E08014 Trigger Cuts and Efficiencies

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1 Trigger Setup

The Hall A triggers are generated when particles go through detectors located in the detector hut of High Resolution Spectrometers (HRS). The tranditional single arm trigger requires both S1 and S2m scintillator planes fired in a marrow overlap time window. More specifically, when a particle hits on a paddle of a scintillator plane, for example, S1, PMT tubes on both side of the paddle generate ADC signals which are strong enough to pass the threhold of a discrimilator, and produce two TDC signals. The ADC of those two TDC signals form a logic signal for this scintillator plane. S2m will also create a logic signal if one of this paddles is also fired, and the coincident (simply logic AND) of those two logic signal give the trigger of the event . The main trigger of HRS-R and HRS-L are called T1 and T3, respectively. For coincident experiments, the main trigger, T5 is the coincident of T1 and T3.

During E08014 experiment, we included gas Cerenkov detector plane (GC) in the main trigger to exclude most of pions events, hence dramatically reduce the total events rate . New types of main triggers are the coincident of logic signals from S1, S2m and GC (we still call them as T1 and T3, but they are 3 out of 3 triggers). We still keep the orignal triggers but gave them different names, T6 and T7 respetively, which are tranditionally triggers from BigBite and HAND, but we kept their events rate as low as 50Hz by setting big prescale factors.

There are also two other triggers, T2 for HRS-R and T4 for HRS-L, which are used for trigger efficiency study. T2 and T4 are so called 2 out of 3 triggers, which mean that only one of two scintillator planes is fired and coincides which a third detector plane, which is GC detector for our experiment. T2 and T4 triggers are generated by sending logic signals from S1, S2m and Cerenkov into a programable moduel,called MLU [1].

Ideally, before the prescaling, T6 (T7) should be exactly the same as T1(T3),if the GC has 100% of detection efficiency and is very clean background. However, T6(T7) has much higher event rates than T1(T3), due to pion contaimination and accidental coincidents between noisy signals from Cerenkov (and its corresponding electrnoic modules) and real signals detected by S1 and S2m. We still need to record the events from T6(T7) to study GC detection efficiency. During the data taking, we applied prescale factors on triggers to control their rates in a certain amount. T1 and T3 are the major production triggers so we tried to keep their rate as high as possible unless the dead time is getting high simutanously. T3, T4,T6 and T7 are prescaled to fix their rates at about 50   100Hz.

2 Trigger Cuts

There are totally 12 different triggers connected to Trigger Supervisor (TS) and when a event happens, or said, any of those triggers forms a level one accept signal in the TS and hence generate a gate, those triggers will be recorded into a TDC on channels from 1 to 12 *AFTER* prescaling. The analyzer decords those values as Hex types and issues a name called "DBB.evtypebits". For our experiment, we are only interested in T1,T2,T3,T4,T6,and T7.

Here is the table of triggers and their corresponding values in different number types:

As long as we understand the corresponding values of all trigger types in the data stream, applying certain types of cuts will select events coming from different triggers. There are several kinds of trigger cuts used durling data analysis and we need to understand the differences in between them:

[1] For more detail about Hall A trigger design, visit http:hallaweb.jlab.orgequipmentdaqtrigsetup_2003.html

Trigger:	T1	T2	T3	T4	T5	T6	T7	T8
TDC Channel:	1	2	3	4	5	6	7	8
Decimal:	2	2^2	2^3	2^4	2^5	2^6	2^7	2^8
Hex:	0x02	0x04	0x08	0x10	0x20	0x40	0x80	0x100

Table 1: Trigger types and their corresponding data types in data stream

1. **DBB.evtypebits=0x02**:
   Only T1 trigger and no other trigger types co-exist.

2. **(DBB.evtypebits&0x02)==0x02**:
   T1 trigger but don't care whether other trigger types co-exist or not.

3. **DBB.evtypebits**$\gg$ 1**&1**:
   This cut is the same as (2).

4. **DBB.evtypebits &(1$\gg$1)**:
   Exactly the same as (2) and (3), but SCALE a histrogram by 2^N times. (We need to be careful when using this cut to plot a histrogram together with other histrogram which cuts on different trigger type.)

   Bob recommends NOT to use the following two trigger types:

5. **DBB.evtype==1**:
   Select events only triggered by T1,and no other trigger present within 5ms window when the TS registers an event.This is almost the same as (1) but there is a slight difference and the reason is unknown. (For our case, most of time, if we have T1, certainly we should have T6, unless Cerenkov trigger has inefficiency, so we should avoid to use this cuts).

6. **fEvtHdr.fEvtType==1**:
   Exactly the same as (5)

3 Trigger Efficiencies

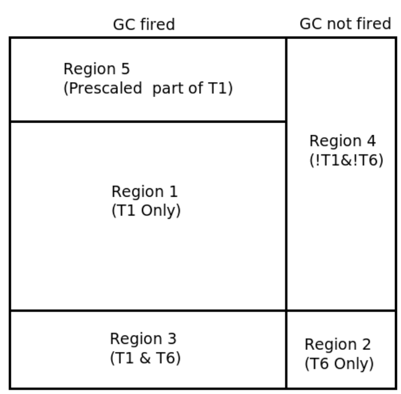

Figure 1: A scheme of events with different Trigger cuts

No all events are recorded by DAQ because detectors are not in 100% detection efficiencies and some events are skipped due to the prescaling. And applying PID cuts, some good events can also be removed due to the cut efficiencies. To calculate the cross section, we need to know the percentage of events we lose.

Fig 1 showes a big box of which area denotes the total events pass through S1, S2m and GC in HRS-R, including events firing or not firing GC, and here we asume all detectors have 100% detection efficiencies and trigger efficiency. The area of Region 1 gives the number of events (N_1) when applying cut on T1 only, which means that those events are recored when S1,S2m and GC are all fired and T1 trigger is prescaled. Region 2 gives the total number of event (N_2) when they trigger S1 and S2m but not GC, and T6 is prescaled. Region 3 indicates the case when T1 and T6 are co-existed in one event (N_3). Region 4 and Region 5 show that the number of events (N_4 and N_5) being prescaled out by prefactor PS6 and PS1, respectively. So there are simply relationship between number of events in those regions and prescale factor:

$$PS1 = \frac{N_1 + N_3 + N_5}{N_1 + N_3}, PS6 = \frac{N_1 + N_2 + N_3 + N_4 + N_5}{N_2 + N_3} = \frac{N_2 + N_4}{N_2}, \tag{1}$$

where N_1, N_2 and N_3 can be extraced from data by applying Trigger cuts:

Events	Cut
N_1	**DBB.evtypebits**$\gg$ 1&1**&&!(DBB.evtypebits**$\gg$ 6&1**)**
N_2	**DBB.evtypebits**$\gg$ 6&1**&&!(DBB.evtypebits**$\gg$ 1&1**)**
N_3	**DBB.evtypebits**$\gg$ 1&1**&&DBB.evtypebits**$\gg$ 6&1
$N_1 + N_3$	**DBB.evtypebits**$\gg$ 1&1
$N_2 + N_3$	**DBB.evtypebits**$\gg$ 6&1

Mathematically, if the prescale factors are known, we can calculate the total number of events in the box by the formula below:

$$N_0 = N_1 + N_2 + N_3 + N_4 + N_5 = PS6 \times (N_2 + N_3). \tag{2}$$

However, T6 is prescaled to keep the trigger rate as low as 50Hz, and the statistical fluctuation of $N_2 + N_3$ is very big, so instread, we should calculate N_4 and N_5, and combine with N_1 to get total number of events in that box:

$$N_0 = N_1 + N_2 + N_3 + N_4 + N_5 = PS1 \times (N_1 + N_3) + PS6 \times N_2. \tag{3}$$

The first term of the formula above is the portion of events that pass through GC and fire the detector, while the second term is the portion of events that pass through GC but do not fire the detector. Since N_0 includes events that don't fire GC, there is not a correction of GC detection efficiency on this value. To avoid double counting issue, we need to exactly follow the cuts in the table above to get the number of events for specific trigger type.

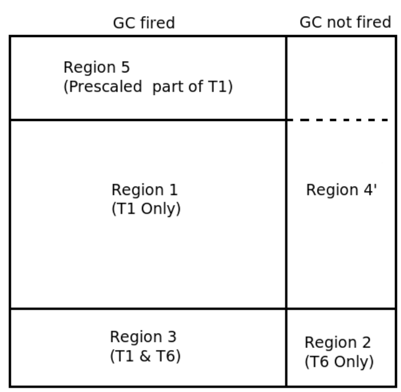

Figure 2: Another scheme of events with different Trigger cuts

If we look at the Fig 2, where we define a new region call Region 4' with number of events $N_{4'}$, we find a new relationship:

$$\frac{N_{4'}}{N_1} = \frac{N_2}{N_3}, \tag{4}$$

and,

$$N_2 + N4 = PS6 \times N_2 = PS1 \times (N_2 + N4') = PS1 \times (N_2 + N_1 N_2 / N_3). \tag{5}$$

So we find a relationship between PS1 and PS6:

$$PS6 = PS1(1 + N_1/N_3). \tag{6}$$

However, we should also avoid to use the result above since PS6 is a fix number, but N_1 and N_6 are measured quantities which introduce uncertainty.

N_0 is not the final total number of events that pass through the detectors package, since we assume all detectors have 100% efficiencies. We need to calculate the tracking efficiency of VDC, trigger efficiency of S1 and S2m,detection efficiency of GC and Calorimeters, and the PID cut efficiencies. Most of detectors' efficiencies have been study in other chapters, so here we just focus on the trigger efficiency.

As we disscuss at the previous section, there are two triggers T2 and T4, which is designed for trigger efficiency study. T2(T4) requires only one of S1 and S2m is fired and coincides with trigger signal from GC, so it picks up the portion of events that are missed by S1 or S2m, of cause, after prescaling. Hence the tranditional way of definingtrigger efficiency for HRS-R can be written as:

$$\epsilon_{trigger} = \frac{N_0}{N_0 + PS2 \times N_{T2}}, \tag{7}$$

where N_{T2} can be extracted by applying cuts **DBB.evtypebits=0x04**. Here we need to be very careful about calculating the trigger efficiency, since number of events from triggers that involve GC, should carry the effect of detection efficiency of GC. In the formula above, N_{T2} involves GC trigger so it should carry the detection efficiency of GC, while N_0 doesn't!.That means that the trigger efficiency we define above should tangle with GC detection efficiency, as:

$$\epsilon_{trigger} = \frac{N_0}{N_0 + PS2 \times N_{T2}/\epsilon^{GC}_{detection}}, \tag{8}$$

where the GC detection efficiency can be directly calculated thanks to the way we design our triggers:

$$\epsilon^{GC}_{detection} = \frac{N_3}{N_3 + N_4}. \tag{9}$$

The GC detection efficiency will be introduced again when we apply PID cut on GC to select elections. So the final total number of events that pass through the detectors is given by:

$$N_{total} = \frac{N_0}{\epsilon_{trigger} * \epsilon_{tracking} * \epsilon^{GC}_{detection} * \epsilon^{Calo}_{detection} * \epsilon^{GC}_{PID} * \epsilon^{Calo}_{PID}}. \tag{10}$$

The results above should hold when we study triggers and events at HRS-L.