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# PHYSICS DIVISION QUARTERLY REPORT

February, March, and April, 1952

June 16, 1952



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*Previous Physics Quarterly Report (UCRL-1729)
November, December, 1951, and January, 1952

# I GENERAL PHYSICS RESEARCH

## 1. Cloud Chamber Program

Wilson M. Powell

Scattering and Absorptions of $\pi^+$ Mesons by Aluminum. J. F. Tracy

Work is in progress on the experimental determination of the scattering and absorption of positive $\pi$-mesons by aluminum. These mesons are in the 50 Mev range. Separate cross sections for the elastic and the inelastic interactions and the angular distribution for elastic scattering are being obtained. Preliminary results indicate the cross section for elastic and inelastic events taken together is of the order of the nuclear area.

The mesons were produced in a two-inch thick polyethelene target placed in the 340 Mev deflected proton beam of the 184-inch cyclotron. A steering magnet separated the forward-moving mesons from the protons by turning them through 90 degrees and into a collimating hole in the five foot concrete shielding. Outside the shielding the resultant meson beam traversed a 22-inch diameter cloud chamber positioned horizontally in a vertical magnetic field of 5200 gauss.

Inside the chamber were five vertical aluminum plates one-eighth inch thick and spaced at two inch intervals. The mesons passed through the plates at a horizontal angle of from 20 to 45 degrees to the normal. In this way only some of the 90 degree scattering events were obscured. The chamber was filled with one atmosphere of argon and a mixture of alcohol and water vapors.

Approximately 600 usable pairs of stereoscopic photographs were taken. These are now being examined in a projector which permits the full scale three-dimensional reconstruction of events. One-third of these photographs have already been examined in some detail. It appears that a total of 150 to 200 events will be obtained and that there will be roughly comparable numbers of elastic and inelastic events. This is exclusive of small angle multiple coulomb scattering.

Many elastic back scatters and large-angle elastic forward scatters have already been observed. Meson-induced nuclear disintegrations with as many as four visible fragments have also been observed. Usually only one or two fragments are seen. At least some of these are energetic protons. In addition some mesons enter an aluminum plate and disappear. These may represent actual cases of meson absorption wherein no charged particles are emitted or merely cases where the charged particles or scattered meson are hidden from view by the geometrical arrangement.

A possible source of error in the determination of absolute cross sections is the $\mu$-meson contamination. The $\pi$-mesons travel fourteen feet and about one-third decay before entering the chamber. Most of the resultant $\mu$'s move at such angles to the main $\pi$-beam that they are excluded from the chamber by the collimation or are rejected when seen inside the chamber because of improper angle. An experimental check on this contamination was made possible by the placing of nuclear plates in the meson beam. These plates have not yet been examined in detail. The number of $\pi - \mu$ decays seen inside the chamber are being counted and should also be indicative of the amount of this contamination. The percentage contamination is expected to be quite small.

## 2. Film Program

Walter H. Barkas

Meson Masses and Energy Balance in Meson Decay. F. M. Smith, W. Birnbaum, W. H. Barkas

The analysis of the latest experimental data on $\pi^{\pm}$-proton and $\pi^{+}$-$\mu^{+}$ mass ratios is now being completed. Because of the small probable errors demanded of the $\pi^{+}$-proton mass ratio, this phase of the program, it is felt, should be repeated. Particular attention will be given to the possibility of systematic errors. In addition, the study of range straggling and decay momentum of the $\mu^{+}$ meson is being continued. The results are of interest since an upper limit of the mass of the neutrino associated with meson decay can be obtained. No further "anomalous" $\pi^{+}$-$\mu^{+}$ decay events have been observed.

Electron-Electron and Positron-Electron Scattering. C. E. Violet, F. C. Gilbert, W. H. Barkas

The electron-electron scattering study at 200 Mev by use of electron sensitive emulsions has been completed. A counter experiment is being designed to measure the scattering cross section for large energy exchange collisions in order to supplement the emulsion data in this region. It is in this region that theory predicts the detection of exchange and spin effects. The data gathered from the emulsion phase of this experiment are in excellent agreement with the Møller differential cross section.

The positron-electron scattering study with 200 Mev positron primaries is drawing to completion, requiring, however, some further operation of the synchrotron. The primary positron tracks are scanned in the same manner as in the electron-electron scattering study with the aim of attaining the same statistical accuracy. Preliminary results indicate a differential cross section similar to the electron-electron scattering cross section.

Nuclear Scattering of Electrons and Grain Density Measurements in Electron Sensitive Emulsions. C. E. Violet, P. C. Giles, W. H. Barkas

Nuclear scatters of greater than $2^{o}$ using electron and positron primaries in photographic emulsions are currently being measured at the primary particle energies of 20, 40, 70, 100, 200, and 300 Mev.

Grain density measurements of electron tracks in emulsion for electron energies ranging from $\sim$ 100 Kev to 300 Mev are being planned. The source of low energy electrons will be the electron linear accelerator. A statistical accuracy of $\sim$ 2 percent is required in order to detect the reported 8-10 percent rise in grain density above minimum ionization for highly relativistic particles. Also if the dE/dx curve is assumed known below minimum ionization, then a functional relationship between grain density and dE/dx is obtained.

Meson Scattering. H. H. Heckman, L. E. Bailey

Further effort is being placed into the task of scanning the emulsion pellicles which were embedded in absorber-scatterers of Al, Cu, and Pb. The scanning is difficult and the accumulation of data is slow. However, the measurements of the cross section for large angle (greater than $90^{o}$) scattering of $\pi^-$ mesons in these elements are approaching the concluding stages. The scattering cross section is merely proportional to the ratio of the backward flux to the forward flux, both of which are measured directly on the same emulsion pellicle.

Focused Meson Beam. J. Vedder, R. Sagane

The possibility of obtaining a focused beam of mesons from the large spiral orbit spectrometer has been investigated with $\beta$-rays using a model magnet equipped with special pole faces. Evidence of suitable vertical and horizontal focusing for several geometries was found.

Analysis of Spallation Process. W. H. Barkas, H. Tyren, R. Deutsch, J. K. Bowker

A means has been developed to analyze the products of violent disintegrations of nuclei in the cyclotron. A program to study the effect of varying the conditions of the bombardment has been started. Since there are six important variables in this experiment, a considerable program is envisaged. The following abstract was presented for the Washington meeting of the American Physical Society:

The spallation fragments of $H\rho \approx 4.5 \times 10^5$ gauss-cm leaving a one mil polystyrene target in the forward direction are brought to a 180° focus in the magnetic field of the 184-inch cyclotron. The spalls enter the surface of Ilford $D_1$ nuclear track emulsion making a small angle with the surface. The position, track-angle, range, and estimated charge are recorded for each track. The calculated radius of curvature plotted against the range provides a nuclide spectrum of the tracks, since each nuclide falls on a definite locus in such a diagram. Resolution of $H^1$, $H^2$, $H^3$, $He^3$ and $He^4$ splinters is unambiguous. A group probably comprising $Li^6$ and $Be^7$ and another group probably of $He^6$ and $Li^7$ are also found, but for lack of good range-energy curves for highly charged particles the resolution is at present uncertain. No $Li^8$, $B^8$, $H^{>3}$ or $He^{<3}$ tracks were found. The abundances of the fragments are as follows: $H^1$, 25.0

percent; $H^2$, 7.4 percent; $H^3$, 4.6 percent; $He^3$, 7.0 percent; $He^4$, 41.5 percent; ($Li^6$, $Be^7$ group), 3.3 percent; ($He^6$, $Li^7$ group) 4.9 percent; other groups plus background, 6.2 percent. Further measurements in other momentum intervals and with other targets are in progress. This work was supported by the A.E.C.

<u>Study of Negative Muon Production and Behavior</u>. D. Sherman, H. Heckman, W. Barkas

This program is essentially completed and a report is being written. It is found that few, if any, muons are directly produced in the target, and that on capture most of the mesons do not produce charged particle stars. A few single prong stars are definitely produced, and probably some two and three prong stars, also.

<u>Test of Charge Symmetry Hypothesis in Meson Production</u>. H. Wilson, W. H. Barkas

The ratio of positive to negative meson production when alpha particles bombard carbon is being measured. If complete symmetry exists, then every process leading to production of a negative meson has an image process leading to the production of a positive meson. Thus, correcting for a small coulomb effect, a +/- ratio of unity would provide evidence favoring the charge symmetry hypothesis.

## 3. Total Proton-Proton Scattering Cross Section (345 Mev)

O. Chamberlain, E. Segre, and C. Wiegand

It is planned to measure the total p-p scattering cross section by attenuation in a liquid hydrogen target. Because of coulomb scattering it is necessary to give some attention to the counter geometry, making a proper choice of the cut-off angle of the counter. Scatterings by more than this cut-off angle would be required in order that the proton in question miss the counter and be counted as a scattered proton. The cut-off angle chosen is about 8 degrees (lab. system). Since our previous measurements of the differential scattering cross section extend down to 6 degrees, this choice should allow a reliable normalization of previous results by an independent method.

This experiment is made possible by the development by Mr. Donald Stork of a reliable liquid scintillation counter of 8 inches diameter. Tests of the Stork counter have been satisfactory, and the liquid hydrogen target has been designed and submitted to the shop for construction.

## 4. Proton-Deuteron Elastic Scattering Using 345 Mev Protons

O. Chamberlain and D. D. Clark

As reported previously, a serious attempt is being made to make a clean separation of the elastic p-d scattering from the much more numerous inelastic scattering processes in which the deuteron is broken up. The most promising method is that involving essentially the simultaneous measurement of specific ionization and total energy of the scattered particles. A thin stilbene crystal is proposed for measurement of the specific ionization, followed by a thick sodium iodide crystal which should measure, in effect, the total energy. In each case the pulse height at the output of a photomultiplier would be used as a measure of the energy lost by the particle in passing through a crystal.

At the present time the counters have been constructed and they are under test. It is not yet clear whether or not the optical arrangements of the crystals and photomultipliers give adequate light collection and adequate uniformity of light collection by the photomultiplier.

## 5. Proton-Proton Scattering at Reduced Energies

John Garrison

It is desired to measure the proton-proton differential scattering cross sections at small angles (down to about 20 degrees in the c.m. system) in the energy range 160 to 250 Mev.

The liquid hydrogen target which was constructed for this purpose, as a modification of the target originally built by Leslie Cook of this laboratory, is not complete. A great deal of difficulty was experienced in fabrication of a reliable liquid hydrogen containing vessel. Several designs were tried before a vessel was obtained that remained vacuum-tight even after many evacuations.

The target has been used in a preliminary run which involved only the full energy (345 Mev) proton beam of the cyclotron. The run was quite satisfactory, giving hope that the experiment may be completed within a few months. Subject to some presumably small corrections based on a future recalibration of the ionization chamber used for monitoring the proton beam, the results from the preliminary run agree fairly well with previous work done at this laboratory on p-p scattering.

## 6. Absolute Yield of $\pi^0$ Mesons in the Proton Bombardment of Carbon

The work of W. E. Crandall and others on the photon spectra received at various angles from targets bombarded with 340 Mev protons allows one to infer the angular distribution of both the photons and the $\pi^0$ mesons. However, in that work it was not possible to use an absolute proton beam monitor, since for reasons of intensities the target was placed within the cyclotron tank and multiple passage of the beam rendered a confident measurement of its current impossible. The relative numbers of photons received at various angles were measured by the use of thin aluminum foils or thin polystyrene foils fastened to the carbon target. The activities of sodium 24 or of carbon 11, respectively, served to give relative normalization.

The present report deals with an absolute evaluation of the photon yield received at 90° from a carbon target bombarded by the external proton beam, whose current could be precisely measured. Comparison with the 90° spectrum received from internal targets then made it possible to place the data upon an absolute scale of intensity. In Table I which follows, there are listed the results for the various angles of observation in the laboratory system. The first column gives the differential cross section presented by the carbon nucleus for the production of photons at the peak of the spectrum seen at the angle specified. The second column gives the total photon yields in terms of the cross sections for the delivery of high-energy photons into unit solid angle in the direction specified. The third column gives the amount of solid angular space to be associated with each of the spectra at the various angles of view. The last column consists of the products of the preceding two columns which, when summed, will give the total cross section of the carbon nucleus for the production of high energy photon radiation.

TABLE I

| ANGLE | $\frac{d\sigma}{dE d\Omega}$ | $\frac{d\sigma}{d\Omega}$ | $\Delta\Omega$ | $\Delta\sigma$ |
|---|---|---|---|---|
| 0 | $4.31 \times 10^{-30}$ | $6.91 \times 10^{-28}$ | 0.84 | $5.80 \times 10^{-28}$ |
| 47° | $3.59 \times 10^{-30}$ | $4.58 \times 10^{-28}$ | 2.30 | $10.53 \times 10^{-28}$ |
| 90° | $2.26 \times 10^{-30}$ | $2.02 \times 10^{-28}$ | 6.28 | $12.70 \times 10^{-28}$ |
| 133° | $2.42 \times 10^{-30}$ | $2.36 \times 10^{-28}$ | 2.30 | $5.43 \times 10^{-28}$ |
| 180° | $1.99 \times 10^{-30}$ | $1.83 \times 10^{-28}$ | 0.84 | $1.54 \times 10^{-28}$ |
| | cm²/sterad. Mev | cm²/sterad. | sterad. | $36.0 \times 10^{-28}$ cm² |

$$\sigma_{photon} = (3.6 \pm 0.8) \times 10^{-27}\ \text{cm}^2$$

$$\sigma_{\pi^\circ} = (1.8 \pm 0.4) \times 10^{-27}\ \text{cm}^2$$

(Error estimated from basic data.)

If all the high energy photons are considered to arise from neutral mesons then neutral meson cross sections are one half of that for photon production, or $1.8 \pm 0.4$.

In Figure 1 is shown a plan view of the experimental arrangement. The pair spectrometer is located where it can first view the internal cyclotron target, for the purpose of receiving sufficient gamma radiation to allow the adjustment of counting conditions to provide satisfactory plateaus, subsequently the pair spectrometer is turned upon its base so as to view through the side wall aperture a carbon target placed in the external

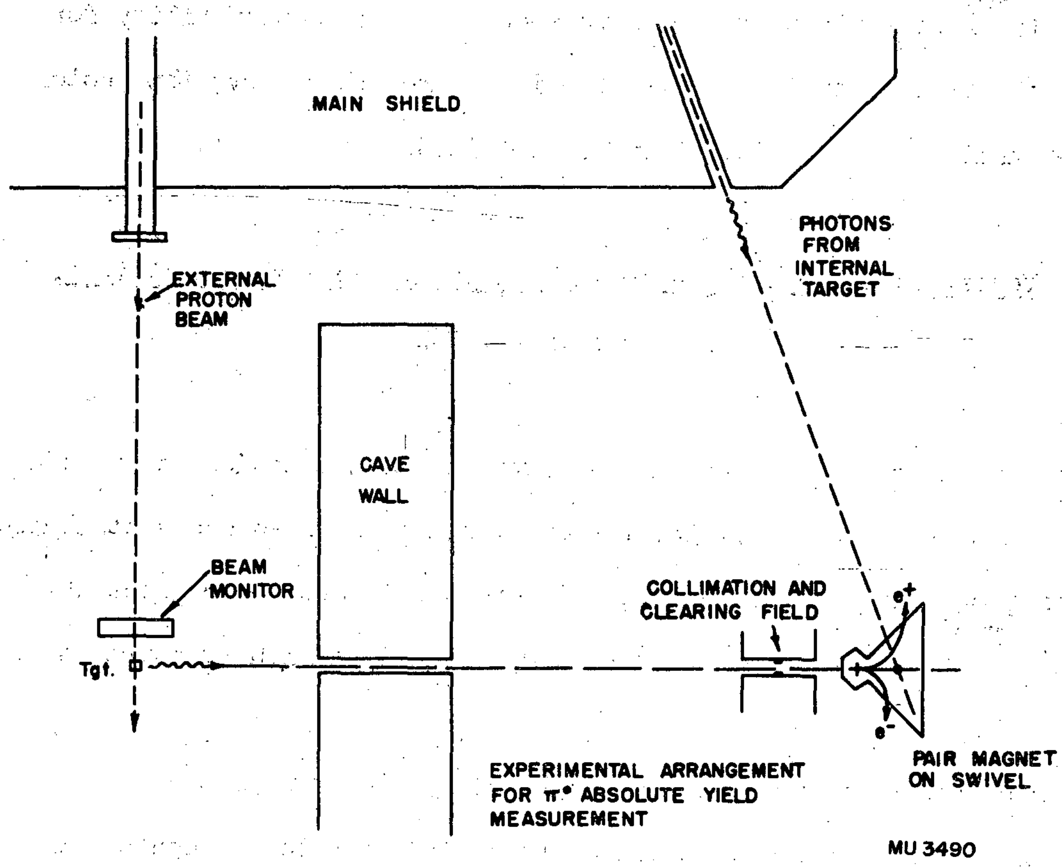

MAIN SHIELD
PHOTONS FROM INTERNAL TARGET
EXTERNAL PROTON BEAM
CAVE WALL
BEAM MONITOR
Tgt.
COLLIMATION AND CLEARING FIELD
e+
e-
PAIR MAGNET ON SWIVEL
EXPERIMENTAL ARRANGEMENT FOR π° ABSOLUTE YIELD MEASUREMENT
MU 3490

Fig. 1

proton beam. Final collimation and an electron clearing field preceding the pair spectrometer gave satisfactorily low converter-out counting rates.

In Figure 2, are displayed sample data from one run showing the dependence of photon counting rate upon tantalum converter thickness. The abscissa is expressed in terms of "effective thickness" which is calculated from actual thickness by taking account of the photon attenuation by the tantalum up to the depth of the point of pair creation and the possibility of electron energy loss to energies below detectability for the pair electrons emerging from that point. From this curve the photon yield per unit thickness of tantalum is obtained.

## 7. Variation of Neutral Meson Yield with Atomic Number of Targets

B. J. Moyer and R. Hales

The work done by Hales on this subject has been extended to provide better statistical accuracy. The target elements employed are distributed from hydrogen through lead. At present experiments are in progress which will measure the yield from deuterium and helium in a high pressure gaseous state.

As has been previously indicated the pi$^{o}$ yield from proton bombardment of the low mass elements shows a proportionality to the neutron abundance. An approximately linear dependence upon atomic number A persists at least as far as aluminum (A = 27), and from there on through lead the dependence seems to blend into an $A^{2/3}$ power variation.

Such characteristics of A-dependence can be qualitatively understood by considering that the neutral mesons for the most part are produced with sufficiently low kinetic energies that their interactions with nucleons

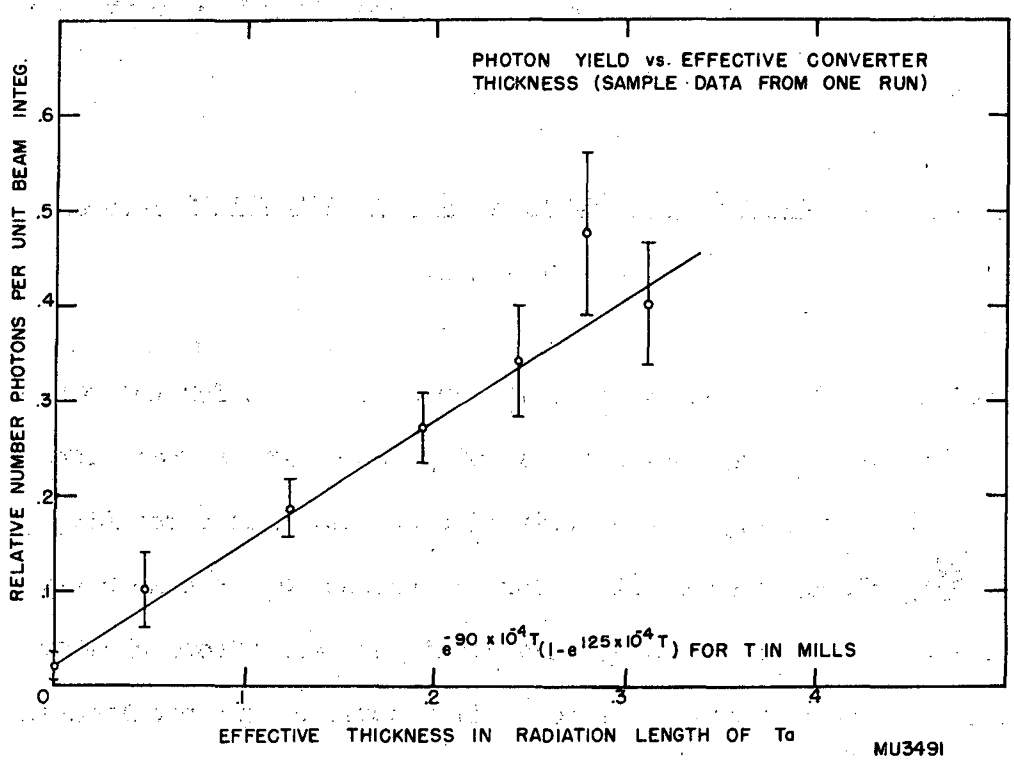

PHOTON YIELD vs. EFFECTIVE CONVERTER THICKNESS (SAMPLE DATA FROM ONE RUN)
RELATIVE NUMBER PHOTONS PER UNIT BEAM INTEG.
.6
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
$e^{-90\times10^{-4}T}(1-e^{-125\times10^{-4}T})$ FOR T IN MILLS
EFFECTIVE THICKNESS IN RADIATION LENGTH OF Ta
MU3491

Fig. 2

are not strong, and that, consequently, their mean free path within nuclear matter is relatively large. The A-dependence then is primarily affected by the mean free path of the incident protons in nuclear matter. From studies of collision cross sections it is known that among the light elements the transparency to the passage of 340 Mev protons is quite complete among the low mass elements, and nuclear opacity does not become prominent until mass numbers of the region of 20 to 30 are reached.

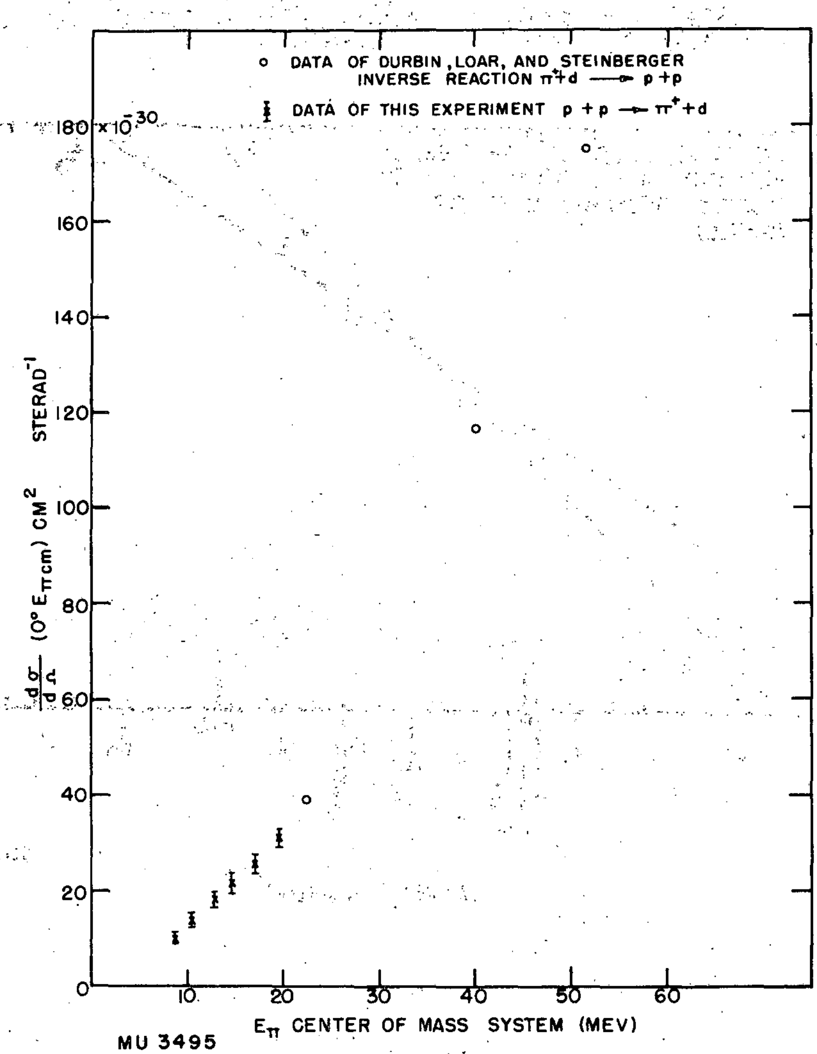
A summary of the present data on yield versus target element is provided by Figures 1, 2, and 3.

## 8. Cross Sections for Products of 90 Mev Neutrons on Carbon

D. A. Kellogg

Determinations have been made of the cross sections for the products of 90 Mev neutrons on carbon in the case of practically all reactions that occur. Beta counting of the activities generated in a rotating polyethylene disc yielded cross sections for the production of some heavy fragments, identified as to isotope and atomic number. Cloud chamber study yielded cross sections for almost all reactions, but resulted in the identification of most of the heavy fragments only by atomic number. The rotating disc method cross sections were normalized to the $C^{12}$ (n,2n) $C^{11}$ cross sections, and the cloud chamber method cross sections were normalized to the n-p cross section.

The relative and absolute yields of protons, deuterons, and tritons of high energies were determined by the cloud chamber method and compared with the results of Hadley and York; the agreement was excellent.



DATA OF DURBIN, LOAR, AND STEINBERGER INVERSE REACTION π⁺+d → p+p
DATA OF THIS EXPERIMENT p+p → π⁺+d
180 ×10⁻³⁰
160
140
120
100
80
60
40
20
0
dσ/dΩ (0° E_π cm) CM² STERAD⁻¹
10
20
30
40
50
60
E_π CENTER OF MASS SYSTEM (MEV)
MU 3495


Fig. 1

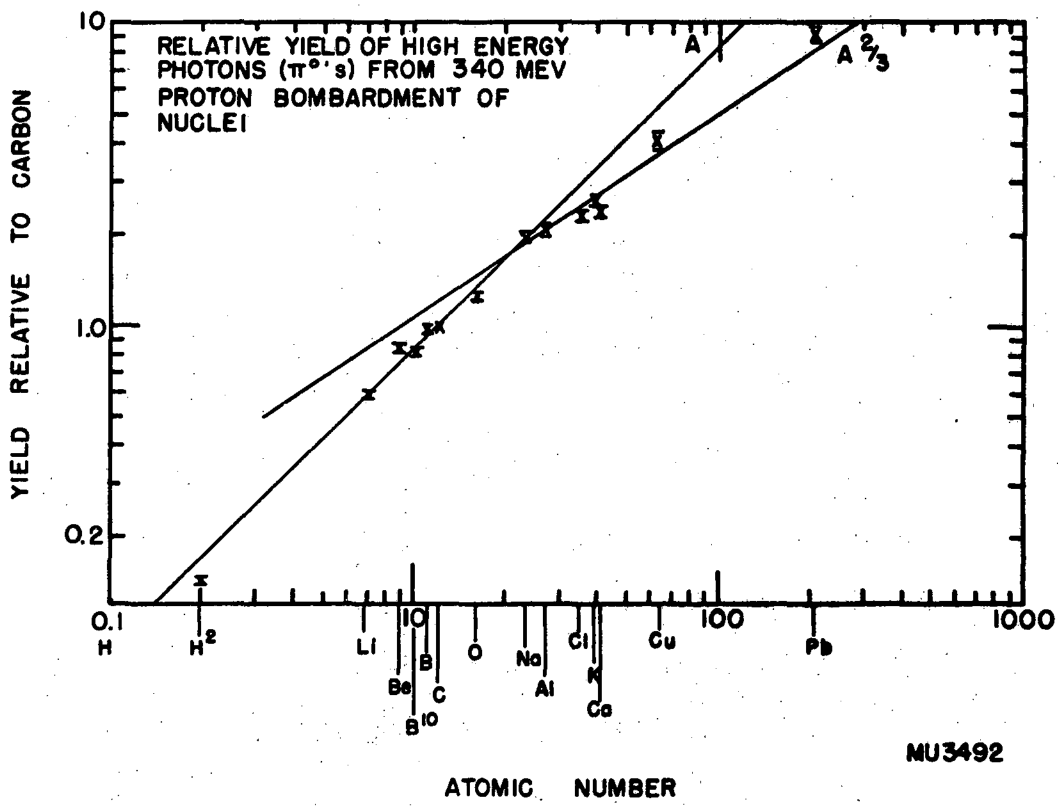
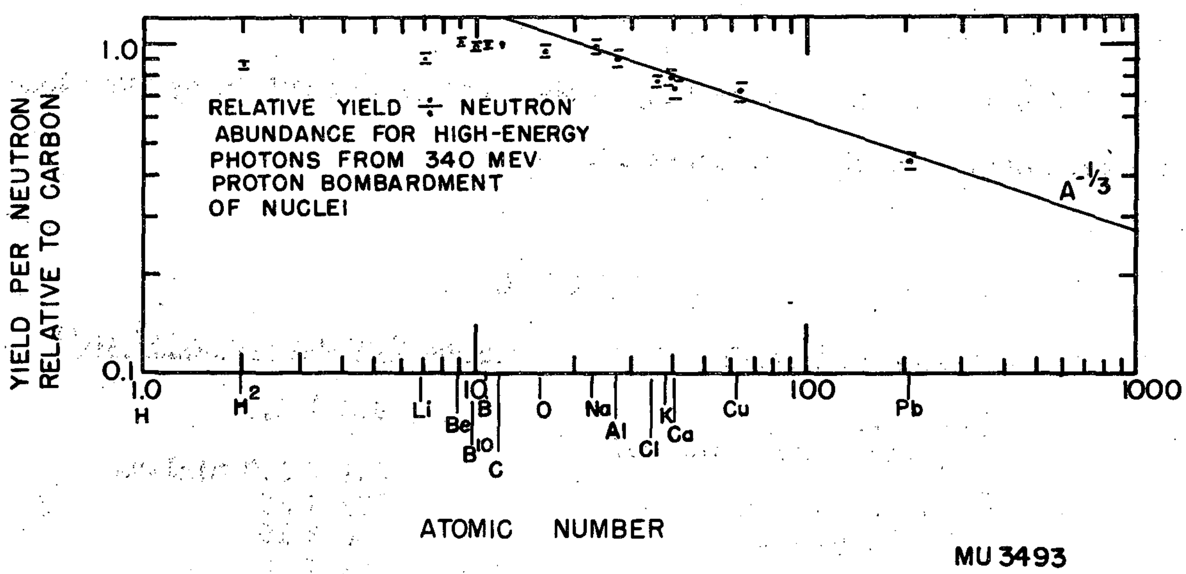

RELATIVE YIELD OF HIGH ENERGY PHOTONS (π°'s) FROM 340 MEV PROTON BOMBARDMENT OF NUCLEI
YIELD RELATIVE TO CARBON
10
1.0
0.2
0.1
10
100
1000
A
A 2/3
H
H2
Li
Be
B10
B
C
O
Na
Al
Cl
K
Ca
Cu
Pb
ATOMIC NUMBER
MU3492

Fig. 2



1.0
0.1
YIELD PER NEUTRON
RELATIVE TO CARBON
RELATIVE YIELD ÷ NEUTRON ABUNDANCE FOR HIGH-ENERGY PHOTONS FROM 340 MEV PROTON BOMBARDMENT OF NUCLEI
A^-1/3
1.0
10
100
1000
H
H2
Li
Be
B10
B
C
O
Na
Al
Cl
K
Ca
Cu
Pb
ATOMIC NUMBER
MU 3493


Fig. 3

The cross sections determined by the rotating disc method are given in Table I.

TABLE I

| Product | Cross Section (in $10^{-27}$ $cm^2$) |
|---|---|
| $B^{12}$ | $4.9 \pm 1.0$ |
| $He^6$ | $2.5 \pm 1.0$ |
| $Li^8$ | $0.8 \pm 0.4$ |
| $C^{10}$ | $0.7 \pm 0.5$ |
| $B^8$ | $<0.6$ |
| $Li^9$ | $<0.6$ |
| $Be^7$ | $8.8 \pm 4.6$ |

A few of the more interesting cross sections determined by the cloud chamber method are given in Table II.

TABLE II

| Reaction - Product | Cross Section (in $10^{-27}$ $cm^2$) |
|---|---|
| $(\alpha, \alpha, \alpha)$ | $9.8 \pm 2.0$ |
| (Li, Li) and/or ($\alpha$, Be) | |
| $Be^7$ | $4.1 \pm 1.0$ minimum |
| Total protons | $173 \pm 15$ |
| deuterons | $90 \pm 10$ |
| tritons | $22 \pm 6$ |
| Protons over 20 Mev | $85 \pm 10$ |
| Deuterons over 27 Mev | $26 \pm 6.5$ |
| Tritons over 33 Mev | $2.9 \pm 1.0$ |

## 9. Comparison of Electron and Charged Meson Yields from Carbon

L. Neher, B. J. Moyer, L. Alvarez, C. Leith

During the past year a question has been raised as to the yield of high energy electrons from a carbon target bombarded by 345 Mev protons. In particular the question is: Are the numbers of electrons compatible with the known sources (a) pair production in the target by the neutral meson decay gamma rays, (b) beta decay of low energy mu mesons in the target. Several experiments are in progress to determine the yield of electrons and positrons relative to the yield of positive and negative $\pi$ mesons for various thickness of target. The apparatus consists of a magnetic channel with about $\pm$ 10 percent momentum selection. At the exit of the channel a time of flight detector is being used to distinguish between electrons and mesons of the same momentum. The electron energy spectrum decreases smoothly with increasing energy. Electrons up to 150 Mev are observed. The positron-electron ratio appears to be unity in the region 50 to 80 Mev. Below 50 Mev, there is an excess of positrons, which are probably due to positive mu decay. Above 80 Mev the number of positrons are uncertain because of positive $\pi$ meson contamination. The total number of electrons and positrons of all energy is about 1/10 the total number of charged $\pi$ mesons. The results are still inconclusive regarding any new process for high energy electron formation.

## 10. On the Ratio of Charged Mesons from Carbon Bombarded by High Energy Neutrons

L. Neher and D. Dixon

Experiments are continuing on the production of positive and negative mesons from carbon bombarded by the 280 Mev neutron beam from the 184 in. cyclotron. We have recently observed at 15° to the neutron beam on carbon. The meson energy range is about 50 Mev $\pm$ 25 Mev. The ratio is $\pi^-/\pi^+ = 3.3 \pm 0.7$. This is a noticeable decrease from the ratio of $\pi^-/\pi^+ = 10 \pm 2$ at 90°. For the same energy range the counting rate at

$15^{o}$ is about four negative mesons per minute. The apparatus consists of time of flight detectors with magnetic channel midway in the flight path. Very little contamination due to recoil protons is found with this arrangement.

## 11. The Photoproduction of Negative Pions from Deuterium

R. Madey, K. C. Bandtel, and W. J. Frank

Synchrotron beam time was limited to one run during the past quarter.

Time of flight requirements were imposed on the detection of pion-proton coincidences so that higher beam intensities from the synchrotron could be used. These time of flight requirements are in addition to the angular and energy correlations reported previously. The results appeared very encouraging because the background counting rate from a water target did not increase as the proton counter was moved within 12 degrees of the beam. The maximum available beam intensity was used during this instrumentation run.

In preparation for an angular distribution measurement on the negative pions, absorber thicknesses and time of flight correlations were calculated. Also, improved triple coincidence circuits were constructed.

## 12. The Triton Reaction $[p + d \rightarrow \pi^{+} + t]$

K. C. Bandtel, W. J. Frank, R. Madey, B. J. Moyer

The two cyclotron runs made during this quarter were concerned with identifying the process and improving the counting rate. The process is identified by imposing the restrictions calculated from the conservation laws for a two-body reaction.

The pion and triton counter telescopes were placed at the correlated angles of 110° for the pion and 8° for the triton. Absorbers calculated from the energies expected at these angles were put between the two crystals of each telescope so that the particle went through the second crystal at the end of its range; the phototube of this crystal was then set at a lower voltage, and only pulses due to particles losing a large amount of energy in the crystal were seen. Because the triton telescope was about eight feet from the target, the tritons ($\beta \sim 1/3$) were debunched in flight from protons ($\beta \sim 2/3$) that were scattered from the beam by the target. Appropriate delay lines in the pion telescope inputs to the quadruple coincidence circuit match the pion pulse to the triton pulse; the scattered protons are matched to whatever the pion telescope may see between the R-F beam pulses of the cyclotron.

The process is observed by taking a difference between $CD_2$ and C targets. A maximum in this difference was observed at the correlated angles when the pion telescope was placed to either side of the correlated angles. The tentative, preliminary cross section, which is $\sim 1$ percent of the reaction $p + p \rightarrow \pi^+ + d$, agrees with theoretical predictions.

## 13. Electron Positron Annihilation in Flight at 200 Mev

S. Colgate and C. Gilbert

The annihilation of positrons in flight into two gamma rays was predicted theoretically many years ago (see Heitler, "Quantum Theory of Radiation,"). It is tentatively believed that this has not been observed until this experiment. There is no theoretical reason to suspect the disappearance of electrons in flight. (Inverse beta decay is smaller by a factor of $10^{-10}$ than the cross sections in question.) However, Barkas, Gilbert, Deutsch, and Violet, UCRL-1527, and F. C. Gilbert, UCRL-1506, have observed two disappearances of electrons in flight at 200 Mev in nuclear emulsions. It was these two events that prompted the present experiment.

A set of three proportional counters of small mass placed in the magnetic field of the pair spectrometer selected electrons or positrons of a given $H\rho$ from a radiator placed in the gamma ray beam from the synchrotron. These three counters in coincidence determined the momentum, charge (+ or -) trajectory, and time of a particle. A fourth counter (scintillation counter) immediately backed up the third or last proportional counter in the direction of flight of the electrons or positrons. If nothing happened to an electron between the third proportional counter and the scintillation counter, then every time a triple coincidence was observed, a count in the fourth counter or quadruple coincidence would be observed. Thus, the lack of a count in the fourth counter indicated a disappearance.

The background impurity = triple-quadruple/triple for no absorber between third and fourth counters was 1/1200. For a 2 cm Be absorber directly in front of the fourth counter, the annihilation disappearance would be theoretically 4/1200. The electron positron difference was observed to be ± 25 percent. The electron disappearances were less than 1/3 the positron disappearances, which would indicate that electrons do not annihilate or disappear in flight for low Z elements by a factor less than 1/6 of the cross section of the two events observed in nuclear emulsion by Barkas, et al.

Absorbers of LiH, Al and Cu were used and within the poor statistics, they indicated nothing different from the above. The scattering out of the absorber-multiple, or single Coulomb is proportional to $Z^2$ and is larger than the annihilation effects for Z = 6 and above.

The energy dependence of positron annihilation was observed to be correct at 100 Mev with error of ± 25 percent. These are only preliminary results and better statistics will soon be available. Also it is planned to observe the annihilation gamma rays in coincidence with a disappearance.

## 14. The Angular Distribution of $\pi^+$ Mesons from 340 Mev Protons on Protons

M. Whitehead

The measurement of the angular distribution of the mesons emitted in the reaction $p + p \longrightarrow \pi^+ + d$, has been completed. The mesons were detected in nuclear emulsions using the same experimental procedure as described previously. The cross sections were measured at 0°, 65° and 104° in the center of mass. The experimental points were fitted to a $\cos^2\theta$ distribution in the center of mass system of the two protons giving:

$$\frac{d\sigma}{d\Omega} = 3.6 \pm 1.2\,(0.09 \pm 0.06 + \cos^2\theta) \times 10^{-29}\ \mathrm{cm}^2\ \mathrm{sterad}^{-1}$$

The errors are based on the "external consistency" between the calculated and measured values.

The cross section for the inverse reaction, $\pi^+ + d \longrightarrow p + p$, can be calculated by the principle of detailed balance, assuming a value for the meson spin, $s_\pi$,

$$\left(\frac{d\sigma}{d\Omega}\right) = \frac{p_p^{\,2}\ 4}{p_\pi^{\,2}\ (2s_\pi + 1)\ 3}\left(\frac{d\sigma}{d\Omega}\right)$$

where $p_p$ and $p_\pi$ are the momenta of the proton and meson.

If $s_\pi = 0$ the inverse cross section is calculated to be:

$$\left(\frac{d\sigma}{d\Omega}\right)_p = 12\ (0.09 + \cos^2\theta) \times 10^{-28}\ \text{cm}^2\ \text{sterad}^{-1} \quad (1)$$

The experimental value for this cross section as measured at Columbia University is:

$$\left(\frac{d\sigma}{d\Omega}\right)_p = 9(0.22 + \cos^2\theta) \times 10^{-28}\ \text{cm}^2\ \text{sterad}^{-1} \quad (2)$$

The agreement, though only fair, of these cross section is a good indication that the spin of the positive pion is zero. If it were one, the measured cross section (2) should be one-third of (1), which is quite improbable.

## 15. Charged Pion Production at 180° from 340 Mev Protons on Carbon

S. Leonard

Work has been continued on an experiment to measure the $\pi^+$ and $\pi^-$ production cross sections for protons on carbon, the mesons being emitted at 180° to the deflected proton beam of the 184-inch cyclotron. Nuclear emulsions were exposed to mesons emitted at 160° to the beam, using no magnetic field, so that $\pi^+$ and $\pi^-$ mesons lodged in the same plate. Scanning of these plates was completed, and preliminary values for the $\pi^+$ cross section at various meson energies were calculated. The $\pi^+/\pi^-$ ratio, however, is so large that too few $\pi^-$ mesons were obtained to give a statistically significant result. The $\pi^+$ cross section, measured in this way, is:

| $E_\pi$ | $d\sigma/d\Omega\, dE_\pi$ |
|---|---|
| 27 Mev | $2.96 \pm 0.65 \times 10^{-30}$ cm$^2$ Mev$^{-1}$ sterad$^{-1}$ |

| | |
|---|---|
| 43 | $3.11 \pm 0.78 \times 10^{-30}$ cm$^2$ Mev$^{-1}$ sterad$^{-1}$ |
| 61 | $0.94 \pm 0.07$ |
| 82.5 | $0.74 \pm 0.17$ |

the errors being standard deviations based on statistics only.

Later, C-2 200 $\mu$ photographic emulsions were exposed to $\pi^+$ and $\pi^-$ mesons which were separated with the aid of a strong magnetic field. Brass channels placed between the pole pieces of the pair spectrometer magnet served to select mesons of predetermined momenta and to reduce the background due to stray particles in the cave. To date, exposures have been made for mesons of 30 Mev only, and these plates are being scanned. It is contemplated that exposures will also be made for mesons of 15, 50 and 75 Mev.

## 16. High Energy Deuterons from 270 Mev Neutrons on Protons

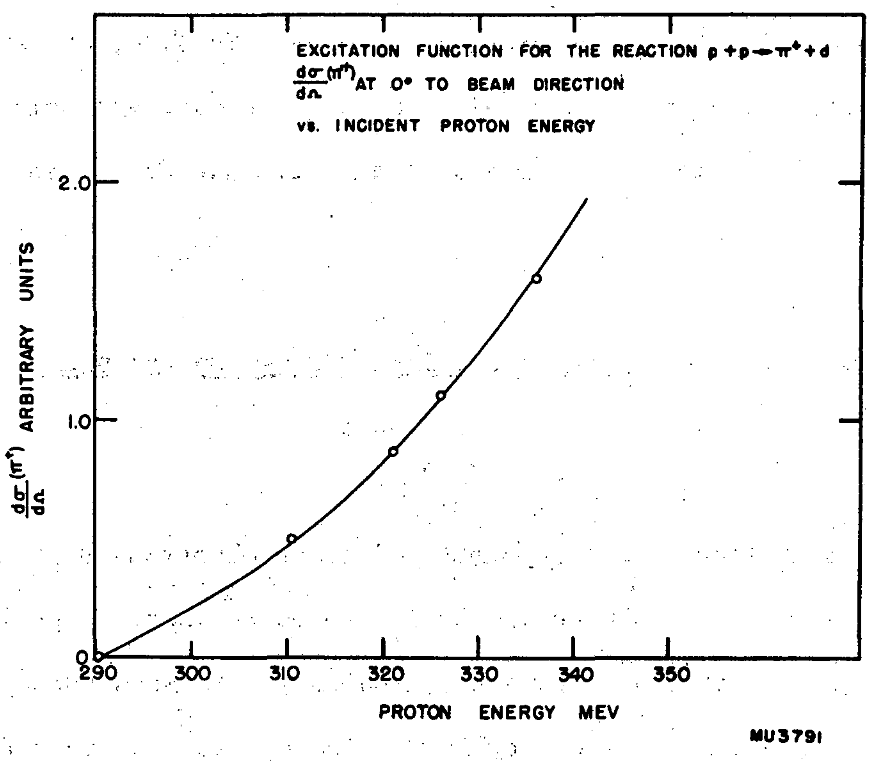
B. Youtz

Instrumentation is nearing completion for observing high energy deuterons produced by the 270 Mev neutron beam on protons. A preliminary attempt was made to observe $\gamma$-rays produced in the forward hemisphere by the n-p collision, using a solid beryllium telescope as a neutron filter. Further efforts will be made in this direction with the goal of obtaining $\gamma$-deuteron coincidences from $\pi^0$ production.

## 17. The Excitation Function for the Reaction $p + p \rightarrow \pi^+ + d$

A. Schulz, D. Hamlin, J. Merritt, M. Jakobson

The reaction $p + p \rightarrow \pi^+ + d$ is an extremely important reaction for the reasons that the kinematics are completely determined by specifying the



EXCITATION FUNCTION FOR THE REACTION $p + p \rightarrow \pi^+ + d$
$\frac{d\sigma}{d\Omega}(\pi^+)$ AT 0° TO BEAM DIRECTION
vs. INCIDENT PROTON ENERGY
$\frac{d\sigma}{d\Omega}(\pi^+)$ ARBITRARY UNITS
2.0
1.0
0
290
300
310
320
330
340
350
PROTON ENERGY MEV
MU3791


196421

Fig. 1

energy and vector momentum of only one particle after the reaction and it is one of the few where the inverse reaction can be studied feasibly. The excitation function can serve as a good test of the functional form of various theories of meson production.

A number of successful runs have been completed at present. About 14,000 mesons have been counted on this reaction at proton energies of 336, 326, 321, and 310.5 Mev, respectively. The points have good internal consistency and join well with the points corresponding to higher proton energies obtained by J. Steinberger and his coworkers at Columbia University using the inverse reaction $\pi^+ + d \longrightarrow p + p$. The experiments is being continued and more points will be added as time permits. Figure 1 shows the data obtained so far.

## 18. N-P Polarization Measurements

L. F. Wouters

The research previously performed on this problem has been reported in UCRL-1470. In order to improve the accuracy and reliability of the measurements, a completely new apparatus has been designed and is under construction.

Mechanically, the two major items include a remotely-controllable LiD target holder and an azimuthal counter mounting frame to be supported directly from the 184-inch cyclotron shielding. The counter support is so designed as to permit 360° azimuthal rotation of the four counters as well as predetermination of the scattering angles to better than 0.1 degree. In order to simplify the set-up, the electronic coincidence circuits between units of each counter telescope will now be located at each counter. The counter telescopes will subtend a sufficiently greater solid angle to obtain a five-fold increase in counting rate; units for use with 1P28 and with C-7165 photomultipliers are being designed.

Further tests of pulsed photomultiplier circuits of various sorts have shown that it is necessary to pulse the entire H. V., rather than only a portion, in order to realize any advantage in terms of gain and higher space-charge limits. Consequently, because of the complexities encountered during the earlier set of experiments, the scintillation counter array will be operated under normal d.c. conditions. Attention has thus been given to low level coincidence circuits for use with 1P28 photomultipliers. A circuit described by Z. Bey (Washington Symposium, NBS, January 1952) may have some advantages over the Neher bridge, in having less sensitive balance requirements as well as less critical dynamic range. Alternate circuits for use with high output photomultipliers (C-7165) will also be tested. (It is desired to avoid the use of intermediate amplifiers because of the "density" of cables and auxiliary items then needed at the counting head.)

The monitoring problem also requires a better answer. The new apparatus will include an isolated neutron scatterer and moderator; the slow neutron flux thus generated will be measured by means of a LiI scintillation counter. It is hoped to avoid polarization effects in the monitor itself by this scheme.

## 19. Synchrotron Studies

A. C. Helmholz

The months of February and March saw some good operation of the synchrotron, but a crack in one of the tubulations on the quartz donut necessitated the removal of that section and its replacement. Since the reassembly of the magnet, it has not been possible to get a good beam at full energy, so that no experimental work has as yet been possible since the shutdown.

W. Gilbert and J. Rosengren completed their runs on the photodisintegration of the deuteron. They have written a report, UCRL-1792, for the Physical Review which will soon be declassified. Their results on the total cross section are two-three times larger than those of Kikuchi, Benedict and Woodward, and Keck and Littauer. The reason for this discrepancy is not apparent.

L. Jones and K. Terwilliger have finished their measurements of $(\gamma,n)$ cross section as a function of energy from 40 to 320 Mev. They find a steadily increasing cross section for neutron production above 80 Mev. They are primarily measuring low energy neutrons, 0 to about 15 Mev, but it seems very probable that the number of high energy neutrons is relatively small. It is hoped to do further work on this problem at lower energies, using a smaller machine. This would essentially fill in the gap from, say, 15 Mev up to 80 Mev.

S. Colgate and F. Gilbert have completed measurements on the annihilation of positrons in flight, using positrons from the pair magnet, which pass through three counters in the magnetic field, pass into an absorber, but not through a counter behind the absorber. The cross section agrees well with the theory. They will have more runs to determine the amount of electron "annihilation".

C. Andre has completed a run on the $\pi^0$ production in hydrogen and deuterium. Because of difficulties in the determination of the background counts, results will not be definite until a further run can be obtained, which should be in the next quarter. J. Carrother's final runs on $\pi^-/\pi^+$ ratios will probably be made at the same time.

## 20. Theoretical Studies

David L. Judd

During the period covered by this report the following abstracts were prepared for presentation at the Washington meeting of the Physical Society:

"Photo Production of $\pi^0$-Mesons from Deuterium", W. Heckrotte, L. R. Henrich and J. V. Lepore.

"Meson Exchange Contributions to the High Energy Deuteron Photoeffect", R. H. Huddlestone and J. V. Lepore.

"Low Energy Properties of Pseudoscalar Interaction with Hard Core", R. Jastrow.

"Phenomenological Potentials in Meson Scattering", R. LeLevier.

"Nuclear Forces Yielded by the Symmetrical Pseudoscalar Meson Theory with Pseudoscalar Coupling", J. V. Lepore.

"On the Fermi-Thomas Model of the Nucleus", R. J. Riddell, Jr.

"Multiple Meson Production", M. Ruderman.

"Interpretation of High Energy p-p Scattering", D. R. Swanson.

<u>Photo-$\pi^0$ Production from Deuterium.</u> W. Heckrotte, L. Henrich, J. Lepore

Calculations of the elastic and inelastic photo-$\pi^0$ production from deuterium were completed. The results indicate that an experimental investigation of the elastic production can lead to a determination of the sign of the nuclear coupling constant. In this case the ratio of the cross section for $g_p = -g_n$ to that for $g_p = g_n$ is about 28. When inelastic production is included this ratio decreases to about 2.6 (near threshold).

Low Energy Properties of Nuclear Forces. R. Jastrow

The low energy properties of nuclear forces are being examined on the assumption that the nucleon possesses a complex structure associated with a particle of mass intermediate between that of the nucleon on a pi-meson. The structure is represented by a strong short range repulsion. The forces outside this region are described by a pseudoscalar meson field. Calculations of the deuteron properties on this model are nearly completed and yield surprising agreement with experiment. Calculations at higher energies will be started shortly, as will a consideration of the saturation properties of the model.

Exchange Contributions to the Deuteron Photoeffect. R. Huddlestone and J. Lepore

Ambiguities have been found in the various exchange contributions to the deuteron photoeffect. An attempt is being made to correlate the meson calculation with a phenomenological model of the exchange contributions. Higher order processes are also being investigated.

Meson Carbon Interaction. R. LeLevier

It has been found that coulomb interference effects in $\pi^+$ and $\pi^-$ carbon scattering do not rule out the possibility of a repulsive region in the meson-nuclei interaction. Such repulsion is indicated by Schiff's nonlinear meson theory. A region of central repulsion surrounded by complex well leads to a proper sign for the nuclear scattering amplitude at small angles. The large angle scattering, however, is still smaller than that indicated by experiment.

P-P Scattering Cross Sections. D. Swanson

The exact calculations of p-p scattering cross sections are appreciably different from the Born approximation results depending on the nature of the cutoff used. Polarization effects of the order of 15 percent, corresponding to a cross section of the form

$$I(\theta, \phi) = I_o(\theta) \{1 + 0.02 \cos \phi\}$$

were found for the model which best fit the 130 Mev and 350 Mev data.

Other Studies.

Calculations by P. Wolff to test the feasibility of a low field (0-100 gauss) high precision magnetometer have been completed.

Interpretation of meson-nucleon scattering in terms of radiation damping rather than as a consequence of the existence of a nucleon isobar has not proved successful. The $\pi^-$ data can be fit but the ratio of $\pi^+$ to $\pi^-$ scattering is much too small. This work has been done by P. Wolff.

Studies by M. Ruderman and P. Wolff in strong coupling meson theory are continuing. Compton scattering from protons, treating the mesons classically, is being investigated.

## II ACCELERATOR OPERATION AND DEVELOPMENT

### 1. 184-inch Cyclotron Operation

J. Vale

Operation of the cyclotron has been quite steady during this period. The average operation of the cyclotron for research experiments has been about 95.7 percent of the time that the crew was on duty. One day during this period was used for the replacement of the bearings and brushes on the rotary capacitor, and all other difficulties were minor ones.

The timing for controlling the oscillator is at present obtained from a set of magnetic pickups mounted at the rotary capacitor. These pickups provide pulses for turning on the oscillator at the proper point in the cycle. Since these pickups are sensitive to stray magnetic fields, their output will vary with the cyclotron magnetic field. In addition, their output is low. For these reasons, a new type of pulser has been designed using automobile ignition points, which overcomes both of the above disadvantages of the magnetic device. This unit has been designed but has not yet been built.

A preliminary investigation has also been started of the possibility of increasing the energy of the accelerated particles of the cyclotron. The results thus far indicate that a proton energy of about 600 Mev would be possible. However, this would necessitate additional exciting coils on the magnet, a smaller magnetic gap, and a new rf system, so that this is a fairly long term project.

## 2. 60-inch Cyclotron Operation and Development

Operations. William B. Jones

The operation of the 60-inch cyclotron during this quarterly period was as follows:

| | |
|---|---|
| Alpha bombardments | 402.2 hrs |
| Deuteron bombardments | 314.4 hrs |
| Proton bombardments | 256.0 hrs |
| Carbon ion bombardments | 161.0 hrs |
| Development | 157.7 hrs |
| OPERATION TOTAL | 1291.3 hrs |
| Outage time | 410.7 hrs |
| TOTAL AVAILABLE TIME | 1702.0 hrs |
| Shutdown | 457.0 hrs |
| Daylight Saving Time change | 1.0 hrs |
| TOTAL TIME | 2160.0 hrs |

Operation efficiency: 75.9 percent

Most of the outage time was spent repairing a leak that developed in the East "U" house cooling system. Leaks of this type have been sealed by flowing shellac through the line and applying 100 pounds of pressure. Attempts to seal this leak by this method were unsuccessful. A gasket between the upper and lower section of the East "U" house was found to be leaking so this gasket was removed by spreading the "U" house with a wedge. A standard 3/8 in. gasket was split and cemented in and a copper wire was tightened around it so as to compress the gasket against the water line. A shield was placed over the whole joint to protect the gasket from rf and to clamp the house together so as to have a constant tension on the gasket. This procedure appears to have sealed the leak.

A second cause of outage was a leak that developed in the beam monitoring probe. This probe had been bombarded with approximately 600 ua maximum beam for short time periods (about 3 - 15 minutes) several times a week. The probe was removed and inspection showed that a small hole had been drilled through to the water line. Work is under way to determine the proper material to be used for the probe head so that beams in the order of one milliampere may be run without destroying the face. This probe has been an important item in determining causes of low external beams.

The Beam Monitoring System. Hugh K. Jennings

The beam monitoring system has been in the process of revision in order to make it more flexible and automatic. The new system when completed will include the following features:

1. Three separate beam integrating and metering systems.
2. A Speedomax recorder.
3. An electrometer for currents from $10^{-12}$ to $10^{-6}$ amperes.
4. A probe amplifier whose operation is based on the heating effect of the probe beam.
5. A built-in beam calibrator with ranges from $10^{-7}$ amperes (with one percent accuracy) to $10^{-4}$ amperes (with 0.1 percent accuracy).
6. A calibrator recorder such that the percent accuracy of any integrator can be read directly from a paper tape.
7. A switch panel for switching inputs to the system or for putting integrators in series for checking purposes.

At present one of three of the new model integrators has been completed. The input is isolated from ground so that either positive or negative input may be used. This feature is desirable in that either positive ion or electron currents may be integrated with the device. Also, in order to tie the new counter area equipment into this metering system, a patch panel has been installed in the Control Room so that, for instance, output from standard UCRL electrometers may be patched to the Crocker Laboratory integrating system.

A model of a calibrator recorder has been built. A heat-and-pressure sensitive paper is used for recording the percent error of any integrator.

For no error, a series of dots appears parallel to the edges of the paper; for a one percent error, a series of dots appears in a line at 45 degrees to the edge of the paper.

The Speedomax and its shunt panel have been installed in the Control Room with range switches from one microampere to one milliampere full scale.

Magnet Current Regulator and Metering Circuit. Kenneth D. Jenkins

A modification has been made to our magnet current regulator so that it holds the current constant to better than one part in ten-thousand for over an hour. The circuit consists of a 200 mv 400 ampere shunt, a reference voltage, a mechanical chopper (Brown), an a.c. amplifier and a pair of Thyratrons (672) controlling the field of the generator. The generator is driven by an induction motor.

The reference voltage is not part of the magnet current regulator but is part of the magnet current metering circuit. Its stability is better than one part in ten-thousand per day. The metering circuit consists of a standard reference voltage varied in taps of 10 mv between zero and 200 mv, also an adjustable voltage between -1 mv and +11 mv, and a galvanometer to read 0 - 10 mv. The Leeds and Northrup 2440 galvanometer reads 0 - 20 amperes of current on a four inch scale. The tap switch adjusts both the magnet current regulator and the differential current meter in steps of 20 amperes, thus both regulator and differential meter are always operating over the same 20-ampere step. The magnet fine control applies the voltage to the magnet regulator and also most of the current to operate the galvanometer. The five milliampere reference current is supplied by 24 Mercury batteries whose voltage decays less than

0.1 millivolt out of 1.34 volts per day. The reference voltage is zeroed against a built-in standard cell at least once each shift. The absolute setting of the magnet current is about 300 milliamperes at 300 amperes but it is resetable within 50 milliamperes.

Lightweight Filament Holder and Adjustment Mechanism. Charles A. Corum

The major benefit of the new lightweight filament holder (Fig. 1) now in operation at the 60 in. Cyclotron has been the reduction of time required to change filaments. The lightness of the holder, plus the quick separation of the two water-d.c. connections and the fast positive release of the clamp, considerably speeds the changing operation. The radiation level in this area is 100 to 500 mr/hr., depending upon the type of previous operation of the machine. Other benefits realized with the new filament holder are: (1) a 55 percent reduction in weight, (2) higher operating voltage, (3) easier fabrication and servicing, and (4) better operation through finer adjustment.

The reduction of weight from 11 to 5 pounds was accomplished by (1) reducing the water cooling lines from four to two, (2) using stainless steel in place of copper and brass, and (3) simplifying the vacuum sealing method and the water and d.c. connection.

Most of the electrical shorting of the old filament holder occurred in the gas chamber and at the back plate. Both have been discarded. With the new water d.c. connections and only two water lines to insulate, the new filament holder holds up to 5000 volts in air as compared to the former of 2000 to 3000 volts.

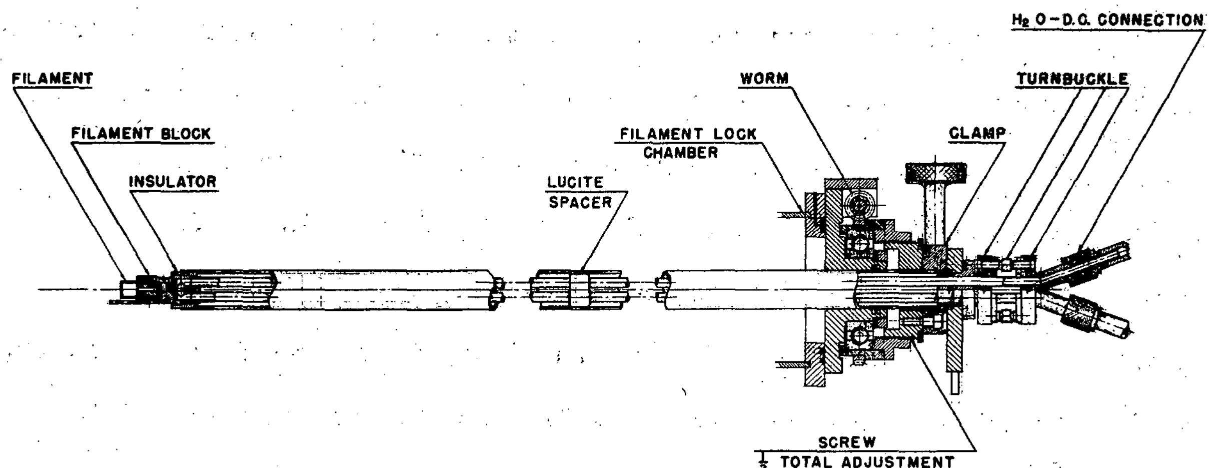
The new filament holder is held together in assembly with a "one force" design by the use of removable turnbuckles. Pressure is applied by spreading the turnbuckles which are held by lucite plates between the backplate and the water d.c. connection. This force pulls the filament blocks into an inside tapered insulator seated in the end of the outer tube. The taper centers the blocks, adds pressure to the gasket which seals the cross feed of the water line and holds the filament in operating position. It also makes a vacuum seal by compressing an O ring to the backplate and rubber gaskets around the water lines. By releasing the pressure and removing the turnbuckles, the new filament holder can be stripped down for servicing without unsoldering. With the turnbuckles out, there is enough clearance to slide one-half of the filament block over the other so that both may be withdrawn through the tapered insulator.

The water and d.c. connection is in one unit and uses a taper joint (copper to copper) for the current and an internal O ring seal for the water.

The filament holder adjustment mechanism is a ballbearing mounter worm drive unit attached to the filament seal plate on the ion source. The worm, which can be operated by hand or by remote control, turns a nut ring that runs the screw in or out to make the filament adjustment. One turn of the worm moves the filament in or out 0.006 inches. With remote control, movement can be timed to 0.0025 inches per second. The clamp ring, attached to the hollow screw, grips the filament holder. By releasing the clamp, the filament holder may be withdrawn and another inserted without losing the adjusted position of the filament.

<u>Carbon Beam Development</u>. G. Bernard Rossi

Continued effort has been placed upon increasing the external and internal $C^{+6}$ beams. Most productive results to date center about geometric changes of the ion source. It was noted in UCRL-1729 that a carbon cone




LIGHTWEIGHT FILAMENT HOLDER
AND ADJUSTMENT MECHANISM

Fig. 1

with an open midsection had been found to be productive of 20 to 35 x $10^{-9}$ amperes of $C^{+6}$ ions in excess of 80 Mev. Changes made in the structure of the midsection, as well as with cone geometry itself, have improved the output. The present arrangement, which is still open to further scrutiny, has produced 100 x $10^{-9}$ amperes of $C^{+6}$ particles whose energy was in excess of 100 Mev. This was measured by an electrometer connected to an rf shielded probe inside the tank system. The energy selection was accomplished by absorber foils of appropriate thickness between the beam and pickup target. Repeat performances yield various peak beams usually in excess of 50 x $10^{-9}$ amperes, depending upon periods of cyclotron adjustments.

Up to this time the external beam was measured by means of a proportional counter and scaling system. At the present time a Faraday cup is situated between two such chambers. The thickness of the first chamber is 36.4 mg/cm$^2$ aluminum equivalent. The full range of $C^{+6}$ ions in aluminum is 53.5 mg/cm$^2$. The Faraday cup was thus equipped with an aluminum foil in excess of 17 mg/cm$^2$. Under these conditions, it was possible to measure the $C^{+6}$ particles in the cup foil after traversal of one chamber and to measure alpha particles in the second chamber after traversal through the cup and preceeding chambers. The two chambers were provided so that cancellation of alpha particles could be made. Under these conditions an external $C^{+6}$ beam of 6 x $10^{-12}$ amperes was recorded. This was the largest beam seen externally. A bombardment was made to produce $At^{203}$ by the $Au^{197}(c,6n)At^{203}$ reaction. A five-minute bombardment yielded 100 counts per minute of alpha particles, measured two minutes after bombardment.

Work is to continue along the above line with the expressed direction of increasing the deflection ratio for external particles. At face value, the ratio is 100 x $10^{-9}$/6 x $10^{-12}$ or approximately 17 x $10^{3}$, where other particles (deuteron, proton, alpha) are deflected at a ratio of 10:1. This carbon ratio may not be valid since the number of internal particles of 120 Mev has not been measured - the value of 100 x $10^{-9}$ including all particles above 100 Mev.

## 3. Synchrotron Operation

George C. McFarland

The synchrotron operated satisfactorily during February and March. In April a cracked quartz segment made it necessary to dismantle the synchrotron. After reassembly, it was not possible to reach maximum beam energy nor to accelerate enough particles to have a useful intensity.

Measurements of the magnetic field showed a marked distortion in the region of the replaced quartz section. This distortion was corrected electrically, which made it possible to increase both beam energy and intensity. At the close of this report period, maximum beam energy had not been acheived.

It is reasonably certain that the field distortions are due to non-uniformity in the electrically conducting coating on the quartz segments.

## 4. Linear Accelerator and Van de Graaff Machines

The preliminary convertor and oscillator for the proposed Van de Graaff regulation system are built. Delivery on the Collins FM - IF amplifiers is expected within the next week, at which time the work will be continued on the integration of these units into a working system, giving a control signal which is a function of the rf phase of the linear accelerator and the output current phase of the buncher.

A continuous non-interrupting linear accelerator beam current monitor has been built which is now ready for preliminary installation. It consists of two - 10,000 turn toroids in series enclosed by a triple magnetic shield. At present it will allow visual observation of the current waveform. Work is in progress to integrate this pulse for direct measurement.

The presentation of a scope "picture" representing the gradient vs length of the linear accelerator as seen by diode loops is being held up while further work is done to make the input signal to the radial beam unit similar in its characteristics to the "slideback voltmeter."

| | | |
|---|---|---|
| Statistics: | Running time | 71% |
| | Maintenance | 16% |
| | Repair | 13% |

## 5. Bevatron Development

W. M. Brobeck

### General

The decision was made to make the aperture 1 ft. x 4 ft. Initial tests at Brookhaven resulted in a 30 Mev beam and indicate that the 1 x 4 aperture will be quite adequate.

### Coil Winding

Only one quarter (44 turns) of the fourth quadrant was completed during this period because the supply of vendor-furnished coil spacers has been exhausted. Owing to the unreliable delivery and quality of vendor-furnished spacers (molded of asbestos filled phenolic bakelite), the 1400 remaining spacers will be machined from masonite "Benelex 70" in the UCRL shop. Seven weeks are required to complete the winding after the spacers become available.

Magnet

Preparations are being made for the magnet tests (without pole-pieces) scheduled for this summer. The possibility of trouble from residual magnetism and transient ripples in the current as it approaches zero is being investigated. Tests have indicated that every pole tip plate instead of alternate plates should be enamelled. Magnet model tests are continuing to determine the final pole plate outline. Earliest possible delivery of steel for the pole bases and tips (which will be fabricated by the Verson Mfg. Co.) is during the third quarter of 1952.

Vacuum System

For the curved tanks, all major parts are in various stages of procurement or fabrication except for the Curve Tank Filler Frame (design just completed), and the Handling and Assembly Fixtures (50 percent designed). Assembly of the first curved tank is expected to be started at UCRL by August 1. The transition tanks (used between the curved and straight tanks) will be fabricated by the Atlas Pacific Engineering Co., and fabrication of the first two tanks should be complete by August 1 and the other six by September 30 if material is delivered on schedule. For the straight tank sections, Mare Island Shipyard will start the fabrication upon completion of material deliveries.

Linac

The design was modified by the addition of one drift tube (bringing the total to 44) at the low energy end to lower the injection energy of the ion gun from 500 to 430 KV. The drift tubes have been installed in the liner and alignment and gap adjustments are being made.

Accelerator Tube

It has been decided to use a single drift tube and to increase the operating voltage from 22 KV to between 30 and 40 KV. As a result, additional Ferroxcube cores are being ordered for the self-tracking amplifiers.

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6/18/52 bw