CLAS-NOTE 2004-031
CVS: docs/clas_analysis/eg3_beamtest.tex
Original: August 26, 2004

Evaluation of rates during eg3 beam tests

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Contents

1 Introduction

We have conducted two beam tests to study the trigger rates for Experiment 04-010, "Search for Exotic Cascades with CLAS using an untagged virtual photon beam." The first test was conducted with an electron beam using the flux of virtual photons produced in the target. The second test used the standard configuration for tagged photon beams of Hall B. In both tests, data were taken with relatively high dead time because the DAQ cannot yet handle the expected rates. We note however, that the DAQ hardware is being upgraded to twice its current rate capability for use during the experiment itself.

2 Test with Virtual Photons

The test with and electron beam was conducted on March 6 and 7 using the beamline configuration of eg2. The data were taken with a 5.014 GeV electron beam, 2 cm liquid deuterium target 30 cm upstream of nominal center[1] and with the torus magnetic field reversed to -2250 and -1500 A. The trigger configuration for both level 1 and level 2 were studied for a variety of thresholds and settings. For this configuration, a beam current of 15.8 nA corresponds to a luminosity of $2{\times}10^{34}$cm^{-2}s^{-1}-nucleon, which is the design luminosity for the experiment.

At the beginning of the test, rates were measured with a variety of trigger configurations. The L1 rates for different thresholds in the calorimeter are given in Table 1. The threshold settings of the trigger are illustrated in Fig. 1 plotted on a typical energy distribution of ECout vs ECin for an electron run.[2] Configurations with a minimum energy requirement either in the inner or the total resulted in trigger rates of approximately 22 kHz at 10 nA. Increased threshold settings could be used to lower the trigger rate, but would have an impact on the efficiency for the physics signal. Therefore, additional studies which required tracks in the drift chambers with the Level 2 trigger we studied using the ECin_hi configuration file.

Table 1: Summary of EC threshold scan taken with an electron beam on a 2 cm deuterium target. The different rates corresponds to various coincidences between ECin (inner calorimeter), ECout (outer calorimeter), and ECtot (sum of inner and outer). All data were taken with a beam current of 10 nA. The configuration ECin_hi was used for all further studies with Level 2. Configurations with lower rates would have reduced trigger efficiency for the signal.

Run Number	Configuration File	ECin (mV)	ECout (mV)	ECtot (mV)	L1 rate (kHz)
42174	ECinECout_hi	20	35	–	11.0
42171	ECinECout_lo	15	20	–	14.4
42176	ECtot_hi	–	–	60	16.1
42175	ECinECtot_hi	20	–	60	16.6
42172	ECinECtot_lo	15	–	30	21.2
42173	ECtot_lo	–	–	30	21.8
42170	ECin_hi	20	–	–	22.7
42169	ECin_lo	15	–	–	23.6

We then studied the effect of adding the Level 2 trigger. Requiring 3, 4 or 5 segments out of 5 for every track[3] in the L2 trigger at 10 nA, the live time increased

[1] Data were taken on a 2-mm solid ^{12}C as well.

[2] A threshold setting of 60 mV corresponds to approximately 400 ADC counts.

[3] Only 4 segments were required in sector 3 to compensate for gaps in the hardware.

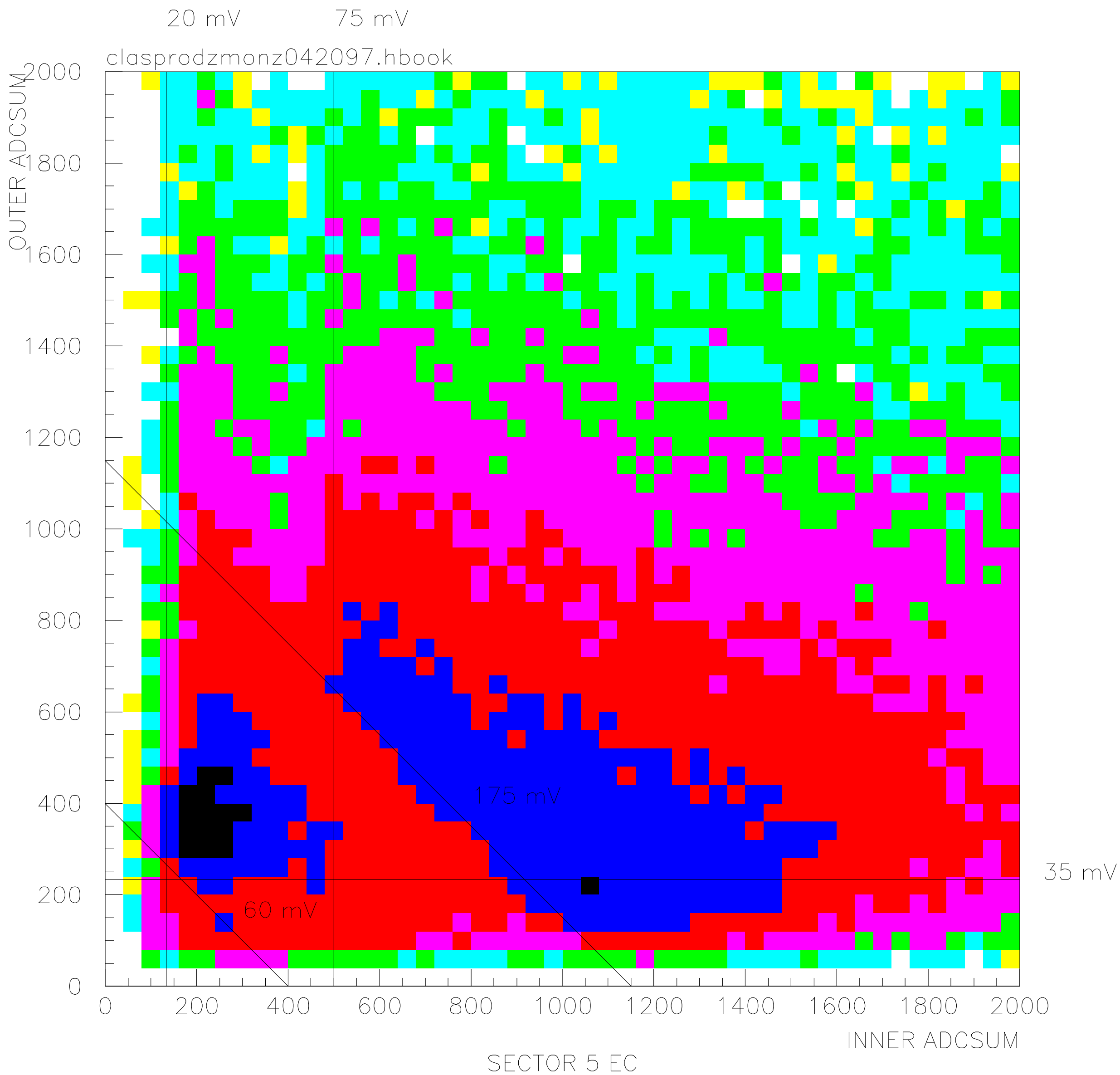

Figure 1: Outer vs. Inner ADC values in the calorimeter (sector 5) with lines corresponding to various (hi) trigger thresholds (in mV). The blue areas in the plot correspond to minimum ionizing particles (bottom left) and electrons (bottom middle)

from 28%, 37% to 60% for a relatively constant event rate of 4.8 kHz. The offline analysis requires 5 segments per track, but it is always desirable to have relaxed conditions at the trigger level. However, we decided to require 5 of 5 segments for further tests which increased the live time by a factor of 2.

Table 2: Summary of current scan taken with an electron beam on a 2 cm deuterium target. Schematically, the level 1 trigger required (ECin*SC)*SC*SC with ECin threshold = 20 mV, TOF threshold = 100 mV. The level 2 trigger requires 3 tracks (one in the same sector as the EC) and 5 of 5 segments per track.

Run Number	Current (nA)	Event Size (kB)	Live Time	L1 Rate (kHz)	L2 accepted (kHz)
42207	2.5	2.4	0.95	4.2	1.0
42204	5.0	2.9	0.86	8.9	2.5
42206	7.5	3.4	0.77	13.9	4.4
42203	10.0	3.9	0.45	21.7	4.8
42210	10.0	3.9	0.47	21.9	4.3
42208	12.5	4.3	0.28	28.1	3.9
42209	17.5	5.2	0.12	45.2	3.5
42177	20.0	5.5	0.07	55.5	3.5

We performed a beam current scan with the nominal eg3test_ECin_hi trigger file for Level 1 and 5/5 segments for Level 2. The resulting event sizes, live times and trigger rates are given in Table 2. The (input) L1 trigger rates are recored from the scaler information. The accepted L2 trigger rates are the rates of the DAQ to disk, and therefore are modified by the live time of the entire system. These data are plotted in Fig. 2 and Fig. 3. As expected, the event size increases from 2 to 6 kB/event,[4] the live time drops beyond the pipeline operation of the DAQ (at about 9 nA) at which point the data rate saturates at about 18 MB/s. The trigger rates, however, are higher than the proposal estimates which were based on a rough simulation of the 3-sector trigger and the e6 data.

2.1 Understanding the live time

In order to determine the expected rates at the design luminosity for the experiment, we need to have a model for the DAQ system with multiple buffering. We have

[4]The event size can be parameterized as 2kB + 0.18 kB/nA Ie, where Ie is the electron current in nA.

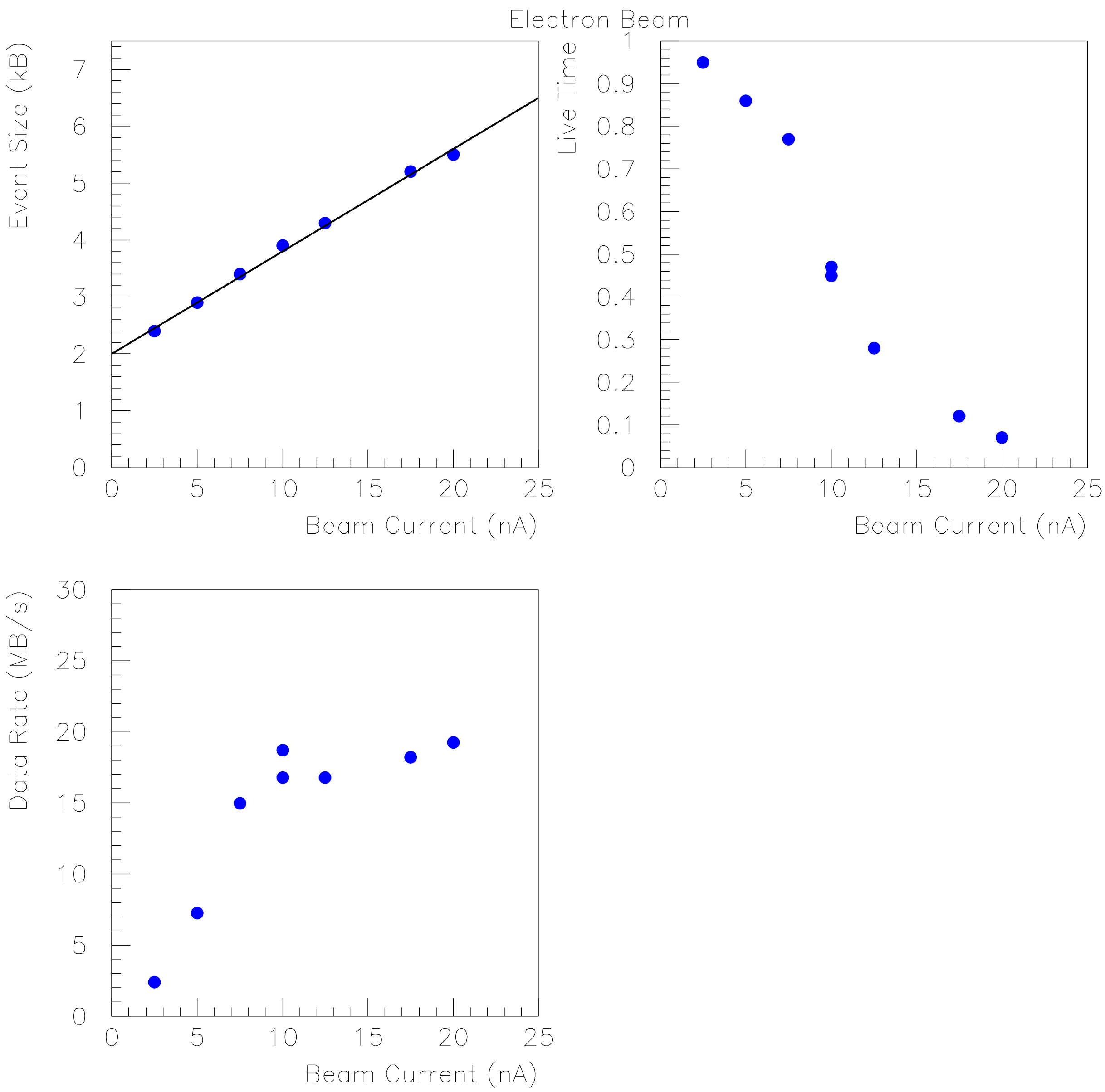

Figure 2: Plot of event size, live time and data rate as a function of beam current.

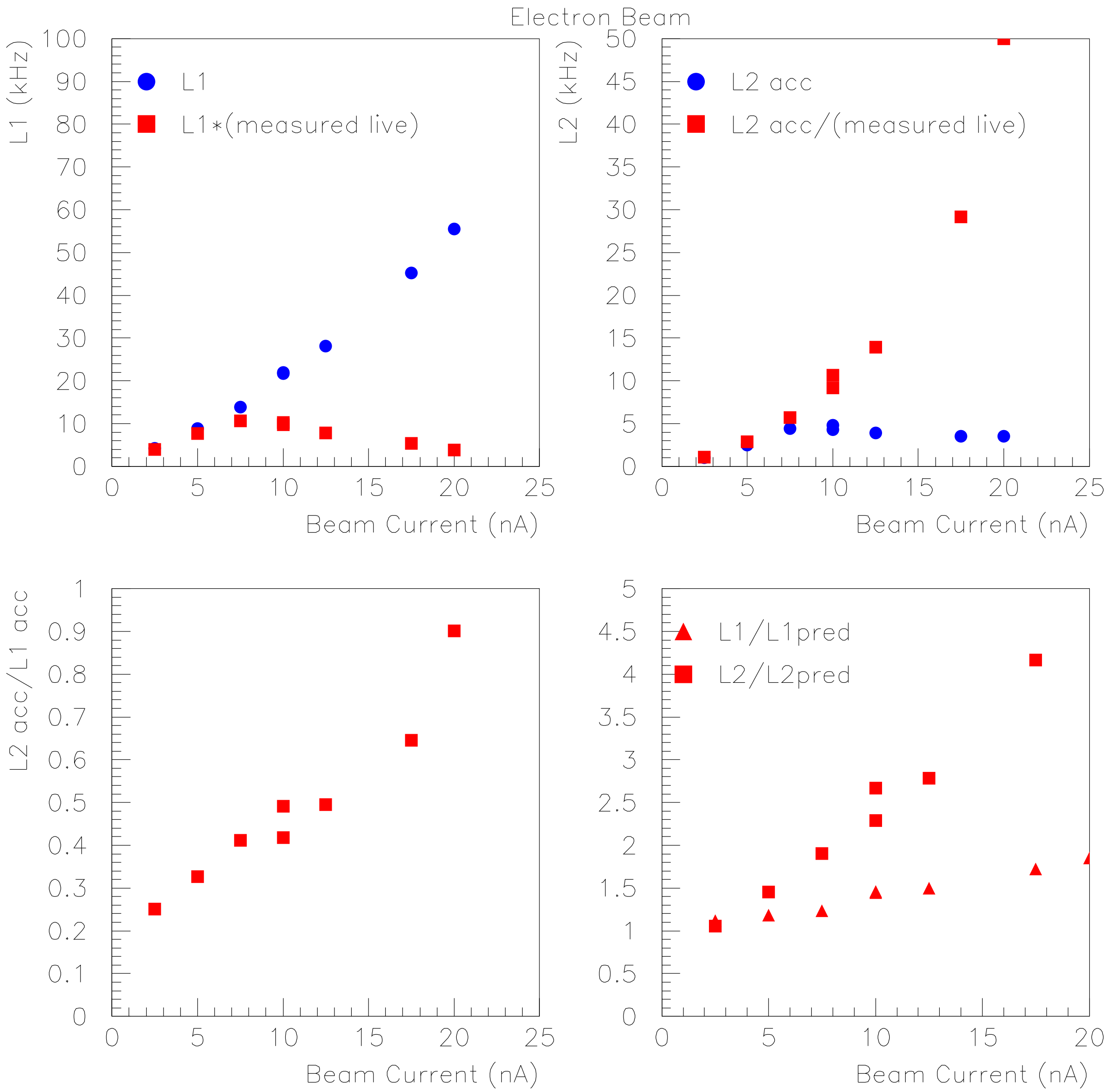

Figure 3: Plot of L1 rates, L2 rates, effectiveness of the Level 2 trigger (ratio of L2/L1) and the ratio of expected L1 and L2 rates assuming a small contribution of accidentals to the trigger. The blue circles are measured rates, the red squares are estimates based on naive a scaling of the rates using the measured live times. See text for a more complete interpretation of the rates.

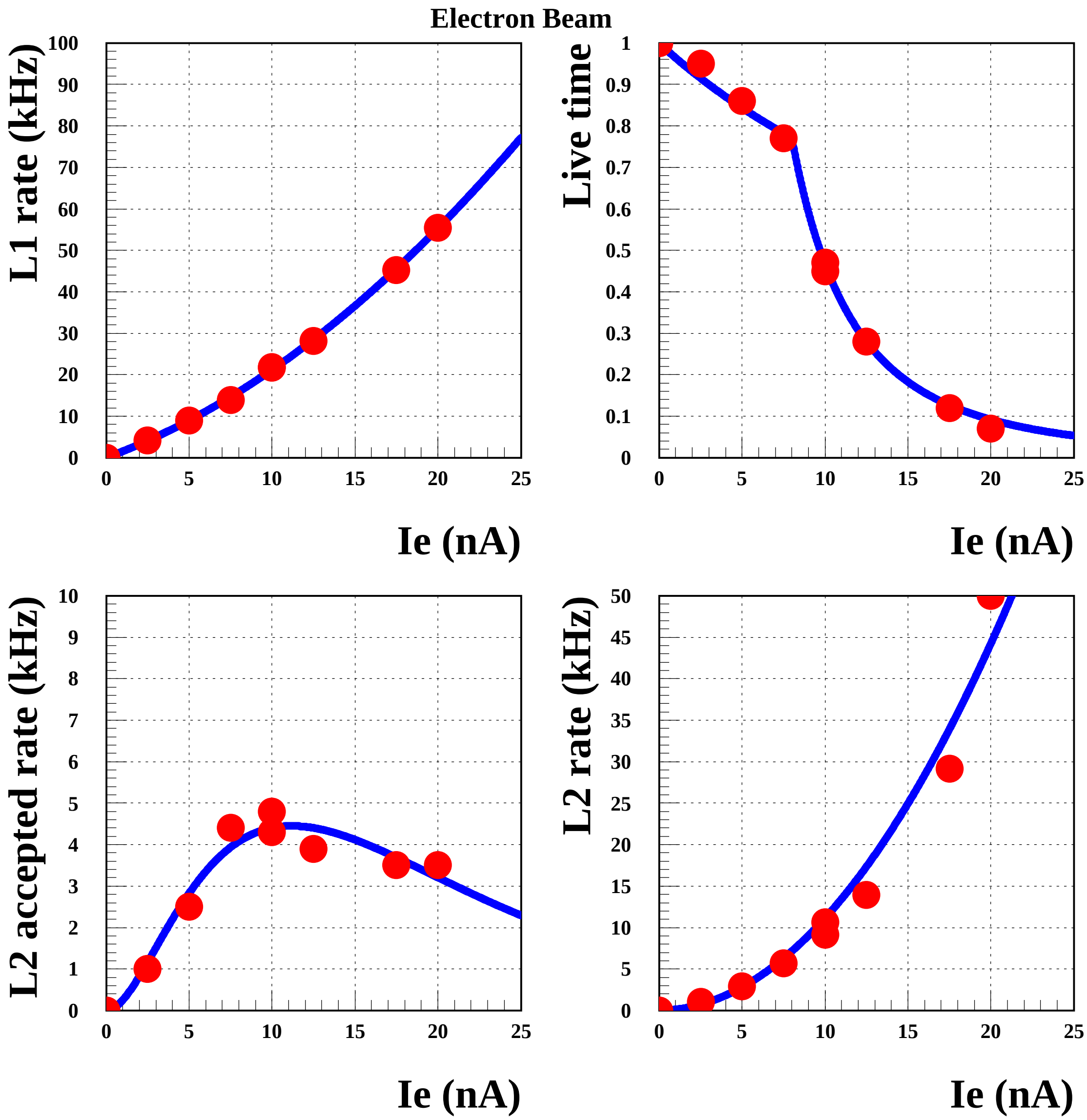

Figure 4: Rates as a function of electron current for (top left) measured L1 rate, (top right) measured live time, (bottom left) measured L2 accepted DAQ rate, and (bottom right) measured L2 rate divided by the measured live time. The curves are parameterizations of the data as described in the text.

Table 3: Occupancies in the drift chambers for electron run 42209 at a beam current of 17.5 nA (left). Variations between sectors is small indicated by the quoted range. The table on the right lists the current draw of the drift chamber wire groups.

Region	Occupancy (%)
R1	3.7 - 5.2
R2	1.6 - 2.5
R3	2.0 - 2.8

Wire Group	Currents (μA)
Field Axial	8.2
Sense Axial	7.4
Field Stereo	6.6
Sense Stereo	6.0

included the essential features of the DAQ system based on the formalism developed in Ref. [1]. In the case of exponentially random processing times, the live time of the DAQ is given by

$$\mathcal{L}^N = \frac{1-(\lambda\tau)^{N+1}}{1-(\lambda\tau)^{N+2}} \tag{1}$$

$$\mathcal{L}^0 \to \frac{1}{1+\lambda\tau} \quad (N=0) \tag{2}$$

$$\mathcal{L}^\infty \to \frac{1}{\lambda\tau} \quad (N\to\infty) \tag{3}$$

The case for N=0 corresponds to no buffering, and is the familiar case where the dead time is linearly dependent on the accepted event rate. We have modeled the DAQ with only two stages of buffering. The first stage, "front-end," corresponds to the conversion of the FASTBUS electronics, which presently is limited by the high-resolution LeCroy 1872A TDCs. The average conversion time is taken to be τ_1 with no buffering (N=0) when the event is accepted, but τ_3 when a Level 1 trigger is rejected by Level 2. The second stage, "back-end," is a combination of the processing times for the first readout list (ROL1), the second readout list (ROL2), the network communication with the online SMP, any event building, and recording data to disk. The combined time for all these stages is parameterized by τ_2, and is assumed to have eight buffers (N=7), although none of calculations are very sensitive to the precise number. Given this model, the input rate can be determined as a function of beam current. This yields the following parameterization of the live time:

$$\mathcal{L}_1 = \frac{1}{1+\lambda_2\tau_1} \tag{4}$$

$$R_2 = \mathcal{L}_1\,\lambda_2 \tag{5}$$

$$\mathcal{L}_2 = \frac{1-[R_2(\tau_1+\tau_2)]^{N+1}}{1-[R_2(\tau_1+\tau_2)]^{N+2}} \tag{6}$$

$$\mathcal{L}_3 = \frac{1}{1 + (\lambda_1 - \lambda_2)\tau_3} \tag{7}$$

$$\mathcal{L} = \mathcal{L}_1 \, \mathcal{L}_2 \, \mathcal{L}_3 \tag{8}$$

The queuing equations between various stages of the system are coupled and cannot in general be solved analytically [2, 1]. We have instead extracted results assuming a form which has the correct limits both at low rates and high rates. In any case this analysis is an approximation since it uses only two stages of processing, but contains the essential features of the data. The processing for the $\mathcal{L}_2$ live time is taken to be $\tau_1 + \tau_2$ in order for the live time to have the proper asymptotic behavior, namely

$$\mathcal{L}_2^{\infty} \rightarrow \frac{1}{R_2(\tau_1 + \tau_2)} \tag{9}$$

$$\mathcal{L}^{\infty} \rightarrow \frac{1}{\lambda_2(\tau_1 + \tau_2)} \mathcal{L}_3 \tag{10}$$

The input Level 1 rate, λ_1, is measured by scalers in the Trigger Supervisor. We take the measured input rate λ_2 to be the live time-corrected DAQ accepted event rate, i.e. the output of the Level 2 trigger for a system which is 100% live. These rates were parameterized by a polynomials as

$$\lambda_1 = 1.4714(I_e + 0.04393 \, I_e^2) \tag{11}$$

$$\lambda_2 = 0.0161(I_e + 6.82648 \, I_e^2) \tag{12}$$

where the rates are given in kHz when the electron current, I_e, is expressed in nA (see Fig. 4). The measured live time can be fit to Eq. 8, for effective processing times τ_1, τ_2 and τ_3, which were parameterized as

$$\begin{aligned} \tau_1 &= p1 \, t_{conv} \\ \tau_2 &= p2 \, t_{proc} \, (1 + p3 \, I_e) \\ \tau_3 &= t_{rej}, \end{aligned} \tag{13}$$

where $t_{rej} = 10$ μs is a time to reject an event which satisfies Level 1 but not Level2, $t_{conv} = 40$ μs is the typical front-end conversion time per event, and $t_{proc} = 100$ μs is about half the typical back-end processing time per event, and the last factor is proportional to the event size which increases linearly with beam current. The result of the fit is shown in Fig. 5 and shows that that this picture is internally consistent. The fitted values for the processing times give $\tau_1 = 21$ μs and $< \tau_2 > = 182$ μs at 10 nA, consistent with expectations. We did not fit for τ_3, as it is relatively small and the fit is not very sensitive to its precise value. The assumption that the τ_2 processing time is proportional to the event size is not only reasonable, but is also required by the steepness with which the live time falls at about 10 nA. This assumption is also confirmed by the fit since the fitted parameter p3=0.092/nA precisely gives the measured behavior of the event size with beam current, which in units of kB is given by $s = 2(1 + 0.09\, I_e)$ (see Fig. 2). The increase in the processing time with beam current is also required by the accepted event rates which decrease with beam current. Asymptotically, the rate is given by $\sim 1/\tau$ (see Eq. 3), so decreasing rates imply that the processing time is increasing. Only a constant processing time results in a constant accepted event rate asymptotically.

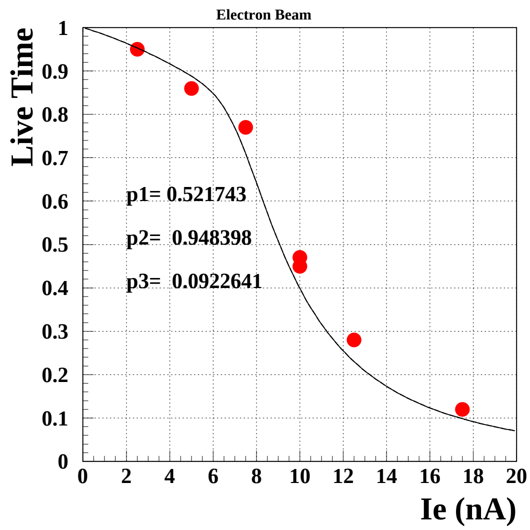

Figure 5: Fit to live time vs beam current assuming two levels of buffering as described in the text. Live time for the test run with an electron beam. The parameters p1, p2 and p3 of τ_2 and τ_3 are defined by Eq. 13.

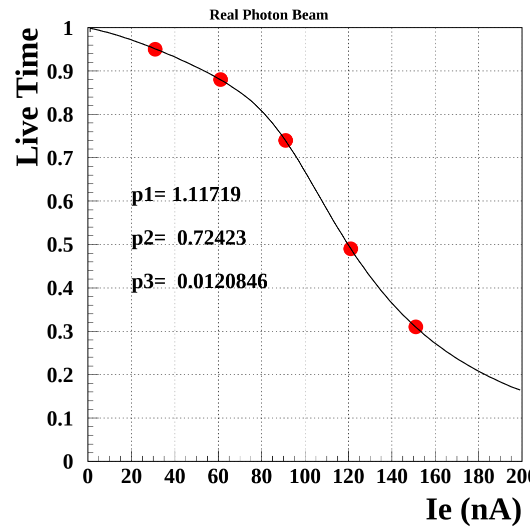

Figure 6: Fit to live time vs beam current assuming two levels of buffering as described in the text. Live time for the test run with real photons. The parameters p1, p2 and p3 of τ_2 and τ_3 are defined by Eq. 13.

3 Test with Real Photons

A second beam test was conducted using with real photons on July 26 and 27. We used the g11 setup, filling their 40 cm target cell with deuterium, and the same 10^{-4} radiator. The pair spectrometer and BOM rates were studied for different collimators to determine the optimum configuration. It was found that the 2.8 mm collimator is not properly aligned in the vertical direction for which there is no remote adjustment, so data were taken with the 8.6 mm collimator in place. [5] The target was moved 21.6 cm upstream from the g11 position, locating the center of the target at -31.6 cm. Data were taken with the torus magnet set at the reversed field settings of -2250 and -1500 A. The electron beam energy was 5.015 GeV. Various triggers were studied, including different photon energy ranges selected using the tagger T-counters.

Table 4: Trigger definitions for Bits 1-4. All triggers were also in coincidence with the asynchronous input which included the tagger and start counter coincidence. Coincidences within one sector are given in parenthesis. The Level 1 trigger for the real photon tests was composed of all 4 bits on, but Bit 2 prescaled.

Bit	L1 Description	Level 2	Prescale
Bit 1	(tof*st)*(tof*st)*(st)	3-tracks	1
Bit 2	(tof*st)*(tof*st)	2-tracks	11
Bit 3	(tof*st)*(tof*st*st)	2-tracks	1
Bit 4	(tof*st)*(tof*st)*(tof*st)	3-tracks	1

The Level 1 trigger consisted of four trigger bits, briefly described in Table 4. The recommended physics trigger would be the OR of Bit 1 and 3, which correspond to two tof sectors in coincidence with three start counters. For reference, we also included Bit 2 which is a two sector-trigger and Bit 4 which is a full three-sector trigger. Each sector required a coincidence between the tof and the start counters in that particular sector (using sector definitions in the Level 1 trigger). The Level 1 trigger also included a coincidence with the asynchronous input which was composed of a tight time coincidence between a range of T counters (we used T counters 1-19 and 1-23) and the OR of all start counter signals.

The breakdown of the event size per component in number of words per sector at 150 nA is as follows: DC (60 words), CC (0.44 words), SC (2.7 words), EC (4.0 words), LAC (0 words). The total size of the event was 4.8 kB, and 1.1 kB came from the TAGE crate.[6] The drift chamber occupancies at 150 nA are given in Table 5. This is well below the typical running conditions with an electron beam.

3.1 Level 1 trigger rates

The Level 1 trigger rates were measured as a function of beam current and plotted in Figs. 7 and 8 for T counters 1-19 and the torus current set at -1500 A. The rates for T

[5] The beam rates were PSMT=620 Hz, ST=3.3 kHz and BOM=25 Hz for a 30 nA beam.

[6] The time window for the e-counter pipeline TDCs was reduced to 700 ns for this test.

Table 5: Occupancies in the drift chambers for real photons at a beam current of 150 nA (left). Variations between sectors is small indicated by the quoted range. The table on the right lists the current draw of the drift chamber wire groups.

Region	Occupancy (%)
R1	1.5 - 1.6
R2	0.25 - 0.4
R3	0.27 - 0.4

Wire Group	Currents (μA)
Field Axial	4
Sense Axial	3
Field Stereo	3.8
Sense Stereo	2.5

counters 1-19 and the torus at -2250 A are plotted in Figs. 9 and separated by trigger bits in Fig. 10. The contribution of Bit 2 to the Level 1 trigger is small, approximately 1 kHz at 150 nA.The variation of rates with torus current is also very modest, slightly higher for the lower field. The setting of the torus current for the actual experiment can be decided based on other factors such as acceptance and resolution. The trigger rates for the increased tagger range of T counters 1-23 at the torus current of -2250 A are plotted in Fig. 11.

The live time-corrected Level 1 rates as a function of beam current are shown with polynomial fits in Fig. 12. These rates were used with the formalism described in Section 2.1 to fit the live time using a single value for the input rate (i.e. $\lambda_2 = \lambda_1$), since the Level 2 requirements were not in the trigger. The result is shown in Fig. 6. The fitted values for the processing times give $\tau_1 = 44$ μs and $< \tau_2 > = 158$ μs at 100 nA, where this last number includes the processing of both the first and second readout lists. We note that the sum of $\tau_1 + < \tau_2 >$ determined for both the electron and photon runs is 202 μs.

3.2 Level 2 trigger rates

The additional requirement of Level 2 in the trigger rates was also studied at the beam current of 150 nA. A summary of the rates is given in Fig. 13 extrapolated from 150 nA to the electron beam current of 160 nA. This current corresponds to the proposed luminosity for eg3, i.e. $2{\times}10^{34}\text{cm}^{-2}\text{s}^{-1}$ on deuterium. Four different trigger configurations are plotted: the Level 1 trigger rate as defined by the sum of four trigger bits defined in Table 4, Level 1 confirmed by any two tracks in Level 2, and two versions of Level 2 confirmation given in Table 4. The two versions of Level 2 differ when multiple Level 1 trigger bits are on, and the logic table is given in Appendix A. The most realistic version of the trigger configuration 'L2' predicts a trigger rate of 8 kHz at a torus setting of -2250 A, and 20% higher at -1500 A.

It is also of interest to know the distribution of trigger bits which fired for different number of tracks in the event. This is shown in Fig. 14 for a run taken at 150 nA and Level requirement set to 2 tracks for all trigger bits. (???check). Generally more trigger bits fire as more tracks are required. The distribution does not change much when 2 tracks are required, but when one requires 3 tracks the bit configuration changes. This is expected since Bits 2 and 3 require only 2 tracks and Bits 1 and 4 require 3 or more tracks to fire in the hardware.

3.3 Tagger range

Two different tagger ranges were studied in this beam test. The T counters 1-19 (1-23) cover the fractional range between 0.78 (0.68) and 0.95. For a 5.75 incident electron beam this corresponds to energies between 4.5 (3.9) and 5.5 GeV.[7] The T-counter range of 1-23 covers the photon energy from threshold for a cascade mass of 1.86 GeV up to the tagger maximum. The restricted range of T counters 1-19 was selected because the counters are smaller and run at lower instantaneous rates (0.9 MHz at 150 nA) compared to the rest of the tagger counters which run 3 times higher [3]. We note that the estimated signal yield between 3.9 and 4.5 GeV is only 10% of the total due to the slow increase in production and acceptance at threshold. The tagging flux for T counters 1-19 (1-23) is estimated to be 1.9 (3.1) $\times 10^7$ Hz at 150 nA on a 10^{-4} radiator. Thus the T counter range of 1-23 increases the photon flux by 60% for only a 10% gain in signal. The trigger rate, howver, only increases by 29% since it has a large contribution due to accidentals. The T restricted T counter range of 1-19 is therefore close to optimal.

3.4 Rates in the start counter and accidentals

During tests for g11, the OR of the rates in the start counter were measured as a function of beam current and found to be perfectly linear up to 50 nA [4]. The rates in each counter showed no deviations up to these currents and are not expected to show any deviations up to much higher beam currents. The average rate per start counter is approximately 6.7 kHz/nA (although there are azimuthal differences) or 1 MHz per counter at our nominal 160 nA operation. At these rates accidental coincidences are quite high. Given the rate of Bit 2 [(tof*st)*(tof*st)] of 12 kHz (at 150 nA), we can calculate the accidental contribution to Bits 1 and 3. Using the formula $R_{acc} = R_2[1 - exp(-R_{ST}\,\Delta t)]$, Δ = 100 ns, and $R_{ST} = 4 \times 4{\times}1\text{MHz} = 16$ MHz, we get R_{acc}(Bit 1) = 9.6 kHz, and $R_{ST} = 3 \times 2{\times}1\text{MHz} = 6\text{MHz}$ gives R_{acc}(Bit 1) = 2.4 kHz. These rates are very close to what we actually observe, which implies that these trigger bits are almost completely dominated by accidentals in the start

[7]The actual energy range for the present test must be scaled to the beam energy of 5.0 GeV.

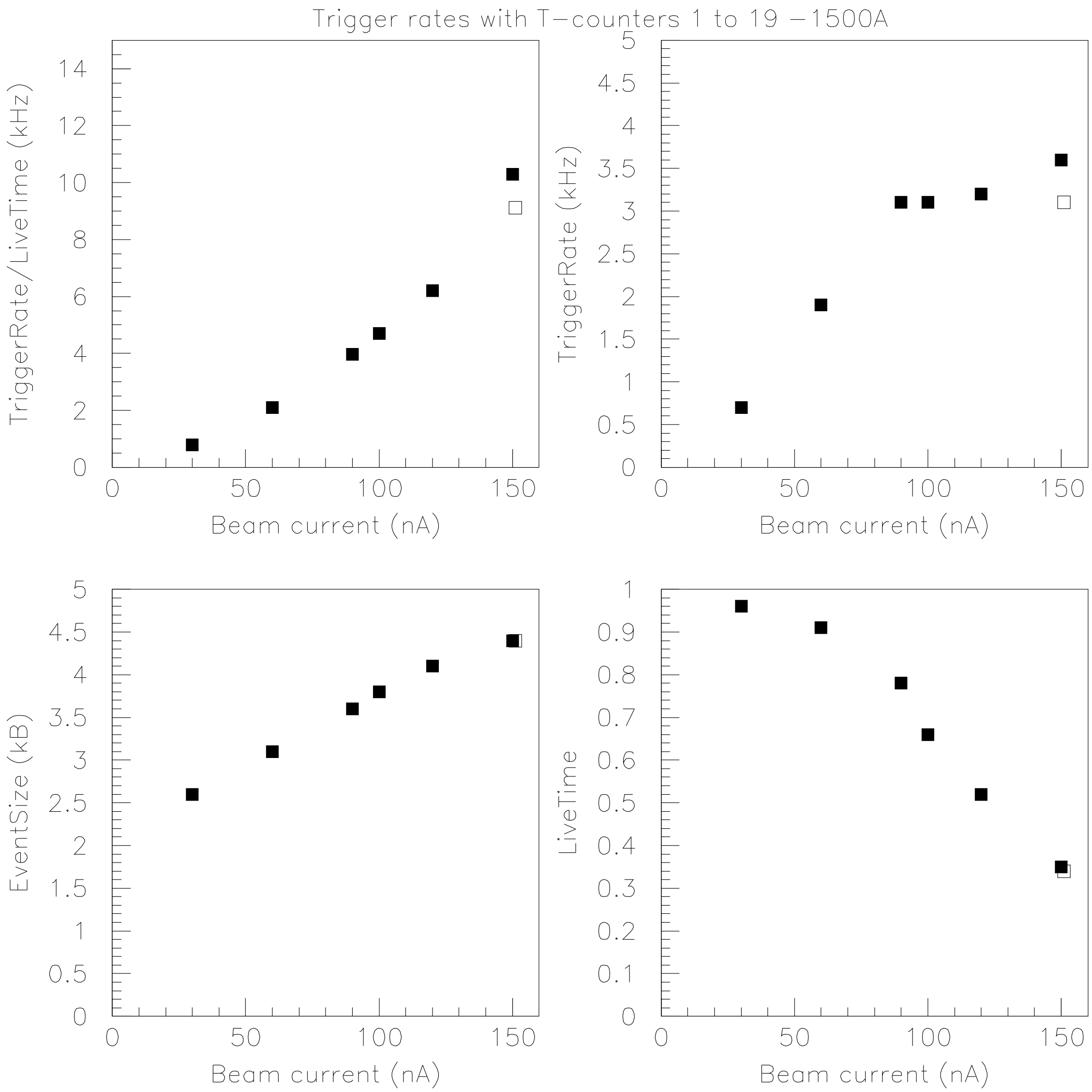

Figure 7: Level 1 live time-corrected trigger rate, Level 1 trigger rate, event size and live time for real photon run with T counters 1-19 and a B field of -1500 A. The open square corresponds to Bit 2 prescaled by 51 instead of 11.

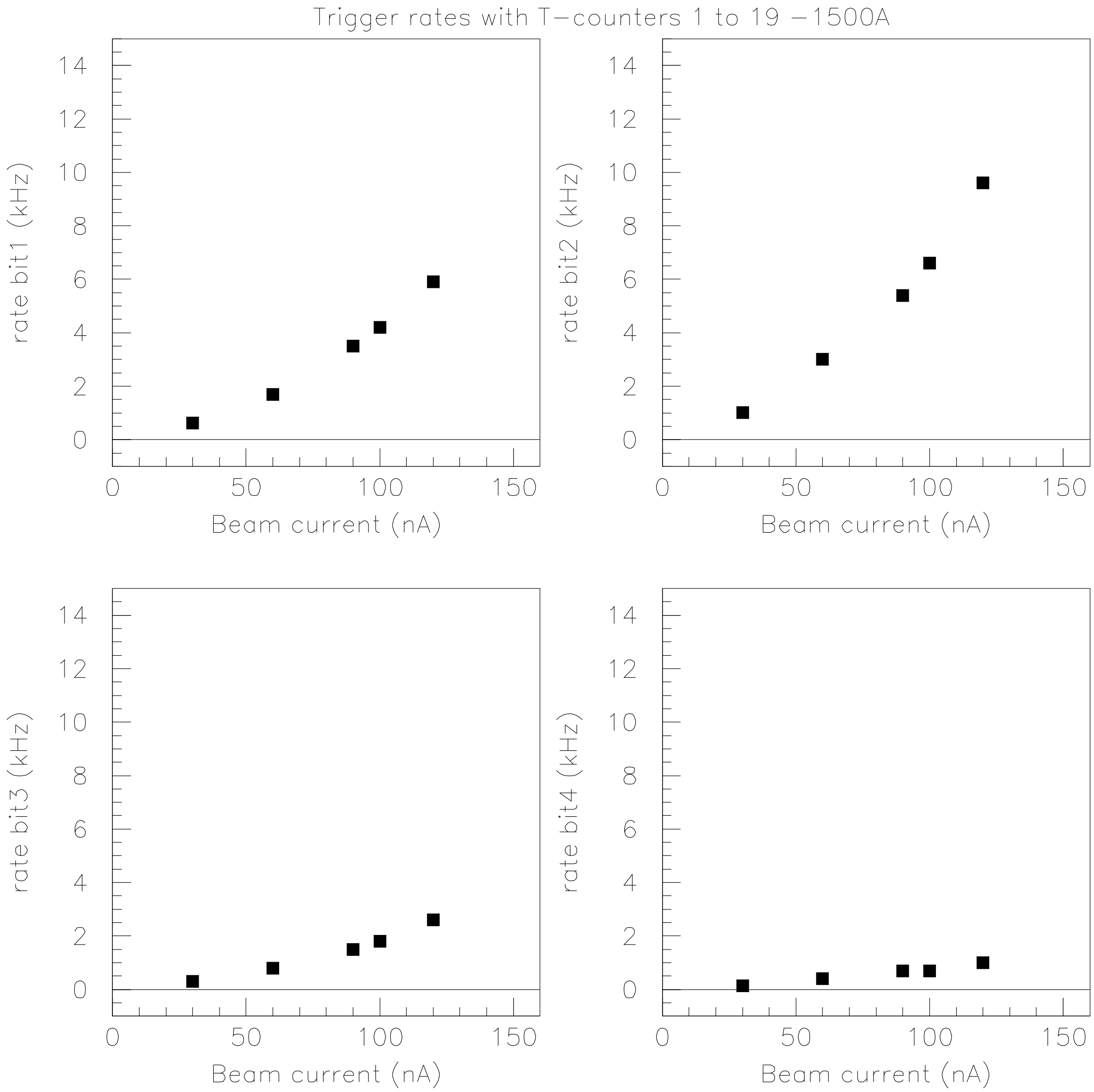

Figure 8: Rates for Bit 1, 2, 3 and 4 in the Level 1 trigger rate for real photon run with T counters 1-19 and a B field of -1500 A.

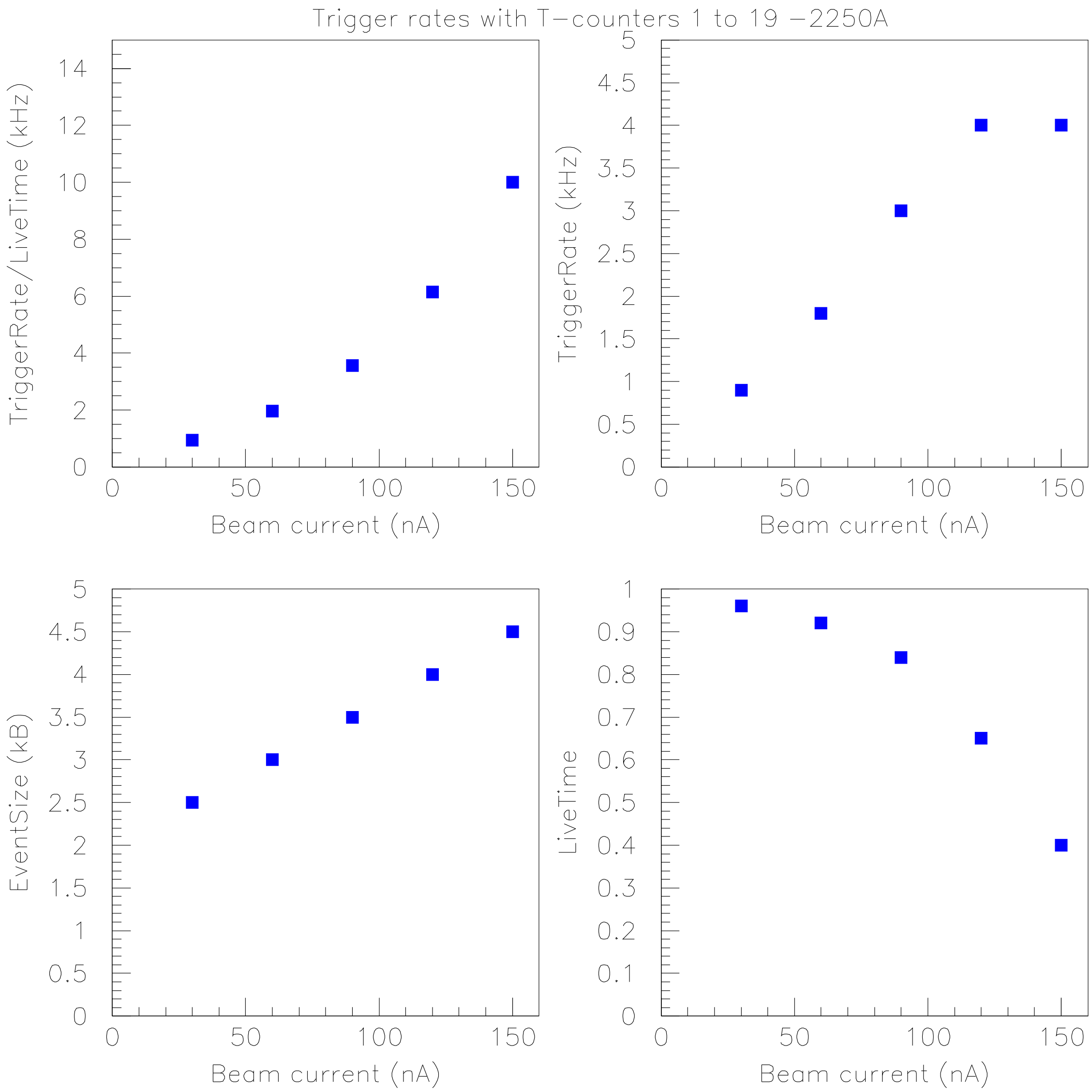

Figure 9: Level 1 live time-corrected trigger rate, Level 1 trigger rate, event size and live time for real photon run with T counters 1-19 and a B field of -2250 A.

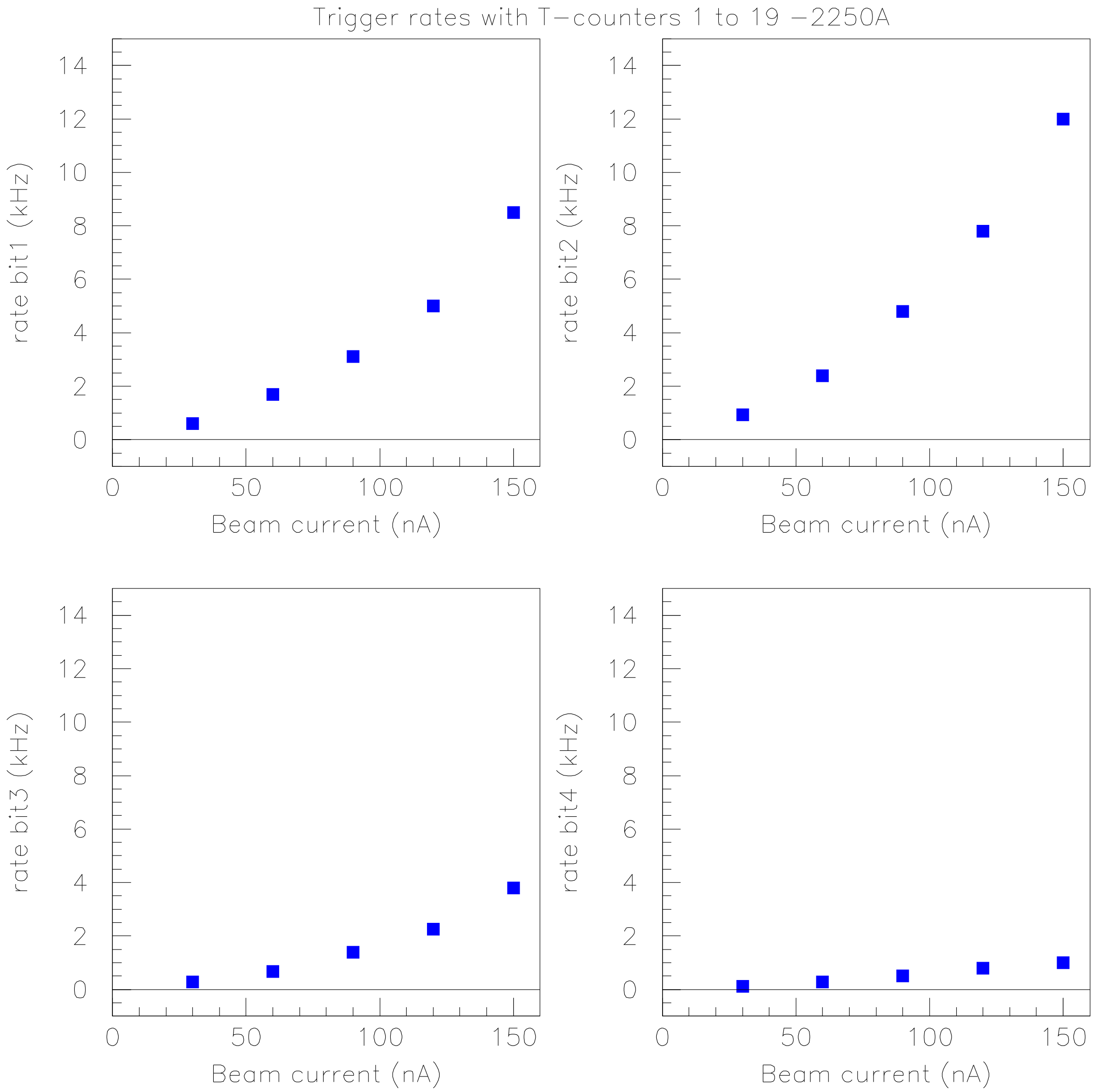

Figure 10: Rates for Bit 1, 2, 3 and 4 in the Level 1 trigger rate for real photon run with T counters 1-19 and a B field of -2250 A.

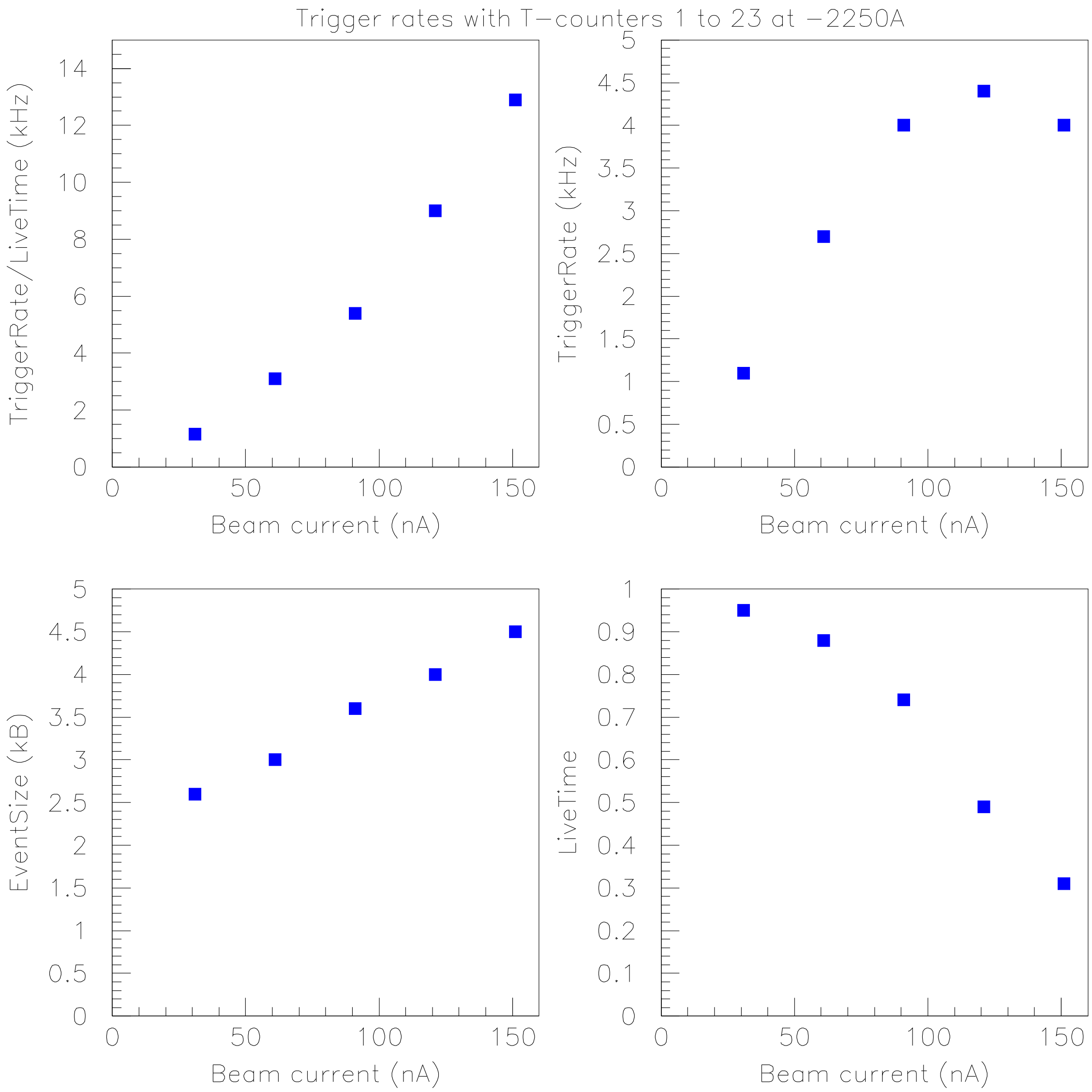

Figure 11: Level 1 live time-corrected trigger rate, Level 1 trigger rate, event size and live time for real photon run with T counters 1-23 and a B field of -2250 A.

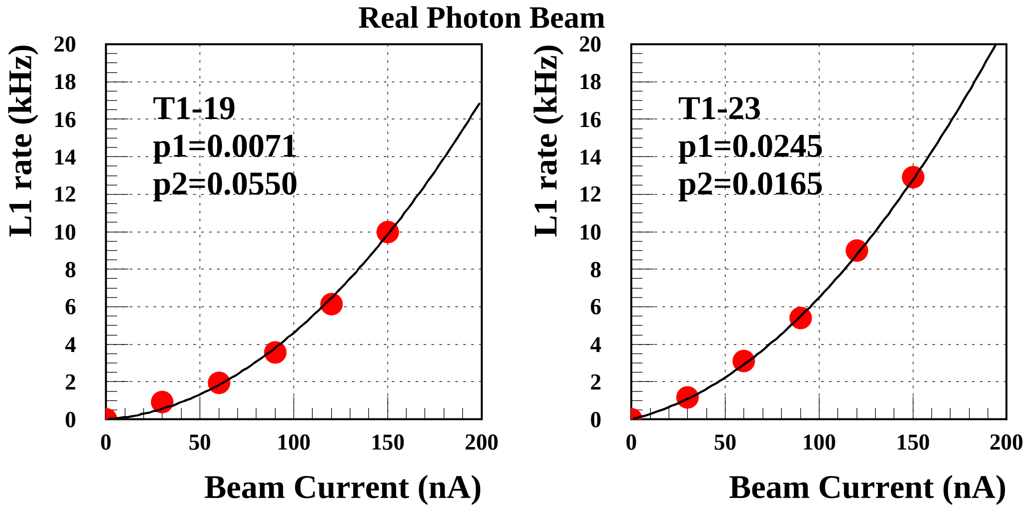

Figure 12: The live time-corrected Level 1 rate is shown when (left) T counters 1-19 were in the trigger, (right) T counters 1-23 were in the trigger. These data were taken at a torus current of -2250 A. The curves show a polynomial fit to the data of the form: $\lambda_1 = p1(I_e + p2\, I_e^2)$.

couter. In the Level 1 trigger, Bit 2 was prescaled by a factor of 11, so it only played a minor role in the trigger rates, but Bit 1 and 3, expected to the our primary triggers differed only in the track requirement in Level 2 aside from accidental hits in the start counter. Saying this is another way, the sum of rates for Bit 1 and 3 is about 10% less than the rate for Bit 2.

We note that the start counter coincidences with other CLAS detectors was formed in the Level 1 processor, where the timing coincidence (estimated at 100 ns) is quite broad to be efficient. A feature which was developed for g11, but never used, included a multiplicity start counter signal which can take advantage of the hardware timing window accessible to the asynchronous input ($\sim$ 15 ns). A tighter timing coincidence in the asynchronous input would reduce the accidental rates by a factor of 3 (4 kHz for Bit 2).

4 Comparison of electron and real photon rates

We can compare the drift chamber occupancies and current draw between the two running conditions. In all cases the electron running configuration has higher activity in the drift chambers (see Tables 3 and 5). The occupancies are a factor of 3 higher for R1 and 6 for R2. The current draw is approximately 2 times higher in all wire

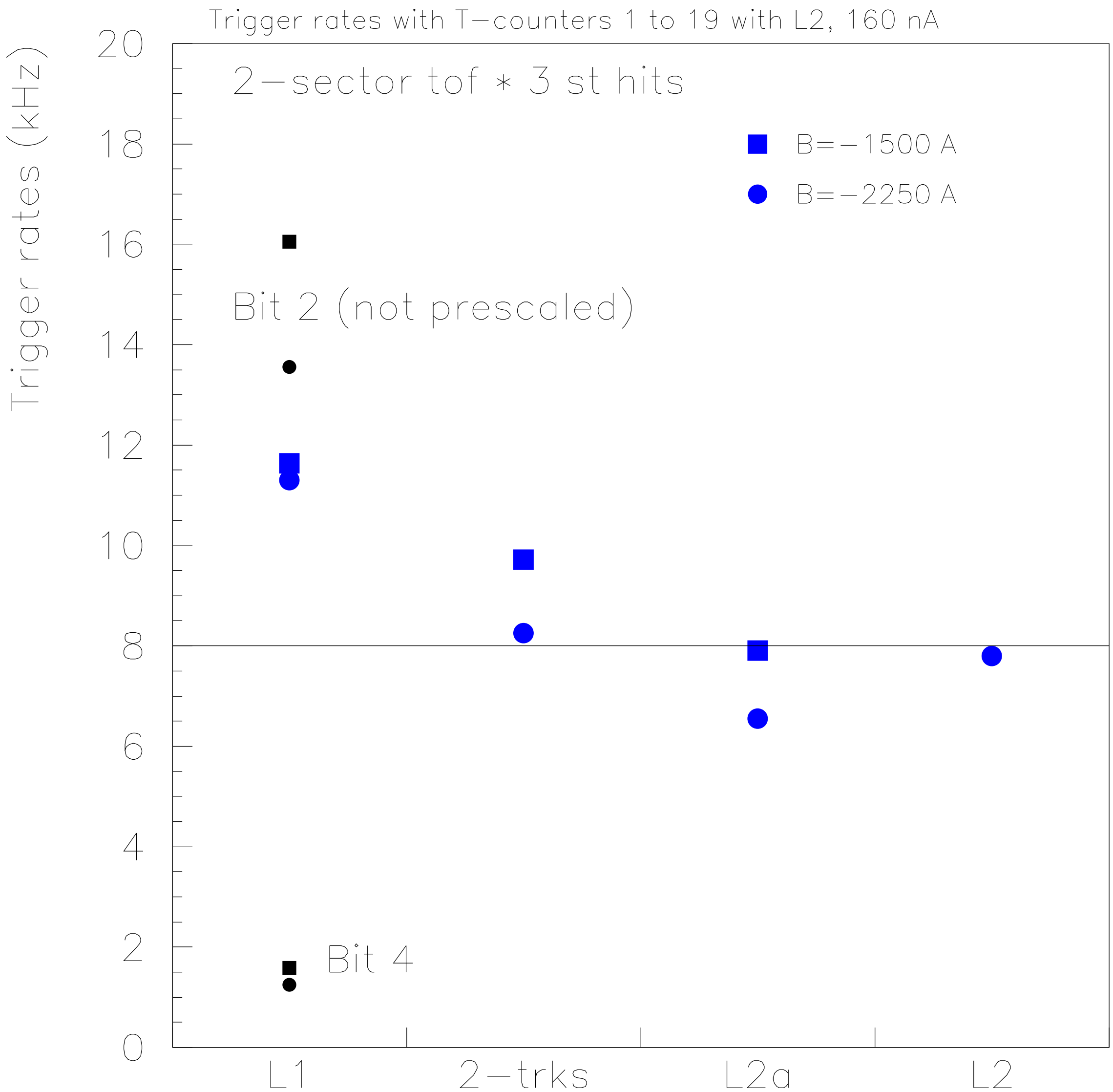

Figure 13: Trigger rates in a real photon beam as a function of various configurations, including Level 1 only, Level 2 requiring 2 tracks only for all trigger bits, and two versions of the Level 2 requirement (see Table 4). These differ in how many tracks are required when multiple bits fire. The rightmost configuration is the optimum for our experiment. The rates have been extrapolated to 160 nA.

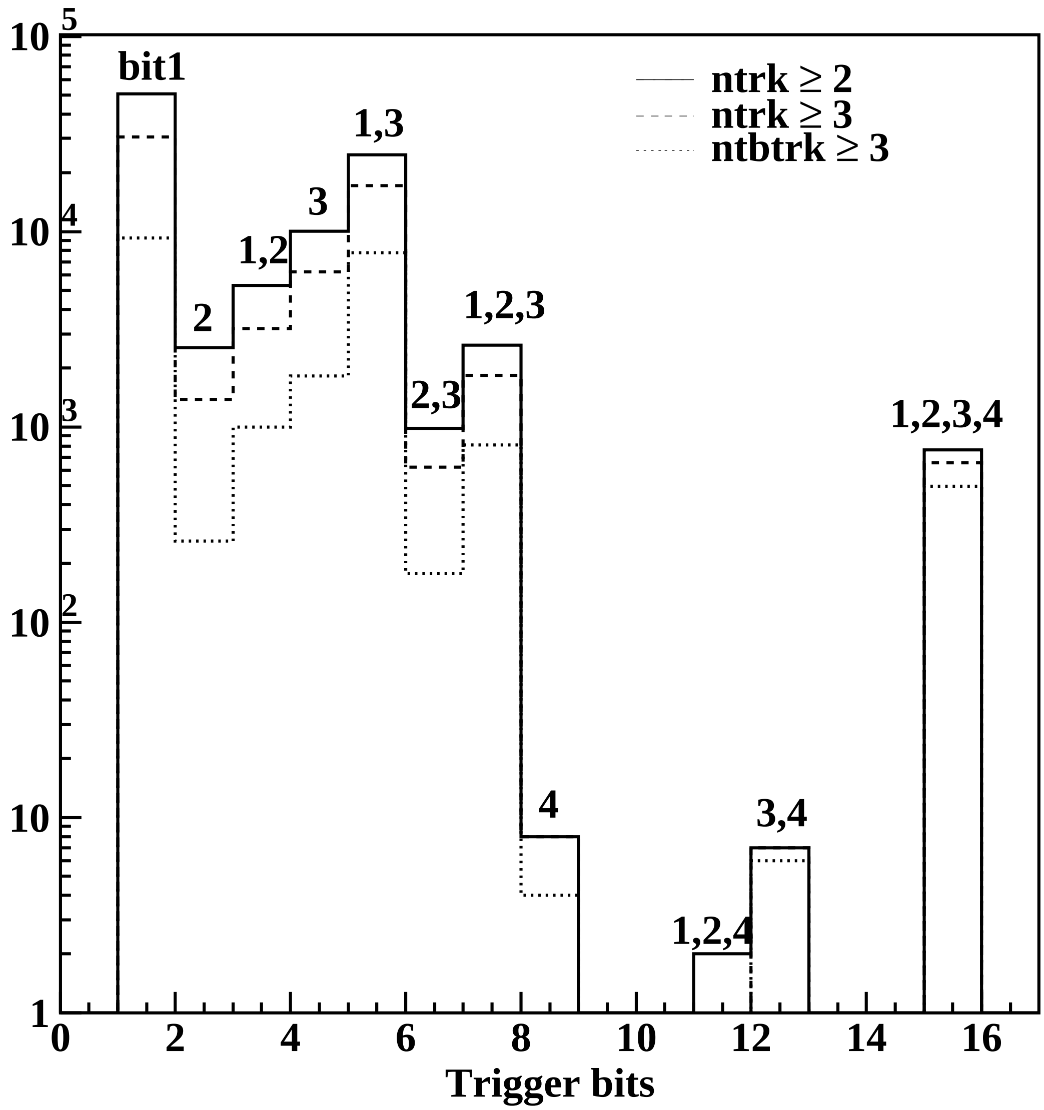

Figure 14: Relative distribution of trigger bits firing requiring various numbers of tracks reconstructed offline. The numbers above each histogram bin indicate the bits which fired. This is the distribution taken for a run at 150 nA.

groups in electron running compared to photon running.

Trigger rates are summarized in Table 6. The 3-sector electron trigger with Level 2 is twice the rate of a 2- and 3-sector Level 1 combination photon trigger, and 20 times the rate of a 3-sector trigger. The real photon experiment clearly benefits from being able to use the tagger and start counter in the trigger in addition to other CLAS detector elements. The background load on the detector, as indicated by drift chamber occupancies, is also substantially smaller during real photon runs.

Table 6: Summary of Level 1 and Level 2 trigger rates for electron and real photon running scaled to the design luminosity of $2{\times}10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$-nucleon.

Trigger Configuration	Electron (15.8 nA)	Real Photon (162 nA)
L1 (SC*EC)*(SC)*(SC)	39.4 kHz	
and L2 3-tracks (5/5 segments)	27.7 kHz	
L1 (SC*ST)*(SC*ST)*(ST) + (SC*ST)*(SC*ST*ST), T1-23		14.6 kHz
L1 (SC*ST)*(SC*ST)*(ST) + (SC*ST)*(SC*ST*ST), T1-19		11.4 kHz
and matched L2 3-tracks + 2-tracks (3/5 segments)		7.8 kHz
L1 (SC*ST)*(SC*ST)*(SC*ST), T1-19		1.3 kHz

References

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A Logic Table for Level 2

Table 7: Logic table for mapping the Level 2 trigger requirement to the Level 1 trigger bits. Versions of L2 differ depending on how many tracks are required when multiple bits are satisfied.In L2a track requirement for Bit 1 (3 tracks) takes preference, in L2 the relaxed 2-track requirement for Bit 3 takes preference when multiple bits are set. The columns under level 2 indicate the number of tracks required by the level 2 trigger condition and the last column has an asterisk when the L2a and L2 have different requirements.

Bit 1	2	3	4	L2a	L2	difference
1	0	0	0	3	3	
0	1	0	0	2	2	
0	0	1	0	2	2	
0	0	0	1	3	3	
1	1	0	0	3	3	
1	0	1	0	3	2	*
1	0	0	1	3	3	
0	1	1	0	2	2	
0	1	0	1	2	3	*
0	0	1	1	2	2	
1	1	1	0	3	2	*
1	0	1	1	3	2	*
1	1	0	1	3	3	
0	1	1	1	2	2	
1	1	1	1	2	2	