Hardware Trigger Throttle Issues

• Context: the triggers
• Purpose of throttle on TKR trigger
• Earlier design using TKR geographic information
• The problem, and the alternative
• Some results from the simulation
• Comments, suggestions
**Instrument Triggering and Onboard Data Flow**

**Level 1 Trigger**

Hardware trigger based on special signals from each tower; initiates readout

Function:
- “did anything happen?”
- keep as simple as possible

- TKR 3 x·y pair planes in a row**
- workhorse γ trigger
- CAL:
  - LO – independent check on TKR trigger.
  - HI – indicates high energy event ➞ disengage use of ACD.

Upon a L1T, all towers are read out within 20µs

**Instrument Total L1T Rate: <4 kHz>**

**4 kHz orbit averaged without throttle (1.8 kHz with throttle); peak L1T rate is approximately 13 kHz without throttle and 6 kHz with throttle.**

**On-board Processing**

full instrument information available to processors.

Function: reduce data to fit within downlink

Hierarchical process: first make the simple selections that require little CPU and data unpacking.

- subset of full background rejection analysis, with loose cuts
- only use quantities that
  - are simple and robust
  - do not require application of sensor calibration constants
- complete event information
- signal/bkgd tunable, depending on analysis cuts:
  - γ:cosmic-rays ~ 1:~few

**Total L3T Rate: <25-30 Hz>**

(average event size: ~8-10 kbits)

**On-board science analysis:**

transient detection (AGN flares, bursts)
**Trigger (formerly L1T)**

*Did anything happen? Keep as simple as possible to allow straightforward diagnostics.*

- Hardware trigger, derived from special signals from the subsystems, initiates readout.

- Information forming the trigger is at the local tower level. Each tower can generate a L1T request, but the trigger is **global**. Upon trigger, all towers are dead during readout.

- Two separate conditions initiate a L1T request from a given tower:
  1. **TKR** 3-in-a-row (really 6-in-a-row, 3x and 3y) the “workhorse” gamma-ray trigger, similar to “triplet” used in EGRET tracking analysis, SAGE. This 6-fold coincidence sets the noise occupancy requirement for the tracker. (For another meeting: should there be OR’d additional triggers, such as 5/6 or 7/8?)
  2. **CAL** (each log end is separate electronics chain) see LAT-TD-00245-01
     - (a) **CAL-LO** any log with >100 MeV (adjustable). primary purpose is to form a trigger that is completely independent of the TKR trigger, enabling important efficiency cross-checks.
     - (b) **CAL-HI** 3 adjacent layers with >0 xtals with > 1 GeV (adjustable): >90% efficient for >20 GeV gammas that deposit >10 GeV in CAL. primary purpose is to disable use of ACD onboard (avoid backsplash self-veto).
Need an option to throttle TKR trigger. Earlier design using two bits of geographic info:

- if trigger is in first silicon layer AND a hit in matching ACD tile, AND no CAL-HI, veto the event
- in any of the 12 outer towers with a 3-in-a-row, if geographic match with hit ACD tile, AND no CAL-HI, veto the event:

  (some details here as to what constitutes a match)

  - also, count number of tiles hit NOT in the back-most two rows.

  - These are designed to work in hardware or the earliest stages of software filtering for flexibility.

  - Note: removing events with zero cal energy is another potential option suggested for additional safety margin. Some issues would need to be worked out (timing, loss of independence of cal-lo trigger, harm to low-E gammas,...)
## Orbit Max Trigger Rates

<table>
<thead>
<tr>
<th></th>
<th>all</th>
<th>chimemax</th>
<th>albedo_p_ max</th>
<th>albedo gamma</th>
<th>CR e- max</th>
<th>albedo e+e-</th>
</tr>
</thead>
<tbody>
<tr>
<td>flux (kHz/m²)</td>
<td>9.9</td>
<td>4.2</td>
<td>2.6</td>
<td>0.92</td>
<td>0.043</td>
<td>2.2</td>
</tr>
<tr>
<td>L1T (Hz)</td>
<td>13,134</td>
<td>7,419</td>
<td>3,501</td>
<td>242</td>
<td>79</td>
<td>1,893</td>
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<tr>
<td>L1T frac</td>
<td>1</td>
<td>0.56</td>
<td>0.27</td>
<td>0.02</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>L1V Throttle (Hz)</td>
<td>5,510</td>
<td>2811</td>
<td>1,679</td>
<td>190</td>
<td>37</td>
<td>793</td>
</tr>
<tr>
<td>L1V Throttle frac</td>
<td>1</td>
<td>0.51</td>
<td>0.30</td>
<td>0.03</td>
<td>0.01</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Notes:**
- with the ACD throttle on the TKR trigger, the total max rate is <6 kHz.
- the effect of the Throttle on final gamma sample was very small in all bins of energy and angle (1% level).
- we see the orbit max rate only for short periods of time
What background sneaks through throttle?
What gamma events don’t pass throttle?

because of this tile

conversion in tile

not this one
Throttle does not affect CAL-Hi rate (by design)
Throttle has little effect on Cal-Lo only rate (by design)
With throttle engaged, Cal-Lo gives a large fractional incremental rate. We will look at adjusting the threshold, and re-evaluate the use of Cal-Lo.
Cal-Hi incremental L1T rate is tiny, but large for downlink. Allow onboard filters to have a simple look at Cal-Hi triggers to reduce (use measured energy deposition instead of Cal-Hi bit at software filter level – a finer knife). No special filters appear to be needed.
So what’s the problem?

- Getting the geographic information out of the towers to the global trigger isn’t as easy as initially thought: either need more wires or implement signaling on the existing wire (risky?).

⇒ must justify the increase in complexity.

The only alternative we can see right now is to define fixed tiles “covering” each tower. The veto is then very simple: one ACD primitive per tower. [Any other suggestions?] It’s not pretty: if a TKR trigger occurs at the back of the stack, but an ACD tile at the top of that tower fires, the event would be vetoed.
A first investigation

- all\_gamma and backgndmax runs with pdrApp v7r2
- in userAlg, map tiles to towers. Each tower has 4 front (top) tiles and 2 tiles per row per side on the side. Thus, for example, corner towers have 12 cover tiles using only the front and the first two side rows (4+2*2*2).
- set bits in a special word for throttle (to select which side rows are used/not used).
Comparisons

For apples-to-apples comparison, use versions of the two throttles that look at the ACD front and front-most two side rows:

TCut L1Vb="((ACD_Throttle_Bits&49)==0&&(ACD_TileCount-ACD_No.SideRow2-ACD_No.SideRow3)<3.)||(Trig_Bits&16)";
TCut L1Vb_nogeo="((user_nogeovetoword&49)==0&&(ACD_TileCount-ACD_No.SideRow2-ACD_No.SideRow3)<3.)||(Trig_Bits&16)";

where the bits in the throttle words are set as follows (note that 49 = 31 hex):

```
  0  0  1  1  0  0  0  1
  side row s3  side row s2  side row s1  side row s0  front (top)
```

Require just an L1T: 24,385 of 110k generated all_gamma events. Then,
# killed by L1Vb and but accepted by L1Vb_nogeo: 0 (check!)
# killed by L1Vb_nogeo but accepted by L1Vb: 800
Wrong to conclude simply a “4% loss” - what are these events?

** notes:  (1) 4% is relative to geographic throttle.
(2) this will be even worse if unmask another higher bit!
Primarily off-axis photons (where most of our photons will be!) for comparison, angular distribution of all L1Ts from all_gamma sample.
Bin and divide the two histograms:

Of course, triggered area is not the whole story. How good are these gammas?
Fractional Visible Energy of Rejects

[“visible” means raw CAL energy]

distribution for rejected gammas

Nent = 800
Mean = 0.2634

distribution for all triggered gammas

Nent = 24382
Mean = 0.4367
Off-axis triggered gammas:

distribution for all triggered gammas with $\cos(\theta) > -0.5$

$\Rightarrow$ the lost events have smaller visible energy fraction than other off-axis gammas (no surprise here)
After all onboard selections

After applying the current set of onboard filters, the fraction of incrementally killed events drops from 4% to ~1.5%, BUT

• the current filter set is still evolving - implementing more flight-like algorithms and improving gamma efficiency. This isn’t (yet) a reliable benchmark.

• even with strawman filters, still losing area preferentially off-axis
Next steps

- Look at inefficiencies in niche areas of parameter space (e.g., might have particularly bad energy ranges)! Suggestions welcome.

- Study background rates and efficiency losses using only row S0 and using S0, S1, and S2. The geographic info throttle is safer to use with S2 information. We want this flexibility.

- With electronics subsystem, make a recommendation to the IDT.