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

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

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

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

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 $\mu$A was the deadtime determined. For the low current runs ($< 5$ $\mu$A) then limit was 1 $\mu$A .

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.

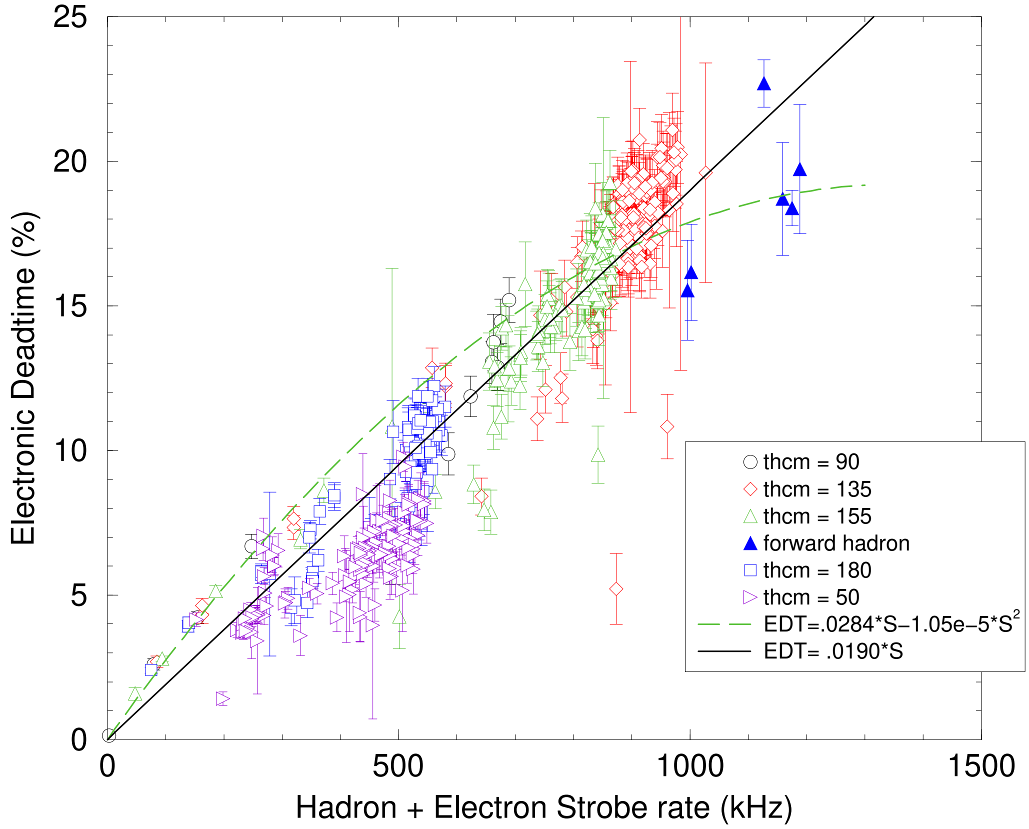
Runs 1099-1101,1113-1118 were carbon target runs with the electron arm fixed and the current varied. The kinematics were hydrogen elastic at $Q^2 = 1.37$. The ratio of (trigger rate - 3.7Hz) divided by current corrected for EDT is plotted in Fig. 3 with the rate normalized to the value at 2 $\mu$A. The 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 $\mu$A. 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 $\theta_{cm}$ = -155. The ratio is plotted as solid points with the ratio normalized to the value at 20 $\mu$A. 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 $\theta_{cm}$ 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*S^2
EDT= .0190*S


Figure 1:

| Run | $\theta_{cm}$ | 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.

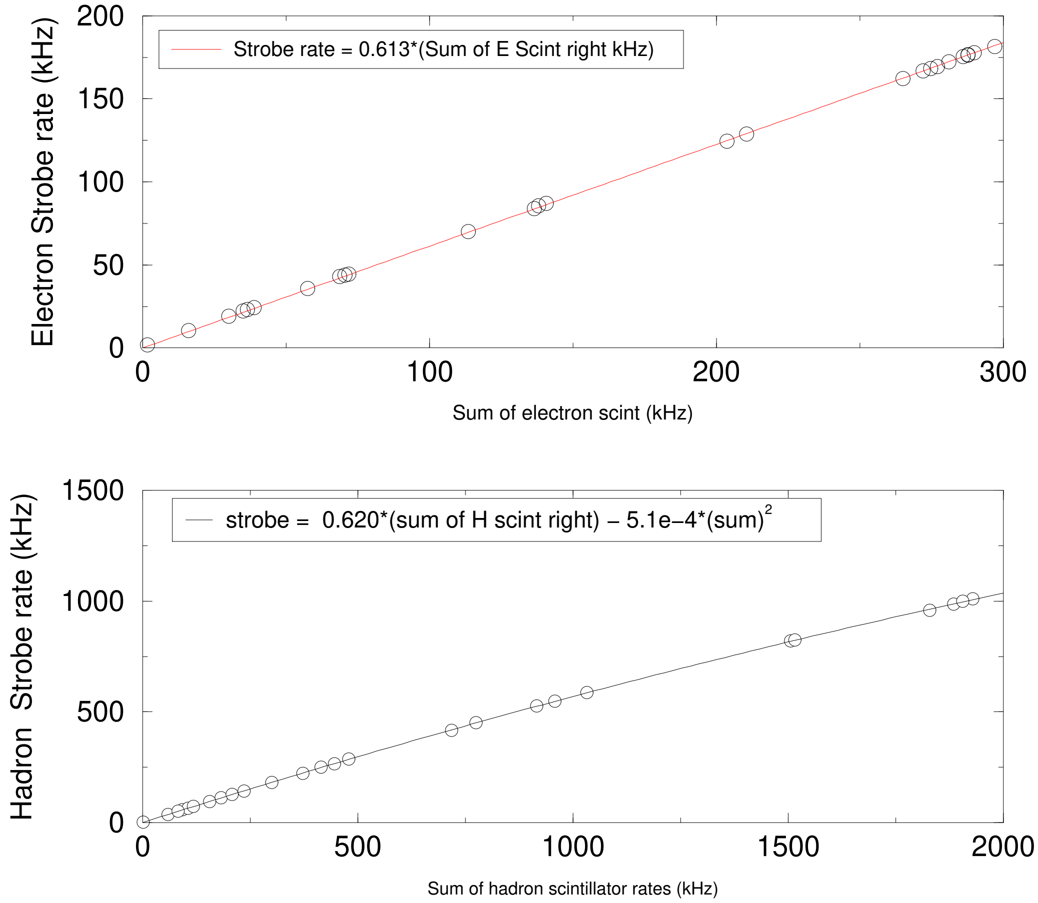

200
150
100
50
0
Electron Strobe rate (kHz)
Strobe rate = 0.613*(Sum of E Scint right kHz)
0
100
200
300
Sum of electron scint (kHz)
1500
1000
500
0
Hadron Strobe rate (kHz)
strobe = 0.620*(sum of H scint right) – 5.1e–4*(sum)^2
0
500
1000
1500
2000
Sum of hadron scintillator rates (kHz)

Figure 2:

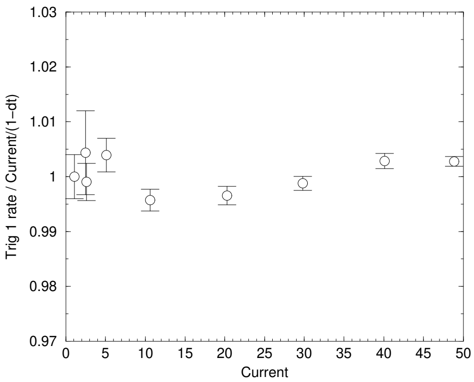



Figure 3: Trigger 1 rate divided by current corrected for deadtime versus current for a carbon target

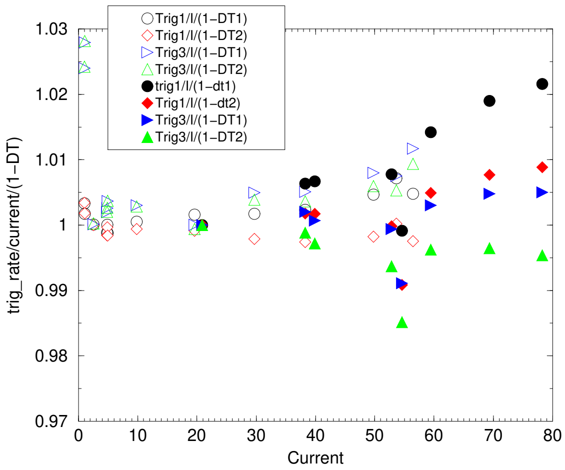



Figure 4: Trigger rate divided by current corrected for deadtime versus current for a hydrogen target

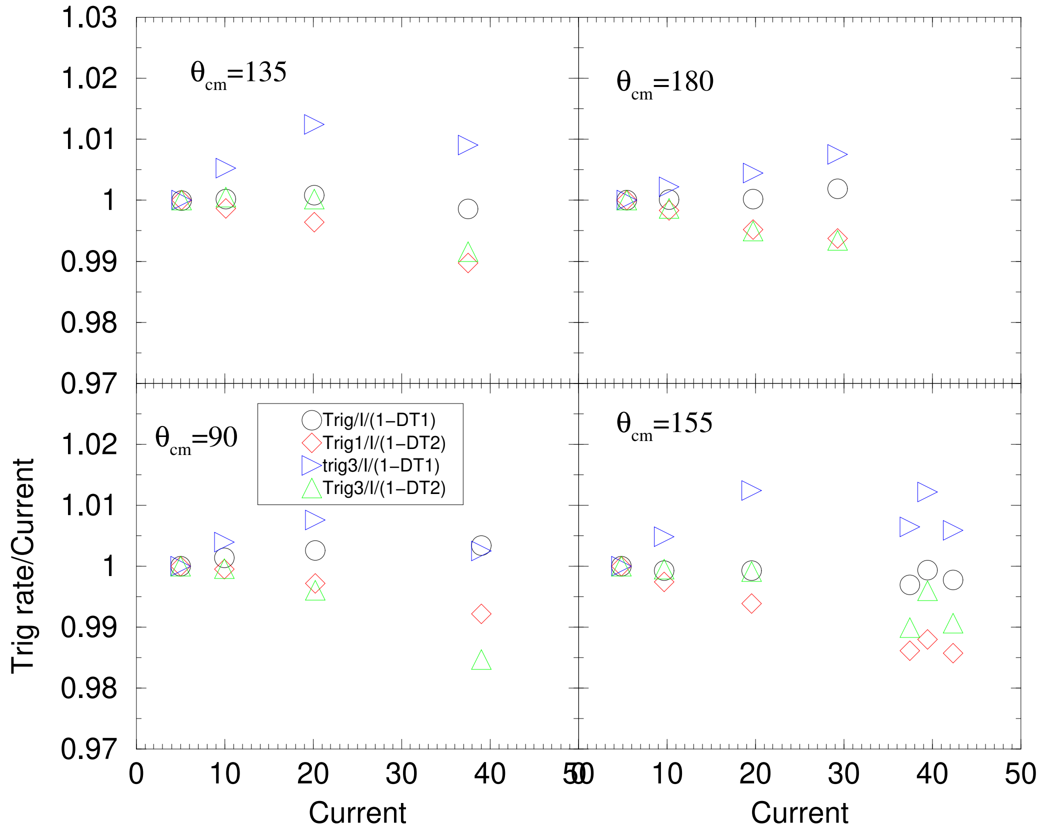



Figure 5: Trigger rate divided by current corrected for deadtime versus current for a hydrogen target at different $\theta_{cm}$ kinematics