Study of the Neutron Detection Efficiency for the CLAS12 Detector

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The goal of Jefferson Lab (JLab) is to understand how quarks and gluons combine to form nucleons and nuclei. The central instrument is a one-mile, racetrack-shaped electron accelerator. The laboratory is undergoing an upgrade that will double the beam energy to 12 GeV and build a new detector in Hall B called CLAS12. When CLAS12 begins running, one of the approved experiments will measure the neutron magnetic form factor(G_M^n) by extracting the ratio of electron-neutron (e-n) to electron-proton (e-p) scattering events. A major source of systematic uncertainty is the neutron detection efficiency (NDE) of CLAS12. Here we describe our work to better understand the NDE for CLAS12.

The CLAS12 Detector

- CLAS12 (Figure 1) is a large acceptance spectrometer that takes data over a large solid angle.
- The detector is composed of a central detector and a forward detector.
- For our experiment CLAS12 will have a unique 2-cell target that will allow us to take calibration and experimental data simultaneously.

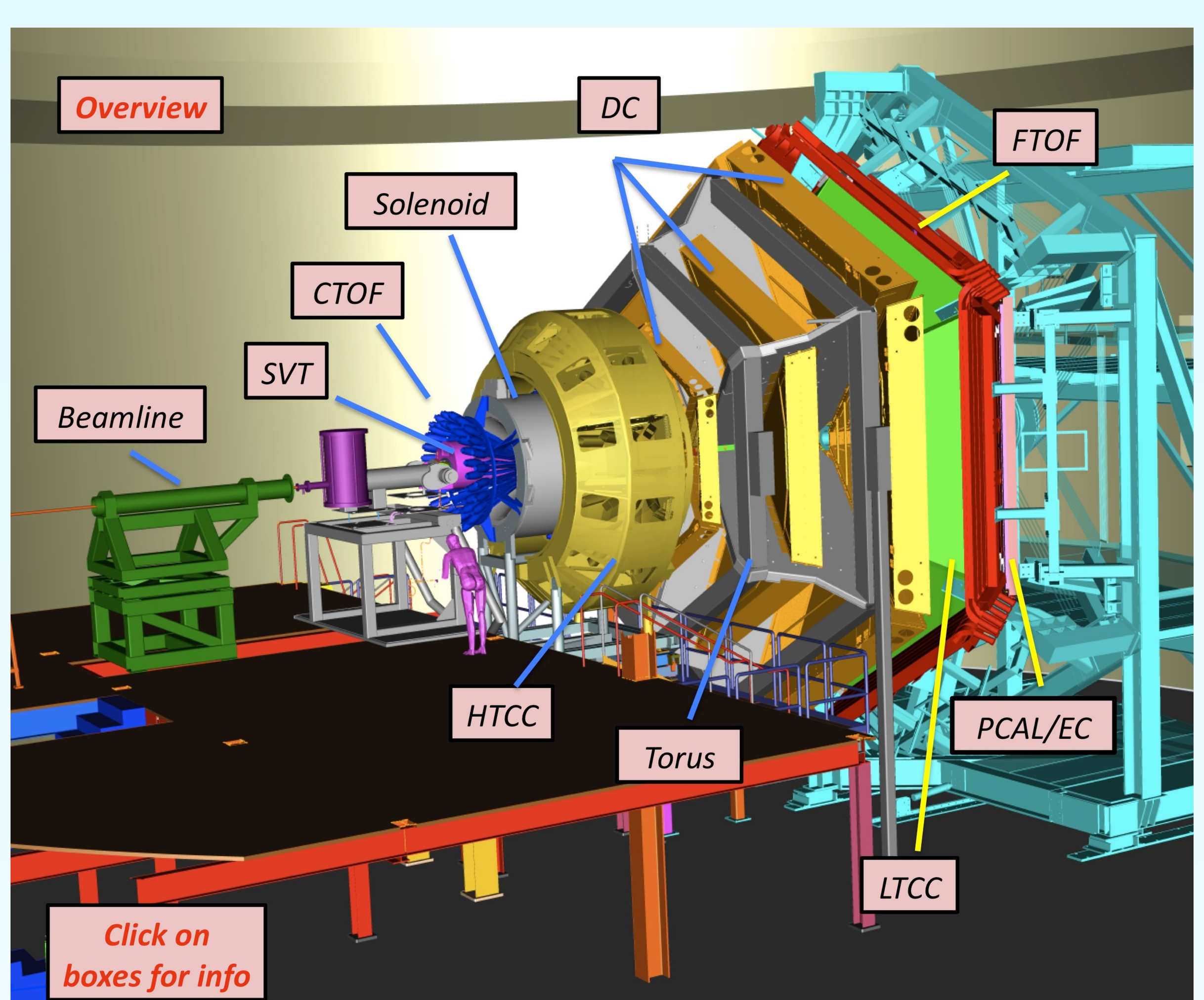
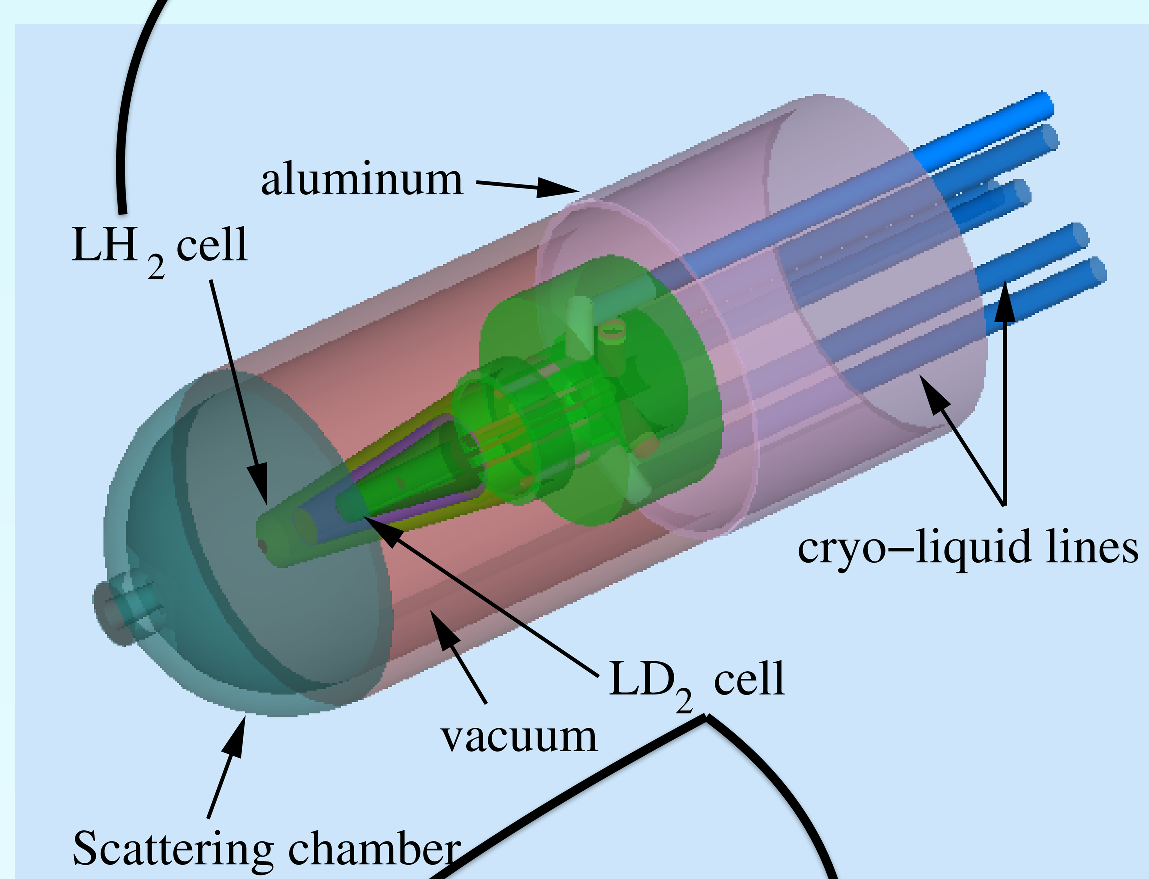


Figure 1. Computer designed image of CLAS12.

The Target

For our experiment we will be using a unique 2-cell target. This will allow us to take calibration and experimental data at the same time. The target, its cells, and the reactions from each cell is shown below in Figure 2. The reaction from the downstream LH_2 cell will produce a set of tagged neutrons that we will be able to use for calibration. The reactions from the LD_2 cell are what will produce our e-n and e-p events for the measurement of G_M^n.

$$p(e, e'\pi^+ n)$$



$$^2H(e, e'p)n \qquad ^2H(e, e'n)p$$

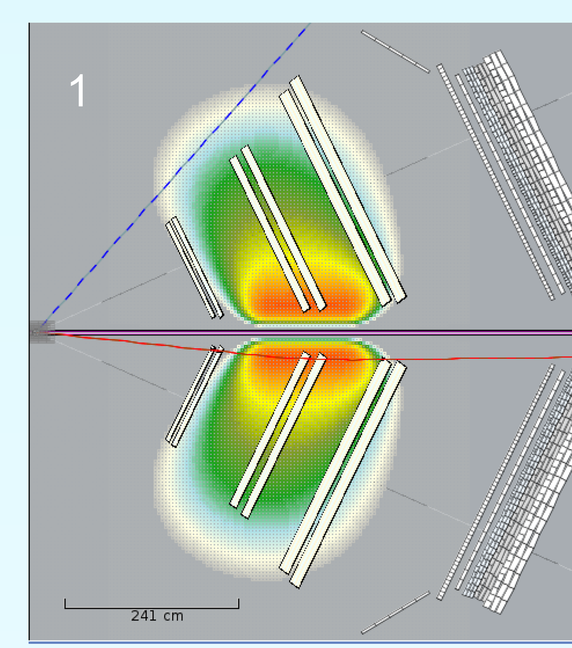
Figure 2. Image of our 2-cell target from the CLAS12 simulation *gemc*. The top reaction is for calibration data (NDE) and the lower two are for production reactions.

Systematic uncertainties for similar experiments have been 5% or higher. However, our target allows us to take calibration data under the exact same conditions we take experimental data. This will enable us to push our systematic uncertainties to less than 3%.

Simulating the NDE

We have been developing algorithms to study the NDE for CLAS12. Eventually, our algorithm will use the $p(e, e'\pi^+ n)$ reaction but as a first step we used an existing quasi-elastic event generator to simulate e-n and e-p events. The algorithm is as follows.

1. Generate quasi-elastic e-n and e-p events.
2. Use electron information to calculate neutron 3-momentum.
3. Swim neutron track to see if it hit electromagnetic calorimeter (EC) or forward time-of-flights (FTOF). If so, count it as reconstructed otherwise discard it.
4. Look for an EC or FTOF hit in a cone around where the neutron is predicted to strike the detector.
5. If there is a hit then count the neutron as a found neutron.



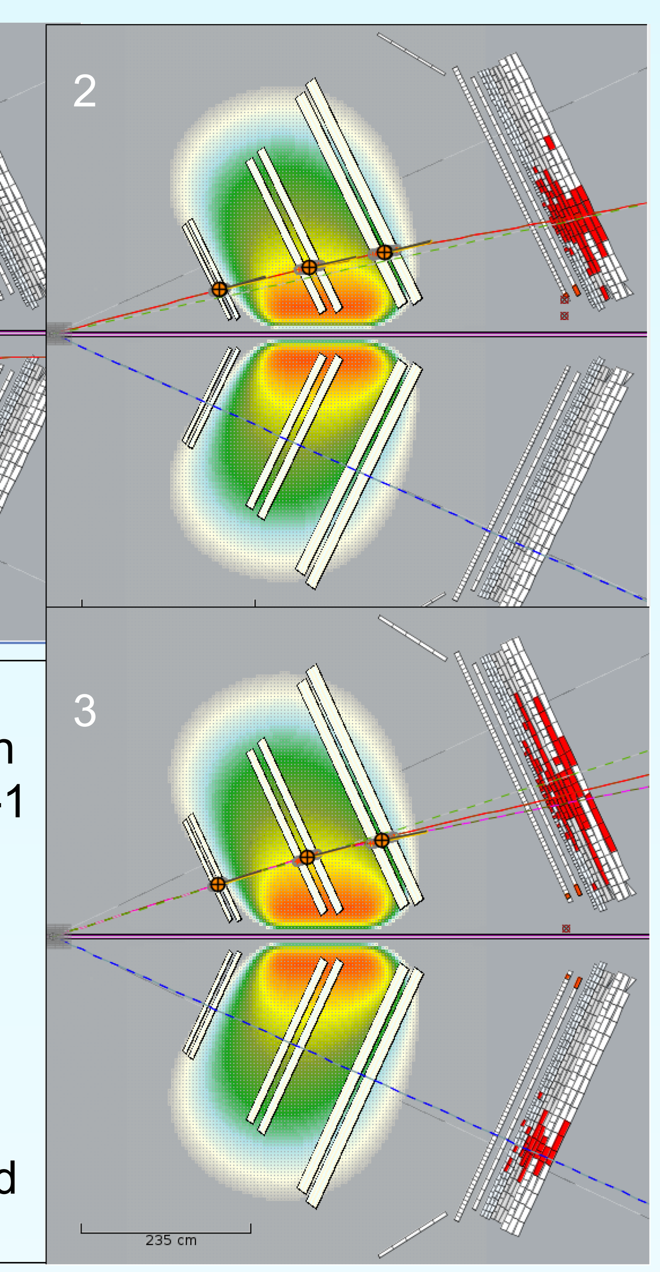


Figure 3. The dotted blue line shows the path of the neutron. Figure3-1 shows a neutron that completely missed the detector, Figure3-2 shows a reconstructed but not found neutron, and Figure3-3 shows a reconstructed and found neutron.

Results

The geant-4 based simulation of CLAS12 (*gemc*) includes two electromagnetic calorimeters (PCAL and EC). The PCAL is new and the EC is reused from the previous CLAS6 detector.

Figure 4 below shows the results our NDE algorithm. With CLAS6 (EC only) we observed a plateau at NDE~0.6 for P_n > 3 GeV. Our data plateaus a little higher because of the addition of the pre-shower calorimeter (PCAL) in front of the EC. Also, the simulated NDE starts to fall off at low and high P_n because the acceptance of CLAS12 starts to go to zero at those momenta.

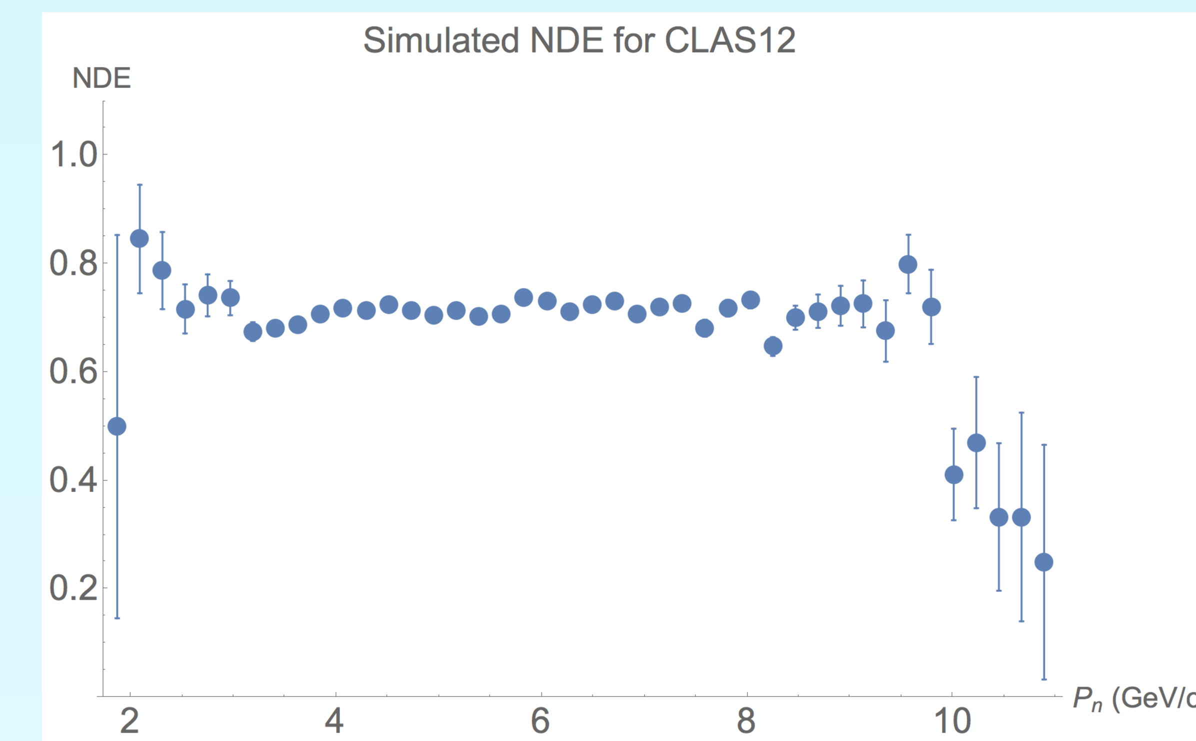


Figure 4. Plot showing the output from our NDE algorithm.

Conclusion

We have written and tested an algorithm for determining the NDE and found that CLAS12's NDE is higher than CLAS6's, due to the PCAL.

Future Work

We are currently working on simulating the $p(e, e'\pi^+ n)$ reaction to apply the algorithm to.

References

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