ISOLDE newsletter Spring 2015

http://isolde.web.cern.ch/

Introduction

The year 2014 was characterized by the consolidation and realisation of many pending tasks. The year started with the technical team working hard and counting down the weeks until the startup. Physicists followed the progress in tuning up the machine and heard with dismay about the stumbling blocks encountered, mainly problems with the controls, and at the same time, they greeted the advances with excitement as they were eager to start.

In parallel the construction of building 508 continued. The new building has more space for the physicists, their laboratories and DAQ rooms and hosts the ISOLDE control room in a spacious and well ventilated room outside the controlled area, a long standing request from the Beams Department. The large control room is ready to accomodate the future TSR controls. The delay in finishing the building, expected for May 2014, soon became clear. The permanent setups most hurt by the delays were COLLAPS and the solid state laboratories. The solid state groups arranged their setups in building 275 while COLLAPS installed part of their lasers in the ISOLDE hall to be able to complete at least one experiment.

The course entitled "ISOLDE Nuclear Reactions and Nuclear Structure" took place the 22-25 of April 2014 with maximum attendance. The course addressed the different nuclear structure and reaction information that can be obtained by reaction studies done at the energies relevant for HIE-ISOLDE. W. Catford, A. Di Pietro and A. Moro gave the lectures and, to complete the picture, B. Jonson gave a seminar on the physics that can be done with reactions at intermediate energies. Practical exercises were led by A. Moro in the afternoon including calculations of an optical model and DWBA using FRESCO for several basic cases and using TWOFNR code for transfer (d,p) reactions. To learn more about the courses given in 2013 and 2014 one can visit, http://isolde.web.cern.ch/isolde-schools-and-courses .

The shut down period was taken advantage of by upgrading some setups, such as ISOLTRAP, and building new ones. Firstly the ISOLDE beta Decay Studies, IDS, permanently equipped with three clover HPGe detectors and a Miniball detector was installed. Depending on the physics case IDS can incorporate Si detectors for beta-delayed charged particle studies, or LaBr3(Ce) scintillators for half-life measurements of excited states. Secondly the previous UHV ASPIC beam line was fully redesigned to host up to three possible experiments including ASPIC. The first part of the new VITO (Versatile Ion-polarized Technique on-line) line was mounted and the first experiment with Cu-beams took place in December.

In spite of the bumpy start and the amount of technical issues discovered on line, leading to multiple updates of the schedule, the capability of the physicists to adapt to the circumstances and the professionalism of the technical team made the year 2014 a successful one for physics as witnessed by the contributions included below in this ISOLDE Newsletter.

The very first experimental run, carried out on the 1st of August, was greeted with a fantastic atmosphere and a real buzz in the air. Samples of lanthanides ^{149}Tb and ^{155}Tb were collected and shipped to PSI, Switzerland and ^{140}Nd to DTU Risø, Denmark. The aim was to identify chemical elements with suitable isotopes for diagnosis and therapy. Among the travelling experiments we also welcomed new devices such as the TATRA tape transport system designed by our Slovak colleagues and dedicated to the study of neutron deficient odd Hg isotopes. A large array of neutron detectors came from CIEMAT (Spain) and LPC-Caen (France) and it was dedicated to the measurement of the delayed neutron - neutron correlation emitted in the ^{11}Li beta decay.

The complementarity between different devices and their state of the art capabilities allowed for the determination of the ground state properties of a long series of At isotopes with production rates and half-lives expanding over a range of 8 orders of magnitude. This successful experiment showed ISOLDE strengths and combined the synergies of three devices: the RILIS lasers, the Windmill setup equipped with silicon and germanium detectors, and the ISOLTRAP Multi-Reflection Time-of-Flight mass spectrometer.

The ENSAR EU Project was prolonged until the end of December 2014. The remaining ENSAR funds for transnational access were distributed between young researchers, students and newcomers. In numbers, the total transnational access funds obtained from ENSAR sponsored 2481 days of 418 users belonging to 90 projects. ENSAR2 was submitted in September and is presently on the reserve list waiting for approval. These funds are very important as they reach the full community and allow many young researchers to participate in the experiments and have a first contact with the facility. We hope for the projects approval.

HIE-ISOLDE progressed well during 2014, the cavities showed good performance and the clean room for the assembling of the cryomodule in SM18 was built. The hall extension was receiving more and more experimental elements and busy with different infrastructure installations. The tunnel was given its final length to host the future linac. All procurements for HIE-ISOLDE phase I were launched. To facilitate the co-habitation of the HIE-ISOLDE works and the low energy physics experiments the hall was divided into two parts with different access and safety conditions. The interest in the facility continued growing worldwide. More countries showed interest in becoming members of the collaboration and many new physics groups are attracted by its potential. The project HIE-ISOLDE was presented at several nuclear conferences and in front of the NuPECC Expert Committee in the meeting of October 2014. We are all looking forward to the start with post-accelerated beams in 2015.

CERN recognised in 2013 the unique scientific opportunity offered by installing the TSR at the HIE-ISOLDE facility. Since then several groups have manifested their commitment to develop instrumentation for the TSR and different working groups were created after the one-day workshop held the 14th of February 2014 with 60 participants (http://indico.cern.ch/event/271980/). In particular, the UK teams joined forces to make an application to the STFC to provide instrumentation for the TSR which was successful. To support the UK grant, CERN has committed to the construction of the third beamline for HIE-ISOLDE including the U-turn to place an external spectrometer in the ISOLDE hall. The TSR working groups are preparing the two-day workshop that will take place at CERN 27-28 of April.

The annual ISOLDE workshop and users meeting was held the 15-17th of December 2014 with a Golden Jubilee session on December 17th precisely 50 years after the approval of ISOLDE by the CERN Council in 1964. The session was opened by Torleif Ericsson, the chair of Nuclear Physics Experiments committee at that moment (equivalent to the Scientific Policy Committee of today) who recommended the ISOLDE project to the council. He recreated the circumstances in which the “Study of

short-lived radioactivities by means of an isotope separator on-line with the CERN Synchro-Cyclotron" was approved. He emphasized the role-played by V. Weisskopf in establishing the laboratory's vision that "CERN should be open to other fields than Particle Physics". In particular he proposed to re-establish the links with Nuclear Physics (Initiative taken in the 1963 Conference on High Energy Physics and Nuclear structure). Afterwards we had presentations by all the former group leaders: B. Jonson, J-H-J Kluge, H. Haas, P. Van Duppen, G. Bollen, J Äystö, P. Butler, K. Riisager and Y. Blumenfeld, who presented the breakthroughs and highlights of the facility during their leadership. The presentations were recorded and they can be seen via http://indico.cern.ch/event/334117. The session was closed by the DG, R. Heuer, who gave the four prizes sponsored by CAEN to the best posters and best young speakers, a new tradition to be added to our annual ISOLDE meeting. The next edition will take place the 2-4th December 2015.
The year 2015 is a very challenging one, with the startup of HIE-ISOLDE. While writing these words the first experimental beamline is being assembled ready to host experiments. We are ready for the start of the new adventure.

Maria J.G. Borge

Information for Users:

Safety

As elsewhere at CERN safety has been a very important issue at ISOLDE in recent months. In this spirit, I would like to remind you that when at ISOLDE you should ensure your own safety and that of others. We have taken many steps to help you.
A range of personal protective equipment for different manipulations, e.g. gloves and glasses, are available in the cabinet by the ISOLDE stairs. Quiet, equipped rooms behind ISOLDE are available for electrical and similar work (see – Laboratories).
You can only perform the work for which you are trained and authorized, i.e. for LN2 manipulations or work with lasers you should follow the relevant CERN class courses or at least get a proper briefing from your local contact who followed the course. For performing electrical work (making cables, putting up HV cages) – you need a 3-day CERN course (all local physicists have followed it). All users who do not perform strictly electrical work have to follow a new 2-h electrical awareness course, see *Courses and access to ISOLDE*.
If you want to use the new mechanical workshop, you will have to provide a document to be signed by your teamleader, yourself, and our workshop supervisor, authorising you to use the selected machines in the workshop. For more information please contact your experiment spokesperson or me.
We have also updated the list of safety contacts for fixed and travelling experiments:
http://isolde.web.cern.ch/safety
In case of an accident (electric shock, LN2 burn, fall, etc.) please do not ignore it, but call the CERN fire fighters who will advise you how to proceed. They might also recommend going to the medical centre (next to ISOLDE). You are also obliged to complete an online incident report: https://edh.cern.ch/Document/General/Accident2. Please inform me asap, so that I can help when the safety team investigates the incident.

Laboratories and local help

From 2015 we have at our disposal the new building behind ISOLDE (b508) and the rearranged b275 (behind CERN fire brigade).

On the ground floor of b508, within the CERN RP controlled area, you are welcome to use: the "detector" laboratory for detector tests, the new machine workshop (see Safety part for access rules), or the chemical laboratory for chemical manipulations. Electrical work should be carried out in the electrical workshop in b275.

On the 1st floor, outside the ISOLDE RP controlled area you will find: the kitchen, meeting room, small DAQ rooms for run preparations, and the main DAQ room meant for the data acquisition while taking online data. We highly encourage all groups to use the DAQ rooms, which have signal connection with the control room and the hall. You can work there while waiting for the RP course needed for ISOLDE access.

In b275, outside the ISOLDE RP controlled area, we have a large electrical workshop (with many useful components), a detector lab, some space for short-term storage, and a large air-conditioned laboratory for offline tests.

Please contact me if you have questions concerning access and use of these labs.

The local physics team can also help you with many aspects of ISOLDE experiments, e.g. turbo and pre pumps, RP sources, chemicals, etc.

Registering as CERN user

To avoid rush and stress once at CERN, we encourage everybody to use the electronic preregistration. For this purpose contact your teamleader who can launch the procedure for you.

The experiment Spokesperson should also check who will participate in the experiment and whether the institute is linked to ISOLDE (which can be verified via Greybook). If it is not, please contact Jenny at the ISOLDE User Support Office and enquire how to add the institute. Otherwise the person will not be able to register.

Courses and access to ISOLDE

The rules for accessing ISOLDE changed when we got the first protons after the long shutdown in July 2014. ISOLDE changed from RP supervised to RP simple controlled area and only CERN permanent dosimeters are accepted to enter the facility. At this point, the present standard RP course was replaced by ISOLDE-tailored online and 2-h hands-on courses. In addition, in order to get a dosimeter a document signed by the institute (and not a doctor) is required.

To work at ISOLDE, you also have to follow courses on electrical awareness: online, and from April 14th 2015 a 2-h course hands-on course which takes place just before the ISOLDE RP course. For details, see http://isolde.web.cern.ch/get-access-isolde-facility

Access to ISOLDE and to the ground floor of b508 takes place from the Jura side, via a tourniquet activated with your dosimeter. Until the end of HIE-ISOLDE works there will be no access for physicists to the ISOLDE hall extension. Moving of equipment through that part of the hall can be done only by local physicists, it should be coordinated with Erwin Siesling, and it will require safety shoes and helmet. For the low-energy area a memorandum exists which, waives the requirement for the above safety equipment, unless you perform work for which it is required (e.g. using the crane).

Shipping equipment

Make sure that you inform your contact person of the delivery and you put their name as the recipient. Info on the shipping company and foreseen delivery time is also welcome. Keep the CERN "delivery paper", because you'll need it when shipping equipment back home.

Because of a lot of equipment moved in and out of ISOLDE every day (mainly due to HIE-ISOLDE work) please make sure that your equipment doesn't stay in the ISOLDE SAS for long.

CERN Hostel booking

This year we succeeded again in booking 20 rooms for the whole running period. The booking requests should be grouped by the spokespersons and communicated to Jenny. Please use this group booking only when you couldn't book a room in the regular way.

Publications

Please note that ISOLDE should be mentioned in the abstract of articles related to experiments performed at the facility and that, if possible, the ISOLDE team should be mentioned in the aknowledgements. Experiments that have benefitted from ENSAR funding at ISOLDE should also mention this in the aknowledgements of any articles they publish.

Other practical info

Other recent practical information (alternative accommodation options, accident insurance, free bike and car rental, etc) can be found on our website.

Magdalena Kowalska

HIE-ISOLDE Status

The following status report aims to provide an overview of the HIE-ISOLDE infrastructure modifications, progress on the high beta Quarter Wave Resonant (QWR) cavities and cryomodule production as well as the installation of the HEBT lines.

The installation of the cryogenic station started in the first quarter of 2014. The LHe liquefier has been re-furbished by LINDE and installed in building 199. The compression station, which is installed in building 198, has been repaired and is currently being commissioned. The cryogenic transfer line, which links the cold box and the different interconnecting ("jumper") boxes feeding from the top, the six cryomodules of the new SC linac, is now installed. The entire cryogenic system is to be commissioned by the end of April 2015.

***Fig.1**: Compressor station (top left); ex-ALEPH cold box in place (top right); Cryo Cold Line & Jumper Boxes installed in bldg.170 (bottom).*

The new high-energy beam transfer line (HEBT), that will bring the beam into the existing extension of the ISOLDE experimental hall, is being installed. The XT00 beam line located inside the Linac tunnel has already been commissioned. Installation of the XT01 beam line is in progress.

Fig.2: XT00 line installed and commissioned (top left); details of the installation of the XT01 beam line (top right & bottom).

The HEBT will be extended during a second stage of the installation foreseen during 2017/18 to accommodate a third experimental station and/or to allow for the connection to a storage ring (TSR) [1].
Elements of the HIE-ISOLDE SC Linac are currently being assembled at the SM18 facility.

Fig.3: Elements of the high-beta cryomodule procured in industry (left & centre) and produced at CERN central workshop (right).

Fig.4: Cryomodule Assembly area equipped with specific toolings (CERN-SM18).

Twelve series SC high-beta cavities have been produced so far (2 at CERN and 10 at Research Instruments). Cavity, QS6, was rejected, but we still have enough for equipping cryomodules 1 and 2.

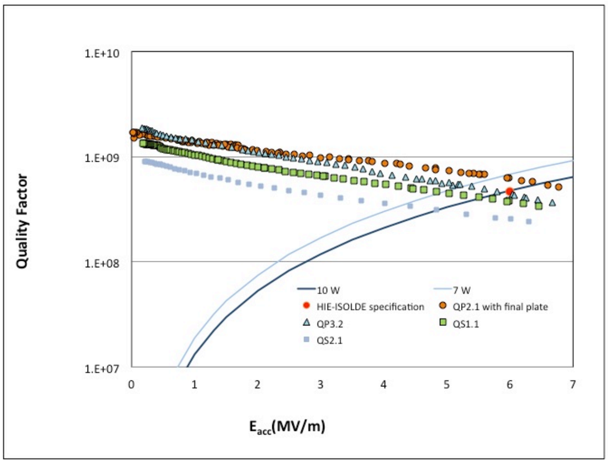

Fig.5: RF Test results (first four series).

The level of performance reached so far is sufficient to start the assembly of the series cavities in CM1, but work will continue in order to secure more margins and cover possible performance losses from the vertical tests to the Linac operation for the remaining cavities.

Fig.6:HIE-ISOLDE Superconducting Solenoid#1 being installaed (left); Final assembly of the first four series cavities (right).

The newly upgraded post-accelerator should be made available by July 2015 in order to provide energies up to 4.3 MeV/u for A/q = 4.5 with only 1 cryomodule. This will be followed by the installation of a second cryomodule during the 2015-2016

Christmas shutdown in order to provide energies up to 5.5 MeV/u for A/q = 4.5.
Following the 2nd HIE-ISOLDE Cost and Schedule Review held on 27-28th October 2014, and considering the firm commitment for funding Phase 1 and Phase 2 by the ISOLDE collaboration, it has been recommended to proceed with the full procurement of the remaining two High-Beta cryomodules. The installation of two additional high-β cryomodules (CM3 and CM4) is needed by 2017 in order to reach nominal beam energies of 10 MeV/u for A/q = 4.5 and provide substantial beam time to ISOLDE physicists before LS2.
In parallel, a lot of effort is being put into preparing the room temperature linac for the commissioning of the SC Linac.

***Fig.7**:REX room temperature linac after refurbishment.*

The hardware commissioning of the XT00 beam line inside the linac tunnel went rather smoothly and by March 12th 2015 all 14 circuits were fully tested and released for operation.

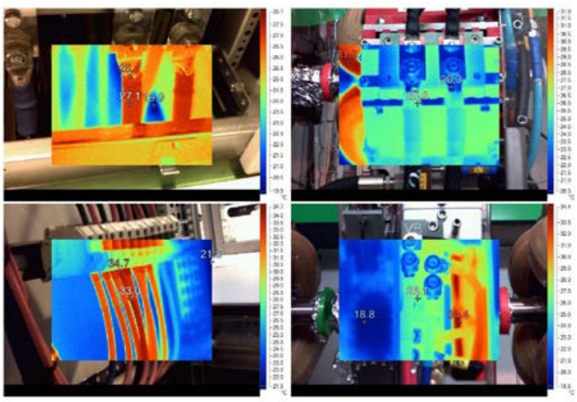

***Fig.8**: IR pictures taken from the 13 hours heat run of the quadrupole and steerer magnets in XT00 line.*

The linac commissioning is foreseen for July 2015 and the first physics should take place early this Fall at 4.3 MeV per nucleon.

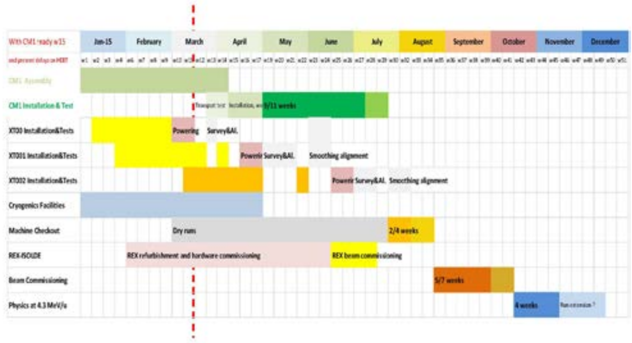

***Fig.9**: HIE-ISOLDE 2015 schedule.*

This brief report summarizes the work of several teams: The ISOLDE Collaboration, the HIE-ISOLDE Project team, and numerous groups at CERN within the accelerator and technology sector.
We acknowledge funding from the Swedish Knut and Alice Wallenberg Foundation (KAW 2005-0121) and from the Belgian Big Science program of the FWO (Research Foundation Flanders) and the Research Council K.U. Leuven.
We would like to particularly acknowledge the tremendous achievements made by our young Researchers within the CATHI Marie Curie Initial Training Network: EU-FP7-PEOPLE-2010-ITN Project number 264330 which came to an end last October 2014.

[1] M. Grieser. et al. Eur. Phys. J. Special Topics 207, 1-117 (2012).

Y. Kadi (for the HIE-ISOLDE Project Team)

Target and Ion Source Developments (TISD)

As reported here, after a long LS 1 shutdown, the TISD activities could restart in 2014 with online tests prepared by extensive offline developments. For 2015 the new team in charge will be composed of Tania Mendonca, Melanie Delonca, Joao Pedro Ramos, WonJoo Hwang, Jochen Ballof, Basil Goncalves and Yisel Martinez. Some of our previous members moved on to other duties; Christoph Seiffert successfully defended his PhD at TUDarmstadt with Prof. T. Kroell, and Alexander Gottberg started at ISAC, TRIUMF as target physicist.

Following the promising results obtained in 2012, a second molten NaF:LiF salt prototype target was built and tested in order to validate the record yields of ^{11}C ($8x10^{8}$ $^{11}CO/\mu C$ [1]) and to systematically study the diffusion coefficient of Ne in this material. Primary focus was therefore given to the release of $^{18,19}Ne$ as a function of the salt temperature up to 760°C. Preliminary analysis validates the previous diffusion constant from 2012 of $6.7x10^{-3}$ mm^2/s [2].

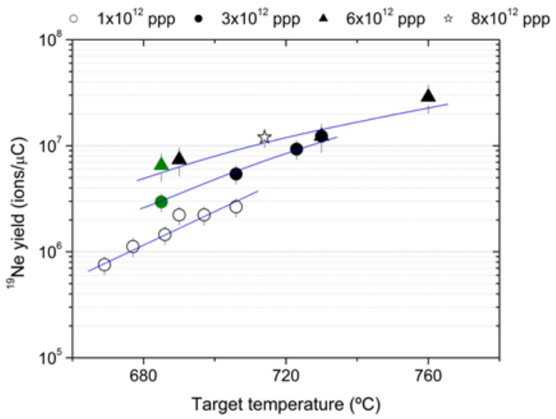

***Fig.1**: ^{19}Ne yield as a function of the target material temperature for different proton beam intensities. The data points highlighted in green have been taken during the 2012 beam time.*

Furthermore, complementary data for ^{19}Ne was obtained (Fig. 1) and an improved intensity of approximately $3x10^{7}$ ions/µC at 760°C was measured, a factor 3 above the best previous yields obtained for oxide targets.

^{11}C beams were also investigated due to their relevance in medical imaging as a PET imaging probe or in hadron therapy replacing stable ions, for solid state physics applications and for astrophysical studies [3]. Values as high as $6.6x10^{8}$ $^{11}CO/\mu C$ have been measured again in 2014, validating the results of 2012 and the applicability of such target materials as an innovative method to produce radiotracers for nuclear imaging and/or treatment.

Within the LIEBE (Liquid eutectic lead-bismuth target loop for EURISOL) project, activities related to the design and offline tests of the lead bismuth (LBE) target loop continued during 2014. Following the first results reported in the previous Newsletter in 2014, a systematic study of the shower formation under vacuum with LBE at 200°C was carried out and promising results were obtained proving the shower feasibility for 0.1 mm diameter grid holes and smallest spacing between holes of 0.5 mm.

The size of droplets was found to be varying with diameters from 0.3 to 0.5 mm in the so-called jetting regime at the start of the shower and from 1 to 1.2 in the case of dripping at the end of the shower. The analysis of the data showed good agreement between theory and experiment [4]. As an important parameter to speed up the release of the radioisotopes, the size of the droplets can be adjusted by controlling the outlet velocity, and smaller droplets can be obtained for velocities higher than 0.62 m/s in the jetting regime. Fig. 2 shows the dripping (top left) and jetting (top right) regimes observed during the shower formation tests. This work is part of the PhD thesis of Melanie Delonca who has joined the team as a fellow this year.

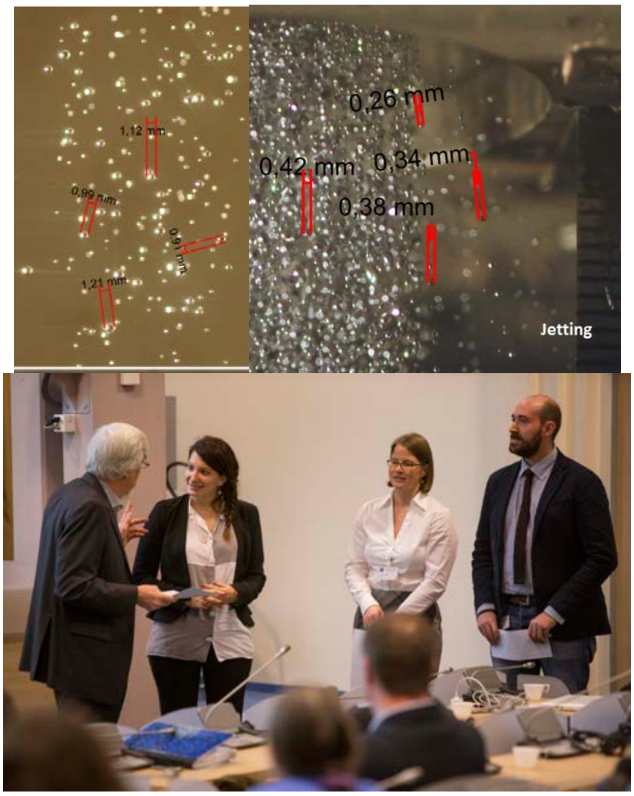

***Fig.2**: Top:Droplet formation regimes: (left) dripping: droplet velocity from 0 to 0.62 m/s and diameter 1.2 mm; (right) jetting: droplet velocity higher then 0.62 m/s and diameter 0.4 mm. Bottom: Best young scientist presentation prize given to M. Delonca at the ISOLDE workshop.*

The ISOLDE nanostructured target materials portfolio has been extended with titanium carbide (TiC) and lanthanum carbide (LaC_2), which have successfully been tested as target for the first time at ISOLDE. Eight different nanocomposites have been synthesized by mixing TiC powder with different carbon allotropes (nanotubes, graphite and carbon black) using an attrition mill and tested at high temperatures (up to 1800°C). Release studies were carried out and the best nanocomposite (TiC + carbon black - 50% vol.) was selected and operated online as a target material. Preliminary results show the production of Li, Na, Al and K isotope beams with very stable yields up to 2000°C. Furthermore, this target was used to provide $1.2x10^6$ $^{37}K/\mu C$ to the IS527 experiment throughout one week of beam time without any signs of degradation. It is, therefore, also important to refer here to ^{31}Ar and ^{35}Ar beams that were extracted from a nanostructured CaO target operated at room temperature. The results on both TiC and CaO nanomaterials are the subject of the PhD thesis of João Pedro Ramos.

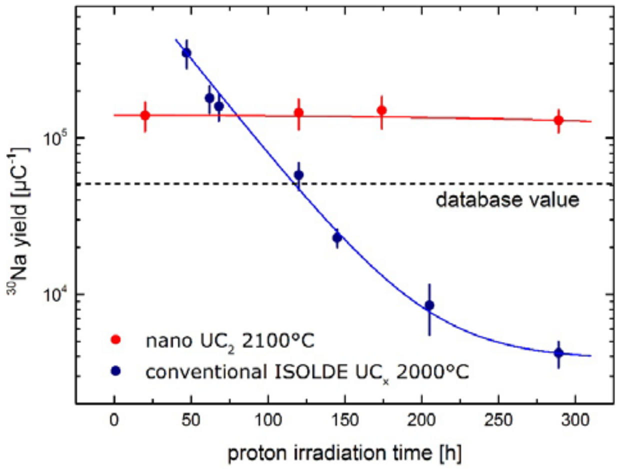

***Fig.3**: ^{30}Na yield as a function of the operation time for the nanostructured UC_2 and the conventional UC_2 material used at ISOLDE. The ISOLDE database value is included in the plot for comparison.*

Within the ENSAR-FP7 joint research activity ACTILAB, a novel nanostructured UC_x target material has been designed, synthesized and tested at ISOLDE. Despite several technical difficulties, a first prototype using this material was tested in 2012 and promising results were already obtained, in particular for ^{11}Be beam production [5]. Following this, a second nanostructured UC_x prototype was tested in 2014, and a systematic characterization of the production and release of several isotopes was performed. For most studied isotopes, the measured yields are higher than the ones exhibited by the conventional ISOLDE UCx target material [6], while the release seems to be much more stable in time, even at high temperatures. In particular, the measured yields for ^{30}Na (shown in Fig.

3), using the nanostructured UC_x target, are stable over time. After some days of operation, the yield for the nanostructured material is orders of magnitude higher than the one exhibited by the conventional material used at ISOLDE. In addition to the isotope yield, its stability and its very low ageing effects, the use of this novel material reduces the actinide waste produced at ISOLDE by more than 50% and reduces the production of secondary particles contributing to the background in the experimental hall and outside of ISOLDE.

[1] T.M. Mendonca et al., Nucl. Instr. Meth. B 329 (2014) 1.
[2] T.M. Mendonca, IPAC Proceedings, CERN-ACC-2014-0183.
[3] T.M. Mendonca et al., CERN-ACC-NOTE-0028.
[4] W. Hoeve et al., Physics Flu. Dyn. (2010); C. Clanet et al., J. Fluid Mech. 383 (1999), 307.
[5] T. Stora, Nucl. Instr. Meth. B 317 (2013) 402
[6] A. Gottberg et al., in preparation.

T.M. Mendonca, M. Delonca, J.P. Ramos, A. Gottberg, T. Stora for the TISD team

The expanding capabilities of the ISOLDE RILIS

The Resonance Ionization Laser Ion Source (RILIS) is the principle ion source at ISOLDE. This is due to its unique combination of chemical selectivity, with an ionization efficiency that can exceed 10% for a number of elements. Equipped with 6 broadly tuneable lasers: three Ti:Sa lasers and three dye lasers, the RILIS excites a series of resonant electronic transitions in the atom of interest, and ionizes through a final step transition to an autoionizing level, or via non-resonant ionization to the continuum. All of the RILIS lasers produce pulsed light at 10 kHz and are pumped by frequency doubled or tripled Nd:YAG lasers. The use of both Ti:Sa and dye lasers, combined with 2ω, 3ω and 4ω frequency conversion, enables continuous spectral coverage between 210 nm and 950 nm [1]. The long shutdown (LS1) provided an opportunity for ionization scheme and ion source development for ISOLDE RILIS, additional upgrades were also made to the general RILIS set up. The results from several of these developments and upgrades are outlined here.

New RILIS elements

RILIS ionization schemes have been developed for Ba, Li, Ge, Hg, Ho, and Cr, bringing the total number of available elements from the ISOLDE RILIS to 34. What is believed to be the first resonance ion-ionization in a hot cavity was demonstrated, creating Ba^{2+} to meet a specific need to eliminate the problem of a surface ionized isobaric background, additional applications of this method are being explored. Further scheme development and efficiency measurements are currently underway.

The Coherent Blaze laser

A non-resonant ionizing step at 532 nm is employed for 62% of the 34 elements currently available from the ISOLDE RILIS. A new 532 nm, 40W, Nd:YVO_4 Lumera Blaze laser has been added to the RILIS laser set-up, the beam quality of this laser, shown in Figure 1, has increased the maximum laser power deliverable to the source by 50%. It is expected that the efficiencies of schemes with a non-resonant final step will increase accordingly [2].

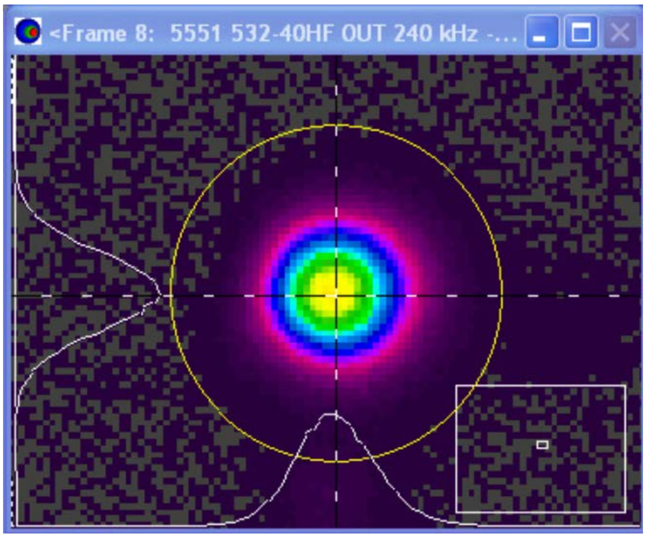

Fig 1. *The beam profile of the Coherent Blaze laser.*

RILIS @ VADIS

Resonance laser ionization inside the anode cavity of the ISOLDE VADIS (Versatile Arc Discharge Ion Source) has been demonstrated. Testing took place off-line using stable gallium and on-line to produce beams of neutron deficient mercury. A “RILIS mode” of operation was identified, operating in an anode voltage regime such that VADIS ionization does not occur and the selectivity of resonance laser ionization is preserved. Developments to explore the potential of joining the two ion source types are ongoing in partnership with EN-STI-RBS, there are three immediate consequences however:

- In-source resonance ionization spectroscopy within the VADIS cavity is now possible. This technique will be applied for the upcoming IS598 in-source laser spectroscopy of mercury experiment [3].
- The ISOLDE RILIS can now be coupled with molten lead targets.
- Switching between RILIS and VADIS ionization modes is a viable option for signal identification or isotope-specific beam purity requirements.

On-call RILIS operation

The addition of a RILIS Machine protection system, coupled with developments towards remote monitoring and control of laser parameters, has enabled on-call operation during runs where stable laser conditions can be established (4). On-call operation was successfully implemented for four runs during the 2014 on-line period.

RILIS websites

The upgraded RILIS website (rilis.web.cern.ch), shown in Figure 2, carries a link to the RILIS status page displaying the wavelengths and beam positions of the RILIS lasers, enabling remote monitoring by both operators and users. A link to the laser ionization scheme database, open to and editable by the community, can also be found on the website in addition to a database of all RILIS publications.

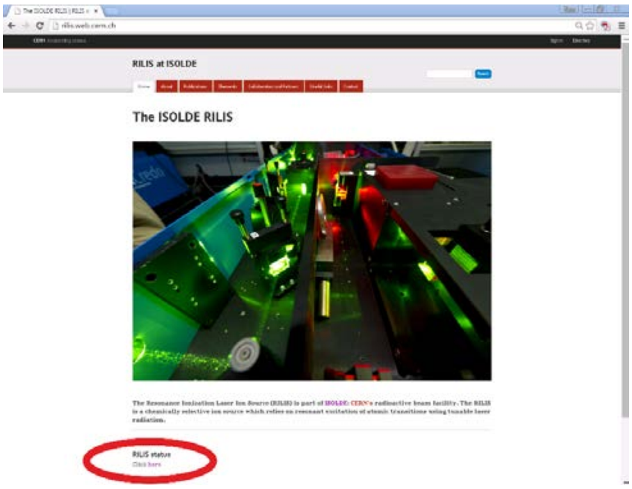

Fig 2. The new RILIS website, the link to the RILIS laser status page is circled in red.

In-source spectroscopy

The RILIS DAQ system has been upgraded and streamlined, automating the links between the RILIS, the Windmill detector system and the ISOLTRAP MR-ToF during in-source laser spectroscopy experiments [4]. This new data sharing infrastructure could be adapted on request to link the RILIS with additional experimental setups. Following the successful 2014 IS534 astatine run, in-source spectroscopy experiments for gold (IS534) and mercury (IS598) isotopes are planned for the on-line period of 2015.

[1] V.N. Fedosseev et al. (2012) Rev. Sci. Instrum. 83, 02A903.
http://dx.doi.org/10.1063/1.3662206
[2] B. Marsh et al. (2013) CERN-ATS-Note-2013-007 TECH.
https://cds.cern.ch/record/1509521/files/Marsh_ATS_note.pdf
[3] L. P. Gaffney et al. (2014) CERN-INTC-2014-060 / INTC-P-424.
https://cds.cern.ch/record/1953719/files/INTC-P-424.pdf
[4] R. E. Rossel et al. (2013) NIM B 317B, pp. 557-560.
http://dx.doi.org/10.1016/j.nimb.2013.05.048

Thomas Day Goodacre on behalf of the RILIS Team

Experiment reports:

IS453: Lattice location of Mg and Be in nitride semiconductors

The second on-line beam time of the EC-SLI (Emission Channeling Short Lived Isotope) collaboration in 2014 used short-lived ^{27}Mg (9.46 min) beams from a specially developed Ti target which combines very high radioactive ^{27}Mg yields with the suppression of stable ^{27}Al and radioactive ^{27}Na contamination in the ion beam. This allowed the measuring of β^--emission channeling effects from the decay of implanted ^{27}Mg with angular resolution twice as good as in our previous experiments on AlN [1]. ^{27}Mg was implanted in GaN of 4 different doping types (undoped, Si-doped *n*-type, Mg-doped *p*-type, Mg-doped but not electrically activated) at temperatures from 20°C up to 800°C and the emission channeling effect of its β^- particles was simultaneously measured using a position-sensitive electron detector. Moreover, in undoped GaN, experiments were also performed for the

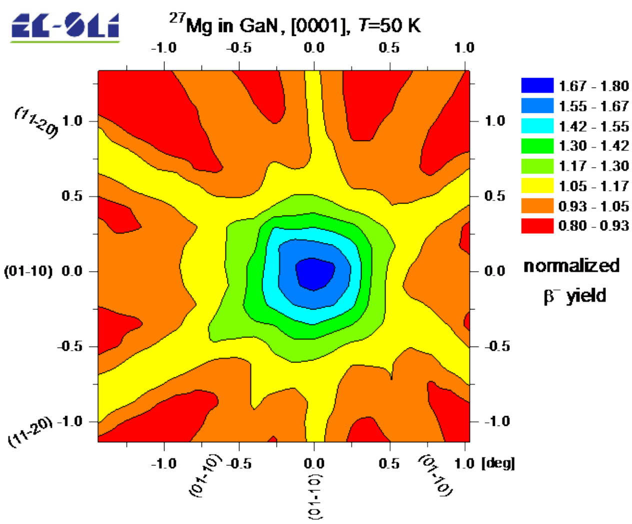

***Fig.1**: Experimental β^--emission yield from ^{27}Mg implanted into GaN at 50 K in the vicinity of the [0001] axis, measured with high angular resolution.*

first time at low temperatures down to 50 K (Fig. 1). The high-angular resolution experiments will allow the determining of the lattice location of implanted Mg on substitutional Ga and interstitial octahedral sites with greater precision than previously.

[1] L.M. Amorim, U. Wahl, L.M.C. Pereira, S. Decoster, D.J. Silva, M.R. da Silva, A. Gottberg, J.G. Correia, K. Temst, A. Vantomme, Appl. Phys. Lett. 103 (2013) 262102.

Ulrich Wahl (for the EC-SLI Collaboration)

IS471: High-resolution collinear resonance ionization spectroscopy of francium isotopes

The CRIS experiment had a successful run in November 2014, measuring the hyperfine structure of ^{206g,206m1,206m2,214,219}Fr. The new results extend our previous CRIS work on the neutron-rich and neutron-deficient francium isotopes [1,2,3]. We have for the first time demonstrated the high-resolution capabilities of CRIS, and the short-lived ^{214}Fr ($t_{1/2}$ = 5 ms) results confirmed the technique's ability to push laser spectroscopy to more exotic species.

The high resolution was achieved using a new method that was developed by the CRIS team at ISOLDE over the past two years. This new method combines the excellent spectral resolution of a continuous wave laser system with some of the advantages offered by a pulsed laser system - namely the minimal optical pumping effects and the ability to delay laser pulses to minimize power broadening or other unwanted effects [4]. Optimizations performed on ^{221}Fr resulted in a reduction of the experimental linewidth by two orders of magnitude (see Fig. 1 for a comparison of the high resolution measurements and the results obtained at CRIS in 2012.).

This excellent resolution and efficiency made it possible to resolve the full hyperfine structure of ^{219,206g,206m1,206m2}Fr. These measurements have enabled us to extract for the first time the electrical quadrupole moment of ^{219}Fr, as well as the quadrupole moments of ^{206m1,206m2}Fr.

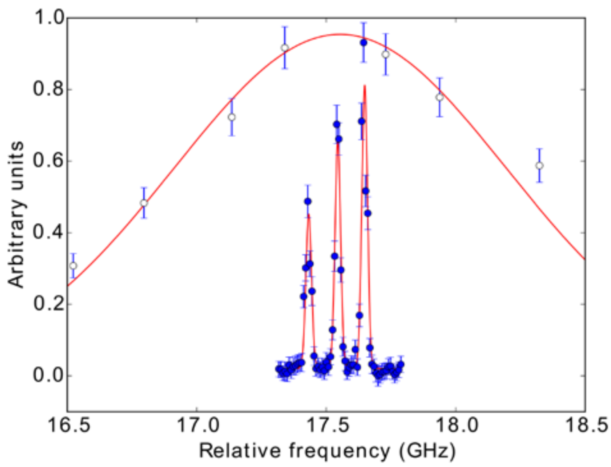

***Fig.1**: Example of a high-resolution spectrum of ^{221}Fr (full symbols), shown underneath a spectrum obtained in 2012 (open symbols). A linewidth of 20 MHz was obtained.*

^{214}Fr is an interesting isotope to study since it has one additional neutron outside of the N=126 shell. The hyperfine structure of this short-lived isotope was investigated with low resolution using the RILIS pulsed laser system and the CRIS technique. As far as we know, ^{214}Fr ($t_{1/2}$ = 5 ms) is the shortest-lived nucleus to have been studied with laser spectroscopy in an online experiment. From the measurements, the magnetic dipole moment and charge radii could be extracted.

These promising results have paved the way for future high-resolution research at CRIS. The addition of a new CRIS laser lab in building 508 will be essential in extending the new high-resolution method to other atomic systems and will allow CRIS to continue pushing laser spectroscopy to more exotic isotopes across the nuclear chart.

[1] I. Budincevic et al., PRC **90**, 014317 (2014)
[2] K.M. Lynch et al., PRX **4**, 011055
[3] K. T. Flanagan et al., PRL **111**, 212501
[4] R.P. de Groote et al., Masters Thesis KU Leuven and article in preparation

Ruben de Groote for the CRIS collaboration

IS484: Direct measurement of the isomer shift in ^{38}K

An experimental campaign aiming at studying the nuclear structure of K isotopes using high-resolution collinear laser spectroscopy on a bunched-beam yielded compelling results considering ground-state spins, magnetic moments and nuclear charge radii. These results were published in Ref. [1-3].

In addition, a direct measurement of the isomer shift in ^{38}K was performed for the first time, by observing the hyperfine spectra of the ground and isomeric state simultaneously (Fig. 1). This allowed us to extract the difference in mean-square charge radii between these two long-lived states. It was found that the mean-square charge radius of the isomeric state is larger by 0.100(6) fm^2 than the ground state. Our result contradicts the conclusion based on an indirect measurement [4], claiming that these two states have similar nuclear charge radii.

The ^{38}K isotope is a self-conjugated nucleus with Z = N = 19 and in the shell-model framework, its nuclear structure can be described with a single hole in the proton and neutron 1d$_{3/2}$ orbit.

From the comparison of the difference in mean-square charge radii between neighbouring isotopes (N = 18, 19 and 20), it was shown that the value for the isomeric state in ^{38}K is larger than the typical odd-even staggering. Additionally, comparing

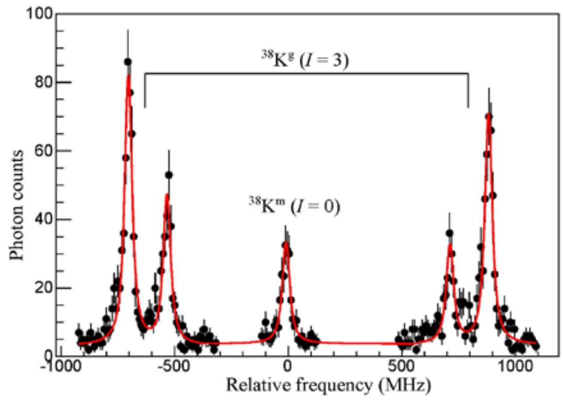

***Fig.1**: Hyperfine spectra for two states in ^{38}K shown relative to the centroid of the ground state. Four peaks are obtained for the ground-state with I = 3, while the single peak in the middel belongs to the isomeric state with I = 0.*

the difference in mean-square charge radii of neighbouring Z = N isotopes, in particular ^{36}Ar, ^{38}K and ^{40}Ca, showed that the radius of the isomeric state lies on the trend-line of both even-even isotopes.

Intuitively this could be explained by the proton-neutron pair which in the anti-parallel spin coupling (I = 0; isomeric state) scatters into the upper orbits much easier than the pair with the parallel coupled proton and neutron spin (I = 3; ground state). The larger scatter into orbits induces a larger nuclear charge radius for the I = 0 state.

The experimental results were compared to shell-model calculations where the excitations across Z = N = 20 were included. Based on the occupation of the proton 0f$_{7/2}$ and 1p$_{3/2}$ orbits, it was confirmed that these excitations are crucial for explaining the significantly larger mean-square charge radius of the isomeric state.

These results were recently published in Ref. [5].

[1] J. Papuga *et al.*, Phys. Rev. Lett. 110, 172503 (2013)
[2] K. Kreim *et al.*, Phys. Lett. B 731, 97 (2014)

[3] J. Papuga *et al.*, Phys. Rev. C 90, 034321 (2014)
[4] J. A. Behr *et al.*, Phys. Rev. Lett. 79, 375 (1997)
[5] M. L. Bissell *et al.*, Phys. Rev. Lett. 113, 052502 (2014)

Jasna Papuga (for the Collaps Collaboration)

IS487: Local symmetry lowering in $CdMn_2O_4$ spinel

The $CdMn_2O_4$ crystal structure can be described as a distorted tetragonal spinel with only diamagnetic cations (Cd^{2+}) on tetrahedral A sites and magnetic Mn^{3+} cations on the distorted octahedrally coordinated B sites (normal spinel). The tetragonal distortions are caused by the Jahn-Teller (JT) instability of the Mn^{3+} (d^4) ions. An atomic scale study of the electric field gradient (EFG) in the tetragonally distorted $CdMn_2O_4$ spinel manganite was

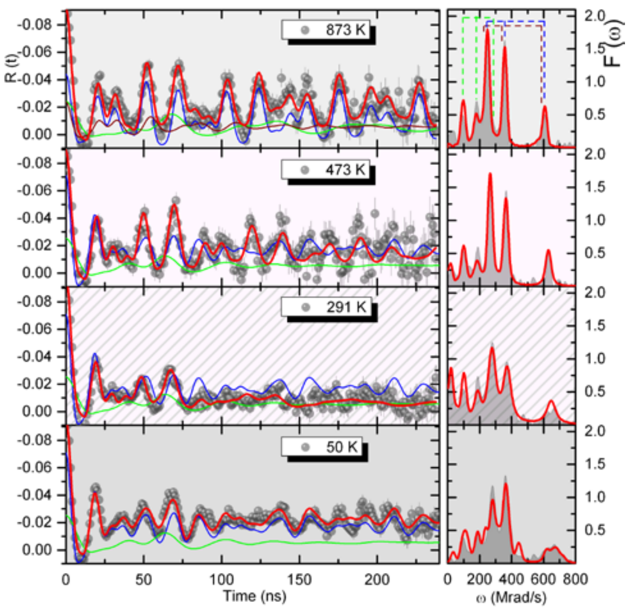

Fig.1: Representative R(t) functions, corresponding fits (Partial fits, corresponding to each individual EFG, are represented in blue and green and the sum in red) and respective Fourier transform taken at different temperatures using the ^{111}Cd probe.

performed. The EFG temperature dependence at the Cd and Mn sites was followed via perturbed angular correlation measurements with the ^{111}In and ^{111m}Cd probes, from 873 down to 12 K at Isolde-CERN (see Fig.1).

The EFG measurements at the Cd and Mn sites in the 12–600 K temperature region clearly demonstrate that a single Jahn-Teller distorted local phase, compatible with the long-range tetragonal average structure, exists. Above the magnetic phase transition, T>100K, and up to 600K, a dynamic lattice distortion, related with a local structural instability, is observed (see Fig.2).

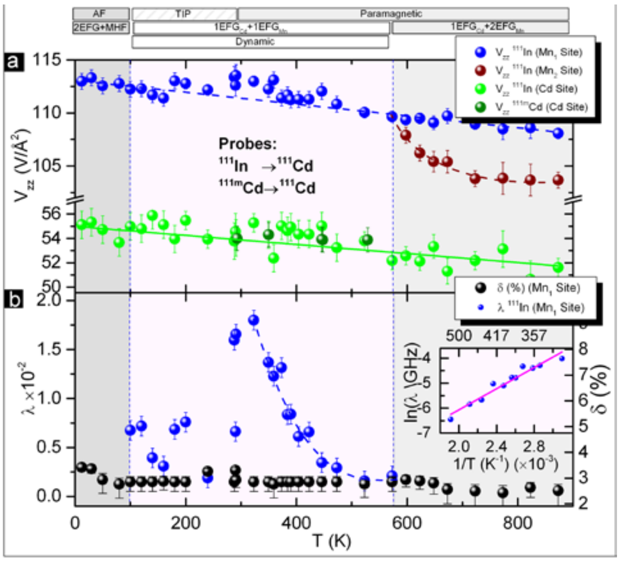

Fig.2: a) Experimental EFG principal component (dots). The continuous lines represent a least-squares fit of the function $V_{zz}(T) = V_{zz}(0)[1 + \alpha T^{\kappa}]$ to the data points. b: Dynamic (left scale) and static (right scale) attenuation parameters of EFG_1^{Mn}. (inset) Natural logarithm of the dynamic attenuation parameter of EFG_1^{Mn}.

In the high temperature region, i.e., above 600 K, a second EFG emerges along with the reciprocal magnetic susceptibility curve slope change. The existence of local inhomogeneities within the tetragonal matrix, also signed by the magnetic anomaly, is however not followed by a tetragonal to cubic crystallographic phase transition. Instead, a phase segregation in two distinct Jahn-Teller distorted local phases was found. In this high temperature region, a relaxed Jahn-Teller distorted octahedral phase grows in the low temperature tetragonal matrix.

[1] Oliveira, G. N. P., et al (2014). J. Appl. Phys., 116(22), 223907.doi:10.1063/1.4903949.

G.N.P. Oliveira (IS487)

IS501, IS576 & IS578: News from the Mössbauer collaboration

2014 was a very good year for the Mössbauer collaboration at ISOLDE/CERN. Interest in emission Mössbauer spectroscopy is increasing, and we started working on two new experiments; IS576 where we investigate the effects of Mn doping in (AlGa)N semiconductors, and IS578 where we investigate magnetism in manganese alloys, in new collaborations with Russia, Spain, China, and Austria.

We hosted a workshop at CERN prior to the 2014 Mn/In beam-time in September, attended by more than 20 participants. Results obtained from previous experiments and detailed plans for the beam-time were discussed. Professor Tomaz Dietl, a distinguished speaker, gave an invited talk on the state-of-the-art of dilute magnetism.

***Fig.1**: Participants of the workshop held in preparation of the 2014 Mn/In beamtime.*

On the educational front, Hilary Masenda graduated with his PhD in 2014 from the University of the Witwatersrand (WITS), entitled "Are Fe and Co implanted ZnO and III-nitride semiconductors magnetic?". Hilary has now started as a Lecturer in the School of Physics at WITS, and we congratulate him on this success.

Torben Esmann Mølholt, who defended his PhD thesis "Paramagnetism in ion-implanted oxides" at the University of Iceland in 2012, started a Fellowship at ISOLDE as the VITO coordinator in February 2015.

H. P. Gunnlaugsson, the group leader of the Mössbauer collaboration, is spending 2015 at ISOLDE as a Scientific Associate.

Many exciting results were obtained during 2014 and it would be overkill to mention them all here. One of the more fascinating discoveries was on the lattice site of In – a possible p-type dopant – in diamond. Some of the spectra obtained are shown in Fig. 2.

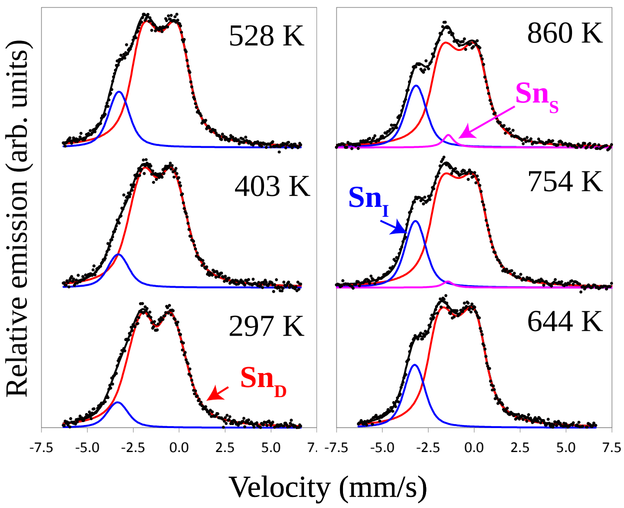

***Fig.2**: ^{119}Sn emission Mössbauer spectra obtained after implantation of ^{119}In ($t_{½}$ = 2.4 min.) into CVD diamond sample held at the temperatures indicated.*

At room temperature, In enters amorphous sites due to the implantation damage (Sn$_D$), and (presumably) interstitial sites (Sn$_I$). Only above 800 K, are there definite signs that In begins to enter substitutional sites (Sn_S) during its 2.4 minute lifetime. These results show that the implantation of In at sufficiently high temperatures is a possible method for its incorporation at substitutional sites in diamond.

Haraldur P. Gunnlaugsson (for the Mössbauer Collaboration at ISOLDE/CERN)

IS515, IS602 and the VITO-collaboration: The new PAC Probe ^{68m}Cu/^{68}Cu measured on the new VITO beamline

In the search for a suitable Cu isotope to study hyperfine interactions with the Perturbed Angular Correlation (PAC) technique, last December we tested the short-lived ^{68m}Cu ($T_{1/2}$ = 3.75 min). ^{68m}Cu ion-implantation of several samples was performed at the central end-station of the new VITO (Versatile Ion-polarized Techniques On-line) beamline intended for traveling setups. The PAC measurements were performed online using the 7.8 ns half-life, 84 keV 2^+ intermediate state of ^{68m}Cu. The sample holder was mounted inside a quartz finger collection chamber (see Fig.1).

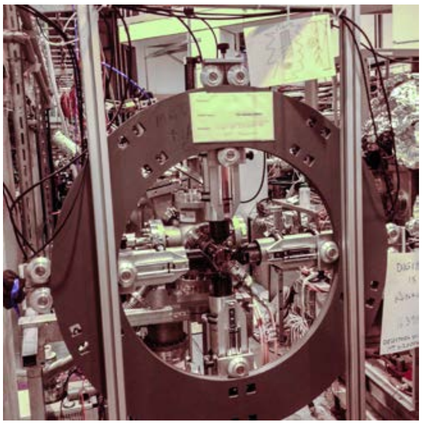

Fig. 1: *The setup of the four $LaBr_3$ gamma detectors around the sample.*

Using four $LaBr_3$ gamma detectors with high energy and time resolution the appropriate cascade was resolved leading to the first ever PAC experiment on the ^{68m}Cu isotope. In the measured PAC spectra both the magnetic (in Cobalt and Nickel foil samples) and electrical quadrupole interactions (in Cu_2O pellet sample) were clearly identified. Consequently, we managed to prove the feasibility of using the ^{68m}Cu isotope as a PAC probe for studying hyperfine interactions.

The data analysis is still in progress and the results will be compared with the expected values from simulations. A publication on the results from the first ^{68m}Cu/^{68}Cu measured PAC time spectra is soon to be submitted.

Measurements took place during 1.5 shifts of beamtime at the new VITO beamline (Fig. 2), which is a modification of the existing UHV line. This was also the first beamtime for VITO, and the careful beam alignment proved fruitful, as 96% transmission was achieved in only ~6 h of ^{27}Al stable beam. The beam tuning was performed both manually and automatically. The VITO beam line is now a big step closer to the new experiments, which have been planned. The next steps will be to connect

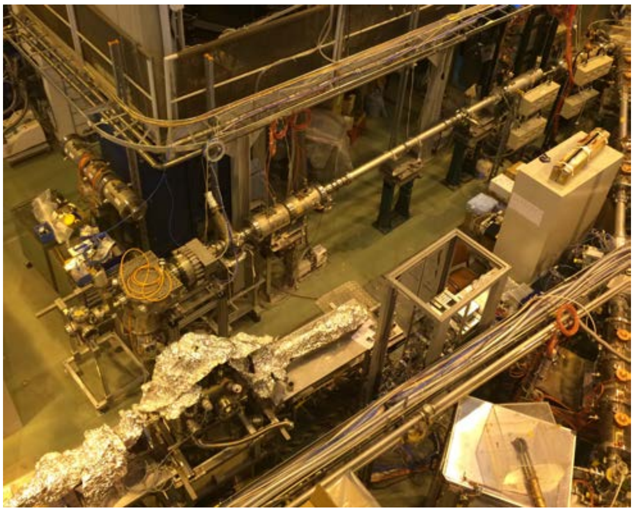

Fig. 2: *The VITO beamline with its three end stations.*

and commission the ASPIC chamber for UHV solid-state surface and interface physics, and to install a polarization system and a β-NMR chamber for biophysics studies.

On behalf of the VITO Collaboration, A. Fenta and S. Pallada (IS515 and IS602)

IS519: Laser spectroscopy of Zn

In December 2014, isotopes of zinc were studied using collinear laser spectroscopy at COLLAPS. Optical spectra were measured for the ground states of $^{62-80}$Zn, and the isomeric states of odd–A isotopes $^{69-79}$Zn. This has unequivocally confirmed the existence of an isomeric state in ^{79}Zn, only recently proposed [1].
For each state, the high resolution, high statistics data obtained provide model independent measurements of the nuclear spin, magnetic dipole and electric quadrupole moments, and changes in mean-square charge radii. Unambiguous assignments of the ground and isomeric nuclear spins alone enable assignments to be carried to higher lying levels, studied via decay spectroscopy techniques.
State of the art shell model calculations (with a ^{56}Ni core) are currently being employed in order to understand a region rich in level migrations [2]. The nuclear moments are a particularly sensitive probe of the nuclear wave function, and will be analysed up to the N=50 shell closure. However, it is already clear that an extension of the model spaces used by current shell model interactions will be required for the heavier isotopes.
Mean-square charge radii measurements, reflecting changes in nuclear size and shape, typically display a characteristic upward 'kink' when crossing a shell closure. The isotopes studied cross the interesting region of N=40, where effects normally associated with shell closure (such as low B(E2) values and high 2^+ energies) are observed in nickel. Such an effect, but a very subtle one, is in fact observed in the charge radii of the gallium isotopes, immediately above zinc. It is reasonable to assume that the magnitude of this effect will be seen to increase as Z=28 is approached.
The evaluation of the mean-square charge radii of the Cu and Ga isotopic chains [3] relies on MCDF (Multi-Configuration Dirac-Fock) calculations of two atomic factors. In the case of Zn however, the higher number of stable isotopes permits a more reliable calibration of these factors using existing non-optical data.

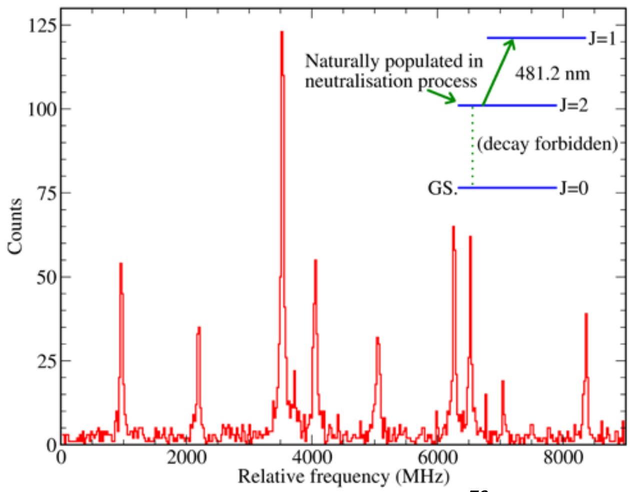

***Fig.1**: Optical spectrum of the ^{79}Zn ground state and isomer state.*

These results demonstrate the successful re-commissioning of the COLLAPS beam line following the long shutdown. An upgrade to the data acquisition system was developed and used which readily enables the dependence of the yield and resonant signal to be studied as a function of time since the proton impact. This can permit an offline analysis of the optimal signal-to-noise ratio, and in the case of simultaneous measurements of ground and isomeric states, tagging of the hyperfine structure with the half-life.

[1] R. Orlandi *et al.* Phys. Lett. B 740 298 (2015).
[2] B. Cheal *et al*. Phys. Rev. Lett. 104 252502 (2010).
[3] T.J. Procter *et al*. Phys. Rev. C 86 034329 (2012).

Bradley Cheal, Calvin Wraith, Xiaofei Yang and Liang Xie
(for the COLLAPS Collaboration)

IS521: New tape system

New traveling setup, the TATRA tape transportation system, has been successfully used for dedicated beta-decay study of neutron-deficient Hg isotopes at the LA1 beamline. The system has been designed at the Institute of Physics, Slovak Academy of Sciences in Bratislava. It uses metallic tape prepared by rapid quenching of an alloy for transportation of the activity from irradiation point to detector station. Rapid quenching produces amorphous material, which has excellent mechanical properties for such purpose. The tape cannot be stretched or broken with the small stepper motor. Its properties are very stable during operation, it does not undergo corrosion. It keeps metallic properties and can be used in a high (possibly also in ultra-high) vacuum environment.
The tape welded to form an endless loop is carried by a single reel, similar to the design of historical 8-track magnetic tapes used in the past for music recording. This concept was widely used at the UNISOR facility at Oak Ridge National Laboratory [1]. To ensure proper operation, composition of an alloy has been specifically selected to keep the surface of the tape slippery enough, similar to original 8-track tapes. Such design allowed only one stepper motor to be used making the control system very simple.
The tape is completely insulated from the rest of the system allowing direct beam current measurement. This, together with the segmented Faraday cup at the entrance makes beam tuning very easy.
During the IS521 experiment, the TATRA operated very well. Excellent decay data for $^{181,183,185,187,189}Hg$ were collected. Broad energy germanium detector, which provided excellent energy resolution, has been used [2]. The data clearly suggest this type of germanium detector as the most promising one for future beta decay studies of odd-mass isotopes [3].
Presently, the TATRA system undergoes major modifications. A powerful pumping system has been added and inner installations are being redesigned in order to improve the vacuum.
The measurement station has been replaced with an aluminum chamber designed by the Atlas Technologies company. State-of-the-art bimetalic ConFlat® flanges are used, that allow the use of copper seals between stainless steel and aluminum parts. Windows of the chamber are made of titanium foils with a thickness of 50 microns, significantly improving the transmission of low-energy gamma rays. These foils are attached to the chamber with unique ConFlat® flanges and sealed with copper gaskets.

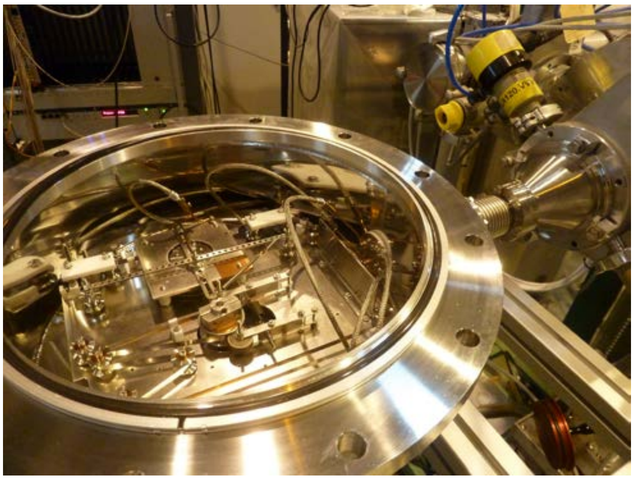

Fig.1*: The TATRA tape transporting system installed at the LA1 beam line in August 2014*

[1] R. L. Mlekodaj *et al.*, Nucl. Instrum. and Methods in Phys. Res. **186**, 239 (1981).
[2] L. J. Harkness-Brennan *et al.*, Nucl. Instrum. Meth, Sect. A **760**, 28 (2014).
[3] M. Venhart *et al.*, in preparation.

Martin Venhart for the IS521 collaboration

IS527: High-precision efficiency calibration of a HP-Ge detector

High-precision measurements of nuclear β-decay characteristics of the super-allowed $0^+ \rightarrow 0^+$ type and β-decay mirror transitions allow the vector coupling constant of the weak interaction to be determined and, from this coupling constant, the V_{ud} element of the Cabibbo-Kobayashi-Maskawa quark mixing matrix can be found. For this purpose, the half-life, the super-allowed branching ratio, and the decay Q value have to be measured with a precision of the order of 10^{-3}. In the case of mirror transitions, the Gamow-Teller to Fermi ratio has to be measured in addition.

In order to measure the branching ratios with this precision, we have calibrated in efficiency a single-crystal, n-type, high-purity germanium detector (70% relative efficiency). We performed an X-ray photography of the detector, scanned the detector crystal with a highly collimated ^{137}Cs source at CSNSM Orsay, measured the relative detection efficiency with 14 different sources, some of which were produced online at ISOLDE, determined the peak-to-total ratio with 10 other sources (some also produced at ISOLDE), and finally measured the absolute efficiency with a ^{60}Co source calibrated in activity below the 0.1% level. These experimental measurements allowed a detector model for Monte-Carlo simulations to be produced which exactly reproduces the experimental measurements [1].

Fig. 1 shows a comparison of the experimental data from a scan along the detector axis with the simulations. For the full-energy peak as well as for the total spectrum excellent agreement is obtained.

Fig. 2 shows the results from the source measurements as the difference between experiment and simulations normalized to measurement. The dotted lines indicate the final precision adopted below and above 100keV γ-ray energy. To achieve this precision it was essential to use sources with a large variety of γ-ray energies and well-known branching ratios.

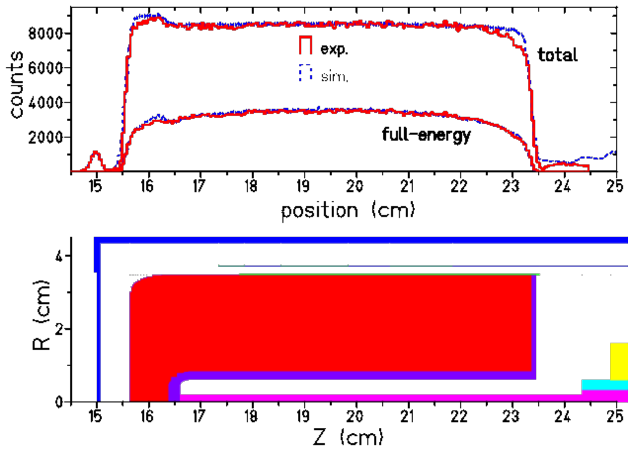

***Fig.1**: Scan with a collimated ^{137}Cs source along the detector axis. Experiment and Monte-Carlo simulations are compared for the full-energy peak and the total spectrum. The lower part shows the detector model.*

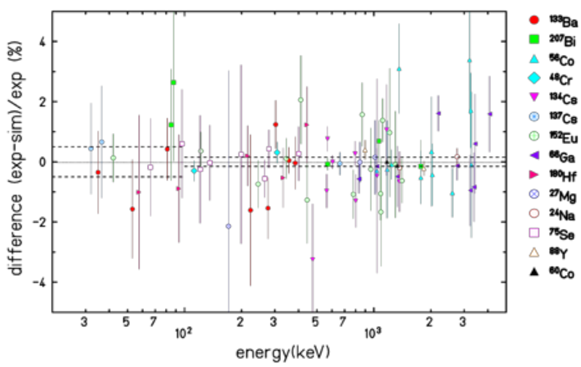

***Fig.2**: Comparison between experimental results and simulations for a large variety of sources. The lines give the adopted precision.*

Similar work was also completed with relatively simple sources having ideally only one γ ray to determine the peak-to-total ratio. These measurements allowed the modeling of the environment around the detector as precisely as necessary.
The detector was recently used to measure the β decay branching ratios of ^{37}K at ISOLDE.

[1] B. Blank et al., NIMA 776 (2015) 34

Bertram Blank (CEN Bordeaux-Gradignan)

IS532: Probing the *N* = 32 shell strength with mass spectrometry

Mass measurements and the elaboration of nuclear-shell structure continue a long association. In last year's newsletter [1], we reported on the use of ISOLTRAP's ancillary MR-ToF mass spectrometer to study ^{52}Ca, which could be considered a doubly magic nuclide [2]. We have continued these studies by probing below the closed Z = 20 shell and measuring the mass of ^{53}K.
The special trait of the N = 32 shell was first highlighted with spectroscopy work (including β-delayed neutrons) [3] by the renowned Strasbourg group at ISOLDE, during the SC era. Not only did they (tentatively) propose the key 2^+-state energy, they also provided a wealth of data, including Q-values of decays from K to the daughter isobars of Ca, Sc and Ti.
Isobaric contamination is usually the scourge of trapped-ion mass spectrometry. For this reason, ISOLTRAP introduced the multi-reflection time-of-flight (MR-ToF) mass separator [4]. For the calcium measurements [2], the alkali potassium ions were stowaways inside the MR-ToF. Unlike in the Penning trap, where single measured ions are present by invitation only and reference scans are made periodically during data taking, the MR-ToF uses simultaneous calibration of isobars that have come along for the ride. Thus, these additional passengers can also have their masses measured while on board. ^{52}K and ^{53}K were measured this way, offering a first glimpse of nuclear structure for N = 32 below Z = 20. (This work, including new results from *ab initio* calculations, has been submitted for publication [5].)
Shell effects are easily seen on the mass surface using two-neutron-separation (S_{2n}) energies. The difference in S_{2n} at and two neutrons after a shell is one way of estimating relative shell strength (although demanding, since the price paid going two neutrons farther can be two orders of magnitude in production).
Fig. 1 shows such empirical neutron-shell gaps for N = 20, 32, and 50. The case of N = 20 is the showcase for shell quenching, as seen by the drop of the shell gap for Z < 14. The N = 50 case, for which the most exotic data was provided by the ISOLTRAP mass measurement for ^{82}Zn [6], shows a slight – if difficult – tendency to stabilize towards the iconic nuclide ^{78}Ni. Between these cases, N = 32 shows a

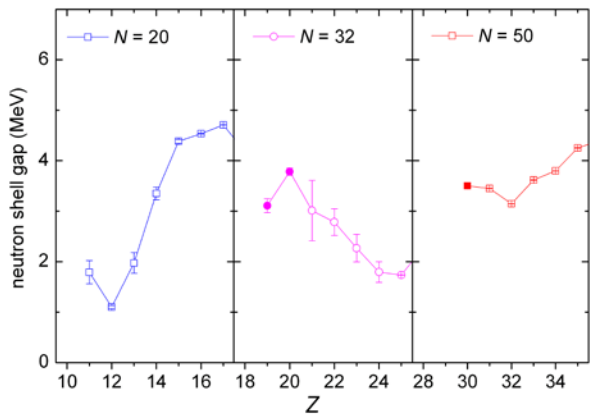

***Fig.1**: Neutron-shell gaps for N = 20, 32, and 50 versus Z (for neutron-rich nuclides). Mass values are taken from the AME2012 [10] (empty symbols) and recent ISOLTRAP measurements (full symbols) of K [5], Ca [2] and Zn [6].*

steady rise up to Ca, for which a local maximum is nicely highlighted by the new ISOLTRAP data for K [5].

While the original spectroscopy data [3] first suggested the doubly-magic nature of ^{52}Ca, nothing could be said about how local this effect might be. This is not only because there is no 2^+ level in the odd-Z ^{51}K but also because of the relatively large uncertainties of the Q_β values.

The recent Penning-trap measurement of the ^{52}Ca mass using TITAN [7] behoves us to examine some of this illustrious history. In the 2003 Atomic-Mass Evaluation [8], two results were relevant for the mass of ^{52}Ca: a time-of-flight mass measurement using the TOFI spectrometer [9] and the ISOLDE Q_β reported in [3]. Using the ^{52}Sc mass also published by TOFI, the ^{52}Ca mass obtained from the Q_β value differed by 10σ with respect to the TOFI mass! Despite its larger uncertainty, the evaluators chose the TOFI mass. In the 2012 AME [10], the more precise TITAN measurement [7] accounted for 95% of the ^{52}Ca-mass influence with the remaining 5% coming from the maligned Q_β value, which turned out to be correct after all! (The point is moot now since the superior precision of the recent ISOLTRAP Penning-trap result [2] has obliterated the others' influence.)

The uncertainties shown in Fig. 1 illustrate the need for relatively good precision: the local maximum for ^{52}Ca is a mere 1 MeV above the value for ^{51}K, meaning that a 1% uncertainty on the shell gap requires mass measurements of better than 10^{-6} relative precision. This is not the case for ^{53}Sc (also measured by TOFI), which was among the measurements proposed in the second Addendum to IS532 [11]. An experiment ran during 2014 but no scandium isotopes were seen, despite a successful RILIS ionization scheme tested offline (although stable ^{45}Sc was seen as an oxide). A more accurate mass of ^{53}Sc would also give the proton gap, which is very important for the adjustment of interaction parameters for shell-model calculations. We hope to clarify these issues in the near future.

[1] F. Wienholtz, ISOLDE newsletter, Spring (2014) p. 29.
[2] F. Wienholtz et al., Nature 498, 346 (2013).
[3] A. Huck et al., Phy. Rev. C 31, 2226 (1985).
[4] R.N. Wolf et al., Int. J. Mass Spectrom. 349, 123 (2014).
[5] M. Rosenbusch et al., Phys. Rev. Lett. (2015) in revision.
[6] R.N. Wolf et al., Phys. Rev. Lett. 110, 041101 (2013).
[7] A.T. Gallant et al., Phys. Rev. Lett. 109, 032506 (2012).
[8] G. Audi, A.H. Wapstra and C. Thibault, Nucl. Phys. A 729, 337 (2003).
[9] X.L. Tu et al., Z. Phys. A 337, 361 (1990).
[10] M. Wang et al., Chin. Phys. C 36, 1603 (2012)
[11] S. Kreim et al., CERN-INTC-2014-024 / INTC-P-317-ADD-1.

D. Lunney (for the ISOLTRAP Collaboration)

IS577: Multi-particle emission from ^{31}Ar at IDS (analysis is on-going)

In the beta decay of exotic nuclei, far from stability, the daughter nuclei might be left in an excited state, which is unstable against particle emission. This phenomenon is called β-delayed particle emission and is due to the high Q-value and low separation energy for particle emission. The decay of the proton drip-line nucleus ^{31}Ar has as a consequence many different β-delayed decay channels: βγ, βp, βpγ, β2p, β2pγ, β3p and perhaps also β3pγ [1].

The aim of the IS577 experiment performed last October at the ISOLDE Decay Station (IDS) was the identification of the β3p-channel from ^{31}Ar as well as to provide important information on excited states in

^{30}S and ^{29}P, relevant for the astrophysical rp-process [2].
The IDS is a new installation at ISOLDE devoted to β-decay measurements. Our collaboration installed a new detection chamber; the *MAGISOL Si-Plugin Chamber,* consisting of 5 Double Sided Si Strip Detectors (DSSSD) backed by un-segmented Si-pad detectors in ΔE-E telescope configuration having high efficiency for the detection of multi-particle emission. This Si-array (Fig.1) detects multi proton emission over a wide energy range with the good energy (25 KeV) and angular (3^{O}) resolution that are needed to characterize the different p-channels of ^{31}Ar. A proton spectrum from one of the DSSSDs is shown in Fig.2.
The IDS station also includes 4 HPGe clover-detectors surrounding the chamber for high gamma ray detection efficiency. Gamma rays from the decay of ^{16}N and ^{15}C were observed indicating the presence of N_2H and CO molecules on mass 31 from the

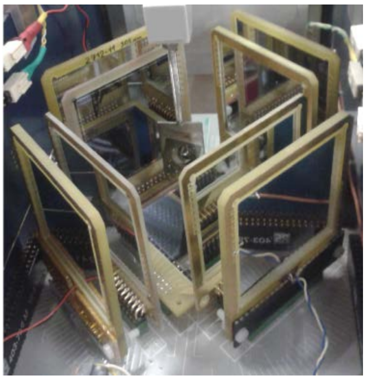

Fig.1: *Charged particle detector setup. The beam was collected in a carbon foil located at the middle of the detector setup.*

CaO target which was operated at an unusual low temperature of ~500ºC. It should be stressed that the ^{31}Ar yield of 1-2 atoms/μC was stable over the 7 days of the experiment. This value remained in spite of a significant power cut on the Meyrin site affecting all systems at ISOLDE.

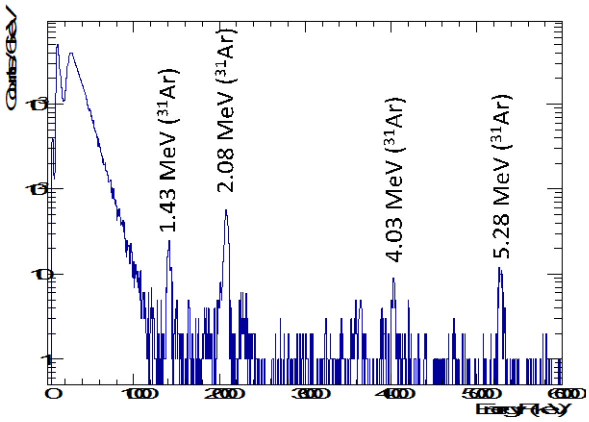

Fig.2: *β-delayed proton spectrum from ^{31}Ar (only small part of the data recorded is shown). Several proton lines from the decay are observed.*

[1] Proposal to the ISOLDE and Neutron ToF Committee, INTC-P-386, September 2013
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Irene Marroquín Alonso, IEM-CSIC (for the MAGISOL Collaboration)

IS580: Emission Channeling with Short-Lived Isotopes (EC-SLI): lattice location of impurities in semiconductors and oxides

(Ga,Mn)As has become the model system, in which to explore the physics of carrier-mediated ferromagnetism in semiconductors and the associated spintronic phenomena. In particular, as the most widely studied dilute magnetic semiconductor (DMS), (Ga,Mn)As is the perfect example of how the magnetic behavior of DMS materials is strongly influenced by local structure. In typical high Curie temperature (Ga,Mn)As thin films (several % Mn regime), the majority of the Mn atoms substitute for Ga (Mn_S), while a minority fraction (several % of all Mn) occupies interstitial sites (Mn_i). Mn_S provides both the localized magnetic moment and the itinerant hole that mediates the magnetic coupling, whereas Mn_i has a twofold compensating effect: (i) magnetically, as Mn_i-Mn_S pairs couple antiferromagnetically and (ii) electrically, since double donor Mn_i compensates Mn_S acceptors.

Following the restart of the ISOLDE facility after the 2013 shutdown, we used the radioactive isotope ^{56}Mn (2.5 h) for on-line β^--Emission Channeling experiments with Short-Lived Isotopes (EC-SLI). We studied the lattice location of the implanted magnetic dopant ^{56}Mn as a function of annealing temperature in a number of Ga-based compound semiconductors, including *p*-type GaN:Mg and *n*-type GaN:Si, GaP, GaSb, and ferromagnetic (Ga,Mn)As. Among the highlights is the first use for EC-SLI experiments of a $Ga_{0.94}Mn_{0.06}As$ thin film DMS sample produced by *ion implantation and pulsed laser melting* (PLM) at HZDR Dresden-Rossendorf (Fig. 1).

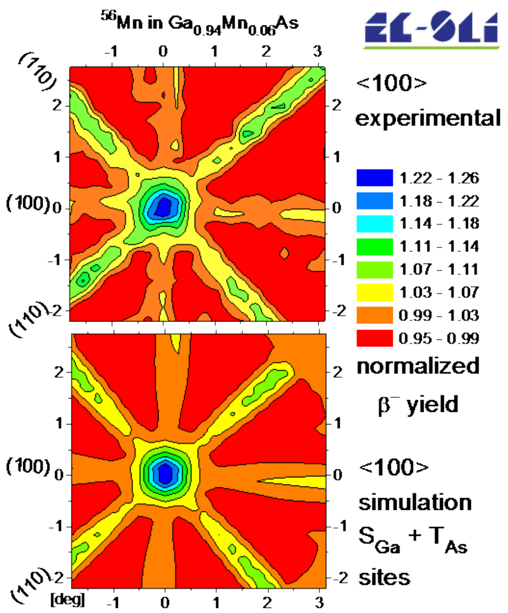

***Fig. 1**: Comparison of experimental β^--emission yield from ^{56}Mn in ferromagnetic $Ga_{0.94}Mn_{0.06}As$ to the theoretical pattern expected for a mixture of emitter atoms on substitutional Ga (S_{Ga}) and interstitial sites with As nearest neighbours(T_{As}).*

This latter experiment fully confirmed results that were previously obtained in similar samples grown by molecular beam epitaxy (MBE) and that we recently reported [1]. In that respect we could show that interstitial Mn_i in (Ga,Mn)As occupies the tetrahedral site with As nearest neighbours (T_{As}) both before and after thermal annealing at 200°C, whereas the occupancy of the tetrahedral site with Ga nearest neighbors (T_{Ga}) is negligible. T_{As} is therefore the energetically favourable site for interstitial Mn_i in isolated form as well as when forming complexes with substitutional Mn. These results shed new light on the long standing controversy regarding T_{As} versus T_{Ga} occupancy of interstitial Mn in (Ga,Mn)As.

[1] T.A.L. Lima, U. Wahl, V. Augustyns, D.J. Silva, A. Costa, K. Houben, K.W. Edmonds, B.L. Gallagher, R.P. Campion, M.J. Van Bael, M.R. da Silva, J.G. Correia, J.P. Araújo, K. Temst, A. Vantomme, and L.M.C. Pereira, Appl. Phys. Lett. 106 (2015) 012406.

Lino Pereira (for the EC-SLI Collaboration)

IS588: ^{207}Tl studied using the ISOLDE Decay Station (IDS).

The recent IS588 experiment at ISOLDE has successfully populated low-lying states in ^{207}Tl, which is one proton short of the doubly-magic ^{208}Pb core. Such states will require breaking a proton or neutron pair across a shell closure, or coupling a collective octupole phonon to the single proton hole, and thus reveal the size of the shell closures and location of single particle orbitals in this region.

The population of these states was achieved via the beta decay of ^{207}Hg, which was produced by shining a beam of protons on to a molten lead target. Extracted reaction products were then mass selected and delivered to the ISOLDE Decay Station

(IDS), shown in Fig.1, for which this was the first experiment.

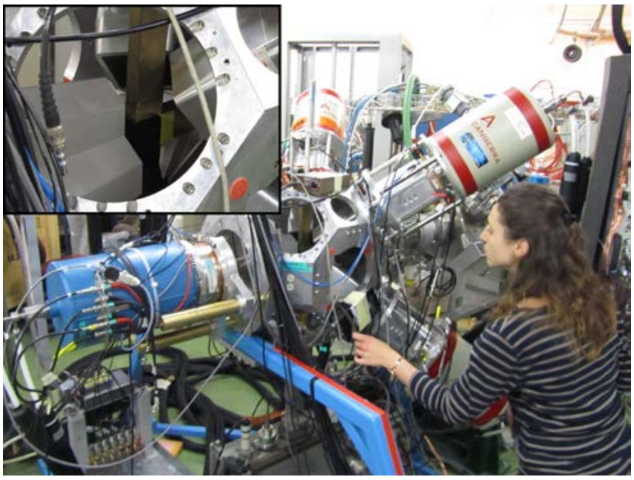

Fig.1: The IDS, comprised of one Miniball cluster (left) at zero degrees and four Clover Ge detectors (right). Three plastic scintillator detectors (inset) surround the implantation position.

The ^{207}Hg beam is N=127 and thus it is required that a neutron be picked up within the molten lead target. A previous experiment attributed this to the (n,2p) reaction [1] following the interaction protons with the molten lead target.

Once implanted on a tape, subsequent beta decays were observed in three plastic scintillator detectors situated close to the implantation position. Four Clover Ge detectors and one Miniball cluster were used to observe gamma-ray emissions.

Data were recorded using a triggerless data acquisition system set up with the help of expert teams from Daresbury Laboratory and Jyväskylä University. Correlations between beta decays and gamma rays were made in software.

The experiment was run in two modes: accumulating ^{207}Hg (beam on) and observing decays (beam off). While the beam was being delivered, data collected would facilitate the exploration of previously

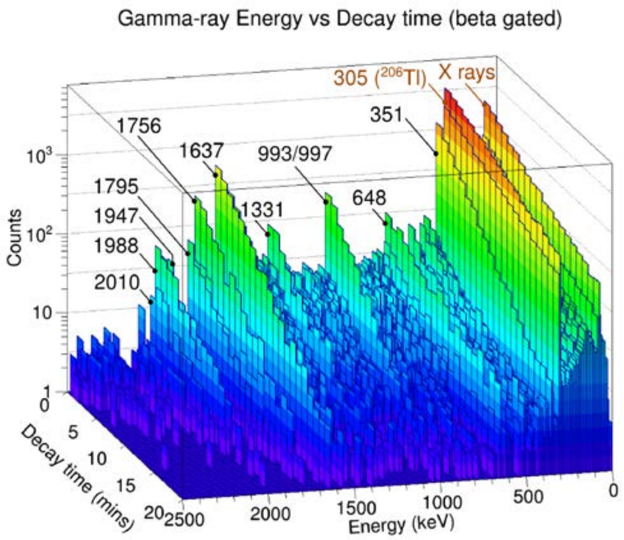

Fig.2: Gamma-ray transitions in prompt coincidence with beta decay. Transitions associated with ^{207}Tl are distinguishable from the few contaminants by their characteristic decay time ($t_{1/2}$ = 2.9 mins).

unobserved low-lying states in ^{207}Tl. When the beam delivery was stopped, the time profiles of emitted radiation could be observed, revealing their characteristic decay times, as shown in Fig.2.

Large statistics were collected during this experiment, owing to both the gamma-ray detection efficiency of the IDS, which was ~14% at 344 keV, and the rate of implantation of ^{207}Hg at the IDS, which was ~12 kHz.

These data have verified the majority of transitions in the existing 207Tl level scheme [1] in addition to identifying upwards of 30 new gamma-ray transitions. This corresponds to 14 new states with excitation energies in the range 1900-3700 keV, where octupole states are expected to lie [2].

[1] B. Jonson et al, Proc. Int. Conf. Helsingor, Denmark. Vol.2 p.640 (1981)
[2] Zs. Podolyák et al., J. Phys.: Conf. Ser. 580, 012010 (2015)

R. J. Carroll (for the IS588 Collaboration)

IS590: Study of the ^{129}Sn structure via the β− decay of ^{129}In

During the first successful fast-timing measurement at the ISOLDE Decay Station (IDS), we investigated the properties of low-lying excited levels in ^{129}Sn. This nucleus has three neutron-holes compared to the doubly magic ^{132}Sn, and represents a good case for testing shell-model calculations near the N=82 shell closure due to the reduced degrees of freedom for low excitation states.

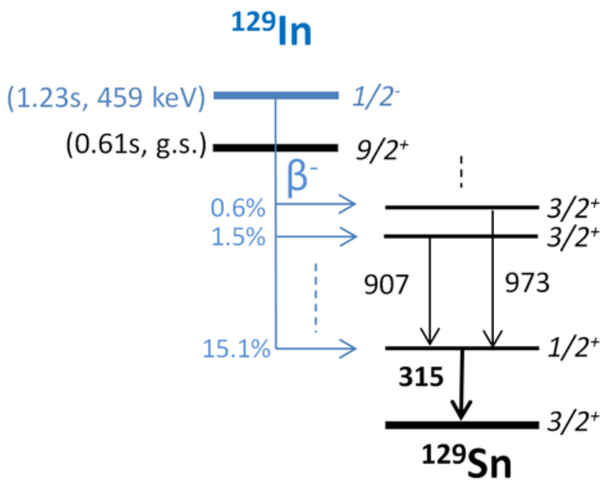

Fig.1: Partial level scheme, as deduced in [1], showing the levels of interest in ^{129}Sn populated in the β^- decay of the $1/2^-$ isomer of ^{129}In.

The states of interest of spin $1/2^+$ and $3/2^+$, shown in Fig. 1, are expected to have a configuration determined by the neutron $s_{1/2}$ (l=0) and $d_{3/2}$ (l=2) single particle states, respectively. Consequently, these states should be connected by a rather slow l-forbidden M1 transition [2]. Shell-model calculations with the CD-Bonn effective interaction [3] using a ^{132}Sn core with effective charges and gyromagnetic factors taken from [4] predict a 4 ns half-life for the $1/2^+$ level. The M1 effective operator $<d_{3/2}|M1|s_{1/2}>$ for neutron holes in this region is unknown and was considered zero.

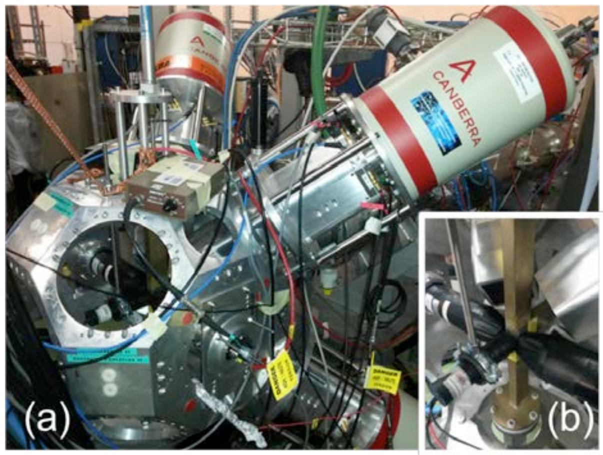

Fig.2: (a) Detection system of IDS during the IS590 experiment; (b) γ and β detectors in close geometry around the implantation point.

The $1/2^+$ state in ^{129}Sn was directly populated from the β^- decay of the 1.23s $1/2^-$ isomeric state in ^{129}In. ^{129}In was produced by a 1.4 GeV proton beam directly sent to a UC_x target. The ^{129}In atoms were surface ionized, separated using GPS, and implanted on the IDS moving tape. Experimental data was recorded during a 12 hours run, having an average proton current of 1 μA and an extraction yield of ~1.2×10^4 ions/second. The detection system, shown in Fig.2, consisted of 4 HPGe Clover-type detectors, 2 $LaBr_3$(Ce) and a ~30% absolute efficiency plastic scintillator as a fast time response β^- detector.

To extract the half-life of the 315-keV $1/2^+$ state in ^{129}Sn, the β^- gated $LaBr_3$(Ce) spectra were analyzed using the fast-timing technique for measuring nuclear lifetimes in the picosecond-nanosecond range [5,6]. Time to amplitude converters (TAC) were used to determine the time interval between coincident signals coming from the beta and $LaBr_3$(Ce) detectors. Afterwards, the timing information was correlated to the amplitude of each signal using the Nutaq digital acquisition of IDS. As shown in Fig.3, the peak at 315 keV, corresponding exclusively to the $1/2^+$ - $3/2^+$ transition in

^{129}Sn, is very well discriminated from the background. By gating on it and subtracting the background components, the time distribution relative to the β^- decay can be extracted and fitted by a Gaussian function.

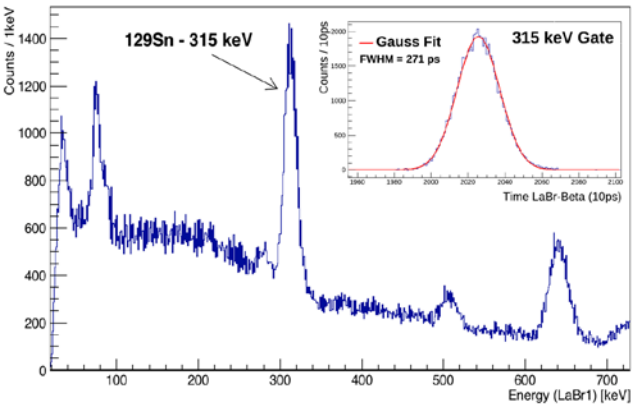

***Fig.3**: Experimental LaBr3(Ce) β-gated energy spectrum and (inset) time distribution of the 315-keV peak from ^{129}Sn.*

The absence of any exponential decay component in the fit suggests a short-lived 315-keV state in ^{129}Sn, within the sensitivity limit of the method used. The preliminary sensitivity has been estimated as 40 ps which thus represents the upper-limit for the 315.3-keV level half-life.

Fig. 4 shows a comparison between the gaussian response of the fast-timing setup and the time distribution expected for a nuclear level of 4 ns half-life. The discrepancy is significant, the measured upper-limit of the half-life being 100 times shorter than the theoretical prediction. This fact does not automatically imply a major change in the shell structure. A slightly different from zero M1 effective operator for neutron holes greatly improves the agreement without changing any other matrix elements.

The present study represents the first successful fast-timing measurement performed at the ISOLDE Decay Station and offers for the first time the possibility to estimate the M1 effective operator of neutron hole configurations in the ^{132}Sn region.

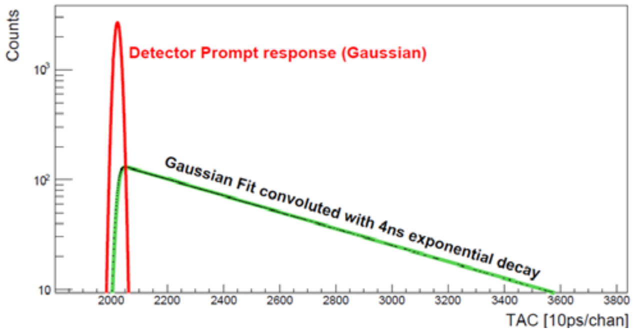

***Fig.4**: Comparison between the gaussian response of the fast-timing setup and the time distribution expected for a nuclear level of 4ns half-life.*

[1] H. Gausemel et. al, PRC 69, 054307(2004)
[2] V. Paar et. al. NPA 303, 96-110 (1978)
[3] A. Gargano, Private Communication (2014)
[4] M. Danchev et. al, PRC 84, 061306(R)(2011)
[5] H. Mach et. al, NIM A 280, no. 1, p 49-72, (1989)
[6] N. Marginean et. al, EPJ A 46, no. 3, p 329-336 (2010).

Razvan Lica (for the IDS Collaboration)

G4IDS: Geant4 simulation for the IDS collaboration

A Monte Carlo simulation package for a versatile experimental setup

In order to support the proposals and the analysis of the experiments performed with the new ISOLDE Decay Station (IDS) [1], a Geant4 [2] Monte Carlo simulation package (C++) has been developed.

Monte Carlo simulations are already an established method to assess various aspects of experiments in nuclear physics e.g. to estimate the true summing effect, to verify the coherence and consistency of decay schemes, and to evaluate the detection efficiency.

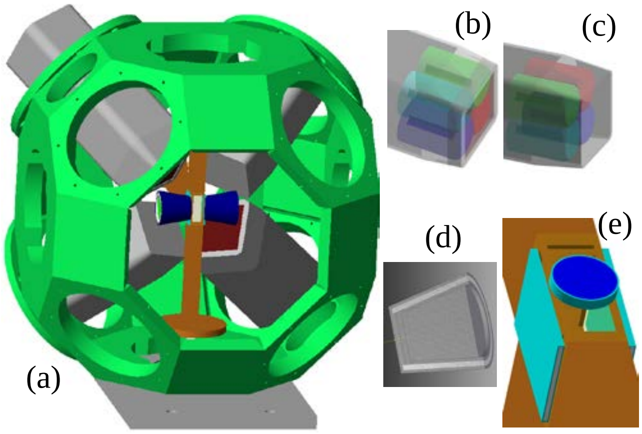

Fig.1 (a) Representation of the fast timing configuration; (b) Ge clover detector with carbon epoxy foil; (c) and Al front cap; (d) conical $LaBr_3$ detector; (e) plastic detectors.

Since the IDS is a versatile setup aiming to be used for all types of decay spectroscopy studies, several detectors and physics libraries have to be implemented. Most of the detectors used during the 2014 campaign are already available (HPGe, $LaBr_3$ and plastic detectors).

In order to improve the original Geant4 geometry construction, the different volumes were built by importing the technical drawings. The later can be drawn from any CAD software and in our case, we employed Autodesk Inventor [3]. It allows the complex detector geometries to be reproduced faithfully thanks to meshed volumes.

Simulation package validation

Since this package would be used to characterize the future developments (e.g. chambers, holding structures) of the experimental setup and also to benchmark the physics interpretations, it was crucial to demonstrate the reliability of the package by performing validation tests.

In the first version of the code, we focused on the reproduction of proper photopeak response of clover detectors (HPGe) and $LaBr_3$ scintillators, used for example for the fast timing experiments, see Fig. 1.

The IDS HPGe array is composed of two types of clovers: the first with an Al front cap and the second with a carbon epoxy foil, see Fig. 1. The latter type aims to detect the low energy radiation more efficiently.

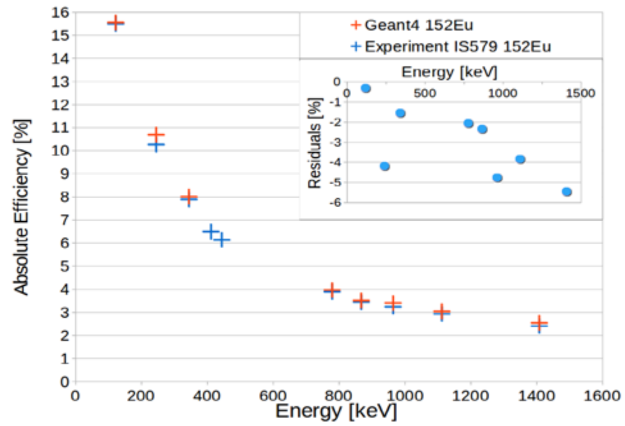

Fig.2 Comparison between experimental and simulated photopeak efficiencies for the clover array in the IS579/IS588 experiment (no add-back algorithm applied). The inset shows the discrepancies between the data and the simulation.

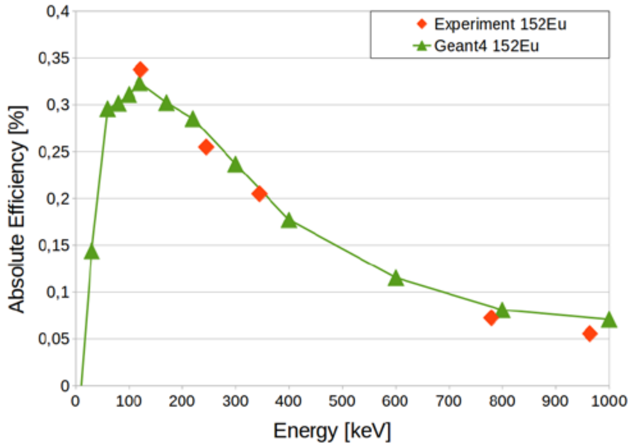

Fig.2 Comparison between experimental and simulated photopeak efficiencies for $LaBr_3$ detector (^{152}Eu source placed at 100 mm).

As illustrated in Fig. 2 and Fig. 3, the simulated results are in excellent agreement with the experimental spectra.

Ongoing / future implementation

We are currently implementing the possibility to simulate a neutron time-of-flight experiment including the neutron detectors and their associated physics libraries (VANDLE and the future IDS neutron array). Fig. 4 shows a representation of the future coupling between the IDS setup and the VANDLE [4] array for the next campaign.

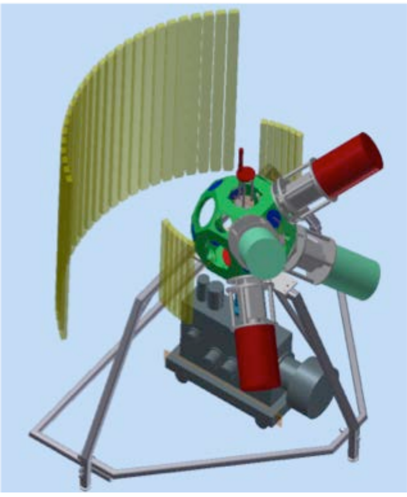

Fig.4 *Comparison between experimental and simulated photopeak efficiencies for $LaBr_3$ detector (^{152}Eu source placed at 100 mm).*

For this purpose, the scintillation physics libraries and interaction time have been introduced in the code and are currently being submitted to validation tests. The following step would naturally be to implement the management of time in the radioactive processes.

The complex geometries of the MiniBall detector [5] and of the charged particle configuration including Silicon detectors (from the MAGISOL collaboration) of different thickness are under construction.

Several radioactive sources are under development such as standard spectroscopy calibration sources and even more specific event generators such as an internal pair creation source including phase space generation.

For challenging experiments implying low count rates (~1 ions/s), it appears crucial to implement a background generator (under investigation).

Summary and outlook

Simulations for various detector configurations of the IDS were performed using the Geant4 toolkit. It will constitute a fundamental tool to guide optimization procedures and resulting future structural changes of the experimental setup and in supporting the different proposals.

Other detector systems are currently being implemented in the code or are in the process of being validated. Also further features such as the implementation of decay chains, time handling and time-of-flight are in the implementation phase.

Christophe Sotty
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for the IDS Collaboration

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[2] http://cern.ch/ph-dep-UsersOffice (Building 61, open 8:30-12:30 and 14:00-16:00, closed Wednesday morning).
[3] Make sure that the registration form is signed by your team leader before coming to CERN or that it can be signed by the team leader or deputy upon arrival.
[4] The Home Institute Declaration should not be signed by the person nominated as your team leader.
[5] http://cern.ch/service-rp-dosimetry (open *only in the mornings* 08:30 - 12:00).
[6] The certificate can be found via http://isolde.web.cern.ch/get-access-isolde-facility
[7] For Information about how to register see http://isolde.web.cern.ch/get-access-isolde-facility
[8] Eventually you can contact Jenny or the Physics coordinator.

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