ρ Production in Deep-Inelastic Electron Scattering*†

D. E. Andrews, K. Berkelman, D. G. Cassel, D. L. Hartill, J. Hartmann, R. Kerchner, E. Lazarus,
R. M. Littauer, R. L. Loveless, R. Rohlfs, and D. H. White
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14850

and

A. J. Sadoff
Ithaca College, Ithaca, New York 14850

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The reaction $e+p\rightarrow e+p+\rho^0$ is measured by observing electron-proton coincidences for ν beyond the resonance region and for $-t=0.07$ to $0.5\ \mathrm{GeV}^2$. We note that the yield of $p+\rho^0$ relative to other hadron final states is less than in photoproduction.

Measurements of inelastic electron-proton scattering made at Stanford Linear Accelerator Center and DESY[2] have revealed that there is a continuum yield which decreases with momentum transfer q^2 much more slowly than does elastic scattering or resonance excitation. This result has stimulated a number of theoretical speculations.[3] We report here a first measurement on the hadron final states pX^0, in which X^0 is any neutral state emitted near the momentum transfer direction $\vec{q}$.

The extracted electron beam of the Cornell synchrotron passes through a 2.7-cm liquid-hydrogen target and on to a Faraday-cup monitor. Scattered electrons pass through a pair of half-quadrupole magnets and are deflected vertically by two bending magnets. The trajectories are observed in six planes of multiwire proportional chambers[4] (256 wires per plane, spaced 2 mm apart), which are gated by a coincidence of two scintillators, a Freon threshold Cherenkov counter, and a lead-glass shower counter. Protons are deflected horizontally in a large-aperture magnet accepting the range of laboratory angles

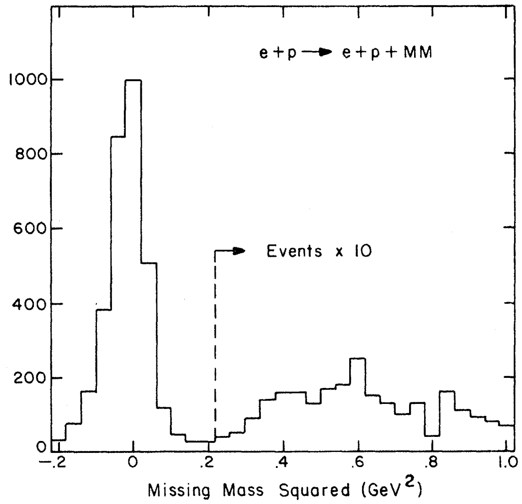

FIG. 1. Missing mass squared distribution for the $q^2=0.3\ \mathrm{GeV}^2$ data. The spread in the radiative peak ($ep\rightarrow ep\gamma$) at zero mass is an indication of the experimental resolution.

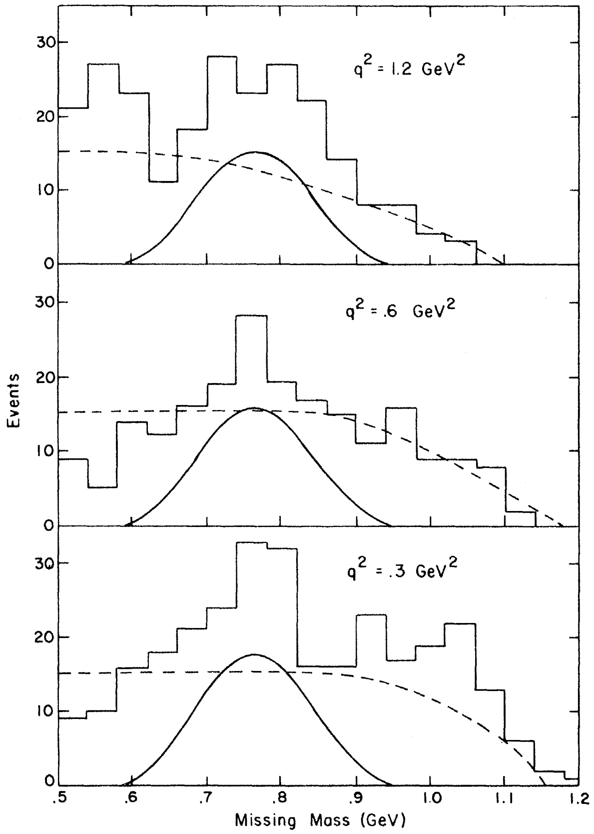

FIG. 2. Missing-mass distributions. The dashed lines indicate the calculated acceptance of the apparatus, plotted in arbitrary units. The solid curves are the estimated yields of ρ^0 and ω electroproduction events taking into account the experimental resolution and aperture and assuming the values of $V(q^2,W)$ reported in Table I with the t and φ distributions noted in the text.

Table I. Running conditions and results for the three electroproduction runs.

q^2	= Squared four-momentum transferred by electron, in GeV^2	0.3	0.6	1.2
E	= Incident lab electron energy, in GeV	7.5	9.5	9.5
E'	= Mean scattered lab electron energy, in GeV	3.0	4.8	4.6
θ_e	= Mean electron lab scattering angle	6.6°	6.6°	9.6°
ε	= Photon polarization parameter	0.68	0.80	0.77
ν	= E - E'	4.5	4.7	4.9
W	= Final hadron effective mass, in GeV	3.0	3.0	3.0
$2M\nu/q^2$		28	15	8
$V(q^2, W)$	= Rho and omega fraction (note: V(0, W) = 0.16 in photoproduction)	.07±.03	.08±.03	.06±.03

from 55° to 90° relative to the electron beam. A wide-gap optical spark chamber records the proton trajectories behind the magnet, and an array of eight scintillation counters provides the proton input to the coincidence trigger. Protons in the hadron spectrometer are identified by momentum and time of flight. Events with hadron momentum higher than 0.75 GeV/c are not used in the analysis, in order to make the π-p separation unambiguous.

For each electron-proton coincidence event we compute the mass of the missing neutral boson state X^0. By far the most prominent feature of this mass spectrum (see Fig. 1) is a peak at zero missing mass due mainly to radiative ep scattering ($ep \rightarrow ep\gamma$). The number of zero-missing-mass events observed and their distribution in the missing momentum vector agree with the predictions of quantum electrodynamics.[5] The radiative peak unfortunately obscures the hadron mass spectrum below 0.5 GeV missing mass. Missing masses near and above 1 GeV are cut off by the small-angle edge of the proton aperture. The most striking feature of the data (Fig. 2) is the fact that the ρ meson is not nearly as prominent as it is in photoproduction.

Let us define $V(q^2, W)$ as the fraction of the hadron electroproduction cross section which goes into the $\rho^0 p$ and ωp channels (W is the total c.m. energy of the final-state hadrons). That is,

$$V(q^2, W) = \left[\frac{d\sigma}{dE'd\Omega_e}(ep \rightarrow ep\rho^0 \text{ and } ep\omega)_{q^2, W}\right]\left[\frac{d\sigma}{dE'd\Omega_e}(ep \rightarrow e + \text{anything})_{q^2, W}\right]^{-1}.$$

$V(0, W)$ is obtained from the corresponding photoproduction cross sections:

$$V(0, W) = [\sigma(\gamma p \rightarrow p\rho^0 \text{ and } p\omega)_W]\,[\sigma(\gamma p \rightarrow \text{anything})_W]^{-1}.$$

The vector-dominance model[6] predicts that $V(q^2, W)$ is independent of q^2 and has the same value $V(0, W)$ as in photoproduction. The photoproduction data[7] at 3 GeV show $V(0, W) = (20\ \mu\text{b})/(120\ \mu\text{b}) = 0.16$.

The value of V implied by our data is obtained for each q^2 run as follows. The denominator of $V(q^2, W)$ is obtained from our measured electron-only rate, corrected for radiative effects.[5] The numerator is obtained by dividing an estimate of the ρ^0 (and ω) yield by the acceptance calculated assuming azimuthal symmetry[8] about the $\vec{q}$ direction and e^{7t} for the t distribution.[9]

The resulting ratios $V(q^2, W)$ are listed in Table I. The quoted errors include the uncertainty in the subtraction of non-vector-meson events, as well as counting statistics. Clearly the vector-meson fraction in electroproduction is smaller than in photoproduction. Perhaps this should not be surprising, since the mismatch in photon and vector meson masses becomes greater as the virtual photon becomes more spacelike. It does imply, however, that other mechanisms besides vector-meson dominance are probably contributing to photon-hadron couplings in order to keep the total hadron production from decreasing with q^2 as rapidly as does the vector-meson production.[10] It also indicates that the absorption of virtual photons in the deep inelastic region is probably not diffraction dominated as some authors have suggested.[11]

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[1] E. D. Bloom *et al.*, Phys. Rev. Lett. 23, 930 (1969); M. Breidenbach *et al.*, Phys. Rev. Lett. 23, 935 (1969).

[2] W. Albrecht *et al.*, DESY Report No. 69/46 (to be published).

[3] Theoretical work has been reviewed by F. J. Gilman, in *Proceedings of the Fourteenth International Symposium on Electron and Photon Interactions at High Energies, Liverpool, England, September 1969*, edited by D. W. Braben and R. E. Rand (Daresbury Nuclear Physics Laboratory, Daresbury, Lancashire, England, 1970), p. 177.

[4] G. Charpak *et al.*, Nucl. Instrum. Methods 62, 262 (1968).

[5] L. W. Mo and Y. S. Tsai, Rev. Mod. Phys. 41, 205 (1969).

[6] Only a weak form of vector dominance is needed; that is, we require that $\sigma(\gamma_{\rm virtual}\, p \to V^0 p) = f\sigma(V^0 p \to V^0 p)$ and $\sigma(\gamma_{\rm virtual}\, p \to \text{anything}) = f\sigma(V^0 p \to \text{anything})$, with the same factor f (a function of q^2, possibly) applying in both equalities. Here V^0 represents either ρ^0 or ω.

[7] Cambridge Bubble Chamber Group, Phys. Rev. 146, 994 (1966), and 169, 1081 (1969); Aachen-Berlin-Bonn-Hamburg-Heidelberg-München Collaboration, Phys. Rev. 175, 1669 (1968); J. Ballam *et al.*, Phys. Rev. Lett. 21, 1541 (1968); Y. Eisenberg *et al.*, Phys. Rev. Lett. 22, 669 (1969); D. O. Caldwell *et al.*, Phys. Rev. Lett. 25, 609 (1970); H. Meyer *et al.*, Phys. Lett. 33B, 189 (1970).

[8] The virtual photon is polarized, but if vector-meson electroproduction is predominantly diffractive as in photoproduction, there will be little or no φ dependence.

[9] For the range of t values detected in the experiment (-0.07 to -0.5 GeV^2) the quoted values for $V(q^2, W)$ are not sensitive to the assumed t dependence for distributions between e^{3t} and e^{10t}. Evidence for $d\sigma/dt = Ae^{(7\pm 2)t}$ in photoproduction can be found in G. McClellan *et al.*, Phys. Rev. Lett. 22, 374 (1969); H. Alvensleben *et al.*, Phys. Rev. Lett. 23, 1058 (1969); and R. Anderson *et al.*, Phys. Rev. D 1, 27 (1970).

[10] Note that the weak form of vector dominance that we have used here cannot be made to agree with the data by modifying the q^2 dependence of the photon-vector coupling or the vector-meson propagator.

[11] H. D. Abarbanel, M. L. Goldberger, and S. Trieman, Phys. Rev. Lett. 22, 500 (1969); H. Harari, Phys. Rev. Lett. 22, 1078 (1969).

Measurement of the $K_L{}^0$ Mean Life*

Kirby G. Vosburgh,† Thomas J. Devlin,‡ Robert J. Esterling, Barton Goz,§ and Douglas A. Bryman‖
Physics Department, Rutgers—The State University, New Brunswick, New Jersey 08903
and
W. E. Cleland**
Physics Department, University of Massachusetts, Amherst, Massachusetts 01002

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We have measured the $K_L{}^0$ mean life to be $(5.154 \pm 0.044)\times 10^{-8}$ sec.

A new measurement of the mean life (τ) of the $K_L{}^0$ meson was made at the Princeton-Pennsylvania Accelerator by observing the exponential decrease in $K_L{}^0$ flux as a function of distance in a collimated neutral beam. We find $\tau = (5.151 \pm 0.044)\times 10^{-8}$ sec.

This scintillation-counter experiment was similar in almost all essential aspects to one described earlier.[1] The chief differences were improved collimator and detector geometries,