COMPARISON OF INELASTIC ELECTRON AND POSITRON SCATTERING CROSS SECTIONS ON ^{12}C AND ^{27}Al

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The ratio $R = \sigma^+/\sigma^-$ of the cross sections for inelastic positron and electron scattering on ^{12}C and ^{27}Al has been measured for four momentum transfers 0.08 (GeV/c)^2 $\leqslant q^2 \leqslant$ 0.45 (GeV/c)^2 of the virtual photon and invariant masses 0.95 GeV $\leqslant W \leqslant$ 3.3 GeV of the hadronic system. The mean value of the ratio is R = (1.005 ± 0.027). No q^2, respectively, W dependence of the ratio is observed.

In the last few years the scattering of high-energy photons from nuclei has become an important method of investigating the properties of nuclear constituents [1] and elementary particles [2–5]. For instance, it is possible to determine the photon structure by inelastic electron–nucleus scattering [15]. Present experimental results do not show significant, if any, shadowing effects for virtual photon absorption [2,3]. A basic assumption in the analysis is the validity of the one-photon exchange approximation for the electron–nucleon cross section:

$$\Gamma_t^{-1}\, d^2\sigma/d\Omega dE = \sigma_t + \epsilon\sigma_e \equiv \sigma \qquad (1)$$

(Γ_t: flux of the virtual photons, $d^2\sigma/d\Omega dE$: twofold differential cross section, σ_t and σ_e: absorption cross section of transverse, respectively longitudinal polarized virtual photons, ϵ: degree of transverse polarization of the virtual photons).

If the one-photon exchange approximation should not hold for the inelastic electron–nucleus scattering, there would be a possibility of explaining the discrepancies between the measurements and the Vector Meson Dominance prediction of nuclear shadowing. Therefore, experimental investigation, determining whether the one-photon exchange is a good approximation for electron–nucleus scattering, is of great importance.

In the present experiment we have exploited the fact that the real part of the ratio of the two-photon exchange amplitude A_2 to the one-photon exchange

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amplitude A_1 [6] determines the deviation of the ratio

$$R = \sigma_+/\sigma_- \qquad (2)$$

(σ_+: inelastic positron–nucleus, σ_-: inelastic electron –nucleus scattering cross sections) from unity:

$$R \approx 1 + 4\mathrm{Re}(A_2/A_1)\,. \qquad (3)$$

In eq. (3) it is assumed that the two-photon exchange contribution is so small that only its interference term with the one-photon exchange amplitude has to be taken into account.

For proton targets, the ratio R was determined recently [7–9] in a wide interval of the four-momentum transfer q^2 of the virtual photons and the effective mass W of the excited hadronic system. No data existed up to now for heavier nuclei, where the two-photon exchange contribution could be larger because of the stronger Coulomb field of the nucleus. In the present experiment the ratio R was determined for two nuclei (^{12}C, ^{27}Al) in the following region of the kinematical variables: 0.08 $(\mathrm{GeV}/c)^2 \leqslant q^2 \leqslant 0.45$ $(\mathrm{GeV}/c)^2$, 1 GeV $\leqslant W \leqslant$ 3.3 GeV.

The scattered electrons, respectively, positrons have been detected by a spectrometer consisting of a bending magnet, four wire spark chambers, trigger and particle identifying counters [10,11]. A presurized Cerenkov counter and a lead scintillator sandwich counter have been used to separate scattered leptons from hadrons. Details of the separation procedure are given in ref. [10]. The effective target length was $6 \times 10^{-3} X_0$. The intensity of the primary beam was measured with a Faraday cup and a secondary emission monitor [12]. A detailed description of the properties of the electron or positron beam, respectively, is given in ref. [10]. For each setting of the spectrometer current the full and the empty target rates were determined. The contribution of Dalitz pairs (typically 2% of the full target rate) was measured by inversion of the magnetic field direction of the spectrometer. The full kinematical region for a given primary energy and electron scattering angle was covered by a maximum of two settings of the spectrometer current. The typical statistical error of the data was 2–4%, the typical systematic error was 2%. Only in the case of ^{27}Al at a primary energy of E_1 = 3.08 GeV was the systematic error 3.4%. No radiative corrections have been applied to the data, because the main contribution to the ratio R, expected for elastic electron–nucleus scattering, is smaller than 0.5% [13].

The ratios R of the two nuclei for the different kinematical parameters are given in tables 1 and 2. In fig. 1 the ratio (2) is plotted as a function of the invariant mass W of the excited hadronic system for a ^{12}C, respectively, ^{27}Al target. The dependence of the ratio R on the four-momentum transfer q^2 of the virtual photon is shown in fig. 2. From figs. 1,2 follows

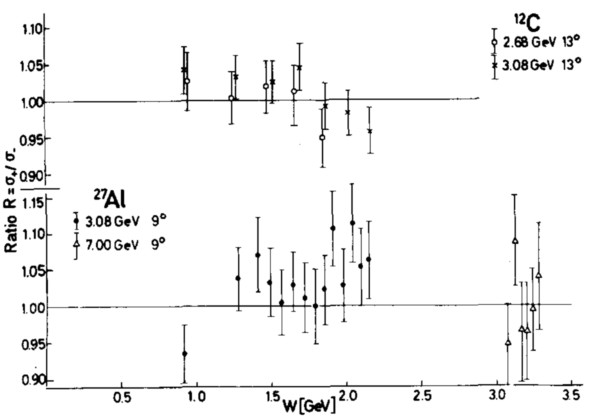

Fig. 1. Ratio $R = \sigma_+/\sigma_-$ of inelastic positron and electron scattering on ^{12}C and ^{27}Al as a function of the invariant mass W of the excited hadronic system, calculated for a free target nucleon.

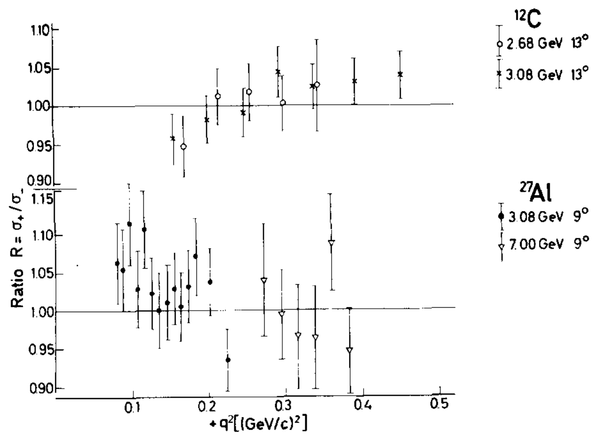

Fig. 2. Ratio $R = \sigma_+/\sigma_-$ of inelastic positron and electron scattering on ^{12}C and ^{27}Al as a function of the four-momentum transfer q^2 of the virtual photon.

Table 1
Ratio $R = \sigma_+/\sigma_-$ for inelastic lepton scattering on ^{12}C. E_1, primary electron energy, θ_e, electron scattering angle, q^2, four-momentum transfer of the virtual photon, W, invariant mass of the excited hadronic system, A_2, amplitude of two-photon exchange, A_1, amplitude of one-photon exchange. All errors include the systematic error contributions given in the text.

E_1 = 2.68 GeV, θ_e = 13°				E_1 = 3.08 GeV, θ_e = 13°			
W (GeV)	q^2 ((GeV/c)^2)	R	Re(A_2/A_1)	W (GeV)	q^2 ((GeV/c)^2)	R	Re(A_2/A_1)
0.95	0.342	1.027 ± 0.06	(0.7 ± 1.5)%	0.928	0.450	1.041 ± 0.031	(1.0 ± 0.8)%
1.247	0.297	1.004 ± 0.037	(0.1 ± 0.9)%	1.275	0.391	1.032 ± 0.029	(0.8 ± 0.7)%
1.478	0.254	1.019 ± 0.037	(0.5 ± 0.9)%	1.520	0.337	1.025 ± 0.029	(0.6 ± 0.7)%
1.670	0.213	1.013 ± 0.037	(0.3 ± 0.9)%	1.702	0.292	1.045 ± 0.032	(1.1 ± 0.8)%
1.855	0.168	0.948 ± 0.04	(−1.3 ± 1.0)%	1.866	0.247	0.992 ± 0.032	(−0.2 ± 0.8)%
				2.022	0.199	0.983 ± 0.031	(−0.4 ± 0.8)%
		0.985 ± 0.025	(−0.4 ± 0.6)%	2.163	0.154	0.957 ± 0.031	(−1.1 ± 0.8)%
						1.019 ± 0.022	(0.5 ± 0.55)%

that in the full kinematical region covered by the present experiment the ratio R is compatible with 1 and the mean value of the ratio – weighted using the statistical errors – is

$$R = 1.005 \pm 0.027 .$$

A systematic error of 2% is included in this result.

The agreement of the ^{12}C and the ^{27}Al data proves that no Z dependent effect exists. This result justifies neglect of the differences of the radiative corrections for electron, respectively, positron inelastic scattering in the analysis of the present experiment.

Using formula (3), the upper limit (90% CL) for the real part of the ratio A_2 to A_1 is

Table 2
Ratio $R = \sigma_+/\sigma_-$ for inelastic lepton scattering on ^{27}Al. The variables are defined in table 1. All errors include the systematic error contributions given in the text.

E_1 = 3.08 GeV, θ_e = 9°				E_1 = 7 GeV, θ_e = 9°			
W (GeV)	q^2 ((GeV/c)^2)	R	Re(A_2/A_1)	W (GeV)	q^2 ((GeV/c)^2	R	Re(A_2/A_1)
0.960	0.223	0.935 ± 0.04	(−1.6 ± 1.0)%	3.080	0.381	0.947 ± 0.055	(−1.33 ± 1.38)%
1.240	0.199	1.038 ± 0.044	(0.95 ± 1.1)%	3.125	0.357	1.089 ± 0.063	(2.2 ± 1.6)%
1.405	0.182	1.071 ± 0.051	(1.8 ± 1.3)%	3.165	0.336	0.964 ± 0.068	(−0.9 ± 1.7)%
1.490	0.172	1.032 ± 0.047	(0.8 ± 1.2)%	3.205	0.315	0.965 ± 0.068	(−0.9 ± 1.7)%
1.570	0.163	1.005 ± 0.045	(0.1 ± 1.1)%	3.245	0.293	0.995 ± 0.058	(−0.1 ± 1.45)%
1.645	0.154	1.029 ± 0.046	(0.7 ± 1.15)%	3.285	0.271	1.040 ± 0.074	(1.0 ± 1.85)%
1.720	0.144	1.011 ± 0.048	(0.3 ± 1.2)%			0.997 ± 0.035	(−0.1 ± 0.9)%
1.790	0.134	1.000 ± 0.051	(0.0 ± 1.3)%				
1.855	0.125	1.023 ± 0.047	(0.6 ± 1.2)%				
1.920	0.115	1.107 ± 0.050	(2.7 ± 1.25)%				
1.980	0.106	1.028 ± 0.049	(0.7 ± 1.2)%				
2.040	0.097	1.114 ± 0.054	(2.85 ± 1.35)%				
2.100	0.087	1.054 ± 0.052	(1.35 ± 1.3)%				
2.150	0.079	1.063 ± 0.053	(1.6 ± 1.3)%				
		1.008 ± 0.040	(0.2 ± 1.0)%				

$$\mathrm{Re}(A_2/A_1) \leqslant 0.011 \ .$$

In conclusion we have shown that the one-photon exchange amplitude for inelastic electron–nucleus scattering is a good approximation in a kinematical region where shadowing effects for the virtual photon on nuclei are observable [4] and where the scaling of the structure functions starts. Tests of the parton model [14] by comparison of inelastic positron–, respectively, electron–hadron scattering cross sections seem only to be feasible at higher four-momentum transfers q^2 of the virtual photon and higher invariant masses W of the hadronic system.

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