The Structure Function Ratio F_2^{Sn}/F_2^C

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Abstract

Results on the structure function ratio F_2^{Sn}/F_2^C measured in deep inelastic muon scattering are presented. Three different beam energies and very high statistics allow a detailled study of the Q^2-dependence of the structure function ratio. In the range $0.01 < x < 0.05$ a significant positive Q^2-dependence is observed. We also present results on the difference of the second structure functions $\Delta R = R^{Sn} - R^C$.

Résumé

Ici sont présentés des résultats du rapport des fonctions de structure F_2^{Sn}/F_2^C. Trois énergies de faisceau différentes et une statistique très grande rendent possible une étude détaillée de la dépendence en Q^2 de ce rapport des fonctions de structure. Dans le domaine $0.01 < x < 0.05$ une dépendence significativement positive est observée. Nous présentons aussi des résultats de la différence des deuxièmes fonctions de structure $\Delta R = R^{Sn} - R^C$.

1. Introduction

Nuclear effects in structure funtions were for the first time observed by the EMC in the comparison of the structure functions of deuterium and iron (EMC-effect) [1]. This caused great theoretical activity, and experimental efforts have been made to extend the kinematic range and to reduce the errors (for a review see [2]). The most precise data on nuclear shadowing were taken by the NMC (CERN-NA37) and can be found in [3], where at large values of x the SLAC data give the best information on nulear structure functions [4].

It has always been an open question, if there is a Q^2-dependence in the nuclear effects. In order to clarify this point the NMC has carried out dedicated measurements on tin and carbon at different beam energies with very high statistics.

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2. Determination of Structure Function Ratios

2.1. Cross Section and Structure Functions

In deep inelastic scattering of a charged lepton on a nucleus the differential cross section for the one-photon-exchange can be written in terms of two structure functions $F_2(x, Q^2)$ and $R(x, Q^2)$:

$$\frac{d^2\sigma(x,q^2)}{dxdQ^2} = \frac{4\pi\alpha^2}{Q^4}\frac{F_2(x,Q^2)}{x} \left\{1 - y - \frac{Q^2}{4E^2} + \frac{y^2 + Q^2/E^2}{2(1+R(x,Q^2))}\right\}, \quad (1)$$

where $F_2(x, Q^2)$ is the nucleon structure function and $R(x, Q^2)$ is the ratio of longitudinally to transversely polarised virtual photon absorption cross sections. The two scaling variables are defined as $x = Q^2/2M\nu$ and

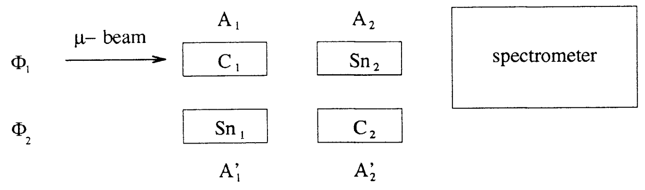

Figure 1. *The principle of the complementary target setup. A target row is exposed to an integrated muon flux Φ; for a target position the spectrometer has the acceptance A.*

$y = \nu/E$ with the energy of the incident lepton E, the four-momentum transfer squared Q^2 and the proton mass M.

2.2. The Experiment

The experiment was performed with an upgraded version of the EMC spectrometer [5] using the CERN SPS muon beam M2. The muon kinematic is measured by segmented szintillators and a magnet before the targets and with an analysing magnet and sets of wire chambers after the targets. The muon is identified behind a thick iron absorber wall.

Additionally the open forward spectrometer was equiped with a target calorimeter, which absorbed all the hadrons from the deep inelastic events and thus decoupled the spectrometer from the hadronic final state. The energy deposited in the calorimeter was used as a trigger information. The target calorimeter enabled the installation of very thick targets (in total 600 g/cm^2) and the use of a high beam intensity to achieve a very high statistics.

2.3. The Complementary Target Setup

The most effective developement to reduce the systematic error of the structure function ratios was the use of a complementary target setup, where two rows of targets were exposed to the beam alternately. Both materials were always in the beam, but in the second row the positions of the materials were interchanged compared to the first row (see figure 1).

The number of events in the first carbon target can be written as :

$$N_{C_1} = \sigma_C \; A_1 \; \Phi_1 \; M_{C_1}, \tag{2}$$

with the cross section for carbon σ_C, the acceptance of the spectrometer for this target A_1, the incident muon flux for the first target row Φ_1 and the number of nuleons in the target M_{C_1}. If we asume that the acceptance does not depend on the target row ($A_i = A'_i$), the expression

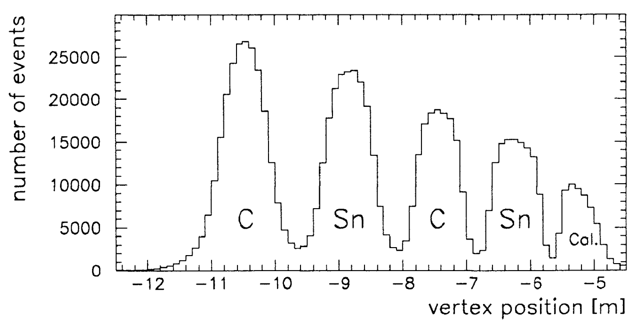

Figure 2. *Vertex distribution of the first target row at a beam energy of 200 GeV.*

for the cross section ratio is:

$$\frac{\sigma_{Sn}}{\sigma_C} = \sqrt{\frac{N_{Sn_1} N_{Sn_2}}{N_{C_1} N_{C_2}} \; \frac{M_{C_1} M_{C_2}}{M_{Sn_1} M_{Sn_2}}} \,. \tag{3}$$

Flux and acceptance cancel in the expression for the cross section ratio, and only the reconstructed vertices have to be counted in the targets.

As a crosscheck one can also define a flux ratio, which must not depend on kinematic variables:

$$\frac{\Phi_1}{\Phi_2} = \sqrt{\frac{N_{C_1} N_{Sn_2}}{N_{Sn_1} N_{C_2}} \; \frac{M_{Sn_1} M_{C_2}}{M_{C_1} M_{Sn_2}}} = const.\,(x, Q^2, \nu, \ldots)\,. \tag{4}$$

To determine the structure function ratio from the measured cross section ratio higher order electro-weak effects are taken into account. These well known corrections are important at low x and reduce the ratio by 40% at $x = 10^{-2}$. Additionally we use the asumption that the second structure function R does not depend on the target material, which is supported by measurements of NMC and SLAC. To correct for the nonisoscalarity of the tin nucleus (neutron excess) a parametrization of the ratio F_2^n/F_2^p measured by NMC is used [6].

2.4. Vertex Distributions

In figure 2 an example of a vertex distribution is shown. We can see the four targets and a contribution from the target calorimeter. ¿From this plot it is clear, that a vertex cannot be located unambigiously in a certain target. More strict kinematic cuts help to reduce, but not to eliminate this problem.

A detailled monte carlo simulation of the experiment (MC) was done to determine the number of wrongly reconstructed events. The MC includes all the material in the experiment and simulates the multiple scattering

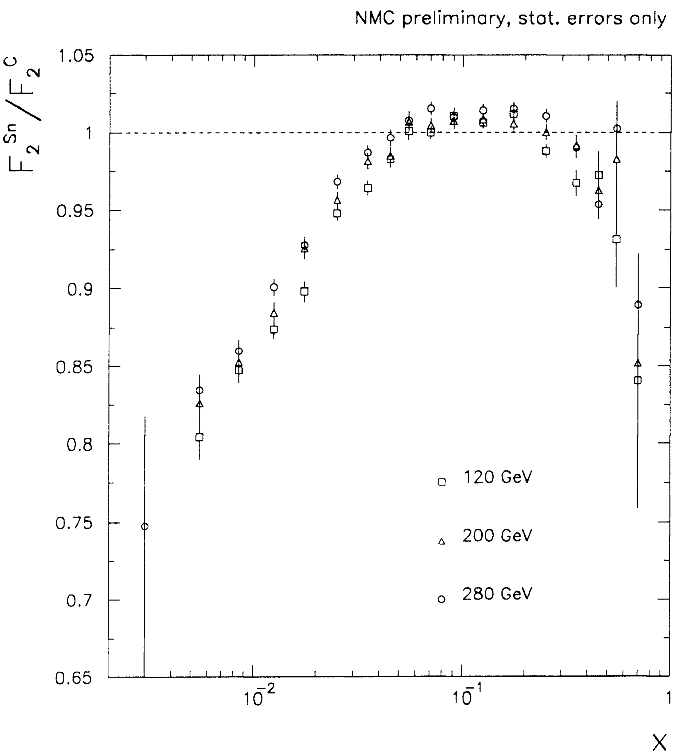

Figure 3. *The structure function ratio F_2^{Sn}/F_2^C for beam energies of 120, 200 and 280 GeV.*

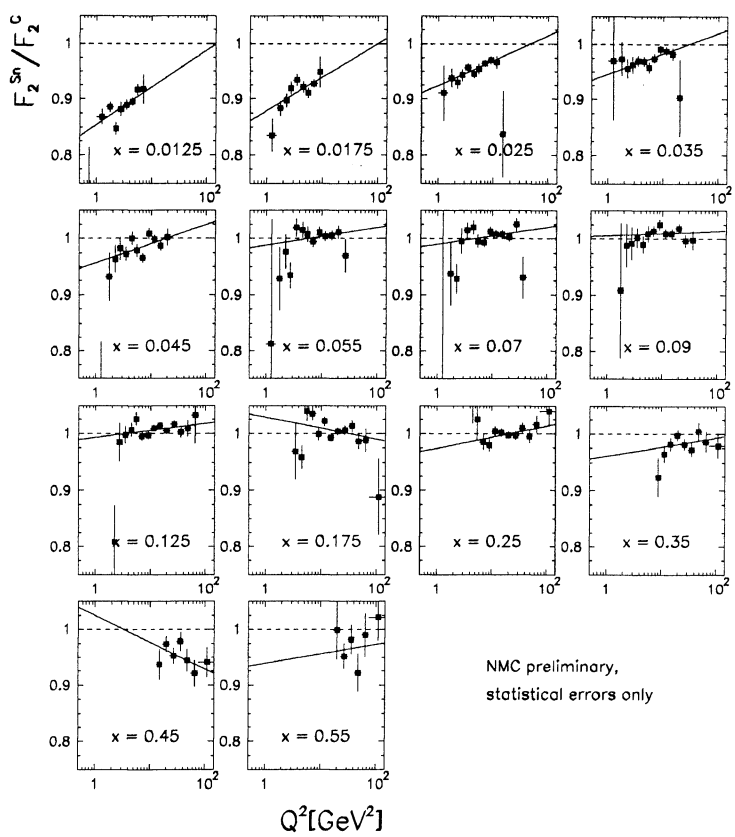

Figure 4. *The Structure Function Ratio F_2^{Sn}/F_2^C as a function of Q^2 in different x-bins together with a line fit in log Q^2. Data from the three beam energies are combined in this plot.*

and the energy loss of the muon, the trigger and all efficiencies of the wire chambers. The generated events were put in the same chain of reconstruction and analysis programs as the data. The MC gives a good description of the vertex distributions and all the kinematic distributions.

Three different beam energies (120, 200 and 280 GeV) have been analysed, and a correction derived from the MC has been applied to the structure function ratio. This correction includes both vertex and kinematic smearing and is small for intermediate and large x and grows with decreasing x; at $x = 10^{-2}$ it moves the ratio up by about 10%.

NOTE: The results presented in the following sections are still preliminary and include only statistical errors.

3. The Structure Function Ratio F_2^{Sn}/F_2^C

3.1. *The x-dependence of F_2^{Sn}/F_2^C*

The structure function ratio F_2^{Sn}/F_2^C as a function of x is plotted in figure 3 for the three different beam energies. Three regions can be distinguished: at low x the ratio is below unity *(shadowing)*, at medium x it is slightly above *(enhancement)*, and at large x we can see the ratio again below one *(EMC-effect)*.

Comparing data taken at the different energies, one observes an ordering in the shadowing region: the points at 280 GeV are always above the points at 200 GeV, and the lowest points were taken at a beam energy of 120 GeV. This indicates already a Q^2-dependence of F_2^{Sn}/F_2^C.

In the following sections we will limit the x-range to $x > 10^{-2}$. In this region we believe that systematic effects are not too big; a detailled determination of the systematic error has not yet been done.

3.2. *The Q^2-dependence of F_2^{Sn}/F_2^C*

In figure 4 the structure function ratio is plotted for fixed values of x as a function of Q^2 for the combined data set of the three energies. As a simple measure for the Q^2-dependence the data are parametrised by a line in log Q^2. The description of the data leads to typical χ^2 values between 0.7 and 1.5 with an average of 1.09.

If we plot the slopes of the lines as a function of x, we see significant positive slopes in the range of

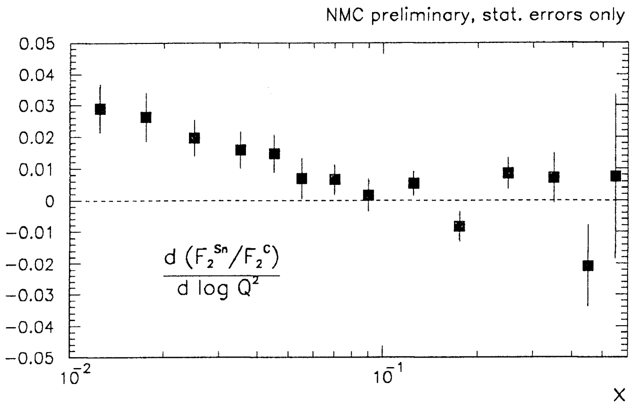

Figure 5. *The slopes of the line fits in log Q^2 as a function of x.*

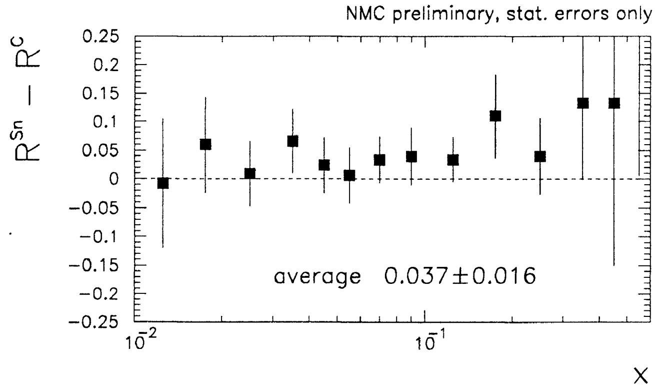

Figure 6. $\Delta R = R^{Sn} - R^C$ *as a function of x.*

$0.01 < x < 0.05$, whereas for larger x the slopes scatter around zero (figure 5). This is the first time that a significant Q^2-dependence in nulear structure function ratios is observed.

This result was checked with the flux ratio (equn. 4), which must not depend on the any kinematic variable, and indeed no significant slopes were found for the flux ratio. It was also compared with an earlier result, where a vertex smearing correction was not derived from a MC simulation but from data, where only the tin targets were exposed to the beam. This method does not include kinematic smearing and has a smaller kinematic range [7]. The slopes from both methods were found to be compatibel.

4. The Difference $\Delta R = R^{Sn} - R^C$

A possible difference in the the second structure funtion R for tin and carbon would influence the cross section ratio at high y (equn. 1). To be sensitive to ΔR it is essential to have at least two different beam energies in order to get data with different y at the same x and Q^2. For every x-bin we fit simultaneously the Q^2-dependence and ΔR to the cross section ratio. The method is described in detail in [8].

$R^{Sn} - R^C$ is compatibel with zero for all x-bins, but the average over all x is postive with a value of 0.037 ± 0.016 (figure 6). We get nearly the same result, if we also allow for a difference in higher twist in the two nuclei (0.031 ± 0.017).

This result is compatibel with earlier NMC results on $R^{Ca} - R^C$ [8] and a preliminary result on $R^D - R^p$ [9]. All results show a positive average, where the statistical precision for tin and carbon is as good as for deuterium and the proton and much better than for calcium and carbon.

5. Summary

Preliminary extremely precise results on the structure function ratio F_2^{Sn}/F_2^C taken at three different beam energies were presented. The ratio shows a positive Q^2-dependence for $0.01 < x < 0.05$. $R^{Sn} - R^C$ is close to zero for all x, but has a positive average of $< \Delta R >= 0.037 \pm 0.016$. The determination of the systematic error will possibly allow to extend the kinematic range down to $x \approx 0.005$.

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