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PHYSICS DIVISION QUARTERLY REPORT

November, December 1954, January 1955

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Radiation Laboratory, Department of Physics
University of California, Berkeley, California

March 15, 1955

GENERAL PHYSICS RESEARCH

PHYSICS RESEARCH

Luis W. Alvarez in charge

SCATTERING OF 30-Mev PROTONS FROM CARBON

George J. Hecht

The investigation of the scattering of 30-Mev protons from carbon is nearing completion. Proton groups due to excited levels of carbon have been found at excitations of 4.4, 7.5, 9.6, and approximately 15 Mev. Angular distributions of the elastically scattered protons and of protons inelastically scattered so as to leave the nucleus with 4.4 Mev of excitation have been taken every 5^{o} from 10^{o} to 160^{o}.

The differential cross section for the 7.5-Mev level is so low that one can only assign upper limits to the actual value of the cross section.

An angular distribution of the 9.6-Mev level has been made with data taken every 10^{o} at forward angles. Some additional data are still needed for the 15-Mev level.

A lower-energy group of scattered particles has successfully been shown to be deuterons from $p + C^{12} \rightarrow d + C^{11}$ by using $\frac{dE}{dx}$ and E counters to identify the type of particle. All the angular distributions so obtained are now being compared to the theoretical distributions of Austern, Butler, and McManus. The deuteron distribution will be compared to normal Butler Theory predictions.

ENERGY LEVELS IN BORON-9

Harrold B. Knowles

A thin proportional counter and other equipment are being prepared for a $p + C^{12} \rightarrow B^{9} + \alpha$ experiment. A differential range method will be used.

ELECTRON-NEUTRINO ANGULAR CORRELATION IN NEON-19

Myron L. Good and Eugene J. Lauer

The short exploratory run with the differential pumping apparatus and the movable-foil method of subtracting background turned out successfully, and therefore a long run was made to accumulate good counting statistics. This run was uneventful, and data from it are now being analyzed.

DIFFERENTIAL CROSS SECTION FOR 30-Mev ELASTIC PROTONS

John Leahy

The resolution of the pulse-height analyzer has been restored and work should proceed now on rhodium.

LIQUID-HYDROGEN GLASER BUBBLE CHAMBER

Luis W. Alvarez group

The 4-inch-diameter 2-inch-thick liquid-hydrogen bubble chamber has been successfully operated in the 5-Bev π^- beam of the Bevatron, at the current Bevatron pulse rate of once in 11 seconds. Probable multiple meson production and V-particle production and decay have been observed. Bubble-producing background was low. Lack of an analyzing magnetic field precluded accurate measurements. A 20-kilogauss field obtained from a pair of Helmholtz coils will soon be installed. A transient-pressure-measuring device has been installed on the chamber and is working successfully. It consists of a metal diaphragm in contact with the liquid hydrogen, and uses the variation of capacitance between the diaphragms and a fixed contact. The 4-inch chamber is being used for design studies for larger chambers. A dark-field illumination scheme has been tested with liquid-hydrogen tracks and works extremely well. It consists of a diffuse light source with "venetian blind" fins tilted at a slight angle to prevent direct light at 0^o from entering the camera aperture. Light scattered at small angles from the bubbles does enter the camera. Some tests have been performed to determine the suitability of lucite for construction of large bubble chambers. Tensile and impact strengths have been found to increase at liquid-hydrogen temperatures. Fatigue tests at liquid-hydrogen temperature are under way. A piece of lucite with different surfaces of varying roughness, and having scratches on polished surfaces, was inserted in the 4-inch hydrogen chamber and tracks were photographed in the chamber. No bubbles were seen forming on the lucite surfaces. Design studies are under way for a chamber of about 50 gallons volume. A chamber of this size should enable one to detect with high probability the decay of both members of neutral V-particles produced in the hydrogen. More immediate plans are for an 8-inch-diameter hydrogen chamber, to be used in an existing cloud chamber magnet delivering 22 kilogauss pulsed.

BEVATRON COUNTER EXPERIMENTS

Luis W. Alvarez, Frank S. Crawford, Jr.,
Myron L. Good, and M. Lynn Stevenson

A cursory search was made --but with negative results-- for a long-lived meson, ($\tau > 0.1$ sec) using a single large Cerenkov counter gated on after the Bevatron beam passed through a plunged target. A more careful search is contemplated.

A preliminary run was made on an experiment designed to determine whether or not the K- and τ-mesons are in fact alternate decay modes of the same particle.

ELASTIC SCATTERING OF 1.6-Mev γ-RAYS FROM NUCLEI

Luis W. Alvarez, Frank S. Crawford, Jr.,
and M. Lynn Stevenson

The elastic scattering of 1.6-Mev γ-rays from the hydrogen nucleus, at 130°, has been observed, through a LiH - Li subtraction. The Thomson cross section was obtained as a result, to about 25 percent statistics. Measurements at the same angle for Li, C, and Al all give the Thomson cross section, to about 10 percent statistics. At higher atomic numbers, the cross section may be rising above the Thomson cross section. The shape of the scattered γ-ray pulse height spectrum in NaI, however, also starts changing in the same atomic number region, and it is believed that the rise in apparent cross section is probably not a real effect. Measurements are in progress to settle this question.

PHYSICS RESEARCH

Walter H. Barkas in charge

OBSERVATIONS ON K^+-MESONS

Harry H. Heckman

The analysis of K-particle tracks found in emulsion that had been exposed to secondary particles from a target bombarded by 4.8-Bev protons is summarized in the following abstract:

Analysis of K^+-Mesons. Harry H. Heckman.

In a stack of 600μ Ilford emulsions exposed to the secondary particles from a target bombarded by 4.8-Bev protons of the Bevatron, five K^+-mesons have been observed. Three of the heavy mesons decay into lightly ionizing secondaries. The other two are τ^+-mesons, having the characteristic 3π meson decay. The average Q value of the τ-meson decay is 74.8 Mev, with a probable error estimated to be approximately 1 Mev. The τ-meson mass is then 965.7 m_e (m_π = 273.2 ± 0.2 m_e). Mass measurements are being carried out on the K^+-mesons by residual range vs ionization and (or) integral gap length, using the τ-meson as the calibrating particle. One of the secondaries from the K^+-mesons has sufficient range to enable one to estimate the mass by multiple scattering vs ionization. The results of this analysis are: (a) the ratio of ionization to that of fast electrons is 1.032 ± 0.028, (b) the average pβc is 102 ± 14 Mev, and (c) there is an approximate 25 percent loss in pβc between the ranges of 1.25 and 10.25 mm. The properties of this particle are thus characteristic of an electron.

Additional data referring to this exposure are in this table.

Numbers of particles found in scanning 9.93 cm^2 of emulsion

Particles	π^+	π^-	p	K	τ
Numbers found	208	114	70	3	2

Another stack of emulsion was exposed specifically for the study of τ-mesons. The proton beam energy was 5.7 Bev. By the end of the report period six K-mesons had been found in this stack.

PRELIMINARY RESULTS ON THE "DIRECT" PRODUCTION OF K-PARTICLES

Frances M. Smith

A stack of G.5 emulsions was exposed directly to the 5.7-Bev proton beam of the Bevatron. The developed film was scanned for K-particle endings. When an ending was found, the track was followed back to its parent star in the emulsion. The present results are:

Parent Star	Prong Followed	Length in Film	Ending
8 + 5p	K^+-particle	3.3 mm	1 fast secondary
9 + 3p	K^+-particle	4.8 mm	1 fast secondary
21 + 3p	K^+-particle	8.9 mm	1 fast secondary
10 + 4p	K^+(possible)	0.3 mm	1 fast secondary
8 + 7p	K^-(probable)	2.1 mm	2 fast prongs (1 stopped--30-Mev π^-)
18 + 6p	τ^+-particle	3.8 cm	3 secondaries (1 stopped--28-Mev π^+)

Two more K^+ and one τ^+ have been found but have not yet been traced back to their parent stars. To date none of the other prongs of the parent stars has been studied. This work was done in collaboration with Sulamith Goldhaber.

MAGNETIC ANALYSIS OF SECONDARY PARTICLES FROM BEVATRON TARGETS

Walter H. Barkas, Frances M. Smith, and Harry H. Heckman

When a flip-up target placed at a Bevatron azimuth angle of 5° is used, it is possible to extract through a thin window both positive and negative beams of particles. The momentum selected is $\approx$ 350 Mev/c. "Beams" of both positive and negative pions, positive K-mesons, and protons have been observed.

NUCLEAR TRACK PHOTOMETER

Frederick W. Inman

A model of a photometer has been built with which it is hoped to improve the rapidity and reliability of track identification. No adequate tests have yet been made of the instrument, and a period of time will be required to calibrate it and to train operators in its use.

DIRECT EXPOSURES TO BEVATRON BEAM

Walter H. Barkas and Peter C. Giles

A number of successful exposures were made in which emulsion stacks were plunged directly into the proton beam. Projections on the stack damped the radial oscillations and shifted the beam over to the center of the stack. Exposures in which the beam entered the emulsion perpendicular to the plane of the emulsion sheets were particularly interesting.

HIGH-ENERGY NUCLEAR DISINTEGRATIONS

L. Evan Bailey and Edward E. Gross

The neutron evaporation spectra from the following elements are being measured: C, Al, Ni, Ag, and Au. The absolute differential cross sections for neutron emission as a function of angle between 0.5 and 15 Mev under 200-Mev proton bombardment is being measured and correlated with the spectra of charged particles simultaneously emitted.

Scanning also has continued measuring the secondary charged particles produced. The reduction of the data on the cross sections has been completed for the protons on silver. Results indicate that

1. The center-of-mass velocity of the evaporating nucleus can be determined.
2. Low-energy deuterons are produced in a pickup process as well as in an evaporation process.
3. Alpha particles are produced principally in an evaporation process.
4. Cascade protons are produced at angles greater than 90° in what appears to be a double scattering process. Rough calculations indicate that the cross section for this process is proportional to A and to (the secondary energy)$^{-1/2}$ for energies lower than a cutoff energy.

INTERACTIONS OF HIGH-ENERGY ALPHA PARTICLES IN EMULSION

Dora F. Sherman

The interactions of 380-Mev alpha particles in Ilford G.5 nuclear research emulsion have been studied. The mean free path for star production is 18.4 ± 1 cm. The frequency distribution of the number of prongs per star is:

Number of Prongs	0	1	2	3	4	5	6	7	8
Percent	0	2.6	36.3	23.2	18.7	9.2	7.1	2.1	0.8

The average number of prongs per star is 3.3.

The star prongs have been divided into two groups, grey and black, according to their ionization. The grey prongs constitute 32.3% of the total number of prongs, and 12% of the stars consist entirely of grey prongs.

The angular distribution of the grey tracks is strongly peaked in the forward direction. Seventy-five percent of the grey tracks lie within 30° of the beam direction. The ratio of the number in the forward hemisphere to the number in the backward hemisphere is 93:1. The front-to-back ratio of the black prongs is 2.8:1.

A lower limit of 20% has been established for the number of events occurring in light nuclei.
Barkas

THEORETICAL GROUP

David L. Judd in charge

A review article is being written on the operator formalism in quantum perturbation theory. It will cover the forms which the abstract operator algebra takes and the relationships between these forms in the following fields: (a) simple scattering theory, (b) adiabatic switching formalisms, (c) bound-state perturbation theory, (d) field theories with renormalization, (e) theory of decay, resonance scattering, line breadth, and the Lamb shift, (f) scattering by many potentials and the theory of nuclear reactions. (Bryce DeWitt)

The relativistic scattering of electrons from protons is being studied. (Sidney A. Bludman)

The fringing and aberration corrections for a magnetic spectrometer, reported on at the Berkeley meeting of the American Physical Society, have been extended consistently to third order, by a new method specialized to symmetric arrangements of source and detector. (Sidney A. Bludman and David Judd)

Work is being continued on an iteration of the Tomonaga approximation.[1] Preliminary calculations for the charged scalar theory indicate that the second iteration deviates from the first iteration just as much as the first iteration deviates from the Tomonaga approximation solution. These calculations are being checked. The procedure is being applied to pseudoscalar symmetric theory. (Kent K. Curtis)

The probability distribution of the force due to a random distribution of particles generating a Newtonian potential (the so-called Holtzmark distribution) has been investigated. One of the difficulties encountered in working with this distribution is that moments, beginning with the second one, do not exist. The divergence of these moments is a reflection of the singularity of the potential at the origin, i.e., there is no mechanism for preventing a particle from getting close to the origin. Clearly the nearst neighbors call for a more careful dynamical treatment, where the correlations are not disregarded. A distribution, excluding N nearest neighbors from statistical considerations, has been derived. (Stephen Gasiorowicz, Maurice Neuman, and Robert J. Riddel, Jr.)

The dynamical friction may be defined as the expectation value of the force acting on a particle which moves in a field of force due to other particles. This quantity has been studied using: (a) a hydrodynamical approach in which the modification of the distribution function of a system due to the introduction of a test particle moving with a fixed velocity under the assumption of small deviations from equilibrium, and (b) a statistical approach using the modified Holtzmark distribution, for which second moments exist. (Robert J. Riddell, Jr., Maurice Neuman, and Stephen Gasiorowicz)

[1] Dalitz and Ravenhall, Phil. Mag. 7 42, 1378 (1951).

A strong-coupling treatment of the Foldy transformed pseudoscalar (γ_5) Hamiltonian is being considered, with reference to the low-energy S-wave meson-nucleon phase shifts. (Charles Goebel)

The implications, for electron-proton scattering, of the meson theory explanation of the nucleon magnetic moments are being studied. (Charles Goebel)

The elastic and inelastic scattering of nucleons from nuclei has been considered. The relation between the optical-model potential and the density distribution of nucleons has been examined. It can be shown that the real and imaginary parts of this potential have different radial dependences. The inelastic scattering of nucleons from nuclei is being examined with reference to current experiments at the linear accelerator with 32-Mev protons. (Warren Heckrotte)

Further studies are being continued on isotopic spin and its theoretical significance. (Joseph V. Lepore and Sidney Bludman)

A paper was presented at the Chicago meeting of the American Physical Society on the validity of the isotopic spin quantum number for light nuclei. Present experimental evidence for a charge-independent interaction between nucleons is very convincing. (William M. MacDonald)

The main features of the problem of ejecting the high-energy beam from the Bevatron have been studied. The initial displacement of the beam has been accomplished, but calculations indicate that removal of the deflected beam will necessitate considerable structural modification. (Lloyd Smith)

Design of the heavy-ion accelerator has been completed. Some of the work concerning radial focusing has been incorporated into a paper to appear shortly in the Review of Scientific Instruments. (Lloyd Smith)

Work on the nature of the nucleon-nucleon potential, as determined from scattering data, is being continued. It has been proved that specification of the energy dependence of the S-wave phase shifts through the shape-dependent term of an effective range expansion is equivalent to specification of the S-state potential at a discrete set of four points. The energy range over which such a representation of the scattering is accurate (0 to 50 Mev) is adequate to distinguish one from the other all the usual potential shapes. Insertion of the correct phase shift, as obtained by the Lomon-Feshbach fit, over this energy range produces a potential exhibiting an anomalous behavior, which is believed to indicate the existence of a short-range core. Computations will soon be started on a more accurate treatment, which will determine the potential that implies the correct scattering over an energy range 0 to 250 Mev, and which will be sufficient to reproduce the core feature, providing its range is not less than 10^{-14} cm. (Robert B. Raphael)

Tomonaga's description of Fermion states in terms of a sound-wave assembly is under investigation for nuclear matter. One consequence of such a treatment is the prediction of a set of dilatational collective coordinates in addition to the usual Bohr coordinates. The energies of such levels can also be estimated phenomenologically from the nuclear compressibility. There are strong indications that $0^+ \rightarrow 0^+$ transitions in nuclei may correspond to

the lowest radial dilatational level. (Alfred Reifman)

A phase-shift analysis of the Berkeley experiments on proton-proton scattering and polarization is being carried out. Eight phase shifts are used to describe the data (S, P, D, F). The program of determining them has been coded for the Univac and the calculations are going forward as machine time permits. (Henry Stapp)

PHYSICS RESEARCH

Burton J. Moyer in charge

NEUTRAL-MESON PRODUCTION IN PROTON-PROTON COLLISIONS

Robert K. Squire

We have measured the intensity at two angles of the decay gammas from neutral mesons produced in proton-proton collisions at 340 Mev. Equations have been developed that will allow the deduction of the angular distribution of the neutral mesons in such events. Also, the excitation function has been measured by counting the gamma emitted at one angle for various incident proton energies below 340 Mev. To analyze the data, the efficiency of the gamma telescope must be known, and this has been checked by measurement of the (known) neutral-meson spectrum at two angles emitted from an internal carbon target bombarded at 340 Mev.

NUCLEAR GAMMA-RAY SPECTROSCOPY

Charles N. Waddell, Hoyt A. Bostick and Harlan C. Shaw

During the month of November an attempt was made to detect the production of the previously reported 15.2 ± 0.2-Mev gamma ray by bombardment of carbon with the 90-Mev neutron beam. Preliminary measurements using a polaroid camera to photograph the pulse-height spectrum from a NaI(Tl) crystal indicated the presence of a weak high-energy gamma ray of approximately 15 Mev. Following the success of the trial run, the instrumentation was improved by using a 10-channel pulse-height analyzer of Radiation Laboratory design with the crystal. The neutron flux was measured by using the n-p cross section as determined in this laboratory. The relative neutron flux was monitored with a bismuth fission chamber.

Because of the large background, subtractions were made by measuring the pulse-height spectrum obtained when the crystal was shielded from the target by lead. The energy was determined by using the γ-rays from Na^{22} (0.51 and 1.28 Mev) and from a PoBe source (4.43 Mev arising from C^{12*}). This method gave an energy of 15±1 Mev. The uncertainty is largely owing to nonlinearity of the cathode follower and its associated circuitry.

We have produced a 15-Mev gamma ray from the bombardment of carbon by protons of energies ranging from 19 Mev to 340 Mev and neutrons of 90 Mev, but efforts to produce the gamma ray in the bombardment of carbon with 200-Mev alpha particles did not produce the line with observable frequency. This may be understood in terms of the postulated T = 1 assignment for this level, as the excited states produced by the collision of an alpha particle have the same T values as the initial nucleus. The ground state of C^{12} is T = 0, so that only T = 0 excited states would be produced.

ELASTIC GAMMA-RAY SCATTERING ON PROTONS

Larry L. Higgins

A run is planned at the synchroton to observe gamma rays scattered from protons. The beam energy will be set at 140 Mev to avoid gammas from π^0 decay. A ring of counter telescopes consisting of antiscintillation, converter, and two coincidence scintillators will surround the target at 90°. The total solid angle of counters is about 2 steradians. A new liquid hydrogen target is being made which will allow observation of scattered particles in almost any direction (solid angle ~10 steradians). Extensive lead and concrete shielding will be used to reduce background to workable level.

A STUDY OF THE REACTION $H^1(H^2He^3)\pi^o$ AT 340 MEV PROTON ENERGY

Kenneth C. Bandtel, Burns Macdonald, Burton J. Moyer and N. Fredrick Wikner

The counters constructed during the last several months did not prove to have sufficiently good pulse-height resolution to separate He^3 particles from other particles. These counters utilize four 1P21 phototubes at some distance from the scintillator. The scintillators viewed were crescent-shaped, with a long dimension of about ten inches, and a width of two inches. It is not clear that sufficiently good resolution can be obtained with this scintillator shape. This configuration is necessitated by solid-angle requirements.

An arrangement using one 5819 tube viewing a light pipe is being tried at the present time. A similar arrangement previously gave successful results with a four-inch-square crystal.

PHOTONS FROM HEAVY-MESON DECAY

John E. Osher and Burton J. Moyer

In the past three months two preliminary runs have been made to observe photons from heavy-meson decay. The gamma counter used consisted of a combination of plastic scintillator telescope and Cerenkov counter, all feeding into a multicoincidence circuit. The first check consisted essentially in testing the reliability of the above counter and its associated electronics equipment as used under the Bevatron duty cycle. The results were very good, showing the expected conversion efficiency (approximately 7:1, lead in:lead out) for lead and carbon. The check on the attenuation of gamma spectrum by use of copper absorbers also gave reasonable agreement for

the spectrum expected.

The second run with 5.7-Bev protons consisted of obscuring the Be target. A flux of gamma rays was observed in numbers and with fall-off in distance downstream as might be expected from reasonable kinematics of associated production of lambda and theta particles and their subsequent decay. A more refined experiment will be run in early February.

PHOTODISINTEGRATION OF THE DEUTERON

Dwight R. Dixon and Kenneth C. Bandtel

The second synchrotron run on this experiment has been completed. The purpose of the run was to obtain data at forward angles. The equipment used has been described in previous reports. In spite of our efforts to reduce background and improve particle identification, we obtained no satisfactory results at 24°. Data were taken at 36°, however, where it was possible to obtain a good separation of protons from the mesons and electronic background. The cross sections were not greatly different from those obtained previously at 49°. Forty-nine-degree data taken in this second run agree well with those obtained in the first run.

Information obtained at the cyclotron on nuclear absorption in the counter has not been entirely satisfactory because of the difficulty of obtaining clean low-energy proton beams. Therefore, another experimental determination of the nuclear attenuation has been made, using p-p scattering to obtain protons of various energies. Fairly consistent results were obtained and the corrections are being applied to the deuteron photodisintegration data.

Results of the experiment, including data at angles of 36°, 49°, 75°, 106°, and 141°, will be presented in a UCRL report.

LINEAR ACCELERATOR BETA-RAY SPECTROMETER

Roger W. Wallace and Selig N. Kaplan

A run was made with the β-spectrometer on October 22, 1954, employing the new decay-rate counters and the various adjustments designed to improve resolution. These adjustments, combined with a lower-than-average beam, gave too low a counting rate and the run was abandoned.

Several changes are being made to improve the counting rate while maintaining the resolution. A new set of two photomultiplier counters, operating in fast coincidence, has been installed viewing a single plastic scintillator through a Y shaped light pipe. Tests indicate a factor-of-ten increase in net counting rate over the former assembly of two plastic scintillators and four photomultipliers operated in double coincidence. In addition, at the operating voltages now being used, the noise rate has been lowered by a factor of five.

A change is now being made in the absorber location so that the proton beam can be attenuated immediately in front of the target, rather than several inches away with resultant scattering. A solenoid switching arrangement

is being designed and built to remove the absorber after each bombardment so that it will not interfere with the electron orbits in the spectrometer.

For the October 22 run, investigation was made of the production of thin targets by the technique using polystyrene film on glass. It has since been found that a variation of this technique involving the thorough pulverizing and mixing of the target material and liquid plastic with a ball mill yields targets of a more uniform density and permits a greater relative amount of target material.

All the phases of this program are at or near completion, and another run is expected soon.

PROTON BREMSSTRAHLUNG AND π^o-PHOTONS

Harlan C. Shaw, Selig N. Kaplan
and Charles N. Waddell

Analysis of the data for π^o production by 340-Mev proton bombardment of carbon has been almost entirely completed, and it has been possible to form the total gamma-energy spectrum by numerically integrating the energy spectra from the laboratory angles of 0^o, 46^o, 90^o, 134^o, and 180^o. If this spectrum is wholly due to the decay of the π^o, then this total spectrum will have the symmetry property such that, when plotted against the logarithm of the energy, it will be symmetrical about a mean energy equal to half the rest mass of the π^o. Our integrated spectrum shows this symmetry property very well except at low gamma energies where the effect of proton bremsstrahlung increases the gamma yield.

Analysis of data on proton bremsstrahlung obtained from 140-Mev proton bombardment of Be, Al, and Cu is currently proceeding. (See Fig. 1)

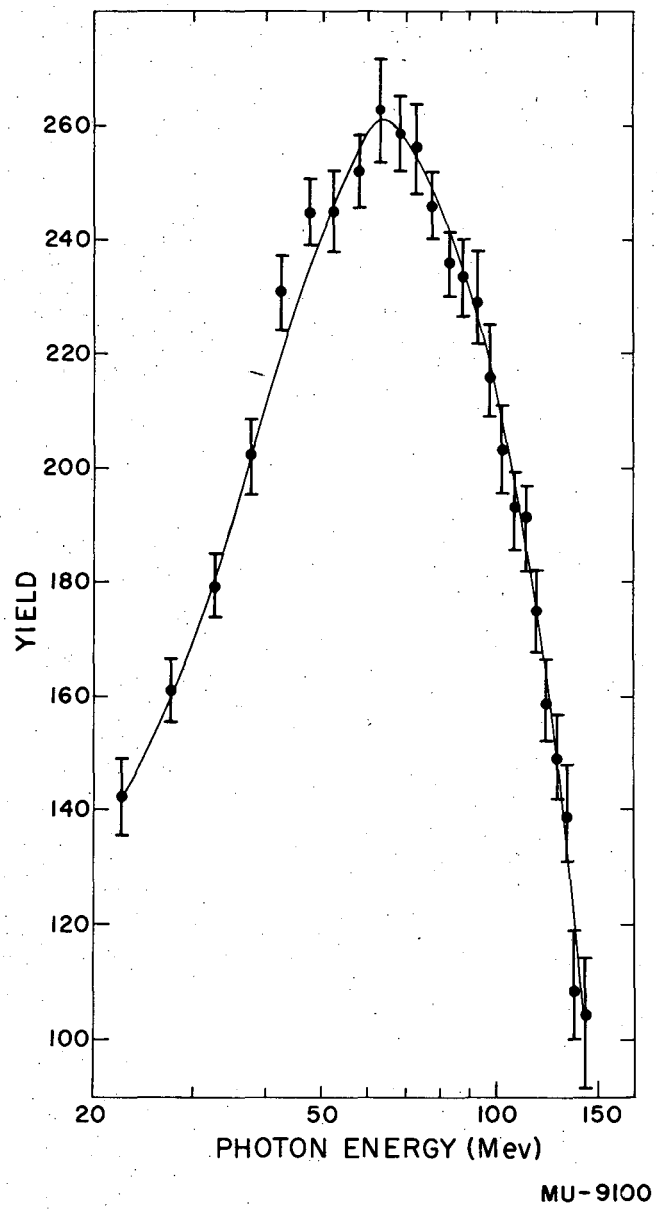

Fig. 1. Total spectrum from 340-Mev proton bombardment of carbon.

CLOUD CHAMBER STUDIES

Wilson M. Powell in charge

THE π^--MESON BEAM FROM THE BEVATRON

The properties of the high-energy π^--meson beam from the Bevatron have been investigated by use of the high-pressure hydrogen diffusion cloud chamber operating in a 22,000-gauss field for momentum analysis.

The π^--mesons from a 1-inch-thick carbon target plunged to 600 inches at the 13.75° target position were deflected and analyzed by both the Bevatron magnet and the new 5-foot steering magnet. With a 4-foot-long steel collimator having a 1-inch-high and 6-inch-wide slot placed between the Bevatron and the steering magnet a clean beam of negative particles was observed in the cloud chamber about 30 feet beyond the steering magnet. With an incident proton energy of 5.7 Bev, preliminary measurements indicate a momentum distribution of the π^- beam from about 4 Bev/c to 5 Bev/c with very little contamination below 4 Bev/c. The positive contamination appears to be zero. Useful discussions on collimation were held with Professor Arthur Rosenfeld of the University of Chicago.

HIGH-ENERGY π^--MESONS ON PROTONS

The interaction of these π^--mesons with protons is being investigated. To date two six-prong, 13 four-prong, and 29 two-prong stars have been observed in 45,000 meson traversals of the chamber. Many of the 2-prong events are inelastic. The total cross section for interactions giving charged outgoing particles is 16.8 ± 3.0 millibarns. This is somewhat lower than expected and may be due to μ contamination in the beam, which has not been measured yet.

In addition, the decay of 2 K-mesons and 40 neutral V-particles produced in the chamber wall have been observed.

REPORTS ISSUED

Recently completed studies have been reported in the following papers:

John L. Need, "The Mechanism of the Reaction $C^{12} + p \rightarrow p+3\alpha$ at 32 Mev" (Thesis), University of California Radiation Laboratory Report No. UCRL-2806, Dec. 3, 1954

George Saphir, "Scattering and Absorption of π^+-Mesons in Lead" (Thesis) University of California Radiation Laboratory Report No. UCRL-2833, Jan. 4, 1955

Peter H. Moulthrop, "Pion Production by Neutrons on Helium" (Thesis), University of California Radiation Laboratory Report No. UCRL-2858, Jan. 31, 1955

PHYSICS RESEARCH

Chaim Richman in charge

BEVATRON EXPERIMENTS

A. With the Bevatron running at 5.7 Bev, nuclear emulsion stacks have been exposed at 60°, 90°, and 180° to the primary beam. The 180° exposure utilized the focusing action of the Bevatron magnet to increase the signal-to-noise ratio. These plates are now being scanned for K-mesons.

B. An emulsion stack 4 by 6 by 2/3 inches was exposed to the 5-Bev/c negative pion beam from the Bevatron. The pions, collimated vertically to one inch, entered parallel to the 6-inch edge of the stack. The maximum track density is 15 passing tracks in a 200μ field of view, giving a total of $\sim 10^5$ pions per square inch entering the stack during the two-day exposure. These emulsions are now being scanned for stars caused by pion-nucleus interactions.

C. An attempt was made to take K particles at 90° to the beam direction from a copper target in the Bevatron and analyze them with a steering magnet after focusing with magnetic quadrupole lenses. A check of the focusing properties was made, using nuclear emulsions with protons of the same Hρ as the K particle. The focus was found and a test stack was exposed to look for K's. Examination of this stack is under way.

D. A preliminary run has been made to measure the half life of K-mesons that decay into high-energy secondaries. A scintillation-counter telescope records particles stopping in a copper block, and a Cerenkov counter detects the delayed secondaries. A second Cerenkov counter in the telescope is being used to discard particles causing prompt coincidences from scattering off the copper block.

CYCLOTRON EXPERIMENTS

The following abstracts have been submitted for the Washington meeting:

Scattering of 22-Mev Positive Pions on Protons

Stanley Whetstone and Donald Stork

A beam of positive pions was passed through a 3.5-inch thickness of liquid hydrogen contained in a polyethylene-lined styrofoam target. The pions entered the hydrogen with a mean energy of 25.0 ± 0.5 Mev, and traversed the target parallel to the face of a stack of G.5 nuclear emulsions, 6 inches long and 1.5 inches high, placed 1 inch from the beam edge. Tracks of scattered pions, identified at the end of their range in the emulsion by the characteristic decay at rest, can be followed back to the front surface of the stack, where measurements of the entrance angles can be made. It is possible to determine the scattering angle and energy for each event. We can therefore distinguish hydrogen events from elastic carbon scatters

occurring in the 0.004-inch polyethylene liner. The pion beam was obtained by selecting pions produced at 0° in the reaction $p + p \rightarrow \pi^+ + d$, using quadrupole magnets to "strong-focus" the electrostatically deflected 340-Mev proton beam of the Berkeley synchrocyclotron. Advantage was taken of the double-focusing properties of a wedge-shaped analyzing magnet. Fourteen scatters from hydrogen established to date yield a preliminary cross section of 3 mb for scattering in the interval 45° to 135° in the laboratory system.

The Cross Section for $p + p \rightarrow \pi^+ + p + n$

Donald Stork and Stanley Whetstone

The 0° cross section for $p + p \rightarrow \pi^+ + p + n$ (1) has been measured as a function of pion energy for protons of energy 338 Mev. The pions were detected in flight by means of scintillation-counter, pulse-height techniques. A combination of quadrupole and wedge-magnetic focusing provided a pion-energy resolution of ± 0.7 Mev. With a spread of proton beam energy of ± 1.2 Mev the pion energy continuum of Reaction (1) was separated from the peak caused by the reaction $p + p \rightarrow \pi^+ + d$(2). The ratio of the total cross sections $(d\sigma/d\Omega)$ for Reactions (1) and (2) is in good agreement with the Watson-Brueckner phenomenological theory.[1] However, the shape of the energy spectrum of Reaction (1) shows a considerable deviation from that given by the phenomenological theory for P-wave pions and a final two-nucleon S-state.[2]

[1] K. M. Watson and K. A. Brueckner, Phys. Rev. 83, 1 (1951).

[2] A. H. Rosenfeld, Phys. Rev. 96, 139 (1954).

Richman

SPIRAL-ORBIT SPECTROMETER

Ryokichi Sagane in charge

The major part of this period was devoted to establishing a procedure for experimentally checking the resolution of the spiral-orbit spectrometer. A part of this period was also devoted to analysis of the preliminary results of photomeson production at low pion energies.

PION-PRODUCTION STUDIES AT THE SYNCHROTRON

Ryokichi Sagane, Walter F. Dudziak, and James Vedder

We have made a preliminary study of photomeson production at low pion energies from carbon, hydrogen, and deuterium at 90° to a photon beam having a maximum photon energy of 300 Mev. For these studies we have used the 40-inch spiral-orbit spectrometer, as is shown schematically in Fig. 2. Pions whose original production energies varied from 14 Mev to 70 Mev were analyzed by the spiral-orbit principle and detected by fast coincidence of pulses from three or four plastic crystals. When a triple-coincidence technique was used, both positive and negative pions were measured simultaneously. When a quadruple-coincidence technique was used only one type of charged pion was measured at one time. As a check on electronic stability and reproducibility, a large carbon target was substituted for the target under investigation during the course of the experiment. Because the counting rates were high such checks were performed very frequently.

For deuterium both a CD_2-C subtraction technique and a high-pressure gas target were used. For the study on hydrogen, however, only a subtraction technique was used.

At this time the magnetic field of the spiral-orbit spectrometer cannot be reversed without destroying the synchrotron beam. As a result the emulsion data reported in the previous Quarterly Report were used to correct for the difference in π^+ and π^- counter detection efficiencies.

Figure 3 is a summary of the results on relative $\pi^{\pm}$-production cross sections as a function of pion energy from carbon. Figure 4 is a similar summary of $\pi^{\pm}$ production from deuterium. Table I presents a summary of π^-/π^+ ratios from carbon and deuterium.

At this time we have not observed any significant difference in π^+ production from hydrogen and deuterium. Within our statistics (which include our known systematic errors) the hydrogen and deuterium π^+ spectra are the same. For this reason no plot is presented of π^+ production from hydrogen.

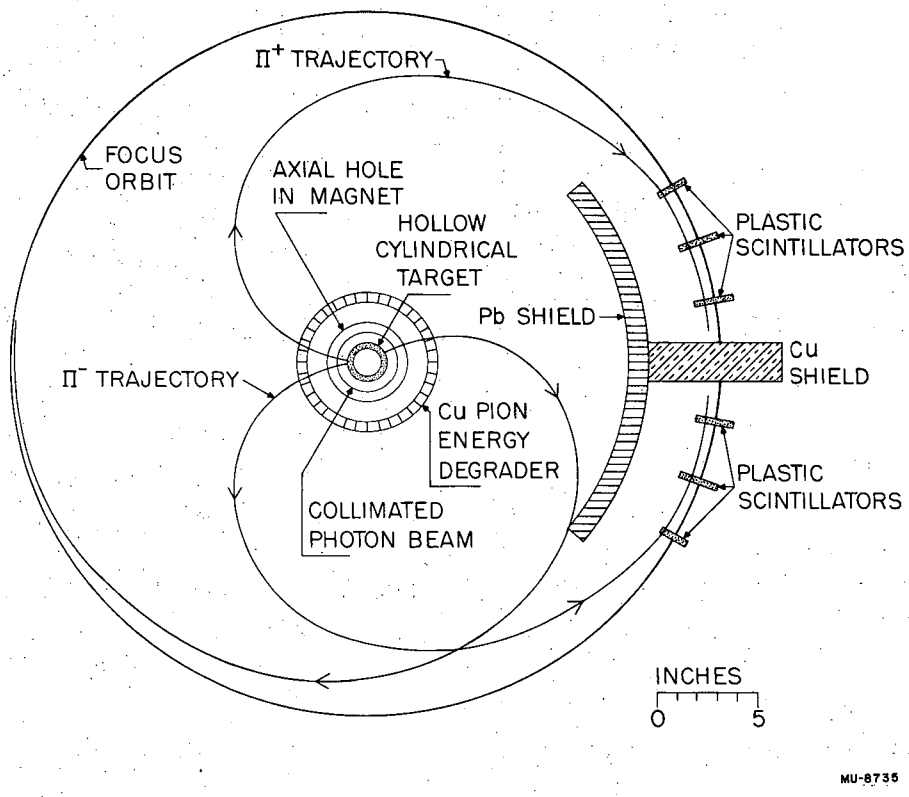

Fig. 2. Experimental arrangement for photomeson production.

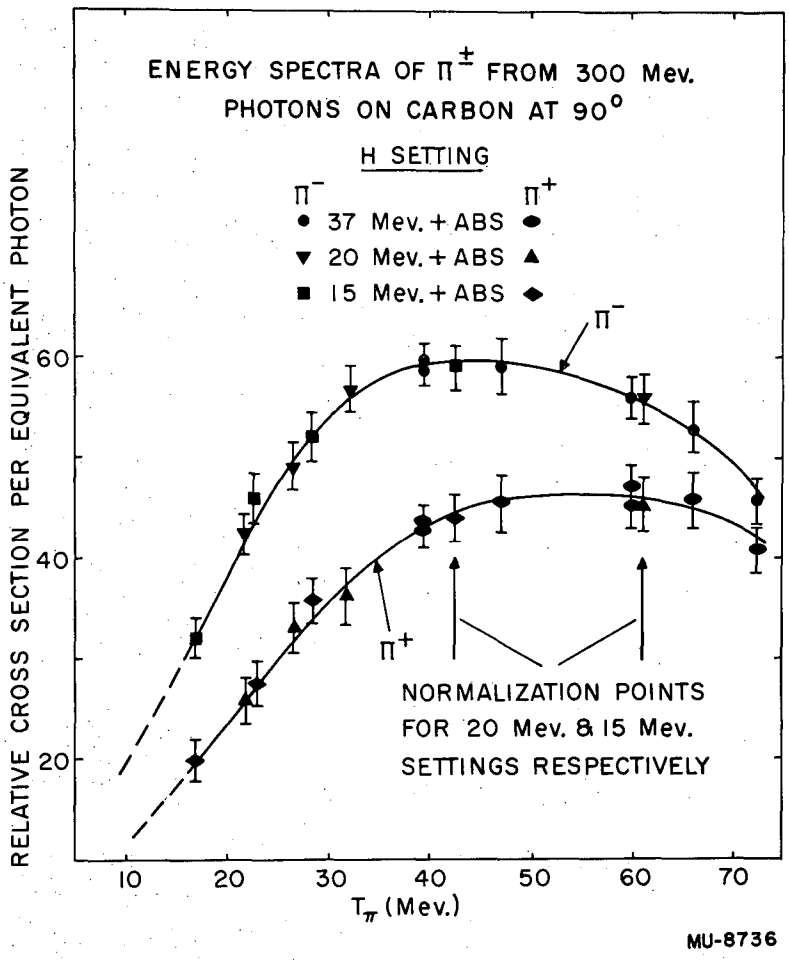

Fig. 3. Energy spectra of $\pi^{\pm}$ from 300-Mev photons on carbon at 90°.

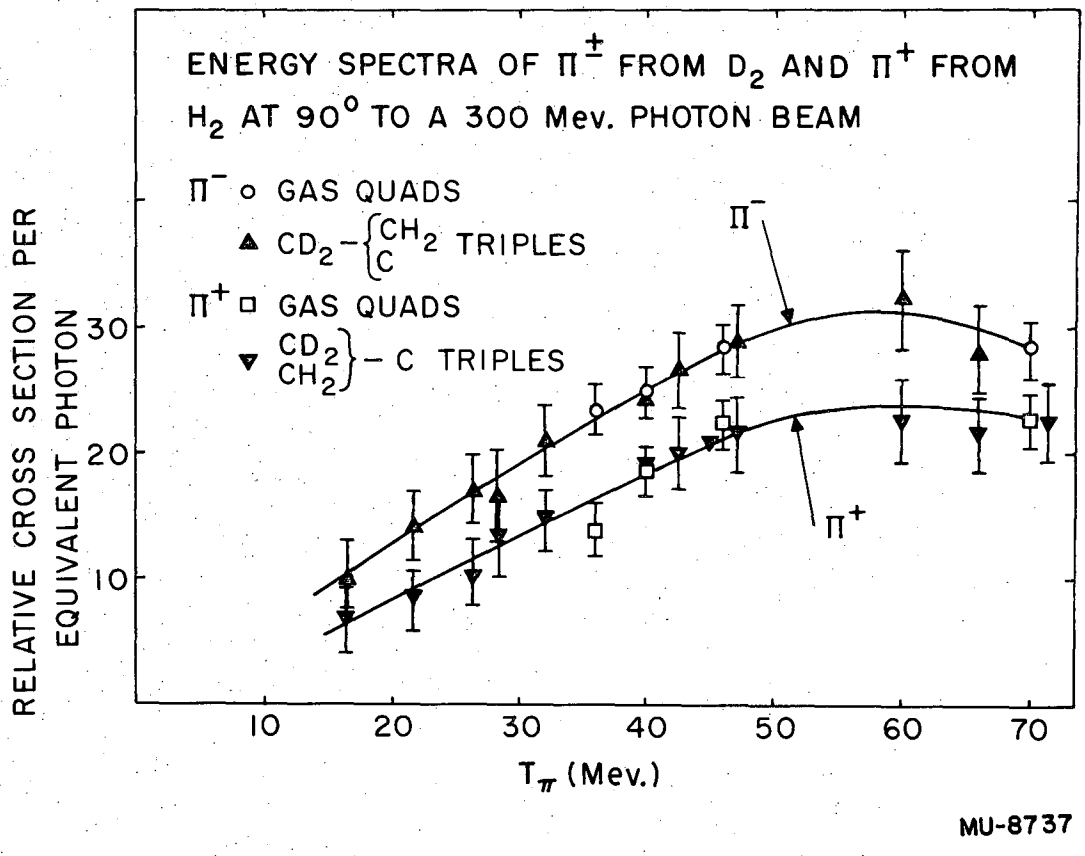

Fig. 4. Energy spectra of $\pi^{\pm}$ from D_2 and π^{+} from H_2 at 90° to a 300-Mev photon beam.

Table I

π^-/π^+ Ratios At 90° To a 300-Mev Photon Beam

Mean Pion Energy	Carbon		Deuterium	
T_π(Mev)	Emulsion	Counters (Triples)	Triples	Quads
72		1.1 ± 0.1		
70				1.25 ± 0.15
66		1.12 ± 0.1	1.18 ± 0.2	
60		1.26 ± 0.1	1.28 ± 0.2	
57	1.2 ± 0.1			
53		1.29 ± 0.15		
47	1.2 ± 0.1	1.30 ***	1.30 ± 0.2	1.27 ± 0.15
42.5		1.3 ± 0.1	1.30 ± 0.2	
40		1.36 ± 0.1	1.28 ± 0.2	1.31 ± 0.15
36	1.4 ± 0.15			1.36 ± 0.15
32		1.48 ± 0.12	1.35 ± 0.2	
28		1.45 ± 0.12		
26.3		1.4 ± 0.15	1.5 ± 0.3	
22	1.4 ± 0.12	1.66 ± 0.2	1.5 ± 0.3	
16.5		1.68 ± 0.2	1.4 ± 0.3	
15.5		1.67 ± 0.2		
12.5	1.62 ± 0.2			

*** Normalization Ratio

Sagane

STUDY OF FOCUSING PROPERTIES OF A SPIRAL-ORBIT SPECTROMETER

Ryokichi Sagane, Walter F. Dudziak, and James Vedder

We have decided to clarify experimentally some of the questions that were raised concerning the resolution of the spiral-orbit spectrometer used in treating the data obtained in our study of the positron spectrum from the decay of the μ-meson. For this purpose we have chosen the monoenergetic α-rays from a Pu^{238} source. Because the range of these α-particles is roughly 5 cm of air, a suitable vacuum chamber had to be built for this experiment. The vacuum chamber consists of two (54-inch diameter) pole tips that are the top and bottom plates, and 18 curved lucite plates that serve as the side walls. Suitable attachments were designed to compress hycar gaskets that were fitted between the components of the vacuum chamber. This arrangement provided ample vacuum tightness.

Our tests are not yet complete; however, we have thus far obtained the following information.

1. A preliminary resultant resolution curve of the spectrometer was obtained by rotating an α-ray source shaped in a strip around the axis of the magnetic field at r = 0.500 inch. As shown in Fig. 5, the shape and width of the resolution curve are in reasonable agreement with those obtained from theoretical calculations.

2. We have verified that with a slit system such as was used for the measurement of the positron spectrum from the μ-meson, the resolution curve did not have a long extended tail on the high-energy side of the focused particles.

3. We have checked the effect of vertical focusing by using cylindrical baffles with a fixed opening parallel to the median plane. This fixed opening was placed at different levels relative to the α-ray source. With this arrangement we could determine that the maximum bending angle is about 15°.

4. By means of a small detector we have obtained good evidence that charged particles oscillate with respect to the median plane. The period of this oscillation is in good agreement with theoretical predictions.

5. Figure 6 illustrates the small effect on the resolution caused by a source having a Z dimension. For this measurement the α-particle source was displaced 1.5 inches above the median plane while all the other parameters were kept the same as when the source was on the median plane.

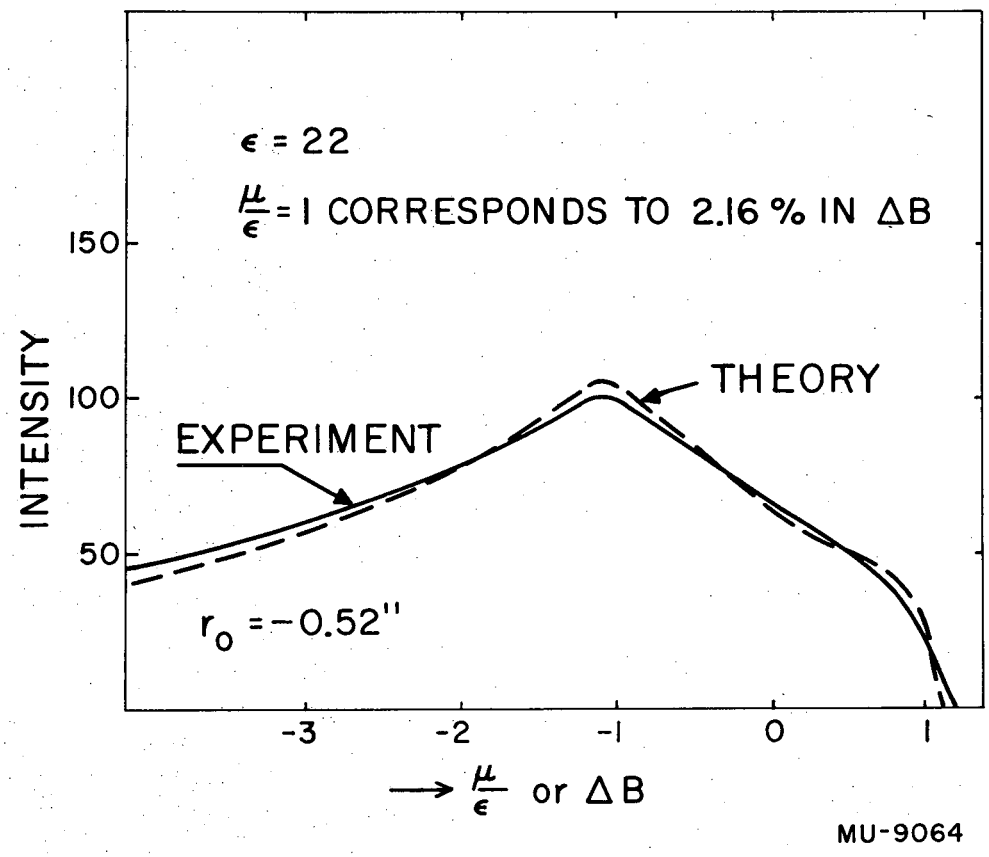

Fig. 5. Resolution curve with no slit near detector.

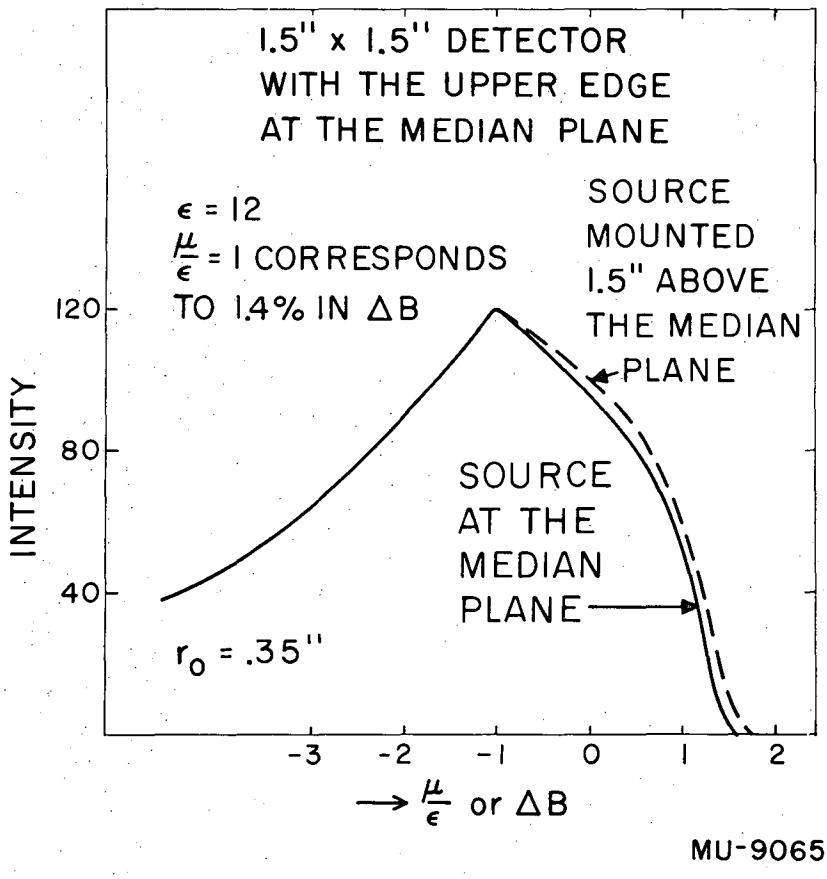

Fig. 6. Effect of Z focusing on resolution curve with ~ 15° slit near detector.

PHYSICS RESEARCH

Emilio Segrè in charge

POLARIZATION STUDIES

Proton-Proton

The work on triple scattering for 300-Mev protons on protons has been completed and reported to the Phys. Rev. See UCRL-2868.

Measurements of the polarization in the pp scattering at 170 Mev has been performed. The main purpose of this experiment is to be able to join with the lower energy measurements done at Harwell, and elsewhere. A curve of the polarization is given in Fig. 7. (John Baldwin and David L. Fischer)

Triple-scattering experiments at lower energies are at present precluded by the intensity of the beam. Focusing magnets are being prepared which should increase the intensity of the polarized beam.

1. The theoretical calculations to determine the phase shifts up to F waves inclusive have been initiated. The algebraic part is finished. The numerical part is being explored with the help of the numerical computing machines at Livermore and Los Alamos. At this writing we have not yet a clear idea of the difficulty of this job, mainly because we do not know how many spurious solutions of the problem will be found.

Other substances

Triple-scattering experiments on Al, and C have been continued in order to completely determine the scattering matrix for elastic scattering by these substances. (Robert Tripp)

BEVATRON

We are preparing an experiment to detect negative protons if they are produced in the bevatron. Parts of this project were discussed with Dr. O. Piccioni of Brookhaven National Lab. The system is to measure velocity and momentum of a particle by time of flight or by Cerenkov counter and magnetic deflection. The equipment for this experiment is being readied. It involves fairly large-strong focusing magnets. The magnets are planned in such a way as to have considerable flexibility and to be useful also for other experiments and for focusing beams of hyperons and K-particles providing these particles have lifetimes of the order of 10^{-8} sec or longer. Plans are also being made to determine the terminal destiny of negative protons if they are detected. (Owen Chamberlain, Emilio Segrè, and Clyde Wiegand)

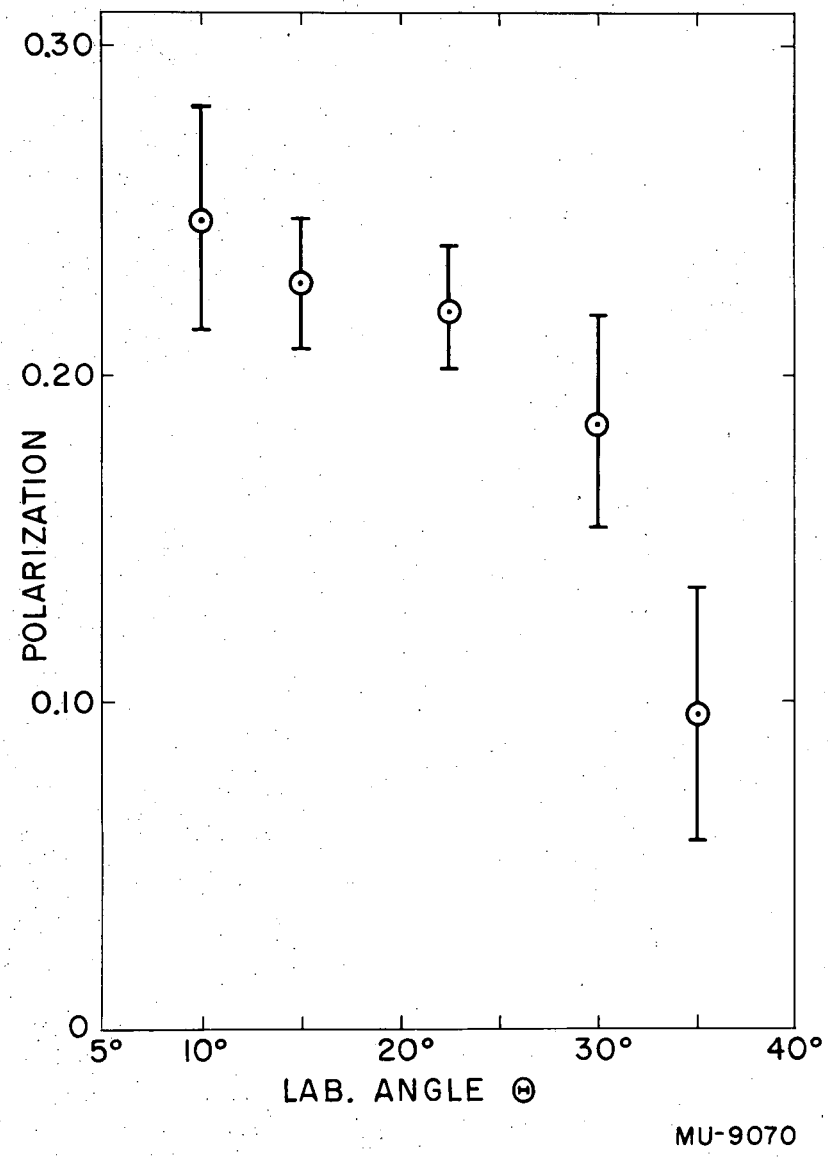

Fig. 7. Polarization P versus laboratory-system scattering angle Θ for proton-proton scattering at 170 Mev.

ACCELERATOR OPERATION AND DEVELOPMENT

BEVATRON

Edward J. Lofgren in charge

Further progress in the Bevatron program is the subject of a separate report by Edward J. Lofgren and Harry G. Heard, "Bevatron Operation and Development. III," UCRL-2822.

184-INCH CYCLOTRON

Robert L. Thornton in charge

MODIFICATION

Richard Burleigh

Magnet

The slots for the ion source in the outer shim rings have been cut.

The field-measuring device is being preassembled on the lower pole disc for testing.

The parts for the leads for the auxiliary coils have been completed.

Radiofrequency System

While a pair of blades was being run in the test tank, one of the blades developed a crack adjacent to the intersection of two cooling-water holes after about 100 hours' running time. The section containing the crack was removed from the blade and examined. The crack appeared to be a fatigue failure originating in a corrosion pit which had eaten through the nitrided case of the hole. Examination with a borescope of the holes in the other blades reveals randomly distributed corrosion in most blades. The most likely explanation for the rapid corrosion appears to be the activation of the surface by the use of acid flux for soldering cooling-water tubes into the fittings which are screwed into the holes in the blades. While sodium chromate was added to the cooling water as a rust inhibitor, it is not certain that this is effective in passivating a surface that is being continually flexed.

If the existing blades are to be salvaged it appears necessary to rebore the cooling-water holes to remove the nitrided case and along with it the corrosion damage, after which the holes would be renitrided. It is proving very difficult, however, to remachine these holes, which are 0.25 inch in diameter, 24 inches deep, and have an extremely hard surface. Honing is the only method of enlarging the holes that has so far proven at all satisfactory, and this is very slow. Thermally recycling a portion of the broken blade at nitriding temperatures reveals two further difficulties: (a) the copper plating blisters or falls off, and (b) the compressive stress in the

case (which is required for endurance) is apparently considerably reduced. While it is believed that the flux is the primary cause of the corrosion, it would be desirable to use a coolant other than water which would not be corrosive to nitralloy if the blades were to be operated as originally intended. Such a coolant would preferably be noninflammable, be nontoxic, and have heat-transfer characteristics and vapor pressure not vastly different from those of water. We have not yet found a satisfactory substitute for water.

Full-scale Radiofrequency tests indicate that it is feasible to operate with only two pairs of blades (instead of four) working at half the original amplitude and half the minimum gap. To facilitate positioning the blades relative to the stator, it is proposed that the stator be mounted on the blade face plate and be connected to the dee with a flexible member, rather than mounted directly on the dee as at present. With this scheme the power required to run the blades is reduced; the Radiofrequency power lost in the blades is increased, however, while the total heat to be removed from the blades remains about the same. With the original system the heat input was predominantly over the motors while in the new system the heat input is predominantly toward the butts of the blades. It is hoped, therefore, that the blades may be cooled by cooling the clamp bars rather than by circulating coolant through the holes in the blades. It is also possible that the temperature, and hence the natural frequency, and in turn the phase of one pair of blades relative to another pair, may be controlled through the temperature of the clamp bars. There is also the possibility that the system may to some extent be self-regulating in phasing, in that if the alternator supplying the current to the motor is run below the natural frequency of both pairs of blades, the pair with its natural frequency further from that of the alternator will require more power to maintain a given amplitude and hence will become hotter, and therefore its frequency will be reduced. Both theoretical work and testing on these and related problems are under way. The possibility of making new blades without cooling holes is also being considered. The possible advantages over the original system of the system presently being considered may be listed as follows:

(a) fewer blades,
(b) more spare blades available,
(c) lower stresses,
(d) simpler controls.

To facilitate further Radiofrequency tests it is expected that a temporary means for varying the capacity, and also a temporary single pair of movable panels in place of the two pairs of movable panels, will be installed soon.

Miscellaneous

The design work on the ion source, the movable scatterer in the dee, the enlarged deuteron cave, the medical cave, and the new lifting device for the poles is complete.

The steel boxes for the meson cave shielding are all tack-welded. The concrete blocks are cast but not delivered.

Because of the continuing medical research program and the setback in the modification due to the cracked blade, the shutdown is provisionally postponed to July 1955, when the situation will be reviewed.

Thornton

60-INCH CYCLOTRON

J. G. Hamilton in charge

OPERATION

G. Bernard Rossi

A summary of operation for the current quarterly period, as prepared by William B. Jones of our staff, is as follows:

Operations Summary

(for the period of November, December 1954 and January 1955)

Alpha Bombardments	451.6 hrs
Deuteron bombardments	201.2 hrs
Proton bombardments	138.5 hrs
Nitrogen bombardments	67.0 hrs
Oxygen bombardments	31.2 hrs
Fluorine bombardments	14.2 hrs
Neon bombardments	42.7 hrs
Experimental bombardments	69.1 hrs
	1015.5 hrs
Outage time	165.6 hrs
Overhaul	24.0 hrs
	1205.1 hrs
Shutdown	918.9 hrs
Holidays	84.0 hrs
	2208.0 hrs

84.1% operating efficiency.

Attempts were made to accelerate heavy ions at the low-frequency–high-field combination provided for during the recent conversion. Continued use of the retractable spider developed some mechanical and electrical difficulties that could not be surmounted without redesign. Sufficient use was made of the equipment, nonetheless, to evaluate operating parameters at the two frequencies, 12.0 and 10.7 megacycles.

At the lower frequency O_{16}^{+6}, Ne_{20}^{+8}, F_{19}^{+8} and C_{13}^{+6} ions were recognized from the magnetic field resonance values and further identified by alpha-particle activity produced on tungsten, platinum, and gold. Internal beams of the order of 10^{-7} amp were obtained.

Measurements of alpha beam density taken at the present external target depot were compared with those taken at the output of the deflector channel. A factor-of-five greater density was found to exist at the channel point. This increase of density proves useful for irradiations involving small quantities of material that can be made to withstand the beam power. Under special conditions of operation, beams as large as 7 μa have been obtained through

a slit 1/4-inch by 1/32-inch, placed in a horizontal position, representing a beam density of 140 μa per cm^2.

Operation of the cyclotron at higher energies, since the Jully 1954 conversion, has pointed out the need for a varying approach in bombardment techniques. The high-density beam referred to above, the increased vertical focusing illustrated in the last quarterly report, the greater power dissipated as a result of increased energy and intensity, all have had to be dealt with for successful operation. It is a function of the mechanical design department to translate ideas, developed by the staff to meet the needs, into workable tools. Flexibility and simplicity are keynoted in the designs so that maximum use can be made of the equipment with a high order of personnel radiation safety. A review of some of these designs appears in this report.

MECHANICAL DESIGN DEVELOPMENTS

Charles A. Corum

Some recent developments by the 60-Inch Cyclotron Design Department include (a) snout plate adjustment, (b) external microtarget, (c) internal target, and (d) ion-source adjustment mechanism.

(a) Target snout plate adjustment. Operation problems have for some time indicated the need for adjustment of the target snout plate that would position a target in the center of the external beam path. This is particularly true of small targets, for which high-density collimated beams are required.

Tests showed that a plate moving in a bedded strip machine slide could be made to maintain a vacuum seal over an O-ring for the necessary amount of travel. It is common practice to use separate movable plates and O-rings for each direction of motion. Geometric restrictions, in this case, required the use of a single plate inside a sliding frame for two degrees of freedom. This was accomplished with one O-ring by square-strip machine slides holding a frame to the snout plate and also the slide plate to the sliding frame. Adjustments are made by two screws adaptable for remote control.

The unit illustrated in Figs. 1, 2 was installed in November 1954 and has been successfully operated. This principle has since been applied to various uses in this and other laboratories.

(b) The external microtarget, now in process of fabrication, was developed to replace the gun target (UCRL)-1729, p 30-33). This development was necessitated by the shape of the external beam resulting from increased vertical magnetic focusing. The 70% intensity fall-off point width is now approximately 1/32 inch in the vertical plane. This new assembly will allow better distribution of scarce target materials with respect to these new beam dimensions.

When completed, the external microtarget will be a compact rectangular unit bearing no resemblance to the gun target. It has been designed so that only three pieces, not including the dish or target sample, are required to change the unit to any shape or size desired up to 1 inch diameter.

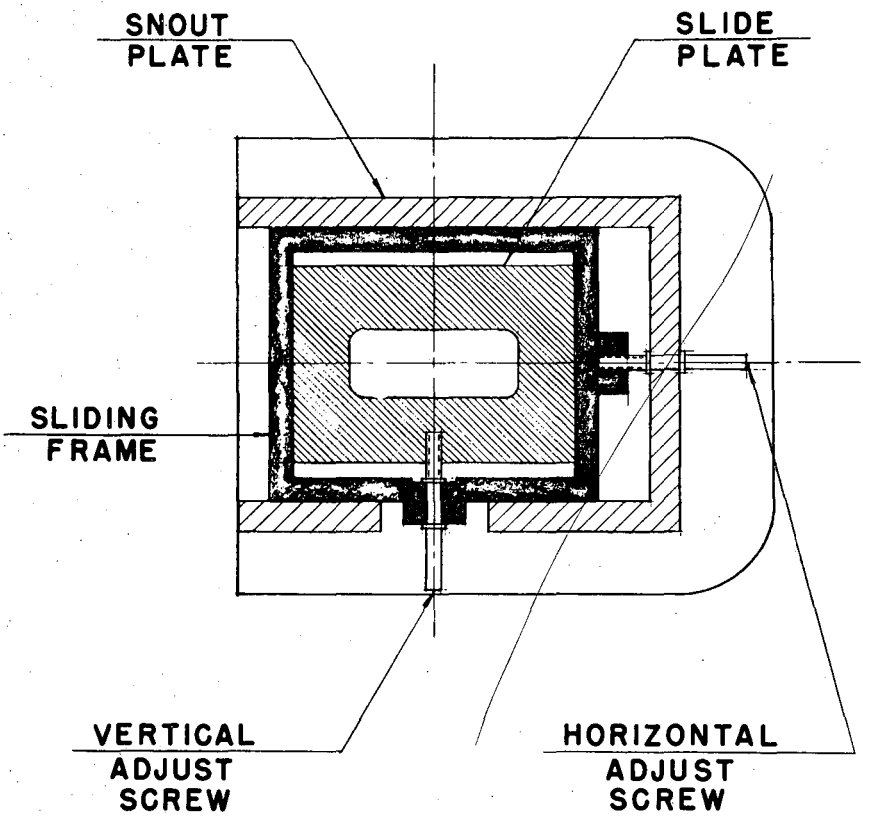

Fig. 1. Schematic layout, 60-inch cyclotron, snout plate two-way adjustment.

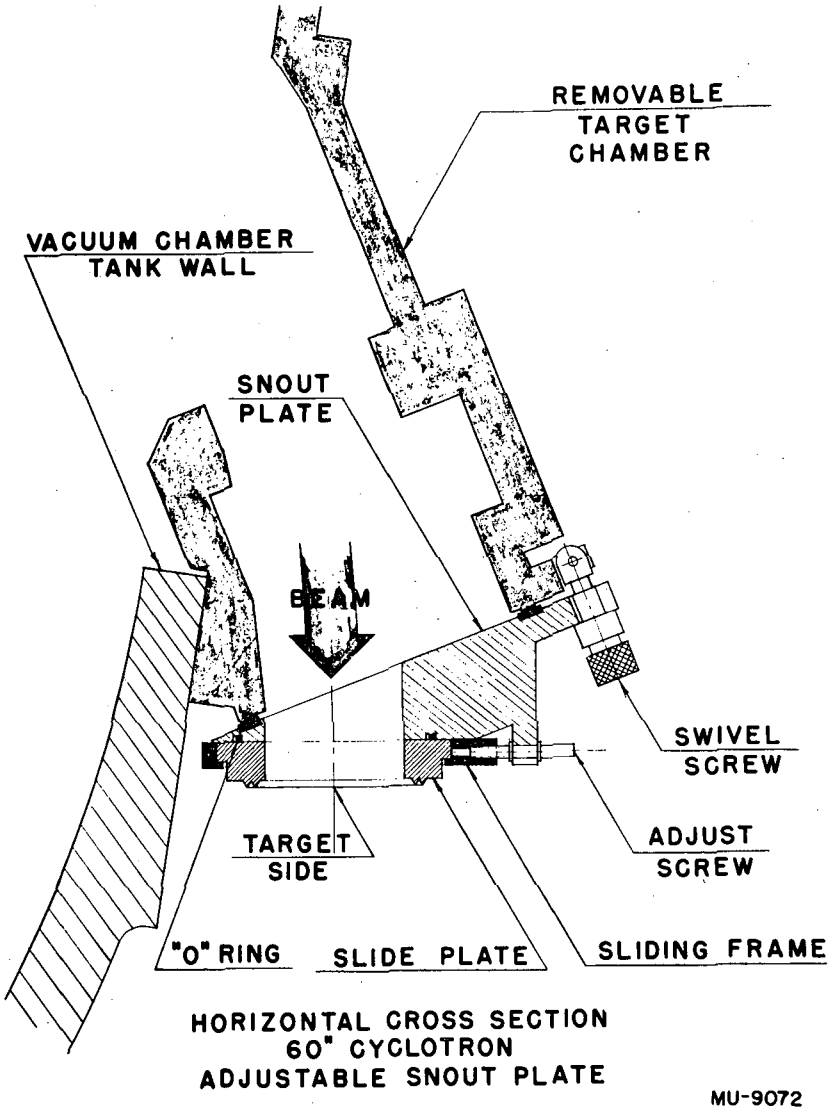

Fig. 2. Horizontal cross section, 60-inch cyclotron, adjustable snout plate.

The window assembly consists of two rectangular chambers with the openings on the side away from the vacuum chamber. The front plate's water-cooled opening of 1 inch diameter acts as a beam precollimator and sets the maximum dimension for any target.

Inserted in the first chamber is a water-cooled collimating plate. (This is one of the three pieces required for any change). Behind the collimating plate are an insulating plate, the first window foil, an air manifold plate, and the second window foil.

The back wall of the chamber is fastened to the sides with four screws. When these are loosened any one or all parts in the chamber may be removed, changed, or replaced. Tightening the screws compresses the series of required O-rings and makes a vacuumtight unit.

A 1 1/4-inch-diameter opening connects the two chambers. In back of the second chamber is a cam rod. When tight it holds the target assembly in place. When it is loose the target assembly may be removed.

The target assembly is small and simply designed so that it may be pretested before it is slipped into bombarding position in the window assembly, and can be easily made accessible for transportation. It consists of three main parts. The front and back plates hold and seal the dish between them. These two pieces and the dish are the only other parts that may require changing if decontamination becomes necessary. Three screws, one a swivel, hold the plates together. For the disassembly, only the swivel screw need be loosened and swung out of the way, allowing the top plate to tip and slide out from under the other two screws, leaving the dish exposed for easy removal. A metal-to-metal seal around O-rings should effectively seal the dish and its covering foil. If leakage between the two develops, cement or a lead washer may be used. To complete the target assembly, a water block (with an outlet for jetting water directly to the back of the dish) is screwed to the back plate.

All parts slide into the window assembly and present a flush face with line openings for water, air, vacuum, and (or) gas. A two-piece manifold clamps to the side of the window assembly by means of three screws (one a swivel), the same method as used on the target assembly. The manifold, made partly of lucite for insulating purposes, contains all utility lines for the functioning of the completed target and distributes the water through O-ring seals from separate lines to the precollimating front plate, to the collimating plate, and to the target dish. It distributes the air to cool the window foils and provides an evacuation or gas line to the back chamber.

In normal operation, to remove the target, one removes the complete manifold, thus disconnecting all lines at once and exposing the end of the target assembly, which can be removed by releasing the cam that holds it in place. A threaded hole has been provided in the target assembly so that a screw-ended tool may be used for target handling.

If there is a contamination danger during disassembly, part of the manifold may be removed, leaving the target water with the window assembly. The whole unit then may be set in a protective box on the service cart for final disassembly. Figure 3 shows a cross section of the assembly.

Hamilton

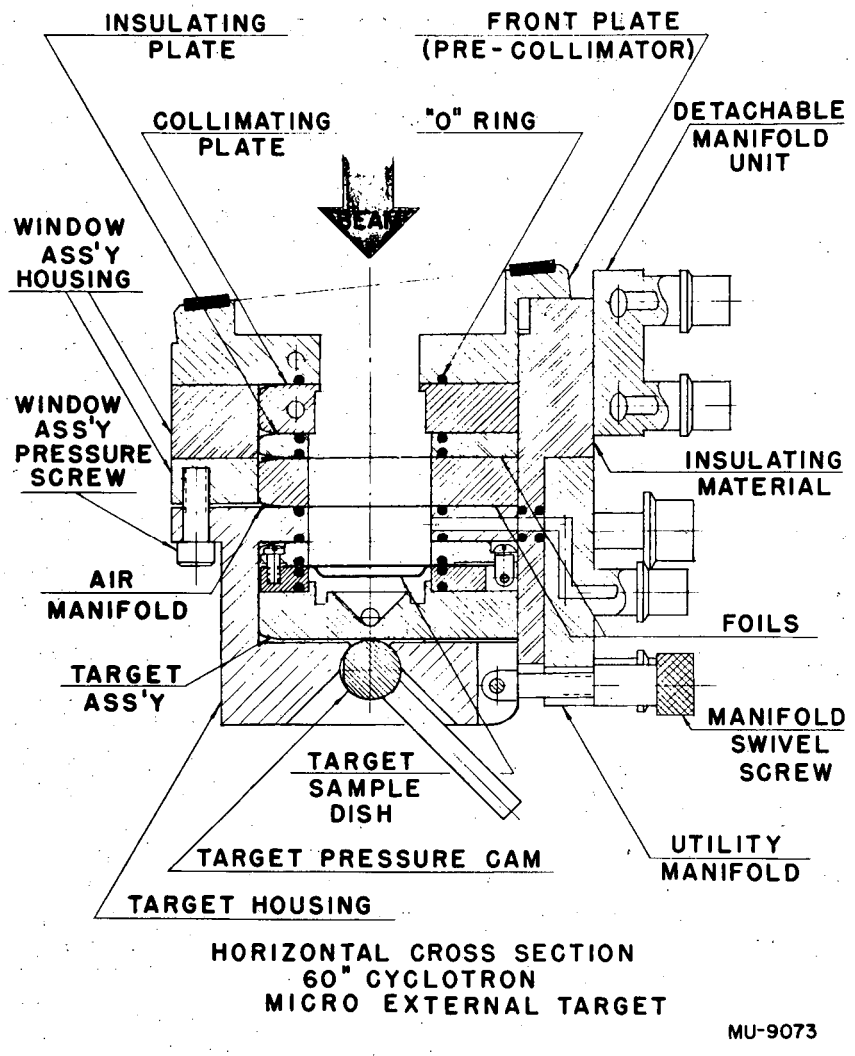

Fig. 3. Horizontal cross section, 60-inch cyclotron, external microtarget.

(c) With the increasing demand for use of the 60-inch beam snouting unit, clearing the target area for standard target runs has become a problem because of the setup and take-down time required. If we could leave the snouting equipment in place and go through the centerline probe port with a target, cyclotron time lost in clearing the external area could be eliminated.

The expected flexibility of the "internal target" hinges upon a manifold plate terminating a multitube shaft. Although the unit was designed for a specific type of bombardment, a variety of targets can be mounted on this plate. The manifold plate is rectangular in shape and faced at an angle of 8°. This permits the mounting of a target assembly so that it will intercept the beam at 90°, with the use of standard centerline probe equipment already on hand (UCRL-2241, p 32).

Mounted on the leading edge of the plate is the air-cooled window plate, with the air lines connected by metal-to-metal O-ring seals as used on other equipment. Foils are placed on both sides of the window plate and clamped, in front by a graphite collimator faced plate and in back with a plate backed by a short length of tubing. O-rings on both sides of each foil make the air and vacuum seal, and four screws hold the window assembly together. The target-support plate is mounted on the opposite end of the manifold plate and contains water and evacuation lines. The outer portion of the support plate has a cylindrical projection with an O-ring groove, so that it slips into the open end of the tubing extending from the window assembly.

On the face of the support-plate projection(that extends into the tubing) is mounted the target head. A machined edge on the projection provides a positioning device so that the head can be held by a single external screw. O-rings around the screw hole and water lines effect a vacuum seal and permit the passage of water from the plate to the target.

The target block is sloped at 30° to present double the area to beam exposure. The target foil, or plate, is clamped in position over a water jet in much the same fashion as used in the target assembly of the micro-external target previously discussed.

As the cyclotron beam is not very high in comparison to its width, this internal target was designed for a maximum-sized beam of 1/2 inch high and 1 inch wide. With the changeable graphite collimator, any smaller dimension could be used. The collimator on the first unit is to be 1/4 inch by 1 inch, with the resultant coverage of the target being 1/2 inch by 1 inch because of the angle at which the target is set. See Figs. 4 and 5.

(d) The method of ion-source adjustment as used on the 60-inch cyclotron, although improved from time to time (UCRL-1729, p 39-40), has never been perfect. Designs were limited by the small opening in the vacuum chamber itself. This opening, although enlarged slightly in 1944, limited source adjustment to a gimbal arrangement where the source tube is essentially pivoted about a point outside the vacuum chamber. Motion of the source, in this gimbal structure, is along an arc permitting as much as 7° tilt from the planes in all directions. Motions with the new adjuster will be parallel to the planes.

In recognition of this basic defect in the source adjustment, steps were

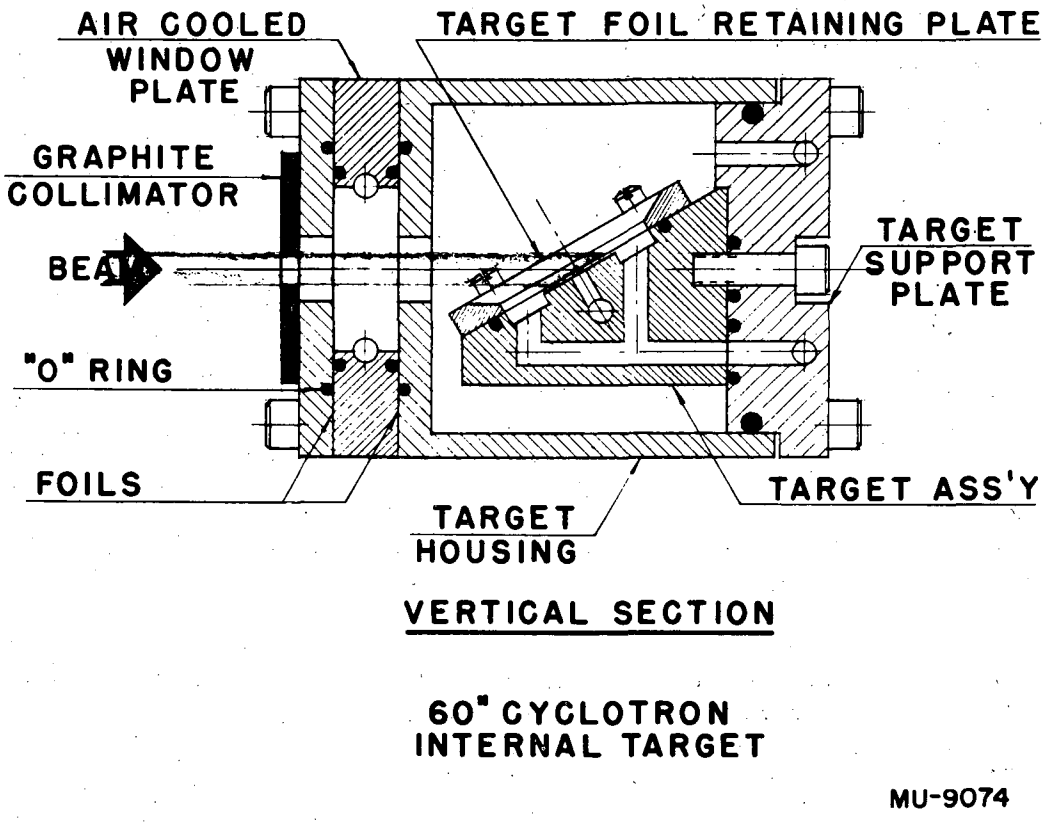

Fig. 4. Sixty-inch cyclotron, internal target, vertical section.

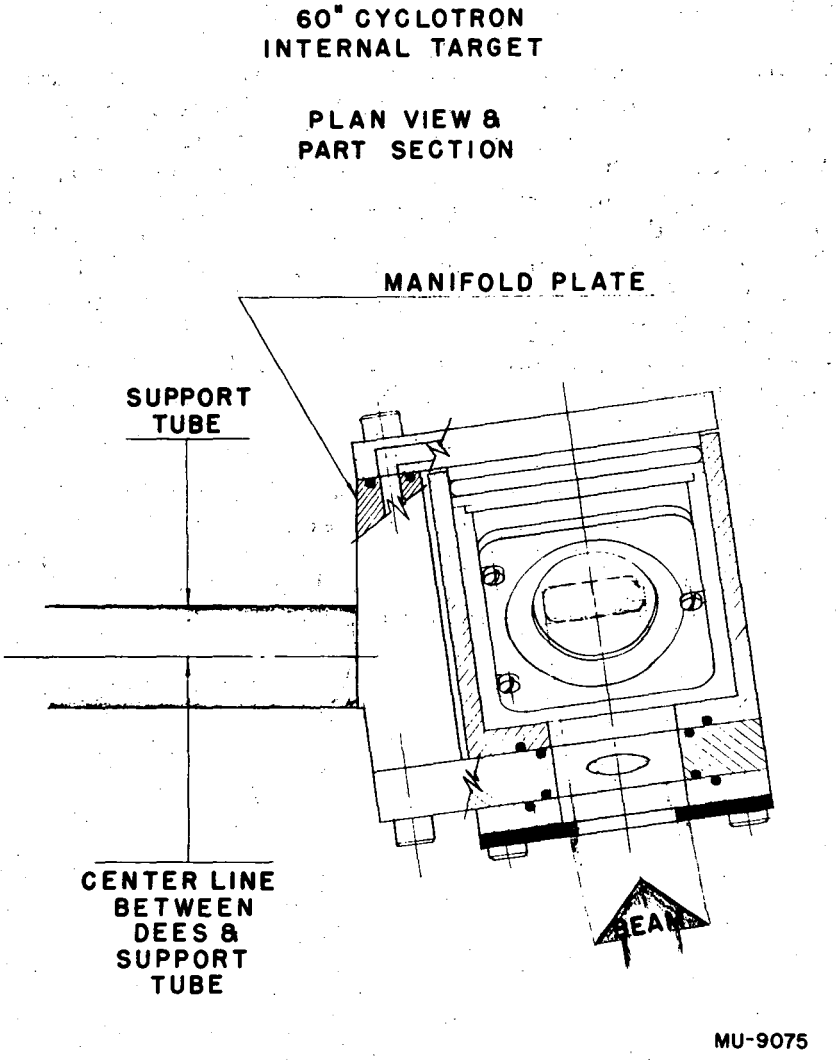

Fig. 5. Sixty-inch cyclotron, internal target, plan view and part section.

taken during the 1954 reconversion of the 60 inch cyclotron to improve the situation. The center post on the south face of the vacuum chamber through which the source was introduced was cut out completely. Two 1 inch by 3 inch brass bars approximately 9 inches high were fitted in place but spaced 3 inches apart. The opening created is 100% greater. The main tank face plate also was altered, with the source opening enlarged from the original inverted keyhole shape to a rectangular opening 3 inches by 8 inches. In the reassembly of the cyclotron, the standard source lock and adjustment equipment were reinstalled.

Near the end of December 1954, a new source adjustment had been designed, the basic change in which was the elimination of the gimbal and pivot mechanism. The new unit, now in the process of detailing, features an enlarged version of the snout plate adjustment (see Fig. 1). That is, a single slide plate in a slide frame, both actuated by worm-driven screws, to give direct up and down or east and west movement. With the source supported through the slide plate in a level position, no tilt can occur. The movement of the new unit will allow 0.75 inch total up and down and 1.25 inches total east and west. These figures, however, are determined by the continuing use of the present source-support tube. Future plans call for a redesign of the source tube, reducing it in weight and in size, with the smaller size allowing greater movement.

Included in the design of the new unit is a source in-and-out adjustment, patterned after the filament adjustment mechanism (UCRL-1854, p 39). A new ion-source vacuum lock and gate will replace those now in operation. They will function in the same way, but will be larger to take advantage of the increased opening to the vacuum chamber.

LINEAR ACCELERATOR

Luis W. Alvarez in charge

OPERATION

James D. Gow

During the period November 1, 1954 through January 31, 1955 the linear accelerator operated a total of 736 hours. The final model of the 4W20000 pre-exciter was placed in operation on the machine. After some initial debugging, satisfactory operation has been obtained. During December there was a mechanical failure of one of the main lexapod textolites along with the failure of one textolite diagonal in the Van de Graaff accelerator. A two-week shutdown was required to replace these. This time was used to make several minor mechanical changes and replacements in the machine.

Difficulty has been experienced with occasional drooping of the Van de Graaff voltage. At present it is suspected that a discharge is occurring inside one of the new diagonals. It is planned to put voltage-grading rings inside these supports at an early date.

SYNCHROTRON

Edwin M. McMillan in charge

OPERATION AND OBSERVATIONS

Robert W. Kenney

During the period November-December, the synchrotron beam intensity was low and the experimental program did not advance as rapidly as expected. The entire month of January was devoted to an extensive overhaul of the synchrotron magnet structure, main coils, and associated circuitry. Power and control facilities for both the electron linear accelerator injector and the magnetic monitor have been installed. The glass doughnut section for the linac injector failed mechanically under vacuum testing, so that the doughnut will be reassembled without this modification. A ceramic doughnut section has been ordered, and a new glass section has been vacuum-tested but is not yet completely prepared for installation.

Kenneth C. Bandtel and Dwight R. Dixon have observed the high-energy photodisintegration of the deuteron to 10 percent statistics at 36°, 49°, 75°, 106°, and 141° proton lab angle. In the region of 130- to 290-Mev photons, $d\sigma/d\Omega \approx 5$ to 6 μb/steradian and is reasonably flat over the energy interval. The angular distribution is also fairly flat in the angular interval, dropping to about 3 μb/steradian at 141°. The proton counter was calibrated in an absolute manner at the 184-inch cyclotron. Statistics can be reduced to 5% fairly easily in the future. Plans also include observing proton angles near 0° and 180° with the aid of a magnetic field to bend the protons out of the photon beam. The work will appear shortly as a UCRL report.

Harry T. Easterday, William L. Imhoff, and Victor Perez-Mendez have used the π-μ gear to observe the π^+ yields from several light elements, and have observed some binding-energy effects. The relative π^+ yields per nucleus at 135 ± 7° and 42 ± 2.5 Mev π^+ energy are:

normal	H	1.00 ± 0.10	
	Li	1.73 ± 0.16	
	Be^9	2.18 ± 0.10	
	B^{10}	2.80 ± 0.12	
	B^{11}	2.63 ± 0.12	
	C^{12}	2.76 ± 0.29	(2.28 - White, Jakobson, and Schultz)
	Pb	25.7 ± 3.8	

At 65 Mev, the ratio B^{10}/B^{11} is 1.33 ± 0.16. Theoretically, owing to binding effects one might expect 14% larger yield from B^{10}.

Data from Cornell at 135°, averaged over the π^+ energy interval from 50 to 80 Mev, using 310-Mev bremsstrahlung, are given for comparison:

H	1.00 ± 0.05
Li	2.25 ± 0.14
Be	2.39 ± 0.01
C^{12}	3.54 ± 0.05
Bi	19.2 ± 1.4

The ratio Pb/C was observed in the same geometry as a function of π^+ energy.

Mev	Pb/C
32	5.4 ± 2.3
42	9.3 ± 1.4
65	6.6 ± 2.9

$A^{2/3}$ ratio for Pb to C = 6.7. Additional work will be done to improve statistics and to extend the measurements to other light nuclei.

Robert K. Squire attempted a calibration of a photon counter, but was unsuccessful.

John D. Anderson, Robert W. Kenney, and C. McDonald extended the angular distribution measurements of the bremsstrahlung beam to very thick targets. An 0.085-inch Pt target gave half angles of 12.5 milliradians for 170 Mev, 11.0 milliradians for 235 Mev, and 9.5 milliradians for 300-Mev photons. The data for 0.020- and 0.085-inch Pt targets are fitted nearly exactly by using Schiff's intrinsic angular distribution for the bremsstrahlung and Lanzl and Hansen's electron-scattering theory. The effective target thickness for 0.020-inch Pt is 0.012-inch. For the 0.085-inch Pt target, the effective thickness is 0.0115 inch for 300-Mev photons and 0.022 inch for 170 Mev. The dependence of effective thickness on energy is not yet understood. Further experiments with very thin targets are planned.

McMillan

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