Measuring Quasi-Elastic e-n & e-p Scattering from Deuterium

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Form Factors at Jefferson Lab

The goal of Jefferson Lab (JLab) is to understand how quarks and gluons form nucleons and nuclei. To reach this goal, JLab is undergoing an upgrade that will double the beam energy to 12 GeV and upgrade the CLAS12 detector in Hall B. We are currently developing algorithms to extract the relative amounts of electron-neutron (e-n) to electron-proton (e-p) scattering events from deuterium in quasi-elastic (QE) kinematics for an approved experiment with the CLAS12 detector. The goal is to find a ratio between e-n events and e-p events to calculate the magnetic form factor of a neutron, G_M^n. Our analysis will focus on selecting QE events by searching for neutrons and protons near predicted positions, and by looking at the angle between the 3-momentum transfer and the measured direction, which we will call θ_{pq}.

The CLAS12 Detector

- CLAS12 (Figure 1) is a large-acceptance spectrometer that takes data over a large solid angle.
- CLAS12 is constructed of forward and central detectors made of layers of gas, scintillator, and silicon that measure the trajectory of reaction products.

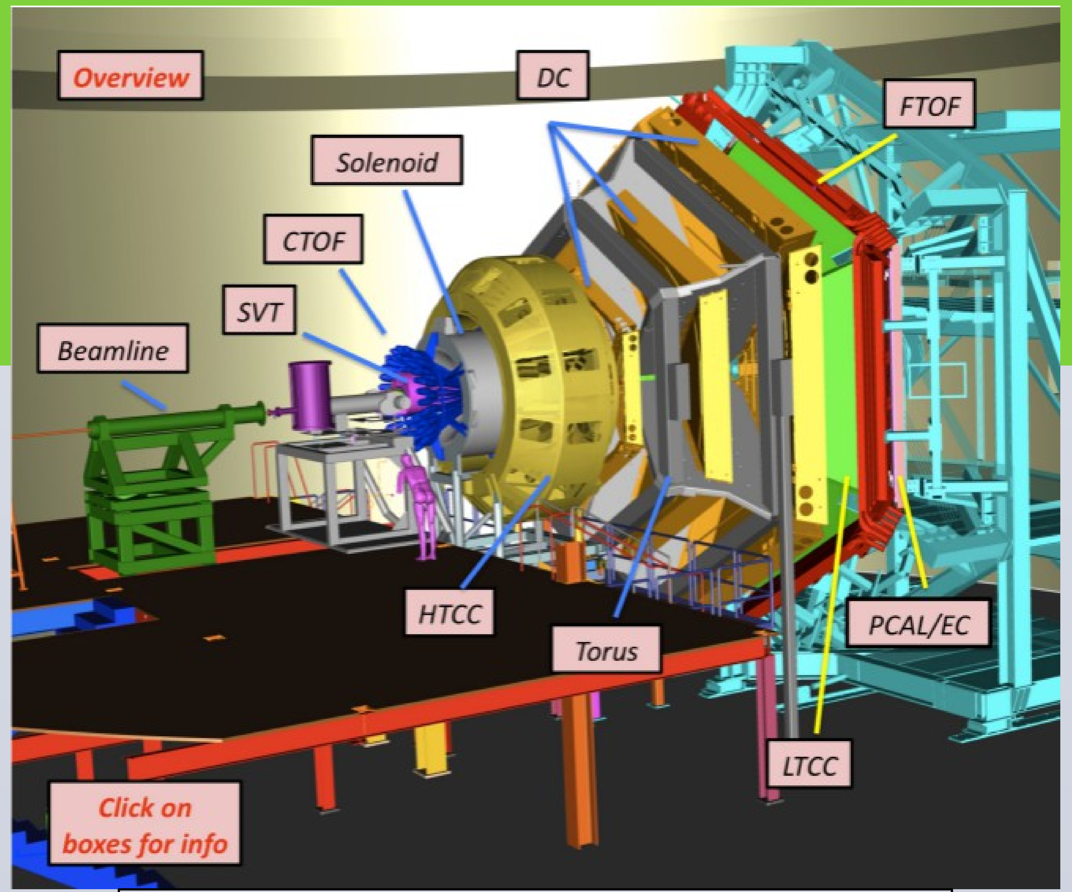


Figure 1. Computer designed image of CLAS12

- The pre-shower and electromagnetic calorimeter (PCAL/EC) is used to reconstruct the shower of particles to locate electrons, protons, and neutrons.
- The torus is used to generate a toroidal magnetic field to measure the momentum of charged particles.
- The Forward Time-of-Flight (FTOF) system consists of plastic scintillator paddles to measure TOF of charged particles. We also use it to detect neutrons.

Neutron Detection

Neutron detection is more difficult then proton detection. The PCAL/EC consists of triangles (Figure 2) composed of alternating layers of scintillator and lead, each layer divided into parallel strips that form the triangular shape of each sector. The strips are rotated 120° within each of the three layers (Figure 3).

Figure 2. EC being installed into the CLAS12 Detector at Hall B, JLab

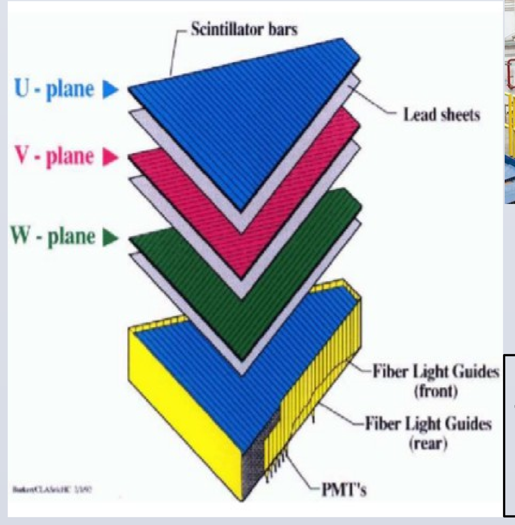
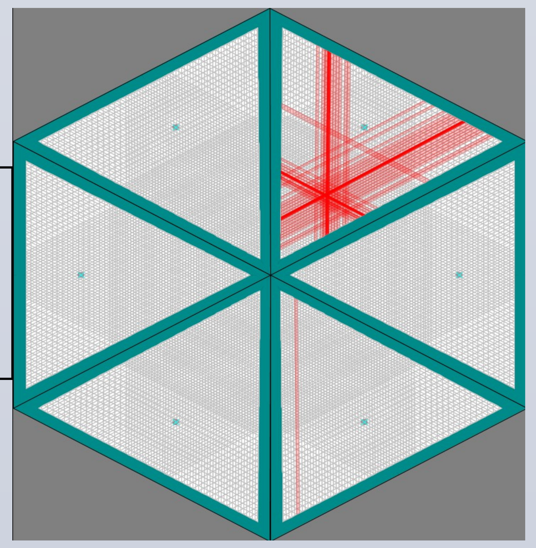


Figure 3. Expanded views of the EC showing lead and scintillator layers.

The particles produce light that is collected by a photo multiplier tube (PMT) and triangulated to find it's position (Figure 4).

Figure 4. Cross sectional view of PCAL showing triangulation of strips to locate a particle.



Simulating e-n & e-p Events

We have been developing algorithms to study e-n and e-p QE events in CLAS12. Eventually, we will use data from JLab, but as a first step we used an existing quasi-elastic event generator (QUEEG) and the CLAS12, physics-based simulation *gemc* to simulate e-n and e-p events. We are using the CLAS12 Java-based common software tools. The procedure is as follows:

1. Generate quasi-elastic e-n and e-p 4-momentum vectors from QUEEG.
2. Pass the events through the Monte Carlo code *gemc* to simulate the CLAS12 response.
3. Reconstruct the QE events using CLAS12 Common Tools.
4. Use electron information to calculate a predicted neutron and proton 3-momentum.
5. Swim each particle track to see if it hit the PCAL/EC or FTOF. If so, count as reconstructed, otherwise discard (Figures 5&6).
6. Look for a PCAL/EC or FTOF hit within an angle of 1.5° to the predicted location relative to the track vertex.
7. If there is a hit then count either the proton or neutron as a found particle.

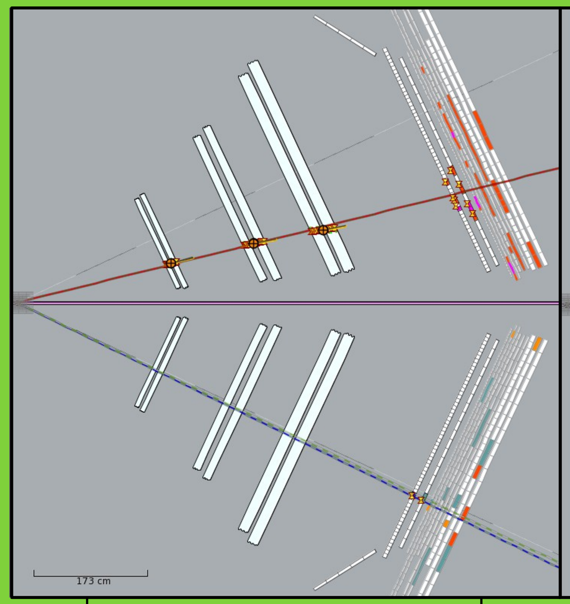


Figure 5. Simulation of found neutron hitting PCAL/EC

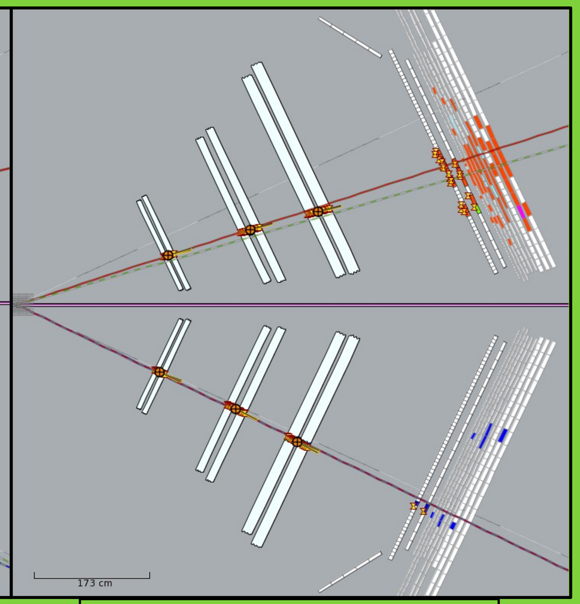


Figure 6. Simulation of found proton through FTOF

Results

We have completed writing the code to apply the algorithm above and are now testing. Figure 7-1 shows the distribution of events in θ_{pq}. It peaks near zero as expected with a large-angle tail. As Q^2 (4-momentum transfer) increases we expect the width of the distribution to shrink.

Figure 7-2 demonstrates this, where we required $Q^2 > 6$ (GeV/c^2)^2.

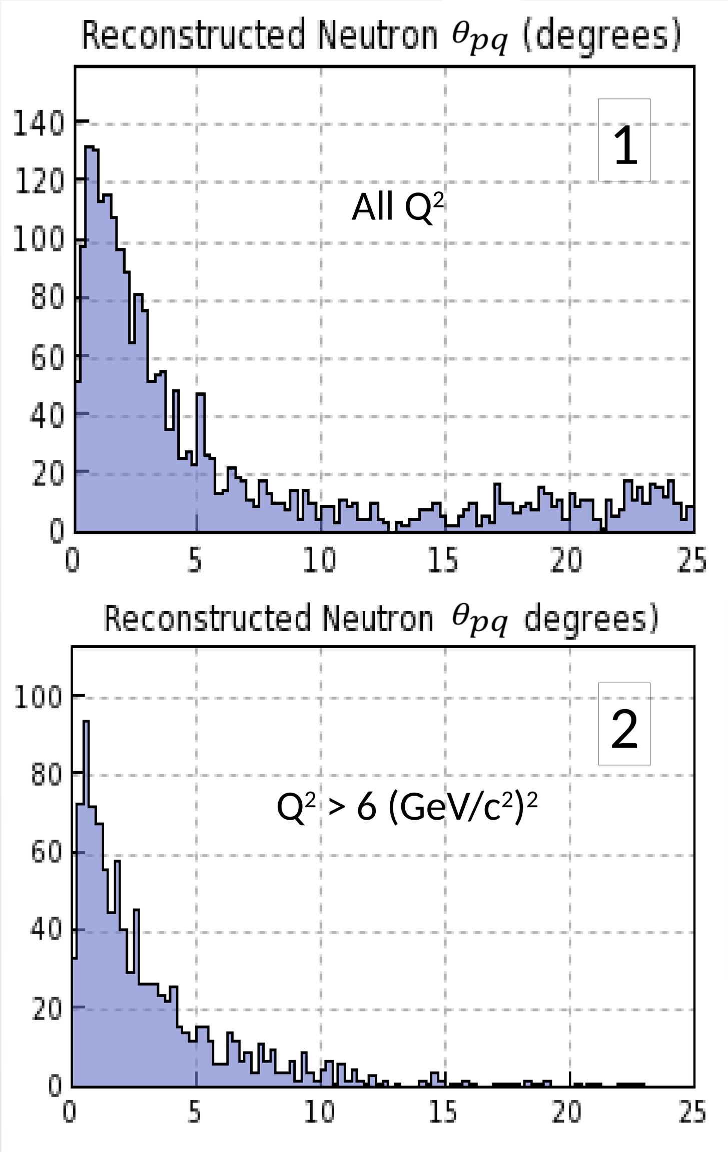


Figure 7. Both histograms display plots comparing angles of predicted path with reconstructed path. Figure7-1 shows reconstructed neutron θ_{pq} with angles up to 25°. Figure7-2 shows reconstructed neutron θ_{pq} with $Q^2 > 6$ (GeV/c^2)^2.

Future Work

JLab is currently installing Forward Micromegas to better track the particles path closer to the target. This will allow us to have better θ_{pq} resolution.

Conclusion

We have written and validated an algorithm for extracting QE e-p and e-n scattering events found in CLAS12. Using these scattering events, we can extract θ_{pq}, the angle between the 3-momentum transfer and the measured direction, for both neutrons and electrons.

References

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