TELLIE PCA:
Processing automation

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This document describes what the TELLIE PCA automation does, why, and how.

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2 Why automation

The process of extracting and validating PCA constants from TELLIE data is complex. This piece of software was developed to streamline the process of obtaining the PCA constants, at reasonably high speed.
Additionally, it was designed to:

- be independent of the method used for Data-taking
- be modular, easily modifiable and configurable
- require minimal human input
- provide monitoring
- be mostly standalone

3 Overview

The TELLIE PCA Automation overview is shown in Figure 1.
There are two main parts: TELLIE `Data-taking` and `Data-processing`.

Data-taking is done independently of the processing (as the exact method was not yet finalised before developing processing). More information can be found in TELLIE Data-taking automation document. It should be noted that `Validation #1` is taken care of by Data-processing.

Data-processing is everything that is done with TELLIE PCA data once it is stored. This includes performing checks on the data, making fits required for further processing, generating tables (both local and online), extracting PCA constants, benchmarking these constants, and a suite of monitoring for these steps. These will be described below.

4 Data-taking

4.1 Validation #1

As mentioned above, even though `Validation #1` is logistically part of Data-taking, it is performed by Data-processing, and is also independent of

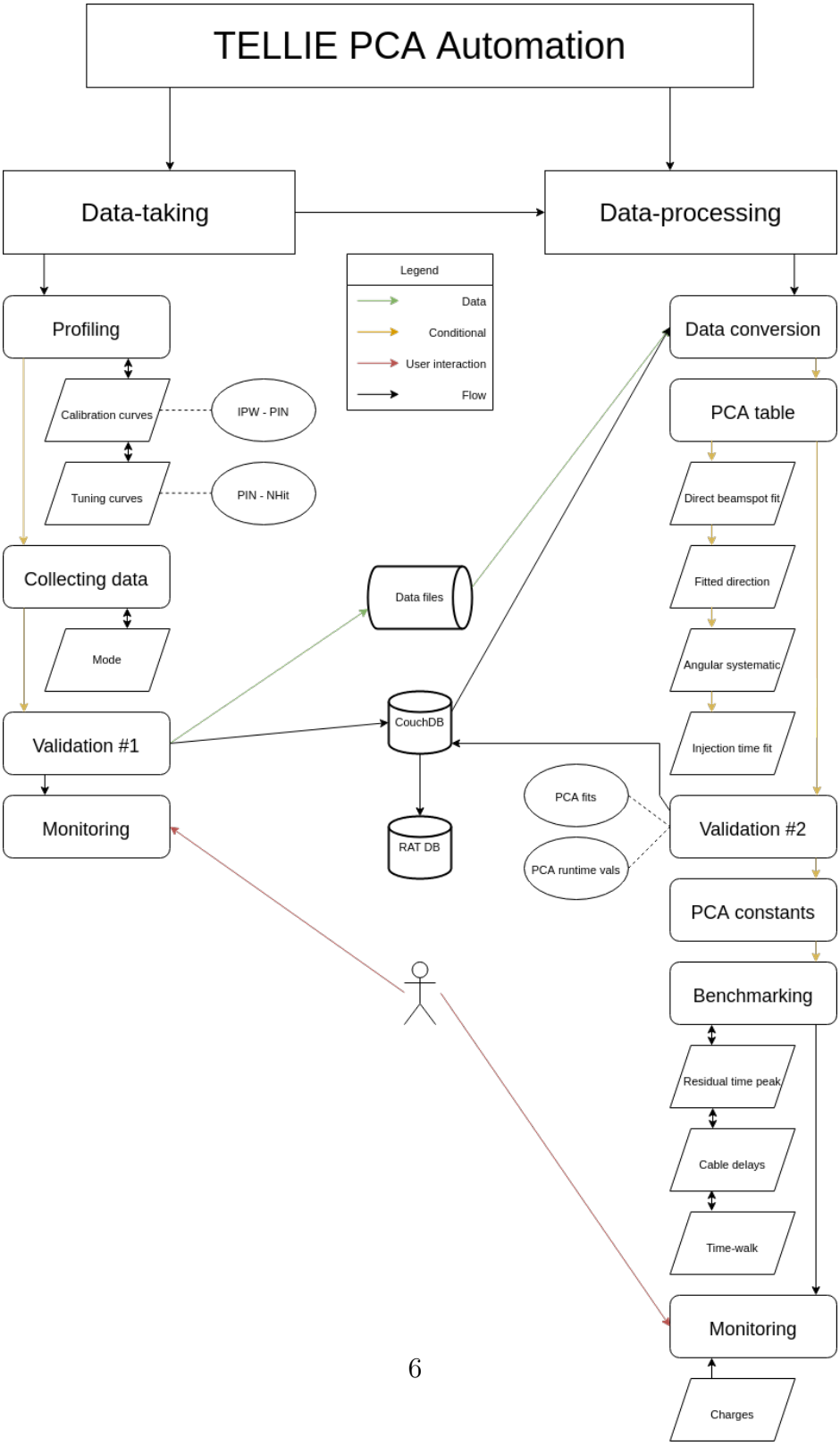


Figure 1: Overview of the TELLIE PCA Automation.

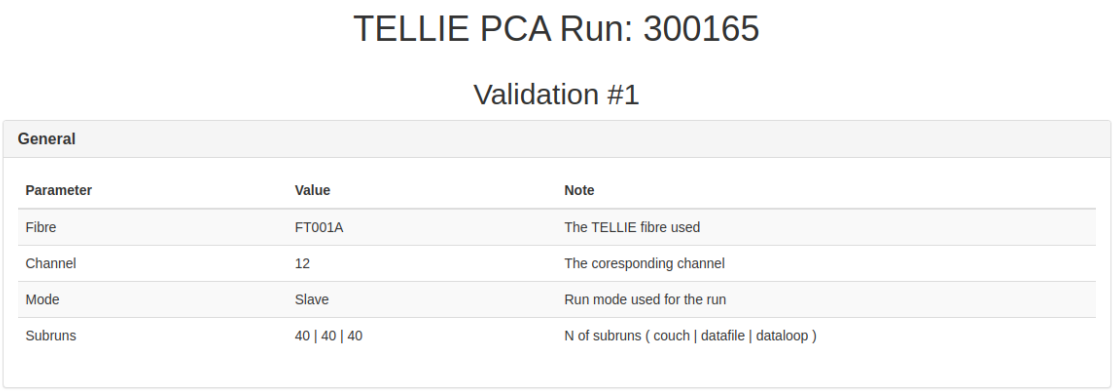


Figure 2: `Validation #1`: General information.
This is useful to confirm that the expected fibre is being used, the mode of firing is correct, and that the number of subruns is consistent.

the method used to take data.
Goal: Validate that the data is of required quality for PCA.

Some of the checks performed are: correct fibre, number of events, number of EXTA events, passed hits, cuts on PMTs, checks on LPC, run lenght, frequency, NHit distribution, NHit over time, delays, time of hits over time, number of peaks, PMTs in beamspot, PMT occupancy, PIN, PIN vs NHit, events over subrruns, and more.

The corresponding monitoring page will show basic information for this run; data for events, hits, and times; NHit information; PMTs information; Cuts; Flags; and associated plots. The flags are of special importance, as they form a 'bitword'. This bitword is shown in the list page for each fibre for particular dataset.
Examples from the monitoring are shown in Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16.

The code running `Validation #1` is located at:

```
Automation/Processing/validate/TestUser.cc
```

This includes the logic for the checks, and generates the bitword. Plots are also made here.

Events / Hits / Times

Parameter	Value	Note
Total events	218061	All events in data file
CouchDB events	200000	All events from couchdb (sum over subruns)
EXTA events	199993	EXTA events in data file
Passed events	199895	Events that pass cuts
Total hits	8322581	Total PMT hits
Passed hits	2100650	PMT hits that pass cuts
Hits - peaks	1	N of found peaks in dirct time distribution
Peak time	277.350874 ns	The peak of the time distribution
Direct hit time	274.661957 ns	The peak of the direct hits time distribution
Time over event - mean	275.692921 ns	Mean of the time over event distribution

Figure 3: `Validation #1`: Information regarding events, hits, and times. Important features: the number of total events should be equal to or more than CouchDB events. CouchDB events should correspond to the number of requested TELLIE events. The number of EXTA events should be close to CouchDB events (some will be lost due to stolen triggers). Most events should pass checks. The percentage of passed hits will be always low ($\sim$25%) mostly due to the angular cut, defining the beamspot. The peak times should all be very similar (within few ns). Finally, the direct hit time should not change (much) over datasets, as long as we are not chaning the environment (scintillator) anymore.

NHIT

Parameter	Value	Note
Rolling NHit min	35.328500	Minimum of the rolling NHit
Rolling NHit max	38.243194	Maximum of the rolling NHit
Rolling NHit mean	37.004809	Mean of the rolling NHit
NHit distribution - mean	37.004883	Mean of the NHit distribution (hist)
NHit distribution - rms	11.790064	RMS of the NHit distribution (hist)

Figure 4: `Validation #1`: NHit information.
The NHit should be close to the expected value (this was 40-42 for old datasets). There should only be a small variation.

PMTs

Parameter	Value	Note
Good PMTs	67.175573 %	Ratio of PMTs with good occupancy in the beamspot
PMTs in beamspot	262 | 2.693257 %	N of PMTs in the beamspot | % to all PMTs
PMTs in BS, good occupancy	176 | 1.809211 %	N of PMTs in the beamspot with good occupancy | % to all PMTs
Occupancy 1-5 to all	33.909507 %	Ratio of PMTs with good occupancy to all PMTs (integral from hist)
Occupancy 1-5 to all - beamspot	70.610687 %	Ratio of PMTs with good occupancy to beamspot PMTs (integral from hist)

Figure 5: `Validation #1`: PMT statistics.
We should make sure we are hitting PMTs in the beamspot, and that these PMTs have good occupancy (between 1-5%, as to have high enough statistics above noise to extract the constants, but to avoid being contamined by multiple PE hits).

Other

Parameter	Value	Note
EXTA length	209.000000 s	The length of the run obtained as Tlast - Tfirst EXTA event
Frequency (from length)	956.244019 Hz	Calculated frequency from the EXTA length
PIN RMS	1	The RMS of the PIN distribution (hist)
Correlation factor	0.113082	The value of the correlation factor (NHit to PIN distribution)
Covariance	0.206720	The coviariance (NHit to PIN distribution)

Figure 6: `Validation #1`: Other information, including calculated run length from EXTA events, calculated frequency, and correlation between PIN and NHit.
We should check the real run length and frequency are as expected (they will be slightly lower than expected, due to missing EXTA triggers).

Cuts

Parameter	Value	Note
CDAQ	0 | 0.00 %	N not-DAQ-enabled hits
CECA	519481 | 6.24 %	N hits with bad ECA bit
CANG	2903647 | 34.89 %	N hits not passing angular cut
CCO	0 | 0.00 %	N hits on offline channel
CPV	0 | 0.00 %	N hits with not valid path (LPC)
CPCA	373503 | 4.49 %	N hits with bad ECA bit
CXT	6961 | 0.08 %	N hits caused by cross-talk
COFF	0 | 0.00 %	N hits on offline PMT
CTIR	600645 | 7.22 %	N hits causing total internal reflection (LPC)
CRH	0 | 0.00 %	N of hits not within locality (LPC)
CMAG	0 | 0.00 %	N of hits on PMT with bad position
CNEXTA	18068 | 8.29 %	N of not EXTA events
CE	0 | 0.00 %	N of hits on not enabled PMT
CDIST	1792853 | 21.54 %	N of near reflection hits (given by LPC endpoint)
CNN	0 | 0.00 %	N of hits on not-normal PMT
CCHS	23992 | 0.29 %	N of hits on bad channel
CDAV	849 | 0.01 %	N of hits with weird path (not completely through AV)

Figure 7: `Validation #1`: Hit statistics, showing the number of hits that were cut, by category.
Check cuts on hits and PMTs. Should especially look for outliers. The angular cut will always be big, and that is ok, as we only want to use PMTs in the beamspot (other fibres will cover other PMTs, to get the preferred occupancy).

Flags

Parameter	Value	Note
Runtime	1	Is the real length close to expected?
Frequency	1	Is the real frequency close to expected?
Subruns	1	Is the number of subruns as expected?
Check on evens in subruns	1	Are there enough events in each subrun?
Event	1	Are there enough events that passed cuts?
EXTA	1	Are there enough EXTA events?
NHit distribution	0	NHit distribution: mean and RMS within limits?
NHit distribution over subruns	1	Is the NHit avg over subruns stable?
Stable NHit	1	NHit fluctuations (rolling avg to global avg) within limits?
PIN RMS	0	Is the PIN distribution RMS within limits?
PIN-NHit cov and corr	0	Is the PIN-NHit relation sensible?
Hit	1	Are there enough valid hits?
Angular cut	1	N of hits cut due to angular cut within limits?
Offline channel	1	N of offline channel hits within limits?
Offline PMT	1	N of offline PMT hits within limits?
Not DAQ enabled	1	N of not DAQ enabled hits within limits?
Not enabled flag	1	N of not enabled channel hits within limits?
Bad PMT position	1	N of bad PMT position hits within limits?
Bad channel	1	N of bad channel hits within limits?
Bad ECA	1	N of bad ECA hits within limits?
Bad PCA	1	N of bad PCA hits within limits?
X-talk	1	N of cross-talk removed hits within limits?
Not normal PMT	1	N of not normal PMT hits within limits?
Hit peak	1	Is the peak of the time distribution as expected?
Peak check flag	1	Direct hits peak value within limits?
Time over event	1	Time fluctuations (rolling avg to global avg) within limits?
Trigger delay dev	1	Is the trigger delay constant over subruns?
Fibre delay dev	1	Is the fibre delay constant over subruns?
Beamspot PMTs	1	Are there enough PMTs in the beamspot?
Occupancy all	1	Are there enough PMTs with good occupancy?
Check on PMTs (beamspot / occupancy)	0	Are there enough good PMTs in beamspot (as number)?
Occupancy beamspot	1	Are there enough PMTs with good occupancy in the beamspot (integral to beamspot PMTs)?
LPC locality	1	N of hits outside of LPC locality within limits?
Near reflection	0	N of near reflection hits within limits?
LPC TIR	1	N of hits with total internal reflection (LPC) within limits?
LPC invalid path	1	N of hits with invalid path (LPC) within limits?
LPC weird path (not AV)	1	N of hits with weird LPC path within limits?

Figure 8: `Validation #1`: Flags. These are the results of checks/tests on a variety of run/hits atributes. The comments should be a reasonable hint to what each check does.

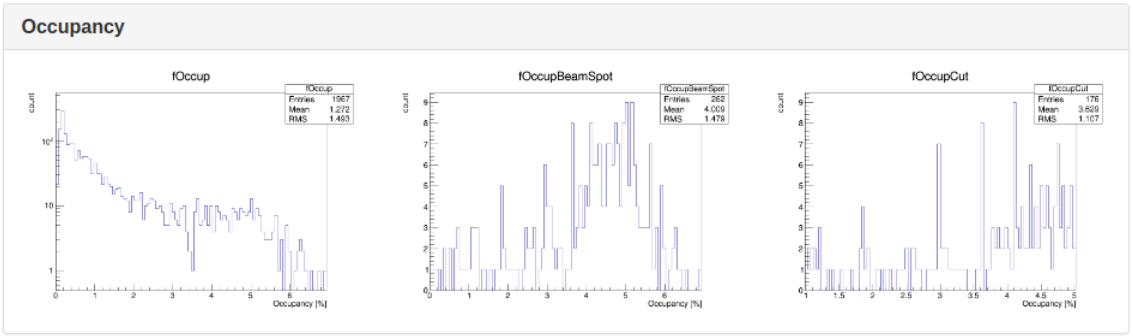


Figure 9: `Validation #1`: Plots showing occupancy information.
We should make sure that there are enough PMTs in the beamspot with the required occupancy (>100).

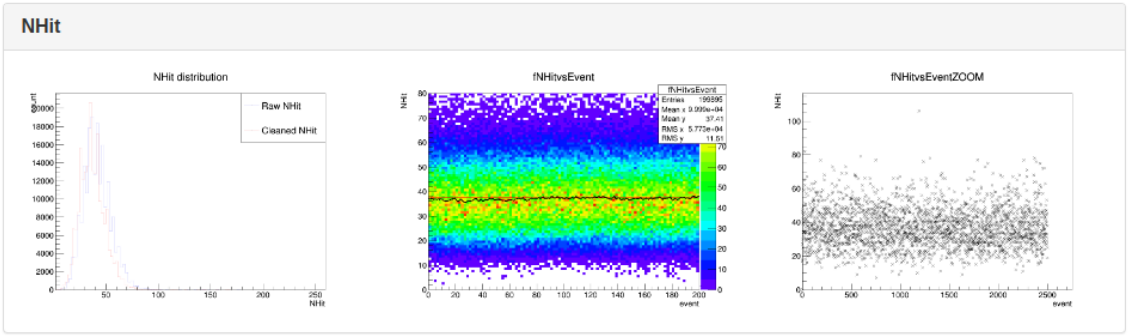


Figure 10: `Validation #1`: Plots showing NHit information.
The NHit distribution should be approximately gaussian, with the peak around the expected value (40-42). The NHit should be stable over time, and there should be no noticeable drop at the start of the run.

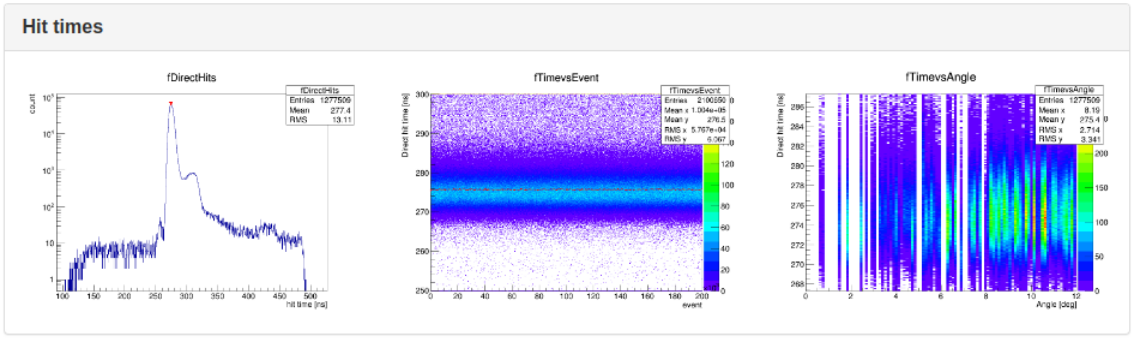


Figure 11: `Validation #1`: Plots showing hit times information. Similar to NHit, we should confirm the peak is around expected value, the times are consistend over events, and there is no high variation with angle.

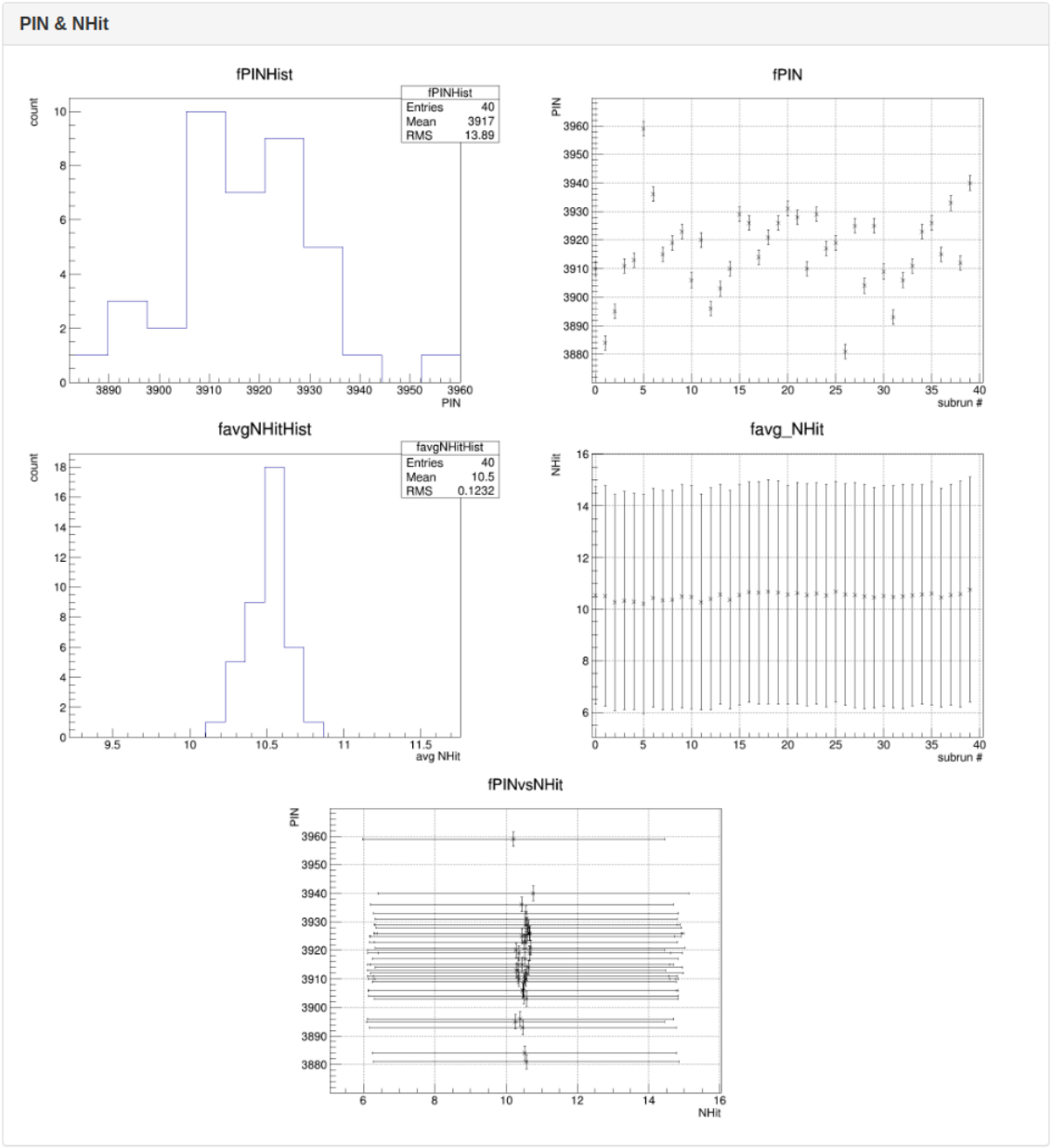


Figure 12: `Validation #1`: Plots showing PIN and NHit information. The PIN values should have low variation (within 100s) and there should be no clear trend over subruns. The NHits here are per subrun, therefore the low value. It should be stable over subruns. Finally, there should be positive correlation between the NHit and PIN (mind the range of erros).

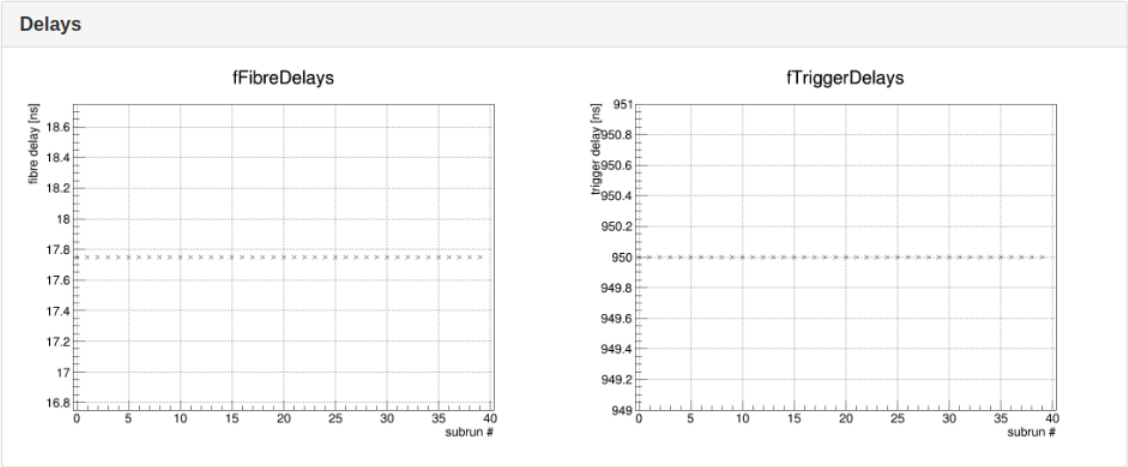


Figure 13: `Validation #1`: Plots showing delays information.
Both fibre and trigger delay have to be constant over subruns! Additionally, the trigger delay should be constant across fibres for a dataset. This is essential for the calibration.

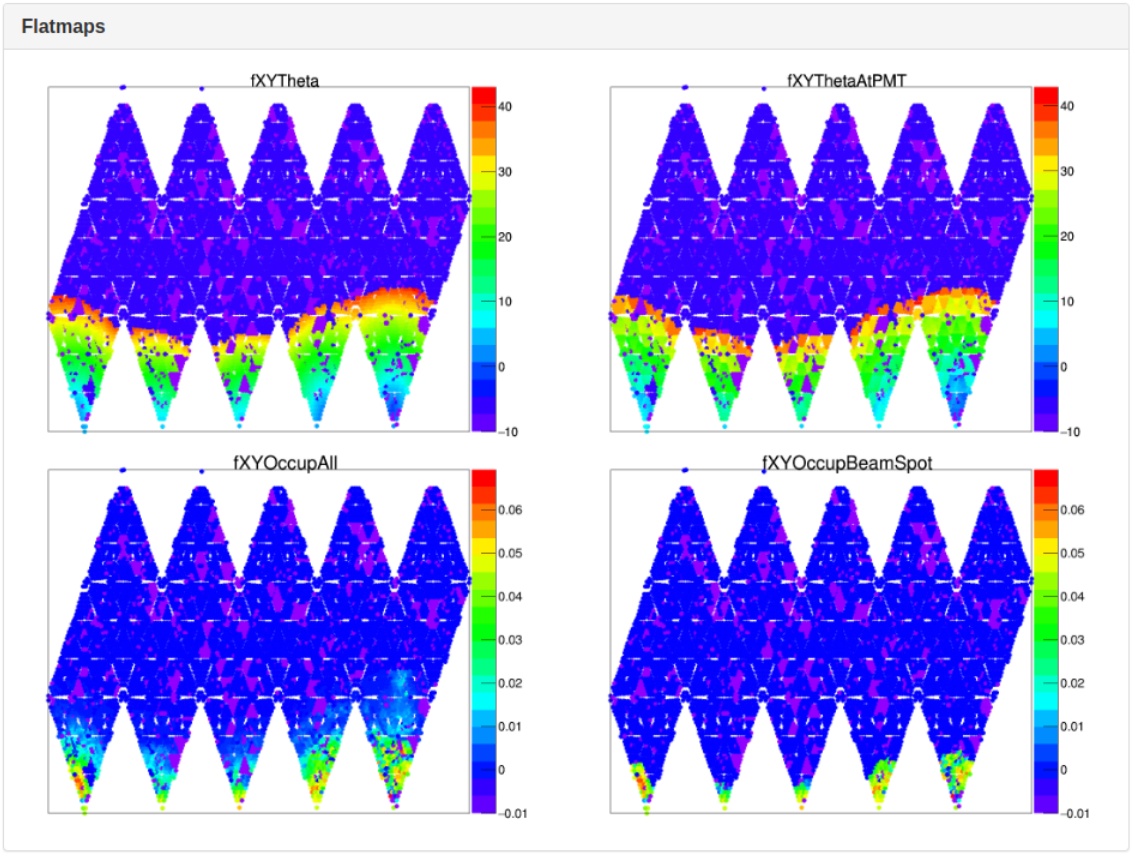


Figure 14: `Validation #1`: Plots showing data using flatmaps.
These are to confirm we are getting a beamspot, that the light is there, is not spread out too much, and the occupancy is correct in the beamspot.

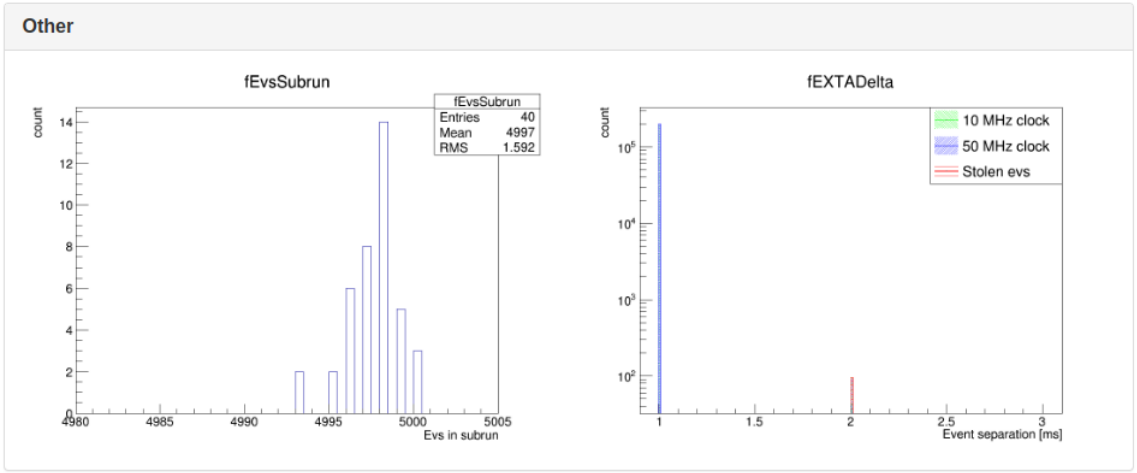


Figure 15: `Validation #1`: Other information.
The number of events should be approximately constant over subruns (again, we lose some due to stolen triggers.

TELLIE PCA dataset:

Fibre	Run	Validation 1	Fitting	Validation 2
FT001A	300165	11111111111111111101011111011111100	43.86 ± 0.093 | 190.72 ± 1.378	111111111110
FT002A	300167	11111101111111111111111111111011110110	30.42 ± 0.080 | 185.21 ± 1.373	111111111000
FT003A	300372	11011101111111111111000111111011110101	7.96 ± 0.083 | 185.64 ± 1.367	111111011111

Figure 16: `Validation #1`: The bitword from `Validation #1` shown on the dataset list page for selection of runs.
The bitword here is made up from the values of flags, corresponding to the checks, for each fibre. Clicking this bitword leads to the `Validation #1` page for this run.

5 Data-processing

5.1 PCA table generation

There are several corrections that need to be fitted for, which are later used for the extraction of PCA constants. The fits need to happen in succession, as the output of one feeds into the next. Between steps, these are stored as text files. After all fits are made, a local table is produced, combining the corrections. This table is loaded by the PCA Processor.
Goal: Make fits, obtain corrections required for the extraction of PCA constants. Produce final PCA table.

5.1.1 Fit: beamspot

5.1.2 Fit: direction

5.1.3 Fit: angular systematic

5.1.4 Fit: Injection time

5.2 Validation #2

Similar to `Validation #1`, `Validation #2` runs checks on data. In this case, it loads the corrections from the PCA table including the fits.
Goal: Check and confirm that the fits are sensible.

Some of the tests included here are: mean, rms, min, and max for each correction; distribution, peak(s), and angular dependence for the residual times; specific trends, and more.

The corresponding monitoring page will show the fits information for this run, including Flags; and associated plots. The flags are of special importance, as they form a 'bitword'. This bitword is shown in the list page for each fibre for particular dataset.
Examples from the monitoring are shown in Figures 17, 18, 19, 20, 21, and 22.

The code running `Validation #2` is located at:

```
Automation/Processing/validate2/TestUser.cc
```

TELLIE PCA Run: 300165

Validation #2

Time-of-Flight

Parameter	Value	Note
TOF mean	82.92 ns	The mean of the time of flight distribution
TOF RMS	0.471 ns	The RMS of the time of flight distribution
TOF min	81.77 ns	Minimum value of the time of flight distribution
TOF max	83.72 ns	Maximum value of the time of flight distribution

Figure 17: `Validation #2`: Information relating to Time-of-Flight. The mean should always be physical, and the RMS should not be very high (>0.5 ns).

Angular systematic effect

Parameter	Value	Note
Ang sys mean	0.47 ns	The mean of the AngSys distribution
Ang sys RMS	0.270 ns	The RMS of the AngSys distribution
Ang sys min	0.00 ns	Minimum value of the AngSys distribution
Ang sys max	0.98 ns	Maximum value of the AngSys distribution

Figure 18: `Validation #2`: Information relating to angular systematic fit. The mean should never be too high (>2 ns).

Bucket time

Parameter	Value	Note
Bucket mean	0.47 ns	The mean of the bucket time distribution
Bucket RMS	0.003 ns	The RMS of the bucket time distribution
Bucket min	0.46 ns	Minimum value of the bucket time distribution
Bucket max	0.47 ns	Maximum value of the bucket time distribution

Figure 19: `Validation #2`: Information relating to bucket time.
The mean should always be (almost) constant (∼0.47 ns) with low RMS.

Hit times, angular dependence

Parameter	Value	Note
Direct peaktime	273.942780 ns	The peak of the direct time distribution
Direct peaks	1	The number of peaks in the direct time distribution
Residual peaktime	189.815674 ns	The peak of the residual time distribution
Residual peaks	1	The number of peaks in the residual time distribution
Direct vs Angle fit	274.97 ± 0.089 ns	Average of the direct time distribution as a function of angle
Residual vs Angle fit	190.67 ± 0.142 ns	Average of the residual time distribution as a function of angle
Dir-Resid fit	-82.97 ± 0.997	Straight line fit to the direct vs residual time distributions

Figure 20: `Validation #2`: Direct and residual hit times.
There should only be 1 peak for each distribution, and the peak times should be where expected. A straigh line is expected.

Flags

Parameter	Value	Note
TOF flag	1	Is the TOF distribution sensible (mean and RMS)?
TOF min-max flag	1	Are the min and max of TOF distribution ok?
TOF progression flag	1	Is the TOF descreasing with angle?
Ang sys flag	1	Is the AngSys distribution sensible (mean and RMS)?
Ang sys min-max flag	1	Are the min and max of AngSys distribution ok?
Ang sys progression flag	1	Is the AngSys increasing with angle?
Bucket flag	1	Is the bucket distribution sensible (mean and RMS)?
Bucket min-max flag	1	Are the min and max of bucket distribution ok?
Resid peak flag	1	Is there only one peak in the residual time distribution? Is it close to expected value?
Direct vs Angle fit flag	1	Is the average of direct light reasonable? Is the distribution flat?
Residual vs Angle fit flag	0	Is the average of residual light reasonable? Is the distribution flat?
Dir-Resid fit flag	1	Is the straight line fit within limits?

Figure 21: `Validation #2`: Flags. These are the results of checks/tests on a variety of run/hits atributes. The comments should be a reasonable hint to what each check does.

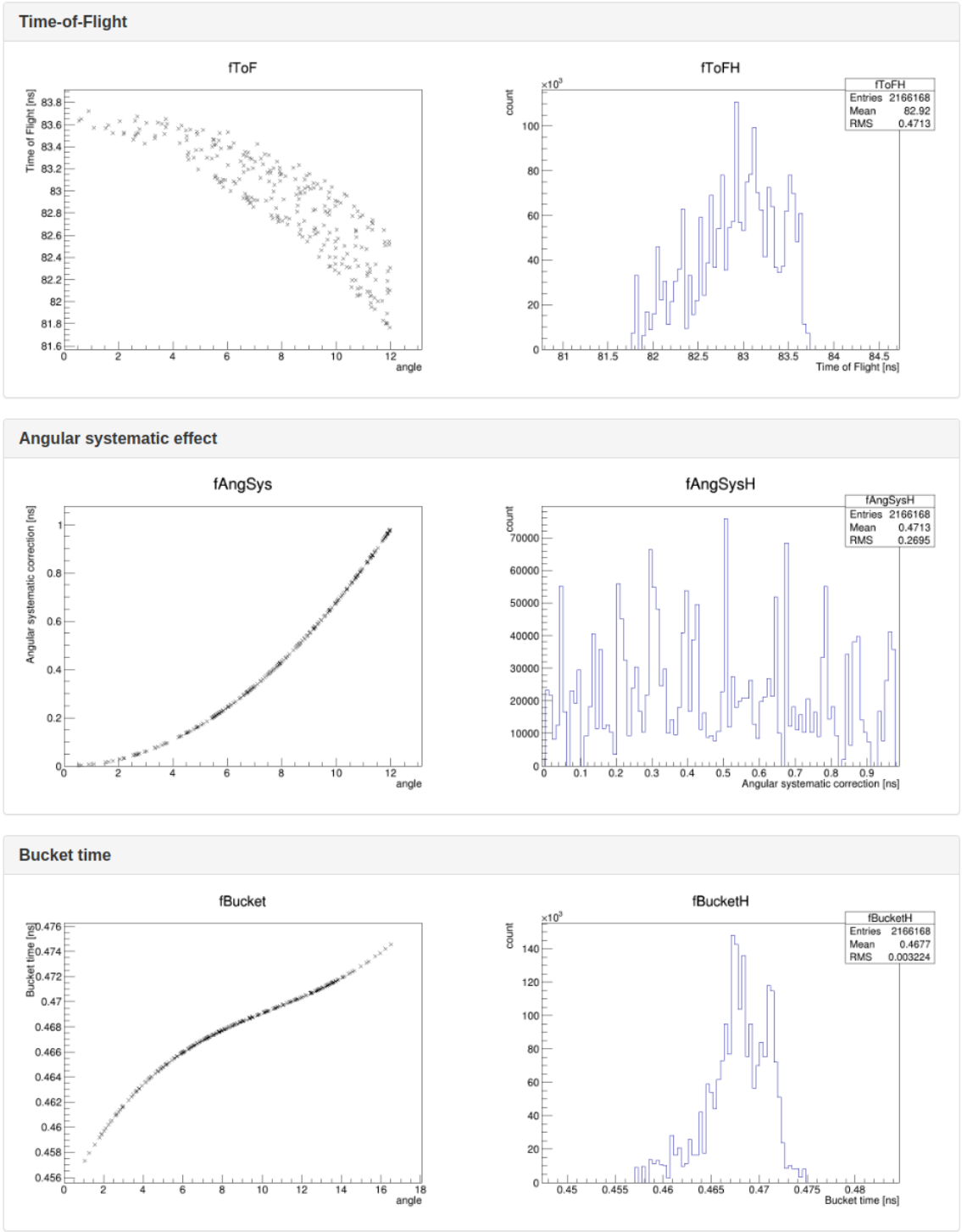


Figure 22: `Validation #2`: Plots showing the distribution of the corrections.

ToF should be decreasing over angle, peaking around 83 ns and can never be more than 84 ns. The angular systematic correction has to be increasing with the angle. Bucket time should be a narrow distribution around 0.47 ns.

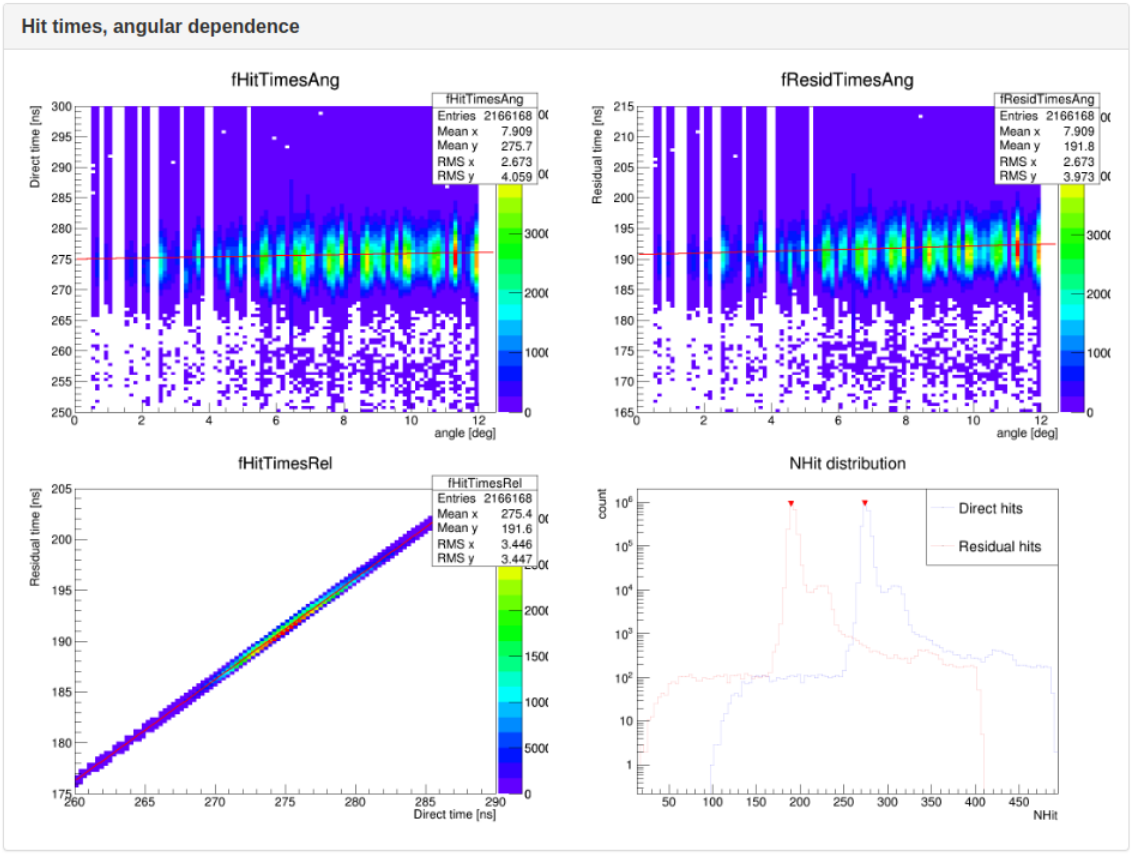


Figure 23: `Validation #2`: Plots showing the angular dependence of hit times, both raw and residual.
After corrections, the hit times should be mostly independent of the angle.

This includes the logic for the checks, and generates the bitword. Plots are also made here.

5.3 Comparing PCA tables

Goal: Compare the PCA tables (including corrections) for neighbouring datasets. This is useful to monitor stability of the system and to highlight outliers.

5.4 PCA constants

Goal: Run the PCA Processor that extract the pca constants (both timing and charge).

5.5 Benchmarking

This process is used to actually load, use, and compare the PCA constants - cable delays, time-walk fit, and charge fits: threshold, peak, hhp for QHS and QHL.
Goal: Compare the set of constants against the closest (previous) set. Useful to see overall stability and for highlighting outliers.

5.6 Monitoring

This is the most important part for the user. Every step of the system creates logs and plots that are available online on Minard. There are many pages, and everything important (and more) is presented. **Goal:** Provide monitoring of each step of the chain. Also compares fibres and PMTs between datasets.

Most parts of the system will be highlighted here. A good rule to using minard portion of the TELLIE PCA processing is that most things are clickable and will lead to detailed page with logs and plots.

5.6.1 Where

The minard page for TELLIE PCA Processing can be accessed using the main header bar, by slecting the **PMTcal** tab, and clicking the **PCA Tellie Processing**, as shown in Figure 24.

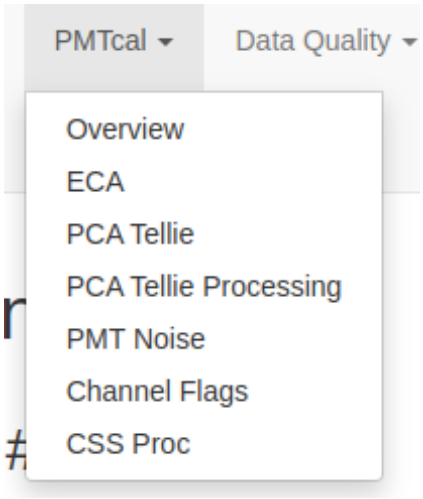


Figure 24: `Validation #2`:

This leads to the **TELLIE PCA datasets page**. This is the main/overview page for the TELLIE PCA Processing. It shows the list of datasets (Figure 25), the PMT search box (Figure 26), and the list of thresholds (Figure 27).

The list of datasets (Figure 25) is the starting point. Again, most cells are clickable and will lead to more detailed page:

- Clicking on the cell in 'Run range' will bring an overview page for that particular dataset, Figure 28.
- The 'PCA table' cell will show a page comparing the PCA table associated with that dataset to previous PCA table. Figures 29, 30, 31, and 32.
- 'PCA processor' page shows the results of PCA Processor: Figures 33, 34, 35, 36, 37, and 38.
- 'Benchmarking' shows plot comparing the PCA constants obtained in this dataset to previous constant, shown in Figures 39, 40, 41, 42, 43, 44, and 45.
- 'Status' presents information from parsed log file from PCA Processor. It will list warnings or errors from the PCA processor, Figure 46.

- 'TW' shows the time-walk information for this set of constants. PMTs with issues such as too high RMS or high Q tail are listed here. See Figures 48, 49, 50, and 51.
- 'GF' shows the time-walk information for this set of constants. PMTs with issues such as QHS TH too high or Peakfinder found multiple peaks are listed here. Figures 47, 49, and 51.
- Additionally, clicking the 'PCA tables' header lead to page comparing PCA tables across all available datasets. Note Figures 52, 53, and 54.
- It is also possible to look at fibre data across datasets (this is perhaps the most interesting feature). One can get here by clicking the fibre name on the dataset page (Figure 28). A selection of plots are shown in Figure 55 and Figure 56.
- Finally, there are plots for PMTs for each dataset (Figure 57 and Figure 58) and over datasets (using PMT search, Figure 26).

TELLIE PCA datasets

Name	Run range	PCA tables	PCA processor	Benchmarking	Status	TW	GF
Jun 2018	[114670, 115753]	114670 table	114670	[114670, 115753]	FAIL	PASS	FAIL
Sep 2018	[117578, 117792]	117578 table	117578	[117578, 117792]	FAIL	FAIL	PASS
Dec 2018	[201388, 201620]	201388 table	201388	[201388, 201620]	FAIL	FAIL	PASS
Mar 2019	[204401, 204605]	204401 table	204401	[204401, 204605]	PASS	PASS	PASS
Nov 2019	[253803, 254052]	253803 table	253803	[253803, 254052]	FAIL	FAIL	PASS
May 2020	[258566, 258811]	258566 table	258566	[258566, 258811]	FAIL	FAIL	FAIL
Apr 2021	[269444, 269707]	269444 table	269444	[269444, 269707]	FAIL	PASS	FAIL
Aug 2021	[273308, 273535]	273308 table	273308	[273308, 273535]	FAIL	PASS	FAIL
Sep 2021	[274958, 275162]	274958 table	274958	[274958, 275162]	PASS	PASS	PASS
Feb 2022	[279374, 279875]	279374 table	279374	[279374, 279875]	PASS	PASS	PASS
May 2022	[300165, 300381]	300165 table	300165	[300165, 300381]	PASS	PASS	PASS

Figure 25: `Validation #2:`

PMT search:

See the progression of cable delay for particular PMT. Use PMT ID.

Go

Figure 26: `Validation #2:`

Limits

Parameter	Value	Note
RUNTIME	2500	[*s*]: allowed length of run
FREQ ± FREQ_DEV	1000 ± 7.5	[*Hz*]: expected frequency + dev
TOT_EVS ± DEV	200000 ± 1	[*N*]: expected number of events + dev
TH_EXTA	10	[%]: *threshold* = maximal allowed percentage of NON-EXTA events
TOT_HITS	20	[%]: *threshold* = minimal allowed percentage of passed hits
N_SUBS	40	[*N*]: number of allowed subruns
EV_SUB ± EV_SUB_DEV	5000 ± 0.5	[*N*]: expected events in subrun + dev
MIN_DIST	900	[*mm*]: allowed distance to evaluate the fibre that was firring (light fit to fibre db position)
DIR_LIGHT_ANG	48	[°]: angular limits for the cone of direct light
REF_LIGHT_ANG	20	[°]: angular limits for the cone of reflected light
NHIT_DIV	0.2	[*R*]: allowed deviation for the ratio of rolling average to global average of the NHit distribution (fibre stability)
NHIT_MEAN ± NHIT_MEAN_DEV	42 ± 12	[*NHit*]: expected mean of the NHit distribution + dev
NHIT_RMS	10	[*NHit*]: allowed RMS for the cleaned NHit dist
SUB_NHIT ± SUB_DEV	10 ± 1	[*NHit*]: expected mean of the cleaned NHit distribution (subrun) + dev
PIN_RMS	3	[*PIN*]: maximal allowed RMS of the pin distribution

Figure 27: `Validation #2`:

TELLIE PCA dataset:

Fibre	Run	Validation 1	Fitting	Validation 2
FT001A	300165	11111111111111111110101111011111100	43.86 ± 0.093 | 190.72 ± 1.378	111111111110
FT002A	300167	11111101111111111111111111111011110110	30.42 ± 0.080 | 185.21 ± 1.373	111111111000
FT003A	300372	11011101111111111111000111110111101 01	7.96 ± 0.083 | 185.64 ± 1.367	111111011111
FT004A	300171	11111101111111111111100111110111000 01	50.88 ± 0.085 | 183.27 ± 1.369	111111111111
FT005A	300173	11111101111111111111111111111111111	62.46 ± 0.090 | 184.10 ± 1.370	111111011111
FT006A	300175	11111111111111111111111111111111110	43.07 ± 0.095 | 185.43 ± 1.378	111111111111
FT007A	300177	11111111111111111111001111111111101	30.48 ± 0.073 | 185.46 ± 1.365	111111111111
FT008A	300179	11111111111111111111001111101110010 0	65.20 ± 0.085 | 184.67 ± 1.361	111111111111
FT009A	300181	11111111111111111110111111111111110	25.81 ± 0.081 | 184.77 ± 1.366	111111111111
FT010A	300183	11111101111111111111001111111111110	16.02 ± 0.081 | 185.72 ± 1.372	111111111000

Figure 28: `Validation #2`:

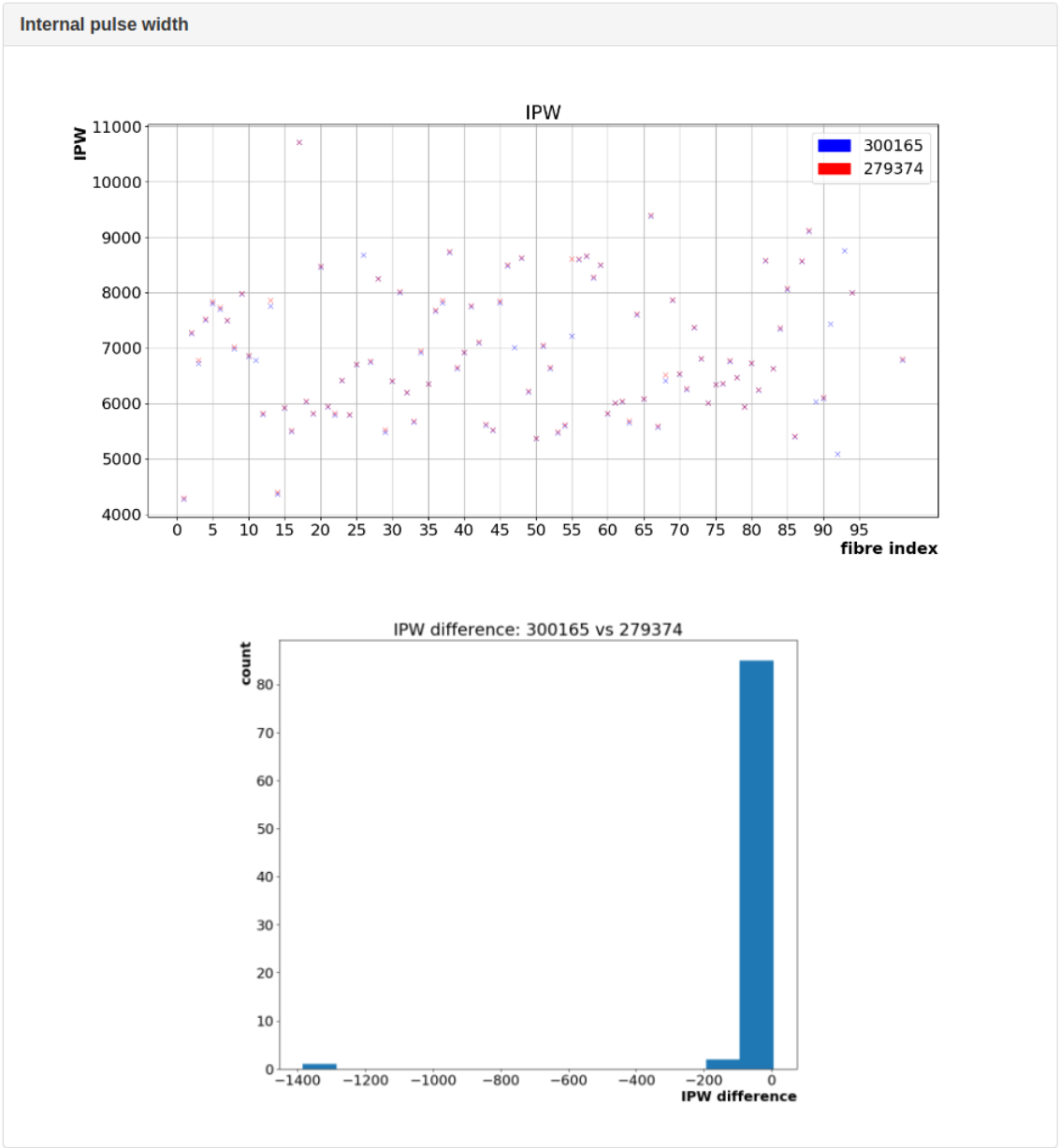


Figure 29: `Validation #2`:

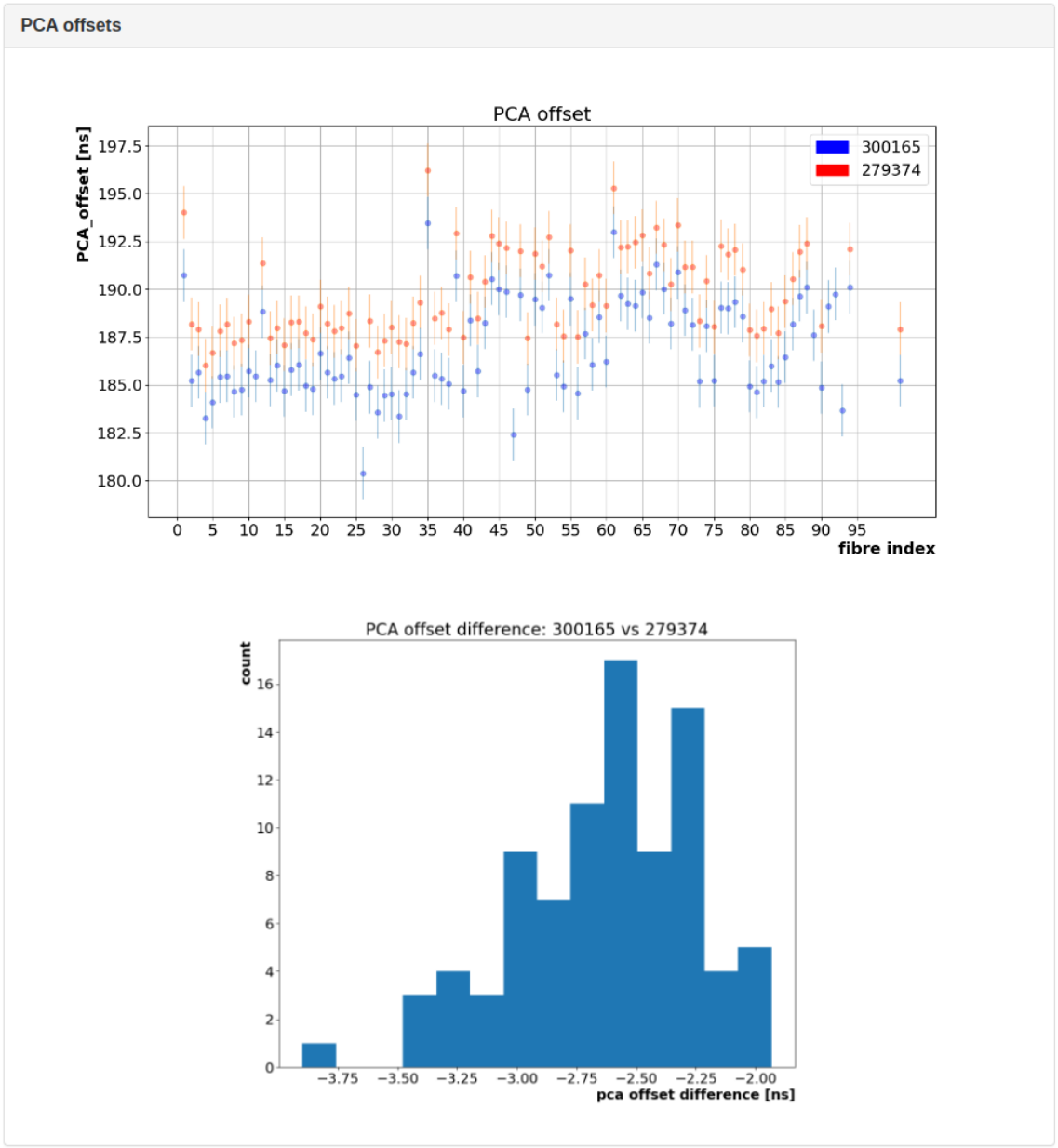


Figure 30: `Validation #2`:

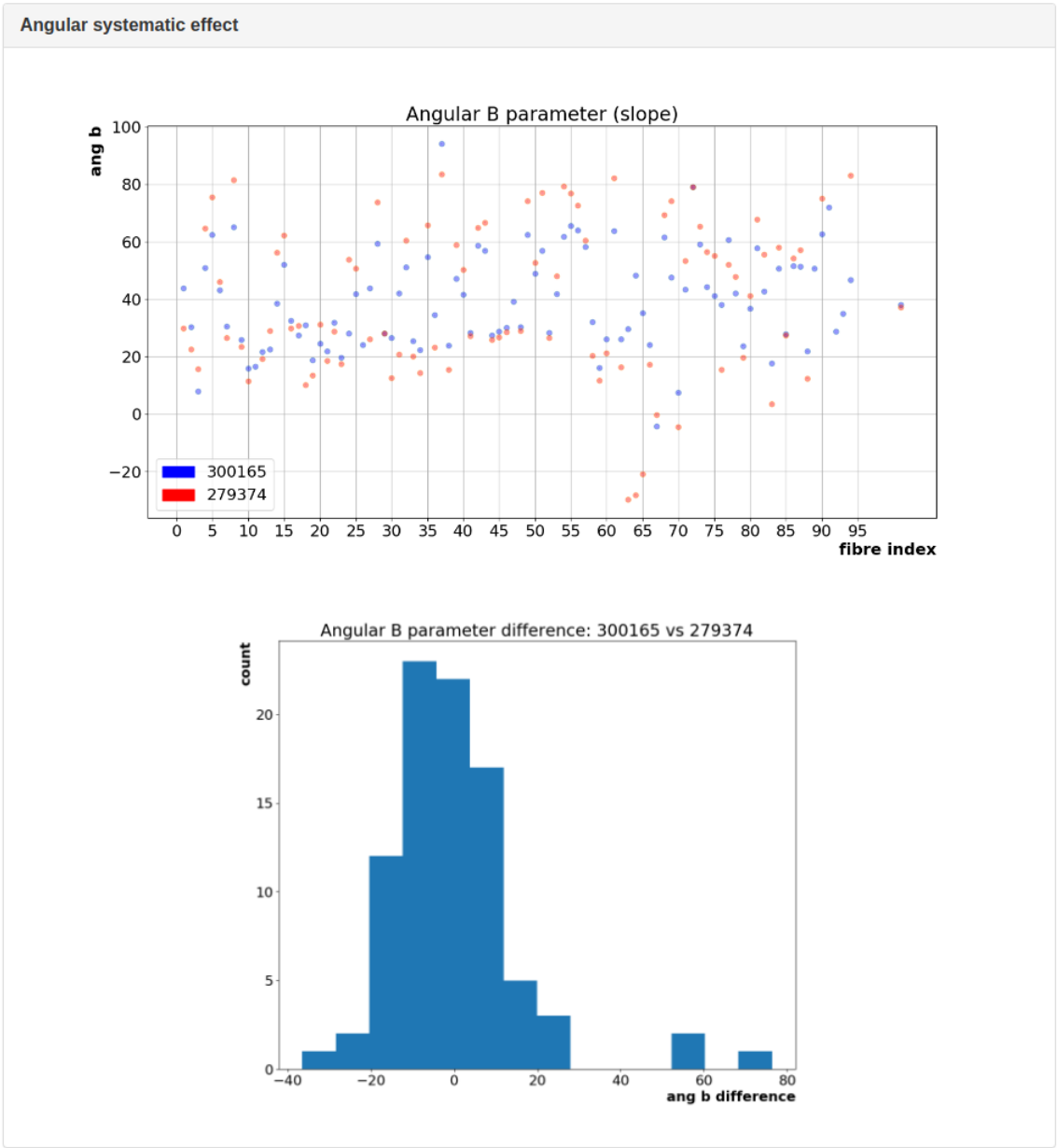


Figure 31: `Validation #2`:

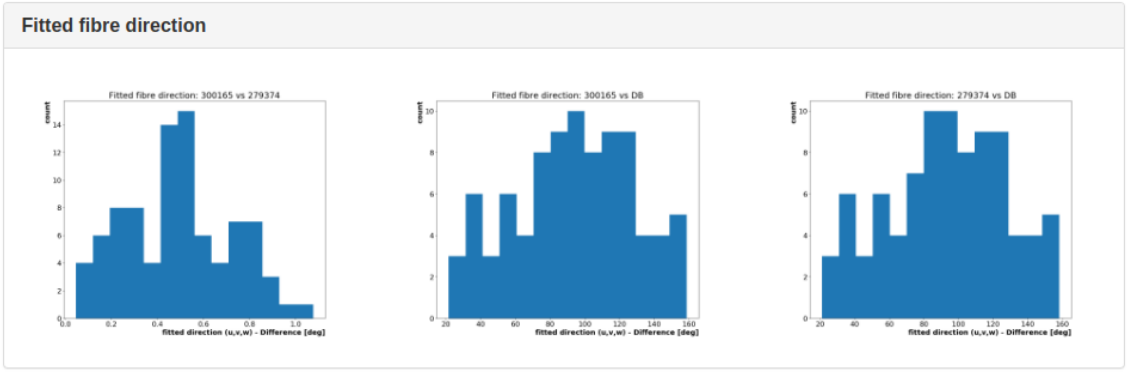


Figure 32: `Validation #2`:

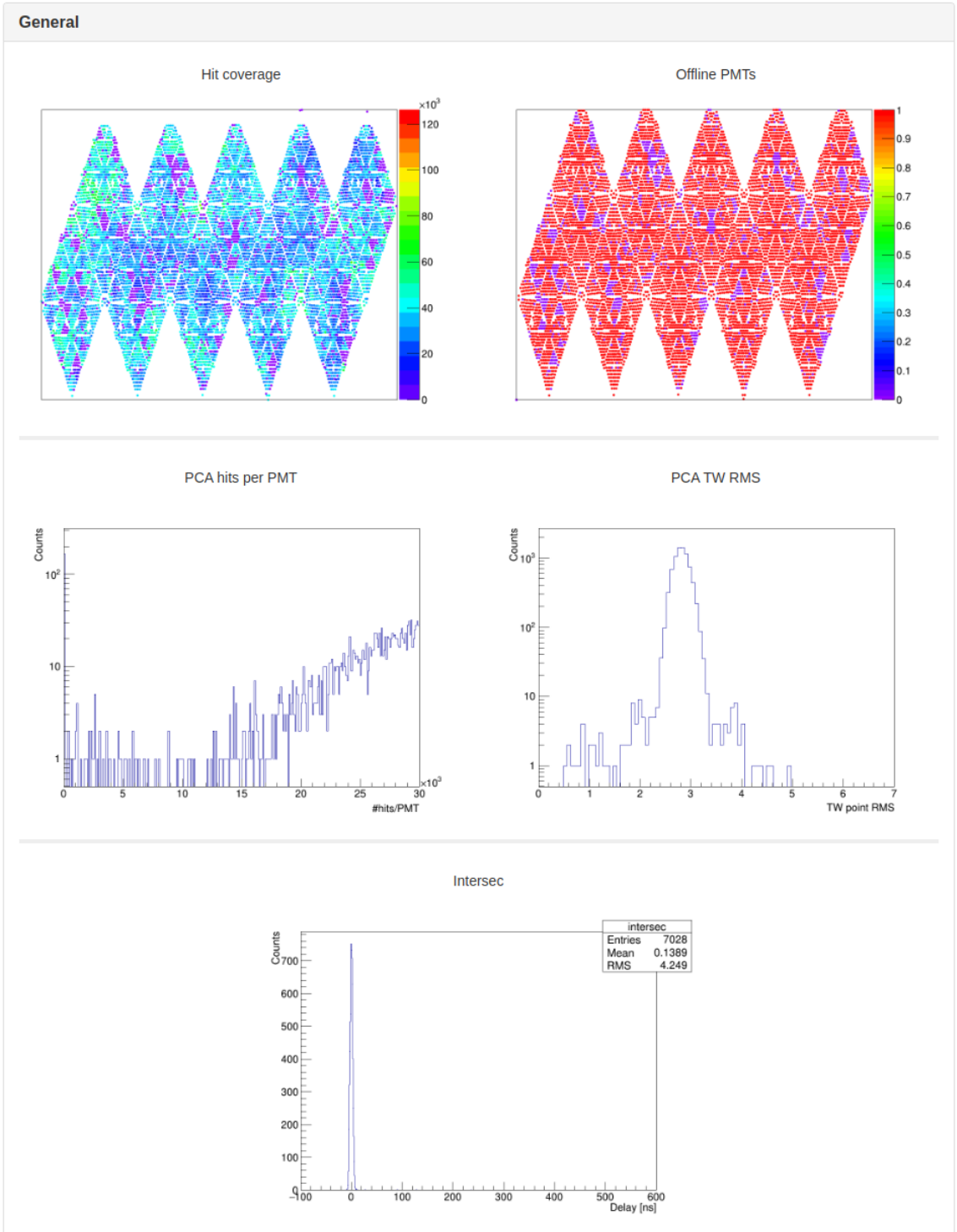


Figure 33: Validation #2:

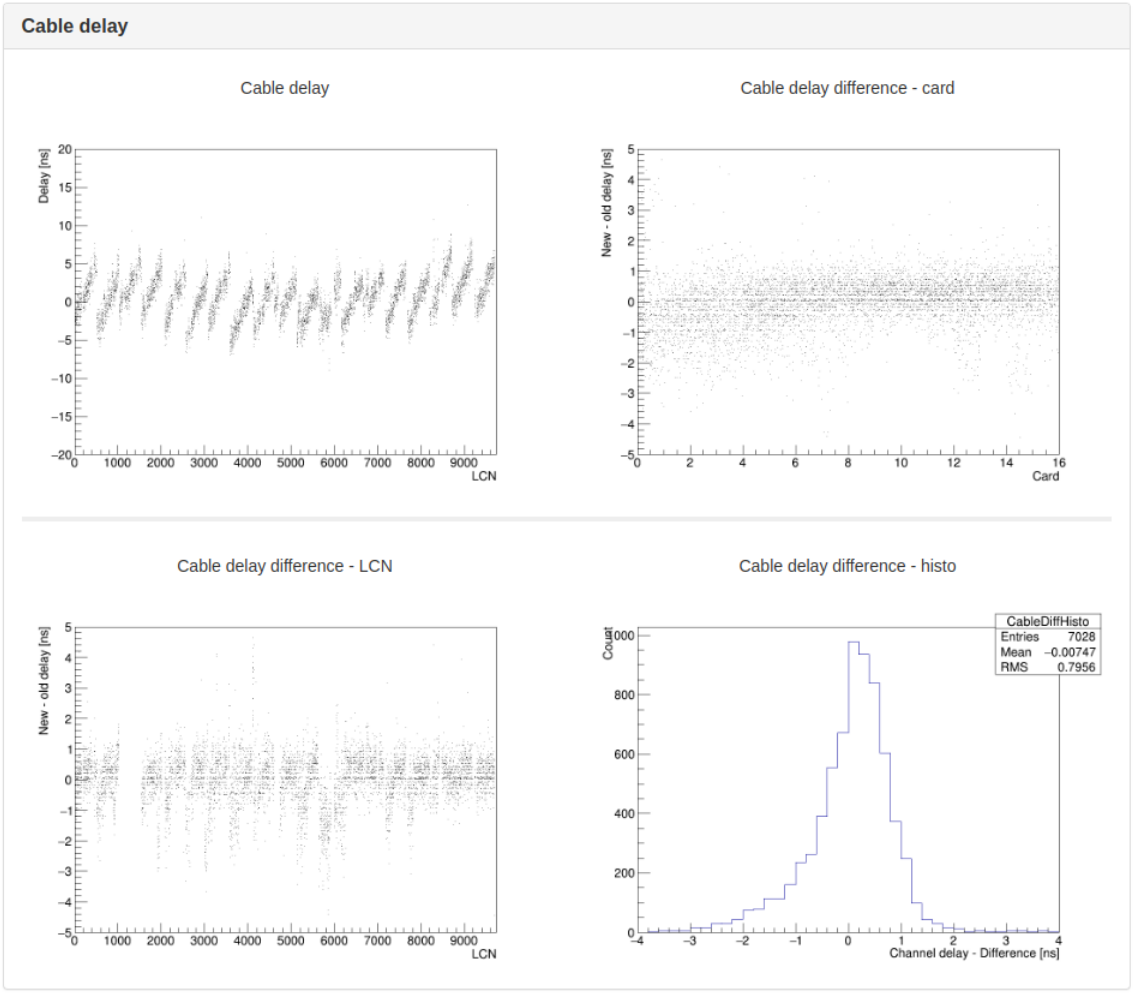


Figure 34: `Validation #2`:

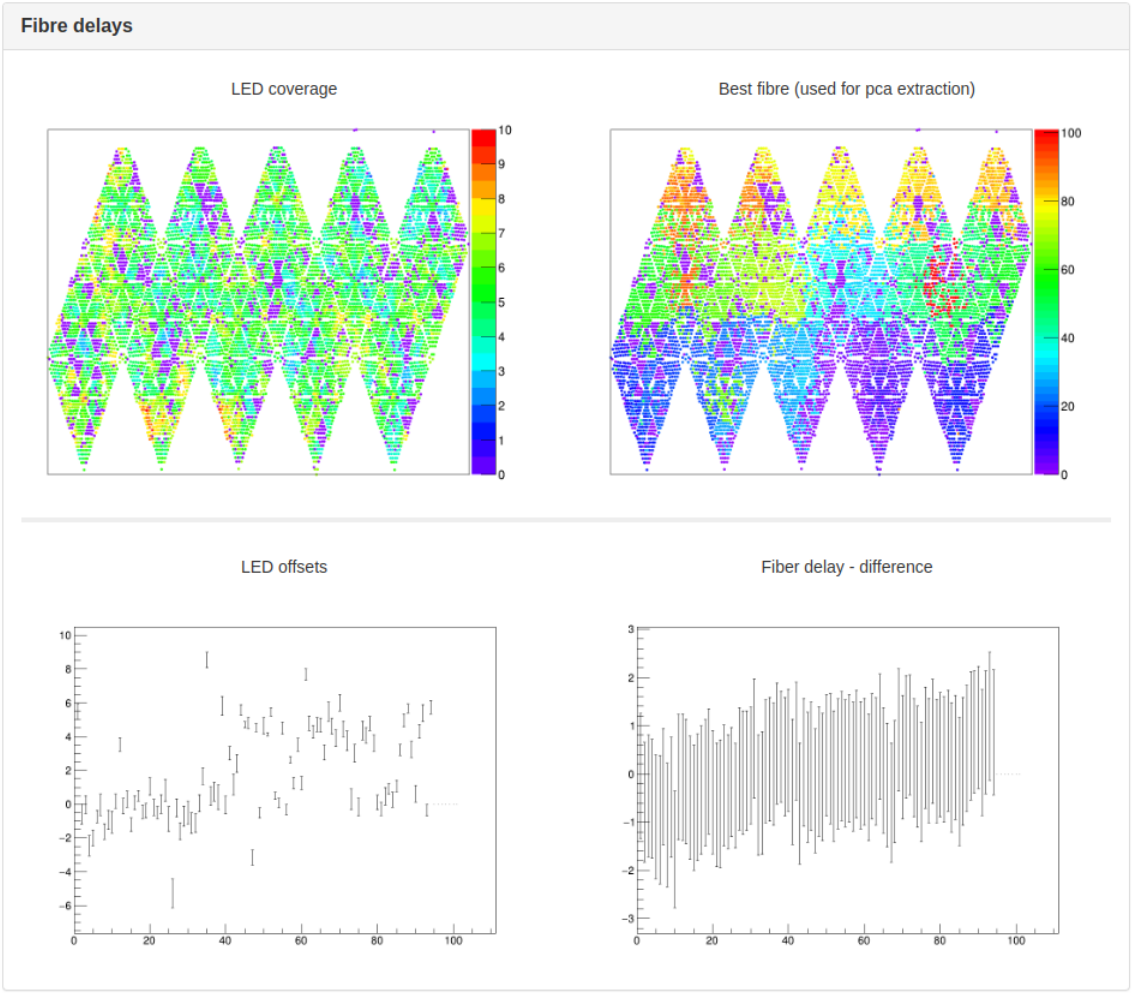


Figure 35: `Validation #2`:

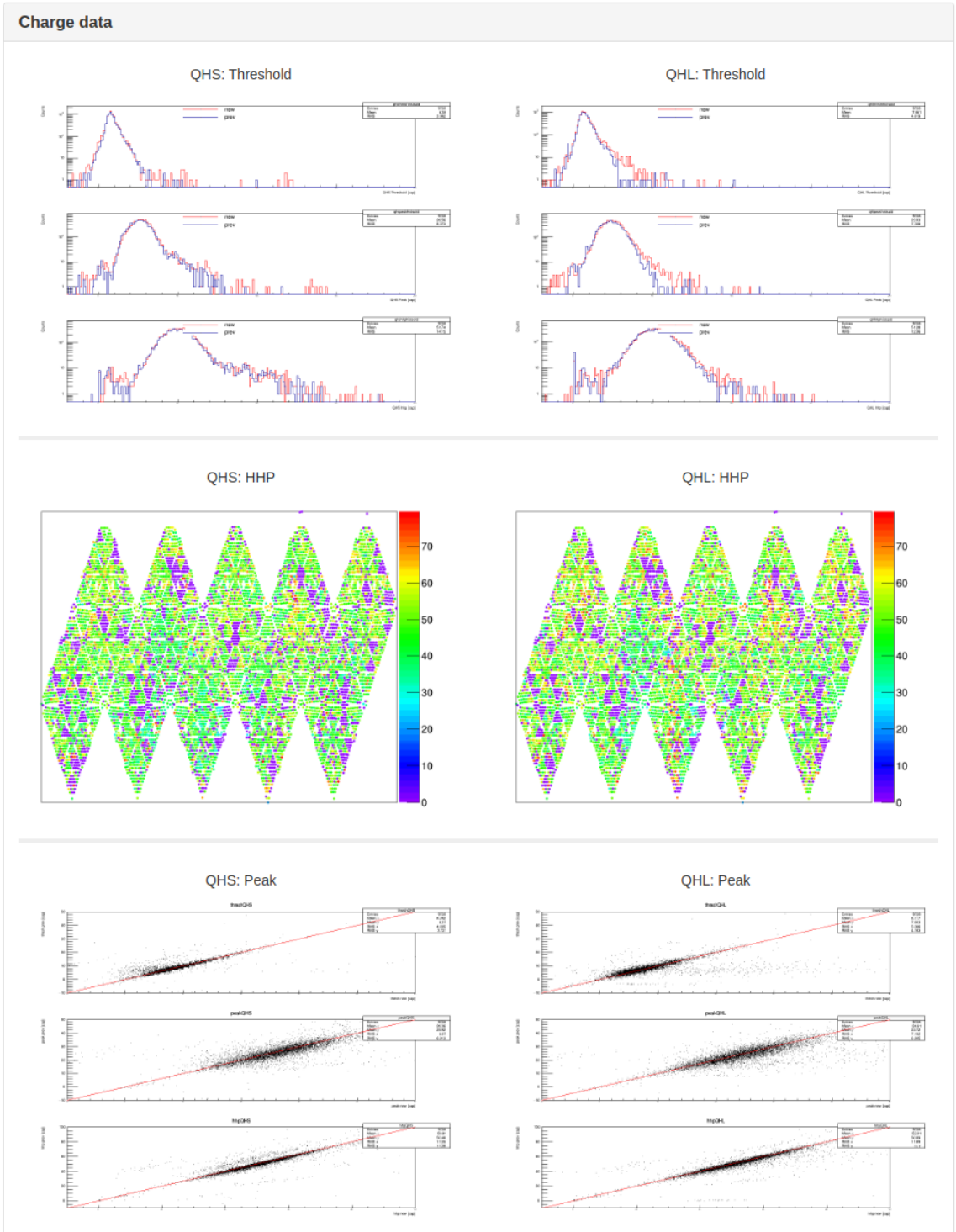


Figure 36: `Validation #2`:

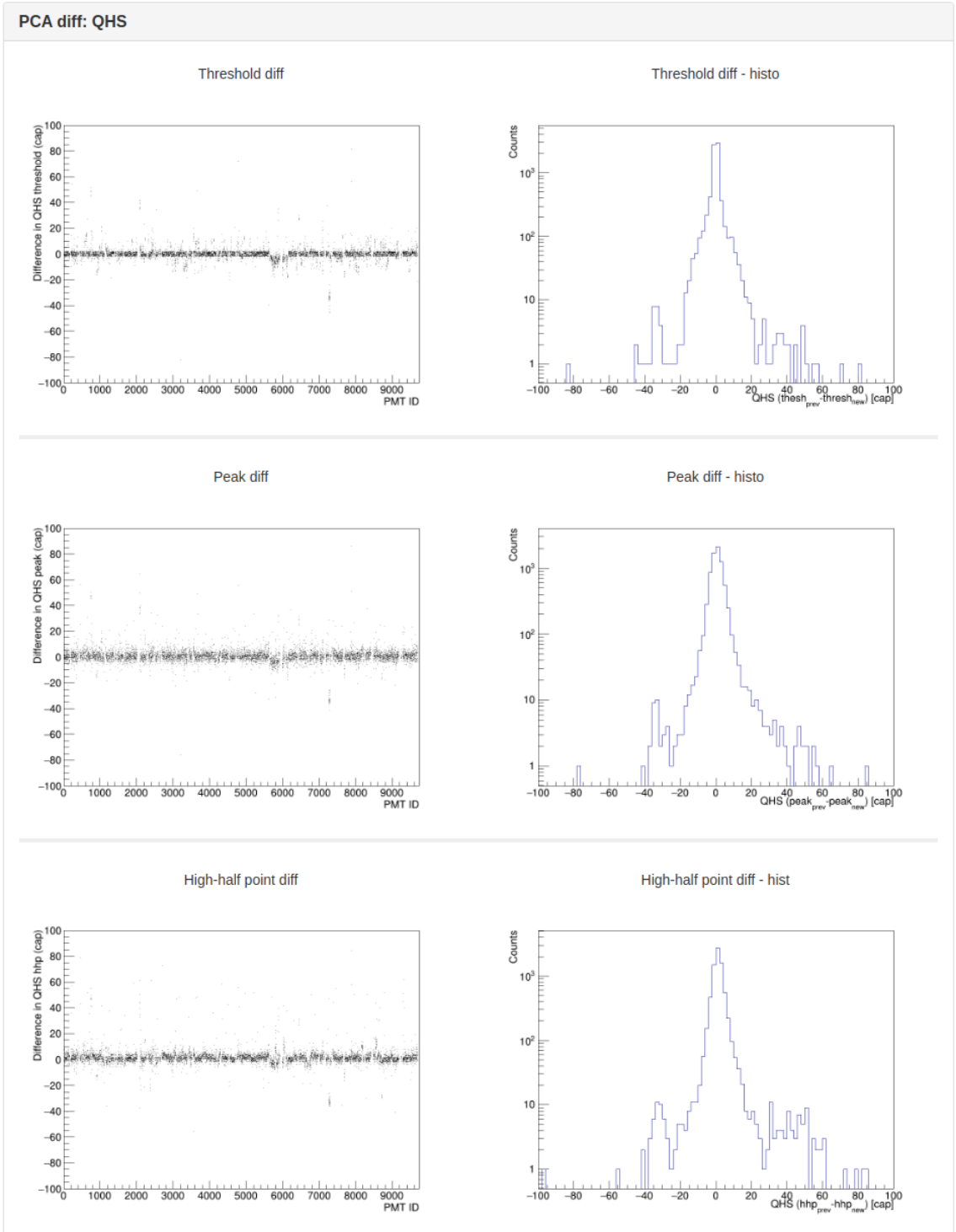


Figure 37: Validation #2:

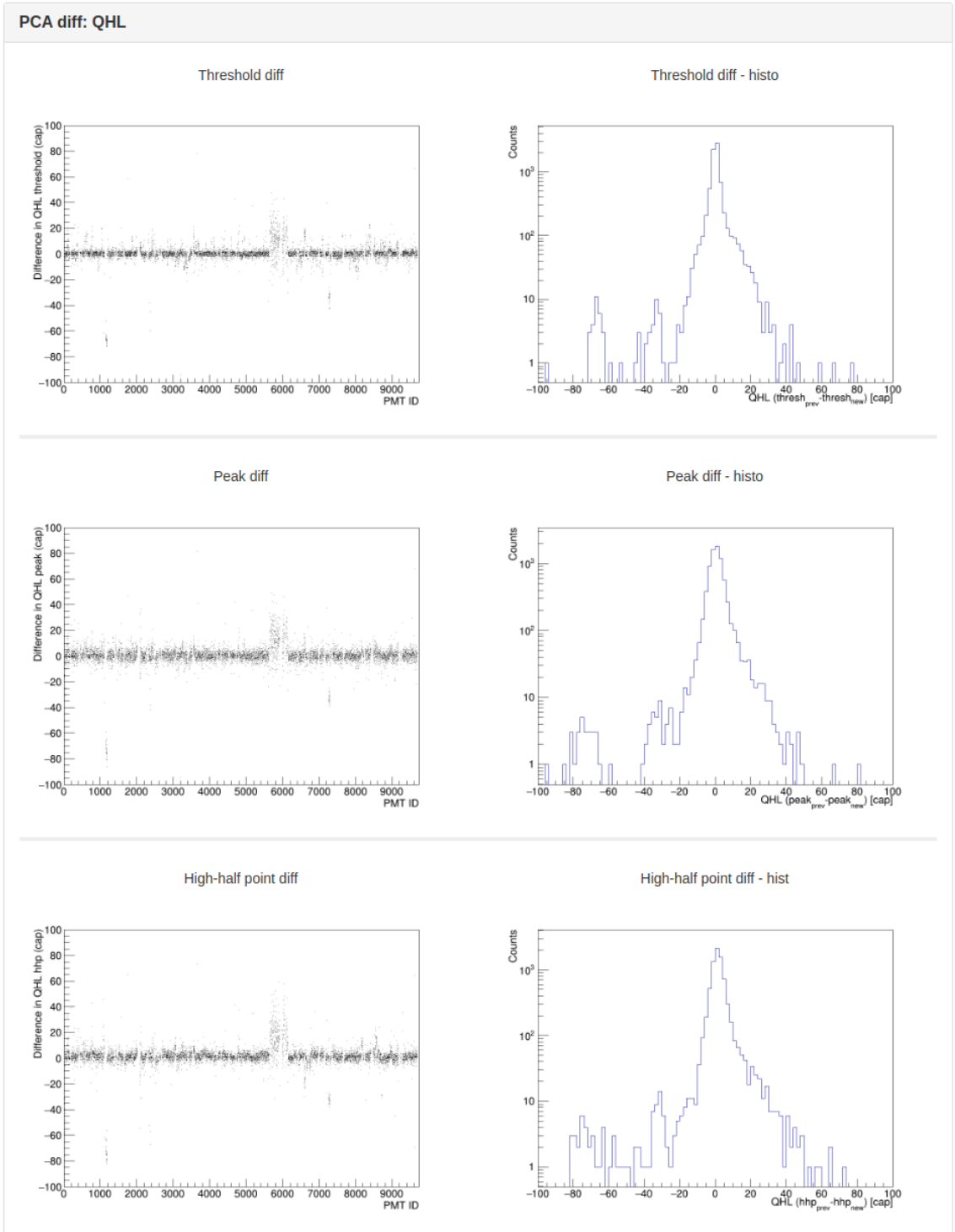


Figure 38: Validation #2:

General

Parameter	Value	Note
Run1	300166	First run of the new PCA dataset
Run2	279375	First run of the previous PCA dataset
Offline PMTs	350	Number of offline PMTs (new dataset)
PMTs with ZERO occupancy	203	Number of PMTs reporting 0 valid hits
PMTs with LOW occupancy	175	Number of PMTs reporting low number of valid hits
Succesfully calibrated PMTs	7644	Number of PMTs with valid calibration

Figure 39: `Validation #2`:

Cable delays

Parameter	Value	Note
Outliers: ID	[4347, 4548, 7611, 8228]	PMTs with calibration very different to previous
Outliers: cable delay	[[127.9, -2.7], [0.8, 153.7], [91.0, 102.6], [1.9, 39.9]]	The values of cable delay for outlier PMTs
Newly calibrated	30, 36, 43, 51, 114, 120, 121, 138, 337, 345, 365, 409, 597, 603, 753, 754, 755, 756, 757, 805, 806, 819, 905, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1050, 1051, 1052, 1053, 1054, 1055, 1056, 1057, 1058, 1059, 1060, 1061, 1062, 1063, 1064, 1065, 1068, 1069, 1070, 1071, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1085, 1086, 1087, 1088, 1089, 1090, 1091, 1092, 1093, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1102, 1104, 1106, 1107, 1108, 1109, 1110, 1111, 1112, 1115, 1118, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1161, 1163, 1164, 1166, 1167, 1169, 1170, 1171, 1172, 1173, 1174, 1175, 1176, 1177, 1178, 1179, 1180, 1181, 1182, 1183, 1184, 1185, 1186, 1187, 1188, 1189, 1190, 1191, 1192, 1194, 1195, 1196, 1197, 1198, 1199, 1200, 1201, 1202, 1203, 1204, 1205, 1206, 1207, 1208, 1210, 1212, 1214, 1216, 1217, 1218, 1219, 1224, 1225, 1226, 1227, 1228, 1231, 1232, 1235, 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1243, 1244, 1245, 1246, 1247, 1248, 1249, 1250, 1251, 1252, 1253, 1254, 1255, 1256, 1258, 1259, 1260, 1261, 1263, 1264, 1265, 1266, 1267, 1268, 1269, 1270, 1271, 1272, 1273, 1274, 1275, 1276, 1277, 1278, 1279, 1281, 1282, 1283, 1284, 1285, 1286, 1287, 1288, 1289, 1290, 1291, 1292, 1294, 1295, 1296, 1297, 1298, 1300, 1302, 1303, 1305, 1306, 1307, 1308, 1309, 1310, 1311, 1312, 1313, 1314, 1315, 1316, 1317, 1318, 1319, 1320, 1321, 1322, 1323, 1324, 1325, 1326, 1328, 1329, 1330, 1332, 1333, 1334, 1335, 1336, 1337, 1338, 1339, 1340, 1341, 1342, 1343, 1344, 1345, 1346, 1347, 1349, 1351, 1352, 1353, 1354, 1355, 1356, 1357, 1358, 1359, 1360, 1361, 1362, 1363, 1364, 1365, 1366, 1367, 1368, 1369, 1370, 1371, 1372, 1373, 1374, 1375, 1408, 1409, 1410, 1411, 1412, 1413, 1414, 1416, 1417, 1418, 1419, 1420, 1421, 1422, 1423, 1424, 1425, 1426, 1427, 1428, 1429, 1430, 1431, 1432, 1433, 1434, 1435, 1436, 1437, 1438, 1439, 1472, 1473, 1474, 1475, 1476, 1478, 1480, 1482, 1483, 1484, 1485, 1486, 1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1498, 1499, 1500, 1501, 1502, 1503, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1527, 1529, 1530, 1531, 1532, 1533, 1534, 1535, 1576, 1610, 1616, 1698, 1699, 1703, 1705, 1707, 1733, 1737, 1738, 1739, 1766, 1798, 1846, 1849, 1850, 1852, 1861, 1862, 1866, 1867, 1870, 1883, 1899, 1956, 1964, 1981, 2002, 2243, 2251, 2355, 2360, 2365, 2411, 2419, 2448, 2639, 2642, 2643, 2650, 2747, 2749, 2750, 2751, 2761, 2777, 2779, 2780, 2782, 2783, 2789, 2790, 2791, 2792, 2794, 2804, 2837, 2875, 2910, 2924, 2929, 2983, 3059, 3067, 3191, 3196, 3280, 3285, 3289, 3294, 3339, 3368, 3369, 3372, 3373, 3381, 3436, 3448, 3449, 3555, 3558, 3570, 3574, 3576, 3577, 3579, 3581, 3582, 3681, 3784, 3806, 3810, 3814, 3818, 3827, 3871, 3874, 3875, 3888, 3890, 3891, 4087, 4092, 4093, 4187, 4224, 4328, 4380, 4381, 4382, 4384, 4434, 4574, 4577, 4580, 4601, 4602, 4604, 4607, 4609, 4610, 4611, 4612, 4614, 4615, 4616, 4617, 4618, 4619, 4620, 4621, 4622, 4623, 4624, 4625, 4627, 4628, 4629, 4630, 4632, 4633, 4634, 4635, 4636, 4637, 4638, 4639, 4640, 4641, 4642, 4643, 4644, 4645, 4646, 4647, 4648, 4649, 4650, 4651, 4652, 4653, 4654, 4655, 4656, 4657, 4658, 4659, 4660, 4661, 4662, 4664, 4666, 4667, 4668, 4669, 4670, 4671, 4673, 4674, 4675, 4676, 4677, 4678, 4679, 4680, 4681, 4682, 4683, 4684, 4685, 4686, 4688, 4689, 4690, 4691, 4694, 4697, 4698, 4699, 4701, 4702, 4703, 4857, 4862, 4934, 4954, 5022, 5026, 5032, 5036, 5037, 5092, 5175, 5320, 5363, 5387, 5388, 5414, 5417, 5419, 5427, 5430, 5434, 5454, 5460, 5461, 5464, 5465, 5469, 5612, 5613, 5665, 5674, 5736, 5738, 5739, 5740, 5741, 5742, 5743, 5802, 5865, 5867, 5874, 5880, 5915, 5988, 5990, 6067, 6071, 6072, 6116, 6462, 6463, 6504, 6510, 6524, 6851, 6853, 6889, 6892, 7029, 7048, 7100, 7101, 7186, 7390, 7411, 7417, 7440, 7441, 7454, 7455, 7483, 7497, 7554, 7557, 7558, 7560, 7563, 7834, 7858, 7873, 7893, 7968, 8208, 8302, 8485, 8715, 8781, 8808, 8834, 8836, 8866, 8877, 8881, 8882, 8922, 8973, 9025, 9323, 9458,	PMTs that have valid calibration now (didn't have previously)
Previously calibrated	[96, 98, 107, 108, 109, 111, 112, 126, 389, 482, 560, 562, 565, 567, 596, 599, 1005, 2005, 2012, 2231, 2648, 2654, 2769, 2771, 2772, 2773, 2774, 2775, 3054, 3141, 3556, 4120, 4122, 4181, 4185, 4186, 4188, 4189, 4190, 4424, 4836, 5406, 5458, 5860, 5920, 5922, 5923, 5924, 5925, 5926, 5928, 5930, 5931, 5932, 5933, 5934, 5935, 5937, 5938, 5940, 5941, 5942, 5943, 5944, 5946, 5947, 5948, 5949, 5950, 5951, 5953, 5954, 5956, 5957, 5958, 5959, 5960, 5962, 5963, 5964, 5965, 5966, 5967, 5968, 5969, 5970, 5971, 5972, 5973, 5974, 5975, 5976, 5977, 5978, 5980, 5981, 5982, 5983, 6005, 6804, 7043, 7044, 7047, 7051, 7053, 7061, 7071, 7520, 7689, 7693, 8215, 8299, 8307, 8319, 8327, 8385, 8407, 8453, 8454, 8455, 8456, 8457, 8459, 8460, 8461, 8462, 8463, 8464, 8465, 8466, 8467, 8468, 8469, 8470, 8471, 8472, 8473, 8474, 8475, 8476, 8477, 8478, 8479, 8981, 9570, 9608]	PMTs that were previously calibrated, but cannot be now
Minimal change	-152.900000	The most negative change to single cable delay
Maximal change	130.600000	The most positive change to single cable delay

Figure 40: `Validation #2`:

Time Walk

Parameter	Value	Note
IDs1	7644	Number of valid PMTs for new dataset
IDs2	7051	Number of valid PMTs for previous dataset
off1	350	Number of offline PMTs for new dataset
off2	493	Number of offline PMTs for previous dataset
goodCount	6956	PMTs that were succesfully calibrated in both datasets
badCount	688	PMTs that were only calibrated in one dataset
min_grad	-0.015700	Minimum value of gradient (fit)
max_grad	0.018700	Maximum value of gradient (fit)
min_inter	-152.900000	Minimum value of intercept (fit)
max_inter	130.600000	Maximum value of intercept (fit)

Figure 41: `Validation #2`:

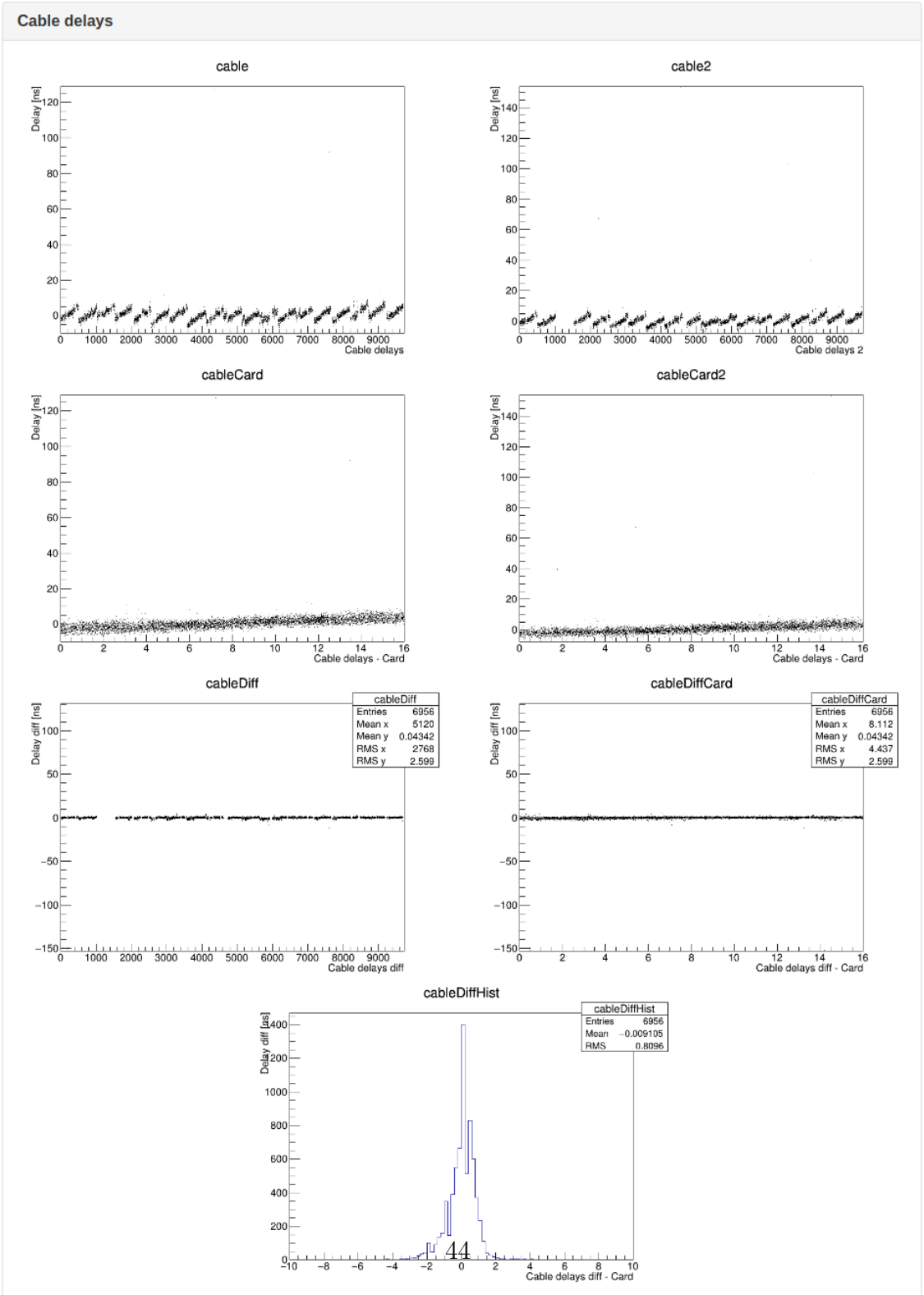


Figure 42: `Validation #2`:

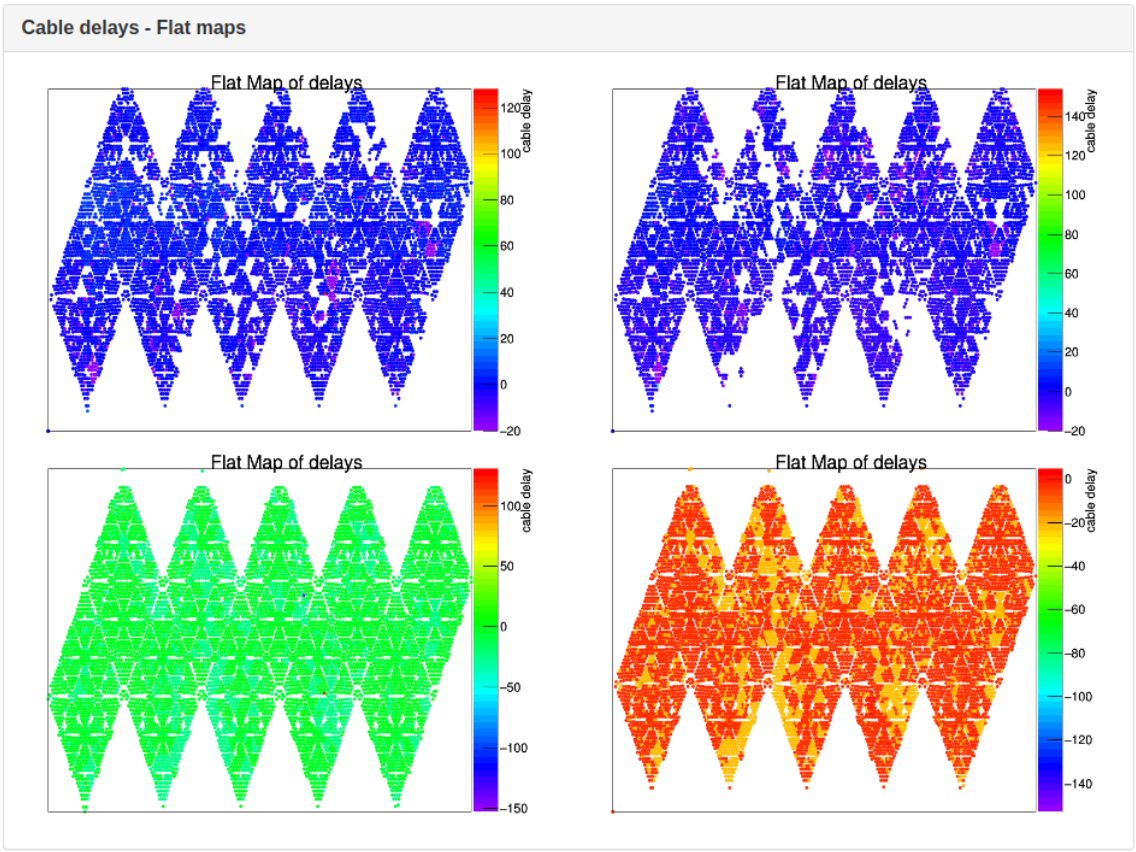


Figure 43: `Validation #2`:

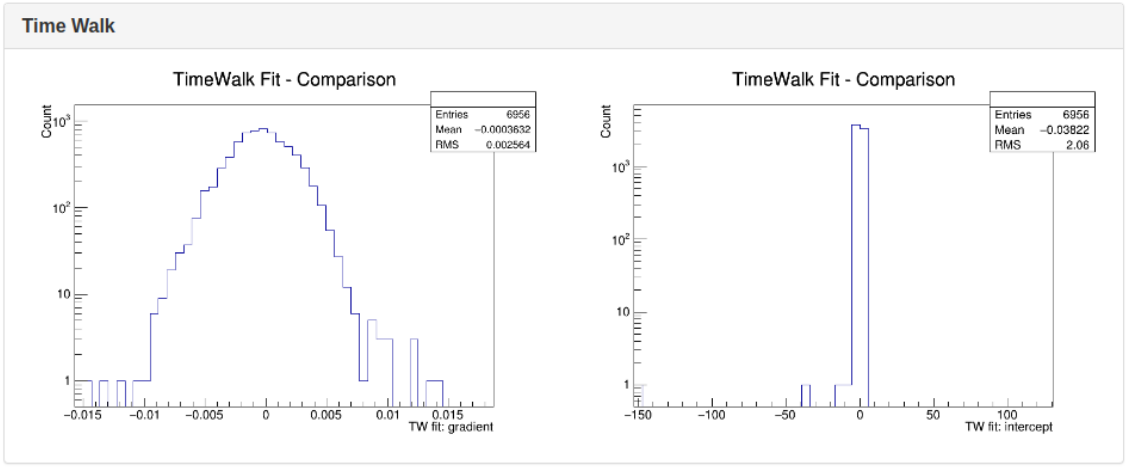


Figure 44: `Validation #2`:

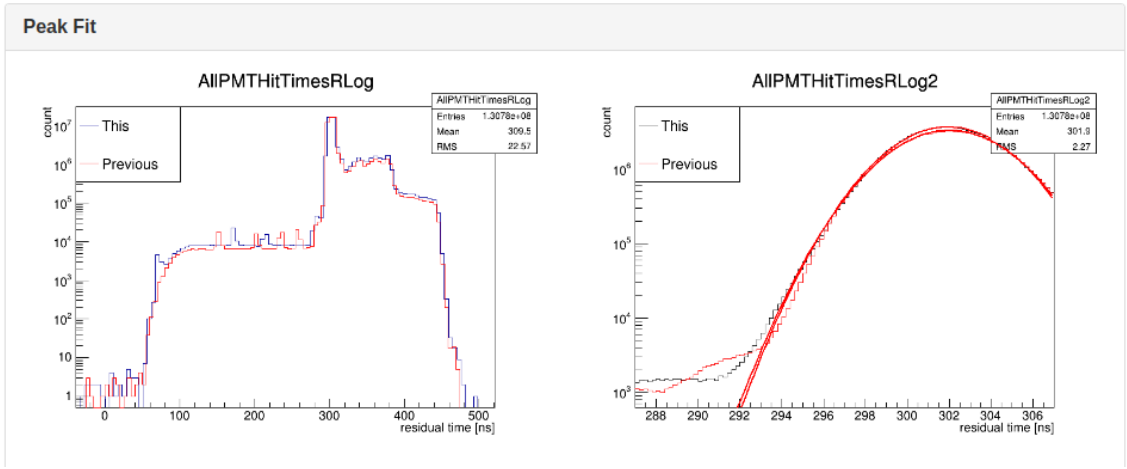


Figure 45: `Validation #2`:

PCA: Log

Flag	Description	Type	Status
0: status PCA	OR of bits 1-31	info	**Flag Raised**
2: status GF	OR of bits 20-31	info	**Flag Raised**
30: too many (#PMTs with QHL TH too low)		info	**Flag Raised**

Figure 46: `Validation #2`:

PCA: Gain Fit

Flag	Description	Type	Count	Images	Show/Hide
0: status	OR of bits 1-31	info	2191		
1: channel offline	FAIL tube is marked as off in DQXX	info	1734		
2: zero occupancy QHS	FAIL tube is marked as on in DQXX but did not see any hits	danger	147		
3: low occupancy	FAIL tube saw less than min hits	danger	28		
4: < 100 hits in 100-bin window for QHS	FAIL	warning	39		
5: < 100 hits in 100-bin window for QHL	FAIL	warning	32		
20: QHS TH too high	bad pedestal?	warning	10		
21: QHL TH too high	bad pedestal?	warning	17		
22: Peakfinder called and used	peakfinder was called and used to determine position of second peak	warning	14		
23: QHS TH too low	WARN, Possible noise peak fitted for threshold	warning	118		
24: QHL TH too low		warning	119		

Figure 47: `Validation #2`:

PCA: Time Walk

Flag	Description	Type	Count	Images	Show/Hide
0: status	OR of bits 1-31	info	2084		
1: channel offline	same as GF	info	1734		
2: zero occupancy	no hits on this PMT, same as GF	danger	147		
3: low occupancy	Less than min hits on this PMT, could be different than GF	danger	28		
8: RMS is too high		warning	9		
9: high Q tail was not fitted		warning	69		
10: Tstep warning	Possible bad ADC charge conversion. This will affect a complete card.	warning	38		
11: Flate warning	The fraction of late light is too large	warning	6		
12: Fout warning	The fraction of hits <QHSmin and < Tpeak-10 is too large	warning	27		
13: Gradient warning	The gradient of the fit to high charge tail is positive	warning	2		

Figure 48: `Validation #2`:

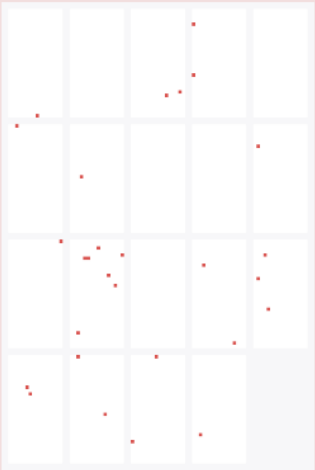
3: low occupancy	Less than min hits on this PMT, could be different than GF	danger	28	

Figure 49: `Validation #2`:

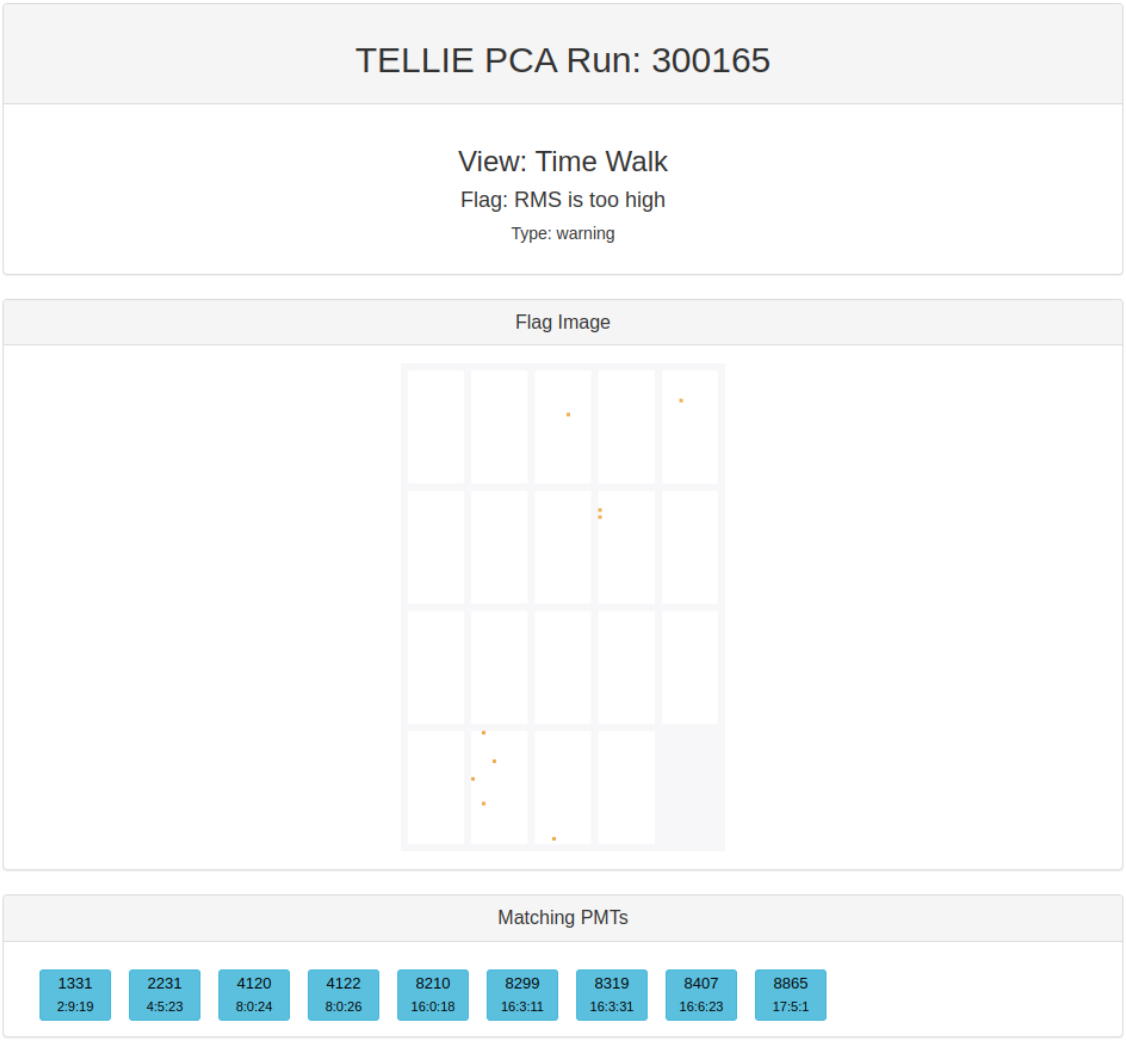


Figure 50: `Validation #2`:

TELLIE PCA Run: 300165

PMT: 8210 flags

Crate: 16 Card: 0 Channel: 18

Time Walk Flags

0: status

8: RMS is too high

Gain Fit Flags

No Gain Fit flags were raised for PMT 8210 in 300165.

Plots

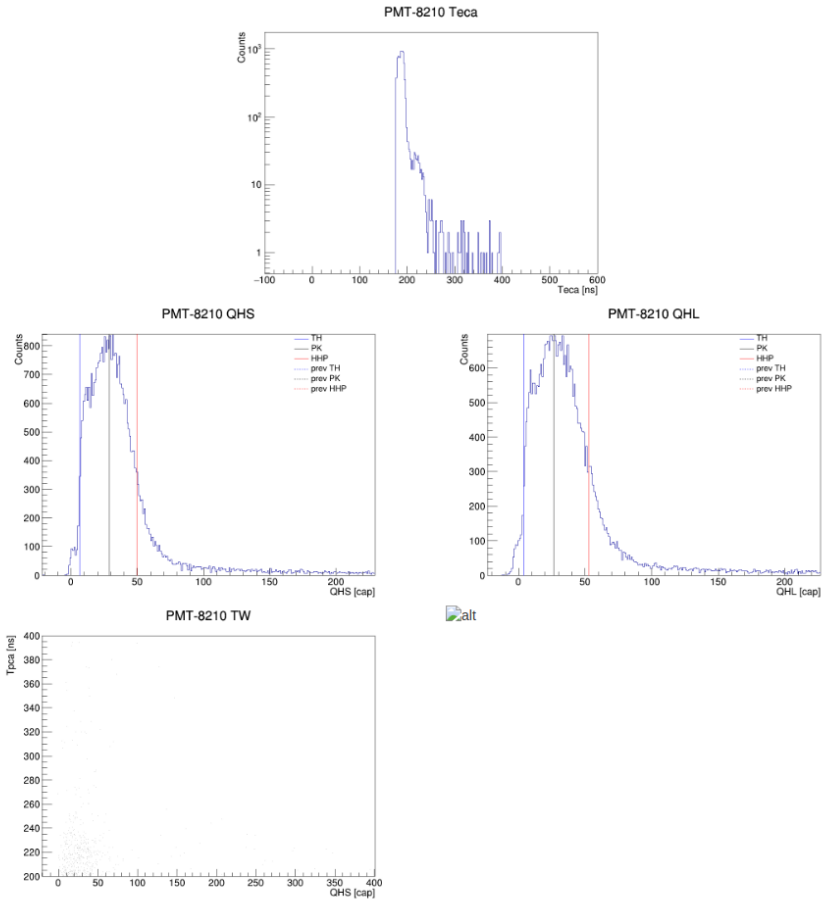


Figure 51: `Validation #2`:

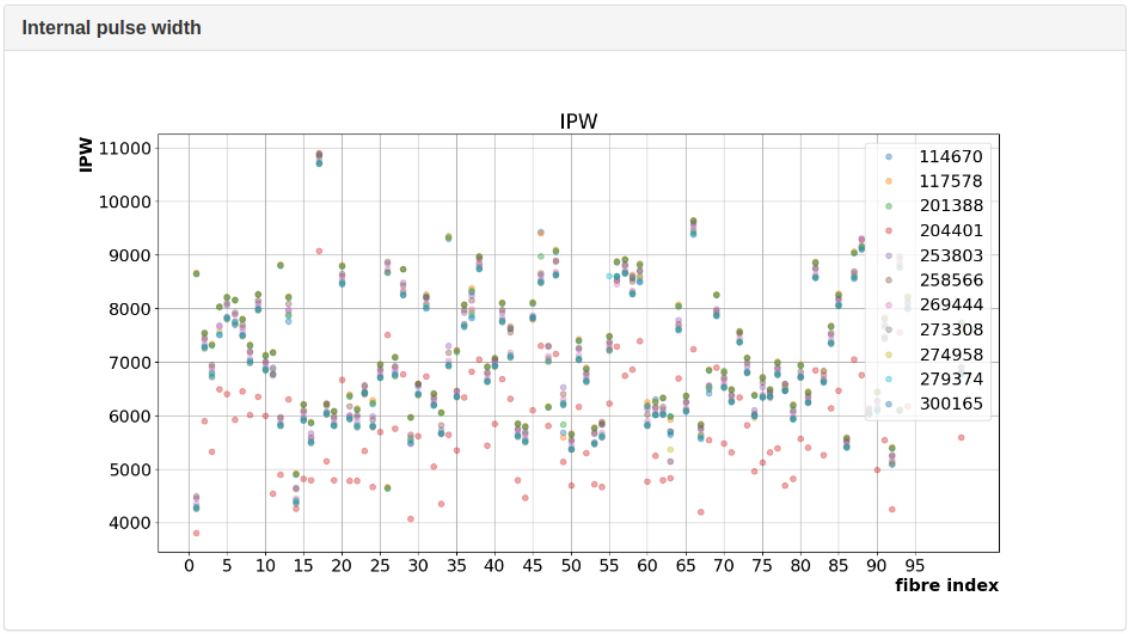


Figure 52: `Validation #2`:

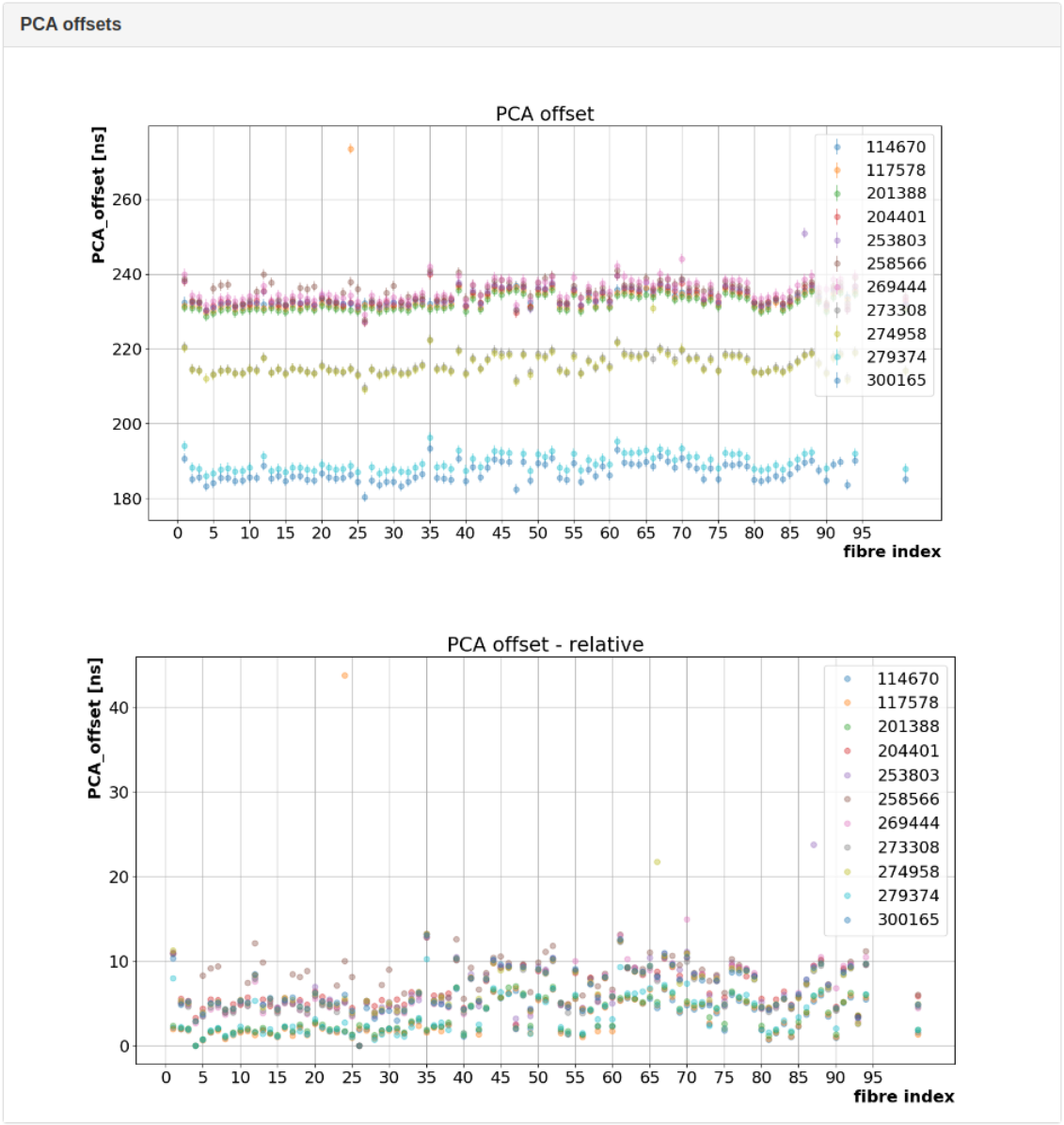


Figure 53: `Validation #2:`

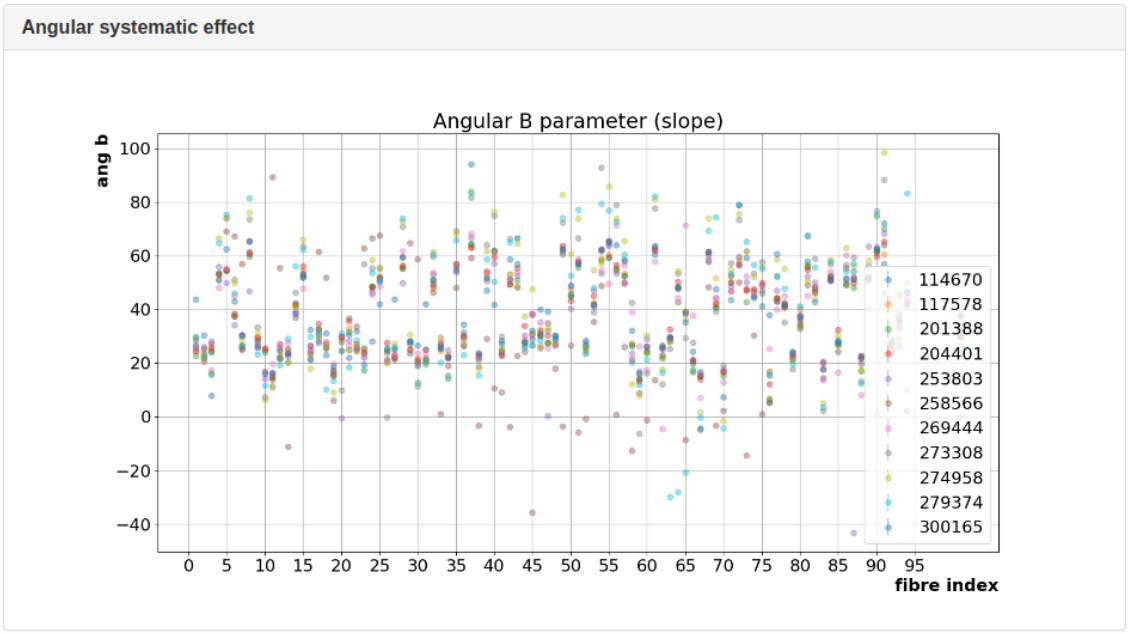


Figure 54: `Validation #2`:

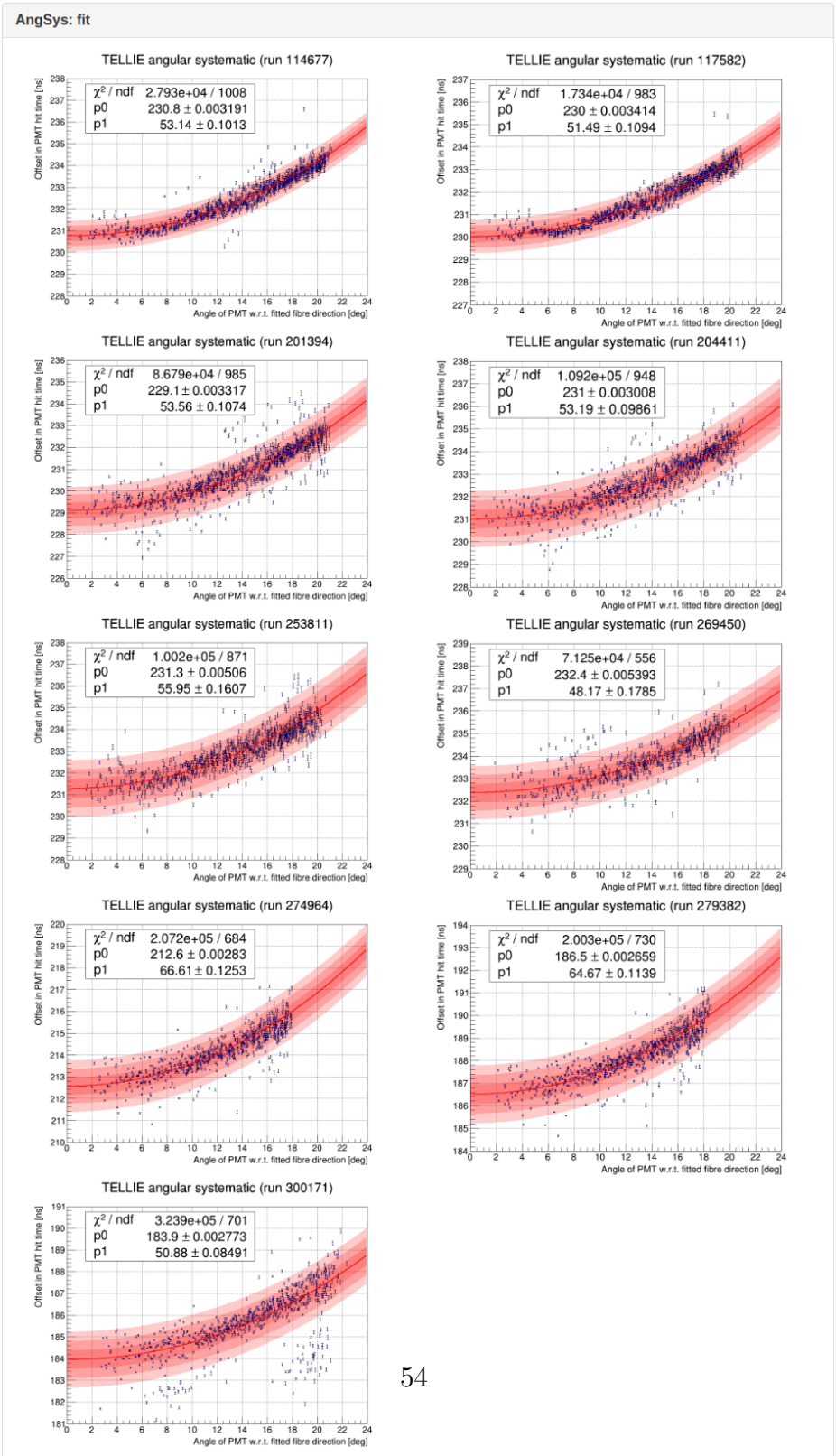


Figure 55: `Validation #2`:

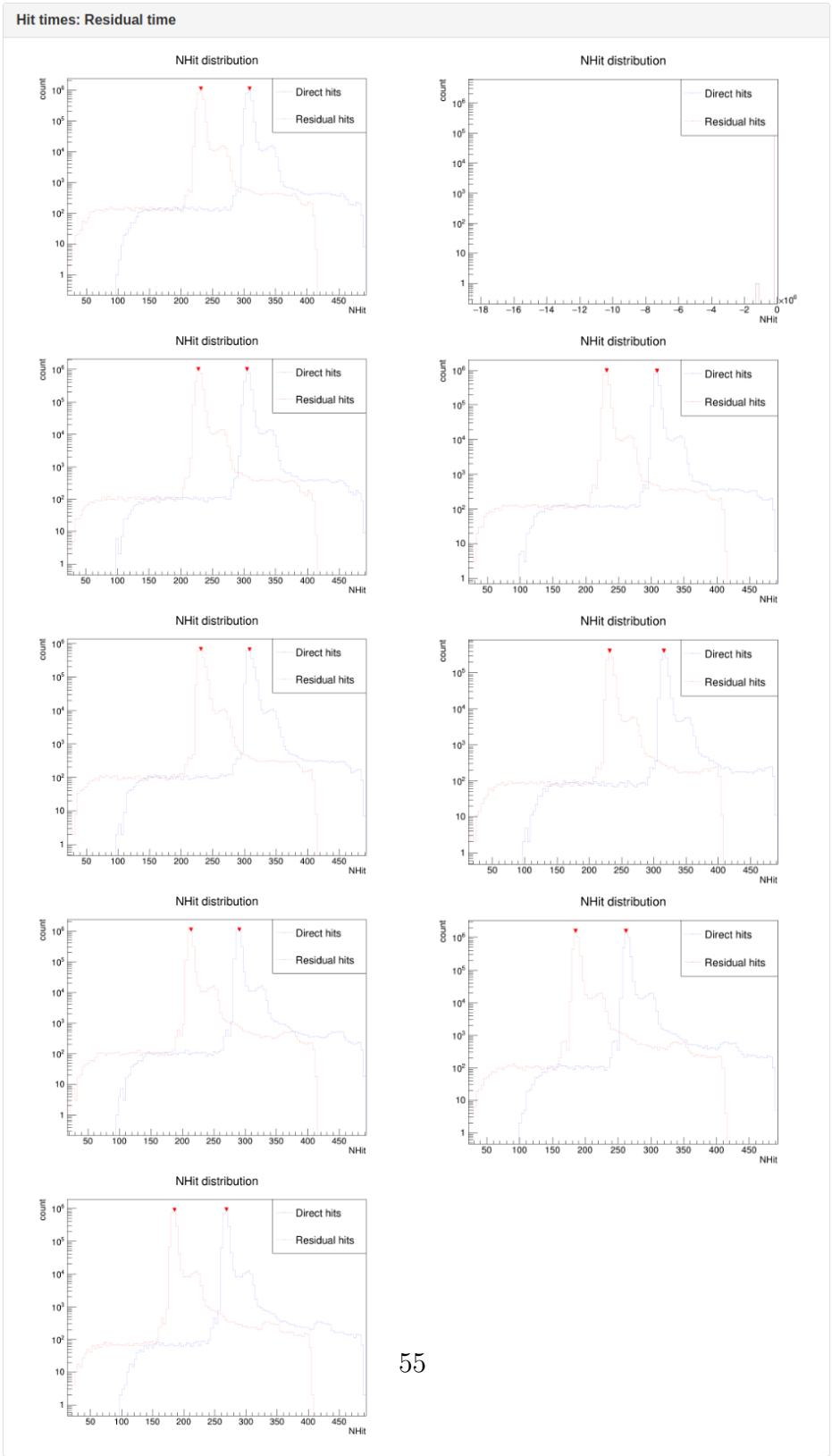


Figure 56: `Validation #2`:

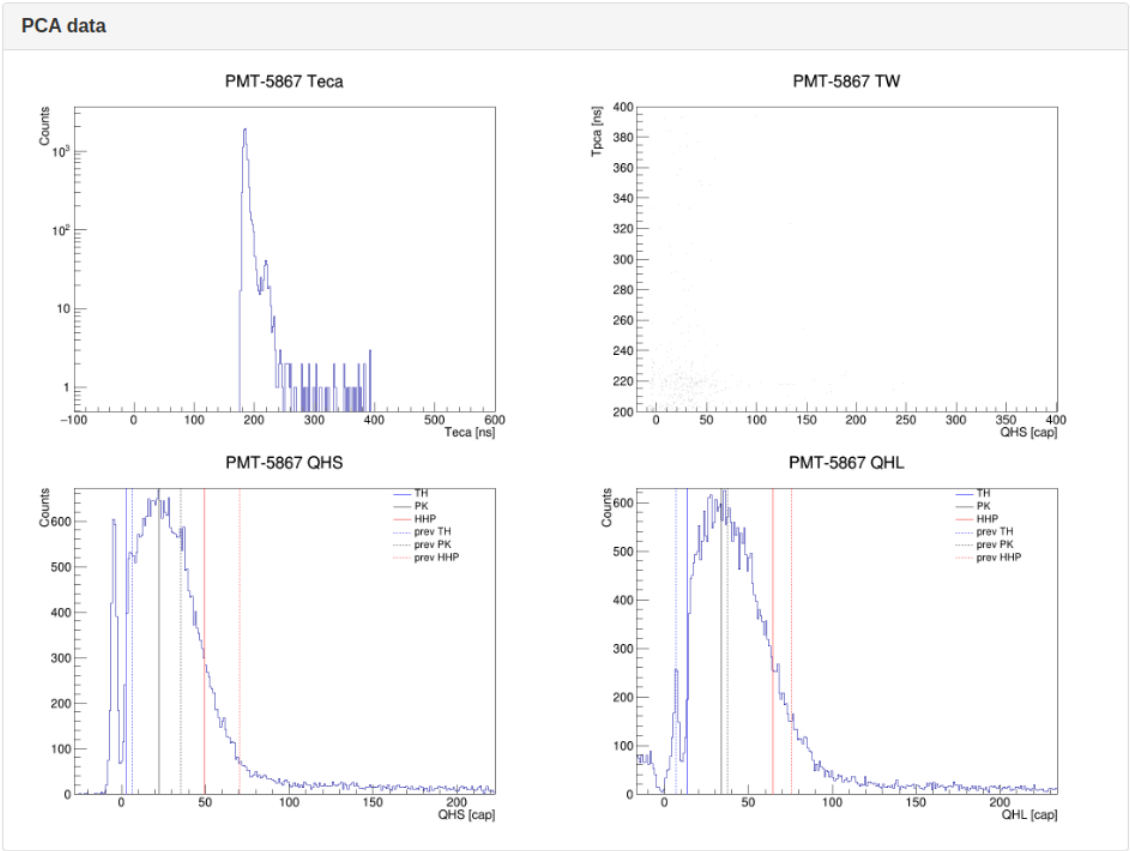


Figure 57: `Validation #2`:

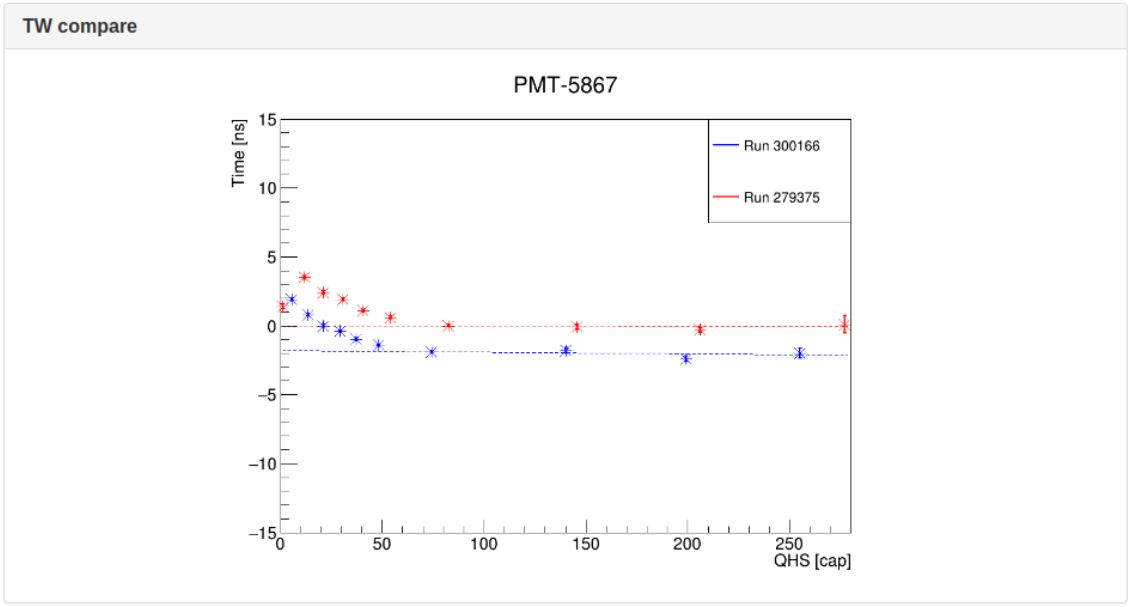


Figure 58: `Validation #2`:

6 System

This section will describe some of the features of the overall processing.

6.1 Simple

The system is based on being very simple and with minimum human input. As it stands, it only needs to be started, providing a single text file with runs corresponding to a dataset.
Example runlist text file:

```
300165
300167
300372
300171
300173
...
```

6.2 Modular

The whole system is a network of multiple individual steps, managed by one master script. The master script spawns subprocessed. Individual steps can be (re)run. Modules can be easily modified, separately.

6.3 Submission platform

To process the whole dataset, many individual jobs need to be run. There are 6 steps for each run: `Validation #1`, `position fit`, `angular systematic fit`, `injection fit`; and addition steps to be run per dataset: `PCA Processor`. There are several other global jobs: creating PCA table, comparing PCA tables, checking PCA output, comparing time-walk data, benchmarking (multiple steps), final compare scripts (multiple). For a single set of 95 runs (one per fibre), this ends up totalling close to 600 (95*6 + global + other) individual processes.

To deal with this, the master scripts has inbuilt submission platform. It spaws child processes (up to a configurable limit) and monitors their status. There is a queue that holds jobs to be submitted. The whole system is run in steps, as usually consecutive steps require the output of previous steps.

If processes fail, they are retried up to a limit. After that, the failed processes need to be investiaged and rerun manually (if needed).

6.4 Customizable

The checks in validation steps are often based on threshold values. There are loaded from environment and should be tuned before running. There are comments explaining what the threshold values are, please see Figure 59.

6.5 Linked

The processing system is linked to multiple databases. The CouchDB holds data on: belly plates, benchmarking, environment constants, list of fibres, runlists, and document for each run/fit combination. An overview of views in the couhdb is shown in Figure 60, while an example environment CouchDB document is shown in Figure 61.

Additionally, the system requires access to ratDB. Finally, there is a plethora of plots created. These need to be linked to minard, usually via nfs mount over network.

6.6 Regulation

The system was developped to have unified cuts, event selection, checks, and ranges.

6.7 Evaluative

There are bitwords used in `Validation #1` and `Validation #2`. There are a proxy for the quality of the data. If tuned correctly, these could be used to ignore specific runs, however, this is not currently implemented.

```
### LIMITS FOR DIRECT AND REFLECTED LIGHT (DEG)
DIR_LIGHT_ANG=48
REF_LIGHT_ANG=20
LOCALITY=10
ANG_SYS_ANG=24
MIN_DIST=900
### VALIDATION 1
TOT_EVS=200000          ### predicted number of events
TOT_EVS_DEV=1           ### deviation for above [%]
TOT_HITS=20             ### threshold = percentage of passed hits
TH_EXTA=10              ### threshold = percentage of NON-EXTA events
TH_BADCHAN=1.75         ### threshold = percentage of bad channel hits
TH_BADECA=10            ### threshold = percentage of bad ECA hits
TH_BADPCA=5             ### threshold = percentage of bad PCA hits
TH_XTALK=0.1            ### threshold = percentage of cross-talk hits
TH_NOTEN=0.1            ### threshold = percentage of not enabled channel hits
TH_OFFPMT=0.1           ### threshold = percentage of offline PMT hits
TH_OFFCHAN=0.1          ### threshold = percentage of offline channel hits
TH_DAQEN=0.1            ### threshold = percentage of not DAQ enabled hits
TH_NNORM=0.1            ### threshold = percentage of NOT normal PMT hits
TH_BADPOS=0.01          ### threshold = percentage of bad position PMT hits
TH_LPCTIR=8             ### threshold = percentage of LPC-total internal reflection hits
TH_LPCIP=0.1            ### threshold = percentage of LPC-invalid path hits
TH_LPCLOC=0.01          ### threshold = percentage of LPC-locality hits
TH_LPCPATH=0.052        ### threshold = percentage of LPC-weird path (not throught AV) hits
TH_ANG=55               ### threshold = percentage of hits cut due to angular cut (0 - 12 deg)
TH_NEARREF=20           ### threshold = percentage of near relfection hits
NHIT_DIV=0.2            ### threshold = nhit deviation tolerance (fibre stability)
NHIT_MEAN=42            ### mean of cleaned NHit dist
NHIT_MEAN_DEV=12        ### allowed deviation for the mean NHit
NHIT_RMS=10             ### allowed RMS for the cleaned NHit dist
SUB_NHIT=10             ### mean of cleaned NHit dist, for a subrun
SUB_DEV=1               ### allowed deviation for the mean NHit, for a subrun
HIT_PEAK=302            ### the assumed mean of the direct hit time distribution
HIT_PEAK_DEV=10         ### allowed deviation for above [value]
TIME_DIV=0.75           ### threshold = time deviation tolerance (fibre stability)
PMTS_BS=200             ### # PMTs in beamspot
PMTS_BSP=2              ### # PMTs in beamspot, percentage
PMTS_BS_GO=150          ### # PMTs in beamspot, with good occupancy
PMTS_BS_GOP=1.5         ### # PMTs in beamspot, with good occupancy, percentage
PMTS_BS_RAT=70          ### ratio of PMTs in beamspot with good occupancy, to all PMTs in beamspot
RUNTIME=2500            ### allowed length of run in seconds
FREQ=1000               ### aimed frequency
FREQ_DEV=7.5            ### tolerance for real frequency (%)
EV_SUB=5000             ### expected evs in subrun
EV_SUB_DEV=0.5          ### tolerance for above (%)
N_SUBS=40               ### number of allowed subruns
INTEG_ALL=30            ### integral of PMTs with good occupancy (all PMTs)
INTEG_BS=70             ### integral of PMTs with good occupancy (beamspot PMTs)
BS_PMTS=150             ### number of PMTs with good occupancy in the beamspot
PIN_RMS=3               ### RMS of the pin distribution
COV=0.0                 ### minimal covariance
CORF=0.6                ### minimal correlation factor
TOF_MEAN=82             ### expected mean for time of flight [ns]
TOF_RMS=0.75            ### maximal allowed RMS for time of flight distribution
BUCK_MEAN=0.47          ### expected mean for bucket time distribution [ns]
BUCK_RMS=0.005          ### maximal allowed RMS for above
AS_MEAN_MIN=0           ### minimal allowed mean for ang sys distribution [ns]
AS_MEAN_MAX=2           ### maximal allowed mean for ang sys distribution [ns]
AS_RMS=0.4              ### maximal allowed RMS for above
COR_DEV=3               ### allowed deviation for the means (tof, buc, angsys) [%]
TOF_MIN=78              ### min allowed for tof
TOF_MAX=85              ### max allowed for tof
BUC_MIN=0.45            ### min allowed for bucket
BUC_MAX=0.48            ### max allowed for bucket
AS_MIN=0.0              ### min allowed for ang sys
AS_MAX=1.5              ### max allowed for ang sys
RESID_PEAK=220          ### the assumed mean of the ersidual hit time distribution
RESID_PEAK_DEV=12       ### allowed deviation for above [value]
DIR_RESID_0=-78         ### fit (pol1) direct-residual time relation, parameter 0: y-intercept
DIR_RESID_1=1.05        ### fit (pol1) direct-residual time relation, parameter 1: slope
FIT_SLOPE=0             ### fit (pol1) both direct and resid vs angle, parameter 1: slope
FIT_SLOPE_DEV=0.1       ### max allowed deviation for above
```

Figure 59: The threshold parameters, used for validation. These can be tuned as required.

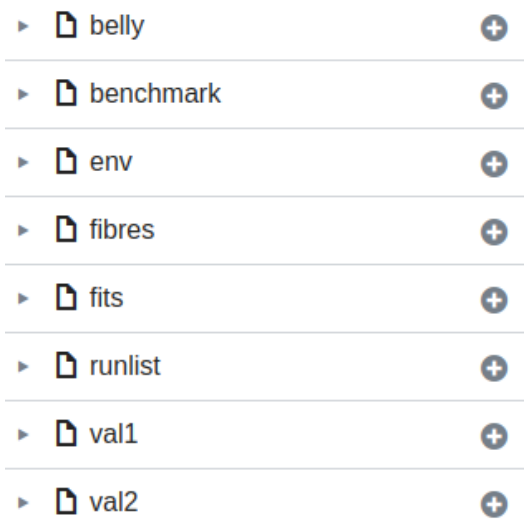


Figure 60: `Validation #2`:

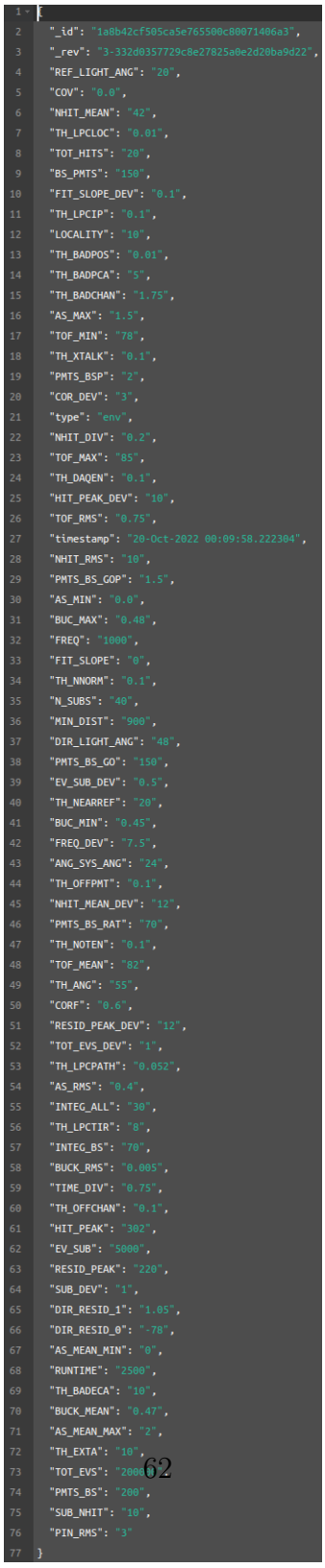


Figure 61: `Validation #2`:

7 Code

7.1 Master scripts

8 Deploying

9 Running

10 ToDos

11 Other documentation