CBPM sampling clock jitter

Antoine

CESR instrumentation meeting – Nov 8th, 2024

CBPM zero-crossing

Collected peak and zero-crossing TBT data. See instr. elog 2374.

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Author:	Antoine T Chapelain
Subject:	Zero-crossing data collection
Category:	
Instrument:	CESR BPM
Sub-System:	CBPM_II
Shift Key:	20240105_1900

Good data for 11W to 48W:

- peak TBT: 474709/474710
- zero-crossing (+41 units) TBT: 474711/474712

South Arc BPMs in West server did not cooperate at all and we even bricked X4B. Zero-crossing is a risky business.

CBPM zero-crossing

Zero-crossing data allows to measure the sampling clock jitter:

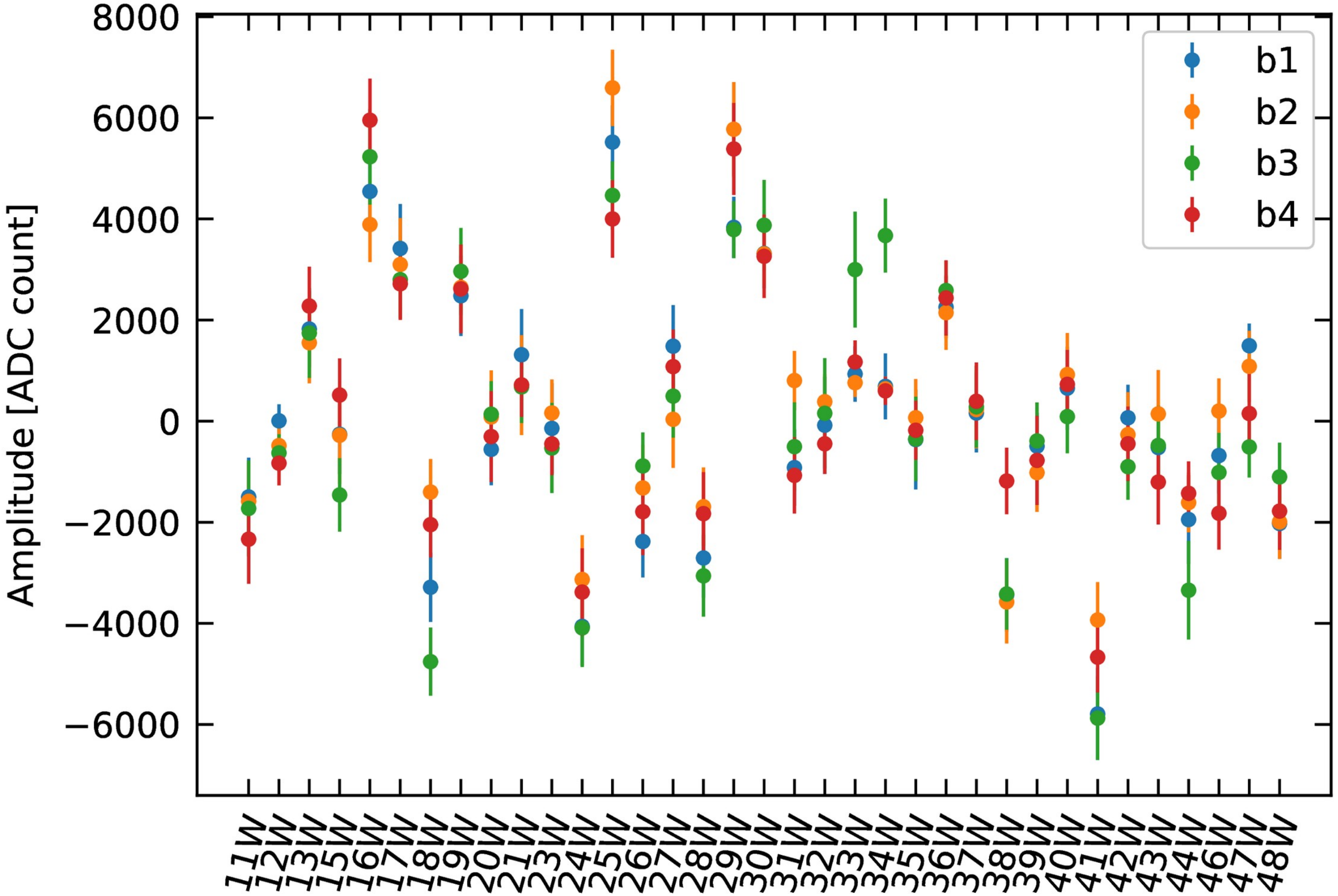
M.G. Billing et al 2017 JINST 12 T09005

signal shown in Fig. 4. At the zero-crossing, the relative amplitude error scales proportionally with the timing jitter δt:

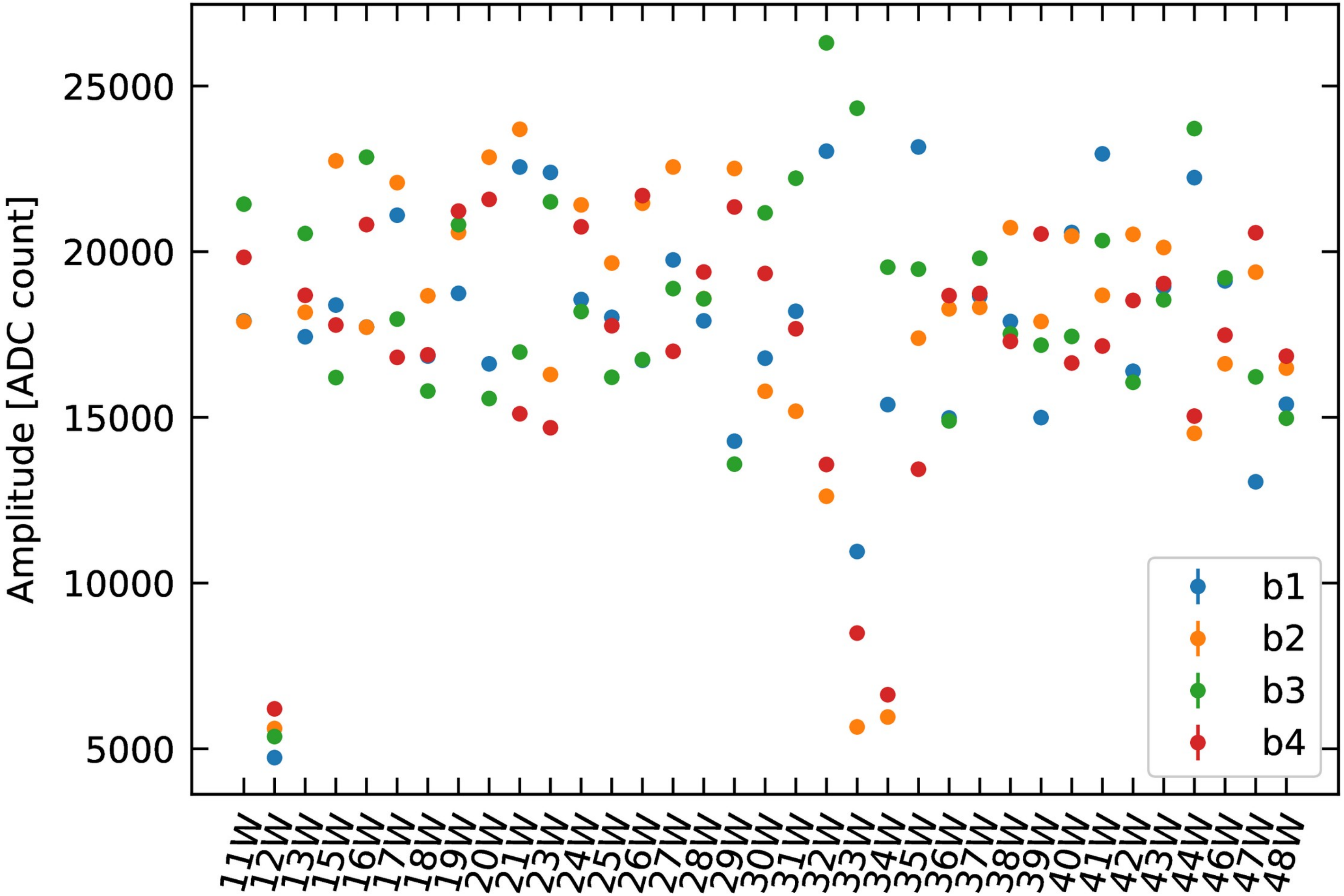
$$\begin{aligned}
\delta b_{n,\,\mathrm{timing}}(t) &\cong \frac{\partial b_n}{\partial t}(t)\delta t \\
&= -2\pi f \hat{b}_n \sin\{2\pi f(t + \Delta t_n)\}\delta t \\
&\cong -2\pi f \hat{b}_n \delta t
\end{aligned} \tag{2.10}$$

where the waveform is taken to be zero at the location of the greatest slope (i.e., no DC offset).

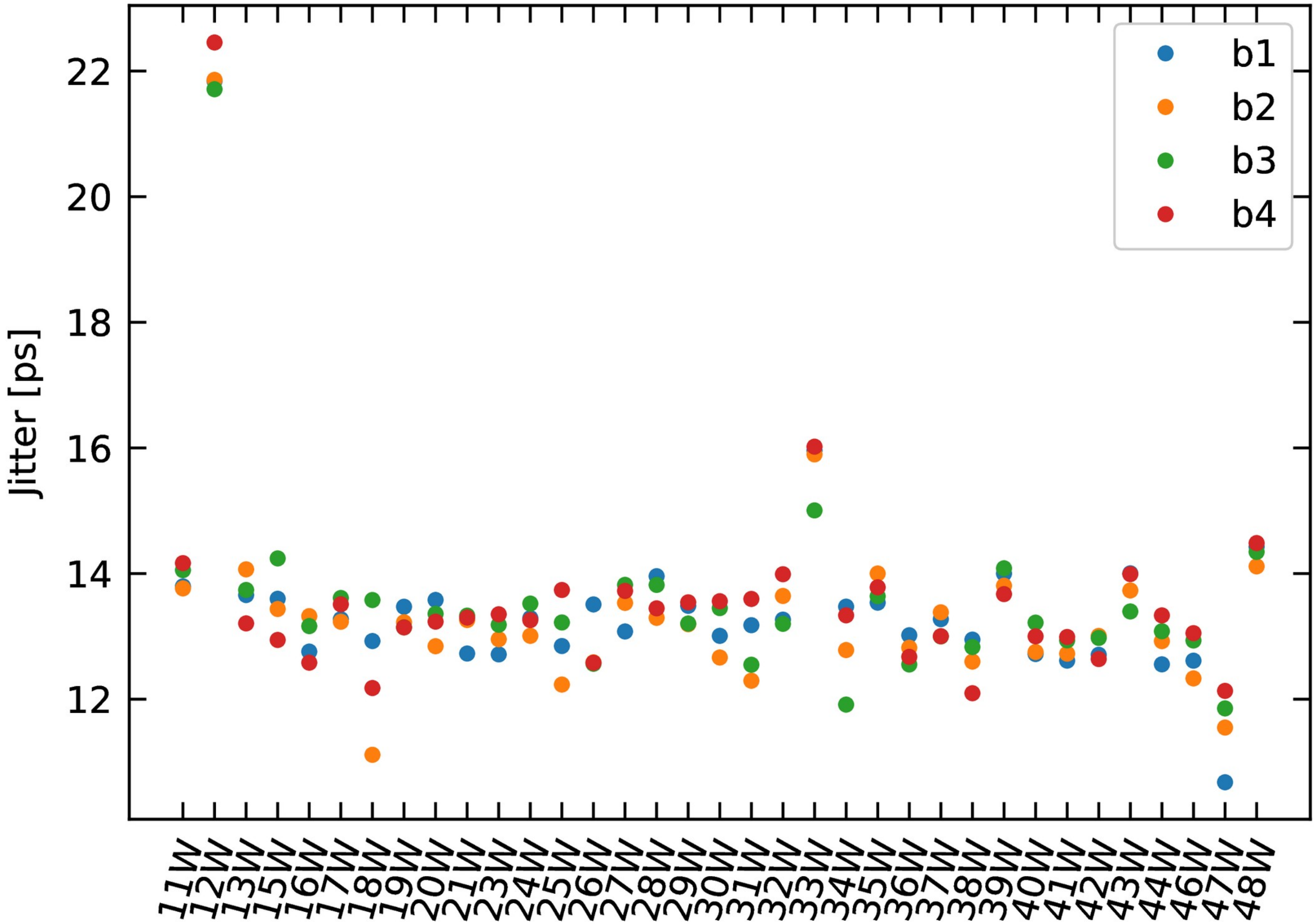
Amplitude ± SD at zero-crossing



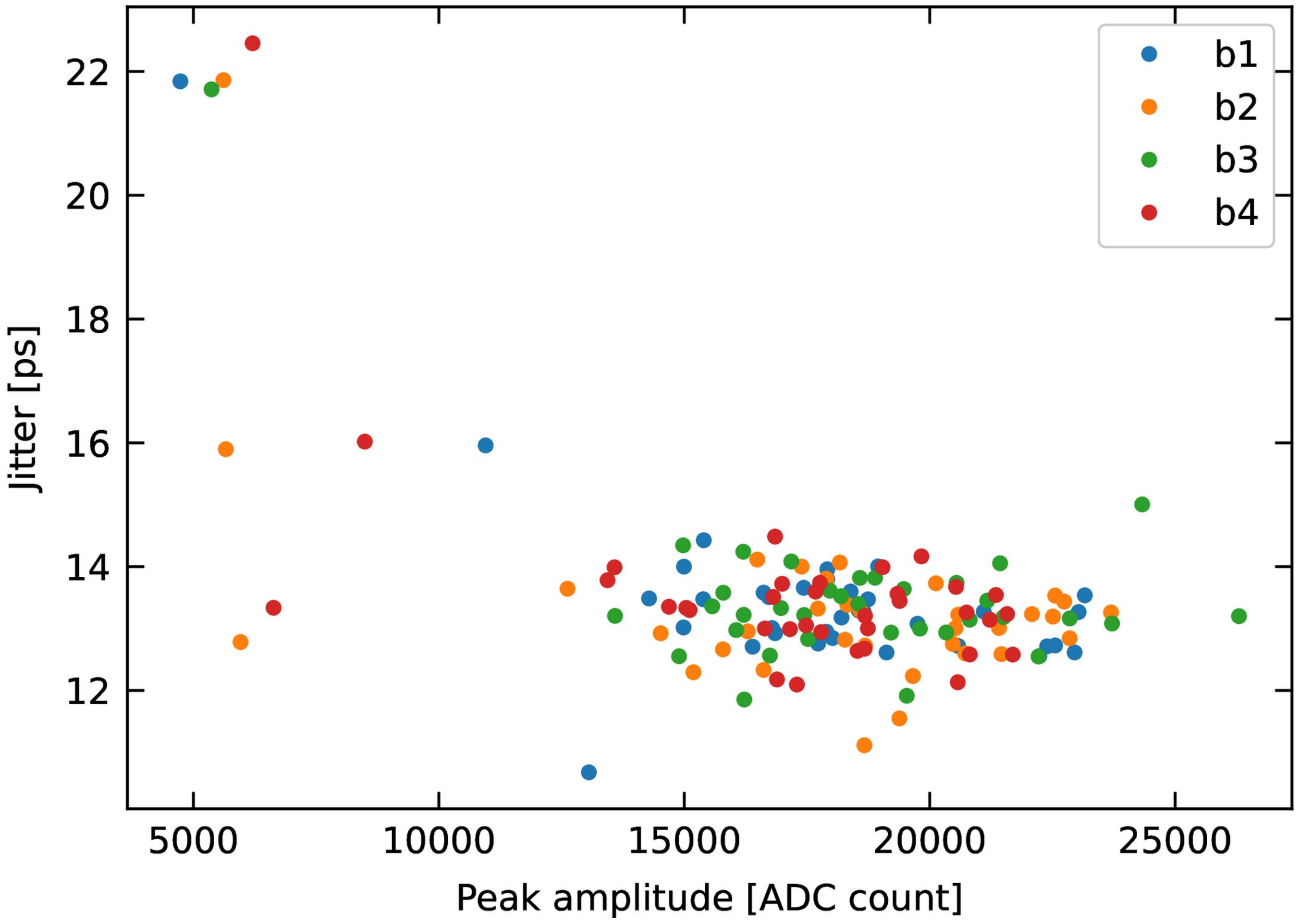
Amplitude ± SD at peak



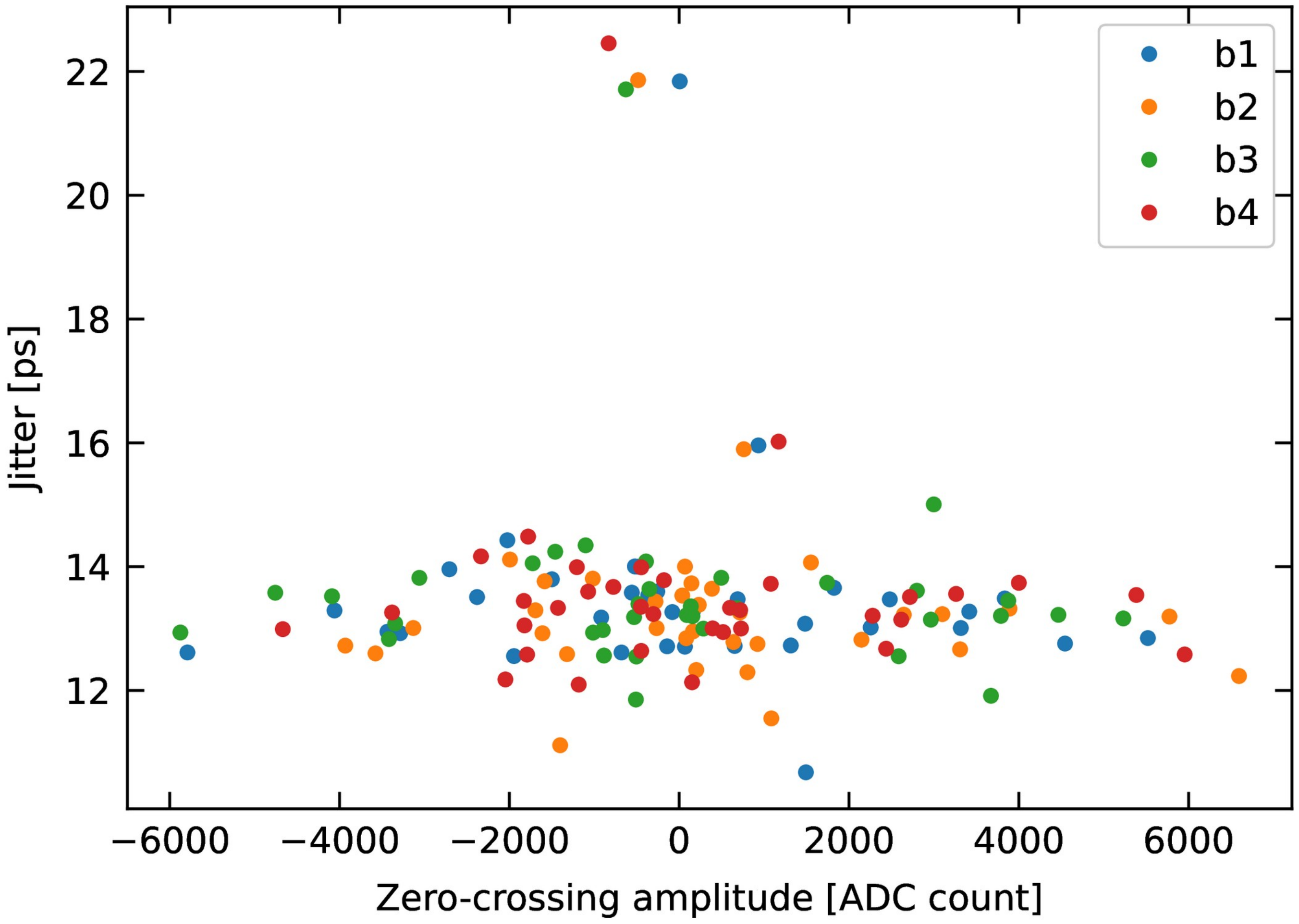
Sampling clock jitter



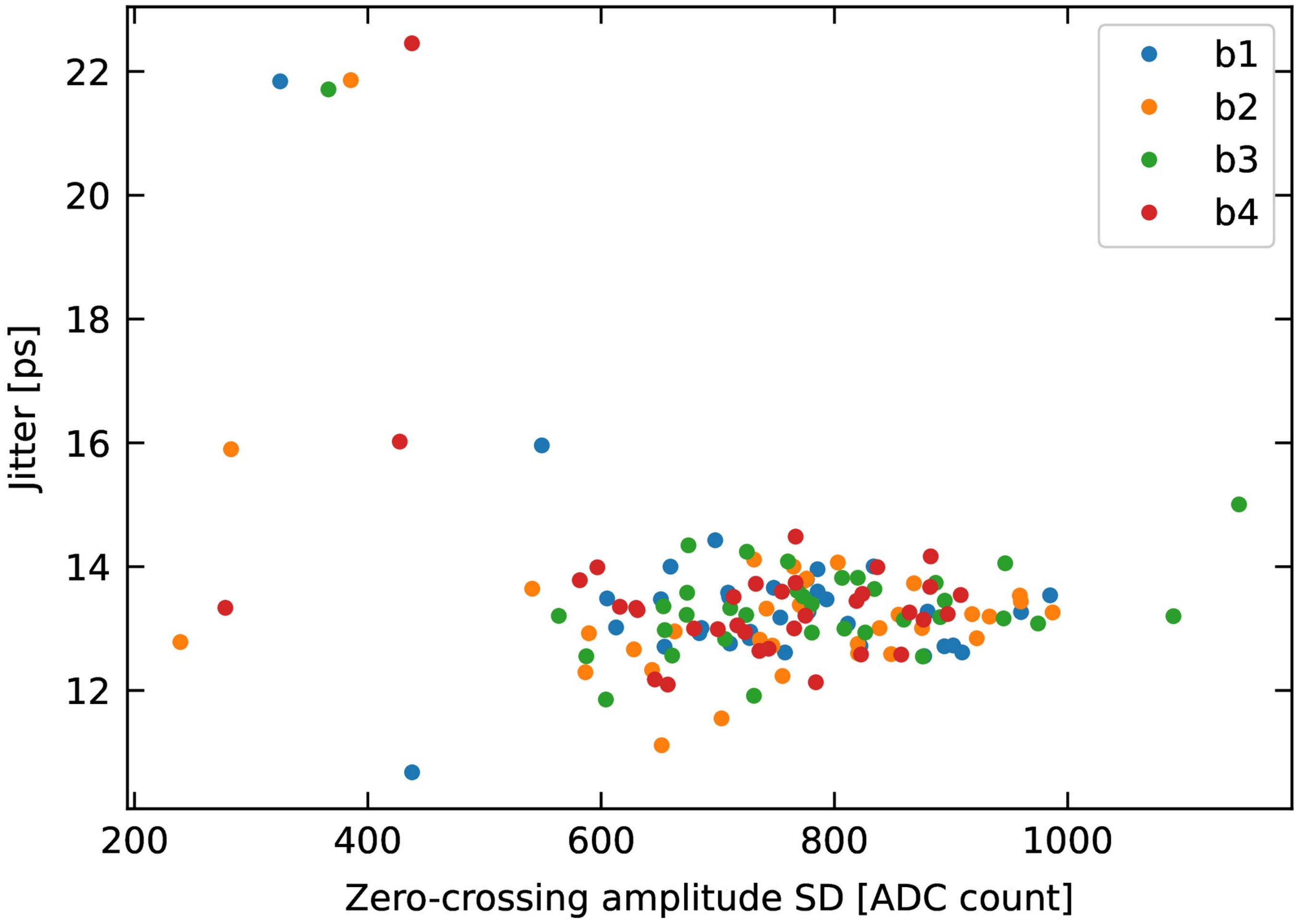
Jitter v. peak amplitude



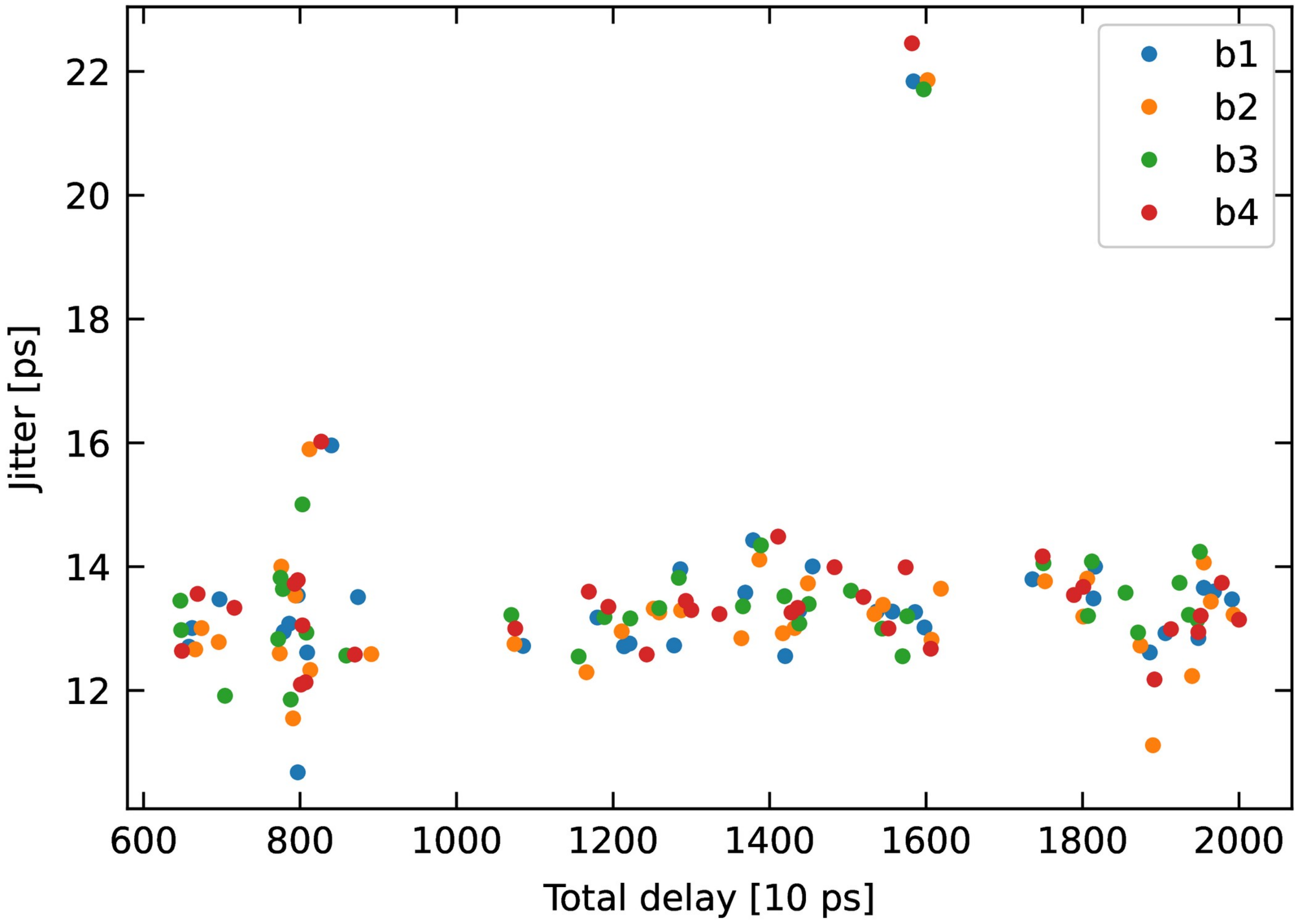
Jitter v. zero-crossing amplitude



Jitter v. zero-crossing SD

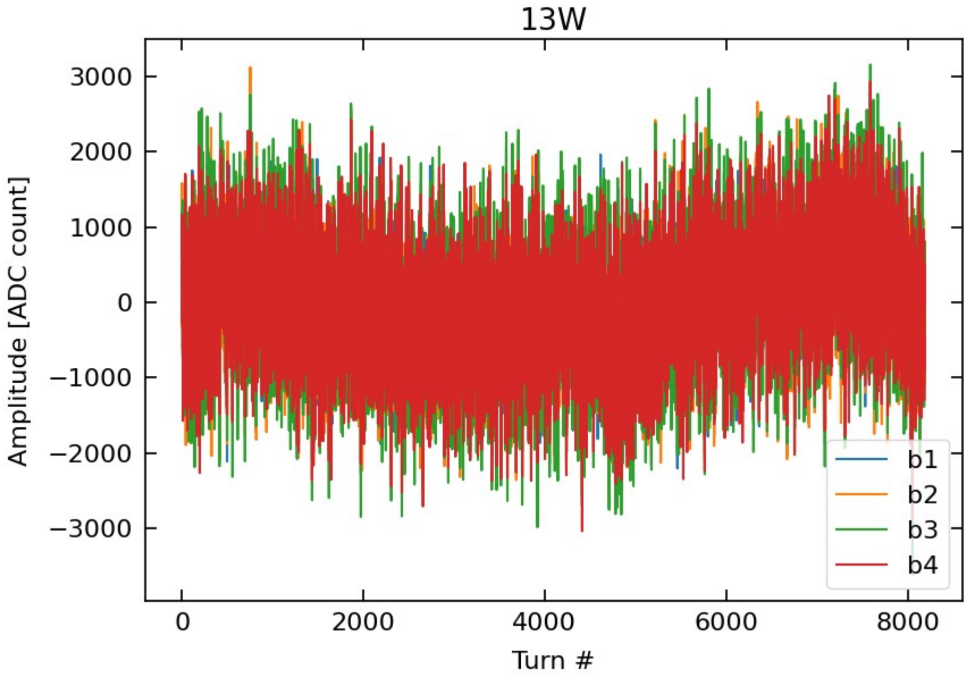


Jitter v. total delay

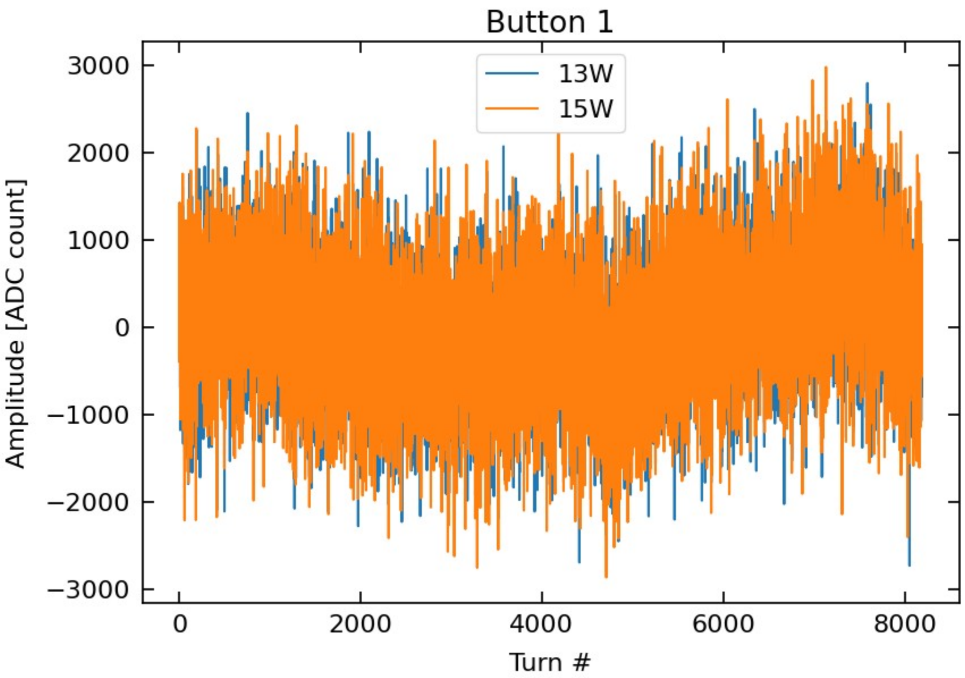


Looking for “jitter” correlation

Look at zero-crossing time series to extract intra- and inter-module correlations. Each time series is average subtracted for easy comparison. Two examples:



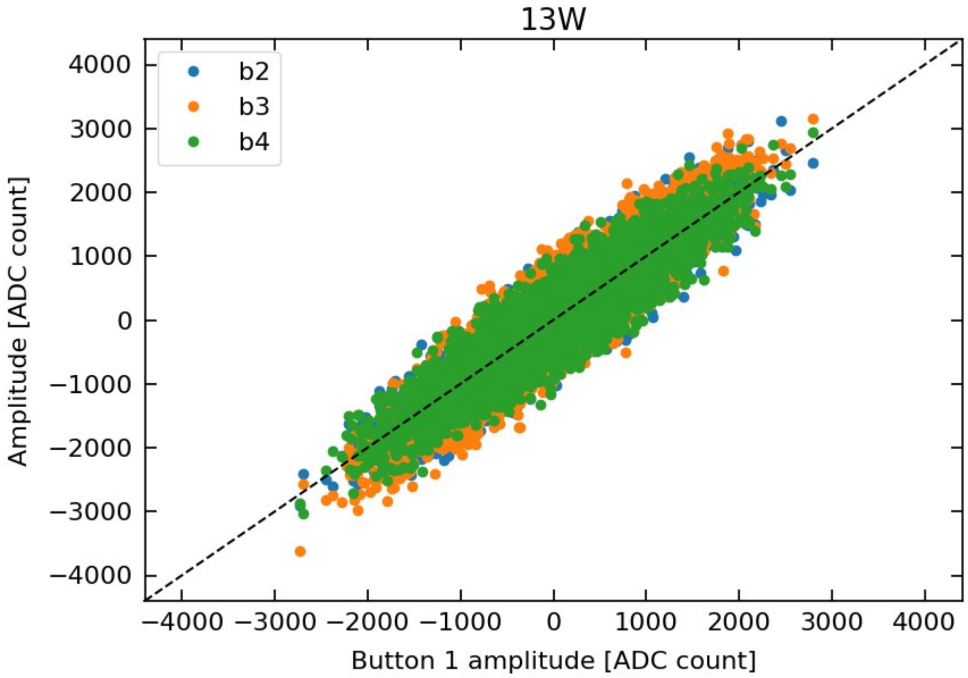
intra-correlation
(channel-to-channel)

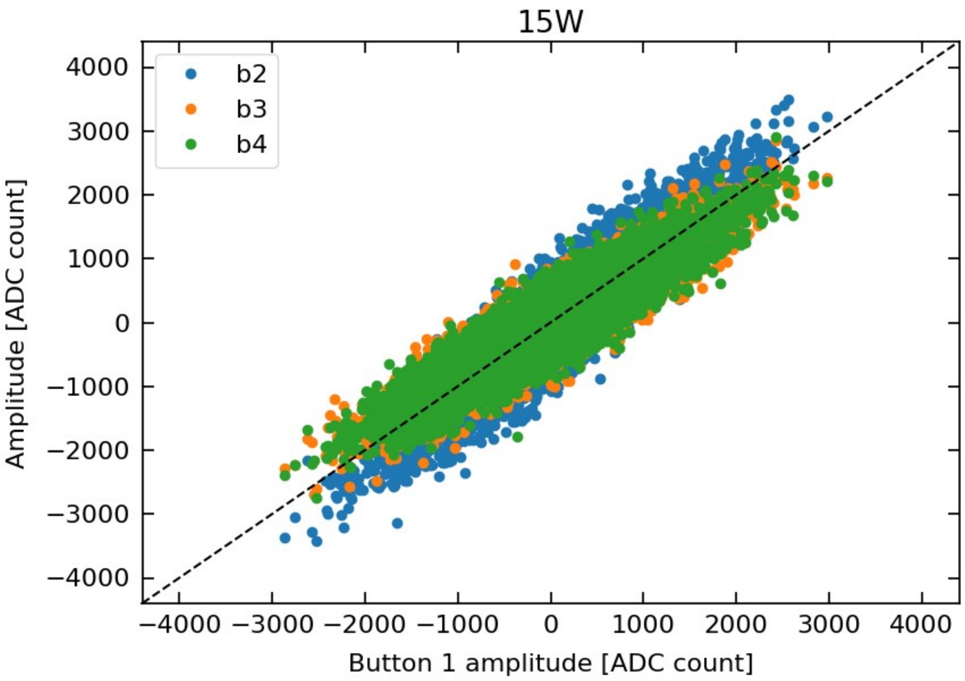


inter-correlation
(module-to-module)

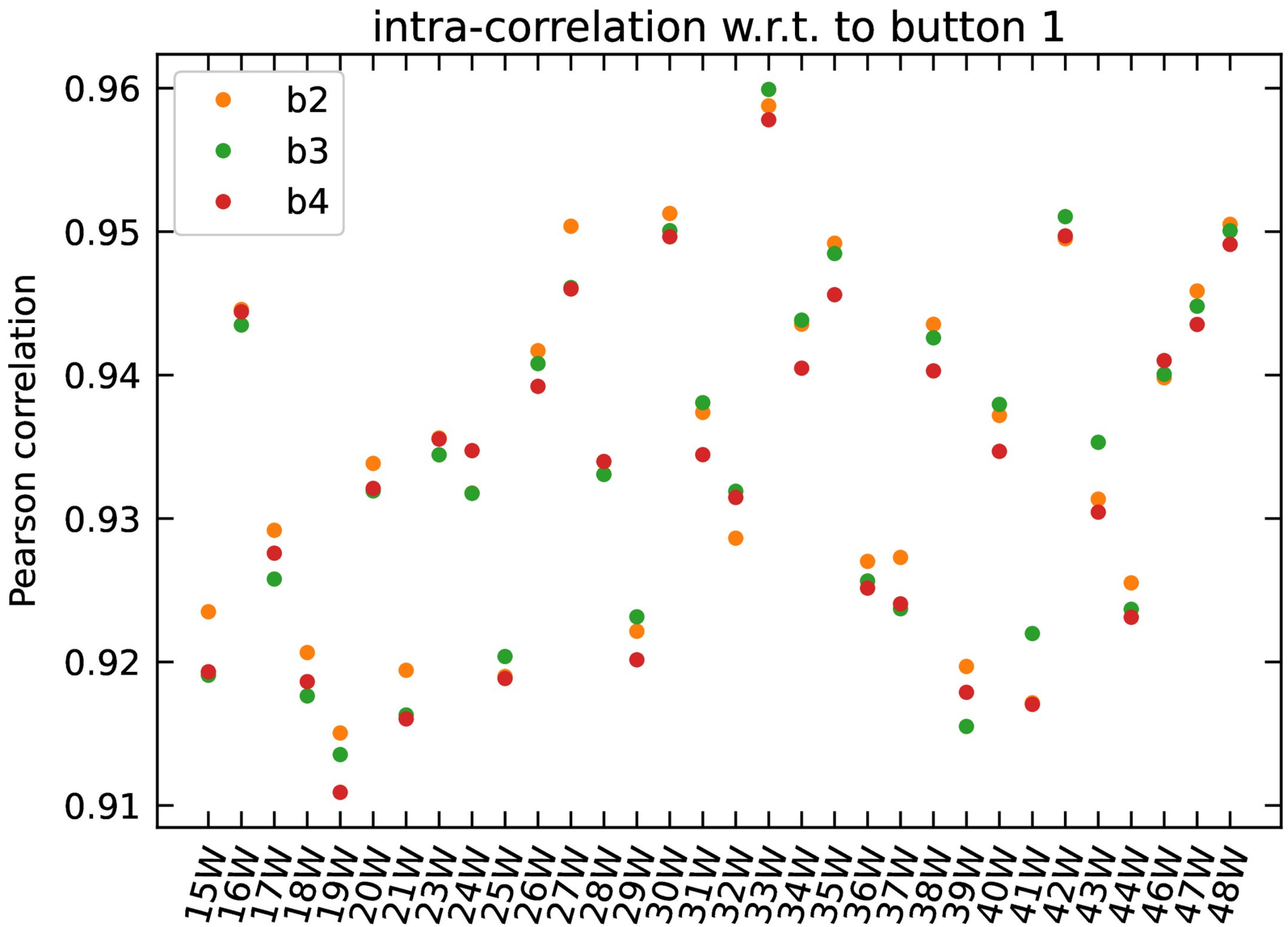
Intra-module correlation

Intra-module correlation from scatter plots, e.g.:

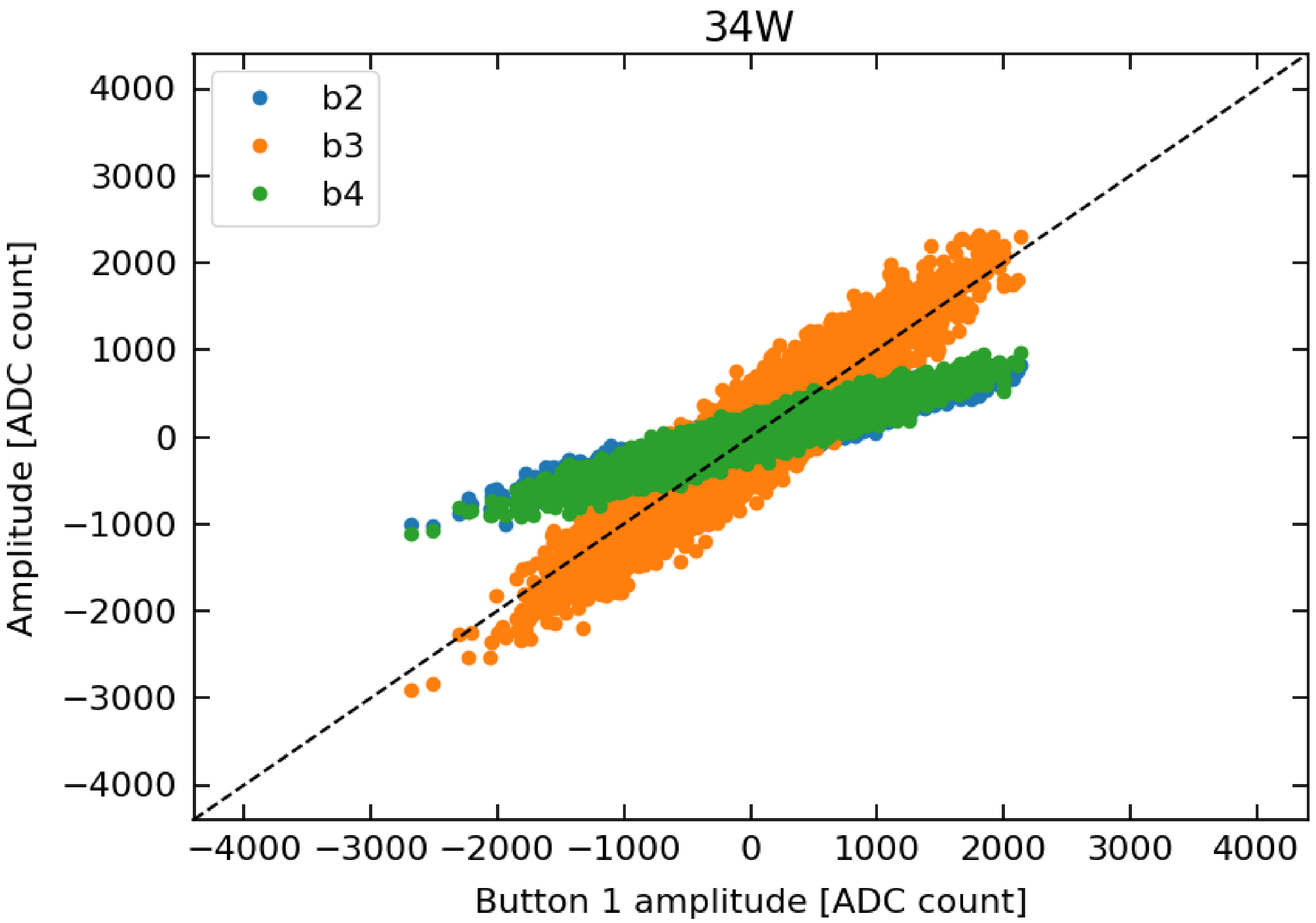




Intra-module Pearson correlation

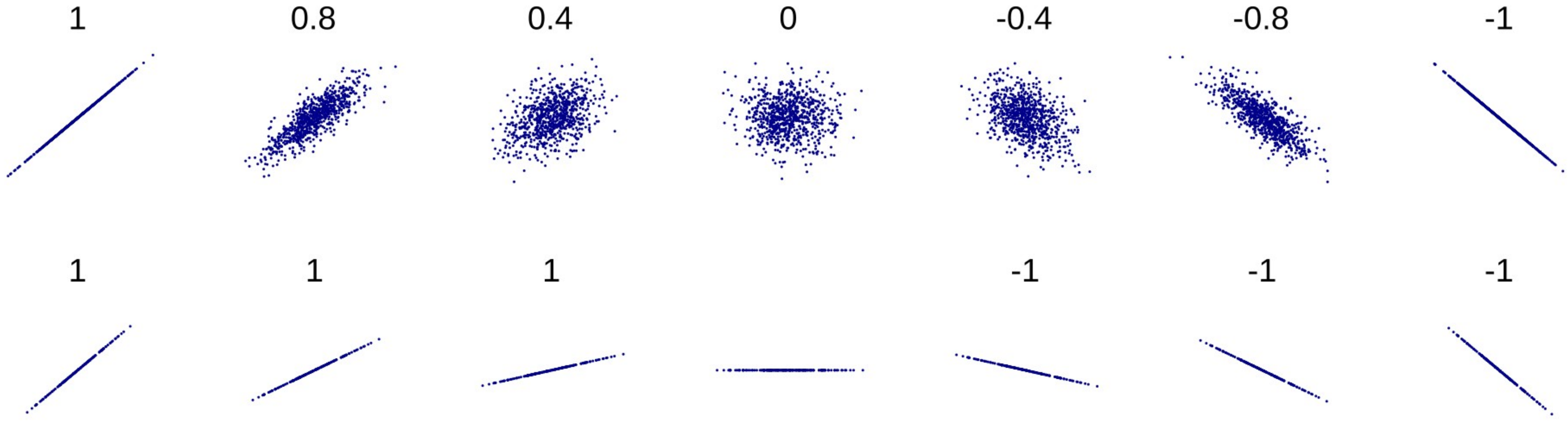


34W: Pearson not capturing slope



Pearson and Concordance correlations

The Pearson correlation measures the linear relationship between two variables. It cares about the spread (precision) but not the slope.



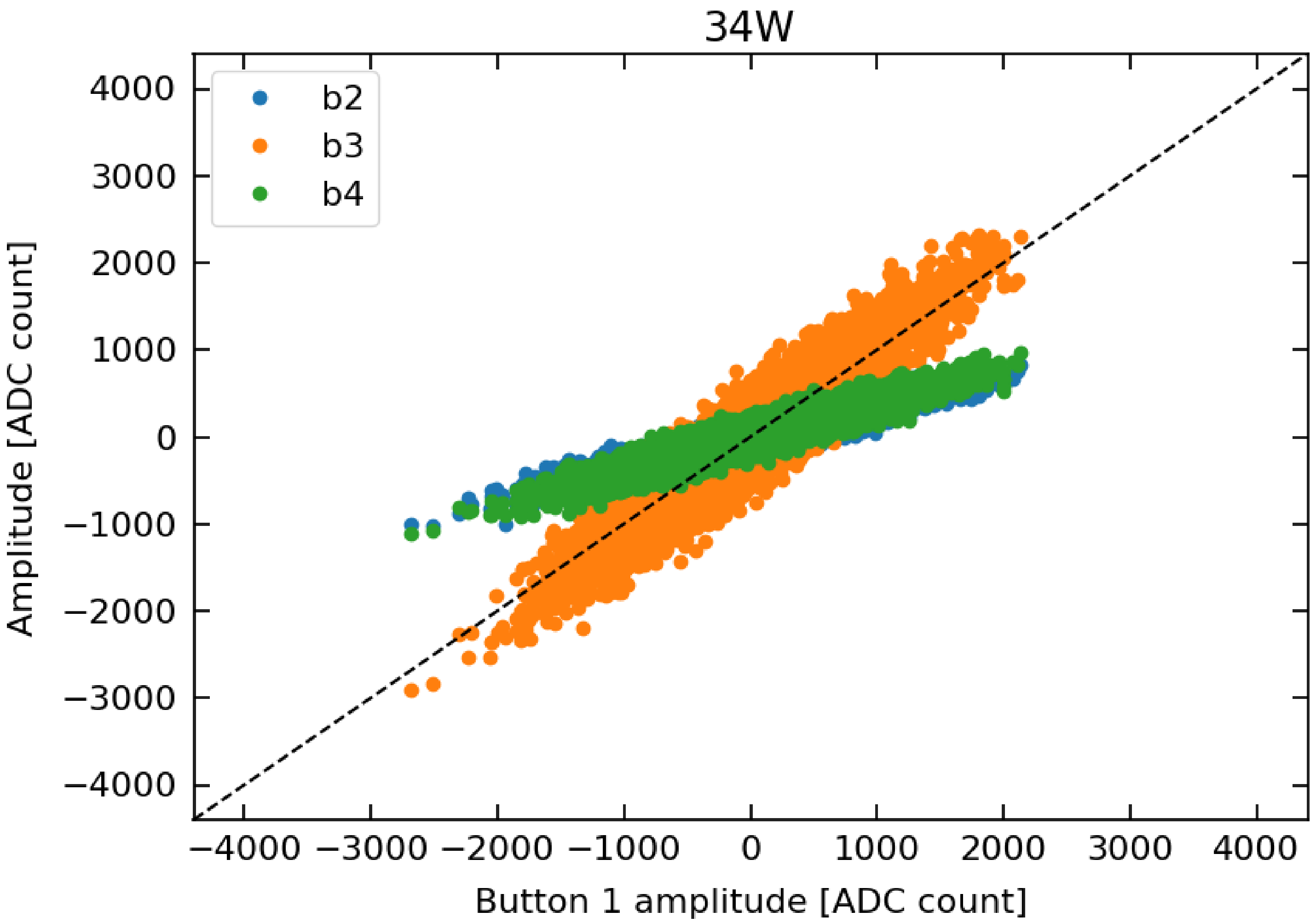
Pearson and Concordance correlations

The Pearson correlation measures the linear relationship between two variables. It cares about the spread (precision) but not the slope.

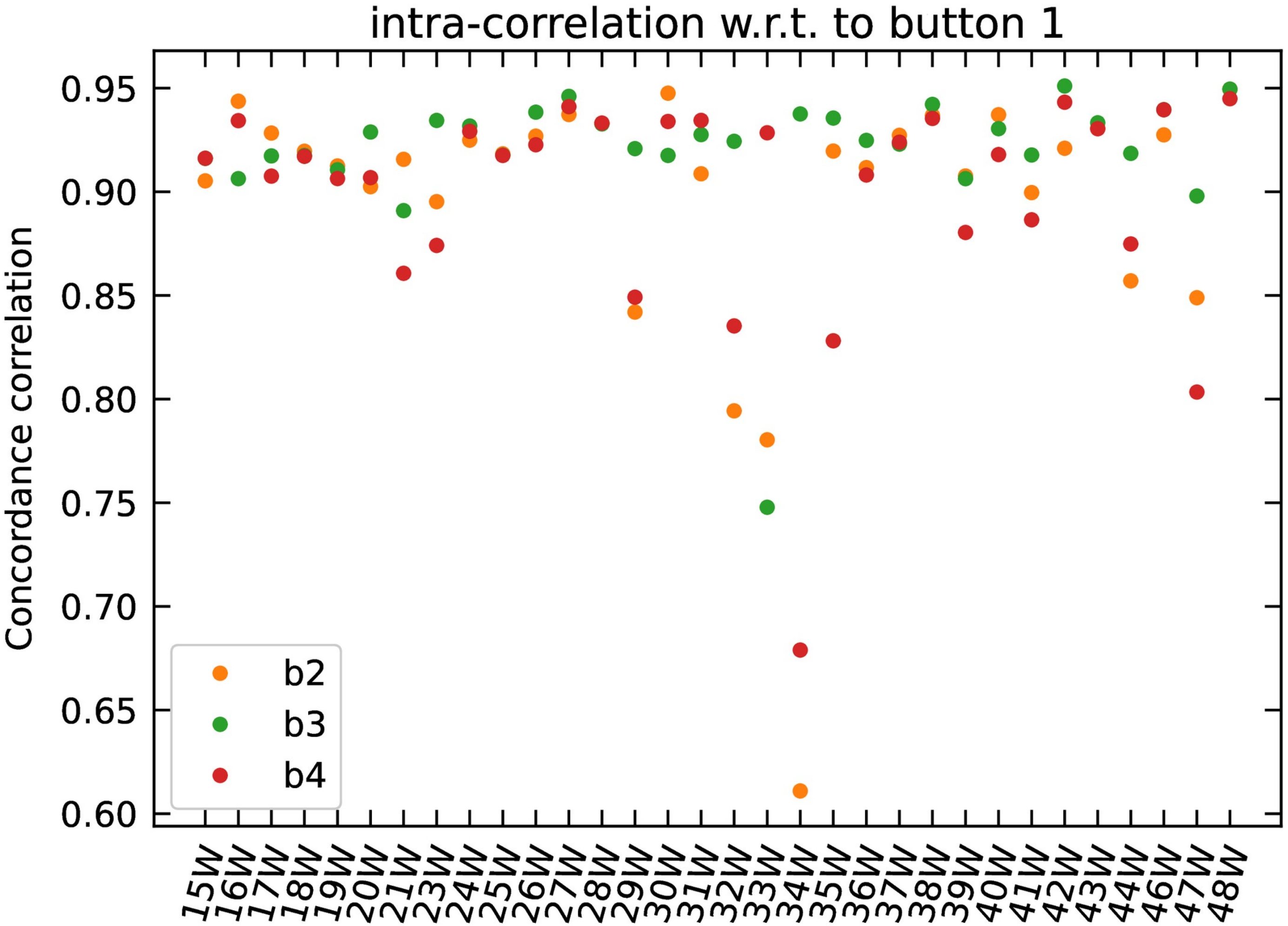
The Concordance correlation care about both: it measures how well pairs of observations fall on the 45-degree line through the origin y=x. It assesses both the accuracy (how close the data are to the line) and precision (how close the data are to each other).

Concordance ≈ Pearson + y=x slope comparison

34W again

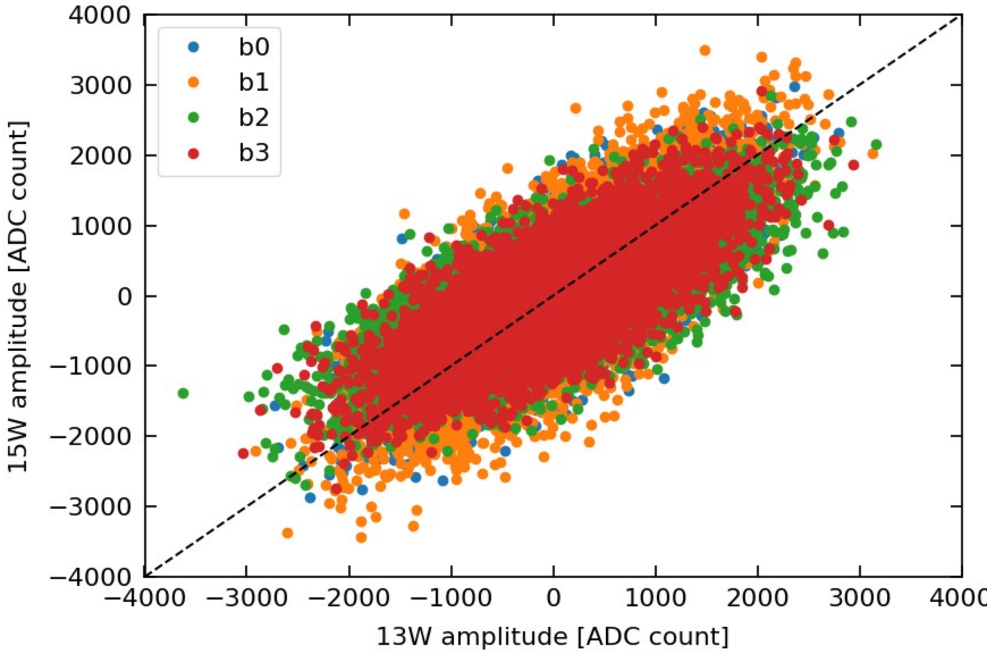

34W
b2
b3
b4
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
Amplitude [ADC count]
−4000 −3000 −2000 −1000 0 1000 2000 3000 4000
Button 1 amplitude [ADC count]

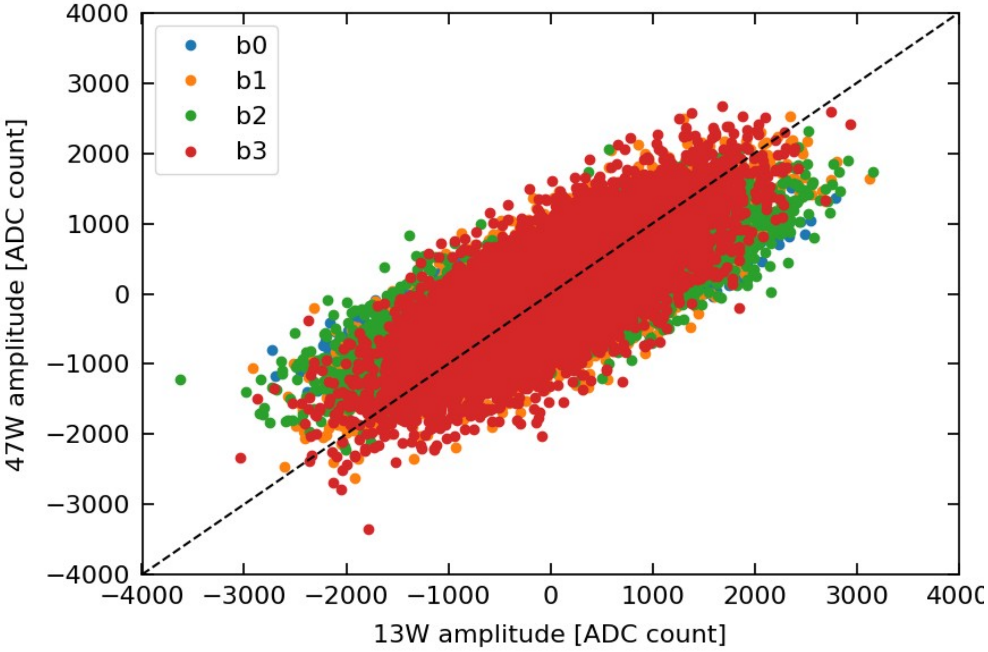
Intra-module Concordance correlation



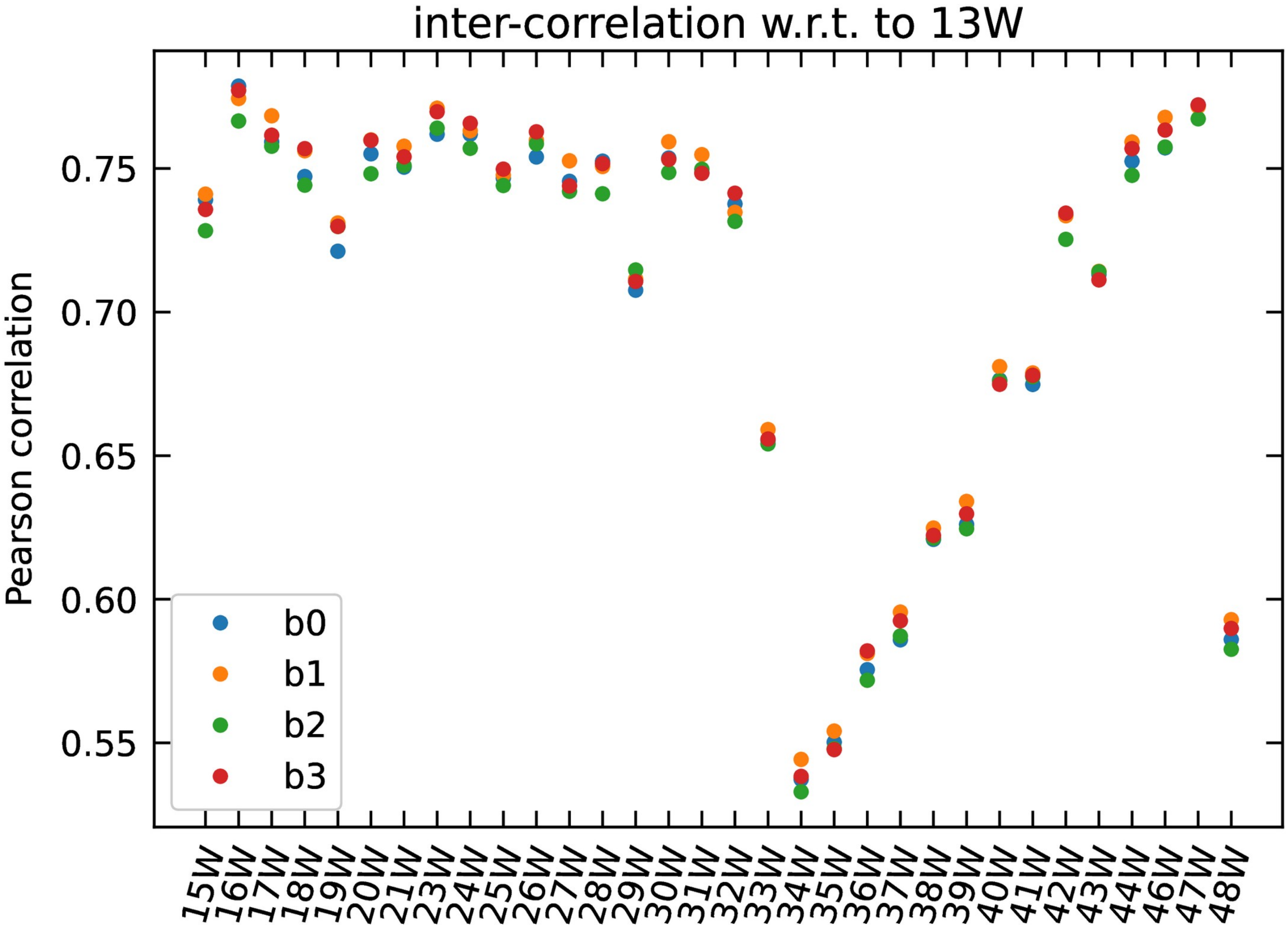
Inter-module correlation

Inter-module correlation from scatter plots, e.g.:

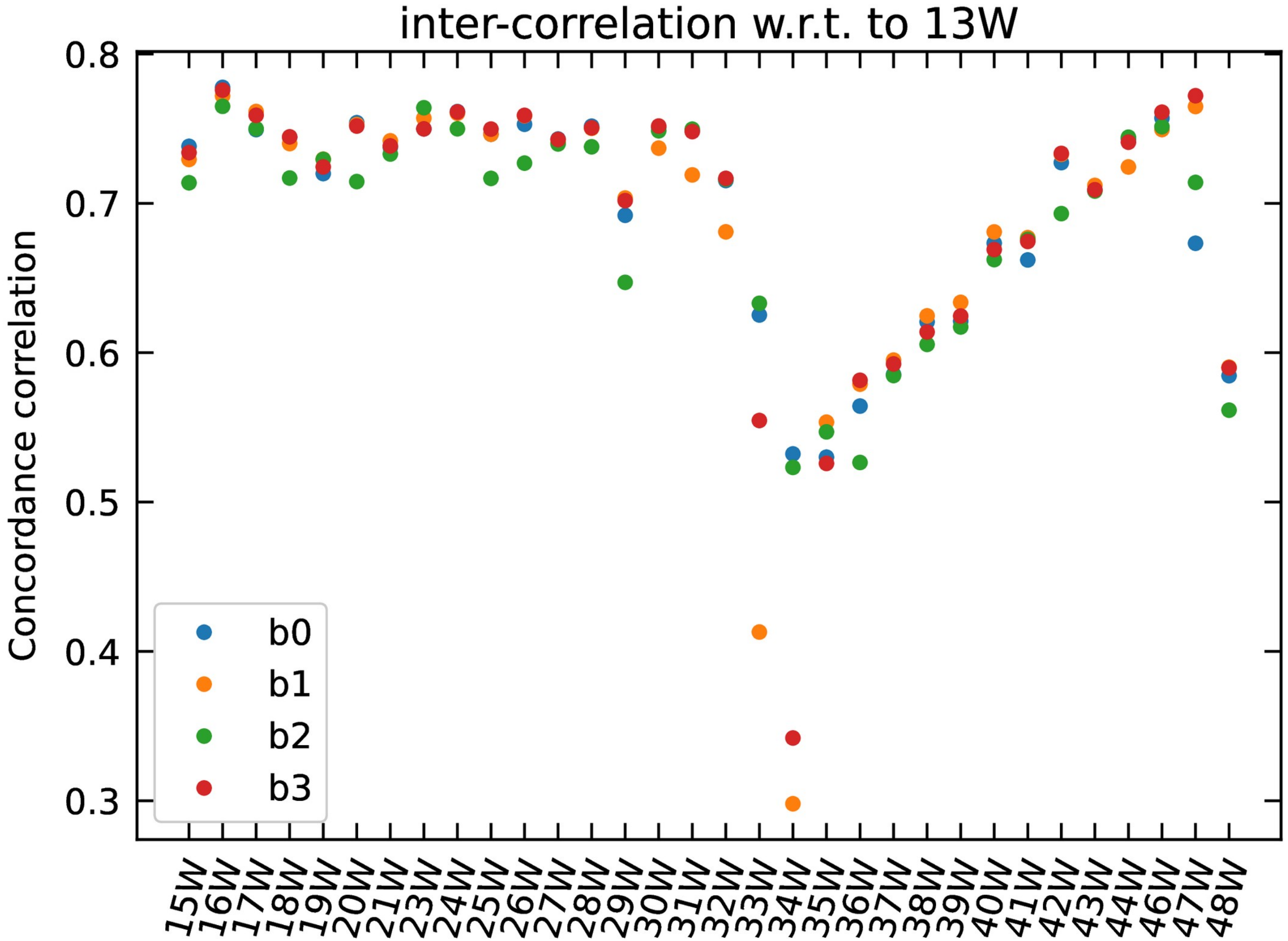




Inter-module Pearson correlation



Inter-module Concordance correlation



Correlation takeaway

Channel-to-channel and module-to-module correlations are very strong

One source driving both?

- longitudinal beam motion (arrival time at detector)?
- other beam motion (but not transverse)?
- common clock jitter?
- something else?

Extras