A NEW ISOTOPE SEPARATOR AT THE CERN SYNCHRO-CYCLOTRON

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ABSTRACT

The Isolde facility has been one of the main clients for beam time at the CERN synchrocyclotron since 1967. It was decided in 1983 to expand the capability of Isolde by the addition of a second primary proton target station and a second on-line isotope separator. At the same time it was decided to run the SC almost exclusively for Isolde in the future. The new separator has two stages of separation and has been designed so as to fit into existing buildings in order to keep the cost to a minimum. At present the separator is being installed, and we expect first beam towards the end of 1986.

INTRODUCTION

Isolde is known throughout the world as the on-line isotope separator facility at the CERN 600 MeV synchrocyclotron. The earliest experiments at Isolde date from 1967, since when there has been a continual improvement in target/ion source techniques and in remote handling, so that what started as an experiment has now become a dependable facility for the users. In 1974/75 the SC was upgraded, with the result that the beam intensity delivered to the Isolde target rose by a factor 40 to at least 2 μA. At the same time the original Isolde installations were upgraded, and the facility then became known as Isolde 2.

By the early 1980's it started to be clear that the Isolde facilities were becoming saturated. At that time Isolde had about 220 shifts each year, or roughly one third of the total beam time available at the SC. However this number of shifts appeared to be close to saturation because of the limited number of target/ion source units which could be manufactured and tested with the resources available. Furthermore, the necessity for repairs and maintenance of parts of the separator in highly radioactive areas required that sufficient "cooling" periods be scheduled. To these limitations were added the difficulties experienced by the experimental teams in the overcrowded experimental zones. Thus ways were sought to improve the situation by constructing a new facility. A relatively cheap solution was adopted finally, whereby a second target station was to be placed in the well-shielded cyclotron vault and a new separator was to deliver its ion beams to an existing experimental hall (known as the Proton Hall). In this way no new buildings were required and the overall cost could be kept low. The proposal[1] was accepted in December 1983 when it was also agreed that the SC would run primarily for Isolde in the future. The new separator was given the title Isolde 3.

2. THE ISOLDE 3 SEPARATOR

2.1 General

A plan view of the new separator is shown in Fig. 1. The extracted proton beam from the SC travels a distance of about 10m to a new target station situated in the corner of the cyclotron vault : the protons arrive from the top in Fig. 1 After passing through the thick target (typically 100mm of heavy metal), the diverging proton beam is dumped in the shielding wall.

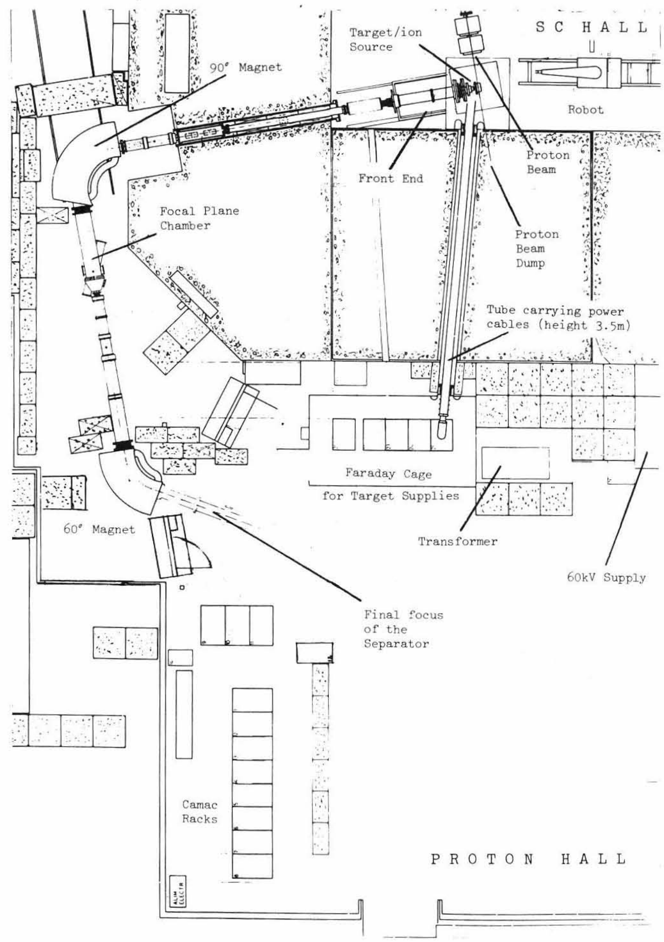

Figure 1 Plan view of the new Isolde 3 separator

Ion beams emerge from the ion source perpendicular to the direction of the protons, and pass through the SC shielding wall to the accessible area beyond, where the two separator magnets are situated. The beam is distributed to the experiments in the Proton Hall.

2.2 Target/ion source units and remote handling

A great deal of development work went into the target/ion source units for Isolde, especially in the late 1970's, with the result that high performance units can be produced, which work reliably in the highly radioactive environment of the SC hall[2]. Figure 2 shows such a unit equipped with a tubular surface ionisation source. The figure shows the unit as seen by the irradiating proton beam. About 50 target/ion source units will be used each year at Isolde.

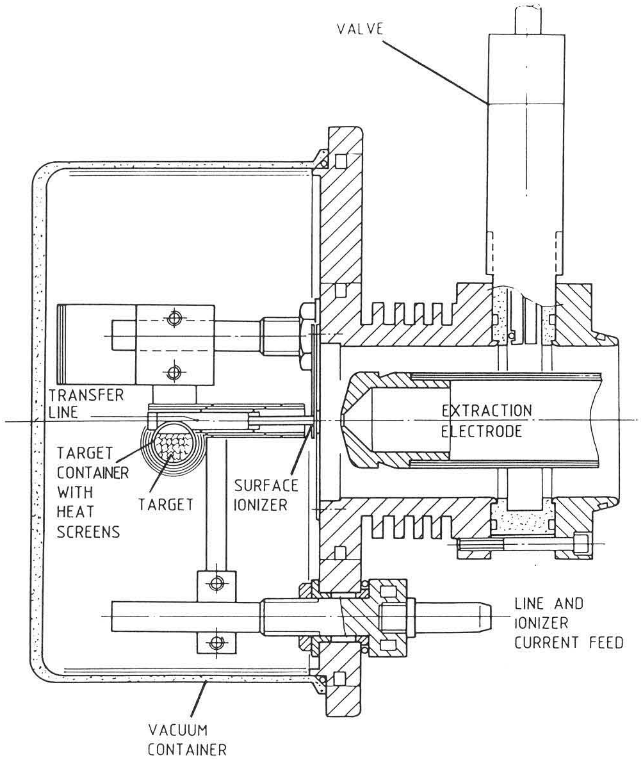

Figure 2 Drawing of a target/ion source unit, equipped with a tubular surface ionisation source.

In 1982 an industrial robot was introduced as the best way to install, remove and store the Isolde 2 target units. A second robot has now been purchased and installed on rails in the SC hall. Its purpose is to make the exchange of the target/ion source units and to store them temporarily in eight niches in the wall of the SC hall, behind lead doors. The robot retires to a safe distance (10 m) during the actual irradiation.

The intention is to use the same targets and ion sources as are used already at Isolde although, of course, there is a constant evolution in this field. Yields which have been obtained at Isolde have been published[3] and Fig. 3 shows which elements are currently available as beams. Plasma ion sources and positive surface ionisation sources are most frequently used, but negative surface ionisation sources are also in demand : all these will be used at IS3. One exciting new feature, however, will be the use of high current slit sources as developed at Isocele[4]. The new separator has been designed with large apertures to accommodate the intense beams from such sources and all the lenses have been fitted with space-charge restoring guard rings. The Isocele group has succeeded in adapting the slit source to fit the geometry at Isolde and currents up to 3 mA are planned.

2.3 Front end

The term "front end" is used to describe the first part of the separator, often known as the "acceleration chamber". It includes the target coupling mechanism, the extraction electrode assembly and the first electrostatic quadrupole lens triplet, the whole mounted on a trolley and fitted with a Faraday cage around the 60 kV section. Two such units are planned initially, one of which is at present being fitted with services (water pipes, cables, compressed air, vacuum connections) in such a way that it will be a fairly quick job in the radioactive SC hall to decouple and exchange it whenever this becomes necessary. A third front end is under active discussion, which would be suitable for new types of ion source such as an ECR source or a laser ion source.

The target/ion source units will be held at a potential of 60 kV during operation, the same as at Isolde 2. The main insulator is made of polystyrene, a material which has good vacuum and radiation properties. A Faraday cage of volume of order 2 m^3 surrounds the high voltage part and includes a patch panel through which the various services arrive. All the power supplies for the target/ion source units are situated in the Proton Hall out of the radiation on the other side of the SC shielding wall, from where the cables run to the target in a coaxial tube high in the wall, designed to have as low a capacity as possible, to keep the stored energy low. The Faraday cage will be supplied with dehumidified air so as to limit sparking and reduce the corrosion produced by acid formation initiated by the passage of the several μA proton beam in wet air. The air will be at a slight under-pressure so as to contain any release of activity should there ever be a leak from a target unit.

The most important element of the "front end" is the extraction electrode developed by the Strasbourg Group. A photograph is shown in Fig. 4.

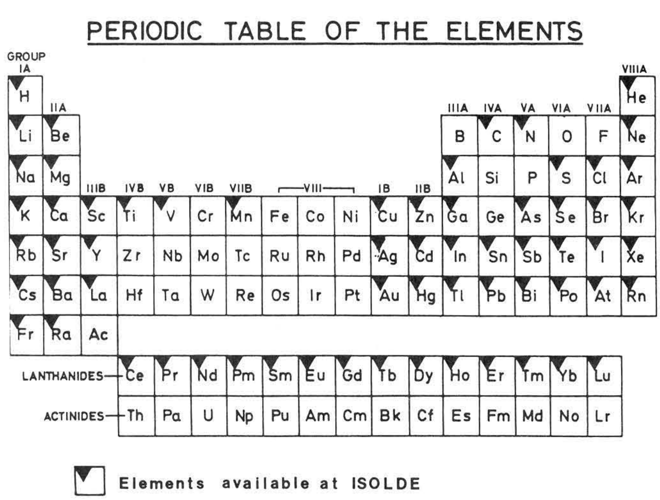

Figure 3 The elements available as beams at Isolde.

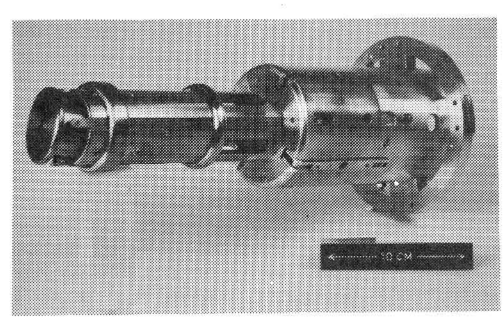

Figure 4 Photograph of the extraction electrode.

The water-cooled electrode is mounted between two insulators but will normally be operated at earth potential : however, if necessary, it could be raised to a potential of 40 kV. The electrode has a longitudinal movement of 150 mm so as to allow an optimum position to be found for all the different ion sources envisaged. At its entrance there is a removable collimator made of Ta which is able to rotate about both a vertical and a horizontal axis by roughly 10°: this is achieved by the push or pull of rods controlled by a water-filled hydraulic system. These rods may be seen in the photograph. A prototype of this rather complicated extraction electrode has been tested in the laboratory under realistic working conditions of vacuum and high temperature.

2.4 Beam optics

Detailed calculations of the optics of the separator have been made in Giessen[5] with the result[6] shown in Fig. 5.

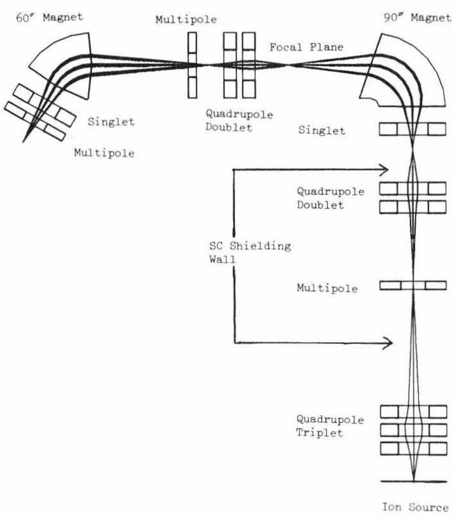

Figure 5 The beam optics in the horizontal plane.

Beams from the ion sources used at Isolde have a typical divergence of up to ±25 mrad and an effective source size of ±0.2mm in each plane : slit sources have a similar emittance in the horizontal plane, but extend vertically to ±7.5mm with a vertical divergence of ±5 mrad. The beam has to be transported a distance of 8m through the SC shielding wall to a focus in front of the first of the two separator magnets. This simple beam transport section contains five wide-aperture electrostatic lenses. After the focus, a singlet lens spreads the beam horizontally so as to fill the useful pole area of the 90° magnet and thus obtain a good resolving power. Calculations show that a resolving power of order 5000 should be possible for the first separator stage.

After this magnet the beams of different masses are focussed along a line inclined at 20° to the axis; here the dispersion is ~15mm per mass unit at mass 100, perpendicular to the beam axis. The central mass is selected by slits and is passed through to the second stage of the separator which includes a 60° magnet, and the beam is finally brought to a focus before being distributed to the experiments in the Proton Hall.

Although the separator consists of nine electrostatic lenses and two magnets we expect a good performance to be achieved relatively rapidly since all the elements have been constructed to high precision and can be accurately aligned. However, the separator has been designed for high quality beams, with a resolving power up to 30,000. Provision has been made for the installation, progressively, of a number of correcting elements : three electrostatic multipoles and two sets of auxiliary coils in each of the two magnets. The aim of these elements is to correct second- and third-order aberrations in the optics. To obtain the ultimate performance of the separator will require careful tuning of all the correcting elements when these are installed and may well be at the sacrifice of intensity, since narrow slits will be required; however, such a high resolving power will permit experiments which are not possible today at Isolde.

A further feature which has been included in the design is the insulation of each of the magnet vacuum vessels in order for them to be maintained at potentials up to 5 kV if required. This feature[6] will allow the rejection of ions of the wrong mass but correct momentum which have found themselves following the correct trajectory after a scattering process in the residual gas, especially in the initial acceleration region. We hope that this feature will bring a distinct advantage when it is necessary to run with a high enhancement factor.

2.5 Magnets

A "C" shape was chosen for the design of the separaator magnets because of the good accessibility this allows. The steel used throughout is of very low coercive force (<50 A/m) and the pole gaps are constant to 20 μm. Magnetic measurements have been completed on both magnets, using Hall plates mounted on a radial arm whose centre of rotation corresponded to the desired 1m bending radius. Two iterations were necessary in the machining of the removable pole ends so that the magnet would have the desired magnetic length. Field maps were obtained at various vertical positions in the gap, and for various excitation currents : furthermore, a study was made of the effect of the SC's fringe field. The 90° magnet has normal entry, but the pole pieces at the exit are inclined at 20° so as to give some vertical focusing to the beam. The gap is 110 mm, of which 76 mm is the aperture inside the vacuum vessel. The radial width of the poles is 420 mm of which the beam occupies 220 mm. Maximum field strengths of almost 0.7T will be used, so both magnets are far from saturation: they are fed from highly stabilised current supplies (one part in 10^5).

2.6 Diagnostics

Several diagnostic tools will be used at Isolde 3, developed mainly by the Copenhagen group and from experience at the present Isolde facility. The Copenhagen group has developed an extremely compact module consisting of motor driven vertical and horizontal slits, a Faraday cup, vertical and horizontal scanners : two of these units will be used at the object points for the two magnets of the separator. In two places at the beginning of the separator, wire grids consisting of 32 x 32, 0.2 mm diameter wires spaced at 2.5 mm will be used to give details of the beam profile in a non-destructive way.

The most important diagnostic devices, however, are the scanners. These will be used at several places in the separator, but they will be independent of the control system, for financial reasons. The scanners developed at Copenhagen have scans of 80mm and are particularly well adapted to places where space is limited as, for example, close to the object points of the two magnets.

We hope that this model of scanner can be developed to yield a 500 mm scan, which will be immediately useful in the focal plane chamber after the first 90° magnet, where masses up to ±10% of the central mass are focussed along a line inclined at 20° to the beam axis. The present 80 mm scanners have the advantage over commercial models in their compactness and their high precision (0.1 mm), although their response is a little slow (2 scans per second). These advantages are not needed in the beam lines in the Proton hall where the separated beam is sent to the experiments, and so commercial units will be used there.

2.7 Target/ion source supplies

A large Faraday cage has been constructed to house the nine supplies for the target/ion source units, insulated for the working potential of 60 kV. Electrically this Faraday cage is an extension of that surrounding the target in the SC hall, on the other side of the 6 m shielding wall (see Fig. 1). The biggest supply produces 1000 A for heating the target, and the total peak power available is 50 kVA, which is supplied by an isolation transformer situated adjacent to the Faraday cage. Commercial units have been purchased throughout. Control will be via a fibre optic link in CAMAC. The power cables run to the target through a co-axial tube designed to keep the stored energy as low as possible in order to reduce any damage from the propagation of transients when there is a 60 kV spark.

2.8 60 kV supply

The 60 kV power supply is subject to a pulsed load because of the time structure of the beam from the synchrocyclotron. The beam passes through ~300 mm air before and after the target, and there is consequently a peak load of order 5 mA due to air ionisation. In order to obtain the required high stability both long-term and in ripple (1 part in 10^5), it was decided that the only solution was to build the 60 kV supply in CERN. Construction is well advanced and the supply will be placed in the Proton hall where the ease of access will be a considerable bonus compared to the present Isolde. The high volts will be controlled by CAMAC and the supply is designed to give a current of up to 30 mA.

2.9 Control

The separator was designed to be fully computer controlled from the beginning, but some concessions had to be made for financial and manpower reasons. In particular it was clear that our resources would limit us to the application of known techniques and standard material already used elsewhere at CERN. Thus the idea to use a central mini-computer was abandoned in favour of a system based on CAMAC units, most of them developed in the CERN-SPS[7]. Three independent consoles will be used, each one controlled by a "mother crate" full of specially designed CAMAC units, several containing Motorola 68000 μ-processors.

The mother crates can handle only a single user and single task at any moment, and for the time-being there will be no communication channels between them. This is a limitation which we hope to circumvent at a later stage. The layout of the control system is shown in Fig. 6 where the tasks allocated to the three consoles are also indicated. A full description is give in Ref.8. The mother crates have to take care of a range of tasks such as running the applications programmes, communicating with the peripheral devices, storing the programmes and data tables, producing the video signals for the display units and the touch screens, and controlling the serial CAMAC highway. Serial CAMAC has been used because of the large distances involved (for example the control room will be situated 150m away from the separator).

Interaction with the computer system will be by means of touch screens (with sixteen sensitive fields), knob encoders, mechanical function buttons (whose task is selected from the touch screen), and a tracker ball. The system is therefore very versatile and since it uses mostly standard units, can be adapted in the future as needs arise.

Application programmes have been written in NODAL, a user-friendly interpretive language much used at CERN[9] and also in KEK[10]. The writing of these programmes was much helped by the preparation of software packages called "equipment modules", also written in NODAL (although later it may be possible to speed them up by writing in a compiled language) : these equipment modules contain all the CAMAC instructions for a particular task, such as setting a value on a power supply, and are very clearly written so that non-specialists can use them easily. We were also able to use the existing software developed in CERN for producing the tree structure of menus on the touch screens.

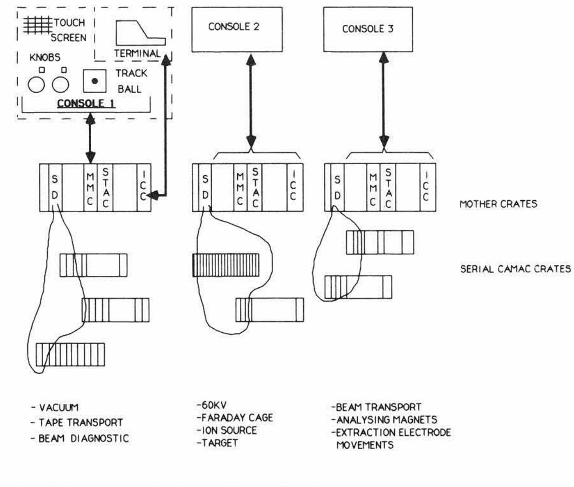

Figure 6 Layout of the control system.

3. CONCLUSION

The present time is an exciting one because all the elements that make up the separator are coming together and progress is very visible. We hope to have assembled the separator by the end of this year, and to run stable beam tests. The intention is to be certain that there are no major problems before we irradiate the target/ion source for the first time. Thereafter there will still be a great deal of work to do before we can really consider the separator a working facility: in particular there will be work to do on improving the monitoring and in integrating it properly with the computer, for this is an area which has received insufficient attention so far, due to lack of manpower.

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