Oneton analysis progress – method about decay muon event selection, with water data, and for hodoscope triggers

10/18/2018

Number of events in the data

	Water runs	WbLS runs	notes
period	3/16/18--7/16/18	8/6/18--10/2/18	
Number of runs	6423	3598	
Run_numbers	23933--30459	32494--36185	
Total_events	64227795	34271069	
Hodo_only (HO)	1816009	702190	(H0 || H2) && (H1 || H3), not multiTrig, not LED
Multi_only (MO)	59100083	31177712	Nhit>6, not LED, not hodo
Hodo_and_multi (HaM)	292655	530530	(H0 || H2) && (H1 || H3) and Nhit>6
Hodo_or_multi (HoM)	61208747	32410432	= HO + MO + HaM
HodoTrig (HT)	2108664	1232720	= HO + HaM, not LED
MultiTrig (MT)			= MO + HaM, not LED
LED_only	3019047	1860627	
GoingThrough_hodo	425042	249118	In HT (HO+HaM, not LED), and hit H4 or H5
StrictHodo	150249	78883	H0 && H2 && H1 && H3, not LED

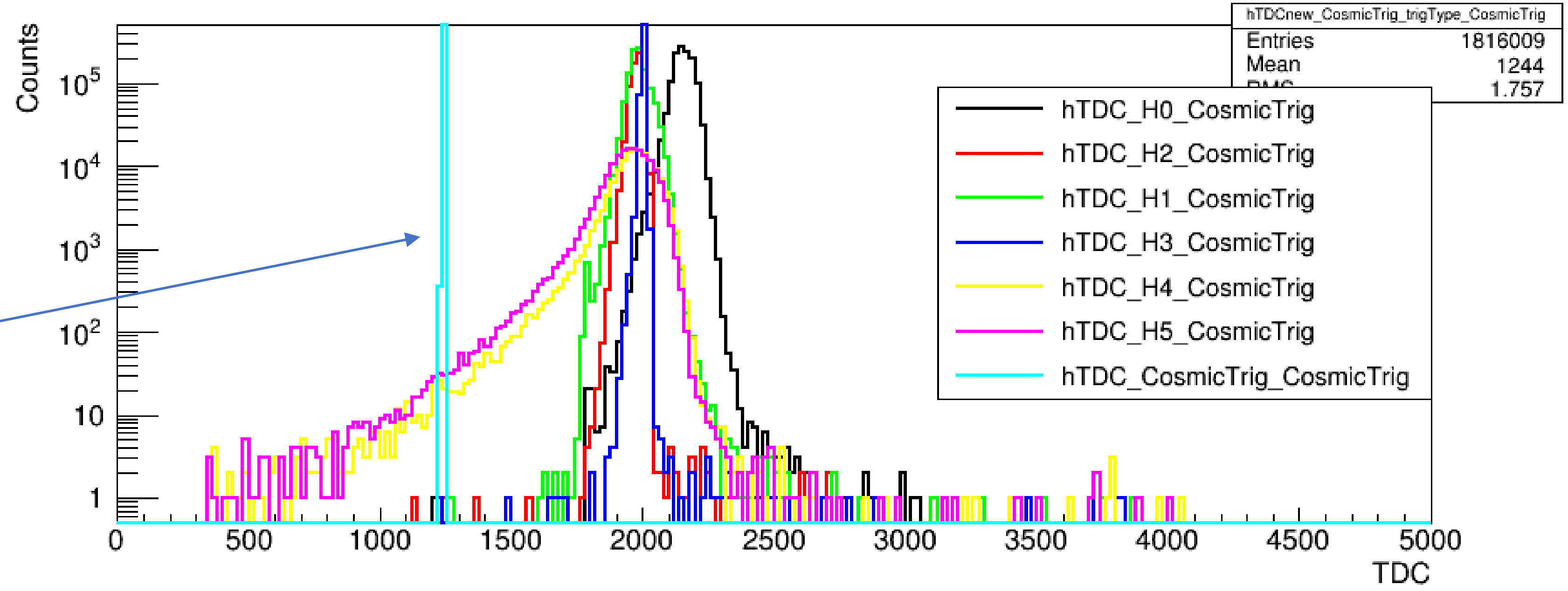
Further notes:
1, Trigger selections are based on TDC entries.
2, There's sure other combinations for producing different samples, but for now I focus on the HodoTrig (HT),Hodo_only (HO), GoingThrough_hodo, and Multi_only (MO) triggers.

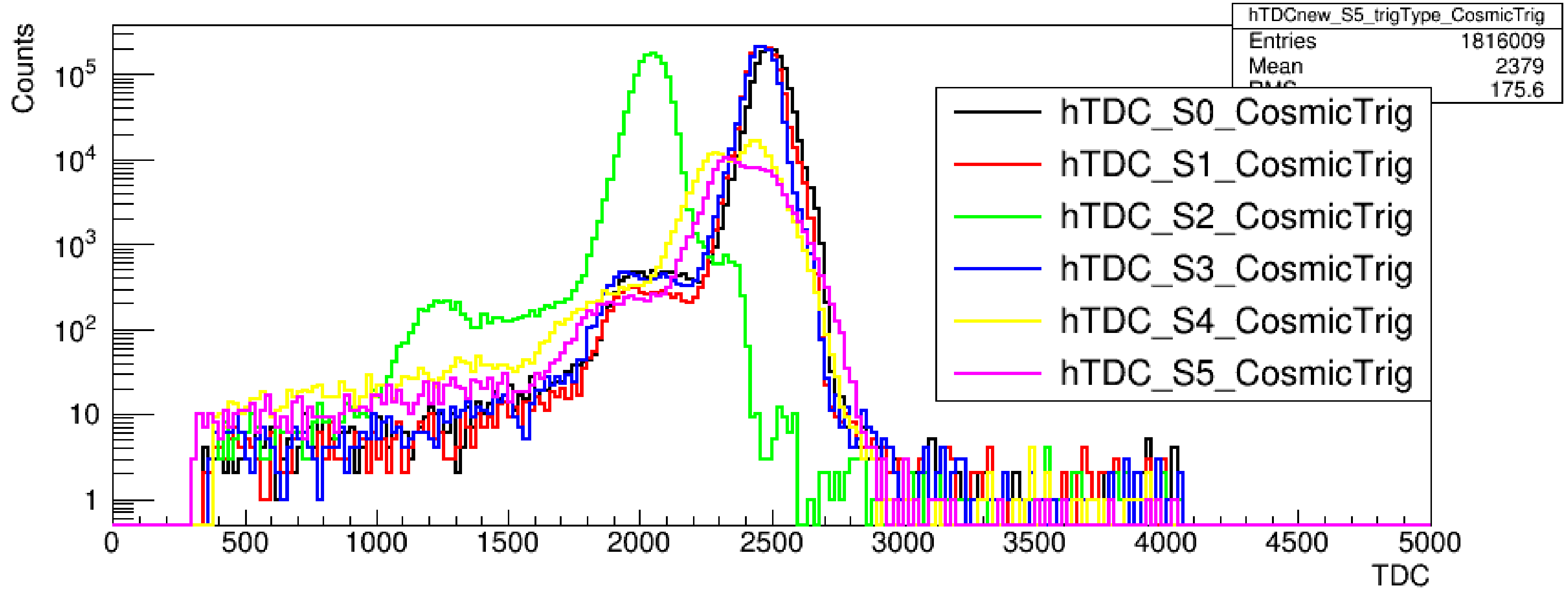
The ratio of going through muons in the hodoTriggers is now consistent for water and WbLS:
425042/2108664=20.16%; 249118/1232720=20.21%

Water data, TDC histograms, the hodoOnlyTriggers

In this sample, the TDC entries for HaM triggers are removed.

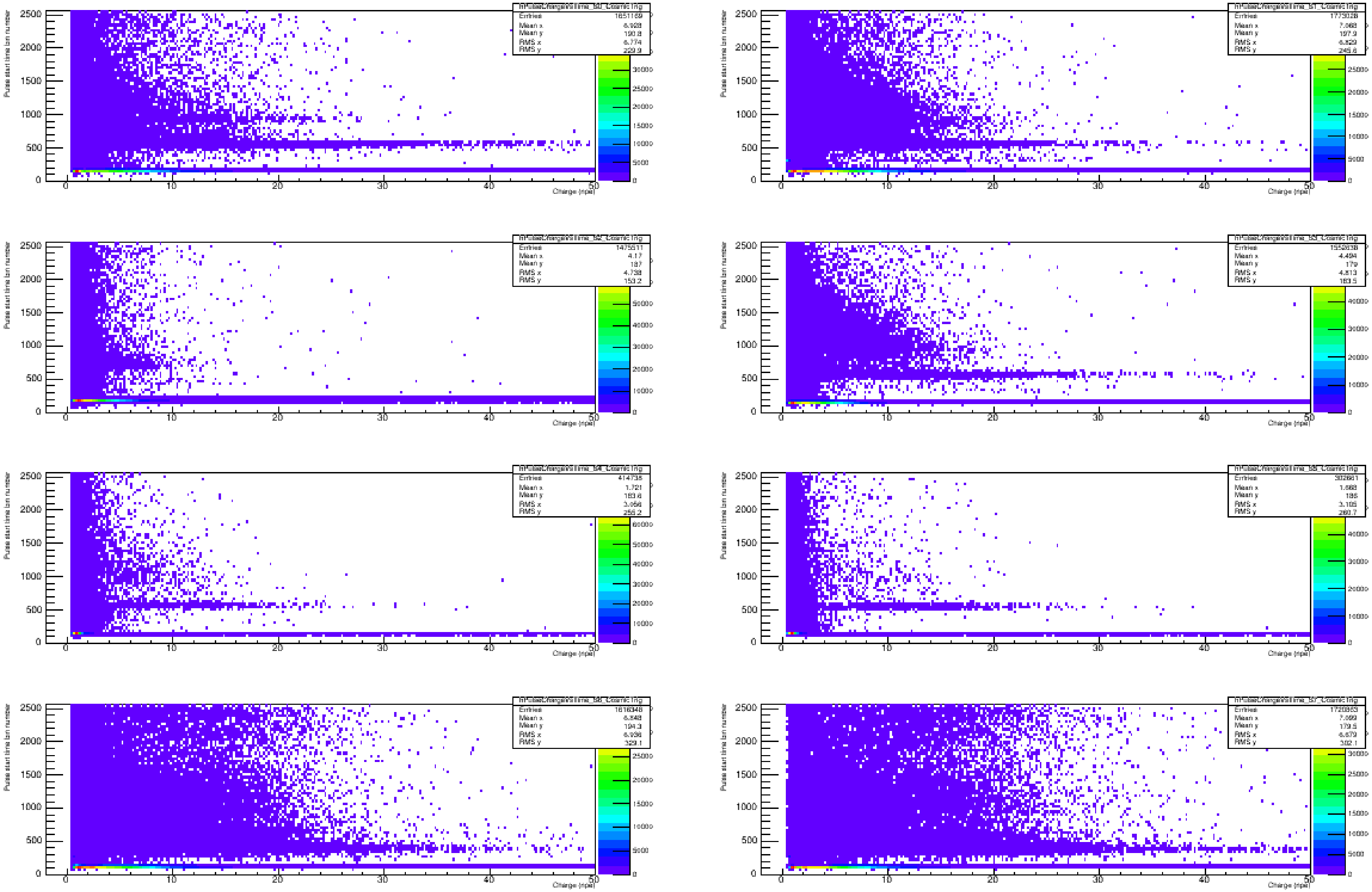
The TDC entries for the hodoscope triggers is almost a constant: its variation region is within 20 TDC channels (1 TDC channel = 35 ps.)





Water data, the hodoTriggers (include HaM triggers)

Pulse charge (npe) vs time, for every pulse



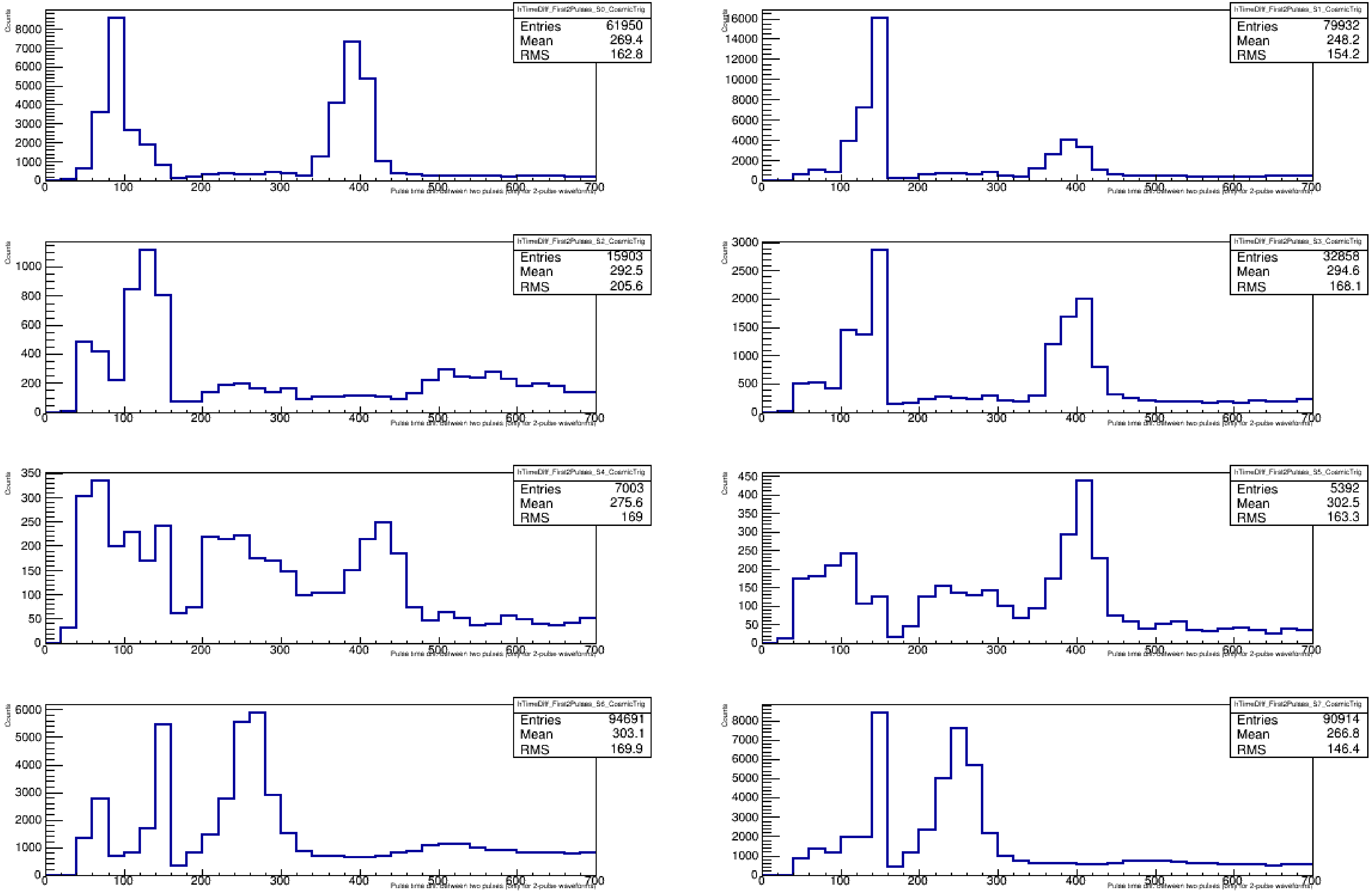
Water data, the hodoTriggers (include HaM triggers)

Time difference of the first two pulses in each PMT (for >=2 pulses waveforms)

The peaks here indicate the after pulses

I didn't try to normalize the histograms, but S2, S4 and S5 seem to have fewer after pulses.

In >=2 pulses waveforms, if the second pulse's time is in these peak regions, I treat it as an afterpulse, and plot its charge vs. the charge of the first pulse on a scatter plot, see next page.

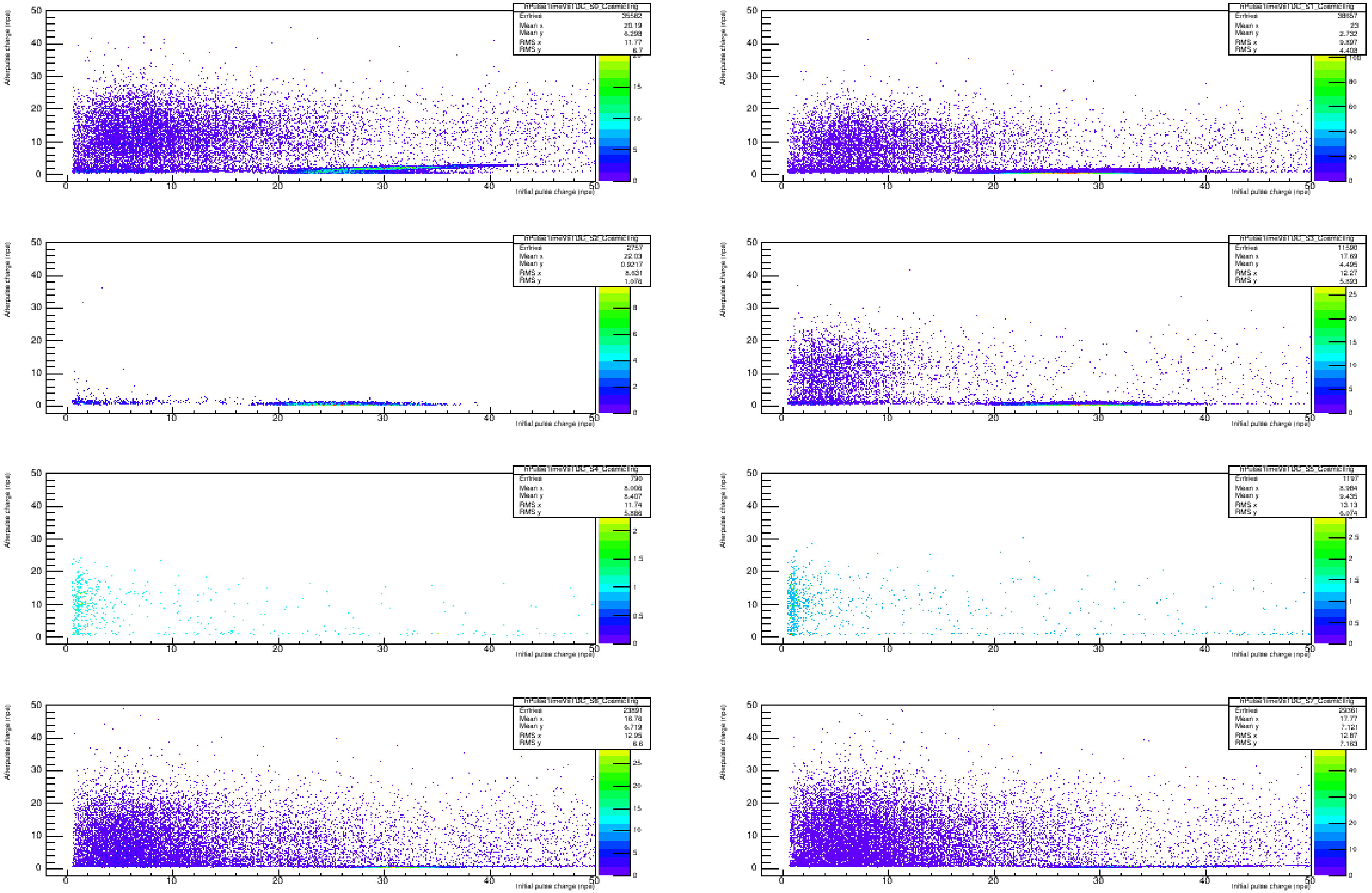


Water data, the hodoTriggers (include HaM triggers)

Afterpulse charge vs. initial pulse charge (require >=2 pulses in waveforms)

I don’t expect the afterpulse charge to depend on the initial pulse charge (or the number of inputting photons).

Here I see more entries at initial charge of 20~30 npe, I think this is just the catachrestic of these PMTs. I’m not sure how to explain this.

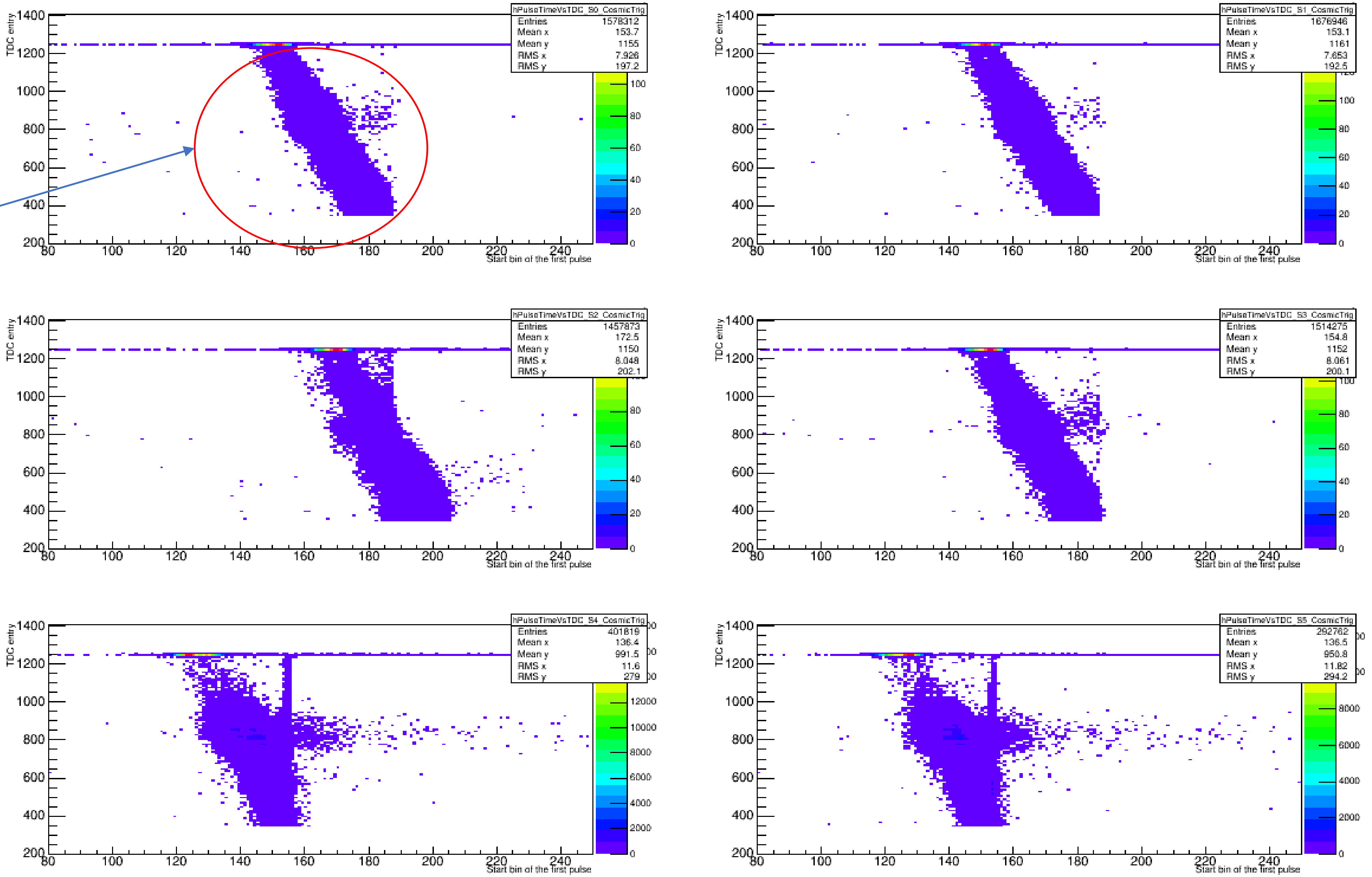


Water data, the hodoTriggers (include HaM triggers)

PMT's TDC entry (hodoscope TDC channel) vs. PMT's first pulse's time

Note no TDC data for S6 and S7

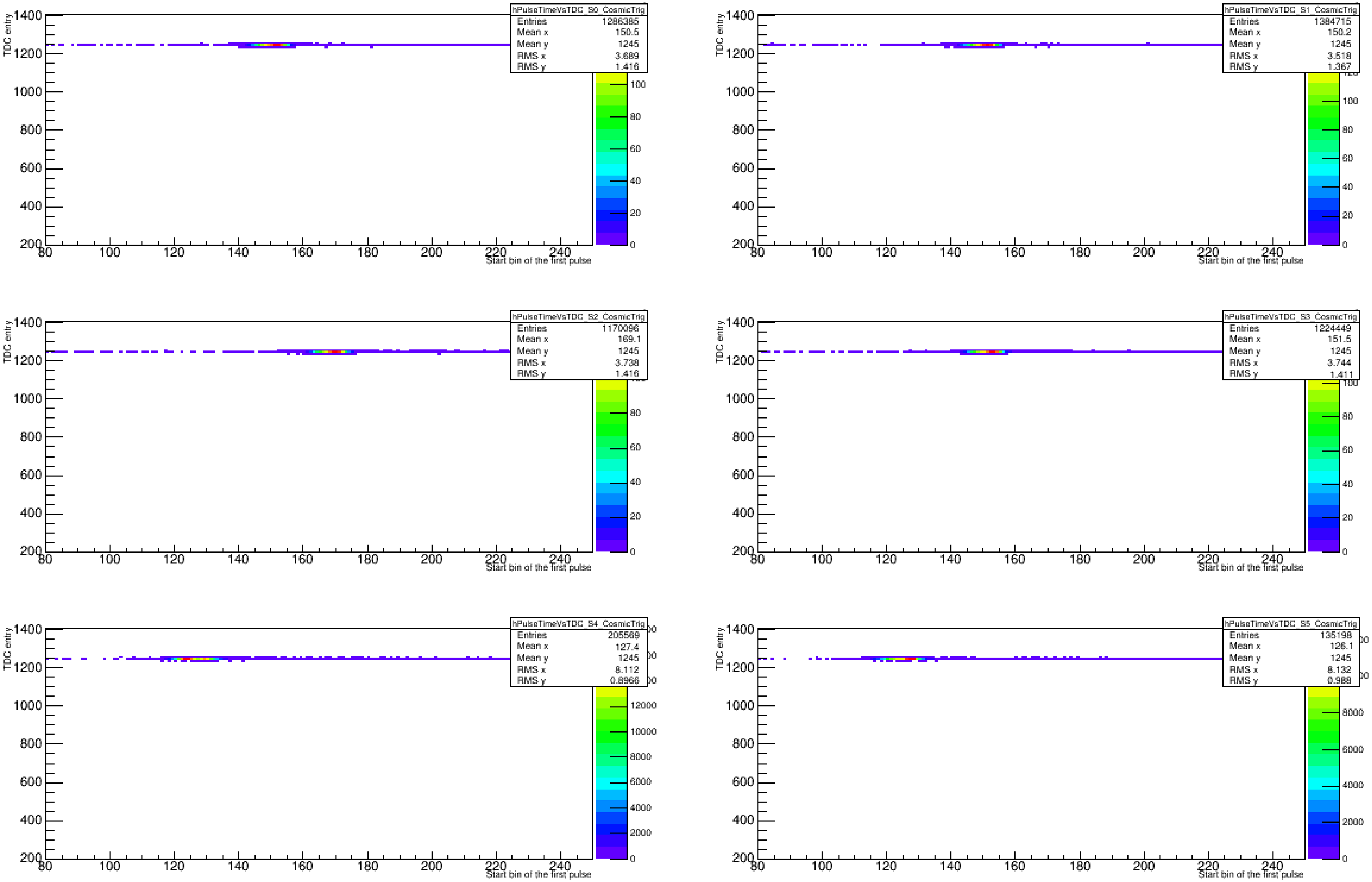
These blocks are events with both multiplicity triggers and hodotriggers, see next page for hodo only triggers.



Water data, the hodoTriggers (**hodo only** triggers)

PMT's TDC entry (hodoscope TDC channel) vs. PMT's first pulse's time

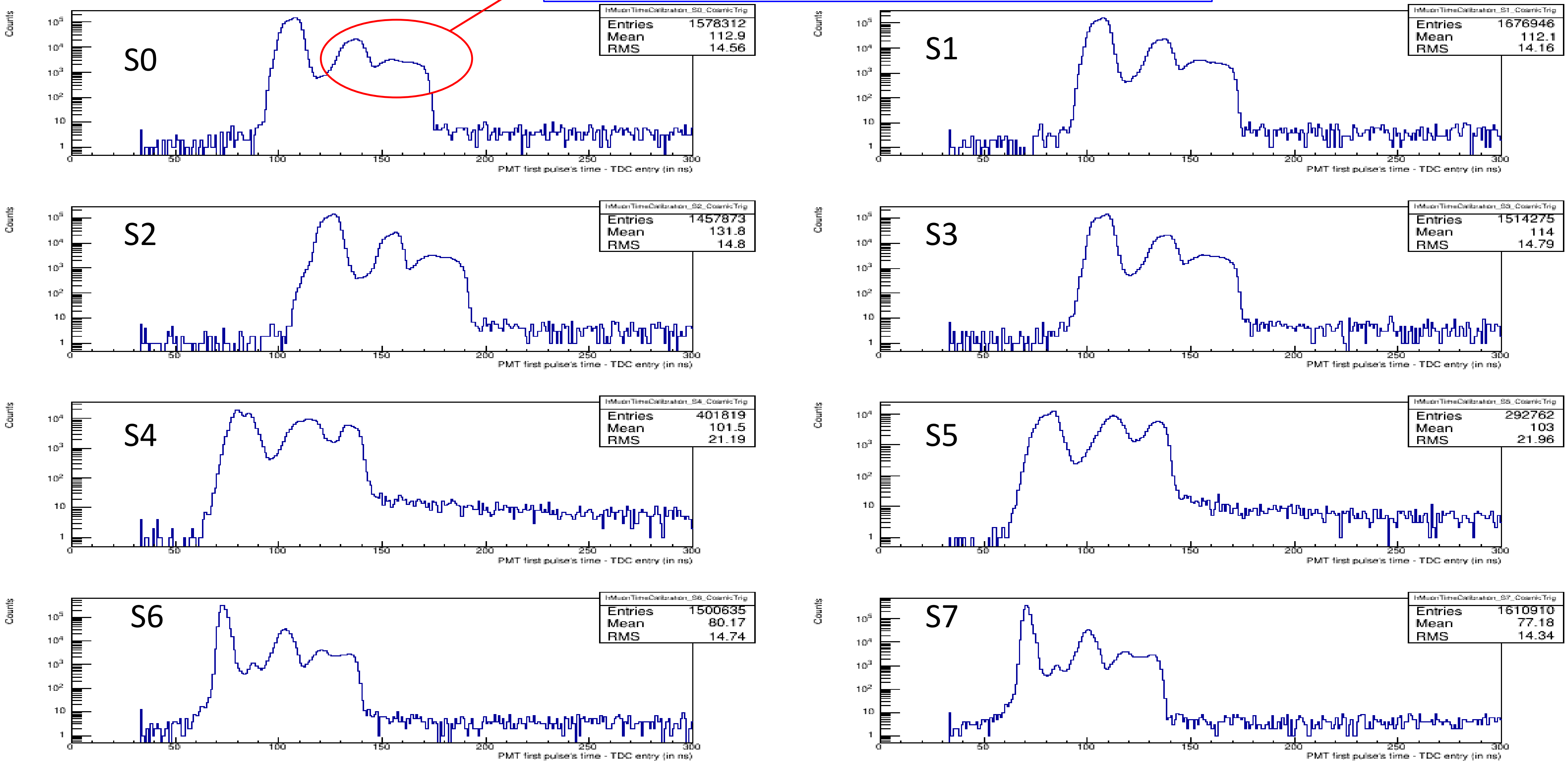
Note no TDC data for S6 and S7



Water data, hodoTriggers (include HaM triggers)

TDC entry for hodoscope triggers is around 1250 TDC channel, which corresponds to 0.035*1250=43.75 ns. (0.035 ns/TDC channel)
The pulse time for muons in digitizers is around 150 bin, or 150 ns.
The two times are with different scales, but relatively, I define the variable t_mu = t_pulse – t_TDC as the muon time.
Now look at t_mu distributions for the PMTs:

Multiplicity triggers, compare with next page



Water data, hodoTriggers (only hodoscope triggers, no multiplicity, no led)

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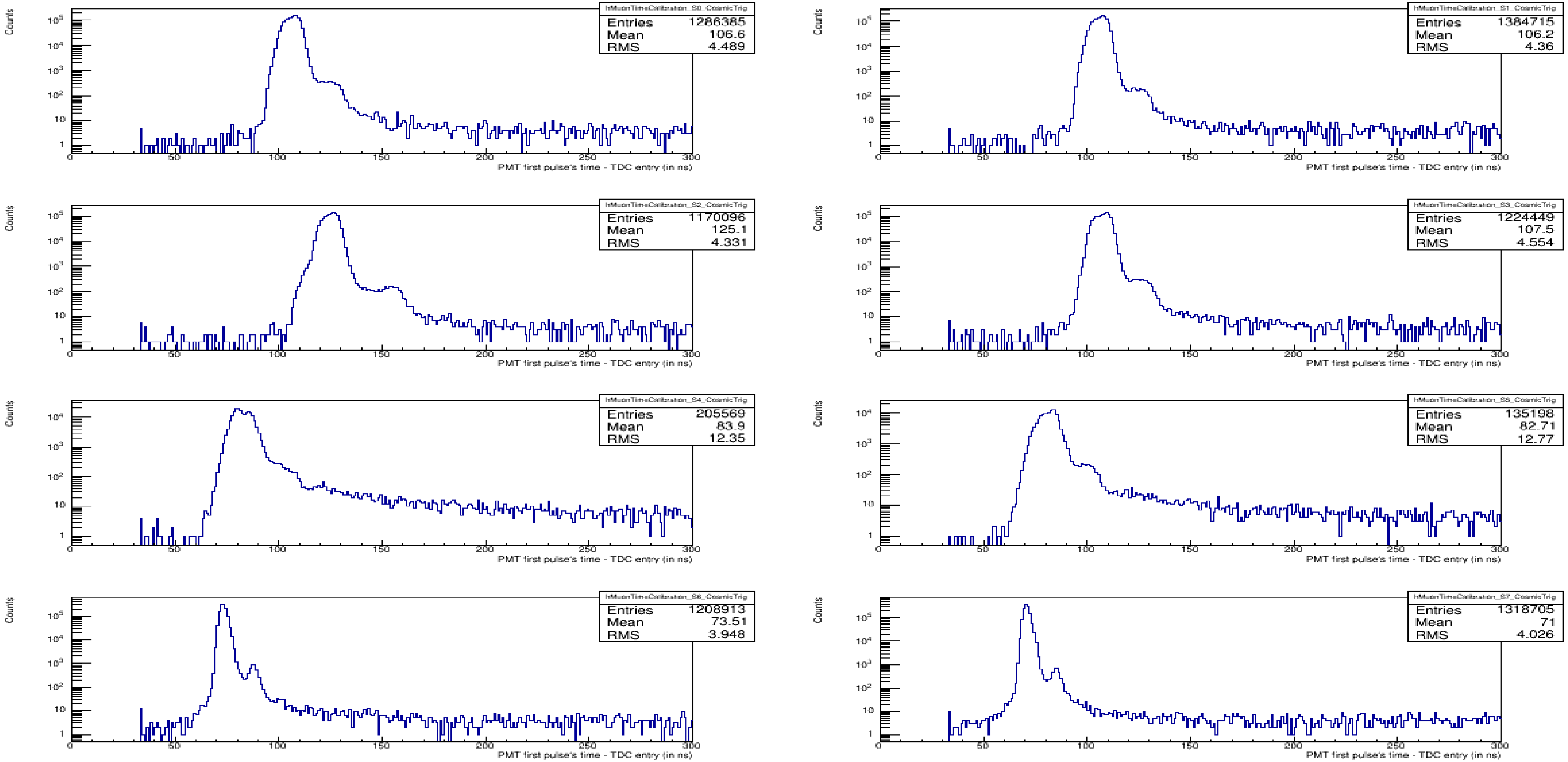
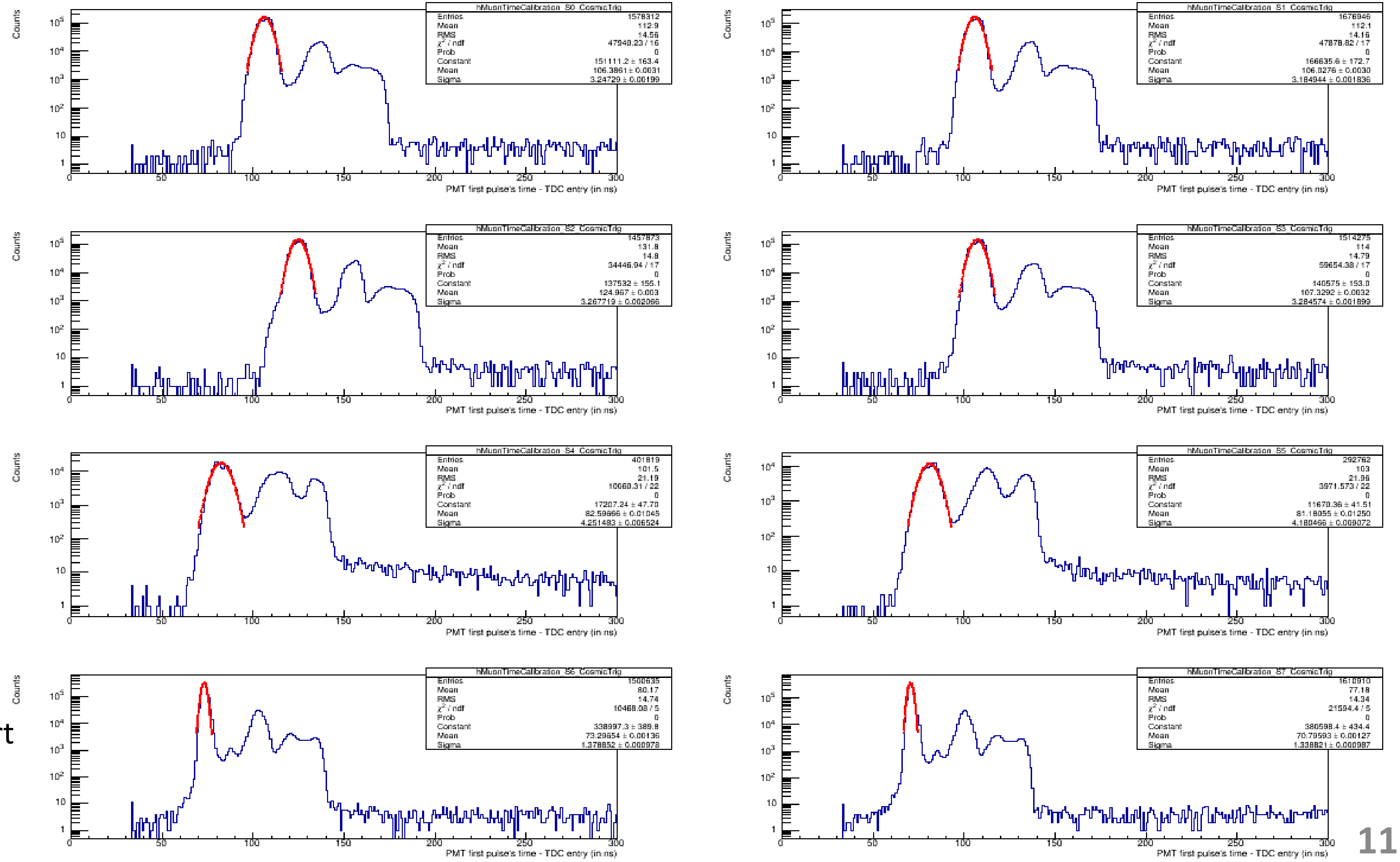


Water data, hodoTriggers (include HaM triggers)

The t_mu = t_pulse – t_TDC distributions for the PMTs are fitted with Gaussians around the peak for hodoOnly triggers.

	Mean_ muTime	width
S0	106.4	3.2
S1	106.0	3.2
S2	125.0	3.3
S3	107.3	3.3
S4	82.6	4.3
S5	81.2	4.2
S6	73.3	1.4
S7	70.8	1.3

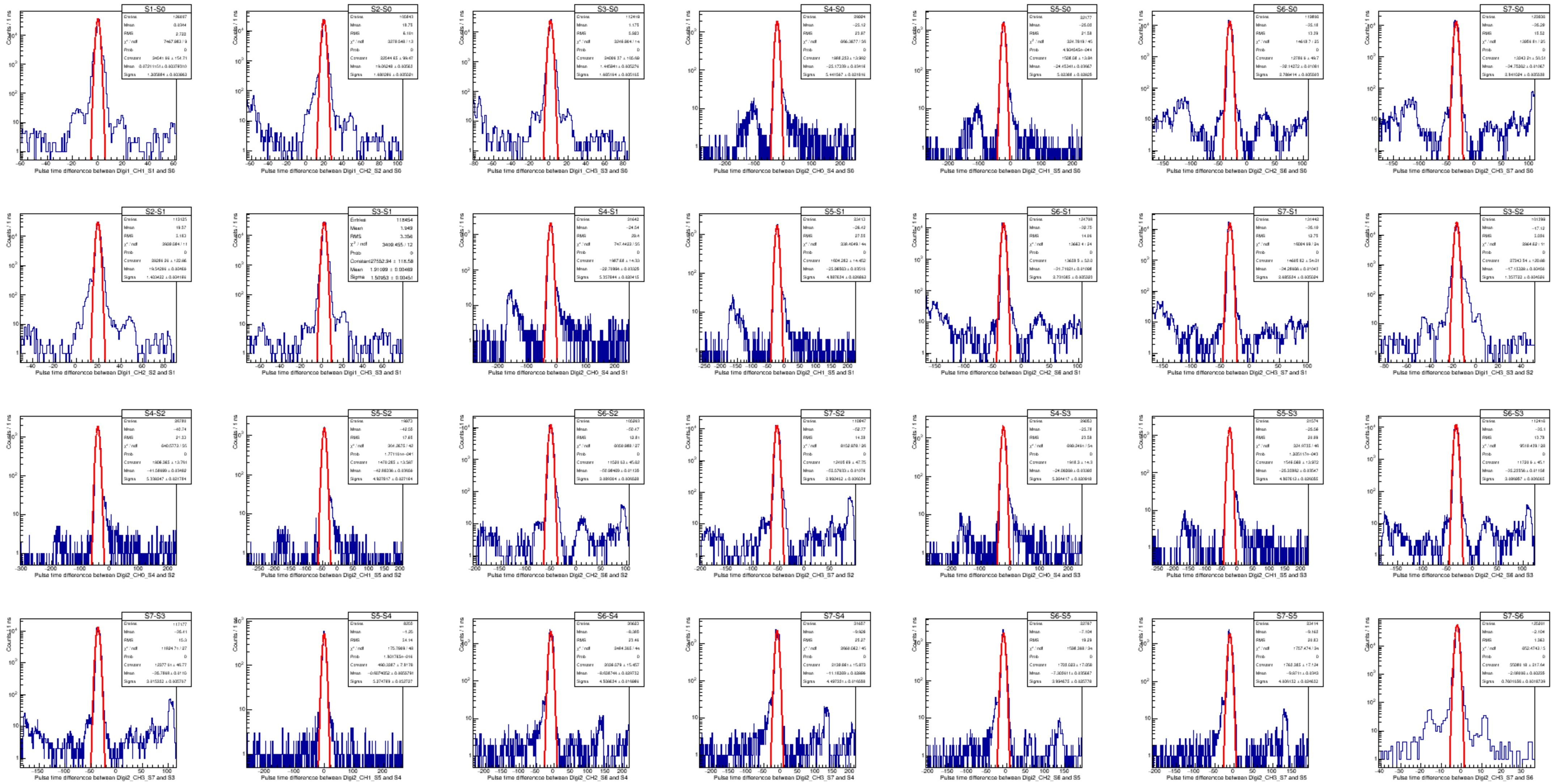


the width is at the same level compare to the case when not using TDC in determining the muon start time.

Water data, the hodoTriggers (include HaM triggers)

Pulse time difference between PMTs for all pulses: E=(t_i – t_tdc – M_iavg) – (t_j - t_tdc - M_javg) for i-th and j-th PMTs, M_i = t_i – t_tdc

(I also tried to not include t_tdc in the definition, I got same result. This is not strange because t_tdc is almost a constant.)



Water data, the hodoTriggers (include HaM triggers)

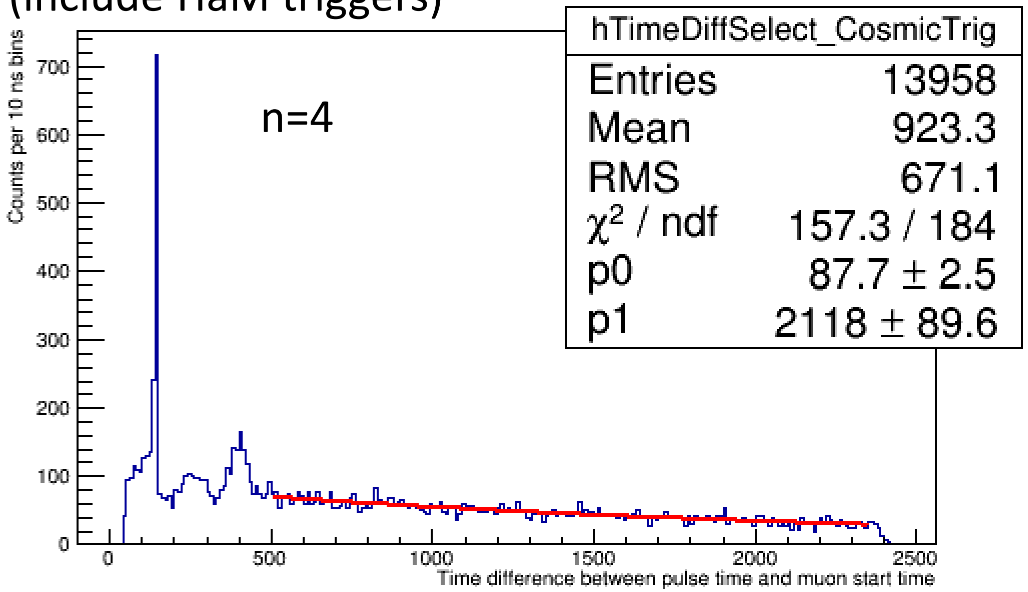
Pulse time difference between PMTs for all pulses: E=(t_i – t_tdc – M_iavg) – (t_j-t_tdc-M_javg) for i-th and j-th PMTs.
M_i = t_i – t_tdc
the fitted values (mean and width) are summarized here

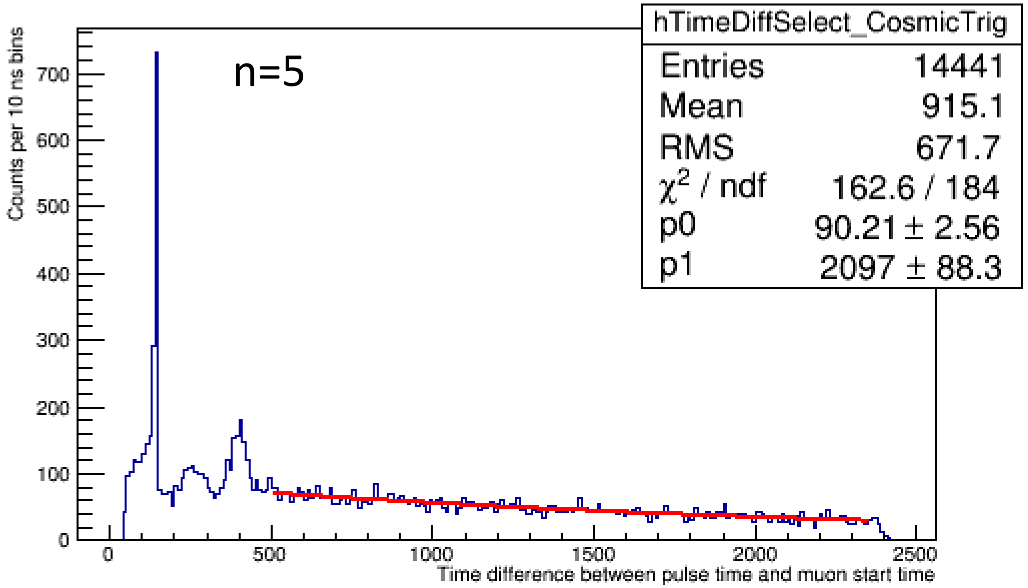
		mean	sigma
S1	S0	0.0739848	1.21532
S2	S0	0.0527475	1.69129
S3	S0	0.43977	1.6704
S4	S0	-0.159319	5.4553
S5	S0	0.447696	5.13083
S6	S0	0.922964	2.77552
S7	S0	0.296518	2.83506
S2	S1	0.530554	1.40872
S3	S1	-0.0985247	1.51714
S4	S1	0.318787	5.37939
S5	S1	-0.0542085	5.02824
S6	S1	0.343448	2.74494
S7	S1	0.771128	2.69697
S3	S2	-0.12697	1.36099
S4	S2	0.458081	5.34831
S5	S2	0.0158028	5.04511
S6	S2	0.0859549	3.09182
S7	S2	0.494532	2.99693
S4	S3	0.0187623	5.26957
S5	S3	0.58527	4.983
S6	S3	0.814555	3.09786
S7	S3	0.266148	3.01839
S5	S4	0.229519	5.40626
S6	S4	0.42671	4.52625
S7	S4	-0.158229	4.4863
S6	S5	-0.118653	4.14029
S7	S5	0.324322	4.14504
S7	S6	-0.0807268	0.756843

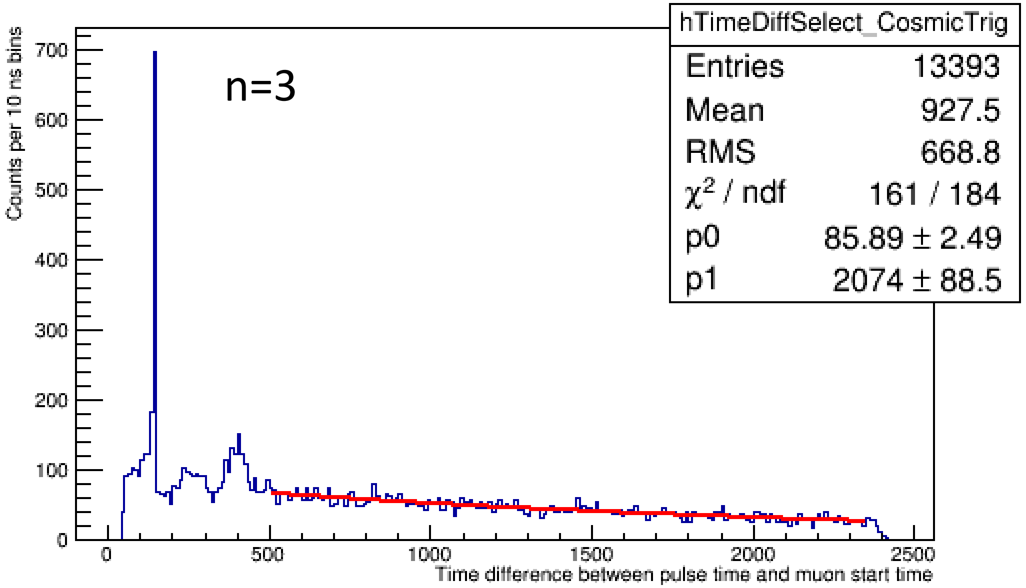
The method to search for coincident pulses:
(1) I use vector of pairs, each pair stores (t_i, pmt_j)
(2) sort the vector in ascending order on the first element of the pair: t_i
(3) in the sorted vector, compare neighboring t_i and t_(i+1)
I know which PMTs these two pulses belong to,
I require the difference between t_i and t_(i+1) to be within a range [mean-n*sigma, mean+n*sigma] for coincidence, mean and sigma are listed on the left table.
I need to pick a proper number 'n'.
Initially I picked n=5, because that sets a larger range for two pulses to be coincident. And in fact, for PMTs other than S4 and S5, since the width is 3 ns at most, n=5 means a range of 30 ns around mean value.
More events will be selected with larger n, next page shows some results. Too small n (eg n=1) is not good because it increases chance to identify in-time pulses in different PMTs to be decay candidates. n>=3 looks ok.
(4) If a pulse is not determined as in coincidence with previous one, then form a new coincidence group and check if the next pulse is in coincidence with this one.
(5) finally I have a few groups of coincident pulses. The number of groups is mainly 2 (so the first group contains muon pulses, the second group is for the electron pulses) for good decayed events. There is chances that the number of groups is >2, the ratio is <4% for all hodoTriggers (and <1% for hodoOnlyTriggers), when n=5 is used.
(6) from the groups of the coincidences, I can calculate average decay time, and summed decay charge.

Water data, the hodoTriggers (include HaM triggers)

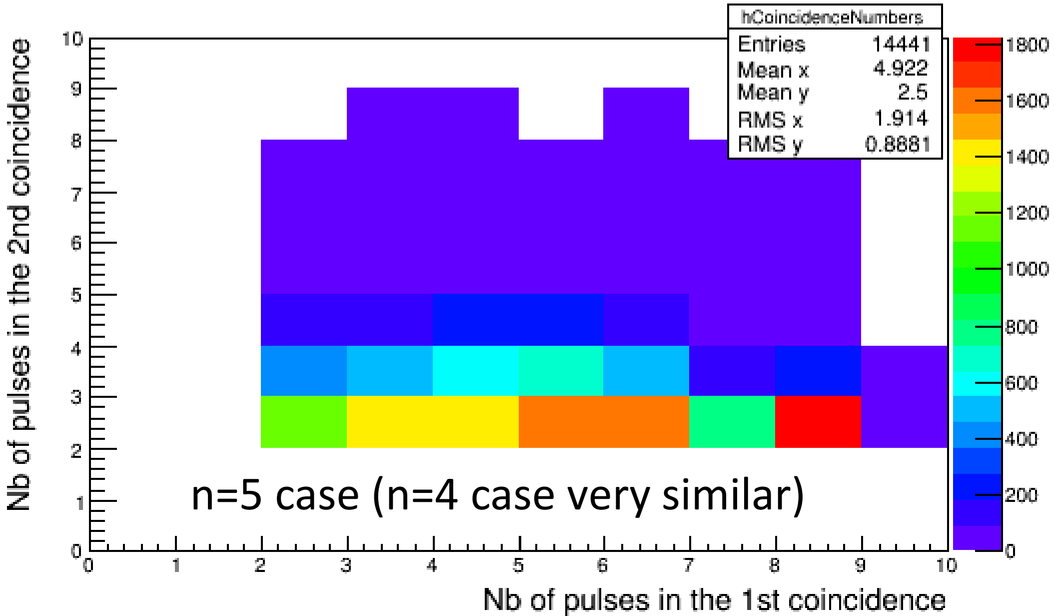
The decay time distributions, selected from the hodoTrig (include HaM triggers)







The number of pulses in coincidence in the main pulse region vs. in the decayed pulse region.

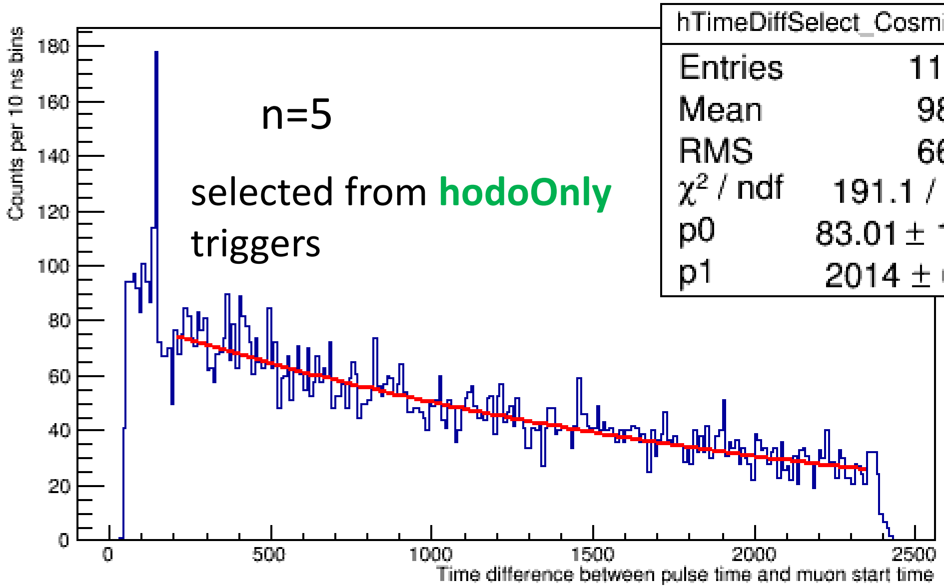


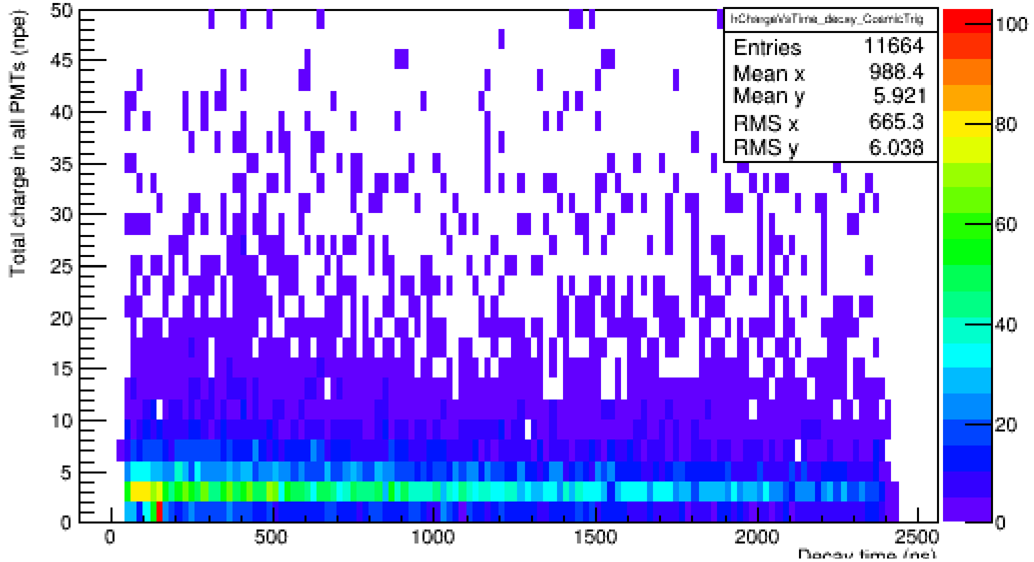
Water data, compare the hodoTriggers vs. hodoOnlyTriggers

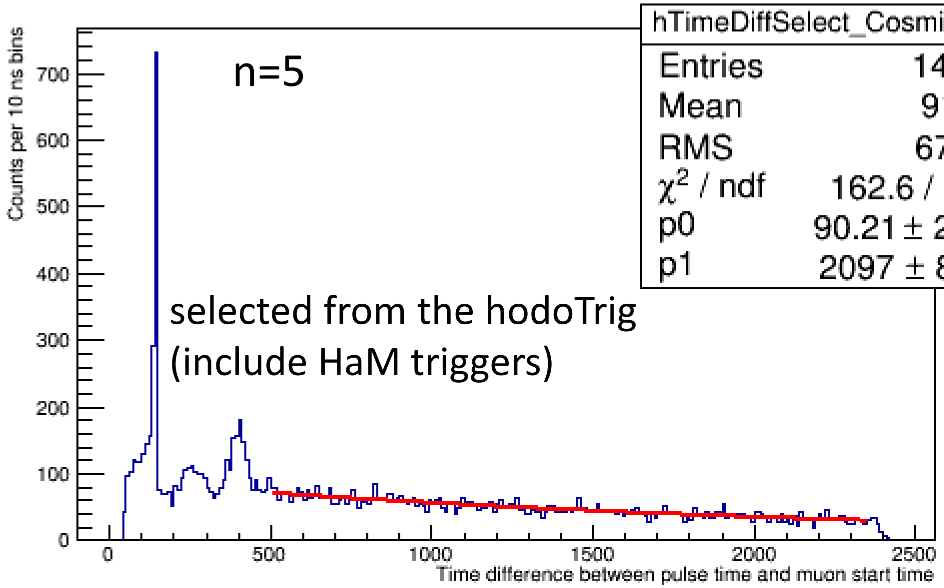
Looks like this method works fine for hodoOnly triggers. The hodoTrigs with multiTrig tags have a different muon start time as shown on page 9.

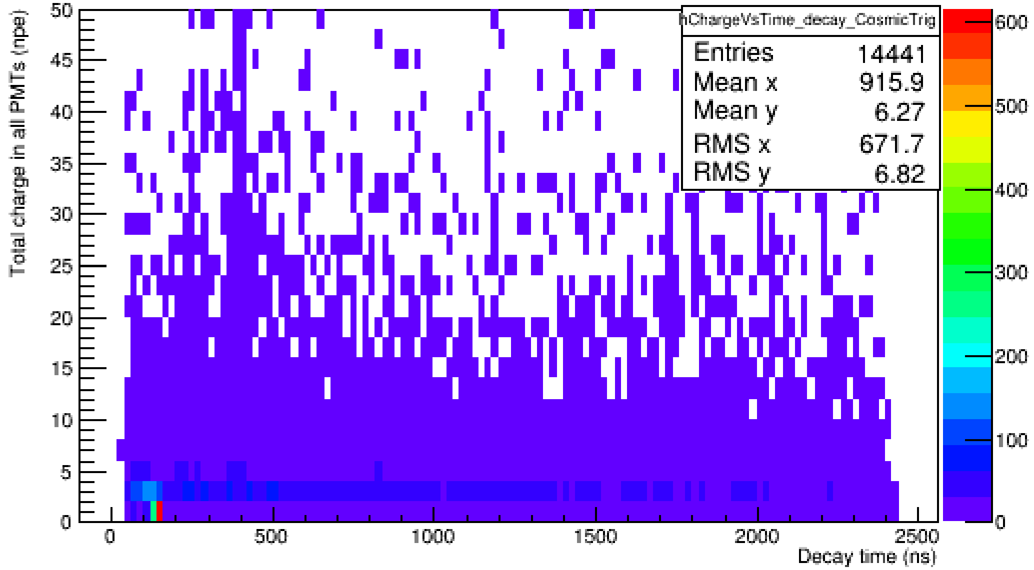
The decay time distributions

Total charge of the decayed pulses vs. decay time



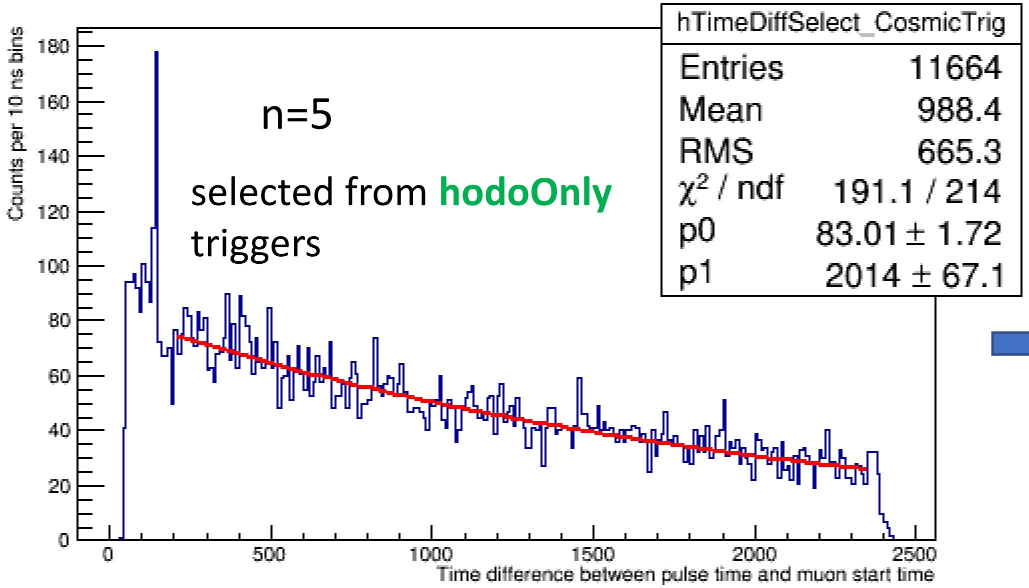






Water data, hodoOnlyTriggers

The decay time distributions



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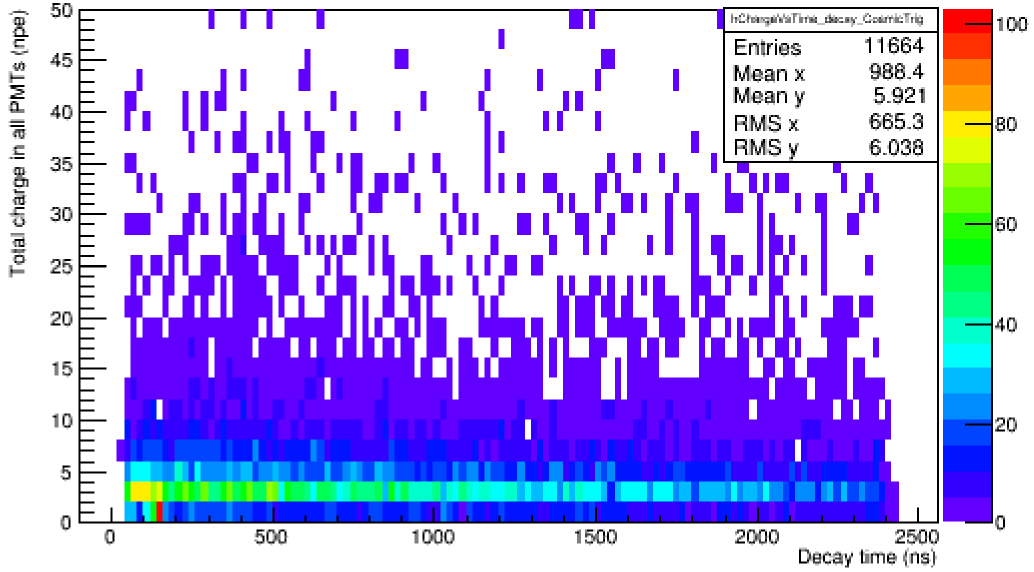

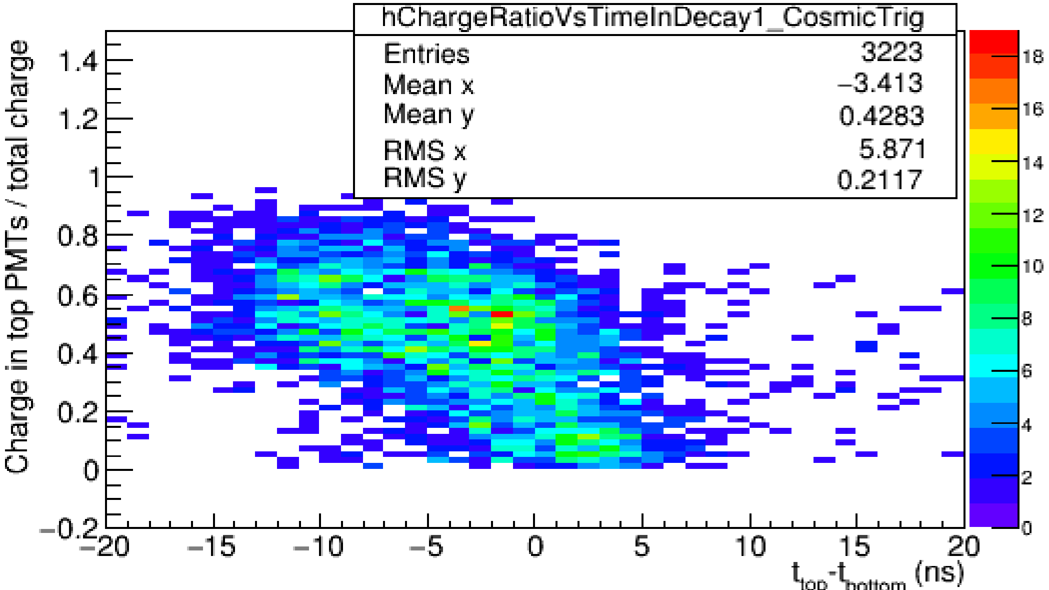

Also looks like the spike on decay time distribution around 150 ns has small charge, see the red bin on the top scatter plot. What if I take out that bin?

The plot on left is ratio of charge in top PMTs over total charge, for the decayed pulses, as a function of the difference of the average decay times in top and bottom PMTs.

I'm thinking how I can use this to interpret the decay locations…