GLAST Large Area Telescope

Trigger and Event Filtering (Brief) Introduction

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Outline

- Review: what the trigger and onboard event filters must do
  - Hardware triggers and throttles
  - Trigger simulations: backgrounds; hardware trigger rates; margins
  - Onboard filters: concepts
- Development approach & status
- What remains to be done; areas needing help

Contributions of many good ideas over the years by many people on the team!

Hardware Triggers

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, but the decision is made **globally**. 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-fold coincidence, 3x and 3y)** the "workhorse" gamma-ray trigger.

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 now is to form a trigger that is completely independent of the TKR trigger, enabling important efficiency cross-checks.

(b) CAL-HI >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) at early stages of event processing (before CAL data are touched).

Importance of Optional Throttles

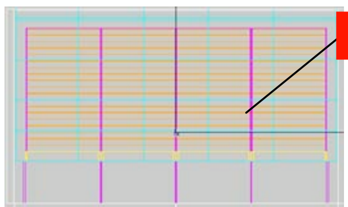
- **While there is no harm to the instrument to run at high rate (no consumables, etc.), there is deadtime (20 μs per event, simplistically). Target maximum trigger rate: 10 kHz. Lower is better.**
- **The rate varies over the orbit. Periods of maximum trigger rate are relatively short.**
- **The rates are uncertain, and have been the subject of much discussion. Some flexibility for the trigger configuration is essential: need options to reduce the rate on orbit, based on what we find after launch.**
- **If the CAL-Lo trigger runs hot, there is a simple knob to turn: the threshold.**
- **There is no analog for the TKR trigger: adding more planes in coincidence is not effective. Conceptually, there are two options:**
  - **use the ACD information (see next slides)**
  - **use the CAL information (in principle possible. Hurts low-energy effective area, but worth keeping in our back pocket, if not a design driver. Would it really work in practice – timing complexity? <u>Make progress on this at this meeting</u>.)**

ACD Throttle at PDR

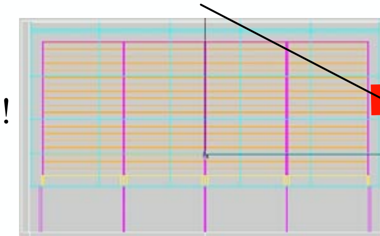
Used two bits of geographic info from TKR trigger:

- 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:

veto these…



…. but not these!



…and, ignore back-most row(s) of ACD tiles for these preselections to preserve gammas whose products scatter out the side.

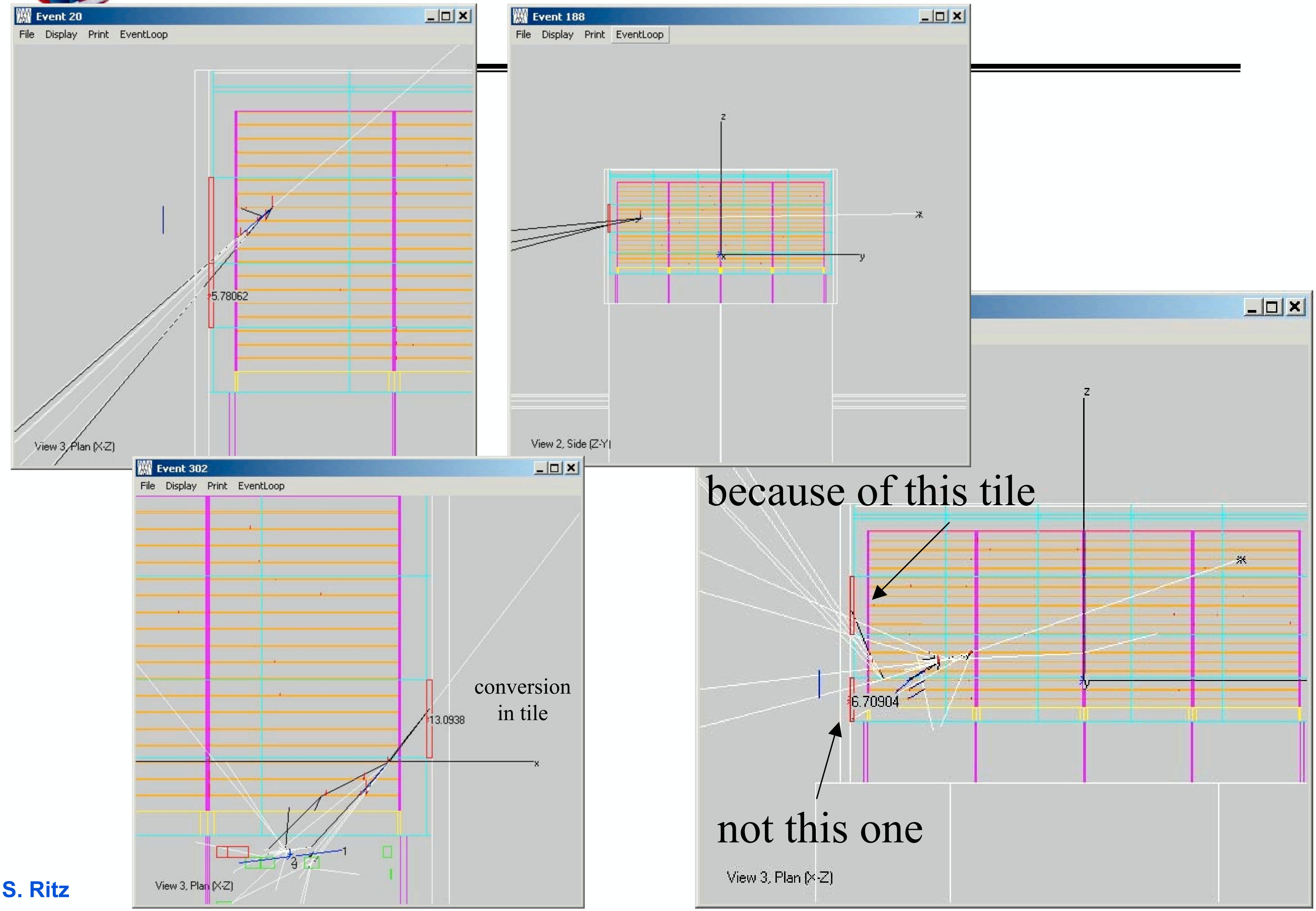
(some details here as to what constitutes a match)

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

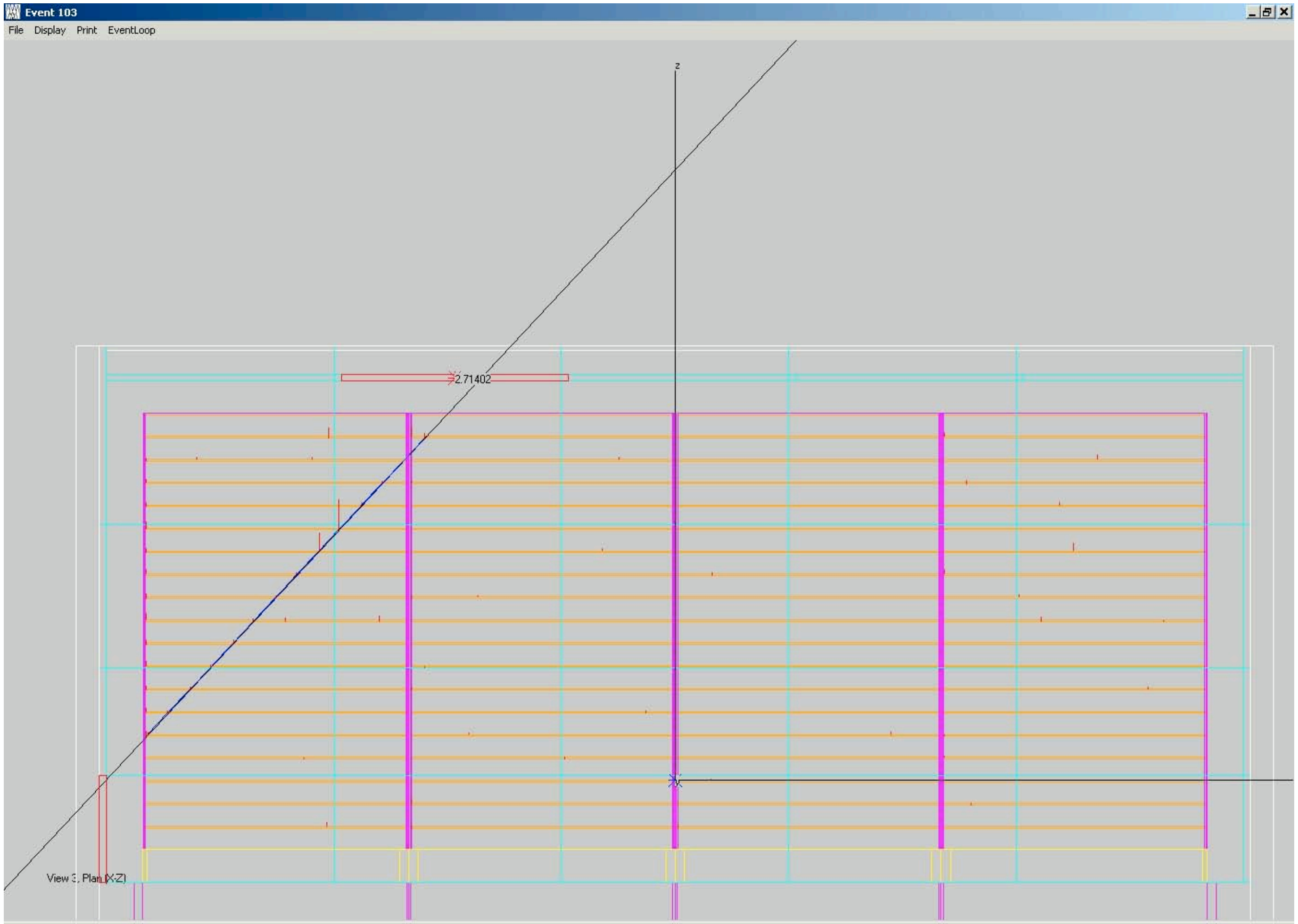
- **These were designed to work in hardware or the earliest stages of software filtering for flexibility.**

- The effect of the Throttle on final gamma sample (using the old tools and recon) was small in all bins of energy and angle (1% level).

What gamma events don't pass throttle?



What background sneaks through throttle?



Modification to ACD Throttle

- Getting the geographic information out of the towers to the global trigger wasn't as easy as initially thought: either need more wires or implement signaling on the existing wire: judged risky.

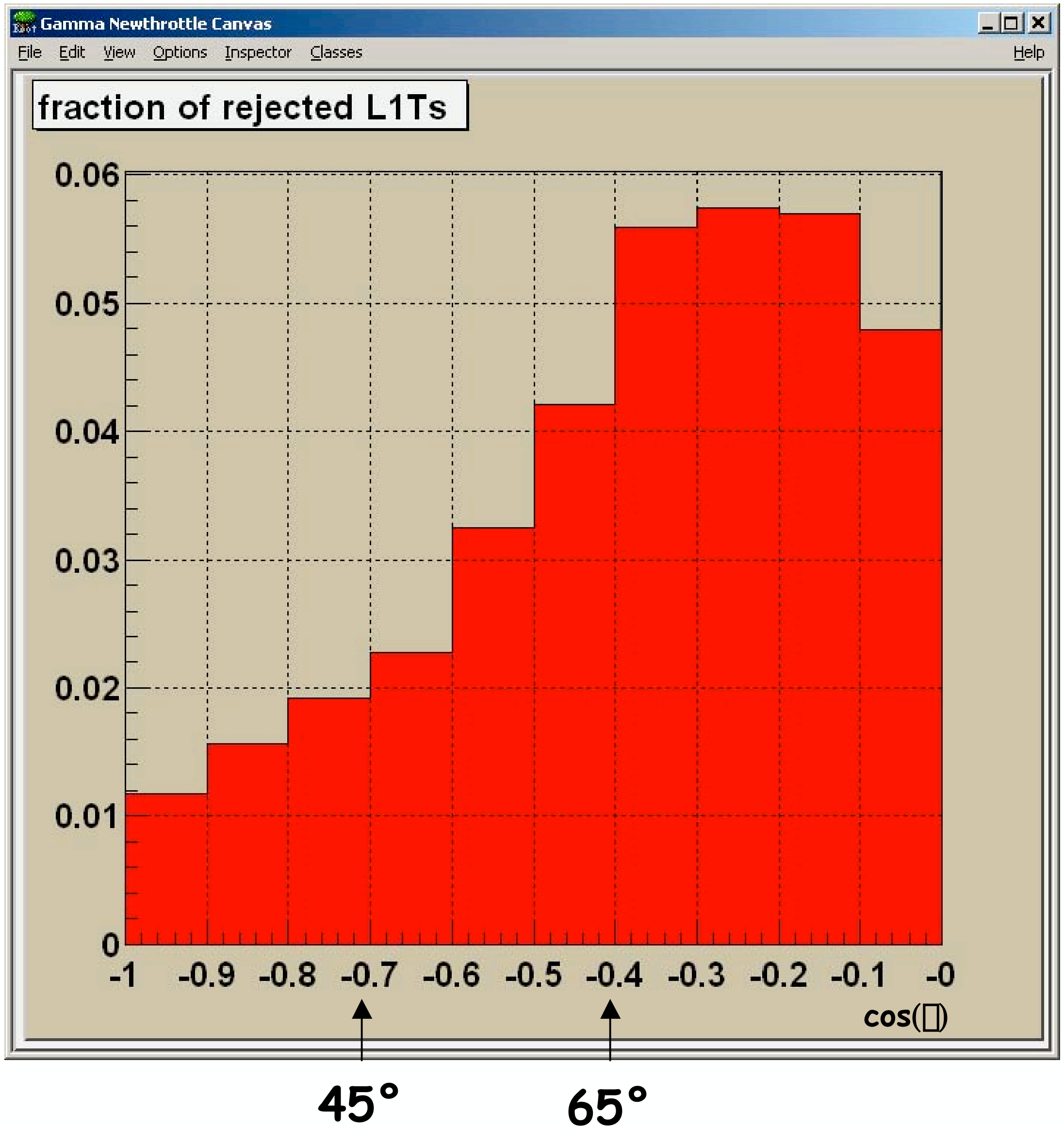
 study the impact of using a non-geographic veto.

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. Note: corner towers have 12 associated tiles.

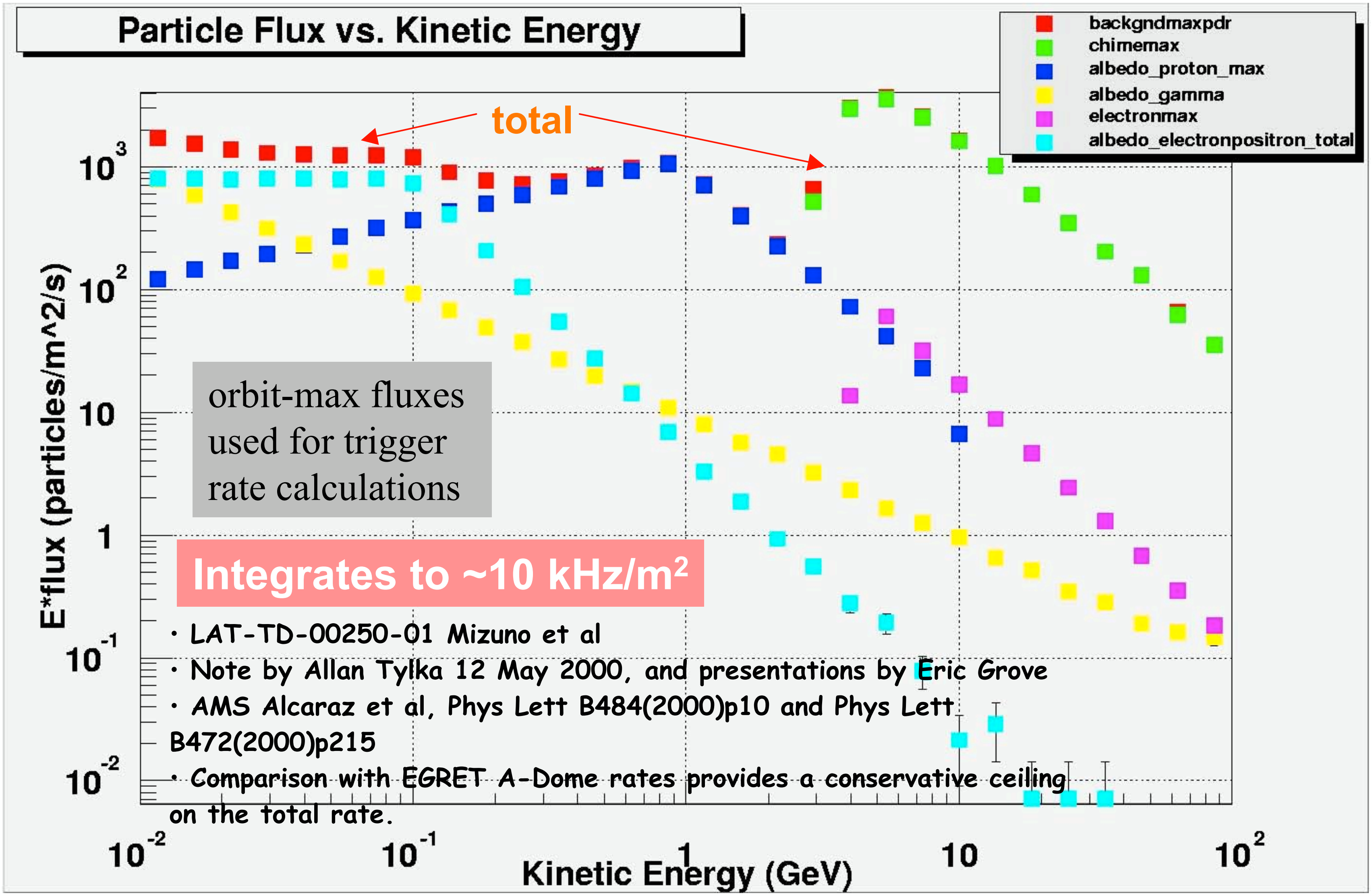
Look at distributions of events that failed the non-geographic veto but passed the geographic veto (details, see June 2002 IDT meeting).

Fractional incremental loss of triggered area

- Losses are not terribly large, and occur mainly far off axis, as expected.
- After further selections, the fractional losses are smaller (these are not particularly good gammas).
- See June 2002 IDT meeting for details.
- Note also that the "splash veto" (counting # hit tiles) is also not very effective, and will likely not be used as a throttle.

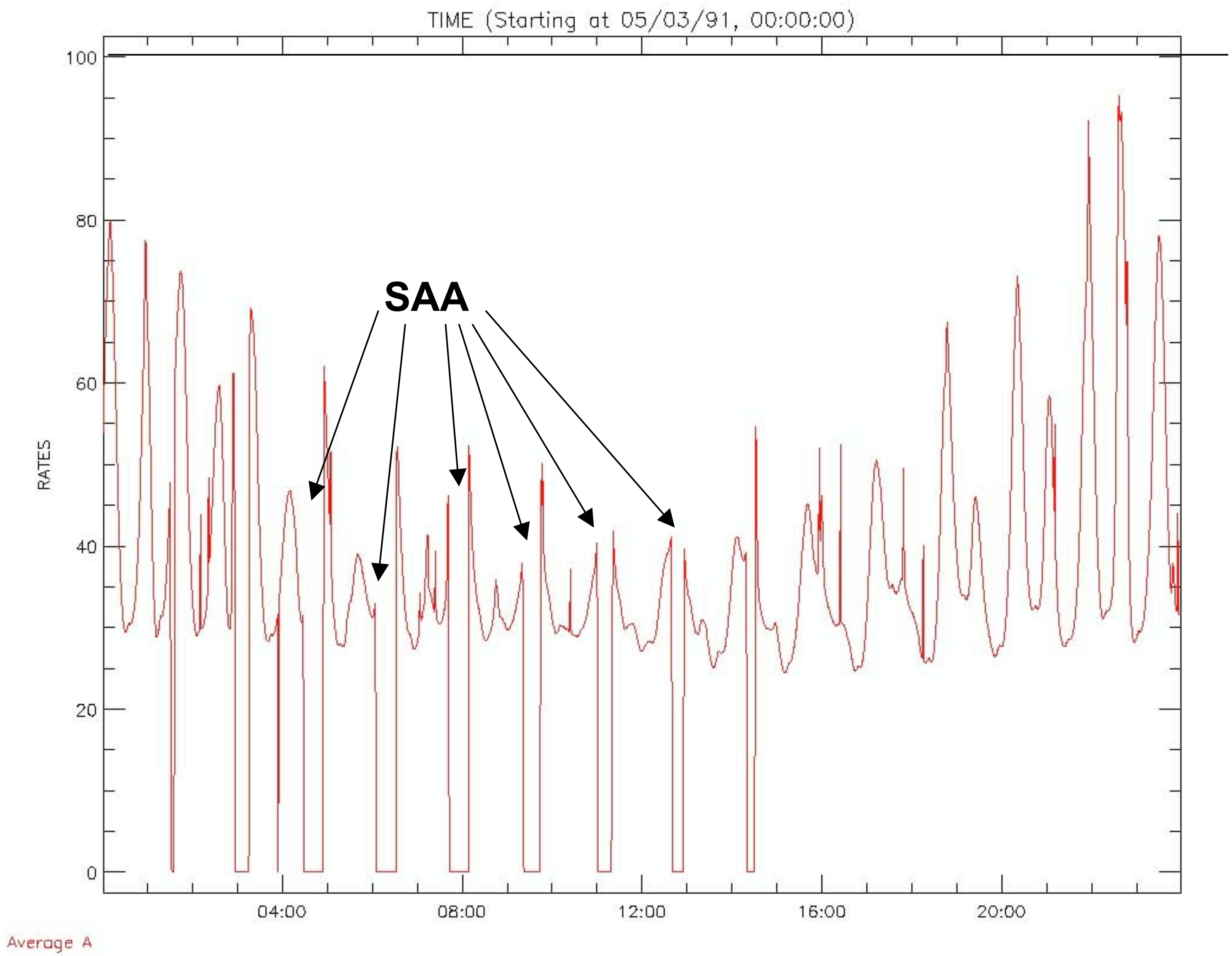


Implemented Orbit-max Background Fluxes



- LAT-TD-00250-01 Mizuno et al
- Note by Allan Tylka 12 May 2000, and presentations by Eric Grove
- AMS Alcaraz et al, Phys Lett B484(2000)p10 and Phys Lett B472(2000)p215
- Comparison with EGRET A-Dome rates provides a conservative ceiling on the total rate.

EGRET A-dome Rates (from D. Bertsch, EGRET team)

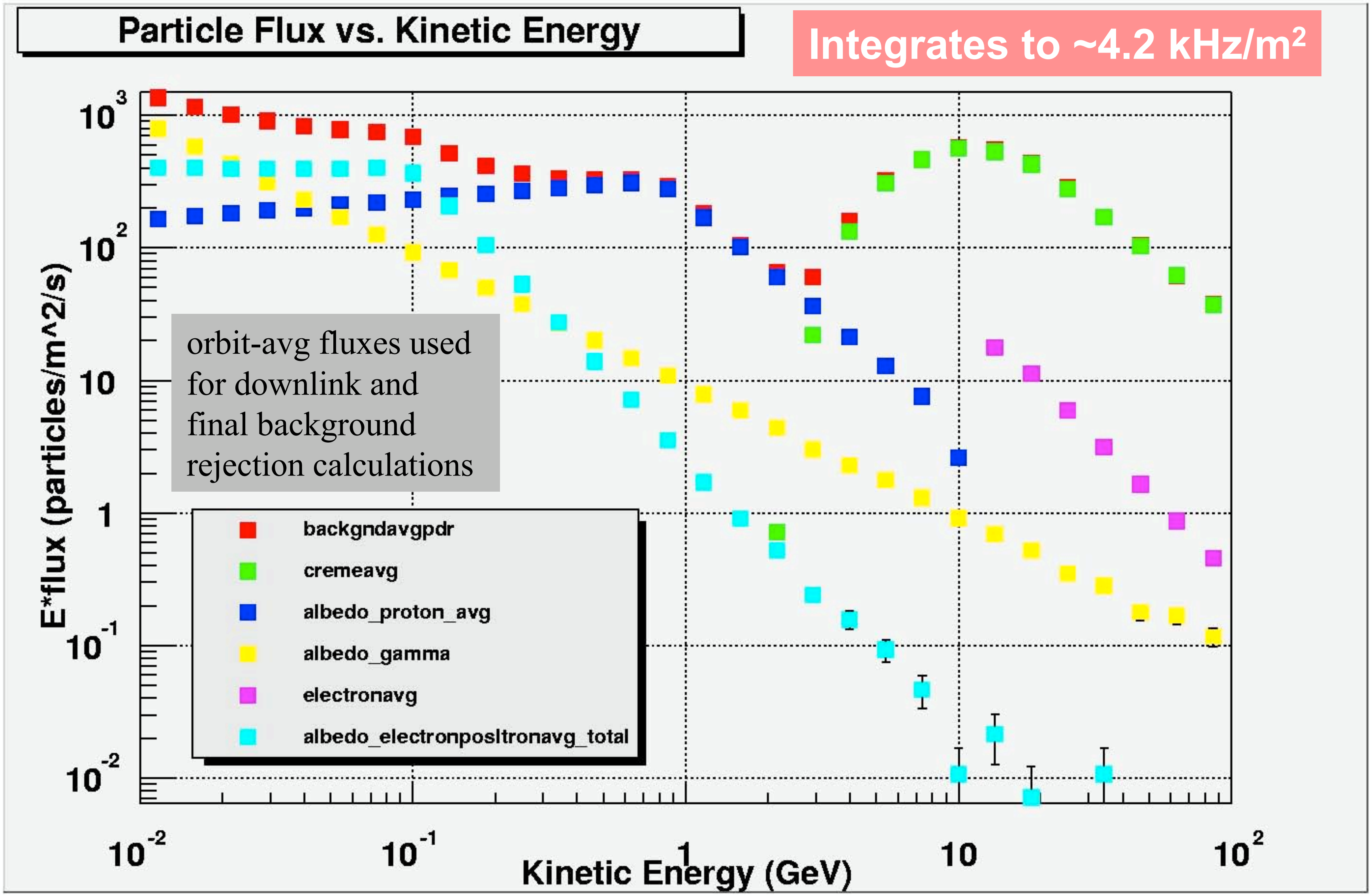


A-dome has an area of ~6 m^2, so orbit max rate (outside SAA and no solar flares) corresponds to **~16 kHz/m^2**

This represents a conservative upper-limit for us, since the A-dome was sensitive down to 10's of keV.

Note peak

Implemented Orbit-average Fluxes

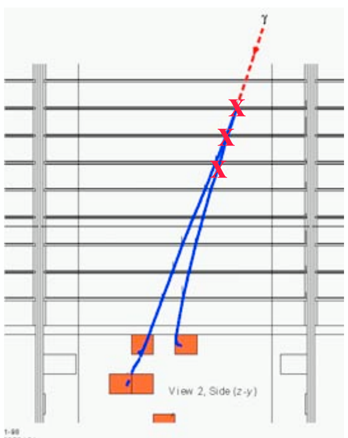


Instrument Triggering and Onboard Data Flow

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 20 μs

Instrument Total L1T Rate: <4 kHz>**

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

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>

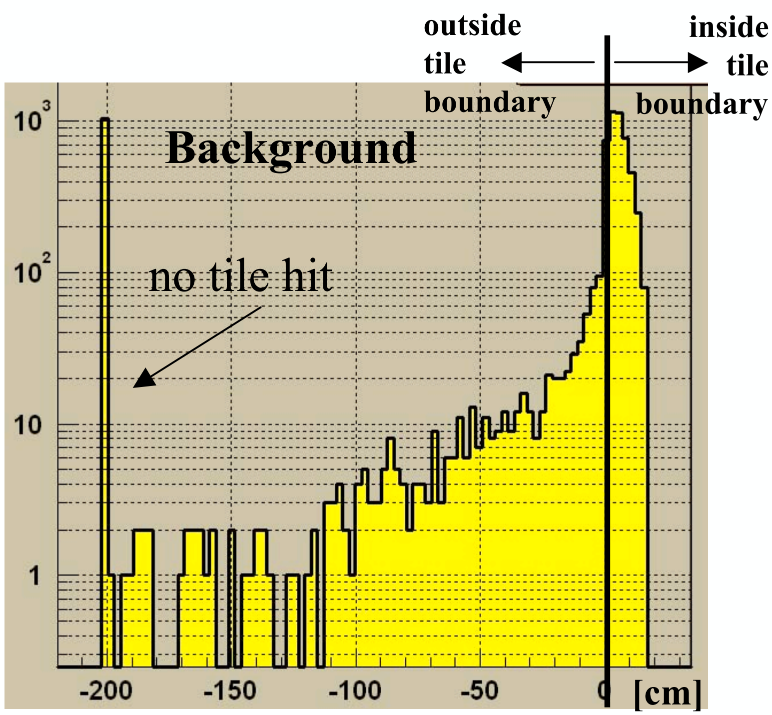
(average event size: ~8-10 kbits)

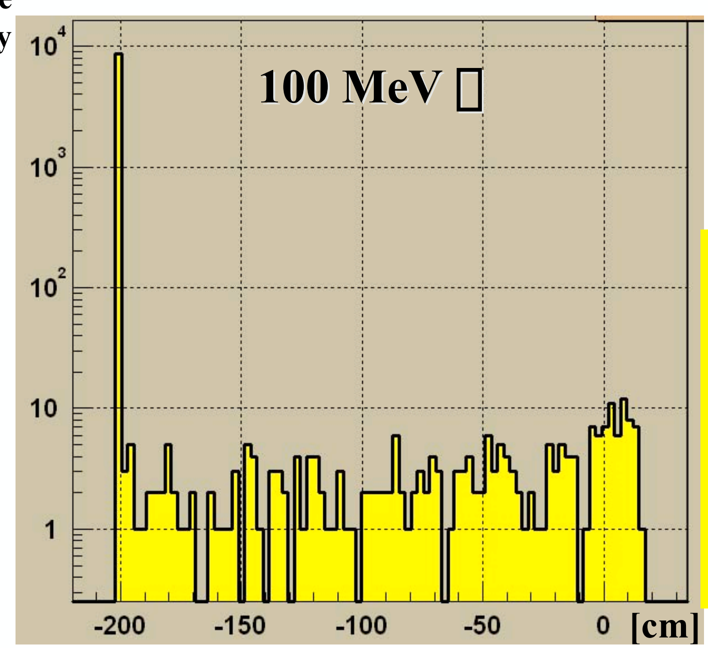
On-board science analysis:
transient detection (AGN flares, bursts)

Spacecraft

On-board Filters Summary

- select quantities that are simple to calculate and that do not require individual sensor calibration constants. Filter scheme is flexible – current set suggestive for for flight development. See JJ's talk.
- order of selections to be optimized. Grouped by category for presentation purposes. Usual optimization procedure (gammas, background effects iteration).
  - ACD info: match track to hit tile, count # hit tiles at low energy





Rate after ACD selections is ~180 Hz orbit-avg (~360 Hz orbit-max)

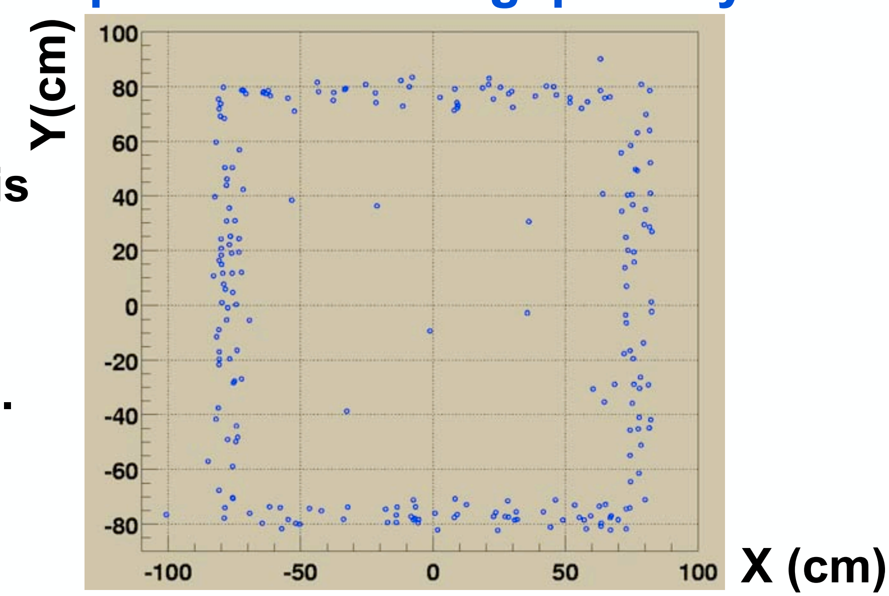
On-board Filters Summary (II)

– CAL info: most of the residual rate at this point is due to albedo events and other upward-going energy events. **Require track-CAL energy centroid loose match, fractional energy deposit in front layer reasonably consistent with downward EM energy flow. If no CAL energy, require track pattern inconsistent with single-prong.**

Rate after CAL selections is ~80 Hz orbit-avg (130 Hz orbit-max)

– TKR info: low-energy particles up the ACD-TKR gap easily dealt with:

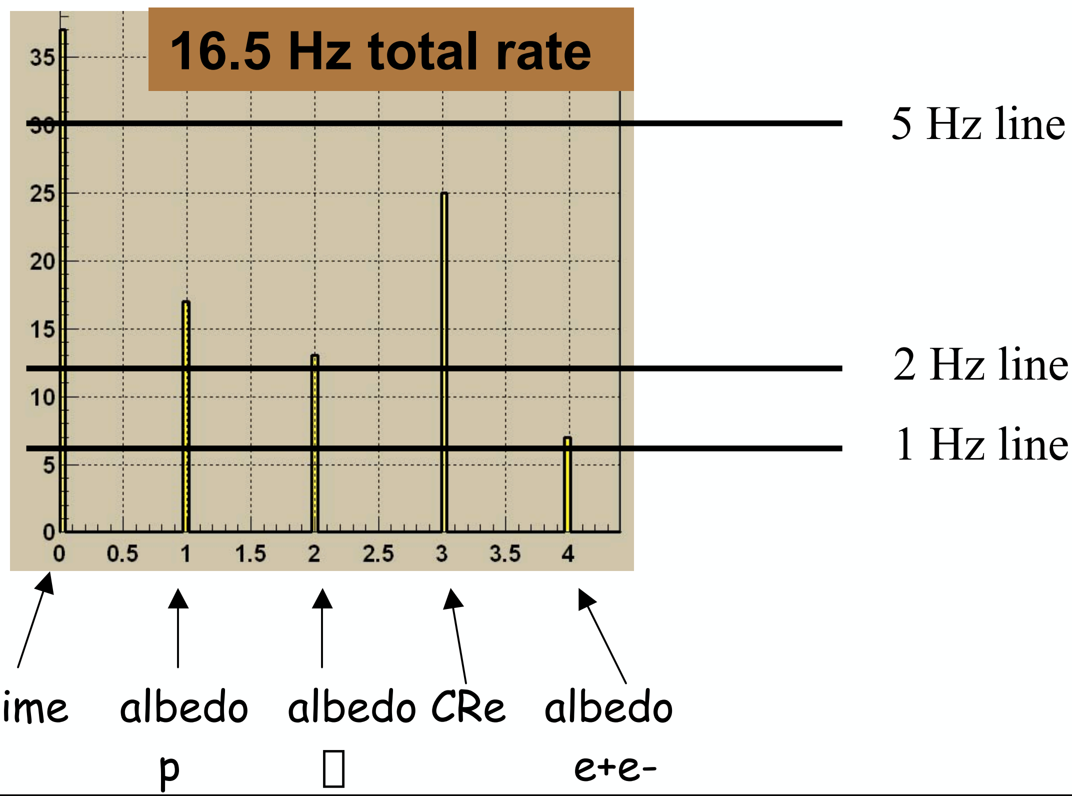
project track to CAL face and require XY position outside this band; for low CAL energy, require TKR hit pattern inconsistent with single prong.



On-board Filter Concept Results

- **After all selections, orbit-average background rate is 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.

Development Approach

- **Basic approach:**

(1) proof of principle with full simulation tools

(2) prototype algorithms with more realism

(3) write flight software

(4) integrate flight software algorithms into full simulation to study and iterate

- **However, until a few months ago, the main issue was data system architecture and CPU requirements. In that context, the 2nd step was judged not to be particularly useful (or would be essentially indistinguishable from the 3rd) and it was largely skipped. Step (3) required reformatting simulated events to dataflow format, which required that to be defined.**

Development Status

- **Basic approach:**

(1) proof of principle with full simulation tools

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(2) prototype algorithms with more realism

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(3) write flight software

↕

(4) integrate flight software algorithms into full simulation to study and iterate

- **(1) was done prior to PDR. (3) lots of progress after logjam broken post-PDR (see JJ's talk next). (4) must now be done – interacts with our SAS development plans and schedule: see next slide.**

Tools

- **PDR studies and JJ's filter studies were done using pdrApp (the GISMO-based simulation and reconstruction package line used since the start of the project). Development has now halted on pdrApp.**
- **GLEAM, which is the new Geant4-based package line, is being debugged and brought up to speed. The architecture is sufficiently different that recon and other analysis tools from pdrApp can not be plugged in. (But the new recon is much better!)**
- **The last essential step for validation of the flight algorithms requires:**
  - **updating JJ's event reformatting algorithm to be adapted for GLEAM**
  - **packaging JJ's algorithms for use in GLEAM. The FSW objects (tracks, selection quantities) must be available in the standard recon output**
- **At this meeting: work out who (not just FSW group) and how (details) and when (soon).**

To Do

- Improve angular distributions of the background flux implementations. Volunteer!
- Finish first flight software filter implementation. This requires a clear statement of priority.
- Include the flight algorithms in reconstruction/analysis packages to study the effects in detail. Migrate JJ's formatter to GLEAM. PLAN AT THIS MEETING. Check everything.