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HIE-ISOLDE: challenges and future plans

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[HIE-ISOLDE radioactive isotopes](#)

HIE-ISOLDE advances the high energy frontier of the facility.



The [ISOLDE Radioactive Ion Beam facility](#), located at the Proton-Synchrotron Booster (PSB) at CERN, is a unique nuclear research facility which can produce a wide range of isotopes for nuclear and medical research. ISOLDE physicists investigate the structure of the nucleus, explore new regions of the nuclear chart, study the abundance of chemical elements in the Universe and try to find new ways to detect and cure diseases.

Aiming to expand from its core low energy science into high energy, the ISOLDE upgrade (referred to as HIE-ISOLDE) is nearly complete. HIE-ISOLDE stands for High Intensity and Energy upgrade of the ISOLDE facility. Currently, ISOLDE takes half of the protons produced at CERN from the PSB and fires them into a target to produce radioactive isotopes. But HIE-ISOLDE will use the new [LINAC4](#) accelerator to deliver more intense protons. The increase in acceleration energy will permit Coulomb excitation and transfer reaction studies in the full domain of the nearly 1300 nuclei from more than 70 elements produced at ISOLDE, providing new exciting research opportunities to test the limits of the theories that explain how everyday matter works. More specifically, HIE-ISOLDE allows researchers to study the properties of heavier isotopes, up to Hg²⁰⁶, and to explore physics areas ranging from studying magic numbers of super-heavy nuclei, shell structure, and stellar nucleosynthesis, to the optimisation of thin film solar cells.

Meet ISOLDE: A high energy upgrade

The HIE-ISOLDE project was approved by CERN in 2009 and delivered the first physics in 2015. During the construction and commissioning stages, it had to overcome a few challenges, ranging from using novel technologies to upgrading a facility in an existing building, which could not be rebuilt:

Providing variable energy (0.45 – 10 MeV) for a wide range of nuclei of different masses

To boost the beam to over 10 MeV per nucleon, a linear accelerator with 32 accelerating superconducting cavities is being constructed. The cavities have geometric velocities (β) of 6.3% and 10.3% and are contained in six cryomodules. The geometric velocity of the low- β cavities permits deceleration down to approximately 0.45 MeV/u. The flexibility of the output beam energy can be varied by switching off cavities. As of 2017, three cryomodules have been installed at the linear accelerator.

The superconducting cavities were manufactured by niobium-coated copper, a material that was first used in the LEP cavities. However, developing a new method to use it with this particular geometrical configuration presented a significant technical challenge for the upgrade team, which was overcome with a robust R&D programme.

Keeping perturbations to the minimum

Keeping the facility running while simultaneously performing the necessary upgrades was made possible through a carefully planned schedule and good coordination of the upgrade

team. Civil engineering works (construction of tunnel, new buildings) to house the HIE-ISOLDE setup were performed during LS1, when no experiments were in progress.

Using ultra high vacuum for the linear accelerator

Space limitations and the need to avoid cold-warm transitions led to the choice of single vacuum, which means that the cryomodules share the same vacuum with the beam pipe. This posed a challenge for the assembly, as there was a risk of dust contamination to the cavities. Operations had to be done in an ISO5 clean room and more than 10,000 parts, ranging in size from sub-millimetres to four cubic metres, were cleaned and conditioned before being assembled.

Overcoming time constraints

The time to develop and test a prototype was limited, so the first cryomodule functioned both as a prototype and was also used for physics. Because of this limitation, some designs had to be revised, e.g. in 2015, a thermal instability was discovered in the radiofrequency power coupler, which had to be removed, redesigned and fitted again in the cryomodule within a period of four months during the extended year-end technical stop. However, operation was in general remarkably smooth and a five-week physics run took place at the facility at that stage in 2015, followed by a more extended experimental programme in 2016, after the new radiofrequency coupler has been installed.

The second phase of the energy upgrade will be concluded next year, when the fourth high-beta cryomodule will be added to the linac. The production of its RF cavities has almost been completed. In 2018, the HIE-ISOLDE linear accelerator, equipped with four cryomodules, will be able to post-accelerate radioactive ion beams to energies up to 10—15 MeV per nucleon, depending on their mass-to-charge ratio, making ISOLDE the only facility in the world that can accelerate medium to heavy radioactive isotopes in this energy range.

The R&D efforts for the HIE-ISOLDE upgrade provide an essential bridge between CERN and other laboratories that host superconducting linear accelerators, for example the [ESS](#) in Lund, [ISOL@MYRRHA](#) in Belgium and [European XFEL](#) in Hamburg.