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ISOLDE TODAY AND TOMORROW

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Abstract

Isolde is known throughout the world as the on-line isotope separator at the 600 MeV synchrocyclotron at CERN, Geneva. Work has been going on there since 1967 on many topics including nuclear physics, solid state, atomic physics, etc. There have been great improvements made over the years but it became clear that the physics output could only be increased if there were to be an expansion of the facility. It was decided to build a second on-line separator to be used alternately with the existing Isolde, thus doubling the potential. The new separator is under construction, called Isolde 3, and is scheduled for first operation next year.

1. Evolution of Isolde

The Isolde separator started to work on-line to the CERN 600 MeV synchrocyclotron (SC) as long ago as 1967, when the accelerator was already 10 years old. In those days the SC could produce an extracted proton beam of up to about 50 nA which, combined with the early target/ion sources used by Isolde at that time, resulted in on-line ion beams of, for example, Hg isotopes with a maximum intensity of 10^7 ions/sec. However, this was adequate for the experiments planned then, and Isolde ran successfully for about 6 years with gradually improving techniques. Finally, about 12% of the SC's beam time was devoted to Isolde physics, or about 800 hours per year.

In 1973/4 the long-awaited SC improvement programme was implemented, and in parallel with it the Isolde group upgraded their installation, from then on labelled Isolde 2. This upgrade converted what had been a fertile series of experiments into an experimental facility. On the accelerator side, the Improvement Programme consisted of fitting a new radiofrequency system, improving the beam optics from the ion source through to extraction, and increasing the extraction efficiency by an order of magnitude with a septum magnet. As a result the SC could deliver beam intensities of 2 μ A to the Isolde target, an increase by a factor of more than 40.

In the underground Isolde zone the changes were equally dramatic. The zone was completely reshuffled so as to gain space, and the separator magnet was moved close to the production target : previously the ion beams drifted 3m through a concrete shielding wall before reaching the magnet. The result was a doubling of the experimental area available for physics, which could now be fully exploited with four separate beam lines from the electrostatic switchyard after the magnet. Targets were another area of improvement with the introduction of disposable, self-contained target/ion source units and a remote target change mechanism, which permitted the full proton intensity to be used on a target of thickness of order 100 gm/cm^2 . The first targets to be used were the highly successful alkali producing targets.

Demand for beam time at IS2 steadily increased after the upgrading, reaching 1900 hours of physics in 1980, or 35% of the SC's beam time. An additional experimental zone of 120 m^2 at ground level was opened in 1978, fed by a vertical extension of one of the beam lines in the underground zone. In 1982 an industrial robot was introduced as a more flexible way of exchanging target units. Meanwhile a great deal of work was done to improve the reliability of the facility and the lifetime of the targets, as well as to extend the range of elements available as beams. Encouraging tests were made with the $303 \text{ MeV/amu } ^3\text{He}^{++}$ beam of the SC which showed that for certain elements (and especially for the isotopes on the neutron-deficient side of the yield curve), there were considerable gains to be made compared to using 600 MeV protons. Beams of $86 \text{ MeV/amu } ^{12}\text{C}$ were also tried, with less encouraging results. The main limitation in both cases was the lack of primary beam intensity, which the SC Group promised to rectify, given sufficient development time.

By the early 1980's it became clear that the Isolde facility was saturated at the level of about 2000 hours of physics per year, and some thought had to be given to the future. Isolde was limited by the physical size of the experimental zones, by the primary proton intensity, and by the need to service the equipment in the highly radioactive target zone. There was also a limitation from the manpower side, since the staff were already fully occupied keeping the facility running, developing new techniques and producing the roughly 30 consumable target/ion source units needed each year.

Various scenarios for the future were investigated, including a move to SIN where very much higher proton intensities would have been available, but the proposal finally accepted in December 1983 was to build a second separator (IS3) at the SC and to run the accelerator primarily for Isolde for 4000 hours per year. A cut-away view of how the complete facility will look is shown in Fig. 1.

Fig. 1 The SC-Isolde facility

2. Present status of IS2

Currently there are about 30 experiments in progress at Isolde, and the facility is used by almost 200 physicists. A detailed catalogue of the

beams available at Isolde was presented last year at the Zinal workshop (Ra84), and a summary of which elements can be produced is shown in Fig. 2.

PERIODIC TABLE OF THE ELEMENTS

GROUP																	
IA																	VIIA
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
		LANTHANIDES															
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		ACTINIDES															
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

☒ Elements available at ISOLDE

Fig. 2 Summary of the elements available at Isolde

Of the 66 elements which may be produced, roughly one half have a high yield from the target, which means $\sim 10^{11}$ atoms/sec at the peak of the yield curve for a 1 μ A proton beam, and are available with good chemical selectivity ; for these elements no further development work is necessary. The remainder could benefit from improvements in selectivity or in the release of the desired radioactivity from the target material into the ion source.

The most popular ion source at Isolde is the plasma source developed from FEBIAD sources found in many laboratories. The latest version of this source has recently been completed and will gradually become standard at Isolde ; it has direct resistive heating of the cathode surface. The target/ion source combination has to be tailored to the particular experiment being performed, in order to optimise the yield and/or the selectivity, and this results in there being several different versions of the target/ion source ; for example, different cases require different temperatures in the

transfer tube between target and ion source. Sources other than the plasma source are also frequently used, notably the surface ionisation source, both positive and negative. Consequently the production of the target/ion source units is not a trivial task and requires a lot of manpower.

Target/ion source units are exchanged by means of the industrial robot which was purchased in 1982. This development has been very successful, especially in its effect on doses to the personnel. Another recent improvement to the facility has been the addition of a second beam line from the underground area to the experimental area at ground floor level.

3. Progress on IS3

The ideal location for IS3 would have been in a new underground zone near to IS2, but the cost excluded this solution. The only way of keeping the cost to an acceptable level was to make use of existing buildings, and it was on this basis that the project was finally accepted (Ce83). As a result the target had to be situated inside the SC vault in spite of the inconvenience that this implied, and the separator had to be designed so that the experiments could be housed in the existing "Proton Hall" of the SC. This results in two separate Isolde installations which can receive beam alternately from the SC, with a switch-over time of an hour or so. It is planned to use the same target/ion source pots for the two separators, so as to maintain only one production line for the targets and thus keep costs to a minimum.

The new separator has the characteristics listed in the table, and the optical properties of the beam are shown in Fig. 3. Electrostatic lenses will be used throughout, with a wide aperture (14 cm) in order to accommodate the beam envelope from a slit source; the intention is to be able to run with both the normal Isolde sources and a slit source developed from the Isocelle design. Unseparated ion beams are transported 8m through the SC shielding wall to a focus before the first 90° separator magnet, which has a highly uniform field. Auxiliary coils and an electrostatic multipole element will be used to correct aberrations in the optics and to permit the best performance of the separator to be realised. The focal plane chamber after the first magnet will be used to measure the beam properties, and to select

the desired isotope. A second stage of separation then follows, via a similar 60° magnet, and the beam is finally distributed to the experiments in the Proton Hall.

Fig. 3 Calculations of the beam in the horizontal plane from the source at bottom right through to a focus after the second bending magnet.

Table - Parameters of the Isolde 3 separator

- Two-stage separation with a combined resolving power of ~ 5000 at high transmission ; possibility to reach $\sim 30,000$ with slits.
- Maximum current to be transported to the first magnet : 3mA using a slit source.
- Acceleration voltage 60 kV maximum.
- Dispersion after the first magnet > 12 mm per %, perpendicular to the beam; the first focal plane to cover a mass range of $\pm 10\%$.
- Enhancement factor $\sim 10^4$ for the first stage, increasing by a further factor of 10^2 to 10^4 in the second stage and by tuning.

The power supplies for the target/ion source will be housed in a Faraday cage in the Proton Hall, joined to the target by a specially-designed high voltage tube of low capacity. All the supplies are commercial and are designed for very high stability and low ripple (1 in 10^5). Power is fed to the supplies from a commercial isolation transformer. The high voltage, 60 kV as at IS2, is generated in a home-made supply with equally demanding specifications. A great deal of attention is being paid to keeping the stored energy to a minimum and to introduce shielding and Faraday cages in order to minimise the effect of sparking on other experimental equipment, especially computers. This has been a considerable problem at IS2. One other important advantage which IS3 will have over IS2 is the ease of access to the high voltage supplies, since the Proton Hall is not a highly radioactive zone.

Control of the separator will be by a microprocessor based serial CAMAC system using standard CERN interfaces, and work is progressing rapidly in this domain. A control room, close to the SC control room, is being prepared, much of the CAMAC hardware is available already, and a start has been made on the software.

The separator is being constructed in a collaborative way by CERN and several participating laboratories. Most pieces are designed and some items have already arrived ; the magnets themselves are to be delivered in October, and all the civil engineering work has been completed. It is our intention to assemble the first part of the separator in the near future for tests in the Proton Hall prior to mounting it in its correct place during the Spring of 1986.

4. Future possibilities

Although exotic possibilities such as the acceleration of radioactive ions or their storage in a storage ring have been discussed there are no firm plans to proceed in this way. However, two development areas are clear, and await only time and manpower.

The use of a $^3\text{He}^{++}$ beam of 303 MeV/amu has already been mentioned as an advantage in certain cases, especially for nuclei far from stability. Such a beam is also advantageous in that it produces less induced radioactivity in the SC vault. However, the $^3\text{He}^{++}$ beam has not so far been produced with sufficient intensity to make its frequent use an interesting proposition compared to 600 MeV protons. Improvements have been made to the r.f. system and to the SC's ion source which should now permit an intensity gain of a factor 3 or 4 to be achieved, but so far this has not been tested. If the $^3\text{He}^{++}$ intensity rises to the proton intensity (i.e. $> 10^{13}$ ions/sec), this beam could become the preferred Isolde production beam of the future.

Ion sources are also an area where it is planned to make improvements, once the new separator is working and manpower is liberated. New ideas for on-line sources include the laser source (which will probably not make new elements available to Isolde but will certainly improve the selectivity), and ECR sources (where the problem will be to adapt existing ECR technology to the high-temperature, high radiation environment of the Isolde separator).

References

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