# Event Selection in Electron Scattering on Deuterium

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## Introduction

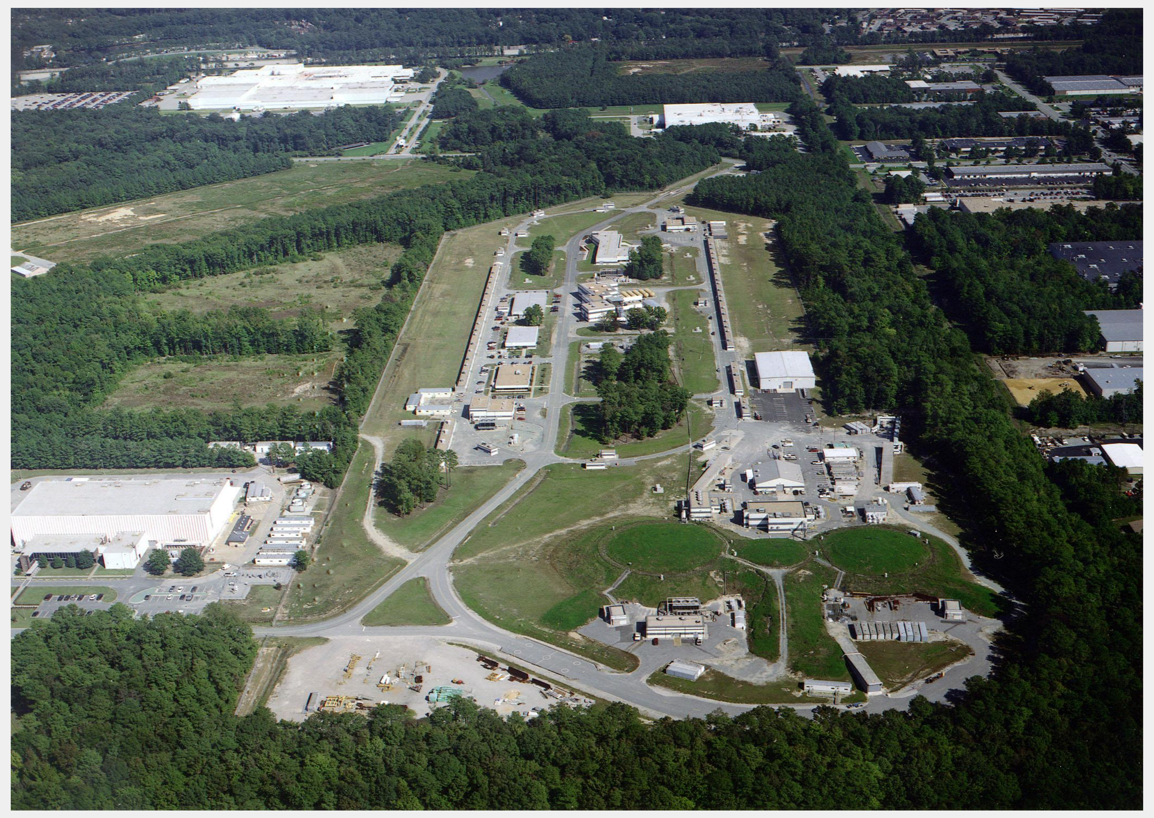

Figure 1: CEBAF site.

Jefferson Lab (JLab) explores the quark-gluon structure of atomic nuclei with the Continuous Electron Beam Accelerator Facility (CEBAF), (Fig. 1). We use electrons scattering off deuterium to measure the distribution of electric current in the neutron [1].

We are developing methods to select quasi-elastic events (electron proton (e-p) and electron neutron (e-n)) to measure the ratio of e-n/e-p and extract the neutron's current distribution or magnetic form factor [2].

## CLAS12

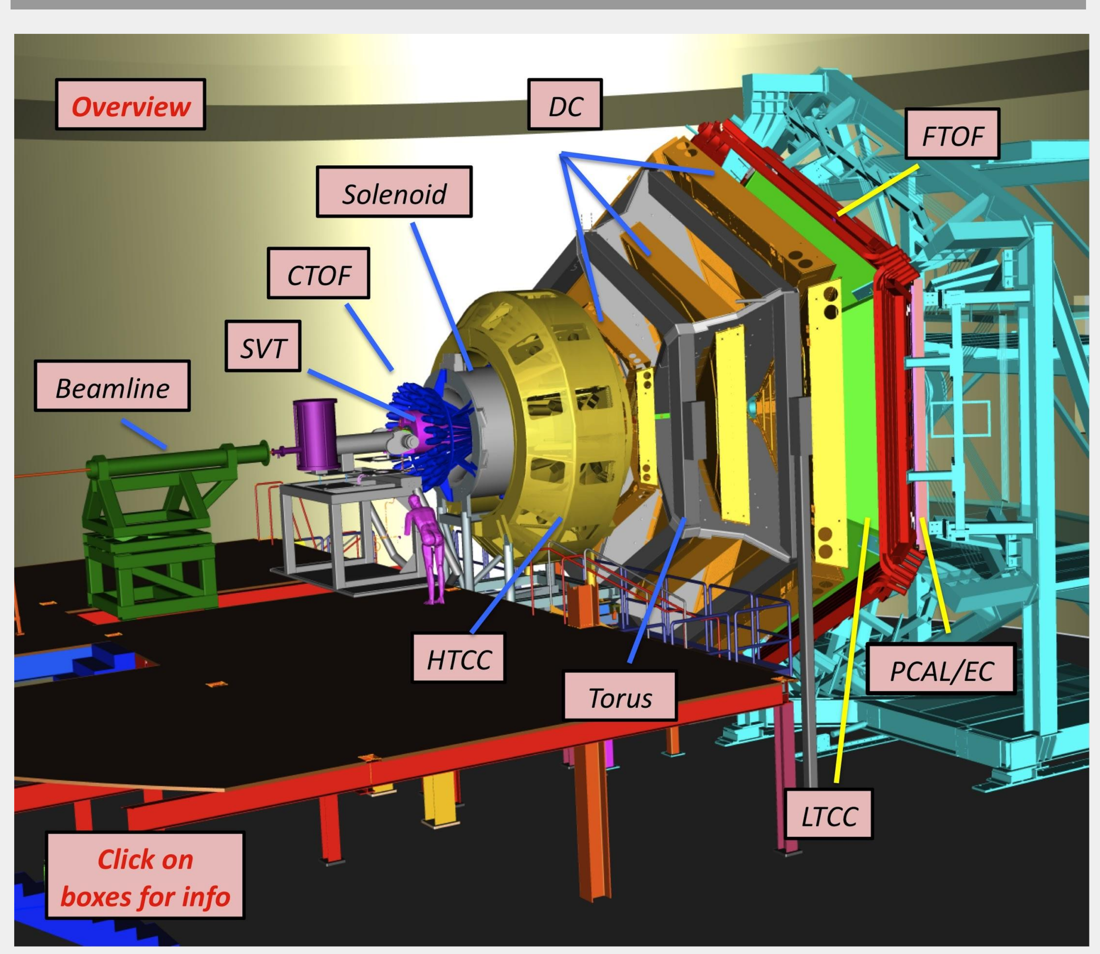


Figure 2: CLAS12 Design Graph

The measurement will be made with the CLAS12 detector in Hall B which allows particle measurements and identification over a wide angle range. It is composed of the Forward Detector (*FD*) and the Central Detector (*CD*).

In the FD, Drift Chambers (*DC* in Fig. 2) measure the trajectory of the charged particles, Cherenkov counters (*LTCC*/*HTCC*) are used to separate electrons from negative pions, and the Forward Time-of-Flight (*FTOF*) system measures the time of flight. Calorimeters (*PCAL*/*EC*) measure charged particle energy.

The CD has more layers of systems to measure tracking, TOF, and neutral particles at large scattering angles. Our focus is on the FD.

## Event Simulation Chain

To develop the analysis techniques and software we implemented a full simulation chain, from event generation to post-reconstruction analysis.

1. Event generation - An electron can scatter off a nucleon nearly elastically (*quasi-elastic* or *QE*) with a large width from Fermi-motion. The program *QUEEG* generates such *QE* events and includes Fermi motion [3].
2. Event generation - Electron-nucleon events can have large energy transfers (*inelastic*). The code *Pythia* supports a wide range of reactions emphasizing the strong interaction [4]. It now has Fermi motion [5].
3. The passage of particles through CLAS12 is simulated with the CLAS12 standard physics-based Monte Carlo code *gemc*, which uses *geant4*.
4. The simulated CLAS12 events are subsequently reconstructed using the CLAS12 Common Tools and stored in *HIPO* files.
5. The Java-like scripting language *GROOVY* is used for post-reconstruction analysis. The language is used for making fiducial and sampling fraction cuts, as well as for event selection.

## Event Selection

Particle selection relies on cuts and constraints on the kinematic properties of the events. Here we discuss a few of the ones we have developed.

- Calorimeter Fiducial Cut - The CLAS12 calorimeters PCAL/EC (see Fig. 3) measure the light produced in particle showers when charged particles stop in them. We restrict the active volume of the detector to where it will capture most of the energy even in showers near the edge. Fig. 3 shows the reduction in coverage with (red) and without (blue) the cuts [6].

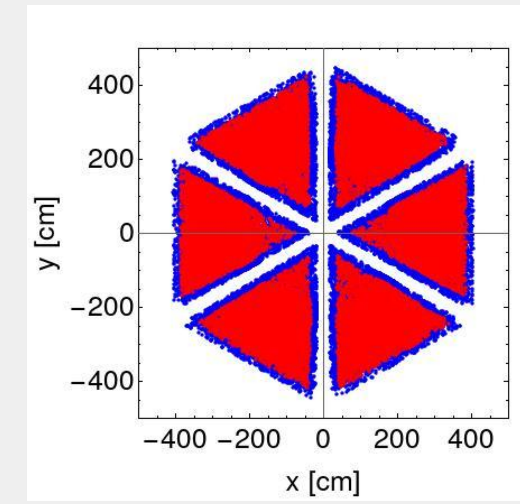


Figure 3: Impact of fiducial cuts on the ECAL.

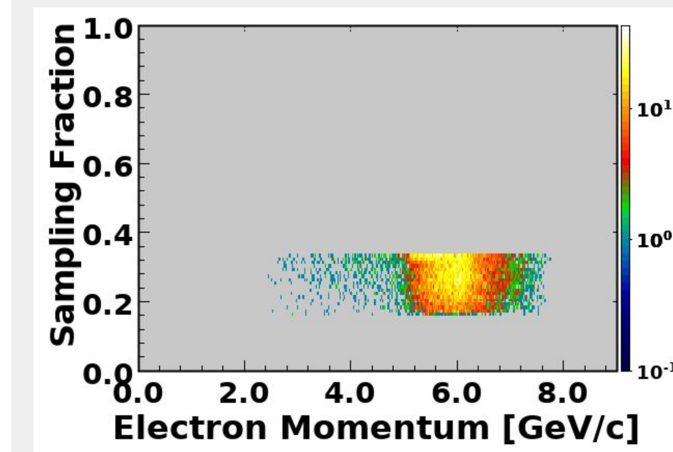


Figure 4. ECAL sampling fraction versus electron momentum.

- Electron Sampling Fraction Cut
  The sampling fraction (*SF*) is ratio of the electron energy deposited ($E_{dep}$) in the *PCAL/EC* to the electron momentum (*P*) measured in the *DC*. The sampling fraction is a central feature of the detector. Only electron events with a sampling fraction in the proper range are kept. Fig. 4 shows the simulated *SF*.
- Selecting Quasielastic *e-p* events
  - Acceptance Matching
    To ensure the e-n and e-p events have the same solid angle, we assume an event is elastic and "swim" both a neutron and proton through CLAS12. Only events where both particles strike the active volume of the detector are kept [7].
  - Angle ($\theta_{pq}$) Limit
    Quasi-elastic events have a small angle $\theta_{pq}$ relative to the 3-momentum transfer when compared to inelastic events. See Fig. 5. To separate QE from inelastic events only those with $\theta_{pq} \leq 3^{\circ}$ were accepted [7].

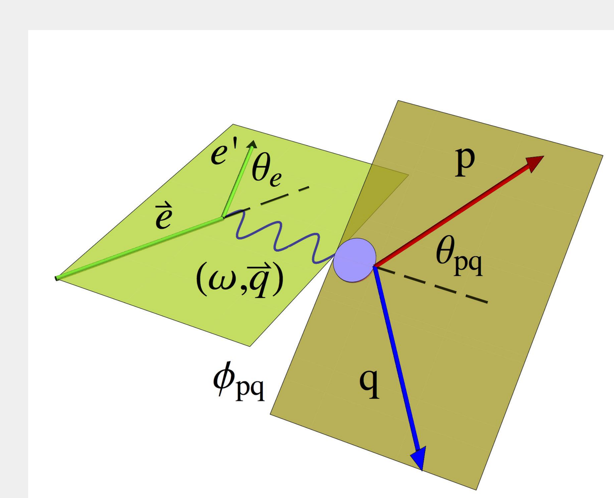


Figure 5: Graph of electron scattering off deuterium.

  - Momentum Transfer Squared ($Q^2$) range
    The analysis here is for $Q^2$= 7-9 GeV$^2$ which lies in the middle of the expected range.
  - Hermiticity Cut
    *QE* events contain only an electron and one nucleon. Events with additional particles will be vetoed. This constraint is now under investigation.

## Results

A primary goal here is to separate quasi-elastic events from inelastic ones. Some results for e-p events are shown in Fig. 6. The left-hand panel shows the $W^2$ distribution including the cuts discussed above except for the acceptance matching and the $\theta_{pq}$ cut. The inelastic background nearly swamps the QE signal. The ratio of QE to inelastic for $W^2 < 2.0$ GeV$^2$ is 0.80+/-0.02. In the middle panel acceptance matching is on. The number of both event types drops considerably (the ratio is 0.50+/-0.02). In the right-hand panel we require $\theta_{pq} < 3$ deg. The fraction of QE events rises by more than an order of magnitude to 6.1+/-0.4. We can significantly reduce the contamination of QE events.

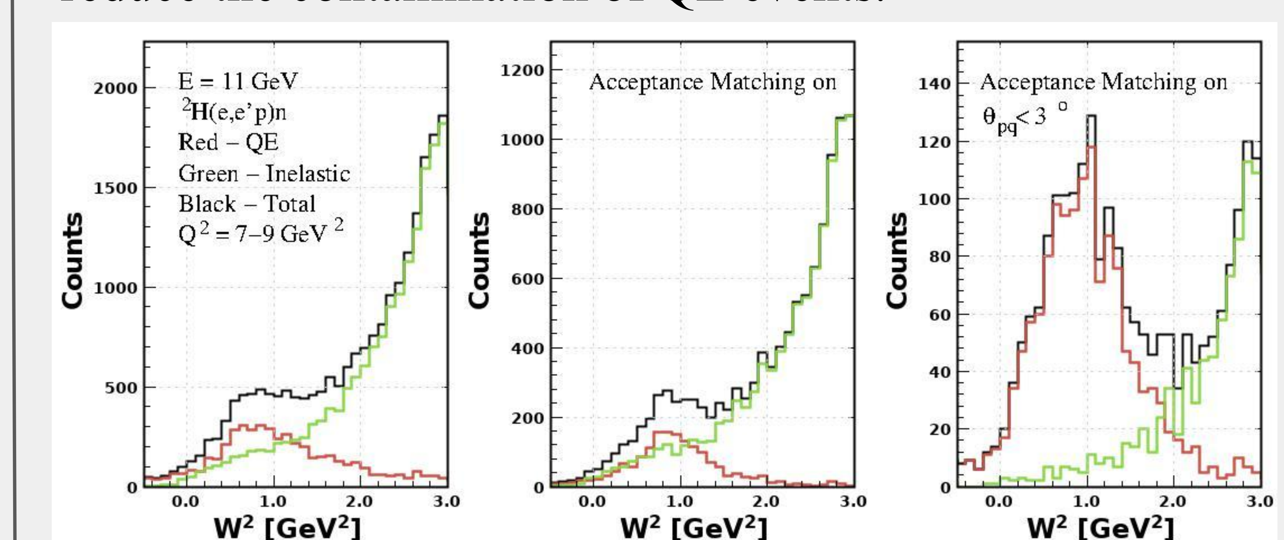


Fig 6. $W^2$ distribution with different cuts applied.

## Conclusion

We have completed an end-to-end simulation of e-p and e-n production from deuterium. This work is in preparation for the analysis of the measurement at JLab. The simulation includes the production of quasi-elastic events and background inelastic ones. We have shown in simulation the use of the constraint on $\theta_{pq}$ dramatically reduces the inelastic events contaminating the QE peak.

## References

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