Thoughts on Dealing with AfterPulsing

- What is the problem?
- What are the issues with attempts to deal with it?
- What principles should guide our work on this?
  - How do we judge the efficacy of solutions?
- Proposed cut for future study.

Summary of The Problem

- PMT afterpulsing contaminates later events
  - Creates fictitious events
  - Distortion of otherwise good events
- Not characterized very well
  - Might never be perfectly characterized, but improvements are almost certain.
- Absent from MC
  - Can be included to the extent that it is characterized

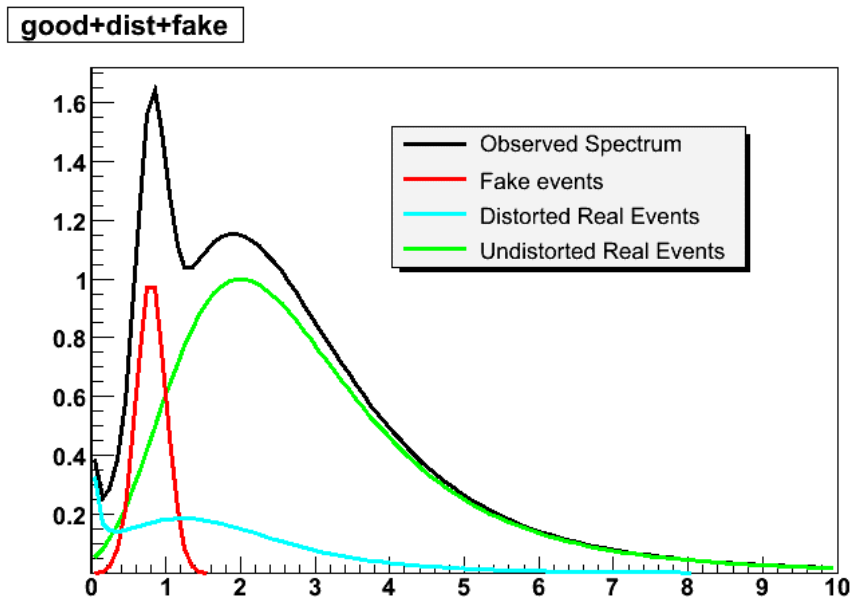
The Problem, cont.

- With no mitigation, comparisons of Data and MC are to some extent invalid.
- Even if MC models effect perfectly, we want to limit unnecessary distortions – use cuts.
- Cuts applied can hurt or help to varying extents.
  - E.g.: Data/MC agreement can improve because it solved the problem, or because it is accidentally compensating another effect, for example physics
  - Activity consistent with afterpulsing can be good activity from current event.
- What are the relative merits of different cuts?
- How can we judge the results?

Goals

- Eliminate data-MC differences in final samples due to afterpulsing
- Minimize biases in reconstruction and event selection

Cartoon spectrum:
In principle, a cut can alter each of these components independently.



Existing cuts (I)

- Timing cut (event duration):
  - Niki found in April that it greatly reduced/eliminated excess peak at low energy.
  - Wide timing presumably due to random association by reco of afterpulsing cuts with each other, or with other hits
  - From 1st principles, would appear to be non-biasing
  - An excellent way to get a pure sample of fake events
  - However, individual afterpulsing hits in a real event can randomly have normal timing, too
    - This is why I suggested a cut on previous activity starting in April

Existing cuts (II)

- Rho Cut: (ratio) – cut on ratio of early ph to current event ph
  - P.S. suggested to (and tried by) Tom in May.
  - Suggested decay time (700ns) weighted version to Brian.
  - Both greatly reduce low energy peak
    - Shown in Ely, and various NC meetings.
  - Will introduce intensity-dependent bias of spectrum
    - Knowable from MC with correct intensity

Existing cuts (III)

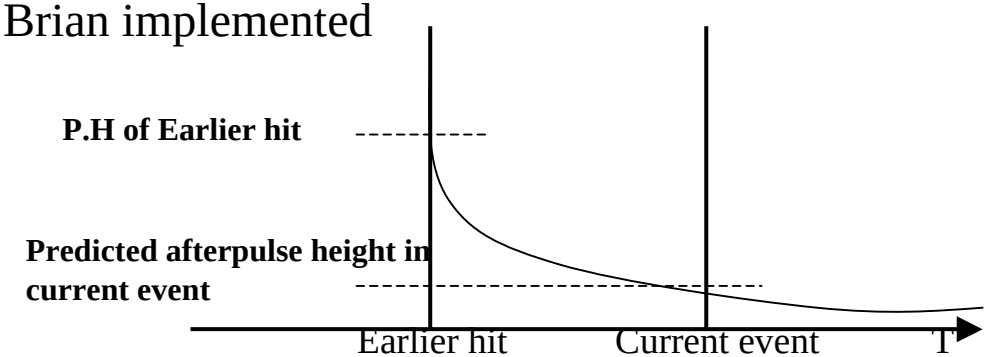
- Multiple strip cut
  - Niki/Libby – September – Also greatly reduces low energy peak.
    - Libby's study: tag events with >20% strips with earlier hits
      - Effectively a version of the rho cut, with no adc info, and no finite time window or weighting.
  - Niki's study (from 9/7) - Remove strips from reconstruction
    - In principle, this will tend to affect good Low Energy events differently than good High energy events.
    - Again, measurable from MC.
- Each of the existing cuts would give good data/MC comparison with perfect MC model
  - What happens before there is a perfect model?
  - What is remaining bias? Is it a smearing affect that will make physics more difficult?

Evaluation

- Seeing Low Energy excess reduce is good,
  - but not sufficient.
  - Any bias needs to be measured.
  - Avoiding any bias if possible is clearly preferable.
- Data/MC comparisons of high level variables will always be conflated with physics issues
  - Are there good low-level variables that are sensitive to this?
- Need to use Data/Data comparisons as much as possible:
  - single batch running, single event snarls (Karol/Tom)
  - 1st events vs. later events (Niki)
  - Spectrum vs. time, number of low PH events vs. time in spill (P.S. and others)

Proposed Cut to Study

- Make a cut on absolute expected activity due to afterpulsing
  - Estimate activity from best model now available
  - Mean ph(t_now)/ph(t_early) vs. (t_now-t_early)
    - Numerator of the rho cut Brian implemented



  - In reality, this is 64x64 matrix, but can try pmt-wise, or strip-wise, ignoring inter-pixel effects for now.
- Cut on maximum acceptable activity for a low-energy event
  - E.g.: require mean afterpulsing activity under every event to be less than 10% for a 500MeV event (50MeV)
  - Apply same cut to all events

Advantages

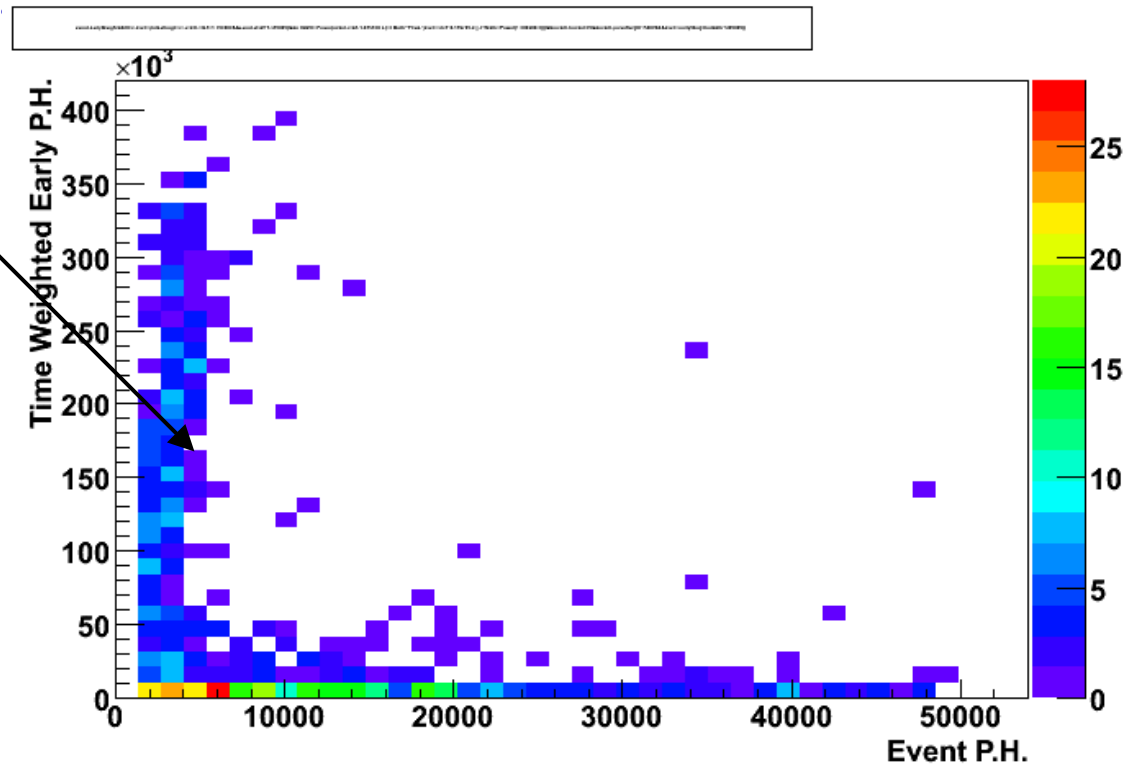
- No distortion of individual event energies
  - Cut on entire event
- No bias vs. energy in rejection of events with no actual contamination
  - Event is judged only on absolute prediction afterpulsing energy, not in any way on it's own energy, number of strips, etc.
  - Bias in remaining spectrum (from remaining contamination) has 2nd order uncertainty mainly from accuracy of model.

Disadvantages

- Aforementioned spectrum distortion (remaining from the original effect) may be difficult to estimate
  - Problem with all of these.
- Statistics?
  - How many events will be lost at high energy to avoid bias?
  - If we revert to a ratio, we can measure resulting bias in good event spectrum, as long as MC models intensity correctly.

Early Time Weighted ADC vs. Event Pulseheight

- Most events with early weighted ADC are low PH peak events:



To Do (for me)

- Follow up on absolute rho cut.
- Understand losses/biases
- Do data/data comparisons mentioned above.