

# CBPM resolution measurement

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CBPM meeting  
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Machine study:  
signal-to-noise ratio

# Toy MC Recap'

Using the measured noise for each of the 12 buttons and toy MC simulations, the vertical resolution of the three CBPMs scales with the signal amplitude as:

|      | 8,192 ADU | 16,384 ADU | 32,768 ADU |
|------|-----------|------------|------------|
| 12W2 | 10.88     | 5.43       | 2.72       |
| 12W3 | 11.02     | 5.51       | 2.75       |
| 12W  | 10.90     | 5.47       | 2.73       |

resolution unit =  $\mu\text{m}$

The resolution is expected to improve with higher signal-to-noise ratio

# Machine study

Machine study on November 13, 2019: [instrumentation elog 1835](#)

Collected triplet CBPM peak-data for different beam intensities:

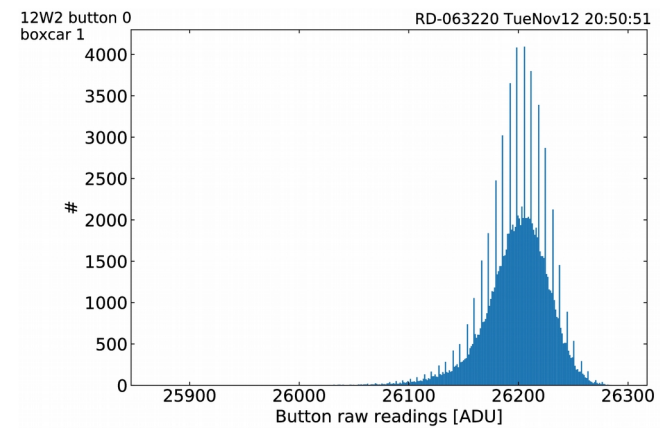
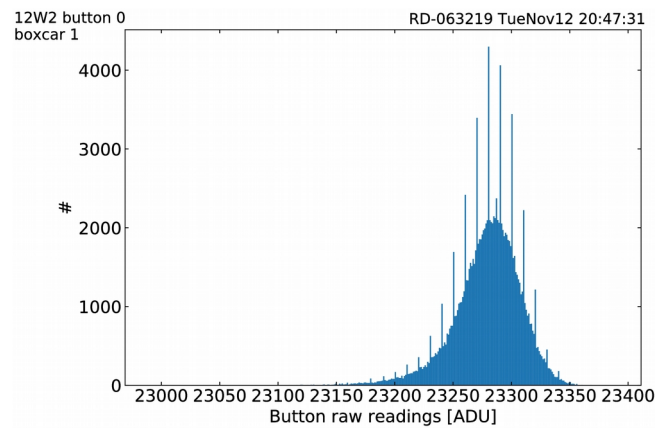
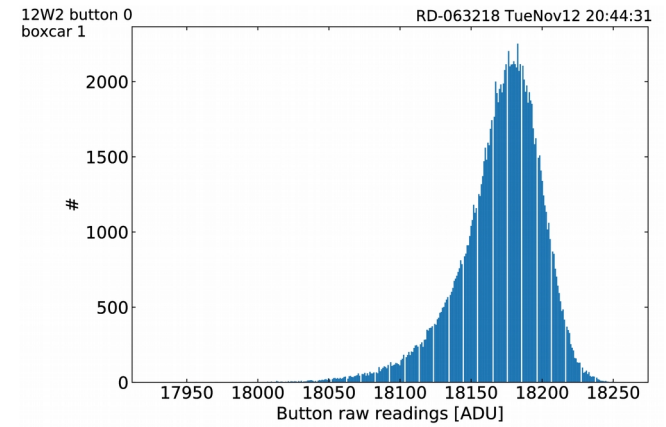
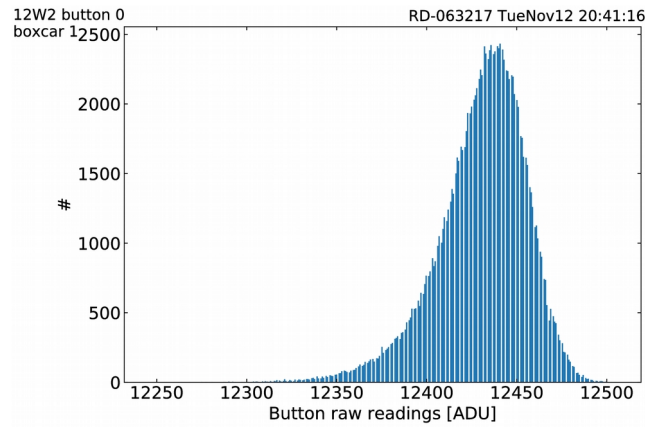
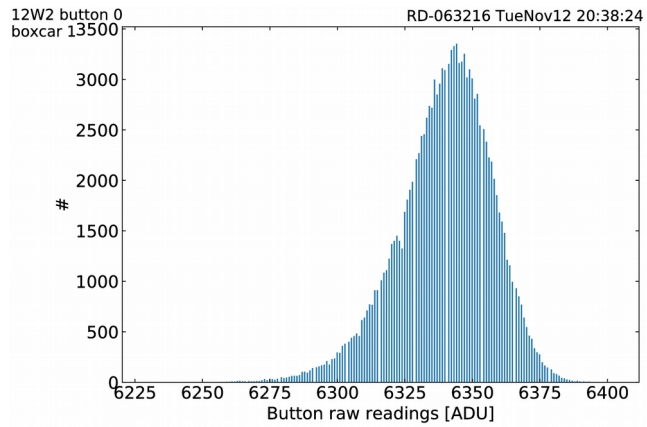
```
1.1-- Time align the triplet CBPMs (12W2, 12W3 and 12W) with 0.75 mA
1.2-- Collect 131,072 turns with the 60 Hz sync trigger for 0.75 mA
data file: RD-063215.dat

2-- Dump the beam and march up-ward intensity-wise to collect CBPMs data with different signal amplitudes

2.1-- collect 131,072 turns with the 60 Hz sync trigger for 0.2? mA
data file: RD-063216.dat
2.2-- collect 131,072 turns with the 60 Hz sync trigger for 0.4? mA
data file: RD-063217.dat
2.3-- collect 131,072 turns with the 60 Hz sync trigger for 0.62 mA
data file: RD-063218.dat
2.4-- collect 131,072 turns with the 60 Hz sync trigger for 0.81 mA
data file: RD-063219.dat
2.5-- collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-063220.dat
```

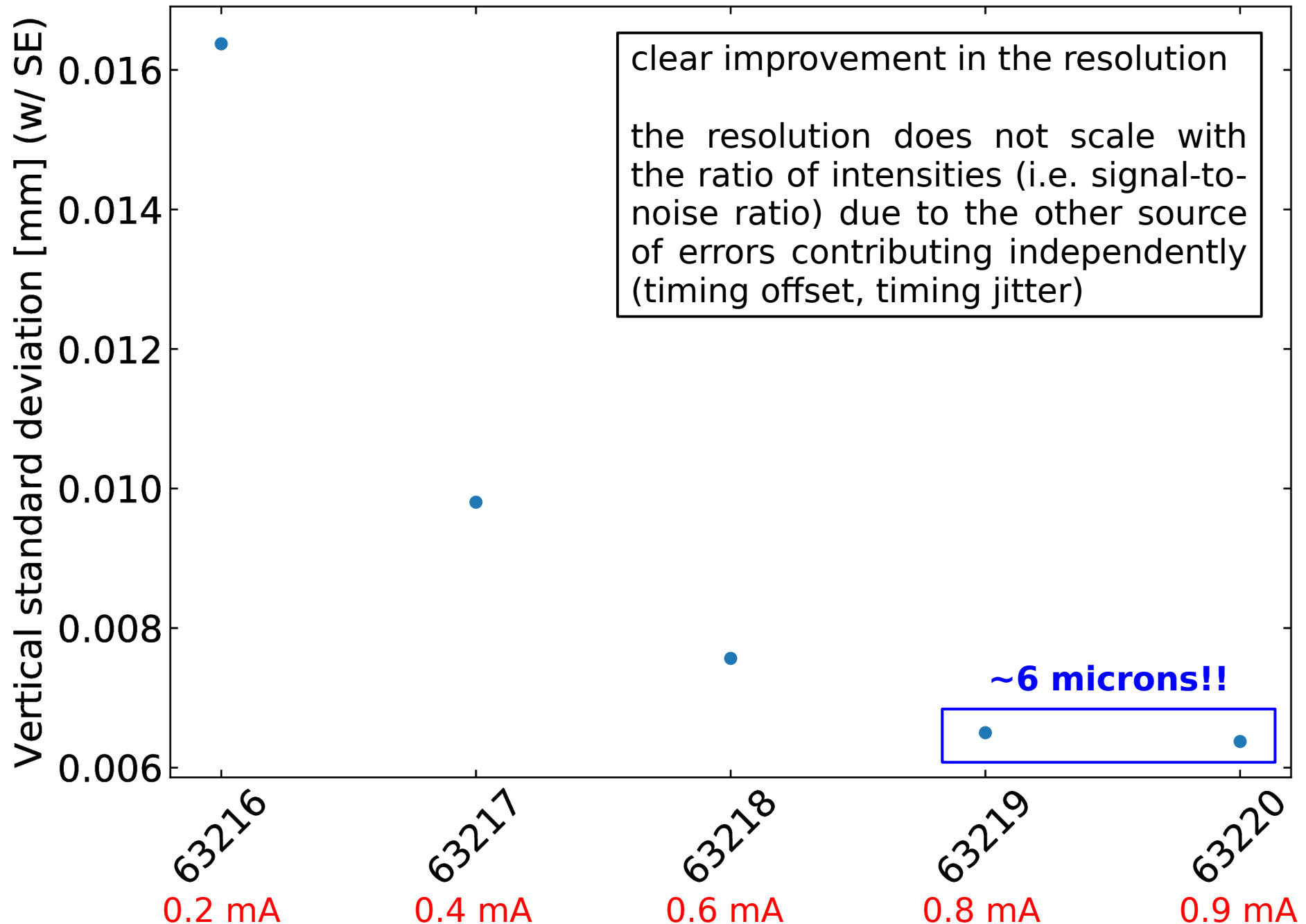
Let's look at the CBPM individual vertical resolutions (small/negligible beam motion folded in) and the triplet resolution

# Raw readings, 12W2 button 0



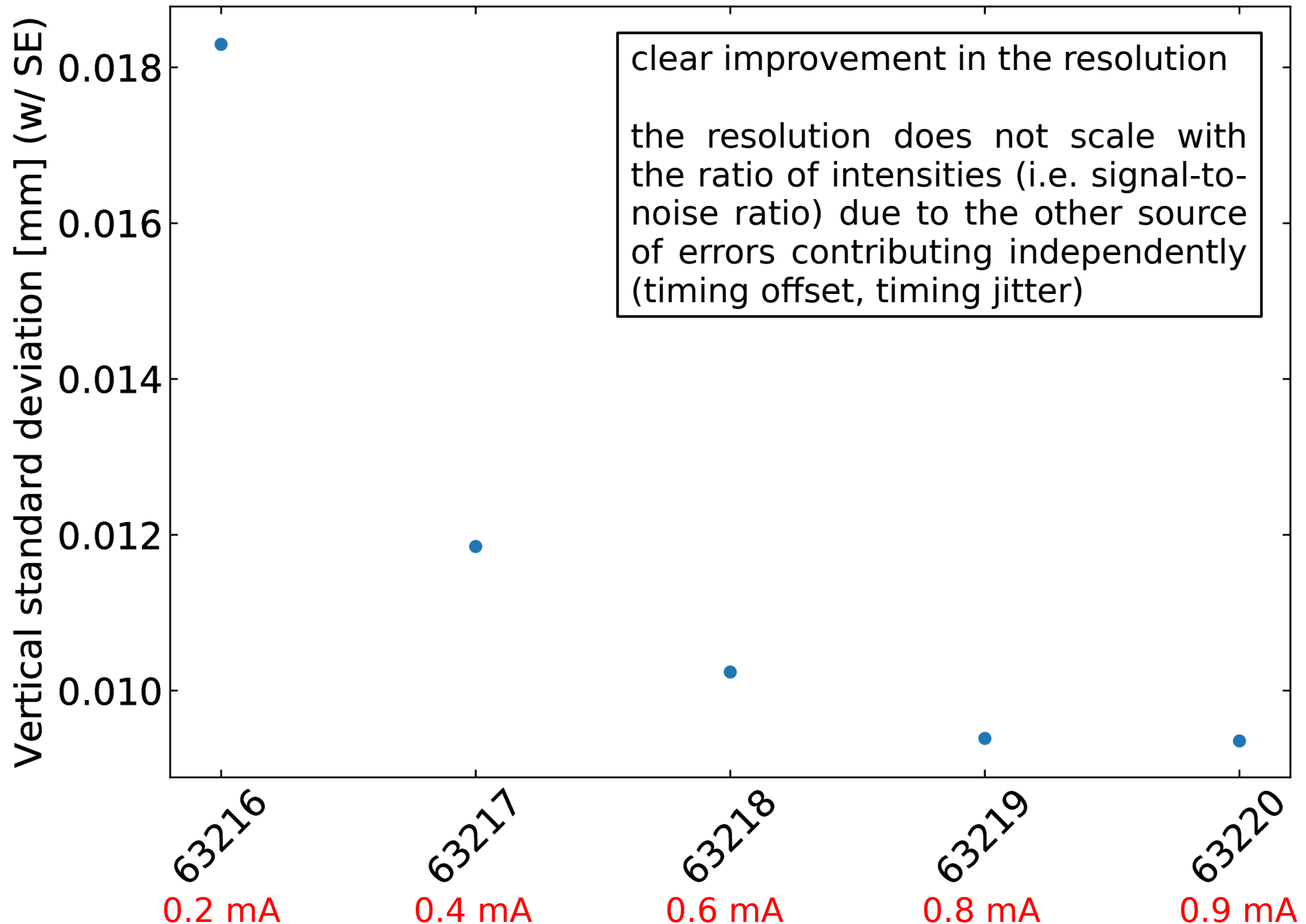
# 12W2 vertical centroid standard deviation ( $\cong$ resolution)

12W2



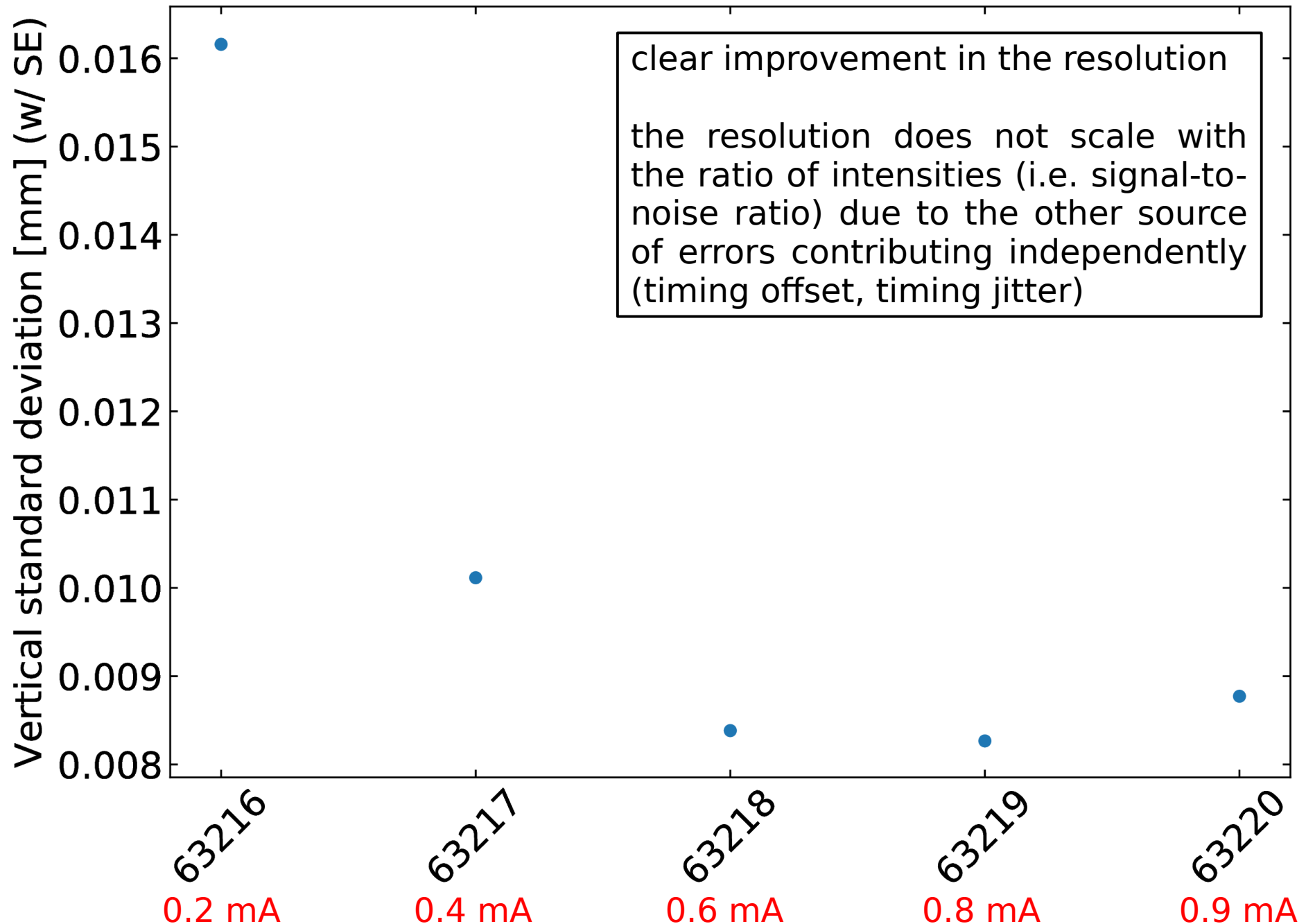
# 12W3 vertical centroid standard deviation ( $\cong$ resolution)

12W3



# 12W vertical centroid standard deviation ( $\cong$ resolution)

12W





# Summary table

'Combined' is the combined resolution of the three individual resolutions

'Triplet' is the resolution from performing the triplet resolution measurement

|              |     | Resolution [micron] |       |       |          |         |
|--------------|-----|---------------------|-------|-------|----------|---------|
|              |     | 12W2                | 12W3  | 12W   | Combined | Triplet |
| Current [mA] | 0.2 | 16.37               | 18.3  | 16.16 | 16.97    | 17.5    |
|              | 0.4 | 9.8                 | 11.85 | 10.12 | 10.63    | 11.05   |
|              | 0.6 | 7.57                | 10.24 | 8.38  | 8.8      | 9.54    |
|              | 0.8 | 6.5                 | 9.39  | 8.27  | 8.14     | 8.85    |
|              | 0.9 | 6.38                | 9.36  | 8.77  | 8.27     | 8.89    |

'Triplet'  $\neq$  'Combined'. From toy MC simulations, 'Triplet' and 'Combined' are:

x same if the three CBPMs have same resolutions

x different if the three CBPMs have different resolution

} new finding

Culprit: triplet fit assuming same uncertainty for the three data points? Constrain uncertainties using the measured individual ones?

Machine study timing study

# Machine study

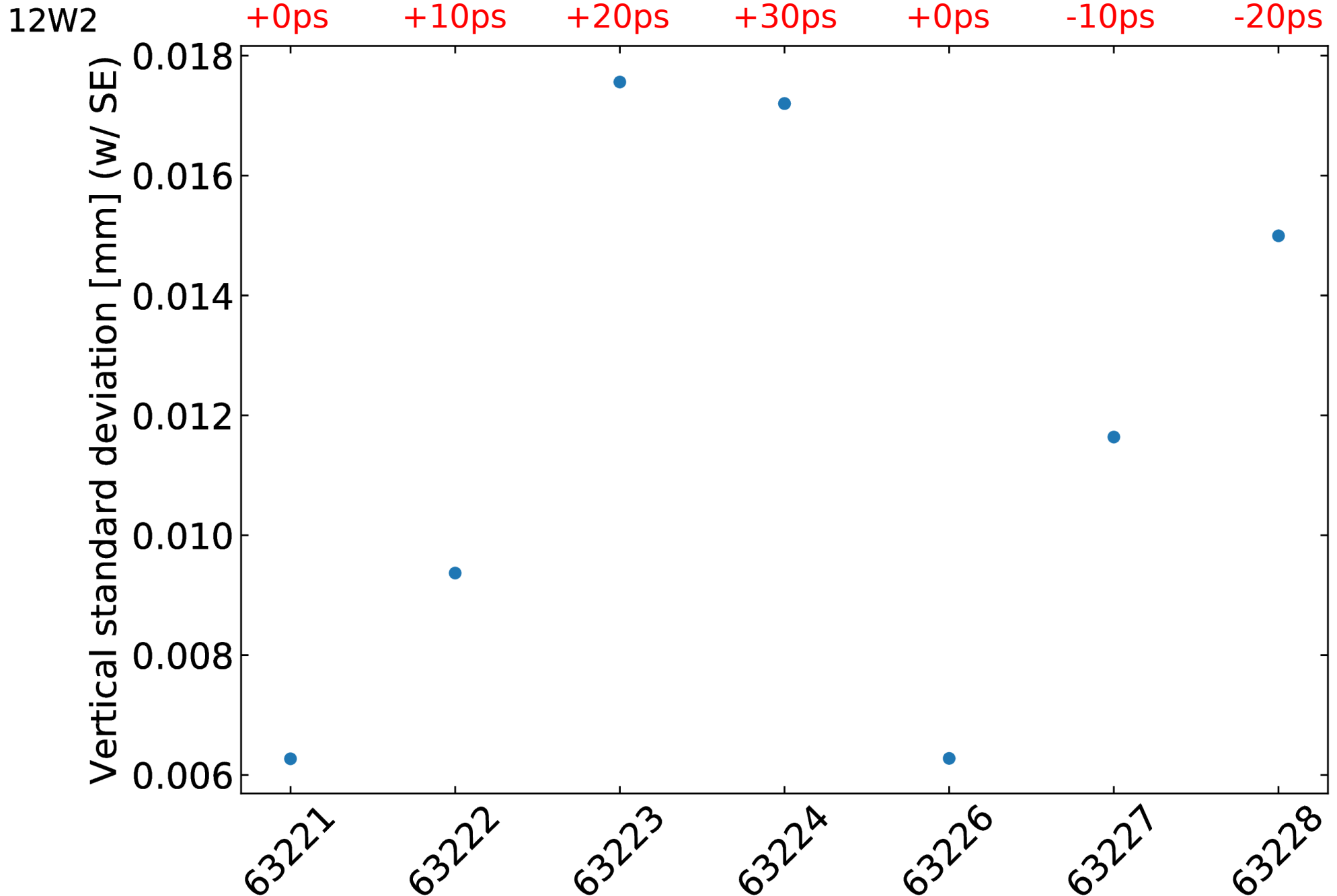
Machine study on November 13, 2019: [instrumentation elog 1835](#)

Collected triplet CBPM peak-data for different timing offset:

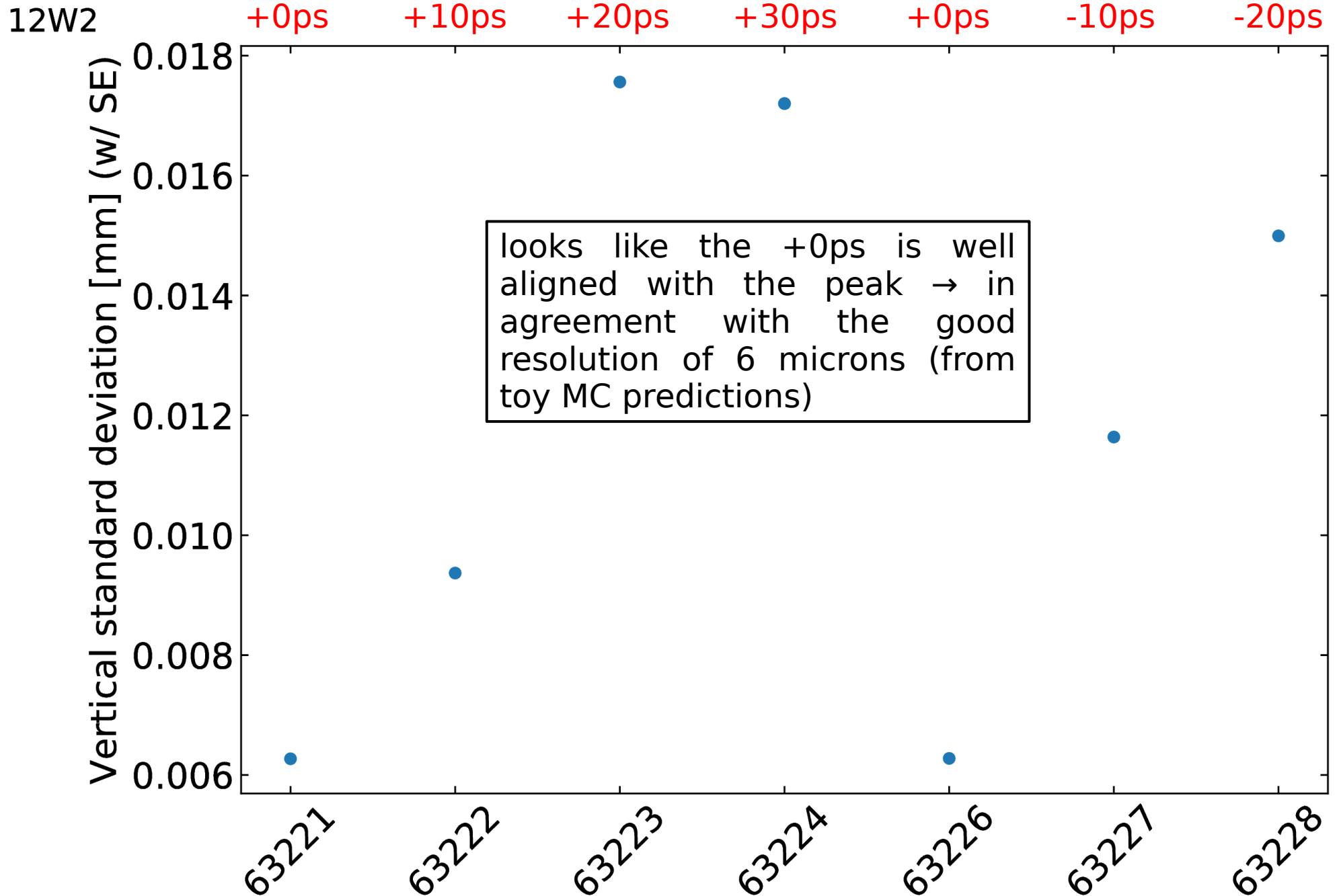
```
3-- Changing the timing offset of all the 12 buttons
3.1-- no change, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06321.dat
3.2-- +10ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06322.dat
3.3-- +20ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06323.dat
3.4-- +30ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06324.dat
3.5-- +40ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06325.dat
3.6-- back to no change, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06326.dat
3.7-- -10ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06327.dat
3.8-- -20ps, collect 131,072 turns with the 60 Hz sync trigger for 0.92 mA
data file: RD-06328.dat
```

Let's look at the CBPM individual vertical resolutions (small/negligible beam motion folded in) and the triplet resolution

# 12W2 vertical centroid standard deviation ( $\cong$ resolution)



# 12W2 vertical centroid standard deviation ( $\cong$ resolution)



# 12W3 vertical centroid standard deviation ( $\cong$ resolution)

12W3

+0ps

+10ps

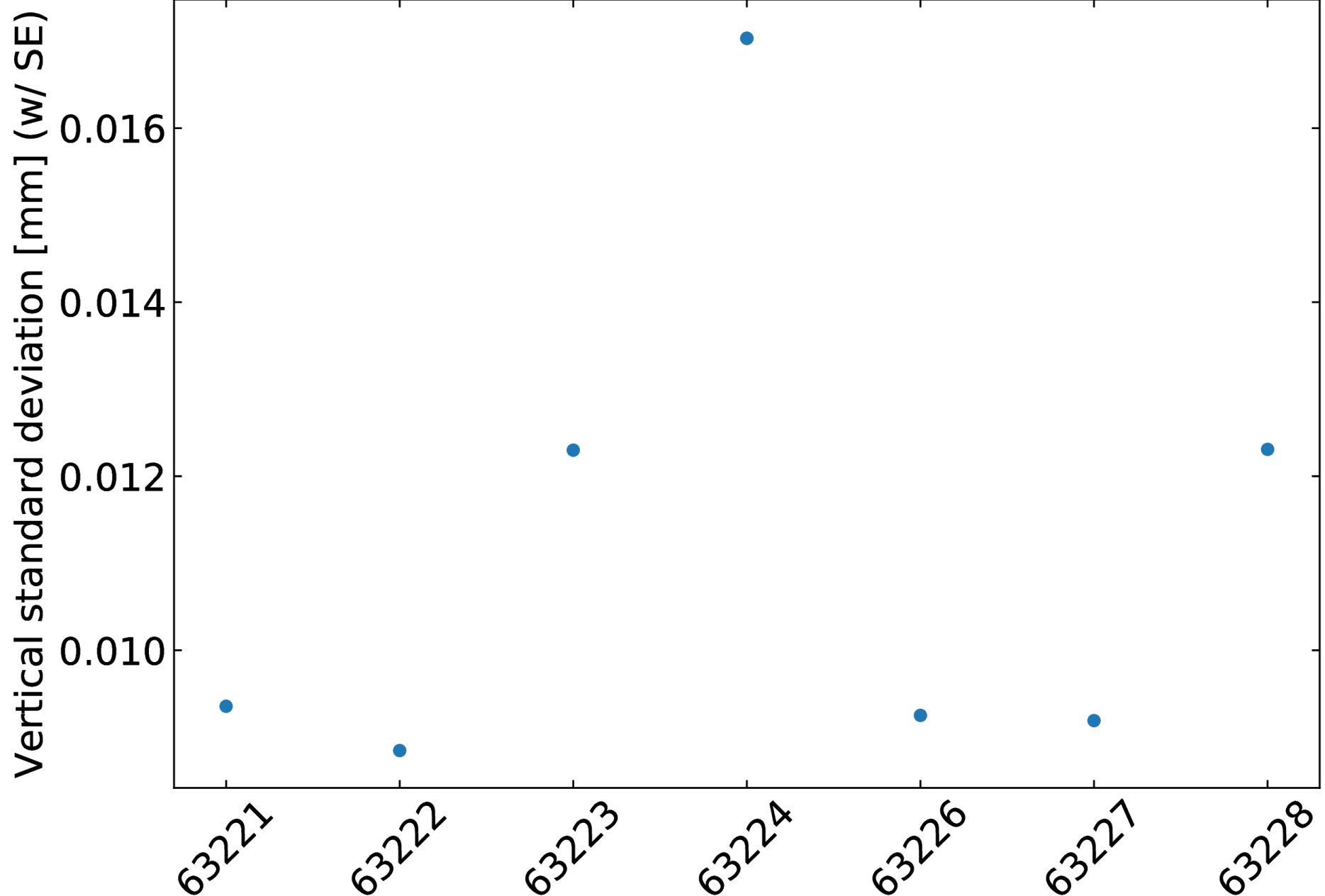
+20ps

+30ps

+0ps

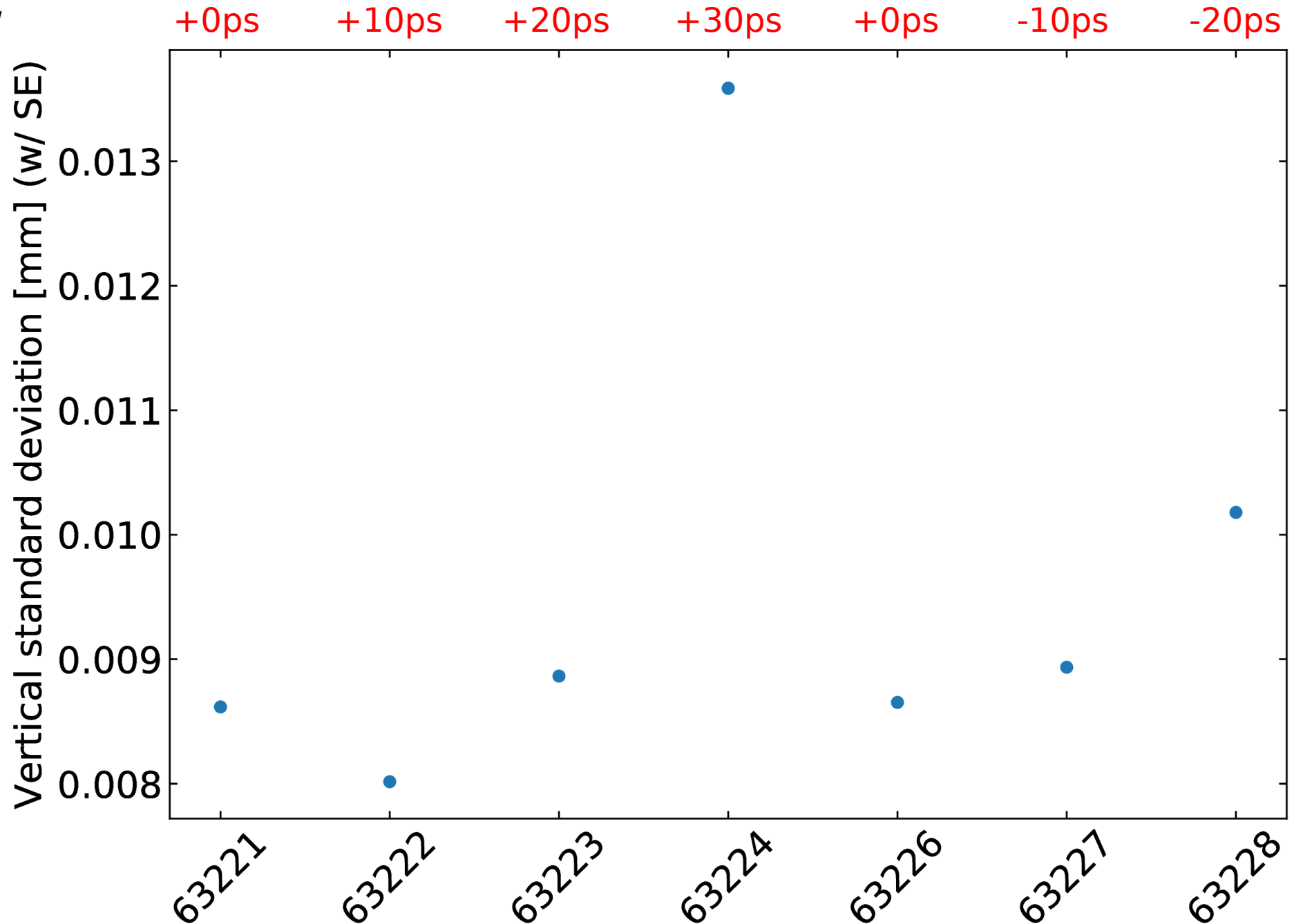
-10ps

-20ps



# 12W vertical centroid standard deviation ( $\cong$ resolution)

12W



1 micron single-shot resolution?



# 1 micron single-shot resolution?

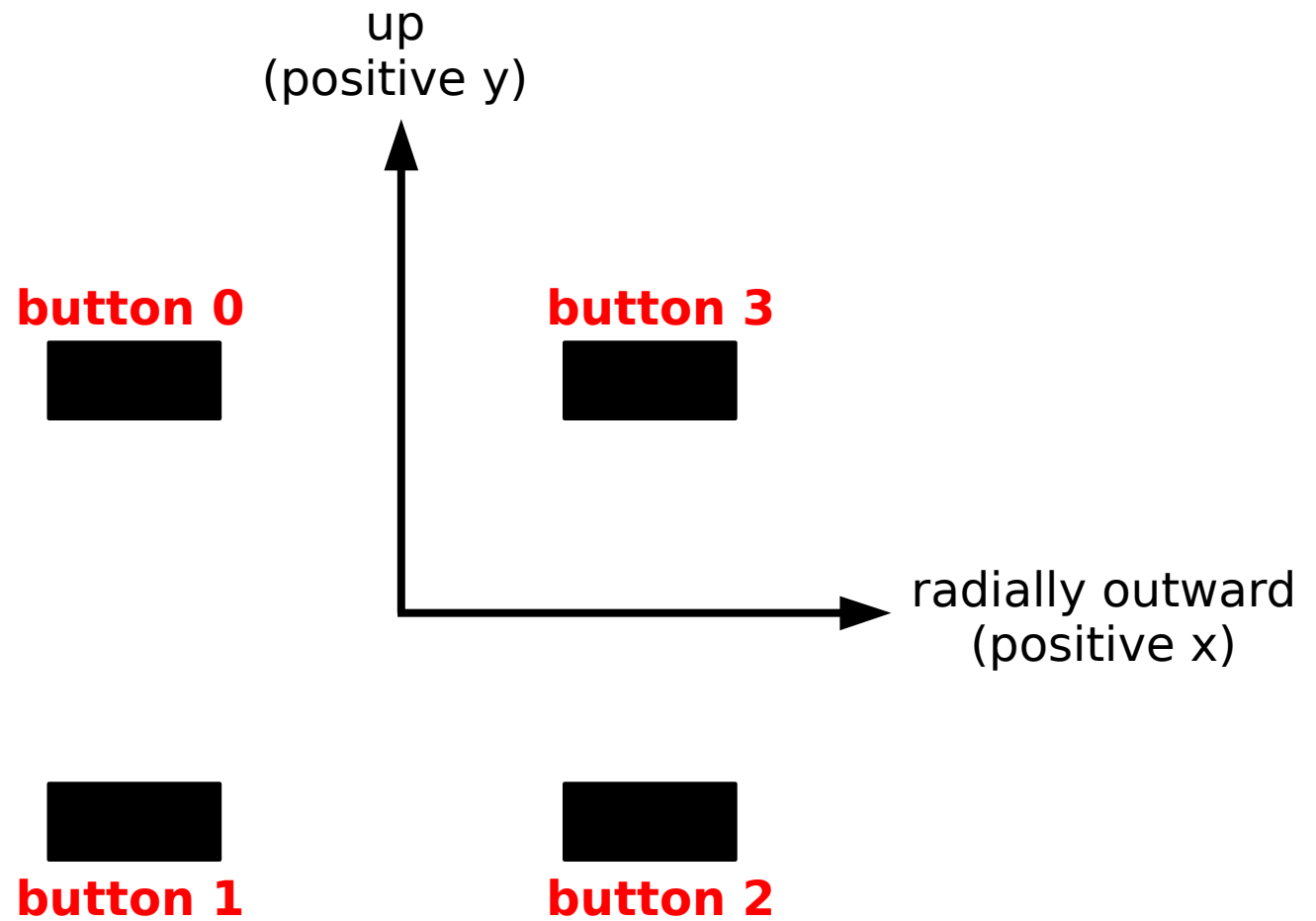
It does not seem realistic:

| Design  |           | Noise [ADU] | ed amplitude | Un-correlated timing jitter [ps] |              |              |           | Timing offset [ps] |              |              |           | Vertical precision [micron] | Vertical accuracy [micron] |
|---------|-----------|-------------|--------------|----------------------------------|--------------|--------------|-----------|--------------------|--------------|--------------|-----------|-----------------------------|----------------------------|
|         |           |             |              | inner top                        | inner bottom | outer bottom | outer top | inner top          | inner bottom | outer bottom | outer top |                             |                            |
| Current | Ideal     | 9           | 32,768       | 10                               | 10           | 10           | 10        | 0                  | 0            | 0            | 0         | 8.5                         | 0                          |
|         | Best      | 9           | 24,576       | 10                               | 10           | 10           | 10        | 0                  | 0            | 0            | 0         | 8.9                         | 0                          |
|         | Realistic | 9           | 16,384       | 10                               | 10           | 10           | 10        | 10                 | 0            | 0            | 10        | 12.7                        | 5.7                        |
|         | Realistic | 9           | 16,384       | 10                               | 10           | 10           | 10        | 10                 | 10           | 10           | 10        | 15                          | 0                          |
|         | Realistic | 9           | 8,192        | 10                               | 10           | 10           | 10        | 10                 | 10           | 10           | 10        | 17.6                        | 0                          |
| Future  | 1         | 9           | 32,768       | 1                                | 1            | 1            | 1         | 1                  | 1            | 1            | 1         | 2.7                         | 0                          |
|         | 2         | 5           | 32,768       | 1                                | 1            | 1            | 1         | 1                  | 1            | 1            | 1         | 1.5                         | 0                          |
|         | <b>3</b>  | <b>5</b>    | <b>65536</b> | <b>1</b>                         | <b>1</b>     | <b>1</b>     | <b>1</b>  | <b>1</b>           | <b>1</b>     | <b>1</b>     | <b>1</b>  | <b>0.8</b>                  | <b>0</b>                   |
|         | 4         | 9           | 32,768       | 5                                | 5            | 5            | 5         | 5                  | 5            | 5            | 5         | 4.4                         | 0                          |
|         | 5         | 9           | 32,768       | 5                                | 5            | 5            | 5         | 1                  | 1            | 1            | 1         | 3.4                         | 0                          |
|         | 6         | 9           | 32,768       | 10                               | 10           | 10           | 10        | 1                  | 1            | 1            | 1         | 8.6                         | 0                          |

Averaging turns might be the only way to get a chance to reach 1 micron precision. Still working on Data and Toy MC to understand the averaging. So far, not so clear as to how/why it might (or not) work.

Additional materials

# CBPM convention



# Horizontal and vertical centroids

$$y = k_y \frac{(b_0 + b_3) - (b_1 + b_2)}{b_0 + b_3 + b_1 + b_2}, \quad k_y = 19.8 \text{ mm}$$

$$x = k_x \frac{(b_2 + b_3) - (b_0 + b_1)}{b_2 + b_3 + b_0 + b_1}, \quad k_x = 25.9 \text{ mm}$$