

NOTIZEN

The Influence of the f_0 Meson in the Two-Photon Exchange on the Relative Ratio of σ_{e^-p} to σ_{e^+p} and the Polarization of the Recoil Protons in Elastic Electron-Proton Scattering

R. RODENBERG

Institut für Theoretische Physik der Universität Frankfurt/M.
(Z. Naturforschg. **20 a**, 841—842 [1965]; received 4 May 1965)

In a former paper¹ we have calculated the two-photon exchange contributions in elastic (e,p)-scattering processes. With this result we have calculated the correction term in α^3 to the ROSENBLUTH formula (interference term of the one- and two-photon exchange amplitude) and that to the proton-antiproton annihilation in an electron-positron pair. Using the procedure given by HEARN and LEADER², an expansion of the photon-nucleon vertex was given in terms of the COMPTON scattering amplitude for the proton. Because one can neglect the cut in the s-plane³ we have considered dispersion relations in the t-channel only. The corrections to the ROSENBLUTH formula and those to the $p\bar{p}$ annihilation into an e^+e^- -pair are smaller by a factor α than the contributions of the one-photon exchange diagram; so we got a deviation of $\sim 1\%$ ^{4,5} for a point nucleon. One can have only a possible influence in the resonances of the COMPTON scattering amplitude. Let A_B be the contribution of the one-photon exchange amplitude and A_C that for the two-photon case. Then near the resonance energy $\omega_R \approx 300$ MeV for COMPTON scattering A_C is predominantly imaginary, being just the shadow of the channel for the photo meson production in the resonant 3-3 channel, as DRELL, RUDERMANN⁶ and FUBINI³ have shown. Therefore A_C is approximately $\pi/2$ out of phase with A_B , a real potential scattering term in BORN approximation, and the interference term in

$$\frac{d\sigma_{e^-p}}{d\Omega} \sim |\alpha A_B + \alpha^2 A_C|^2 \approx \alpha^2 |A_B|^2 + 2\alpha^3 \text{Re } A_B^* A_C + \dots \quad (1)$$

is actually very small^{7,8}.

FLAMM and KUMMER⁹ have calculated the influence of A_C by introducing a tensor resonance model for

COMPTON scattering. The result is, that the maximal deviation from the straight line behaviour as a function of $\text{tg}^2(\vartheta/2)$ ^{10,11}

$$[A(t) + B(t) \text{tg}^2(\vartheta/2)] \quad (2)$$

appears only at very small scattering angles ϑ .

The deviation from the ROSENBLUTH formula comes out to be $\sim 10\%$ for an impulse transfer of $t = -30 f^{-2}$ and small ϑ and the assumption, that the coupling constants used in this model are of the order of 1. We find⁸, that the deviations from (2) give a correction of 7% for $t = -30 f^{-2}$ and $\vartheta = 5^\circ$ and the f_0 meson in the intermediate state, using dispersion relation methods.

But if we introduce the POMMERANCHUCK trajectory¹² for the f_0 meson, the correction amounts to be 12%. For the coupling constants we have assumed $f_{\gamma f_0} = f_{\gamma \pi}$ and $f_{f_0 \mathcal{N}} = f_{\pi \mathcal{N}}$ in both cases.

In order to get quantities for a better discussion in experiments and to have a direct measure for the contribution of A_C , we have calculated from (1) the relative ratio

$$A = \frac{\sigma_{e^-p} - \sigma_{e^+p}}{\sigma_{e^-p} + \sigma_{e^+p}} = 2\alpha \frac{\text{Re } A_B^* A_C}{|A_B|^2} \quad (3)$$

and the polarization P of the recoil protons in the elastic (e,p)-scattering processes, using unpolarized electrons^{8,13}

$$P = \frac{\text{Tr. } \{M^+ \sigma s M\}}{\text{Tr. } \{M^+ M\}} \quad (4)$$

M denotes the transition matrix, σ the PAULI matrices and s the spin direction of the recoil proton ($s^2 = 1$).

Expanding the S-matrix in powers of α , we get

$$S = 1 + i M_2 + i M_4 + \dots, \quad (5)$$

where M_2 corresponds to the one-photon exchange term A_B (hermitian!) and M_4 to the A_C . To lowest order in α , the polarization is then given by

$$P = 2i \frac{\text{Tr. } \{M_2(\sigma s) \text{Im } M_4\}}{\text{Tr. } \{M_2^+ M_2\}} \quad (6)$$

In order to calculate the M_4 resp. A_C , the unitarity condition, calculated for the channels given in Fig. 1, was used.

¹ R. RODENBERG, Z. Naturforschg. **17 a**, 1038 [1962].

² A. C. HEARN and E. LEADER, Phys. Rev. **126**, 789 [1962].

³ S. D. DRELL and S. FUBINI, Phys. Rev. **113**, 741 [1959].

⁴ R. RODENBERG, Internat. Rutherford Jubilee Conf. 1961, C 1/5, p. 240.

⁵ R. RODENBERG, Z. Naturforschg. **16 a**, 1242 [1961].

⁶ S. D. DRELL and M. A. RUDERMANN, Phys. Rev. **106**, 561 [1957].

⁷ S. D. DRELL, Form Factors of Elementary Particles, Proc. Intern. School of Physics, Enrico Fermi, Course XXVI, p. 206/207.

⁸ R. RODENBERG, Elektromagnetische Struktur der Atomkerne und Nukleonen, Lecture Notes, Frankfurt/M., Institut für Theoret. Physik (1963/64).

⁹ D. FLAMM and W. KUMMER, CERN, 4538/T. H. 289 (10. 8. 1962).

¹⁰ M. GOURDIN, Nuovo Cim. **21**, 1094 [1961].

¹¹ R. RODENBERG, Z. Naturforschg. **16 a**, 1243 [1961].

¹² W. KUMMER, CERN, 3272/T. H. 255 (13. 3. 1962).

¹³ F. GUERIN and C. A. PIKETTY, Laboratoire de Physique Theoretique et Hautes Energies (Orsay) (T. H. 33, Sept. 1963).



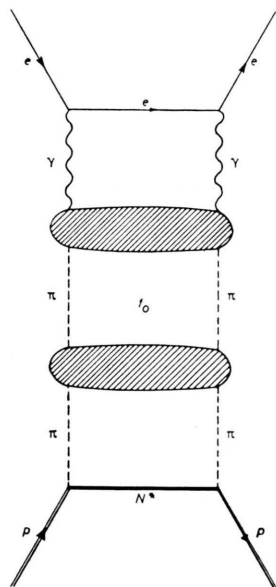


Fig. 1.

To calculate the contribution of this diagram, we have used for the $(\pi N N^*)$ -vertex the isobaric model

¹⁴ M. GOURDIN and PH. SALIN, *Nuovo Cim.* **27**, 1, 193 [1963].

¹⁵ M. GOURDIN and PH. SALIN, *Nuovo Cim.* **27**, 309 [1963].

¹⁶ The Sienna International Conf. Elementary Particles (31. 8. 1963).

¹⁷ A. BROWMAN, F. LIU, and C. SCHAEFER, *Phys. Rev. Letters* **7**, 183 [1964].

Electron Paramagnetic Resonance of Eu^{2+} in CdF_2

H. J. GLÄSER and D. GEIST

Institut für Angewandte Physik der Technischen Hochschule Clausthal, Germany

(Z. Naturforschg. **20 a**, 842—844 [1965]; received 6 May 1965)

The paramagnetic resonance spectrum of Eu^{2+} in CdF_2 (about 0,1 mole % Eu) shows the same characteristics as in other alkaline earth fluorides with a CaF_2 -type lattice¹⁻⁴.

The angular variation shows that the Eu^{2+} -ions in

of GOURDIN and SALIN^{14, 15}, who calculated the photo production processes.

Further, to calculate $\text{Im } M_4$ for the channels given in Fig. 1, a technique similar to that given in¹³ was used. To obtain the form factor in the $(\gamma \pi)$ -vertex, the f_0 resonance was introduced and for the pion form factor a subtracted dispersion relation⁷ was used, viz.:

$$F_\pi(q'^2) = \exp - \left[\frac{q'^2}{\pi} \int_{4\mu^2}^{\infty} \frac{\delta_1(\sigma^2) d\sigma^2}{\sigma^2(\sigma^2 - q'^2 - i\varepsilon)} \right], \quad (7)$$

where $\delta_1(\sigma^2)$ is the d-wave $\pi\pi$ -scattering phase shift.

At the resonance there holds

$$\delta_1(q_r^2) = \pi/2 \quad (q_r^2 = m_{f_0}^2).$$

With the assumptions used in¹³⁻¹⁵ we find that

$$A_{\text{theoret.}} \sim -0,079 \quad \text{for } t = q^2 = -19,5 f^{-2}.$$

The experiments^{16, 17} give

$$A_{\text{exp.}} = -0,094 \pm 0,046 \quad \text{for } q^2 = -19,5 f^{-2}.$$

For the polarization (projection on a plane perpendicular to the coplanar reaction plane) we find a maximum value of $-1,2\%$ for electron energies $E_1 = 1,2 \text{ GeV}$ and $\cos \vartheta_{\text{CMS}} = \pi/2$. The experimental results¹⁸ are of the same order.

¹⁸ J. C. BIZOT, J. BUON, J. LEFRANÇOIS, J. PÉREZ-Y-JORBA, and P. ROY, *Sienna Intern. Conf. Elementary Particles* (1963), Abstract No. 139 and *Phys. Rev. Letters* **11**, 10, 480 [1963].

CdF_2 are in an electric field of cubic symmetry occupying Cd sites. The ground state of the Eu^{2+} -ions is $^8S_{7/2}$. For this case BAKER, BLEANEY and HAYES² give a spin HAMILTONIAN of the following form:

$$H = g\beta \mathbf{H} \cdot \mathbf{S} + A \mathbf{I} \cdot \mathbf{S} + B_4(O_4^0 + 5 O_4^4) + B_6(O_6^0 - 21 O_6^4).$$

Taking this spin HAMILTONIAN, the splitting of the $^8S_{7/2}$ ground state in a cubic crystal field (8-fold coordination) and with hyperfine interaction in the magnetic field H was calculated^{2, 4, 5}. The magnetic dipole transitions $\Delta M = \pm 1$ (without hyperfine interaction) are given by

$$\begin{aligned} M = \pm 7/2 \rightarrow \pm 5/2 \quad [\text{abbreviated: } \pm 7/2]: \quad h\nu = \Delta E_{\pm 7/2}(H) &= g\beta H_{\pm 7/2} + Q_7, \\ Q_7 &= \pm 20 p b_4 \pm 6 q b_6 + (-1 + 114 \varphi - 345 \varphi^2 + 84 \psi) 10 b_4^2 / (g\beta H_{\pm 7/2}); \\ M = \pm 5/2 \rightarrow \pm 3/2 \quad [\pm 5/2]: \quad h\nu = \Delta E_{\pm 5/2}(H) &= g\beta H_{\pm 5/2} + Q_5, \\ Q_5 &= \mp 10 p b_4 \mp 14 q b_6 + (-92 \varphi + 455 \varphi^2 - 441 \psi) 20 b_4^2 / (3 g\beta H_{\pm 5/2}); \end{aligned} \quad (1)$$

¹ C. RYTER, *Helv. Phys. Acta* **30**, 353 [1957].

² J. M. BAKER, B. BLEANEY, and W. HAYES, *Proc. Roy. Soc., Lond. A* **247**, 141 [1958].

³ R. S. TITTLE, *Phys. Letters* **6**, 13 [1963].

⁴ V. M. VINOKUROV, M. M. ZARIPOV, V. G. STEPANOV, G. K. CHIRKIN, and L. YA. SHEKUN, *Soviet Phys.—Solid State* **5**, 1415 [1964].

⁵ R. LACROIX, *Helv. Phys. Acta* **30**, 374 [1957].