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I GENERAL PHYSICS RESEARCH

1. Cloud Chamber Program

Evans Hayward

Synchrotron X-rays. The cloud chamber group has continued with the measurements in the experiment to determine the energy distribution of the synchrotron x-rays. Fig. 1 shows the intensity distribution based on the measurement of 2222 pairs. Fig. 2 shows the energy distribution of the positrons of the pairs produced by x-rays with energies between 100 and 300 Mev. The abscissa is the fraction of the energy possessed by the positron and the ordinate is the percentage of positrons contained in a ten percent interval of the abscissa scale. This curve is based on 891 of the higher energy pairs.

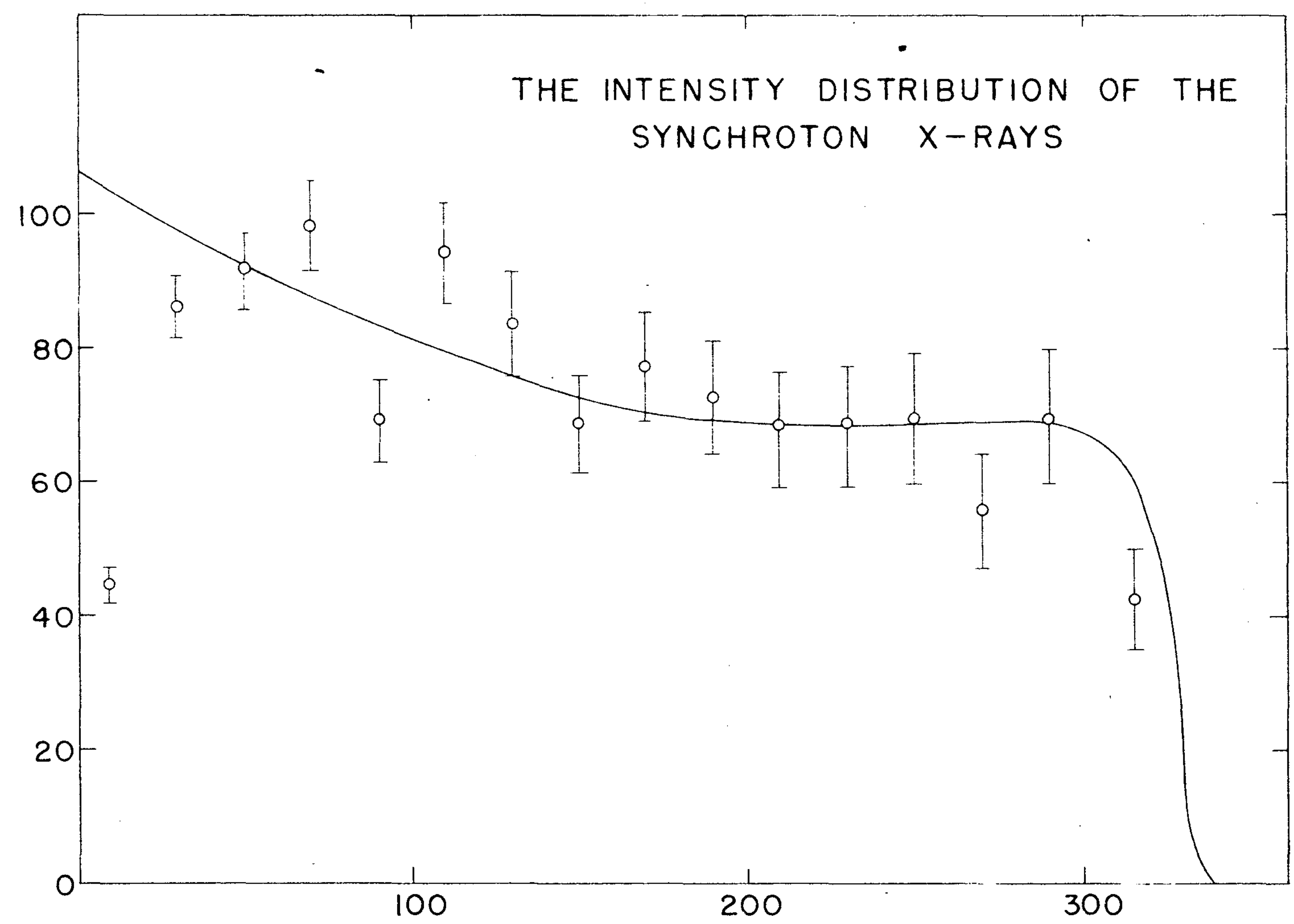
THE INTENSITY DISTRIBUTION OF THE SYNCHROTON X-RAYS
100
80
60
40
20
0
100
200
300
MEV →

FIG. I

14241-1

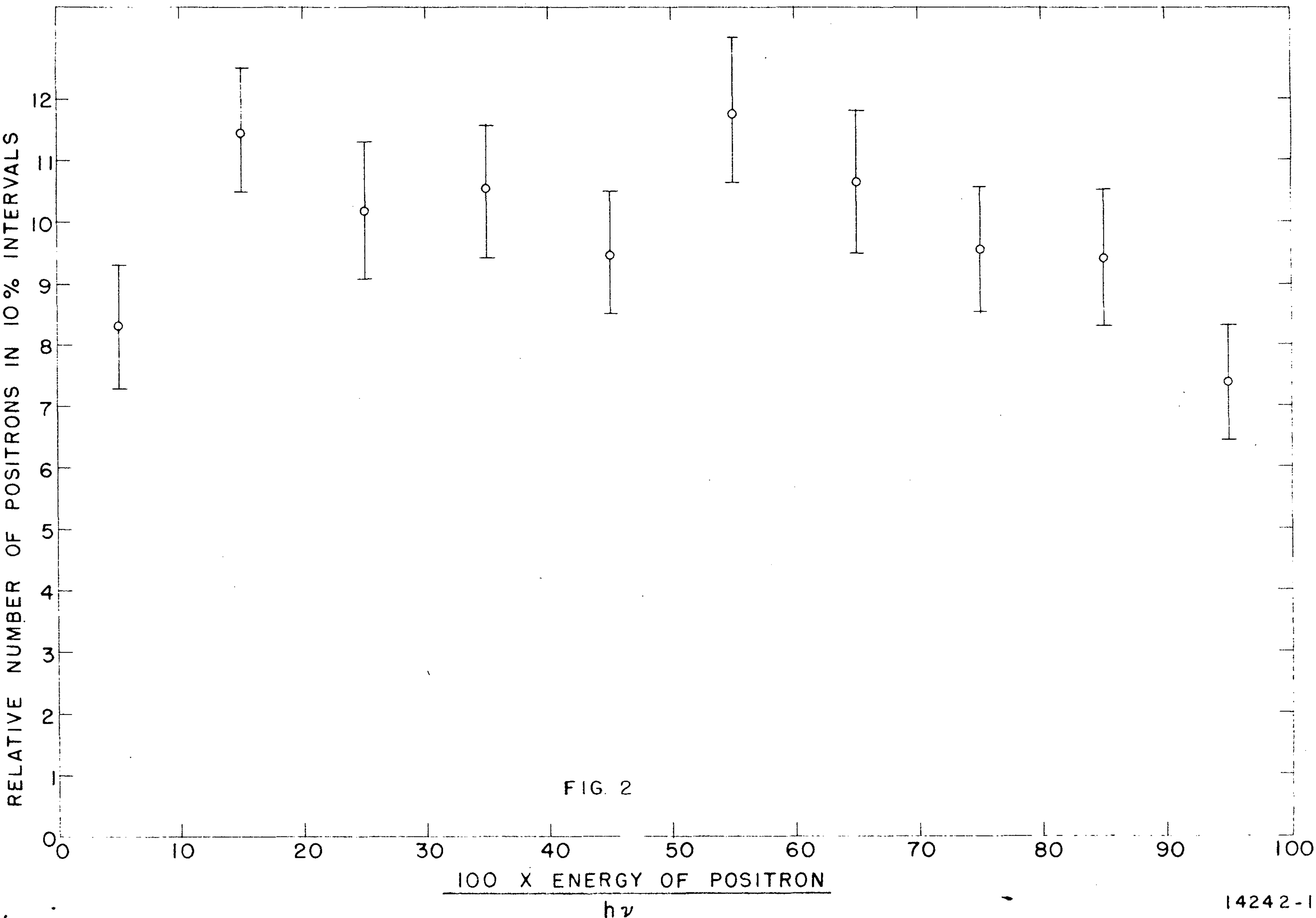
RELATIVE NUMBER OF POSITRONS IN 10% INTERVALS
0
1
2
3
4
5
6
7
8
9
10
11
12
0
10
20
30
40
50
60
70
80
90
100
100 X ENERGY OF POSITRON
hν

FIG. 2

14242-1

2. Film Program

Hugh Bradner, Eugene Gardner, F. M. Smith, W. H. Barkas, and A. S. Bishop

A review of the work on artificially produced mesons has been written and is being distributed under the report number UCRL-486.

3. A Multiple Scattering Deflector for the 184-inch Cyclotron

C. E. Leith

The electromagnetic deflector for the 184-inch cyclotron provides a deflected 350 Mev proton pulse of 0.1 μsec duration with a repetion rate of 60 cycles. The short duration of this pulse makes it difficult to use counters of existing types in doing many types of particle experiments. A deflector system has been developed which lengthens the proton pulse duration to 50 μsec maintaining the same repetition rate. A 0.1 cm thick Th scatterer is placed at the position usually occupied by the electric deflector. Some of the protons, multiply scattered in passing through the Th, experience the correct deflection to allow them to enter the magnetic channel and thus be brought out of the cyclotron. The time average proton current obtained in this way outside of the main shielding is 10^{-11} amperes in a 2.5 cm diameter beam. This current is 10^{-2} times that obtained with the electric deflector.

4. Bismuth Fission Chamber Measurements

James DeJuren

The variation in the bismuth fission cross section relative to the n,2n cross section of carbon was investigated by placing an 1/8 in. thick, 1 11/16 in. diameter polystyrene disc in front of a fission chamber mounted in the collimated neutron flux outside the concrete shielding. Ten minute bombardments were made with both the 90 and 270 Mev neutrons and the beta activity resulting from the carbon (n,2n) reaction was measured on a standard Geiger-Mueller counter. Bombardments were also made with brass plugs in the collimator to eliminate background effects. The ratio of the bismuth fission cross section to the n,2n cross section of carbon increased by 3.56 ± .11 (average of two runs) when the neutron energy was increased from 90 to 270 Mev.

Measurements were also made inside the shielding by varying the proton energy on the 2 in. Be target (change of target radius). A fission chamber and polystyrene disc were placed near the cyclotron tank wall behind 4 inches of lead which absorbed stray protons but allowed the neutrons to reach the detectors. The results indicated that the ratio of the bismuth fission to carbon n,2n cross section increased quite linearly with proton energy and presumably, therefore, linearly with the average energy of the neutrons ejected. Since the carbon (n,2n) cross section is in theory fairly flat in the interval between 90 and 270 Mev decreasing by less than a factor of two, the bismuth fission cross section increases slowly from 90 to 270 Mev.

The absolute value of the fission cross section for bismuth was measured for the 90 Mev neutrons by using a polyethylene disc to monitor the neutron flux through a 2 in. diameter collimator in the igloo. The beta activity was measured on a calibrated Geiger counter and the neutron flux was calculated from the n,2n cross section (measured by this same technique). The disc and a shallow type fission chamber were bombarded for 10 minutes with a steady neutron beam and the number of fission pulses was recorded. The chamber collecting plates are 4.5 in. in diameter and the collimator was used so that fission fragments would not ionize beyond the perimeters of the plates and give small pulses. The value obtained for the bismuth fission cross section is 31 ± 8 millibarns for the 90 Mev neutron distribution.

5. Fission Induced in Uranium by π^- Meson Capture

S. Al-Salam, W. K. H. Panofsky

Plates have been impregnated with uranyl nitrate and exposed to mesons in the 184-inch cyclotron. Thus far 8 mesons terminating in the characteristic fission "T" have been observed. The length of the fission fragments agrees with that observed in neutron induced fissions. This is in agreement with the ion chamber experiments on fission induced by high energy neutrons in which the fission energy is found to be essentially independent of primary energy. This is also a reasonable result since the fission energy is presumed to be of electrostatic origin. The maximum content of the plates is calibrated by α particle counts. The results are compatible with the assumption that any negative π meson captured in any U nucleus produces a fission. In one case a secondary fast ionizing particle has been found; in the other cases the excess energy is presumably carried away by neutrons.

6. Shower Curves in Matter Produced by 335 Mev Bremsstrahlung

W. Blocher and R. Kenney

A thin ionization chamber (1/2 in. thick, 12 in. in diameter) has been used to investigate the ionization along showers initiated by the x-ray beam from the synchrotron. The showers have been studied in C, Al, Cu and Pb. The position of the peaks, ultimate slope and area are in satisfactory agreement with theory. One of the matters of interest found was in unexpectedly large amount of backward flux of ionizing particles in the heavy elements which made the large diameter of the chamber mandatory. It has been possible to resolve the Compton scattering and pair production contributions in the initial part of the shower. Using this information and theoretical values for the pair production cross sections these experiments established the intensity standard for the synchrotron beam.

7. Neutron-proton Scattering at Small Scattering Angles

R. W. Wallace Jr., J. Steller, W. K. H. Panofsky

The geometry of photographic plates used in the linear accelerator proton-proton scattering experiments has been enlarged to extend the 90 Mev neutron-proton scattering data to small scattering angles, i.e., small proton energies. Thus far about 1500 tracks have been tabulated. The results are in good agreement with the prior n-p scattering data in the region where they overlap. The points added at small angles preclude complete symmetry of the n-p scattering curve. These had been assumed in analyzing the curves on the basis of a 50 percent exchange, 50 percent non-exchange interaction.

8. π^- Capture in H_2

W. K. H. Panofsky

An apparatus containing 600 cc of H_2 at -211° C and 300 p.s.i. pressure (density = .04) has been tested and is being installed in the 184-inch cyclotron. Its purpose is to study the expected γ-rays from the reaction $\pi^- + H \rightarrow p + \gamma$.

9. P-p Scattering Near 30 Mev

F. Fillmore and W. K. H. Panofsky

The plates read by different observers taken in the linear accelerator with protons scattered in hydrogen are being sampled to estimate the deviations caused by observer error. The primary energy used in the experiment has been fixed by measuring range-energy relations in the same emulsions used. The primary energy is now fixed at 29.6 ± .3 Mev..

10. Excitation Curve for $C^{12}(p,pn)C^{11}$ Reaction

V. Peterson and W. K. H. Panofsky

The positron C^{11} activity produced when carbon is bombarded with high energy particles (neutrons, protons, alphas or deuterons above 20 Mev) has become a very useful monitor and detector in various experiments. Considerable effort has accordingly been expended to establish absolute excitation curves for the reactions. The (p,pn) process has been studied at lower energies (threshold to 32 Mev) with the Berkeley linear accelerator, and at higher energies (up to 350 Mev) with the 184-inch cyclotron. Fig. 1 shows a preliminary plot incorporating previous work done here in the middle energy region (32-100 Mev) as well as the present results. The decrease of the cross section with energy above 100 Mev is in agreement with a semi-transparent model of the nucleus, in which the mean free path for nuclear collisions increases with particle energy.

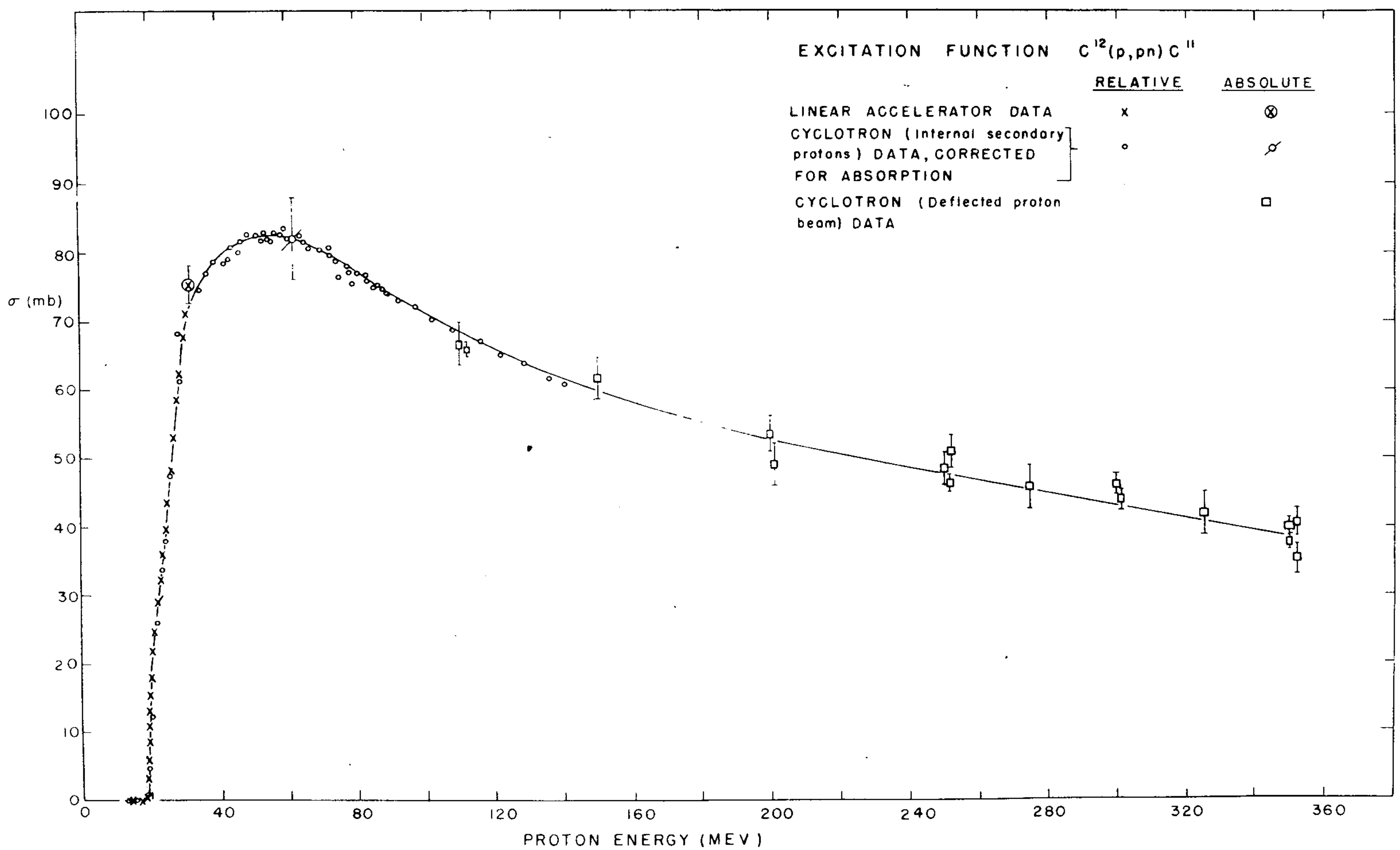
EXCITATION FUNCTION C12(p,pn)C11
RELATIVE
ABSOLUTE
LINEAR ACCELERATOR DATA
CYCLOTRON (Internal secondary protons) DATA, CORRECTED FOR ABSORPTION
CYCLOTRON (Deflected proton beam) DATA
σ (mb)
PROTON ENERGY (MEV)
0
40
80
120
160
200
240
280
320
360
10
20
30
40
50
60
70
80
90
100

FIG. 1

11. Proton-proton Scattering -340 Mev

E. Segrè

Measurements of the differential scattering cross section with proportional counters are very nearly finished. They cover the range of scattering angles in the center of mass system 41° to 90°. With this equipment it will not be possible to extend the range of angles

Results are shown in Table I.

TABLE I

	Angle of Scattering, Center of Mass System	Differential Cross Section Center of Mass System
Method I:	60°	6.0 ± 0.8 mb/sterad.
	64°	5.6 ± 0.9
	85°	6.5 ± 0.9
	90°	5.8 ± 0.8
Method II:	41°	5.5 ± 0.9
	43°	5.3 ± 1.1
	49°	5.1 ± 1.1
	62°	5.0 ± 0.7
	90°	4.8 ± 0.6

Method I employs one counter telescope of three proportional counters in coincidence. Method II involves the detection of both protons involved in a scattering process. It uses one telescope of two counters and a third counter placed about 90° from the telescope to detect the other proton. Also in Method II, the three counters are in coincidence.

In every case the scattering material is polyethylene or graphite, the difference being a measure of the counting rate due to hydrogen. The beam intensity is registered by a parallel plate ionization chamber with thin walls through which the beam passes before striking the target. This ionization chamber has been calibrated against the Faraday cup and other experimental equipment of V. Peterson of this laboratory.

Method II is regarded as being more reliable, inasmuch as there may be a component other than protons being detected in Method I.

Extension of the results to other angles depends on the construction of very fast amplifiers and coincidence circuits for use with stilbene scintillation counters. This construction is in progress. A resolving time of 2.10^{-8} seconds seems assured at the present time; however no test of resolving time has as yet been made with the pulses from the photomultiplier tubes.

12. Beta Spectra of Zn^{62} and Cu^{62}

A. C. Helmholz and R. W. Hayward

During the past three months, the beta spectra of Zn^{62} and Cu^{62} have been investigated. Zn^{62} is produced in the 184-inch cyclotron by deuteron bombardment of Cu. It has a 9.2 hour half-life and decays to Cu^{62} which in turn has a 10 minute half-life, decaying to Ni^{62}. The beta spectrum shows an upper limit of 2.92 Mev. The Fermi plot is a straight line back to .665 Mev where it starts to deviate. Previous work with this beta-ray spectrograph has indicated that such spectra should follow the straight line back to .2 Mev or less. Consequently, the end point of the Zn^{62} spectrum is assumed to be at .665 Mev.

Previous measurements on the spectrum of Cu^{62} had indicated an upper limit of about 2.6 Mev. The measurement of relative numbers in the 2.9 Mev spectrum and the .66 Mev spectrum indicate a ratio of 10 to 1, indicating that the Zn^{62} decays 10 percent by positron emission and 90 percent by K capture. Simple theory indicates that for an allowed transition, the positrons would constitute 25 percent. This agreement is satisfactory in view of the approximation made in the calculation. In addition, the K-L conversion lines of a 41.8 Kev gamma-ray are found. The K-L difference indicates that the gamma-ray occurs in Cu, so it presumably follows the Zn^{62} decay. The K/L ratio indicates the gamma-ray is probably either electric or magnetic dipole.

Some work on a coincidence arrangement for counting gamma-rays in coincidence with beta-rays has also been done. Initial tests with Co^{60} indicate fairly satisfactory performance.

13. Transition Curves in Lead of Photons Responsible for Nuclear Reactions

Karl Strauch

Transition curves in Pb of photons responsible for nuclear reactions have been taken by irradiating detector foils embedded in varying thicknesses of lead with the synchrotron x-ray beam. The relative activity produced by photonuclear reactions in the foils is counted, and then plotted against depth in lead. When the activities induced by $Cu^{63}(\gamma,n)Cu^{62}$ and $C^{12}(\gamma,n)C^{11}$ are used as detector, these transition curves show (1) a decrease due to photon absorption; (2) a maximum due to multiplication by cascade process; (3) an exponential decrease is approached.

The area under the transition curves, or "track length", determines an average energy of the photons responsible for the reactions. Calculations carried out by Dr. L. J. Eyges give 20 and 30 Mev for the Cu and C reactions, respectively, in good agreement with the excitation curves measured by Baldwin and Klaiber. The ratio of track lengths using the same detectors but different maximum photon energies is predicted by the shower theory: experimental values using the C and Cu reactions with maximum energies of 335 and 210 Mev agree within 5 percent with the theoretical value.

Transition curves have been started using the following reactions as detectors: $Zn^{64}(\gamma,n)Zn^{63}$, $Zn^{64}(\gamma,2n)Zn^{62}$, $Zn^{64}(\gamma,np)Cu^{62}$, $Al^{27}(\gamma,2pn)Na^{24}$, $Ta^{181}(\gamma,?)$60 minutes, $B^{209}(\gamma,?)$? ; the last two reactions are due to high energy x-rays as shown by a nearly straight absorption curve. Chemical separations carried out by Dr. Wilkinson show that the 60-minute activity belongs to a rare earth; the activity in the Bi is composed of several half-lives and might be due to photofission.

14. Theoretical Studies

R. Serber

P-p Scattering. The 350 Mev results can be explained by assuming a very singular tensor interaction (inverse square potential). A paper is being prepared on p-p scattering.

Mesons. The energy distribution of mesons produced by protons seems to agree well with expectations based on phase space arguments. The positive-negative ratio found with x-ray production has been explained in terms of the current carried by the proton. In principle this measurement can give information on the meson magnetic moment. The angular distribution of the synchrotron mesons suggests that the meson is abnormally weakly involved in the photoeffect , and that observation of the x-ray by the proton magnetic moment makes a sizable contribution. The pseudoscaler theory is an example of a meson theory which would have such odd properties. Strong coupling meson theories are being investigated.

Showers and (γ,x) Reactions. The shower theory has been compared with the measurements of (γ,x) reactions in a lead block. The agreement is quite good, with the simple assumption that a particular energy x-ray is effective for a given reaction. Work is still in progress. Work on the theory of the deuteron photoeffect is also being carried out.

Neutron Cross Sections. It has been found that the absorption cross sections of 280 Mev neutrons agree quite well with the values calculated from the cloudy ball model. The discrepancies in total cross section thus are connected with the elastic scattering. Possibilities of explaining this exist and will be investigated.

Machines. Various calculations on cyclotron designs have been made and are in progress.

II ACCELERATOR OPERATION AND DEVELOPMENT

1. 184-inch Cyclotron

James Vale

Proton Probe. The meson film program, and certain other experiments, made the use of more shielding necessary around the equipment on the probe than could be inserted in the tank through the probe lock. This necessitated the installation of additional shielding inside the vacuum tank. The procedure had the disavantage of time lost in opening the tank to install such equipment and the subsequent pump down, as well as radioactive hazard for those working inside the tank.

It was decided that a larger probe vacuum lock was needed to eliminate these difficulties. At the same time it seemed advantageous to keep the old probe lock and build a new one. A size of eighteen inches high, twenty-four inches wide and forty-eight inches long with a load limit of two tons was agreed upon. A flat cart was designed to support the load which could be pushed or pulled by a three inch stainless steel tube running through a chevron seal. The cart was designed with multiple wheels taking into account the gaps in the tracks for the probe lock door and the probe lock face plate. The double sets of wheels allow the cart to bridge these gaps and thus run smoothly through the lock. See Fig. 1 and Fig. 2. The motor drive is shown in Fig. 3.

Electric Deflector. The only practical position for the new probe in the tank interfered with the electric deflector. A mechanism to move the electric deflector out of the way of the new probe was designed. It seemed advantageous to build into the mechanism, additional controls so that the operating position of the electric deflector could be more efficiently controlled from outside the tank. It now has, in addition to radial motion, a vertical control for each end. The radial position for each end has a motor that can be run from the control room during operation. This has speeded optimizing the position of the deflector during set-up time. In addition, the distributed capacity of the system was cut down by the use of fewer and smaller support insulators and by increasing clearances of the electrode to all ground electrodes. This was an attempt to get higher voltage on the electrodes with the existing pulse equipment.

In line with the policy of reducing radioactive hazards, the electrodes were made of carbon. This is an improvement because a large fraction of the circulating beam hits the deflector bars and consequently makes them very radioactive. Since carbon has no long life activity, any activity induced in the carbon will become very low in a few hours. See Fig. 4.

Movable Shield. The meson film program group needed a shield in the throat of the dee to prevent scattered beam from the target from getting to the plates. The position of this shield depended upon the position of the target inside the cyclotron. In the past, a fixed block of carbon was mounted inside the dee for this purpose which generally restricted experimental work of this nature to one target radius. In order to eliminate this difficulty, a shield was designed that could be moved from outside the tank. It was installed during this period. See Fig. 5.

Carbon Dee Shield. During normal operation of the cyclotron, some beam is scattered from the target which in turn can traverse another 180 degrees and hit the dee. Also, the vertical oscillations of the beam increase enough at about 82 inch radius to enable the beam to hit the dee. Thus the dee becomes quite radioactive all along its front edge, but particularly so at about the 82 inch radius point. To reduce the activity produced on the dee edge by these mechanisms, a carbon shield was installed in the vacuum tank to stop these particles. It extends from about the center of the tank to the edge of the pole piece. It also extends from the pole pieces to one-half inch into the gap, both top and bottom, thus effectively shielding the dee and dummy dee structures. The shield is made of carbon, because of the short half-life activities, and is eighteen inches thick in the direction of the beam. This thickness is sufficient to stop the 350 Mev protons produced in the cyclotron.

Magnetic Deflector Sections. During this shutdown considerable work was done on improving the magnetic deflector. New iron sections of elliptical cross section, with a round hole for the beam to go through, were installed and magnetic measurements were taken. These elliptical sections replaced the rectangular bars in use previously. The elliptical sections have two distinct advantages; namely they give a more uniform magnetic field over a given cross sectional area hole, and the hole area can be larger for a given amount of shielding iron. Initial tests on the deflected beam in the cave indicate that more total beam can be gotten through the new channel, although the beam density seems to be about the same. Further tests are going on at the present time.

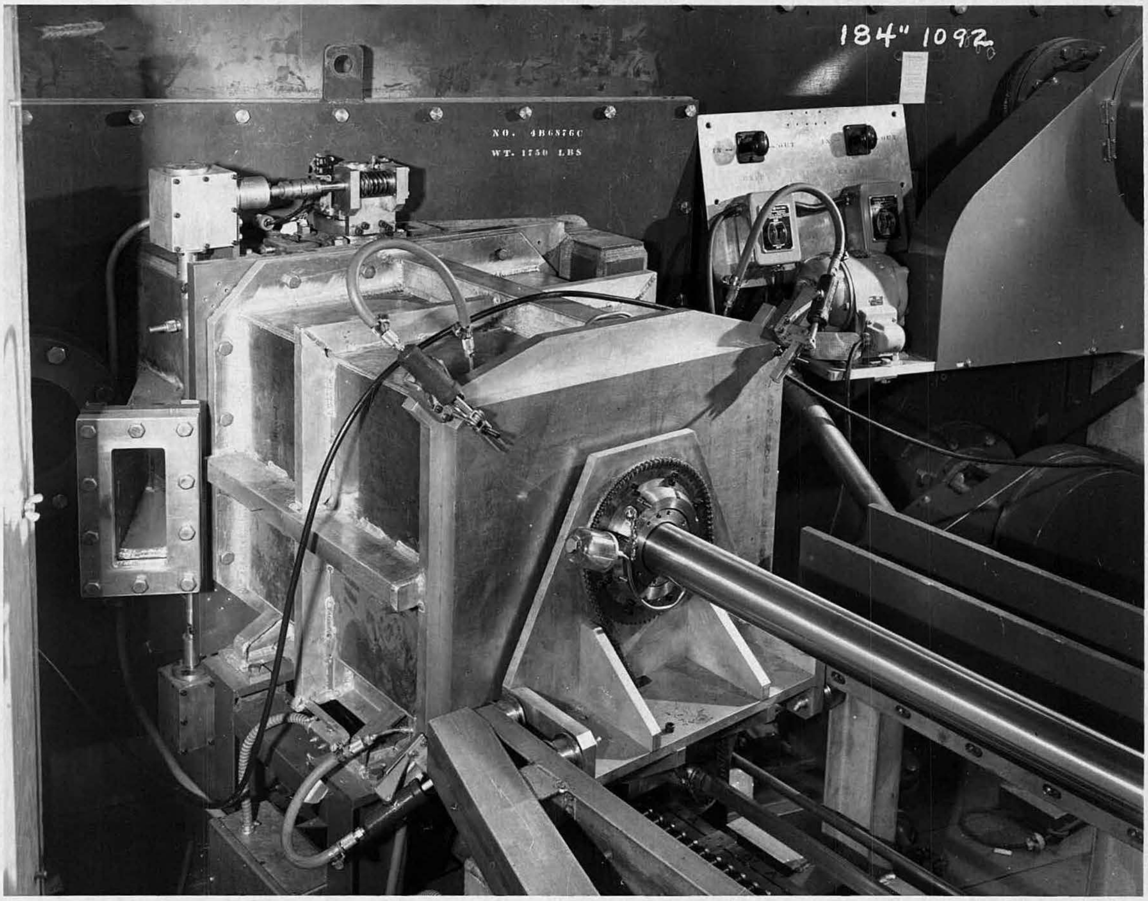

FIG 1

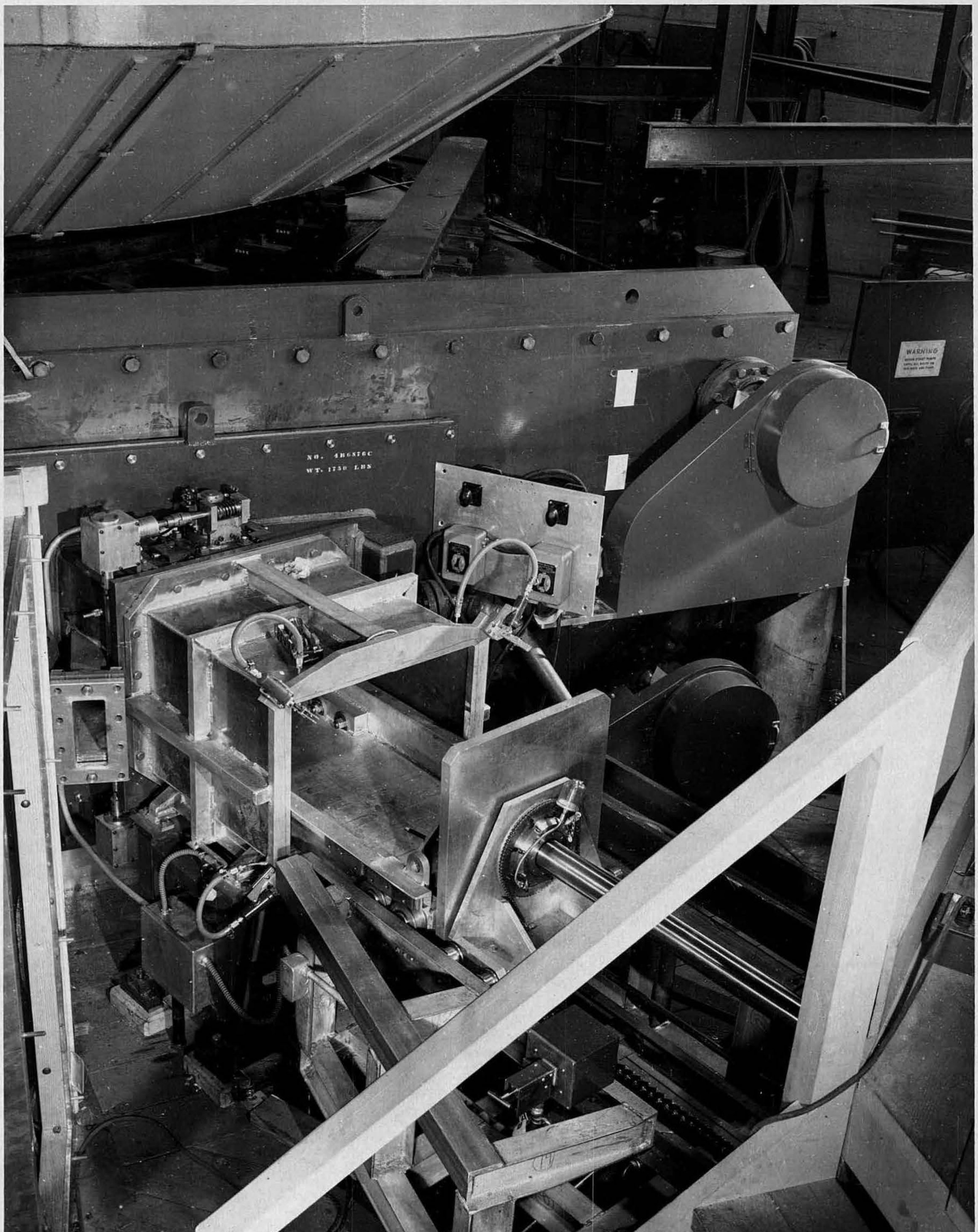

FIG. 2

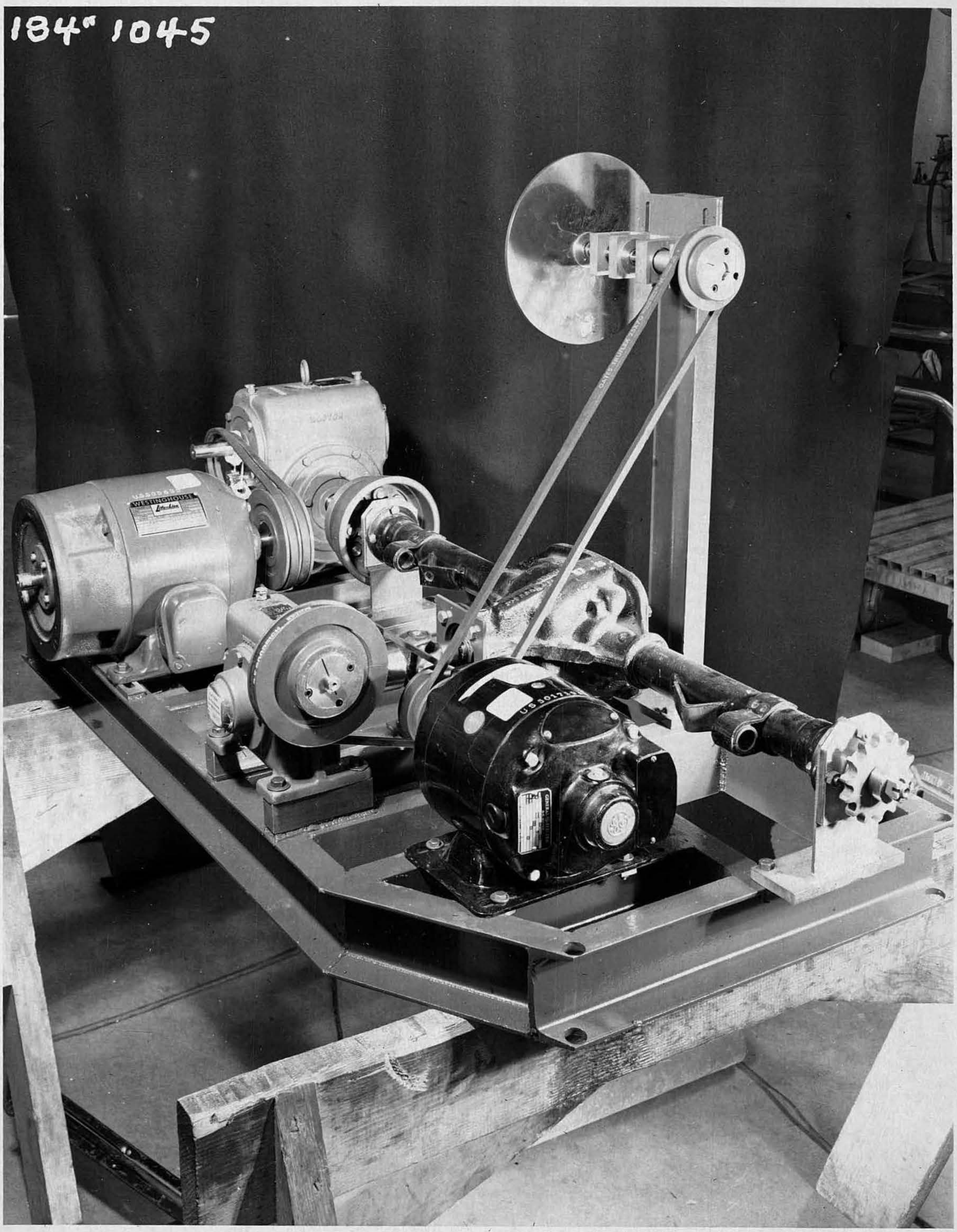

FIG. 3

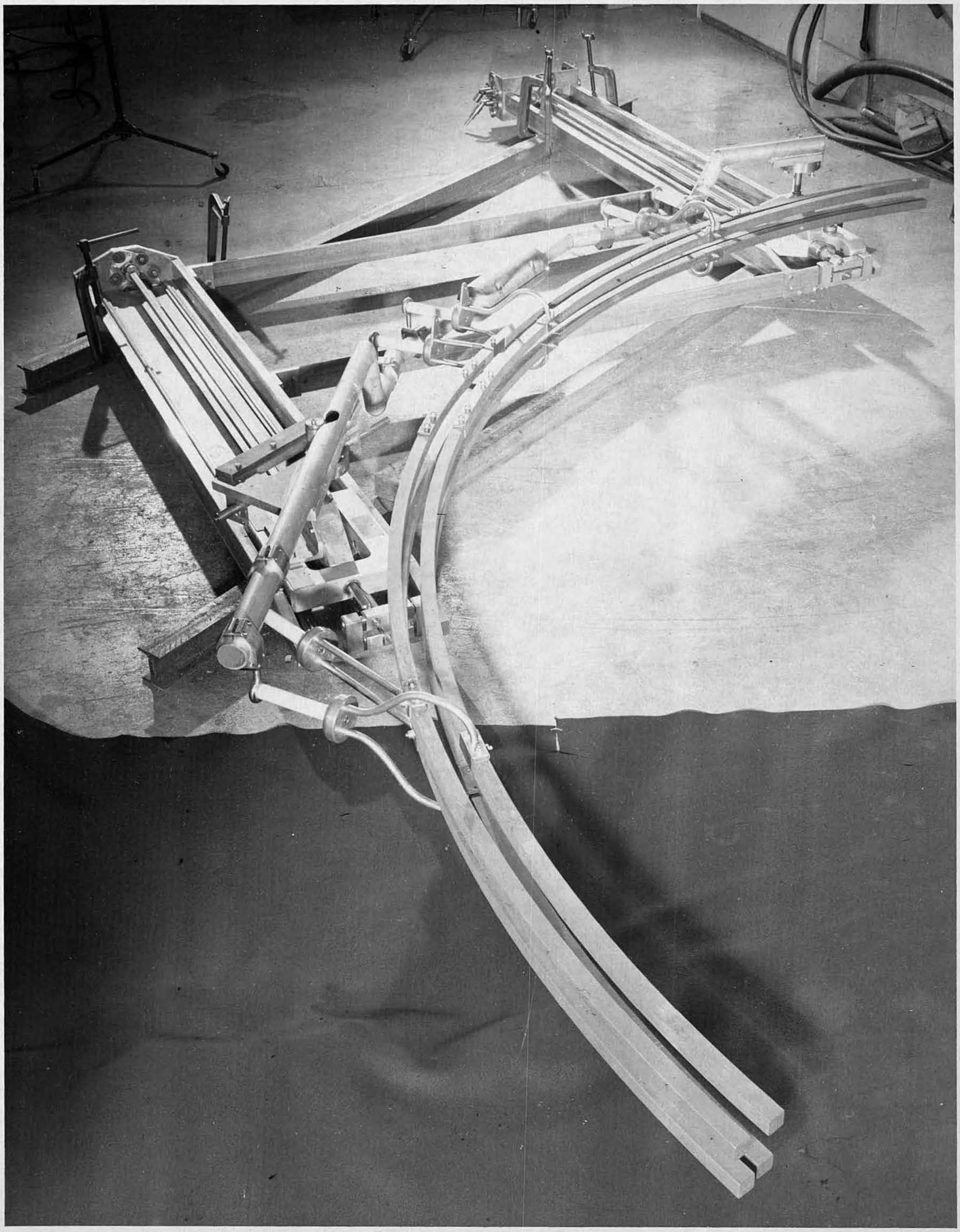

FIG. 4

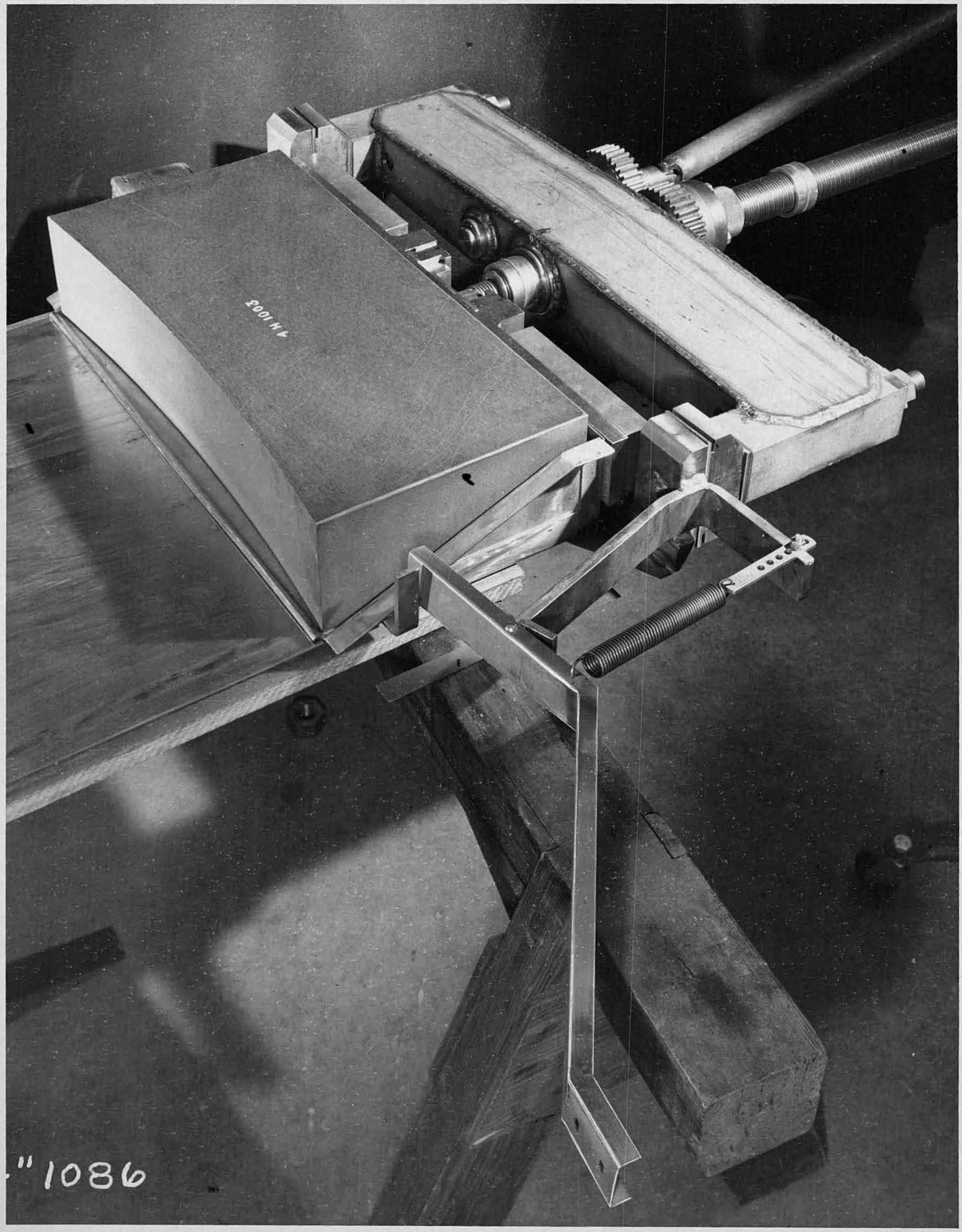

FIG. 5

2. 60-inch Cyclotron

Thomas M. Putnam, Jr.

The newly designed dee stems, vacuum tank and stem liners, and the pole faces of the 60-inch cyclotron have been assembled. Preliminary checks showed a tight vacuum system, working oscillator and adequate frequency alignment. An unmeasured quantity of internal beam is present. Secondary radiation effects are consistent. Radiation is magnet-, arc- and power-sensitive. Due to outgassing of the new equipment, there has not been sufficient dee voltage to permit a search for external beam.

3. Synchrotron

Walter D. Gibbins

During the period covered by this report operation has been interrupted by two machine shutdowns. A one week cessation of the experimental program was caused early in the month of August by a stress failure in the tubulation of one of the quartz vacuum segments. This particular tubulation apparently caused trouble because of a manufacturing flaw in the quartz and was precipitated by stresses from the injector mounted in this tubulation. A new quartz with a sound tubulation was installed and several other changes were made to prevent further failures. These included:

1. Repair of the contract point between the oscillator transmission line and the cavity.
2. Installation of new quartz segment grounding fingers.
3. Installation of annealed copper conductors in the magnet compensating loops across the pole tips.
4. Installation of remote control on the injector horizontal axis rotation.
5. Installation of position indication of the injector tangential position.
6. Tightening of the main energizing coils to prevent motion.

The second shutdown, which was of minor importance, was planned. During a two day period in the second half of October an automatic liquid nitrogen dispensing system was installed to effect a saving of liquid N_2 and a saving in beam time. Other improvements made at this time included revamping of some of the console controls and the installation of a roll-away mounting for a beam telescope used to accurately align equipment in the beam.

The output of the machine has increased after the eradication of charging up phenomena which were present for several days after the one week shutdown. Upon reassembly of the magnet, the beam intensity did not go above 500-700 R per hour and possessed the characteristic of a definite slow decrease and sudden rise on a fixed time constant. Lowering of the injector filament emission current increased the period of the intensity alterations. A drop of 10 percent in injector filament current increased the intensity alternation period from 1 to 2-1/2 minutes in this particular case. The intensity was charted during these tests and led to proof of electrostatic charge buildup and sudden breakdown on insulated patches of the quartz wall. Removal of these spots by respraying the inner surface of the quartz segments (with the exception, of course, of the electroplated r.f. cavity) eradicated the phenomenon.

Since that time the intensity has steadily increased until a peak intensity of 3,300 R per hour has been reached. The beam is quite dependable and very flexible in intensity, enabling the operator to vary the intensity in a stepwise manner for the experimentalist at will. During a recent long bombardment, the synchrotron was operated continuously for 28 hours. During the last 11 hours no controls on the machine were touched with the exception of the injector peaking strip-bias controlling the time of injection of the electrons. This adjustment was made twelve times in the 11 hour period.

There have been short periods of operation which produced two characteristics. These were a very slow decay in intensity over a period of from 30 to 40 minutes followed by no rise in intensity without adjustment, and pulse to pulse erratic variations in intensity. Two things are though to play a major role in these deterring factors of operation: (1) Variations in line voltage at the inputs to the various electrical components of the machine, and (2) changes in the electron gun optics by warping of the spiral W filament.

The first problem is under attack with recording voltmeters in an attempt to correlate beam intensity amplitude jitter with line voltage amplitude jitter, Sola transformer regulation of the magnet pulser chassis which furnishes the firing pulses to the GL-506 ignitrons, electronic regulation of the injector high voltage supply, and raising of the transformer taps to maintain the voltages slightly higher. Most of these things have been done very recently and it is too early to determine the results except in the case of the electronic regulator on the injector h.v. supply. This has been in for some time and seems desirable to retain.

The second problem of injector filaments is being combated in several ways concurrently. Correlation of decaying beam intensity with aged injector filaments has been noted. During the past month a policy has been adopted of removing injectors before complete filament failure and observing particularly the shape of the filament. The injectors removed show warping of the filament. An electronic switch was designed which will cut off the injector a.c. filament current during the time the magnet is on in order to remove the magnetic field interaction forces from the filament. The current will then be turned back on during the magnet dead time between pulses. This device may prevent some of the warping but has not yet been installed. A new improved design of a dispenser type Ba-Zi oxide cathode electron gun has been accomplished and is 30 percent complete. This injector is expected to give longer life, higher emission with better focusing, and more stable operation. Also a more flexible injector test tank has been 70 percent completed. This tank will enable better study of emission and will enable injectors to be tested under conditions the same as those in the synchrotron.

During the past 1-1/2 months a device has been used which has given consistent improvement in beam intensities of a factor of 2:1. This consists of a thyratron, triggered at injection time, releasing a pulse of d.c. current from a capacitance. This pulse is allowed to flow through the two north magnet compensating octants in series. This equipment has been used experimentally for several weeks but has now been included as a permanent part of the machine. The exact effect of this pulse on the orbit is not known but it is assumed that it enables more electrons to pass the injector during the early portion of the betatron acceleration. Further investigations of its effect are planned.

During the past three months a system of monitoring the effect of the octant manget compensation on magnetic field phasing has been designed and installed. The adjustment of the sixteen compensating resistors (each in series with an upper or lower octant loop in the magnetic gap) is a complicated procedure due to the multiple effect of each change and interactions between the flux compensating loops. It was thought that a more comprehensive picture of a well compensated field could be obtained if the effects of compensation as seen on peaking strip signals measuring the time of zero magnetic field were studied. #479 Permalloy peaking strips were installed adjacent to the pole tips in the center of each octant loop. The first 16 peaking strips were found to give time signals inconsistent with the actual phase differences in the magnetic field. This inconsistency was found to be due to poor technique in the manufacture of the peaking strips wherein the small cores were work hardened in varying amounts by shearing and the core to winding space tolerance had not been held closely enough. A method of heat treating the Permalloy at 1000°C in vacuo was devised. This has brought uniformity into the magnetic properties of the core material when the heat treating followed shearing and much sharper, narrower signals are obtained. Also the technique of manufacture was improved to include the winding on a paper form .001 in. thick with a dummy core. This dummy core was then removed and replaced with a .001 in. x .025 in. x .750 in. piece of Permalloy. Before controlling the space tolerance in this manner, variations of $\pm$ .4 μ sec were encountered. Using the methods outlined above has facilitated accumulation of peaking strips which agree within $\pm$ .05 μ sec. The preliminary investigations are complete and it is planned to make a study of the phasing versus compensation adjustments as soon as duplicate lengths of coaxial cable are installed from the peaking strips to the monitoring equipment.

A good deal of experimental work has been carried on using the 7-1/2 ton steering magnet mentioned in the last report. During the past month the steering magnet was mounted on its own movable dolly so that it can, with special handling equipment, be rolled in and out of the synchrotron beam as desired. Also the stray external field from it has been more effectively shielded by enclosing the 7-1/2 ton magnet in a square cover comprising two 1/2 in. thick steel plates spaced 1/2 inch apart on the top and four sides. This shielding has reduced the stray field outside the shielding below 3 gauss. However, when the corner of this shielding is approximately 2 meters from the orbit and the steering field is raised to any value higher than 5 kilogauss, recompensation of the synchrotron magnetic field is necessary to prevent disappearance of the synchrotron beam. The peak steering field available is 13 kilogauss in a 7 cm gap between rectangular poletips measuring 30 cm x 70 cm. With experience, recompensation of the synchrotron magnet is now readily done and presents no particular difficulty.

Experimental Program. During the quarter just ending, the cloud chamber has been used in detection of mesons in cloud chamber photographs, nuclear fragment studies induced by the gamma ray beam, and investigations of the energy spectrum of electrons at maximum of gamma induced showers in Pb. Also concluded were the pair production studies started last quarter.

The work on the absorption coefficients in Pb and Cu of the radiation producing various nuclear reactions has been continued. Shower theory is able to account satisfactorily for the data obtained in the cases of Zn, Cu, and C with Pb absorbers and a measurement of the areas of the curves of induced activity versus absorber thickness has been found to furnish information concerning the energy of the incident radiation.

Experiments have been started on measurements of (γ,p) energy distribution but this work is in a very preliminary stage. γ-heavy particle counting rates have been taken but proof of these particles has not as yet been derived.

In the meson program additional bombardments were performed on the new geometry designed for energy spectrum data. This apparatus is called the "copper sea" and was used in the bombardment of Pb and C targets. One run was made with a total exposure of 12,800 R, with nuclear plates being removed at various intervals during the run on a cylindrical Pb target. A second run of 6,400 R was made using a .600 inch C sphere. These plates are now being scanned.

Further meson energy spectrum data has been taken with two consecutive bombardments of a liquid hydrogen target. The liquid hydrogen was contained in a thin stainless steel cylinder, 5 cm in diameter by 30 cm long, placed at the bottom of the hydrogen reservoir. The gamma ray beam traversed the length of this thin cylinder and nuclear plates, type C.2, 100 μ, were radially disposed in a semicircle around the lower half of the target. Each group of plates was mounted behind a different thickness of copper absorber. Two bombardments of 10,000 R and 30,000 R were made.

Another experiment was performed in which the gamma ray beam was allowed to strike nuclear plates directly. These plates have produced meson tracks.

Work is being done with scintillation counters in an effort to detect mesons directly by counting methods. One experiment comprises detection by coincidence in a pair of crystal counters wherein monoenergetic negative mesons are allowed to traverse the first crystal and decay in the second. The steering field is used to bend these mesons in an evacuated channel. The second experiment consists of detection by coincidence based on the gamma ray, meson, and decay electron without the use of the steering field. Both experiments are in the preliminary stages and will be continued.

The transition curves of lead, copper, aluminum and graphite are complete except for minor checking.

Use of a thin window (.006 in. Al) ionization chamber for beam integration has been successful. This instrument is now complete and is ready for calibration.

4. Linear Accelerator and Van de Graaff Machines

W. K. H. Panofsky

During the quarter year covered by this report, the linear accelerator has operated for a few chemistry bombardments only. The remainder of the time the operational characteristics of the linear accelerator have been studied and various improvements and repairs of the Van de Graaff generator have been made.

The operation of the linear accelerator was studied without focusing grids principally in order to check whether focusing grids, which are costing about a factor of two in intensity, are necessary. The second reason for investigating the necessity for grids was that after the recent current improvement the neutron background from the machine became excessive for safe operation and it was thought that neutron production at the grids contributed appreciably. The results showed that no appreciable loss of beam was encountered when no grids were used but that the neutron production was essentially the same. This indicated that the production was probably due to defocused protons striking the drift tubes. Accordingly, the drift tubes were lined with graphite sleeves to reduce neutron production and the grids were re-inserted. The focusing action without grids was somewhat surprising and appears to be due to the fact that the forty foot accelerator is essentially "short", as far as the wave lengths of phase and focusing oscillations is concerned. This effect is now being investigated theoretically in detail.

Various troubles have been encountered with the Van de Graaff generator, most of which are concerned with the pumping system in the high voltage electrode. Experiments were made to trap oil vapor from the diffusion pump in the electrode with a refrigerated baffle, but these experiments were unsuccessful. Owing to accumulation of carbon deposits in the column as the result of pump back-streaming, it was found necessary to dismount the column and sandblast it for cleaning. The machine is now again in operating condition.

5. Bevatron Development

W. M. Brobeck

Operation of the quarter scale model has steadily improved until a beam of 200 million protons per pulse was reliably obtained. The control of the oscillator frequency from the magnetic field which is an inherent feature of the proton synchrotron was developed to the point that no further improvement was considered worthwhile. As all the major objectives of the program had been reached the model was shut down on October 18.

Model tests on the 2 x 6 ft. aperture now planned for the full scale machine show the maximum proton energy to be 3.5 Bev.

All preparations for fabrication and assembly of the magnet steel were completed but shipments from the mill originally scheduled to start October 8 have been delayed by the steel strike.

Progress on the building has been good with about 30 percent of the concrete placed by the end of the period. The structural steel however will also be delayed by the strike.

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