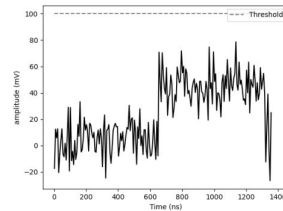
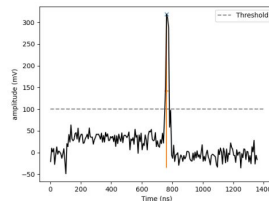
The background of the slide features a collage of photomultiplier tube (PMT) components. On the left, a large, clear glass PMT tube is shown in a perspective view. In the center, a yellow rectangular box contains the main title and meeting information. On the right, several smaller PMT tubes and components are arranged, including a cylindrical tube with a black base, a smaller tube with a silver base, and a small black cylindrical component. The overall scene is brightly lit, highlighting the metallic and glass surfaces of the tubes.

PMT analysis – Update

Cygnoreco and analysis meeting - 28/04/2022

David Marques
Gianluca Cavoto

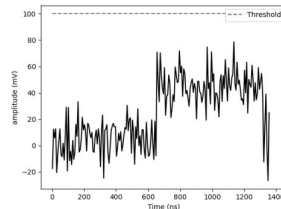
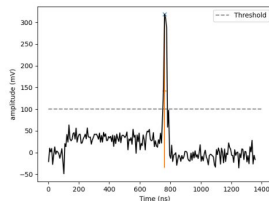
1. Problems with data:
 - a. High baseline
 - b. Stepping baseline.



PMT analysis - Data correction

1. Problems with data:

- High baseline
- Stepping baseline.



2. Solution: CAEN *automatic* data correction.

- Waveforms have 1024 cells.
- A correction table is applied point by point to each cell.

```
1 Calibration values from cell 0 to 1024 for channel 0:
2
3 42 -40 82 -46 31 10 44 -21 cell = 0 to 7
4 -7 -12 23 -17 45 -42 20 2 cell = 8 to 15
5 18 -31 17 -23 81 -33 66 -21 cell = 16 to 23
6 35 -28 57 -63 76 -35 33 -40 cell = 24 to 31
7 54 0 86 3 47 15 20 -4 cell = 32 to 39
8 13 -11 67 -1 51 26 54 -18 cell = 40 to 47
9 30 -23 19 -23 77 -30 1 -16 cell = 48 to 55
10 29 2 62 -4 55 -22 38 -37 cell = 56 to 63
11 51 13 52 -50 37 32 74 -71 cell = 64 to 71
12 33 -24 53 -25 32 23 55 25 cell = 72 to 79
13 60 -2 94 4 -56 -19 53 -18 cell = 80 to 87
14 -5 26 48 52 27 1 64 21 cell = 88 to 95
15 53 -36 29 -16 62 -5 72 -24 cell = 96 to 103
16 32 1 73 -19 47 6 8 -23 cell = 104 to 111
17 60 2 25 -15 45 10 35 -29 cell = 112 to 119
18 -7 -27 88 -27 37 -31 28 13 cell = 120 to 127
19 33 17 8 -30 50 21 61 14 cell = 128 to 135
20 31 -7 67 21 60 10 85 -17 cell = 136 to 143
21 50 8 24 4 54 -38 38 -39 cell = 144 to 151
22 17 -51 39 -5 51 -24 23 -23 cell = 152 to 159
23 44 9 71 18 12 -25 61 -28 cell = 160 to 167
24 24 15 -12 3 62 -37 56 -17 cell = 168 to 175
25 31 -9 48 -15 68 -9 49 -8 cell = 176 to 183
26 48 3 61 -33 23 -47 61 -32 cell = 184 to 191
27 23 -32 46 -8 76 -24 68 -42 cell = 192 to 199
28 38 37 67 -19 20 5 31 -13 cell = 200 to 207
```

```
st_ind = (uint16_t)(data->StartIndexCell);
for (i=0; i<MAX_X742_CHANNEL_SIZE; i++) {
    size1 = data->ChSize[i];
    for (j=0; j<size1; j++) {
        if (cellCorrection)
            data->DataChannel[i][j] -= CTable->cell[i][((st_ind+j) % 1024)];
        if (nsampleCorrection)
            data->DataChannel[i][j] -= CTable->nsample[i][j];
    }
}
```

CAEN  Electronic Instrumentation

Cell Index Offset Correction

The analog capacitors of the DRS4 chip might have small differences between each other due to the construction processes. According to the cell index where the stop acquisition arrives, the same input signal can be reconstructed in different ways. For this reason it is required a cell amplitude calibration to compensate for the amplitude differences in the capacitors. The correction adjusts the baseline of the input (i.e. its offset).

Taking into account the internal noise of each channel, Fig. 8.5 shows the sampled waveform on the left and the noise distribution histogram on the right, measured as the occurrence of the ADC counts. Plots are made before the correction. Fig. 8.6 shows the same quantities after the correction. As expected, the noise in Fig. 8.6 is flatter with no patterns, and its distribution has a smaller RMS.

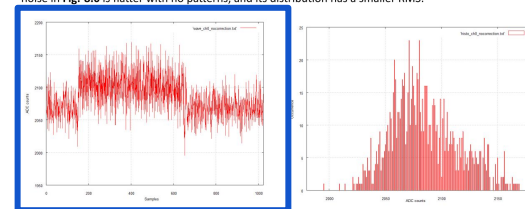


Fig. 8.5: Sampled waveform (left) and noise histogram (right) before cell index offset correction

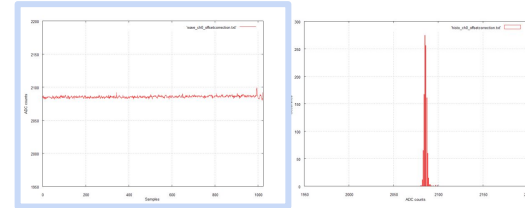
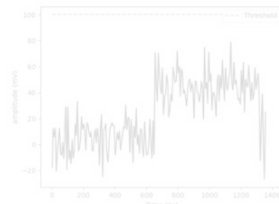
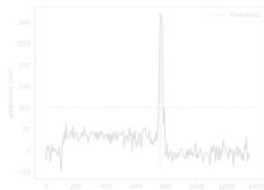


Fig. 8.6: Sampled waveform (left) and noise histogram (right) after cell index offset correction

PMT analysis - Data correction

1. Problems with data:

- a. High baseline
- b. Stepping baseline.



2. Solution: CAEN *automatic* data correction.

- a. Waveforms have 1024 cells.
- b. A correction table is applied point by point to each cell.

```
Calibration values from cell 0 to 1024 for channel 0:  
42 -48 82 -46 31 10 44 -21 cell = 0 to 7  
-7 -12 23 -17 45 -42 28 2 cell = 8 to 15  
10 -13 17 -23 01 -33 06 -21 cell = 16 to 23  
125 -78 57 -63 75 -35 83 -48 cell = 24 to 31  
54 8 86 1 47 15 38 -4 cell = 32 to 39  
13 -11 67 -1 51 26 54 -18 cell = 40 to 47  
108 -23 19 -23 77 -38 1 -10 cell = 48 to 55  
29 2 62 -4 23 -23 86 -27 cell = 56 to 63  
51 13 62 -58 37 32 74 -71 cell = 64 to 71  
13 -24 53 -25 32 23 55 25 cell = 72 to 79  
68 -2 50 4 -36 -19 53 -18 cell = 80 to 87  
-5 28 -48 -37 27 1 64 21 cell = 88 to 95  
53 36 29 -16 62 -5 77 -24 cell = 96 to 103  
32 1 73 -19 47 6 9 -22 cell = 104 to 111  
98 2 25 -15 40 18 35 -29 cell = 112 to 119  
-7 -27 08 -17 13 -31 08 -12 cell = 120 to 127  
53 17 8 -36 58 21 61 14 cell = 128 to 135  
21 7 67 21 68 18 95 -17 cell = 136 to 143  
18 8 24 4 54 -38 58 -39 cell = 144 to 151  
17 -31 38 -5 61 -14 23 -23 cell = 152 to 159  
64 8 71 18 12 -22 51 -28 cell = 160 to 167  
24 15 -12 3 62 -37 56 -17 cell = 168 to 175  
31 -9 48 -15 68 -9 49 -8 cell = 176 to 183  
108 8 61 -31 23 -47 61 -32 cell = 184 to 191  
12 -32 66 8 76 -24 66 -42 cell = 192 to 199  
18 37 67 -14 28 8 31 -13 cell = 200 to 207
```

```
st_ind = (uint16_t)(data->StartIndexCell);  
for (i=0; i<MAX_X742_CHANNEL_SIZE; i++) {  
    size1 = data->ChSize[i];  
    for (j=0; j<size1; j++) {  
        if (cellCorrection)  
            data->DataChannel[i][j] -= CTable->cell[i][((st_ind+j) % 1024)];  
        if (nsampleCorrection)  
            data->DataChannel[i][j] -= CTable->nsample[i][j];  
    }  
}
```

CAEN Electronic Instrumentation

Cell Index Offset Correction

The analog capacitors of the DR54 chip might have small differences between each other due to the construction processes. According to the cell index where the stop acquisition arrives, the same input signal can be reconstructed in different ways. For this reason it is required a cell amplitude calibration to compensate for the amplitude differences in the capacitors. The correction adjusts the baseline of the input (i.e. its offset).

Taking into account the internal noise of each channel, Fig. 8.5 shows the sampled waveform on the left and the noise distribution histogram on the right, measured as the occurrence of the ADC counts. Plots are made before the correction. Fig. 8.6 shows the same quantities after the correction. As expected, the noise in Fig. 8.6 is flatter with no patterns, and its distribution has a smaller RMS.

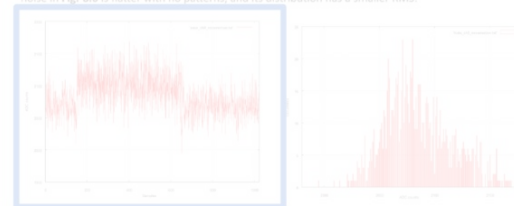


Fig. 8.5: Sampled waveform (left) and noise histogram (right) before cell index offset correction

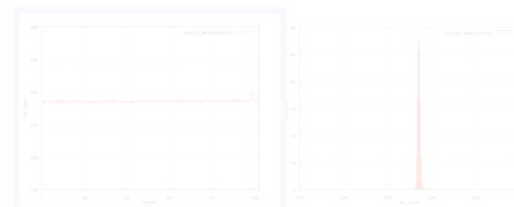


Fig. 8.6: Sampled waveform (left) and noise histogram (right) after cell index offset correction

What's the Start Index Cell?

Message from CAEN Support

08/04/2022 10:14:44

Dear Marques,

Thanks for clarification.

I'm sorry to inform you that **without the start index cell you can't apply the corrections needed to read the data**. This parameter **is not calculated**, it just indicated from which capacitor the measurement starts (that means **on which capacitor the read cycle was on when the trigger arrived**). Every capacitor has its own corrections, so, if you don't know which capacitor you were reading when the measurement starts, you can't correct the data.

Best regards,

Matteo

to each cell.

```
Calibration values from cell 0 to 1024 for channel 0:  
42 -48 82 -46 31 18 44 -21 cell = 0 to 7  
-7 11 23 -17 45 -42 28 2 cell = 8 to 15  
18 -15 17 -25 81 -73 86 -71 cell = 16 to 23  
15 -28 21 -63 76 -65 83 -68 cell = 24 to 31  
54 8 88 1 47 15 38 -48 cell = 32 to 39  
13 -11 67 1 51 26 54 18 cell = 40 to 47  
38 -23 19 -25 77 -58 1 -10 cell = 48 to 55  
74 2 82 -4 63 76 -65 83 -68 cell = 56 to 63  
51 13 82 58 37 27 74 -71 cell = 64 to 71  
13 -24 53 -25 32 23 55 25 cell = 72 to 79  
88 -7 34 4 -36 -19 53 -18 cell = 80 to 87  
-5 28 48 37 27 1 64 21 -68 cell = 88 to 95  
81 36 29 16 62 5 77 -24 cell = 96 to 103  
32 1 73 -19 47 6 8 9 -22 cell = 104 to 111  
88 2 25 -15 45 18 35 -29 cell = 112 to 119  
-7 -27 88 -17 15 -31 38 12 cell = 120 to 127  
84 8 11 18 12 -25 14 -28 cell = 128 to 135  
11 17 8 36 58 21 61 14 -15 cell = 136 to 143  
81 7 67 21 68 18 85 -17 cell = 144 to 151  
18 8 21 3 54 -38 58 -39 cell = 152 to 159  
17 -31 38 -5 61 -24 21 -23 cell = 160 to 167  
84 8 11 18 12 -25 14 -28 cell = 168 to 175  
24 15 -12 3 62 -37 36 -17 cell = 176 to 183  
31 -9 48 -15 68 -9 88 -8 cell = 184 to 191  
84 8 11 -31 23 -47 61 -32 cell = 192 to 199  
13 -22 85 8 76 -24 88 -42 cell = 200 to 207  
18 37 67 -14 28 8 31 -13 cell = 208 to 215
```

```
st_ind =(uint16_t)(data->StartIndexCell);  
for (i=0;i<MAX_X742_CHANNEL_SIZE;i++) {  
    size1 = data->ChSize[i];  
    for (j=0;j<size1;j++) {  
        if (cellCorrection)  
            data->DataChannel[i][j] -= CTable->cell[i][((st_ind+j) % 1024)];  
        if (nsampleCorrection)  
            data->DataChannel[i][j] -= CTable->nsample[i][j];  
    }  
}
```



Fig. 8.5: Sampled waveform (left) and noise histogram (right) before cell index offset correction

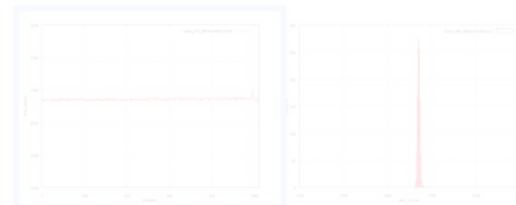


Fig. 8.6: Sampled waveform (left) and noise histogram (right) after cell index offset correction

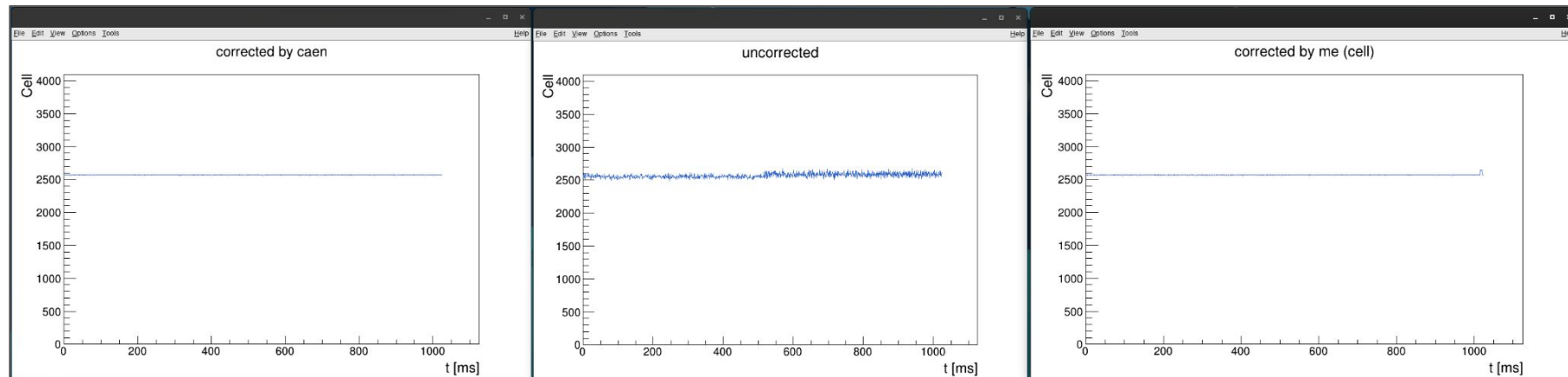
Solution?

1. Discover the start index cell by brute force
 - a. Test all the 1024 cell as being the start
 - b. Choose the one with the cell RMS.
2. Data tested:
 - a. MANGO fake data (because I had the corrected and uncorrected data available)

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2. Data tested:
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```
The RMS of the wf corrected by caen is :1.49449
The RMS of the wf uncorrected is :23.0888
Corrections opened: MANGO_X742Table_1GHz_gr0_cell.txt
Corrections opened: MANGO_X742Table_1GHz_gr0_nsample.txt
Corrections opened: MANGO_X742Table_1GHz_gr0_time.txt
The RMS of the wf corrected by me (only cell) is :1.40979
Start index cell found: 507 ...with an RMS of: 1.40979
```

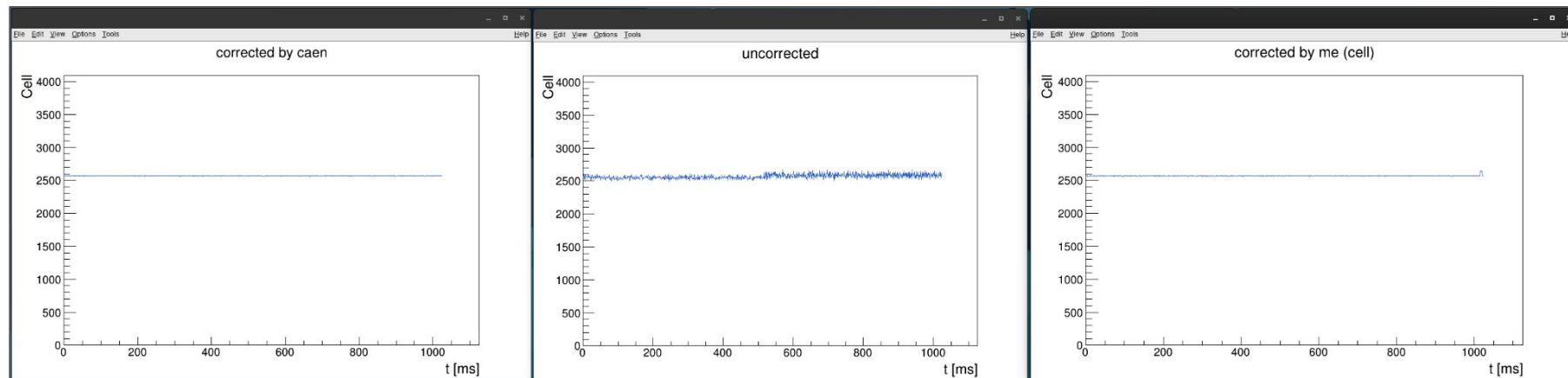
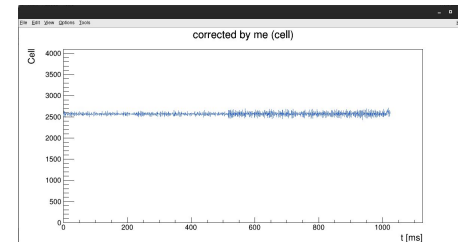


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Corrections opened: MANGO_X742Table_1GHz_gr0_time.txt
The RMS of the wf corrected by me (only cell) is :1.40979
Start index cell found: 507 ...with an RMS of: 1.40979
```

Example of waveform corrected with start index cell = 508, instead of 507 → **Clear difference**



Outcome:

1. Ok, it works.

Next step:

2. Let's apply this to LIME data.

Outcome:

1. Ok, it works.

Next step:

2. Let's apply this to LIME data.

```
File opened: test_histograms_Run04441.root
Corrections opened: MANGO_X742Table_750MHz_gr0_cell.txt
Corrections opened: MANGO_X742Table_1GHz_gr0_cell.txt
Corrections opened: MANGO_X742Table_2_5GHz_gr0_cell.txt
Corrections opened: MANGO_X742Table_5GHz_gr0_cell.txt
Channel: 0

*** RMS seems to big... Check please. ***

Start index cell found: 184 ...with an RMS of: 25.8476

*** RMS seems to big... Check please. ***

Start index cell found: 184 ...with an RMS of: 25.5263

*** RMS seems to big... Check please. ***

The RMS of the wf initial is :23.4892
```

Tested all the *frequencies*, “*channels*”, “*groups*”, and all the *capacitors*.

-> Always find higher RMS that the original one == corrections not working.

Outcome:

1. Ok, it works.

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```
File opened: test_histograms_Run04441.root
Corrections opened: MANGO_X742Table_750MHz_gr0_cell.txt
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Corrections opened: MANGO_X742Table_5GHz_gr0_cell.txt
Channel: 0

*** RMS seems to big... Check please. ***

Start index cell found: 184 ...with an RMS of: 25.8476

*** RMS seems to big... Check please. ***

Start index cell found: 184 ...with an RMS of: 25.5263

*** RMS seems to big... Check please. ***

The RMS of the wf initial is :23.4892
```

Tested all the *frequencies*, “channels”, “groups”, and all the *capacitors*.

→ Always find higher RMS that the original one == corrections not working.

What could be the issue?

1. Maybe digitizers were **swapped** (LNGS <-> Frascati)
 - a. So I don't have the **correct** correction tables
 - b. It's not so easy to get them now because they are performing software upgrades and not all the libraries are properly working.
2. But now all the digitizers are working properly, why not during last summer?
 - a. Maybe there was some miss-calibration.
 - b. It could mean the data might never be correctable...

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```
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Corrections opened: MANGO_X742Table_750MHz_gr0_cell.txt
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Corrections opened: MANGO_X742Table_2_5GHz_gr0_cell.txt
Corrections opened: MANGO_X742Table_5GHz_gr0_cell.txt
Channel: 0

*** RMS seems to big... Check please. ***

Start index cell found: 184 ...with an RMS of: 25.8476

*** RMS seems to big... Check please. ***

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*** RMS seems to big... Check please. ***

The RMS of the wf initial is :23.4892
```

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2. But now all the digitizers are working properly, why not during last summer?
 - a. Maybe there was some miss-calibration.
 - b. It could mean the data might never be correctable...

What now?

→ Carry on the analysis nonetheless. Maybe it's better to prepare the analysis for when better data arrives.

→ If the data seems to much broken, try to manually fix it:

◆ With a man-made correction table (?)

◆ Bringing back the initial study with the moving average (?)