To gain confidence in the method we decided to mix two samples (copper and lead), in which the peaks of the (γ, n) reactions occur at different energies, and measure the resulting activation curve. By changing the relative amounts of these samples it is possible to represent the various cases which occur in practice.

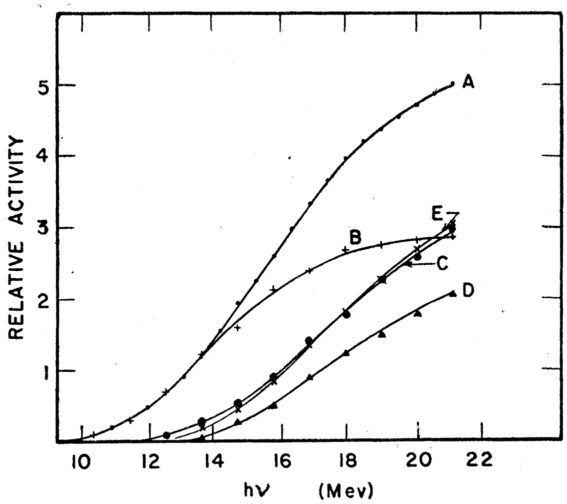

FIG. 1. Neutron yield curves. (A) Sample of Cu (0.45 mole) and Pb (0.072 mole) irradiated simultaneously. (B) Pb sample only. (C) Cu sample only. (D) Curve A minus curve B. (E) Curve D corrected for photon absorption in sample.

The first experiment consisted in mixing 0.45 mole of copper and 0.072 mole of lead, which should result in about the same number of disintegrations from each of the elements. This represents those cases where the elements measured have two isotopes of about equal abundance with close thresholds. The activation curves for each of the samples (Pb and Cu) and for both together were measured in the arrangement described[5] on the same day. This was done to make conditions reproducible as closely as possible. The combined curve was taken with a lead disk sandwiched between two copper disks. The results are shown in Fig. 1. Also plotted in the same figure is the copper curve (D) obtained by subtracting the lead curve (B) from the (copper +lead) curve (A). Applying a correction for absorption of the

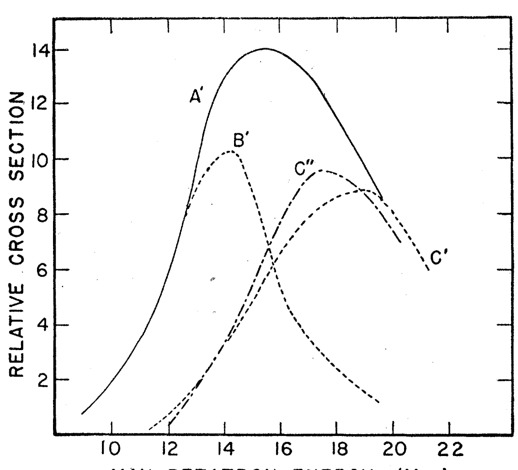

FIG. 2. Cross-section curves. (A′) Calculated from yield curve A. (B′) Calculated from yield curve B. (C′) Calculated from yield curve C. (C″) Difference between cross sections A′ and B′.

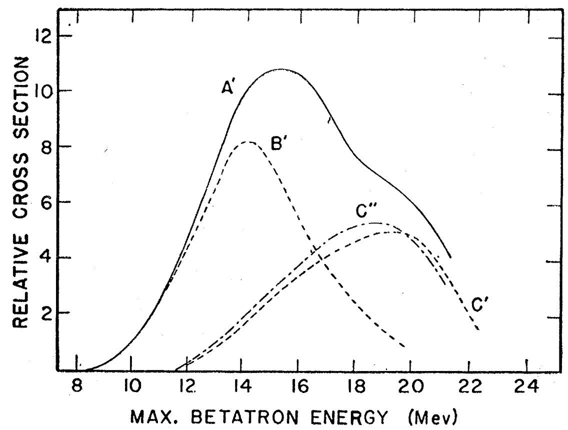

FIG. 3. Cross-section curves from yield curves similar to those of Fig. 1, except that 0.23 mole of Cu and 0.072 mole of Pb were used. Notation as in Fig. 2.

beam reaching the rear sample, curve (E) is obtained, which is to be compared with the copper curve measured directly (C). Figure 2 shows the cross sections obtained by applying the "photon difference method" to the activation curves (A), (B), and (C). The difference (C″) between the cross-section curves (A′) and (B′) is to be compared to the cross section (C′) calculated directly.

Figure 3 shows the results for a mixture of 0.23 mole of copper and 0.072 mole of lead analyzed in the same manner. This combination was chosen to represent some of the $(\gamma, 2n)$ reactions.

It must be emphasized that small changes in the activation curves can *distort* the shape of the cross sections; thus accurate measurements are necessary for obtaining reliable results with the "photon difference method."

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Photoproduction of Neutral Mesons in Hydrogen at High Energies*

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PRELIMINARY measurements have been made with the newly operating California Institute of Technology synchrotron on the cross section for photoproduction of neutral pions in hydrogen at photon energies up to 450 Mev. The differential cross section at 90° in the laboratory system was measured in the manner of Silverman and Stearns,[1] by observing the recoil proton in coincidence with one decay photon from the π^0. The energy and angle of the recoil proton define, through the conservation laws, both the energy of the incident photon, and the meson angle. The meson angle in the present measurements was 90° in the laboratory system, which corresponds to 107° to 111° in the center-of-mass system, depending on the photon energy.

The arrangement of target and counters is shown schematically in Fig. 1. Recoil protons were counted with a coincidence-anticoincidence scintillation crystal "telescope" which measured their range and their specific ionization (given by the pulse height in the first counter). Decay photons from the π^0's were detected in a γ-ray counter consisting of an anticoincidence scintillator followed by a $\frac{1}{4}$-inch lead converter and two scintillators in coincidence. The calculated efficiency of this detector for counting the π^0

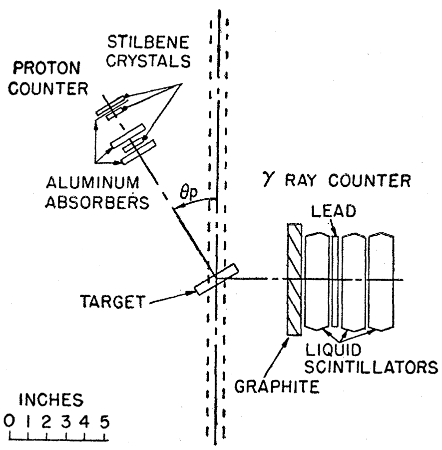

FIG. 1. Experimental arrangement. The proton angle θ_p was near 32° in the present measurements.

associated with an observed recoil proton was between 0.15 and 0.28 in this experiment, depending on the incident photon energy.

Measurements were made with polyethylene and graphite targets and a subtraction made to obtain the cross section in hydrogen. The "carbon background" was between 15 and 40 percent, depending on the photon energy.

The bremsstrahlung spectrum assumed in calculating the cross sections was normalized to give the same total energy in the x-ray beam as measured by a Cornell type ionization chamber with 1-inch copper walls. We are indebted to R. Littauer and the Cornell synchrotron group for both the design of this chamber and its absolute calibration.

The measured cross section at 90° is shown as a function of the incident photon energy in Fig. 2, together with the data of Silverman and Stearns[1] at lower energies. The existence of a maximum in this cross section has been the subject of considerable discussion and is predicted, for example, in the theory of Brueckner and Watson.[2] This theory assumes that the π^0 photo-

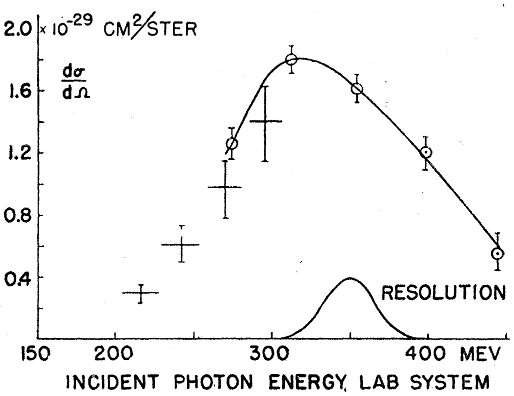

FIG. 2. Differential cross section at 90° in the laboratory system for the photoproduction of neutral pions in hydrogen. The crosses at lower energies are the data of Silverman and Stearns.[1] The indicated errors include estimated instrumental errors in so far as they affect the *relative* cross section.

production involves a resonant interaction between meson and nucleon in a state of isotopic spin and angular momentum $\frac{3}{2}$. Whereas this theory is probably not unique in giving a maximum in the cross section, an interpretation in terms of a resonance is suggested by the sharpness of the observed maximum. The observed cross section at 90° falls off above the maximum considerably more rapidly than the curve given by Brueckner and Watson.[2]

Further work is being undertaken to obtain data with somewhat better energy resolution and to investigate the angular distribution.

Because of the importance of the data at 400 and 445 Mev, we have tried to investigate the extent to which these points might be in error because of uncertainties in the upper end of the incident bremsstrahlung spectrum, arising in part from an uncertainty in the synchrotron energy itself. This has been done by making measurements at three different "nominal" synchrotron energies, E_0=480, 420, and 370 Mev and taking a weighted average for Fig. 2 in such a way that the internal consistency of the three sets of data is as great as possible.

From this analysis, which is given in Fig. 3, it is concluded that the errors introduced by uncertainties in the upper end of the incident bremsstrahlung spectrum are probably less than 10 percent for the 400-Mev point, and 25 percent for the 445-Mev point.

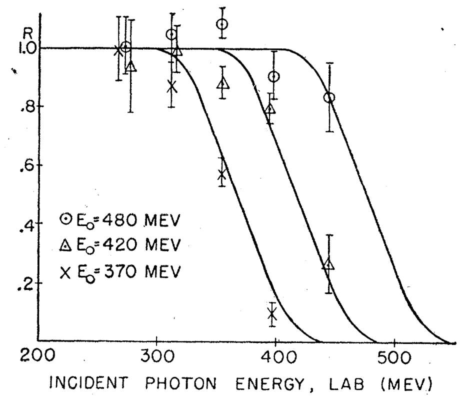

FIG. 3. Internal consistency of data taken at three different "nominal" synchrotron energies E_0=480, 420, and 370 Mev (obtained from a magnetic field integrator). For each E_0 is plotted the ratio R of counts observed to the counts which would be expected if the incident bremsstrahlung spectrum did not fall off near E_0, and if the cross section of Fig. 2 were correct. The three curves have been drawn in such a way that the energies at which R=0.5 are in the same ratio as the three "nominal" energies E_0 but with an absolute scale adjusted to make the two lower curves agree with the data as well as possible. This determines the curve for E_0=480 Mev, and thus the correction factor $1/R=1/0.85$ to be applied to the cross section at 445 Mev as measured with E_0=480.

This experiment owes much to the work of all the members of the synchrotron group, and we wish to acknowledge especially the contributions of Dr. R. F. Bacher, Dr. M. L. Sands, Dr. R. V. Langmuir, Dr. J. G. Teasdale, Dr. V. Z. Peterson, Dr. J. C. Keck, and our chief engineer, Bruce Rule.

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The (n, γ) and $(n, 2n)$ Reactions in Iodine*

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CROSS sections for the $I^{127}(n, \gamma)^{128}$ reaction from 0.25 to 1.6 Mev and the $I^{127}(n, 2n)I^{126}$ reaction from 12 to 18 Mev have been measured by irradiating NaI(Tl) crystals and observing the induced activity with a photomultiplier. The crystals thus served both as targets and as nearly 100 percent efficient detectors.

For the (n, γ) reaction, monoergic neutrons were provided by bombarding a tritium gas target[1] with a monatomic proton beam from the 2.7-Mev electrostatic accelerator. The NaI(Tl) crystals were irradiated at 10 cm and 0° from the gas target; the energy of the neutrons from the $T(p, n)He^3$ reaction[2] was selected by