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THE KOFFLER ACCELERATOR IN REHOVOT

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Résumé. — Le nouvel accélérateur 14UD à Réhovot a été réceptionné le 1.4.77. On décrit ses caractéristiques de fonctionnement ainsi que divers équipements supplémentaires, le sélecteur de charge au terminal, la source d'ions à *sputtering* et le hacheur-groupeur.

Abstract. — The new 14UD accelerator in Rehovot has been accepted on april 1st, 77. The acceptance performance is described, as well as some supplementary devices : the terminal charge selector, the sputtering ion source and the chopper-buncher.

I would like to start this presentation with a short survey of the history of our project. The main events are outlined in figure 1. Altogether the project took seven years from the moment the first tentative ideas came up, to completion. Two years were spent on deciding on specific goals and a plan of operation as well as getting the project approved and funded. The technical planning took about a year and a half and the construction of the building three and a half years. This period includes a six months' break caused by the october war. The assembly of the accelerator proper and the testing of the machine took about sixteen months, mostly overlapping with the construction work.

The accelerator as it stands now is a standard 14 UD Pelletron of the NEC company with the following additions and innovations :

1. Enclosed corona tubes for the voltage distribution along the HV structure. There are four tube systems in all : one each for the stack and the acceleration tubes, in the low energy and high energy sections.
2. An enlarged terminal with a total length of 3.6 meters for the installation of beam optical equipment which will be described later.

3. A dead section in the middle of the LE tube, housing an electrostatic quadrupole triplet and a vacuum pump. The performance of the accelerator in the acceptance tests is summarized in table I.

Some additional points relating to the test runs are worth mentioning :

1. The proton beam transmission through the accelerator was about 90 %.
2. The short term voltage stability, without any feedback correction, was at least as good as the voltmeter read-out accuracy — about 10 kV — over the entire range up to 14 MV.

A number of additions to the accelerator are planned and we hope to install them in the course of the coming year. They are summarized in table II.

The charge selector is part of a general policy to transmit the entire beam through the accelerating tubes and to keep it clear of the tube electrodes. The overall optical plan of the Pelletron is shown in figure 2. The charge selector was devised for work with heavy ions. It acts as a filter transmitting one and only one charge state out of the mixture

TABLE I
Acceptance test performance

Particle	Voltage MV	Stripper	Final energy MeV	Beam current on Faraday cup after analysing magnet
p	4	C-foil	8	3 μ A
p	9	C-foil	18	5
p	14	C-foil	28	3
Cl	14	C-foil	140	50 pA
Cl	14	nitrogen	112	50

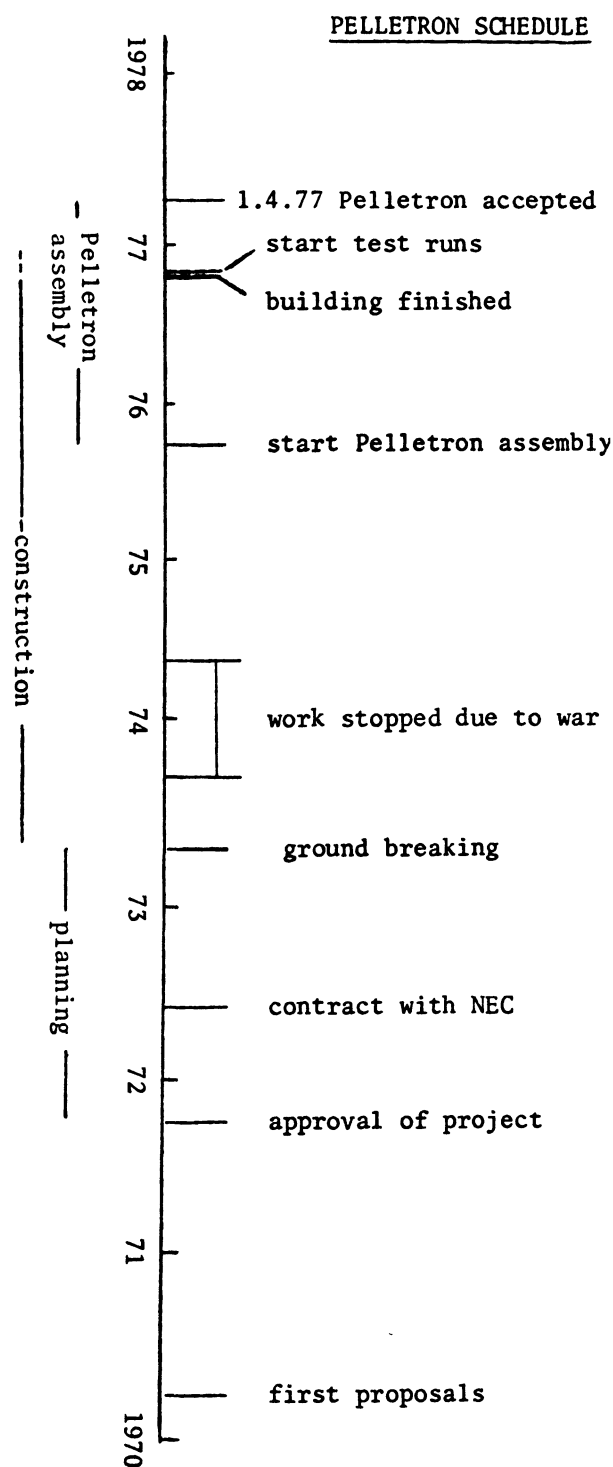


FIG. 1. — Pelletron schedule.

TABLE II
Additions to the Pelletron

Equipment	Objective
1. General Ionex sputtering source	Large variety of available ions.
2. Charge selector in HV terminal	Heavy ion beams of high energy and high intensity.
3. Chopper-buncher	Beam pulses of less than 100 ps.

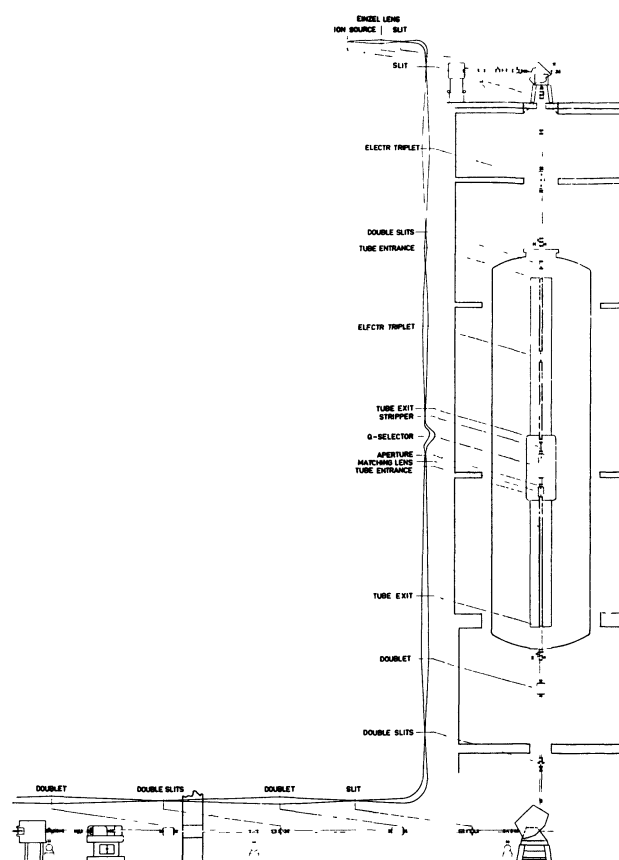


FIG. 2. — General layout of the Pelletron and the beam transport system.

emanating from the stripper. The charge selector was designed and developed in our laboratory by Z. Segalov and E. Skurnik from our Laboratory following a suggestion by D. Larson who worked with us on the beam optics of the accelerator installation. The instrument is a quadrupole triplet with each of the three elements displaced from the optical axis, causing the selected charge to be transmitted on-axis and focussed on an aperture behind the selector, while other charges are defocussed and deflected (Fig. 3). The biggest uncertainty in the projected operation of the selector was the beam aberration and its possible effect on the intensity and the quality of the transmitted beam. In the course of the development work it was ascertained that under certain conditions the aberrations were small and essentially insignificant. Following this work an operational instrument has been manufactured by NEC. This has now been shipped to us and we expect to install it in the course of the next six months. A schematic view of the HV terminal incorporating the charge selector and its associated matching lens is shown in figure 4. The charge selector will be operated through standard NEC lucite control rods and the beam diagnosis will be effected through a beam profile monitor and a retractable Faraday cup, with their outputs transmitted to the outside through an optical link.

Figures 5 and 6 portray two instances of the expected

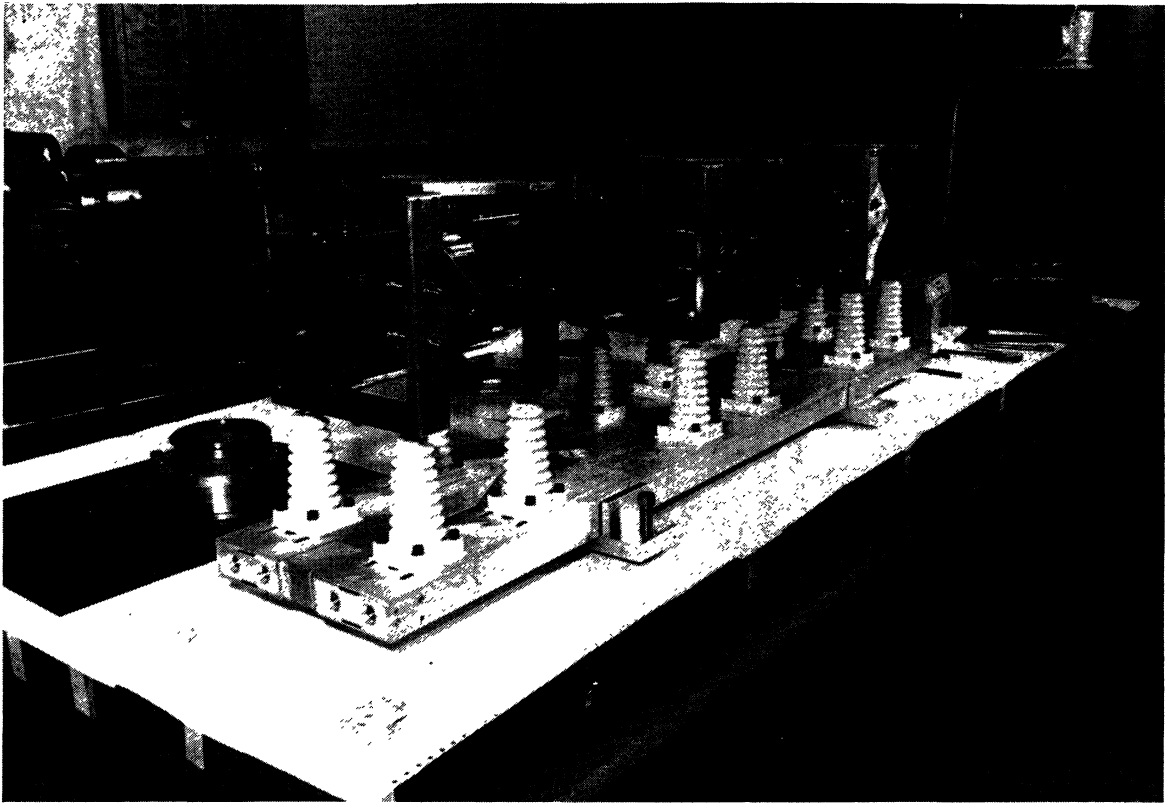


FIG. 3. — Photograph of the working model of the charge selector without the vacuum envelope.

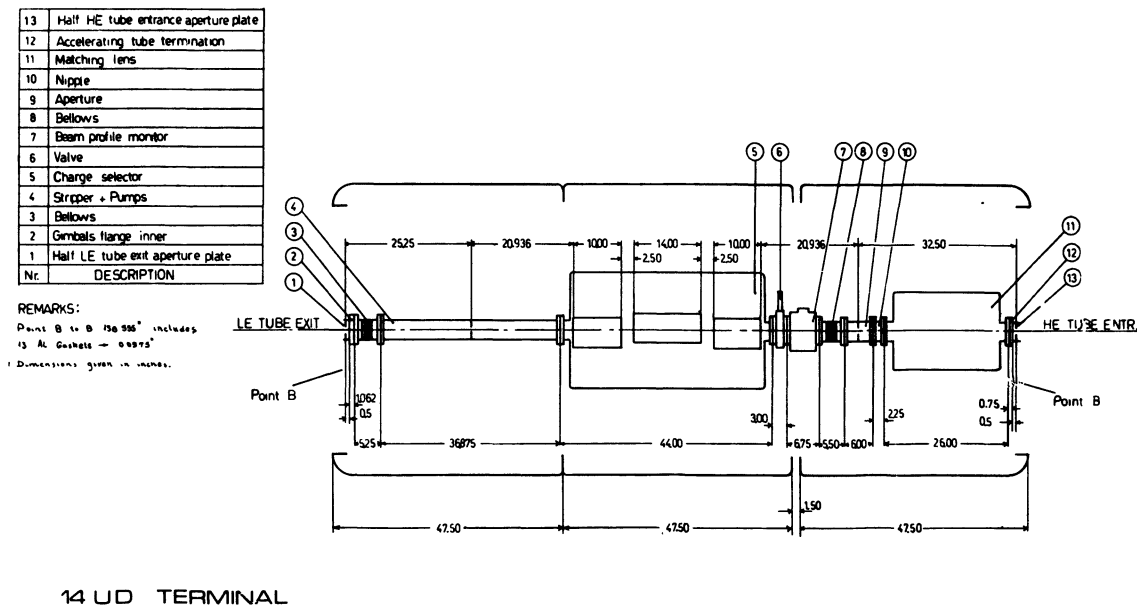


FIG. 4. — Schematic view of the HV terminal.

ted performance of the charge selector, based on measurements on the model with a proton beam.

The chopper buncher is a system designed by I. Ben Zvi from our laboratory with the objective of obtaining short beam pulses with a width of less than 100 ps. It is intended for velocity selection of particles emitted in nuclear reactions. The system is shown schematically in figure 7. The first element is an achromatic electrostatic chopper (Fig. 8) of a design that

was first proposed by Zieher. This design is free of the velocity spread introduced in the operation of conventional choppers (without redeflectors). The chopper is followed by a conventional pre-buncher situated inside the accelerator tank immediately before the low energy tube in order to minimize the effect of the velocity inhomogeneity in the beam. The buncher is made of two parts operating at the fundamental frequency of 4 MHz and the third harmonic. The

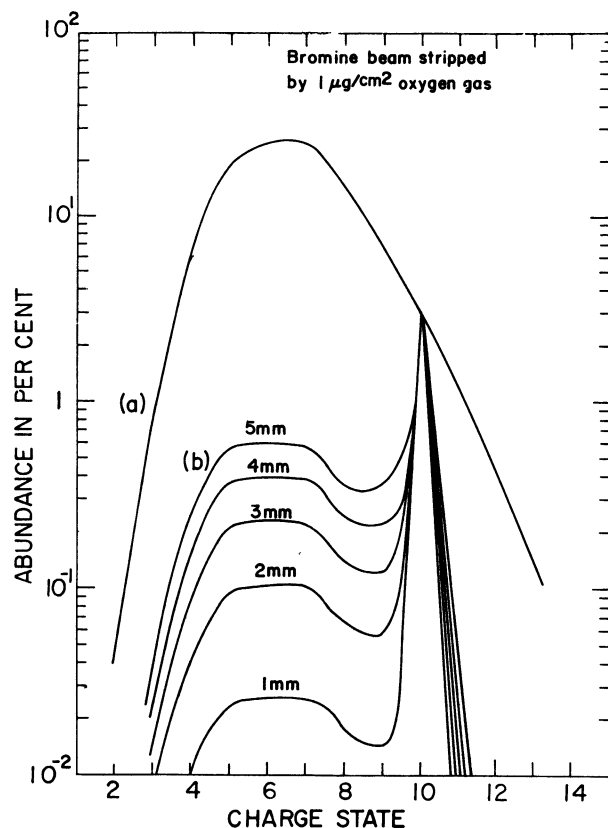


FIG. 5. — Selection quality of an offset triplet charge selector for a 14 MeV bromine beam stripped by $1 \mu\text{g}/\text{cm}^2$ oxygen gas leading to an angular divergence of ± 3 mrad. The initial beam width at the object plane is 1 mm. (a) Equilibrium charge state distribution after stripping. (b) Charge state distribution after selection for the various image apertures marked on the curves.

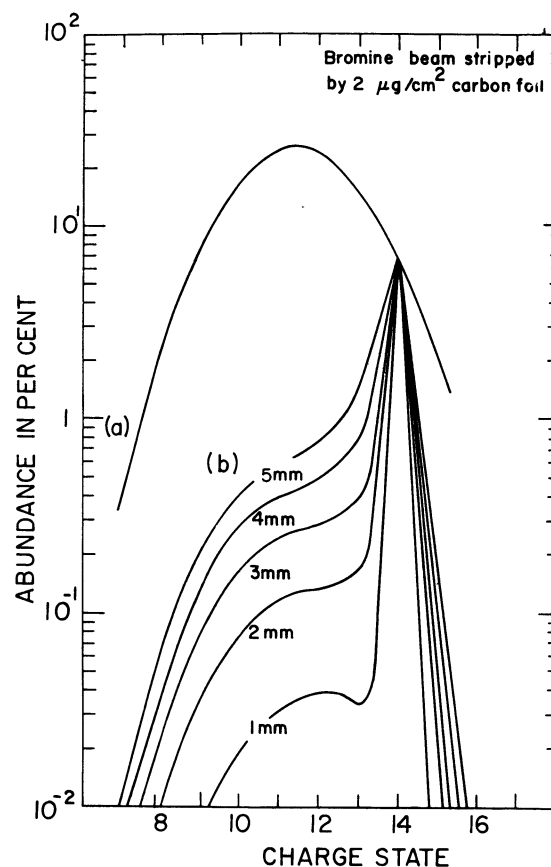


FIG. 6. — Similar to figure 5, for carbon foil stripper of $2 \mu\text{g}/\text{cm}^2$.

ensuing beam pulses are spaced 250 ns apart. The most important and novel element is a klystron buncher made out of two superconducting doubly reentrant niobium cavities operating at 430 MHz situated in close proximity (~ 2 meters) to the target. The superconducting buncher is shown in figure 9 and the cavities are shown in figure 10. Computed intensity distributions after the analysing magnet and at the target position are shown in figures 11 and 12.

I would like to conclude with a few remarks concerning the organization of the installation and assembly of the accelerator and other work in the laboratory during that time. Our laboratory has one target area and one control room. They are common to both the old EN tandem and the new Pelletron accelerator. The plan of the ground floor of the laboratory is shown in figure 13. With the new accelerator it was found necessary to introduce some modifications in these rooms and in the equipment housed in them (e.g. upgrading the vacuum equipment). Throughout this period we endeavoured to interfere as little as possible with the experimental work conducted with the EN tandem; modifications in the target area were concentrated in a few relatively short periods that were scheduled well in advance. Operators were available

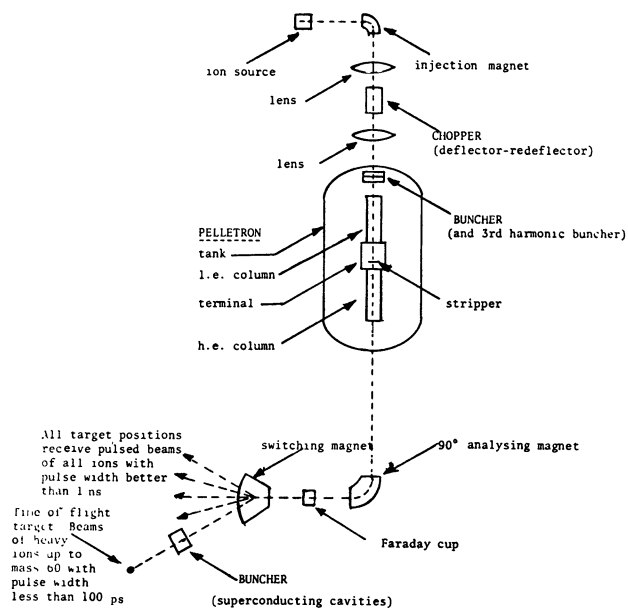


FIG. 7. — Chopper-buncher system.

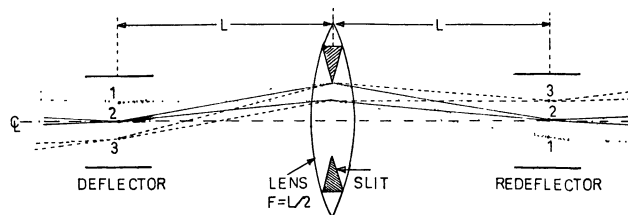


FIG. 8. — Schematics of the achromatic electrostatic beam chopper.

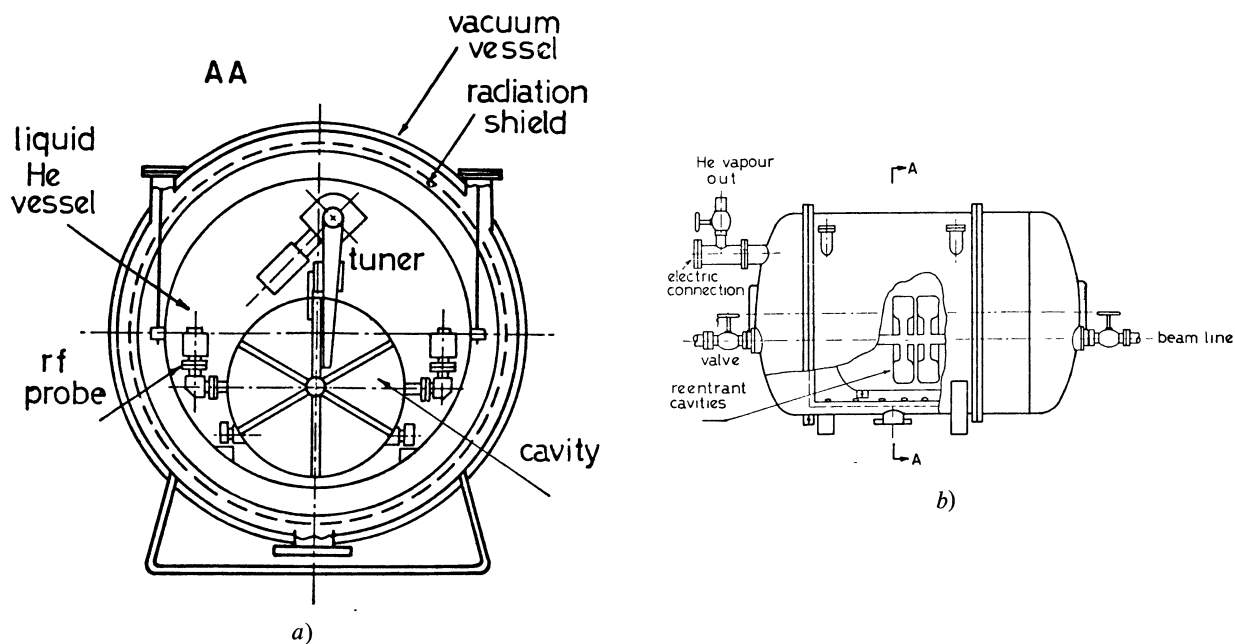
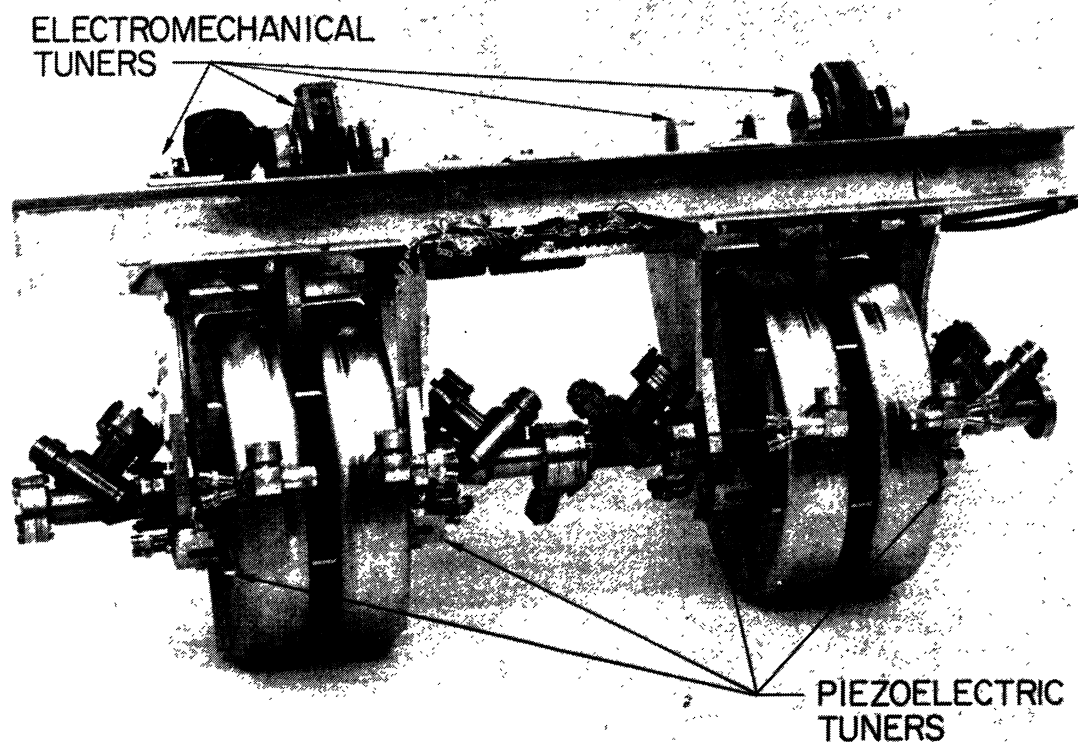


FIG. 9. — Superconducting buncher.



ASSEMBLY OF TWO DOUBLE CAVITIES.

FIG. 10. — The niobium cavities of the buncher. (The structure shown is an acceleration device assembled at Stanford university. Only one double cavity will be used in the buncher.)

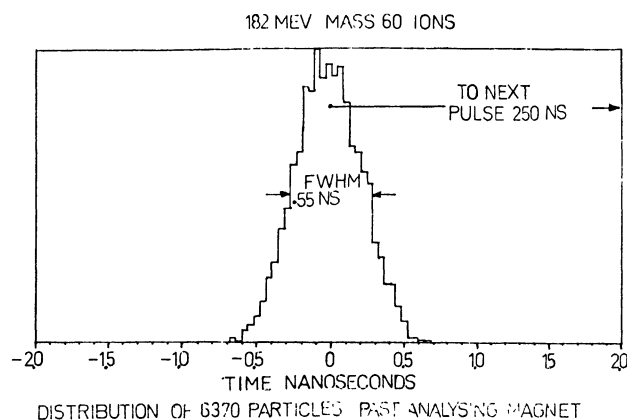


FIG. 11. — Calculated beam intensity distribution at the position of the stabilizing slit (or the Faraday cup Fig. 7), exhibiting the action of the chopper and the pre-buncher.

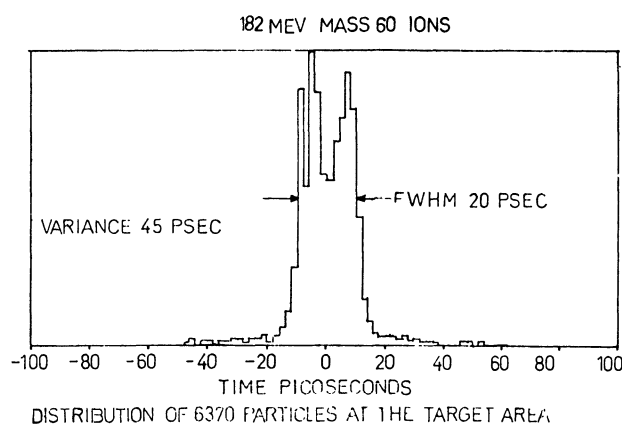


FIG. 12. — Calculated beam intensity distribution at the position of the target exhibiting the action of the full bunching system. The peak comprises about 15 percent of the total beam issuing from the ion source. The time between pulses is 250 ns.

on an on-call basis to help with the running of the tandem through two shifts although all the technicians were heavily involved in the installation of the Pelletron.

The first experiments on the Pelletron were started last week. In the year to come our technical crew will still be very much involved with the various modifications and additions that I have indicated and in that period we plan to have alternating six week periods of 14 UD and EN operation so that there will be ample prescheduled time for development work on the Pelletron and at the same time there will, hopefully, always be one accelerator available for experiments.

The very first experiment on the Pelletron was a study of the Coulomb explosion of the OH^- mole-

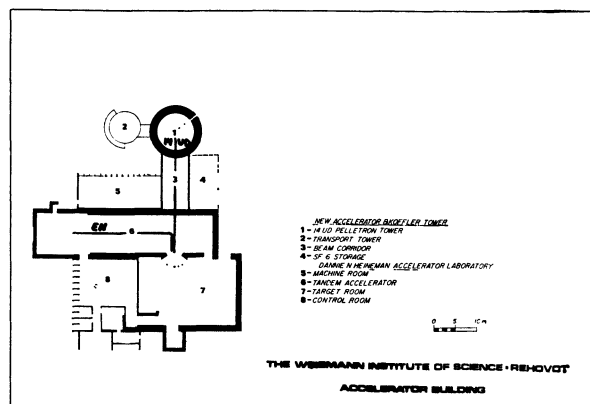


FIG. 13. — Plan of the ground floor of the laboratory.

cular ion as it dissociates in the strippers in the terminal of the Pelletron. The measurements were conducted at constant terminal voltage using the 90° magnet as a spectrometer.

In a control measurement an H^+ beam of 24 MeV was analysed and the result is shown in figure 14. The

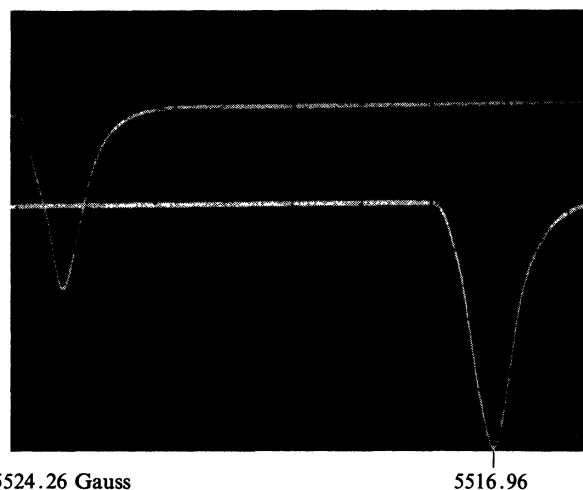


FIG. 14. — Magnetic analysis of an H^+ beam of 24 MeV issuing from the Pelletron. The duration of the sweeps across the H^+ line was about 1 s. The peak positions in the two sweeps are at 5524.26 gauss and 5516.96 gauss.

sweep across the H^+ line took about 1 s. The width and the shape of the line is consistent with the magnet slit apertures and it can therefore be surmised that in the short term the energy homogeneity in the Pelletron beam is better than the line width which is $\sim 5 \times 10^{-4}$ in $\Delta E/E$ (FWHM). Over longer period (of several minutes) the line was found to spread about two or three times as much.