RUNNING IN OF VICKSI AND FIRST OPERATING EXPERIENCE

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Summary

The assembly of the accelerator combination VICKSI is essentially completed. Six different ions have been accelerated to 15 different energies during the running in and acceptance period. The tests have shown that all essential beam specifications are fulfilled. 1160 hours of beam time for experiments have been scheduled since March of this year. About 60% of that time the beam was actually available. Training of operators, a higher degree of automatic tune up, and finishing the beam transport system to the target areas will be the main task for the coming year.

Introduction

The accelerator combination VICKSI is essentially completed after five years of design, construction and assembly. VICKSI consists of a 6 MV single stage Van de Graaff (model CN of High Voltage Engineering Corp.) as injector for a separated sector isochronous cyclotron, which was built by Scanditronix in Uppsala, Sweden. Detailed accounts of design specifications and design features have been given earlier[1,2,3]. I will therefore only briefly give the main parameters and then describe the running in of the different subsystems in more detail. Positive ions of mass $1 \lesssim A \lesssim 86$ and a charge q_i (typically 1^+ to 4^+) are produced in an axial Penning ion source in the terminal of the Van de Graaff. After preacceleration in the Van de Graaff the ions are stripped into charge state q_s and injected into the cyclotron. In the cyclotron the ions are accelerated further to about 17 times the injection energy. Thus the final energy is given by $E_f = q_i \times 6 \times 17$ MeV $\approx$ $q_i \times 100$ MeV. The energy limit given by the design of the cyclotron magnets is $E \lesssim 128$ MeV $\cdot\, q_s^2/A$. This condition is fulfilled for energies $E < 200$ MeV and ions of mass $12 \leq A \leq 40$ using the most abundant charge state q_s (~30%) from the stripper. For these energies and ions one can expect beam intensities of ~100 pnA at the exit of the cyclotron with our present ion source. If higher charge states out of the ion source are needed, a factor of ten less intensity for every increase of the charge state by one unit will result[4]. Three bunchers compress about 50% of the dc-intensity of the ion source into a 6° phase interval of the cyclotron radio-

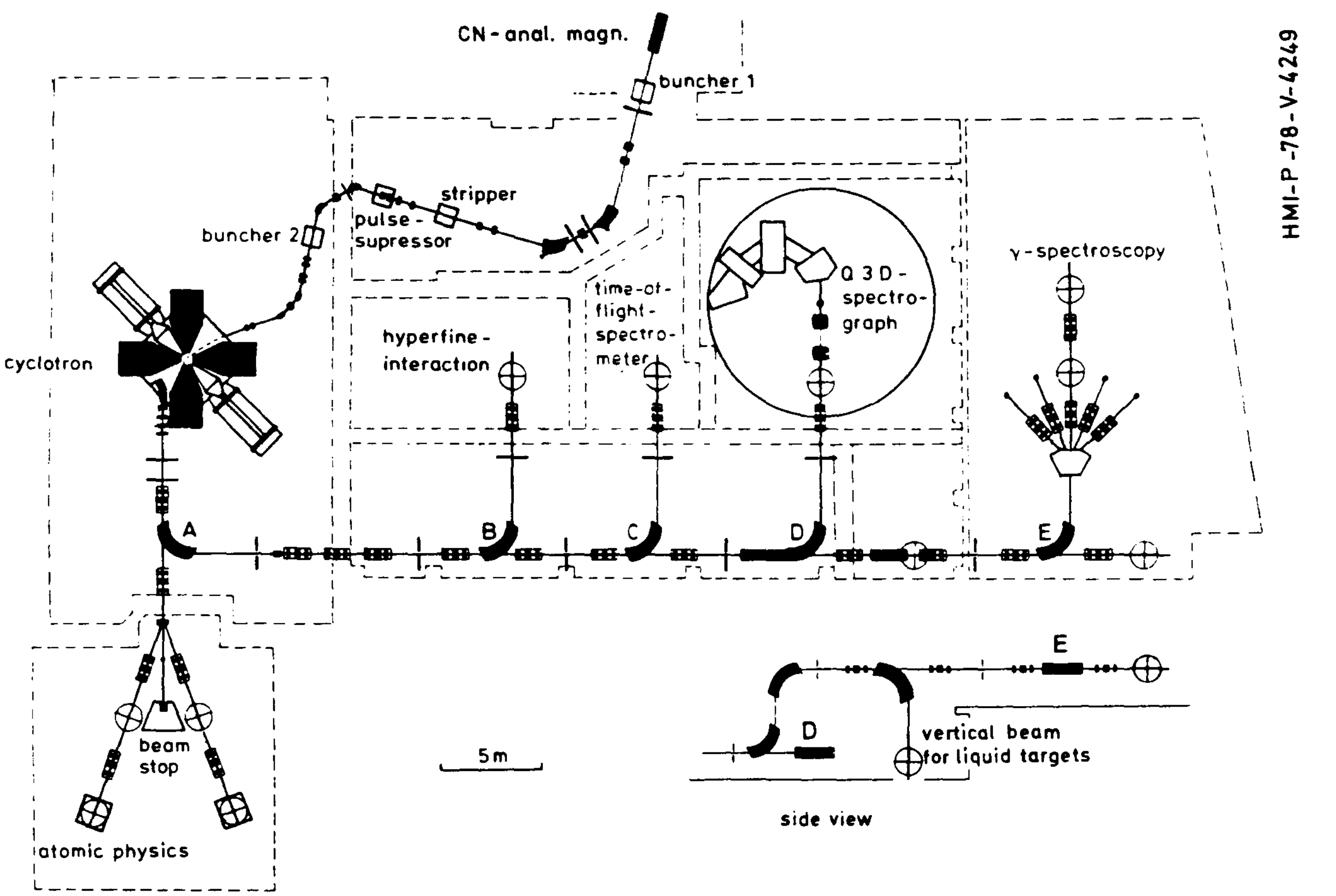

Fig. 1: Layout of the VICKSI facility. The Van de Graaff is located in a tower above the CN-analyzing magnet. Beam defining slits are indicated along the beam path. The pulse suppressor can select one out of 20 pulses for acceleration. The analyzing magnets A,B,C,D,E after the cyclotron are used together with the quadrupole tripletts to produce the desired beam properties at the target stations.

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frequency. One of them, a prebuncher, is located in the terminal of the Van de Graaff, the two others in the beam line between the Van de Graaff and the cyclotron, In principle the intensity losses due to bunching and stripping of the beam are the only losses to be anticipated, so one can expect about 15% of the dc-output of the ion source to be accelerated in the cyclotron and extracted with an energy resolution of $\Delta E/E=10^{-3}$. A layout of the VICKSI facility is shown in Figure 1. Three target locations, the one for hyperfine interaction, for the time of flight spectrometer and the one in front of the Q3D-spectrograph are completed. They have received beam and first experiments were done.

At a rather early state it was recognized that the number of controls necessary for VICKSI was too large to be easily done manually. Therefore it was decided to install a computer assisted control system. Details of the concept have been given previously[5)6)]. Only five different types of CAMAC modules have been specified as unique interface between computer and accelerator components. This has caused a high degree of standardization for the accelerator components. The availability of the interpreter MUMTI[6)], which is used for device testing, maintenance routines and machine physics, has proved to be extremely useful during the test and running in period. A detailed description of this control system is given in another contribution to this conference.[7)]

Running in of the subsystems

Van de Graaff and Terminal

In the course of converting the Van de Graaff into a heavy ion injector a completely new terminal has been built[8)]. Besides producing heavy ions, it also is used to select the charge state to reduce beam loading on subsequent terminal components and the Van de Graaff. Furthermore it contains a prebuncher to minimize the intensity loss in converting the dc output of the source into the required pulses for the cyclotron acceleration. It also includes three Einzel-lenses to focus and optically adapt the beam to the requirements of the accelerating tube. To provide the necessary vacuum of 10^{-8} mbar a turbomolecular pump and three ion getter pumps are installed. All the elements and the completed terminal have been tested in a pressure tank to ensure the necessary reliability before installation on the Van de Graaff. Data transmission between the terminal and ground potential is done via an infrared data link capable of transmitting 20 analogue values plus 40 set pulses to the terminal and a total of 600 bits in form of analogue values or status information from the terminal to the ground station. To adapt the Van de Graaff to the acceleration of larger currents of heavy ions, the old accelerating tube needed to be replaced by an ultrahigh vacuum tube. A bakeable all metal-ceramic tube from National Electrostatic Corporation was chosen. The tube is made up out of 20 modules with heating sections between the modules. The vacuum in the tube is now routinely in the low 10^{-9} mbar region about a factor of 100 better than in the old tube. To make room for the new terminal the electrostatic cover, the so-called spinning, was increased from 1.5 m length to three meters. Also the shape of the spinning was optimized, which reduced the maximum electrical field strength by 20%.

The reconstruction of the Van de Graaff and the installation of the new terminal was completed towards the end of 1976[9)]. In January 1977 the first Ar^{3+} beam was accelerated in the converted Van de Graaff. The first tests already indicated that all components behaved as precalculated and no modifications were necessary. The beam was properly guided from the ion source through the terminal to the entrance of the Van de Graaff tube. The transmission through the tube was 100%. During a conditioning period the terminal was on 6.2 MV for about 20 hours without a spark. However to reach voltages above 5.6 MV during routine operation some conditioning of the accelerating tube is necessary. The terminal voltage was calibrated against the NMR-frequency of the magnetic field of the analyzing magnet with the nuclear thresholds of the reactions $^{19}F(p,n)$ and $^{7}Li(\alpha,n)$. The voltage stability was determined to be $\Delta V/V= \pm 3 \cdot 10^{-5}$. During the test period two pressure leaks in the accelerating tube developed at weld connections between thin titanium sheets and the rigid flange at the end of a tube module. This was attributed to material fatigue caused by flexing of the titanium sheet when the tank is pressurized to 16 bar necessary with the insulating gas mixture we used. We then decided to switch to pure SF_6 as insulating gas, which enabled us to keep the maximum pressure down to 7 bar. No leaks have developed since that change. During running in with beam it proved to be somewhat tedious to align the beam out of the Van de Graaff with the axis of the following beam guiding system. Using small programs written with the interpreter MUMTI[6)], it is possible to couple steering magnets in such a way to produce a pure beam offset or to keep the beam position fixed and change only beam angle. This drastically reduces the tune up time. We now routinely obtain close to 100% transmission from the terminal to the Faraday cup after the analyzing magnet. This demonstrates the power and convenience of the computer control system.

Injection beam line system

The beam line system from the Van de Graaff analyzing magnet to the cyclotron contains the necessary magnetic focusing and bending elements, two identical klystron-bunchers, and a combined gas- or foil-stripper. The basic concept, set up and instrumentation of this beam transport line has been described earlier[10)11)]. All magnetic elements have been carefully measured as far as their mechanical and magnetic specifications are concerned and great care has been taken to align the system to better than ± 0.5 mm. This has paid off nicely during the original running in period. Beams are transported from the Van de Graaff analyzing magnet to the cyclotron with very little steering necessary. To set up the beam line for a new beam a computer routine is called on the control-computer. This routine needs as input the stiffness of the beam, given by the setting of the analyzing magnet and the charge state of the ions before and after the stripper. It calculates all magnet settings using the calibration curves and upon command sets all magnets (the dipoles with an overshoot procedure). These settings usually are accurate enough to transport the beam to the stripper. Some tune up and optimization is needed to obtain the best transmission through the stripper channel without gas or stripper foil in place. With the stripper in operation the selected charge state is transported to the entrance of the cyclotron and only minor readjustments are necessary to obtain the proper emittance.

So far only the first beam line buncher is in operation. It is used to produce a time focus at the center of the cyclotron. In the final configuration, a focus in all three dimensions longitudinal, horizontal, and vertical will be at the stripper location, in order to minimize phase space increase due to energy and angle straggling[1)10)]. The second buncher will then refocus the beam to the center of the cyclotron to obtain a ±3° phase width, necessary to get the required energy resolution of $\Delta E/E = 10^{-3}$.

The operation of the stripper has been quite satisfactory. As expected we had no problems with the nitrogen gas stripper. The foil stripper is needed for ions heavier than neon to obtain the necessary charge state for acceleration in the cyclotron. Using carbon foils of 5 μg/cm^2 or 3 μg/cm^2 we got average lifetimes of 2.5 to 3 hours for a beam of 50 to 100 pnA of Argon ions. In addition only an adjustment of the injection phase of a few degrees was necessary when changing foils to obtain the same beam intensity extracted out of the cyclotron. No other tuning was required. At present the foilholder, capable of carrying 110 foils, is wobbled on a circle of 4 mm diameter. We plan to change the wobble mechanism so as to cover a small surface area of the foil rather than just a circular line. An increase of foil lifetime is expected from this change. For ^{84}Kr, the heaviest ion we have tried so far, the average foil lifetime was 45 min with a beam of 30 pnA. Somewhat larger adjustments of the injection phase (~5°-6°) were necessary, but still no readjustment of magnets. With the second buncher operating, however, even these adjustments will no longer be necessary, because it will produce a point to point image from the stripper to the center of the cyclotron. This is true as long as the change of mean energy at the stripper is small enough so that the beam is still arriving at the buncher in the linear part of the sine wave (±30°).

Cyclotron

The cyclotron was completely assembled beginning of October 77. A layout of the cyclotron is shown in Fig. 2. Injection elements, extraction elements and some of the beam diagnostic devices are indicated. The main technical parameters for the cyclotron have been described in earlier publications[1].

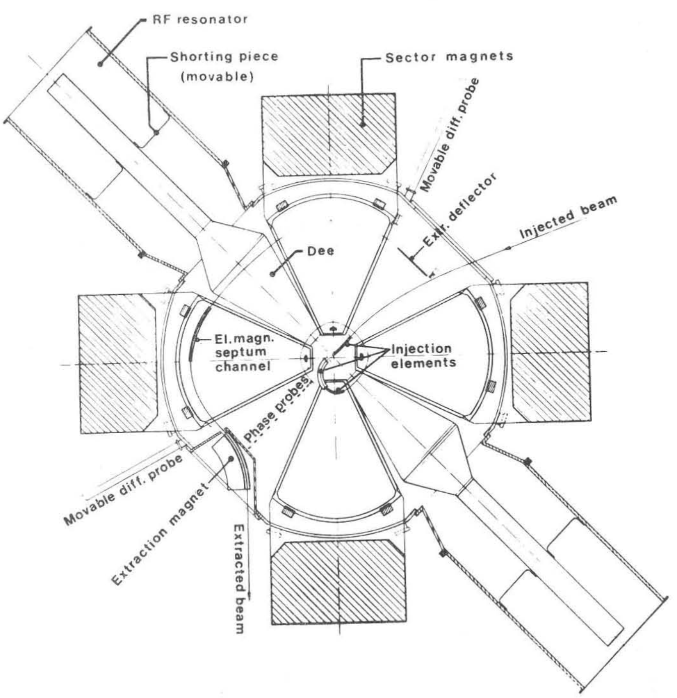

Fig. 2: Plan view of the cyclotron. The injection elements, extraction elements, and the two radial differential probes are indicated.

At the entrance of each injection and extraction element slits are installed to facilitate beam centering into the element. In order to test subsystems as early as possible with beam, we injected a dc-beam into the first orbit in Feb. 77, essentially with 100% transmission. The test showed that the injection system[12], which was believed to be a critical part, was working as designed. In June 77 the first beam was accelerated to extraction radius. At that time the extraction system had not been installed. From middle of October 77 until the end of 77 we were running beam tests from Thursday to Monday morning, using the rest of the time to install beam lines behind the cyclotron and eliminate weak points we had found during the tests. Due to hardware problems on the extraction magnet and the electromagnetic septum magnet (see Fig. 2) we were not able to extract beam at first. When the elements had been repaired, on the first try we did extract the beam of 170 MeV Ne-ions with an efficiency of about 90% (on Dec. 4th, 77). The acceptance tests were completed in middle of March 78 when we formally took over the cyclotron from Scanditronix. In table 1 a comparison of some specifications and their measured values are shown. Results on stability tests of the RF-systems are given in a separate contribution to this conference[13].

The running in of the cyclotron was greatly aided by making full use of the capabilities of the computer control system. This is clear from a description of how the cyclotron is set up for beam and how the machine is optimized for accelerating the beam through the cyclotron. Scanditronix supplied a program called PARSET that calculates all cyclotron settings. This program was adapted so it could be run on the control computer. The input for this program is ion species and extraction energy. It then calculates the necessary charge state and the orbit-frequency and asks for the selected charge state, on which harmonic the particles should be accelerated and which turn separation at injection is desired. With this information it then calculates all cyclotron parameter settings. These setvalues are stored on a magnetic disc. Upon a command all injection elements, extraction elements, trim coils and harmonic coils are then set to these values. Only the setting of the main magnet and the tuning of the RF-system is still done separately.

Injection. Threading the beam through the injection system is done with the help of a computer routine. With a horizontal steering magnet in front of the cyclotron the beam is swept across the entrance slit of the first inflector magnet I1 and simultaneously the slit current is recorded. Thus one obtains a setting for the steering magnet which centers the beam into the entrance of the first inflector magnet. Similarly looking at the slits in front of inflector I2 the setting for the magnet I1, and with the slits in front of I3 the setting for I2 is found. Finally by adjustint the voltage of the electrostatic inflector I3 and observing beam current on one of the radial differential probes moved all the way into the machine, in general more than 50% of the beam is transmitted through the injection system. This procedure takes only a few minutes. To optimize the transmission through the injection system one then can couple for instance I1 and I2 so as to keep the position of the beam at the entrance of I3 constant and change only the angle or vice versa. The limiting aperture in the injection system is the channel of the electrostatic inflector I3. It is 27 cm long and 8 mm wide[11]. For most beams, however, we were able to transmit essentially 100% of the beam.

Acceleration. For all beams we have produced so far, it was possible to accelerate the particles to full radius with the precalculated setting of trimcoils and harmonic coils by only adjusting the main field. The necessary change of the main magnet current to achieve this was always less than about 1%. With the

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	Design Aim	Measured Value
Energyfactor $K = \frac{E \cdot A}{q^2}$	120	127 for heavy Ions } from field measurement 144 for light Ions } from field measurement 128 $^{20}Ne^{5+}$ accelerated to 160 MeV
Energyspread $\frac{\Delta E}{E}$	$5 \cdot 10^{-3}$	$2 \cdot 10^{-3}$ full intensity $0.5 \cdot 10^{-3}$ at 50 % intensity through analyzing slit
Transmission through cyclotron	100 % (30 % guarantee)	> 35 % for all extracted beams
Emittance	10 π mm mrad	2 π mm mrad
Time structure	< 1 % intensity outside ±30° RF phase around beam pulse	In a scattered beam no particles between pulses with 10^4 particles in pulse
Pulse width	6°	9° (1.5 ns at 16 MHz)

Table 1: Comparison of design specifications and actually measured values for several machine parameters.

beam accelerated to full radius a first optimization of injection phase usually results in separated turns for most of the radial region. A computer routine PHOP based on the use of the phase measuring system[14] with the ten fixed phase pickups in the extraction valley (see Fig. 2) determines the phase history of the beam. The operator then selects the desired dependence of phase on radius and PHOP calculates the necessary changes in trimcoil currents. Upon command these new currents are set and the beam phase is measured again. After one or two iterations the field is isochronized to within ±2°. A more detailed description of this routine is given in a separate contribution to this conference[15]. From the very beginning of running in the cyclotron, this routine was operating and clearly was a tremendous help and a time saving factor.

Centering. The original plan for centering the beam in the cyclotron was to adjust the injection system, particularly the position of the electrostatic inflector I3, to bring the beam onto a centered orbit at the very first turn. Calculations done in Eindhoven[16], however, showed that centering could also be achieved by using a first harmonic bump in the radial region between 500 mm and 600 mm. This bump can be produced with a combination of harmonic coils 2 and 3. The computer routine HARMSET calculates the necessary harmonic coil currents to obtain a bump of a given amplitude and at a specified azimuth without changing the average field[15]. So far, centering is done by looking at the turn pattern between 1000 mm and 1300 mm, moving the bump around and changing its amplitude until the ΔR-plot taken from the turn pattern does not show any precessional motion. An automatic centering procedure is planned for the future[15]. We found that the bump we can produce with trim coils 2 and 3 is sufficient to center every beam. Therefore we decided during running in of the cyclotron to fix the position of the inflector channel I3. The complicated motion mechanism and its hydraulic activating system were taken out, thus eliminating possible sources of difficulties.

Extraction. For all ions except the very light ones the orbits are nicely separated all the way to extraction radius. To further increase the turn separation for extraction, the $\nu_R = 1$ resonance is excited

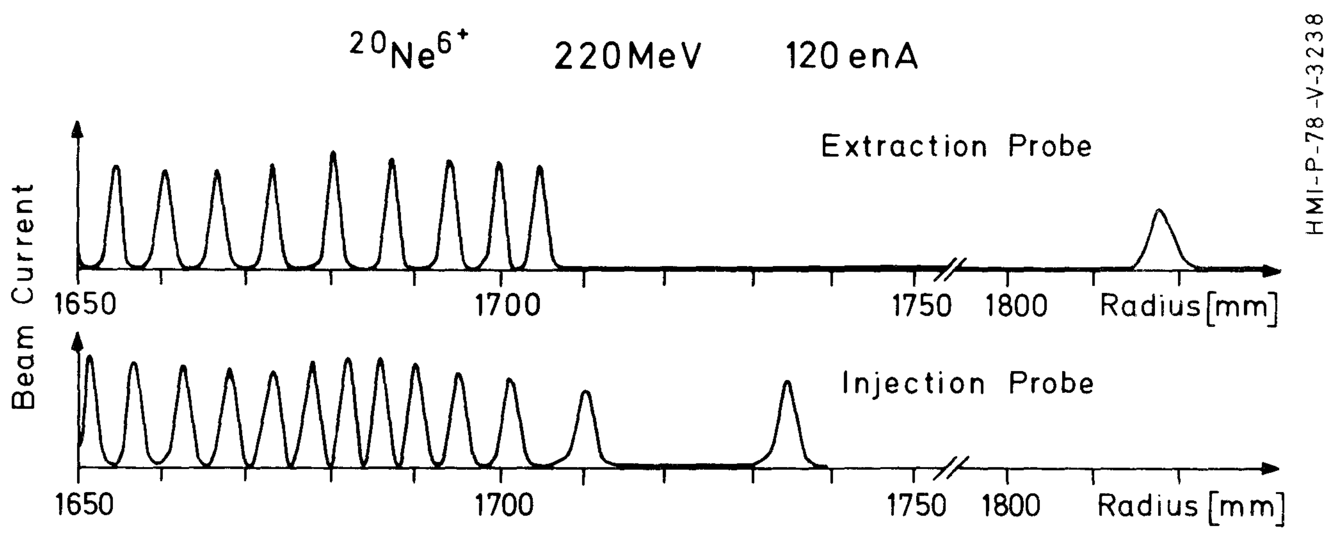

Fig. 3: Turn pattern in the extraction region taken with the radial differential probes in the injection valley and the extraction valley. The turn at 1735 mm radius of the injection probe is behind the electrostatic deflector E1. On the extraction probe the turn at 1820 mm radius is in front of the extraction magnet E3.

with a small first harmonic produced by harmonic coil 11. This effect of the $\nu_R = 1$ resonance can nicely be seen on Fig. 3 showing the turn pattern of a $^{20}Ne^{6+}$-beam in the extraction region taken with the radial differential probe in the injection valley (injection probe) and in the extraction valley. The enhancement of the turn separation in the injection valley can be recognized. The turn at 1735 mm at the injection probe is after the beam has passed through the electrostatic deflector E 1. The turn at 1820 mm at the extraction probe is behind E 1 and the electromagnetic channel E 2 in front of the extraction magnet E 3 (see Fig. 2). Clearly, single turn extraction and high extraction efficiency is obtained. A procedure suitable for automatic set up of the extraction process has not been established yet. The azimuth and amplitude for the first harmonic produced by trim coil 11 has to be found by trial and error. We have found however that the last orbit before extraction must be at a rather definite radius in the injection as well as in the extraction valley. It seems feasible to use a shadowing technique by setting the differential probes at these radii and change trim coils until they share the beam. This procedure however has not been tested yet.

Beam line to target areas

Just as at the exit of the Van de Graaff, it was tedious at the exit of the cyclotron to align the beam with the axis of the transport system. A computer routine coupling the extraction magnet E 3 with a horizontal steering magnet downstream makes it possible to keep the position of the beam at the entrance slit of the beam line system fixed, while changing only its angle. This procedure makes it quite easy for the operator to line up the beam with the beam line system. The settings for the transport system[17] after the analyzing magnet dipole A (see Fig. 1) are calculated from the beam stiffness given by the setting of the analyzing dipole. The program also automatically couples the appropriate quadrupoles to obtain the desired optical mode for the transport system. During fine tuning of the system then the optical mode automatically is preserved. An emittance measuring device is installed immediately behind the analyzing magnet A (see Fig. 1) after the cyclotron. An example of a vertical emittance at this location is shown in Fig. 4 for a beam of 180 MeV Ne^{6+}-ions. It is not possible to measure the horizontal emittance at this location. Due to the dispersion of the analyzing magnet, the longitudinal space (energy, time) is coupled to the horizontal space (position, angle), resulting in a smeared out x-emittance. The beam guiding system to the target stations as far as it has been tested worked as calculated with only one minor realignment of one dipole magnet being necessary.

Conclusion of running in period

The running in period of the facility since fall last year has been surprisingly smooth with much less difficulty than we had anticipated. The problems we had like leaking, shorted coils, and unreliable power supplies, etc., were within the limits one expects for a project of this size. In no instance did we encounter a basic problem necessitating a redesign or change of concept.

Operating Experience with VICKSI

At the beginning of this year, even before the cyclotron had been accepted, a few preliminary experiments have been started. From March of this year until the end of July we have scheduled 1160 hours of beam time. We were able to actually deliver 727 hours of beam to experiments, which means that about 60% of the scheduled time the beam was available. 44% of the unscheduled

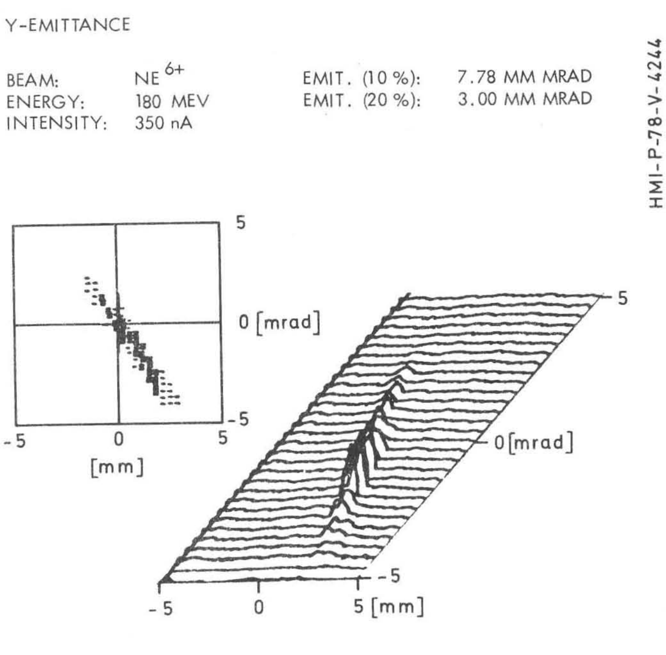

Fig. 4: Y-Emittance of a 180 MeV Ne^{6+}-beam measured after the analyzing magnet behind the cyclotron.

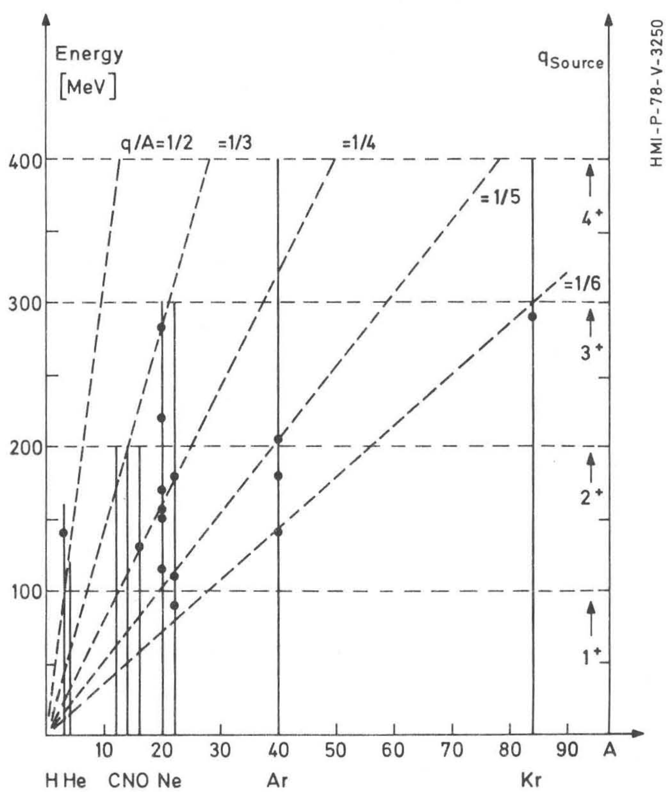

Fig. 5: Summary of beams produced so far. The final energy is plotted versus nucleon number A. The vertical lines indicate ions which have been tested and can be produced. The dots are beams which have been accelerated. On the right side the limit due to the charge state of the ions out of the source is shown. The limit of the cyclotron magnets for charge to mass ratios 1/2 to 1/6 are also indicated.

down time was due to problems on the injector including the terminal, 43% due to the cyclotron, 11% due to difficulties in the beam guiding system including stripper and bunchers, and 2% due to the computer control system. The down time caused by the injector is so high because any repair which requires an opening of the Van de Graaff pressure tank has the time for opening and closing the tank added on. The down times of the cyclotron were mainly due to problems with the main magnet supply, which we think we have solved now.

We have accelerated six different ions from ^{3}He to ^{84}Kr to a total of 15 different energies. Another five ions have been extensively tested in the ion source test stand and could be accelerated any time an experimenter asks for that ion. In Fig. 5 the final energy out of the machine is plotted versus the nucleon number A. The vertical lines indicate ions we have produced and tested in the ion source, the length of the line giving the energy which can be reached. On the right hand side the energy limit due to the charge state of the ion out of the source is indicated. Also shown is the limit due to the cyclotron magnets for charge to mass ratios 1/2 to 1/6. The dots are beams we have accelerated and extracted out of the cyclotron.

The particle transmission from the ion source to the Faraday cup behind the cyclotron in the best case was 12.5% for a beam of ^{16}O-ions. Routinely, transmission values between 5% and 10% are obtained. For the heavier ions however ^{40}A and ^{84}Kr, the transmission was only around 5%. We attribute this to the necessary use of the foil stripper, which gives larger energy straggling than gas, leading to a large phase width in the cyclotron. Therefore the orbits are not quite as well separated and additional losses during extraction occur. However with the second buncher operating and the proper time focus in the cyclotron center, this effect should be eliminated.

Outlook

The main task for the future will be the training of the operators to take away some of the burden from the experts of the different subsystems. They have been always available so far to develop a new beam. It still takes 16 to 20 hours to bring the beam from the source to the target for experiments. More automatic optimization should help to reduce this time considerably.

The setting up of the beam transport system to the other target stations, connecting it to the computer and testing it will be the other major task for the coming year. In spite of the interference due to running and servicing the machine, we hope to have the whole transport system ready by the end of 1979.

Acknowledgement

We gratefully acknowledge the advice and help we received from a number of institutions during the whole construction period. Especially we want to thank Dr. Susini and Dr. Benvenuti from CERN for their expert advice and cooperation on RF- and vacuum questions and Prof. Hagedoorn, Dr. van Heusden and Dr. Schulte for their valuable contribution on beam dynamics and beam diagnostics. The design, assembly and running in of VICKSI was the work of a large number of people at HMI and Scanditronix. The quick and smooth running in of VICKSI would not have been possible without their effort and strong personal commitment.

References

1) K.H. Maier, Status of the VICKSI project, Proc. 7th Int. Conf. on Cyclotrons and their Applications, Basel, Birkhäuser, 75, 68.

2) W. Busse et al., Status of the VICKSI Heavy Ion Accelerator, IEEE Trans. Nucl. Sci., NS-22, No. 3, 1643, June 75.

3) VICKSI Collaboration, Status of the VICKSI Heavy Ion Accelerator, IEEE Trans. Nucl. Sci., NS-24, No. 3, 1159, June 77.

4) P. Arndt, W. Jenter, and H.-E. Mahnke, A Penning Ion Source in a 7-MV Van de Graaff, IEEE Trans. Nucl. Sci., NS-22, No. 3, 1715, June 75.

5) W. Busse, H. Kluge, A Fully CAMAC Interfaced Computer System for the VICKSI Accelerator, IEEE Trans. Nucl. Sci., NS-22, No. 3, 1109, June 75.

6) W. Busse, H. Kluge, Concept and Status of the Control System for the VICKSI Accelerators at HMI-Berlin, Proc. 7th Int. Conf. On Cyclotrons and their Applications, Basel, Birkhäuser, 75, 557.

7) W. Busse, The Computer Aided Control System of the VICKSI Accelerators, Contribution F-1 to this conference.

8) P. Arndt, W. Bertschat, W. Jenter, and H.-E. Mahnke, The Van de Graaff Terminal for VICKSI, IEEE Trans. Nucl. Sci., NS-24, No. 3, 1162, June 77.

9) D. Hilscher, D. Renner, B. Spellmeyer, The Berlin CN-Van-de-Graaff-Injector, Revue Phys. Appl. 12, 1337, Okt. 77.

10) G. Hinderer, K.H. Maier, The Beam Matching System between Pre- and Main Accelerator for the Van de Graaff Cyclotron Combination VICKSI, IEEE Trans. Nucl. Sci., NS-22, No. 3, 1722, June 75.

11) C. Egelhaaf, D. Erdmann, H. Homeyer, and W.-D. Zeitz, The VICKSI Beam Line Instrumentation and Control System, IEEE Trans. Nucl. Sci., NS-24, No. 3, 1745, June 77.

12) S. Lindbäck, H. Lindquist, Injection in the VICKSI Cyclotron, Proc. 7th Int. Conf. on Cyclotrons and their Applications, Basel, Birkhäuser, 75, 226.

13) W. Pelzer, Stability Measurements of the VICKSI RF-Systems, Contribution D-21 to this conference.

14) G.C.L. van Heusden, W.M. Schulte, G. Hinderer, A Multi-Input Phase Measuring System, Contribution D-24 to this conference.

15) G. Hinderer, Automatic Isochronization and Computer Aided Centering in the VICKSI Cyclotron, Contribution F-13 to this conference.

16) W.M. Schulte, Beam Centering in the VICKSI Cyclotron, Internal report NK-260, Technical University of Eindhoven, 1977.

17) F. Hinterberger, B. Efken, G. Hinderer, and K.H. Maier, The VICKSI Beam Handling System, Nucl. Instr. and Methods, 121, 525, 1974.

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** DISCUSSION **

G. DUTTO: What inconveniences are there in a 5 MeV Van De Graaf, compared to a 6 MeV?

K. ZIEGLER: It is simply a question of beam intensity. If you can go to a lower charge state out of the ion source and still obtain the same final energy by using higher terminal voltages, you gain about a factor of 8 to 10 in beam intensity.

H. BLOSSER: Is your phase measuring system based on fixed pickups? Have you looked in between the fixed pickups for "looping" of the phase curve?

K. ZIEGLER: Yes. We have ten fixed pick-ups in the center of the extraction valley. We did have a movable pick-up attached to the radial probe. Using it we did not observe any looping of the phase curve, so this pick-up has been taken out for the moment.

W. DAVIES: How long does it take to develop a new beam? Could you also comment on the amount of time taken to inject the beam into the cyclotron, compared with the time taken to get the beam through the cyclotron in new beam development?

K. ZIEGLER: To develop a new beam from the ion source to the faraday cup after the cyclotron takes on the average 16-20 hours, particularly if we also try to train the operator during the beam development. In the best case we have done it in eight hours. The injection into the cyclotron takes 1 to 1½ hours; threading a beam through the whole cyclotron, I would say between 4 and 6 hours. We do not yet have an automatic procedure for centering.

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