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THE PHOTONUCLEAR EFFECT AND THE COMPLEX POTENTIAL-WELL NUCLEAR MODEL

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THE PHOTONUCLEAR EFFECT AND THE COMPLEX POTENTIAL-WELL NUCLEAR MODEL§*

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The recent success of the complex potential-well nuclear model applied to neutron and proton scattering from complex nuclei[1-3] have led the author to investigate this model for the photonuclear process.

The so-called "giant resonance" for the photonuclear effect has long been known; however, of the most successful models[4-6] to date that of Goldhaber and Teller[4], while explaining many of the general features of the (γ,n) cross section, fails to account in any detailed manner for the width of the resonance. On the other hand the more detailed treatment of this general hydrodynamical model by Steinwedel and Jensen[5] does give the large resonance width only at the expense of the ad hoc introduction of a "coefficient of viscosity" or damping coefficient. (A more serious defect of all of these hydrodynamic, harmonic oscillator models is the theoretical prediction of similar "giant resonances" at higher energies which, of course, have not been observed).

The present work assumes that the incident photon is absorbed by one nucleon giving rise to one of two effects. In one of thse the nucleon leaves

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vertical slit obtained with stainless steel bricks. Twenty feet away, outside of the biological sheild, was a second collimator of 3/8 inch diameter. Following this the beam was deflected a second time with an auxiliary magnet.

The arrangement of the experiment is shown in Fig.1. The proton beam already analyzed in the fringing magnet field of the cyclotron enters the experimental area through the collimator A, is reanalyzed by the auxiliary magnet B, then passes through an auxiliary shield J used to avoid extraneous background.

The proton beam is defined by 2 monitoring telescope coincidence counters C, which also cout the number of protons in the incoming beam in a particular measurement. The beam traversing counters C then proceeds through a hole in a heavy steel shield D and reaches the absorbers.

The protons coming to rest in the absorbers, scattered out, or absorbed are counted by a large anticoincidence counter F. The preliminary alignment of the system was aided by a cathetometer H in the beam path at the end of the experimental area farthest from the cyclotron.

III. COUNTERS AND ELECTRONICS

The monitoring counters were circular counters made of plastic scintillator "Pilot B" of 1/8 inch thickness and 1 inch diameter. The anti-coincidence counter F is a large circular liquid scintillator, 9 1/4 inches in diameter and 1 inch thick.

This range determination was conducted as an auxiliary experiment to a measurement of total cross sections, as the setup was thought suitable. Thus only a brief description of the electronic equipment will be given here as this equipment is described elsewhere in detail[3].

Fast counting systems and fast resolving time coincidence circuits are necessary to obtain reliability with the counting rate used and in order to minimize background caused by accidental coincidences. The signal pulses from the monitor counters C1 and C2 (Fig. 2) were amplified by two and a half distributed amplifiers of 200 megacycles band width and a voltage gain of 10 each. The pulses were clipped to 8×10^{-9} seconds by shorted cables and fed into a two channel crystal diode coincidence circuit developed at the University of Chicago by J. Fischer.

The pulses from the two photomultiplier tubes of the anticoincidence counter F were amplified by three distributed amplifiers and connected without clipping to a diode coincidence-anticoincidence circuit which also received the pulses from the first two counters by parallel connection from the first coincidence circuit. The output of the coincidence-anticoincidence circuit was fed to a Hewlett-Packard 10 megacycle scaler. Both fast scalers were followed by slower scalers (scale of 1000) and mechanical registers. In order to correct for the time of flight of the particles and the transit time of signals in the tubes, amplifers, and connecting cables, the signals were transmitted through a 180 - line switch-box capable of giving integral time delays from 1 to 63 millimicroseconds.

IV. ABSORBERS

The absorbers consisted of 115 discs of Ilford G5 stripped emulsion, 5/8 inch in diameter and ranging in thickness from 1170 to 620 microns. The length of the stack was 11.30 cm. Maintained at a relative humidity of 47 per cent by geing kept in equilibrium with a saturated solution of potassium nitrite, the emulsion had an average density of 3.85 ± .01 g/cm^3. This agress, within experimental error, with the density predicted by Wilkins'[4] curve of density vs. relative humidity if one takes 4.18 g/cm^3 as the density of absolutely dry emulsion as published by Ilford[5].

The electrolytic copper absorbers used to establish the energy of the beam had a density of 8.91 ± .02 g/cm^3.

V. RESULTS

First the attenuation of the proton beam in copper was measured using the anticoincidence method, from which the integral range curve (Fig. 3) was drawn. In this curve the relative number of counts (coincidences minus anticoincidences) is plotted against range in g/cm^2. From the point of steepest slope of the curve the mean range R* was obtained. This range R*, measured to be 40.9 g/cm^2, is not the actual range along the trajectory but rather a projected range. The rectified range R, because of multiple scattering in the absorber, is somewhat longer and may be obtained by adding a small correction[6], which for protons is approximately given by $R-R^* = RZ/6400$ where Z is the atomic number of the absorber. The corresponding energy of the proton beam was found to be 208 ± 4 Mev from Aron's[7] range-energy tables for a mean range R of 41.1 ± .1 g/cm^2. The beam energy inhomogeneity, ± 4 Mev was calculated from the experimental straggling using the range extrapolation method.

The G5 nuclear emulsion mean range was measured by reducing the 1 inch diameter beam used for the copper measurement to a 1/8 inch diameter beam by the use of a copper collimator.

The mean range of the beam in G5 nuclear emulsion was determined in the same way as that for copper, and is also given in Fig. 3. The projected mean range was found to be 41.1 ± .2 g/cm^2. Applying the R-R* correction, one obtains 41.3 ± .2 g/cm^2 as the rectified mean range of 208 ± 4 Mev protons in G5 nuclear emulsion. This is about 1.2 percent longer than the value calculated from Heinz's results, using his measured range in C2 at 342.5 Mev and his measurements of dE/dx. The errors of the two values just overlap. The measured range in G5 of 208 Mev protons is about 1.3 percent shorter than that calculated by Vigneron(and extended to higher energies by Barkas). With respect to the range in copper of 208 Mev protons the measured range in emulsion is about .5 percent longer and Vigneron's calculated value is about 1.8 percent longer, whereas the range in emulsion calculated from Heinz's results is about .7 percent shorter.

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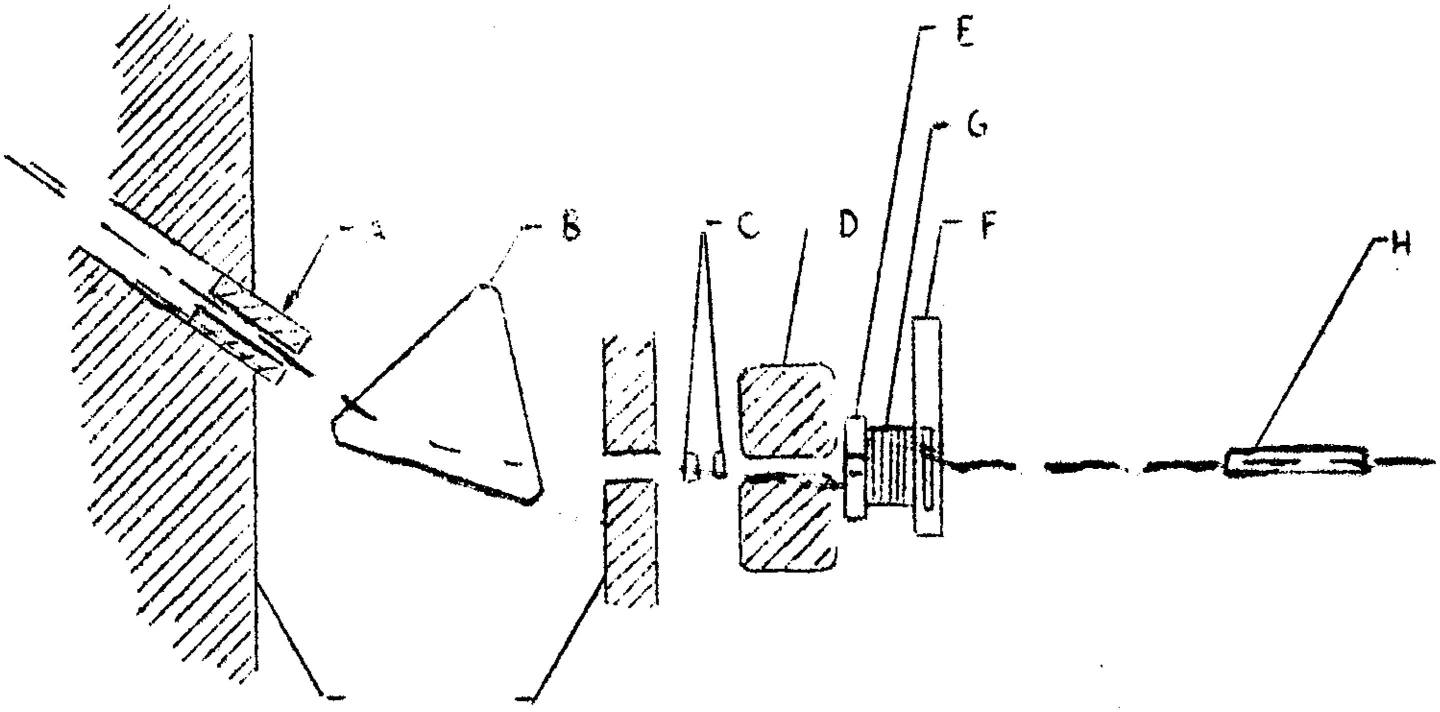

A - COLLIMATOR

B - AUXILIARY MAGNET

C - MONITOR TELESCOPE
COINCIDENCE COUNTERS

D - SHIELD

E - NARROW COLLIMATOR

F - ANTICOINCIDENCE COUNTER

G - ABSORBERS

H - CATHETOMETER

I - HEAVY SHIELD

J - AUXILIARY SHIELD

FIG. 1

COUNTING SYSTEM

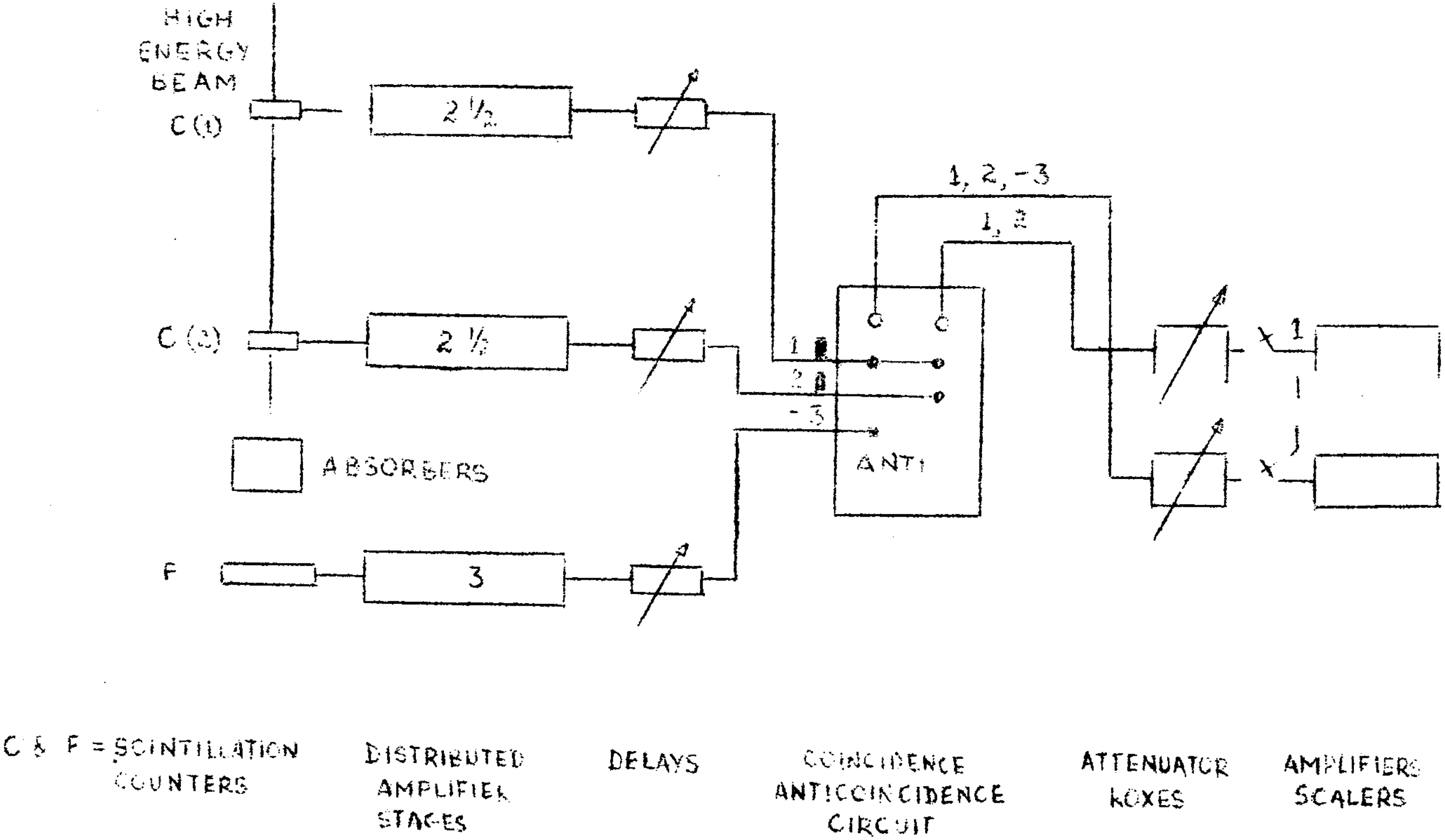

FIG. 2

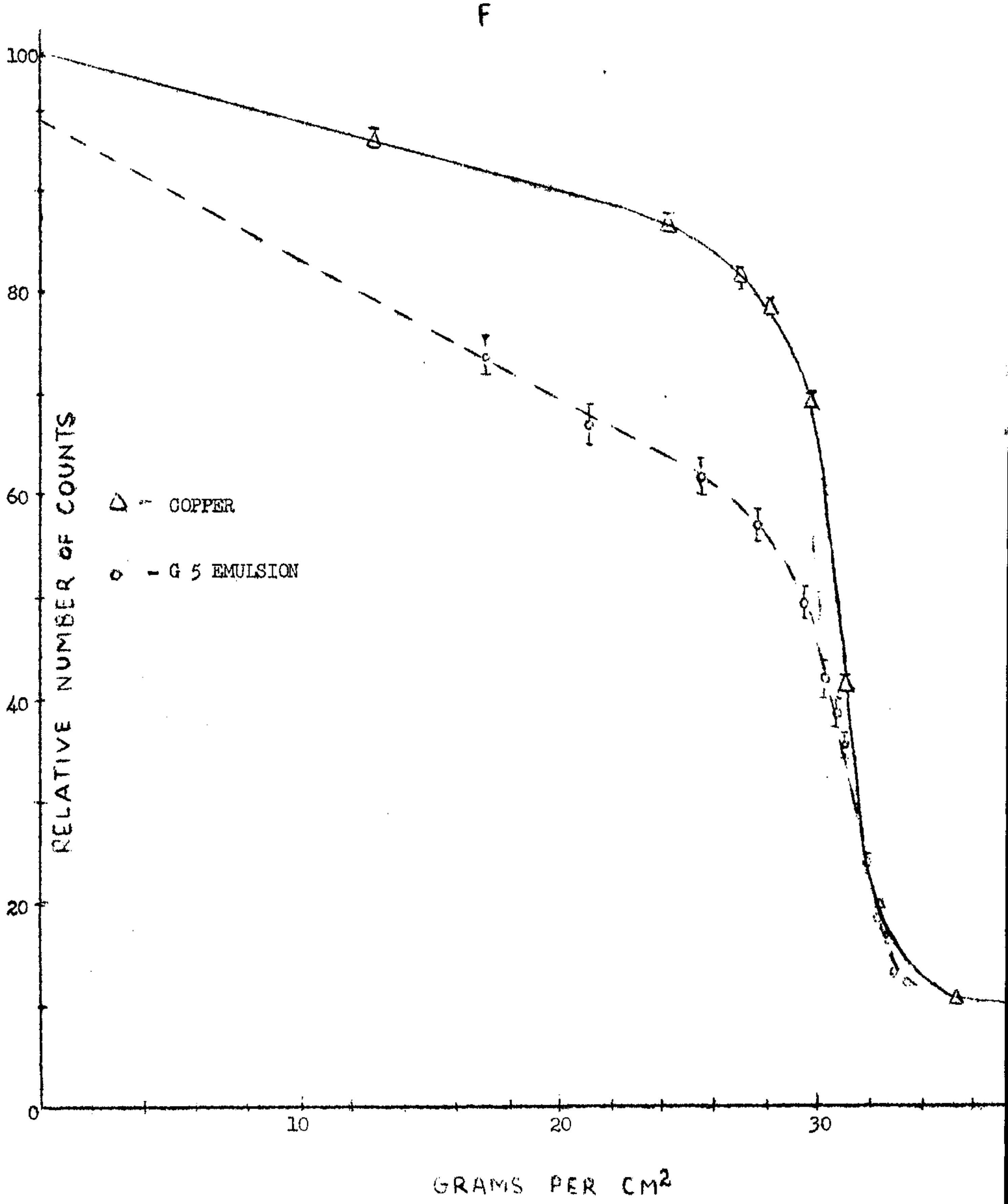
F
100
80
60
40
20
0
RELATIVE NUMBER OF COUNTS
△ – COPPER
o – G 5 EMULSION
10
20
30
GRAMS PER CM^2

FIG. 3