



Overview of my 4 years at ISOLDE

Gerda Neyens

November 5, 2021



content

- Staff
- Research fellows
- Applied fellows
- PhD students
- Associates
- Collaboration membership
- EPIC project
- ISOLDE outreach
- ISOLDE Visits
- Financial situation
- Summary

ISOLDE Staff 2017-2021

- Staff members on CERN LD contracts (currently max. 8 years)
 - Karl Johnston, physics coordinator (Aug 2015 – Sept 2022)
 - Magdalena Kowalska (Oct 2015 – Sept 2018) ERC beta-drop NMR
 - Stephan Malbrunot-Ettenauer (Feb 2017 - Jan 2022) ERC MIRACLS
- Permanent CERN staff:
 - Magdalena Kowalska (Jan 2020 -)
- ISOLDE User Support
 - Jennifer Weterings (2002 -) 100% user at University of Oslo
 - ✓ Funded via the ISOLDE Collaboration Team Account



New Team Account rules installed 01/2020:

- ➔ Subsistence payments of staff on-site via Team Accounts maximum for a period of 8 years
- ➔ OK till December 2027

CERN Research Fellows 2017-2021

From Maria's period:

- Vladimir Manea (Jan 2016 – April 2018) ISOLTRAP
- Liam Gaffney (Oct 2016 – Sep 2019 - COFUND) Miniball
- Hanne Heylen (Oct 2017 – sept 2020 – COFUND) COLLAPS-VITO

Hired since Nov 2017:

- Ronald Garcia Ruiz (Jan 2018 – Dec 2019) CRIS
- Maxime Mougeot (Sept 2019 – August 2021) ISOLTRAP
- Razvan Lica (June 2020 – May 2022) IDS
- Liss Vasquez Rodriquez (Oct. 2020 – Sept. 2022) COLLAPS
- Erich Leistenschneider (April 2021 – March 2023) PoP MR-TOF/MIRACLS
- Agi Koszorus (October 2021 – September 2023) CRIS

↓ Learning curve

On average 3 hires over 2 years (2/year during last years)
Need EXCELLENT candidates (CV, motivation letter, project)

CERN Applied Fellows 2017-2021

From Maria's period:

- | | | |
|--|----------------------------|------------|
| ● Frank Wienholtz (Jan2016 – Dec 2018) | MR-TOF-MS for ISOLDE | ERC/ENSAR2 |
| ● Andree Welker (Aug 2017 – July 2018) | HIFI spectrometer / WIZARD | EP-IS |
| ● Lina Pallada (Apr 2017 – May 2019) | betadrop-NMR | ERC |

Hired since Nov 2017:

- | | | |
|---|-------------------------|-----------------|
| ● Joonas Konki (March 2018 – Feb 2020) | HIE-ISOLDE experiments | ENSAR2 |
| ● Simon Sels (March 2018 – Feb 2020) | MIRACLS | ERC |
| ● Dinko Atanasov (April 2019 – June 2021) | WISArD | EP-IS |
| ● Markus Vilen (Oct 2019 – Sept 2022) | MIRACLS / ISOLDE MR-TOF | ERC/ENSAR2/ISCC |
| ● Bruno Olaizola (Sept. 2020 – August 2022) | HIE-ISOLDE ISS | EP-IS |
| ● Jared Croese (Aug. 2021 – June 2023) | VITO | ENSAR/EP-IS |
| ● Frank Brown (Sept. 2021 – August 2023) | HIE-ISOLDE Miniball | EP-IS |

ISOLDE quota from EP-IS: 1 person every 2 years
Recent success: propose cost sharing
→ suggest 1 year other funding (e.g. ENSAR2, ISCC, ...) – 1 year EP funding)

CERN Doctoral Students 2017-2021

From Maria's period:

Razvan Lica (Sep2014 – August 2017)	IDS	CERN EP-IS
Andree Welker (Feb 2015-Jan2018)	ISOLTRAP	Gentner (Uni. ...)
Jonas Karthein (Nov 2017- Oct 2020)	ISOLTRAP	Gentner (Uni. Heidelberg)

Hired during my time:

● Varvara Lagiki (Sept 2017 – Feb. 2021)	MIRACLS	ERC (Greifswald)
● Simon Lechner (Sept 2017 – Feb. 2021)	MIRACLS	Austrian Prog. (TU Vienna)
● Jared Croese (Feb 2018 – July 2021)	betaDROPNMR	CERN EP-IS +ERC (Geneva)
● Peter Plattner (August 2018 – Dec 2021)	MIRACLS	Austian Prog. (Innsbruck)
● Katarzyna Dziubinska-Kuhn (Sept 2018 – Feb. 2022)	betaDROPNMR	SWISS Fund/KT-Med (Univ. Geneva)
● Karolina Kulesz (Oct 2018 – March 2022)	betaDROPNMR	ERC (Univ. Geneva)
● Lukas Nies (Nov 2019 – Oct 2022)	ISOLTRAP	Gentner (Univ. Greifswald)
● Franziska Maier (Feb. 2020 – Jan 2023)	MIRACLS	Gentner (Univ. Greifswald)
● Michail Atanasakis (Sept. 2020 – Aug. 2023)	CRIS	EP-IS
● Marcus Jankowski (Jan. 2021 – Dec. 2023)	VITO	Gentner (TU Darmstadt)
● Tim Lellinger (March 2021 – Febr. 2024)	COLLAPS	Gentner (TU Darmstadt)

- ➔ Use external funding programs !
- ➔ Need a German / Austrian / Swiss (co-)promotor

Associates 2017-2021

From Maria's period (scientific associates):

- Angela Bracco (– July 2017)
- Bertram Blank (– August 2017)
- Andrei Andreyev (July 2017– June 2018)
- Joakim Cederkall (September 2017 – August 2018)

Hired since Nov. 2017:

➔ Increase success rate by not asking full year, but e.g. 6 months and then extend with 3-6 months

● Scientific Associates

- Deyan Yordanov, 11 months (February – Dec 2019)
- Giacomo de Angelis, 6 months (July – Dec 2020)
- Ismael Martel, 6 months (Oct. 2020 – March 2021)
- Robert Berger, 5 months (May 2021 – Sept 2021)
- Sorin Pascu, 7 months (Feb. 2021 – Aug 2021)
- Alexandre Obertelli, 1 year (Sept. 2021 – Aug 2022)
- Janne Pakarinen, 8 months (Dec. 2021 – July 2022)

➔ Increase success rate by asking at most 3 months (then extend if needed)

● Corresponding Associates

- Luis Fraile, 3 months (May – August 2018)
- Maria Borge, 3 months (August – October 2018)
- Mikael Reponen, 6 months (March – August 2020)
- Mikolaj Baranowski 5 months (July – Nov. 2021)

ISOLDE Users

In-house group: 43 scientists

- 25 paid by CERN (staff, fellows, PhD, associates)
- 18 externally paid users (PhD and post-docs 100% at CERN)

Visiting Users at ISOLDE

- October 2017: 1238 users
- October 2018: 1315 users
- **October 2020: 841 users – all non-active users removed**
- On November 2, 2021: **937** users (increasing thanks to restart of ISOLDE)

Collaboration Memberships

- 16 member countries in 2017 (including CERN)
- 17 members in 2021
 - Bulgaria joined in 2021
- NEW: Institute memberships
 - Czech TU Prague since 2019
- Payments without signed agreement
 - Portugal
- In preparation:
 - Czech Republic is preparing to become a full member
 - Institute for Research in Fundamental Sciences, Tehran, prepares for institute member

EPIC project

thinking about the long-term future of ISOLDE

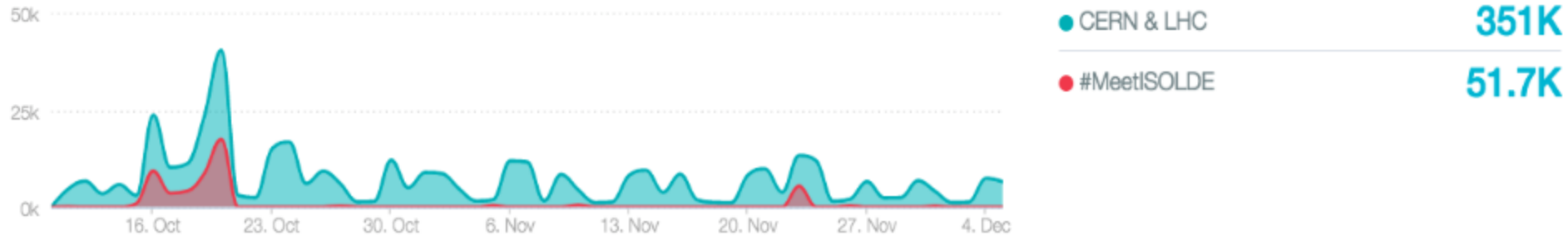
- May 2018: request from CERN directorate to think about long-term future and major projects for ISOLDE, in relation to the upcoming strategy update for the European PP community
- July 2018: call for 'big projects' in the UK
 - Project prepared by K. Flanagan, G. Neyens, R. Catherall
 - EPIC Project submitted (Exploiting the Potential of ISOLDE at CERN)
- December 2018: submit an extended version of the EPIC project as the ISOLDE Collaborations input to the ESPP (European Strategy for Particle Physics update), authors RC, GN, B Blank (ISCC chair), K Rissager (INTC chair)
- May 2019: ESPP Granada meeting
 - ISOLDE/EPIC mentioned in several presentations
 - Outcome: CERN should foster and intensify collaborations with the nuclear physics and astro-particle physics communities (consequence: CERN became associate member of NuPECC in 2021)
- 1st EPIC Workshop, December 2019 - present ideas for ISOLDE upgrades / discuss priorities
- 2nd EPIC Workshop, November 2020, on-line – focus on synergies between ISOLDE and other CERN facilities/experiments, space for new experimental set-ups using ISOLDE's low-energy RIB's, upgrade plans for the near future (~5-years) and consolidate ideas for the long-term future)
- Proceedings in preparation

Outreach activities

- Typically 6 to 10 outreach publications in CERN-related media per year
- Special thanks to Karl for writing several articles in EP Newsletter
- Thanks also to Magda and several users and their teams (ISOLTRAP, Miniball, CRIS, SSP, ...) for presenting their highlight results to the CERN community
- Special Events:
 - 50 years of ISOLDE – October 2017 (initiated by Maria, YouTube life, 5 video's on Facebook and Twitter, ...)
 - CERN Open Days – September 2020

50 years of ISOLDE events

Increase ISOLDE mentions on social media



Between 11 October and 5 December, #MeetISOLDE was mentioned **51.700 times** (CERN&LHC 351.000 times)

A peak of mentions was observed on 20 October (17.461 mentions), probably due to the Instagram grid and the fact that we republished the Facebook live on CERN's Facebook page.



Outreach 2018 - 8

● ISOLDE Workshop 2018 in CERN Courier, Jan 2019

153 participants, 40 talks, 29 posters
4 prizes (sponsored by CAEN)

CERN-COURIER.COM

FIELD NOTES

ISOLDE WORKSHOP

Users highlight successful campaigns

On 5–7 December 2018, the annual ISOLDE Workshop and Users meeting took place at CERN, attracting 153 participants. The programme consisted of 41 presentations, of which 22 were invited talks and 19 were oral contributions selected from 74 submitted abstracts.

ISOLDE, CERN's long-running nuclear research facility, directs a high-intensity proton beam from the Proton Synchrotron Booster (PSB) at a target station to produce a range of isotopes. Different devices are used to extract, ionise and separate the isotopes according to their mass, forming low-energy beams that are delivered to various experiments. These radioactive ion beams (RIBs) can also be re-accelerated using the REX/HIE-ISOLDE linear accelerators (linacs). An energy upgrade of the HIE-ISOLDE superconducting linac was completed this year, enabling RIBs with an energy up to about 10 MeV per nucleon.

A focus of the 2018 ISOLDE workshop



beam lines. A total of 17 different RIBs were accelerated during July–November 2018. Beams of isotopes with an atomic mass from 7 to 228, with the radium-228 beam being the heaviest ever accelerated beam at ISOLDE, were delivered. The HIE-ISOLDE campaign began with seven experiments at the first beam line, with the MINIBALL detector array and its ancillary detectors. In October two experiments used the new ISOLDE sole-noid spectrometer at the second beam line

Prize winners

The workshop organiser Gerda Neyens (second from right) with Victoria Araujo-Escalona and Natalia Sokolowska (two most left), who won for the best poster, and Tiago De Lemos

had been irradiated earlier. The first HIE-ISOLDE physics paper, accepted for publication in *Physical Review Letters*, was also highlighted. It provides the first direct proof that the very neutron-rich tin-132 nucleus, considered to be doubly magic, does indeed merit this special status.

Other sessions were dedicated to the rich low-energy experimental physics programme at ISOLDE. Overview talks were presented on recent achievements in high-precision mass studies, with indium-100 as a highlight; on collinear laser spectroscopy studies, with a long series of antimony isotopes and isomers; on decay-spectroscopy experiments; and on the solid-state physics programmes. Participants also heard about recent studies with antiprotons at the Antiproton Decelerator at CERN and about the extremely exotic isotopes produced at the Radioactive Isotope Beam Factory (RIBF) facility at RIKEN in Japan. The study of exotic isotopes using the VAMOS spec-

Outreach 2019

thanks to Karl and several active users

- CERN Accelerating News 28, March-April 2019,
ISOLDE's new solenoid spectrometer by Panos Charitos (CERN)
- EP Newsletter, March 2019
Resolving a long-standing question at ISOLDE by Karl Johnston (CERN)
- based on Nature Physics 14, 1163 (2018).
- EP Newsletter, June 2019
HIE-ISOLDE: a unique window into the nucleus by Karl Johnston (CERN)
- based on Nature Communications **10** (2019) 224,226Rn Coulex
- based on Phys. Rev. Lett. **121** (2019) 132Sn Coulex
- **CERN Courier, News Digest, July 2019**
EDM search goes pear-shaped – by Matthew Chalmers (CERN)
- based on Nature Communications, Rn Coulex
- CERN Open Days – September 14-15, 2019
➤ More than 80.000 visitors (about 2400 visited ISOLDE)
- CERN Accelerating News, October 2019
ISOLDE's new Offline 2 source nears completion by Achintya Rao (CERN)
- EP Newsletter, December 2019
Finding the best candidates for atomic EDM searches
by Peter Butler & Liam Gaffney (University of Liverpool), Joonas Konki (CERN)
- **CERN Courier, December 2019**
Obituary Ernst Otten (by J. Kluge)



EP Newsletter of the EP department



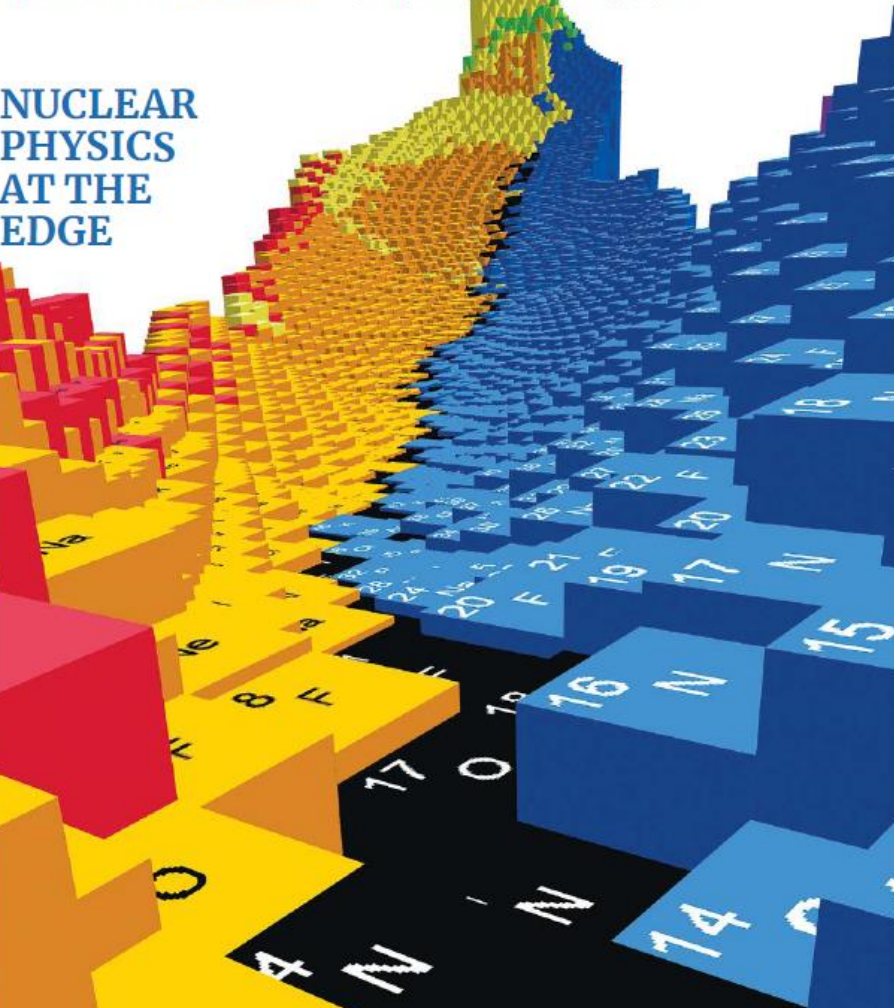
ISOLDE @ CERN

Cern Courier Sept/October 2020 (D. Lunney and G. Neyens)

CERN COURIER

September/October 2020 cerncourier.com Reporting on international high-energy physics

NUCLEAR PHYSICS AT THE EDGE



EXPLORING THE LIMITS OF THE STANDARD MODEL

Recent studies of exotic nuclides using traps and lasers at CERN's ISOLDE facility are not only helping researchers understand nuclear structure, explain David Lunney and Gerda Neyens, but also offer new ways to look for physics beyond the Standard Model.

Understanding how the strong interaction binds the single clusters of atomic nuclei is the central quest of nuclear physics. Since the 1950s CERN's ISOLDE facility has been at the forefront of this quest, producing the most extreme nuclear systems for examination of their basic characteristic properties.

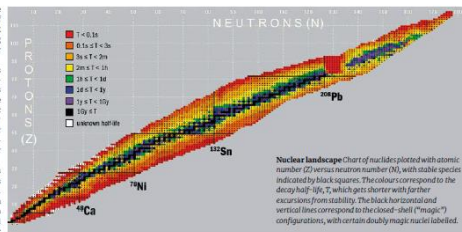
A chemical element is defined by the number of protons in its nucleus, with the number of neutrons defining its isotope. Apart from a few interesting exceptions, all elements in nature have at least one stable isotope. These form the so-called valley of stability in the nuclear chart of atomic number versus neutron number (see "Nuclear landscape" figure). Adding or removing neutrons disturbs the nuclear equilibrium and creates isotopes that are generally radioactive: the greater the proton-neutron imbalance, the faster the radioactive decay.

The mass of a nucleus reveals its binding energy, which reflects the interplay of all forces at work within the nucleus from the strong, weak and electromagnetic interactions. Indications of sudden changes in the nuclear shape, when adding neutrons, are often revealed first indirectly as a sudden change in the mass, and can then be predicted better by measurements of the charge radius and electromagnetic moments. Such diagnostics – performed by ion-trapping and laser-spectroscopy experiments on short-lived (from a few milliseconds upwards) isotopes – provides the first vital signs concerning the nature of nuclei with extreme proton-neutron ratios.

Recent mass-spectrometry measurements and high-precision measurements of nuclear moments and radii at ISOLDE demonstrate the rapid progress being made in understanding the enigmatic mysteries of the nucleus. ISOLDE's state-of-the-art laser-spectroscopy tools are also opening an era where molecular radioisotopes can be used as sensitive probes for physics beyond the Standard Model.

Progress in understanding the nucleus has gone hand in hand with the advancement of new techniques. Mass measurements of stable nuclei pioneered by Francis Aston nearly a century ago revealed a near-constant binding energy per nucleon. This pointed to a characteristic structure of the nucleus, which underlies the liquid-drop model and led to the semi-empirical mass formula for the nucleus developed by Bethe and von Weizsäcker.

With the advent of the article materials in the 1950s, nuclear isotopic mass data became available from reactions and decays, bringing new surprises. In particular, compar-



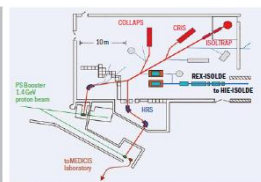
Nuclear landscape Chart of all nuclei populated with atomic number (Z) versus neutron number (N), with stable species indicated by black squares. The colour corresponds to the decay half-life, with lighter colour with further excursions from stability. The black horizontal and vertical lines correspond to the closed-shell ("magic") configurations, with certain doubly magic nuclei isolated.

isons with the liquid drop revealed conspicuous peaks at certain so-called "magic" numbers (2, 8, 20, 28, 50, 82, 126), analogous to the high-magnetic-moment potentials of the closed electron-shell noble-gas elements. These findings inspired the nuclear-shell model, developed by Maria Goeppert-Mayer and Hans Jensen, which still holds as an important benchmark today. The difference with the atomic system is that the force that governs the nuclear shell is poorly understood. This is because nucleons are themselves composite particles that interact through the complex interplay of three fundamental forces, rather than the strong electromagnetic force governing atomic structure. The most important question in nuclear physics today is to describe these closed shells from fundamental principles (e.g. the strong interaction between quarks and gluons inside nucleons), to understand why shell structure emerges and how it varies far from stability.

A key to reaching a deeper understanding of nuclear structure is the ability to measure the size and shape of nuclei. This was made possible using the precision trap-and-laser spectroscopy, which was pioneered with tremendous success at ISOLDE in the late 1990s. While nuclear binding energy is a well-trodden topic of deformation nuclei, it gives no specific information concerning nuclear size or shape. Closed-shell configurations tend to favour spherical nuclei, but since these are rather rare, a particularly important feature of nuclei is their deformation. Improving the electromagnetic moments derived from the measured atomic hyperfine structure, the change in charge radii derived from an isotopic shift provides detailed information about nuclear shape and deformation, beautifully complementing mass measurements.

During the past half-century, nuclear science at ISOLDE has expanded beyond fundamental studies to applications involving radioactive tracers in materials (including bi-materials) and the fabrication of isotopes for medicine (with the MEDICIS facility). But the bulk of the ISOLDE physics programme, around 70%, is still devoted to the elucidation of nuclear structure and the properties of fundamental interactions. These studies are carried out through nuclear reactions, by decay spectroscopy or by measuring the basic global properties – mass and size – of the most exotic species possible.

Half a century of history
The fabrication of exotic nuclear systems requires a clever combination of considerable energy and CERN's expertise here has been instrumental. After many years receiving proton beams from a 600-MeV synchrotron (the SC



ISOLDE from above Laser and trap experiments (red) in the low-energy section of ISOLDE and the REIS-ISOLDE post-accelerator and the recent REIS-ISOLDE post-accelerator produce radioactive ion beams of higher energy. A target behind that of the high-resolution separator REIS can be practically irradiated and then moved with robots to the MEDICIS facility to extract long-lived radioisotopes for medical research.

now a museum piece at CERN, ISOLDE now lies just off the beam line to the Proton Synchrotron (PS), receiving a 1.6-MeV beam pulse from the Booster (see "ISOLDE from above" figure). ISOLDE in fact receives typically 50% of the pulses in the so-called super-cycle that links the intricate complex of CERN's injectors to the LHC.

The heart of ISOLDE is a cylindrical target that can contain various different materials. The stable nuclei in the target are dissociated by the proton impact and form exotic combinations of protons and neutrons. Heating the target to 2000 degrees helps these fleeting nuclei to escape into an ionisation chamber, in which they form ions that are electrostatically accelerated to around 30 keV. Isotopes of one particular mass are selected using one of two available mass separators, and subsequently directed to the experiments through more than a dozen beamlines. A similar number of permanent experimental setups are operating several millimetres apart along the beamline. Each year, more than 20 experiments are performed at ISOLDE by more than 500 users. More than 300 users from 26 European and 17 non-European countries around the world are registered as members of the ISOLDE collaboration.

ISOLDE sets the global standards for the production of exotic nuclear species and low energy, producing beams that

installing a post-accelerator that enables exotic nuclei to be delivered at 400 keV energies for the study of rare stable nuclear reactions, such as Coulomb excitation and transfer. Post-accelerated radioactive ion beams superimposed optically compared to the G4 beams from Fragment separator so that the radioactive beams available in the REIS and more recent REIS-ISOLDE superconducting lines enable nuclear scientists to extend aspects of nuclear structure studies to the end of the experimental facilities that have evolved from more than 30 years of innovation from a dedicated 1950s-era facility, which is continuously being expanded and also includes material scientists and biochemists. The pioneering experiments concerning isotopic energies, charge radii and moments will all be performed at CERN during the year. This work, spearheaded by the Ours group of the late Robert Kluglichs, saw the first use of on-line mass separation to the identification of many new exotic species, such as ¹¹¹Bi. This particular success led to the first precision mass measurements in 1995 that hinted at the unexplained discrepancy of the ¹¹¹Bi to ¹¹¹Pb ratio, eight years before that the stable nucleus ¹¹⁰Sn, in collaboration with atomic physicists of Ohio State University, also performed the first laser spectroscopy of ¹¹⁰Sn in 1978, revealing the unexpected large size of this exotic isotope.

To reach the unexplored large space of this exotic isotope, the ion-trapping and laser spectroscopy of ¹¹⁰Sn was required, so the work naturally continued at the expanding ISOLDE facility in the early 1990s. Meanwhile, another pioneering experiment was initiated by the group of physicist Wilhelm Koenigs, after having developed the use of optical pumping with spectral traps in Mainz to create ¹¹⁰Sn ions. This work, spearheaded by ISOLDE's first director of neutron-deficient Bi isotopes and offering the unique feature of shape-flagging in 1977. Through continued technical progress, the Mainz group established the collinear laser spectroscopy (COLLAS) programme at ISOLDE in 1976, with results on rubidium and ytterbium isotopes. When stable nuclei and ion traps became available in the early 1990s, the era of high-precision measurements of radii and masses began. This atomic-physics instrument now routinely provides a study of isotopes far from stability and the initial experimental set-up are still in use today thanks to continuous upgrades and the introduction of new measurement methods. Most of these developments have been supported to other radioisotopes and have been instrumental in the development of ISOLDE's state-of-the-art experimental facilities that have evolved from more than 30 years of innovation from a dedicated 1950s-era facility, which is continuously being expanded and also includes material scientists and biochemists. The pioneering experiments concerning isotopic energies, charge radii and moments will all be performed at CERN during the year. This work, spearheaded by the Ours group of the late Robert Kluglichs, saw the first use of on-line mass separation to the identification of many new exotic species, such as ¹¹¹Bi. This particular success led to the first precision mass measurements in 1995 that hinted at the unexplained discrepancy of the ¹¹¹Bi to ¹¹¹Pb ratio, eight years before that the stable nucleus ¹¹⁰Sn, in collaboration with atomic physicists of Ohio State University, also performed the first laser spectroscopy of ¹¹⁰Sn in 1978, revealing the unexpected large size of this exotic isotope.

Mass measurements with ISOLTRAP
ISOLTRAP is one of the longest established experiments at ISOLDE. Initiated in 1974 by the group of Walter Koenigs, ISOLTRAP is used to study the precision trap-and-laser spectroscopy of ¹¹⁰Sn in 1978, revealing the unexpected large size of this exotic isotope. To reach the unexplored large space of this exotic isotope, the ion-trapping and laser spectroscopy of ¹¹⁰Sn was required, so the work naturally continued at the expanding ISOLDE facility in the early 1990s. Meanwhile, another pioneering experiment was initiated by the group of physicist Wilhelm Koenigs, after having developed the use of optical pumping with spectral traps in Mainz to create ¹¹⁰Sn ions. This work, spearheaded by ISOLDE's first director of neutron-deficient Bi isotopes and offering the unique feature of shape-flagging in 1977. Through continued technical progress, the Mainz group established the collinear laser spectroscopy (COLLAS) programme at ISOLDE in 1976, with results on rubidium and ytterbium isotopes. When stable nuclei and ion traps became available in the early 1990s, the era of high-precision measurements of radii and masses began. This atomic-physics instrument now routinely provides a study of isotopes far from stability and the initial experimental set-up are still in use today thanks to continuous upgrades and the introduction of new measurement methods. Most of these developments have been supported to other radioisotopes and have been instrumental in the development of ISOLDE's state-of-the-art experimental facilities that have evolved from more than 30 years of innovation from a dedicated 1950s-era facility, which is continuously being expanded and also includes material scientists and biochemists. The pioneering experiments concerning isotopic energies, charge radii and moments will all be performed at CERN during the year. This work, spearheaded by the Ours group of the late Robert Kluglichs, saw the first use of on-line mass separation to the identification of many new exotic species, such as ¹¹¹Bi. This particular success led to the first precision mass measurements in 1995 that hinted at the unexplained discrepancy of the ¹¹¹Bi to ¹¹¹Pb ratio, eight years before that the stable nucleus ¹¹⁰Sn, in collaboration with atomic physicists of Ohio State University, also performed the first laser spectroscopy of ¹¹⁰Sn in 1978, revealing the unexpected large size of this exotic isotope.

spanning the entire nuclear chart. The most recent results, published this year by Vladimir Mazurek (Paris-Saclay), Jean Karimides (Delft) and colleagues, concern the strength of the N=2 shell closure below the magic Z=28 from the masses of ²⁺²⁰Ca²⁰ and ²⁺²⁰Ti²⁰. The team found that the binding energy only two protons below the closed shell was much less than what was predicted by global spectroscopy models, stimulating low-abundance calculations based on a nucleus-nucleon interaction derived from CNO through chiral effective-field theory. These calculations were previously available for lighter systems are now, for the first time, feasible in the region just south-west of ⁴⁸Ca, which is of particular interest for the rapid neutron-capture process creating elements in merging neutron stars.

Further exotic doubly magic nuclei ⁷⁰Se and ⁷⁸Se are not yet available at ISOLDE due to the refractory nature of the nuclei, which shows its release from the third target to the second target in the way out. However, the production of copper – just one proton above – is so good that CERN's Andrei Vobler and colleagues at COLLAS were enabled to probe the N=50 shell by measuring the mass of its nuclear neighbours ⁷⁰Se, finding the consistent with the doubly magic ⁷⁰Se nuclei. Masses from large-scale shell-model calculations were included against the observed copper masses, indicating the presence of the N=50 shell strength but with some deformation when the N=50 shell is filled. Complementary observations from laser spectroscopy helped to fill the full story, with results on moments and radii from the COLLAPS and the more recent COLLAPS Resonance Ionization Spectroscopy (CRIS) experiments adding an interesting twist.

Laser spectroscopy with COLLAPS and CRIS
Quantum electrodynamics provides a prediction on atomic energy levels mostly by assuming the nucleus is point-like and unchanging. However, characteristic nuclear size has a finite mass as well as non-zero charge and current distribution, which impacts the fine structure. This complexity to the high-energy exciting experiments and to the nuclear structure, the energy levels of the ionising electrons affect the energy of the electric and magnetic properties of the nucleus. This fact is exploited by the unique technique of laser spectroscopy, a fruitful marriage of atomic and nuclear physics realised by the COLLAPS collaboration since the early 1990s. COLLAPS provides tunable continuous-wave lasers for high-precision studies of exotic nuclei radii and moments and similar setups are now running at other facilities, such as JYFL in Finland, TRISOP in Canada, and ISOLDE in the UK. An earlier highlight from COLLAPS, obtained this year, Simon Kaufmann of TU Darmstadt and co-workers, is the measurement of the charge radius of the exotic, semi-magic isotope ⁷⁰Se. Such medium-mass exotic nuclei are now the main focus of nuclear shell-model effective-field theories, which aimed at understanding the nuclear charge radii and its dipole polarizability of ⁷⁰Se, both of which have a specific function for preparing the ion of interest to be weighed.

Since the first results on calcium, published in 1987, ISOLTRAP has measured the masses of more than 500 species

spanning the entire nuclear chart. The most recent results, published this year by Vladimir Mazurek (Paris-Saclay), Jean Karimides (Delft) and colleagues, concern the strength of the N=2 shell closure below the magic Z=28 from the masses of ²⁺²⁰Ca²⁰ and ²⁺²⁰Ti²⁰. The team found that the binding energy only two protons below the closed shell was much less than what was predicted by global spectroscopy models, stimulating low-abundance calculations based on a nucleus-nucleon interaction derived from CNO through chiral effective-field theory. These calculations were previously available for lighter systems are now, for the first time, feasible in the region just south-west of ⁴⁸Ca, which is of particular interest for the rapid neutron-capture process creating elements in merging neutron stars.

Further exotic doubly magic nuclei ⁷⁰Se and ⁷⁸Se are not yet available at ISOLDE due to the refractory nature of the nuclei, which shows its release from the third target to the second target in the way out. However, the production of copper – just one proton above – is so good that CERN's Andrei Vobler and colleagues at COLLAS were enabled to probe the N=50 shell by measuring the mass of its nuclear neighbours ⁷⁰Se, finding the consistent with the doubly magic ⁷⁰Se nuclei. Masses from large-scale shell-model calculations were included against the observed copper masses, indicating the presence of the N=50 shell strength but with some deformation when the N=50 shell is filled. Complementary observations from laser spectroscopy helped to fill the full story, with results on moments and radii from the COLLAPS and the more recent COLLAPS Resonance Ionization Spectroscopy (CRIS) experiments adding an interesting twist.

Laser spectroscopy with COLLAPS and CRIS
Quantum electrodynamics provides a prediction on atomic energy levels mostly by assuming the nucleus is point-like and unchanging. However, characteristic nuclear size has a finite mass as well as non-zero charge and current distribution, which impacts the fine structure. This complexity to the high-energy exciting experiments and to the nuclear structure, the energy levels of the ionising electrons affect the energy of the electric and magnetic properties of the nucleus. This fact is exploited by the unique technique of laser spectroscopy, a fruitful marriage of atomic and nuclear physics realised by the COLLAPS collaboration since the early 1990s. COLLAPS provides tunable continuous-wave lasers for high-precision studies of exotic nuclei radii and moments and similar setups are now running at other facilities, such as JYFL in Finland, TRISOP in Canada, and ISOLDE in the UK. An earlier highlight from COLLAPS, obtained this year, Simon Kaufmann of TU Darmstadt and co-workers, is the measurement of the charge radius of the exotic, semi-magic isotope ⁷⁰Se. Such medium-mass exotic nuclei are now the main focus of nuclear shell-model effective-field theories, which aimed at understanding the nuclear charge radii and its dipole polarizability of ⁷⁰Se, both of which have a specific function for preparing the ion of interest to be weighed.

Since the first results on calcium, published in 1987, ISOLTRAP has measured the masses of more than 500 species

spanning the entire nuclear chart. The most recent results, published this year by Vladimir Mazurek (Paris-Saclay), Jean Karimides (Delft) and colleagues, concern the strength of the N=2 shell closure below the magic Z=28 from the masses of ²⁺²⁰Ca²⁰ and ²⁺²⁰Ti²⁰. The team found that the binding energy only two protons below the closed shell was much less than what was predicted by global spectroscopy models, stimulating low-abundance calculations based on a nucleus-nucleon interaction derived from CNO through chiral effective-field theory. These calculations were previously available for lighter systems are now, for the first time, feasible in the region just south-west of ⁴⁸Ca, which is of particular interest for the rapid neutron-capture process creating elements in merging neutron stars.

Further exotic doubly magic nuclei ⁷⁰Se and ⁷⁸Se are not yet available at ISOLDE due to the refractory nature of the nuclei, which shows its release from the third target to the second target in the way out. However, the production of copper – just one proton above – is so good that CERN's Andrei Vobler and colleagues at COLLAS were enabled to probe the N=50 shell by measuring the mass of its nuclear neighbours ⁷⁰Se, finding the consistent with the doubly magic ⁷⁰Se nuclei. Masses from large-scale shell-model calculations were included against the observed copper masses, indicating the presence of the N=50 shell strength but with some deformation when the N=50 shell is filled. Complementary observations from laser spectroscopy helped to fill the full story, with results on moments and radii from the COLLAPS and the more recent COLLAPS Resonance Ionization Spectroscopy (CRIS) experiments adding an interesting twist.

Outreach 2020

thanks to Karl and several active users

- EP Newsletter, March 2020

ISOLDE dives deeper in the mystery of the odd-even staggering effect

by Panos Charitos (based on Nature Physics Cu paper)

PUMA: Exploring exotic nuclear phenomena with antimatter

by Alexandre Obertelli and François Butin (CERN, PUMA project manager)

- CERN Accelerating Science, May 2020

ISOLDE steps into unexplored region of the nuclear chart by Liam Gaffney



- EP Newsletter, June 2020

Secrets of beta decay unraveled at ISOLDE

by Zsolt Podolyák (PRL 125, 2020)

Exotic radioactive molecules could reveal physics beyond the Standard Model

by Gerda Neyens (based on Nature 451, 2020)



EP Newsletter of the EP department

- CERN Courier, May/June 2020

➤ Obituary Robert Klapish (by D. Lunney)



- CERN Courier, Sept/Oct 2020

Exploring Nuclei at the Limits (by D. Lunney and G. Neyens)

Outreach 2020 - continued

thanks to Karl and several active users


- **ISOLDE on Twitter, September 2020**

ISOLDE facility at CERN @ISOLDEatCERN

- **EP Newsletter, Sept 2020**

Pinpointing the structure of the SnV centre in diamond using emission channeling at ISOLDE
(based on a PRL)

by Karl Johnston



EP Newsletter of the EP department

- **CERN Courier, November 2020**

Nuclear win for ISOLDE physicists (Lise Meitner Prize) by Craig Edwards, editorial assistant



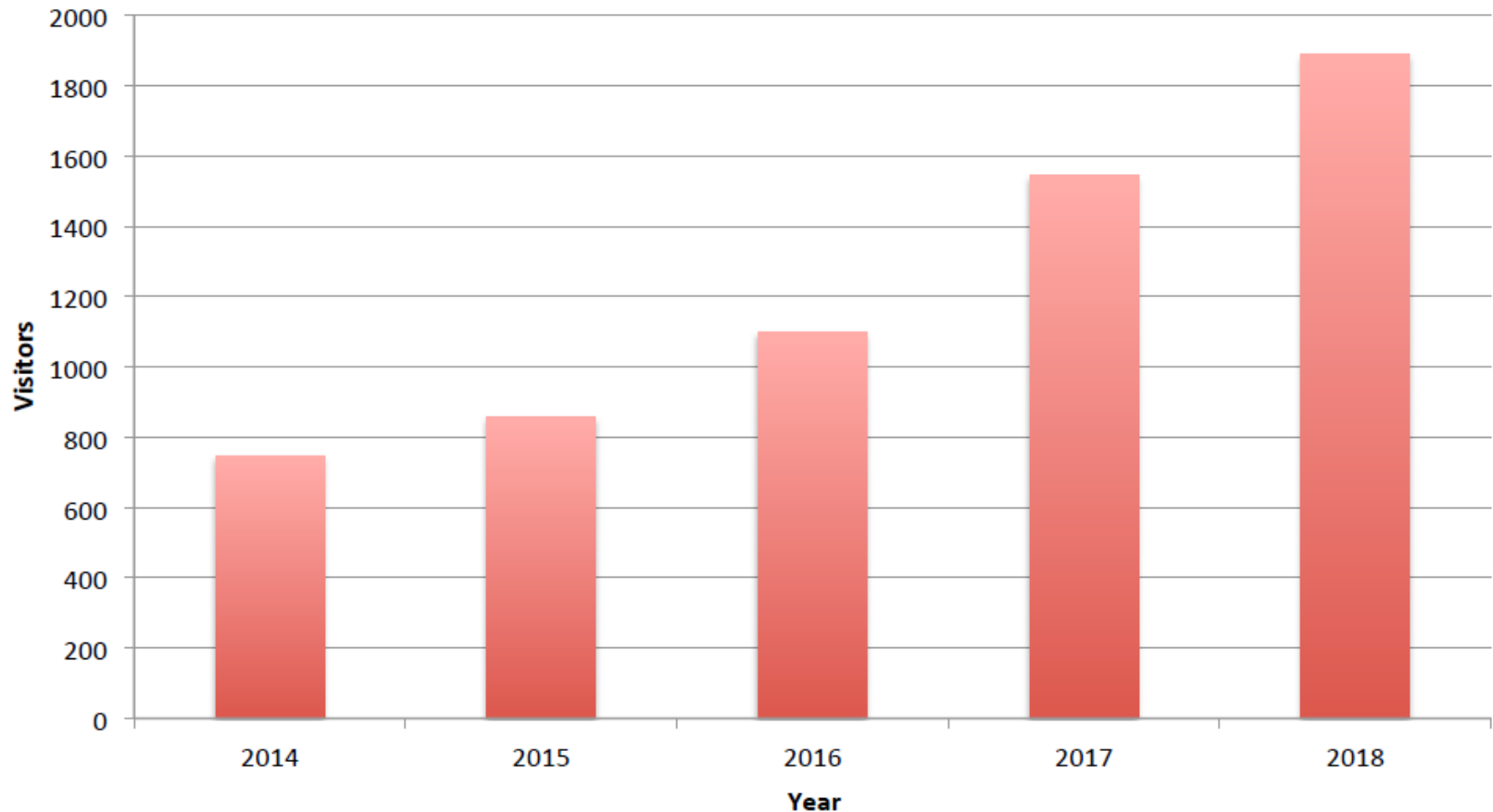
- **EP Newsletter, December 2020**

PUMA: antiprotons to probe the surface of radioactive nuclei

by A. Obertelli and F. Butin on behalf of the PUMA collaboration

ISOLDE Visits 2018

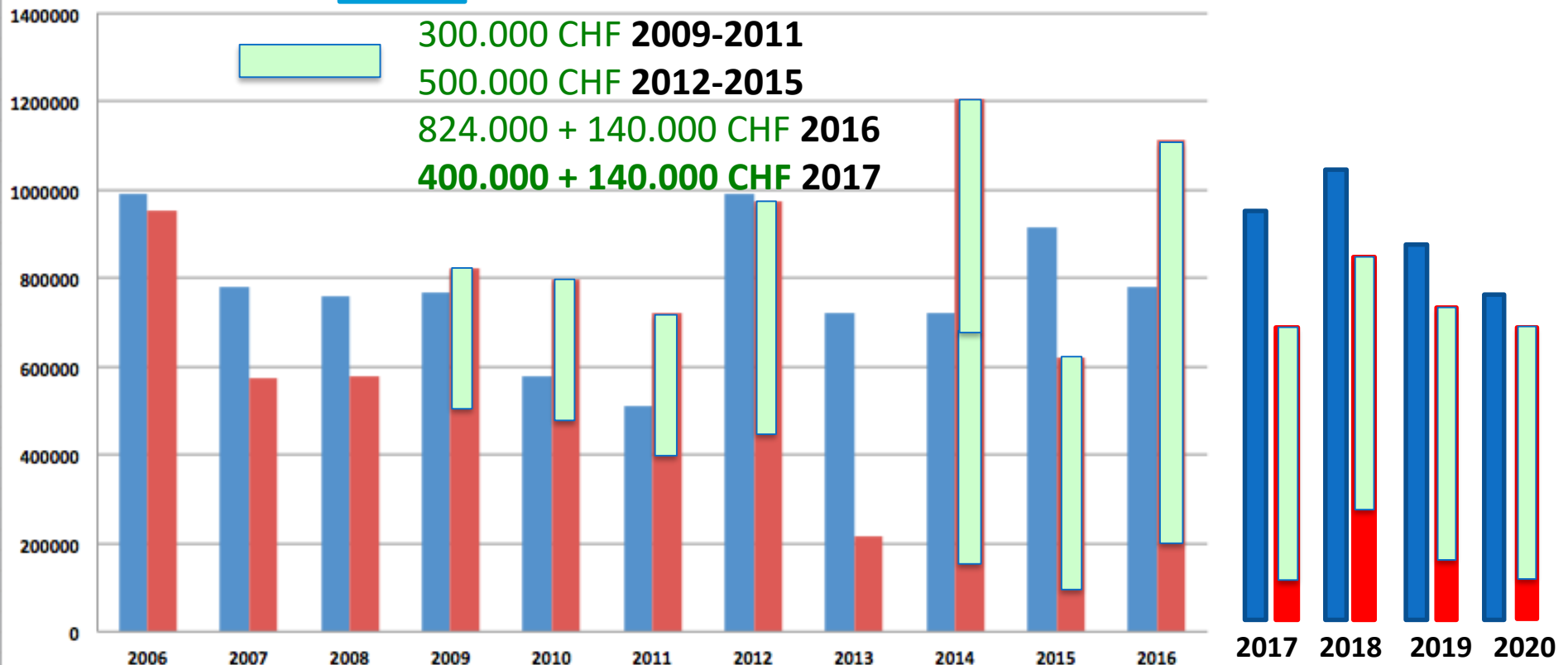
- ISOLDE Visits: increase by almost factor 3 in 5 years !
- Thanks to enthusiastic help of many local PhD, Post-docs, Fellows, ...
- Thanks to coordination by Hanne Heylen (Fellow since 2017)



Financial situation

Bleu: income on average 850 kCHF / year
 Red: expenditure/year
 Green: re-payments to CERN for ISOLDE investments (HIE-ISOLDE)

INCOME & EXPENDITURE 2006 - 2016 /CHF



HIE-ISOLDE repayment to CERN

The total cost of HIE-ISOLDE was 39.4 MCHF, pre-financed by CERN
 The ISOLDE Collaboration contribution to HIE-ISOLDE is 7.1 MCHF, part of which
 needs to be paid back as loans

- **Phase 1: 140 kCHF /year 2016 – 2020 (5 years) Loan of 700 kCHF**
- **Phase 2: 400 kCHF /year 2017 – 2023 Memo sent to E. Elsen 2.791 kCHF**

Funding Source	2007-2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
FWO I (BE)	4'460										4'460
ISOLDE Coll.	2'477	500									2'977
MPI (DE)	115										115
Aarhus (DK)	77										77
CERN loan (KM2180)			140	140	140	140	140				700
Phase 1 - TOTAL	7'129	500	140	140	140	140	140				8'329
FWO II (BE)	494	104									598
ISOLDE Coll.			433								433
CERN pre-payment			400	400	400	400	400	400	400	391	3191
Phase 2 - TOTAL	494	104	833	400	400	400	400	400	400	391	4222
Total paid by ISOLDE Collaboration and partners	7'623	604	973	540	540	540	540	400	400	391	12'551

Summary

Positive points:

- Increase of the local team of scientists (on all levels)
- Excellent collaboration with the technical teams (participation in the weekly group meetings, seminars, joined projects, ..)
- Very good visibility at CERN – good contacts with all media
- New web page (again) thanks to Jenny (following new CERN guidelines)
- Started thinking about long-term future of ISOLDE at CERN – with support from CERN (but financially still difficult in the next years)
- A very smooth transition from Richard to Joachim/Erwin
- Excellent collaboration with Karl, who takes care of all the ‘practical’ problems (even more important during covid)

Not so good:

- The GUI has met at most once per year / not enough follow-up of decisions
- Not all suggestions from Maria have been implemented (LN2 in the hall)