LowUp Online Filter Proposal for 2009

Olle Engdegård (olle@fysast.mun.se)
for the wimp working group
(carlos.de-las-heros@fysast.mun.se)

January 19, 2009

Changes
To this proposal version, changes have been made to reflect the new proposed FeatureExtractor settings. The changes concern mostly the last summary table and the last summary plot, both of which now contain roughly the same information. The conclusion has the single change that the proposed ZTravelCut is -10 m instead of -5 m. Also, it now seems that the 2009 detector will be called IC59. No changes to the filter has been made.

1 Executive Summary
This proposal concerns the LowUp filter that was successfully proposed, accepted and run for the IceCube data year 2008, here updated for IC59. The only changes to the filter are

• No TWR
• Considers SMT, String and ULEE triggers instead of only SMT triggers
• A veto consisting of the 5 topmost DOMs on most strings
• Using HLC DOMLaunches to count Nch instead of RecoPulses

2 Physics motivation
This filter targets low-energy up-going neutrinos in general, to be used e.g. for WIMP searches and atmospheric neutrino analyses. It tries to capture up-going muons below 1 TeV.

3 Description of filter
The filter uses HLC Time-window-cleaned RecoPulses from FeatureExtractor, and a reconstruction based on these. If available, a LLH reconstruction is used, otherwise a simple Linefit. Only events triggered by the SMT8, String or ULEE triggers will be considered. These modules are needed for processing:

• 3DOMLaunchCleaning
• I3LCCleaning
• I3DOMCalibrator
• I3FeatureExtractor
• I3TimeWindowCleaning
• (I3SimpleFitter if used by other filter)
• I3Linefit
• I3FilterModule:< I3LowUpFilter>

3.1 Cuts

Six simple cuts are applied:

• **Nch ≥ 5**, defined as the number of HLC DOMLaunches.
• **Reconstructed zenith ≥ 80°**, using LLH if available otherwise Linefit
• **ZTravel > ZTravelCut**, which is defines as the average drift in z of the hits taken from the z average of the first quartile. Taking the average z of the earliest quartile, where q is the number of hits n divided by 4,

\[
(z_{\text{quartile1}}) = \sum_{i=1}^{q} \frac{z_i}{q}
\]

of hits and comparing this to later hits gives the observable

\[
z_{\text{travel}} = \frac{\sum_{i=1}^{n} z_i - (z_{\text{quartile1}})}{n}
\]

ZTravelCut is a tuning parameter which defaults to -10 (2008 settings).

• **TimeExtension < 3000 ns**, defined as (time of last pulse) - (time of first pulse)
• **ZExtension < 600 m**, defined as (max z of hit DOMs) - (min z of hit DOMs)
• **Veto depth = 440 m**, no hits above 400 m in standard IC coordinates (corresponds to the topmost 5 DOMs on most strings.)
3.2 The Time Extension parameter

![Graph showing Corsika rate vs. WIMP passing ratios](image)

Figure 1: Corsika rates in Hz and WIMP passing ratios in % versus TimeExtension in ns. An increase from 3000 to 6000 ns would give an 11% increase of 1000 GeV WIMPs but a 52% increase of total Corsika rate.

4 Simulation

The filter was evaluated with the following MC samples produced with IceSim2.2.9:

- IC40 single muon Corsika 1540
- IC40 double muon Corsika 1567
- IC58 single muon Corsika 1516
- IC58 double muon Corsika 1511
- NuGen NuMu E^- 1542

- Private samples of 5 solar WIMP channels: 100 GeV hard, 250 GeV soft, 250 GeV hard, 500 GeV hard and 1000 GeV hard

The Corsika and NuGen data was retrigged from IC80 to IC58 with a script\(^1\) inspired by IC80toIC60Retriggering.py written by Peter Redl, that includes SMT8, StringTrigger and ULEETrigger. Note that as of writing this, the most

\(^1\)http://www.iccube.wisc.edu/~olle/retrig.py
probable 2000 detector will be called IC56. For the atmospheric neutrino sample, only events with \( E < 1 \) TeV and zenith > 90° was used in this evaluation. The trigger rate for single+double corsika is 1795 Hz and Table 1 shows the distribution on the different triggers.

<table>
<thead>
<tr>
<th></th>
<th>SMT8</th>
<th>String</th>
<th>ULEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive</td>
<td>268 Hz</td>
<td>317 Hz</td>
<td>2.2 Hz</td>
</tr>
<tr>
<td>Inclusive</td>
<td>1474 Hz</td>
<td>1511 Hz</td>
<td>90 Hz</td>
</tr>
</tbody>
</table>

Table 1: Trigger rate distribution for single+double muon Corsika.

For comparison, the trigger distribution of two WIMP channels is shown in Table 2, as percentages of the total number of triggered events.

<table>
<thead>
<tr>
<th>WIMP mass</th>
<th>SMT8</th>
<th>String</th>
<th>ULEE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Exclusive</td>
<td>7%</td>
<td>27%</td>
<td>25%</td>
</tr>
<tr>
<td>Inclusive</td>
<td>19%</td>
<td>70%</td>
<td>66%</td>
</tr>
</tbody>
</table>

Table 2: Trigger distribution for the hard WIMP channels of the masses 100 GeV and 500 GeV, as percent of the total number of triggered events.

![Nch at IC58 triggerlevel, normalised](image)

Figure 2: Nch(HLC DOMLaunches) for a few WIMP channels and single muon Corsika. Note how the WIMP channels divide in two groups, with 100 GeV hard and 250 GeV soft in one group and 500 GeV hard and 1000 GeV hard in another group.
Figure 3: Nstr(HLC DOM Launches) for a few WIMP channels and single muon CORSIKA. It is clear why 100 GeV hard and 250 GeV soft are so difficult to reconstruct: most of these events have hits on only one string.

5 Rates for the 2008 version of LowUp

The 2008 LowUp filter was tested on various datasets. A significant change in CORSIKA rate is seen when going from the 2008 FeatureExtractor settings to the 2009 settings, especially for IC58 CORSIKA. The rate of LowUp during 2008 has been 12 Hz, which scales up to 17.7 Hz with a detector size increase of $\frac{59}{57}$. This is confirmed by the the IC58 single, double and triple CORSIKA rates below. Applying the new 2009 FeatureExtractor settings make things a bit different, which is why some modifications will be done for the 2009 version of LowUp.
Table 3: Rates with Linefit only using the 2008 LowUp version. IC40 trigger rate was taken from http://internal.icecube.wisc.edu/status/detector-summary.xml. The FeatureExtractor settings for 2009 are those proposed during the autumn of 2008 and not the final ones.

6 New in the 2008 LowUpFilter

6.1 Nch and triggers

Due to the new FeatureExtractor settings, many DOMLaunches do not survive to make RecoPulses. By counting Nch in this filter as the number of HLC DOMLaunches instead of reconstructed pulses, the Nch cut is made independent of the FeatureExtractor. To maximise the passing ratio for very low energy signal channels, the Nch cut must be set lower than 8, including the String and ULEE triggers.

6.2 Veto

A veto is defined as a disregard for all events with hits (HLC DOMLaunches) above 440 m in standard IceCube coordinates, which corresponds to the topmost 5 DOMs on most strings and also all IceTop DOMs.

6.3 Using SLC hits

When using information from the SLC hits which will be available in the 2009 DAQ, a most significant increase in angular resolution for the really low-energy events has been seen in a preliminary study. This proposal only uses HLC hits however, since the status of how the SLC hits will be handled online is too uncertain at this point.
7 Summary table

<table>
<thead>
<tr>
<th>Linefit</th>
<th>CORSIKA (Hz)</th>
<th>Filter passing ratios [%]</th>
<th>NuGen 100h 250s 250h 500h 1000h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nch</td>
<td>ZTC [m]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15.0</td>
<td>6.9 3.5</td>
<td>45 33 37 47 50 49</td>
</tr>
<tr>
<td>5</td>
<td>10.0</td>
<td>7.9 4.0</td>
<td>47 38 41 53 55 54</td>
</tr>
<tr>
<td>5</td>
<td>5.0</td>
<td>10.1 5.0</td>
<td>49 41 46 57 60 58</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>12.3 6.1</td>
<td>51 48 52 63 64 63</td>
</tr>
<tr>
<td>5</td>
<td>-5.0</td>
<td>15.0 7.6</td>
<td>52 50 54 65 66 65</td>
</tr>
<tr>
<td>5</td>
<td>-10.0</td>
<td>16.8 8.4</td>
<td>52 51 54 66 68 68</td>
</tr>
<tr>
<td>5</td>
<td>-15.0</td>
<td>22.7 11.4</td>
<td>53 52 55 67 68 67</td>
</tr>
<tr>
<td>5</td>
<td>-20.0</td>
<td>24.8 12.4</td>
<td>53 52 55 68 69 68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LLH</th>
<th>CORSIKA (Hz)</th>
<th>Filter passing ratios [%]</th>
<th>NuGen 100h 250s 250h 500h 1000h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nch</td>
<td>ZTC [m]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15.0</td>
<td>6.8 3.3</td>
<td>45 33 37 47 50 49</td>
</tr>
<tr>
<td>5</td>
<td>10.0</td>
<td>7.2 3.5</td>
<td>47 38 41 53 56 55</td>
</tr>
<tr>
<td>5</td>
<td>5.0</td>
<td>9.4 4.6</td>
<td>50 42 48 58 61 59</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>11.6 5.7</td>
<td>51 50 54 64 66 64</td>
</tr>
<tr>
<td>5</td>
<td>-5.0</td>
<td>14.2 6.9</td>
<td>53 52 56 67 68 66</td>
</tr>
<tr>
<td>5</td>
<td>-10.0</td>
<td>15.7 7.7</td>
<td>53 54 57 69 70 68</td>
</tr>
<tr>
<td>5</td>
<td>-15.0</td>
<td>21.2 10.3</td>
<td>54 55 58 70 71 70</td>
</tr>
<tr>
<td>5</td>
<td>-20.0</td>
<td>23.1 11.3</td>
<td>54 56 58 71 72 71</td>
</tr>
</tbody>
</table>

Table 4: Summary of the filter evaluation, varying ZTravelCut

8 Conclusion

We propose to run the LowUpFilter during the IceCube data year 2009 with the following settings:

- NchCut = 5
- ZenithCut = 80°
- ZTravelCut = -10 m
- TimeExtensionCut = 3000 ns
- ZExtensionCut = 600 m
- VetoDepth = 440 m
- Reconstruction = LLH

This gives a rate of 7.7 GB/day without overlap with other filters. The ZTravelCut is a tuning parameter of which the impact on background and signal is seen in Figure 4. An example script using this filter is found at www.icecube.wisc.edu/~olle/example_lowup.py.
Figure 4: Corsika rate and signal passing ratios for up-going atmospheric neutrinos below 1 TeV and two solar WIMP channels, using NchCut=5 and LLH as reconstruction