Report on Electronic Deadtime
(updated 9/11 /00)

The electronic deadtime was measured using a pulser which sent a scintillator-type signals to a linear-or with the S1 paddle 1 and S2 paddle 1 in each arm. The pulser signal was also sent to a TDC channel in each arm so that the event was tagged as a pulser event. In addition the pulser was sent to a scaler. This was added to the trigger circuitry during July shutdown. So runs 2838 and onward the pulser was in the datastream. For runs 3038 to 3263 are not good for using the pulser, because there was a problem with the timing of T1 versus T3 for pulser signals. This problem was corrected (see halog 46685) and runs 3296 onward are fine.

There was no direct measurement of the electronic deadtime (EDT). The EDT was determined from the global computer deadtime (CDT) and the combination of computer and electronic deadtime (ECDT) assuming the following:

$$\begin{aligned} ECDT &= 1-(1-EDT)*(1-CDT) = EDT+CDT-EDT*CDT \\ EDT &= (ECDT-CDT)/(1-CDT) \end{aligned}$$

The ECDT was determined dividing the number of pulser events in the datastream,N_{pul}, by the number of initial pulser events measured by the scaler, S_{pul}.

$$ECDT = 1-\frac{\sum N_{pul}}{\sum S_{pul}/PS}$$

The pulser event was identified by putting a cut between 1650 and 1750 on the TDC channel 84 in slot 9 for the hadron and a cut between 2650 and 2750 on TDC channel 84 in slot 19 for the electron. In practice the prescales for T1 and T3 were set so high that there were only pulser events for T5 events. The CDT was determined by

$$CDT = 1-\frac{\sum N_i}{\sum \frac{S'_i}{PS_i}}$$

$$S'_1 = S_1-\frac{S_5}{PS_5}-N_{14} \qquad ; \qquad S'_3 = S_3-\frac{S_5}{PS_5}-N_{14}$$

$$S'_{2,4,5} = S_{2,4,5} \quad ; \quad S'_6 = S_6 - \frac{S_3}{PS_3}; \quad S'_{14} = N_{14}$$

where S_i is the scaler for each trigger and PS_i is the prescale factor. i is the trigger types 1,2,3,4,5,6 and 14 and N_i is the number of triggers accepted for each event type. N_{14} is the number of trigger 14 which occurs when there is an overlap of 10ns between triggers at the trigger supervisor. There were very few trigger 14 in any of the runs. With high prescales on all trigger types except T5 meant that the global computer deadtime was basically equal to the T5 computer deadtime. The data was selected so that only when the current was above 5 μA was the deadtime determined. For the low current runs (< 5 μA) then limit was 1 μA .

Table 1 lists the runs used in studying the deadtime. At four different kinematic settings of the experiment a current scan was done. For runs 3928-3934 the hadron arm was moved forward to increase the hadron rate and see the effects on the electronic deadtime. The deadtimes are listed in Table 2 and they are plotted in Fig. 1. In addition in Fig. 1 the deadtimes are plotted for all the runs which had the pulser. Three equations predicting EDT in % are plotted in Fig. 1:

$$EDT = 0.0284 * (\text{strobe rate kHz}) - 1.05x10^{-5} * (\text{strobe rate kHz})^2 \quad (1)$$

$$EDT = 0.0190 * (\text{strobe rate kHz}) \quad (2)$$

Eq. 1 is a fit to the values in Table 2. Eq. 2 is a eyeball fit to the deadtime excluding the $\theta_{cm} = 50$ data. None of the fits is consitent with all the data.

In Table 3 and Fig. 2 the strobe rates are plotted versus the sum of the rates in the right scintillator paddles in all planes in an arm. The electron arm was fit linearly. The hadron is fairly linearly, but was fitted with a quadratic.

$$\text{E-arm Strobe rate} = (0.613 \pm 0.001) \cdot (\text{ESUM})$$

$$\text{H-arm Strobe rate} = (0.620 \pm 0.0007) \cdot (\text{HSUM}) - (5.1 \pm 0.04x10^{-5}) \cdot (\text{HSUM})^2$$

where ESUM and HSUM are the sum of the rates in the right scintillator paddles in all planes in an arm. The rates in the scintillator paddles were in the data stream for all experiments so one can use these rates to predict the strobe rate during the run and therefore the EDT. The relative error on the EDT from the determining the strobe rate from the sum of right scintillator

paddles is 0.2% for this experiment since the scintillators seem to be stable during the experiment. I would think for experiments within the last year this is also true.

Runs 1099-1101,1113-1118 were carbon target runs with the electron arm fixed and the current varied. The kinematics were hydrogen elastic at Q^2 = 1.37. The ratio of (trigger rate - 3.7Hz) divided by current corrected for EDT is plotted in Fig. 3 with the rate normalized to the value at 2 μA. The 3.7Hz is the cosmic rate. The EDT for the carbon runs is very low. The plot indicates no dependence on current. Runs 1097,1098,1102-1112 were hydrogen runs at the same kinematics. The ratio is plotted as a function of current for trigger 1 and trigger 3 and normalized to the value at 2 μA. It is plotted with correction for the deadtime DT1 using Eq. 1 and the deadtime DT2 using Eq. 2. Later higher current runs 1837-1844 with hydrogen target were done at kinematics for pion production at θ_{cm} = -155. The ratio is plotted as solid points with the ratio normalized to the value at 20 μA. The statistical error bars are smaller than the data points. The two data sets disagree at the 1% level. One expects the ratio either to be flat or drop off with decrease in target density with increasing current. When using DT from Eq. 2 the data is more consistent with being flat. Looking at the pion production data in Fig 5 the ratio is plotted for each of the θ_{cm} settings. Using Eq. 2 the ratio falls off faster than what is seen for the earlier runs. Using Eq. 1 the ratio for trigger 3 is rising which does not make sense. It seems that systematic uncertainty for the correction due to deadtime and target density is at the 1-2% level.

In conclusion, an attempt to estimate systematic errors. In Fig. 1, below 500 kHz in the total strobe rate there is a large variation in the EDT with some data agreeing better with Eq. 2, some with Eq. 1 and some with neither. I would put a 25% error on the slope in Eq. 1, so

$$EDT = (0.0190 \pm 0.0048) * (\text{Strobe rate}) \tag{3}$$

In Fig. 1, above 500 kHz in the total strobe rate there is better agreement between data sets and with a linear fit. I would put a 10% error on the slope in Eq. 1, so

$$EDT = (0.0190 \pm 0.0019) * (\text{Strobe rate}) \tag{4}$$

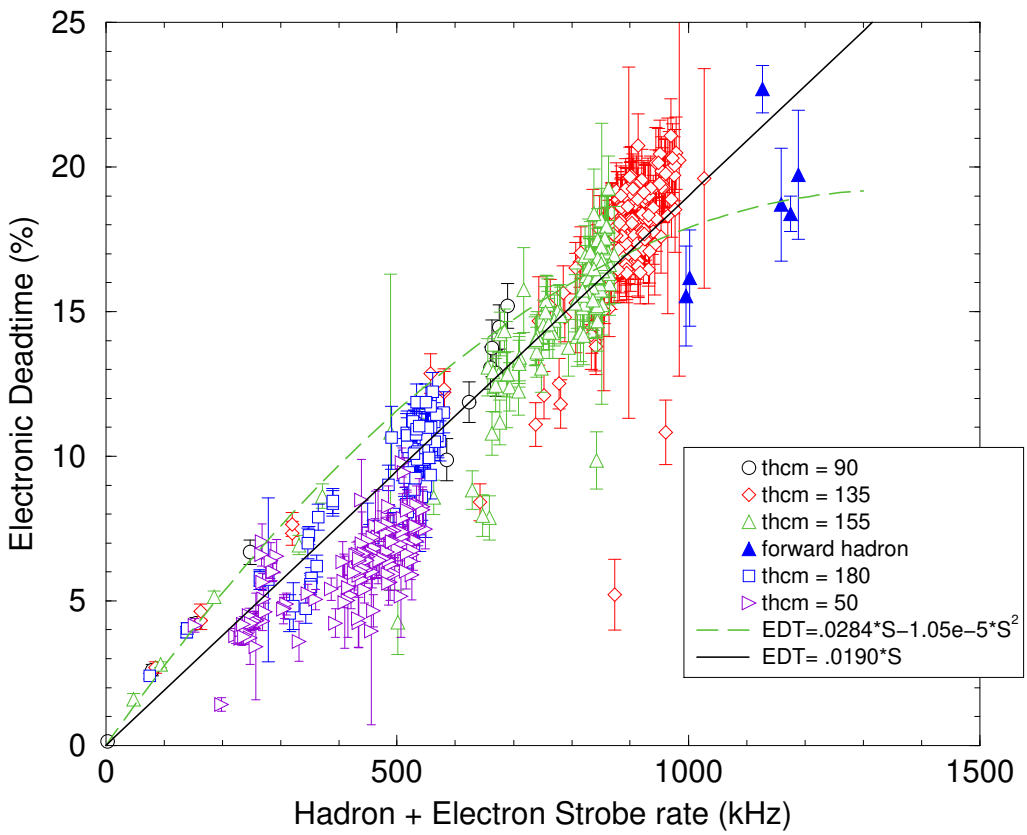
Electronic Deadtime (%)
Hadron + Electron Strobe rate (kHz)
0
5
10
15
20
25
0
500
1000
1500
thcm = 90
thcm = 135
thcm = 155
forward hadron
thcm = 180
thcm = 50
EDT=.0284*S−1.05e−5*S2
EDT= .0190*S

Figure 1:

Run	θ_{cm}	Prescale	Current
3296	cosmic	1,1,1,100,1,65535	cosmic
3297	90	4500,400,9000,2500,1,14000	5.0
3298	90	4500,400,9000,2500,1,14000	9.8
3299	90	4500,400,9000,2500,1,14000	20.2
3300	90	4500,400,9000,2500,1,14000	39.0
3318	135	4000,50,80000,2800,1,15000	5.2
3319	135	4000,50,80000,2800,1,15000	10.1
3320	135	4000,50,80000,2800,1,15000	20.1
3321	135	4000,50,80000,2800,1,15000	37.5
3623	135	4407,297,13322,2718,1,21190	2.0
3763	155	5234,394,14661,2845,1,21040	4.8
3764	155	5234,394,14661,2845,1,21040	9.7
3765	155	5234,394,14661,2845,1,21040	19.6
3766	155	5234,394,14661,2845,1,21040	37.5
3767	155	5234,394,14661,2845,1,21040	39.5
3768	155	5234,394,14661,2845,1,21040	42.4
3928		7500,50,44000,5200,1,21040	41.0
3929		7500,50,44000,5200,1,21040	41.2
3930		7500,50,44000,5200,1,21040	41.2
3932		7500,50,44000,5200,1,21040	40.3
3933		7500,500,50000,6000,3,21040	40.6
3934		7500,500,50000,6000,3,21040	39.0
3951	180	6968,488,18592,3078,1,21040	29.3
3952	180	6968,488,18592,3078,1,21040	19.7
3953	180	6968,488,18592,3078,1,21040	10.3
3954	180	6968,488,18592,3078,1,21040	5.5

Table 1:

Run	H-Strobe	E-Strobe	ECDT	CDT	EDT
3296	1.7	1.8	0.547±0.039	0.444	0.103±0.039
3297	57.5	23.1	2.629±0.200	0.000	2.629±0.200
3298	111.3	44.0	4.859±0.246	0.396	4.481±0.247
3299	222.9	87.0	10.636±0.444	4.072	6.843±0.463
3300	417.0	168.2	25.168±0.634	17.019	9.820±0.764
3318	65.5	19.0	2.661±0.165	0.000	2.661±0.165
3319	127.4	35.7	4.714±0.258	0.087	4.631±0.258
3320	250.1	70.0	10.343±0.400	2.931	7.636±0.412
3321	451.8	128.8	27.443±0.572	17.241	12.327±0.691
3623	36.6	10.6	1.618±0.166	0.000	1.618±0.166
3763	72.5	22.2	2.781±0.123	0.000	2.781±0.123
3764	143.4	42.9	5.769±0.239	0.554	5.244±0.240
3765	286.8	85.5	13.086±0.433	4.825	8.680±0.455
3766	525.8	162.3	28.636±1.469	18.095	12.870±1.794
3767	548.2	169.4	30.976±1.178	18.006	15.818±1.437
3768	586.2	181.6	32.732±0.746	21.440	14.374±0.950
3928	820.1	176.4	46.172±1.102	36.242	15.575±1.728
3929	825.8	176.5	44.481±1.098	33.765	16.179±1.658
3930	1011.0	177.9	53.242±1.270	41.665	19.846±2.177
3932	987.0	172.3	50.079±1.256	38.421	18.932±2.040
3933	1000.0	175.5	20.117±0.580	1.518	18.886±0.589
3934	959.6	166.8	24.387±0.844	1.626	23.137±0.858
3951	265.6	124.6	15.718±0.393	7.940	8.449±0.427
3952	180.9	83.9	9.103±0.263	3.506	5.800±0.273
3953	95.2	44.6	4.327±0.200	0.297	4.042±0.201
3954	51.0	24.3	2.401±0.132	0.000	2.401±0.132

Table 2:

Run	H-Strobe	E-Strobe	Sum Hadron right scint	Sum Electron right scint
3296	1.7	1.8	1.8	1.8
3297	57.5	23.1	93.2	36.5
3298	111.3	44.0	182.9	70.5
3299	222.9	87.0	372.4	140.8
3300	417.0	168.2	718.7	274.7
3318	65.5	19.0	106.1	30.1
3319	127.4	35.7	208.2	57.5
3320	250.1	70.0	415.4	113.5
3321	451.8	128.8	775.3	210.6
3623	36.6	10.6	58.9	16.0
3763	72.5	22.2	117.9	35.0
3764	143.4	42.9	235.7	68.8
3765	286.8	85.5	480.0	138.1
3766	525.8	162.3	916.5	265.0
3767	548.2	169.4	958.2	277.1
3768	586.2	181.6	1032.3	297.0
3928	820.1	176.4	1506.5	287.7
3929	825.8	176.5	1516.1	287.8
3930	1011.0	177.9	1929.3	289.9
3932	987.0	172.3	1884.5	281.0
3933	1000.0	175.5	1906.3	286.0
3934	959.6	166.8	1829.4	272.0
3951	265.6	124.6	445.7	203.7
3952	180.9	83.9	300.2	136.6
3953	95.2	44.6	156.0	72.0
3954	51.0	24.3	83.1	38.9

Table 3: The "Sum of hadron right scint" is the sum of scalers for each right side scintillator in all paddles. The "Sum of electron right scint" is the sum of scalers for each right side scintillator in all paddles.

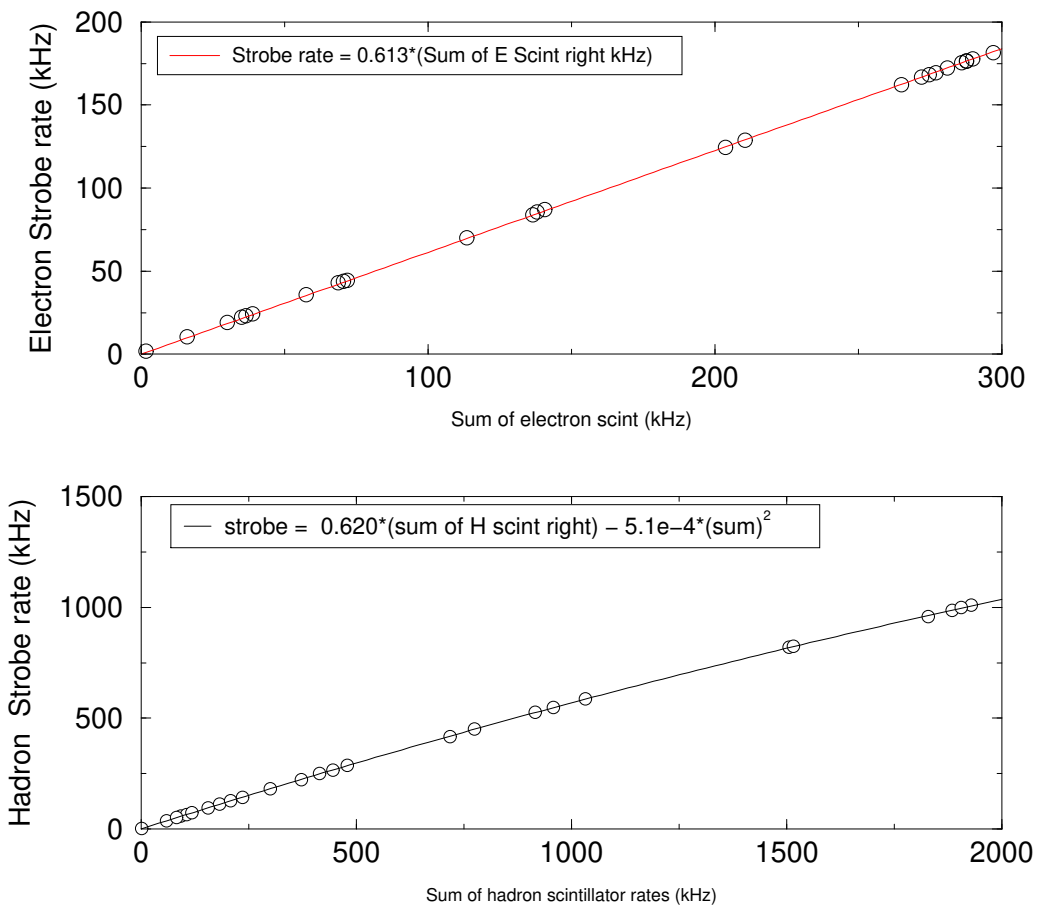
Strobe rate = 0.613*(Sum of E Scint right kHz)
Electron Strobe rate (kHz)
Sum of electron scint (kHz)
0
50
100
150
200
0
100
200
300
strobe = 0.620*(sum of H scint right) – 5.1e–4*(sum)^2
Hadron Strobe rate (kHz)
Sum of hadron scintillator rates (kHz)
0
500
1000
1500
0
500
1000
1500
2000

Figure 2:

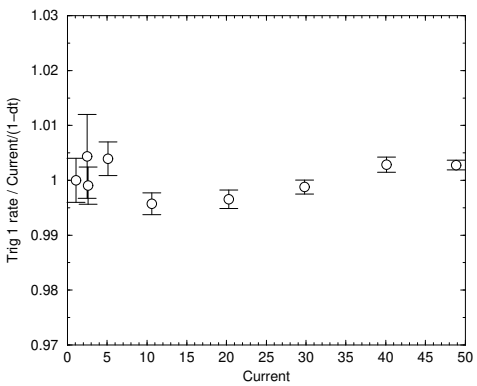

Figure 3: Trigger 1 rate divided by current corrected for deadtime versus current for a carbon target

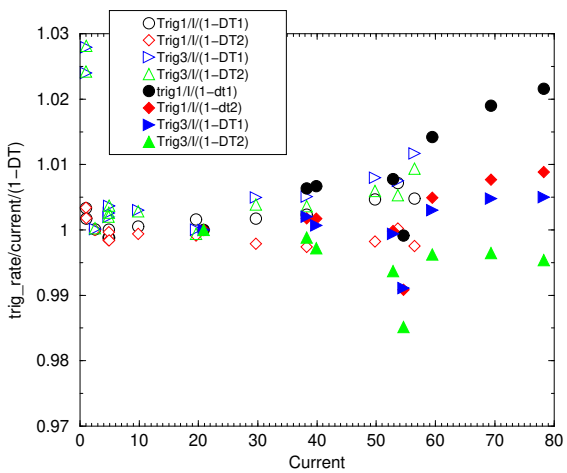

Figure 4: Trigger rate divided by current corrected for deadtime versus current for a hydrogen target

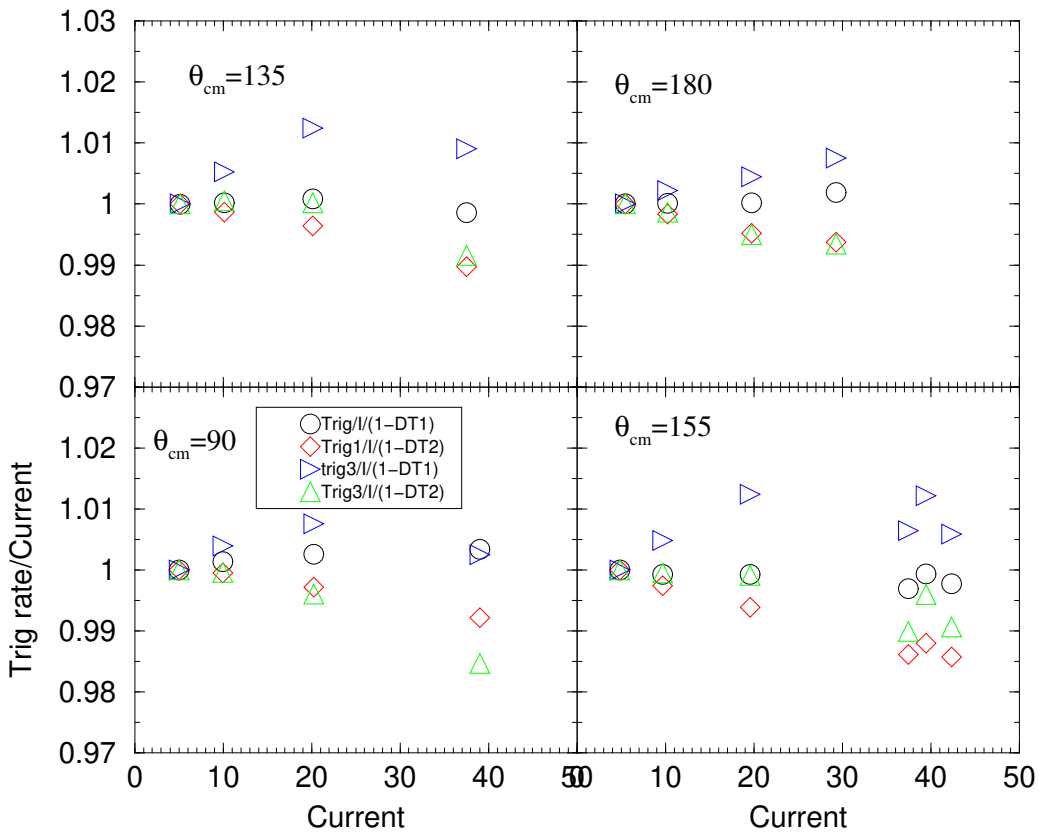

Figure 5: Trigger rate divided by current corrected for deadtime versus current for a hydrogen target at different θ_{cm} kinematics