

## ISOLDE INPUT TO THE NEXT CALL FOR INFRASTRUCTURES – horizon Europe

Below please find some questions that we would greatly appreciate and need to have your response. Please feel free to add your comments and/or additional questions.

a) How do you see *Strengths, Opportunities, Aspirations, Results (SOAR)* for your RI within the framework of this call. The *Strengths* of the RI, should not only be in terms of beams, accelerator and detectors, but also focus on various specific expertise available at your lab. This also needs to include technical and engineering aspects which can be highlighted.

### Strengths of ISOLDE

- More than 50 years of experience in RIB production based on ISOL method. More than 1300 isotopes/isomers of 75 elements available, from light (He) to heavy (Ac). Limited or no availability of refractive elements due to slow release from the thick target.
- Isomer separation possible (for elements heavier than Cu) using the RILIS ion source, providing pure isomeric beams for research.
- Post-acceleration up to about 8 MeV/u for A/Q up to 4.5 and up to 10.5 MeV for A/q=3.
- Mass resolving power of HRS in routine operation is 2000, that of GPS is around 400.
- Possibility for beam bunching using the gas-filled ion cooler/buncher on HRS.
- Good beam quality (purity, emittance, time structure) for high-precision studies, both at low energy and for nuclear reaction experiments up to 10 MeV/u.
- Flexibility and adaptability to the user's needs through a broad combination of target materials, ion sources, and manipulation techniques.
- Versatility and flexibility of fixed experimental setups, allowing to perform complementary measurements semi-simultaneously using two or 3 set-ups or to assist with one technique in an experiment performed by another one (e.g. ISOLTRAP assisting laser spectroscopy, IDS assisting ISOLTRAP or VITO, RILIS assisting IDS, etc...)
- Possibility for users to bring their own set-up, as a stand-alone experiment or to be combined with one of the existing set-ups.
- Limited multi-user capability: GLM/GHM (solid state physics) in parallel to beams in another ISOLDE experiment.
- Parasitic target irradiation during ongoing physics program, for "winter physics" using extracted long-lived isotopes when protons have stopped, e.g. RaF experiment, [Nature 581 \(2020\) 396](#)

### Opportunities

- Improve the beam purification, up to mass resolving power 20.000 and even better, using a fast high-voltage (30 keV) MR-ToF as a mass separator (under development).
- Enhance further multi-user capability
- Take advantage of the LIU upgrades at CERN (higher proton beam intensity and energy from PS Booster) to boost the ISOLDE beam intensities (by factor 0.5 to 20, isotope dependent)

## Aspirations

- Not enough space to host all the low-energy experimental set-ups permanently. Need for a larger experimental hall, both for low-energy and for accelerated beam experiments.
- High demand for beam time, with low- and accelerated beams competing for the same time (increasing multiuser capability by parallel GPS/HRS operation would be desirable).
- Specific requests from the solid state / materials science community (collections, off-line space, radioactive sample handling, regular access for short periods of time on short notice, ...).
- There is a clear need for high-quality, low-energy RIBs, either for soft landing studies in solid state physics or for high-efficiency trapping for the next generation investigations, in particular of physics beyond the standard model (and interaction with anti-protons).
  - ⇒ It seems that many groups are currently developing similar technologies on that respect, while there could be a global approach towards providing beams of ~100 eV energy (or less) to complement the current 10-100 keV beams and high-energy beams.
- Reactions studies would benefit from a recoil separator, that can be moved behind each of the 3 beam lines.

## Results

Increased access and beam delivery to the user community

Improved flexibility to deliver beams to time-sensitive experiments with high impact

b) Can you please highlight possible common projects with other RI, of interest for specific and "hot" physics cases, to increase the impact for our and related fields ? Please also identify the weaknesses, for which you deem that the collaboration (possibly already existing) and the exchange with other structures can help. Your inputs about further highlighting and improving the coherence between your lab and the various RI are highly appreciated.

It would be good if the involved labs would distribute the R&D tasks they have in common among them, and avoid that every lab tries to cover all aspects themselves. By doing so one would attain sufficient critical mass and momentum for well-defined tasks in a laboratory, to make decent progress under better working conditions (financial and manpower). Of course, good exchange of experience and results with the relevant partner laboratories is crucial in such case, and mechanisms to realize that has to be put in place. An option would be that experts who developed particular items in one lab, stay for an extended period later in another lab to transfer the knowledge. Below are several topics that could be distributed:

- Targets
- Plasma and surface 1+ ion sources
- RILIS
- Separators
- Cavity development
- High-voltage MR-TOF
- Traps and spectrometers
- Detectors

- Charge breeding EBIS / ECR

A related important point in this context is the status of the collaboration with groups of theorists within your lab and between different RI.

We have no in-house theorists at ISOLDE. There is a theory group at CERN, but their focus is on particle physics experiments and the Standard Model (and beyond) mostly. Occasionally there is a 'lower-energy' theory fellow (e.g. Gonzales-Alonso recently on complementarity of low-energy precision studies in beta-decay to high-energy studies at LHC).

c) Do you think that we missed some European RI in the last call (or are missed in this mail) that can help improve the versatility and range of our activities in the last call? If so, which ones?

We should make sure that all facilities where radioisotopes are used for science in Europe, in the broadest context, are partner in our next initiative. The amount of funding that goes to each facility that provides radioactive isotopes to answer scientific questions in a variety of disciplines, should depend on the amount of available isotopes and beam time, and the amount of (non-national) users. Quantification of this has to be based on previous years achievements (e.g using a 'normal' year of operation to specify the nr. of non-national users, nr. of experiments, scientific output, ...).

d) Can you please provide information about the data management policy (DMP) in your RI ? If you already have one, can you please send the link with this information? If not (or the DMP is being built), what are your plans and schedules to do so? What is your involvement in issues related to open access ?

CERN data policy (see text at the end\*) has been recently adapted for all LHC experiments, and will be shared with ISOLDE in a short while.

We have to apply the CERN Data Protection Policies, which can be found via <https://privacy.web.cern.ch/>. The Office of Data Privacy Protection (ODPP) was set up in 2017 to make sure CERN adopts best practice for handling personal data, especially in light of the new General Data Protection Regulation (GDPR), which became law in Europe in May 2018.

e) Our field is one of the best fields to promote engineers and analysts of complex problems, able to tackle multiple high tech ( e-m waves, nuclear, material, computing, big data, simulations and analysis). We consider it important to point this out, providing a plan to further increase this impact. What would your suggestions be about this point ?

I fully agree. Our field is very multidisciplinary. We do have the Knowledge Transfer section at CERN that can setup consulting between CERN specialists and external companies, but this has a marginal impact. Not sure how this could be improved.

MEDICIS could be constructed and operated only because of ISOLDE expertise and know how.

Suggestion to promote our field and its societal impact by training experts in a variety of disciplines: identify the current field of work of our former graduates from some of the universities and laboratories in our field, e.g. where are the ISOLDE-based CERN Doctoral Students today, this could be an action at several places ...

f) Your strategy towards Education of Masters and PhD (in our field, Exp. and Theory ): what would you suggest to further improve the training opportunities at your RI ?

Would you be ready to host hands-on-training of students for short-term visits at your laboratory, using available facilities ?

The best way to get funding for PhD students and train them across our laboratories, is by providing training via EU funded programs for Marie Curie fellows (for Horizon 2020 info on [https://cordis.europa.eu/programme/id/H2020\\_MSCA-ITN-2014-ETN](https://cordis.europa.eu/programme/id/H2020_MSCA-ITN-2014-ETN) ). If our groups would have funding for PhD students in such a network, they would happily contribute to the training of all the PhD students in the network. This also guarantees close collaboration between the labs on developments relevant to everybody. Recent successful examples of such are:

- **MEDICIS-PROMED (2015-2019)** 2.8 MEuro for PhD students hosted in 7 partner universities. The project was coordinated by CERN, who also trained several PhD students on-site, but with a link to one of the partner universities. Goal was to develop new techniques or improving on existing methods for producing novel medical isotopes. <https://cordis.europa.eu/project/id/642889>
- **LISA Training Network (MSCA-ITN)**, also coordinated by CERN, pays for 15 PhD students, hosted at 12 universities and RIB facilities around Europe (<https://lisa-itn.web.cern.ch/> ), focusing on training students in the fields of laser resonance ionization for beam production and for research. The PhD students are strongly connected to one or more facilities and based at the facility or at a university. Extended stays at another place are in the planning, along with hands-on training provided also by partner universities, labs and industry.  
⇒ Similar training networks could be set-up in other fields. This requires a good collaboration between the partners.
- An example: **use of recoil separators for nuclear reaction studies**. ISOLDE is interested to have such recoil separator. A project for development of a novel type, based on superconducting ring, is under development (funding request planned). Several institutes could profit from having their students trained in this, and also the facilities would profit by having e.g. some of these students on-site at existing such facilities.
- Yes, ISOLDE would be ready to receive students for hands-on training in tools of interest, either on the side of the operations and beam developments sections, as on the physics side (in that case, to be agreed with the respective collaborations).
- Another example: **production methods for very low energy (< 100 eV) high-quality beams** for high-precision studies in traps or for materials research – of interest to ISOL-type facilities, existing and new ones. Good synergies with developments at university laboratories are possible. By exchange we can gain a lot of momentum ...

- Another example (could be included as part of the RI initiative): towards common data acquisition and control for similar experiments across different facilities. This is very important for exchange of data e.g. (data handling). This exists now only in the Penning Trap Community (mass measurements). We could consider setting up activities to also prepare such common systems for laser spectroscopy studies, for recoil separators, for gamma detection.

CERN has already a strong Summer Internship Program, and we host at ISOLDE each summer between 10 and 15 summer students in our teams. It could be beneficial to advertise this opportunity centrally and broadly, together with similar opportunities from other research infrastructures (e.g. GSI has a similar program, maybe also JYFL), so that their respective visibility is increased by cross fertilization.

g) The number of users per year and the size of the user community./

There are about 500 people coming to ISOLDE for experiments every year (pre-LS2). There are currently 922 people linked to ISOLDE experiments, in the CERN greybook (after we revised the approved experiments and reduced the backlog by 25%). The number of ISOLDE users will increase as soon as ISOLDE starts operation again in summer 2021.

h) Your suggestions on topics at the boundaries of our scientific frontiers. How would you consider:

(1) Opening of TNA access to others communities, especially like high Power lasers, quantum computing, cosmology, condensed matter physics, material science beyond usual nuclear medicine.

At ISOLDE, we are already open to other communities and we are always welcoming new users, also from new fields if interested in using our beams.

Solid State and related fields could attract industrial R&D, where there is strong high-level R&D (e.g. collaborations with IMEC in Belgium, ...)

(2) Regarding the scientific impact of the TNA in this direction:

Can you please provide examples, statistics, milestones and achievements in activities related to energy, environment, nuclear power and innovation for society?

We can point to some impact on the use of nuclear methods to resolve some outstanding questions in semiconductor physics e.g location of the Cu impurity in silicon using emission channelling – a long-standing problem which is directly linked to semiconductor device performance.

The measurement of the electron affinity and ionization potential of At, and all-radioactive element, using radioactive isotopes of At, led to a better chemical understanding of

this element. This activity feeds not only to pure chemistry – and particularly chemical calculations – but also allows this isotope to be potentially used in nuclear medicine.

Unconventional/novel medical isotopes, a research program that was initiated at ISOLDE two decades ago, has stimulated the growth of dedicated facilities such as MEDICIS and ISOLPharma for the distribution of radioisotopes for medical applications across Europe. The production and study of isotopes such as Tb have also attracted interest from isotope producers such as Aronax who have put in place dedicated programmes to transfer the production to smaller scale facilities where the potential of these novel isotopes could be realized. This also spined off to PRISMAP which is very keen in keeping the link to the nuclear physic community ( I think EU would like to see our link with other consortia ?)

Advanced biophysics techniques utilizing beta-NMR methods have the potential to reveal the role of otherwise “hidden” elements in biological systems such as K, Mg and Cu.

Other fundamental properties (new isomers, etc) are required to expand the field of applications.

(3) Possible applications of Artificial Intelligence and machine learning for data management, accelerator control, environment and climate related issues and for tools related to open access.

AI is being considered for beam steering, but not very successful so far at CERN ...

Harnessing AI for the control of spectrometers and analysis of data is currently being explored within the solid state groups at ISOLDE. A new program funded by the German BMBF is calling for proposals within this domain and a proposal is being prepared. The aim being to generalize software currently used for nuclear solid state physics with the aim to remove most of the complexity of data analysis and operation using AI. In so doing, a more general audience that is less experienced with nuclear methods, should be attracted to the facility and thus increase the users community from those fields and raise the impact of this field of research at our facilities.

A second round within this program will concentrate on hardware related aspects and it could be foreseen to harness machine learning methods for automatic control of accelerators etc. The program is called ErUM data. <https://indico.desy.de/event/28330/>

i) We would appreciate your views and plans about:

(1) our plans about advertising our lab activities to a general public, during the four years covered in this call, to emphasize the crucial impact of the RI on various aspects: scientific and technical breakthroughs, attracting youngsters to science, training opportunities, applications to other fields (material science...), link with industry and return to society.

The measures taken to publicize the opportunities for access are the following:



- a dedicated web site: <https://isolde.web.cern.ch/> giving information on: who can apply, how to apply, call for Proposals information, financial Support options, Application Forms, Structure and Services of the research infrastructure
- group leaders of scheduled projects are informed via email
- the user community is informed at the annual user meeting
- international workshops/conferences are used to inform a wider scientific community
- We launched the ISOLDE Twitter account in 2020
- We organize many visits to ISOLDE (for VIP, students, teachers....) – more than 100 visits per year with more than 1500 visitors attending. A significant increase of visits during the ENSAR2 period from around 800 to 1500 per year
- We prepared a series of videos about ISOLDE for the 50th anniversary of the facility and which have been put on youtube and the CERN website. #meetISOLDE: These videos addressed many aspects of the science and technical side of ISOLDE and are aimed at a general audience
- We organized in 2017 a facebook live event as part of the #meetISOLDE programme: introducing ISOLDE scientists to the general public
- In 2019, ISOLDE participated for the first time in the CERN open days. ISOLDE was presented to the general public, receiving more than 2000 people per visit day
- Participation in “the night of the researcher” at CERN in 2017 and 2018  
Close contact with CERN comms team to publicize high interest papers and other news stories e.g. first African led experiment at CERN <https://videos.cern.ch/record/2275088>
  - 20% of the scientific programme of ISOLDE is for solid state, biophysics and medical physics, which means we address a broad community outside the nuclear one (and it is continuously growing, so there is room for other facilities to be promoted in this context).
  - A full list of outreach is available on the ISOLDE website: <https://isolde.cern/outreach>
  - ISOLDE is represented in the CERN Summer Students program (with lectures and about 10-15 summer students trained at ISOLDE each summer). We also are present our facility at international schools (e.g. in the African school of physics, or recently in the Tastes of physics conference).
  - Participation in IAEA meeting about applications of “unstable nuclei” with a presentation on ISOLDE applications in domains using radioisotopes outside the nuclear research field. An IAEA technical doc is being prepared to communicate this activity to a wider field. The eventual aim would be a training programme or a cooperative research project targeting these activities and methods to developing countries.

Link to Industry: members of the ISOLDE user community are sitting on the CERN Knowledge Transfer Forum and the CERN Knowledge Transfer Forum on Medical Applications (TE Cocolios for Belgium, D Zamfir from Romania <https://kt.cern/kt-forum> ), with the mandate to promote the valorization of CERN technology as a whole back in their member state, but with the added knowledge of the ISOLDE facility to best bring it to their local industries. Advertising the names of these people to our broader community would help others to help in these efforts, by providing input to these contact points and vice versa.

(2) our plans about advertising, in general, our strengths and vision beyond the connectivity of our RI and showing our dynamism to the EU.

- The participation of ISOLDE in wider CERN events has allowed ISOLDE to gain considerable visibility at CERN and the wider public (e.g CERN open days, night of the researcher events etc....)
- Dedicated articles and video features have also allowed presentation to a wide public and it is planned to continue this program
- Leveraging and using the resources available at CERN for public outreach and adapting them to the communication of nuclear physics to the general public: in particular, the new science gateway at CERN will allow us to foresee specific events / exhibitions being hosted related to nuclear physics

Communication of achievements and progress should be done in a modern and coordinated way, including all potential channels from social media, to official channels (press release, ...) and direct communication with our key stakeholders. A dedicated strategy should be established and not left as an afterthought.

j) Which non-European homologues to your RI, that offer complementary or more advanced services than those available in Europe, do you think we should include in this call as RI?

FRIB, RIBF, IThemba, Triumf, Korea(?),

k) Do you have a suggestion for an acronym for the name of our proposal for the next call ?

A suggestion would be, for e.g,

EURO-LABS (EUROpean Laboratories for Accelerator Based Sciences), it misses the core of our science, what makes us unique compared to other RI's: radioactive isotopes

Therefore, I would like to propose following name:

**European Facilities for Radioactive Isotope Sciences - EuFRIS**

l) Could you please also provide the name and email of a CONTACT person, in case you will be not doing it yourself.

I will act as contact (G. Neyens)

\* CERN Open Data Working Group (ODWG)with LHC collaborations just issued :

The Scientific Information Policy Board welcomes the initiative to establish a CERN Open Data Policy, and praises the "ODP Working Group for the LHC experiments" for its preparatory work, for the drafting of the policy document, and for achieving its approval by the experiments. The policy comprises two documents: a public one, outlining the general principles, and an internal document, outlining the implementation of the policy by each experiment. The SIPB strongly supports the CERN principle of openness and its various initiatives towards open science. The new Open Data Policy fully meets this spirit, while meeting the constraints set by the complexity of the LHC data and of their public use. In endorsing the Open Data Policy, the SIPB encourages the CERN management to extend its scope and implementation to cover the non-LHC experiments as well, and remains available to contribute.