Neutron Detection Efficiency of the CLAS12 Detector

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Introduction

Knowledge of the neutron detection efficiency (NDE) of a 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 Jefferson Lab 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 all the particles from a certain 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, the CEBAF Large Angle Spectrometer (CLAS) almost completely surrounds the target, and is composed of many layers of drift chambers, Cerenkov counters, time-of-flight scintillators (TOF), and electromagnetic calorimeters. 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 will have a new detector in Hall B called CLAS12 (see figure 1). 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.)

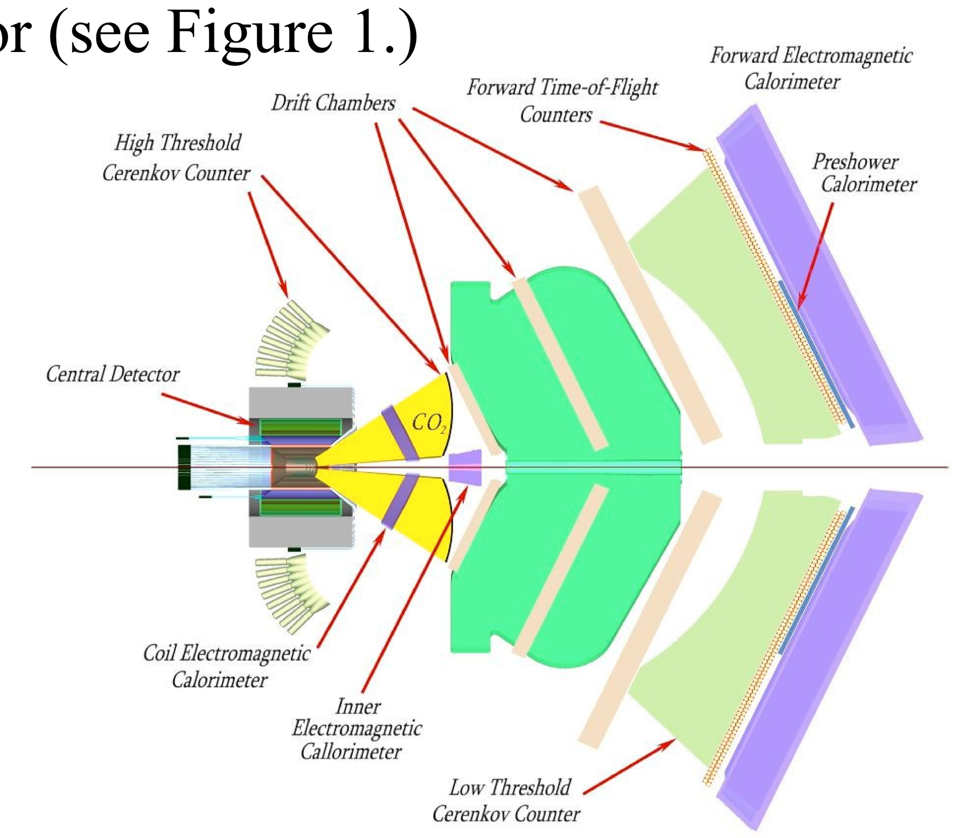

Figure 1: CLAS12

Software

We simulated the neutron detection efficiency 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 software 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 code 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

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 create plots and perform the final analysis of the simulation.

Analysis

To extract the neutron detection efficiency from the simulation we analyze the Monte Carlo results event-by-event. First we see if an electron was detected for a given event. If one was detected 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 (see Figure 2). 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 (see Figure 2.)

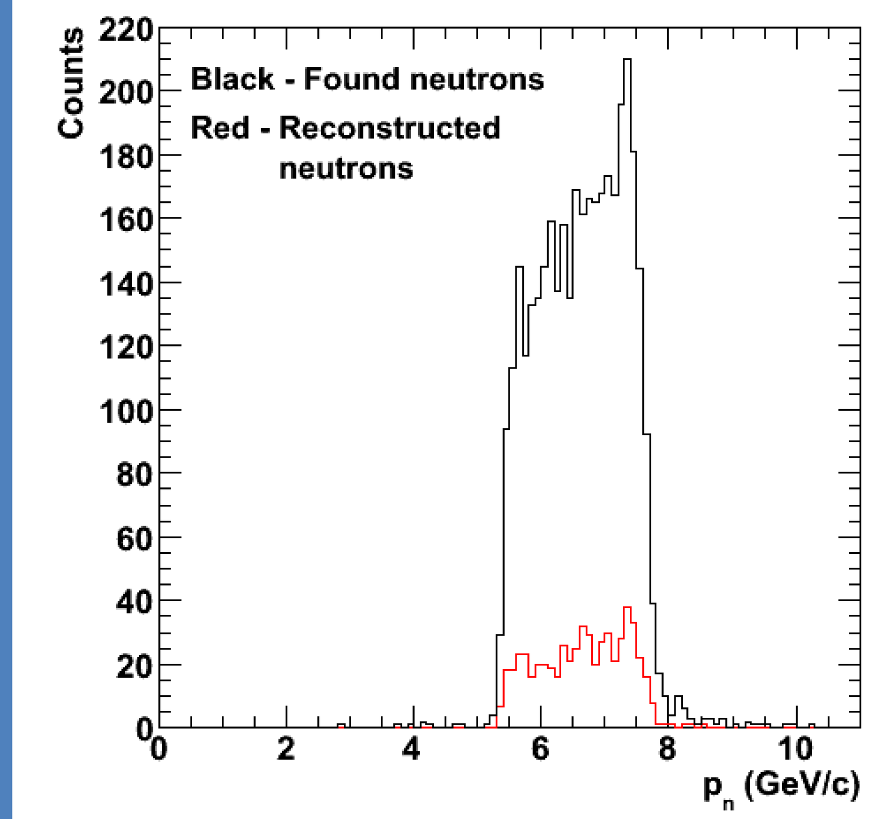

Figure 2: The number of counts for found (black) and reconstructed (red) neutrons in the simulation.

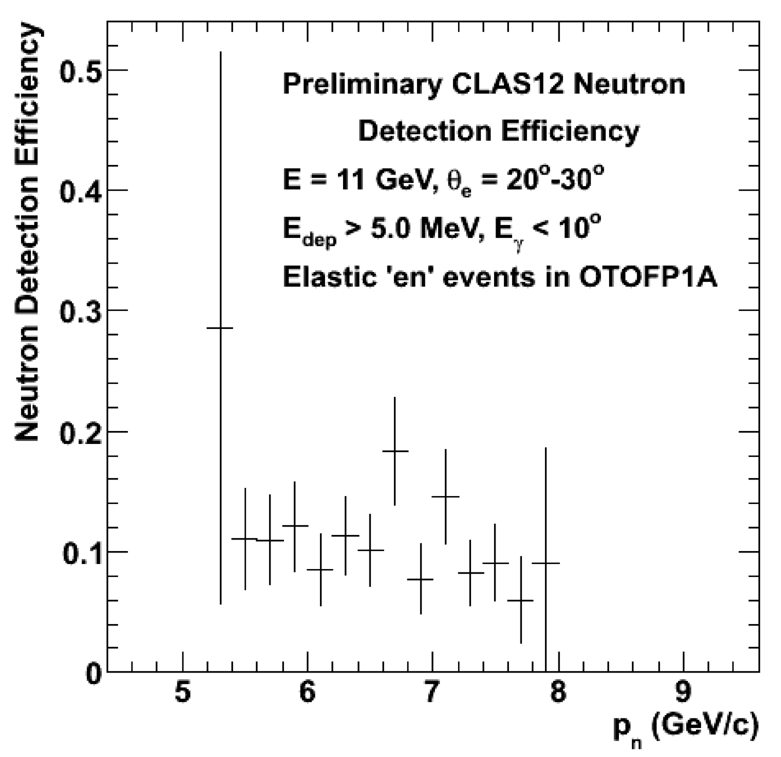

Figure 3: The preliminary simulated detection efficiency of the forward time of flight scintillators.

By taking the ratio of reconstructed to found neutrons we extract the neutron detection efficiency of the forward TOF scintillators. See Figure 3. In the TOF scintillators low-energy background photons can produce signals. To remove these signals we require a minimum light output equivalent to a 5 MeV electron (E_{dep} in Figure 3.) The uncertainties are statistical Monte Carlo ones. Within the uncertainties, the neutron detection efficiency is constant at about 10%. The electron angle is $20^\circ < \theta < 30^\circ$. The expected NDE based on a measurement with CLAS is 8.5% (1).

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 agrees with the NDE measured in CLAS6 within the uncertainties.

1) J. Lachniet et al., Phys. Rev. Lett., 102, 192001 (2009).