Contents

1 Data Acquisition and Electronics

1.1 Electronics Overview

The PrimEx electronics will consist of Fastbus, VME, CAMAC, and NIM standards crates. The digitization will be done entirely by Fastbus LRS1877 TDC and LRS1881M ADC modules. Additionally, some VME scalers will be read out and periodically inserted into the datastream. The triggering electronics will be done using NIM modules for fanning in calorimeter signals and discrimination. Three CAMAC programable memory lookup units will implement the logic of the trigger.

1.1.1 Crates and Modules

The various crates used to hold the PrimEx electronics will be fixed in 4 electronics racks which are of the same style as those already in use in Hall-B. A diagram illustrating the layout of these crates is shown in figure 1. A total of 30 LRS1881M ADC modules will be required. The space required for each delay cable bundle prevents any ADC modules from being placed in adjacent slots. Thus, 3 fastbus crates are needed to hold all 30 ADC modules and 1 LRS1877 TDC module.

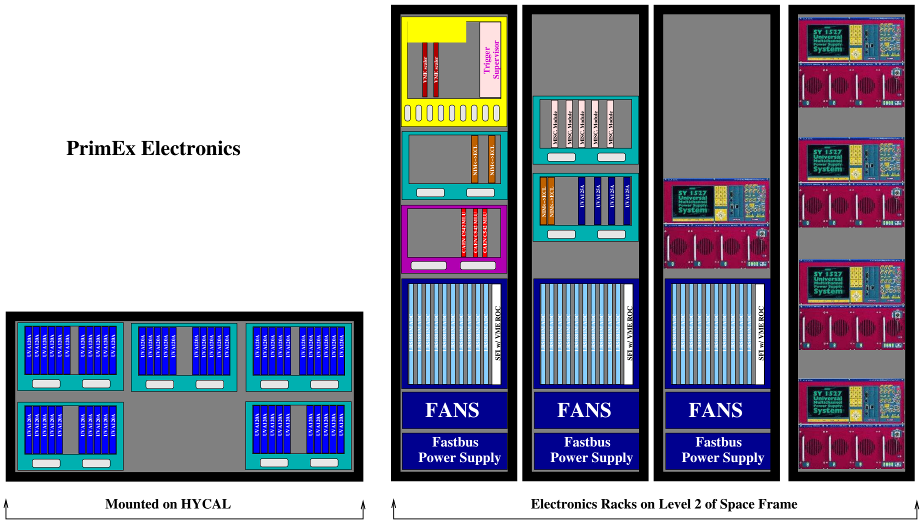

Figure 1: Map of PrimEx Electronics Racks. This is not exactly to scale, but it is reasonably close.

The trigger (described in section 1.2.1) is based on UVA120A and UVA125A NIM modules. The design of these modules was modified specifically for primex based on the signal size and timing requirements expected. A total of 56 UVA120A modules (36 input, 2 output linear fan-ins) and 4 UVA125A (quad 9 input linear fan-in with discriminator) modules are needed. The power requirements of the UVA120A units are quite modest while those of the UVA125A are somewhat more demanding. UVA has provided primex with 6 high powered NIM crates for use with these modules.

1.1.2 Cabling

The main issue with cabling (external to HYCAL) has been the over 1700 channels of delay cables needed for the HYCAL detectors. Delay cables were constructed using special order RG58 coaxial cable with a CL2 fire rating, non-contaminating jacket, and suplemental foil shield. Approximately 1/2 million feet of cable was purchased for this. The cables were cut to 400 ns lengths. Each channel was tested to be within 2ns of 400ns. The cables were soldered to custom designed printed circuit boards with connectors which could be mated directly to the LRS1881M ADC modules. The HYCAL end used a similar type of mass termination. The delay cables were produced in bundles ranging from 25 to 32 cables each. Work on these cable bundles was completed during the summer of 2003.

1.2 Event Triggers

Several event triggers will function during the taking of production data. These are described in the following sections. The triggers will be implemented using the Trigger Supervisor's ability to accept up to 12 independant triggers.

1.2.1 π^o trigger

The π^o trigger will be the primary trigger for physics events. The electronics basically use information from HYCAL to create a trigger when two clusters exist in the calorimeter. This is done by essentially fanning in strips of detectors 5 or 6 high which span the calorimeter. The strip signals are discriminated on. By having strips which span the entire calorimeter, showers are guaranteed to be at least 50% contained in a single strip. Because the strips are at least 10cm apart, events in which two non-adjacent strips fire would signal two clusters in the calorimeter. This explanation is somewhat simplified since shapes, amplitudes and timing of signals from the lead-glass and PbWO4 differ, preventing one from mixing the two detector types in a single fan-in. Another consideration is that two clusters could occur on opposite sides of the same strip, causing only that strip to fire. This is addressed by replicating the logic, but for strips rotated 90 degrees with respect to the first.

This algorithm is implemented in the electronics in the following way: UVA120A linear fan-in modules housed in crates mounted under the HYCAL will fan-in between 25 and 36 dynode signals from the detectors (see fig. 2). The UVA120A's have two inverted outputs. High speed (0.87c), low-impedance coaxial cables are then used to carry the inverted [1] signals up to the UVA125A modules in the racks on level 2 of the space frame. The UVA125A modules perform a second stage of fan-in and apply a discriminator. The discriminator will see the sum of the entire strip. Discriminator thresholds are set via a front panel DC input. These are in turn, driven by a CAMAC controlled DAC so that the discriminator thresholds can be adjusted from the counting house.

Th π^o trigger will actually be dominated by accidentals from Compton scattering and scattering from the beam pipe upstream of the PS dipole (see section 1.2.6). The rate can be adjusted by either raising the threshold, or lowering the beam current. These will be adjusted so that the π^o trigger rate is about 2kHz.

1.2.2 PS trigger

The purpose of the pair spectrometer trigger is to provide a gate well-timed with the pair spectrometer ADC signals. This will be used to monitor the gains of the paddles. In particular, to monitor the gain's dependance on the rate. The Pair Spectrometer trigger will come from a 4-fold coincidence of the upstream-left/right, downstream-left/right pair spectrometer paddle groups. This trigger has been used successfully in CLAS data taking.

[1] Inverting the dynode signal makes it "right-side-up" i.e a negative going pulse as is expected in the UVA125As

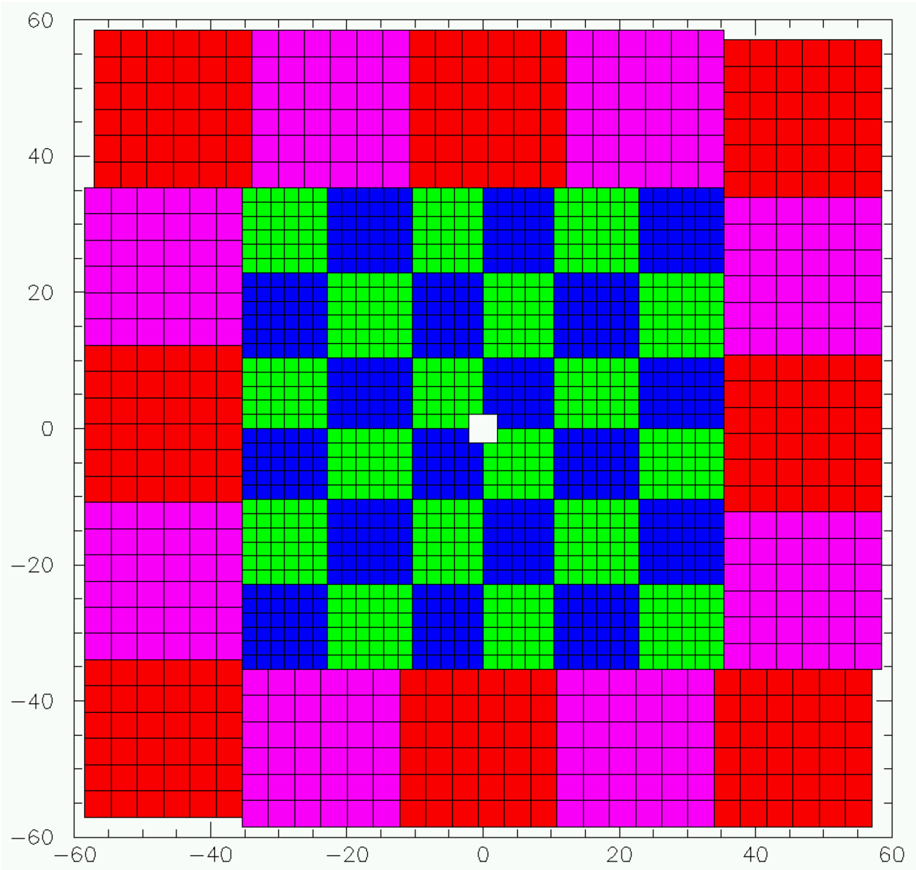

Figure 2: The detector groups formed by the first stage fan-ins.

As a special purpose monitoring trigger, the rate of PS triggered events will contribute a small fraction of the total event rate. We plan to prescale the PS trigger so that it's rate does not exceed 0.5% of the total trigger rate.

1.2.3 LMS trigger

The Light Monitoring System trigger will occur whenever the LMS sends a light pulse to the HYCAL detectors. This will be used as a separate trigger which can be individually prescaled so as to give control over the rate from the counting house. One caveat of the LMS is since it will light every detector in HYCAL, it will also cause π^o triggers. To avoid this, the π^0 logic programmed into the MLU modules will not fire when every strip fires as this will be assumed a LMS event.

Another concern of the LMS events is that since every channel is above threshold, all 1728 detectors will be read. The LMS events will therefore contain more than 10 times as much data from HYCAL as π^o events. For this reason, the LMS trigger rate will not exceed 1Hz [2].

1.2.4 Clock (luminosity) trigger

The clock trigger is used for luminosity monitoring. The idea is that we need an unbiased sample of hits in the tagger to measure the average luminosity. In principle, we could use out-of-time events in the π^o triggers, but these are susceptable to higher frequency beam fluctuations which can be difficult to monitor and even more difficult to correct for. The clock will be produced using a crystal oscillator. A module designed by the Hall-B fast electronics group has been built for primex which will provide 10^4, 10^3, 10^2, and 10^1 Hz signals. Primex will use the the 10kHz trigger prescaled by a factor of 10 using the Trigger Supervisor. This will give us the option of fine tuning the clock trigger rate easily from the counting house.

1.2.5 Trigger Rates

For the August 2002 beam test, the DAQ system was pushed to an event rate of around 6kHz. This corresponded to a fairly low live time of about 20%. For PrimEx production running, we will run such that the live time does not fall below 80%. This will correspond to a DAQ rate of approximately 3 kHz. A summary of the primex triggers and their anticipated rates is shown in table 1.2.5.

1.2.6 Monte Carlo Trigger Studies

With the modifications required for the trigger due to the new geometry of HYCAL, a new Monte Carlo study was performed to estimate the acceptance

[2] There are preliminary plans for a smarter LMS trigger which will fire at an increased rate (10Hz) automatically during beam trips.

Trigger	Rate
π^o	2 kHz
PS	10 Hz
LMS	2 Hz
Clock	1 kHz
Total	3kHz

Table 1: Triggers that will be used during primex and their anticipated rates during production running.

efficiencies and trigger rates. The new study had several improvements over the original including energy smearing, a more accurate beamline definition, more realistic detector geometry, and realistic bremstrahlung angular distribution.

The first part of the study focused on the trigger's acceptance efficiency for Primakoff π^o events. The programming of the C542 MLU units was emulated in software so that the algorithm could be fully tested. Figure 3 shows the event viewer used to analyze simulated data. The acceptance efficiency is expected to be nearly 100% for π^o decays whose photons each have a given minimum energy (determined by discriminator threshold settings) and have trajectories pointing to the fiducial part of HYCAL. The few trigger failures expected are due to energy leakage through the cracks between detectors in HYCAL. Figure 4 shows a plot of the trigger efficiency vs. the minimum decay photon energy if the trigger were set to accept all 500MeV or greater photons. This plot shows that the triggering efficiency is quite insensitve to the discriminator threshold.

The second part of the Monte Carlo study focused on estimating the trigger and detector rates due to backgrounds and accidentals. Figure 5 shows an upper limit of the PrimEx trigger rate as a function of the decay photon energy, estimated by simulation. This upper limit was calculated assuming a 50 ns coincidence window. In reality, PrimEx will use something closer to 20 ns. A "worst case scenario", however, was employed in order to obtain a believable upper limit. An arrow on the plot indicates the 750MeV photon energy point with an event rate of approximately 1.5kHz. Unlike the triggering effciency, the background rate is very sensitive to the value of the discriminator thresholds. For the actual experiment, the thresholds will be set as low as possible such that the deadtime does not exceed 5%.

The primary contribution to background rates come from two sources: 1.) e+e- pair production upstream of the Helium bag and 2.) Compton scattering from the Helium itself. Figure 6 shows the sources of these backgrounds along the beamline. Backgrounds originating in the beampipe are due to large angle bremstrahlung photons showering in the beampipe. Occasionally, some energetic shower photons will pass down the beamline, through the magnet, and into HYCAL. These types of events will be easily rejected in software.

Further simulation studies estimated discriminator rates and detector rates. The expected discriminator rates are shown in figure **??** for the PbWO4 detector strips. The rates corresponding to the minumum decay photon energy of

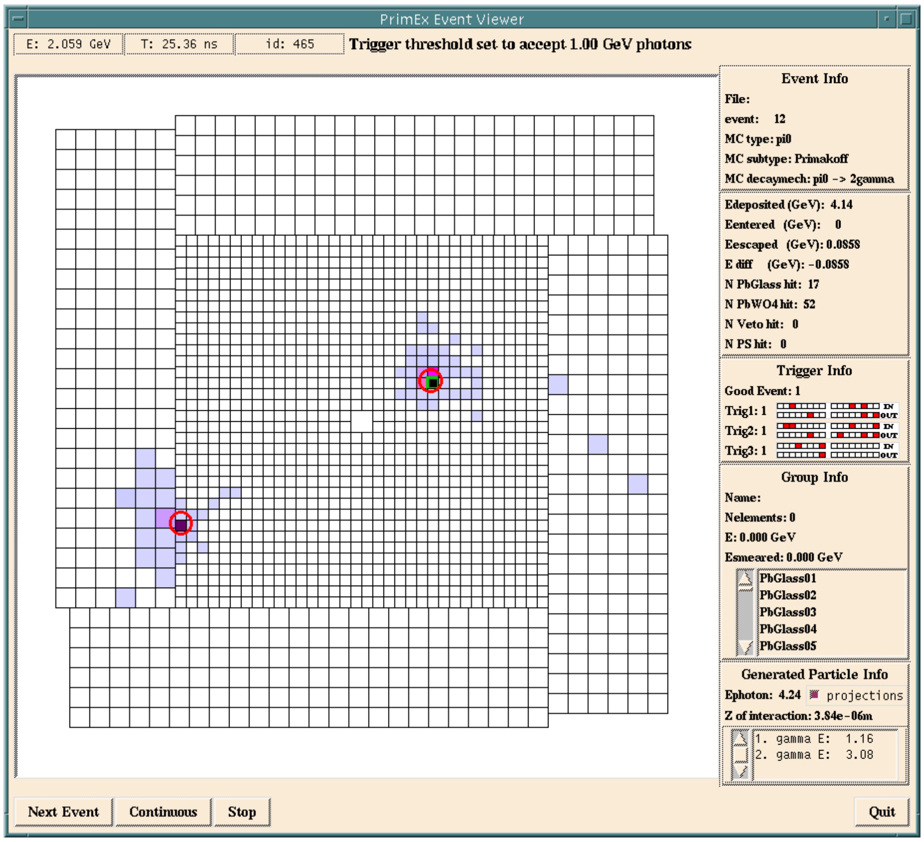

Figure 3: PrimEx event viewer for Monte Carlo data. This is used to diagnose individual events and the trigger's response.

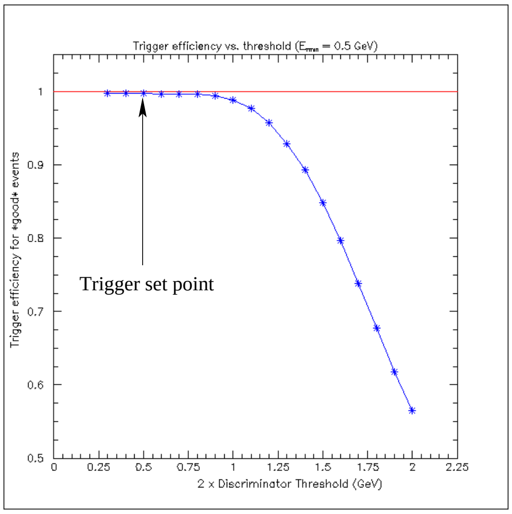

Figure 4: Plot of the trigger acceptance efficiency (estimated from simulation) vs. discriminator threshold. The acceptance effciency is based on accepting 500MeV or greater photons. The arrow indicates where the threshold should be set for accepting 500MeV photons. The curve shows that the acceptance effciency is very insensitive to the discriminator threshold.

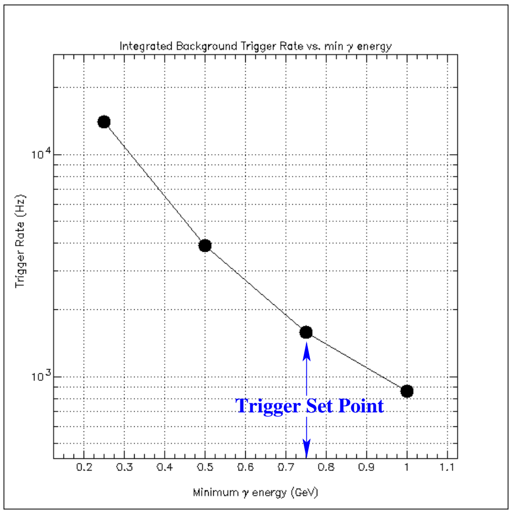

Figure 5: Trigger rate (upper limit) due to background vs. the minimum decay photon energy. The rate includes accidentals from combining several background events. The discriminator values will initially be set to correspond to the 750MeV decay photon energy point. The final discriminator values will be determined by the deadtime in the DAQ system.

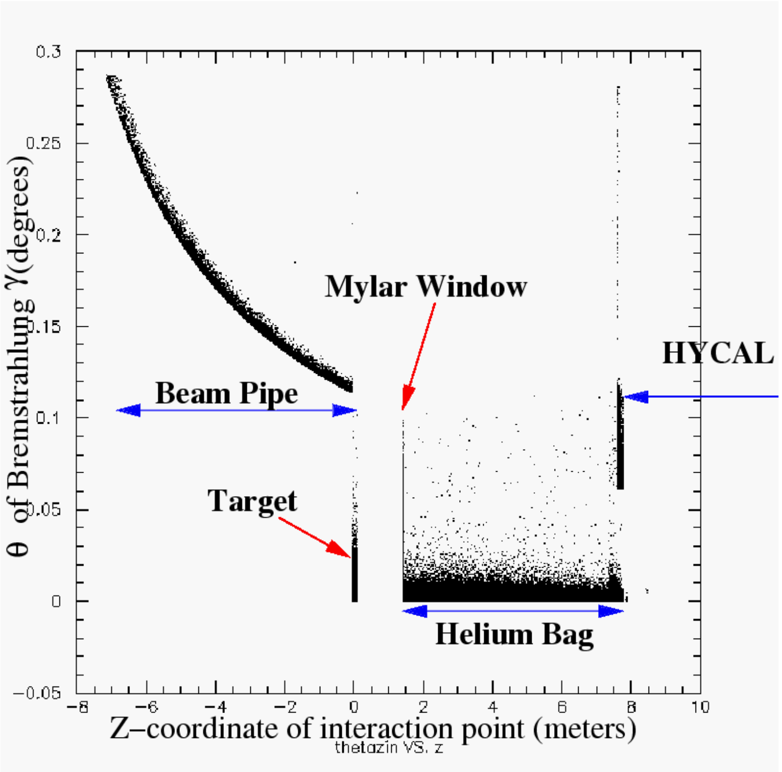

Figure 6: Location of background sources along Hall-B beamline. The angle of the bremstrahlung generated beam photon is plotted vs. the position along the beamline at which the initial interaction took place. The relevant beamline components included in the simulation are shown.

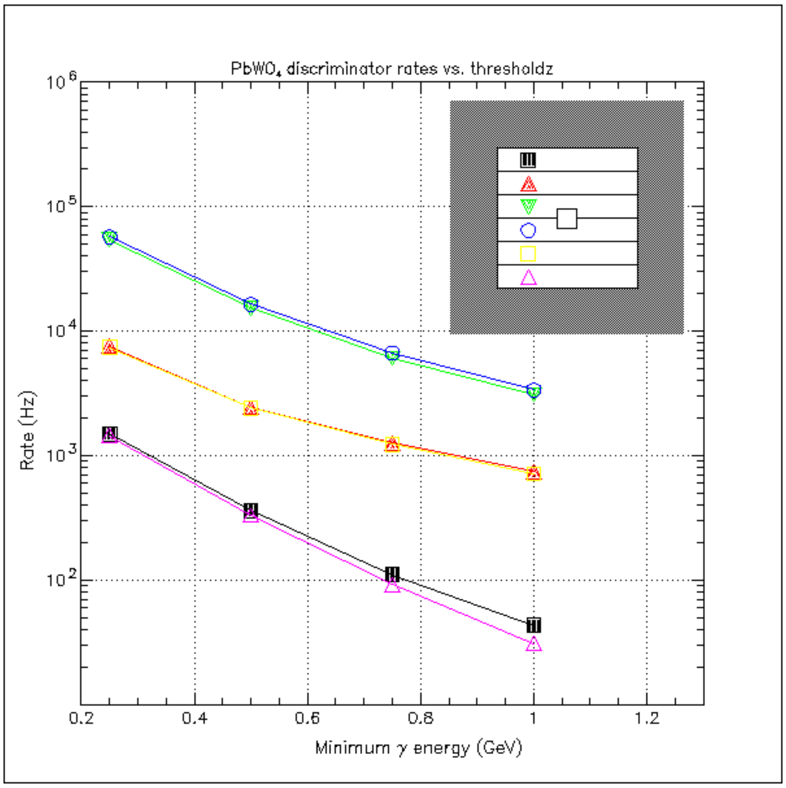

Figure 7: Discriminator rates for different sections of HYCAL based on simulation study.

750MeV(initial PrimEx trigger point) for the innermost strips will fire at less than 10kHz.

1.3 Data Format and Data Rates

1.3.1 Data Format

Primex will use the CODA format for recorded data. The CODA physics events will contain the words as read from the fastbus modules. All decoding will take place offline. The primex analysis software has already implemented a library of IO functions to read, write and parse the CODA formatted files. Additionally, a CODA bank definition has been created to record and read/write primex "banks" (see sections 1.4-1.4.2).

1.3.2 Data Rates/Event Sizes

The photon tagger will almost completely dominate the event size. With an average of 1MHz per T-counter and 19 T-counters, we expect a 19MHz rate for the tagger. With a $10\mu s$ TDC window, we expect 190 photons per event. The post-bremstrahlung electron will hit 1 T-counter and 1 2/3 E-counters on average. This translates to about 6.1MB/sec for an event rate of 3kHz. For the same event rate, hycal will provide only about 1.2 MB/sec assuming only 100 detectors pass sparsification per event on average.

1.4 Analysis Software

Considerable development of analysis software has been made for primex. The modular code is kept under CVS control on the JLab CUE on the primex group disk. The programs have been developed to read the CODA formatted data from HYCAL-0 beam tests in August 2002. This format has also been fully implemented into the simulation code to allow seamless analysis of both real and simulated data.

Primex has implemented a calibration database based on the design of the CLAS database using MySQL.

There currently exists over 50k lines of primex simulation and analysis code in the primex CVS repository.

1.4.1 Object Framework

The Primex analysis software is built on a framework made of several C++ objects. The important feature is the PEvent_Loop class which implements an event loop which can be used by all programs. Analysis programs typically have main() routines with only 5-10 lines of code. This makes development time of new programs minimal since all common functions are handled by the PEvent_Loop object.

1.4.2 Bank Definitions (BDML)

To facilitate communication between different modules of the primex analysis software, a bank structure was defned. Some properties include standard access mechanisims, dynamic resizing, and extensibility. Top level definitions of the banks was done by creating a flavor of XML dubbed the Bank Definition Markup Language (BDML)[1]. With BDML, a new bank is easily added to a single BDML file and the neccessary code is automatically generated by make. Additionally, the bank printing routines and documentation are standardized and generated directly from the BDML source.

1.5 Online Monitoring Software

1.5.1 ET system

The CODA data acquisition system has been integrated with the CEBAF Event Transfer or ET system. This allows one to copy events from the ET system for online analysis without interrupting the data flow onto disk. The Hall-B counting house has several computers dedicated for online monitoring. Primex successfully tested an et2et program which copied events from the primary data acquisition computer clon10 to a secondary machine, clon00, where online monitoring programs were run. The analysis software discussed in section 1.4.1 has been written to allow events to be read from an ET system as easily as from a file. This gives primex the flexability to run any program written for offline in an online environment.

1.5.2 Monitoring Programs

A philosophy has been adopted for the primex software which is as follows: Each detector system (hycal, tagger, pair spectrometer, ...) will have its own library of reconstruction software. In addition, each system will have a program which will satisfy 3 criteria:

1. Produce plots (histograms, scatter plots, ...) which indicate the system is working properly.
2. Produce plots which enable one to derive calibration constants easily
3. Produce plots which check the quality of the existing calibration.

It is in this context that a number of programs have been developed for primex. These are:

- hycal_calib
- tagger_calib
- ps_calib
- tac_calib

- prim_monitor

These programs will all be run online to both check the functioning of the various detector systems as well as provide a means for quickly calibrating the detectors so that the quality of the data may be monitored as well.

1.5.3 PrimEx Event Viewer (pev)

In addition to the statistical monitors described in the previous section, a graphical single event viewer has been written. The PrimEx Event Viewer or *pev* was written to provide a way of quickly looking at individual events in detail. It has views of the HYCAL, tagger, and Pair Spectrometer. Figure 3 shows a screen shot of an early version of the viewer looking at Monte Carlo data. The event viewer will read events from the ET system on clon04 in the counting house and will be in continuous operation during data taking.

1.6 DAQ and Electronics Summary

- The primex experiment will utilize fastbus technology to digitize signals from all of it's detector systems (HYCAL, tagger, PS, ...) This equipment was used successfully during the August 2002 beam test.
- The primary physics trigger will be implemented using UVA designed , NIM standard modules (UVA120A and UVA125A). The trigger will occur when 2 clusters separated by at least 10cm are present in HYCAL. Simulation studies indicate high efficiency with little sensitivity to thresholds.
- All modules and crates are currently on site and are in possession.
- Primex will take production data with an event rate of approximately 3kHz and an data rate of approximately 7.3MB/sec.
- Over 50K lines of code has already been written for primex. Approximately 30K lines of this is specifically for data analysis and online monitoring.

References

[1] PrimEx Note 17: *The PrimEx Bank Definition Markup Language* $http:\backslash\backslash www.jlab.org\backslash primex\backslash primex\_notes\backslash primex\_notes.html$