Deadtime Analysis Progress and Summary

Salina Ali

June 12, 2018

1 Using Live and Raw scaler rates: deadtime and livetime

The deadtime is defined as the ratio of the number of live events going into the electronics or computers to the total number of events. The electronic deadtime (EDTM) corresponds to signals for activated triggers to compute the deadtime, but is not independent of current. As a result, the EDTM was not used to correct the DVCS rates for this run as there was a beam current variation for run 13418.

The deadtime and livetimes can be computed for each trigger. The electronic and computer deadtime need to be quantified in order to eventually extract precision measurements of the cross section and apply any uncertainties.

The live and raw events are represented by live and raw scalers. Equation 1 is used calculate the raw rate. Equation 2 is used to calculate the livetime, and subsequently the deadtime using Equation 3:

$$Raw\ rate = \ Live\ rate \times \frac{1}{1 - Deadtime} \tag{1}$$

$$Livetime = \frac{Live\ scaler\ rate}{Raw\ scaler\ rate} \tag{2}$$

$$Deadtime = 1 - Livetime \tag{3}$$

1.1 Beam Current Variation

In order to verify the deadtime for DVCS rates, runs that have beam current variation within the same kinematic settings should be recoverable when normalized with the current. The run currently being used to verify the deadtime and thus recover the DVCS rates is 13418. This run was taken in Spring 2016 data and belongs to kinematic 48_4, and has three different currents at 10 μA, 15 μA, 20 μA, as shown in Figure 1 through a Beam Current Monitor (BCM) during the run.

This study was originally done analyzing the scalers for the triggers used to determine the livetime associated with DVCS rates (ARS valid, ARS Stop,

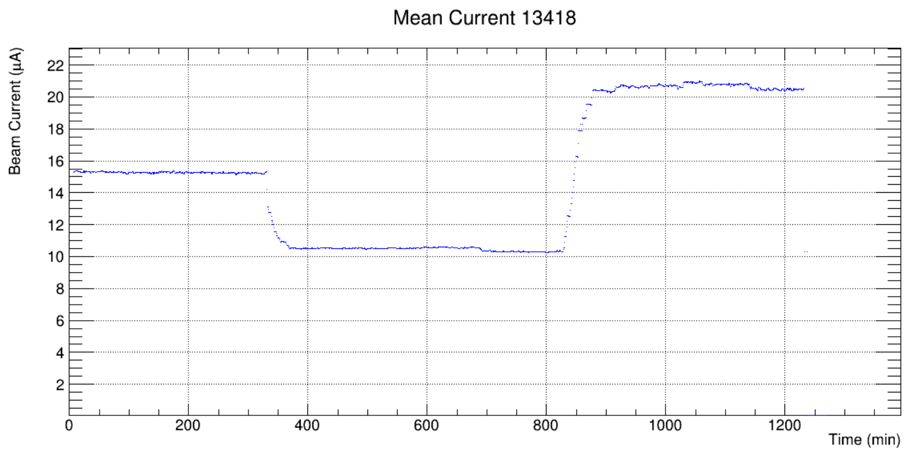


Figure 1: Mean currents shown at 10, 15, 20 μA for run 13418.

Master OR, Master OR Live). However, the livetime computed this way is shown to scale with the DVCS rates as there is a current dependence present despite normalization. As a result, the study shifted gear to look at the data from run 13418 event-by-event and apply cuts in addition to hardware and software corrections to recover the rates to better than 5%.

Other runs of interest are 12985 (15 μA) and 12901 (10 μA), part of kinematic 48_3.

1.2 Trigger Setup and Scalers

Scalers corresponding to each active trigger for the run were read out to determine the number of live events and total events. The triggers associated with DVCS and DIS events were the S2m and Cherenkov detectors, with simultaneous signals forming a trigger and thus indicating a DIS or a DVCS event, as shown by Figure 2.

Internal scalers have a "gated_accum_" or "accum_" prefix in the root tree, whereas external scalers have a"cpt" prefix.

2 Normalized Live and Raw Rates

General live and raw rates from the triggers (units in Hertz) were calculated by looking at the data event-by-event, and old rates are shown in Table 1.

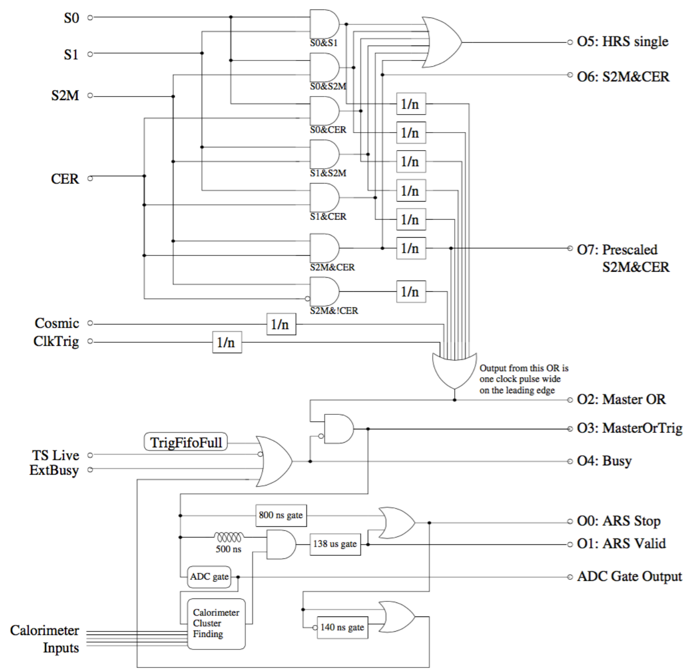


Figure 2: Internal trigger setup for the DVCS-3 experiment in Hall A, Spring 2016

2.1 Application of new cuts: the DVCS3 Event Selection algorithm

Hashir's DVCS3 Event Selection Algorithm was used to apply good electron cuts in both the DVCS rates and accidental calculations. The "GoodEventCut" was applied to all rates and includes:

- single tracking cut (L.tr.n==1) and cuts on the u1,v1,u2,v2 planes of the Vertical Drift Chamber (VDC)
  - $u1 == 1\&\&u2 == 1\&\&v1 == 1\&\&v2 == 1$
  - $(u1 > 1\&\&u2 == 1\&\&v1 == 1\&\&v2 == 1)||(u1 == 1\&\&u2 > 1\&\&v1 == 1\&\&v2 == 1)||(u1 == 1\&\&u2 == 1\&\&v1 > 1\&\&v2 == 1)||(u1 == 1\&\&u2 == 1\&\&v1 == 1\&\&v2 > 1)$
- Cherenkov detector photoelectron channel peak or Cherenkov amplitude sum: $L.cer.asum\_c > 150$ (accepting more than 1.5 photoelectrons).
- Pion Rejector cut (PR)
  - $L.prl1.asum\_c$: PR layer 1 > 60% of full energy peak

Current (μA)	S2m&&Cer LT	Rate: no cuts (old)	DIS Normalized Rate (old)	DVCS Normalized Rate (old)	DVCS Normalized Rate corrected (old)
10.61	0.985	9.27	3.422	5.212	4.111
15.32	0.976	10.26	3.450	5.615	4.194
20.53	0.965	11.26	3.449	5.936	3.863

Table 1: Table summarizing the old rates and results. DIS rates have tracking (ntr) & TDC & Cer & trigPatW&0x00080 cuts applied, DVCS rates have tracking (ntr) & TDC & Cer & trigPatW&0x00100 cuts applied. These cuts were applied after the clustering of the calorimeter blocks. Rates are normalized with the S2m && Cer livetime and current. DIS normalized Rates have a 0.77% agreement per 10 μA , and DVCS normalized rates have a 13% agreement per 10 μA and a 6 to 7% agreement per 5 μA.

Current (μA)	S2m&Cer LT	GoodEventCut&TDC&DIS Raw (Hz)	GoodEventCut&TDC&DVCS Raw (Hz)
10.61	0.981	13.66	20.86
15.32	0.971	19.48	31.92
20.53	0.960	26.09	45.02

Table 2: Table showing the DVCS and DIS raw rates with all cuts and corrections applied. All raw rates are normalized with the 103.7 kHz clock from LHRS in DVCS crate. DIS rates have GoodEventCut & TDC & DIS (triggerPatternWord) cuts applied, DVCS rates have GoodEventCut & TDC & DVCS (triggerPatternWord) cuts applied and have units Hz. The S2m && Cer livetime is pedestal subtracted, e.g tates and Livetime taken when beam current is $< 0.8\ \mu A$ during the run.

  - $L.prl2.asum\_c$: PR layer 2 > 20% of full energy peak

- Alexa's R Function cut for kin 48_4

Additionally, cuts on the Time-to-Digital Converter (TDC) and triggerPatternWord were made:

- TDC cut: $tdc\_val[27] - tdc\_val[7]/10 < -24$
- TriggerPatternWord cut for DIS: $TPW\&0x00080 == 128$
- TriggerPatternWord cut for DVCS: $TPW\&0x00100 == 256$

In addition to Hashir's good event cuts, another correction for missed events after passing the tracking cuts must be applied to the whole analysis. For kinematic 48_4, this correction factor was 1.06 and was applied to the number of events contained in all the rates. More information on Hashir's cuts is in the elog entry here: `https://hallaweb.jlab.org/dvcslog/12+GeV/487`.

Current (μA)	No Cuts ($\frac{Hz}{\mu A}$)	Trk ($\frac{Hz}{\mu A}$)	Trk&TDC ($\frac{Hz}{\mu A}$)	Trk&TDC &Cer ($\frac{Hz}{\mu A}$)	GoodEventCut ($\frac{Hz}{\mu A}$)	GoodEventCut &TDC&DIS($\frac{Hz}{\mu A}$)	GoodEventCut &TDC&DVCS ($\frac{Hz}{\mu A}$)
0	17.78	0.541	0.541	0.357	0.1650	n/a	n/a
10.61	9.773	5.042	4.991	4.619	1.950	1.288	1.966
15.32	10.83	5.429	5.336	4.973	2.073	1.272	2.083
20.53	11.90	5.653	5.593	5.190	2.185	1.271	2.193

Table 3: Table showing the different pedestal subtracted rates normalized with the current, after additional cuts applied. DIS rates had GoodEventCut & TDC & DIS cuts applied, DVCS rates had GoodEventCut & TDC & DVCS cuts applied. Note that these results were not normalized with the S2m&&Cer Livetime(LT), and have units ($\frac{Hz}{\mu A}$).

3 Accidental Studies

Accidentals make up most of the background and are present in the rates. Accidentals are any photons and electrons from the DVCS calorimeter and LHRS that are NOT in coincidence. Real coincidences occur when photons and electrons are simultaneously in coincidence with one another, with each coincidence considered a "signal", also known as a DVCS event.

3.1 Waveform Analysis and Clustering

Waveform analysis is a method that works to extract the amplitude of a pulse coming from the ARS (Analog Ring Sampler), which is used to sample events and record from active triggers. The analysis was done using libraries unique to DVCS such as TARSWave.h anc TEventCalo.h. The waveform analysis detects pulses coming from the ARS based on the energy of photons hitting blocks in the calorimeter, and fits to a one or a two-pulse wave using the χ^2 value. If the χ^2 for the fitting is very high, the waves are fit to a two pulse. This two-pulse fit was forced despite the χ^2 to correct for the low statistics for the run.

After the two-pulse fit from the waveform analysis, the clustering of the blocks in the DVCS calorimeter determined the "good" photon and electron from the LHRS. All cuts and corrections were applied during the clustering, including Hashir's good electron cuts for DVCS events.

3.2 Extending Accidental window

The ultimate goal of this analysis was to correct the deadtime by obtaining an accidental rate from the coincidence and accidental timing in the calorimeter clusters, and subtract it from DVCS event rates (shown in Table 3). The clustering of the blocks in the calorimeter provided time spectra based on a clustering energy threshold set for each block, $E_\gamma > 1.5$ GeV or the "triggerSim" threshold[1].

The main coincidence peak is centered at [-2,2] which shows us the photons, electrons and accidentals, and is shown in Figure 3 for all three currents. Taking the area under the coincidence peak gives the background which contains both the real coincidences and accidentals, as shown in Equation 5. Equation 4 is used to determine the signal or real coincidences by subtracting the background.

$$\textit{Signal or real coincidences} = \textit{Area main coincidence peak or background} - \textit{Area of accidental 4 ns or 6 ns peak} \tag{4}$$

$$\textit{Area of main coincidence peak} = \textit{Background} \tag{5}$$

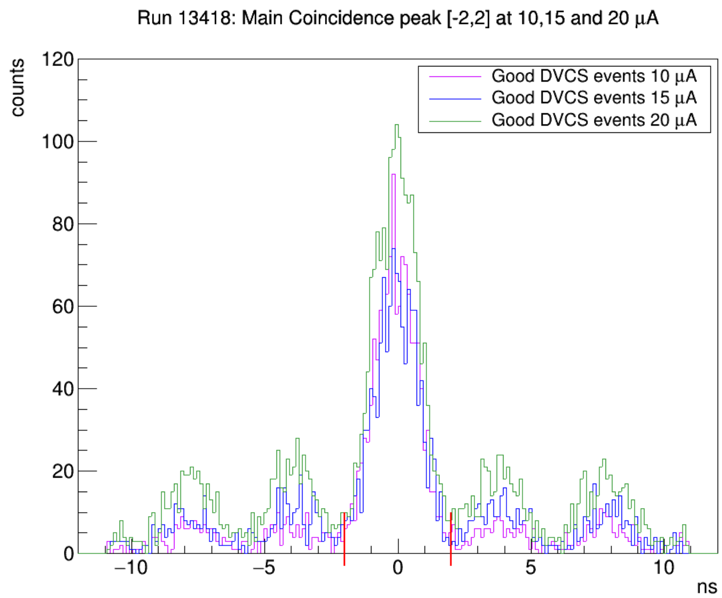


Figure 3: DVCS time coincidence spectra, with all events passing the Good Event cut in the clustering. Main coincidence peaks highlighted are shown at [-2,2] for 10, 15, 20 μA. The events in this range is equivalent to the total amount of hits including photons, electrons and background.

To account for low statistics in past analyses, the accidental windows were extended from 4 ns to 6 ns and compared. Any 4 ns window from [-11,11] could have been chosen, but for statistical purposes different scales of windows were

[1]Previously this threshold was set to 1.0 GeV, but after Mongi and Frederic's ADC calibration for each kinematic (December 2017), the noted energy threshold for kinematic 48_4 was used. See the elog entry here: `https://hallaweb.jlab.org/dvcslog/12+GeV/489` for more information.

	10 μA	15 μA	20 μA
No cuts	1920	2126	3530
4 ns main coinc window [-2,2]	1324	1225	1843
[-11,-5] 6 ns acc window	164.3	228.9	451.6
[-10,-6] 4 ns acc window	135.7	181.3	372.1
[5,11] 6 ns acc window	173.8	236.4	449.4
[6,10] 4 ns acc window	145.2	202.5	384.8
Avg 6 ns acc windows	169.1	232.7	450.5
Avg 4 ns acc windows	140.5	191.9	378.4
Avg 6 ns acc sig/back ratio	0.8723	0.8101	0.7556
Avg 4 ns acc sig/back ratio	0.8939	0.8434	0.7947

Table 4: Table showing accidentals and the coincidence window of 4 ns at [-2,2], rounded to the nearest significant figure. The accidentals are from window cuts made on the time coincidence spectrum (tmoy), and are not normalized with the current. The "Avg 6 ns acc windows" and the "Avg 4 ns acc windows" rows contain the averages of the accidentals in [-11,-5] and [5,11] for the former and [-10,-6] and [6,10] for the latter. The main coincidence window or "4 ns main coinc window" row is the [-2,2] cut on the coincidence spectrum that contains the signal and the background. The results in "Avg 6 ns acc sig/back ratio"and "Avg 4 ns acc sig/back ratio" rows were calculated using 6

chosen, compared and averaged. Accidental windows were in the range [-11,-5] and [5,11] for a 6 ns span, and [-10,-6] and [6,10] for a 4 ns span.

The ratios of the real coincidences (signal) to the background were calculated using Equation 6 for each current. Results are in the "Avg 6 ns acc sig/back ratio"and "Avg 4 ns acc sig/back ratio" rows for each current shown in Table 4.

$$Signal/Background = \frac{Background - Accidental\ peak}{Background} \tag{6}$$

The different scaled windows are presented to demonstrate low statistics in the 4 ns windows as compared with the extended 6 ns accidental windows. As the range of events in [6,10] and [-10,-6] is already contained in the ranges of [5,11] and [-11,-5], the window that is best representative of the accidentals is the 6 ns averaged window of accidentals.

3.3 Applications of Accidental Rates to DVCS Rates

Applying the accidental ratios from Table 4 to the DVCS rates involves the relationship to the beam current and active triggers in the experimental setup during the run. Accidentals and random coincidences scale with the beam current (μA) squared (I^2), whereas the signal or real coincidences scale directly with the beam current, I. As such, the ratios calculated from the average accidentals in the 6 ns windows from Table 4 using Equation 6 have been applied

Current (μA)	S2m&&Cer LT	Rate: No Cuts	DIS Normalized Rate	DVCS Normalized Rate	DVCS 6 ns $\frac{signal}{background}$	DVCS Normalized Rate corrected
10.61	0.981	9.773	1.313	2.004	0.8723	1.748
15.32	0.971	10.83	1.310	2.146	0.8101	1.738
20.53	0.960	11.90	1.324	2.284	0.7556	1.726

Table 5: DIS rates have GoodEventCut & TDC & DIS (triggerPatternWord) cuts applied, DVCS rates have GoodEventCut & TDC & DVCS (triggerPatternWord) cuts applied and normalized with the S2m && Cer livetime, and have units ($\frac{Hz}{\mu A}$). DIS normalized rates had a $< 1\%$ agreement per 10 μA , and DVCS normalized rates had a 13% agreement per 10 μA and a 6 to 7% agreement per 5 μA, the same agreement from the old rates shown in Table 1. The DVCS signal/background ratios applied to the DVCS normalized rates result in a discrepancy of 1.27% per 10 μA and $< 1\%$ per 5 μA.

to the DVCS rates by using Equation 7.

$$DVCS\ normalized\ rate\ corrected = \frac{DVCS\ rate\ (Hz) \times DVCS\ signal\ to\ background\ ratio}{I\ (\mu A) \times S2M\&\&Cer\ LT} \tag{7}$$

A sample calculation using Equation 7 is shown for 10 μA in Equation 8. Subtracting the accidentals from the DVCS normalized rates in order to minimize the current dependence led to recovered DVCS rates to agree 1.27% per 10μA and 0.63% per 5 μA for run 13418.

$$DVCS\ corrected\ normalized\ rate\ at\ 10\ \mu A = \frac{20.86\ \frac{Hz}{\mu A} \times 0.8723}{10.61\ \mu A \times 0.981} = 1.748\ \frac{Hz}{\mu A} \tag{8}$$

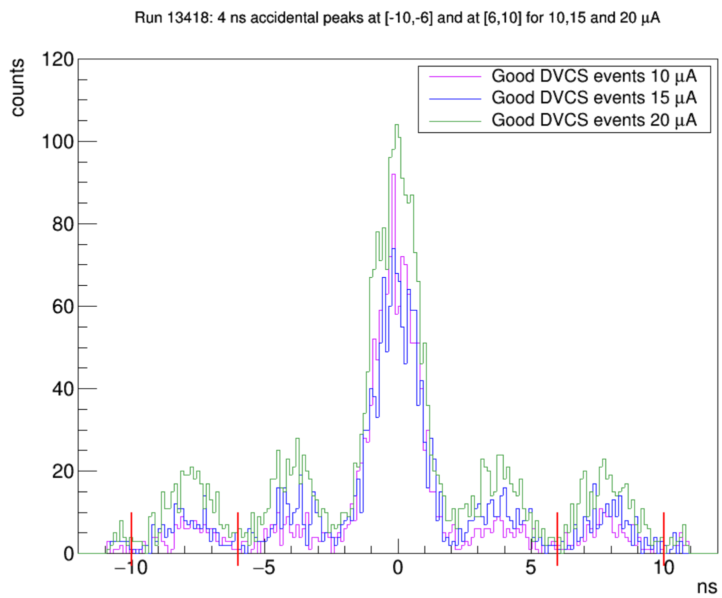
4 Summary and outlook

Since the DVCS normalized rates were dependent on the current despite normalization with the current, the accidentals coming from the DVCS calorimeter and the Left High Resolution Spectrometer (LHRS) were subtracted from the DVCS rates to minimize the current dependence and recover the rates. Corrected DVCS rates are shown in Table 5 after the application of the signal/background ratios to eliminate the accidentals from the DVCS rates. There is a 1.27 % agreement per 10 μA and 0.63% agreement 5 μA for run 13418.

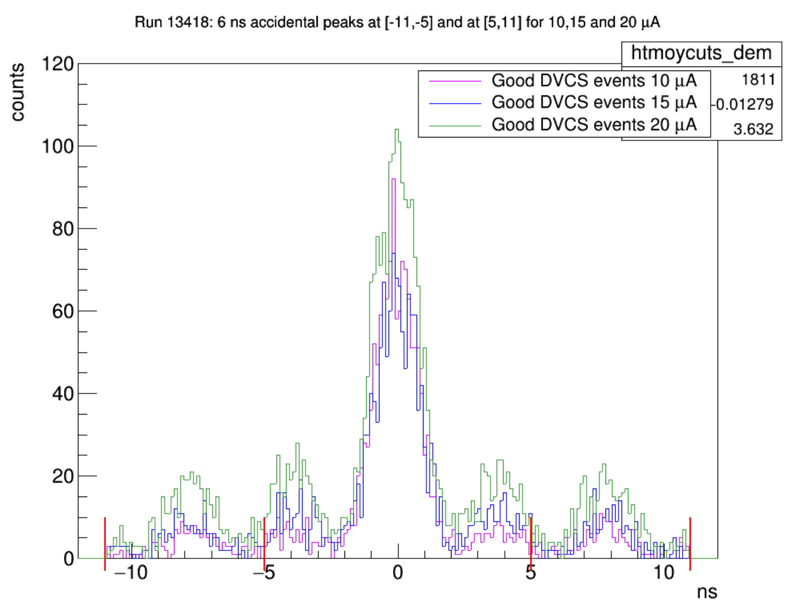
A possible way is to verify this analysis and to check for reproducibility, is to look for runs at different currents with the same kinematics for future deadtime studies. So far, these include 12985 (15 μA) and 12901 (10 μA) which are part of kinematic 48_3. Note that there is no other run at different currents that we know of. Mongi had looked at other runs in the past using runs 10555(4.8

μA),10595(7.2 μA),10640 (9.7 μA),10622(6.8 μA) and found that the rates are recoverable to better than 1%.

A previous analysis used active DIS triggers in the accidental subtraction as there was no known way at the time to subtract the accidental contribution from the DVCS rates. That analysis was performed before applying Hashir's cuts and performing the two-pulse waveform analysis. Photons in coincidence with electrons, or DIS and DVCS events, are detected in the clustering process in the calorimeter, after the waveform analysis. Hashir's Good event cuts were applied during the clustering process thus representing a good photon from the calorimeter, and a good electron from the LHRS.



(a)



(b)

Figure 4: DVCS time coincidence spectra, with all events passing the Good Event cut in the clustering. Accidental peaks (red) that are 4 ns wide are in the range [-10,-6] and [6,10] for 10, 15, 20 μA. Accidental peaks (red) that are 6 ns wide are in the range [-11,-5] and [5,11] for 10, 15, 20 μA. The integral over this range has the total amount of hits including photon, electron and background. Accidentals shown in red at [-10,-6] for 10, 15, 20 μA.