

NUCLEON MOMENTUM DISTRIBUTIONS FROM A MODIFIED SCALING ANALYSIS OF INCLUSIVE ELECTRON-NUCLEUS SCATTERING.

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Inclusive electron scattering from nuclei at low momentum transfer (corresponding to $x \geq 1$) and moderate Q^2 is dominated by quasifree scattering from nucleons. In the impulse approximation, the cross section can be directly connected to the nucleon momentum distribution via the scaling function $F(y)$. The breakdown of the y -scaling assumptions in certain kinematic regions have prevented extraction of nucleon momentum distributions from such a scaling analysis. With a slight modification to the y -scaling assumptions, it is found that scaling functions can be extracted which are consistent with the expectations for the nucleon momentum distributions.

Quasielastic (QE) electron scattering can provide important information about the distribution of nucleons in nuclei. With simple assumptions about the reaction mechanism, functions can be deduced that should scale (*i.e.* become independent of momentum transfer), and which are directly related to the nucleon momentum distribution. The concept of y -scaling of the quasielastic response was first proposed¹ in 1975. It was shown that in the plane wave impulse approximation (PWIA) a scaling function, $F(y)$, could be extracted from the inclusive cross section which was related to the nucleon momentum distribution. In the simplest approximation, the scaling variable y is the initial momentum of the struck nucleon along the direction of the virtual photon. We determine y from energy conservation assuming a spectator model of the interaction and neglecting the transverse momentum of the struck nucleon:

$$\nu + M_A = \sqrt{M_N^2 + (y + q)^2} + \sqrt{M_{A-1}^2 + y^2}, \quad (1)$$

where M_A is the mass of the target nucleus and M_{A-1} is the ground state mass of the $A - 1$ nucleus (assumed to be in an unexcited state).

Measurements of inclusive electron-nucleus scattering from deuterium and heavy nuclei at $x > 1$ have been performed² at JLab up to $Q^2 \approx 7 \text{ GeV}^2$. At low Q^2 values the scaling function depends strongly on Q^2 due to final state interactions (FSIs). As these FSIs become small the extracted scaling function becomes nearly independent of Q^2 and depends only on y , as predicted in the y -scaling picture. However, while the data show scaling in y , this by itself does not ensure that the scaling function is connected to the momentum

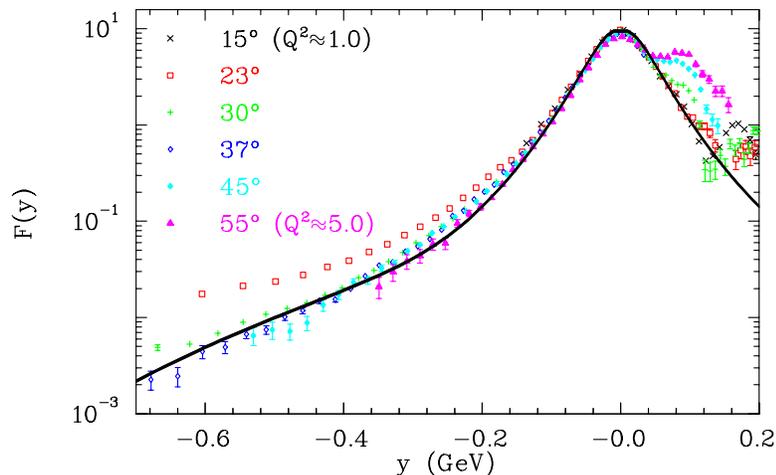


Figure 1. Scaling function $F(y)$ for deuterium from E89-008 for scattering angles between 15 and 55 degrees, after subtracting a model of the inelastic contributions (large for $y > 0$, generally negligible for $y < 0$). Errors shown are statistical only. The solid line represents the expected $F(y)$ based on a calculation of the deuteron momentum distribution using the Av14 NN potential.

distribution. We present here an attempt to test the assumptions of the scaling analysis and the extraction of the nucleon momentum distributions.

Figure 1 shows $F(y)$ for deuterium, as extracted from the cross sections measured in E89-008². As the momentum distribution is related to the derivative of $F(y)$, the lack of high precision data on deuterium at large $|y|$ makes it difficult to directly extract the momentum distribution from this data. We can, however, compare the scaling function to what we expect based on a calculation of the deuteron momentum distribution. The solid line is a calculation of $F(y)$ using a momentum distribution calculated from the Argonne-v14 N-N potential. The normalization of the scaling function extracted from the data is consistent with unity (as it must be if it is related to the momentum distribution) and the distribution is in generally good agreement with the calculation. In particular, they are in very good agreement at very large values of the nucleon momentum, (y). This region is especially important because these high momentum components are generated by short range interactions of the nucleons. It has been suggested that final state interactions in this region, where the nucleons are close together, may not disappear as Q^2 increases. If there were large final state interactions that were nearly independent of Q^2 ,

one might see scaling but the scaling function would not yield the proper momentum distribution in the tails. The data from deuterium indicate that such Q^2 -independent FSIs are small or absent, although higher precision data at high Q^2 and large $|y|$ would allow a much stronger limit to be set.

While the y -scaling analysis of the deuterium data appears to yield the correct deuteron momentum distribution, this is not the case for the heavier nuclei. The momentum distribution extracted from $F(y)$ for heavy nuclei falls off much more rapidly at large y , indicating that the high momentum components in heavy nuclei are much smaller than in deuterium, which is the opposite of what one might expect. In addition, the normalizations of the scaling functions for heavy nuclei are ~ 20 - 30% lower than they should be if $F(y)$ is related to the nucleon momentum distribution. These problems indicate that there is a failure of some kind in the scaling analysis for heavy nuclei. The breakdown for $A > 2$ nuclei comes from the assumption that the residual $(A - 1)$ nucleus remains in an unexcited state. This is a reasonable approximation when removing a single nucleon from a shell at low missing energy. However, the high momentum nucleons are predominantly generated by short range correlations, meaning that the momentum of the struck nucleon is mostly balanced by a single nucleon, leaving a high momentum nucleon in the residual nucleus. In the following analysis, we take this into account by assuming a simple three-body breakup of the nucleus, where the struck nucleon is assumed to be one of a correlated pair of nucleons moving within the residual $(A - 2)$ nucleus. The scaling variable in this case is $y^* = k + K_{2N}/2$, where y^* is the total momentum of the struck nucleon, coming from the relative momentum of the two correlated nucleons, k , and the momentum of the pair within the residual nucleus, K_{2N} .

Figure 2 shows $F(y^*)$ from iron, along with the fit to the deuterium scaling function (note that for deuterium there is no $(A - 2)$ residual nucleus, so $y^* = y$). The high momentum behavior is identical for deuterium and heavy nuclei (carbon, iron, and gold), indicating that the two-nucleon correlations that dominate in deuterium are the main source of high momentum components in heavy nuclei. Using the modified scaling variable, the normalization of $F(y^*)$ is also consistent with unity, as it should be if the scaling function is related to the nucleon momentum distribution.

While this data indicates that the modified scaling analysis is valid and allows extraction of the nuclear momentum distributions, the data at large nucleon momentum is somewhat limited, especially for few-body nuclei where the extracted distributions can be compared to essentially exact calculations of nuclear structure. Future measurements are planned with 6 GeV beam³ which will significantly increase the amount of data in the scaling region at

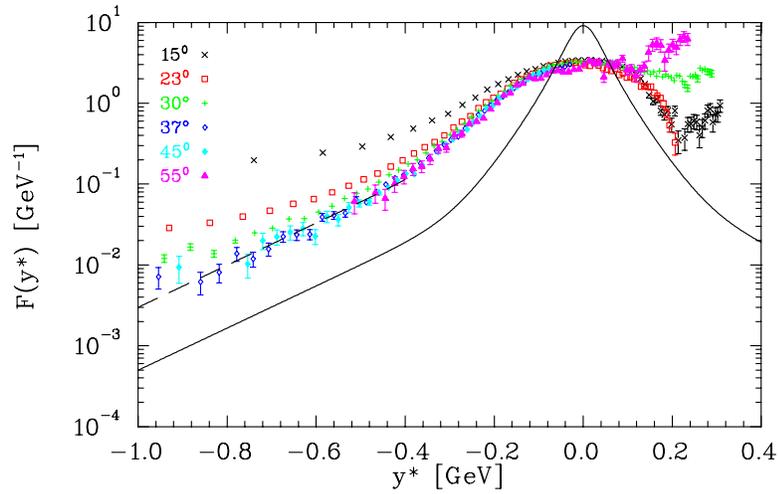


Figure 2. Scaling function $F(y^*)$ for iron from E89-008, after subtracting a model of the inelastic contributions which dominate for $y > 0$. The solid line is a fit to the measured $F(y^*)$ for deuteron. The dashed line is the tail of the deuteron fit, scaled up by a factor of six.

large nucleon momenta. This data will significantly improve the data at large $|y|$ and Q^2 , and will include measurement on ${}^3\text{He}$ and ${}^4\text{He}$. We can then use this to extract information on the momentum distributions in heavy nuclei, and study in more detail the nature of their short range correlations.

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References

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