Outrigger Timing Calibration & Reconstruction

- Purpose:
  - **To incorporate outrigger hits in event angle fitting**
  - Additionally incorporated **muon layer** hits in angle fit.

- Tasks Performed:
  - Determined calibrations constants from laser data
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  - **Checked for improvements in angle fitting using MC gammas and real data**.

Outrigger Timing Calibration & Reconstruction

- Calibrations:
  - Need tped, slewing and TOT to PE
    - **Andy S. made first attempt at PE cals.**
  - Laser calibration set used:
    - Set collected in July & August 2003 by Matt Wilson, Xianwu Xu, and Scott DeLay (**THANKS to ALL!**)
    - Two functional sets:
      - Tpeds set
        - **Matt ran a single (same) fiber to each outrigger**
        - Outrigger 116 as reference (periodically fired to check systematics)
        - Fixed high light level of HiTOT > 500, couple thousand shots
      - Slewing set
        - used installed fiber network and new optical switch
        - fired full patch at a time (varied from 1 to 10 tanks per patch)
        - light levels from < 1 PE to ~ 1000 PE, ~ 1000 shots per light level

Outrigger Timing Calibration & Reconstruction

- Calibrations (cont):
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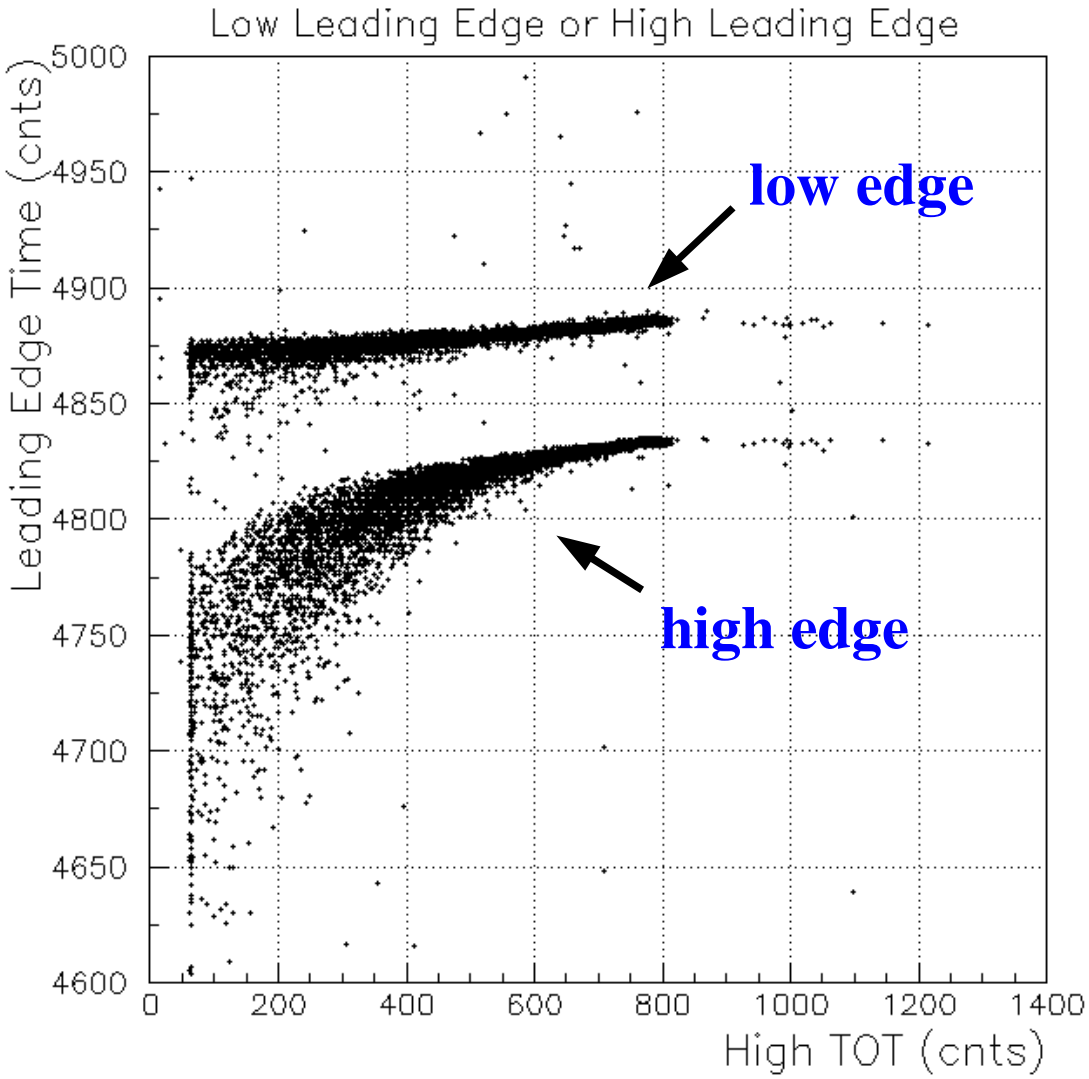
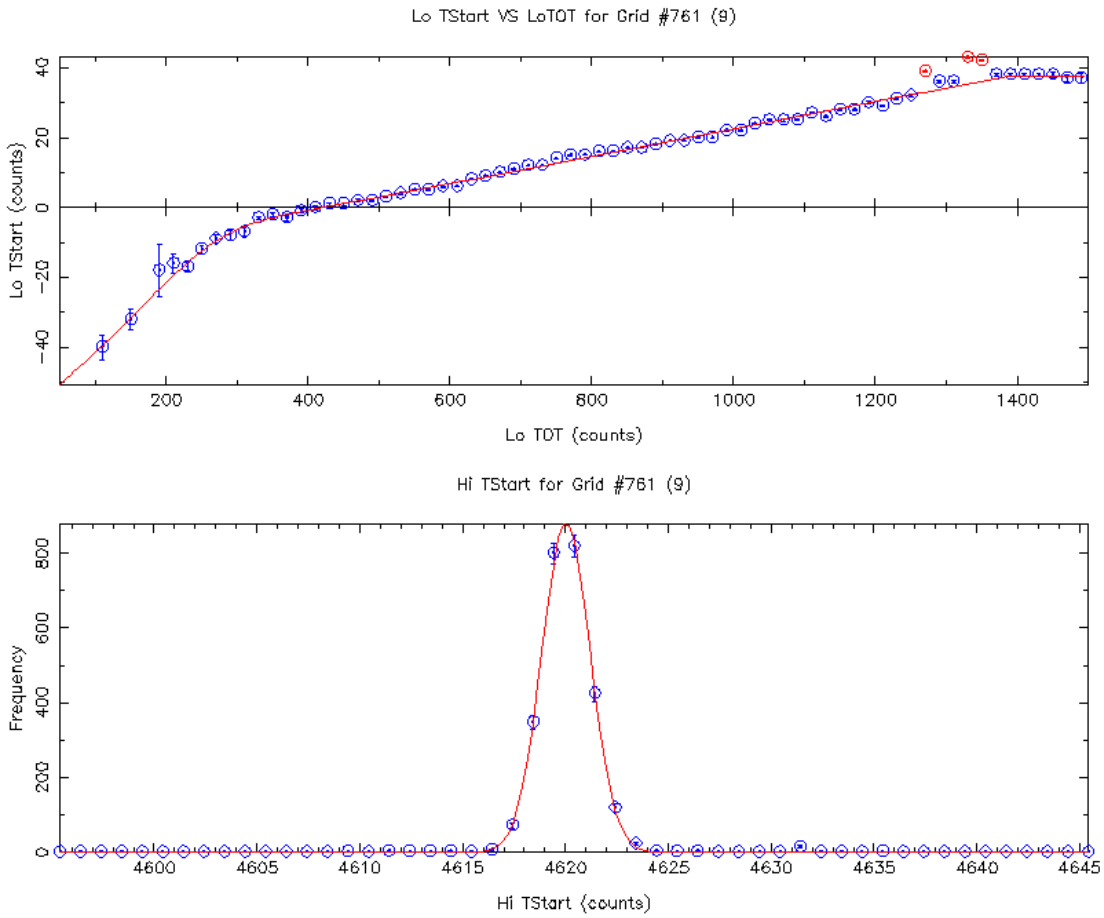
Outrigger Timing Calibration & Reconstruction

- Calibrations (cont):
  - Slewing determination
    - Computed median/peaks of leading edges versus tot
    - Fit to same functional form as pond pmts, except added parameter of max. TOT value above which slewing is flat
    - Determined that timing resolution for low leading edge is better than high leading edge:



Outrigger Timing Calibration & Reconstruction

- Calibrations (cont):
  - Slewing & Tped determination
    - Applied the slewing corrections before fitting Tpeds
    - Example slewing curves and Tped distributions:



Good slewing curve: large TOT range!

Outrigger Timing Calibration & Reconstruction

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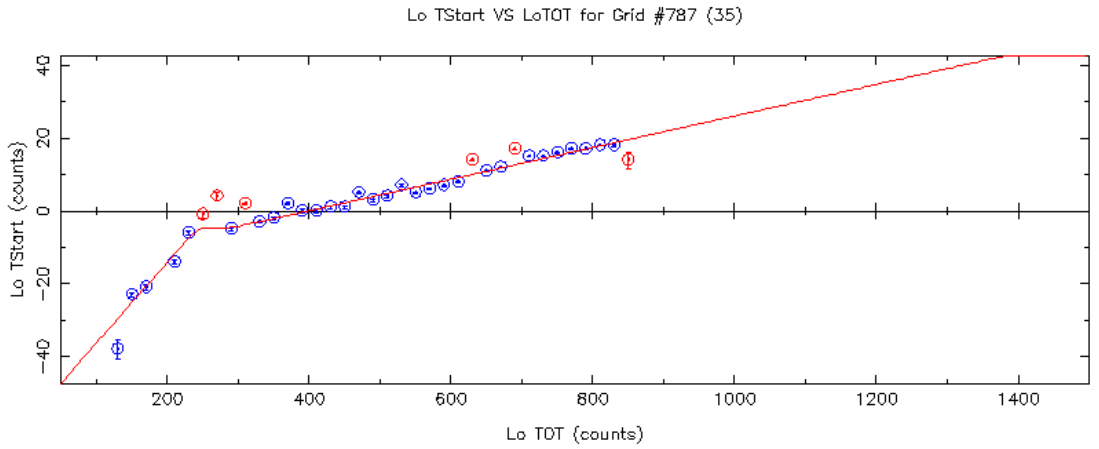
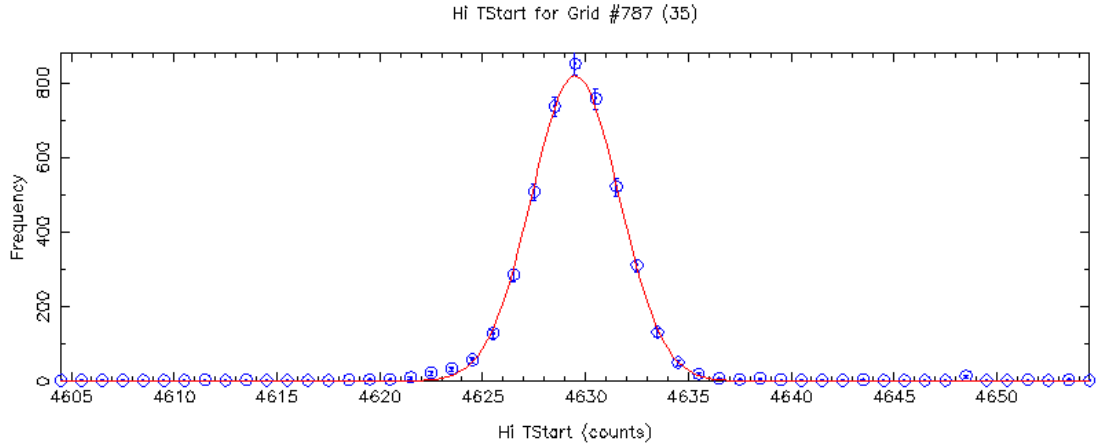




Poor slewing curve: small TOT range!

Outrigger Timing Calibration & Reconstruction

- Calibrations (cont):
  - Need outrigger array – pond timing offset.
    - Used real data events with theta < 10° and cores fitted on pond.
    - Used “inner ring” of outriggers (#1 - #32)
    - MC gammas indicate these hits should be centered at zero, so free of any shower front shape/width effects
    - The Tx peaks of these outriggers were distributed rough Gaussian with width of ~ 1.5 ns.

  - **Summary**: I have **141** out of **175** outriggers with fair to good slewing and tped cals.

Outrigger Timing Calibration & Reconstruction

- Shower front shape/width timging effects parameterization
  - curvature, sampling, weights
  - **From experiences with Cygnus experiment decided to do timing corrections and weights (i.e. Tchi widths) as two 2-D functions of counter-core distance (m) and hit pulse height.**
  - Used MC 3.2 gammas with nfit > 50.
  - Parameterized shifts in angle fit Tchi peaks and Tchi widths vs. counter-core distance and pulse heights
  - **Divided counter-core distance into thirteen 10 m bins**
  - For each of these bins, **divided pulse heights into 69 PE bins** with widths:
    - 1-10 PE – 1 PE
    - 10-20 PE – 2 PE
    - 20-100 PE – 5 PE
    - 100-500 PE – 10 PE
    - Did this for AS layer, MUON layer and outriggers separately

Outrigger Timing Calibration & Reconstruction

- Shower front shape/width timging effects parameterization (cont.)
  - For each of the 3 x 897 histograms, I fit the peak region to a Gaussian
  - For hits > 10 PE I used the fitted Gaussian width
  - For hits < 10 PE I determined the FWHM and divided by 2.38
  - I then fit the peaks vs. pulse height and widths vs. pulse height for each of the 13 counter-distance bins.
  - Sample plots: Please see memo!

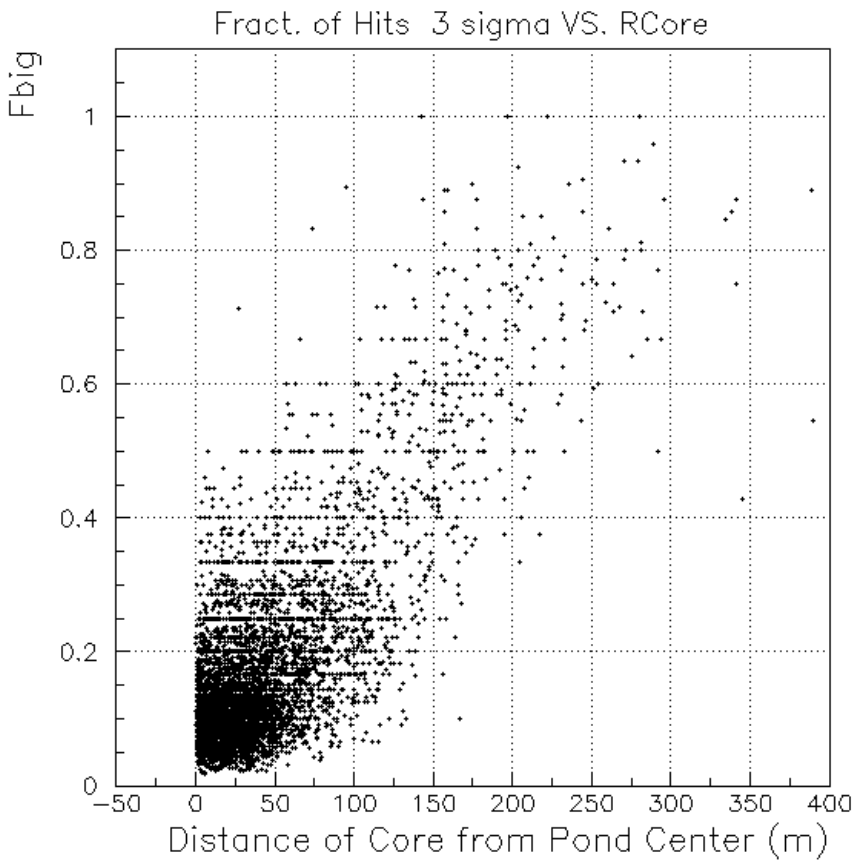
- Optimized angle fit method
  - Since changed timing widths/weights, and included many more hits in the angle fits, needed to re-optimize the following parameters:
    - Tchi cuts for keeping hits in the angle fit
      - they were: 2.75, 1.75, 1.00 **0.50** sigma
      - changed to: 5.00, 3.00 2.50, **1.00** sigma

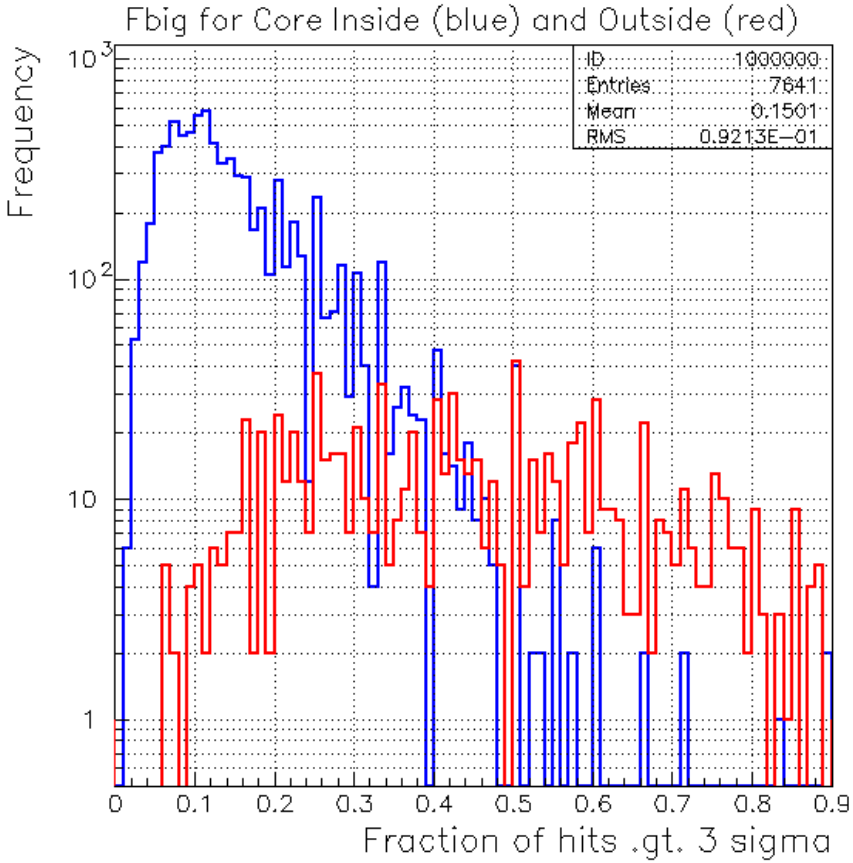
Outrigger Timing Calibration & Reconstruction

- Optimized angle fit method (cont.)
  - Since changed timing widths/weights, and included many more hits in the angle fits, needed to re-optimize the following parameters:
    - PE cuts for each fit pass:
      - they were: 2.25, 1.75, 1.25, 0.75, 0.50 PE
      - changed to: 3.00, 2.50, 2.00, 1.50, 0.50 PE
    - Introduced relative global hit weights between the AS layer, MUON layer and outriggers
    - RELAX parameter – if nfit is < than this, relax pe cut one level
      - **change from 450 to 1000**

Outrigger Timing Calibration & Reconstruction

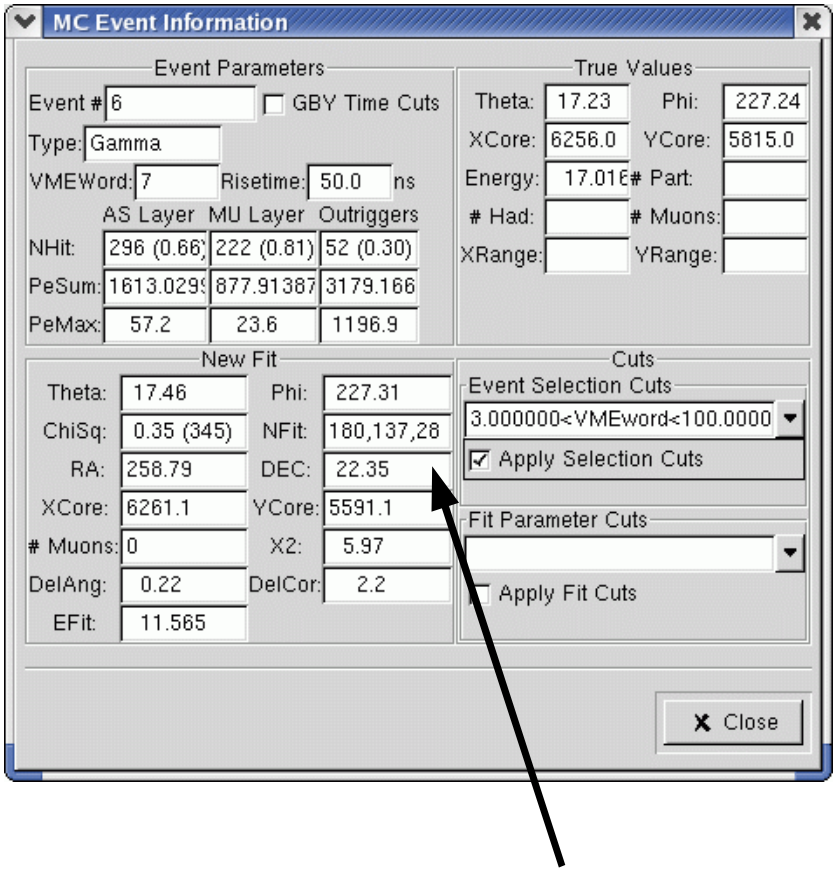
- Optimized angle fit method (cont.)
  - **Added cut on fraction of hits with PE > 3 and Tchi > 3 σ. (F_{big})**
    - Cuts out large fraction of gamma events with cores outside array
      - example can cut 80% outside cores and only lose 5% inside cores.



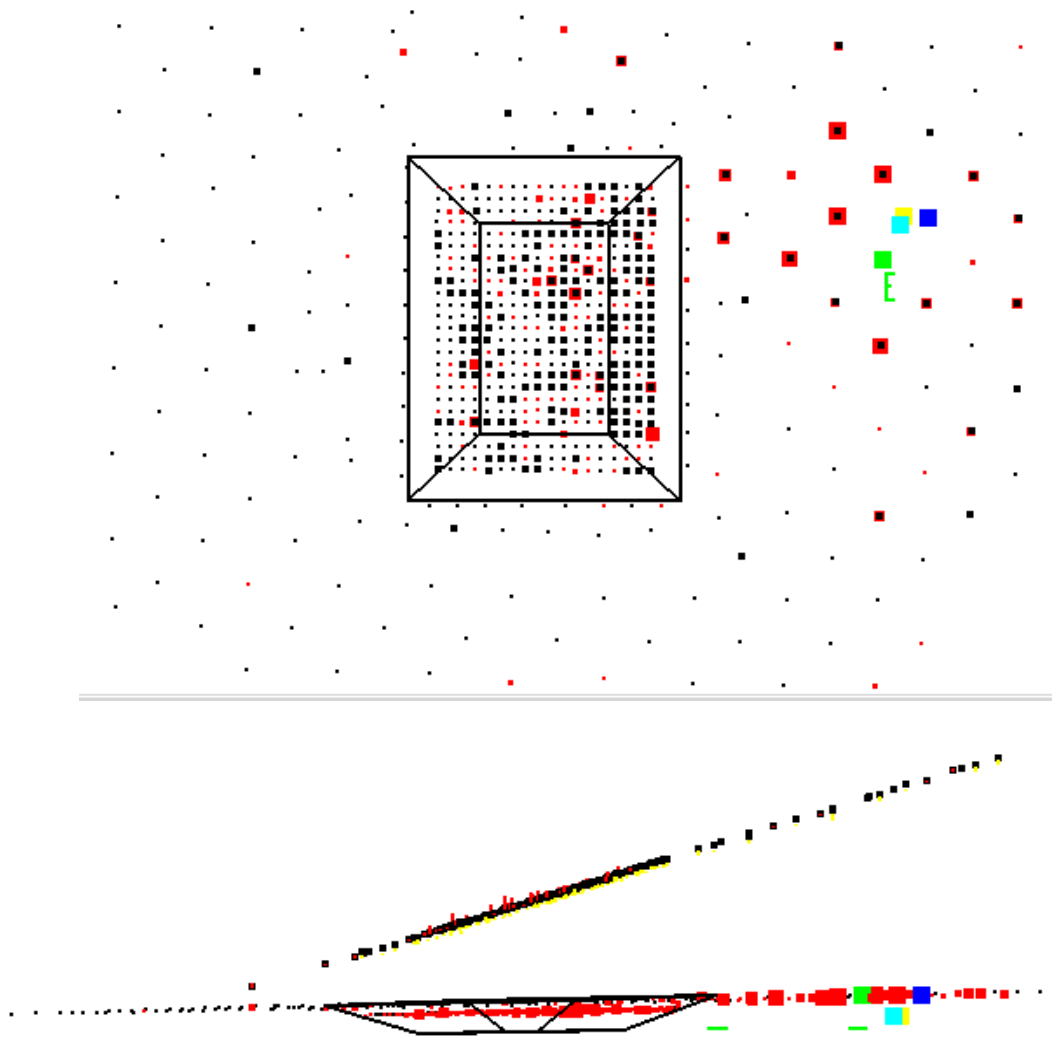


Outrigger Timing Calibration & Reconstruction

- Predictions from MC gammas:
  - Example MC gamma fit:



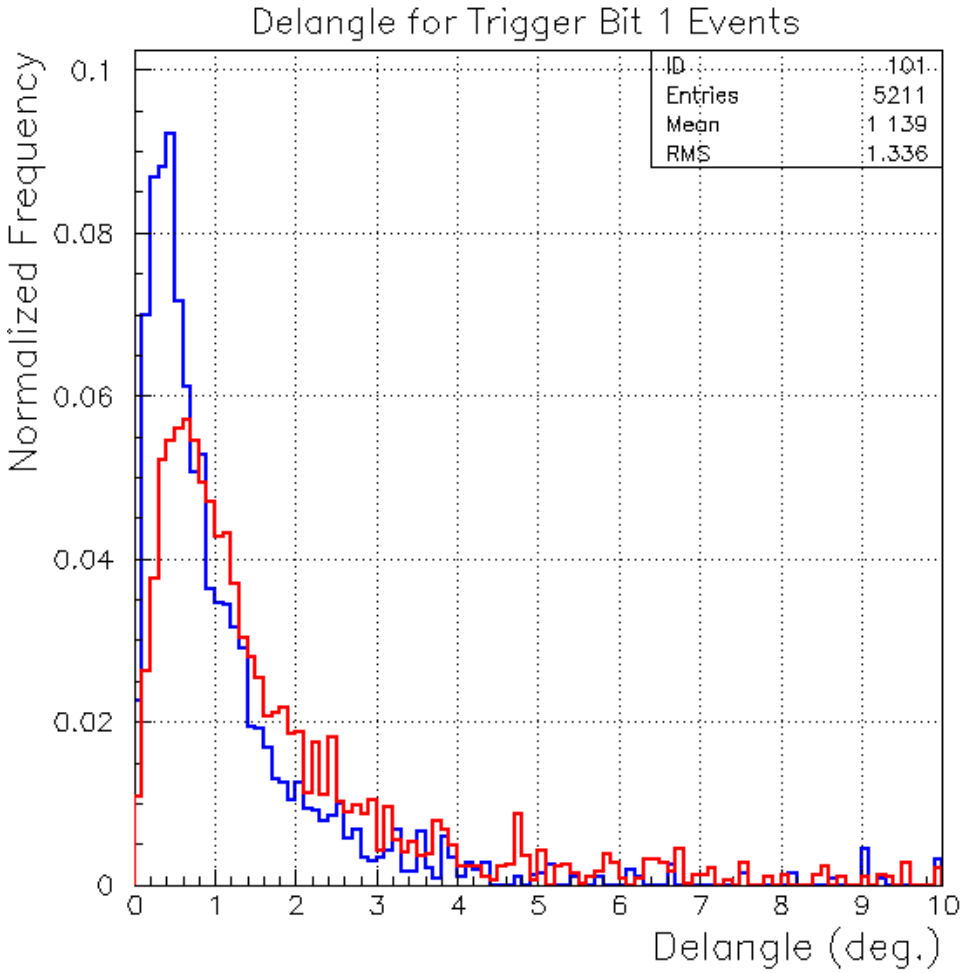
black dots indicate used in fit



nfit for as, muon, outriggers

Outrigger Timing Calibration & Reconstruction

- Predictions from MC gammas (cont):
  - Delangle distributions for various triggered events
    - Blue – new fit, Red – old fit
    - medians: Blue: 0.56°, Red: x.xx°



Outrigger Timing Calibration & Reconstruction

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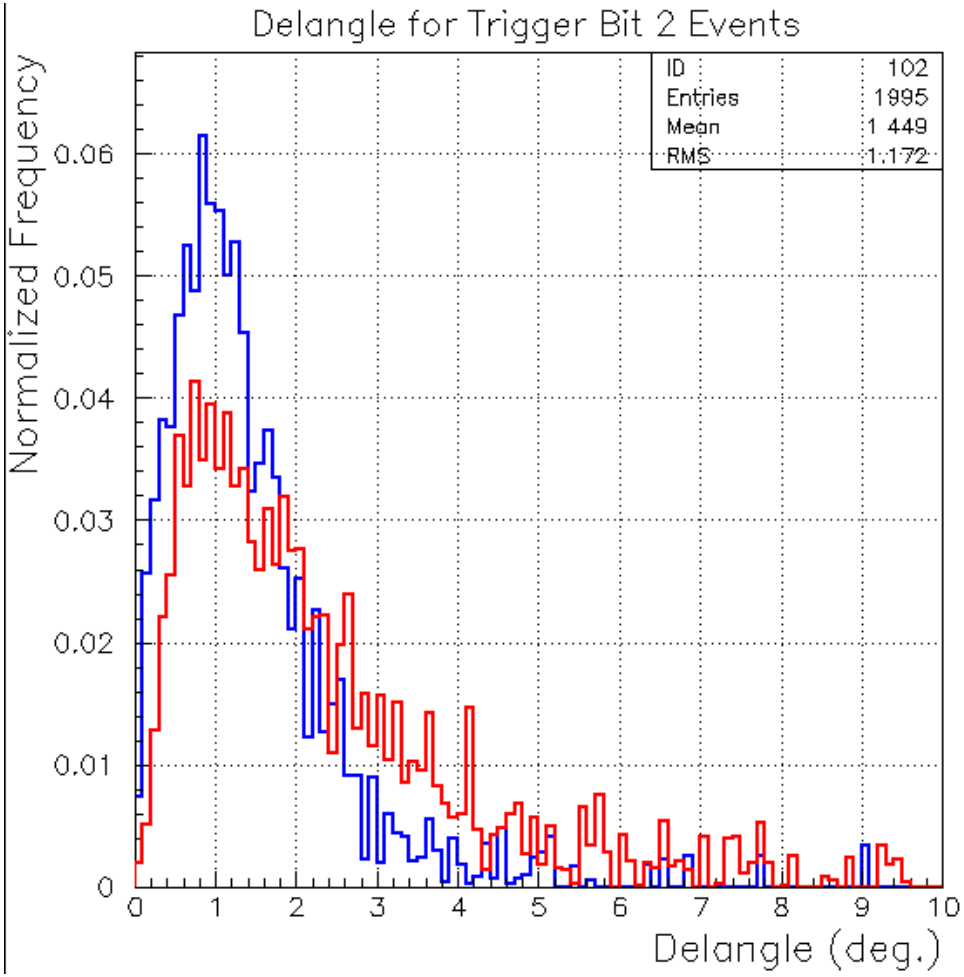
    - medians: Blue: x.xx^{o}, Red: x.xx^{o}



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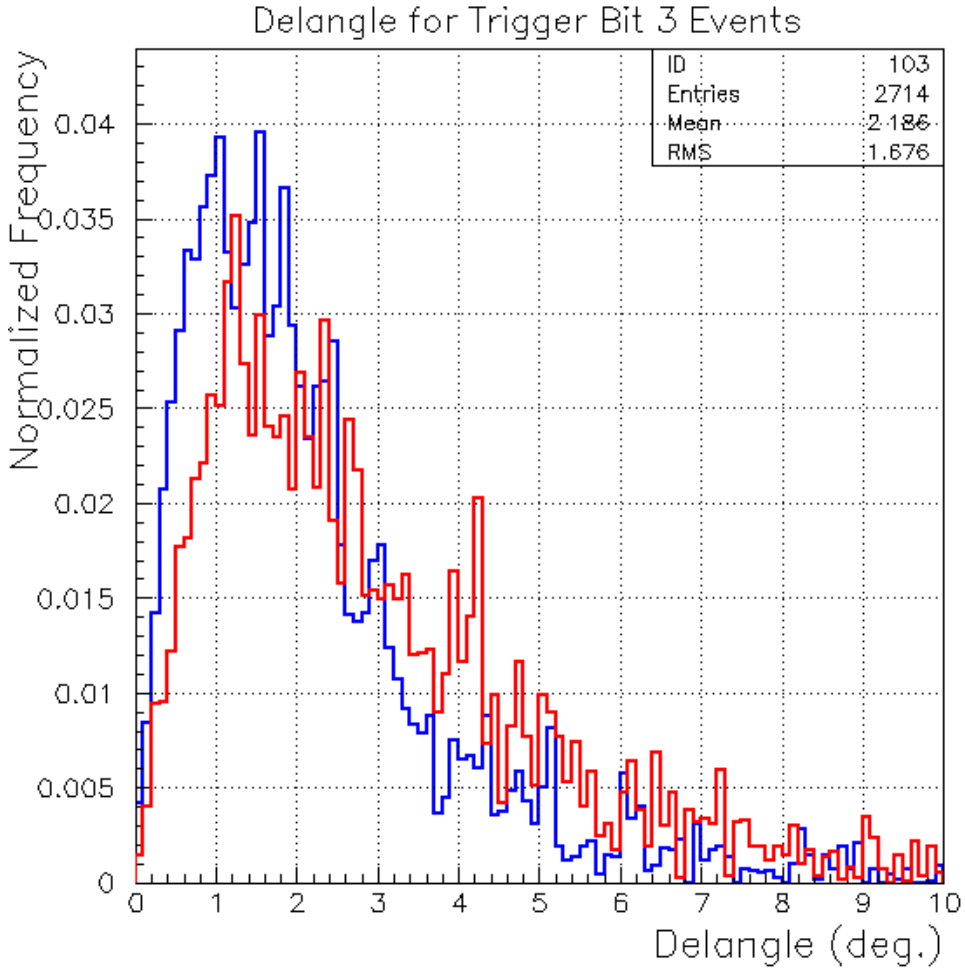
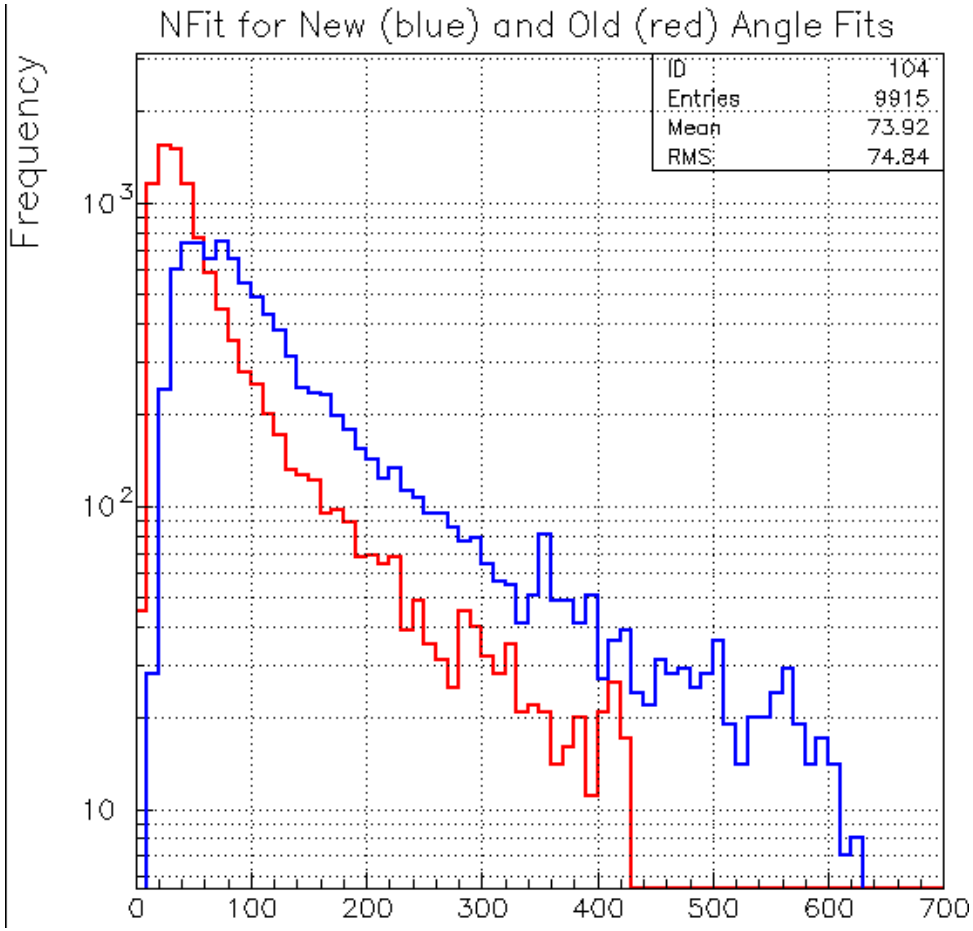


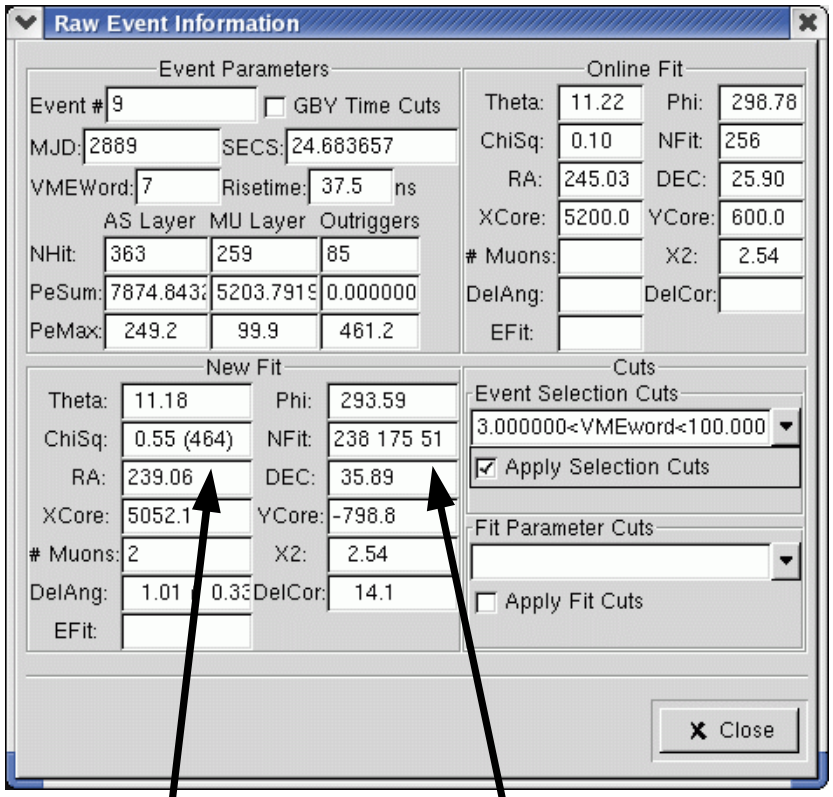
Outrigger Timing Calibration & Reconstruction

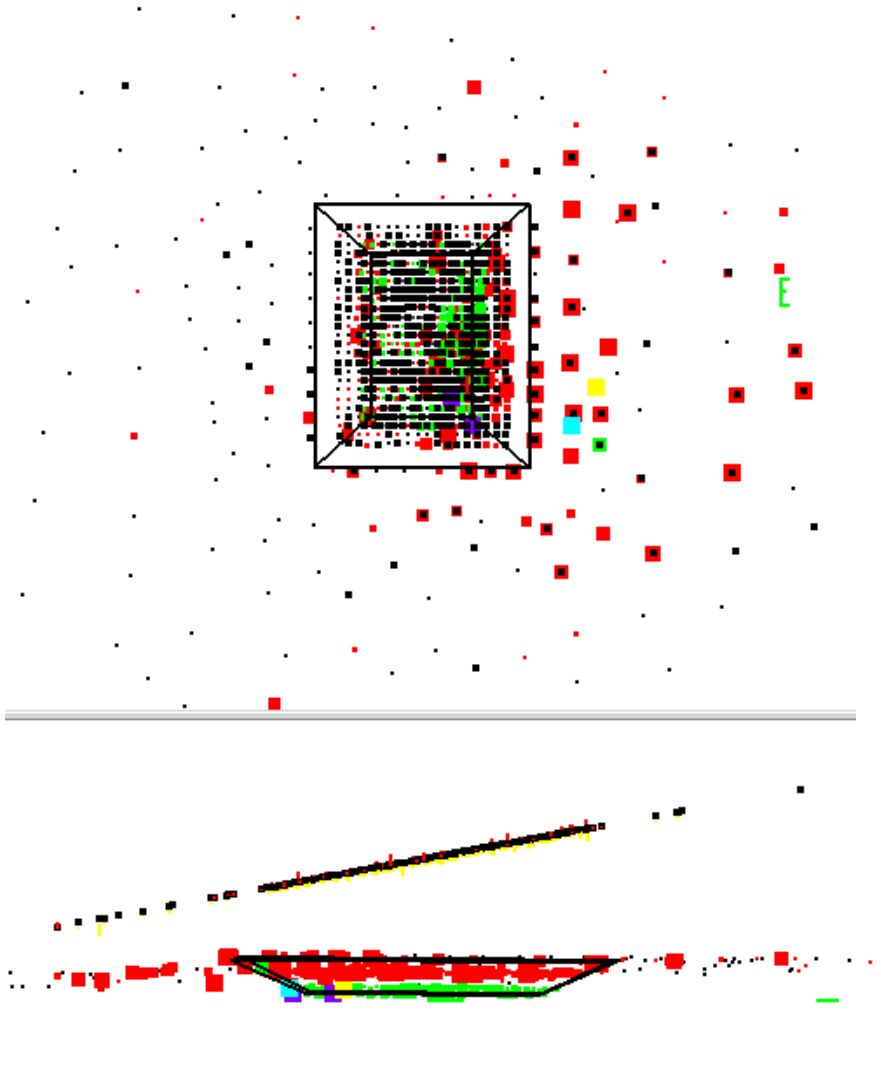
- Predictions from MC gammas (cont):
  - Nfit distributions
    - Blue – new fit, Red – old fit
    - medians: Blue: 100, Red: 46
    - All trigger types



Outrigger Timing Calibration & Reconstruction

- Results using real events:
  - Example fitted event:



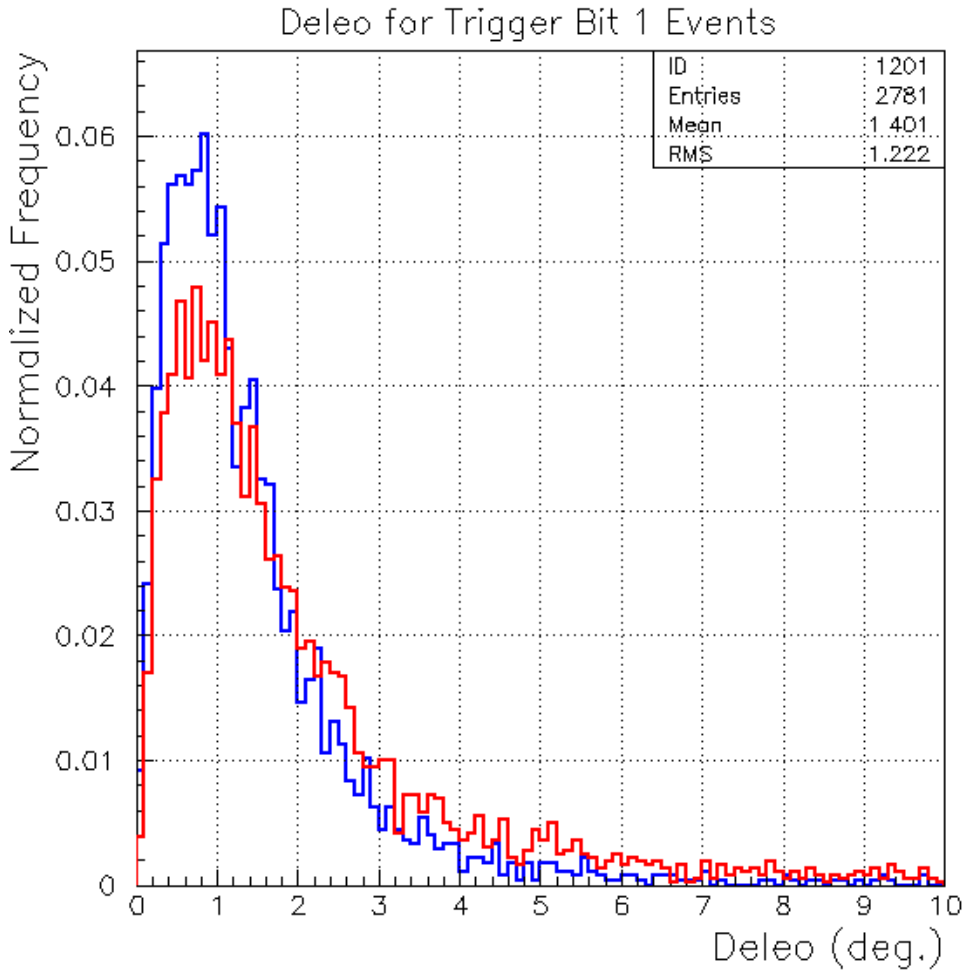


Total nfit

nfit for as, muon, outriggers

Outrigger Timing Calibration & Reconstruction

- Results using real events:
  - Deleo distributions for various trigger events
    - Blue – new fit, Red – old fit
    - medians: Blue: x.xx, Red: x.xx



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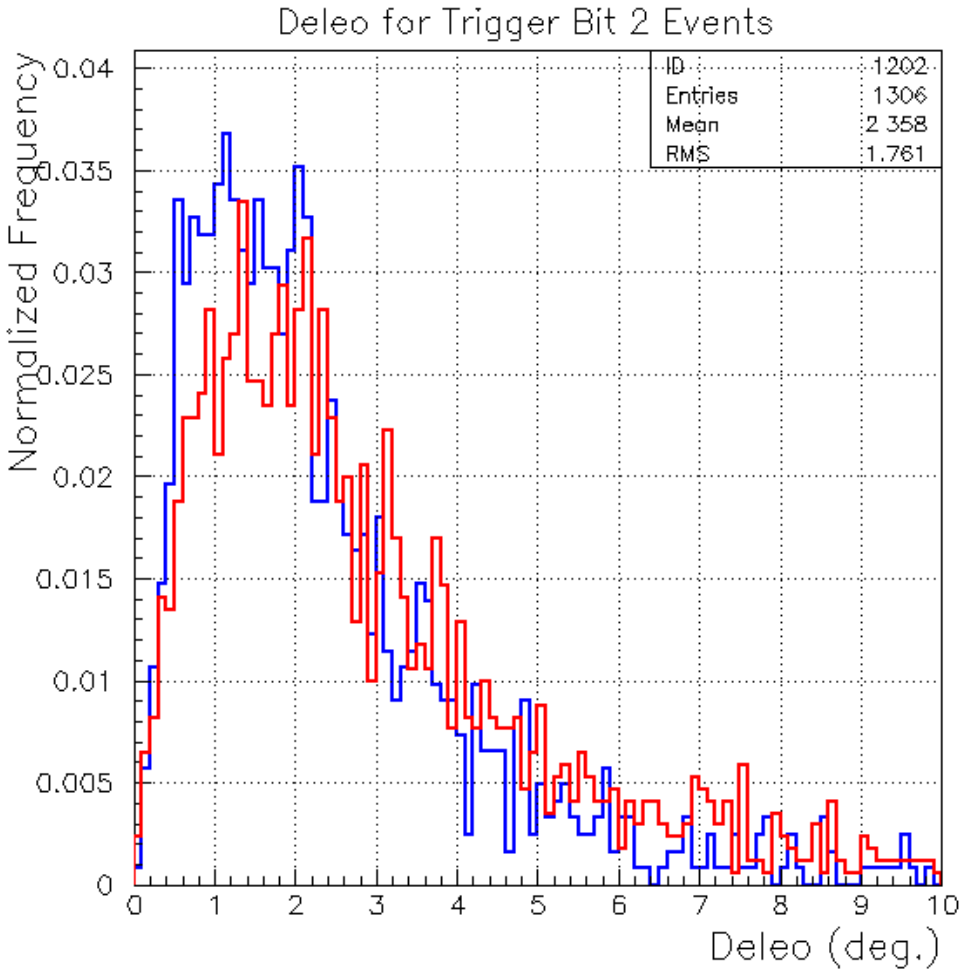

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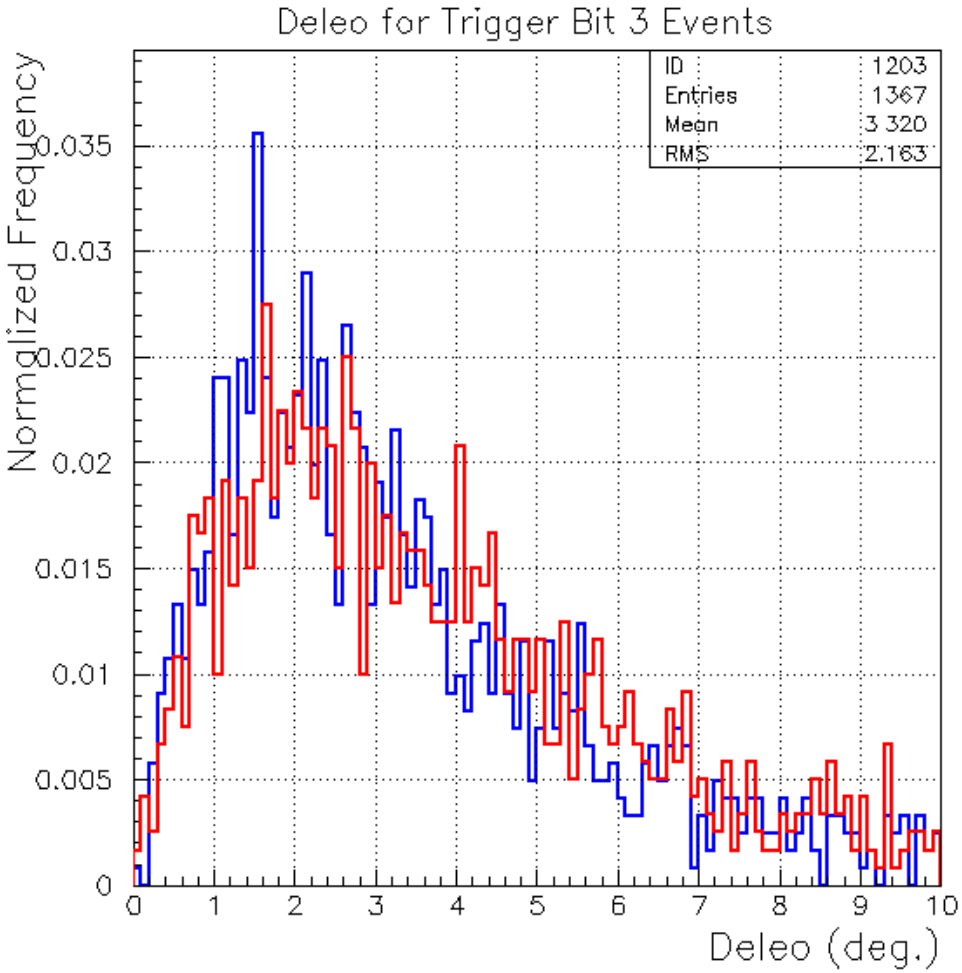

Outrigger Timing Calibration & Reconstruction

- Results using real events:
  - Ran new fitting on crab
    - only 95 days so far
    - $\sigma = 1.29 +/- 0.45^{o}$
    - $N_{\sigma} \sim 2.1$