UPGRADING THE SIN FACILITIES TO HIGHER INTENSITIES

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Summary

At present the SIN facility is operated routinely with a proton beam current of about 150 μA. It is planed that the current be increased in stages to a level of 1 to 2 mA over the next few years. The main items of the improvement program for the accelerator facility are, a new injector, upgrading of the RF-system of the 590 MeV ring cyclotron, modified traget stations and probably a new beam splitter.

Introduction

SIN operates an accelerator facility for research in nuclear and particle physics as well as for other applications. The accelerators have been described in detail in several reports [1,2] and only a short description is given here. Protons are accelerated to a fixed energy of 590 MeV in two steps. The first stage, an isochronous cyclotron built by Philips Company, Netherlands, accelerates the protons to 72 MeV. It is equiped with a radial PIG-type ion source for high intensity proton beams of 100 - 200 μA and an atomic beam type source for polarized ions, which however, is only occasionally used to produce 590 MeV beams. Acceleration to the final energy of 590 MeV is achieved in the second stage, a ring cyclotron consisting of eight separated sector magnets and four main accelerating RF-cavities operating at 50 MHz. A flattop cavity is used to reduce the energy spread of the internal beam. Extraction losses are very small, typically 0.02% during routine operation. The ring cyclotron was developed and built by SIN.

During 25% of the time the injector cyclotron is used to accelerate various particles at variable energies in a stand alone mode for low energy experiments.

In 1978, the construction of a new injector was started, with the goal to provide the con-

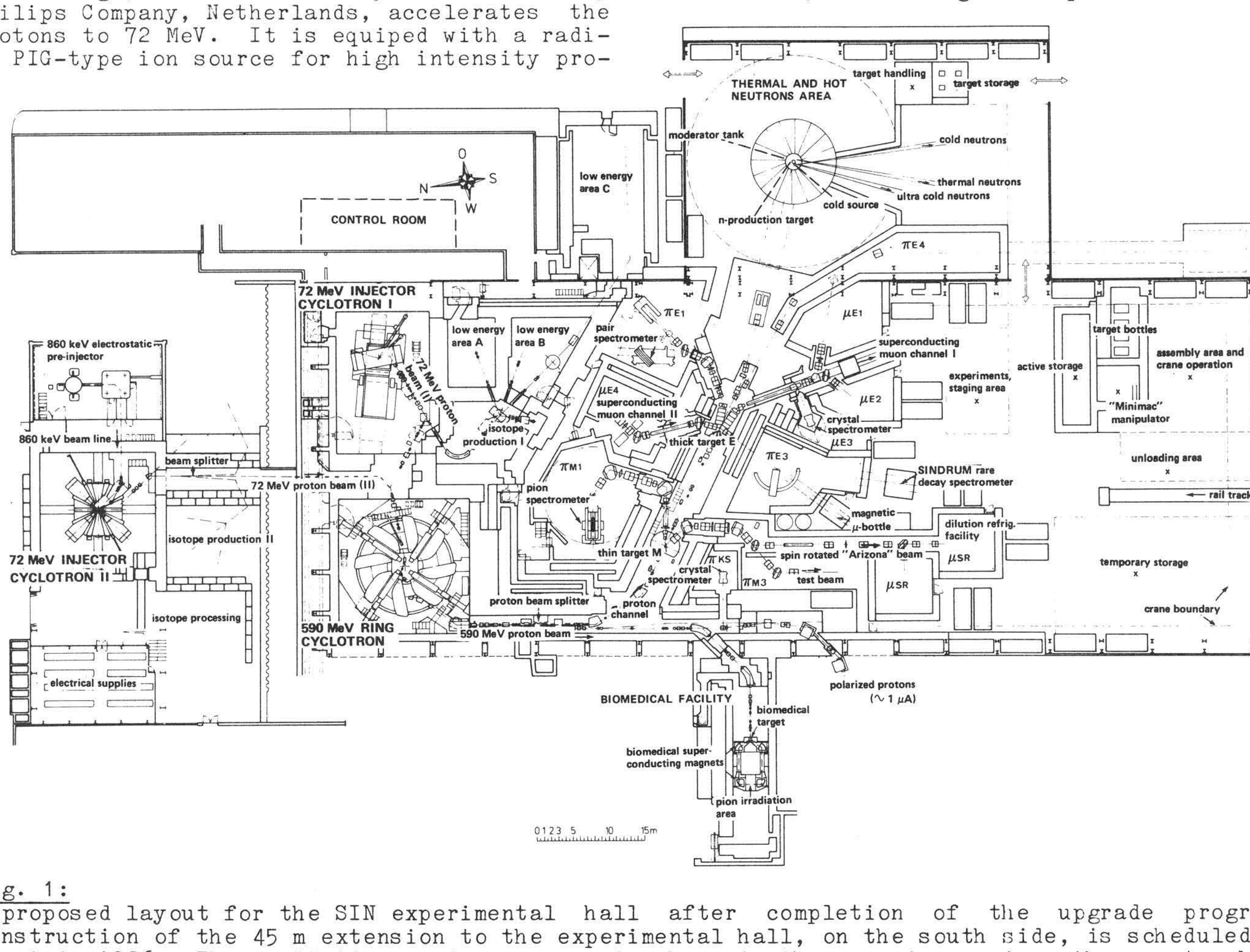

Fig. 1:
A proposed layout for the SIN experimental hall after completion of the upgrade program. Construction of the 45 m extension to the experimental hall, on the south side, is scheduled to start in 1986. The spallation neutron source is shown in the version using the waste beam after the second target and in a separate building; an alternative arrangement, with the neutron source in the new hall extension, is under consideration.

ditions to exploit the high current capabilities of the ring cyclotron and to avoid the interference between high energy and low energy mode of operation. The new injector, designed for proton currents above 1 mA, combines an electrostatic preaccelerator and an isochronous ring cyclotron [3]. The main components of the cyclotron are four sector magnets, two 50 MHz accelerating systems and two flattoping systems operating at 150 MHz. The new injector is expected to go into operation in the middle of 1984.

The arrangement of the accelerators, the beamlines and the target stations in the experimental hall is shown in fig. 1. Between the ring cyclotron and the first pion production target an electrostatic beam splitter is installed. Typically a beam of 20 µA is peeled off and mainly used in a medical facility, where cancer patients are treated regularly with negative pions.

Routine operation of the SIN-accelerators started exactly ten years ago. In the time since, the ring cyclotron has delivered a total of 8500 Coulomb of 590 MeV protons. In response to the demand of the running experiments, the operational beam current has steadily increased to an average of 160 µA during 1983. Peak currents of up to 180 µA were achieved and maintained during several weeks.

In the future, the evolution of the beam current will again be dictated by the needs of experiments. In the long term, medium energy physics will shift to more difficult and elaborate experiments which require higher beam luminosities (and therefore higher beam currents). Some important experiments of this type being planed are on forbidden muon decays, very rare pion decays and on parity violation in muonic atoms.

On the application side, SIN plans the construction of a spallation neutron source with a liquid Pb/Bi-target [4]. The maximum neutron flux would be 10**14 n/cm2.s for a 590 MeV proton beam of 1 mA. In order to make the neutron source competitive with medium flux reactors, it must be operated with a current of at least 1 mA. The location of the source is not yet decided. At present, two possible arrangements are under discussion:

1) The source makes use of the waste proton beam after the second pion production target, but scattering of protons in the target gives a reduction of the beam current of 30 to 40% depending on the target thickness.

2) The neutron source terminates a new beam line. The main beam would be split in a ratio of typically 30% : 70%, the smaller fraction being used for the pion targets. To take this fundamental decision which has an irreversible impact on the medium and long range experimental program, also operational and financial aspects have to be weighted.

After ten years of exploitation of our medium energy facility, the possibility to expand to energies in the range of 20 to 30 GeV is being investigated. Preliminary studies show that the beam from the 590 MeV ring cyclotron could be fed into a rapid cycling synchrotron [5]. As an interface between the two machines another cyclotron, called ASTOR [6], and an accumulator would be needed. ASTOR was originally conceived as a 2 GeV machine with operation in either a continuous or a pulsed mode. As an interface to the synchrotron, only the pulsed mode is used. The repetition rate of ASTOR would be 1300 Hz and it would cut pulses of 30 µs out of the 590 MeV beam. Assuming an average beam of 2 mA from the ring cyclotron, the synchrotron could accelerate an average current of about 80 µA.

The upgrading program

Routine operation with beam currents of 1 to 2 mA can only be reached in numerous steps and over a period of several years. A catalogue of the major improvements and measures is given below.

1) Replace injector I by injector II. The current of injector I is limited by the extraction system to about 250 µA.

2) The 590 MeV ring cyclotron. It was originally designed for beam currents of 100 µA and has by far not reached any significant current limit. The main items of the ring upgrading program will be the RF-systems, local shielding and the diagnostic system.

3) Upgrading and partial renewal of the control system. Sophisticated methods, based on computers, will be used to give fast and more detailed information on the beam. Typical examples are the beam tomography and the automatic centering of the beam in the accelerators and in the beam lines. The interlock system has to be modified to have a response time adequate to the thermal destruction potential of the beam (t = 50 µs).

4) Improvements of the 590 MeV beam transport systems and targets.

The underlined items will be treated in more detail in the following paragraphs.

Injector II:
The preaccelerator for the new injector cyclotron (see fig. 2) consists of a 900 kV Cockcroft-Walton high voltage generator, a high voltage dome with the ion source and an accelerating column [7]. A 15 mA d.c. beam is required from the preaccelerator to produce a 1.5 mA beam at 72 MeV.

The injection of a d.c. beam, instead of a bunched one, is preferred in order to avoid detrimental longitudinal space charge effects. This, of course, puts high demands on the pre-injector since only 10% of the injected beam will be further accelerated by the cyclotron (the phase acceptance of the 72 MeV ring cyclotron is approximately 36°, therefore 90% of the injected d.c. beam has to be stopped on a high power collimator located in the center of the cyclotron).

The 60 keV-multicusp ion source is connected to the accelerating column by a 3 m long beam line. A pair of solenoids allow the cleaning of the parasitics from the beam by focussing the protons through a small iris diaphragm which then stops most of the H2+ and H3+ on it. The beam current may be changed by varying the diameter of a second diaphragm installed between the two solenoids, thus leaving the ion source parameters unchanged, or by varying the extraction voltage applied to the ion source.

The ion source is connected to the arc power supply via a fast electronic switch. This device allows the pulsing of the arc between 1 Hz and a few kHz with duty cycles between 1% and 100%. It will be used to control the average current during beam set-up. It can also be used to switch off the beam in case of an interlock condition since the quenching time of the arc is of a few micro-seconds.

The accelerating structure consists of a 77 cm long constant gradient tube (E~13 kV/cm) enclosed in a 3 m long acrylic jacket filled with SF6 gas at atmospheric pressure. The accelarating tube was made of 15 titanium rings brazed to Alumina ceramic spacers. The stainless steel accelerating electrodes are spring clamped to the Ti rings for easy removal if the need arises.

Conditioning of the accelerating tube to 850 kV was achieved within a few hours. A 1 mA d.c. proton beam was accelerated to 860 keV for the first time in December 1983. The ion source was operated at an extraction voltage of 40 kV. The normalized emittance amounts to 0.5 x π mm mrad (see fig. 3). The proton yield from the ion source is about 30%, work is under way to increase this value by at least a factor of two.

The beam from the Cockcroft-Walton pre-accelerator is now regularly used for beam development experiments in the new 72 MeV ring machine and proves to be a reliable piece of equipment delivering very reproducible beams. The spark rate is less than 1 per shift. The set-up takes typically 1 hour.

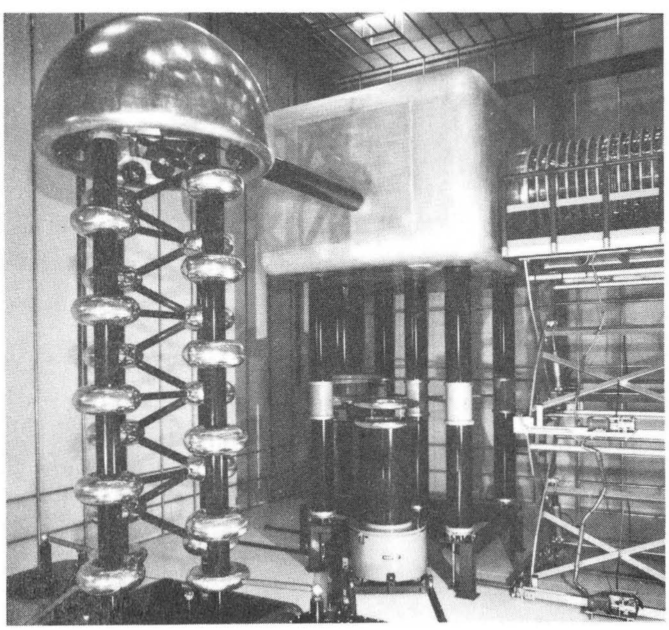

Fig. 2:
860 keV pre-accelerator for the injector II cyclotron. The high voltage generator is of the Cockcroft-Walton type. The dome houses the 60 keV ion source and a beam transport system. The accelerating column is seen on the right hand side of the picture and shown with the service platform in working position.

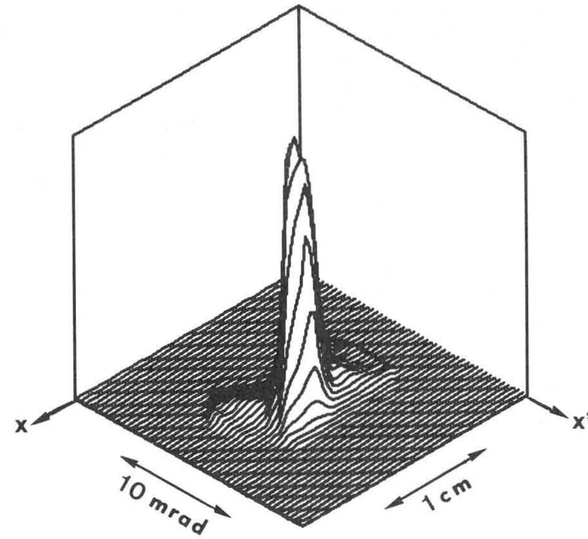

Fig. 3:
Current distribution in the horiz. phasespace of the proton beam from the Cockcroft-Walton pre-accelerator. The distribution is reconstructed from three profile monitors using a tomographic method. The measured normalized emittance, containing >90% of the total beam current, is 0.5 x π mm mrad. The halo, most probably, consists of residuals of the parasitic H2+ and H3+ ions.

The injector II cyclotron is illustrated in fig. 4. In January 1984, all the relevant parts including the control system had reached a state such that beam could be accelerated on the first few orbits. Before discussing the results of the beam tests the layout of the cyclotron will be reviewed briefly.

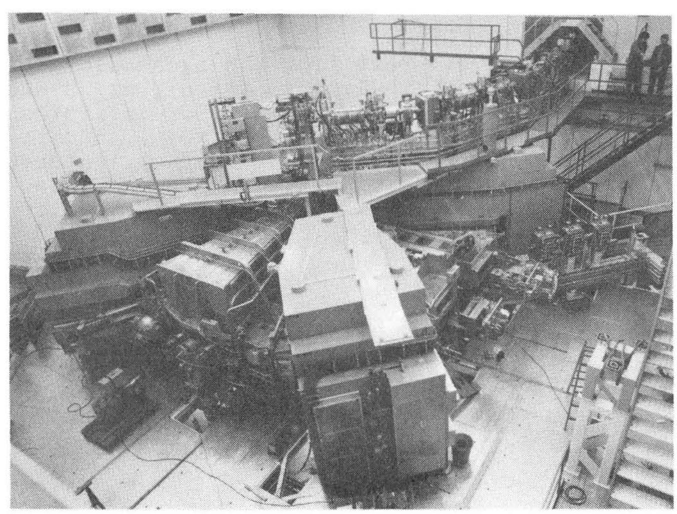

Fig. 4:
The 72 MeV ring cyclotron of injector II (status April 1984) with the 860 keV beam line above sector magnet 1. A 50 MHz resonator, between two of the sector magnets, can be seen on the left side of the picture. The two extraction magnets (withdrawn from the vacuum chamber) and part of the 72 MeV beam line are visible on the right hand side.

Four sector magnets with a parallel gap of 35 mm produce a hill field of 11.0 kG. Each magnet has exchangeable side shims to allow coarse shimming and nine pairs of trimcoils installed on the side of the pole plates outside the vacuum chamber. These trim coils cannot affect the first few orbits for geometrical reasons; two additional pairs of gap coils are installed in the center part of magnets one and three.

The side-shimming of the magnets was completed two years ago. The result is demonstrated in fig. 5, which shows the calculated phase errors of the protons between injection and extraction in the two gaps of the RF-resonators. The curves were produced from the results of an orbit integration in the maped field of the magnets. The phase excursions are so small, that acceleration to the full radius will most probably not require the trimcoils.

The main RF-system consists of two 50 MHz resonators each being fed by an individual chain of amplifiers. (The 50 MHz corresponds to the 10th harmonic of the revolution frequency.) The resonators are of the transmission-line type and have two accelerating gaps 20° apart. They produce an RF-voltage of 125 kV at injection and 250 kV at extraction radius (see fig. 6). The corresponding energy gain per revolution of 4 x 125 kV and 4 x 250 kV respectively results in a radial turn separation of 80 mm at injection and 20 mm at extraction. As a consequence of the radially increasing RF-voltage the beam phase width will be compressed from 36° at injection to 18° at extraction. Without beam, the power consumption is 130 kW per resonator.

The flattopping is done on the 3rd harmonic of the accelerating voltage with two H101 cavities each producing a peak voltage of 100 kV. Only very tight tolerances on amplitude and phase of the 50 MHz and 150 MHz systems make the flattopping successful.

The 860 keV d.c. beam from the preaccelerator is injected vertically into the cyclotron and bent into the midplane by a 90°-inflection magnet [8]. A magnetic cone (n =0.6), located in the gap of the first sector magnet, steers the beam onto the equilibrium orbit. The sector magnet following the first 50 MHz accelerating structure acts as a momentum analyser and therefore as an RF-phase analyser. The phase acceptance of the cyclotron is defined by the position of a high power collimator on the first revolution, where about 90% of the injected d.c. beam is stopped. The final shaping of the RF-phase is achieved with a pair of collimators on the 4th revolution. A beam stopper is provided on the 6th revolution (3 MeV) so that the injection can be optimized without activation of the cyclotron.

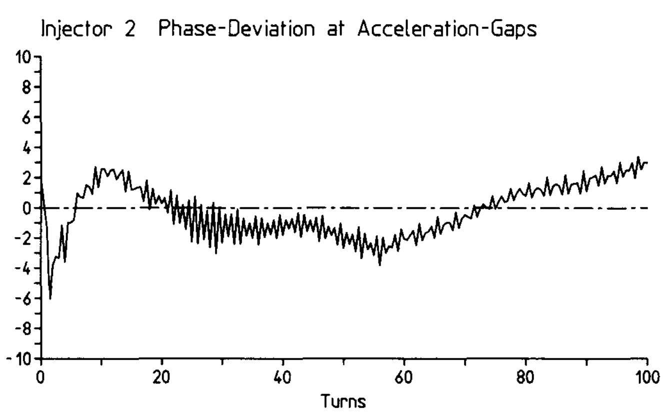

Fig. 5:
Phase excursion at the gap of the 50 MHz resonators as a function of turn number. The phase excursion was computed from the measured magnetic fields of the sector magnets.

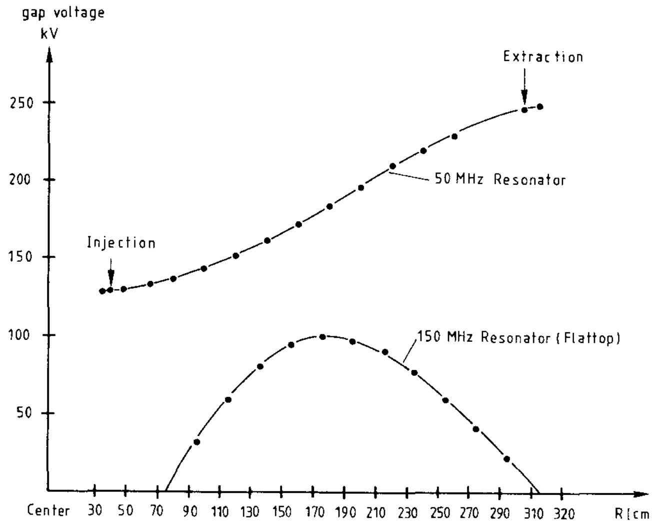

Fig. 6:
Voltage distribution along the gaps of the two 50 MHz accelerating systems and the two 150 MHz flattop resonators. The 50 MHz resonators, which are of the transmission line type, produce an energy gain per revolution of 500 keV at injection and 1 MeV at extraction. The flattop cavities are short circuited wave guides excited on the H101-mode.

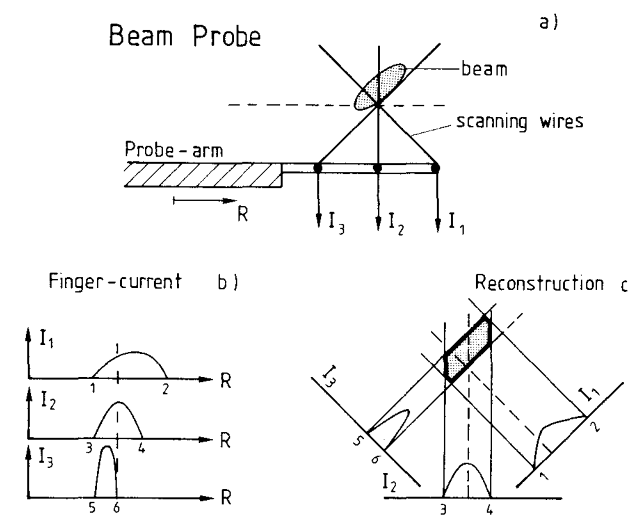

Fig. 7:
Beam probes used in the injector II cyclotron. Three isolated wires (diameter 0.5 mm), tilted relatively to one another as shown in (a) are simultanously scanned through the beam (b). The beam position in the (R,Z)-plane and the radial beam profile can easily be reduced from the three profiles (c). Using tomographic methods, the complete density distribution may be reconstructed.

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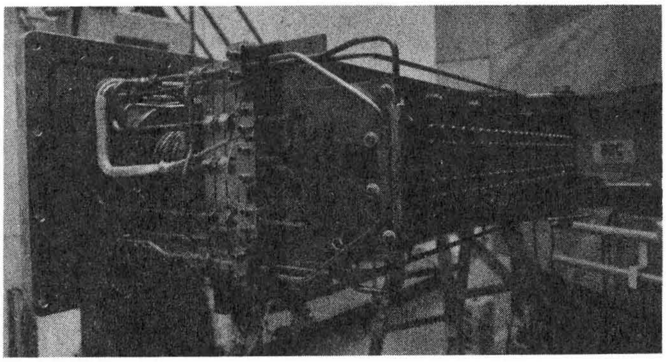

Fig. 8:
Extraction magnet for the injector II cyclotron (seen from the beam exit side). The septum coil is made of four turns of a hollow conductor and insulated with aluminium oxide. The thickness of the septum is 6 mm. With a turn separation at the extraction radius of almost 20 mm, an extraction efficiency of 100% is expected. The septum coil is protected from missteered beam and halo by a collimator. Remote control of the radial position and tilt are available.

New probes have been developed for the measurement of the radial and vertical intensity distribution in the cyclotron. The principle is shown in fig. 7, [9].

The 72 MeV beam is extraced by a septum magnet followed by a 39° window frame magnet. Both are installed inside the vacuum chamber of one of the flattop cavities. The septum has a thickness of 6 mm and is insulated with aluminium oxide (see fig. 8). The extraction efficiency is expected to be 100% . A set of collimators connected to the beam interlock system will protect the magnet from missteered beam and from any halo.

A high power beam dump has been installed a few meters downstream from the cyclotron (see fig. 9), so that beam development experiments can be done with high beam currents and independent of the 590 MeV ring cyclotron.

The theoretical studies on the current limits of the cyclotron were continued. The longitudinal space charge forces on the first few orbits are the dominating effects. Near the limits they cause an irreversible increase of the horizontal phase space. Serious effects are expected to appear at currents above 1 to 2 mA.

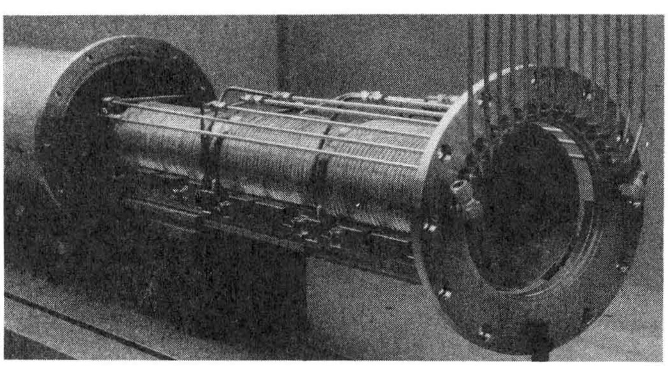

Fig. 9:
72 MeV high power proton beam dump, designed for currents up to 3 mA, before assembly. The beam stopper consists of three water cooled copper cylinders and a collimator forming a conical hole for the beam.

On the 1st of March 1984, the first beam was injected into the 72 MeV ring cyclotron and accelerated to over 5 revolutions. Since then the influence of all injection parameters on the beam has been investigated. Fig. 10 shows the cross sections of the accelerated beam which were made using the new beam probes described in fig. 7. It should be mentioned that for this plot only little effort was made to optimize the settings of the injection parameters. At the time being the further acceleration is hindered by the arm of a temporary probe, which is installed in the midplane of the cyclotron. It is expected that the first beam will be extracted by the end of April 1984.

590 MeV-ring cyclotron:
In the near future, the development of the beam current of the 590 MeV ring cyclotron will be limited by the effects listed in fig. 11. Many of them may be overcome by technical means.

The power requirements per cavity versus beam current is shown in fig. 12. Wall losses and power absorbed or deposited in the cavity by the beam are taken into account. The power

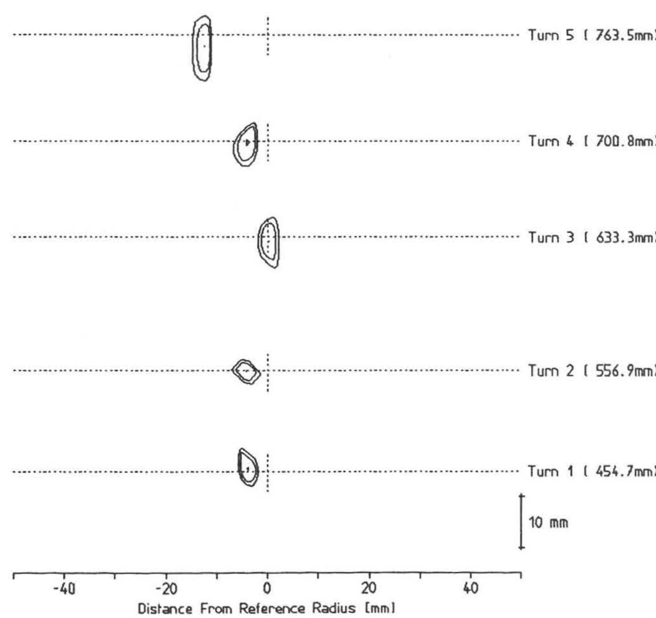

Fig. 10:
Beam profiles for the first five turns in injector II. The diagram shows the beam cross section and its deviations in the horizontal and vertical directions from the computed reference positions (dashed line). The phase collimators were set to select a beam phase width of about 4°. The beam fraction contained inside the two contour lines correspond to about 50% and 80% of the total beam current. From the plots it can be seen that the beam shows a coherent oscillation with an amplitude of 5 mm and that the accelerating voltage is slightly below the expected value. The matching of the vertical phase ellipse also needs to be improved.

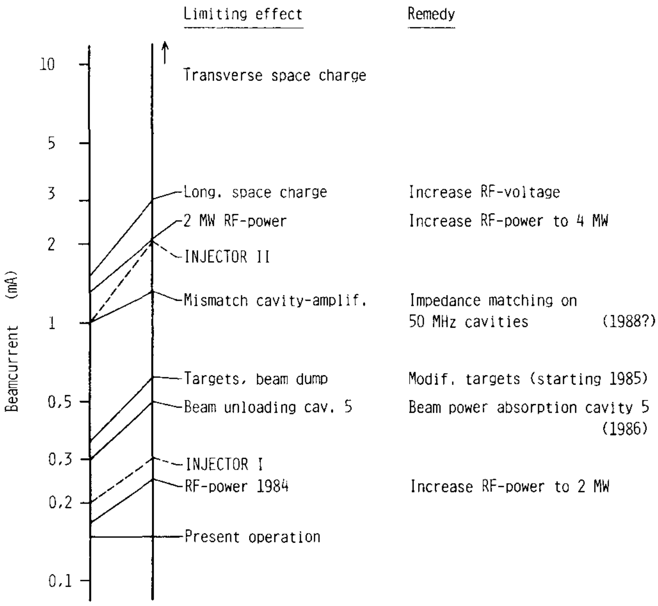

Fig. 11:
Beam current limitations of the 590 MeV ring cyclotron, targets and beam dump and their remedy.

required by the main accelerating cavities increases linearly with beam current (beam loading) whereas the power needed by the flattop system decreases ("beam unloading"). It is assumed that the accelerating voltage is kept constant, an assumption which will certainly not be true at very high beam currents for reasons described later.

The present RF-power amplifiers were developed 12 years ago by Telefunken Company in Germany. Originally designed for a nominal RF-power of 250 kW CW, the effective power output is in practice rarely more than about 160 kW, which is sufficient for 180 µA. In order to overcome this restriction, the power amplifiers are in the process of being upgraded by implementing a new Siemens tetrode (type RS 2074) with a rated power dissipation of 500 kW. On a test stand, the first modified power amplifier has delivered a maximum RF-power level of 680 kW into a 50 Ohm load. It is expected that they will deliver operational output power levels of 500 kW each, which would enable the acceleration of about 2 mA protons including an eventual increase of the accelerating voltage by 20%. For reasons of convenience the same amplifiers are also installed at injector II.

The four existing d.c.-power supplies of the amplifiers will be replaced by units each delivering 1.6 MW at 16 kV. This very generous d.c.-power capacity was chosen in view of an eventual further increase of the nominal RF-power level to a total of about 4 MW.

As shown in fig. 12, the flattop system will be completely unloaded at beam currents of about 600 µA and therefore control on amplitude and phase would be impossible. Without countermeasures this effect will obstruct the operation already at currents above 400 µA. Several methods to solve this difficulty are under investigation. One is to increase the power consumption of the flattop cavity, for instance with a resistive load, at the price of a more powerful amplifier. A more elegant way is to absorb RF-power from the cavity at the same rate as the beam deposits power in it. This could be done by a regulated beam power absorber linked to the cavity via a separate coupling loop. Such a system, sketched in fig. 13 is under construction [10] and will be ready by 1986.

The beam loads or unloads the accelerating cavity, changing the impedance seen by the power amplifier. At SIN, the RF-power is coupled inductively into the cavities through a 50 Ohm-transmission line. The impedance of the coupling loop is adjusted to match the transmission line at low beam currents. With increasing beam current the power of the reflected wave will increase with the square of the beam current, reaching 100 kW at 1.5 mA protons (see curve b in fig. 12). One could say, that the cavities refuse to accept the RF-power when they are under heavy beam load. Based on the first operational experience with the 500 kW amplifiers it is assumed that they can withstand a reflected RF-power level of about 50 kW which corresponds to 1.2 mA protons. For higher currents automatic matching of the loop impedence to the power transmission line and amplifier is necessary. At present, only vague ideas exist on the technical solution of this problem and therefore it will not be discussed here.

The longitudinal space charge effects in the 590 MeV-ring were investigated by Adam and Joho [11]. The protons contained in the beam bunches in the cyclotron produce an electrical potential, the azimuthal component of which reaches values of the order of Volts/cm for a 1 mA beam in our case. It acts on the protons over the whole acceleration path of almost

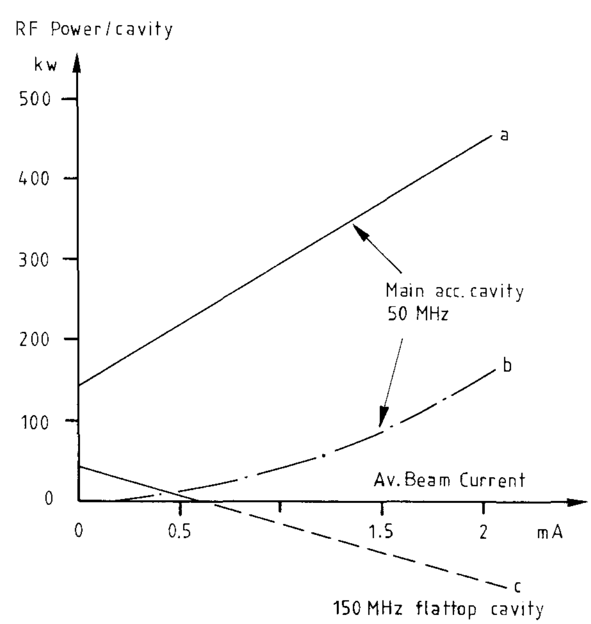

Fig. 12:
Power requirement of the RF-cavities of the 590 MeV ring. Wall losses and beam power absorbed or deposited in the cavities are included. Curve (a) shows the power needed by the 50 MHz cavity under beam load. It is assumed that the RF-voltage is kept constant. Curve (b) shows the reflected RF-power. At heavy beam loading it reaches values which might endanger the power amplifier.

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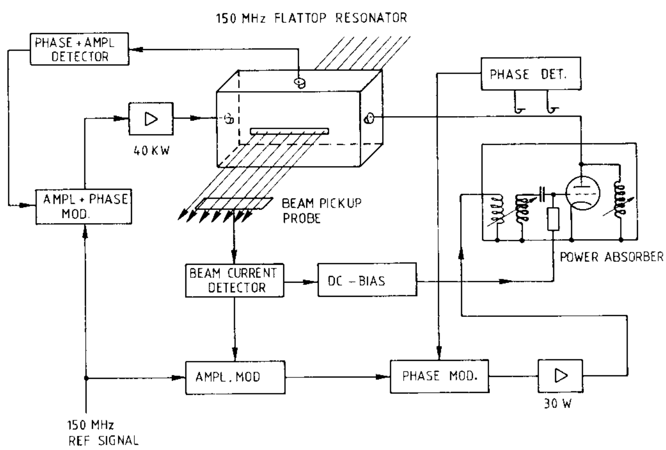

Fig. 13:
Schematic layout of a proposed beam power absorbtion circuit for the flattop cavities. The absorber consists of a power triode load tube (without DC-plate supply) in tuned $\lambda/4$ coaxial resonators. It absorbs RF-power from the cavity at the same rate as the beam deposits power in it.

10 Km inside the cyclotron. The resulting energy spread is of the order of a few MeV and depends on the azimuthal position of the protons in the bunch. A first order compensation of this effect is possible by introducing an appropriate tilt of the flattop voltage. It has been predicted, however, that above beam currents around 2 mA the longitudinal space charge effects will smear out the turn separation so much, that extraction losses will become intolerable. It should be mentioned that if necessary the longitudinal space charge limit also can be shifted toward higher beam currents by a substantial increase of the accelerating voltage.

After the discussion of the limiting effects in the ring cyclotron, the question arises how a current limit manifests itself as it is approached. The most important criterion is the beam loss. Interaction of the beam with the extraction elements not only leads to activation of the cyclotron but also produces beam halo, that activate the following beam lines. At present the losses in the 590 MeV-ring are on the very comfortable level of about 20 nA during routine operation with 150 µA. It is agreed that beam losses up to 5 µA could be tolerated, but at the price of additional shielding, severly restricted access and extended repair times. This means that, assuming a beam current of 1.5 mA, the extraction losses may not exceed 0.3%, even in the vicinity of a current limit!

Beam transport systems and targets:
The proton beam extracted from the 590 MeV ring cyclotron is guided through a 60 m long beam line on two pion production targets in tandem and stopped in a copper beam dump.

In order that the beam line is operational on a long term basis, it is of crucial importance that the activation and therefore the beam losses are kept as low as possible. The main source of beam losses along the 590 MeV beam line are the target stations and the beam splitter which peals off a fraction of the main beam for the medical facility. The target stations have their individual local shield whereas it is difficult to provide an adequate shield for the beam splitter.

The beam splitter is an electrostatic septum (effective length 78 cm, foil thickness 0.07 mm) between two cathodes at a fixed position. The splitting ratio is varied by moving the septum foil. The applied voltage, the bending angle of a steering magnet and the septum position are correlated by the control computer such that the axis of the split beams remain unaffected [12].

The present beam splitter has been in operation since 1981. The typical beam loss amounts to 0.8% of the primary beam at a splitting ratio of 1:8. Although this loss may be further reduced by increasing the beam amplitude at the entrance of the splitter, it is very questionable if this method is still practicable for splitting beams above 1 mA. The losses would be about 10 µA which is as high as the activation potential of our thin target today.

A new splitter is now under investigation at SIN which will theoretically produce no beam loss. Splitting will be done in time space by making use of the 50 MHz structure of the beam. The present concept is based on kicking an arbitrary selection and number of pulses from a train of 12. The deflection voltage will be achieved by superimposing 12 harmonics on one or more deflector electrodes. The ratios and the phases of the harmonics will be determined by the (discontinuous) splitting ratio and the desired pulse sequence of the split beams. It is obvious that the new beam splitter will be a complex and expensive piece of equipment, compared to the electrostatic splitter which is simple and very reliable.

The targets have the shape of a dishlike conical wheel. The beam passes through the target cone along a line intercepting the cone axis. The wheels rotate so that the power deposited in the target is distributed over the whole surface. The targets are radiation cooled.

In the first, the "thin target", carbon or beryllium wheels can be used. With respect to its thermal properties, carbon is potentially a much superior material than beryllium, but its pion yield is about 30% lower. Four different wheels are mounted inside the target vacuum chamber and can be exchanged by remote control within a few minutes. The typical thickness is 0.9 g/cm2 (C) or 1.45 g/cm2 (Be). In the second target station, the "thick target", only one wheel either carbon or beryllium with 20 g/cm2 is available.

At the thin target, the pions are collected by two quadrupole channels. The vacuum is separated between target chamber and the two channels by aluminium windows, each 0.4 mm thick. The windows in the thick target station have been removed to allow the extraction of low energy pions.

The targets were originally designed for proton currents of 100 to 150 µA. It is planned to reconstruct both target stations and the beam dump with the goal to make them usable for high currents and also to improve the quality of the pion beams. The main problems for the targets are as follows:

In the target wheel, mechanical stresses develop at high temperature due to the conical geometry of the wheel. This effect, which might lead to the rupture of the wheel excludes the use of beryllium in the thick target for currents above 120μA (fig. 14 shows an example of a fractured Be-wheel, used as a thick target). In the future only graphite will be used for the main pion production targets and the wheel diameter will be made as big as possible.

With increasing temperature the carbon target suffers from a kind of corrosion, an effect which manifests itself as a ^{11}C-contamination in the exhaust of the vacuum pumps. This effect, on which very little details are known, is considered to be an oxidation of the target material in the residual gas.

Similar to the corrosion of the target, sublimation of the target material increases with increasing temperature. We estimate that with an increased wheel diameter, hence lower operating temperatures, neither oxidation nor sublimation will restrict routine operation with currents below 2 mA.

The target vacuum chambers are exposed to the radiation of heat and secondary particles, mainly neutrons and protons from the target. (Radiation of heat contributes ~35%, protons ~43% and neutrons ~22% of the total energy deposited by a 590 MeV beam in a carbon target.) At a proton current of about 250 μA the aluminium windows of the thin target will be destroyed from excess heat. At the present time, these windows represent the weakest point in the target system. They will be eliminated during the reconstruction of the thin target station beginning of 1985. Other critical parts are the vacuum flanges connecting the chamber of the thick target with the pion beam

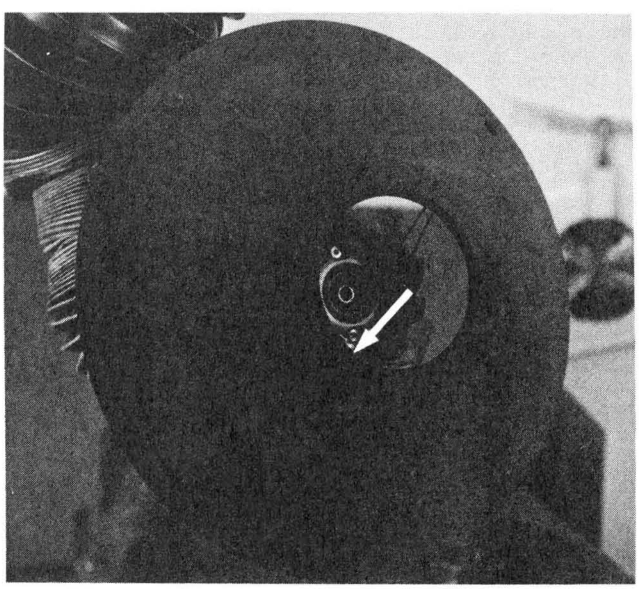

Fig. 14:
This conical beryllium wheel was used as a thick target (20 g/cm). The arrow indicates the direction of the incident beam. When used, it is rotated so that the power deposited by the beam is distributed over the whole surface. The rupture, which is clearly visible, was caused by thermal stresses and occurred at a beam current of 120 μA.

lines. Heated up, they deform and may develop vacuum leaks. Contrary to the target itself, the thermal effects on the vacuum chamber depend on the total power absorbed in the target and may therefore be controlled by an appropriate choice of the target thickness within practical limits.

The present beam dump is built from a number of water cooled copper plates. The current limit, given by the yield point of the material, depends on the diameter of the waste beam and therefore of the target in use. For normal operating conditions the current limit will be reached at 0.6 mA.

The present beam dump cannot be upgraded to currents considerably higher then those mentioned above. When it will be replaced and the concept of the future beam dump depends strongly on the location of the spallation neutron source, a decision which has to be taken in the near future.

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