PRECISE MEASUREMENT OF THE NUCLEAR DEPENDENCE OF STRUCTURE FUNCTIONS IN LIGHT ^{3}HE AND ^{4}HE

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The EMC effect has been with us for over 20 years. During this time, the nuclear dependence of the structure functions, and thus quark distributions, has been studied with much success. However, the bulk of the experimental effort has been to measure the effect in heavy nuclei where it has the same x dependence and differs only in magnitude. Calculations predict large differences in both the magnitude and x-dependence of the EMC effect in ^{3}He and ^{4}He and precise measurements of the EMC effect in these nuclei could be used to distinguish between existing models. To that end, E03-103 has performed the first measurement of the EMC effect on ^{3}He above $x > 0.4$, and improved upon the existing measurement of the effect on ^{4}He.

1. Introduction

The European Muon Collaboration (EMC) discovered in 1983 [1] that the structure function per nucleon measured in heavy nuclei differs from that measured in deuterium. Since then, significant experimental and theoretical effort has been expended in an effort to understand the, since dubbed, EMC effect. Although these gross features can be explained by different processes, no single picture has been able to describe the effect over all x. Furthermore, the experimental effort has focused primarily on A>4 nuclei. Data on few-body nuclei are scarce, but are crucial in order to form a complete picture of the effect. Few body nuclei can be compared to exact calculations, and therefore provide a crucial link between the nuclear structure of deuterium and nuclear matter.

2. Experimental Overview

The experiment was performed in Hall C at Jefferson Laboratory in Newport News, Virginia during the fall of 2004. The inclusive electron scattering cross sections were measured for several nuclei using a 5.8 GeV beam. The data cover $3.0 < Q^2 < 7.5$ (GeV/c)^2 and $7.0 > W^2 > 1.7$ (GeV/c^2)^2. Some of the data are, therefore, in the resonance region and care must be taken when comparing our results with data at higher Q^2. But it also provides a unique opportunity to study the Q^2 dependence of the EMC ratio and the structure functions in the resonance region. Electrons were detected with the High Momentum Spectrometer (HMS). The HMS has an angular acceptance of approximately 6-8 mStr, and an effective momentum bite of ±8%. The detector stack consists of two sets of drift chambers for tracking; four planes of scintillators which form the basis of the trigger; and a gas Čerenkov and lead-glass calorimeter for particle identification. Special efforts were made to reduce the systematic uncertainty, including dedicated target boiling studies, frequent beam-current monitor calibrations, and carbon data taken during both the helium and hydrogen runs in order to cross check the overall normalizations of the two data sets. In the end, we achieved statistical uncertainty of better than 1%, and systematic uncertainties on the order of 1-2% in the cross section ratio.

3. Results

The results for carbon, ^{3}He and ^{4}He are shown in Figs. 1-3. The data are presented with a parameterization from SLAC [4]. The data shown are for the highest Q^2 settings, the lowest of which is $Q^2 > 5.5$(GeV/c)^2 at the lowest W^2 shown 1.7 (GeV/c^2)^2. Inner error bars are statistical uncertainties and outer error bars are statistical and systematic error added in quadrature. In general, our data agree well with existing data. The agreement of the carbon data with higher Q^2 data from SLAC [4] and the lower Q^2 data from JLab [5] is a good indication of the Q^2 independence of the cross section ratio. The ratio for ^{4}He agrees well with the SLAC data, and also with the SLAC parameterization for A=12, indicating the effect is as strong as in carbon. The calculations shown are from Smirnov [7], and from Benhar based on Benhar *et al.* [6]. The ^{3}He data are shown as raw cross section ratios and as the cross section ratio corrected for proton excess. The correction for proton excess was computed using $F_2^n/F_2^p = 1 - 0.8x$ from SLAC data [10]. The interpretation of the ^{3}He data is presently limited by the uncertainty in this correction. Nevertheless, the effect in ^{3}He appears to be larger than predicted by the calculations of Smirnov [7] and Afnan [8].

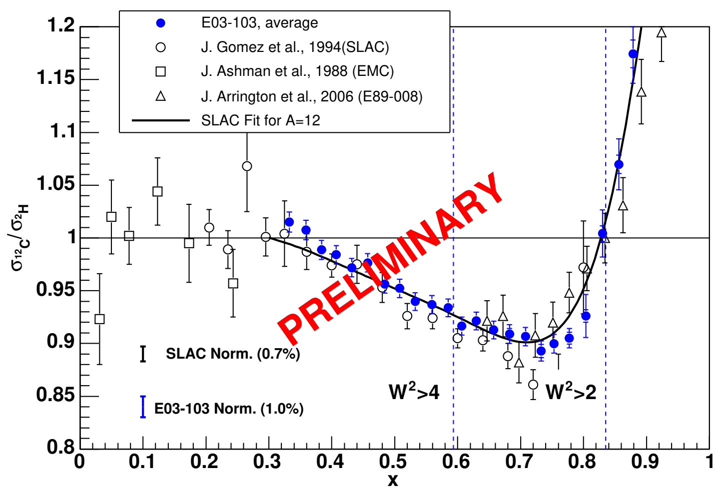

Figure 1. Cross section ratio for carbon. The agreement with both low and high Q^2 data shows the Q^2 independence of the ratio.

We have measured the EMC effect for a range of nuclei. These data provide the first measurement of the effect in ^{3}He above $x = 0.4$, and a significant improvement in the measurement of the effect in ^{4}He. The effect in ^{4}He is very similar to the effect in carbon, and the effect in ^{3}He appears to be larger than predicted.

References

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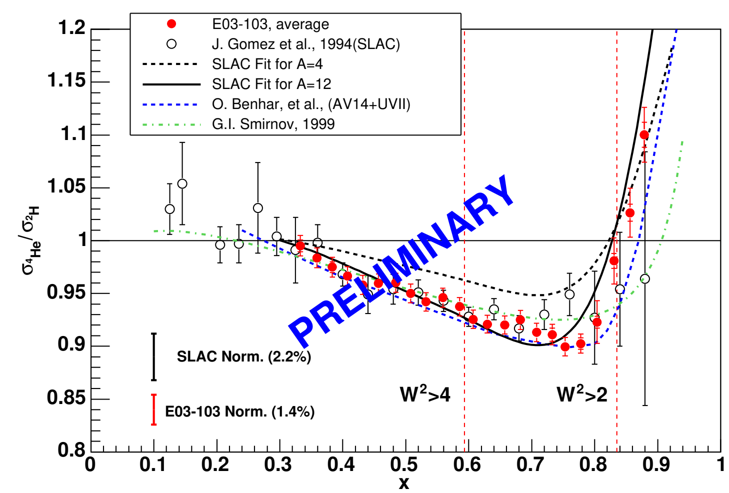

Figure 2. Cross section ratio for ^{4}He. The effect is as strong as in carbon, indicating that the effect may depend on nucleon number density

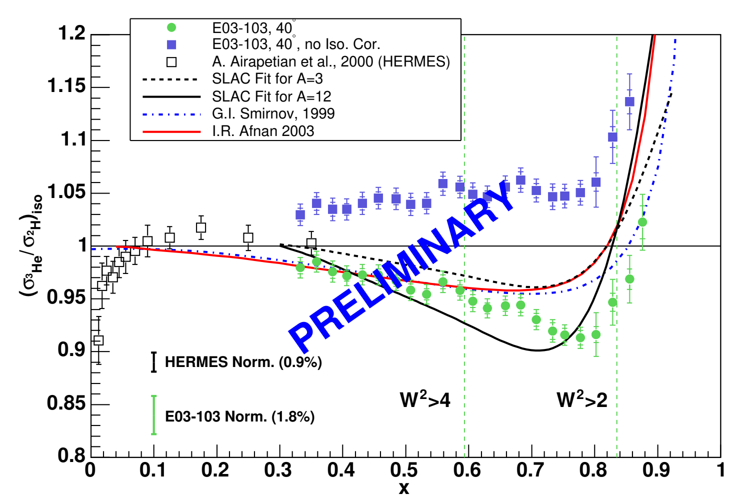

Figure 3. Cross section ratio for ^{3}He. Both the raw cross section ratio and the isoscaler corrected ratio are shown in order to show the size of the isoscaler correction.