ISOLDE NEWSLETTER 2020

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Introduction

Gerda Neyens for the ISOLDE collaboration

The year 2019 was the first year of the long CERN shutdown period, which started around mid December 2018, after a very successful year of exciting experiments at ISOLDE. The year started with the removal of the 4th cryomodule (CM4) from the HIE-ISOLDE accelerator cave. That was necessary because after its installation in the spring of 2018, it was found that one of its rf-cavities could not be switched on. At the end of January 2020, the repaired and tested HIE ISOLDE Cryo Module 4 came back from the cleanroom in SM18 to the ISOLDE hall and has been remounted in the HIE ISOLDE LINAC together with its intertank sectors and infrastructure (see Fig. 1). Most of the installation work had finished when CERN went into safe-mode due to COVID19 on March 20. Since then, access is limited to persons that are essential to keep the equipment and site safe and secured. The Cryogenics team had just prepared the Cryo plant for its restart. Three new HIE ISOLDE type Diagnostic Boxes are ready to be installed in the normal conducting part of the LINAC, in order to improve the quality and transmission of the beams through the REX part of the accelerator. The RF and vacuum maintenance on the REX LINAC had finished and REX TRAP has already seen beam from its local ion source. At REX EBIS a new electron gun is under construction, to be ready for installation and testing later this year.

With the restart of the HIE ISOLDE Cryo plant originally foreseen in April and the cooldown of the superconducting RF-cavities in May, the Hardware conditioning would finish end of June, and this would have been followed by a Beam Commissioning and Test Development run as of mid-August until the end of the year. We are currently evaluating the impact of the CERN-wide shutdown on these plans, while some on-site activities are gradually restarting. It is clear however, that there is a delay of about two months in the start-up of HIE-ISOLDE and that many of the test that were planned, will not be happening unfortunately. At the low-energy side, the new Front-End-10 has been extensively tested at the Off-line2 laboratory, and was transported to building 179 at the end of February. Since then it is remaining there, ready to be installed in the target area as soon as activities on-site will resume. Testing of the low-energy part of ISOLDE is still planned for this year using stable beams from GPS, after FE-10 has been installed. The construction of FE-11 was progressing well, and will also be resumed as soon as on-site activities are permitted. More information on the start-up of CERN and ISOLDE in 2019 is given by Karl, further in this Newsletter.

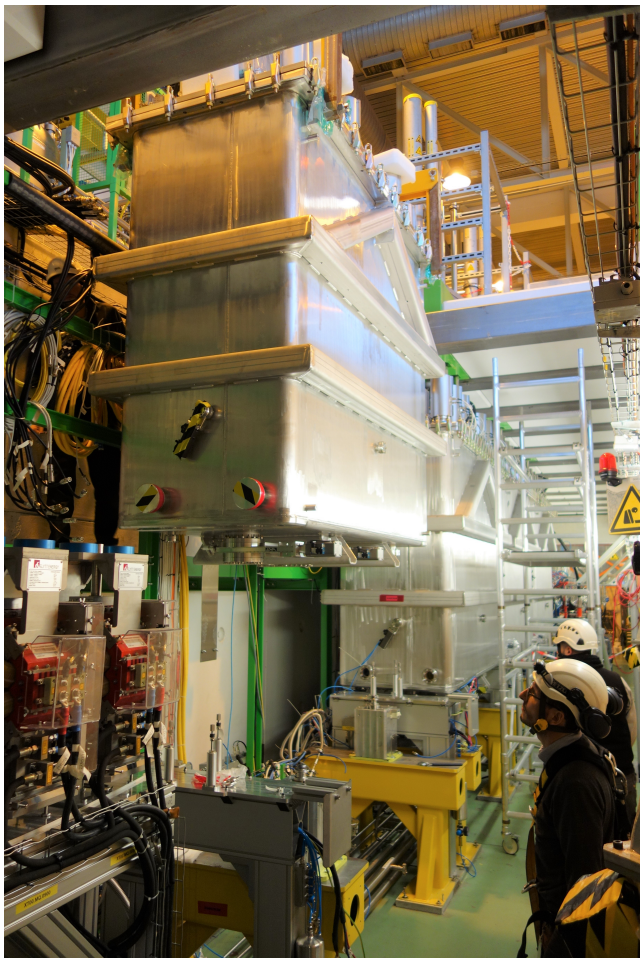

Figure 1: Installation of Cryomodule 4

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Many exciting experiments, performed in 2018, have been published already. After the first HIE-ISOLDE physics paper was published at the end of 2018 many more followed since. Also from the low-energy side, several papers appeared from all experimental devices. Since the shutdown started, more than 100 papers have been published. Several of our high-impact papers attracted the attention of the CERN media. You can find an overview of all our outreach articles published in the EP Newsletter, the CERN Courier, the CERN News website, on the refreshed ISOLDE website, under “Experiments - Outreach”. If you would like to give some visibility to your work in one of the CERN media, please contact me or Karl, or you can directly contact the CERN media responsibles.

The ISOLDE local team of PhD students, post-docs and staff has been very actively participating in the CERN Open Days, which took place mid September. During two days, we have been welcoming about 1400 visitors in building 508, and a similar amount of visitors passed by the MEDICIS tent ouside. A big thanks to Erwin, who installed lights to illustrate the beams going into the different beam lines, giving a very nice light show to be seen from the visitors room. Video’s from the 50 years of ISOLDE celebration where presented in the DAQ room, posters were placed in the visitors room and along the corridor and Dinko prepared a small demo of an ion trap. Pictures from those days are shown on the front page of this Newsletter.

The year 2019-2020 also brought us some sad news: two eminent members of the former ISOLDE community have passed away. First Ernst Otten, who is one of the pioneers of the high-resolution collinear laser spectroscopy method applied to radioactive nuclei, a method that is used since 40 years at ISOLDE and still provides very competitive results. An obituary appeared in the CERN courier of November, highlighting his many achievements, also outside of CERN (https://cerncourier.com/a/breadth-and-eminence-across-disciplines-ernst-wilhelm-otten-1934-2019/). The second is Robert Klapisch, a pioneer in mass spectrometry as well as laser spectroscopy, and later also director at CERN. He passed away in March this year and an obituary was published on CERN’s Accelerating News web page (https://home.cern/news/obituary/physics/robert-klapisch-1932-2020). Let’s end with a positive note: as always when bad things happen (being blocked at home due to COVID19) one can also find advantageous in the situation: many groups now have the time to wrap up their analysis and to sit down and produce papers. Let’s hope that we will have reported many of our interesting results by the end of this year, so that we are ready to take new data in 2021! We are all eagerly looking forward to the start-up in 2021, which will hopefully not be delayed too much.

Gerda Neyens, ISOLDE Physics Group Leader

Information for Users

ISOLDE during Covid19 and the end of LS2

ISOLDE and CERN — like everywhere else — have naturally been affected by Covid-19. Currently, at the time of writing, the entire CERN site is in a mode akin to the annual Christmas shutdown: all machines are turned off and access to the site is strictly controlled. The expected loosening of these measures will take place from 18th May onwards but a return to "normality" on the CERN site will be quite some way off. Until September it can be expected that access to the CERN site for users not currently in the area will be difficult — if not impossible — and will be allowed only in very special circumstances.

From May 18th, CERN will enter a so-called "phase 1" stage which will be the precursor before normal access to the CERN site is possible. This stage will involve a gradual ramping up of personnel — including CERN employees, associates and contractors — on the CERN site to allow LS2 work to continue. However, this will be limited until mid-June for more essential works when "phase 2" will allow people and groups who can successfully telework to come back on site. A more normal state of CERN access can then be expected from mid-September.

Information from CERN concerning Covid-19 can be found here. During phase one personal protective equipment (PPE) e.g. masks and visors, along with ensuring appropriate distances while working on the CERN site will be necessary, as will specific trainings for access to the CERN site during this time. Meetings will be held remotely, the restaurants will be open for take-out only and annual programmes such as the Summer student programme have been cancelled.

The enforced shutdown will naturally have an affect on the LS2 work which was due to be finished in 2020. The installation of the GPS and HRS frontends will be subject to a delay, but this is not expected to impact on the physics programme in 2021. Delays to the injector chain will probably mean that the restart with protons in 2021 will be later than expected and may now be sometime in June 2021 rather than April. In addition the beam commissioning programme which had been foreseen at ISOLDE — especially for HIE-ISOLDE — will now be severely compromised. However, the construction of the new nanolab for nanostructured actinide targets is expected to adhere to the original schedule.

During the shutdown period access to an enlarged number of journals and e-resources than usual can be found through the CERN library. Details can be found on the CERN library website.

The INTC meetings in 2021 are as follows:

- 64th meeting of the INTC
  - June 24 and 25. This meeting is for low energy physics proposals **only** and will be held remotely: using Vidyo or Zoom. Deadline for proposals is May 13th 2020.
- 65th Meeting of the INTC
  - November 3 and 4. This meeting will accept proposals for High and low energy physics. It is not yet known if it will be held as usual on the CERN site. The deadline for proposals is expected to be 22 September. **NOTE the unusual days: Tuesday and Wednesday**.

User registration for 2020

A full description of the procedure for registering at CERN is given below. Visiting teams should use the pre-registration tool (PRT) to register new users. As in 2019: the teamleader and deputy teamleader who sends the information via PRT must have a valid CERN registration. Please register under "ISOLDE" rather than a specific experiment. If the teamleader or deputy

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do not have a valid registration, the users office will refuse to accept the documents.

Access to ISOLDE: ADAMS

Access to ISOLDE is now entirely managed through ADaMS (Access Distribution and Management System). The access permission required for ISOLDE is **ISOHALL**. Once submitted it will be sent for approval to the physics coordinator where training ranks will be checked before access is granted.

Required training courses for access to ISOLDE hall and chemical labs

All training is now accessed 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.

Enrollment for courses should take place for these courses 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 EDH in order to validate the training.

Before Covid-19 struck, the hands-on training was taking place once a month. This is currently suspended and may be difficult to guarantee for the rest of the year. In the case of new users coming — from earliest September onwards — the physics coordinator may on occasion give special training courses to those who are unable to attend the normal training so that access can be granted. Please notify us as soon as possible of when this might be required.

- Pre-requisite online training courses (can be followed prior to arrival at CERN)
  - Mandatory courses for everybody at CERN:
    - Emergency evacuation
    - Radiation Protection - Awareness
    - Safety at CERN
    - Computer Security
    - Covid-19
  - Additional courses for ISOLDE users:
    - Electrical Safety Awareness - Facilities
    - Electrical Safety Awareness - Fundamentals
- Required hands-on courses
  - ISOLDE - Experimental Hall - Electrical Safety - Handling
    - Course code: STELS05I
  - 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. It is required to 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.

Visits to ISOLDE

Note that visits to the CERN site are currently suspended during the covid shutdown period. The possibility of a "remote" visit via video conference exists for those brave enough. Once CERN returns to a more normal mode of operation, Visits to ISOLDE are expected to be still possible. 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 one remains 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. All visits are coordinated by Dinko Atanasov (dinko.atanasov@cern.ch) and he

should be contacted well in advance with your wishes.

ISOLDE Publications and open access

Please note that 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 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*. Furthermore, please note that **all** publications which have received ENSAR2 funding need to be available as open access. This can be either green or gold but at the very least green open access will be expected of all publications which have received EU funding. Green access open access can be fulfilled by submitting a manuscript copy of a paper to the library following publication.

CERN is committed to open access. Its policy can be found here. For certain publications open access will automatically be granted upon the presence of a CERN author, see e.g. here.

Since May 2020, a new agreement with Institute of Physics Publishing — which includes Journal of Physics G — allows for any paper from a collaboration or experiment hosted at CERN to be published as Open Access. Details of this new agreement can be found here; this will also allow for papers in which the corresponding author is not affiliated to CERN to be included for open access if the work was carried out at ISOLDE.

In other — more exceptional cases — CERN may be able to assist with open access fees by contacting the library in advance. Please contact the physics coordinator in this instance for more information.

Publications on CDS

It is increasingly important that papers from ISOLDE have proper visibility at CERN. To faciliate this, 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 can be found here. If there are any problems with uploading, please contact the physics coordinator. *A preprint of an article can also be uploaded to this area satisfying open source requirements for projects which have received TNA funding from ENSAR2*.

Safety in the ISOLDE hall

During the covid-19 measures, there will be additional safety measures at CERN which may last into the free opening of CERN in September. In particular, the wearing of masks within CERN buildings will be mandatory; the preservation of social distance to >2m will be required at all times. In cases where this is not possible masks or visors will be required. Alcohol-gel dispensors have been installed throughout the CERN site and in the ISOLDE hall. Tools and workspace will have to be cleaned before and after working with them. The hand-foot monitors are to be used, but one should disinfect your hands after use.

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 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 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.

For those performing electrical work (e.g. making cables, putting up HV cages) —- a 3-day CERN course needs to be followed (all local physicists have followed it). If you require more information about this, please do not hesitate to contact the coordinator.

The mechanical workshop in building 508 is fully

operational. If you wish to use it a document will need to be provided which signed is 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 http://isolde.web.cern.ch/safety. All visiting setups should ensure that they have had a safety inspection before their experiment starts at ISOLDE. Please allow sufficient time for this to be done. You can contact me for more information to prepare for this.

Removal and shipping of equipment from the ISOLDE hall.

All equipment which has been in the ISOLDE experimental hall requires a control by radiation protection before it can be transported elsewhere or back to home institutes. A new “buffer zone” has been installed in the ISOLDE hall (close to the SAS and the HIE-ISOLDE tunnel) which implements the CERN-wide TREC system to ensure that all controlled equipment has traceability. This is now incorporated into the EDH flow for all transport requests from the ISOLDE hall.

Karl Johnston, ISOLDE Physics Coordinator

ISOLDE facility

ISOLDE Facility Upgrades and Developments

J.Cruikshank, S.Marzari, L.Lambert, K.Chrysalidis, S.Wilkins, S.Rothe, V.Samothrakis, J.Ballof, R.Heinke, D.Leimbach, N.-T.Vuong for the ISOLDE technical teams from EN-STI-RBS and EN-STI-LP

1 New Frontends for HRS and GPS

During the Long shutdown (LS2), we are tasked with replacing the previous generation of target stations, more commonly known as Frontends (FE6 and FE7) installed in 2010 and 2011. Due mainly to aging and high levels of radiation, the expected FE's lifetime is typically 7 years and LS2 presents a unique opportunity to install the new generation of FEs that will operate until LS3.

The FE6 and FE7 were successfully removed in 2019 and transported for storage in the CERN Radioactive Waste Treatment Center for cool-down before dismantling.

We used this unique opportunity to recuperate sensitive pieces from the old FEs, such as the PEEK insulators, pneumatic motors and position potentiometers for post mortem analysis. The analysis is done in close collaboration with radiation to materials experts from the EN-STI-TCD section and the objective is to define and perform systematic material tests on irradiated PEEK samples extracted from the old FE's insulators.

The new FE10 and FE11 are designed to remain compatible from an handling and mechanical standpoint with the previous generation of ISOLDE Targets but with additional and improved features. This includes the implementation of two Radio Frequency connectors, the presence of three gas lines and an additional power connector. These enhancements have opened up an array of possible target design adaptations. Some of these details are shown in Fig. 1.

Furthermore, the FE design has been extended to integrate electrostatic X-Y deflectors, a new SEM Grid and Faraday cup, shown in Fig. 2.

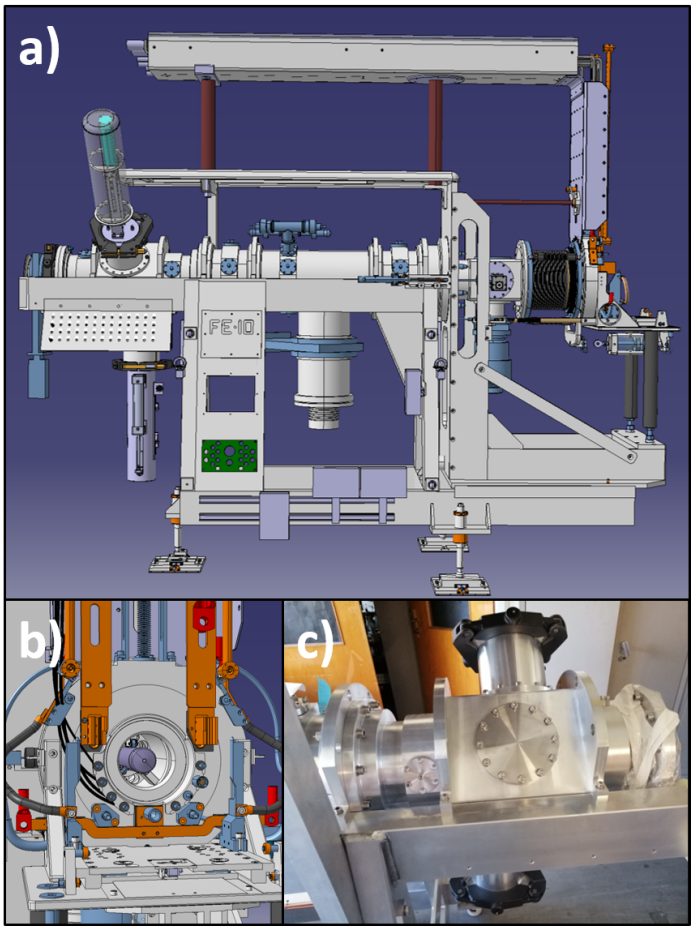

Figure 1: Frontend modifications. a) Side view of the FE CAD model. b) View of the FE coupling table and the connectors receiving the target. Two additional gas lines and two RF connectors are now available. Right: The wiregrid and the total beam Faraday cup. c) Location of the additional deflectors and beam instrumentation.

Additionally, the robustness of the FE operation has been increased thanks to the use of radiation-hard pistons developed "In-house". These modifications have

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once again increased the FE's versatility that makes ISOLDE target stations unique. CERN's expertise in the design and operation of Frontends is acknowledged worldwide and the RBS section is providing support and collaborating with other RIB facilities and projects.

Figure 2: The wiregrid and the total beam Faraday cup.

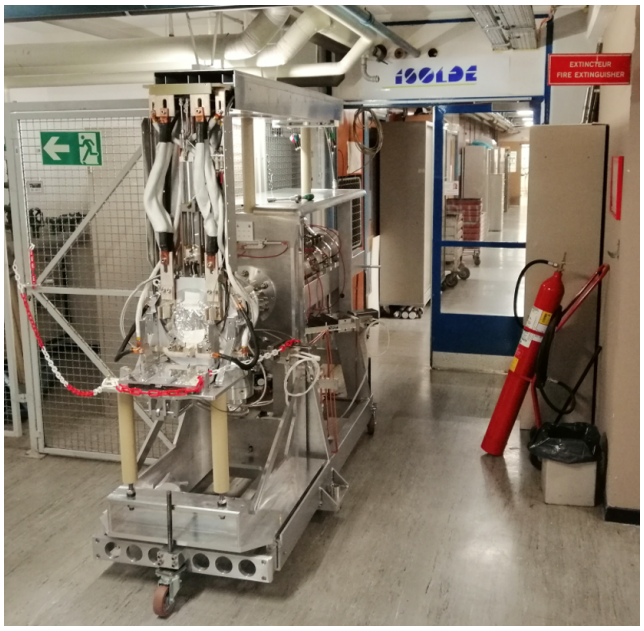

Figure 3: Picture of FE10 waiting outside the workshop prior to its transfer to ISOLDE by the CERN transport service

The FE10 is being installed on the General Purpose Separator (GPS) and will be first used to provide stable beams for the commissioning of the ISOLDE beam lines, shown in Fig. 3. The FE11 is still in its final stages of assembly in our mechanical workshop and is to be tested on our off-line 2 separator prior its installation at the HRS.

The Frontend is a very unique device with design benefiting from decades of experience and continuous improvement in RIB production techniques. The design, final assembly and commissioning with stable beam is made at CERN, whilst the mechanical parts production is subcontracted to companies in member states (UK, Italy, Greece, Belgium, etc...) or provided as in-kind contribution by external partners (Pakistan for example).

2 The Nano-Lab: A laboratory dedicated to nano-structured actinide targets for ISOLDE

Nanomaterials are the future for the production of exotic beams with ISOLDE targets. The highly porous nano structure encourages a higher release rate for short lived isotopes and generally higher isotopic yields. At ISOLDE, targets are operated at very high temperatures of 2000°C and above, to accelerate diffusion through the grains of the target material. The elevated temperature leads to sintering of the material over time, resulting in larger grains and increased diffusion times.

A lever to shorten the diffusion time is the decrease of the particle size. Nano-structured materials have shown to exhibit unmatched release properties, promising higher overall yields of short-lived isotopes despite their lower density and associated production rate. However, entering the nano world also has its drawbacks and pitfalls. For example, additional protection measures have to be implemented to safely handle nano powders in general. In addition, when it comes to nano-actinide carbides, the increased reactivity of the material with air resulting from the massively increased surface area prevent the handling of the carburized material in air.

To allow the safe production of nano-actinide carbide targets, an infrastructure upgrade has started in the framework of the nano-lab project. The first phase started in March 2020 with civil engineering work to extend the building 179. In parallel, developments are being performed to streamle the protocols for actinide nano-materials production and specify the necessary equipment and the lab layout which is shown in Fig. 4.

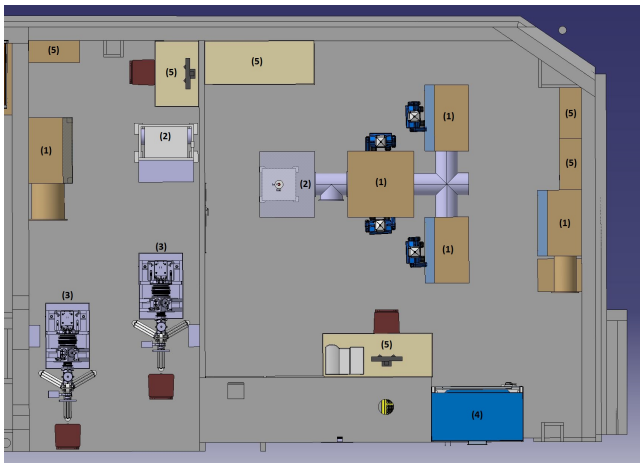

Figure 4: Design layout of the new nano laboratory: (1) Glove boxes (2) Pill press + electrical rack (3) Pump stands (4) Fumehood (5) Workbenches and storage cupboards

The idea is to separate the two labs into oxide and carbide laboratories. The oxide lab will contain a T-shaped glove box layout which will allow the technicians producing the materials to go through the entire chemical procedure, ending with oxide pellets, in a fully enclosed space. This maximizes efficiency as well as nano-safety and radiation protection. Once the pellets are complete they will then be transferred over to the carbide lab where the materials will undergo carburization in one of the ovens. The final step of loading the nano carbide target will take place inside a glove box operating under inert atmosphere and with a custom design to be able to handle full-size target vessels.

With the project in full swing, the aim is to start producing nano materials by the end of 2021.

3 RILIS upgrades

As mentioned in last year's edition of the newsletter, the RILIS reference area was redesigned and extended in 2019. The new layout comprises separate areas for observing and stabilizing reference beams from both the GPS and HRS separators. This will allow beam stabilization to be set up for the unused separator while RILIS is in operation for the other. This will reduce the time required for switching between ionization schemes/separators between on-line runs. An additional laser beam stabilization system was purchased for this upgrade, which acts as a hardware backup for components of the previous system.

In addition, RILIS has undergone some further, albeit small, improvements. As is the case for all of ISOLDE, severe space limitations in the laser lab necessitate careful planning of the existing space. In order to improve the situation, new shelving space has been added above the laser beam stabilization area and on top of the main laser table. This was partially possible due to the replacement of old computer equipment. The new PCs will be installed and tested during a major campaign of re-cabling the laboratory and rearranging the laser tables to eventually fit a new dye laser. The new dye laser is foreseen for installation in late 2020, and will be operational for 2021. The old dye laser, which has been in use for over 10 years, will be moved to the off-line laboratory and continue its use for ion beam development.

The Raman laser development work, already mentioned in last year's newsletter, has continued and is described in greater detail in a dedicated contribution to this newsletter.

4 A laser lab for Off-line 2

Work on commissioning a new laser lab at Off-line 2 has continued over the past year. Once completed, the lab will act as a hub for future off-line laser activities. It will also enable laser-ion-source developments to be performed without taking up time during the on-line periods at ISOLDE.

By utilising older laser systems that have since been replaced by newer ones at the on-line RILIS lab, a greater degree of hardware redundancy will be achieved. This will help to mitigate the impact of pump

laser failures at the operational RILIS and MELISSA labs by allowing an already fully operational spare to be installed.

Several milestones were realised in the past year. The laser interlock system was installed and is awaiting final testing to be operational. Additionally, a laminar flow unit, its support frame and plastic curtains were installed to isolate the laser table environment from the rest of the lab. Numerous orders of optics and optomechanics were delivered and the lab was equipped with two PCs.

Figure 5: Off-line 2 laser lab.

The initial laser installation in the lab will consist of two Ti:sapphire lasers pumped by a Photonics Industries DM-60 Nd:YAG laser. The first atoms will be ionized using the 2-step, 1-laser resonance ionization scheme for samarium. The setup will be expanded to include an EdgeWave InnoSlab system. This will enable non-resonant laser ionization as well as pumping of dye lasers, if required.

5 Molecular beam development: tin sulphide

Tin isotopes are in high demand at ISOLDE and other facilities such as ALTO at IPN Orsay. In particular, n-rich tin (Sn) isotopes benefit from a delivery as a sulphide molecule, as the then heavier Sn-containing molecule falls into a mass region where contaminants are less of a problem.

In an experimental campaign in 2018, we introduced a new delivery system for the sulphur reactant to ensure provision of sulphur throughout the experiment. The prototype is shown in Fig.6. The campaign at ISOLDE was unfortunately not successful, which has triggered an investigation into the reasons and potential improvements. Additionally, an on-line experiment was scheduled at the ALTO facility, enabling us to test this target design once more under on-line conditions.

During the campaign at the ISOLDE offline-separator 1, we have looked at the robustness of the delivery system as well as the ionization efficiency of SnS in combination with standard target and ion source configuration, chosen to be as close to the foreseen on-line experiment as possible.

The main result from the off-line campaign is the successful measurement of the overall efficiency for SnS delivery, which includes the formation of the molecule Sn + S -> SnS, the survival of the molecule while transported to the ion source, the ionization process itself, and finally the mass separation.

Two consecutive ionization efficiency measurements were performed, yielding 4.9% and 7.9% respectively. This result is very promising for on-line applications of this molecule. We have confirmed the results from earlier measurements that the transport capillary must be made from molybdenum; tantalum has been found to react too well with sulphur, leading to embrittlement of the capillary. The usage of a sample of 100mg enriched sulphur (^{34}S) has been found sufficient for a typical on-line operation period of 5-10 days. Larger sample sizes require an increase of the boron nitride cartridge inner volume, which should be feasible if a

bigger quantity should become necessary.

Furthermore, we have operated the ion source for 14 days with sulphur atmosphere, potentially reacting with the metallic surfaces of the source and consequently effecting the ionization performance. Therefore, the krypton ionization efficiency was monitored as a reference throughout the campaign; it was found to be rather stable.

In conclusion, the sulphur delivery system was found to be reliable and robust, therefore two ion sources and sulphur delivery systems were produced at CERN and shipped to IPN Orsay where they were used successfully for off-line and on-line experiments at ALTO.

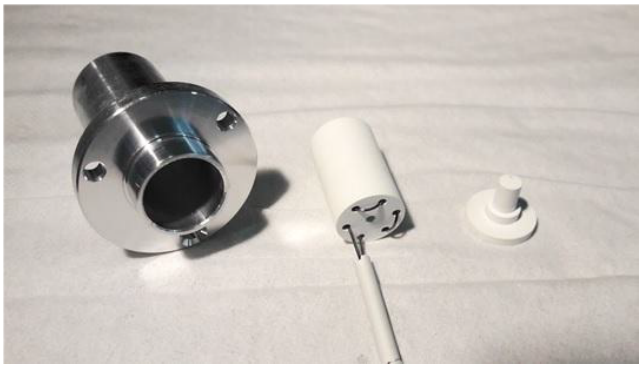

Figure 6: Heater assembly for reactants with low boiling point (first prototype). From left to right: Aluminum case, heating cartridge: boron nitride insulating the tantalum heating wires and contains the sulfur powder, plug.

6 A reaction chamber for molecular beam studies

In a collaboration between CERN and SPES (INFN Legnaro), a new concept for the provision of stable isotopes to the target and ion source assembly was designed and successfully tested.This so called mass marker (MM), is used for stable beam tuning, optimization and tuning of the laser ion source RILIS or for ionization efficiency measurements.

A drawback of the current capillary design is the strong thermal gradient across the resistively heated tantalum tube.

As an alternative, an externally heated container was proposed, once more with the goal to separate the heating function from the containment function. This allows us to optimize the container material, depending on the element we want to evaporate.

We have since added another feature: A calibrated gas leak enables us to study the formation of molecular species in a well-defined environment. A photograph of the system is shown in Fig. 7. This concept has been tested for the production of intense BaF^+ ion beams through injection of CF4 to a BaO sample, held in a graphite container. It was possible to control the ion beam intensity through the temperature of the reaction chamber as well as the leak rate of the reactive gas.

This new system will be used to investigate reaction kinetics for molecular beam production relevant for ISOLDE.

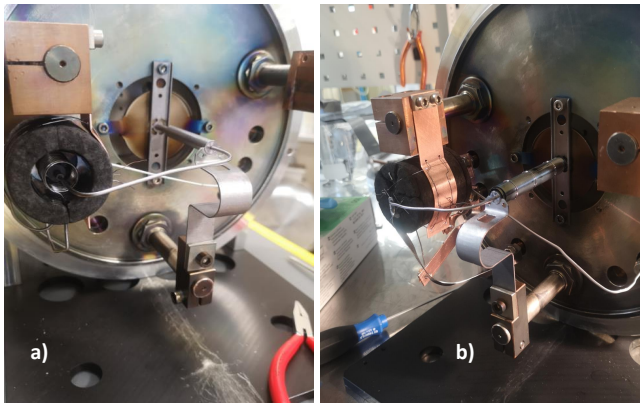

Figure 7: Mass marker oven. a) inner view b) total assembly

7 Molecular breakup studies

Many elements, such as the refractory metals, have proven difficult to extract due to their low volatility at the operating temperature of the target, or due to their reactivity and consequently their unavailability in atomic form.

A possible route to deliver isotopes of these elements is in the form of molecular ion beams. One example is the delivery of radioactive Hf isotopes in the form of HfF_3^+.

Ionization of such molecules often relies upon non-selective electron-impact ion sources, which can result in an excess of isobaric contaminants at the mass of interest. As an additional disadvantage, molecular ion

beams are incompatible with certain experiments which require atomic ions, e.g. laser spectroscopy at CRIS or COLLAPS.

A possible approach to deliver elemental refractory metal beams is to break up the extracted volatile molecule inside the ion source and subsequently ionize the resulting fragments using the RILIS, profiting from its combination of efficiency and selectivity. One method of fragmenting the molecules is to use high-peak-power lasers to drive the typically multi-photon absorption processes that lead to break up. These processes have been studied in depth within several fields, including mass spectrometry and molecular reaction dynamics.

An exploratory investigation of molecular breakup inside of typical ISOLDE ion sources was undertaken in October 2019 at the Off-line 1 Separator. Significant effort was invested into obtaining the loan of a suitable laser system for these tests. Eventually, a PHAROS Yb:YAG laser (made by *Light Conversion*) was delivered and used to produce high-energy, single-spatial-mode, sub-picosecond pulses of 3 different wavelengths (343 nm, 515 nm, 1030 nm).

This laser system was also used as part of the photocathode tests described in the next section. The analysis of the data resulting from these tests is ongoing.

8 FEBIAD Photocathode

The *in-situ* volatilization of refractory elements as volatile molecules has proven to be a successful strategy in the past. However, it is difficult to find suitable molecular carriers for certain elements. The carrier molecule must be stable at typical operation temperatures, and chemically inert with respect to target and construction materials present in the target and ion source unit. For some of the most refractory elements like Mo, Tc or Os, oxides have been proposed [1], which are unfortunately incompatible with hot tantalum surfaces in our ion sources. Alternatively, the extraction as a carbonyl complex has been investigated, however these compounds are also incompatible with hot surfaces inside the ion source.

Despite the problem that electron impact ionization is not very selective, it is typically an efficient means of ionization for molecules. This is particularly true in comparison to radiofrequency plasma ion sources, which have an unfavourable electron energy distribution, often causing molecule breakup instead of ionization.

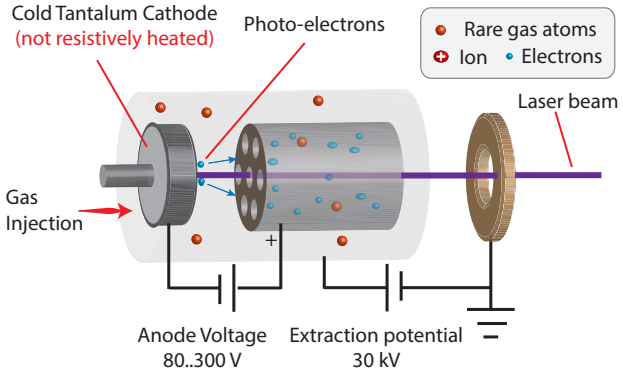

Figure 8: Schematic of the photo cathode ion source.

To overcome the limitations of hot surfaces in ion sources but still to exploit the advantages of electron impact ionization, we performed first experiments towards ionization employing a photocathode electron source. Along with the molecular breakup tests, detailed in the previous section, we used the PHAROS Yb:YAG laser to generate photo electrons on the cathode of a VADIS ion source (see Fig. 10). Here, the cathode was not resistively heated, which is normally required for the thermionic electron emission. The obtained ionization efficiencies for $Mo(CO)_6$ exceed efficiencies from all other tested sources, including COMIC, HELICON and a customized heated VADIS source. First results were promising, but further development work would be necessary to build a dedicated photocathode ion source for radioactive beam applications.

9 New features of the LIST

The Laser Ion Source and Trap (LIST) is an ISOLDE ion source designed to provide high purity beams to the users. It comprises an extension to the well-established Resonance Ionization Laser Ion Source (RILIS): The

hot atomization cavity, where unselective surface ionization processes occur, is spatially separated from a cold and clean atom - laser interaction volume inside a radio-frequency quadrupole (RFQ) unit directly downstream. Electrostatic repelling electrodes only allow neutral particles to enter and get element-selectively ionized by the RILIS lasers.

In 2018, a LIST was successfully utilized to provide highly pure ^{22}Mg for the IS614 experiment on measurements of its super-allowed branching ratio, where suppression of isobaric sodium was crucial. Systematic online performance evaluations demonstrated suppression factors of more than 10^6 of surface-ionized contamination, while the inevitable loss in ion yield of the desired element stayed below a factor of 30. Data analysis of the experiment is ongoing.

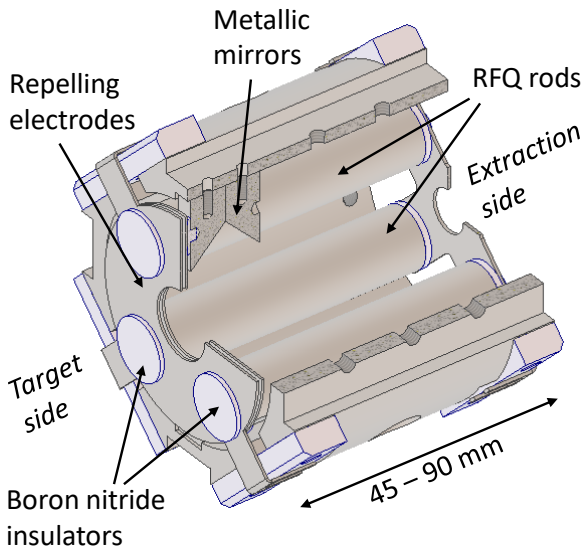

Figure 9: CAD cut view of the LIST ion source. Two repelling electrodes suppress ionized contamination stemming from the adjacent upstream RILIS hot cavity, and solely element-selective laser ionization takes place inside. The robust metal mirrors at the structure's side can be used for perpendicular laser illumination, greatly reducing the Doppler broadening in spectroscopic applications.

In the course of the ISOLDE Frontend replacement, both separators are being equipped with two independent supply lines for RF voltage for various ion source types. While this will enable LIST operation at HRS for the first time, it also gives flexibility for simplification and enhanced robustness of the existing system.

Different RF generation and delivery alternatives, including a MHz-switched square wave pattern, are under investigation for this purpose. Additionally, the electric insulation design in the direct vicinity of the hot cavity has been revised. The aim was to improve the design of a second repeller electrode. This newly added, negatively biased electrode now also inhibits electrons from entering the RFQ where they could cause unselective electron impact ionization. An overview of the LIST design is given in Fig. 9.

A new field of application was added to the LIST by introducing perpendicular laser illumination of the effusing atom beam for high resolution spectroscopy. This technique features experimental linewidths down to 100 MHz, one order of magnitude lower than achievable in the Doppler-broadened hot atom vapor environment inside the hot cavity.

Following successful off-line studies, this operation mode will be used, for example, for nuclear structure investigations on actinides within an upcoming Marie Sklodowska-Curie network (LISA).

10 Negative ion sources: New and Old

In recent years, the negative ion program at ISOLDE has been re-established, leading to a successful measurement campaign to determine the electron affinity of astatine in 2018 and a new proposal envisaging isotope shift measurements of electron affinities.

To expand the negative ion production capabilities and deliver beams of elements with lower affinities, new surface ionizer materials and other negative ionization processes are being investigated.

One alternative to surface ionization is the application of a sputter type ion source such as the kinetic ejection negative ion source (KENIS), which was used to successfully deliver negative fluorine beams at Oakridge national lab, where it was developed [2]. Here, positive cesium ions are accelerated to kinetically

eject atoms, which previously condensed on a cold surface (see Fig. 10 top).

Due to the similar geometry (see Fig. 10 bottom), it seemed feasible to perform this kind of negative ion production also with a VADIS source. Therefore, a VD5 source was equipped with a cesium mass marker and tested in a negative mode.

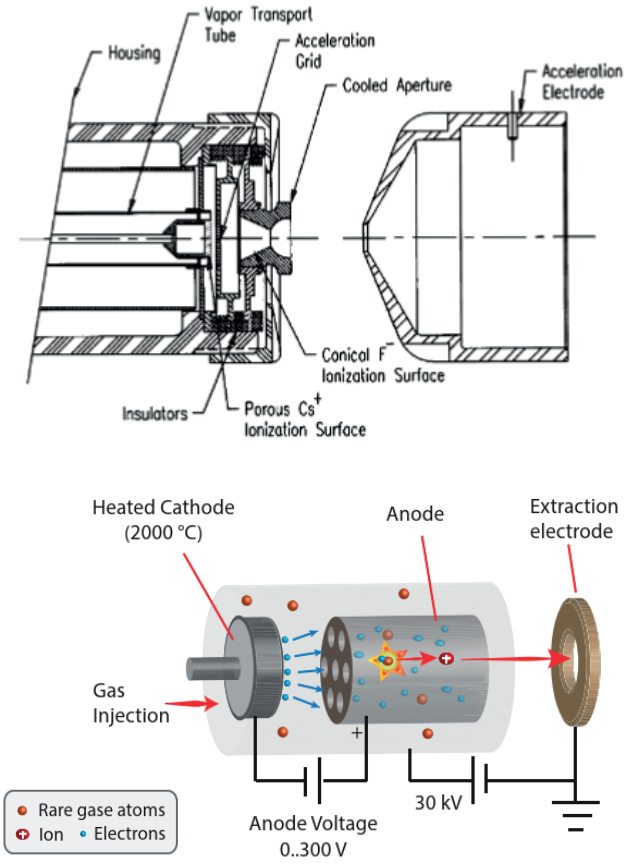

Figure 10: Top: Schematic of the KENIS ion source. A vapour of neutral atoms is condensing on a cooled aperture. Positive cesium ions are accelerated onto this aperture, creating negative ions in a kinetic ejection process which can then be extracted from the ion source. Bottom: Working principle of a VD5 ion source. In the negative mode, the polarity of the anode Voltage is switched and electrons are replaced by positive cesium ions, originating from the heated cathode.

Initial tests with iodine and fluorine beams seemed to show two working regimes of the negative VADIS: One being a surface ionization effect, probably caused by the cesiated surfaces of the transfer line and anode volume, the second one due to the kinetic ejection of negative ions from the anode volume by the interaction with accelerated positive cesium ions.

With these two working modes, beams of negative halogens (fluorine, chlorine, iodine), as well as some fluorine molecules were observed. In 2020, the investigation of the negative VADIS mode will be continued and efficiencies compared to the newly rebuilt KENIS ion source.

In addition, alternative surface ionizer materials will continue to be investigated.

11 Target container and ion source heating development

One of the main goals of the target development from the engineering and mechanical design perspective is to obtain a temperature control and homogeneity across the target container, the ion source and the transfer line, avoiding cold spots where the isotopes can condense and are thus be lost during the extraction process.

The following different approaches are discussed in the coming paragraphs: The re-design of the target container itself, a new material and concept for the thermal screening and an external heating concept.

A new ISOLDE target container design shown in Fig. 11.a) has been studied and a prototype design was finalised. Here, a new position and design for the transfer line current connection has been proposed to minimize the cold spots along the transfer line. Thinner container extremities (50% reduction) in conjunction with a new end cap design will contribute to the reduction of cold spots along the container.

Thermal insulation screens (typically Ta, W, Mo foils) are used to reduce the power deposition to the target vessel, and to provide thermal homogeneity. Currently these screens are fixed to the resistively heated elements, whilst each layer is separated by a wire, reducing electrical and thermal contact points. This wrapping solution has limited flexibility in tailoring the temperature distribution, involves manual work by the technicians and proved to be unstable over time as the screening efficiency varies during heating cycles. To mitigate this, a new thermal insulation solution has been investigated. The new thermal screen consists of

a carbon foam, Ta and Mo foils and held independently in place by two graphite supports. A 3D CAD model of this concept is shown in Fig. 11.b). It is expected that this target concept allows a faster assembly time and a more reproducible production through pre-fabricated parts. The floating design should avoid bypass current through the heat screens and is therefore expected to exhibit an increased stability and repeatability of the temperatures during the life span of the target.

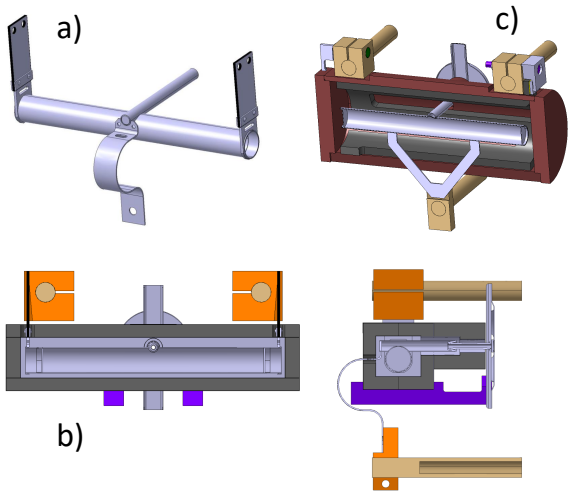

Figure 11: ISOLDE target container heating prototypes, 3D design. a) The new ISOLDE target container prototype b) Thermal insulation design proposal c) Indirect heating concept

An alternative to the conventional direct heating (through the container) is an indirect heating concept, illustrated in Fig. 11.c). Here, an external, thermally insulated graphite heater is used to radiatively heat the tantalum target container. This concept is very promising for the future as it has many advantages:

- intrinsic temperature homogeneity though placement inside a black body
- requires lower electric currents
- The separation of the heating and containment functions allows the reduction of wall thickness and potentially non-conducting materials
- the graphite heater is potentially reusable
- The design can be up-scaled to larger diameters as required for MEDICIS targets or the internal neutron converter target for ISOLDE).

Two new ISOLDE container prototypes have been ordered to realize tests using a thermal test stand: One with the standard metallic heat screens as thermal insulation and the other one with the new thermal insulation concept. Tests with the indirect heating method are ongoing.

12 Thermal analyses of uranium carbides for the disposal of irradiated UCx targets

The production of radioisotopes requires the irradiation of a thick mixed uranium dicarbide and graphite (UC_x) target. While UC_x is pyrophoric and cannot be kept in this form for long-term storage, a safe process for the conversion into oxide is investigated.

UC_x oxidation in air is a highly exothermic reaction that is associated with the risk of thermal runaway. The reactivity of UC_x material depends on its microstructure (e.g. grain size, porosity, etc.), and currently, the microstructural properties of irradiated targets that have been stored for years or even decades remain unknown. Therefore, systematic investigations including detailed material characterization and thermal analyses of UC_x materials with different microstructures have been performed to provide a better understanding of occurring oxidation mechanisms.

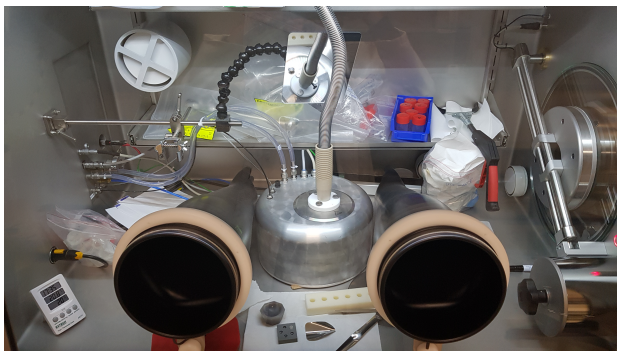

Figure 12: Inert atmosphere nuclear glovebox for the handling and the thermal analysis of UC_x sample under controlled atmosphere.

To perform oxidation studies on uranium carbides,

a thermal analyser enclosed in an inert atmosphere glovebox has been set-up in the ISOLDE Class A laboratories Fig. 12. As the mass of UC_x sample evolves when it reacts with oxygen to produce carbon dioxide, it is possible to monitor the rate of the reaction with a thermogravimeter (a highly sensitive balance coupled to an oven in which one can control the temperature and the gas atmosphere) and a residual gas analyser.

So far, 5 different UC_x materials have been studied. The ongoing analysis of experimental data will allow the prediction of the reactivity of current and future UC_x target materials. It will also and enable the development of a safe stabilization protocol for the disposal of irradiated ISOLDE targets, which could be applied at other facilities worldwide, as a new waste disposal channel.

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Diamonds for RILIS: improvements in wavelength coverage and resolution via Raman conversion

Eduardo Granados for the RILIS team

The Resonance Ionization Laser Ion Source (RILIS) is the most commonly used ion source at ISOLDE, providing over half of the ion beams during 2018 with an ionization efficiency that can exceed 10% for a variety of elements. At RILIS, tunable light in the visible spectral range is produced by dye lasers, which require frequent maintenance (due to dye degradation) compared to solid-state lasers. These interventions hinder continuous 24/7 operation, particularly when producing wavelengths < 540 nm, which require UV pumping.

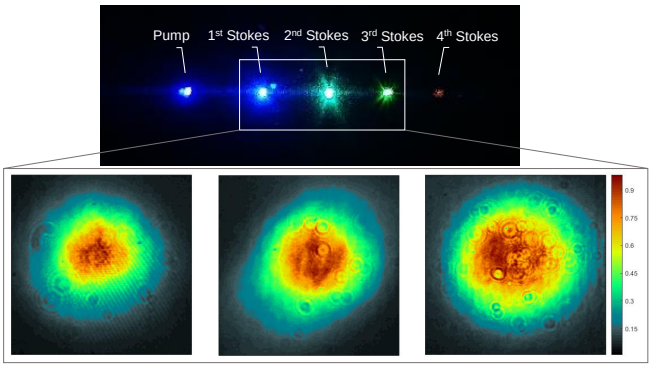

Figure 1: Measurement of the Stokes near-field beam profiles including the 1st, 2nd and 3rd Stokes orders (at 479 nm, 511 nm and 549 nm respectively).

During 2019, the long shutdown (LS2) provided an ideal opportunity for exploring all-solid-state alternatives, in particular for testing crystalline Raman conversion of RILIS Ti:Sapphire lasers. The first results were published by Katerina Chrysalidis *et al.* [1], which showed an efficient conversion from 450 nm to 479 nm, maintaining the linewidth of the frequency-doubled Ti:Sapphire laser. By mid-2019, the Raman laser development team was expanded with the arrival of two new members working on different aspects of Raman conversion using diamond: Daniel T. Echarri as a PhD student and Vaila Leask as a technical student.

Daniel T. Echarri *et al.* worked on finding an efficient way of extending the wavelength coverage via cascading of the Raman process, which led to the demonstration of a fully tunable diamond Raman laser from 450-600 nm [2] (an example of cascaded Stokes output is shown in Fig. 1). The output of this laser exhibited a linewidth resembling the one of the Ti:Sapphire laser for all Raman outputs, with a conversion efficiency of over 60% from pump to Stokes orders. We look forward to using this laser in a real experimental run.

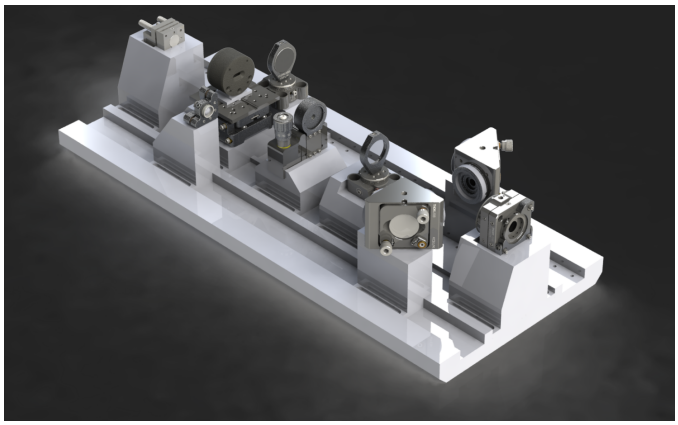

Figure 2: Computer rendered image of the Singular Light Raman converter (Courtesy of Daniel T. Echarri).

As part of the Raman laser development work, an alternative Raman laser design producing narrow linewidth output was successfully demonstrated (shown in Fig. 2). This system already produced a continuously tunable output in the visible with a linewidth of around 100 MHz, enhancing the available spectral resolution by nearly an order of magnitude. We gratefully acknowledge the CERN Knowledge Transfer Fund for supporting this project, which aims to bridge the visible spectral gap by developing an efficient, simple and agile multi-mode to single mode converter, bringing unprecedented capabilities to the laser industry [3]

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RIB Applications

Unraveling multiferroic $Ca_3Mn_2O_7$ structural path by TDPAC spectroscopy

Results of experiment IS647

Pedro Rocha-Rodrigues, Armandina Lopes
for the IS647 collaboration

Within the framework of IS647 "Local Probing of Ferroic And Multiferroic Compounds" a comprehensive study on multiferroic materials is ongoing, including materials in which the ferroelectricity order arises from proper, improper and hybrid improper mechanisms. In this respect hybrid improper ferroelectrics based on naturally layered perovskites (NLP), such as the Ruddlesden-Popper (R.P) phases ($A_3B_2O_7$), have appeared as a fascinating route to design non-expensive room temperature multiferroic materials [1]. The novel idea behind these NLP is that the ferromagnetic and ferroelectric orders can be coupled through the same BO_6 octahedral rotation and tilting modes, providing an indirect but very strong magnetoelectric coupling [1]. Within the hybrid improper ferroelectrics research field, the IS647 experiment has focused on the R.P. $Ca_3Mn_2O_7$ compound. Benedek and Fennie proposed, by first principles calculations, that $Ca_3Mn_2O_7$ should present hybrid improper ferroelectricity [1]. In fact, experimental evidence for ferroelectricity and magnetoelectric coupling were recently observed in $Ca_3Mn_2O_7$, unfortunately, the considerable high conductivity character of $Ca_3Mn_2O_7$ has prevented the observation of its ferroelectric polarization for temperatures much higher than 25 K [2]. However, according to high resolution x-ray diffraction measurements, published by Senn *et al.* [3], it was proposed that the polar $A2_1am$ structure should nucleate upon cooling around 320 K in a first order structural transition, from an intermediate phase of *Acaa* symmetry [3]. Additionally, controversy regarding the temperature onset for the transition to the $Ca_3Mn_2O_7$ undistorted $I4/mmm$ symmetry has persisted until now. In Liu *et al.* reports the $I4/mmm$ was proposed to be established, during heating, around 673 K [2], while in Senn *et al.* x-ray diffraction measurements, performed up to 1150 K, revealed the single presence the *Acaa* phase [3]. Time differential perturbed angular correlation (TDPAC) experiments combined with density functional theory (DFT) simulations provide a unique tool to characterize the $Ca_3Mn_2O_7$ structural transitions at the atomic scale [4]. The detailed measurement of the electric field gradient (EFG), and local symmetry analysis, allow the MnO_6 octahedral rotations that underlie the $Ca_3Mn_2O_7$ structural transitions and functional properties to be probed accurately. TDPAC measurements were performed at ISOLDE for a wide temperature range (11-1200 K) during ^{111m}Cd beamtimes [4]. In Fig. 3 two representative R(t)-functions and their respective Fourier transforms (FT), obtained at the highest and lowest measured temperature, are displayed. In the highest temperature region, a single axially symmetric EFG, a signature for a highly symmetric local environment, is evidenced by the equidistant frequency triplet in the FT. Bellow room temperature, a frequency doublet characteristic of an axially asymmetric EFG is present. By combining such local atomic scale experimental information with ab-initio DFT simulations, we were able to ultimately clarify the structural path that the $Ca_3Mn_2O_7$ follows from the high temperature $I4/mmm$ symmetry, through the *Acaa* one, before achieving the low temperature polar $A2_1am$ symmetry. Our study clearly shows that the phase that stabilizes at the highest temperatures has the $I4/mmm$

symmetry, establishing also the critical temperature for the $Acaa \leftrightarrow I4/mmm$ second order phase transition to be around 1163 K. We have detected the presence of a polar $A2_1am$ phase up to 500 K, in contrast with the previous long range characterization results that already showed a near full conversion to the *Acaa* phase around 350 K [3]. The presented study offered us a deeper understanding of this unique system but also inspired us to pursue the design of novel Cd-based Ruddlesden-Popper multiferroic materials [4].

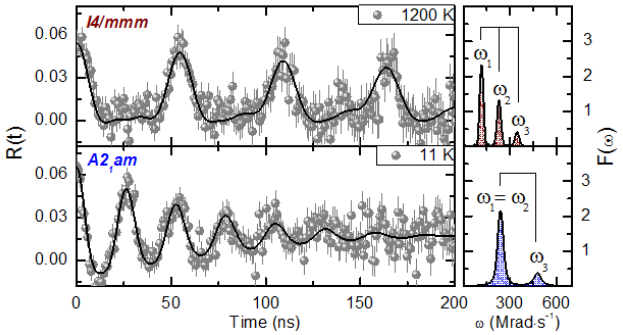

Figure 1: R(t)-function and respective FT for the $Ca_3Mn_2O_7$ compound obtained at 1200 K and 11 K, highlighting the reduction of axial symmetry from the undistorted $I4/mmm$ to the polar $A2_1am$ phase.

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Populating the unique ^{229}Th isomer state and studying its lattice location in CaF_2 with ^{229}Ac

Results of experiment LOI198 *Janni Moens and Sandro Kraemer for LOI198*

The ^{229}Th nucleus can be excited to a nuclear isomer state with an extremely low energy (8.28 ± 0.17 eV[1]) , within range of current laser technologies, which makes it an ideal candidate for an optical nuclear clock application [2]. This ^{229}Th isomeric state has two possible decay channels towards the ground state: radiative decay ($t_{1/2} = 10^3 - 10^4$ s [3]) and internal conversion (IC) ($t_{1/2} = 7(1)\,\mu$s [4]). Because of the significant difference in half-life IC is the dominant decay channel. According to density functional theory, this dominant IC channel can be blocked by doping ^{229}Th atoms into a CaF_2 crystal in a substitutional Ca site[5]. In this configuration, the isomer's energy lies within the CaF_2 bandgap and cannot excite electronic states, thus allowing the study of the isomer's radiative decay. To prepare such a study, two experiments using laser ionization of actinium for the first time at ISOLDE were performed.

In the first experiment ^{229}Ac ions (30 keV) were implanted into CaF_2 in the EC-SLI set-up. The β^- emission channelling patterns from ^{229}Ac in the vicinity of the CaF_2 $\langle 211 \rangle$, $\langle 111 \rangle$, $\langle 100 \rangle$ and $\langle 110 \rangle$ are shown in Fig. 3. First analysis results point to a 90% Ca substitutional fraction. However, there are indications that the implanted depth profile is shallower than that obtained from SRIM calculations. Since channeling effects, dechanneling in particular, are highly dependent on the electron path length within the crystal, analyzing the data assuming a shallower depth profile would result in a decrease in the fitted substitutional fraction. Further experiments to determine the depth profile are being performed, which should lead to an improvement in precision and accuracy. Since the data show no signs of any other sites being populated, close to 100% of the ^{229}Ac atoms are expected to be in this Ca substitutional position. After their β^- decay, the ^{229}Th daughter nuclei occupy the same substitutional sites because the β decay recoil energy of 2.3 eV is not sufficient to cause atomic displacements.

The second experiment, studying the feasibility of using the β^- decay of ^{229}Ac in order to feed the ^{229}Th isomer state, takes advantage of the dominant IC decay channel [6]. A newly developed set-up with a dedicated low-energy electron detector for conversion electrons emitted in the decay of the isomer was used. Actinium was implanted at low energies around 2 keV close to the surface of niobium and gold foils and a ^{229}Ac ion current of 10^6 pps was observed. Time-delayed coincidences between γ signals of the beta decay of actinium registered in a germanium detector and the low-energy electron signal partially stemming from the converted decay of the isomer were recorded. The level scheme found in literature matches the observed γ-spectra. However, the observed time behavior of the γ-electron coincidence count rate is not compatible with an isomer's half-life between 4 μs and 50 μs within a 95% confidence level. This includes the 7(1) μs half-life reported in literature.

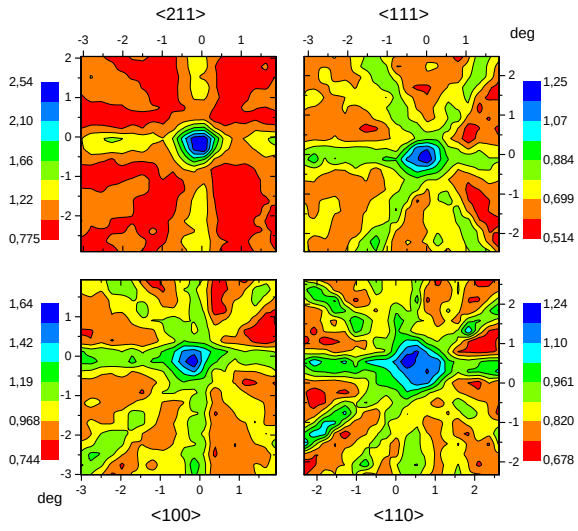

Figure 1: Experimental β^- emission channelling patterns from ^{229}*Ac* in *CaF_2* following room temperature implantation.

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Ground-state properties

Exploring the antimony (Z = 51) isotopic chain with laser spectroscopy

Results of experiment IS635

Simon Lechner, Zhengyu Xu
for the COLLAPS collaboration

Antimony (Sb) contains 51 protons, one proton above the Z = 50 shell closure. Therefore, magnetic moments of Sb isotopes serve as ideal cases to probe the proton single particle behavior over a long isotopic chain. Experimentally, magnetic moments can be obtained from the hyperfine structure, which also reveals nuclear spins, quadrupole moments and charge radii.

In the IS635 experiment hyperfine spectra of $^{112-134}$Sb ($N = 61 - 83$), including many isomers, were measured for the first time by high-resolution collinear laser spectroscopy at COLLAPS [1]. For this purpose, radioactive ISOLDE beams of Sb were formed by selective laser-ionization using RILIS. After buffer-gas cooling, accumulation and bunching in ISCOOL, the ions were delivered to the COLLAPS beamline. Since ionic Sb does not provide a suitable transition for laser spectroscopy, the ions were neutralized in a potassium-filled charge-exchange cell. The neutral Sb atoms were probed by laser light at a wavelength of 217 nm using the $5s^2 5p^3\ ^4S_{3/2} \rightarrow 5s^2 5p^2 6s\ ^4P_{3/2}$ transition.

The N = 82 shell closure was crossed by observing the hyperfine spectrum of ^{134}Sb, as shown in Fig. 3. At this mass, ^{134}Cs constituted a large contamination in the ISOLDE beam, which led to additional fluorescence light following excitations of Cs atoms in the charge-exchange cell. Hence, it took several hours to record such a spectrum on top of this increased photon background. In order to fully isolate the structural changes across N = 82 from the odd-even staggering in the charge radii, a measurement of ^{135}Sb was attempted, but could not be completed due to overwhelming ^{135}Cs contamination. A future more sensitive experiment could reach ^{135}Sb by adding a filter in front of a photomultiplier tube to block the fluorescence of ^{135}Cs and by using Cs in the charge-exchange cell to predominantly populate the atomic ground state of ^{135}Cs.

Previously, only scarce data on Sb have been reported in literature, especially on quadrupole moments ($^{115,117,119,121-124}$Sb) and charge radii (^{121,123}Sb) [2, 3, 4]. Hence, this data set will give new insights into the nuclear structure in this mass region around magic tin (Z = 50) by comparing the measured nuclear properties to state-of-the-art shell-model and ab-initio calculations. In addition to the single particle behavior exposed by magnetic moments, quadrupole moments shed light on collectivity and core polarization effects as a function of neutron number towards the shell closure at N = 82. Furthermore, the change in charge radii across N = 82, and the comparison with neighboring isotopic chains, can provide a stringent test on modern nuclear structure theories.

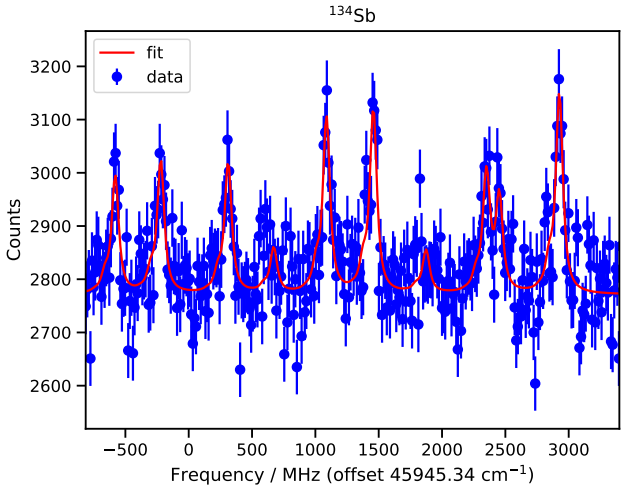

Figure 1: Hyperfine spectrum of the isomer of ^{134}Sb for the 217 nm transition.

https://collaps.web.cern.ch

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High-resolution laser spectroscopy of neutron-rich scandium isotopes

Results of experiment IS649 *Shiwei Bai for the COLLAPS-ISCOOL collaboration*

Neutron-rich isotopes in the Ca (Z = 20) region, have gained significant experimental and theoretical attention in recent years. With one proton added onto the Z = 20 shell closure, the nuclear properties of Sc isotopes can be sensitive to the single-particle effects in the *pf* shell and influence of nucleon excitations across $N = Z = 20$. The charge radii of the nuclei, as one of the fundamental properties, can be of great importance to test microscopic theoretical approaches based on chiral effective field theory [1] and to investigate pairing effects [2]. In addition, the nuclear moments of Sc isotopes, with a simple configuration, could also probe the effect of meson exchange currents in the two-nucleon interaction [3].

In order to study the neutron-rich scandium isotopes, the IS649 experiment was performed in June 2018 at the high-resolution collinear laser spectroscopy setup (COLLAPS) [4]. The Sc isotopes were produced from a Ta foil target. Using the resonance ionization laser ion source (RILIS), Sc ions in the 3d4s $^3D_1$ state were produced through the resonance exciation to an auto-ionization state of Sc atoms. The 3d4s $^3D_1 \rightarrow$ 3d4p $^3F_2$ ionic transition of Sc ion was probed by a continuous wave (cw) laser with 364.3 nm wavelength in the COLLAPS beamline. The full hyperfine structure spectra of $^{44-49}$Sc were measured for the first time in this ionic transition, which were fitted with Voigt profile, as shown in Figure 3.

In order to optimize the long-term stabilization of the wavelength meter, it was kept in a home-made cooler housing, which provided a stable and controllable environmental temperature. In addition a diode laser, locked to one of the hyperfine components of the ^{87}Rb atom, was used to perform its real-time calibration. Thanks to the collinear geometry and the special care for the long-term control and stabilization of the wavelength meter, the hyperfine parameters and the isotope shifts extracted from this measurement reached a higher precision compared to the previous measurement [5]. This is essential for a precise extraction of nuclear charge radii for isotopes in the light-mass region [6]. Ground state properties, such as nuclear spins, electromagnetic moments and charge radii of $^{44-49}$Sc were then determined and the uncertainty of these observables showed a significant improvement. Note that the quadrupole moments of ^{48,49}Sc and the charge radii of $^{47-49}$Sc were determined for the first time.

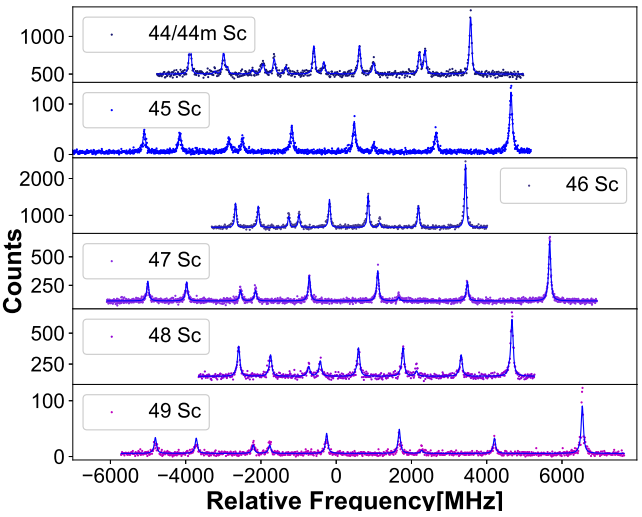

Figure 1: Hyperfine spectra of $^{45-49}$Sc isotopes in the 364.3 nm ionic transition.

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https://collaps.web.cern.ch

Magnetic moments with part-per-million accuracy using liquid-state β-NMR

Results of experiment IS645

Katarzyna M. Dziubinska-Kühn
for the BetaDrop NMR Team

The aim of the experiment IS645 is to use β-NMR to study the interaction of Na cations with DNA molecules in liquids and perform online studies to understand the formation of secondary DNA structures called G-quadruplexes [1]. The selected sodium isotope to perform this investigation is ^{26}Na, due to its relatively long half-life ($t_{1/2}$ = 1.1 s) and small electric quadrupole moment. The latter allows the acquisition of narrower resonances in comparison with stable ^{23}Na NMR.

In order to obtain accurate Larmor frequencies, from which one can derive the chemical environment of the investigated nuclei, in our first studies in the liquid state, it was important to improve the main aspects of β-NMR measurements. For this purpose, in 2018 we installed a new tailor-made H_2O NMR probe, providing an active magnetic field stabilization system based on the ^{1}H resonance frequency. This allowed us to control the field stability with ppm (part-per-million) precision and consequently improved the accuracy of the acquired resonances. We also installed new shimming coils, improving the magnetic field homogeneity to a ppm level.

As the first step, these improvements allowed us to determine an accurate value of the magnetic dipole moment (μ) of our probe nucleus ^{26}Na. This is important in NMR studies, because μ determines the absolute reference frequency for chemical shift measurements. And no such references existed so far in β-NMR. We have determined μ^{26}Na through its ratio to the corrected magnetic moment of the stable isotope, ^{23}Na. This ratio was based on the resonance frequencies of both isotopes in the same chemical environment.

Using liquid-state β-NMR allowed us to obtain narrower NMR resonances (and thus more accurate chemical shifts) than in solid-state experiments. This is because the studied nucleus experiences a more homogeneous chemical environment, as the dependence of the observed magnetic field on the orientation is averaged out by the rapid molecular tumbling. We selected two Ionic Liquids (ILs) to serve as liquid hosts for ^{26}Na and ^{23}Na, as they are compatible with high vacuum conditions. During β-NMR measurements, laser-polarized ^{26}Na atoms were implanted into 20 μL of the host solution and placed in a magnetic field of 1.2 T.(see Fig. 2). ^{23}Na Larmor frequencies came from conventional NMR performed on the same solutions with ^{23}Na concentration equivalent to samples measured with β-NMR, added in the form of NaCl and placed in the magnetic field of 7.05 T. Ab initio calculations of the NMR shielding constants were required to overcome the inconsistency of the ^{23}Na magnetic moments obtained experimentally with NMR [2] and Atomic Beam Magnetic Resonance [3]. They were performed by A. Antušek from the Slovak University of Technology, based on the coupled cluster theory.

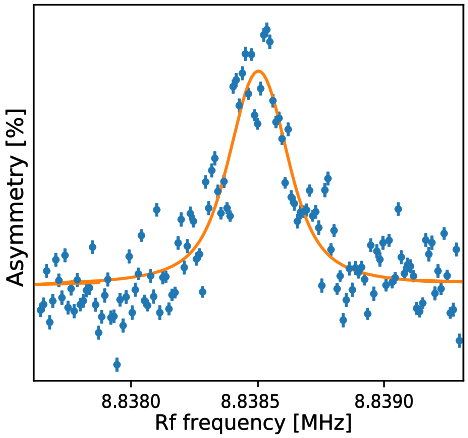

Figure 1: ^{26}Na β-NMR spectrum in EMIM-DCA.

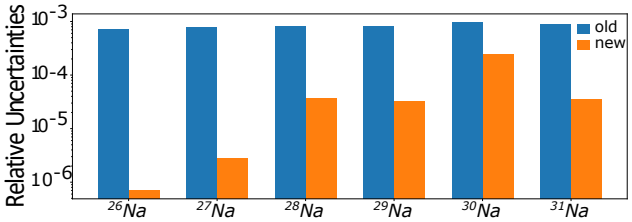

Figure 2: Relative uncertainties of $^{26-31}$Na from this work (orange) compared to literature (blue).

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The above β-NMR studies together with conventional NMR and the *ab initio* calculations allowed us to obtain the $\mu(^{26}Na)$ with a ppm accuracy [4]. This is two orders of magnitude better than the previous result determined from the hyperfine structure measurement [5].

In addition, we could achieve an order of magnitude higher precision in the magnetic moments of $^{27-31}$Na [4], because their magnetic moments, determined earlier with solid-state β-NMR [6], were linked to that of ^{26}. Fig. 2 for the comparison of relative uncertainties.

We hope that our work will establish a bridge between the emerging β-NMR spectroscopy and conventional NMR spectroscopy, paving the way for β-NMR applications in chemistry and biochemistry.

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Extending the limits of sensitivity at the CRIS experiment

A. R. Vernon for the CRIS collaboration

By the end of run 2 the setup of the CRIS experiment was successfully used to extract the nuclear root-mean-square charge radii and electromagnetic moments of a wide range of isotopes across the nuclear chart, reaching some of the most exotic isotopes measured by laser spectroscopy ($^{222-233}$Ra, $^{202-207,211,214,218-221,229,231}$Fr, $^{64,66,68-78}$Cu, $^{101-131}$In, $^{104-111,113}$Sn, $^{38-47,50-52}$K) [1], down to rates of 20 ions/s [2]. The measurements have addressed several open questions in nuclear physics. In addition preliminary measurements of molecular systems with short-lived isotopes ($^{223-226,228}$RaF) [3] show promise as a sensitive and unexplored direction for fundamental physics studies [4].

In order to ensure access to lower abundance neutron-deficient isotopes around the N = 50, Z = 50 shell closures, further neutron-rich isotopes and challenging reactive elements, improvements in measurement sensitivity were required. This was the principal focus of developments during long shut down 2 for the CRIS experiment. By implementing multi-step excitation schemes to Rydberg states and field ionization, a factor of 4 reduction in ionization volume and corresponding increase in background suppression was realised, with a further factor of 400 possible by incorporation of energy selection [5].

So far schemes have been demonstrated for indium and zinc, which will permit planned measurements towards N = 50 and beyond N = 82 for indium. Example spectra from field ionization of ^{113,115}In is shown in Fig. 1, where the Rydberg state contributes negligibly to the hyperfine structure and isotope shift- giving a less ambiguous extraction of atomic parameters for testing modern calculations [6]. Along with continued progress in developing an improved decay spectroscopy station, a dedicated cooler-buncher for CRIS and improvements to the electrostatics of the CRIS beamline, sensitivity of measurements on many elements of produced at yields of down to single ions per second is now a realistic goal for studies during run 3 at the CRIS experiment.

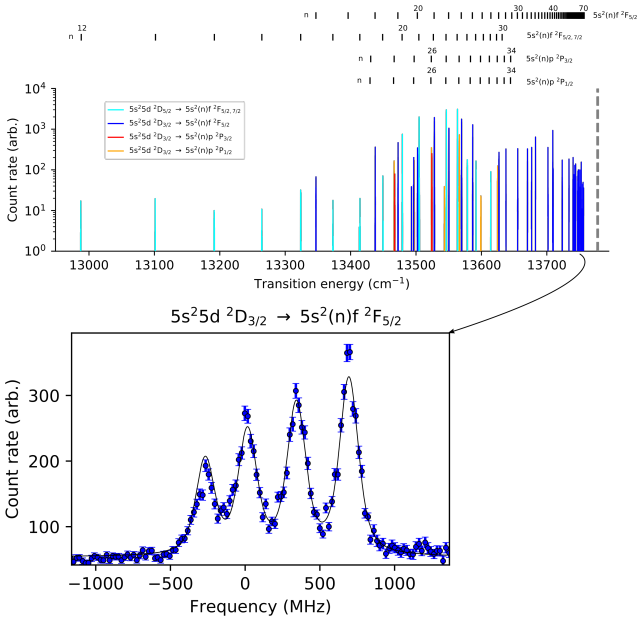

Figure 1: Top: Summary of the high-resolution measurements of the transitions to Rydberg states from the $^2P_{1/2}$ $5s^2(n)$p, $^2P_{3/2}$ $5s^2(n)$p and $^2F_{5/2}$ $5s^2(n)$f series, showing the spectrum of resonances measured in the 770-720 nm range. Bottom: An example hyperfine spectrum of ^{115}In from $5s^25d$ $^2D_{3/2}$ lower states.

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Beta-decay studies

γ-Spectroscopy of the low spin states of ^{213}Fr following the β^+/EC decay of ^{213}Ra

Results of experiment IS608

Cristina Clisu, Andrei Andreyev for the IDS collaboration

The structure of nuclei in the proximity of shell closures is a subject of great interest in current nuclear structure research, as it provides direct information on the underlying shell model orbitals. ^{213}Fr is a neutron magic nucleus, having 126 neutrons and 87 protons, five protons above the last closed shell. Therefore, the low-lying single particle states are predicted to be described by proton excitations in one of the orbits: $1g_{9/2}$, $2f_{7/2}$, $1i_{13/2}$, $3f_{5/2}$, $3p_{3/2}$, $3p_{1/2}$ coupled to the $0^+_{gs}(^{208}\text{Pb})$. The current knowledge about the nuclear structure of ^{213}Fr includes the existence of a multitude of high-spin excited states previously identified in heavy-ion fusion-evaporation reactions with energies up to about 8 MeV and spins as high as 65/2 $\hbar$. No information about the low spin states in this nucleus has been obtained before this experiment in which low-spin excited states in ^{213}Fr were populated in the EC/β+ decay of the $1/2^-$ ground state of ^{213}Ra and studied for the first time through γ-ray spectroscopy.

The ^{213}Ra ions were obtained at ISOLDE using the standard UC_x target. CF_4 gas was inserted into the target chamber such that the radium combined with the fluorine forming the $^{213}\text{Ra}^{19}\text{F}$ molecule with the total mass A=232. The molecules were accelerated by a 40 kV potential, mass separated using GPS and then implanted onto the movable tape of the ISOLDE Decay Station. The ^{213}Ra EC/β^+ decay was studied using an array of 4 HPGe Clover detectors arranged in a close geometry. The data was acquired using the triggerless NUTAQ acquisition system during a 3 min 34 s long experimental run.

In the singles γ-ray spectrum shown in Fig. 3 (a), only the ^{213}Ra decay is visible along with the decay of its daughters, indicating that the molecular beam had almost no contaminants. From all the ^{213}Fr γ-transitions present in the spectrum, the only one that was previously known is 498.3-keV that depopulates the first excited state ($7/2^-$). Figure 3 (b) shows the γ-ray spectrum gated on the 498.3-keV peak.

Using the 498-keV transition and the coincidence of the transitions with the characteristic X-rays of francium, the low spin level scheme was constructed. Over 15 new excited states and 30 transitions have been identified.

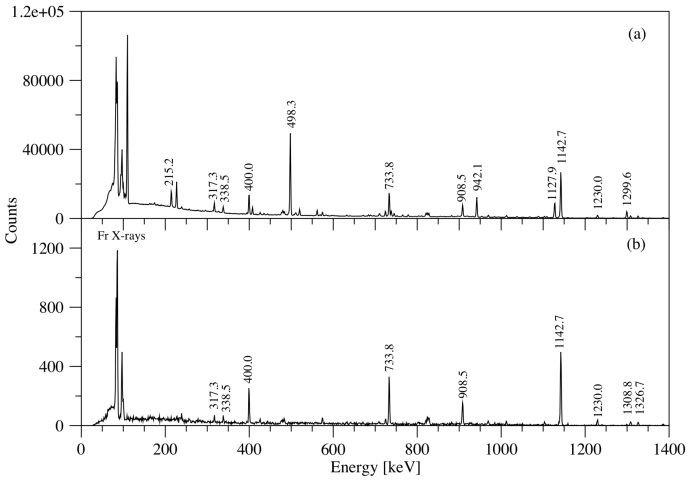

Figure 1: (a) Singles γ spectrum showing the γ-transitions following the decay of ^{213}Ra. Only the γ-rays coming from ^{213}Fr are labeled. (b) Gamma energy spectrum obtained by gating on the 498.3-keV $(7/2^-) \rightarrow 9/2^-$ transition.

Besides the γ spectroscopy analysis, the data allowed the estimation of half-lives ranging from tens to hundreds of nanoseconds using the electronic timing method with the HPGe Clover detectors. Using this method, the excited state at 1170.0 keV was identified to be isomeric ($T_{1/2} \sim 30$ ns).

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The purpose of the on-going analysis is to finalize the level scheme of ^{213}Fr and give tentative assignments of spins and parities for several excited states using the log*ft* values and the comparison with the shell model calculations [1].

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Studies with post-accelerated beams

Evolution of octupole deformation in radium nuclei from Coulomb excitation of radioactive ^{222}Ra and ^{228}Ra beams

Results of experiment IS552

Peter Butler for the IS552 collaboration

We have carried out measurements, using Miniball, of the γ-ray de-excitation of ^{222,228}Ra and ^{222,224,226}Rn nuclei Coulomb-excited by bombarding ^{60}Ni and ^{120}Sn targets. The beams of radioactive ions, having energies of between 4.25 and 5.08 MeV.A, were provided by HIE-ISOLDE. The purpose of these measurements was to determine the nature of the octupole collectivity in radon and radium nuclei and look for other cases of permanent octupole deformation in addition to those of ^{224,226}Ra already reported [1, 2].

One objective of the experiment was to determine the level schemes of ^{224,226}Rn in order to characterise these isotopes as octupole vibrational or octupole deformed. Our results [3] showed that radon even-even nuclei in this mass region are all octupole vibrational, which has implications for EDM searches in radon atoms.

Another aim of these measurements was to determine the intrinsic quadrupole and octupole moments in these nuclei using the method of sub-barrier, multi-step Coulomb excitation. Up to now we have determined $E1$, $E2$ and $E3$ matrix elements in ^{222}Ra and ^{228}Ra using the method [4] of fitting the values of the matrix elements to the Coulomb excitation γ-ray yields (similar analysis of data for 222,224Rn is in progress). The behaviour of these matrix elements for different nuclear transitions reveals a pattern, see figure Fig. 1, that enables ^{222}Ra to be classified as having rigid octupole deformation. On the other hand the behaviour of ^{228}Ra is consistent with that of an octupole vibrator, and is similar in this respect to ^{148}Nd [5].

We conclude that there are only three cases in nature, ^{222,224,226}Ra, for which there is incontrovertible evidence for nuclear pear shapes. These results have recently been published [6].

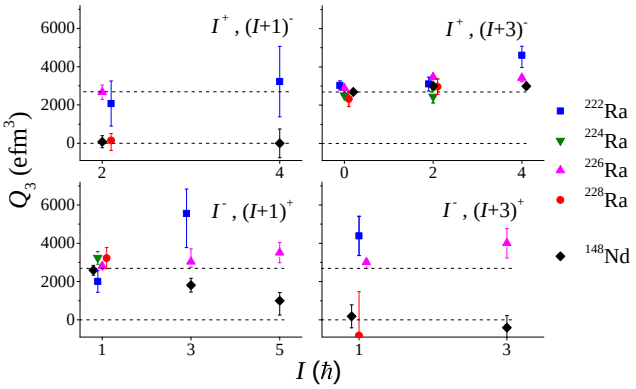

Figure 1: Values of the intrinsic octupole moments, $\mathcal{Q}_3$ plotted as a function of spin, where $\langle I_i||\mathcal{M}(E3)||I_f\rangle = \sqrt{(2I_i+1)}\sqrt{7/16\pi}(I_i030|I_f0)\mathcal{Q}_3$. Here the values of $\mathcal{Q}_3$ are shown separately for transitions connecting $I^+ \rightarrow (I+1)^-$, $I^+ \rightarrow (I+3)^-$, $I^- \rightarrow (I+1)^+$ and $I^- \rightarrow (I+3)^+$. The upper dashed line is the average value of $\mathcal{Q}_3(0^+, 3^-)$ for the radium isotopes. To aid comparison the values of $\mathcal{Q}_3$ for ^{148}Nd have been multiplied by 1.78. See [6] for details.

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Successes and future plans for ISS and SpecMAT

The ISS and SpecMAT collaborations

The ISOLDE Solenoidal Spectrometer (ISS) has been constructed in the HIE-ISOLDE experimental hall, occupying the second beam line, XT02. Its distinctive yellow and green shielding walls envelope the former 4T MRI magnet. Operating on the principles of HELIOS at Argonne National Laboratory (ANL) [1], ISS performed its first experiments in the autumn of 2018 using the prototype detector array and data acquisition system on loan from HELIOS. This contribution details the successes of that first campaign in collaboration with ANL and provides an update on the progress of the bespoke detector systems being readied for the return of protons to ISOLDE in 2021.

Before CERN's second long shutdown (LS2) at the end of 2018, the ISS collaboration performed two experiments taking advantage of the HIE-ISOLDE energy upgrade. The first, a study of the ^{28}Mg(d,p) reaction that looked to shed light on single-particle states approaching the island-of-inversion, broke the record for the highest energy (per-nucleon) radioactive ion beam delivered by HIE-ISOLDE, achieving 9.47 MeV/u. At the other end of the nuclear chart, first steps into the terra-incognita region above $N = 126$ with elements lighter than Pb were taken with the study of the ^{206}Hg(d,p) reaction [2]. The latter of these was selected as a news highlight for the CERN website and was the subject of an article in the CERN Courier, informing the whole CERN community about ISOLDE and ISS. The results of this experiment, published in Phys. Rev. Letts. [2], describe the importance of this region to the astrophysical r-process and highlight how ISOLDE is currently a unique facility worldwide that can make these first steps thanks to production of beams in this exotic region.

A bespoke Si-detector array, shown in Fig. 1, has been built at the University of Liverpool, in collaboration with the University of Manchester and STFC Daresbury Laboratory. As the construction phase of this project comes to a close, installation and commissioning of the array at ISOLDE are the final steps, currently on-going at XT02. The array itself will be positioned on the beam (and magnetic-field) axis and has a hexagonal geometry to give maximal solid angle coverage for the light detection of charged particles. Characterisation tests are planned for the coming months using an alpha source inside the magnetic field to obtain the optimum resolution for all 1,800 individual channels of the array. Stable beam tests are planned for the autumn, using residual gas from REX-TRAP and EBIS, available during the startup and commissioning of the HIE-ISOLDE linac.

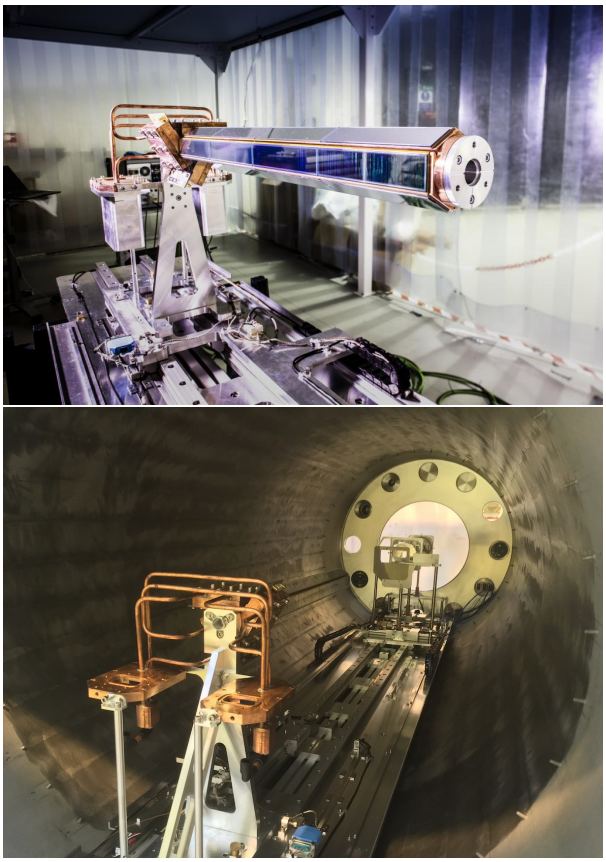

Figure 1: The new bespoke Si detector as assembled at Daresbury Laboratory UK, before being shipped to ISOLDE last year (top) and after being installed inside the magnet at the end of February 2020 (bottom).

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

ISS has been constructed as a flexible and adaptable experiment allowing for integration of a number of ancillary detection systems. In the ^{28}Mg early implementation experiment described already, a Si-telescope detector was used in the downstream direction to make event-by-event identification of recoils. At heavier masses, a gas ionisation chamber can be used to give (Z,A) identification by analysing the charge deposited as a function of distance in the gas volume. Such a detector is under construction and is to be used in the first instance for inelastic scattering experiments, where events of interest in the on-axis Si array will be hidden in a background of charged particles from fusion evaporation reactions. In this case the ionisation chamber can act as a veto of such events using timing and energy conditions, demonstrated recently in a proof-of-principle experiment with HELIOS.

An ambitious programme to study neutron-induced fission of short-lived species by employing the (d, p) surrogate method in inverse kinematics is also envisioned at HIE-ISOLDE. An array of four gas-filled recoil detectors will detect the heavy-ion fission fragments that are forward focused in the laboratory frame of reference. In order to detect both fragments in coincidence, following the (d, p) reaction in the centre of the magnet, the ionisation chambers will be arranged into pairs on the downstream flange of the ISS, as shown in Fig. 2.

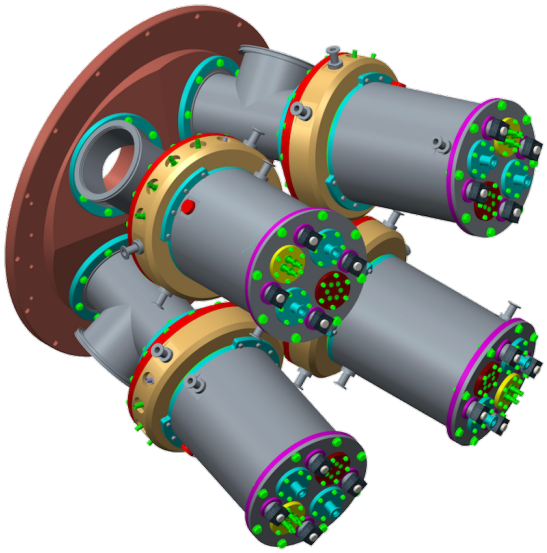

Figure 2: Fission fragment ionisation chambers designed and built at the University of Manchester.

This in turn will be correlated to the ejected protons detected in the on-axis Si array to define the Q-value of the reaction and thus the excitation energy of the state from which the fission occurred.

One further configuration of ISS is being realised at KU Leuven within the SpecMAT project. SpecMAT is an active target, which will be used at HIE-ISOLDE for reactions studies with very weak radioactive beams. The main part of the detector is a time-projection chamber (TPC), shown in Fig. 3, with a highly-granulated gaseous detector based on the Micro Mesh Gaseous Structure technology (MICROMEGAS) and a cylindrical electric-field shaper.

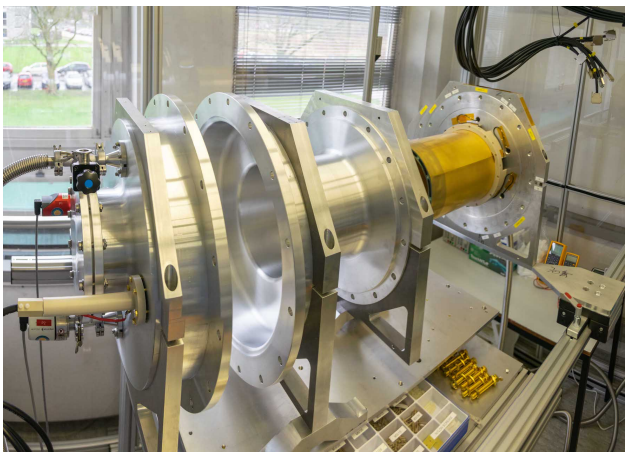

Figure 3: Assembly of the SpecMAT TPC at KU Leuven, beginning of March 2020.

This detector will be used to collect the 3D tracks and kinematics of a reaction on an event-by-event basis. Both parts of the TPC, the electric field shaper and the MICROMEGAS were produced by the Micro-Pattern Technologies group at CERN using advanced technologies and unprecedented accuracy. During an experiment, the inner volume of the TPC will be filled with a gas mixture suitable to the studied case, with the nuclei of the gas atoms serving as target of the reaction of interest. An array of 45 $CeBr_3$ scintillation detectors insensitive to the magnetic field will be installed around the active target to perform detailed gamma-ray spectroscopy of the nuclear states populated in transfer reactions. The first 30 detectors of the array were successfully installed and calibrated at KU Leuven (Fig. 4).

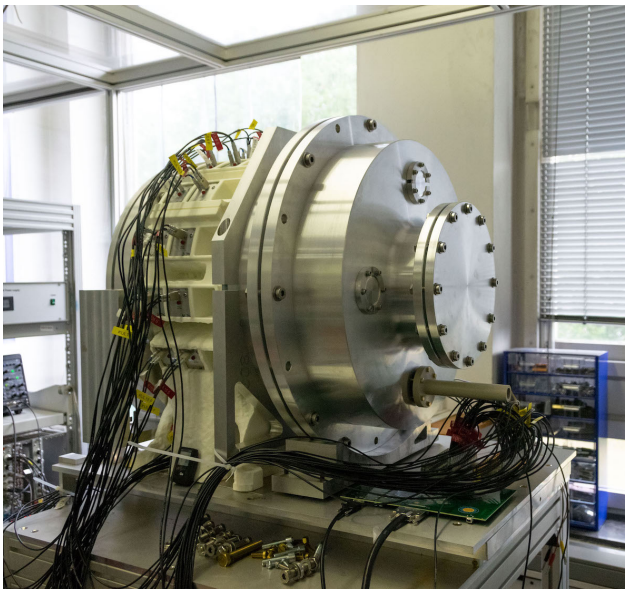

Figure 4: The assembled SpecMAT active target with the array of 30 (out of 45) $CeBr_3$ scintillation detectors at KU Leuven.

The mounting rails have been tested and aligned inside the magnet this year and detector tests are on-going at KU Leuven. It is expected that source tests will take place at ISOLDE during the summer, with the potential for stable beam commissioning in the autumn.

A workshop to discuss new physics cases to be presented to the November 2020 INTC meeting will be organised during the summer. More information and latest news about the ISOLDE Solenoidal Spectrometer can be found at http://cern.ch/isolde-iss.

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Resonance excitations in the ^{7}Be + d reaction

Results of experiment IS554

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

The *cosmological lithium problem* [1, 2] is at present a widely studied and yet unresolved problem in nuclear astrophysics where there is a pronounced abundance anomaly for ^{7}Li between the observation and prediction of the Big Bang Nucleosynthesis theory. It has been argued that resonance enhancement in reactions with ^{7}Be could lead to a solution to this long standing problem [3, 4, 5, 6]. The IS554 experiment studied the resonance excitations in the ^{7}Be + d destruction channel extensively up to about 20 MeV for the first time to study this ^{7}Li problem.

The experiment was carried out during November 2018 at the SEC (Scattering Experiment Chamber), in the XT03 beamline at the HIE-ISOLDE accelerator. A 5 MeV/A ^{7}Be beam of intensity $\sim 5 \times 10^{5}$ pps impinged on a 15 μm thick CD_2 target. The setup consisted of 5 double sided 16$\times$16 silicon strip detectors (DSSD) of thickness 60 μm (ΔE) backed by unsegmented silicon-pad detectors of thickness 1500 μm (E). These detectors were placed in a pentagon geometry covering $\theta_{lab} = 40^{\circ} - 80^{\circ}$ for charged particle detection. The forward angles from $8^{\circ} - 25^{\circ}$ were covered by an annular detector of thickness 1000 μm. The back angles from $120^{\circ} - 140^{\circ}$ were covered by two 32$\times$32 DSSDs of thickness 60 μm and 140 μm backed by unsegmented silicon-pad detectors of thickness 1500 μm.

Data analysis shows higher excitations of ^{8}Be apparent from the energy (E) vs scattering angle (θ) plot of the protons detected in coincidence with the alphas from dissociation of ^{8}Be (Fig. 3). In particular, the 16.63 MeV state of ^{8}Be has been confirmed from detailed analysis. Further analysis is in progress to separate other nearby excited states where the elastic protons from impurity in the CD_2 target overlap with the protons from the above transfer reaction.

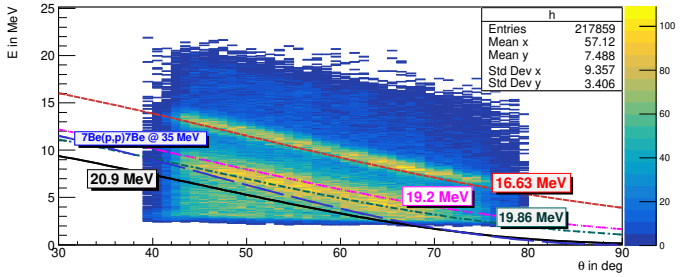

Figure 1: E vs θ plot of the protons from the ^{7}Be(d,p)^{8}Be* reaction.

The IS554 collaboration thank the ISOLDE engineers in charge, RILIS team and Target group at CERN for their support. DG acknowledges financial support from ENSAR2 (Grant no. 654002) and ISRO, Govt. of India (Grant no. ISRO/RES/2/378/15−16).

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

Other News

MEDICIS and MELISSA operation in 2019 during LS2

MEDICIS and MELISSA

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for the MEDICIS local team, coordination and collaboration

For MEDICIS the year 2019 started with a 6 months period of maintenance followed by successful commissioning. In February, the MEDICIS storage shelves were fully operational followed by the commissioning of the fume hood in March.

Figure 1: MEDICIS fume hood and class A laboratory

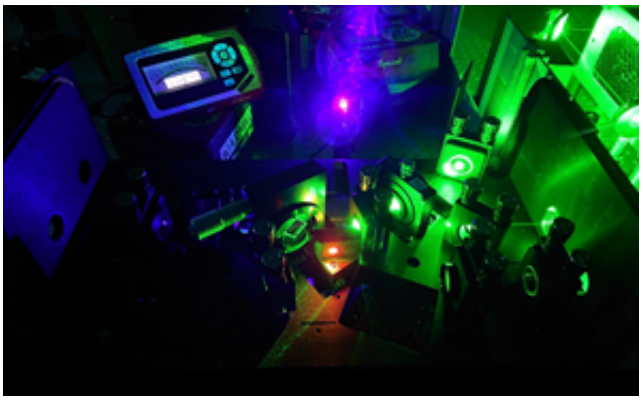

Figure 2: MELISSA lasers

Work on constructing the MEDICIS Laser Ion Source for Separator Assembly (MELISSA) laboratory was completed in 2019 and delivered the first laser ions at the facility in April 2019. The current laser setup consists of two Z-cavity Ti:sapphire lasers pumped by two InnoLas Nanio 532-18-Y systems. Additional tunable lasers will be delivered during 2020 including a grating-tunable Ti:sapphire cavity that will greatly aid any scheme development performed at the lab.

In June, the CERN-MEDICIS front-end was back in operation after replacement of the faulty electrode. The beam permit has been signed on the 26th of June allowing the first collection to start on the 2nd of July. In 2019 MEDICIS operated during LS2 and ran offline with external samples irradiated at the nuclear reactor of the Institut Laue Langevin ILL (Grenoble, France) and at the ARRONAX cyclotron (Nantes, France) until the end of the year. Enriched Er-168, Yb-174 and Pt-194, in oxide or chloride form, were exposed to a neutron flux from the ILL reactor to produce Er-169, Yb-175 and Pt-195m, respectively, by (n,γ) reactions. After irradiation the vials were sent to CERN-MEDICIS where they were decontaminated in acid and ethanol baths, opened in ethanol and the content of the vials transferred to a rhenium (Re) boat. Once the content was dried in a Re boat, the boat was inserted into the empty target tantalum (Ta) container. Arronax uses their 30 MeV proton beam to produce Tb-155 from a natural gadolinium (Gd) target. Tb-155 needs to be separated from the target material (Gd) and the other produced Tb isotopes. First collections were performed introducing directly the metallic Gd foil inside the empty Ta target container. Some radiochemistry developements were then performed towards the end of 2019 at Arronax in order to reduce the proportion of Gd atoms which are laser ionised at the same time as Tb and which could inadvertently saturate the ion source load. A new type of sample holder has been developed by the EN-STI-RBS workshop in order to safely evaporate the radioac-

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tive solution inside and to transport it towards CERN-MEDICIS without any dispersion. In addition, this approach allows for the introduction of the sample into the target container that minimizes the risk of contaminating the operators and the laboratory. In 2020 this type of sample holder will be used to receive radioactive samples coming from KU Leuven/SCK in Belgium, Arronax in France, JRC Karlsruhe in Germany and PSI in Switzerland. In 2019 four radionuclides of medical interest were processed at CERN-MEDICIS and the activities distributed to four hospitals or collaborating insitutes: the Paul Scherrer Institute (PSI) in Switzerland, the Hopitaux Universtaires de Geneve (HUG) in Switzerland, the National Physical Laboratory (NPL) in the United-Kingdom and KU Leuven/SCK-CEN in Belgium. The first collection of the year started on the 2nd of July during which 7 MBq of Er-169 were collected for PSI. This was followed by six supplementary Er-169 collections for a total collected activity of 350 MBq. These collections were sent to PSI and allowed their research team to start with the first pre-clinical trials. PSI also received activities coming from four collections of Yb-175 summing up to a total activity of 520 MBq. Four collections of Tb-155 were performed at CERN-MEDICIS with a total activity of 222 kBq distributed to NPL and KU Leuven/SCK for radiochemical studies, detector calibration and isotope qualification. MEDICIS operation in 2019 sums up to 15 collections carried out within 922 hours and a total of 870 MBq. Eight target units were used for operation with some of them re-used up to three times. Last but not least MEDICIS successfully welcomed 1400 visitors during CERN's Open Days.

Figure 3: MEDICIS stand during the CERN Open Days 2019

In 2020 CERN-MEDICIS continues running with external sources provided by collaborating institutes. Tb-155 will be produced at Arronax, Tm-167 will be sent from PSI and Sm-153 from KU Leuven/SCK. In addition, the feasibility of separating Ac-227 from Ac-225 will be assessed at CERN-MEDICIS from sources coming from JRC Karlsruhe. Complementary to this, studies of the extraction of long lived actinides from targets irradiated at ISOLDE are envisaged. An online monitoring of the activity collected on the foil will now be possible through the installation of a calibrated Cadmium-Zinc-Tellurium (CZT) detector purchased from the Kromek company (UK). Further funding has been secured to invest in expanding the capabilities of MELISSA in 2020. Motorized etalon mounts and a laser beam stabilization system will be installed to improve the long-term stability of the laser ion source. A beam imaging system will also be implemented to enable remote monitoring and diagnosis of the setup. These upgrades, combined with the additional laser systems, will further improve the performance and reliability of the laser ion source during radioisotope collections as well as increase the number of elements for which the ion source can operate.

ISOLDE support

Access and contacts

1. Use the online 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.
3. 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).
4. Get your CERN access card in Building 55
5. Follow the online mandatory CERN safety courses: safety at CERN; Radioprotection awareness, Emergency evacuation, Computer security and Covid-19.
   - If you have activated your CERN account, you can access the mandatory courses online 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).
6. 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 entry 5.
7. Obtain a Permanent radiation dosimeter at the Dosimetry service, located in Building 55[3] (Opening 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" [4] signed by your institute will be required.
8. Follow the practical RP safety course and Electrical Awareness Module for which you will have to register in advance[5]. These take place on Tuesday afternoons from 13:00 until 17:00 at the training centre (building 6959) in Prevessin. If you do not have your own transport, you can take CERN

[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] http://cern.ch/service-rp-dosimetry (open only in the mornings 08:30 - 12:00).
[4] The certificate can be found via http://isolde.web.cern.ch/get-access-isolde-facility
[5] For information about how to register see http://isolde.web.cern.ch/get-access-isolde-facility

shuttle 2 from building 500. The timetable for this is here.

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

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[6] Eventually you can contact Jenny or the Physics coordinator.