboratory will focus on expanding available space, improving personnel safety, and introducing new operational features. A key enhancement will be the separation of laser launch areas for the two separators (GPS and HRS), enabling parallel operation of RILIS on both ISOLDE Frontends. Currently, this is only feasible for a limited number of elements, and the upgrade will significantly enhance RILIS's capabilities to provide laser-ionized beams more efficiently. One of the major challenges in implementing this upgrade is the limited available space in the laboratory's current location (see Fig. 4). The presence of Faraday cages for REXEBIS and ISCOOL, along with stability requirements necessary to support laser tables, further constrains the layout, making careful integration studies essential. These studies, which have already been initiated, will ensure that the upgraded facility meets both spatial and operational requirements, allowing RILIS to continue playing a crucial role in ISOLDE's experimental program.

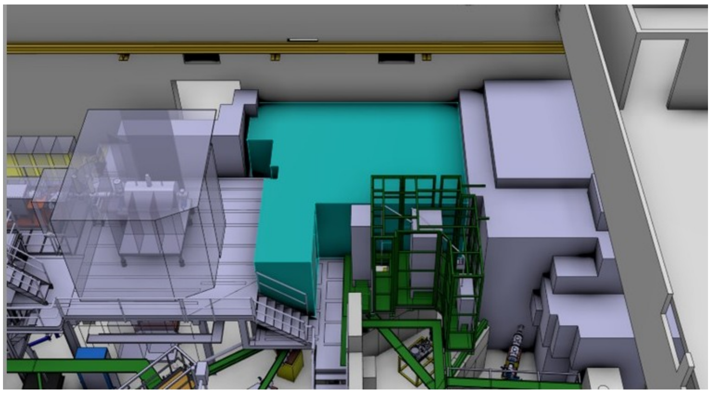

Figure 4: 3D rendering of the current RILIS laboratory location in the experimental hall (light blue).

To optimize facility usage, one of the planned improvements for the RIB transport and delivery is the implementation of automatic beam switching on the central beam line (CA0), which is shared by the two separators (see Fig. 5). This enhancement will require new timing hardware, synchronized beam gates, and a switching system for electrostatic power supplies. Pulsing CA0 could facilitate future beam-sharing scenarios, enabling different experiments to receive beam alternately, allowing, for example, the tuning of a beamline while another experiment collects data.

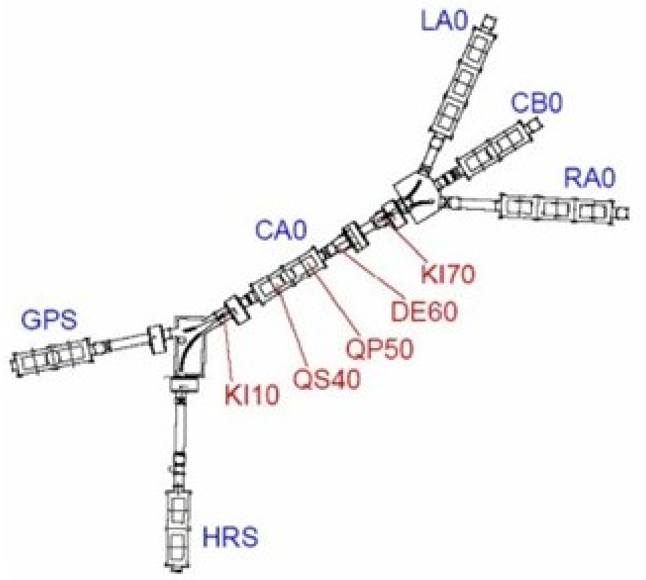

Figure 5: Layout of the CA0 beamline showing the electrostatic elements requiring time switching in shared beam operation mode.

Other improvements to the RIB delivery systems in the low-energy beamlines, proposed for funding, include the upgrade of NMR probes for the HRS separator magnets and hardware upgrades and studies to enhance the cooling and bunching efficiency of the ISCOOL cooler-buncher, benefiting experiments requiring time-structured beams.

As physics with post-accelerated beams is in high demand, improving both reliability and maintaining/improving performances of the REX HIE-ISOLDE Linac for future experimental campaigns remains a key priority (see Fig. 6 for the Linac layout). Several systems of the REX Linac, including REXTRAP and REXEBIS, are proposed or scheduled for consolidation and upgrades to enhance reliability for the next operational period. Improvements envisioned include addressing discharges in REXTRAP and installing a new electron collector for the REXEBIS. A major focus will be addressing issues with the normal conducting cavities, particularly investigating the cause of instabilities as well as opening the 9GP RF structure to replace its vacuum sealing and retuning to improve performance. A proposal to upgrade the RF system with a new 202 MHz solid-state amplifier for the 9GP cavity and a digital Low-Level RF system has been put forward as a natural complement to the already approved consolidation of the 101 MHz solid-state amplifiers for the five other cavities. The HIE-ISOLDE superconducting LINAC has experienced a decline in performance, impacting the high-energy physics program. For this part of the machine, the top priority for LS3 is the refurbishment of Cryomodule 1 (CM1) which has experienced a decline in accelerating gradient. Additionally, NEG pumping will be added upstream of CM1 to improve vacuum conditions for the refurbished CM1. Further efforts, if funding is approved, will focus on integrating and commissioning a 2 kL LHe dewar into the cryoplant, and studying an LN_2/GHe heat-exchanger cooling system to possibly maintain the cryomodule shields at 90° K during annual winter stops in the future. Beyond LS3, the possibility of producing a spare cryomodule (CM5) for future exchange is being considered. However, this effort will depend on available resources, as its assembly requires specialized technical skills and cleanroom facilities, which are also in high demand for other CERN projects. While the timeline for this remains flexible, having a spare module would allow for a rolling refurbishment strategy, ensuring that future maintenance can be carried out without disrupting the physics program.

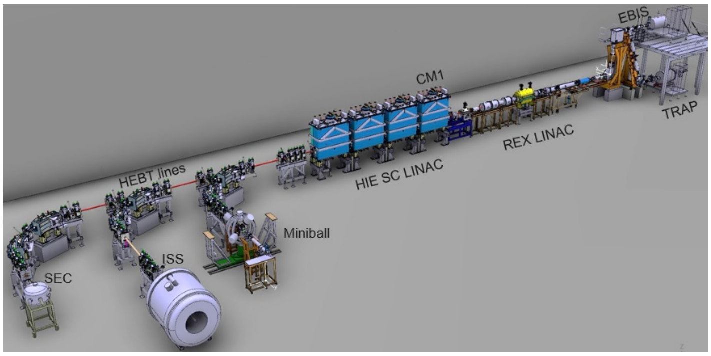

Figure 6: Layout of the REX HIE-ISOLDE Linac.

While the full scope of the activities described above will be determined before the summer with the approval of the CERN Mid-Term Planning, scheduling the already approved LS3 activities at ISOLDE requires careful coordination to ensure the availability of technical teams from multiple departments, many of which are also engaged in other large CERN projects. The IBDRS project implementation is the longest of all planned or proposed activities with an expected duration of 24 months. This exceeds the foreseen shutdown of the PS Booster by approximately 4 to 5 months. To address this, a detailed planning study was conducted, taking into account the availability of specialized teams and the objective of maximizing high-energy physics beam time. As a result, it was decided to synchronize ISOLDE's LS3 activities with the restart of the PS Booster in spring 2028. Consequently, 2025 will be the last year of proton operation before ISOLDE enters a two-year-long shutdown for the implementation of LS3 projects.

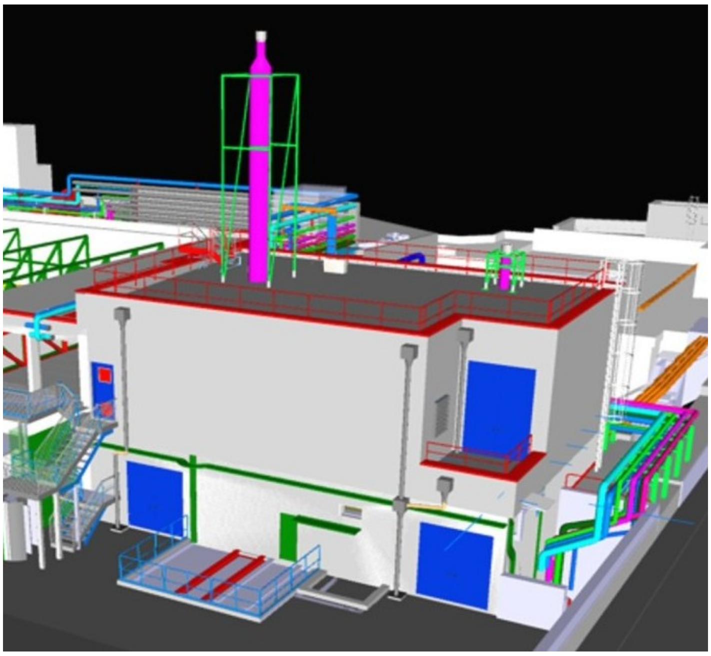

Figure 7: 3D rendering of the Building 197 extension. The tall stack on top of the building ensures the dispersion of short-lived radioisotopes resulting from air activation in the target area.

Although the activities described above are planned for LS3 (2026–2027) at ISOLDE, one project is already advancing in 2025 to avoid co-activity with the IBDRS project and will be completed early in LS3. This project, the ISOLDE Primary Area Ventilation and Fire Safety upgrade, was initiated a few years ago following a fire safety review assessing the radiological impact of a potential fire in the ISOLDE target area. The upgrade includes the extension of Building 197 to accommodate the new HVAC equipment serving the primary areas (see Fig. 7 for the layout of the extension). To enhance safety and containment, the system will feature charcoal filters to trap radioactive volatile species, fire dampers, and the physical separation of the HVAC systems from the experimental hall, where the equipment is currently housed. The construction of the Building 197 extension is already underway, marking a key step towards completing this critical safety improvement and ensuring that ISOLDE meets modern radiation safety standards.

The preparation of this ambitious upgrade program is the result of dedicated work by numerous technical teams over the past years, with experts designing solutions, preparing detailed proposals (e.g., the Ventilation and Radiation Safety upgrade, the ISOLDE Beam Dump Replacement study and the 2 GeV upgrade design), and identifying the necessary resources. The people responsible for equipment across the facility have also actively reviewed the performance of their systems, identified obsolescence risks, and proposed consolidations or improvements. In addition, CERN management, various scientific and technical committees, and the ISOLDE Collaboration have demonstrated strong support for the ISOLDE consolidation and upgrade plans, from endorsing the physics case to approving and supporting budget requests. Although a two-year shutdown is a significant constraint for physics, restarting operations with a modernized, upgraded, and consolidated facility will provide long-term benefits, ensuring greater reliability, increased operational flexibility, and enhanced experimental capabilities. With the continued commitment of the ISOLDE community, the technical teams, and the CERN management, the facility is well prepared to take full advantage of the LS3 shutdown.

References

[1] S. Freeman, 'ISOLDE Consolidation and Improvements', Tech. rep., CERN, Geneva (2023).

[2] Courtesy of H. Ravn.

[3] M. Fraser, *et al.*, *JACoW IPAC* **2024**, THPR28 (2024).

[4] (2024), Courtesy of D. Del Alamo.

Target production and developments 2024

Simon Stegemann
on behalf of SY-STI-RBS and SY-STI-LP

The year 2024 was despite challenges a productive and successful year for CERN-ISOLDE. Over the course of 36 weeks, including two weeks of winter physics, just over 10^{20} protons from the PSB where used to deliver radioactive ion beams to around 50 experiments. To enable such a rich research program, 31 new target units were built, and a few resilient targets from previous years were reused. Figure 1 shows a breakdown of these targets across their respective target materials.

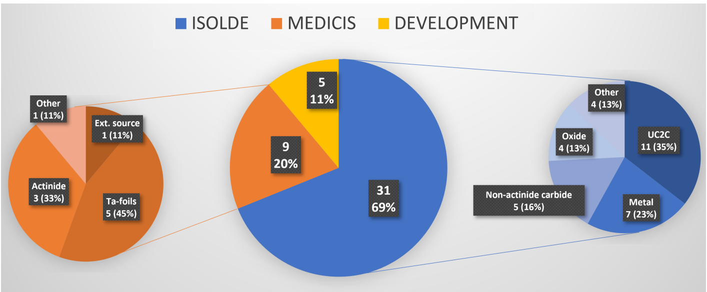

Figure 1: Target production 2024.

Noticeably fewer uranium carbide targets were employed (35% compared to typical 60%), compensated by an increasing number of metal (foils and liquids), non-actinide carbides and oxide materials. 1.7 GeV protons, which were introduced in 2022 to study the benefit of a proton energy upgrade, were employed for the first time as operational beam for two physics experiments.

Next to the annual target production, the technical teams led an extensive machine development (MD) and target-ion source development (TISD) program, to improve and consolidate ISOLDE's beam portfolio. New or improved target materials (nano-ZrO_2 and TaC) showed promising results for Zn and low-Z beams such as lithium. Molecular beam extraction, which gained popularity in recent years, was further studied (TbF_x, YF_x) and used for physics experiments (SnS, RaF, CeF_x). Issues with sulfur-injection and CeF_x extraction were observed and are being addressed in ongoing development efforts. MDs investigating the proton delivery to the ISOLDE frontends, included firstly, newly developed 2D proton scan software packages to find the optimal horizontal and vertical deflector settings. RP radiation monitors data were linked to the proton beam position on target which can now be used to identify the best configuration (see Fig. 2).

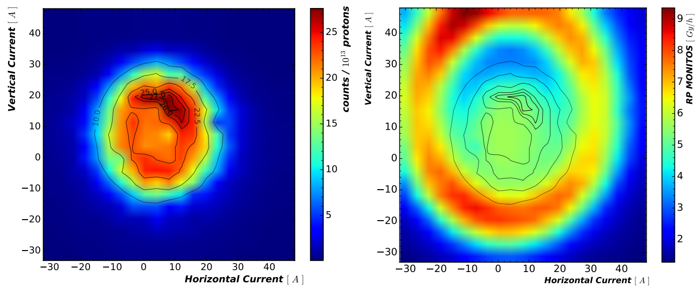

Figure 2: 2D proton scan using ^{26}Na and the ISOLDE fast tape station [1] (left) and radiation monitors (right). Taken from [2]. The prompt gamma radiation from the high-Z Ta container can be clearly seen, also the location of the target material is clearly visible.

This can be useful to reduce the load on the fast tape station [1] and the need for the central beam line for a proton scan.

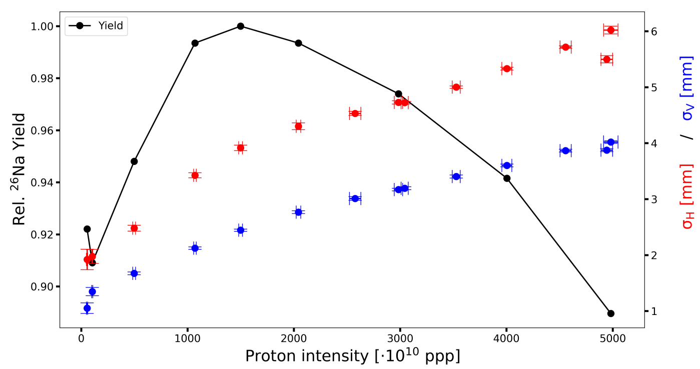

Figure 3: Subset of the yield-progression study for high intensity protons beams (PSB-MD1256). The graph shows the secondary ^{26}Na yield (black) and associated horizontal (red) and vertical (blue) proton beam size (normal distribution). Some outliers were removed for clearness. The full dataset can be found in [3].

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Secondly, MD studying the yield dependency on high intensity proton beam delivery to the ISOLDE targets was performed. Record intensities of $5000 \cdot 10^{10}$ protons per pulse delivered to ISOLDE were achieved by the PSB team. (Fig. 3). The results were semi-conclusive, endorsing on the one hand the importance of looking into beam focusing at high proton intensities. On the other hand, ambiguity at low proton intensities and reproducibility highlight the demand for further systematic studies [3].

Outlook

As the ISOLDE nanolab is nearing completion of its installation and commissioning program, we are launching production of first nano-LaC_x and nano-UC_x target materials to be tested online in 2025.

References

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[2] J. B. Frederiksen, 'Optimization of yield measurements and study of ^{229}Ra decay', Tech. rep., CERN (2024).

[3] I. Frank, et al., Tech. rep., CERN (in preparation).

Ground-state properties

CRIS in 2024

Osama Ahmad, Carlos M. Fajardo-Zambrano
for the CRIS collaboration

The past year at ISOLDE featured several successful experiments for CRIS, including exciting technical upgrades. CRIS proved its versatility by studying isotopes and isomers in the lead and tin regions, investigating atomic physics interests in francium, and demonstrating the production of RaF^- anions alongside the first measurement of its electron affinity. A major highlight was the implementation of a new Field Ionization Unit (FIU) at CRIS. By using field ionization from a resonantly excited Rydberg state, the need for a high-power ionisation laser becomes redundant, and consequently the non-resonant laser ionization of isobars in the beam (often molecules) are strongly reduced. Reducing the ion background counts significantly boosts the sensitivity. The FIU was successfully commissioned using a potassium beam (see Figure 1) from ISOLDE, and later applied to francium, marking a significant leap forward in the CRIS measurement capabilities for more exotic isotopes.

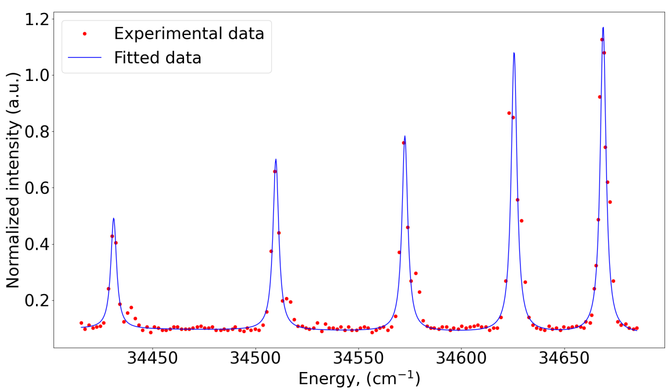

Figure 1: Measurement of the Rydberg series (14D to 18D) in potassium using the new FIU at CRIS.

In 2024, CRIS performed four experimental campaigns, starting in June with high-resolution laser spectroscopy of light gold (Au) isotopes. The hyperfine structure of 14 isotopes and two isomers was measured, from ^{197}Au down to ^{180}Au, to investigate the so-called "island of deformation", noted for its unusually large nuclear charge radii in lighter gold isotopes. Data on the quadrupole moments of these isotopes give an understanding on how their ground and long-lived excited states are deformed, a key to exploring shape coexistence. CRIS confirmed the tentative spin assignments of ^{181,182,183}Au. The results will provide a benchmark for theoretical predictions and illustrate how single-particle and collective behaviors interplay in these nuclei.

Following the study of magic numbers, the next experiment focused on the tin region, measuring the hyperfine structure of neutron-deficient antimony (Sb) isotopes (Z=51). Given its single proton above the closed-shell Z = 50, this element offers a simple yet robust test for nuclear theories. Isotopes from ^{123}Sb down to ^{111}Sb have been studied (N = 60), revealing nuclear structure evolution in this region of the nuclear chart.

Changing the focus to atomic physics, CRIS identified the $9P_{1/2,3/2}$ and $10P_{1/2,3/2}$ electronic states in francium (Fr) and measured their lifetime. Additionally, we indirectly observed the $6D_{5/2}$ state in ^{221}Fr, an electronic state of high interest for its proposed sensitivity to parity non-conservation effects (PNC). These measurements are instrumental for future experiments and provide valuable information for benchmarking quantum electrodynamic effects in Fr, crucial for PNC studies.

Finally, the year ended with the production and

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study of RaF^- anions through double charge exchange in the CRIS charge exchange cell filled with sodium vapor, followed by successful photodetachment studies producing neutral RaF detected in a dedicated laser-transparent neutral atom detector mounted at the end of the CRIS beam line. With these measurements, a possible pathway to efficiently cool and trap RaF was characterized, a molecule proposed for its sensitivity to parity and time reversal violation studies.

Collinear Laser Spectroscopy with the COLLAPS setup: Probing Nuclear Structure in Calcium and Thulium Isotopes

Results of experiment IS529 & IS740

Jack Hughes for the COLLAPS collaboration

Collinear laser spectroscopy is a versatile probe of nuclear ground and isomeric state properties, such as spin, electromagnetic moments and changes in mean square charge radius between nuclei. Through these nuclear model independent measurements, information regarding the size and shape of nuclei across isotope chains can be found. Using the COLLAPS set up, two main regions that were focused on this year were the calcium region (Z=20), in particular ^{54}Ca, and the thulium region (Z=69) heading towards the proton emitter ^{147}Tm.

The first scheduled experiment for 2024 was for the calcium region, using the ROC (Radioactive detection of Optically pumped ions after state selective Charge exchange) technique [1]. The ROC technique, combined with technical upgrades, resulted in record sensitivity for collinear laser spectroscopy measurements of $\approx$ 0.5 ions/s out of the target. This experiment culminated with the measurement of ^{54}Ca, seen in Figure 1. The change in mean square charge radii obtained from this measurement will explore effects around the N = 32 and N = 34 shell closures.

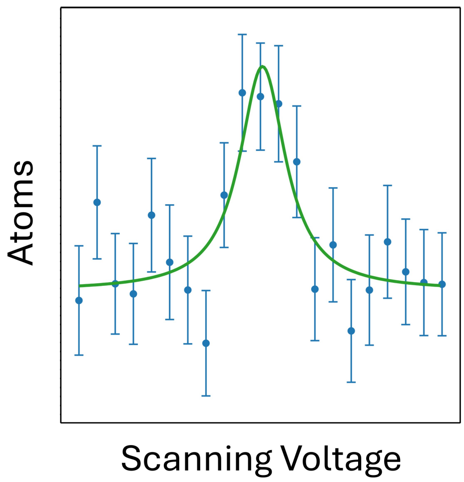

Figure 1: peak of ^{54}Ca obtained during the 2024 ROC beamtime.

The second experiment of the year was for the thulium isotope chain, performed using collinear fluorescence laser spectroscopy. From a letter of intent in 2023, initial exploration reached a limit at ^{155}Tm due to heavy isobaric contamination, identified as oxides by ISOLTRAP. To suppress the contamination faced at the neutron deficient isotopes a LIST (Laser Ion Source and Trap) target module was used. Reducing the isobaric contamination allows for an increase in bunch accumulation time and a suppression of photon background. This improved sensitivity allowed for the measurements of neutron deficient isotopes of thulium down to ^{152}Tm, as seen in Figure 2. Although the Ta foil target degraded during the experiment, a partial measurement of ^{151}Tm was also conducted.

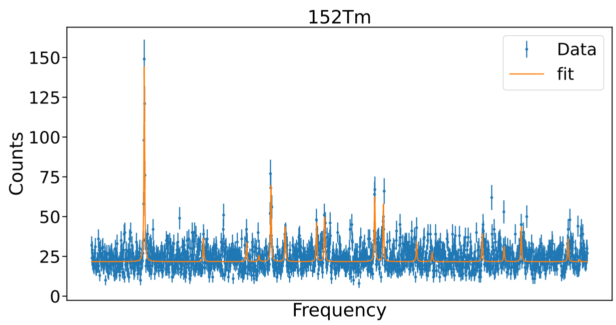

Figure 2: preliminary fit of the hyperfine structure of the ground and first isomeric state of ^{152}Tm

While a measurement of the proton emitter ^{147}Tm was not obtained, these measurements will enable the extraction of nuclear moments and change in mean square charge radii of the neutron deficient region as well as follow-up measurements in 2025 towards the ultimate goal of reaching the proton emitter ^{147}Tm.

https://collaps.web.cern.ch

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First online measurements with the high-voltage MIRACLS setup

A. Roitman for the MIRACLS collaboration

The Multi-Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) is designed to increase the experimental sensitivity of fluorescence-based collinear laser spectroscopy (CLS) by exploiting a Multi-Reflection Time-of-Flight (MR-ToF) device. This device utilizes two electrostatic ion mirrors to reflect ion bunches back and forth for several thousands of revolutions. While the ions are trapped between the mirrors, a laser beam intersects collinearly with the MR-ToF axis, allowing photointeraction during the entire storage time. This lasts typically up to tens of milliseconds compared to a few microseconds in conventional, single-passage CLS. As a result, the CLS sensitivity is largely improved, opening a path to study exotic radionuclides with very low production yields [1].

After the successful demonstration of the MIRACLS concept in a low-energy, offline apparatus, a new setup has been constructed which is now coupled to ISOLDE's online facility and operates at higher ion beam energies for enhanced CLS resolution and sensitivity. The year 2024 marks the successful commissioning and first online operation of this new instrument.

Based on insights gained during test measurements in 2023, the apparatus was upgraded in terms of its vacuum system and high-voltage stability of the electrostatic mirrors, allowing its commissioning: in early 2024, stable Mg ions could be trapped with an energy of around 10.5 keV for up to 3000 revolutions. Laser spectroscopy was performed first with ions from MIRACLS offline ion source and then with radioactive Mg ions delivered from ISOLDE. The accuracy of the MIRACLS apparatus has been confirmed in two online campaigns by comparing our CLS measurements on even-even Mg radioisotopes with those previously performed by COLLAPS [2]. After this, unexplored Mg isotopes were successfully accessed. An example of a resonance obtained by MIRACLS is shown in Fig. 1.

This new MIRACLS data extends our knowledge on nuclear charge radii of neutron-rich Mg isotopes, providing valuable insights on the island of inversion around the N = 20 region and serving as a stringent benchmark of recent advances in ab-initio nuclear theory [3, 4].

Following up on the successful performance in its first physics case, the next plans for MIRACLS include investigations of the cadmium isotopic chain.

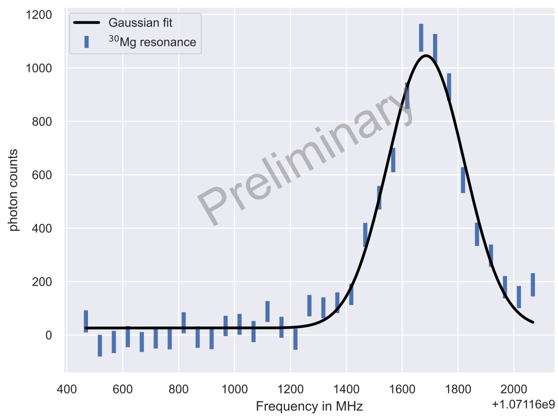

Figure 1: An example of a ^{30}Mg resonance measured by MIRACLS.

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ISOLTRAP's results and developments during 2024

Results of experiment IS756

Daniel Lange for the ISOLTRAP collaboration

The ISOLTRAP [1] mass spectrometer is composed of a series of ion traps, including a Multi-Reflection Time-of-Flight mass spectrometer (MR-ToF MS) and a tandem Penning-trap system, to perform high-precision mass measurements on radioactive nuclei for studies of nuclear structure and nuclear astrophysics.

Following the successful joint LOI244 [2] with IDS for the development of neutron-rich mercury beams beyond ^{208}Hg [3] using a UC_x target equipped with a low-temperature quartz transfer line for isobaric contamination suppression (especially Fr), a dedicated beamtime for the mass measurement of ^{209,210}Hg was carried out in 2024 [4]. Further optimisation of the target heating reduced isobaric contamination (compare Fig. 1 of this article with Fig. 2 in [3]) and enabled the measurements of neutron-rich mercury isotopes beyond ^{208}Hg without systematic limitations caused by space-charge effects [5] to study the nuclear structure south-east of doubly-magic ^{208}Pb.

In addition to the aforementioned opimization of the target conditions, further reduction of isobaric contamination can be handled more generally with the implementation of mass-selective re-trapping [6] at ISOLTRAP. For this, an additional RFQ buncher, designed by MIRACLS [7], has been installed in a horizontal beamline extension following the MR-ToF MS (Fig. 2). This will enable the use of the $3 \cdot 10^5$ resolving power of the MR-ToF MS for subsequent isobar and isomer mass separation and spectrometry. Thus, the isobar separated bunch ejected from the MR-ToF MS is re-bunched in the Mini-RFQ before being re-trapped in the MR-ToF MS with suppressed contamination to enable measurements with improved sensitivity and free from systematic space-charge effects.

Besides upgrading the MR-ToF MS with the Mini-RFQ, further improvements were made to the instrument through the implementation of temperature stabilization. The MR-ToF MS itself and its voltage stabilization devices have been enclosed and temperature stabilized using Peltier elements in conjunction with a PID loop. This measure serves to reduce ToF drifts and to enhance the instrument's long-term stability. It allows the reduction of calibration measurements during experimental procedures and reduces systematic errors, particularly in the context of low-yield beams.

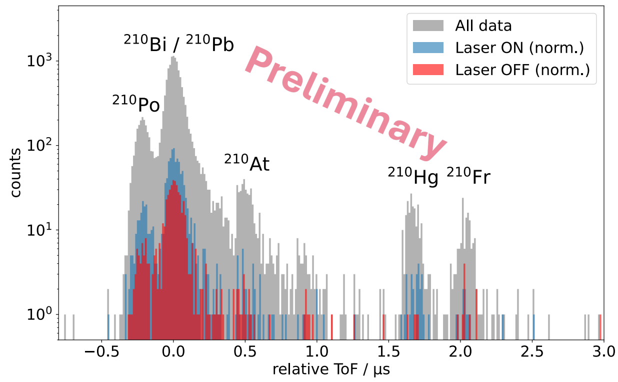

Figure 1: Time-of-Flight spectrum for the $A = 210$ ISOLDE beam from a UC_x target equipped with a low-temperature quartz transfer line and laser ionization tuned for mercury.

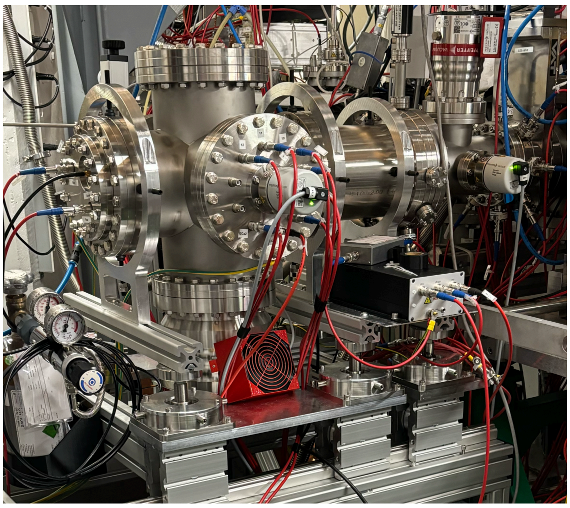

Figure 2: The horizontal beamline extension, including the Mini-RFQ, installed following the MR-ToF MS to realize mass-selective re-trapping.

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Beta-decay studies

High-statistics decay spectroscopy of ^{178,182}Au at IDS

Results of experiment IS665

Jozef Mišt (Comenius University in Bratislava), Chris Page (University of York) for the IS665 IDS collaboration

Neutron-deficient gold and platinum isotopes near the N = 104 mid-shell, well-known for shape evolution and shape coexistence, have been extensively studied using various techniques [1, 2]. One of them is the β-delayed γ-ray spectroscopy, which can provide a wealth of information on excited states in nuclei. Beta decay is sensitive to the structural changes between the mother nucleus and the populated state, therefore β-decay feeding patterns and log *ft* values can be used to study nuclear structure. A coexistence of at least two configurations, a weakly-deformed and a strongly-deformed, has been observed for platinum isotopes in this region. Our data provide extensive information on the differences in feeding of the corresponding bands.

The ^{178,182}Au isotopes were studied as part of the IS665 experiment, focused on searching for β-delayed fission in neutron-deficient gold isotopes. The nuclei were produced using a UC_x target, selectively ionised by RILIS, mass separated and implanted into a movable tape of the ISOLDE Decay Station (IDS). Isomeric separation provided by RILIS allowed the selective study of the low-spin ground state and high-spin isomeric state in ^{178}Au. Four HPGe Clover detectors were used for γ- and X-ray detection. An array of seven Si-PIN diodes was placed close to the implantation point. High-quality decay spectroscopy data were obtained thanks to the uniquely pure, intense beams and high γ-ray detection efficiency (12% at 200 keV and 4.3% at 1 MeV).

A large statistics was collected, namely 3.3(1) $\times$ 10^8 decays of ^{182}Au, while for ^{178}Au^{g,m} it was 5.4(3) $\times$ 10^8 and 1.3(1) $\times$ 10^7 decays, respectively. This allowed us to significantly expand the information on excited levels in platinum daughters using the prompt γ-γ coincidence technique. Additionally, α and β decays of the long chains of daughter products were studied. Examples of the coincidence spectra gated on the 170-keV and 155-keV $2_1^+ \to 0_1^+$ transitions in ^{178}Pt and ^{182}Pt, respectively, are shown in Fig. 1.

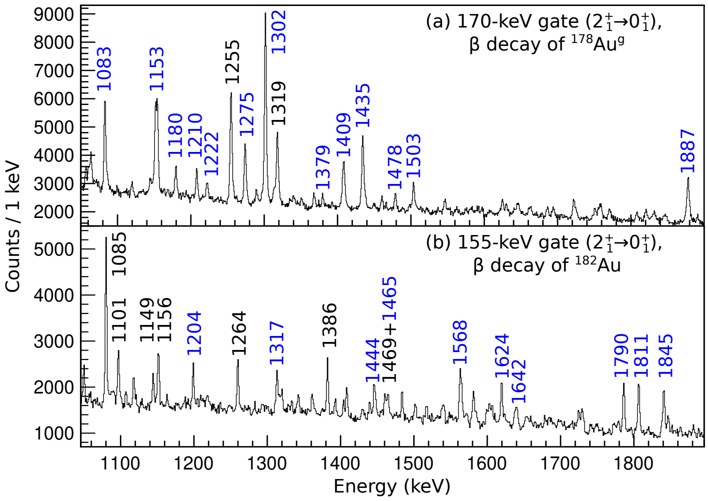

Figure 1: γ-ray coincidence spectra of the (a) 170- and (b) 155-keV transitions following the β decay of ^{178}Au^g and ^{182}Au, respectively. Thanks to the high γ-γ efficiency of the detector configuration, many new transitions (labelled in blue) were observed, especially at high energies.

We confirmed the previously known part of the level schemes of ^{178,182}Pt [3] with minor changes. Moreover, we added 74 new γ-ray transitions and 39 new levels to the level scheme of ^{178}Pt, extending it up to 6.7 MeV in excitation energy. A large expansion was also achieved for ^{182}Pt (333 new γ rays and 124 levels up to 3.7 MeV). This new information led to significant decreases in β-decay feeding intensities for many low-lying states, showing that a large part of previous apparent feeding was caused by the pandemonium effect. This highlights the importance of detailed knowledge of

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the decay schemes. High-purity ^{178,182}Au beams delivered by RILIS were crucial in obtaining such results.

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Production of intense, high-purity beams of neutron-rich Cd isotopes at ISOLDE

IS685

M. Llanos-Expósito, J. Benito, L.M. Fraile, A. Illana et al.
for the IS685 and IDS collaborations

The IS685 experiment investigates exotic, neutron-rich indium isotopes using high-resolution γ-ray spectroscopy and fast-timing techniques [1]. The focus is on single-proton-hole states and core excitations in ^{131}In, and proton-neutron couplings in two-nucleon systems like ^{130}In and ^{132}In. ISOLDE uniquely enables their production via the β-decay of Cd isotopes, directly or through β-delayed neutron emission. High beam purity and intensity are essential. This is achieved through: (1) a UC_x target coupled to a neutron converter, where 1.4 GeV protons from the CERN PS Booster generate spallation neutrons that induce fission, suppressing Cs isobars [2]; (2) a temperature-controlled quartz transfer line acting as a chemical filter, delaying the release of alkali elements such as Cs [3, 4]; (3) laser ionization with RILIS [5], offering isotopic and isomeric selectivity via hyperfine structure, as already used for similar IDS experiments [6]. Mass separation is performed with the ISOLDE General Purpose Separator. The experiment used ISOLDE target unit #759. The beam intensity and purity were evaluated using the IDS setup with four Clover HPGe detectors. Yields were derived from experimental gamma-ray intensities, branching ratios, and release fractions using the characteristic release curves. Fig. 1 compares RILIS-on and -off γ spectra for A = 130 and 131. Cd is ionized only via RILIS, while surface-ionized species (e.g. Cs, In) may appear in RILIS-off spectra. Table 1 summarizes yields and limits (1σ) for contaminants. With RILIS the amount of In is consistent with Cd decay. Cs is suppressed below the detection detection limits. The measurements can be compared with Cd yields for A = 130–133 with protons on the converter [7, 8]. Reference yields from direct bombardment are provided in Ref. [7].

These results confirm the excellent purity of the Cd beams achieved with this procedure: Cs is undetectable and In is suppressed by over three orders of magnitude. Data analysis is ongoing and results are expected soon.

IS685 thanks the ISOLDE technical teams and the ISOLDE and IDS Collaborations, and acknowledges support from EU's Horizon Europe research and innovation programme under EURO-LABS (grant agreement no. 101057511).

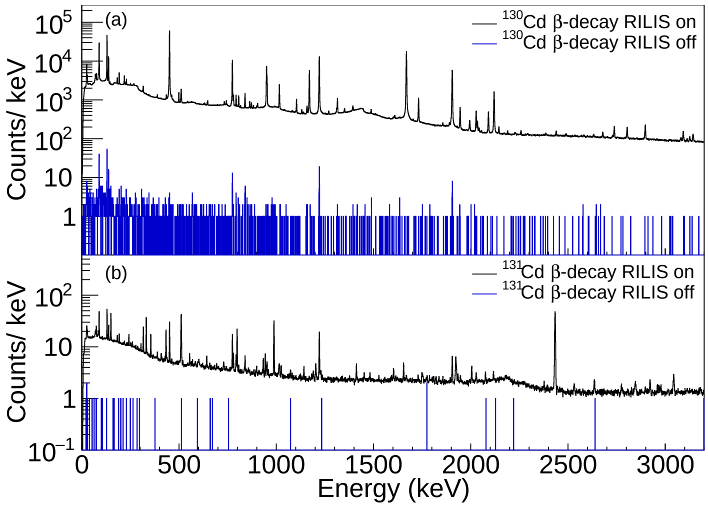

Figure 1: **(a)** β-gated γ-ray spectra from ^{130}Cd decay, 400 ms after proton impact. Black: RILIS on; blue: RILIS off. The RILIS-on spectrum is normalized to proton dose. **(b)** Same for ^{131}Cd.

Isotope	Yield (ions/μC) RILIS on	Yield (ions/μC) RILIS off
^{130}**Cd**	$3.6(2)\times10^3$	—
^{131}In	—	0.92(7)
^{130}Cs	$\leq$7	—
^{131}**Cd**	$1.06(3)\times10^2$	—
^{131}In	—	—
^{131}Cs	$\leq$0.1	—
^{132}**Cd**	4.7(4)	—
^{133}**Cd**	0.16(2)	—

Table 1: Measured yields for Cd and contaminants from the UC_x target with quartz line, with/without RILIS.

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Studies with post-accelerated beams

Single-neutron Transfer Reaction on ^{68}Ni

Results of experiment IS587

Andreas Ceulemans, Riccardo Raabe
for the ISS collaboration

In recent years, substantial progress has been made in understanding the microscopic, single-particle origin of shape coexistence and shape transition in various region of the chart of nuclei [1, 2, 3, 4]. Below ^{68}Ni, the increased collectivity observed in the neutron rich Fe and and Cr isotopes [5, 6, 7] is related to the energy of the $\nu d_{5/2}$ orbital, which allows quadrupole excitations through the promotion of neutrons from the lower-lying $\nu g_{9/2}$. We attempted the measurement of this energy gap in ^{69}Ni through the one-neutron transfer reaction on the radioactive ^{68}Ni nucleus.

Experiment IS587 was performed in November 2022. A beam of ^{68}Ni nuclei was accelerated at HIE-ISOLDE to an energy of 6 MeV/nucleon and fired on a deuterated polyethylene target located at the centre of the ISOLDE Solenoidal Spectrometer (ISS). States in ^{69}Ni with a single neutron outside the N = 40 core were populated through the (d,p) reaction. ISS uses a magnetic field to detect the outgoing protons, eliminating the kinematic compression effect that usually affects the measurements in inverse kinematics.

The background-subtracted proton spectrum, rescaled to the corresponding excitation energy in ^{69}Ni, is shown in Fig. 1. The peaks, corresponding to populated states in ^{69}Ni, were fitted with Gaussian functions. The most probable angular momentum transfer were identified through the angular distributions of the detected protons. Above the ℓ = 4 ground state (one neutron in the $g_{9/2}$ orbital), the largest peak at E^* = 2.56 MeV was unambiguously assigned an ℓ = 2 transfer, corresponding to a neutron in the $d_{5/2}$ orbital. Fig. 2 shows the corresponding angular distribution.

Based on the calculated spectroscopic factors and on a preliminary comparison with large-scale shell model calculations [8] we deduce a slightly larger $\nu g_{9/2}$-$\nu d_{5/2}$ gap than the one observed in lighter Ni isotopes.

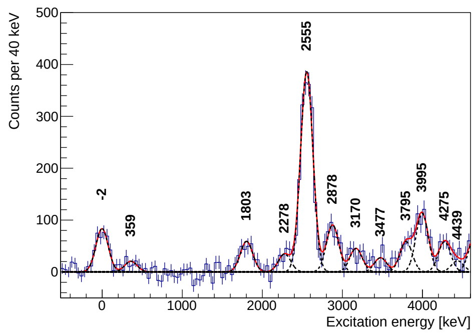

Figure 1: Excitation energy spectrum of ^{69}Ni from the ^{69}Ni(d,p) reaction, up to the neutron-separation energy at 4586 keV. The peaks were fitted with Gaussian functions, their excitation energy is indicated in keV.

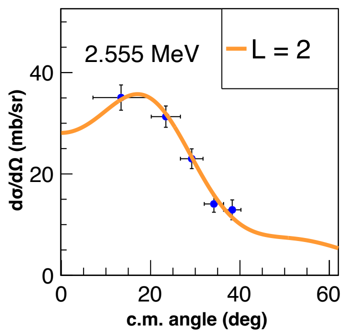

Figure 2: Angular distribution of the protons detected in the peak at E^* = 2.56 MeV. The curve is the result of an ADWA calculation.

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Single-neutron contributions to the Mirror Energy Differences of the $T = 1/2$ $A = 39$ Mirror Pair

Results of experiment IS757

C. R. Hoffman for the ISS collaboration

Mirror energy differences (MEDs) between analog states, when viewed as a function of the total angular momentum, $\Delta E = E(J, T_z = -1/2) - E(J, T_z = +1/2)$, provide isospin-symmetry tests along the collectivity plane. Within the $1s0d - 0f1p$ shells, the MEDs for the $A = 31$, 35, and 39, $T = 1/2$ pairs have been determined through the yrast $J^{\pi} = 13/2^-_1$ state (Fig. 1) [1, 2]. For each, the same pattern is observed as a function of spin highlighted by the abrupt change between the yrast $11/2^- - 13/2^-$ states. This sudden change in the MEDs is postulated as being a result of the maximally-aligned nature of the $13/2^-$ state within the $(0d_{3/2})^2_{J=3}(0f_{7/2})^1_{J=7/2}$ space. To investigate this possibility for the $A = 39$ MEDs the ^{38}K(d,p)^{39}K reaction was completed to provide a first look at the single-neutron contributions to the yrast levels.

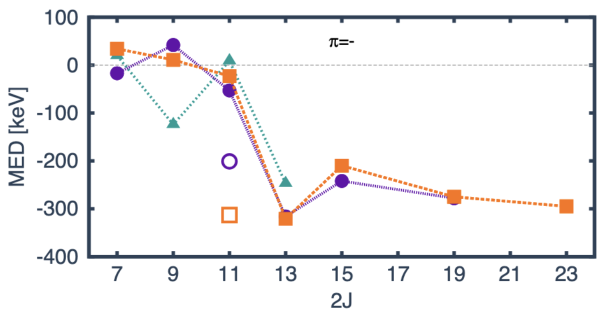

Figure 1: Mirror energy differences (MEDs) between the negative parity yrast excited states (filled points) in the T_z=±1/2 mirror nuclei of masses A=31 (blue), 35 (orange), and 39 (purple) [2].

A ^{38}K beam at $\sim$ 7.5 MeV/u was delivered to the ISOLDE Solenoid Spectrometer (ISS) by HIE-ISOLDE at a rate of $> 10^6$ pps. The beam was determined to be predominantly in its 3^+ ground state configuration and had no evidence for isobaric contamination. The (d,p) reaction took place within the 2.5 T solenoid field of the ISS using a $\sim$ 100 μg/cm^2 CD_2 target. Outgoing proton energies and positions were detected by the ISS position-sensitive Si array. Coincidence time requirements were made with both the incoming proton beam pulses as well as the EBIS release times.

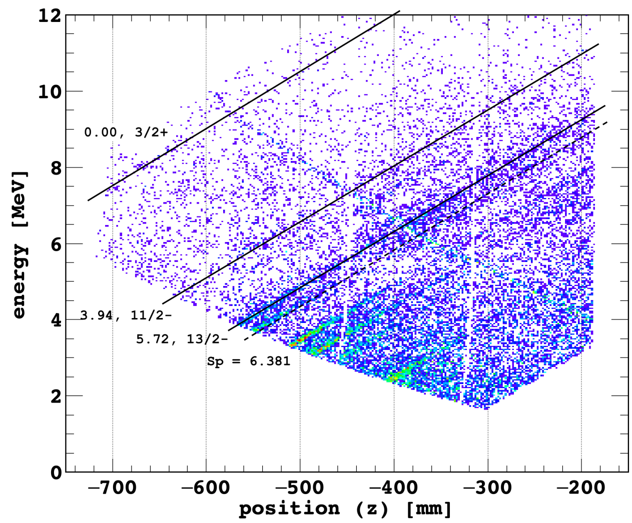

Figure 2: Measured proton energy vs. upstream distance traveled from the target (z) for outgoing protons measured by the ISS (2.5 T field) following the ^{38}K(d,p) reaction at $\sim$ 7.5 MeV/u.

Figure 2 shows a preliminary plot of the measured proton energies versus corresponding distances traveled from the target (z). The locations of the kinematic lines for the $11/2^-_1$ and $13/2^-_1$ states in ^{39}K, populated only via ℓ = 3 neutron transfer, are overlaid on the figure. In addition to other yrast states, a few non-yrast states up to $>$ 8 MeV in excitation energy were also observed. The relative yield to the $13/2^-_1$ state is larger than all other populated states below the proton threshold in the peak angle region of the ℓ = 3 transfer. This is consistent with an aligned configuration in this state and supports the single-particle explanation of the observed MEDs.

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The 2024 Coulomb-excitation campaign at Miniball

Carlotta Porzio for the Miniball collaboration

The Miniball gamma-ray spectrometer [1], located at HIE-ISOLDE, is aimed at investigating nuclear structure properties via nuclear reactions like Coulomb-excitation and particle-transfer reactions. An image of the setup is shown in Fig. 1.

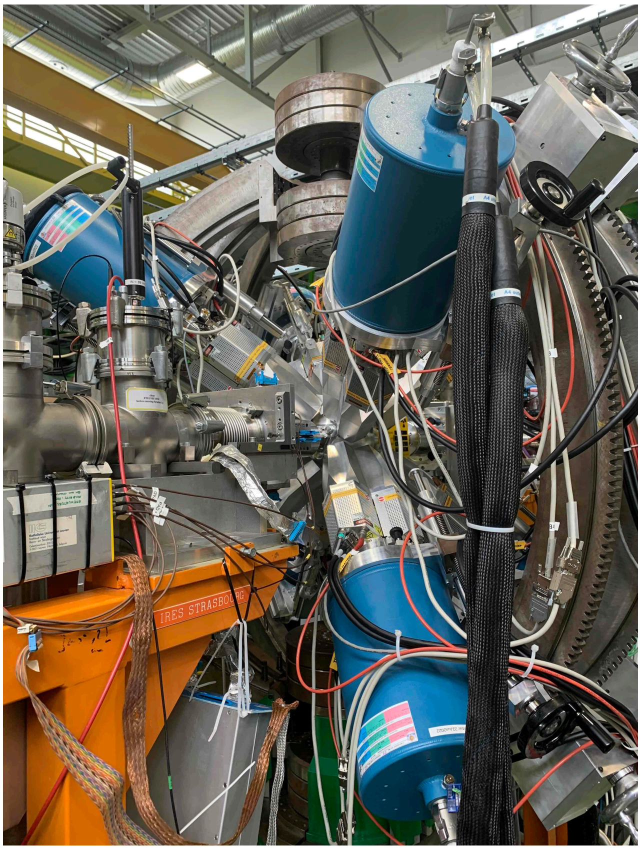

Figure 1: The Miniball spectrometer installed at HIE-ISOLDE.

The 2024 campaign of Miniball focused on Coulomb-excitation experiments. Four different runs were performed, that aimed at studying different aspects of nuclear structure.

The first two experiments focused on investigating shape coexistence in neutron-rich Zn isotopes, which lie close to the doubly magic ^{78}Ni, in which shape coexistence has been suggested [2]. The RILIS source was employed for Zn beam production. Furthermore, these runs exploited the Miniball ionization chamber for beam composition analysis. The ionization chamber, which hadn't been operational for some time, was put back into operation during the summer of 2024 by Ivan Anastasov, a summer student.

The following experiment studied Ra isotopes, to test the validity of the seniority scheme in Ra isotopes at and close to $N = 126$. The beam of interest was extracted as a RaF molecule from the primary target, to increase beam purity. Beam delivery was extremely successful and the goals of the experiment could be met within the first hours of the allocated beamtime. Happy users can be seen in Fig. 2.

The last Miniball experiment of the year focused on ^{144}Ba, aiming to probe octupole collectivity in the lanthanide region and to benchmark state-of-the-art theory predictions.

The Miniball collaboration is grateful to the ISOLDE machine supervisors, the target team, and the RILIS team, which put substantial work in delivering beams to the spectrometer.

Figure 2: The IS748 collaboration, celebrating a successful experiment.

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https://miniball.web.cern.ch

Investigating the deformation of the intruder isomeric $1/2^+$ state in ^{79}Zn (N=49) via Coulomb excitation

Results of experiment IS646

Filippo Angelini, Andrea Gottardo, Magda Zielińska
for the Miniball collaboration

Multiple experimental results support the occurence of shape coexistence in N$\sim$50 nuclei close to ^{78}Ni [1, 2, 3]. In particular, the $1/2^+$ isomeric state at $\sim$940 keV in ^{79}Zn, first observed in a (d,p) transfer measurement [4] and recently studied with high-precision mass measurements [2], has been interpreted as an intruder state, related to neutron excitations across N = 50. Laser-spectroscopy measurements found a large isomeric shift for this state with respect to the ^{79}Zn $9/2^+$ ground state, indicating a significantly larger mean squared charge radius [1]. Assuming an axial quadrupole shape, this would suggest a deformation of β = 0.22, considerably larger than β = 0.15 of the ground state [1], and would imply a significant admixture from the $2d_{5/2}$ neutron orbital.

In order to probe the collectivity of the intruder isomer in ^{79}Zn and of the excited band built on it, we used a ^{79}Zn beam from HIE-ISOLDE, post-accelerated to 4.0 MeV/A, that consisted of a mixture of nuclei in the $9/2^+$ ground state and the $1/2^+$ isomeric state (amounting to around 7% of the total), to populate via Coulomb excitation the excited states built on these two different configurations. A 3 mg/cm^2 ^{196}Pt target and a 4 mg/cm^2 ^{208}Pb target were employed in the measurement: the former for normalization to the known $B(E2)$ values of ^{196}Pt, the latter for minimizing background from target excitations. In the experiment, the Miniball array [5] was used to detect γ rays, while scattered beam and target recoils were measured by an annular DSSD detector placed at forward angles.

From the preliminary analysis of the data of the run in September 2024 γ-ray spectra from the de-excitation of ^{79}Zn were obtained. Figure 1 shows the Doppler-corrected γ-ray spectrum measured with the ^{208}Pb target and requiring that the scattered beam was detected in the DSSD. Several transitions are recognized from previous studies of ^{79}Zn [4, 6] and we observe clear evidence of excitation of the intruder band built on the $1/2^+$ isomer. Further analysis will aim at extracting the electromagnetic matrix elements from the measured γ-ray yields with the GOSIA code [7] to characterize the collectivity of the intruder band.

This work is part of the Ph.D. thesis of Filippo Angelini, student at the University of Padova, Italy.

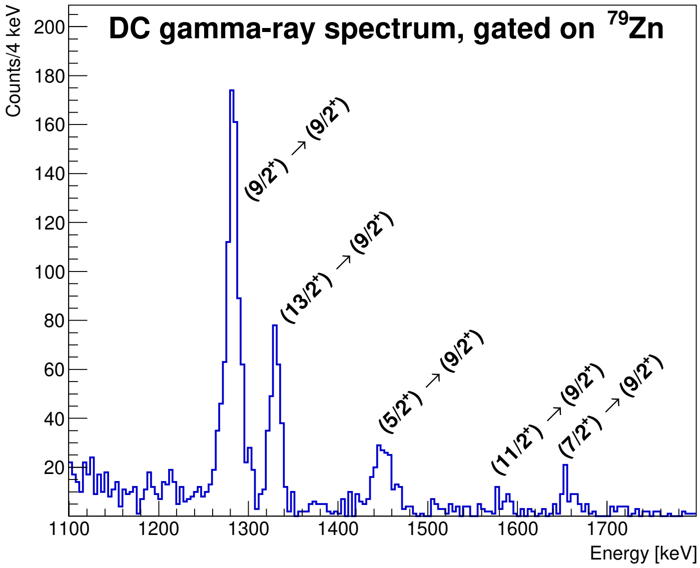

Figure 1: Miniball Doppler-corrected γ-ray energy spectrum in coincidence with a ^{79}Zn detection in the DSSD detector. Tentative spin assignments are taken from [6] and from a comparison with the systematics.

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IS690: Investigating the excited structure of ^{11}Li via the ^{9}Li(t,p)^{11}Li reaction.

Results of experiment IS690

Daniel Fernandez Ruiz, Olof Tengblad, Maria Jose García Borge for the MAGISOL collaboration

IS690 was carried out at the HIE-ISOLDE facility at CERN between the 15th and 22nd of October 2024. Its objective was to probe the excited states of the ^{11}Li halo nucleus through the ^{9}Li(t,p)^{11}Li reaction in inverse kinematics [1]. While the ground state (g.s) of ^{11}Li has been well-established as a mixture of *p* (59(1)%), *s* (35(4)%), and *d* (6(4)%) waves [2], its excited states remain controversial. Previous experiments attempted to populate the higher energy states of ^{11}Li by exciting the (very complex) g.s. By starting with the simpler ^{9}Li g.s nucleus, we aimed to avoid the ^{11}Li complexity and investigate the excited states through the residual proton [3].

Our experimental challenges were to provide a high-energy ^{9}Li beam with a good yield, a ^{3}H target, and an experimental setup offering good angular coverage and energy resolution at ranges where protons were likely to be emitted (calculated by A. Moro using DWBA [4]).

To address these challenges, a novel TaC$_x$ production target and a 1.7 GeV proton beam (the highest proton energy tested at ISOLDE and used for the first time for this experiment) were employed to produce ^{9}Li at a 1.27(21)$\times$10^{6} ions/μC rate according with the tape station values. The ^{9}Li^{+1} beam was accelerated in HIE-ISOLDE to 7 MeV/nucleon and directed through the XT03 beamline to the Scattering Experimental Chamber (SEC), where the tritium target (^{3}H absorbed in a 0.1 μm Ti foil with a 0.4 ^{3}H/Ti ratio) was placed within our detection setup. This setup (Figure 1-Left) consisted of three groups of Si-particle telescopes surrounding the target. A pentagon formed by five telescopes (W1-60 μm DSSD backed by an MSX25-1500 μm Si-PAD) that covers angles from 37° to 84° relative to the beam direction; a forward telescope formed by two CD detectors covering 6° to 32°; and a CD detector covering 100° to 145°. In total, we have 324 electronic channels in this setup.

A five-slot target ladder was positioned between the pentagon and backward telescopes. Four targets were used: a 15 μm deuterated polyethylene (DP) target, a 0.1 μm ^{3}H/Ti target, a 0.1 μm thick Ti foil, and an Au target. An empty slot was used to perform yield measurements at the beam dump telescope and determine frame scattering. An external actuator was employed to switch between targets.

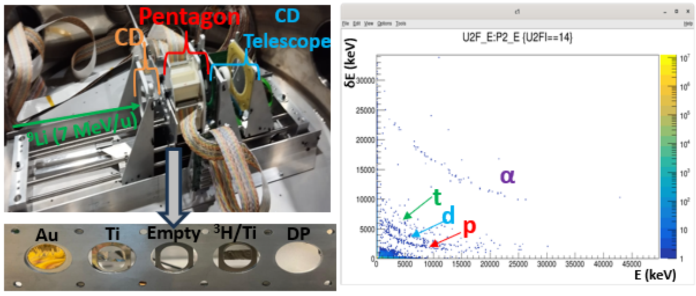

Figure 1: Left: Set up of experiment IS690. Right: Online ΔE-E plot of one of the telescopes.

The experiment began with a stable ^{12}C beam impinging on the Au target for detector testing and in-beam calibration. Subsequent runs, lasting 2–8 hours each, alternated between the Ti target, the ^{3}H/Ti target, an empty target frame, and the DP target, with the Ti and DP runs used to measure background channels.

Production of ^{9}Li was monitored using the beam dump telescopes, which measured an average intensity of 12,500 ^{9}Li ions/s. Online analysis of the ΔE-E spectra (Figure 1, right) successfully identified protons among the reaction fragments. A significant enhancement in the number of protons was observed when comparing the Ti target with the ^{3}H/Ti target. Since the only difference between these targets is the presence of tritium, this discrepancy can likely be attributed to the (t,p) reaction.

Unfortunately, a power cut on October 17th shut down the full CERN accelerator complex for a very short time. The subsequent technical issues with the machine hampered further data taking for the remain-

https://isolde.web.cern.ch

der of the run.

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Direct and Sequential Breakup of ^{7}Be on ^{12}C at 5 MeV/u

Results of experiment IS554

Ritankar Mitra, Dhruba Gupta for the IS554 collaboration

The ^{7}Be nucleus has a prominent α + ^{3}He cluster structure and a low breakup threshold of 1.587 MeV. Extensive studies on breakup reactions of the mirror nucleus ^{7}Li are available in the literature. However, similar studies on ^{7}Be do not exist. Previous experiments with ^{7}Be on ^{12}C and ^{58}Ni targets did not yield any significant breakup counts due to limited detection efficiency [1, 2]. Interestingly, Amro *et al.* [1] reported the predominance of α-transfer reactions over breakup. The present work is the first exclusive breakup measurement of ^{7}Be on ^{12}C at 5 MeV/u. The experiment was carried out at HIE-ISOLDE with a ^{7}Be beam of intensity $\sim 10^5$ pps incident on a CD_2 target. A pentagon detector array consisting of annular S3 and W1 DSSDs from Micron [3], was used in the SEC to detect the scattered particles. The experimental details are described in Ref. [4]. The fragments ^{3}He and α from the breakup of ^{7}Be were extracted considering coincidences between W1-W1 and W1-S3 detectors of the pentagon. The reconstructed relative energy (E_{rel}) distribution from the experimental data are shown in Fig. 1(a). The peak at $\sim$ 2.99 MeV corresponds to sequential breakup through the 4.57 MeV $(\frac{7}{2}^-)$ state of ^{7}Be. The breakup is predominantly direct at $E_{rel} > 3.8$ MeV. Now, the orientation of the relative velocity of the breakup fragments (β) in their center of mass frame can be derived using the relation,

$$\sin\beta = \frac{v_1 v_2 \sin\theta_{rel}}{\left(v_2^2 u_1^2 + v_1^2 u_2^2 + 2u_1 u_2 v_1 v_2 \cos\theta_{rel}\right)^{1/2}}, \qquad (1)$$

where θ_{rel} is the opening angle between α and ^{3}He, v_i is the laboratory velocity for each breakup fragment and u_i is the velocity of each fragment in their center of mass frame. By examining the β - θ_{rel} correlation plot in Fig. 1(b), crucial information like the time-scale and proximity of breakup can be extracted. When breakup occurs asymptotically, there will be a direct mapping between β and θ_{rel} [5]. This correlation is clearly observed for sequential breakup of ^{7}Be from the $\frac{7}{2}^-$ state. For prompt breakup events occurring close to the target, this correlation becomes featureless, as apparent for the direct breakup events in Fig. 1(b). Further work on the coincidence efficiencies, exclusive breakup cross sections and CDCC calculations are in progress.

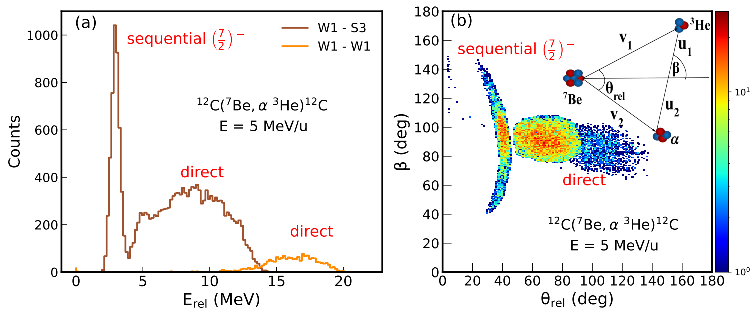

Figure 1: (a) The relative energy distribution of coincident ^{3}He and α from the breakup of ^{7}Be on ^{12}C at 5 MeV/u. (b) The β-θ_{rel} correlation of the breakup fragments. The inset in (b) is the schematic representation of β.

The IS554 collaboration thank the ISOLDE engineers in charge, RILIS team and Target group at CERN for their support. D. Gupta acknowledges financial support from ENSAR2 (Grant no. 654002) and ISRO, Govt. of India (Grant no. ISRO/RES/2/378/15−16). R. Mitra acknowledges the support of DST-INSPIRE fellowship (DST/INSPIRE/03/2021/000155, IF No. IF200499).

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RIB Applications

Two New Detectors for the VITO Beamline

Daniel Paulitsch for the VITO collaboration

In β-NMR experiments the recorded signal is the β asymmetry[1]. Nuclei can have β transitions which exhibit opposite β asymmetry leading to a low net asymmetry. One such case is ^{11}Be[2] which is investigated with β-NMR at VITO [3]. A way to increase the measured β asymmetry is to only capture the most energetic β events which correspond to just one transition with the highest Q(β) value. To do this β detectors with good energy resolution are required.

Two new detectors were developed at VITO to exploit this potential gain. In order to have energy resolution, a β-particle should deposit its full energy within the scintillator volume. The new detectors are thus 6 cm thick with diameters of 4 cm and 17 cm. Collecting the scintillation light uniformly from such a large volume poses an additional challenge. If only a small area of the surface is covered by photon detectors, the amount of light collected would depend on the position of the β particle. To have a uniform light collection and thus good energy resolution, the path of the scintillation photons was simulated in Geant4. The conclusion of these studies was that a light guide (diffuser), in combination with 128 6x6 mm SiPMs (Broadcom AFBR-S4N66P024M) should be used.

The EJ200 plastic scintillator was bonded to a PMMA light guide after plasma treatment of the surfaces. The 128 SiPMs were then coupled to the light guide using EJ-560 silicone rubber optical interfaces. The detectors predominantly rely on total internal reflection to direct light to the SiPMs. However, photons escaping from the scintillator are directed back into the volume by enclosing it with highly-reflective PTFE.

During our November beamtime, the smaller detector was tested for the first time with high energy decays of ^{9}Li, ^{26}Na and ^{11}Be as illustrated in Figure 2. The detector was able to handle high count rates and energies up to 14 MeV, the ^{9}Li endpoint, without encountering limitations. The new detector fulfilled all requirements. The new, now operational pair of β detectors will enable the measurement of β asymmetry as a function of energy in all future measurements.

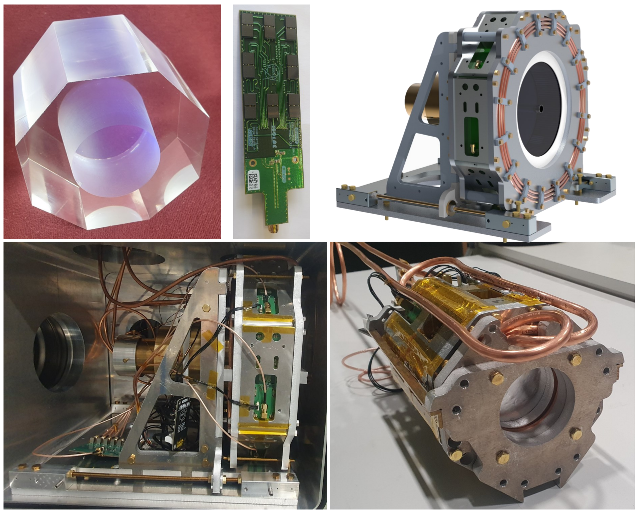

Figure 1: Top left: the scintillator and the light guide of the small detector glued together. Top middle: one of the PCBs for the small detector. Top right: a rendering of the big detector. Bottom: the two new β detectors.

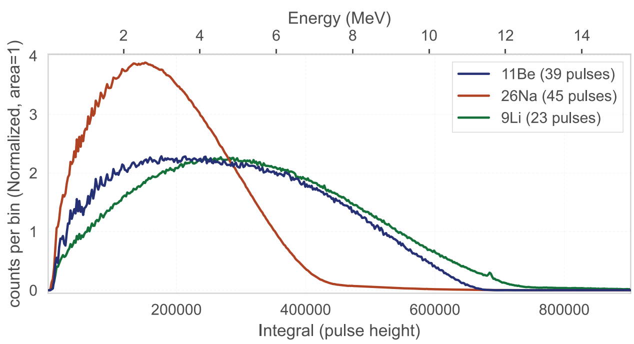

Figure 2: The β spectra of ^{9}Li, ^{11}Be and ^{26}Na recorded by the small detector.

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Implanted GeV centers in different doping types of diamond

Results of experiment IS668

Ulrich Wahl for the EC-SLI collaboration

Group-IV vacancy centers in diamond are, thanks to their symmetry properties (split-vacancy configuration), of high interest as spin-photon interfaces for a number of quantum applications, and how to create them efficiently is subject to intensive research. In the case of SnV^- centers, a considerable increase in optical activation (factor of 3.4) was observed following implantation in P-doped samples [1, 2]. This was attributed to the creation of negatively charged vacancies V^- which suppress agglomeration into divacancies V_2 via a repulsive Coulomb effect, thus leaving more single vacancies available for SnV formation and resulting in an increased formation yield. We report on the structural formation yield of GeV centers in split-vacancy configuration in five differently doped types of diamond: SC plate from Element 6 with [N]<1 ppm, 500 nm thick homo-epitaxial layers doped in-situ during CVD growth with B (1×10^{21} cm^{-3}) or P (9×10^{19} cm^{-3}), and samples ion implanted with B or P up to a concentration of 2×10^{18} followed by 1600℃ annealing for electrical activation. All samples were (100) oriented, except for the P-doped during growth, which was (111). GeV centers were created by means of implanting radioactive ^{75}Ga atoms, which decay into ^{75}Ge. The lattice location of the probe isotope ^{75}Ge ($t_{1/2}$=83 min) was investigated as a function of implanted fluence in the range of 3×10^{10} cm^{-2} to 2×10^{12} cm^{-2} and for annealing temperatures up to 900℃ using the emission channeling technique. We find (Fig. 1) that in the RT as-implanted state significant fractions of ^{75}Ge (35-40%) are found on BC sites, which are characteristic for the split-vacancy configuration, but that post-implant thermal annealing at 900℃ reduces these values to 0-20%, similar to previous results in undoped diamond [3]. Remarkably, the structural behavior of implanted Ge was found to be independent of the doping type, i.e. no preferential formation of the split-vacancy configuration was observed in P-doped samples and no suppression in B-doped, thus no evidence of a Coulomb effect. Our results hence suggest that the enhanced optical activation of other negatively charged color centers such as SnV^- or MgV^- observed in P-doped diamond [1, 2] may simply result from a Fermi-level effect which favors their negative charge state in a more n-type environment, rather than an increase in the structural formation yield of these centers due to a Coulomb effect involving negatively charged vacancies.

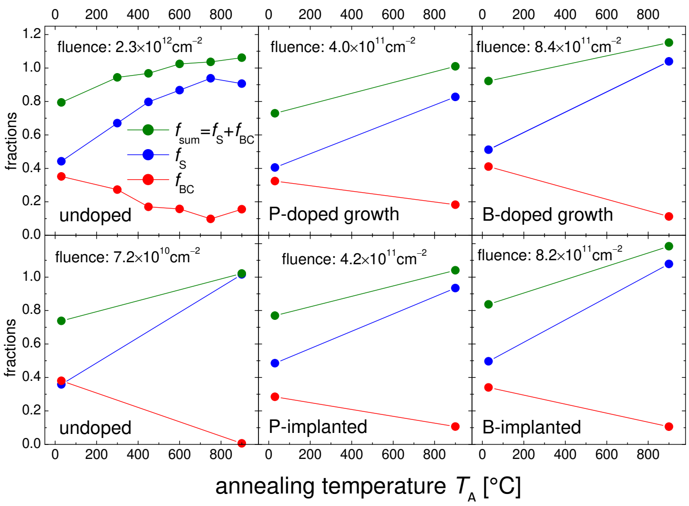

Figure 1: Fitted fractions of ^{75}Ge on S and BC sites and sum of both as a function of annealing temperature T_A for six different samples used.

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Local Structural Order in Layered Perovskite Solid Solutions

Results of experiment IS738

António Neves Cesário, for the IS738 collaboration

Recent discoveries have revealed Uniaxial Negative Thermal Expansion (NTE) in Ruddlesden-Popper (RP) perovskites, driven by an atomic corkscrew mechanism [1, 2]. This breakthrough has sparked renewed interest in the RP family due to their potential applications in electronics and engineered materials, where precise control over thermal properties can be achieved through chemical composition adjustments. To explore this phenomenon, we investigate $Ca_2Mn_{1-x}Ti_xO_4$ solid solutions using Perturbed Angular Correlation (PAC) spectroscopy in ceramics, complemented by Density Functional Theory (DFT) simulations.

Unlike other nuclear hyperfine methods, PAC [3] does not require high concentrations of foreign atoms, preventing unwanted chemistry modifications. Additionally, PAC works regardless of temperature, making it particularly well-suited for investigating temperature dependent phase transitions.

As part of an ongoing PhD project, we conducted PAC measurements at ISOLDE during ^{111m}Cd beam times (see Fig. 1). Our study revealed an intriguing case study in the probing of the electric field gradients (EFGs) to study nanoscopic phenomenology within solid solutions.

Instead of measuring a continuous EFG distribution, the introduction of Ti into the Ca_2MnO_4 lattice shows two well defined local environments. Aided by DFT simulations, we were able to show that we can directly probe how Mn and Ti atoms are positioned in the lattice, relative to the average distribution of the ^{111m}Cd probe at the Ca-sites (see Fig. 2) within the Rock-Salt layer. As a result, we can resolve previously unreported site specific interactions, offering a more detailed picture of atomic-scale order in these materials. Our findings may also offer insights into atomic arrangements in related RP materials, some of which exhibit superconductivity and magnetoelectric couling effects.

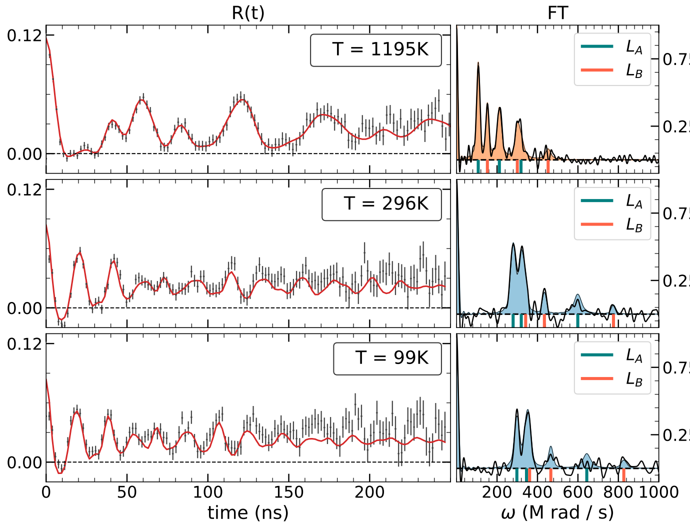

Figure 1: Representative ^{111m}Cd PAC measurements on $Ca_2Mn_{0.75}Ti_{0.25}O_4$ ceramics.

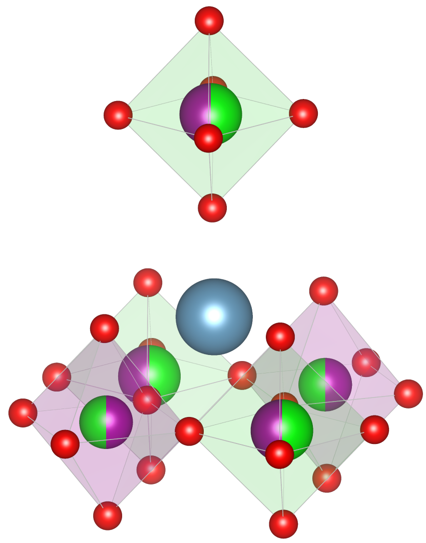

Figure 2: Illustration of the ^{111m}Cd (blue) local environment, where the violet, green, and red spheres represent Mn, Ti, and O atoms, respectively. Two-color spheres represent atomic sites that can either be filled by a Mn or a Ti atom with a given probability.

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From analog to digital: upgrading the LINE-PAC data acquisition with PACIFIC^2 and optimizing time-stamping methods

Results of experiment LOI 276

Pedro Rocha-Rodrigues, António Neves Cesário, André Costa Miranda for the LOI 276 collaboration

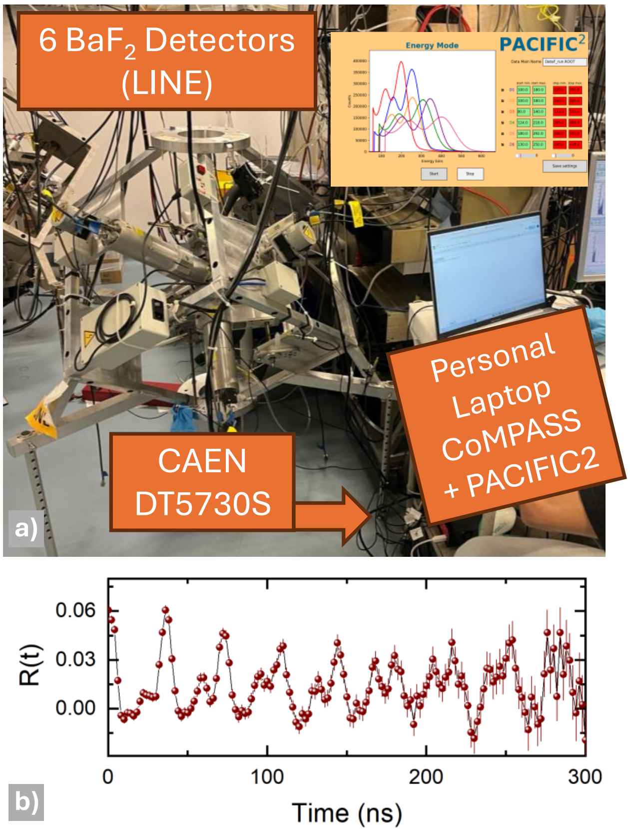

Figure 1: **(a)** Substitution of the LINE analog acquisition with the CAEN 5730S digitizer and PACIFIC^2 Suite. **(b)** Perturbation function (R(t)) of a perovskite sample measured within the IS738 proposal.

The γ-γ Perturbed Angular Correlation (PAC) spectroscopy technique has been a cornerstone of ISOLDE solid-state physics for over four decades [1]. Traditionally, ISOLDE's PAC setups have relied on aging analog equipment—some in operation for over 30 years—or bulky and expensive digital processing systems. The CAEN DT5730S digitizer compact unit, with 8 input channels, a 500 MS/s sampling rate, and a 14-bit ADC, seamlessly integrates into a 6-detector PAC configuration setup. Building upon previous work to modernize current PAC data processing systems [2], we have now successfully tested the PACIFIC^2 software and the digitizer under real-time conditions while using a BaF_2 based 6-detector array, previously connected to the LINE analog PAC setup (Fig. 1). During the last ^{111m}Cd beam time, the upgraded system facilitated over 50 successful PAC measurements, one of them highlighted in Fig. 1. A key milestone achieved in this study was the real-time processing capability on a modern laptop running simultaneously the CAEN Communication software (CoMPASS) and the γ-γ coincidence search mode of the PACIFIC^2 suite. The setup seamlessly handled live data acquisition and analysis, reinforcing the potential of our Python-based PACIFIC^2 suite for real-time processing without compromising performance. This marks a significant step forward from prior tests, where post-acquisition processing was the primary mode of operation [2].

While this new setup can replace the previous analog ones for experiments using ^{111m}Cd and ^{111}In probes (84 ns half-life), studies with PAC probes with much shorter probing half-lives such as ^{181}Hf (10.8 ns) and ^{199m}Hg (2.46 ns) were not yet possible due to the need for an accurate sub-sampling binning, a known limitation of digitizer units [3]. In the standard approach, the time of arrival of an anode electric pulse, corresponding to a detected γ ray, is determined by a simple linear interpolation of the zero-crossing of the Constant Fraction Discriminator (CFD) implemented in the FPGA of the digitizer. However, when the time delay between the γ detections is asynchronous (phase shifted) relative to the sampling clock, this method introduces periodic artifacts which can only be eliminated through post-processing techniques applied to the detector signals [3]. To address these limitations, we are developing alternative methods that fit approximate analytical functions to the recorded waveforms as an alternative time-stamping method. Our preliminary tests, conducted using 511 keV - 511 keV photon coincidences from ^{22}Na β^+-decay, demonstrate a significant improvement in decreasing time binning while keeping the necessary experimental sub-ns time resolution independent of the delay between the arrival of two γ-photons (see Fig. 2). The challenge for the next beam time is to implement and optimize real-time analysis of the waveforms using our fitting methods, enabling crucial analyses to be performed during the beam time itself.

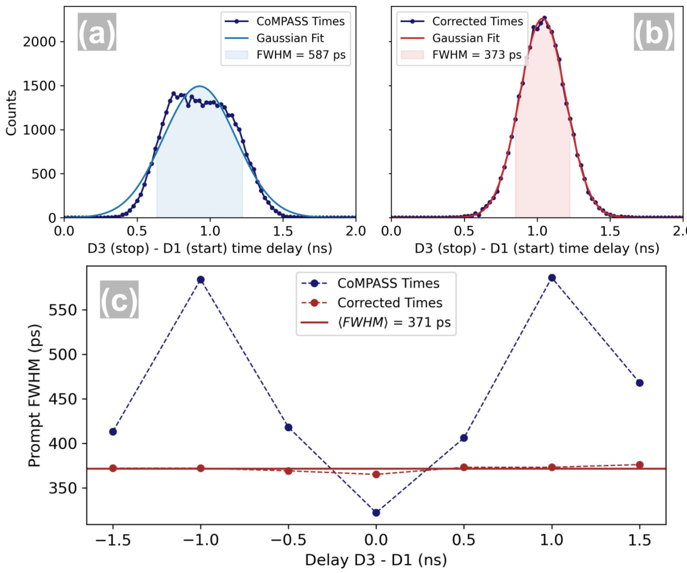

Figure 2: **(a, b)** Prompt-resolution curves from ^{22}Na 511-511 keV coincidences. A BNC 1 ns cable delay was introduced into the electronic path of the stop detector, introducing distortions visible in **(a)** due to the asynchronous recording of stop and start events. These artifacts are effectively removed in **(b)** after applying our time-stamping correction algorithms. **(c)** Prompt FWHMs for various imposed delays between the detectors, demonstrating a reduced temporal dependency after our corrections.

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Other News

MEDICIS and MELISSA operation and highlights in 2024

Cyril BERNERD, Charlotte DUCHEMIN, Manikanta ELLE, Jake JOHNSON, Patricija KALNINA, Muhammad INZAMAM, Laura LAMBERT, Edgars MAMIS, Ralitsa MANCHEVA, Ralf ROSSEL, Joachim VOLLAIRE, Thierry STORA on behalf of the CERN-MEDICIS collaboration

1 Highlights from operation in 2024 and insights for 2025

In 2024, MEDICIS entered its sixth year of operation since its commissioning at the end of 2017, with a high demand from the collaboration as well as from the PRISMAP users across Europe, mostly focused on alpha emitters for Targeted Alpha Therapy (TAT). A total of 2 GBq was collected and delivered for the biomedical program, excluding machine development runs [1, 2, 3]. MEDICIS will restart in 2025 for a year of radionuclide production with protons and external sources. The MEDICIS programme has been extended up to 2030, following a very positive international review held in 2023.

The year 2024 witnessed again, as in 2023, a high demand for two radionuclides produced efficiently at MEDICIS from the irradiation of ThC targets: Ra-224 and Ra-225. A record efficiency of 72% has been obtained this year. An activity of 1.8 GBq, of Ra-224 and Ra-225, has been delivered to medical projects in the UK, Germany, Switzerland and Belgium (i.e. 90% of our total activity collected this year). Moreover, a newly developed double collection system allowed the output of the facility to be increased for these radionuclides by collecting them both at the same time, therefore optimizing the use of the protons, the running time and the amount of radioactive waste produced.

Other radionuclides such as K-43, Sc-43/44, Eu-145, Gd-149, Tb-155 and Tm-165 have been provided with an activity per batch up to 100 MBq to our external partner institutes and PRISMAP users for research and preclinical projects. Machine Development (MD) runs on Tb-155 using a new target, TaC, have been performed to progress further on the delivered Tb activity, associated with dedicated release studies (see also part.3).

A total of 7 new targets have been built to support operation in 2024, with 5 reused targets from previous years, with the objective of optimizing their use and minimizing the radioactive waste produced. MEDICIS received 4.1E19 protons on target (poT), about 1/3 of those delivered to ISOLDE, by coordinating closely with the ISOLDE team so there was no disturbance of the ISOLDE physics program. A total of 18 radioactive transports have been organised. Thanks to improvements and the constant support of the Radiation Protection team, the handling of our radionuclides remained very well optimized with a 328 μSv collective dose received over the year despite the high activities collected.

After a few months of maintenance and upgrades, MEDICIS restarts operation in March 2025 with a rich program. Several demands of Ra-224 and Ra-225 are still in the planning with the addition of Ra-223, for a new PRISMAP user research project in France. Ba-128 will be investigated again at CHUV Hospital, Lausanne. A last batch of Tm-165/Er-165 will be produced for completion of a research project on the use of Auger emitters in medicine. Additional requests for the newly

https://medicis.cern

developed Eu-145 beam, which is now part of the portfolio of isotopes ionized by MELISSA following the successful first collection, triggering a new assessment of nuclear data of high interest at the National Physics Laboratory (NPL) in London. A newly approved MEDICIS project, notably including Ac-226 for HUG Hospital, will be a new addition to the radionuclides to be collected this year with proton irradiation at CERN. External sources of Sm-153 are foreseen for enrichment by mass separation from the Sm-152 target for medical applications, and are subject to approval by the CERN council for first clinical trials at the hospital of Heidelberg in Germany. Last, but not the least, development time will be managed around Sc and Tb production optimization and Cu-67 production development.

MEDICIS welcomed several external visitors and collaborators, including David Townsend, co-inventor of the PET-CT, a group from the European Observatory on the Supply of Medical Radioisotopes, a Pakistan Council delegation and collaborators, a Lithuanian VIP protocol office visit, a Latvian experimental and solid state physics delegation and the TRIUMF Life Science director Paul Schaffer.

2 MELISSA laser laboratory update

In 2024, the MELISSA laser laboratory has been used for collections of radioisotopes including Tb/Dy, Sm, Tm, Gd and Eu. In addition to these collections, MELISSA has been involved in the first Cu-67 machine development test, and for laser ionization tests during Sc mass separation and machine development. Overall, MELISSA was operated in 2024 during 20 weeks between May and December. In the light of an expected busy program for 2025, MELISSA will again be a highly favored ion source for the rich programme ahead.

The addition of Eu-145 to the MEDICIS portfolio was made possible thanks to the laser scheme development performed by the RILIS team at ISOLDE at the beginning of the year (See Figure 1). At the end of 2024, a complementary measurement was performed, leading to better enhancement of ionization with a slightly different wavelength scheme. As a result, the expected efficiency for the collection of Eu-145 will be improved this year.

In 2025, new laser developments will be conducted in order to improve the facility's performance. The design of a Raman laser, aiming at producing exotic laser wavelength, will be finalized and implemented at MELISSA. Its use for the ionization of Radium has already shown great promise and should lead to a new record collection efficiency. Two new projects will complete this exciting programme in 2025; the full automation of the laser system will start, to facilitate future operation; in parallel, the study of the use of nonlinear processes (namely Difference and Sum Frequency Generation) will be conducted. These processes will lead to the generation of wavelength in a range only accessible with Dye lasers, which are not implemented in MELISSA. Hence, the laser capabilities and schemes accessible will be greatly improved [4].

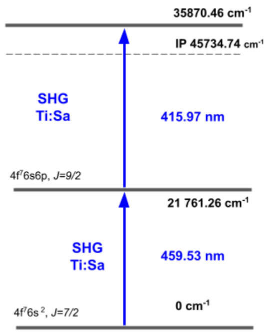

Figure 1: Eu laser scheme recently developed

3 Release studies

Different radionuclides, such as Scandium (Sc) and Terbium (Tb), have garnered significant interest in nuclear medicine due to their suitability for both cancer diagnostics and therapy, making them promising candidates for theranostics. However, achieving high molar activity and radiochemical purity remains a challenge for medical applications. One potential solution to this issue is physical isotope mass separation, a method which enhances sample purity for medical use. Despite advancements in mass separation, notably at CERN-MEDICIS and at other facilities, the extraction efficiency and yield of certain radionuclides, particularly those considered as difficult to extract, such as Sc and Tb, remain suboptimal for producing medically relevant activities.

To address this, the method to investigate the thermal release of various radiotracers from activated target materials was adapted to investigate the impact of the environment within an ISOL target unit, and more specifically the role of the environment driven by the tantalum structural materials [5]. This technique was first applied to study the release of Sc radionuclides from activated natural titanium and vanadium metallic foils (embossed and non embossed). The relative thermal release patterns of Sc from metallic ^{nat}Ti foils and ^{nat}V samples were systematically studied in the MEDICIS and ISOLDE mass separator target units. Full Sc release within one hour after reaching the set temperature was achieved at 1200 ℃ for non-embossed ^{nat}Ti and at 1450 ℃ for embossed ^{nat}Ti foil samples (See Figure 2).

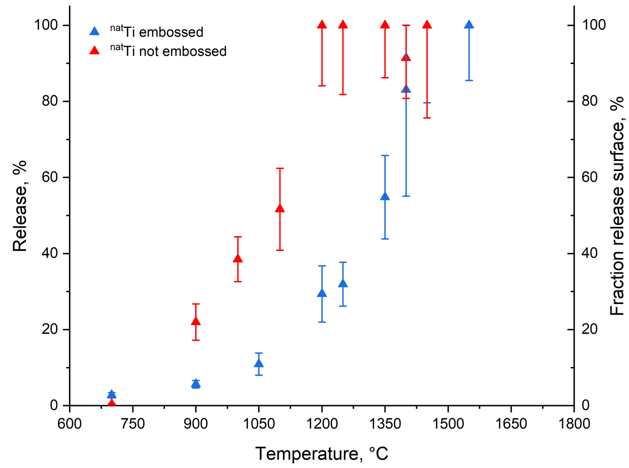

Figure 2: Total Sc thermal release from embossed and non embossed ^{nat}Ti foil samples [5]

Interestingly, the release of Sc from embossed metallic^{nat}Ti foils was shifted toward higher temperatures in contradiction of the expected shift if sintering would be prevented or effusion enhanced from the geometry. Preliminary results for Sc release from ^{nat}V foil samples indicate complete (100%) release at 1600 ℃ within one hour, see Figure 3.

In 2024, the method was further refined to accommodate the study of ^{155}Tb, a particularly challenging radionuclide to extract. A total of 40 samples were analyzed, including 3 types of metallic foils and TaC pellets, to study the thermal release behavior of ^{155}Tb. Additionally, due to the wide range of radionuclides generated from high-energy proton irradiation of natural tantalum foils, several other release curves were obtained, including radionuclides of medical interest. These findings provide valuable insights for optimizing the mass separation process, ultimately improving radionuclide production efficiency for both fundamental physics research and medical applications [6].

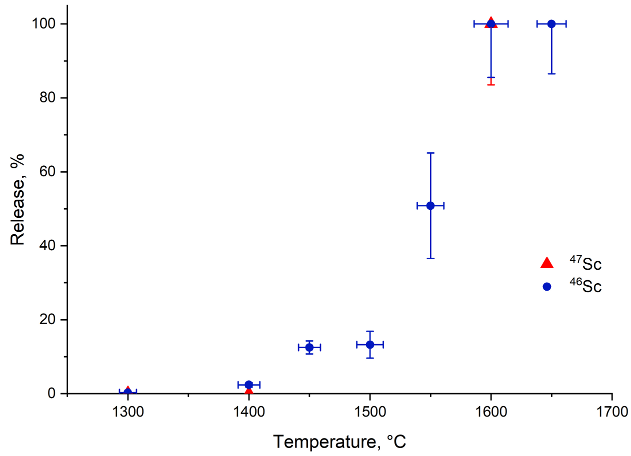

Figure 3: ^{46}Sc thermal release from non-embossed ^{nat}V foil samples [5]

4 Acknowledgments

We wish to thank all our colleagues from SY-STI, BE-CEM, BE-OP, HSE-RP, EP-SME and the institutes that are part of the collaboration for their support.

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ISOLDE support

Access and contacts

1. Use the online EDH Pre-Registration tool[1] which should be launched by your team leader or deputy team leader. You need to attach the following documents to the pre-registration:
   - Home Institution Declaration[2] **signed by your institute's administration (HR)**.
   - Passport
2. When your pre-registration is accepted by the CERN users office you will receive an email telling you how to activate your CERN computer account. However, you cannot activate your CERN EDH account until you arrive at CERN and complete the registration process; this means you should register for hands on safety courses via email, see Item 7.
3. Follow the online mandatory CERN safety courses: Safety at CERN, Radioprotection Awareness, Emergency evacuation, Computer Security, Security - Awareness and Data Privacy Basics - elearning.
   - If you have activated your CERN account, you can access the mandatory on-line courses at the web page lms.cern.ch, from your computer, inside or outside CERN.
   - If you have not activated your CERN account, there are some computers available for use, without the need to log in, in the reception building 33 (Your CERN badge will be needed in order to prove your identity).
4. Complete the following online courses available at https://lms.cern.ch:
   - Electrical Safety - Awareness Course - Fundamentals
   - Electrical Safety - Awareness Course - Facilities

   If you have not activated your CERN account see the second part of Item 3.
5. When you arrive at CERN go to the Users Office to complete your registration (Opening hours: 08:30 - 12:30 and 14:00 —- 16:00 but closed Wednesday mornings).
6. Get your CERN access card in Building 33
7. Follow the in-person ISOLDE RP safety course and the "Electrical Safety-Working in EP experiments" course for which you will have to register well in advance[3]. These take place on Tuesdays at the training centre (Building 6959) in Prevessin; the Electrical course takes place on Tuesday morning and the RP course on Tuesday afternoon. If you do not have your own transport, you can take CERN Shuttle 2 from building 500. The timetable for this is here.
8. Obtain a permanent radiation dosimeter at the Dosimetry service, located in Building 33[4] (Open-

[1] For information see the CERN users' office
[2] The Home Institute Declaration should not be signed by the person nominated as your team leader.
[3] For information about how to register see http://isolde.cern/get-access-isolde-facility
[4] http://cern.ch/service-rp-dosimetry (open only in the mornings 08:30 - 12:00).

ing hours: Mon. to Fri. 08:30 —- 12:00). *If you do not need the dosimeter in the following month, it should be returned to the Dosimetry service at the end of your visit.* The "certificate attesting the suitability to work in CERN's radiation areas" [5] signed by your institute will be required.

9. Apply for access to "ISOHALL" using ADAMS: https://www.cern.ch/adams. (This can be done by any member of your collaboration, typically the contact person, having an EDH account[6]). Access to the hall is via your dosimeter.

   Find more details about CERN User registration see the Users Office website. For the latest updates on how to access the ISOLDE Hall see the ISOLDE website.

   New users are also requested to visit the ISOLDE User Support Office while at CERN. Opening hours: Monday to Friday 08:30 - 12:30

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More contact information at
ISOLDE contacts and at ISOLDE people.

[5] The certificate can be found via http://isolde.cern/get-access-isolde-facility
[6] Eventually you can contact Jenny or the Physics coordinator.