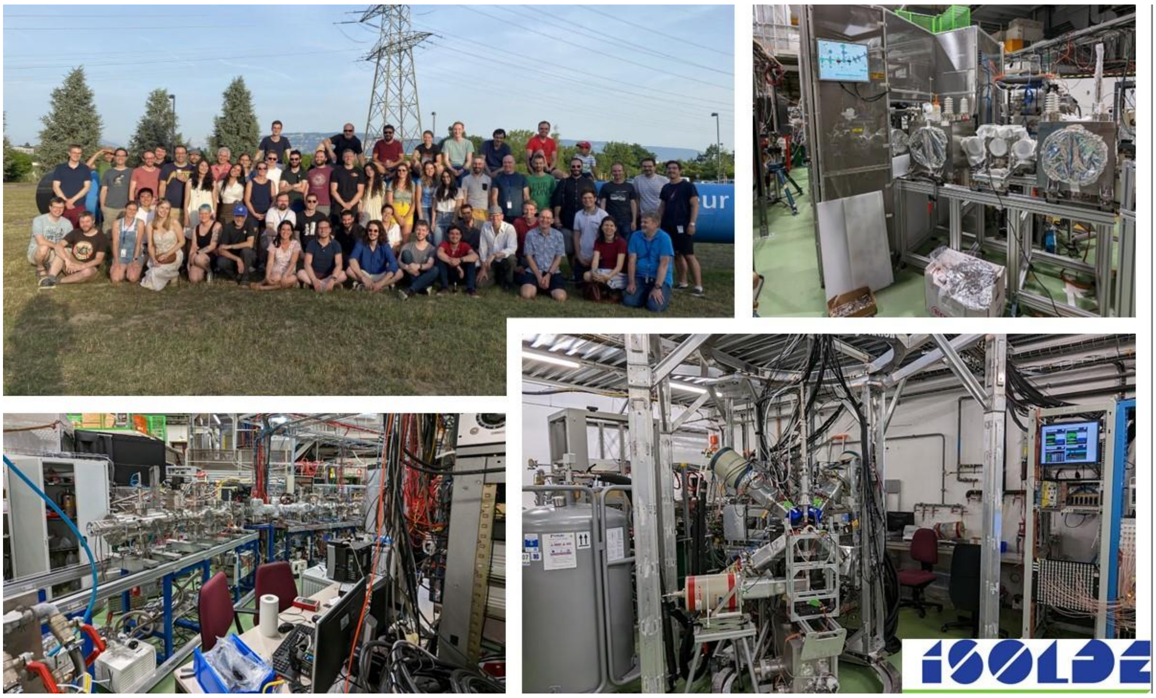
ISOLDE NEWSLETTER 2023



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Introduction

Sean J Freeman

Welcome to the 2023 ISOLDE Newsletter!

The past year was a very good one for ISOLDE, getting back to a normal as COVID restrictions gradually disappeared - although perhaps it is a new kind of normal in some respects! The ISOLDE Facility continues to be very productive, as you will see from the articles in this newsletter. During the 2022 running period, there were 52 experiments, including a very successful CRIS experiment on radioactive AcF molecules performed as Winter Physics with a pre-irradiated target. In total, more than 520 users visited the Facility from all around the Globe for experiments and around 20% were women. One of the pleasures of being based at CERN is meeting many of these diverse visitors.

The running period began with low-energy experiments in March with some exciting highlights. Spins, moments and radii of Te isotopes near to ^{132}Sn were measured with COLLAPS. VITO saw resonances of K ions in DNA complexes for the first time. The refurbished Total Absorption Spectrometer was used to study neutron-rich Zn. CRIS performed laser spectroscopy experiments of Al isotopes into the island of inversion. The Decay Station had several interesting runs this year, particularly for Ac and Po decays and enjoyed some unusual publicity, shown in Figure Fig. 1. The solid-state programme was productive including experiments on multiferroics, perovskite materials and colour centres in diamond. Miniball was welcomed back and, newly refurbished, it started its campaign with Coulex studies of ^{130}Sn and ended with a measurement of ^{182}Hg, where electron-γ measurements with a radioactive beam where performed for the first time without the use of magnets for electron transport using SPEDE. Six different HIE-ISOLDE beams from ^{11}Be to ^{110}Sn were used to initiate (d,p) reactions in the Solenoidal Spectrometer, which is now well into data production mode. And some novel targets composed of helium gas trapped in a silicon nanomatrix were used to measure α elastic scattering using Sn beams with relevance to the astrophysical p process. Tin was "flavour of the month" being delivered an entire four-week period by HIE-ISOLDE in the autumn. There's always a danger in selection of highlights, so it is probably wise to say that there were too many excellent experiments to mention them all here!

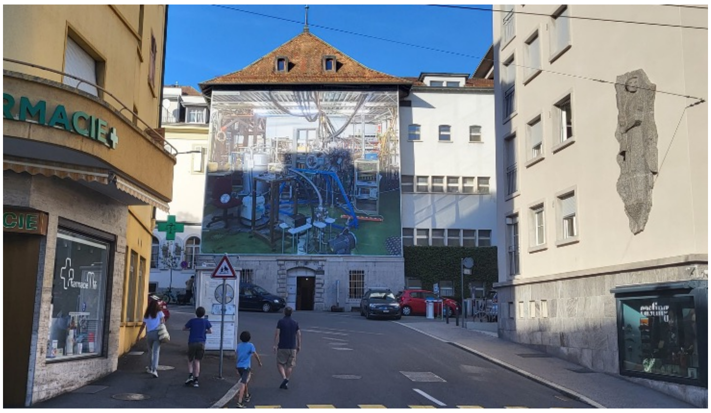

Figure 1: Festival des Images in Vevy, 2022. IDS poster by Thomas Struth. Photo credit: Chris Page.

Important steps have been taken in the development of an improvements programme for ISOLDE. The ideas that were developed during the collaboration workshops in 2019 and 2020 were classified into two different groups: those that could be implemented on the timescale up to and including Long Shut Down 3 and longer term aspirations. The major elements of the mid-term improvement programme are the replacement of the proton beam dumps and upgrade of the BTY line to deliver 2-GeV protons, but a series of other improvements and consolidation items are included.

During the summer, tests were run using a 1.7-GeV proton beam at reduced intensity to compare yields with those at 1.4 GeV. Overall these tests verified the results of simulations, giving faith in their predictions for yields at 2 GeV. After replacement of the dumps, the combination of increased proton energy and the possibility for increases in intensity will significantly improve many

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radioisotope yields. This should enhance the capacity of the facility as some experiments will take shorter times to execute. In other experiments, increased yield will give greater statistics with more detailed and higher precision results. And it will allow experiments on new radioisotopes, improving the capability of ISOLDE. The other improvements will address the cryo-system for HIE-ISOLDE and a 5th cryo-module, consolidation of REX amplifiers, RILIS infrastructure developments, improvements to fire safety and smaller items.

The technical aspects were discussed amongst colleagues from across many groups in the Accelerator and Technology Sector (ATS) at a special mini-workshop in October, and were presented to the CERN Joint Accelerator Performance Workshop in December. In parallel, discussions at the ISCC were followed by a Letter of Intent (LoI) summarising the scientific justifications to the INTC in February 2023. A previous LoI on 2-GeV delivery, authored by Maria Borge, Magda Kowalska and Thierry Stora, was a very helpful starting point. Scientific and technical threads were brought together in a discussion at the Research Board in March. This process has been a lot of work, particularly from our colleagues in the ATS and I am very grateful for their efforts. For several different reasons, there were elements of the programme that required more urgent funding so these, along with fire safety initiatives, have been put into the CERN Medium Term Plan (MTP) 2023 that was considered by Council in June. As you might imagine, there is some uncertainty over costs of excavation works for the beam dumps; over the coming months estimates will be refined and the improvements programme undergo cost review in the autumn. Following that, a decision can be made about inclusion in the MTP 2024 so that work can be planned ahead of LS3. The financial climate is not easy, but feedback has been very positive, so keep your fingers crossed!

The longer term improvements are larger in scale and cost. The timescales for project development and approval place them into the period where the post-LHC future for CERN becomes relevant. We will have to remain agile and try to develop and align our longer term goals for ISOLDE with CERN's emerging strategy, but we have started conversations with the various post-LHC projects to identify opportunities.

Open Science is an increasingly important aspect of research and many funders are now making it a requirement. The desires of member states is also reflected in a new CERN Open Science Policy. The ISCC has developed a policy suitable for ISOLDE, along with advice for ISOLDE Spokespersons, that has been circulated and can be found on our web page. For EURO-LABS funding, we are required to keep a record of the necessary Open Data arrangements, which we tried to capture as a very short questionnaire when beam requests are made, trying to reduce administrative burdens as much as possible. A quick reminder to make publications open access and to ensure that EURO-LABS support is credited in publications, theses and talks: *"This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511."*

The order of individuals on a publication is a very crude tool for signalling different levels of contribution amongst authors. So, it can be a source of worry, especially for early career researchers who are keen for their contributions to be recognised. It might not be so well known that conventions on the author list varies between different fields and even within them. Some areas of physics flag individuals who made big contributions at the start of the list, others are strictly alphabetical and, indeed, in some areas the last author on the list is the important one! One way to make your contributions clear is to add a short sentence for each item in the publication list in your CV, concisely describing what you brought to the research. At least then your contribution is clear when you are applying for jobs, and that is often when such things matter most.

A quick reminder to everyone to use necessary personal protective equipment in the ISOLDE Hall and follow the approved procedures concerning your activities. EP Safety is available to help you with any ISOLDE related work; if you have any concerns or if a procedure does not seem appropriate for your activities, they are on hand to discuss and advise. I have been working with them in a number of areas where I have found them to be very supportive.

It was great to host the 2022 ISOLDE Workshop in person, the first opportunity since before the pandemic. After having larger numbers of registrations for the pandemic online events, we decided to try a hybrid meeting. There were a couple of minor IT issues, but on the whole worked well with 121 people on site at CERN and 100 joining online, representing together more than 25 different countries. It was an great event with lots of interesting science and excellent presentations. Congratulations to the prize winners (Peter Plattner, Silvia Bara, Tobias Treczoks and Ralita Mancheva) and thank you to our sponsors, CAEN. Those of us who were there in person were able to enjoy a traditional fondue with accompanying alpine horns; the yodelling was a surprise, even for the organisers!

ISOLDE schedule 2023

The physics period in 2023 started on April 20th and will run with protons until October 30th. This relatively short running period is due to a CERN-wide reduction of 20% for all accelerators in 2023 due to energy considerations. The most affected scientific programme due to these restrictions are for the post-accelerated experiments, and priority will be given to them in the latter part of the year. The relatively early stop with protons will allow for up to three weeks of winter physics including it is hoped at least one for a HIE ISOLDE experiment.

The schedule up to week 39 for 2023 can be found online here, and the weekly schedules here. The remaining part of the schedule will be published in the coming weeks.

As in 2022, EUROLABS TNA support will be available and spokespeople of scheduled experiments will be contacted in advance of their experiments running by Jenny.

Preliminary dates for start-up in 2024 are as follows:

- Start of low energy Physics
  - 8th April 2024, or week thereof.
- Start of High Energy Physics
  - Tentatively, towards 3rd week of July.

The end of protons in 2024 is likely to be around the end of October, again due to energy considerations, but this may change depending on the situation.

The above dates are preliminary, and have yet to be approved at various CERN committees until the end of 2023. The final dates will be approved at the Research Board in December 2023.

Proximeters

A recall campaign is currently in place for the return of all proximeters issued during the Covid-19 pandemic. Local users at ISOLDE have already mostly returned theirs, but if there are users who have a proximeter either at their home institute or which may be in a drawer in an office or lab at CERN, please let Jenny know so that they can be accounted for.

User registration for 2023

A full description of the procedure for registering at CERN is given at the end of this newsletter. Please note that PRT no longer exists, and has now been replaced by a new form: PREG (Pre-REGistration). This form will be the basis for registering all users for ISOLDE experiments.

As in 2022: the teamleader and deputy teamleader who sends 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.

INTC meetings in 2023

The last remaining INTC meeting in 2023 is the following:

- 74th meeting of the INTC
  - November 7th and 8th. The deadline for submission of proposals is September 26th 2023.

The preliminary date for the first INTC in February has been set for 7th and 8th of February, with a deadline for submission likely to be 10th January. This will be confirmed later in the year.

Although the lifting of the majority of Covid restrictions means that meetings can once more take place in person, it has been found that remote presentations to the INTC have worked well, and this policy will remain: this ensures a level playing ground for those who would be unable to travel and will reduce the carbon footprint

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of such meetings. The open session will take place in the presence of the committee, but all presentations will be given using zoom.

Access to ISOLDE

Access to ISOLDE is entirely managed through ADaMS (Access Distribution and Management System). The access permission required for ISOLDE is **ISOHALL**. If the appropriate training ranks have been gained, the access will be granted, it is no longer approved by the physics coordinator.

Required training courses for access to ISOLDE hall and chemical labs

All training is managed via the CERN training hub. There are a variety of training courses required before access to the ISOLDE hall can be granted. These are divided into hands-on courses, which take place at the CERN training centre in Prevessin, and online courses which can be taken via the CERN online training.

- Pre-requisite online training courses (can be followed prior to arrival at CERN). The links to these courses can be found here
  - Mandatory courses for everybody at CERN:
    - Emergency evacuation
    - Radiation Protection - Awareness
    - Safety at CERN
    - Computer Security
    - Data Privacy Basics - elearning
  - Additional courses for ISOLDE users:
    - Electrical Safety Awareness - Facilities
    - Electrical Safety Awareness - Fundamentals

Please note that the EP electrical course requires the home institute to sign a form prior to registration. This form can be found here. These courses take place on a Tuesday from 0830 until about 1700: electrical safety in the morning and RP training in the afternoon. The registration deadline for the hands-on courses is 15 days prior to their taking place.

Enrollment for courses should take place in advance of coming to CERN; in the event that 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 LMS in order to validate the training once the User has arrived at CERN and has completed their User registration.

- Required hands-on courses
  - EP Electrical safety in EP Experimental areas
    - Course code: STELS03I
  - ISOLDE - Experimental Hall - Radiation Protection - Handling
    - Course code: STIRP06I
  - B. 508 chemical labs: The laboratories on the ground floor of 508 where solid state physics perform chemistry also have their own access. Please follow the online LMS course "Chemical Safety Awareness" before requesting the permission **ISOCHEM** for 508 R-002 and **ISOEXP** for 508 R-008 for the measurement area.
  - ISOLDE Traka Box: the ISOLDE TRAKA box is now integrated into Adams. To request access to the box it is necessary for users to ask for the "0508K1-002" permission in Adams.

Visits to ISOLDE

Visits to ISOLDE can be arranged by contacting isolde-visits@cern.ch.

A typical visit consists of an overview presentation in the visitors' area in building 508 and — when possible — a tour of the ISOLDE facility itself along the pre-arranged visit path. In the event of a machine intervention or a conflict with physics which happens to be running, the tour of ISOLDE may be cancelled, and visitors remain in the 508 gallery area. Please note that weekend visits of groups are no longer possible and are not advised for individuals except in exceptional circumstances. The possibility of a fully virtual visit also now exists, which can be attractive for large groups e.g. university students.

More details can be found on the area of the ISOLDE website dedicated to visits.

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 now a requirement for the receipt of EUROLABS support. All experiments are now requested to provide information about their Open data policy at the time of beam requests. ISOLDE has also recently published an open data policy, following approval by the ISCC, and this can be found here.

Safety in the ISOLDE hall

The wearing of safety helmets and shoes is mandatory inside the ISOLDE hall. It is also mandatory to check yourself on the hand-foot monitor before leaving the ISOHALL zone.

Once within the ISOLDE hall you have at your disposal additional RP protective equipment such as gloves and contamination monitors to ensure your safety. These are located in the cupboard close to the old control room. A new suite of PPE for electrical investigations can now be found close to the IDS setup in the ISOLDE hall.

A variety of "expert" courses are available for those required to perform more demanding operations such as those involving cryogenics, using the crane and lasers. Please ensure that you have followed these courses before performing these tasks.

All experimental setups need to pass safety clearance before they can perform experiments. The first step in obtaining this clearance is to fill out the ISIEC form which can be found here. For any additional questions regarding safety of setups please contact the ISOLDE coordinator for further information.

The mechanical workshop in building 508 is fully operational. If you wish to use it a document will need to be provided which is signed by your team-leader, yourself, and our workshop supervisor, authorising you to use the selected machines in the workshop. For more information, please contact your experiment spokesperson, local contact or the coordinator.

The list of contacts for safety both for local experiments and visiting setups can be found via https://isolde.cern/safety.

ISOLDE facility

Emittance Measurements at ISOLDE

Niels Bidault for the ISOLDE Emittance Meter team

Emittance measurements play an important role in beam quality optimization, and a low beam emittance is often critical in high-precision experiments. We measured the emittance of beams produced at ISOLDE to verify that they meet the desired quality requirements in the scope of the PUMA project.

To probe the phase space of low-energy ion beams, two Allison scanners were provided by colleagues from TRIUMF. The main elements of this diagnostic tool are a front slit, two deflecting plates, a rear slit and a Faraday cup. The position density profile of the beam is sliced through the front slit, and the transverse velocity components of the beam are scanned by the rear slit while applying potentials to the deflecting electrodes. The main figures of merit of the Allison scanner are described in [1]. The minimum achievable resolution due to the slits' opening and the general geometry of the detector is 0.03 mm·mrad. The Allison scanners were first installed and commissioned at the Offline 2 facility (page 10), which included the development of required control systems, determination of beam intensity limitations and first test measurements. Subsequently, they were installed at the end of the RC6 beam-line in ISOLDE to measure the typical beam properties, relevant in the context of the PUMA project.

Surface ionized ^{39}K ions with 30 keV beam energy were produced at GPS and delivered to RC6. Excellent beam transmission of about 95% was achieved using the reference setups provided by the ISOLDE machine operators. The total beam intensity in RC6 was limited to 80 nA to maximize the signal-to-noise ratio while avoiding space charge effects. Figure 1 shows the phase space measured for each transverse plane, which are rotated by 45° compared to the horizontal and vertical axes. Emittance values and Twiss parameters were determined for an ellipse of size 1σ, including 39% of the beam particles. RMS errors are estimated

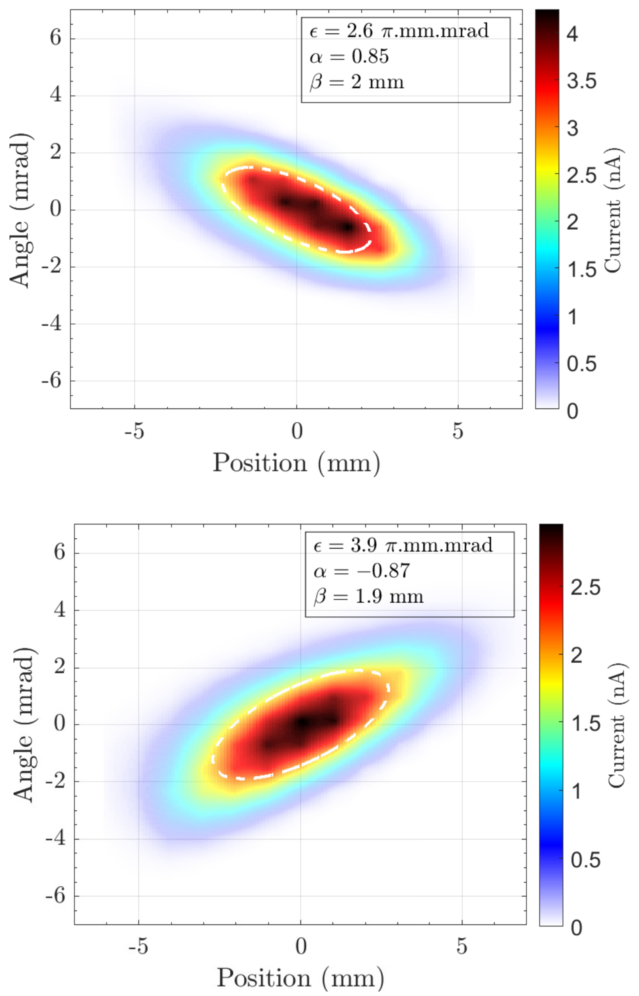

Figure 1: Transverse phase space measured from both emittance meters installed at the end of the RC6 beam-line.

to be ±0.2 mm.mrad. The apparent asymmetry in the transverse beam emittance is to be expected from the multiple deflections to RC6 or points of reduced acceptance during transport. The emittance meters

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are now re-installed at OFFLINE2 to characterise the beams produced from different ion sources.

References

[1] A. Laxdal, *et al.*, *Linac14* pp. 829–833 (2014).

The Offline 2 Facility

Maximilian Schuett, Sebastian Rothe
for the STI RBS section

The Offline 2 mass separator laboratory is part of the CERN-ISOLDE Offline facilities - a suite of installations required to perform essential quality control on target and ion source units before irradiation at CERN-ISOLDE. The facility is also used for extended preparatory offline studies as a prerequisite before conducting any beam development on-line. The Offline 2 separator resembles the on-line CERN-ISOLDE Frontend with respect to beam instrumentation, gas delivery system, laser ionization and the equipment control system. The facility is able to generate DC as well as bunched non-radioactive beams up to an energy of 60 keV. The ion beams can be cooled and bunched in an unmodulated RFQcb.

1 Simulations & RFQ preparations

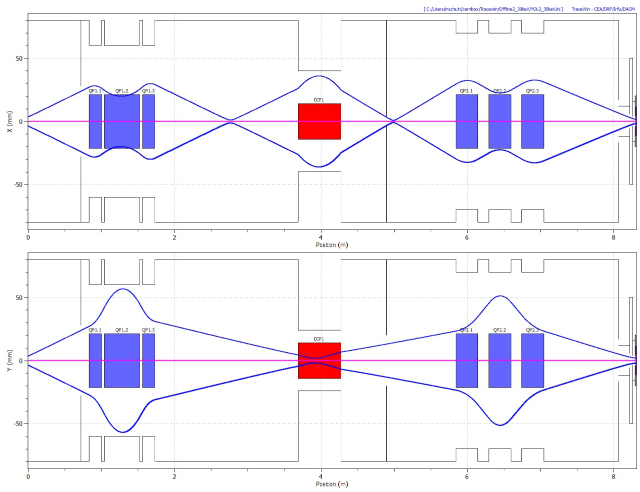

Figure 1: Beamline envelopes in the horizontal and vertical plane of the Offline 2 facility from the ion extraction electrode to the entrance of the RFQ.

In order to find a suitable beam dynamics solution the following constraints have to be considered: To increase mass separation, a slit has been integrated behind the dipole and the RFQ has an entrance aperture of 4 mm. Therefore, the quadrupoles have to be adjusted in both horizontal and vertical planes, to focus the beam into the RFQ. The beamline simulations are calculated with the PIC code Tracewin including space charge (see Fig. 1). The input Twiss parameters have been calculated according to the worst assumption of a beam fitting through the extraction electrode of the ion source being defocused.

For overall beam-simulations including the RFQcb, the 3D fields of the RFQ have been simulated - both DC and RF fields. To transversally confine the ions, the longitudinal DC potential is overlayed with a quadrupol RF field and the ions are gathered at the end of the quadrupole channel. The simulated longitudinal DC field along the beam axis is shown in Fig. 2.

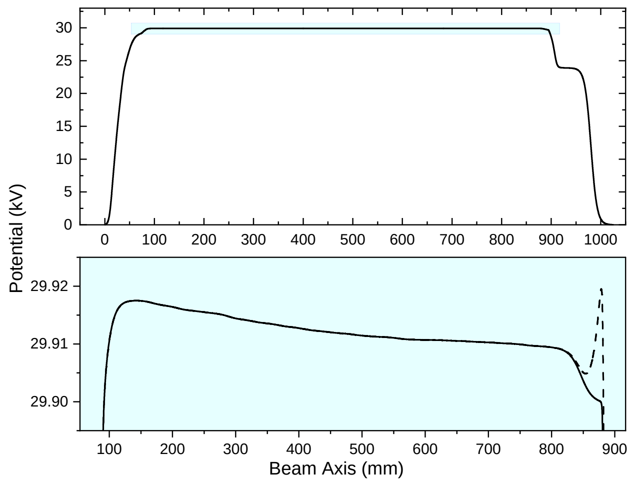

Figure 2: Longitudinal DC potential along the full RFQcb beam axis in transmission mode (solid) and bunching mode (dashed). The graph below shows a zoom on the inner ramped DC field where the RF field is present.

2 Outlook

The next important step for studying molecule formation is the commissioning of the RFQcb and to increase transmission. Downstream from the RFQcb a Wien filter, Einzel lens and detectors have to be installed.

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RIB Applications

Applying β-NMR in biochemistry: ^{47}K and DNA G-quadruplex interaction studies

Results of experiment IS666

Tobias Patrick Treczoks for the BetaDrop NMR Team

The β-NMR beamline at ISOLDE has proven its capabilities in the field of nuclear spectroscopy, enabling measurements with hundredfold increased precision compared to conventional NMR [1]. In 2021 the setup received a number of major upgrades, including a new superconducting 4.7 T magnet and a new data acquisition system. These improvements and achievements paved the way towards novel applications of β-NMR in the field of biochemistry. Hence, studying the interaction of DNA G-quadruplexes with beams of K isotopes, as planned in experiment IS666 [2, 3], was the main objective of the measurements in the past year.

Alkali metals, such as potassium, are considered to be among the most difficult NMR-active nuclei, but their observation can provide new details on the structure and dynamics of these DNA structures [2]. First, different K isotopes were polarised, proving ^{47}K to be the most sensitive isotope for these measurements.

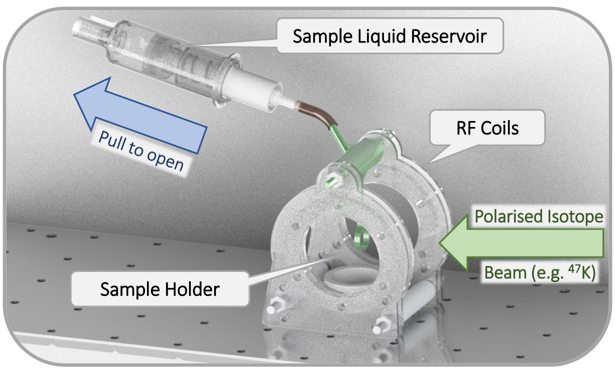

Figure 1: Rendering of the new liquid sample holding system including the sample holder and the sample liquid reservoir, openable from the outside.

To host the biological samples, ionic liquids and deep eutectic solvents, such as EMIM-DCA and Glycholine [4], were used. Despite their low vapor pressure, introducing liquids into a high vacuum setup poses some technical challenges. The molecular tumbling inside the liquid should provide a narrowing of the NMR resonances with respect to solid state samples. However, the first measurements showed a spectral broadening of the resonance peaks over time, due to outgassing of the liquid.

In order to tackle this issue, a new sample holding system was developed. The new system introduced an in-vacuum liquid reservoir, that could be opened from outside the beamline. This design (see Fig. 1) allowed the sample to be refreshed without venting the beamline.

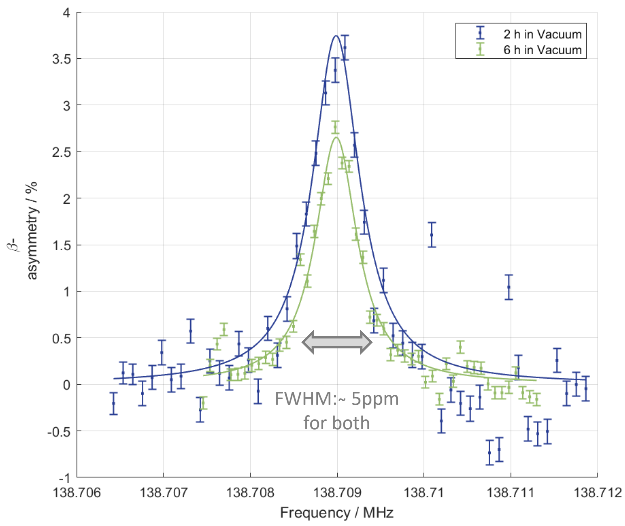

Figure 2: β-NMR resonances of ^{47}K in Glycholine samples over time.

During the beamtime in November 2022 this system was successfully used. With the option to renew the sample when required, measurements were conducted without interruptions even over several shifts. The width of the measured β-NMR resonances stayed consistently small over that time, in the range of 5 ppm as shown in Fig. 2.

In the upcoming year, the team will turn towards new challenges and further applications of our technique. Precise magnetic moment measurements of the ^{11}Be halo nucleus [5] are part of this plan along with β-decay spectroscopy studies of neutron-rich potassium isotopes [6].

References

[1] R. D. Harding, *et al.*, *Physical Review X* **10** (2020).

[2] B. Karg, M. Kowalska, and others, *INTC proposal, CERN-INTC-2020-034 / INTC-P-560* (2020).

[3] B. Karg, M. Kowalska, *INTC proposal, CERN–INTC-2022-001, INTC-P-560-ADD-1* (2022).

[4] K. M. Dziubinska-Kühn, *et al.*, *ChemPhysChem* **23**(10) (2022).

[5] M. Bissell, *et al.*, *INTC proposal, CERN-INTC-2023-014; INTC-P-655* (2023).

[6] M. Piersa-Siłkowska, *et al.*, *INTC proposal, CERN-INTC-2023-026 ; INTC-P-662* (2023).

Production of metastable xenon nuclei for gamma-MRI

Results of IS691

Mateusz Chojnacki and Karolina Kulesz
for CERN gamma-MRI team

Gamma-MRI is a project devoted to developing a new imaging modality based on the detection of asymmetric gamma emission from aligned unstable nuclei, and change of this asymmetry upon RF excitation in a gradient magnetic field. It should pave the way to a new medical imaging modality, capable of overcoming the limitations of existing imaging techniques: MRI, SPECT and PET [1].

The study will use $11/2^-$ isomers of three xenon isotopes: ^{129m}Xe ($T_{1/2}$=8.88 d), ^{131m}Xe ($T_{1/2}$=11.84 d) and ^{133m}Xe ($T_{1/2}$=2.19 d). In 2021, three methods of their production were tested [2].

The first method allows to produce ^{129m}Xe and ^{131m}Xe via neutron irradiation of stable xenon isotopes ^{128}Xe and ^{130}Xe enclosed in quartz ampoules inside a reactor core. In 2021, the irradiation took place at the ILL reactor in Grenoble (the strongest thermal neutron flux in the world: $1 \cdot 10^{15}$ n/s·cm^2). The quartz ampoules prepared at ISOLDE were irradiated for 7 days. After returning to CERN, they were opened and transferred to transport vials in a specially prepared setup (Fig. 1) by using an LN_2 trap. Gamma spectroscopy before and after the procedure showed that the transfer efficiency was 84% (the final activities: 170-240 MBq). As the ILL reactor will shut in 2022, the irradiation are now planned at the Maria reactor in Poland, which has the second strongest thermal neutron flux in the world ($2 \cdot 10^{14}$n/s·cm^2).

The second method is based on production from UC_x target and plasma ionization at ISOLDE. This method access to be produced all three ^{m}Xe isotopes. In 2021, we tested online production at GPS (with proton on the target) and offline production (the target was irradiated behind the regular HRS target a few days prior to being placed at the GPS position). The ^{m}Xe isotopes were implanted in gold foils at the GLM collection chamber, extracted after heating the foils to 300-400^{o}C, and collected in transport vials. Gamma spectroscopy of implanted gold foils showed that all three Xe isomers are produced in both modes. However, the extraction in offline mode provides less intensity. The ratios of activities produced for online and offline mode are: 30 for ^{129m}Xe, 40 for ^{131m}Xe and 2 for ^{133m}Xe.

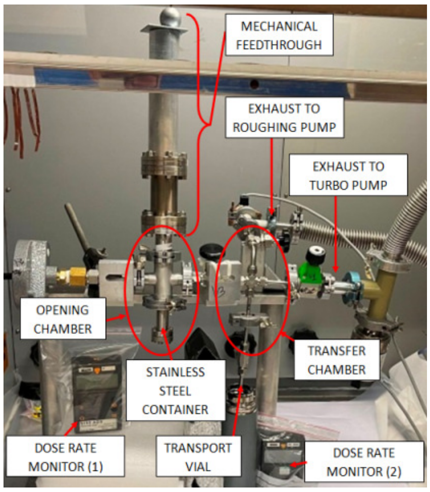

Figure 1: The setup for opening quartz tubes with ^{129m}Xe, ^{131m}Xe .

The last method of production uses ^{131}I ($T_{1/2}$=8 d) which decays to ^{131m}Xe (branching ratio: 0.39%). In 2021, a sodium iodine powder (NaI) was used as a source of ^{131}I, commonly used in nuclear medicine. ^{131}I was decaying to ^{131m}Xe for several days inside a specially prepared setup, then ^{131m}Xe was extracted from the powder by heating it to 100-200^{o}C. Up to 100 kBq were obtained from 50 MBq of ^{131}I. For the GBq sample of ^{131}I, several MBq of ^{131m}Xe should be reached. The main disadvantage of this method of production that during the heating process gaseous chemical contaminants are produced from NaI powder excipitiens (useful in therapeutic applications).

https://gamma-mri.eu/

References

[1] Y. Zheng, et al., *Nature (537), 652 (2016)* .

[2] K.Kulesz, M.Kowalska, *CERN-INTC-2021-019, INTC-P-597* .

Structural formation yield of Ge*V* centers from implanted Ge in 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 [1]. In the case of Ge*V*, the larger orbital ground state splitting would allow for operation at maximum temperatures 0.4-8 K, compared to 0.1-2 K for Si*V*. However, the reliable and reproducible fabrication of Ge*V* defects has remained a key challenge for practical development of Ge*V*-based devices. In that respect, the formation yield of *optically active* Ge*V* following ion implantation was reported to be as low as 0.4-0.7% [2], considerably lower than for Si or Sn (∼2.5%).

We investigated the lattice sites of ^{75}Ge ($t_{1/2}$=83 min) as a function of implantation (T_i) and annealing temperature (T_a) in single-crystalline CVD diamond. ^{75}Ge was introduced as a decay product of 30 keV-ion implanted short-lived ^{75}Ga (126 s). Two samples were studied: a) higher fluence (∼2x10^{13} cm^{-2} per implantation step), studied with 3 different beam spots for T_i= RT, 300℃, 600℃ and T_a= 300℃, 600℃, 900℃, and b) lower fluence (∼2x10^{12} cm^{-2} per step), with a single beam spot as function of T_i= RT, 300℃, 600℃, and 900℃. The results (Figure 1) show the majority of Ge on substitutional sites following RT implantation, with only a fraction of ∼23% on BC sites, evidencing a lower *structural* formation efficiency of the Ge*V* complex in comparison to other foreign atoms, e.g. Sn, Mg or Xe. Moreover, following annealing or implantation at high temperatures, the BC fraction decreased further to 6-9%. No major difference was found between the higher- and lower-fluence samples.

The major conclusions of the study are that Ge*V* forms directly during RT implantation, hence no annealing is required for its creation. On the contrary, increasing temperature seems to transform Ge*V* into substitutional Ge, indicating that Ge*V* is thermally unstable. While the *structural* formation yield of Ge*V* was found to be low, it appears a factor of ∼10 higher than its *optically active* formation yield. Further investigations will center on low-temperature implantation and exploring whether post-implantation creation of vacancies (e.g. by irradiating the sample with other ions) has a beneficial effect on Ge*V* formation.

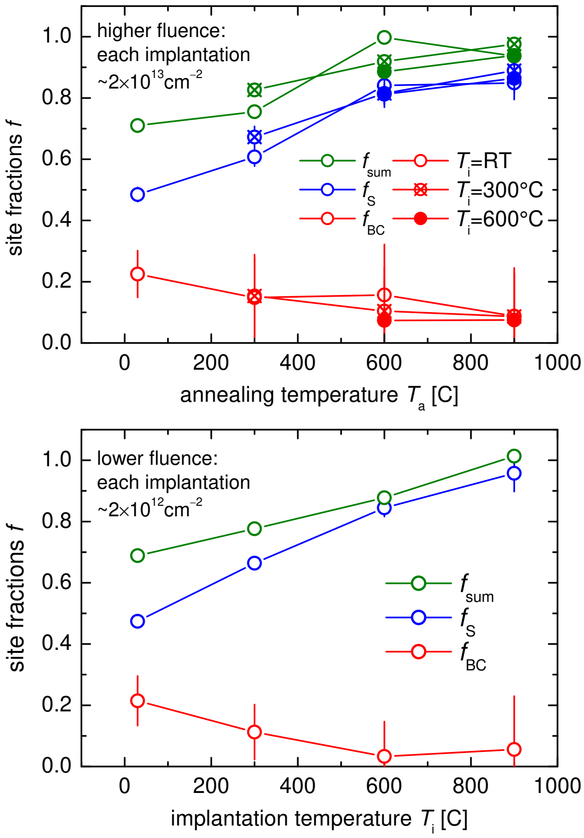

Figure 1: Fitted fractions of ^{75}Ge on S and BC sites and sum of both as functions of annealing temperature (higher-fluence sample, top) and implantation temperature (lower-fluence sample, bottom).

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MULTIPAC - Setup for Perturbed Angular Correlation Experiments in Multiferroic (and Magnetic) Materials

Results of experiment LOI249

Nicole Pereira de Lima, Alexandre Pinho dos Santos Souza for the SSP collaboration

The ISOLDE MULTIPAC setup is a state-of-the-art instrument system installed at CERN in building 275 that consists of a complete spectrometer device designed to measure Time Differential Gamma-gamma Perturbed Angular Correlation (TDPAC). Its design enables scientists to impose variable conditions on the sample environment during measurements, such as temperature and magnetic field. In its initial configurations, the system allows magnetic fields up to 8.5 T and a temperature range between 4 K and 325 K; however, new devices can be purchased to enhance the temperature limit up to 1000 K or even to add new sample measurements characteristics like resistivity or thermal capacity. This unique cryogenic magnetic system also possesses digital TDPAC and software, including digitizers, $LaBr_3$ scintillation crystals, and multi-pixel photon counters. All these characteristics make the MULTIPAC setup a complete system for performing the whole process of creating different environments for studying samples, detecting correlated gamma rays, and analyzing correspondent data [1].

Figure 1: MULTIPAC setup being installed at ISOLDE in November 2022. Photo by Nicole Lima.

At ISOLDE, the TDPAC technique has been used to study hyperfine interactions for more than four decades, resulting in a great number of achievements and correlated publications. Data derived from this technique can give scientists a lot of information about the hyperfine magnetic field and the electric field gradient [2]. In addition, the very local nature of the TDPAC technique allows it to provide important information about the environment around the probe nuclei. Within this information, one can infer different macroscopic characteristics of the sample, such as local magnetism and local symmetry changes, as well as dynamic processes in a certain frequency window due to charge movement or spin fluctuations.

MULTIPAC's contribution to the solid-state physics community is unprecedented. As a result, new research projects and partnerships with ISOLDE-CERN, involving postgraduate students and other researchers from internationally renowned universities and institutions, are expected. For instance, the MULTIPAC team has been able to establish material projects that should present new results of measurements in the near future, e.g., $RMnO_3$ and RMn_2O_5, where R is a rare-earth element such as Ho or Tb.

This project has received funding from the Federal Ministry of Education and Research (BMBF) under grants 05K16PGA, 05K22PGA and 05K22PGB.

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ASPIC News

Results of experiment LOI248

Levy Scalise, Juliana Schell for the SSP collaboration

ASPIC, the Apparatus for Surface and Interface Physics, is a unique tool developed for ISOLDE-CERN. Its objective is to exploit hyperfine techniques in surfaces, thin films, and multilayered systems. This is achieved through the use of Time-Differential Perturbed Angular Correlation Spectroscopy (TDPAC) in an ultra high-vacuum environment (UHV). ASPIC also enables surface preparation and thin film growth to be carried out in situ [1].

ASPIC uses Ultra-Low Energy (ULE) Ion Implantation for precise surface modification. Ions are slowed down to 20 eV before impact, coming to rest in the first few monolayers and eliminating the need for post-implantation annealing. This minimizes the energy deposited and defect creation, leaving structures pristine. The ability to freely select the implantation energy opens new avenues for surface and 2D material studies.

When the results obtained by the TDPAC technique are complemented with ab initio simulations and conventional characterization methods, local phenomena at the surface and interface of materials can be explored and unique information can be obtained [2].

ASPIC has recently undergone an upgrade of its experimental capabilities with the introduction of the ASCII chamber. Like the original ASPIC chamber, it is maintained at ultra-high vacuum ($\leq 10^{-9}$ mbar). It has three main components: the deflector plates near the ion beam inlet, the deceleration stage, and the sample manipulator [3].

The upgrade provided by the German Federal Ministry of Education and Research has expanded the experimental capabilites of ASPIC, enabling research into hyperfine techniques across various systems. ISOLDE's pioneering work in surface and interface physics shows great potential for the future [4].

The authors would like to acknowledge the Federal Ministry of Education and Research (BMBF), which supported this project with grants 05K19MG1, 05K16PGA, and 05K22PGA.

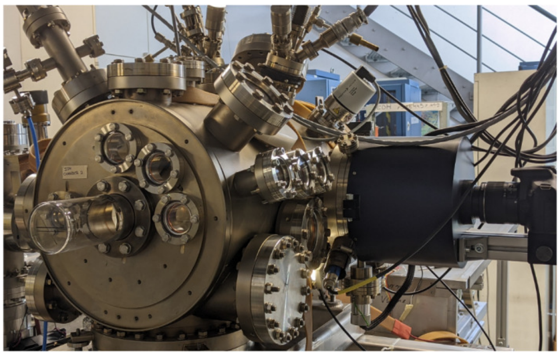

Figure 1: The ASPIC setup, being upgraded at the Georg-August-University Göttingen. The main body of the chamber has a diameter of around 330 mm (i.e., DN275), and depth of 600 mm. Source: [3].

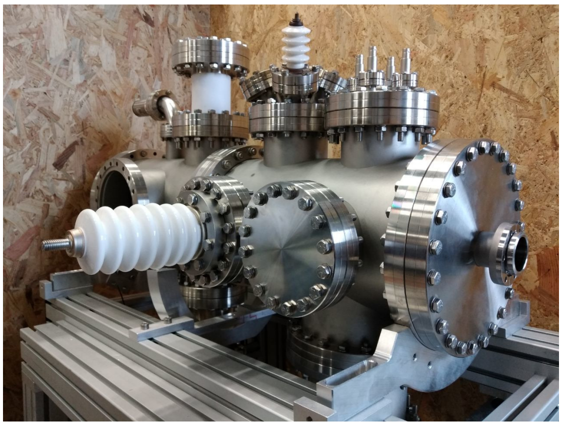

Figure 2: The ASCII chamber, now at ISOLDE-CERN, being prepared for installation. Photo taken in February 2023. Source: the authors.

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Ground-state properties

First spectroscopy of AcF during winter physics at CRIS

Results of experiment IS706

Michail Athanasakis-Kaklamanakis
for the CRIS collaboration

The spectroscopy of radioactive molecules has received a lot of attention as an avenue for precision tests of the Standard Model (SM) [1]. High-precision spectroscopic experiments search for tiny signatures in molecular spectra that stem from electronic and nuclear moments that violate *CPT* symmetries at levels beyond the predictions of the SM [2]. The sensitivity to these moments is maximized in molecules containing heavy and deformed nuclei, which tend to be radioactive.

Because of the complications that radioactivity introduces, most radioactive molecules proposed for such precision tests have never been studied experimentally. The CRIS collaboration at ISOLDE performed the first experimental study of RaF in the past years [3], which has received a lot of theoretical attention for its sensitivity to the electric dipole moment of the electron and nuclear-spin-dependent parity violation [4].

In 2022, as part of nuclear- and atomic-structure experiments on Al, Ag, and U^-, the CRIS collaboration continued its activities on radioactive molecules with the first laser spectroscopy of ^{227}AcF, following the official end of protons at CERN. Actinium monofluoride has been identified for its sensitivity to the nuclear Schiff moment of the Ac nucleus [5], which emerges as a result of strong *CP* violation and whose measurement would thus probe the limits of the SM [2]. As all actinium nuclei are radioactive, with ^{227}Ac having the longest half-life of just 21.8 years, experiments at radioactive facilities like ISOLDE are needed even for the first spectroscopy to identify its electronic levels.

Ab initio calculations of AcF predicted a rich electronic structure. Guided by the predictions, the CRIS team deployed a total of 14 continuous-wave and pulsed lasers, covering a range of 350-950 nm, to search for all states.

Despite an unexpected source of spectroscopic background that complicated the search for electronic states, CRIS successfully recorded the first known laser resonance in AcF, within just 350 cm^{-1} from the corresponding prediction. A spectrum of the vibrational substructure of this electronic transition is shown in Fig. 1. As this transition preserves the sensitivity to the nuclear Schiff moment that theory suggests, the CRIS experiment is a first step towards future precision tests of the SM using AcF. The help of the ISOLDE technical teams is gratefully acknowledged in this project.

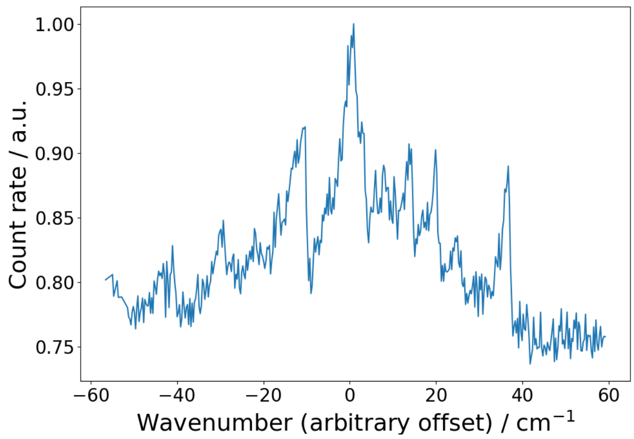

Figure 1: First optical spectrum of vibrational-electronic transitions in AcF, measured with CRIS in 2022. Results are preliminary.

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Mass measurements in 2022 and a new Mini-RFQ buncher for beam purification

Daniel Lange, Lukas Nies and Christoph Schweiger
for the ISOLTRAP collaboration

The ISOLTRAP [1] mass spectrometer performs high-precision mass measurements on radioactive ions at ISOLDE/CERN, which are used to determine the atomic mass of radioactive nuclei. This mass is unique to each isotope and reflects the masses of the constituents as well as the forces binding them together. These measurements contribute to our understanding of nuclear structure, nuclear astrophysics, neutrino physics, and weak interaction studies.

ISOLTRAP uses various ion traps, including a tandem Penning-trap system and a Multi-Reflection Time-of-Flight mass spectrometer (MR-ToF MS). The latter is suitable for both mass separation and fast precise mass measurement. With the implementation of mass-selective ion ejection from the MR-ToF via the pulsed in-trap lift [2] and active voltage stabilization for the mirror electrodes [3], isobaric mass separation with a resolving power of up to $5 \cdot 10^5$ was recently achieved [4].

In July 2022, neutron-rich zinc beams were delivered by a target with a quartz transfer line for the suppression of isobaric contamination [5]. Using the MR-ToF MS, yields were measured out to ^{82}Zn. Following up past ISOLDE results from a transfer-reaction [6] and laser-spectroscopy [7] on ^{79}Zn, the $9/2^+$ ground state and $1/2^+$ isomeric state were well separated in the device, enabling a direct excitation-energy measurement. A time-of-flight spectrum of the clean $A = 79$ beam is shown in Fig. 1. This precision result now enables the investigation of possible shape coexistence in ^{79}Zn using large-scale shell model calculations.

However, for most rare isotopes, precision measurements are impeded due to low production cross-sections and, especially, isobaric and molecular contamination (see Fig. 2(b) and Fig. 2(c)).

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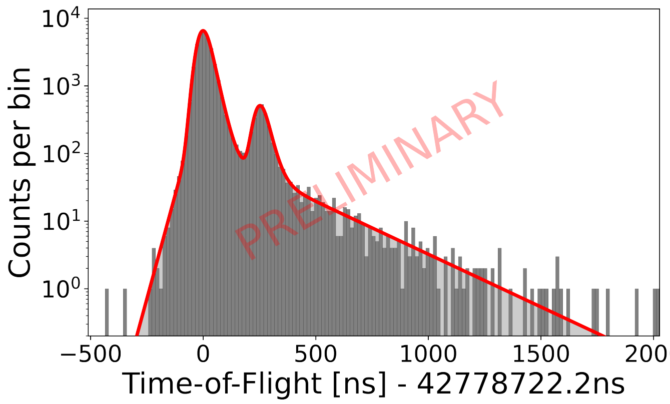

Figure 1: Time-of-flight spectrum for the $A = 79$ ISOLDE beam from a UC_x target with quartz transfer line and laser ionization tuned for zinc. The ground (left) and isomeric (right) states are well separated.

This was observed, for example, during the measurements of neutron-deficient tin isotopes in September 2022. There, the tin yields were dropping quickly toward the proton drip line while the production of the contaminating strontium-fluoride (SrF) molecules remained nearly constant. While the measurement of ^{103}Sn was performed in a short amount of time, the observation of ^{102}Sn and ^{101}Sn was impossible due to the strong tailing of the SrF contamination (see Fig. 2(c)).

Unfortunately, purification by quartz transfer line is limited to only a few cases. To handle strong contamination more generally, a new radio-frequency quadrupole (RFQ) cooler and buncher will be implemented for beam purification following the MR-ToF device. The new Mini-RFQ buncher, designed by MIRACLS [8], will be used to perform mass-selective re-trapping [9] and re-bunching of the ions of interest from the isobarically separated bunch ejected from the MR-ToF MS. By re-trapping in the Mini-RFQ, a contamination suppression up to 10^{-4} is expected [10]. Additionally, tuning the injection energy of the beam into the Mini-RFQ will allow the study of collision-induced dissociation (CID) of isobaric molecular contamination.

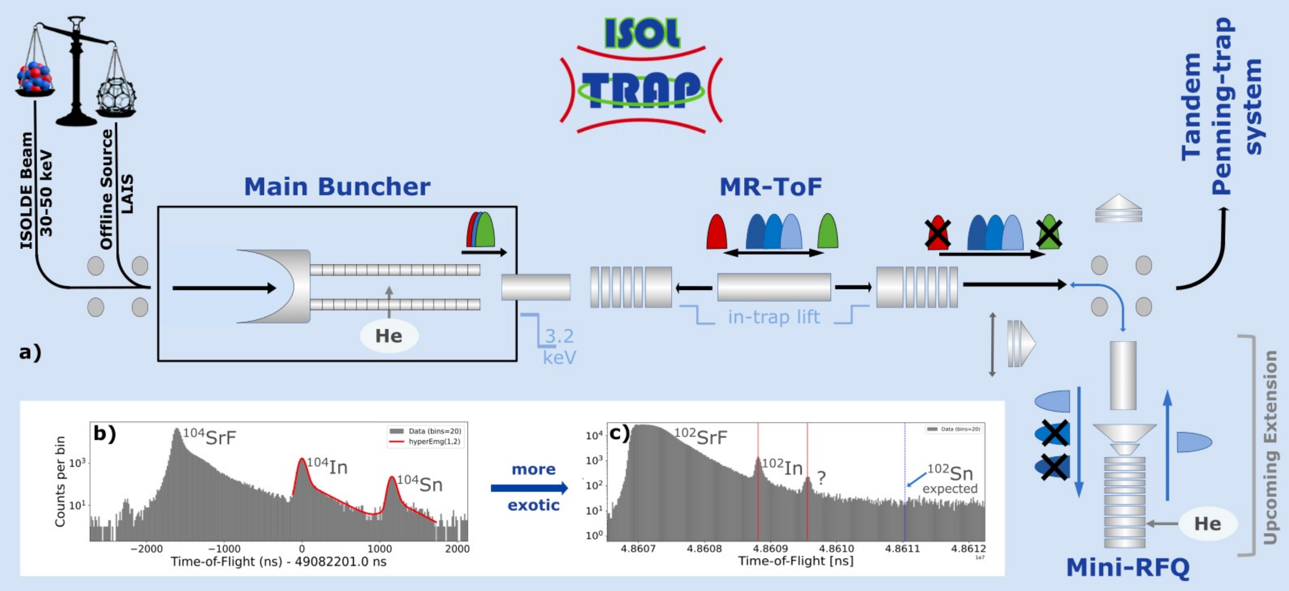

Figure 2: A schematic of the current setup of ISOLTRAP is displayed in (a) together with the upcoming extension by the Mini-RFQ. Inset (b) presents the ToF spectrum of the isobaric mass separation at A = 104, where the tails of each mass peak are clearly visible. Inset (c) displays the ToF spectrum of more exotic neutron-deficient ^{102}Sn, where tails of contamination such as SrF impede the mass measurements.

With this, the transmission of molecular contamination can be reduced by a factor up to 10^2 [11]. After re-trapping in the Mini-RFQ, the ions will be re-injected in the MR-ToF device, providing mass measurements free of space-charge effects.

In addition to these developments, temperature and pressure sensors as well as flux-gate magnetometers will be installed to monitor slow drifts of environmental influences and systematic studies for the MR-ToF MS and Penning traps will be performed with carbon clusters produced by the laser-ablation ion-source (LIAS), successfully implemented in 2022 [12].

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Laser spectroscopy of neutron-rich tellurium isotopes

Results of experiment IS667

Tim E. Lellinger for the COLLAPS collaboration

Following the successful measurements of magic lead isotopes in 2021, the COLLAPS experiment continued on from previous investigations in the tin region by measuring neutron rich tellurium isotopes in May 2022. In total, 25 tellurium isotopes (^{112}Te - ^{136}Te) and eight isomers were probed by high resolution laser spectroscopy. The isomers are of particular interest due to the unique parity character of the $h_{11/2}$ orbital expected to give rise to their nuclear structure. In the shell-model framework, the configuration of these states comprises a proton core ($Z = 50$) with two additional protons on top and the neutrons filling this unique-parity orbital. A direct comparison of the extracted moments with those previously measured at COLLAPS along the isotopic chains of tin and cadmium [1, 2] allows a direct test of the robustness of the $Z = 50$ core while quantifying the polarizing effect on the quadruple moments of the two additional protons in tellurium.

On the neutron rich side, the tellurium isotopes were produced by bombarding a neutron converter with protons from the CERN PSB. Through spallation processes the converter then produced fast neutrons that impinged a uranium carbide target. The neutron converter is usually a tungsten rod below the target container, but during our experiment it was found that the copper current connectors of the target also work as a spallation source, although with some loss in efficiency [3]. For the neutron deficient isotopes, the uranium carbide was directly bombarded with protons. In both cases the produced tellurium atoms were ionized using the resonance ionization laser ion source (RILIS), and subsequently bunched and cooled with the ISOLDE cooler-buncher (ISCOOL). At the COLLAPS experiment the ion beam was neutralized in a potassium vapor cell, and the spectroscopy was performed on the $5p^4\,{}^3P_2 \rightarrow 5p^3\,6s\,{}^3S_1$ atomic transition, which offered the best sensitivity to the nuclear moments, but was technically challenging due to its short wavelength of 214 nm. To keep the experimental conditions stable for the entire measurement period, an active beam stabilization system was deployed for the first time.

From the recorded spectra (see e.g. the spectrum of ^{119}Te in Fig. 1) isotope shifts, isomer shifts and the hyperfine parameters A and B were extracted, which then allowed the determination of differential mean-square charge radii, magnetic dipole, and electric quadrupole moments. While common patterns are perceived, the trends of the isomeric nuclear moments in particular defy the expected simple model picture and pose a challenge for microscopic nuclear theory.

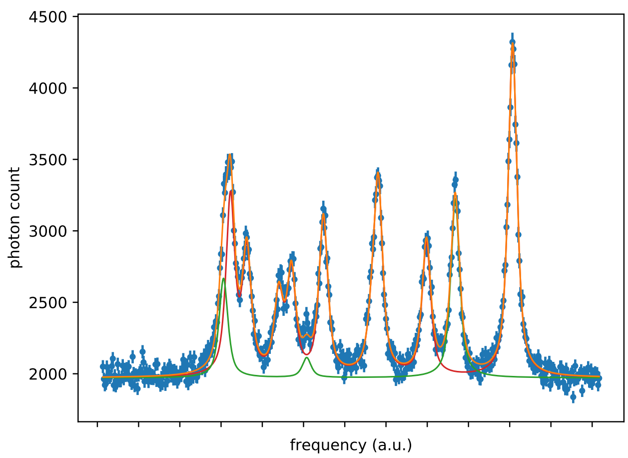

Figure 1: Spectrum of ^{119}Te. The fit for the $1/2^+$ ground state is depicted in green, the $11/2^-$ isomer is shown in red. The nuclear properties of the isomer were measured for the first time.

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https://collaps.web.cern.ch/

Beta-decay studies

ISOLDE Decay Station++

James Cubiss, for the ISOLDE Decay Station collaboration

The university of York (U.K) has led a collaborative effort between the University of Liverpool (U.K.), University of Warsaw (Poland), IFIN-HH (Romania), Universidad Complutense de Madrid (Spain), Instituto de Fisica Corpuscular (Spain), the University of the Western Cape (South Africa), and the University of Tennessee, Knoxville (U.S.) to design and construct a new support structure for the detector system of the ISOLDE Decay Station (IDS). The parts from the different workshops were collected in York, assembled, and then shipped to ISOLDE where initial tests of the new system with germanium clover detectors have been successfully conducted (see Fig. 1).

With phase one of the upgrade finished, the new structure is now ready to be positioned and aligned in time for the 2023 campaign, following repairs to the floor in the IDS area of the ISOLDE Hall[1]. The current system allows the use of up to six germanium detectors in combination with the existing IDS auxiliary detection systems and tape station. Work has already commenced on phase 2 of the upgrade, which will allow up to fifteen clover detectors to be used at once, with the aim of completing the project by the end of the year.

The final support structure will consist of five "gantries", upon which up to three clover detectors (fifteen clovers in total) can be mounted in vertical alignment. The gantries are mounted on circular rails centred on the IDS tape station, allowing for easy positioning of the clover detectors around the implantation position.

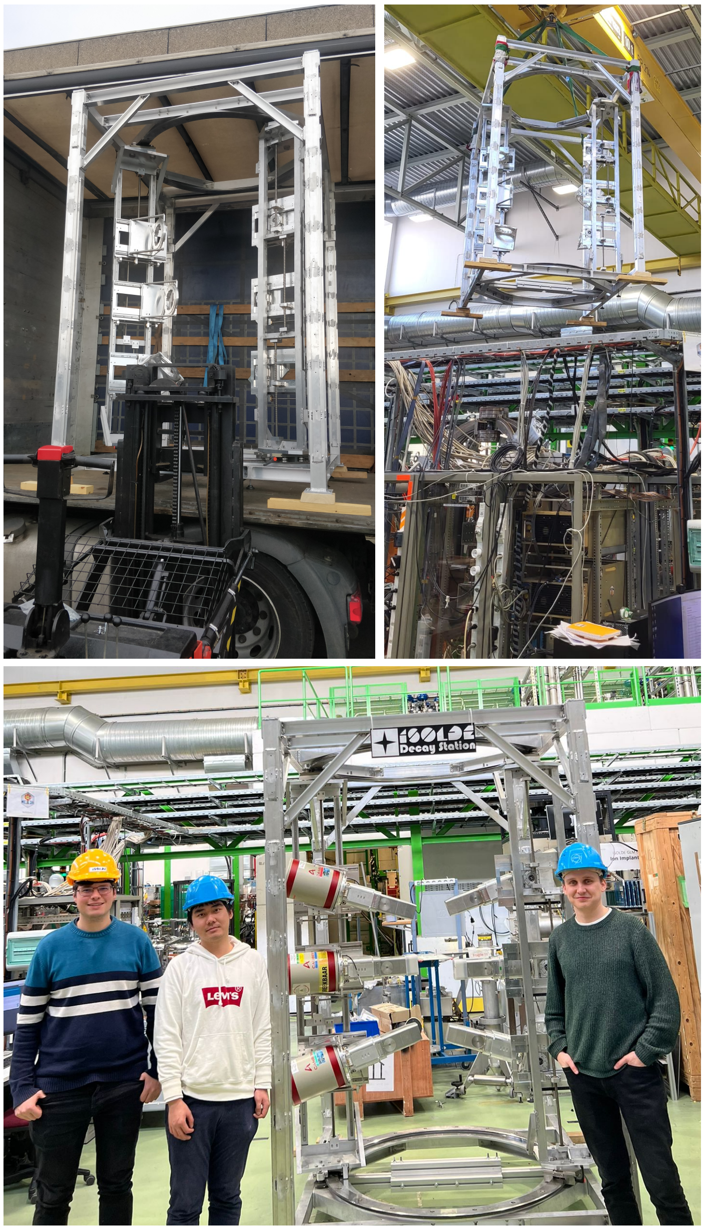

Figure 1: Top-Left: The new support structure with two detector "gantries" being loaded onto a truck at York; Top-Right: The structure gives HIE-ISOLDE a flyby; Bottom: The new structure with six clover detectors mounted, and a happy York IDS team looking forward to the 2023 campaign.

https://isolde-ids.web.cern.ch/

[1] The collaboration would like to take this opportunity to apologise for the bad smell in the hall caused by these repair works.

When mounted, each clover detector will be translatable in both vertical and radial directions relative to the implantation point, as well as the ability to tilt in the vertical direction and rotate upon their long axis. The new design provides excellent flexibility for arranging the IDS germanium array, and opens up opportunities for expanding ancillary detection systems such as those for fast timing and neutron time-of-flight measurements, as well as a secondary measurement position between the implantation position and the tape station for studying long-lived decays, the work for which is currently under way.

News from WISArD: on the way to the next experiment

Jeongsu Ha for the WISArD collaboration

Weak interaction, one of the four fundamental interactions in nature, is responsible for β decay of unstable nuclei. Since the discovery of the maximal parity violation of ^{60}Co β decay in Wu's experiment [1], the vector-axial vector ($V-A$) theory has hitherto explained the phenomena of weak interaction. However, Lorentz symmetry allows not only the specific form of the vector and axial-vector currents but also scalar and tensor ones [2]. The WISArD collaboration has prepared an experiment, dedicated to searching for such an exotic current, which has not been observed yet. In the experiment, the β-ν angular correlation, which relates to the amplitude of the exotic current, is deduced from the kinetic energy shift of protons emitted following the ^{32}Ar β decay.

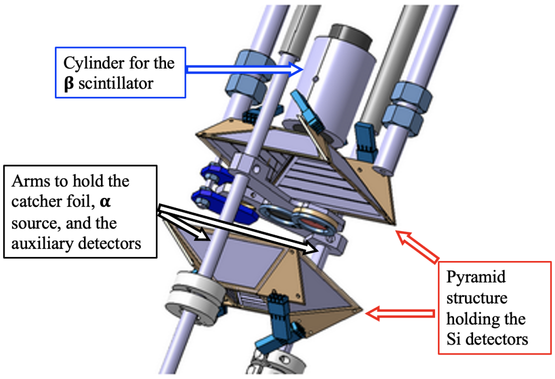

Figure 1: The new detector assembly for the next WISArD experiment [3].

After the proof-of-principle experiment conducted in November 2018 [4], the collaboration has focused on improving the experiment by decreasing systematic uncertainty and increasing statistics. First, to increase the detection efficiency of β-delayed protons, the disk-shaped silicon detectors have been replaced with tailor-made ones, which surround the catcher centered on the beamline. Figure 1 shows the pyramid-shaped structure, mounted with the new silicon detectors. The resolution of the new detection system was verified with a proton beam with energy of up to 2 MeV to be of the order of 10 keV [3]. Second, the new β detector has been made for detecting low-energy signals. The plastic scintillator for the detection of β particles, guided by the magnetic field, is coupled to a 3x3 array of silicon photomultipliers. The dual gain mode allows to measure the full β spectrum and determine the detection threshold with a precision of a few keV. In parallel with the detector setup, further studies for ion-beam transportation show the possibility of a significant improvement in transportation efficiency.

A test performed in October 2021 verified this setup's capabilities for the upcoming experiment. As an example, the singles and β-coincident proton energy spectra measured by one of the strips in the upper and the lower hemispheres are displayed in Fig. 2. We can confirm that the new measurement can attain the expected per-mil precision on the β-ν angular correlation parameter. The data taking is foreseen in fall 2023.

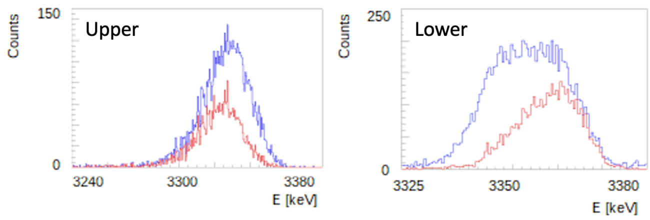

Figure 2: The proton spectra of the isobaric analogous state for singles (blue) and β-coincident (red) events obtained from one of the strips in both hemispheres [5]. A shift of the β-coincident proton peak with respect to the singles one (opposite for the upper and lower detector) is clearly seen.

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Beta decay of ^{64}Ge measured with TAS

Results of experiment IS570

S. Parra, E. Nacher, J.A. Briz
for the ISOLDE-TAS collaboration

Nucleosynthesis in explosive hydrogen burning at high temperatures (T $> 10^8$ K) is characterized mainly by the rapid proton capture rp-process. One of the possible sites for the rp-process are Type I X-ray bursts (XRBs). Several N=Z nuclei, such as ^{64}Ge, act as waiting points in the nuclear flow. The beta decays of these waiting points are needed in theoretical modelling for astrophysical calculations of XRBs light curves. Several such theoretical calculations have shown that, in the conditions of XBRs, continuum electron capture and decay rates from excited states play an important role, in particular for nuclear species at and around the waiting-point nuclei.

In the experiment IS570 we applied the Total Absorption Spectroscopy (TAS) technique to measure the beta decay of $^{64-66}$Ge and their daughters $^{64-66}$Ga, with the main goal of determining the B(GT) distribution for these decays. Comparing the experimental data with the available evaluated data, the most noticeable difference that can be seen lies in the region 1800 to 3000 keV as it can be seen in Fig. 1. This difference emerges from unknown levels in the evaluated ENSDF data [1].

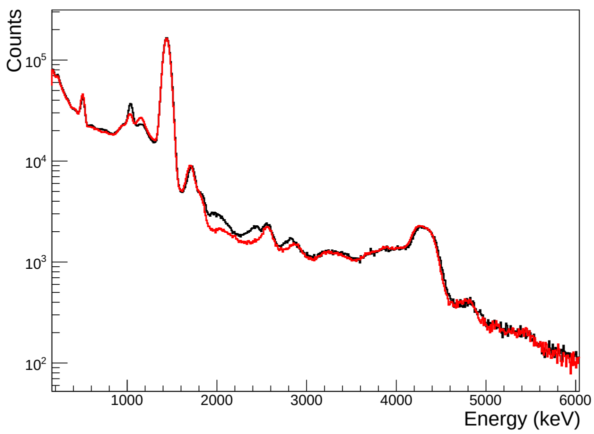

Figure 1: Comparison between measurement, in black, and simulation with background and daughter contributions included, in red, for the ^{64}Ge. Noticeable differences are found around 1000 keV and 1800-3000 keV.

Preliminary results of ^{64}Ge B(GT) show a good agreement with ENSDF data except for the ground state and the region above the last known level (817 keV), as seen in Fig. 2. The B(GT) from our TAS data is approximately 3 times bigger than the B(GT) from ENSDF.

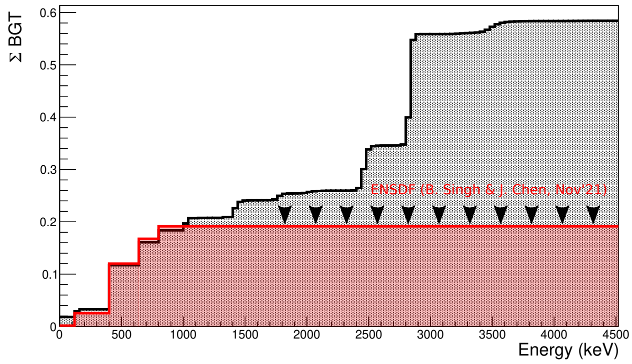

Figure 2: B(GT) measured in the decay of ^{64}Ge, in red the B(GT) from ENSDF data and in black the TAS data.

The new TAS results account for the missing beta strength above the last level measured in beta decay at 817 keV. These new results are very relevant for astrophysical calculations along the rp-path and for constraining the theoretical models used in this region [2].

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Studies with post-accelerated beams

Single-neutron Transfer Reaction on ^{68}Ni

Results of experiment IS587

Andreas Ceulemans, Oleksii Poleshchuk and Riccardo Raabe for the ISS collaboration

The neutron-rich nickel isotopes and their surrounding region form an interesting subject for nuclear structure studies. Corresponding to the magic proton number Z=28, there have been substantial investigations into the exotic doubly-magic ^{78}Ni [1]. Slightly less exotic, the region around N=40 below ^{68}Ni is characterised by a large amount of collectivity [2].

^{68}Ni has been the subject of debate regarding its possibly doubly-magic status. It displays some doubly-magic characteristics, such as high first 2^+ energy and low B(E2), whereas the measured two-neutron separation energy opposes its magic nature [3]. Going lower in the nuclear chart, the degree of collectivity increases [4], with ^{66}Fe and ^{64}Cr having deformed ground states. In explaining this collectivity the location of the $\nu 2d_{5/2}$ orbital plays an important role as input for shell model calculations. However, this orbital has not been experimentally observed yet in the neutron-rich nickel isotopes.

For this reason, a single-neutron transfer reaction measurement on ^{68}Ni was proposed. Experiment IS587, performing the ^{68}Ni(d,p)^{69}Ni reaction in inverse kinematics, was conducted in November 2022. For this reaction, ^{68}Ni ions were accelerated to an energy of 6 MeV/u and fired onto a deuterated polyethylene target. Single-neutron transfer populates states in ^{69}Ni that exhibit a single-neutron character outside the ^{68}Ni core. The dependence of the angular distribution on the L-transfer allows us to assign spin and parity for the observed energy levels.

This study aims to improve on the results of a similar experiment held at GANIL [5] and extend the knowledge of the single-particle states further to the neutron-rich side compared to the previous experiment measuring the ^{66}Ni(d,p)^{67}Ni reaction [6]. The IS587 experiment was performed at ISOLDE using the Isolde Solenoidal Spectrometer (ISS). ISS uses a magnetic field to detect the outgoing protons without the kinematic compression effect that usually affects measurements in inverse kinematics, resulting in an improved energy resolution. In addition, the ISS setup is also able to detect heavy recoils using a gas-based detector.

A preliminary excitation energy spectrum is shown in figure 1. A number of (new) energy levels have been discovered in ^{69}Ni and a possible candidate for the $\nu 2d_{5/2}$ has been identified at an excitation energy of ~2.5 MeV. Further analysis of the experimental data is ongoing.

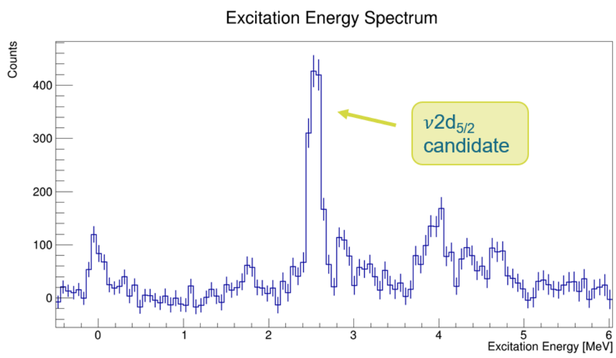

Figure 1: Preliminary energy spectrum of ^{69}Ni (background subtracted). The candidate peak corresponding to the $\nu 2d_{5/2}$ orbital has been indicated.

https://isolde.cern/experiments/isolde-solenoidal-spectrometer-iss

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Characterisation of the SpecMAT active target in the 2.5T ISS solenoid

Oleksii Poleshchuk, Andreas Ceulemans and Riccardo Raabe for the SpecMAT and ISS collaborations

Figure 1: The SpecMAT active target at ISOLDE.

SpecMAT is a detector that combines active target technology [1, 2] with a scintillation spectrometer for transfer reaction studies. The active target of the detector is used for snapping 3-dimensional tracks of the light reaction ejectiles, while the array of scintillation detectors is used for γ-ray spectroscopy of the γ-rays emitted by heavy nuclei produced in the reactions. The detector was designed for operation in a strong magnetic field. Charged particles are identified as they traverse the gas volume, based on the curvature of their tracks and the specific energy loss. Additionally, the total energy and emission angles are measured and used in the reconstruction of the reaction kinematics. The active target has a much larger total thickness compared to thin solid foils used in reaction studies in inverse kinematics. Combined with high efficiency, this allows for the study of exotic nuclei with low production yields or via reactions with small cross sections. The $CeBr_3$ detectors used in the scintillation array maintain good γ-ray energy resolution while operating in a magnetic field. The γ-rays recorded in coincidence with charged particles can help to identify and separate states populated in nuclei of interest. Also, γ-rays can be used for the extraction of angular distributions [3] or identification of half-lives of the states populated in nuclei [4].

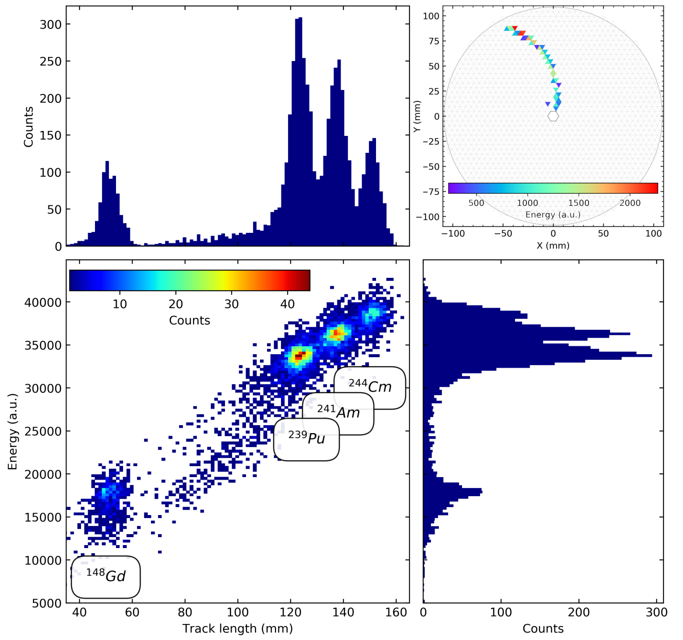

Figure 2: Spectra of α-particles emitted by a quadruple α source based on the length of spiral tracks and the amount of ionisation electrons generated by the particles along the tracks (energy). An example of an α-particle track recorded in a 2.5T magnetic field is shown in the top right panel.

The performance of the detector in a magnetic field was characterised at ISOLDE in the superconducting magnet of the ISOLDE Solenoidal Spectrometer (ISS). The detector installed in the ISS solenoid is shown in Fig. 1. The detector was characterised offline, with a measurement of the α-decay of ^{148}Gd, ^{239}Pu, ^{241}Am and ^{244}Cm isotopes. Obtained α-particle spectra from the spiral tracks (see Fig. 2) are similar to those obtained during the characterisation of the detector without a magnetic field [4]. The resolution of the length-based spectrum is $\sim$ 190 keV at $\sim$ 5.5 MeV. This characterisation showed that the detector can operate in a strong magnetic field and is ready for its first online experimental campaign.

https://isolde-solenoidal-spectrometer.web.cern.ch/specmat

Acknowledgements

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013) / ERC Grant Agreement n. 617156.

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Measurement of the ^{7}Be(d,^{3}He)^{6}Li* reaction at 5 MeV/u

Results of experiment IS554

Sk Mustak Ali, Kabita Kundalia, Dhruba Gupta
for the IS554 collaboration

The *cosmological lithium problem* [1, 2] delineates an anomaly in the abundance of ^{7}Li, where the BBN theory overestimates the abundance by $3-4$ times compared to observations. A more severe anomaly for ^{6}Li also exists, where the BBN predictions underestimate the observed abundance by a factor of ~ 1000 [3]. The ^{6}Li abundance in metal-poor halo stars exhibits a plateau as a function of metallicity [4] similar to ^{7}Li, suggesting a primordial origin. Though some of the ^{6}Li abundances have been questioned, there are also a few metal-poor stars where a significant excess of ^{6}Li has been verified [3]. Considerable efforts were given to solve the lithium problems through nuclear physics, astrophysics or new physics [1]. Recent experiments studied the destruction of ^{7}Be through the $^7\mathrm{Be} + d \rightarrow p + \alpha + \alpha$ reaction [5], considering even contributions of higher excited states of ^{8}Be [6]. However, the extent of the ^{7}Li anomaly could not be explained.

The reaction ^{7}Be(d,^{3}He)^{6}Li may impact both the lithium anomalies, producing ^{6}Li and destroying ^{7}Be. Till date, there is only a single experiment measuring this reaction at E_{cm} = 4.0 and 6.7 MeV [7]. However, the authors relied only on Monte Carlo simulation gates to select the reaction products ^{3}He and ^{6}Li. No kinematical signatures were shown to verify that the selected particles are indeed from the above reaction, thus requiring further experimental investigation.

The present experiment [6] was carried out at HIE-ISOLDE with a 5 MeV/u ^{7}Be beam incident on a CD_2 target. An array of Silicon detectors, in the Scattering Experiment Chamber detected the charged particles emitted from the reaction. The ^{3}He and ^{6}Li from ^{7}Be(d,^{3}He)^{6}Li are detected in coincidence at the forward annular detector ($8^\circ - 25^\circ$). Energy correlation gates from Monte Carlo simulations of the reaction were applied to filter the events of interest. For ^{3}He detected $\sim 50^\circ$, the corresponding ^{6}Li is detected at the forward angles. Fig. 1 shows clear kinematic signatures of ^{3}He and ^{6}Li from ^{7}Be(d,^{3}He)^{6}Li. Another ^{3}He band could be seen, corresponding to the 2.186 MeV (3^+) state of ^{6}Li. The ^{6}Li breakup threshold being 1.474 MeV, it breaks up into α and d. Thus, triple coincidence resulted in a clear separation of the ^{3}He band corresponding to ^{6}Li*. Further analysis is in progress to generate the excitation function and angular distributions.

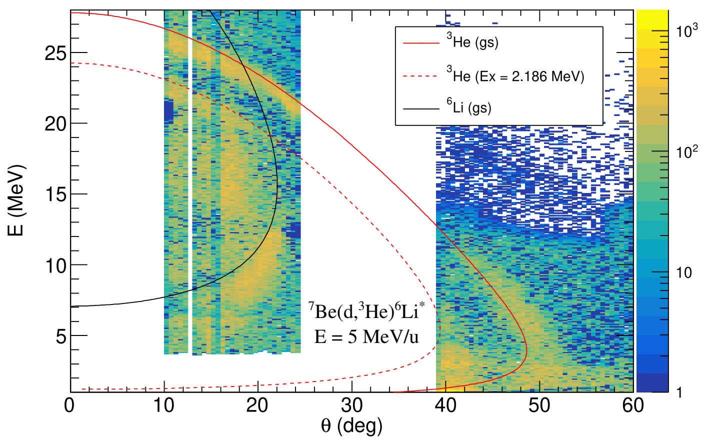

Figure 1: The energy (E) vs scattering angle (θ) plot of ^{3}He and ^{6}Li from ^{7}Be(d,^{3}He)^{6}Li* reaction at 5 MeV/u. Kinematic lines correspond to ^{3}He (red) and ^{6}Li (black) respectively.

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https://isolde.web.cern.ch

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Miniball reborn for physics at HIE-ISOLDE

Results of experiments IS563 and IS702

Frank Browne, Liam Gaffney, Thorsten Kröll, Janne Pakarinen, Peter Reiter, Kasia Wrzosek-Lipska for the Miniball collaboration

Last year saw the first Miniball physics campaign at ISOLDE since its return from performing experiments at the Paul Scherrer Institute, Switzerland and RIKEN, Japan. The campaign was preceded by an intensive installation period which included a new target chamber to house the SPectrometer for Electron DEtection (SPEDE, described in another contribution to this newsletter), as well as the new digital electronics.

Veterans of Miniball experiments will be impressed at the new look of the endcaps, pre-amplifier enclosures, and electric-blue cryostats. Under the hood, the endcaps house the same triply clustered high-purity germanium crystals with 6-fold-segmented outer electrodes. Figure 1 shows three Miniball clusters in a close-pack geometry about the SPEDE chamber.

The experimental campaign focussed on nuclei just outside of the doubly magic ^{132}Sn, and of the mid-shell nucleus ^{182}Hg. In both cases, Coulomb excitation of the radioactive beams, travelling at around 10% the speed of light, was employed to populate known nuclear excited states. In this reaction, the beam travels close to a heavy target and becomes excited through the exchange of a virtual photon. This process is measured through detection of the de-excitation gamma rays in Miniball and by conversion electrons in SPEDE. The Coulomb-excitation reaction cross section is sensitive to the so-called reduced transition probability between two states, which is calculable by theoretical models.

Calculations of reduced transition probabilities are sensitive to the assumed nuclear structure, therefore, comparison to the experimentally-derived values can constrain the models used. In the experiments around ^{132}Sn, the transition probabilities are sensitive to single-particle degrees of freedom, such as the neutron-neutron and neutron-proton interactions. Conversely, the transition probabilities of ^{182}Hg are reflections of its collective nature, in particular will inform as to the different nuclear shapes taken on at different excitation energies, or its "shape coexistence".

Preliminary results from the experiments described above indicate the Miniball array has survived its journeys and transformation, and is ready to take on tougher experimental challenges than ever before. Moreover, the introduction of SPEDE opens new avenues of spectroscopy, enabling even more physics questions to be addressed by Coulomb-excitation experiments at Miniball.

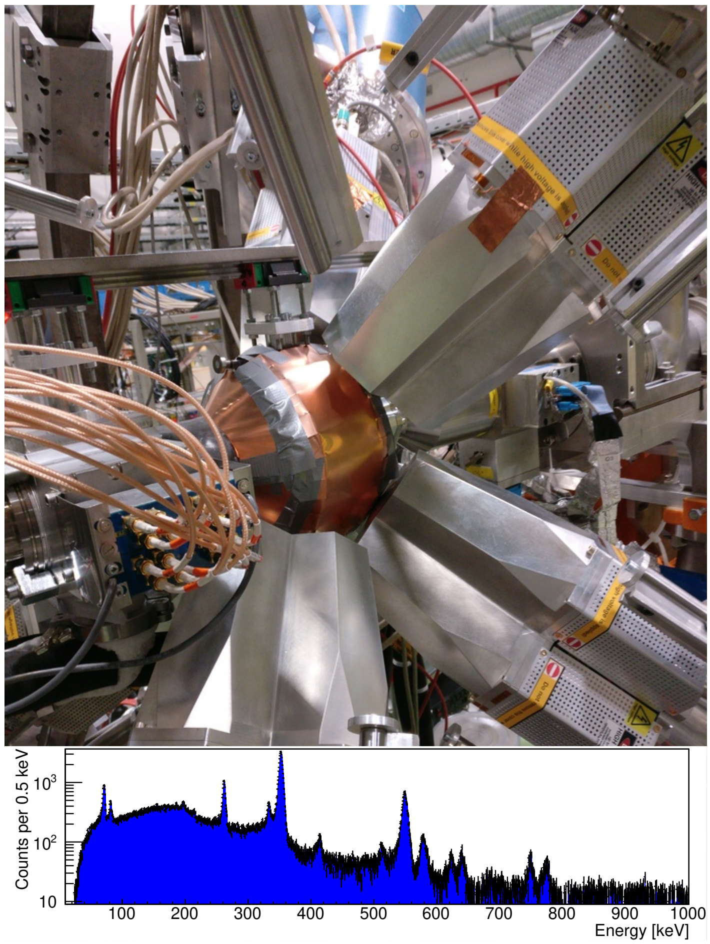

Figure 1: The Miniball array surrounding the SPEDE target chamber. The gamma-ray energy spectrum associated with Coulomb excitation of ^{182}Hg is shown at the bottom.

https://cern.ch/Miniball

The SPEDE spectrometer - novel instrument for nuclear structure studies

Results of experiment IS563

Janne Pakarinen, Philippos Papadakis, Frank Browne, Liam Gaffney for the Miniball collaboration

In order to understand diverse phenomena in atomic nuclei, a versatile set of tools, techniques and methods are needed. In an ideal case, a number of these could be employed simultaneously in a single experiment. Such an approach does not only allow for more efficient use of beam times, but also provides different perspectives for the case of interest and prospects to obtain complementary information.

An important milestone was reached at the end of the 2023 HIE-ISOLDE campaign when the SPEDE spectrometer was employed, for the first time, in a radioactive beam experiment. This marked years of research and development work conducted in the University of Jyväskylä, Finland, in close collaboration with the University of Liverpool, UK. SPEDE introduces a novel concept that allows for direct measurement of conversion electrons from radioactive nuclei without use of transportation magnets, see Figure 1, a development which enables kinematic correction of electrons emitted in flight.

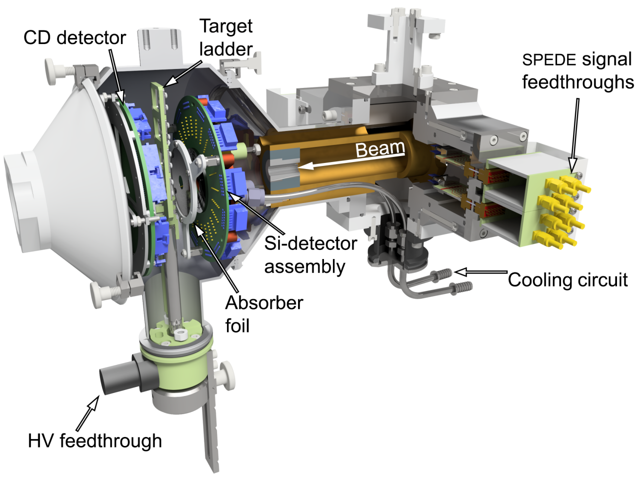

Figure 1: Reconstruction of the SPEDE detector chamber highlighting the main parts of the set-up. Reproduced with kind permission of The European Physical Journal (EPJ) [1].

SPEDE was designed to work in conjunction with the Miniball germanium detector array for simultaneous observation of electrons and γ rays. It employs a 24-fold segmented annular silicon detector connected to AMPTEK A250F/NF charge-sensitive preamplifiers and cooled to sub-zero temperatures using circulated ethanol. The detector is mounted upstream of the target and collinearly to the beam, which passes through an aperture in the centre of the detector before impinging on the target. Following beam-target interactions, a large flux of primarily forward-focused, low-energy δ electrons is generated. Its impact on spectral quality and detection sensitivity is reduced by the positioning of the SPEDE detector, in combination with an aluminised Mylar absorber foil mounted between the target and detector, and by applying up to +5 kV potential on the target to decelerate the emitted electrons. Results from the nearline sort obtained in the IS563 experiment are presented in Figure 2.

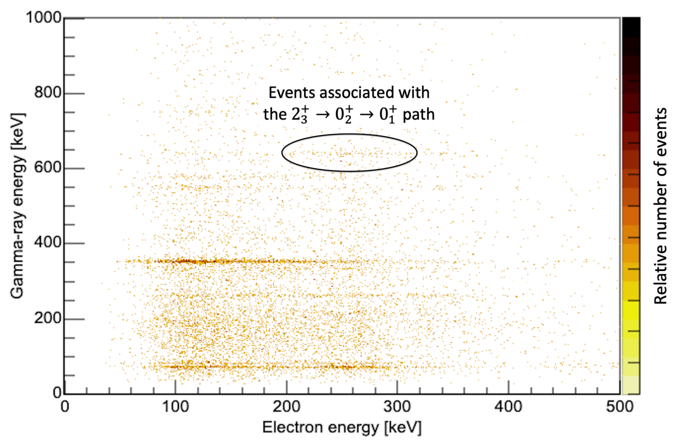

Figure 2: Particle-gated, γe^- coincidence energy spectrum, Doppler corrected for ejectile, obtained in the ^{182}Hg Coulomb excitation experiment IS563.

The successful commissioning of SPEDE in real experimental conditions can be considered as a new opening for future campaigns and is likely to attract more experiment proposals.

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https://cern.ch/Miniball

Other News

The CERN-MEDICIS facility: an update

Cyril Bernerd, Charlotte Duchemin, Qaiser Khan, Laura Lambert, Edgars Mamis, Ralf Rossel, Thierry Stora
on behalf of the CERN-MEDICIS collaboration and local team

In 2019 and 2020, CERN-MEDICIS ran exclusively using externally irradiated target materials due to the Long Shutdown 2 [1, 2]. From these external target materials, high purity grade and high molar activity radionuclides such as Sm-153, Tb-155, Er-169 and Yb-175 were produced and delivered to research institutes, demonstrating the feasability and interest of such mode of operation. These materials have been produced at partner institutes, such as the ILL reactor, the SCK CEN BR2 reactor, the ARRONAX cyclotron and the PSI injector II. Irradiations at ISOLDE became possible again from 2021 by placing a target between the ISOLDE High Resolution Separator station and the beam dump. Since 2022 a new irradiation station placed on the ISOLDE Global Purpose Separator front-end has been commissioned and a first MEDICIS target has been irradiated, allowing for additional irradiation possibilities. Since 2021, the two possible modes of operation are being exploited: using externally irradiated targets and profiting from the 1.4 GeV beam delivered at ISOLDE [3].

3 MEDICIS medical radionuclides

The list of approved projects is available on the CERN-MEDICIS website (medicis.cern). It provides an overview summarising the radionuclides of interest from within the collaboration after 5 years of operation. **??** shows the list of radionuclides that have been considered since LS2 with the number of weeks of operation, the total activity collected per year, as well as the institutes that received batches from the facility.

In 2021, a record separation efficiency for Tm-167 of 53 % was achieved, which resulted in 22.5 % efficiency on the collection foil due to sputtering effects [3, 4]. Since 2021, few new radionuclides have been studied and collected at CERN-MEDICIS: the theranostic pair Sc-44/Sc-47 and Ba-128/Cs-128, the latter being studied by our partner at CHUV as in-vivo generator. The release of the Sc isotope is being studied as molecular beams using gases such as Cl_2, NF_3 and CF_4 [5].

Year of operation	2019	2020	2021	2022
Mode of operation	External sources (LS2)	External sources (LS2)	CERN PSB beam & external sources	CERN PSB beam & external sources
Radio-nuclides	Tb-155, Er-169m, Yb-175, Pt-195m	Sm-153, Tb-155, Tm-167, Ac-225	Sc-44/47, Ba-128, Sm-153, Tb-155, Tm-167, Pt-191, Yb-175, Ac-225	Sc-44/47, Ba-128, Sm-153, Tb-155, Tm-165/167, Pt-195m, Ac-225/227
Number of week of op./coll.	15	17	25	26
Total activity collected (MBq)	870	540	1300	840
Institutes receiving	KU Leuven (BE), PSI (CH), HUG (CH), NPL (UK)	KU Leuven (BE), PSI (CH), SCK CEN (BE), NPL (UK)	KU Leuven (BE), PSI (CH), SCK CEN (BE), CHUV (CH), NPL (UK), PAEC (PK)	KU Leuven (BE), PSI (CH), SCK CEN (BE), CHUV (CH), NPL (UK)

Figure 1: CERN-MEDICIS operation and radionuclide production since the CERN Long-Shutdown 2 (LS2)

Two recent articles have been published thanks to purified samples produced at CERN-MEDICIS. One concerns the use of Sm-153 high specific activity as proof-of-concept for applications in targeted radionu-

https://medicis.cern

clide therapy and the second one resulted from the production of mass-separated Tb-155 which was used to precisely evaluate its half-life [6].

4 Upgrade to double collections

As part of the CERN-MEDICIS upgrades which are performed to increase the outcome of the facility, a new double-collection slit system has been installed in 2022. A schematic view of the slit design is shown in Fig. 2. The slits 1 and 3 depicted in the Fig. 2, were already in place, and used to block the neighboring mass ions coming from the separator towards the implantation foil. A new central slit (2) has been added, with a horizontal and rotational movement, located on the top of the surrounded shielding. This feature is of great interest for parallel collections, such as Sc-44 and Sc-47, Tb-149 and Tb-152, Tb-152 and Tb-155, Tm-165 and Tm-167, Ac-225 and Ac-227. A first successful double collection has been performed after its installation. It led to a dual collection of 150 MBq of Tm-165 and 60 MBq of Tm-167, collected on two separate foils, without detectable traces of contaminants [7].

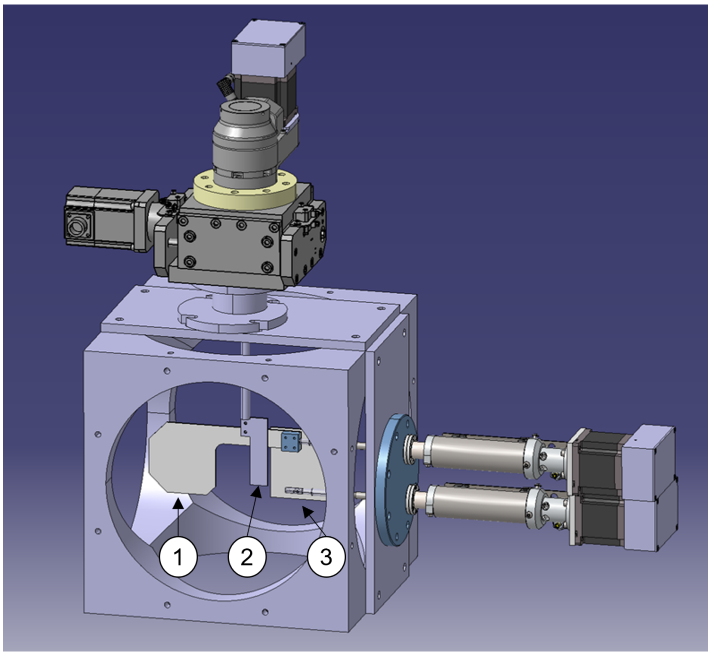

Figure 2: Schematic representation of the double collection slit system at MEDICIS. The left (1), center (2) and right (3) slits are all independently controlled by 3 different stepper motors from Nanotech®.

5 Radiochemistry developments

Radiochemistry activities continued in 2022 with an emphasis on non-carrier added purification of radio-lanthanides implanted on Zn/Al coated gold foils and a NaCl layer on Al foil employing ion exchange chromatography on LN resin (TrisKem, UK). The initial work focused on the purification of these isotopes, collected on Zn coated gold foils, using an AMINEX A5 cation exchange resin with addition of stable La carrier for better separation. The addition of stable carrier adds impurity in the final product and increases the processing steps and time. To make the radiochemical separation efficient and reduce sputtering effects, Sm-153, Tb-155, Tm-165, and Tm-167 were also implanted on a sodium chloride layer on aluminum foils or aluminum coated gold foils. The Aluminum and Zinc from the target matrix were quantitatively separated on the same LN resin, an advantage that makes the chromatographic separation elegant and less time consuming. The purification parameters were successfully developed for Sm-153, Tb-155, Tm-165, Tm-167. In addition, four Ba-128 consignments after radiochemical separation were shipped to CHUV Hospital Lausanne for pre-clinical and metrological studies.

6 MELISSA laser laboratory update

Since 2021, MELISSA has been the favored ion source for 8 isotopes of interests: Ba-128, Tb-149, Sm-153, Tb-155, Tm-165, Tm-167, Yb-175, Ac-225. Tests have also been performed punctually for the ionization of Dy-155 (collected as a generator for Tb-155) and the theranostic pair Sc-44/Sc-47.

In the frame of the machine development for the collection of Ba-128, the first laser scheme development in MELISSA has been performed. A new blue-blue scheme (413 nm – 406 nm), achievable with the laser system of MELISSA, has been chosen for collections in MEDICIS.

In parallel of regular operation, MELISSA has been used for laser development, with the double objective of increasing its versatility and reliability. To this extent, shutters have been installed, in order to block the laser at regular intervals, for short times. This feature allows the determination of the beam intensity ratio of the laser on/off over the collection, and give important information for post-analysis of complex collections.

The use of a crystal oven for frequency conversion has been studied in MELISSA, for two reasons. First, the oven has been used for stabilization of the laser power, as a temperature variation inside the MELISSA laser lab during the day was shown to induce a laser power drop, especially during summer. The use of the crystal oven showed high long-term stability over more than 3 days of laser running. The oven can also be used to tune the conversion efficiency depending on the wavelength, to perform wavelength scanning in the blue region (350 – 475nm), when used inside a grating-TiSa cavity. A program has been developed in MELISSA to perform such scanning and has been tested at the end of 2022 in ISOLDE during the scheme development of chromium.

Finally, a new design of laser cavity is under development in MELISSA. It is a diamond z-fold Raman cavity which has the capability to shift the wavelength of the pump beam, leading to an extension of the achievable range. First tests in MELISSA were successful in 2022, and the full characterization and baseplate design is ongoing.

7 Conclusions and Highlights

In 2023, CERN-MEDICIS will continue providing high purity radionuclides to its partner institutes with a focus on Sc-44/47, Ba-128/Cs-128, Tb-152, Tb-155, Tm-165/167, Er-169 and Ac-225. A first collection of Cu-67 from a UCx target irradiated at ISOLDE will also be considered. On top of this, the European Medical Isotope Programme - PRISMAP, a consortium of 23 key European institutes, funded by the European Commision within the H2020 Research Infrastructures INFRA-2–2020 program, started in June 2021. Fifteen User Projects have already been selected [8] and allows Europe to conduct research in nuclear medicine using the radionuclides provided by PRISMAP and the infrastructures made available for their experiments. CERN-MEDICIS is one of the key players within PRISMAP and one of the facilities that will provide the first batches of pure radionuclides to PRISMAP users from 2023.

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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 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 on the first floor of Building 55 (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 55
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 55[4] (Opening hours: Mon. to Fri. 08:30 —- 12:00). *If you do not need the dosimeter in the following month, it*

[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).

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 from the Jura side 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

Contacts

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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.