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ABSTRACT

The cross section for inelastic electron scattering on ^{12}C and ^{27}Al nuclei has been measured for energy transfers of the virtual photon $\nu \leq 6.2$ GeV and four momenta $0.075\ (\frac{GeV}{c})^2 \leq q^2 \leq 1\ (\frac{GeV}{c})^2$. The influence of different sources of the radiative corrections is studied in detail. Shadowing effects, which increase with decreasing values of the scaling variable x, are observed for both nuclei.

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The inelastic electron scattering on nucleons and nuclei can be described as an absorption process of virtual photons by hadronic matter. The process is parametrized by the absorption cross section

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

Γ_t is the flux of virtual photons, $d^2\sigma/d\Omega dE$ is the measured twofold electron scattering cross section |1|. For real high energetic photons it was shown that the number of effective nucleons A_{eff} of a nucleus is smaller than its atomic number A |2|. This effect, well known for absorption processes where only hadrons are involved |3|, has been explained by the vector meson dominance model to be due to a hadronic component of the photon |4,5,6|. On the other side it is known from deep inelastic electron scattering that at four momentum transfers $q^2 \geq 1\ (\frac{GeV}{c})^2$ the interaction between the virtual photon and the hadron has a point-like structure. Therefore it is of interest to study the damping of the photon hadronic component by increasing the mass q^2 of the virtual photon |6|. Foregoing experiments have found weak evidence for shadowing effects |7|. In order to study this effect in more detail we have measured the inelastic electron scattering cross section on hydrogen, deuterium, ^{12}C and ^{27}Al nuclei for four momenta $0.075\ (\frac{GeV}{c})^2 \leq q^2 \leq 1\ (\frac{GeV}{c})^2$ and energies of the virtual photon $\nu \leq 6.2$ GeV at the DESY synchrotron |8|.

The scattered electrons have been detected by a spectrometer consisting of a bending magnet, four wire spark chambers, trigger and particle identifying counters |8,9|. A pressurized Cerenkov counter and a lead-scintillator sandwich counter have been used to separate scattered electrons from hadrons. Details of the separation procedure are given in |8|. The efficiency of the counters and the acceptance of the set up have been derived directly from the experimental data. The effective target length for the different target materials was chosen to be approximately the same and amounted to $6 \cdot 10^{-3}$ radiation lengths. The intensity of the primary beam was monitored with the help of a Faraday cup and a secondary emission monitor. For each setting of the spectrometer current the full and the

empty target rate was determined, typically the latter one amounted to 15% of the full target rate. The contribution of Dalitz pairs (typically 2% of the full target rate) was measured by inversion of the magnetic field direction of the spectrometer. Because of the large momentum acceptance of the spectrometer, at most four settings of the spectrometer current were necessary to cover the full energy range of the scattered electrons for a given primary energy and electron scattering angle. The four intervals were chosen to overlap. The typical statistical error is 2% to 4% and the systematic error of the data is 3.5%.

The main corrections, which had to be applied to the raw data, were due to radiative processes. The calculations have been performed using the formulae of Mo and Tsai |10| for the radiative tail of the elastic electron scattering and the formula of Tsai |11| for the elastic electron scattering. We have used the formfactor parametrization of Hofstadter |12| to calculate the radiative tail for elastic electron scattering on ^{12}C and ^{27}Al. If necessary the parametrization of the nucleus formfactor has been extrapolated to regions of larger four momentum transfers. By comparison of electron and positron scattering data we have checked that the one photon exchange approximation (1) holds in the region of the kinematical variables of the present experiment |13|.

The measured absorption cross section $\sigma_{\gamma A}$ on a nucleus has been compared with the corresponding one on nucleons

$$R = \frac{A_{eff}}{A} = \frac{\sigma_{\gamma A}}{A\,(1 - \frac{N}{\omega'})\sigma_{\gamma p}} , \qquad (2)$$

where

$$\omega' = \frac{2M\nu + M^2}{q^2}$$

M = nucleon mass, A = atomic number, N = neutron number, $\sigma_{\gamma p}$ = absorption cross section for virtual photons on protons. Relation (2) is derived from an empirical relation between neutron and proton cross sections |14,15|. The ratio R is a measure of the shadowing effect. The influence of different sources of radiative corrections on the ratio (2) has been studied.

If the radiative process is not modified by the fact, that for a nucleus part of the possible final states, accessible to a scattered nucleon, are occupied by spectator nucleons, the radiative tail due to the contribution of quasielastic electron nucleon scattering should factorize in the measured inelastic electron nucleus scattering cross section. Therefore this contribution to the radiative corrections should cancel in the ratio (2). If this assumption holds the only corrections which have to be taken into account are due to the radiative tail from elastic electron nucleus scattering. In figs. 1a, 2a typical results of the present experiment are plotted for the case that the factorization assumption holds. The data show clear evidence for a shadowing effect at small four momentum transfers q^2.

In fig. 3 the ratio $R = A_{eff}/A$ is plotted as a function of the scaling variable $x = q^2/2M\nu$ together with the results of S. Stein et al. |7|. In both cases radiative corrections based on the factorization assumption of figs. 1a, 2a were used. The general agreement between the two data sets is good. The ratio R of the present experiment seems to be systematically smaller than that of reference |7|. The strong increase of the shadowing at small values of the scaling variable x is due to the neglection of the Pauli principle to be discussed next.

At small q^2, where the momentum of the struck nucleon after the scattering process is small, the occupation of possible final states by spectator nucleons is important. Because of the Pauli principle the contribution of the quasielastic radiative tail should decrease compared to the radiative tail of elastic electron nucleon scattering. In the extreme case the radiative tail contributes to the measured cross section only for free electron-nucleon scattering, while the electron does not radiate for electron-bound state nucleon scattering, because all possible final states are occupied. This extreme case is taken into account, if one applies only radiative corrections due to the elastic electron proton scattering, but no

corrections due to electron bound state nucleon scattering. The result for this extreme case is shown in figs. 1b, 2b. The shadowing effect nearly disappears. A realistic correction should yield results for the ratio $R = A_{eff}/A$ between the two extreme cases of figs. 1a, 2a and figs. 1b, 2b respectively.

An approach to the realistic computation of radiative corrections due to the radiative tail of electron bound state nucleon scattering was given by Bernabeu |16|. He has described the influence of the Pauli principle to the quasielastic electron nucleon scattering by an effective nucleon formfactor. We have used the effective nucleon formfactor, which has been computed by Bernabeu |16| for the ^{12}C nucleus, to determine the radiative tail for the quasielastic electron nucleon scattering on ^{12}C and ^{27}Al. The results of this analysis are given in figs. 1c, 2c, showing a shadowing effect for both nuclei. For comparison the ratio R measured with real photons |2| is included in fig. 1c. Since we used the effective nucleon formfactors computed for the ^{12}C nucleus also in the case of ^{27}Al, the systematic error for this nucleus is larger for the lower q^2 values, where the influence of the Pauli principle is strongest.

In conclusion we have shown that a shadowing effect exists for the absorption cross section of virtual photons. It increases with decreasing four momentum transfer q^2 |17|. The magnitude of the effect and its q^2 dependence is in agreement with the prediction of the generalized vector meson dominance model |5|. The important difference of the radiative tail for electron scattering on free and bound state nucleons is stressed.

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FIGURE CAPTIONS

Fig. 1 Ratio A_{eff}/A for inelastic electron scattering on ^{12}C, primary electron energy $E_1 = 6$ GeV, electron scattering angle $\theta_e = 12^o$. The figures a,b,c result from different treatments of the radiative corrections (see text). The result for $q^2 = 0\ (\frac{GeV}{c})^2$ was taken from reference |2|.

Fig. 2 Ratio A_{eff}/A for inelastic electron scattering on ^{27}Al, $E_1 = 7$ GeV, $\theta_e = 9^o$. The figures a,b,c result from different treatments of the radiative corrections (see text).

Fig. 3 Ratio A_{eff}/A for ^{27}Al as a function of the scaling variable. Besides the result of the present experiment (▲ $E_1 = 7$ GeV, ● $E_1 = 3.08$ GeV, $\theta_e = 9^o$) data of S. Stein et al. |7| are included for comparison. Radiative corrections according to fig. 2a were applied.

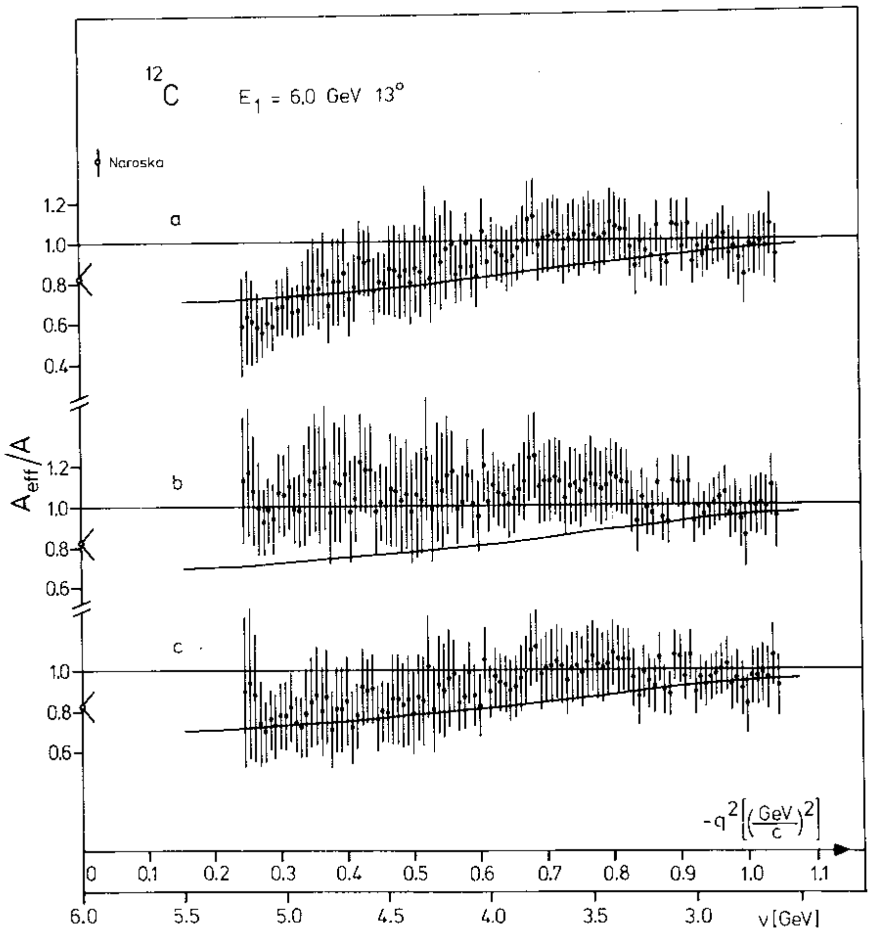

Fig. 1

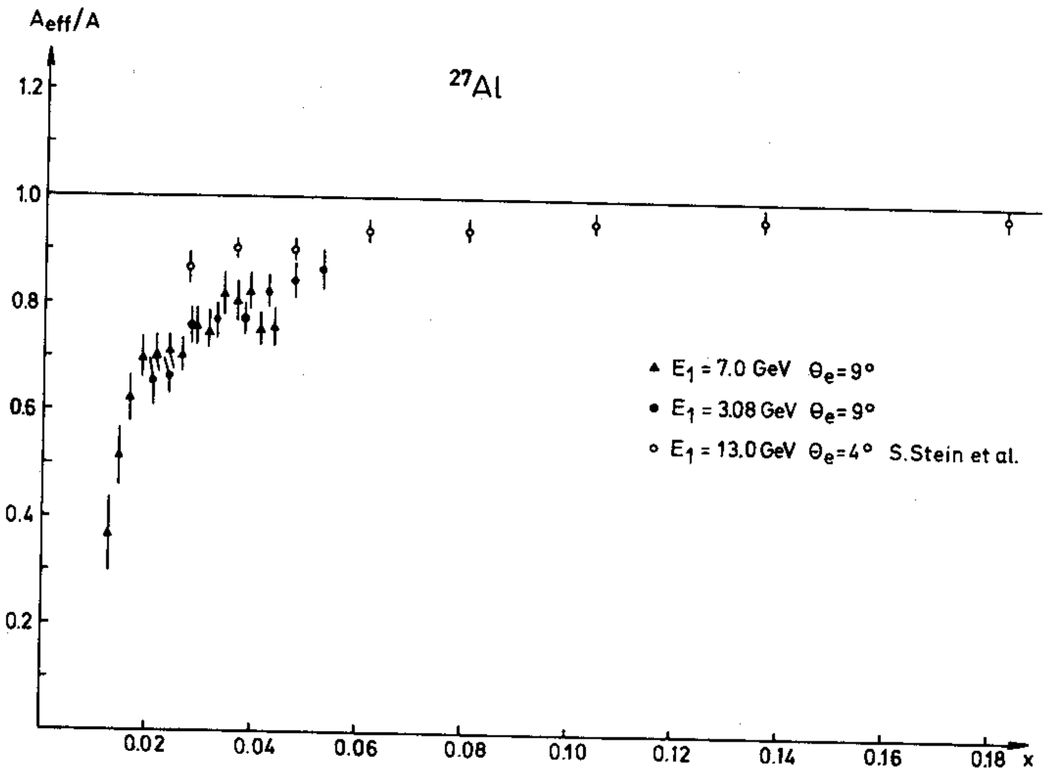
A_{eff}/A
^{27}Al
1.2
1.0
0.8
0.6
0.4
0.2
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
x
▲ $E_1 = 7.0$ GeV $\Theta_e = 9°$
● $E_1 = 3.08$ GeV $\Theta_e = 9°$
○ $E_1 = 13.0$ GeV $\Theta_e = 4°$ S.Stein et al.

Fig. 3

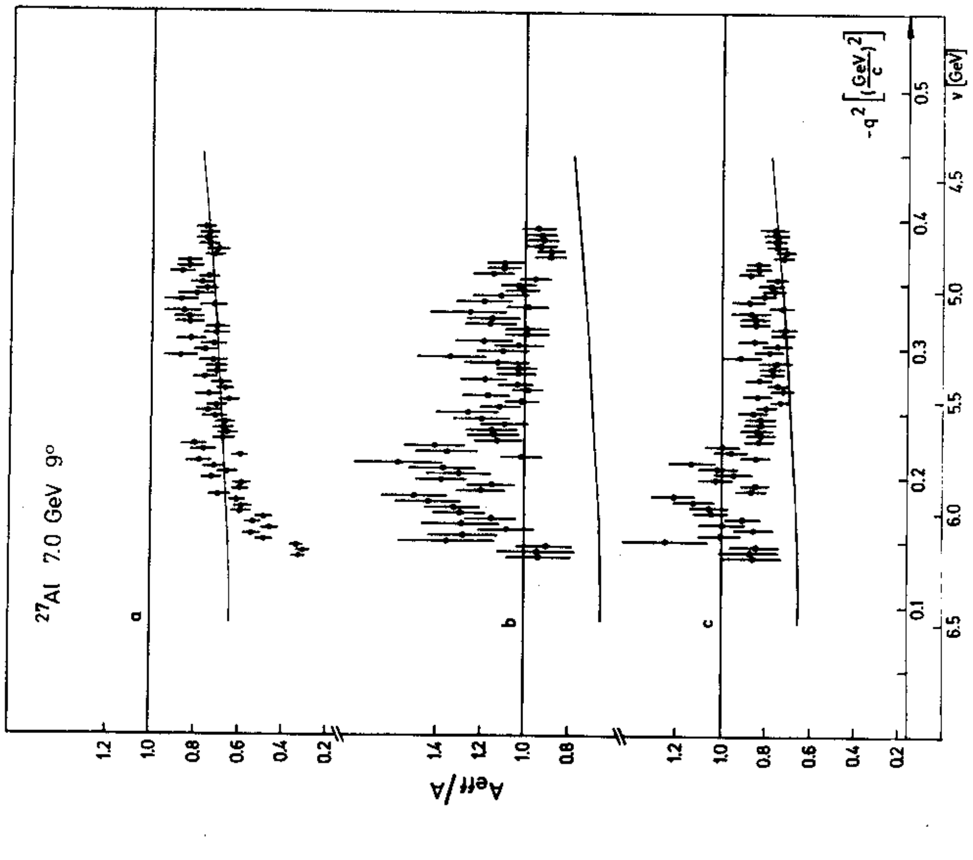
^{27}Al 7.0 GeV 9°
a
b
c
A_{eff}/A
1.2
1.0
0.8
0.6
0.4
0.2
1.4
1.2
1.0
0.8
1.2
1.0
0.8
0.6
0.4
0.2
$-q^2 \left[\left(\frac{GeV}{c}\right)^2 \right]$
ν [GeV]
0.1
0.2
0.3
0.4
0.5
6.5
6.0
5.5
5.0
4.5

Fig. 2