GLAST Large Area Telescope

Onboard Filter Status
LAT Collaboration Meeting
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work done by
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Outline

• Onboard filter design
• Embedding the filter
• Results and next steps
• Summary
**GLAST LAT Project**

**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
  - OR

- 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 average without throttle (1.3 kHz with throttle); peak L1T rate is approximately 12 kHz without throttle and 3.8 kHz with throttle.**

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**On-board Processing**

full instrument information available to processors.

Function: reduce data to fit within downlink

Hierarchical filter 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)

* assumes no compression

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**Spacecraft**
On-board Filter Design

- done first in “offline” SAS environment
- select quantities that are simple to calculate. Intelligent use of ACD information to preserve acceptance of high-energy events. Filter scheme is tunable.
- Filters use
  - ACD info: match simple tracks to selected hit ACD tiles, count # hit selected tiles at low energy
  - CAL info: energy deposition pattern consistent with downward-going electromagnetic interactions.
  - TKR info: remove low-energy particles up the ACD-TKR gap by projecting track to CAL face and selecting on XY position; for very low CAL energy, require TKR hit pattern inconsistent with single prong.
After all selections, average background rate: 17 Hz.

composition:

Additional margin available: much of the residual rate is due to high-energy proton and electron events with CAL E>5GeV -- if apply ACD selections onboard to higher energy, rate can be cut in half (to 8 Hz), with ~5% reduction in Aeff at 10 GeV.
Onboard Filter Development

- Filter designs done with the full simulation and ground-based reconstruction, in consultation with FSW group. Demonstration of principles, included in science performance evaluations.
- FSW implemented most of the filter design for benchmarking on the flight processor (JJ Russell).
  - Filtering is hierarchical. Most important to implement the selections that are run first (highest rate, largest multiplier on CPU demand). More cycles/event available for remaining event sample after each step.
- **NEW:** FSW implementation is now wrapped and included in the simulation/recon packages (N. Golpayegani, D. Wren, JJ Russell).
  - Very early functional testing of the flight algorithms, with high fidelity. Examine details (e.g., existing track finding) using full set of SAS tools, event display, etc.
  - Detailed evaluation of the filter effects on the science performance. Have a look!
  - Opportunity for a tuning iteration and optimization of the final set of selections
- Filter is documented (order of processing, logic, definitions of bits in analysis tuple, etc.) by D. Wren, based on JJ’s code.
### Summary of FSW Implementation Relative to Design

<table>
<thead>
<tr>
<th>Primary Info</th>
<th>Design Selection</th>
<th>FSW Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD</td>
<td>Tile counts (energy dependent)</td>
<td>DONE</td>
</tr>
<tr>
<td>ACD-TKR</td>
<td>Track match with tile</td>
<td>DONE</td>
</tr>
<tr>
<td>CAL</td>
<td>Simple energy selections</td>
<td>DONE</td>
</tr>
<tr>
<td>CAL</td>
<td>Layer ratios</td>
<td>DONE</td>
</tr>
<tr>
<td>CAL</td>
<td>Simple topologies</td>
<td>DONE</td>
</tr>
<tr>
<td>TKR-CAL</td>
<td>Track match with energy centroid</td>
<td></td>
</tr>
<tr>
<td>TKR</td>
<td>Skirt only cut</td>
<td>DONE</td>
</tr>
<tr>
<td>TKR</td>
<td>Simple hit pattern inconsistent with single prong at low energy</td>
<td>DONE</td>
</tr>
<tr>
<td>TKR-CAL</td>
<td>Minimal #tracks and CAL E, or make additional demands</td>
<td>DONE</td>
</tr>
<tr>
<td>TKR</td>
<td>Earth direction</td>
<td></td>
</tr>
<tr>
<td>TKR</td>
<td>TKR hits consistent with a track near CAL if E&gt;0</td>
<td>DONE</td>
</tr>
</tbody>
</table>

**IMPORTANT:** We might not need to implement all the later-stage selections! First evaluate effects at this stage.
The 16 reasons for vetoing an event are contained in bits 15-30 of a 32-bit status word:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Reason for veto</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Low energy, no 2 track evidence</td>
</tr>
<tr>
<td>16</td>
<td>Event into the skirt region</td>
</tr>
<tr>
<td>17</td>
<td>No tracks</td>
</tr>
<tr>
<td>18</td>
<td>Track Row 2 match</td>
</tr>
<tr>
<td>19</td>
<td>Track Row 0 or 1 match</td>
</tr>
<tr>
<td>20</td>
<td>Track Top match</td>
</tr>
<tr>
<td>21</td>
<td>No tracks into CAL with energy</td>
</tr>
<tr>
<td>22</td>
<td>E layer 0/ETOT &gt; 0.90</td>
</tr>
<tr>
<td>23</td>
<td>E layer 0/ETOT &lt; 0.01</td>
</tr>
<tr>
<td>24</td>
<td>Event has a side face veto</td>
</tr>
<tr>
<td>25</td>
<td>Event has a top face veto</td>
</tr>
<tr>
<td>26</td>
<td>Event has a splash veto</td>
</tr>
<tr>
<td>27</td>
<td>Event &lt;350Mev + Filter tiles</td>
</tr>
<tr>
<td>28</td>
<td>Event 0 energy + tile hit</td>
</tr>
<tr>
<td>29</td>
<td>Event has a splash veto</td>
</tr>
<tr>
<td>30</td>
<td>No CAL LO trigger + filter tile</td>
</tr>
</tbody>
</table>

• **Remember: filter is hierarchical!**
  - end result is important, but so is intermediate processing result
  - can run in 2 modes: quit when the first reason to veto is found, or calculate all bits (for offline studies and for pass-throughs onboard)
The Filter Logic

Start

Y
CAL LO trigger?

N
ACD hits in TOP or upper 2 rows?

VETO 30

Y
CAL HI trigger?

N
> 3 ACD bits set?

Y
VETO 29

N
AFC_splash() see a veto?

N
Any hits in ACD?

Y
Energy < 10 MeV ?

Y
Energy < 40 GeV

N
Energy < 350 MeV

N
Hits in top or upper ACD?

Y
AFC_splash() see veto?

N
ACD bit count > 3 ?

Y
VETO 26

N
Next Page
Any tracks in towers?

Any ACD projection tile matches?

Energy == 0?

Track through skirt?

Any tracks at all?

E<350 MeV and no evidence of 2+ tracks?

Event not rejected. Repeat process for next event.

VETO 17

VETO 18, 19 or 20

VETO 16

VETO 15

CANCEL VETO 16!
Summary of Performance (require L1T and pass filter)

VERY PRELIMINARY!

First look at rejection rate:
96%-97%
[using old simulation, JJ saw ~98% rejection. studying differences]

Aeff (cm²) versus θ (deg)

- 1 GeV, 10 GeV
- 100 MeV
- 20 MeV
Improvements/Next Steps

• The Aeff performance is not bad. Some room for improvement, particularly at ~100 MeV, and there is an odd inefficiency in the track counting (probably an implementation issue?). Now easy to study where we are losing events using all the SAS tools.

• Useful for data challenge.

• Iterate and add final reduction steps
  – can run cutting fewer events with data compression
  – implement and test remaining filters

• Tracks found by filter are now also being made available in the SAS environment, including in the event display.
  – first step for prototyping onboard science algorithms. Some improvements will likely be necessary, but this is the place to start!
  – important for albedo gamma rejection design
  – useful diagnostic to understand all aspects of track use in filter.
Filter Tracks in Event Display

- incoming gamma
- green lines are filter tracks
- black lines are MC truth charged particle trajectories
- red lines are strip hits
Filter Tracks in the Event Display

(conversion in the ACD...)

Filter Tracks in Event Display
Filter Tracks in the Event Display

The event display is not without problems....
Filter Tracks in the Event Display

Incoming proton

Check track-tile association
Filter Tracks in the Event Display

More complicated event…

…can turn filter track extensions (both up to ACD and down to CAL face) on and off in display.
Another tile veto background event.
Summary

• The FSW filter is now wrapped and “stuffed” into the SAS environment. Status bits available in analysis tuple. Many benefits:
  – detailed studies of what the filter is doing to your favorite physics enabled.
  – high-fidelity detailed checks of filter functionality and performance much easier.
  – iteration
  – include in data challenge (more tomorrow)

• Onboard tracks added to event display, and info also added to the transient data store (available to anyone’s analysis).
  – checking for bugs now. after code review, will release.
  – a starting point for onboard science algorithm prototyping