Measurement of "radiation tail"—electron spectrum in the reaction $ep \to e'p\gamma$

B. B. Voitsekhovskiĭ, D. M. Nikolenko, S. G. Popov, and D. K. Toporkov

Institute of Nuclear Physics, Siberian Branch, USSR Academy of Sciences
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A comparison is made of the spectrum of scattered electrons in the reaction $ep \to e'p\gamma$—measured at the initial energy of 111 MeV and scattering angle of 58.3°—with several theoretical calculations. A good agreement is observed, for the first time, over a wide spectral range between the experiment and calculations[6] which are based on the procedure of "exponentiation."

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The accuracy of experiments in the electron scattering by nuclei has significantly improved in recent years. For instance, the form factor of elastic electron scattering were measured with accuracies better than one percent,[1,2] and the energy resolution attained 4×10^{-4}.[3]

In all the cases of electron interaction with charged particles processes associated with emission of real and virtual γ-ray must be taken into account. A variety of approaches were used[4–7] to allow for the effects of higher orders in the scattering of electrons, spallation of the muon vacuum, and recoil and emission of a nucleus. Analysis of the experiment[8] according to theories[5,6] leads to results for the proton form factor which differ by 2–2.5%. Theoretical error of this magnitude suggests a need for experimentation to verify the theories.

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Comparison of the shape of electron spectrum in a broad range of energy losses with the calculated shape is made easier at small transmitted momenta for which changes in the proton form factor in the emission region of the spectrum may be neglected.

The shape of the spectrum was studied in a number of experiments in the measurement of the proton form factor[1,8] for which the errors were less than the difference between calculations in Refs. 5 and 6. However, these experiments were carried out at large momentum transfers for which a peak approximation must be used,[5] and the spectral region is limited to 2–3% near the peak of the elasticly-scattered electrons.

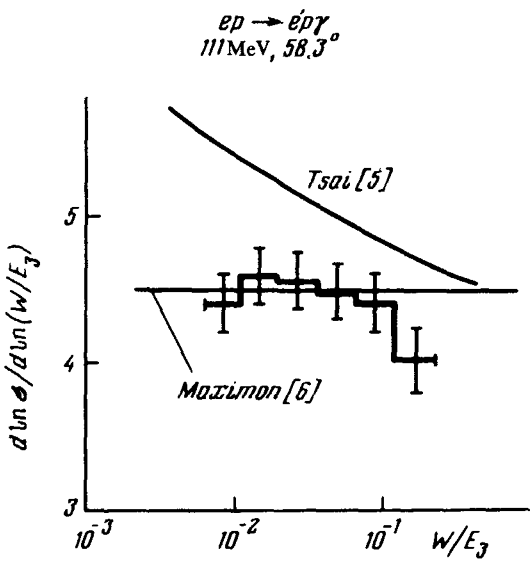

FIG. 1.

Our present experiment was carried out using the VEPP-2 storage tank at a beam energy of 111 MeV and electron scattering angle of 58.3°. Apparatus for recording the scattered electron, the target and special features of the experimental program involving a super-thin target in the storage tank were all described in Refs. 9 and 2. In this article we shall point out two important features of the apparatus. First, the energy acceptance of the spectrometer enables us to measure a broad spectrum of scattered electrons and to thus determine the relative cross sections in the various ranges without resorting to monitoring. Second, the measurement of six coordinates of the electron track in the spark chambers, the two subsequently calculated coordinates of electron leaving the target, and the deviation of its trajectory from coplanarity give us many ways of isolating background events, of controlling solid angles and of carrying out other checks.

The average electron beam current at the time of experiment was 0.5 A and the beam size 6 mm. The target consisted of a 4-mm molecular hydrogen gas jet with density 2×10^{14} mol/cm^3. Resolution with respect to electron energy was $\Delta E_{1/2}\simeq 200$ KeV.

TABLE 1. Spectrum and corrections $E_1 = 111$ MeV, $\theta = 58.3°$.

1	$\frac{W}{E_3}$		0,0060	0,0060 – –0,0110	0.0110 – –0,0200	0.0200 – –0,0366	0.0366 – –0,0668	0,0668 – –0,1220	0,1220 – –0,2228
2	N initial		23892 ±155	899 ±30	886 ±30	873 ±30	861 ±29	863 ±29	804 ±28
3	N corrections	background	–42 ±15	–22 ±7	–27 ±9	–37 ±12	–30 ±15	–30 ±15	–30 ±15
		resolution	+25 ±5	–25 ±5					
		foil	770 ±38	–188 ±9	–145 ±7	–109 ±5	–94 ±5	–89 ±5	–77 ±4
4	N resulting		24645 ±162	664 ±32	714 ±32	727 ±33	737 ±33	744 ±35	697 ±40

Table I shows the results of processing the spectrum. The first row shows the range of summation intervals of events counted from the elastic peak as fractions of the energy of elasticly-scattered electrons. The first interval contains the elastic peak. The original spectrum provides data on the number of background event—determined from non-coplanarity of trajectories and the target escape coordinates[2]—and allows corrections for energy resolution. Subsequently, distortion of the spectrum due to the ionization and radiative electron losses in the spectrometer foils were taken into account (90 mg, 0.004 rad length).

Table I shows values of these corrections and also the net electron spectrum (row 4). Errors, shown in the table include uncertainty in the background level and foil thickness, errors in the calculations of the "tail" which occurs during transit through the foils, and uncertainty in the shape of elastic peak in addition to the statistical.

Figure 1 shows a comparison of the experimental data with results of two different theoretical approaches: one allowing for "exponentiation"[6] and the other taking into account diagrams of the electron scattering of the first and second orders, and proton emission.[5] Clearly, the first calculations are in an extremely good agreement with the experimental data. A correct allowance for the radiation corrections in the proton scattering of our electron will noticeably alter the accepted value of the proton form factor at different transmitted momenta, and the value of its mean square radius. Results of experiments for scattering angles 49, 90 and 99° and a description of methods for the elimination of background verification of solid angles will soon be published. The authors thank E.A. Kurayev for useful discussions.

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