GLAST Large Area Telescope

Onboard Filter Status

LAT Collaboration Meeting
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work done by
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Outline

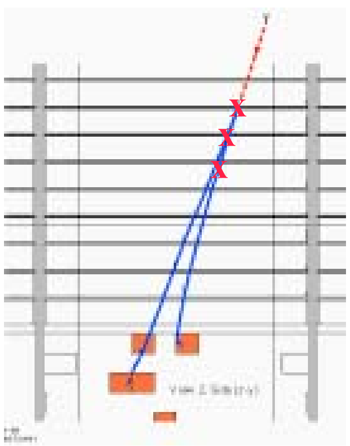
- Onboard filter design
- Embedding the filter
- Results and next steps
- Summary

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).

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

*** assumes no compression**

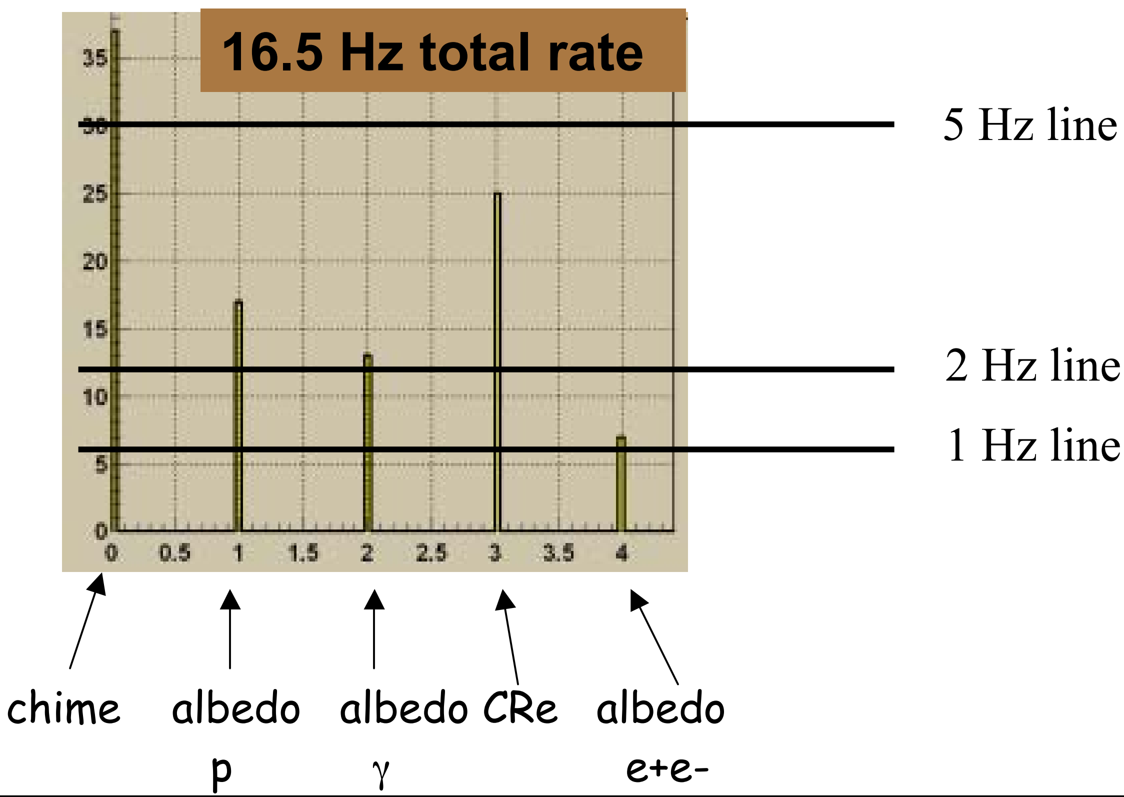
On-board Filter Design

- 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.

On-board Filters Design Results (PDR/CDR)

- **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

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

IMPORTANT: We might not need to implement all the later-stage selections! First evaluate effects at this stage.

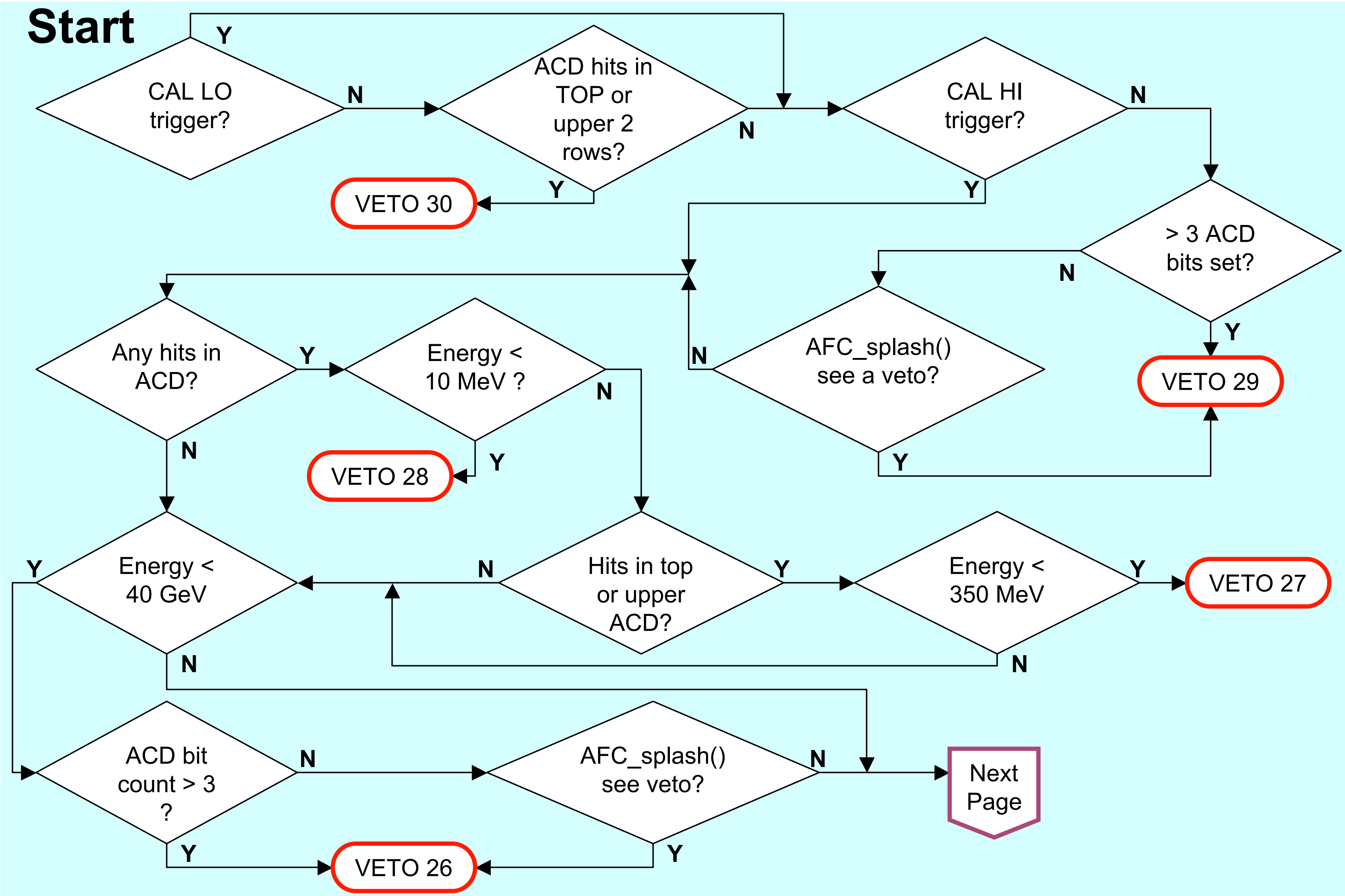
Filter Vetoes

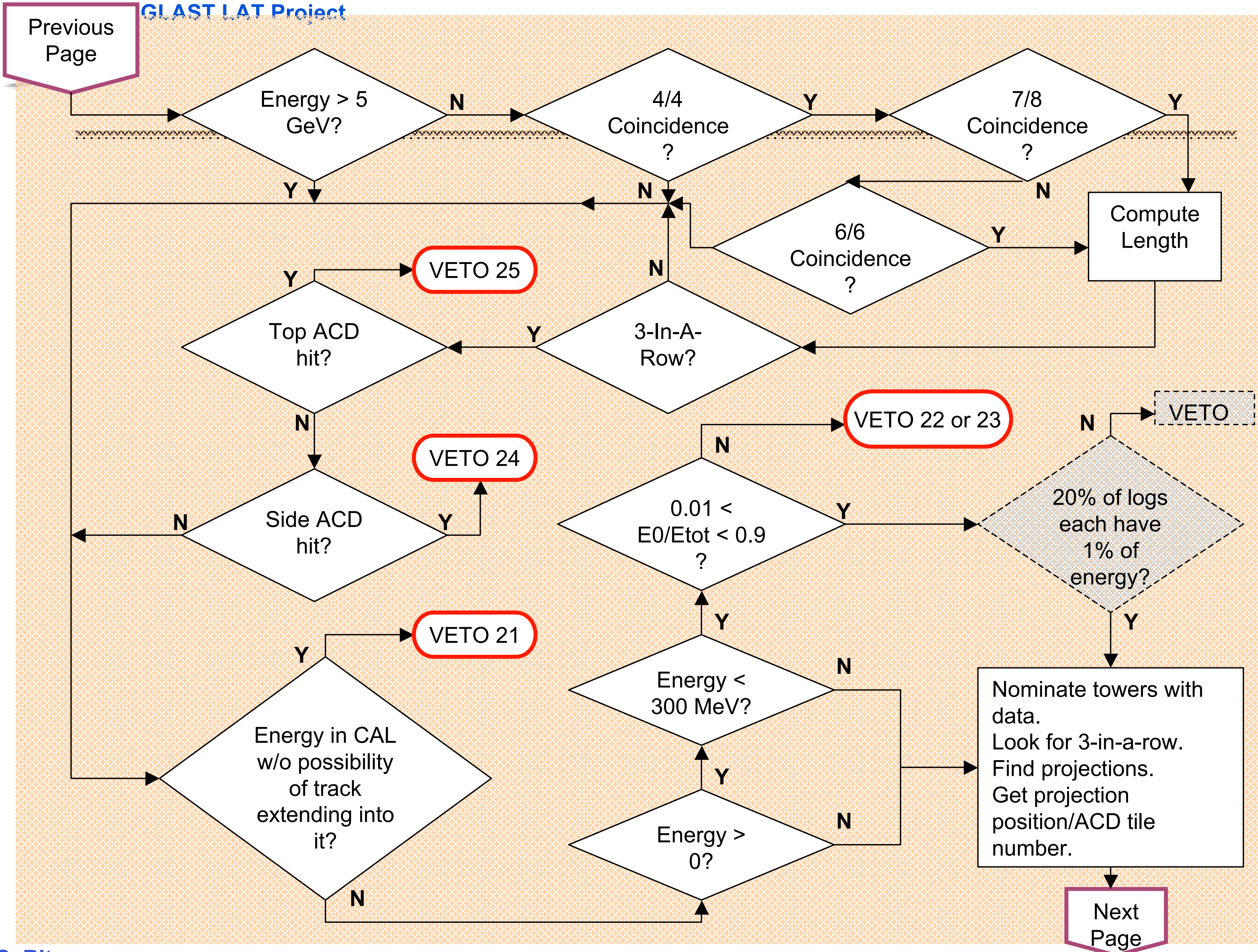
The 16 reasons for vetoing an event are contained in bits 15-30 of a 32-bit status word:

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

- **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





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Energy > 5 GeV?
N
Y
4/4 Coincidence ?
Y
N
7/8 Coincidence ?
Y
N
6/6 Coincidence ?
Y
Compute Length
3-In-A-Row?
N
Y
Top ACD hit?
Y
VETO 25
N
Side ACD hit?
N
Y
VETO 24
Energy in CAL w/o possibility of track extending into it?
Y
VETO 21
N
Energy > 0?
Y
N
Energy < 300 MeV?
Y
N
0.01 < E0/Etot < 0.9 ?
N
VETO 22 or 23
Y
20% of logs each have 1% of energy?
N
VETO
Y
Nominate towers with data.
Look for 3-in-a-row.
Find projections.
Get projection position/ACD tile number.
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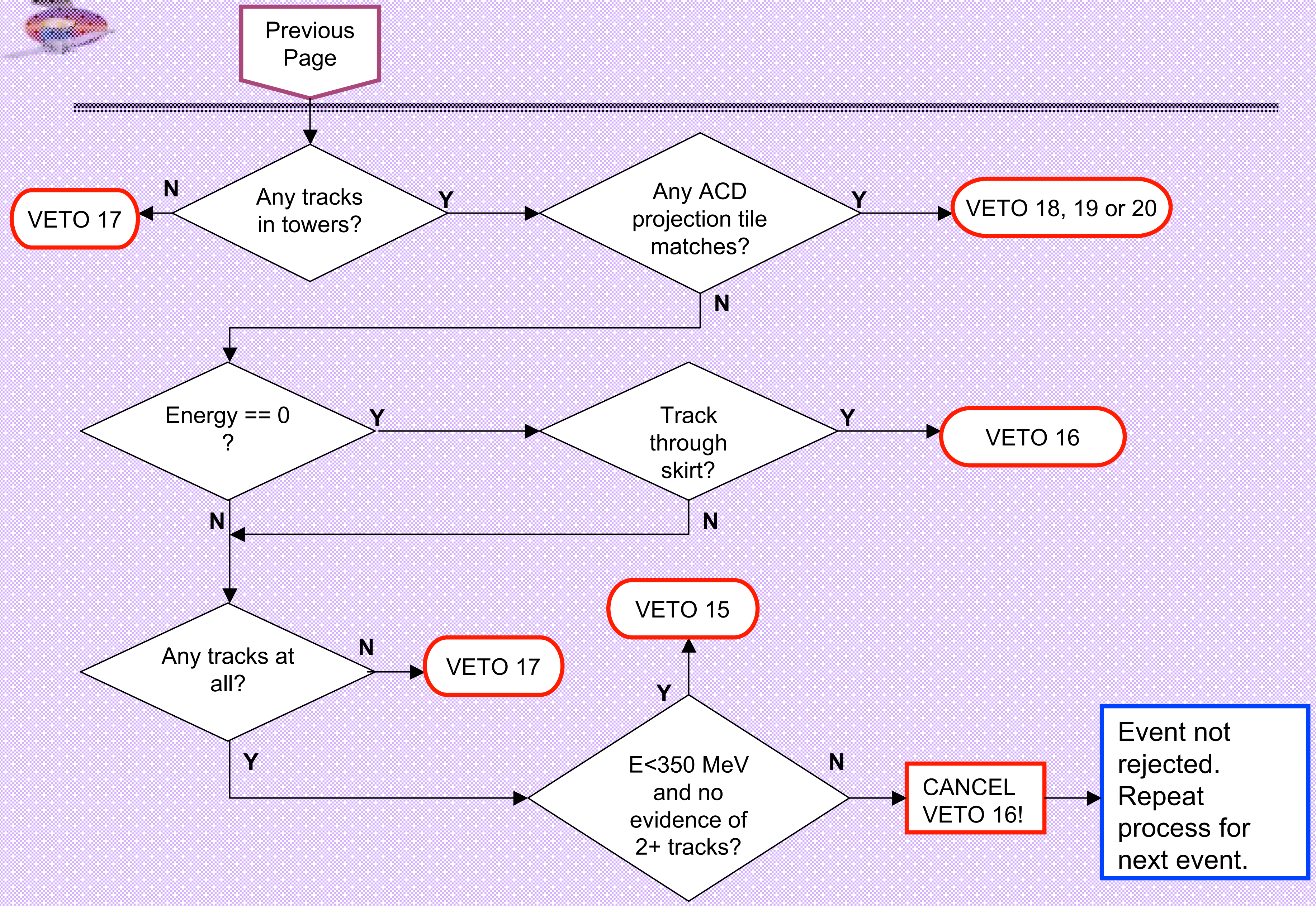
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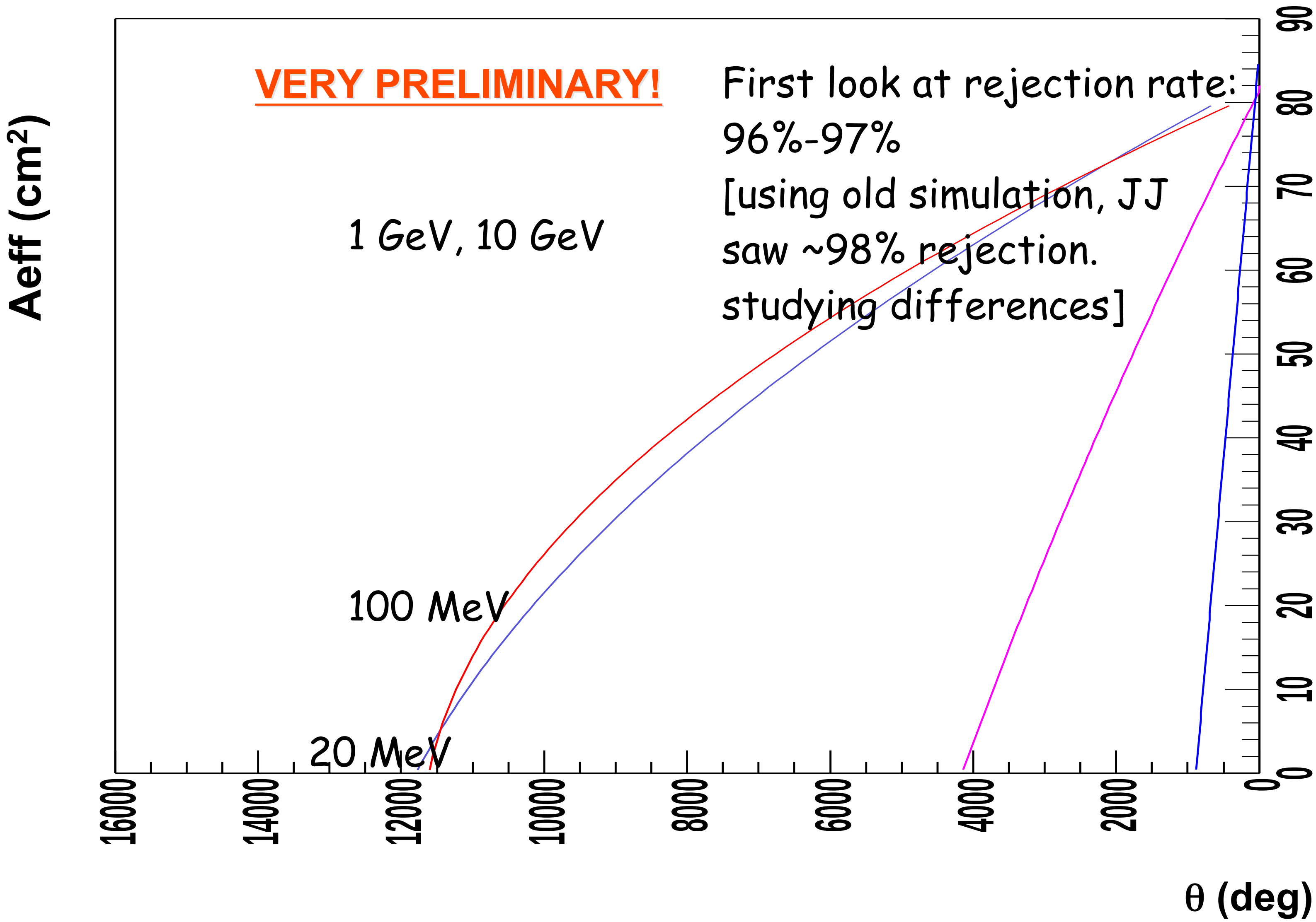
Any tracks in towers?
N
VETO 17
Y
Any ACD projection tile matches?
Y
VETO 18, 19 or 20
N
Energy == 0 ?
Y
Track through skirt?
Y
VETO 16
N
N
Any tracks at all?
N
VETO 17
Y
E<350 MeV and no evidence of 2+ tracks?
Y
VETO 15
N
CANCEL VETO 16!
Event not rejected. Repeat process for next event.

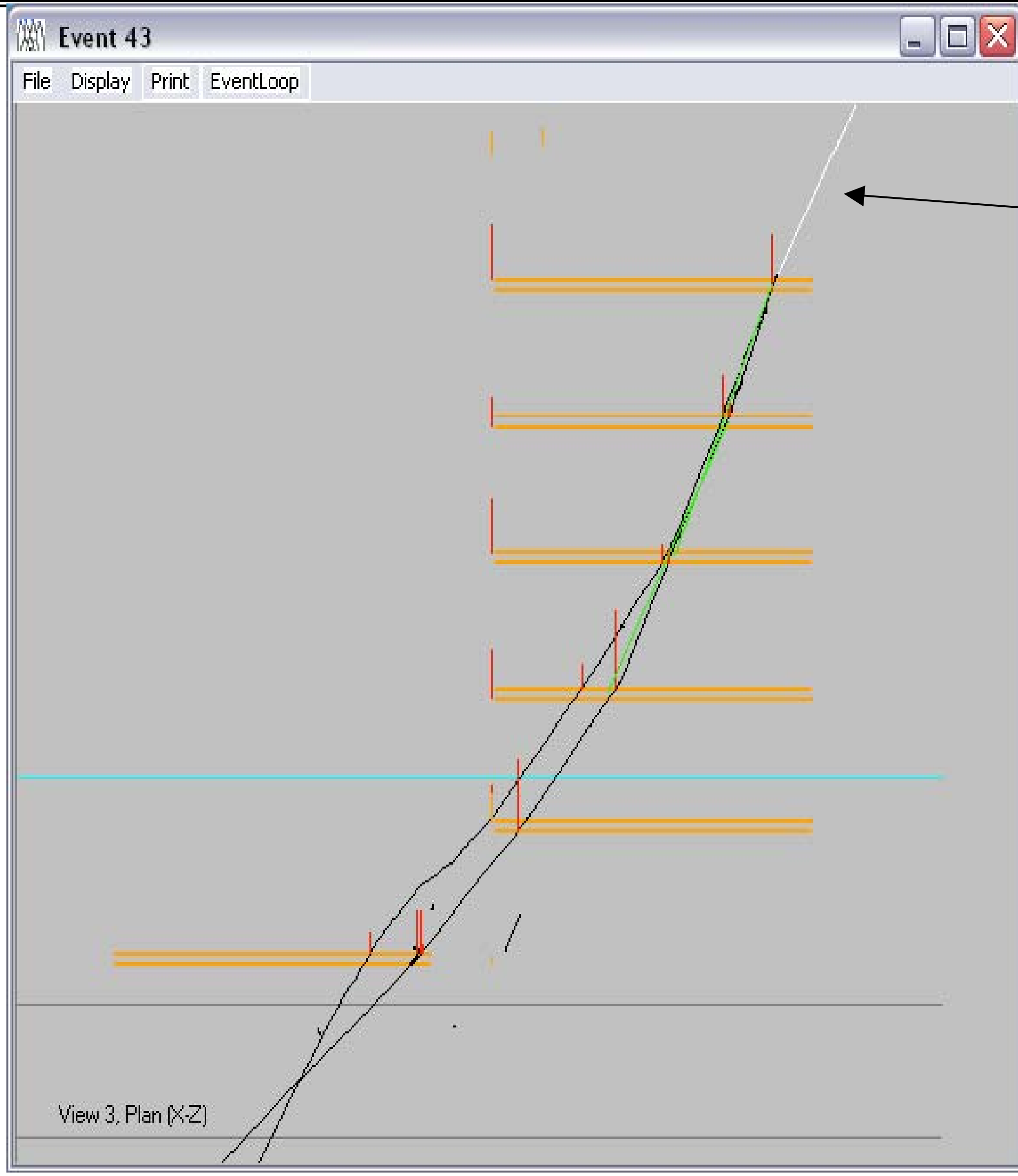
Summary of Performance (require L1T and pass filter)



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

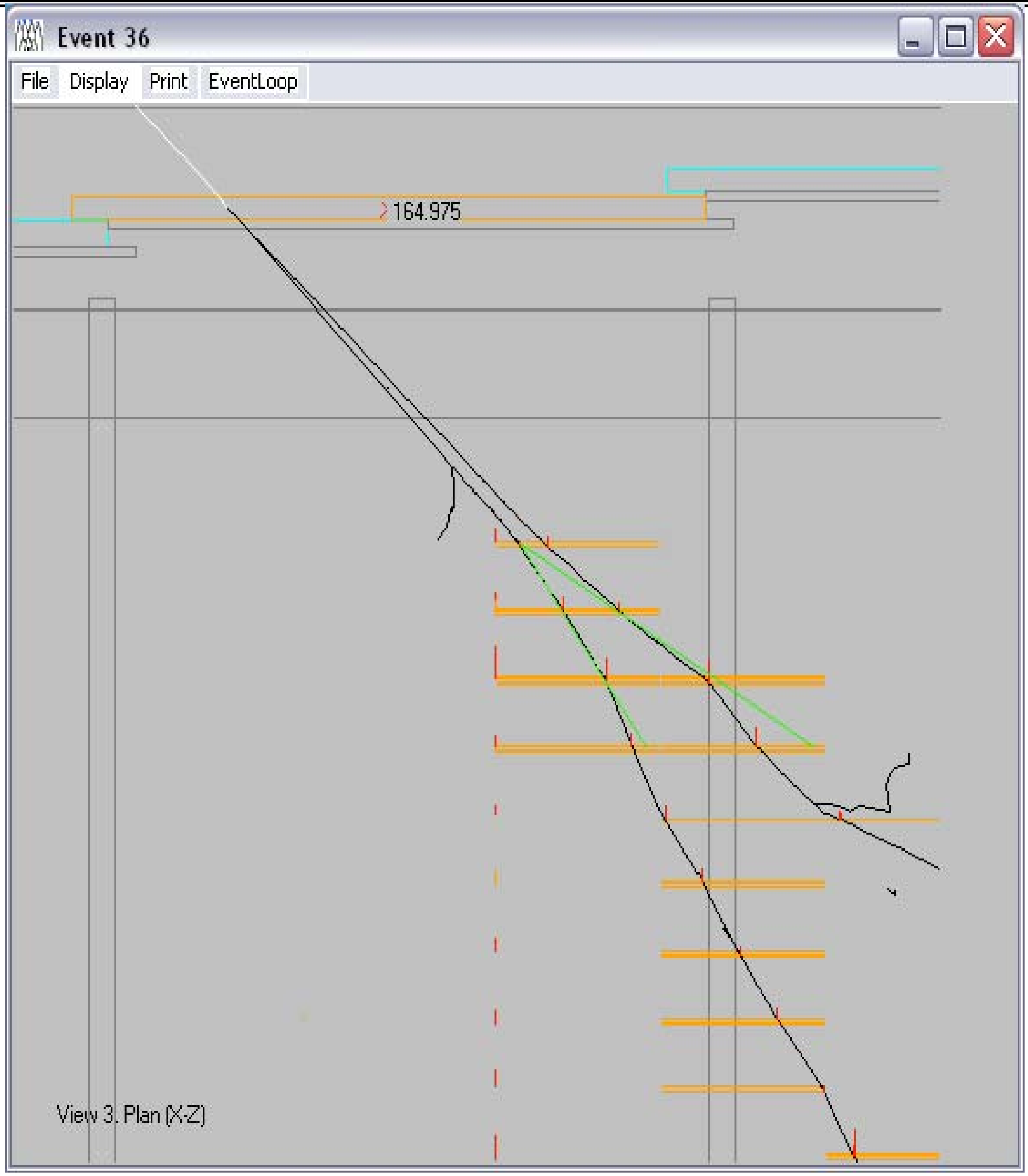
green lines are filter tracks

black lines are MC truth charged particle trajectories

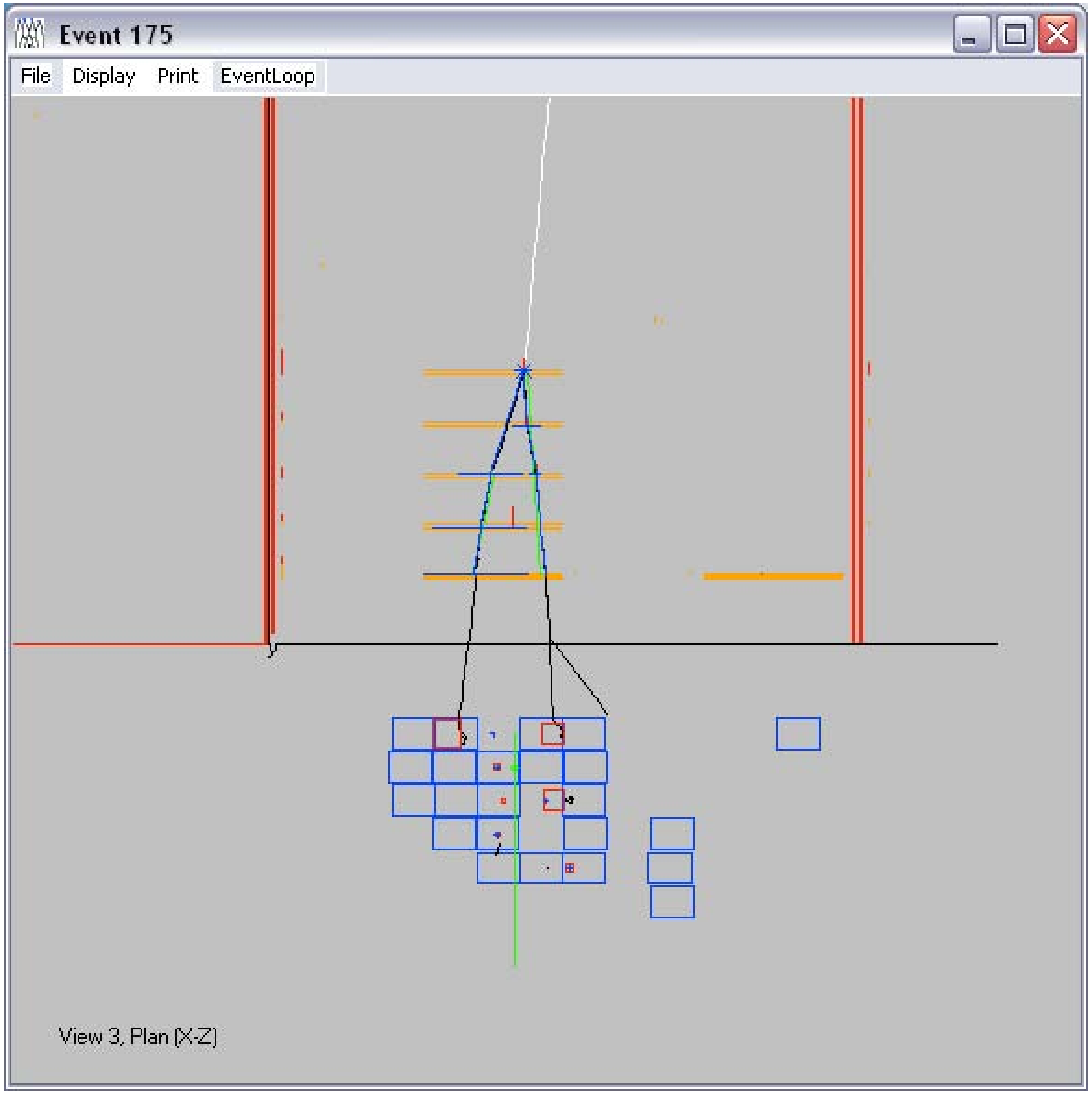
red lines are strip hits

Filter Tracks in the Event Display

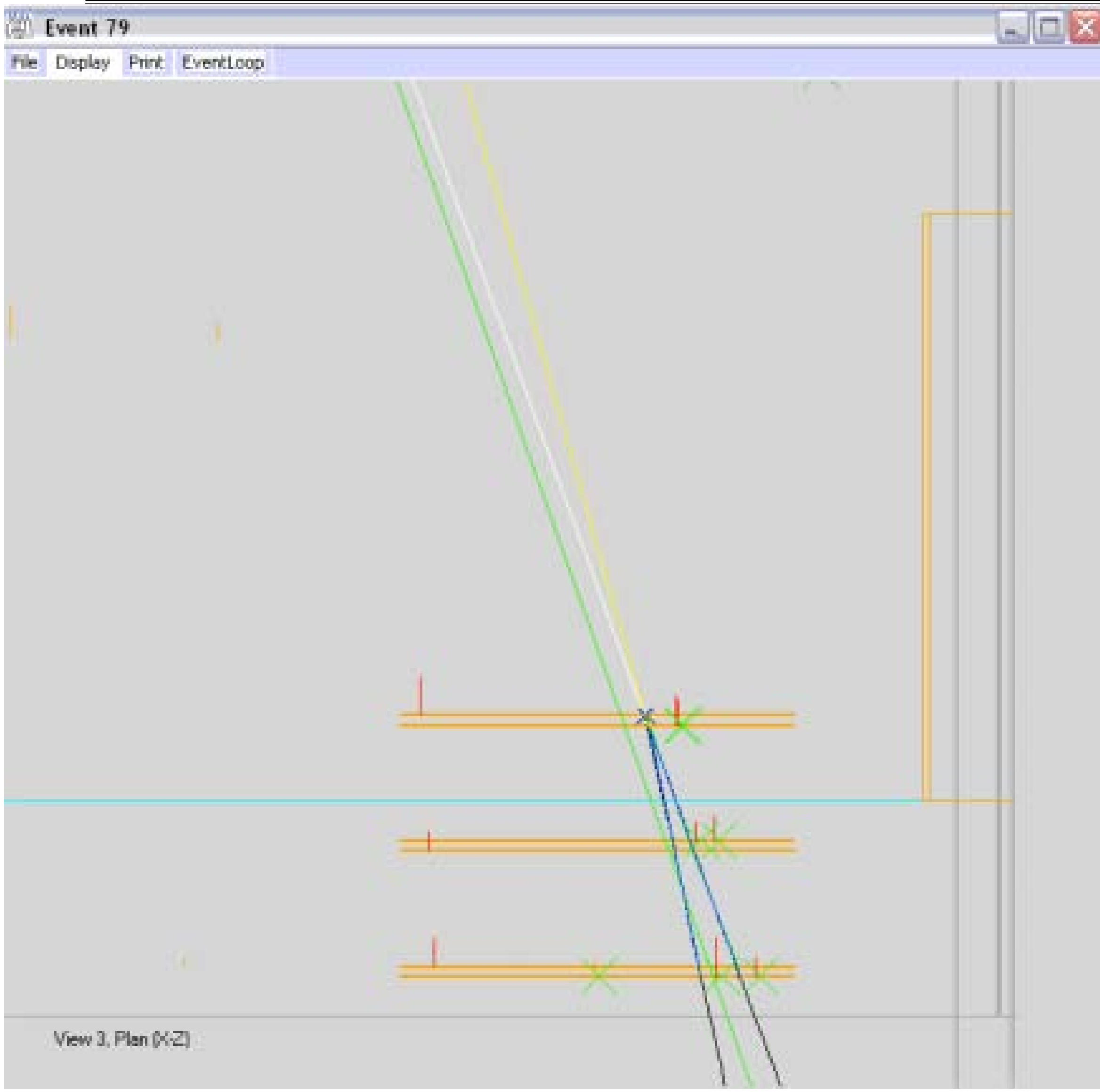
(conversion in the ACD…)



Filter Tracks in Event Display

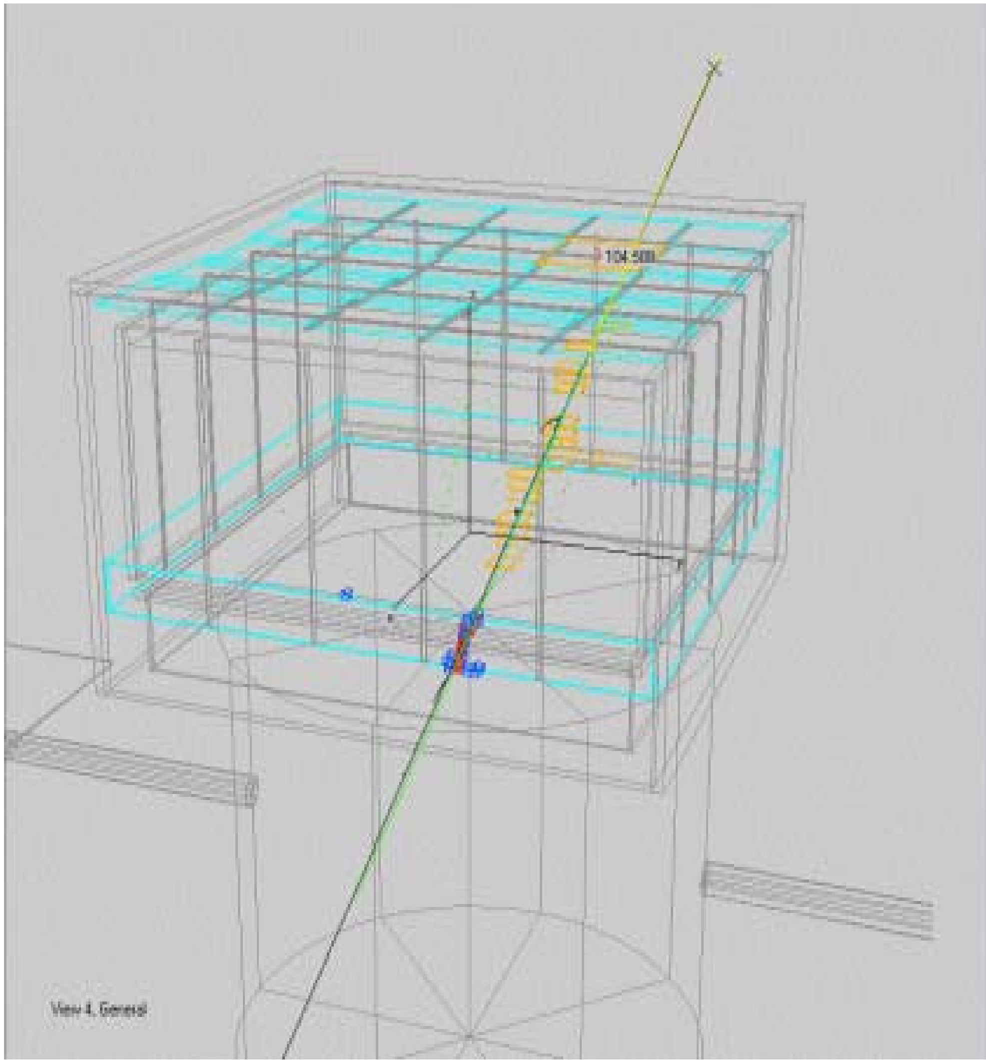


Filter Tracks in the Event Display



The event display is not without problems….

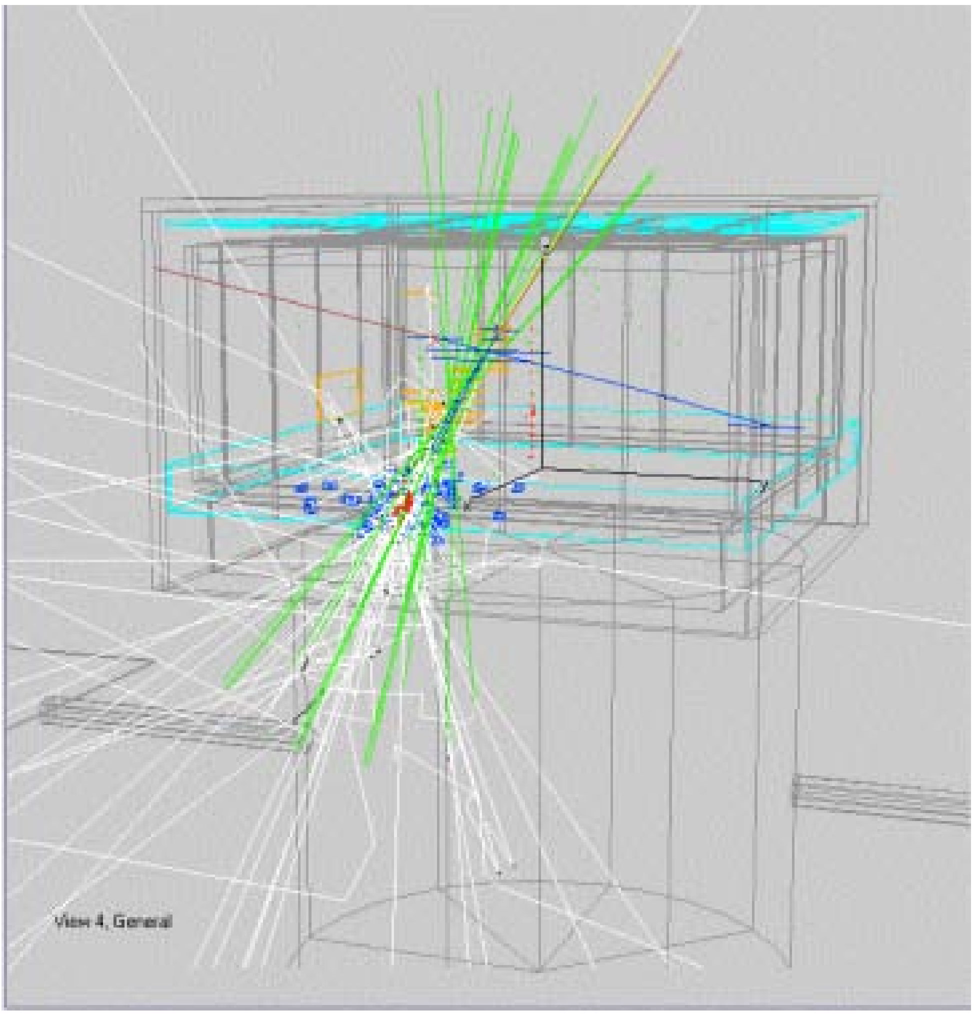
Filter Tracks in the Event Display



Incoming proton

Check track-tile association

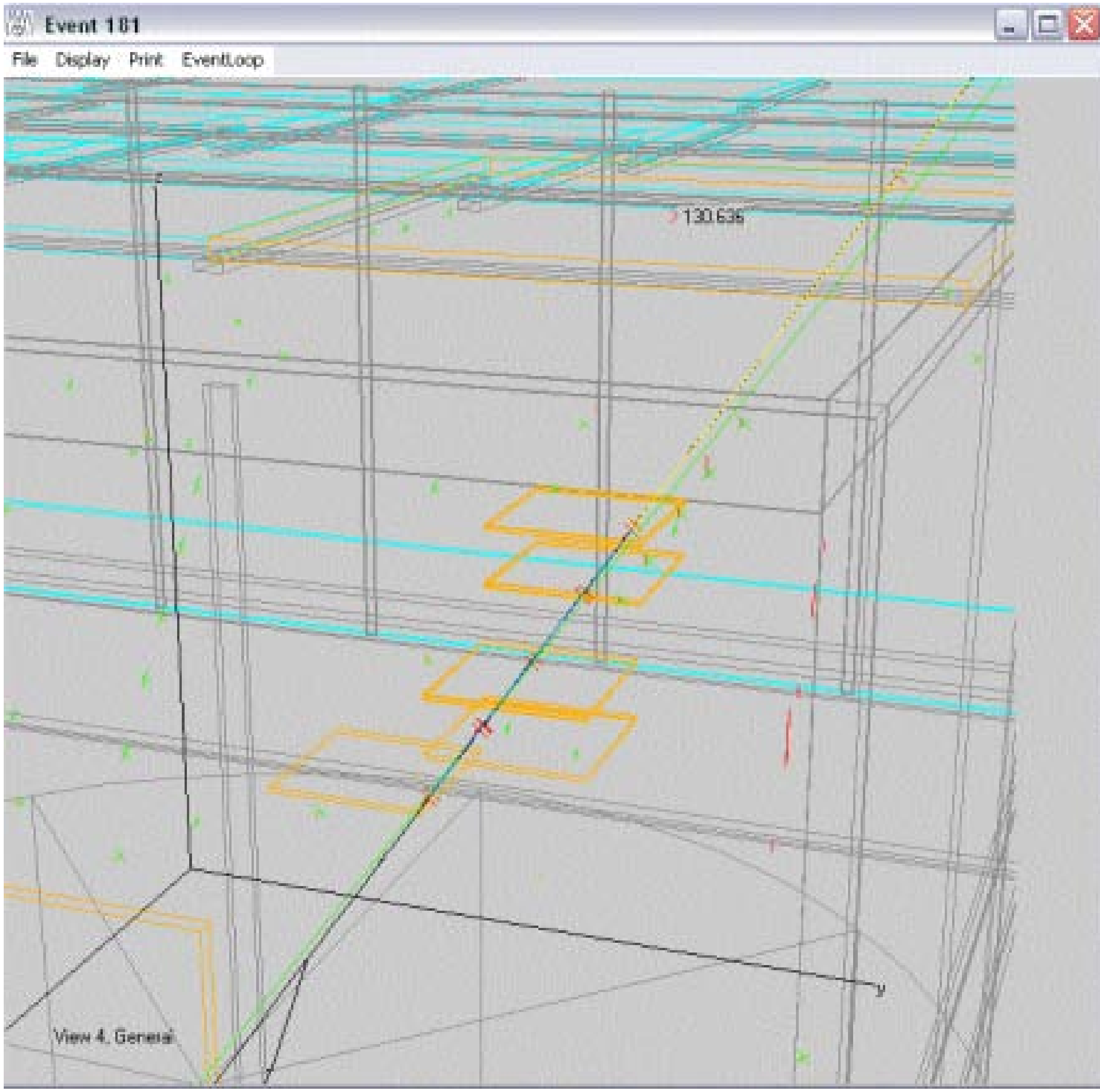
Filter Tracks in the Event Display



More complicated event…

…can turn filter track extensions (both up to ACD and down to CAL face) on and off in display.

Filter Tracks in the Event 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