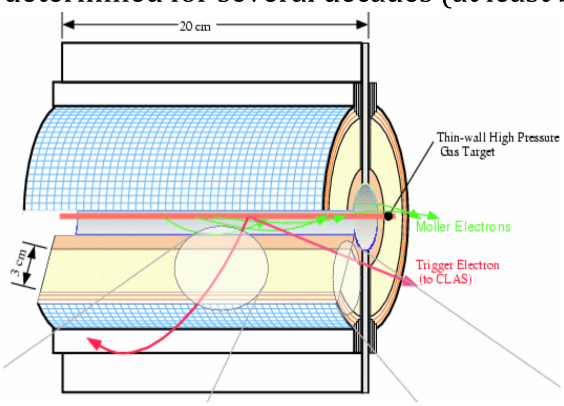
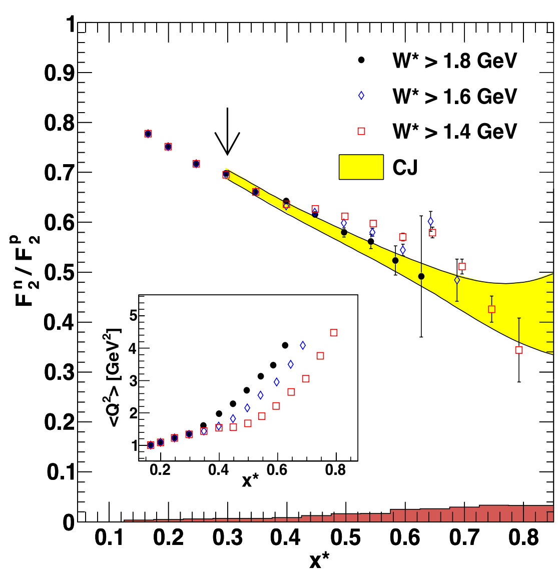
Neutron Structure With BoNuS

While much is known about how quarks and gluons make up a proton, the analogous structure of its sibling, the neutron, is not as well studied. This is especially true when we focus on the three valence quarks that are responsible for most of the properties of these two nucleons, including their charge and their excited states (nucleon resonances). The usual method to study these quarks is by scattering electrons from nucleons at rest - something easily done with protons since they form the stable nuclei of hydrogen atoms. However, neutron structure information has to be inferred from experiments on composite nuclei such as deuterium (a nucleus containing one proton and one neutron). Unfortunately, the uncertainties from nuclear binding corrections in deuterium become large in the region most dominated by valence quarks, so that their properties in the neutron have remained largely undetermined for several decades (at least beyond a momentum fraction of $x \sim 0.6$).



A new experiment (dubbed "BoNuS") with CLAS at Jefferson Lab and a novel recoil detector (a "Radial Time Projection Chamber" – see Figure to the left) has greatly reduced these nuclear model uncertainties [N. Baillie et al., PRL **108**, 142001 (2012)]. BoNuS has looked, for the first time, for the slow "spectator" protons that are liberated from deuterium nuclei when electrons scatter from their nearly free neutron partners. That way, only neutrons that are relatively unencumbered by strong binding effects contribute to the measured signal. In addition, one can correct for the kinematic "smearing" due to the motion of nucleons inside nuclei that washes out the signal in traditional inclusive scattering experiments on deuterium.



Indeed, the results reveal clear peaks in the scattered electron spectrum, corresponding to neutron resonance excitations, which have never been observed directly before. The experiment also provided the first model-independent information on the ratio of neutron to proton structure functions, F_{2n}/F_{2p}, over the range $0.2 < x < 0.8$ (see Figure to the right). These structure functions tell us how likely it is to find quarks with these high momentum fractions in either nucleon. Ultimately, the continuation of "BoNuS" with the upgraded 12 GeV CEBAF will complete our understanding of the fastest quarks in the nucleon.