Title
PRELIMINARY RESULTS ON THE PRODUCTION OF MESONS BY PHOTONS ON CARBON AND HYDROGEN



Authors
Steinberger, J.
Bishop, A.S.

Publication Date
1950-03-08

# UNIVERSITY OF CALIFORNIA

# Radiation Laboratory



BERKELEY, CALIFORNIA

COPY 2



UCRL 632
Unclassified Distribution

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

# PRELIMINARY RESULTS ON THE PRODUCTION OF MESONS BY PHOTONS ON CARBON AND HYDROGEN

J. Steinberger and A. S. Bishop

March 8, 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 |
| Brookhaven National Laboratory | 8 |
| Bureau of Medicine and Surgery | 1 |
| Bureau of Ships | 1 |
| Carbide & Carbon Chemicals Corp. (K-25) | 4 |
| Carbide & Carbon Chemicals Corp. (Y-12) | 4 |
| Chicago Operations Office | 1 |
| Cleveland Area Office | 1 |
| Columbia University (Dunning) | 2 |
| Columbia University (Failla) | 1 |
| Dow Chemical Company | 1 |
| General Electric Company, Richland | 6 |
| Idaho Operations Office | 1 |
| Iowa State College | 2 |
| Kansas City | 1 |
| Kellex Corporation | 2 |
| Knolls Atomic Power Laboratory | 4 |
| Los Alamos | 3 |
| Mallinckrodt Chemical Works | 1 |
| Massachusetts Institute of Technology (Gaudin) | 1 |
| Massachusetts Institute of Technology (Kaufmann) | 1 |
| Mound Laboratory | 3 |
| National Advisory Committee for Aeronautics | 2 |
| National Bureau of Standards | 2 |
| Naval Radiological Defense Laboratory | 2 |
| NEPA Project | 2 |
| New Brunswick Laboratory | 1 |
| New York Operations Office | 3 |
| North American Aviation, Inc. | 1 |
| Oak Ridge National Laboratory | 8 |
| Patent Advisor, Washington | 1 |
| Rand Corporation | 1 |
| Sandia Base | 1 |
| Sylvania Electric Products, Inc. | 1 |
| Technical Information Branch, ORE | 15 |
| U. S. Public Health Service | 1 |
| UCLA Medical Research Laboratory (Warren) | 1 |
| University of California Radiation Laboratory | 5 |
| University of Rochester | 2 |
| University of Washington | 1 |
| Western Reserve University (Friedell) | 2 |
| Westinghouse | 4 |
| Total | 117 |

Information Division
Radiation Laboratory
Univ. of California
Berkeley, California

# PRELIMINARY RESULTS ON THE PRODUCTION OF MESONS BY PHOTONS ON CARBON AND HYDROGEN

J. Steinberger and A. S. Bishop

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

March 8, 1950

. The method of meson detection described in the previous letter is being applied to the study of the production of positive mesons by $\gamma$-rays on hydrogen and heavier nuclei. We report here (Figures 1, 2 and 3) some preliminary results in which the hydrogen cross sections are obtained by subtracting the yields on carbon from those on paraffin. All the measurements reported here are being continued, and hydrogen cross section measurements with a liquid hydrogen target are in progress.

In interpreting these results it should be kept in mind that both energy and angle of production of the meson are measured, and these determine the incident $\gamma$-ray energy by momentum and energy conservation in the case of production on hydrogen. This means, for instance, that a knowledge of the energy distribution of the mesons at a fixed angle of production and of the energy distribution of the incident $\gamma$-ray beam allows a determination of the excitation function for photo meson production. We feel however that the energy, angular and statistical accuracies of the data reported here do not yet warrant such an analysis.

Figure 1 shows the relative number of mesons produced by carbon atoms and hydrogen atoms at $90^{\circ}$ in the laboratory system as a function of their energy. The incident photons have a bremsstrahlung spectrum of 330 Mev maximum energy.

The meson energy is determined from the energy-range relationship, and it is assumed that the nuclear absorption of mesons is zero.[1] The carbon cross sections have already been determined by photographic detection methods,[2] and the two results agree within the statistical inaccuracies. The most startling fact shown in Figure 1 (and also in Figure 3) is that the cross section of the six bound protons in a carbon atom is only somewhat greater than that of a single free proton. It is perhaps surprising that the effects of nuclear binding are so pronounced. However a more detailed analysis[3] shows that since the energy of the recoil nucleons is not very much greater than the Fermi energy, this inhibition of the reaction in the case of complex nuclei may be no more than a manifestation of the exclusion principle.

In Figure 2 an attempt is shown to get similar information at several other angles. However the statistical accuracies are not great enough to make the subtraction meaningful. So the data are added, instead of subtracted, and the points represent the production by a molecule of composition $C_{17}H_{14}$. The interesting thing here is that the cross sections are fairly independent of angle. This is shown again in Figure 3. Here the cross sections are shown for five angles. At each angle a different amount of absorber is used, so that for hydrogen the photon energy at all angles is unique, 253 Mev. For the carbon points the analysis has been carried through in the same way, although there the binding of the nucleons makes the momentum and energy conservation arguments

---

(1) If instead the nuclear mean free path of mesons in aluminum were 200 $g/cm^2$, this would mean that the 100 Mev points would be too low by about 15 percent; lower energies would have proportionately smaller errors.

(2) E. McMillan, J. Peterson, S. White, Science 110, 579 (1949).

(3) The calculations for helium targets have been made by G. Chew and H. Lewis. They show that one may easily account for a $\sigma$(free proton)/ $\sigma$(bound proton) = 3, but it is not possible to make an accurate prediction of the expected effect. We wish to express our thanks to the authors for permission to quote their results before publication.

invalid. The cross sections have been plotted in absolute units; however, the error of the absolute value may be quite large. The errors indicated are the statistical errors, and represent the likely errors in the relative values. The theoretical curve in Figure 3 is a plot of the function $\left(\frac{\sin\Theta}{1-(v/c)\cos\Theta}\right)^2$, the angular distribution of a simple electric dipole photo effect. It is also substantially the prediction of the scalar meson theory.(4) It can be seen that the actual distribution is quite incompatible with this, in fact the only theories which predict such a flat distribution are those in which the electromagnetic interaction is chiefly with the magnetic moment of the nucleons rather than the electric charge of the meson. This is so for the pseudoscalar meson theory with both types of coupling.(5) However the same theories which, because of the tight coupling of the mesons to the magnetic moment of the nucleon, predict a flat angular distribution, also predict nuclear radii of the dimensions of the Compton wave-length of the nucleons and can therefore hardly be taken seriously. On the one hand, the theories which predict a different distribution cannot be rejected because there remains the possibility, though small, that the disagreement is caused by the fact that the calculations are incorrect because relativity and the largeness of the coupling constant are not simultaneously taken into account. On the other hand those theories which predict the observed result disagree violently with experiment in the nuclear force problem. It seems therefore impossible to make a meaningful comparison of the experiment with existing theory.

---

(4) In the scalar theory this result is obtained in relativistic perturbation theory, and also rigorously without expansion in g if the nucleons are assumed to have infinite mass. We are indebted to Drs. K. M. Case and K. Watson who have independently obtained this result.

(5) The perturbation theoretical results have been obtained by Feshbach and Lax, Phys. Rev. 76, 134 (1949) and more completely by K. Brueckner, Phys. Rev., to be published.

We wish to thank Prof. E. McMillan for his support, Prof. R. Serber for theoretical discussions, and Mr. Gibbins and the synchrotron crew for their assistance.

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

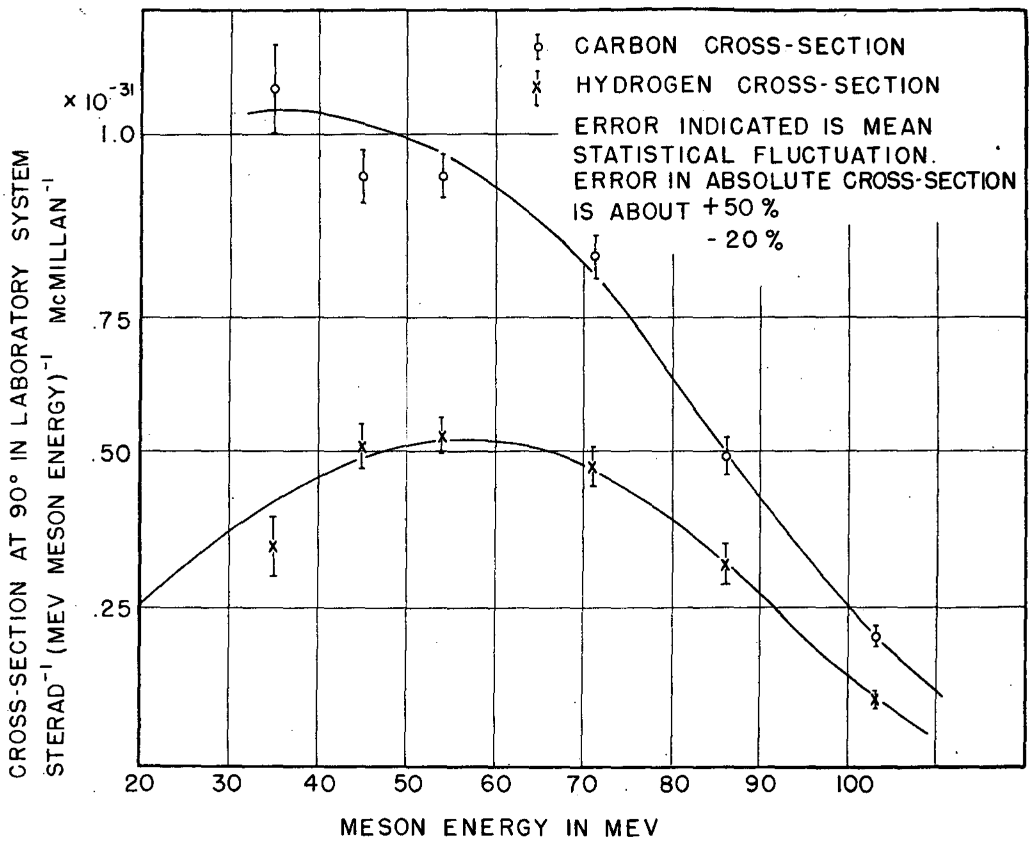
Information Division
scb/3-9-50

Figure Captions

Fig. 1 Production of mesons by photons on carbon and hydrogen at $90^{\circ}$. The photons have a bremsstrahlung spectrum with a 330 Mev maximum energy. The number of McMillans in a bremsstrahlung beam is defined as the total energy in the beam divided by the maximum photon energy.

Fig. 2 The production of mesons in $C_{17}H_{14}$ at various angles as a function of the meson energy.

Fig. 3 The angular distribution of the mesons produced by 250 Mev (laboratory system) photons on hydrogen and carbon. The theoretical curve is that for a pure photo effect, $\left(\frac{\sin \Theta}{1 - v/c \cos \Theta}\right)^2$.



CARBON CROSS-SECTION
HYDROGEN CROSS-SECTION
ERROR INDICATED IS MEAN STATISTICAL FLUCTUATION.
ERROR IN ABSOLUTE CROSS-SECTION IS ABOUT +50 % -20 %
x 10^-31
1.0
.75
.50
.25
CROSS-SECTION AT 90° IN LABORATORY SYSTEM STERAD^-1 (MEV MESON ENERGY)^-1 McMILLAN^-1
20
30
40
50
60
70
80
90
100
MESON ENERGY IN MEV


FIG. 1

Mu 63

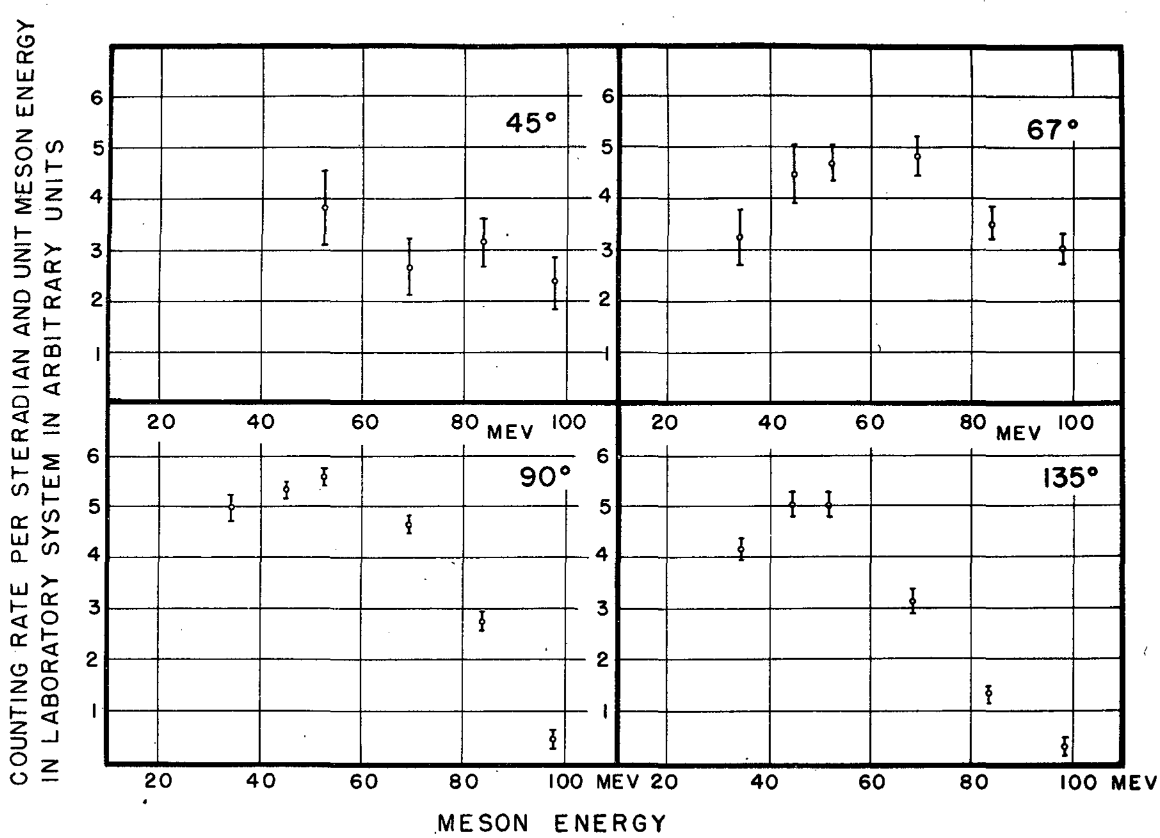
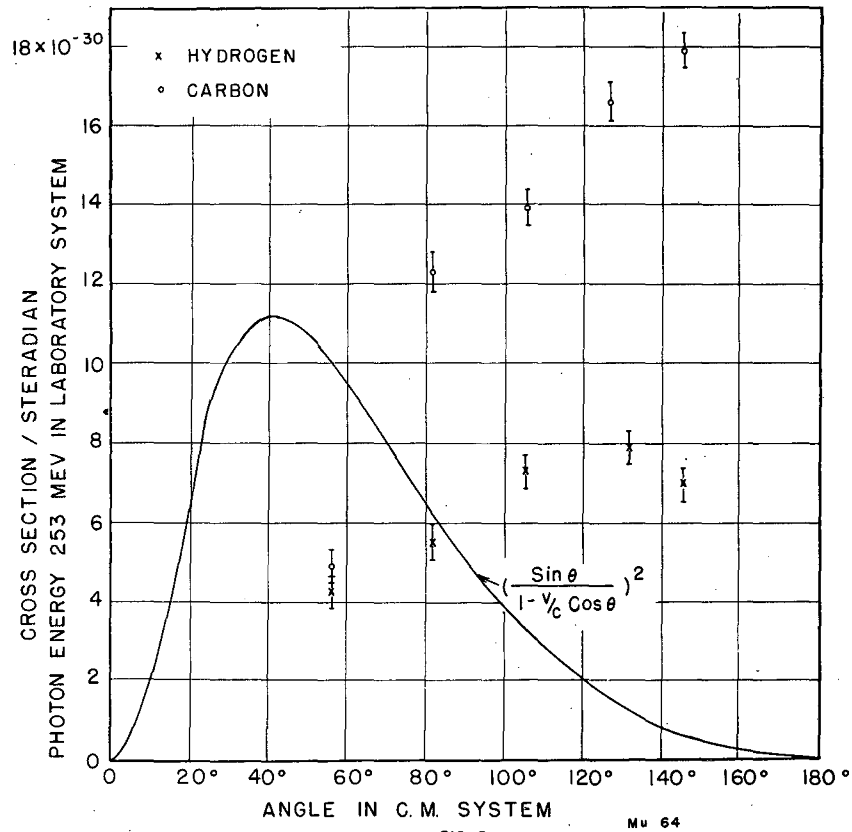

COUNTING RATE PER STERADIAN AND UNIT MESON ENERGY
IN LABORATORY SYSTEM IN ARBITRARY UNITS
45°
67°
90°
135°
1
2
3
4
5
6
20
40
60
80
100
MEV
MESON ENERGY

FIG. 2

Mu 62



18 × 10^-30
16
14
12
10
8
6
4
2
0
× HYDROGEN
○ CARBON
CROSS SECTION / STERADIAN
PHOTON ENERGY 253 MEV IN LABORATORY SYSTEM
$\left(\frac{\sin\theta}{1 - v/c \cos\theta}\right)^2$
0
20°
40°
60°
80°
100°
120°
140°
160°
180°
ANGLE IN C.M. SYSTEM


FIG. 3

Mu 64