Simulating the Neutron Detection Efficiency of the CLAS12 Detector

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Introduction

Knowledge of the neutron detection efficiency (NDE) of a particle detector is important when designing experiments, as well as calculating systematic uncertainty for measurements made with the detector. We are simulating the CLAS12 detector, which is part of the Jefferson Lab 12 GeV upgrade. The 12-GeV Upgrade is important for multiple reasons, including mapping of the transition to the quark-gluon degrees of freedom, and to probe new and exciting features of the fundamental constituents of matter.

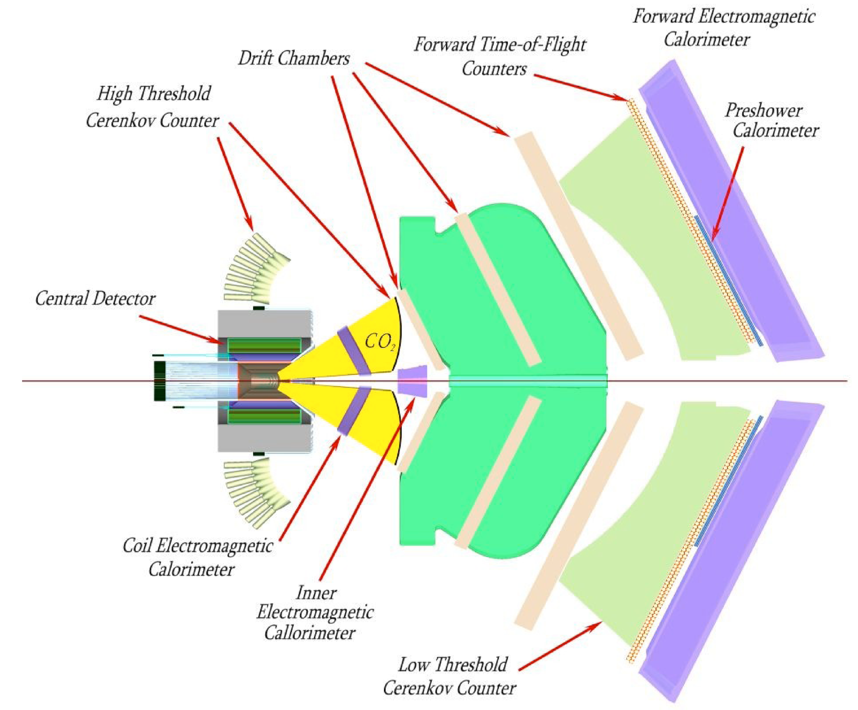
JLab and CEBAF

Jefferson Lab (JLab) is located in Newport News Virginia focusing on understanding the nature of the quark-gluon interaction that binds proton, neutron, and nuclei together. The central scientific instrument at JLab is the Continuous Electron Beam Accelerating Facility (CEBAF). CEBAF creates a precise, continuous, beam of electrons that allows exclusive measurements (we can measure many particles from each event) to be made. CEBAF runs at energies up to 6 GeV. Hall B currently houses the CEBAF Large Acceptance Spectrometer (CLAS).

CLAS and CLAS12

The current detector in the Hall B detector CLAS will be replaced as part of the Upgrade [1]. The new CLAS12 will, like its predecessor, rely on layers of drift chambers, Cherenkov counters, time-of-flight scintillators (TOF), and electromagnetic calorimeters (See Figure 1). These components each contribute to the identification and measurement of particles produced in nuclear reactions. JLab is being upgraded to twice its current operating energy and the new detector is based on what we learned from CLAS and modified for higher luminosity and other enhancements. We are developing simulations of CLAS12 to prepare for this new physics program. Specifically, we are simulating the neutron detection efficiency of the forward TOF of the CLAS12 detector (see Figure 1) which consists of three layers. We are focused on layers P1A and P1B, which are most relevant for neutron detection.

Figure 1: CLAS12



Software

We simulated the neutron detection efficiency (assuming elastic scattering) of the forward time of flight scintillators for quasielastic electron-neutron scattering using a series of software packages.

ElasticEventGen

by Mark Moog and Jerry Gilfoyle

This code generates elastic electron-neutron events for a beam energy of 11 GeV and with a uniform angular distribution to feed into gemc

↓

Geant Monte Carlo (gemc)

By Maurizio Ungaro

This program simulates the particle's interaction with each component of the CLAS12 (see Figure 1.) It is based on GEANT 4 from CERN, a tool used to simulate high energy particles traveling in matter.

↓

Socrat

By Sebastian Procureur, Moog and Gilfoyle

This program reconstructs the electron in each event. Socrat takes the information generated by gemc (the simulated signals from the detector) and uses a Kalman filter algorithm to extract the electron 4-momentum. We modified Socrat to analyze the results from the time of flight scintillators to look for neutrons.

↓

Root

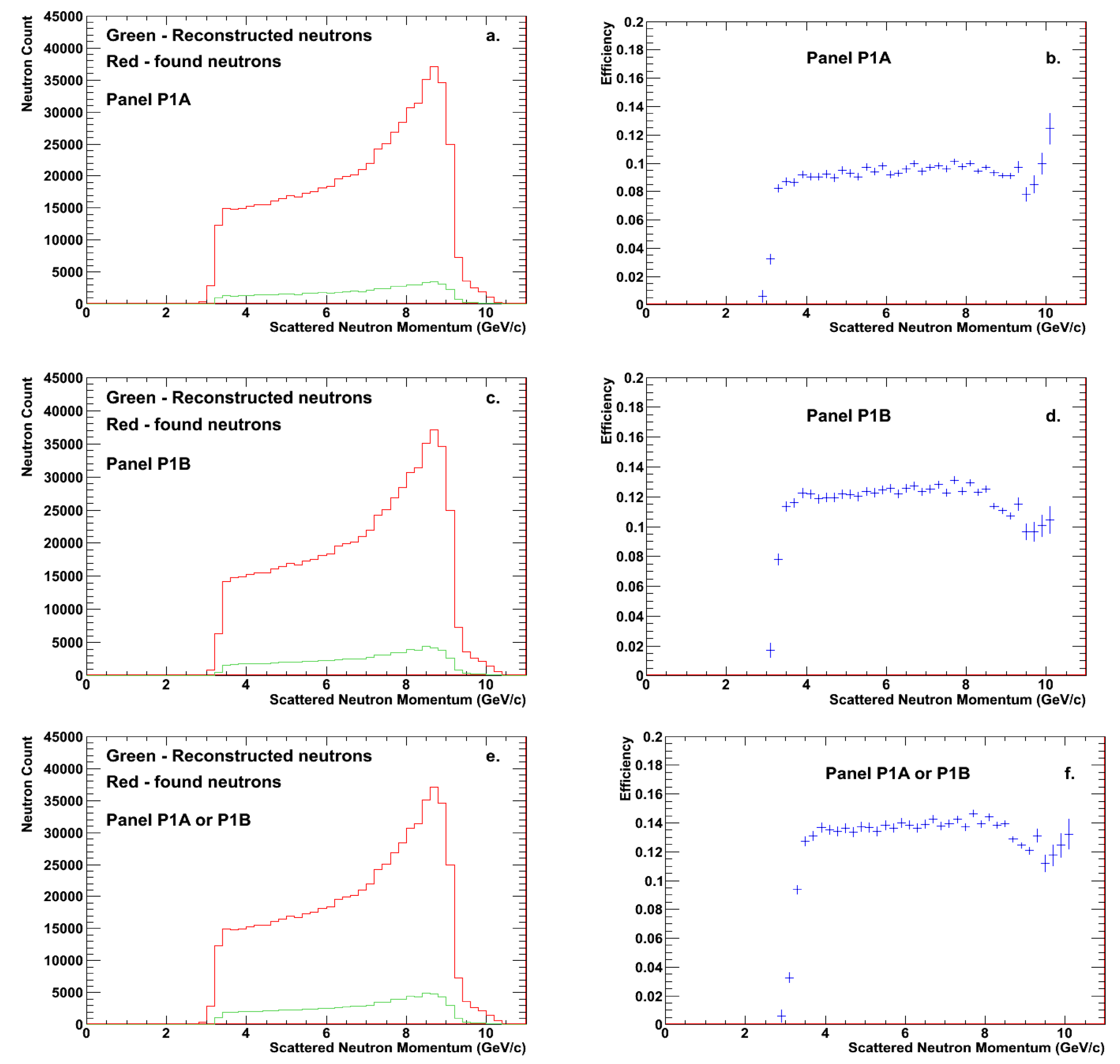
From Cern

Socrat writes out data in Root Trees. We then use Root to apply cuts to our data, create plots and perform the final analysis of the simulation.

Analysis and Results

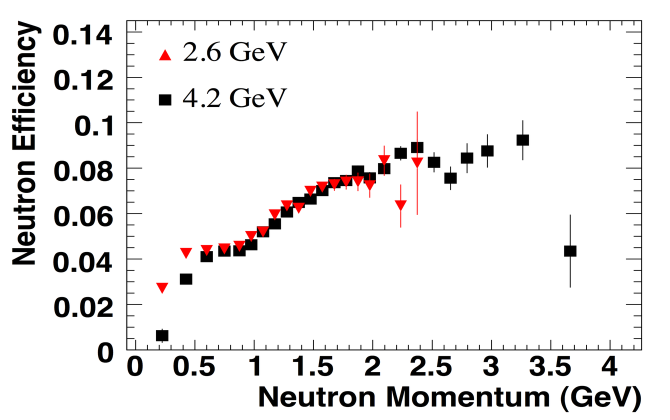
To extract the neutron detection efficiency from the simulation we first select a scattered electron. Next we predict where the elastic neutron should be detected on the forward time of flight scintillators using only the results of the electron reconstruction. This predicted neutron is called a found neutron. We then search the TOF data to see if a hit occurred within 10 degrees of the predicted location on the time of flight scintillators. If a hit is found we call it a reconstructed neutron. By taking the ratio of reconstructed to found neutrons we extract the neutron detection efficiency of the forward TOF scintillators. To remove signals from background photons we require a minimum light output equivalent to a 5 MeV electron.

Figure 2: Simulated Neutron Detection Efficiencies



Our results are shown in Figure 2 for each panel separately and for when a neutron was reconstructed in either panel. Efficiency was highest in the latter mode (an average of 13.5%). For comparison we show the NDE for the current CLAS6 TOF (see Figure 3), which will be reused as layer P1A in CLAS12. Our simulated NDE agrees with existing data for P1A at a neutron momentum of ~3GeV/c.

Figure 3: Current Neutron Detection Efficiency of the CLAS TOF (P1A), [2].



Conclusion

We have simulated quasi-elastic scattering of electrons off neutrons in CLAS12, a new detector being built at Jefferson Lab. The preliminary, simulated CLAS12 neutron detection efficiency is about 13% for a beam energy of 11GeV when both time of flight layers are used. Our simulation agrees with previously measured efficiency

1- 'The Hall B 12 GeV Upgrade Preconceptual Design Report', Thomas Jefferson National Accelerator Facility, 2005.
2- J.D.Lachniet, 'A High Precision Measurement of the Neutron Magnetic Form Factor Using the CLAS Detector', thesis, Carnegie-Mellon University, Pittsburgh, PA, 2005.

Work supported by the US Department of Energy, the National Science Foundation, and the APS