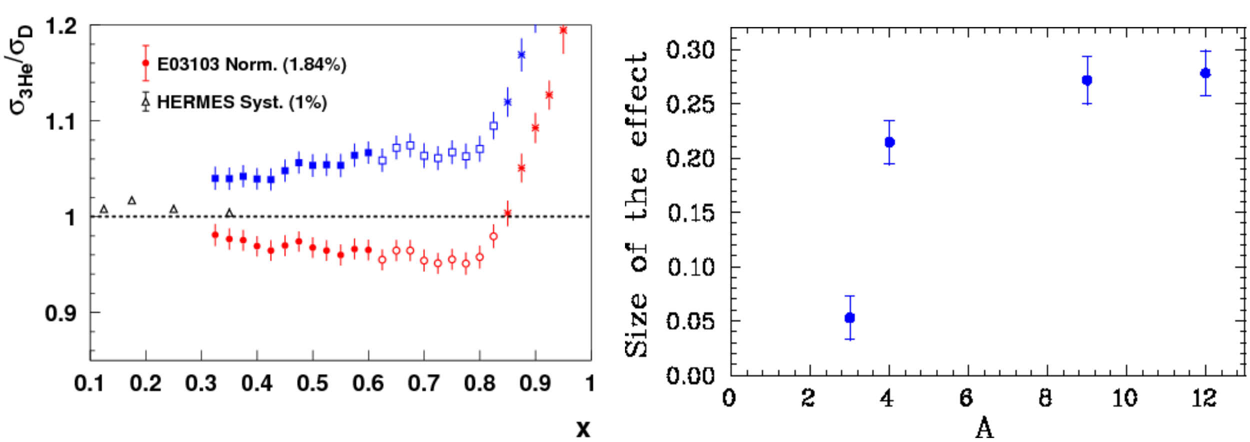
Density dependence of the quark structure of nuclei

Measurements of structure functions in nuclei have shown a clear difference in the quark distributions in heavy nuclei compared to deuterium, referred to as the EMC effect. The difficulty involved in modeling these complex heavy nuclei has limited our ability to make quantitative conclusions about the origin of these differences. It has been impossible to determine if the modification scales with the mass or average density of the nucleus, and it is still unclear how much of the effect is the result of binding nucleons in nuclei, and how much is a due to modification of the intrinsic quark sub-structure of the nucleons themselves.

The Argonne MEP group proposed and executed JLab experiment E03-103, a clean and precise measurement of the structure functions of very light nuclei. These data allow for direct comparisons to reliable few-body calculations, bridging the gap between measurements on complex nuclei and new but model-dependent attempts to isolate modification to nucleon structure. We find that the EMC effect is similar for ^{4}He and ^{12}C, but much smaller for ^{3}He. The very large difference between ^{3}He and ^{4}He rules out the mass-dependent fit used to describe previous data, and favors the density-dependent description. While the comparison of ^{3}He and ^{4}He was the main motivation, there have been two other significant and unexpected results. First, the unusual structure of ^{9}Be, essentially two alpha-like clusters and an additional neutron, provides a unique test on the scaling of the EMC effect. The orbiting clusters yield a large radius and an anomalously low *average* density, even though most nucleons are contained within the high *local* densities of the alpha clusters. The large EMC effect for ^{9}Be provides the first evidence that it is the *local* density that determines the impact of the nuclear environment. [J.Arrington, arXiv:nucl-ex/0701017; Publication for Phys. Rev. Lett. in preparation]



Left: Preliminary ^{3}He to ^{2}H cross sections ratios before (top) and after (bottom) correction for the proton excess, compared to previous data from HERMES. Right: Size of the modification, as determined by the x-dependence for 0.3<x<0.75, vs. A for light nuclei.

In addition, one can see that there is a large correction applied to ^{3}He to account for the imbalance between the number of protons and neutrons. This correction is also important for heavy nuclei and depends on the neutron to proton cross section ratio for the nucleus of interest. Previous results used the ratio for free nucleons, and we find a substantially different correction using an updated analysis of the neutron structure function, performed in collaboration with the ANL theory group, and taking cross sections for nucleons embedded in the target nucleus [J. Arrington, F. Coester, R. J. Holt, and T.-S. H. Lee, arXiv:0805.3116, submitted to J. Phys. G]. This improved correction, as well as previously neglected Coulomb distortion effects, are being applied to these data and our results for heavier nuclei, and will yield significant modifications to the extrapolation to the effects in nuclear matter.

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