Software to Monitor CLAS12 Data Quality

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Introduction

The physics program at Jefferson Laboratory (JLab) in Newport News, VA will probe the quark sub-structure of the nucleus with the Continuous Electron Beam Accelerator Facility (CEBAF). We use the CEBAF Large Acceptance Spectrometer (CLAS12) in Hall B to measure the charge, momentum, and energy of particles produced by electron-nucleus collisions (see Fig. 1).

Figure 1: JLab site view of the CEBAF accelerator and end stations (Halls A-D).

We have developed monitoring software with a tabbed graphical user interface (GUI) that processes CLAS12 data to monitor quality for the analysis of a planned experiment to measure the neutron magnetic form factor (G^n_M) [1,2]. This form factor describes the distribution of magnetization and electric current inside the neutron.

CLAS12 Detector

CLAS12 is a large-acceptance, magnetic, spectrometer covering most of the total solid angle and divided into six, identical azimuthal sectors. See Fig. 2.

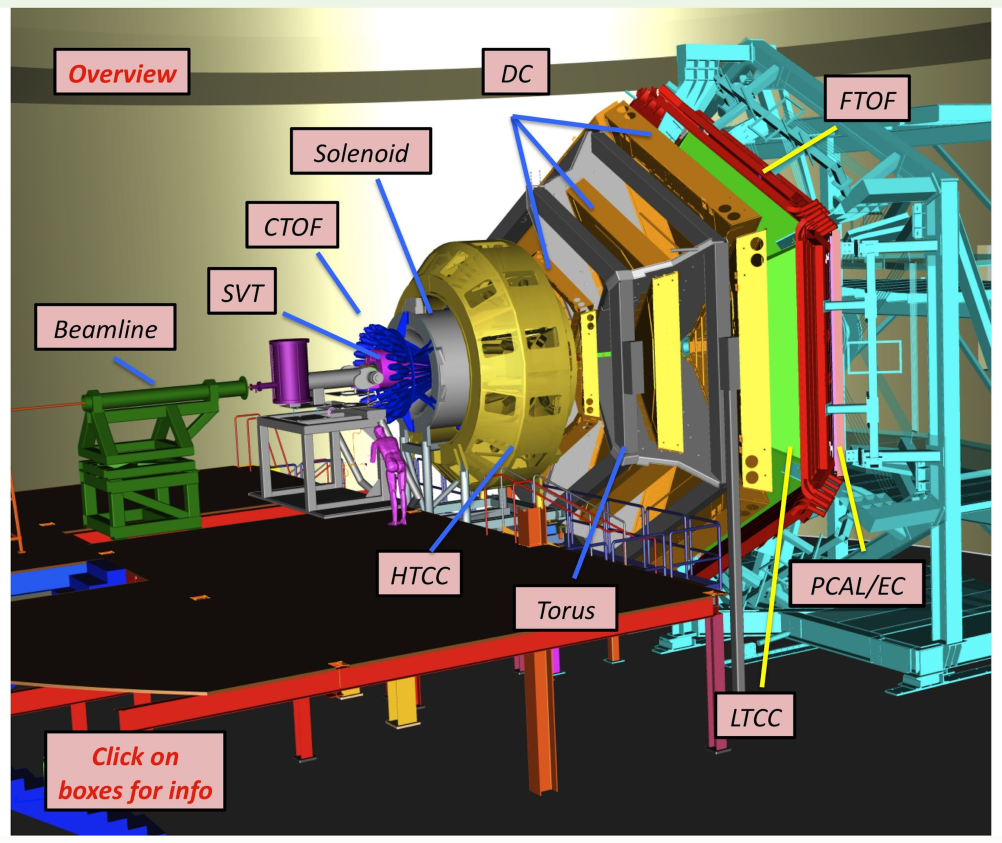

Figure 2: The CLAS12 detector showing the components of the Forward and Central Detector. The Central Detector is used to measure large-angle scattering events.

The Forward Detector is the focus of the G^n_M experiment and is described below.

- High and Low Threshold Cerenkov Counters (HTCC & LTCC) identify π/K/p using Cerenkov radiation [3].
- Drift chambers (DC) measure the momentum and trajectory of charged particles bent in the magnetic field created by the CLAS12 superconducting torus [3].
- The Forward Time-of-Flight (FTOF) measures TOF of charged particles using plastic scintillators [3].
- The Pre-Shower and Electromagnetic Calorimeters (PCAL/EC) measure the energies of charged particles and detect neutrons that create a particle shower in alternating layers of lead and scintillator [3,4,5].
- The Central Detector detects particles at large angles and consists of a superconducting, solenoid magnet and the components shown in Fig. 2.

Monitoring Software

The code takes reconstructed data from e-^{2}H scattering and extracts quantities important to the analysis of the G^n_M experiment. Those quantities are plotted as functions of run number or sector to scan for anomalies which may indicate a change in operating conditions.

The monitoring code was written using a java-like scripting language called groovy and uses the CLAS12 Common Tools [3]. The GUI is divided into tabs that can be easily viewed by clicking on the desired tab. See Figure 3 for the first tab which summarizes the results. The quantities displayed include electron momentum, sampling fraction of the PCAL/EC, and the ratio of protons and neutrons to electrons. The sampling fraction and particle ratios are plotted by run number and sector number to identify changes. See Figs 3-9. Electrons and protons are identified by their charge, velocity, and momentum; neutrons by their interaction in the EC.

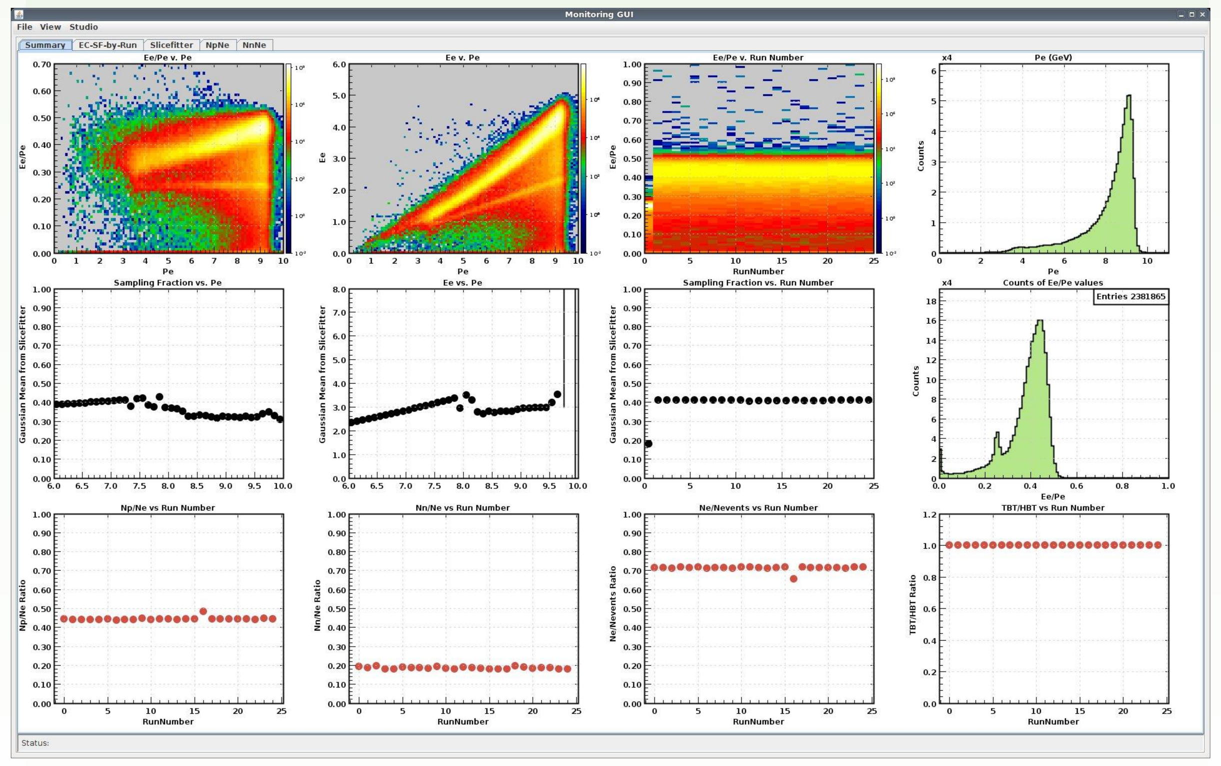

Figure 3: Summary tab, Test Configuration.

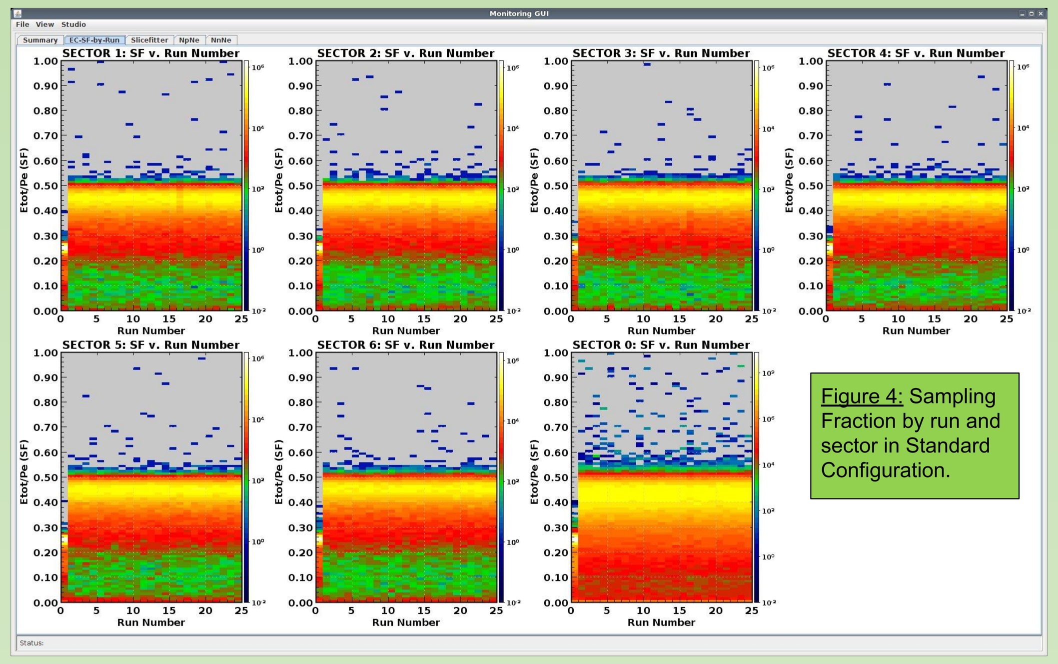

Figure 4: Sampling Fraction by run and sector in Standard Configuration.

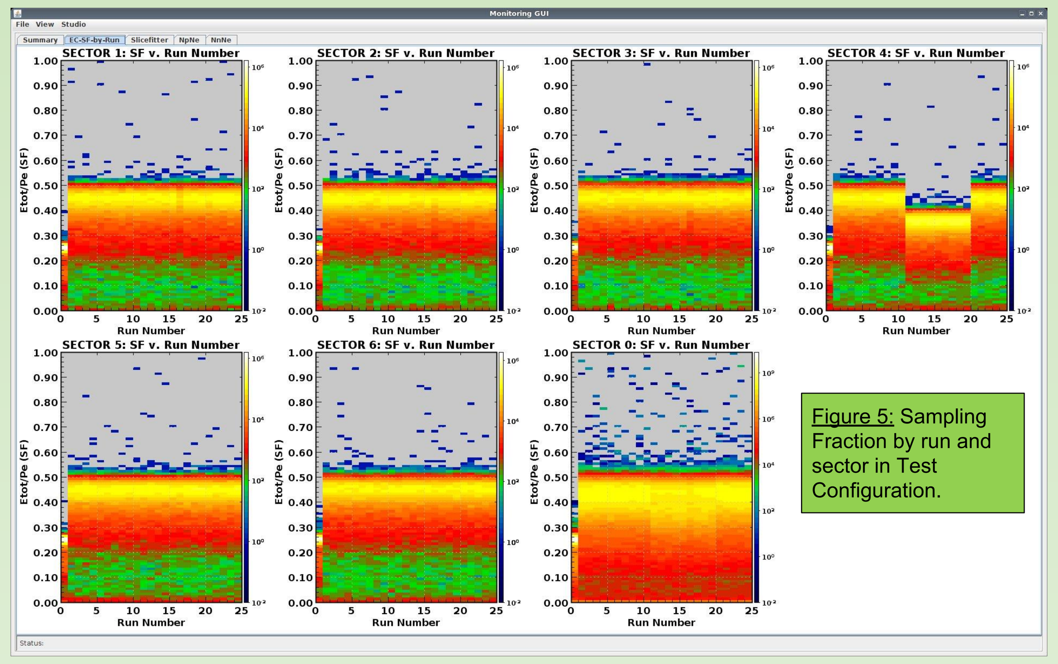

Figure 5: Sampling Fraction by run and sector in Test Configuration.

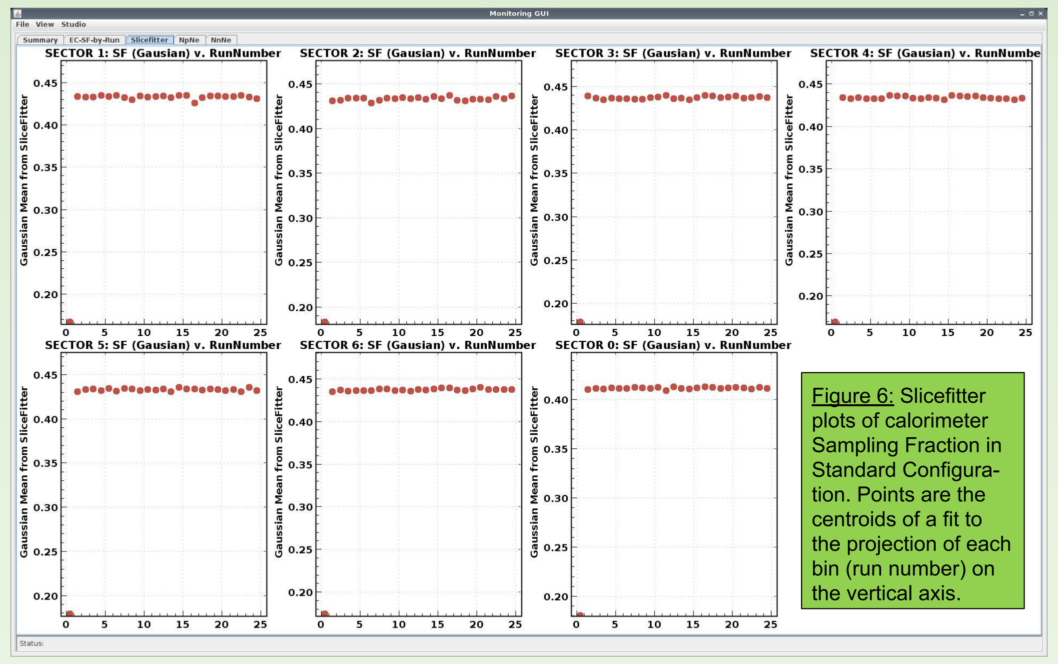

Figure 6: Slicefitter plots of calorimeter Sampling Fraction in Standard Configuration. Points are the centroids of a fit to the projection of each bin (run number) on the vertical axis.

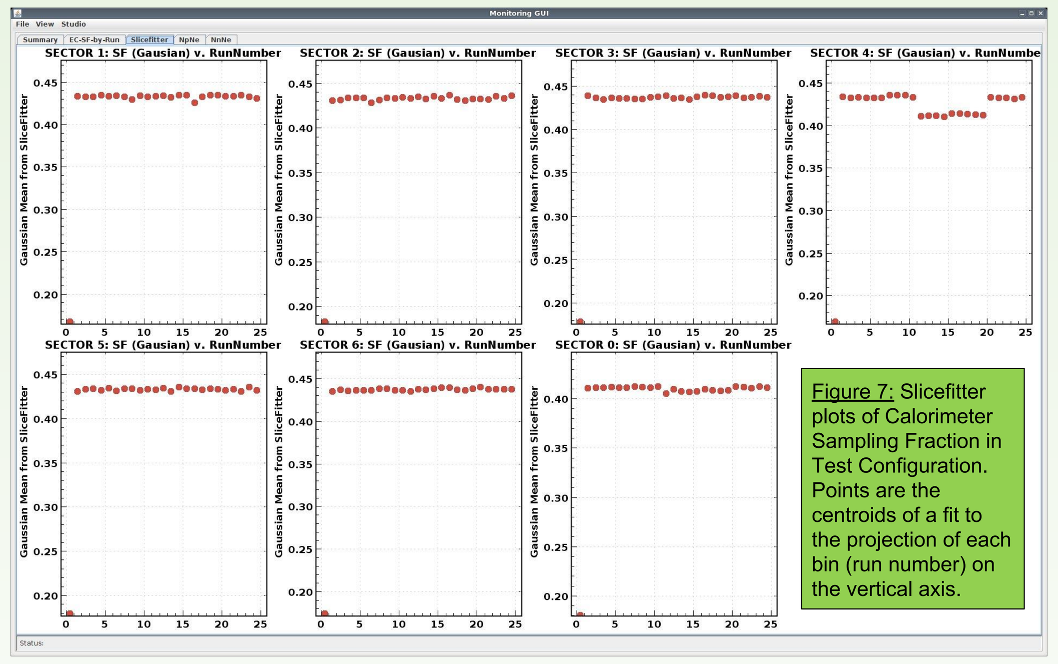

Figure 7: Slicefitter plots of Calorimeter Sampling Fraction in Test Configuration. Points are the centroids of a fit to the projection of each bin (run number) on the vertical axis.

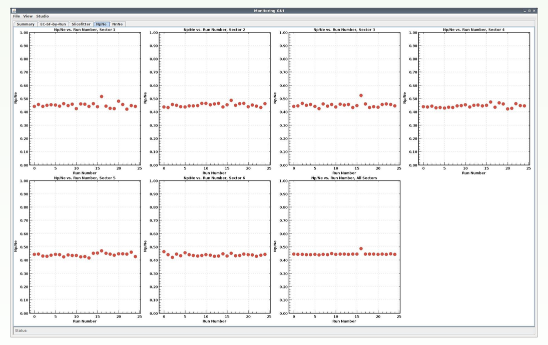

Figure 8: Ratio of Protons to Electrons Tab in the Standard Configuration.

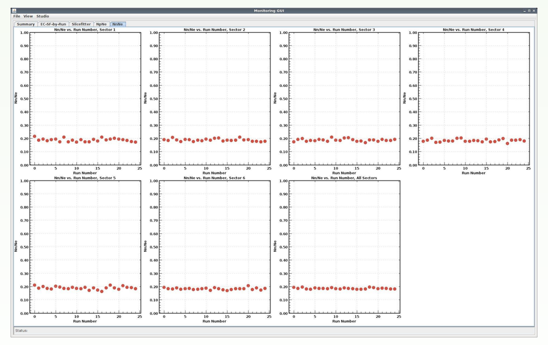

Figure 9: Ratio of Neutrons to Electrons Tab in the Standard Configuration.

Software Testing and Validation

To test the code we used simulation. Events were generated with the Quasi-Elastic Event Generator (QUEEG) and passed to the Monte Carlo code *gemc* to simulate the CLAS12 response [1,2]. These simulated events were reconstructed with the CLAS12 Common Tools and analyzed in our groovy code to obtain quantities as a function of run number and sector.

The sampling fraction is the energy of an electron measured by the EC divided by the momentum measured with the DC. For runs 10-20 and sector 4, the energy from the calorimeter was multiplied by 0.95 to mimic an EC problem (*e.g.* a gain shift) and see the effect here. The 'Standard Configuration' is the initial set of conditions and 'Test Configuration' has the altered EC energy.

The effect could show up in the Sampling Fraction vs Run Number on the Summary tab (Fig .3). However this plot is averaged over all the sectors so the effect is small. On the Sampling Fraction tabs (Figs. 4-5) and the Slicefitter tab (Figs. 6-7) we show the same results for both configurations, but sector by sector. The effect is clearly visible in sector 4 for the runs we expect (Figs 5 and 7). In Sector 0 (all sectors averaged together), the effect is small.

It is worth noting another feature in Figs 4-7. The peak in the sampling fraction for run 1 shows an unexpected drop. This drop is due to different calibration values for that run (the attenuation length is set to a large, unphysical value). This feature is also visible in the Summary tab (Fig. 3). It serves as a second, unintended validation test.

Summary and Conclusion

We have developed software using the CLAS12 Common Tools to provide run-by-run and sector-by-sector methods to monitor data quality in preparation for the G^n_M experiment. The software was validated in simulation and responded to testing of the EC sampling fraction as expected. We will continue to develop other monitoring quantities and apply the code to real data.

References

1. J.Lachniet et al. "Precise Measurement of the Neutron Magnetic Form Factor $G^n m$ in the Few-GeV^2 Region", Phys. Rev. Lett., 102, 1092001, 2009.
2. G.P. Gilfoyle et al. "Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium", E12-07-104, Jefferson Lab, Newport News, VA, 2007.
3. Jefferson Lab Experimental Hall B (Accessed: 22nd October 2018) <https://www.jlab.org/Hall-B/clas12-web/>.
4. Stepanyan, S. "CLAS12-Preshower Calorimeter (PCAL)." (n.d.): n. pag. Web. <https://www.jlab.org/Hall-B/clas12-web/specs/pcal.pdf>.
5. G.P. Gilfoyle, M. Ungaro et al. "Simulation of the Electromagnetic Calorimeter in CLAS12", CLAS-NOTE 2011-019, Jefferson Lab, 2011.