Measuring the Neutron Detection Efficiency in CLAS12

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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 nearing completion of the 12 GeV upgrade and a new detector is under construction 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.

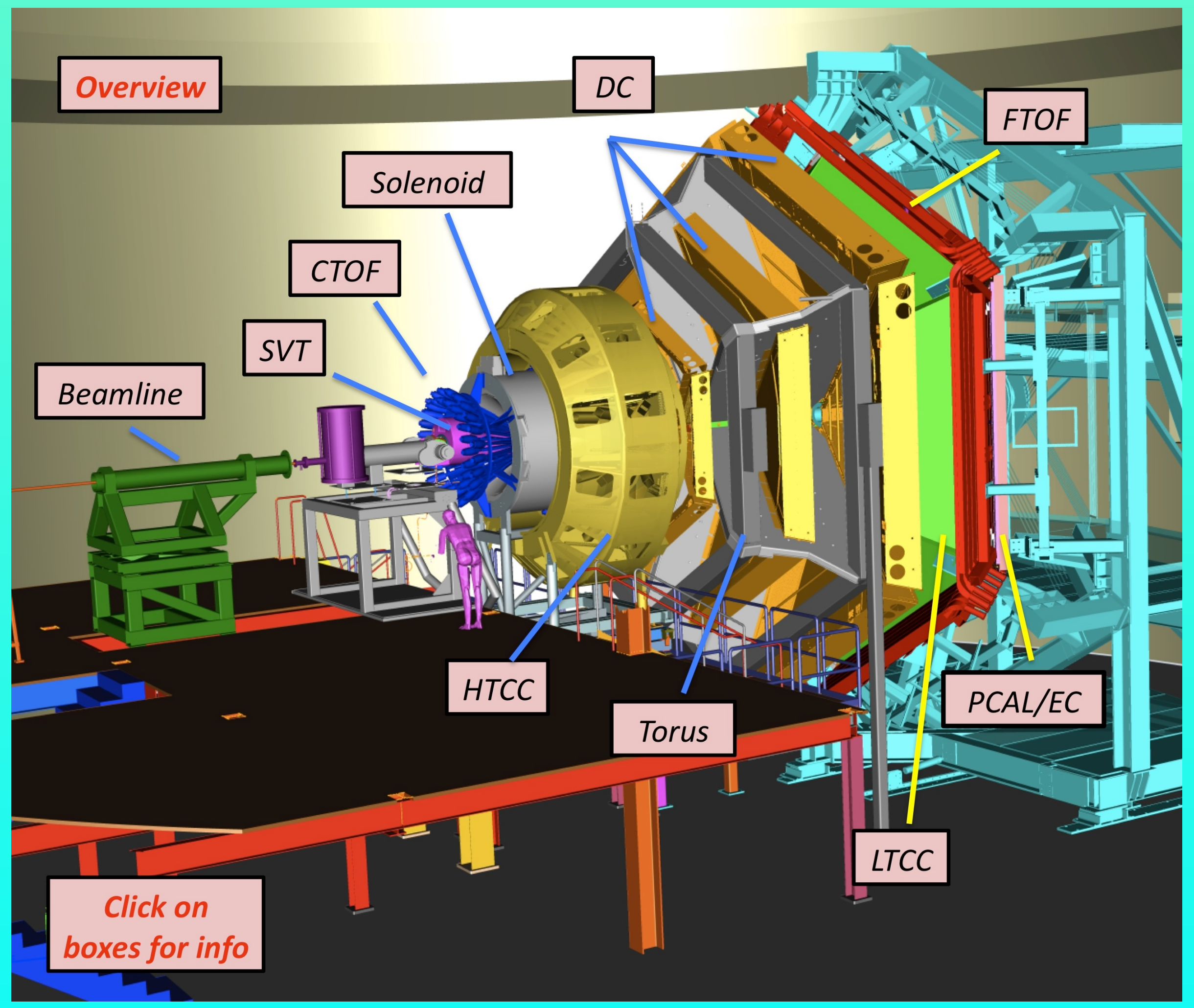
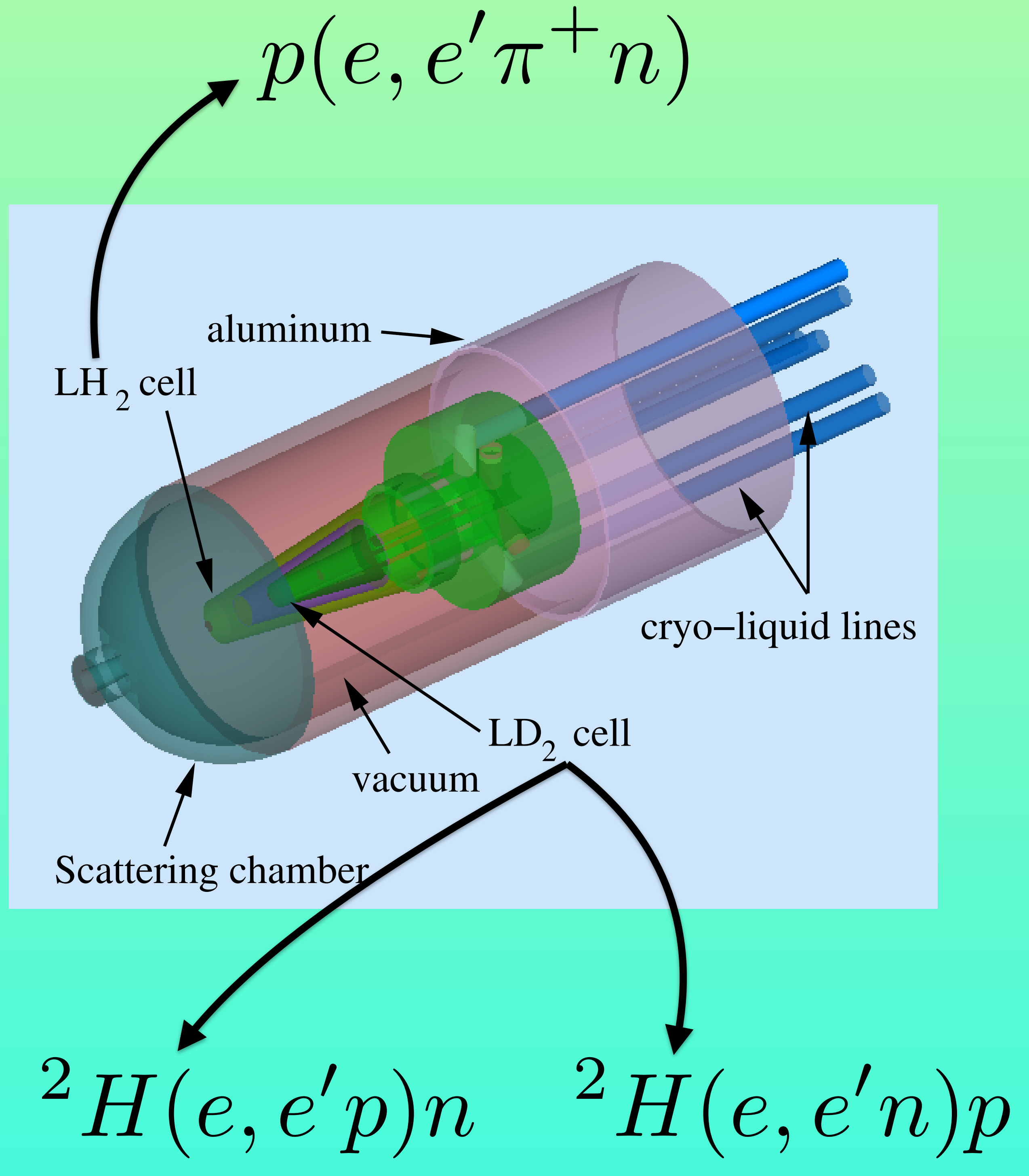


Figure 1. Computer designed image of CLAS12.

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 are shown below in Figure 2. The $p(e,e'\pi^+n)$ reaction from the downstream LH_2 cell will produce a set of tagged neutrons that we plan 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 production reactions.

The NDE is the largest source of systematic uncertainty in this experiment. 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 3% or less.

To develop the algorithms to measure the NDE we will simulate the $p(e,e'\pi^+n)$ reaction and use the results to validate our code.

Generating Events

To generate the $p(e,e'\pi^+n)$ events we are interested in, we are using the fortran-based event generator PYTHIA 6.4. We chose to use PYTHIA 6.4 because it is a widely used and well known event generator that supports electro-production, which we need for our reaction.

Calculating the NDE

Once we have generated, simulated, and reconstructed the $p(e,e'\pi^+n)$ events, we use the following algorithm to calculate the NDE for CLAS12.

1. Use the Java-based CLAS12 reconstruction code to get 4-momentum for e' and π^+.
2. Use initial beam, e', and π^+ 4-momentum to calculate missing mass squared.
3. If the square of the missing mass is between 0.87 - 0.89$(GeV/c^2)^2$ then use the e' and π^+ information to calculate 3-momentum for the neutron.
4. Swim neutron track to see if it hit the electromagnetic calorimeter (EC) or forward time-of-flights (FTOF). If so, count it as reconstructed otherwise discard it.
5. Look for an EC or FTOF hit in a 1.5° cone around where the neutron is predicted to strike the detector.
6. If a hit is found then count the neutron as found.
7. The ratio of found to reconstructed neutrons is the NDE.

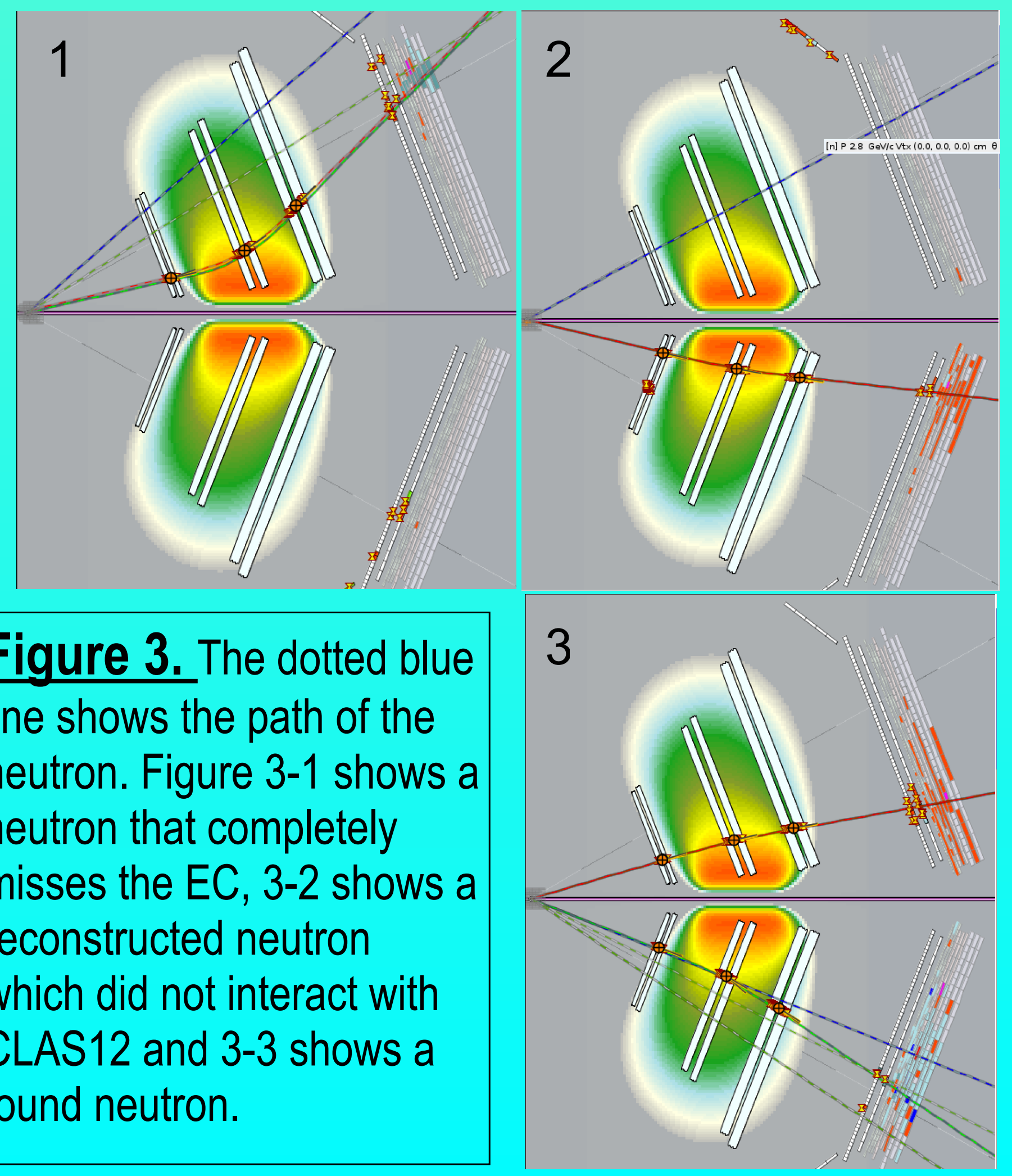


Figure 3. The dotted blue line shows the path of the neutron. Figure 3-1 shows a neutron that completely misses the EC, 3-2 shows a reconstructed neutron which did not interact with CLAS12 and 3-3 shows a found neutron.

Results

In order for us to use the $p(e,e'\pi^+n)$ reaction for calibration we need to be able to distinguish the neutrons this reaction generates from the background. Figure 4 below shows how the missing mass is distributed after we have placed a cut to only count events with 3 particles in the final state. As can clearly be seen we get a very nice peak right at the square of the neutron mass as expected.

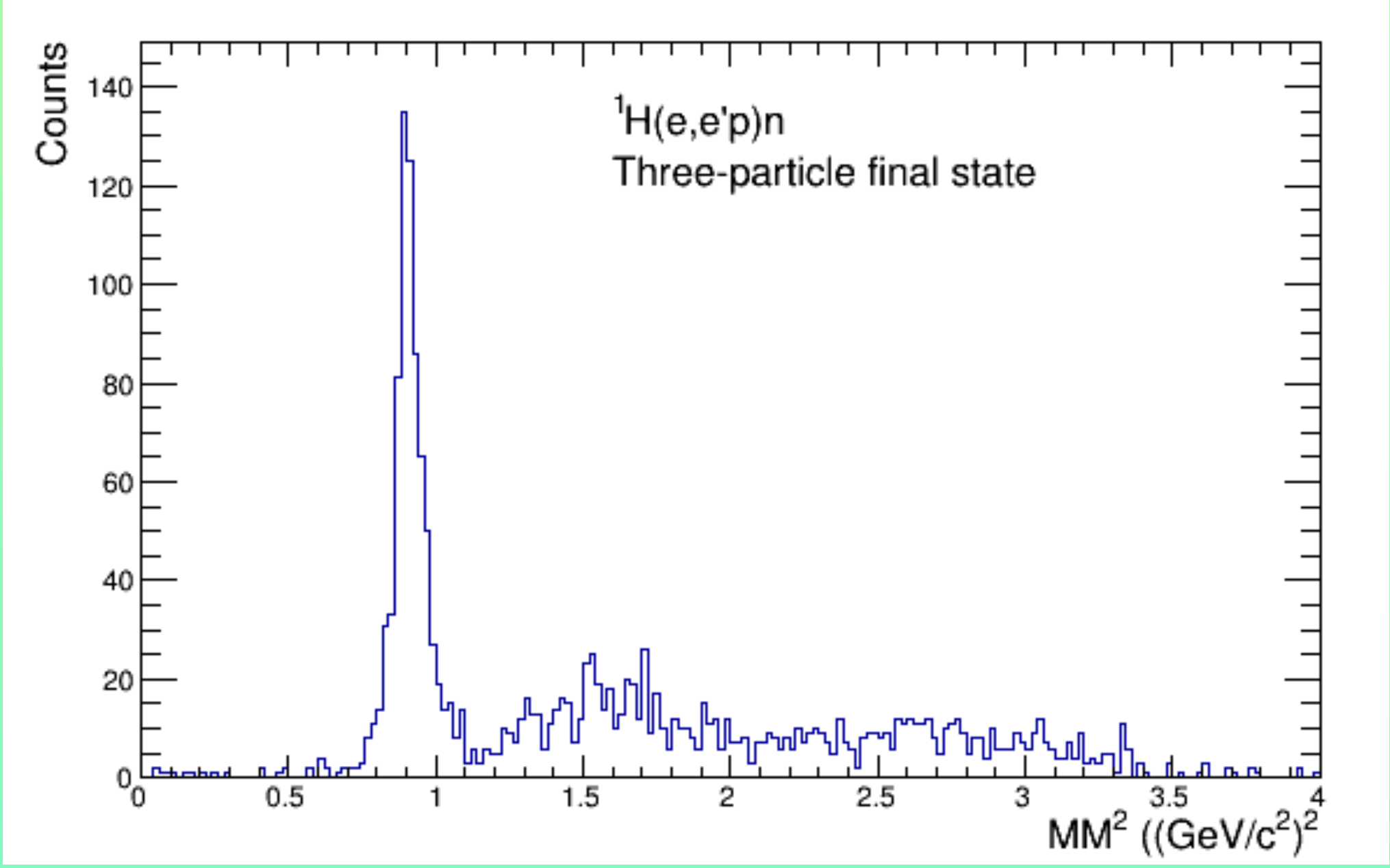


Figure 4. This plot shows the outcome for calculating the square of the missing mass. As expected we get a nice peak around the square of the mass of a neutron (≈0.88).

Using this data we get a preliminary NDE of 49.1% ± 3.3% averaged over neutrons with momentum from 1-6 GeV/c.

Conclusion

From our results we have validated that the software works. We are now ramping up to make production level runs which should give us the NDE for neutrons with momentum from 1-9 GeV/c.

References

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