STATUS REPORT ON VICKSI

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ABSTRACT

The VICKSI facility has been in operation since more than ten years now. Originally it consisted of a 6 MV single ended Van de Graaff used as injector for a four fold symmetry K=132 separated sector cyclotron. In 1986 a 8 MV tandem Van de Graaff went into operation as alternate injector, enlarging the energy range and the number of available ion species. VICKSI can deliver beams in the energy range from a few MeV/A up to a maximum of 33 MeV/A. The mass range extends from A=1 to about A=130. With these beams a wide variety of experiments have been performed at VICKSI. However lately it became apparent, that the experimental program at VICKSI would benefit, if the beam intensities could be increased, especially for the heavier ions. Therefore we have started to think about the feasibility of a small compact injector cyclotron with an external ECR-ion source. It appears, that without the need of a stripper between the cyclotrons the intensities of most beams could be greatly improved.

1. GENERAL DESCRIPTION OF VICKSI

The accelerator combination VICKSI went into operation in 1978. Originally it consisted of a 6 MV single-ended Van-de-Graaff injecting into a four-fold symmetry separated sector isochronous cyclotron[1,2,3]. The injection radius and the extraction radius of the cyclotron are fixed, giving an energy gain factor of about 17,2. Thus the energy of the beam extracted from the cyclotron is determined by the energy of the beam injected into the cyclotron. With the 6 MV single ended Van-de-Graaff we could never reach injection energies which required to operate the cyclotron at its bending limit. Also the number of ion species was limited by the fact, that we had to operate the ion source in the terminal of the Van-de-Graaff with gaseous substances only. To overcome these restrictions we proposed to install as alternate, second injector an 8 MV tandem. This proposal was approved and in 1986 the tandem went into operation, extending considerably the energy range of the facility and the number of available ion species. Since this time we are operating VICKSI with two injectors; with the 6 MV single ended Van-de-Graaff for lower energy beams and beams which can only be provided by the penning ion source in the Van-de-Graaff terminal. For higher energies and ion species which can be obtained from the sputter sources for negative ions the 8 MV tandem Van-de-Graaff is used as injector for the cyclotron.

In figure 1 an artists view of the accelerator

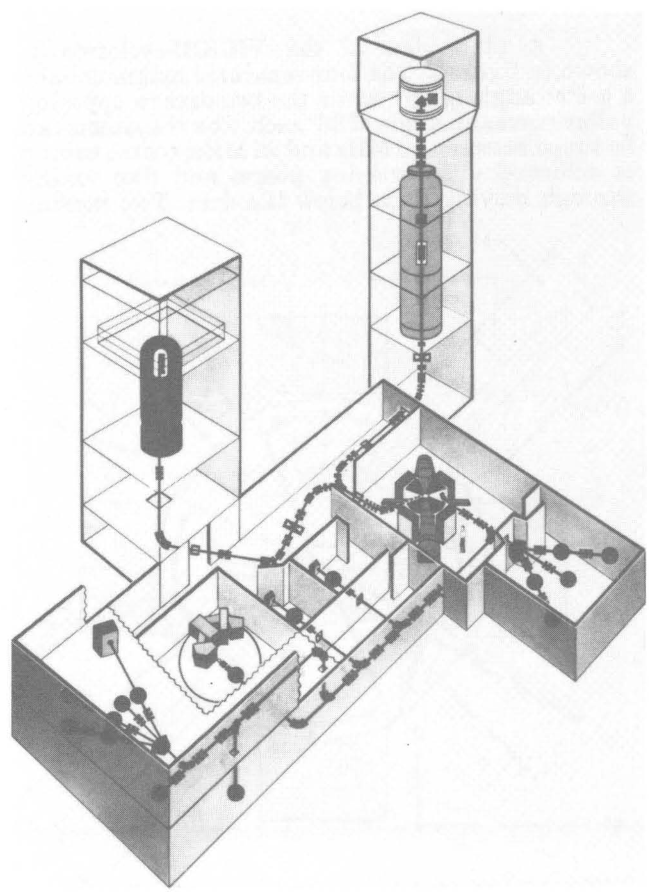

Fig. 1: An artists view of the VICKSI accelerator facility

facility VICKSI is shown. The beam lines connecting the two electrostatic injectors and the cyclotron join each other about 8 m before the cyclotron. These beam lines are designed in such a way to optimally adapt the beams from the electrostatic injectors to the requirements for the acceleration in the cyclotron. Each beam line contains a stripper to increase the charge state of the preaccelerated beams and also a buncher which compresses over 50% of the dc-intensity of the injector-beam into 1 ns wide pulses desirable for cyclotron acceleration. The common beam line in front of the cyclotron is then used to match the emittance of the beam horizontally, vertically and longitudinally to the acceptance of the cyclotron. In the beam lines between the injectors and the cyclotron and between the cyclotron and most of the target stations a pulsing system is installed[4], which enables the experimentator to select periods between beam pulses from 50 ns up to milliseconds. From the 16 target-locations about half are equipped with permanent installations like a Q3D-magnetic spectrometer, different size scattering chambers for neutron time of flight (TOF) or heavy ion TOF measurements or for kinematic coincidences. At one target location irradiations at cryogenic or elevated temperatures can be performed. For the remaining target locations moveable platforms are provided on which the experimental set-up can be installed off-line, and afterwards rolled into position and connected to the accelerator vacuum system.

A plan view of the VICKSI-cyclotron is shown in figure 2. The four separated magnets have a sector angle of 50°, while the two dees in opposing valleys cover an angle of 36° each. The rf-systems can be tuned between 10 MHz and 20 MHz; coarse tuning is achieved via a moving piston and fine tuning through moving flaps below the dees. Two moving differential probes allow to observe the beam from the first orbit at injection until the last orbit at extraction. Each injection and extraction element is equipped with readable slits at the entrance to enable optimum positioning of the beam into each element. Ten fixed phase probes in the extraction valley are used to measure the phase history of the beam, and with the help of a semiautomatic computer routine[5] the magnetic field of the cyclotron is then adjusted to assure isochronous acceleration of the beam.

The whole facility, injectors, beam lines and cyclotron are controled via computer, a PDP 11/44. An identical machine is used for software development and maintenance and also as back up machine for the case, when the control computer has a hardware failure.

The VICKSI beam properties are given in table 1. The mass of the ions which can be accelerated

Table 1:

VICKSI Beam Properties

Mass range:	$1 \leq A \leq 130$
Energy range:	$40 \leq E \leq 960$ MeV
Energy width:	$\Delta E/E \leq 2 \times 10^{-3}$
Pulse width:	$\tau \leq 1$ ns
Intensity	$I \geq 1$ pnA ($\sim 6 \times 10^9$ p/s)

range from mass 1 (protons) to mass 130 (Xenon-ions). Beam energies behind the cyclotron can vary between 40 MeV and 960 MeV, with relative energy width of the beam of better than 2×10^{-3}. The beam pulses have a width of less than 1 ns and the intensity of the beams

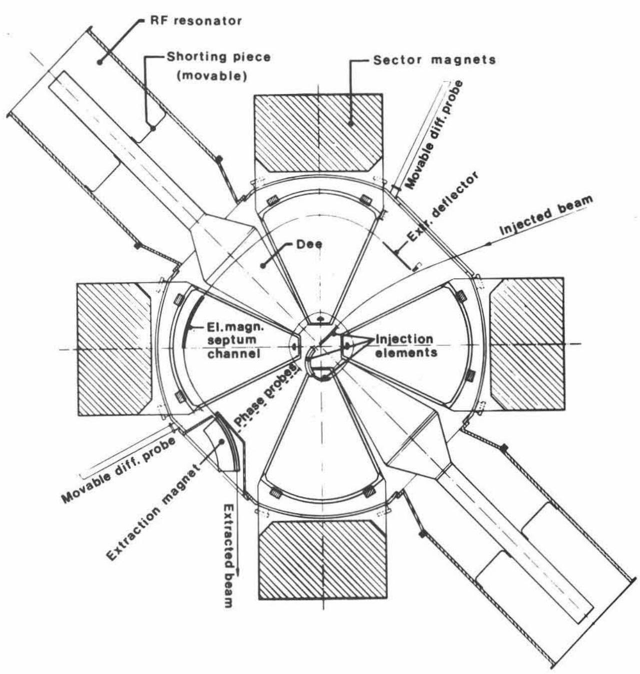

Fig. 2: Plan view of the VICKSI cyclotron

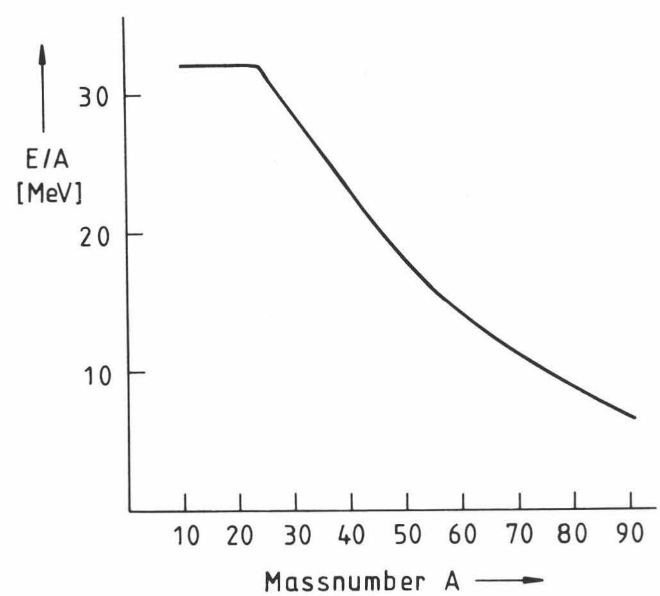

Fig. 3: Energy-Mass curve for the VICKSI facility

is greater than 1 particle nanoampere (~6 · 10^9 particles/s). A energy-mass diagram for the VICKSI facility is shown in figure 3.

2. RECENT IMPROVEMENT AND OPERATING PERFORMANCE

From the beginning the stability of the VICKSI beam was limited due to the relatively large high voltage ripple of the terminal of the single ended CN-Van-de-Graaff. This is caused by the inherent inhomogeneities of the charge carrying capability of the belt, which is used to transport the charge from ground to the high voltage terminal. This became especially apparent when the 8 UD tandem went into operation with its pelletron charging system, a chain of metal pellets separated by insulating nylon links. The pellets are inductively charged at ground potential and discharged at the high voltage terminal. The beam from the tandem was much more stable than the CN-beam. The installation of a pellet-chain in the CN-accelerator was out of the question, because it would have required a completely new column-structure and a complete redesign of the high voltage terminal. Therefore we decided to try to regulate the terminal voltage with a 'fast' capacitive regulating system. An insulated ring was mounted near the tank wall opposing the high voltage terminal of the Van-de-Graaff. The ring is connected to a power amplifier which receives as input the error signal of the Van-de-Graaff slit control system. This regulation system[6,7] has considerably reduced the terminal ripple and thus increased the stability of the CN-beams.

Another improvement concerns the 8 UD-tandem accelerator. This machine was delivered with corona voltage grading systems along the acceleration tube and along the column structure.These corona grading systems have several disadvantages. They should be operated always at about the same current. This requires the adjustment of the gas pressure in the tandem tank, when a change in the terminal voltage is desired. Due to the many corona discharges burning along the grading systems a continious production of SF_6-decay products is taking place, necessitating a replacement of the purifying Al_2O_3 pellets in the recirculating system every 6 to 9 month. It has been shown[8] that the voltage gradient is not very constant along the accelerator and also in time due to flickering of the corona discharge and the burning of the corona needles. This requires continuous checking and maintenance of the corona needle settings and replacement of needles. Therefore we planned from the beginning the replacement of the corona grading systems by resistor chains. This was first done along the accelerating tube and after this chain had shown to be reliable we also replaced the corona grading system along the column. This improvement has not only reduced the maintenance work necessary around the tandem injector, but also had a positive effort on the stability of the tandem beam.

As far as the cyclotron is concerned, it turned out that no larger modifications or improvements were necessary. One modification we made when we installed the tandem injector was to increase the maximum current output of the main magnet power supply from 1800 to 2000 A. This increased the bending limit of the main magnet by about 4% enabling us to get somewhat higher energies with the tandem injector. Running these high energy beams however, for instance a 960 MeV ^{32}S-beam, it turned out, that it would be quite desirable to also increase the Dee-voltage in order to have less turns in the machine and to have a higher turn separation at extraction. Preliminary tests indicated that the Dees could reliably hold voltages up to 140 kV a considerable increase of the original design aim of 100 kV. To operate the cyclotron on a routine basis at these higher voltages however we need to increase the power of the driving amplifiers from 1 kW to 2 kW and at the same time improve the cooling on some critical spots in the rf-systems. The work for these improvements is going on and two new driving amplifiers are on order, with delivery scheduled for spring 1990.

Looking back on the over ten years of operation of VICKSI we can now say that the facility has performed remarkably reliable. Except for the first six months, when the original bugs had to be found and cured, the machine consistently delivered beams on target at a rate of 60-70% of the operating time. The down time due to machine failures was generally below 10%. Maintenance, tests and service took 10-14%. The remaining time, about 12-16%, was needed for beam set up. This might appear much, but one has to consider that we are operating a multiparticle variable energy machine, requiring a new set up for every beam. At the beginning the beam set up from ion source to target took over 20 hours, now this takes 4-8 hours depending on the hardware changes necessary for the new beam. Unfortunately the number of beams requested by the experimentors has steadily increased so that the time saved for setting up a new beam is to a large part eaten up by the larger number of beam settings. At present we set a new beam every 2.5 to 3 days.

The use of the facility has changed considerably since it came into operation in 1978. Originally the major part of the beam time was dedicated to nuclear physics experiments. The emphasise of the experimental program has since gradually shifted so that now more time is used for experiments dealing with solid state problems investigated with nuclear methods. More and more solid state physicists also ask for low energy beam for irradiations, Rutherford back scattering analysis (RBS), elastic recoil detection (ERDA), and nuclear reaction analysis (NRA). We have therefore decided to use the 'idle' injector not used for VICKSI operation, to provide low energy beams in parallel with the VICKSI beam. This mode of operation of course puts additional strain on the operators and also puts demands on the reliability of the injectors themselves. In 1988 about 15% of the operating time was used to deliver low energy beam in parallel with VICKSI operation.

3. PLANS FOR THE FUTURE

When we look at the possibility for improvements within the constraints of existing buildings and property limit it becomes apparent, that an increase of the VICKSI energy by the addition of a booster would be very costly and most likely provide only energies already available at GANIL and other places in the world. In discussions with our experimenters however we found out, that the experimental program would benefit greatly if the VICKSI beam intensities could be increased, especially for the heavier elements. The present VICKSI beam intensities are limited by the maximum intensity we can put onto the stripping foils for reasonable life times and by the efficiency of the stripping process. Therefore we have observed the development of the ECR-ion-sources rather carefully. This development has now reached a point where the charge states provided by ECR-sources are quite comparable to the charge states we obtain after stripping behind the injectors, but with an order of magnitude better intensities for most but the highest charge states. Even without expecting further improvements in the performance of ECR-sources it is therefore worthwhile to consider an ECR-source and a small compact cyclotron as a replacement for both injectors. A logical solution for the small cyclotron would be to choose the extraction radius of the compact machine to be equal to the injection radius of the VICKSI cyclotron and to operate the small machine with the same average field as the VICKSI cyclotron. Effectively this would mean that the small syclotron would replace the missing part of the VICKSI cyclotron. The rf-frequency of both machines would be equal making a two dee-system and a 4-fold-symmetry compact machine a natural choice.

At first glances there seem to be no major technical obstacles to such an arrangement. We therefore plan to make a more detailed study of this improvement for VICKSI.

4. REFERENCES

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