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ELECTRON COMPTON SCATTERING AT $\theta = 180^\circ$.

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Recent experiments(1,2) on high energy elastic pion nucleon scattering have demonstrated the existence of a peak in the differential cross section at 180°. One expects a backward peak from a perturbation theory type calculation of a Fermion exchange in the crossed channel. However, the experimental peak is much smaller and narrower than might be anticipated from the perturbation calculation. The energy dependence of the magnitude and width of the peak have been interpreted as evidence for Regge behavior of the Fermion propagator(3). It seemed interesting to explore the possibility that the attenuation of the backward peak is a general property of the Fermion propagator in the crossed channel, not just connected with strong interactions. A comparable situation in quantum electrodynamics is provided by the Compton effect. The center of mass Klein-Nishina cross section(4) has a strong peak at 180° for energies much greater than the electron rest mass. This peak comes from the proximity of the Fermion propagator to the pole at $u = + m_e^2$ in the crossed channel for scattering angles near 180°. Fig. 1 shows the center of mass cross section for an incident laboratory photon energy of 1 BeV. The backward peak contains a substantial fraction

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of the total Compton cross section. Consequently, to observe attenuation, it is sufficient to measure the integral under the peak inside any reasonable angular range containing 180°, rather than try to delineate the peak in detail. With this goal in mind, we have measured the Compton cross section for bremsstrahlung photons of maximum energy 500 MeV and 950 MeV.

DESCRIPTION OF THE EXPERIMENT

The experiment was set up on the 100 inch spectrometer at Mark III Linear Accelerator at Stanford University. Figure 2 shows a schematic of the experimental geometry. A photon beam was generated by passing an electron beam through 0.0118 radiation lengths of copper and then sweeping it out of the way. The photon beam passes through a 10.7 cm hydrogen target and then through a hole in the rear return yoke of the spectrometer magnet. The spectrometer has a square angular aperture of $\pm 8.25 \times 10^{-3}$ radians in the horizon plane and $\pm 25.0 \times 10^{-3}$ radians in the vertical plane. The inherent momentum resolution of the spectrometer is better than $\pm 0.3\%$. We used a counter telescope in the focal plane to intercept $\frac{\Delta P}{P} = 0.0742$.

High energy electrons are produced in hydrogen by the Compton effect and by the pair production process. If we assume the energy spectrum of pair electrons is identical to that of the positrons, then the number of Compton electrons in a particular momentum band is given by the difference between the number of electrons and positrons coming out of the hydrogen in that momentum band. Near the end of the bremsstrahlung spectrum, the number of Compton electrons is greater than the pair electrons, so this is a particularly good place to measure the Compton cross section.

With the incident electron energy fixed at 950 MeV, we took curves of rate vs spectrometer momentum for each sign of charge and for full and empty target. The spectrometer momentum was varied from 400 MeV/c to 1 BeV/c. The experiment was repeated with an incident beam energy of 500 MeV. To check that we were observing Compton effect a 0.091 radiation length copper target was substituted for the hydrogen and the experiment with 950 MeV electrons was repeated. A convenient additional check on the z dependence was provided by our empty target measurements since the front and rear walls of the target constituted 0.0043 radiation lengths of aluminum. The data from aluminum and copper are consistent with our interpretation of the source of the electrons.

The experiment was run at beam current levels between 2×10^5 and 3×10^6 electrons per pulse. We used an ionization chamber to monitor the electron beam during the experiment. The ionization chamber was calibrated several times against the laboratory Faraday cup. From the scatter in these calibrations, we estimate the uncertainty in the absolute beam calibration to be $\pm$ 2.0%.

RESULTS AND COMPARISON WITH THEORY

Curves for the number of events vs. spectrometer momentum were calculated for pair production and Compton effect. For the Compton effect we used the Klein-Nishina cross section. We are presently trying to obtain a reliable calculation for the radiative corrections. Using the Weizsäker-Williams method in which the probability of the final electron or energy E, radiating a photon, of energy K, is given by

$$w(K)dK = \frac{2\alpha}{\pi}\left[\log\frac{2E}{m} - \frac{1}{2}\right]\frac{dK}{K}$$

we judge the correction is important (15% at the end of the spectrum with our overall momentum resolution of 1.5%). However, radiative corrections are not included in the curves we are presenting here.

The curve for pair production was calculated from the paper of Wheeler and Lamb[5] with the electron contribution corrected according to the prescription of Joseph and Rohrlich[6]. To be explicit we give the formula in the notation of Wheeler and Lamb[5].

$$d\sigma = \alpha r_0^2 \frac{dE}{K^3} \quad (E_+^2 + E_-^2)\ [\Phi_1(\gamma) + \psi_1(\epsilon) - 4] +$$

$$\frac{2}{3} E_+ E_-\ [\Phi_2(\gamma) + \psi_1(\epsilon) - \frac{10}{3}]$$

The bremsstrahlung spectrum was calculated from a computer program of R. Alvarez[7]. The curves also include the following corrections.

1. The spread in energy of the incident beam ($\pm$ 0.25%) and the vertical extension of the photon beam at the target (1.2 cm diameter beam height is equivalent to a momentum spread of $\pm$ 0.13%) were folded into the bremsstrahlung spectrum.
2. The divergence of the photon beam, the finite width of the photon beam, and the multiple scattering of the electrons on emerging from the target were lumped together to construct a gaussian angular resolution function which was folded in as a correction. This correction was less than 2% for the run with beam energy of 950 MeV. However, for the low beam energy run this correction varied from 3% at the end of the spectrum to 20% at the lowest spectrometer momentum.
3. A correction was made for the bremsstrahlung radiation of the final electron in the hydrogen target.

4. The attenuation of the photon beam amounted to a correction of 0.6%.

5. Annihilation of the final positron was calculated and found to be negligible.

The calculated curves are presented in figures (3) and (4). The ordinate is the number of events per 1.21×10^8 incident electrons in which the final electron has momentum between P_e, the coordinate of the abscissa, and $1.0742\ P_e$. On the same curve, we have plotted the experimental points after they were corrected for counter dead time (typically 1%) and the counter telescope efficiency (0.986 ± 0.003). The errors shown are the statistical ones alone. We have not yet evaluated the uncertainties originating from the beam calibration, and items 1 thru 3 listed above.

Both the pairs and Compton points fit the calculated curves for the 950 MeV run. There is a slight tendency for the Compton points to run a little high at the lower momenta. The data for the 500 MeV run behaves qualitatively the same but the surplus of Compton events at momenta far below the end point is more marked. We have no clear understanding of this at the present time. This could come from poor knowledge on our part of the horizontal angular acceptance of the spectrometer and the angular resolution function. These play an important role at low momenta but almost none near the end of the spectrum. Furthermore, the correction to the pair spectrum is much smaller than to the Compton spectrum because the pair angular distribution is narrower.

Another source which might account for the deviation between theory and experiment is the asymmetry in the electron-positron spectrum in pair production. We can expect an asymmetry since half the pair cross section comes from the atomic electron. We are presently trying to estimate how large this might be. This asymmetry is not important near the end of the bremsstrahlung spectrum where the Compton process is dominant.

Our tenative conclusions are based on the upper 20 or 30% of the momentum spectrum where the analysis and interpretation of the data is much clearer. The validity of the Klein-Nishina cross section at 180° has been verified to within experimental errors. In particular a 15% diminution of the backward peak would have shown up as more than a 3 standard deviation effect, and we can say that there is no attenuation of the Fermion exchange propagator in electrodynamics which is comparable in magnitude to the effect in strong interactions.

REFERENCES

1. H. Brody, et. al., PRL 16, 828, 968(E) (1966).

2. W. R. Frisken, et. al., PRL 15, 313 (1965).

3. V. Barger and D. Cline, PRL 16, 913 (1966).

4. O. Klein and Y. Nishina, Z Physik, 52, 853, (1929)

5. J. A. Wheeler and W. E. Lamb, Phys. Rev. 55, 858 (1939).

6. J. Joseph and F. Rohrlich, Rev. Mod. Phys., 30, 354 (1958).

7. R. Alvarez, Internal Report, High Energy Physics Laboratory, HEPL-228, (July, 1961).

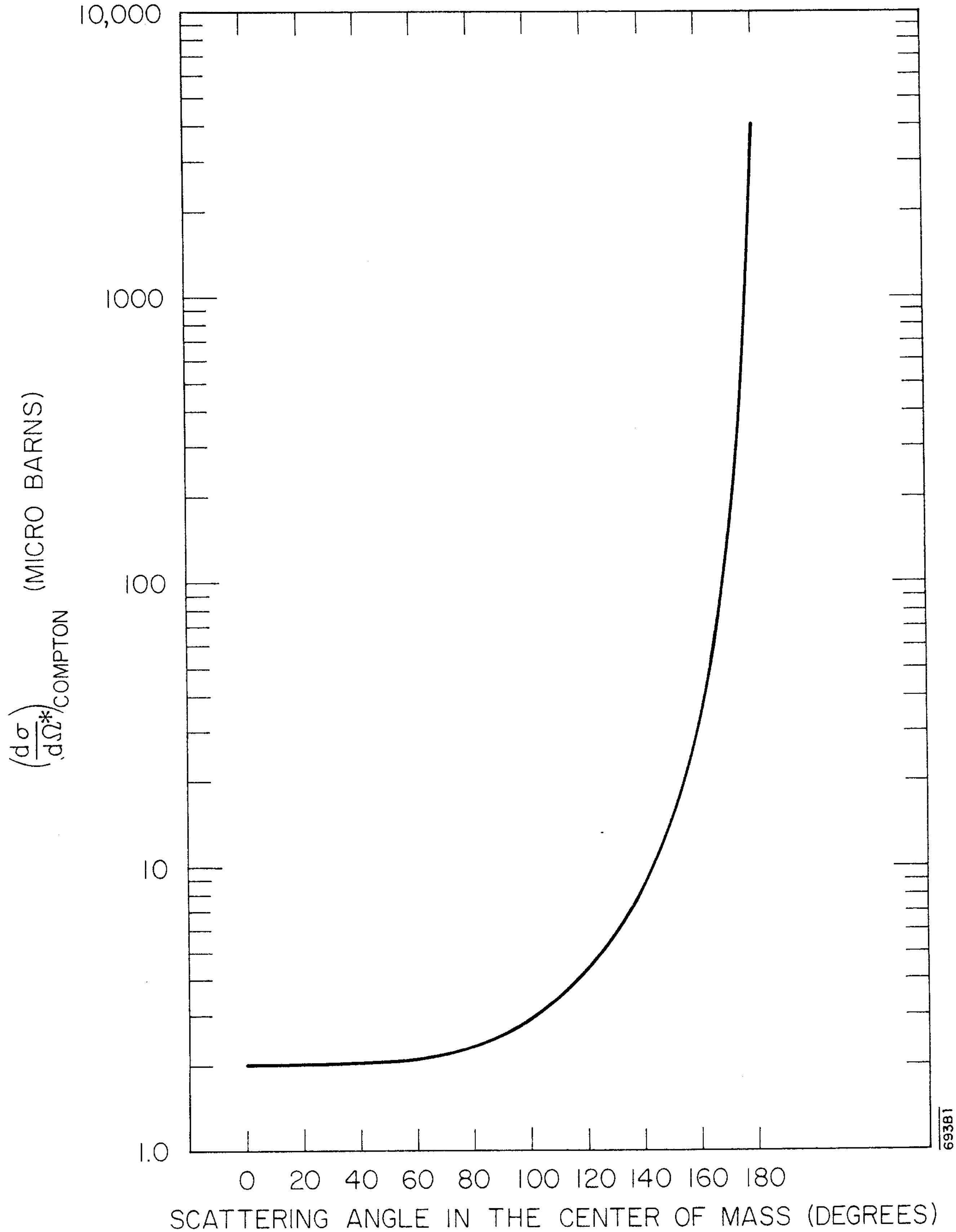


FIG. 1-- CENTER OF MASS COMPTON CROSS SECTION

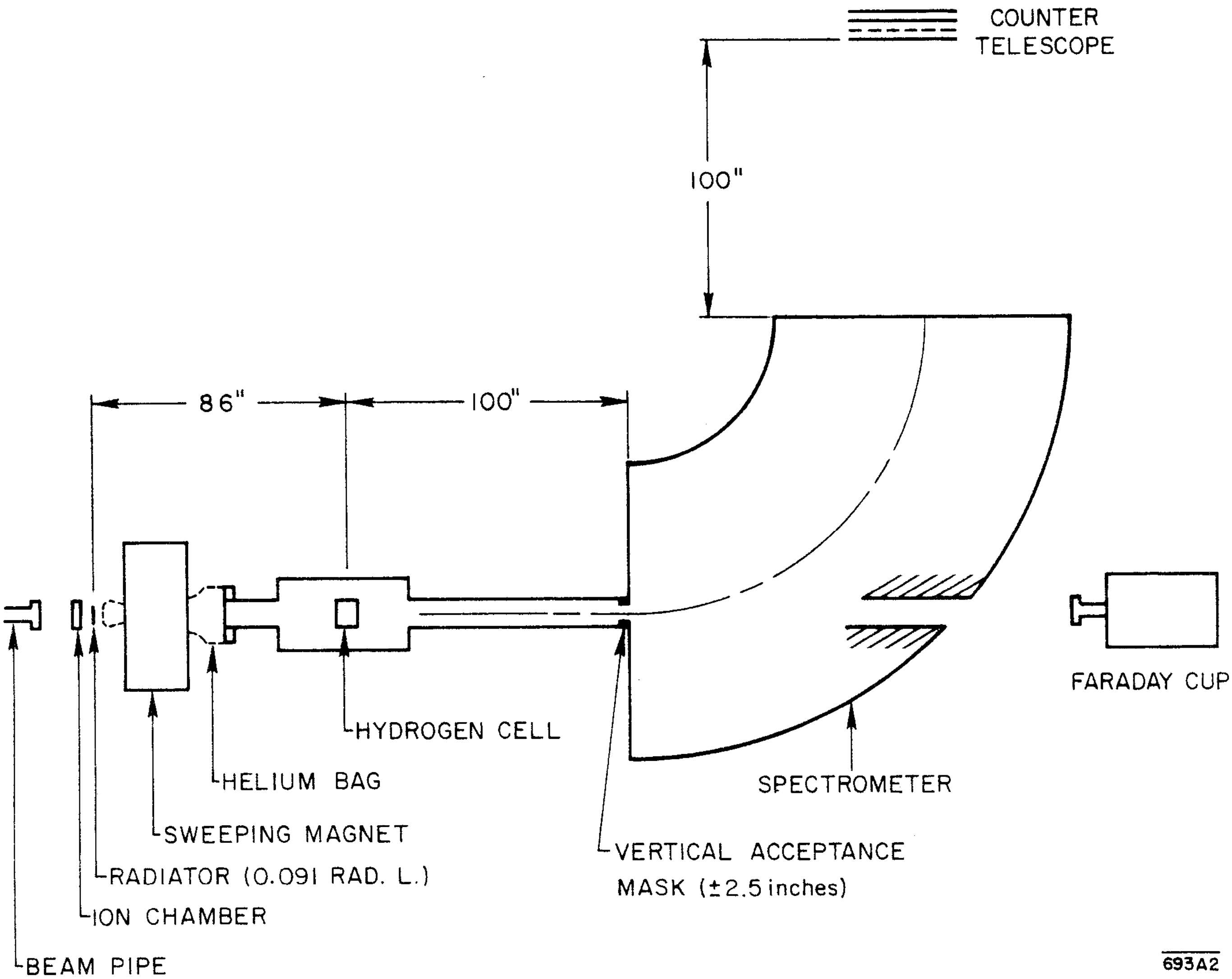


FIG. 2 -- SCHEMATIC OF EXPERIMENTAL GEOMETRY

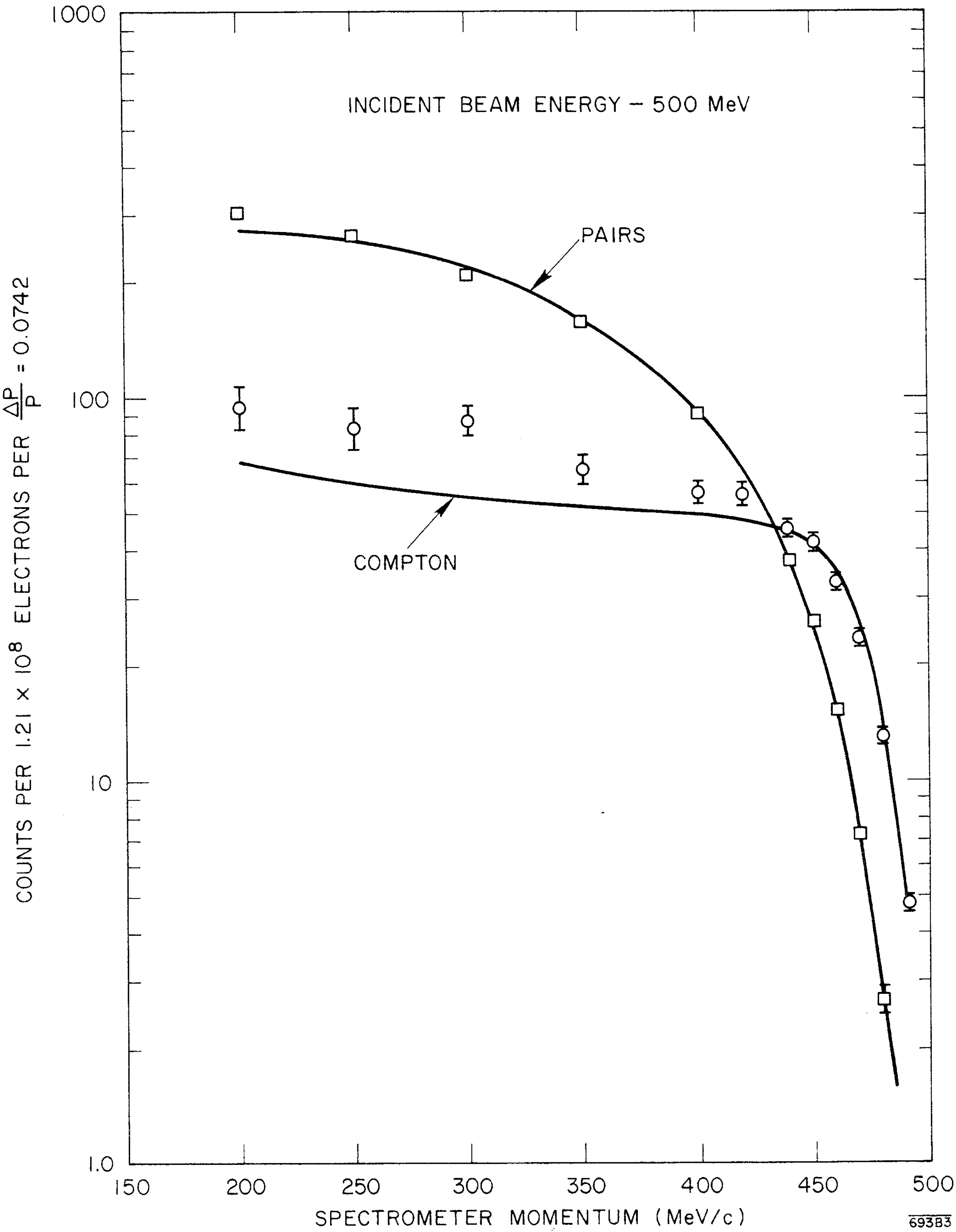
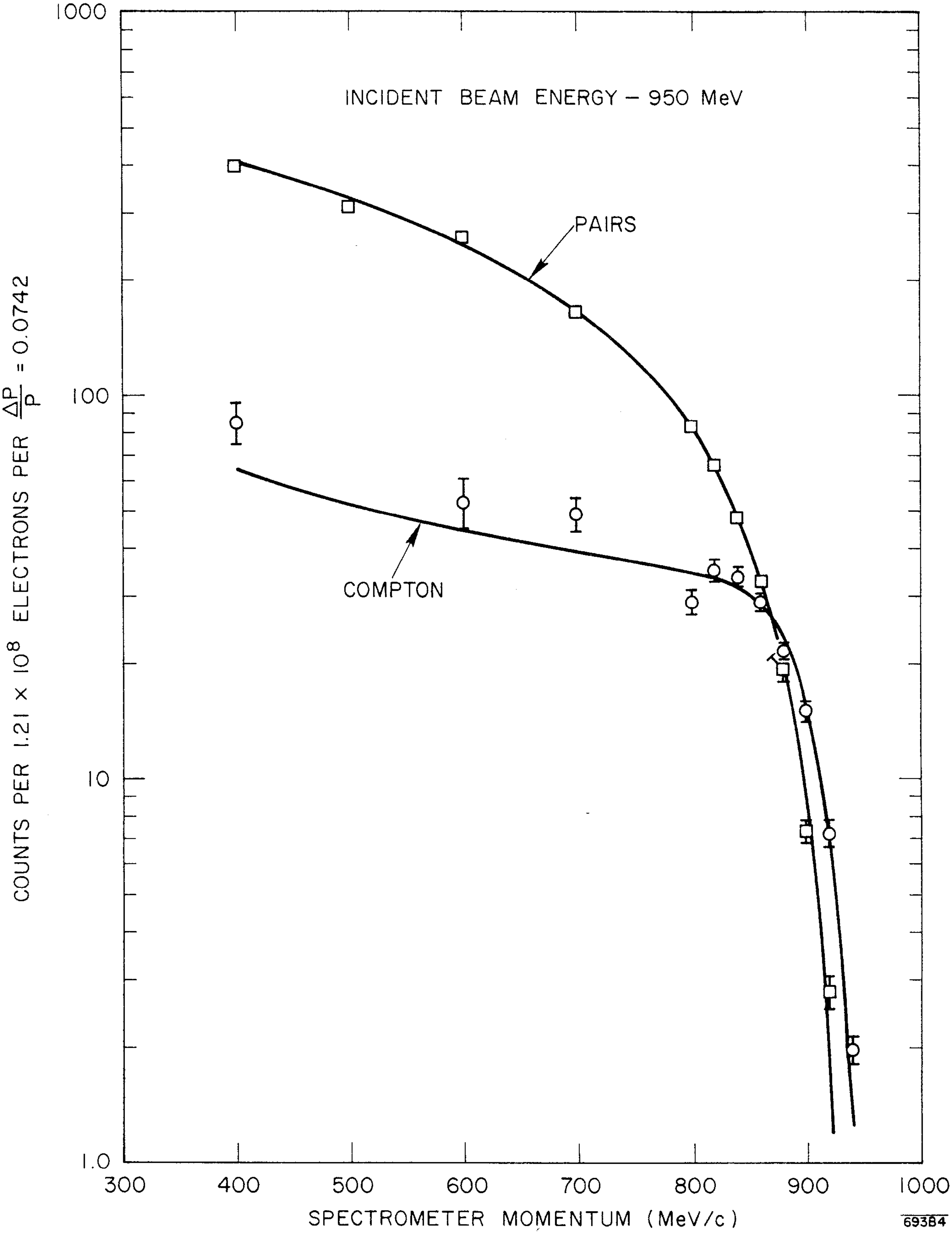

INCIDENT BEAM ENERGY – 500 MeV
PAIRS
COMPTON
COUNTS PER 1.21 × 10^8 ELECTRONS PER ΔP/P = 0.0742
SPECTROMETER MOMENTUM (MeV/c)
1000
100
10
1.0
150
200
250
300
350
400
450
500
693B3

FIG. 3



INCIDENT BEAM ENERGY — 950 MeV
PAIRS
COMPTON
1000
100
10
1.0
300
400
500
600
700
800
900
1000
SPECTROMETER MOMENTUM (MeV/c)
COUNTS PER 1.21 × 10⁸ ELECTRONS PER ΔP/P = 0.0742
69384

FIG. 4