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MUON SCATTERING AT 219 GeV*

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ABSTRACT

Results on the proton structure function, F_2, are presented for $0.3 < q^2 < 80.0$ GeV^2 and $10 < \nu < 200$ GeV. The results support the conclusions of earlier work at 96 and 147 GeV that scaling is violated. A new value for $R = \sigma_S/\sigma_T = 0.44 \pm 0.25$ for $0.009 < x < 0.1$ and $1 < q^2 < 12$ GeV^2 has been obtained using all the Fermilab proton measurements. A tabulation of all the Fermilab μp and μd measurements is given.

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In this paper we report the most recent measurements at Fermilab of the cross section for scattering of 219 GeV muons from a hydrogen target, and tabulate them together with earlier measurements at 96 and 147 GeV.[1,2] The data were taken using the Fermilab muon scattering facility, details of which have been published previously.[1,2] The results at 219 GeV are based on a total of 7.5×10^{10} incident muons yielding 2.0×10^4 useful events in the kinematic range $0.3 < q^2 < 80$ GeV^2 and $10 < \nu < 200$ GeV, where q^2 is the square of the four momentum transfer of the muon and ν its laboratory energy loss. There were 1.5×10^4 events with $q^2 > 1.0$ GeV^2.

The cross section for muon inclusive scattering, in the one photon exchange approximation, is related to the structure function F_2 by

$$\frac{d^2\sigma}{dq^2 d\nu} = \frac{2\pi\alpha^2}{p^2 q^4} \frac{F_2(q^2,\nu)}{\nu} \left[2EE' - q^2/2 + \frac{(q^2 - 2m_\mu^2)(1 + \nu^2/q^2)}{1 + R(q^2,\nu)} \right],$$

where E, p, E' and p' are the incident and scattered muon laboratory energies

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and momenta, $q^2 = 2(EE' - pp'\cos\theta - m_\mu^2)$, $\nu = E - E'$, θ is the muon scattering angle, m_μ the muon mass, R the ratio of the total cross section on protons of scalar and transverse virtual photons and α is the fine structure constant.

The value of R has been determined by comparing cross sections at the same q^2 and ν using the 219-GeV data and all earlier measurements at 96 and 147 GeV. First, the two sets of measurements made under different conditions at 147 GeV were combined. Then the three different energy measurements were compared and χ^2 minimized as a function of F_2 and R where an overlap occurred. Taking R = constant, the best value of R was $R = 0.44 \pm 0.25$. The error includes a statistical error of ± 0.16 with a $\chi^2 = 159$ for 148 degree of freedom, a normalization uncertainty of ± 0.05, a ± 0.10 uncertainty in the acceptance, and a ± 0.15 uncertainty in the track finding efficiency. This value of R refers to the range $0.009 < x < 0.1$ and $1 < q^2 < 12$ GeV^2.

In view of the uncertainties in the value of R measured at low energy[3] for $x > 0.1$ and since our data is insensitive to these uncertainties for $x > 0.1$ (as shown in Fig. 2) we use our value to derive our best estimate for $\nu W_2(q^2,\nu) \equiv F_2(x,q^2)$. Figure 1 shows the values of the proton structure function as a function of q^2 for various values of ω. The values are weighted to give correct values at the bin centers. Only statistical errors are shown. The overall systematic error is estimated to be 5%. There is agreement between these new measurements and our previous values which are also shown recalculated for R = 0.44. A consistency check shows that the data have a $\chi^2 = 148$ for 126 degrees of freedom. In Fig. 2 we have combined all the data for muon scattering on hydrogen to show the variation of F_2 with x for various q^2 ranges. The

MIT-SLAC data[4,5] are also shown. The sensitivity of our results at each point to a variation of R between 0.19 and 0.69 is also indicated. These results exhibit a now well-known pattern of scaling violation[2,6,7] which may be characterized by a power law dependence of F_2 on q^2 for various x values where

$$F_2(x,q^2) = F_2(x,q_0^2)(q^2/q_0^2)^b \quad . \tag{1}$$

Figure 3 shows the variation of b as a function of x for the combined data for various assumed values of R for $q^2 > 1.0$ GeV^2. The rise of F_2 with increasing q^2 at small x may be reduced with a smaller value of R but will not disappear for any reasonable variation of R as a function x and q^2.

For those who want to use our data in their own way we present a complete tabulation. Table I gives the values of $F_2(x,q^2)$ for a liquid hydrogen target at 96, 147 and 219 GeV. These were calculated from the observed cross sections taking R = 0.44. The errors shown as δF_2 are statistical only and do not include the estimated 5% systematic error. By presenting the data at the separate energies with a given value of R it is straightforward to combine the data at any other value of R or with an R that varies with x and q^2, or both. In Table I it is easy to see the regions of overlap used to calculate the value of R.

In Table II all the data for the hydrogen has been combined using R = 0.44. In addition, the deuterium data, also evaluated for R = 0.44, is given. The deuterium data is for one energy only, 147 GeV, and is less extensive than that for hydrogen. Note that F_2^d is given per deuteron. The ordering of the data is somewhat different from Table I.

Our new data enables us to make an improved calculation of the Nachtmann[8] modification of the moments $\int x^{n-2} F_2(x,q^2)dx$ for n = 2, 4, 6 in different q^2 bands. The procedure used has been modified from that described in Ref. 2 by a numerical integration of the MIT-SLAC data including the resonance contributions. The results are given in Table III.

The results of this work reinforce the conclusions suggested by the earlier muon scattering data that $F_2(x,q^2)$ increases as x goes to zero for fixed q^2 greater than 2 GeV^2 and increases with q^2 for fixed x less than 0.1. This behavior combined with the decrease of F_2 with increasing q^2 for x greater than 0.2 is consistent with that predicted by quantum chromodynamics (QCD) for a scale parameter Λ = 500-700 MeV.[9] The integrals of F_2^P for n = 2 show that the quarks carry about half of the total energy-momentum of the proton, falling slightly with q^2.[9] Unfortunately the present statistical and systematic uncertainties prevent any meaningful comparison of R with QCD predictions.[10]

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TABLE I

Values of $F_2^P(x,q^2)$ for Liquid Hydrogen Target

R = 0.44

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.66667	9.0000	0.0590	0.0240	0.0740	0.0265	0.0	0.0
0.66667	12.5000	0.0350	0.0160	0.0444	0.0113	0.0500	0.0090
0.66667	22.5000	0.0	0.0	0.0340	0.0085	0.0320	0.0050
0.66667	40.0000	0.0	0.0	0.0	0.0	0.0331	0.0090
0.40000	3.7500	0.0	0.0	0.2140	0.0765	0.0	0.0
0.40000	4.5000	0.1681	0.0420	0.2210	0.0485	0.0	0.0
0.40000	5.5000	0.1851	0.0500	0.2761	0.0625	0.0	0.0
0.40000	6.5000	0.2052	0.0591	0.2861	0.0745	0.2790	0.0990
0.40000	7.5000	0.1352	0.0551	0.2437	0.0578	0.2050	0.0440
0.40000	9.0000	0.1593	0.0511	0.1610	0.0317	0.1651	0.0240
0.40000	12.5000	0.1304	0.0391	0.1615	0.0247	0.1891	0.0200
0.40000	22.5000	0.2734	0.0699	0.1436	0.0225	0.1964	0.0190
0.40000	40.0000	0.0	0.0	0.2331	0.0530	0.1360	0.0242
0.28571	2.8750	0.3001	0.1010	0.4041	0.1095	0.0	0.0
0.28571	3.2500	0.2301	0.0580	0.3941	0.0725	0.0	0.0
0.28571	3.7500	0.3382	0.0780	0.3221	0.0745	0.0	0.0
0.28571	4.5000	0.2422	0.0540	0.3781	0.0675	0.0	0.0
0.28571	5.5000	0.2633	0.0661	0.2760	0.0531	0.3881	0.0540
0.28571	6.5000	0.2965	0.0821	0.2899	0.0537	0.2771	0.0380
0.28571	7.5000	0.3428	0.1032	0.2050	0.0500	0.2321	0.0370
0.28571	9.0000	0.2619	0.0763	0.2497	0.0443	0.3022	0.0340
0.28571	12.5000	0.1219	0.0463	0.2474	0.0353	0.2893	0.0280
0.28571	22.5000	0.2323	0.0833	0.3094	0.0392	0.2460	0.0241
0.28571	40.0000	0.0	0.0	0.2940	0.0644	0.2934	0.0426
0.22222	2.1250	0.4061	0.1050	0.0	0.0	0.0	0.0
0.22222	2.3750	0.3591	0.0850	0.2290	0.0675	0.0	0.0
0.22222	2.6250	0.1821	0.0690	0.5591	0.1105	0.0	0.0
0.22222	2.8750	0.3392	0.0981	0.2190	0.0735	0.0	0.0
0.22222	3.2500	0.2692	0.0700	0.3721	0.0755	0.0	0.0
0.22222	3.7500	0.4304	0.0961	0.5012	0.1015	0.0	0.0
0.22222	4.5000	0.2794	0.0641	0.3279	0.0495	0.2991	0.0400
0.22222	5.5000	0.1874	0.0621	0.2532	0.0468	0.2721	0.0350
0.22222	6.5000	0.2438	0.0883	0.2883	0.0588	0.2451	0.0370
0.22222	7.5000	0.1968	0.0883	0.2792	0.0651	0.2812	0.0430

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.22222	9.0000	0.2585	0.0865	0.2757	0.0505	0.3333	0.0380
0.22222	12.5000	0.3037	0.0840	0.2481	0.0396	0.3146	0.0321
0.22222	22.5000	0.3443	0.1390	0.3031	0.0455	0.3435	0.0322
0.22222	40.0000	0.0	0.0	0.0	0.0	0.2241	0.0442
0.16667	1.3750	0.4121	0.1310	0.0	0.0	0.0	0.0
0.16667	1.6250	0.3811	0.0620	0.3800	0.0755	0.0	0.0
0.16667	1.8750	0.3231	0.0510	0.2770	0.0515	0.0	0.0
0.16667	2.1250	0.3092	0.0560	0.3101	0.0565	0.0	0.0
0.16667	2.3750	0.4463	0.0750	0.2421	0.0525	0.0	0.0
0.16667	2.6250	0.4213	0.0831	0.2631	0.0595	0.0	0.0
0.16667	2.8750	0.3563	0.0821	0.3411	0.0715	0.3431	0.1210
0.16667	3.2500	0.2853	0.0571	0.4486	0.0544	0.4141	0.0570
0.16667	3.7500	0.3826	0.0741	0.2657	0.0422	0.2901	0.0370
0.16667	4.5000	0.3248	0.0561	0.3131	0.0359	0.3451	0.0280
0.16667	5.5000	0.3794	0.0733	0.2886	0.0412	0.3442	0.0300
0.16667	6.5000	0.3700	0.0875	0.2133	0.0392	0.3373	0.0330
0.16667	7.5000	0.3456	0.0957	0.2139	0.0462	0.3074	0.0350
0.16667	9.0000	0.3297	0.0799	0.3210	0.0451	0.3536	0.0311
0.16667	12.5000	0.4294	0.0871	0.2873	0.0361	0.3312	0.0261
0.16667	22.5000	0.0	0.0	0.3144	0.0399	0.3620	0.0274
0.16667	40.0000	0.0	0.0	0.0	0.0	0.4424	0.0582
0.12500	1.1250	0.2611	0.0600	0.0	0.0	0.0	0.0
0.12500	1.3750	0.3491	0.0440	0.3641	0.0635	0.0	0.0
0.12500	1.6250	0.3832	0.0540	0.3061	0.0575	0.0	0.0
0.12500	1.8750	0.4453	0.0670	0.4631	0.0735	0.0	0.0
0.12500	2.1250	0.3263	0.0651	0.3681	0.0695	0.0	0.0
0.12500	2.3750	0.3784	0.0791	0.3242	0.0695	0.3631	0.0890
0.12500	2.6250	0.2413	0.0731	0.3442	0.0775	0.3651	0.0660
0.12500	2.8750	0.3105	0.0902	0.3631	0.0676	0.3411	0.0590
0.12500	3.2500	0.3177	0.0702	0.4076	0.0549	0.3411	0.0410
0.12500	3.7500	0.4132	0.0903	0.3665	0.0552	0.3842	0.0440
0.12500	4.5000	0.3546	0.0683	0.3359	0.0432	0.3383	0.0300
0.12500	5.5000	0.3555	0.0836	0.3128	0.0474	0.3374	0.0330
0.12500	6.5000	0.5284	0.1212	0.3708	0.0599	0.3546	0.0391
0.12500	7.5000	0.4159	0.1258	0.3841	0.0696	0.4099	0.0471
0.12500	9.0000	0.4529	0.1135	0.3957	0.0594	0.3311	0.0361
0.12500	12.5000	0.4026	0.1104	0.3604	0.0471	0.3706	0.0332
0.12500	22.5000	0.0	0.0	0.4633	0.0798	0.4112	0.0349
0.12500	40.0000	0.0	0.0	0.0	0.0	0.4615	0.0680
0.10000	0.9500	0.2581	0.0470	0.0	0.0	0.0	0.0
0.10000	1.1250	0.3391	0.0400	0.2890	0.0625	0.0	0.0
0.10000	1.3750	0.3282	0.0470	0.4491	0.0765	0.0	0.0
0.10000	1.6250	0.3032	0.0540	0.3431	0.0685	0.0	0.0
0.10000	1.8750	0.4075	0.0721	0.2961	0.0655	0.0	0.0
0.10000	2.1250	0.3966	0.0811	0.3411	0.0643	0.4681	0.0820
0.10000	2.3750	0.2725	0.0761	0.3494	0.0685	0.2741	0.0570
0.10000	2.6250	0.4871	0.1153	0.4454	0.0786	0.3581	0.0670
0.10000	2.8750	0.1925	0.0792	0.1827	0.0529	0.4082	0.0680
0.10000	3.2500	0.5289	0.1004	0.3548	0.0565	0.3862	0.0460
0.10000	3.7500	0.2924	0.0844	0.4004	0.0656	0.3673	0.0470
0.10000	4.5000	0.3516	0.0776	0.3321	0.0472	0.3945	0.0370

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.10000	5.5000	0.3804	0.0992	0.3316	0.0541	0.3386	0.0381
0.10000	6.5000	0.6440	0.1526	0.3651	0.0661	0.3359	0.0431
0.10000	7.5000	0.7377	0.1916	0.2911	0.0651	0.1907	0.0361
0.10000	9.0000	0.3002	0.1070	0.4444	0.0710	0.3670	0.0422
0.10000	12.5000	0.4624	0.1727	0.3186	0.0505	0.3379	0.0364
0.10000	22.5000	0.0	0.0	0.5762	0.1182	0.3977	0.0409
0.08000	0.7500	0.2991	0.0630	0.0	0.0	0.0	0.0
0.08000	0.8500	0.2241	0.0400	0.0	0.0	0.0	0.0
0.08000	0.9500	0.2851	0.0460	0.0	0.0	0.0	0.0
0.08000	1.1250	0.3022	0.0350	0.2811	0.0555	0.0	0.0
0.08000	1.3750	0.3073	0.0420	0.2361	0.0505	0.0	0.0
0.08000	1.6250	0.3334	0.0521	0.4923	0.0745	0.0	0.0
0.08000	1.8750	0.3737	0.0631	0.3783	0.0685	0.0	0.0
0.08000	2.1250	0.5252	0.0852	0.3188	0.0578	0.3381	0.0590
0.08000	2.3750	0.4032	0.0842	0.4811	0.0751	0.3512	0.0580
0.08000	2.6250	0.4426	0.0994	0.2842	0.0591	0.3002	0.0530
0.08000	2.8750	0.4771	0.1125	0.2369	0.0552	0.4704	0.0661
0.08000	3.2500	0.3621	0.0754	0.3044	0.0489	0.2603	0.0340
0.08000	3.7500	0.6129	0.1119	0.3740	0.0584	0.2864	0.0370
0.08000	4.5000	0.3432	0.0709	0.3874	0.0464	0.4238	0.0351
0.08000	5.5000	0.3753	0.0918	0.3728	0.0531	0.3681	0.0371
0.08000	6.5000	0.4820	0.1257	0.4346	0.0645	0.4028	0.0432
0.08000	7.5000	0.2149	0.0981	0.2806	0.0608	0.4064	0.0493
0.08000	9.0000	0.3199	0.1091	0.4123	0.0638	0.3804	0.0404
0.08000	12.5000	0.0	0.0	0.4506	0.0579	0.4242	0.0377
0.08000	22.5000	0.0	0.0	0.0	0.0	0.4826	0.0458
0.05882	0.6500	0.2621	0.0320	0.0	0.0	0.0	0.0
0.05882	0.7500	0.3612	0.0380	0.0	0.0	0.0	0.0
0.05882	0.8500	0.2852	0.0360	0.0	0.0	0.0	0.0
0.05882	0.9500	0.3223	0.0410	0.0	0.0	0.0	0.0
0.05882	1.1250	0.3264	0.0300	0.2721	0.0455	0.0	0.0
0.05882	1.3750	0.3486	0.0371	0.4203	0.0565	0.0	0.0
0.05882	1.6250	0.4130	0.0481	0.3674	0.0536	0.0	0.0
0.05882	1.8750	0.3642	0.0522	0.3164	0.0526	0.0	0.0
0.05882	2.1250	0.3164	0.0552	0.4251	0.0557	0.4463	0.0550
0.05882	2.3750	0.4194	0.0714	0.4098	0.0583	0.2582	0.0410
0.05882	2.6250	0.3042	0.0665	0.2075	0.0425	0.3704	0.0501
0.05882	2.8750	0.3582	0.0767	0.4037	0.0619	0.3785	0.0491
0.05882	3.2500	0.3385	0.0648	0.2797	0.0396	0.2775	0.0301
0.05882	3.7500	0.3446	0.0712	0.3262	0.0452	0.3479	0.0351
0.05882	4.5000	0.3652	0.0626	0.3504	0.0361	0.4005	0.0291
0.05882	5.5000	0.4077	0.0813	0.3171	0.0391	0.3853	0.0322
0.05882	6.5000	0.5012	0.1109	0.4326	0.0532	0.4469	0.0393
0.05882	7.5000	0.2701	0.1098	0.3191	0.0545	0.4150	0.0425
0.05882	9.0000	0.0	0.0	0.4072	0.0527	0.3851	0.0336
0.05882	12.5000	0.0	0.0	0.5510	0.0727	0.4149	0.0313
0.05882	22.5000	0.0	0.0	0.0	0.0	0.4310	0.0486
0.03636	0.6500	0.2382	0.0240	0.0	0.0	0.0	0.0
0.03636	0.7500	0.2383	0.0250	0.0	0.0	0.0	0.0
0.03636	0.8500	0.2925	0.0290	0.0	0.0	0.0	0.0
0.03636	0.9500	0.2235	0.0281	0.0	0.0	0.0	0.0

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.03636	1.1250	0.2789	0.0221	0.3655	0.0456	0.0	0.0
0.03636	1.3750	0.3616	0.0312	0.4078	0.0446	0.0	0.0
0.03636	1.6250	0.3576	0.0363	0.3871	0.0446	0.0	0.0
0.03636	1.8750	0.3434	0.0404	0.3383	0.0437	0.0	0.0
0.03636	2.1250	0.3486	0.0466	0.3005	0.0393	0.3648	0.0411
0.03636	2.3750	0.3347	0.0509	0.3208	0.0420	0.3499	0.0391
0.03636	2.6250	0.3077	0.0532	0.4164	0.0492	0.4535	0.0441
0.03636	2.8750	0.3608	0.0648	0.3674	0.0481	0.3946	0.0412
0.03636	3.2500	0.3041	0.0477	0.3790	0.0363	0.3861	0.0292
0.03636	3.7500	0.4558	0.0686	0.3426	0.0362	0.3677	0.0302
0.03636	4.5000	0.4056	0.0589	0.3848	0.0305	0.3944	0.0233
0.03636	5.5000	0.5041	0.1124	0.3991	0.0428	0.4572	0.0295
0.03636	6.5000	0.6388	0.2565	0.4836	0.0494	0.4870	0.0339
0.03636	7.5000	0.0	0.0	0.4371	0.0624	0.3783	0.0333
0.03636	9.0000	0.0	0.0	0.6385	0.0918	0.3657	0.0276
0.03636	12.5000	0.0	0.0	0.0	0.0	0.4779	0.0347
0.03636	22.5000	0.0	0.0	0.0	0.0	0.9763	0.2224
0.02500	0.6500	0.2656	0.0381	0.0	0.0	0.0	0.0
0.02500	0.7500	0.2979	0.0421	0.0	0.0	0.0	0.0
0.02500	0.8500	0.1807	0.0351	0.0	0.0	0.0	0.0
0.02500	0.9500	0.2794	0.0482	0.0	0.0	0.0	0.0
0.02500	1.1250	0.3213	0.0373	0.3500	0.0647	0.0	0.0
0.02500	1.3750	0.4036	0.0496	0.3164	0.0588	0.0	0.0
0.02500	1.6250	0.4221	0.0590	0.4257	0.0679	0.0	0.0
0.02500	1.8750	0.3339	0.0594	0.3158	0.0641	0.0	0.0
0.02500	2.1250	0.3792	0.0734	0.4366	0.0727	0.3688	0.0593
0.02500	2.3750	0.3415	0.0783	0.3910	0.0703	0.3582	0.0574
0.02500	2.6250	0.3638	0.0910	0.3230	0.0614	0.3114	0.0534
0.02500	2.8750	0.2287	0.0816	0.3320	0.0652	0.4654	0.0656
0.02500	3.2500	0.3619	0.0827	0.4057	0.0520	0.4152	0.0446
0.02500	3.7500	0.0	0.0	0.3443	0.0537	0.5150	0.0519
0.02500	4.5000	0.0	0.0	0.4701	0.0520	0.4676	0.0391
0.02500	5.5000	0.0	0.0	0.4224	0.0885	0.4164	0.0429
0.02500	6.5000	0.0	0.0	0.0	0.0	0.4664	0.0515
0.02500	7.5000	0.0	0.0	0.0	0.0	0.4239	0.0587
0.02500	9.0000	0.0	0.0	0.0	0.0	0.4859	0.0649
0.01905	0.6500	0.1225	0.0241	0.0	0.0	0.0	0.0
0.01905	0.7500	0.2071	0.0332	0.0	0.0	0.0	0.0
0.01905	0.8500	0.2568	0.0403	0.0	0.0	0.0	0.0
0.01905	0.9500	0.3179	0.0484	0.0	0.0	0.0	0.0
0.01905	1.1250	0.3226	0.0355	0.3729	0.0598	0.0	0.0
0.01905	1.3750	0.4303	0.0480	0.3307	0.0549	0.0	0.0
0.01905	1.6250	0.3400	0.0496	0.3694	0.0602	0.0	0.0
0.01905	1.8750	0.2988	0.0545	0.3569	0.0635	0.0	0.0
0.01905	2.1250	0.3993	0.0726	0.4247	0.0619	0.2552	0.0444
0.01905	2.3750	0.3930	0.0819	0.4217	0.0611	0.4349	0.0577
0.01905	2.6250	0.3465	0.0886	0.3779	0.0572	0.4352	0.0568
0.01905	2.8750	0.4121	0.1297	0.3903	0.0603	0.4123	0.0560
0.01905	3.2500	0.0	0.0	0.3963	0.0475	0.4333	0.0420
0.01905	3.7500	0.0	0.0	0.4491	0.0823	0.3777	0.0414
0.01905	4.5000	0.0	0.0	0.4989	0.0803	0.4476	0.0359

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.01905	5.5000	0.0	0.0	0.0	0.0	0.4998	0.0438
0.01905	6.5000	0.0	0.0	0.0	0.0	0.4615	0.0554
0.01905	7.5000	0.0	0.0	0.0	0.0	0.5103	0.1072
0.01429	0.6500	0.2559	0.0342	0.0	0.0	0.0	0.0
0.01429	0.7500	0.3344	0.0424	0.0	0.0	0.0	0.0
0.01429	0.8500	0.2849	0.0436	0.0	0.0	0.0	0.0
0.01429	0.9500	0.2504	0.0433	0.0	0.0	0.0	0.0
0.01429	1.1250	0.2537	0.0308	0.3100	0.0500	0.0	0.0
0.01429	1.3750	0.2802	0.0387	0.3220	0.0523	0.0	0.0
0.01429	1.6250	0.3342	0.0514	0.4167	0.0619	0.0	0.0
0.01429	1.8750	0.3461	0.0630	0.4281	0.0656	0.0	0.0
0.01429	2.1250	0.5375	0.1001	0.2595	0.0396	0.3459	0.0498
0.01429	2.3750	0.4338	0.1450	0.3634	0.0483	0.3886	0.0511
0.01429	2.6250	0.0	0.0	0.4072	0.0543	0.4343	0.0535
0.01429	2.8750	0.0	0.0	0.3628	0.0571	0.4002	0.0529
0.01429	3.2500	0.0	0.0	0.4702	0.0709	0.3981	0.0378
0.01429	3.7500	0.0	0.0	0.6841	0.1579	0.4499	0.0419
0.01429	4.5000	0.0	0.0	0.0	0.0	0.4243	0.0348
0.01429	5.5000	0.0	0.0	0.0	0.0	0.4993	0.0682
0.01000	0.6500	0.2634	0.0303	0.0	0.0	0.0	0.0
0.01000	0.7500	0.3164	0.0338	0.0	0.0	0.0	0.0
0.01000	0.8500	0.2830	0.0361	0.0	0.0	0.0	0.0
0.01000	0.9500	0.2829	0.0386	0.4538	0.0787	0.0	0.0
0.01000	1.1250	0.3869	0.0331	0.3693	0.0435	0.0	0.0
0.01000	1.3750	0.3506	0.0414	0.3498	0.0377	0.0	0.0
0.01000	1.6250	0.4074	0.0717	0.3437	0.0365	0.0	0.0
0.01000	1.8750	0.0	0.0	0.3448	0.0375	0.0	0.0
0.01000	2.1250	0.0	0.0	0.4165	0.0498	0.3960	0.0386
0.01000	2.3750	0.0	0.0	0.4954	0.0752	0.4363	0.0391
0.01000	2.6250	0.0	0.0	0.4201	0.1070	0.4316	0.0387
0.01000	2.8750	0.0	0.0	0.0	0.0	0.4247	0.0394
0.01000	3.2500	0.0	0.0	0.0	0.0	0.4070	0.0306
0.01000	3.7500	0.0	0.0	0.0	0.0	0.4470	0.0481
0.01000	4.5000	0.0	0.0	0.0	0.0	0.5902	0.0979
0.00714	0.6500	0.2306	0.0374	0.0	0.0	0.0	0.0
0.00714	0.7500	0.2082	0.0377	0.0	0.0	0.0	0.0
0.00714	0.8500	0.2904	0.0496	0.2206	0.0632	0.0	0.0
0.00714	0.9500	0.4269	0.0693	0.3094	0.0676	0.0	0.0
0.00714	1.1250	0.3379	0.0591	0.3672	0.0414	0.0	0.0
0.00714	1.3750	0.0	0.0	0.2839	0.0355	0.0	0.0
0.00714	1.6250	0.0	0.0	0.3326	0.0433	0.4001	0.0536
0.00714	1.8750	0.0	0.0	0.7955	0.1638	0.3265	0.0333
0.00714	2.1250	0.0	0.0	0.0	0.0	0.3974	0.0342
0.00714	2.3750	0.0	0.0	0.0	0.0	0.3998	0.0377
0.00714	2.6250	0.0	0.0	0.0	0.0	0.3892	0.0524
0.00714	2.8750	0.0	0.0	0.0	0.0	0.4479	0.0886
0.00500	0.4500	0.2386	0.0404	0.0	0.0	0.0	0.0
0.00500	0.5500	0.2765	0.0364	0.0	0.0	0.0	0.0
0.00500	0.6500	0.2566	0.0351	0.3387	0.0752	0.0	0.0
0.00500	0.7500	0.2526	0.0443	0.2838	0.0514	0.0	0.0
0.00500	0.8500	0.3653	0.0737	0.3641	0.0453	0.0	0.0

		96 GeV		147 GeV		219 GeV	
x	q^2	F_2^P	δF_2^P	F_2^P	δF_2^P	F_2^P	δF_2^P
0.00500	0.9500	0.0	0.0	0.2753	0.0434	0.0	0.0
0.00500	1.1250	0.0	0.0	0.2930	0.0311	0.3669	0.0503
0.00500	1.3750	0.0	0.0	0.3904	0.0667	0.3856	0.0271
0.00500	1.6250	0.0	0.0	0.0	0.0	0.3773	0.0238
0.00500	1.8750	0.0	0.0	0.0	0.0	0.4313	0.0348
0.00500	2.1250	0.0	0.0	0.0	0.0	0.4632	0.0619
0.00312	0.3500	0.2099	0.0318	0.0	0.0	0.0	0.0
0.00312	0.4500	0.2179	0.0267	0.2719	0.0506	0.0	0.0
0.00312	0.5500	0.2752	0.0448	0.2460	0.0311	0.0	0.0
0.00312	0.6500	0.0	0.0	0.2595	0.0318	0.0	0.0
0.00312	0.7500	0.0	0.0	0.2901	0.0384	0.4999	0.1078
0.00312	0.8500	0.0	0.0	0.4546	0.0743	0.4407	0.0410
0.00312	0.9500	0.0	0.0	0.2580	0.0942	0.3051	0.0255
0.00312	1.1250	0.0	0.0	0.0	0.0	0.3688	0.0212
0.00312	1.3750	0.0	0.0	0.0	0.0	0.4294	0.0343
0.00200	0.2500	0.1522	0.0189	0.0	0.0	0.0	0.0
0.00200	0.3500	0.2077	0.0322	0.1687	0.0230	0.0	0.0
0.00200	0.4500	0.0	0.0	0.2132	0.0239	0.0	0.0
0.00200	0.5500	0.0	0.0	0.1823	0.0341	0.2672	0.0249
0.00200	0.6500	0.0	0.0	0.0	0.0	0.2727	0.0181
0.00200	0.7500	0.0	0.0	0.0	0.0	0.2881	0.0216
0.00200	0.8500	0.0	0.0	0.0	0.0	0.3627	0.0374
0.00125	0.2500	0.1517	0.0235	0.1790	0.0166	0.0	0.0
0.00125	0.3500	0.0	0.0	0.1892	0.0241	0.1714	0.0217
0.00125	0.4500	0.0	0.0	0.0	0.0	0.2506	0.0188
0.00125	0.5500	0.0	0.0	0.0	0.0	0.2924	0.0198
0.00125	0.6500	0.0	0.0	0.0	0.0	0.6264	0.2128
0.00083	0.2500	0.0	0.0	0.1879	0.0273	0.2345	0.0330
0.00083	0.3500	0.0	0.0	0.0	0.0	0.3255	0.0320

TABLE II

Values of F_2 for the Combined Hydrogen and the 147 GeV Deuterium Data All Evaluated at R = 0.44

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
40.000	0.6667	0.033	0.010	0.066	0.024
40.000	0.4000	0.152	0.023	0.230	0.065
40.000	0.2857	0.294	0.039	0.411	0.122
40.000	0.2222	0.224	0.045	0.756	0.239
40.000	0.1667	0.442	0.059	0.355	0.171
40.000	0.1250	0.462	0.069		
22.500	0.6667	0.032	0.005	0.073	0.014
22.500	0.4000	0.179	0.015	0.300	0.039
22.500	0.2857	0.261	0.021	0.413	0.055
22.500	0.2222	0.331	0.026	0.461	0.067
22.500	0.1667	0.347	0.023	0.428	0.057
22.500	0.1250	0.419	0.033	0.740	0.107
22.500	0.1000	0.417	0.039	1.168	0.210
22.500	0.0800	0.483	0.046		
22.500	0.0588	0.431	0.049		
12.500	0.6667	0.046	0.007	0.120	0.023
12.500	0.4000	0.172	0.015	0.287	0.040
12.500	0.2857	0.246	0.021	0.424	0.055
12.500	0.2222	0.299	0.025	0.492	0.068
12.500	0.1667	0.323	0.021	0.601	0.064
12.500	0.1250	0.369	0.027	0.619	0.075
12.500	0.1000	0.335	0.030	0.568	0.082
12.500	0.0800	0.432	0.032	0.723	0.090
12.500	0.0588	0.436	0.029	0.891	0.139
12.500	0.0364	0.478	0.035	1.917	0.634
9.000	0.6667	0.066	0.019		
9.000	0.4000	0.163	0.019	0.274	0.054
9.000	0.2857	0.231	0.026	0.409	0.068
9.000	0.2222	0.297	0.029	0.576	0.090
9.000	0.1667	0.342	0.025	0.692	0.080
9.000	0.1250	0.355	0.030	0.517	0.083
9.000	0.1000	0.378	0.035	0.550	0.098
9.000	0.0800	0.363	0.033	0.705	0.102
9.000	0.0588	0.391	0.029	0.687	0.083
9.000	0.0364	0.338	0.027	0.541	0.095
9.000	0.0250	0.486	0.065		
7.500	0.4000	0.195	0.030	0.207	0.078
7.500	0.2857	0.232	0.029	0.426	0.089
7.500	0.2222	0.269	0.034	0.256	0.074
7.500	0.1667	0.279	0.027	0.456	0.080
7.500	0.1250	0.403	0.038	0.746	0.118
7.500	0.1000	0.228	0.032	0.648	0.123
7.500	0.0800	0.338	0.036	0.634	0.113
7.500	0.0588	0.370	0.033	0.781	0.105
7.500	0.0364	0.391	0.030	0.752	0.130
7.500	0.0250	0.424	0.059		
7.500	0.0190	0.510	0.108		
6.500	0.4000	0.244	0.043		
6.500	0.2857	0.283	0.030	0.308	0.069
6.500	0.2222	0.258	0.030	0.378	0.081

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
6.500	0.1667	0.293	0.025	0.530	0.077
6.500	0.1250	0.371	0.032	0.770	0.105
6.500	0.1000	0.360	0.036	0.511	0.094
6.500	0.0800	0.418	0.035	0.528	0.087
6.500	0.0588	0.446	0.031	0.717	0.086
6.500	0.0364	0.489	0.028	0.786	0.078
6.500	0.0250	0.466	0.052	0.639	0.228
6.500	0.0190	0.462	0.056		
5.500	0.4000	0.221	0.040		
5.500	0.2857	0.315	0.034	0.419	0.094
5.500	0.2222	0.252	0.026	0.493	0.082
5.500	0.1667	0.331	0.024	0.465	0.063
5.500	0.1250	0.332	0.026	0.494	0.074
5.500	0.1000	0.340	0.030	0.508	0.084
5.500	0.0800	0.370	0.030	0.725	0.090
5.500	0.0588	0.362	0.024	0.553	0.063
5.500	0.0364	0.442	0.024	0.792	0.064
5.500	0.0250	0.418	0.039	0.873	0.154
5.500	0.0190	0.500	0.044	0.650	0.376
5.500	0.0143	0.499	0.069		
4.500	0.4000	0.191	0.033		
4.500	0.2857	0.295	0.043		
4.500	0.2222	0.304	0.029	0.464	0.079
4.500	0.1667	0.332	0.021	0.568	0.061
4.500	0.1250	0.337	0.024	0.462	0.062
4.500	0.1000	0.369	0.028	0.531	0.075
4.500	0.0800	0.402	0.027	0.537	0.069
4.500	0.0588	0.379	0.022	0.548	0.056
4.500	0.0364	0.392	0.018	0.722	0.051
4.500	0.0250	0.469	0.032	0.796	0.086
4.500	0.0190	0.456	0.033	0.934	0.164
4.500	0.0143	0.424	0.035		
4.500	0.0100	0.590	0.098		
3.750	0.4000	0.214	0.078		
3.750	0.2857	0.330	0.055		
3.750	0.2222	0.464	0.071		
3.750	0.1667	0.292	0.027	0.436	0.070
3.750	0.1250	0.302	0.033	0.440	0.080
3.750	0.1000	0.364	0.035	0.521	0.097
3.750	0.0800	0.333	0.031	0.531	0.090
3.750	0.0588	0.340	0.026	0.619	0.080
3.750	0.0364	0.368	0.023	0.679	0.064
3.750	0.0250	0.433	0.038	0.902	0.114
3.750	0.0190	0.392	0.038	0.944	0.103
3.750	0.0143	0.470	0.041	1.106	0.387
3.750	0.0100	0.447	0.049		
3.250	0.2857	0.294	0.046		
3.250	0.2222	0.328	0.052		
3.250	0.1667	0.385	0.033	0.466	0.092
3.250	0.1250	0.356	0.030	0.367	0.070

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
3.250	0.1000	0.391	0.034	0.769	0.113
3.250	0.0800	0.285	0.027	0.417	0.079
3.250	0.0588	0.271	0.023	0.652	0.082
3.250	0.0364	0.375	0.021	0.649	0.064
3.250	0.0250	0.404	0.032	0.567	0.082
3.250	0.0190	0.417	0.032	0.778	0.085
3.250	0.0143	0.414	0.034	0.751	0.136
3.250	0.0100	0.497	0.031		
2.875	0.2857	0.348	0.075		
2.875	0.2222	0.252	0.060		
2.875	0.1667	0.347	0.050	0.421	0.212
2.875	0.1250	0.343	0.041	0.543	0.120
2.875	0.1000	0.252	0.038	0.592	0.141
2.875	0.0800	0.352	0.040	0.592	0.130
2.875	0.0588	0.382	0.035	0.461	0.095
2.875	0.0364	0.379	0.029	0.554	0.086
2.875	0.0250	0.358	0.041	0.491	0.106
2.875	0.0190	0.493	0.040	0.667	0.108
2.875	0.0143	0.383	0.039	0.307	0.103
2.875	0.0100	0.420	0.040	1.233	0.289
2.875	0.0071	0.448	0.039		
2.625	0.2222	0.258	0.060		
2.625	0.1667	0.317	0.049		
2.625	0.1250	0.320	0.042	0.627	0.135
2.625	0.1000	0.410	0.047	0.512	0.130
2.625	0.0800	0.313	0.037	0.693	0.144
2.625	0.0588	0.282	0.030	0.573	0.110
2.625	0.0364	0.402	0.029	0.395	0.075
2.625	0.0250	0.324	0.038	0.619	0.122
2.625	0.0190	0.397	0.037	0.617	0.100
2.625	0.0143	0.421	0.039	0.562	0.113
2.625	0.0100	0.430	0.037	0.597	0.185
2.625	0.0071	0.389	0.053		
2.375	0.2222	0.279	0.054		
2.375	0.1667	0.309	0.044		
2.375	0.1250	0.352	0.046	0.289	0.120
2.375	0.1000	0.297	0.039	0.324	0.104
2.375	0.0800	0.400	0.041	0.338	0.104
2.375	0.0588	0.328	0.031	0.420	0.096
2.375	0.0364	0.336	0.026	0.357	0.074
2.375	0.0250	0.354	0.039	0.410	0.114
2.375	0.0190	0.421	0.038	0.576	0.098
2.375	0.0143	0.379	0.035	0.583	0.082
2.375	0.0100	0.449	0.035	0.744	0.138
2.375	0.0071	0.490	0.038		
2.125	0.2222	0.436	0.146		
2.125	0.1667	0.310	0.041		
2.125	0.1250	0.346	0.049		
2.125	0.1000	0.392	0.044	0.477	0.137
2.125	0.0800	0.366	0.038	0.643	0.142

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
2.125	0.0588	0.396	0.033	0.430	0.106
2.125	0.0364	0.336	0.025	0.320	0.076
2.125	0.0250	0.391	0.040	0.989	0.207
2.125	0.0190	0.329	0.033	0.558	0.119
2.125	0.0143	0.315	0.030	0.453	0.075
2.125	0.0100	0.404	0.031	0.714	0.069
2.125	0.0071	0.397	0.035		
2.125	0.0050	0.463	0.082		
1.875	0.1667	0.300	0.037		
1.875	0.1250	0.453	0.051		
1.875	0.1000	0.347	0.049		
1.875	0.0800	0.376	0.047		
1.875	0.0588	0.341	0.038		
1.875	0.0364	0.341	0.031		
1.875	0.0250	0.326	0.045		
1.875	0.0190	0.323	0.042		
1.875	0.0143	0.385	0.046	0.270	0.200
1.875	0.0100	0.345	0.039	0.633	0.066
1.875	0.0071	0.347	0.033	0.920	0.200
1.875	0.0050	0.431	0.035		
1.625	0.1667	0.381	0.049		
1.625	0.1250	0.347	0.040		
1.625	0.1000	0.319	0.043		
1.625	0.0800	0.336	0.044		
1.625	0.0588	0.393	0.037		
1.625	0.0364	0.369	0.029		
1.625	0.0250	0.424	0.046		
1.625	0.0190	0.352	0.039		
1.625	0.0143	0.368	0.041		
1.625	0.0100	0.357	0.034	0.718	0.076
1.625	0.0071	0.361	0.035	0.767	0.076
1.625	0.0050	0.377	0.024	2.977	2.252
1.375	0.1667	0.412	0.132		
1.375	0.1250	0.354	0.037		
1.375	0.1000	0.361	0.041		
1.375	0.0800	0.278	0.033		
1.375	0.0588	0.370	0.032		
1.375	0.0364	0.377	0.027		
1.375	0.0250	0.367	0.039		
1.375	0.0190	0.387	0.037		
1.375	0.0143	0.295	0.032		
1.375	0.0100	0.350	0.029	0.521	0.110
1.375	0.0071	0.384	0.037	0.622	0.061
1.375	0.0050	0.386	0.026	0.714	0.095
1.375	0.0031	0.429	0.035		
1.125	0.1250	0.261	0.061		
1.125	0.1000	0.325	0.035		
1.125	0.0800	0.296	0.031		
1.125	0.0588	0.310	0.026		
1.125	0.0364	0.295	0.021		

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
1.125	0.0250	0.328	0.033		
1.125	0.0190	0.335	0.032		
1.125	0.0143	0.269	0.027		
1.125	0.0100	0.360	0.027		
1.125	0.0071	0.358	0.035	0.540	0.070
1.125	0.0050	0.314	0.027	0.644	0.052
1.125	0.0031	0.369	0.022		
0.950	0.1000	0.258	0.068		
0.950	0.0890	0.235	0.047		
0.950	0.0588	0.322	0.042		
0.950	0.0364	0.223	0.029		
0.950	0.0250	0.279	0.049		
0.950	0.0190	0.318	0.049		
0.950	0.0143	0.350	0.045		
0.950	0.0100	0.316	0.036		
0.950	0.0071	0.367	0.049		
0.950	0.0050	0.275	0.044	0.525	0.074
0.950	0.0031	0.302	0.025	0.885	0.140
0.850	0.0890	0.224	0.041		
0.850	0.0588	0.265	0.037		
0.850	0.0364	0.293	0.030		
0.850	0.0250	0.181	0.036		
0.850	0.0190	0.257	0.041		
0.850	0.0143	0.265	0.045		
0.850	0.0100	0.283	0.037		
0.850	0.0071	0.264	0.040		
0.850	0.0050	0.364	0.040	0.469	0.132
0.850	0.0031	0.444	0.036	0.635	0.060
0.850	0.0020	0.383	0.038		
0.750	0.0890	0.299	0.064		
0.750	0.0588	0.361	0.039		
0.750	0.0364	0.238	0.026		
0.750	0.0250	0.298	0.043		
0.750	0.0190	0.207	0.034		
0.750	0.0143	0.334	0.043		
0.750	0.0100	0.316	0.037		
0.750	0.0071	0.208	0.039		
0.750	0.0050	0.266	0.035		
0.750	0.0031	0.314	0.037	0.494	0.050
0.750	0.0020	0.288	0.022		
0.650	0.0588	0.262	0.033		
0.650	0.0364	0.238	0.025		
0.650	0.0250	0.266	0.039		
0.650	0.0190	0.122	0.025		
0.650	0.0143	0.256	0.035		
0.650	0.0100	0.263	0.032		
0.650	0.0071	0.231	0.033		
0.650	0.0050	0.271	0.033		
0.650	0.0031	0.259	0.033	0.477	0.043
0.650	0.0020	0.273	0.019		

q^2	x	F_2^p	δF_2^p	F_2^d	δF_2^d
0.650	0.0012	0.626	0.213		
0.550	0.0050	0.277	0.037		
0.550	0.0031	0.255	0.027	0.383	0.062
0.550	0.0020	0.230	0.021	0.338	0.071
0.550	0.0012	0.292	0.020		
0.450	0.0050	0.239	0.041		
0.450	0.0031	0.230	0.025	0.241	0.121
0.450	0.0020	0.213	0.025	0.417	0.033
0.450	0.0012	0.251	0.019	0.596	0.419
0.350	0.0031	0.210	0.033		
0.350	0.0020	0.182	0.019	0.426	0.037
0.350	0.0012	0.179	0.017	0.388	0.033
0.350	0.0008	0.325	0.033		
0.250	0.0020	0.152	0.020		
0.250	0.0012	0.170	0.015	0.286	0.022
0.250	0.0008	0.207	0.022	0.306	0.043

TABLE III

The Nachtmann moments, including the elastic contribution for n = 2, 4, 6 for various values of q^2. The elastic contribution is shown. Errors include a 2.5% systematic error.

	n = 2			n = 4			n = 6		
<QSQ>	ELASTIC	MOMENT	MOMERR	ELASTIC	MOMENT	MOMERR	ELASTIC	MOMENT	MOMERR
40.00000	0.00000	0.16575	0.01543	0.00000	0.01277	0.00137	0.00000	0.00263	0.00049
22.50000	0.00001	0.16759	0.00646	0.00001	0.01520	0.00048	0.00001	0.00369	0.00010
11.50000	0.00007	0.17083	0.00520	0.00006	0.01702	0.00045	0.00005	0.00428	0.00011
6.00000	0.00062	0.18495	0.00490	0.00051	0.02015	0.00050	0.00041	0.00547	0.00014
3.00000	0.00492	0.19138	0.00476	0.00352	0.02472	0.00064	0.00240	0.00766	0.00027
1.50000	0.02637	0.20946	0.00530	0.01502	0.03485	0.00158	0.00799	0.01211	0.00081

FIGURE CAPTIONS

Fig. 1 F_2 for hydrogen as a function of q^2 for various $\omega = 1/x$ bins for R = 0.44 showing the 219-GeV data (closed circles), the earlier Fermilab data[2] recalculated for R = 0.44 (open circles) and the MIT-SLAC data[4] (open triangles). Note the difference in scales and the suppressed zeroes for the ordinate. The solid lines are the fits with Eq. (1) for all Fermilab data.

Fig. 2 $F_2(x,q^2)$ for hydrogen as a function of x for various q^2 bins for R = 0.44 using all Fermilab data (open circles) and the MIT-SLAC data (open triangles, Ref. 4, crosses, Ref. 5). The upper and lower horizontal bars indicate the change in F_2 for R = 0.69 and 0.19. The errors shown are statistical only.

Fig. 3 The scaling violation parameter b of Eq. (1) as a function of x for all Fermilab data (closed circles) and for the MIT-SLAC data[4] (open circles). The upper and lower horizontal bars indicate the change in b for R = 0.69 and 0.19. The errors are statistical only.

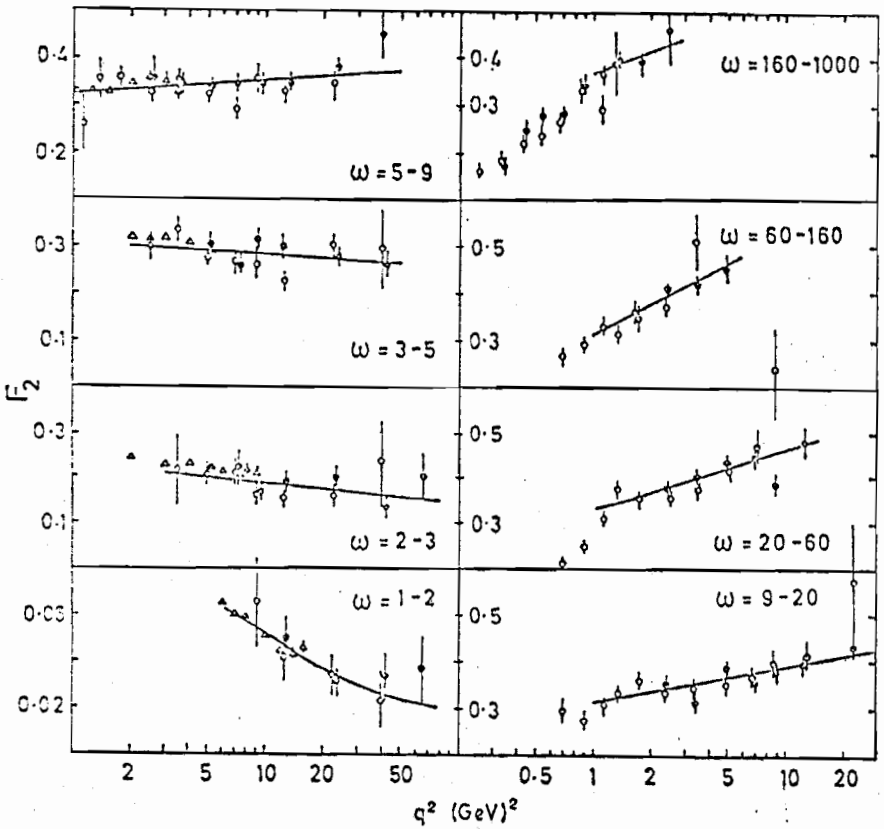

Figure 1

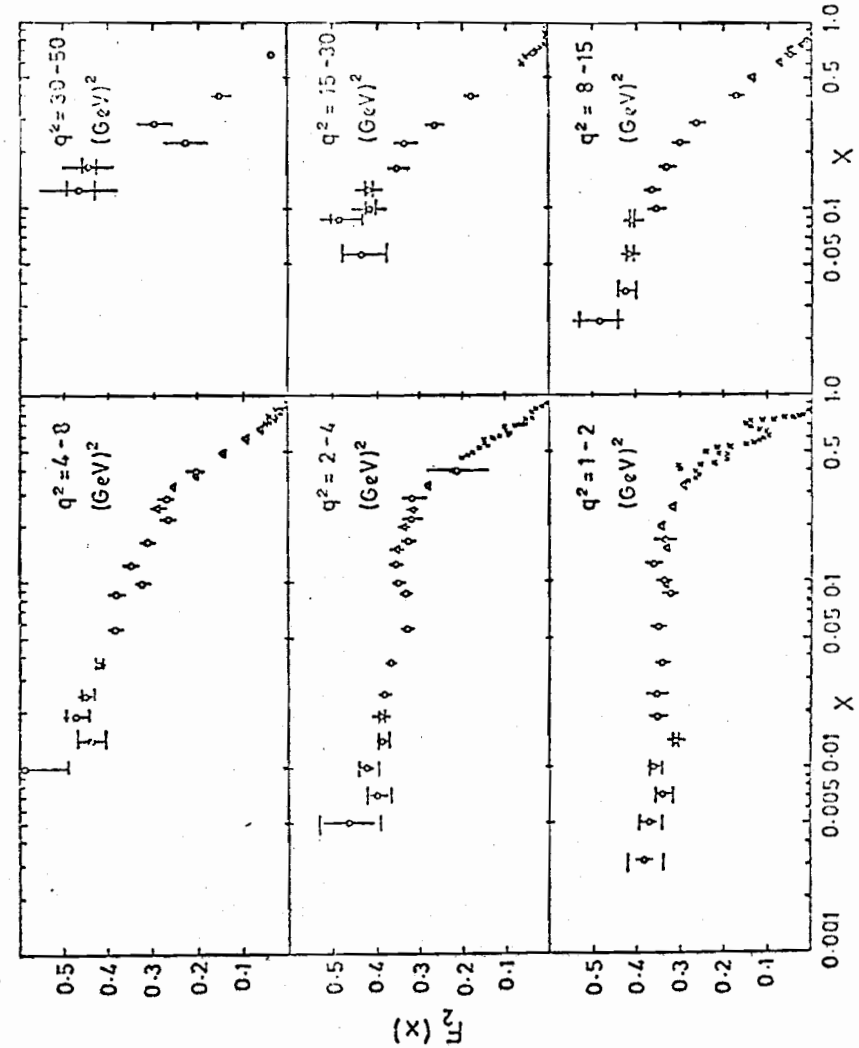

Figure 2

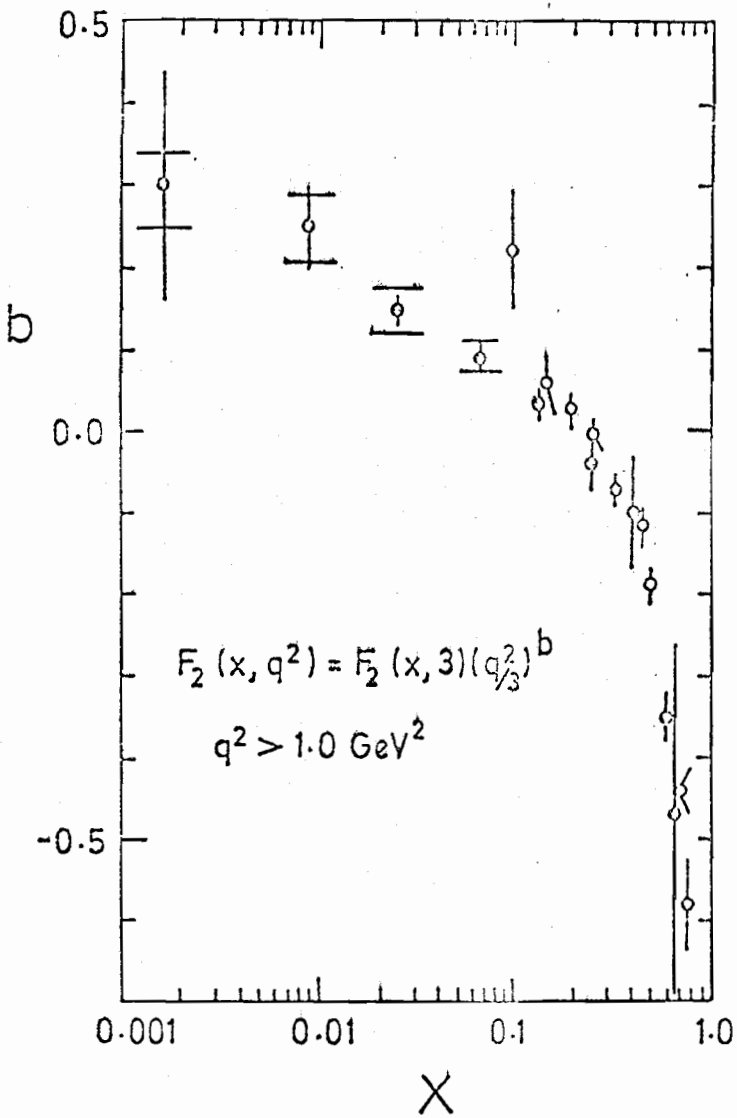

Figure 3