

for a region located a few mm from the entrance window the maximum will, in fact, occur at around 0°C. (At such a pressure the fluorescent beam decreases in intensity by more than 25 percent in the first 5 mm of its path.⁴) In general, more strongly absorbed components should exhibit intensity maxima at lower pressures. Irrespective of the direction from which one observes the resonance, in order to draw any definite conclusions one has to make large corrections for the decay of the beam, shape of the exciting line, angle of observation, imprisonment of the radiation, distance from the observation window (reabsorption), and so forth.⁵ As a result, no reasonably accurate results for the relative intensities can be expected without using a highly refined technique. It is for this reason that direct measurements of the absorption are superior to an indirect method consisting of a determination of the intensity of resonance fluorescence.

¹ Bitter, Plotkin, Richter, Teviotdale, and Young, *Phys. Rev.* **91**, 421 (1953).

² A. C. G. Mitchell and M. W. Zemansky, *Resonance Radiation and Excited Atoms* (Cambridge University Press, Cambridge, 1934), see pp. 224 and 235-6.

³ A. v. Malinowski, *Ann. Physik* **44**, 935 (1914), Fig. 1 and pp. 951-2.

⁴ Absorption coefficient data for 2537Å are given, for instance, in M. W. Zemansky, *Phys. Rev.* **36**, 219 (1930).

⁵ A very good discussion of these corrections can be found in P. Kunze, *Ann. Physik* **85**, 1013 (1928).

Internal Compton Effect in Ba¹³⁷

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CONTINUOUS gamma rays accompanying internal conversion were recently detected¹ for the first time. The process bears the same relationship to the Compton effect as internal pair production does to pair production, and will be referred to as the internal Compton effect. The ratio of the total number of gamma rays between 50 and 200 keV to the number of internally converted electrons was found to be in crude agreement with the ratio predicted by the only theory available, the semiclassical calculations of Wang Chang and Falkoff,² but the angular distribution

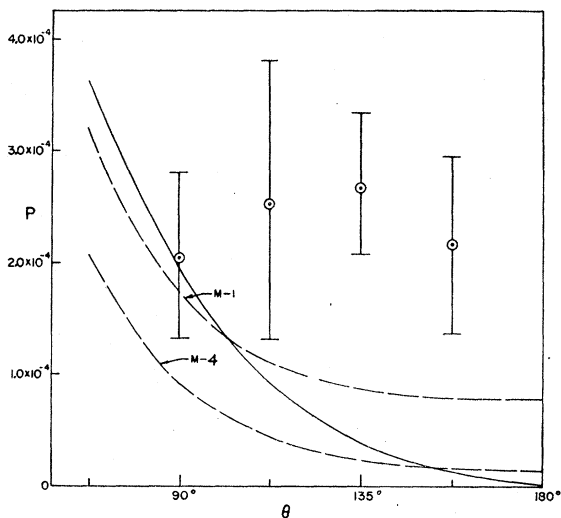


FIG. 1. Angular correlation between direction of conversion electron from Ba^{137m} and of the gamma ray of the continuous radiation. Circled points represent the experimental measurements of Brown and Stump; the solid curve is the value predicted on the basis of semiclassical theory. The dotted curves represent the values predicted for the actual case, an *M4* transition, and, for comparison, for an *M1* transition. *P* is the probability of emission of a gamma ray of the continuous radiation with an energy between 50 and 200 keV into a unit solid angle at an angle of θ° with respect to the electron.

differed markedly from the theoretical prediction. The disagreement is not surprising, for the theory neglects the recoil of the electron upon emission of the real gamma ray, an approximation which is not completely justifiable for the electron and gamma-ray momenta involved. The theory also ignores the mechanism by which the electron is ejected and is, therefore, independent of the multipole character of the virtual gamma ray and of the initial spatial distribution of the electron. Finally, it ignores the effect of the Coulomb field on the electron in the intermediate and final state.

All but the last defect are eliminated by a quantum calculation using the Born approximation. This latter approximation is still quite a serious one for Ba¹³⁷; in fact, the Born approximation calculation of the internal-conversion probability, which forms one of the two parts of the calculation, is only 0.4 of the true value. It would seem, though, that the ratio of continuous gamma rays to internally converted electrons should be more reliable than either calculation separately, since quite similar approximations are involved. Nevertheless, as seen from Fig. 1, the quantum calculations do not represent an improvement. The error is not due to the neglect of *L* shell conversion and it is highly unlikely that it is due to the neglect of *E5* conversion. The source of the error must then be the neglect of the Coulomb field. It should be noted that in the experimental results the beta-decay bremsstrahlung background was subtracted off on the basis of a calculation which also ignored the effect of the Coulomb field.

The quantum calculations, which should be valid for small charge and large energy, have been performed for an arbitrary magnetic multipole. It is found that the ratio of continuous gamma rays to internally converted electrons is independent of the nuclear matrix element and *decreases* as the charge or the multipole increases. The transition rate for continuous gammas, however, increases as *Z* increases. The details of these calculations will be submitted for publication shortly.

¹ H. B. Brown and R. Stump, *Phys. Rev.* **90**, 1061 (1953).

² C. S. Wang Chang and D. L. Falkoff, *Phys. Rev.* **76**, 365 (1949).

Kinematic Criterion for Meson Production in Fundamental Particle Collisions*

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WHEN one or several mesons are made in a nucleon-nucleon or pion-nucleon collision at cosmotron energies,¹ the angle of recoil of the nucleons in the laboratory system cannot exceed a maximum value θ_m which depends on the energy of the incident nucleon or pion and on the number of mesons produced. As an example, θ_m is 68° for a collision of a 2.2-Bev neutron with a proton in which one pion is made. This result can be used to establish that a particle which goes off at an angle greater than θ_m in an inelastic *n-p* collision cannot be a nucleon and must, therefore, be a pion (or a heavy meson). Such a criterion is useful in the analysis of cloud-chamber pictures.

In order to obtain θ_m , the maximum possible velocity of a nucleon in the center-of-mass system (c.m.s.) must be calculated. In order that the nucleon have maximum velocity, it is necessary that all of the other particles move in a direction opposite to the nucleon. The masses, momenta, velocities, and total energies of the particles in the c.m.s. will be denoted by m_i , p_i , v_i , and E_i , respectively; the subscript $i=1$ pertains to the nucleon considered; the other particles are labeled by $i=2, \dots, k$. In view of conservation of energy and momentum, v_1 is given by

$$v_1 = c^2 \sum_{i=2}^k p_i / (E - \sum_{i=2}^k E_i), \quad (1)$$

where $E = \sum_{i=1}^k E_i$ is the total energy in the c.m.s. v_1 is to be