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Publication Date

1958-07-29

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UCRL-8399

(corrected 9-16-58)

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

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July 29, 1958

For publication Physical Review Letters

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The possibility of the "transmission" of polarization effects through matter by means of electromagnetic cascade showers has been suggested by Goldhaber and emphasized by Dyson and McVoy.¹ If the showers are generated by polarized high-energy electrons, this effect can be used to measure the polarization of the incident electron beam by observing the resulting bremsstrahlung photons.² We have therefore made preliminary calculations for the effect by means of a Monte Carlo technique.³

At the present time, the cross sections used for the polarized bremsstrahlung and pair-production processes are essentially those of Dyson and McVoy¹ for the case of complete screening. The $(2/9)$ term neglected by Dyson and McVoy has been combined with the da_{FFF} cross section because it was noticed that in pair production the inclusion of any fractional part of this term with either of the other two cross sections allowed them to become negative. Calculations using more accurate cross sections are planned.⁴

For given initial conditions, i.e., particle, energy, and spin,⁵ three numbers were determined by making correspondences between the cross sections and random numbers. The procedure was as follows: the distance to an interaction was found by a correspondence between the total cross section for an event⁶ and a random number; the energy loss was calculated if the particle was an electron, and the polarization

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combination was obtained by a correspondence between the polarization cross sections (integrated over the energy range) and random numbers; by use of the appropriate polarization cross section, the energies of the resulting particles were obtained by another random-number correspondence. Each particle generated was followed through the material in a similar fashion until the shower "died." Electrons and photons with energies less than one Mev were considered "dead." The random numbers ranged over the integers from 0 to 10^7 . A constant energy loss was assumed, and for our calculations, which are for lead, the value 19.6 Mev/cm was used. The final results obtained were the numbers, polarizations, and energies of electrons, positrons, and photons after traversing a particular distance in the material. In these calculations, multiple scattering has been neglected.

The polarization transmitted in a shower is defined as

$$P(x) = \frac{\gamma_+(x) - \gamma_-(x)}{\gamma_+(x) + \gamma_-(x)} 100 ,$$

where $\gamma_+(x)$ is the number of "spin-forward" photons at a given distance, x , for a particular shower, and $\gamma_-(x)$ refers to the "spin-backward" photons. Table I gives $\bar{P}(x)$, the average polarization, for an incident 30-Mev electron, polarized forward, on the basis of 500 showers. The symbol $(E_\gamma > 5)$ signifies that only those photons present at x with an energy greater than 5 Mev were counted; similarly for $(E_\gamma > 10)$. Physical significance is to be attached only to the top entry in the left column and to the top two entries of the right column of the Table; the present statistical accuracy is poor for large x , while the various defects in the theoretical model become more important for particles at the lower energies. The balance of the Table is included to indicate

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the qualitative nature of these preliminary calculations. An indication of the statistical accuracy is given by the 95% confidence intervals (estimated as $2\sigma_{\bar{P}}$, where $\sigma_{\bar{P}}$ is the standard deviation of $\bar{P}$) listed where such intervals have statistical significance. Future computations of 5000 showers, using the correct cross sections⁴, are expected to give mean polarizations reliable to within a few percent.

We are indebted to Dr. D. L. Judd for suggesting this calculation. This work was performed under the auspices of the United States Atomic Energy Commission.

TABLE I

Average polarization for an incident 30-Mev electron polarized forward.

x (cm)	$E_Y > 5$		$E_Y > 10$	
	$\bar{P}(x)$	$2\sigma_{\bar{P}}$	$\bar{P}(x)$	$2\sigma_{\bar{P}}$
0.5	55	10	72	12
1.0	61	8	90	10
1.5	55	14	80	22
2.0	43	20	39	54
2.5	40	26	64	

FOOTNOTES

1. K. W. McVoy and F. J. Dyson, Phys. Rev. 106, 1360 (1957).
2. Crowe, Haddock, and Macq, The Helicity of the Electron and Positron in Muon Decay, UCRL-8263, April 24, 1958 (to be published in Physical Review).
3. Similar Monte Carlo calculations without polarization transmission have been performed: Robert R. Wilson, Phys. Rev. 86, 261 (1952).
4. The correct cross sections have been calculated: H. Olsen and L. C. Maximon, Phys. Rev. 110, 589 (1958).
5. We consider only 100% polarization for the incident particle.
6. Only the primary effects are included, i.e., we have neglected photoelectric effect, Compton effect, electron atomic-electron bremsstrahlung, etc.