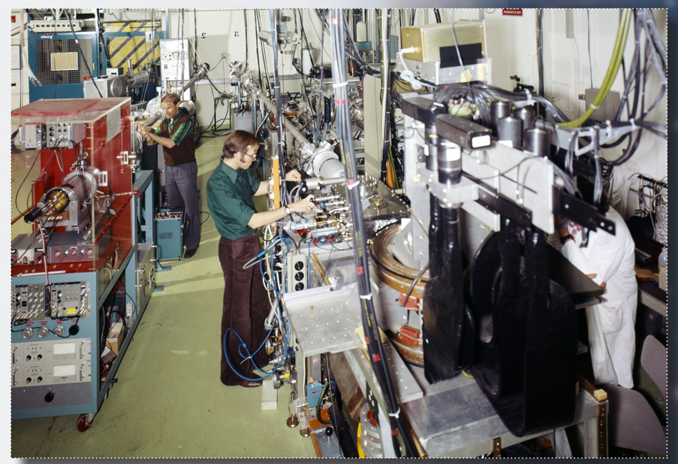
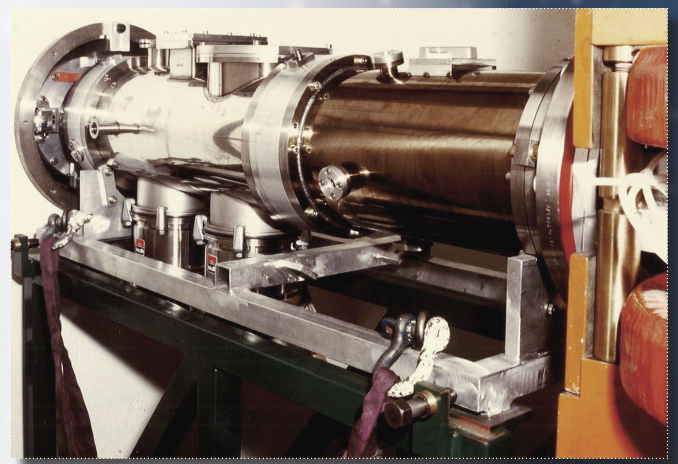
ISOLDE *exploring exotic nuclei*

1967 SC-ISOLDE I

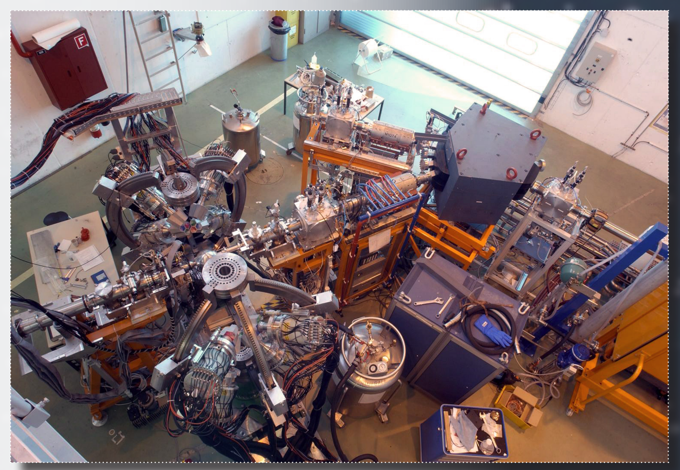


1974 SC-ISOLDE II

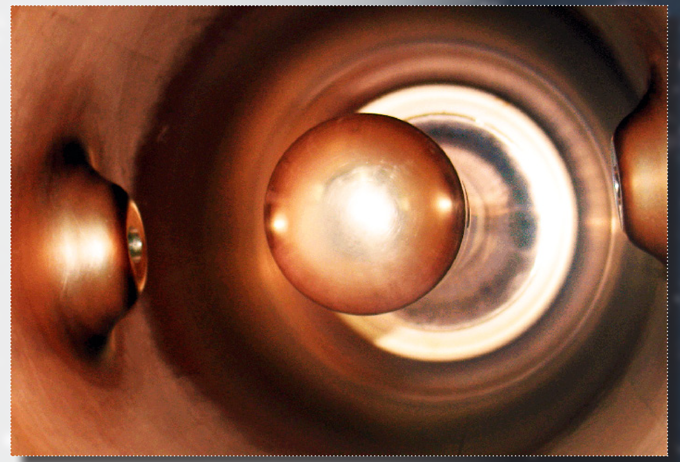


1987 SC-ISOLDE III

1992 PSB-ISOLDE



2001 REX-ISOLDE



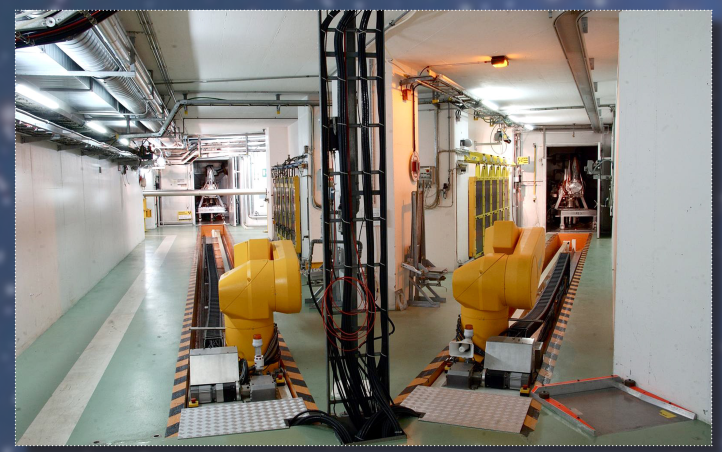
2014 HIE-ISOLDE

ISOLDE uses protons from the CERN PS-Booster to produce exotic nuclei. Many areas of science profit from the facility, including nuclear physics, astrophysics, particle physics, condensed matter physics and radiobiology.

All atoms contain a nucleus consisting of a specific number of protons and neutrons. The number of protons characterizes the element, whilst the number of neutrons determines stability against radioactive decay. The exotic nuclei produced at ISOLDE are so called because they contain a very different number of neutrons to their stable counterparts. This makes them very short lived. Although they do not exist on Earth, such nuclei play a major role in the life and death of stars.

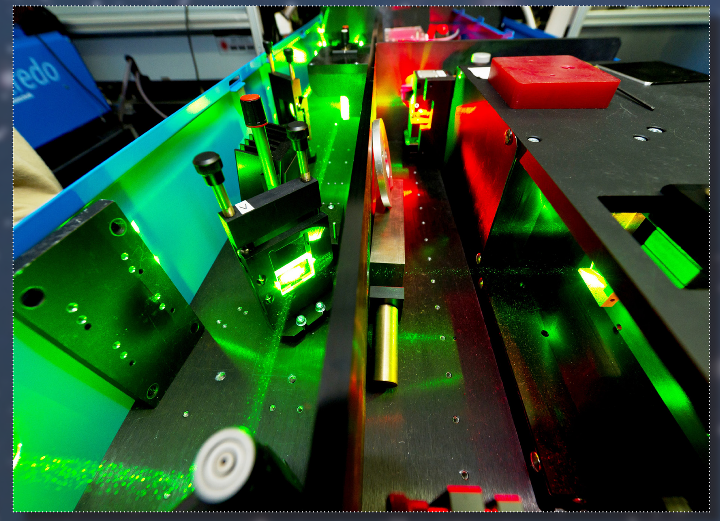
Production

ISOLDE produces exotic nuclei in reactions between protons of 1.4 GeV energy and stable nuclei in a range of special targets. Multiple reactions take place, generating a vast range of nuclei. The targets are heated so that the exotic radioactive species diffuse out quickly before they decay. Scientists and engineers at ISOLDE have worked for decades to develop the best materials and designs for the targets.



Target handling with robots

A view of the low-energy beamlines



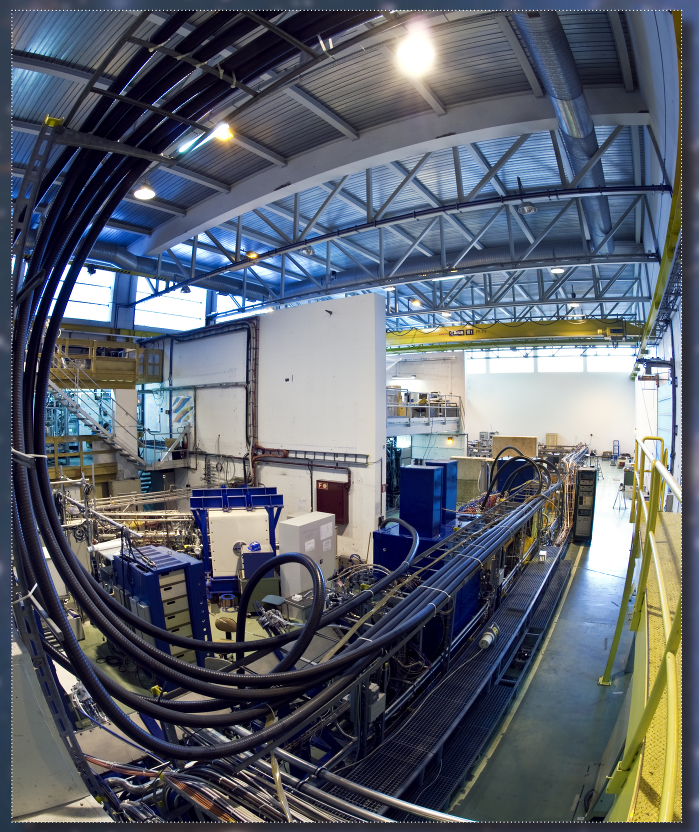
RILIS lasers in action

Selection

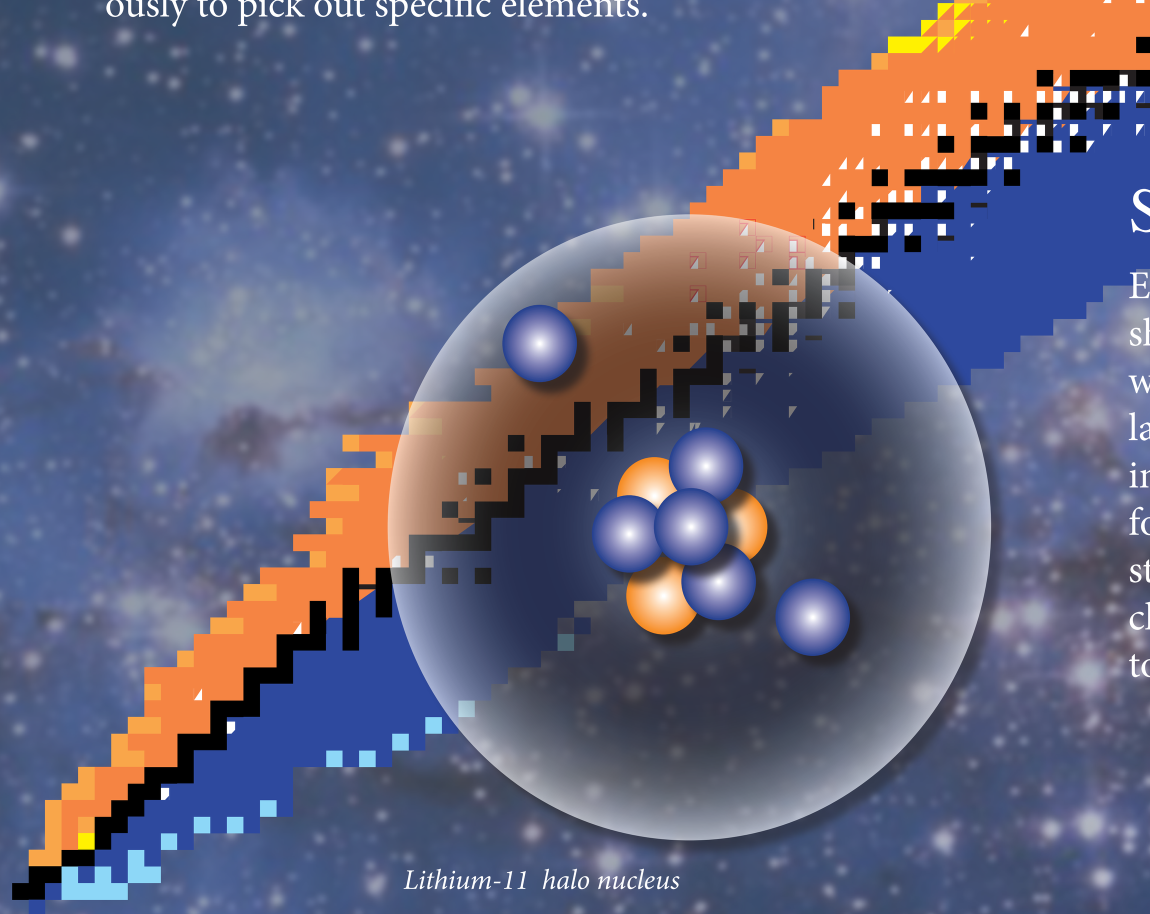
To produce a beam of a chosen exotic nucleus requires not only the right choice of target material, but also methods to extract the nuclei as ions (with fewer electrons than atoms) and to separate them electromagnetically from other species. ISOLDE has pioneered a very selective ionization technique that uses several wavelengths of laser light simultaneously to pick out specific elements.

Acceleration

To make the most of the nuclei produced at ISOLDE, the REX ISOLDE system provides an acceleration stage. Here the nuclei are trapped, bunched, stripped of additional electrons, selected according to mass, and finally fed into a linear accelerator to boost their energy to 3 MeV per nucleon.



The REX accelerator



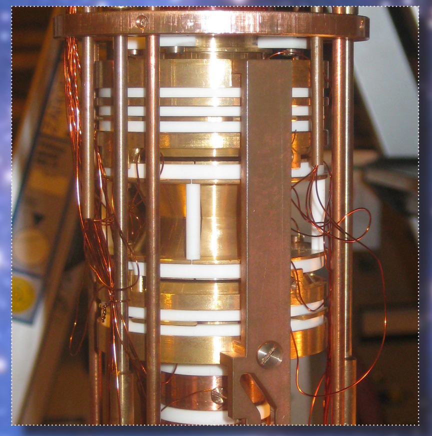
Lithium-11 halo nucleus

Facts and Figures

- *ISOLDE today offers the largest range of available isotopes worldwide at an ISOL facility*
- *So far more than 700 different beams of isotopes from 70 chemical elements have been delivered*
- *We run usually for 7 months per year*
- *In the last 4 years, 175 experiments have been performed*
- *In 2011 we had 90 active experiments*
- *We have about 450 active users from 100 institutes in 25 countries*
- *The ISOLDE collaboration includes 13 countries and CERN*
- *In 2009-2010 we had over 70 publications, including around 20 Letters*

Fundamental symmetries

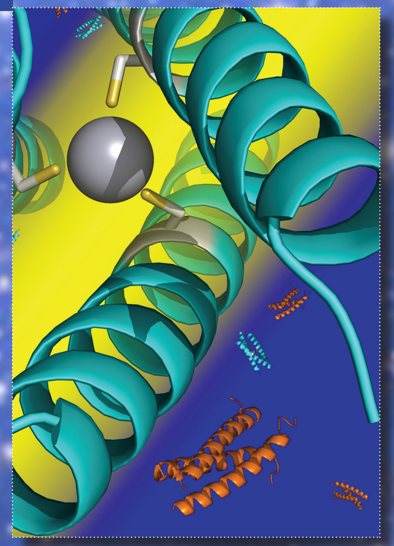
The nuclei produced at ISOLDE, with proton-to-neutron numbers varying over a wide range, provide an interesting microscopic laboratory for low-energy tests of the Standard Model of elementary particle physics. The high quality of the beams allows high-precision measurements of beta decay, particle correlations and atomic masses.



Penning trap: an ideal tool to store and study exotic nuclei

Bio- and Medical physics

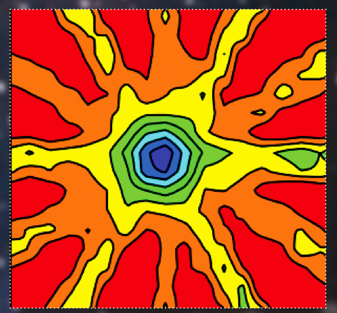
The applications in Biophysics aim at the study of the structure, bonding and transport mechanisms in a variety of biological molecules such as proteins and amino-acids. Other studies investigate which isotopes are most suitable for Medical diagnostics and cancer therapy.



Mercury atom binding to protein

Condensed matter

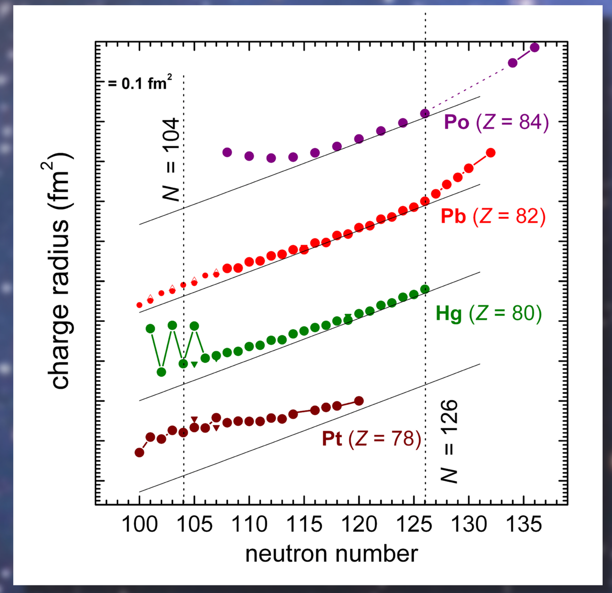
The beams at ISOLDE can also be used to study structural, electrical, optical, magnetic and transport properties in a variety of technologically and fundamentally relevant materials, including semiconductors, metals, high-temperature superconductors and ceramic oxides.



Emission pattern from radioactive nuclei implanted in a target reveals their position inside the lattice

Sizes and shapes

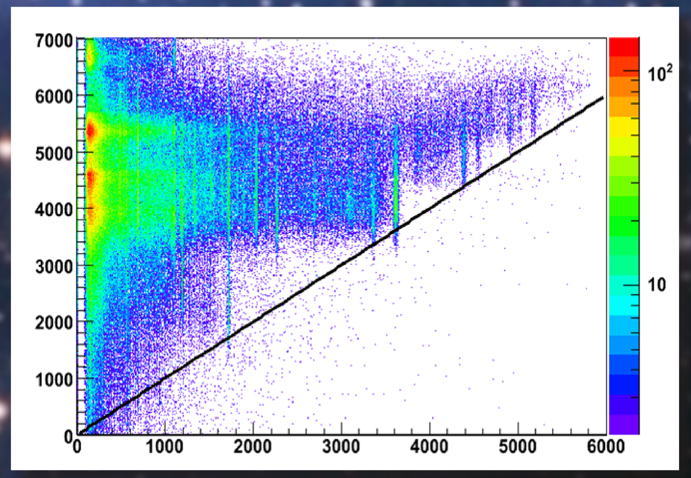
Exotic nuclei come in a variety of sizes and shapes, from spherical to deformed shapes, which can be "prolate" (cigar-shaped) or "oblate" (like a discus). Experiments at ISOLDE can investigate the transitions between extremes, for example, the development of a neutron-halo structure in lithium-11, which makes this nucleus with only 11 nucleons (neutrons and protons) as big as a lead nucleus with 208 nucleons.



Charge radii of heavy nuclei in the lead region, showing evidence of different shapes

Excitation and Decay

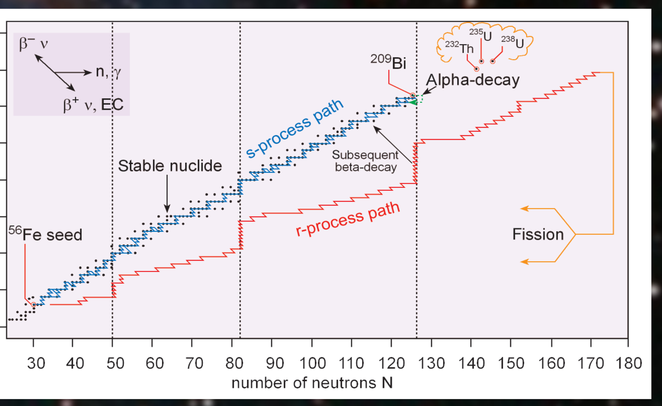
Nuclei are governed by the laws of quantum mechanics and exhibit "excited states" with well-defined energies and other properties predicted by theory. Radioactive decays and nuclear collisions can leave nuclei in excited states that decay to the ground state by emitting gamma rays. These can be detected by advanced germanium detectors cooled to liquid nitrogen temperature, as in the MINIBALL array. The properties of the gamma-rays (energy and angle) provide information on the excited states, which can be used to test theories.



Proton energy versus gamma ray energy in a one-neutron transfer reaction on nickel-66

Nuclear astrophysics

One of the most fundamental and challenging questions of the 21st century is how the elements from iron to uranium were created. Nuclear reactions occurring in explosive stellar environments, such as novae, supernovae and X-ray bursters, are believed to play an important role in the synthesis of these heavier elements. The pathways of the reactions leading to them involve short-lived radioactive exotic nuclei, which can be studied at ISOLDE.



Possible paths of the stellar nucleo-synthesis

Contents: Mark Bissell, Yorick Blumenfeld, Bjorn Jonson, Magdalena Kowalska, Piet Van Duppen, ISOLDE collaboration
Photos: CERN Photo Service, ISOLDE collaboration, NASA
Layout: Megan Dinius - August 2011