OnboardFilter Performance Update and Prospective Albedo Cuts

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OnboardFilter: Current Status

- Geometry now agrees with Gleam
  - Previously, it was out of date
- FilterAlg now emulates OnboardFilter logic
- 2 significant bugs were found
  - One is fixed in OnboardFilter
  - Both are fixed in FilterAlg
- We expected the performance to change now that the geometry is correct and two bugs have been fixed…

Background Performance Before and After Fixes (zenith pointed)

Source	TKR Triggered (Hz)	% Vetoed	Rate Remaining (Hz)
Backgndmaxpdr (includes albedo from limb)	? / 10710	? / 94.9	? / 546
Backgndavgpdr (includes albedo from limb)	3358 / 3381	90.1 / 93.1	332 / 234
Albedo Upward	259 / 258	48.3 / 45.9	134 / 138

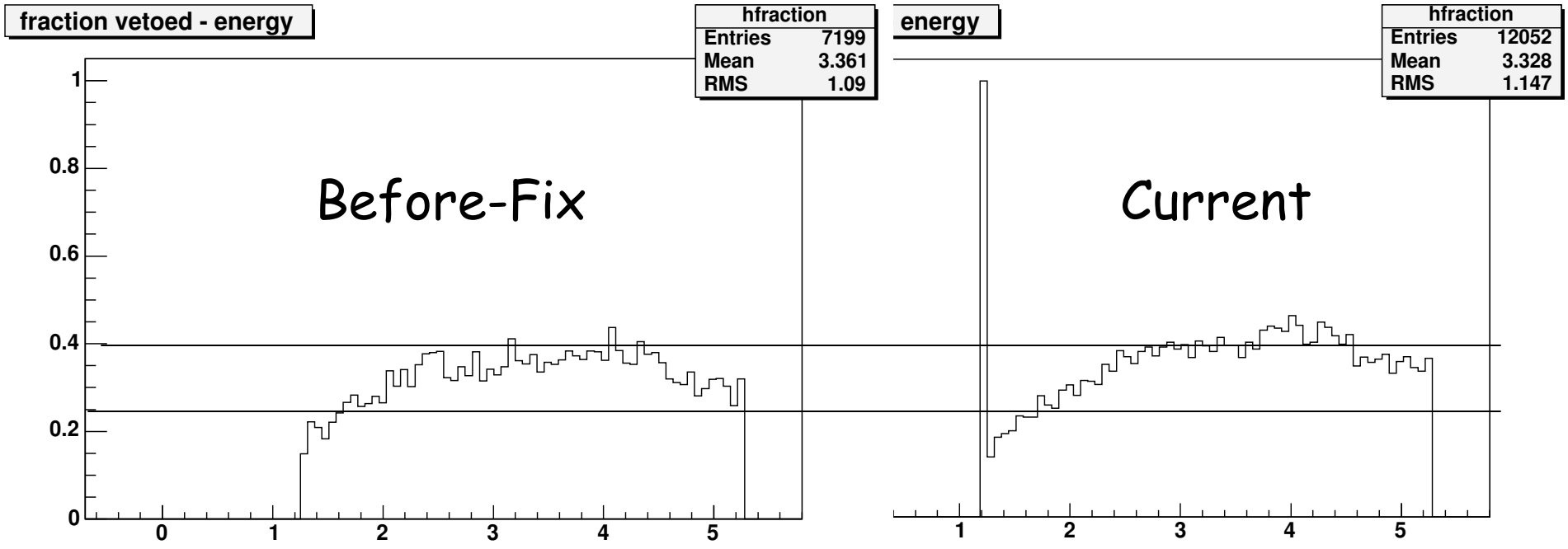
Average Background Before: 332 + 134 = 466 Hz

Average Background Now: 234 + 138 = 372 Hz

20% improvement, but albedo rate still too high

Before-Fix vs. Current Performance

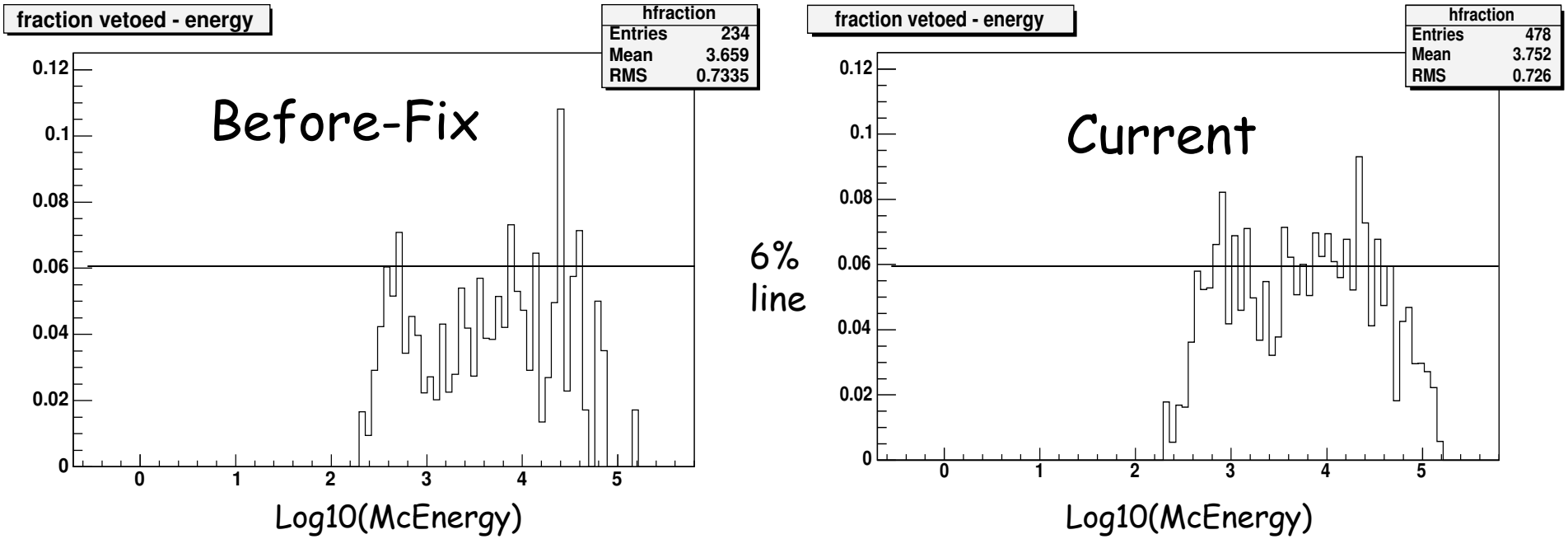
Fraction of TKR Triggered Gammas
Vetoed vs. log10(McEnergy)



Gamma performance suffers mostly
above ~300 MeV by about 5% or so

"GoodEvent" Performance

Fraction Vetoed vs. log10(McEnergy)



Stats are low, but maybe 1-2% worse for goodEvents

(goodEvents defined by ALL DC1 cuts)

Effective Area & Field of View – TKR Triggered

Source and Cut →	Before Fixes - TKR Triggered Events		**After Fixes** – TKR Triggered Events	
Energy (MeV) and Cut(s)	Aeff at Normal Incidence (cm^2)	Field of View (sr)	Aeff at Normal Incidence (cm^2)	Field of View (sr)
0-50 TKR trig	6877	4.059	7652	3.49
Filter Applied	5929	3.66	**6579**	**3.212**
50-100 TKR trig	12386	3.544	11278	3.887
Filter Applied	10617	3.021	**9925**	**3.204**
100-200 TKR trig	11397	4.804	13333	4.12
Filter Applied	9888	3.772	**12047**	**3.175**
200-300 TKR trig	10939	5.485	12558	4.634
Filter Applied	9613	3.961	**11163**	**3.383**
300-1000 TKR	11577	5.187	13404	4.559
Filter Applied	10567	3.726	**12329**	**3.058**
1000-10000 TKR	12980	5.133	13536	4.946
Filter Applied	12388	3.419	**12262**	**3.268**
10000-30000 TKR	13385	5.481	12620	5.707
Filter Applied	12231	3.717	**11734**	**3.528**
30K-180K TKR	15152	5.347	14859	5.439
Filter Applied	14015	3.96	**13598**	**3.796**

Effective Area & Field of View – "Good" Events

Source and Cut →	Before Fixes – "Good" Events		**After Fixes** – "Good" Events	
Energy (MeV) and Cut(s)	Aeff at Normal Incidence (cm^2)	Field of View (sr)	Aeff at Normal Incidence (cm^2)	Field of View (sr)
0-50 Good events	711	2.369	1144	1.45
Filter Applied	711	2.369	**1144**	**1.45**
50-100 Good	4826	1.665	4624	1.708
Filter Applied	4826	1.665	**4624**	**1.708**
100-200 Good	5698	3.065	6784	2.377
Filter Applied	5698	3.058	**6784**	**2.373**
200-300 Good	7624	2.645	7774	2.672
Filter Applied	7624	2.6	**7774**	**2.644**
300-1000 Good	8913	2.782	10242	2.422
Filter Applied	8637	2.741	**10115**	**2.325**
1000-10000 Good	9587	2.803	9334	2.895
Filter Applied	9479	2.717	**9093**	**2.807**
10K-30K Good	8885	2.844	9742	2.602
Filter Applied	8538	2.823	**9520**	**2.494**
30K-180K Good	9924	2.224	10234	2.173
Filter Applied	9697	2.226	**9953**	**2.154**

This would be no different if albedo cuts were applied

Eliminating Albedo

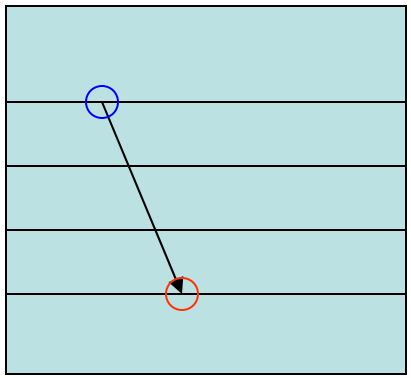
- Looked at many ntuple quantities, but albedo and low energy gammas look nearly identical
  - There are three significant differences, however
    - Difficult to reconstruct tracks from OnboardFilter projections for albedo, because few events have x-y projection pairs starting in the same layer
    - Albedo are much less likely to deposit energy in the Cal
      - ~10-15% of albedo vs. ~80+% of gammas of the same energy range
    - Albedo come from "below," gammas from "above"
- All methods of eliminating albedo should focus on events with CalEnergySum==0
- Tried three methods
  - Method 1: exploit the fact that few albedo events have an x and a y projection starting in the same layer
  - Method 2: look at multiple scattering angles (Steve's suggestion)
  - Method 3: reject based on incoming direction

Killing Albedo: Method 1

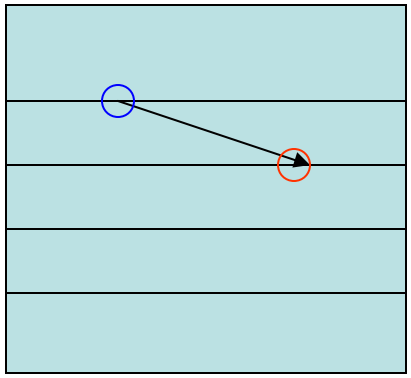
- The one obvious difference between albedo and other gammas: albedo come from "below," gammas come from "above"
- 3-D tracks are formed from two projections: one X, one Y (each 2-D).
- For a given track, both projections are likely to start in the same layer, but may end in different layers (due to scattering)
  - For consistency, we define "start" as the top layer of a 3-in-a-row (or better), even though albedo tracks really start at the bottommost layer of a 3-in-a-row.

Method 1: Albedo vs. Other Gammas in the Tracker

Ordinary gammas



X View

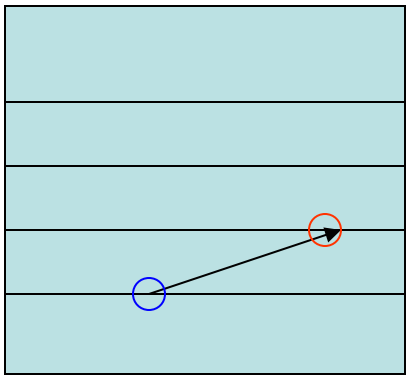


Y View

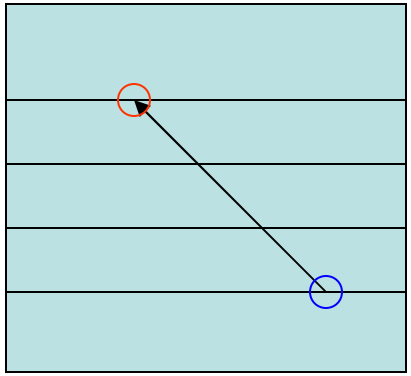
X and Y projections are likely to start in the same layer, but may end in different layers, due to multiple scattering and the way OnboardFilter assigns hits to tracks.

A reasonable requirement for the formation of a 3-D track from 2-D projections, is that they both start in the same layer. This layer is assumed to be towards the top of the tracker, farthest from the Cal. It is less likely for albedo to meet this condition, because their start is closest to the Cal.

Albedo gammas



X View



Y View

Method 1: Albedo Cut

Require that there be one X and one Y projection that start in the same layer in any given tower.

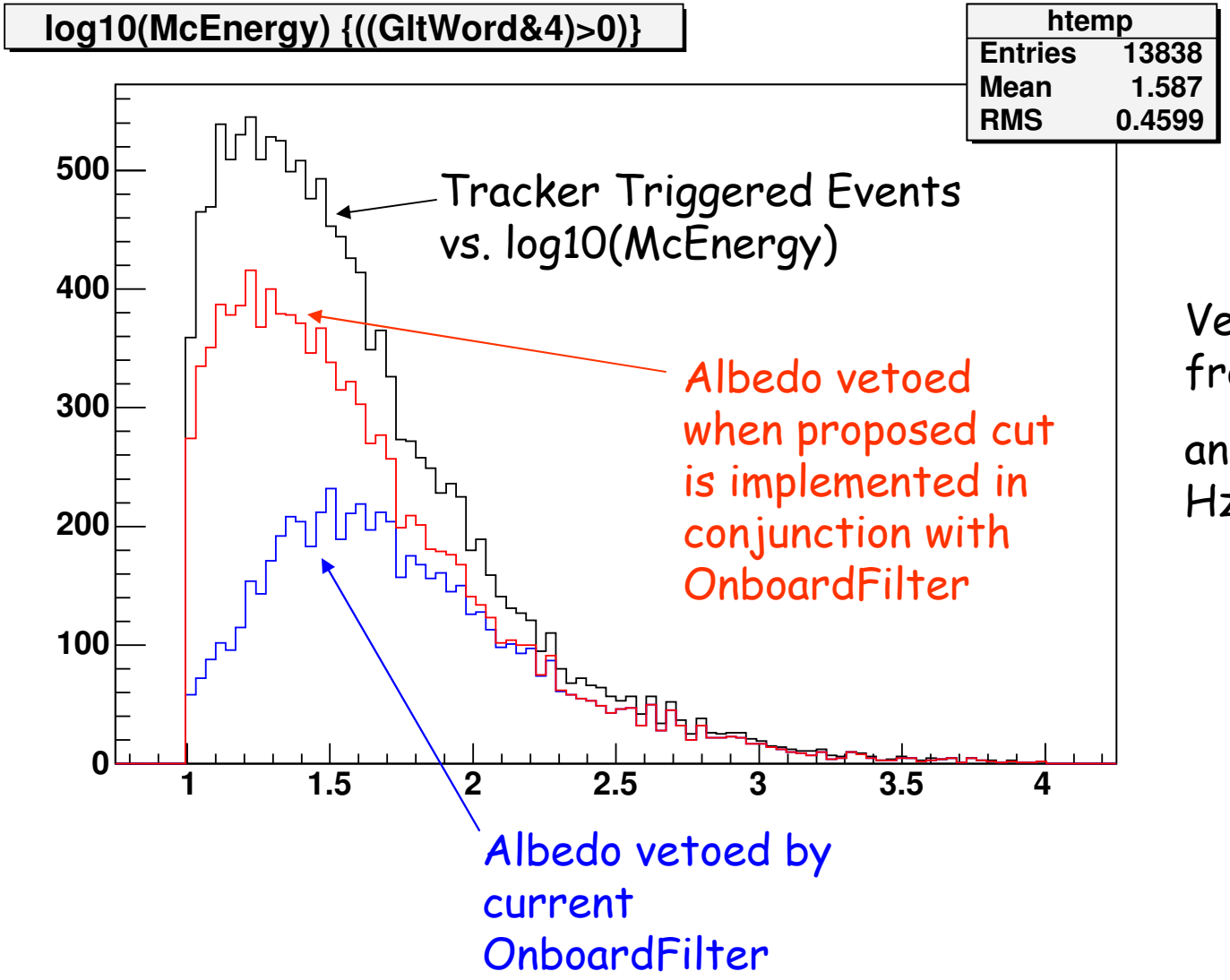
The starting layer is always defined as the top-most layer, closest to the front of the ACD.

Make no requirement on where the projections end.

Also require that there be no energy deposit in the Cal. No "good gammas" will be eliminated.

Problem: if track finding improves, this method could become less useful.

Method 1: Impact on Albedo Upward

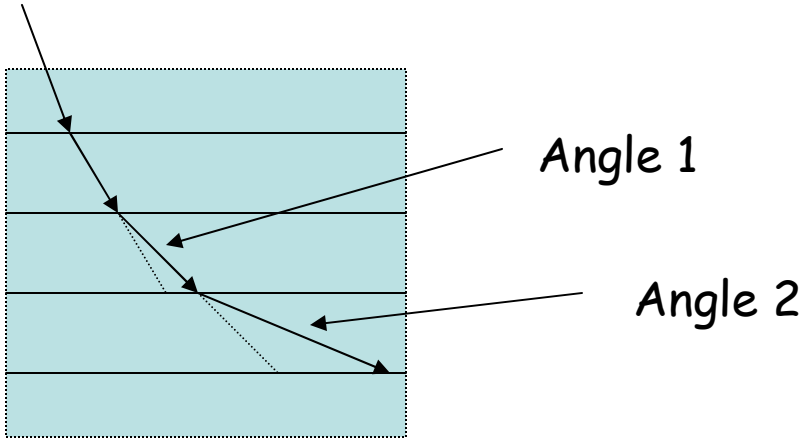


Veto percentage goes from 46% to 76%,

and the rate from 138 Hz to 63 Hz.

Method 2: Multiple Scattering Angles

- If a projection has 4 or more hits, calculate the scattering angles.
- We expect events coming from "above" to have increasing scattering angles, with the reverse happening from below



If gamma is coming from above, expect angle 1 to be less than angle 2.

For albedo, the opposite should be true.

Method 2: Comments

- Advantage: based on sound physics instead of a clever trick
- Problem: not enough albedo projections have at least 4 hits
- Possible that OnboardFilter track finding will improve, increasing the number of projections with 4 or more hits, so we can keep this on the back burner

Method 3: Cut on direction

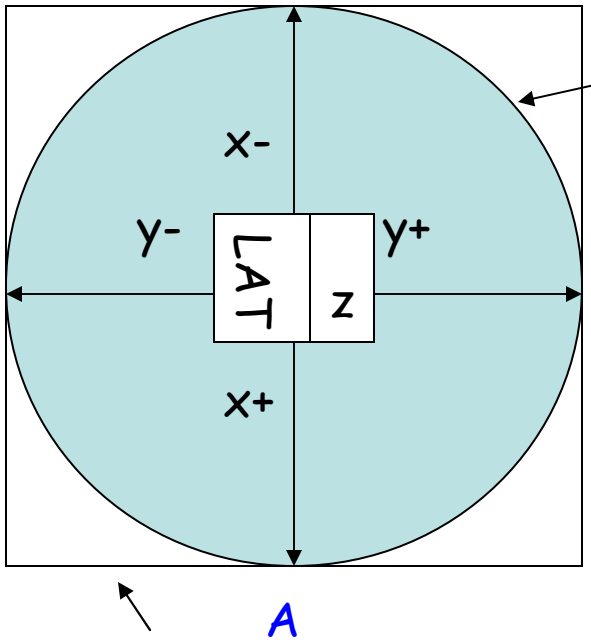
- If the event comes from a direction consistent with Earth's atmosphere, eliminate it.
- Problem: recall that Method 1 is based on the fact that it is difficult to reconstruct tracks and get a direction for albedo! So how can we cut on direction?
- Approach: don't use 3-D tracks, just use 2-D projections
  - Very effective!

Method 3: Details

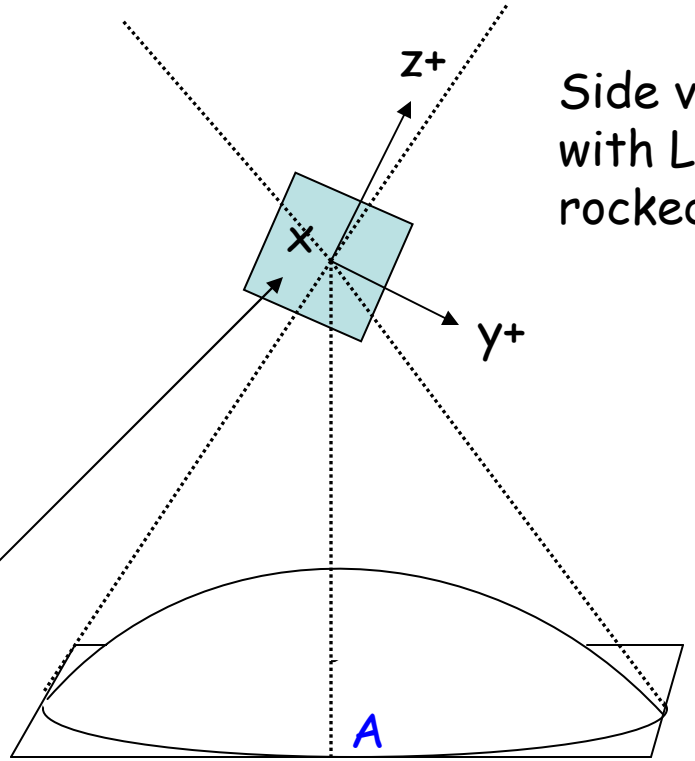
- Only consider events with CalEnergySum==0
- Only consider events with triggers in the outermost towers
  - Albedo are more likely to trigger these than core towers
- Only consider x projections for x face towers, and y projections for y face towers
  - The projection must be perpendicular, not parallel to, the face of the tower

Method 3: Geometry

Top down view of Earth with Lat above (rocked towards y+).



Earth



Side view with LAT rocked

Eliminate events from the pyramid defined by this square

For x sides, must take care to correctly calculate the angle the projection makes with respect to the point perpendicular to face (point A).

For y sides, this is trivial.

Performance Comparison – Zenith Pointed

Backgndavgpdr and albedo			Method 1	Method 2	Method 3
Albedo Upwards	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	258	138	63	114	59
% eliminated		45.9%	75.5%	55.9%	77%
Backgndavgpdr	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	3381	234	174	Did not calculate	189
% eliminated		93.1%	94.8%	Did not calculate	94.4%
Albedo from limb (this is also included in backgndavgpdr!)	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	158	83	37	Did not calculate	47
% eliminated		47%	77%	Did not calculate	70%

Total was ~372 Hz, now could be ~248 Hz (Method 3)

Performance Comparison – Zenith Pointed

Gammas eliminated Method 1 Method 2 Method 3

Energy Range	% Vetoed by OnboardFilter	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut
0-20 MeV	17.9	55.4	43.4	60.7
20-50	19.6	42.3	34.9	43.9
50-100	25	34	32.7	37.7
100-300	32.5	35.5	34.5	35.7
300-1000	36.7	37.2	37	37
0-1000	30.9	37	35.3	37.9

However, no increase in "good gammas" eliminated because nothing with any Cal energy deposit is touched.

Performance Comparison – Rocked 35 deg

Backgndavgpdr and albedo			Method 1	Method 2	Method 3
Albedo Upwards	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	243	141	62.5	119	64
% eliminated		41.8%	75.4%	51%	73.6%
Backgndavgpdr	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	3448	232	175	Did not calculate	180
% eliminated		93.3%	94.9%	Did not calculate	94.8%
Albedo from limb (this is also included in backgndavgpdr!)	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	182	83	53	Did not calculate	54
% eliminated		45.6%	70.7%	Did not calculate	70.2%

Total was ~373 Hz, now could be ~244 Hz (Method 3)

Performance Comparison – Rocked 35 deg

Gammas eliminated Method 1 Method 2 Method 3

Energy Range	% Vetoed by OnboardFilter	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut
0-20 MeV	31.3	58.2	41.8	58.2
20-50	20.2	41.3	36.0	47.9
50-100	26.8	34.5	34.0	37.4
100-300	35.1	37.6	36.7	38.5
300-1000	41.5	41.8	48.7	42.2
0-1000	34.1	39.4	38.2	41.2

However, no increase in "good gammas" eliminated because nothing with any Cal energy deposit is touched.

Performance Comparison – Rocked 60 deg

Backgndavgpdr and albedo			Method 1	Method 2	Method 3
Albedo Upwards	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	274	179	85	Didn't Calculate	91
% eliminated		34.5%	68.8%	Didn't Calculate	66.9%
Backgndavgpdr	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	3591	264	206	Didn't Calculate	216
% eliminated		92.6%	94.3%	Didn't Calculate	94.0%
Albedo from limb (this is also included in backgndavgpdr!)	Triggered	After OnboardFilter	After OF or Albedo Cut	After OF or Albedo Cut	After OF or Albedo Cut
Rate in Hz	213	137	89	Didn't Calculate	100
% eliminated		35.9%	58.1%	Didn't Calculate	52.9%

Total was ~443 Hz, now could be ~307 Hz (Method 3)

Performance Comparison – Rocked 60 deg

Gammas eliminated Method 1 Method 2 Method 3

Energy Range	% Vetoed by OnboardFilter	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut	% Eliminated by OF or Albedo Cut
0-20 MeV	25.4	59.3	35.6	69.5
20-50	23.7	45.1	38.8	51.8
50-100	30.8	39.5	38.3	43.2
100-300	39.9	43	41.7	44.2
300-1000	49.7	50.1	50.0	50.7
0-1000	40.0	45.7	44.0	47.8

However, no increase in "good gammas" eliminated because nothing with any Cal energy deposit is touched.

Backup Methods

- What if Earth's location is not available to the filtering software?
  - Method 3 cannot be used
  - Use method 1, which is also very effective, or use a "method zero"
- Method 0: eliminate ANYTHING with no Cal Energy
  - Or to allow for noise, and for consistency with ground cuts, maybe put the threshold at 5 MeV (reject if E<5 MeV)

Method 0 Performance

Backgndavgpdr and albedo	Zenith	Rocked 35	Rocked 60
Albedo Upwards	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated
After OnboardFilter	138 / 45.9%	141 / 41.8%	179 / 34.5%
After OF or M0 cut	15 / 94.0%	15 / 93.8%	25 / 90.7%
Backgndavgpdr	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated
After OnboardFilter	233 / 93.0%	230 / 93.3%	264 / 92.6%
After OF or M0 cut	130 / 96.1%	127 / 96.3%	146 / 95.9%
Albedo from limb (this is also included in backgndavgpdr!)	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated	Rate (Hz) / % eliminated
After OnboardFilter	91 / 44.7%	99 / 45.6%	137 / 35.9%
After OF or M0 cut	8 / 95.4%	16 / 91.2%	42 / 80.3%
Total after OF / after OF or M0	**371 Hz** / **145 Hz**	**371 Hz** / **142 Hz**	**443 Hz** / **171 Hz**

Method 0 Performance – Tkr Triggered Gammas

	Zenith Pointed		Rocked 35		Rocked 60	
Energy Range	% Vetoed by OnboardFilter	% Eliminated by OF or M0 Cut	% Vetoed by OnboardFilter	% Eliminated by OF or M0 Cut	% Vetoed by OnboardFilter	% Eliminated by OF or M0 Cut
0-20 MeV	17.9	81%	31.3	88%	25.4	97%
20-50	19.6	77%	20.2	78%	23.7	79%
50-100	25	54%	26.8	53%	30.8	57%
100-300	32.5	40%	35.1	42%	39.9	49%
300-1000	36.7	40%	41.5	43%	49.7	52%
0-1000	30.9	48%	34.1	50%	40.0	56%

Summary

- Bug and geometry fixes to OnboardFilter improve background rejection, do not improve albedo rejection, and do some damage to gammas
  - Need a method to kill albedo
- Of 3 albedo killing methods studied, one performs well *and* is likely to improve if track finding improves.
  - This is the "directional cut" method (Method 3)
- Average background (including all albedo) was reduced from ~470 Hz before fixes, to ~370 Hz after fixes, to <250 Hz with an additional albedo cut, without eliminating any more "good gammas"
  - Requires knowledge of Earth's position
  - If Earth's position is not known, Method 1 or Method 0 can be used, but damage to Tkr triggered gammas is greater
    - Still no damage to "goodEvent" gammas, though