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Structure Functions and Structure Function Ratio F_2^n/F_2^p at Low x_{Bj} and Q^2 in Inelastic Muon Scattering

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STRUCTURE FUNCTIONS AND STRUCTURE FUNCTION RATIO F_2^n/F_2^p AT LOW X_{Bj} AND Q^2 IN INELASTIC MUON SCATTERING

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ABSTRACT

Preliminary measurements of the structure functions F_2^p and F_2^d, and the structure function ratio F_2^n/F_2^p, in inelastic μN scattering are presented. The data were obtained by the Fermilab E665 experiment using a 465 GeV muon beam and liquid hydrogen and deuterium targets. The structure functions are presented in the range $x_{Bj} > 8 \times 10^{-4}$ and $Q^2 > 0.2\ GeV^2/c^2$. The structure function ratio is presented as a function of x_{Bj} for $x_{Bj} > 10^{-6}$.

1. Introduction

In the single photon exchange approximation the double differential cross-section for lepton-nucleon scattering can be written as

$$\frac{d^2\sigma_{1\gamma}}{d(Q^{-2})d(lnx)} = 4\pi\alpha_{em}^2 F_2(x,Q^2)[1 - y - \frac{Mxy}{2E} + \frac{y^2(1+4M^2x^2/Q^2)}{2(1+R(x,Q^2))}] \qquad (1)$$

where E is the incoming lepton energy, M is the target mass, and $-Q^2$ is the square of the 4-momentum transferred from the lepton. In the lab frame ν is the lepton energy loss, $x = Q^2/2M\nu$ is the Bjorken scaling variable, and $y = \nu/E$.

In order to extract the structure function F_2 from the measured total cross-section, radiative corrections are calculated by the computer program FERRAD35[1] according to the formulation of Mo and Tsai.[2] The input F_2 is constructed from published fits to data and the low Q^2 interpolation at high W^2 of Donnachie and Landshoff.[3] R is taken as R_{slac}.[4]

The data presented here were collected during the 1991 run of Fermilab experiment E665. The experimental apparatus is described in ([5]) . A muon beam with average energy of 465 GeV impinged on cryogenic liquid H_2 and D_2 targets and on an evacuated vessel. The targets were cycled $\sim$ once/minute to reduce systematic uncertainty in the ratio measurement.

2. F_2^p and F_2^d

The behavior of the structure function F_2 is expected to be different in the small and large Q^2 limits. For $Q^2 \to \infty$ (Deep Inelastic Scattering - DIS), one expects

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scattering off point-like partons to dominate the total cross-section. Hence F_2 almost scales with x_{Bj} having only a logarithmic Q^2 dependence due to QCD radiative effects. For $Q^2 \to 0$ one expects the virtual photon cross-section to tend to the real photoproduction cross-section $\sigma_{\gamma N}$. Due to gauge invariance, $\lim_{Q^2 \to 0} F_2 = \frac{\sigma_{\gamma N} Q^2}{4\pi^2 \alpha}$. For point-like scattering one would expect $\sigma_{\gamma N}$ to vary as inverse square of energy. However $\sigma_{\gamma N}$ is measured to have a weak increase with energy at high energy, indicating a different scattering mechanism. The measurement of F_2 at low and high Q^2 helps to understand the transition between the dynamics of DIS and the real photoproduction limit.

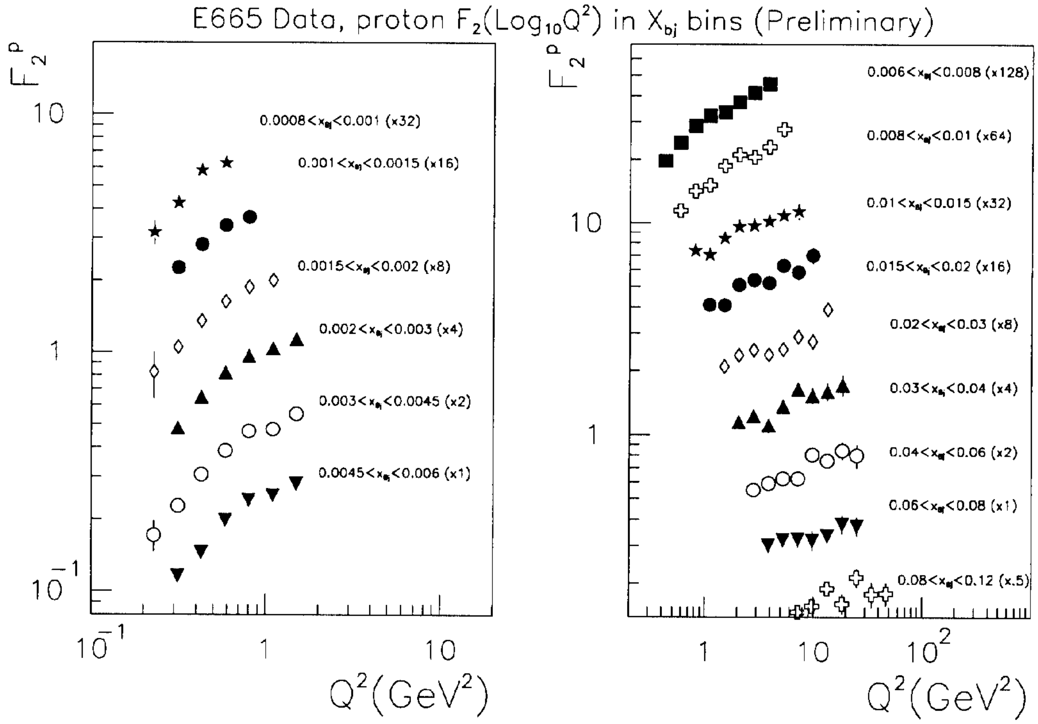

Fig. 1. F_2^p as a function of Q^2 in x_{Bj} bins. The errors shown are statistical only.

The muon small angle trigger (SAT) events were used for the F_2 measurement and the following kinematic cuts were made: $350 < E_{beam} < 600$ GeV, $\nu > 25$ GeV and $E_{scat\mu} > 80$ GeV. The sample consists of 664 nb^{-1} of μp and 749 nb^{-1} of μd data. The F_2 results for the proton are shown in Fig. 1 . The systematic uncertainty is of the order of 10-20% and is dominated by the level of knowledge of the reconstruction efficiency of the scattered muon. The results for the deuteron F_2 are similar. The results are preliminary and the systematic uncertainty is expected to reduce as the analysis progresses.

The measurement covers the range $8 \times 10^{-4} < x_{Bj} < 0.12$ and $Q^2 > 0.2$ GeV^2. The x_{Bj} values are comparable to those obtained at HERA and extend to lower values than those achieved at previous fixed target experiments. The Q^2 range extends from the regime of perturbative QCD at high Q^2 down to low Q^2 values where F_2 has a strong Q^2 dependence approaching the photoproduction limit.

3. F_2^n/F_2^p

For the extraction of the ratio the following cuts are made on the H_2 and D_2 data samples: $0.1 < y_{Bj} < 0.8$, $\nu > 40$ GeV, $\delta\nu/\nu < 0.3$, $Q^2 > 0.1$ GeV^2 (SAT) or $Q^2 > 0.001$ GeV^2 (Calorimeter trigger), and 350 GeV $< E_{beam} <$ 600 GeV. The neutron cross-section is assumed to be the difference of the deuteron and the proton cross-sections. Three different methods are used to extract the structure function ratio, each method giving the best result in a different range of x_{Bj}. The ratio σ_n/σ_p (which is equal to F_2^n/F_2^p if $R^n = R^p$ ([4])) is shown in Fig. 2 for the three techniques, each being shown where it has the smallest systematic error. The total systematic uncertainty is less than 3.5%, including uncertainties in the relative normalization, trigger acceptance and the effect of analysis cuts.

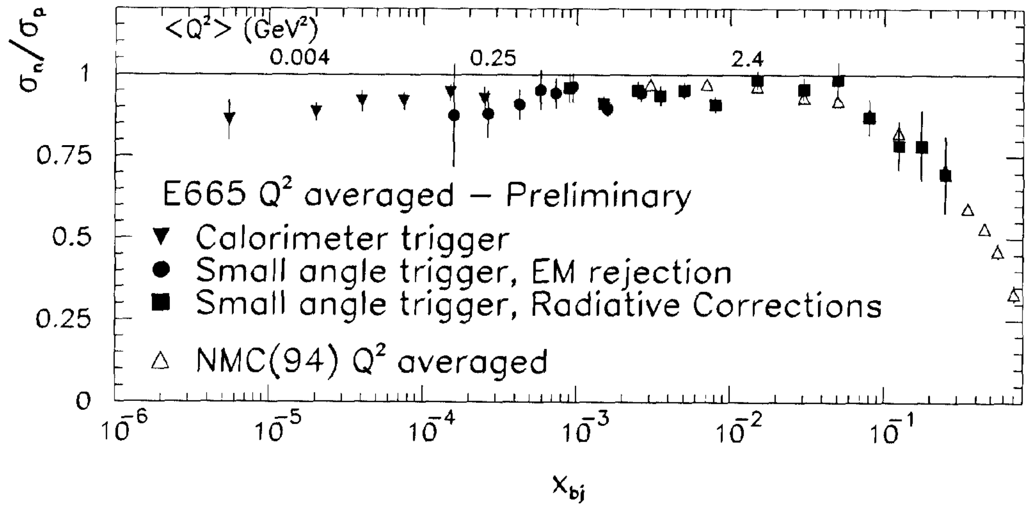

Fig. 2. σ_n/σ_p as a function of x_{Bj} . The errors shown are statistical only. Also shown are results from the CERN NMC experiment (CERN-PPE/94-32).

The cross-section ratio is presented at the average Q^2 of each x_{Bj} bin. There is good agreement with NMC in the region of overlap, while the E665 measurement extends three decades lower in x_{Bj}.

The average value of the ratio is $\sim 0.94 \pm 0.01$(stat)± 0.035(syst) for $x_{Bj} < 0.05$. This may be due to shadowing in the deuteron. Using model calculations of shadowing[6] to correct the deuteron data can reduce the Gottfried sum by 10-15%. The measurement may also be interpreted as a difference in the proton and neutron structure functions. If this is the case then, using the measured Q^2 dependence to extrapolate the ratio to $Q^2 = 4$ GeV^2, the Gottfried sum will increase by ~ 0.05 per decade in x_{Bj}.

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