VARIABLE ENERGY CYCLOTRON AT CALCUTTA

VEC Staff
Variable Energy Cyclotron Centre, Bhabha Atomic Research Centre, I/AF, Bidhan Nagar, Calcutta-700064, INDIA

Summary

Variable Energy Cyclotron (VEC) at Calcutta is a medium energy cyclotron similar to the Berkeley 88 inch and Texas A & M University cyclotrons. It started regular operation in 1982 and is since then being used by a large number of users from all over India. At present we are operating only with alpha beams. Currently, three beam lines are in operation where low resolution experiments are carried out. A number of experimental, data processing and computational facilities have been provided for effective utilization of the machine. Being the largest accelerator in the country, VEC is a national facility, and hence, the users' demand is extremely heavy. We propose to develop and augment our accelerator to deliver energetic heavy ion beams. Plans have been chalked out and action initiated on some of them. In this paper current status of the cyclotron and its facilities and future outlook is presented.

Introduction

VEC is being routinely operated for accelerating alpha particle beams which are in heavy demand from the experimentors. A large number of research institutions and universities spread all over the country are using VEC for research in basic nuclear physics, solid state physics, radiation damage, radiochemistry, radiation chemistry, biophysics and other related fields. The utilization pressure is so high that very little time is available for development of the machine leaving aside the routine maintenance time. In the past three years alpha beams of all energies between 25 to 75 MeV have been routinely delivered on target. However, we have also extracted 85 MeV beam and have accelerated a 100 MeV beam up to the extraction radius. Figure 1 shows the layout of the accelerator wing and the existing and proposed beam transport lines.

Recently, funding has been obtained for the development and installation of an ECR source and an external injection system for VEC. Simultaneously, a PIG heavy ion source is also being developed which is expected to be used before the ECR operates.

Cyclotron

Our radiofrequency system is a driven system utilizing an RCA 4648 tetrode tube[1]. The performance of RF has significantly improved. At lower frequencies up to 60 kV dee voltage is available with careful tuning. Stable 50 kV is available for frequencies up to 13 MHz. Overhauling of the dee, during a recent shut down to repair a water leak in the dee stem, has helped in this improvement. The round dee lip rod was machined down to increase the minimum dee - liner gap by about 3 mm. A new wide band tuned amplifier using single aircooled tetrode - Eimac 5000, has been built and tested on the cyclotron up to 12 MHz frequency. Its performance has been very satisfactory. This microprocessor controlled unit will soon replace the old power distributed amplifier (PDA). With the increased operating RF power level, we now have a new problem of RF pick by various magnet power supplies. This problem and its elimination are being studied.

Due to space restriction we had to change the plan of installation of the 6000 l/s turbomolecular pump on the dee chamber[1]. A z shaped vacuum chamber of about 50 cm cross section diameter now connects the pump with the dee chamber. Consequently, the pump has now moved to a region where the magnetic field is only a few tens of gauss. This, however, is at the cost of pumping speed. The pump will be operated from November this year.

A number of components on the high resolution beam line beyond the analyzing magnet have been installed up to the 6 port switching magnet SM2 (Fig.1). The frame of this magnet is now in position and its coils and vacuum chamber are nearing completion in our workshop. Initially, however, only the undeflected beam line will be made operational towards the middle of 1987.

Cyclotron Operation

VEC is operated in the cycles of 3 weeks round-the-clock running followed by 1 week of maintenance and other jobs. This mode of operation, as compared to the earlier 96 hrs/week round-the-clock running[1], has improved the performance of the machine considerably. The breakdowns are less. Table-1 shows the operational statistics for the year 1985.

Table-1

Scheduled operating time	4190 h (100%)
Cyclotron operational	2746 h (66%)
Scheduled maintenance (filament changes, channel change-over, etc. included)	166 h (4%)
Unscheduled maintenance	1123 h (27%)
Grid power failures	125 h (3%)

Out of the total cyclotron operational time about 90% is used for experiments and the rest for beam tuning and development. About 75% of the machine time is used for basic nuclear physics experiments and the remaining for the other experiments. Major part of the unscheduled maintenance time was spent on the failure of services while the main components worked fairly reliably.

Beam Development

Improvement in the time structure of the beam, when an unbevelled slit is used instead of a bevelled slit, was reported at the last conference[1]. Use of an unbevelled slit primarily narrows down the pulse width. Subsequently, we carried out the energy resolution studies on the extracted beam when such a slit is used. We have observed that the time structure and energy structure are correlated[2]. The energy resolution improves by a factor of about 2 when a change over from a bevelled slit to an unbevelled slit is done. Figure 2 compares the elastic spectra of alpha particles from gold target for the two types of slits at the ion source. The resolution goes bad even with an unbevelled slit if double peaking occurs in the time structure. These two peaks are sharp and of almost equal heights but are separated by 2-3 times the fwhm peak width. We are studying the causes for double peaking. In another study we could improve the 'effective' experimental resolution by gating the desired spectrum at the MCA by a selected portion of the α-RF time spectrum. Figure 3 shows this improvement. This technique is, however, complicated and cumbersome.

PIG Source

The first step towards heavy ion acceleration at VEC is the development of a PIG source. A cold cathode PIG source will very soon be tested on an elaborate test bench set-up installed in the high bay area. This will be an internal source. Modifications at the central region of VEC to accelerate heavy ions will be required. The fabrication of removable central region inserts, dummy dee etc. is going on. Figure 4 shows the test bench set up for the PIG source.

ECR Source and External Injection System

We have started development work on a room temperature ECR source similar to the LBL source[3]. Initially a permanent magnet hexapole will be used. A provision will be kept to use an octupole, if required, in future. For this we propose to inject the microwave power axially into the second stage. The first and second stage frequencies will be 14.7 and 6.4 GHz, respectively.

Design of an external injection system based on the telescopic optics has been worked out[4]. Layout of this system along with the ECR source in the high bay area above the cyclotron is shown in the Fig.5. Design of the horizontal beam transport system of solenoids has been slightly modified. There will now be six solenoids and the first order transformation is +I over 3 unit cells. Each unit cell comprises of a solenoid with drift spaces on the either side. Each solenoid rotates the beam by 45^{o}. Charge state analysis is done after a horizontal 90^{o} bend. The beam is vertically bent down by an identical bending system and transported up to the machine centre. A mirror inflector will be used to place the beam in the median plane. All the components on the injection line would be magnetic. Beam transport in the axial injection line is done by the magnetic lenses. We plan to accelerate the ECR produced heavy ions in VEC by the first half of 1989. High energy beam lines are being upgraded in order to obtain better vacuum for the heavy ions.

Research Facilities and Utilization

A powerful on-line data acquisition system based on the NORSK DATA ND-560 computer is fully operational for the past one year. The cyclotron utilization efficiency is enhanced, considerably, with the installation of this system.

The magnetic frame of the QSD type magnetic spectrometer has been delivered at site. Its track has been installed in position. Fabrication of the coils and other components is being carried out at our workshop.

The other major facilities include a 915 mm scattering chamber, a solenoid spectrometer, in-house target and detector laboratories, nuclear instrumentation and Canberra series 80 and 88 multichannel analyzers. More facilities for the high resolution beam lines are being planned.

Over 25 institutions spread all over the country are using VEC regularly for nuclear physics, solid state physics, radiochemistry, radiation chemistry and biophysics experiments.

Future Outlook

By the time the VEC + ECR combination delivers heavy ion beams, we propose to start work on yet another phase of heavy ion acceleration at our Centre. In this phase a booster cyclotron is proposed to be installed. At present a Separated Sector Cyclotron (SSC) is being considered. The K value is being debated but about 300 seems to be the optimum. This optimum is to be struck between the physics to be done and the funds available. The present thinking is to avoid making a new building and house the SSC in the existing built area with minimum civil modifications. In this case the present infrastructure and the services will require only some augmentation. If we go along with this idea the K value may be further restricted. The SSC would then be installed in the area presently occupied by the HI caves and some more area around them as shown in the Fig.1. The HR caves would then serve as the experimental areas for the VEC + SSC combination accelerator.

References

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4. R.K. Bhandari and A.S. Divatia, Proc. 10th Int. Conf. on Cyclotrons and Their Applications, East Lansing, Michigan, U.S.A. (1984) p 165.

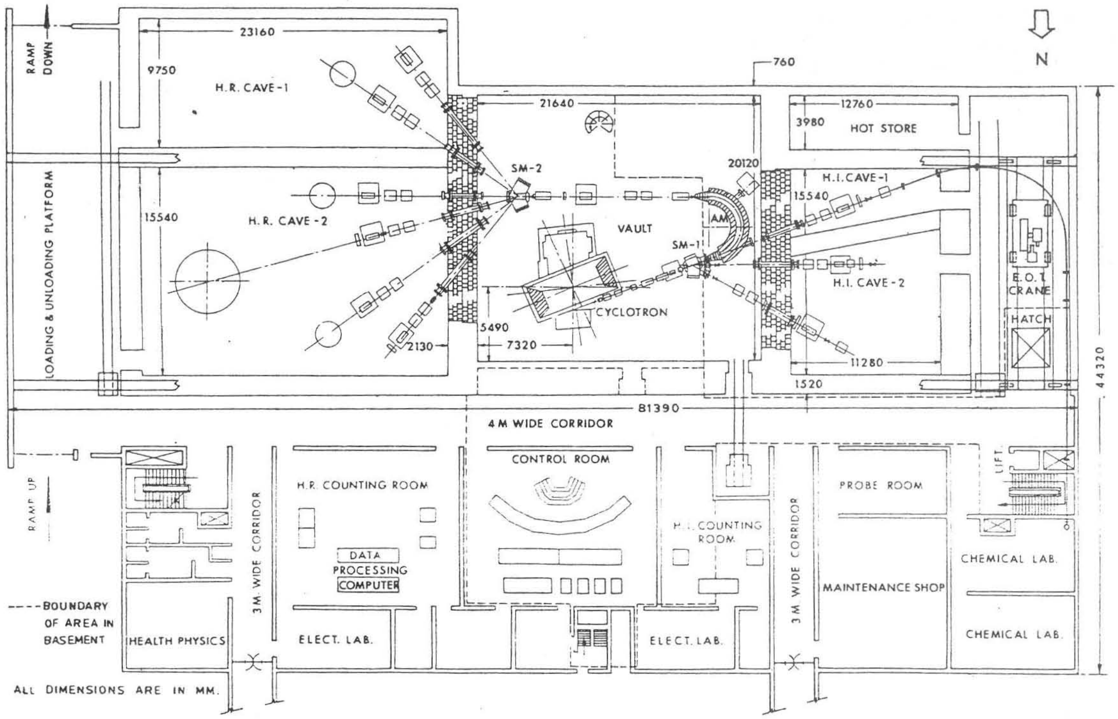

Fig.1 : Plan view of the accelerator wing at the VEC laboratory. At present only 3 low resolution beam lines leading to the HI cave-1 and 2 are operational. Most of the components on the high resolution beam line between the analyzing magnet (AM) and the switching magnet (SM-2) have also been installed.

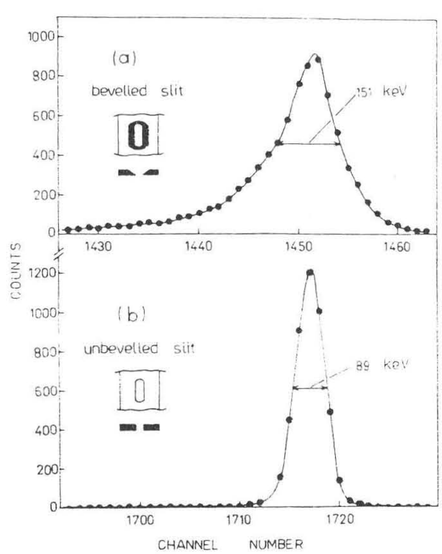

Fig.2 : Relative studies on the energy resolution of the VEC external beam when bevelled and unbevelled slits are used on the ion source. In both cases the slit width is 1.5 mm and height about 10 mm. The bevel angle is 60°. This figure shows the elastic spectrum of alpha particles from the gold target for (a) bevelled slit, E_{α}=40 MeV, 1000 μg/cm^2 target, and (b) unbevelled slit, E_{α}=45 MeV, 200 μg/cm^2 target.

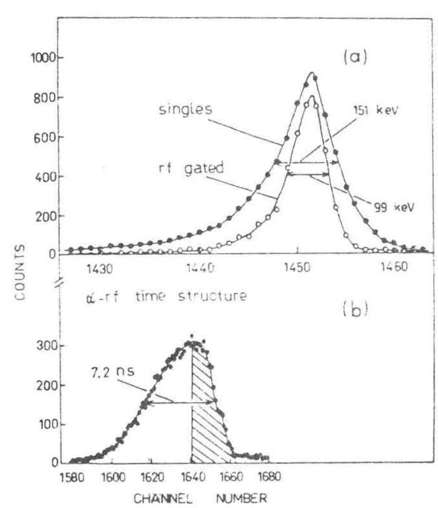

Fig.3 : Improvement in the 'effective' experimental energy resolution by gating technique. The spectrum is gated at the MCA with respect to a selected slice of the α-RF time spectrum. This figure shows (a) the gated and ungated elastic spectra of 40 MeV alpha particles from a 1000 μg/cm^2 gold target for a bevelled slit at the ion source, and (b) the α-RF time spectrum. Gating done with respect to the shaded portion.

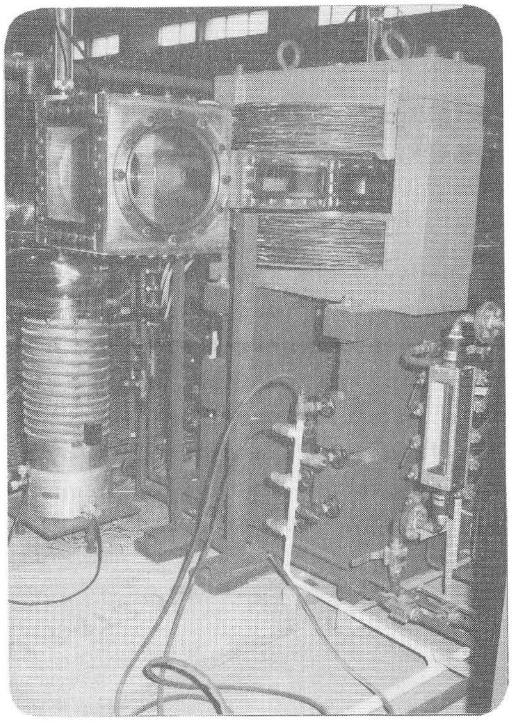

Fig.4 : A PIG heavy ion source test bench set-up being assembled in the high bay area above the cyclotron vault.

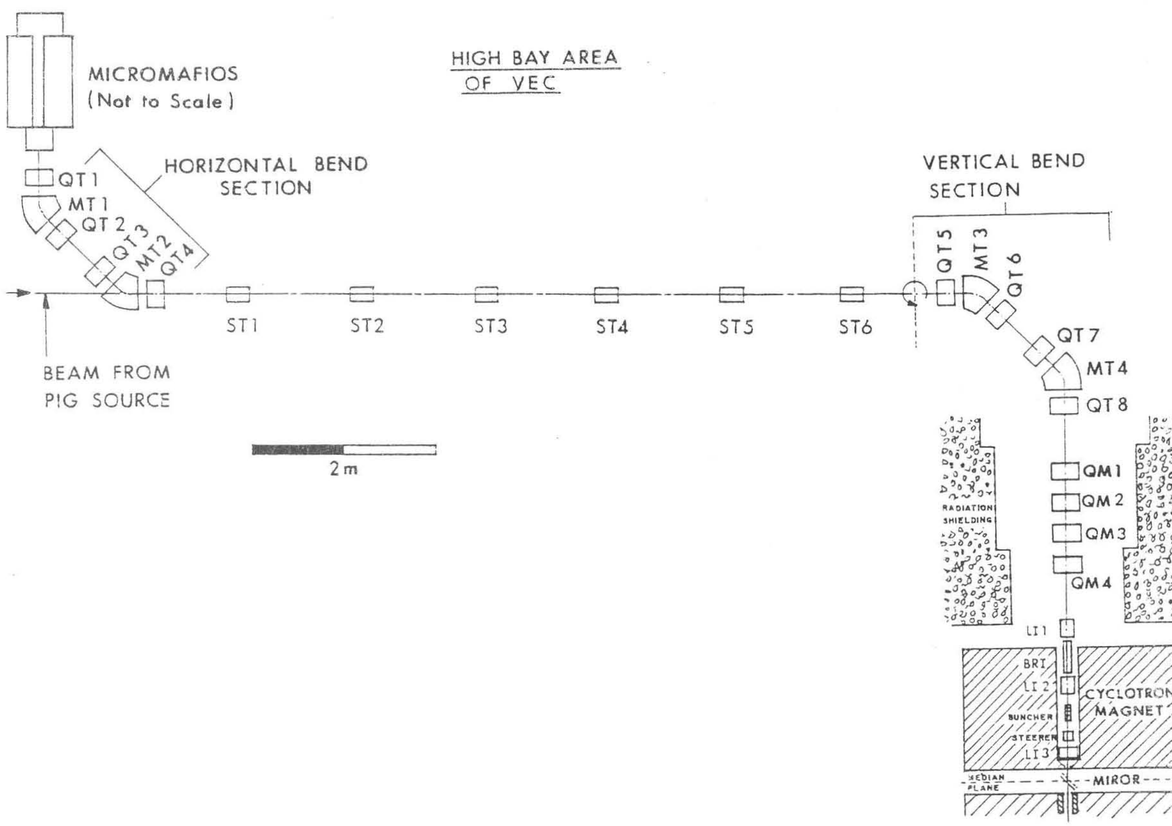

Fig.5 : Layout of the ECR source and external injection system being developed for VEC. They will be installed in the high bay area. Beam transport over the identical solenoids ST1 to ST6 is telescopic with +1 magnification. The horizontal bend section and vertical bend section placed in succession, without the rotation of the plane, constitute a 'second order achromat'. All the dipoles MT1,2,3,4 are identical. Quadrupoles QT1,3,5,7 are identical and so are the quadrupoles QT2,4,6,8. Quadrupoles QM1 to QM4 constitute a phase space matching system. Identical magnetic lenses LI1 and LI2 constitute a telescopic transport system with -1 magnification. An electrostatic mirror inflector is used to inflect the beam. BRI is a beam rotator solenoid and LI3 is a strong magnetic lens.