we obtain

$$\sigma(H_2) = 26.43(60)\times 10^{-6}.$$

This is in good agreement with the theoretical value of Ramsey[5,12] for H_2,

$$\sigma(H_2)_{\rm theor} = 26.2(4)\times 10^{-6}.$$

Our determination thus corroborates the presently accepted values of the shielding constant for protons in H_2 gas and water. We anticipate that the precision of the experiment will be substantially improved and thus serve to check details of shielding calculations to which no experiment has so far been sensitive. Even at the present level of accuracy, however, the result eliminates the possibility of an error in the proton moment as an explanation for the discrepancy in the fine-structure constant as obtained from fine- and hyperfine-structure measurements.

We wish to thank R. V. Pound and R. E. Richards for guidance in selection of the magnet used, which was designed and constructed by the Mullard Co., England, and D. A. Gray for assistance in construction of the apparatus.

---

*Work supported by the National Science Foundation and the U. S. Office of Naval Research.

†Alfred P. Sloan Foundation Fellow.

‡Present address: Department of Physics, Duke University, Durham, North Carolina.

[1]S. H. Koenig, A. G. Prodell, and P. Kusch, Phys. Rev. 88, 191 (1952).

[2]R. Beringer and M. A. Heald, Phys. Rev. 95, 1474 (1954).

[3]J. S. Geiger, V. W. Hughes, and H. E. Radford, Phys. Rev. 105, 183 (1957).

[4]E. B. D. Lambe, thesis, Princeton University, 1959 (unpublished).

[5]N. F. Ramsey, Phys. Rev. 78, 699 (1950).

[6]E. R. Cohen and J. W. M. DuMond, Rev. Mod. Phys. 37, 537 (1965).

[7]D. Kleppner, H. M. Goldenberg, and N. F. Ramsey, Phys. Rev. 126, 603 (1962).

[8]W. E. Lamb, Phys. Rev. 60, 817 (1941).

[9]D. T. Wilkinson and H. R. Crane, Phys. Rev. 130, 852 (1963).

[10]H. A. Thomas, Phys. Rev. 80, 901 (1950).

[11]H. Gutowsky and R. E. McClure, Phys. Rev. 81, 276 (1951).

[12]N. J. Harrick, R. G. Barnes, P. J. Bray, and N. F. Ramsey, Phys. Rev. 90, 260 (1953).

SCATTERING OF POSITRONS AND ELECTRONS FROM PROTONS*

R. L. Anderson,† B. Borgia,‡ G. L. Cassiday, J. W. DeWire, A. S. Ito, and E. C. Loh

Laboratory of Nuclear Studies, Cornell University, Ithaca, New York

(Received 12 July 1966)

We wish to report some results from an experiment which compares the scattering of 1200-Mev positrons and electrons from protons. The beams of positrons and electrons were obtained from the electron pairs produced by the photon beam from the Cornell synchrotron operating at 1400 MeV. A five-magnet system served to analyze the electrons or positrons into a beam whose spread in momentum was ten percent and to transport the particles to a location suitable for performing the scattering experiment. The electron intensity was measured by a Quantameter[1] and was approximately 10^6 sec^{-1}, about one-tenth the maximum beam.

A schematic plan of the experiment is shown in Fig. 1. The electrons passed through a cylindrical liquid-hydrogen target, 45 cm long and and 3.2 cm diam. The target had double walls of 0.25-mm stainless steel and double entrance and exit windows of 0.025-mm stainless steel.

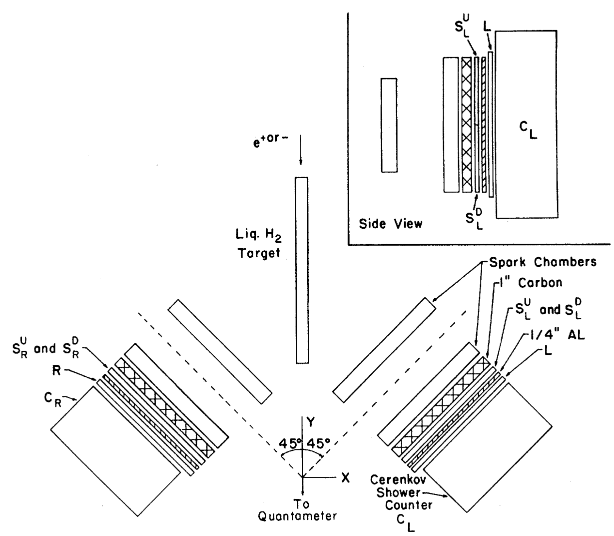

FIG. 1. Schematic plan of the detection equipment. The spark chambers are triggered on any one of the coincidences $LS_L^UC_LRS_R^D$, $LS_L^DC_LRS_R^U$, $RS_R^UC_RLS_L^D$, and $RS_R^DC_RLS_L^U$.

The detection system, consisting of thin-foil spark chambers and counter telescopes arranged symmetrically about a vertical plane through the beam, was designed to collect data which would provide a clear distinction between elastic-scattering events and a background of photoprocesses, inelastic electroprocesses, and pion-scattering events. On each side of the electron beam a counter telescope, consisting of two scintillation counters and a lead-glass Cherenkov shower counter, was oriented at an angle of 45° to the incoming beam and was of sufficient aperture to detect scattered electrons having polar angles between 25 and 75° and azimuthal angles between 20° above and 20° below the horizontal plane. In this way a wide range of scattering angles could be observed simultaneously, corresponding to values of the square of the four-momentum transfer, q^2, between 0.3 and 1.0 $(\mathrm{GeV}/c)^2$. The spark chambers were triggered by a five-fold coincidence of the four scintillation counters and one of the Cherenkov counters. Stereo views of the tracks of the scattered electrons and recoil protons were photographed by a single 35-mm camera. For each event the pulse heights in the two Cherenkov counters and four scintillators were recorded on a multidimensional analyzer.[2] This information was used to check counter stability and to verify the absence of any detectable background due to pion scattering. The trigger rate was approximately three per minute.

The measurements of track coordinates were done manually. The data were punched on cards which were fed in to a CDC 1604 computer in which, for each pair of tracks, the scattering and recoil angles were determined, and from these the incident electron energy and the value of q^2 were calculated from the kinematics for elastic scattering. A second computation produced distribution plots of the parameters and enabled us to set limits for the selection of elastic events.

In Fig. 2 we show plots of the distribution of calculated incident energies, E, and deviations from coplanarity, $\Delta\beta$, for positrons and electrons from identical beam exposures. In Fig. 3 the distribution of events as a function of q^2 is shown. This plot includes all events which have tracks originating in the target and which have values of $\Delta\beta$ or E between the limits shown in Fig. 2.

The results of the experiment are given as

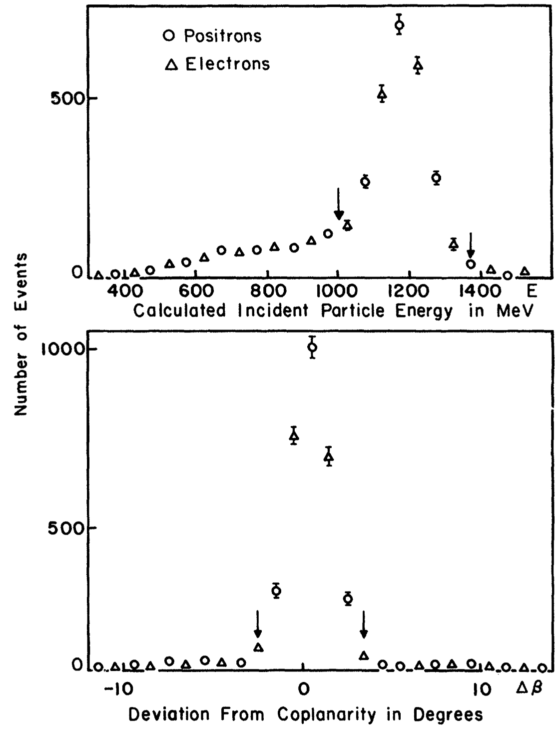

FIG. 2. Distributions of calculated incident energies E and deviations from coplanarity $\Delta\beta$ for positrons and electrons. Limits used for selecting elastic events are shown by the arrows.

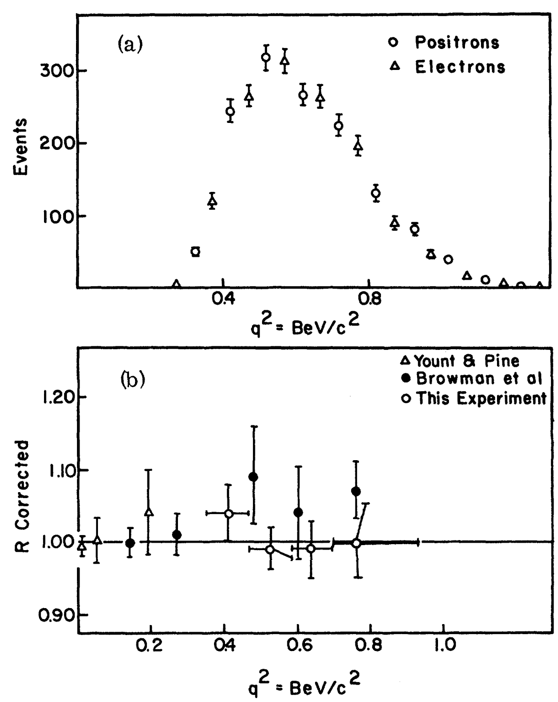

FIG. 3. (a) Plot of q^2 distributions for elastically scattered positrons and electrons. (b) The ratio of positron- and electron-scattering cross sections, plotted against q^2.

ratios $R=\Delta\sigma^+/\Delta\sigma^-$ where the $\Delta\sigma$'s are the partial cross sections for identical increments of solid angles or q^2. Values of R calculated from data taken in two separate runs agree within the statistical errors. The combined values are reported here. The results of the second run indicated a 0.5% shift of the positron energy relative to the electron energy, which was verified by magnetic analysis of the beams at the target position. We have calculated a correction to R of about 1.5% on the basis of the measured shift. A radiative correction has been calculated[3] using Eq. (3.23) of the paper of Yennie, Frautschi, and Suura.[4] For our kinematic limits this correction is made by subtracting from the measured R a quantity Δ given by

$$\Delta=0.011-0.0026\ln q^2,$$

where q^2 is given in (GeV/c).[2]

Values of R are determined from plots such as Fig. 3(a) which shows the distribution in q^2 of the elastic events from the first run. From the combined data from both runs we obtain, after making the radiative correction,

$$R=0.996\pm0.020$$

for $0.35\leq q^2\leq0.93$, where the error is the statistical error which is dominant.

In Fig. 3(b) we plot R for four intervals of q^2 together with the results of Yount and Pine[5] and Browman, Liu, and Schaerf.[6] These earlier Stanford results suggested that R may be increasing slowly with q^2, but our results do not support this. We conclude that the two scattering cross sections are the same within our experimental error after correcting for the radiation of real photons by the scattering and recoil particles.

The results given here come from about 80% of the 40 000 pictures taken at 1200 MeV. We have also taken 25 000 pictures at 810 MeV. A more detailed description of the experiment and final results will be given in a future paper.

We wish to thank Professor R. R. Wilson, who suggested this experiment and helped us design the positron beam, and Professor Martin Feldman for his contribution to our preliminary studies. We are grateful for the efficient and patient work of our scanners, Mrs. Mary Johnson, Miss Geraldine Jackson, and Mr. Richard Johnson. Several discussions with Mr. Anil Rae and Professor Donald Yennie are gratefully acknowledged. We also thank the operating crew of the Cornell synchrotron for their generous cooperation.

*Work supported in part by the U. S. Office of Naval Research and the National Science Foundation.

†Now at Stanford Linear Accelerator Center, Stanford, California.

‡Now at Istituto di Fisica, Università di Roma, Rome, Italy.

[1]R. R. Wilson, Nucl. Instr. Methods 1, 101 (1957).

[2]R. Littauer and L. Tepper, Nucl. Instr. Methods 26, 285 (1964).

[3]A. Rae, Cornell University, private communications.

[4]D. Yennie, S. Frautschi, and H. Suura, Ann. Phys. (N.Y.) 13, 379 (1961).

[5]D. Yount and J. Pine, Phys. Rev. 128, 1842 (1962).

[6]A. Browman, F. Liu, and C. Schaerf, Phys. Rev. 139, B1079 (1965).

MESON-BARYON COUPLING CONSTANTS IN BROKEN SU(3) AND THE ALGEBRA OF CURRENTS

S. K. Bose* and Y. Hara†
International Atomic Energy Agency, International Centre for Theroetical Physics, Trieste, Italy
(Received 23 June 1966)

Using the algebra of currents, we study the renormalization effects on the meson-baryon coupling constants, due to SU(3) breaking.

Using the algebra of currents[1] and the hypothesis of partial conservation of axial-vector currents (PCAC), we obtain sum rules for meson-baryon coupling constants in broken SU(3) with symmetry-breaking effects taken into account to first order. Our sum rules are much stronger than those obtained by earlier workers using pure group-theory methods.[2] The most important aspect of our results is the following: Those sum rules which involve only pion-baryon couplings or only kaon-baryon couplings are exactly the same as the corresponding sum rules obtained in the limit of SU(3) symmetry.[3] Likewise for η couplings. To first order, renormalization effects due to symmetry breaking are thus entirely absent