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POSSIBLE INDICATION OF AN A-DEPENDENCE OF R IN DEEP-INELASTIC ELECTRON SCATTERING FROM NUCLEI* †

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ABSTRACT

Measurements of R for deuterium, He, Al, Fe and Au were made at $Q^2 = 5$ $(\mathrm{GeV/c})^2$ and $x = 0.3$, 0.5 and 0.7. An indication of a possible A-dependence of R has been found which would result in large differences among σ^A/σ^d, F_2^A/F_2^d and F_1^A/F_1^d.

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The A-dependence of the EMC effect has been studied by measuring differential cross sections for the inelastic scattering of electrons from deuterium (d), He, Be, C, Al, Ca, Fe, Ag, and Au over a large kinematic range of $0.09 \leq x \leq 0.9$ and Q^2 values of 2, 5, 10 and 15 $(\mathrm{GeV/c})^2$. The experiment was carried out at the Stanford Linear Accelerator Center (SLAC) using the SLAC 8 GeV/c spectrometer.

The measured cross sections were compensated for neutron excess, such that σ^A represents the cross section per nucleon of a hypothetical nucleus with equal number ($A/2$) of protons and neutrons. The deuterium cross sections extracted from the data are in excellent agreement ($\pm 2\%$) with a fit to previous data[1] in the same kinematic region. Systematic uncertainties (Δ) in the ratios σ^A/σ^d are estimated to be $\leq \pm 1\%$, due mostly to uncertainties in the thicknesses of the targets.

The ratios of the cross sections per nucleon (σ^A/σ^d) are related to the structure functions per nucleon $W_2(x,Q^2)$ and $W_1(x,Q^2)$ and to $R(x,Q^2) = \sigma_L/\sigma_T$, the ratio of the cross sections for absorption of longitudinal and transverse polarized photons, by:

$$\frac{\sigma^A}{\sigma^d} = \frac{W_2^A + 2W_1^A \tan^2\theta/2}{W_2^d + 2W_1^d \tan^2\theta/2} = \frac{W_2^A(1+\epsilon R^A)(1+R^d)}{W_2^d(1+\epsilon R^d)(1+R^A)} = \frac{W_1^A(1+\epsilon R^A)}{W_1^d(1+\epsilon R^d)} \tag{1}$$

where $\epsilon = 1/(1+2(1+Q^2/4M^2x^2)\tan^2(\theta/2))$ is the degree of longitudinal polarization of the virtual photon, M is the proton mass and θ the scattering angle.

Results[2] from this experiment for σ^A/σ^d have been recently published so this talk will concentrate on our measurement of R and its effect on the ratios of the structure functions $W_2^A/W_2^d = F_2^A/F_2^d$ and $W_1^A/W_1^d = F_1^A/F_1^d$. Measurements of R were made at $Q^2 = 5$ $(\mathrm{GeV/c})^2$ and $x = 0.3$, 0.5 and 0.7 using two different scattering angles for each value of x. Figure 1 shows our data for d, He, Al, Fe and Au. The results are consistent with the average value for deuterium ($R_w^d = 0.24 \pm 0.1$) from previous measurements[3] in our kinematic region but are also consistent with an A-dependence of R at each x.

Figure 2(a) shows our data for the ratio σ^{Fe}/σ^d (taken at Q^2 values of 2, 5, 10 and 15 $(\mathrm{GeV/c})^2$), along with data from higher energy muon experiments.[4,5] While our data alone show no significant Q^2 dependence, ($\chi^2/df = 1.2$ to this hypothesis) comparison with the higher Q^2 and $\epsilon \approx 1$ muon data[4] ($\Delta \approx \pm 6\%$) may indicate a Q^2 dependence for $x \leq 0.3$, a change of R with A or a mixture of both. Figure 2(b) shows Q^2-averaged ratio of σ^{Fe}/σ^d in finer x bins than in Fig. 2(a). Also shown are data from Stein et al.[6] for Cu ($\Delta = \pm 4.2\%$) and from Bodek et al.[7] for Fe ($\Delta = \pm 1.1\%$). Systematic differences between our results and the earlier data are within systematic errors.

Figure 3 shows our σ^{Fe}/σ^d ratios vs ϵ (statistical errors only) so that a better comparison can be made to the data obtained by other experiments. From Eq. (1), $\sigma^{Fe}/\sigma^d \approx (1 + \epsilon(R^{Fe} - R^d))W_2^{Fe}/W_2^d$ for R small. Then, if $R^{Fe} = R^d$, σ^{Fe}/σ^d is independent of ϵ. However, the best linear fits to our $Q^2 = 5$ data at $x = 0.3$, 0.5 and 0.7 have slopes $d(\sigma^{Fe}/\sigma^d)/d\epsilon = 0.15 \pm 0.12$, 0.19 ± 0.11 and 0.11 ± 0.11. Since $R = R(x, Q^2)$, we must be careful when averaging these results. The average value of the slope of 0.15 gives $(R^{Fe} - R^d) \approx 0.16 \pm 0.08$ (a 2 standard deviation effect). Lines with slope 0.15, which have been separately normalized at each value of x to best fit our data ($\chi^2/df = 1.2$), are shown in Fig. 3. The best horizontal lines ($R^{Fe} = R^d$) have a $\chi^2/df = 2.5$. The data from Stein et al.[6] for Cu seem to agree well with the fit to our data.

Figures 4(a) and (b) show F_2^{Fe}/F_2^d and F_1^{Fe}/F_1^d extracted from our data using $d(\sigma^{Fe}/\sigma^d)/d\epsilon = 0.15 \pm 0.11$ with the large error accounting for possible x dependence of R. The error bars shown include the statistical errors on σ^{Fe}/σ^d and the statistical uncertainty on the R measurement (which is common to all data points). Systematic errors are still under investigation but are expected to be smaller than the statistical errors. Our results for F_2^{Fe}/F_2^d have large errors but are consistent with the muon data for all x.

None of the theoretical ideas presently proposed to explain the EMC effect seem to account for a possible A-dependence of R.

REFERENCES

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FIGURE CAPTIONS

1. Values of R obtained at $Q^2 = 5\ (\mathrm{GeV/c})^2$ for deuterium, He, Al, Fe, and Au.

2. (a) σ^{Fe}/σ^d as a function of x for various values of Q^2, as well as higher energy muon data from Refs. 4 and 5. (b) σ^{Fe}/σ^d averaged over Q^2 as a function of x, as well as electron data from Refs. 6 and 7.

3. σ^{Fe}/σ^d as a function of ϵ for various values of x.

4. (a) F_2^{Fe}/F_2^d and (b) F_1^{Fe}/F_1^d as a function of x for various values of Q^2, as well as higher Q^2 muon data from Ref. 4.

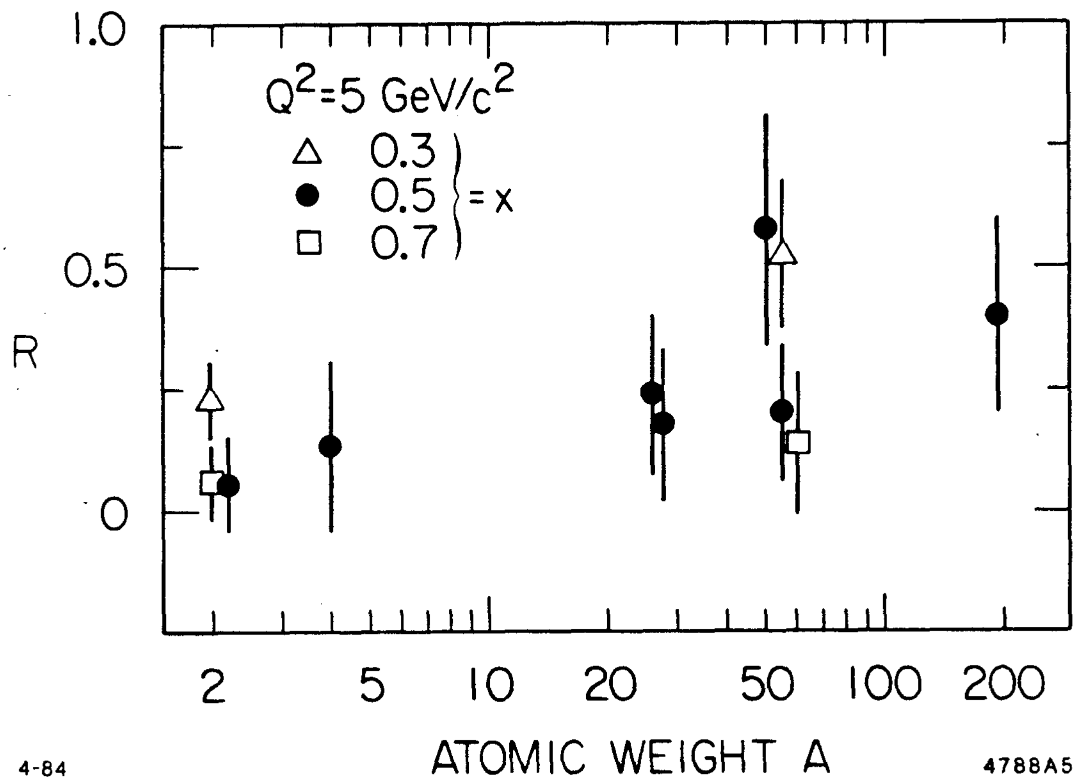
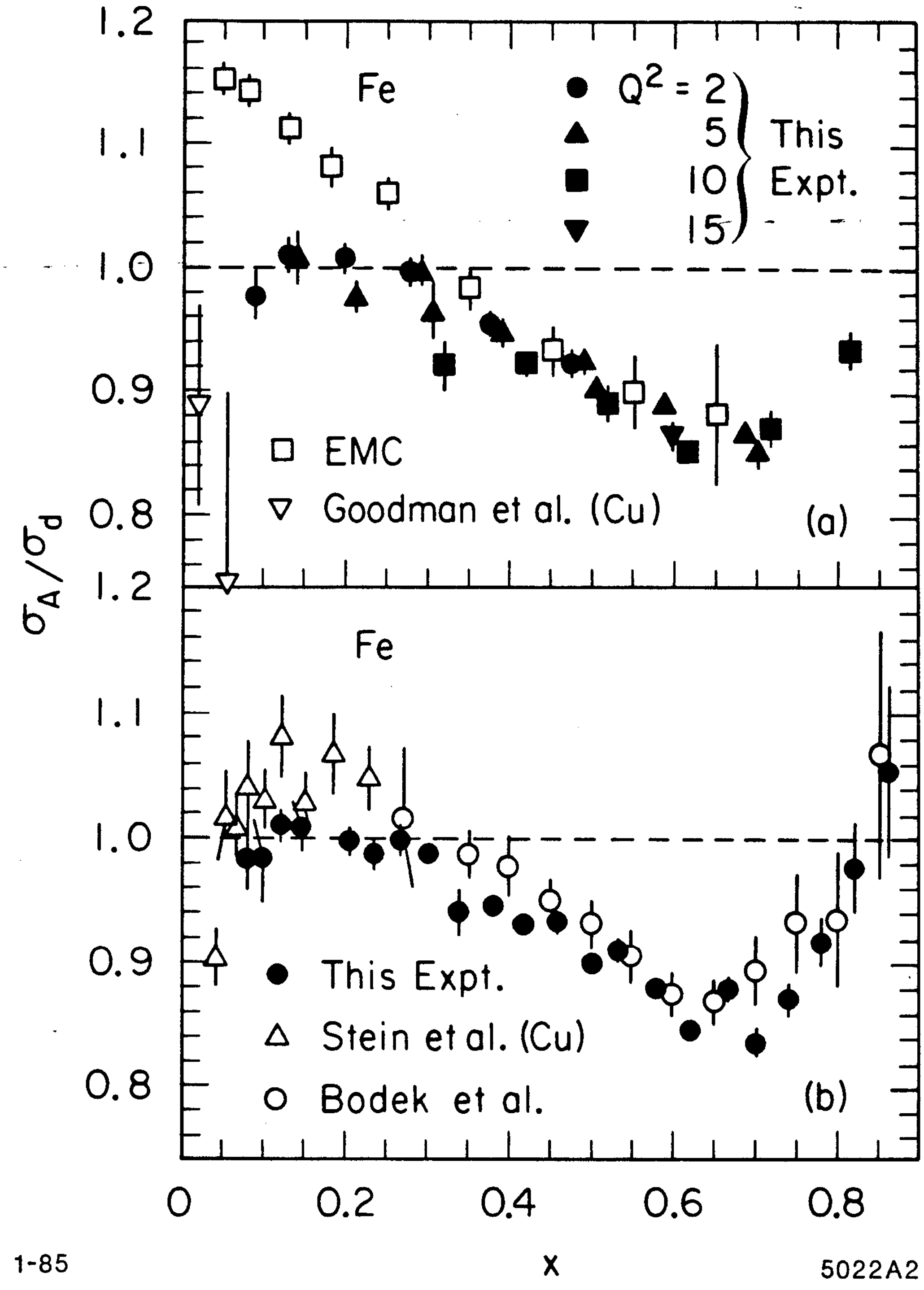
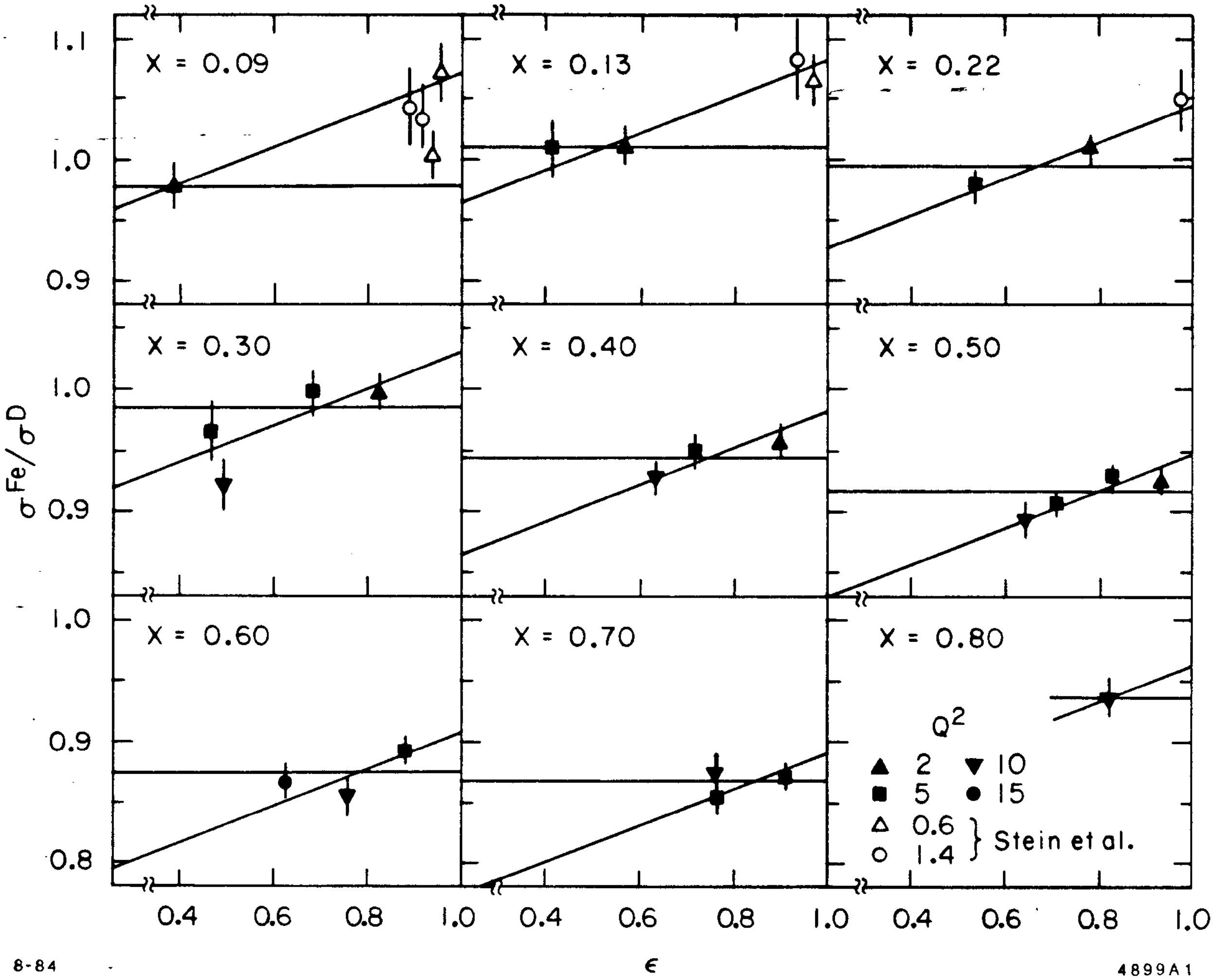


Fig. 1



1.2
1.1
1.0
0.9
0.8
Fe
● Q^2 = 2
▲ 5
■ 10
▼ 15
This Expt.
□ EMC
▽ Goodman et al. (Cu)
(a)
σ_A/σ_d
1.2
1.1
1.0
0.9
0.8
Fe
● This Expt.
△ Stein et al. (Cu)
○ Bodek et al.
(b)
0
0.2
0.4
0.6
0.8
x
1-85
5022A2

Fig. 2



X = 0.09
X = 0.13
X = 0.22
X = 0.30
X = 0.40
X = 0.50
X = 0.60
X = 0.70
X = 0.80
1.1
1.0
0.9
0.8
σ^Fe/σ^D
0.4
0.6
0.8
1.0
ε
Q²
2
10
5
15
0.6
1.4
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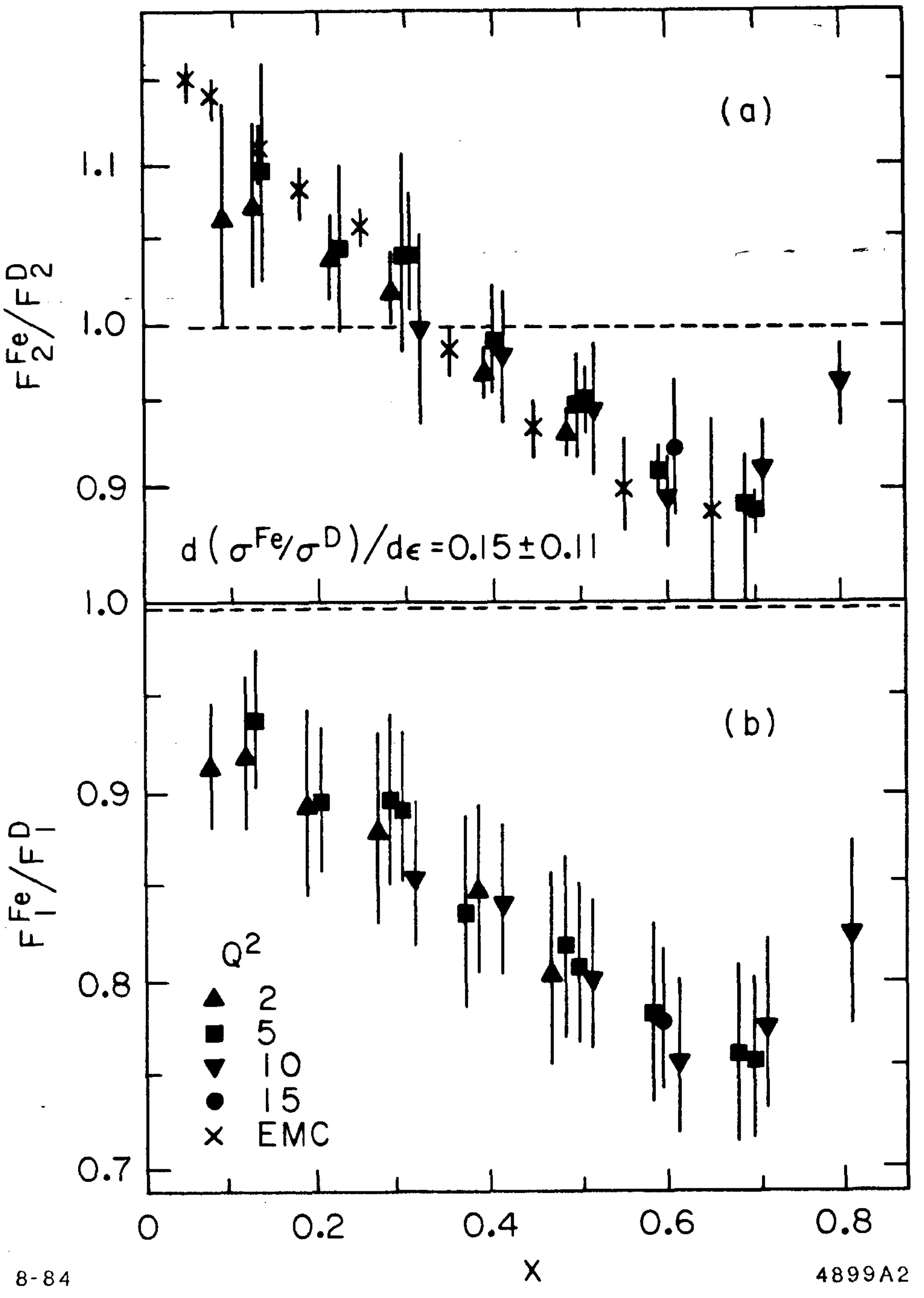
4899A1

Fig. 3



(a)
(b)
F_2^{Fe}/F_2^D
F_1^{Fe}/F_1^D
$d(\sigma^{Fe}/\sigma^D)/d\epsilon = 0.15 \pm 0.11$
1.1
1.0
0.9
1.0
0.9
0.8
0.7
Q^2
2
5
10
15
EMC
0
0.2
0.4
0.6
0.8
X
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Fig. 4