A Deuteron Quasielastic Event Simulation for CLAS12

Omair Alam and Gerard Gilfoyle
Department of Physics, University of Richmond

Introduction

One of the fundamental goals of nuclear physics is to understand the structure and behavior of strongly interacting nuclei in terms of its basic constituents, quarks and gluons. An important step towards this goal is the characterization of the internal structure of the nucleon; the elastic electric and magnetic form factors of the proton and neutron are key ingredients of this characterization. The elastic electromagnetic form factors are directly related to the charge and current distributions inside the nucleon and are among the most basic observables of the nucleon.

JLAB, 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 (measure particles from each event) to be made. CEBAF runs at energies up to 12 GeV. Hall B currently houses the CEBAF Large Acceptance Spectrometer (CLAS12). CLAS12 consists of eight detector subsystems for the base equipment with more than 60,000 channels. It consist of two major ports, the forward detector and the central detector. It will detect and measure the properties of charged and neutral particles.

Figure 1: Jefferson Laboratory in Newport News, Virginia

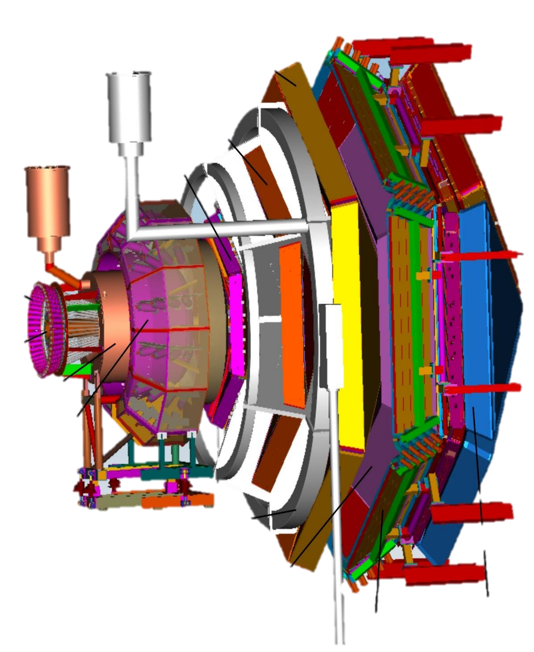

Figure 2: CLAS12

Measuring the Neutron Magnetic Form Factor

An experiment to measure the neutron magnetic form factor is planned for the new CLAS12. This form factor is extracted from the ratio of quasielastic electron-neutron to electron-proton scattering off a liquid deuterium target. In order to realistically simulate this experiment, we have developed the QUasiElastic Event Generator (queeg) which models the internal motion of the nucleons in deuterium. It extends a previous version used at Jefferson Lab.

Quasielastic Event Generator

The original code for QUEEG was developed by J.Lachniet for the analysis of the CLAS6 $G_M N$ experiment. To simulate the quasielastic production we treat the deuteron as composed of two, on-shell nucleons, one of which will act as a spectator in the interaction. The quasielastic interaction is then elastic scattering with the target nucleon.

More options were added to QUEEG to improve the simulation of the experiment to measure $G_M N$

1) Include 'a dependence on' the azimuthal angle between the scattering plane (defined the incoming and scattered electrons) and the reaction plane (defined by the final nucleon momenta).
2) Simulating a realistic event vertex distribution for a cylindrical target

   a) The event vertex was randomly distributed along the beamline in the target region and von Neumann rejection was used to select random points in the plane transverse to the beamline within a fixed radius from the beam.

   i) We randomly distributed the vertex in the z component, so when the centre of the target was at -15 and the target was 20 mm long, the plot we obtained was a rectangle spanning from -25mm to -5 mm which was representative of the length of the target, as we would see while looking through the z axis. (Figure 8)

   ii) We also randomly distributed the x and y components in a circle of radius vR. By discarding all the points in the x-y plane whose length from the target radius was greater than the target radius itself, we obtained uniformly distributed x and y components in a circle of radius vR. So, when the target centre was (0,0) and vR was 6.5 mm, we obtained a circle of radius 6.5 mm which represented the cross section of the target. (Figure 7)
3) Adding a threshold on the missing momentum, pm, i.e. the momentum of the spectator nucleon.
4) Exporting the simulated results in LUND format for use with GEMC.
5) Incorporating minimum and maximum limits on the electron scattering angle.

We also streamlined the Makefile so the software build is more robust.

Geant4 Monte Carlo and Root

QUEEG generates events that are used as input to the CLAS12, physics-based simulation Monte Carlo (GEMC). This program simulates the particle's interaction with each component of CLAS12 and therefore is a tool to study the response of the detector.

Root, a data analysis framework provided by CERN, was used for histogramming and graphing to view and analyze the distribution of the x, y and z vertices of the electrons and neutrons.

Plot Results

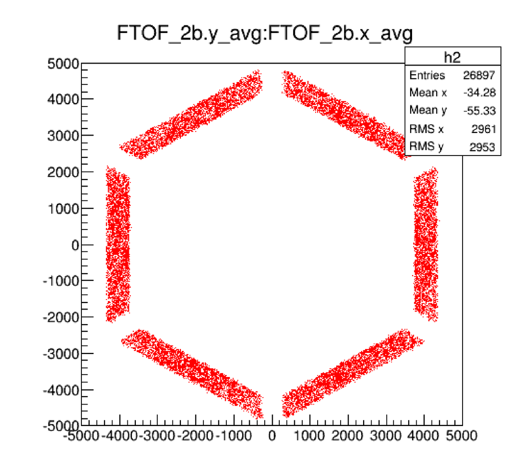

Figure 3: Forward Time of Flights 2b Plot

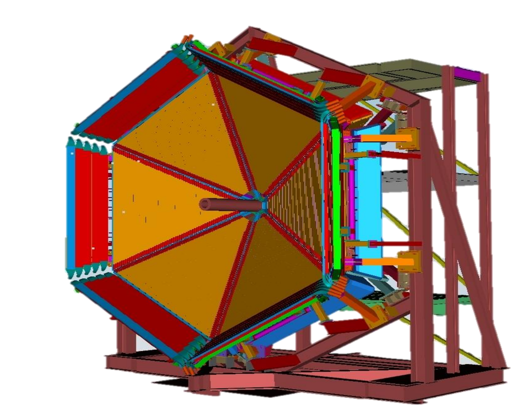

Figure 4: Forward Time of Flights CLAS12

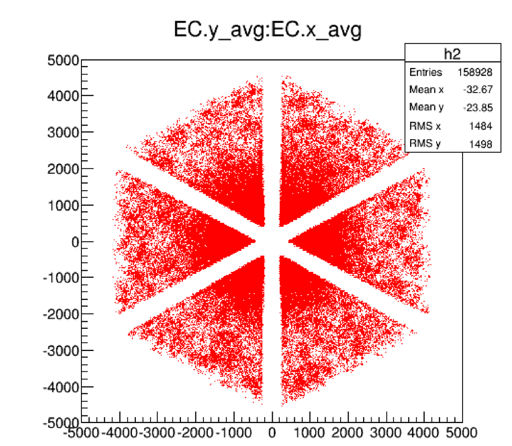

Figure 5: Electromagnetic Calorimeter Plot

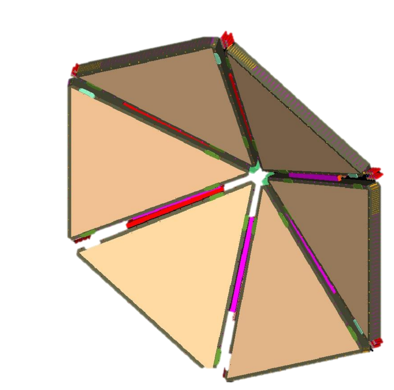

Figure 6: Electromagnetic Calorimeter CLAS12

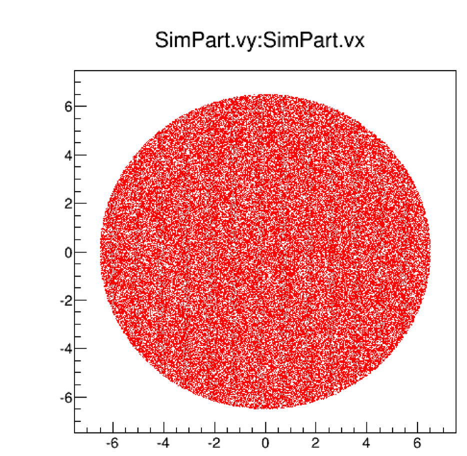

Figure 7: Cross section of LD_2 target

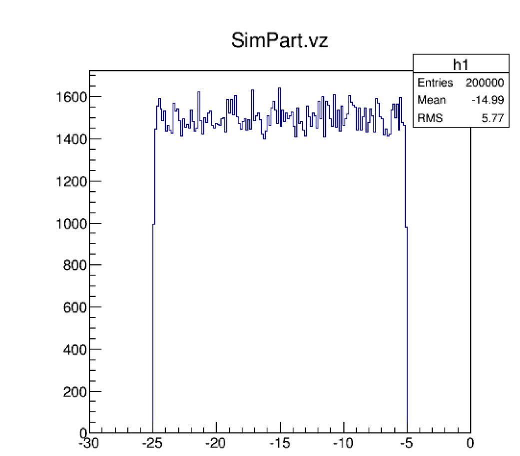

Figure 8: Z axis of LD_2 target

Figure 3 and 5 are plots obtained by the particles interactions with Forward Time of Flights and Electromagnetic Calorimeter constructs of CLAS12. These plots were compared with their corresponding structures in CLAS12 (Figures 4 and 6) to confirm whether the new option of exporting data from QUEEG in the LUND format was working or not.

Concluding Remarks

We modified source code for queeg to produce output in the LUND format, set the position of the center of the LD_2 target, and simulate a realistic deuterium target. An initial study of the impact of the target structure and material revealed only limited effects

References

G.P. Gilfoyle et. al. CLAS-NOTE 2014, Jefferson Lab., 2014