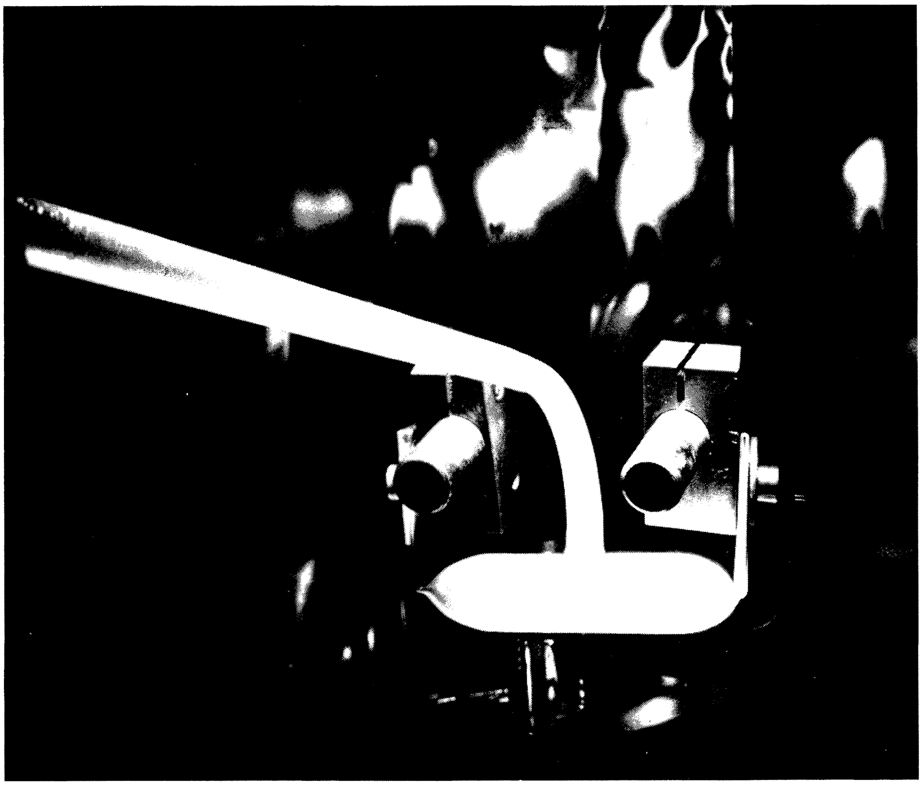
At ISOLDE
Isotope separator on-line



A new type of liquid metal target for the isotope separator, ISOLDE. An alternating current (the high current leads can be seen behind the target) keeps the metal at this glowing temperature in a tantalum container which is placed axially in the path of the SC beam. Ions of barium, cesium, xenon, iodine and tellurium, for example, can be obtained from a lanthanum target.

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There are now about sixty scientists coming to CERN as visitors to take part in the experimental programme of the isotope separator on-line, ISOLDE. The facility was described in vol. 7, page 23. Its essential ability is to make possible the study of short lived nuclei (far from the stability line) produced by bombarding targets with protons accelerated in the 600 MeV synchro-cyclotron.

A great many of the experiments are in the traditional field of nuclear spectroscopy — the painstaking work of pinning down the excitation energies, quantum numbers, etc., observed in the decays of the rare nuclei. Ultimately, the mapping of nuclear properties is the touchstone against which our attempts to interprete the nucleus stand or fall. We will mention three other experiments.

The first (by a Mainz team led by E.W. Otten) involves 'optical pumping', which has become familiar in connection with the laser, and a whole range of other atomic and nuclear techniques in order to unearth properties of nuclei far from stability. The panoply of techniques is necessary because the nuclei are in most cases available in very small numbers.

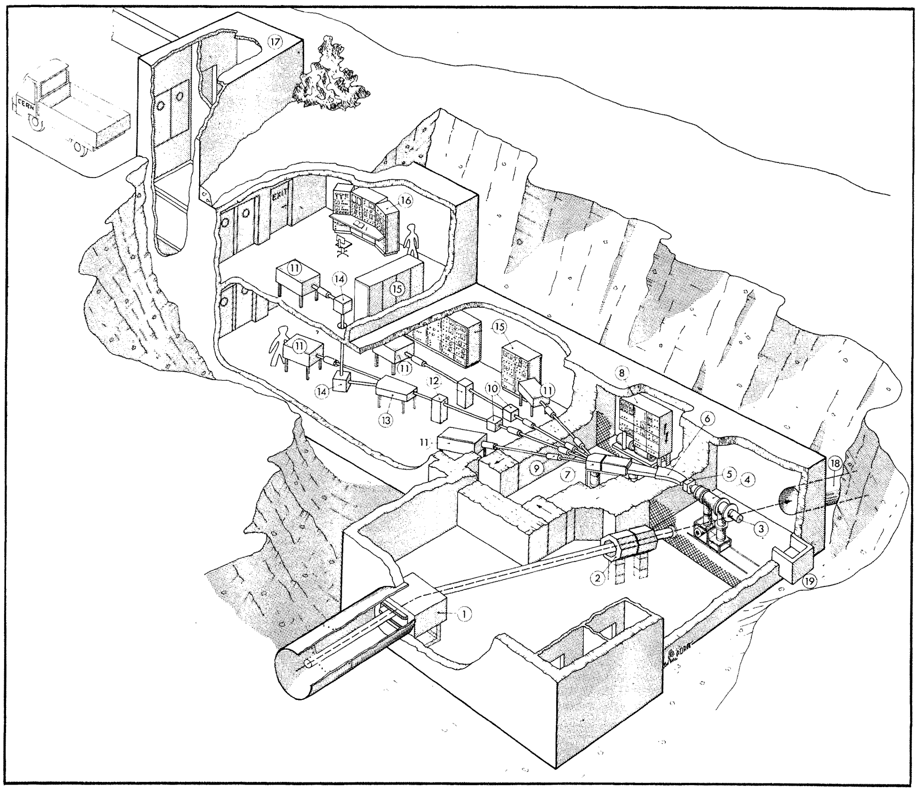
Without going through the experimental method again (see vol. 11, page 321) we will simply report their most intriguing result. They measured the atomic energy levels along a long chain of mercury isotopes and compared them with a stable isotope. This energy level difference (the 'isotope shift') is related to the nuclear shape (more specifically — the mean squared radius of the nucleus). For measured mercury isotopes from mass 205 down to mass 107 a neat straight line could be drawn through the measured energy differences corresponding to the expected decrease in nuclear radius with decreasing neutron number. Then, abruptly, for isotope 185 the energy difference veered a long way from the straight line — the change from 107 neutrons to 105 neutrons in the nucleus abruptly increased its effective radius. This change is sustained in measurements on mercury 183 and (a very recent result) 181.

The popular explanation is that for these three isotopes the nucleus is deformed into an ellipsoidal shape (such as is familiar for the rare earth elements). However another consequence of this type of deformation would be the possibility of rotation of the nucleus (again as with the rare earths) which should lead to observable fine structure in alpha decay. A newly developed target system has made it possible to look at mercury 184 produced from the alpha decay of lead 188. The experiment which was carried out by a team from Aarhus, CERN and Copenhagen, showed no sign of rotation.

An alternative idea, promoted by C.Y. Wong in October 1972, is that the nucleus transforms into something like a bubble with particles clustering around the outside of the sphere. This gives calculated energy differences in line with the Heidelberg results but needs other experimental investigation before it becomes more than an intriguing surmise.

A second series of measurements at ISOLDE has concerned the energy spectra of nuclei emitting 'delayed' particles. In the early studies of uranium fission it was observed that nuclei which are unusually rich in neutrons can sometimes survive for several seconds after their formation (an enormously long time on the nuclear timescale) before they emit neutrons. The same phenomenon for protons has been observed in a number of heavier nuclei at ISOLDE (see vol. 10, page 5) and at Dubna.

Cut-away view of the planned ISOLDE experimental area. The 600 MeV proton beam from the SC enters through a switching magnet (1) and focusing quadrupoles to the ISOLDE target and ion source (3). A beam of radioactive ions is set up by means of the acceleration electrodes (4) and mass-analyzed in a magnet (6). Individual masses are selected electrostatically in the switchyard (7) and taken to the various experiments (11) via secondary beam lines. Up to four experiments will be able to operate on-line simultaneously. A novel feature will be a second magnetic analysis stage (13) which is expected to provide a very clean beam for special low-intensity experiments. It is possible that at a later stage this beam will be taken by electrostatic deflectors up to the low background area (16) which also houses the controls of the isotope separator.



In recent work the fluctuations in the delayed particle spectra have been studied. This has revealed fine structure which is very reproducible for a particular nucleus but which varies in a seemingly random way from nucleus to nucleus. This is a way of looking at the nuclear 'noise' and the treatment of the results has followed the theory of noise in electrical circuits. From the measured spectra the average densities of the nuclear energy levels were deduced. Also information about how the levels are populated emerges.

The last series of measurements we will single out concerns the 'strength function' behaviour in beta decay. In the decay of nuclei far from stability, a very large number of states can be populated because the energy available is large. Instead of studying individual transition probabilities to isolated levels, their strength function behaviour can be studied — that is the total transition probability per unit energy interval with any trivial energy dependence removed. Studies as a function of mass number and atomic number has shown some surprising effects.

Beta decay of a particle inside a nucleus is very different from the beta decay of the same particle in the free state because the other nucleons affect the properties of the particle. One phenomenon is collective beta decay in which the beta decay process is produced jointly by a group of nucleons. Similar processes are known to occur in electromagnetic transitions in nuclei and in muon capture. The collective effects in beta decay manifest themselves by a different energy dependence for electron and positron emission. This can be seen by comparing the CERN data with that taken at the Studsvik reactor and also from analyses of delayed neutron emission results by A.C. Pappas and Y. Takahashi.

These studies indicate new 'simple' excitations of the nucleus. They may also be relevant to theories of stellar synthesis — the attempts to explain how the heavier elements (beyond lead) were built up when stars were formed.

Plans have been prepared for a major revamping of ISOLDE to go on at the same time as the SC shutdown so as to be able to make full use of the higher intensities. In fact a 10 μA SC beam is probably as much as the ISOLDE target could reasonably hold down and the SC improvement programme lines up well with the wishes of the ISOLDE collaboration.

Because of the high radiation levels a new layout will put the separator behind a shield wall with the target behind a second shield wall. Another change will be that the analysing magnet will be in the shield wall structure. Mobile electrostatic lenses will give much greater flexibility in beam selection to each experiment and should provide up to four simultaneous secondary beams in the experimental area.

Recent work on targets looks very promising. A new type of molten target and surface ionization source has been developed. The source has been fitted with a rhenium tip (which has a high work function) and it is then possible to have nuclei of earth alkalies and of certain rare earths accelerated into the separator. A high temperature oxide target (developed by the Copenhagen group) will be used to obtain the elements from thallium up to radon. Another development is a target where it is possible to vibrate the molten metal in order to get at the very short lived nuclei.

These modifications will open up further possibilities in the ISOLDE programme with the improved SC.