

Signal After pulse

31 March 2020

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Strategy

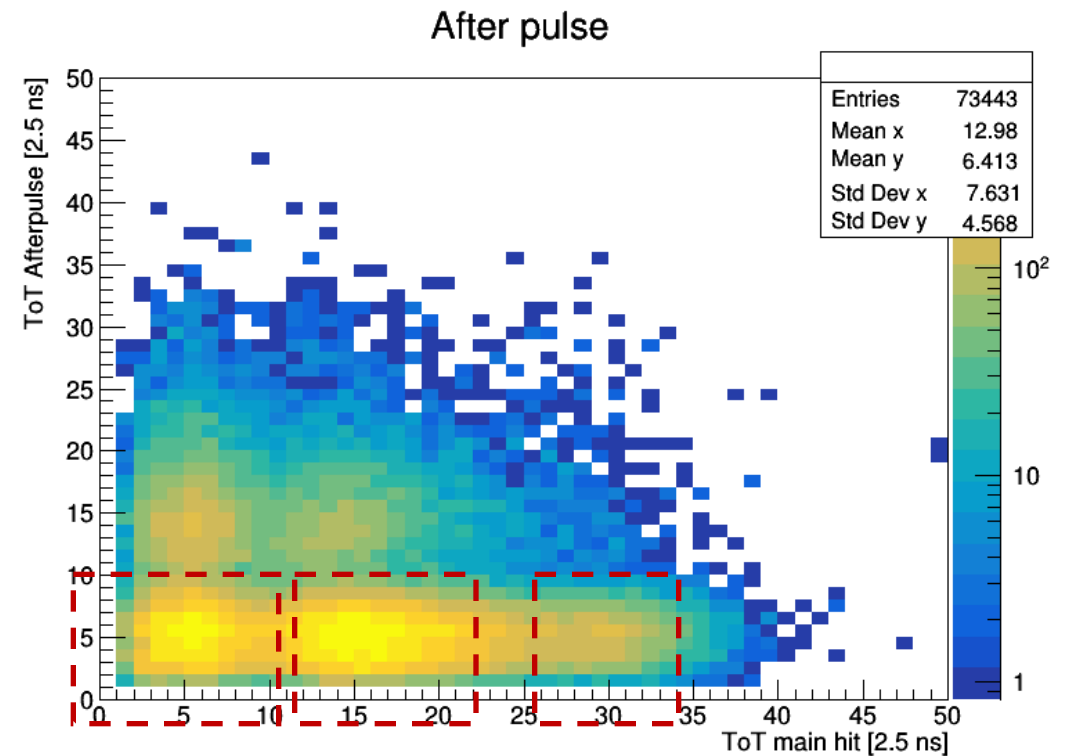
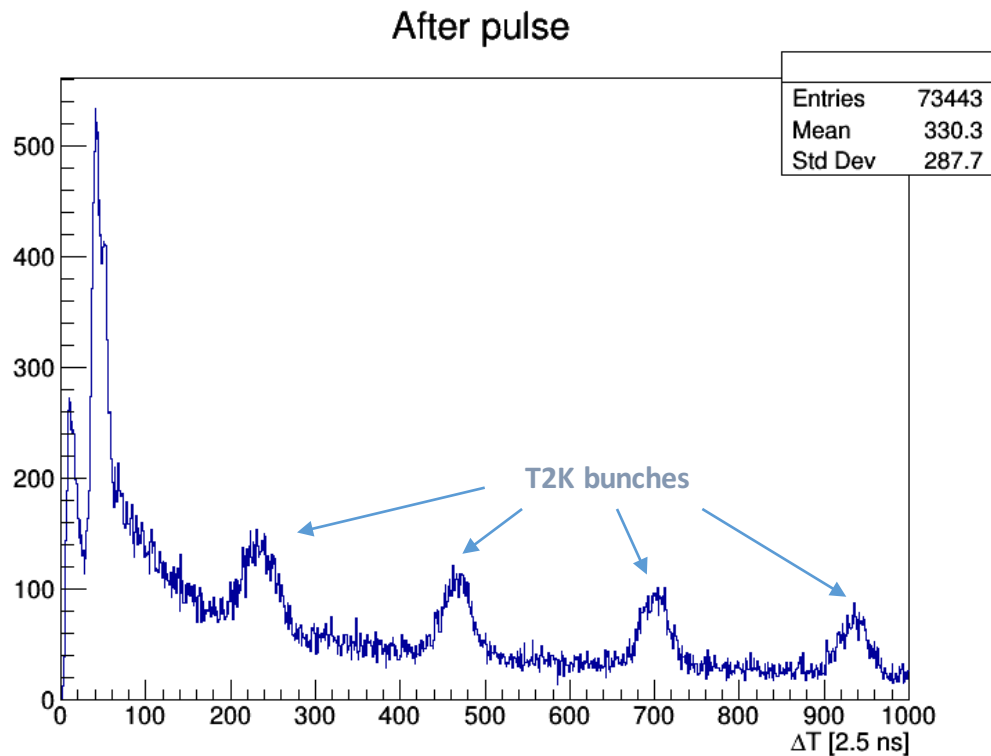
studying signal after pulse

- For every hit in the detector open a search window (100 ticks = 250 ns).
- Record secondary hits which occur on the same channel in the search window.
- Put Amplitude cut for the secondary hit (ToT <10 ticks)
- Vary initial hit amplitude and observe after pulse behavior

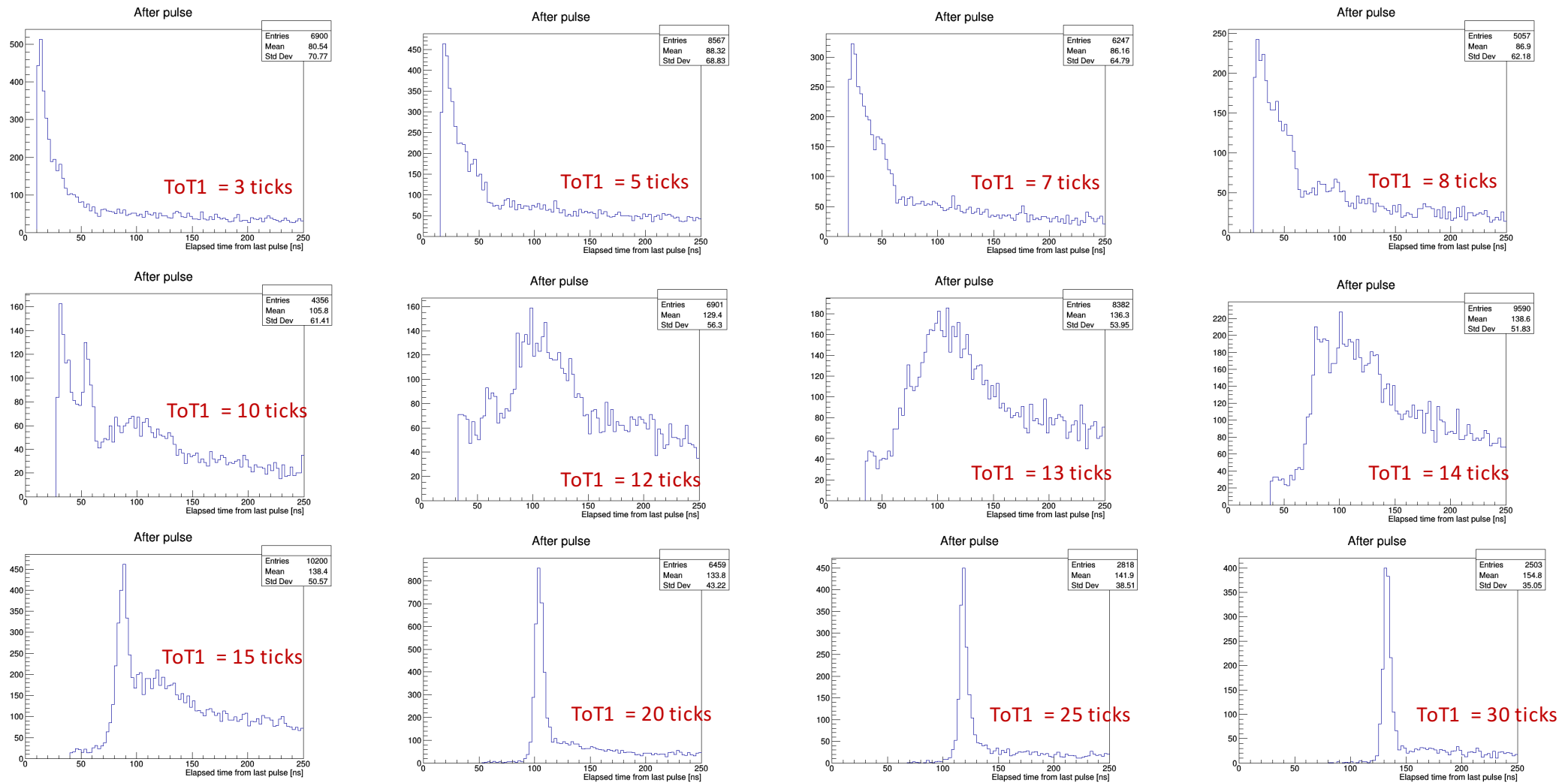
In these slides I call all the secondary hits in the search window *after pulse*, regardless of the mechanism that generates them.

Elapsed time from the last pulse

In order to check that the results make sense, I increased the search window to 1000 ticks ($2.5 \mu\text{s}$). In this time window we can recognize secondary hits belonging to the T2K bunches which are 581 ns apart so we can see 4 of them.



Distribution of elapsed time for different amplitudes of the first pulse

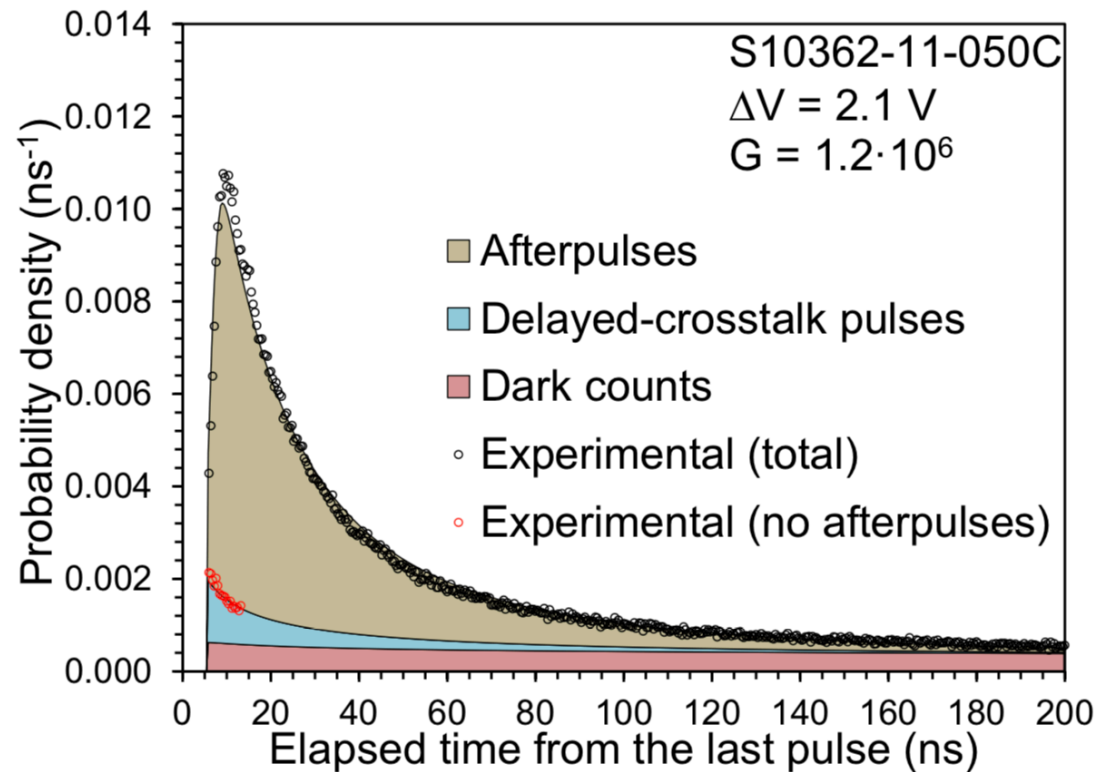


ToT main signal [2.5ns]	3	5	7	8	10	12	13	14	15	20	25	30
N main hits	611557	887716	499479	334188	256888	395137	447249	445901	394391	88293	22212	11382
N secondary hits	6900	8567	6247	5057	4356	6901	8382	9590	10200	6459	2818	2503
Percentage of after pulse	1%	1%	1%	1.5%	1.6%	1.7%	1.8%	2.1%	2.6%	7.3%	12.9%	22%

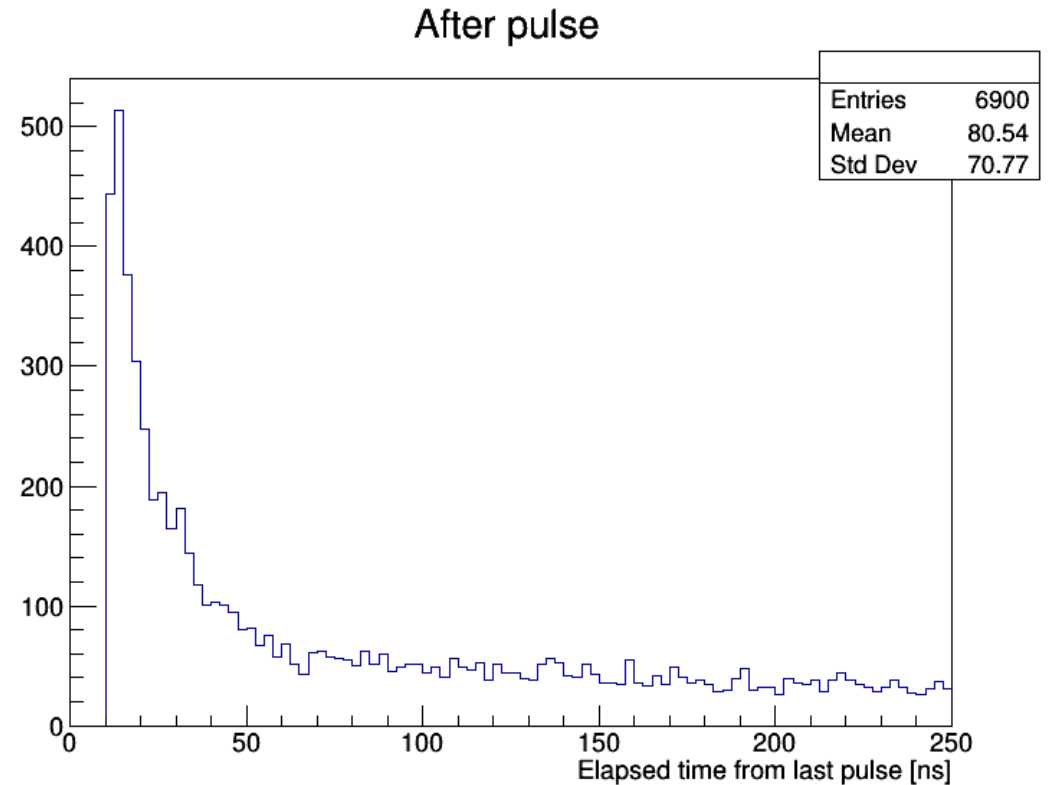
MPPC Pixel after pulse

For very low amplitude levels -> ToT = 3 ticks (7.5 ns)

we recover MPPC pixel after pulse as described in the paper [left plot].



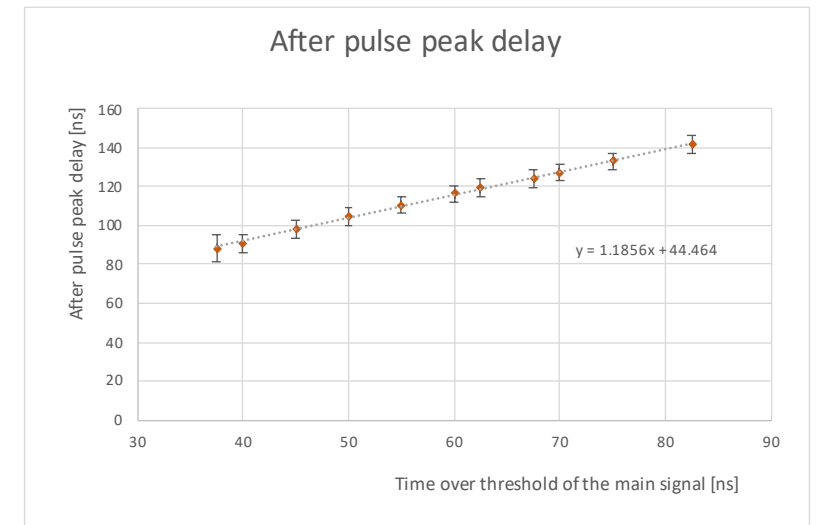
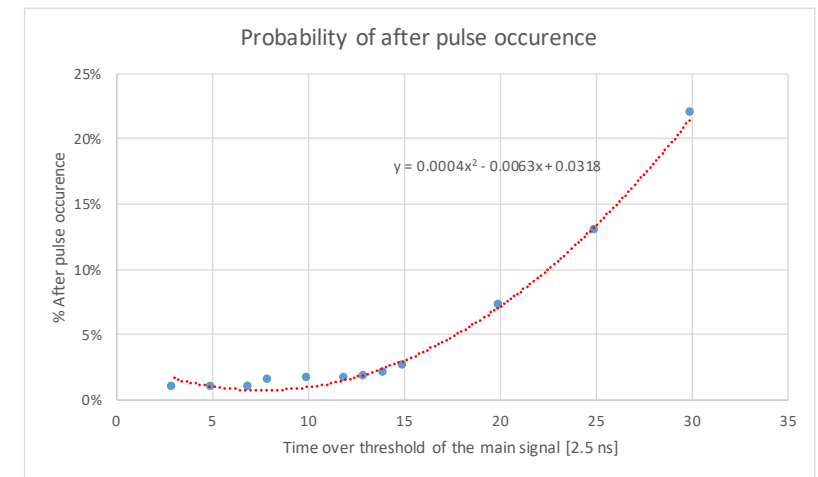
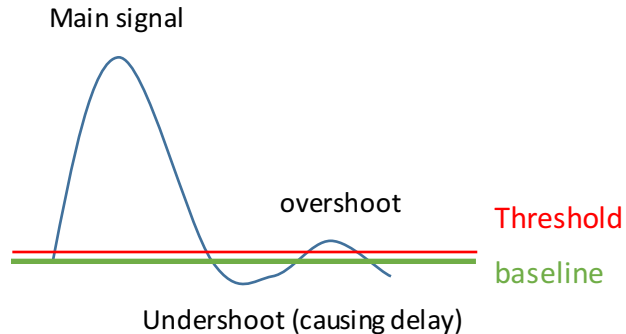
After pulse for signals of 1 p.e



After pulse for signals with ToT: 3 (7.5 ns)

Amplitude dependence of After pulse

- For very low amplitude levels -> ToT = 3 ticks (7.5 ns)
we recover MPPC pixel after pulse as is described in the paper.
- For amplitude range 7 ticks <ToT<15 ticks
There is a transition region. Not well understood. Wide bump at 100 ns.
- For Large amplitudes ToT>15
There is a linear dependence between ToT of the main signal and after pulse peak position (delay). Pixel after pulses are merged in the main signal. (This is probably electronics effect not MPPC)



ToT main signal[2.5ns]	15	16	18	20	22	24	25	27	28	30	33
ToT main signal[ns]	37.5	40	45	50	55	60	62.5	67.5	70	75	82.5
Afterpulse Peak location [ns]	88.2	90.8	98.2	104.6	110.4	116.3	119.2	124	127.3	133	141.8
sigma	6.9	4.7	4.5	4.4	4.3	4.3	4.6	4.5	4.2	3.9	4.9
constant	100	212	495	843	1210	1600	1526	2012	2438	3269	2764
time of undershoot	50.7	50.8	53.2	54.6	55.4	56.3	56.7	56.5	57.3	58	59.3

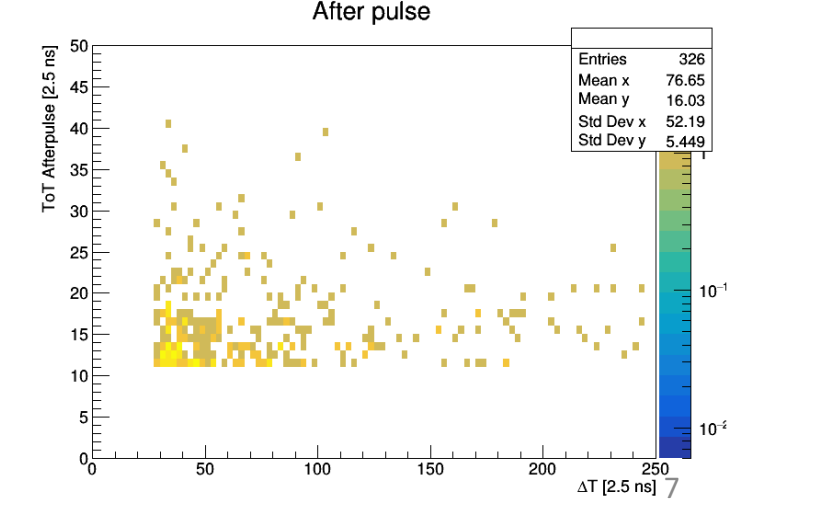
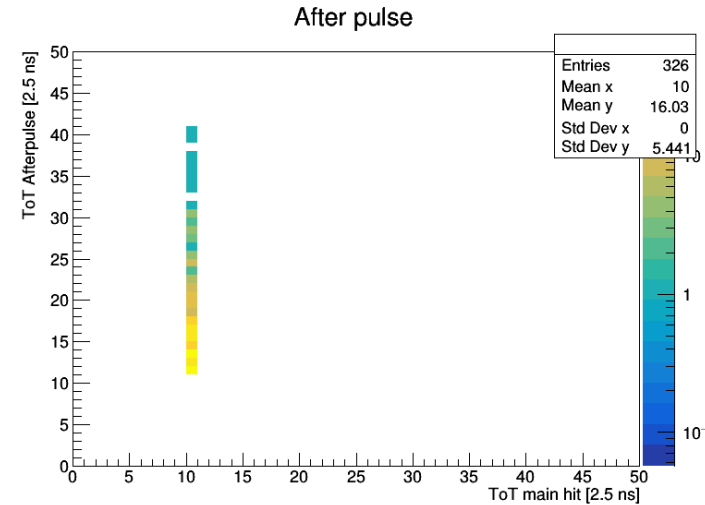
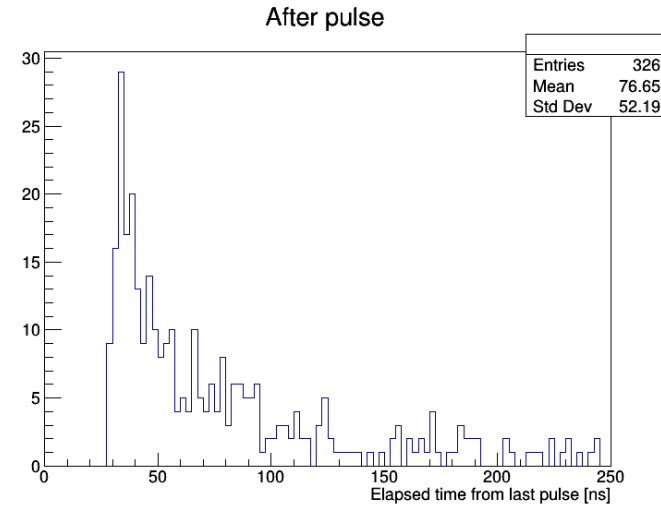
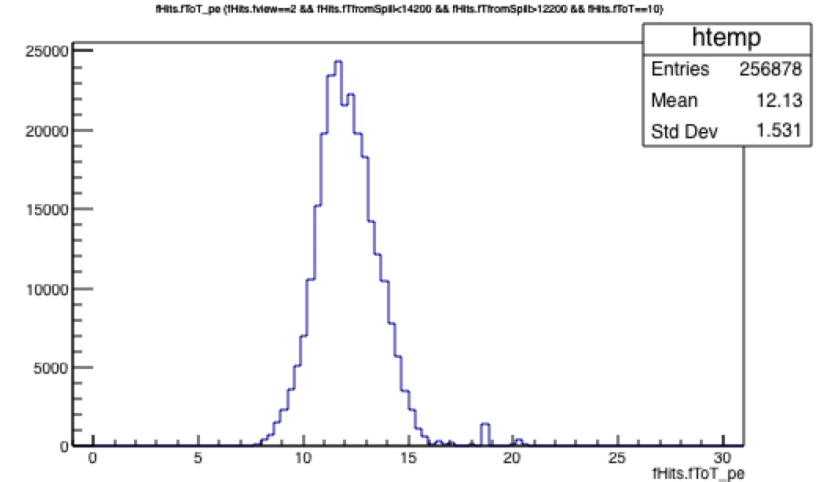
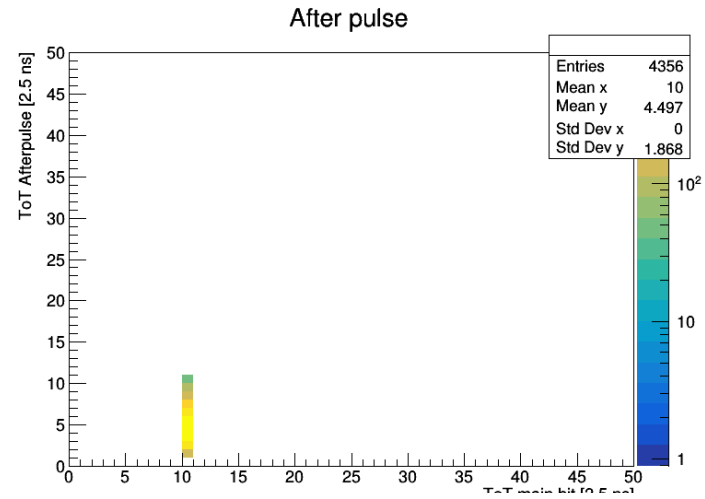
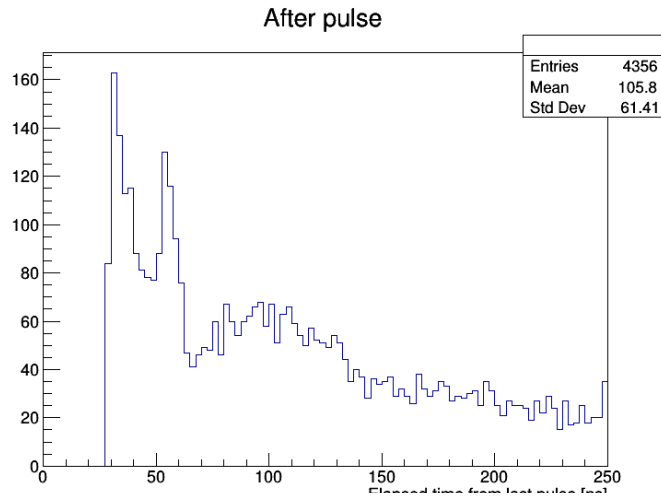
Additional slides

Main signal ToT:10

Plotting secondary hits (after pulses) with ToT > 10

N Total: 256888

p.e distribution for hit with ToT 10 ticks

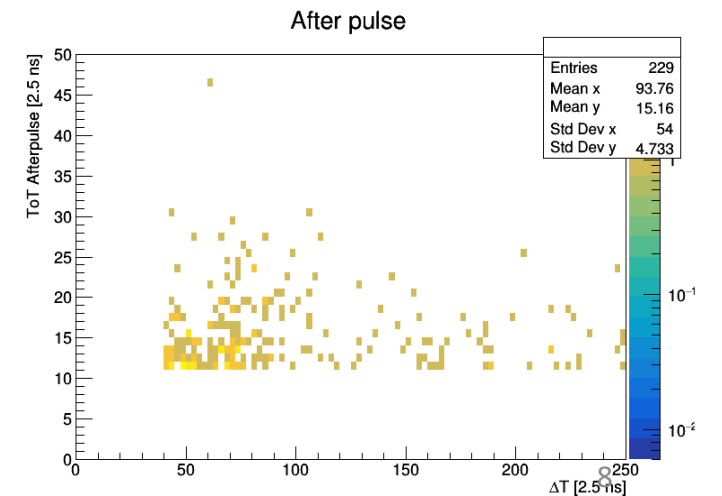
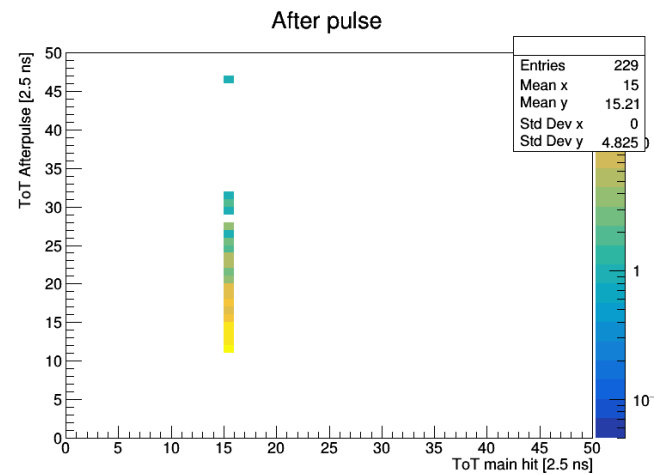
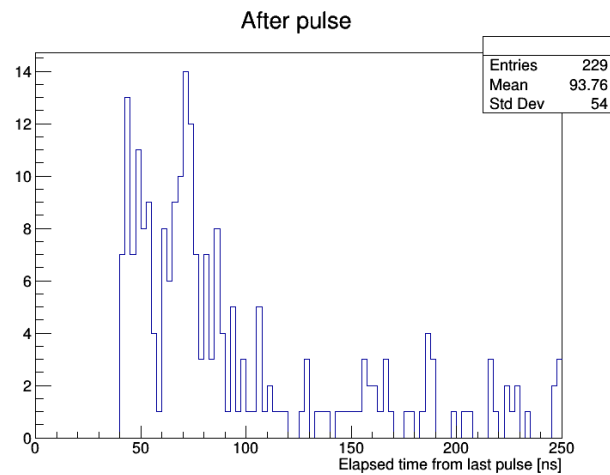
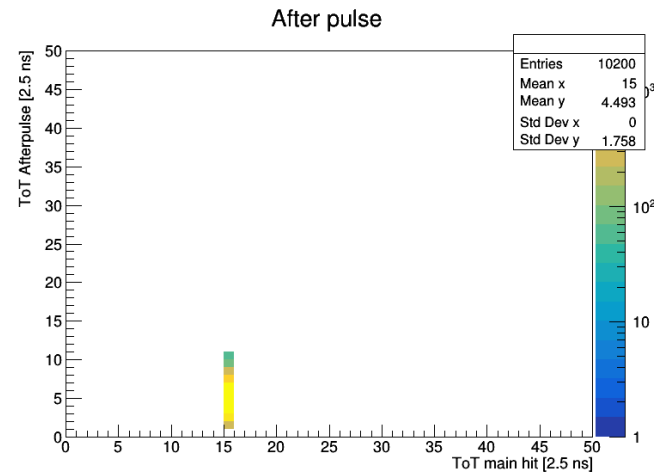
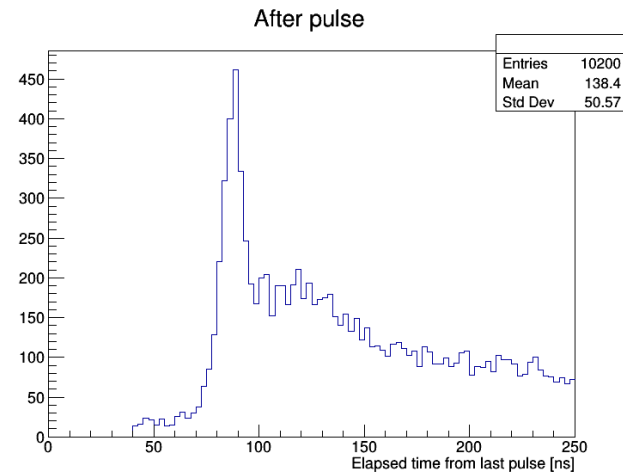


Additional slides

Main signal ToT: 15

Plotting after pulses with ToT >10

N Total: 256888

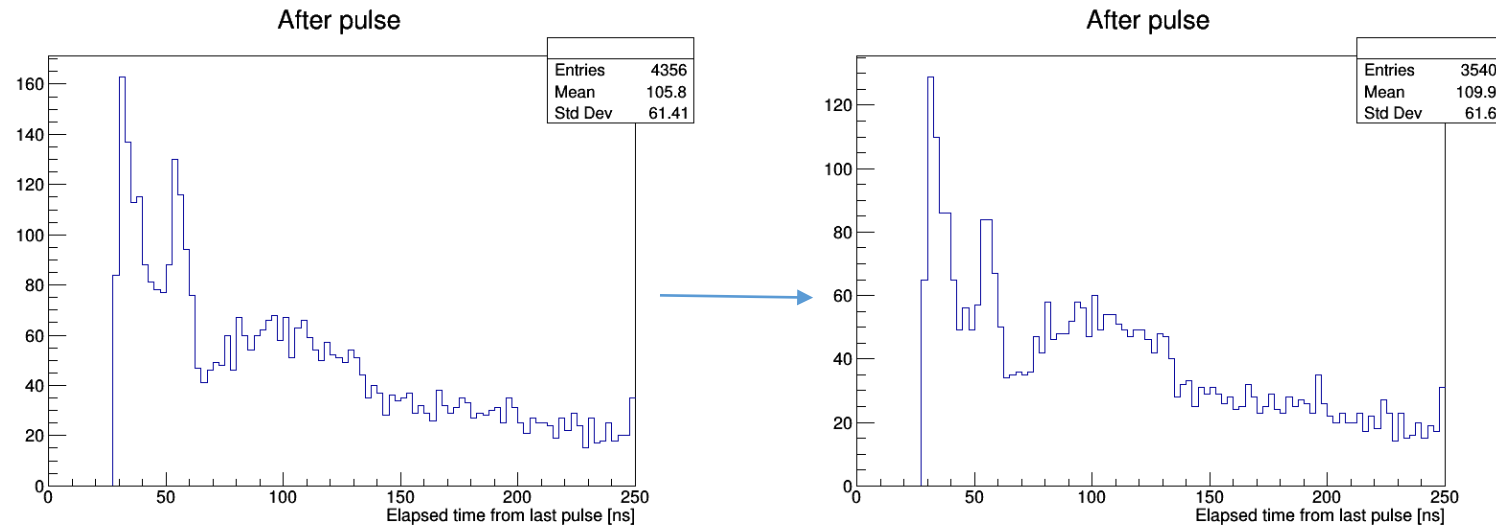


Additional slides

Main signal ToT: 10

Applying a coincidence cut on the main signal (excluding darkcounts)

N Total: 256888 -> N Total: 217567



Nothing changes

Additional slides

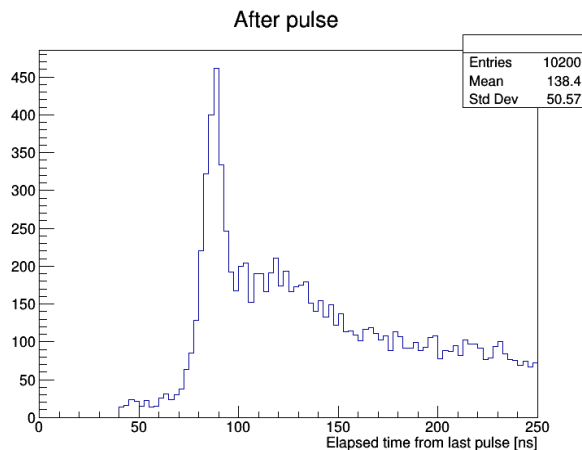
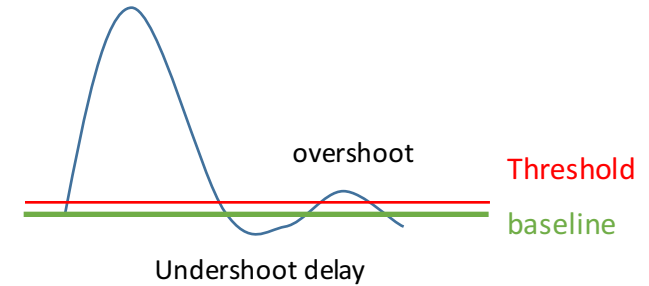
Main signal ToT: 15

Applying a coincidence cut on the main signal (excluding dark counts)

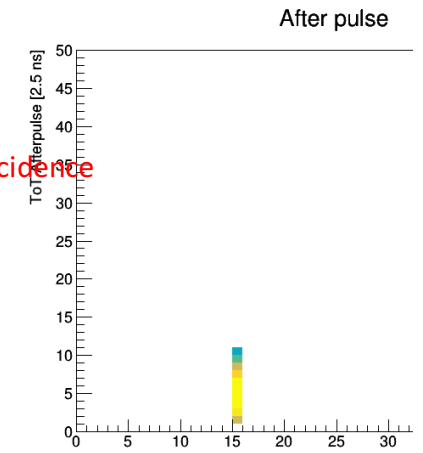
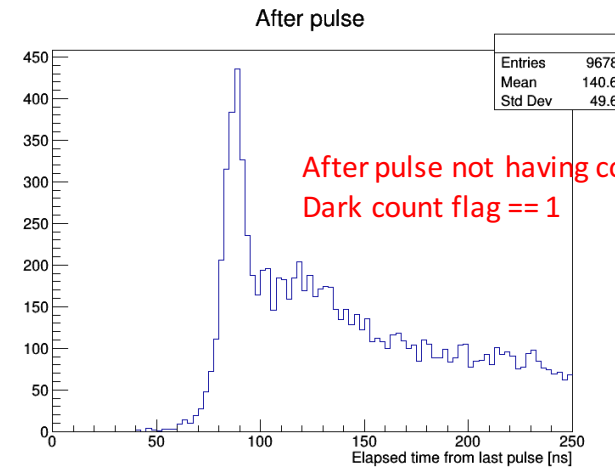
Applying Dark count cut on the after pulse (excluding coincidence)

N Total: 394391 -> N Total: 392799

Large amplitude Main signal after shaper

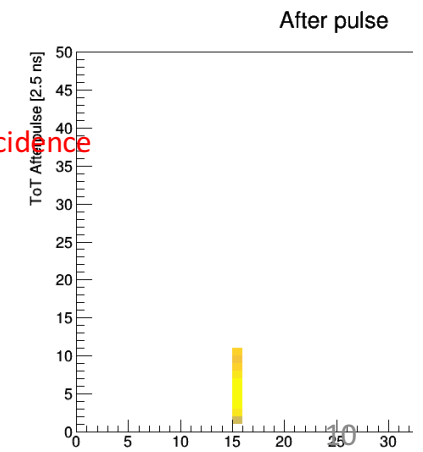
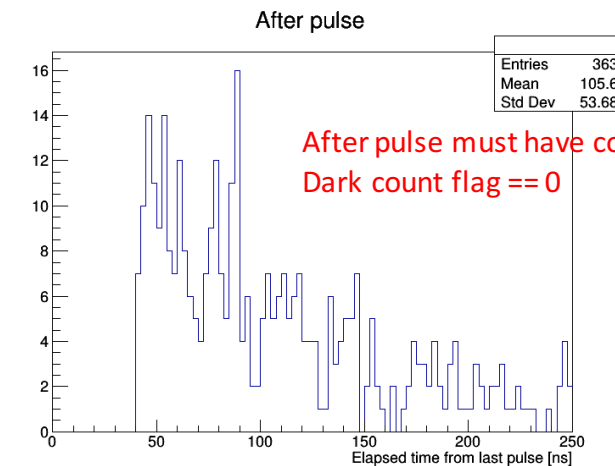


Nothing changes



The after pulse we see is probably the overshoot of the shaped signal

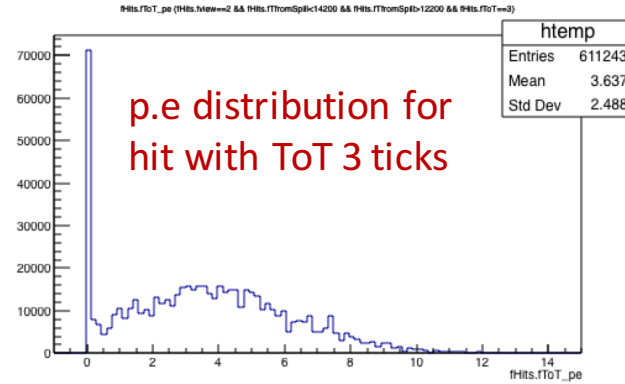
Right plots show:
 If there is a real particle signal, it will be recorded even between end of ToT of main signal and the after pulse. There is no recovery time in which the shaper is out of function.



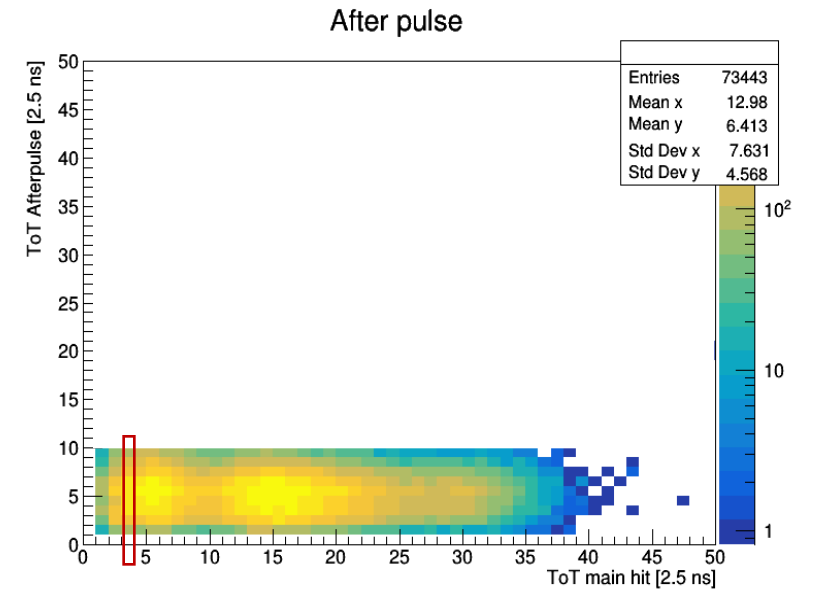
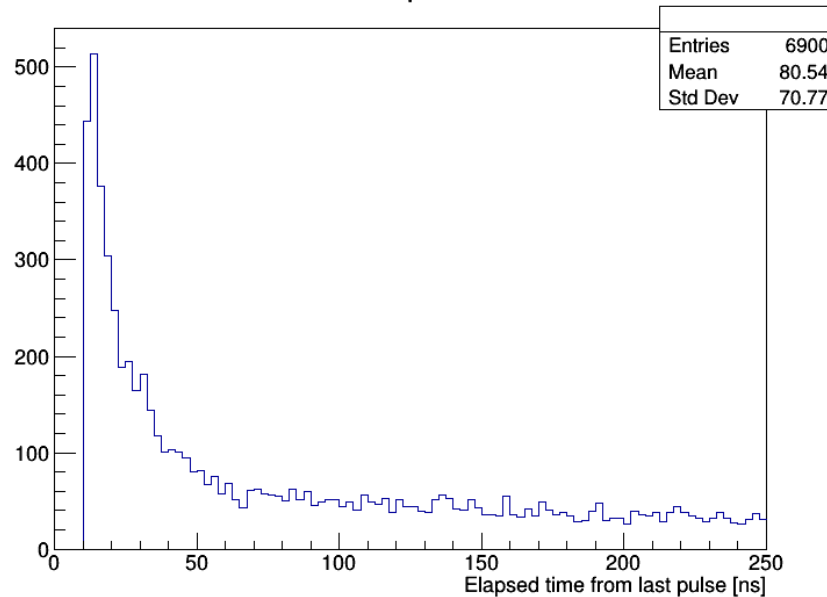
Back ups

Slicing main signal amplitude

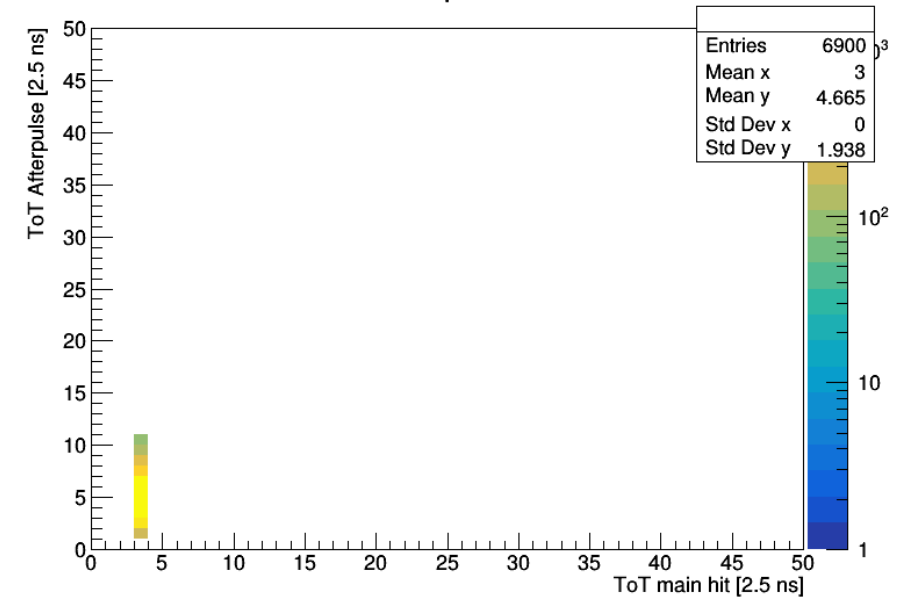
Main signal ToT: 3 ticks
 N Total: 611557
 Afterpulse: 1%



After pulse



After pulse

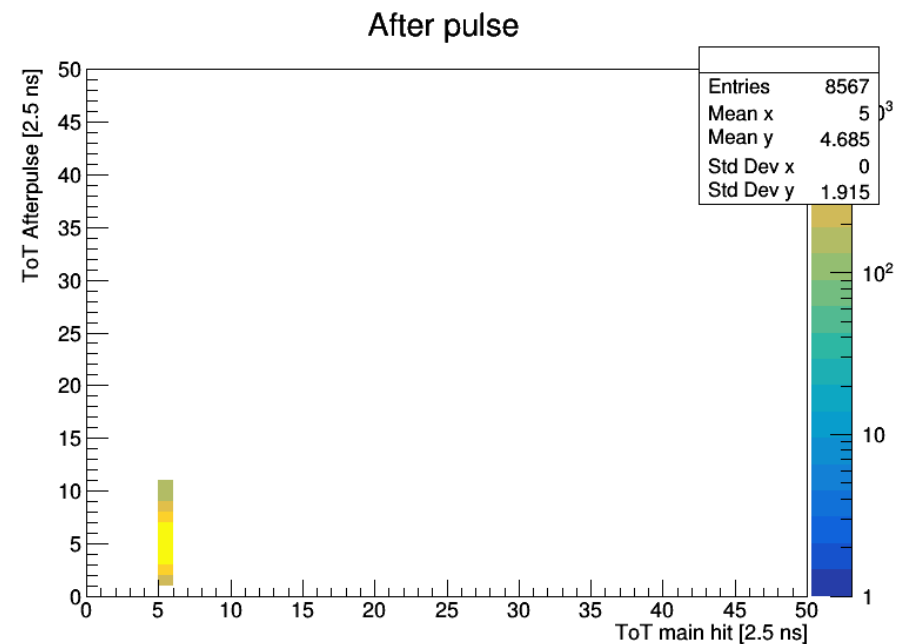
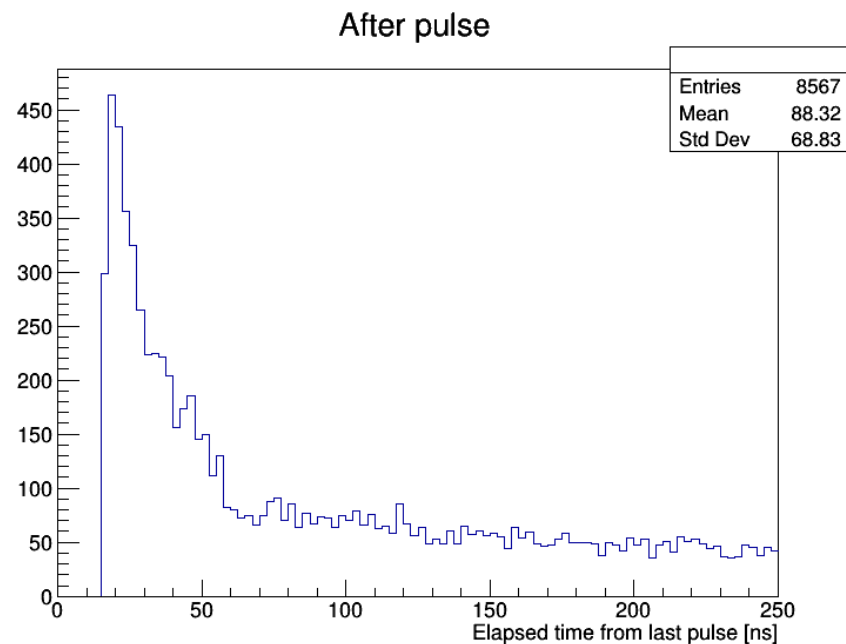
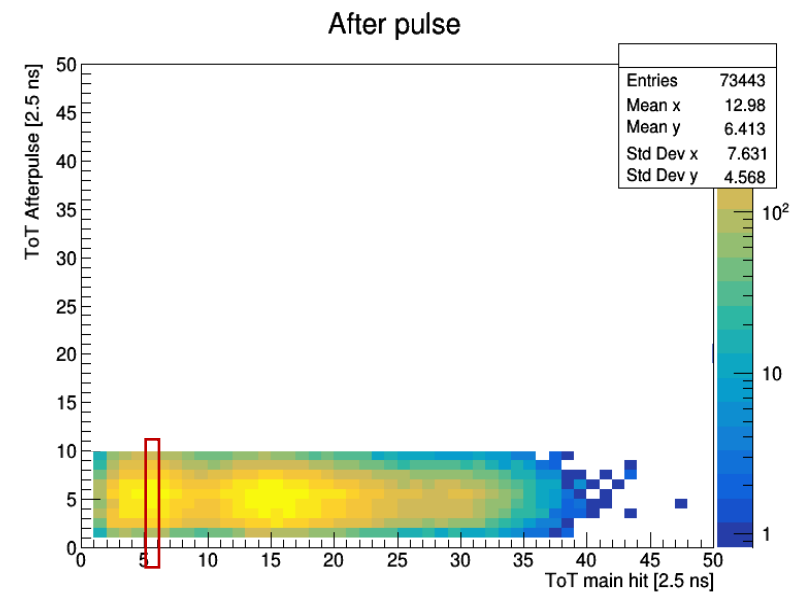


Slicing main signal amplitude

Main signal ToT: 5 ticks

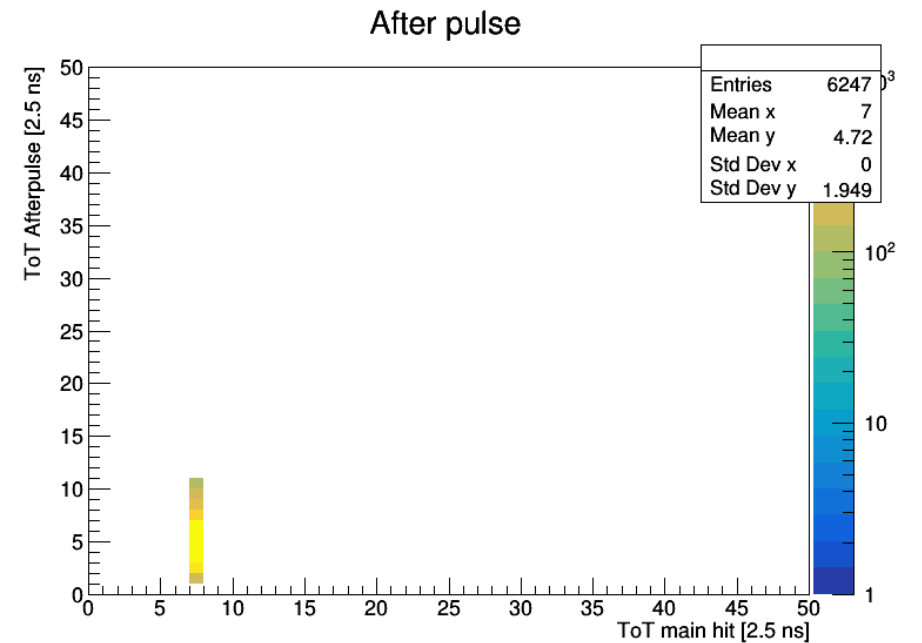
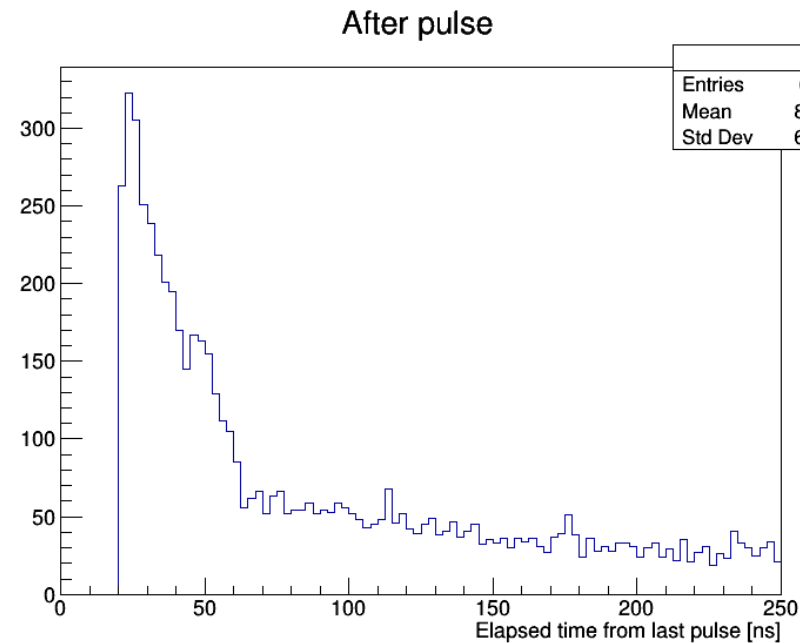
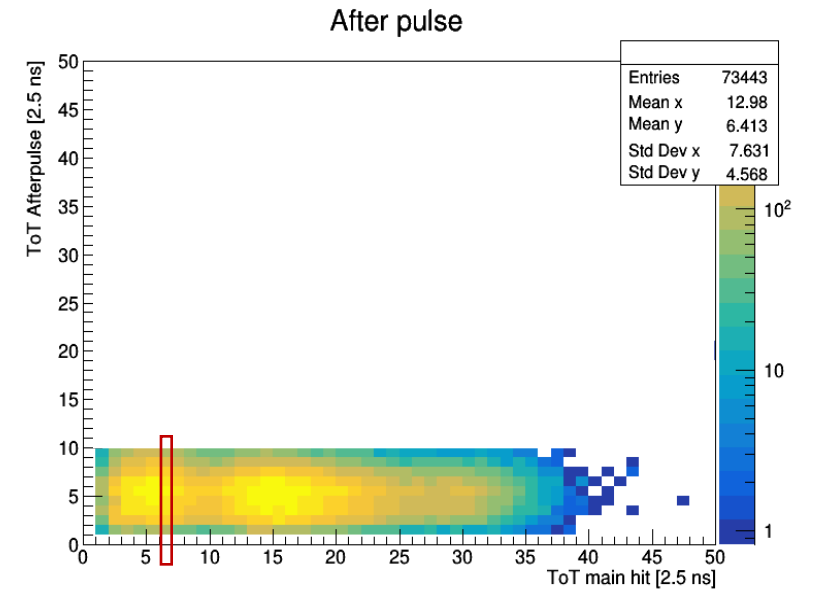
N Total: 887716

Afterpulse: 1%



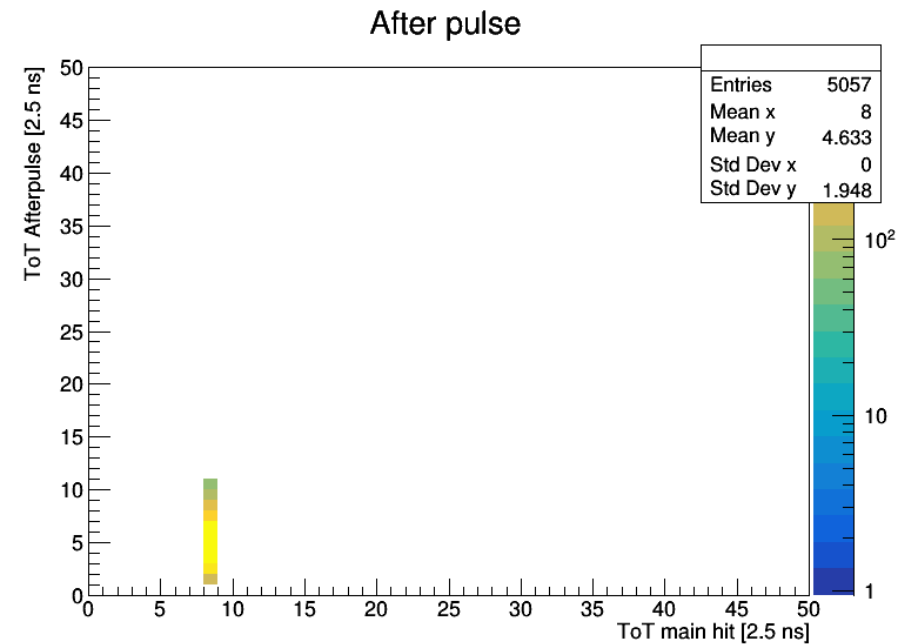
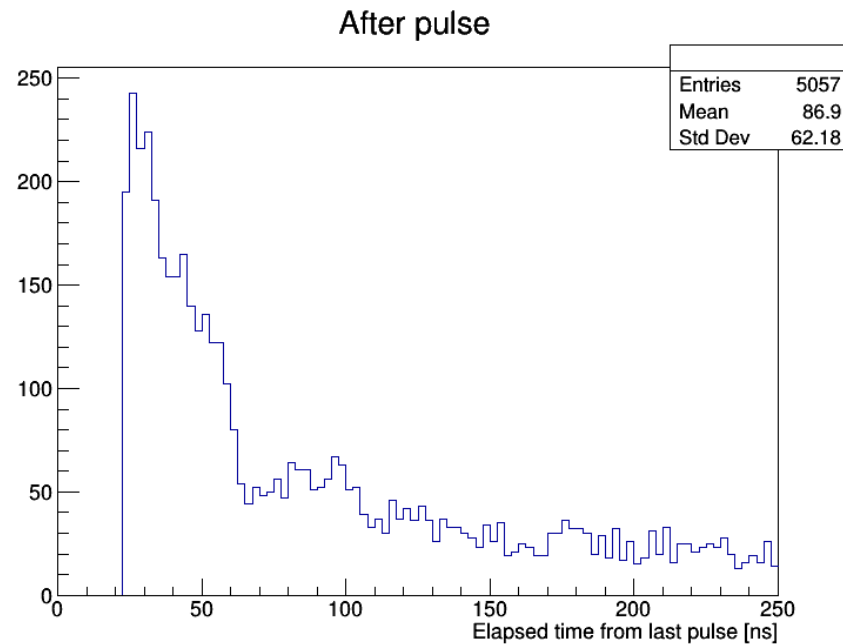
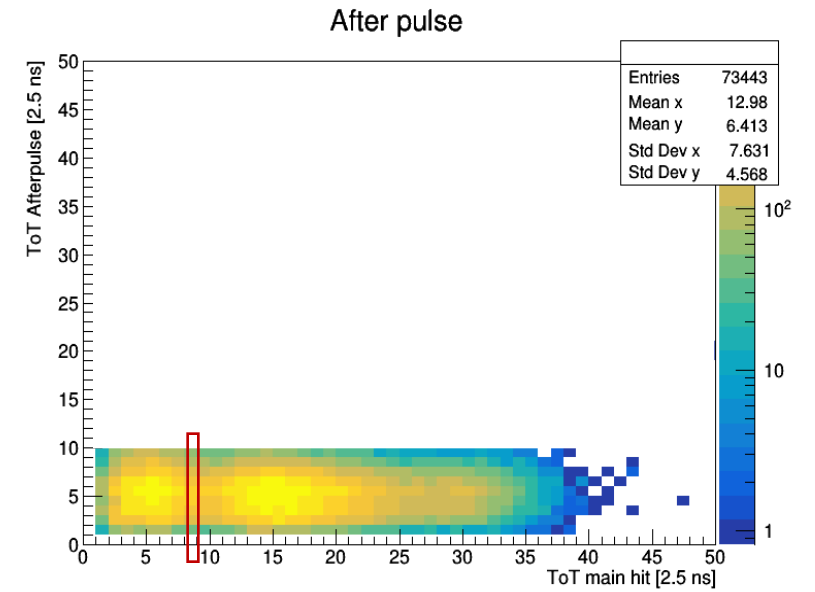
Slicing main signal amplitude

Main signal ToT: 7 ticks
N Total: 499479
Afterpulse: 1%



Slicing main signal amplitude

Main signal ToT: 8 ticks
N Total: 334188
Afterpulse: 1.5%

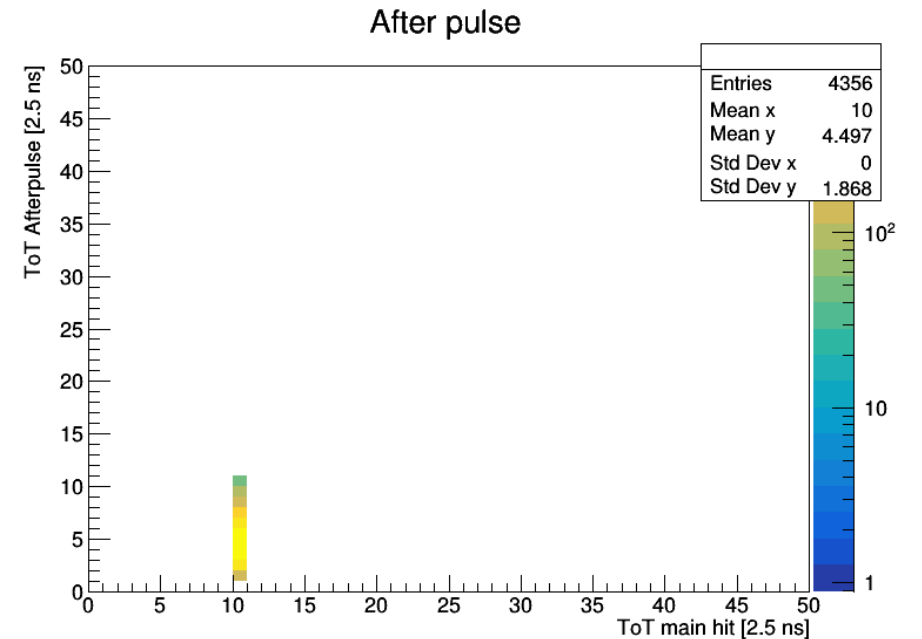
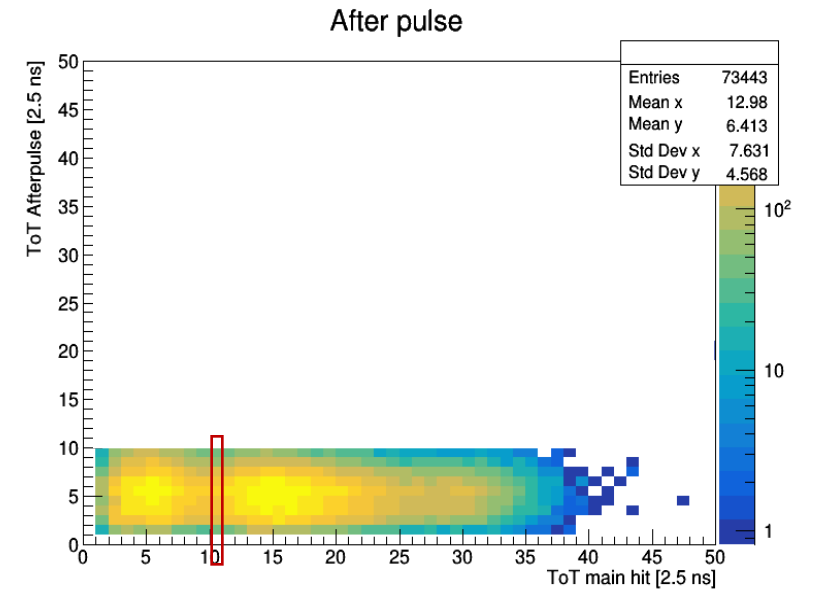
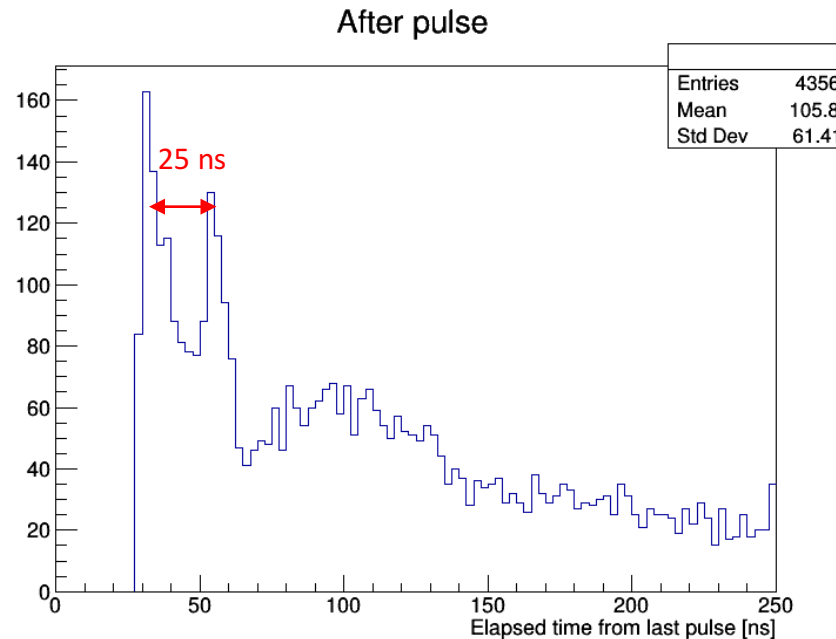


Slicing main signal amplitude

Main signal ToT: 10 ticks
 N Total: 256888
 Afterpulse: 1.6%

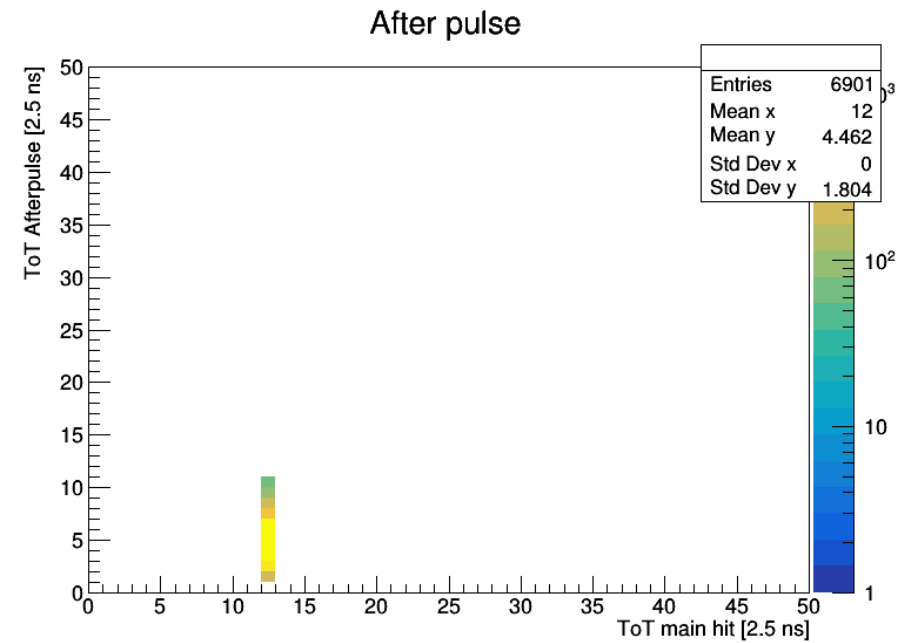
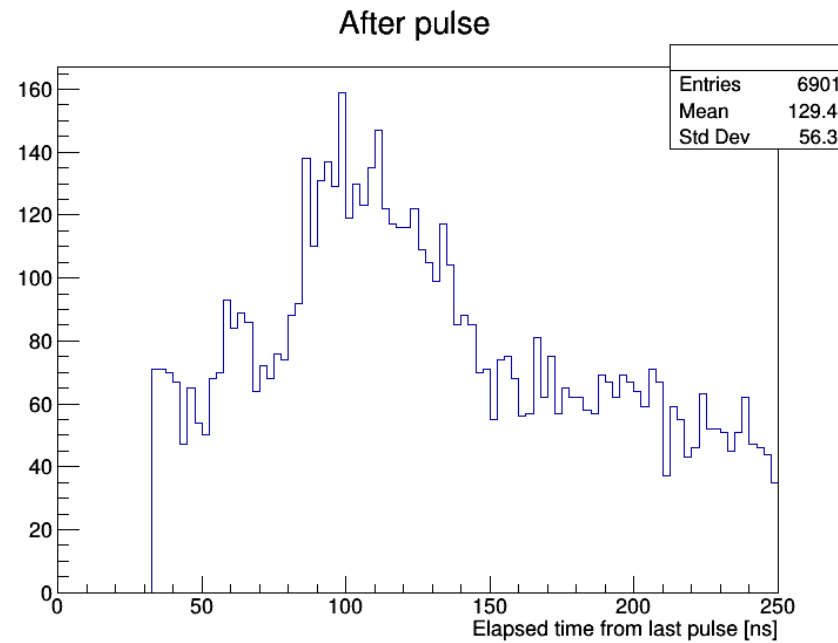
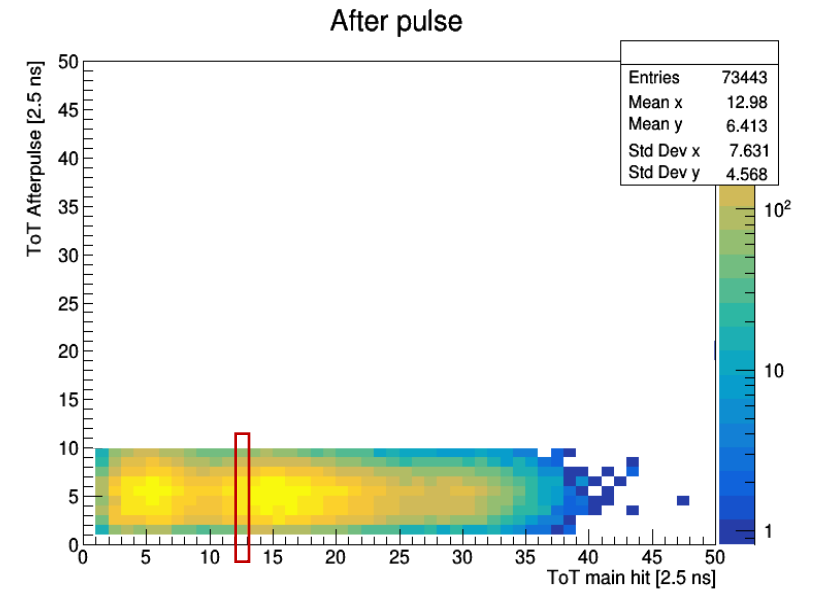
Possibilities:

- After pulse of pixels
- Late arrival of photons from fiber
- reflection of signal from fiber end? (35 ns at most)
- over shoot of the shaped wave form



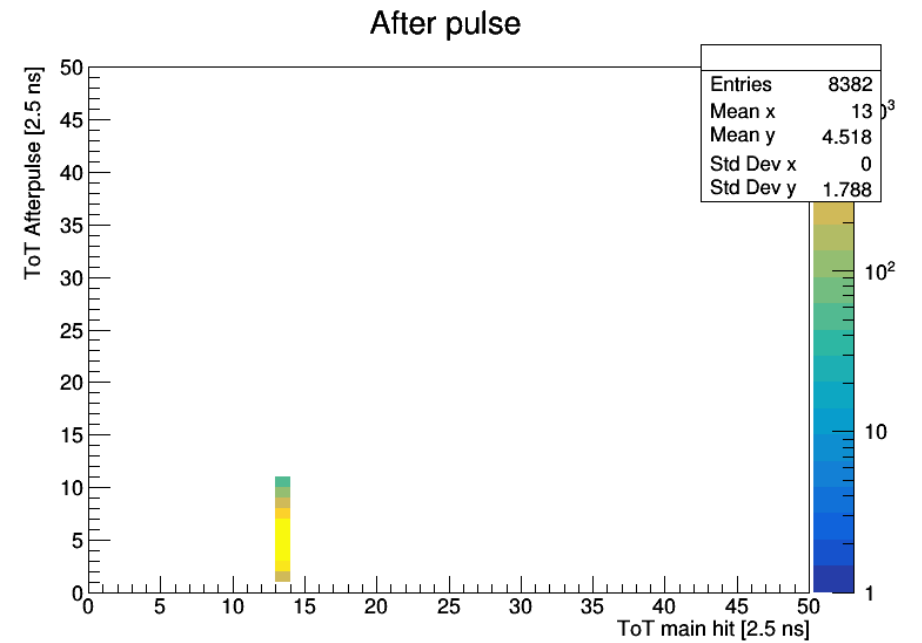
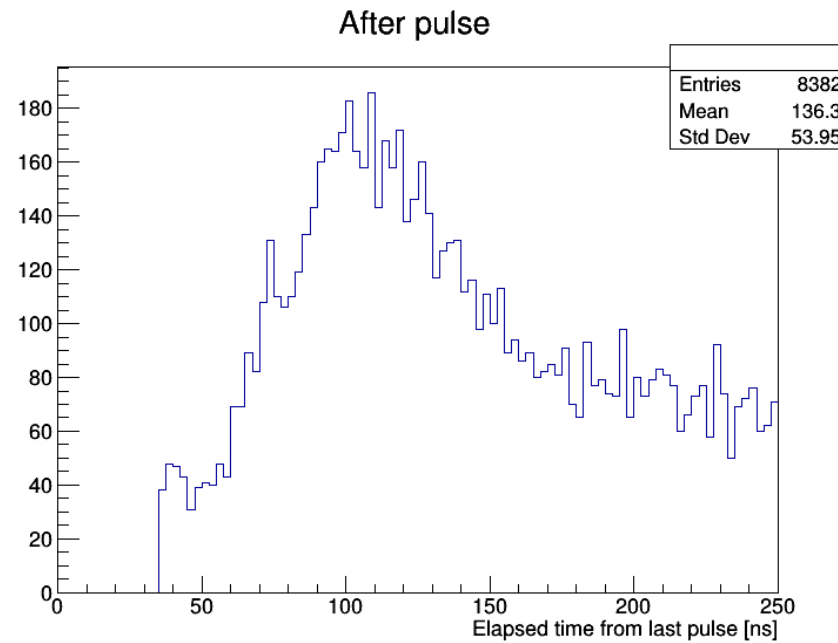
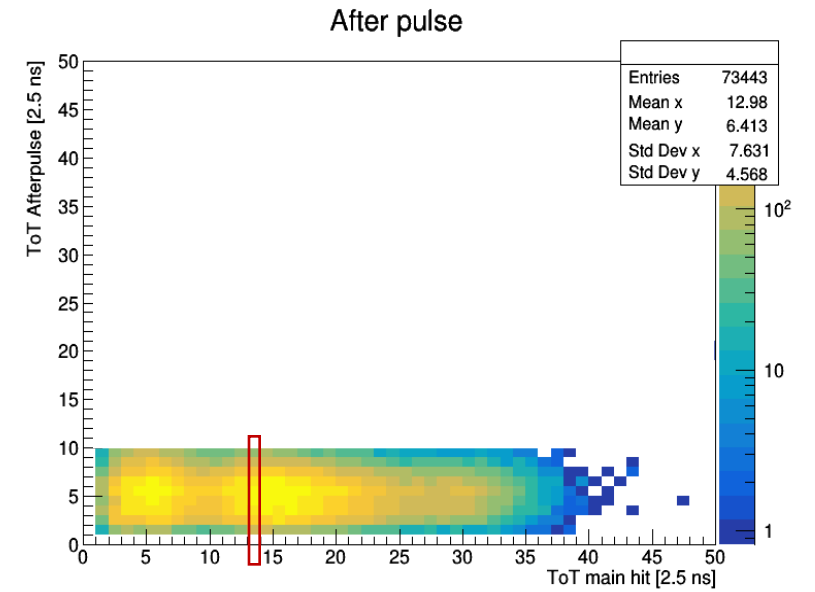
Slicing main signal amplitude

Main signal ToT: 12 ticks
N Total: 395137
Afterpulse: 1.7%



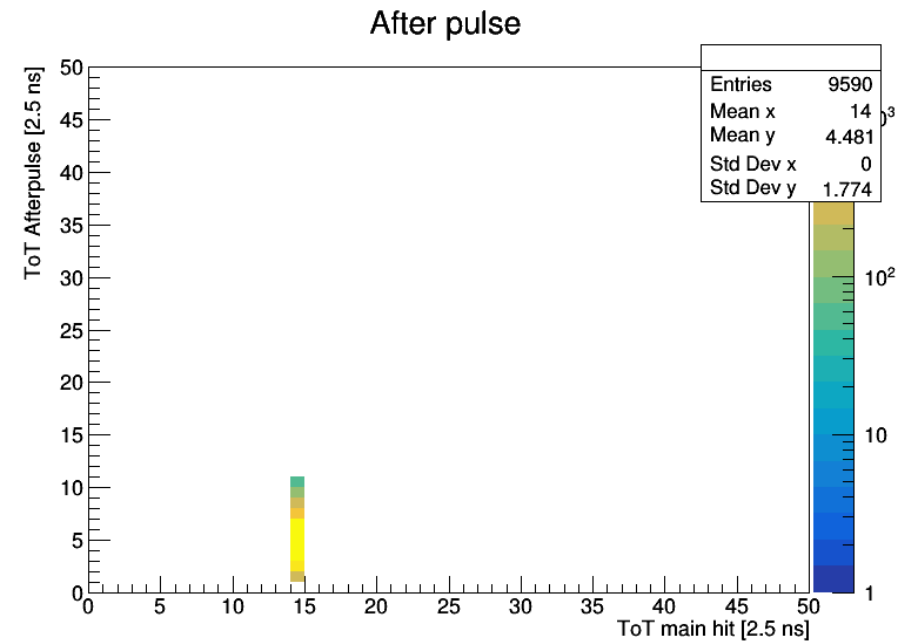
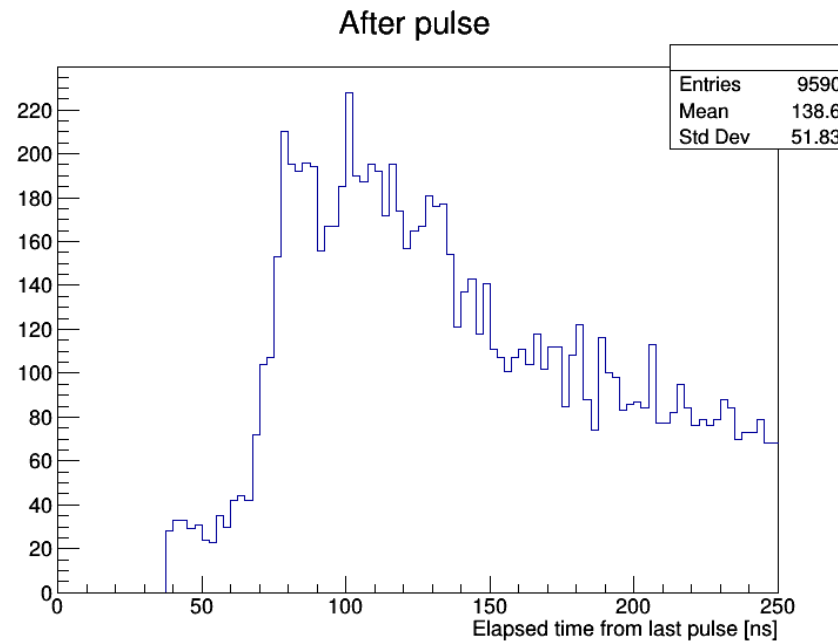
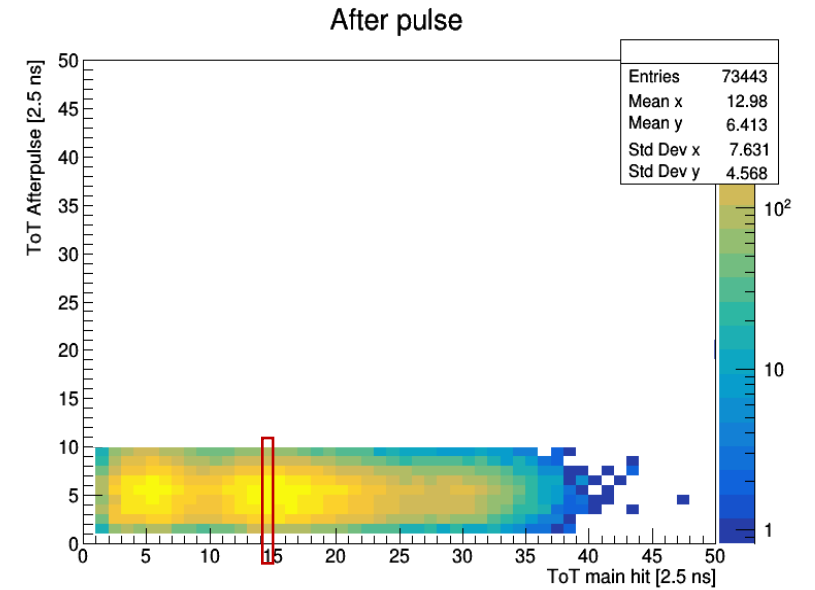
Slicing main signal amplitude

Main signal ToT: 13 ticks
N Total: 447249
Afterpulse: 1.8%



Slicing main signal amplitude

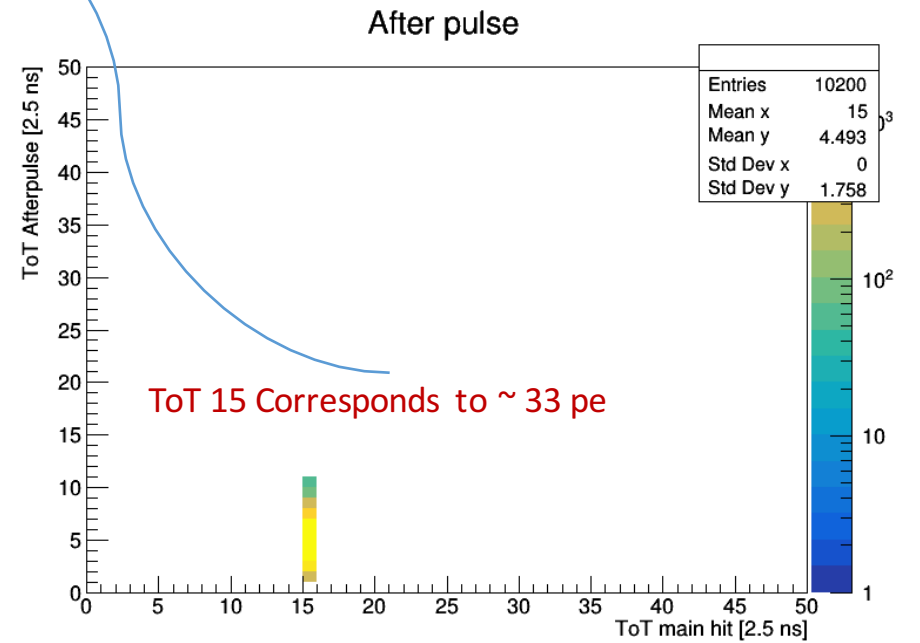
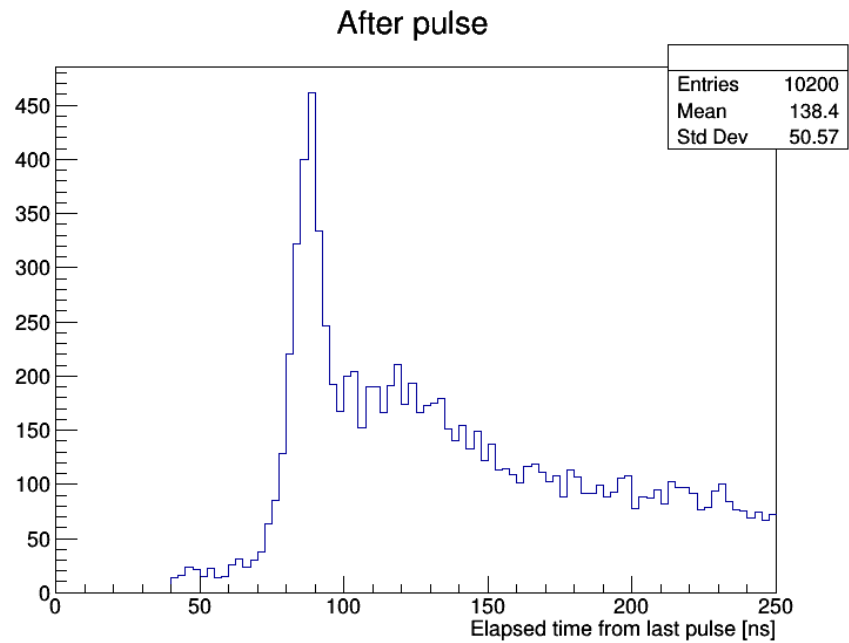
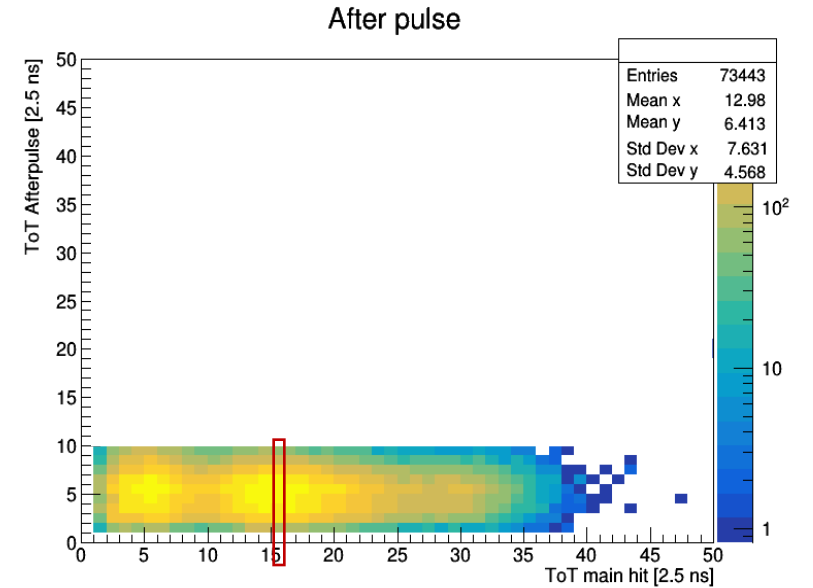
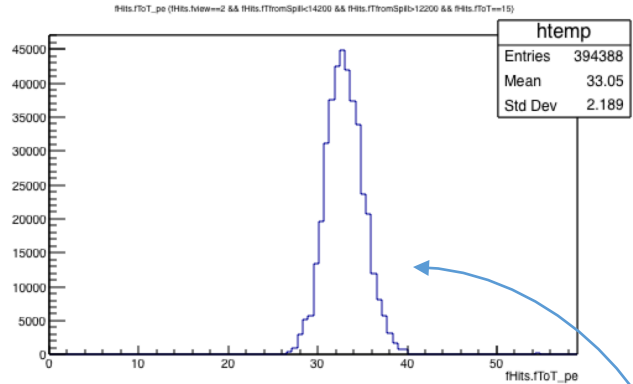
Main signal ToT: 14 ticks
N Total: 445901
Afterpulse: 2.1%



Slicing main signal amplitude

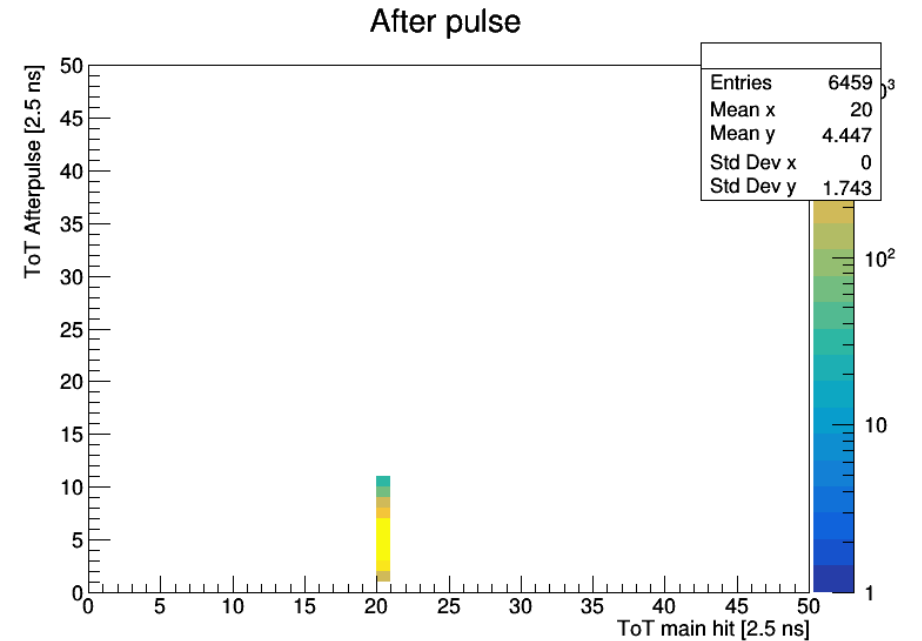
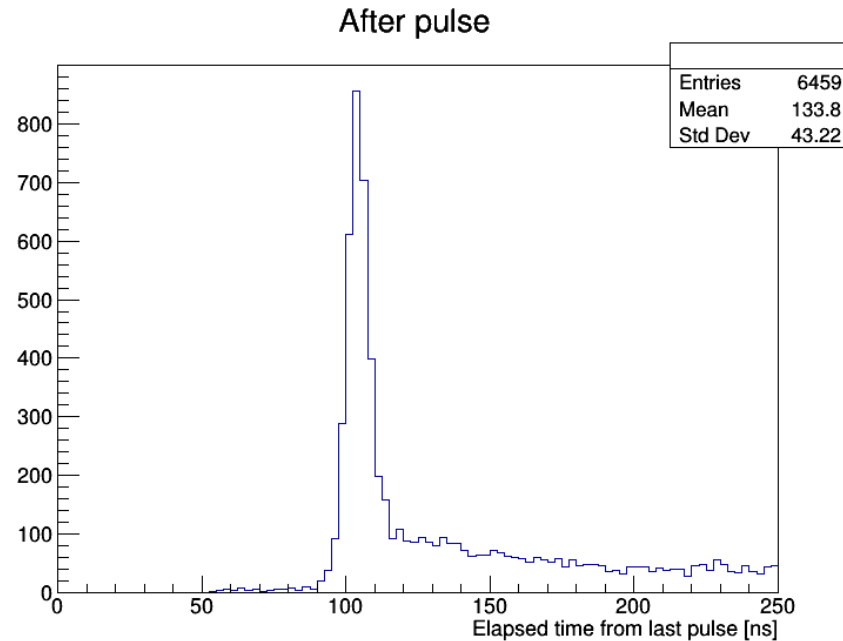
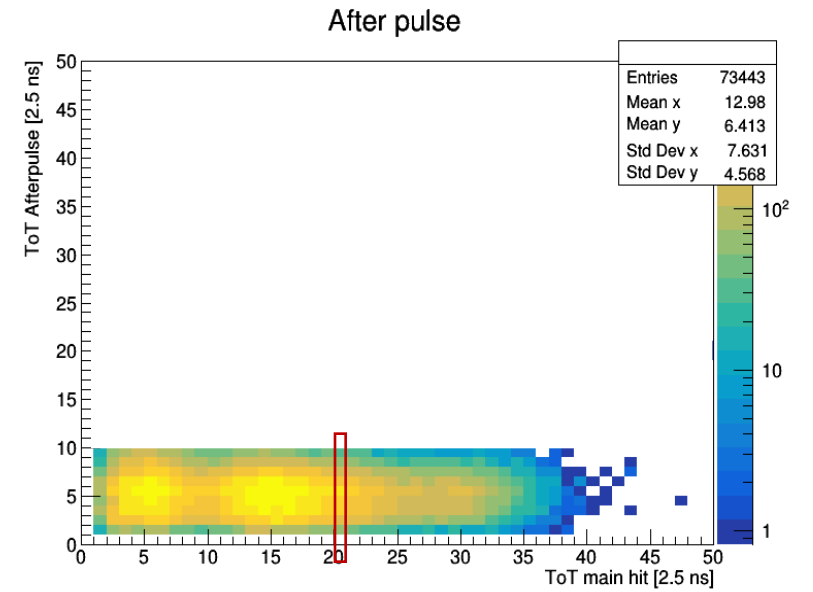
p.e distribution for hit with ToT 15 ticks

Main signal ToT: 15 ticks
N Total: 394391
Afterpulse: 2.6%



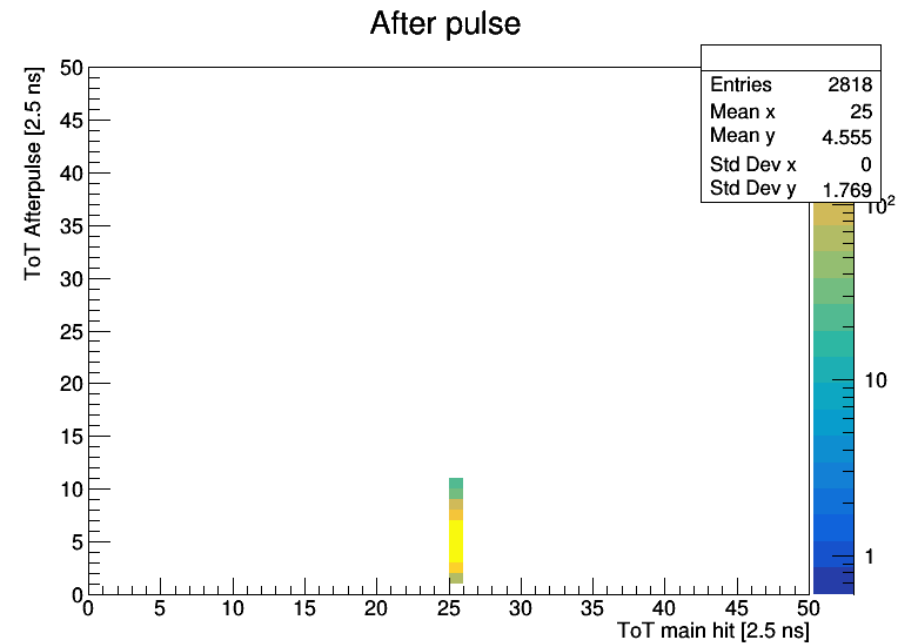
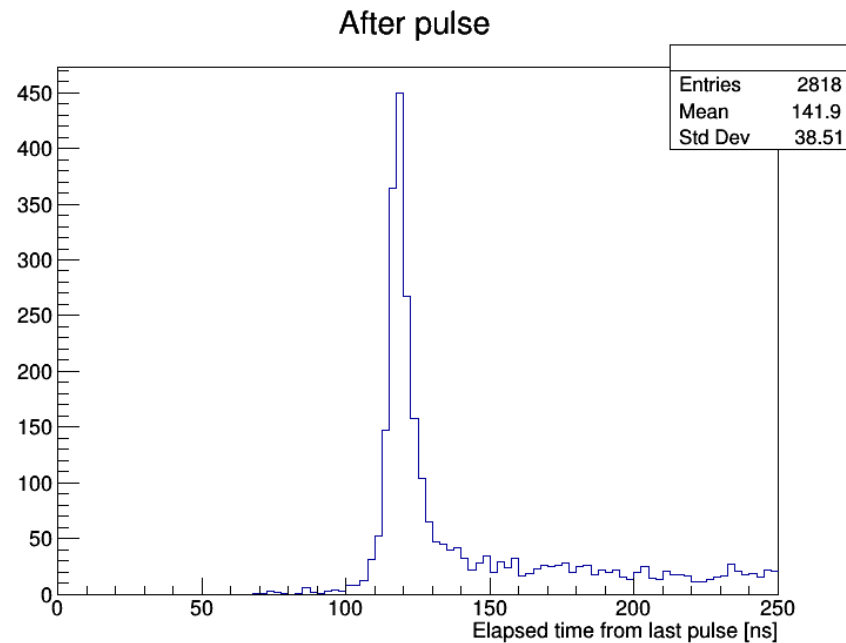
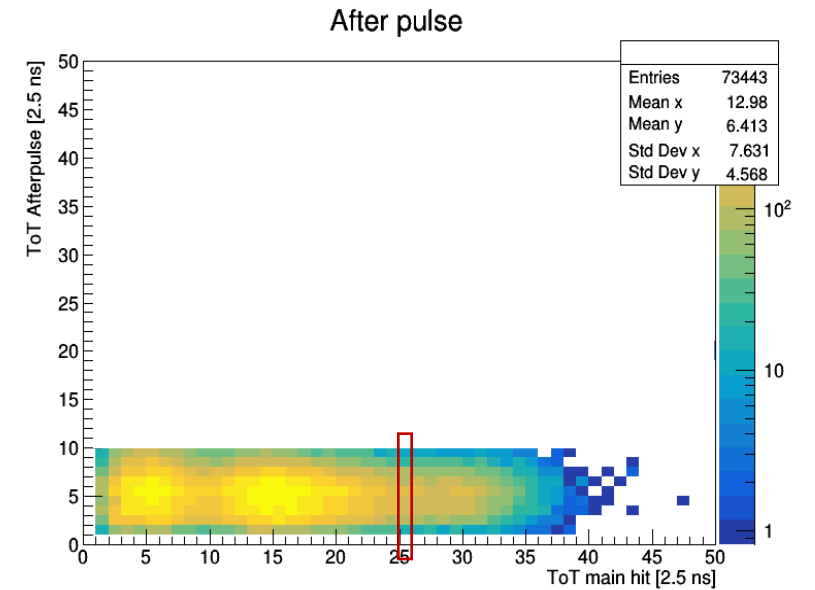
Slicing main signal amplitude

Main signal ToT: 20 ticks
N Total: 88293
Afterpulse: 7.3%



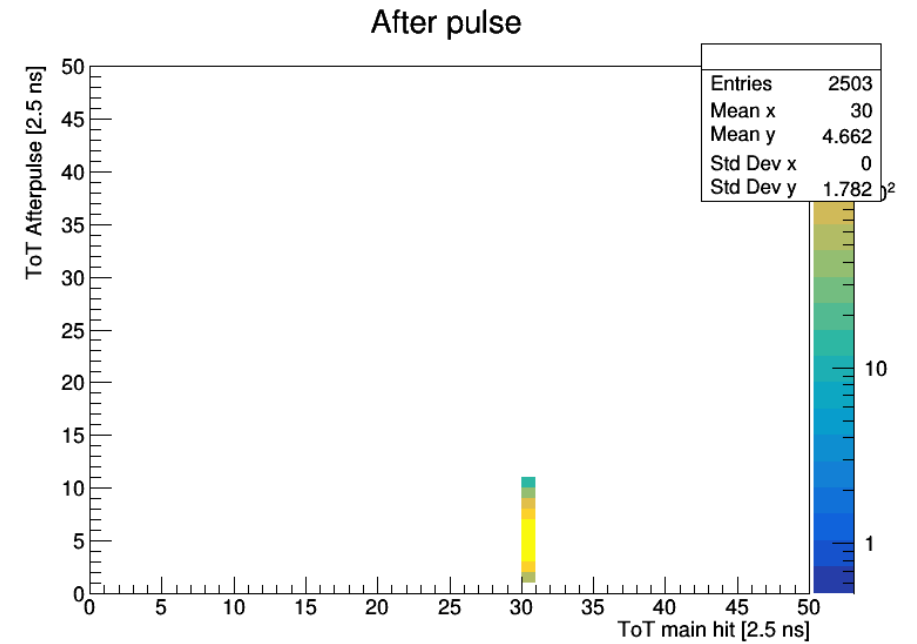
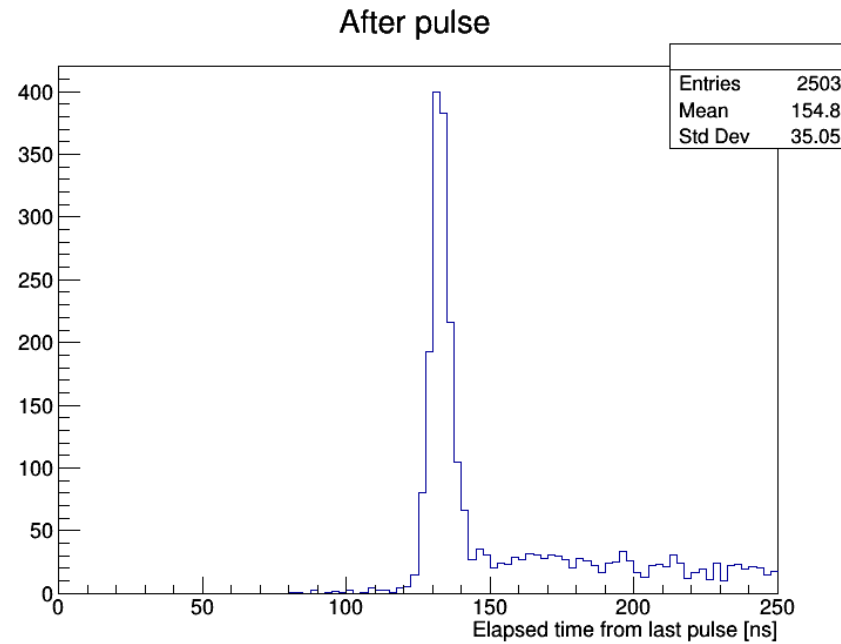
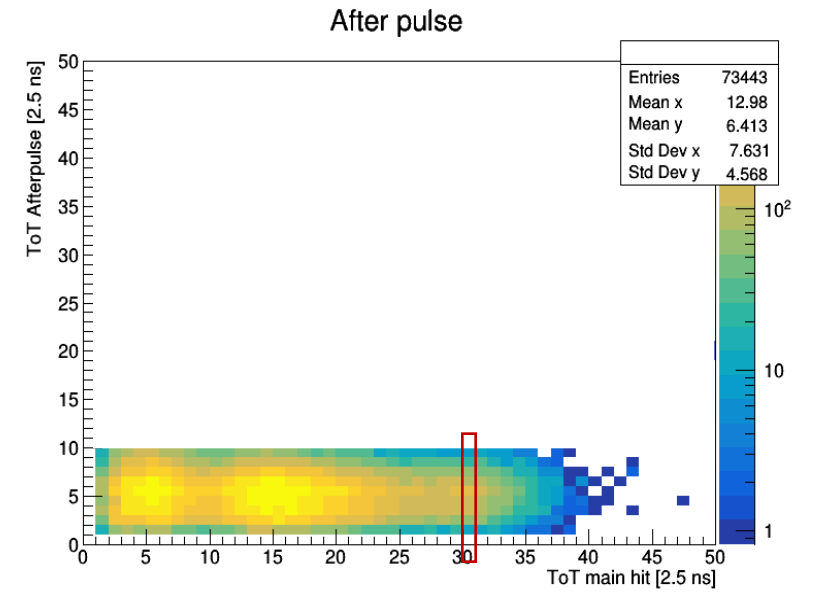
Slicing main signal amplitude

Main signal ToT: 25 ticks
N Total: 22212
Afterpulse: 12.9%



Slicing main signal amplitude

Main signal ToT: 30 ticks
N Total: 11382
Afterpulse: 22%



After pulse

After pulse

Prompt pixel crosstalk (Dark count fingerplot)

