INTRODUCTION

A good start has been made on the project to supply the SPS with antiprotons at 26 GeV/c, and all the signs are that the very tight schedule can just be met. Multi-batch filling to increase the SPS intensity is also progressing satisfactorily. These two projects have repercussions in every corner of the PS complex, and although the imagination may be more readily fired by some of the stranger aspects, such as antiprotons going the "wrong" way round in a proton synchrotron, most of the real effort will go into the design and production of essential hardware. Further improvements in PS performance may be anticipated when the new Linac, which has started up most successfully, comes "on stream" next year.

The SC, too, has been taking an effective interest in particles other than protons. The acceleration of helium ions is now a fully operational facility, and ISOLDE has already used them for two running periods. The project for acceleration of other light ions, principally $^{12}\text{C}^4$, is well under way.

Both the SC and the three PS accelerators have performed with creditable reliability, time lost due to faults having fallen once again this year. Bearing in mind that each one per cent is harder to get than the last, this current success speaks well for the — seldom mentioned — efforts of all the staff concerned with the humdrum work of maintenance. In this context, it is only fair to say that doubts have been expressed in some quarters as to whether enough maintenance work is being done, since a high proportion of the available manpower is being absorbed by new projects.

Mention should be made of the assistance given to other Divisions, particularly in the fields of instrumentation and experimental area equipment. Members of the Division have also contributed to studies and design of accelerators being built elsewhere, in particular at GSI Darmstadt, the Rutherford Laboratory, Peking and Los Alamos.
1. THE PHYSICS PROGRAMME

1.1 Operation

Continuing machine studies carefully followed up by the operating crews have developed performance to the point where the number of protons in each pulse transferred to the SPS frequently exceeds $1.1 \times 10^{13}$. Higher levels will no doubt be attained in the near future when the new Linac, which has already shown promising qualities during trials with injection to the Booster in October, comes into regular service.

After the long shutdown at the beginning of the year the three accelerators came back into normal operation in an exceptionally short time, thanks to a programme which permitted adequate preliminary tests and to the exemplary efforts of operating and support staff. Extensive use continues to be made of the facilities of pulse-to-pulse parameter programming, to meet the differing requirements of the various customers for high energy protons and to accommodate such machine studies as can be carried out in parallel.

During the early part of the year a 10 GeV/c cycle for the SPS was followed by three 24/26 GeV/c cycles for the ISR and PS East and South experimental areas. From July onwards the SPS received two half-length batches with a 1.2 second interval for each of its accelerating cycles, and the beam was partially pre-bunched at 200 MHz in the PS before transfer. At first, a technique of staggered ejection was used to separate the bunched protons from the remainder, so that the latter fraction could be dumped before beginning acceleration. Later, however, the SPS was able to accept the whole beam, leading eventually to the successful acceleration of $1.7 \times 10^{13}$ protons per cycle. The overall performance was further improved by modifications to the control system of the main magnet power supply which gave the 10 GeV/c cycles better reproducibility.

The fault rate has again been gratifyingly low. The IBM 1800 controls computer was responsible for two major breakdowns, and to minimise the down-time from this cause in future a procedure has been established for manual control of the injection line to the Booster. A long interruption in the supply of protons to the SPS resulted from vacuum trouble in the transfer line, and work is going on to improve reliability of this vitally important link (which also serves the ISR). It should also be mentioned that on two occasions the Booster Machine Experiment session on a Saturday at the end of a run was almost entirely lost because of the time required to re-start after a complete mains failure. Operating statistics are shown in the table below.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled operation</td>
<td>6339 h</td>
</tr>
<tr>
<td>Experimental physics</td>
<td>5505 h</td>
</tr>
<tr>
<td>- time lost due to breakdowns</td>
<td>172 h (3.1%)</td>
</tr>
<tr>
<td>Machine development and start-up</td>
<td>834 h</td>
</tr>
</tbody>
</table>
Distribution of accelerated protons (units of $10^{16}$):

<table>
<thead>
<tr>
<th>SPS</th>
<th>ISR</th>
<th>External Dump</th>
<th>ICE</th>
<th>Slow ejection (East Hall)</th>
<th>Target 01</th>
<th>Internal dump</th>
</tr>
</thead>
<tbody>
<tr>
<td>2827</td>
<td>87.8</td>
<td>527.1</td>
<td>89.3</td>
<td>2203</td>
<td>306.1</td>
<td>154.3</td>
</tr>
</tbody>
</table>

1.2 Experimental areas

The East Hall beam layout was partially reconstructed during the annual long shutdown in order to add a new low-momentum $\bar{p}$ beam ($k_{23}$) for experiments S158 and S161. At the same time the end-stop of the central branch of the primary proton beam and the shielding of the secondary beam $k_{22}$ were modified to improve background conditions for experiment S154 (strangeness exchange reaction on nuclei). The test beam facilities provided for large detection chambers gave place in May to a $K^-$ beam, providing momentum of up to 1.5 GeV/c ($k_{24}$) which is in use for experiment S159 (strange dibaryon systems). The new $p$ and $K$ beams show considerable improvement over previous versions with respect to low-momentum flux.

After completion of experiment S158 ($\bar{p}$ X-ray studies on isotopically pure targets) the same group set up experiment S161 (strongly bound $\bar{p}p$ states) in the antiproton beam $k_{23}$. In between, the Heidelberg group used this beam for tests with $K^-$ mesons. Several minor modifications were made to the high-resolution $\pi$ beam, $p_{17}$, shared by experiments S153 and S157, and a test zone was added at the far end. The test beam areas in the South Hall continue to be fully occupied, with more than twenty users in each running period and a rather fast turnover.

During the early part of the year, the specially-constructed fast extraction system and beam transport line installed in the South-East area supplied the ICE experiment with protons of 1.73 GeV/c, and was also successfully tested at low momentum (50 and 100 MeV). Stochastic cooling experiments carried out in the ICE ring rapidly confirmed the feasibility of the Antiproton Accumulator project proposal (see 3.5 below). Then in July the first part of the transport line was modified to accept protons of up to 18 GeV/c and a target for antiproton production installed. This enabled antiprotons to be stored, for the first time in history, in the ICE ring. With the help of specially-developed highly sensitive non-destructive detection systems, a new lower limit (32 hours) for antiproton lifetime was quickly established; this was already some seven orders of magnitude better than previously published figures. Work continues, using high-density bunches from the PS operating in the five- and ten-bunch modes, to obtain higher currents of stored antiprotons (see 2.6).
1.3 Experimental area equipment

Almost all the available short electrostatic separators are now in use, distributed between four beams. A long (10 m) separator is being prepared for the m16 beam to be used by the RMS experiment. The beam transport maintenance workshop is fully occupied with preparation and modification of equipment from DESY and RHEL for the new beams to be installed at the beginning of next year.

The new network of emergency stops in the experimental areas, acting on the 18 kV distribution system, has been installed and will be tested during the next long shutdown.

The servo-manipulator "Mascot" for remote handling applications (see e.g. Annual Report for 1976) has been converted into a mobile unit, christened "Mantis". It can now be deployed almost wherever its services may be required, and will be used during the next shutdown inside the extremely radioactive SPS neutrino experiment tunnel.

Apart from maintenance work on the various systems used for beam and target monitoring, good progress has been made in improving the accuracy and stability of the secondary emission chambers employed in primary proton beams.

2. CURRENT TECHNICAL DEVELOPMENT

2.1 Linac

The Linac started up efficiently after the shutdown. Stability of the 50 MeV beam has been substantially improved by supplying the debuncher with a radio-frequency generator, from the new Linac project, which is equipped with feedback control of RF phase and amplitude.

2.2 Booster synchrotron

The Booster has continued to operate with an average downtime of better than 1%. Accelerating cycles in between those providing beam to the PS are in regular use for some twenty hours a week for machine studies, adjustment and optimisation of variable parameters and similar activities. In the early part of the period under review, they were largely employed by an experimental physics group exploring possibilities for neutrino physics at low energies, as discussed at last year's Workshop on Intermediate Energy Physics.

Later in the year, protons from the new Linac were supplied to the Booster for the first time. From the experience gained, it is to be anticipated that the reproducibility of output beam at 800 MeV will shortly be improved. However, exploiting the full potential of the new injector will require hardware development and more machine studies. Supervision of Booster running continues to be shared between its own staff and the PS operations personnel, with excellent results.
By concentrating effort on the highest priority items, the limited staff available has made good progress on various improvement projects, in particular the modifications required for the reduction of cycling time. The reactive power compensator is due to arrive early in 1979, and the building to house it is ready. The associated switch-gear has been installed, and additional filter elements ordered. All other items required for the projected increase in SPS beam intensity are progressing according to plan.

The antiproton programme requires the 800 MeV transfer line to produce ten bunches instead of the usual twenty. This entails the design and construction of a double septum magnet, the replacement of solid-core by laminated magnets, conversion of d.c. power supplies to pulsed operation, and the provision of appropriate beam observation apparatus. Work began in July, and good progress has been made on most items.

Details of the system for active damping of transverse instabilities have been determined and its practical realisation began in the second half of the year. Eight pick-up (beam observation) electrodes of a new design are on order. Nearly all the orders for spare septum magnets (mentioned last year) have been placed, and some are in an advanced stage of fabrication.

The specific interface for connecting the PSB systems to the standard NORD computer controls has been defined in detail and the required hardware ordered. Data acquisition and treatment for various existing beam diagnostics was transferred to the NORD beam measurement computer, and new programs have been developed for density measurements (see 1977 report), "Q" calculations and the control of multipole correcting elements.

Machine studies have been principally aimed at providing better beam for PS users, preparing for the higher beam intensity from the new Linac, and producing intense antiproton bursts for the projected accumulator ring (see below). The intensity provided at 800 MeV for cycles destined for SPS injection has been raised as far as $1.5 \times 10^{13}$ protons, and for the vertically dense beam sent to the ISR to $5 \times 10^{12}$. Lengthy studies of the new working point, involving the simultaneous dynamic compensation of several stop-bands (including one which is systematic i.e. structural), have progressed satisfactorily. The technique of combining beams from two PSB rings in the vertical plane and transferring to the PS with appropriate matching is now well understood. Studies are under way on various methods of obtaining a more comprehensive control over particle distribution in longitudinal phase space.

2.3 Main proton synchrotron

The installation of new poleface windings, end-block clamping, and vacuum chamber modification was carried out on half of the (100) magnet units during the annual long shutdown. At the same time, the figure-of-eight windings were replaced, using more radiation-resistant material. The successful termination of this heavy programme in time for adequate tests and checks to ensure a smooth start to operations was due in no small measure to exceptional efforts on the part of the staff concerned, including helpers from other Divisions (particularly ISR and SB).
Preparations for completing the second half of the poleface winding installation during the shutdown at the beginning of 1979 are well advanced. Plans include replacement of the interconnecting cables. When the new arrangement is finally completed, it will be possible to evaluate the merits of a five-current system for the control of "Q" and chromaticity.

The five new power supplies required for the poleface windings have already been installed, together with their controls and the distribution switchboard, and one of them has been field-tested on the figure-of-eight loop in the PS. With the new switchboard the operational mode can be changed (one, three, or five circuits), or a faulty power supply replaced, by push-button controls.

Rearrangements of machine components in connection with multibatch SPS injection have necessitated the manufacture of two new quadrupoles for installation in the 1979 shutdown. Four electrostatic septa are also being fabricated; one is a spare for the continuous transfer system and three are units of a new design with improved vacuum couplings for the slow extraction supplying the East experimental area.

The original 800 MeV injection kicker no longer meets current operational requirements, and some effort has been required to keep it working. A replacement is now nearing completion; the pulse generators are ready and will be commissioned before the end of the year, and the magnet, in spite of some difficulties with a supplier of ceramics, will be ready for installation in the shutdown at the beginning of 1979.

An 18 kV link has been installed between the SPS power supply network and the PS magnet power supply. In the case of a major breakdown of the PS motor-generator set, which could take several months to repair, this facility will enable the PS to continue to supply protons to the SPS and, with some limitations on performance, to the ISR and "25 GeV" experimental physics.

Ten higher power amplifiers for the large-aperture quadrupoles used at injection have been put into service, including computer control and data acquisition facilities. For the amplifiers supplying dipoles used for small orbit corrections at high energy, new cooling systems have been designed and ordered.

2.4 Ejection and targets

The two new extraction magnets for the East Hall primary proton beam in straight sections 61 and 62, replacing the former single unit in ss 62, have come into operation successfully. Reduction of the septum current density to a more reasonable value is confidently expected to lengthen the magnet's lifetime. New minitoposcopes attached to the units will give beam profile measurements with a resolution of 1 mm.

Further improvements have been made to the continuous transfer system supplying the SPS, mainly in the interests of obtaining better reliability and greater constancy in performance. The back-up computer
for the beam transfer line can now perform the same function for the continuous transfer computer. More sophisticated programs have come into service, including one which automatically optimises the angle of the electrostatic septum in straight-section 31, helping to reduce beam losses in the PS. The emittance reduction dipole, reported on last year, has been very successful in practice. The whole equipment was rapidly improvised using available components, and a more permanent version is now being designed.

With the present 200 MHz RF system, a significant fraction of the beam remains untrapped. This could be separately extracted by using the magnetic field to split the two portions, and then employing the full-aperture kicker firstly to eject the untrapped beam and secondly to cancel its effect upon the remainder. Before this could be done, modifications had to be made to the kicker timing system, the extraction magnet power supply and the beam transfer line. Although not at present in operational use, the technique was invaluable in reducing beam losses in the PS during early tests of bunch-to-bucket transfer.

The second rapid internal dump unit has been installed in straight section 97, and the mechanism of a third unit is being constructed to provide a fully-equipped spare. The former dump targets, of 1963 vintage, have now been removed. Two fast-operating targets for beam measurement are ready for installation when the vacuum tank arrives. New targets for extracted primary proton beams, capable of withstanding higher intensities, are under development, and an improved optical system for their alignment has been built.

2.5 Computer Control

The existing (IBM 1800) controls computer underwent overhaul and preventive maintenance during the shutdown at the beginning of the year. In spite of two hardware failures in the central processor unit, which underlines the urgency of the controls conversion project (see 3.2 below), this veteran has largely been adequate for its task. In line with Divisional priorities, resources devoted to the old controls complex have been kept to the strictly necessary.

The program controlling an azimuthally adjustable orbit distortion has become operational, and was successfully used to locate an obstacle in the vacuum chamber. Harmonic function analysis is now also "on line" for low energy corrections. Some generalised orders have been introduced to simplify start and stop procedures.

Further developments have taken place in the programs for the autonomous function generators, used to control many important accelerator elements. These include facilities for access from several consoles as well as preparations for the new poleface winding system and multi-batch transfer to the SPS.
2.6 Performance developments in the PS

Techniques for trapping high density beams with the 200 MHz RF system, after debunching, have been studied at 1 GeV and 10 GeV/c. With beam-loading compensation on the RF accelerating cavities at 9.5 MHz, and using controlled longitudinal expansion just before debunching, a trapping efficiency of 85% has been obtained at 10 GeV/c with a longitudinal acceptance of 100 mrad at 200 MHz. This technique has been used operationally and, with double-batch injection, has enabled the SPS to reach accelerated beam intensities of more than $1.7 \times 10^{13}$ protons per pulse.

Work has also continued on increasing the number of protons per pulse accelerated in the PS, and a maximum of $1.4 \times 10^{13}$ has been obtained. Problems studied have included choice of working point (in the Q diagram) and programmed compensation of resonances, as well as transverse multi-turn instabilities which occur both at low energies and, with a 200 MHz bunched beam, on the 10 GeV/c flat top. These instabilities are caused by impedance effects from the resistive wall of the vacuum chamber, and the possibility of using an active damping system in the frequency range concerned is under consideration.

For the production of antiprotons, high linear beam density is required. The first step in obtaining this is to add the beam from two pairs of Booster rings in the vertical plane to produce ten bunches instead of the usual twenty. An intensity of $9.5 \times 10^{12}$ protons per pulse could be obtained at 26 GeV/c. The next step was to combine the ten bunches in pairs by azimuthal manoeuvres at 800 MeV and trap them in five PS buckets. This method yielded $7 \times 10^{12}$ protons per pulse at 26 GeV/c, and further development will be required to reach the target of $2 \times 10^{12}$ protons per bunch, especially on reduction of the 20% loss presently incurred during RF capture. Another possibility is to perform the transformation from ten bunches to five at 26 GeV/c; trials of this method have just begun, and it looks promising.

Both ten and five-bunch high-density beams have been used at 18 GeV/c to produce antiprotons for ICE. For the same experiment, the techniques of decelerating the 800 MeV beam to 200, 100, and 50 MeV have been successfully developed. This work has provided a basis for studies on possible experimental facilities using low energy antiprotons, notably LEAR (Low Energy Antiproton Ring). In turn, this has led to considerations of how to considerably increase the duration of slow extraction, and a method called "stochastic ejection" is currently being tried out.

3. FURTHER DEVELOPMENTS AND FUTURE PLANS

3.1 New Linac

During the period under review, construction of the new Linac was essentially completed, and its initial tests as an accelerator took place. The first of the three tanks containing the accelerating structure was installed in 1977, and so that tests on this up to 10 MeV could continue the third tank was installed before the second. Tank No. 2 was
finally put in position in July, and connected to the others whilst the RF system, controls and beam measurement equipment were being completed. By the end of August a good enough vacuum was obtained throughout, and at the beginning of September the first beam was accelerated to 50 MeV. Only a month later the design intensity of 150 mA was reached, and in October first tests of injection to the Booster were made.

First impressions are that it is a machine which not only reached its design targets with ease but also displays remarkable stability and functional reproducibility. The design options chosen have thus passed the crucial test, as have also the computational techniques for beam optics taking into account strong space-charge effects; in this latter field, the staff responsible for building the new linac have made important contributions.

Completion of many constructional details is now alternating with test runs in which the behaviour of the machine is being analysed in detail. Spare parts are being prepared in readiness for full-time operation.

3.2 Development of the control system

As previously reported, the first stage of this project was the conversion of one sub-process - the "continuous transfer" extraction system - using mainly SPS hardware and software. First on-line tests took place at the end of 1977, and were followed by two weeks in routine operation early in 1978. This exercise has permitted the framework of the new control system to be defined in detail. With SPS philosophy as the starting point, it will include four all-purpose operator consoles, a computer network linked by a message transfer system, the interpreter command language NODAL and the data module concept. New features include more extensive use of manufacturer-supported software, decentralisation of program files, further decentralisation of computing (e.g. to microprocessors in the interface) and employment of a compiled high-level language for speed-critical programs (additional reduction in the use of assembler language). Process interfacing will be done according to a pattern worked out in 1977, based on the international standard of serial CAMAC.

The first controls package to be converted consists of the Booster and accelerator cycle programme generator. Work on this started at the beginning of the year, and involves close collaboration between a number of specialized groups, sections and individuals; Operations and Booster staff are especially involved and are actively participating in the design and implementation. Specifications for the operational aspects of the first package are almost complete. The Antiproton projects have added a new factor since the original schedule was established and, together with the later date chosen for the long shutdown in 1980, somewhat extended the duration of the first stage of conversion. Target dates are now set at July 1980 for the Antiproton Accumulator, November 1980 for the Booster and Cycle Programme Generator, and January 1981 for antiproton acceleration in the PS.
The Main Control Room has been rearranged to permit installation of the four operating consoles; hardware is beginning to arrive and the software is well under way. Commercially available CAMAC hardware for the new process interface has been ordered, and other modules have been specified and are up for tender. The second batch of computers and peripherals has been delivered and integrated with the message handling system, which is itself now being commissioned. Systems software is in an advanced stage. Software supporting the extensive use of microprocessors in the interface is under development; the first version of the serial CAMAC driver is in operation. The layout of the applications software framework must cope with the extensive pulse-to-pulse changes of control parameters in PS operation, and the new short cycling time (650 ms) for SPS multi-batch filling, as well as numerous other specific operational requirements. It has, in consequence, proved to be a complex, delicate and lengthy task, but has now reached an advanced stage.

3.3 Multi-batch filling for the SPS

The new elements which will be required for the continuous transfer system are progressing satisfactorily. The prototype of the pulse generator for the fast bumpers, possibly the most critical component, has already been tested for more than $10^7$ pulses, and meets its specifications fully. The power supply for the extraction magnet and the fast bumper magnets themselves are under construction, and the building extension will be completed in March of 1979.

The 200 MHz radio-frequency system to supply the SPS with a pre-bunched synchronised beam is progressing according to schedule. Four cavities are already in operation, and the remainder will be installed in the next long shutdown (early 1979). The operating experience already gained has led to a number of modifications which should eventually bring the reliability of the system up to PS standards.

3.4 Antiproton projects

The Division will be responsible for the production of anti-protons, their "cooling" and storage until a sufficient stock has been accumulated, and their subsequent acceleration to 26 GeV/c and dispatch along the transfer line to the SPS. This programme affects many aspects of the Division's work, and has therefore been reported under various different sub-headings. It will be summarized here.

An "Antiproton Accumulator" (AA) is being constructed for cooling and storage (see below). This has one-quarter of the circumference of the synchrotron, and the proton beam must therefore be concentrated into this length in order to fill the Accumulator ring efficiently. To achieve this end, the twenty bunches circulating in the Booster are combined into ten in the transfer line and then reduced to five in the PS itself. The process as developed so far is described in paragraph 2.6. To become operational it will require some rather delicate manoeuvring of the RF accelerating system, and numerous modifications to the 800 MeV transfer line (see 2.2).
The AA ring is constructed alongside the transfer tunnels leading to the SPS and ISR and supplied through them. A loop tunnel will have to be built in order to bring the cooled antiprotons back to the PS via the same transfer lines, and the design of this is well advanced. The techniques required for the acceleration of antiprotons in the PS are being studied. Owing to the particular shape of the bunches obtained from the AA, the RF accelerating cavities will have to be phased in a pattern different from the normal one, and at the end of the accelerating cycle the bunch must be shrunk to the very short length acceptable to the 200 MHz RF system of the SPS.

Extraction of the antiprotons will require a new channel since they circulate in the reverse direction. Fortunately, existing material can be used for the greater part of the extraction equipment. The trajectory, the required transport elements, and the layout of the junction between the PS and the new transfer tunnel have been determined.

Finally, a conceptual study has been made of a small storage ring for experiments with decelerated antiprotons; the technique of deceleration has already been established (see 2.6 above).

3.5 The Antiproton Accumulator

Following the publication in January of the "Design Study of a Proton-Antiproton Colliding Beam Facility", a group was formed to proceed with the detailed design and cost estimates for the Antiproton Accumulator (AA). In order to allow a rapid start to be made and to maintain the possibility of completing construction within two years, specifications were prepared for many of the major components so that they could be ordered immediately after the project approval in June.

The AA will be located in a semi-underground building alongside the transfer tunnel carrying beam to the SPS and ISR. In this building pulses of 26 GeV/c protons at the maximum available intensity will be focussed on to a tungsten target. From the secondaries produced, up to $2.5 \times 10^7$ antiprotons per pulse at 3.5 GeV/c will be captured by a magnetic horn and injected into a storage ring of average radius 25 m. To reach the desired stack intensity of $6 \times 10^{11}$, it will be necessary to collect about 30,000 pulses over a period of one day. This is made possible by a technique proposed and developed at CERN, called "stochastic cooling". A two-stage procedure will be employed, in which the momentum spread of each injected pulse is reduced (pre-cooling), and it is then deposited at the higher-momentum side ("top") of the stack. The whole stack is continuously cooled, longitudinally (azimuthally) and transversely, so that particles slowly migrate to the bottom where finally a beam of sufficient density will be formed. This will then be extracted in twelve batches and transported to the PS for acceleration to 26 GeV/c before transfer to the SPS.
Excavations for the building began in July, and it is scheduled to be structurally complete by August 1979. Layout and shielding for the target area have been finalized, and prototypes of the target and the magnetic horn are being tested. The magnet system is made up from two types of dipoles and of quadrupoles, with apertures up to 75 cm in width. The wide quadrupole has a steel length of only 54 cm, and a prototype has been constructed so that the exact pole profile needed can be determined by field measurements.

The ultra-high vacuum system ($<10^{-10}$ torr) is completely specified, and prototypes of all critical components are undergoing tests; in particular, samples of ferrite are being checked for their ability to withstand the high bake-out temperatures required. Fast-moving shutters, needed to shield the stacked beam from the fields of the injection and pre-cooling kickers, are also under test. Fabrication of the magnet vacuum chambers has begun, and it is hoped to place orders for the large-diameter vacuum tanks before the end of the year.

Experimental results from ICE together with more refined calculations have confirmed the feasibility of the plans for stochastic cooling. Prototypes have been made of most types of pick-up and kicker that will be required, and of a section of coaxial line for the "notch" filter; their characteristics are being measured so that orders for production can be placed shortly. Specifications have been prepared for the radio-frequency system, beam diagnostics and controls. Overall progress is sufficient to maintain the possibility of beginning first tests of the Accumulator in the second half of 1980.

Edited by J.Y. Freeman

B. SYNCHRO-CYCLOTRON

1. OPERATION

The performance of the accelerator has been good, with only about 2% of running time lost due to faults in the first ten months of 1978. The experimental programme remained very active, with eighteen experiments at the data-taking stage of which six were completed. ISOLDE used 1,852 hours of machine time, with an average of 1.8 users per shift (of 8 h). In addition, a number of irradiation experiments were performed.

The annual long shutdown started at Easter and lasted eight weeks. This represented the time required for installation of equipment for $^3$He $^+$ ion acceleration and for rearrangement of the external beam area inside the SC Hall.
Between November 1st 1977 and October 31st 1978 the functional division of SC machine time was as follows (figures in hours):

<table>
<thead>
<tr>
<th>Category</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine time for Nuclear Physics</td>
<td>5474 (496 with $^3$He$^{++}$)</td>
</tr>
<tr>
<td>One user during</td>
<td>3056</td>
</tr>
<tr>
<td>Two users during</td>
<td>2418</td>
</tr>
<tr>
<td>Parasitic use</td>
<td>2079</td>
</tr>
<tr>
<td>Technical development</td>
<td></td>
</tr>
<tr>
<td>Machine studies</td>
<td>256</td>
</tr>
<tr>
<td>Beam studies</td>
<td>258</td>
</tr>
<tr>
<td>Unscheduled stops</td>
<td></td>
</tr>
<tr>
<td>Breakdowns</td>
<td>94</td>
</tr>
<tr>
<td>Ion source filament changes</td>
<td>44</td>
</tr>
<tr>
<td>Scheduled stops</td>
<td>2634</td>
</tr>
<tr>
<td>Beam changes, maintenance and cooling</td>
<td>814</td>
</tr>
<tr>
<td>Shutdown and official holidays</td>
<td>1820</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8760</td>
</tr>
</tbody>
</table>

The machine has been running at internal beam intensities of 3.5 - 4.2 μA, using the rotary condenser Rotco 2. This was modified in 1977, and able to operate using alternate RF cycles for acceleration, with up to 20 kV on the Dee. Another modification made to Rotco 2 during this year's shutdown, namely increased inductance of the compensating coils, makes it feasible to further raise the average RF power. However, this will not be attempted until the other available Rotco has also been upgraded, which is planned for 1979.

In May, for the first time in its history, the SC accelerated and delivered to an external target particles other than protons - helium ions ($^3$He$^{++}$). Subsequently, two running periods were devoted to this kind of operation. When accelerating $^3$He$^{++}$, the power limitation at present imposed for Rotco 2 is reached if one out of every four RF cycles is used. Nevertheless, a 0.7 μA beam was provided for ISOLDE.

To satisfy the demand for experimental time, a sharing mode of operation is frequently used in which an internal target intercepts a fraction of the accelerated beam, the rest being extracted. To obtain a good filling factor for both internal and external beams, the non-accelerating extraction mode is most commonly used. In this mode, the beam is first stacked at a point just inside the radius for extraction when the radio-frequency is cut off. The coasting beam is then driven in a programmed fashion by a dipole (KIM coil) towards the resonant ejection point. Overall duty factors of between 50% and 80% have been reported by users.
2. DEVELOPMENT

2.1 Helium ion \((^3\text{He}^{++})\) acceleration

The equipment for \(^3\text{He}^{++}\) acceleration and the ion source work well. Some difficulties have been encountered with RF conditioning, which appears to be more critical than in the case of protons.

The change from proton to \(^3\text{He}^{++}\) operation requires the introduction of a transmission line between the Dee and the Rotco. The mechanical installation of the line and the rearrangements of the vacuum connections and of the RF generator can be done in less than one shift (8 hours). Pumping and RF conditioning take a further 4 or 5 shifts. For this reason it is most convenient to schedule time with a \(^3\text{He}^{++}\) beam in blocks a few times each year.

2.2 Beam switching

The extracted beam is used either by ISOLDE or for the production of secondaries for experiments in the Proton Hall. The change-over between these different modes requires the displacement of a 20-ton bending magnet, a lens doublet and a target station. This process has been mechanized during the annual shutdown. The whole operation can now be done in two to three hours and the eight-hour radiation cooling period preceding the change is no longer required. Scheduling is more flexible, available beam time has been increased by about 10% and, most important, the radiation dose received by the people doing the work has been considerably reduced.

A new external target positioner, based on the SPS design, was also installed during the shutdown. The secondary emission beam profile monitor, developed by specialists and incorporating a microprocessor, has recently been mounted on the target positioner. As expected, it is a considerable aid in optimising the external beam on the target.

2.3 Extracted beam quality

All windows were taken out of the ISOLDE beam line and retractable alumina screens and secondary emission monitors were installed. Removing all scattering material in the beam line resulted in an improvement in the spot produced at the ISOLDE target and a reduction of the transmission losses. Total suppression of beam losses appeared impossible, probably due to the fact that the extracted beam has two components. Further investigations will be required.

3. FUTURE DEVELOPMENTS

A "shopping list" of possible SC developments was presented to the Workshop on the Role of CERN in European Intermediate Energy Physics, held in September 1977. Two SC projects were given importance: firstly acceleration of \(^{12}\text{C}^{++}\) ions (and a limited number of other ions having \(Q/A = 1/3\)) for use by ISOLDE and for counter experiments, and, secondly construction of an "Arizona" polarized \(u\) beam for the active solid-state physics and chemistry programme using Muon Spin Resonance.
Competition from other CERN projects prevented authorization of the Arizona beam, but the possibilities of providing a reasonable beam of polarized $\mu^+$ from an internal target are being investigated.

Work is in progress to develop and construct the hardware required to adapt the SC for $^{12}\text{C}^+$ acceleration. This programme comprises a water-cooled ion-source head, new central geometry, transmission line between Rotco and Dee, Rotco modifications and ion-beam intensity measuring equipment. The facility will be of an experimental nature, and it is expected that the first experiments with light ions on the SC can start in September 1979.

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