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STATUS OF THE VICKSI HEAVY ION ACCELERATOR

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Summary

The combination of a Van de Graaff injector and a separated magnet cyclotron VICKSI for heavy ions is nearing completion. All subsystems are functioning, most of them at specifications. Final assembly and debugging are going on now. In a first trial a beam has been injected into the first cyclotron orbit.

Introduction

The specifications and the layout of VICKSI have been published earlier[1,2]. Therefore we will only give the main parameters here briefly and then describe the present status and some special features and experiences. A single ended 6 MV Van de Graaff accelerates ions of mass $1 \leqslant A \leqslant 40$ and charge q_i (1^+ to 3^+). Then the ions are stripped into a charge state q_s, injected into the cyclotron and further accelerated to about 17 times the injection energy. Therefore the final energy is $E \leqslant q_i \cdot 17 \cdot 6\ \mathrm{MeV} = q_i \cdot 100\ \mathrm{MeV}$. A second limit given by the cyclotron magnets $E \leqslant 120\ \mathrm{MeV} \cdot q_s^2/A$ is fulfilled for $12 \leqslant A \leqslant 40$ and $E \leqslant 250$ MeV using the most abundant (~30 %) charge state from the stripper. The current limit is mainly set by the present ion source which delivers some 10 pμA of Ne^{2+} and a factor 10 less for other gases or every increase of charge state by one unit[3]. The DC-beam from the source is compressed by a prebuncher in the terminal and two bunchers between Van de Graaff and cyclotron into pulses of 6°phase width with 50% intensity loss. Combining this with the yield from the stripper, the only other source of intensity loss, in principle 15 %, of the source output can be accelerated to full energy and extracted with a resolution of $\Delta E/E \sim 10^{-3}$.

Van de Graaff

The Van de Graaff terminal comprising the ion source, a charge state selector, prebuncher and three Einzel lenses is described in another contribution to this conference[4]. It is fully operational now and has delivered a beam over 48 h and practically no readjustment of the settings became necessary. The Van de Graaff (High voltage model CN) has been equipped with a bakeable all metal ceramic acceleration tube delivered by NEC. The pressure in the tube is routinely below 10^{-8} torr even with beam being accelerated. In late summer 75 the tube was tested for 2 months. After initial conditioning 5.8 MV could be reached from zero in a few minutes and 6 MV within one hour. With a preliminary terminal then also 10 μA Ne^+ were accelerated without any difficulties. The voltage devider along the acceleration tube was a three needle corona discharge system exposed to the normal insulation gas. After 500 h under

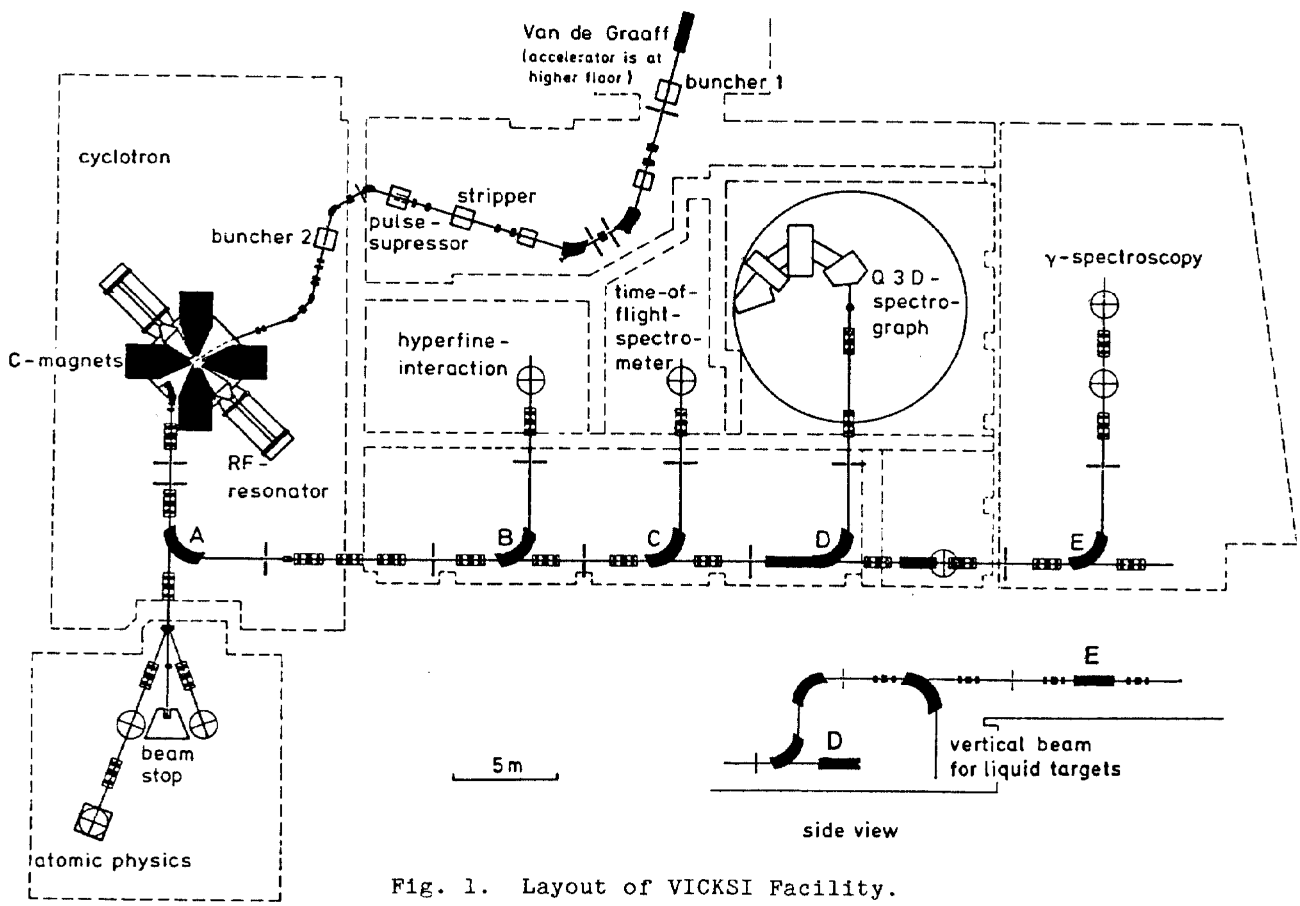

Fig. 1. Layout of VICKSI Facility.

voltage the gas pressure had to be decreased from 16 atm to 10 atm to obtain enough discharge current of 20 μA. Simultaneously the discharge became unstable, probably due to deposited belt dust. We then switched to a resistor chain instead and in August 76 the machine held 6 MV over 34 h without any spark. After installation of the terminal the Van de Graaff worked very smoothly at 5.5 MV. The voltage stability is around 1 kV, the beam is fully transmitted, and with 3 μA of Ar being accelerated no effects of beam loading have been observed. To reach more than 5.8 MV however was nearly impossible. It turned out that one of the 220 acceleration gaps of the tube is shorted (40 KΩ at 0.7 V). The nature of the short is not yet clear and no new trial to reach voltage has been made[4,5].

Beam matching

The matching system between the two accelerators as described in ref. 6 is fully assembled except for the two bunchers. The first buncher is ready to be installed after successful tests. Both bunchers consist (Fig. 2)

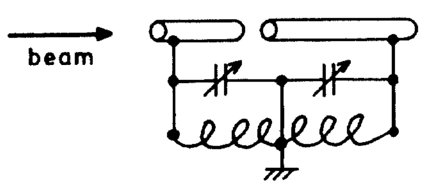

Fig. 2 Buncher principle

of two drift tubes whose potentials oscillate with opposite phase with the cyclotron RF-frequency and velocity modulate the beam. For most efficient use of the buncher voltage both drift tubes should be of equal length. However the length would have to vary as $1/h$ with the harmonic number h ($h=2..7$) of acceleration in the cyclotron. Optimization for all harmonics simultaneously with fixed tubes resulted in different lengths for the two tubes.

The magnetic field of all dipoles and quadrupoles has been measured and all elements optically aligned to +0.2 mm perpendicular to the beam. This made it possible to guide a DC-beam in a first trial run into the cyclotron without any steering elements and all settings close to those calculated before. Except for some ambiguity at the stripper transmission was close to 100 %. The beam diagnostics are described in contribution L-28 to this conference[8].

Beam lines

Installation of the beam lines to the target positions has just started. All elements are delivered except for some of the dipoles and diagnostic elements. The matching of beam handling up to the target with any type of spectrometer for the reaction products has been investigated. The aim is to eliminate the contributions to the energy resolution arising from the finite phase space of the beam, especially its energy spread (dispersion matching) and angular spread (emittance matching). A clear and general formalism has been developped[9]. As a practical consequence an easy way for a complete matching to the Q3D spectrometer resulted.

Cyclotron

During summer 76 the magnets were assembled at Scanditronix and detailed field maps measured. The main results are: (i) energy constant K=127 to 144 MeV at extraction for heavy ions and $^3He^{++}$ respectively, (ii) the main field is isochronous within 10^{-3} for the shim particle, namely 60 MeV deuterons, (iii) the disturbances due to the injection and extraction elements are well within the range of the correction coils. A parameterization of the field maps has been found that makes it easy to calculate all of the about 35 settings needed for injection, acceleration, and extraction of a beam (contribution C-14)[10]. In cooperation with H. L. Hagedoorn, G. C. L. van Heusden, and W. Schulte, Eindhoven, a program has been developped, that calculates the required corrections for isochronizing the field from measured phase deviations of the beam. From the orbit pattern measured with the radial probes a similiar program determines the corrections for centering the beam after injection. The coupling between radial and longitudinal phase space during acceleration, that can deteriorate the energy spread, has been studied also[11]. As a result it became clear how to inject the beam to minimize this effect.

The magnets, the RF-cavity, central region injection elements, and the vacuum chamber have been transported to Berlin and assembled. In the first trial a DC-beam of 0.2 pμA Ne^{5+} at 7 MeV was injected into the cyclotron. With at most 10 % intensity loss it passed the injection elements and was detected after the first completed unaccelerated orbit. The setting of the main field was within the uncertainty of 2 % at this time and also the two injection magnets and the electrostatic inflector had to be set as anticipated. The remaining problems of the central region are (i) the cooling of the first injection magnet has to be improved and (ii) the electrostatic deflector has yet to reach full voltage in the cyclotron as it did in a test before.

Both RF-resonators have been run at the specified amplitude of 80 kV and above over the whole frequency range of 10-20 MHz. The Q is around 10 000 and only 10 kW RF-power or less are needed for 80 kV (see contribution L-15)[12].

The vacuum we aim for is 10^{-7} torr. Two 3° K liquid Helium bath pumps provide 20 000 l/s pumping speed for H_2 and H_2O. The total surface area is around 400 m² which means that an average effective outgassing rate of $5 \cdot 10^{-10}$ torr l/s cm² has to be achieved. The system is all metal sealed. It contains however many elements like pole pieces with trimcoils, RF, and injection elements for which one has to reach a compromise between the requirements of their primary function and vacuum. So far one RF-cavity has been pumped to $2 \cdot 10^{-7}$ torr and the main magnet chamber to $3 \cdot 10^{-7}$ torr both times with one pump only. Though the surface area per pump will be about 50 % larger in the completed machine the outgassing should decrease also and 10^{-7} torr seem feasible. The pump down time to 10^{-6} torr, the minimum required for operation, can now be estimated to be 12 h.

Control system

The control system as previously described[13] uses some 300 Camac modules of 4 different types for control of the accelerator and around 100 for measuring. The computer, a PDP-11-40, links these modules with the control desk shown in fig. 3. The operator receives information mainly through 2 colour TV sets. He selects what he wants to monitor or adjust with the touch panels. These are small black and white TV's with 4 times 4 touch sensitive areas on top of the screen. Touching one of them results in the action that is displayed below it. About 100 different displays corresponding to roughly 1000 pushbuttons will be implemented in the beginning. Knobs simulating potentiometers are provided for fine adjustments.

One important part of the software is the interpreter MUMTI. It is very easy to learn and use. For instance typing "DIPE1 = 14.3" sets dipole E1 to 14.3 kG. Also sequences as for measuring and displaying the emittance of the beam can be easily programmed. The main use of MUMTI is in dealing with arising

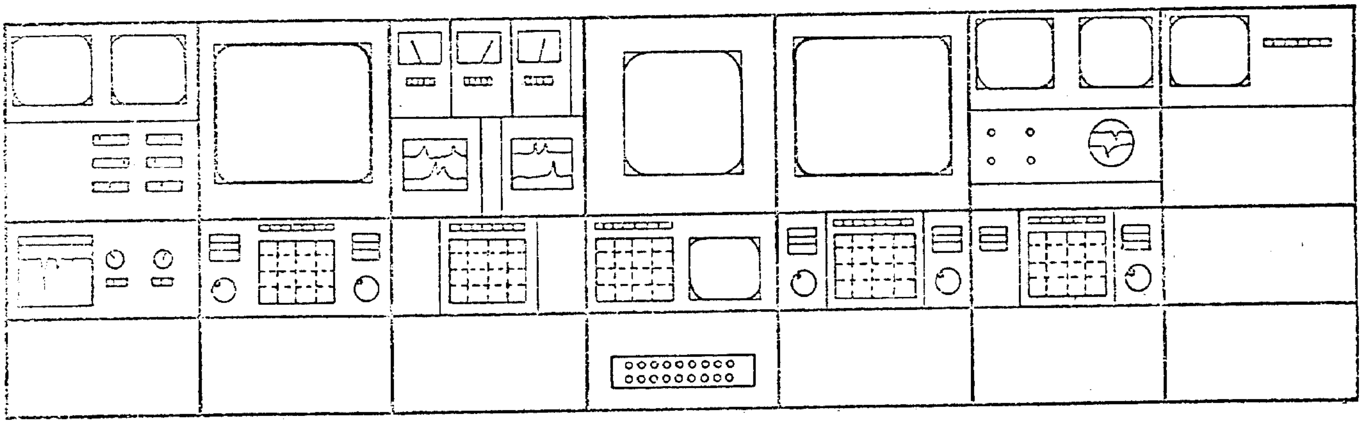

Fig. 3. Control Desk.

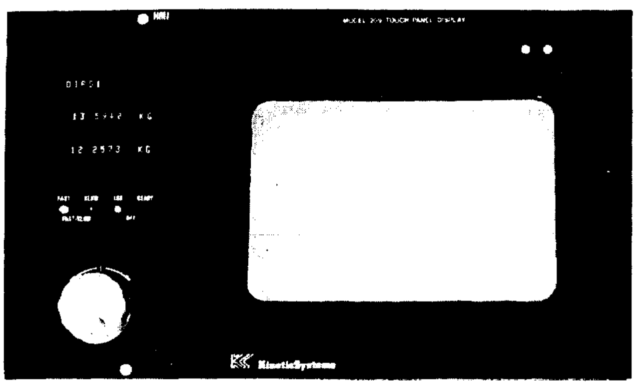

Fig. 4 Touch Panel

problems. So e. g. a program with 5 commands can automatically check and readjust an unstable power supply.

The experience with the computer control system has been very favourable. It influenced the design of all accelerator components towards a high degree of standardization, clarity, and reliability. Also the attitude in tuning the accelerator changes. Since more information and with higher precision becomes available adjustments are made more deliberately.

Conclusions and Outlook

So far less problems were encountered in putting the major subsystems into operation than we had expected. The second RF-cavity e. g. reached full voltage within one day, the data link by light transmission between the Van de Graaff terminal and ground with all its complicated electronics has not been damaged by sparks, and the cyclotron magnets and vacuum chamber fitted together without real difficulties. The most crucial part in terms of ion optics, the cyclotron injection scheme, worked right away with a real, though not yet bunched, beam. We anticipate to accelerate a beam in the cyclotron in May and have the whole system in regular operation around the end of the year.

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