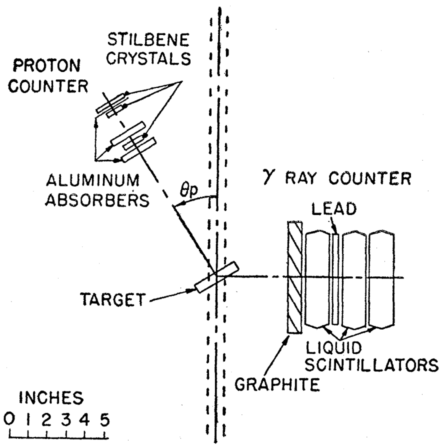

FIG. 1. Experimental arrangement. The proton angle θ_p was near 32° in the present measurements.

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 photoproduction 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]

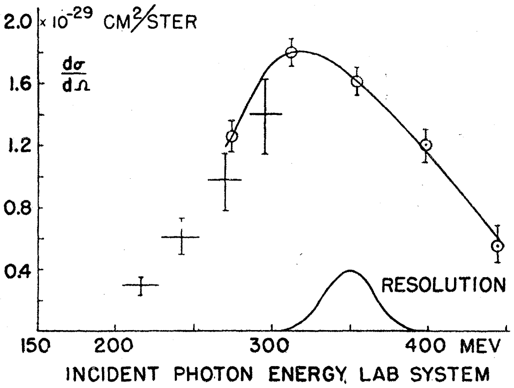

FIG. 2. Differential cross section at 90° in the laboratory system for the photoproduction of neutral pions in hydrogen. The crosses at lower energies are the data of Silverman and Stearns.[1] The indicated errors include estimated instrumental errors in so far as they affect the *relative* cross section.

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.

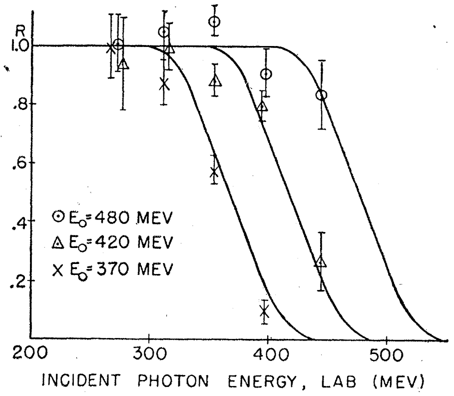

FIG. 3. Internal consistency of data taken at three different "nominal" synchrotron energies $E_0=480$, 420, and 370 Mev (obtained from a magnetic field integrator). For each E_0 is plotted the ratio R of counts observed to the counts which would be expected if the incident bremsstrahlung spectrum did 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.

[*] This work was supported by the U. S. Atomic Energy Commission.

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

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(Received January 29, 1953)

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

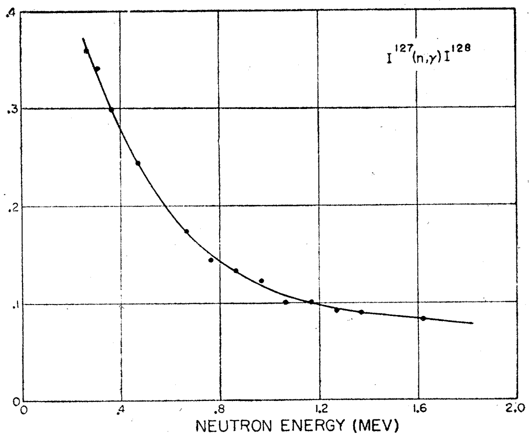

FIG. 1. Cross section for the $I^{127}(n, \gamma)I^{128}$ reaction.

varying the proton energy. Several clear cubic crystals weighing from 2.5 to 5 grams were used in obtaining the data. Each crystal was placed in a cadmium-shielded test tube and covered with mineral oil; for each datum a crystal was irradiated for 1600 seconds. A flat-response long counter,[3] also at 0°, monitored the neutron flux during the irradiation. The absolute flux was determined by comparison with a standard RaBe source, calibrated to ±5 percent, placed at the gas target. In each case the transmission of the sample was measured so that a correction could be made for attenuation of the neutron beam in passing through the crystal.

After irradiation the crystals were submerged in a mineral oil well on a 5819 photomultiplier, and their activities were detected by feeding pulses from the photomultiplier to an amplifier and scaler. In all cases clean 25-minute activities due to I^{128} were observed. Extrapolation of the detecting system's integral bias curve to zero bias indicated that about 98 percent of all pulses from the scintillator were above normal operating bias. Within experimental error, the value obtained for the cross section at a given neutron energy was found to be independent of the size of the activated crystal. No induced activity was observed in a crystal that was irradiated behind a 30-cm long tungsten shadow-cone, indicating a negligible slow neutron background.

Figure 1 shows the (n, γ) cross section as a function of neutron energy. The estimated error in the absolute values is ±7 percent; the energy spread for each datum is about 50 kev. The cross section is very nearly proportional to $1/E$ in this energy range. These results are essentially in agreement with values for the (n, γ) cross section that have been obtained at several isolated points.[4]

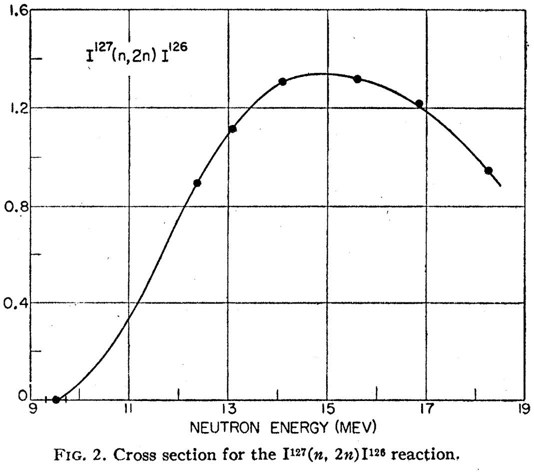

FIG. 2. Cross section for the $I^{127}(n, 2n)I^{126}$ reaction.

A relative $(n, 2n)$ activation curve was obtained by placing the NaI(Tl) crystals at appropriate angles around the tritium gas target at a distance of 12 cm and accelerating monatomic deuterons to 2.00 Mev to produce the $T(d, n)He^4$ reaction.[2] The crystals were counted as in the case of the (n, γ) reaction, and for each crystal the 13.1-day I^{126} activity was observed for about 40 days with no longer-lived period becoming apparent. While the error in the relative activities of the crystals is only about ±4 percent, the cross-section values shown in Fig. 2 depend upon the angular distribution of the $T(d, n)He^4$ neutrons, which is known to about ±10 percent. For a deuteron energy of 2 Mev, at the angular positions where the crystals were irradiated, the laboratory differential cross sections for neutrons shown in Table I have been used. These values seem most consistent with presently available data on the $T(d, n)He^4$ reaction.[2,5] To fix the absolute value of the $(n, 2n)$ cross section, a crystal was irradiated with 14.1-Mev neutrons produced by a Cockcroft-Walton accelerator, with the absolute neutron flux monitored to ±5 percent by observing the alpha-particles from the $T(d, n)He^4$ reaction. The error in the absolute value of the $(n, 2n)$ cross section at 14.1 Mev is estimated to be ±6 percent. The neutron energy spread at each point is about 0.7 Mev; the threshold of 9.52±0.20 Mev is determined from the value reported for the (γ, n) reaction.[6]

TABLE I. Laboratory differential cross sections for $T(d, n)He^4$ neutrons at a deuteron energy of 2 Mev.

θ_{lab} deg	0	52.5	75	127.5	150
$\sigma(\theta_{\text{lab}})$ mb/sterad	23.0	13.4	10.1	8.0	8.0

We are indebted to Mr. Arthur Frentrop for the irradiation at the Cockcroft-Walton accelerator.

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* Work done under the auspices of the U. S. Atomic Energy Commission.
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Precision Measurement of Co^{60} Gamma-Radiation

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(Received January 19, 1953)

BECAUSE of the usefulness of Co^{60} as a gamma-ray standard, Lind, Brown, and DuMond have made[1] precision determinations of the gamma-ray energies from this isotope. Their values of 1.1715±0.0010 Mev and 1.3316±0.0010 Mev are based on curved crystal spectrometer measurements of wavelengths. Recently it was reported[2] by Muller, Hoyt, Klein, and DuMond that an unsuspected nonlinearity was present in the crystal spectrometer at the time of the Co^{60} experiments. From Fig. 7 of their paper it can be seen that if a correction is made for this, it would raise the Co^{60} values by about 0.1 percent.

In order to obtain a check on the Co^{60} gamma-rays, we have determined their energies in the following way. The K line of the highly converted 1.41-Mev transition occurring in the decay of 20-min RaC (electron energy about 1.32 Mev) was first measured absolutely in a semicircular focusing uniform field spectrometer. The technique was similar to that previously described[3] in connection with ThC″ measurements except that both photographic and counter detection were used. In the latter case a NaI gamma-ray monitor counter was employed to correct for decay. Sources consisted of tungsten wires 20 microns in diameter on which the activity had been collected electrostatically. Measurements of both the magnetic field along the path in terms of the proton resonance and the source to slit (or image) distance were done according to previous procedures. The weighted average of two counter and two photographic measurements gives a momentum