

# Outtrigger Timing Calibration & Reconstruction

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

- Tasks Performed:

- Determined calibrations constants from laser data
- Tpeds & electronic slewing

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- Modified standard offline code to implement these changes
- **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  $\sim 1000$  PE,  $\sim 1000$  shots per light level

# Outtrigger Timing Calibration & Reconstruction

- Calibrations (cont):
  - Slewing determination
  - Computed median/peaks of leading edges versus tot

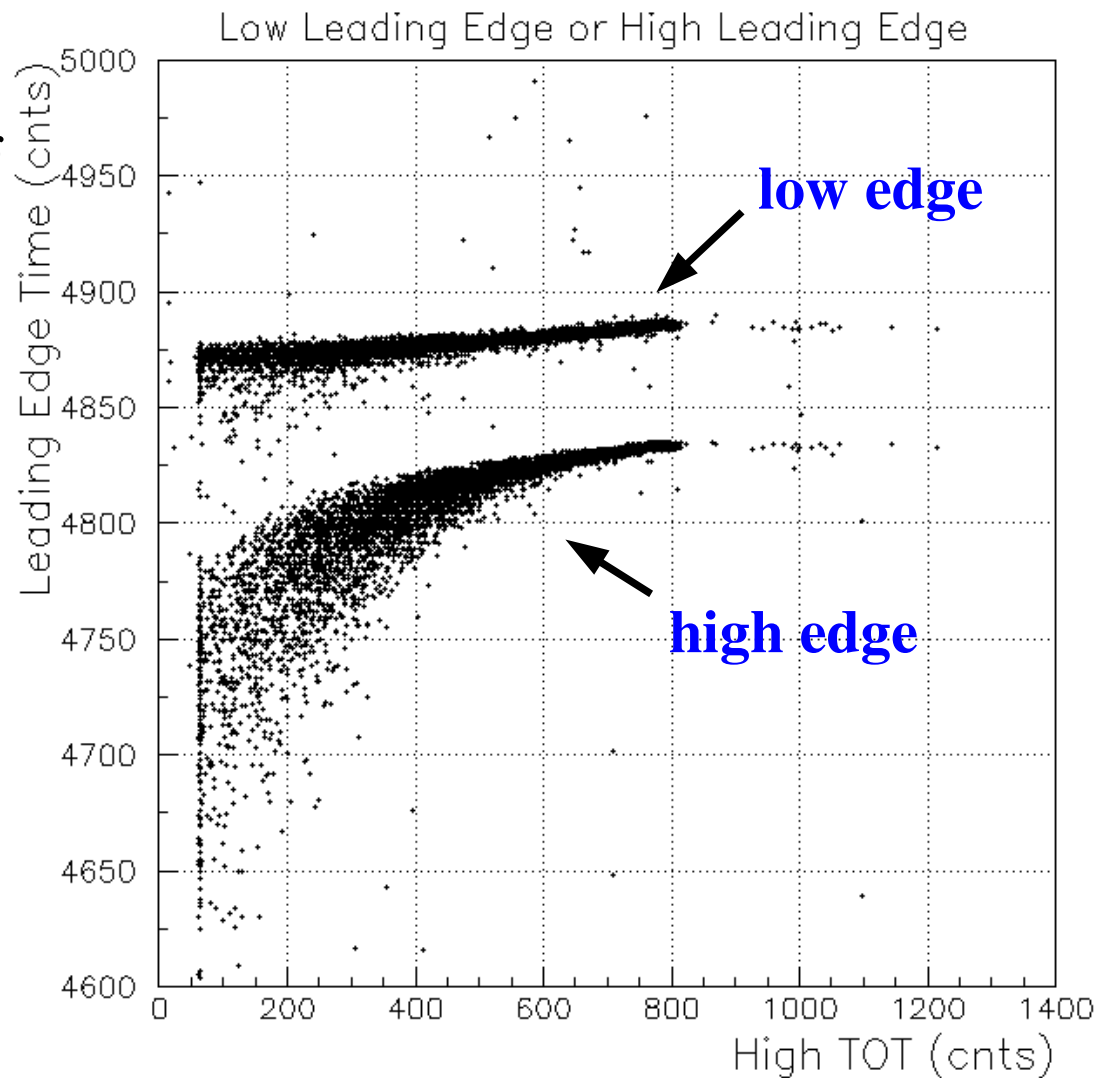
# Outtrigger Timing Calibration & Reconstruction

- 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



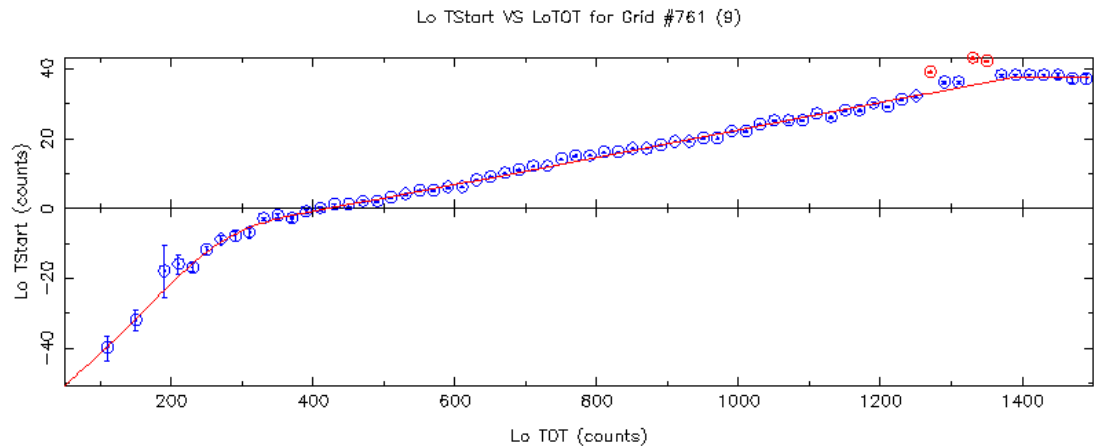
# Outtrigger Timing Calibration & Reconstruction

- 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:

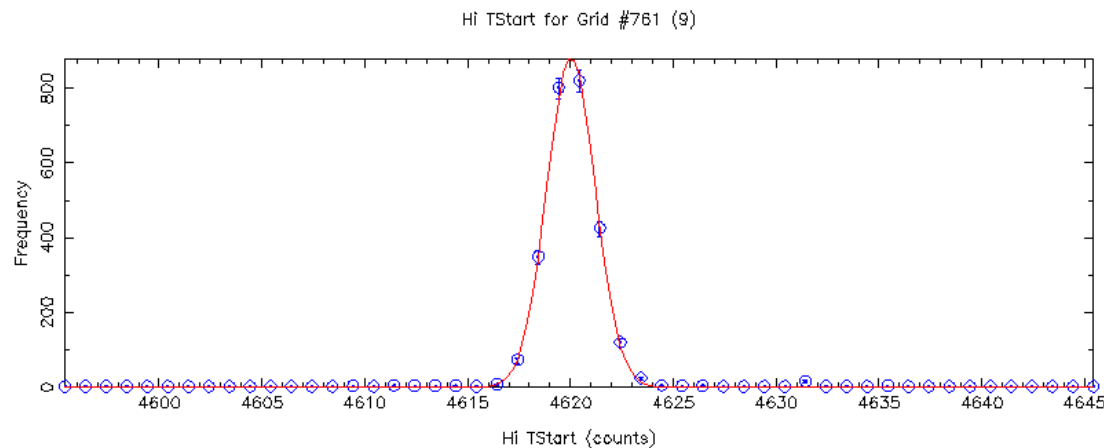


# Outtrigger Timing Calibration & Reconstruction

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

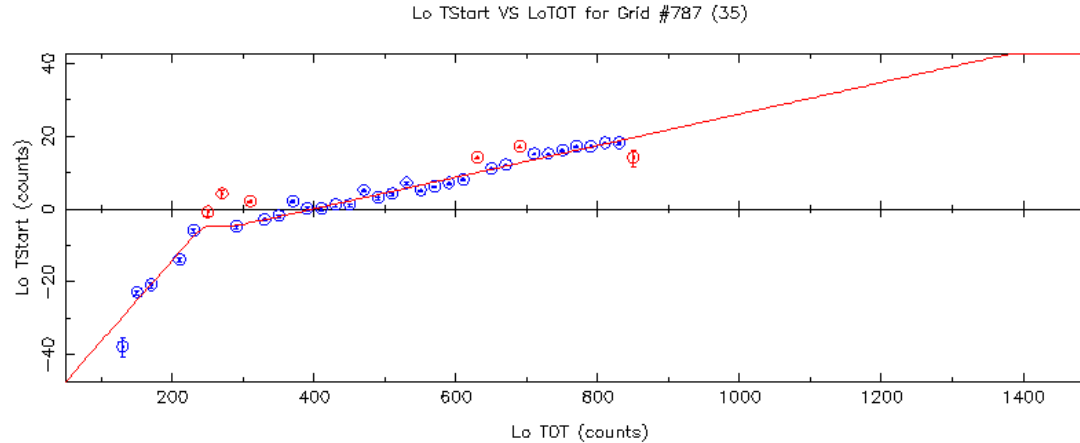


Good slewing  
curve: large  
TOT range!

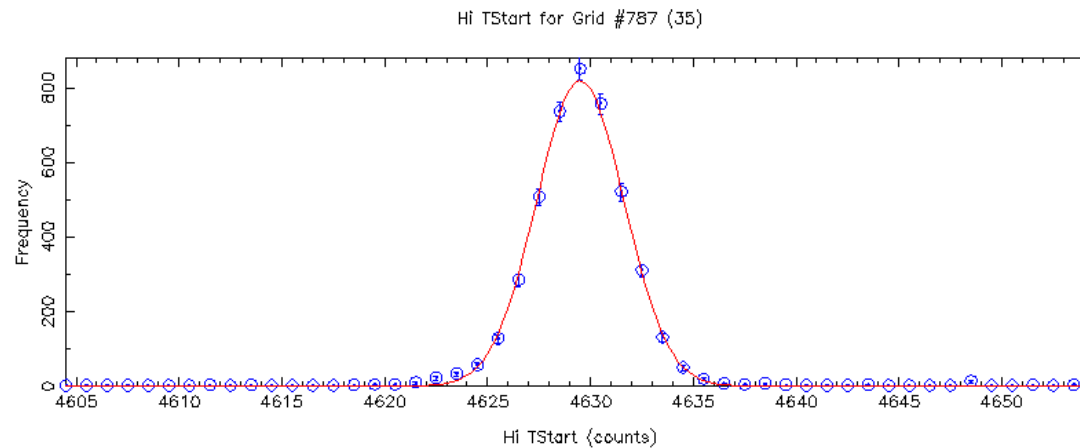


# Outtrigger Timing Calibration & Reconstruction

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



Poor slewing  
curve: small  
TOT range!



# Outrigger Timing Calibration & Reconstruction

- Calibrations (cont):
  - Need outrigger array – pond timing offset.
  - Used real data events with  $\theta < 10^\circ$  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  $\sim 1.5$  ns.
- **Summary:** I have **141** out of **175** outriggers with fair to good slewing and tped calcs.

# Outrigger Timing Calibration & Reconstruction

- Shower front shape/width timing 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

# Outtrigger Timing Calibration & Reconstruction

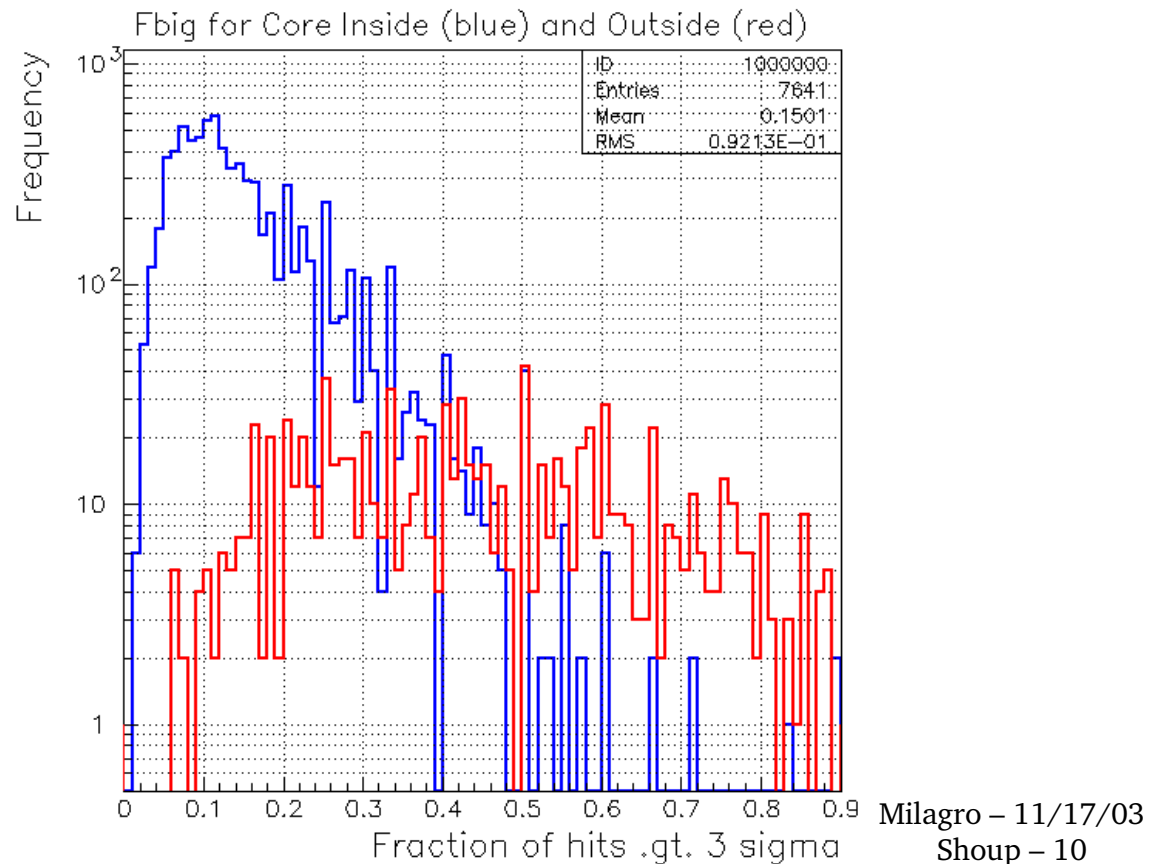
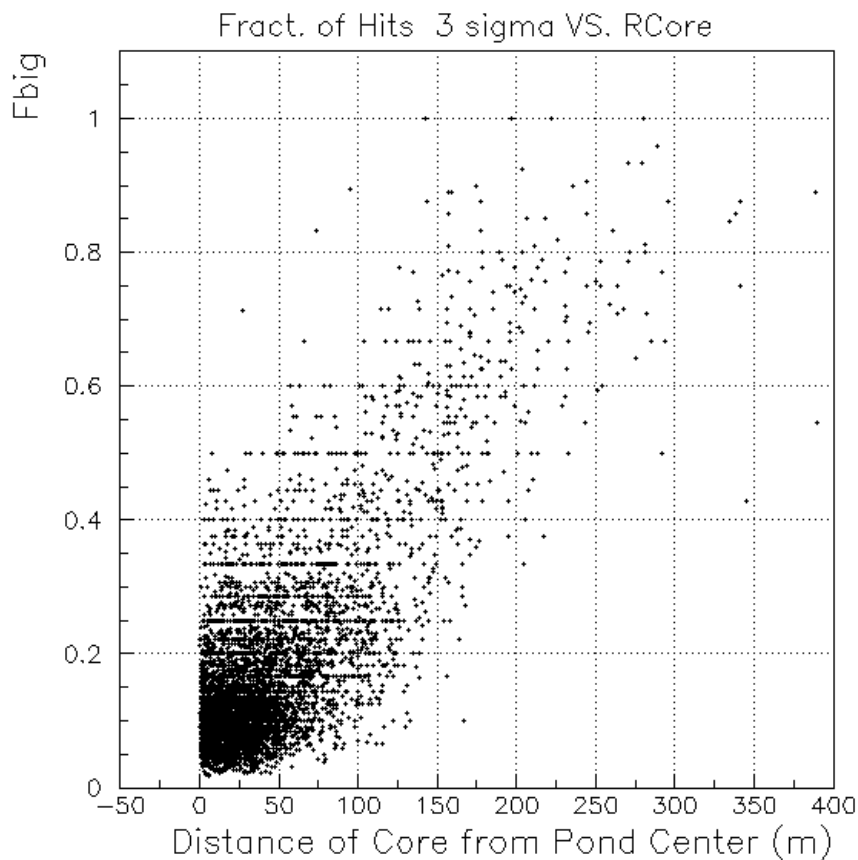
- Shower front shape/width timing effects parameterization (cont.)
  - For each of the 3 x 897 histograms, I fit the peak region to a Gaussian
  - For hits  $> 10$  PE I used the fitted Gaussian width
  - For hits  $< 10$  PE I determined the FWHM and divided by 2.38
  - I then fit the peaks vs. pulse 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

# Outtrigger 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**

# Outtrigger Timing Calibration & Reconstruction

- Optimized angle fit method (cont.)
  - **Added cut on fraction of hits with PE > 3 and Tchi > 3  $\sigma$ . ( $F_{big}$ )**
  - 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:

MC Event Information

Event Parameters			True Values				
Event #	6	<input type="checkbox"/> GBY Time Cuts	Theta:	17.23	Phi:	227.24	
Type:	Gamma		XCore:	6256.0	YCore:	5815.0	
VMEWord:	7	Risetime:	50.0 ns	Energy:	17.01E#	Part:	
	AS Layer	MU Layer	Outriggers	# Had:		# Muons:	
NHit:	296 (0.66)	222 (0.81)	52 (0.30)	XRange:		YRange:	
PeSum:	1613.029	877.91387	3179.166				
PeMax:	57.2	23.6	1196.9				

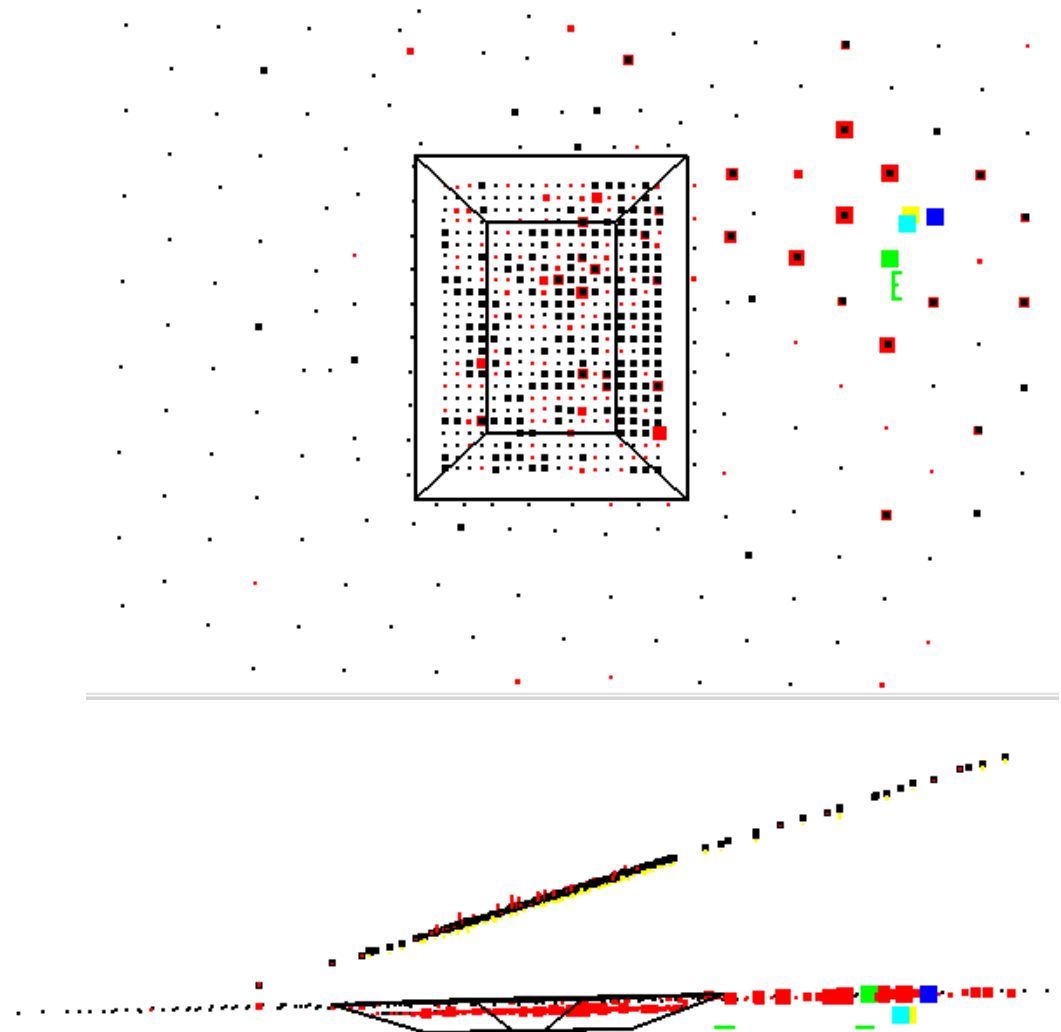
New Fit		Cuts	
Theta:	17.46	Phi:	227.31
ChiSq:	0.35 (345)	NFit:	180,137,28
RA:	258.79	DEC:	22.35
XCore:	6261.1	YCore:	5591.1
# Muons:	0	X2:	5.97
DelAng:	0.22	DelCor:	2.2
EFit:	11.565		

Event Selection Cuts  
3.000000<VMEword<100.0000  
 Apply Selection Cuts

Fit Parameter Cuts  
 Apply Fit Cuts

Close

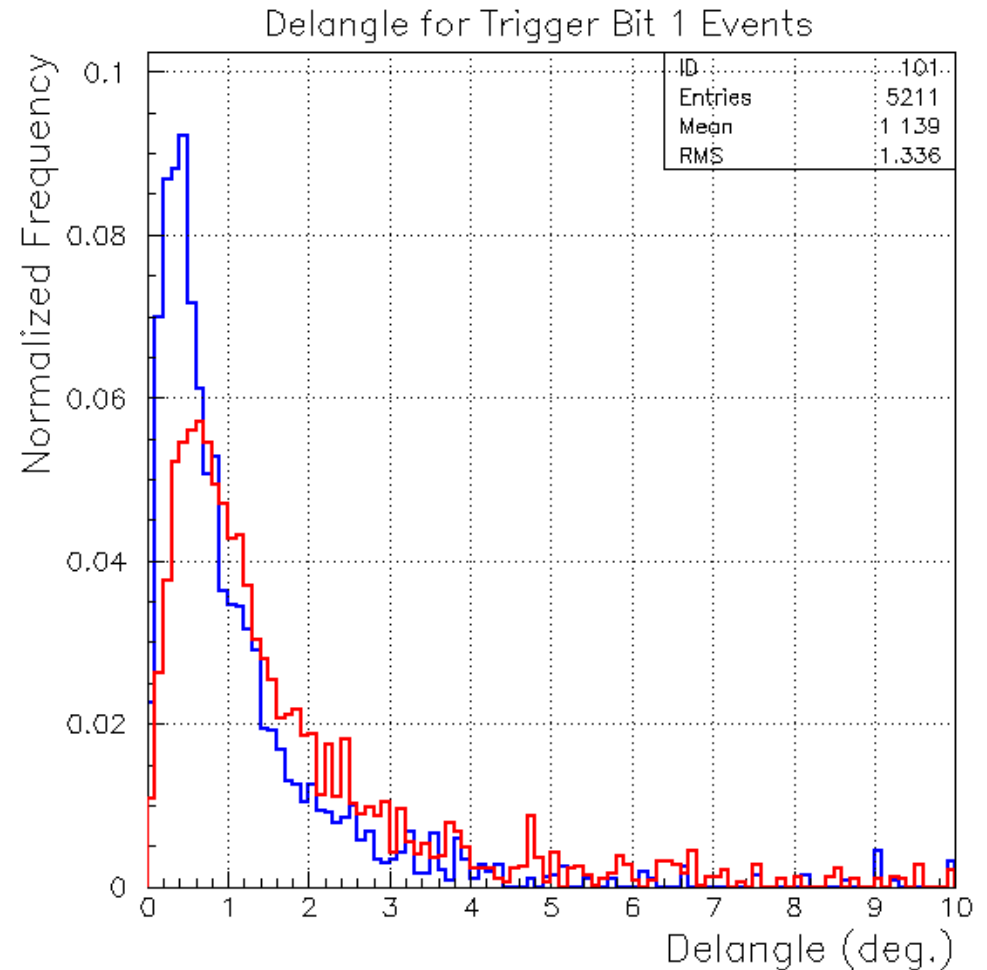
black dots indicate used in fit



nfit for as, muon, outriggers

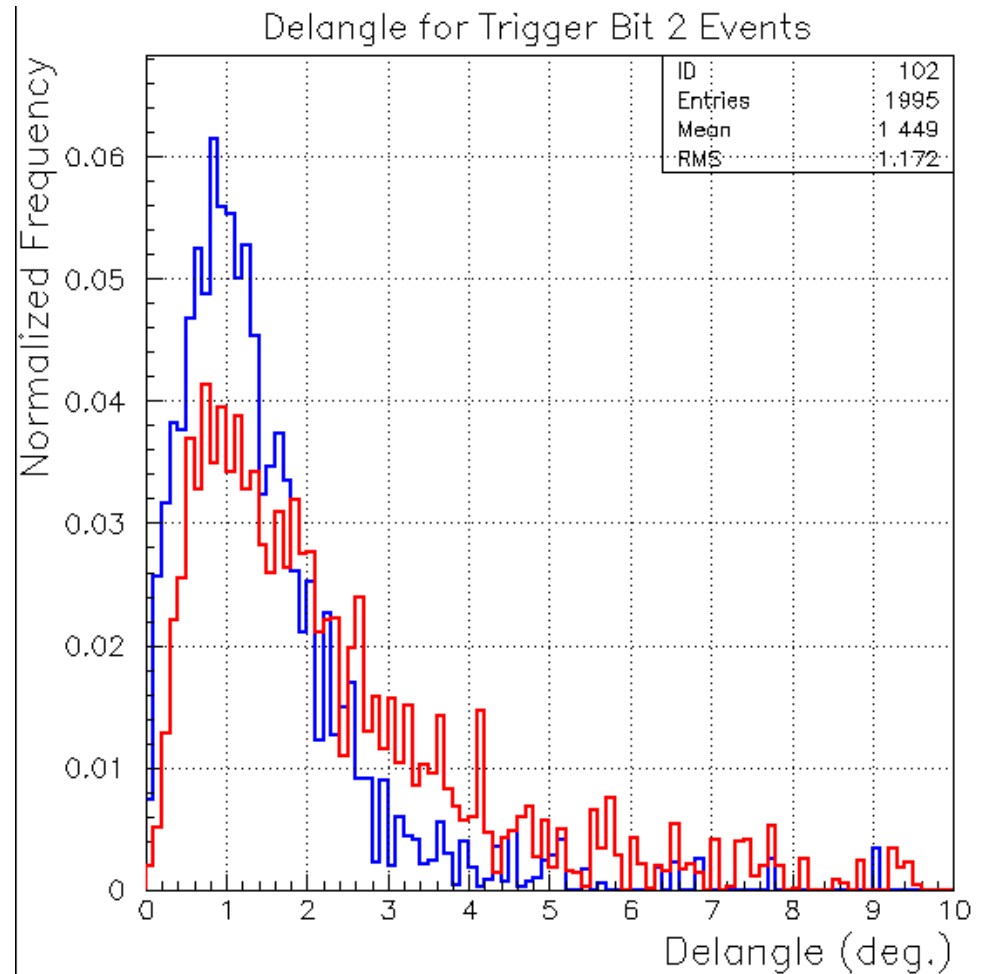
# Outtrigger Timing Calibration & Reconstruction

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



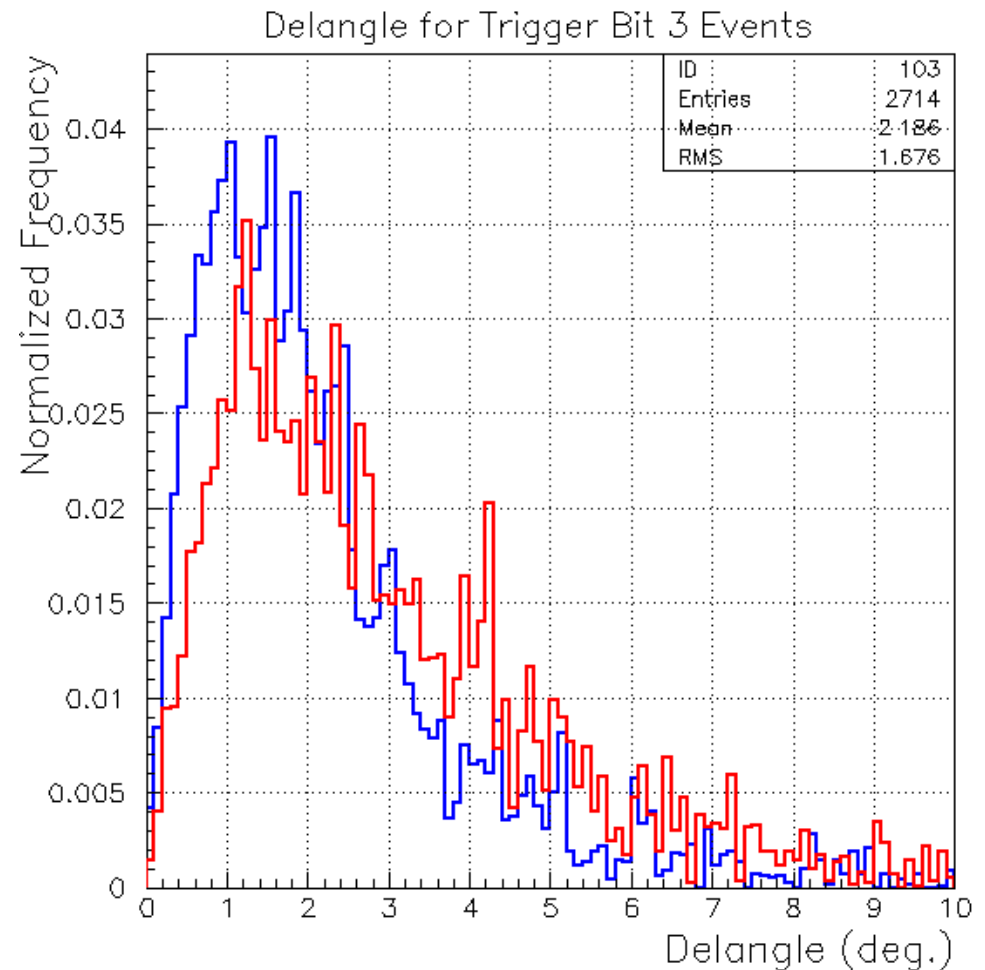
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    - Blue – new fit, Red – old fit
    - medians: Blue: x.xx°, Red: x.xx°



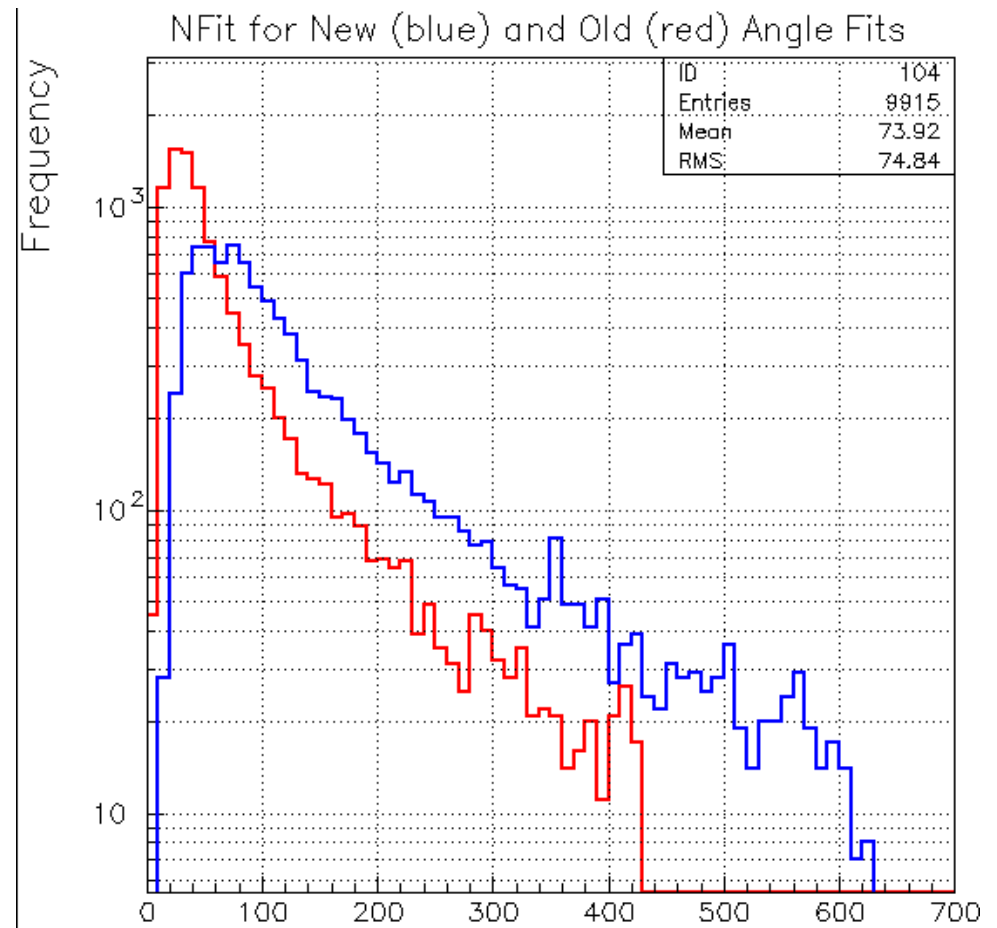
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    - medians: Blue:  $x.xx^\circ$ , Red:  $x.xx^\circ$



# Outtrigger 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:

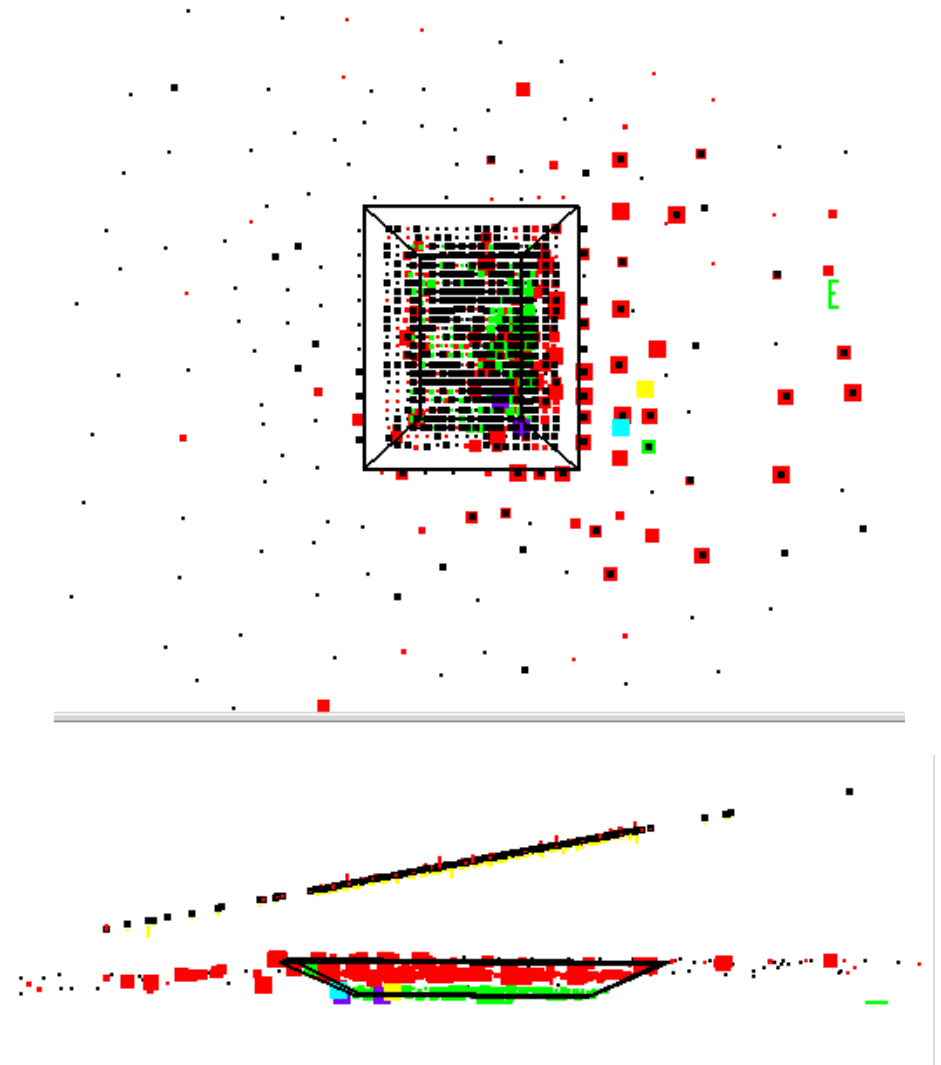
black dots indicate used in fit

The screenshot shows a software window titled "Raw Event Information" with several sections:

- Event Parameters:** Event # 9, GBY Time Cuts (unchecked), MJD: 2889, SECS: 24.683657, VMEWord: 7, Risetime: 37.5 ns.
- AS Layer MU Layer Outriggers:** NHit: 363, 259, 85; PeSum: 7874.843, 5203.791, 0.000000; PeMax: 249.2, 99.9, 461.2.
- Online Fit:** Theta: 11.22, Phi: 298.78, ChiSq: 0.10, NFit: 256, RA: 245.03, DEC: 25.90, XCore: 5200.0, YCore: 600.0, # Muons: (empty), X2: 2.54, DelAng: (empty), DelCor: (empty), EFit: (empty).
- New Fit:** Theta: 11.18, Phi: 293.59, ChiSq: 0.55 (464), NFit: 238 175 51, RA: 239.06, DEC: 35.89, XCore: 5052.1, YCore: -798.8, # Muons: 2, X2: 2.54, DelAng: 1.01, 0.3, DelCor: 14.1, EFit: (empty).
- Cuts:** Event Selection Cuts: 3.000000 < VMEword < 100.000, Apply Selection Cuts (checked). Fit Parameter Cuts: (empty), Apply Fit Cuts (unchecked).

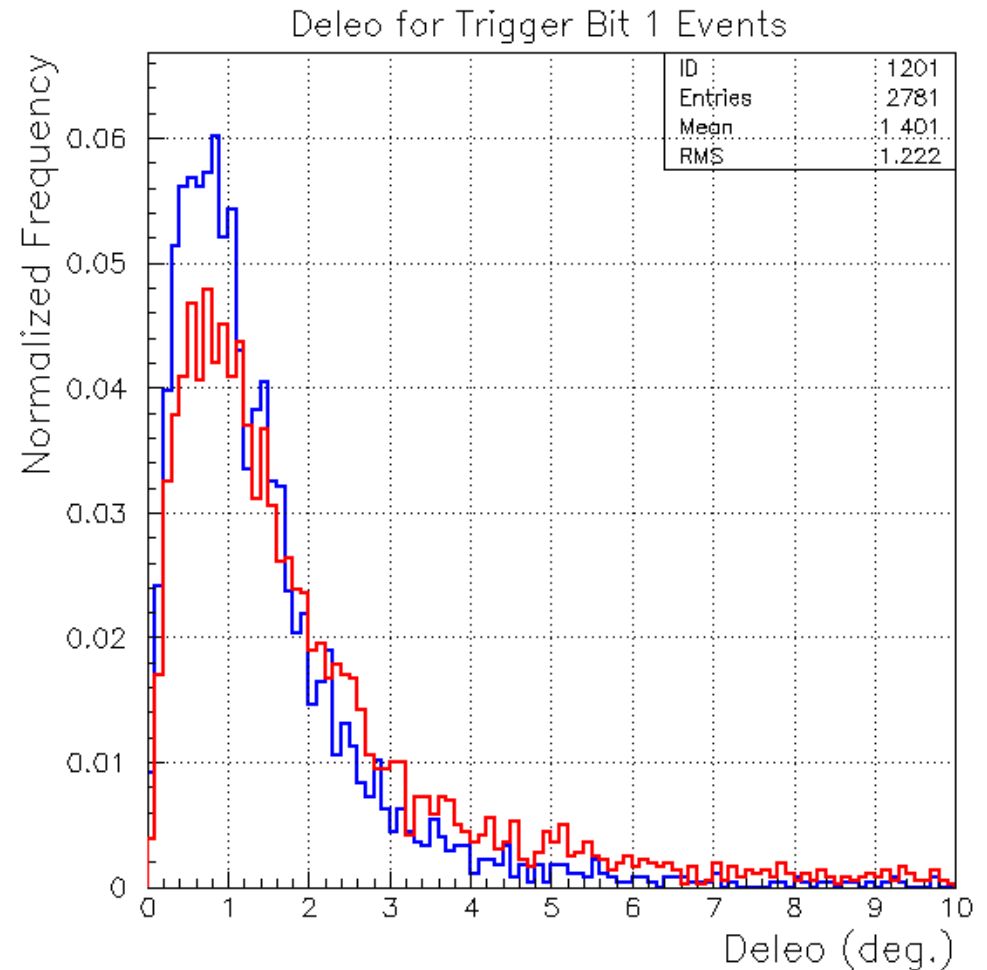
Total nfit

nfit for as, muon, outriggers



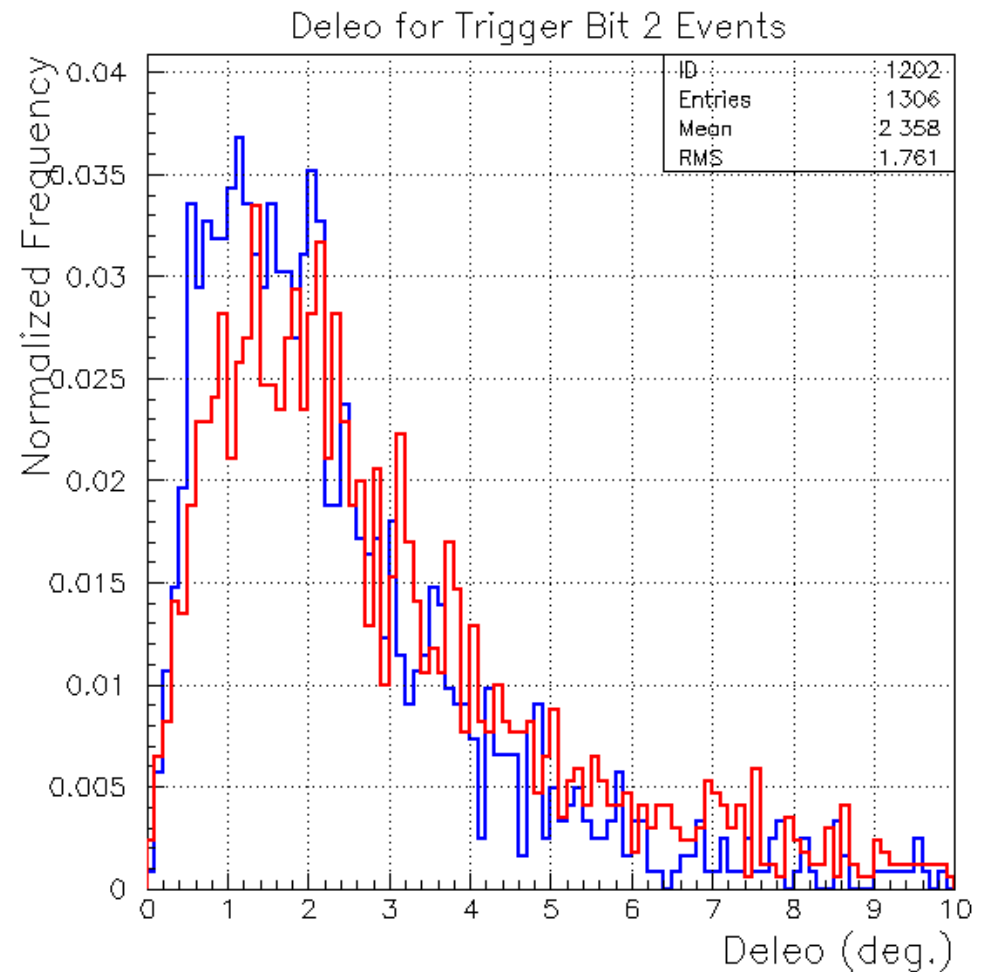
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- Results using real events:
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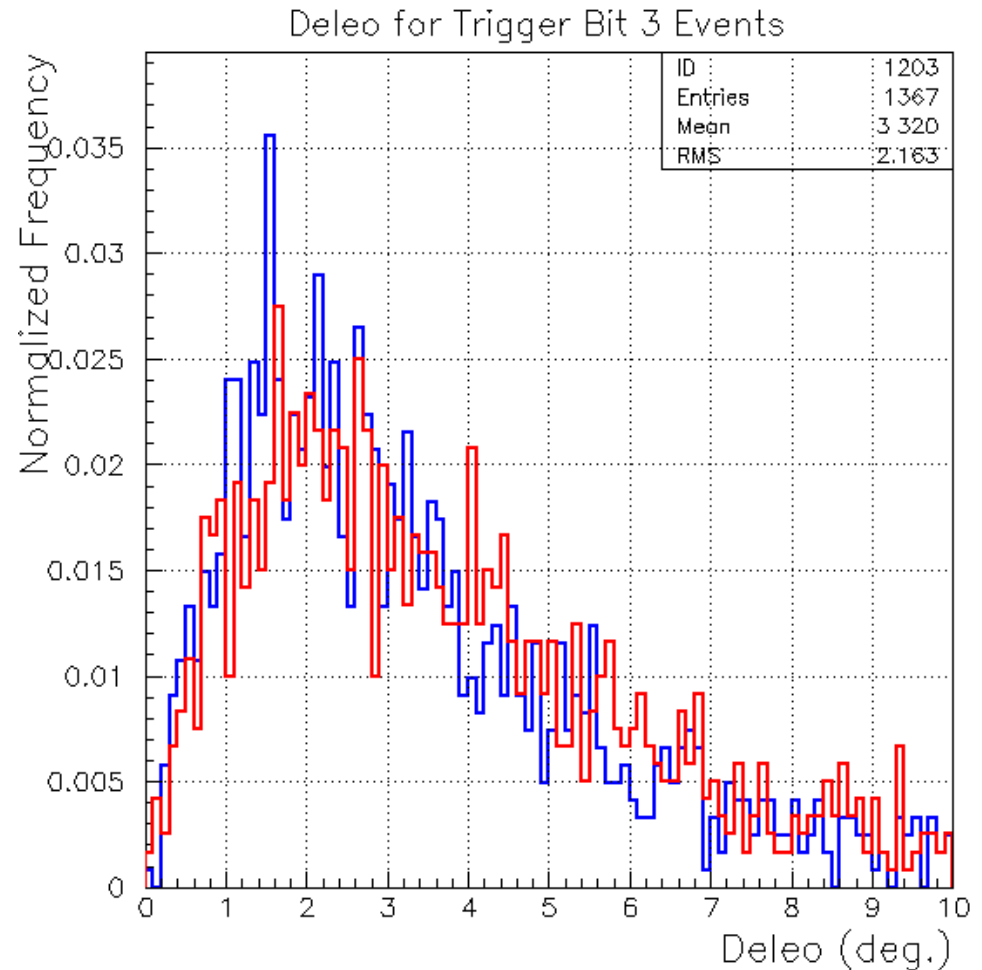
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- Results using real events:
  - Deleo distributions for various trigger events
    - Blue – new fit, Red – old fit
    - medians: Blue: x.xx, Red: x.xx



# Outtrigger Timing Calibration & Reconstruction

- Results using real events:
  - Ran new fitting on crab
  - only 95 days so far
  - $\sigma = 1.29 \pm 0.45^\circ$
  - $N_\sigma \sim 2.1$

