Determining the Trigger Efficiency for E08-027: Update

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February 11, 2014

Abstract

E08-027 requires trigger scintillator efficiencies to make an absolute cross-section measurement. Efficiencies were calculated on production, dilution and packing fraction runs from both high-resolution spectrometers. The left-HRS efficiencies are all above 99% with 1448 runs calculated in total. On the right-HRS efficiencies are above 99% for 929 out of 945 runs. The sixteen right-HRS runs with under 99% efficiency are dilution runs. Results have been uploaded into the MySQL experiment database. This is an update to my previous report and includes an updated calculation with full PID cuts and also a summary of the trigger system and initial scintillator calibration.

1 Introduction

The E08-027 (g2p) experiment used inclusive electron scattering to measure both electron-proton scattering asymmetries and cross-sections in order to determine the g_2 structure function. The absolute cross-section measurement requires that the raw detected electron counts be corrected for detector efficiencies (along with prescale, deadtime, etc.) to obtain the true scattering rate at the target. This technical note will present the analysis of the trigger-scintillator efficiencies for both spectrometers.

2 High Resolution Spectrometer Detectors

Each high-resolution spectrometer (HRS) had its own independently functioning trigger and data acquisition (DAQ) setup. The HRS-R detector package is shown in Figure 1. Scattered electrons first pass through a pair of vertical drift wire-chambers (VDCs). The electrons ionize the gas inside the wire chambers and timing information from the ionization trail determines the position and angle of the trajectory. Next the electrons pass through a pair of segmented plastic scintillators (s1 and s2m), which form the data acquisition trigger. The scintillators consisted of segmented plastic scintillator readout on both sides via photomultiplier tubes (PMTs). The s1 detector had six 0.5 cm x 30 cm x 36 cm pieces of scintillator in a 1 x 6 arrangement and the s2m scintillator had sixteen 43.2 cm x 5.1 cm x 14 cm scintillators in a 1 x 16 arrangement. In the detector hut, the two scintillating planes were separated by about two meters [1].

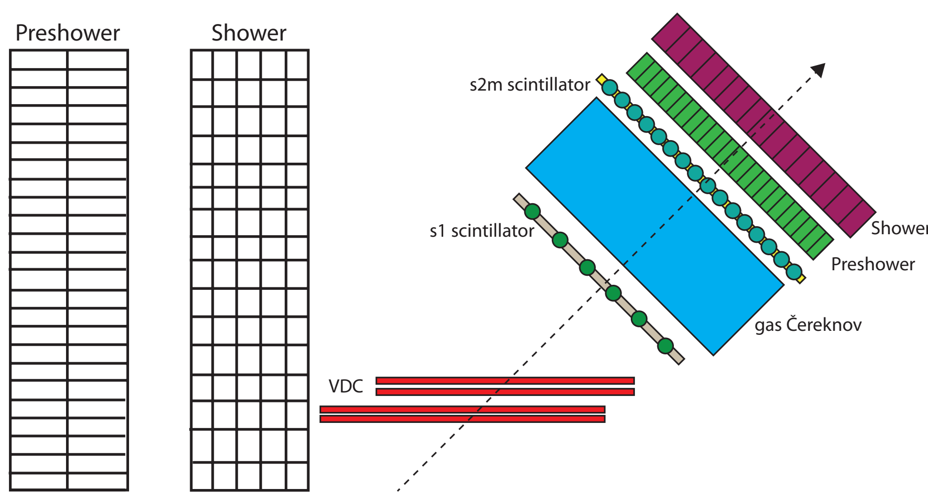

Figure 1: Frontal view of the lead glass blocks and side-view of the HRS-R detector stack. The HRS-L stack only differs in the layout of its electromagnetic calorimeters.

Particle identification (PID) is provided by a gas Čerenkov detector and a two-layer electromagnetic calorimeter (Preshower and Shower). The gas Čerenkov uses the production of Čerenkov light in CO2 to distinguish electrons from other negatively charged particles. The calorimeters use a collection of lead glass blocks to induce a cascade of pair production and bremsstrahlung radiation from energetic particles. A detailed treatment of the PID detector calibration can be found in [2, 3].

2.1 Scintillator Calibration

Photomultiplier tube voltages for the scintillators were initially calibrated using cosmic rays. The flux of cosmic ray muons at sea level is approximately 1 $\mathrm{cm}^{-2}\ \mathrm{min}^{-1}$ [4]; PMT voltages were set to give the appropriate rate on the scintillator given its dimensions. The raw PMT signals were split: one copy was sent to the DAQ analog-to-digital converters (ADC) and the other was sent to a discriminator for use in the trigger logic and DAQ time-to-digital converters (TDC). A sample of the raw and discriminated signals for the s1 scintillator is shown in Figure 2.

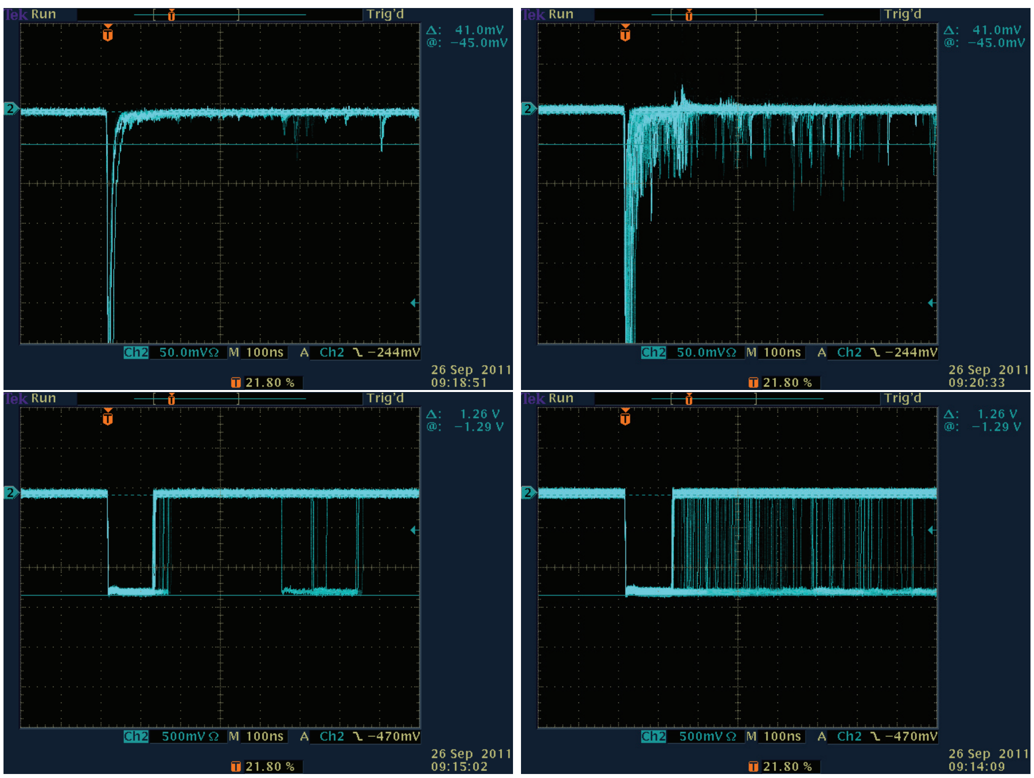

Figure 2: Raw and discriminated HRS-L s1 PMT signals. The top row is the raw signal for PMT 5R and 6R. The horizontal line is the discriminator threshold (40mV). The bottom row is the corresponding discriminated output.

The ADC signals were also checked to make sure the detected signal did not bleed into the ADC pedestal. A larger PMT voltage would place the detected signal at a higher channel in the ADC spectrum, but too high a voltage and then signal noise might be amplified above the discriminator threshold, creating spurious

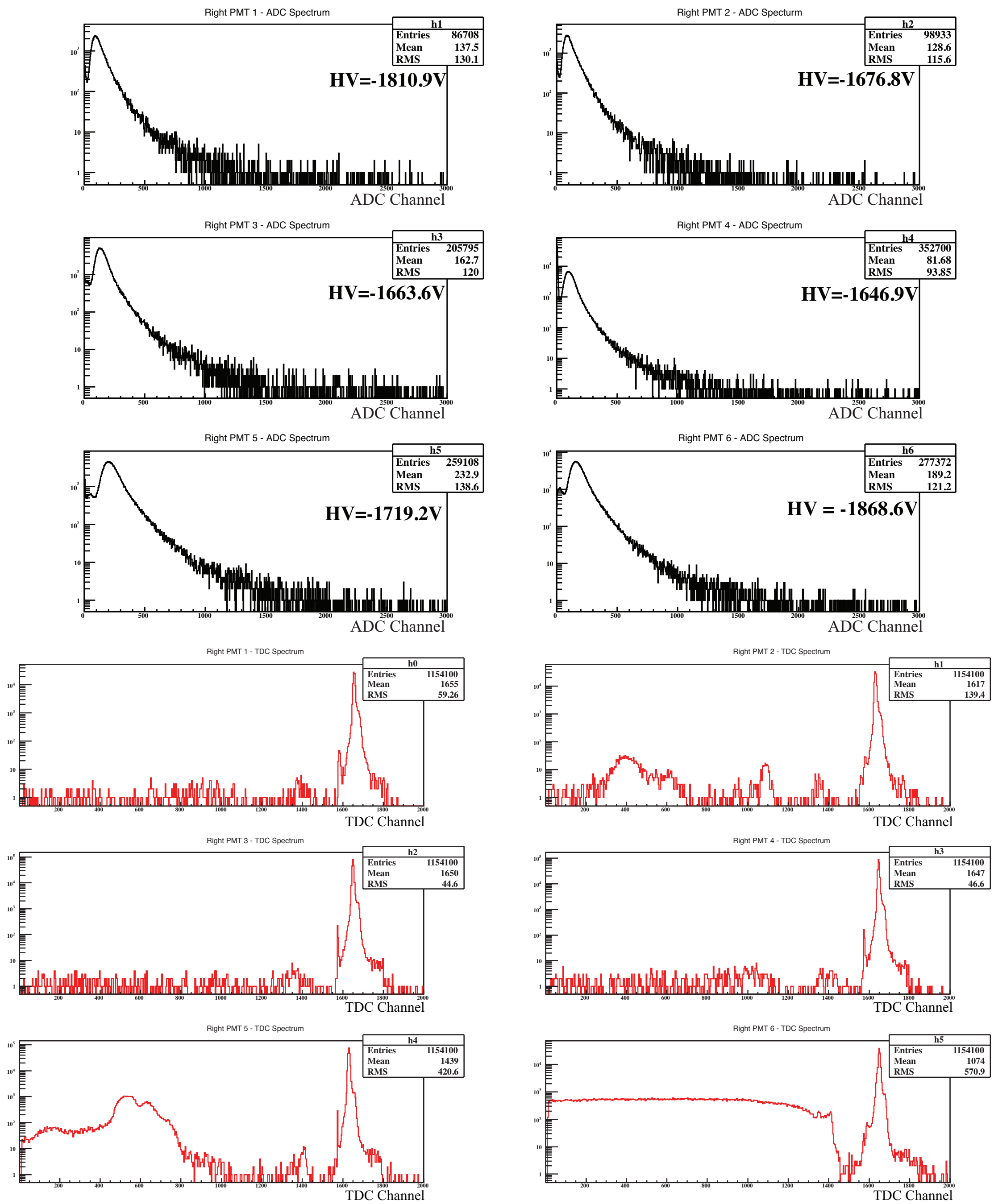

Figure 3: ADC (top/black) and TDC (bottom/red) signals for the right PMTs of the s1 scintillator plane on HRS-L. The ADC plots show the corresponding PMT high-voltage setting.

triggers. The corresponding ADC and TDC spectrums are shown in Figure 3. The noisy discriminated signal for the 6R PMT in Figure 2 shows up in the large shoulder to the left of the main peak in the TDC spectrum. Instead of raising the discriminator threshold and possibly lowering efficiency, the noisy PMT's were replaced. Five PMT's were changed in total on the HRS-L s1 scintillator: 5L, 6L, 2R, 5R, 6R. No PMT's were replaced on the remaining scintillators of both spectrometers. The scintillator voltage settings for the entire experiment are shown in Table 1.

Table 1: Scintillator high voltage settings for the E08-027 experiment. All values are in Volts and HRS-L is on the left and HRS-R is on the right.

s2mL	s2mR	s1L	s1R
-1595	-1520	-1702	-1702
-1504	-1649	-1637	-1657
-1929	-1781	-1795	-1637
-1781	-1708	-1792	-1688
-1811	-1803	-1553	-1740
-1614	-1794	-1513	-1780
-1768	-1816		
-1714	-1952		
-1748	-1939		
-1858	-1807		
-1893	-1844		
-1754	-1562		
-1827	-1637		
-1812	-1679		
-1628	-1694		
-1488	-1645		

s2mL	s2mR	s1L	s1R
-1719	-1850	-1651	-1681
-1689	-1630	-1801	-1601
-1695	-1636	-1721	-1752
-1757	-1702	-2071	-1632
-1659	-1751	-1673	-1686
-1745	-1652	-2081	-1642
-1586	-1774		
-1745	-1778		
-1811	-1711		
-1682	-1586		
-1821	-1720		
-1843	-1731		
-1576	-1911		
-1586	-1934		
-1625	-1921		
-1670	-1940		

3 Spectrometer Trigger Overview

The experiment used two separate singles triggers. The main trigger for data acquisition was defined by an electron passing through both scintillator planes. It was formed as the logical AND of the following:

- The Left and Right PMTs of scintillator segment of S1 fire
- The Left and Right PMTs of scintillator segment of S2m fire
- The event causes both S1 and S2m to fire
- No restriction was made on which scintillator segments fired between S1 and S2m

The main trigger was named T_1 on the right spectrometer (HRS-R) and T_3 on the left spectrometer (HRS-L). The explicit trigger logic of the scintillators on HRS-L is shown in Figure 4. The logic is identical

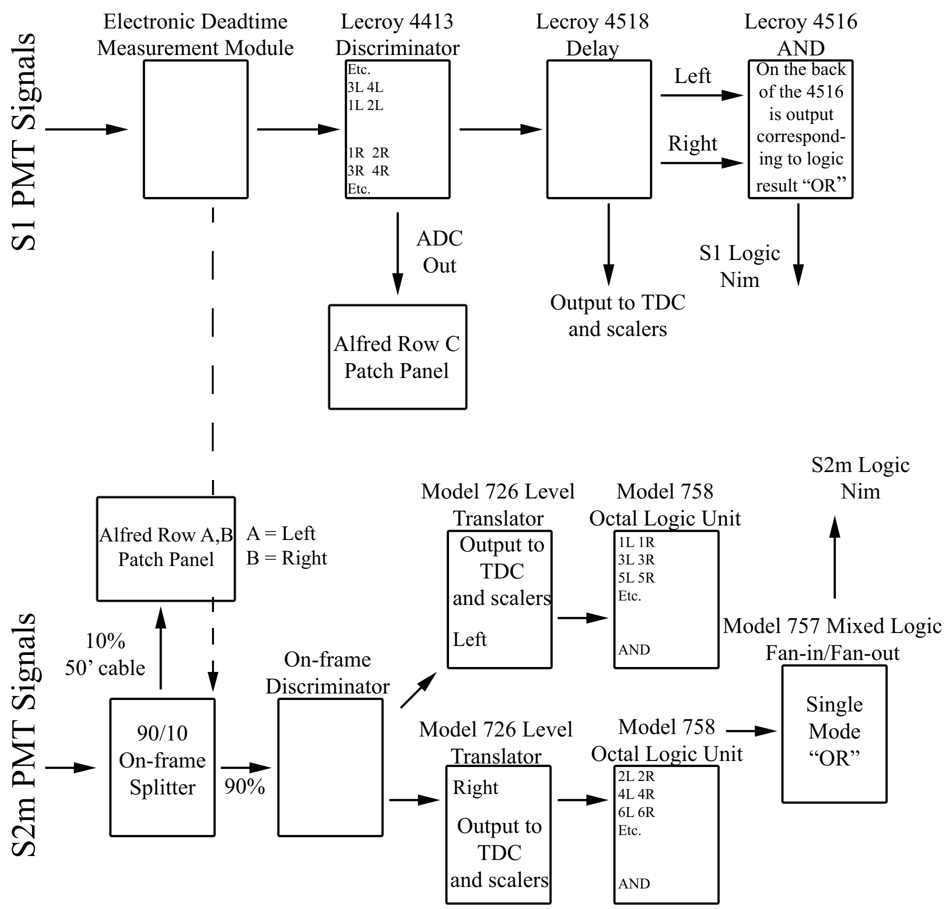

Figure 4: Trigger logic for the s1 and s2m scintillators on HRS-L. The Electronic Deadtime Measurment (EDTM) Module inserts a constant frequency signal into the raw s1 and s2m PMT signals. This EDTM signal is also sent to a TDC and by looking at how many EDTM events seen versus expected, the electronic deadtime can be estimated.

on HRS-R, but the module layout is slightly different.

A secondary trigger T_2 (T_4) for the RHRS (LHRS) measured the efficiency of the main trigger. Formed exclusive to the main trigger, the efficiency trigger was defined as the logical AND of the following:

- Either the S1 OR S2m scintillator planes fire but not both
- The event also led to a signal being detected in the gas Čerenkov

The first requirement excludes main triggers while the second defines events that should have been been detected by both scintillator planes. The creation of the gas Čerenkov logic is shown in Figure 5.

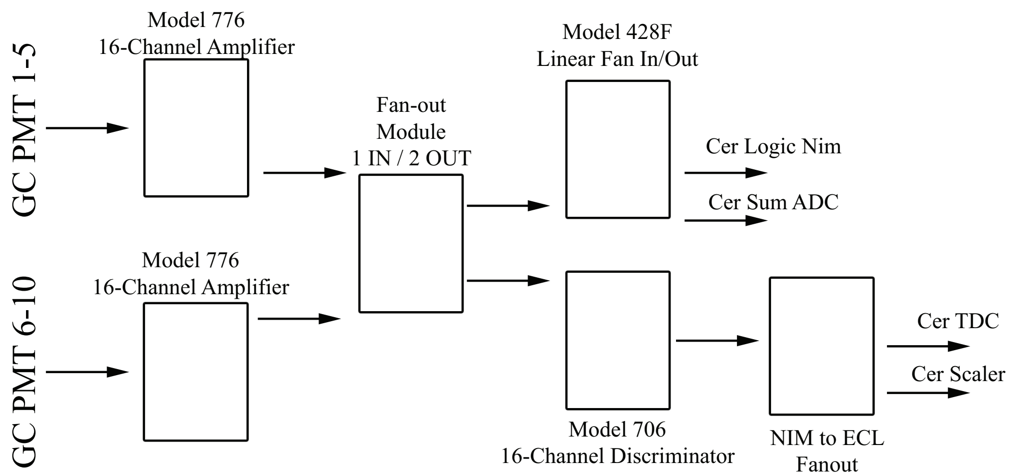

Figure 5: NIM logic for the gas Čerenkov trigger, TDC and scaler signals. The Model 428F also creates a sum of all the Čerenkov ADC signals which can then be used for particle identification during analysis.

The layout and formation of the rest of the data acquisition logic is shown in Figure 6 and used a combination of NIM, CAMAC and VME modules. The efficiency trigger was created in a programable Lecroy 2373 MLU, while the main trigger was created using a Phillips-Scientific Model 754. After the triggers were formed they were sent to the trigger supervisor (TS), which decided whether or not the data acquisition system recorded the event. If the event was accepted, then the TS issued a level-one accept (L1A) signal. Ultimately the L1A, in conjuction with a retime signal (s1 OR s2m), was used to generate the gates and stops for the ADCs and TDCs, but first the signals were sent to the retiming (RT) module. The RT module ensured that there was a RT signal for every L1A, which kept the DAQ synchronized. Under normal operation, the timing of the L1A signal was adjusted (using the programable Lecroy 4518) to arrive approximately 60 ns before the RT signal. If there was data pile-up and the L1A arrived after the RT or the L1A arrived greater then 200 ns before, the timing of the output (RTO) was shifted. This shift was detectable in the TDC spectrum. The gates and stops generated in the Transition Module were based on an overlap from the L1AO and RTO signals. The use of the retime signal helps align the time spectrum of the different trigger types.

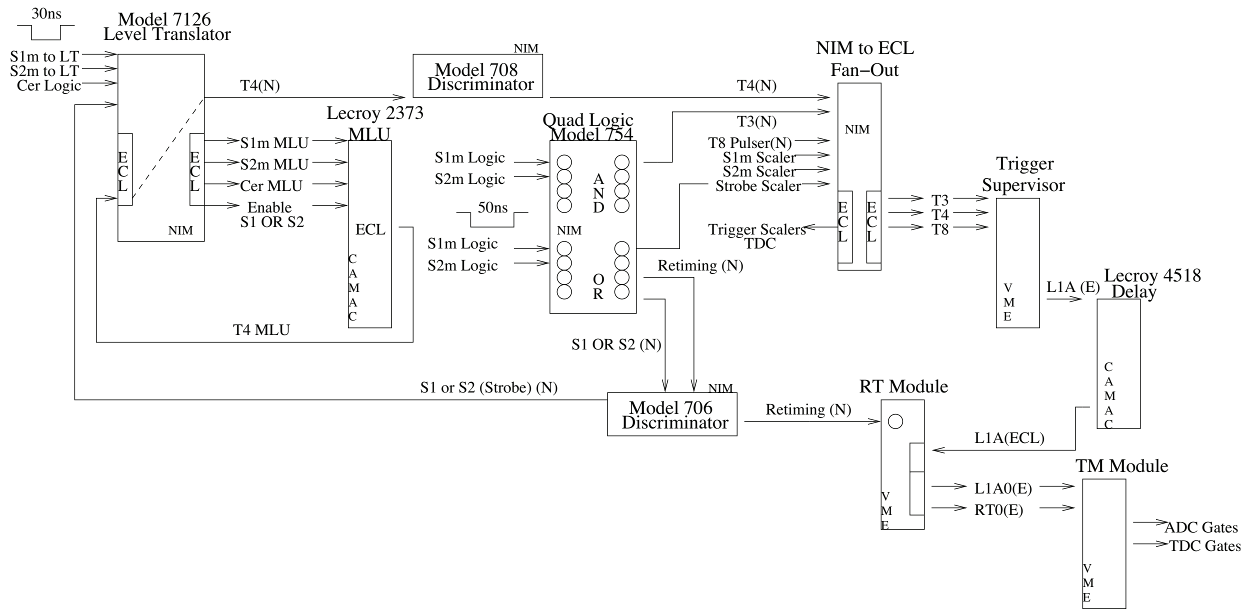

Figure 6: E08-027 DAQ logic modules and schematic.

4 Determining Trigger Efficiency

The trigger efficiency is

$$\epsilon_{\mathrm{trig}} = \frac{T_{\mathrm{main}}}{T_{\mathrm{main}} + T_{\mathrm{eff}}}, \tag{1}$$

where $\mathrm{T}_{\mathrm{main}}$ and $\mathrm{T}_{\mathrm{eff}}$ are the total number of trigger counts for the main and efficiency triggers respectively. These counts can be determined from either the trigger scalers or the trigger latch pattern. The trigger latch pattern, which is created by sending the trigger signals to a TDC, is favored over the scalers because it is tied directly to recorded events and allows for cuts to be made in analysis. This correlation with recorded events also makes the trigger latch pattern susceptible to deadtime effects. The deadtime correction for the latched triggers is

$$T_{\mathrm{corr}} = \frac{T_i ps_i}{1 - DT_i}, \tag{2}$$

where i is the trigger type (1-4), T_i is the accepted trigger count, ps_i is the prescale factor for the trigger and DT_i is the deadtime associated with the trigger. The deadtime is determined from the livetime (LT) with

DT = 1 - LT. The livetime is then the ratio of accepted triggers to total triggers adjusted by the prescale factor such that

$$LT = \frac{ps_i T_i^{acc}}{T_i^{tot}}, \tag{3}$$

where the accepted triggers are determined from the latch pattern and the total trigger count is from the trigger scalers.

5 Analysis Cuts

Analysis cuts were used to insure that only electron events were included in the efficiency calculations. These cuts are shown in Figure 7 for run 3288. The tracking cut requires that the event created a single track in the VDC. The particle identification cuts on the gas Čerenkov, and pion rejector layers eliminated pion contamination.

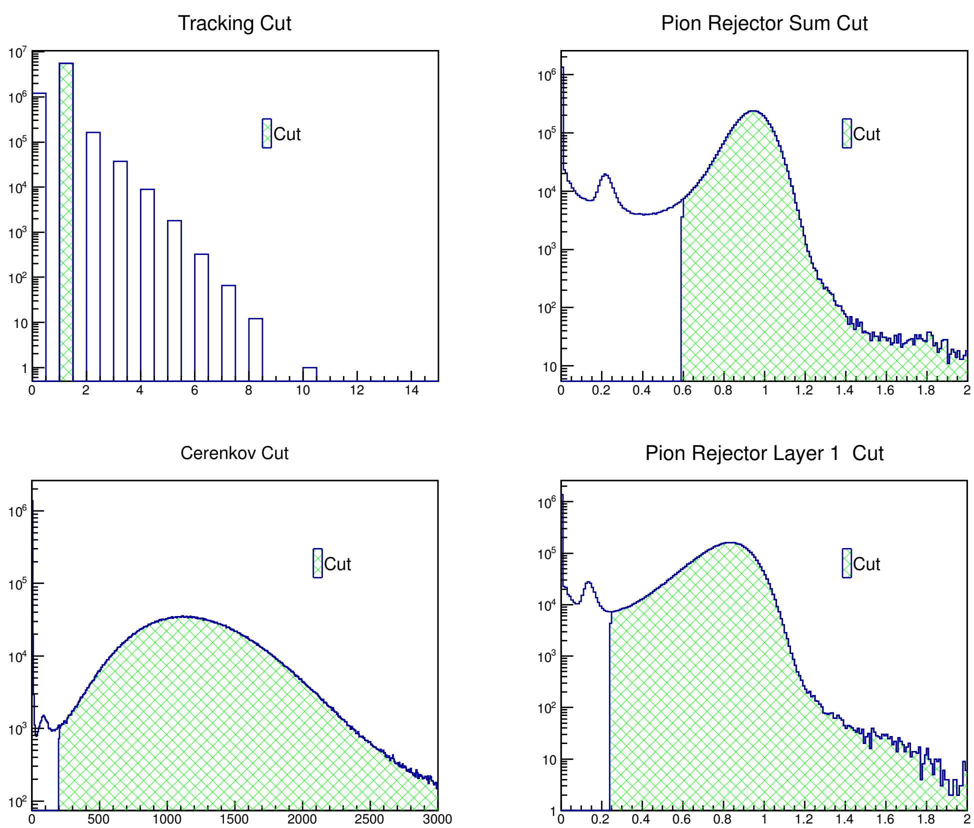

Figure 7: Good electron cuts for run 3888 on HRS-L. $E_0 = 2253$ MeV and $p_0 = 899$ MeV.

6 Results

The results of the trigger efficiency calculation are shown in Figure 8. All HRS-L runs have a trigger efficiency greater than 99% while they are 26 HRS-R runs with trigger efficiencies below this number. These HRS-R runs have been listed in Table 2. It should also be noted that no efficiencies were calculated for the right-HRS at 2.253 GeV and a 2.5 T target field. The efficiency trigger, T_2, was broken during this run period.

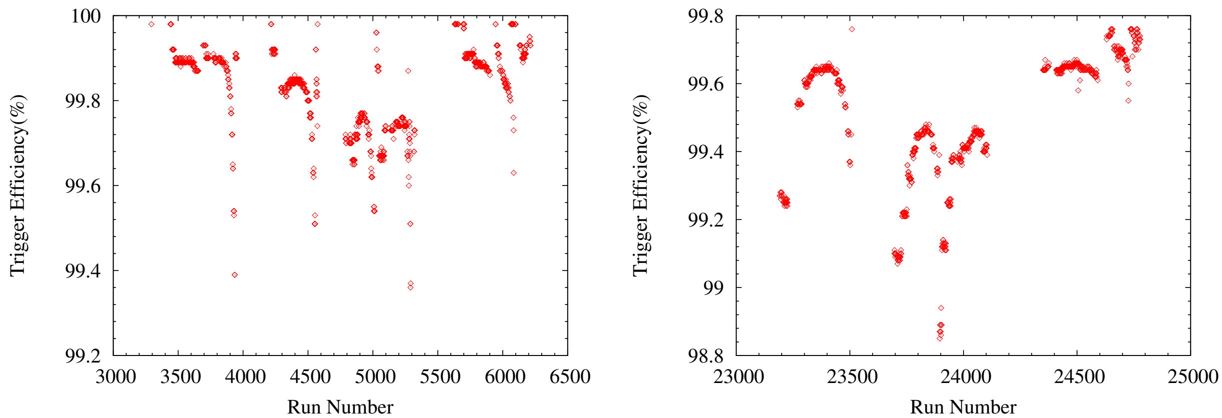

Figure 8: Trigger efficiency plotted against run number. HRS-L is on the left and HRS-R is on the right.

7 Conclusion

Trigger scintillator efficiencies are calculated for all applicable runs on the left and right high-resolution spectrometers. The efficiency and deadtime results were added into the MySQL database for all the runs calculated. Results show that this efficiency is almost always less than a one-percent effect on the cross-section normalization.

References

[1] J. Alcorn *et al.*, Nuc. Instrum. Meth. **A522**, 297 (2004).

[2] M. Cummings, E08-027 Tech. Note 04, http://hallaweb.jlab.org/experiment/g2p/technotes/E08027_TN2013_04.pdf.

[3] M. Cummings, E08-027 Tech. Note 05, http://hallaweb.jlab.org/experiment/g2p/technotes/E08027_TN2013_05.pdf.

[4] J. Beringer *et al.*, Phys. Rev. D**86**, 307 (2012).

Table 2: RHRS runs where the trigger efficiency falls below 99%. A run status of "1" corresponds to production runs and a run status of "3" corresponds to dilution runs.

Run Number	E0 (GeV)	P0 (GeV)	RunStatus	Eff
23685	1.15	1.017	3	98.88
23686	1.15	1.017	3	98.89
23687	1.15	1.017	3	98.92
23688	1.15	1.017	3	98.94
23689	1.15	1.017	3	98.96
23690	1.15	1.017	3	98.97
23895	1.15	1.081	1	98.86
23896	1.15	1.081	1	98.85
23897	1.15	1.081	1	98.88
23898	1.15	1.081	1	98.88
23899	1.15	1.081	1	98.86
23900	1.15	1.081	1	98.86
23901	1.15	1.081	1	98.86
23902	1.15	1.081	1	98.93
23903	1.15	1.081	1	98.89
23904	1.15	1.081	1	98.89
24779	3.35	1.945	3	97.86
24780	3.35	1.945	3	98.04
24781	3.35	1.945	3	97.85
24788	3.35	1.945	3	97.73
24789	3.35	1.945	3	97.80
24790	3.35	1.945	3	97.84
24791	3.35	1.945	3	97.79
24792	3.35	1.945	3	97.74
24793	3.35	1.945	3	97.78
24794	3.35	1.945	3	97.50