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STATUS REPORT ON THE NEW INJECTOR AT SIN

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Abstract.- At SIN proton currents up to 190 µA have been accelerated to an energy of 590 MeV. Theoretical considerations indicate that the current limit of the 590 MeV-ring is above 1 mA. A new injector is under construction in order to exploit fully the current capabilities of the ring cyclotron. It is designed for a fixed proton energy of 72 MeV and beam currents above 1 mA (average). The protons will be accelerated in two stages. The first stage is an electrostatic accelerator delivering a 860 keV DC beam of max. 30 mA. The second stage is a ring cyclotron consisting of 4 sector magnets and a RF-system that will provide an energy gain of 1 MeV per revolution at extraction. The new SIN injector will tentatively go into operation toward the end of 1983.

1. Introduction.

- SIN operates a cyclotron facility for research on nuclear and particle physics and its applications. The production of intense pion and muon beams from 590 MeV protons on external targets is of main importance for the research at SIN.

The protons are accelerated in two stages. The first stage, built by Philips company, Holland, is a variable energy sector focused isochronous cyclotron producing a variety of beams from protons to light ions [1]. Used as an injector, it accelerates protons to 72 MeV which is the injection energy for the second stage, an isochronous ring cyclotron with a fixed energy of 590 MeV. The ring cyclotron, designed for beam currents >100 µA, was developed and built by SIN. It consists of eight separated magnets and four high Q cavities operating at 50 MHz [2][3][4][5].

The ring structure was chosen because of some inherent properties which promised minimum beam losses in the cyclotron. The most important ones are the large energy gain per revolution and the ample space for injection and extraction elements between the sector magnets.

The first 590 MeV proton beam was extracted in February 1974. Since then the beam current for routine operation has continuously increased to 170 µA. Short runs with peak currents of 190 µA have been made. At the moment normal operation is at a level of 100 µA due to a temporary limitation in one of the target stations.

The extraction efficiency from the ring cyclotron reached a value of 99.9% prior to the incorporation of the flattop system into the ring. The flattop system [6] consists of an additional RF-cavity operating in the 3rd harmonic of the accelerating voltage. The superposition of a higher harmonic voltage to the accelerating voltage results in a considerable reduction of the energy spread of the beam at the extraction radius provided the

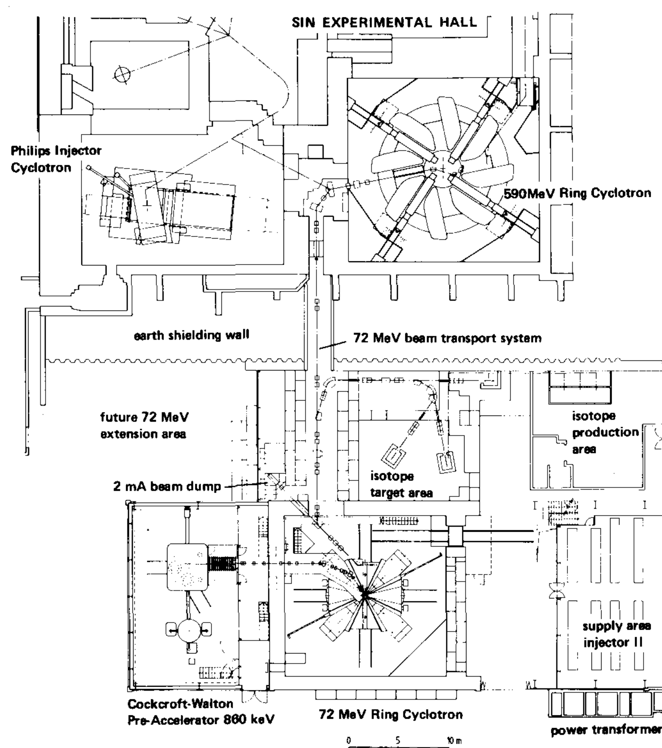

Fig. 1: Plan view of the accelerators at SIN The existing accelerators, a 590 MeV-ring and an injector cyclotron, are shown in the upper half of the drawing. The new injector under construction is a combination of a 860 keV pre-accelerator and a 72 MeV ring cyclotron. The isotope production facility is in the planning stage. A separate building was erected for the new installations.

relative phase and amplitudes are well adjusted. The energy spread is a result of the sinusoidal accelerating voltage and of the longitudinal space charge effects at high beam currents. With the flattop system in operation, the extraction efficiency reaches 99.98% [7].

From the experience gained during the last few years we may conclude, that the ring cyclotron is potentially capable of accelerating proton currents well above the design goal of 100 µA. Of course, considerable extensions and improvements, such as an increase of the available RF power, will be necessary to reach the limits. Recent theoretical investigations show that the limitations will be most probably determined by longitudinal space charge effects at a current level between 1 and 2 mA.

The new injector was proposed in 1972 [8] and described in [9][10]. Over the years, not only the layout, but also the weight factors in the argumentation to build a new injector have changed. Originally there were severe doubts in the capability of the present injector to accelerate proton currents of 100 µA reliably.

These doubts are still justified for beam currents above say 200 µA. In addition, the new injector will considerably improve the exploitation of the medium energy facility, because the present injector is now regularly operated for low energy experiments during 25% of the total machine time. For several years the high current capabilities of the new injector were emphasized. This is because SIN plans to build a spallation neutron source for thermal and cold neutrons. To be competitive with medium flux reactors this application calls for an average proton current above 1 mA at 590 MeV.

2. General layout of the new injector.- The new injector is a fixed energy proton accelerator which combines a 0.86 MeV electrostatic pre-accelerator with an isochronous ring cyclotron. This combination was mainly chosen for the following reasons: 1) A ring cyclotron offers the necessary space between the sector magnets to install large RF-systems which can provide an energy gain per turn as high as 1 MeV. This is an important condition for a complete beam extraction. 2) Many design features and components for the ring cyclotron can be adopted from the 590 MeV ring. 3) Air insulated DC accelerators with voltages > 1 MV become impractical.

The arrangement of the new injector with respect to the existing accelerators is shown in fig. 1. The new 72 MeV beam transport system will be joined to the existing beam transport system coming from the Philips cyclotron by means of a switching magnet. In the future the Philips cyclotron will serve as a stand-by injector and for the acceleration of polarized protons.

The area between the new injector and the 590 MeV ring cyclotron will be dedicated to the production of isotopes, a project which is undertaken in collaboration with our neighbouring reactor research institute EIR. A production area with three target stations is planned. An electrostatic beam splitter will peel off a variable fraction (up to about 100 µA) from the main beam.

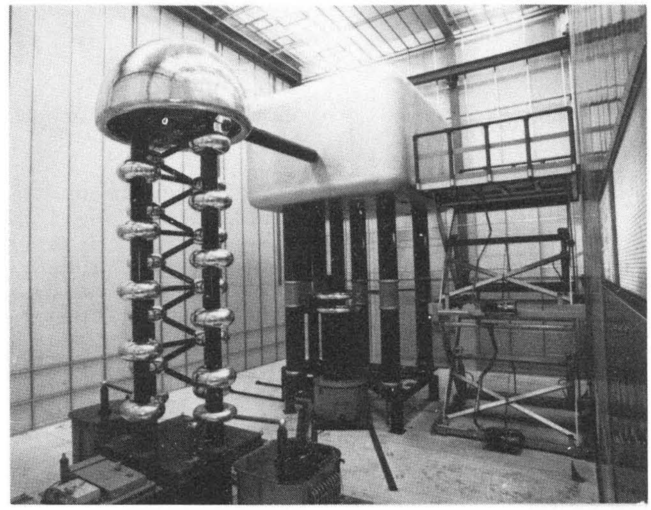

Fig. 2: View showing the main components of the 860 keV pre-accelerator: The Cockcroft - Walton generator designed for 900 kV (left) and the high voltage dome (right) which will house the ion source and the 60 keV beam line. The accelerating tube is not yet installed. A scissors-type lifting platform will provide access to the dome.

3. The 860 keV pre-accelerator.- The pre-accelerator consists of a 900 kV, 30 mA DC Cockcroft-Walton generator, a high voltage dome housing an ion source with a 60 keV beam line, and an accelerating column (fig. 2). It will deliver an 860 keV, 25 mA DC proton beam with an energy spread $\Delta E/E < 10^{-4}$ and a normalized emittance of less than $\pi \cdot 0.5$ mm mrad. With these beam characteristics, and taking into account phase compression effects and flattop acceleration in the 72 and 590 MeV ring cyclotrons, a proton beam intensity of about 2.5 mA is potentially achievable.

The layout of the high voltage dome is shown in fig. 3. A solenoid and an iris-diaphragm are placed between the ion source and the accelerating tube. The idea behind this arrangement is to separate the protons from the H_2^+ and H_3^+ ions by focalizing the H_1^+ component of the beam into an iris-diaphragm. The suppression of the parasitic ions reduces sparking in the accelerating tube, lowers the current load in the high voltage power supply and saves an analyzing system in the 860 keV beam line.

The decoupling of the ion source from the acceleration tube brings some further advantages worthwile to be mentioned: 1) Because of the high initial proton velocity at the entrance of the acceleration tube, a simple constant gradient tube can be used instead of a complex

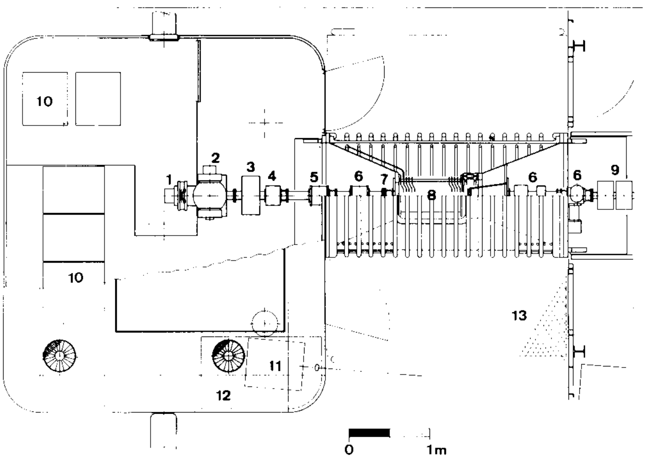

Fig. 3: Dome layout showing the location of the ion source, the 60 keV beam line, the accelerating tube and the auxiliary equipment. 1. Ion source, 2. 2000 l/s turbo pump, 3. Solenoid, 4. Pulser, 5. Iris-diaphragm, 6. Diagnostic elements, 7. Collimator, 8. SF_6 insultated accelerating tube, 9. Quadrupoles, 10. Power supplies, control and auxiliary equipment, 11. Laser data link, 12. Cooling system.

Pierce type column. 2) Free space in the 60 keV beam line may be used for diagnostic and for the installation of time structure devices (buncher, etc.). 3) Maintenance and repair work on the ion source may be done without venting the accelerating tube.

The above mentioned scheme suffers from an inherent difficulty. The 60 keV protons are subject to severe space charge forces which must partially be neutralized, for instance by electrons from the residual gas. However, collisions with gas molecules are a source of beam losses. In order to investigate these problems a 300 kV test stand was built. Experimental results indicate that a 10 mA DC beam can be produced reliably. Future experiments will include the investigation of alternative ion source arrangements in the dome which might later be incorporated in the new injector.

The accelerating tube will be of constant gradient with a length of 80 cm. The outside of the tube will be isolated with SF_6 gas at normal pressure.

Status: The high voltage generator, built by Haefely AG, Basel, was commissioned and assembled in the Faraday cage. Manufacturing of the accelerating tube is under way. Most of the components of the 60 and 860 keV beam transport systems have already been delivered.

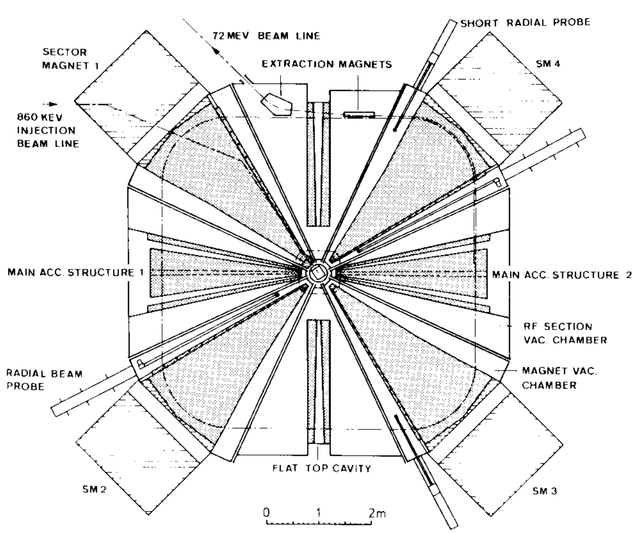

Fig. 4: Plan view showing the main components of the 72 MeV ring cyclotron.

4. 72 MeV ring cyclotron.- The layout of the 72 MeV ring cyclotron is shown in fig. 4. The main components are the four RF-systems in the free sections. The unique ratio of extraction to injection energy of 85 leads to a relative small injection radius and therefore to a rather crowded center region (see fig. 5).

The 860 keV beam is injected vertically along the machine axis. If it were injected horizontally through the midplane, the beam would be deflected in an intolerable way by the stray field of the sector magnets.

Table 1

Beam Characteristics		
Extracted beam:		
Energy	72	MeV
Average current (design goal)	> 1	mA
Beam quality horiz. and vertical	< $\pi \cdot 2$	mm mrad
Energy spread (FWHM)	∿150	keV
Phase width	∿ 15°	(RF)
Cyclotron Parameters		
Sector magnets:		
Number of sector magnets	4	
Angle of sector magnets	26°	
Flux density	11	kG
Gap width	35	mm
Injection radius (between magnets)	∿ 0.38	m
Extraction radius (between magnets)	3.0	m
Extraction radius (inside magnets)	3.75	m
Cyclotron frequency	5.063	MHz
Harmonic number	10	
RF-Systems:		
Accelerating system: frequency	50.63	MHz
two $\lambda/2$-resonators: peak voltage at injection	125	kV
at extraction	250	kV
Power consumption per $\lambda/2$-resonator	<140	kW
Flattop-System: frequency (3rd harmonic)	151.9	MHz
two Flattop-Cavities: peak voltage	∿ 70	kV
Power consumption per cavity	< 3	kW
Internal beam:		
Orbit separation at injection (for ΔE = 0.5 MeV)	8	cm
Orbit separation at extraction (for ΔE = 1.0 MeV)	1.9	cm
Number of revolutions	∿100	
Extraction efficiency	100	%
Injection:		
Axial beam transport system		
90° bending magnet (B = 12 kG, n = .4) deflects beam into mid plane. Magnetic cone with field index of n = 0.6 in the gap of sector magnet 1		
Extraction:		
Septummagnet: length	∿ 60	cm
deflection angle	5.50	mrad
Extraction magnet: deflection angle	39.5°	

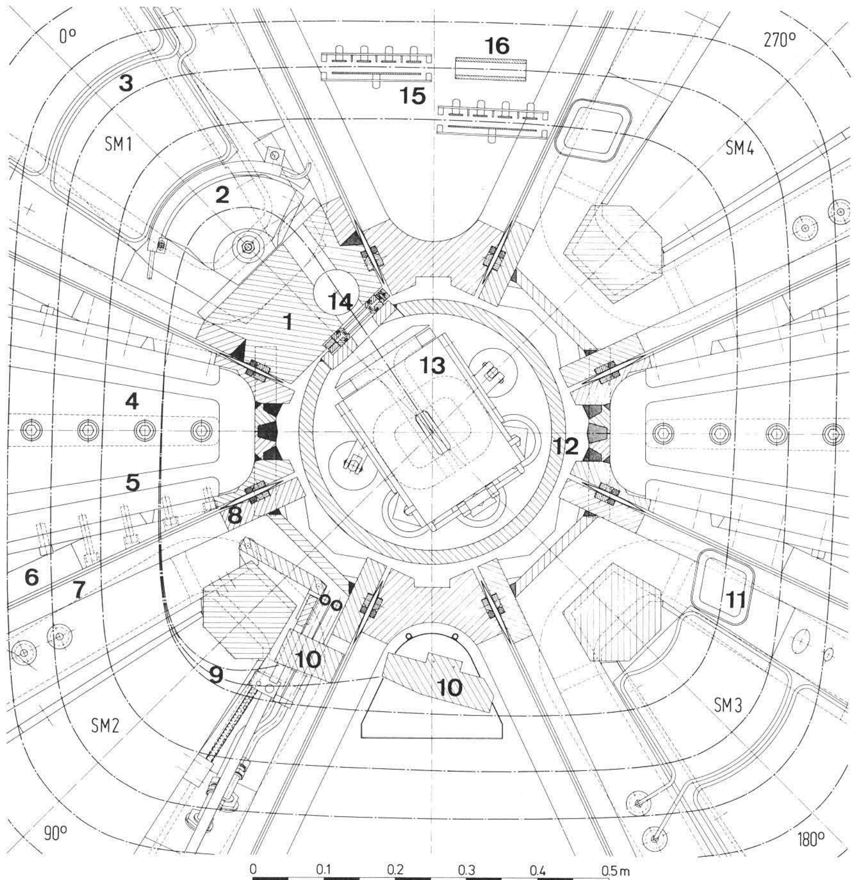

Fig. 5: Center region of the 72 MeV ring cyclotron
SM 1,2,3,4 sector magnets

1. gap spacer
2. magnetic conus with correction winding
3. gap trim coils (SM 1 and 3 only)
4. λ/2-resonator, accelerating electrode
5. accelerating gap
6. flange of RF Section
7. flange of magnet vacuum-chamber
8. inflatable seal
9. beam orbit no. 1 for RF-phases 0^o, 90^o, 180^o respectively
10. high power collimators
11. vertical steering electrodes
12. magnetic shield
13. 90^o-bending magnet with mirror plates
14. beam observation port.
15. RF centering electrodes
16. focusing magnet

In order to allow fast and sufficient access to the ring center, provisions are taken that the RF-sections can be removed quickly.

The main parameters of the 72 MeV ring are listed in table 1. Acceleration is achieved by two Delta type half-wave length resonators operating at the 10th harmonic of the revolution frequency. The peak voltage increases from 125 kV at injection to 250 kV at extraction. The maximum energy gain per turn therefore varies between 500 and 1000 keV which results in a phase compression factor of approximately 2. Flattopping is achieved with two separate H(101)-cavities operating at 152 MHz. This will reduce the energy spread of the beam at extraction to less than 200 keV. In combination with a turn separation of almost 2 cm we expect a complete extraction of the beam. A 7 mm septum magnet located at the extraction radius will steer the beam into a 39^o C-magnet. Both extraction magnets are placed inside the vacuum chamber of a flattop cavity.

The 860 keV beam transport line is schematically presented in fig. 6. Most of its complexity concentrates in the vertical section consisting of 8 quadrupoles and two 90^o-bending magnets. They allow a proper matching of the beam phase ellipses and of the dispersion trajectory in both transverse directions to the acceptance of the cyclotron. The vertical beam line is partially surrounded by an iron tube to protect the beam from the axial stray field of the sector magnets. The beam line will be operated in a regime where the optic is strongly influenced by space charge forces. The tuning will therefore depend on the beam current and also on the current distribution. The space charge forces will be partially neutralized by electrons from the residual gas, however, the degree of neutralization is hardly known and it may be different along the beam transport line. Therefore when the beam guiding system was laid out unneutralized currents up to 40 mA DC were considered. Special attention was paid to optical solutions which show minimal sensitivity to variations in beam intensity. But there is no doubt that the quadrupole strengths have to be adjusted for DC beam currents exceeding 5 mA (corresponding to approximately 500 µA accelerated).

The addition of a buncher and a fast chopper is also considered. The benefit from these gadgets, however, is still an open question, because the bunches have tendency to dilute in longitudinal direction and because neutralization will take place in an even more unpredictable manner.

The injected beam is steered into the first orbit by means of a magnetic cone (n=0.6) located in the gap of sector magnet 1.

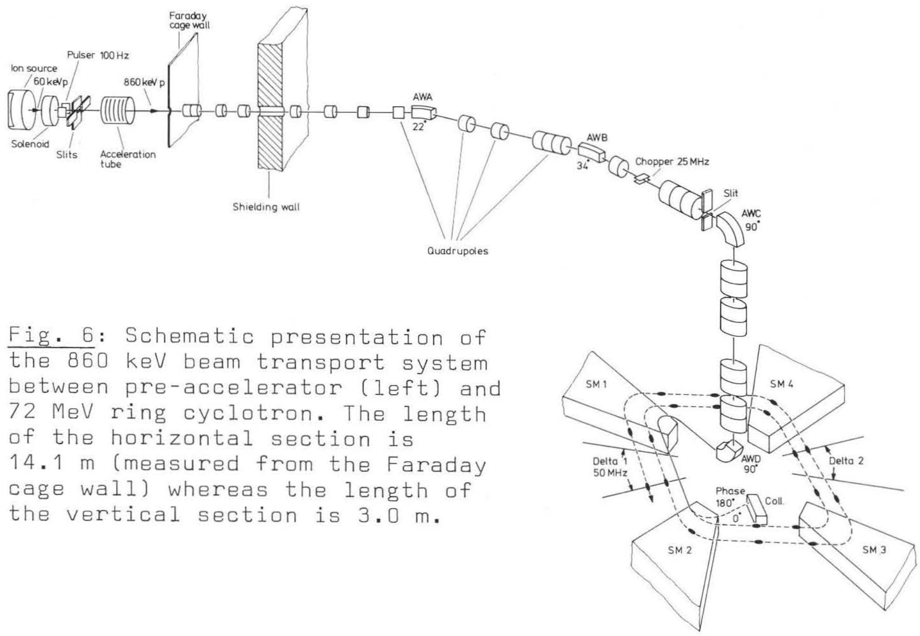

Fig. 6: Schematic presentation of the 860 keV beam transport system between pre-accelerator (left) and 72 MeV ring cyclotron. The length of the horizontal section is 14.1 m (measured from the Faraday cage wall) whereas the length of the vertical section is 3.0 m.

The entrance and exit of the cone provide extra vertical edge focusing. Furthermore the edges are curved to correct for aberrations. The maximum field in the cone along the beam trajectory is 15.5 kG.

In the cyclotron the phase selection will take place after the first half orbit where the unaccepted protons will hit a pair of high power collimators.

Because particles with different RF-phases require individual injection positions and directions, two pairs of centering electrodes operating at 152 MHz are provided to compensate for the orbit center spread.

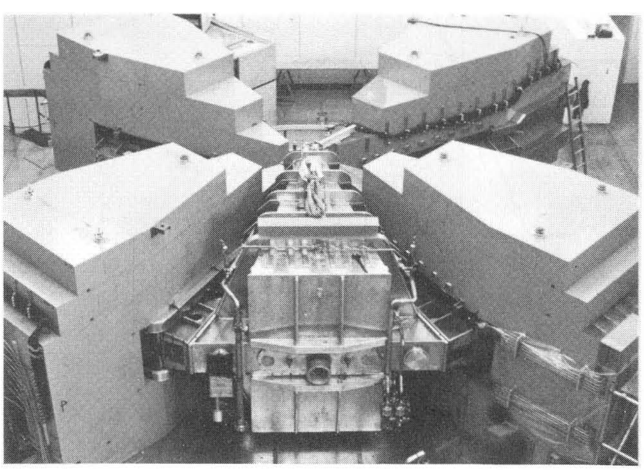

Fig. 7: The 72 MeV ring cyclotron under construction in May 1981. The prototype of the 50 MHz-resonators is installed between two sector magnets. A new Type of inflatable vacuum seals was developed to be used as joints between neighbouring vacuum sections. Vacuum tests which involved the resonator and two magnets demonstrated the excellent performance of the new seals.

4.1 Sector magnets.- Since May 1981 all four sector magnets are installed. This can be seen on picture 7. Each magnet consists of 9 hot rolled thick iron plates with a total weight of 180 tons. The carbon content was specified to be less than 0.8%. A pair of pole plates and two gap spacers are welded together, thus forming a pole package. The stainless steel gap spacers define the radially constant magnet gap of 3.5 cm. The field integral is a function of radius. It will be governed by the azimuthal width of the pole. The ideal contour is approximated by 5 planes at the beam exit side of the pole plates. The fine shimming is achieved by 12 pairs of shims with different thicknesses. They are screwed in a groove on the beam entrance side of the poles as can be seen in fig. 8, [11)12)13)]

The main coils are manufactured from hollow copper conductors. They provide the required 36500 Amp turns with a power consumption of 28 kW per magnet. The main coils of all magnets are connected in series. Correction coils are incorporated in the main coils. They allow to compensate for minor differences in the machining and assembly tolerances between the sector magnets.

Each magnet vacuum chamber consists of two sections which were premanufactured and then rigidly welded to the pole package. Finally the two flanges were machined to form an angle of 40° between them. The material used is an AISI 304 LN stainless steel with a susceptibility of < 0,01. The big aperture of the vacuum chamber on the entrance side gives reasonable access to the shims and provides the space necessary for the installation of beam probes. The aperture of the opposite vacuum chamber was made as small as possible in

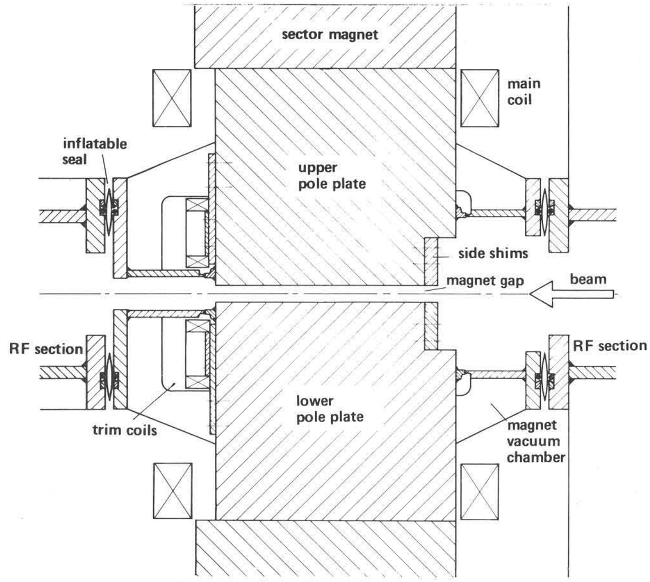

Fig. 8: Cut through a sector magnet showing schematically the pole plates with the main coils, the trim coils and the vacuum chamber. Poleplates, gap spacers and vacuum chamber are connected by welding, thus forming a rigid pole package.

order to minimize the distance of the trim coils from the symmetry plane.

A new type of inflatable seal was developed to be used between the magnet and the RF-vacuum chamber. It consists of a pair of stainless steel plates 1 mm thick shaped like a stretched "O". They are welded together on the inner and outer circumference. Pressurized with two bars they form a cushion which exerts the necessary forces to the aethylene propylene O-rings. These seals have been successfully tested. A good vacuum was achieved in the first tested section consisting of two sector magnets and a RF-resonator (see fig. 7).

Twelve pairs of identical trim coils are installed on each magnet. Their conceptual design is rather unconventional [14][15]. Since they are outside the vacuum chamber, their design is very simple and cheap. They do not affect the field in the gap, but just modify the fringe field of the magnet.

A computer controlled measuring device was developed for the mapping of the magnetic field [16]. Measurements are usually taken in radial steps of 2 cm and in azimuthal steps of 1/4 degree over a full quadrant. This device has already provided field measurements of a prototype magnet in summer 1979. The evaluation of these measurements led to the decision to increase the hill field from 10.3 to 11.0 kG and therefore to make the pole width narrower. This resulted in an increase of the focusing strength to the values shown in fig. 9. The betatron frequencies remain now in a reasonable region even for average beam currents up to a few mA.

As it has been mentioned at other occasions, the actual orbit in a 4-sector cyclotron tends to deform to a diamond shape (see fig. 10). This effect is pronounced when the radial gain per turn is large at small radii. In order to compensate for this effect (which is called the GABA-effect at SIN), magnets 1 and 3 have to be made azimuthally narrower than magnets 2 and 4 by a few millimeters. The resulting equilibrium orbit looses its 90°-symmetry, but the actual accelerated orbit becomes more regular.

The thickness of the 12 side shim pairs is determined by the requirement to compensate the GABA effect and by the need for proper isochronism. We hope that the desired characteristics of the magnetic field can be achieved in three iterative steps. They include mapping of the magnetic field, evaluation of the orbit properties and remachining of the shims. The required precision of the field integral corresponds to a tolerance of 0.3 mm in shim thickness.

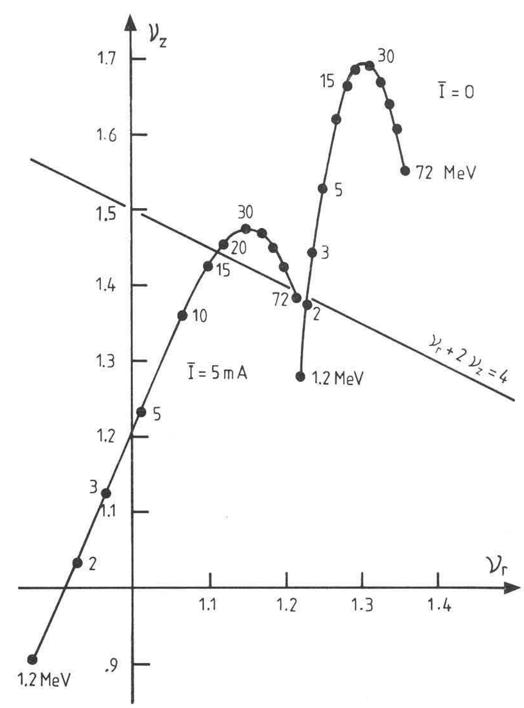

Fig. 9: The two curves show the horizontal and vertical betatron frequencies of the 72 MeV ring for average beam currents of 0 and 5 mA respectively. The points are labelled with their corresponding energy. The resonances $\nu_r + 2\nu_z = 4$ and $\nu_r = 1$ (for high beam currents only) are crossed in a few turns and are therefore considered uncritical. At high currents the second crossing of $\nu_r + 2\nu_z = 4$ seems to impose an upper limit for the beam current due to transversal space charge effects.

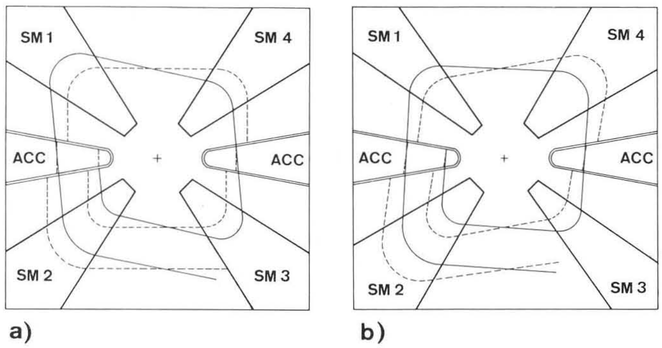

Fig. 10: Orbit deformation in a four sector cyclotron. When the radial gain per turn is large and the 4 sectors are identical, the orbits will deform to a diamond shape as seen in sketch a). The dotted lines represent the equilibrium orbits. (Discontinuities occur in the accelerating gaps as a result of the energy increase). Making sector magnets 2 and 4 wider and magnets 1 and 3 narrower the beam orbits become more regular and the equilibrium orbits will change to a diamond shape.

4.2 RF-systems.- Injector design includes three pairs of different resonators with its associated amplifier chains. Two half wave delta resonators for acceleration, two flat-top cavities to reduce the energy spread and two coaxial resonant lines for phase dependent centering of the injected beam. The six independent amplifier chains are driven by a master oscillator common with the 590 MeV ring cyclotron, as can be seen in fig. 11.

All systems may be adjusted for any phase relationship and resonator voltage up to the design maxima. Once established, phase and resonator voltages are maintained by closed loop control circuits. All six resonators are kept at exact resonance by individual tuning systems; the tuners of the delta resonators

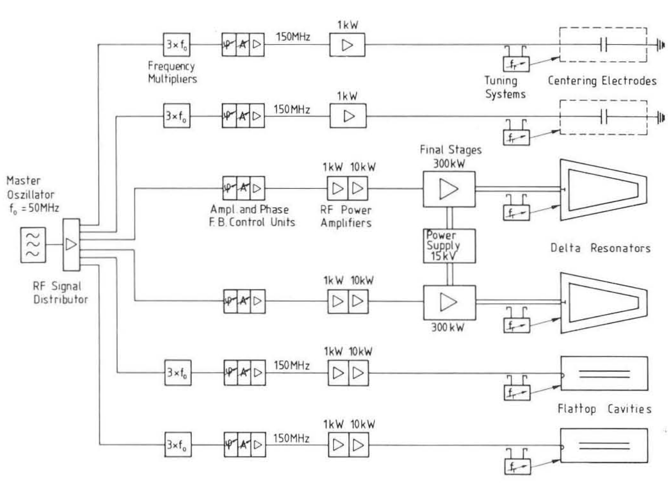

Fig. 11: Block diagram showing the 3 different resonators with its associated amplifier chains. They all have their own amplitude and phase regulation loops (not shown).

also adjust the input impedance of the coupling system to the characteristic impedance (50Ω) of the feeding coaxial line. The location of the different RF-systems is shown in fig. 4 and 5.

The main acceleration in the injector is produced by two half wave delta resonators. In this type of resonator, two delta shaped accelerating electrodes are located in the voltage maximum of a vertical half wave transmission line (see fig. 12 and [17]). One of these RF-structures, a single wall aluminium vacuum chamber resonator [18], has already been delivered in spring 1980 (see fig. 13). Measurements have confirmed the expected Q-value and the radial voltage distribution. Surprisingly high sensitivity of the half wave resonator for geometrical asymmetry between upper and lower parts of the half wave transmission line has been found. Consequently the mechanical tolerances of the welding structure have to be as tight as possible to prevent RF radiation from leaking out of the beam gap. (In numbers: the total radial length of the resonator is about 4 m, the mechanical tolerances are < 2 mm).

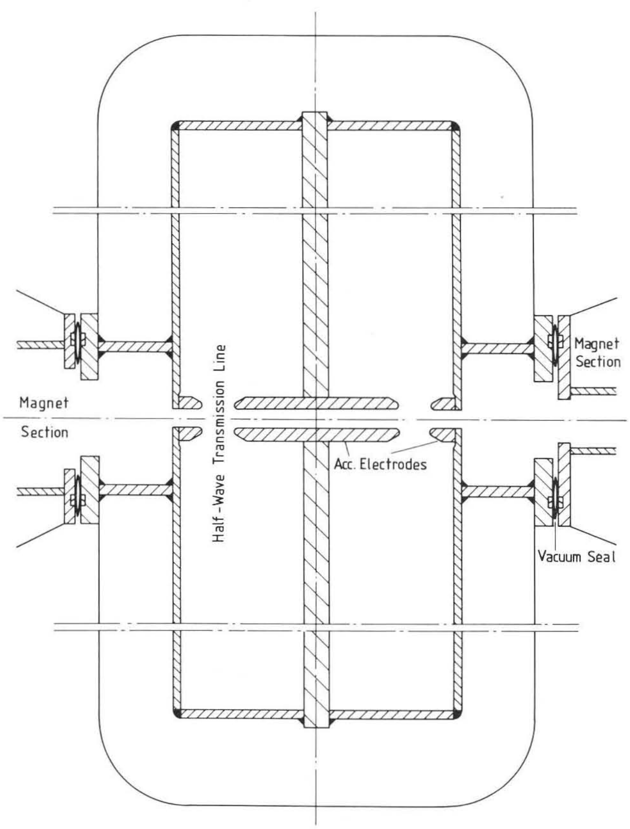

Fig. 12: Cut through a 50 MHz resonator, the main accelerating structure of the 72 MeV ring cyclotron. The accelerating electrodes are located in the voltage maximum of a half wave transmission line. The resonance frequency is adjusted by variing two capacitors between the accelerating electrodes and the chamber wall. The beam aperture is 4 cm.

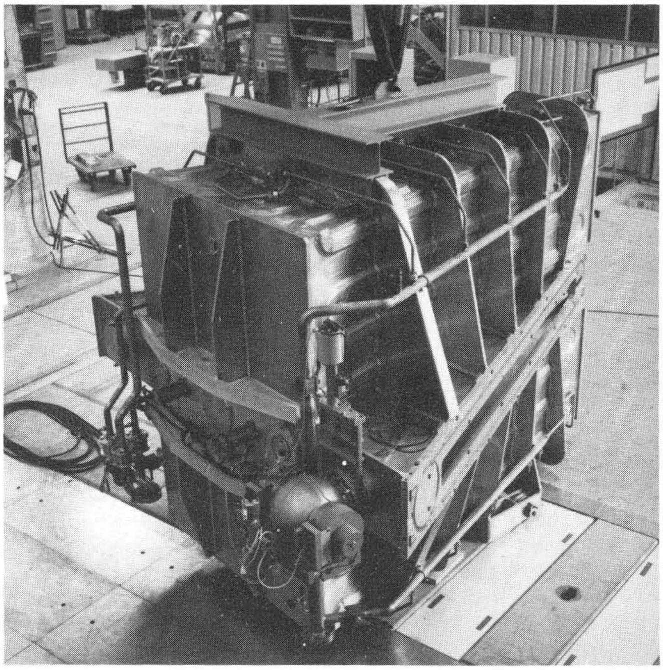

Fig. 13: View showing the first 50 MHz delta resonator. It is made from aluminium. The Q-value is 14'000. The inner conductor and the outside walls will be cooled with demineralized water. The mechanical structure itself is not rigid enough but it needs the additional support provided by the neighbouring magnets when the resonator is under vacuum. Clamps will transmit the tensile forces between the flanges of the resonator tank and the magnet vacuum chamber.

Flattop accelerating voltage in the injector is delivered by two H(101)-cavities operating at 152 MHz. These structures are similar to the one incorporated in the 590 MeV ring [7]. They differ, however, in the following important aspects: 1) The flattop cavity cannot be built to reach the first 10 revolutions for geometrical reasons. This implies that within this radial range not even partial compensation of the longitudinal space charge forces is possible. The cavity has to be slotted along the beam plane to avoid interference with the beam. 2) The accelerating gap must be rather small to keep transit time effects tolerable.

Measurements performed on a 1:1-model of the cavity again demonstrated the importance of good symmetry.

The prototype of a flattop cavity with its associated vacuum chamber is under construction. It will be delivered towards the end of 1981.

The centering electrodes will be operated with voltages < 10 kV at 152 MHz. Since they are sections of coaxial resonators, the power consumption will be < 1 kW. The main restrictions of the final resonator design are space limitations inside the vacuum chamber, see fig. 5.

The six resonators are driven by two types of amplifier chains with different operating frequencies. The first stage of a 50 MHz chain is a commercial solid state wideband amplifier with a maximum output power of 20 W. The next two stages produce output power levels of 1 and 10 kW respectively. They are commercial TV tube type amplifiers. The final stage is a modified version of the successful 250 kW amplifier design operating in the 590 MeV ring cyclotron. Improved efficiency increased the output power of the amplifier with the tetrode YL 1491 to about 300 kW.

A 150 MHz chain consists of a 10 W solid state wideband amplifier followed by two commercial TV-band amplifiers of 1 and 10 kW power level with their frequency range extended to 150 MHz.

Amplitude and phase controllers maintain the different resonator voltages within specifications. In particular, they reduce random amplitude and phase errors generated in amplifier chains and amplitude and phase modulators. In the case of the flattop RF-systems the feedback controllers have to fulfil a second requirement: the flattop accelerating voltages have to closely track the sum of the main resonator voltages. Analytical studies with a digital control model and measurements on the feedback loops have shown that tuning for optimal reference tracking behavior requires different parameter settings than tuning for minimal disturbance. Therefore the regulation loops have been designed with compromised values of the feedback

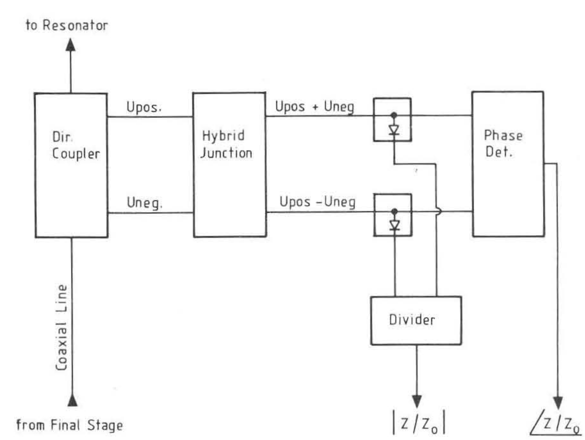

Fig. 14: Block diagram showing the circuit which measures the input impedance of the capacitive coupling system. From phase angle and absolute value feedback signals are derived for the frequency tuning system and for the coupling capacitor. It has to be noted that the beam load exerted on the resonator will have a strong influence on the coupling impedance.

parameters to satisfy all boundary conditions.

The specifications and block diagrams of the feedback loops are similar to a system already described for the 590 MeV ring cyclotron [6)7)]. As mentioned in a previous paper [17)] the half wave resonators are frequency tuned by variation of two capacitors between accelerating electrodes and chamber wall. These hydraulically driven trimmers provide a tuning range of 500 kHz. The feedback signal for the f-tuning loop is furnished by an impedance measuring cicuit; see fig. 14. This device derives the input impedance at the capacitive coupling system from the information delivered by a directional coupler. The phase angle of the coupling impedance generates an error signal for the frequency tuner; whereas from the absolute value a feedback signal for the coupling capacitor is produced.

The flattop cavities will be tuned by movable pistons which penetrate the cavity walls in a region where maximum magnetic RF field occurs. The tuning pistons under consideration will have a diameter of 25 cm and a maximum stroke of 1 cm. The resulting tuning range will be 300 kHz (see fig. 15).

4.3 Vacuum system.- The vacuum of the 72 MeV ring is characterized by the following approximative values: The total volume is 24 m^3 with a surface of 300 m^2 (70% Al-surface, the rest is stainless steel and Ni-plated magnet iron). Aethylen propylen O-rings (diameter 10 mm) with a total length of 100 m will be used. A bending magnet with an epoxy impregnated coil isolation will be placed in the ring vacuum.

The aim is to achieve an oil free vacuum of 10^{-6} torr. Six turbomolecular pumps with a pumping speed of 2000 l/s each will be necessary. They will be attached to the RF-sections.

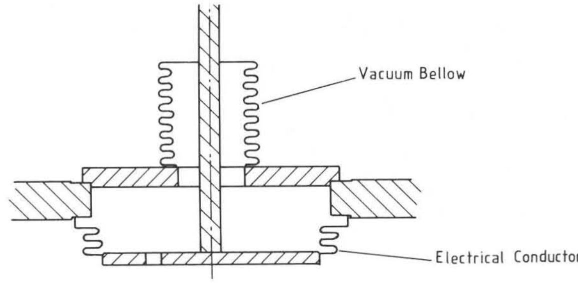

Fig. 15: Sketch of a tuning piston for the 152 MHz flattop cavities. It will penetrate the cavity wall in a location where maximum magnetic RF-field occurs. With a stroke of 1 cm a tuning range of 300 kHz is achieved.

5. Building.- The building for the new installation consists of four dedicated structural units. Fig. 6 shows a longitudinal section through the pre-accelerator building, the cyclotron vault and the supply area (see also fig. 1). Three walls and the ceiling are built from reinforced concrete. The thickness of the shielding walls was determined by assuming a beam loss of a few µA at extraction. (It has to be mentioned that additional local shielding may be installed around the extraction system). An independent concrete structure serves as a foundation for the ring cyclotron. The shielding wall towards the supply area will be erected with mobile concrete blocks. A 32 t-crane covers the vault and the supply area. A 80 t concrete beam can be moved on the crane rails. It serves as a shielding port for the crane aperture.

The pre-accelerator building is basically a steel structure. X-rays from the accelerating tube are shielded by a 38 cm wall made from cement bricks.
Construction work was completed early in 1980.

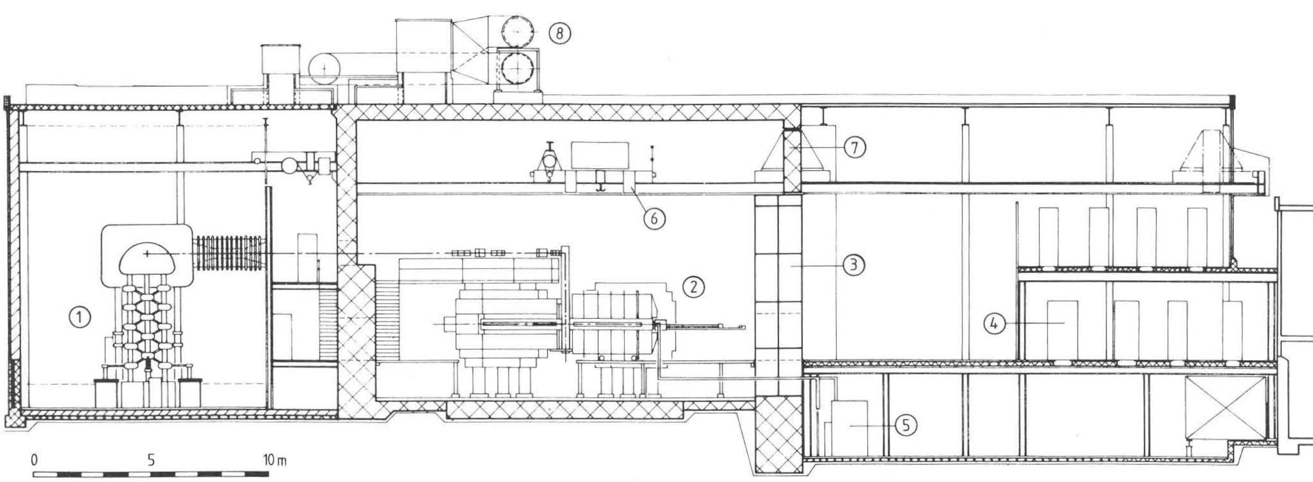

Fig. 16: Longitudinal section through the injector building. 1. Cockcroft-Walton pre-accelerator, 2. 72 MeV ring cyclotron, 3. Shielding wall erected from movable blocks, 4. Power supplies, 5. 50 MHz power amplifier with 50 Ω coaxial line, 6. Crane 32/3,2 t, 7. Mobile shielding port, 8. Ventilation systems.

6. Time schedule and future plans.- The time schedule for the completion of the new injector is determined by the final field shaping of the sector magnets and the subsequent installation of the RF-systems. It is planned to have the first 50 MHz system ready for RF-tests in April 1982. Installation of the remaining RF-systems will be completed by spring 1983. The pre-accelerator will deliver its first beam into the 860 keV beam transport system toward the end of 1982. First beam tests with the 72 MeV ring are planned for summer 1983. At that time only the first section of the 72 MeV beam line will be ready for tests. A high power beam dump designed for beam currents up to 3 mA will be installed for the purpose of beam developments. Completion of the 72 MeV beam line and first injection into the 590 MeV ring will hopefully take place by the end of 1983.

For a reliable operation with the beam currents envisaged the 590 MeV-ring as well as the proton channel (which guides the extracted proton beam to the pion production targets) need some important upgrading and improvements. Main point of the ring improvement program is the increase of the RF-power for the 50 MHz accelerating system. This will be achieved by implementing a new type of power tetrodes into the existing 250 kW-amplifiers. The new tubes are potentially capable to deliver > 500 kW RF-power each. The heavy beam load exerted on the accelerating cavities and the flattop cavity will also necessitate fast regulating systems to keep the coupling impedance constant. In addition, a new interlock system with a considerably reduced response time will have to be implemented in order to protect the facility from damaging. These new features will be implemented during a six months shut down in 1985, the duration of which is determined by the reconstruction program of the 590 MeV proton channel.

Acknowledgements.- The realization of the new facility would not be possible without the enthusiastic engagement of numerous members of the SIN staff. Nevertheless the authors would like to stress a few names which will remain connected with the new injector: R. Alpsteg, G. Biemans, D. Brombach, M. Daum, M. Dubs, W. Fischer, D. George, M. Humbel, M. Märki, E. Mariani, E. Mollet, D. Rossetti, W. Rothacher, G. Rudolf, M. Werner, E. Wiedemeier, O. Szavits.

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" DISCUSSION "

H.W. SCHREUDER : Do you intend to use elastomers in combination with the inflatable seals between magnets and RF structures ?

U. SCHRYBER : Yes, ethylene propylene O-rings will be used. Our experience from the 590 MeV ring indicates that they get destroyed rather by thermal effects than by irradiation.

G. DUTTO : What phase acceptance do you expect with RF flat-topping ?

U. SCHRYBER : The phase acceptance of the new injector will be approximately 40°. However, the phase width of the accelerated beam will be not more than 20° at 72 MeV due to the phase compression effect.

" DISCUSSION " (continued)

Y. JONGEN : What kind of problems do you expect, due to beam loading effects on the R.F. system and on its regulation ? How do you plan to solve those problems?

U. SCHRYBER : The beam loading effects will be more pronounced in the 590 MeV ring cyclotron than in the new 72 MeV ring.

One effect comes from the current dependence of the coupling impedance of the main accelerating structures. It will be necessary to imply control loops which keep the coupling impedance matched to the coaxial power transmission line.

A second effect will show up in the flat-top system. For beam currents above approximately 300 µA, one needs to couple out the RF power deposited in the cavity by the beam. This is necessary in order to keep voltage and phase of the flat-top systems within the very tight specifications.

Possible solutions to these problems are under discussion.

K. ZIEGLER : What is the anticipated intensity out of the 590 MeV ring with the new injector ?

U. SCHRYBER : With the RF-power presently available for the 590 MeV-ring, the maximum beam current will be close to 500 µA. In order to achieve beam currents above 1 mA, the RF-system will need considerable upgrading.
The intensity limits of the ring are still under investigation (see contribution of W. JOHO to this conference). A tentative value ranges from 1 to 2 mA. The limiting factor is the energy spread of the internal beam introduced by longitudinal space charge forces. To a certain extent, the space charge effects can be compensated by operating the flat-top system to produce a "tilted top" rather than a "flat-top".