Title
THE X-RAY SPECTRUM PRODUCED BY 322 MEV ELECTRONS STRIKING A PLATINUM TARGET

Authors
Hartsough, Walter
Hill, Milton
Powell, Wilson M.

Publication Date
1950-08-01

COPY 2

UCRL-660

UNIVERSITY OF CALIFORNIA — BERKELEY

RADIATION LABORATORY

COPY 2

UCRL 660
Unclassified Distribution

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

THE X-RAY SPECTRUM PRODUCED BY 322 MEV ELECTRONS STRIKING A PLATINUM TARGET

Walter Hartsough, Milton Hill, and Wilson M. Powell

August 1, 1950

Berkeley, California

INSTALLATION:	No. of Copies
Argonne National Laboratory	8
Armed Forces Special Weapons Project	1
Atomic Energy Commission - Washington	2
Battelle Memorial Institute	1
Brush Beryllium Company	1
Brookhaven National Laboratory	4
Bureau of Medicine and Surgery	1
Bureau of Ships	1
Carbide and Carbon Chemicals Division (K-25 Plant)	4
Carbide and Carbon Chemicals Division (Y-12 Plant)	4
Chicago Operations Office	1
Columbia University (J. R. Dunning)	1
Columbia University (G. Failla)	1
Dow Chemical Company	1
H. K. Ferguson Company	1
General Electric, Richland	3
Harshaw Chemical Corporation	1
Idaho Operations Office	1
Iowa State College	2
Kansas City Operations Branch	1
Kellex Corporation	2
Knolls Atomic Power Laboratory	4
Los Alamos Scientific Laboratory	3
Mallinckrodt Chemical Works	1
Massachusetts Institute of Technology (A. Gaudin)	1
Massachusetts Institute of Technology (A. R. Kaufmann)	1
Mound Laboratory	3
National Advisory Committee for Aeronautics	1
National Bureau of Standards	3
Naval Radiological Defense Laboratory	2
New Brunswick Laboratory	1
New York Operations Office	3
North American Aviation, Inc.	1
Oak Ridge National Laboratory	8
Patent Branch (Washington)	1
Rand Corporation	1
Sandia Corporation	1
Santa Fe Operations Office	2
Sylvania Electric Products, Inc.	1
Technical Information Division (Oak Ridge)	15
USAF, Air Surgeon (Lt. Col. R. H. Blount)	1
USAF, Director of Armament (Captain C. I. Browne)	1
USAF, Director of Research and Development (Col. R. J. Mason, Fred W. Bruner)	2
USAF, Eglin Air Force Base (Major A. C. Field)	1
USAF, Kirtland Air Force Base (Col. Marcus F. Cooper)	1
USAF, Maxwell Air Force Base (Col. F. N. Moyers)	1
USAF, NEPA Office	2
USAF, Office of Atomic Energy (Col.H.C. Donelly, A.A. Fickel)	2
USAF, Offutt Air Force Base (Col. H. R. Sullivan, Jr.)	1
USAF, Wright-Patterson Air Force Base (Rodney Nudenberg)	1

INSTALLATION	No. of Copies
U. S. Army, Atomic Energy Branch (Lt. Col. A. W. Betts)	1
U. S. Army, Army Field Forces (Captain James Kerr)	1
U. S. Army, Commanding General, Chemical Corps Technical Command (Col. John A. MacLaughlin thru Mrs. Georgia S. Benjamin)	1
U. S. Army, Chief of Ordnance (Lt. Col. A. R. Del Campo)	1
U. S. Army, Commanding Officer, Watertown Arsenal (Col. Carroll H. Deitrick)	1
U. S. Army, Director of Operations Research (Dr. Ellis Johnson)	1
U. S. Army, Office of Engineers (Allen O'Leary)	1
U. S. Army, Office of the Chief Signal Officer (Curtis T. Clayton thru Maj. George C. Hunt)	1
U. S. Army, Office of the Surgeon General (Col. W. S. Stone)	1
U. S. Geological Survey (T. B. Nolan)	2
USAF, Director of Plans and Operations (Col. R.L. Applegate)	1
U. S. Public Health Service	1
University of California at Los Angeles	1
University of California Radiation Laboratory	5
University of Rochester	2
University of Washington	1
Western Reserve University	2
Westinghouse Electric Company	4
Naval Medical Research Institute	1
University of Rochester	1
California Institute of Technology (R. F. Bacher)	1
TOTAL	139

Information Division
Radiation Laboratory
University of California
Berkeley, California

THE X-RAY SPECTRUM PRODUCED BY 322 MEV ELECTRONS STRIKING A PLATINUM TARGET

Walter Hartsough, Milton Hill, and Wilson M. Powell

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

August 1, 1950

Abstract

The differential energy spectrum of the photons produced by 322 Mev electrons striking a 20 mil platinum target was measured by observing the energy of 3467 pairs produced in a one mil thick lead foil in a Wilson cloud chamber in a magnetic field of 10,000 gauss. The spectrum is found to agree with that predicted by the Bethe-Heitler bremsstrahlung theory using a Thomas-Fermi model with suitable corrections for the thickness of the target. The energy of the 322 Mev electrons was determined by the spectrum of the photons observed in this experiment.

THE X-RAY SPECTRUM PRODUCED BY 322 MEV ELECTRONS STRIKING A PLATINUM TARGET

Walter Hartsough, Milton Hill, and Wilson M. Powell

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

August 1, 1950

Introduction

The Berkeley synchrotron produces 322 Mev electrons as estimated from the results of this experiment. These electrons make x-rays by striking a 20 mil thick platinum target inside the quartz vacuum chamber of the machine. The x-rays pass through 1.5 to 2 cm of quartz before reaching the air where practically all experiments are performed. This paper gives the energy distribution of the x-rays as obtained from the measurement of the energy of 3467 pairs produced in a 1 mil thick lead plate placed in the x-ray beam from the synchrotron.

Apparatus

A 16-inch diameter Wilson cloud chamber with a magnetic field of 10,000 gauss was placed in the x-ray beam from the synchrotron, with its center 88.5 feet from the 20 mil thick platinum target of the synchrotron. A six-inch thick lead collimator, 35 feet from the target, collimated the x-rays so that they formed a beam at the chamber approximately 6.5 inches wide and 1 inch high. The beam entered the chamber through a 5 mil aluminum window and passed through a vertical lead plate 1 mil thick across the center of the cloud chamber. Electron-positron pairs were produced in the lead and the gas (a mixture of half argon and half helium with water and ethyl alcohol for the vapor) of the chamber. Only those pairs produced in the lead plate were used in the data given below.

The synchrotron gives a pulse of x-rays six times a second which can be interrupted at suitable intervals by changing the timing of the high voltage on the synchrotron injector so that it fires too late to produce a beam. The procedure is to monitor the beam by means of a Zeus meter placed just out of the main beam. The beam is run steadily at some low value, interrupted for about a second before and after the pulse used by the cloud chamber. The timing sequence of the cloud chamber is synchronized with the x-ray signal in the following way. First the cloud chamber magnet is energized, reaching full field in 2.3 seconds, at which time a ready signal is given so that the next pulse of the synchrotron magnet sends a signal to expand the chamber. The expansion is delayed so that the x-rays from the following pulse reach the chamber just after the expansion. The lights are flashed 0.035 to 0.045 second after the arrival of the beam. Two General Electric FT-22 flash tubes charged to 1700 volts with 250 microfarads of capacity each are used for illumination and the 127 cm focal length camera lenses were set at f.8 using Eastman Orthochromatic Linagraph film. Because of the early timing of the lights, it was necessary to open the lenses so as to give about four times the light usually required. This early timing and control of the temperature of the chamber to 0.1 degree centrigrade resulted in turbulence free pictures where the spurious radius of curvature was greater than 50 meters.

T. C. Merkle, Jr., suggested that a mixture of argon and helium be used in the chamber for the following reasons. Argon gives a larger number of ion pairs per cm length of track than helium but has the disadvantage of a low heat conductivity and, therefore, takes a long time to reach thermal equilibrium. By mixing in equal amounts of helium, which has a heat conductivity some nine times greater than that of argon, the heat conductivity of the mixture is four or more times greater and the waiting period necessary to achieve thermal equilibrium in this large chamber is reduced to 45 seconds. The tracks are much heavier than they would be with pure helium.

Experimental Results

Table I contains the experimental data with Column 2 giving the number of pairs observed in the 10 Mev energy intervals indicated in Column 1. Column 3 contains numbers proportional to the pair production cross section in lead as calculated from Heitler.[1] Column 4 is obtained by dividing Column 2 by Column 3 and is a set of numbers proportional to the number of photons in each interval. Column 5 is a set of numbers proportional to the average energy of each interval with unity corresponding to 322 Mev. The numbers in Column 6, obtained by multiplying Column 4 by Column 5, are proportional to the number of photons per Mev multiplied by the average energy of the photons, or they are proportional to the total energy carried by the photons in each energy interval. This will be called the differential energy spectrum of the photons. The numbers in Column 6 were added in pairs so as to give a single number for each 20 Mev interval, and these are shown by the points in Fig. 1. The last energy interval goes from 300 Mev to 335 Mev and was weighted properly by multiplying by 20 and dividing by 35. The errors shown are statistical errors obtained by dividing the values given by the square root of the number of pairs shown in Column 2 of Table I but taken in 20 Mev intervals. There is no estimate of possible systematic errors included with these errors.

Theory

The 20 mil platinum target is bombarded by electrons, and the energy distribution of the x-rays produced is a function of this thickness. The spectrum

[1] W. Heitler, Quantum Theory of Radiation, p. 201

Table I

Experimental Differential Distribution

Pair Energy Interval in Mev	Measured Number of Pairs N	Calculated Relative Cross Section in Lead σ	N/σ	Average Pair Energy Divided by 322 Mev	Experimental Differential Energy Distribution
0-10	153	2.0	76.5	.0155	1.09
10-20	441	4.9	90.0	.0466	4.19
20-30	441	6.4	69.0	.0777	5.36
30-40	317	7.2	44.0	.1088	4.79
40-50	276	7.7	35.8	.1399	5.01
50-60	230	8.0	28.7	.1710	4.91
60-70	230	8.4	27.4	.202	5.54
70-80	192	8.7	22.1	.233	5.15
80-90	136	8.9	15.3	.264	3.88
90-100	140	9.1	15.4	.295	4.54
100-110	139	9.2	15.23	.336	5.11
110-120	124	9.35	13.28	.357	4.72
120-130	115	9.45	12.18	.388	4.72
130-140	94	9.55	9.74	.420	4.07
140-150	90	9.65	9.34	.451	4.21
150-160	76	9.70	7.85	.482	3.79
160-170	78	9.80	7.96	.513	4.08
170-180	89	9.85	9.04	.544	4.92
180-190	81	9.90	8.19	.575	4.71
190-200	52	9.95	5.32	.606	3.23
200-210	51	10.0	5.10	.627	3.20
210-220	63	10.05	6.26	.668	4.18
220-230	59	10.10	5.9	.700	4.13
230-240	51	10.15	5.0	.732	3.66
240-250	52	10.15	5.1	.761	3.88
250-260	51	10.20	5.0	.793	3.96
260-270	38	10.25	3.7	.824	3.05
270-280	43	10.30	4.2	.855	3.59
280-290	43	10.35	4.2	.886	3.72
290-300	34	10.35	3.3	.917	3.02
300-335	57	10.40	5.5	.987	5.37

for an infinitely thin target was calculated by R. Christian following the Bethe-Heitler[2,3] bremsstrahlung theory using a Thomas-Fermi model for the atom. The theoretical differential energy spectrum for an infinitely thin target produced by electrons of 322 Mev energy is given in Column 2 of Table II. This spectrum is modified by the thickness of the target as the result of the following process. First the original electrons lose energy by radiation so that their original energy is lowered and the x-rays produced by them farther along in the target will show a lower average energy. This lowering in energy would be more marked were it not for another effect which reduces this considerably. The electrons which have been multiply scattered are no longer pointing in their original direction. Using the multiple scattering formulas of E. J. Williams it can be shown that after traversing about the first 4 mils of the target the electrons are sufficiently out of line so as to make most of the photons produced by them miss the cloud chamber altogether. This effect was first pointed out by E. M. McMillan[4] and its result is to give a spectrum more like that for an infinitely thin target. The spectrum comes almost entirely from the first fifth or quarter of the target and, therefore, these quanta will be absorbed in passing through the remaining three quarters of the target. Only about 10 percent of the quanta are absorbed in the target, and the absorption coefficient changes by only twelve percent from 40 Mev on up. The correction is practically a constant one and reduces the intensity almost uniformly by ten percent. The spectrum resulting after all these corrections is given in Column 3 of Table II.

[2] H. A. Bethe, W. Heitler, Proc. Roy. Soc. 159, 432 (1937)

[3] B. Rossi, K. Greisen, Rev. Mod. Phys. 13, 253 (1941)

[4] E. M. McMillan, private communication

Table II

Average Pair Energy Divided by 322 Mev	Differential Energy Distribution for an Infinitely Thin Pt Target	Differential Energy Distribution for a 20 mil Thick Pt Target	Differential Energy Distribution for a 20 mil Target with 2.5% Probable Error
0.1	18.6	17.5	17.5
0.2	17.0	15.7	15.7
0.3	15.6	14.3	14.3
0.4	14.5	13.1	13.1
0.5	13.8	12.4	12.4
0.6	13.4	11.9	11.9
0.7	13.2	11.6	11.6
0.8	13.1	11.2	11.2
0.9	12.8	10.5	10.5
0.92		10.3	9.8
0.94		9.8	9.0
0.95	12.0		
0.96	11.8	8.9	7.5
0.98	10.0	7.05	5.7
0.99	7.75	5.2	
1.00	0	0	3.7
1.02	0	0	2.0
1.04	0	0	0.87
1.06	0	0	0.30

In order to compare this with the experimental results, it is necessary to assume a pair production cross section for the x-rays in the lead plate and to make any necessary corrections for the passage of the x-rays through the quartz wall of the vacuum chamber and the 88.5 feet of air between it and the cloud chamber. The pair production cross section for x-rays in lead was taken from the curve for lead in Heitler[1] and is given relative to the cross section at 190 Mev in Column 3 of Table I. The pair production cross section for lead was measured by J. L. Lawson[5] for 88 Mev x-rays and was found to be 31.3 barns instead of the theoretical value of 34.9 barns or lower by eleven percent than the simple theory at 88 Mev. G. D. Adams[6] measured an absorption coefficient for lead at 19.1 Mev which was 9.6 percent lower than experiment and R. L. Walker[7] finds it 9.8 percent lower at 17.6 Mev. Both of these experiments indicate that the cross section for pair production is lower for lead but lower by nearly the same amount from 17 Mev up to 88 Mev. This difference can become appreciable here only if the ratio of the cross sections changes with energy, and since there is no evidence that this occurs, no correction has been made.

The one mil thick lead plate is sufficiently thin so that the probability that a particle produced in the lead will radiate before leaving the lead is very small. Only 0.2 percent of the particles will radiate more than 40 percent of their energy. The absorption of the x-rays by the quartz and the air amounts to 13 percent of the incoming x-rays and is practically uniform over the entire spectrum. The total cross section for 88 Mev x-rays for aluminum as measured by J. L. Lawson[5] is 1.128 barns and the theoretical cross section

---

[5] J. L. Lawson, Phys. Rev. 75, 440 (1949)

[6] G. D. Adams, Phys. Rev. 74, 1707 (1948)

[7] R. L. Walker, Phys. Rev. 76, 527 (1949)

is 1.103 barns. This is a good indication that the theory gives the correct result for light elements and that no large error would result from calculating the absorption of the quartz and the air between the target and the chamber from theory, especially since the maximum percent absorption in the neighborhood of 300 Mev amounts to only 15 percent. In the quartz and the air between the target and the lead plate in the cloud chamber there are 2.7 gr/cm^2 of oxygenm 1.7 g/cm^2 of silicon and 2.5 g/cm^2 of nitrogen. The effect of the argon in the air and the chamber plus the 5 mil aluminum window on the chamber is neglected. Using the cross sections given by Heitler[1] for the nuclear pair production plus the cross section for the pair production due to the electrons, plus the Compton scattering cross section, the percentage of the x-rays transmitted is found to be 87 percent from 30 Mev to 204 Mev, 88 percent at 15 Mev, and 86 percent at 300 Mev. This has no observable effect on the energy distribution of the x-rays.

In order to be sure that higher energy x-rays absorbed in the quartz and air were not producing secondary quanta which would distort the spectrum at lower energies, the electrons entering the chamber with the x-ray beam were counted for a few pictures taken without magnetic field. The secondary quanta in the beam should be comparable in number with the secondary electrons accompanying the beam. There were 16 electrons accompanying the beam for every pair produced in the lead plates. Since about 4000 photons are necessary to produce one pair, the secondary quanta form a negligible fraction of the x-ray beam.

The theoretical differential energy spectrum given in Column 3 of Table II for a 20 mil thick platinum target drops to zero at energies above that of the electrons in the synchrotron. If there is an error in measurement of the energy of the pairs, this will change the shape of the theoretical curve making it less steep and extending it above this energy. The random experimental errors were estimated to give a probable error of 2.5 percent. Actually the errors arise from the fact that the templates used to match curvatures[8] are about four percent apart in radius, and the error due to multiple scattering of the particles in the gas amounts to about one percent. Although the errors arising from the templates are not gaussian but cut off more rapidly, they were assumed to be gaussian. The theoretical differential energy spectrum, modified so as to correspond to one observed with a probable error of 2.5 percent, is given in Column 5 of Table II.

The average angle between the direction of the incoming photon and the pair fragments is of the order of the energy of the photon divided by the energy of the electron; and since this is very small above energies of 20 Mev, the pair fragments lie very nearly in the same plane which is very nearly perpendicular to the direction of ... magnetic field. As a consequence of this, no correction for large angles is necessary above 20 Mev such as was necessary in the energy spectrum obtained by Koch and Carter[9] from 19.5 Mev electrons. The first point on the energy spectrum curve disagrees markedly with theory both because no correction was made for these angles and because electrons with energies less than 1 Mev were easily missed because of their very great curvature. Figure 2 shows a typical cloud chamber photograph with seven pairs coming out of the lead and one pair produced in the gas just above the lead. The low energy pair to the left above the plate illustrates how the electrons and positrons stay in nearly the same plane for many revolutions. The illuminated region is only 1.5 inches high.

The normalization of the experimental data involves fitting the data by means of two points and a slope. This is necessary first because absolute

---

[8] Brueckner, Hartsough, Hayward, Powell, Phys. Rev. 75, 555 (1949)

[9] H. W. Koch, R. E. Carter, Phys. Rev. 77, 165 (1950)

intensities are not known, and second because the exact energy of the accelerated electrons is unknown. This experiment can be used to determine the energy of the original electrons if the theory of pair production and x-ray production is assumed to be correct. The first estimate of 335 Mev for the energy of the synchrotron electrons was made from measurements of the magnetic induction around the orbit of the electrons in the synchrotron. Actually the field at a radius of one meter was found to vary by 2.6 percent. The absolute measurement of the field was made with a search coil having an error in effective area of one percent and a voltmeter having an error of 1.5 percent. The voltage on the condensers which discharge into the synchrotron magnet is measured on another voltmeter which was not recalibrated at the time of this experiment and might be in error by 2 percent. The position of the target is accurately known, but the position of the center of curvature of the beam of electrons has never been determined and might be one or two centimeters away from the center of the machine. This would make a one or two percent error in the energy. Also the synchrotron magnet has been disassembled twice since the measurement of the magnetic field. The total air gap in the magnet is 2.5 inches and on replacing the top of the magnet this may be changed by as much as 20 mils, 10 mils in the large air gap and 10 mils in changes in the thickness of the bakelite sheets which insulate the 70 ton top of the magnet from the rest of the magnet. This change might be irregular in azimuth and cause shifting in the center of curvature as well as changes in the average value of the field. Errors of as much as four percent can easily be accounted for by a combination of all of these factors.

The cloud chamber magnetic field was measured by means of a search coil with effective area accurate to 1 percent and fluxmeter consisting of an integrator operating into a cathode ray oscilloscope. Most of the signal from the search coil was bucked out by a secondary flux standard accurate to 1 percent, and the fluxmeter could be read to a tenth of a percent. Each time a picture was taken, the current going to the cloud chamber magnet was read from the ammeter used in making the field calibration. The error in magnification of the pictures on reprojection is less than half a percent. The conclusion is that a systematic error in the measurement of the energy of the particles in the chamber could not exceed two percent unless a systematic error were made in comparing the curves on the templates with the tracks. Since the tracks, with a few exceptions, were measured twice by independent observers, a systematic error of a size sufficient to raise this error seems unlikely.

The conclusion is that the electron energy of 322 Mev as determined by the measurements made in the cloud chamber is probably accurate to two percent and is a better value than the 335 Mev estimated from magnetic measurements on the synchrotron.

The Energy of the Electrons in the Synchrotron

In order to be able to compare theory with experiment it is necessary first to determine the energy of the electrons in the synchrotron. As shown above the cloud chamber measurement of the pair spectrum gives a better estimate of this than the magnetic field measurements made on the synchrotron if a satisfactory way can be devised for treating the pair spectrum to obtain the energy of the electrons. This comparison was made in the following way. First the theoretical differential energy spectrum adjusted to account for a 2.5 percent random probable error in the measurement of the energy given in Column 4 of Table II was divided by the average energy of each set of pairs so as to give a set of numbers proportional to the actual number of photons. These values were integrated with respect to energy from infinity down and a plot of these values down as far as 0.9 of the full energy of the electrons is shown as the circles in Fig. 3. A similar integral curve was made from the pair data, and on comparing the two as shown by the x's in Fig. 3 the agreement was excellent if the energy of the electrons was assumed to be 322 Mev. Both the experimental and theoretical numbers were integrated down to 60 Mev and normalized as to magnitude at this point. The agreement achieved by these two adjustments is that shown in Fig. 3, and the shape of the foot of the integral curve indicates that the estimate of random errors agrees with the facts.

E. M. McMillan estimated the energy of the electrons by using the ratio of the number of pairs above 290 Mev to the number between 200 and 290 Mev and comparing this ratio to that obtained for the theoretical curve for various assumptions about the energy of the electrons. This comparison should be independent of the errors in measurement if they are random. The result of this calculation gave an energy of 320 Mev with a statistical error of plus or minus 2 Mev. The two methods of determining the energy of the electrons from the data agree well within the experimental errors.

The differential energy distribution of the photons is plotted in 20 Mev groups in Fig. 1. The solid curve is the theoretical curve (Column 4 in Table II) modified by the 2.5 percent probable error in the experimental determination of the energies of the pairs. The departure of experiment from theory at the lowest point representing photons with energies up to 20 Mev arises from the fact that the curvature of the tracks was too great to be measurable in many instances for this group. Pairs with energies less than 5 Mev were not measured and were not included in this data. The experimental errors shown in Fig. 2 are statistical errors and it is evident that the experiment shows no appreciable deviation from the theory.

The Fraction of the Photon Energy Possessed by the Positron

If we let W be the energy of the photon and U that of the positron belonging to a pair then $F = U/W$ is the fraction of the energy of the photon possessed by the positron. A group of 1060 pairs between 100 and 300 Mev was divided into ten groups according to the value of F and the results are shown in Table III and compared with the theoretical values given by B. Rossi and K. Greisen,[3] page 261. The theory and experiment agree well within the limits of error. In the zero to ten percent group and the 90 to 100 percent group the number of pairs is low, and if no allowance is made for statistical errors, it would appear that 1.6 percent of the pairs were missing in both groups. It has not been possible for us to give any explanation for this low value other than the fact that the number of observations is insufficient to exclude the statistical error.

The number of Compton electrons is negligible in this range of energies. This was borne out by the experimental fact that there were 12 positrons and 10 electrons appearing singly. There should have been about 4 additional electrons over and above positrons from the Compton effect. The numbers observed are not inconsistent with this.

Conclusions

The differential energy distribution of the photons produced by 322 Mev electrons is that which is predicted by the Bethe-Heitler bremsstrahlung theory using the Thomas-Fermi model for the atom. The fraction of the energy carried by the positron in a group of 1060 pairs agrees with the theoretical predictions.

The energy of the electrons produced by the Berkeley synchrotron for this experiment was 322 ± 6 Mev.

Table III

Energy Interval of the Positrons in Percent of Pair Energy	Number of Pairs	Experimental Percent of Total Number of Pairs	Theoretical Percent of Total Number of Pairs
0-10	81	7.6	9.0
10-20	126	11.9	11.0
20-30	112	10.6	10.4
30-40	111	10.5	9.9
40-50	106	10.0	9.7
50-60	119	11.2	9.7
60-70	120	11.3	9.9
70-80	100	9.4	10.4
80-90	105	9.9	11.0
90-100	80	7.6	9.0

The relative energy distribution of the positron pairs of total energy lying between 100 and 300 Mev

Acknowledgments

Many of the energy measurements were made by M. Lemmon and Dr. E. Hayward who also helped in the reduction of the results. The cooperation of Mr. Walter Gibbins and numerous others in the operation of the synchrotron and in making the careful adjustments necessary for good cloud chamber pictures was indispensable in the success of the experiment.

This work was performed under the auspices of the Atomic Energy Commission.

Information Division
scb/8-2-50

Figure Captions

Fig. 1 The differential energy distribution of the photons. The pairs are taken in 20 Mev groups up to 300 Mev. The group at the highest energy is taken over 35 Mev and normalized appropriately. The mean error or statistical error is plotted for each point.

Fig. 2 Seven pairs produced in a one mil thick lead foil across a cloud chamber in the x-ray beam. The two pairs produced in the gas were not used in obtaining the energy spectrum. The field is 10,000 gauss.

Fig. 3 The number of pairs above a given energy plotted against the energy of the photons divided by 322 Mev. The circles give the theoretical values and the crosses, the experimental values.

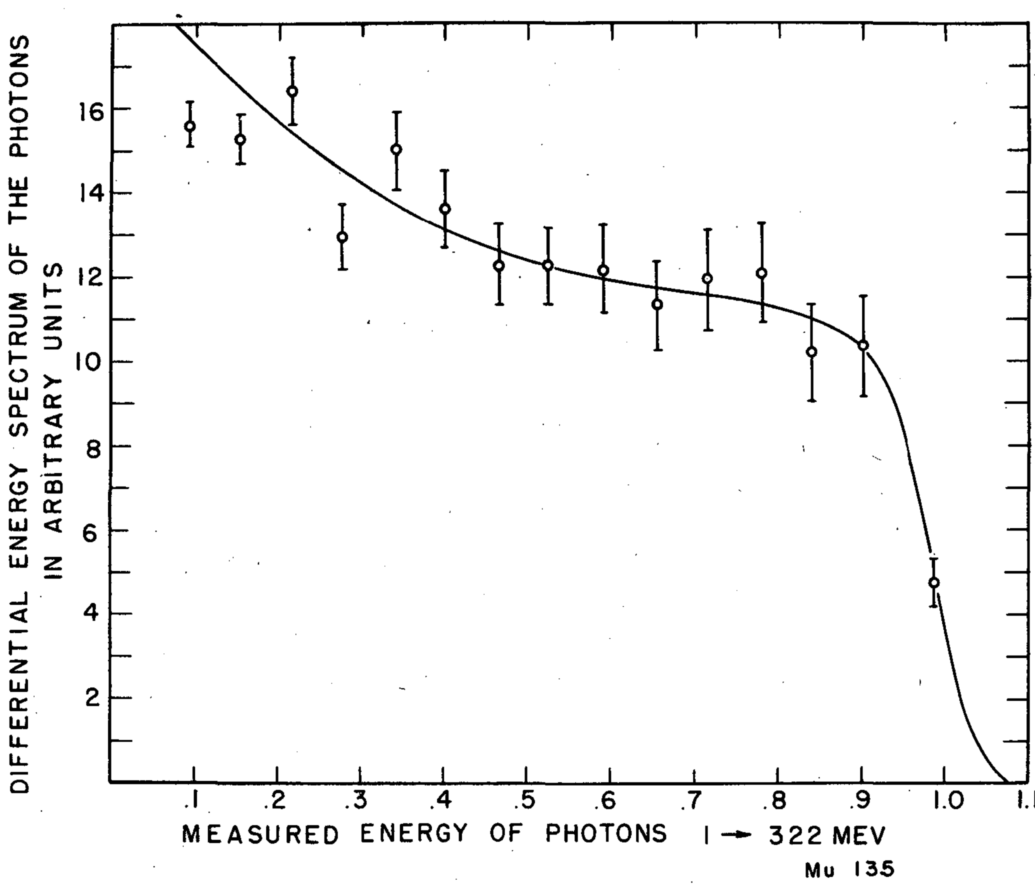
DIFFERENTIAL ENERGY SPECTRUM OF THE PHOTONS
IN ARBITRARY UNITS
16
14
12
10
8
6
4
2
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
MEASURED ENERGY OF PHOTONS 1 → 322 MEV
Mu 135

Fig. 1

FIG. 2