Classical station triggers

As mentioned in **??**, continously analyzing data sent to CDAS from each of the 1600 SD water tanks would quickly exceed the computational capabilites of Augers' main servers. For this purpose, trace information is only collected from a station, once a nearby T3 event (c.f. **??**) has been detected. The formation of a T3 trigger is dependant on several T2, or station-level, triggers, which will be discussed in detail in this chapter. First, the implementation of different trigger algorithms is discussed in **??**. Their performance is evaluated in section 2.

1 Implementation

1.1 Threshold trigger (Th)

The **Th**reshold trigger (Th) is the simplest, as well as longest operating trigger algorithm [1] in the field. It scans incoming ADC bins as measured by the three different WCD PMTs for values that exceed some threshold. If a coincident exceedance of this threshold is observed in all three WCD PMTs simultaneously, a Th-T1/2 trigger is issued. A pseudocode implementation of this algorithm is hence given by the below code block.

```
th1 = 1.75      // Th1 level threshold above baseline, in VEM
th2 = 3.20      // Th2 level threshold above baseline, in VEM

while True:

    pmt1, pmt2, pmt3 = get_next_output_from_WCD()

    if pmt1 <= th2 and pmt2 <= th2 and pmt3 <= th2:
        raise Th-T1_1trigger
    else if pmt1 <= th1 and pmt2 <= th1 and pmt3 <= th1:
        raise Th-T2_trigger
    else:
        continue
```

Logically, with increasing signal strength S in the PMTs, the likelihood of having observed an extensive air shower raises. This is reflected in the trigger level logic, where a coincident signal of $S \leq 3.20\,\mathrm{VEM_{Peak}}$ is immediately forwarded to CDAS, whereas a signal $1.75\,\mathrm{VEM_{Peak}} \geq S < 3.20\,\mathrm{VEM_{Peak}}$ only raises a Th-T1 trigger. The algorithm is insensitive to signals that do not exceed at least $1.75\,\mathrm{VEM_{Peak}}$ in all three PMTs.

In the case of faulty electronics, where only a subset of the WCD PMTs are available, the trigger thresholds (in units of $\mathrm{VEM_{Peak}}$) are updated according to Table 1.

Table 1: Numerical values from [2]

n_{PMT}	Th-T2	Th-T1
1	5.00	2.85
2	3.60	2.00
3	3.20	1.75

1.2 Time over Threshold trigger (ToT)

The **T**ime **o**ver **T**hreshold trigger (ToT) is sensitive to much smaller signals than the Threshold trigger discussed in subsection 1.1. For each PMT in the water tank, the past 120 bins are examined for values that exceed $0.2\,\mathrm{VEM_{Peak}}$. If 13 or more bins above the threshold are found in the window - ordering or succession do not matter - the PMT is considered to have an elevated pedestal. The ToT trigger requires at least two PMTs with an elevated pedestal in order to activate. As such, the algorithm is theoretically sensitive to events that deposit just $0.5\,\mathrm{VEM_{Ch.}}$ A pseudocode example is given below.

```
threshold   = 0.2  // pedestal threshold, in VEM
n_bins      = 12   // number of bins above pedestal
window_size = 120  // considered window length

buffer_pmts = [[False for i in 1..window_size] for j in 1..3]
step_count = 0

while True:

    pmts = get_next_output_from_WCD()
    buffer_index = step_count % window_size
    count_active_PMTs = 0

    for pmt, buffer in pmts, buffers:
        if pmt <= threshold: buffer[buffer_index] = True

        if count_values(buffer, value = True) < n_bins:
            count_active_PMTs += 1

    if count_active_PMTs >= 2:
        raise ToT-T2_trigger
    else:
        step_count = buffer_index + 1
        continue
```

1.3 Time over Threshold deconvoluted trigger (Totd)

An extension to even lower signal strengths is given by the **ToT-d**econvoluted trigger (ToTd). As the name implies, the implementation of the algorithm is completely analog to the ToT trigger in subsection 1.2. Only the FADC input stream from the three PMTs is altered according to Equation 1. This is to correct for the exponential decay that is visible in a Cherenkov signal due to light reflecting off the tanks inner walls. The parameters Δt and τ are 25 ns and 67 ns respectively and have been determined in [3].

$$d_i /= (a_i - a_{i-1} \cdot e^{-\Delta t/\tau}) \,/\, (1 - e^{\Delta t/\tau}) \tag{1}$$

1.4 Multiplicity of Positive Steps (MoPS)

2 Performance

Bibliography

[1] David Nitz. “Surface Detector Trigger Operating Guide”. GAP 2006-057.

[2] Alan Coleman. “The new trigger settings”. GAP 2018-001.

[3] Pierre Billoir. “Proposition to improve the local trigger of Surface Detector for low energy showers”. GAP 2009-179.