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Comparison of Inelastic Electron and Positron Scattering Cross Sections on ^{12}C and ^{27}Al

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ABSTRACT

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 $0.08\ (\frac{GeV}{c})^2 \leq q^2 \leq 0.45 (\frac{GeV}{c})^2$ of the virtual photon and invariant masses $0.95\ GeV \leq W < 3.3\ GeV$ of the hadronic system. The mean value of the ratio is $R = (1.005 \pm 0.007)$, no q^2 respectively W dependence of the ratio is observed.

From the analysis of the inelastic electron scattering on nucleons |1| and nuclei |2-4| important information concerning the constituent structure of hadrons was derived |5|. A basic assumption of these analyses is the validity of the one photon exchange approximation for the inelastic electron nucleon cross section |6|

$$\frac{1}{\Gamma_t}\frac{d^2\sigma}{d\Omega dE} = \sigma \qquad (1)$$

(Γ_t flux of virtual photons, $d^2\sigma/d\Omega dE$ measured twofold electron scattering cross section, ε degree of transverse polarization of the virtual photons, σ absorption cross section for virtual photons). It is therefore important to prove experimentally that the one photon approximation holds.

In the present experiment we have exploited the fact that the real part of the two photon exchange amplitude A_2 determines the deviation of the ratio

$$R = \frac{\sigma_+}{\sigma_-} \qquad (2)$$

(σ_+ inelastic positron nucleus, σ_- inelastic electron nucleus scattering cross sections)

from unity:

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

(A_1 one photon exchange amplitude).

In (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

$$0.08\ (\frac{GeV}{c})^2 \leq q^2 \leq 0.45\ (\frac{GeV}{c})^2$$

$$1\ GeV \leq W \leq 3.3\ GeV \quad .$$

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 pressurized 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 $6\cdot 10^{-3}\ X_0$. 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 is 2%-4%, the typcial systematic error is 2%. Only in the case of ^{27}Al at a primary energy of E_1 = 3.08 GeV the systematic error was 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 ratio R for the two nuclei for the different kinematical parameters are given in table I. In fig. 1a,b 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. 2a,b. From figs. 1,2 follows that in the full kinematical region covered by the present experiment the ratio R is compatible with 1, the mean value of the ratio is

$$R = (1.005 \pm 0.007) \quad .$$

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

As an upper limit (90% CL) for the real part of the two photon exchange amplitude A_2 follows with formula (3)

$$\mathrm{Re}A_2 \leq 0.011\, A_1 \quad .$$

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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REFERENCES

1. J.I. Friedman, H.W. Kendall
Ann. Rev. Nucl. Sci. 22 (1972) 203

2. S. Stein, W.B. Atwood, E.D. Bloom, R.L.A. Cottrell, H. DeStaebler, C.L. Jordan, H.G. Piel, C.Y. Prescott, R. Siemann, R.E. Taylor
Phys. Rev. D12 (1975) 1884

3. W.R. Ditzler, M. Breidenbach, J.I. Friedman, H.W. Kendall, J.S. Poucher, E.D. Bloom, R.L.A. Cottrell, D.H. Coward, H. DeStaebler, C.L. Jordan, H. Piel, R.E. Taylor
Phys. Lett. 57B (1975) 201

4. S. Hartwig, F.H. Heimlich, G. Huber, E. Rössle, J. Bleckwenn, M. Köbberling, J. Moritz, K.H. Schmidt, D. Wegener, D. Zeller, P. David, H. Mommsen
Phys. Lett. B (to be published)

5. V.I. Zakharov
Rapp. talk, 18th International Conference on High Energy Physics, Tbilissi 1976

6. L. Hand
Phys. Rev. 129 (1963) 1834

7. J. Mar, B.C. Barish, J. Pine, D.H. Coward, H. DeStaebler, J. Litt, A. Minten, R.E. Taylor, M. Breidenbach
Phys. Rev. Lett. 21 (1968) 482

8. S. Hartwig, F.H. Heimlich, G. Huber, E. Rössle, M. Köbberling, J. Moritz, K.H. Schmidt, D. Wegener, D. Zeller, J. Bleckwenn
Lett. Nuovo Cim. 15 (1976) 429

9. D.L. Fancher, D.O. Caldwell, J.P. Cumalat, A.M. Eisner, T.P. McPhalin, R.J. Morrison, F.V. Murphy, S.J. Yellin
Phys. Rev. Lett. 37 (1976) 1323

L.S. Rochester, W.B. Atwood, E.D. Bloom, R.L.A. Cottrell, D.H. Coward, H. DeStaebler, M. Mestayer, C.Y. Prescott, S. Stein, R.E. Taylor, D. Trines
Phys. Rev. Lett. 36 (1976) 1284

10. G. Huber
thesis, Freiburg University 1976 and
DESY Internal Report F23/77-1

11. S. Galster, G. Hartwig, H. Klein, J. Moritz, K.H. Schmidt, W. Schmidt-Parzefall, D. Wegener, J. Bleckwenn
Phys. Rev. D5 (1972) 519

12. A. Ladage and H. Pingel
DESY Report 65/12 (1965)

13. Y.S. Tsai
Phys. Rev. 122 (1961) 1898
SLAC-PUB-848 (1971)

14. P. M. Fishbane and R.L. Kingsley
Phys. Rev. D8 (1973) 3074

G.T. Bodwin and C.D. Stockham
Phys. Rev. D11 (1975) 3324

TABLE Ia 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.

E_1 = 2.68GeV, θ_e = 13°				E_1 = 3.08 GeV, θ_e = 13°			
W [GeV]	q^2 $[(\frac{GeV}{c})^2]$	R	$\frac{Re\ A_2}{A_1}$	W [GeV]	q^2 $[(\frac{GeV}{c})^2]$	R	$\frac{Re\ A_2}{A_1}$
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)%
		0.987±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)%

FIGURE CAPTIONS

Fig. 1 Ratio $R = \sigma_+/\sigma_-$ of inelastic positron and electron scattering on

a.) ^{12}C and

b.) ^{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

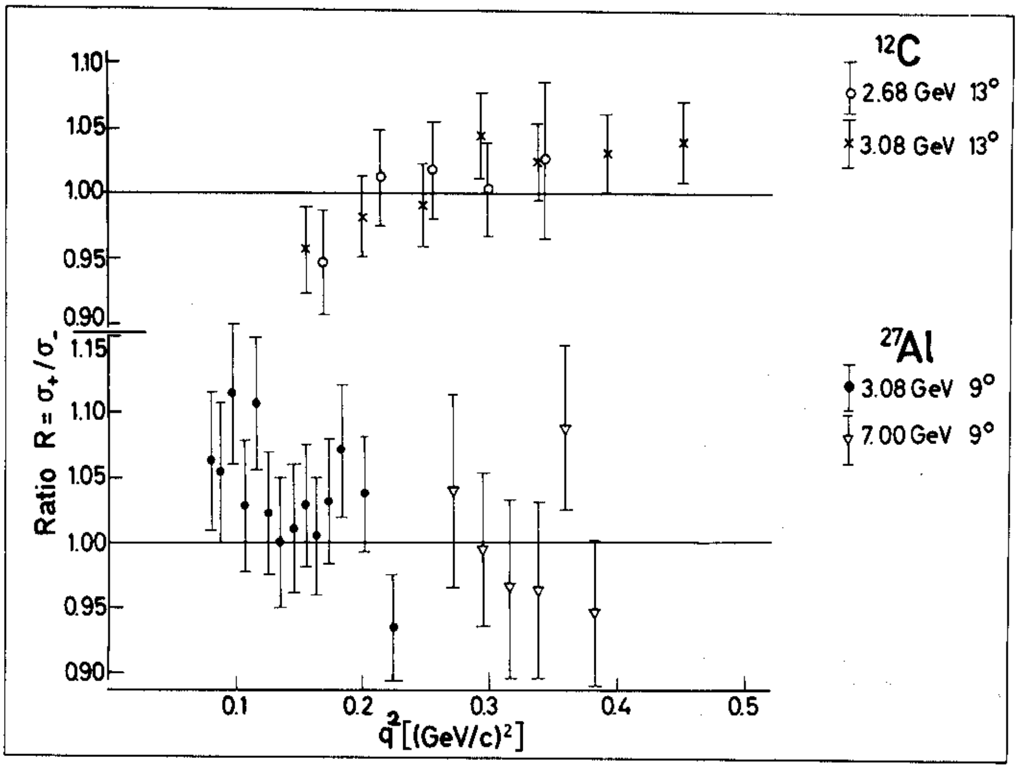
a.) ^{12}C and

b.) ^{27}Al

as a function of the four momentum transfer q^2 of the virtual photon.

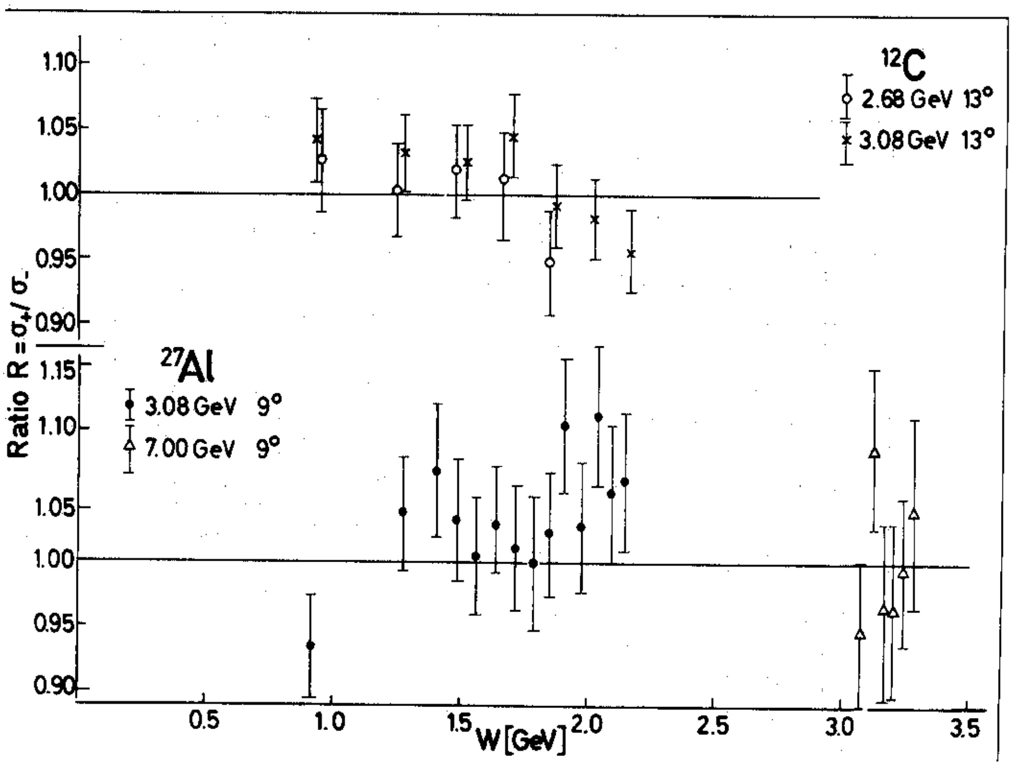
TABLE Ib Ratio $R = \sigma_+/\sigma_-$ for inelastic lepton scattering on ^{27}Al. The variables are defined in table Ia.

$E_1 = 3.08$ GeV, $\theta_e = 9^o$				$E_1 = 7$ GeV, $\theta_e = 9^o$			
W [GeV]	q^2 $[(\frac{GeV}{c})^2]$	R	$\frac{Re\ A_2}{A_1}$	W GeV	q^2 $[(\frac{GeV}{c})^2]$	R	$\frac{Re\ A_2}{A_1}$
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)%				



¹²C
2.68 GeV 13°
3.08 GeV 13°
²⁷Al
3.08 GeV 9°
7.00 GeV 9°
Ratio R = σ+/σ-
q²[(GeV/c)²]

Fig. 2



¹²C
2.68 GeV 13°
3.08 GeV 13°
²⁷Al
3.08 GeV 9°
7.00 GeV 9°
Ratio R = σ+/σ-
W [GeV]

Fig. 1