A Re-Evaluation of the nuclear Structure Function Ratios for D, He, ^{6}Li, C and Ca

THE NEW MUON COLLABORATION (NMC)

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Abstract

We present a re-evaluation of the structure function ratios F_2^{He}/F_2^D, F_2^C/F_2^D and F_2^{Ca}/F_2^D measured in deep inelastic muon-nucleus scattering at an incident muon momentum of 200 GeV. We also present the ratios F_2^C/F_2^{Li}, F_2^{Ca}/F_2^{Li} and F_2^{Ca}/F_2^C measured at 90 GeV. The results are based on data already published by NMC; the main difference in the analysis is a correction for the masses of the deuterium targets and an improvement in the radiative corrections. The kinematic range covered is $0.0035 < x < 0.65$, $0.5 < Q^2 < 90$ GeV^2 for the He/D, C/D and Ca/D data and $0.0085 < x < 0.6$, $0.84 < Q^2 < 17$ GeV^2 for the Li/C/Ca ones.

For footnotes see next page.

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Results on the structure function ratios F_2^{He}/F_2^D, F_2^C/F_2^D and F_2^{Ca}/F_2^D [1] as well as F_2^C/F_2^{Li}, F_2^{Ca}/F_2^{Li} and F_2^{Ca}/F_2^C [2] were recently published by NMC. The kinematic range covered was $0.0035 < x < 0.65$, $0.5 < Q^2 < 90$ GeV^2 for the He/D, C/D and Ca/D data and $0.0085 < x < 0.6$, $0.84 < Q^2 < 17$ GeV^2 for the ^{6}Li/C/Ca ones. Here $-Q^2$ is four momentum squared of the virtual photon and $x = Q^2/(2M\nu)$ is the Bjorken scaling variable, with M the proton mass and ν the virtual photon energy in the laboratory frame. In this paper we present the results of a re-evaluation of these ratios.

The data were collected using the NMC spectrometer [3] at the CERN SPS muon beam line at nominal incident energies of 200 GeV for the He/D, C/D and Ca/D data and 90 GeV for the ^{6}Li/C/Ca ones.

In refs. [1, 2] radiative corrections were computed according to the prescription of Mo and Tsai [4]. The procedure corrects for the radiative tails of coherent elastic scattering from nuclei and of quasi-elastic scattering from nucleons, as well as for the inelastic radiative tails. The evaluation of the inelastic tail requires the knowledge of F_2 over a large range of x and Q^2. A fit [5] to the results of deep inelastic scattering experiments and to low energy data in the resonance region was used for F_2^d. The bound nucleon structure functions F_2^A were obtained by multiplying F_2^d with empirical fits to our cross section ratios together with the SLAC-E139 data [6] for $x > 0.4$.

Since the publication of refs. [1, 2] new measurements of the structure function F_2^d in the range $0.006 < x < 0.6$ and $0.5 < Q^2 < 55$ GeV^2 have become available [7]. At x less than 0.07 the measured values of F_2^d differ from those of the fit [5], by up to 18% at $x = 0.0035$ and $Q^2 = 0.6$ GeV^2. Furthermore the SLAC structure function ratios have been reanalysed [8]. These new ratios differ from the old ones by up to a few per cent.

In addition, it was found that the masses of the liquid deuterium targets used in ref. [1] for the C/D and Ca/D data had been incorrectly evaluated. Correcting these has increased the corresponding structure function ratios by 0.74%.

We therefore recomputed the radiative corrections using the new F_2^d data, the results of the SLAC reanalysis and the correct deuterium target masses for our C/D and Ca/D ratios. This has resulted in an increase of the structure function ratios at the smallest values of x which is negligible for the He/D data but ranges up to 2.5% for Ca/D.

Radiative corrections were calculated with three different programs. The first was the one used to obtain the results presented in refs. [1, 2], based on the Mo and Tsai formalism; the second was an improved version of the first including vacuum polarisation by quark and τ loops and electroweak interference terms. The third program is based on the covariant approach described in ref. [9]. The results obtained with the three methods are consistent. The ratios presented in this paper were obtained with the third method.

In fig. 1 the present results are shown as a function of x and are compared with the old ones. The new results are also given in table 1 and table 2 for the measurements at 200 GeV and 90 GeV, respectively. In fig. 2 we present our data for He/D, C/D and Ca/D together with the reanalysed SLAC results [8]. Finally, fig. 3 shows the logarithmic Q^2 slopes b obtained from fits of the form $F_2^A/F_2^D = a + b \ln Q^2$ to the He/D, C/D and Ca/D ratios in each x bin separately. The Q^2 dependences are essentially unchanged with respect to those presented in ref. [1].

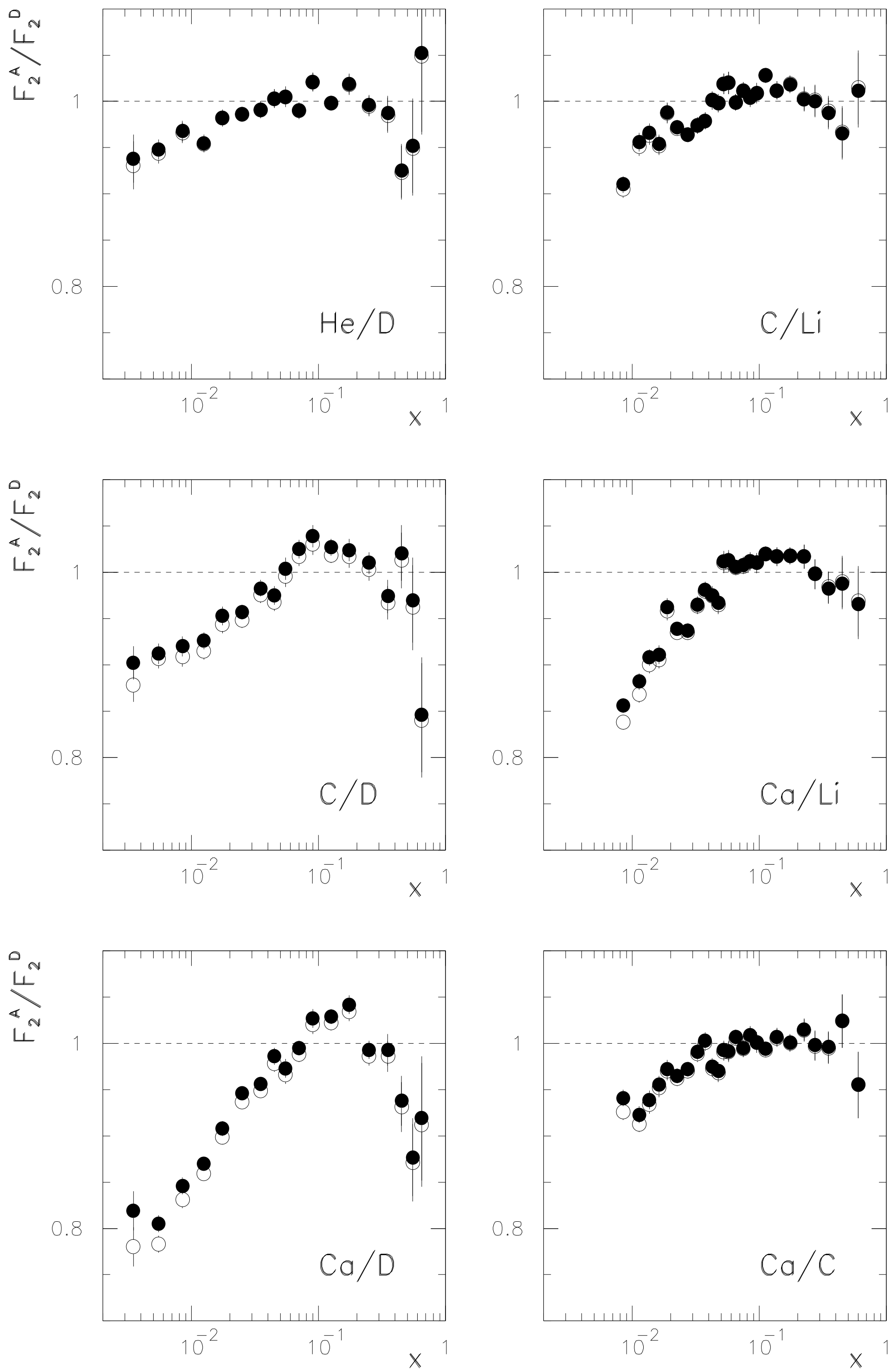

Figure 1: Structure function ratios as function of x, averaged over Q^2. The full circles represent the re-evaluated ratios, the open circles the old ratios. Only statistical errors are shown.

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x	$\langle Q^2 \rangle$ [GeV^2]	$\langle y \rangle$	F_2^{He}/F_2^D	stat	syst
0.0035	0.77	0.65	0.938	0.026	0.022
0.0055	1.3	0.65	0.948	0.011	0.018
0.0085	1.8	0.59	0.968	0.011	0.014
0.0125	2.4	0.53	0.955	0.009	0.011
0.0175	3.0	0.47	0.982	0.009	0.009
0.025	3.8	0.42	0.986	0.008	0.008
0.035	4.7	0.37	0.991	0.009	0.007
0.045	5.6	0.34	1.003	0.010	0.007
0.055	6.3	0.31	1.005	0.011	0.007
0.070	7.3	0.29	0.990	0.009	0.006
0.090	8.7	0.26	1.021	0.010	0.006
0.125	11	0.24	0.998	0.008	0.006
0.175	14	0.22	1.019	0.011	0.005
0.25	19	0.21	0.996	0.011	0.005
0.35	24	0.19	0.987	0.019	0.005
0.45	31	0.19	0.925	0.029	0.005
0.55	38	0.19	0.952	0.051	0.005
0.65	44	0.18	1.052	0.085	0.005

x	$\langle Q^2 \rangle$ [GeV^2]	$\langle y \rangle$	F_2^{C}/F_2^D	stat	syst
0.0035	0.74	0.62	0.902	0.018	0.016
0.0055	1.2	0.57	0.912	0.011	0.010
0.0085	1.7	0.54	0.920	0.011	0.008
0.0125	2.3	0.51	0.926	0.009	0.007
0.0175	3.0	0.47	0.953	0.010	0.006
0.025	3.8	0.42	0.957	0.008	0.006
0.035	4.9	0.38	0.983	0.009	0.005
0.045	6.0	0.37	0.975	0.010	0.005
0.055	7.2	0.36	1.004	0.012	0.005
0.070	8.8	0.34	1.025	0.010	0.005
0.090	11	0.33	1.039	0.012	0.005
0.125	14	0.31	1.027	0.009	0.005
0.175	17	0.27	1.024	0.012	0.005
0.25	21	0.23	1.010	0.012	0.005
0.35	26	0.21	0.974	0.018	0.005
0.45	31	0.19	1.021	0.030	0.006
0.55	37	0.19	0.970	0.046	0.006
0.65	42	0.17	0.846	0.062	0.007

x	$\langle Q^2 \rangle$ [GeV^2]	$\langle y \rangle$	F_2^{Ca}/F_2^D	stat	syst
0.0035	0.60	0.47	0.819	0.021	0.019
0.0055	0.94	0.46	0.805	0.009	0.013
0.0085	1.4	0.43	0.846	0.009	0.010
0.0125	1.9	0.41	0.870	0.007	0.008
0.0175	2.5	0.40	0.908	0.008	0.007
0.025	3.4	0.38	0.946	0.006	0.006
0.035	4.7	0.36	0.956	0.007	0.005
0.045	5.7	0.35	0.986	0.009	0.005
0.055	6.8	0.34	0.973	0.010	0.005
0.070	8.1	0.32	0.995	0.008	0.005
0.090	9.7	0.30	1.027	0.010	0.005
0.125	12	0.26	1.029	0.008	0.005
0.175	14	0.23	1.042	0.010	0.005
0.25	19	0.21	0.993	0.010	0.005
0.35	24	0.19	0.993	0.017	0.006
0.45	30	0.19	0.938	0.027	0.006
0.55	35	0.18	0.877	0.042	0.006
0.65	41	0.17	0.919	0.067	0.007

Table 1: The structure function ratios F_2^A/F_2^D measured at 200 GeV and averaged over Q^2. The normalisation uncertainty of 0.4% is not included in the systematic errors. The variable y is defined as ν/E, where E is the incident muon energy.

x	$\langle Q^2 \rangle$ [GeV^2]	$\langle y \rangle$	F_2^C/F_2^{Li}	stat	syst	F_2^{Ca}/F_2^{Li}	stat	syst	F_2^{Ca}/F_2^C	stat	syst
0.0085	0.8	0.57	0.910	0.009	0.012	0.856	0.008	0.022	0.941	0.009	0.023
0.0113	1.1	0.59	0.956	0.010	0.009	0.882	0.009	0.017	0.923	0.009	0.015
0.0138	1.2	0.53	0.966	0.010	0.007	0.908	0.009	0.013	0.939	0.010	0.011
0.0163	1.4	0.52	0.954	0.010	0.005	0.911	0.010	0.010	0.955	0.010	0.008
0.0188	1.6	0.52	0.988	0.011	0.004	0.962	0.010	0.008	0.972	0.010	0.007
0.0225	1.8	0.49	0.972	0.008	0.004	0.939	0.007	0.006	0.965	0.008	0.005
0.0275	2.0	0.44	0.964	0.008	0.003	0.937	0.008	0.004	0.972	0.008	0.003
0.0325	2.2	0.41	0.974	0.009	0.002	0.965	0.009	0.003	0.991	0.009	0.003
0.0375	2.3	0.37	0.979	0.009	0.002	0.981	0.009	0.002	1.003	0.009	0.002
0.0425	2.4	0.34	1.001	0.010	0.002	0.975	0.010	0.002	0.975	0.009	0.002
0.0475	2.6	0.33	0.998	0.010	0.002	0.967	0.010	0.002	0.970	0.010	0.002
0.0525	2.7	0.31	1.019	0.011	0.002	1.012	0.011	0.002	0.993	0.010	0.002
0.0575	2.8	0.29	1.020	0.012	0.002	1.013	0.011	0.002	0.992	0.011	0.002
0.065	3.0	0.28	0.999	0.009	0.002	1.006	0.008	0.002	1.007	0.008	0.002
0.075	3.3	0.27	1.012	0.009	0.002	1.008	0.009	0.002	0.995	0.009	0.002
0.085	3.6	0.26	1.004	0.010	0.002	1.012	0.010	0.002	1.009	0.010	0.002
0.095	3.9	0.25	1.009	0.011	0.002	1.010	0.011	0.002	1.001	0.011	0.002
0.113	4.3	0.23	1.028	0.008	0.002	1.020	0.008	0.002	0.994	0.008	0.002
0.138	5.1	0.22	1.012	0.010	0.002	1.017	0.010	0.002	1.007	0.010	0.002
0.175	6.2	0.22	1.018	0.009	0.002	1.018	0.009	0.002	1.001	0.009	0.002
0.225	7.7	0.21	1.002	0.013	0.002	1.017	0.013	0.002	1.015	0.012	0.002
0.275	9.1	0.20	1.000	0.017	0.002	0.998	0.016	0.002	0.998	0.016	0.002
0.35	11	0.19	0.987	0.017	0.002	0.983	0.017	0.002	0.996	0.017	0.002
0.45	14	0.18	0.965	0.028	0.002	0.988	0.028	0.002	1.024	0.029	0.002
0.60	17	0.17	1.012	0.040	0.004	0.966	0.038	0.004	0.955	0.036	0.002

Table 2: The nuclear structure function ratios measured at 90 GeV and averaged over Q^2. The normalisation uncertainties (not included in the systematic errors) are 0.7%, 0.8% and 0.5% for C/Li, Ca/Li and Ca/C, respectively. The variable y is defined as ν/E, where E is the incident muon energy.

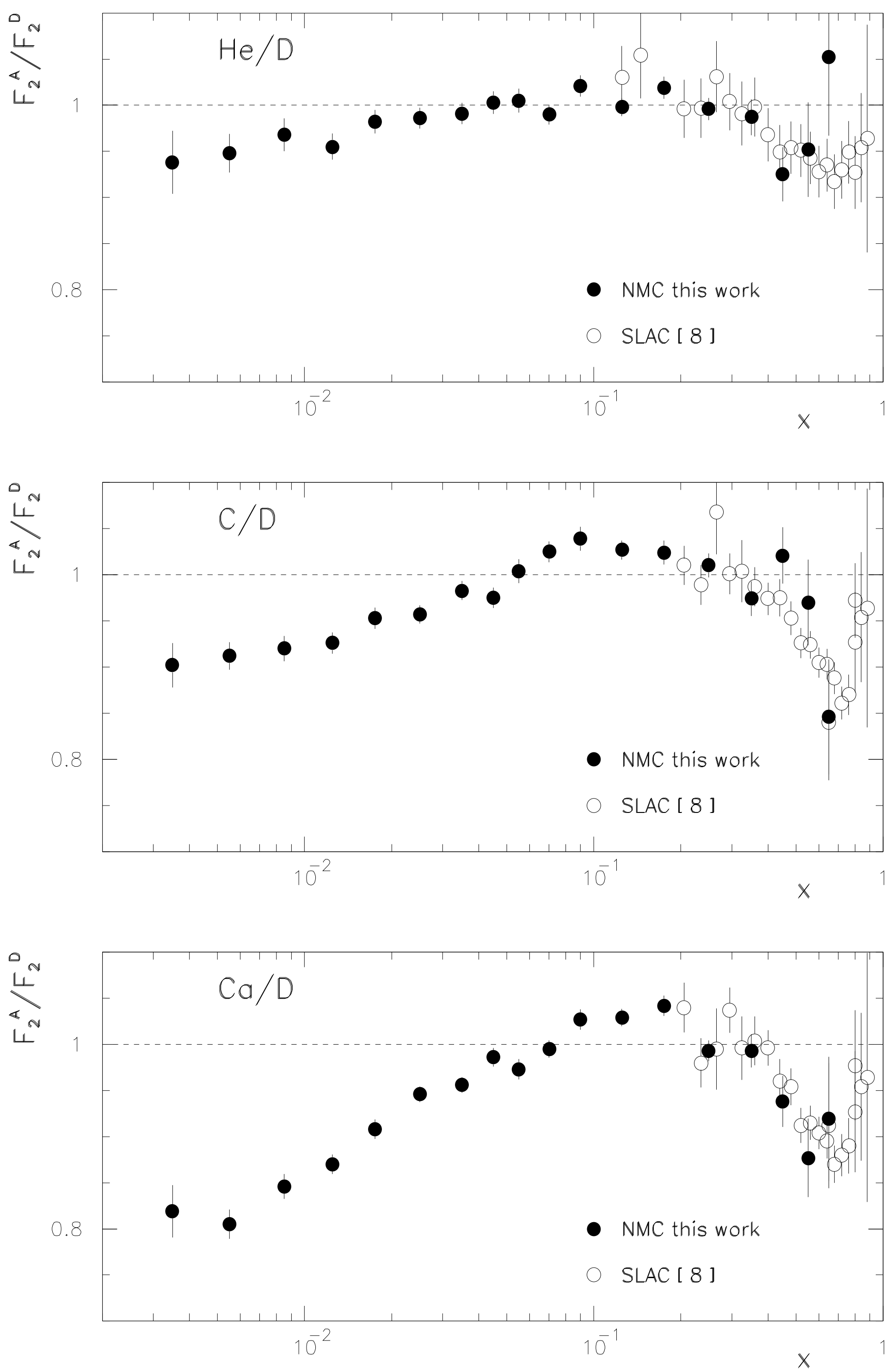

Figure 2: The re-evaluated NMC structure function ratios for He/D, C/D, Ca/D together with the reanalysed SLAC results. The error bars show the statistical and systematic errors added in quadrature. The normalisation uncertainties are not included.

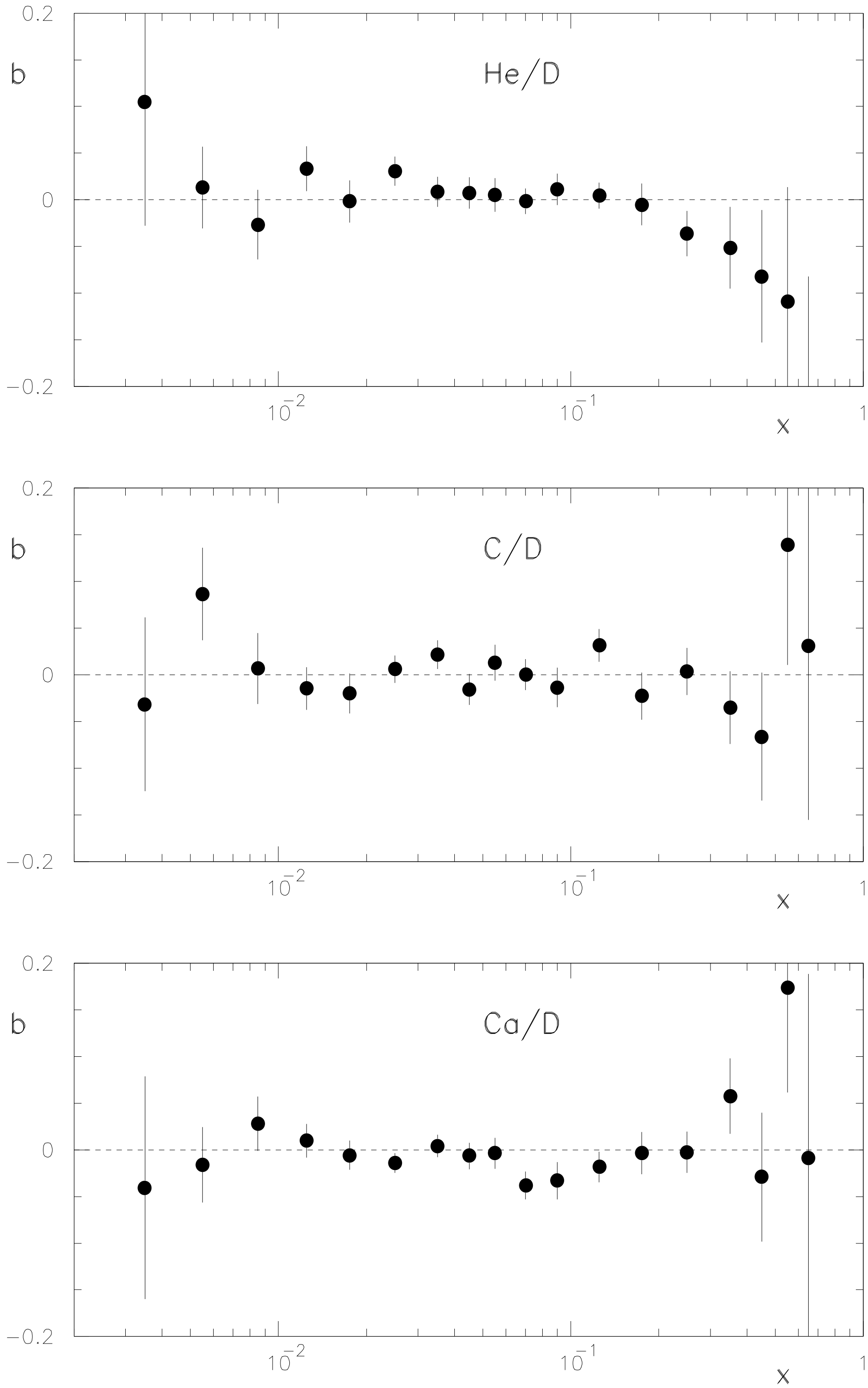

Figure 3: The slopes b from a linear fit in $\ln Q^2$ for each x bin separately. The errors shown are statistical only.