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PHYSICS DIVISION QUARTERLY REPORT

August, September, October, 1953

December 15, 1953

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Berkeley, California

PHYSICS DIVISION QUARTERLY REPORT

August, Septemb er, October, 1953

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PHYSICS DIVISION QUARTERLY REPORT

August, September, October, 1953

GENERAL PHYSICS RESEARCH

CLOUD CHAMBER STUDIES

Kenneth E. Relf

Part I: A Diffusion Cloud Chamber of Unusually Large Dimensions

Introduction

A diffusion cloud chamber eight feet long, four feetwide, and five inches deep has been constructed and operated continuously for 720 hours; very satisfactory operation was maintained for 540 out of the 720 hours. The chamber was used to investigate the structure of cosmic-ray air showers near the core at sea level. The results of this experiment are discussed in Part II of this report. The present discussion is devoted to a description of the chamber with emphasis upon its construction.

Construction of The Chamber

The Bottom

A sheet of dural 8 ft. long, 4 ft. wide and 1/4 in. thick was selected to be the floor of the chamber. This was black-anodized to provide a background against which to photograph the tracks. The anodizing process did not produce a jet black surface, and therefore a pool of alcohol mixed with black Putnam dress dye was allowed to form 1/16 in. deep over the surface of the dural sheet. A rubber dam, 1/4 in. high and set in about 1 in. from the edges, was put around the periphery of the dural bottom. (B, Fig. 1). This wall consisted of ordinary weather-stripping material (Rubbershim) which, after being put in place, was coated with a mixture of Vulcalock and black Apiezon wax dissolved in toluene. To allow the bottom to drain the excess alcohol provided by condensation of the downward diffusing alcohol vapor, a 1/4 in. pipe 2 in. long was threaded into one corner of the sheet so that it protruded 1/16 in. above the floor. The other end was connected through a hose to a sump.

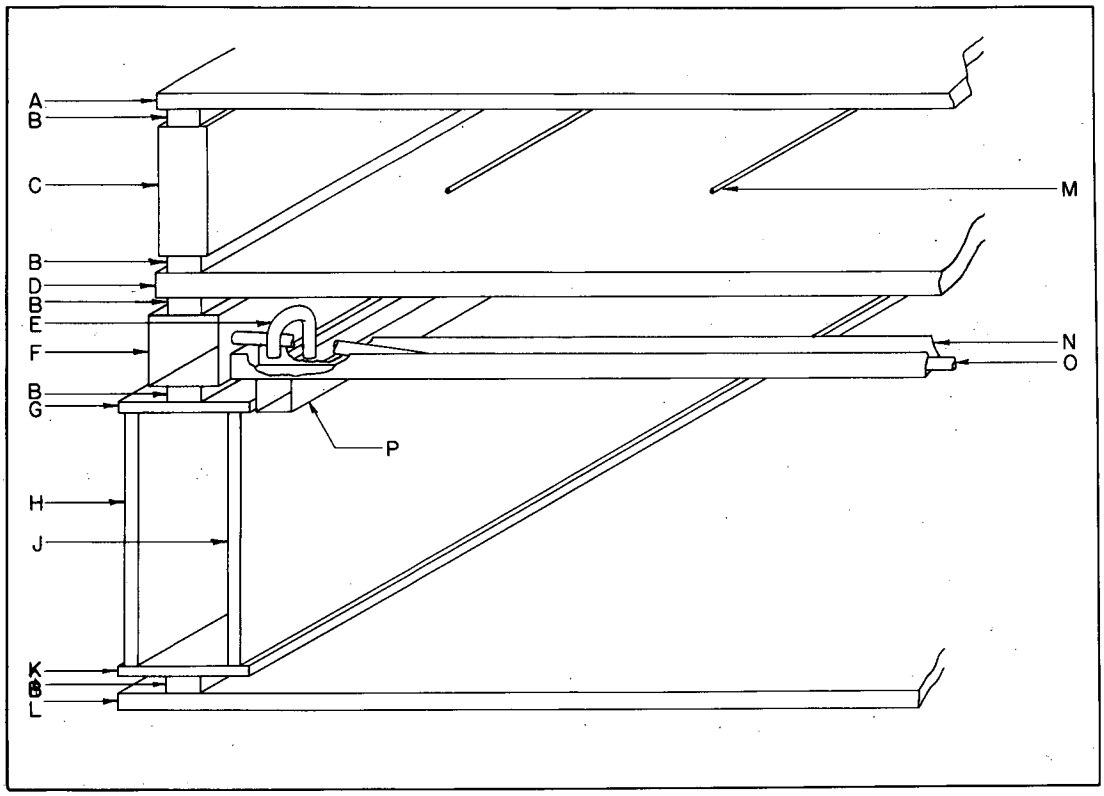

Figure 1

The Side Walls

The side walls of the chamber are 4 in. high and are double with a 1 in. air space between them. The inner side walls are 1/4 in. plate glass 92 in. long; the outer side walls are 1/2 in. plywood 94 in. long. Between the inner and outer walls a length of mirror was inserted to reflect the light back into the chamber for better illumination of the tracks. Each wall was hermetically sealed by sealing the top, bottom, and two ends with strips of Homolite cut to proper size and glued in place with Pliobond No. 30 cement. The hermetic seal served to prevent condensation of water vapor on the mirrors and inner surfaces of the glass walls.

The End Walls

The end walls were constructed in a manner similar to that of the side walls. The two principal differences were that both walls were made of 1/4 in. plate glass and that mirrors were attached to the end walls as shown in Fig. 2. The chamber was illuminated through the end walls; consequently, it was necessary to utilize these mirrors to lengthen the optical path of the light beam so that it could widen out to the entire width of the chamber.

The four walls were assembled by resting them on the rubber dam around the dural bottom plate and sealing the inside and outside corner intersections with photographic Scotch tape painted with the Vulcalock-wax mixture.

The Vapor Source

The vapor source consisted of a set of eight trays spaced 12 in. apart and suspended by a metal frame resting on the top of the glass walls (N, Fig. 1). Each tray was 1/2 in. wide, 3/8 in. deep, and 44 in. long. A piece of 1/8 in. copper tubing was soldered to the inside bottom surface of the tray (0, Fig. 1) and cut off so as to allow a 1/2 in. protrusion at each end of the tray. These ends were thrust into holes drilled in the metal frame and soldered in place. The tubing carried warm water to supply the heat of vaporization to the alcohol in the tray.

The frame into which the ends of the tubing were soldered was constructed from 1-in. square brass tubing (F, Fig. 1). An inlet and an outlet pipe were soldered into the frame and two square plugs were so

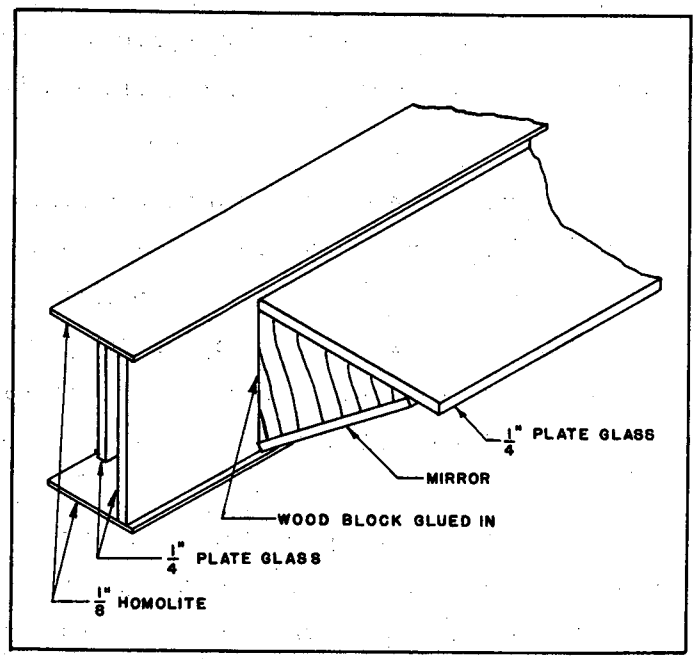
1/4" PLATE GLASS
MIRROR
WOOD BLOCK GLUED IN
1/4" PLATE GLASS
1/8" HOMOLITE

Figure 2

placed that the circulating water was forced to flow through the eight parallel paths provided by the 1/8-in. copper tubes.

A reservoir of 5-gallon capacity and mounted on a 6-foot platform fed methyl alcohol into the trays through the distributing system shown in Fig. 1. It consisted of another length of square brass tubing, sealed at one end, into which arched feed pipes were soldered (E, P-Fig. 1). A solenoid valve controlled by a timing motor allowed any desired amount of alcohol to flow into the trays at intervals of 80 minutes. The temperature of the incoming alcohol was approximately the same as that of the circulating water; the circulating water was automatically maintained at 18°C.

The air space between the two top glasses A and D of Fig. 1 was maintained at 30°C. by controlling the heating current in a set of heating wires (M, Fig. 1).

The Cooling System

The cloud chamber was mounted on a large chest as shown in Fig. 3. This chest contained a set of three 1-in. spray pipes, a return chute, and a 17-gallon reservoir. A gear pump was mounted below the chamber and circulated ethyl alcohol through the spray pipes. The alcohol, after making contact with the chamber bottom, fell into the chute, which was loaded with 400 pounds of dry ice, and finally returned to the reservoir. The coolant alcohol ran usually at -67°C.

The Camera and Shutter

A stereo camera using Leica f/4 lenses of 90-mm focal length was used in such a way that each lens photographed half the chamber. A solenoid-operated shutter was controlled by the pulse from the coincidence circuit.

The Mirror System

The optical path length between the chamber floor and the camera lens was about 10 ft. To avoid building a housing of such a large vertical dimension and to allow the camera to be set at a level easily accessible, a system of mirrors was used to direct the image of the chamber to the camera lens. The arrangement is shown in Fig. 4.

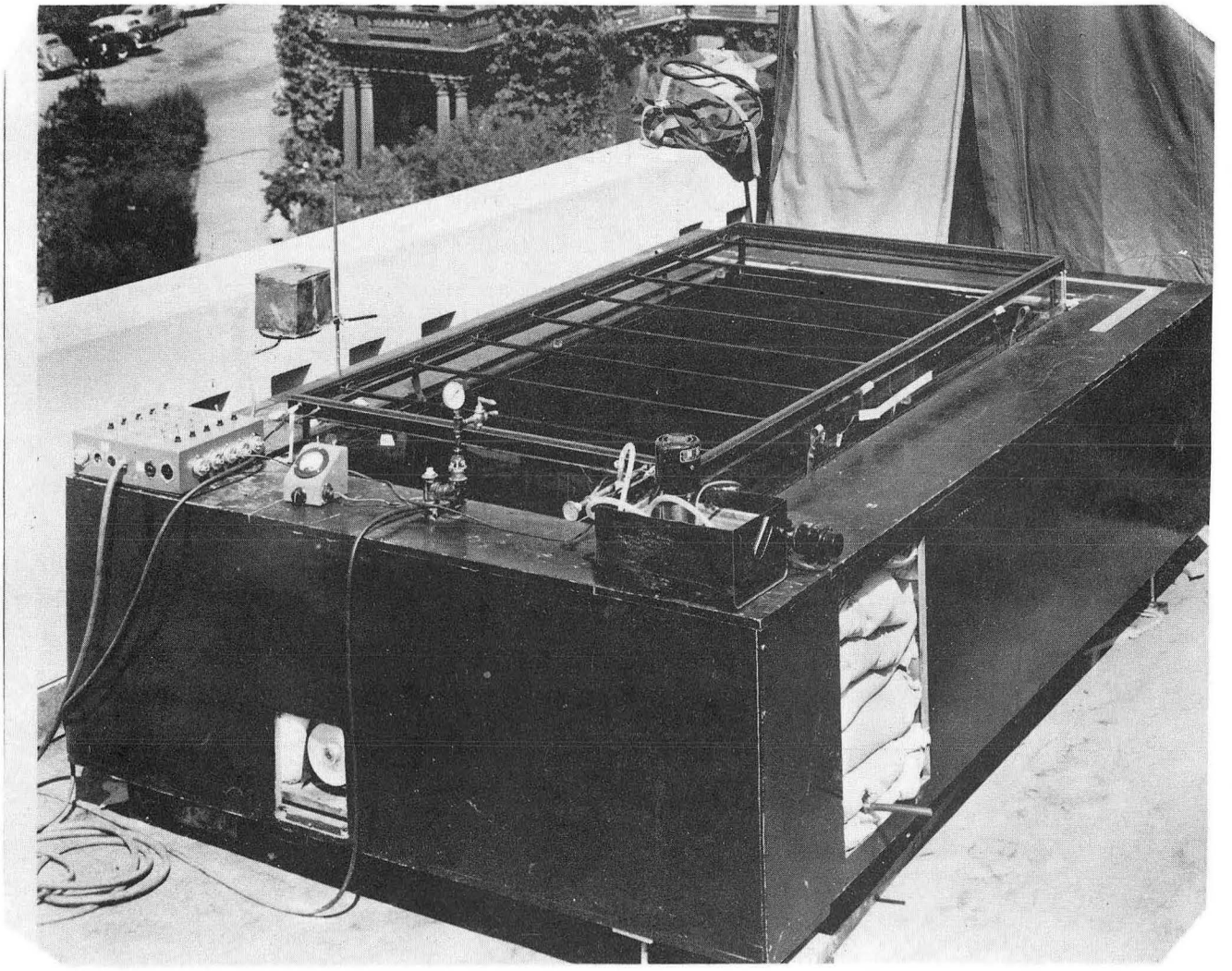

Figure 3

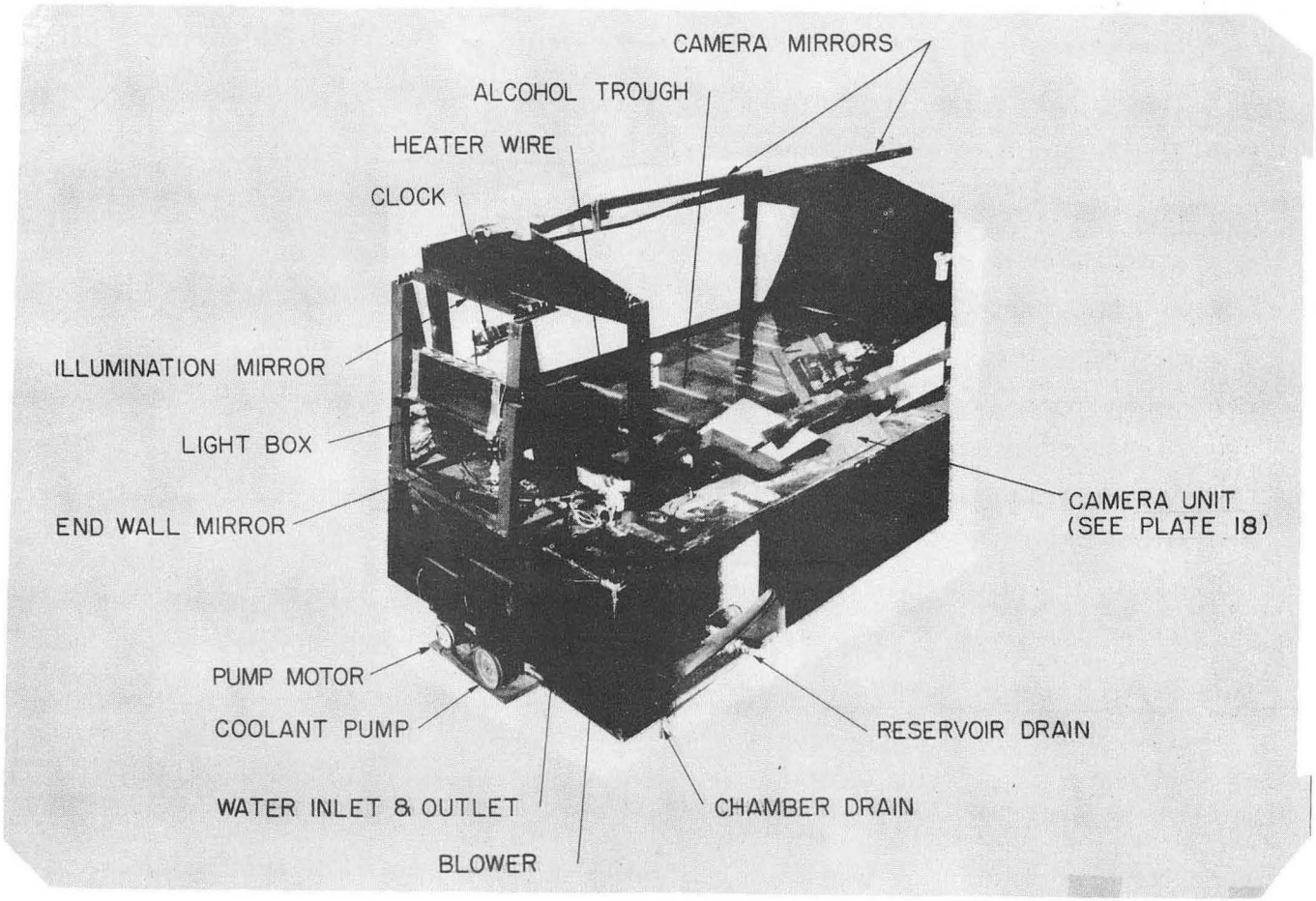
CAMERA MIRRORS
ALCOHOL TROUGH
HEATER WIRE
CLOCK
ILLUMINATION MIRROR
LIGHT BOX
END WALL MIRROR
CAMERA UNIT
(SEE PLATE 18)
PUMP MOTOR
COOLANT PUMP
RESERVOIR DRAIN
WATER INLET & OUTLET
CHAMBER DRAIN
BLOWER

Figure 4

The Photographic Lights and the Viewing Light

The photographic lights were two General Electric FT-422 flash tubes mounted behind focusing lenses of 5-in. focal length (Fig. 4). They were fired from a bank of capacitors totaling 1000 microfarads charged to a potential of 1.5 kilovolts, one such bank for each light.

The viewing light used was a General Electric AH6, 1000-watt, water-cooled mercury arc using a commercial power supply.

The delay time between the arrival of a shower and the taking of a picture by flashing the lights was measured to be 0.4 second.

Part II: A Cloud-Chamber Study of Cosmic-Ray Air Showers at Sea Level

Introduction

A diffusion-type cloud chamber 8 ft. long, 4 ft. wide, and 5 in. deep has been used to study the lateral structure of cosmic-ray air showers in a region near the core. Three showers were recorded in which the core lay within 60 to 90 cm. from some point on the periphery of the chamber. The results show that the lateral distribution of the shower particles in all but one photograph follows exceedingly well the Molière distribution. The deviations from the Molière distribution are almost all within the expected Gaussian fluctuations. In those pictures exhibiting little or no gradient, the deviations from the average density were normal.

Description of the Apparatus

The cloud chamber has been discussed in detail in Part I of this report.

The air showers were detected with an arrangement of four Geiger tubes each of approximate area 275 cm^2 connected in a fourfold coincidence circuit. Three of them were housed under a 1-in. lead roof resting on four 2-in. side walls. Within this lead house, the three tubes were dispersed at the corners of an isosceles triangle 8 in. on a side. The lead house was centered beneath the cloud chamber. A fourth Geiger tube was placed 1 m. away from the lead house; it served to prevent the recording of showers produced in the lead shielding.

The Experimental Results

Criteria for Shower-Track Identification

The three criteria established for identifying the shower tracks were direction, length, and age, the age being estimated by the density and

sharpness of the tracks. Most of the shower tracks in a photograph appeared to be nearly parallel. This is to be expected if a shower has a single core (or one dominant core) around which the shower particles are radially symmetric. Since most showers arrive at angles not greater than 30° from the vertical, the projected lengths of the tracks were quite short; this helped to distinguish the shower tracks from the background tracks. The distortion introduced by viewing the tracks as a point projection had to be considered, but this was not difficult.

The effect of the normal random cosmic-ray background was determined by making a detailed study of a series of random exposures. The error introduced by the presence of background tracks turned out to be negligible because there were so few straight background tracks compared to shower tracks.

The probability of a random shower's occurring between the time the desired shower particles traversed the chamber and the time the photograph was taken was estimated to be only one chance in six thousand and was considered negligible.

Method of Data Reduction

The three steps necessary to obtain the final data from the original 1-1/4 x 1-1/4-in. negatives were:

1. Make enlargedpositive transparencies 8-1/2 x 8-1/2 in. on Kodalith film.

2. Make Ozalid tracings of the shower tracks in each picture by putting tracing paper over the transparency and drawing in each track.

Locating the Shower Axis

The first two steps are self-explanatory. The core was located in the manner illustrated in Fig. 5. Two sections whose counts could be reasonably called identical (perhaps 5 to 10 percent difference) were selected. The geometric center of each of these two sections was located. These two midpoints were connected, the joining line bisected, and a perpendicular to it drawn in the direction of the shower axis. Visual inspection of the picture allowed one to select the quadrant in which the axis lay. Two other sections at the far end of the chamber were selected in which the track count was quite certain. The midpoints of these sections were located, the connecting line drawn, this line bisected, and the

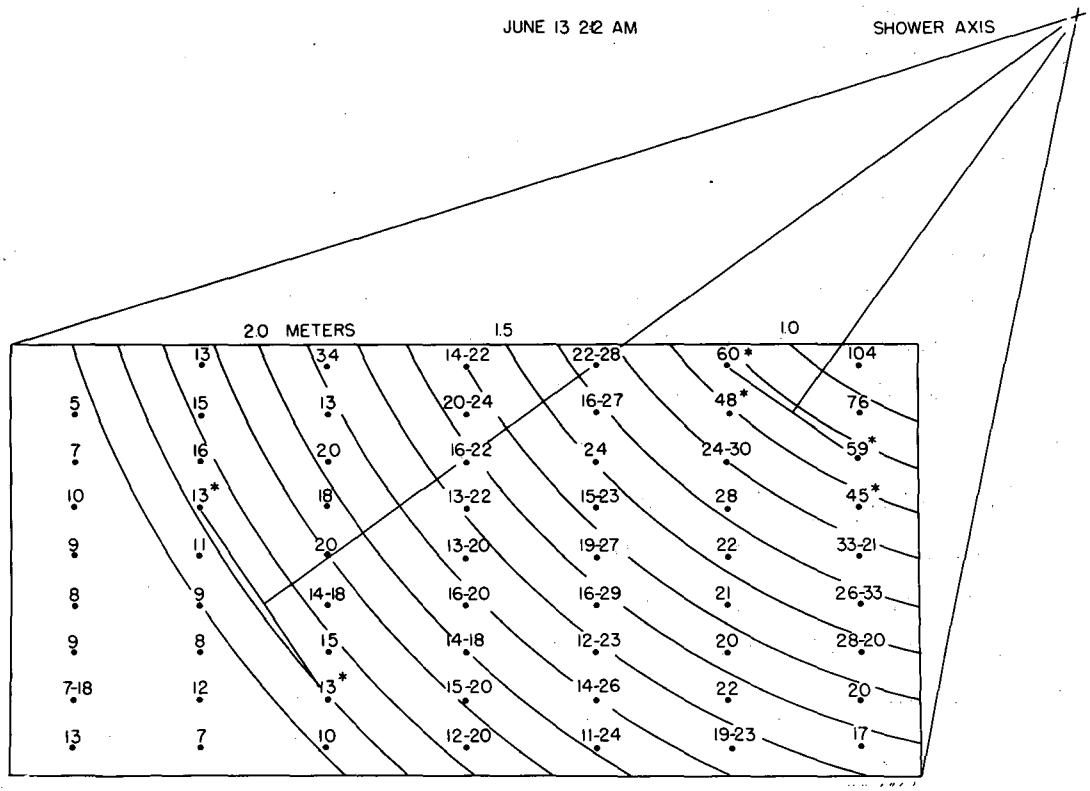
JUNE 13 2:2 AM
SHOWER AXIS
2.0 METERS
1.5
1.0
13
34
14-22
22-28
60*
104
5
15
13
20-24
16-27
48*
76
7
16
20
16-22
24
24-30
59*
10
13*
18
13-22
15-23
28
45*
9
11
20
13-20
19-27
22
33-21
8
9
14-18
16-20
16-29
21
26-33
9
8
15
14-18
12-23
20
28-20
7-18
12
13*
15-20
14-26
22
20
13
7
10
12-20
11-24
19-23
17

Figure 5

perpendicular drawn out to intersect the first perpendicular that was drawn. The intersection determined the position of the shower axis. A point of best fit was determined in this manner.

When the shower axis has been located in this manner, the distances of the geometric centers of each of the sections from the core position were measured and recorded. Convenient intervals of distance were assumed (9 cm) and a chart prepared in which the number of tracks in a section was entered in the appropriate column designating the distance of the geometric center of this section from the axis position. Upon completion of the chart, the number of tracks in each distance interval was averaged and this value taken as the average number to be expected at a distance from the core corresponding to the midpoint of that interval. A graph was made with the number of tracks per section as the ordinate and the distance from the shower axis as the abscissa. A smooth curve was drawn through the points in such a way as to best represent the data.

For those pictures which did not exhibit a strong gradient, the position of the shower axis was estimated using the Molière distribution function.

The results of the study of twelve photographs are presented in Table I. (Not all the photographs are included in this report.)

Conclusions

That only three showers exhibited an appreciable gradient was an expected result. Calculations based on other recent experimental work predicted five.

That air showers might originate at these low altitudes indicated in Table I was also not unreasonable in the light of some recent hypotheses and experimental observations.

Estimates based on work done by Dr. W. E. Hazen of the Randall Physics Laboratory utilizing the Fermi model of high-energy nucleon-nucleon collisions indicates that multiple cores would not have been observed in this experiment even if they were present.

The results of the experiment may be summarized as follows:

1. Multiple cores were not observed. Each shower, within statistical errors, consists of a single core. This observation is not inconsistent with the Fermi theory of nucleon-nucleon collisions, which predicts multiple cores, because they would be so closely spaced as to be unresolved in this

experiment. This does not imply that air showers are necessarily originated by the decay of neutral mesons, however. The data obtained from this experiment do not allow one to make any definite statements about the detailed mechanism of air-shower origin or to discriminate between different modes of origin.

2. The Molière distribution function describes the lateral structure of these showers up to distances of 60 cm. from the shower axis within Gaussian fluctuations.

3. The statistical distribution of the shower particles 3 to 4 m. from the shower axis is Poissonian.

Our first result, the absence of multiple cores, is typical of the results of other workers who have sought to identify multiple cores on the basis of density observations alone. Those who have reason to believe in the existence of multiple cores(with the exception of one) base their belief on data obtained from an energy distribution. The second result can be considered to extend the results of Williams and Cocconi, Tongiorgi, and Greisen from two or three meters down to distances of one meter and less. The third result is not a surprising one; it is to be expected, as was pointed out by Blatt.

The experimental results do not contradict the experimental work of El-Mofty or the theoretical predictions of Fermi. The results, together with those of Cocconi and his collaborators, do provoke a question, however, in regard to the Molière distribution function. Unless the large errors pointed out by Green and Messel are of such a nature as to cancel one another, it is difficult to understand the excellent agreement of experiment with theory.

Table I

Plate No.	No. of tracks in chamber	Average no. per section	Standard Deviation	Estimated no. of shower particles	Estimated energy of Initiating Ray	Distance of Axis from Chamber Center	Gradient Observable	Height of Origin	Angle with respect to verticle
1	1708			2.0×10^5	2.15×10^{14} ev	1.85 m.	Yes	14 r.l.	8°
2	1042			1.91×10^5	2.0×10^{14}	1.65	Yes	14	13
3	643			1.0×10^5	9.7×10^{13}	1.5	Yes	13	18
4	1641	28.8	10.1	10^6	$3. \times 10^{15}$	4	No	15	24
5	651	11.2	5.6	$3. \times 10^5$	10^{15}	3.6	No	14.5	7
6	625	9.6	4.8	$3. \times 10^5$	10^{15}	4	No	14.5	26
7	418	6.8	3.8	$3. \times 10^5$	10^{15}	4.6	No	14.5	7
8	2906	46.3	14.1	$\times 10^6$	$3. \times 10^{15}$	4	No	15	11
9	1078	17.2	6.1	$3. \times 10^5$	$\times 10^{15}$	3	No	14.5	9
10	693	11.2	5.5	$3. \times 10^5$	$\times 10^{15}$	3.6	No	14.5	9
11	345	5.6	3.5	$\times 10^5$	9.7×10^{13}	2.6	No	13	12
12	632	10.	3.7	$3. \times 10^5$	10^{15}	4.	No	14.5	21

The numbers in the box are order-of-magnitude estimates only.

MESON RESEARCH WITH THE SPIRAL-ORBIT SPECTROMETER

Ryokichi Sagane and Walter F. Dudziak

The following is a brief summary of the work that has been accomplished and is being undertaken with the 22-inch and 40-inch spiral-orbit spectrometers.

Research with the 22-inch Spiral-Orbit Spectrometer

A. The problem of $\pi^{\pm}$ -meson production cross sections resulting from the interaction of 340-Mev protons with complex nuclei has been studied using the nuclear emulsion technique. The laboratory phase of this experiment has been completed. However, before all the information concerning this problem is made available, many nuclear plates must be scanned. For the experiment eight targets have been used. These were Be, C, Cu, Al, Ag, Ta, Pb, and U. The study was made at the following meson energies: T_{π} = 12.5, 27, 37, 56, 71 Mev. A preliminary experiment prior to this has been reported in UCRL-2284 and the Phys. Rev. Oct. 1, 1953. Its title is "Dependence of the 33-Mev π^{+} Production Cross Section on Atomic Number".

A preliminary report on low-energy meson production study has likewise been made. The respective titles of these reports are as follows:

a) The Dependence of Negative Pion Production Cross Section on Neutron Number (UCRL-2304)

b) Dependence of Positive Pion Production Cross Section On Atomic Number at Low Energies (UCRL-2317)

A report on the preliminary data (T_{π} = 12.5, 27, and 37 Mev) of the relative yields of $\pi^{\pm}$ mesons will be made at the Physical Society Meeting at Stanford. Likewise a report will be made on the variation of the π^{-}/π^{+} ratio at these three energies at the Annual Meeting of the Physical Society.

B. The production cross sections of $\pi^{\pm}$ pions resulting from the interaction of 340-Mev protons with deuterons has been studied at six pion energies (T_{π}=12.5, 20, 27, 37, 55, 70) using the emulsion technique. Five exposures were also made between T_{π}=65 and T_{π}=70 Mev, so that one could determine an order of magnitude for the cross section $p + d \rightarrow t + \pi^{+}$. (At 90° the calculated π^{+} energy resulting from triton formation is 69.2 Mev).

A preliminary scanning of the plates has been made and a report on the results will be presented at the Annual Meeting of the Physical Society.

C. Meson production studies are in progress at the Synchrotron. The magnetic shielding studies of the synchrotron magnet from the strong leakage magnetic flux of the spiral-orbit spectrometer were highly successful. It is now possible to use a spiral-orbit spectrometer very close to the synchrotron without an appreciable loss of beam intensity. This was made possible by placing large steel plates in required positions and using a large compensating coil. For the first spiral-orbit experiment at the synchrotron a study was made of the low-energy pion production spectrum resulting from the interaction $\gamma + p \rightarrow \pi^+$. The pion energies investigated were $T_\pi = 10$, 20, 35, 45, 55 Mev. For the lowest energies hollow cylinders of CH_2 and C were used. The detector was the C-2 Ilford nuclear emulsion. The results of this preliminary experiment will be presented at the Physical Society meeting at Stanford.

The experiment on $\gamma + p$ using the subtraction technique in the low pion-energy region will be repeated. At the same time the meson spectrum from $\gamma + p \rightarrow \pi^\pm$ will be studied in the same energy region.

Progress Made on the 40-inch Spiral-Orbit Spectrometer

A. Construction. The 40-inch magnet was assembled in June at Bldg. 51. After some adjustments and measurements related to mechanical problems, it was transported by Bigge Company to Bldg. 6. The transportation required about one hour and was found to be quite simple and inexpensive.

Tests on assemblies of pole pieces to produce several different geometries were made and the results were satisfactory. A successful test was made of flipping over the magnet through 90° so that the axis of the magnet field was horizontal. This is a necessary requirement for using the magnet as a spiral-orbit spectrometer with any accelerator.

Magnetic-field measurements and the magnetization-curve measurements were made with all the return paths as well as with only half of the return paths in place. The characteristics were found to be a little better than the expected design values. Thus the magnet itself is ready for experimental use.

The construction of the adjustable platform for the magnet has been delayed for several reasons, and as a result the magnet is not available at present for experimental use.

B. Low-Energy Meson Scattering Experiments. Preparation for the exposure of G-5 emulsions to a high-density flux of approximately 20-Mev mesons have been completed. This type of experiment will give information on low-energy π-meson scattering from hydrogen.

Tests were made to obtain a roughly monoenergetic π^+ meson beam from 50 to 30 Mev by bombarding proper thicknesses of CH_2 targets and then degrading the meson energy. The results have indicated the possibility of measuring scattered mesons from protons at 90° very efficiently with the use of the spiral-orbit spectrometer.

C. μ-Meson Decay Electron Spectrum. The calculation of the resolution curve of the spiral-orbit spectrometer has shown that a resolution of $\pm$ 2 percent (an probably a resolution of $\pm$ 1 percent) can be obtained for measurement of the μ-meson decay electron spectrum. Targets and counting equipment for this experiment are nearly completed.

GAMMA-RAY SPECTROSCOPY

Charles Waddell and Harlan Shaw

A run was made at the linear accelerator in an attempt to measure the excitation function for a gamma line of approximately 15 Mev, excited by proton bombardment of carbon. This gamma line has previously been reported in connection with pair spectrometer work at the 184-inch cyclotron at various bombarding energies from 30 Mev to 340 Mev. This experiment was performed using a NaI (Tl) crystal 2 inches in diameter by 2 inches long, and pulse-height analysis with photographic recording. Background difficulties prevented obtaining the excitation function, but it was possible to establish the existence of this gamma line at 32 Mev bombarding energy. Further work on the excitation function and the angular distribution of the gamma lines is planned. A more accurate determination of the gamma-ray energy is to be made using the 180° focusing pair spectrometer at the 184-inch cyclotron.

NUCLEAR INTERNAL MOMENTUM DISTRIBUTIONS

John Wilcox and George Merkel

A cyclotron run was made observing one proton from each collision only. The gates are formed by a double coincidence in two stilbene "slit" crystals. This gives a high counting rate, and allows one to check the uniformity of the 35 spectrometer channels. The electronic tubes in the 35 channel amplifiers were rearranged to make the response more uniform. The shielded cable leads from the 35 phototubes have been shortened and made the same. The width of the defining slit was cut to 1/8 inch and the target sizes were cut in half, in order to sharpen up the energy resolution of the spectrometer. The hydrogen peak now falls in about two of the 35 channels. With this method CH_2, CD_2, lithium, beryllium, carbon, and aluminum were observed. The beryllium and carbon spectra are very similar but are somewhat wider than the lithium spectrum. Better statistics are needed.

Correlated proton spectra have been obtained for CH_2, CD_2, Li, Be and B with the improved electronics obtained from the above runs. Lithium shows a sharp hydrogen-like peak, and the boron spectrum suggests something similar. Quantative calculations on these data are in progress.

HIGH-ENERGY PAIR SPECTROMETER

David Cohen, Harlan Shaw, and Charles Waddell

During this period the pair spectrometer was again set at 90° to the proton beam of the synchrocyclotron and viewed internal targets through the hollow probe. The gamma-ray data are not yet fully evaluated, but it now appears that:

1. The proton bremsstrahlung spectrum shape closely follows $\frac{d\nu}{\nu}\sqrt{E_{o/2} - h\nu}$, where E_o is the laboratory bombarding energy. This involves a correction for nuclear momentum distribution. Elements bombarded up to now are carbon, Be, Al, and Cu.

2. One-hundred-and-ninety-Mev deuterons on a Be stripping target definitely produce a hump in the 15-Mev region of the continuous spectrum. This hump is presumably a nuclear line. Since the line-producing particles can be either deuterons, neutrons, or protons, there is a good deal of investigation yet to be done on this line. It is possibly a very small yield of the same line as seen in strong yield in the proton bombardment of carbon.

3. A rapid method of determining the accidental spectrum was found, so that past spectra can now be cleaned up considerably and higher beam levels can be used in the future.

CERENKOV RADIATION COUNTER

Robert Squire and John Osher

In view of the useful natural energy-discrimination properties of a Cerenkov counter, a trial counter was made of a lucite Y with a 10-inch effective radiation depth for fast charged particles, and using two separated 6292 phototubes as detectors. In conjunction with this counter a fast Neher-type coincidence circuit was developed with a time resolution of better than 5×10^{-9} for 0.2-volt pulses, and a discrimination ratio of at least 25:1 for 0.4 volt pulses. In an effort to minimize accidental coincidences from tube noise, cooling tests were run, and it was found that tube noise drops sharply for moderate cooling.

Two trial runs have been made observing π^{o} gammas. The first was directly in the neutron beam using a carbon target, and gave pulses around 0.15 volt with excellent 0° to 180° ratios, and also the counting rate

attenuated properly for gamma-rays of the right energy range. The second was a run inside the shielding, observing π^0 gammas from both uranium and carbon targets. In the latter run considerable rf pickup and some low gamma energy pile-up was encountered. Future trials will include more adequate rf shielding of the counter and coincidence circuits, as well as observing charged-particle orbits directly, which will allow the counter to be shielded from gammas coming directly from the target.

Ferramic cores were investigated further and the conclusion was reached that, although they are useful in coincident matrices and memory circuits, availability of reliable samples was doubtful, and actual use would have to wait on further manufacturing progress.

ELASTIC PHOTOPRODUCTION OF NEUTRAL PIONS FROM DEUTERIUM

Dwight Dixon and Kenneth C. Bandtel

It has been decided to attempt to identify the reaction $\gamma + d + \rightarrow \pi^0 + d$ by detecting the identifying of the deuteron only. This method appears feasible, since there is no other known process of appreciable cross section whereby photons can eject high-energy deuterons from a pure deuterium target. If deuterons are found with the expected energy spectrum one can be quite certain that the above reaction is being observed.

Energy and specific ionization are to be measured to identify the deuterons. Pulse-height counters for this purpose have been constructed using plastic scintillators. The resolution of these counters was measured at the cyclotron, using scattered protons of about 60 Mev energy. Corrections have yet to be applied to the data, but it appears that the resolution is probably good enough to separate the deuterons from protons. Protons are expected to be the most serious source of background.

A sychrotron run using the above method is to begin in a few days.

FAST DEUTERONS FROM 340-MEV PROTONS ON NUCLEI

Wilmot Hess

In order to improve the problem of the accidental coincidence counting rate encountered whenever the magnetic particle spectrometer is used, new electronic units have been built to use with the 35-channel scintillation

counters. The old units were built to use with GM counters, not scintillation counters, and therefore these units consisted of amplifiers which were fed from the 35-channel counters and gated on by a second signal. The input pulse was about 1×10^{-6} seconds long at the point where it was mixed with the gating signal. This time was long enough to allow accidental counts to be recorded owing to the background counting rate of the 35-channel counters. New electronic units have been built to correct this situation. These new units consist of first a mixing circuit where six inputs are combined to give a single output pulse whenever one of the inputs has a pulse. Then the output from this mixer is fed into a double coincidence circuit of the Garwin type. (The other input into the coincidence circuit was used previously as the gating signal.) The output from the coincidence circuit is fed into an EFP-60 amplifier where it is lengthened to about 1 microsecond, and then it can be fed through a conventional linear amplifier and scaler. The input pulses into the coincidence circuit are both about 4×10^{-8} sec. long. This decrease in mixing time should cut down the accidental counting rate by a factor of about 25. Of course combining inputs will increase the accidentals again, but even with 5 inputs the accidentals should be less by a factor of 5.

A run has been made at the cyclotron using this new electronics. A beam intensity of six times that used with the old electronics could be used with comparable accidental rates. The reliability of the apparatus is demonstrated by the fact that good voltage and delay plateaus were obtained with it. The one drawback appears to be the sensitivity of the output diode in the coincidence circuit to temperature changes, but by taking care to maintain a moderately uniform temperature, changes in counting rate were made quite small.

GAMMA-RAY SCATTERING FROM LIGHT NUCLEI

L. W. Alvarez, F. S. Crawford, Jr., and M. L. Stevenson

An investigation of the elastic scattering of 2.8-Mev gamma-rays at 90° from carbon and hydrogen nuclei is being made. Toroidal-shaped carbon, CH_2, and liquid-hydrogen targets have been used as scatterers.

The source of 2.8-Mev gamma-rays has been Na^{24}, the strength of which has varied from a fraction of a curie up to five curies depending on the run.

The fact that the half-life of this source is only 14 hours, together with the existence of a large background counting rate, has made it impossible to reproduce the measurements under exactly the same conditions. As a result, reliable values of the cross sections have not been obtained.

In order that these difficulties may be circumvented, a Co^{56} source with a 3.3-Mev gamma-ray and an 80-day half-life has been ordered.

RESONANCE EXCITATION OF DELAYED HEAVY PARTICLE EMITTERS

S. W. Kitchen

Further attempts to measure the excitation curve of Al^{24} using a transparent integrator were unsuccessful. The resonance peak was clearly there, but saturation effects in the integrating counter above 4×10^{-8} beam current together with the low yield of Al^{24} prevented accurate measurements.

GLASER BUBBLE CHAMBER*

L. W. Alvarez, F. S. Crawford, Jr., M. L. Stevenson, and J. Wood

A Glaser* bubble chamber designated to operate using liquid nitrogen and liquid hydrogen has been constructed. The chamber was shown to be sensitive to radiation when filled with liquid nitrogen. Appropriate changes are being made in the construction before testing with liquid hydrogen.

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*Donald A. Glaser, Phys. Rev. 91, 762 (1953)

ELECTRON-NEUTRINO ANGULAR CORRELATION IN Ne^{19}

M. L. Good and E. J. Lauer

In the effort to measure the time-of-flight spectrum of recoiling nuclei in the beta-decay of Ne^{19}, the no-beam background in the recoil counter has been greatly improved by carefully shielding all grounded insulators from the accelerating field.

A run using this system gave, for the first time, delayed coincidences above random background, which is an encouraging indication that the counter is detecting recoiling nuclei.

The time delays, however, are so short that it is apparent that most of the events counted are occurring in the wrong part of the apparatus, where it is impossible to interpret the time of flight in terms of recoil momentum.

Differential pumping to concentrate the Ne^{19} in the desired part of the recoil chamber is now being studied, and looks quite promising at present.

EXPERIMENT ON POLARIZATION IN P-N-P DOUBLE SCATTERING

H. Bradner and R. E. Donaldson

On October 24 and 25, a neutron polarization experiment was run on the 184-inch cyclotron. Two coincidence telescopes of 10^{-8} sec. resolution were set up at about 22° right and left of a tantalum target situated on the low-energy neutron beam line of sight, in order to detect right and left counting difference. A gold target was run in on the main probe to the low-energy line of sight, giving neutrons at 0° to the beam and thus unpolarized neutrons. The equipment was checked out at this point and the right and left telescopes were adjusted in angle until they were recording equal numbers of counts. Runs were then made with tantalum targets at full-energy orbits on the low-energy line of sight. These gave neutrons coming off at 45° right and 45° left and a check on misalignment. One target was then moved along the line of sight until the neutrons were coming off at 30° left and then at 20° left. All alignments were made optically, and errors due to target misalignment were measured to be of order of 1 percent. The electronics were inverted and found to be symmetric. Background ratios

were of the order of 8 or 10 to 1.

The results were reproducible both days, and were zero at all points to within about 4 percent.

A future run is planned adding a third counter on each telescope to take two absorber points at the same time, in order to reduce the effect of multiple collisions in the target nucleus.

p-p TOTAL CROSS SECTION

O. Chamberlain, G. Pettengill, E. Segrè, and C. Wiegand

Discrepencies have been reported between the differential scattering cross section measured by us and at Harwell and Rochester. Measurements at Chicago, on the other hand, agree with our results.

The whole situation has been unsatisfactory for some time and we have decided to measure, by a method entirely different and independent from our previous one, the p-p cross section.

Since everybody agrees on the constancy (except at very small angles which are insignificant for σ_{total}) of $\frac{d\sigma}{d\omega}$ (C. M.) it is enough to measure $\int \frac{d\sigma}{d\omega} d\omega = \sigma_{total}$.

This can be accomplished by an attenuation measurement of a proton beam in liquid H_2.

In our experiment the incident beam was defined and detected by scintillation counters in coincidence. It passed 14 in. of liquid H_2 in a stryofoam container and particles not scattered were detected in a large liquid scintillator in coincidence with the defining crystals. The ratio between double and triple coincidence allowed us to measure the attenuation of the beam. The double and triple coincidences were registered electronically and photographically.

Two energies were used: 340 Mev and 245 Mev (lab.) The C. M. total cross section was found to be 24 ± 2 mb for both energies. This corresponds to $d\sigma/d\omega$ at 90° = 3.8 ± 0.3 mb/ster., in agreement with our old measurements and with new Chicago data. These numbers are still subject to some revision when the whole experiment is calculated in detail.

POLARIZATION OF PROTON BEAM IN SCATTERING AT HIGH ENERGIES

O. Chamberlain, E. Segrè, C. Wiegand, and T. Ypsilantis

In this experiment we have attempted to produce a polarized proton beam by a first scattering process and then to detect the polarization by a second scattering process. This effect should manifest itself as an asymmetry of the second scattered intensity in the median plane of the first scattering. This experiment has been done at Rochester by Oxley, Cartwright and Rouvina. Our intention was to repeat and extend this work as far as possible.

From theoretical considerations one would expect maximum polarization in a p-p collision in the scattered beam at 45° in the center-of-mass system. This corresponds to a 22.5° angle in the laboratory system. Relativistic effects decrease this angle.

We have plotted proton orbits in the 184-inch cyclotron fringing field and found that if a target is placed near the main probe radial line, at 80-inch radius, a 20° scattered proton beam should be analyzed into the deuteron tube. This beam could then be deflected into the cave by action of the steering-magnet field.

Experimentally we have found that if we put a carbon target 1-1/4-in. in thickness at the 80-1/4-inch radius, displaced 8.3 in. along this radius away (north) from the main probe radial line, a beam was obtained in the cave of intensity 2×10^5 protons/sec.

The beam has an energy of 296 Mev, which corresponds to a first scattering angle of 17° if one assumes that the energy change is due to nucleon-nucleon scattering ($E = E_o \cos^2\theta$). This angle agrees with the angle obtained by plotting the orbit in the magnetic field for a particle of this energy. The pulses of beam as seen on an oscilliscope have a length of 100 μ sec. Thus the duty cycle of this beam is better by about a factor 4 than usual scattered beam; the intensity, however, is down by a factor of 10^3 from the usual scattered beam.

A scattering experiment was then performed using this beam in the cave. The second scattering target was also of carbon. The experimental arrangement was quite simple and consisted of a telescope of two stilbene crystals, each of which was viewed by a 1P21 photomultiplier tube. The 1P21's were doubly shielded by soft-iron housings. The defining crystal of the telescope has dimensions 1-in. x 1-1/2-in x 0.4-in. The crystals of the telescope were separated by 4-in. to allow insertion of absorbers between the crystals. The telescope was placed on one arm of the scattering table, which was free to rotate in the median plane. The carbon target was fixed so as to be always perpendicular to a line between target and telescope. This was done in order to reduce as much as possible the angular variation of the scattered intensity. The carbon target was 0.8-in. thick and its other dimensions were large compared to the beam dimensions.

In the scattering experiment we placed enough absorber between the crystals of the telescope so that only those particles having energy corresponding to the nucleon-nucleon scattering as defined above, or to an elastic scattering would be counted. The experimental quantity obtained is an asymmetry in the scattered intensity which is called e and is defined as $e = \frac{I_E - I_W}{I_E + I_W}$, where I_E is the intensity on the east side of the cave at a given second scattering angle and I_W is the intensity on the west side of the cave at that same second scattering angle. We have found e to be as large as 0.4 at 15°; e goes to zero at 30°. These data would indicate that the beam obtained has polarization of greater than 60 percent.

To insure that these effects were not due to misalignments, we have observed the quantity e at 15° as a function of absorber between crystals. When no absorber was present the asymmetry e became 0.05, and as more and more absorber was added the factor e rose to the value 0.4.

Further experiments are planned, in particular using liquid hydrogen as second scatterer, as well as an experiment of this type on the usual scattered beam to determine whether or not it is polarized and some experiments with scatterers of different materials to investigate the influence of Z or A on the polarization.

It must, however, be emphasized that the experiments described above have been performed only once and that there have not been repeat runs to confirm and measure quantitatively the effects.

SMALL-ANGLE NEUTRON-PROTON SCATTERING USING 90-MEV NEUTRONS

J. W. Easley and O. Chamberlain

The differential neutron-proton scattering cross section is being measured in the angle range 10° to 40° in the center-of-mass system. This range of angles was not covered in earlier counter experiments because the recoil protons (previously used to observe the scattering) were too low in energy, although cloud-chamber experiments have been made which included this range of angles. In the current experiment a neutron counter is used at small angles to the beam. Only the angular distribution is measured, and the magnitude of the cross section will be matched to that of previous work at an angle of 40° C.M.

This experiment uses a liquid-hydrogen target (1.0 g/cm^2) placed in the 90-Mev neutron beam and a neutron counter placed at small angles ranging between 5° and 20° in the laboratory coordinate system.

The neutron counter assembly uses the following components:

a) A copper absorber sufficient to stop protons formed in the target;

b) A thin (2 mm thick) plastic scintillation counter (counter I) connected in anticoincidence to cause charged particles that originate in the copper absorber to be eliminated from the events counted;

c) A CH_2 converter (about 1.5 g/cm^2) in which neutrons to be counted cause proton recoils;

d) A thin (3 mm thick) counter (counter II) connected in coincidence to register the recoil proton;

e) A copper absorber (about 3 g/cm^2) adjusted to the desired minimum neutron energy (about 60 Mev); and

f) The last counter (counter III), connected in coincidence to assure that only those protons are counted that are above the desired minimum energy.

Results of a recent run indicate that the neutron-proton differential scattering cross section in the laboratory system is about a factor of 2 greater at 5° than at 18.5°. Background counting rates are more or less as anticipated, and come principally from the metal (aluminum and stainless steel) parts of the liquid-hydrogen target. Counting rates taken with the CH_2 converter removed are down by a factor of 3.5. This seems reasonable in view of the calculated neutron conversion in the counters themselves. (Parts of both counter I and counter II contribute.)

The observed counting rates are quite sensitive to the low-energy cutoff set by the second copper absorber. A somewhat different counter arrangement using a larger counter in place of the present counter III will be tried in an attempt to reduce this sensitivity.

This scheme is not guaranteed of success because accidental background coincidence rates will be higher when the large last counter is used; however, it seems to offer some promise. If successful it will allow a better guarantee that the 10 percent change in energy of the scattered neutrons (which occurs when the counter is moved from 5° lab to 20° lab) does not cause appreciable change in the sensitivity of the neutron counter.

INELASTIC PROTON-DEUTERON SCATTERING USING 345-MEV PROTONS

R. D. Tripp and O. Chamberlain

It has been proposed to study the inelastic p-d scattering by measuring simultaneously the energies of two outgoing protons from p-d scattering events. It was proposed to do this by observing the pulse heights made by these protons in counters located at two different angles to the beam (one counter on each side of the beam). It was expected that among other things a momentum distribution for the deuteron would come out of this work.

At the present time this method does not look as good as anticipated, the obtainable pulse-height resolution in the counters being inadequate to give a clear measure of the deuteron internal momentum.

It is now planned to return to the method used by Bloom, and measure only the angular correlation of outgoing protons (irrespective of their energy).

FILM PROGRAM

Walter H. Barkas

I. The following articles and letters were submitted to the Physical Review for publication:

(a) "Yield of Low-Energy Protons and Alphas Resulting from High-Energy Bombardment of Ag," by R. W. Deutsch.

(b) "Range Distribution of Alpha-Particles Following the Decay of Li^8 and B^8," by F. C. Gilbert.

(c) "Pion Production Ratios by Proton Bombardment," by R. Sagane.

(d) "The Dependence of the 33-Mev π^+ Production Cross Section on Atomic Number," by R. Sagane and W. Dudziak.

(e) "The Dependence of Negative Pion Production on Neutron Number," by W. Dudziak and R. Sagane.

(f) "The Dependence of π^+ Production Cross Section on Atomic Number at Low Energies," by R. Sagane and W. Dudziak.

II. Additional UCRL reports were prepared as follows:

(a) "Meson Mass Measurements. I - Theory of the Mass Ratio Method", Walter H. Barkas, UCRL-2327

(b) "Employment of the Spiral-Orbit Spectrometer to Measure Pion Production Ratios by Proton Bombardment," R. Sagane, UCRL-2161.

(c) "An Alternative Interpretation of the Results on the μ-Meson Decay Electron Spectrum," R. Sagane, UCRL-2275.

III. Work was completed on a thesis for an M.S. degree in electrical engineering, "The Scattering of Electrons by Atomic Nuclei", by Peter Giles.

IV. Effort at present is chiefly concentrated on the following experiments:

(a) Extension of spallation reaction studies to high-momentum particles, to two-body disintegrations, and to the measurement of absolute cross sections.

(b) Selective scattering of gamma rays by atomic nuclei.

(c) Utilization of the spiral-orbit spectrometer as a meson and electron spectrometer.

SYNCHROTRON STUDIES

A. C. Helmholz

The operation of the synchrotron was satisfactory during the first two months of the period although leaks in a rubber boot adjacent to the resonator gave trouble. Finally a large leak opened up and it was decided to tear the machine down for a good overhaul. Since the machine had been in operation for more than a year, this procedure was undoubtedly advisable. Getting the beam back has not been so rapid as hoped, but experiments should be under way by November 15.

Fred Coensgen has completed his investigation of the electron Compton effect at 250 Mev. The results, which are incorporated in his thesis, show that the angular variation of the cross section agrees very well with the Klein-Nishina formula. The angles covered are 4° to 25°. The absolute cross section at 8°, where the most accurate data were taken, agrees with theory to about 15 percent, which is as far as the calibration of the number of quanta is now trusted.

G. Repp and R. S. White made some short runs, first to expose more nuclear emulsions to π^{+} photomesons at 0° from hydrogen, and then to attempt to count π^{+} photomesons from hydrogen at 180°. The counting rate at 180° with the setup used was not sufficient to make continued running worth while, so a revision of the setup is planned.

J. Jungerman completed his runs on the photofission cross section of U, Th, and Bi. The upper limit of the spectrum was varied and energies measured on the pair spectrometer. Results were good except for Bi, where the counting rate is very low and statistics are poor. Present results indicate the cross section continues to rise up to 330 Mev.

C. McDonald made a further run on the CH_2 - CH difference in absorption of 300-Mev quanta. The operation of the synchrotron was not so good as hoped, so the results need improvement. At least one further run will be required.

The calibration program which has been carried on mainly by W. Imhof has progressed fairly well so that Berkeley results on the basis of Blocker-Kenney tests, Cornell and Illinois results on the basis of their standard chambers, are all in quite good agreement. The discrepancy is about 10 percent with a few points remaining to be looked into.

THEORETICAL GROUP

David L. Judd

I. Nuclear Physics

In the strong-coupling treatment of Bohr and Mottelson (in the coupled single particle–collective mode model of the nucleus) only axially symmetric deformations have been considered. The question of whether in certain cases the nucleus is asymmetrically deformed (i.e., is a three-axis ellipse) has been investigated, and preliminary considerations have indicated an affirmative answer. (Segall)

Investigations of polarization effects in proton-deuteron scattering continues. It has been found possible to treat this process formally as a two-body process, and detailed calculations are now under way. (Tamor)

Work is continuing on the theory of the energy spectrum of the high-energy neutrons produced by proton bombardment in the cyclotron. (Vaughan)

II. Meson Physics

An estimate is being made of meson and nucleon production cross sections by high-energy nucleons. A statistical model is being employed which is based on a generalization of Fermi's treatment. (Lepore and Stuart)

Work was started on an extension of Fermi's method of high-energy processes based on the idea of the grand canonical ensemble. (Neuman)

The first-order corrections to the impulse approximation are being studied, in order to assess its applicability to the scattering of π-mesons by bound systems. The corrections include multiple-scattering effects and those arising from the binding potential. (Segall)

The phenomenological study of meson production in proton bombardment of nuclei has been completed. A very good fit of the data for π^+ and π^- production at 13 and 27 Mev from various nuclei from aluminum to lead has been obtained by taking into account the proton energy degeneration and meson reabsorption. (Gasiorowicz)

An impulse-approximation calculation of the reaction $n + d \rightarrow \pi^- + p + d$ has been carried out under the assumption that meson production results from n - n collisions only. The experimental p - p π^+ excitation function and angular dependence are taken to apply to the n - n π^- process by assuming charge symmetry. (Huddlestone and Macdonald)

A thesis is being written on the nucleon Compton effect and on high-energy deuteron photodisintegration. (Huddlestone)

III. Field Theory

Maxwell's equations are being studied in general coordinate systems in order to examine the transformation properties of classical radiation. The field of a charge at rest in an arbitrarily moving (i.e., noninertial) system has been obtained; when transformed to an inertial system, in which the charge's motion is arbitrary, the conventional velocity and radiation field are obtained. (Bludman)

Attempts to treat the divergencies of the relativistic two-body equation by Riesz's method are being made. (Neuman)

The Bethe-Salpeter equation for a deuteron has been considered in the adiabatic limit, with rigorous inclusion of the negative energy components. An estimate indicates that neglect of these components by other workers may have been unjustified, and the first nonadiabatic corrections to the second-order potential have been calculated. (Arnowitt and Gasiorowicz)

Work on the meson-nucleon equation in the adiabatic limit is continuing. Methods for numerical solutions are being considered. (Arnowitt)

An approximate method solving the quantum mechanical problem of meson scattering from a fixed nucleon has been developed, and has been applied to the charged scalar meson field. In finding the cross section, attention is focused upon the matrix elements of the field and isotopic spin operators and on the equations of motion, no attempt being made to calculate explicitly the scattering-state vector. It has been demonstrated that in both the weak and strong coupling limits this procedure gives the scattering correctly. For intermediate coupling the cross section is found numerically using information obtained from the Tomonaga solution of the one-body problem (one real nucleon, no real mesons). Curves of cross section vs. energy have been computed. It has been found that this same approach gives the correct isobar separation in the strong-coupling limit and thus may be regarded as an alternative method of carrying out strong-coupling theory. Details may be found in UCRL-2341. (Riddell and Fried)

IV. Miscellaneous

Some work has been done to establish a suitable set of parameters for a linear accelerator for heavy ions (C, N, and others). It should be possible to use magnetic strong focusing for most of the length, thus eliminating most of the grid losses. It was tentatively decided that the machine would require an ionization of at least C^{4+} and similar specific charges for the other ions in order to be economically practicable, but the question is still under study. (Smith)

An investigation of eddy-current distribution in the 184-inch cyclotron dees resulting from rapid changes in the magnetic field is being made to aid in determining the structural strength required of the new dees. (Judd)

The Milne problem for the infinite slab has been formulated as a Fredholm equation by integrating the transport equation. The Neumann expansion, appearing as an expansion in number of collisions, seems applicable where age theory is not. (Bludman)

The calculations of target corrections to bremsstrahlung in platinum and copper have been completed and will be reported upon soon. (Tamor)

ACCELERATOR OPERATION AND DEVELOPMENT

184-INCH CYCLOTRON OPERATION

J. Vale

A new type of ion source was installed during this period for the purpose of studying beam conditions. This ion source, in contrast to the standard open one that is normally used, had the arc enclosed inside a thin-walled tube. The outside diameter of this tube was 1/4 inch. In addition, the arc was of the cold-cathode type, in contrast to the standard source which employs a hot filament. Furthermore, feelers were installed on the dee and the dummy dee to reduce the gaps between the ion source tube and the dee to approximately 1/4 inch and thus increase the electric field gradients. In addition, a rod was inserted on the dee feelers and a plate on the dummy dee feelers to straighten the electric field in the region of the ion source.

In order for the ions to clear this arrangement of ports during the first few turns, it was necessary to raise the dee voltage during injection time by about fifty percent.

This ion source was expected to do two things: (1) increase the beam current, and (2) decrease the radial oscillations. The beam current obtained was only about one-half of that normally obtained, but it was found upon removal of the ion source that the arc may not have been properly distributed along the tube. However, it was definitely established that the radial oscillations of the beam were less with this source and thus will be a help to the program of beam extraction after the conversion of the cyclotron to a higher energy.

As has been reported earlier, there is a condition in the 184-inch cyclotron by which the magnet-cooling oil in the upper coil tank can seep into the vacuum system. At the time of the proton conversion, considerable effort was made to seal the oil away from the system. However, in the past few months there was evidence that this oil was again leaking into the vacuum. It was hoped at that time that this difficulty would not cause too much trouble until it could be eliminated. It was planned to repair the defective pole slab at the time of the higher-energy conversion, when it

could be removed. The seepage became too great, however, and steps had to be taken to correct this trouble. Fortunately, most of the leaks could be reached and temporarily repaired, and it now looks as if the oil seepage has been controlled for the present.

184-INCH CYCLOTRON MODIFICATION

Marvin Martin

Magnet

The auxiliary coil tanks were fabricated, machined and vacuum-tested during this quarter, and one of them has been delivered to Westinghouse in preparation for coil winding. All materials required for coil winding are on hand with the exception of a portion of the silicone glass tape with which the conductor is to be wrapped. A portion of this order was returned to the supplier for correction of some defects in its manufacture.

The pole disc blanks have been received and the machining is nearly complete on the first disc. Design work is nearing completion on the pole-base and pole-tip bolts with the strain gages for insuring that the initial prestress is not relieved during operation. Planning is well along on the sequence of operations involved in installing the auxiliary coils and new pole pieces.

The model magnet measuring program has reached the point where preliminary shim design can be started. Final shims, however, must be adjusted on the full-scale magnet to achieve the desired precision in the magnetic field.

Radiofrequency Design

The half-scale rf model has been operating throughout its frequency range and has verified the calculations of frequency, voltages and currents. Several parasitic modes of operation appeared during the tests and means of eliminating them have been devised. The rf geometry is now frozen, and detailed design is proceeding.

The calculation has been made of forces on the dee caused by eddy currents interacting with the magnetic field in case magnet excitation should be lost. This calculation resulted in redesign of the dee-insulator

supports to insure against their breakage should such a situation arise for any reason, e.g., power failure. The oscillator and transmission-line geometry has been tentatively selected. Some additional work remains on the model to verify the points.

Vibrating Condenser

The forgings from which the vibrating blades are to be made have been completed and inspected by ultrasonic means. Negotiations are nearing completion for the selection of a machining contractor for these parts. Some difficulty has been encountered in finding a machine shop with facilities for drilling the holes through which the controlled-temperature water is passed. These holes require extremely careful machining in order to prevent weakening of the blades. A method similar to that used for gun-barrel drilling is now available and it is believed will be satisfactory.

Deflector and Experimental Arrangements

A cost estimate of the pulsed magnetic channel deflector scheme has indicated that this component will be very expensive. It has, therefore, been decided to postpone the decision as to whether or not to construct this item until after a circulating beam has been obtained and measurements made of the amount of beam that reaches a radius equal to $n = 1$. If a reasonable fraction of the beam reaches this point, as it does in other cyclotrons similar to the 184-inch it is believed that a much simpler deflector scheme can be designed, resulting in obtaining a deflected beam. It is believed that this extra delay can be limited to about two months or less.

60-INCH CYCLOTRON

William B. Jones

INTERNAL BEAM DEFLECTION

G. Bernard Rossi

The deflection of internal cyclotron beams has presented many problems, including voltage requirements of the deflector, geometry associated with exit opening, deflector curvature and exit strip design. Two types of deflecting systems are in common use—the rf shielded system or the unshielded system. The unshielded type offers the advantage of lower DC potentials, since some aid is obtained from the rf voltage gradient.

An unshielded rf deflector*, grounded through a vacuum condenser to permit varying amounts of DC voltage to be applied, is used with the Crocker Laboratory 60-inch Cyclotron. The entrance to the deflector channel is lined with a tungsten exit strip, cut with a V shape to simulate erosion patterns caused by bombardment with high-energy ions. This type of strip has been used for some time and has performed satisfactorily in that no water cooling is necessary. Under these conditions from 10 to 20 percent of the internal beam is deflected, which is normal in comparison with other machines.

We were able to further evaluate our deflecting method by varying the geometry of both the deflector and the exit strip. The first step taken was to install an open-section tubular deflector (Fig. 1) which would permit ions of large radii to negotiate the channel geometry. The original tube spacing (one-half inch) was unsatisfactory because of two related reasons: (1) the rf voltage gradient was too low for normal deflector-to-dee wall spacing and (2) excessive dee voltage (DC) was needed to compensate for the lack of rf voltage. In addition, a large amount of P. I. G. electron oscillation between tubes caused excessive drains. A tubular separation of 1/8 inch was tried and proved more satisfactory. Beams were recorded of 15 microamperes of alpha particles at 75 kw of power. Operation under this arrangement was hampered by the need for high DC voltage—in excess of that available without heavy corona discharge. A standard deflector, grooved at the heel to allay beam erosion, produced 33 microamperes of alpha-particles at 65 kw with DC voltage of 25 to 35 kv, compared to the

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* UCRL-759, p. 30

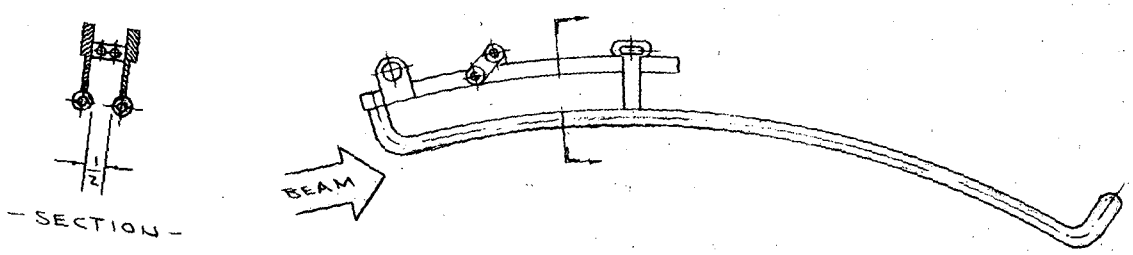


Figure 1

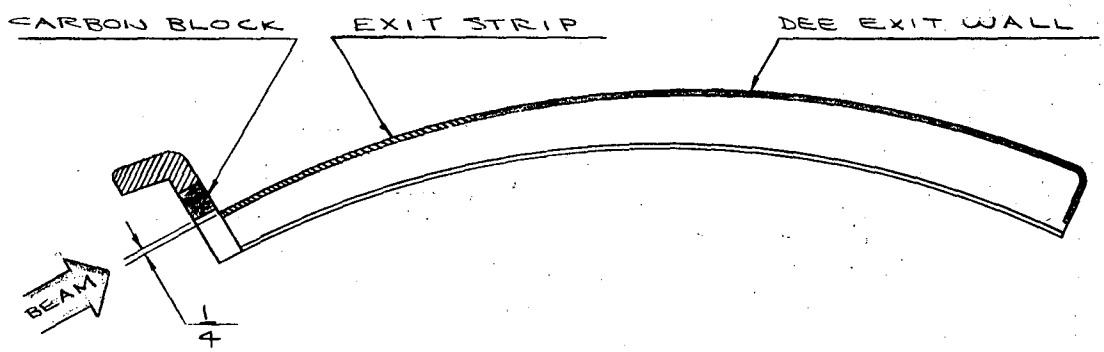


Figure 2

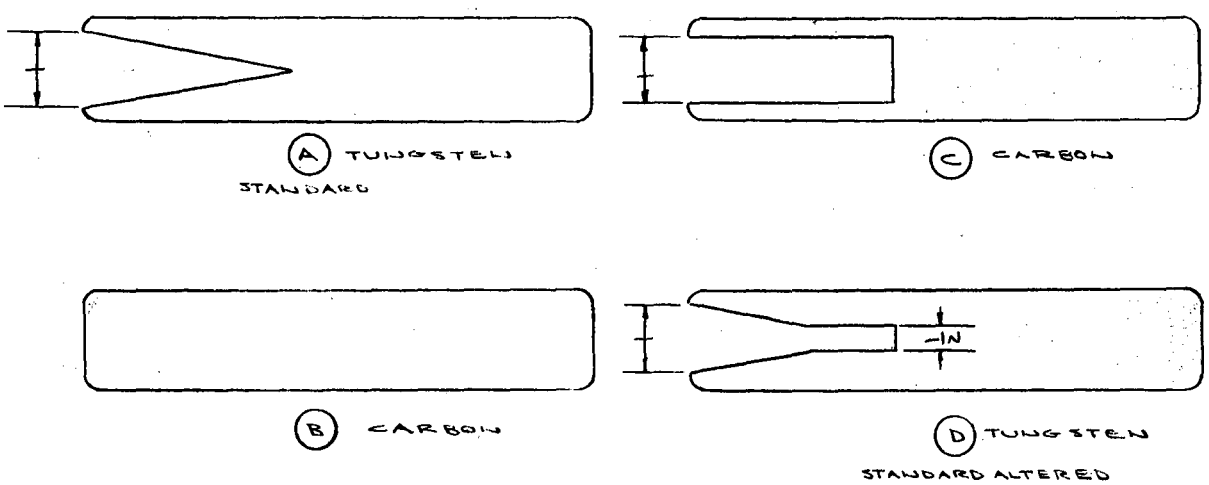

A TUNGSTEN
STANDARD
C CARBON
B CARBON
1N
D TUNGSTEN
STANDARD ALTERED

Figure 3

40-plus kv required by the tubular model. The resulting opinion is that an open-style deflector can operate beneficially when the DC voltage requirements can be met.

The standard V-notched tungsten exit strip was replaced by a solid carbon sheet, 1/32 inch thick. In addition, the entrance to the channel was narrowed from 1 inch to 1/4 inch, by the insertion of a 3/4-inch carbon block (Fig. 2). This limitation was set to determine the effective width of this entrance. Exit strips A, B, and C of Fig. 3 were run with this block in place.

Table I

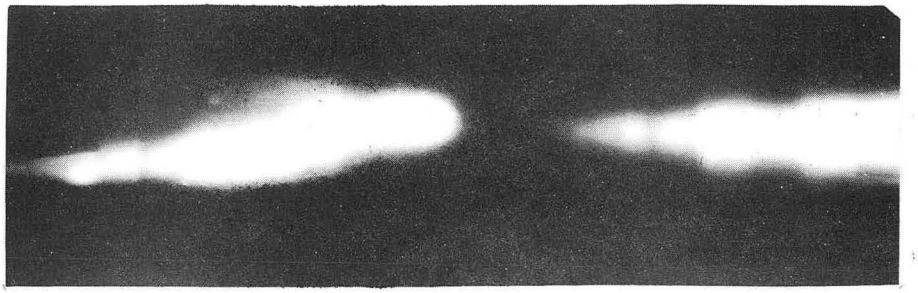
Operational Characteristics of Various Exit Strips

Exit Strip	Material	Autograph	Maximum Alpha Beam (ua)	Deflector Voltage (kv)
A	Tungsten	A	25	30
B	Carbon	B	6	--
C	Carbon	--	Unstable	Unstable
D	Tungsten	D	33	--

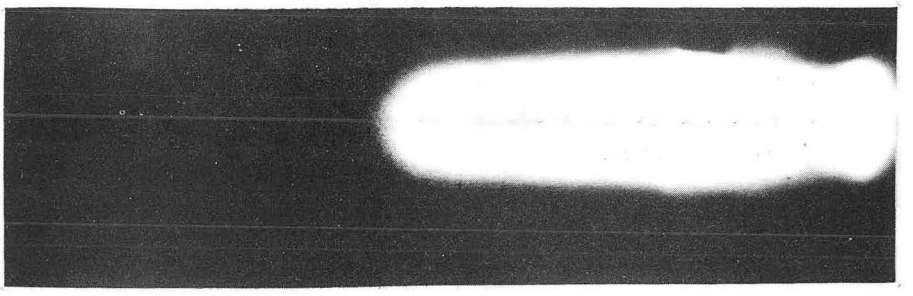
Autograph A was taken after operation with standard, grooved and tubular deflectors. The mirror image of the V notch recorded on the solid tungsten surface indicates that the beam entered the deflector channel through the notch but had not been deflected down the channel. The major amount of the image beam activity was accumulated with the 1/2-inch tube spacing, as no other autographs evidenced these results.

Autograph B taken on the solid carbon strip was overexposed, but indicates a splitting of the internal beam before entrance to the channel in the manner shown in Fig. 5.

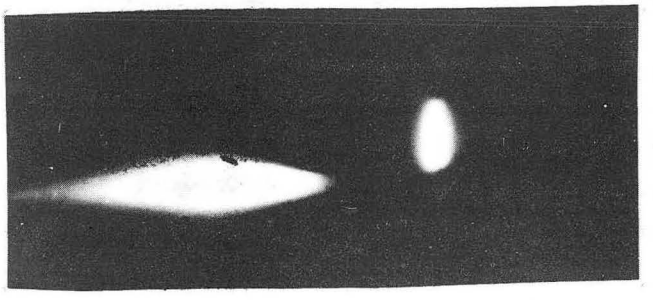
It is presumed from Autograph B that the point of tangency of the beam to the exit strip was at Point P (Fig. 5). This distance became the basis for notching Strips C and D. Strip C proved ineffective since the 1/32-inch carbon split and caused considerable arcing difficulty. Strip D, cut from a standard V-notch tungsten strip, performed very satisfactorily.



Autograph A



Autograph B



Autograph D

Figure 4

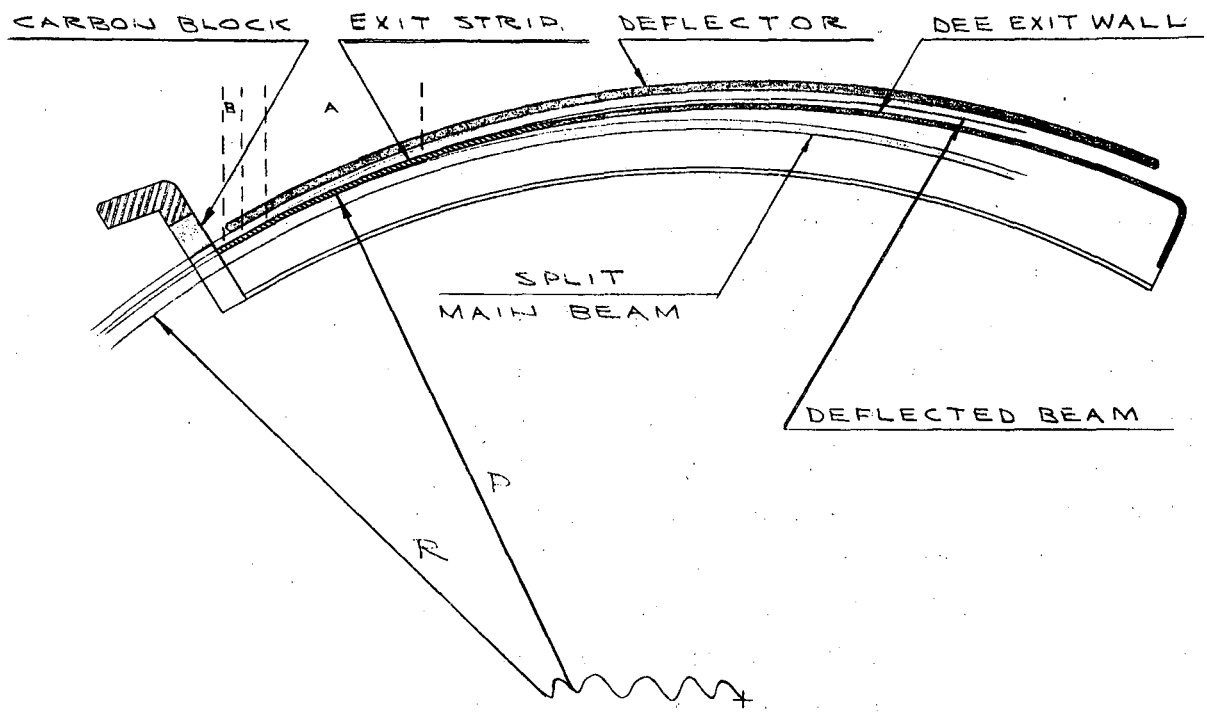

CARBON BLOCK
EXIT STRIP
DEFLECTOR
DEE EXIT WALL
B
A
SPLIT
MAIN BEAM
DEFLECTED BEAM
P
R

Figure 5

The alpha beam of 33 microamperes recorded was achieved without the carbon feelers.* In fact, the use of such a feeler reduced the beam by almost a factor of two, compared to an increase by a factor of three caused when Exit Strip A was used. The reasons for such inconsistent performance become evident upon comparing Autographs A and D. The large amount of activity along the V notch of Autograph A indicates the loss of a large amount of beam along this edge, while much less beam is lost on Strip D. When the feeler is used with Exit Strip A, a reduction in verical particle oscillation (greater than two) results in a sharply increased external beam. Opening Exit Strip A, as with Strip D, has the same effect. Beam patterns taken at the exit port indicate that with the feeler–Strip A combination, a vertical beam height of 1/8 inch is achieved; without the feeler, but with Exit Strip D, the beam height is more than 1/4 inch. When the feeler was installed with Strip D, the reduction of beam seemed to be caused by a larger radial oscillation induced by the feeler, causing the ions to be blocked by the carbon insert in the deflector channel. From external beam patterns, evidence for this beam reduction showed the horizontal beam width to be approximately one inch without the feeler but approximately three inches with the feeler. Further evidence was obtained when an optical system was used to view the exit strip under bombardment. Without the feeler, no evidence of heating occurred on the carbon block used to reduce the deflector channel opening; with the feeler, the carbon block was intensely heated.

Results indicate that (1) the feeler is a useful tool for regulating the vertical oscillation of the beam, (2) a strip of type D, designed to eliminate the low field gradient (deflector voltage) at its entrance edge, helps deflection, (3) a grooved deflector provides a wider channel without loss of gradient. This combination is being prepared and results will be reported later.

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*UCRL-2241, p. 33

Operation Summary, August - October, 1953

Alpha bombardments	207.0 hrs.
Deuteron bombardments	110.0 hrs.
Proton bombardments	188.5 hrs.
Carbon bombardments	16.0 hrs.
Nitrogen bombardments	55.0 hrs.
Experiment and development	288.5 hrs.
OPERATION TOTAL	865.5 hrs.
Outage	242.0 hrs.
AVAILABLE TIME	1107.5 hrs.
Shutdown--week ends	1092.5 hrs.
Labor Day holiday	8.0 hrs.
Daylight Saving time change	1.0 hrs.
TOTAL TIME	2209.0 hrs.

Operation efficiency: 78 percent.

SYNCHROTRON

George C. Mc Farland

No difficulties were experienced in operating the synchrotron during the first half of this report period. During August, however, a fissure developed in the gasket joining two of the quartz sections. This fissure was successfully patched but gained in proportions until patching was no longer possible. Early in October the synchrotron was disassembled, and the vacuum gaskets were replaced. At this time a new resonator section was installed in place of the original section. Toward the end of October, reassembly was completed. As was expected, it was extremely difficult to gain a full-energy beam. A survey of the magnetic field showed considerable loss in the field at the location of the new resonator. Efforts at correcting this field error were under way at the close of this report period.

LINEAR ACCELERATOR AND VAN DE GRAAFF

J. D. Gow

Operation

There was no operation of the linear accelerator for the first month of this quarter. The rebuilding of the Van de Graaff required by the mechical failure of the textolite high-voltage terminal supports was completed around August 20. During this period a complete new control system was installed. The new system uses a single string from the high-voltage terminal to ground for each control function. A large amount of electrical complication in the old high-voltage shell control circuits was eliminated. On September 2, the linear accelerator and Van de Graaff were returned to routine operation.

Measurements on the background neutron level in various areas of the building had shown that additional shielding was needed. Therefore, a one-foot-thick concrete wall was installed along the south side of the machine, as well as some temporary shielding along the beam exit pipe between the accelerator and bombardment area. New measurements to determine the neutron reduction attained by this shielding are underway.

Oscillator Group

The oscillator group (J. V. Franck, Glen Eckman, Ken Ehlers) has been engaged in the design of a new type of coupling loop for coupling the oscillators into the linear accelerator resonator. This loop will be designed in such a way that the coupling can be varied from outside the vacuum without breaking the vacuum. This will make possible even loading of the oscillators. They have also continued work on the pre-exciter, which will use an Eimac 4W20000 tetrode. This pre-exciter will replace the old BC677 radars on both the 40-foot linear accelerator and the bevatron injector.

Statistics (Aug. 16 to Oct. 31):

Running time	496 hours	70 percent
Repair and Maintenance	208 hours	30 percent

BEVATRON

W. M. Brobeck

Magnet

The magnet assembly was completed during the period and the magnet was first energized on October 2. During the month of October about 3,000 pulses were applied. The first week was spent in debugging the motor-generator equipment which had not operated since the fall of 1952. The remainder of the month was spent preparing for measurements of the magnetic field. This work was somewhat delayed by trouble with electronic measurement equipment. It is hoped to start routine measurements during the first part of November.

Vacuum System

The vacuum system was pumped down for the first time on August 27. During the four pumpdowns prior to opening the tanks for magnetic measurement equipment, a minimum pressure of 10^{-5} mm was reached without liquid nitrogen. This is expected to be adequate for operation.

It was found that 16 to 24 hours of roughing was required before the diffusion pumps could be started, apparently owing to the adsorption of water vapor inside the vaccum tube. Some method of reducing this time

through the use of refrigerated forevacuum lines is being sought.

Injector

The ion gun and linear accelerator have been running quite steadily during this period, being used for proton scattering. It was decided to change the deflection angle of the inflector from 40° to 35° in order to increase the energy acceptance of the inflector.

Tests are also to be made with the ion gun in line with the linear accelerator, rather than through the deflecting magnet now used, in the hope of increasing the beam current. The linear accelerator output beam is now about 70 microamperes peak at 9.8 Mev.

The machine work on the inflector electrodes was completed at the end of October and assembly of the complete inflector is in progress in the shop.

Accelerator

A radiofrequency voltage of about 25 kv has been obtained over the full frequency range on the accelerating electrode using the power amplifier tube as a self-excited oscillator. Some testing was done with the magnetic field under vacuum. This indicated that biasing of the electrode would be necessary to prevent a glow discharge and that magnetic shielding of a number of electronic components was needed.

The magnet current peaking transformer and shunts have been installed and their testing is in progress. The master oscillators and frequency control components have not yet been installed in the machine.

Shielding

Bids have been received for concrete shielding and for the work required to provide foundation for the shielding wall. It is expected that the foundation work will begin during the month of November.

Schedule

Three to four weeks of magnetic measurements will be required which, it is hoped, will start early in November. After this the magnet will be shut down and the installation of the pole-face windings will be completed. At the same time, the inflector and beam pickup electrodes will be installed and the linear accelerator moved into its final position. It is barely possible that some operation will be obtained by the end of the year.

Information Division
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